BNL-74679-2005
FORMAL REPORT

RIKEN BNL Research Center

SCIENTIFIC PRESENTATIONS

11th MEETING OF THE MANAGEMENT STEERING COMMITTEE OF THE RIKEN BNL COLLABORATION

Brookhaven National Laboratory, Upton, NY

May 27, 2005

RBRC Scientific Articles

Volume 11

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 include a recently completed and operational 10 teraflops QCDOC computer. The 0.6 teraflops parallel processor computer is also still operational since completion in August 1998 and was awarded the Supercomputer 1998 Gordon Bell Prize for price performance. 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

*Work performed under the auspices of U.S.D.O.E. Contract No. DE-AC02-98-CH10886.

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RBRC OPERATIONS AND ACCOMPLISHMENTS

Nicholas P. Samios

Current Activities & Future Perspectives Report

RHIC Operations & Accomplishments

Nicholas P. Samios

Presentation
11th Meeting of The Management Steering Committee of RIKEN BNL Collaboration

May 27, 2005
Brookhaven National Laboratory, Upton, NY

RBRC Operations & Accomplishments

Auspicious Year

April 5, 2004	New Discoveries at RHIC Vol. 9 RBRC Scientific Articles
May 14-15, 2004	Workshop: Busza, Gyulassy & McLerran Vol. 62, RBRC Nuclear Phys. A750. March 2005

"One of the major discoveries emerging from RHIC is the creation of a form of hot dense (10 to 30 times denser than a nucleon) matter whose properties are consistent with those of a strongly coupled plasma of subatomic quarks and gluons – the so-called quark-gluon plasma that existed a few microseconds after the birth of the universe."

Analyzed Runs 1, 2, 3

Run 4	Au x Au	200 GeV/A	1,000 μb^{-1}
		62 GeV/A	20 μb^{-1}
Run 5	Cu x Cu	200 GeV/A	15 nb^{-1}
		62 GeV/A	0.5 nb_{-1}

Investigate properties of hot dense matter.

Color Glass Condensate

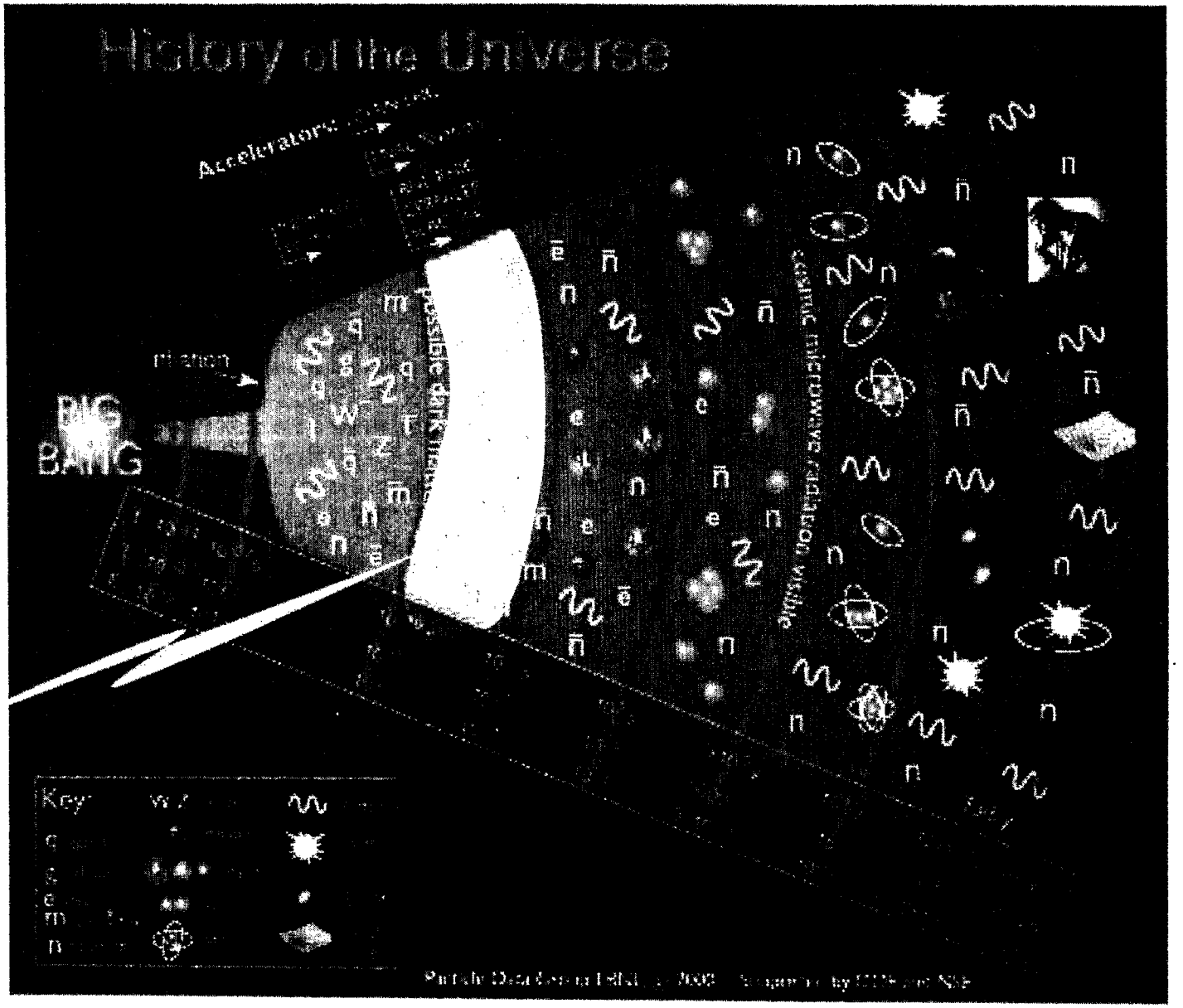
New Probes: J/ψ

Direct photons

Open Charm

The Thermal Universe

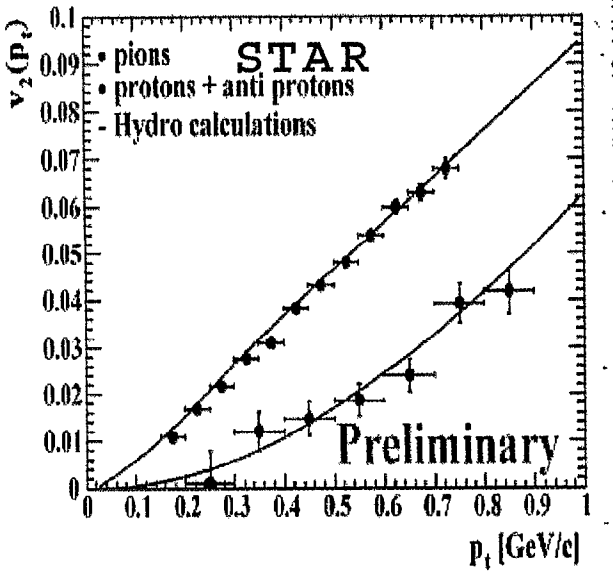
- 10 GeV/fm^3
  ~ 10^{16} gm/cm^3
- T ~ 170 MeV
  ~ 2 x 10^{12} K
- Conditions that prevailed ~ 10 μs after the Big Bang



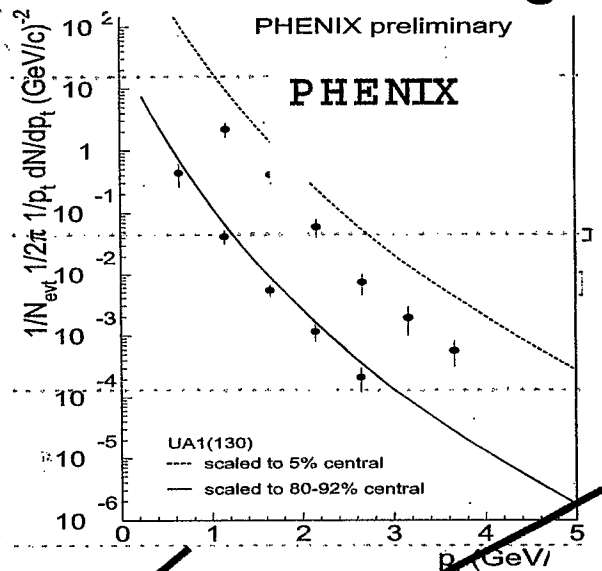
Day 1 "New Physics" at RHIC

1400

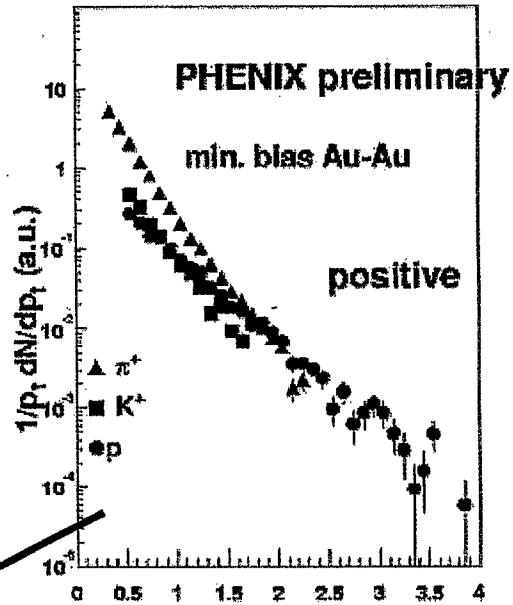
Collective Flow



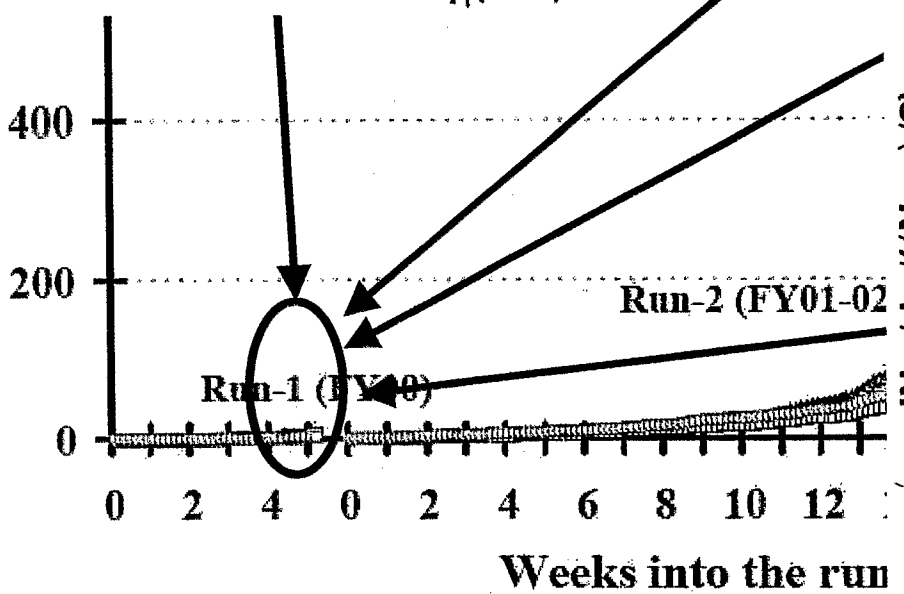
Jet Quenching



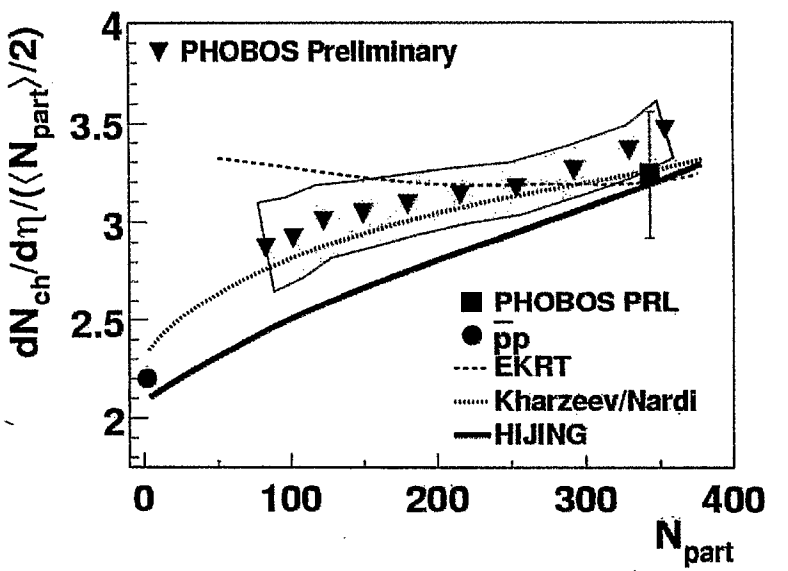
Baryon anomaly



Luminosity $(\mu b)^{-1}$

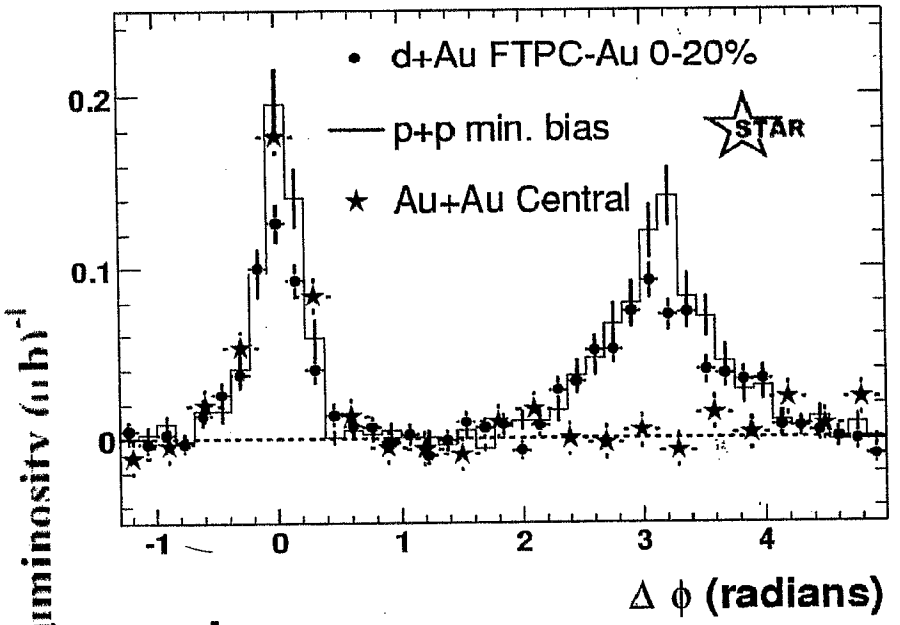


Color Glass

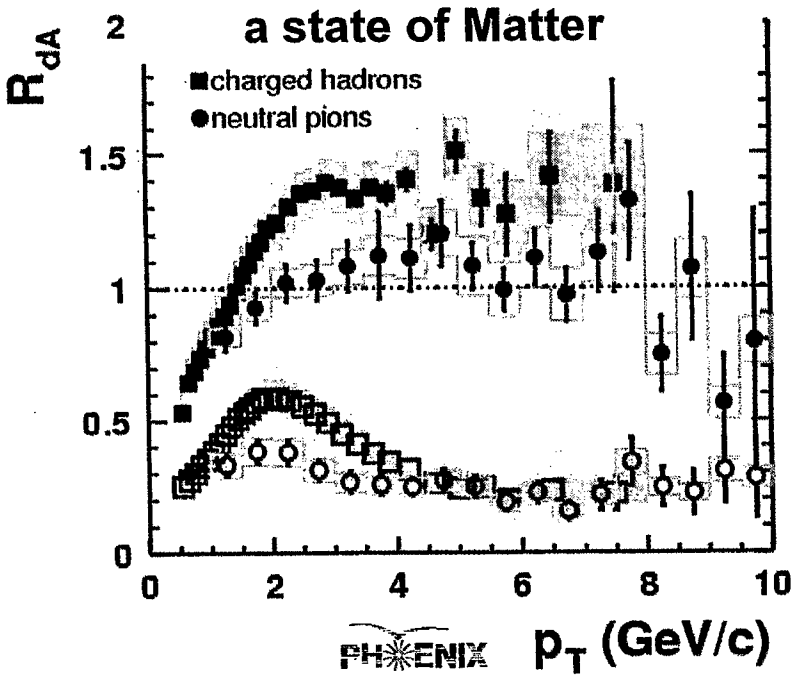


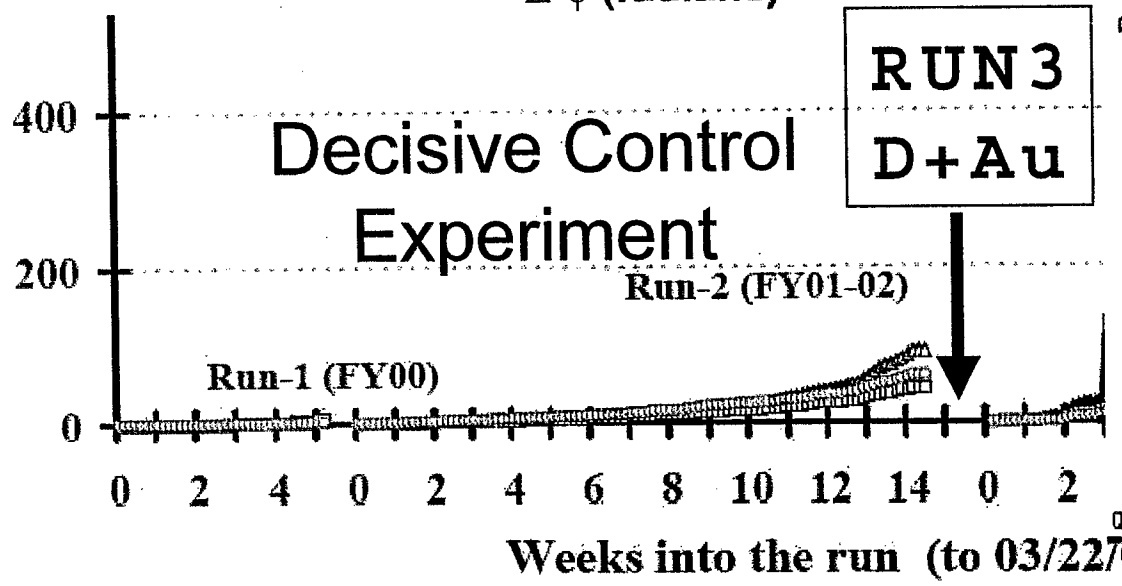
Physics Control

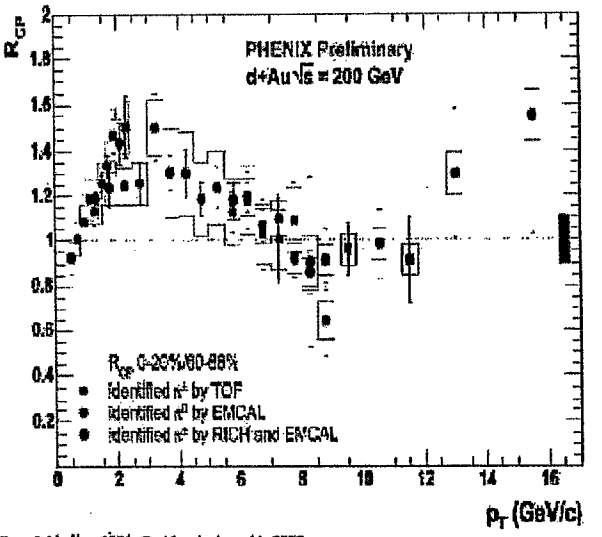
1400 Return of Di-Jets in D+Au



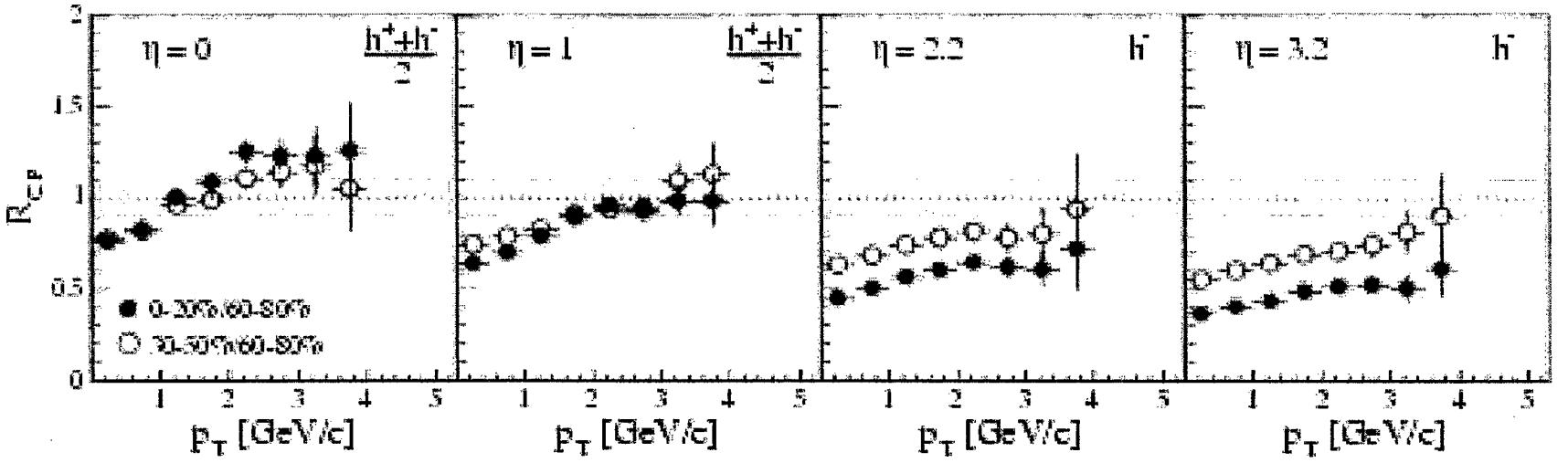
The Open Y=0 Window on a state of Matter



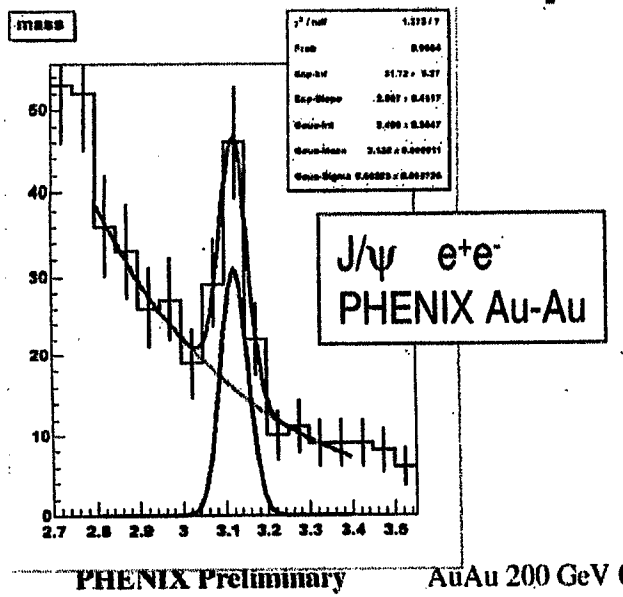


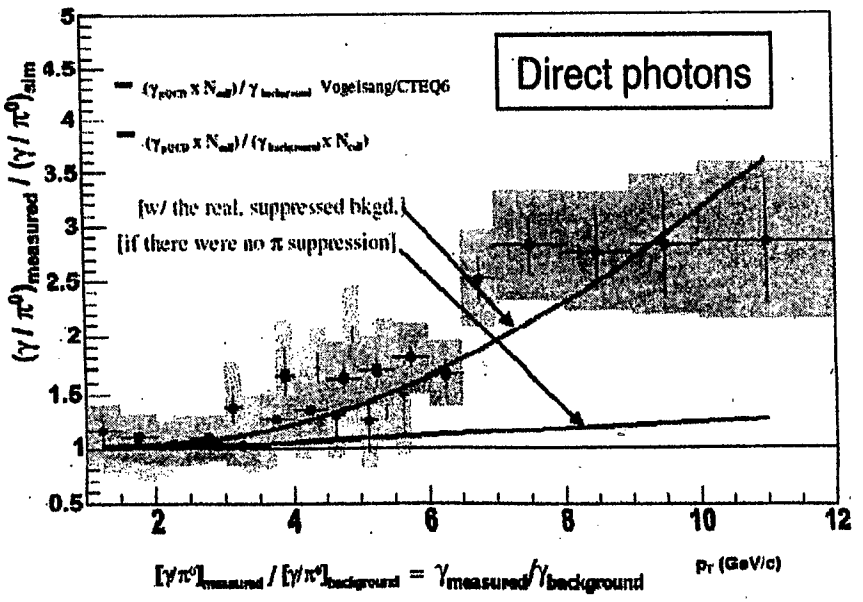


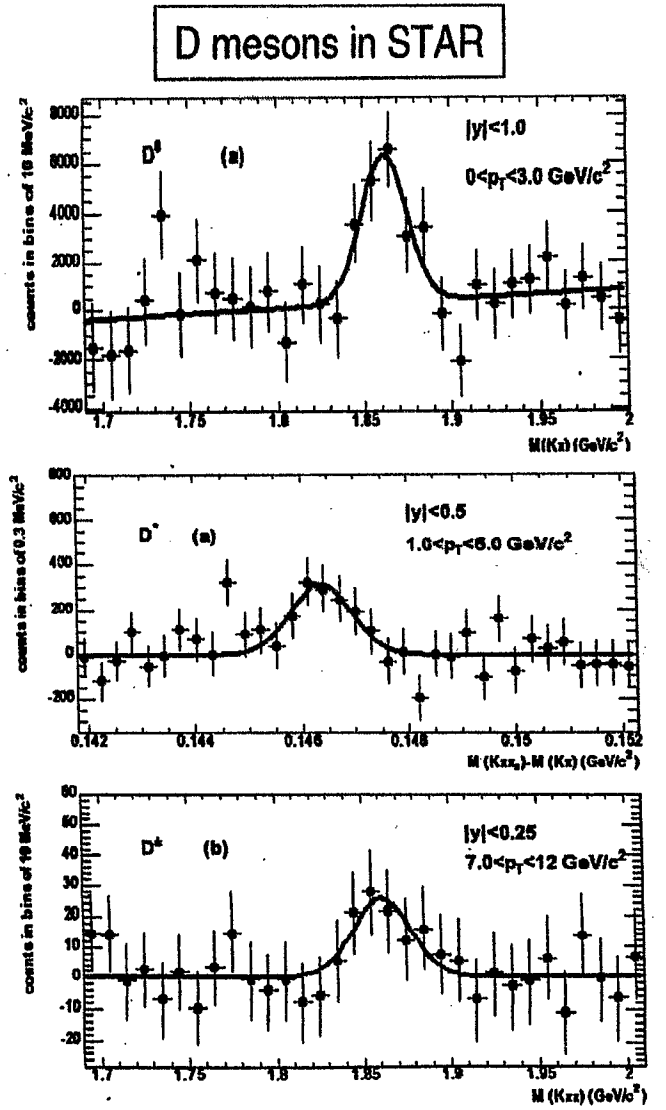
Quark Matter 2004, Oakland, Jan. 14, 2003

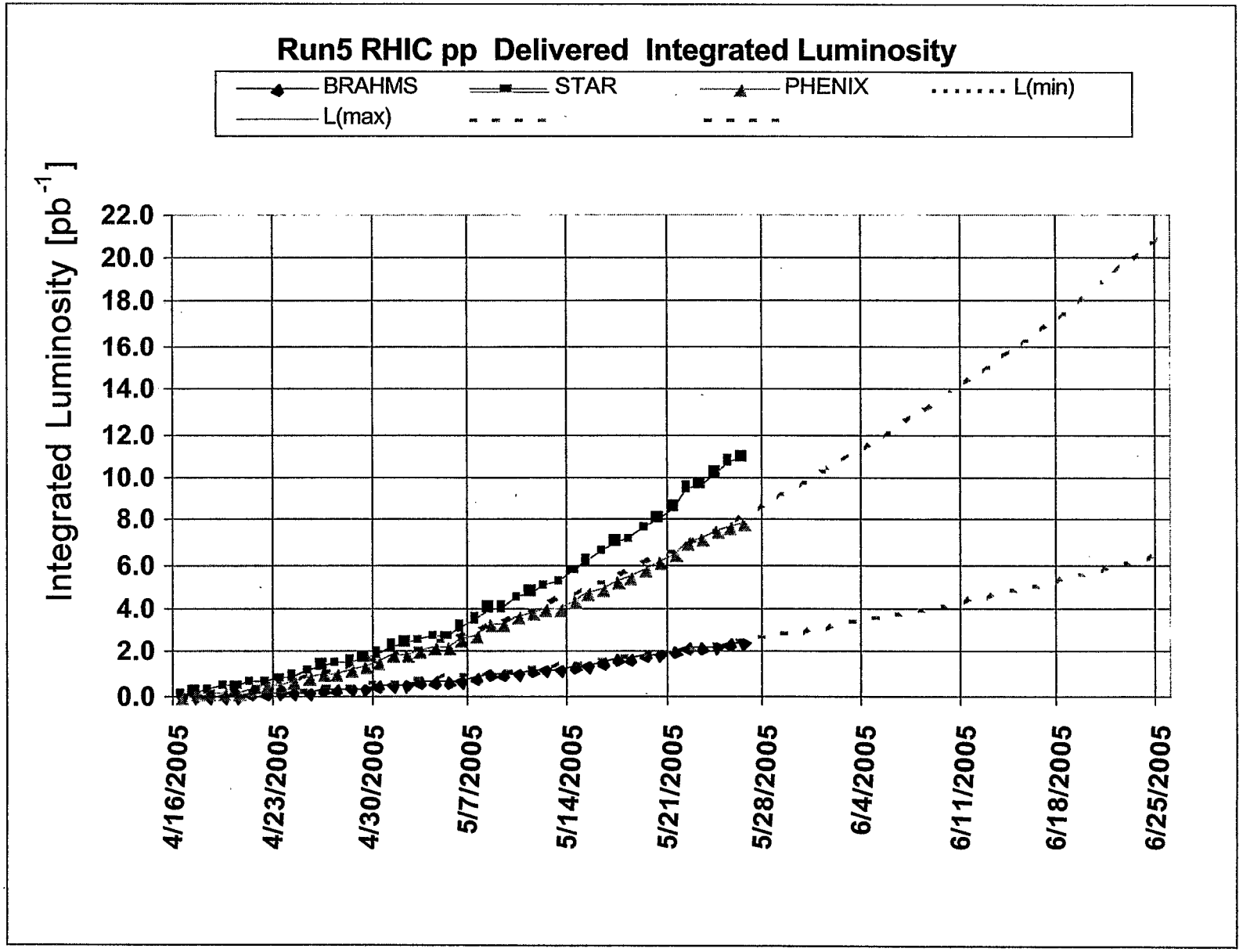

R_{CP}
$\eta = 0$
$\frac{h^+ + h^-}{2}$
$\eta = 1$
$\frac{h^+ + h^-}{2}$
$\eta = 2.2$
h^-
$\eta = 3.2$
h^-
0-20%/60-80%
30-50%/60-80%
p_T [GeV/c]
p_T [GeV/c]
p_T [GeV/c]
p_T [GeV/c]

A Glimpse of future probes

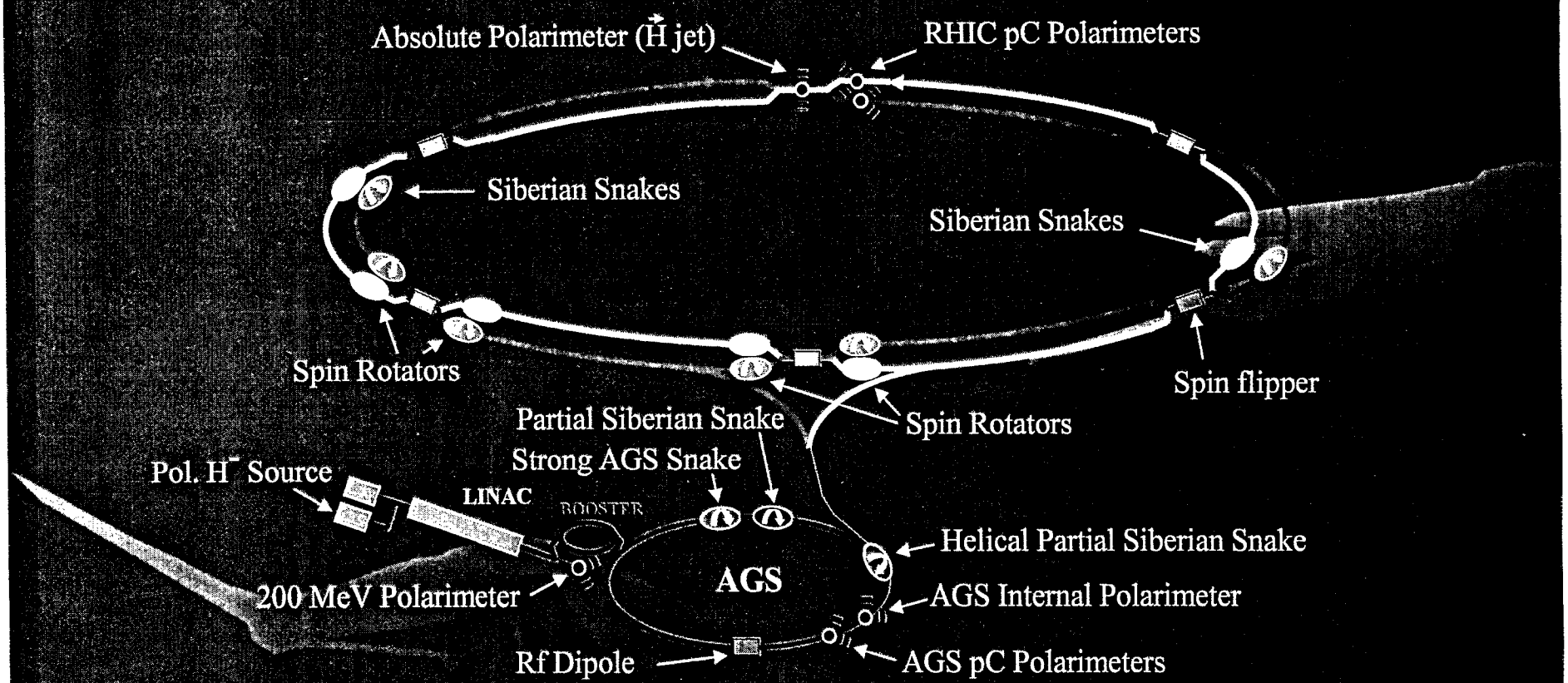






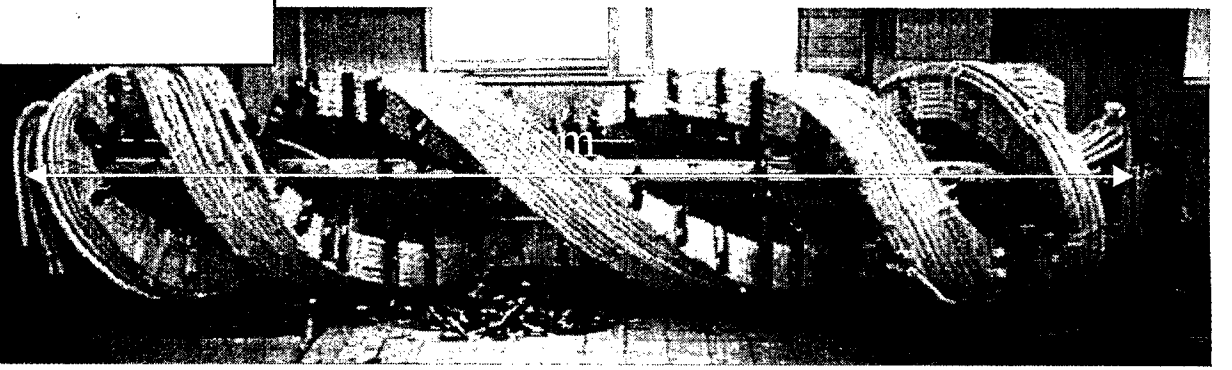

Run5 RHIC pp Delivered Integrated Luminosity
BRAHMS
STAR
PHENIX
L(min)
L(max)
Integrated Luminosity [pb^{-1}]
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
4/16/2005
4/23/2005
4/30/2005
5/7/2005
5/14/2005
5/21/2005
5/28/2005
6/4/2005
6/11/2005
6/18/2005
6/25/2005

RHIC pp accelerator complex

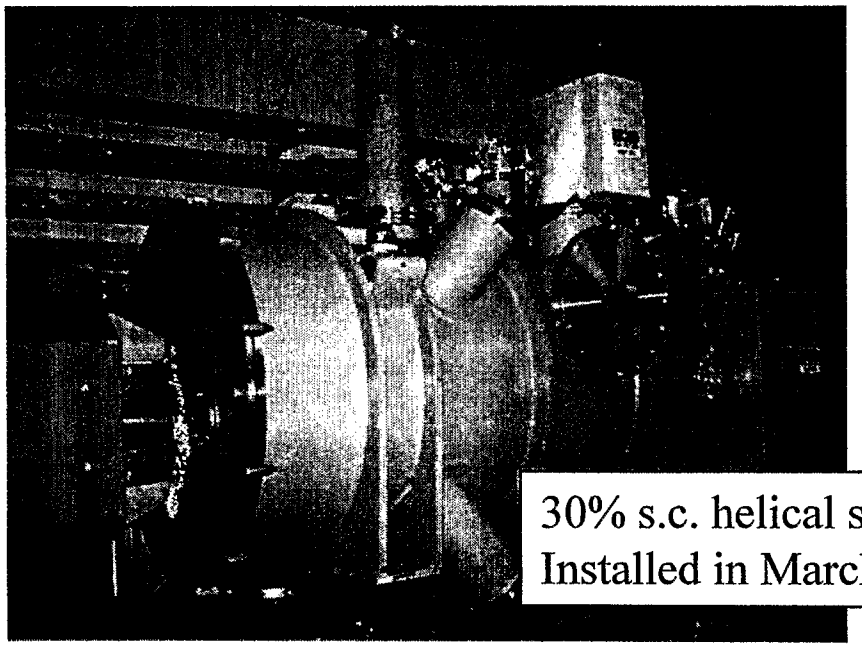


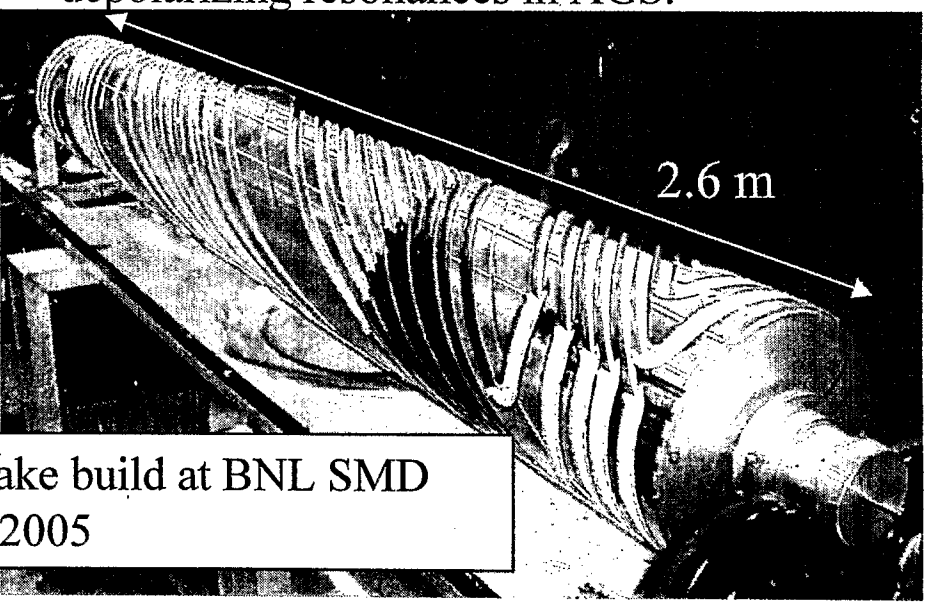
New AGS helical snakes

5 % helical snake build at Tokana Industries funded by RIKEN.



