BNL-73171-2004
FORMAL REPORT

RIKEN BNL Research Center

SCIENTIFIC PRESENTATIONS

10th MEETING OF THE MANAGEMENT STEERING COMMITTEE OF THE RIKEN BNL COLLABORATION

RIKEN, Wako, Japan

March 25-26, 2004

RBRC Scientific Articles

Volume 10

Building 510A, Brookhaven National Laboratory, Upton, N.Y 11973-5000, USA

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Preface to the Series

The RIKEN BNL Research Center (RBRC) was established in April 1997 at Brookhaven National Laboratory. It is funded by the "Rikagaku Kenkyusho," (RIKEN) The Institute of Physical and Chemical Research, of Japan. The Center is dedicated to the study of strong interactions, including hard QCD/spin physics, lattice QCD and RHIC (Relativistic Heavy Ion Collider) physics through nurturing of a new generation of young physicists. The first Director of RBRC (1997 – 2003) was Professor T. D. Lee.

A Memorandum of Understanding between RIKEN and BNL was signed on April 30, 2002 extending this collaboration and the RIKEN BNL Research Center (RBRC) for another five years.

Since its inception the Center has now matured with both a strong theoretical and experimental group. These consist of Fellows, Postdocs, RBRC Physics/University Fellows and an active group of Consultants/Collaborators. Computing capabilities consist of a 0.6 teraflops parallel processor computer operational since August 1998. It was awarded the Supercomputer 1998 Gordon Bell Prize for price performance. This is expected to be augmented by a ten teraflops QCDOC computer in JFY 2004. The Center also organizes an extensive series of workshops on specific topics in strong interactions with an accompanying series of published proceedings.

Members and participants of RBRC on occasion will develop articles in the nature of a status report, a general review, and/or an overview of special events, such as this one.

N. P. Samios
Director, RIKEN BNL Research Center

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Other RBRC Scientific Articles Proceedings Volumes

RBRC OPERATIONS

Nicholas P. Samios

Current Activity Report

RBRC OPERATIONS

Nicholas P. Samios

Presentation
10th Meeting of The Management Steering Committee of RIKEN BNL Collaboration

March 25-26, 2004
RIKEN, Wako, Japan

RBRC

1997 – 2003 In existence for 6 years
Director: T. D. Lee
Three Components: Theory, Experiment, Computing

High Energy Density Nuclear Matter (RHIC)
Spin Component of Proton
Lattice QCD

RHIC

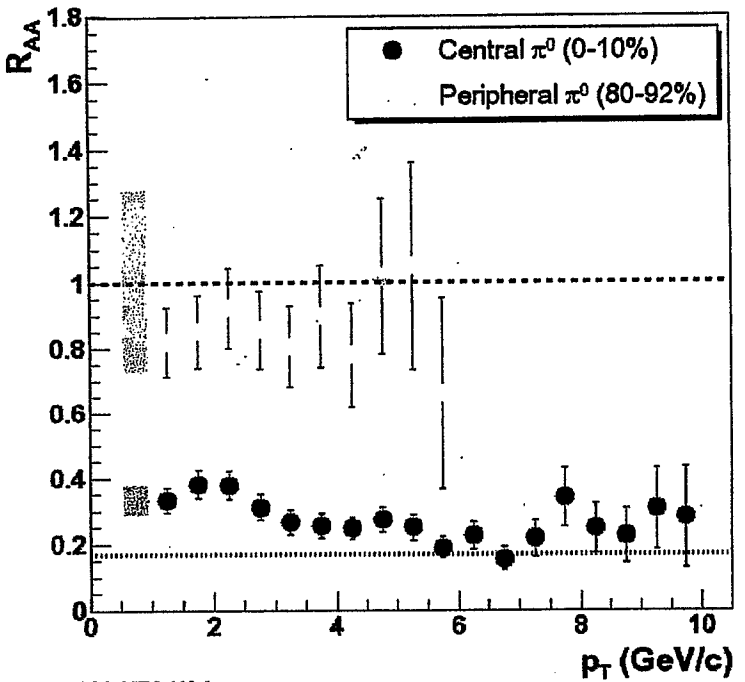
Great Year (if not spectacular)
Previous Au x Au, p x p running
d x Au Run. Technical feat – asymmetric operation
Exciting results:

Multiplicities	New Phenomena
Radial & Elliptic Flow	
HBT size measurements	Hot, dense nuclear matter
R_{AA} = Factor of 5 decrease	
Jets	Color glass condensate
High y, small x effects	

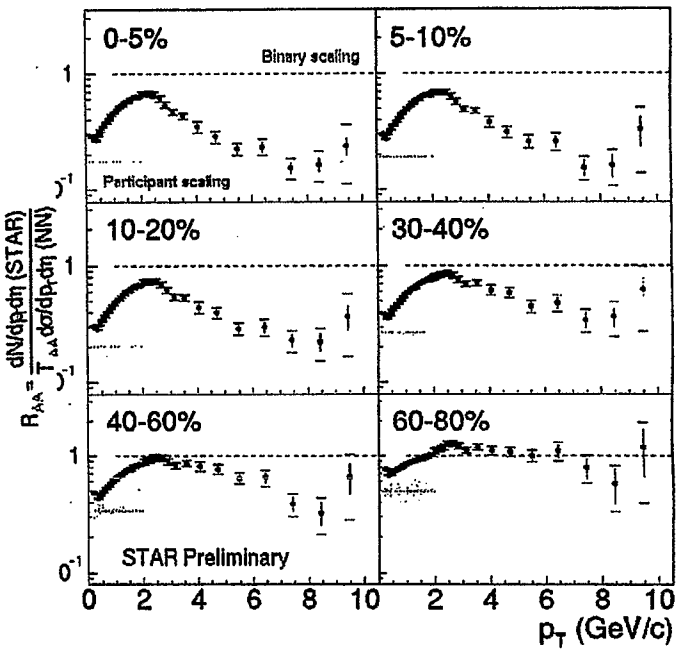
Suppression of leading hadrons in RHIC data

$\sqrt{S_{nn}}$=200: Au+Au

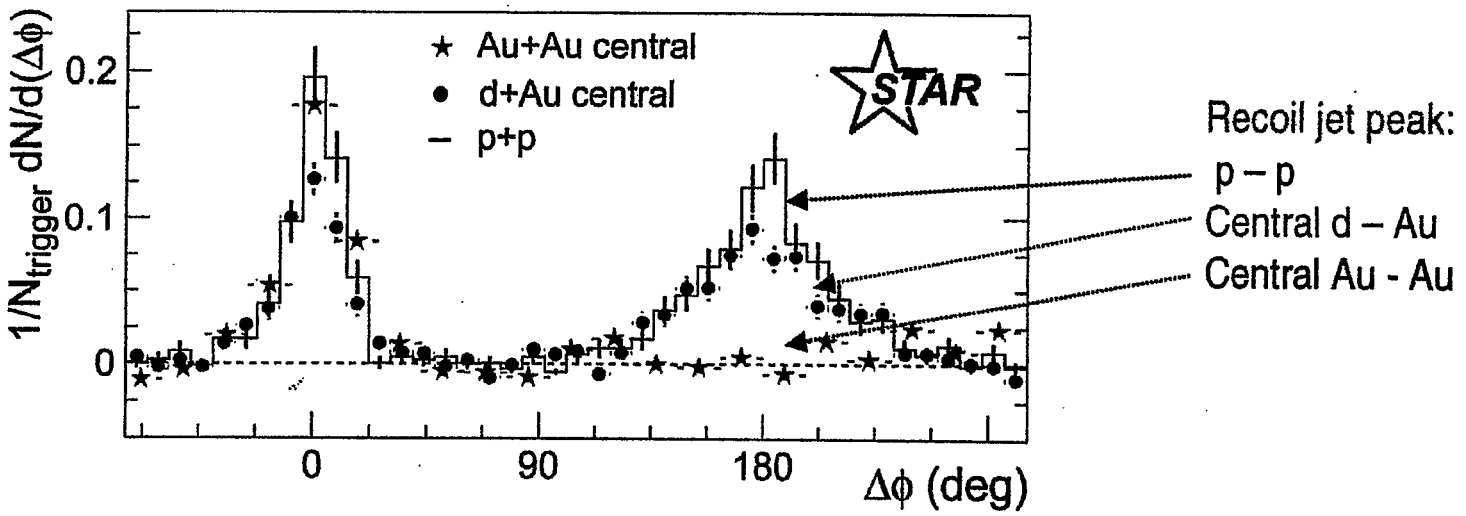
$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T d\eta}{T_{AA} d^2\sigma^{NN}/dp_T d\eta}$$



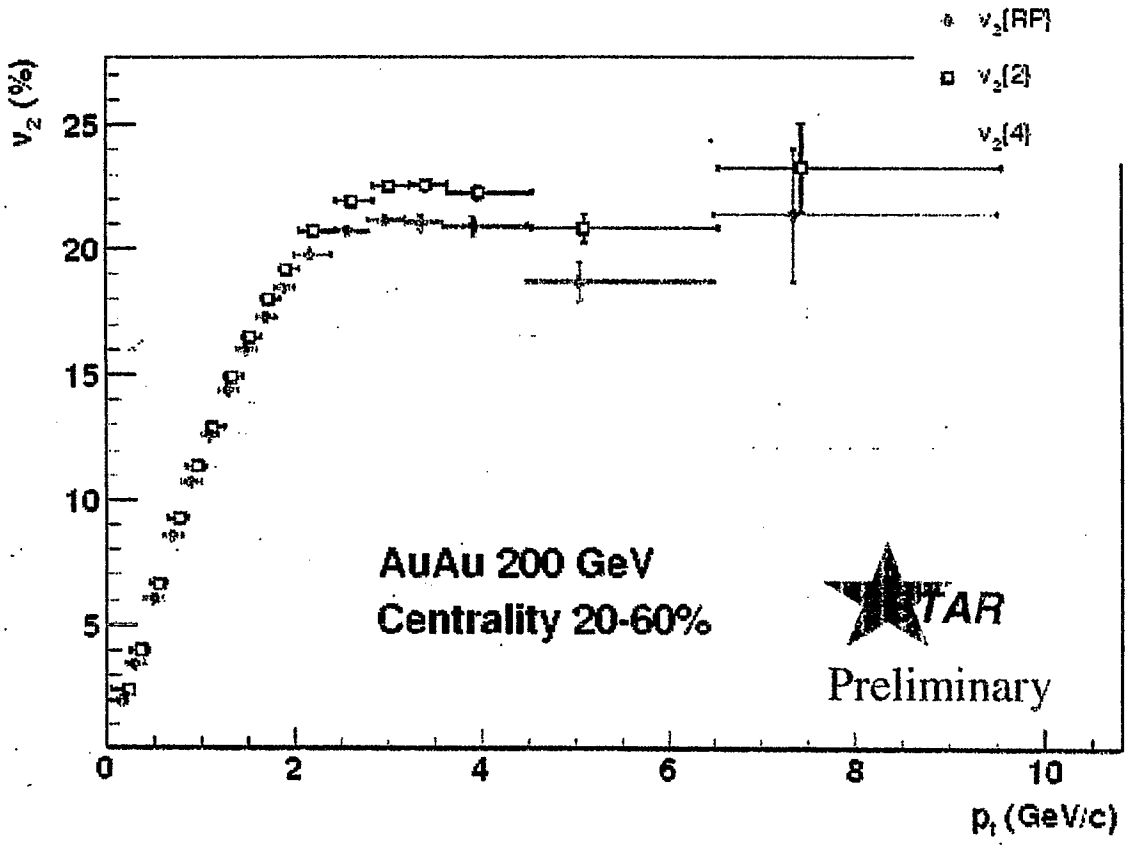
PHENIX:
Inclusive π^0 in central & peripheral collisions



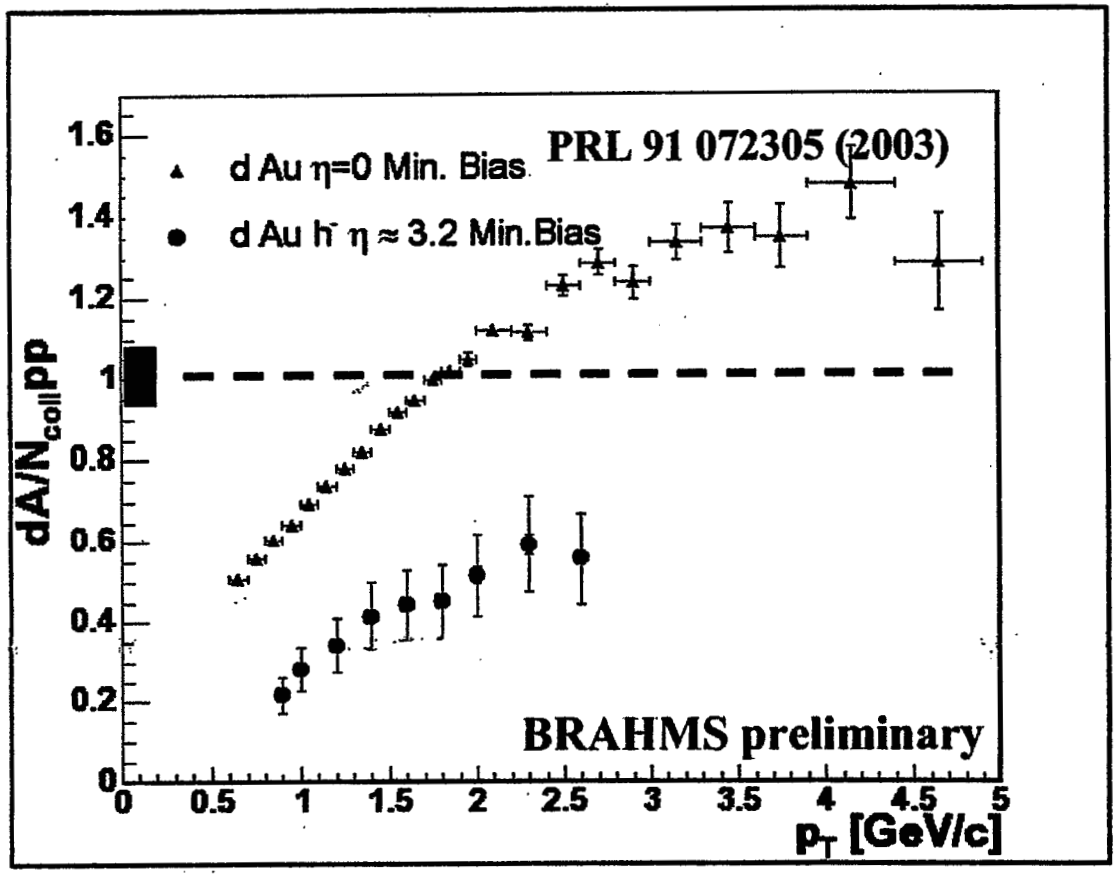
STAR Charged hadrons:
Dependence on centrality


Au+Au central
d+Au central
p+p
STAR
$1/N_{trigger}\ dN/d(\Delta\phi)$
0.2
0.1
0
0
90
180
$\Delta\phi$ (deg)
Recoil jet peak:
p – p
Central d – Au
Central Au - Au

Anisotropy vs. p_T at 200 GeV



Significant anisotropy in Au+Au up to 7 GeV/c



RdAu compares the yield of **negative particles** produced in dAu to the scaled number of particles with same sign in p-p

The scale is the number of binary collisions:

N_{coll}=7.2
(minimum biased)

SPIN Polarized Protons

AGS 30%, RHIC ~25% - polarization-Technical feat

Measured Asymmetries, π^{o}'s Snake

Different tune

Next runs pol. AGS warm snake, 2004/5 Pol. 50%

Cold snake, 2006/7 Pol. 70%

Plus gas jet polarimeters

PHENIX – Complete detector operational (x 2 μ arm)

Major RIKEN contributions

Spin results PHENIX

RBRC Collaboration

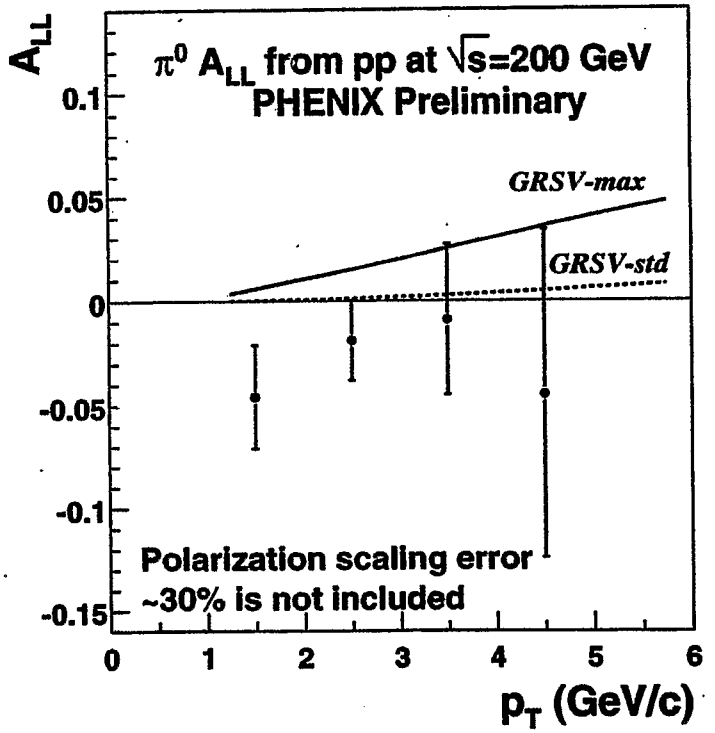
STAR

Computing QCDSP > 99.8% efficiency

QCDOC - Going well – Summer of 2004

A_{LL}: PHENIX vs theory

B.Jäger e al., PRD67, 054005 (2003)

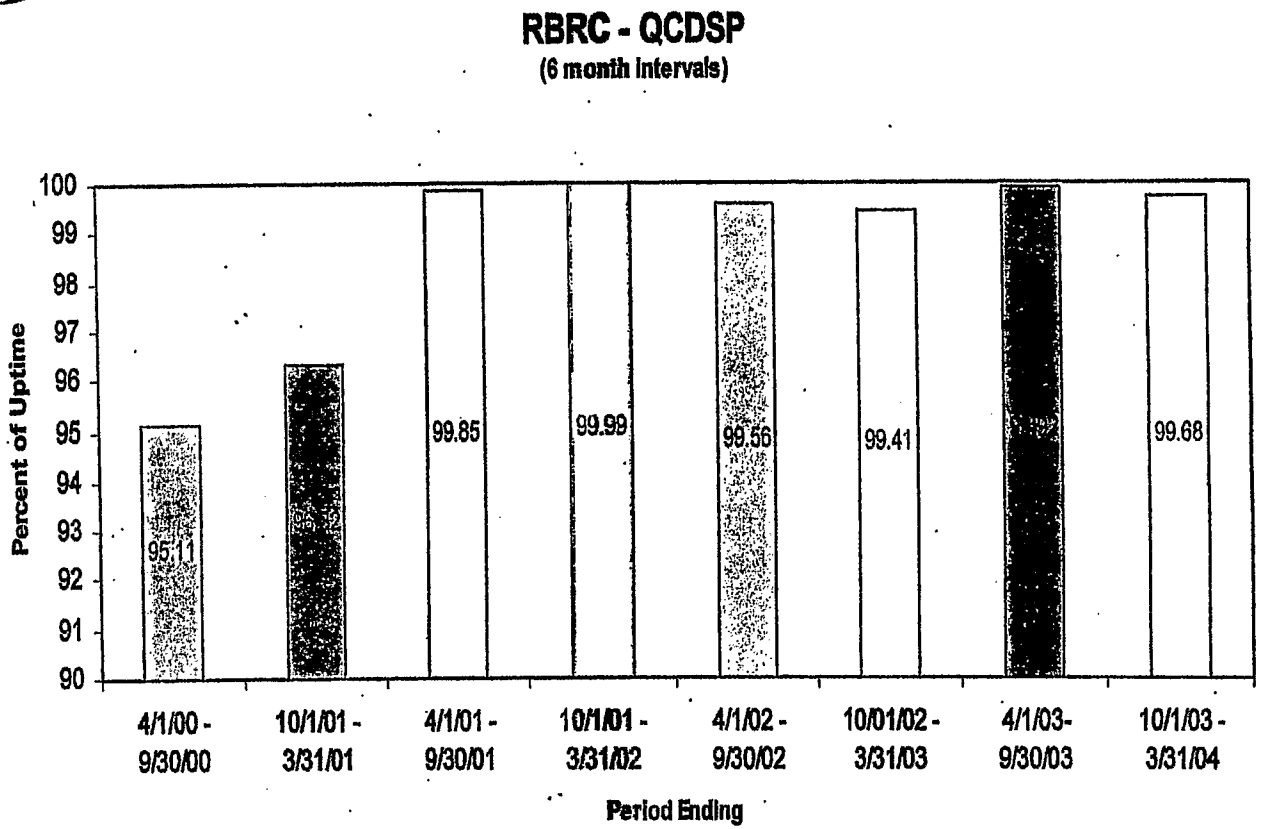


PHENIX

RIKEN BNL Research Center

- QCDSP:
  - Inauguration-September 1997, Production-August 1998
  - Gordon Bell Prize, 1998 Supercomputing Conference
  - 12,288 processors on 192 motherboards
  - Maintains better than 99% Uptime
  - BNL contribution, space & power, $57,000 per year
- QCDOC:
  - Prototype phase of QCDOC, a success.
    (256 processors on 4 Motherboards)
  - 12,500 chips order to IBM, February 2004.
  - Front-end IBM server delivered, February 2004.

RIKEN BNL Research Center



QCDOC: .

- Eight Motherboards running physics April 2004
- Aug 2004, assembly of 10 TeraFlop system
  - 12,500 processors on 192 motherboards
- Production Physics October 2004

RBRC

Director Emeritus:	T. D. Lee
Director:	N. P. Samios
Associate Director:	H. En'yo
Theory Group Leader:	L. McLerran
Deputy Group Leader:	A. Baltz
Experimental Group Leader:	H. En'yo
Deputy Group Leader:	G. Bunce

Theory Advisory Committee:

T. D. Lee
L. McLerran
A. Baltz
M. Creutz
M. Gyulassy
R. Pisarski (T. L. Trueman)

Experimental Advisory Committee:

A. Masaike
J. Sandweiss
S. Nagamiya

Workshops: 9
Publications: 93 Theory/68 Experiment
Seminars: 6/week
Other Articles: 1/8

Proceedings of RIKEN BNL Research Center Workshops

(~April 1, 2003 to March 31, 2004)

Volume 52 RIKEN School on QCD, "Topics on the Proton" (BNL- 71694-2003)
March 26, 2003
Organizers: H. En'yo, M. Hayakawa, H. Kawai, N. Saito, T.-A. Shibata, T. Tada, Y. Watanabe, and K. Yazaki

Volume 53 Theory Studies for Polarized pp Scattering (BNL-71747-2003)
August – September 2003
Organizers: S. Kretzer and W. Vogelsang

Volume 54 RHIC Spin Collaboration Meetings XVII, XVIII, XIX (BNL-71751-2003)
June 20, 2003, June 30, 2003, and August 18, 2003
Organizer: Brendan Fox

Volume 55 Collective Flow and QGP Properties (BNL-71898-2003)
November 17-19, 2003
Organizers: S. Bass, S. Esumi, U. Heinz, P. Kolb, E. Shuryak, N. Xu

Volume 56 RBRC Scientific Review Committee Meeting (BNL-71899-2003)
November 20-21, 2003
Organizers: N. P. Samios and T. D. Lee

Volume 57	High $p_\perp$ Physics at RHIC (BNL-72069-2004) December 2-6, 2003 Organizers: Stefan Kretzer, Dave Morrison, Raju Venugopalan, W. Vogelsang
Volume 58	RHIC Spin Collaboration Meeting XX (BNL-71900-2004) November 18, 2003 Organizer: Les Bland
Volume 59	RHIC Spin Collaboration Meeting XXI, XXII, XXIII (BNL-) January 22, 2004, February 27, 2004, March 19, 2004 Organizer: Akio Ogawa
Volume 60	Lattice QCD at Finite Temperature and Density (BNL-72083-2004) February 8-12, 2004 Organizers: T. Blum, M. Creutz, and P. Petreczky

Future Workshops: RBRC/BNL

The Strongly Interactive QGP
Organizers: W. Busza, M. Gyulassy, L. McLerran
Proposed Dates: May, 2004

Summer School on Spin Physics
Organizers: L. Bland, A. Deshpande, D. Fields, M. Grosse Perdekamp, E. Hughes, E. Leader, N. Saito, L. Trueman, W. Vogelsang, S. Wissink
Dates: June 5-13, 2004

THEORY PUBLICATION LIST

April 1, 2003 to March 31, 2004

RBRC-318 A. Mukherjee, M. Stratmann, and W. Vogelsang, "Next-to-leading Order QCD Corrections to ATT for Prompt Photon Production," [hep-ph/0303226], Physical Review D 67, 114006 (2003).

. . . . . .

RBRC-411 Takanori Sugihara, "Density Matrix Renormalization Group in a Two-Dimensional $\lambda\,\phi^4$ Hamiltonian Lattice Model," [hep-lat/0403008], JHEP (submitted).

RBRC Experimental Publications
April 2003 – March 2004

POLARIZED PROTON COLLIDER AT RHIC, By I. Alekseev et al., Nucl.Instrum.Meth.A499:392-414,2003

RHIC ACCELERATOR ADVANCES FOR SPIN, By G. Bunce, Prepared for 3rd Circum-Pan-Pacific Symposium on High Energy Spin Physics (SPIN 2001), Beijing, China, 8-13 Oct 2001 Int.J.Mod.Phys.A18:1255-1261,2003

THE AGS CNI POLARIMETER, Workshop on increasing the AGS Polarization, Ann Arbor, Nov. 2002. G. Bunce et al., AIP Conf. Proc. 667, 77 (2003).

MID-RAPIDITY NEUTRAL PION PRODUCTION IN PROTON-PROTON COLLISIONS AT S**(1/2)=200 GEV, S.S. Adler et al., to be published in Phys. Rev. Lett. (2003), hep-ex/0304038

MEASUREMENT OF SINGLE TRANSVERSE SPIN ASYMMETRY IN FORWARD PRODUCTION OF PHOTONS AND NEUTRONS IN PP COLLISIONS AT ROOT(S)=200 GEV, A. Bazilevsky et al., Spin 2002, AIP Conf. Proc. 675, 584 (2003)

RHIC pC CNI POLARIMETER: EXPERIMENTAL SETUP AND PHYSICS RESULTS, I. G. Alekseev et al., Spin 2002, AIP Conf. Proc. 675, 812 (2003)

RHIC pC CNI POLARIMETER: STATUS AND PERFORMANCE FROM THE FIRST COLLIDER RUN, O. Jinnouchi et al., Spin 2002, AIP Conf. Proc. 675, 817 (2003)

POLARIZED H- JET POLARIMETER FOR ABSOLUTE PROTON POLARIZATION MEASUREMENTS IN RHIC, A. Zelinski et al., Spin 2002, AIP Conf. Proc. 675, 954 (2003)

PHYSICS WITH RHIC SPIN COLLIDER., By H. Enyo (Wako, RIKEN & RIKEN BNL). 2003. 8pp. Published in Nucl.Phys.A721:143-150,2003

SPIN ROTATOR COMMISSIONG AT RHIC, W. Mac Kay {et al} and the PHENIX collaboration, Proceedings of EPAC 2003

NEUTRAL PION MEASUREMENTS IN POLARIZED PROTON COLLISIONS FROM PHENIX AT RHIC, Y. Goto for the PHENIX Collaboration, PANIC 2002, Nucl. Phys. A721 (2003) 360-363.

PROSPECTS OF THE GLUON POLARIZATION MEASUREMENT AT PHENIX, Y. Goto for the PHENIX Collaboration, SPIN 2002, AIP Conf. Proc. 675 (2003) 493-503.

COMMENT ON E+E- ANNHILATION INTO J / PSI J / PSI. By Belle Collaboration (K. Abe et al.). BELLE-PREPRINT-2003-7, KEK-PREPRINT-2003-24, Jun 2003. 6pp. e-Print Archive hep-ex/0306015.

IMPROVED MEASUREMENT OF THE PARTIAL RATE CP ASYMMETRY IN B+ ---> K0 PI+ AND B- ---> ANTI-K0 PI- DECAYS. By Belle Collaboration (Y. Unno et al.) KEK-PREPRINT-2003-7, BELLE-PREPRINT-2003-4, Apr. 2003. 7pp. Published in Phys. Rev. D68:011103,2003. e-Print Archive: hep-ex/0304035.

MEASUREMENT OF BRANCHING FRACTION RATIOS AND CP ASYMMETRIES IN B+- ---> D(CP) K+-. By Belle Collaboration (S.K. Swain et al.) KEK-PREPRINT-2003-8, BELLE-PREPRINT-2003-3, Apr. 2003. 10pp. Published in Phys. Rev. D68:051101, 2003. e-Print Archive: hep-ex/0304032.

EVIDENCE FOR CP VIOLATING ASYMMETRIES B0 ---> PI+ PI- DECAYS AND CONSTRAINTS ON THE CKM ANGLE PHI(2). By Belle Collaboration (K. Abe et al.). KEK-PREPRINT-2002-131, BELLE-PREPRINT-2003-1, Jan. 2003. 26pp. Published in Phys. Rev. D68:012001, 2003. e-Print Archive hep-ex/0301032.

NOVEL SILICON STRIPIXEL DETECTOR FOR PHENIX UPGRADE. Z. Li et al. Nucl. Instrum. Methods, A 518, 300 (2004).

DEVELOPMENT OF A NOVEL SILICON STRIP DETECTOR FOR THE RHIC-PHENIX DETECTOR UPGRADE, J. Tojo et al. IEEE Nuclear Science Symposium and Medical Imaging Conference, Portland, USA, October 19-25, 2003.

SPIN PHYSICS WITH HIGH ENERGY POLARIZED PROTON-PROTON COLLISIONS, J. Tojo, Spin and Quantum Structure of Hadrons, Nuclei and Atoms (SQS04), Tokyo, Japan, February 19-21, 2004.

AN UPDATE FROM STAR - USING STRANGENESS TO PROBE RELATIVISTIC HEAVY ION COLLISIONS. By STAR Collaboration (H. Caines *et al.*). 2004. Prepared for 7th International Conference on Strangeness in Quark Matter (SQM 2003), Atlantic Beach, North Carolina, 12-17 Mar 2003. Published in J.Phys.G30:S61-S73,2004

PARTICLE TYPE DEPENDENCE OF AZIMUTHAL ANISOTROPY AND NUCLEAR MODIFICATION OF PARTICLE PRODUCTION IN AU + AU COLLISIONS AT S(NN)**(1/2) = 200-GEV. By STAR Collaboration (J. Adams *et al.*). Jun 2003. 6pp. Published in Phys.Rev.Lett.92:052302,2004. e-Print Archive: nucl-ex/0306007

EVIDENCE FROM D + AU MEASUREMENTS FOR FINAL STATE SUPPRESSION OF HIGH P(T) HADRONS IN AU+AU COLLISIONS AT RHIC. By STAR Collaboration (J. Adams *et al.*). Jun 2003. 6pp. Published in Phys. Rev. Lett. 91:072304, 2003. e-Print Archive: nucl-ex/0306024

Weekly Seminars

Spin Physics *(Theory & Exp)*	Tuesdays (10:00 a.m.)	Organized by Y. Goto W. Vogelsang A. Deshpande
Nuclear Physics	Tuesdays (11:00 a.m.)	Organized jointly by W. Vogelsang P. Petreczky with BNL Staff
High Energy-RIKEN Theory	Wednesdays (1:30 p.m.)	Organized jointly by S. Ohta with BNL Theorists
QCD and RHIC Physics *(Theory & Exp)*	Thursdays (12:30 p.m.)	Organized by W. Vogelsang
High Energy Theory Lunch Talks	Fridays (12:00 Noon)	Organized by S. Dawson
Nuclear Physics-RIKEN Theory	Fridays (2:00 p.m.)	Organized jointly by S. Kretzer, C. Dawson with BNL Staff

Other RBRC Scientific Articles Proceedings Volumes:

Volume 1 **Prospects for Spin Physics at RHIC**
Gerry Bunce, Naohito Saito, Jacques Soffer, Werner Vogelsang
July 2000

Volume 2 **Status Report on the Calculation of ε'/ε**
RBRC-Brookhaven-Columbia Collaboration
November 2000

Volume 3 **Scientific Presentations: 7th Meeting of the Management Steering Committee of the RIKEN BNL Collaboration, RIKEN, Wako, Japan, February 13-14, 2001**

Volume 4 **CP Violation in K Decay From Lattice QCD**
Thomas Blum and Robert Mawhinney
RBRC-Brookhaven-Columbia QCDSP Collaboration
July 26, 2001

Volume 5 **Scientific Presentations: 8th Meeting of The Management Steering Committee of The RIKEN BNL Collaboration, RIKEN, Wako, Japan, March 11-12, 2002**

Volume 6 **BNL/RIKEN RHIC Spin Physics Symposium**
RIKEN BNL Research Center Fifth Anniversary Celebration, April 30, 2002

Volume 7 **Reflections on My Contributions to Particle Physics and Recent Experimental Results from RHIC**
N. P. Samios
Dubna, Russia, January 18, 2002

Volume 8 **RBRC/CCAST Symposium on Spin Physics, Lattice QCD and RHIC Physics, CCAST, Beijing, China,**
April 7, 2003

The Outstanding Junior Investigator Award in Nuclear Theory was established by DOE in 2000. Since Then, five RBRC members have received the OJI Awards:

Son, D. T.	(2000)
Stephanov, M.	(2001)
van Kolck, U.	(2001)
Schaefer, T.	(2002)
Bass, S.	(2003)

RBRC Tenure Track RHIC Physics Fellow Program - Status

RHIC Physics Fellow Graduates	RBRC Dates	Position	New Position	Present Institution
Bödeker, Dietrich	12/2000 to 12/2001	RHIC Physics Fellow, BNL	Professorship, C-4	U. of Bielefeld, Germany
Kharzeev, Dmitri	08/1997 to 09/1999 10/1999 to 03/2000	RIKEN BNL Fellow RHIC Physics Fellow, BNL	Physicist, Tenured Staff	BNL
Rischke, Dirk	09/1997 to 09/2000 10/2000 to 01/2001	RIKEN BNL Fellow RHIC Physics Fellow, BNL	Professorship, C-4	Inst. f. Theor. Phys. J.W. Goethe-Univ. Frankfurt, Germany
Son, Dam Thanh	10/1999 to 03/2002	RHIC Physics Fellow, Columbia U.	Tenured Position	U. of Wash, Seattle, Natl. Inst. for Nucl. Th
Venugopalan, Raju	10/1/98 10/1/00 to 6/30/03 (06/1/02 Tenure)	Asst. Physicist, BNL; RHIC Physics Fellow, BNL	Physicist, Tenured	BNL
Present Program				
Bass, Steffen	09/01/2000-	RHIC Physics Fellow, Duke U./Asst. Prof.		RBRC/Duke U
Blum, Thomas	10/1998 to 09/2003 01/01/2004 -	RIKEN BNL Fellow RHIC Physics Fellow/ UConn/Asst. Prof.		RBRC/U. Connecticut
Izubuchi, Taku	04/01/2003 -	RHIC Physics Fellow, Kanazawa U., Japan/ Physicist with Tenure		RBRC/Kanazawa U.
Jeon, Sangyong	01/01/2001 -	RHIC Physics Fellow; McGill /Asst. Prof.		RBRC/McGill
Kusenko, Alexander	10/1999 - 05/2003 (Tenure)	RHIC Physics Fellow; UCLA/Asst. Prof	Tenured Associate Professor	RBRC/UCLA
Schaefer, Thomas	01/2000 01/2003 (Tenure) -	RHIC Physics Fellow, SUNY, SB/Asst. Prof. NCSU	Tenured at NCSU Associate Professor	RBRC/NCSU
Stephanov, Mikhail	10/1999 - 08/2003 (Tenure)	RHIC Physics Fellow, UIC/Asst. Prof.	Tenured Associate Professor	RBRC/U. of Illinois, Chicago

RHIC Physics Fellow Present Program	RBRC Dates	Position	New Position	Present Institution
van Kolck, Ubirajara	08/2000 - 08/2003 (Tenure)	RHIC Physics Fellow; U. of Arizona/Asst. Prof.	Tenured Associate Professor	RBRC/U. of Arizona
Vogelsang, Werner	4/1/2000 to 9/30/2003 10/1/2003 -	RIKEN BNL Fellow RHIC Physics Fellow BNL/Associate Physicist		RBRC/BNL
Wettig, Tilo	10/1999 -	RHIC Physics Fellow, Yale/Asst. Prof.	Associate Professor (2003)	RBRC/Yale
Experimentalists				
Deshpande, Abhay	02/01/2000 to 12/31/03 01/01/2004 – present	RIKEN BNL Fellow RHIC Physics Fellow, SUNY, SB/Asst. Prof.		RBRC/SUNY, Stony Brook
Fields, Douglas	09/2001	RHIC Physics Fellow, U. of New Mexico/Asst. Professor		RBRC/U. of New Mexico
Grosse Perdekamp, Matthias	01/1999 to 8/31/02 09/01/2002 -	RIKEN BNL Fellow RHIC Physics Fellow, U. of Illinois, Urbana Champaign/Asst. Prof.		RBRC/U. of Illinois Urbana Champaign

RBRC Graduates

Name	Dates at RBRC	RBRC Position	New Position Title	New Position Institution
Aoki, Yasumichi	05/2000 to 04/2003 04/2003 to 7/31/2003	Research Associate Visiting Scientist	Post-doctoral Fellow Research Associate	Columbia University U.Wuppertal, Germany
Bazilevsky, Alexander	3/10/1999 to 3/09/2002 3/10/2002 to 4/1/2003	Research Associate RIKEN BNL Fellow	Assistant Physicist	BNL
Blum, Thomas	10/1/1998 to 9/30/03 1/01/2004 -	RIKEN BNL Fellow	RHIC Physics Fellow/Asst. Professor	RBRC/U. of Connecticut
Bödeker, Dietrich	12/2000 to 12/2001	RHIC Physics Fellow, BNL	Professorship, C-4	U. of Bielefeld, Germany
Boer, Daniël	10/1998 to 06/2001	Research Associate	Academy Researcher, Tenure Track	Dutch Royal Academy of Sciences, Free University, Amsterdam
Deshpande, Abhay	02/01/2000 to 12/31/03 01/01/2004 – present	RIKEN BNL Fellow RHIC Physics Fellow	Assistant Professor	RBRC/SUNY, Stony Brook
Fujii, Hirotsugu	09/1997 to 09/1999	Research Associate	Assistant Professor	U. of Tokyo, Komaba, Inst. of Physics
Goto, Yuji	11/1999 to 03/2002 4/2002 - present	RIKEN BNL Fellow RIKEN Spin Program Researcher	Scientist Sr. Research Scientist	RIKEN
Grosse Perdekamp, Matthias	01/1999 to 8/31/02 09/01/2002 - present	RIKEN BNL Fellow .	RHIC Physics Fellow/Asst. Professor	RBRC/U. of Illinois Urbana Champaign
Itakura, Kazunori	06/2002 to 05/2003	Research Associate	JSPS Fellow	Service of Theoretical Physics, Saclay, France
Kharzeev, Dmitri	08/1997 to 09/1999 10/1999 to 03/2000	RIKEN BNL Fellow RHIC Physics Fellow, BNL	Physicist, Tenured Staff	BNL
Kurita, Kazuyoshi	[04/1997 to 09/1997 10/1997 to 03/2000] 04/2000 to 03/2002 03/2002 to present	[Postdoc. Res. RIKEN Special Postdoc Res., RIKEN] RIKEN BNL Fellow RSP Visiting Scientist	Associate Professor	Rikkyo University, Tokyo
Nara, Yasushi	10/1999 to 09/2002	Research Associate	Research Associate	U. of Arizona, Tucson
Orginos, Konstantinos	10/2000 to 8/31/2003	Research Associate	Research Scientist	MIT, Lab. For Nucl. Sci
Rischke, Dirk	09/1997 to 09/2000 10/2000 to 01/2001	RIKEN BNL Fellow RHIC Physics Fellow, BNL	Professorship, C-4	Inst. f. Theor. Phys. J.W. Goethe-Univ. Frankfurt, Germany

Name	Dates at RBRC	RBRC Position	New Position Title	New Position Institution
Saito, Naohito	[04/1995 to 03/1996] 04/1996 to 03/2001 04/2001 to 03/2002 03/2002 - present	[RIKEN Special Postdoc. Fellow] RIKEN/RBRC Res. RIKEN Spin Prog. Res RSP Visiting Scientist.	Associate Professor	Kyoto U., Japan
Sasaki, Shoichi	09/1998 to 09/2000	Research Associate	Assistant Professor	U. of Tokyo, Japan
Schaffner-Bielich, Jürgen	09/1998 to 10/2001	Research Associate	Research Associate	Columbia University University of Frankfurt
Son, Dam Thanh	10/1999 to 03/2002	RHIC Physics Fellow, Columbia U.	Associate Professor, Tenured	U. of Wash, Seattle, Natl. Inst. for Nucl. Th
Venugopalan, Rajagopal	10/1/2000 to 6/30/2003	RHIC Physics Fellow, BNL	Physicist with Tenure 6/1/02	BNL
Vogelsang, Werner	4/1/2000 to 9/30/2003 10/01/2003	RIKEN BNL Fellow	RHIC Physics Fellow/Associate Physicist	RBRC/BNL
Wingate, Matthew	09/1997 to 09/2000	Research Associate	Assistant Professor	Ohio State U., Columbus
Yasui, Yoshiaki	09/1997 to 09/2000	Research Associate	Postdoc Postdoctoral Fellow	Radiation Lab, RIKEN, KEK, Theory Group, Japan

03/31/04

N. P. Samios, RBRC Director
T. D. Lee, RBRC Director Emeritus
Hideto En'yo, RBRC Associate Director
RBRC Research Scientists (JFY – 2003)

Theory Group

L. McLerran, Theory Group Leader
Anthony J. Baltz, Deputy Theory Group Leader

Research Associates (Post Docs)

Aoki, Y. (4/30/03)*
Itakura, K. (5/31/03)*
Kretzer, S. (Joint NT)
Nemoto, Y.(5/31/04)*
Noaki, J. (6/30/04)*
Orginos, K. (9/30/03)*
Yamada, N.

RSP Research Associates

Hirano, T.
Ikeda, T.
Sugihara, T.

Fellows

Blum, T. (9/30/03)*
Dawson, C.
Petreczky, P. (Joint NT)
Vogelsang, W. (9/30/03)*

RBRC Theory Advisory Committee

Baltz, A.
Creutz, M.
Gyulassy, M.
McLerran, L.
Pisarski, R. (9/30/03)*
Trueman, T. L. (reappointment)

RSP Young Researcher

Hatta, Y.
Yokoya, H.

Consultants/ Visiting Scientists

Gyulassy, M.
Jaffe, R.
Ohta, S.
Orginos, K.
Shuryak, E.

Tenure Track/RHIC Physics/Visiting Fellows

Bass, S.	(Duke)
Blum, T. (1/1/04)	(U. of Conn)
Izubuchi, T.	(Kanazawa U.)
Jeon. S.	(McGill)
Kusenko, A.	(UCLA)
Schaefer, T.	(NCSU)
Stephanov, M.	(U. of IL, Chicago)
van Kolck, U.	(Arizona)
Venugopalan, R.(6/30/03)	(BNL)
Vogelsang, W.	(BNL)
Wettig, T.	(Yale)

Collaborators

Hashimoto, K.
Mawhinney, R.

Computer Scientist

Dong, Z.

*Appointment terminates RSP = RIKEN SPIN PROGRAM

N. P. Samios, RBRC Director
T. D. Lee, RBRC Director Emeritus
Hideto En'yo, RBRC Associate Director
RBRC Research Scientists (JFY – 2003)
Experimental Group
Hideto En'yo, Group Leader, Gerry Bunce, Deputy Group Leader

Research Associates
Jinnouchi, O.
Kaneta, M.
Okada, K.

Fellows
Bazilevsky, A. (4/1/03)*
Deshpande, A. (12/31/03)*
Fox, B. (10/15/03)*
Messer, F. (4/1/03)*
Xie, Wei

Tenure Track/RHIC Fellow
Deshpande, A. (SUNY, SB)
Fields, D. (UNM)
Grosse-Perdekamp, M. (UIUC)

RIKEN Spin Program (RSP) Researchers
Akiba, Y.
Goto, Y.
Ichihara, T.
Taketani, A.
Tanida, K.
Watanabe, Y.

RIKEN Spin Program (RSP) Research Associates
Kobayashi, H. (9/30/03)*
Yokkaichi, S.
Tabaru, T.
Torii, H.

RIKEN Spin Program/ Visiting Scientists
Kurita, K.
Lange, J. S. (4/1/04)*
Li, Zheng
Ogawa, A.
Saito, N.

*Terminates

Advisory Committee

Experiment
Masaike, A.
Nagamiya, S.
Sandweiss, J.

Consultants
Jaffe, R.
Roser, T.
Makdisi, Y.
Tannenbaum, M.

RBRC Young Researchers
Siegle, V. (3/31/03)
Gabbert, Dominik

RIKEN Jr. Res. Assoc.
Fukao, Y.
Hachiya, T.
Horaguchi, T.

Visiting Res. Assoc.
Kiyomichi, A.
Sato, H.
Tojo, J.

RIKEN Researchers
Okamura, A.

RIKEN Young Res.
Kamihara, N.
Okada, H.
Togawa, M.

Technical Collaborator
Hiejima, H. (UIUC)

4/1/04

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T. D. Lee, RBRC Director Emeritus
Hideto En'yo, RBRC Associate Director

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Anthony J. Baltz, Deputy Theory Group Leader
RBRC Research Scientists (April 1, 2004)

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Yamazaki, T.
Yuan, Feng

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Trueman, T. L.

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Stephanov, M.*	(U. of IL, Chicago)
van Kolck, U. *	(Arizona)
Vogelsang, W.	(BNL)
Wettig, T. *	(Yale)

Computer Scientist
Dong, Z.

*Appointment will terminate RSP = RIKEN SPIN PROGRAM

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T. D. Lee, RBRC Director Emeritus
Hideto En'yo, RBRC Associate Director
* * * *

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Gerry Bunce, Deputy Group Leader

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Fellows
Kawall, D.
Xie, W.

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RBRC Young Researchers
Gabbert, Dominik
RIKEN Jr. Res. Assoc.
Fukao, Y.
Hachiya, T.
Horaguchi, T.
Kajihara, F.
Takano, J.
Tsuchimoto, Y.
Visiting Res. Assoc.
Kiyomichi, A.
Sato, H.
Tojo, J.
RIKEN Researchers
Okamura, A.
RIKEN Young Res.
Kamihara, N.
Okada, H.
Togawa, M.

Technical Collaborator
Hiejima, H. (UIUC)

THEORETICAL PHYSICS AT RIKEN BNL RESEARCH CENTER—STRONG INTERACTIONS AND QCD

Larry McLerran

Theoretical Physics at RIKEN-BNL Center

Strong Interactions and QCD

How are strongly interacting particles made from fundamental constituents?

How do fundamental interactions of QCD produce mass and confinement?

What is the behavior of strongly interacting matter in bulk?
Nuclear Matter $\longrightarrow$ Quark Gluon Plasma

What is the physics beyond the standard model?
Tests of CKM matrix.

All issues intertwined!
Require understanding and computation.

Current Interests in RIKEN-BNL Center

Lattice Gauge Theory

Masses and matrix elements of hadrons
CKM matrix
Properties of QGP and hadronic matter

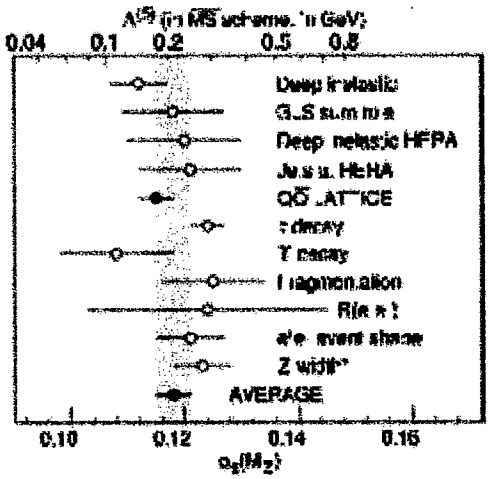
Color Glass Condensate and Quark Gluon Plasma

RHIC Phenomenology
Everything for $x \leq 10^{-2}$

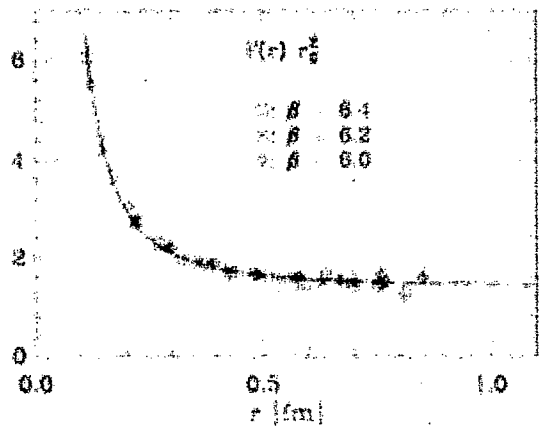
Structure of Hadrons

Origin of spin
Quark and gluon distribution functions
Perturbative QCD at RHIC and LHC

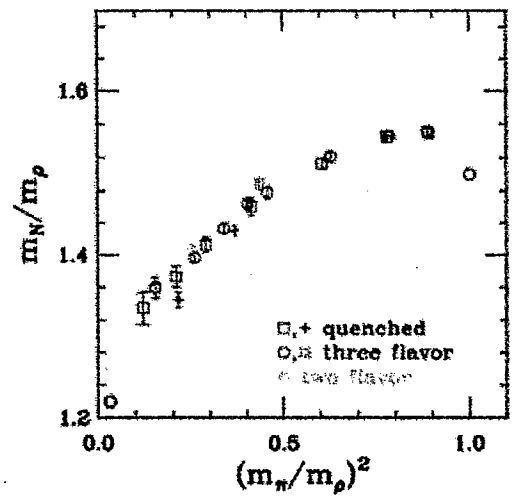
Lattice Gauge Theory



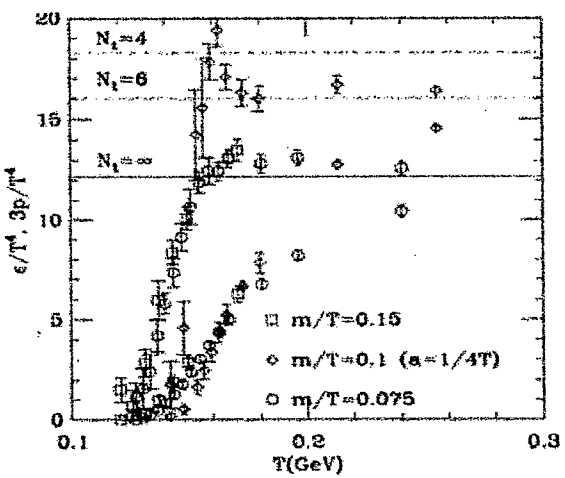
Tests QCD



Tests Confinement



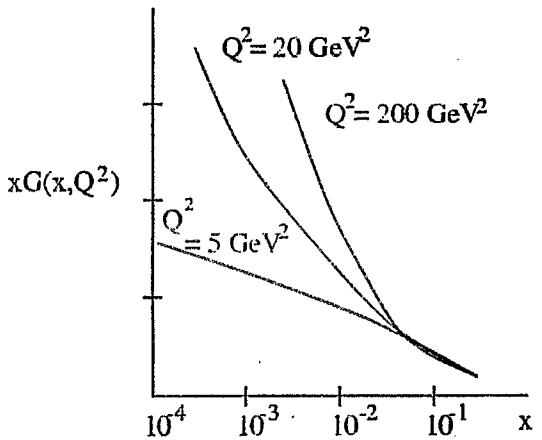
Computes Masses



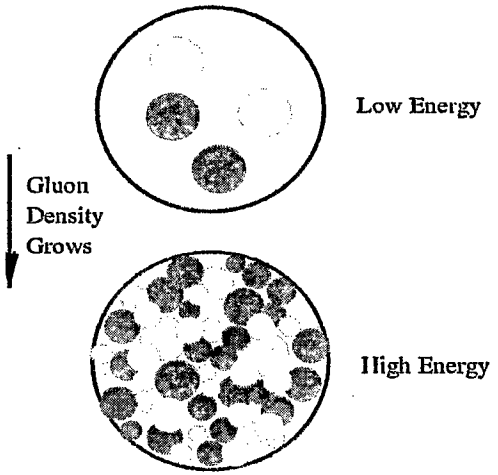
Compute Finite T QCD

QCDOC Project promises 10+ TFlops
Allowing great progress for realistic computations
with realistic quark masses

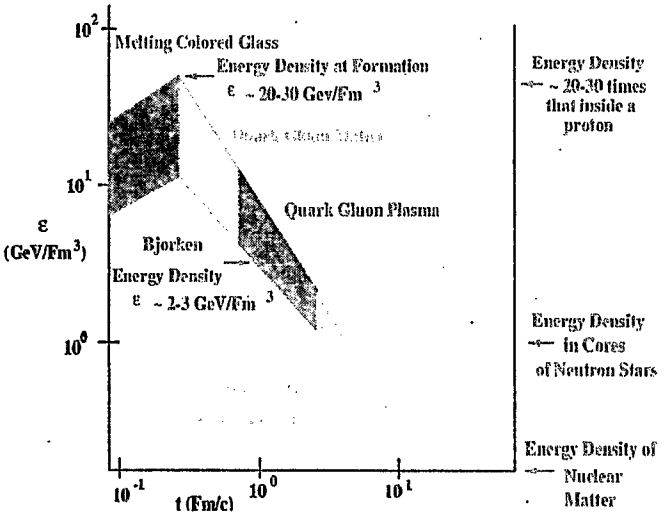
Matter at High Density



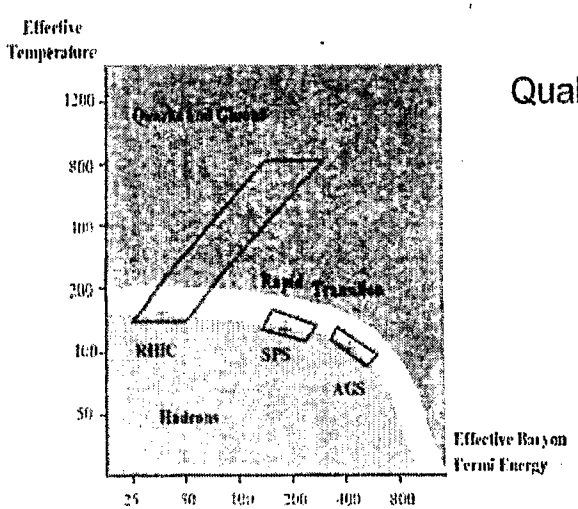
High Energy => High Gluon Density



High Density => Short Distances



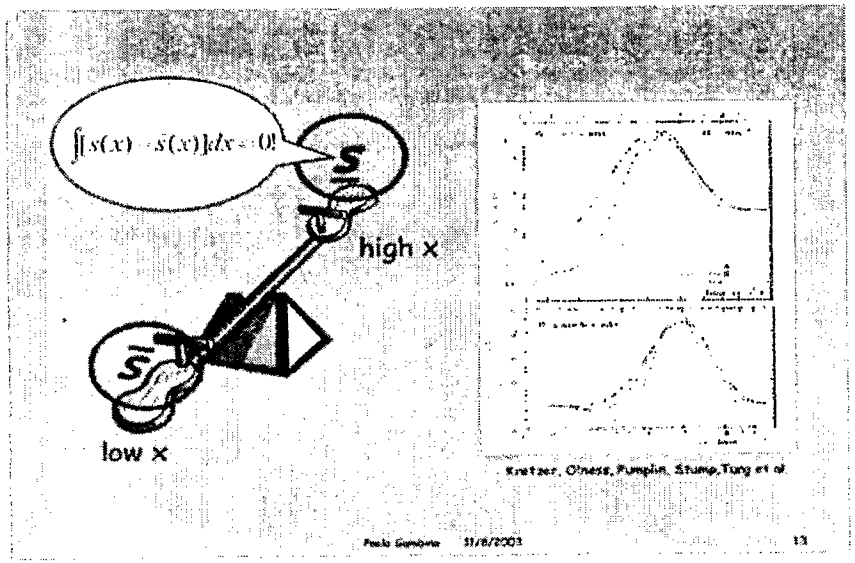
Energy Density High
Matter Strongly Interacting
Quark Gluon Plasma

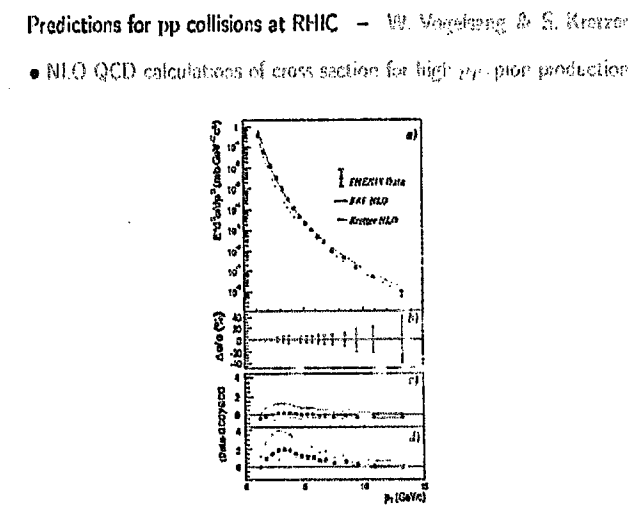


Qualitatively New Region
Of Phase Space

Strongly Interacting QGP
Color Glass Condensate

Spin and Perturbative QCD





Spin structure functions
Flavor Content of the sea

High pT production
Baseline for CGC
And QGP predictions

Why is BNL a Good Place to Study QCD?

T. D. Lee
RHIC
QCDOC

Strong theory groups:
BNL, Columbia, Stony Brook

In both HEP and NP strong interest in theory and experiment

Supportive atmosphere for young people

Relations

QCDOC and Lattice Gauge Theory

Joint Columbia-RBRC Project
NT hired Jung as Junior Faculty
NT hired Petreczky as RBRC fellow
Offer out to Karsch for Senior Scientist
with funds available for various junior faculty

Spin and pQCD

Vogelsang became joint BNL RBRC fellow
Kretzer a joint PD with NT
Koike visits for 1 year
PD fellow in RBRC works with Vogelsang

RHIC Physics

Strong collaboration continues.

RIKEN-BNL Physics Fellows

Graduates

D. Bodeker, Tenured C4, Bielefeld
D. Kharzeev ,, Tenured BNL
D. Rishke, Tenured C-4 Frankfurt
D. Son, Tenured U of Washington
R. Venugopalan, Tenured BNL
T. Wettig, Tenured C-3 Regensburg
M. Stephanov Tenured U of Ill, Chicago
U. Van Kolck, Tenured U of Arizona
T. Schaefer, Tenured U of N. Carolina
A. Kusenko, Tenured UCLA

Current Fellows

S. Bass, Duke
T. Izubuchi, Kanazawa
S. Jeon, McGill
T. Blum, U of Connecticut
W. Vogelsang, BNL
P. Petreczky, BNL

In Negotiation:

UCLA, Maryland, Purdue,
Iowa State, Stony Brook,
Illinois, Arizona……

RBRC EXPERIMENTAL GROUP AND WAKO BASE

Hideto En'yo/Gerry Bunce

RBRC Experimental Group and Wako Base

Activity Summary from
the organizational point of view

MSC meeting, 25-26 March 2004

Hideto En'yo

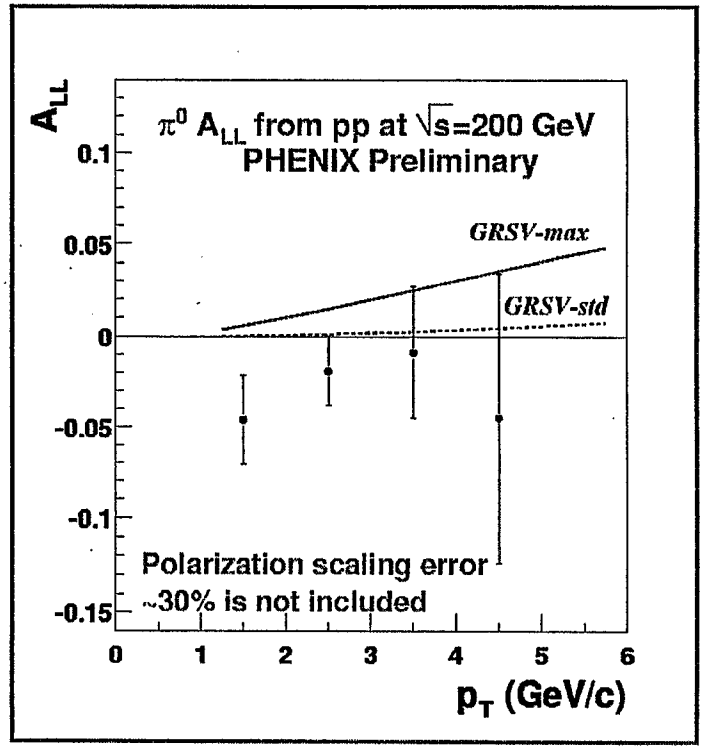
1

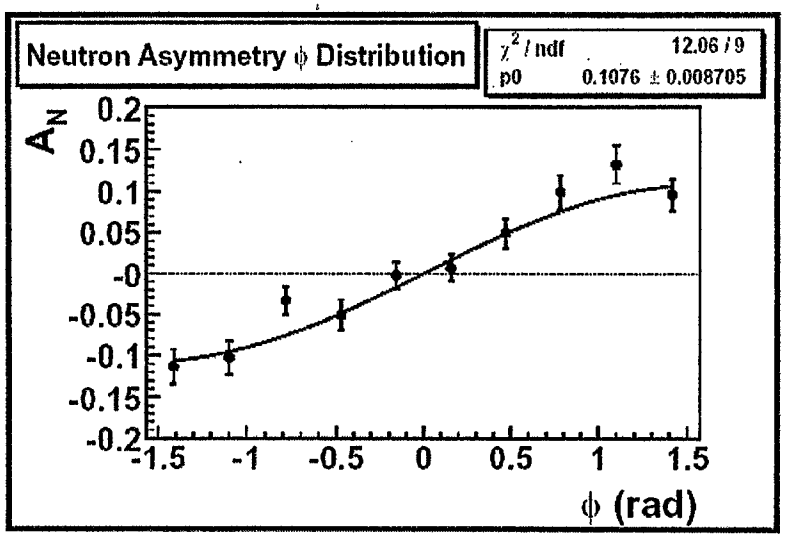
We Have Data Now !

- Although we still need significant progress in Polarization and Luminosity, surprises from RUN2 and RUN3

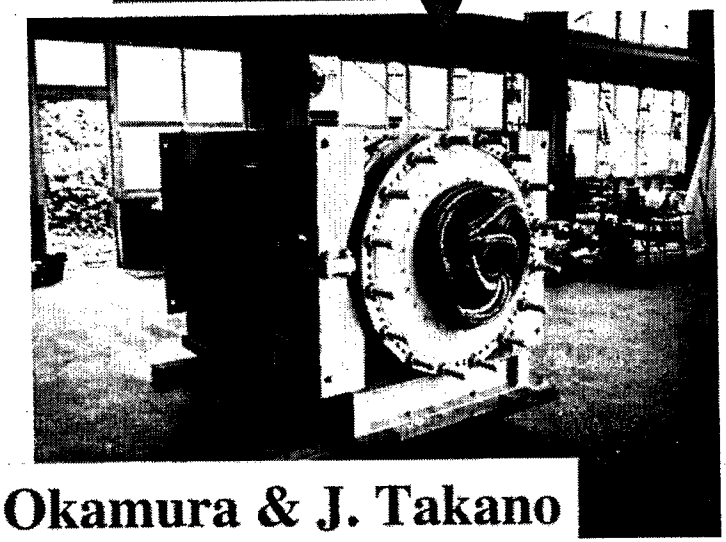
  Y.Goto's presentation

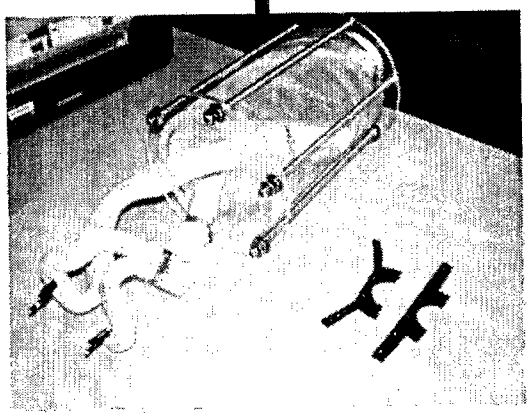
- *Important addition, AGS snake, was completed as promised a year ago, and now in operation.*





AGS warm snake, made in Japan



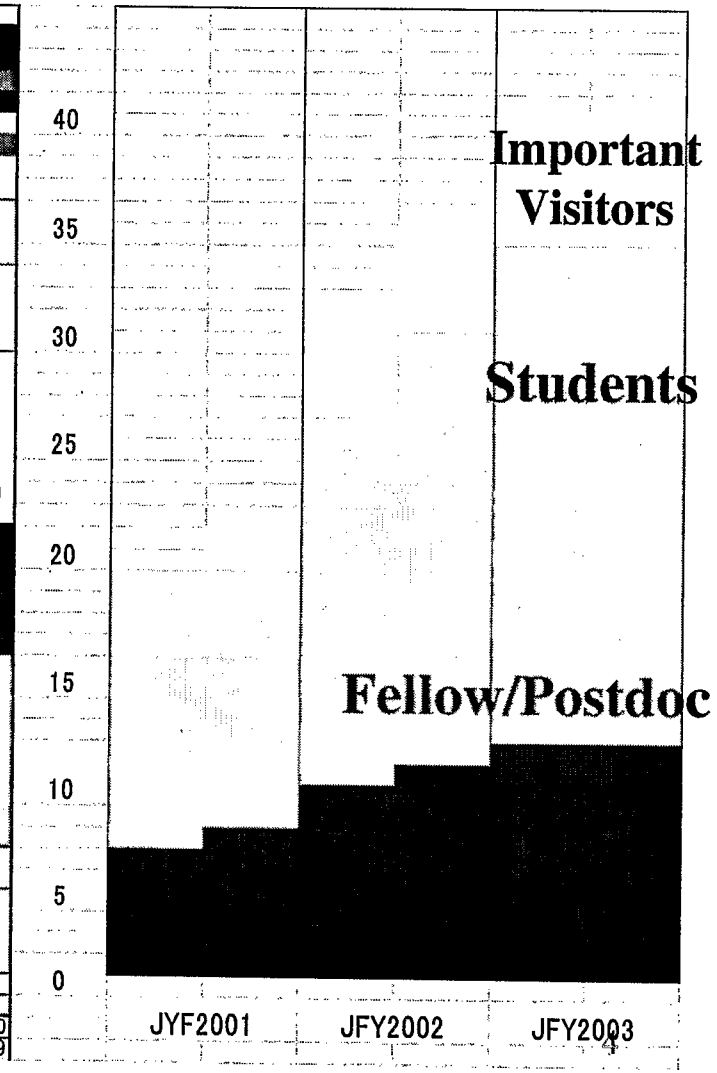


M. Okamura & J. Takano

3

Member of RBRC Experiment 2003

	03Status		2001	2002	2003
	Admin	H.Enyo			
		G.Bunce			
RBRC	Fellow	M.Perdecamp			
		A.Deshpande			
		B.Fox			
		D.E.Fields			
		F.Messor			
		A.Bazilevski			BNL
	RA	M.Kaneta			
		K.Okada			
		O.Jinnnouchi			
	RSP RA	H.Kobayashi			
		T.Tabaru			
		T.Kawabata		Tokyo-U	
		H.Torii			
	RSP VR	N.Saito		Kyoto U	
		K.Kurita		Rikkyo-U	
		J.Mirata	RIKEN>Rikkyo		
		H.Sato			Kyoto-U
		S.Lange	Frankfurt-U		
		A.Ogawa	PenState>BNL		
		Z.Li			BNL instrumentation
		H.Hiejima		Ilinois-U	
RIKEN	Tenure	T.Ichihara			
		Y.Watanabe			
		A.Taketani			
		K.Tanida			
		Y.Goto			
		Y.Akiba			
	RA	S.Yokkaichi			
		H.Ohnishi			
		J.Tojo			
		T.Chujo			
		R.Rykov			
		J.Hauser			
		K.Hasuko			
		H.Kano			
		A.Kiyomichi			
Student	TITech	N.Kamihara			
		T.Horaguchi			
	Kyoto	M.Togawa			
		Y.Fukao			
		H.Okada			
		K.Aoki			
	Heiderberg	V.Siegle			
	Hiroshima	T.Hachiya			
		Total	19 21	31 35	40 40
		Visitor	0 2	4 5	7 9



Experiment G. Organization JFY03

UPGRADE@CERN
Hiroaki Ohnishi
Johann Hauser
Hiroyuki Kano

RIKEN@RBRC
Yasuyuki Akiba
Yuji Goto
Hideyuki Kobayashi
Takahiro Kawabata
Tsuguchika Tabaru

RBRC STUDENTS
Hiroki Sato
Viktor Siegel
Nobuyuki Kamihara
Takuma Horaguchi
Manabu Togawa
Yoshi Fukao
Hiromi Okada
Takashi Hachiya

RBRC
Hideto Enyo
Gerry Bunce
Matthias Grosse Perdekamp
Abhay L Deshpande
Douglas E. Field
Brendan Fox
Alexander Bazilevsky
Kensuke Okada
Osamu Jin-nouchi
Masashi Kaneta
Naohito Saito (Visitor)

~40 active member
+~3 active visitors

BELLE
Soeren Lange (Visitor)
Akio Ogawa (Visitor)
Kazumi
Hasuko(RIKEN)

RIKEN/Wako

Masahiro Okamura
Kiyoshi Tanida
Atsushi Taketani
Rykov Vladimir
Junji. Tojo
Hisa Torii
Tetsuya Chujo

WAKO/CCJ
Takashi Ichihara
Yasushi Watanabe
Satoshi Yokkaichi
Akio Kiyomichi

New Movements

- RIKEN+RBRC is now the second biggest PHENIX participating institute next to BNL.
- M.G.Perdekamp (RBRC University Fellow), Yasuyuki Akiba (Started last April as a Vice Chief Scientist of RIKEN/Wako, resident in RBRC) are both appointed as deputy spokes persons of PHENIX collaboration.
- Y. Akiba is now responsible for the construction of the vertex detector upgrade in PHENIX.
- Since Akiba started, RBRC gradually expand the QGP physics activity (1 JRA student now, +2 JRA students in coming year).

Graduations/Promotions/New Comers since last MSC

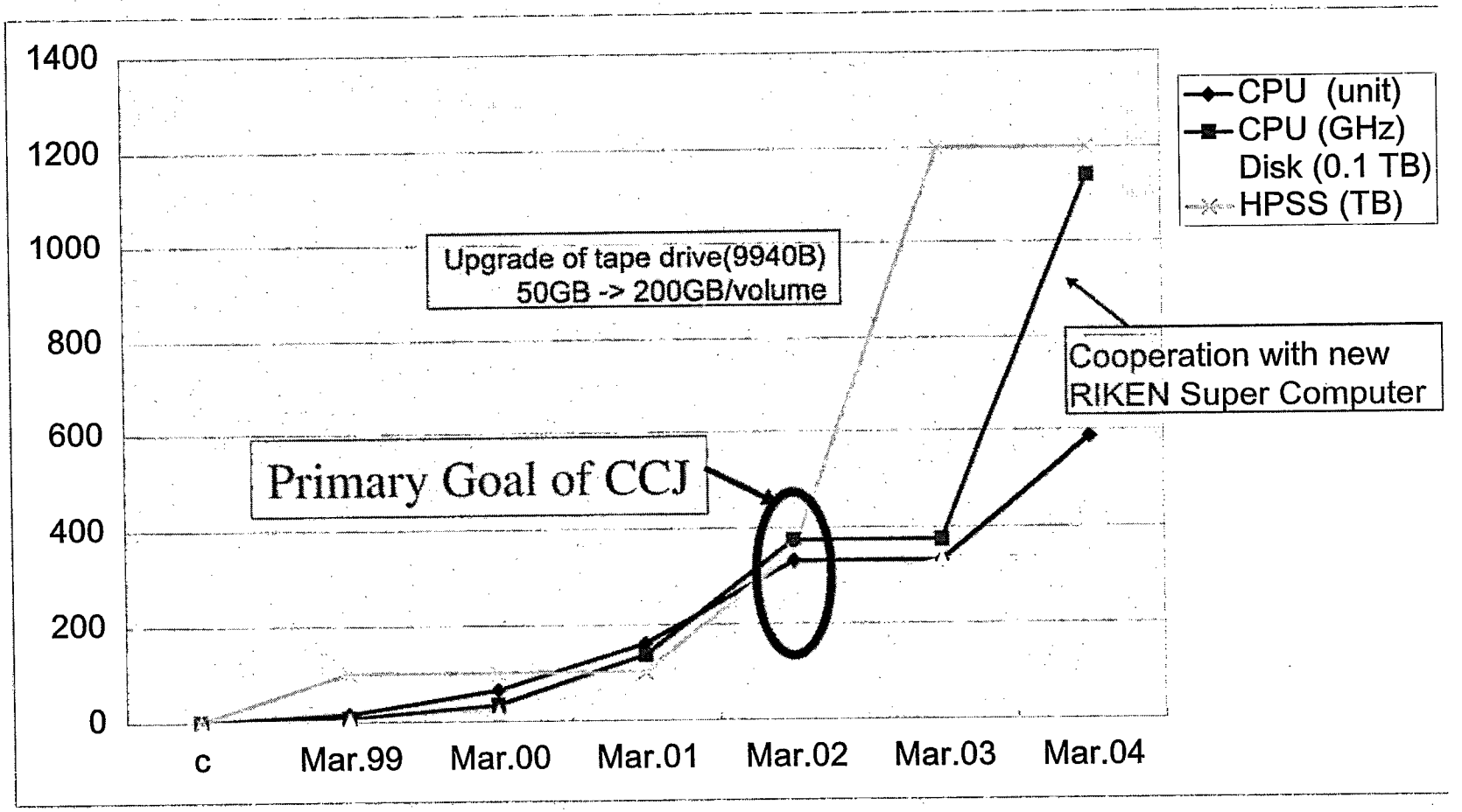
- Yasuyuki Akiba from KEK; Vice Chief Scientist of RIKEN/Wako, resident in RBRC, 1st April '03
- Alexander Bazilevsky; Move to BNL, still a big partner
- Osamu Jinnouchi; became RBRC RA, April '03
- K.Okada; became RBRC RA, April '03
- Hiroki Sato; finished PhD, JSPS *post doctoral* Fellow
- Hisa Torii; RIKEN Spin Program RA (Kiso Tokken)
- Tsuguchika Tabaru; RIKEN Spin Program RA (Kiso Tokken)
- Hiroyuki Kano; RIKEN/Wako postdoc, resident in CERN
- **Masahiro Okamura joined Radiation Laboratory 1st December03**
- **Junkichi Asai will join 1st of April04, RIKEN Spin Program RA (Kiso Tokken)**

- Powerful Fellows,Brendan Fox, Federica Messer, both left due to the personal reason.
- **Wei Xie (Fellow, started Jan. 04)**
- **Dave Kawall (Fellow, starts June 04)**

Students in 2003/2004

- Longtime issue: RIKEN could support students only when they were Junior Research Associate or JSPS fellow.
- Hiroki Sato, now phD, AGS-RHIC Thesis Award, JSPS Fellow
- Established the RBRC Young Researcher (Many Thanks to MSC)
  - Viktor Siegle (Heiderberg) =>Finished his diploma at home
  - Yoshi Fukao (Kyoto-U, RBRC-YR =>JRA from April 03)
  - Takuma Horaguchi (TITech, RBRC-YR=>JRA from April 03)
  - Hiromi Okada (Kyoto-U, became JRA2 from April 03)
  - Takashi Hachiya (Hiroshima-U, became JRA2 from April 03)
  - Kazuya Aoki (Kyoto-U, will be this year's candidate)
  - Junpei Takano (T.I.T, JRA,from April04)
  - Fukutaro Kajihara (Tokyo U, CNS, JRA, from April4)
  - Yuji Tuchimoto (Hiroshima U. JRA, from April 04)
- RIKEN relaxed the limitation for stuents

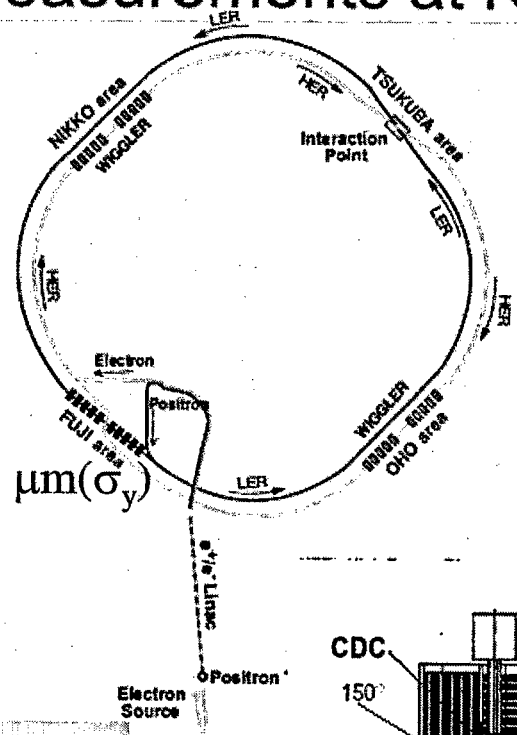
CCJ in JFY2004

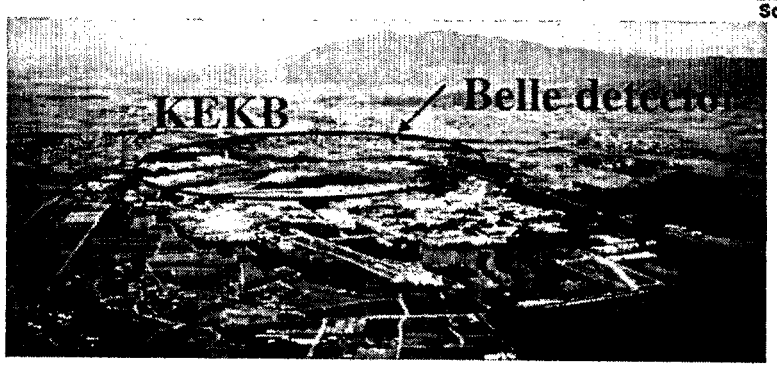


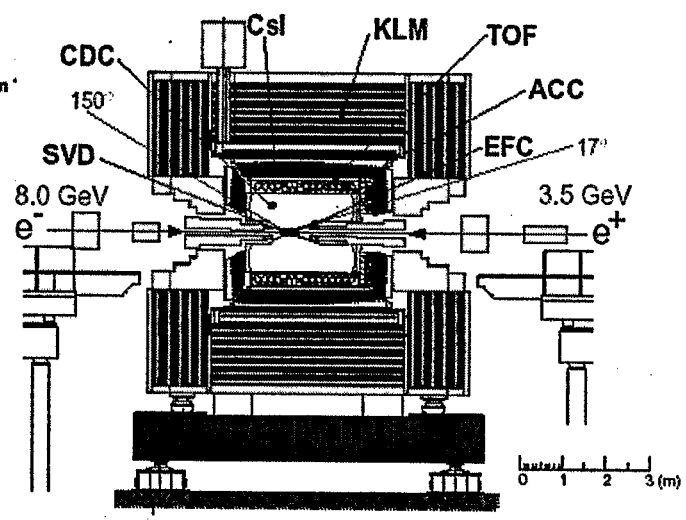
This cooperation helped us a lot,
2-3 time CPU capability with less operation cost
Storage is enough for three years of RHIC data

Prospects of Spin Dependent Fragmentation Function Measurements at KEK-Belle

- KEKB
  - Asymmetric collider
  - 8GeV e^- + 3.5GeV e^+
  - $\sqrt{s}$ = 10.58GeV (Y(4S))
  - Beam size: 100 $\mu m(\sigma_x)$ x 3 $\mu m(\sigma_y)$
  - Crossing angle: 11mrad

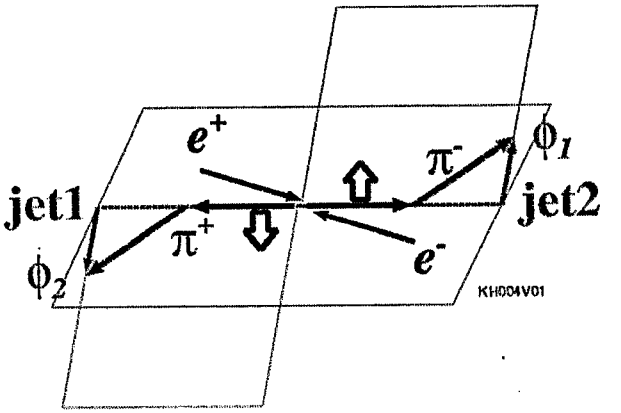




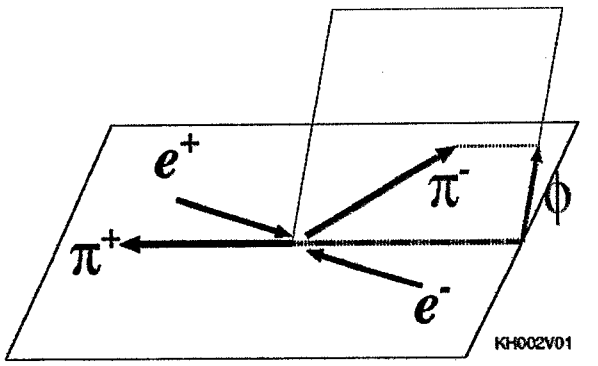


Collins Fragmentation Function

- $e^+e^- \rightarrow \pi^+_{jet1}\pi^-_{jet2}X$
- Reaction plane defined with beam (z-axis) and jet axis
- Product (π) plane defined with π and jet axis
- ϕ: angle between the planes
- $A \propto H_1^{\perp}(z_1) H_1^{\perp}(z_2) \cos(\phi_1+\phi_2)$



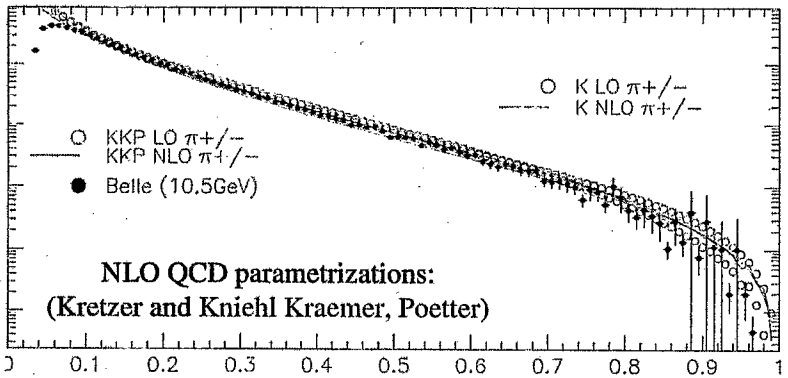
- Can analyze with/without using jet axis
  $A \propto H_1^{\perp}(z_1) H_1^{\perp}(z_2) \cos(2\phi$ Analysis Method



Spin Averaged FF

Viktor Siegle, Soeren Lange, MGP

Charged Pion Fragmentation
with 0.3% of total sample



$$z = \frac{2E_\pi}{\sqrt{s}}$$

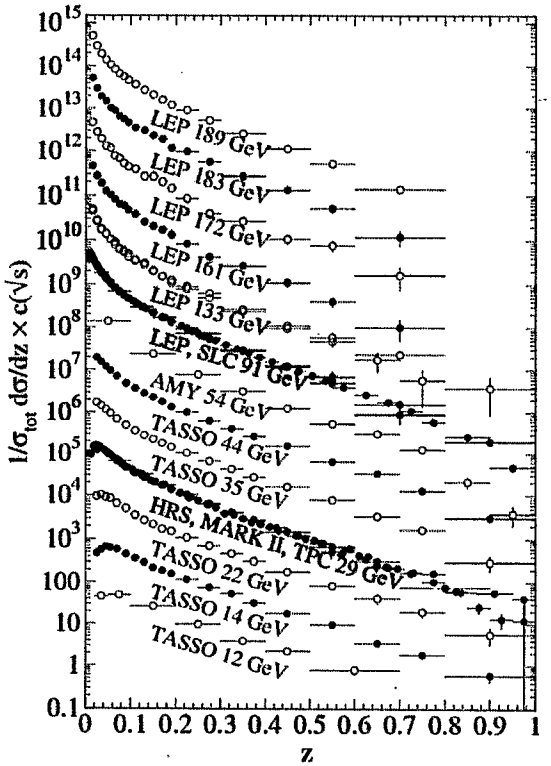
→Belle FFs consistent with LEP

→*VERY* large sample:

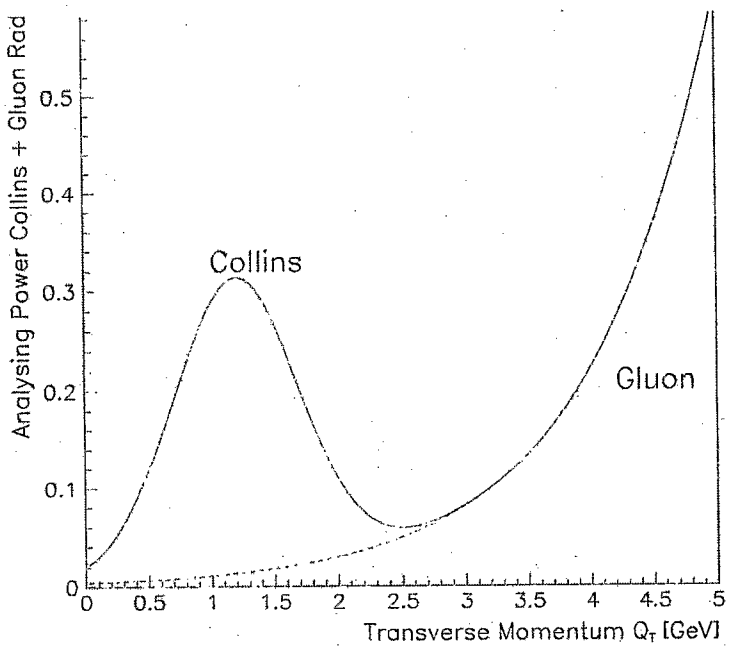
→Inupt for A_{LL} in inclusive hadron production at RHIC?

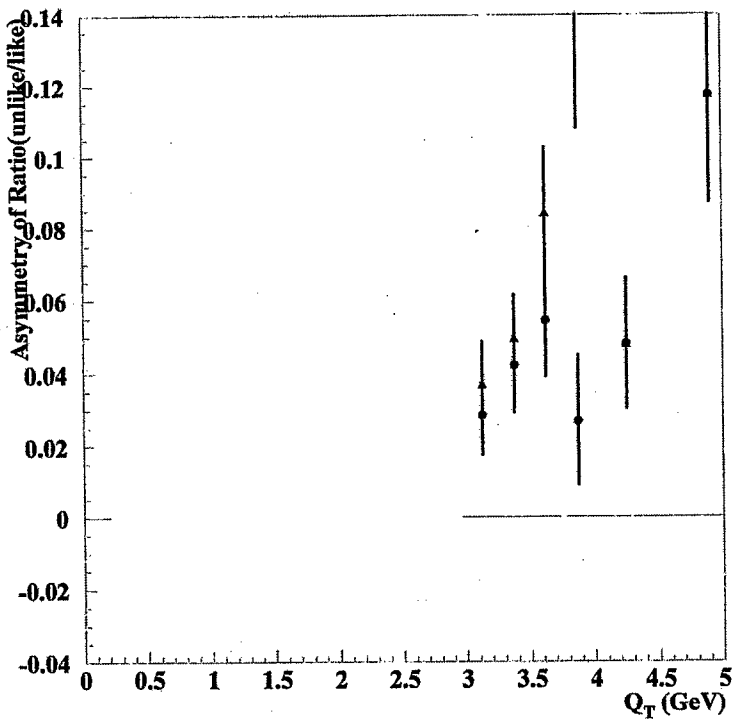
→Map out high z-fragmentation

"World Data" for charged hadrons

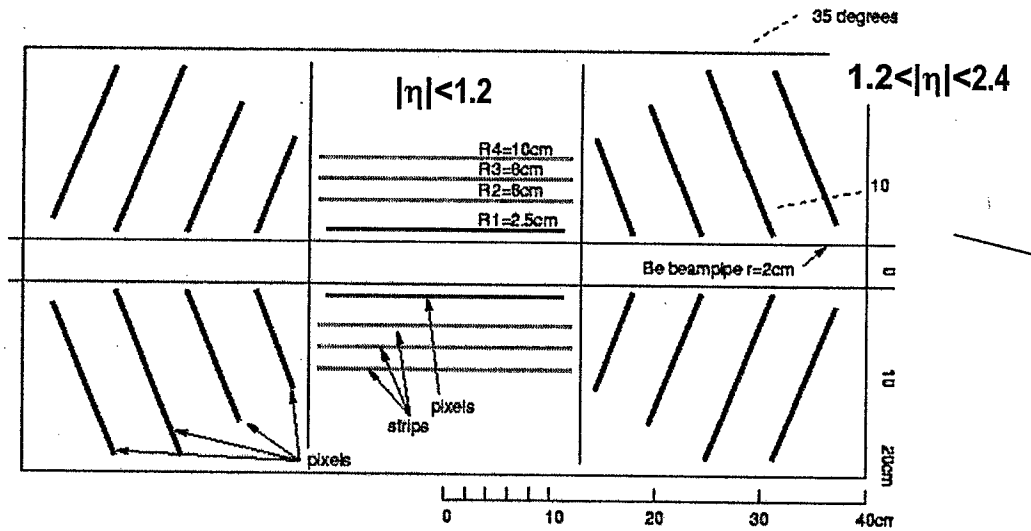


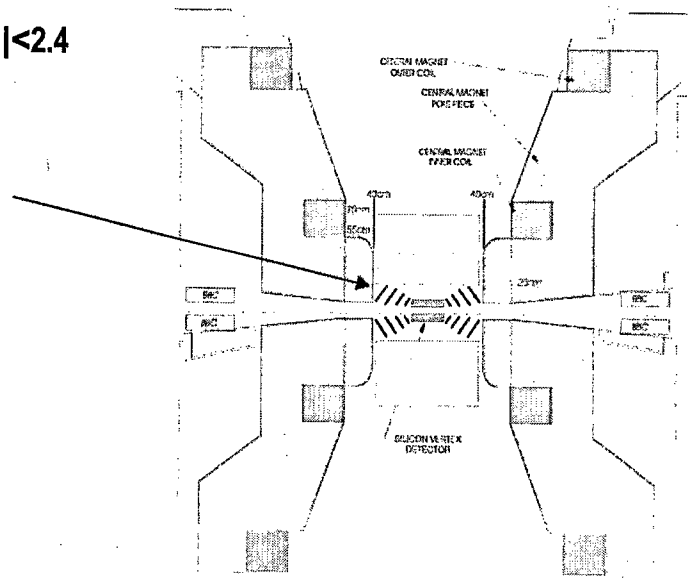
Collins: QCD radiative Background





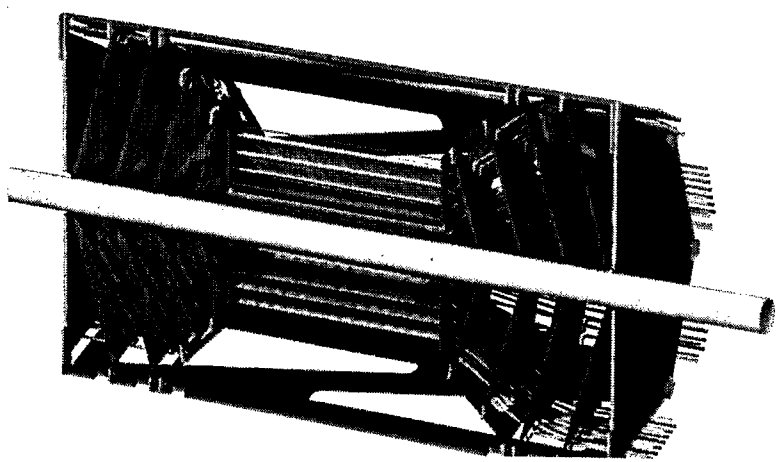
Silicon Vertex Tracker in PHENIX





Pixel barrels **(50 μm x 425 μm)**
Strip barrels **(80 μm x 3 cm)**
(50 μm x 2 mm)

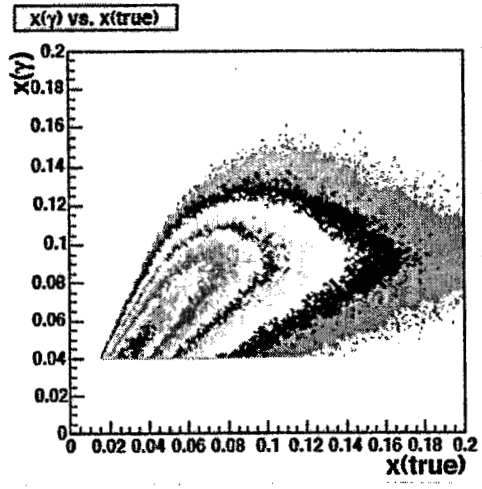
1 - 2% X_0 per layer
barrel resolution < 50 μm
endcap resolution < 150 μm



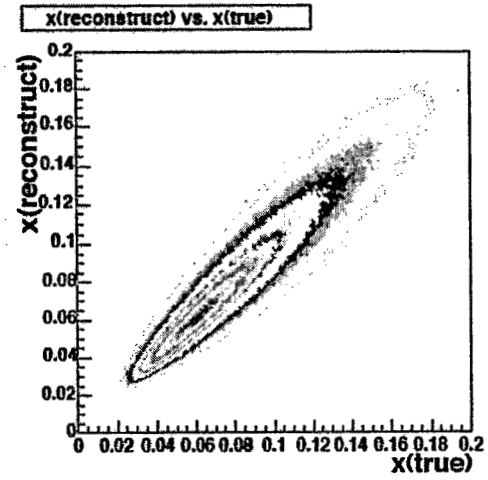
Gamma+Jets

- In p+p or p+A collisions, the VTX works as a stand alone, large solid angle tracker
- The VTX is used to detect the recoil jets in the direct photon events.
- PYTHIA simulation with the VTX acceptance
  - RMS resolution of initial parton x is ~20% with the VTX

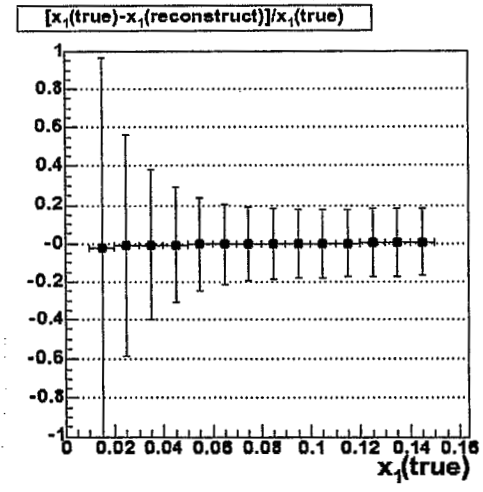
Without the VTX



With the VTX

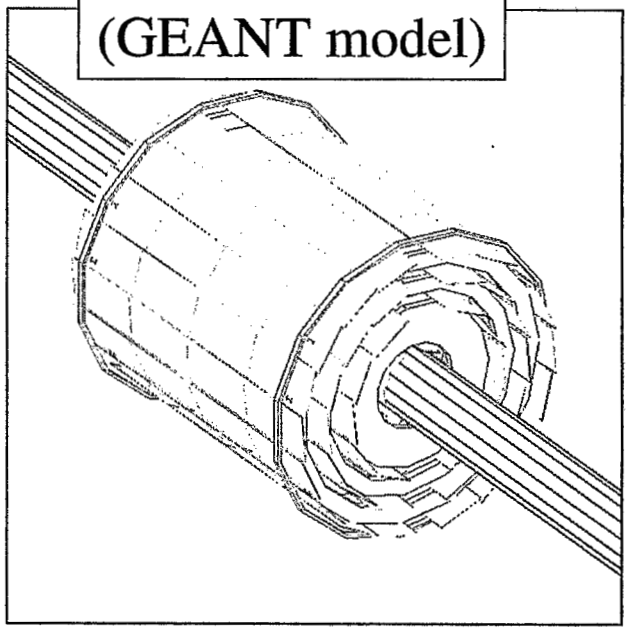


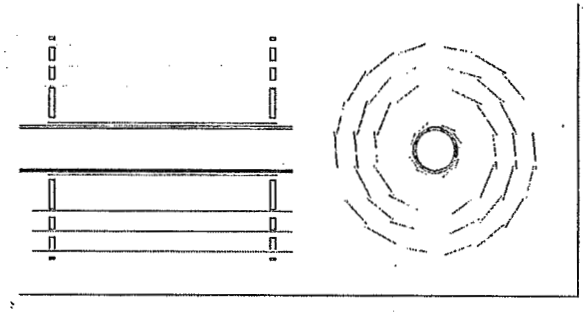
RMS resolution of x_1



Barrel VTX detector

Barrel detector (GEANT model)



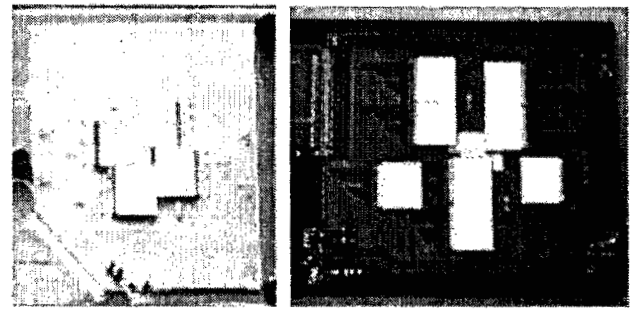


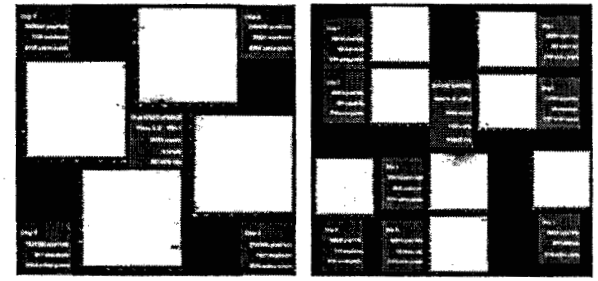
Summary of the parameters of the VTX

VTX	Layer	R1	R2	R3	R4
Geometrical dimensions	R (cm)	2.5	6	8	10
	Δz (cm)	21.8	25.8		
	Area (cm^2)	280	890	1240	1600
Channel count	Sensor size R × z (cm^2)	1.28 × 1.36	3.43 × 6.46		
	Channel size	50 × 425 μm^2	80 μm × 3 cm (effective 80 × 1000 μm^2)		
	Sensors/ladder	2 × 8	4		
	Ladders	10	10	14	18
	Sensors	160	40	56	72
	Readout chips	160	480	672	864
	Readout channels	1,310,720	61,440	86,016	110,592
Radiation length (X/X0)	Sensor	0.2%	0.4%		
	Readout	0.16%	0.7%		
	Bus	0.14%			
	Ladder & cooling	0.7%			
	Total	1.2%	1.8%		

Pixel at CERN (NA60)

- The Pixel detector is used for target spectrometer of NA60 experiment at SPS
- A part of RIKEN and StonyBrook group participates in NA60 to gain experience of using the pixel detector in a real experiment
- The pixel detector worked very well in the recent In+In RUN of NA60
- The success of NA60 run demonstrates the capabilities of the pixel technology:
  - High efficiency
  - Low noise hit rate
  - It worked in extremely high radiation environment (>M rad during the run)

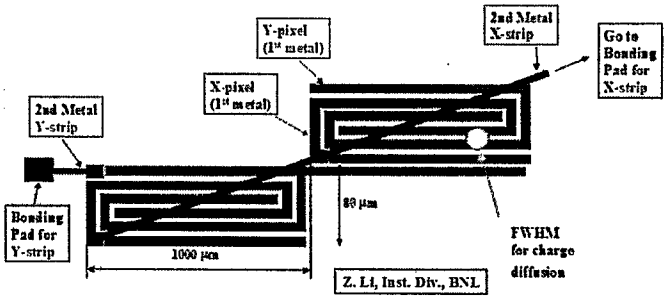




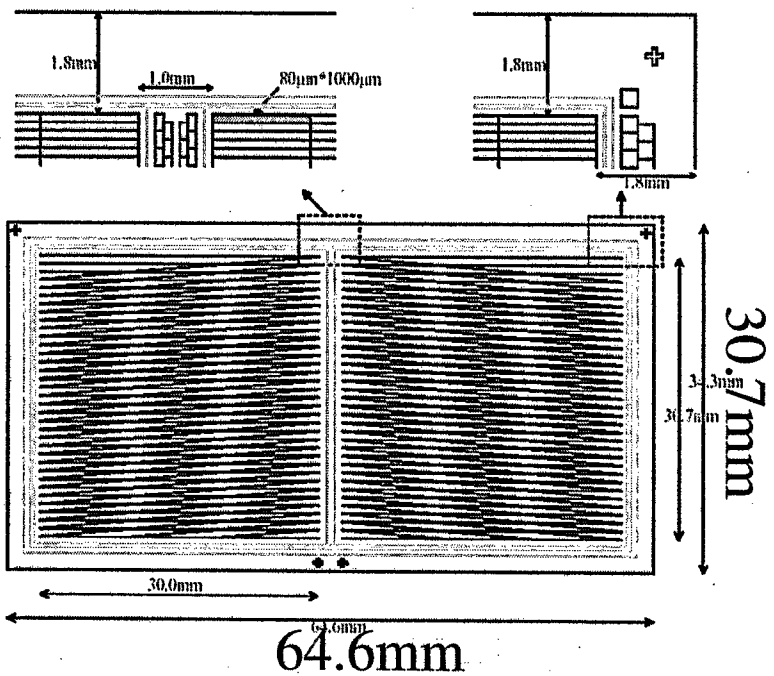
Barrel strips detector

- Outer 3 layers use Si strip detector technology
- Use a novel, single sided, two dimensional read-out sensor developed by Z. Li of BNL Inst. Division
- 80 μ x 3 cm strip
- X/U stereo read-out
- 384 x 2 x 2 per sensor chip (64.6 mm x 30.7 mm)
- V1 prototype was tested by RIKEN group
- V2 prototype 400 μ and 300 μ thick is being made. (Will be delibered in this year)
- 4 sensor chips / ladder
  - R2 (R=6cm) 10 ladders
  - R3 (R=8cm) 14 ladders
  - R3 (R=10cm) 18 ladders

Sensor structure (ver1)



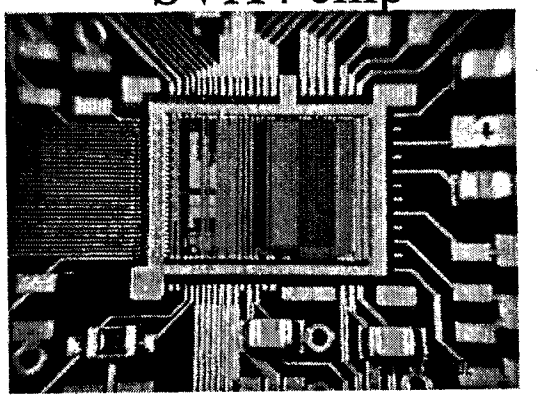
One strip sensor chip

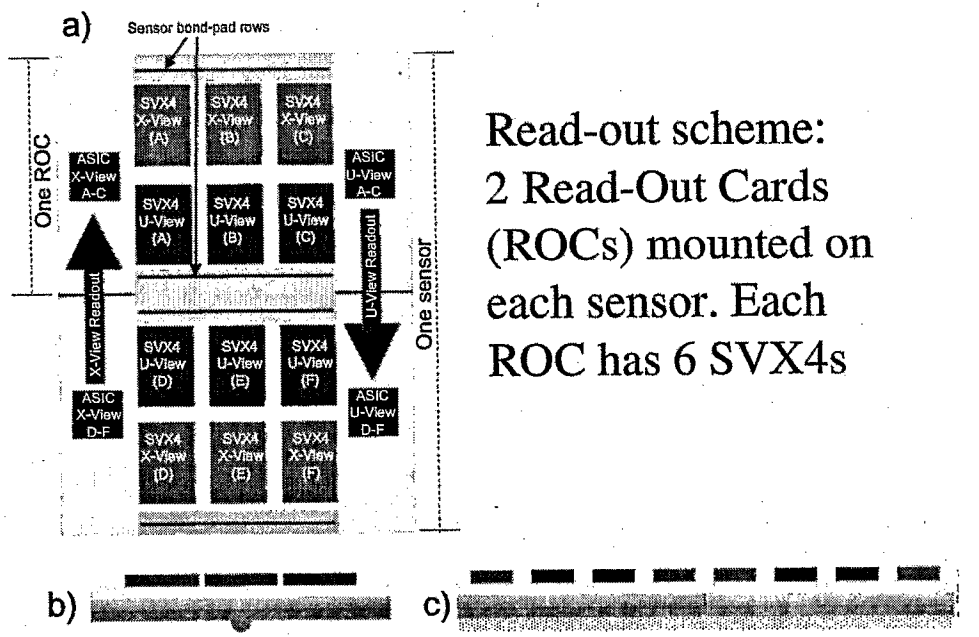


Strips detector read-out

- Use SVX4 chip developed by FNAL/LBNL for the Tevatron SVTX upgrade
  - 128 ch/chip
  - 50 μ pitch read-out
  - 42-deep pipe line
  - On-board 0-suppression
- Designed for AC coupled device. (Z.Li sensors DC-coupled)
  - Frequent storage-cap reset
  - AC/DC conversion by RC chip in the pitch adaptor
- Recently, Tevatron SVTX upgrade project was cancelled. Three are already sufficient SVX4s produced. We are in negotiation with FNAL to purchase these chips.

SVX4 chip

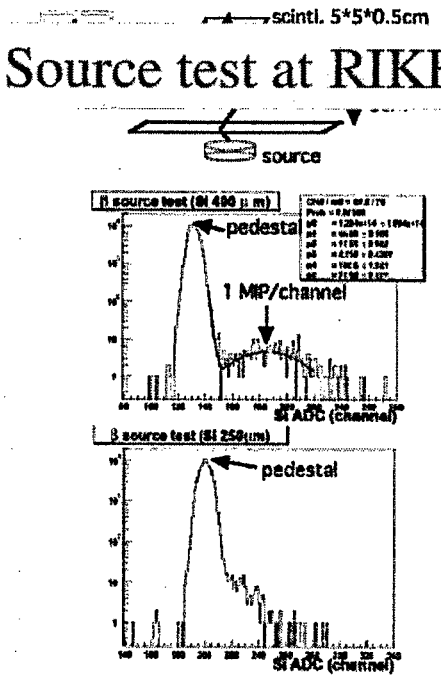




Read-out scheme: 2 Read-Out Cards (ROCs) mounted on each sensor. Each ROC has 6 SVX4s

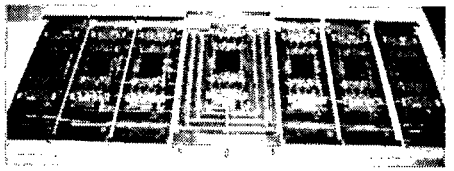
Silicon Vertex Tracker R&D

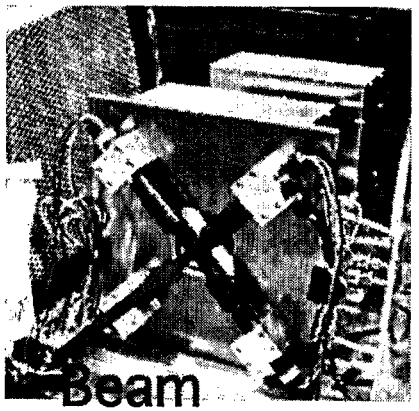
Source test at RIKEN

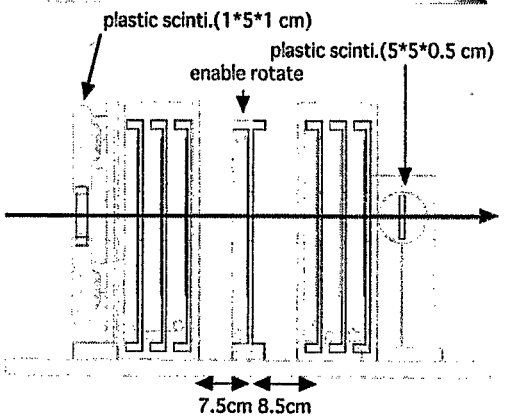


Beam test at KEK by RIKEN/Kyoto

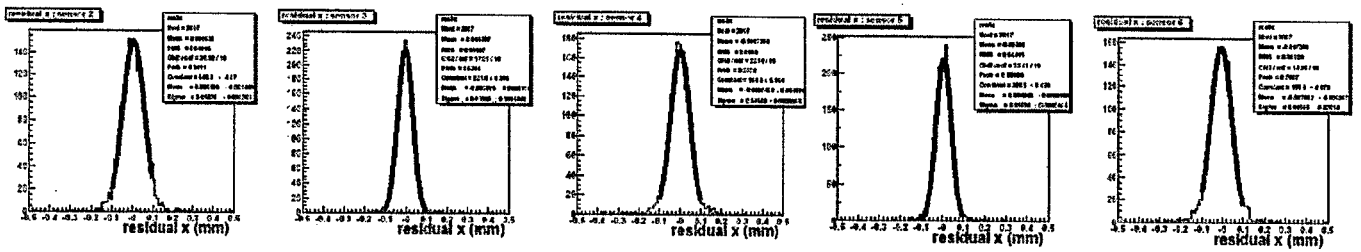
- Location at KEK-PS T1 beam line
- Various particles(0.5-2.0GeV/c)
- We put 7 silicon sensors and 3 scintillators for trigger counters
- CAMAC and VME hybrid







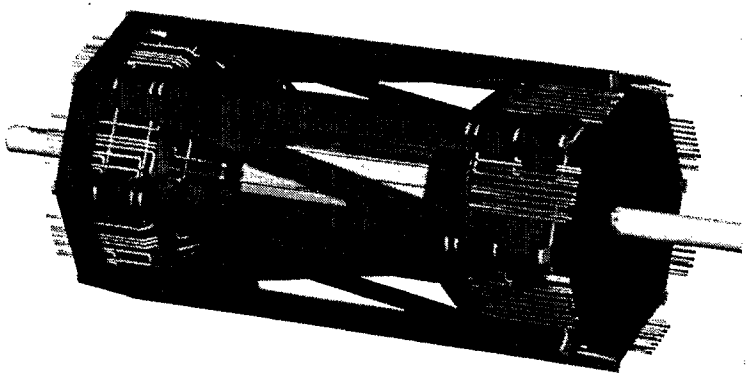
*distance of other sensors is 3cm



$\sigma = 52\mu$ $\sigma = 35\mu$ $\sigma = 45\mu$ $\sigma = 35\mu$ $\sigma \overset{20}{=} 49\mu$

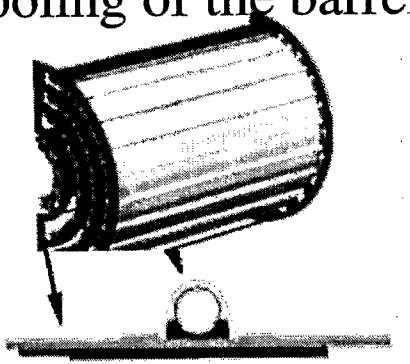
Mechanical structure and cooling

Design of support structure by HYTEC



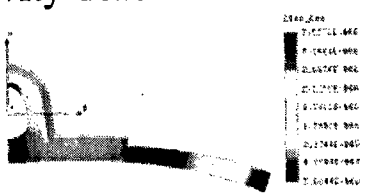
- Different structures were considered
  → Choose single-barrel shape.
- Material: GFRP
- Cooling
- Radiation length: <1% per layer

Cooling of the barrel



FEM analysis

Gravity deformation



Distortion from thermal strains

The world first Polarized Collider
is now producing Physics Results

HEAVY ION PHYSICS AT RHIC: A STATUS REPORT

Samuel Aronson

Heavy Ion Physics at RHIC: A Status Report

What has been measured?

What does it mean?

What is next?

Sam Aronson, BNL

March 24, 2004

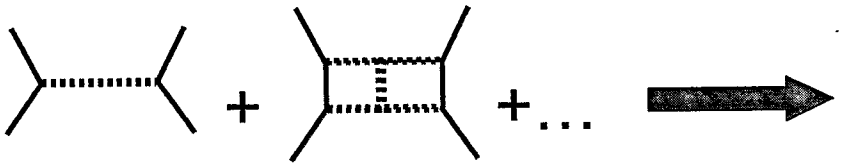
BROOKHAVEN NATIONAL LABORATORY

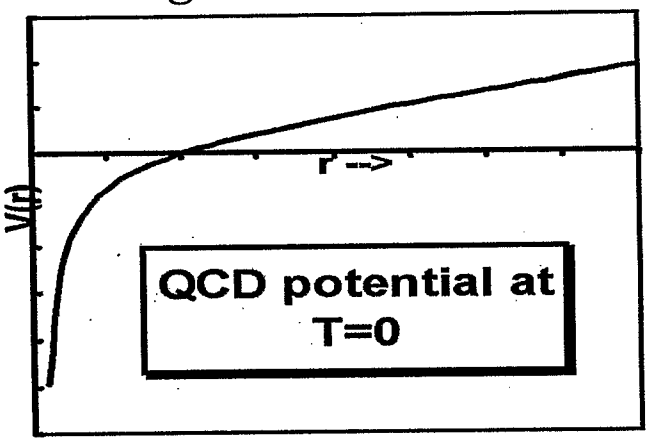
The Physics of Heavy Ion Collisions

- Create very high temperature and density matter
  - as existed a few μsec after the Big Bang
  - hadron-hadron separation comparable to that in neutron stars
  - collide heavy ions to achieve maximum volume
- Study the matter produced
  - how hot and dense is the medium?
  - is thermal equilibrium reached?
  - what are the transport properties and equation of state?
  - do the hadrons dissolve into a quark gluon plasma?
- Collide Au + Au ions at $\sqrt{s}$ = 200 GeV/nucleon pair
  - Study p+p and d+A to compare
  - Also polarized p+p collisions to study nucleon spin structure

Quantum ChromoDynamics at RHIC[3]

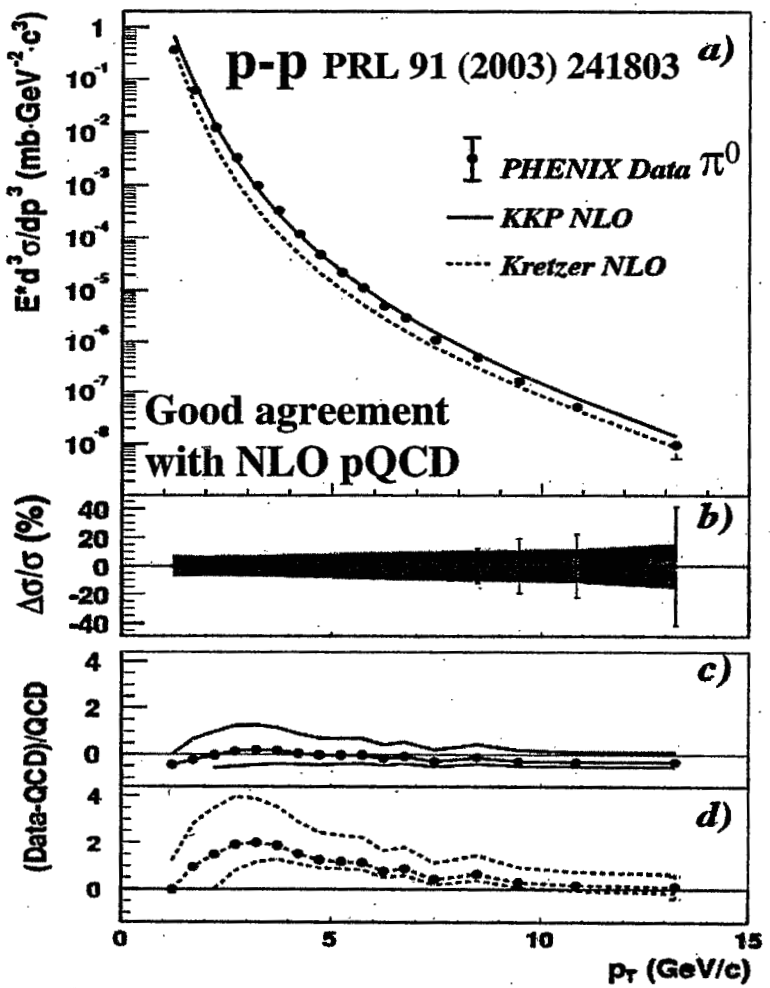
- Color charge of gluons ⇒ they interact among themselves
  - theory is non-abelian
  - curious properties at long distance, including confinement





short distance: force is weak (probe w/ high Q^2, calculate with perturbation theory)
large distance: force is strong (probe w/ low Q^2, calculations must be non-perturbative)
high temperature: force becomes screened by produced color-charges (gets weak)

From simple to complex systems: p+p, p+A, A+A



start with pQCD & p+p collisions: it works!

Have a handle on initial NN interactions by scattering of q, g inside N

We also need:

$f_{a/N}(x, Q^2)$ Parton distribution functions

$D_{h/a}(z_c, Q^2)$ Fragmentation functions

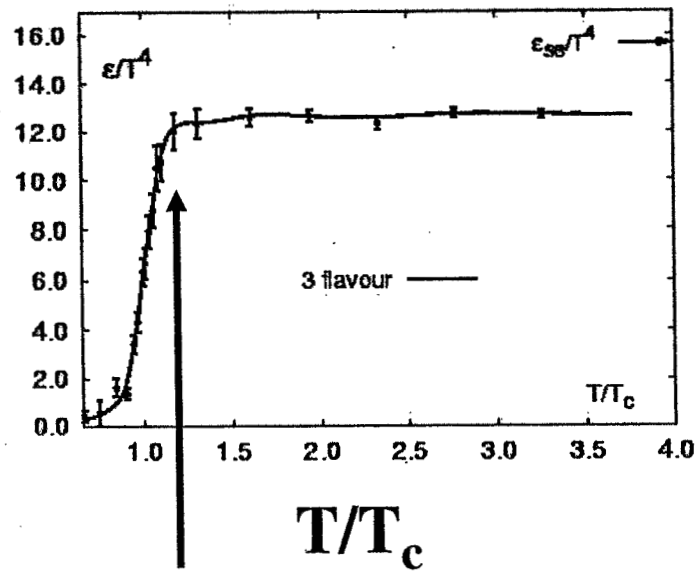
QGP physics is non-perturbative: calculate on **lattice**

we look for physics beyond simple superposition of NN at low momentum/large distance scales:

Equilibration
Collective effects } **EOS**
Energy, color transport in dense medium
Deconfinement?

Karsch, Laermann, Peikert '99

ε/T^4

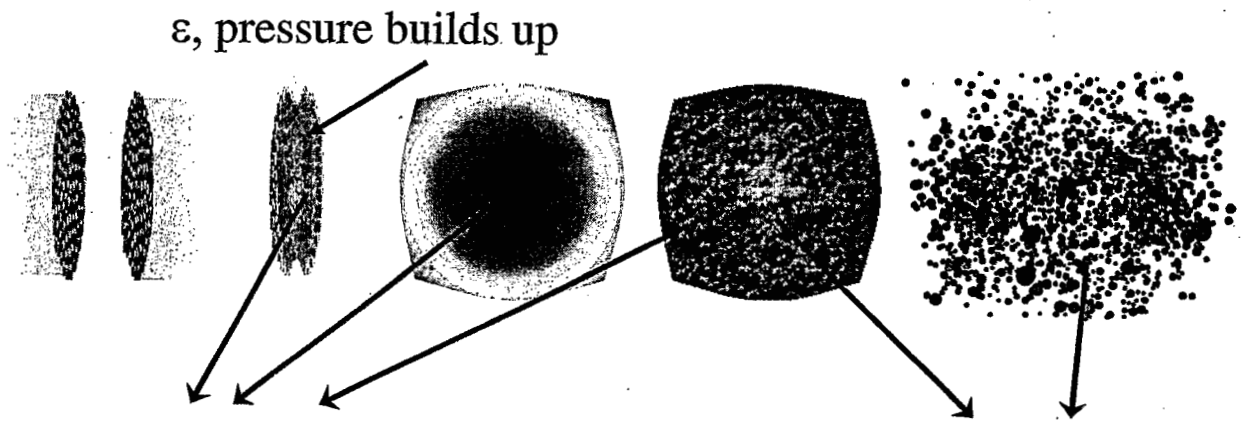


T/T_c

$T_c \sim 170 \pm 10$ MeV $(10^{12}K)$
$\varepsilon \sim 3$ GeV/fm^3

Lattice QCD says we must create these conditions to study quark gluon plasma

history of a heavy ion collision



$\gamma, \gamma^* \rightarrow e^+e^-, \mu^+\mu^-$

Real and virtual photons from quark scattering most sensitive to the early stages.
Probe also with q, g scattered (hard) out of incoming nucleons

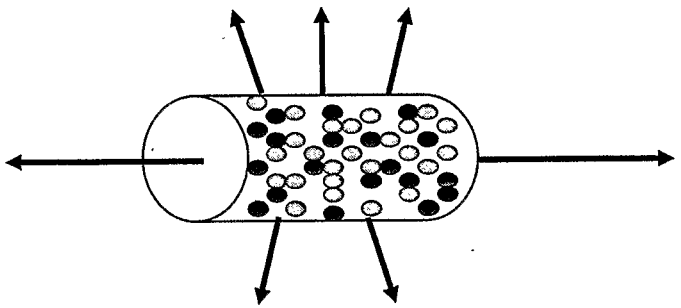
$\pi, K, p, n, \phi, \Lambda, \Delta, \Xi, \Omega, d,$

Hadrons reflect thermal properties when inelastic collisions stop (chemical freeze-out).

focus on mid-rapidity (y=0): the CM of colliding system
90° in the lab at collider

did something new happen at RHIC?

- Study collision dynamics (via final state)



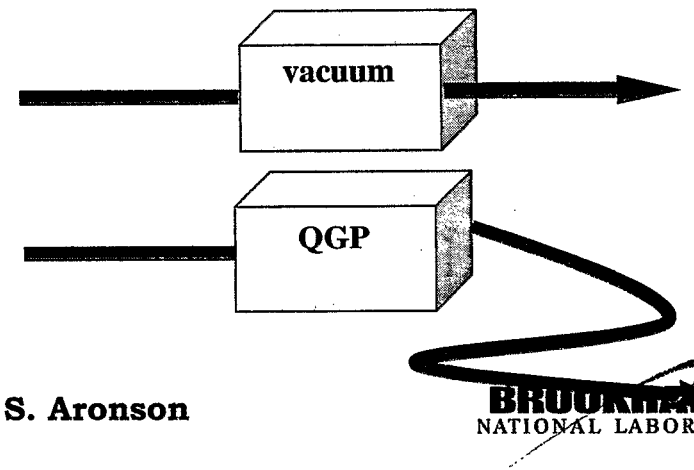
Equilibrium?
→ hadron spectra, yields

Collective behavior?
i.e. pressure and expansion
→ elliptic, radial flow

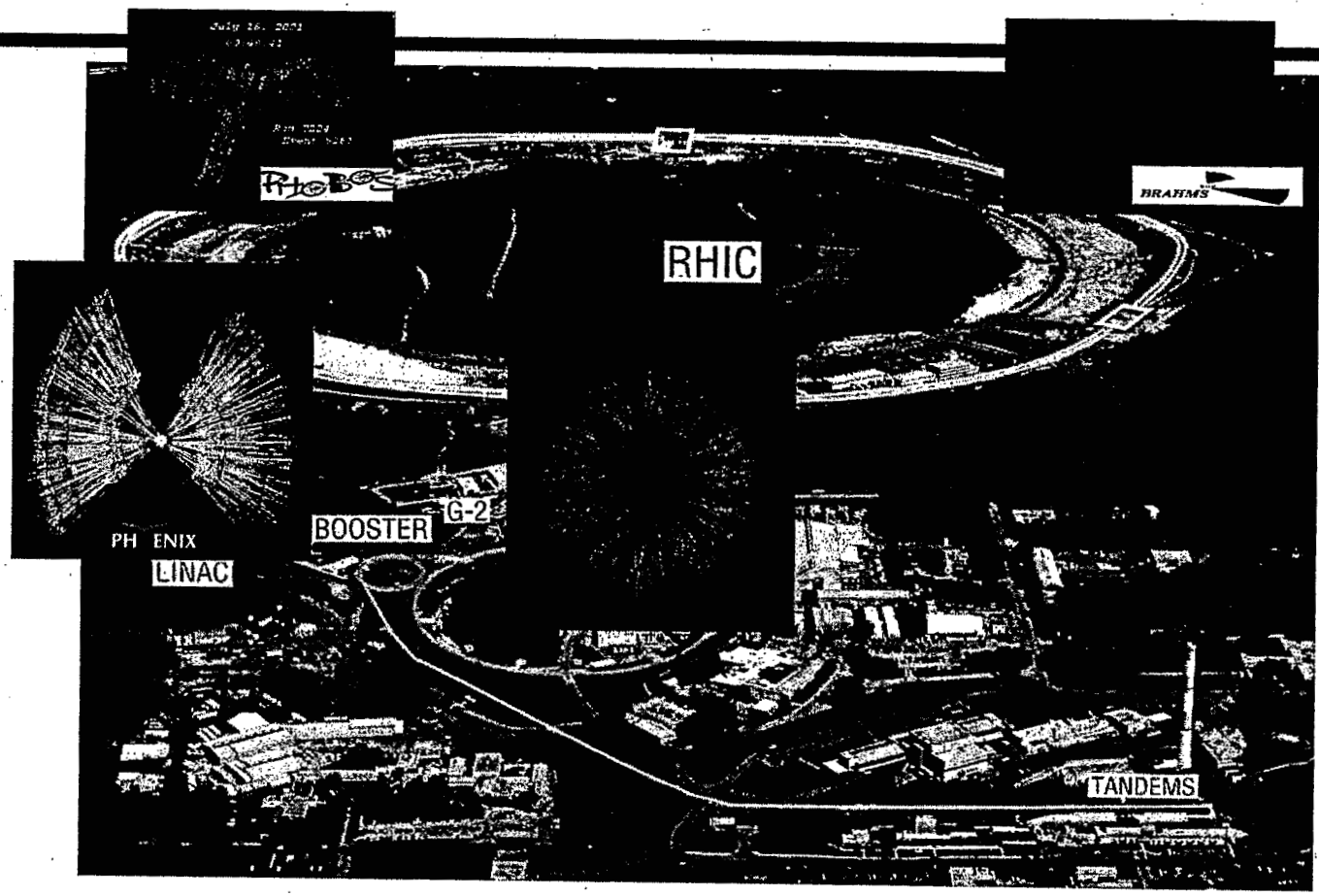
- Probe the early (hot) phase

Create probes in the collision itself:
predictable quantity, interact
differently in QGP vs. hadron matter

fast quarks/gluons, J/ψ, D mesons
thermal radiation



RHIC at Brookhaven National Laboratory

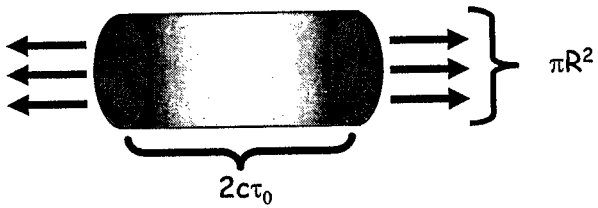


RHIC is first dedicated heavy ion collider
10 times the energy previously available!

Is the energy density high enough?

PRL87, 052301 (2001)

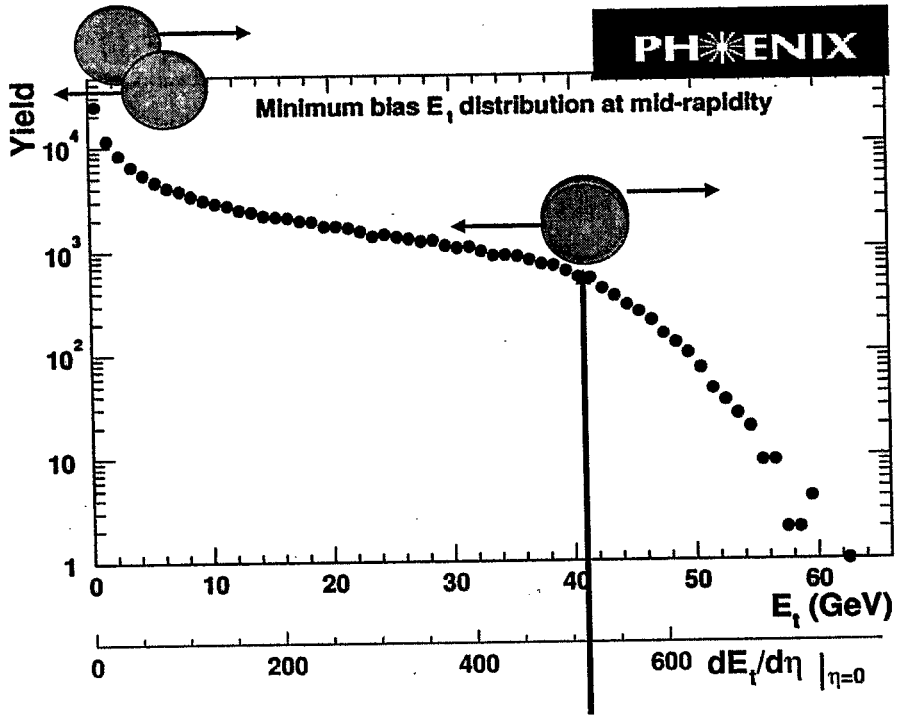
Colliding system expands:



Energy ⊥ to beam direction

$$\varepsilon_{Bj} = \frac{1}{\pi R^2}\frac{1}{2c\tau_0}\left(2\frac{dE_T}{dy}\right)$$

per unit velocity ∥ to beam

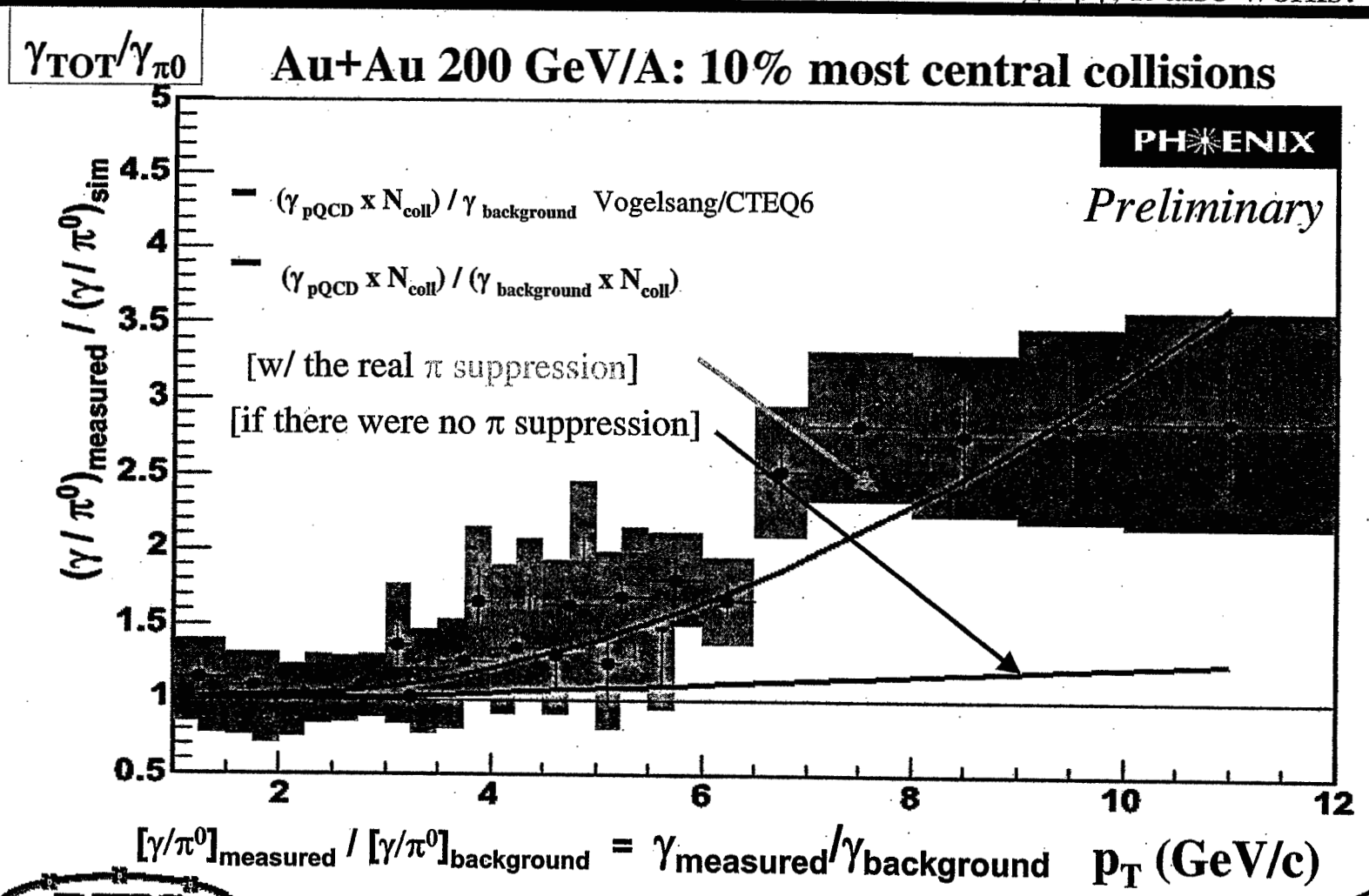


$\rightarrow \varepsilon \geq 5.5\ GeV/fm^3$ (200 GeV Au+Au)

YES - well above predicted transition!

pQCD in Au+Au? direct photons

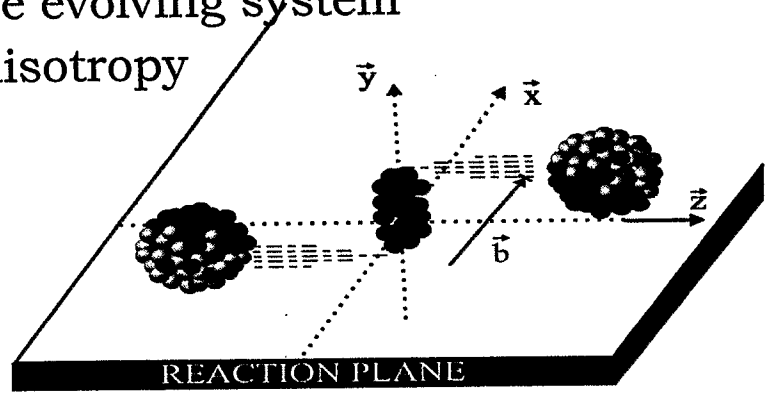
At high p_T, it also works!