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





30% s.c. helical snake build at BNL SMD
Installed in March 2005

Spin Program

All components in place

Polarimeters

Gas jet polarized target

Warm helical snake (RIKEN)

Cold helical snake

Spin rotators and Siberian snakes

Run 4 $\vec{p} \times \vec{p}$ 200 GeV/C 3 pb^{-1}

Run 5 200 GeV/c 20-30 pb^{-1}

Polarization – blue & yellow 45-50%
with cold snake 70% expected

Spin Program

Determine source of nucleon spin

Gluon contribution $\Delta G/G$

A_{LL} from π^0's

Theoretical understanding crucial

QCD – Next to Leading Order (NLO)

$pp \rightarrow \pi^0 X$ $\qquad$ $pp \rightarrow \gamma X$

Aim $\vec{p}\,\vec{p}$ 200 GeV/C ~ 300 pb-1

500 GeV/C 900 pb-1

Anti quark distributions

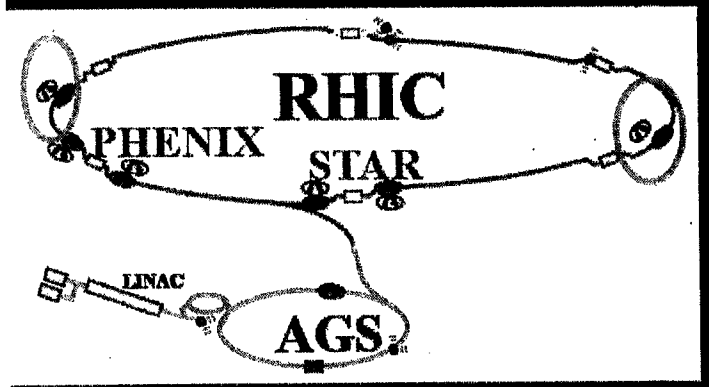
See 5-10 year plan-Spin Physics at RHIC

Gluon spin in the nucleon — a world class problem

RHIC

A conjunction of good fortune —

- A polarizable collider
- Strong accelerator physics group
- DOE and RIKEN support



Major Japanese Physics & Financial Support

RIKEN BNL Research Center

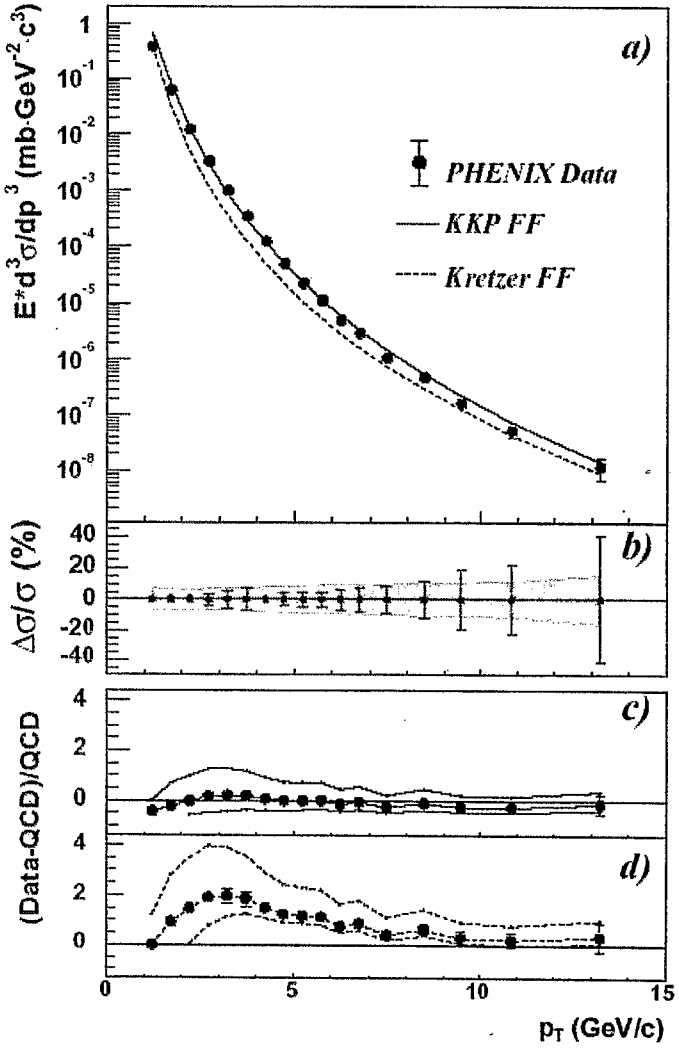
Polarized pp – collider — gluons enter at leading order

$gq \rightarrow q\gamma$ observed as γ + jet

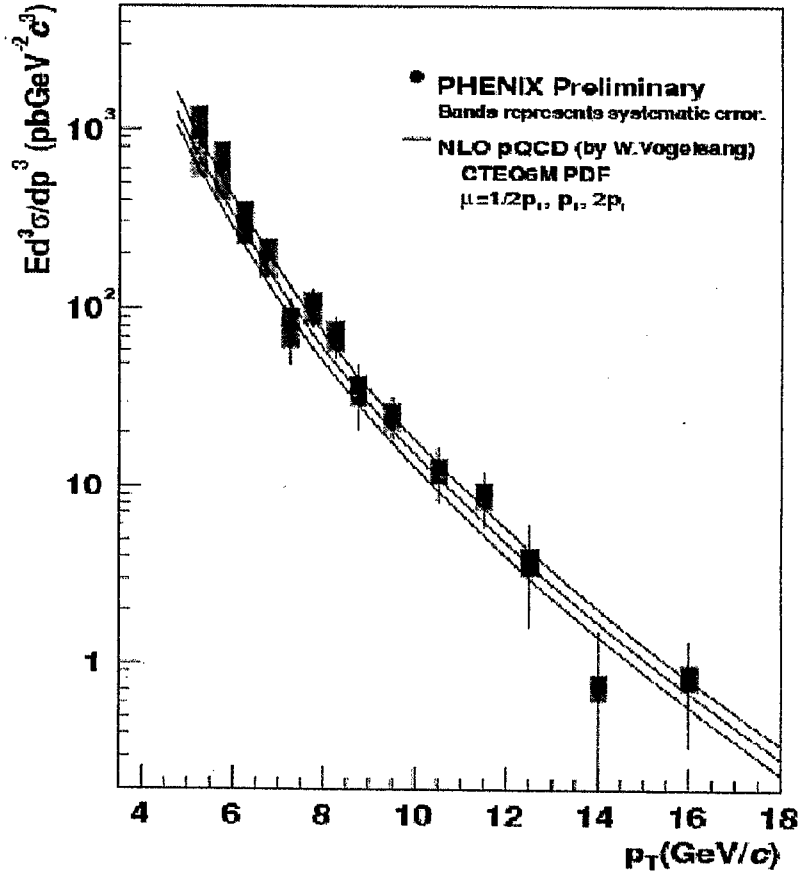
$gg \rightarrow gg$ or $q\bar{q}$
$gq \rightarrow gq$ observed as π^0 + jet

Cornerstone to the RHIC Spin program

$pp \rightarrow \pi X$

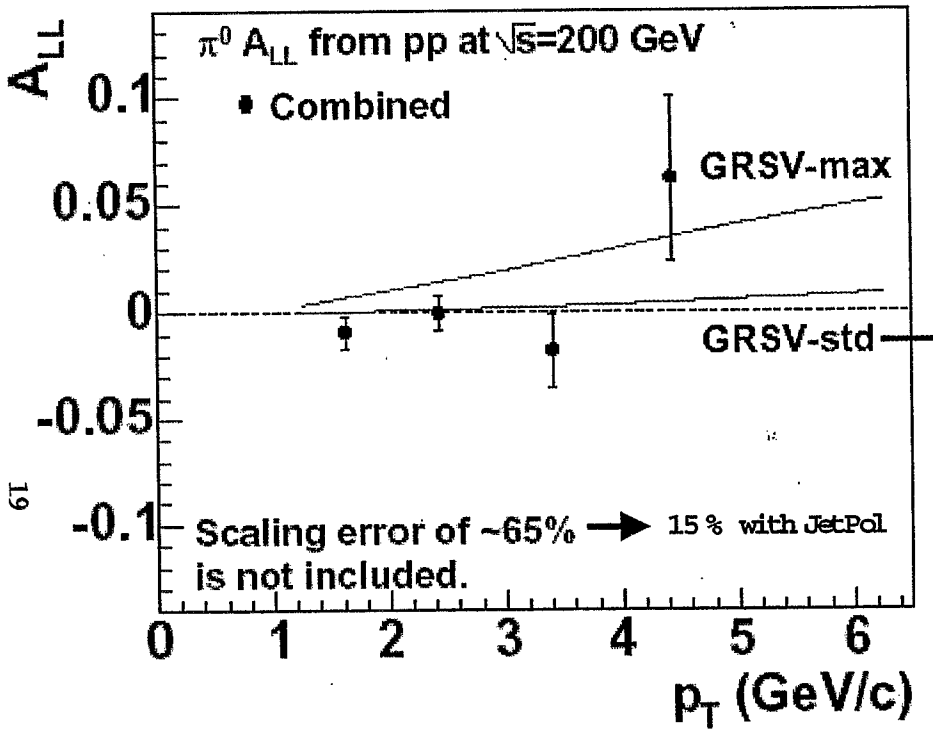


$pp \rightarrow \gamma X$

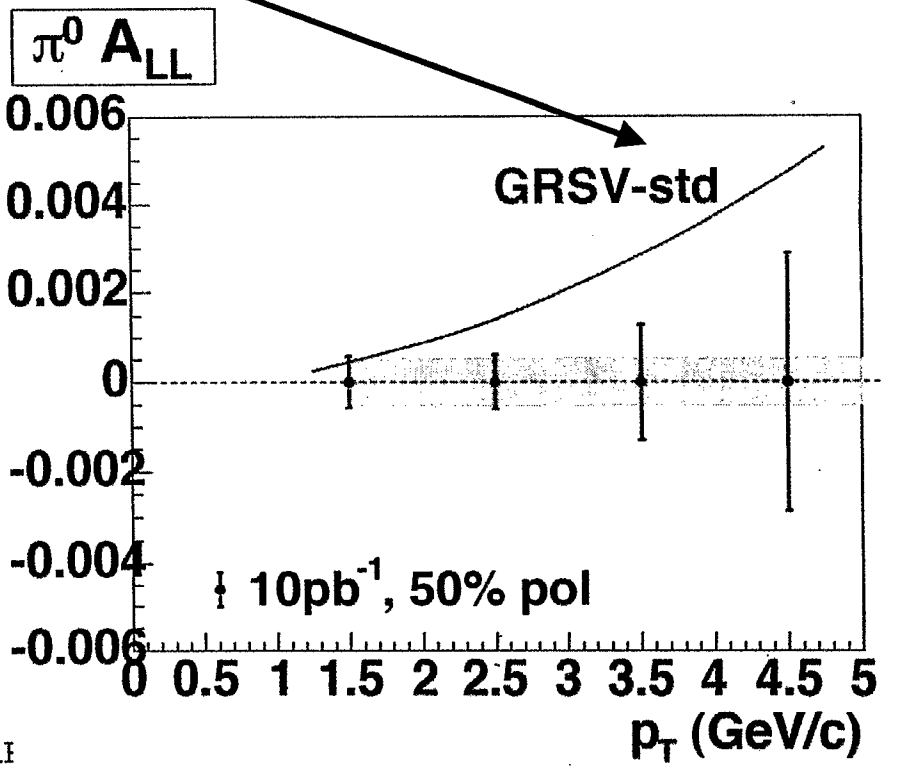


Unpolarized data are well described by NLO

ΔG/G: Measurements have begun!

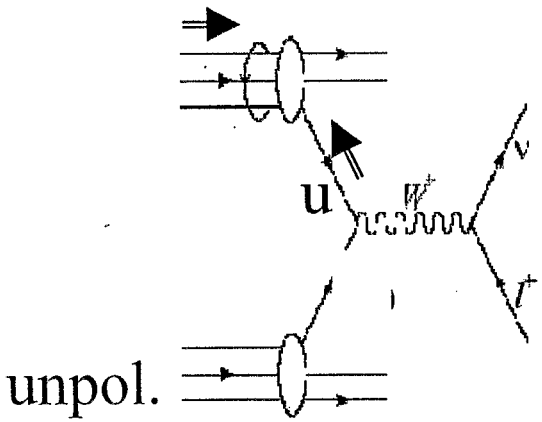


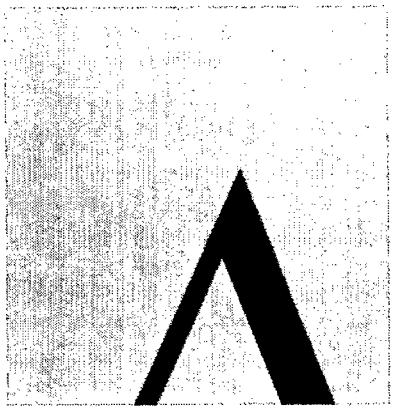
PHENIX data
Run-3 & 4 combined
~200nb^{-1}, 16% pol
~100nb^{-1}, 26% pol



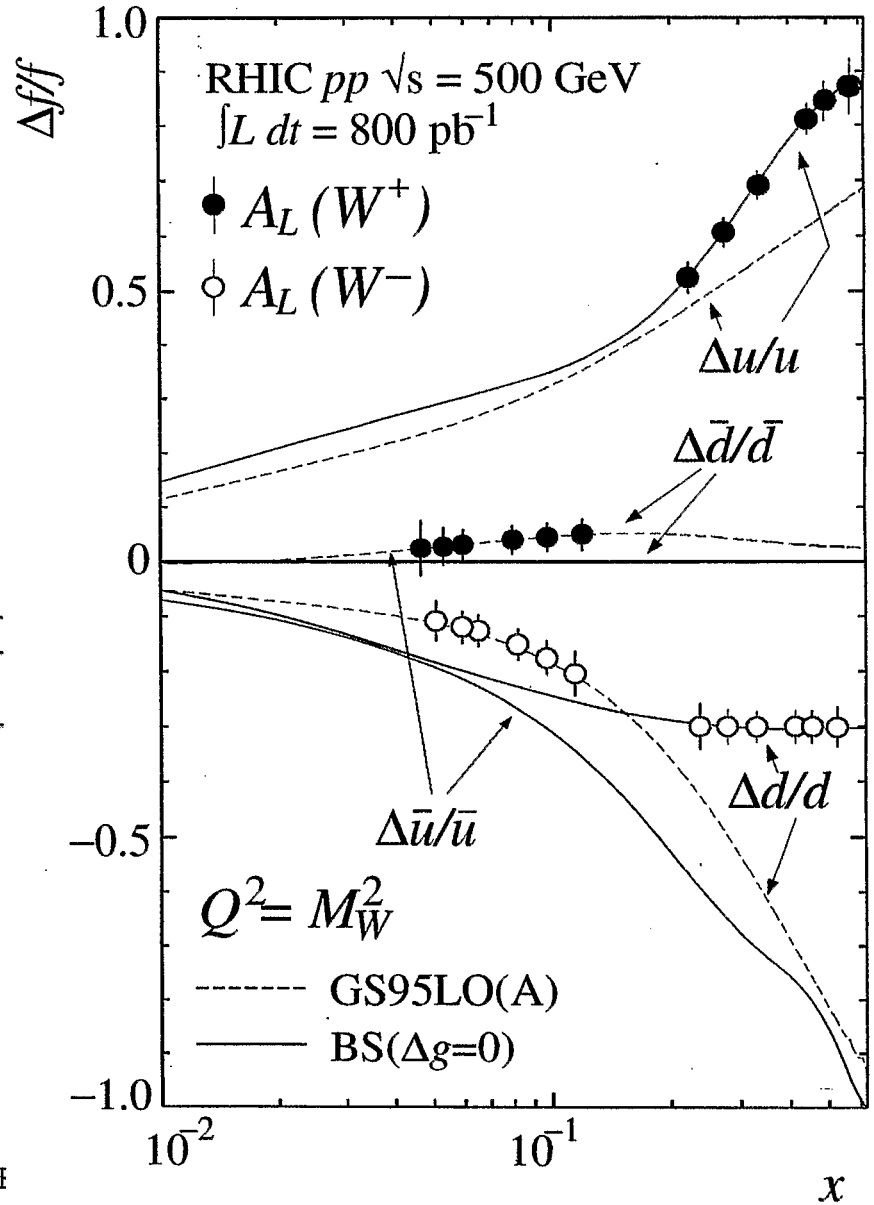
Run 5 starting next week

Δq-$\Delta\bar{q}$ at RHIC via W production





$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$



PHENIX & STAR Upgrades:
Axel Drees's talk

QCDSP/QCDOC

QCDSP	Operations (0.6 teraflops)
	Efficiency > 99%
QCDOC	Operational 10 teraflops
	Dedicated May 26, 2005
	90% Lattice QCD
	10% other
UK QCDOC	10 teraflops
	Assembled, tested, and shipped
DOE QCDOC	10 teraflops
	Assembled, being tested

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, Chair
- A. Baltz
- M. Creutz
- M. Gyulassy
- R. Pisarski

Experimental Advisory Committee:

- A. Masaike
- J. Sandweiss
- N. Saito

Workshops:	13
Publications:	107 Theory/77 Experiment
Seminars:	6/week
Other Articles:	2/10

THEORY PUBLICATION LIST

April 1, 2004 to March 31, 2005

RBRC-412 B. Jäger, M. Stratmann, and W. Vogelsang, "Single Inclusive Jet Production in Polarized pp Collisions at $O(\alpha_s^3)$ [hep-ph/0404057], Phys. Rev. D 70, 034010 (2004).

. . . . . .

RBRC-518 Simon Turbide, Charles Gale, Sangyong Jeon, and Guy D. Moore, "Energy Loss of Leading Hadrons and Direct Photon Production in Evolving Quark-Gluon Plasma," [hep-ph/0502248], Phys. Rev. C (accepted).

Proceedings of RIKEN BNL Research Center Workshops

(April 1, 2004 to March 31, 2005)

Volume 61 RIKEN-TODAI Mini-Workshop on "Topics in Hadron Physics at RHIC," (BNL-72336-2004)
March 23-24, 2004, Nishina Memorial Hall of RIKEN, Wako, Saitama, Japan
Organizers: H. En'yo, H. Hamagaki, T. Hatsuda, Y. Watanabe, and K. Yazaki

Volume 62 New Discoveries at RHIC (BNL-72391-2004)
May 14-15, 2004
Organizers: Wit Busza, Miklos Gyulassy, Larry McLerran

Volume 63 RHIC Spin Collaboration meetings XXIV, XXV, XXVI (BNL-72397-2004)
May 21, 2004, May 27, 2004, June 1, 2004
Organizers: Akio Ogawa and Greg Rakness

Volume 64 Theory Summer Program on RHIC Physics (BNL-73263-2004)
May – September 2004
Organizers: D. Kharzeev, S. Kretzer, D. Teaney, K. Tuchin,
R. Venugopalan, W. Vogelsang

Volume 65 RHIC Spin Collaboration Meetings XXVII and XXVIII (BNL-73506-2004)
July 22, 2004, September 2, 2004, December 6, 2004
Organizer: Akio Ogawa

Volume 66 RHIC Spin Collaboration Meeting XXIX (BNL-73534-2004)
October 8-9, 2004 at Torino, Italy
Organizer: Akio Ogawa

Volume 67 High Performance Computing with BlueGene/L and QCDOC Architectures (BNL-)
October 27 & 28, 2004
Organizers: Gyan Bhanot, Norman Christ, Jim Davenport, Ed Jedlicka, Robert Mawhinney, Edward McFadden, Michael McGuigan, Thomas Schlagel, and William Pulleyblank

Volume 68 Workshop on the Physics Programme of the RBRC and UKQCD QCDOC Machines (BNL-73604-2004)
November 12-13, 2004
Organizers: Norman Christ, Richard Kenway, Robert Mawhinney, and Shigemi Ohta

Volume 69 RBRC Scientific Review Committee Meeting (BNL-73546-2004)
November 16 & 17, 2004
Organizer: N. P. Samios

Volume 70 Strongly Coupled Plasmas: Electromagnetic, Nuclear & Atomic
December 16-17, 2004 (BNL-73867-2005)
Organizers: Barbara Jacak, Edward Shuryak, Tim Hallman, Steffen Bass, and Ron Davidson

Volume 71	Classical and Quantum Aspects of the Color Glass Condensate (BNL-737930-2005) March 7-11, 2005 Organizers: Dmitri Kharzeev, Anna Stasto, Kirill Tuchin, Werner Vogelsang
Volume 72	RHIC Spin Collaboration Meetings XXXI, XXXII, XXXIII (BNL-73866-2005) January 14, 2005, February 10, 2005, March 11, 2005 Organizer: Akio Ogawa
Volume 73	Jet Correlations at RHIC (BNL-73910-2005) March 10-11, 2005 Organizers: M. Gyulassy, M.J. Tannenbaum, F. Wang

Future Workshops: RBRC/BNL

Single Spin Asymmetries
Organizers: Feng Yuan and Werner Vogelsang
Dates: June 1-3, 2005

Odderon Searches at RHIC
Organizers: Wlodek Guryn, Yuri Kovchegov, Larry Trueman and Werner Vogelsang
Dates: September 13-15, 2005

Heavy Flavor Production and Hot/Dense Quark Matter
Organizes: Yasuyuki Akiba, H.Huang, R. Rapp, Kirill Tuchin, and Wei Xie
December 7-9, 2005

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 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 P. Petreczky K. Iida
High Energy Theory Lunch Talks	Fridays (12:00 Noon)	Organized by A. Soni
Nuclear Physics-RIKEN Theory	Fridays (2:00 p.m.)	Organized jointly by P. Petreczky with BNL Staff

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
Kusenko, Alexander	10/1999 – 09/30/04 05/2003 (Tenure)	RHIC Physics Fellow; UCLA/Asst. Prof.	Tenured Associate Professor	RBRC/UCLA
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
Schaefer, Thomas	01/2000-12/31/02 01/2003-12/31/04	RHIC Physics Fellow, SUNY, SB/Asst. Prof. NCSU	Tenured at NCSU Associate Professor	NCSU
Son, Dam Thanh	10/1999 to 03/2002	RHIC Physics Fellow, Columbia U.	Tenured Position	U. of Wash, Seattle, Natl. Inst. for Nucl. Th
Stephanov, Mikhail	10/1999 – 09/30/04 08/2003 (Tenure)	RHIC Physics Fellow, UIC/Asst. Prof.	Tenured Associate Professor	RBRC/U. of Illinois, Chicago
van Kolck, Ubirajara	09/2000 – 08/31/2004 08/2003 (Tenure)	RHIC Physics Fellow; U. of Arizona/Asst. Professor	Tenured Associate Professor	RBRC/U. of Arizona
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
Wettig, Tilo	10/1999 – 09/30/2004	RHIC Physics Fellow, Yale/Asst. Prof. Associate Professor (2003)	Professorship	U. of Regensburg, Inst. for Theoretical Physics, Germany
Present Program				
		University Fellows Have Research Collaborator Appointments at BNL		

RHIC Physics Fellow Present Program	RBRC Dates	Position		Present Institution
Theorists				
Aoki, Sinya	04/01/2004 -	RHIC Physics Fellow, U. of Tsukuba, Japan, Permanent Position		RBRC/U. of Tsukuba
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
Vogelsang, Werner	4/1/2000 to 9/30/2003 10/1/2003 -	RIKEN BNL Fellow RHIC Physics Fellow BNL/Associate Physicist		RBRC/BNL
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
David Kawall	06/1/2004 to 1/2005 01/2005 to present	RIKEN BNL Fellow RHIC Physics Fellow/Assistant Physicist U. of Mass, Amherst		RBRC/U. of Massachusetts, Amherst

New Universities:

Theory

Definite 9/1/05

Iowa State University
Purdue University, W. Lafayette, IN
SUNY, Stony Brook

Prospective

UCLA
Texas A&M

Experiment

U. of Massachusetts, Amherst

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
Fox, Brendan	03/01/2001-10/15/2003	RIKEN BNL Fellow	Voluntary Termination	
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
Hirano, Tetsufumi	03/24/03 to 08/31/04 09/01/04 to present	Research Associate Visiting Scientist	Research Associate	Columbia University
Ikeda, Takashi	04/01/02 to 03/2005	RSP Research Associate	Researcher	ASTOM R&D, Co. Ltd. (Advanced Simulation Tech. of Mechanics), Wako-shi, Saitama, Japan
Itakura, Kazunori	06/2002 to 05/2003	Research Associate	JSPS Fellow Permanent Position	Service of Theoretical Physics, Saclay, France 5/05: KEK, Japan
Jinnouchi, Osamu	04/01/03 to 02/28/05	Research Associate	Research Associate	KEK, Japan
Kaneta, Masashi	11/01/02 to 02/15/05	Research Associate	Assistant Professor	Tohoku U., Japan

Name	Dates at RBRC	RBRC Position	New Position Title	New Position Institution
Kawall, David	06/01/04 to 01/21/05 01/2005 to present	RIKEN BNL Fellow	RHIC Physics Fellow/ Assistant Professor	RBRC/U. of MA, Amherst
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 03/2004	[Postdoc. Res. RIKEN Special Postdoc Res., RIKEN] RIKEN BNL Fellow RSP Visiting Scientist	Associate Professor	Rikkyo University, Tokyo
Kusenko, Alexander	10/1999 to 9/2004	RHIC Physics Fellow, Assistant Professor, UCLA	Associate Professor Tenure (5/2003)	UCLA
Messer, Frederica	09/01/2002 to 04/01/2003	RIKEN BNL Fellow	Voluntary Termination	
Nara, Yasushi	10/1999 to 09/2002	Research Associate	Research Associate	U. of Arizona, Tucson
Nemoto, Yukio	09/01/01 to 05/31/04	Research Associate	Research Associate	Nagoya U., Japan
Noaki, Junichi	07/01/01 to 6/30/04	Research Associate	JSPS Fellow	U. of Southampton, UK
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
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
Schaefer, Thomas	01/2000-12/31/02 01/2003-12/31/04	RHIC Physics Fellow SUNY, SB/Asst. Prof. NCSU	Tenured at NCSU Associate Professor	North Carolina State U., Raleigh, NC
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, Assistant Professor, Columbia U.	Associate Professor, Tenured	U. of Wash, Seattle, Natl. Inst. for Nucl. Th

Name	Dates at RBRC	RBRC Position	New Position Title	New Position Institution
Stephanov, Mikhail	10/1999 to 9/2004	RHIC Physics Fellow, Assistant Professor, UIC	Associate Professor Tenure (08/2003)	U. of Illinois, Chicago
van Kolck, Ubirajara	09/2000 to 8/2004	RHIC Physics Fellow, Assistant Professor, U. of Arizona	Associate Professor Tenure (08/2003)	U. of Arizona
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 to 5/31/2005	RIKEN BNL Fellow RHIC Physics Fellow/ Associate Physicist/BNL	Physicist with Tenure 6/1/05	BNL
Wettig, Tilo	10/1999 to 9/2004	RHIC Physics Fellow, Assistant Professor, Associate Professor (2003) Yale	Professorship	U. of Regensburg, Inst. for Theoretical Physics, Germany
Wingate, Matthew	09/1997 to 09/2000	Research Associate	Research Associate	Ohio State U. Columbus; U. of Washington, INT
Yamada, Norikazu	12/2002 to 10/31/2004	Research Associate	Assistant Physicist	KEK, Japan
Yasui, Yoshiaki	09/1997 to 09/2000	Research Associate	Postdoc Postdoctoral Fellow	Radiation Lab, RIKEN, KEK, Theory Group, Japan; Tokyo Management College
Yokoya, Hiroshi	4/23/03 to 3/21/05	RSP Young Researcher	Research Associate	Niigata, Japan

THEORETICAL PHYSICS AT RIKEN-BNL CENTER - STRONG INTERACTIONS AND QCD

Larry McLerran

RBRC Theory Group

Larry McLerran

Presentation
11th Meeting of The Management Steering Committee of RIKEN BNL Collaboration

May 27, 2005
Brookhaven National Laboratory, Upton, NY

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

Structure of Hadrons

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

Color Glass Condensate and Quark Gluon Plasma

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

Accomplishments and Goals of Lattice Gauge Theory at RBRC

Have built and are now operating QCDOC (also machine in Edinburgh and DOE machine)

Developed practical methods for small mass quarks, and taking the continuum limit

Developed methods for understanding:

The weak interactions in strongly interacting particles

CP violation in kaon decays

Distributions of quarks and gluons in hadrons

Spectra of exotic hadronic states, such as pentaquark

With QCDOC:

Do the above with precision, particularly CKM tests

QCD thermodynamics

Understand origins of mass generation

Accomplishments and Goals in Study of Spin and Perturbative QCD

Achievements:

Developed GRSV Spin Structure Functions

Developed one set of standard structure functions used in heavy ion, dA and pp

Used GRSV for analysis at RHIC

NLO spin asymmetry in pp ->pion X (gluon spin measurement)

Spin effects in Drell-Yan

Goals

Extract gluon spin from RHIC experiments

Understand hard processes in larger program

Accomplishments and Goals in Study of High Energy Density Matter

Accomplishments:

Complete 3-d computations of distributions of particle produced in heavy ion collisions and relation to QGP

Developed a theory of matter at small x: Color Glass Condensate

Understood initial conditions in heavy ion collisions and early stages of evolution

Goals:

Turn study of high energy density matter into a precise science

Understand from first principles in QCD, the high energy limit

Why is BNL a Good Place to Study QCD?

RHIC
QCDOC

Strong theory groups:
BNL, Columbia, Stony Brook

In both HEP and NP at BNL strong interest in theory and experiment
Beginning of a new BNL lattice gauge theory group

Supportive atmosphere for young people

Relations

QCDOC and Lattice Gauge Theory

Joint Columbia-RBRC Project
NT has Jung as Junior Faculty
Hired Karsch and began new group
Soni and Creutz
SCIDAC project

Spin and pQCD

Vogelsang is tenured
Kretzer a joint PD with NT
Larry Trueman in HEP

RHIC Physics

Strong collaboration with NT group continues.

RIKEN-BNL Theoretical 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
W. Vogelsang, Tenured at BNL

Next Year:

Texas A&M
UCLA?.....

Current Fellows

S. Bass, Duke
T. Izubuchi, Kanazawa
S. Jeon, McGill
T. Blum, U of Connecticut
P. Petreczky, BNL (NT)
S. Sasaki, Tokyo (NT)
S. Aoki, Tsukuba
K. Iida (NT)

New Fellows:

D. Molnar: Purdue
K. Tuchin: Iowa State

U. Weidemann? Stony Brook

RBRC Postdoctoral Fellows:

Spin:

S. Kretzer

F. Yuan

H. Yokoya

High Density Matter-Phenomenology

Y. Hatta

T. Doi

K. Fukushima

K. Iida

T. Sugihara

A. Mocsy

Lattice:

S. Ohta

Y. Nemoto, J. Noaki, N. Yamada, T. Yamazaki

K. Hashimoto

RBRC EXPERIMENTAL GROUP AND WAKO BASE (RADIATION LAB.)

Hideto En'yo

RBRC Experimental Group and

Wako Base (Radiation Lab.)

Activity Summary and Future Prospecives

Brief introduction / Organization

Physics highlights => G.Bunce and Y.Akiba

CCJ (PHENIX Computer Center in Japan)

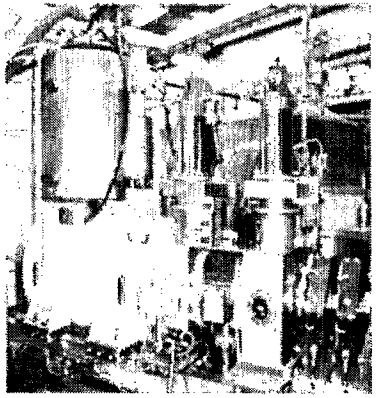
Detector upgrade for future => Y.Akiba

MSC meeting, 27 May 2005

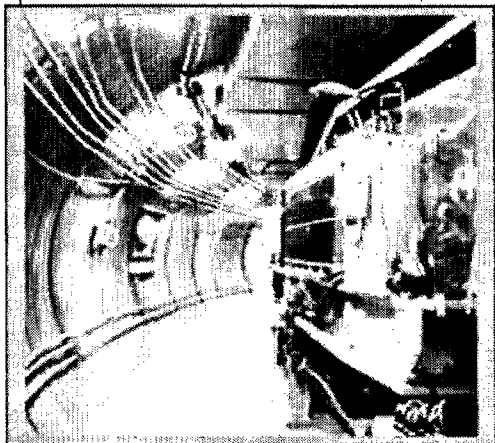
Hideto En'yo

Polarized Proton in RHIC

The first spin collider

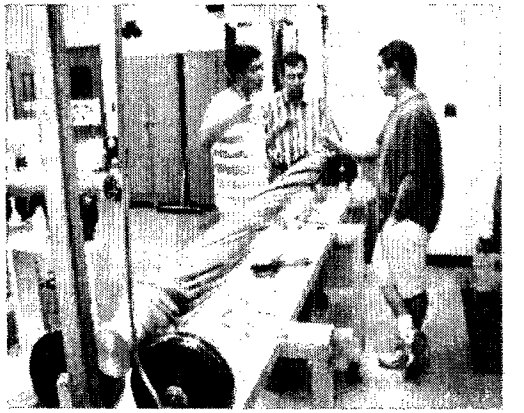


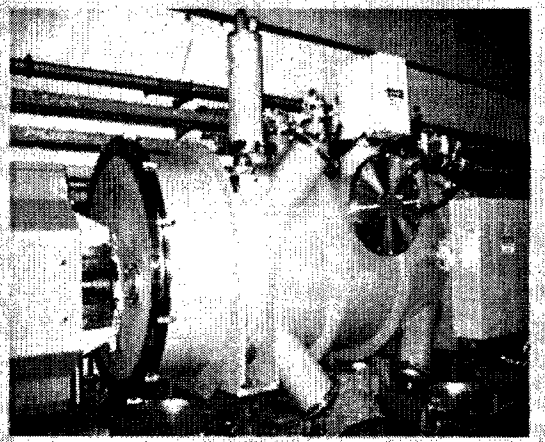
KEK OPPPS, Tuned for RHIC at TRIUMPH



Booster: No Spin Resonance

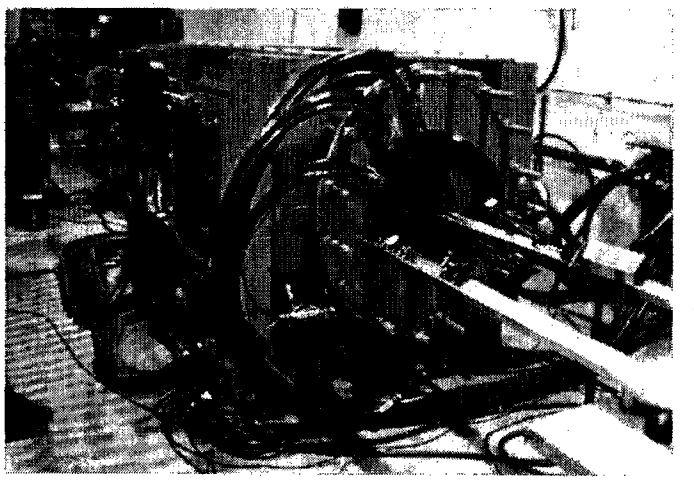
Snakes and Spin Rotators in the Tunnel

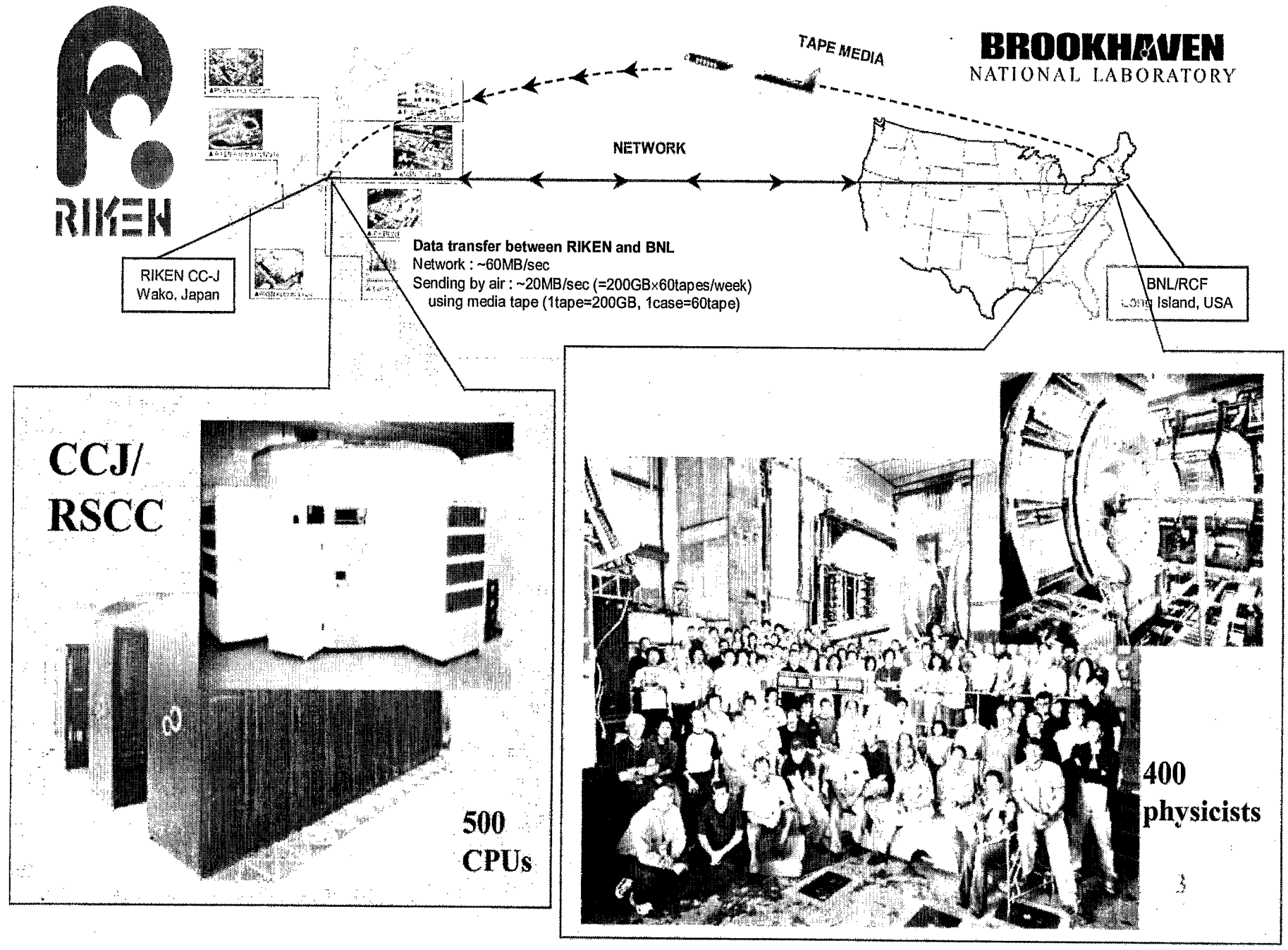




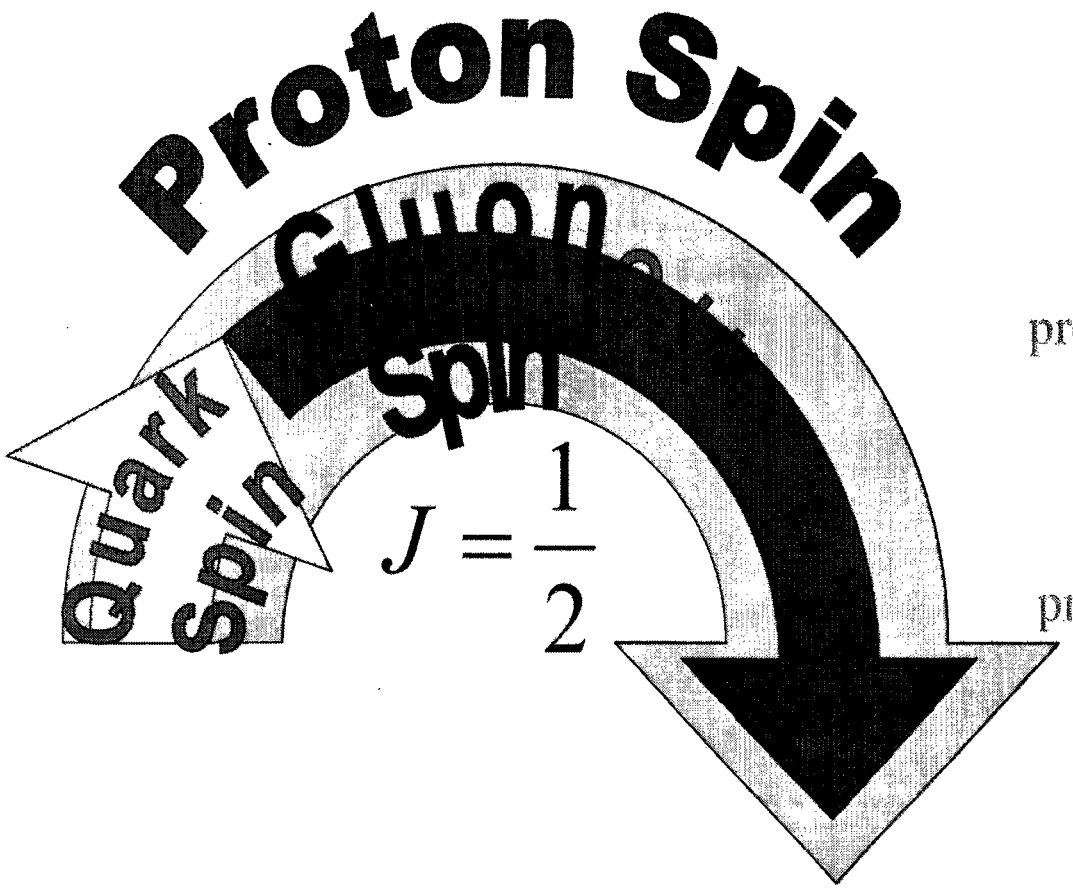
AGS cold snake

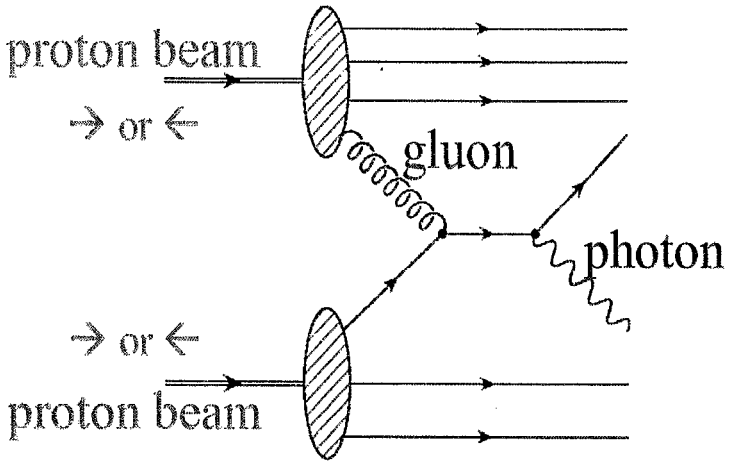
AGS New SNAKE made in RIKEN

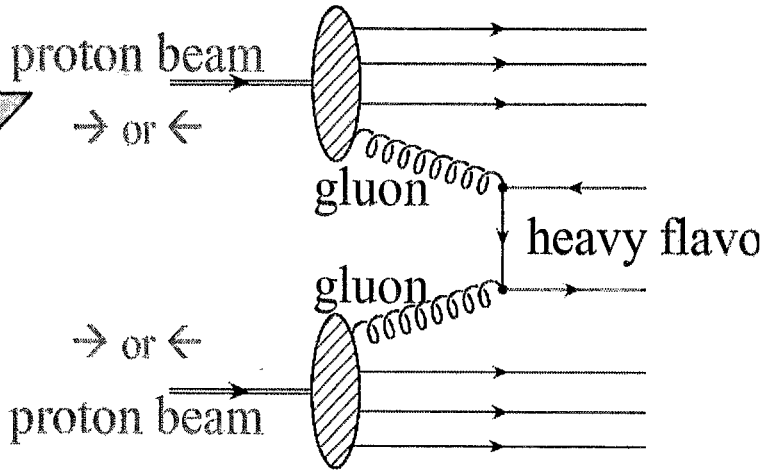



RIKEN
BROOKHAVEN
NATIONAL LABORATORY
TAPE MEDIA
NETWORK
RIKEN CC-J
Wako, Japan
Data transfer between RIKEN and BNL
Network : ~60MB/sec
Sending by air : ~20MB/sec (=200GB×60tapes/week)
using media tape (1tape=200GB, 1case=60tape)
BNL/RCF
Long Island, USA
CCJ/
RSCC
500
CPUs
400
physicists