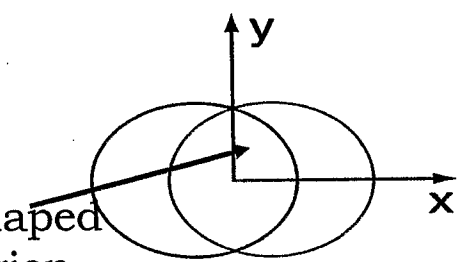
pressure: a barometer called "elliptic flow"

Origin: spatial anisotropy of the system when created, followed by multiple scattering of particles in the evolving system

spatial anisotropy → momentum anisotropy

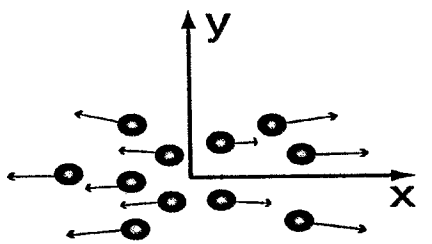


v_2: 2nd harmonic *Fourier coefficient* in azimuthal distribution of particles with respect to the reaction plane



Almond shaped overlap region in coordinate space

$$\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle}$$

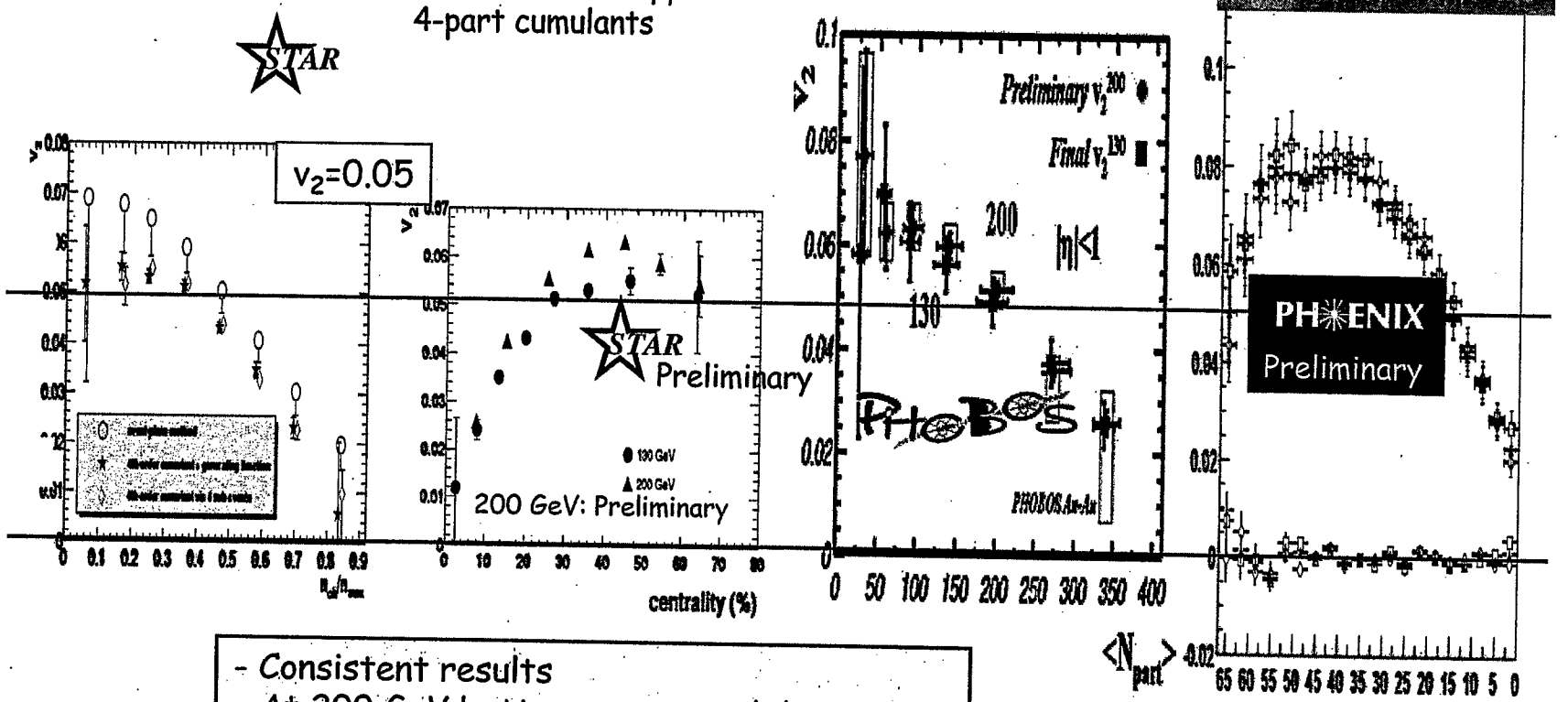


$$v_2 = \langle \cos 2\phi \rangle$$

$$\phi = \operatorname{atan} \frac{p_y}{p_x}$$

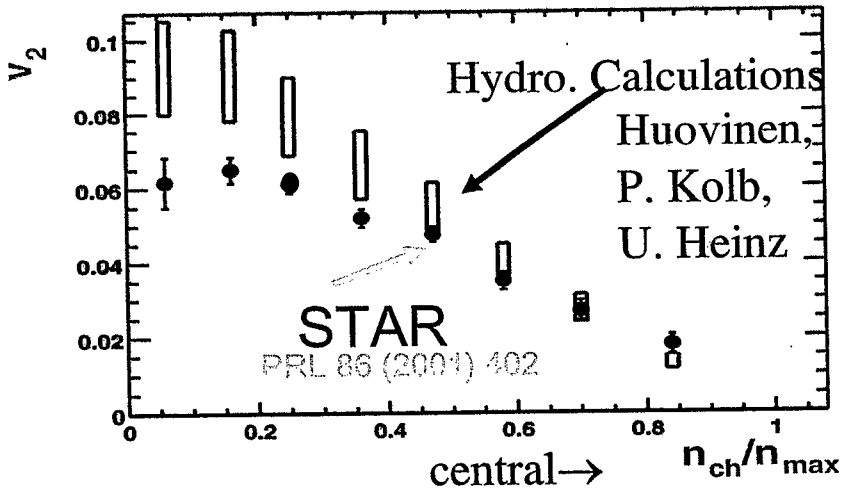
v_2 measured by the experiments

130 GeV: $0.075 < p_t < 2.0$
200 GeV: $0.150 < p_t < 2.0$
4-part cumulants



- Consistent results
- At 200 GeV better pronounced decrease of v_2 for the most peripheral collisions.

v_2 predicted by hydrodynamics

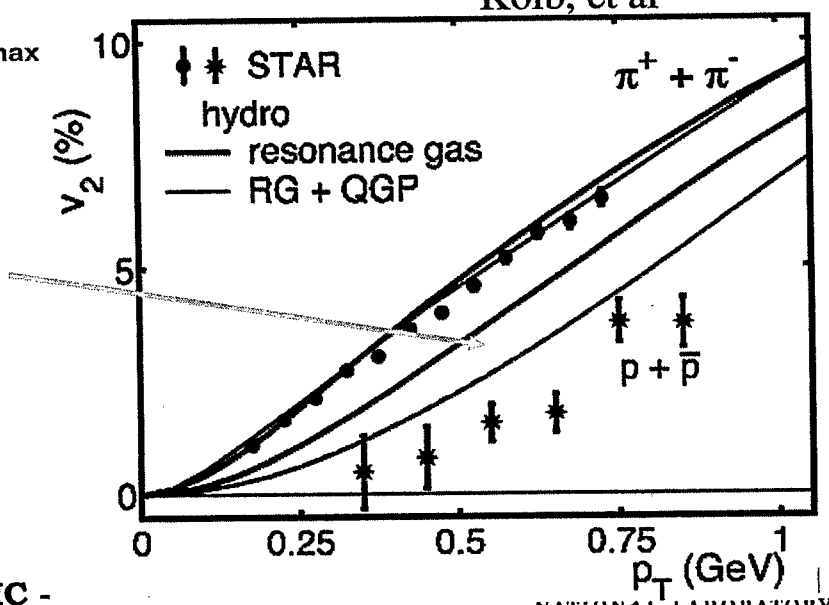


- see large pressure buildup
- anisotropy → happens fast
- v_2 reproduced by hydro
  → early equilibration !

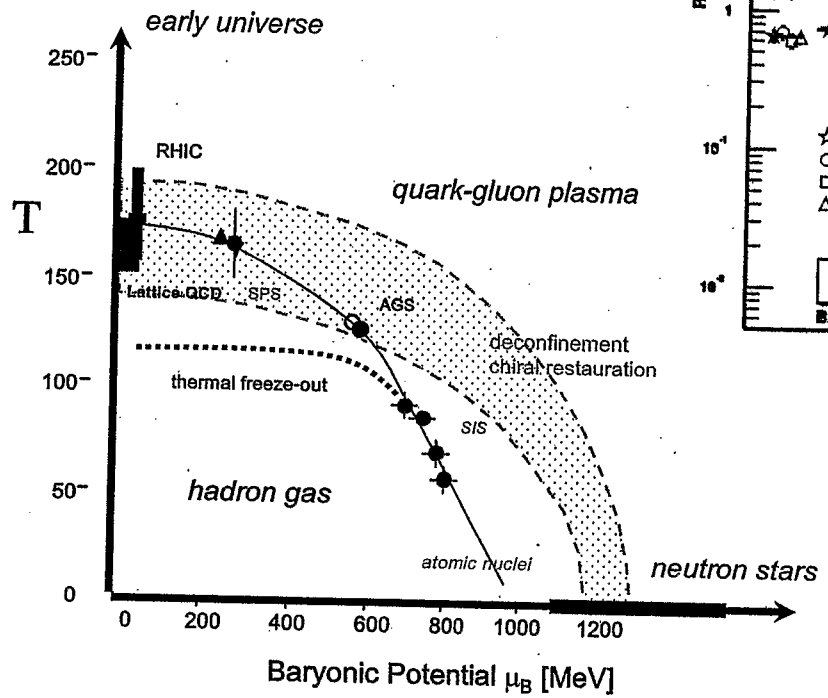
Hydro can reproduce magnitude of elliptic flow for p, $\bar{p}$. BUT *must add QGP to hadronic EOS!!* (Similar conclusion reached by Ko, Kapusta, Bleicher, others...)

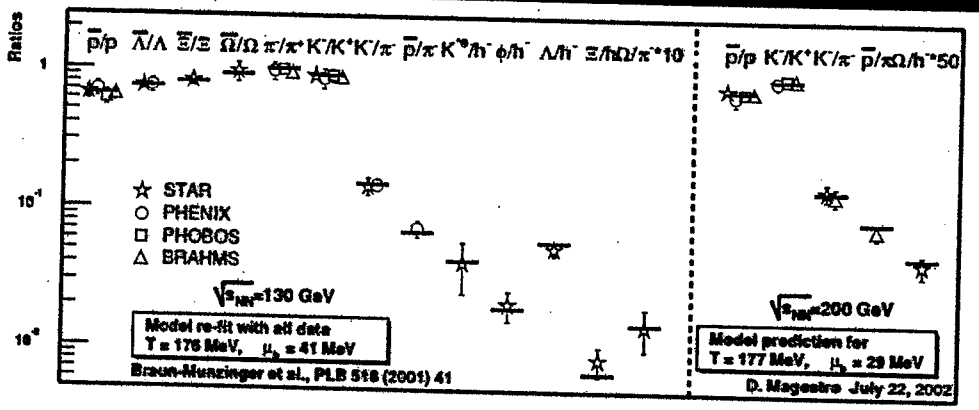
Large v_2 and fast equilibration
→ **huge cross-sections**

Kolb, et al



Locating RHIC on the phase diagram





From fit of yields vs. mass (grand canonical ensemble):

T_{ch} = 176 MeV
m_B = 41 MeV

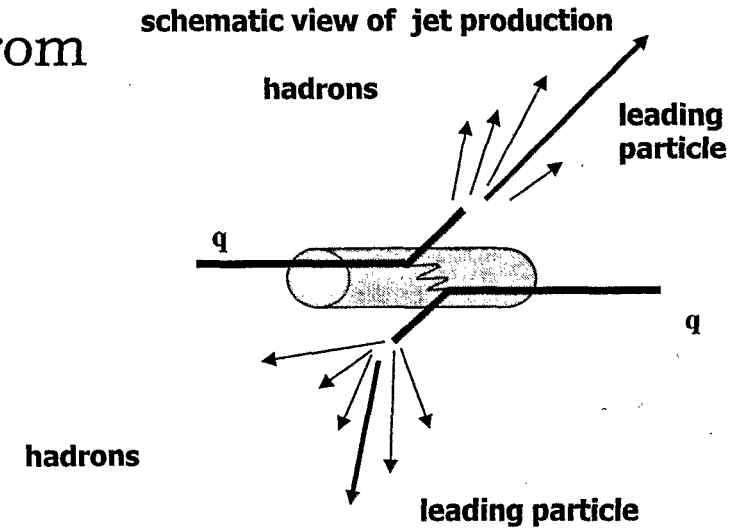
These are the conditions *when hadrons stop interacting*

Observed particles "freeze out" at/near the deconfinement boundary!

Jets: calibrated probe of the medium

Jets of hadrons arise from hard scattered quarks

Observed via fast leading particles or azimuthal correlations between the leading particles



But, before they create jets, the scattered quarks radiate energy (~ GeV/fm) in the colored medium
→ decreases their momentum
→ fewer high momentum particles ⊥ beam
→ "jet quenching"

Central Au-Au: high p_T suppressed!

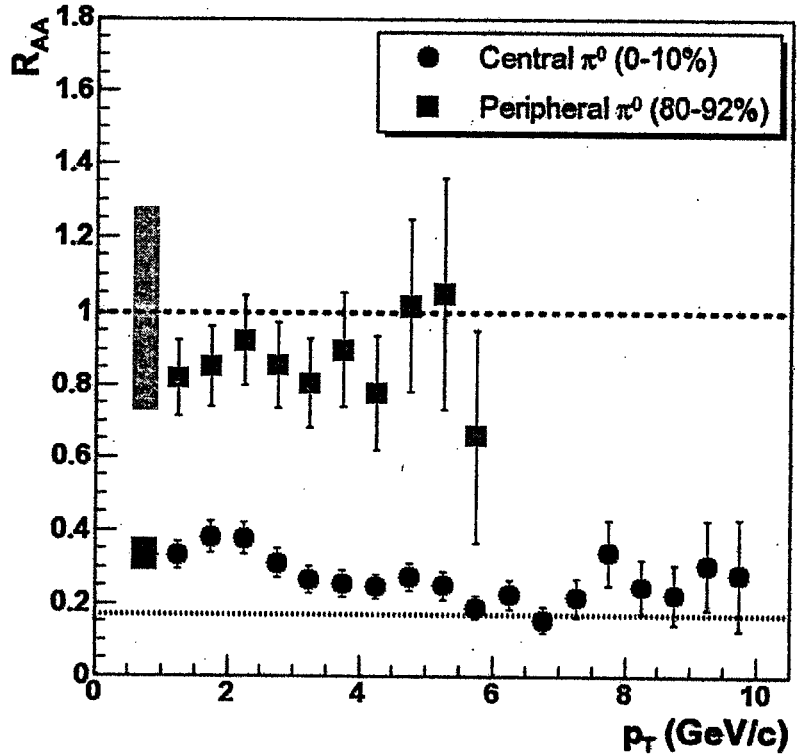
$\sqrt{s}$ = 200 GeV

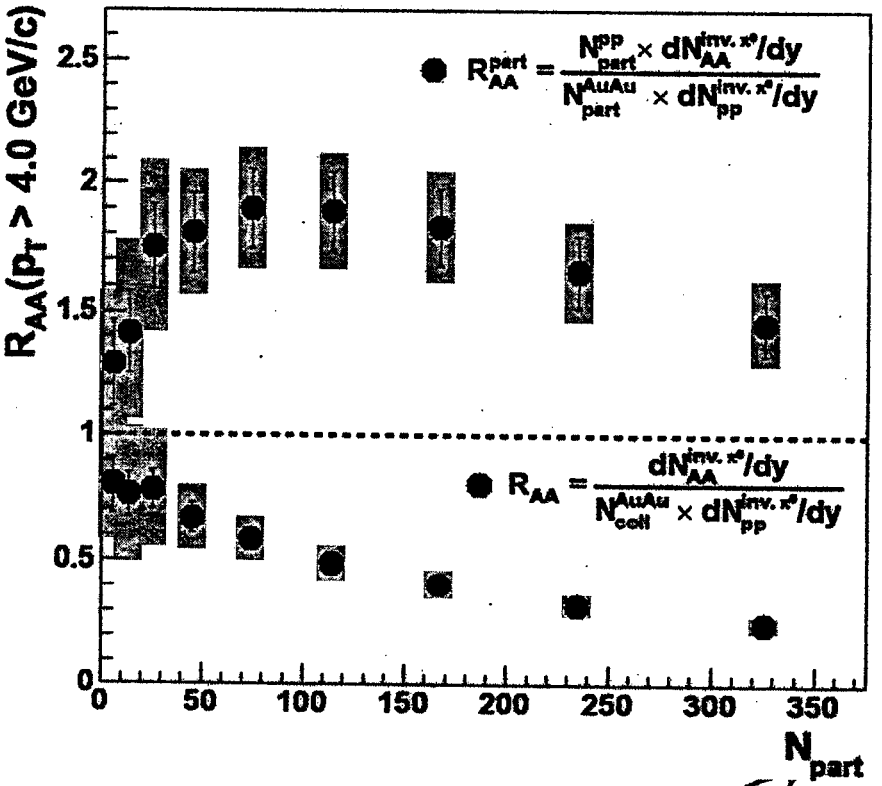
PRL91, 072301(2003)

PHENIX

$$R_{AA} = \frac{\text{Yield}_{AuAu} / \langle N_{binary} \rangle_{AuAu}}{\text{Yield}_{pp}}$$

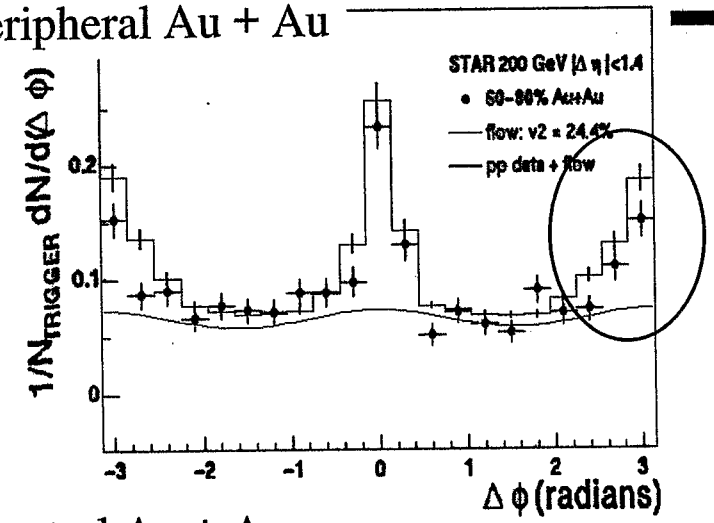
$$R_{AA}^{part} = \frac{\text{Yield}_{AuAu} / \langle N_{part} \rangle_{AuAu}}{\text{Yield}_{pp} / 2}$$



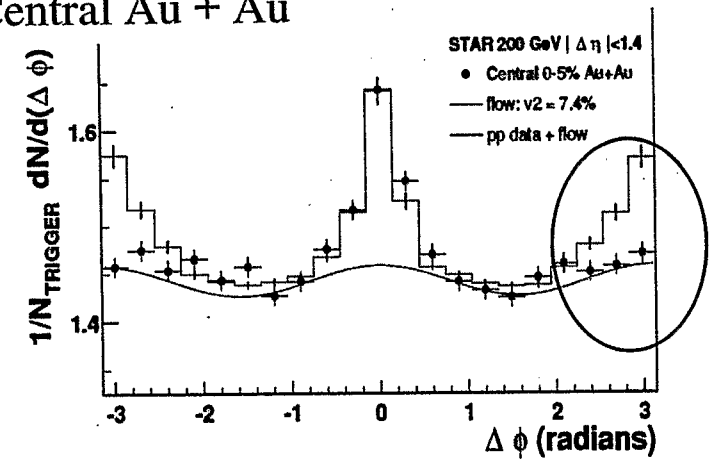


can look for the jet on the other side

- Peripheral Au + Au

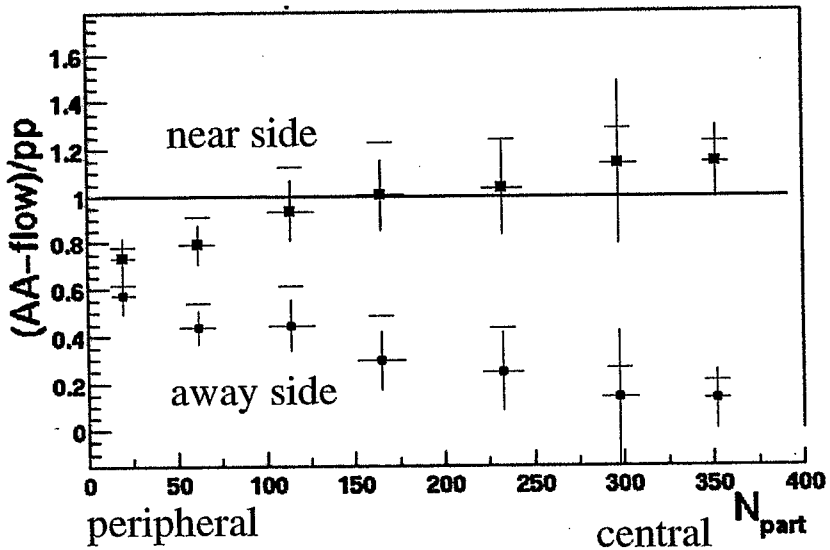


Central Au + Au



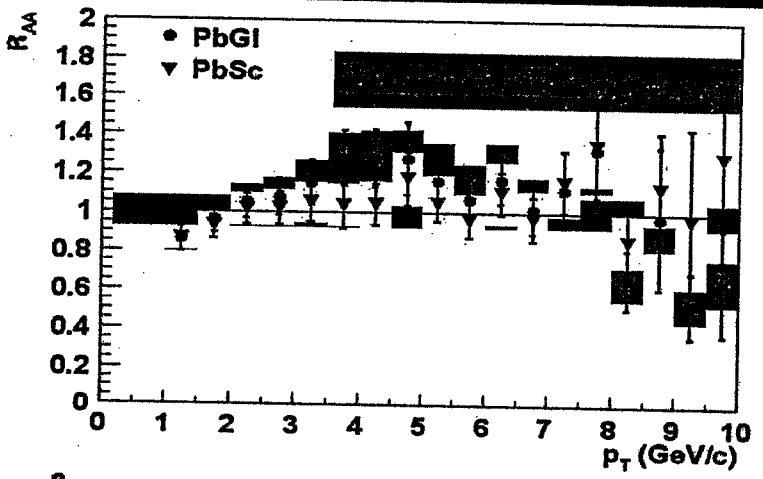
STAR PRL 90, 082302 (2003)

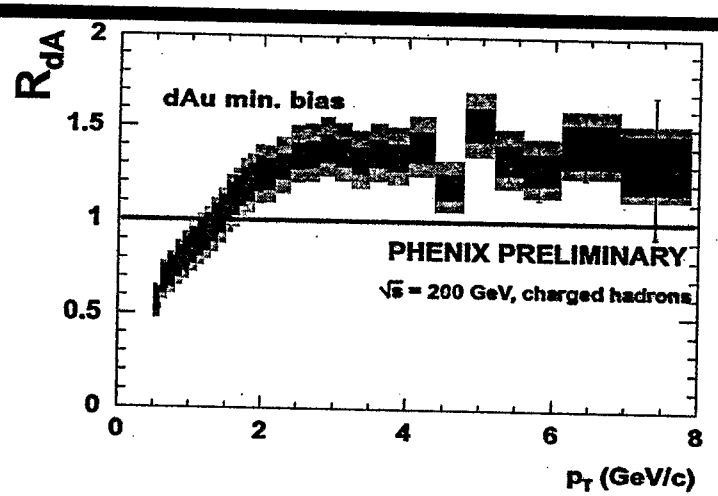
$$D_2(Au+Au) = D_2(p+p) + B(1+v_2^2\cos(2\Delta\phi))$$

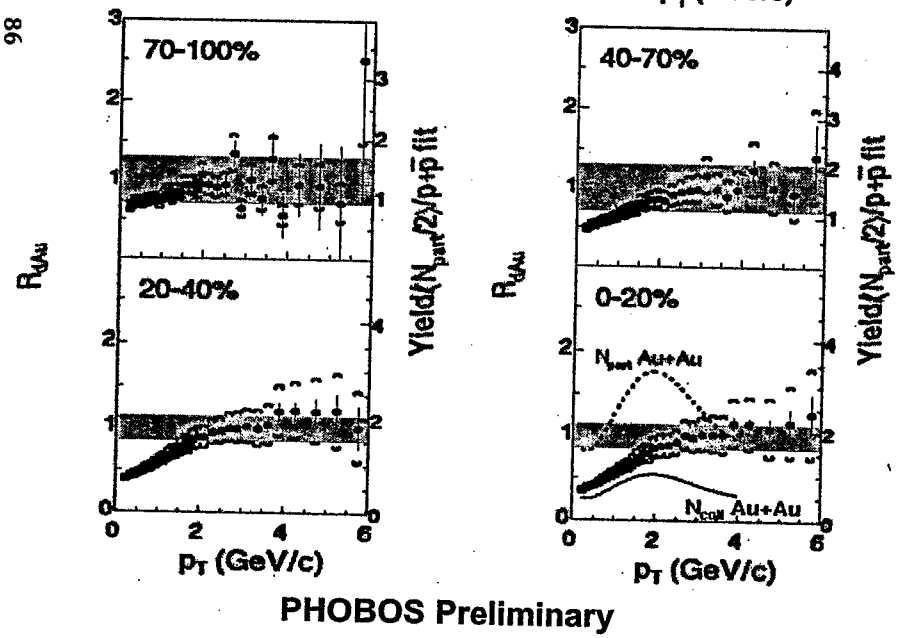


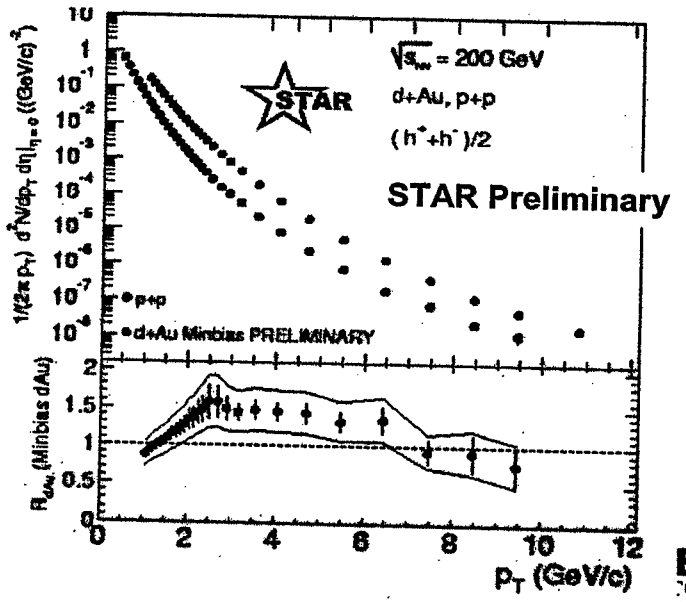
Back-to-back jets are suppressed in central collisions!

Experiments show NO suppression in d+Au!



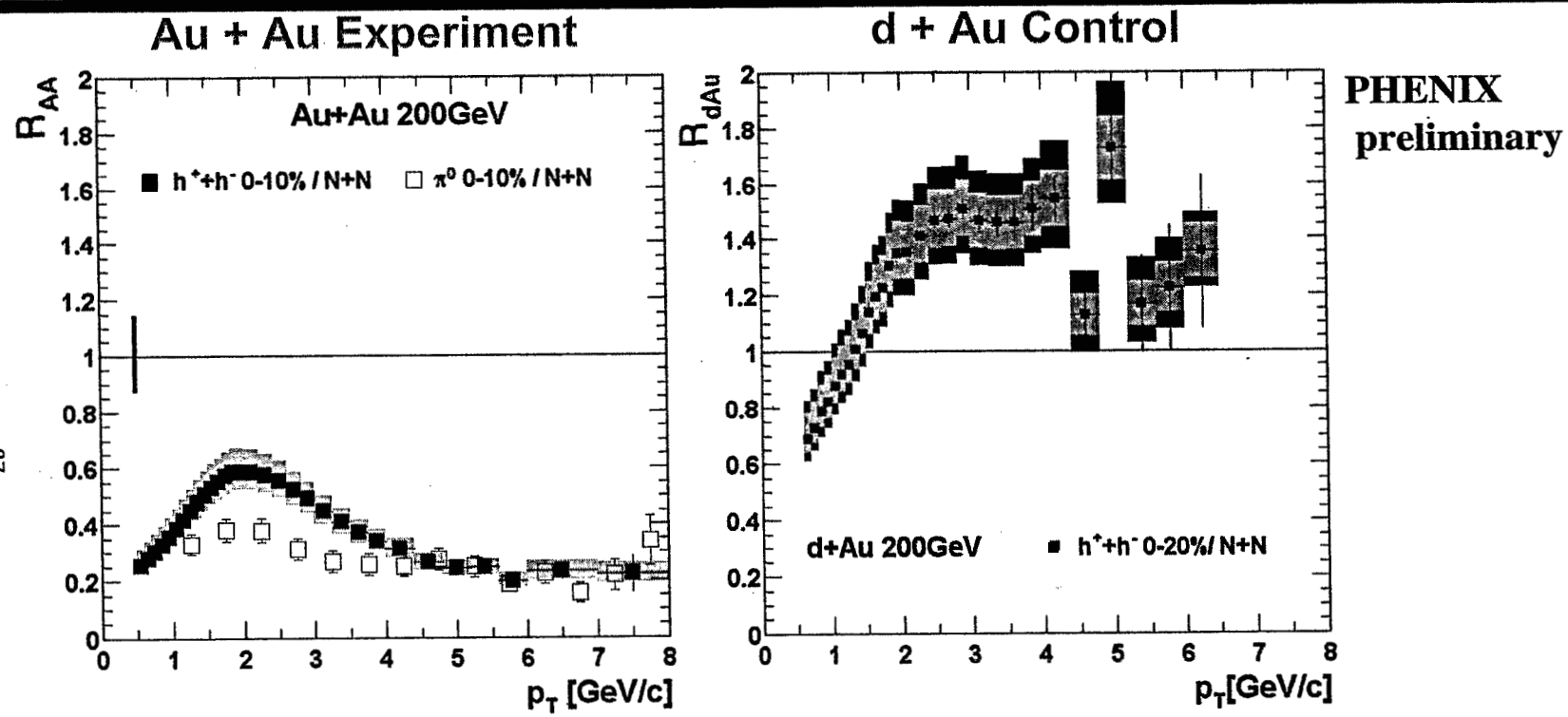






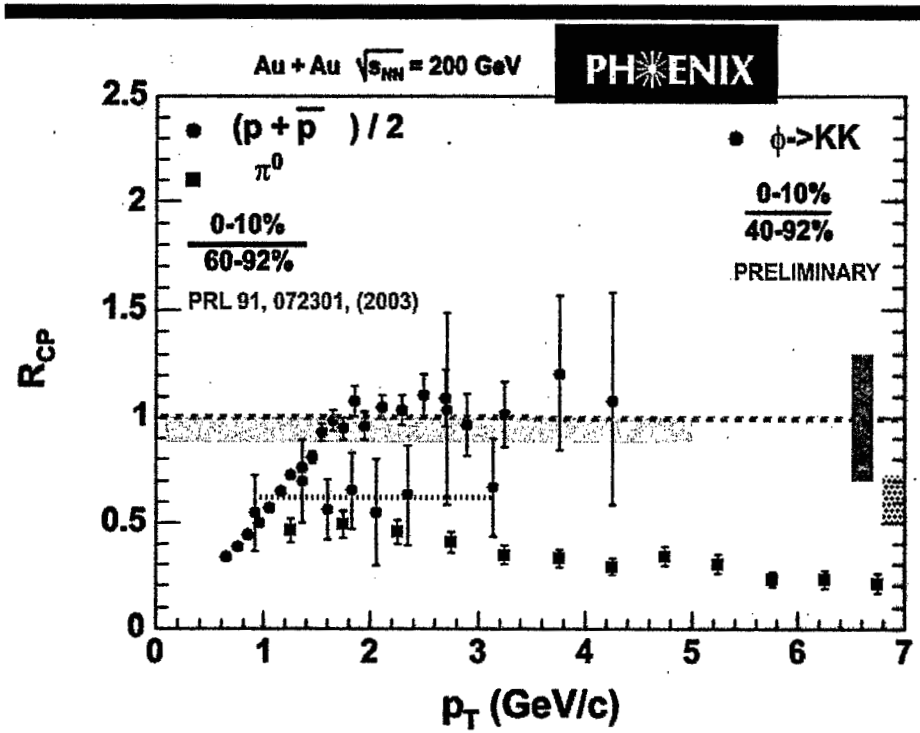
S.

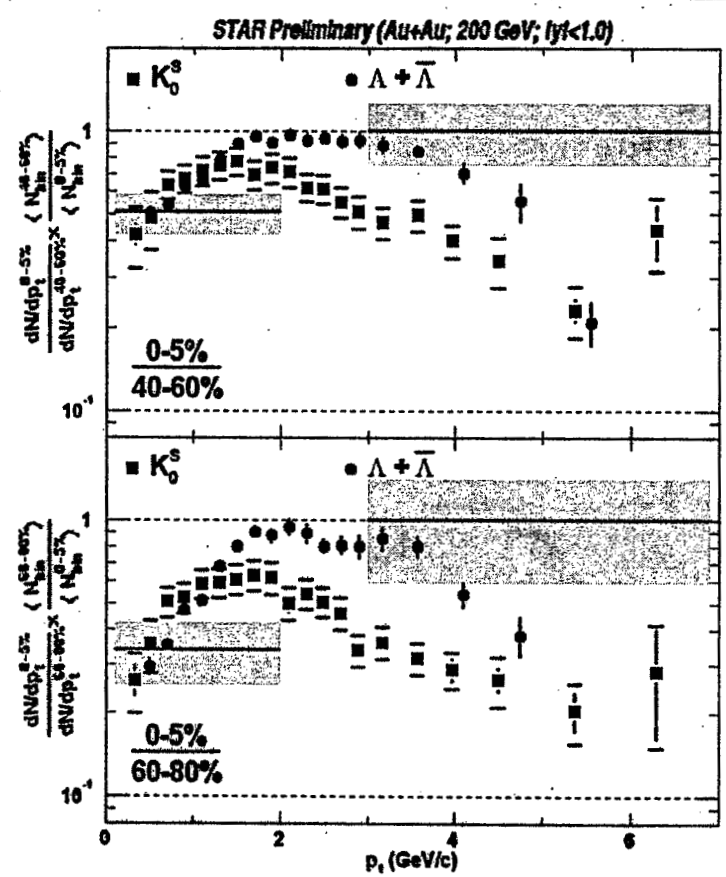
Centrality Dependence



- Dramatically different and opposite centrality evolution of AuAu experiment from dAu control.
- Jet Suppression is clearly a final state effect.

Are baryons from jets suppressed?



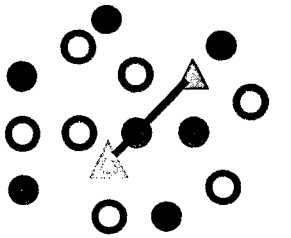


Baryons look *not* suppressed
$\propto N_{coll}$ at p_T = 2 – 4 GeV/c

Mesons, including ϕ are suppressed .: Effect governed by quark content

What about heavy quarks?

- J/ψ
  - *Test confinement: do bound c + $\bar{c}$ survive? or does QGP screening kill them?*

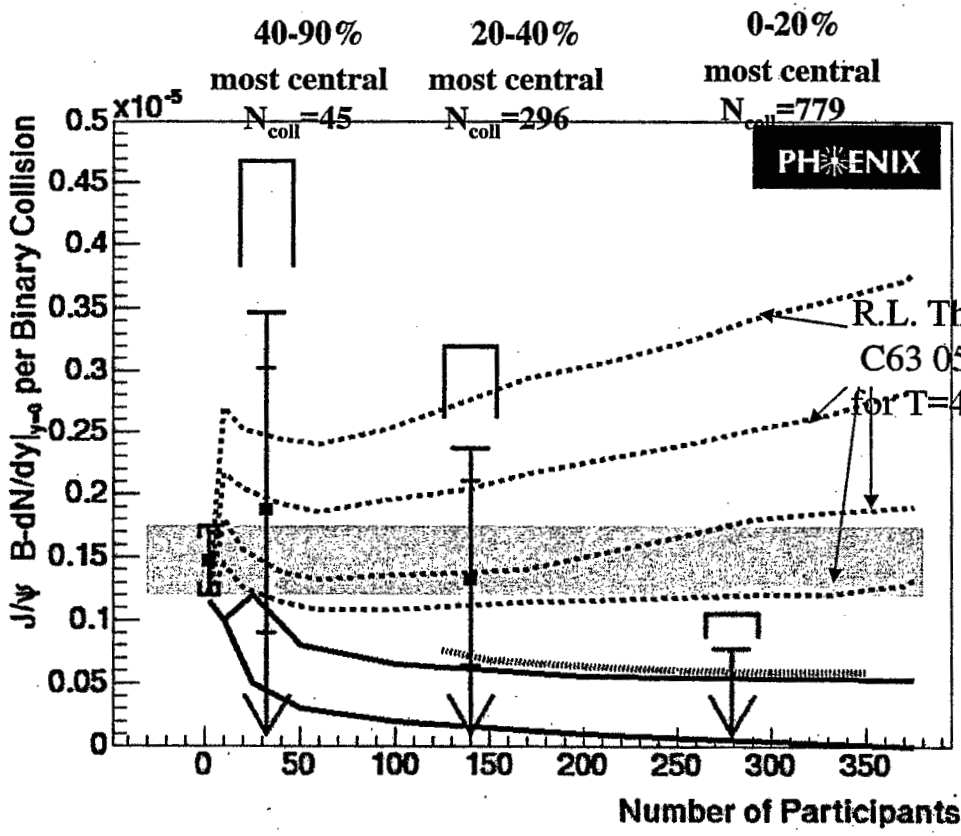


- Open Charm
  - *Extra heavy quarks from hot, dense gluon gas?*
  - *Do the c quarks lose energy like the light quarks?*

Need (a lot) more statistics (currently being collected)

But can take a first look...

J/ψ at RHIC



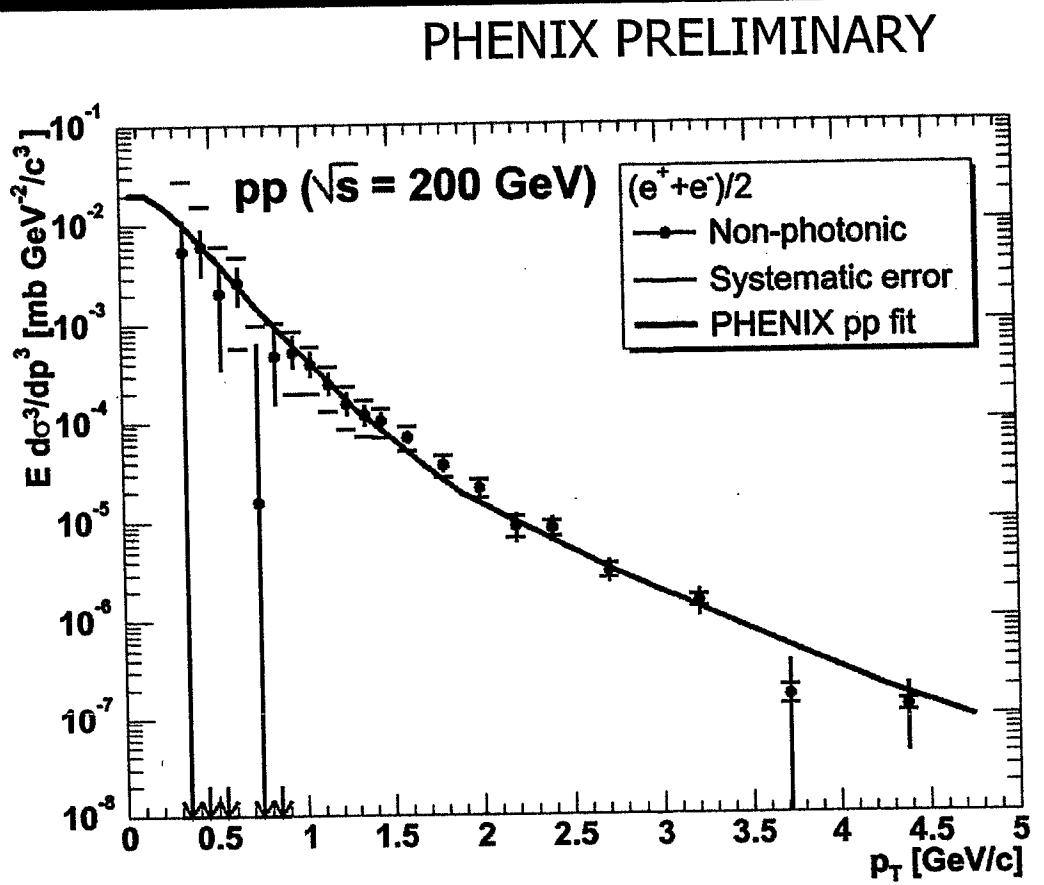
Look at J/Ψ
nucl-ex/0305030

R.L. Thews, M. Schroedter, J. Rafelski Phys. Rev. C63 054905 (2001): Plasma coalesence model for T=400MeV and y_{charm}=1.0,2.0, 3.0 and 4.0.

L. Grandchamp, R. Rapp Nucl. Phys. A&09, 415 (2002) and Phys. Lett. B 523, 50 (2001): Nuclear Absorption+ absorption in a high temperature quark gluon plasma

Can't say yet about deconfinement, but don't see EXTRA (thermal) J/ψ

Open charm: baseline is p+p collisions



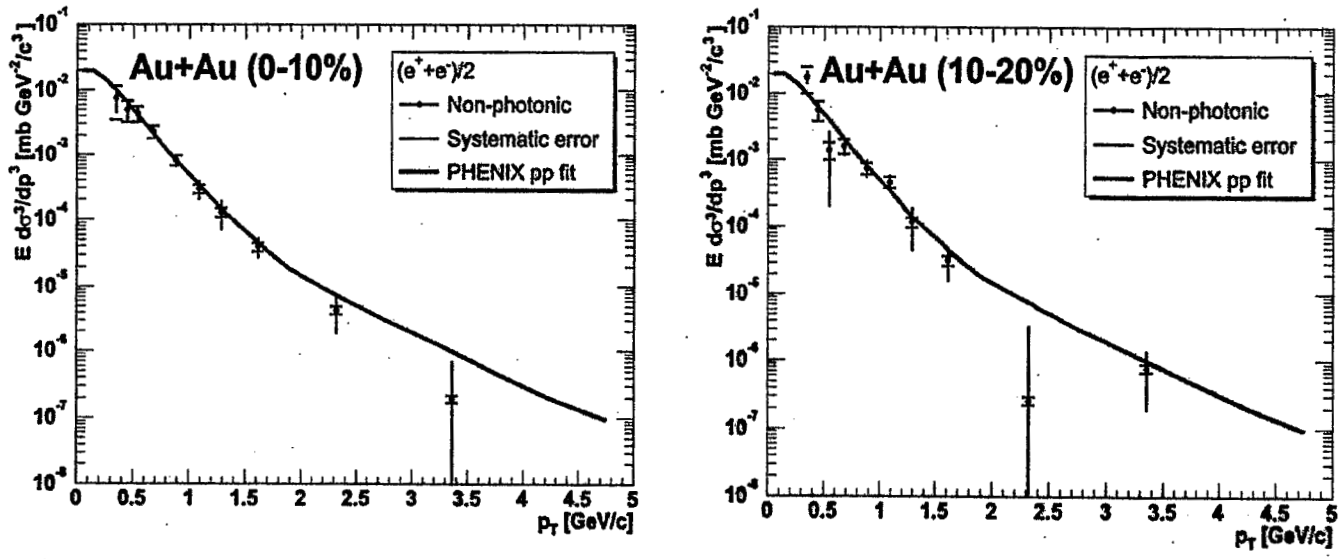
Measure charm σ via semi-leptonic decay to e^+ or e^-

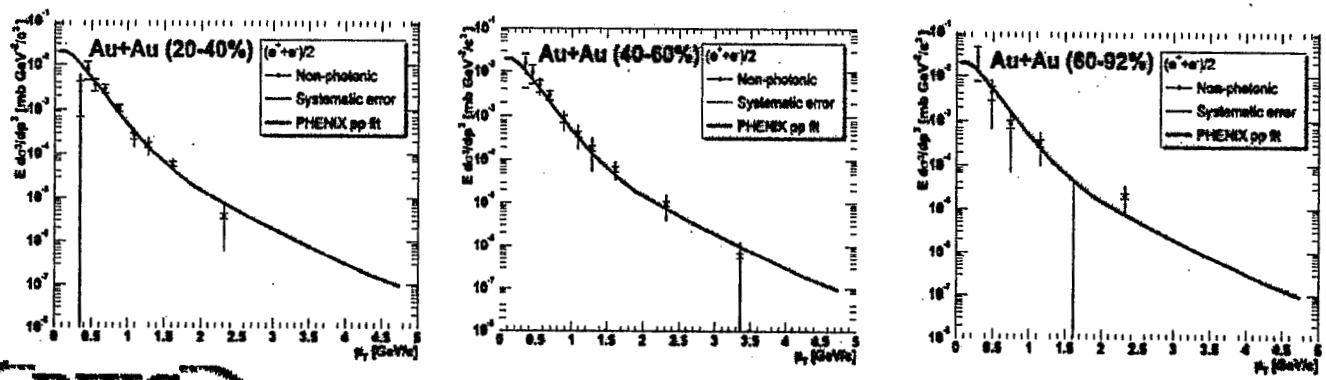
π^0, η, photon conversions are measured and subtracted

fit p+p data to get the baseline for d+Au and Au+Au

Au+Au: NO large suppression as for light quarks!

PHENIX PRELIMINARY





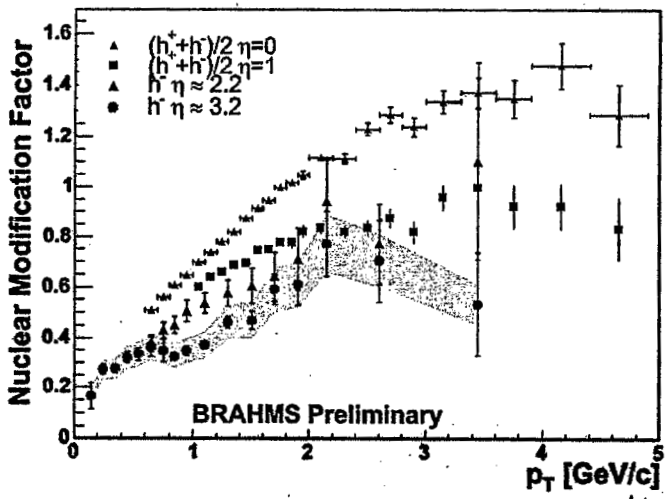
Curves are the p+p fit, scaled by the number of binary collisions

Implications of the results for QGP

- Ample evidence for equilibration
  - Hydrodynamics reproduces elliptic flow, hadron spectra
  - Yields ⇒ chemical equilibrium
  - Success of quark coalescence ⇒ hadronization of thermalized, expanding $q - \bar{q}$ medium
- v_2 & jet quenching measurements constrain initial gluon density, energy density, and energy loss
- parton interaction cross sections >> perturbative σ
  - parton correlations at $T > T_c$
  - complicates $c\ \bar{c}$ bound states as deconfinement probes!
- Hadronization by coalescence of thermal, flowing quarks
  - v_2 & baryon abundances point to quark recombination as hadronization mechanism
  - Jet data imply must *also* include recombination between quarks from jets and the thermalized medium

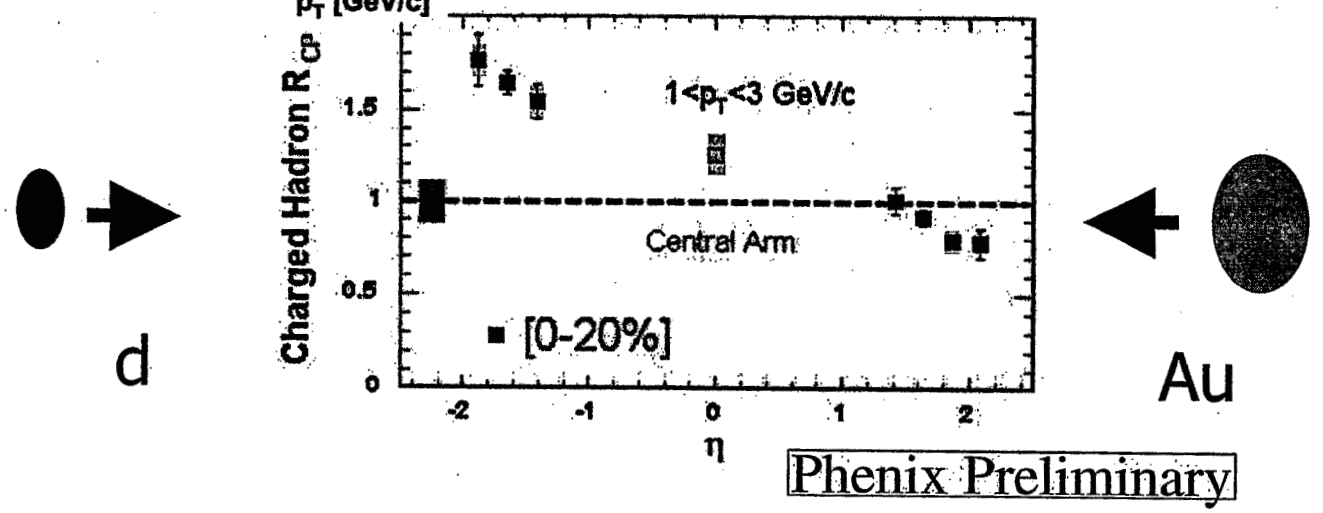
$\therefore$ medium modifies jet fragmentation!

But at forward rapidity reach smaller x



y = 3.2 in deuteron direction
→ x ≈ 10^{-3} in Au nucleus

Strong shadowing, maybe even saturation?
Color Glass Condensate?



conclusions

- Rapid equilibration at RHIC; hydrodynamics works
  - *EOS is <u>not</u> hadronic but do not have perturbative plasma!*
- Parton scattering cross section is very large
- The hot, dense matter absorbs & transports energy
- Modifies fragmentation function of moderate energy jets
  - *Color Glass Condensate? Maybe at $x \sim 10^{-3}$ ($y>2$)*

- QGP discovery?
  - Probably, though probably not the long-predicted QGP
  - Need at RHIC: $T_{initial}$ (thermal γ, dileptons) & heavy quark behavior (J/ψ, open charm, beauty)

    Need from theory: consistent model of many observables

    Both are on the way...

RHIC SPIN PHYSICS (PART I)

Yuji Goto

RHIC Spin Physics (Part I)

MSC Meeting at RIKEN, Wako

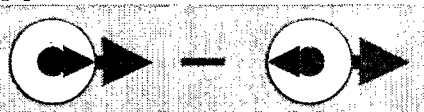
March 25, 2004

Yuji Goto (RIKEN/RBRC)

RIKEN

Spin Physics at RHIC

- Longitudinal polarized proton collision
  - helicity structure of the proton
    - gluon polarization
  - parity violating asymmetries



Run-3 (2003)

- Transverse polarized proton collision
  - transverse structure/motion
    - orbital angular momentum ?
  - transversity distribution
    - last unmeasured leading-twist distribution
  - single transverse-spin asymmetries
    - transversity, higher twist, T-odd structure and fragmentation, ...

Run-2 (2001-2003)

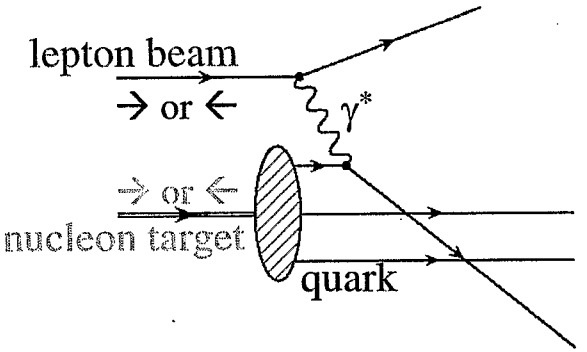
- Small-angle *pp* elastic scattering
  - unpolarized and polarized measurements

100

Helicity Structure of the Proton

- Origin of the proton spin 1/2 ?

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta g + L$$



  – polarized DIS experiments

$$\Delta\Sigma = 0.1 \sim 0.3$$

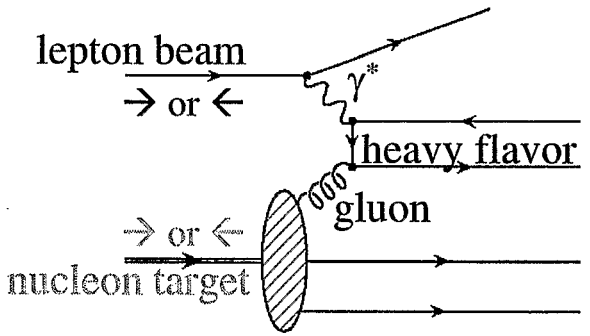
  – gluon contribution
    - known poorly from scaling violations in pol. DIS experiments, spanning a small range of Q^2
    - SMC

$$\Delta g = 1.0^{+1.0}_{-0.3}(\text{stat})^{+0.4}_{-0.2}(\text{sys})^{+1.4}_{-0.5}(\text{th})$$

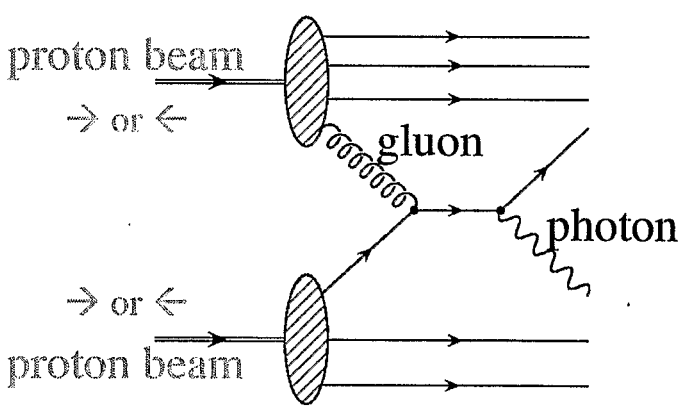
$$(Q^2 = 1\text{GeV}^2)$$

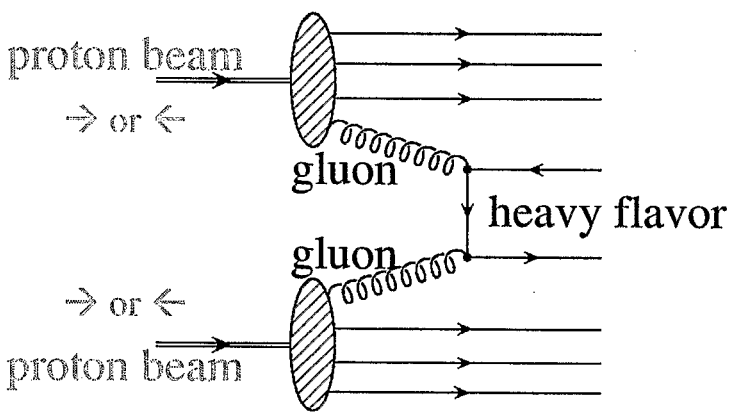
Gluon Polarization in the Proton

- Polarized semi-inclusive DIS
  - COMPASS/SMC/HERMES



- Polarized hadron collision
  - Fermilab E704 π^0/multi-photon ($\sqrt{s}$ = 19.4 GeV)
  - RHIC polarized proton collider ($\sqrt{s}$ = 50 ~ 500 GeV)

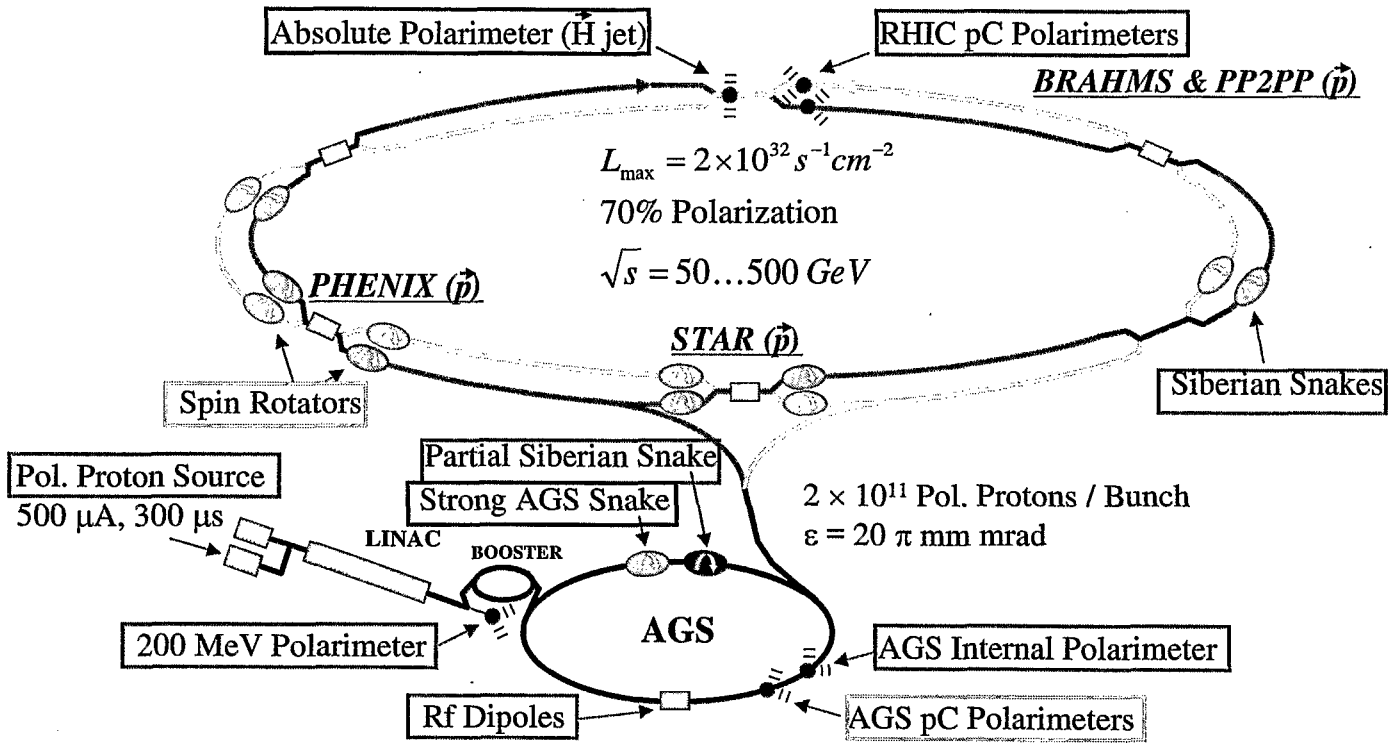




Present Emphasis

- Precision measurement of π^0 cross section
  - experimental basis of the asymmetry measurement established
  - theoretical basis by the perturbative QCD obtained
- First A_{LL} measurement of π^0
  - discussion of the gluon polarization in the proton started

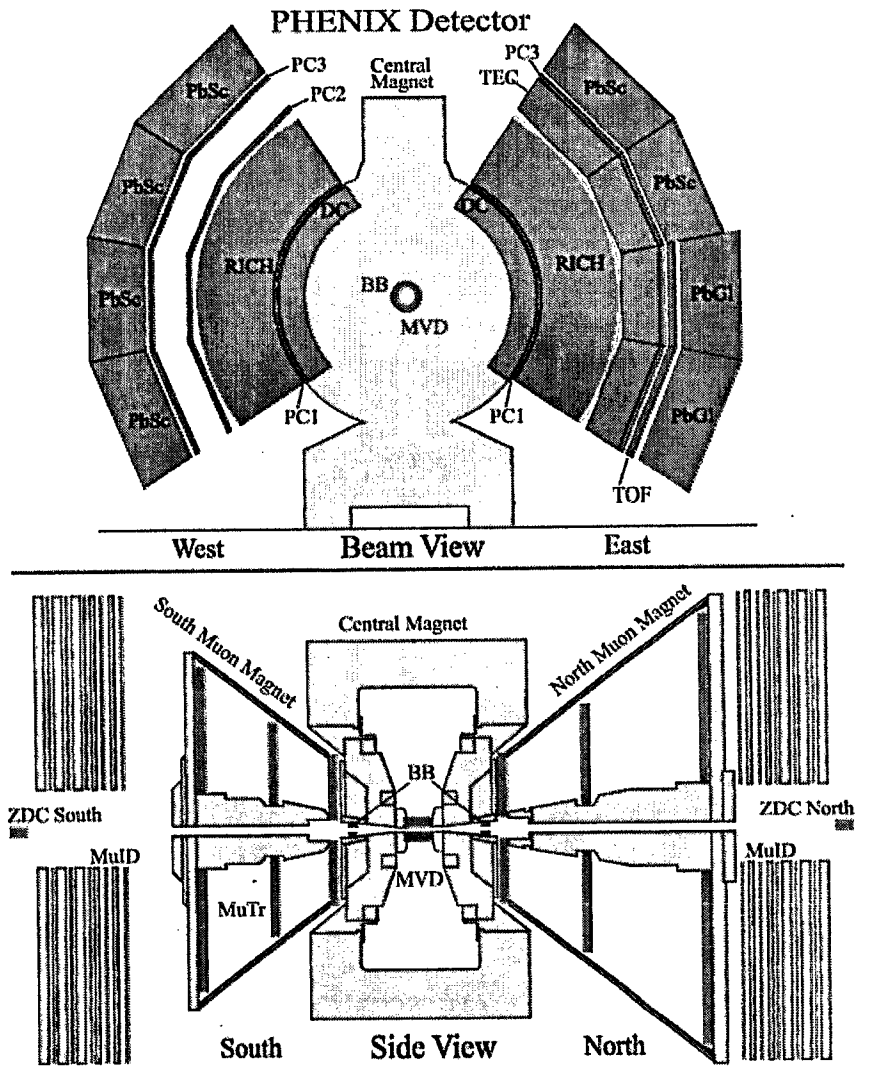
RHIC Polarized Proton Collider



2001 - 2002	**√s = 200 GeV transverse polarized proton collisions**
2003	**√s = 200 GeV transverse+longitudinal polarized proton collisions**
2004 –	**√s = 200 GeV longitudinal polarized proton collisions**

PHENIX Detector

- All baseline detectors now running
  - central arms and south muon arm ready in Run-2 (2001-2002)
  - north muon arm ready in Run-3 (2003)
- Common apparatus with HI experiment



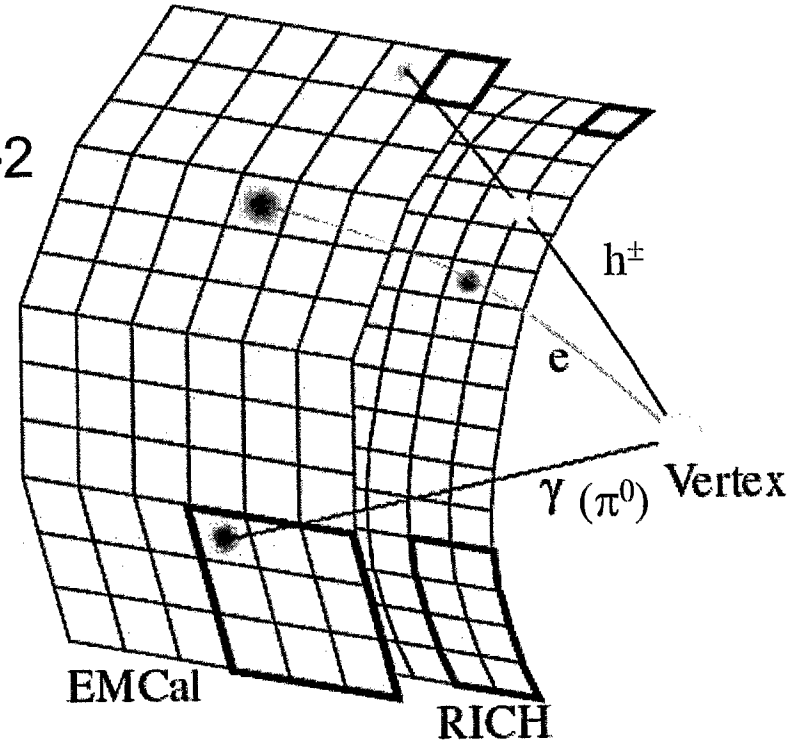
PHENIX Detector for the Spin Physics

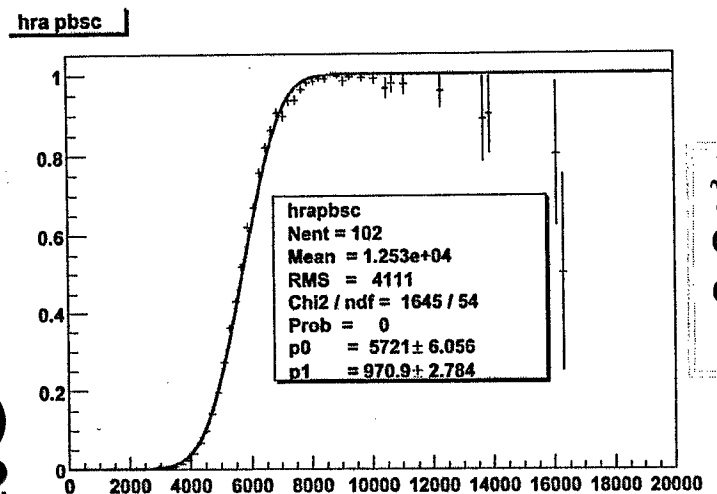
- To survive higher event rate in *pp* collisions … and, smaller number of multiplicity
  - *pp* event rate ~4 MHz at $\sqrt{s}$ = 200 GeV full luminosity
  - HI event rate ~2 kHz at full luminosity, all minimum-bias events recordable …
  - extended minimum-bias trigger & luminosity monitor devices
    - baseline detector: BBC & ZDC
    - NTC (normalization trigger counter)
    - GL1P crossing-by-crossing scaler
  - rare-event trigger systems
    - EMCal-RICH trigger in the central arms
    - muon trigger in the muon arms
  - high-rate DAQ system (by PHENIX DAQ group)
    - 1.4 kHz, 100 MB/sec achieved in Run-3
    - much higher design rate to be achieved (~5kHz, 200MB/sec)

EMCal-RICH Trigger

K. Okada
M. Grosse Perdekamp

- EMCal
  - width/threshold 29% in Run-2 → 17% in Run-3
  - acceptance 75% in Run-2 → 95% in Run-3
- RICH
  - acceptance 15% in Run-2 → 70% in Run-3

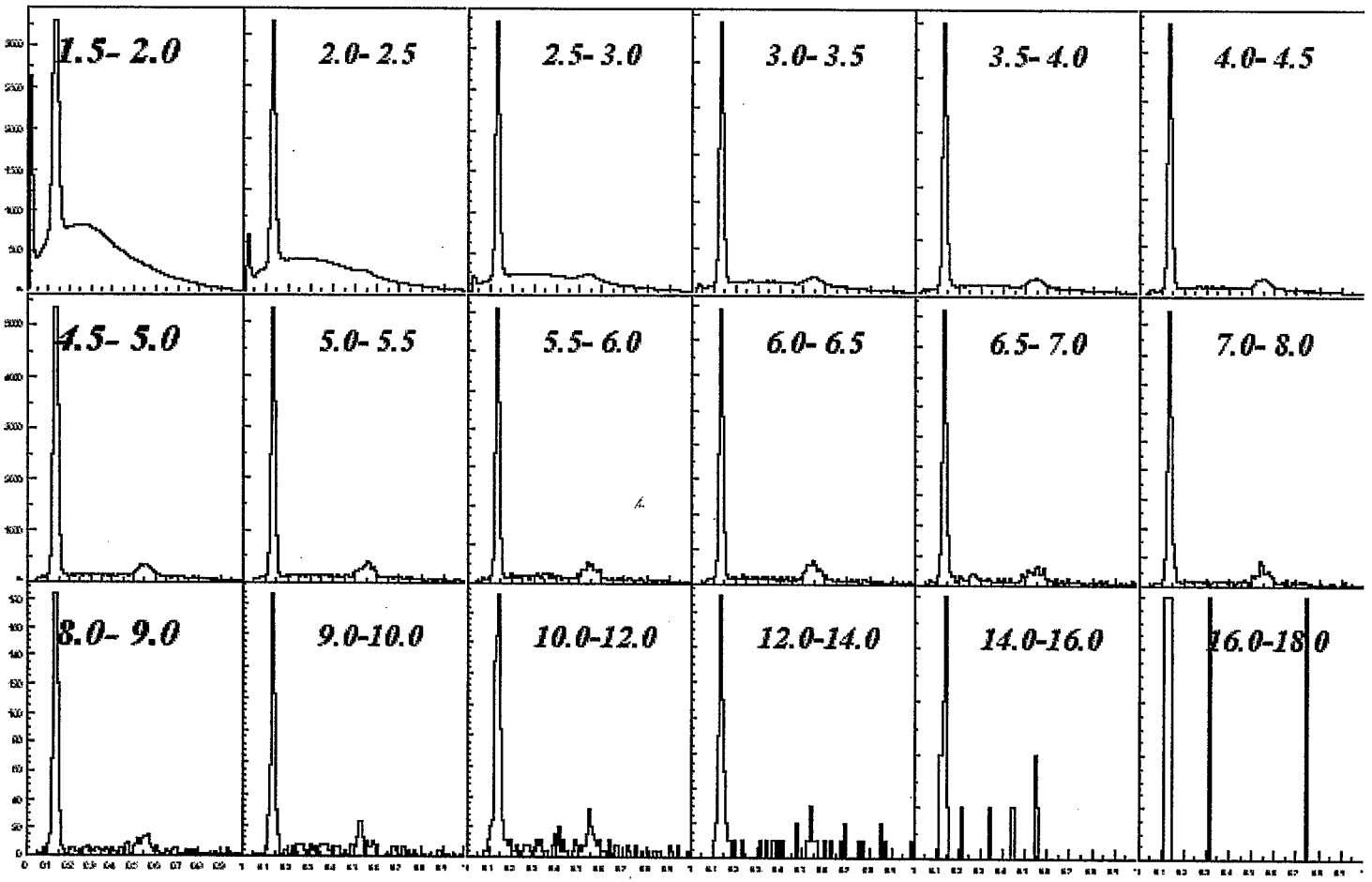




γ's and π^0's	: EMCal
electrons	: EMCal and RICH
charged hadrons	: EMCal (through hadronic interactions) and RICH

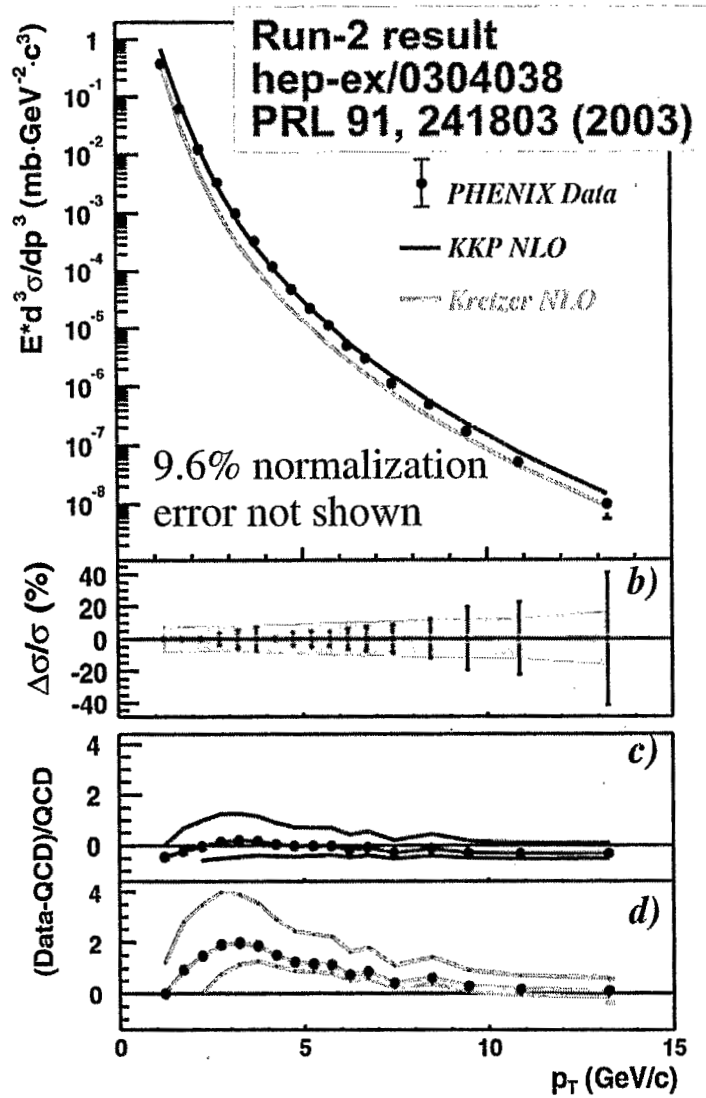
π^0 Reconstruction

A. Bazilevsky, A. Deshpande, B. Fox
H. Torii, Y. Fukao, T. Horaguchi



π^0 Cross Section

- Data covers over 8 orders of magnitude
  - p_T = 1 ~ 13 GeV/c
- NLO pQCD calculation is consistent with our data
  - within the scale $\mu = p_T/2 - 2p_T$
- Confidence in understanding sub-processes
- Input to the fragmentation-function uncertainty



A_{LL} Measurement of π^0

K. Tanida, M. Togawa, Y. Fukao,
N. Saito, Y. Watanabe
M. Kaneta, A. Deshpande, B. Fox

- Relative luminosity
- PHENIX local polarimeter
  - neutron asymmetry discovered at IP12 in Run-2
  - ZDC+SMD at PHENIX
  - commissioning of spin rotators
  - monitoring transverse/longitudinal components of the beam polarization vector during the physics run
- Asymmetry analysis procedure
  - bunch fitting method for asymmetry & relative luminosity evaluation
  - bunch shuffling method for systematic error evaluation

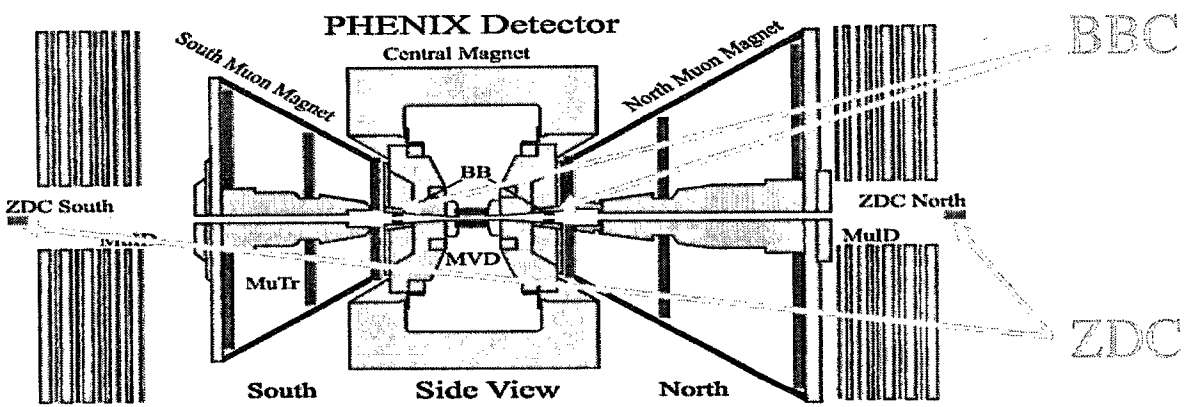
$$A_{LL} = \frac{d\sigma_{++} - d\sigma_{+-}}{d\sigma_{++} + d\sigma_{+-}} = \frac{1}{P_1 \cdot P_2} \cdot \frac{N_{++} - R \cdot N_{+-}}{N_{++} + R \cdot N_{+-}}$$

$$R = \frac{L_{+-}}{L_{++}}$$

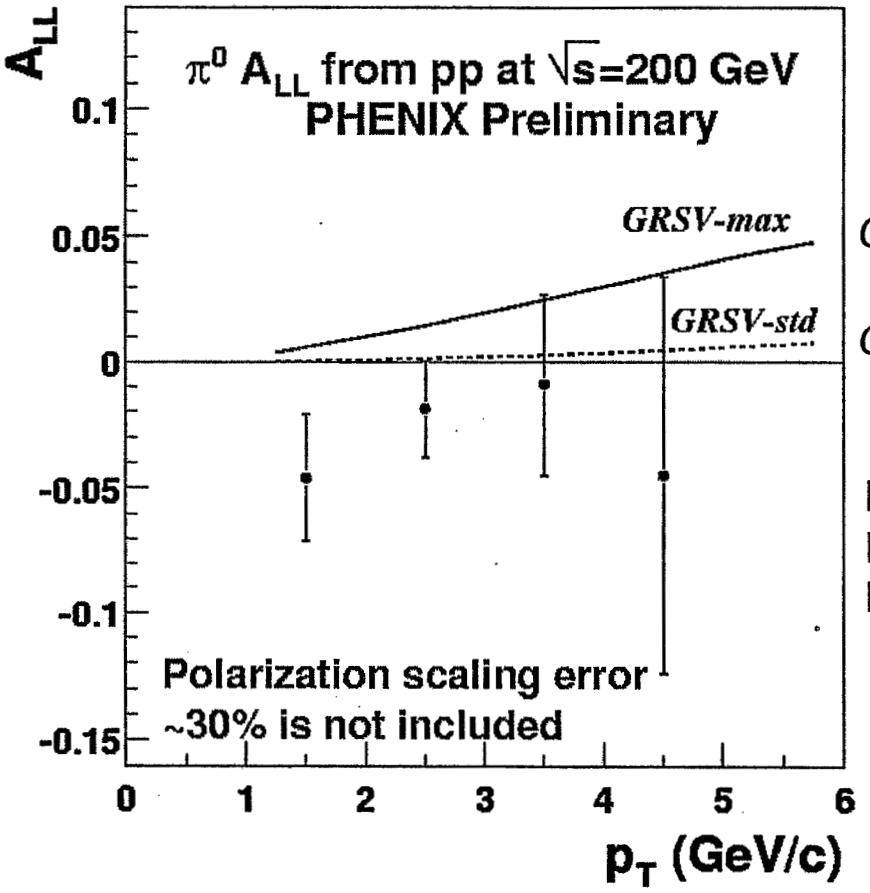
P: polarization
N: yield of signal
R: relative luminosity

Relative Luminosity

- GL1P crossing-by-crossing scaler
  - 4 × 120 32-bit scalers: BBC, ZDC, NTC, …
- Achieved precision $\delta R = 2.5\times10^{-4}$ ➔ $\delta A_{LL} = 0.2\%$
  - evaluation limited by ZDC statistics
    - 30 times less than BBC statistics
- A_{LL} of BBC relative to ZDC smaller than 0.2%
  - consistent with zero
  - strong indication that both A_{LL}'s are zero
    - very different kinematical regions, different physics signals)



A_{LL} Measurement of π^0



paper in preparation
circulating in the collaboration
to be submitted to PRL

GRSV-max: ΔG = 1.84

GRSV-std: ΔG = 0.42
(at Q^2 = 1 GeV^2)

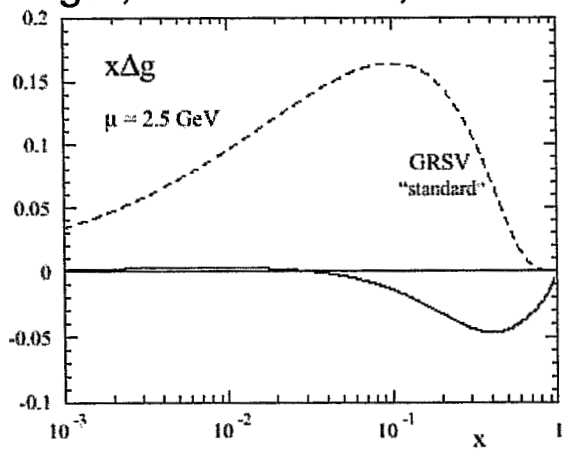
B. Jäger et al.,
PRD 67 (2003) 054005
NLO pQCD calculation

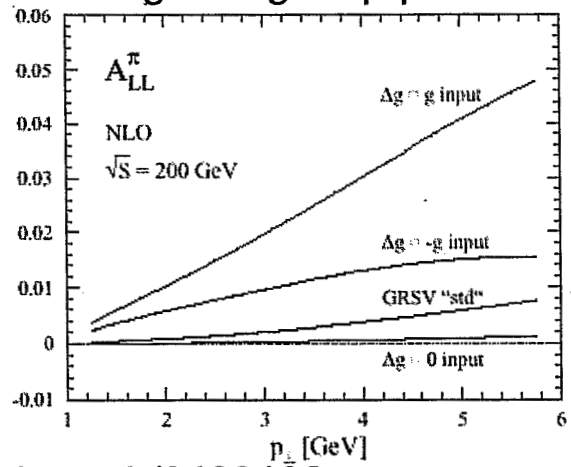
polarization scaling error $\delta P/P$ ~30% is not included:
- analyzing power A_N(100 GeV) = A_N(22 GeV) is assumed
- $\delta P/P$ ~ 30%: combined stat. and syst. error for A_N(22 GeV) [AGS-E950]

Gluon Polarization

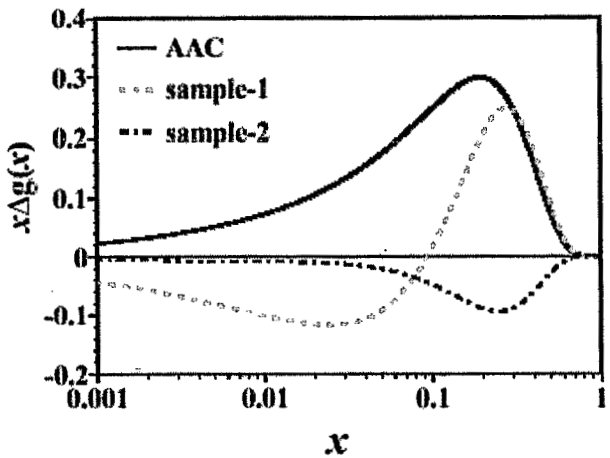
- NLO pQCD calculations

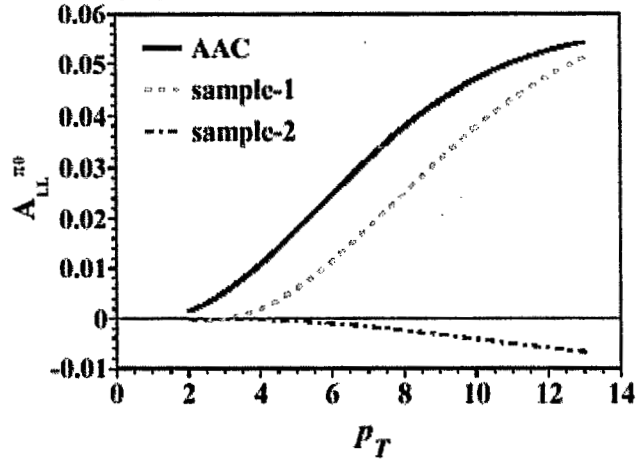
B. Jäger, M. Stratmann, S. Kretzer, and W. Vogelsang: hep-ph/0310197





M. Hirai and K. Sudoh: hep-ph/0403102



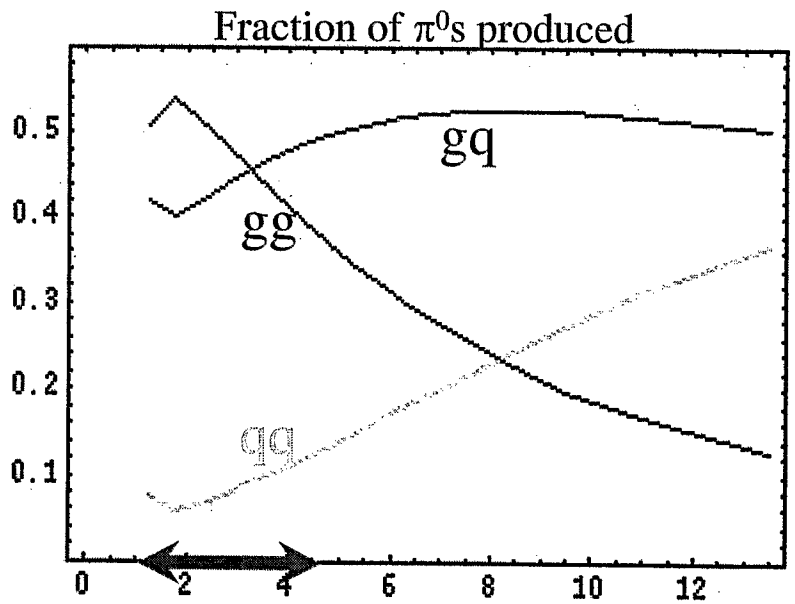


Gluon Polarization

- NLO pQCD calculations
  - cannot make sizable negative A_{LL} in this kinematic range: gluon-gluon interaction dominant

$$\Delta g(x_1) \times \Delta g(x_2) > 0$$

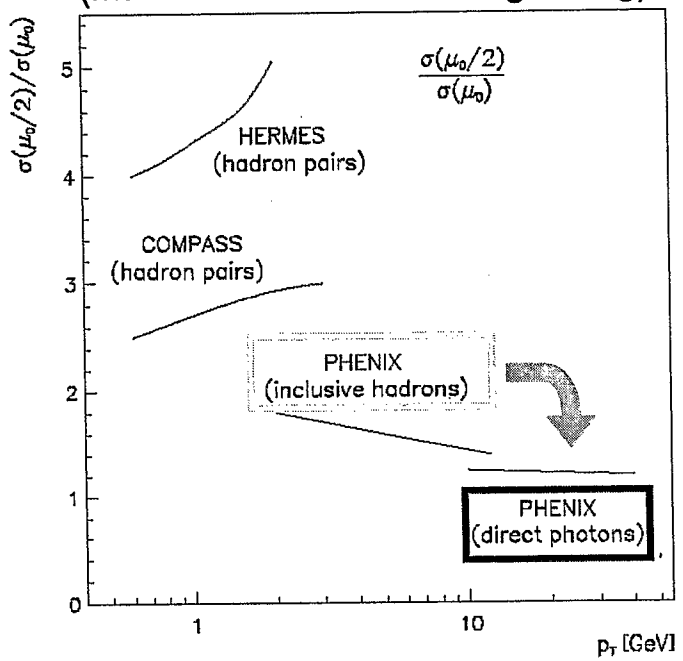
  - sizable negative A_{LL} possible at higher p_T range: gluon-quark interaction



Advantage of RHIC Polarized Proton Collider

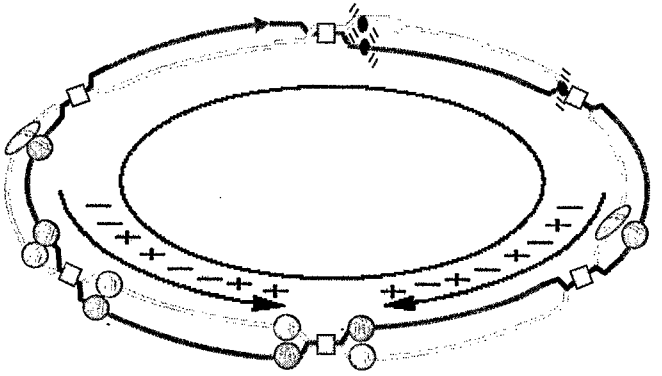
- High $\sqrt{s}$ and high Q^2
  - $\sqrt{s}$ = 200 GeV
  - ➔ 500 GeV in the future
- Perturbative QCD applicable
  - scale dependence of the NLO pQCD calculation in the cross section measurement
    - π^0: down to 1 GeV/*c*
    - ➔ direct photon in the future
  - scale dependence is expected to largely cancel in the asymmetry measurement

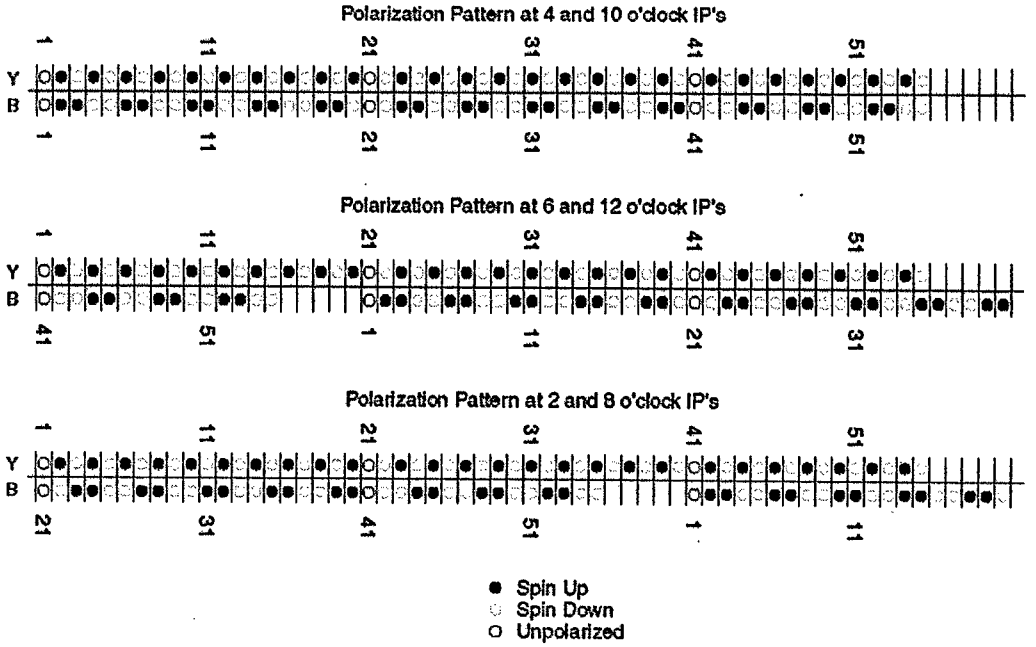
scale dependence of NLO pQCD
(M. Stratmann and W. Vogelsang)



Advantage of RHIC Polarized Proton Collider

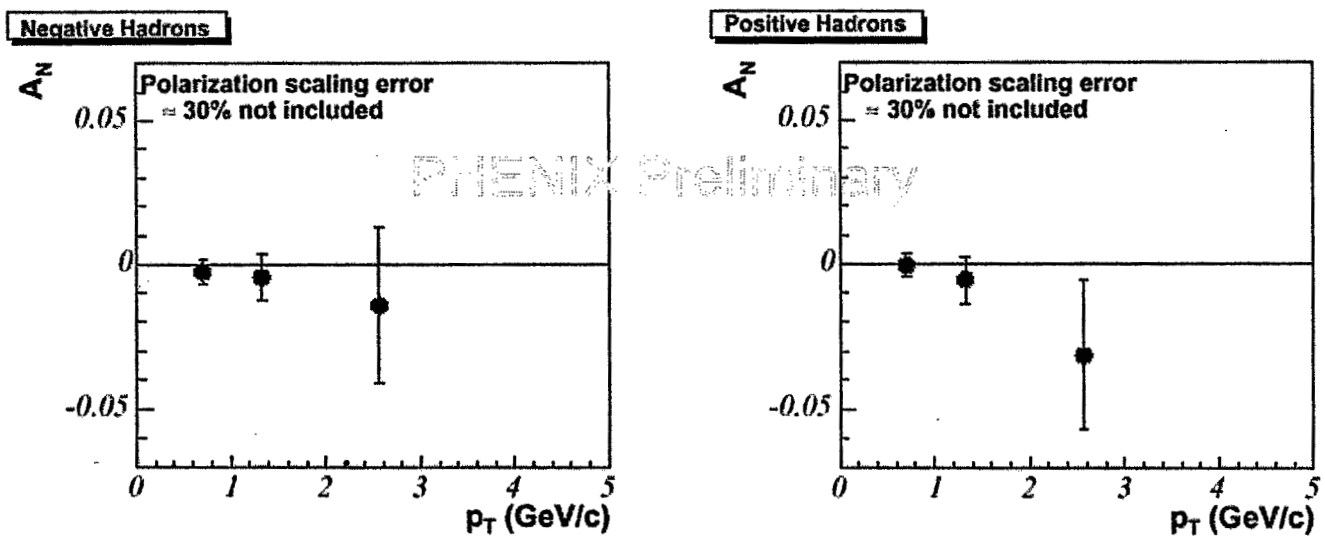
- Cancellation of systematic uncertainty
  - flexible combination of spin direction every crossing





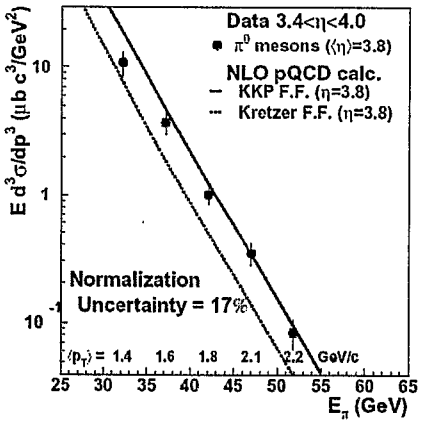
Single Transverse-Spin Asymmetries

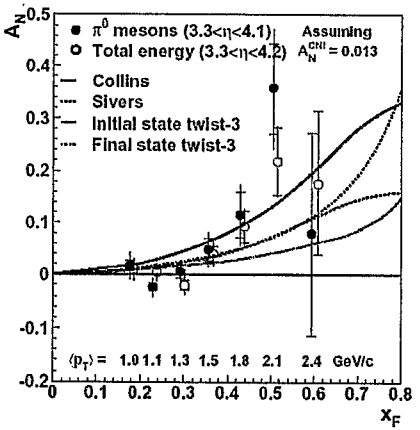
- BBC (beam-beam counter)
  - STAR BBC (η: 2~5)
    - $A_N \sim +0.5\%$
  - PHENIX BBC (η: 3~4)
    - $|A_N| < 0.3\%$
    - $A_N \sim -5\%$ with same-side ZDC coincidence
    - $A_N \sim +3\%$ with opposite-side ZDC coincidence
- Mid-rapidity π^0 / charged hadron



Single Transverse-Spin Asymmetries

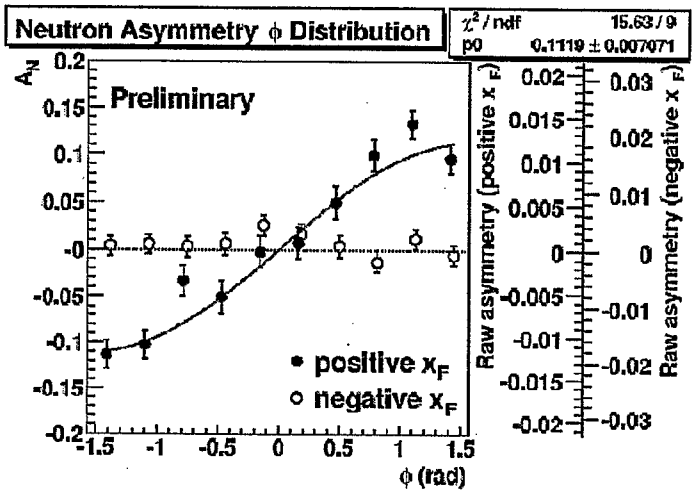
- Forward π^0 at STAR





hep-ex/0310058
to be published
in PRL

- Neutron at IP12
  - $A_N \sim -11\%$



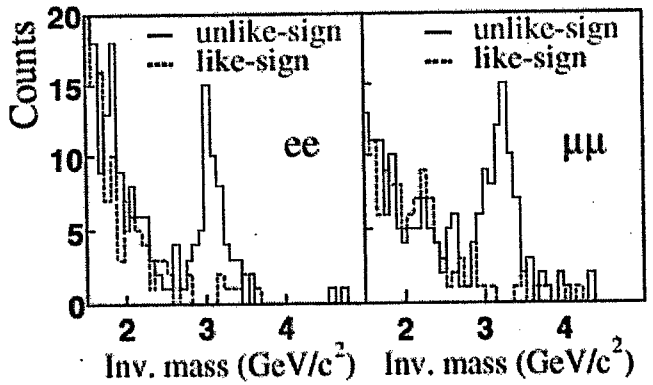
paper in preparation
to be submitted
to PRL

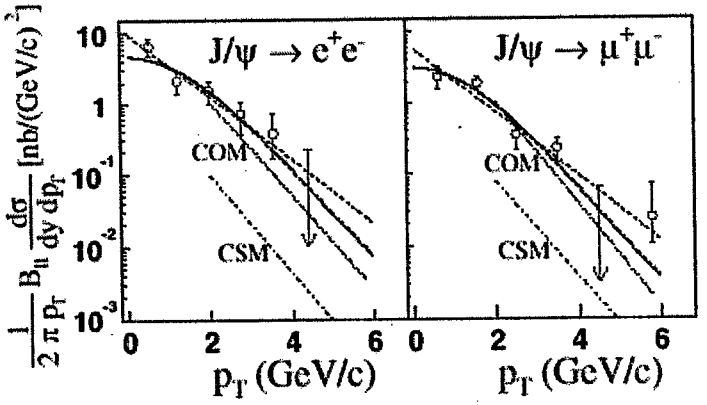
J/ψ

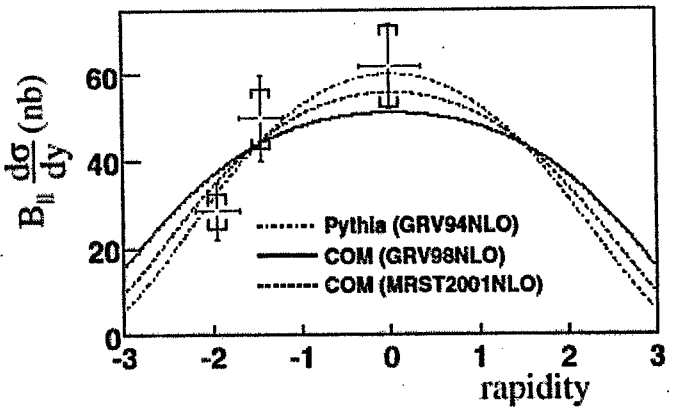
H.D. Sato, N. Kamihara, A. Taketani
H. Kobayashi, D.E. Fields

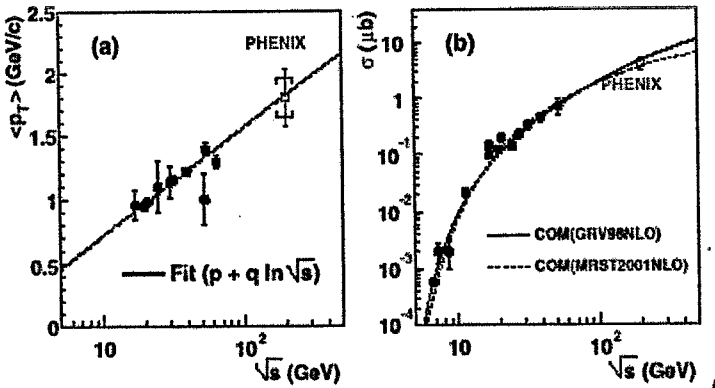
- First heavy-flavor measurement in *pp* collisions at PHENIX

Run-2 result
hep-ex/0307019
PRL 92, 051802 (2004)









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Silicon Upgrade

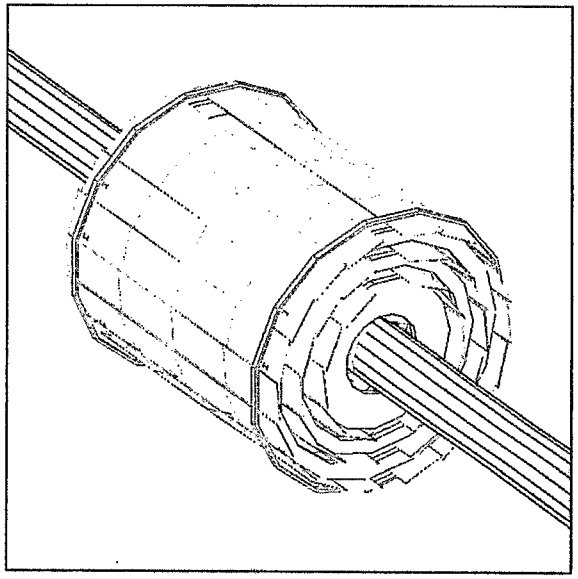
Y. Akiba, J.M. Heuser, H. Kano, H. Ohnishi,
V. Rykov, A. Taketani, J. Tojo,
N. Saito, M. Togawa, M. Wagner
A. Deshpande, D.E. Fields

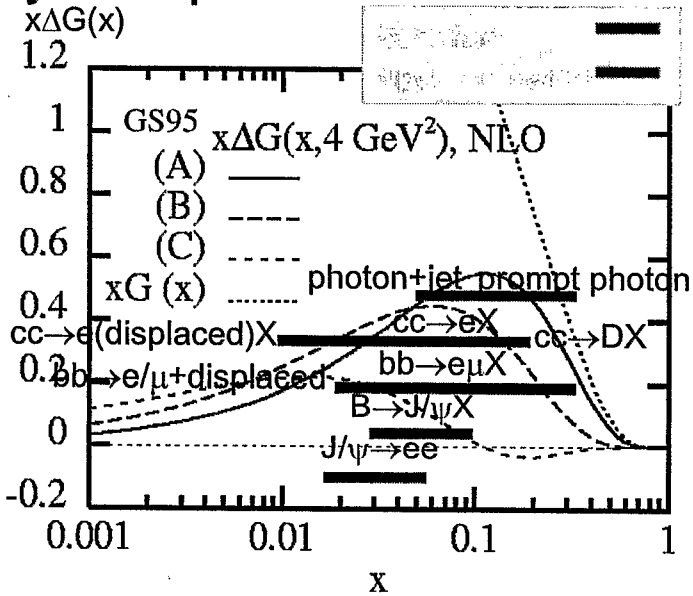
- Robust measurement of heavy-flavor production
- Reconstruction of jet over large acceptance

➔ Gluon polarization measurement

– enhanced x_{gluon} coverage

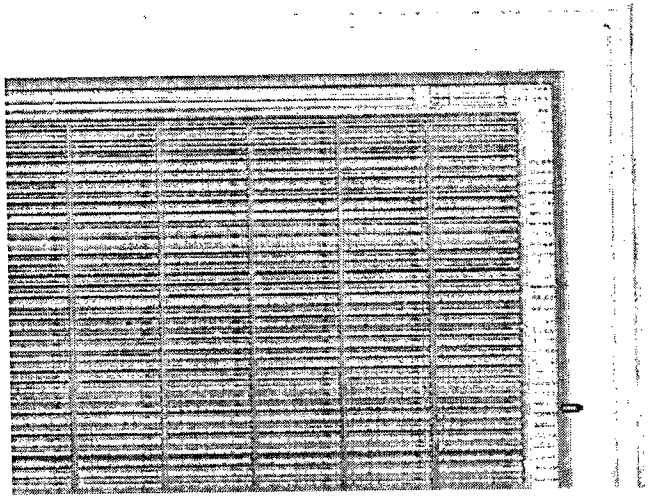
– overlap of the coverage by multiple channels

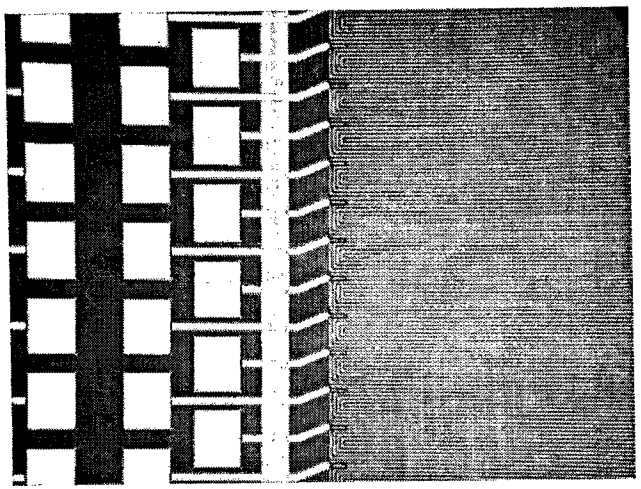




Silicon Upgrade

- Silicon pixel detector R&D
  - RIKEN-ALICE collaboration
  - ALICE beam test done in Oct.–Nov. 2003
  - collaboration with NA60
- Silicon strip detector R&D
  - "stripixel" detector by Zheng Li (BNL instrumentation)
  - KEK beam test done in Dec. 2002
  - collaboration with ORNL for SVX4 (FNAL/LBNL) readout
- PHENIX VTX proposal
  - submitted to BNL on Oct. 2003

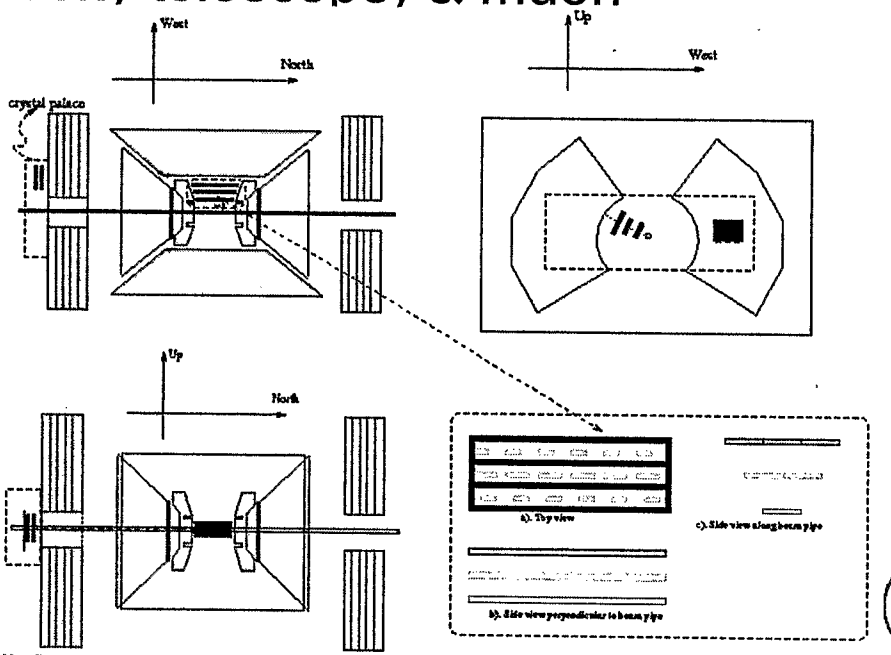




Other R&D's

W. Xie, M. Grosse Perdekamp, D.E. Fields
M. Wagner, K. Aoki, N. Saito, A. Taketani

- Luminosity measurement
  - how to count multi-collisions …
- W-trigger upgrade
  - how to survive full luminosity …
- R&D's in Run-4 (Apr-May)
  - RLT (relative luminosity telescope) & muon background study
  - STAR scaler



Summary

- We are giving first results of spin physics at RHIC
  - precision measurement of π^0 cross section
  - first A_{LL} measurement of π^0
  - single transverse-spin asymmetries
  - J/ψ, ...
- Many developments have been done and are ongoing
  - extended minimum-bias trigger & luminosity monitor devices
  - rare-event trigger systems
  - polarimetry
  - asymmetry analysis procedure
  - detector upgrades
- Many future topics ...

RIKEN and RBRC Activities at PHENIX

- EMCal
  - A. Bazilevsky, A. Deshpande, B. Fox, H. Torii, Y. Fukao, T. Horaguchi
- Muon
  - H.D. Sato, N. Kamihara, A. Taketani, H. Kobayashi, D.E. Fields
- Trigger
  - EMCal-RICH trigger
    - K. Okada, M. Grosse Perdekamp
  - MuID trigger
    - H.D. Sato, N. Kamihara
- Local polarimeter
  - A. Deshpande, B. Fox, K. Tanida, M. Togawa, Y. Fukao, N. Saito, Y. Watanabe
- Asymmetry analysis procedure
  - K. Tanida, M. Kaneta, B. Fox
- R&D's
  - silicon upgrade
    - Y. Akiba, J.M. Heuser, H. Kano, H. Ohnishi, V. Rykov, A. Taketani, J. Tojo, N. Saito, M. Togawa, M. Wagner, A. Deshpande, D.E. Fields
  - luminosity measurement
    - W. Xie, M. Grosse Perdekamp, M. Wagner
  - W-trigger
    - W. Xie, M. Grosse Perdekamp, D.E. Fields, K. Aoki, N. Saito, A. Taketani

RHIC SPIN, RBRC, RHIC SPIN GROUP

Gerry Bunce

25 March 2004
RBRC Management Steering Committee
G. Bunce

RHIC Spin, RBRC, RHIC Spin Group

Progress in RHIC Spin Program

Polarimetry: AGS, RHIC, Polarized Jet, Local

Longitudinal polarization established

First measurement of gluon polarization with strongly interacting probe in 2003

Discussion of 2004 and future

---new 5% Siberian Snake for AGS from RIKEN in 2004; new 20% Snake for AGS from BNL in 2005---toward achieving P = 70%, high L

---polarized gas jet for RHIC in 2004 --- P

---sensitive gluon polarization measurements in 2004/5 from π^0

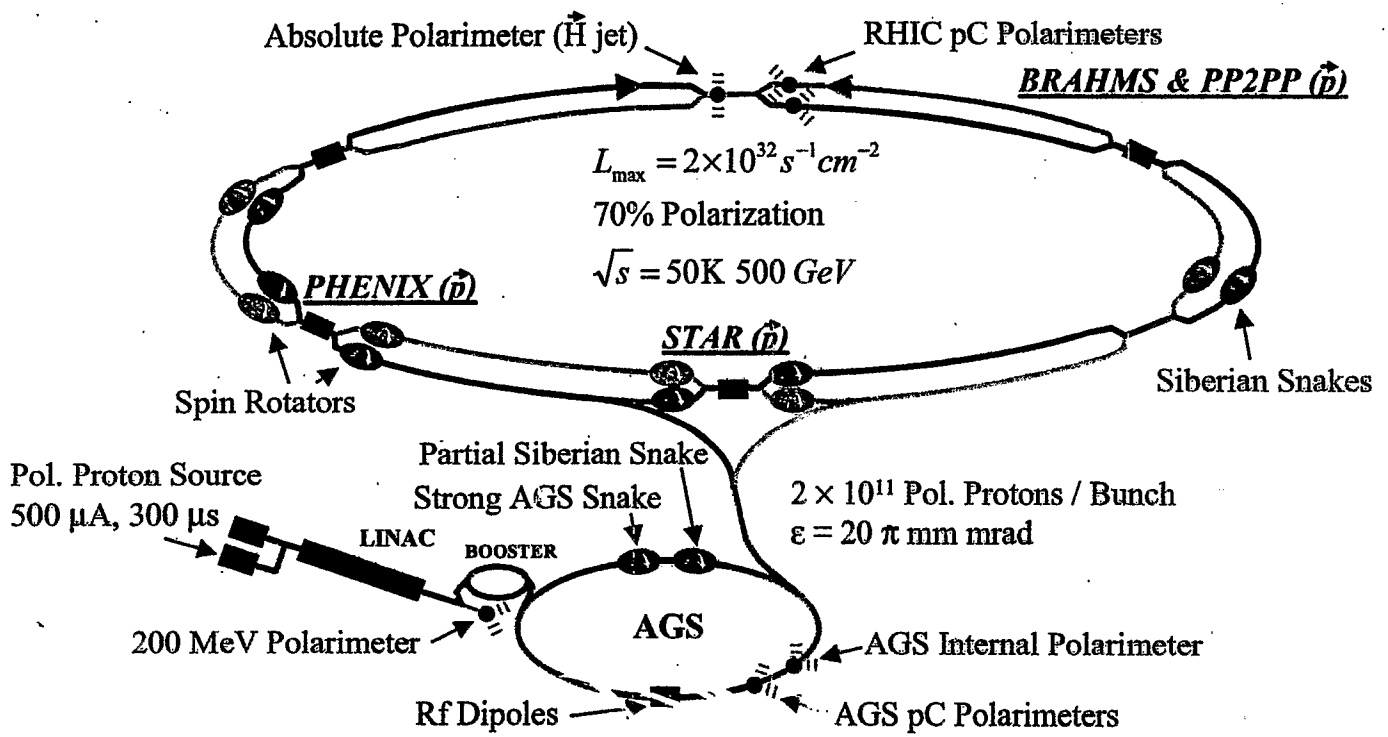
---precise gluon polarization measurements in 2005/6 from γ

RBRC: developing and leading the study of the spin structure of the proton

---

RHIC Spin Group: STAR, PHENIX and polarimetry

Polarized Proton Collisions in RHIC



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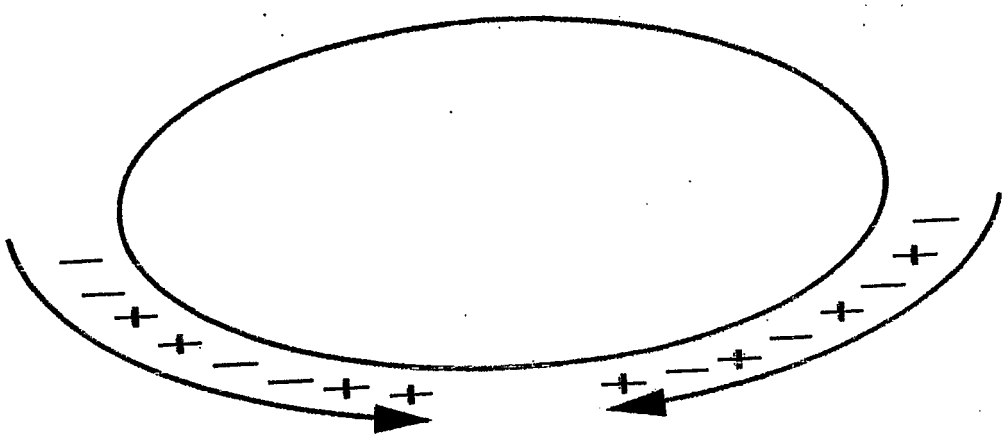
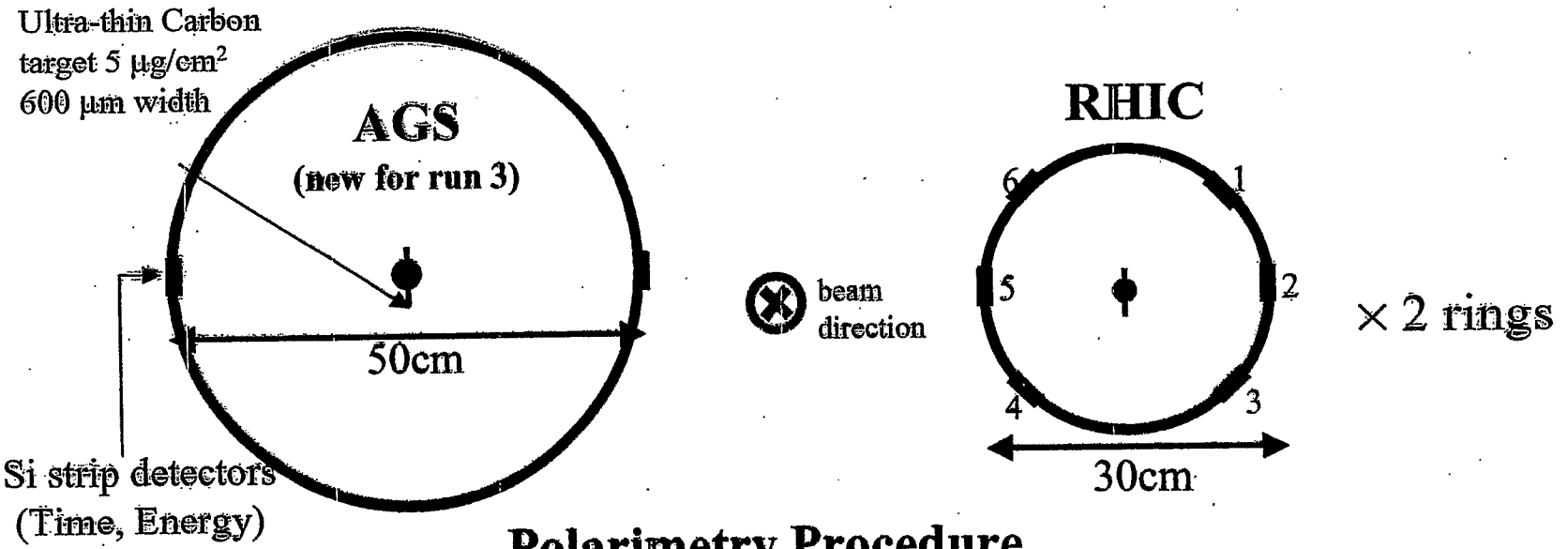
NATIONAL LABORATORY



CNI Polarimeters



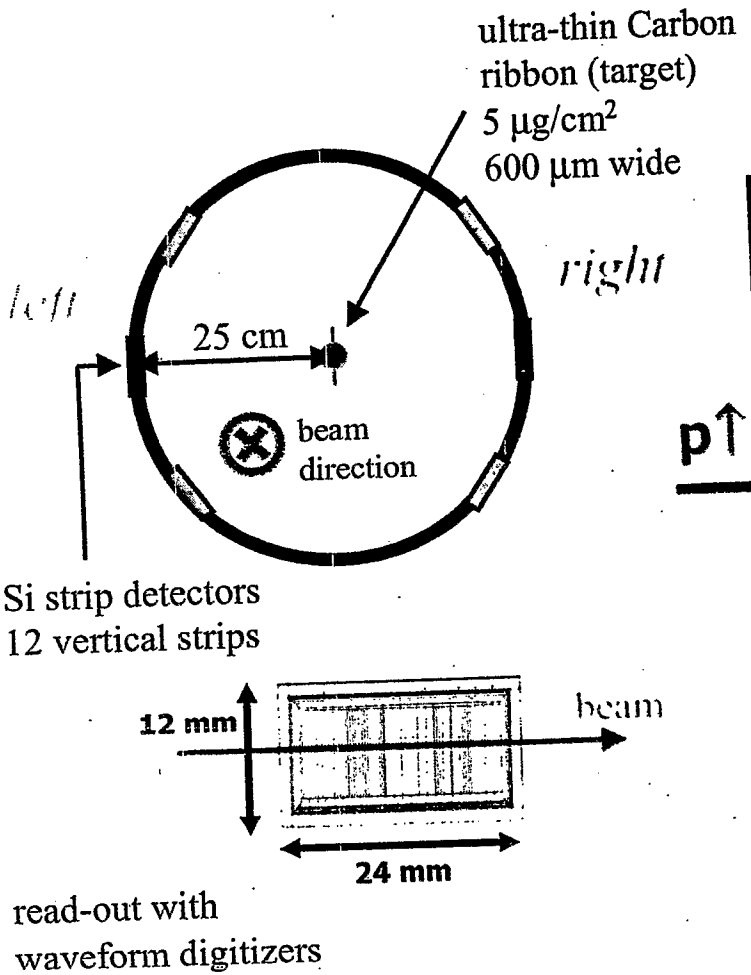
Polarimetry Procedure

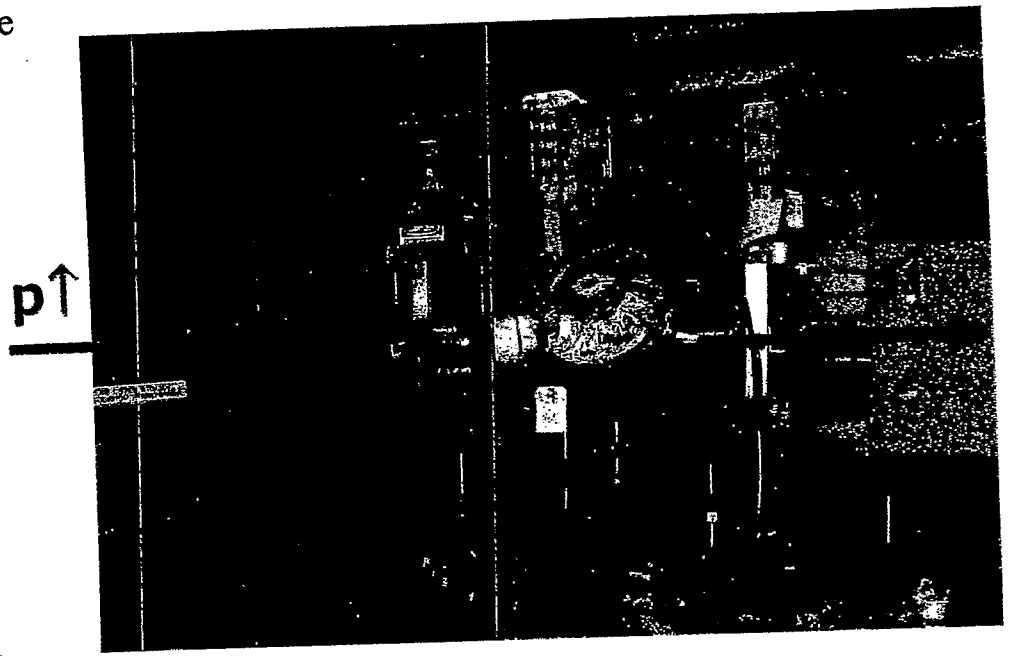
- Measure recoil carbons from $p^{\uparrow}C \rightarrow p^{\uparrow}C$ elastic scattering
- Exploit analyzing power, $A_N \approx 0.01$, originating from anomalous magnetic moment of proton. Calibration of A_N required.
- Measure left/right (more generally, azimuthal variation) spin-dependent asymmetry

$$\varepsilon_{LR} = \frac{\sqrt{N_{L\uparrow}N_{R\downarrow}} - \sqrt{N_{L\downarrow}N_{R\uparrow}}}{\sqrt{N_{L\uparrow}N_{R\downarrow}} + \sqrt{N_{L\downarrow}N_{R\uparrow}}}, \quad P_{beam} = \frac{\varepsilon_{LR}}{A_N}$$

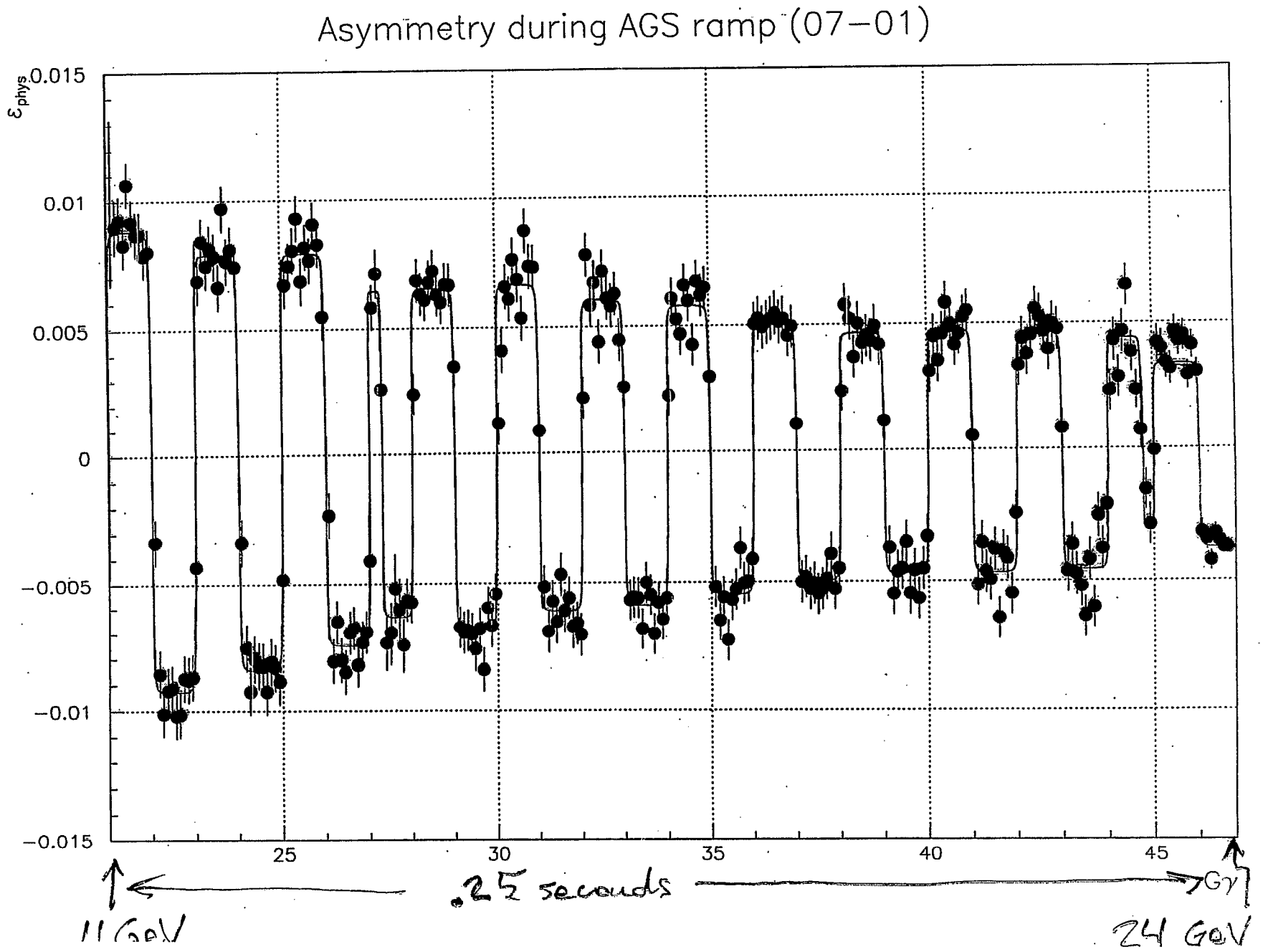
BROOKHAVEN NATIONAL LABORATORY

Elastic $p\uparrow C$ Scattering Setup in the AGS Ring

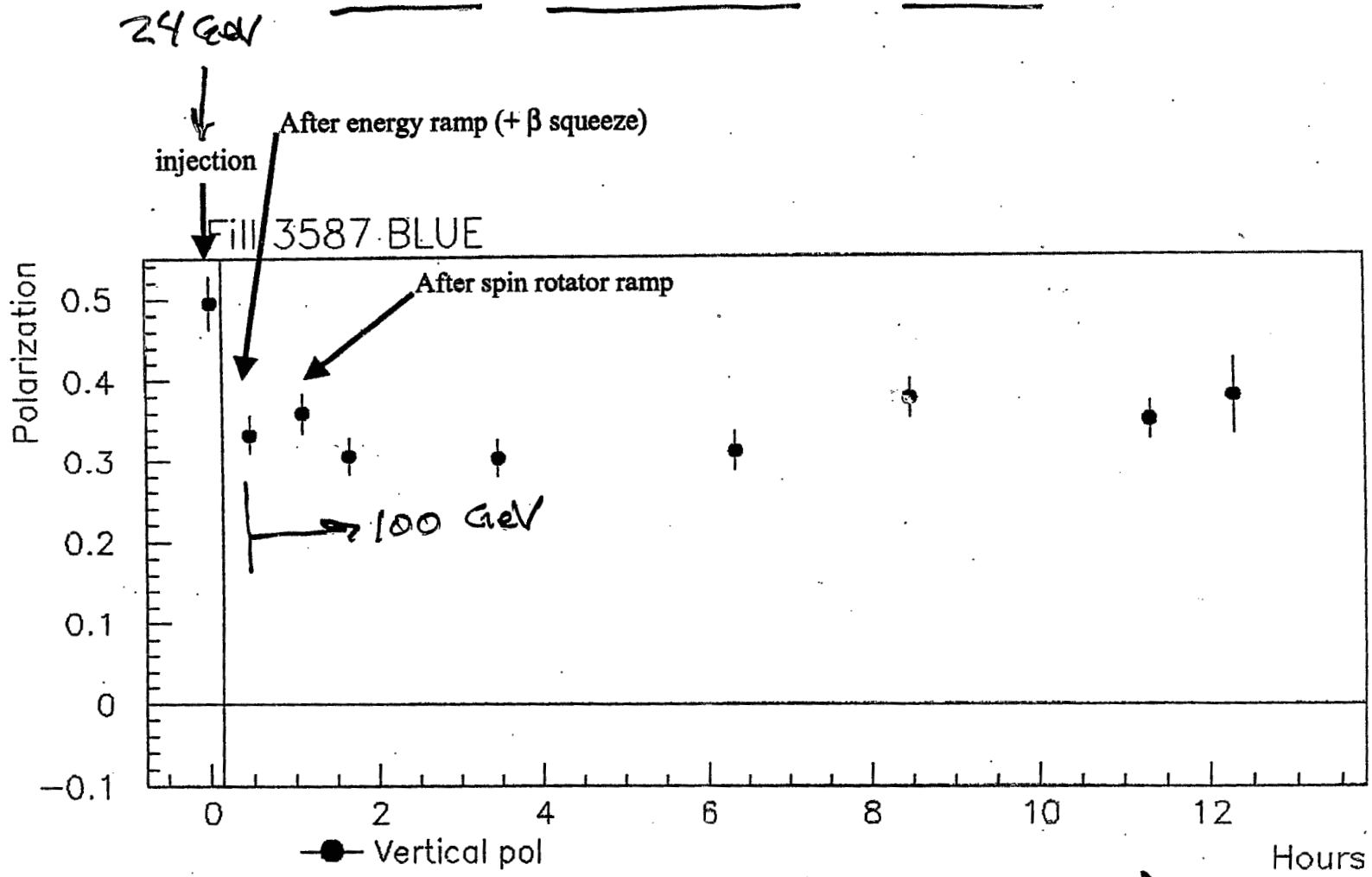




similar setups in RHIC for each beam


Asymmetry during AGS ramp (07−01)
ε_{phys}
0.015
0.01
0.005
0
−0.005
−0.01
−0.015
25
30
35
40
45
.25 seconds
Gγ
11 GeV
24 GeV

RHIC Polarimeter – 2003



assumes $A_N(100\ \text{GeV}) = A_N(24\ \text{GeV})$

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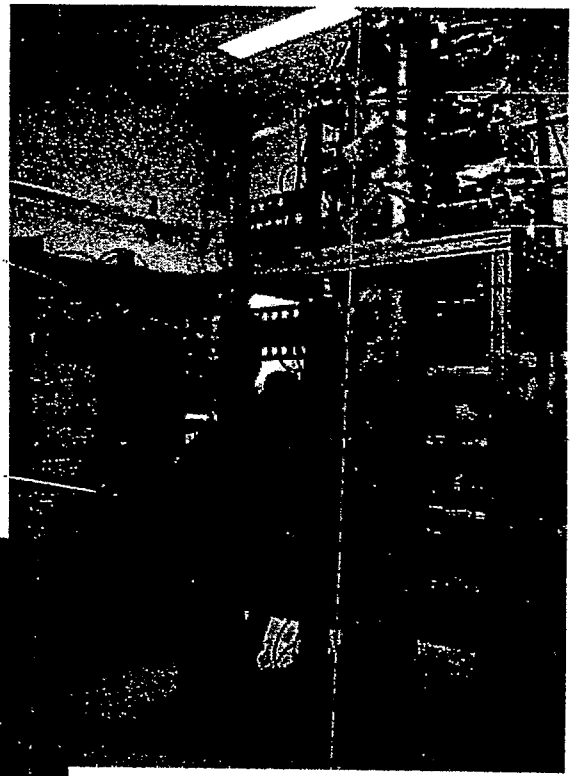
The Polarized Jet Target

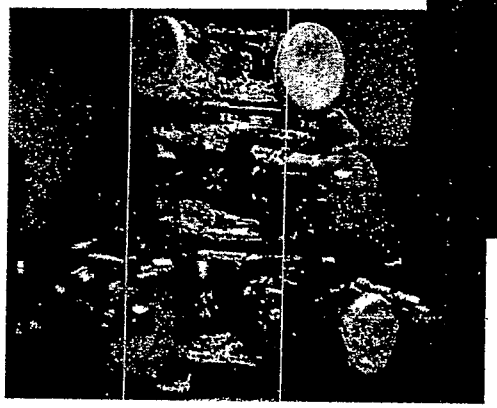
Electronics racks

Vac. gauges monitors

Turbo pump controllers

Dissociator RF systems





Target chamber &
beam pipe adapters

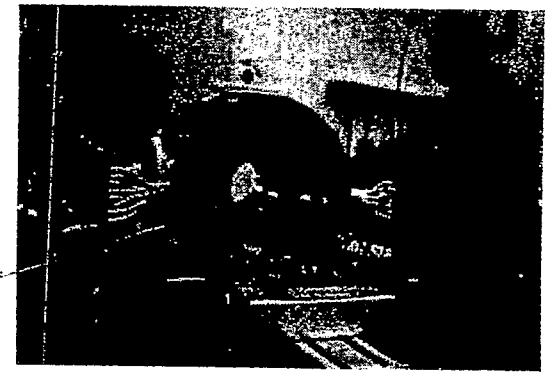
Dissociator stage

Baffle location
Sextupoles 1-4

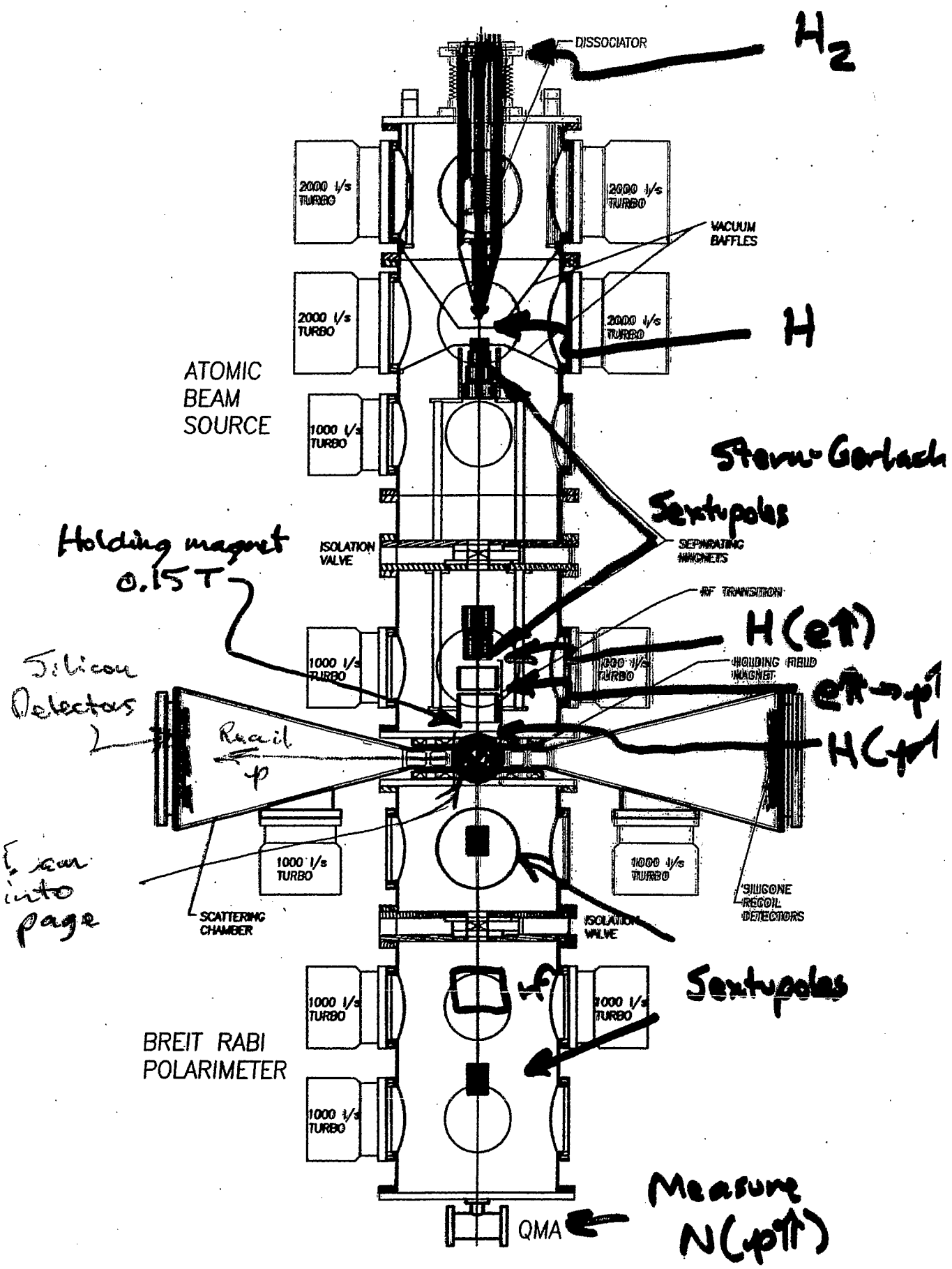
Sextupoles 5-6

Profile measurement

BRP vacuum vessel

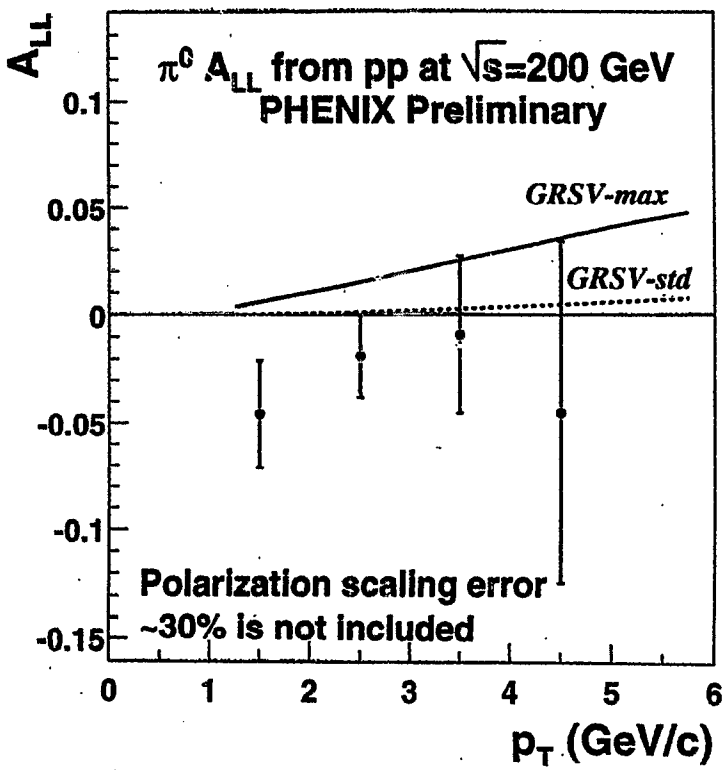


Magnet ready
for measurements


DISSOCIATOR
H_2
2000 l/s TURBO
2000 l/s TURBO
VACUUM BAFFLES
2000 l/s TURBO
2000 l/s TURBO
H
ATOMIC BEAM SOURCE
1000 l/s TURBO
Stern-Gerlach
Sextupoles
Holding magnet 0.15 T
ISOLATION VALVE
SEPARATING MAGNETS
RF TRANSITION
H(e↑)
1000 l/s TURBO
1000 l/s TURBO
HOLDING FIELD MAGNET
Silicon Detectors
e↑→p↑
Recoil p
H(p↑)
1000 l/s TURBO
1000 l/s TURBO
Beam into page
SCATTERING CHAMBER
SILICONE RECOIL DETECTORS
ISOLATION VALVE
Sextupoles
1000 l/s TURBO
1000 l/s TURBO
BREIT RABI POLARIMETER
1000 l/s TURBO
QMA
Measure N(p↑↑)