What is the fly wheel in the proton



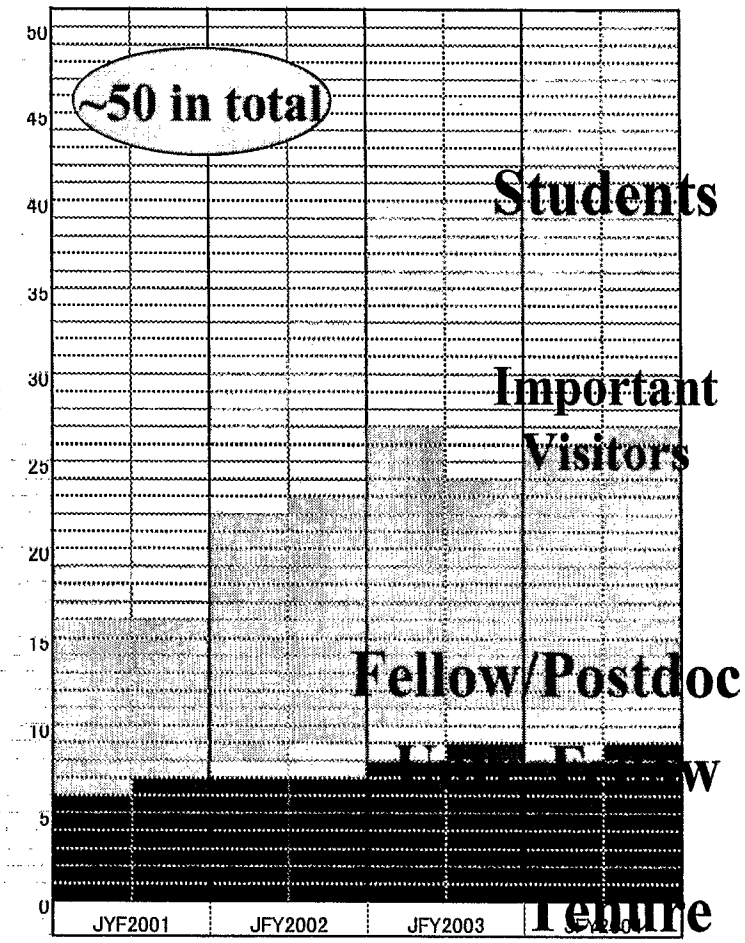




Proton Spin Crisis

Member of RBRC Experiment 2004/5

	04 Status		2001		2002		2003		2004	
RBRC	Admin	H.Enyo								
		G.Bunce								
	Fellow	M.Perdecamp				Illinois-U				
		A.Deshpande								
		B.Fox								
		D.E.Fields			NewMexico-U					
		F.Messor								
		A.Bazilevski					BNL			
		W.Xei								
		D. Kawall								
	RA	M.Kaneta								
		K.Okada								
		O.Jinnnouchi								
	RSP RA	H.Kobayashi								
		T.Tabaru								
		T.Kawabata				Tokyo-U				
		H.Torii								
		J. Asai								
	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				Illinois-U				
		M.Wagner								
		R.Seidl								Illinois-U
RIKEN	Tenure	T.Ichihara								
		Y.Watanabe								
		A.Taketani								
		K.Tanida								
		Y.Goto								
		Y.Akiba								
		M.Okamura								
		I. Nakagawa								
	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								
		K.Nakano								
		H.Kanou								
		J.Takano								
	Kyoto	M.Togawa								
		Y.Fukao								
		H.Okada								
		K.Aoki								
		S.Kohei								
	Heiderberg	V.Siegle								
	Hiroshima	T.Hachiya								
		Y.Tsuchimoto								
	CNS Tokyo	F.Kajihara								
	Rikkyo	Y.Inoue								
	Niigata	K.Fujiwara								
		Total	19	21	31	35	40	40	49	51
		Visitor	0	2	4	5	7	9	8	9
		Students	3	3	5	7	6	7	15	15
		Researcher	16	16	22	23	27	24	26	27

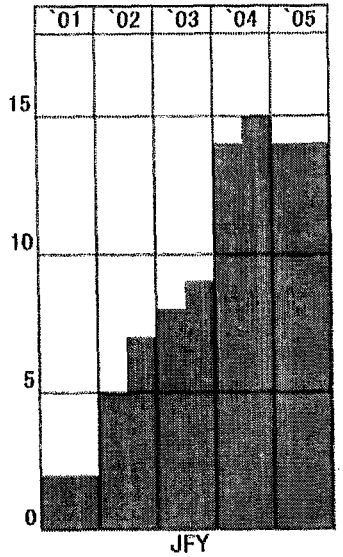


15 Students,
8 Spin, 3 HI, 4 Upgrade

Student Status (RBRC&Wako)

EXPERIMENT		2001	2002	2003	2004	2005	
TITech	N. Kamihara	JRA	JRA	JRA	PT	RSPD	Muon
	T. Horaguchi			JRA	JRA	JRA	Direct Gamma
	K. Nakano				PT	JRA	Jet
	J. Takano				JRA	JRA	Snake Pol-Acceleration
Kyoto	H. Sato	JSPS	JSPS	JSPS			Muon
	M. Togawa		JRA2	JRA2	JRA2	JSPS	Local Polarimeter
	Y. Fukao			JRA	JRA	JRA	Pi-0 Analysys
	H. Okada			JRA2	JRA2	JRA2	Polarimeter
	K. Aoki				PT	JRA2	Muon upgrade
	K. Shoji					PT	Muon upgrade
Niigata U	K. Fujiwara				JRA	JRA	Silicon upgrade
Hiroshima	Y. Tsuchimoto				JRA	JRA	A+A --> electron
	T. Hachiya			JRA2	JRA2		d+A --> electron
U.Tokyo	F. Kajihara				JRA	JRA	A+A --> electron
Rikkyo U	Y. Inoue				PT	PT	
Heiderberg	V. Siegle						Belle
T.U. Muenchen	D. Gabbert						Belle
	R. Seidl						Belle

THEORY							
U.Tokyo	Y. Hatta		JRA	JRA	RSPD	RSPD	High Density
Hiroshima U.	H. Yokoya			JRA	JRA		pQCD



RBRC Young Researcher
RIKEN Junior Research Associate
RIKEN Student Part Timer
JSPS DC Student
RIKEN Special Doctral Fellowsh PostDOC

This physics program attracts young people.
They graduate, and new ones join.

Experiment G. Organization

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)

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

Status and recent movements

- **RIKEN+RBRC is the second biggest PHENIX participating institute next to BNL.**
- **Yasuyuki Akiba and Matthias Perdecamp are appointed as deputy spokes persons of PHENIX collaboration (two out of two),**
- **Yasuyuki Akiba is responsible for the construction of the vertex detector upgrade in PHENIX.**
- **Since Akiba started, RBRC is expanding QGP physics activity**

- M. Kaneta moved to Tohoku University (tenure)
- O. Jinnouchi moved to University of Tokyo (tenure)
- J. Heuser to GSI and A. Kiyomichi to JAERI (tenure equiv.)
- Dave Kawall (Fellow, starts June 04)
- New RIKEN tenure I. Nakagawa joined 1st of Dec.04
- J. Asai will joined 1st of April04, (Kiso Tokken)
- N. Kamihara joined 1st of April05, (Kiso Tokken from JRA)
- S. Kametani and Y. Onuki joined 1st of April05 for Upgrade work at Wako

Physics Results

the Bulletin

BROOKHAVEN NATIONAL LABORATORY

Vol. 58 - No. 11 April 2, 2004

AGS Beam Runs Through Warm Snake

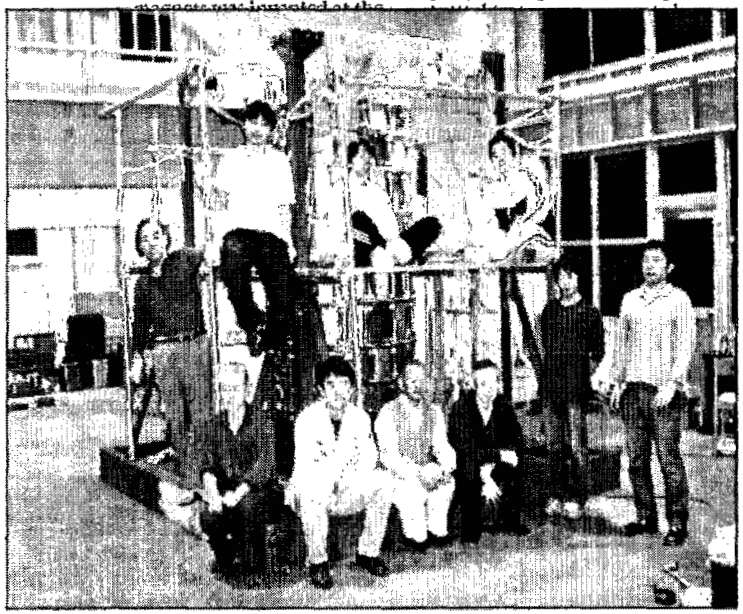
50 percent polarized proton beam measured in tests

Get to Know Snakes, Polarized Protons

Snakes

Snake magnets get their name from the snake-like undulation of the beam as it travels through the helical, or twisting, form of the magnet. The original idea of snake

A BNL team recently installed a warm, helical Siberian snake (see box, left), among other magnets in the Alternating Gradient Synchrotron (AGS). Designed by Masahiro Okamura of RIKEN and Junpai Takano of the Tokyo Institute of Technology, and built by the Takano Original Magnet Company in Japan, the magnet's



understanding the structure of the proton," MacKay said.

The warm snake story began a little over a year ago, when Thomas Roser of C-A proposed building the snake. The new helical snake was expected to minimize the depolarization from coupling resonances as the beam of polarized protons accelerated around the AGS ring before entering RHIC. It would replace the older solenoidal snake magnet in the AGS, which also promoted polarization, but had other disadvantages.

"Then, RIKEN designed and produced the final product in record time," said MacKay. "The magnet was delivered to BNL at the end of October."

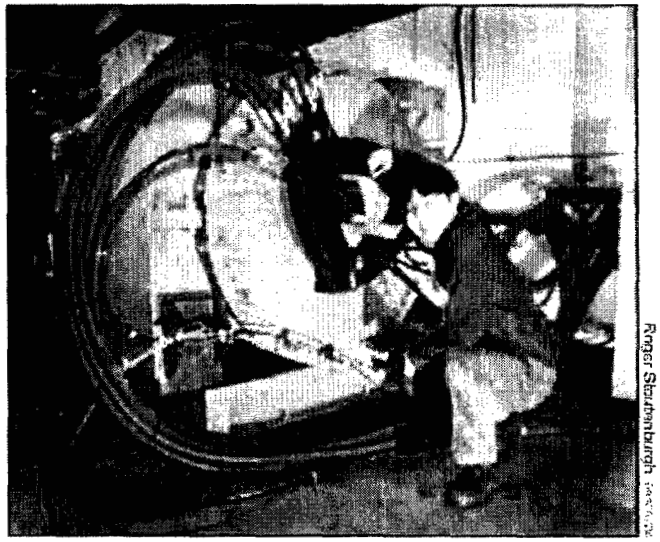
The snake magnet was first set up in the Superconducting Magnet Division, where a detailed series of measurements of ele netic pletec

"These measurements were made by Magnet teams led by George Ganetis and Animesh

ments and adjusted mechanical shims to compensate the field at the ends of the magnet.

Everything went well.

"More recently, we have gotten some measurements



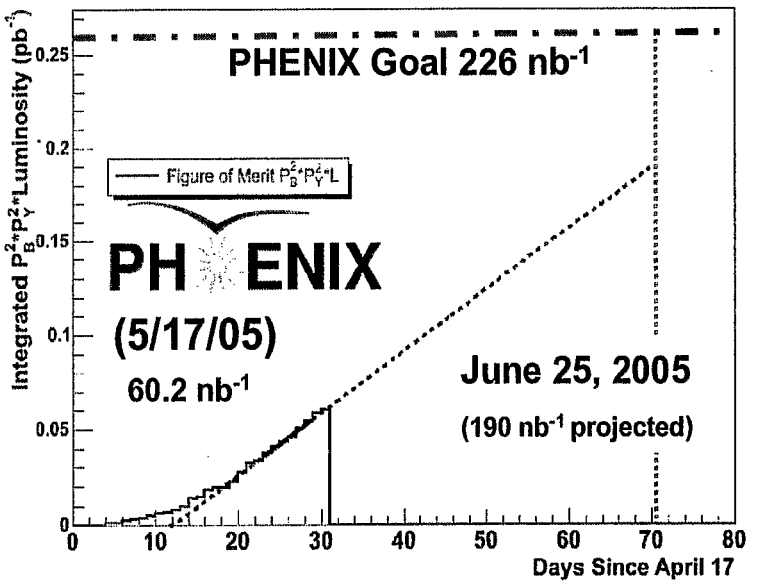
Roger Stoughenburgh

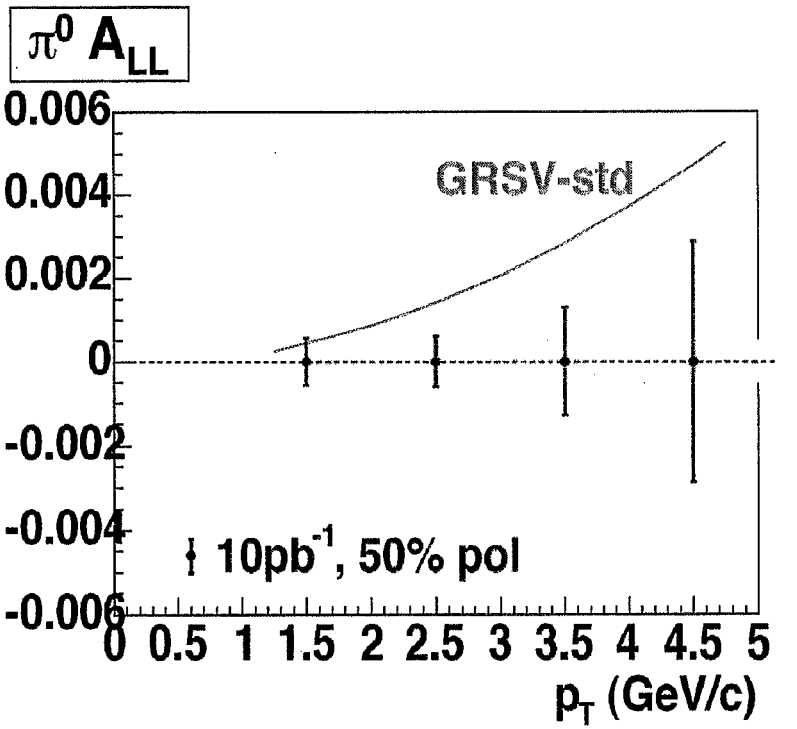
Pictured with the new warm helical Siberian snake magnet is Junpai Takano of the Tokyo Institute of Technology, who designed the magnet with Masahiro Okamura of RIKEN. Built by the Takano Original Magnet Company in Japan, the new snake was funded by RIKEN.

M. Okamura & J. Takano (Student)

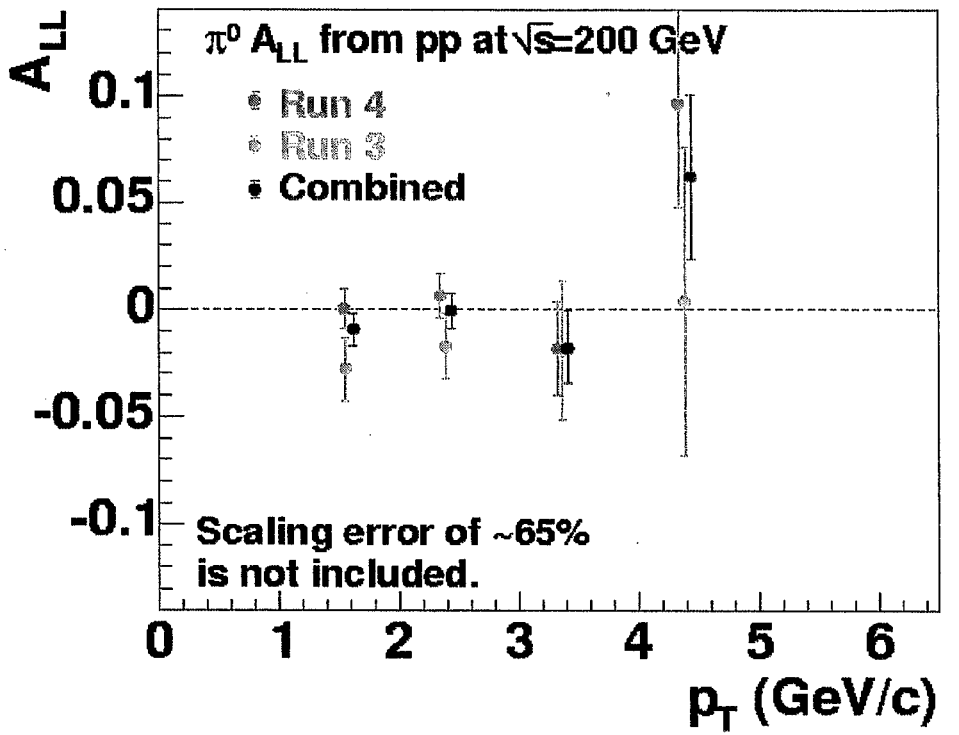
200 GeV pp "Figure of Merit"

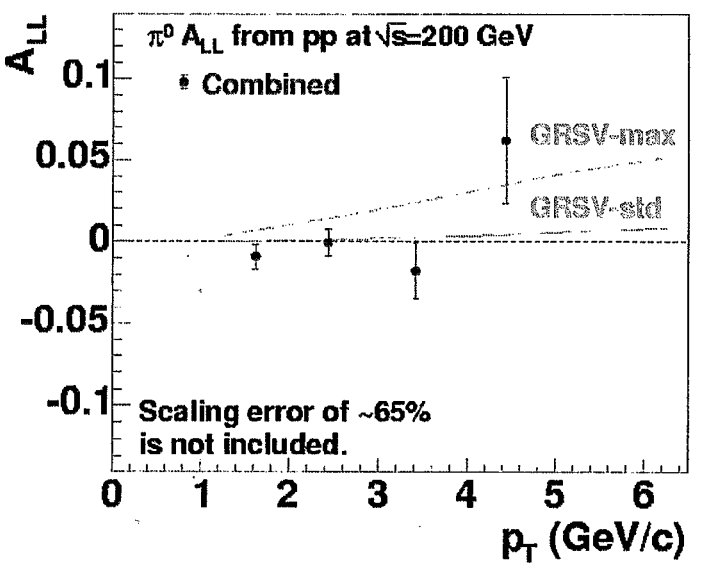
	Run Time	Int. Lumi	Pol.	P^4L
Run 3 (2003)	4 weeks	220 nb^{-1}	27%	1.17 nb^{-1}
Run 4 (2004)	4 days	75 nb^{-1}	40%	1.92 nb^{-1}
Run 5 (2005)	10 weeks	5500 nb^{-1}	50%	226 nb^{-1}





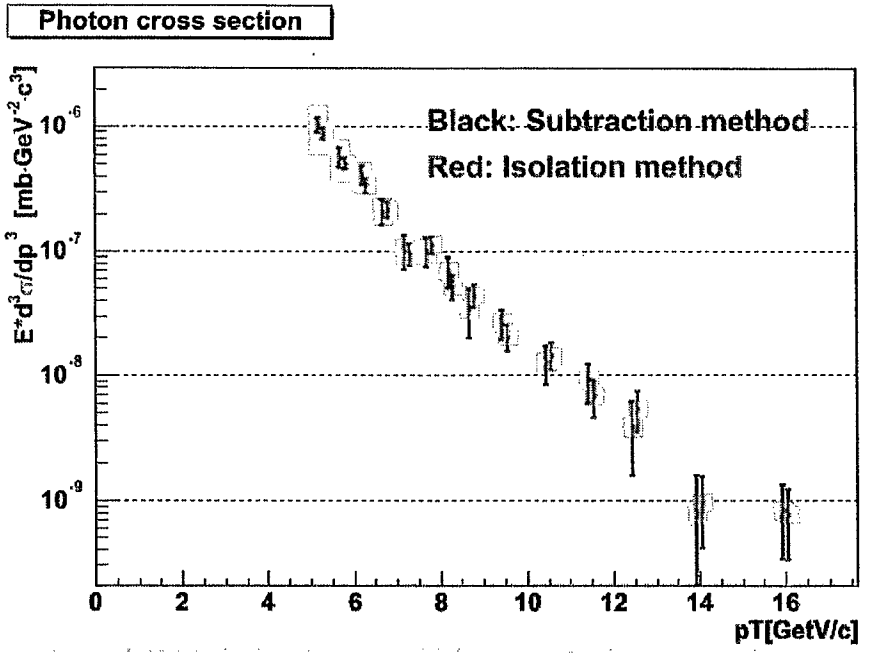
- With Improved Pol. Pi0 A_{LL} measurements became more significant.

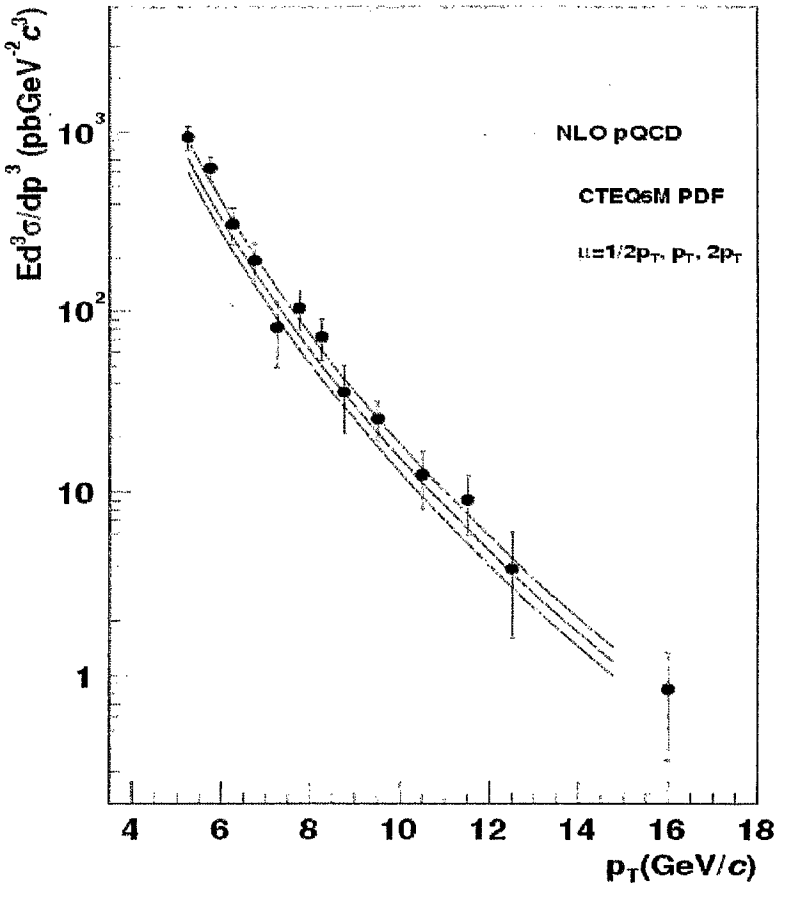




Consistent with GRSV-std
Less consistent with GRSV-max

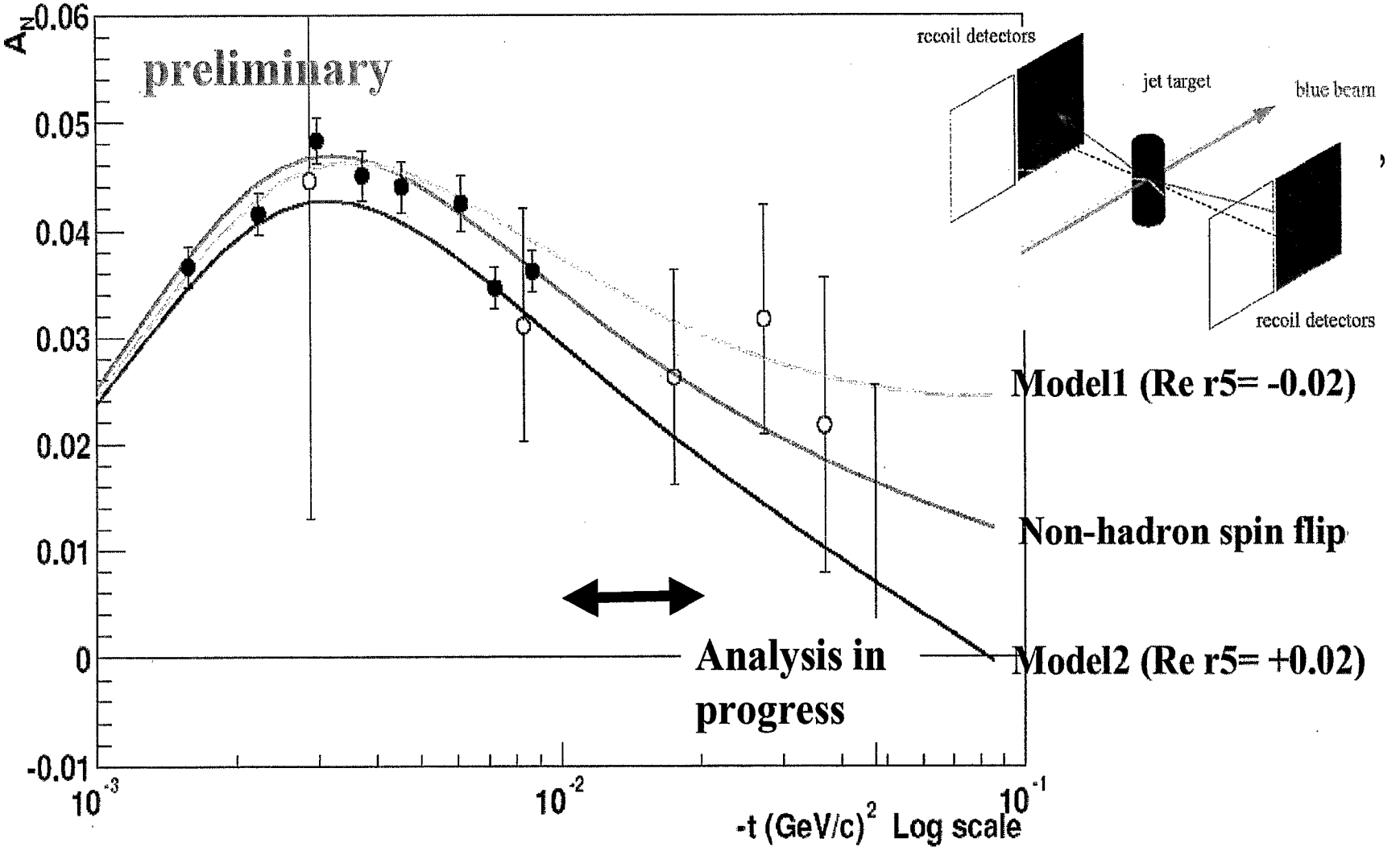
Prompt Photon





- pQCD calculation can describe the present data within their scale dependence.
  - By CTEQ6M

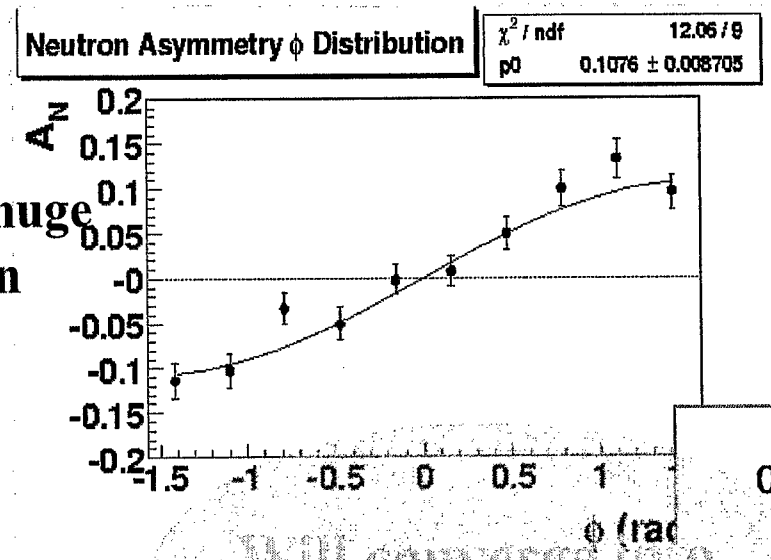
Gas Jet ! (p+p CNI) H. Okada et al.



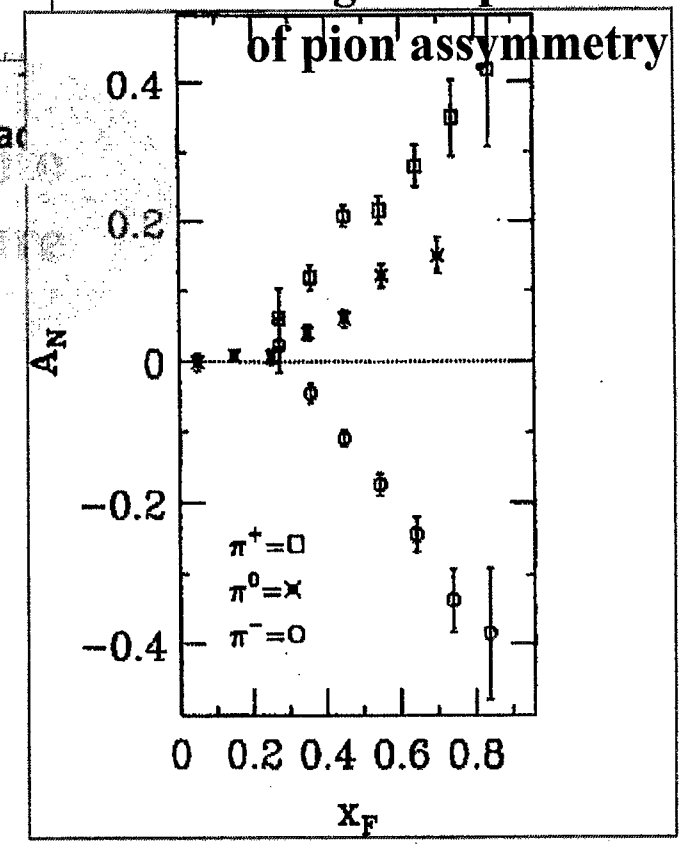
Our results will severely constrain for poorly known r_5

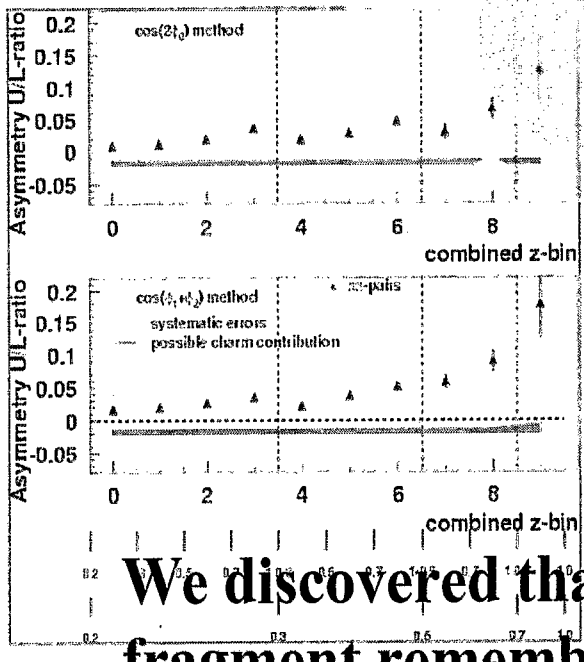
Transversity (or Orbital motion)

We discovered huge forward neutron asymmetry



Long time puzzle of pion assymmetry

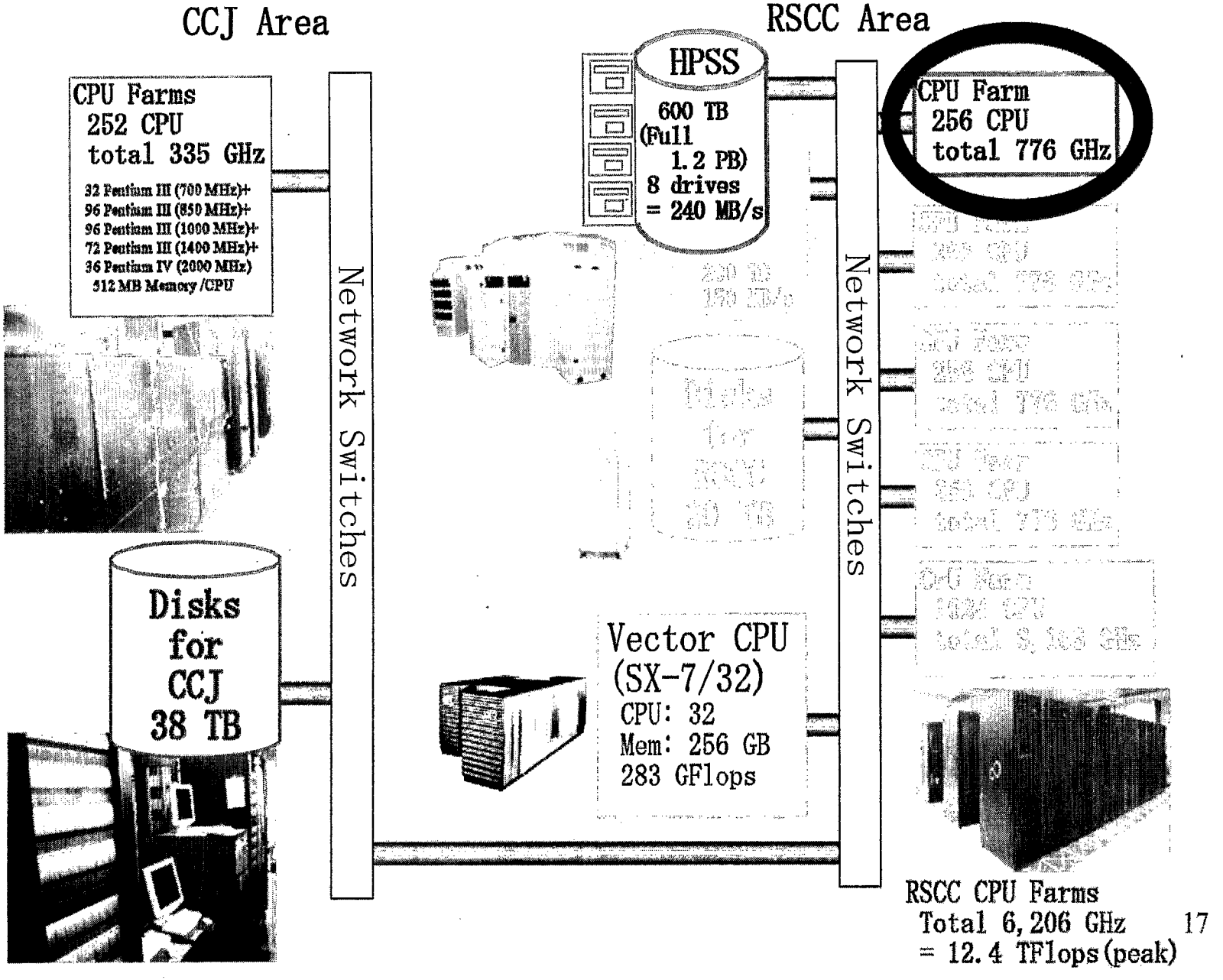




We discovered that Jet fragment remembers spin

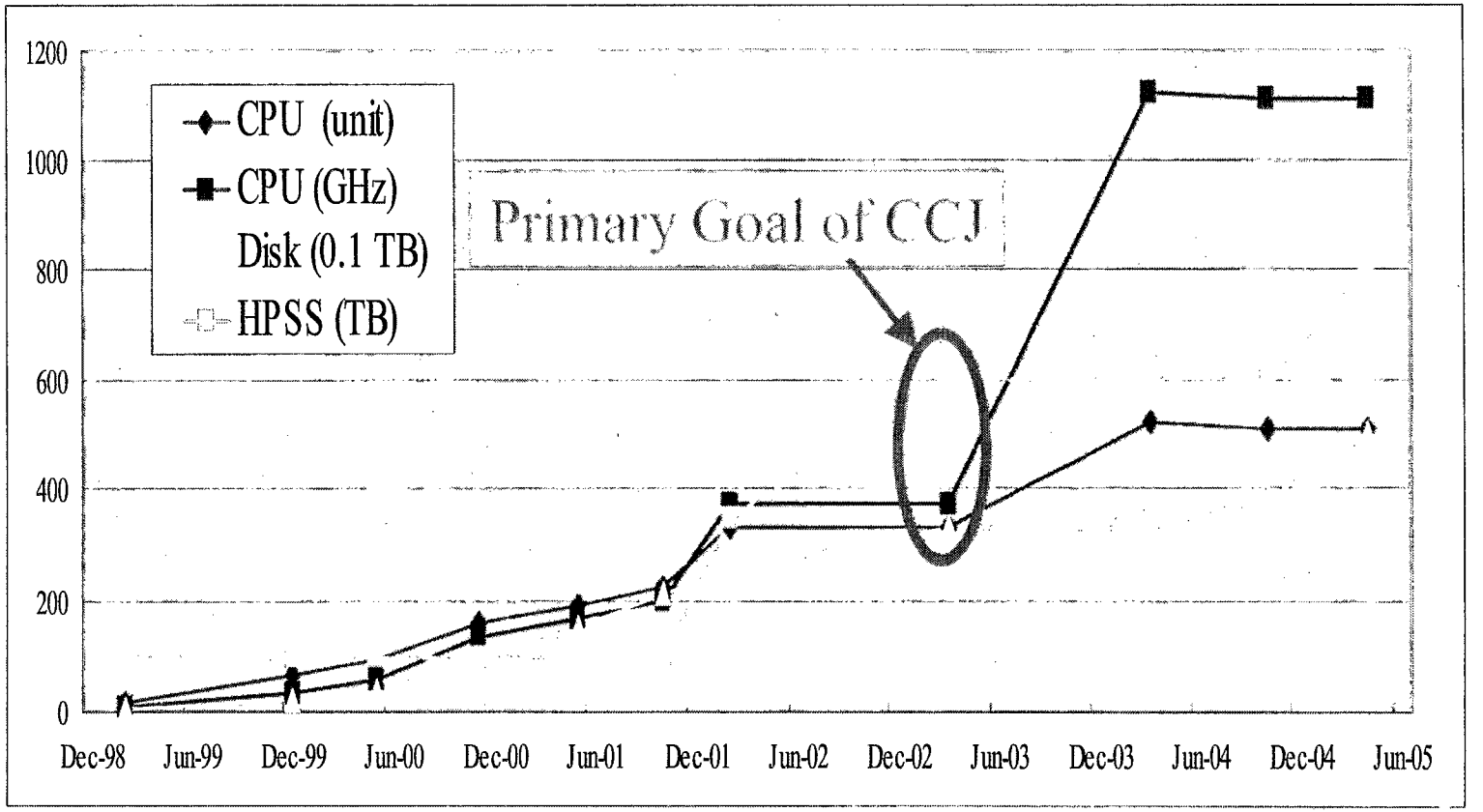
Activities at Wako

Current configuration of CCJ with RSCC



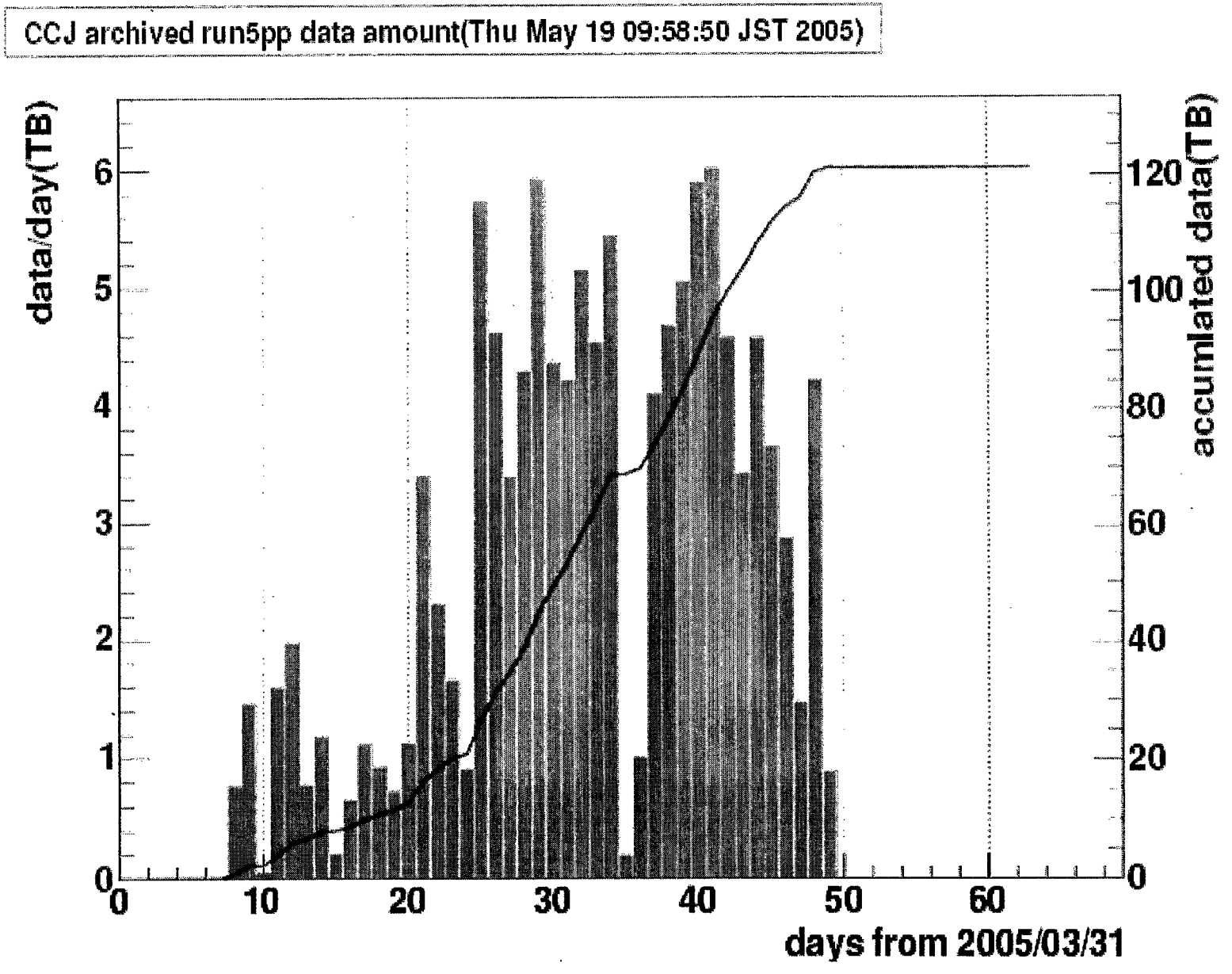
17

Cooperation of CCJ with Riken Super Combined Cluster (RSCC)

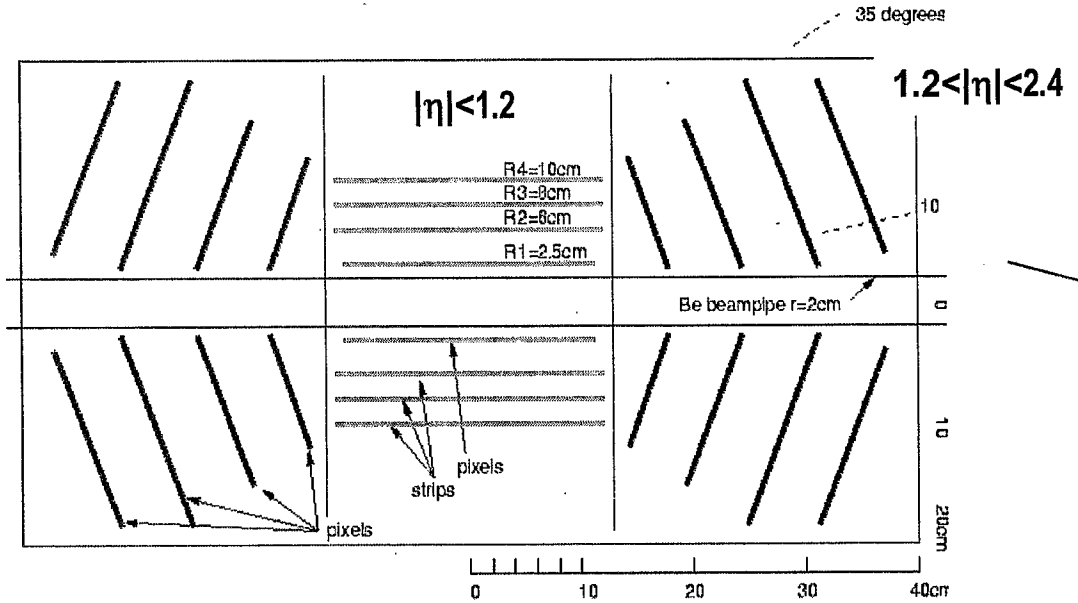


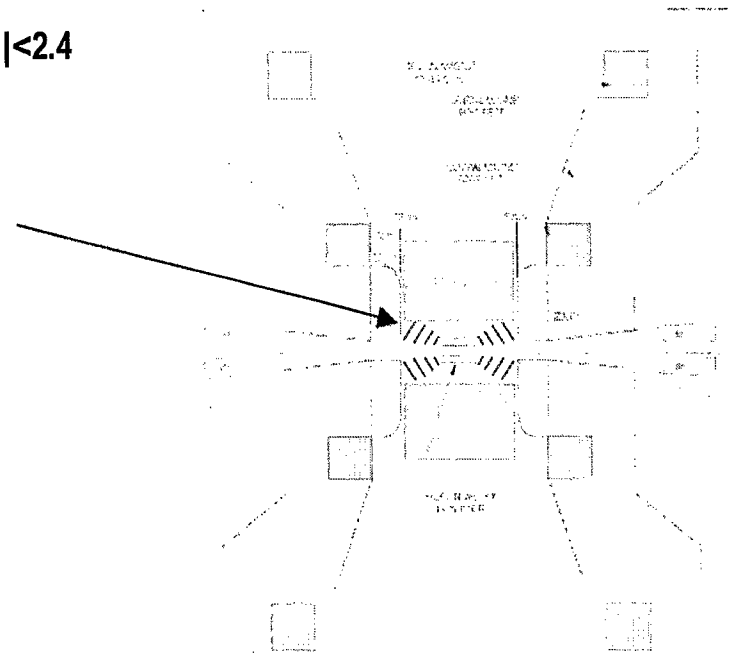
- CPU power reached to 3 times
  - CCJ: 252 CPU + RSCC pc2c 256 CPU
  - Storage is enough for three years of RHIC data

Data transfer challenge



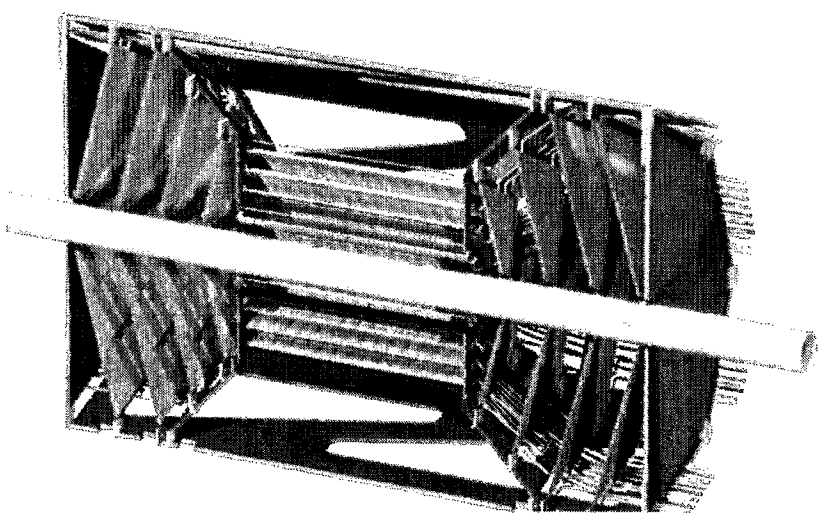
Detector Upgrade in PHENIX





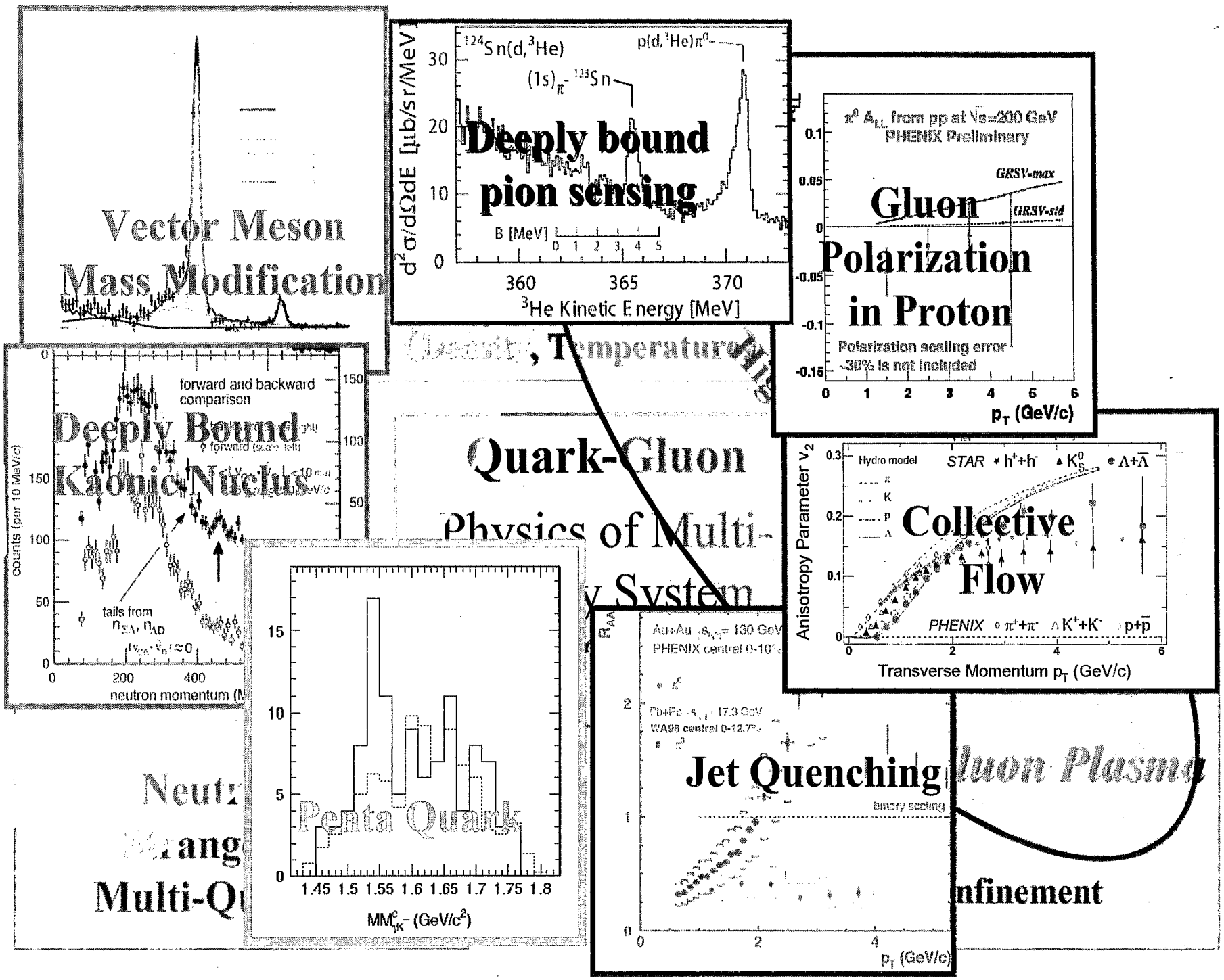
Pixel barrels (50 μm x 425 μm)
Strip barrels (80 μm x 3 cm)
(50 μm x 2 mm)

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



The world first Polarized Collider
is now producing Exciting Physics Results

We are in full swing
and will continue to be


Vector Meson
Mass Modification
Deeply bound
pion sensing
Gluon
Polarization
in Proton
Deeply Bound
Kaonic Nuclus
Quark-Gluon
Physics of Multi-
Collective
Flow
Penta Quark
Jet Quenching
Multi-Q
nfinement
luon Plasma
forward and backward
comparison
counts (per 10 MeV/c)
neutron momentum
tails from
n_{SA}, n_{AD}
^{124}Sn(d,^{3}He)
p(d,^{3}He)π^0
(1s)$_\pi$ - ^{123}Sn
B [MeV]
$d^2\sigma/d\Omega dE$ [μb/sr/MeV]
^{3}He Kinetic Energy [MeV]
π^0 A_{LL} from pp at $\sqrt{s}$=200 GeV
PHENIX Preliminary
GRSV-max
GRSV-std
Polarization scaling error
~30% is not included
p_T (GeV/c)
Hydro model
STAR
$h^+ + h^-$
K^0_S
$\Lambda + \bar{\Lambda}$
Anisotropy Parameter v_2
PHENIX
$\pi^+ + \pi^-$
$K^+ + K^-$
$p + \bar{p}$
Transverse Momentum p_T (GeV/c)
$MM^c_{\pi K^-}$ (GeV/c^2)
R_{AA}
Au+Au
PHENIX central 0-10%
Pb+Pb
WA98 central 0-12.7%
binary scaling
p_T (GeV/c)

THE QCDOC PROJECT OVERVIEW AND STATUS

Norman H. Christ

The QCDOC Project
Overview and Status

Management Steering
Committee Meeting

May 27, 2005

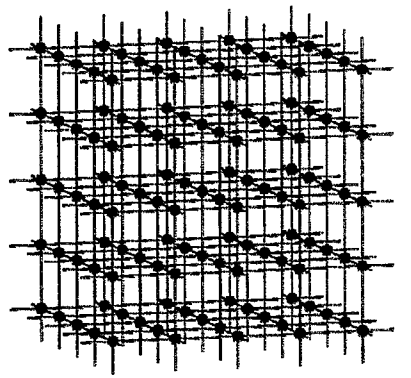
Norman H. Christ

Outline

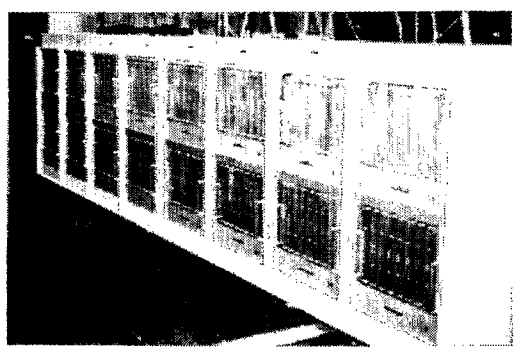
- Project goals
- QCDOC collaboration
- Architecture
- Software
  - Operating system
  - Run-time environment
  - Programming environment
- Construction and packaging
- Construction status
- Final bring-up issues
- Application performance
- Future plan

Project Goals

- Lattice QCD provides the only first-principles window into non-perturbative phenomena of QCD.
- All significant errors are controlled and can be reduced with faster computers or better algorithms.



- Regular space-time description: easily parallelized.
- $1/sustained Mflops cost/performance.
- Low power, easily maintained modular design.



8192-node, 0.4 Tflops QCDSP machine

QCDOC Collaboration
(people)

- Columbia (DOE)
  - Norman Christ
  - Saul Cohen
  - Calin Cristian
  - Zhihua Dong
  - Changhoan Kim
  - Ludmila Levkova
  - Sam Li
  - Xiaodong Liao
  - Guofeng Liu
  - Meifeng Lin
  - Robert Mawhinney
  - Azusa Yamaguchi
- BNL (SciDAC)
  - Robert Bennett
  - Chulwoo Jung
  - Konstantin Petrov
  - David Stampf
- UKQCD (PPARC)
  - Peter Boyle
  - Mike Clark
  - Balint Joo
- RBRC (RIKEN)
  - Shigemi Ohta
  - Tilo Wettig
- IBM
  - Dong Chen
  - Alan Gara
  - Design groups:
    - Yorktown Heights, NY
    - Rochester, MN
    - Raleigh, NC

QCDOC Collaboration
(money)

Institution/funding source	Design and proto-typing	Large installations
Columbia/DOE	$500K	$1M (UKQCD)
RBRC/RIKEN	$400K	$5M
UKQCD/PPARC	$1M	$5.2M
BNL/DOE	-	$5.1M

Personnel and site prep costs are not included.

QCDOC Architecture

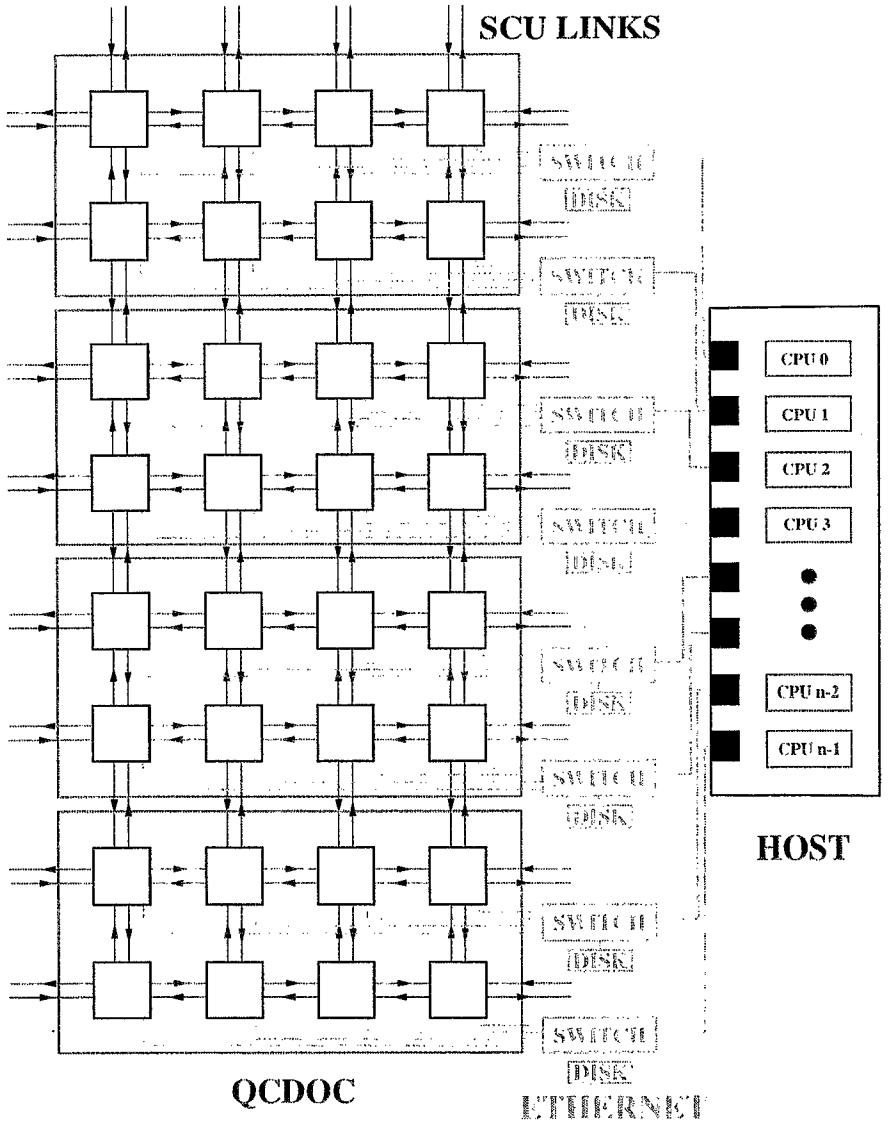
- IBM-fabricated, single-chip node.
  [50 million transistors, 5 Watt, 1.3cm x 1.3cm]
- Processor:
  - PowerPC 32-bit RISC.
  - 64-bit, 1 Gflops floating point unit.
- Memory/node: 4 Mbyte (on-chip) & o2 Gbyte DIMM.
- Communications network:
  - 6-dim, supporting lower dimensional partitions.
  - Global sum/broadcast functionality.
  - Multiple DMA engines/minimal processor overhead.
- Ethernet connection to each node: booting, I/O, host control.
- ~7-8 Watt/node, 15 in^3 per node.

Software Environment

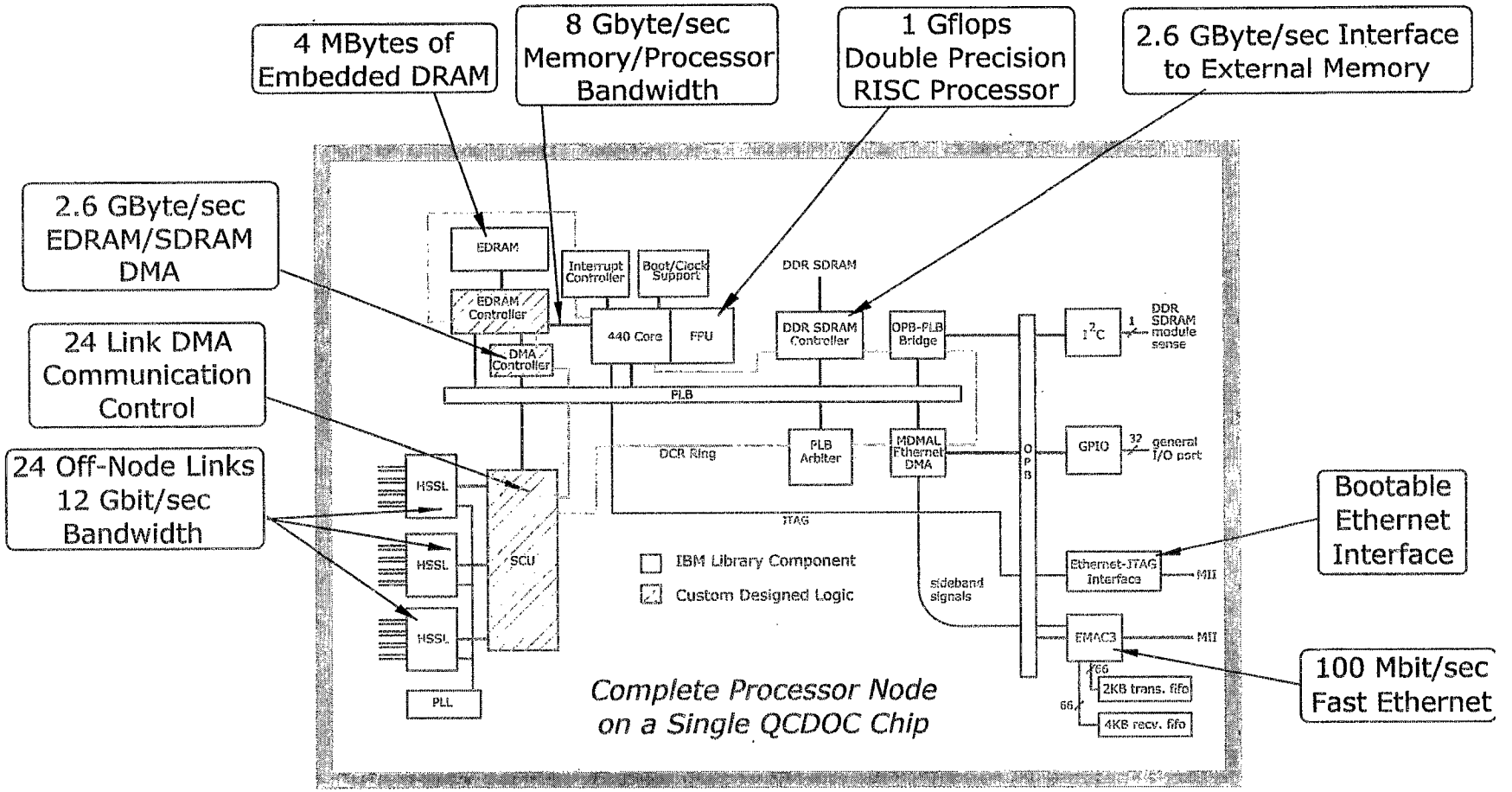
- Lean kernel on each node
  - Protected kernel mode and address space.
  - RPC support for host access.
  - NFS access to NAS disks (/pfs).
  - Normal Unix services including stdout and stderr.
- Threaded host kernel
  - Efficient performance on 8-processor SMP host.
  - User shell (qsh) with extended commands.
  - Host file system (/host).
  - Simple remapping of 6-D machine to (6-n)-D torus.
- Programming environment
  - POSIX compatible, open-source libc.
  - gcc and xlc compilers
- SciDAC standards
  - Level-1, QMP protocol
  - Level-2 parallelized linear algebra, QDP & QDP++.
  - Efficient level-3 inverters
    - Wilson/clover
    - Domain wall fermions
    - ASQTAD
    - p4 (underway)

Network Architecture

- Red boxes are nodes.
- Blue boxes mother boards.
- Red lines are communications links.
- Green lines are Ethernet connections.
- Green boxes are Ethernet switches.
- Pink boxes are host CPU processors.

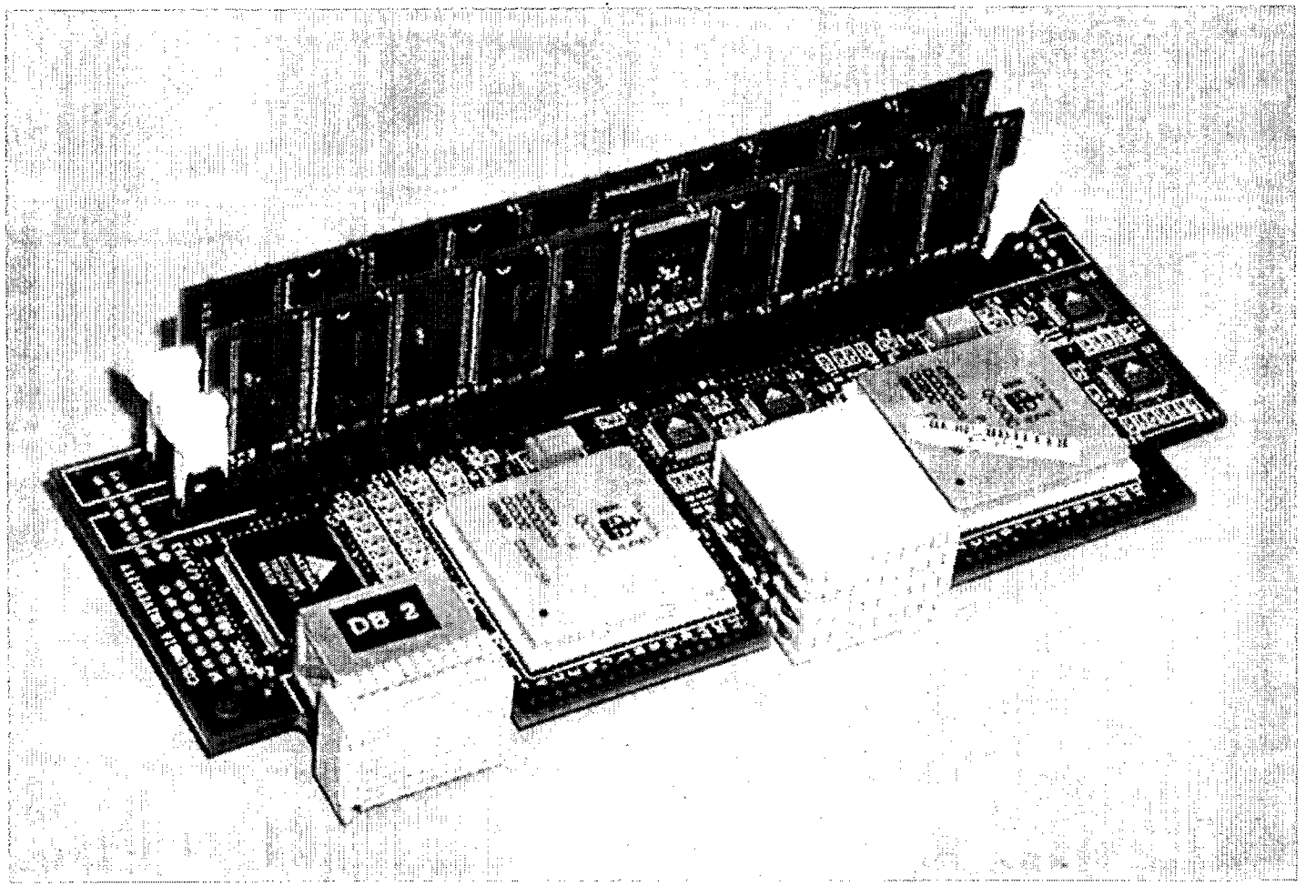


QCDOC Chip

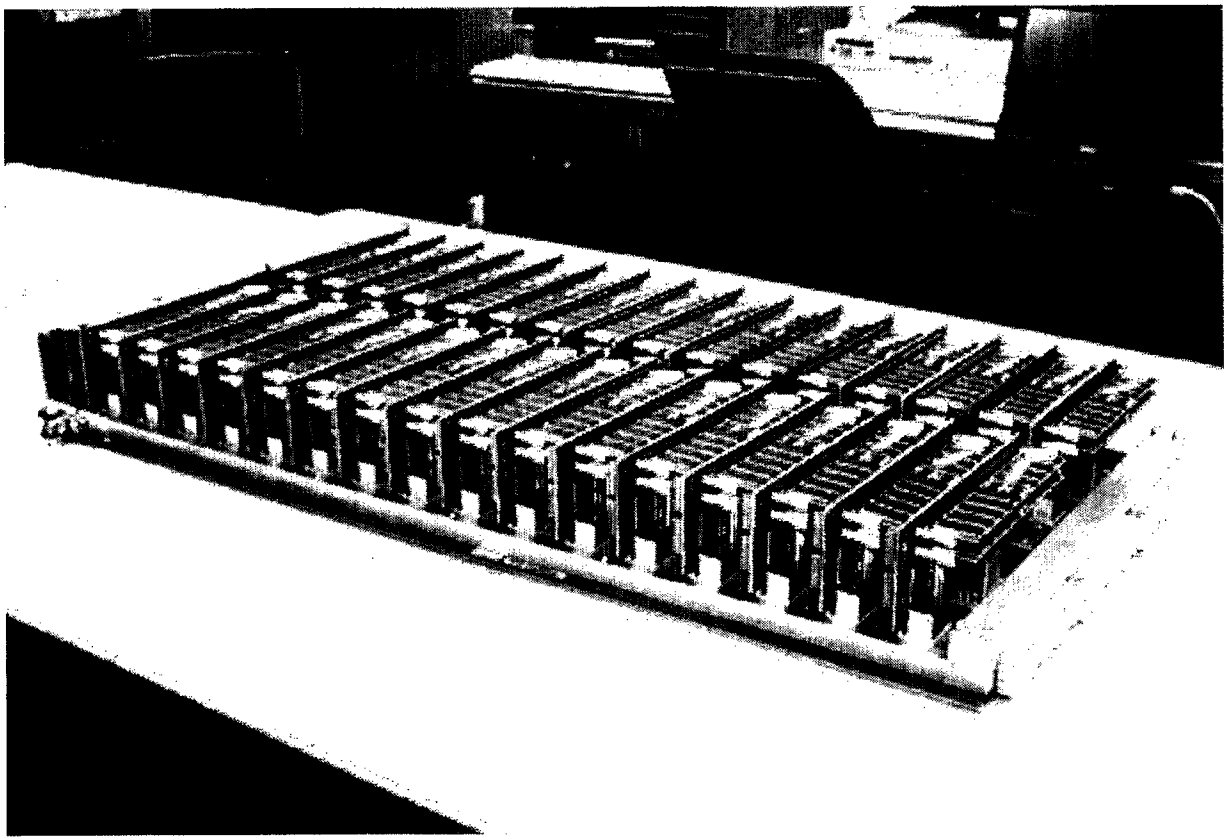


50 million transistors, 0.18 micron, 1.3 x 1.3 cm die, 5 Watt

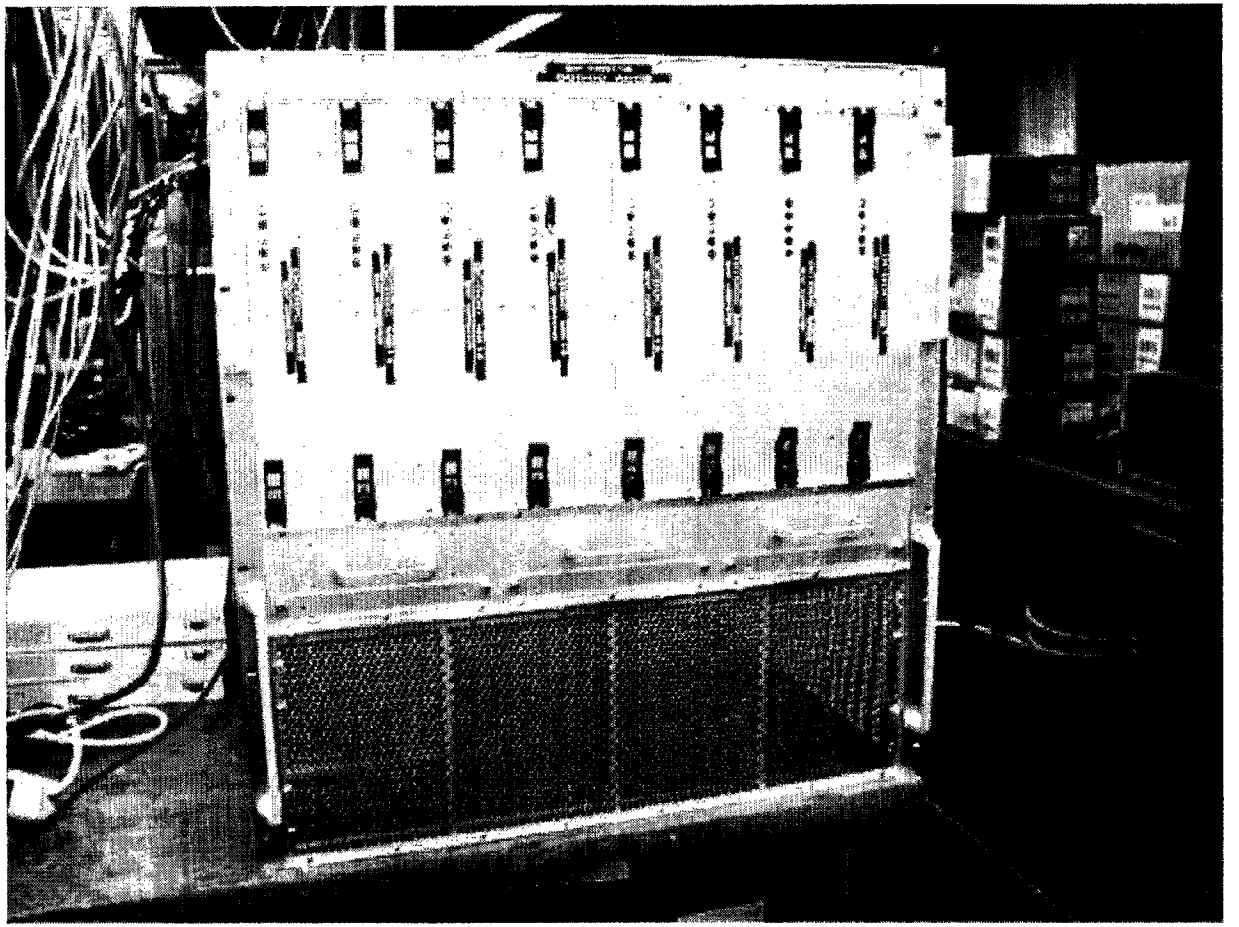
Daughter board (2 nodes)



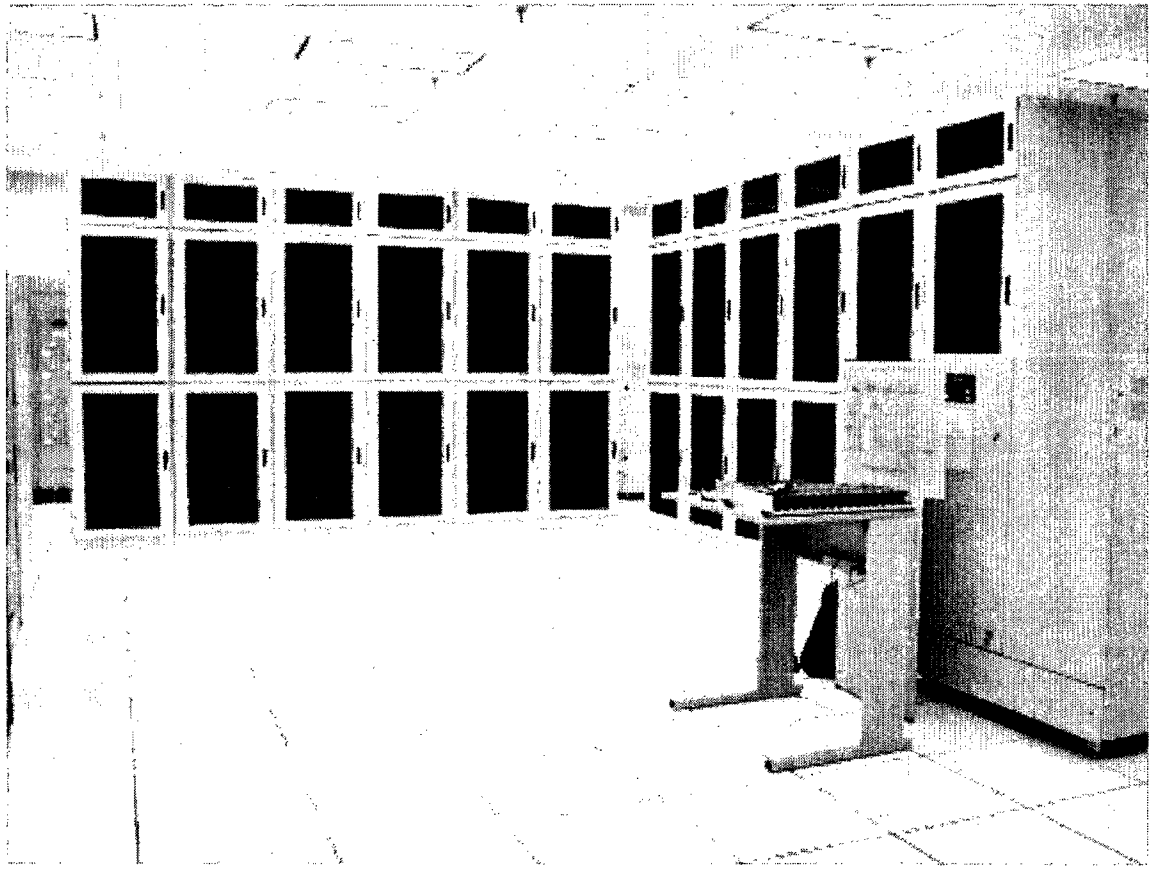
Mother board (64 nodes)



512-Node Machine



Brookhaven Installation



RBRC (right) and DOE (left) 12K-node QCDOC machines

Project Status

- UKQCD – 13,312 nodes --$5.2M – 4-5 Tflops sustained.
  - Installed in Edinburgh 12/04.
  - Running production at 400 MHz/100% reprod.
- RBRC– 12,288 nodes -- $5M – 4-5 Tflops sustained.
  - Installed at BNL 2/05.
  - 1/3 in production. 420 MHz/100% reprod.
  - 2/3 performing physics tests.
- DOE– 12,288 nodes -- $5.1M – 4-5 Tflops sustained
  - Installed at BNL 4/05.
  - 3/4 performing physics tests.
  - 1/4 being debugged.
- Price/performance of ~$1/Mflops.

Final Bring-up issues

- FPU errors
  - Lowest two bits infrequently incorrect. (Not present at 400MHz.)
  - Remove slow nodes at 432MHz and run at 400MHz.
- Serial communication errors.
  - Induced by Ethernet activity.
  - 0.25/month at 400 MHz/1K nodes.
  - Further reduced by PLL tuning.
  - Protected by hardware checksums with no performance loss.
- Parallel disk system
  - 12 Tbyte RAID servers.
  - 512-nodes achieve 12 Mbytes/sec.
  - Installed 04/05
- Larger machine partitions
  - Two 4096-node partitions assembled.
  - Expect to run as 4096 + 4096+4*1024 node machines?
- Spares
  - 1% non-functioning daughter boards
  - 1.5% non-functioning mother boards
  - ~12 mother boards for small jobs/code development.