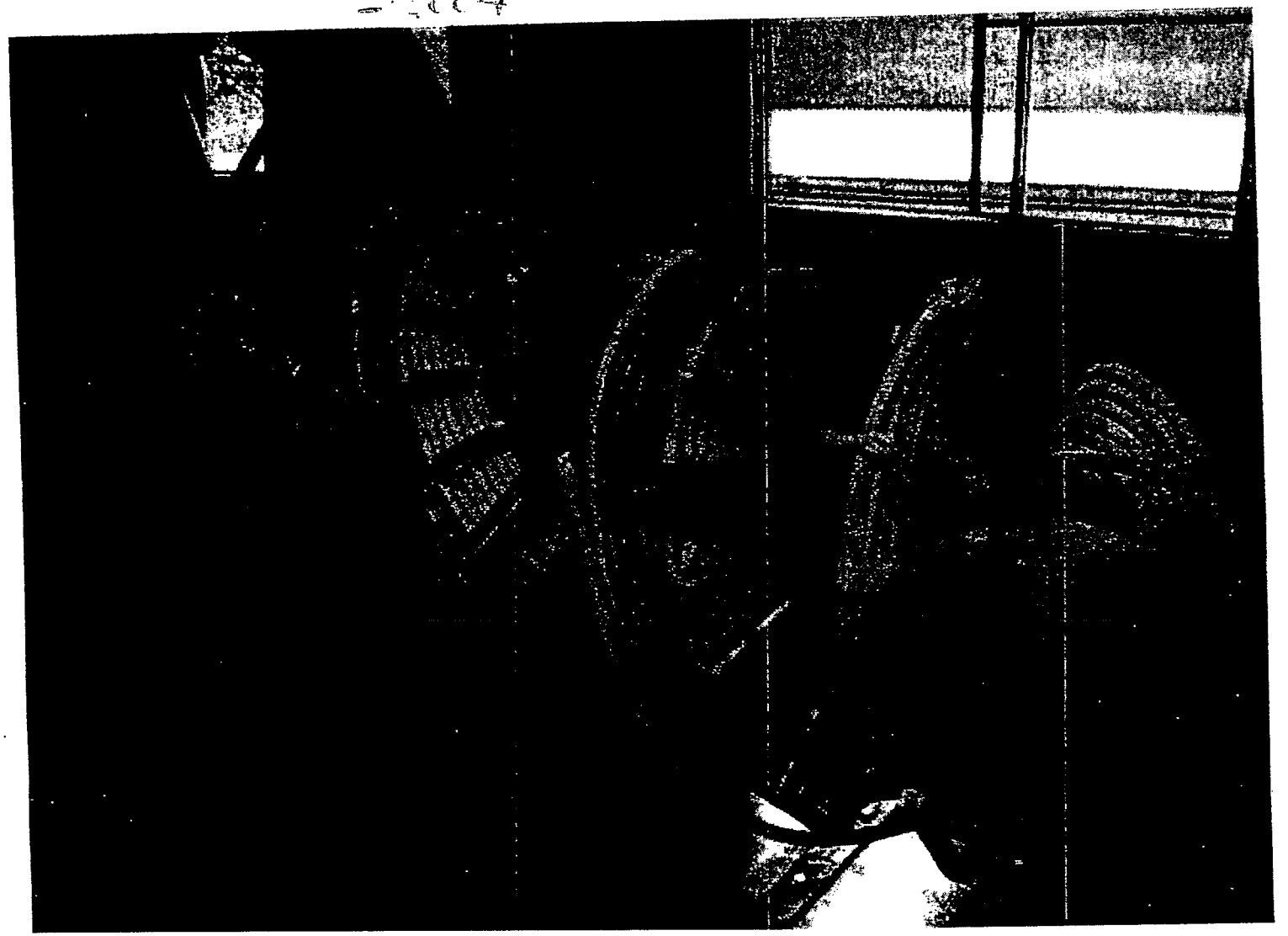
A_{LL}: PHENIX vs theory

B.J✶ger e al., PRD67, 054005 (2003)

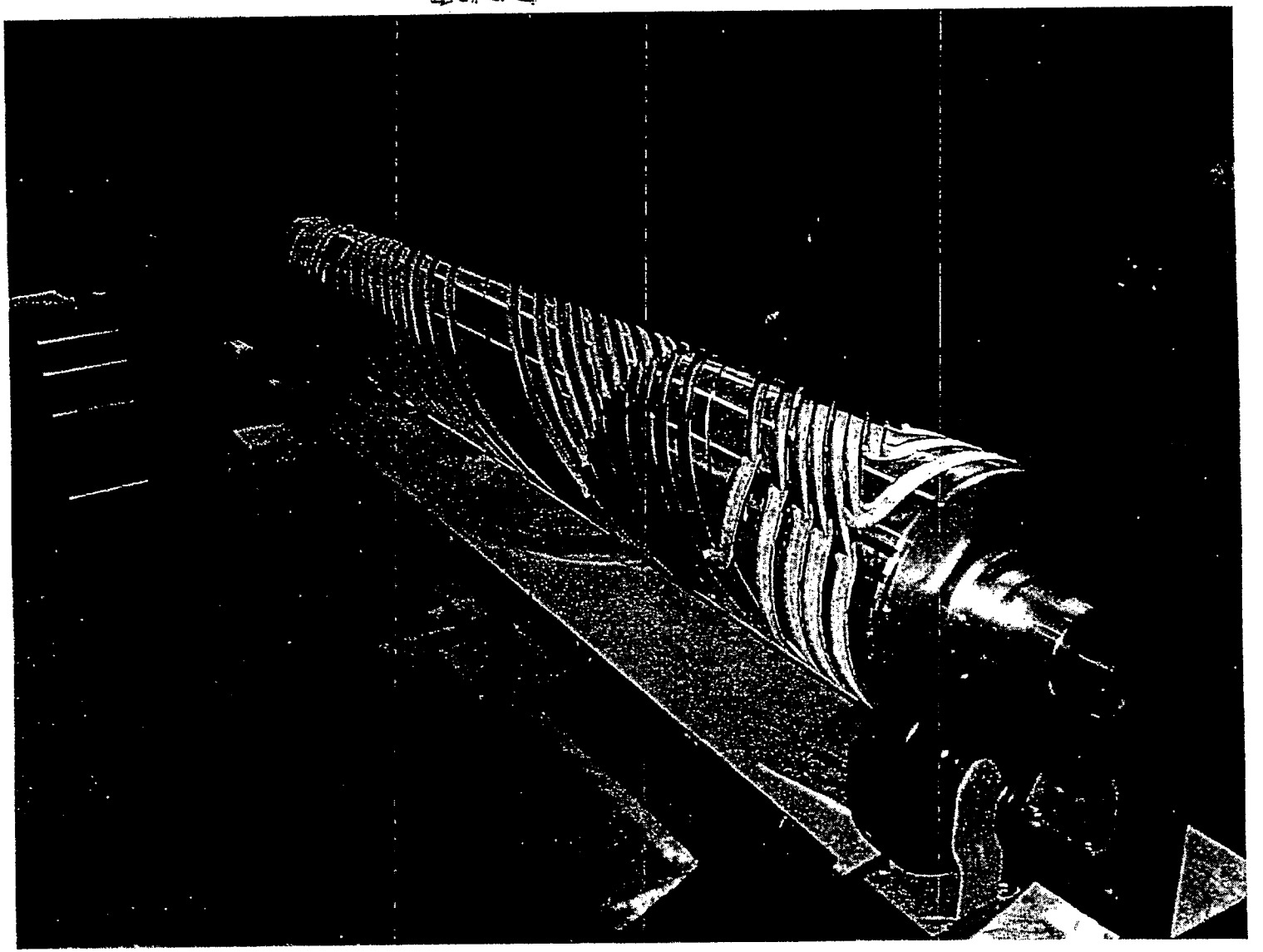


PHENIX

Siberian Snake for AGS: 5% x 180°

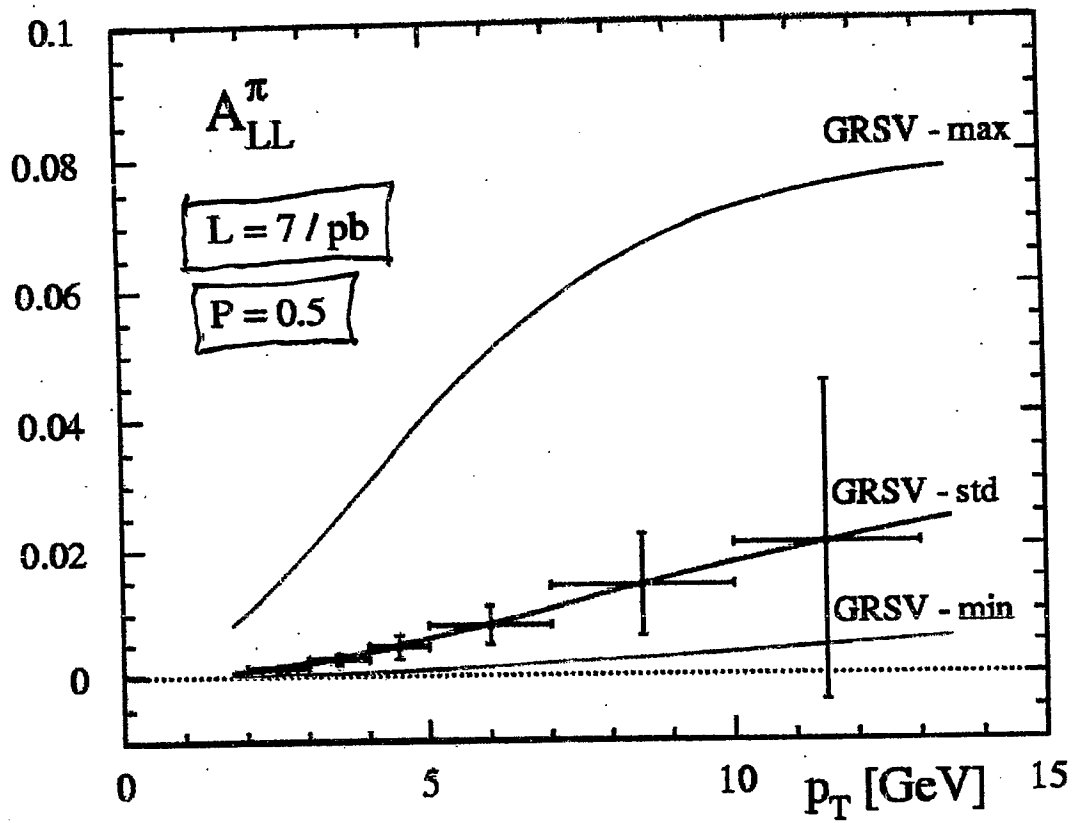


Siberian Snake for AGS: 20% x 180°
- 2005



π^0 Production and ΔG

π^0 can be used to determine ΔG with limited L & P

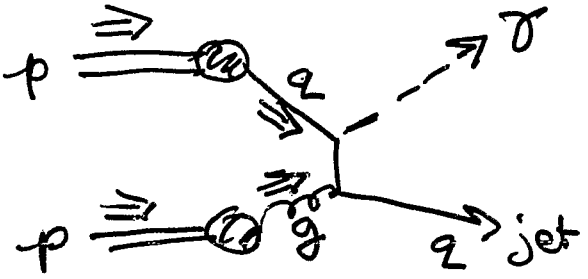


Jager, Schafer, Stratmann, Vogelsang

RHIC Spin Probes

Gluon polarization:

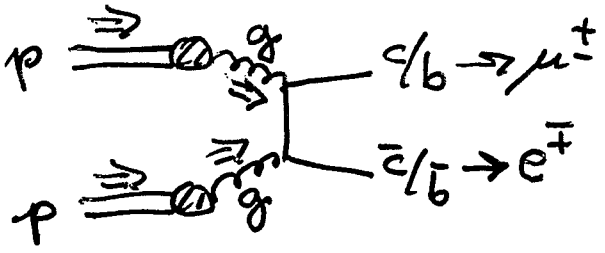
$$A_{LL} = \frac{1}{P^2}\frac{N_{++}(\vec{\gamma}) - N_{+-}(\vec{\gamma})}{N_{++} + N_{+-}}$$



$$A_{LL} = \frac{\Delta G}{G}(x_g)\, A_1^p(x_q)\, \hat{a}_{LL}$$

$$(.3) \quad (.6)$$

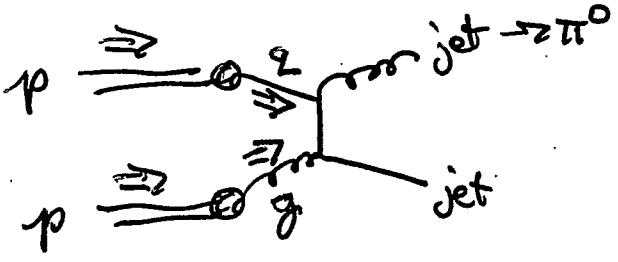
$$\simeq \frac{1}{5}\frac{\Delta G}{G}(x_g)$$



$$A_{LL} = \frac{\Delta G}{G}(x_1)\,\frac{\Delta G}{G}(x_2)\,\hat{a}_{LL}$$

$$(.5?) \quad (.15)$$

$$\overset{?}{\simeq} \frac{1}{12}\frac{\Delta G}{G}(x_1)$$



$$A_{LL} = \frac{\Delta G}{G}(x_1)\,\frac{\Delta u}{u}(x_2)\,\hat{a}_{LL}$$

$$(.4) \quad (.6)$$

$$\simeq \frac{1}{4}\frac{\Delta G}{G}(x_1)$$

$+ gg \to gg/q\bar{q}$

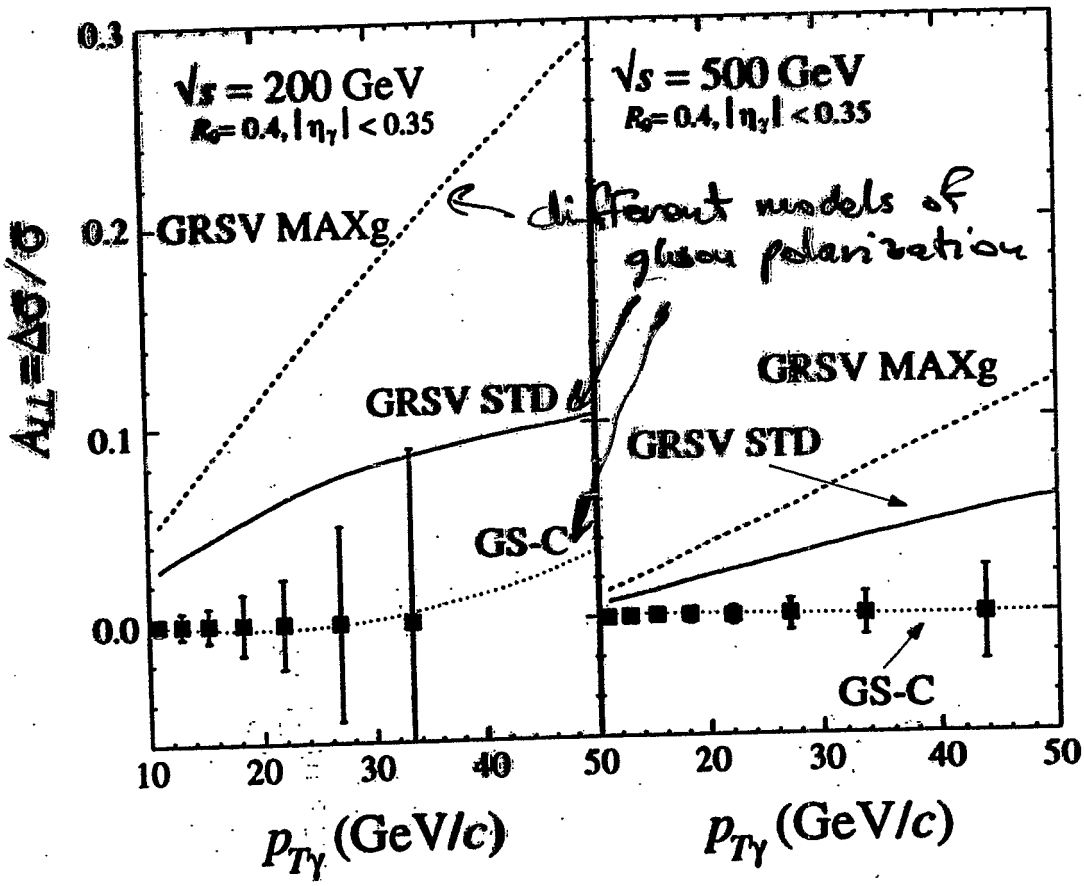
also J/ψ (but production mechanism)

Sensitivity at PHENIX for gluon pol.

$\int L\,dt = 320\ pb^{-1}$ $\sqrt{s} = 200$

$= 800\ pb^{-1}$ 500

$P_{beams} = 70\%$



$p\uparrow + p\uparrow \to \gamma + X$: A_{LL}

2004 - 2006...

RBRC (and RIKEN) --- remarks

1. Brendan Fox and Abhay Deshpande built a small experiment to search for a method to measure the spin direction at collision at Phenix for the 2002 spin run. This was crucial for the establishment of longitudinal polarization in 2003.

2. Event selection (triggering) in Phenix for pp is based on work by Matthias Perdekamp, Kensuke Okada, and Wei Xie.
   ---from 100 kHz collision rate to 1 kHz data rate

3. π^0 cross section from p_T = 1-13 GeV/c, over 8 orders of magnitude, led by Sasha Bazilevsky, Brendan Fox, Yuji Goto. Established that RHIC collisions, for p_T > 1.5 GeV/c are described by collisions of gluons and quarks.

4. First measurement of A_{LL} for π^0 in 2003. First measurement of gluon polarization with strongly interacting probe at collider. Led by Sasha Bazilevsky, Kiyoshi Tanida, Yoshi Fukao, Yuji Goto, Brendan Fox, Abhay Deshpande.

5. Polarization measurements in AGS with new pC polarimeter in 2003. Osamu Jinnouchi, Gerry Bunce. First measurement on AGS acceleration ramp, demonstrating spin flip at each of 40 resonances (every 10 ms on ramp).

6. Polarization measurements in RHIC in 2003. Led by Osamu Jinnouchi. Measurements to 2% in 20 s.

7. New AGS helical snake built by RIKEN. Suggested Nov. 2002, installed Feb. 2004. Led by Masahiro Okamura and Jun Takano. Early results: major improvement.

8. Polarized jet to measure absolute polarization in RHIC. Detectors by RBRC (Hiromi Okada, Gerry Bunce) and BNL RHIC Spin Group. First run in 2004.

9. Online spin monitoring, heavy ion flow measurement, heavy ion event plane from spectator neutrons—Masashi Kaneta

RBRC (continued)

10. Construction of muon tracking chambers, completed for both muon arms for 2003, led by Doug Fields.

11. Development of the proposal for the electron-RHIC collider is being led by Abhay Deshpande.

Matthias Perdekamp was PHENIX Run Coordinator for 2003. Matthias Perdekamp and Yasuyuki Akiba were named Deputy Spokesmen for PHENIX Feb. 2004.

Members of RBRC (2003/4):

Matthias Grosse Perdekamp (University Fellow, Illinois)
Abhay Deshpande (University Fellow, Stony Brook)
Brendan Fox (Fellow, left Nov. 03)
Doug Fields (University Fellow, New Mexico)
Wei Xie (Fellow, started Jan. 04)
Dave Kawall (Fellow, starts June 04)

Masashi Kaneta (Post Doc, started Nov. 02)
Kensuke Okada (Post Doc, started April 03)
Osamu Jinnouchi (Post Doc, started April 03)

Graduates in 2003: Sasha Bazilevsky (to BNL), Abhay Deshpande (to Stony Brook, shared RBRC/SB).

Students: Yoshi Fukao (Kyoto), Hiromi Okada (Kyoto), Manabu Togawa (Kyoto), Takuma Horaguchi (Tokyo Inst. Tech.), Nobu Kamihara (Tokyo Inst. Tech.), Kazuya Aoki (Kyoto)

Group Leader: Hideto En'yo (RIKEN)
Deputy: Gerry Bunce (BNL)

BNL RHIC Spin Group --- remarks

Mission: develop and lead the spin program at RHIC

The BNL RHIC Spin Group is modeled after and works in close collaboration with RBRC, providing new ideas, leadership, and new physics potential to the RHIC spin program.

Core group at Brookhaven for the spin program

- **---STAR: Les Bland, Akio Ogawa, Greg Rakness**
  - **---built beam-beam counters and forward π^0 detector**
    - **---large transverse asymmetries, major new result from RHIC spin**
    - **---provide leadership for STAR spin**
- **---PHENIX: Sasha Bazilevsky, Gerry Bunce**
- **---Polarimetry: Sandro Bravar (leads polarimetry, also on STAR), Ron Gill**
- **---pp2pp Experiment: Wlodek Guryn, Ron Gill**

Future: expect to grow to 4 to 5 physicists for STAR, PHENIX; pp2pp experiment data-taking completed in 2003.

BNL Theory Group

Werner Vogelsang (RBRC/BNL) is a world leader in spin theory (perturbative QCD).

Stephan Kretzer (RA) is an expert in quark and gluon fragmentation within pQCD.

Feng Yuan (RA) joins Sept. 2004 (spin expert).

Marco Stratmann is frequent visitor (pQCD expert).

Additional Remark:

The frequent workshops sponsored by RBRC have been crucial to develop new ideas, bring other experts into the RHIC spin community, and to coordinate work between accelerator, theory, and experiment, and between experiments.

RIKEN CCJ
COMPUTING CENTER IN JAPAN FOR SPIN PHYSICS AT RHIC

Takashi Ichihara

RIKEN CCJ

Computing Center in Japan for spin physics at RHIC

T. Ichihara

RIKEN, RBRC

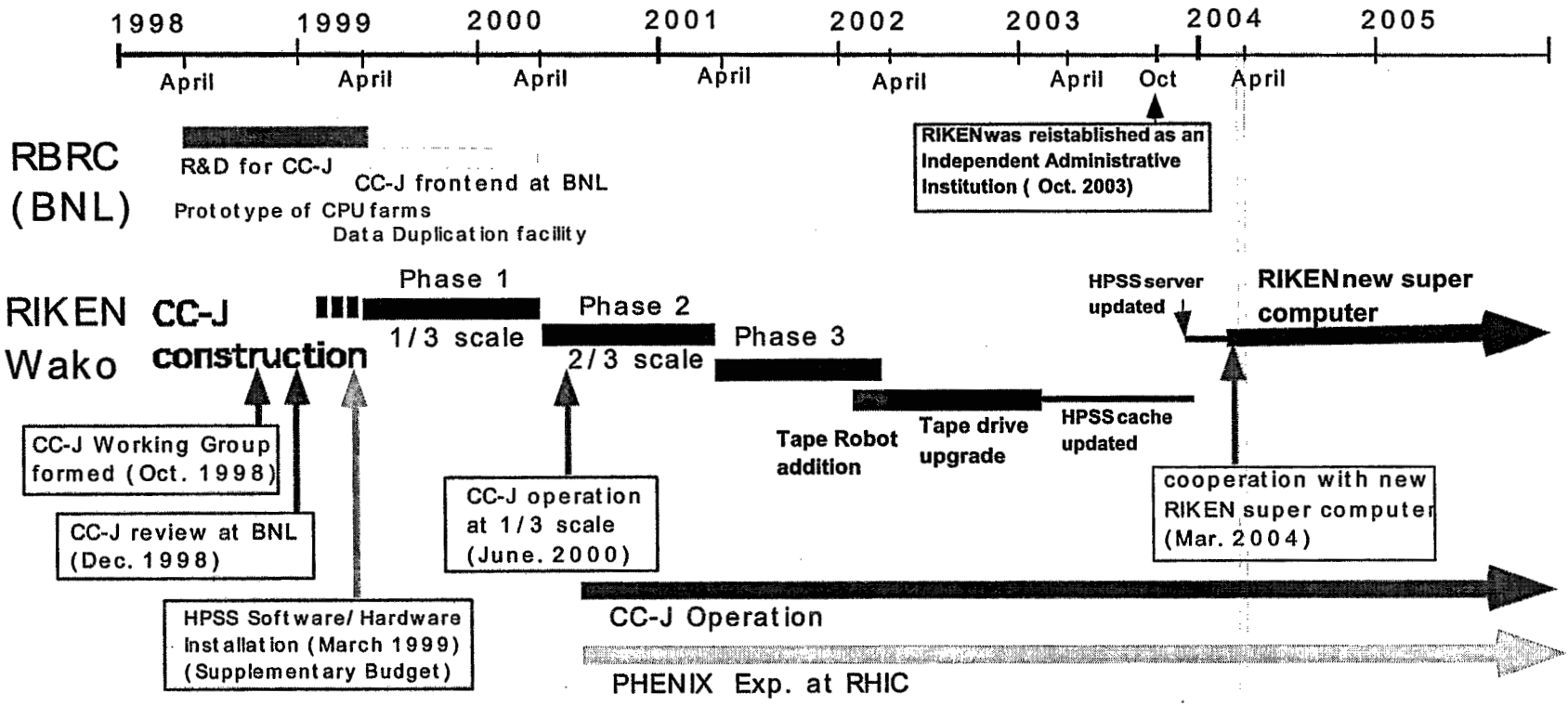
Presented on 25 March 2004

at RIKEN-BNL MSC at RIKEN

RIKEN CCJ : Overview

- Scope
  - Center for the analysis of **RHIC Spin Physics**
  - Principal site of computing for PHENIX simulation
  - **Regional Asia** computing center
- Size (initial estimation)
  - Data amount: handing 225 TB /year
  - Disk Storage : ~ 20 TB, Tape Library: ~500 TB
  - CPU performance : 13 k SPECint95
- Schedule
  - R&D for the CC-J started in April '98 at RBRC in BNL
  - Construction began in **April '99**
  - CCJ started operation in June **2000**
  - cooperation with a new RIKEN Supercomputer (2004)

Plan and Current Status of RIKEN CCJ



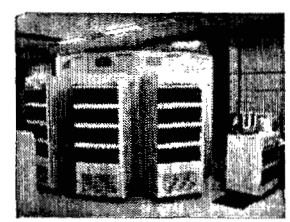
CCJ system upgrade in JFY 2002-2003

- Major Hardware Upgrade in JFY **2003**
  - Wide Area Network (WAN) bandwidth : 100Mbps -> **1 Gbps** (Aug. 2003)
  - **Cooperation with the new Supercomputer (March 2004)**
    - **New HPSS servers (IBM p-series 630, 5-node)**
    - **New CPU farms (Intel Xeon 3GHz x 256 CPU = 768 GHz)**
  - Network switch upgraded, hpss cache disk updated

- Major Hardware Upgrade in JFY **2002**
  - **Disk(RAID) : 25.2 TB ⇒ 33.2 TB**
  - HPSS Tape Library : **350(150)TB ⇒ 1200(600) TB**
    - **Replacement of the Tape Drive**

      Tape dive : 9400A (5 units) ⇒ 9940B (6 units)

9940A	10 MB/s	**50 GB/volume**
9940B	30 MB/s	**200 GB/volume**



Overview of the new RIKEN Supercomputer

- Five segments of PC-cluster system
  - **total 1024 node, 2048 CPU**
  - total performance: 12.4 TFLOPS

  - **PC Cluster 1 (1 system)**
  - For Large scale parallel computing
    - **512 node, 1024 CPU**
    - **CPU : Intel Pentium Xeon 3GHz**
    - **Memory : 4GB/node**
    - **HDD : 100GB/node**

  - **PC Cluster 2 (4 systems)**
  - For mission oriented
    - **128 node、256 CPU (for each system)**
    - **CPU : Intel Pentium Xeon 3GHz**
    - **Memory : 2GB/node**
    - **HDD : 100GB/node**

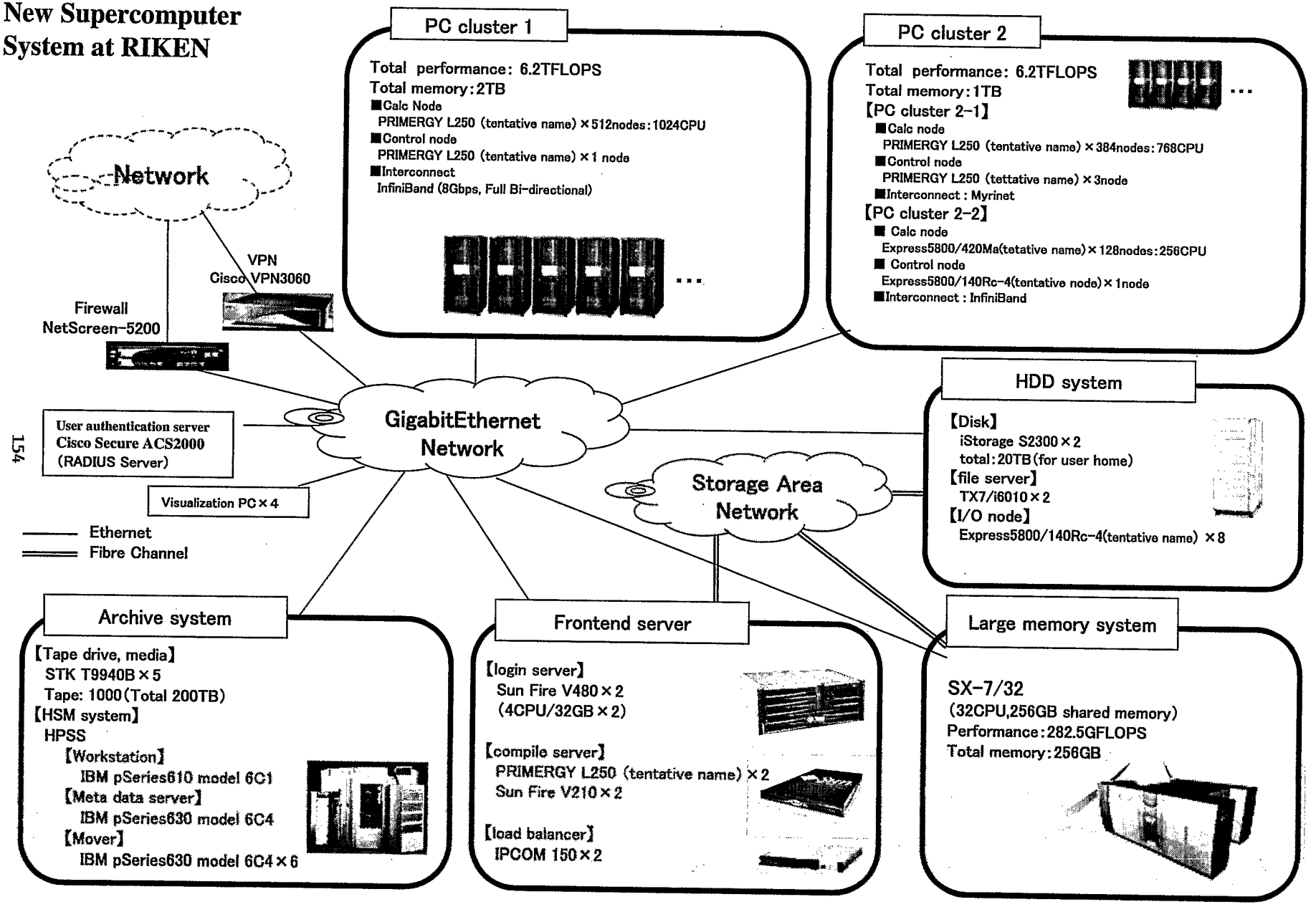
- SX-7/32 (Vector processor)
  - **32 CPU**
  - **Performance : 282.5 GFLOPS**
  - **Memory : 256 GB**
    - **Upto 256 GB Memory can be used for one process**

- Hard Disk Drive(Raid) unit
  - **User Area : 20TB**

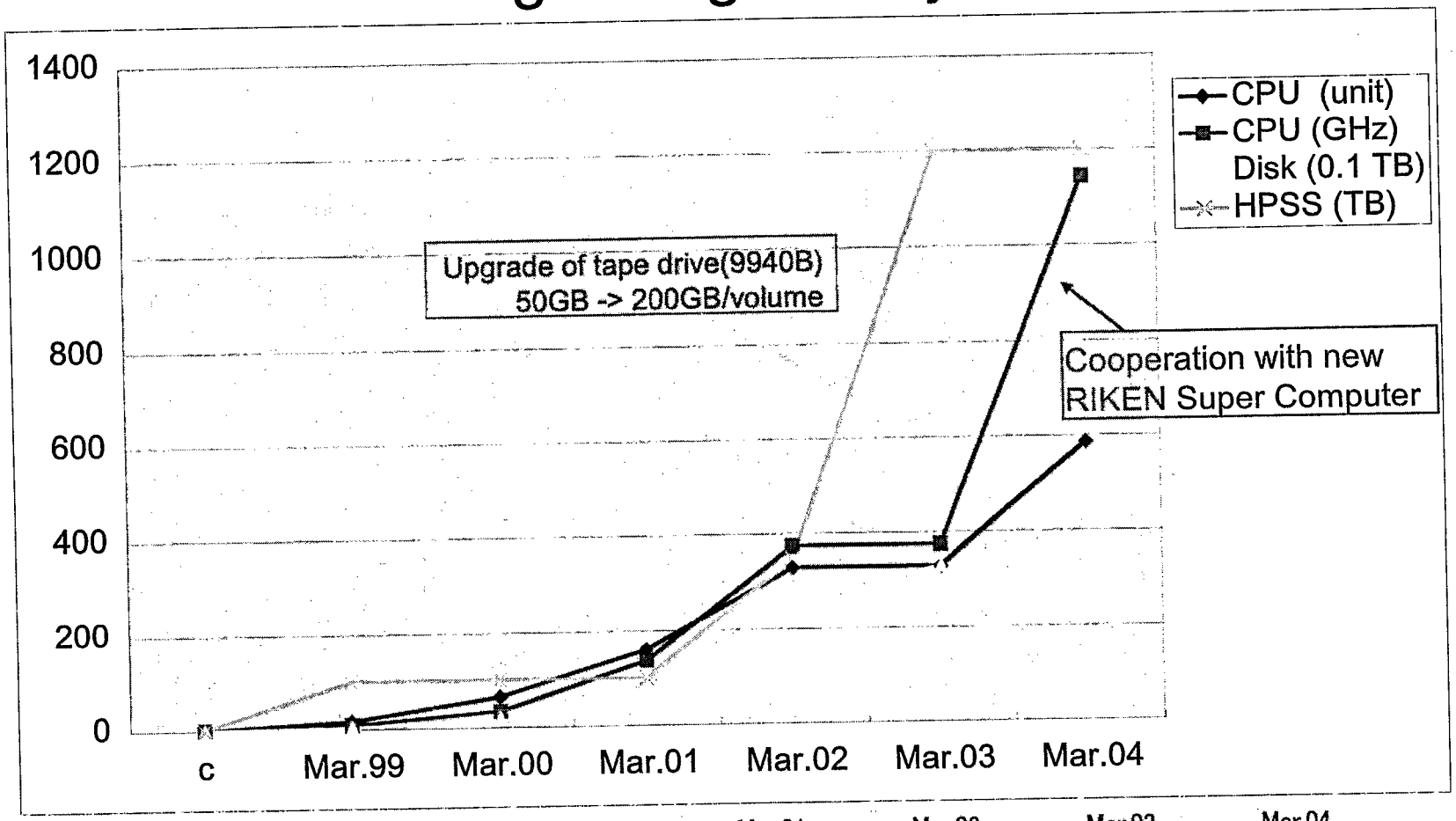
- Storage system (HPSS)
  - 200TB

Test operation started in March 2004

New Supercomputer System at RIKEN

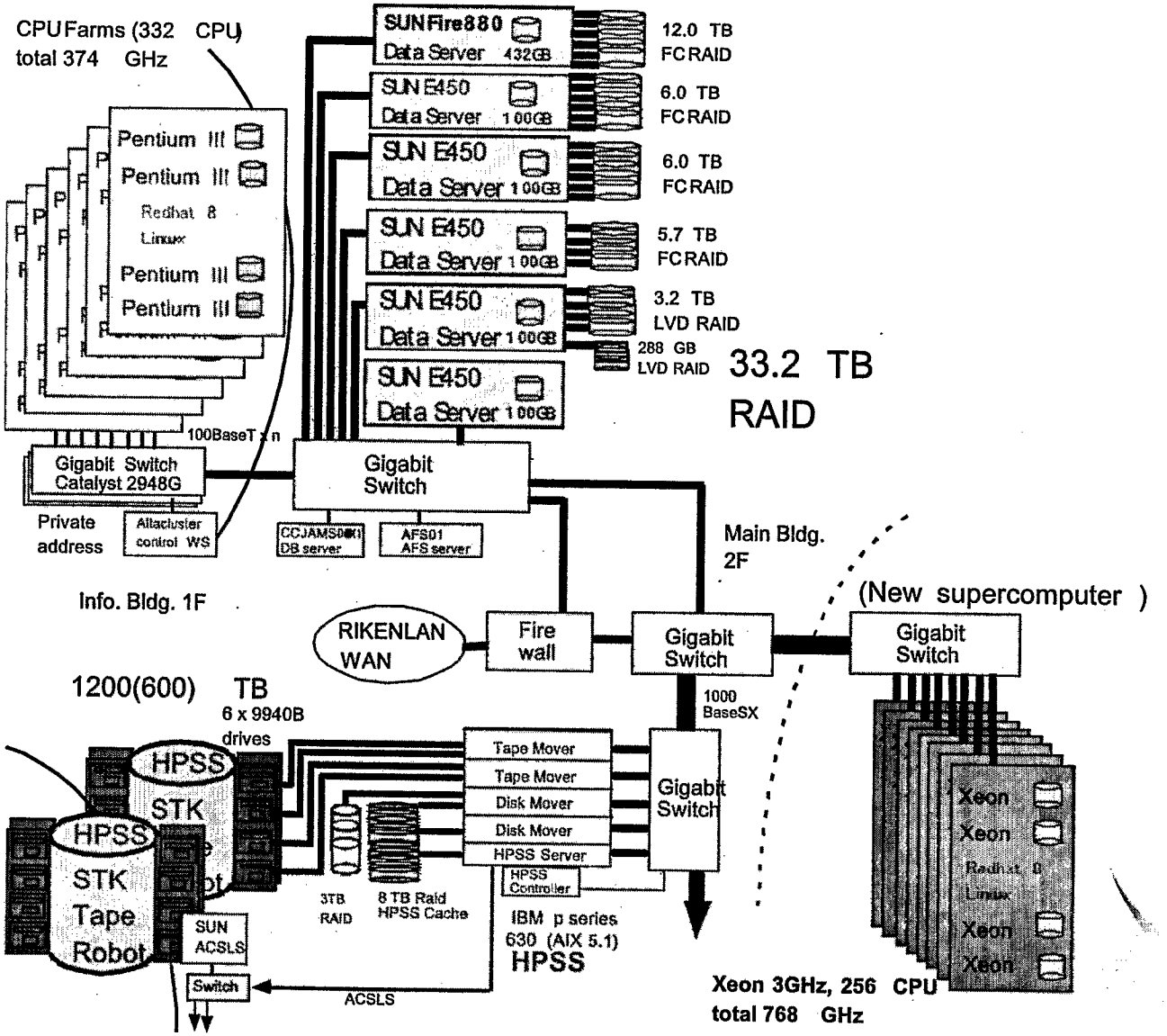


CCJ growing history



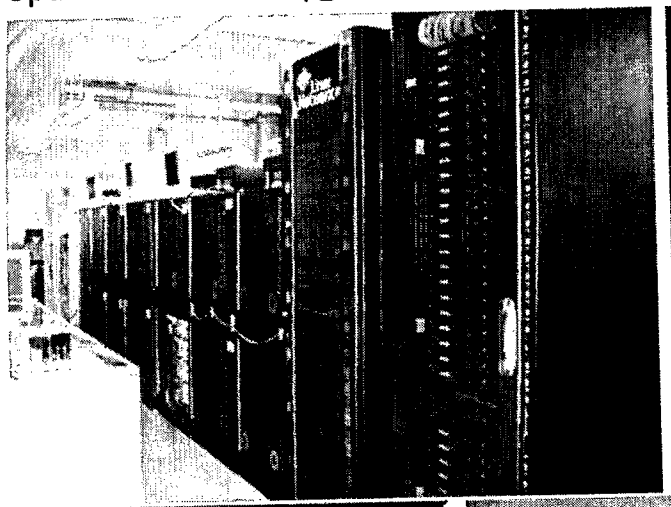
	c	Mar.99	Mar.00	Mar.01	Mar.02	Mar.03	Mar.04
CPU (unit)	0	16	64	160	330	330	580
CPU (GHz)	0	8	34	136	374	374	1142
Disk (0.1 TB)	0	3	19	92	252	332	332
HPSS (TB)	0	100	100	100	350	1200	1200

Current configuration of CCJ

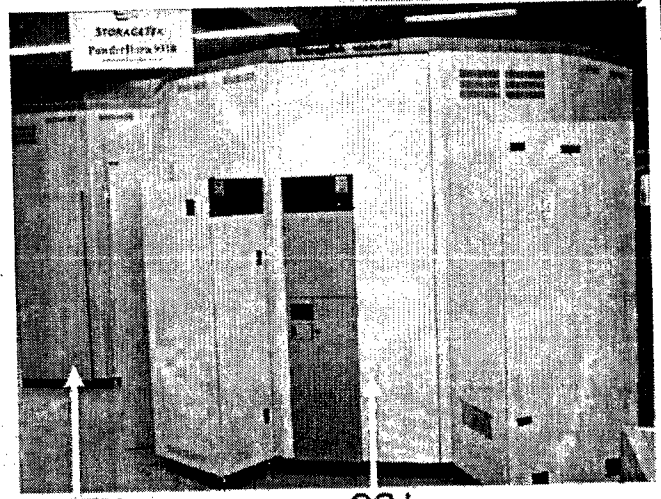


Components of RIKEN CCJ (1)

Cpu farms 328 CPU(@0.7-2GHz) 374 GHz

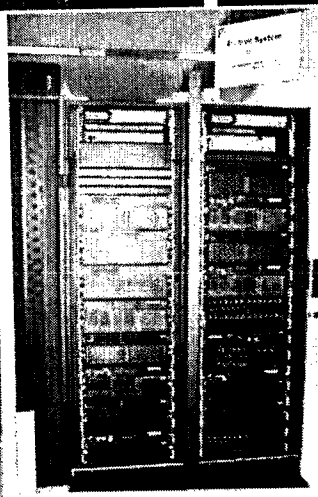


3.2 TB Raid | 5.7 TB Raid | 12 TB Raid | 12 TB Raid

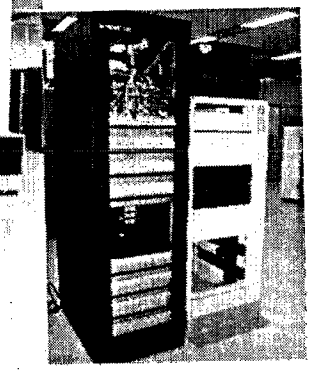


RIKEN common | CCJ

Tape silo (Storage Tek Powder Horn)



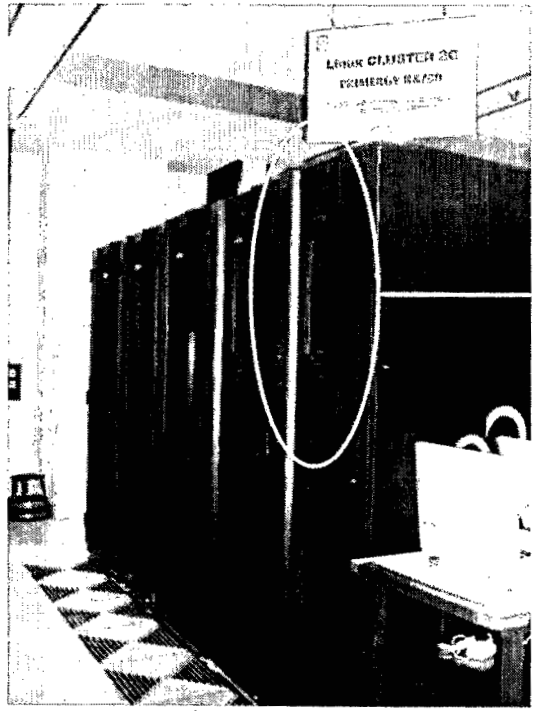
HPSS Server

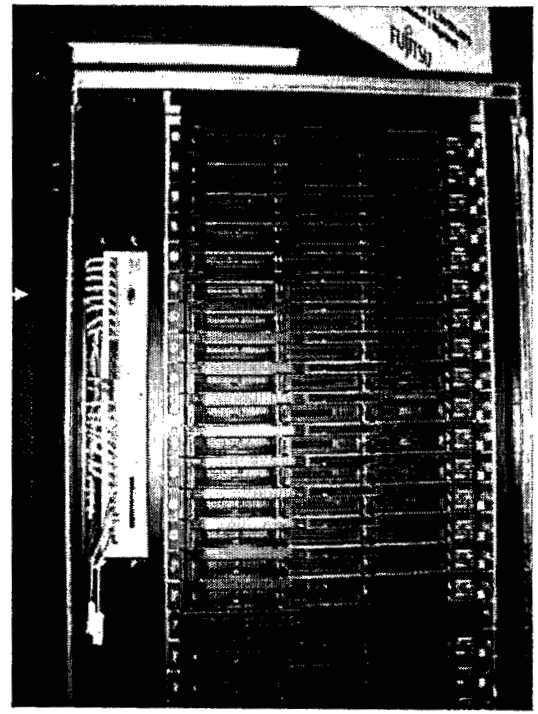


HPSS cache disk

Components of RIKEN CCJ (2)

cooperation with the new RIKEN Supercomputer





CCJ allocated part of new RIKEN Supercomputer:
128 nodes 256 CPU (Intel Xeon 3 GHz)

Proposal and Research Plan at CCJ

Official Production/Simulation

submitted	title	contact	status	resource	webpage
2000/07/11	Gamma acceptance of EMCal	T. Sakaguchi	finished		
2000/08/01	100K run00a	N. Hayashi	finished(pisa)	/ccj/w/tmp01	100K MC page
2000/09/13	100K run00b	N. Hayashi	finished(pisa/DST)	/ccj/w/tmp01	100K MC page
2000/11/10	100K run00c	N. Hayashi	finished(pisa/DST)	/ccj/w/tmp01	100K MC page
2001/05/10	Muon MDC	T. Thomas / H.D.Sato	finished	/ccj/w/data06 (650GB)	
2002/03/11	Test Production for Belle Monte Carlo Production	M. G. Perdekamp	finished	/ccj/w/data16	
2003/01/23	Study of the conversion and Albedo stuffs in the pp->pi0 analysis	H. Torii/A. Bazilevsky (for Spin/Photon PWG)	finished		
2003/05/03	Run2pp DST production	H. Kobayashi J. Rak	in progress (target:030615)	5TB(data24,25,28,29...)	
2003/05/03	Run3pp filtered data fast analysis	T. Horaguchi Y. Goto	finished	4TB(data21,22,23,26)	
2003/07/03	run3pp data refiltering + spin-nanoDST + gamma3 process	Y. Goto	in progress	4TB(data27,30, 23,26)	
2003/08/25	PbGl data analysis for the pi0 asymmetry fast analysis	Y. Goto/O. Zaudtke/S.Bathe	in progress	-	
2003/08/25	Run2-pp pi0 A_N analysis	Y. Goto/H. Torii/C. A. Aidala	in progress	100GB(/ccj/w/data14/)	

Research Plan

ID	submitted	title	contact	status	resource	expiration date
1	2000/11/14	Test DST production for EMCal	T. Matsumoto	finished	/ccj/w/tmp02(100GB)	2001/03/31
2	2001/01/03	Estimation of photon conversion in PHENIX spectrometer	T. Hachiya	finished	/ccj/w/tmp05(100GB)	2001/03/31
3	2001/02/09	MicroDST production using recent TOF parameters	A. Kiyomichi	finished (2001/03/05)	/ccj/w/tmp04(100GB)	2001/03/31
4	2001/03/26	DST production for EMCal timing calibration	H. Torii	finished	/ccj/w/data06(100GB)	2001/04/30
5	2001/08/23	Muon tracker geometry calibration	H. Kobayashi/ N. Kamihara	finished	/ccj/w/data04(100GB)	2001/09/30
6	2001/11/16	Pizero Analysis Using EMCal	K. Oyama	finished	/ccj/w/tmp02(100GB)	2001/11/30

7	2001/11/21	Trigger study for PHENIX run-2 analysis	K. Homma	in progress	/ccj/w/data07(300GB)	2001/12/05
8	2001/11/21	fast turn around analysis for spin	Y. Goto	in progress	/ccj/w/data08,13(2TB) (for pp rawdata)	2002/01/31
9	2001/12/22	Single particle MC production for run-1 Lambda and Anti-Lambda analysis	H. Ohnishi	finished	/ccj/w/data14 (500GB)	2002/01/31
10	2002/01/09	Quick analysis of pp muon events	H. Sato	finished	/ccj/w/data09,10,15(3TB) (for pp rawdata)	2002/03/31
11	2002/01/09	Search for non-hadronic sources of photon at RHIC	T. Sakaguchi	finished	/ccj/w/data17(400GB) (for uDSTprduction)	2002/07/31
12	2002/01/11	simulation for electron analysis	K. Katou	finished	/ccj/w/data17(50GB)	2002/01/31
13	2002/01/17	Acceptance Calculation of Pair Electron	M. Tamai	finished		2002/02/15
14	2002/01/18	photon polarimeter analysis	Y. Goto	in progress	/ccj/w/data04(200GB)	2002/01/31
15	2002/01/29	Run2 TOF calibration	H. Masui	in progress	/ccj/w/data01(600GB)	2002/03/31
16	2002/02/20	simulation for RICH/electron analysis	K. Katou	finished	/ccj/w/data12(500GB)	2002/07/31
17	2002/02/27	simulation for silicon vertex detector	K. Tanida	in progress	/ccj/w/data04(50GB)	2002/09/31
18	2002/03/08	Simulation for Correction of Identified Hadron	A. Kiyomichi	in progress	/ccj/w/data12(400GB)	2002/07/31
19	2002/04/01	Monte-Carlo Calculation for Pizero Analysis	K. Oyama	finished	-	2002/04/30
20	2002/06/05	EMCal calibration for QM2002	H. Torii	finished	/ccj/w/data14(100GB)	2002/07/31
21	2002/08/21	Alignment study using Cosmic Ray	N. Kamihara	finished	/ccj/w/data11(400GB)	2002/09/30
22	2002/08/28	EMCal calibration for for publication of pp/AuAu->pi0 measurement	H. Torii	in progress	/ccj/w/data14(100GB)	2002/10/31
23	2002/08/29	E325 DST production and analysis for JPS and PANIC 02	S.Yokkaichi/R.Muto	finished	/ccj/w/data11,data17(1000GB)	2002/09/30
24	2002/11/01	Single muon Run2 pp analysis(uDST->nDST)	H. Kobayashi	finished	-	2002/11/15
25	2002/12/17	Analysis for silicon strip detector in PHENIX Upgrades	J. Tojo	in progress	/ccj/w/data07(100GB)	2003/03/31
26	2002/12/25	Searching for Non-hadronic sources of photons in Au+Au Collisions at $\sqrt{s_{NN}}$=200GeV at RHIC-PHENIX	T. Sakaguchi	in progress	/ccj/w/data17(500GB)	2003/06/30
27	2003/01/08	E325 DST production	R. Muto	finished	/ccj/w/data11,17(1000GB)	2003/01/31

28	2003/02/14	Identified Hadron Spectra and Yields at 200 GeV AuAu Collisions from the PHENIX experiment at RHIC	T. Chujo	finished	/ccj/w/data11(400GB)	2003/02/22
29	2003/03/05	Reproduction of SpinLuml root files for analysis of BBC single spin asymmetry with ZDC coincidence	K. Tanida	in progress	/ccj/w/data10(1000 GB)	2003/03/31
30	2003/03/14	Pico DST production for pi0 anisotropy analysis from micro DST of 200 GeV Au+Au data	M. Kaneta	finished	/ccj/w/data02(900 GB)	2003/04/15
31	2003/07/17	Single particle MC simulation for hadron spectra(run2 pp)	S. Kaminaga	finished	/ccj/w/data11(900 GB)	2003/09/24
32	2003/07/31	2nd scan of pi0 anisotropy analysis	M. Kaneta	finished	(/ccj/w/data02)	2003/08/10
33	2003/08/26	Monte-Carlo event generation for the study of dimuon production at CERN-SPS	H. Ohnishi	in progress	900GB(/ccj/w/data15)	2003/10/30
33	2003/08/29	Run#91720 MUIDS1D triggered events production	K. Aoki	finished	(/ccj/w/tmp03)	2003/9/10
34	2003/09/17	Direct photon mesurement in RHIC-PHENIX	T. Horaguchi	in progress	200GB(/ccj/w/data17)	2003/12/31
35	2003/10/27	Simulation study for the Aerogel Cherenkov Counter	S. Takagi	finished	500GB(/ccj/w/data11)	2004/2/14
36	2003/12/02	Simulation Study for Muon Trigger Upgrade	K. Aoki	in progress	300GB(/ccj/w/data10)	2004/3/31
37	2003/12/09	E325 simulation for QM2004	M. Naruki	in progress	100GB(/ccj/w/data12)	2004/1/30
38	2003/12/09	Single muon A_LL analysis using Run-3 data	H. Sato	in progress	100GB(/ccj/w/data24)	2004/4/1
39	2003/02/24	3rd scan of pi0 anisotropy analysis	M. Kaneta	in progress	(/ccj/w/data26,data15, 1.3TB)	2003/08/01
40	2003/02/29	Anti-Pentaquark search from PHENIX run2 Au+Au data	M. Kaneta	in progress	-	2003/03/20

ccj/proposals/index.html

- 32 research plans were finished and 20 research plans are now in progress
- Details can be found at the URL of
  http://ccjsun.riken.go.jp/ccj/proposals/index.html

CCJ Operation

- Operation, maintenance and development of CC-J are carried out under the charge of the CCJ Planning and Coordinate Office (PCO).

CCJ Director (Chief Scientist of the Radiation Lab.)

H. En'yo

Planning and Coordination Office

manager	T. Ichihara	(RIKEN and RBRC)
technical manager	Y. Watanabe	(RIKEN and RBRC)
scientific programming coordinator		
	H. En'yo	(RIKEN and RBRC, PHENIX-EC)
	H. Hamagaki	(CNS-U-Tokyo, PHENIX-EC)
PHENIX Liaison	Y. Goto	(RIKEN and RBRC)
computer scientists	S. Yokkaichi	(RIKEN and RBRC)
	A. Kiyomichi	(RIKEN and RBRC)
	O. Jinnouchi	(RIKEN and RBRC)

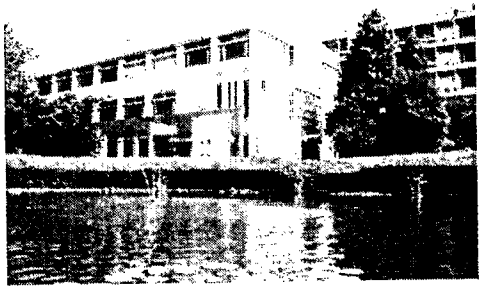
Technical Management Office

Manager, Data duplication	Y. Watanabe	(RIKEN and RBRC)
Tape duplication coordinator	O. Jinnouchi	(RIKEN and RBRC)

RIKEN'S CURRENT STATUS AND FUTURE PLANS: OUTLINE OF RIKEN

Hiromichi Kamitsubo

RIKEN



Outline of *RIKEN*

"Rikagaku Kenkyusho" (RIKEN)

理化学研究所　（理研）

(2) H.Kamitsubo

History of RIKEN- From Foundation to Independent Administrative Institution

Since
1917
Foundation
RIKEN

Since
1948
Stock Company
RIKEN

Since
1958
Semi-Public
Research
Institute
RIKEN

Since
2003
Independent
Administrative
Institution
RIKEN

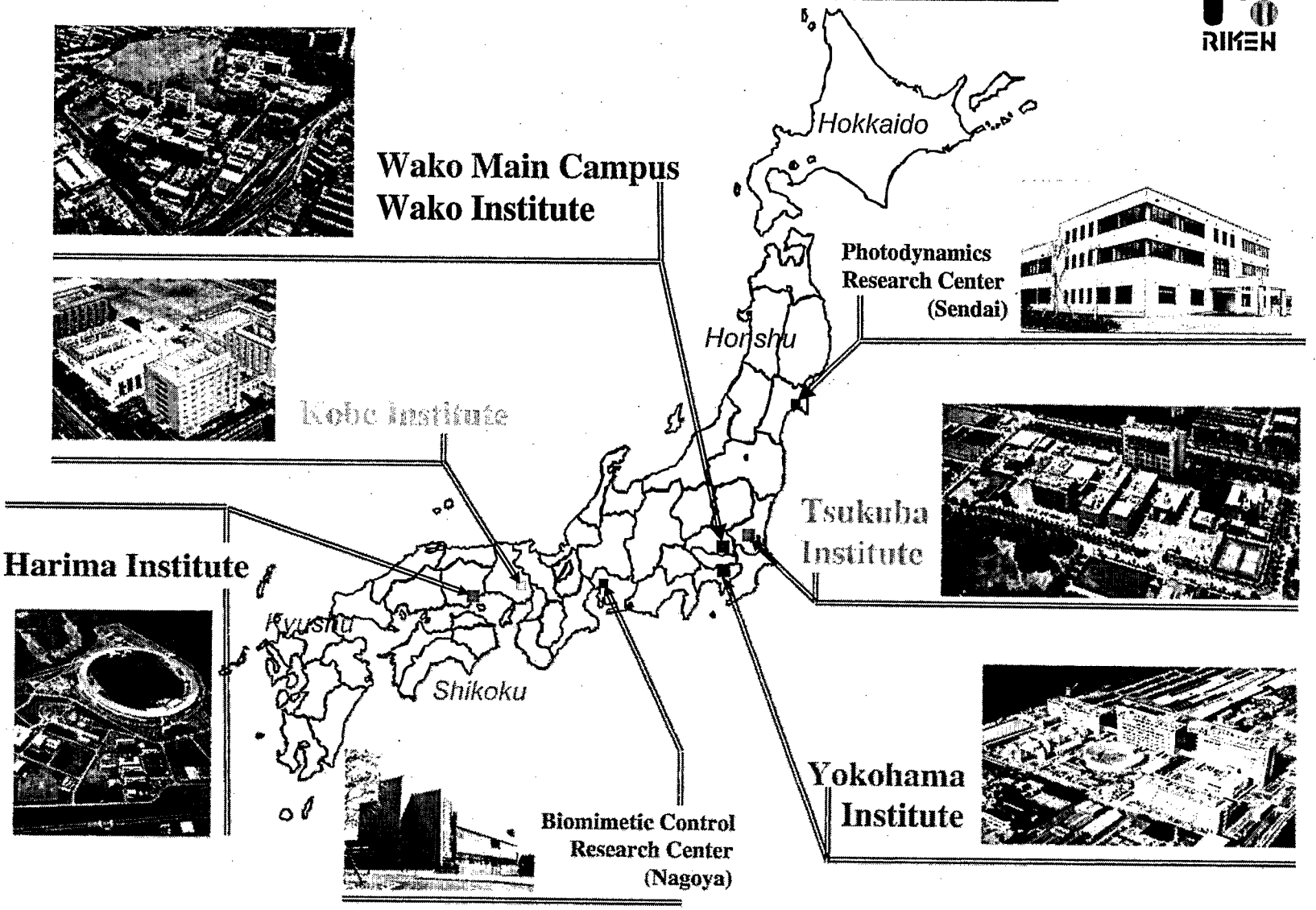
RIKEN CONZERN
Conglomerate, RIKEN GROUP
Consisted of over
60affliated companies.

RIKEN

Independent Administrative Institute

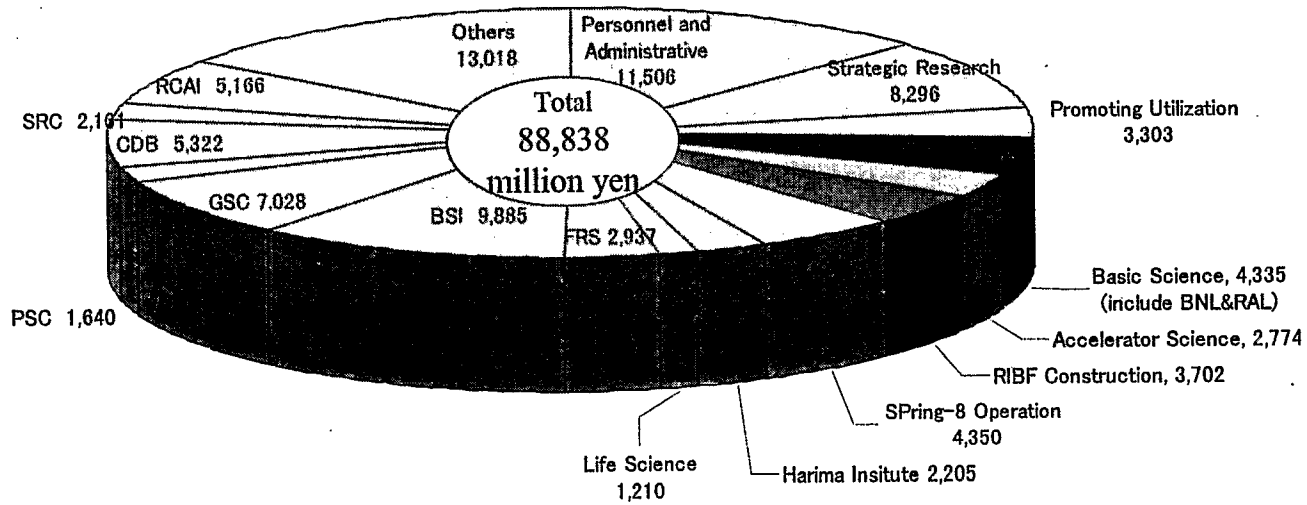
1. President has more autonomy than before
2. Midterm (five years) objectives and midterm plans
3. Annual review of accomplishment and final review at the end of midterm by the government
4. Fixed amount of subsidy for management and research activities

RIKEN's Research Locations



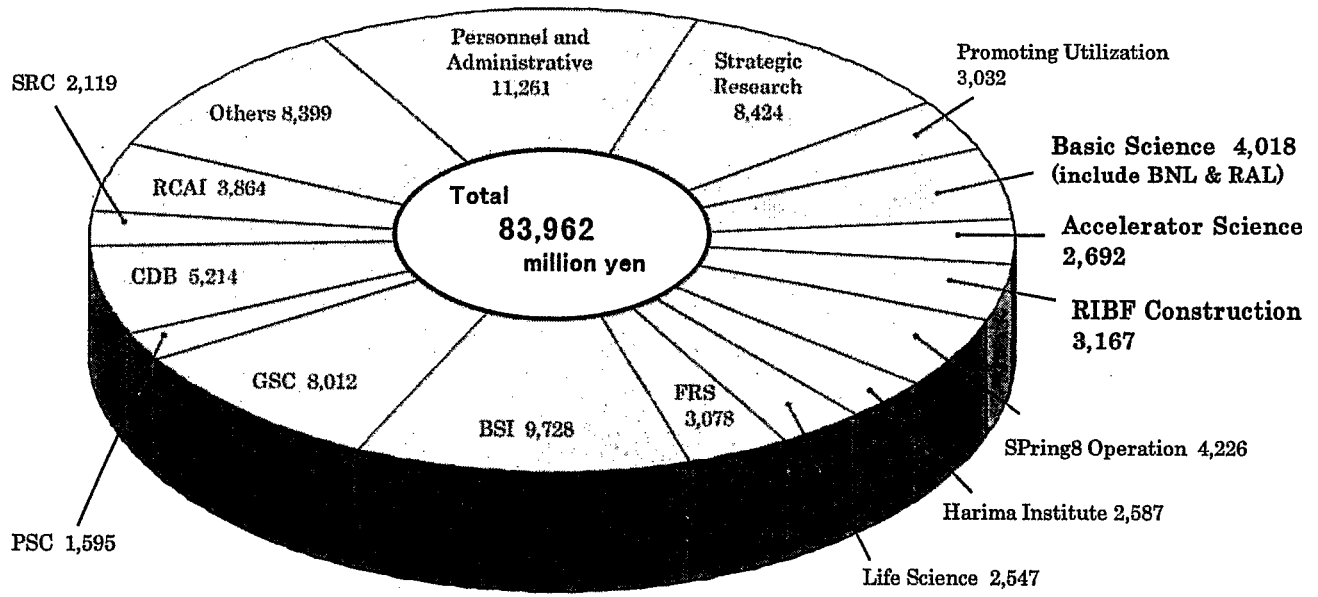
Budget (2003JFY)

DRI:
10,811 million yen
(12.2%)



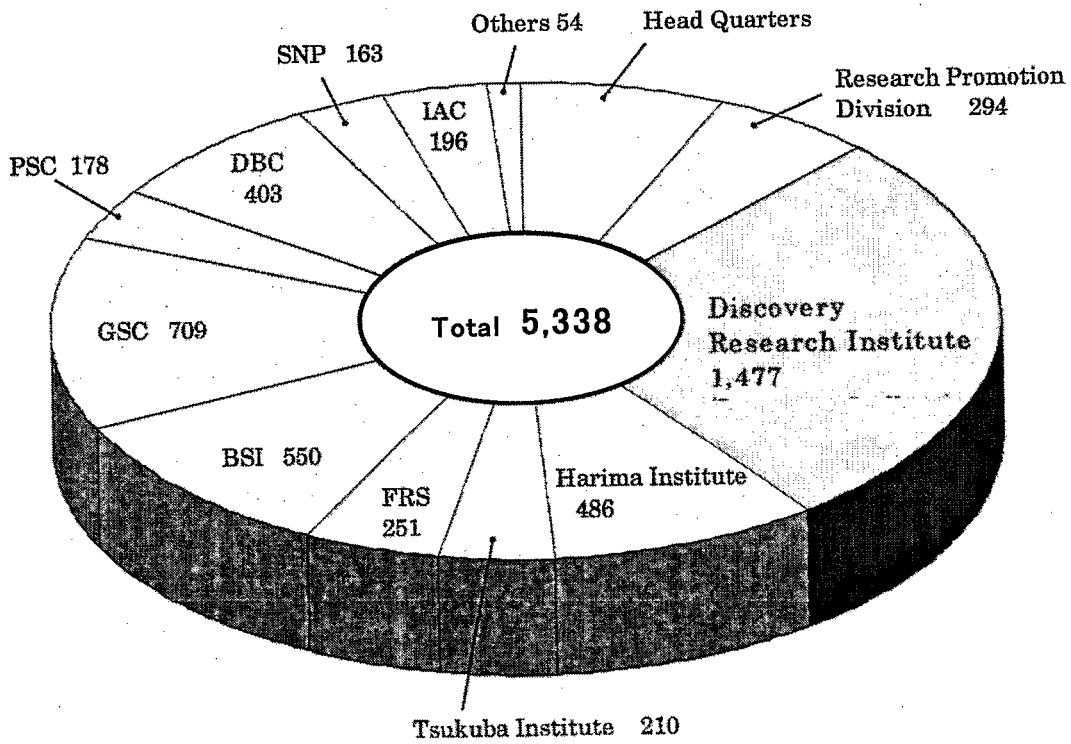
Budget (2004JFY)

DRI :
9,877 million yen
(11.8%)



RIKEN

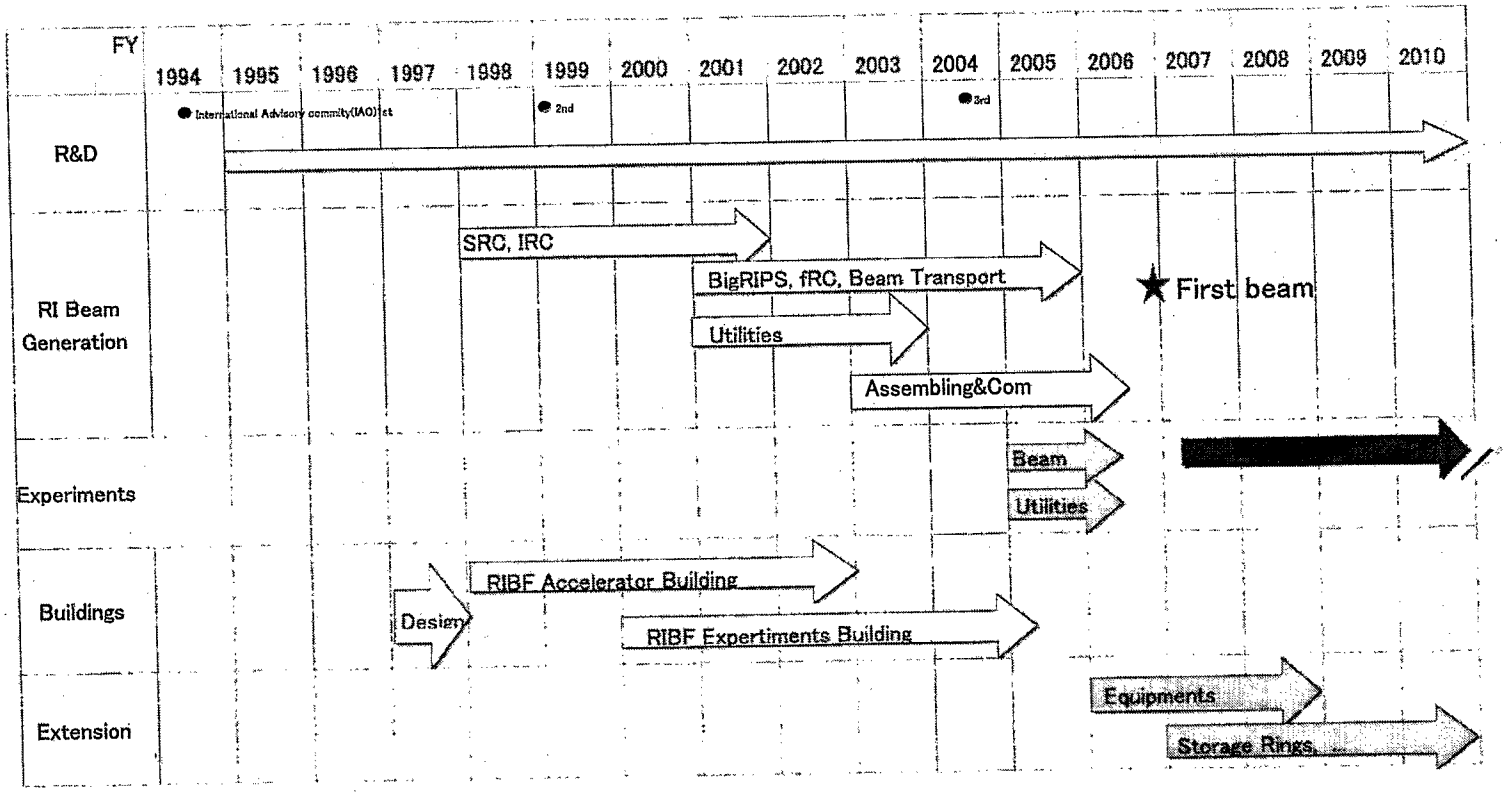
Personnel (2004. 3. 1)



Staff in RIKEN

Permanent	Executives	8
	Researchers & Engineers	413
	Administrations	272
	Total	693
Contract	Frontier Researchers	137
	Brain Science Institute Researchers	535
	Genomic Science Center Researchers	214
	Plant Science Center Researchers	100
	Center for Developmental Biology Researchers	243
	SNP Research Center Researchers	81
	Bio Resource Center Researchers	17
	Research Center for Allergy and Immunology Researchers	153
	Total	1,480
	Tenure Researchers (Tentative name)	9
	Initiative Research Unit	24
	Special Postdoctoral Researchers	192
	Junior Research Associates	139
	Other Contract Researchers	371
	Total	735
Visiting Scientists		1,789
Student Trainees		1,083

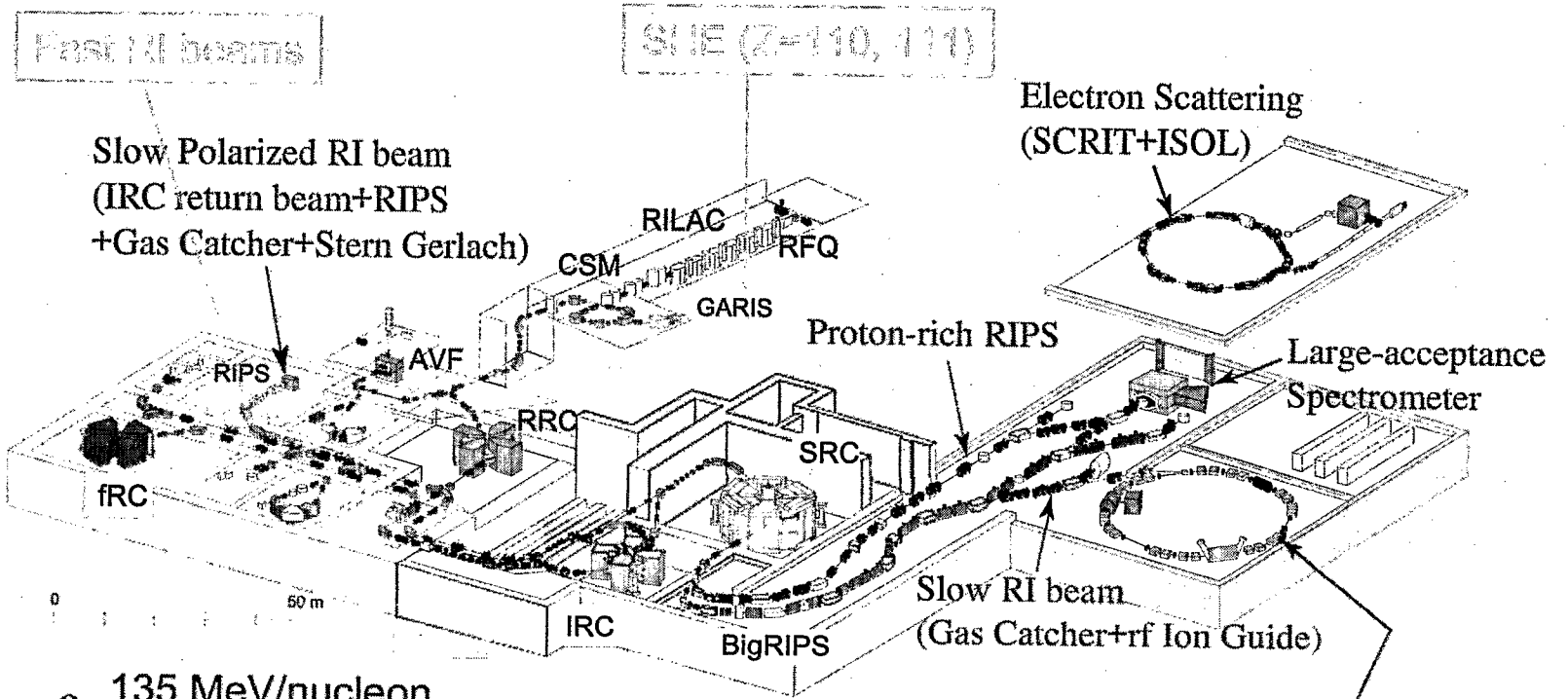
RIBF Schedule



Spectrometer(s), p-RIPS, SCRIT, RI-Ring, ...

RIKEN Accelerator Research Facility and RI Beam Factory Project

RIBF Experimental Setups under Priority Discussion



0 135 MeV/nucleon for light nuclei

1 350 MeV/nucleon up to U
1st beam in 2006

2 Proton Scattering (Accumulater+Cooler)
under consideration

In 2004

- Wako Institute
  - **Discovery Research Institute**
    - **44 Laboratories**
    - **Research Units**
    - Cyclotron Center
    - Accelerator-based Research Group
    - RI Beam Factory Project Group
    - **Advanced Development and Supporting Centor**
    - **Japan Collection of Microorganisms**

In 2006

- Wako Institute
  - **Discovery Research Institute**
    - **44 Laboratories**
    - **Research Units**
    - RIBF Center
      - Accelerator Group
      - Research Group
    - **Advanced Development and Supporting Centor**

User Community

RIKEN

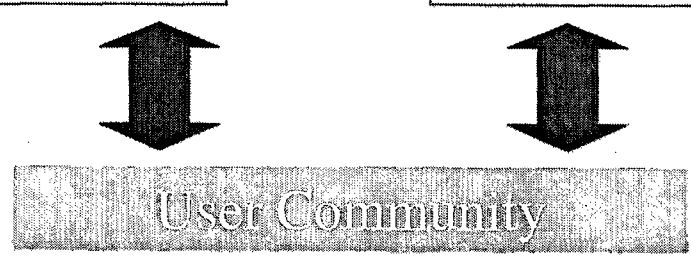
Status of SPring-8

In 2004

- Harima Institute
  - 9 Laboratories & 1 Division
  - SR Research Network
  - High-throughput Factory
  - **SPring-8 (JAERI / RIKEN / JASRI)**

In 2005

- Harima Institute
  - 9 Laboratories & 1 Division
  - SR Research Network
  - High-throughput Factory
  - **SPring-8 (RIKEN / JASRI)**

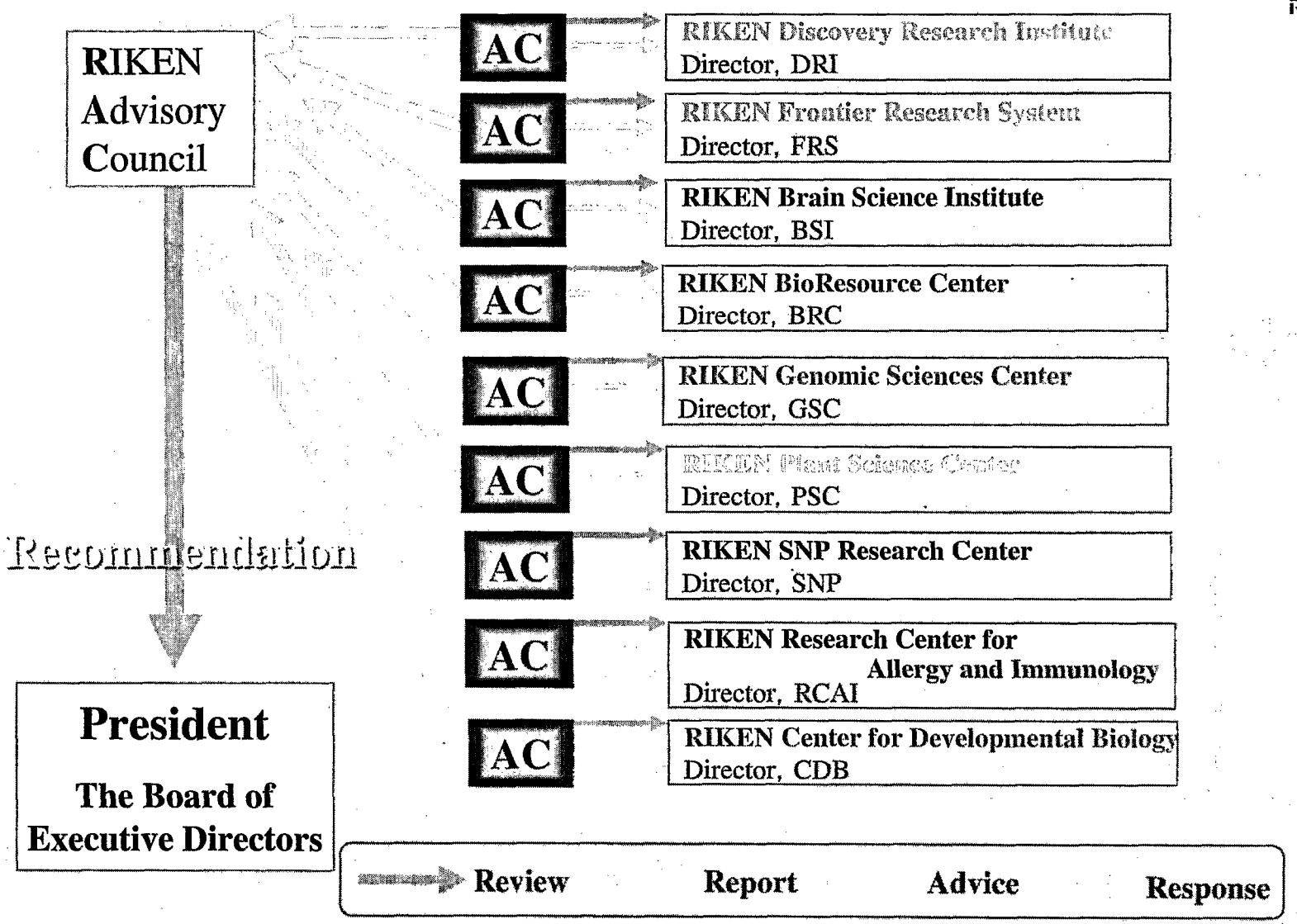


Eight features of RIKEN

1. Comprehensive research institute of natural sciences with outstanding tradition
2. Broad research activities from basic science to applications
3. Flexible organization to accommodate wide variety of researches.
4. Cooperation with industries and promotion of technology transfers
5. Wide variety in budget sources and competitive distribution of budget
6. Widely open research system
7. High international reputation and strong international collaborations
8. Multistage review and advisory system from research to administration

RIKEN

Review System at RIKEN



RIKEN President Noyori's Initiative

1. Forging a RIKEN with presence

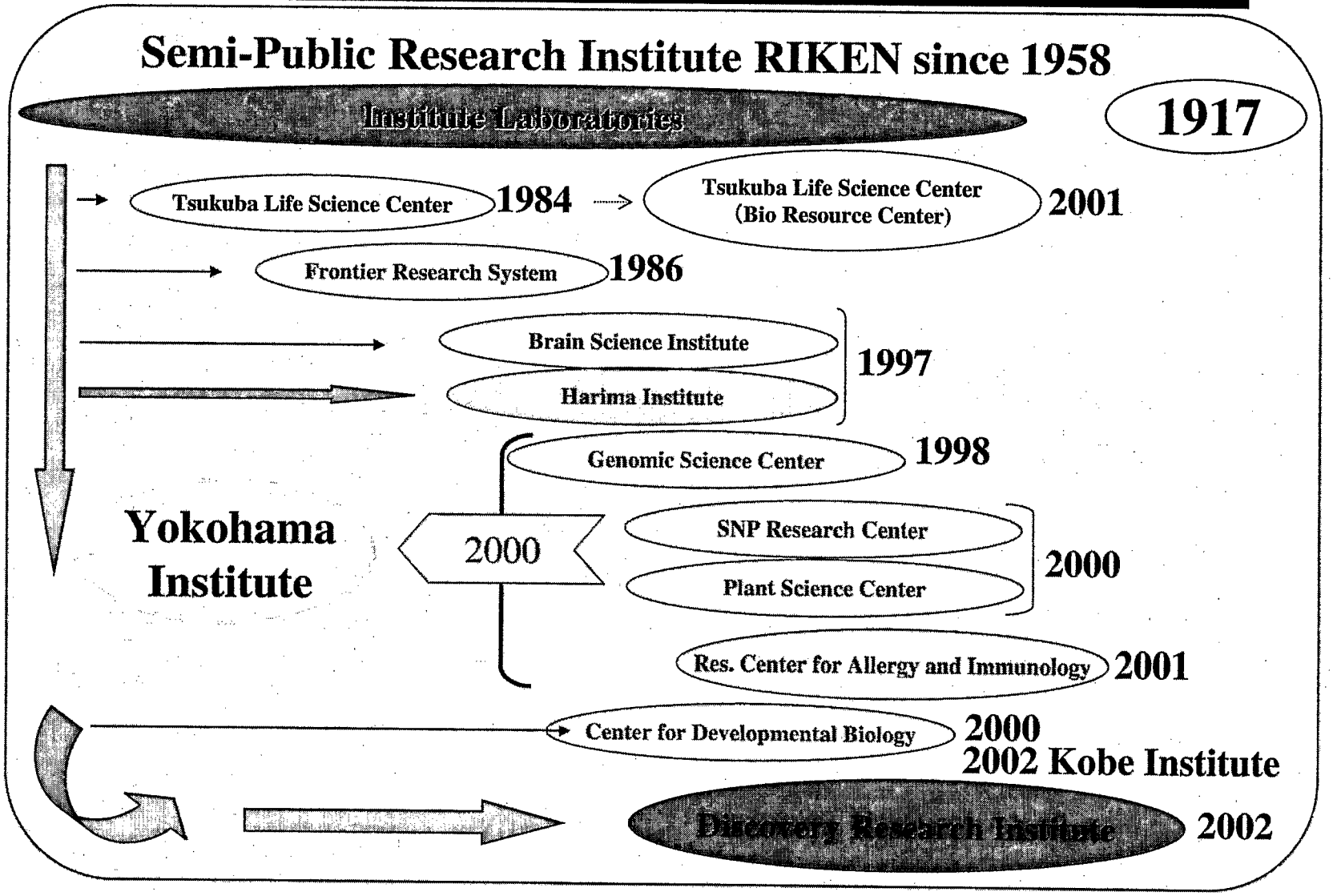
2. Securing a place for RIKEN in science and technology history

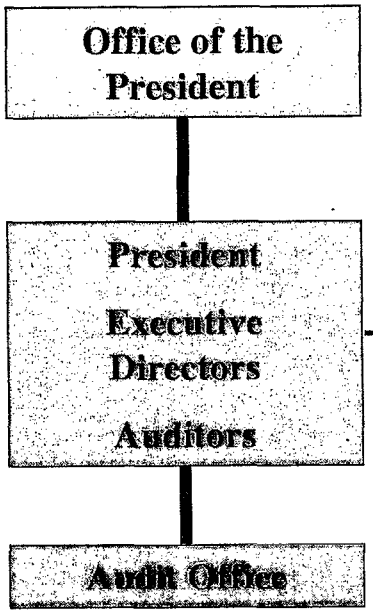
3. Enhancing RIKEN's creative environment

4. Ensuring that RIKEN makes meaningful contribution to the betterment of humankind

5. Building a RIKEN that will seek out and transmit knowledge of value to the humanities and social science

History of Centers in RIKEN since 1958





Head Quarter RIKEN Wako Main Campus

Planning of Budget and Program / Personnel Management / Financial Management / Organizational Management / External affairs / Procurement / Public Relations / Intellectual Property Management / Research Collaboration Management / Facility Management

RIKEN Wako Institute

RIKEN Discovery Research Institute/ RIKEN Brain Science Institute/ RIKEN Frontier Research System/ Integrated Volume-CAD System Research Program/ Nanoscience Research Program/ Initiative Research Unit/ Sponsored Laboratories/ DRI*FRS Promotion Division/ Brain Science Promotion Division

RIKEN Tsukuba Institute

RIKEN Bio Resource Center/ Bio Resource Collaborative Groups/ Tsukuba Research Promotion Division/ Tsukuba Safety Center

RIKEN Harima Institute

9 Laboratories (RLs)

Division of Bio-Crystallography Technology

Synchrotron Radiation Research Network

RIKEN Yokohama Institute

RIKEN Genomic Sciences Center/ RIKEN Plant Science Center/ RIKEN SNP Research Center/ RIKEN Research Center for Allergy and Immunology/ Yokohama Research Promotion Division/ Yokohama Safety Center

RIKEN Kobe Institute

Center for Developmental Biology/ Kobe Research Promotion Division/ Kobe Safety Division

BNL: CURRENT STATUS AND FUTURE PLANS

Satoshi Ozaki

BNL: Current Status and Future Plans

RIKEN BNL Collaboration
10th Management Steering Committee Meeting

Wako-shi, Saitama, Japan
March 25, 2004

Satoshi Ozaki
Brookhaven National Laboratory

BNL Plans

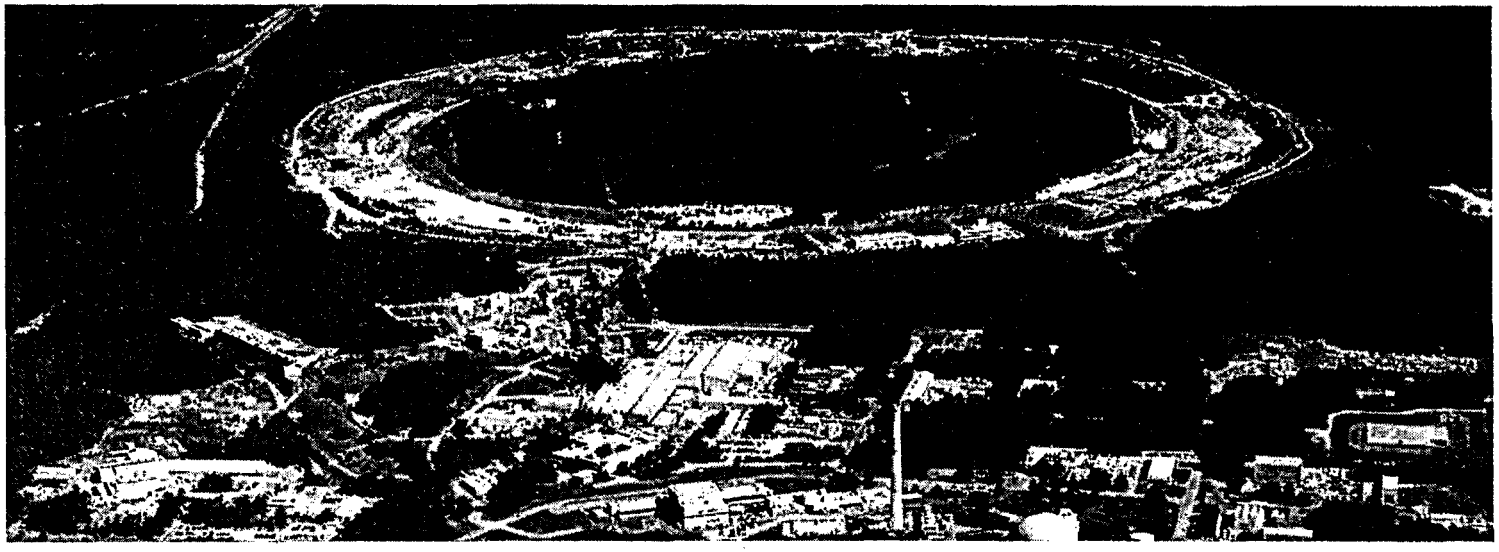
RHIC Operation
RHIC Up-grade: RHIC II & e-RHIC (Physics by Sam Aronson)
RSVP at the AGS (NSF)
Long Baseline ν Program with the AGS as the Proton Driver
Large Synoptic Survey Telescope (LSST) Project (Sam Aronson)

Brookhaven Science Associates
U.S. Department of Energy

BROOKHAVEN
NATIONAL LABORATORY

(3) S.Ozaki/S.Aronson

RHIC Operations and Plans



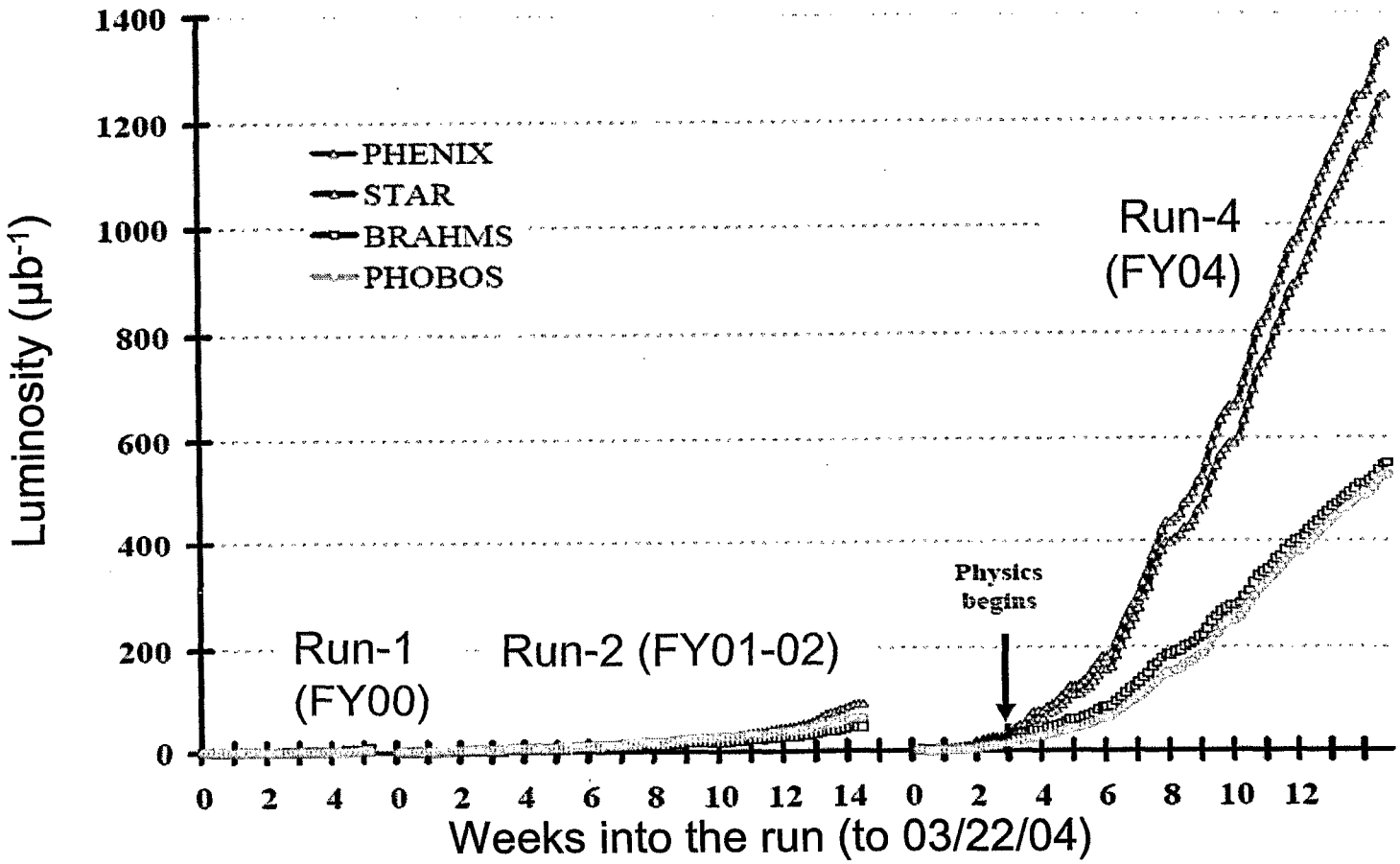
- Run 1: FY 2000 28 wks total Au-Au (200 GeV/A)
- Run 2: FY 2001-02 40 wks total Au-Au (200 GeV/A) p↑-p↑ (100 GeV)
- Run 3: FY 2003 29 wks total d-Au (200 GeV/A) p↑-p↑ (100 GeV) ~30% Pol.
- Run 4: FY 2004 27 wks total Au-Au (200 GeV/A) 5 wks for p↑-p↑ (100 GeV)
- Run 5 FY 2005 Extensive run on p↑-p↑ with higher polarization.

Near term improvements in progress

- Room temperature and superconducting helical snakes in AGS for higher polarization
- Development of EBIS ion source for flexibility of ion operation (He3↑?)

RHIC Delivered Au-Au Luminosity

Run-1 (FY00), Run-2 (FY01-02), and Run-4 (FY04)



Brookhaven Science Associates
U.S. Department of Energy

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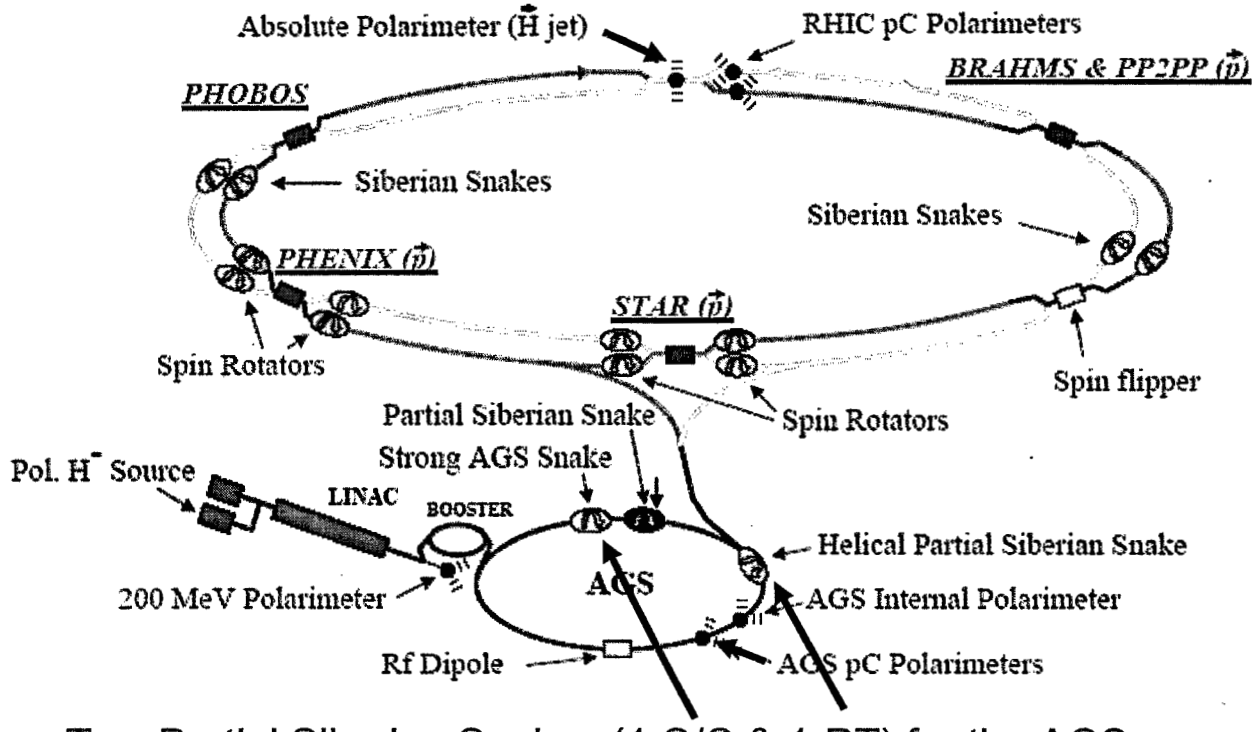
RHIC Layout for SPIN Physics

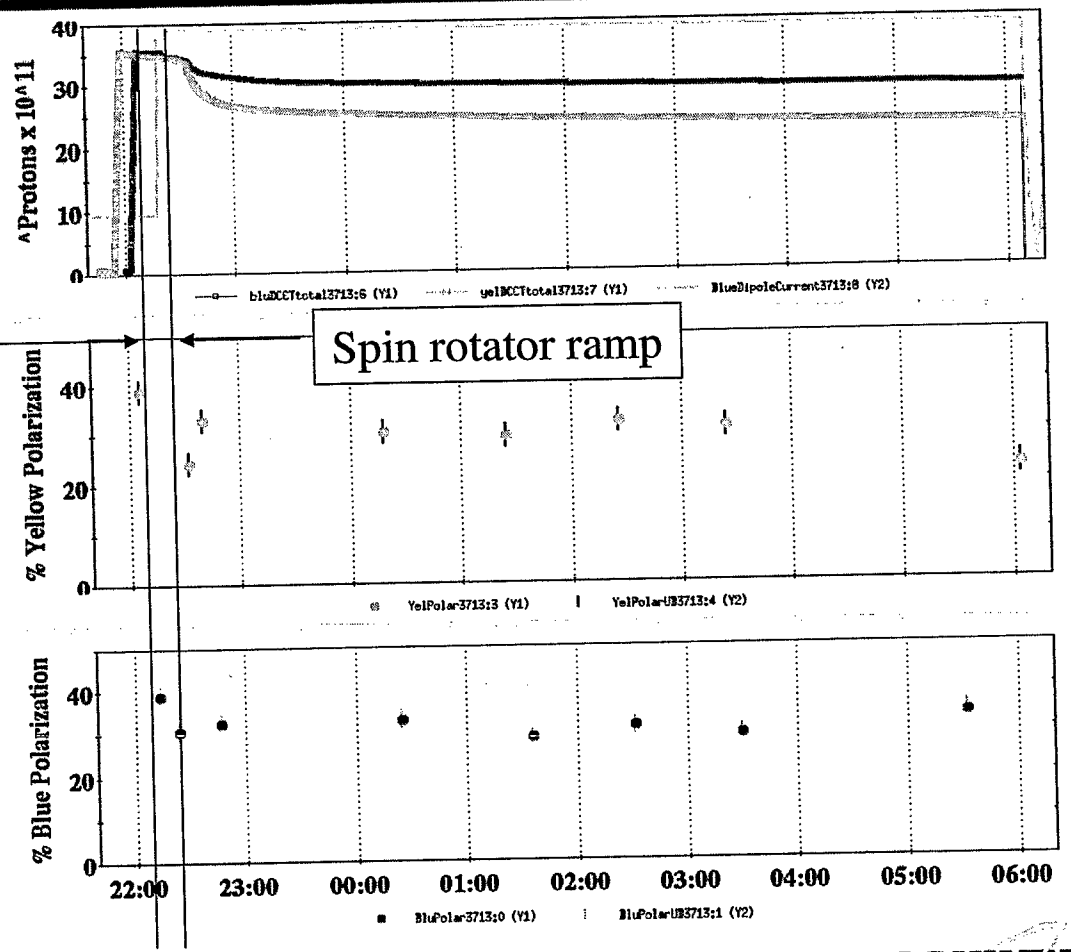
RIKEN-BNL Collaboration in Spin Physics:

4 Siberian Snakes &
8 Spin Rotators are in place



Two Partial Siberian Snakes (1-S/C & 1-RT) for the AGS
→ improvement of the AGS proton polarization to ~70%

Polarization Survival in RHIC (store # 3713)



Acceleration and squeeze ramp

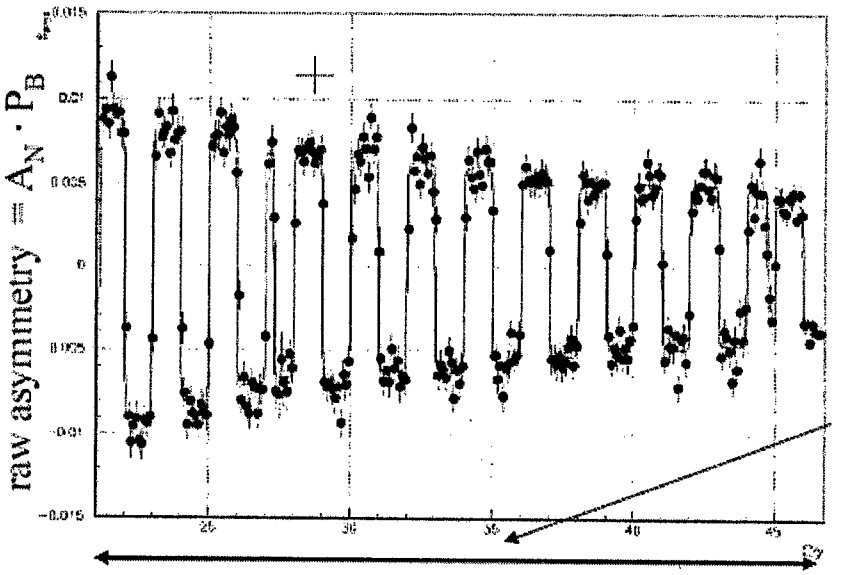
Spin rotator ramp

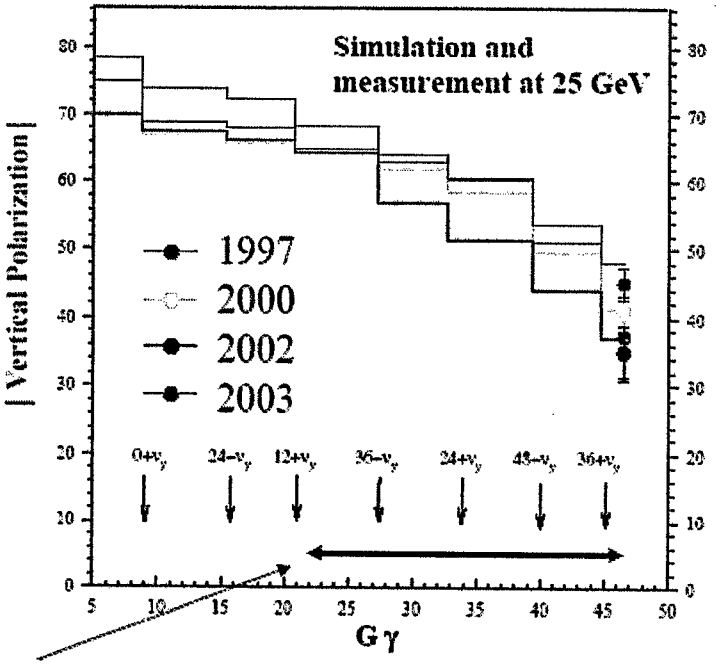
Some losses during the acceleration & squeeze ramp (tune too close to ¼)

No loss during spin rotator ramp and during store

Proton Polarization at the AGS

Ramp measurement with new AGS p-C CNI polarimeter:
Full spin flip at all imperfection and strong intrinsic resonances using partial Siberian snake and rf dipole





Remaining polarization loss from coupling and weak intrinsic resonances

New RT helical partial snake (RIKEN)

Strong SC AGS helical Siberian snake (RIKEN/BNL: Installation: 10/04)

Target: 70%

The Room Temperature Snake in the AGS Ring

- Commissioning of the new warm helical snake started March 5 with proton beam.
- Magnet has been run in the ring at 2700A.

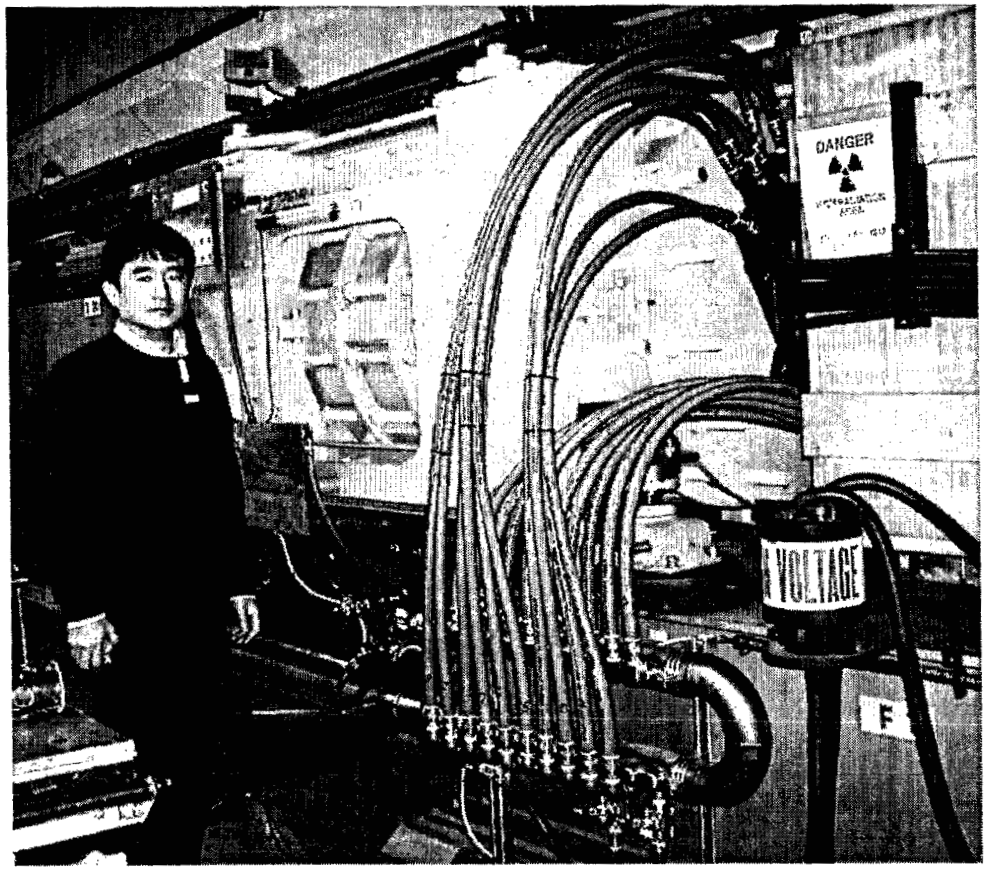
This Year:
Weak coupling resonances.
→ run the snake hard

Faster Bdot
→faster resonance crossing

No scraping in the Booster
→ higher intensity

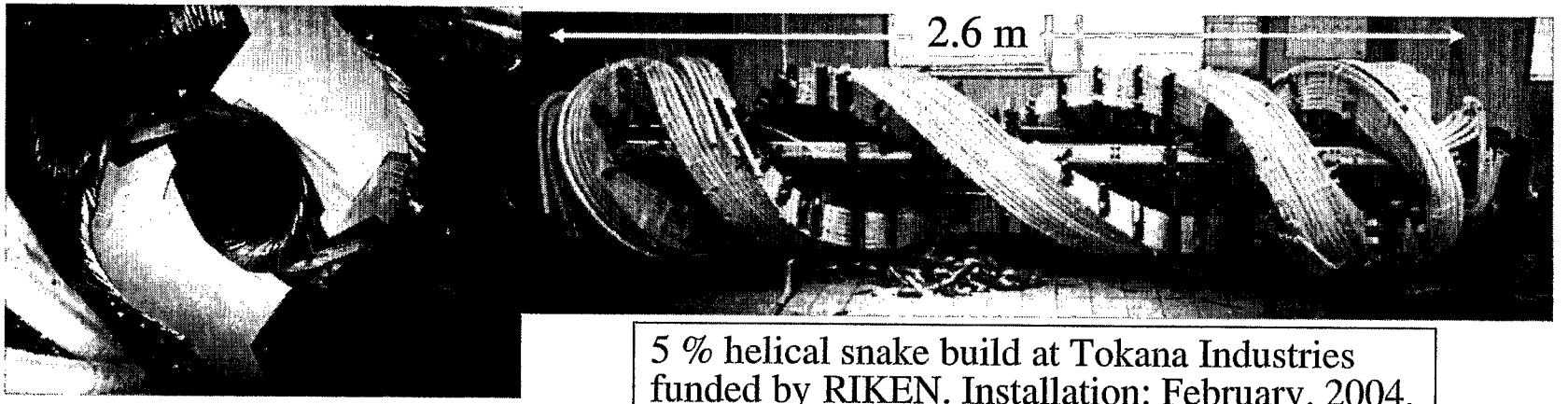
New CNI polarimeter
→Faster Measurement

→ ~44% at first try



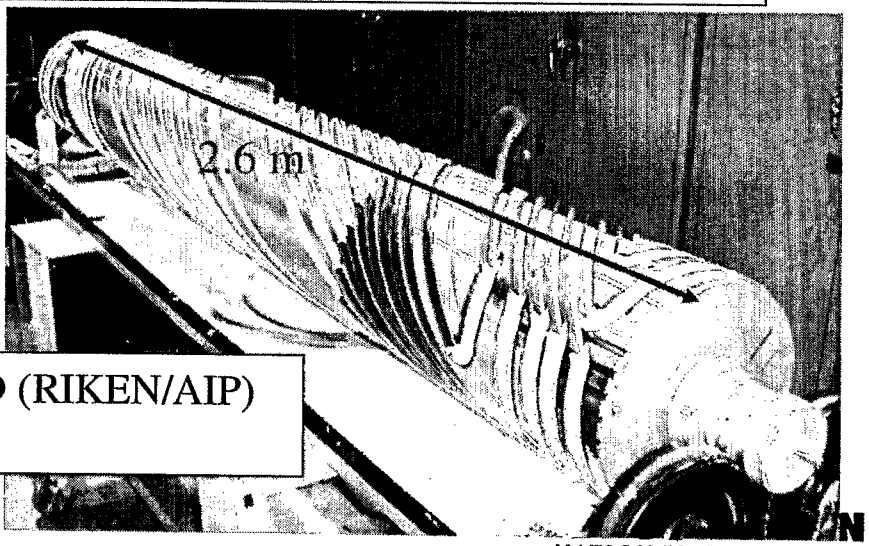
M. Okamura and his Room Temp. AGS Snake

New AGS Helical Snakes



5 % helical snake build at Tokana Industries funded by RIKEN. Installation: February. 2004.

- Warm snake deals with coupling resonances and avoids polarization mismatch at AGS injection and extraction.
- Cold strong snake eliminates all depolarizing resonances in AGS.



30% SC helical snake build at SMD (RIKEN/AIP)
Installation: Oct. 2004

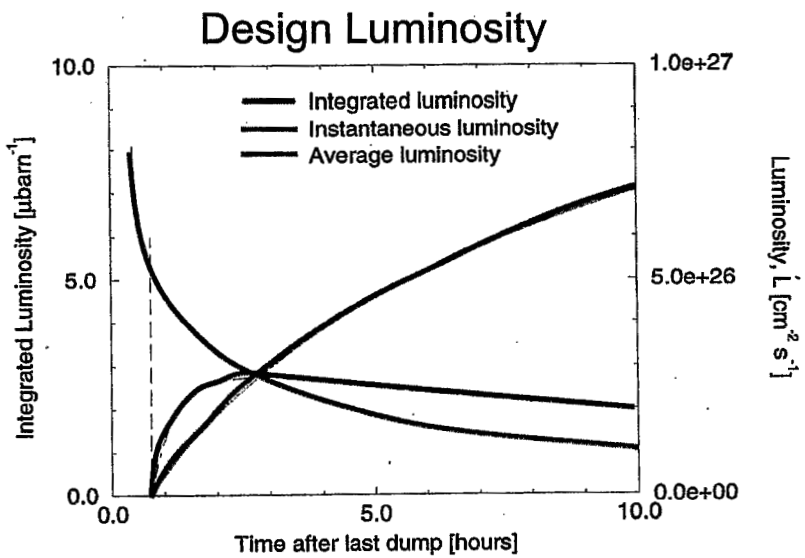
RHIC Luminosity

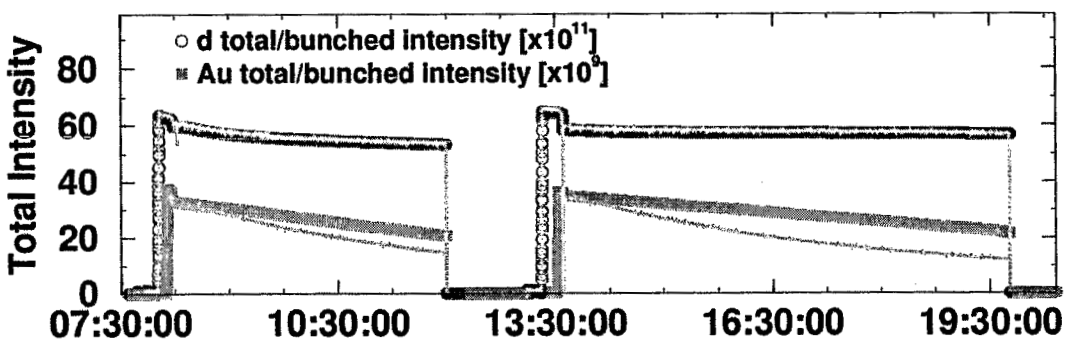
$$L = \frac{3 f_{rev} \gamma}{2} \frac{N_b N^2}{\varepsilon \beta^*} = 9 \text{ to } 1\times10^{26}\,\text{cm}^{-2}\text{s}^{-1} \text{ over } 10\,\text{h}$$

$$N_b = 56;\ N = 1\times10^9;\ \varepsilon = 15 \text{ to } 40\pi\mu\text{m};\ \beta^* = 2\text{m}$$

Deuteron and gold beams behaved differently because of Intra-beam scattering effect

Emittance growth by strong coulomb interactions high charge ions in a bunch





RHIC II Luminosity Upgrade Strategy

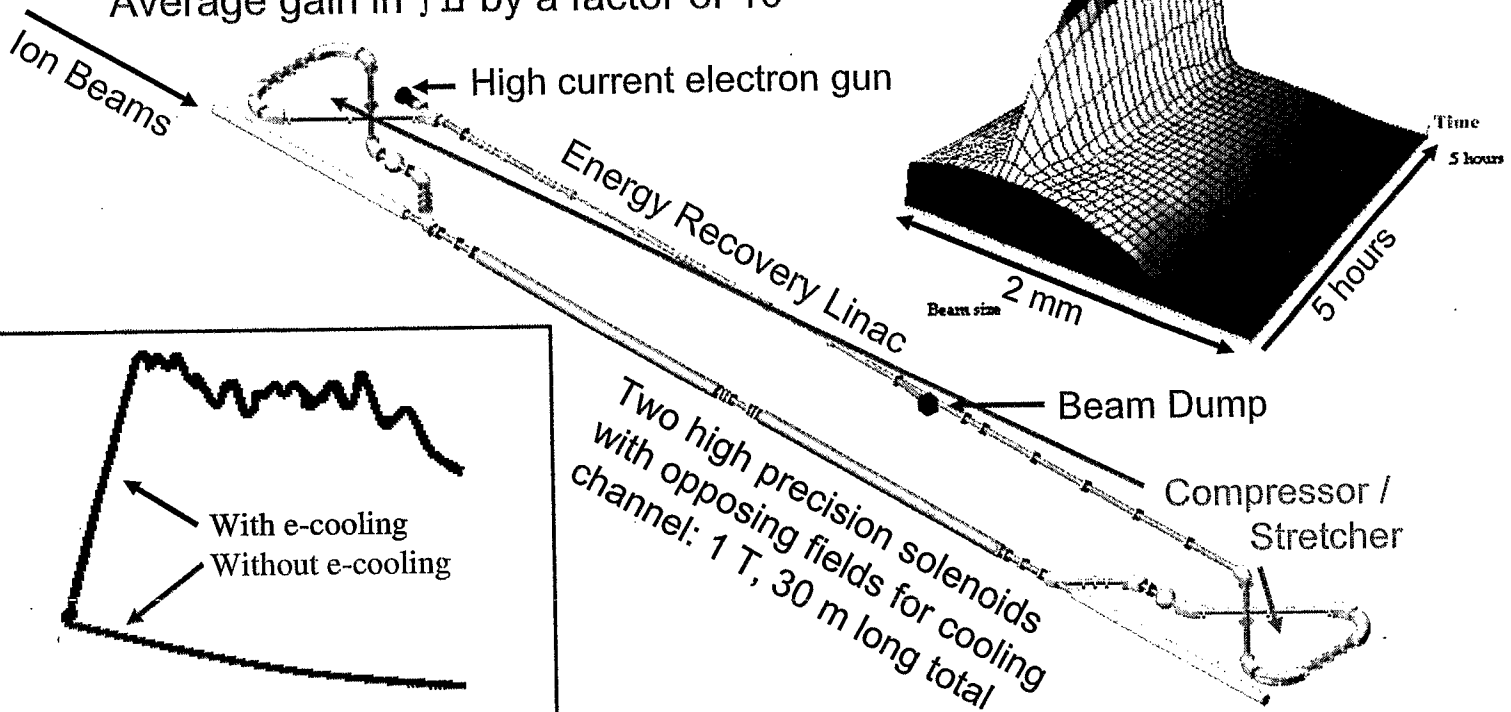
- Eliminate beam blow-up from intra-beam scattering using electron beam cooling at full energy! → Significant technical challenge
- What will remain the same in the RHIC operation:
  - 120 bunch pattern
    - 100 ns collision spacing (→ same data acquisition system)
    - Only one beam collision between DX magnets
  - 20 m magnet-free space for detectors
    - No "mini-beta" quadrupoles
  - Approx. the same bunch intensity
    - No new vacuum or instability issues
    - Background similar as before upgrade
- What changes:
  - Smaller transverse and longitudinal emittance
    - Smaller vertex region
  - Variable β-squeeze during store to level the luminosity
  - Store length limited to ~5 hours by "burn-off" due to Au-Au interactions (σ ~200 b)

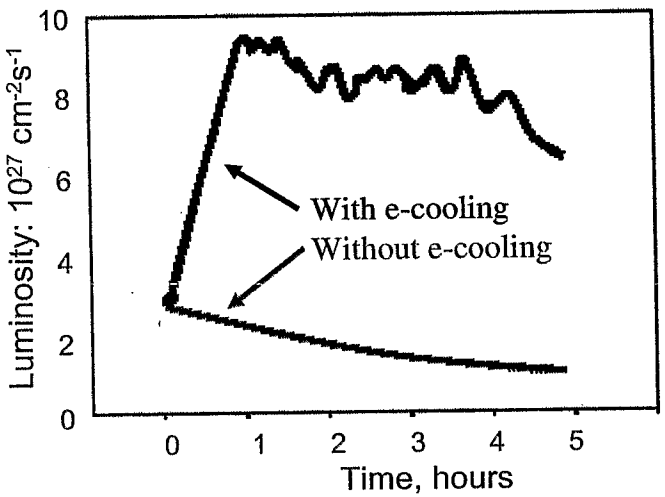
Electron Cooling for RHIC II

For 100 GeV/u Au beam cooling: need electron beam

E = 54 MeV, $I_{AVERAGE}$ ~ 100 mA, or ~ 5 MW → High Power ERL

Average gain in $\int L$ by a factor of 10





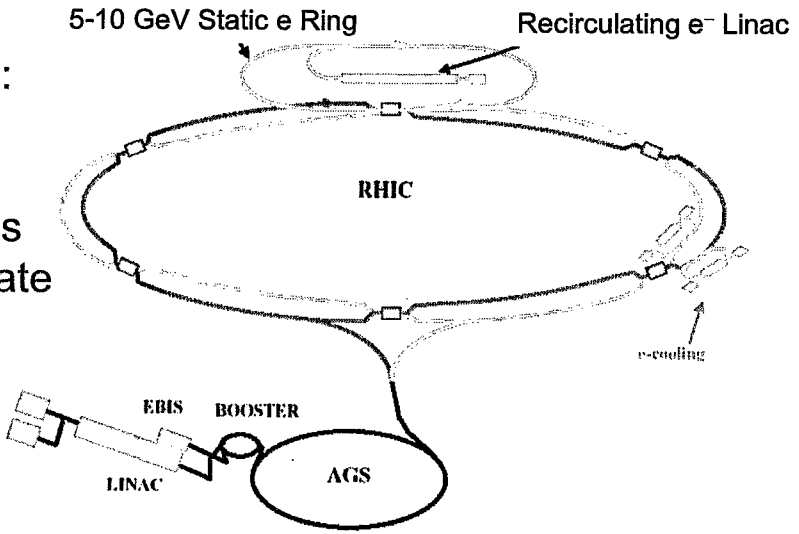
Stochastic cooling for the hot part of the bunches

e-RHIC Program

Scientific Frontiers Open to e-RHIC (Sam)
Further studies of nucleon/nuclear structure:

- Quark and gluon distributions in nuclei
- Hadronization in nucleons and nuclei
- Partonic matter under extreme conditions
- New phenomena: Color Glass Condensate

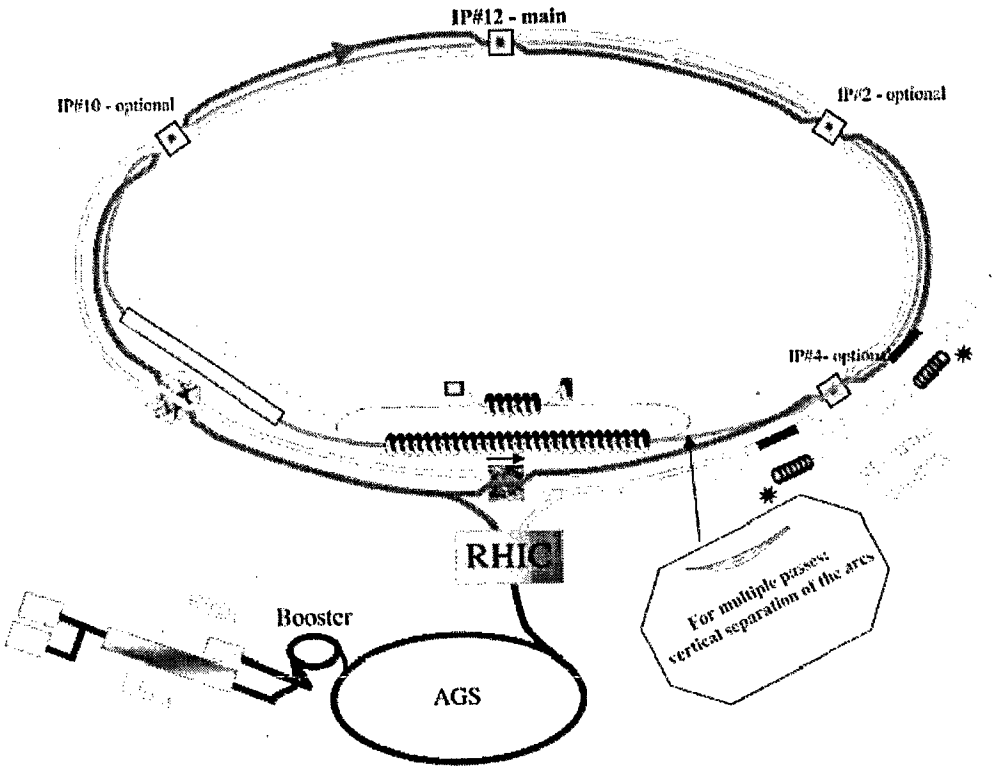
Extend QCD physics of RHIC Spin
to further sophistication!



e-RHIC Collider Parameters

- E_{Beam}: 5-10 GeV electrons (polarized)
  25-250 GeV protons (polarized)
  100 GeV/u Au
- Luminosity: up to10^{33} $cm^{-2}s^{-1}$ for e-p
- Polarization: ~70% electrons and protons: longitudinal at IP point
- Bunch separation ? 35 nsec

Alternative eRHIC with DRL-ring Design



Rare Symmetry Violating Processes (RSVP)

Experiment utilizing the high intensity capability of the AGS:

Support Shifting from DOE to NSF

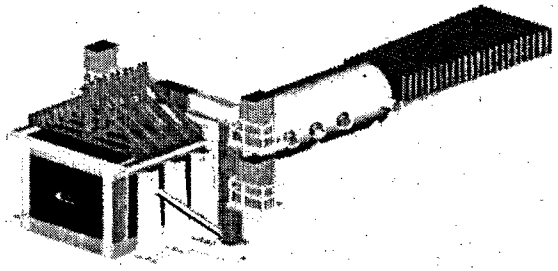
KOPIO: $K^0 \rightarrow \pi^0 \nu\nu$-bar

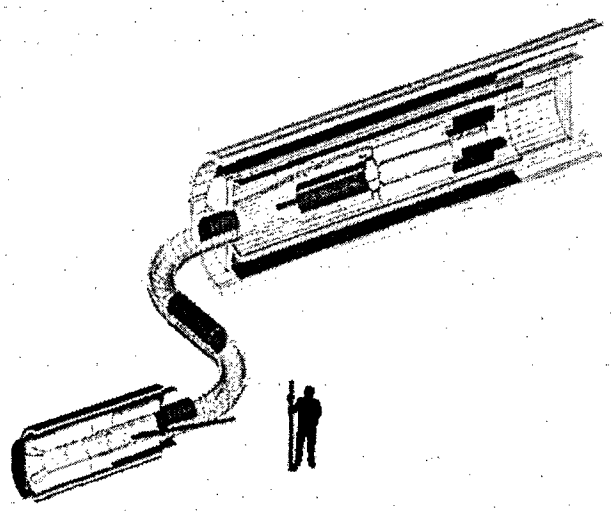
Further study of CP-violation

MECO Experiment

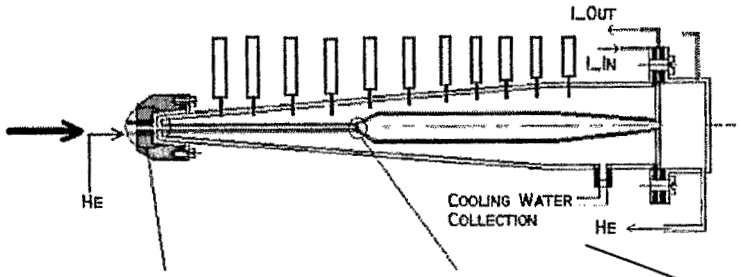
$\mu \rightarrow e$ conversion

Construction fund in FY2005 Presidential Budget





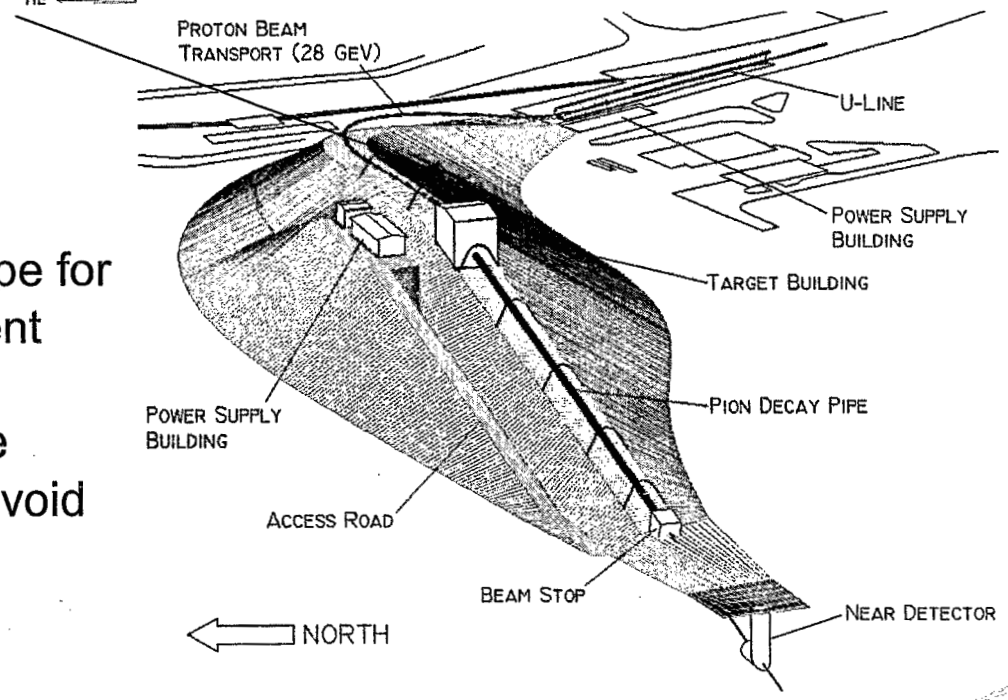
ν Beam Concept for Very Long Baseline Experiment



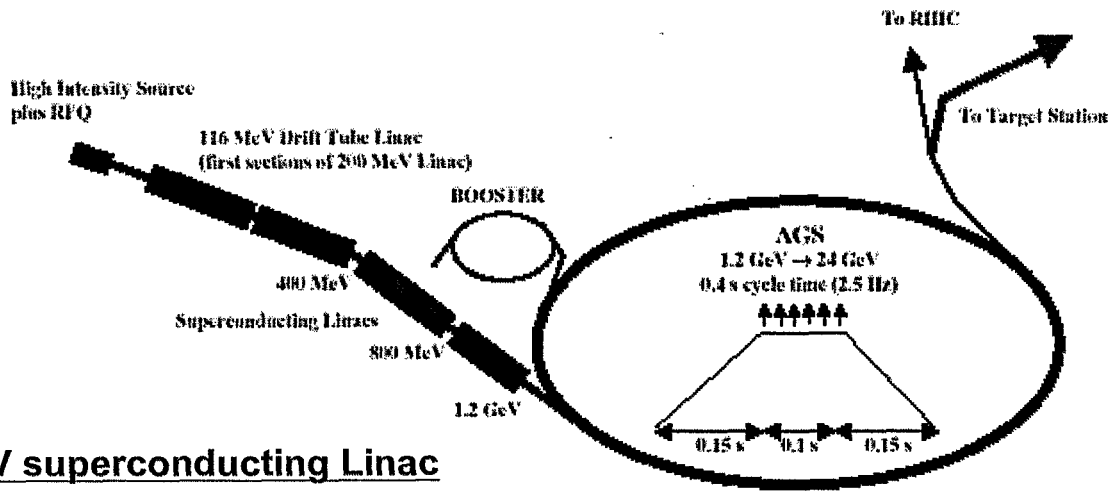
BNL to Lead, SD (Homestake): 2540 km

BNL to Carlsbad, NM (WIPP) : 2880 km

- 1 MW He gas-cooled Carbon-carbon target
- Target on down-hill slope for long baseline experiment
- New horn design
- Beam dump well above ground water table to avoid water activation



AGS Up-Grade to 1 MW Proton Driver (Conceptual Plan)



1.2 GeV superconducting Linac

Beam energy	rf gradient	Length
0.12 - 0.4 GeV	3.8 MeV/m	75 m
0.4 - 0.8 GeV	6.1 MeV/m	65 m
0.8 - 1.2 GeV	7.0 MeV/m	57 m

Extendable to 4 MW Operation
With Additional RF Power

3-4 Folds Magnet & rf Power Upgrade

Cycle time (0.5 → 2.5 Hz)	400 ms
Beam energy	24 GeV
Average current	42 mA (1×10^{14})
Number of micro-bunches	6
Micro bunch spacing	20 ms
Bunch length (rms)	3 ns
Peak bunch current	400 A

Thomas. Roser Study II meeting

"Connecting Quarks with the Cosmos"*

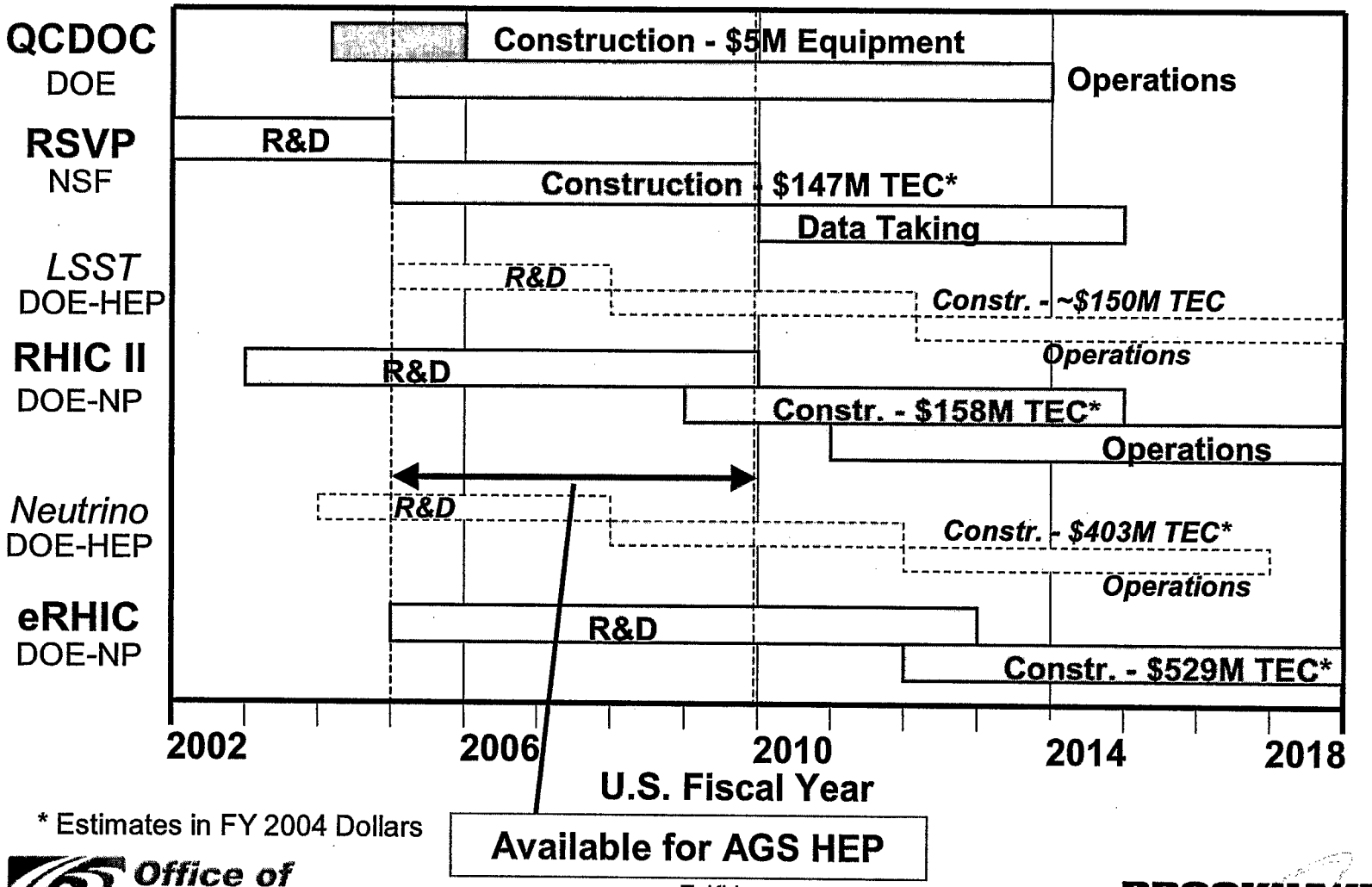
(BNL HENP Vision for Future Facilities Development)

1. What is Dark Matter? – *ATLAS Experiment & Upgrade*
2. What is the nature of the Dark Energy? – *LSST Collaboration*
3. How did the Universe Begin?
4. Did Einstein have the Last Word on Gravity?
5. What are the masses of the neutrinos and how have they shaped the Evolution of the Universe? – *MINOS; VLB Neutrino Experiment & Super Beam*
6. How do Cosmic Accelerators work and what are they accelerating?
7. Are Protons Unstable? – *UNO Experiment Collaboration*
8. What are the New States of Matter at exceedingly High Density and Temperature? – *RHIC, RHICII & eRHIC Collider and Experiments; QCDOC*
9. Are there additional Space-Time Dimensions? – *ATLAS Experiment & Upgrade*
10. How were the elements from Iron to Uranium made?
11. Is a new theory of Matter and Light needed at Highest Energies? *RSVP*

Approved & Funded Projects Underlined

* "Connecting Quarks with the Cosmos", National Research Council of the National Academies, 2003

BNL HENP Facility Initiatives



* Estimates in FY 2004 Dollars

Available for AGS HEP

Office of Science
U.S. DEPARTMENT OF ENERGY

T. Kirk
March 19, 2004

BROOKHAVEN
NATIONAL LABORATORY

Summary

- The new Laboratory Director, Dr. P. Chaudhari, took office on Apr. 1, 03.
- RHIC is running very well and producing good data and physics results.
- The up-grade of RHIC, RHIC II, is in the planning and preparatory stage. It is on the DOE 20-year-plan list.
- The e-RHIC collaboration is making good progress. ZDR is available. This project is also on the DOE 20-year-plan list.
- The US NSF is about to begin funding for the RSVP program (KOPIO and MEKO) and incremental cost to run AGS.
- A very long baseline ν experiment, using the up-graded AGS (1 MW) as the source of the super ν-beam, is in the planning stage. This type of facility is also on the DOE 20-year-plan list.
- LSST is an exciting future direction for the HEP at BNL.
- QCD-OC (DOE supported) will enhance the RBRC's efforts in the forefront of the Lattice Gauge work and other computational science.