Application Performance
(Demonstrated on a 1024-node machine)

Fermion action	Local volume	Dirac performance	CG performance
Wilson	2^4	44%	32%
Wilson	4^4	44%	38%
Clover	4^4	54%	47.5%
DWF	4^5	47%	42%
ASQTAD	4^4	42%	38%

These are our present numbers and should improve as more code tuning is done.

Outlook

- New QCDOC machine offers >10x capability.
- They will be used to generate large sets of lattice configurations: Dynamical domain wall fermions
- Increased US/Japan/UK collaboration.
- We are now beginning to dream of petaflops computers with price/performance of $0.01/Mflops.

The Future: QCDOC++

- Reduced feature size and increased integration permits many nodes per chip (multi-core trend).
- QCDOC → QCDOC++
  - Clock speed (GHz): 0.4 → 1?
  - Integration (nodes/chip): 1 → 64?
  - Performance (Gflops): 0.4 → 2?
  - Inter-node comms (Gbyte/sec): 1 → 10?
  - On chip memory (Mbytes/chip): 4 → 32?
- Target: $0.01/Mflops price performance (1/100 x QCDOC).
- 100x speed-up permits increased 2x problem size per node.
- Production machine in 2009?

RHIC SPIN PROGRAM

Gerry Bunce

RHIC SPIN Program

Gerry Bunce

Presentation
11th Meeting of The Management Steering Committee of RIKEN BNL Collaboration

May 27, 2005
Brookhaven National Laboratory, Upton, NY

RBRC Management Steering Committee
27 May 2005
G. Bunce

RHIC Spin Program

...to study the spin structure of the proton

- History
- 2004 Spin Run
- Physics results: Spin2004 at Trieste, Italy
- 2005 Spin Run
- Spin Plan

a history of the strong interaction:

1964: **"quarks" ...to understand the zoo of strongly interacting particles; "color" quantum number ...to describe the** Ω^- (sss, S=3/2)

1967: **quarks are real! ...from hard inelastic scattering of electrons from protons at SLAC**

1973: **the theory of QCD ...quarks and "gluons" and color; *perturbative* QCD**

1980s to present: **e-p and pbar-p colliders ...beautiful precision tests of pQCD, *unpolarized***

.....

1970s: ***polarized* beams and targets**

1988: **the spin of the proton is not carried by its quarks!**

1990s to present: **confirmed in "DIS" fixed target experiments using electrons and muons to probe the spin structure of the proton**

2001 to present: **probe the spin structure of the proton using quarks and gluons *(strongly interacting probes see both the gluons and quarks in the proton):* RHIC**

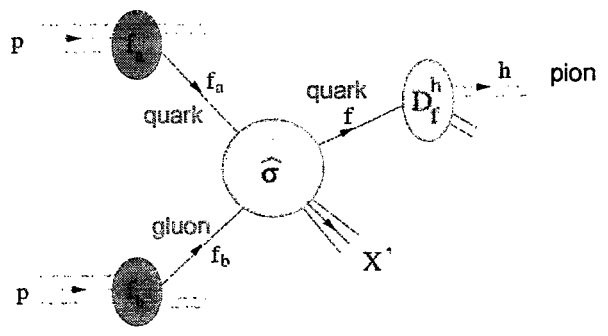
Spin is one of the most fundamental concepts in physics, deeply rooted in Poincare invariance and hence in the structure of space-time itself. All elementary particles we know today carry spin, among them the particles that are subject to the strong interactions, the spin ½ quarks and the spin 1 gluons. Spin, therefore, plays a central role also in our theory of the strong interactions, QCD, and to understand spin phenomena in QCD will help to understand QCD itself.

To contribute to this understanding is the primary goal of the spin physics program at RHIC.

Measuring the proton spin structure…

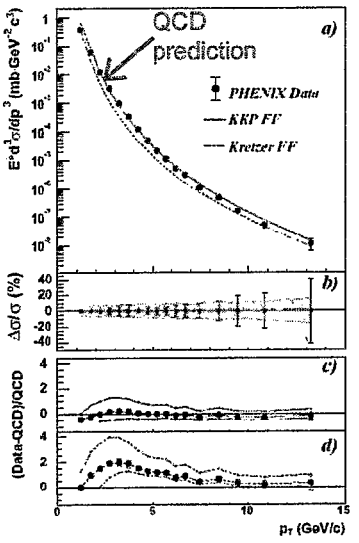
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

Quarks contribute only 20%!



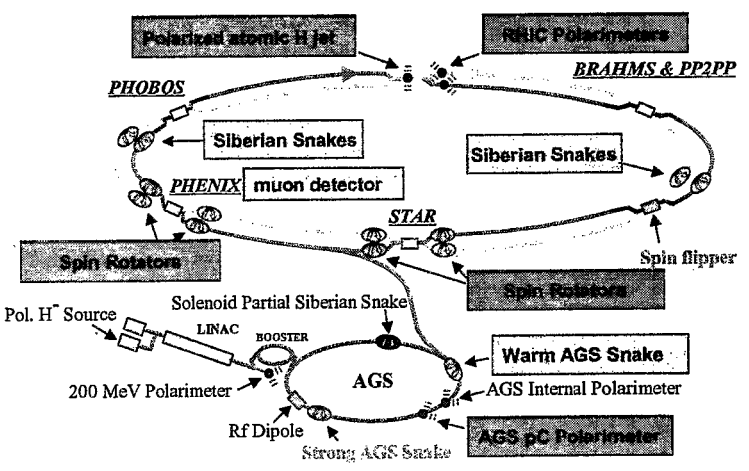
Cornerstone to the RHIC Spin program

$pp \rightarrow \pi X$



Physical Review Letters **91**, 241803 (2003)

RHIC Polarized Collider



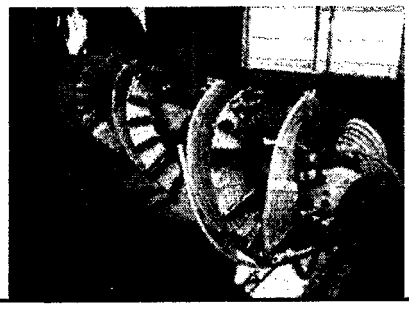
RIKEN/RBRC

DOE/RIKEN/RBRC

RIKEN/RBRC: RHIC Spin Hardware

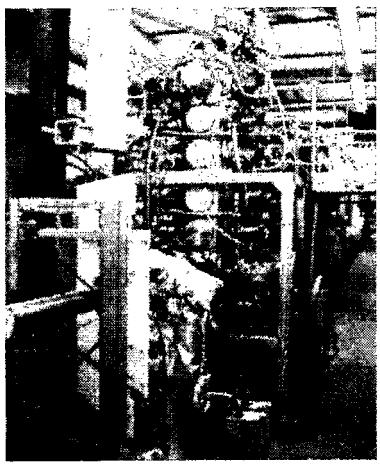
1996-2000: PHENIX Muon Detector

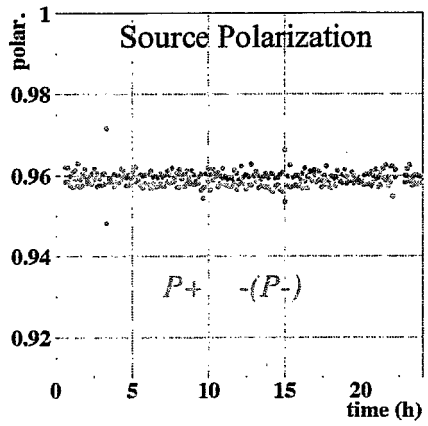
1996-2001:
Siberian Snakes



2003-4: Warm AGS Snake

2004: RHIC Polarized Atomic H Jet

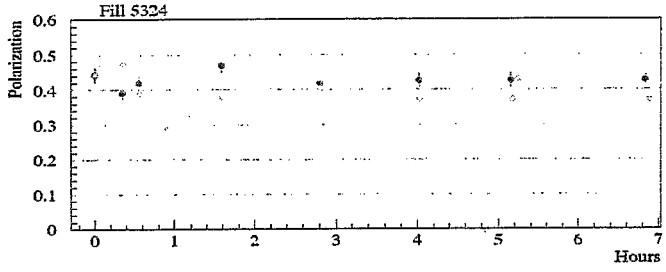




$$P_{Beam} = P_{Jet} \times \frac{\epsilon_{Beam}}{\epsilon_{Jet}} \text{ where } \epsilon = \frac{N_{up} - N_{down}}{N_{up} + N_{down}}$$

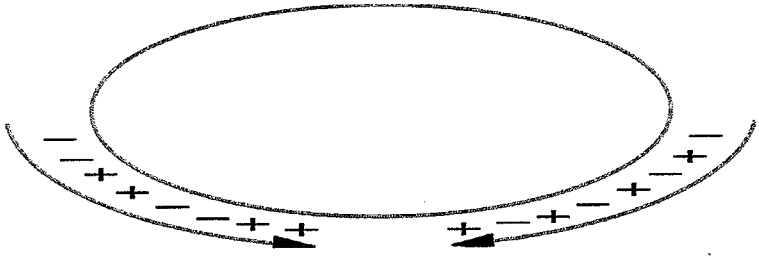
4

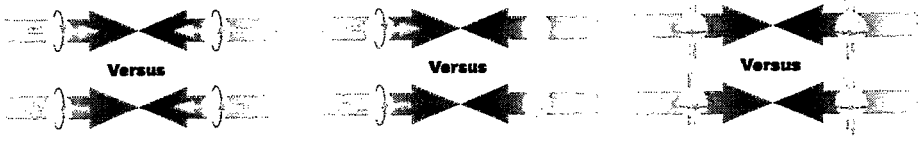
2004: Polarization in RHIC



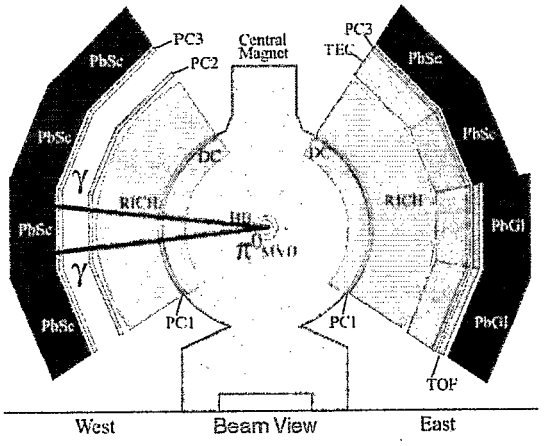
RUN4

Exquisite Control of Systematics



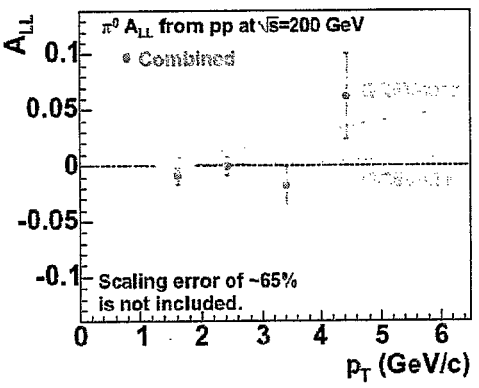


PHENIX Experimental Setup



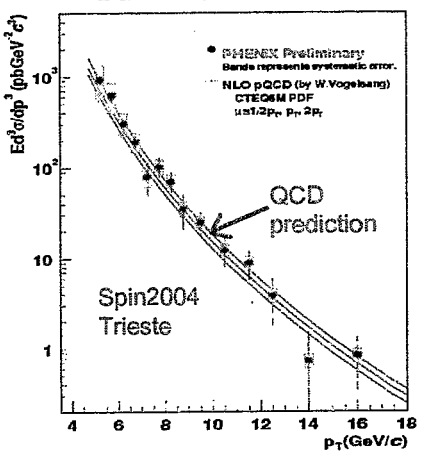
- Central spectrometer arms $|\eta| < 0.35$
  - γ, π^0 via $\pi^0 \rightarrow \gamma\gamma$
  - Electromagnetic calorimeter (EMCal)
    - Lead scintillator calorimeter (PbSc)
    - Lead glass calorimeter (PbGl)

2004: Gluon polarization and Direct γ



Spin2004, Trieste:
2003: Phys. Rev. Lett. **93**, 202002 (1994) and 2004 data combined

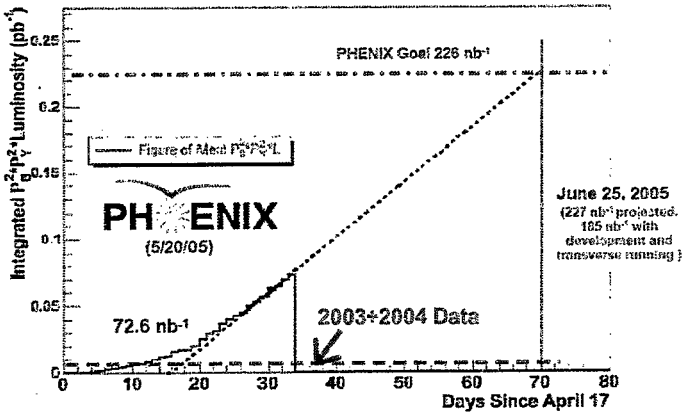
$pp \rightarrow \gamma X$



...also a cornerstone of the RHIC Spin program

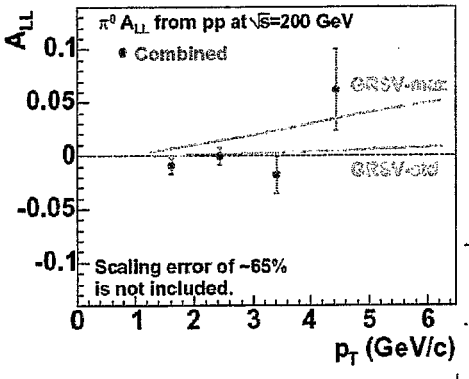
2005 Run

200 GeV pp "Figure of Merit"

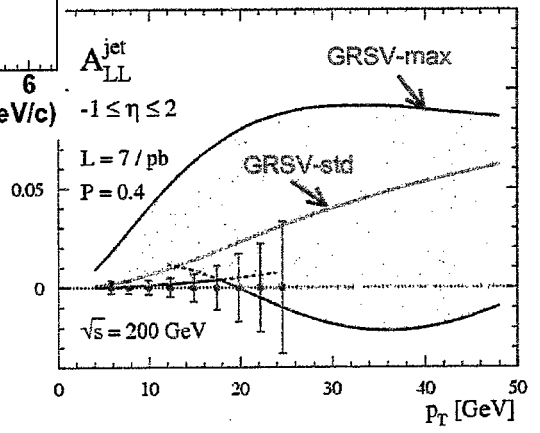


5/24/05 J. Lajoie - RHIC Time/Machine-Expt Meeting 3

2003+2004 Data



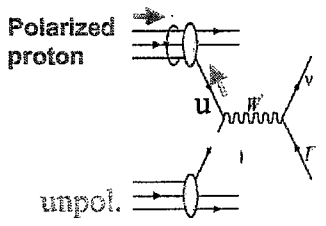
Projected 2005 sensitivity



RHIC Spin Physics Program

- *Direct measurement* of polarized gluon distribution *using multiple probes*
- Direct measurement of *anti-quark polarization* using parity violating production of $W^{+/-}$
- Transverse spin: Transversity & transverse spin effects: possible connections to orbital angular momentum?

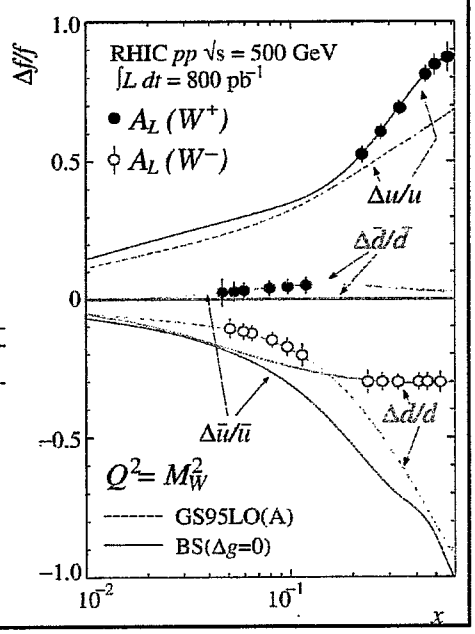
Δq-$\bar{\Delta} q$ at RHIC via W production

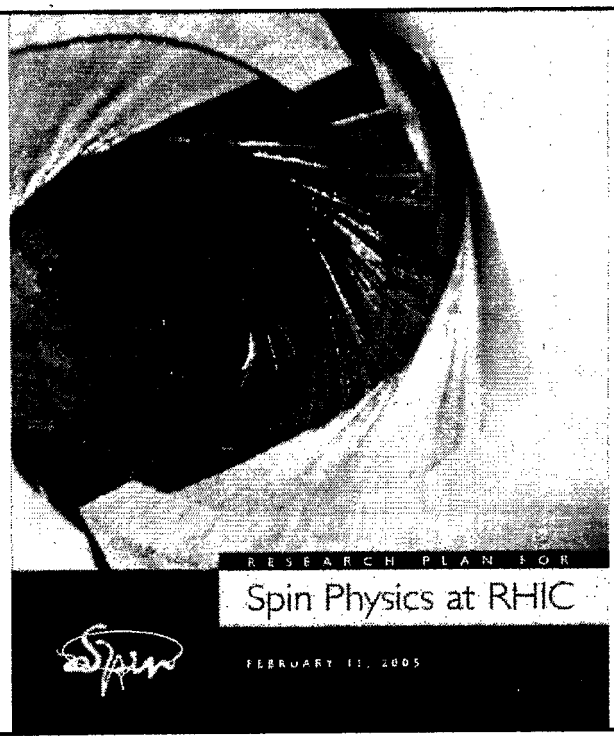


$$\Delta d + \bar{u} \rightarrow W^-$$
$$\Delta \bar{u} + d \rightarrow W^-$$
$$\Delta \bar{d} + u \rightarrow W^+$$
$$\Delta u + \bar{d} \rightarrow W^+$$

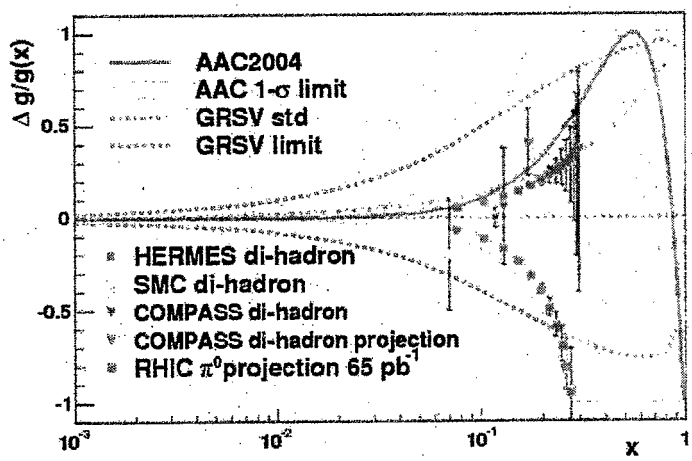
$$\mathbf{A_L} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

PHENIX & STAR Upgrades:
Begin 2009

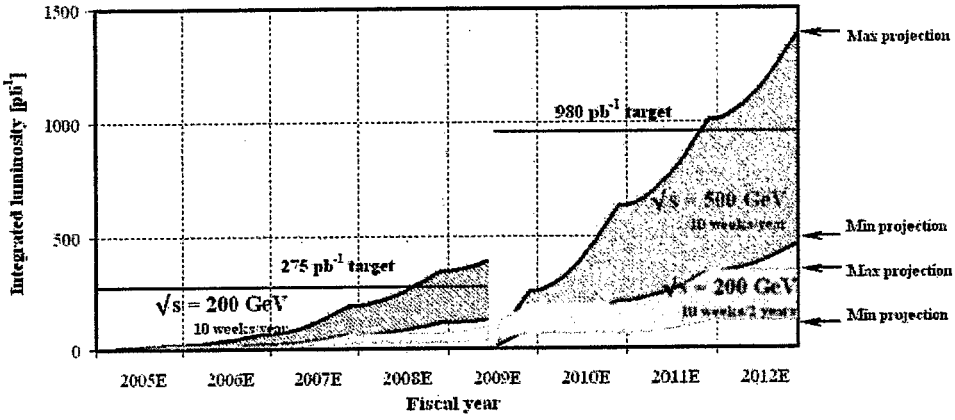




Gluon Polarization Sensitivity Of RHIC Spin



RHIC Spin Plan: Luminosity Projections



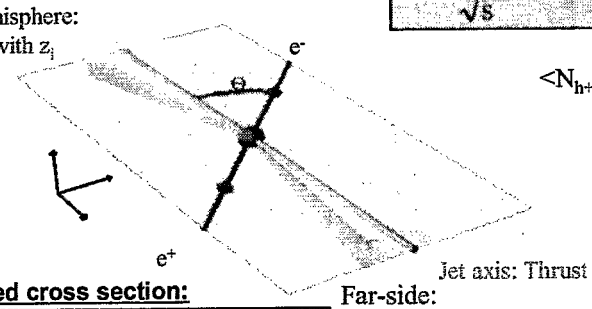
RBRC at Belle: quark analyzing power

e^+e^- CMS frame:

$z = \frac{2E_h}{\sqrt{s}}$, $\sqrt{s} = 10.52\ GeV$

Near-side Hemisphere:
h_i, $i=1,N_n$ with z_i

$\langle N_{h+,-} \rangle = 6.4$



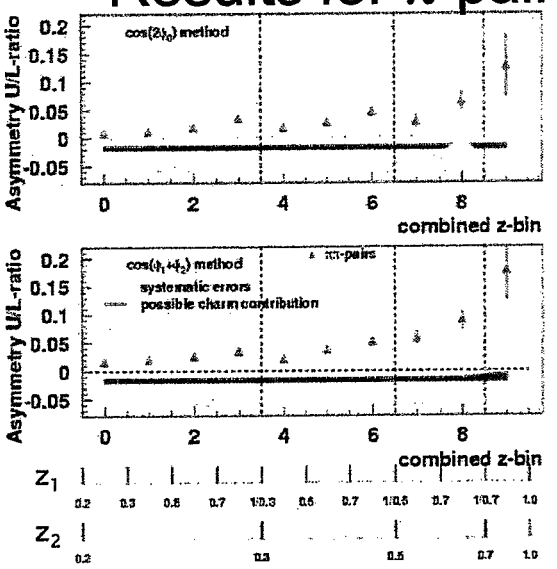
Far-side:
h_j, $j=1,N_f$ with z_j

Spin averaged cross section:

$$\frac{d\sigma(e^+e^- \to h_1 h_2 X)}{d\Omega dz_1 dz_2} = \frac{3\alpha^2}{Q^2} A(y) \sum_{a,\bar{a}} e_a^2 D_1(z_1) \bar{D}_1(z_2)$$

$$A(y) = \left(\frac{1}{2} - y + y^2\right) \overset{(cm)}{=} \frac{1}{4}(1 + \cos^2\Theta)$$

Results for π-pairs for $30fb^{-1}$



Ralf Seidl (RBRC) at DIS05, Madison, Wisc. April 05

Quark fragmentation has very large analyzing power!

RHIC HEAVY ION PROGRAM

Yasuyuki Akiba

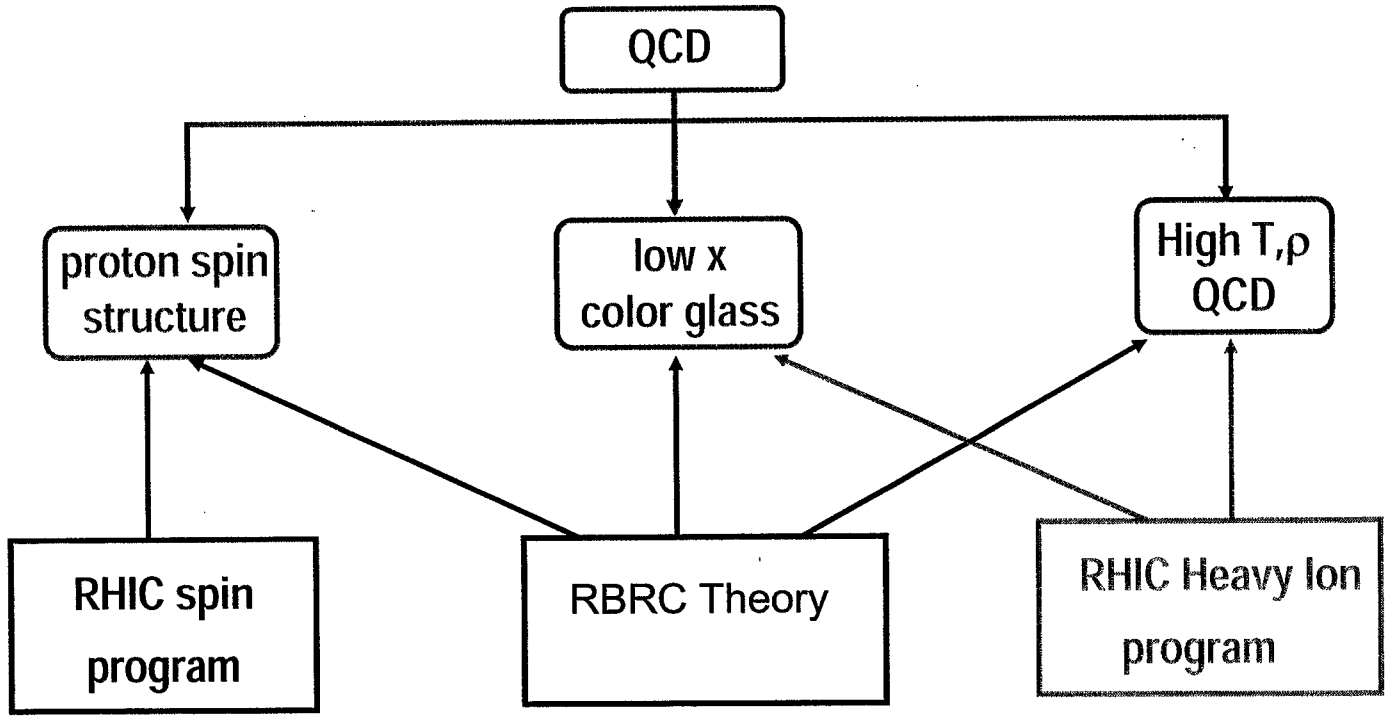
RHIC Heavy Ion Program

Y. Akiba

Presentation
The management Steering committee of
RIKEN BNL collaboration

May 27, 2005
Brookhaven National Laboratory, New York, USA

RBRC and RHIC: Unique QCD laboratory



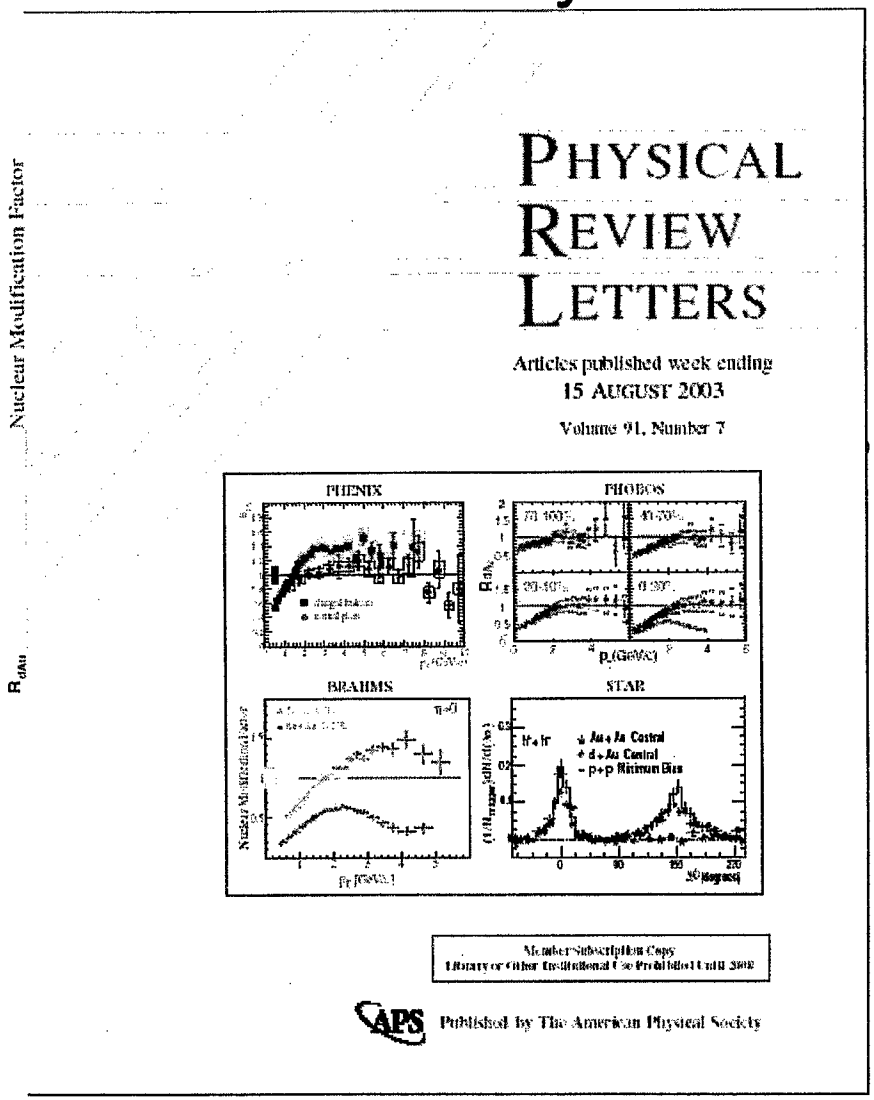
RHIC: Accelerator dedicated for study of QCD (strong nuclear force)
RBRC theory: Center of QCD theory from Lattice to pQCD to Heavy Ion
RBRC and RIKEN plays leading role in both of the spin and heavy ion physics

Heavy Ion Physics at RHIC

- Create very high temperature and dense matter
  - As existed a few μ sec after the BIG BANG
  - Collide heavy nuclei to achieve maximum volume
  - 5 Runs since the start of RHIC in year 2000

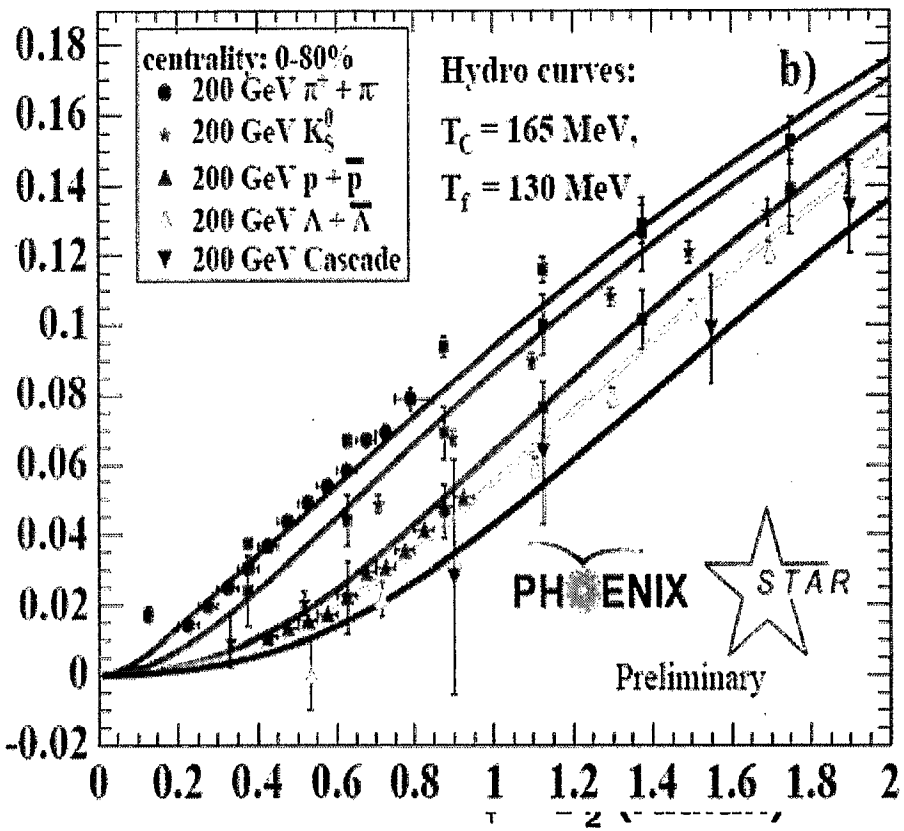
    Au+Au (Run1,2,4) d+Au (Run3) Cu+Cu (Run5)
- RHIC has produced high density partonic matter
  - The four experiments of RHIC concluded in their white papers that RHIC Au+Au collisions produced very high density matter
  - The matter is strongly interacting, and it behaves like an ideal fluid (perfect liquid) – unexpected discovery.
- Next step: Detailed study of the newly discovered matter
  - How hot and dense is the medium?
  - Is thermal equilibrium achieved?
  - Is the matter de-confined?
  - What is the equation of state?

Discovery of dense partonic matter



- Jet Quenching
  - Strong suppression of high p_T particle production in Au+Au collision at RHIC
  - Direct evidence of formation of very dense matter
- Absence of suppression in d+Au collision
  - The suppression effect is due to *high density matter* produced in Au+Au collision

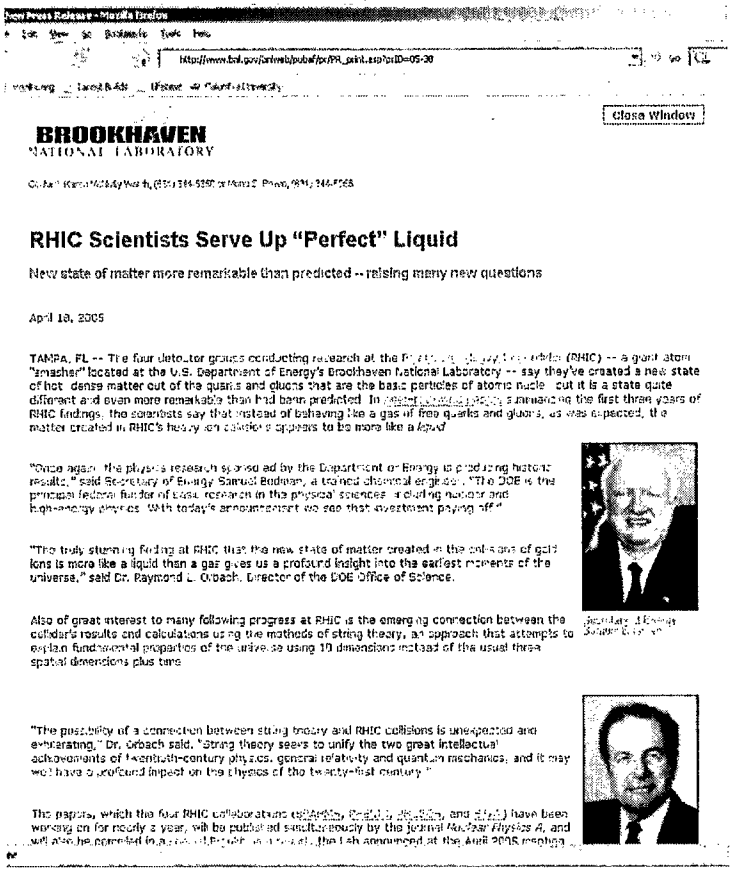
The behavior of the matter



- The matter produced at RHIC behaves like fluid. It "flows".
- The flow is strong evidence for rapid thermalisation of the matter.
- The pattern of the "flow" is described by hydrodynamic calculation of ideal fluid (no viscosity)

→ Near "Perfect Liquid"

RHIC Success



close window

BROOKHAVEN
NATIONAL LABORATORY

RHIC Scientists Serve Up "Perfect" Liquid

New state of matter more remarkable than predicted -- raising many new questions

April 18, 2005

TAMPA, FL -- The four detector groups conducting research at the R[illegible] (RHIC) -- a giant atom "smasher" located at the U.S. Department of Energy's Brookhaven National Laboratory -- say they've created a new state of hot, dense matter out of the quarks and gluons that are the basic particles of atomic nuclei -- but it is a state quite different and even more remarkable than had been predicted. In [illegible] summarizing the first three years of RHIC findings, the scientists say that instead of behaving like a gas of free quarks and gluons, as was expected, the matter created in RHIC's heavy ion collisions appears to be more like a *liquid*.

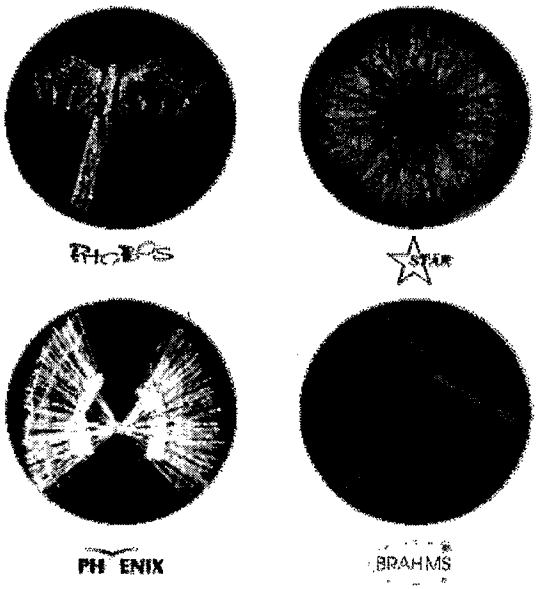
"Once again, the physics research sponsored by the Department of Energy is producing historic results," said Secretary of Energy Samuel Bodman, a trained chemical engineer. "The DOE is the principal federal funder of basic research in the physical sciences, including nuclear and high-energy physics. With today's announcement we see that investment paying off."

"The truly stunning finding at RHIC that the new state of matter created in the collisions of gold ions is more like a liquid than a gas gives us a profound insight into the earliest moments of the universe," said Dr. Raymond L. Orbach, Director of the DOE Office of Science.

Also of great interest to many following progress at RHIC is the emerging connection between the collider's results and calculations using the methods of string theory, an approach that attempts to explain fundamental properties of the universe using 10 dimensions instead of the usual three spatial dimensions plus time.

"The possibility of a connection between string theory and RHIC collisions is unexpected and exhilarating," Dr. Orbach said. "String theory seeks to unify the two great intellectual achievements of twentieth-century physics, general relativity and quantum mechanics, and it may well have a profound impact on the physics of the twenty-first century."

The papers, which the four RHIC collaborations (PHENIX, PHOBOS, BRAHMS, and STAR) have been working on for nearly a year, will be published simultaneously by the journal *Nuclear Physics A*, and will also be posted in a [illegible] at the lab announced at the April 2005 meeting.

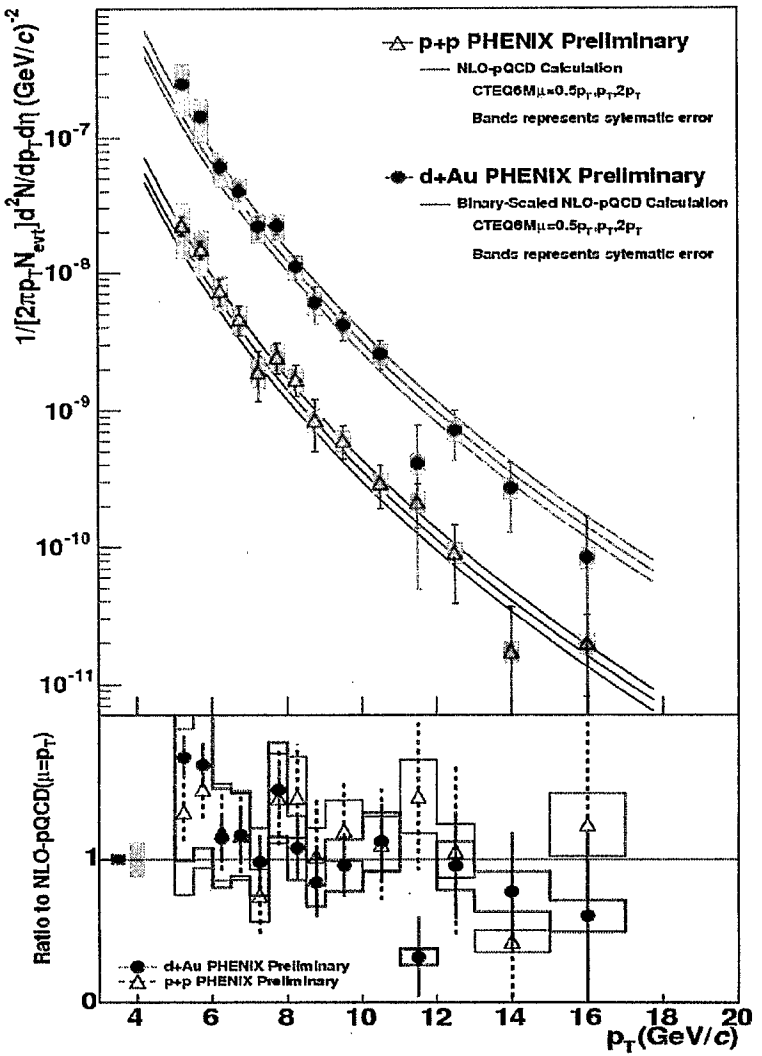


- The results of the first 3 years of RHIC is summarized in the White Papers of the 4 experiments. (Accepted in Nuclear Physics A in April 2005)
- Concluded that *a new state of dense matter* is formed.

Success ≠ Done

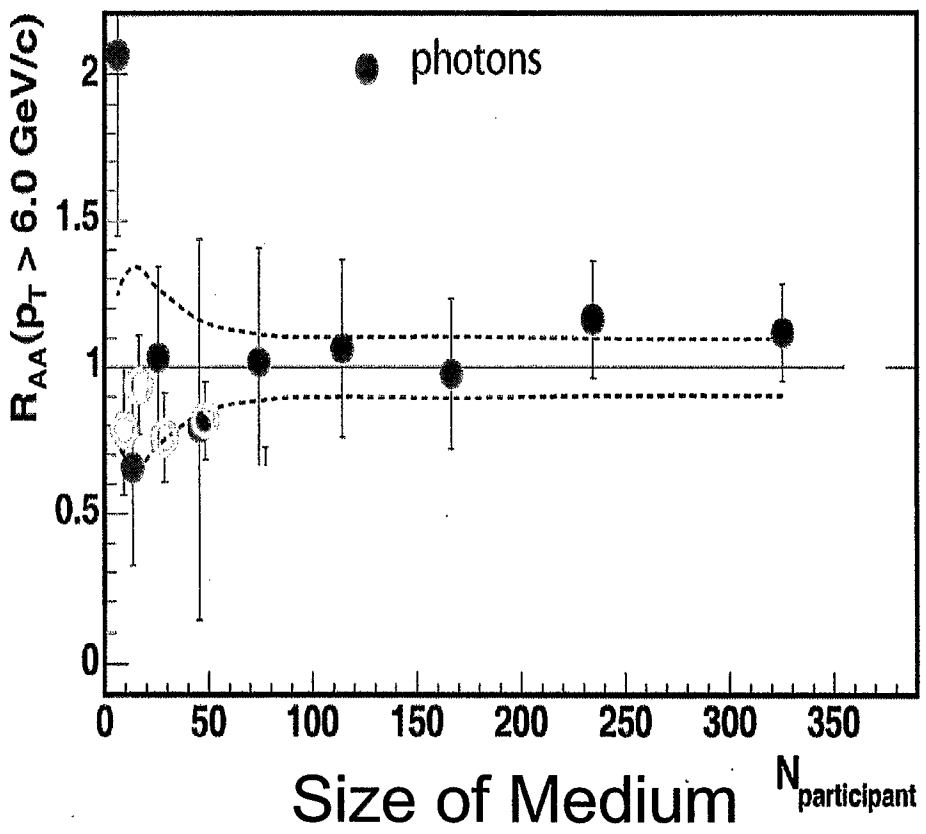
- Discovery of a new form of dense matter is just beginning of the further research
- There are still many unanswered questions
  - Direct Evidence of de-confinement
  - The mechanism of (apparently) instant thermalisation of the matter
  - Quantitative measurements of the property of the matter
    - Temperature
    - Energy density
    - Degree of Freedom
    - Hydro-dynamical properties
    - etc
- Investigation of deep inside of the dense matter using penetrating probes is more and more important
  - EM probes (direct photon, thermal di-lepton)
  - Open Heavy Quarks (charm, bottom)
  - High p_T jets

Highlights in the last year (1)
Direct Photon in p+p and d+Au



- Direct photon is among the cleanest probe of the dense matter
- pQCD calculation agrees very well with the direct photon data measured by PHENIX
  - Direct photon is a calibrated probe of the initial state
- In d+Au collision, the yield of direct photon scales with the number of binary N+N collisions
  - No significant nuclear effect in the initial state
- Important contribution by RIKEN and RBRC personnel to these analyses
  - K. Okada (RBRC) p+p direct photon
  - H. Torii (RIKEN) d+Au direct photon

Highlights (2)
Direct photon in Au+Au

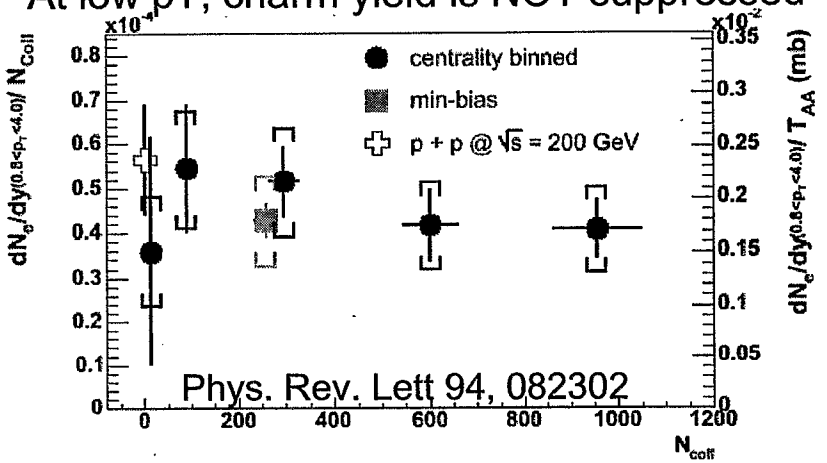


PHENIX nucl-ex/0503003
Accepted in PRL

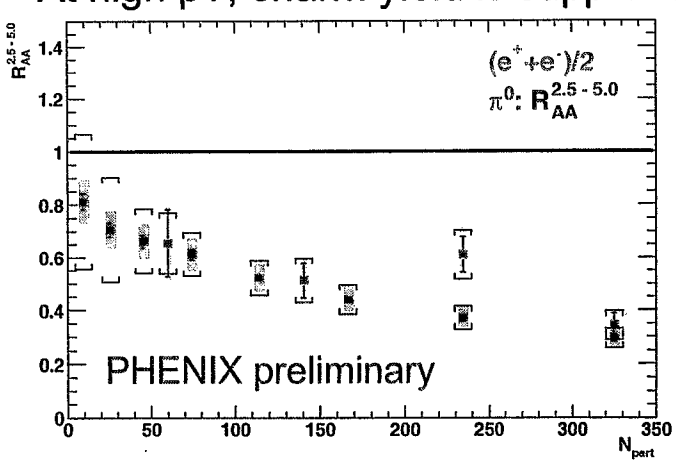
- Direct photon is measured in Au+Au collision as function of size of reaction zone
- In Au+Au collision, the yield of direct photon scales with number of N+N collisions
- In contrast, high p_T π^0s from quarks and gluons disappear in the medium
- Confirm again that the jet quenching is due to the effect of the dense matter created at RHIC

Highlight (3)
Is heavy quark stopped in medium?

At low pT, charm yield is NOT suppressed

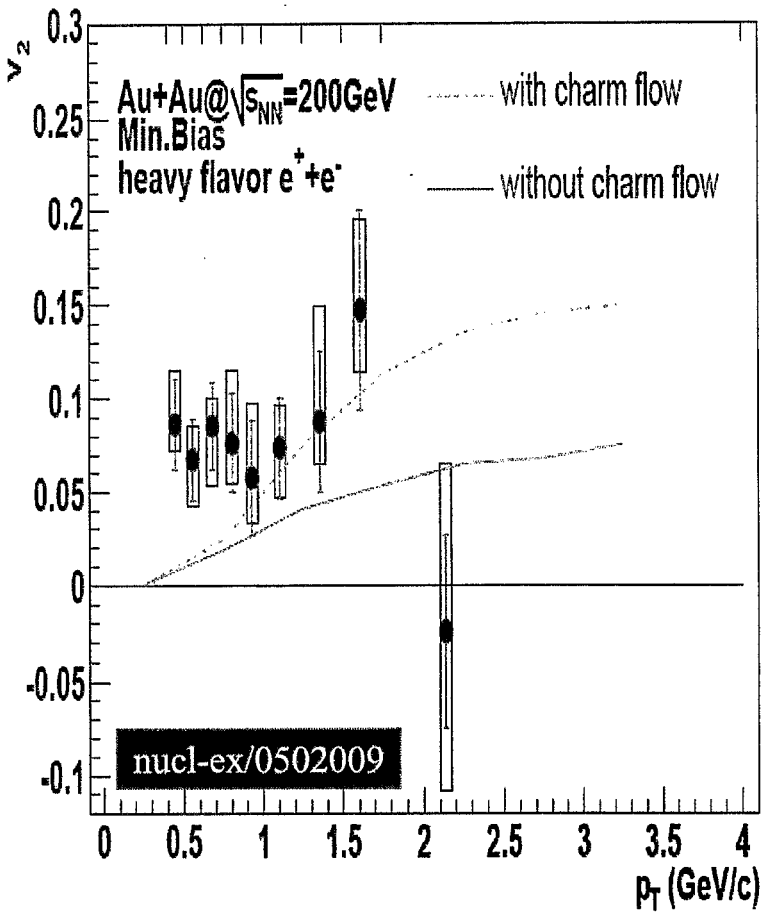


At high pT, charm yield is suppressed



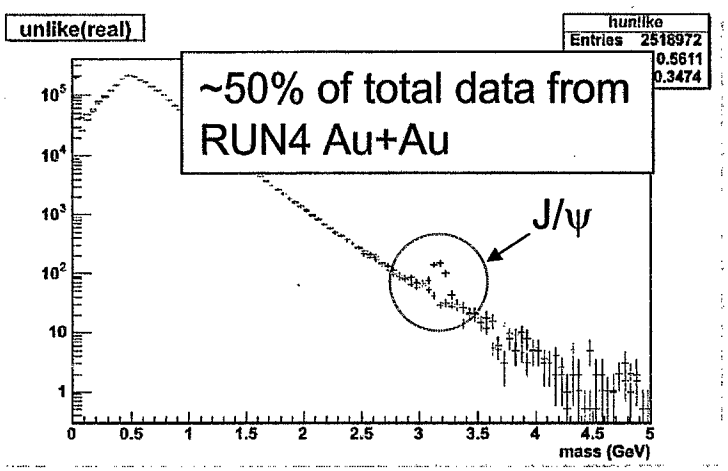
- Heavy quarks (charm and bottom) are probes of dense matter created in RHIC collisions
- PHENIX pioneered charm measurement at RHIC through electron decay channel.
- PHENIX measurement of charm production suggests that charm lose significant energy in the dense medium.
- Important contribution by RIKEN personnel to the analysis
  - T. Hachiya (RIKEN, JRA2)
  - YA

Hightlights (4)
Does heavy quark flow like light quark?

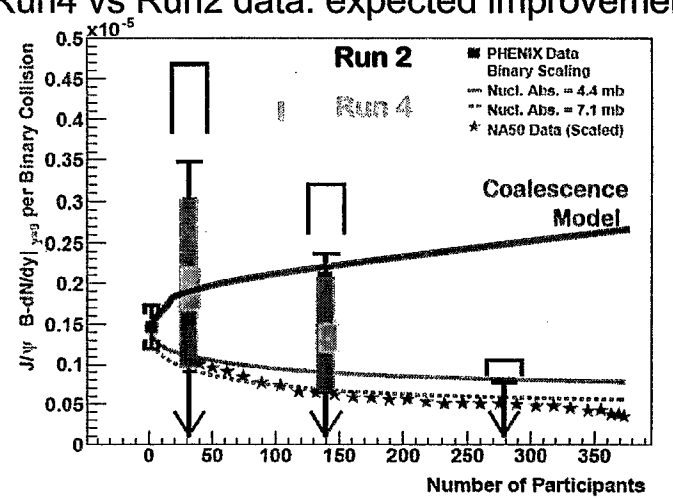


- PHENIX has measured significant elliptic flow of electrons from charm (heavy quark) decay.
- The present data (RUN2) is statistically limited, and we can not conclude if charm quark in the medium flows or not.
- Measurement of charm flow is important to determine the property of the dense matter.
- Much improved data from RUN4 Au+Au will be available soon.

Coming soon
J/ψ in Au+Au --- probe of deconfinment

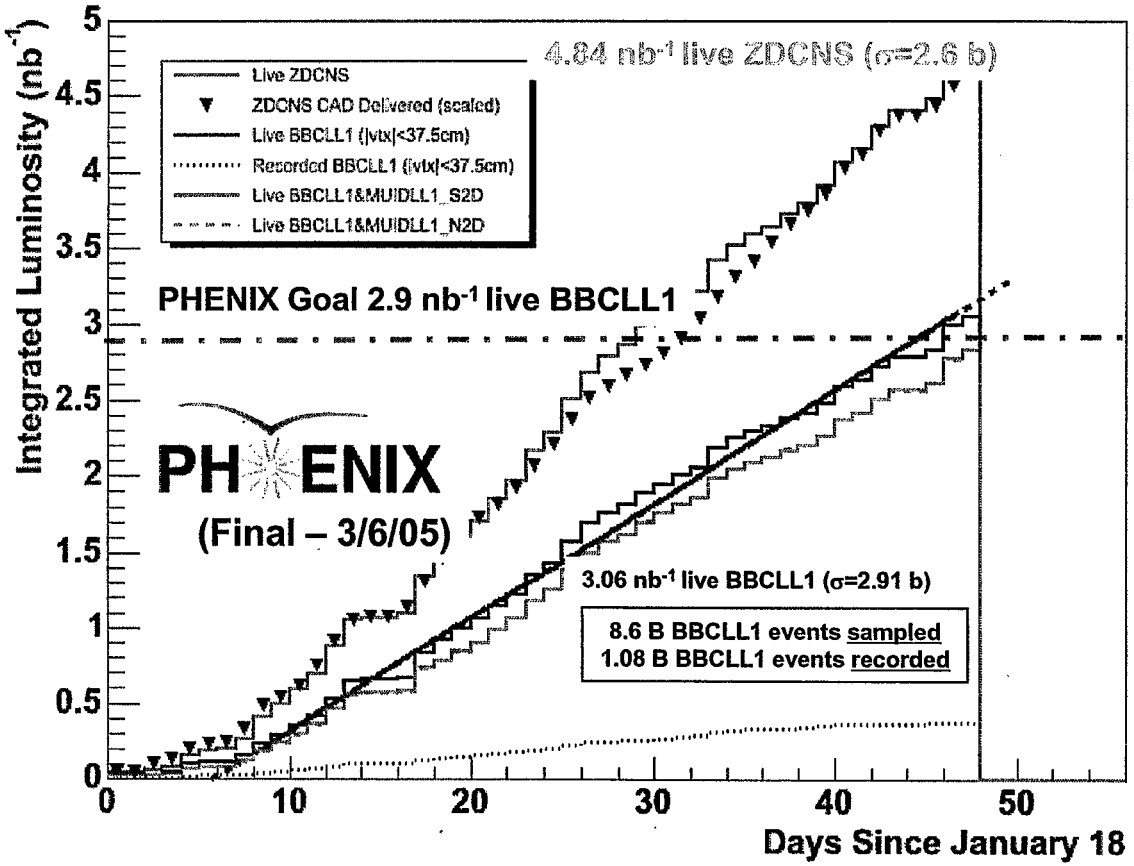


Run4 vs Run2 data: expected improvement



- It is predicated that J/ψ meson (bound state of c and cbar) disappears in de-confined medium.
- The first measurement of J/ψ by PHENIX in RHIC RUN2 (2001-2) is inconclusive due to limited statistics.
- The results from much higher statistics RUN4 data will be available soon.

More data from RHIC/PHENIX RUN5 Cu+Cu



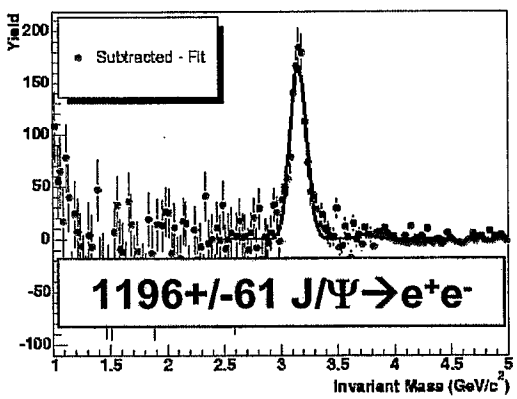
Experiment to study "size" effect

Important step to complete baseline program at RHIC

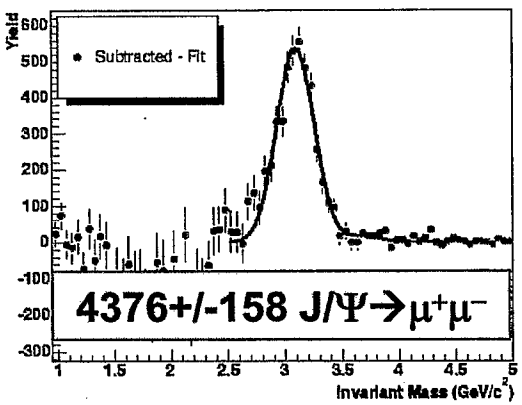
Data taking has been completed. Exceeded the goal of amount of recorded data.

Online results from RUN5 Cu+Cu

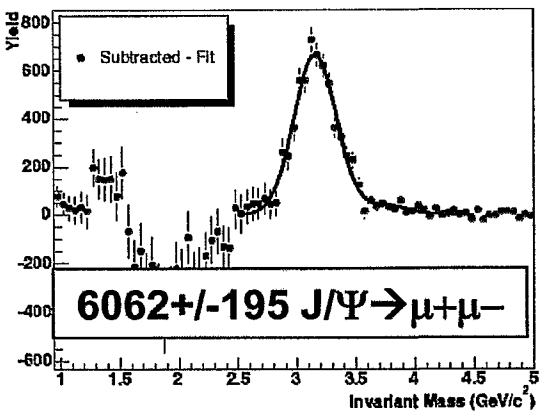
Central Arms



North Muon Arm

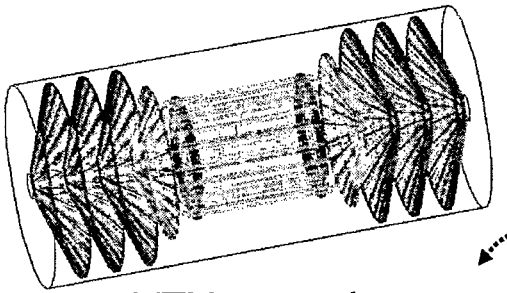


South Muon Arm



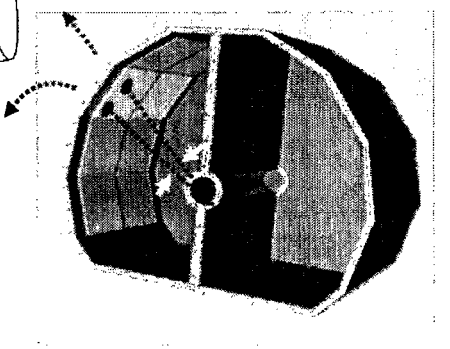
- Heavy Ion part of RHIC RUN5 (Cu+Cu) is very successful
- Clear signals of J/ψ (a very rare but important probe of dense matter) are seen in online reconstruction. 1,200 J/ψ→ee and 10,000 J/ψ→μμ are reconstructed
- Polarized p+p part of RUN5 is on-going

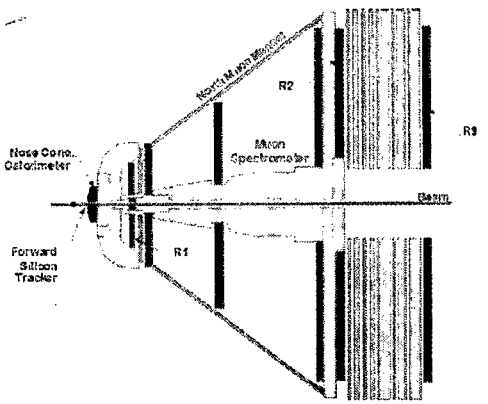
For Future --- detector upgrade



VTX upgrade

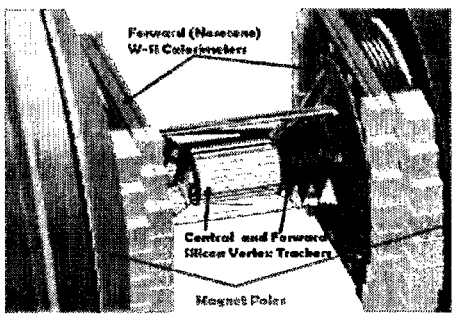
Hadron Blind Detector upgrade





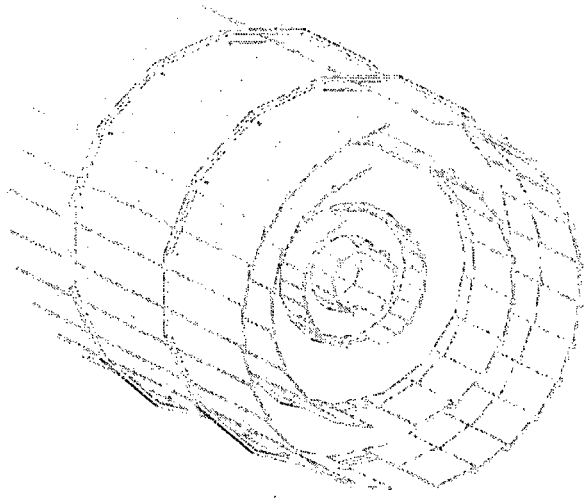
Forward muon Trigger upgrade

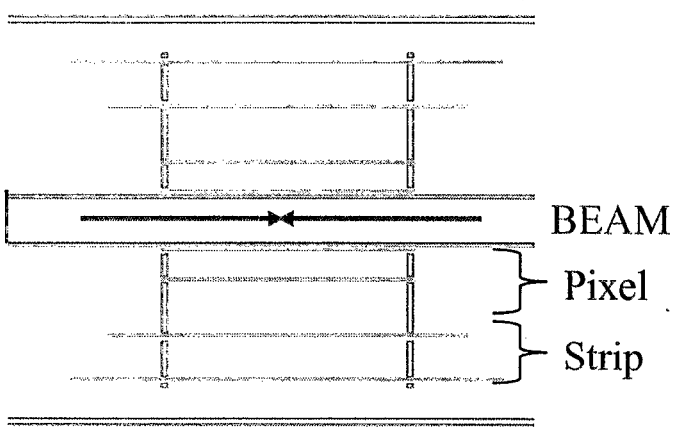
Nose cone calorimeter



- The present PHENIX detector is already very successful. However, in order to explore full physics potential that RHIC provides, upgrades of the detector is required.
- Several upgrade projects are underway.
- RIKEN/RBRC have large contribution to
  - **VTX detector upgrade**
  - Forward muon trigger

PHENIX VTX upgrade project

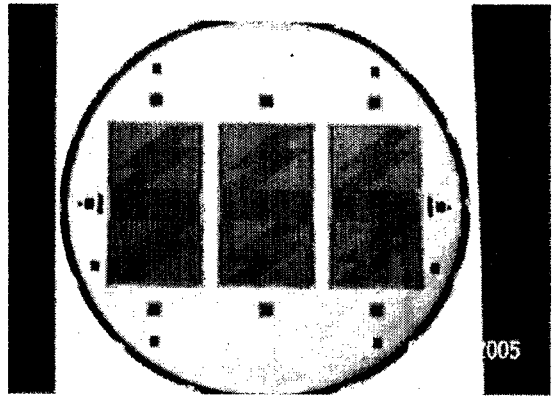




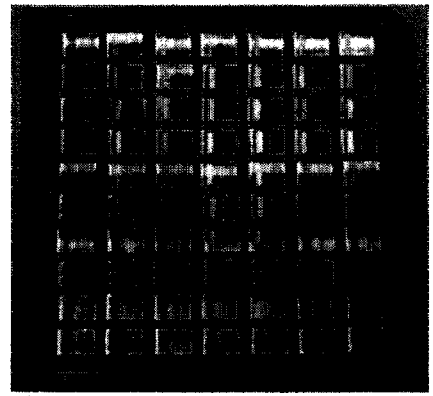
- Key device to improve heavy quark measurement at RHIC/PHENIX
  - Identify charm/bottom decay by precision tracking ($\sigma \sim 50\mu$)
  - Provides near 4π acceptance
- Project lead by RIKEN/RBRC
  - Y. Akiba (RIKEN) : project manager
  - H. Ohnishi (RIKEN): pixel manager
  - A. Deshpande (StonyBrook/RBRC) strip manager
- Proposal submitted to DOE in summer 2004
  - 72 authors from 14 institutions
- Recommended as the 1st priority in NSAC subcommittee report in November 2004
- Aims to complete in FY2008

VTX upgrade activities in 2004-2005

People in a new clean room for strip detector test at BNL

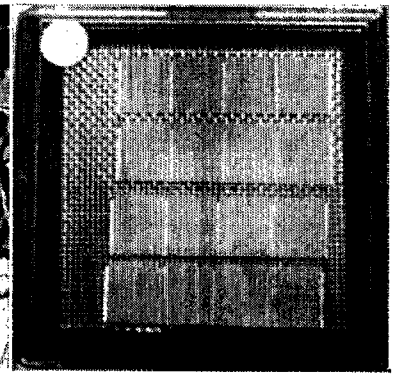


Pre-production strip sensors



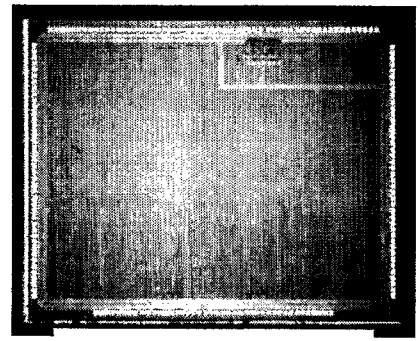
SVX4 read-out chips for the strip detector

Pixel readout chip test at CERN



Pixel sensors bump bonded with the read-out chips

Dr. Kano(RIKEN) designing an ASIC for pixel detector



Produced ASIC

RIKEN/RBRC in PHENIX

- 2 deputy spokesperson (out of 2)
  Y. Akiba (RIKEN)
  M. G-Perdekamp (U. Illinois/RBRC)
- 4 EC members (out of 13)
  Y. Akiba (RIKEN)
  M. G-Perdekamp (U. Illinois/RBRC)
  A. Deshpande (StonyBrook/RBRC)
  N. Saito (Kyoto/RIKEN)
- 3 PWG conveners (out of 14)
  M. Kaneta (RBRC → Tohoku)
  X. Wei (RBRC)
  A. Deshpande (StonyBrook/RBRC)
- PHENIX VTX upgrade project
  Y. Akiba (RIKEN): project manager
  H. Ohnishi (RIKEN): pixel subsystem manager
  A. Deshpande (StonyBrook/RBRC): strip subsystem manager
- Large role in PHENIX operations and data analysis
  - PHENIX Level-1 trigger system
  - Local Polarimeter
  - RICH
  - EMCal
  - Muon arms
- Large role in PHENIX publications
  - 7 out of 14 published/accepted journal publications (most of them Phys. Rev. Letters) since the last MSC meeting have RIKEN/RBRC members in the paper preparation group

Summary

- A new form of dense matter is created in heavy ion collision at RHIC
  - Suppression of high pT particles due to matter effect
  - Large elliptic flow --- the matter behaves like a perfect liquid
- The next step of heavy ion physics at RHIC is to determine the property of the newly discovered matter
  - Importance of penetrating probes such as direct photon, heavy quarks and J/ψ.
  - Upgrade of the detector for better measurement of the mater properties and to explore the full physics opportunity
- RIKEN and RBRC plays very important role in this rapidly evolving field of phyiscs

RIKEN's CURRENT STATUS AND FUTURE PLANS

Yoshiharu Doi

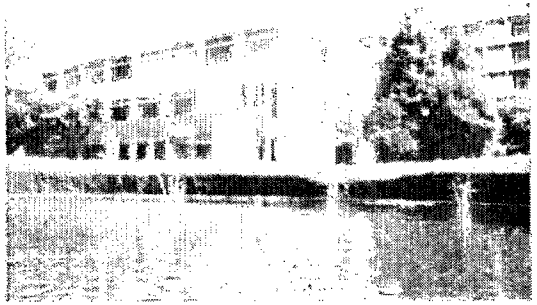
RIKEN's Current Status and Future Plans

Yoshiharu Doi

Presentation
11th Meeting of The Management Steering Committee of RIKEN BNL Collaboration

May 27, 2005
Brookhaven National Laboratory, Upton, NY

RIKEN



Outline of *RIKEN*

"Rikagaku Kenkyusho" (RIKEN)

理化学研究所　（理研）

History of RIKEN- From Foundation to Semi-Public Research Institute

Since
1917
Foundation
RIKEN

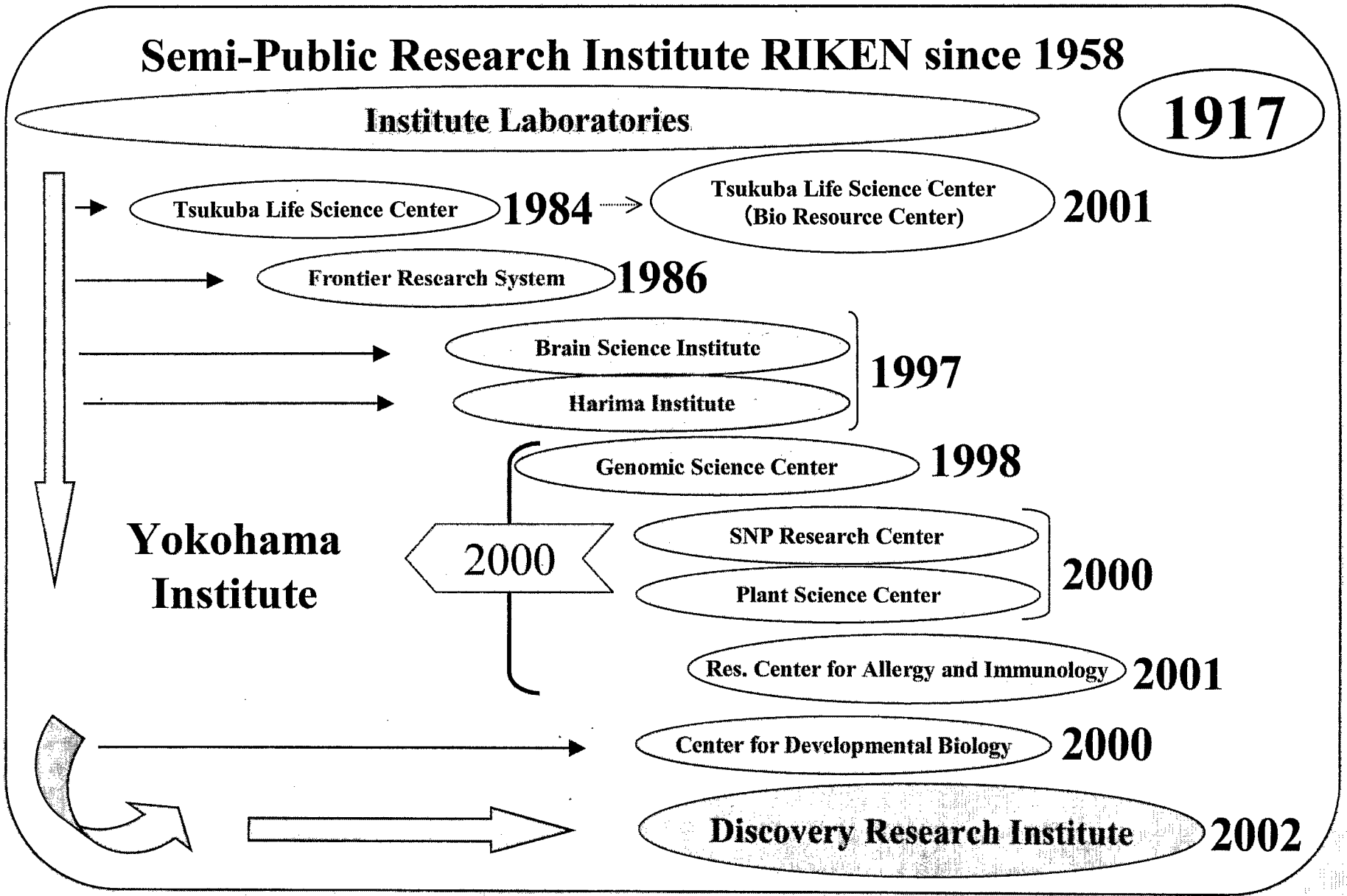
Since
1948
Stock Company
RIKEN

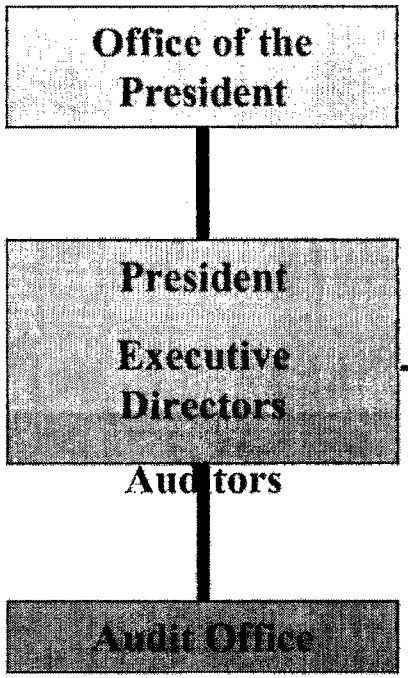
Since
2003
Independent
Administrative
Institution
RIKEN

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

RIKEN

History of Centers in RIKEN since 1958





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 ResearchUnit/ Sponsord 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 Labolatories (ILs)

Division of Bio-Crystalography 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

RIKEN Wako Main Campus

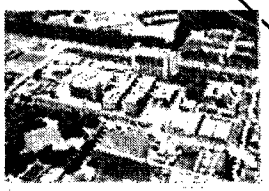
Planning Division/ Public Relations Office/ General Affairs Division/ Personnel Division/ Finance Division/ Contract Management Division/ Technology Transfer and Research Coordination Division/ Safety Division/ Facilities and Utilities Division/ Advanced Center for Computing and Communication/ Internal Auditing Office

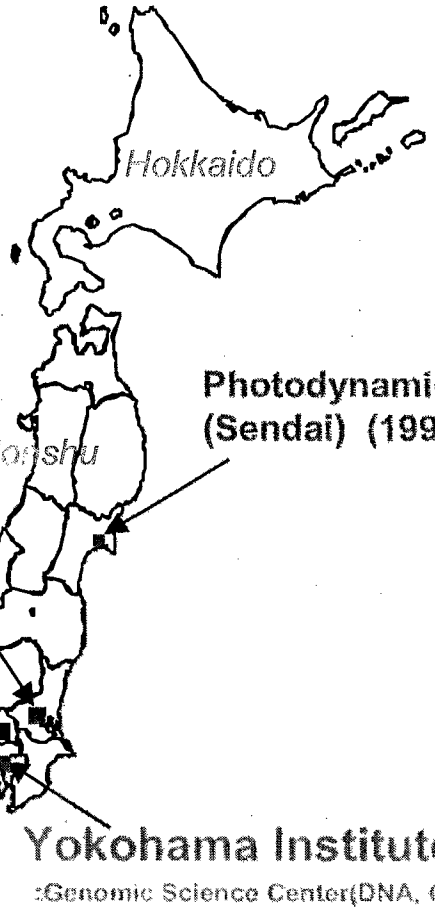
RIKEN's Research Locations

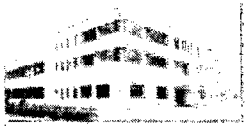
RIKEN

Wako Main Campus (1956 -)
Discovery Research Institute (2002-)
Frontier Research System (1986 -)
:Further Advanced Fields
Brain Science Institute (1997 -)
:Understand/Protect/Create the Brain

Tsukuba Institute (1984 -)
:Recombinant Technology
Bio Resource Center

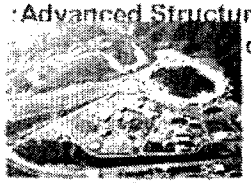




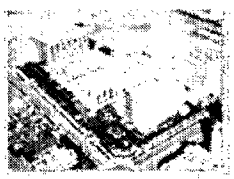


Photodynamics Research Center (Sendai) (1991 -)

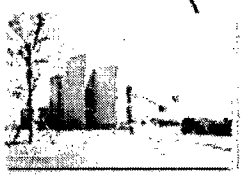
Harima Institute(SPring8)(1997 -)
:Advanced Structural Biology and Application
diation



Yokohama Institute (2000)
:Genomic Science Center(DNA, Genome, Proteins)
RIKEN Genomic Sciences Center
RIKEN Plant Science Center
RIKEN SNP Research Center
Research Center for Allergy and Immunology

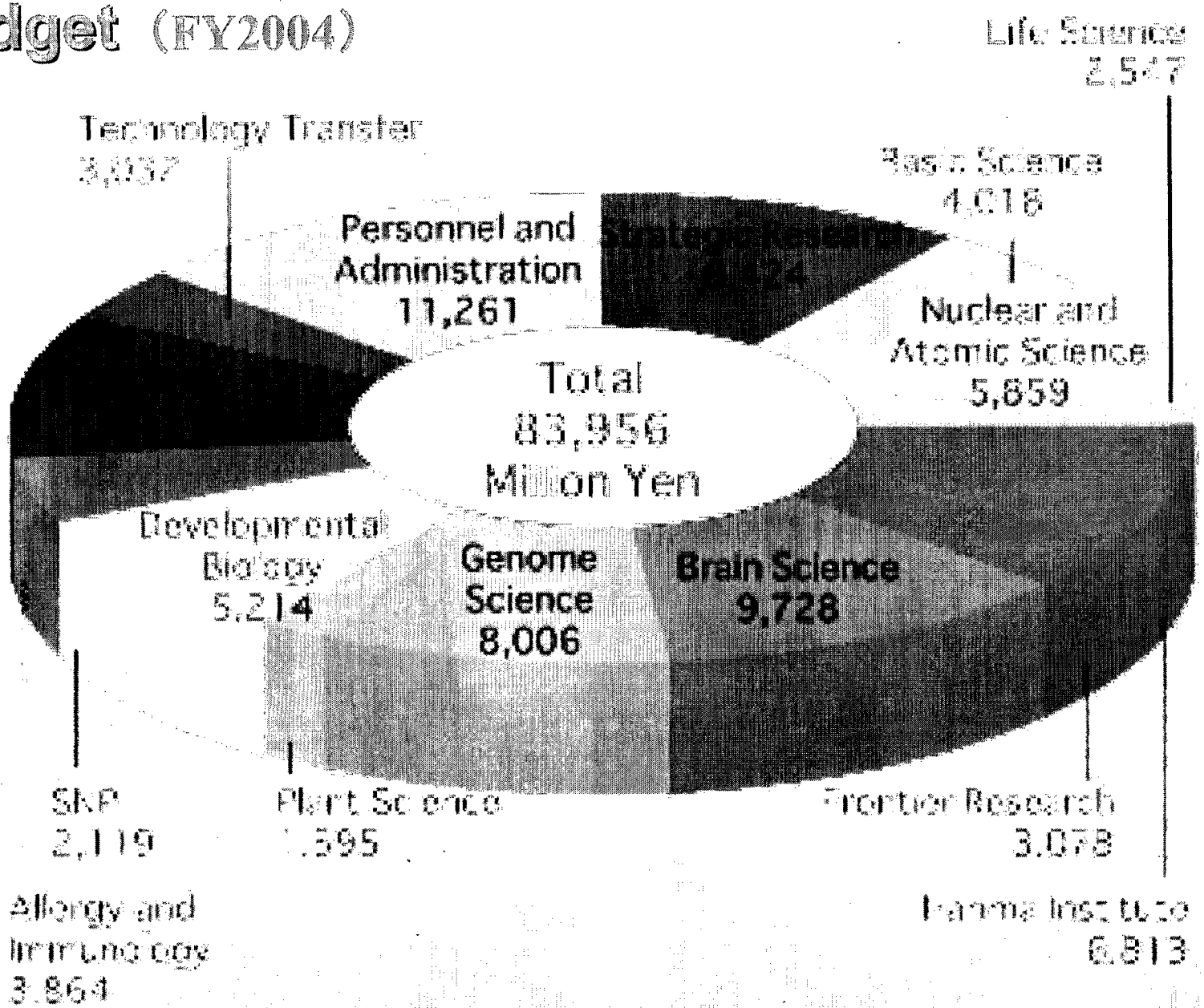


Center for Developmental Biology (Kobe) (2000 -)