BNL: CURRENT STATUS AND FUTURE PLANS

Samuel Aronson

BNL: Current Status and Future Plans

RBRC 10th Management Steering Committee Meeting

March 25, 2004

S. Aronson

BNL

- **RHIC II** and **eRHIC**: Research goals & detector upgrades
- **LSST**: New initiative in cosmology & astrophysics

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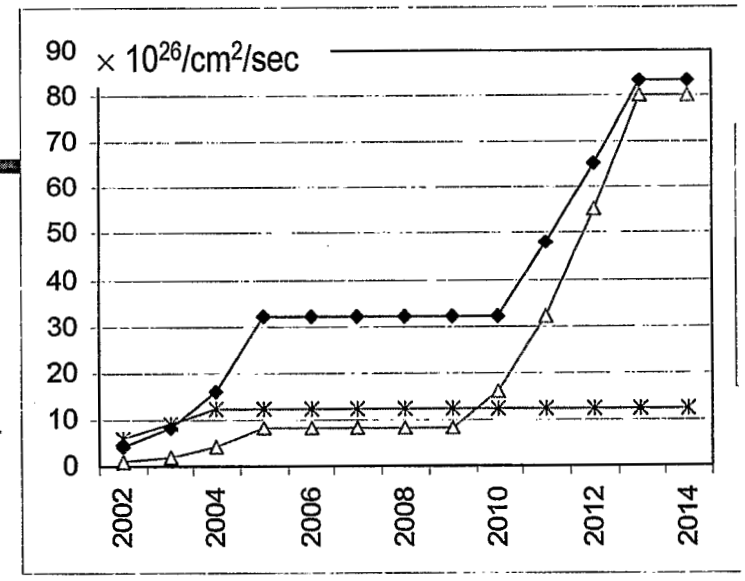
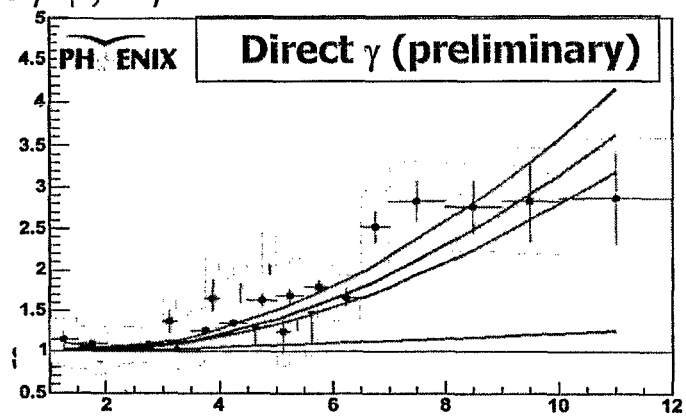
RHIC II



- What is RHIC II?
  - Upgrade the accelerator
    - ×10 increase in luminosity
  - Upgrade PHENIX and STAR
    - study rare processes
- Why do we need RHIC II?
  - Learn the properties of the new hot dense matter discovered in **heavy ion** collisions at RHIC
  - Extend the study of **spin physics** to higher energies via $W^{\pm}$ production and decay
  - Study gluon density saturation in cold nuclei at very low Bjorken x with **p+A** collisions
- This will take more data (integrated luminosity) and more sophisticated detectors

RHIC II Physics drivers

- Establish the nature of the matter created in A+A collisions
- Determine if the description of such matter as a quark-gluon plasma is appropriate, quantify both the equilibrium and non-equilibrium features of the medium
- Will require measurement of
  - Particle production at high p_T
    - inclusive spectra of ID'd hadrons
    - multi-particle correlations and jet production.
  - Direct γ, γ+jet and virtual γ (l^+l^-) production.
  - Light and heavy vector mesons (ρ, ω, J/ψ, Υ)
  - Heavy flavor (c, b) production
- Dominated by rare probes
  - ➡ *This program is* ***luminosity limited***



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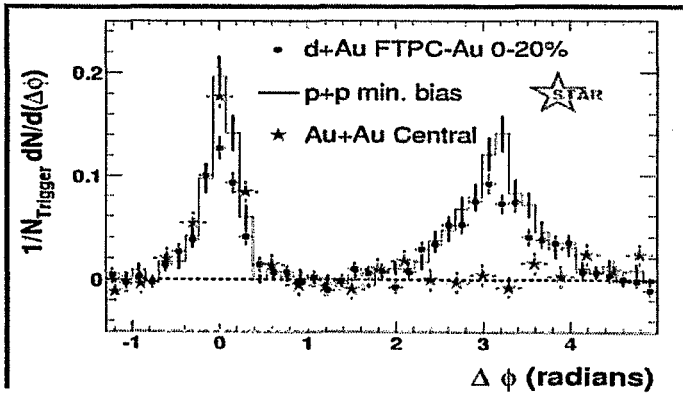

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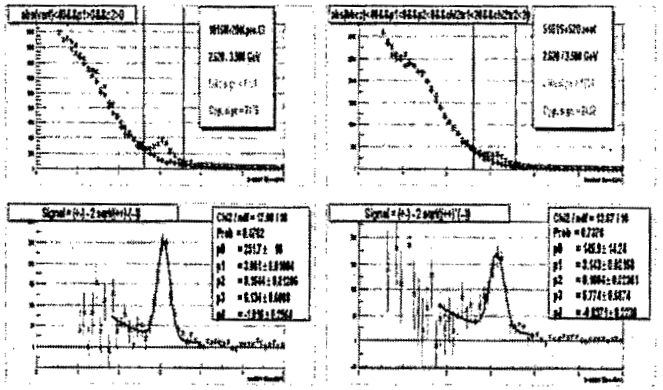
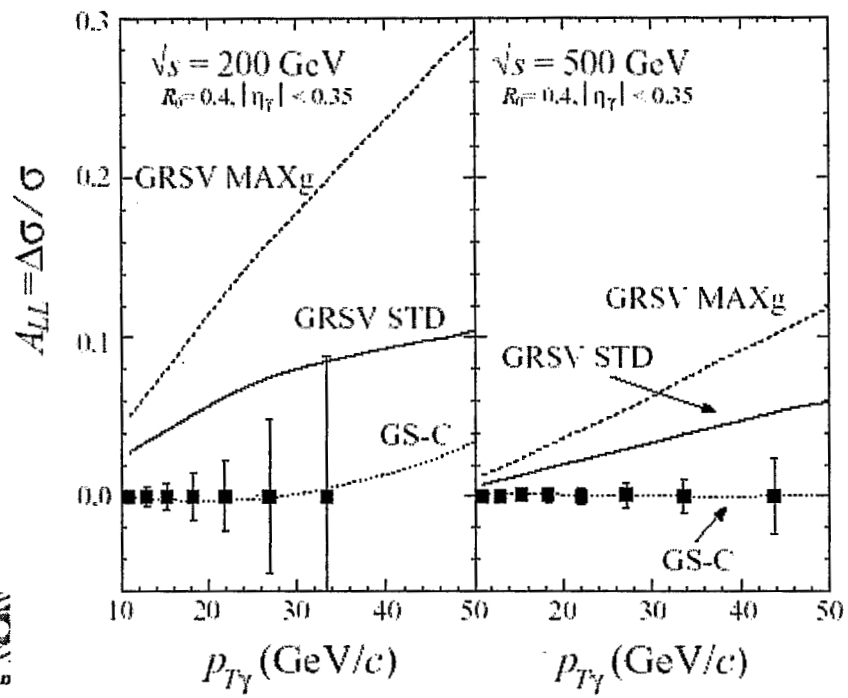
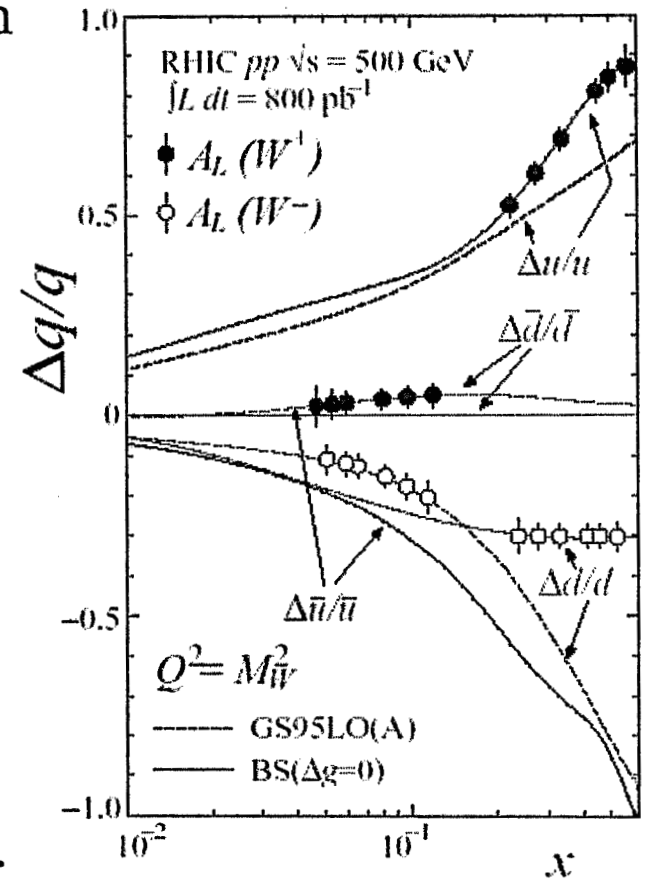


RHIC II Physics drivers: spin & p-A

- Precision measurements, via polarized p+p collisions, of
  - the gluon structure of the proton
  - the spin structure of the gluon
  - proton sea-quark distributions

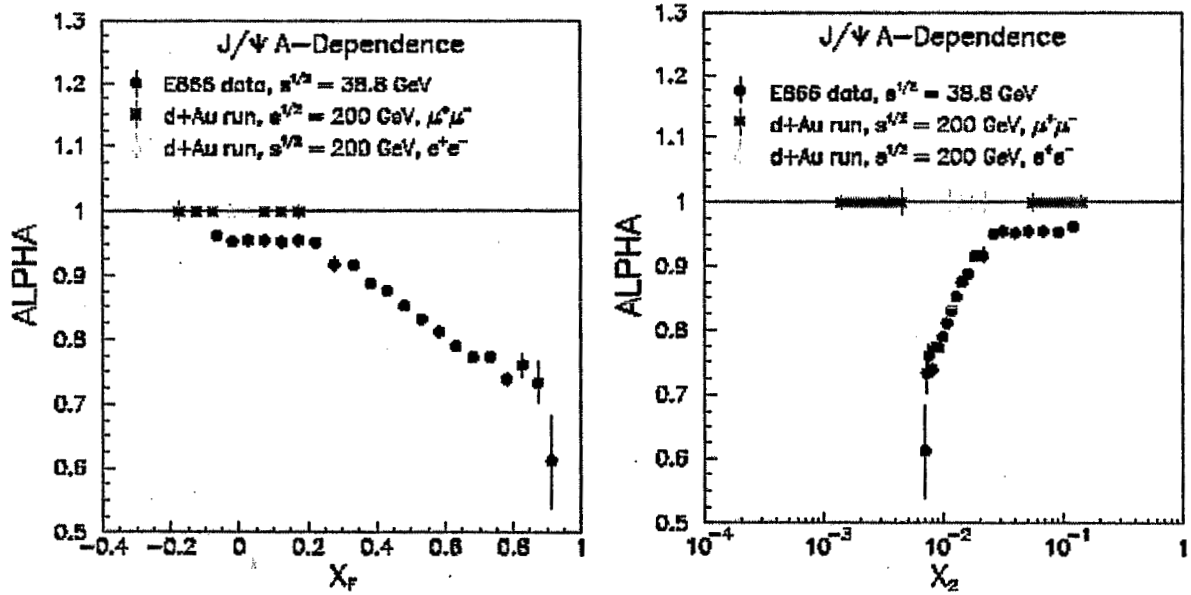




RHIC II Physics drivers: spin & p-A

- p-A collisions at RHIC are complementary to e-A collisions and will provide
  - information on $\bar{q}$ and g shadowing down to $x \approx 10^{-3}$, comparable to fixed target e-A experiments but at much larger Q^2
  - the flavor symmetry of the nucleon sea at small x
  - New information on nucleon structure via study of hard processes in coincidence with forward p or n
    - e.g., J/ψ or Drell-Yan

Example: PHENIX central and muon arms' x_F and x_2 reach in J/ψ production



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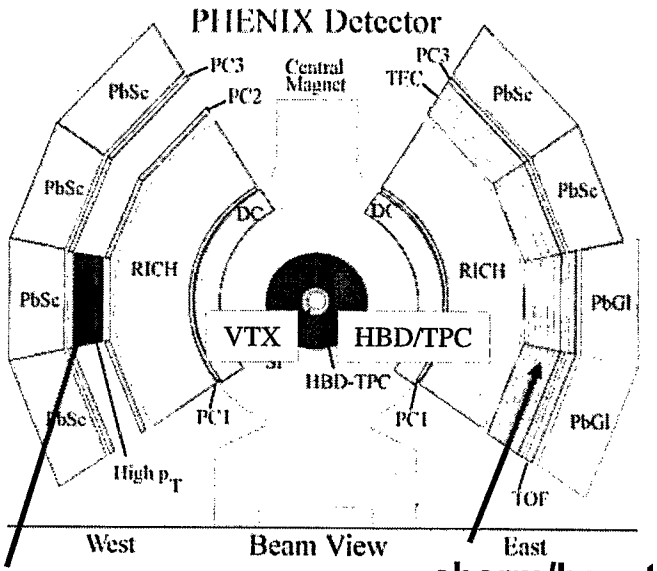
PHENIX Central Arm Upgrades

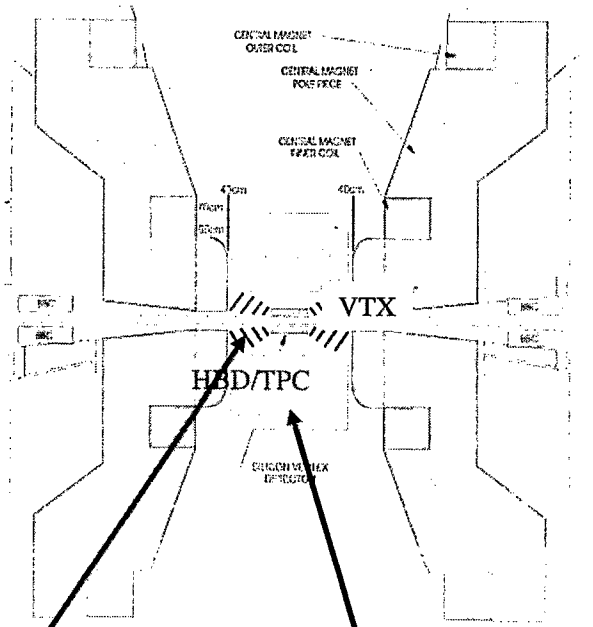
- Enhanced Particle ID
  - **TRD (east)** ✓
  - Aerogel/TOF (west)



High p_T phenomena:
Aerogel/TOF
π, K, p separation to 10GeV/c

charm/beauty: TRD
e/π above 5 GeV/c

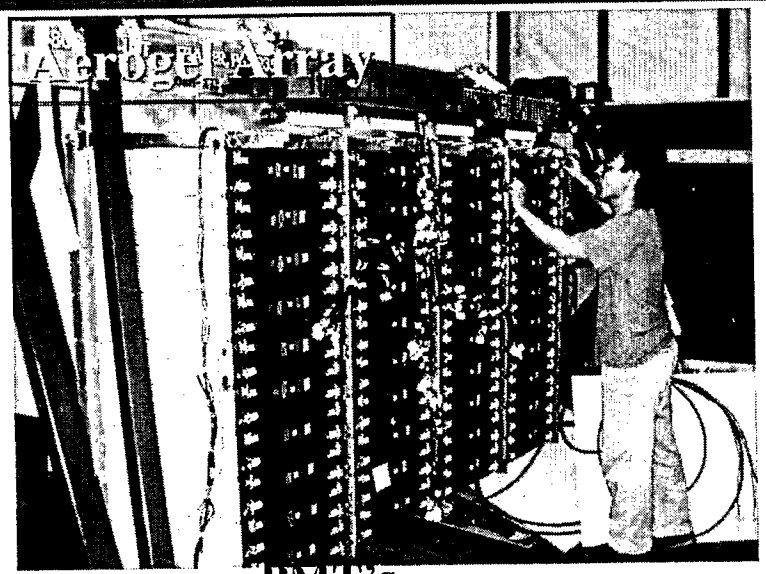
- Vertex Spectrometer
  - **flexible magnetic field** ✓
  - VTX: silicon barrel vertex tracker
  - HBD and/or TPC



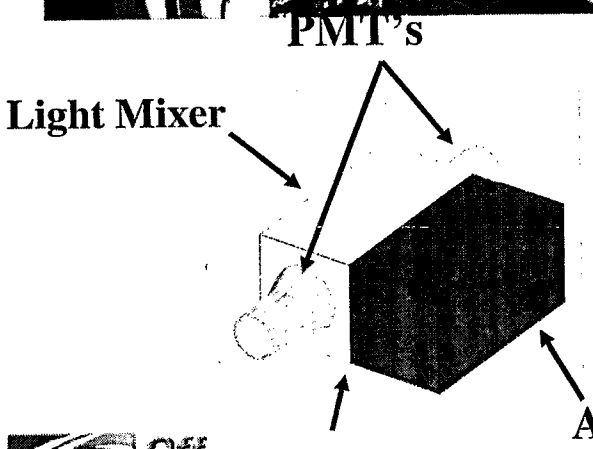
charm/beauty: VTX
displaced vertex

e^+e^- continuum: HBD
Dalitz rejection

PHENIX Aerogel detector



- The Aerogel detector is a threshold Cherenkov counter
- Aerogel is a very low density, SiO_2 – based solid
- It has an index of refraction between gases & liquids.
- Identifies charged particles in a momentum range inaccessible with other technologies.



Aerogel Cell ($11x22x11\ cm^3$)

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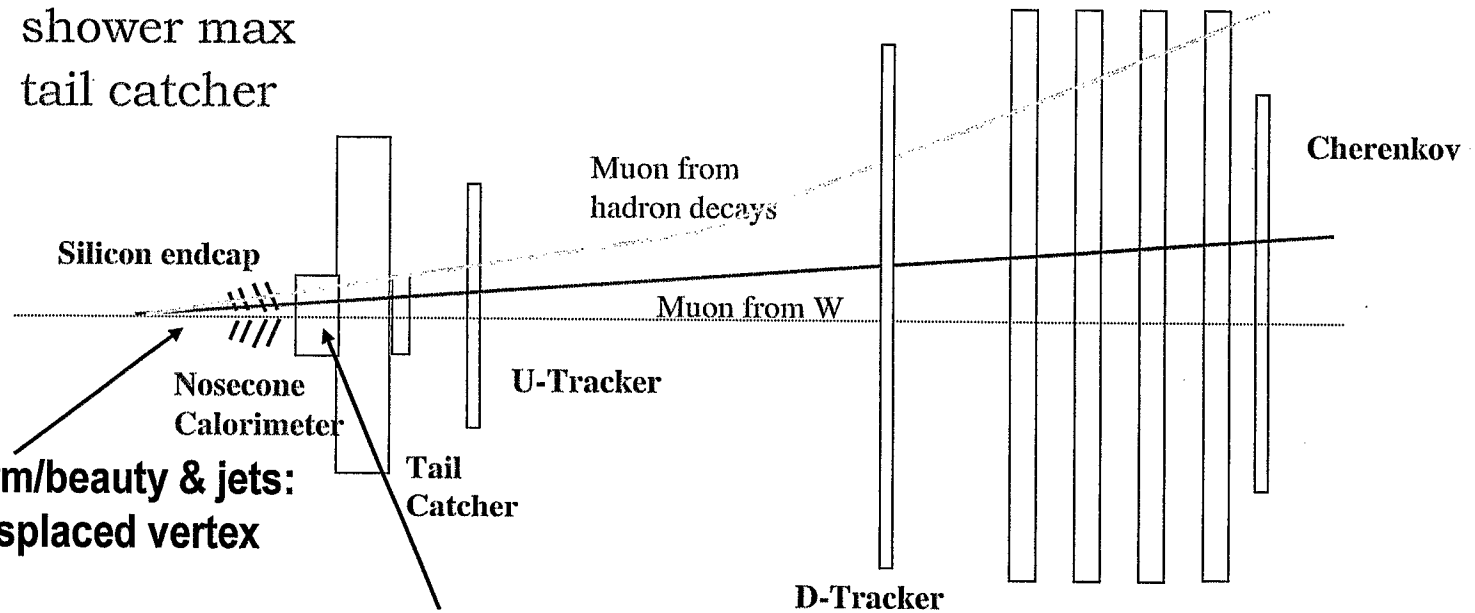
PHENIX Forward Upgrade Components

- Endcap Vertex Tracker
  - silicon pixel detectors
- Nosecone EM Calorimeter
  - W-silicon (20-50 X/X_0)
  - shower max
  - tail catcher
- Muon trigger
  - U-tracker (MuTr or new)
  - D-tracker (timing with RPC's?)
  - Cherenkov



charm/beauty & jets: displaced vertex

γ,γ-jet,W,π^0,η,χ_c: calorimeter

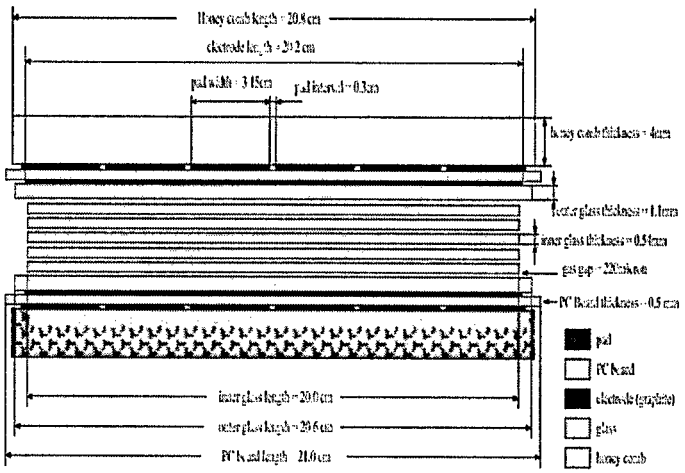
W and quarkonium: improved μ-trigger

STAR's future program needs:

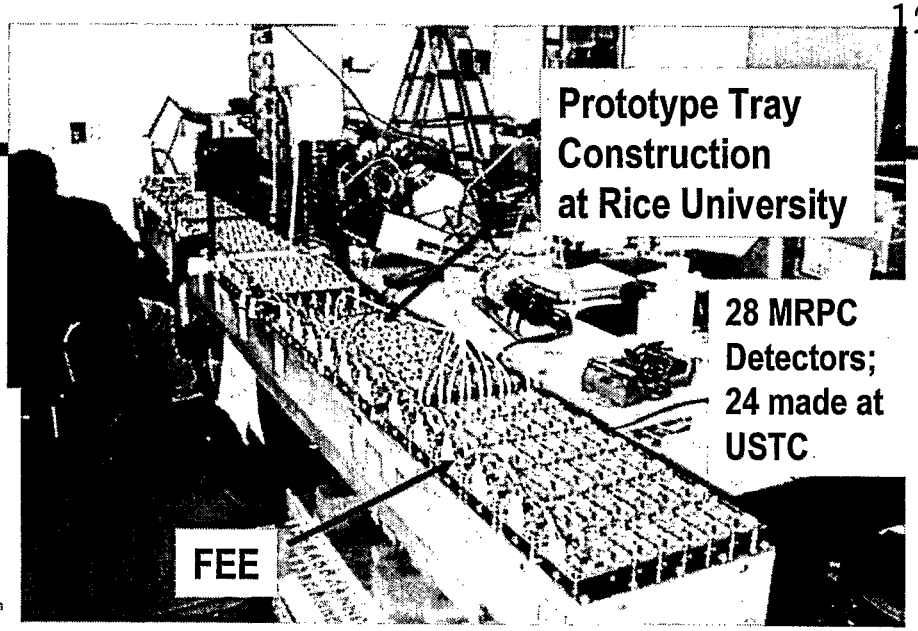
■ **A Barrel MRPC TOF**	**PID information for > 95% of kaons and protons in the STAR acceptance; extended scientific reach for key observables**
■ **A micro-vertex detector**	**precise (3 μm) hit position close to the primary vtx → D's ,flavor-tagged jets**
□ A DAQ/ TPC FEE Upgrade	new architecture / FEE → 1 khz of events sampled at L3; effective integration of 10 x more data
□ Development of GEM tech.	preparation for a compact, fast, next generation TPC for 40 x L
□ Forward Tracking Upgrade	W charge sign identification
□ High Luminosity	10 - 50 × the luminosity (10 nb^{-1}) integrated at RHIC up to 2010

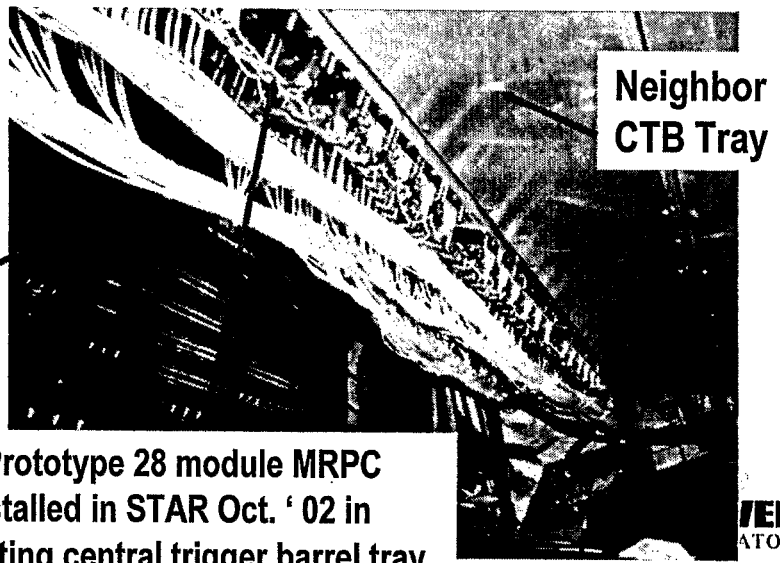
The STAR Barrel TOF MRPC Prototype

MRPC design developed at CERN, built in China



$\sigma \sim 70$ ps, 2 meter path
Strong team including 6 Chinese Institutions in place





Completed Prototype 28 module MRPC TOF Tray installed in STAR Oct. '02 in place of existing central trigger barrel tray

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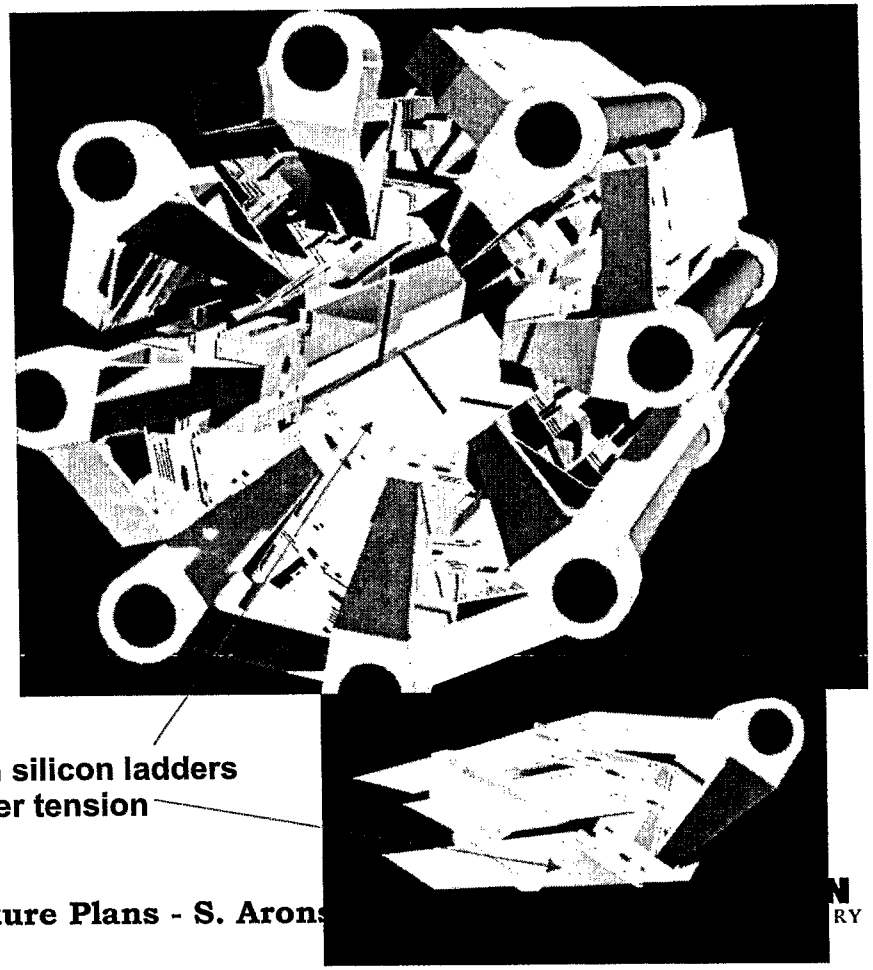
BNL Status

VEN
ATORY

The STAR μVertex detector

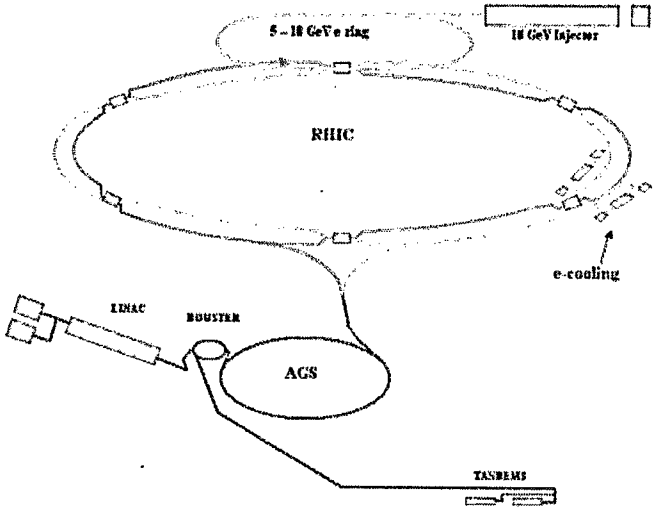
- Open charm
  - Charm quark yield
    - Reconstructing D0
  - Charm hadron chemistry
    - Reconstructing D^+, D_s^+, ... decays
  - Charm hadron flow
    - Constructing D^0 spectra
- Open beauty
  - Identifying B mesons
- Identifying heavy quark jets



Thin silicon ladders under tension

eRHIC

- What is eRHIC?
  - Added capability to collide polarized electrons with the heavy ion and polarized proton beams at RHIC
    - S. Ozaki will discuss machine configuration and options



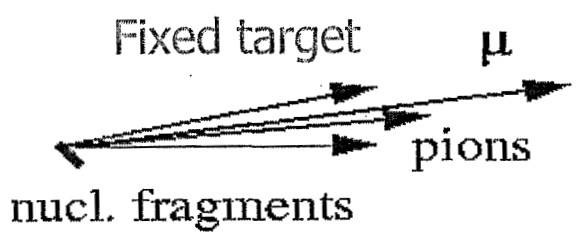
- Why do we need eRHIC?
  - Many fundamental issue in QCD can be addressed with a high energy collider capable of studying polarized deep inelastic scattering

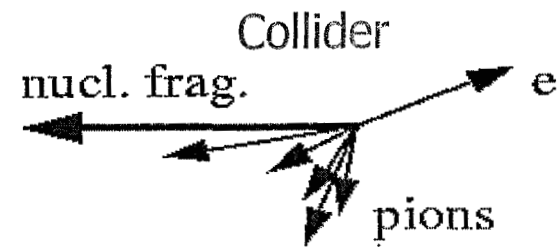
Scientific Frontiers Open to eRHIC

- Nucleon Structure: polarized, unpolarized e-N scattering
  - Role of quarks and gluons in the nucleon
    - Unpolarized quark & gluon distributions, confinement in nucleons
    - Spin structure: polarized quark & gluon distributions
  - Correlation between partons
    - Hard exclusive processes → Generalized Parton Distributions (**GPD**'s)
- Meson Structure:
  - Mesons are goldstone bosons and play a fundamental role in QCD
- Nuclear structure: unpolarized e-A scattering
  - Role of quarks and gluons in nuclei, confinement in nuclei
  - e-p vs. e-A physics in comparison and variability of A: from d→U
- Hadronization in nucleons and nuclei
  - Effect of nuclear medium
  - How do DIS'd partons evolve into colorless hadrons?
- Partonic matter under extreme conditions
  - e-A vs. e-p scattering; study as a function of A

Why use a Collider for DIS?

- Past polarized DIS experiments: in fixed target mode
- Collider has distinct advantages --- Confirmed at HERA

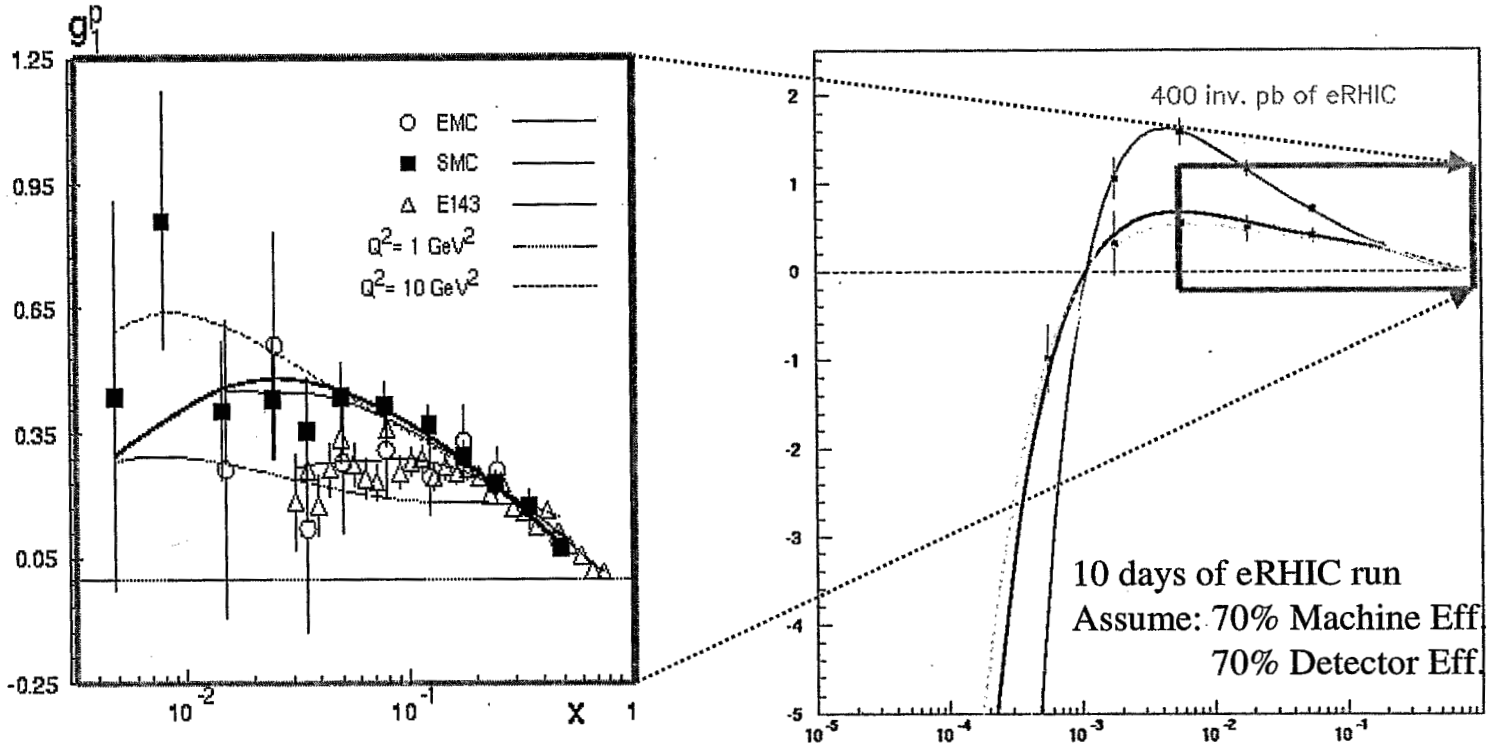




- Better angular separation between scattered lepton & nuclear fragments
  - → Better resolution of electromagnetic probe
  - → Recognition of rapidity gap events (recent diffractive physics)
- Better measurement of nuclear fragments
- Higher center of mass energies reachable
- BUT: tricky integration of insertion, beam pipe & detector

Proton $g_1(x,Q^2)$ low x eRHIC

Fixed target experiments 1989 - 1999 eRHIC 250 x 10 GeV, L ≅ 85pb^{-1}/day



Studies included statistical error & detector smearing to confirm that asymmetries are measurable.
No present or future approved experiment will be able to make this measurement

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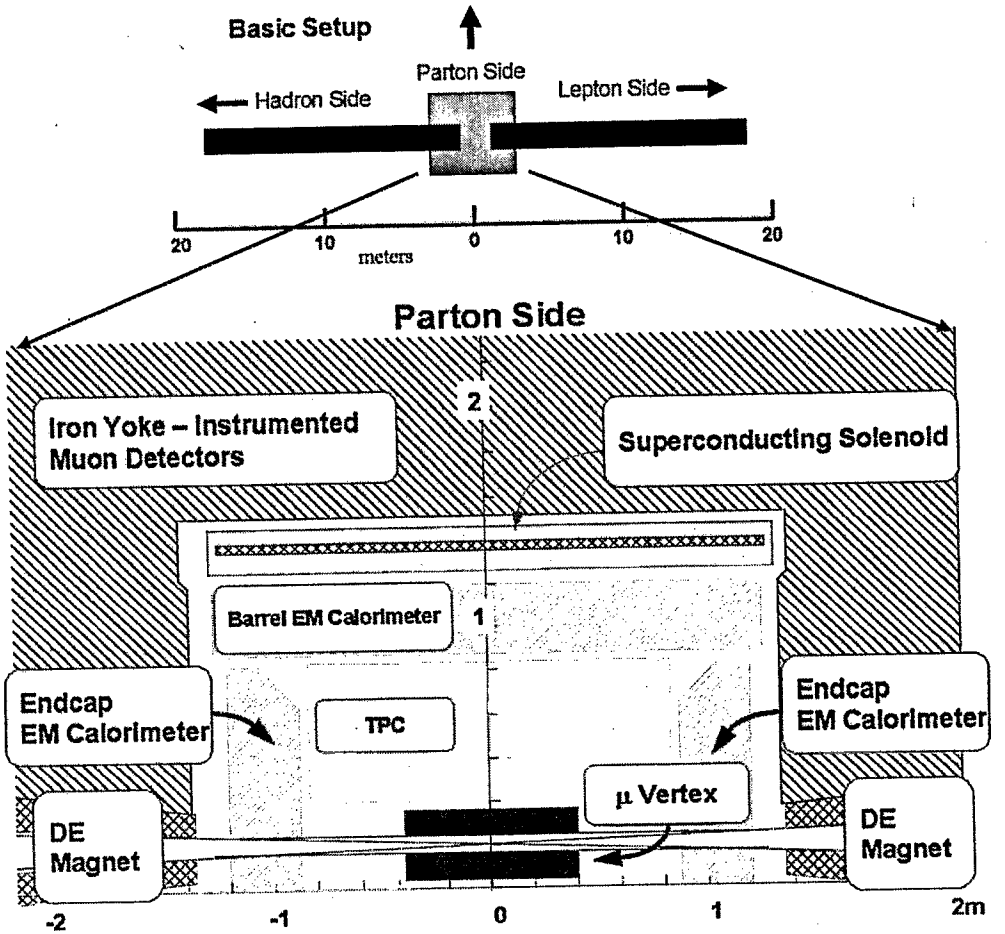
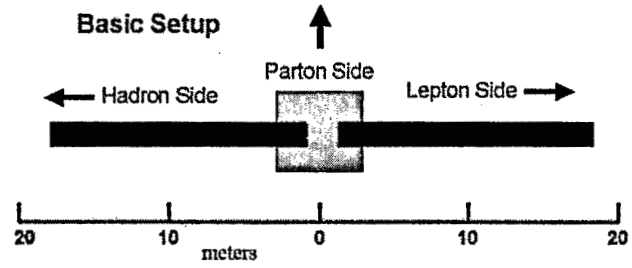
Polarized Gluon Measurement at eRHIC

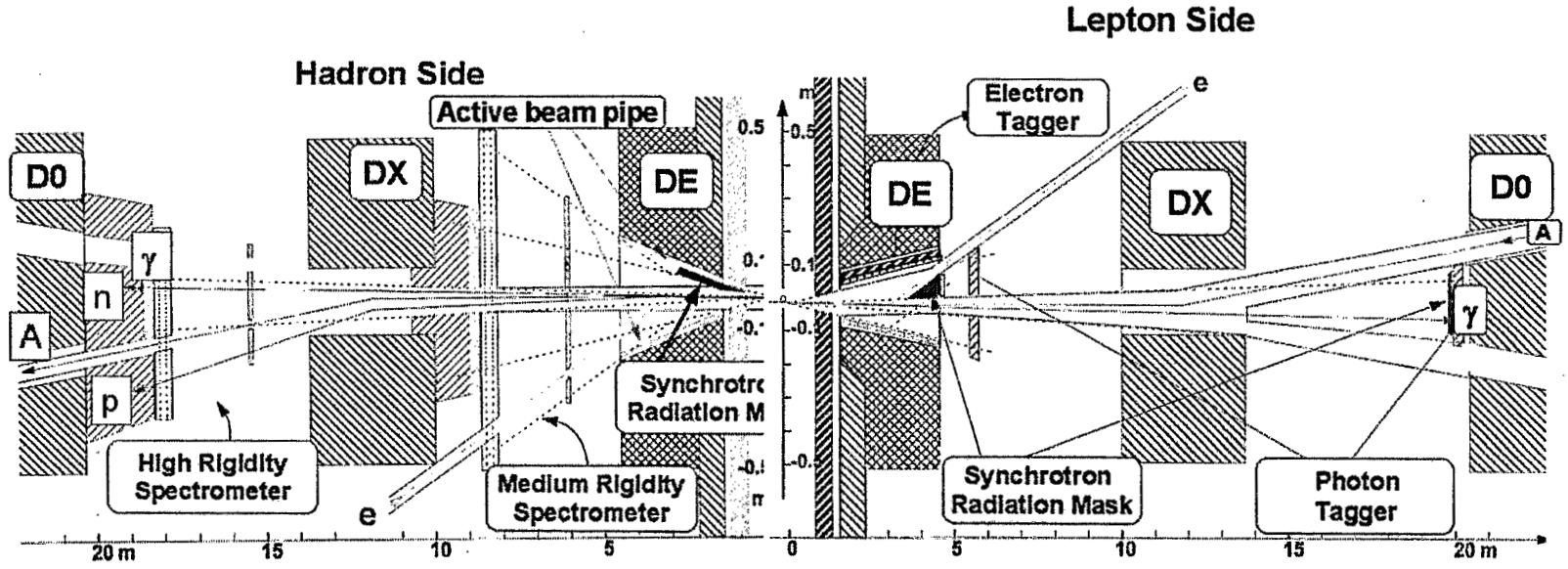
- This is the hottest of the experimental measurements being pursued at various experimental facilities:
  - HERMES/DESY, COMPASS/CERN, RHIC-Spin/BNL & E159,160/SLAC
  - Reliability of applicability of pQCD without doubt leaves only RHIC
- Measurements at eRHIC: complementary with RHIC
- Deep Inelastic Scattering kinematics at eRHIC
  - Scaling violations (pQCD at NLO) of $g_1 \rightarrow 1^{st}$ moment of ΔG
  - (2+1) jet production in photon-gluon-fusion process $\rightarrow$ } ***Shape of $\Delta G(x)$***
  - 2-high p_T hadron production in PGF $\rightarrow$
- Photo-production (real photon) kinematics at eRHIC
  - Single and di-jet production in PGF
  - Open charm production in PGF

Detector Design (I)... others expected



Detector Design (I)... others expected





BNL participation in LSST

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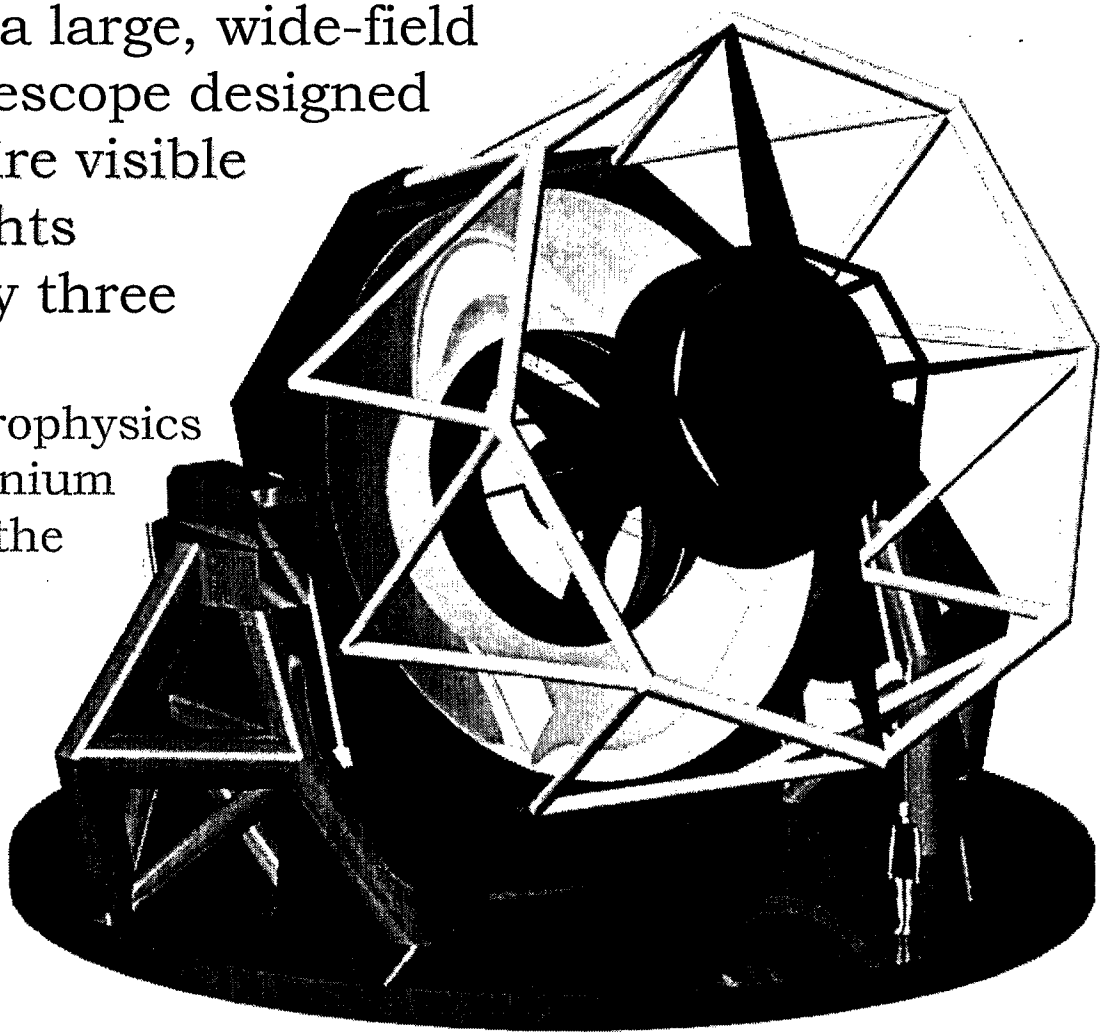
What is LSST?

- The LSST will be a large, wide-field ground-based telescope designed to survey the entire visible sky every few nights
- LSST endorsed by three NAS studies:
  - Astronomy & Astrophysics in the New Millennium
  - New Frontiers in the Solar System
  - From Quarks to the Cosmos



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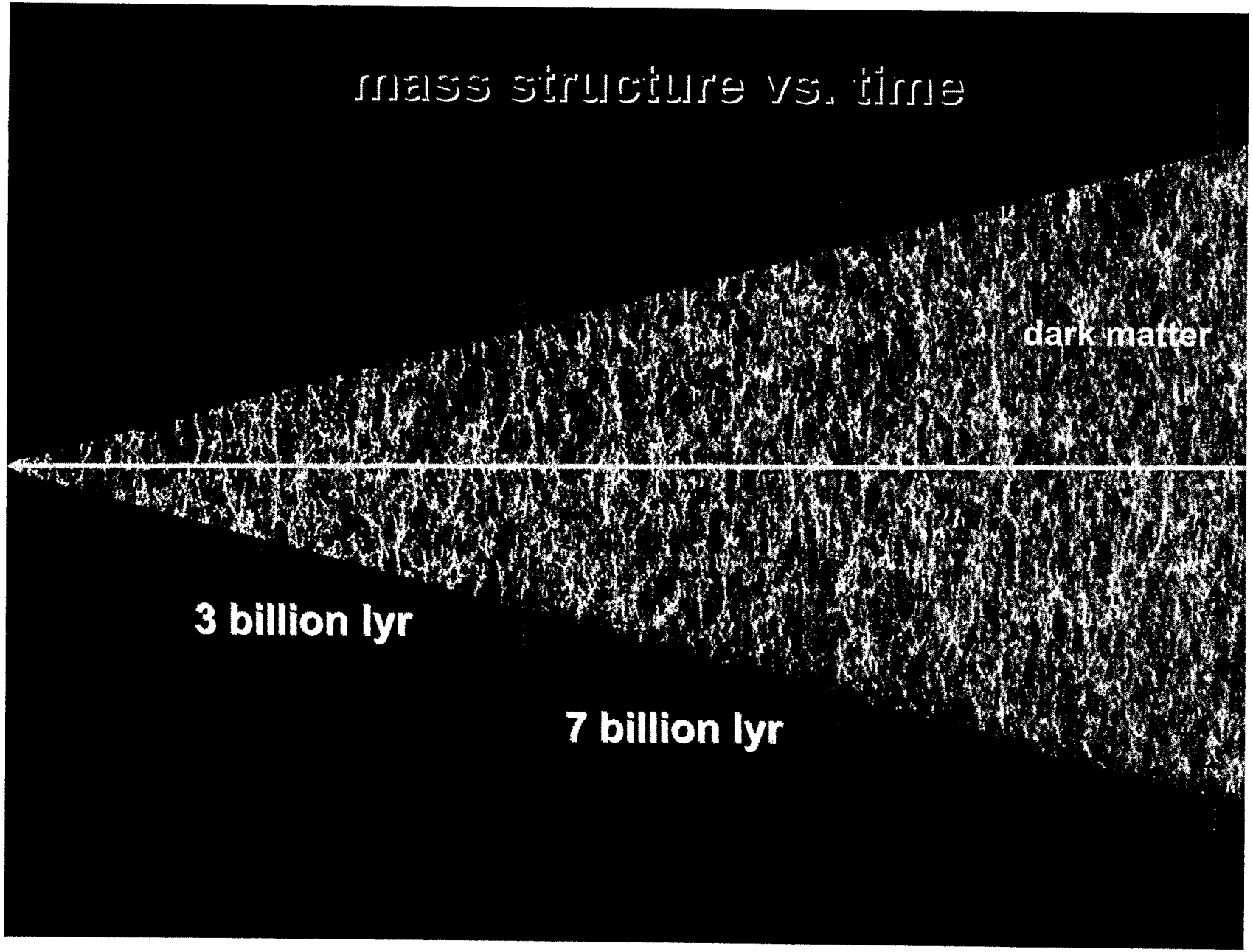
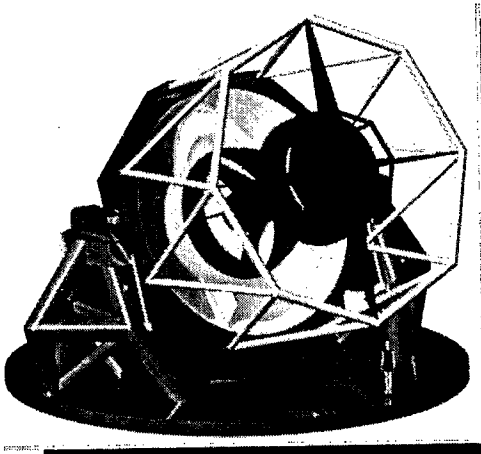
BNL

LSST Motivation

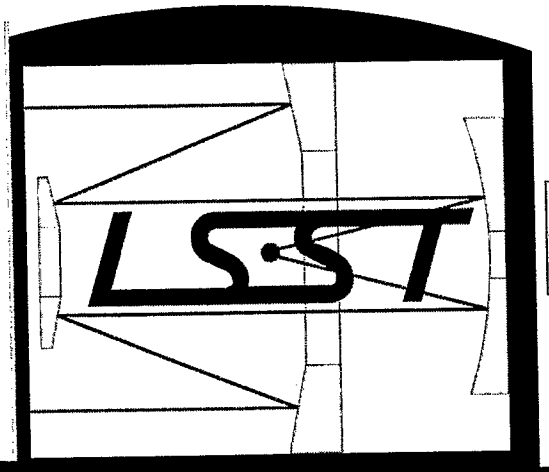
- LSST will enable a wide variety of complementary scientific investigations, utilizing a common database
  - These range from searches for small bodies in the solar system to precision astrometry of the outer regions of the galaxy to systematic monitoring for transient phenomena in the optical sky.
- Probe Dark Energy & Dark Matter
  - Dark matter/dark energy via weak lensing
  - Dark matter/dark energy via supernovae
- Open the Time Window
  - Faint Transients (GRB, SN, ...?)
  - Variability studies: stars, galaxies...
- Unprecedented Planetary Probes
  - NEO > 300m, KBO, Comets, debris
  - Requires: reach 24 V mag in <15 sec over ~5-10 sq deg field

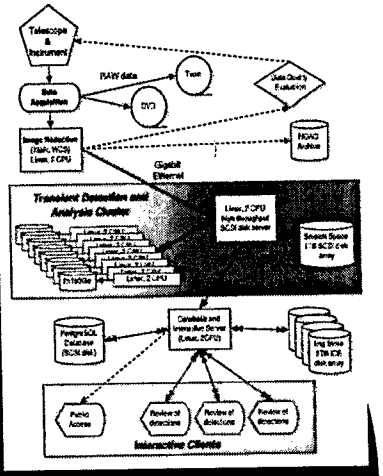

mass structure vs. time
dark matter
3 billion lyr
7 billion lyr

LSST Major subsystems

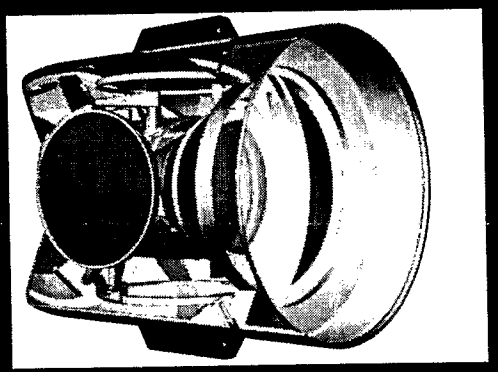


8 meter-class optics





18 Terabytes/night



2.3 Gpixel Camera

DOE participation:

BNL, SLAC, LLNL, Harvard, Illinois, etc.

Background: BNL involvement

- LSST is the focus of BNL's development of a research effort in astrophysics and cosmology
  - Consonant with BNL's research and technical expertise
  - Complementary to current program in HENP – Exp. & Theory
    - **RHIC, ATLAS, RSVP, DZero**
  - Start-up supported by Laboratory discretionary funds, pending future programmatic support (requested of DOE-HEP)
  - Physics Department & Instrumentation Division
    - **15 scientists, students and engineers, currently devoting a few FTE to the project**
    - **A mixture of LDRD funded and unfunded efforts**

Approach

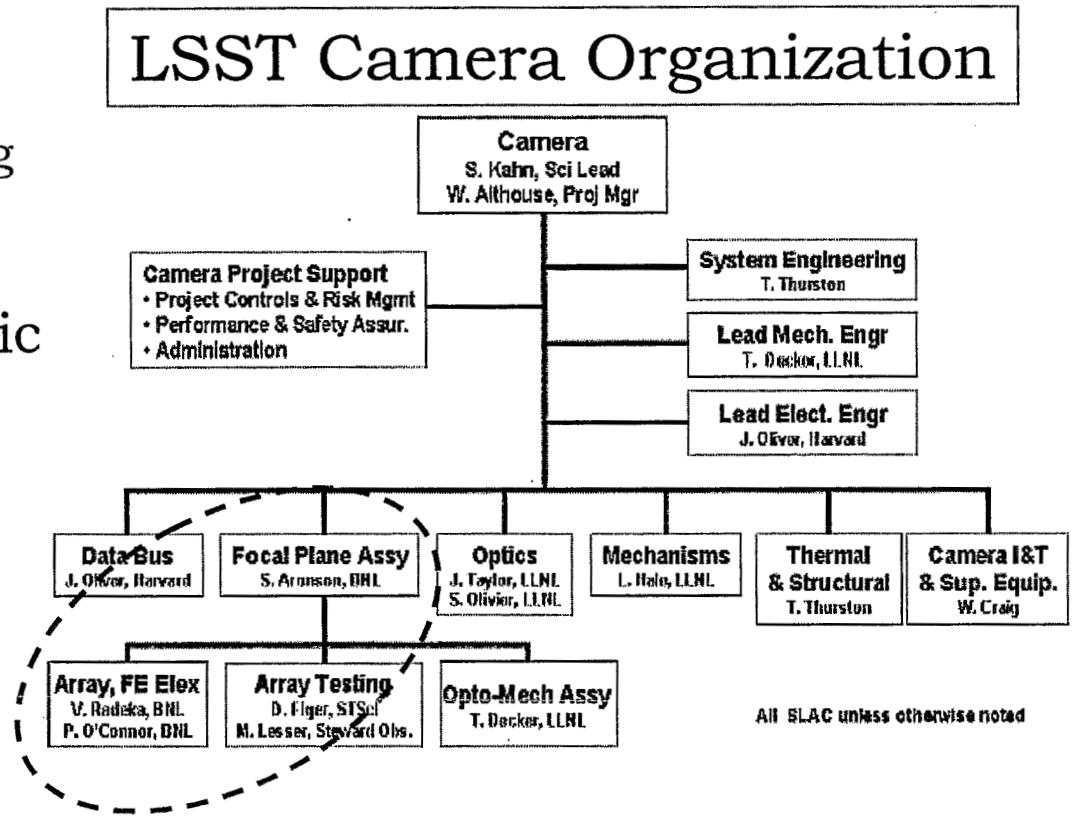
- Scientific
  - BNL's interest within the broad science scope of LSST is centered on the exploration and characterization of **Dark Energy**
  - We are developing the capability to perform this research primarily through weak gravitational lensing
    - Map of galactic shear → map of the mass which acts as the gravitational lens
    - Photometric redshift data is used to give the third dimension to this map
    - Spatial distribution of mass as a function of redshift → cosmological parameters

Approach

- Technical
  - Si detectors, infrastructure and systems; low-noise electronics; data acquisition, computing and analysis
  - **Focal plane detector** –
    - Instrumentation Division expertise in Si pixel detectors with low noise ASIC readout (RHIC, LHC, NSLS, etc.)
    - We expect to play a leading role in the technology choice, design and construction
  - Data Management –
    - Tera-scale Computing Facilities and major analysis efforts for RHIC and ATLAS (100's of Tbytes/year, > 1 Pbyte logged so far)
    - BNL is considering the development of a "regional computing facility" for LSST

BNL's principal LSST role

- Focal Plane Array
  - Detector design
  - Technology choice
  - Procurement/testing
  - Assembly & commissioning
- Front-end Electronic
  - Significant effort
    - # of detector modules, volume of data
  - More reliance on ASICs than any previous high performance imager for astronomy/astrophysics



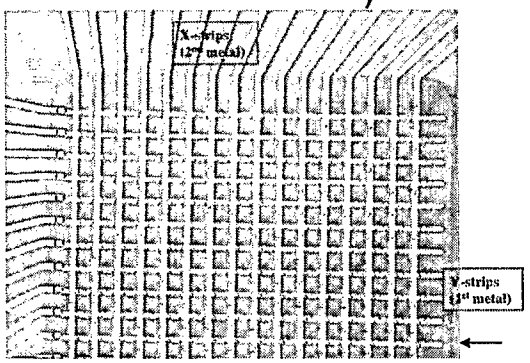
Si Detector Development and Processing at BNL

- **Instrumentation Division has**
  - **A unique ability within the DOE labs and US universities to fabricate complex silicon detector devices**
    - **The highest sensitivity low noise ICs**
  - **Experience designing Si pixel detectors with low noise ASIC readout for RHIC and ATLAS**
  - **Experience in large-scale integration of Si-based detectors:**

Novel Detectors

- **Stripixel detectors**

  1-sided 2D position sensing (PHENIX barrel VTX)



- **Active matrix pixel sensors**
- **Edgeless detectors**
- **Semi-3D rad hard sensors**

Tera-scale computing

- LSST: 600MB/sec → 18 Tbytes/night → Pbytes in total
  - Tera-scale computing resources, including sustained computing power in the 1-10 Tflops range, will be required to keep up
- BNL computing resources operating on this scale now
  - RHIC Computing Facility
    - RCF Linux farm ⇔ 3 Tflops
  - US ATLAS Tier I Computing Facility
  - High speed networking capability
    - RCF/ACF enables data analysis at institutions worldwide
    - Constantly improving speed

FUTURE PERSPECTIVES: RBRC

Nicholas P. Samios

Future Perspectives

RBRC

Nicholas P. Samios

Presentation
10th Meeting of The Management Steering Committee of
RIKEN BNL Collaboration

March 25-26, 2004
RIKEN, Wako, Japan

Future Perspectives - RBRC

RBRC — Will continue to aim to be the intellectual leader in the new field of High Energy Nuclear Physics

RHIC — Non-Perturbative QCD, Spin Physics Program, Computing

Explore:

New Form of Nuclear Matter

Nuclear Spin and Nuclear Structure

More complete Lattice Gauge Calculations

QCD – RHIC

High Energy Density Matter Formed

Quark Gluon Plasma – not weakly interacting (gas)
strongly interacting (liquid)

Define this matter

In addition

Color Glass Condensate – small x phenomena

Future Projects:

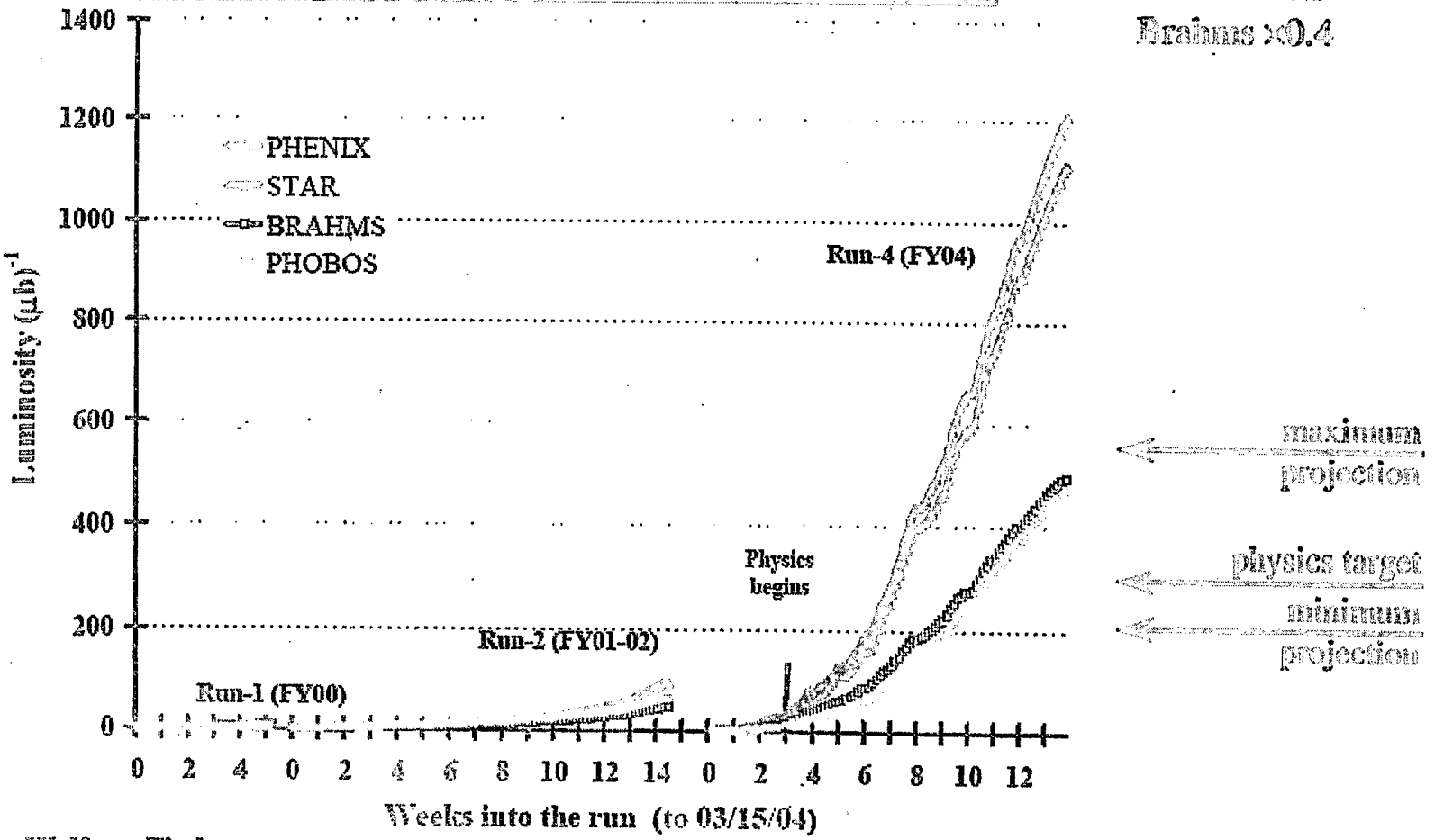
- Detector Upgrades
- Increased performance of RHIC
- Luminosity – RHIC II
- Enhanced capability
- e-RHIC

Other:

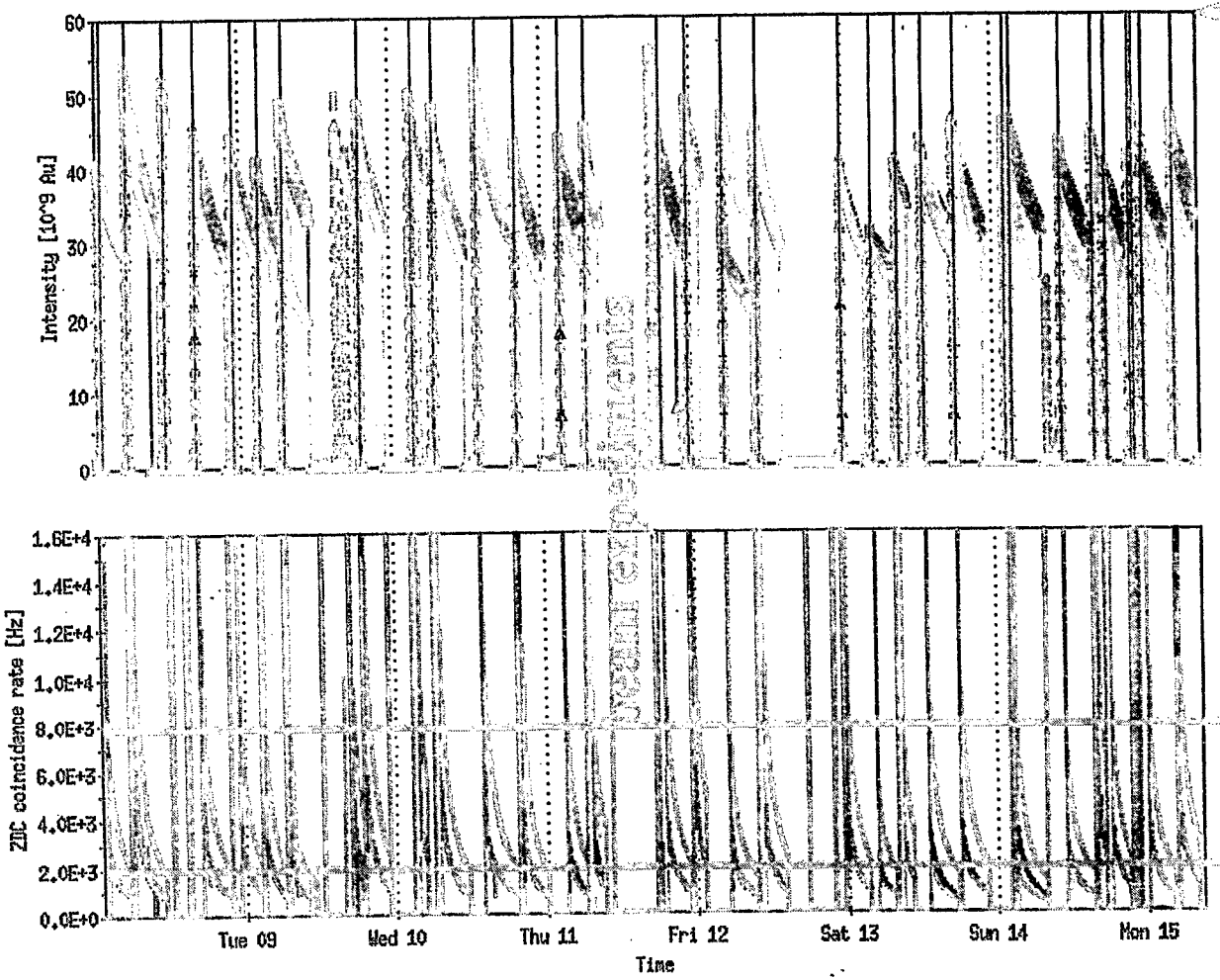
- LHC
- Astrophysics

Delivered 1196 $(\mu b)^{-1}$ to Phenix [week ago : 1060]
136 $(\mu b)^{-1}$ last week [best week: 158]