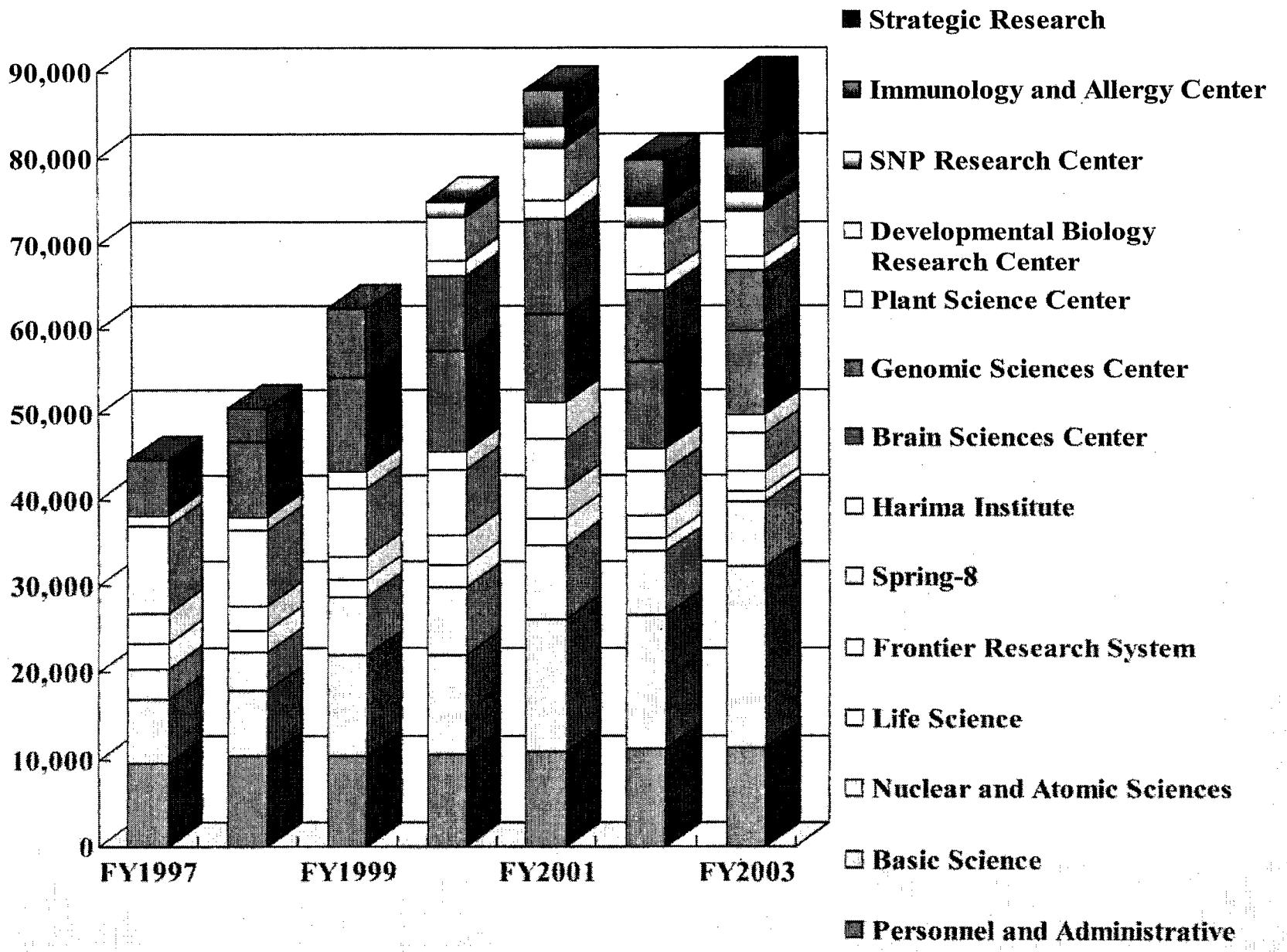


Biomimetic Control Research Center (Nagoya) (1993 -)

Budget (FY2004)



Changes in RIKEN's Budget

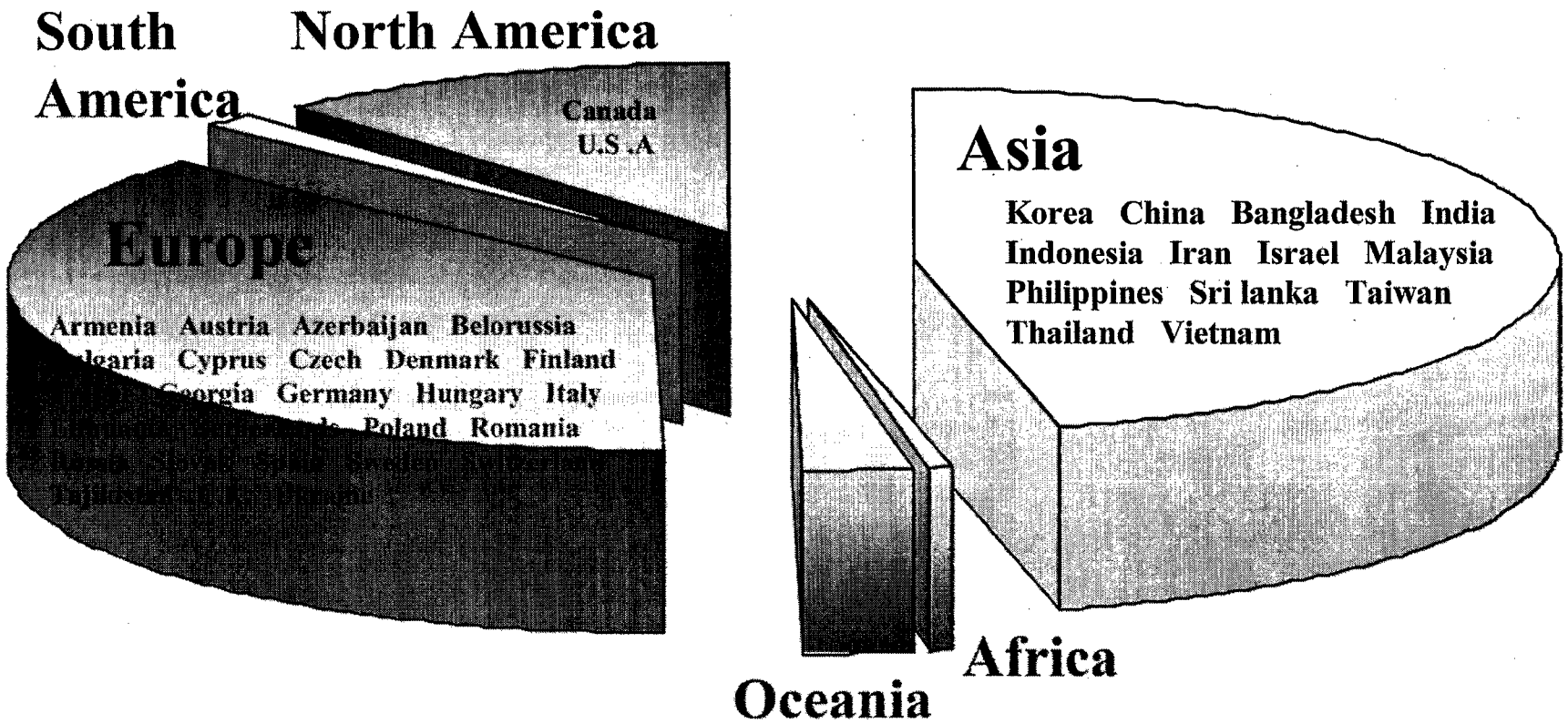


Staff in RIKEN

Permanent		
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

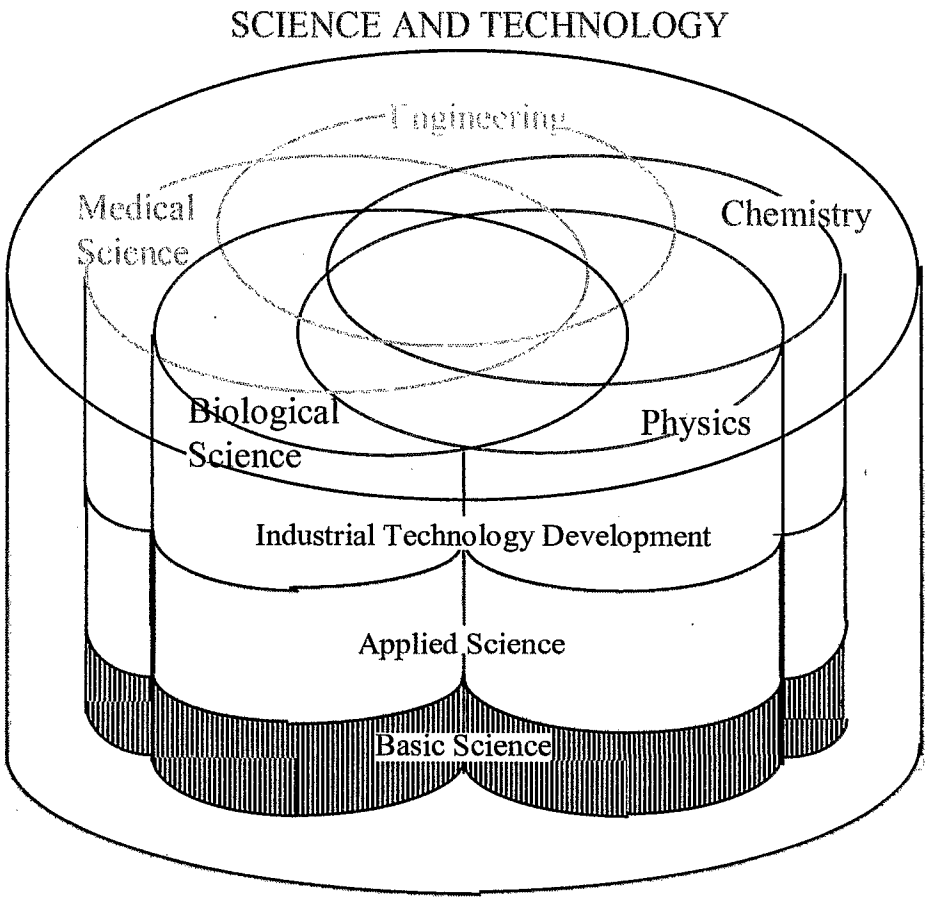
Visiting Scientists from Overseas by Country Origin

as of 1st. October, 2003



TOTAL 494 people, 48 countries

Diversity in Research Area



Diversity in Research Area

Flexible Research Management

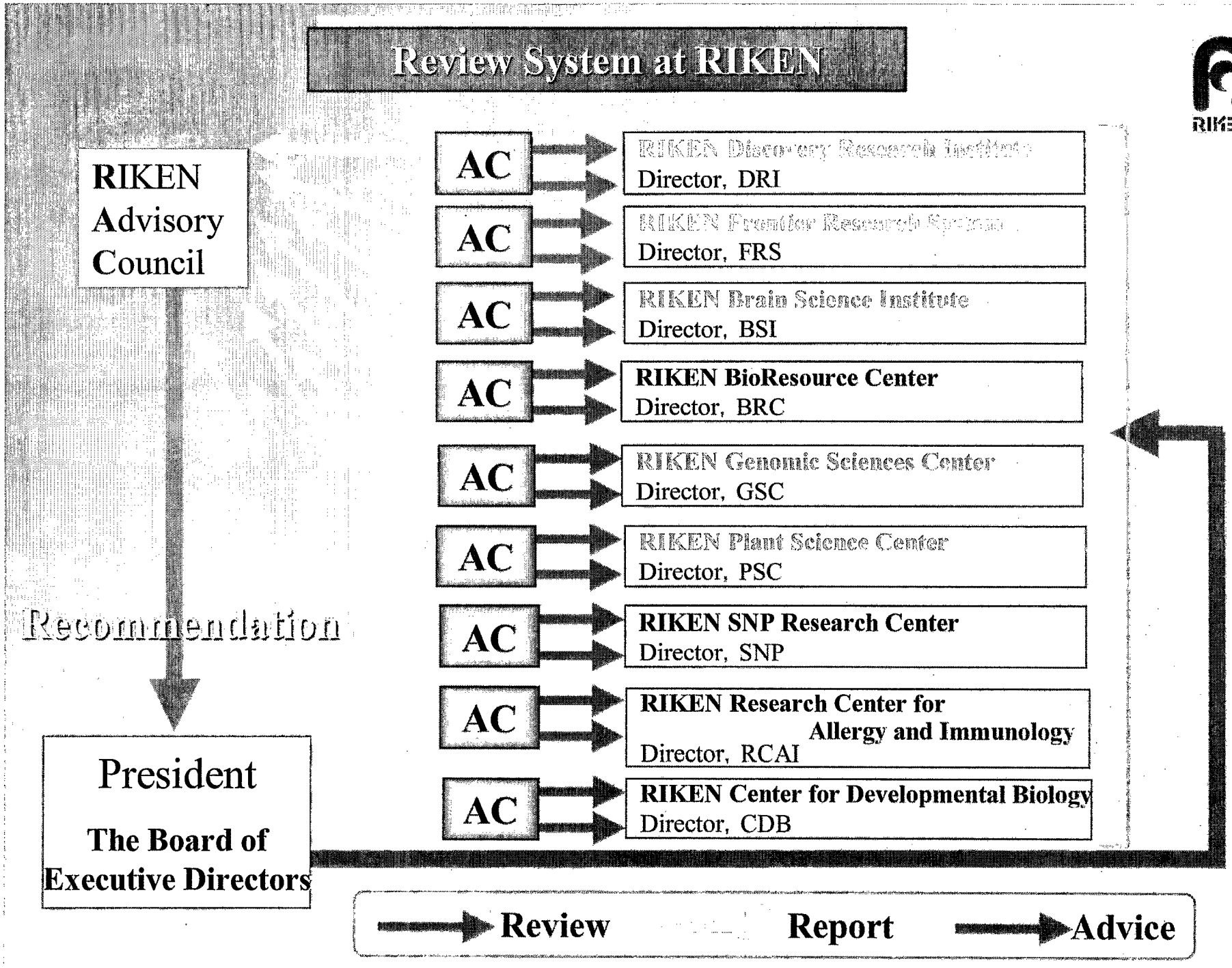
Interdisciplinary Research

"RIKEN is to conduct comprehensive research in science and technology ..... and also to disseminate the results of research." (the RIKEN Law Article 1)

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

Review System at RIKEN



RIKEN President Noyori's Initiative

1. RIKEN's Public Image
2. RIKEN's Place in Science and Technology History

3. RIKEN's Research Environment
4. RIKEN's Global Role
5. RIKEN's Contribution to Culture

1. RIKEN's Public Image

Improving the general public's perception of RIKEN.

Encouraging research and staff members to appeal to the general public about the importance of technology.

2. RIKEN's Place in Science and Technology History

- Continuing to advance the sprit of RIKEN.
- Stressing the importance of research quality and differentiating the RIKEN brand.
- Enhancing the intellectual property system to better contribute to society and industry.

3. RIKEN's Research Environment

Freedom to conceive novel ideas.

Development and pursuing innovation research themes

Turning out independent researchers

4. RIKEN's Global Role

Building stronger relationship between industry and society.

Creating advancements in science and technology, which cannot be best produced by universities and industry, that benefit society.

5. RIKEN's Contribution to Culture

Improving oneself and improving RIKEN's culture.

Disseminating information to society and the social sciences.

BNL AND RHIC: CURRENT STATUS AND FUTURE PLANS

Samuel Aronson

BNL and RHIC: Current Status and Future Plans

11th RBRC Management Steering Committee Meeting

May 27, 2005

BNL

S. Aronson, High Energy and Nuclear Physics

NP: RHIC Luminosity Upgrade, **eRHIC, L**attice **G**auge **T**heory
HEP: Brief updates – ATLAS, RSVP, LSST, VLBνO

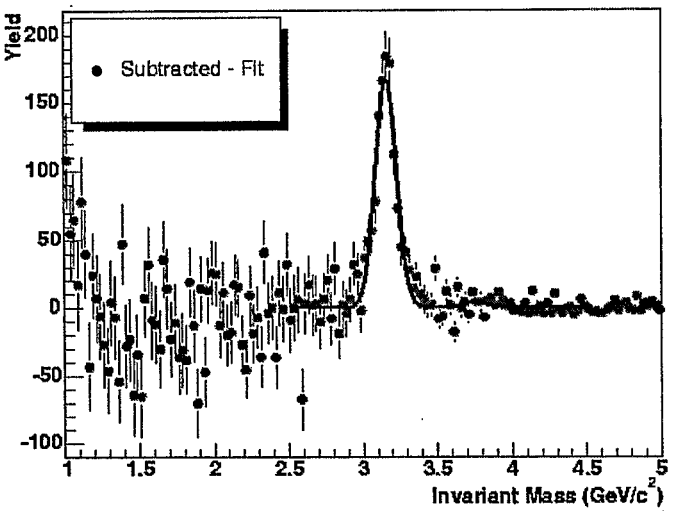
Office of Science
U.S. DEPARTMENT OF ENERGY

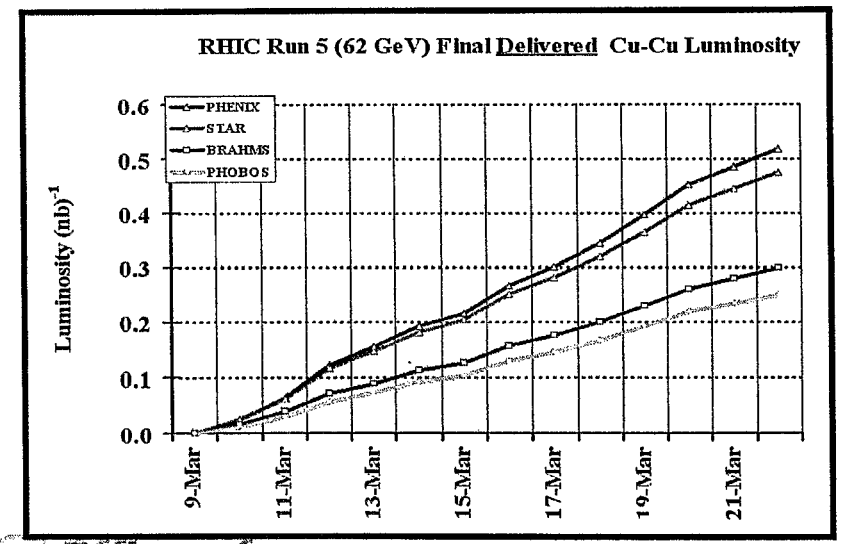
BROOKHAVEN
NATIONAL LABORATORY

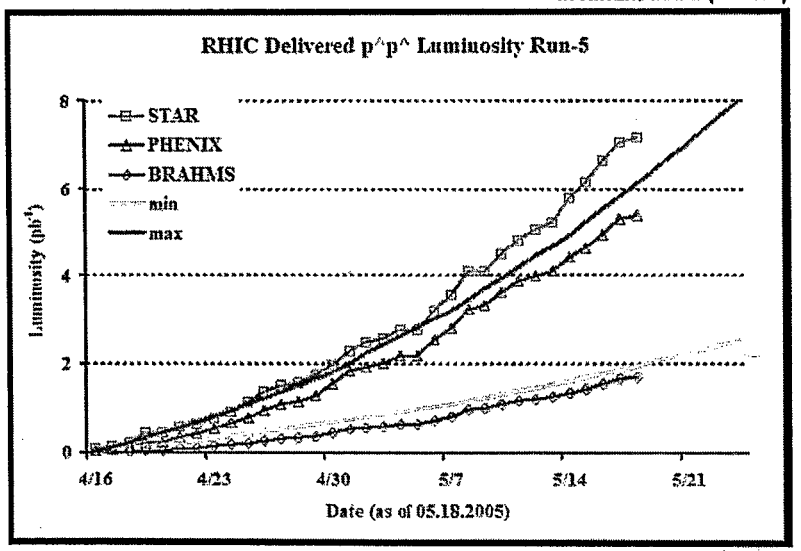
Nuclear Physics

RHIC Performance this year

- RHIC and experiments in Run 5
  - Successful Cu + Cu run at several energies
  - Polarized p + p run in progress with excellent polarization (~ 50%), thanks to the warm partial Siberian Snake in the AGS
  - Plan a spin development run at $s^{1/2}$ = 410 GeV for future spin running

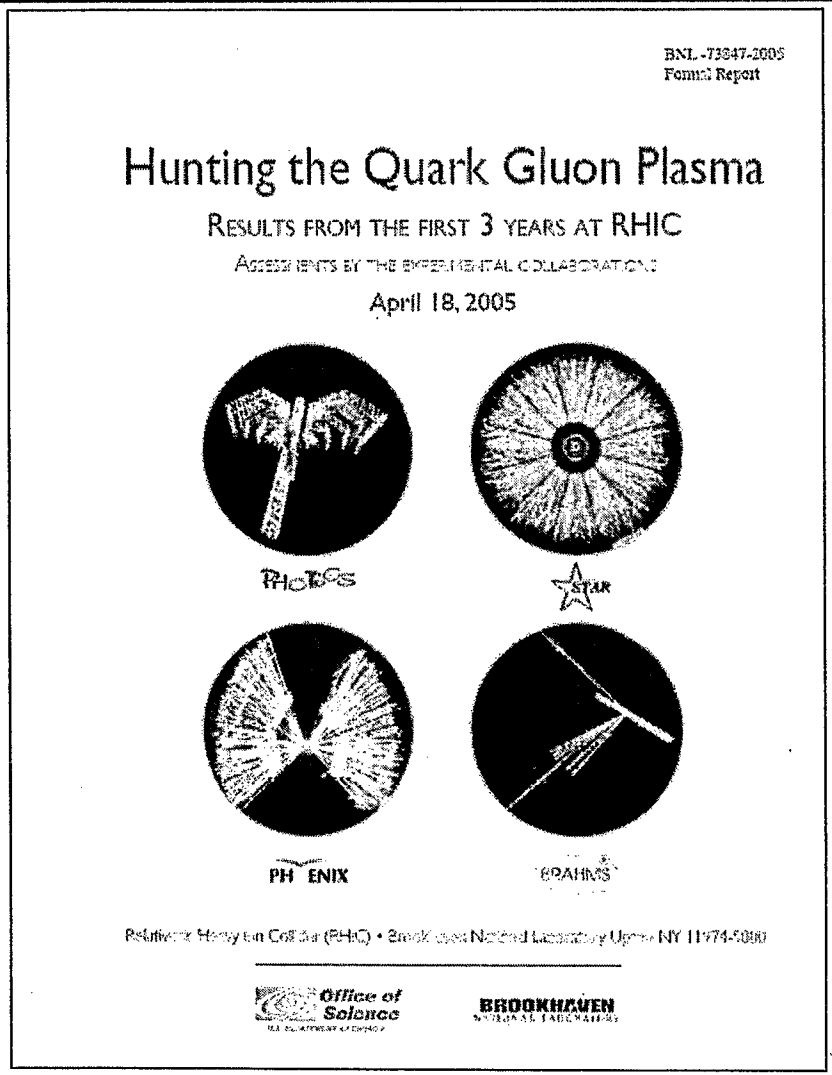






RHIC Accomplishments in last year

- "White papers" – collaborations assess the first 3 years of running
  - BNL internal report; to be published in *Nuclear Physics A*
  - Strong evidence of a rapidly thermalized, strongly coupled (i.e., low viscosity) **liquid**
  - Consistent with predictions based on a plasma of quarks and gluons (sQGP)
- Press event at the April meeting of the APS in Tampa, FL


BNL-73847-2005
Formal Report

Hunting the Quark Gluon Plasma

RESULTS FROM THE FIRST 3 YEARS AT RHIC

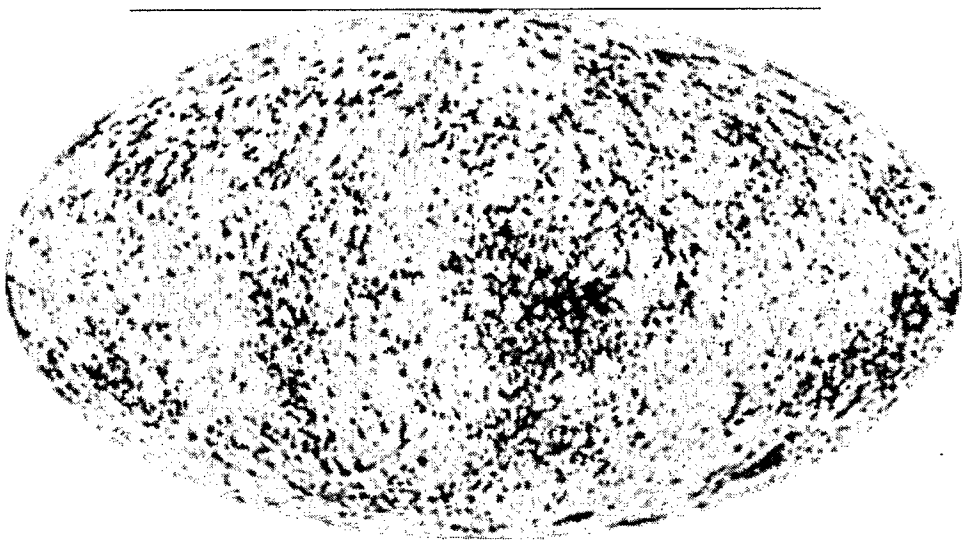
April 18, 2005

Office of Science

BROOKHAVEN

Liquid?

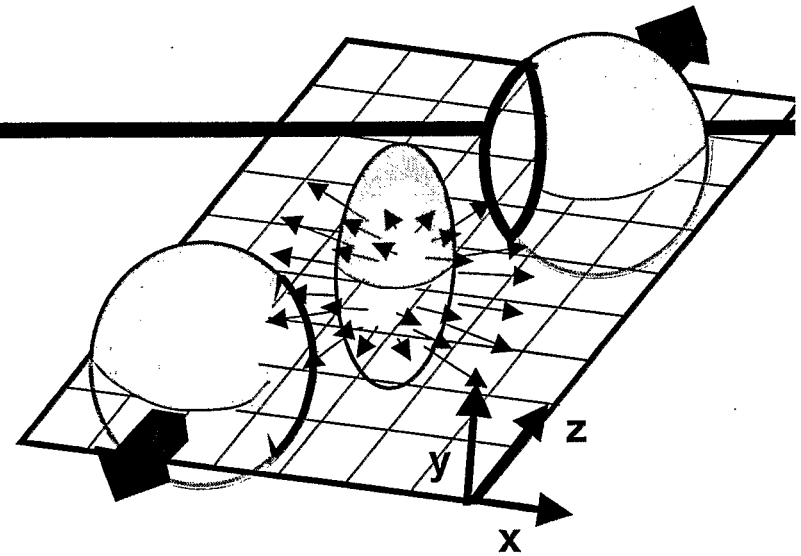
- Hard to see what's liquid about a RHIC collision

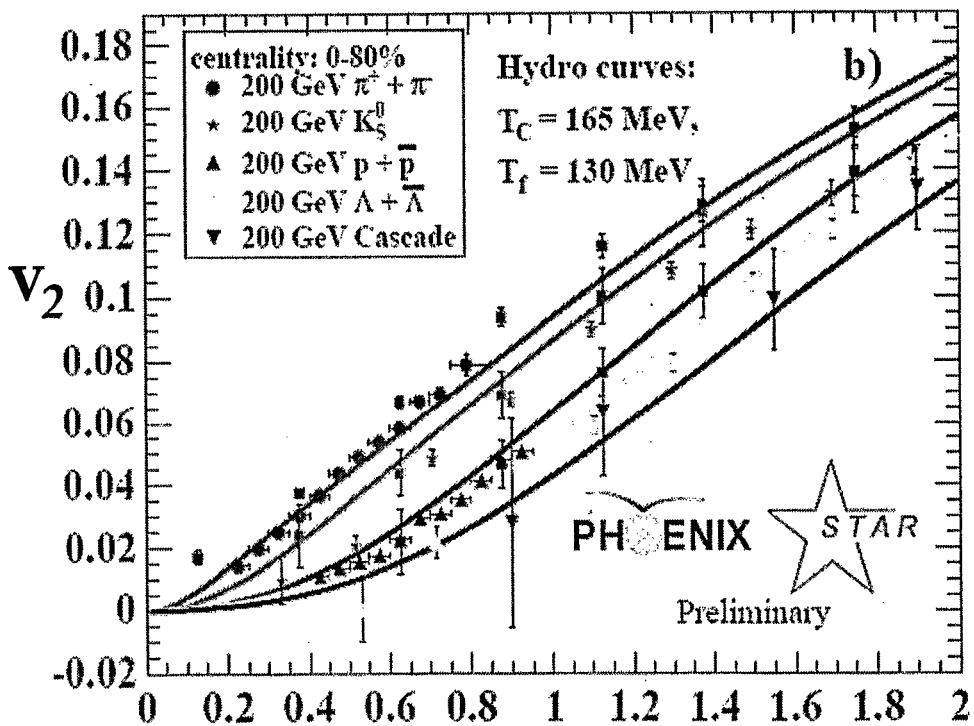


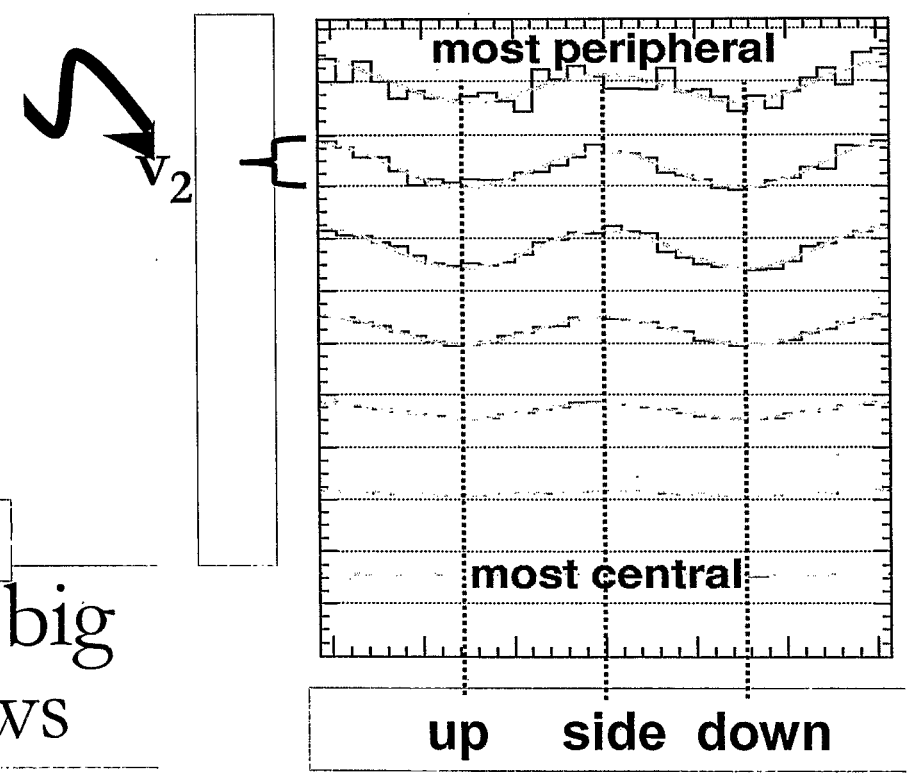
- The liquid lives for 10^{-23} seconds, and is long gone before the particles reach the detector
- But the liquid structure is imprinted on the *distribution* of these particles, much as the structure of the early universe is imprinted on the cosmic microwave radiation we see now

What is the "imprint?"

- Modulation of particle flux relative to Reaction Plane







Slower ⟷ Faster

- v_2 is measured to be as big as "perfect" hydro allows

RHIC budgets and politics

- Very successful Research and Operations!
- Dire budget projections for FY 2006-2010
  - 2006 – President's Budget → 12 weeks of operations
  - 2007-2010 – Flat dollar budgets → lights out?
- NSAC is considering how to deal with this
  - Possible shutdown of one of NP's major facilities – RHIC or CEBAF – recommendations on June 15
  - The RHIC community made a very strong presentation to the NSAC sub panel
- Recent positive development
  - Restoration of 2006 RHIC budget and increases for science proposed in the Congress

RHIC's Future Science Goals

- The RHIC scientific community is continuing to develop the scientific program and the facility requirements for the future
- We want to explore the role of QCD:
  - At high temperature and density
  - At high energy and low x
  - In the structure of hadrons
- Science workshops are exploring these topics

  http://www.bnl.gov/physics/rhicIIscience/default.asp

  http://www.phenix.bnl.gov/WWW/publish/abhay/Home_of_EIC/

The Fundamental Questions

- Future - RHIC and eRHIC should address:
  - QCD at High Temperature and Density
    - Is there a QCD **Phase Transition** to Quark Gluon Plasma and what are the **properties** of QGP?
    - **Thermalization**: How do we evolve from a low-entropy initial state to a maximal entropy state on short time scales?
    - **Deconfinement**: Do the degrees of freedom in the initial state have deconfined color charges?
    - **Chiral Symmetry**: Is chiral symmetry restored at high temperature and density?

The Fundamental Questions

- QCD at High Energy and Low x
  - What is the **nature of gluonic matter** inside of strongly interacting particles?
  - Is this gluonic matter a **color glass condensate** and is it the source of Quark Gluon Plasma?
  - Is the low-x structure of **nucleons in nuclei** different from that of free nucleons?
- QCD and the Structure of Hadrons
  - How do **gluons** contribute to the proton spin?
  - What are the patterns of **u, d and s** quark and antiquark **polarizations** in the proton?
  - What **orbital angular momentum** is carried by the quarks and gluons in a proton?
  - What role does **transverse spin** play in QCD?

Evolution of RHIC

- The key observables to address these questions require
  - Accelerator development
    - Luminosity increase
    - Electron capability
  - New detector capabilities
    - PHENIX and STAR upgrades
    - New e+p/e+A detector

RHIC II

eRHIC

3 slides from the DOE Office of Nuclear Physics follow
See back-up slides for more RHIC II/eRHIC details

U.S. Department of Energy

Office of Science

Investments in New Capabilities

Office of Nuclear Physics

Exploring Nuclear Matter - Quarks to Stars

	Priority	Program	Facility
	1	FES	ITER
	2	ASCR	UltraScale Scientific Computing Capability
Near-Term	Tie for 3	HEP	Joint Dark Energy Mission
		BES	Linac Coherent Light Source
		BER	Protein Production and Tags
		NP	Rare Isotope Accelerator
	Tie for 7	BER	Characterization and Imaging
		NP	CEBAF Upgrade
		ASCR	ESnet Upgrade
		ASCR	NERSC Upgrade
		BES	Transmission Electron Achromatic Microscope
	12	HEP	BTeV
	13	HEP	Linear Collider
Mid-Term	Tie for 14	BER	Analysis and Modeling of Cellular Systems
		BES	SNS 2-4 MW Upgrade
		BES	SNS Second Target Station
		BER	Whole Proteome Analysis
	Tie for 18	NP+HEP	Double Beta Decay Underground Detector
		FES	Next-Step Spherical Torus
		NP	RHIC II
Long-Term	Tie for 23	BES	National Synchrotron Light Source Upgrade
		HEP	Super Neutrino Beam
		BES	Advanced Light Source Upgrade
		BES	Advanced Photon Source Upgrade
		NP	eRHIC
		FES	Fusion Energy Computing
		BES	NGB Second Oak Ridge Spallation Neutron Source
		FES	Magnetic Fusion Experiment

Nuclear Physics Facilities:

Rare Isotope Accelerator (RIA): near-term priority
Nuclear properties at the limits of stability; origin of the heavy elements; stellar burning; fundamental symmetries of nature

12 GeV CEBAF Upgrade at TJNAF: near-term priority
Quark structure of the nucleon; tests of fundamental symmetries; mechanism of quark confinement

Underground Detector Experiment: mid-term priority
Double beta-decay measurement; masses of neutrinos; revision of Standard Model

RHIC luminosity upgrade (RHIC II): mid-term priority
Upgrade RHIC's luminosity by x10 to study new states of matter at high energies and densities with rare probes; direct probe of the early universe

Electron-Heavy Ion Collider (eRHIC): far-term priority
First electron-heavy ion collider; unique capabilities to study the quark structure of nucleons and saturated gluonic matter

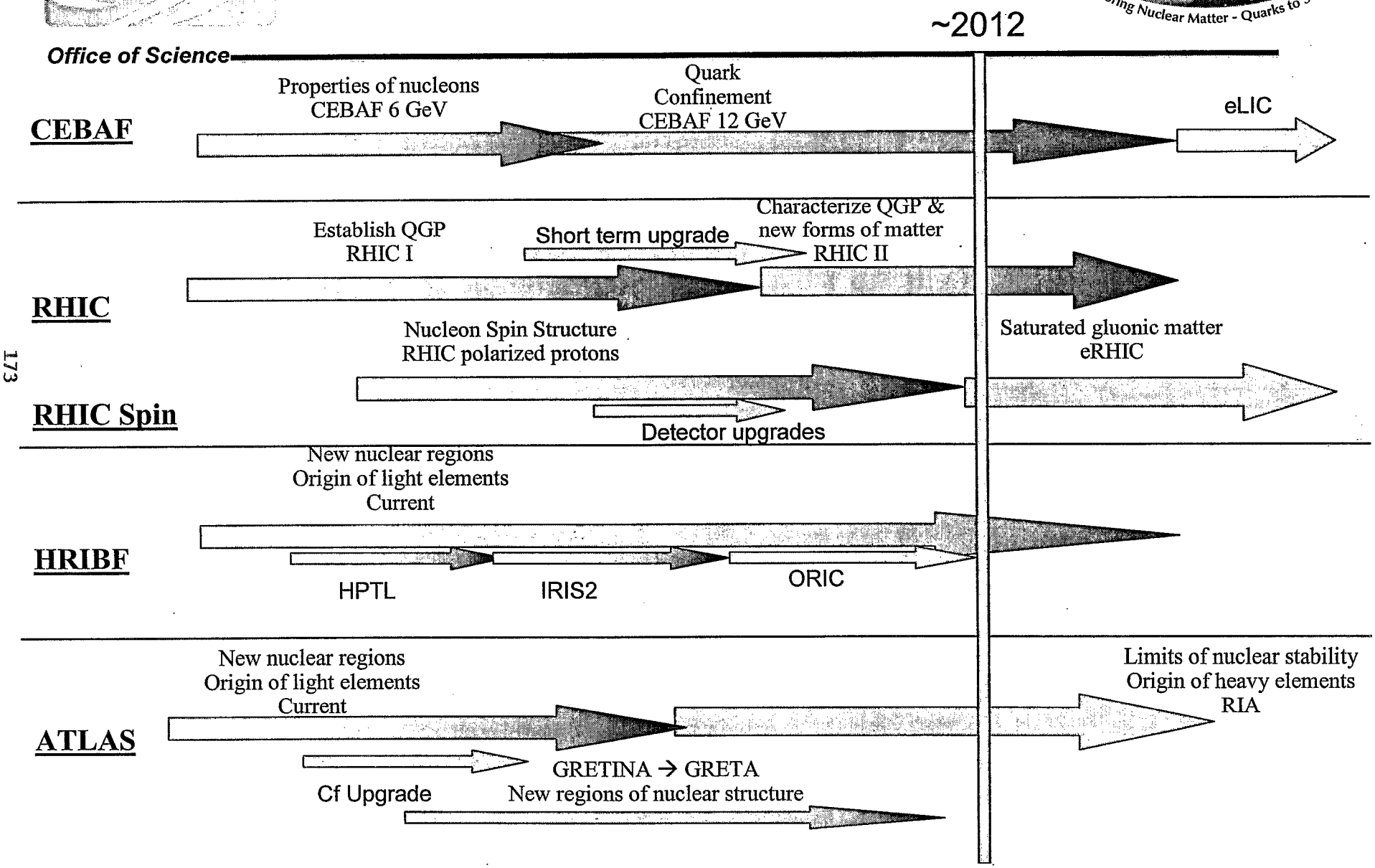
U.S. Department of Energy

Office of Science

Facility Strategic Plan

Office of Nuclear Physics

Exploring Nuclear Matter - Quarks to Stars



Cost of 20 Yr Initiatives

Project AY $ M	04	05	06	07	08	09	10	11	12	13	14	15
RIA	6	6.7	4	16.3	54.3	66.7	170	222	185	107	100	58
12 GeV Upgrade	0.7	2.3	4.5	19.5	41.5	64	62	34	5.5			
Double Beta				2.3	12.9	16.3	17.2	7.1	1.8	0.4		
eRHIC/ RHICII				2	5	32	51	122	213	150	105	

Incremental Operating costs of Facility:

RIA	$ 100 M
12 GeV	$ 15 M
eRHIC/RHICII	$ 50 M

DOE accepted escalation rates for projects is 2.7%

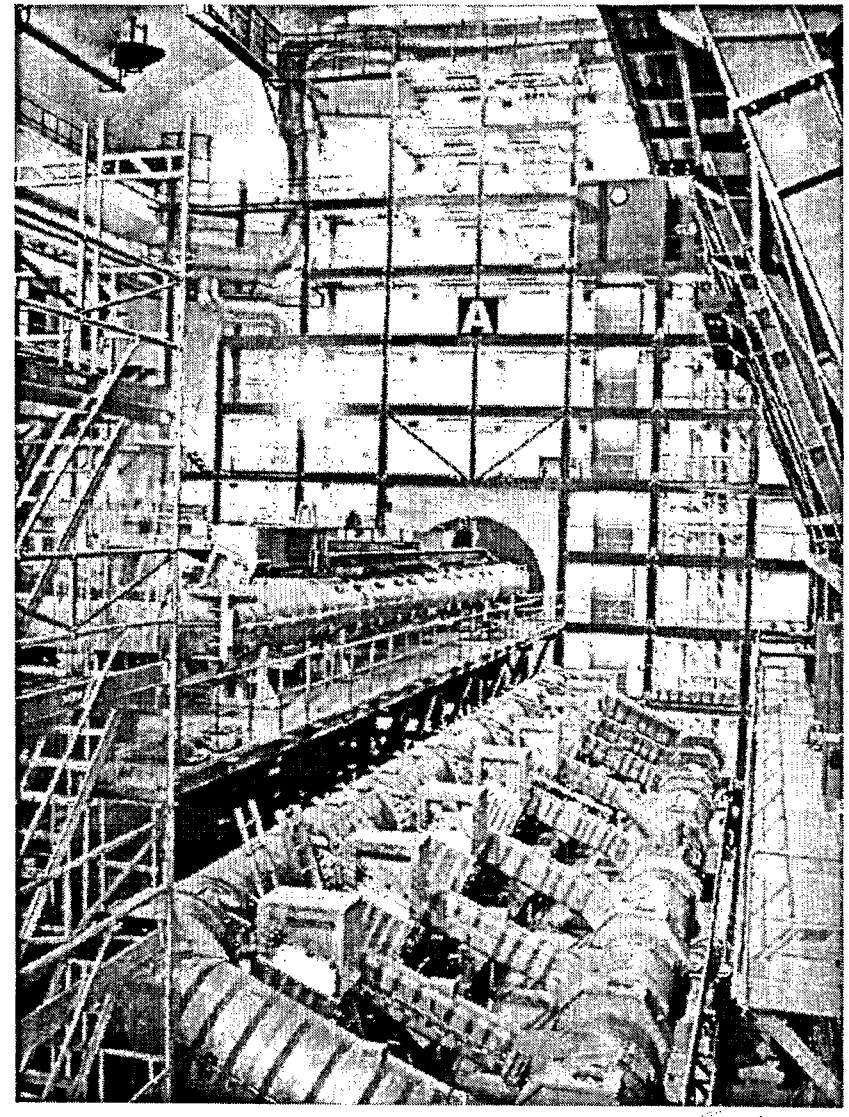
Lattice Gauge Computing

- New Group Started in the BNL Physics Department this year
- Led by Frithjof Karsch
  - Focus on finite temperature lattice QCD
- Synergistic with RBRC, BNL NT and BNL HET
- Resources (RBRC and DOE QCDOC machines) represent a 50-fold increase for finite T QCD on the lattice