As of 03/14/04 24:00
Star ×0.9
Phobos ×0.3
Brahms ×0.4



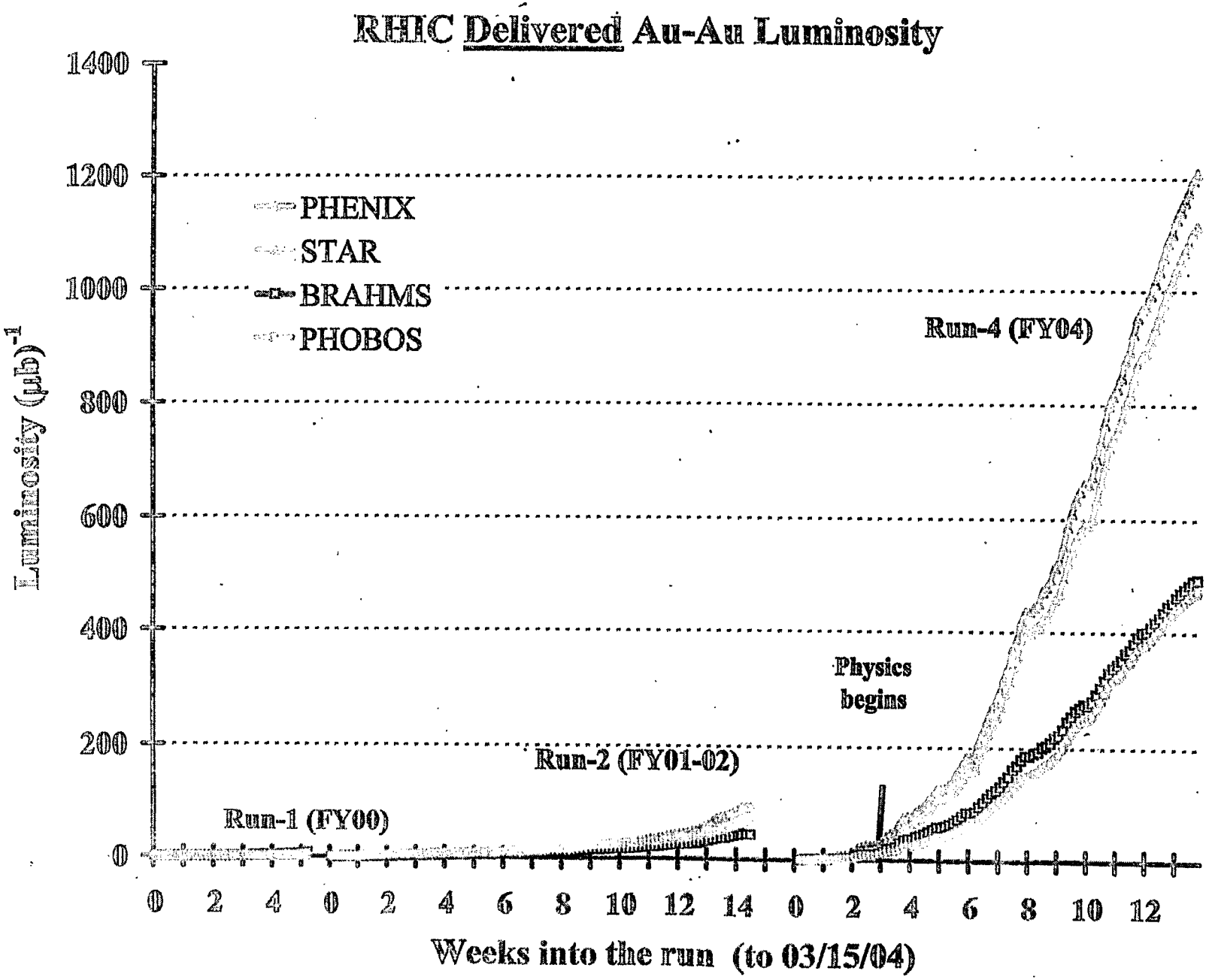
Stores during last week, Monday to Monday



60e9 Au intensity

enhanced luminosity

design luminosity


RHIC Delivered Au-Au Luminosity
Luminosity (μb)$^{-1}$
1400
1200
1000
800
600
400
200
0
PHENIX
STAR
BRAHMS
PHOBOS
Run-4 (FY04)
Physics begins
Run-2 (FY01-02)
Run-1 (FY00)
0 2 4 0 2 4 6 8 10 12 14 0 2 4 6 8 10 12
Weeks into the run (to 03/15/04)

Spin Program

Preparations essentially completed
Detectors, snakes, rotators, polarimeters

'04 – '06 Long Runs $\sqrt{s}$ = 200 GeV
Gluon polarization (π^o 's , direct γ's)

'07 – '12 $\sqrt{s}$ = 500 GeV
Gluon polarization
$W^{\pm}$ anti-quark distributions
Parity violating effects

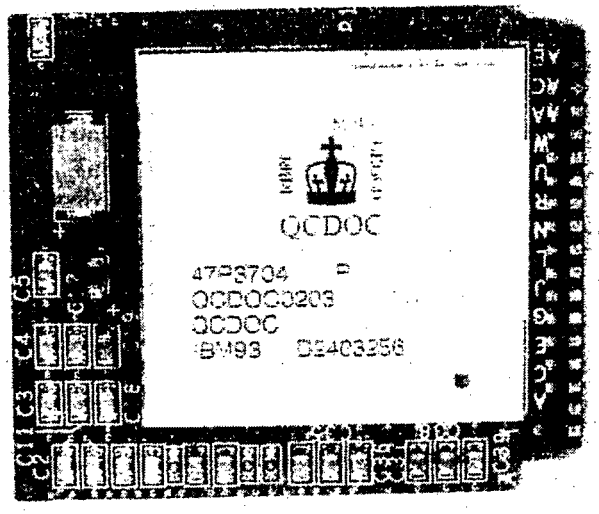
Computing

'04 QCDOC operational
10 Teraflops + QCDSP 1 Teraflops

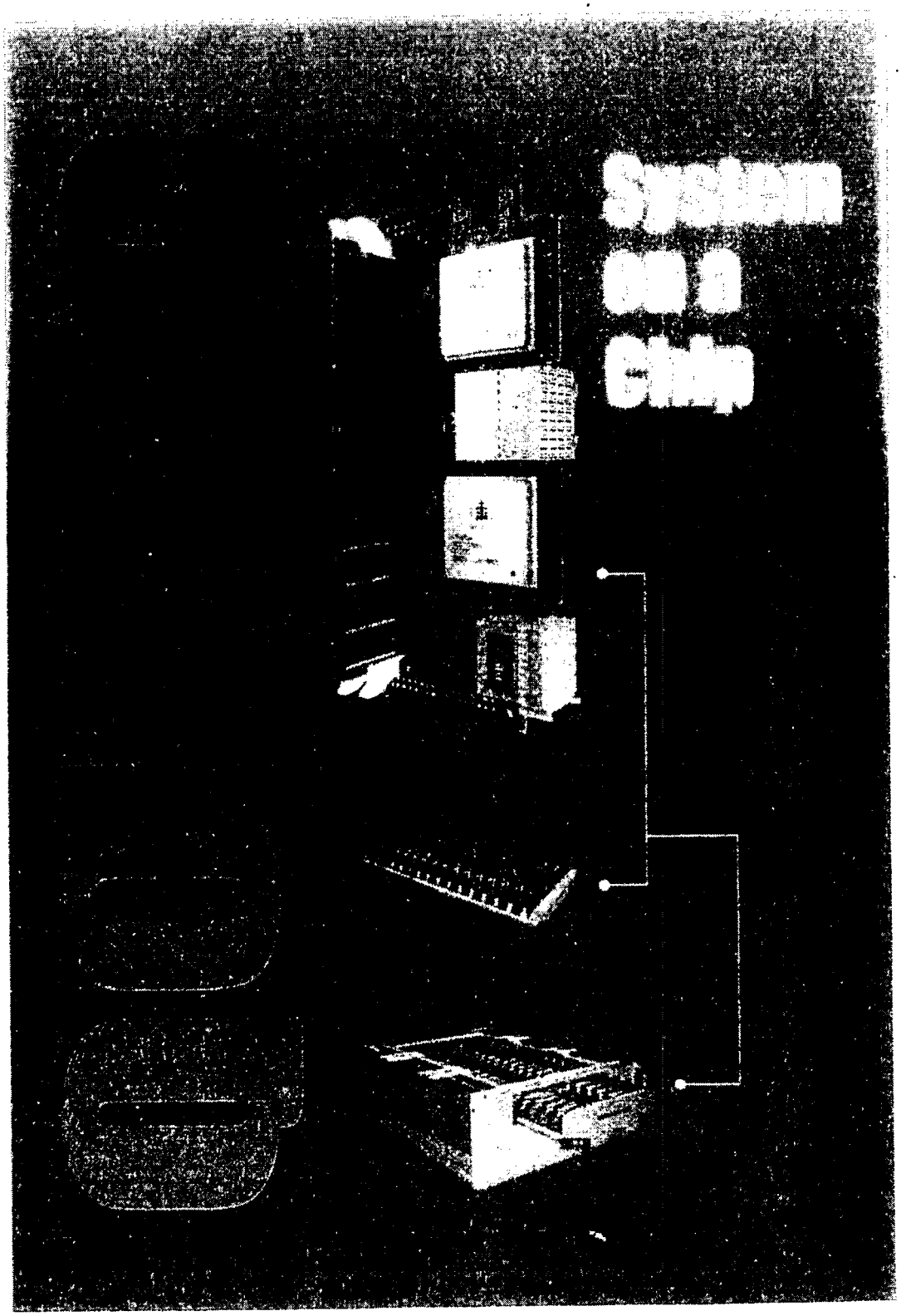
Strong theoretical Lattice Gauge Group
Aoki, Creutz, (Karsch), Christ, +

'06 – '07 R&D for next generation computer

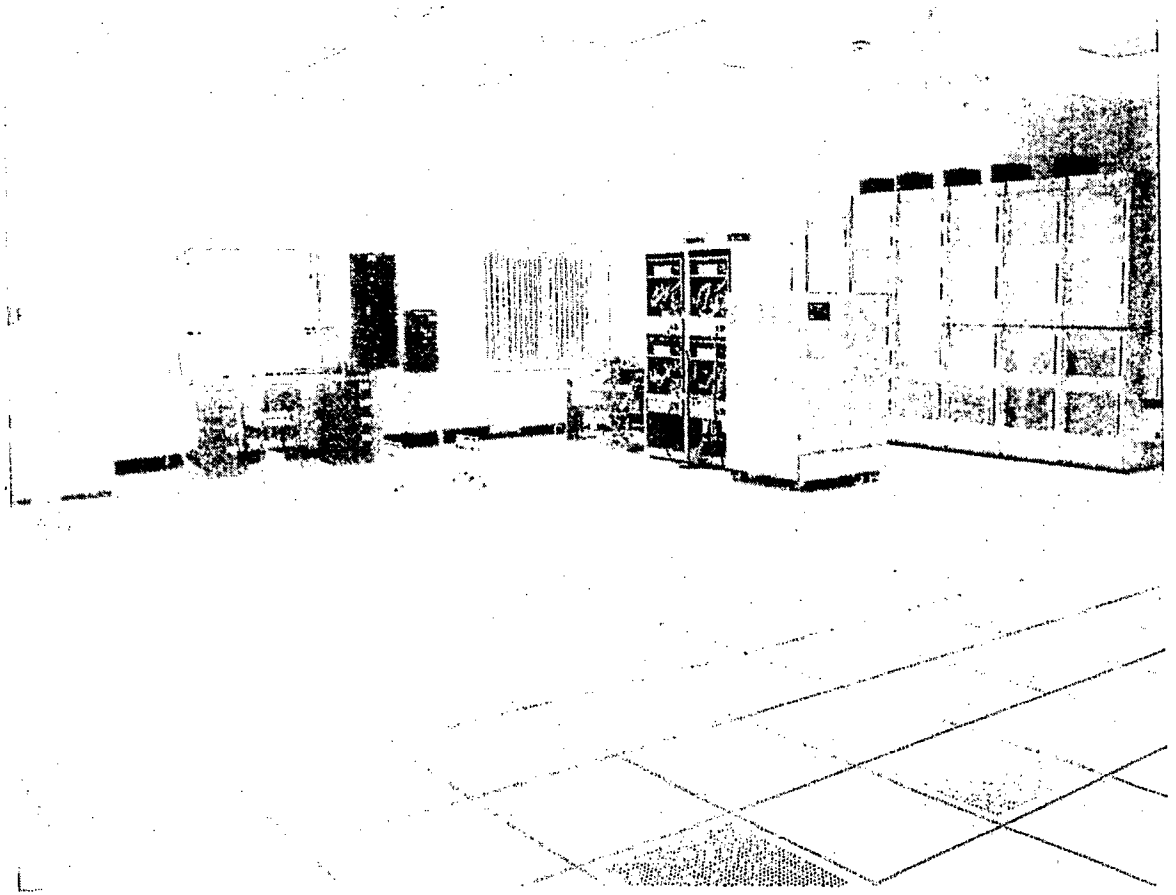
QCD SuperComputing Advances to System on a Chip



QCDOC will provide tens of TeraFlops capability for Quantum Chromodynamics calculations


System
on a
Chip

RIKEN BNL Research Center



Future Perspectives - RBRC

RBRC Will continue to aim to be the intellectual leader in the new field of High Energy Nuclear Physics

RHIC Non-Perturbative QCD, Spin Physics Program, Computing

Explore:

New Form of Nuclear Matter

Nuclear Spin and Nuclear Structure

More complete Lattice Gauge Calculations

FUTURE DIRECTIONS: LATTICE GAUGE THEORY

Larry McLerran

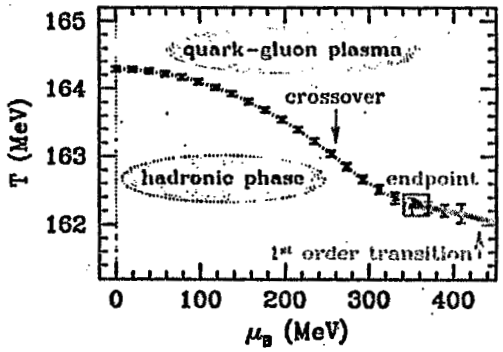
Future Directions:

Lattice Gauge Theory

Forming a Lattice Gauge Theory Group at BNL
Collaborate with RBRC, Columbia
DOE HEP and NT Center for Lattice Gauge Theory

Longer term future: 1000 TFlop Machine

Ultimate physics goals:
Precision test of non-perturbative QCD
Precision computations of CKM parameters
Gluon and quark structure of hadrons
Non-perturbative understanding of CGC



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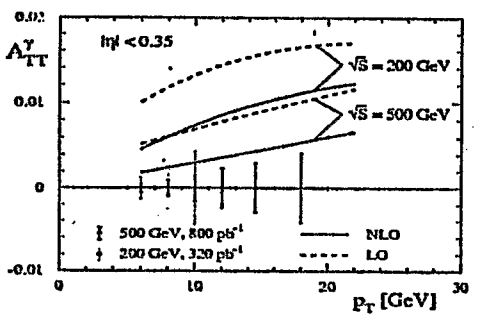
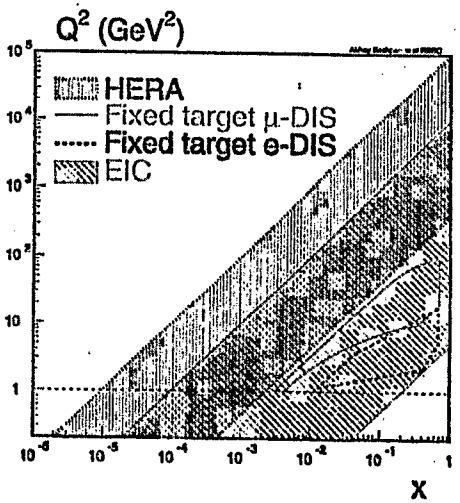
(6)-b) L.McLerran

New Directions:

RHIC II and eRHIC

Understanding the origin of sea quarks and glue
The nature of spin in hadrons
Tests of CGC and QGP ideas with hard probes:
photons, charm
Thermalization: Where CGC meets QGP
Tests of CGC ideas in forward physics eRHIC





LHC Phenomenology: Very Small x, Heavy Ions, EW

Scientific Frontiers at eRHIC

- **Nucleon Structure:** polarized & unpolarized e-p/n scattering
- -- Role of quarks and gluons in the nucleon
- >> Unpolarized quark & gluon distributions, confinement in nucleons
- >> Spin structure: polarized quark & gluon distributions
- -- Correlation between partons
- >> hard exclusive processes leading to Generalized Parton Distributions (GPD's)

- **Meson Structure:**
- -- Mesons are goldstone bosons and play a fundamental role in QCD

- **Nuclear structure:** unpolarized e-A scattering
- -- Role of quarks and gluons in nuclei, confinement in nuclei
- -- e-p vs. e-A physics in comparison and variability of A: from d→U

- **Hadronization in nucleons and nuclei & effect of nuclear media**
- -- How do partons knocked out of nucleon in DIS evolve in to colorless hadrons?

- **Partonic matter under extreme conditions**
- -- e-A vs. e-p scattering; study as a function of A

FUTURE PERSPECTIVES EXPERIMENTAL GROUP JFY 04 AND BEYOND

Hideto En'yo

Future Perspectives

Experimental Group
JFY04 and beyond

H. En'yo

JYF2004-2006
(MoU#2: 2002-2006)

- RHIC Spin Experiment is in *FULL SWING with larger polarization and luminosity.*
- Will obtain more accurate results for ΔG.

We will know how much gluons are carrying the proton spin which is our primary goal of the project.

We will start the measurements for anti-quark polarization at 500GeV.

- Upgrade Project R&D => Construction

Experiment G. Organization JFY04

UPGRADE@CERN

Hiroaki Ohnishi
Johann Hauser
Hiroyuki Kano
Kohei Fujiwara (stdnt)

RIKEN@RBRC

Yasuyuki Akiba
Yuji Goto
Tsuguchika Tabaru
Junkichi Asai

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Douglas E. Field
Kensuke Okada
Osamu Jin-nouchi
Masashi Kaneta
Naohito Saito (Visitor)
Kazu Kurita (Visitor)
Wei Xie
Dave Kawall

~38 active member
+~3 active visitors

BELLE

Akio Ogawa (Visitor)
Kazumi Hasuko(RIKEN)
Dominik Gabbert(UIUC)

RIKEN/Wako

Masahiro Okamura
Atsushi Taketani
Rykov Vladimir
Junji. Tojo
Hisa Torii
Junpei Takano

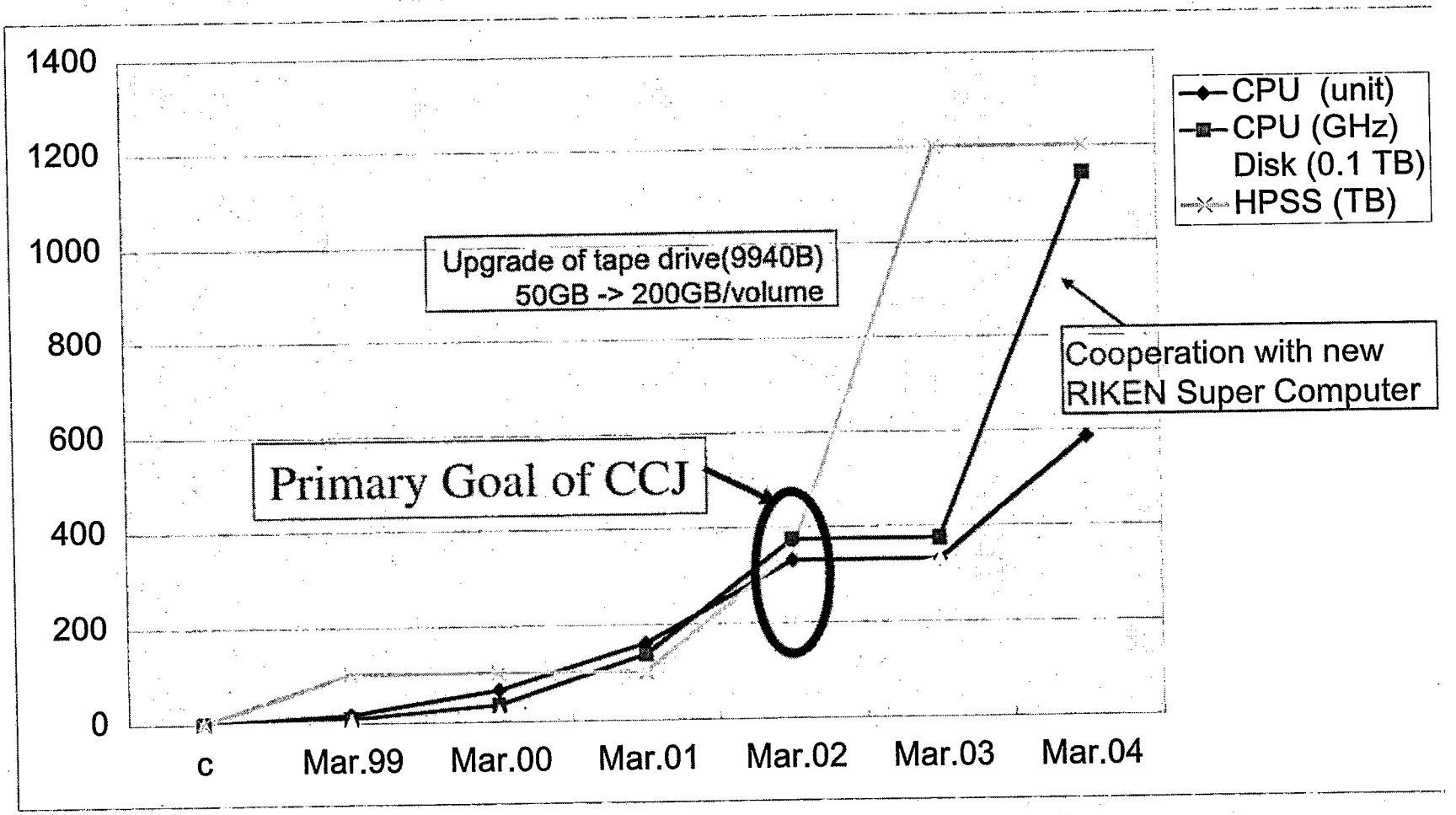
WAKO/CCJ

Takashi Ichihara
Yasushi Watanabe
Satoshi Yokkaichi
Akio Kiyomichi

BRBC in 2004

- **Core of the project**
  - **Entering the most exciting phase**
  - 3 RHIC physics fellows (joint with Univ.) will enlarge American student's participations.
  - 2 new fellows will secure the local activity.
  - Promote physics data accumulation and analyses @ CCJ.
  - Build up the future beam time strategy with other spin experiments and the accelerator
    - AGS/RHIC polarimetry
  - Okamura/Takano for Polarization Improvements

CCJ in JFY2004



This cooperation helped us a lot,
2-3 time CPU capability with less operation cost
Storage is enough for three years of RHIC data

Upgrade proposal

Proposal for a Silicon Vertex Tracker (VTX) for the PHENIX Experiment

M. Baker, R. Nouicer, R. Pak, P. Steinberg
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Z. Li
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J.S. Haggerty, J.T. Mitchel, C.L. Woody
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J. Crandall, J.C. Hill, J.G. Lajoie, C.A. Ogilvie, H. Pei, J. Rak, G.Skank, S. Skutnik, G. Sleege, G. Tuttle
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M. Tanaka
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H.W. van Hecke, G.J. Kunde, D.M. Lee, M. J. Leitch, P.L. McGaughey, W.E. Sondheim
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T. Kawasaki, K. Fujiwara
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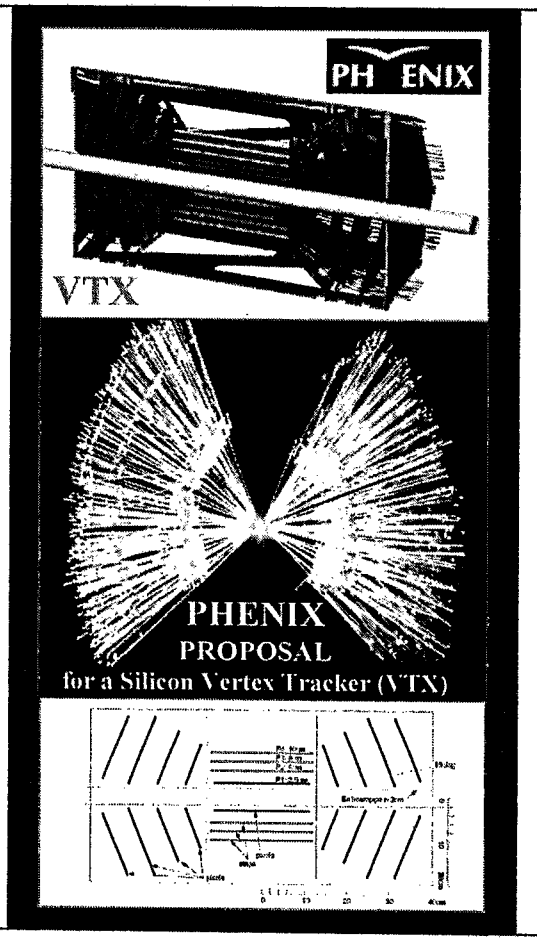
T.C. Awes, M. Bobrek, C.L. Britton, W.L. Bryan, K.N. Castleberry, V. Cianciolo, Y.V. Efremenko, K.F. Read, D.O. Silvermyr, P.W. Stankus, A.L. Wintenberg, G.R. Young
Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

Y. Akiba, H. En'yo, Y. Goto, J.M. Heuser, H. Kano, H. Ohnishi, V. Rykov, T. Tabaru, K.Tanida, J. Tojo
RIKEN (The Institute of Physical and Chemical Research) Wako, Saitama 351-0198, Japan

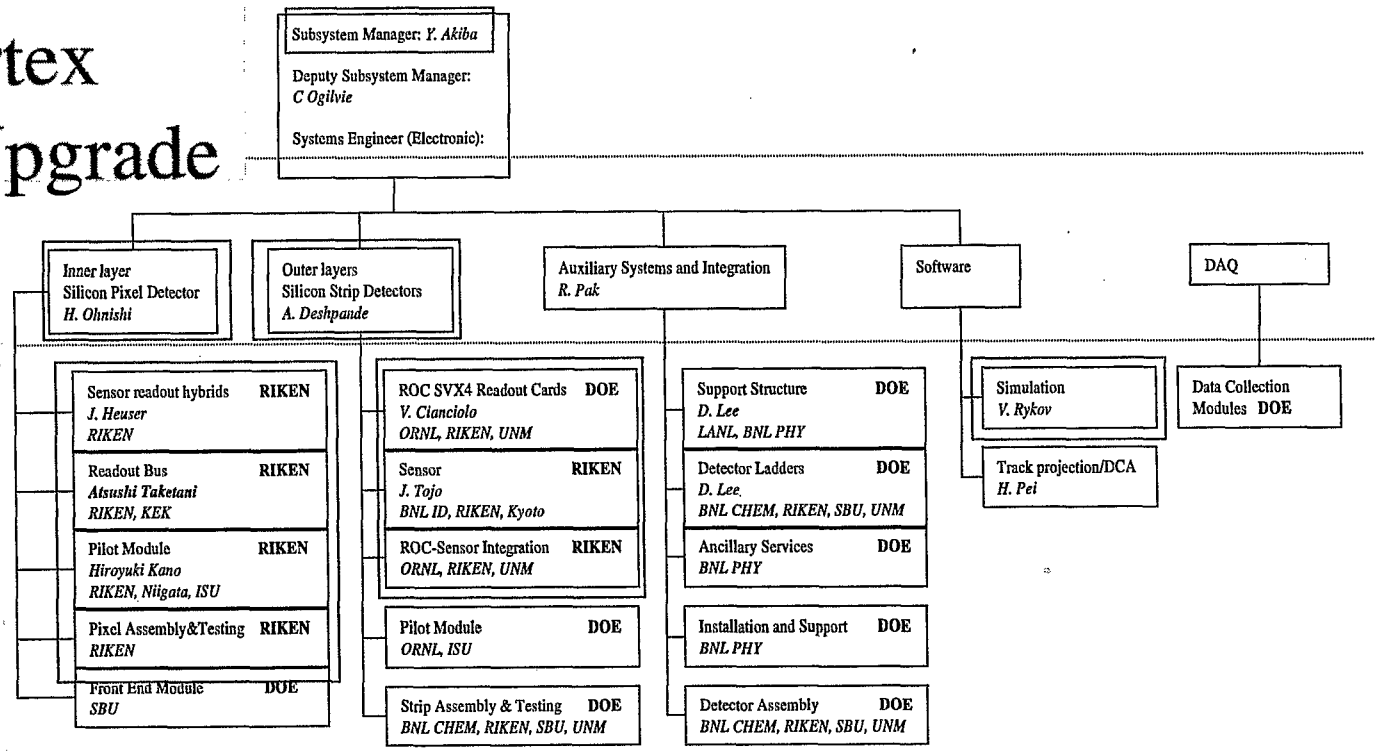
S. Abeytunge, R. Averbeck, A. Deshpande, A. Dion, A. Drees, T.K. Hemmick, B.V. Jacak, C. Pancake, V.S. Pantuev, D. Walker
Stony Brook University, Department of Physics and Astronomy, Stony Brook, NY 11794, USA

B. Bassalleck, D.E. Fields, M. Malik
University of New Mexico, Albuquerque, NM, USA



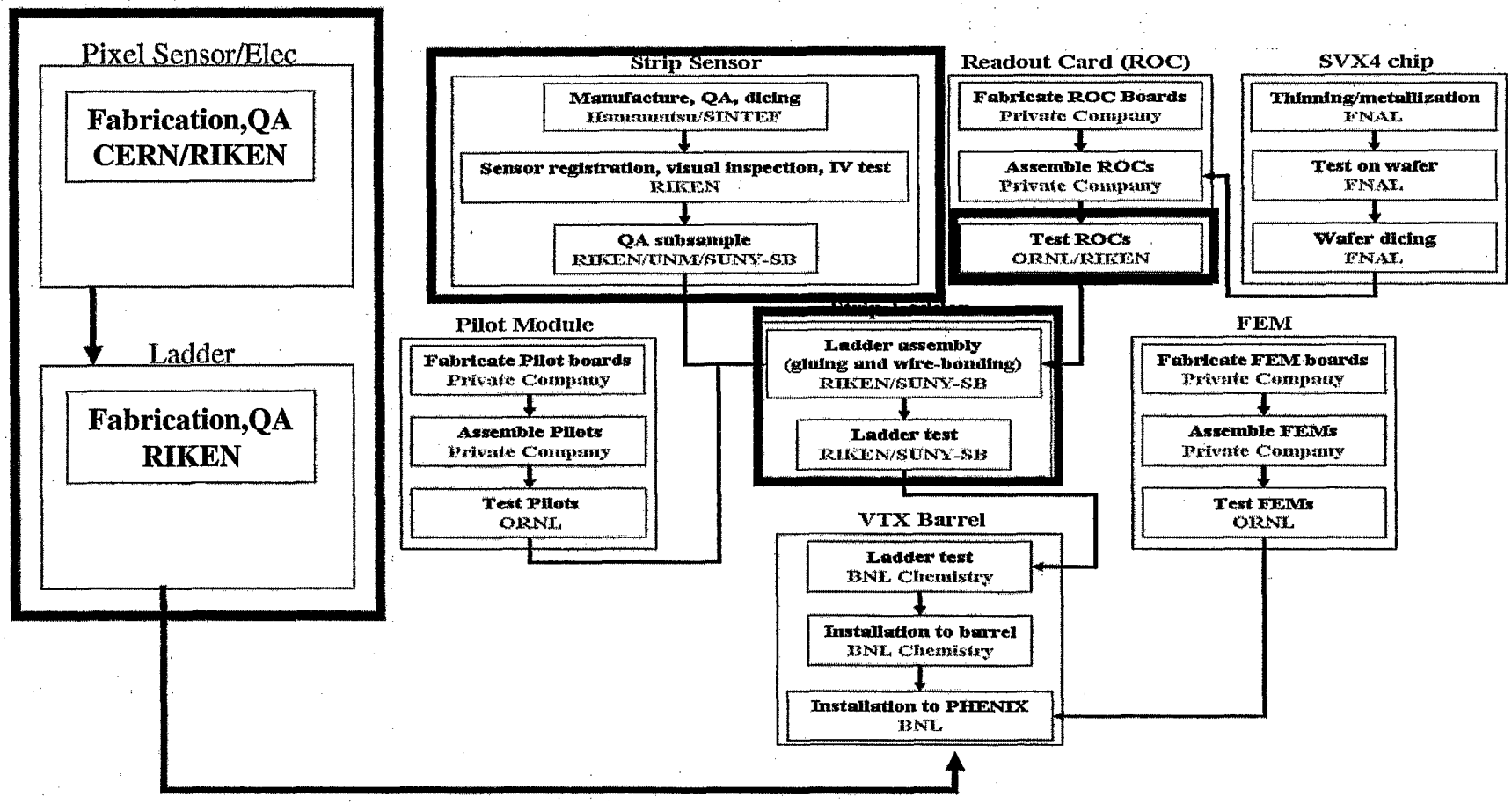
- Submitted to BNL/DOE
- DoE Critical Decision 0 (OK for the project) is expected in sometime in FY05.
- ~0.5M$(DoE) will be available in coming year.

Organization for the Vertex Detector Upgrade



- Leading positions filled
  - System Manager: Y. Akiba
  - Deputy System Manager C. Ogilvie
  - Pixel subsystem leader H. Ohnishi
  - Strips subsystem leader A. Deshpande
  - Auxiliary system and integration R. Pak

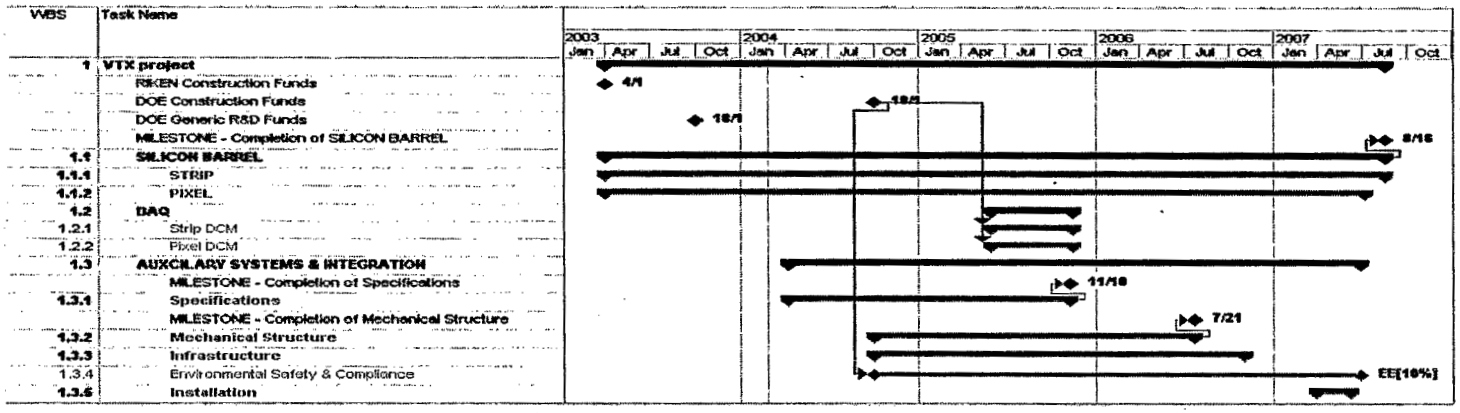
Towards the Installation



Upgrade: Budget and Schedule

Table 15 Overview of the total estimated cost for the VTX project

WBS	Name	DOE	RIKEN	Total
1.1.1	STRIP	2,180,695	1,302,125	3,482,820
1.1.2	PIXEL	575,700	1,690,375	2,266,075
1.2	DAQ	441,450	0	441,450
1.3	AUXCILARY SYSTEMS & INTEGRATION	2,360,013	67,500	2,427,513
1	Total	5,557,858	3,060,000	8,617,858

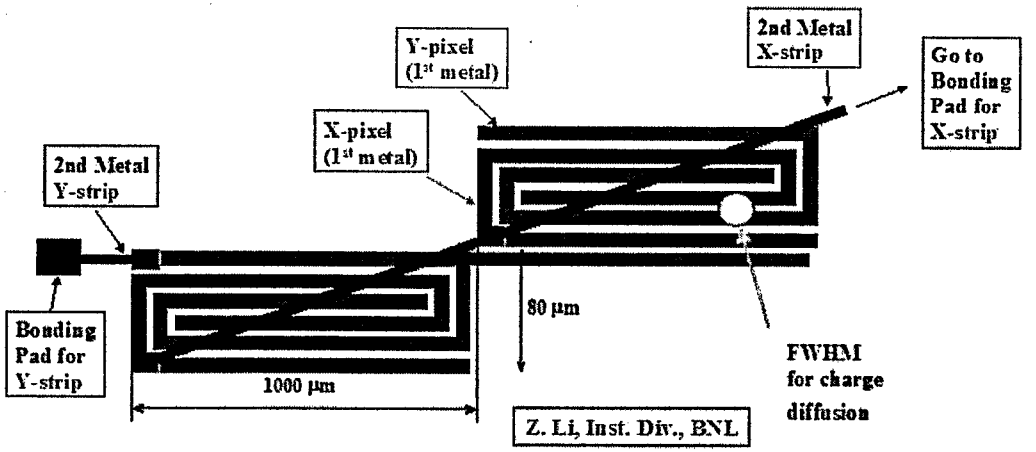


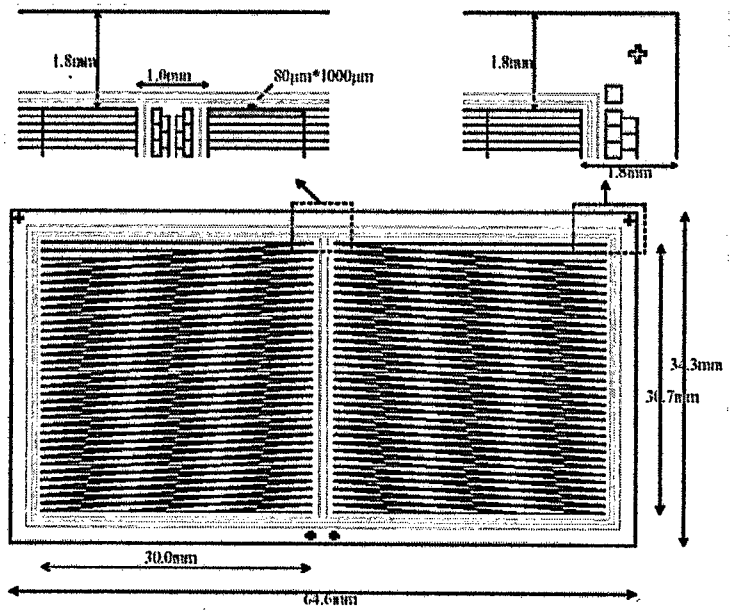
Cost: $5.6M (DOE)+ RIKEN(~3M) within the current RIKEN-approved budget frame (not by MEXT)

Complete in 2007 to be ready for RUN8

Strip Sensor

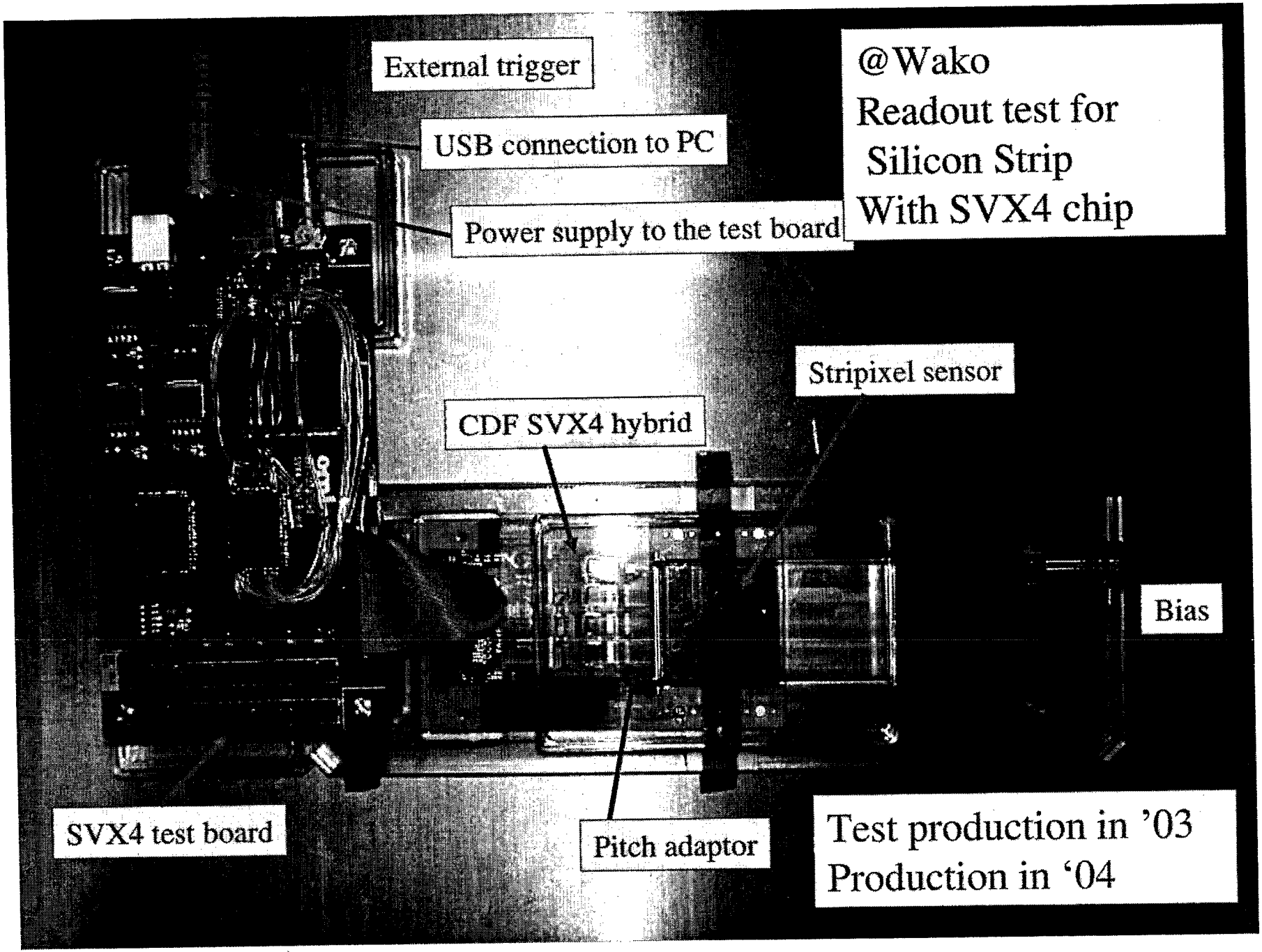
- 80 μ x 1000 μ
- Each pixel region has 2 serpentine-shaped metal strips to collect charge
- Any hit will deposit charge on both metal strips (one x and the other u: 4.6° with each other)





Prototype sensor and dimensions:

- 3.43 cm x 6.46 cm
- divided in to 2 sides of sensitive areas 3.07cm x 3.0cm
- Each strip sensor: 1536 channels
  - 2 x 384 per side x 2
  - half in x and half in u direction
- First prototypes were 250 and 400 μ thick
- Tested in laboratory & test beam
- Second generation will be tested early this year

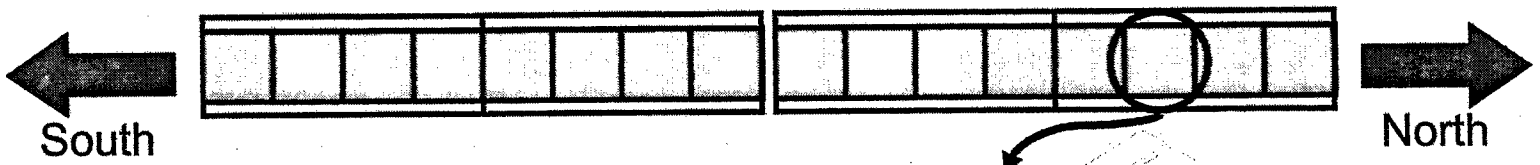

External trigger
USB connection to PC
Power supply to the test board
@Wako
Readout test for
Silicon Strip
With SVX4 chip
Stripixel sensor
CDF SVX4 hybrid
Bias
SVX4 test board
Pitch adaptor
Test production in '03
Production in '04

Strip Sensor, Some Time Lines

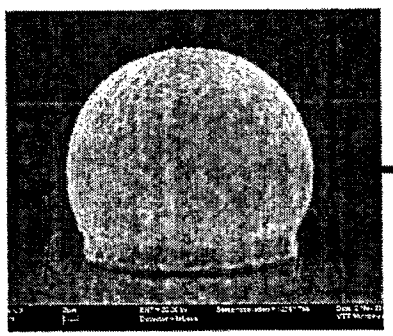
Date	Test	Location
Apr. 2004	Si Sensor/SVX4 on the testboard	ORNL/RIKEN/BNL
Oct. 2004	Full ROC (SVX4/FPGA/strip bus)	ORNL
Dec. 2004	Si sensor/full 1st round ROC	RIKEN
Jul. 2005	Si sensor/full 2nd round ROC	RIKEN & SBU
Jul. 2006	1st full ladder	RIKEN

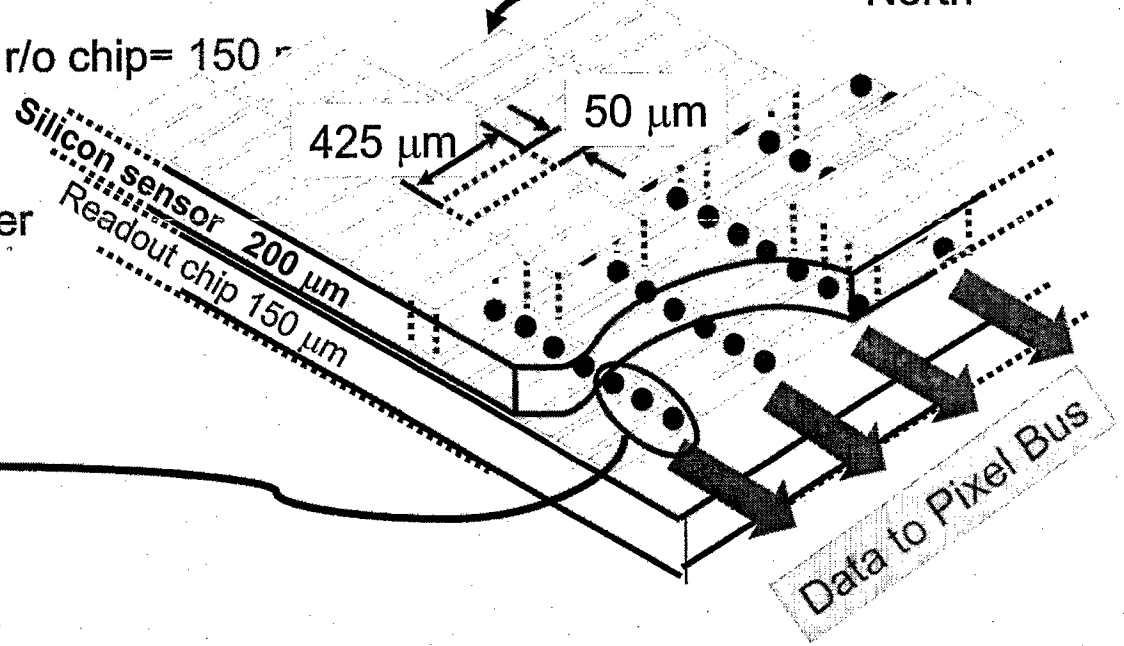
PHENIX Pixel detector@CERN

- One Pixel ladder consists from 16 pixel chips.
  Ladder contains four times "four-chip" ladder on it.
  Smallest detector component is "four-chip" ladder
- 10 ladders are placed surrounding beam pipe,
  2.5 cm away from x=y=0.0



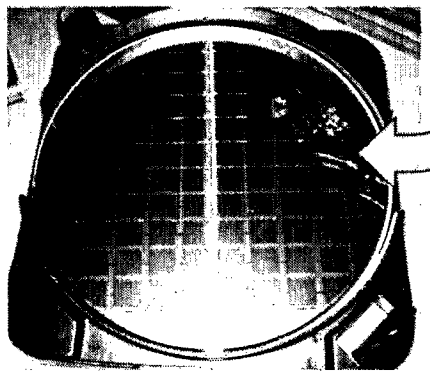
- Thickness; Sensor = 200 mm; r/o chip= 150 μ
- We need 10x16 = 160
  pixel readout chips in total
  to complete the inner most layer
  silicon pixel detector



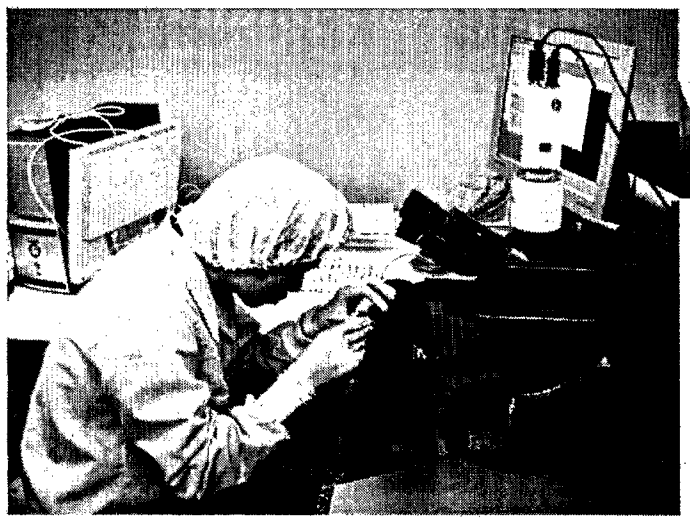


Status of Ladder production@CERN

- Pixel readout chip
  - 16 pixel readout chip wafers, each wafer will contain around 40 good chips on it, are already in our hand.
- Preparation for Pixel readout chip QA test is in progress
  - Installation of the Probe station to one of clean room at CERN is completed.

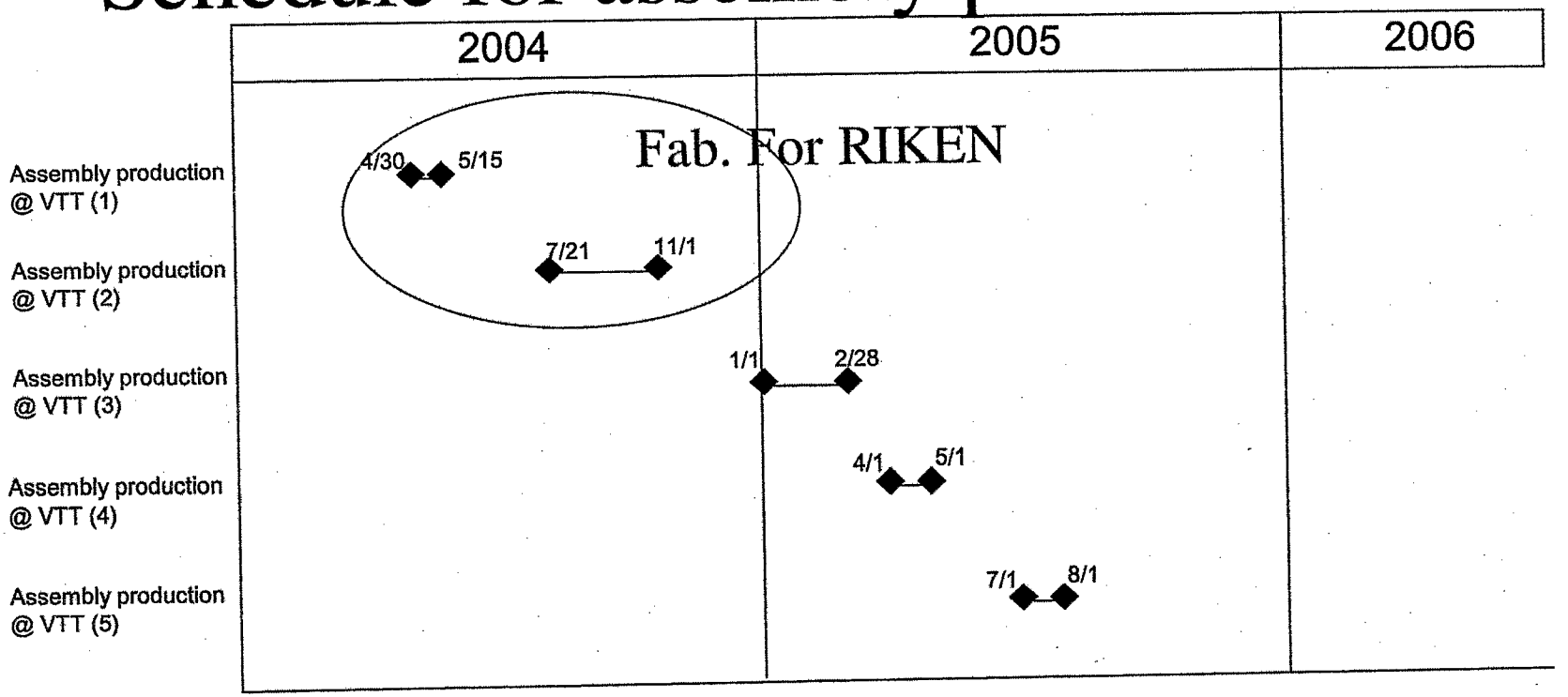


ALICE-LHCB 1
pixel readout chip wafer



A.Taketani (RIKEN)
and
K.Fujiwara (RIKEN / Niigata-U)

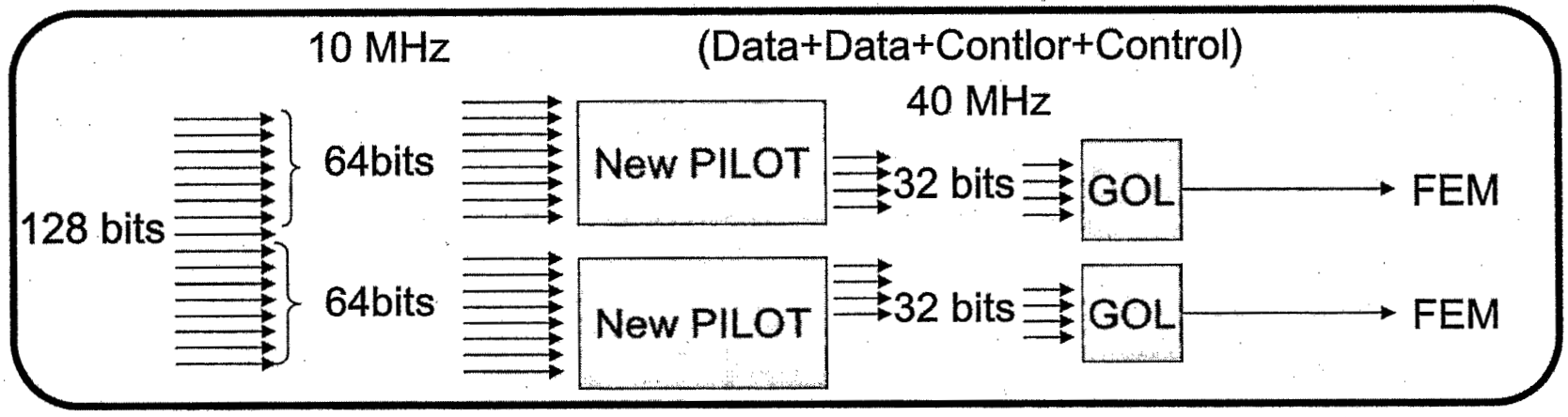
Schedule for assembly production



Production of assemblies are scheduled 5 times for ALICE during next 2 years
Assembly production for PHENIX should go together with ALICE production

For PHENIX, we need 40 ladder + spears(20?)

new development



We only need to modify number of input and output channel.
(We can keep "core" design inside ALICE Pilot chip as it is)

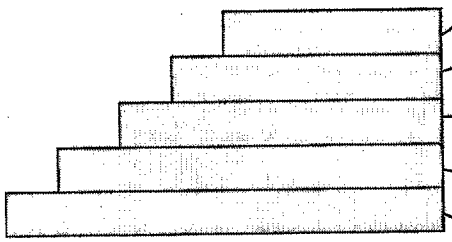
Size of new pilot chip will be a little bigger than ALICE Pilot chip
~ 8x6 mm^2 (4x6 mm^2)

This design is going to submit May/2004.

Hiroyuki Kano (RIKEN) is working on it.

ALICE Pixel BUS structure

For the ALICE case;
44 control lines
+ 32 data lines in 1.38 cm.



5 layer of Al-capton

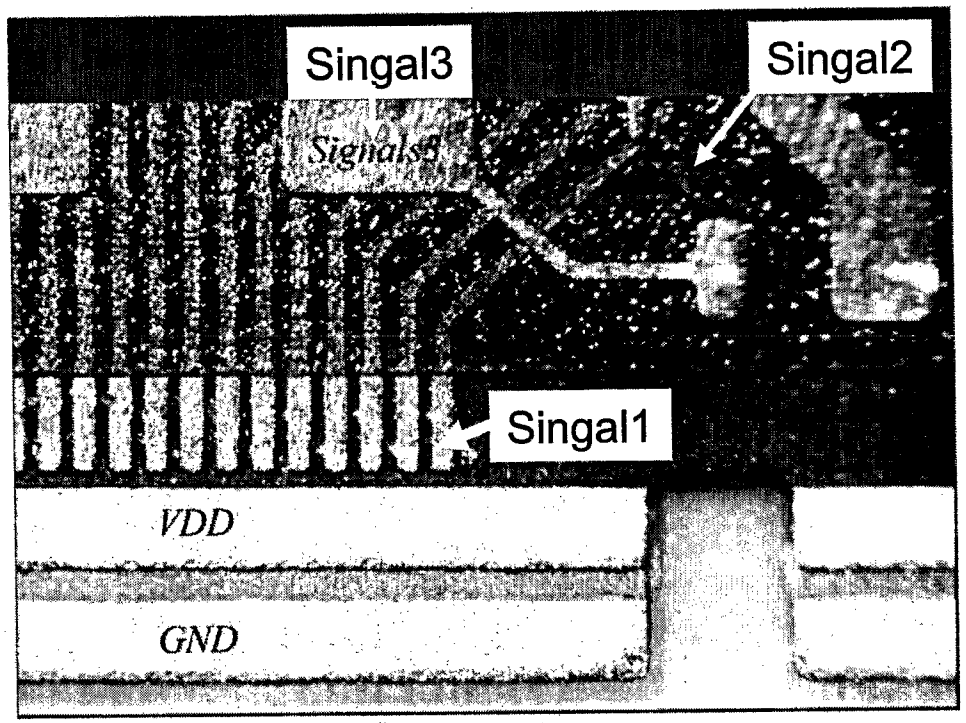
Signal (for SMD)

Vertical line

Horizontal lines

VDD (power line)

GND



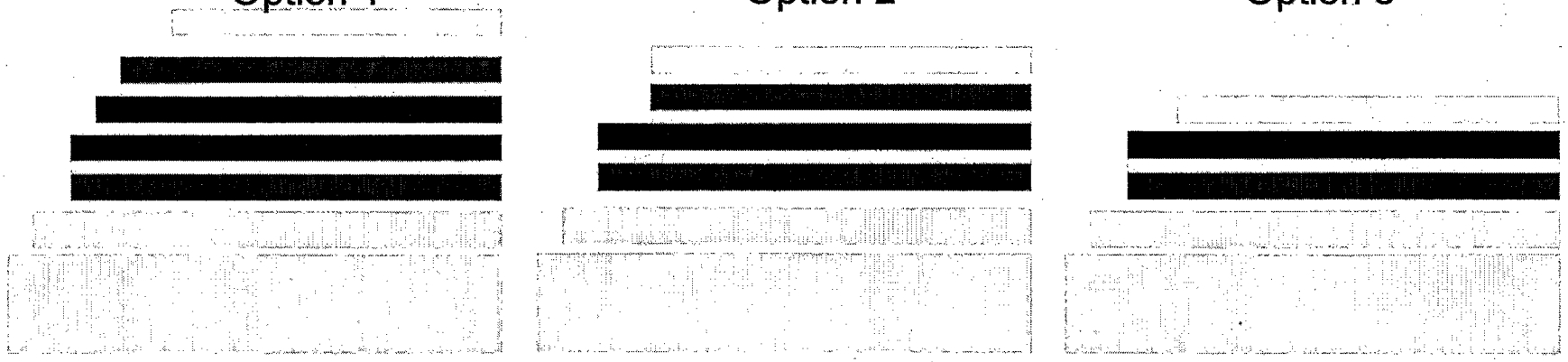
Signal 1; (Vertical line)
line connected with
pixel chip with wire bonding

Signal 2; (Horizontal line)
connected with vertical line
with through hole

Signal 3; (for SMD)

Summary

Easy (relatively) ⟷ Aggressive



Option 1	Option 2	Option 3
Line spacing; 140 um pitch	Line spacing; 140 um pitch	Line spacing; 70 um pitch
Material Budget;	Material Budget;	Material Budget;
Cu; Total ~ 0.376 %	Cu; Total ~ 0.306 %	Cu; Total ~ 0.236 %
Al; Total ~ 0.139 %	Al; Total ~ 0.128 %	Al; Total ~ 0.117 %

- Fine pitch ~70 μm Cu trace is technically available.

  Option-3 Cu signal lines will be 1st option (Base line)
  Option-2 Al signal lines will be a 1st step to build full Al pixel bus.

We are working together with company in JAPAN.

JYF2004-2006
(MoU#2: 2002-2006)

- RHIC Spin Experiment is in *FULL SWING with larger polarization and luminosity*.
- Will obtain more accurate results for ΔG.

We will know how much gluons are carrying the proton spin which is our primary goal of the project.

We will start the measurements for anti-quark polarization at 500GeV.

- Upgrade Project R&D => Construction

PUBLICATION LIST

RBRC - EXPERIMENT

RBRC Experimental Publications
April 2003 – March 2004

POLARIZED PROTON COLLIDER AT RHIC, By I. Alekseev et al., Nucl.Instrum.Meth.A499:392-414,2003

RHIC ACCELERATOR ADVANCES FOR SPIN, By G. Bunce, Prepared for 3rd Circum-Pan-Pacific Symposium on High Energy Spin Physics (SPIN 2001), Beijing, China, 8-13 Oct 2001 Int.J.Mod.Phys.A18:1255-1261,2003

THE AGS CNI POLARIMETER, Workshop on increasing the AGS Polarization, Ann Arbor, Nov. 2002. G. Bunce et al., AIP Conf. Proc. 667, 77 (2003).

MID-RAPIDITY NEUTRAL PION PRODUCTION IN PROTON-PROTON COLLISIONS AT S**(1/2)=200 GEV, S.S. Adler et al., to be published in Phys. Rev. Lett. (2003), hep-ex/0304038

MEASUREMENT OF SINGLE TRANSVERSE SPIN ASYMMETRY IN FORWARD PRODUCTION OF PHOTONS AND NEUTRONS IN PP COLLISIONS AT ROOT(S)=200 GEV, A. Bazilevsky et al., Spin 2002, AIP Conf. Proc. 675, 584 (2003)

RHIC pC CNI POLARIMETER: EXPERIMENTAL SETUP AND PHYSICS RESULTS, I. G. Alekseev et al., Spin 2002, AIP Conf. Proc. 675, 812 (2003)

RHIC pC CNI POLARIMETER: STATUS AND PERFORMANCE FROM THE FIRST COLLIDER RUN, O. Jinnouchi et al., Spin 2002, AIP Conf. Proc. 675, 817 (2003)

POLARIZED H- JET POLARIMETER FOR ABSOLUTE PROTON POLARIZATION MEASUREMENTS IN RHIC, A. Zelinski et al., Spin 2002, AIP Conf. Proc. 675, 954 (2003)

PHYSICS WITH RHIC SPIN COLLIDER., By H. Enyo (Wako, RIKEN & RIKEN BNL). 2003. 8pp. Published in Nucl.Phys.A721:143-150,2003

SPIN ROTATOR COMMISSIONG AT RHIC, W. Mac Kay {et al} and the PHENIX collaboration, Proceedings of EPAC 2003

NEUTRAL PION MEASUREMENTS IN POLARIZED PROTON COLLISIONS FROM PHENIX AT RHIC, Y. Goto for the PHENIX Collaboration, PANIC 2002, Nucl. Phys. A721 (2003) 360-363.

PROSPECTS OF THE GLUON POLARIZATION MEASUREMENT AT PHENIX, Y. Goto for the PHENIX Collaboration, SPIN 2002, AIP Conf. Proc. 675 (2003) 493-503.

THE QUEST FOR NUCLEON SPIN, VERNON W. HUGHES; THE LAST DECADE: 1993-2003, A. Deshpande, Proceedings of "Symmetries and Spin 2003", Prague, to be published by World Scientific.

eRHIC: THE ELECTRON ION COLLIDER AT BNL, A. Deshpande, European Journal of Physics A, to be published in the Proceedings of International Meeting on Perspectives on Hadronic Physics, ICTP, Trieste, Italy, May 2003.

COMMISSIONING OF RHIC POLARIMETERS, A. Bravar, et al., BNL-Report-68976

TESTING OF QCD THROUGH SPIN OBSERVABLES IN NUCLEAR TARGETS, Workshop Summary of Experimental Talks, A. Deshpande, University of Virginia, April 20, 2003, World Scientific, Editors: D. Crabb, D. Day, J. Chen

MULTISTRANGE BARYON PRODUCTION IN AU-AU COLLISIONS AT S(NN)**1/2=130 GEV, Submitted to Phys. Rev. Lett, e-Print Archive: nucl-ex/0307024.

PHENIX DETECTOR OVERVIEW, PHENIX Collaboration (K. Adcox et al.), Nucl. Instrum. Meth. A499 (2003) 469-479.

PHENIX Magnet System, PHENIX Collaboration (S. H. Aronson et al.), Nucl. Instrum. Meth. A499 (2003) 480-488.

PHENIX Central Arm Particle ID Detectors, PHENIX Collaboration (M. Aizawa et al.), Nucl. Instrum. Meth. A499 (2003) 508-520.

PHENIX CALORIMETER, PHENIX Collaboration (L. Aphecetche et al.), Nucl. Instrum. Meth. A499 (2003) 521-536.

PHENIX Muon Arms, PHENIX Collaboration (H. Akikawa et al.), Nucl. Instrum. Meth. A499 (2003) 537-548.

PHENIX Inner Detectors, PHENIX Collaboration (M. Allen et al.), Nucl. Instrum. Meth. A499 (2003) 549-559.

PHENIX On-Line Systems, PHENIX Collaboration (S. S. Adler et al.), Nucl. Instrum. Meth. A499 (2003) 560-592.

PHENIX On-Line and Off-Line Computing, PHENIX Collaboration (S. S. Adler et al.), Nucl. Instrum. Meth. A499 (2003) 593-602.

ABSENCE OF SUPPRESSION IN PARTICLE PRODUCTION AT LARGE TRANSVERSE MOMENTUM IN S(NN)**(1/2) = 200-GEV D + AU COLLISIONS, PHENIX Collaboration (S.S. Adler et al.), Phys. Rev. Lett. 91 (2003) 072303.

SCALING PROPERTIES OF PROTON AND ANTI-PROTON PRODUCTION IN S(NN)**(1/2) 200-GEV AU+AU COLLISIONS, PHENIX Collaboration (S.S. Adler et al.), Phys. Rev. Lett. 91 (2003) 172301.

SUPPRESSED PI^0 PRODUCTION AT LARGE TRANSVERSE MOMENTUM IN CENTRAL AU+ AU COLLISIONS AT S(NN)**1/2 = 200 GEV, PHENIX Collaboration (S.S. Adler et al.), Phys. Rev. Lett. 91 (2003) 072301.

CENTRALITY DEPENDENCE OF THE HIGH P(T) CHARGED HADRON SUPPRESSION IN AU+AU COLLISIONS AT S(NN)**(1/2) = 130-GEV, PHENIX Collaboration (K. Adcox et al.), Phys. Lett. B561 (2003) 82-92.

UNCERTAINTY OF POLARIZED PARTON DISTRIBUTIONS, Asymmetry Analysis Collaboration (M. Hirai et al.), SPIN 2001, Int. J. Mod. Phys. A18 (2003) 1203-1210.

SEARCH FOR NEW STATES OF MATTER WITH THE STAR EXPERIMENT AT RHIC., J. S. Lange (STAR Collaboration), Nucl.Phys.A718:367-374,2003

B PHYSICS AT STAR, J. S. Lange, nucl-ex/0306005

OBSERVATION OF THE D*(SJ)(2317) AND D*(SJ)(2460) IN B DECAYS, BELLE Collaboration, supersedes hep-ex/0307041, submitted to Phys. Rev. Lett., hep-ex/0308019

OBSERVATION OF A NEW NARROW CHARMONIUM STATE IN EXCLUSIVE B+- ---> K+- PI+ PI- J / PSI DECAYS, BELLE Collaboration, hep-ex/0308029

NET CHARGE FLUCTUATIONS IN AU + AU COLLISIONS AT S**(1/2) = 130-GEV, J. Adams, et al. (STAR), Phys. Rev. **C68** (2003) 044905.

STAR DETECTOR OVERVIEW, K.H. Ackermann, et al. (STAR), Nucl. Instrum. Meth. **A499** (2003) 624-632.

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