High Energy Physics

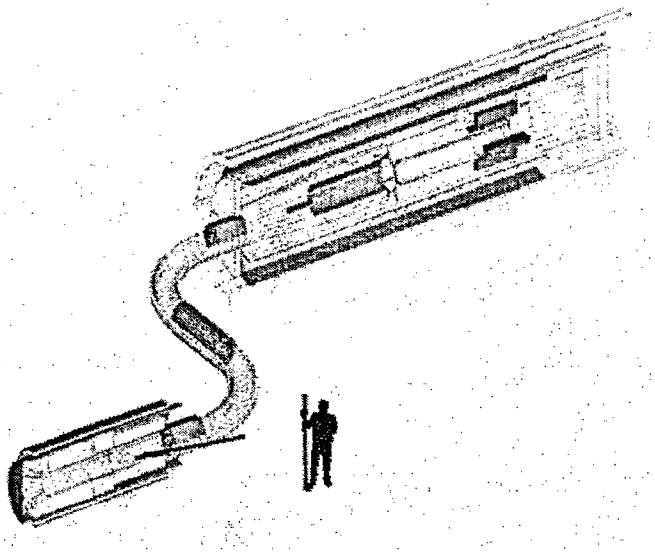
HEP progress (in brief)

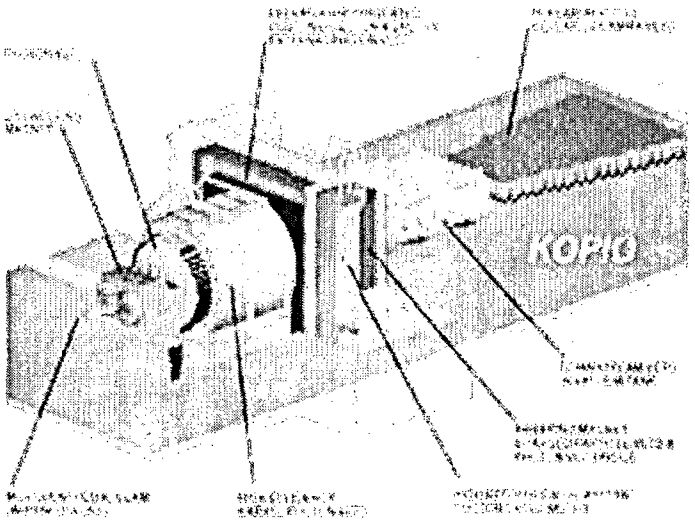
- ATLAS
  - BNL is the host lab for US ATLAS
  - Very successful construction effort nearing completion
  - Look forward to very exciting physics from day-1 (2007/8)
  - Physics Analysis Center at BNL is growing



HEP progress

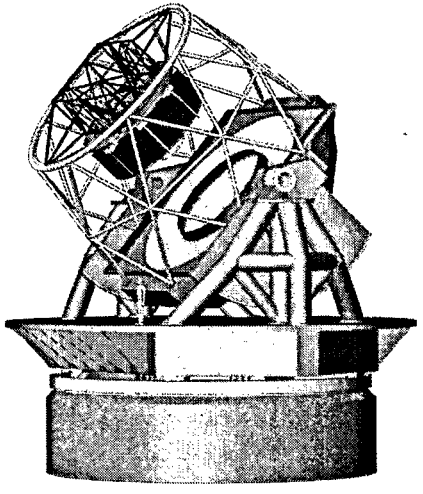
- RSVP
  - BNL scientists involved in both the MECO and KOPIO experiments
  - Successful recent reviews
    - Scientific merit (HEPAP)
    - Cost/schedule (NSF)
  - Look forward to project approval by NSB (September), followed by project start

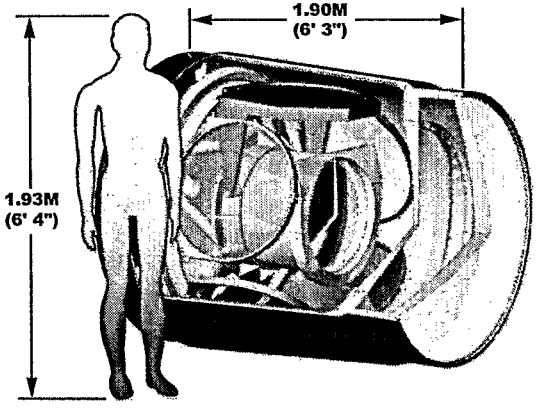




HEP plans

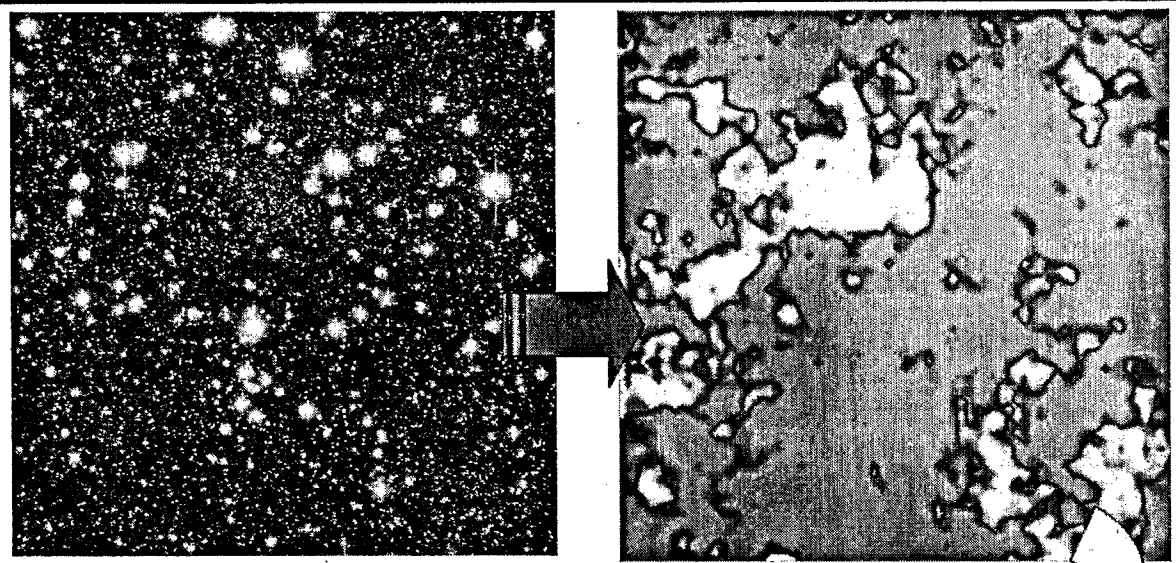
- LSST
  - Ground-based survey telescope; NSF, DOE, private funding sought
  - Deep, wide-field, frequent sky maps in 5 filter bands
  - Broad science program including Dark Energy
  - BNL playing a central role in development of the camera – **sensor development**
  - R&D starting, with private and NSF funds.
  - Looking for DOE support, awaiting Dark Energy Task Force report

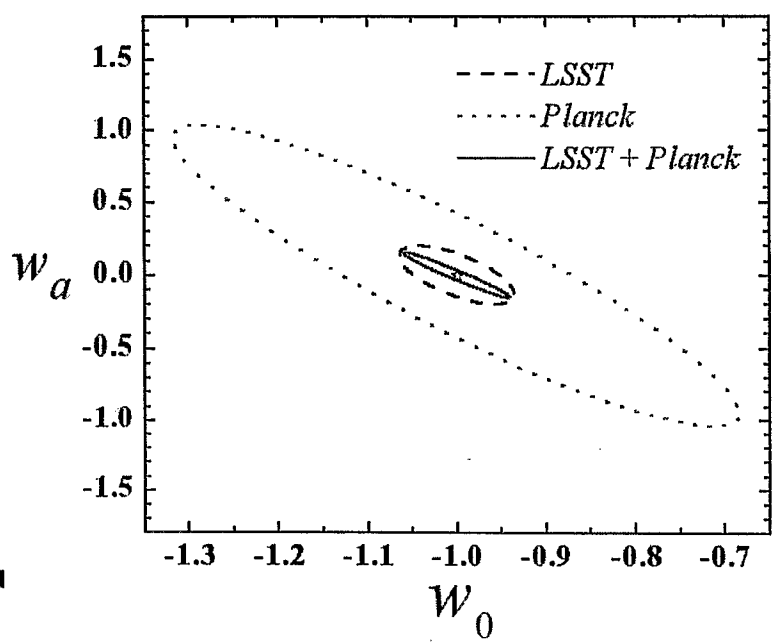




HEP plans

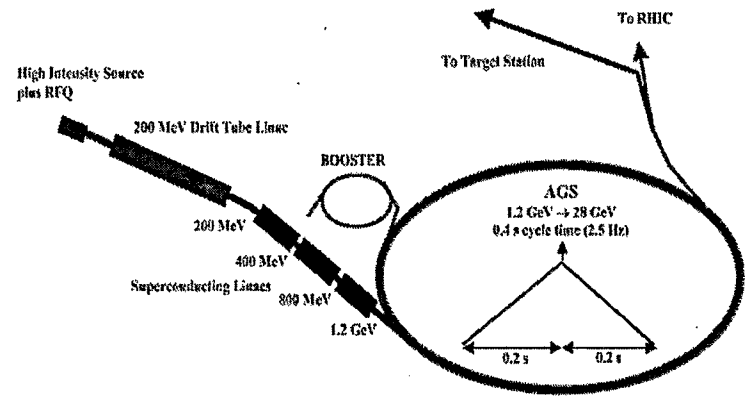
- LSST
  - BNL involved in weak gravitational lensing science and in data management
  - If LSST goes ahead soon, it could be operational in 2012/13

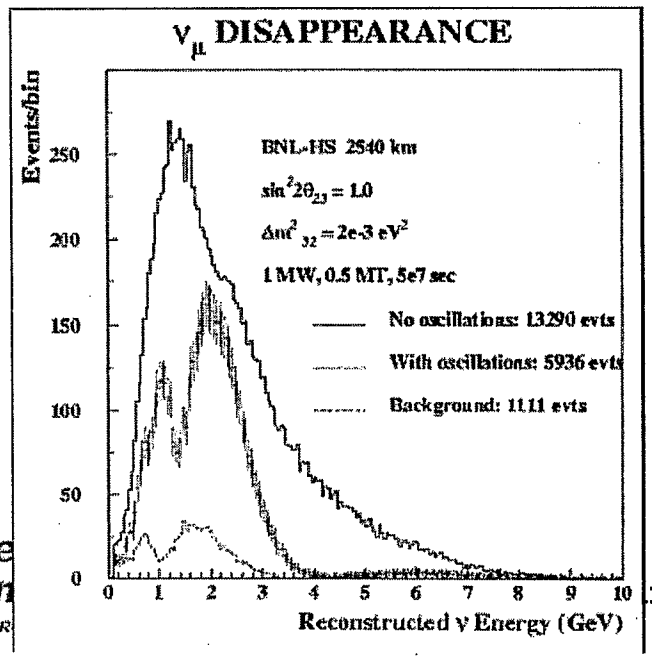


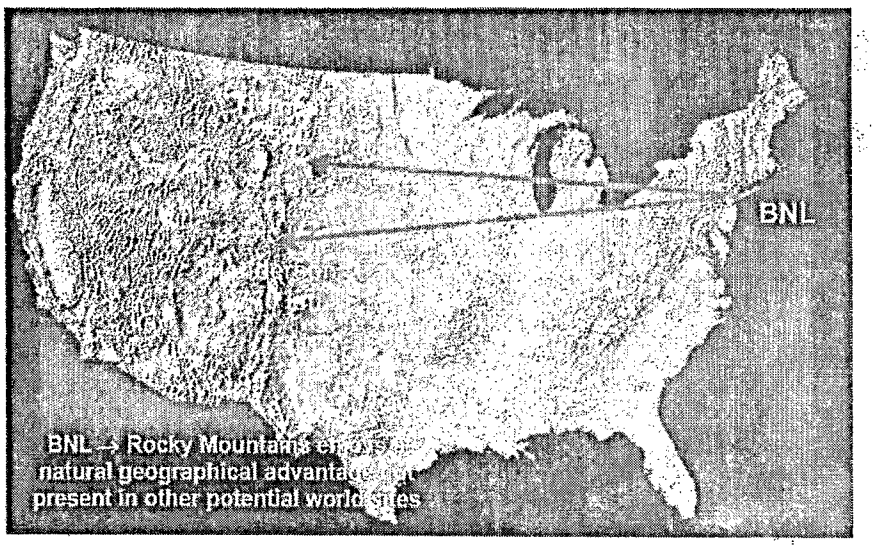


HEP plans

- Very Long Baseline Neutrino Oscillations
  - BNL Approach:
    - MW-class proton driver producing
    - Broadband ν super beam traveling ~2500km to
    - MTon-class detector







HEP plans

- BNL will compete for this phase of neutrino oscillations
  - Currently involved in MINOS at Fermilab and planning to collaborate on reactor θ_{13} experiment
- BNL is developing R&D proposals for further development of super beam and detector

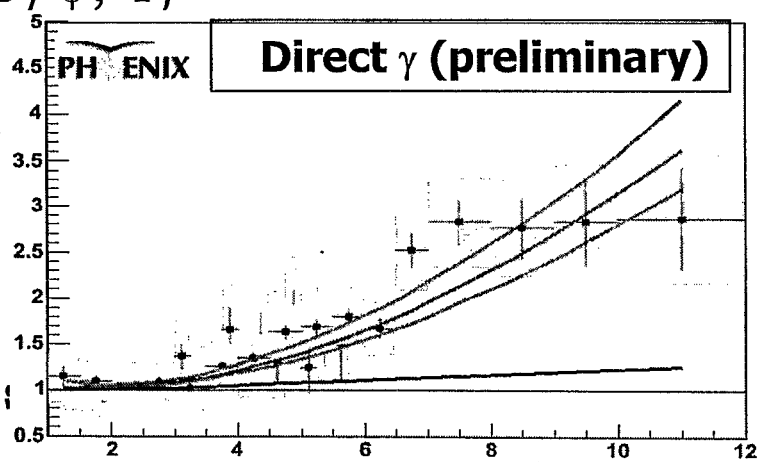
Summary

- BNL present and future in nuclear and particle physics is centered on RHIC
- BNL has significant other activities – at CERN (ATLAS) and probably also at the AGS (RSVP)
- Plans for the future (in addition to RHIC and eRHIC) involve accelerator (neutrinos) and non-accelerator (dark energy) physics

Additional material

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 sp ectra 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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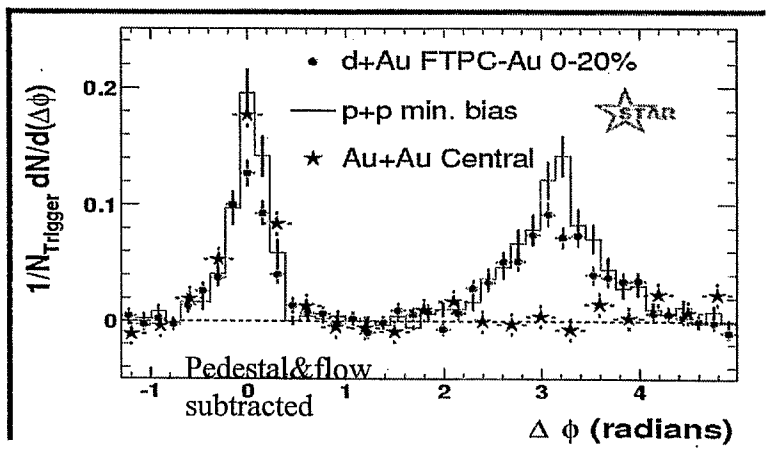

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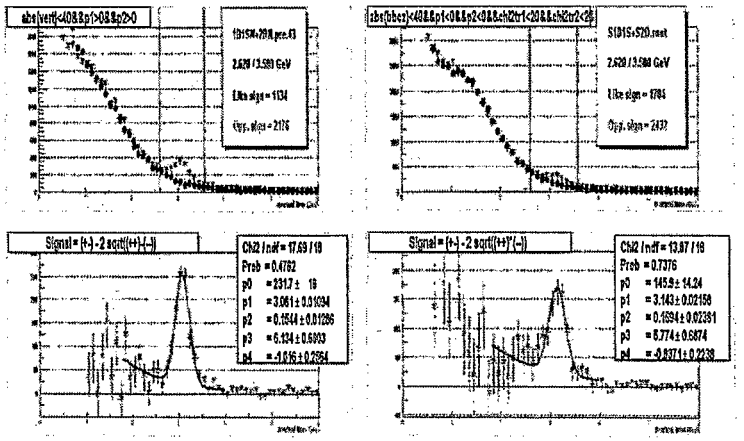
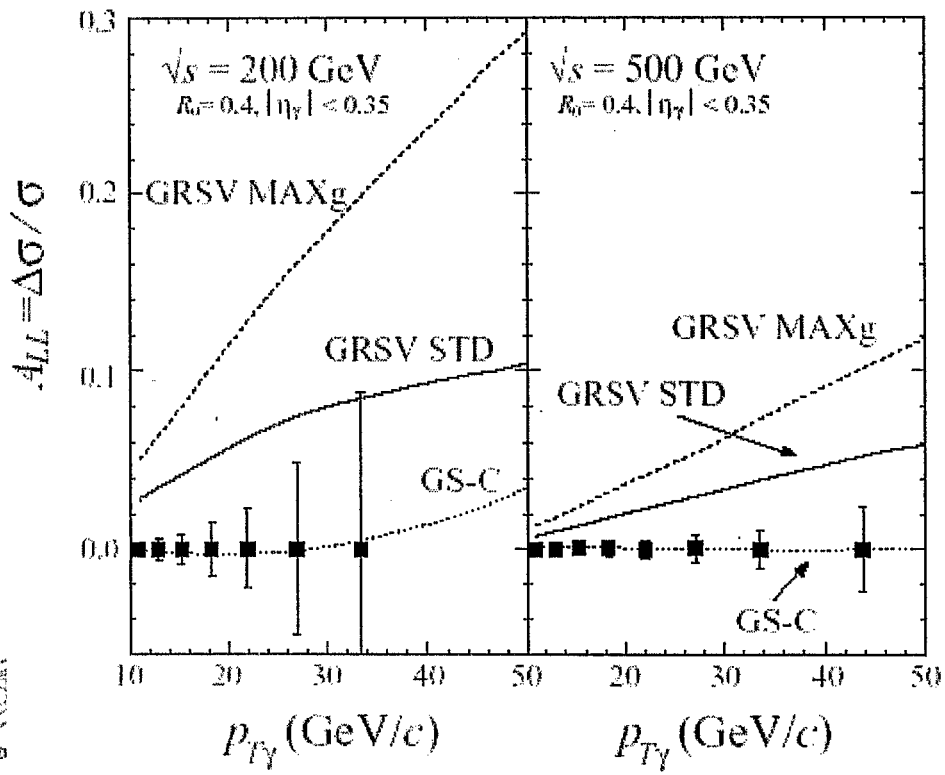
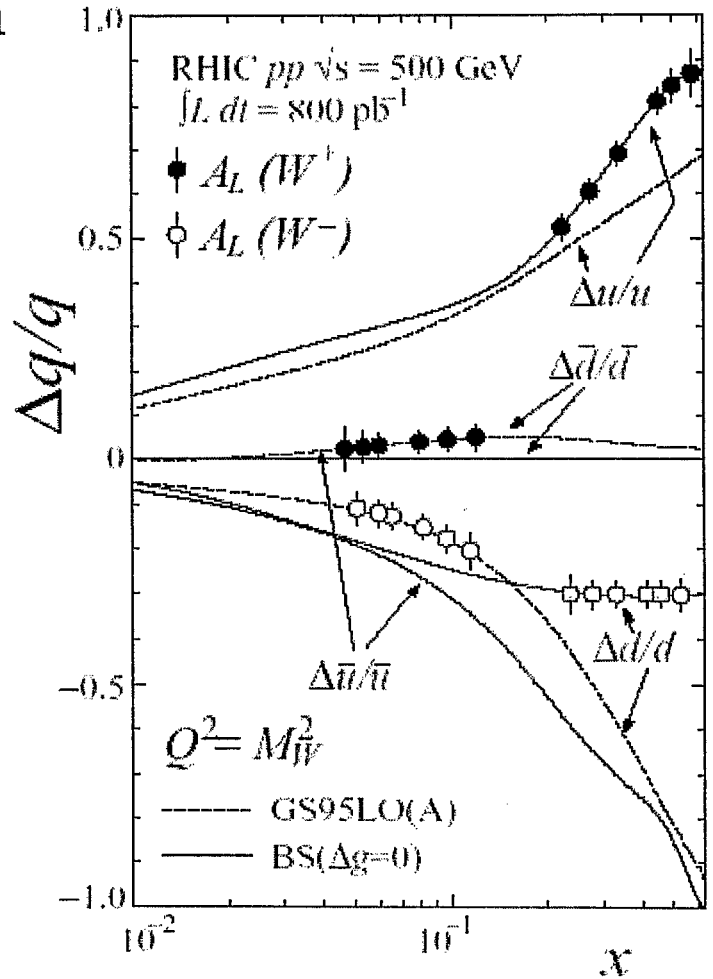


RHIC II Physics drivers: spin & p-A

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

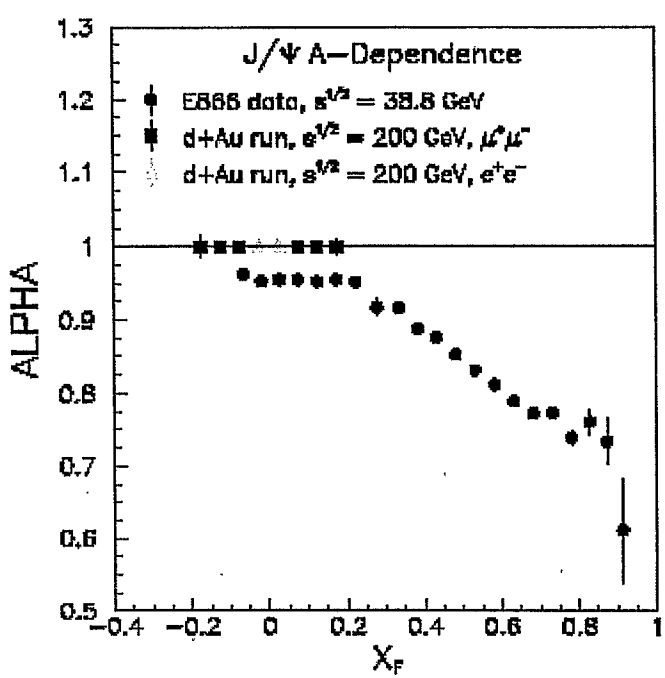


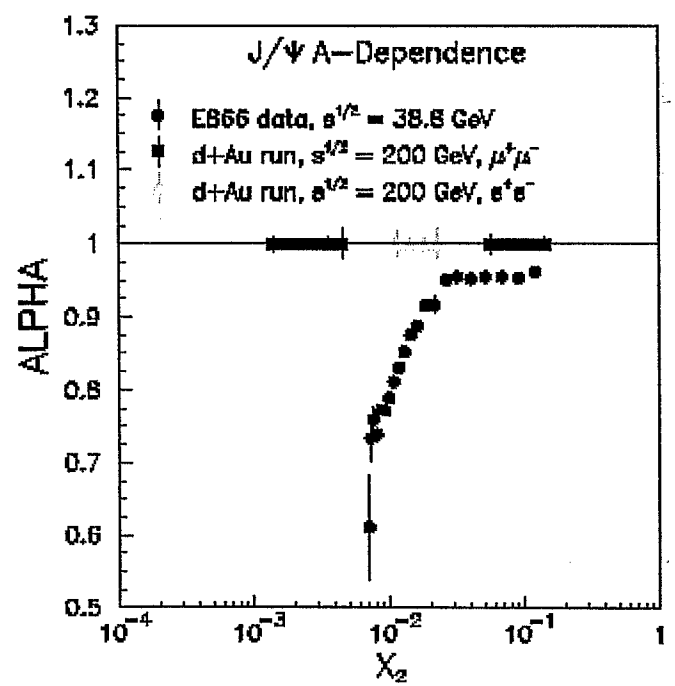


RHIC II Physics drivers: spin & p-A

- 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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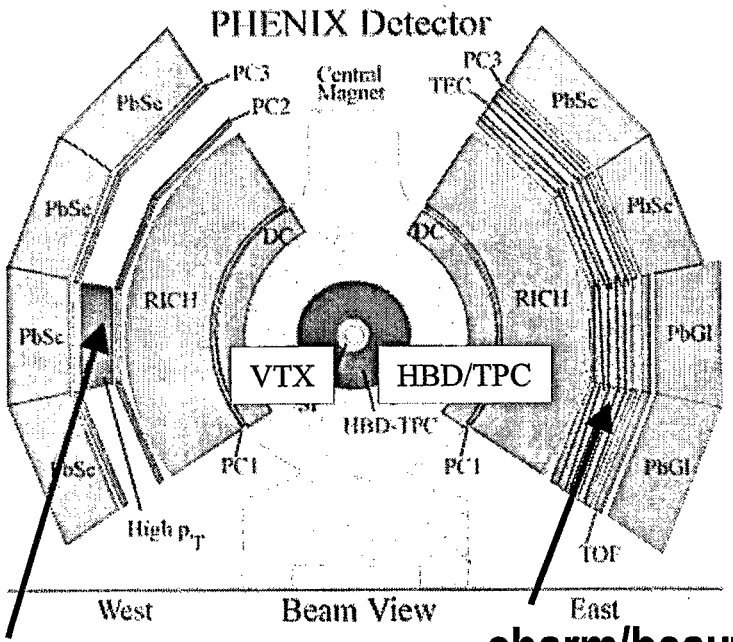
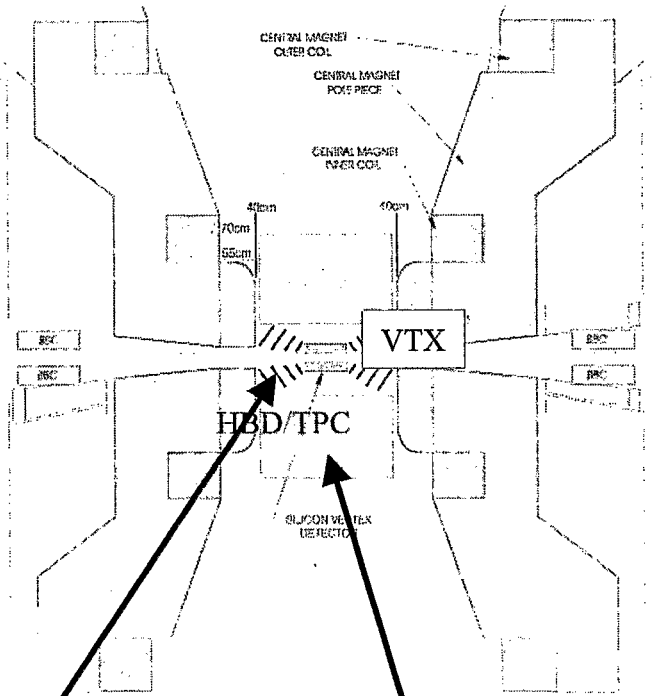
PHENIX Central Arm Upgrades

- Enhanced Particle ID
  - **TRD (east)** ✓
  - Aerogel/TOF (west)
- Vertex Spectrometer
  - **flexible magnetic field** ✓
  - VTX: silicon barrel vertex tracker
  - HBD and/or TPC





High p_T phenomena: Aerogel/TOF

π, K, p separation to 10GeV/c

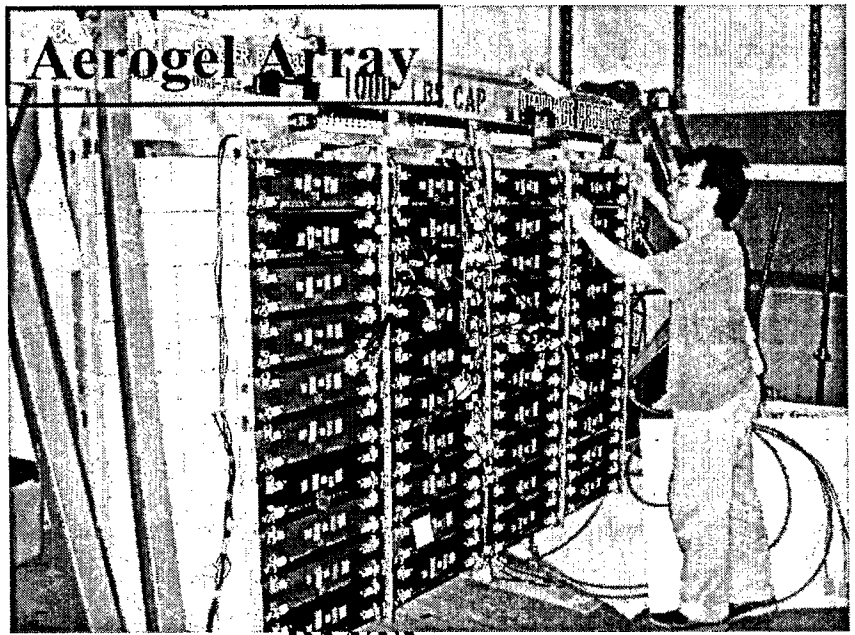
charm/beauty: TRD

e/π above 5 GeV/c

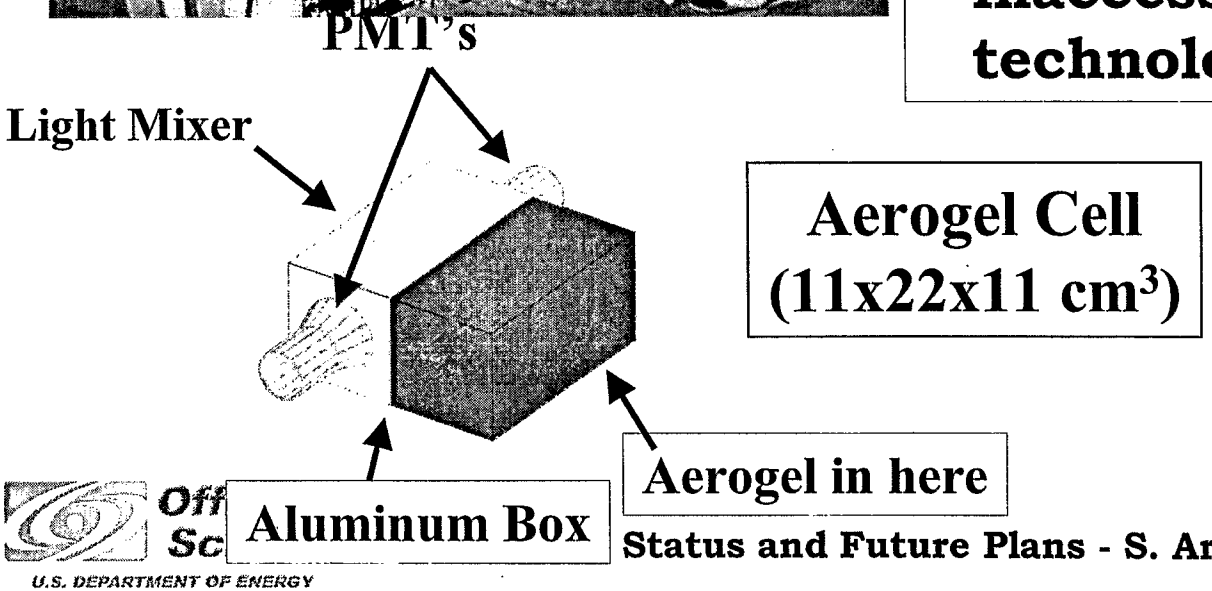
charm/beauty: VTX displaced vertex

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.**



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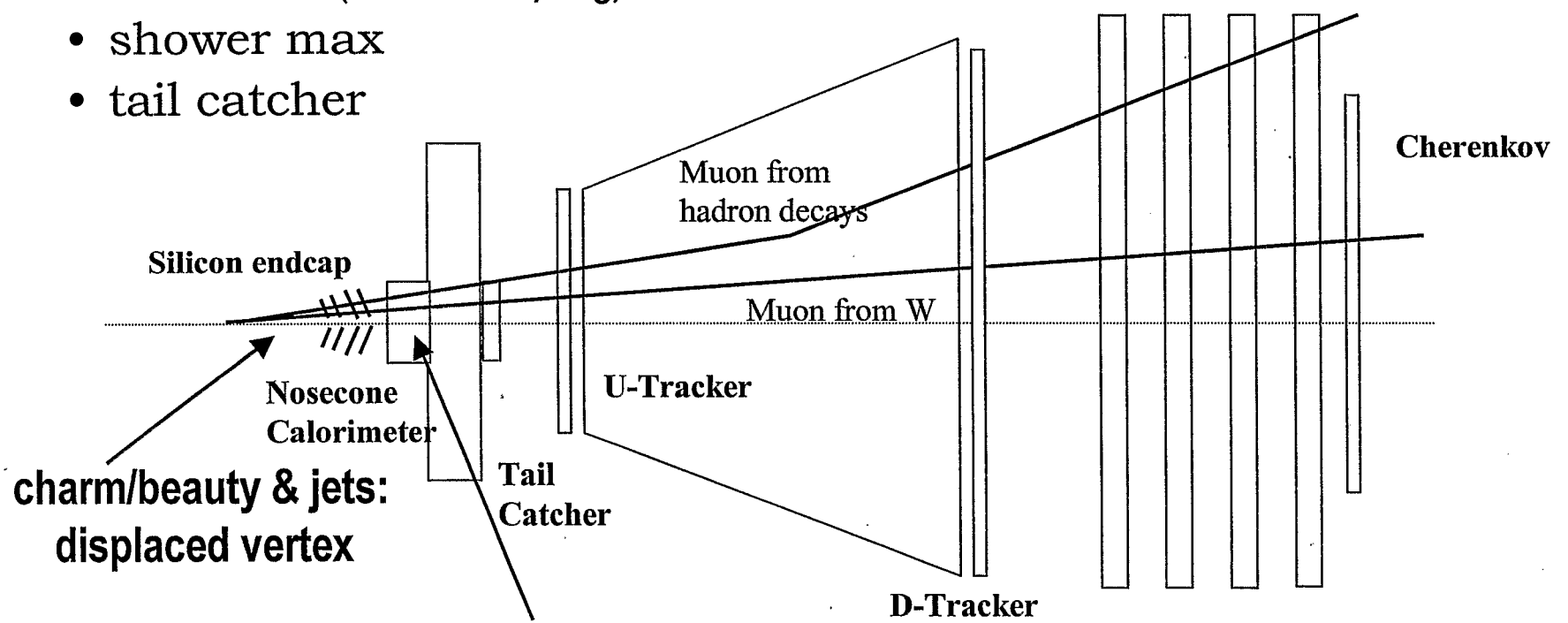
PHENIX Forward Upgrade Components

- 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

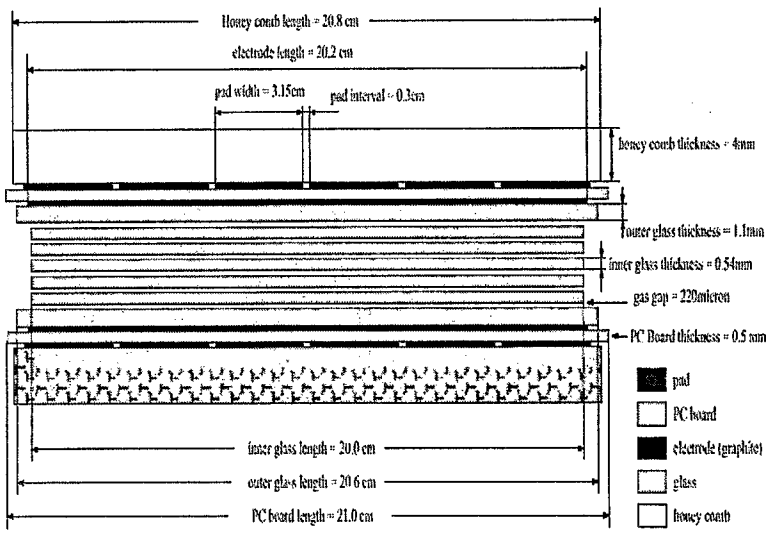
W and quarkonium: improved μ-trigger

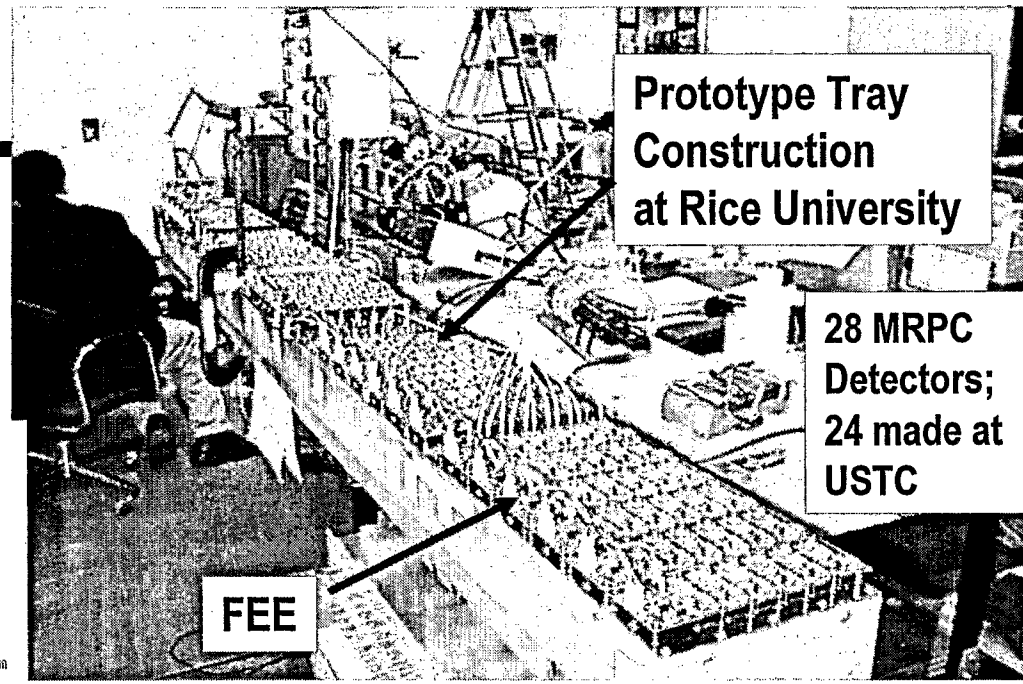
STAR's future program needs:

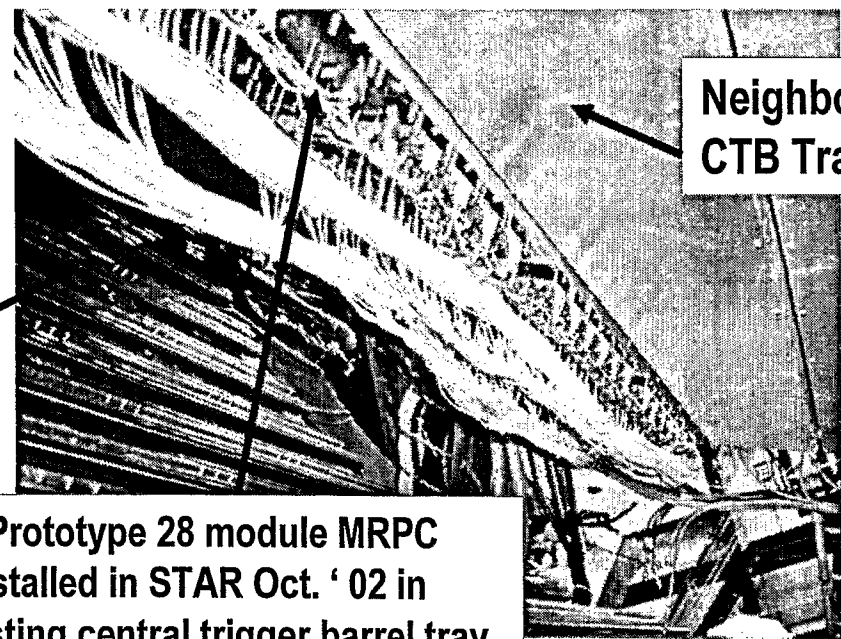
■ A Barrel MRPC TOF	PID information for > 95% of kaons and protons in the STAR acceptance; extended scientific reach for key observables
■ A micro-vertex detector	precise (3 μm) hit position close to the primary vtx → D's ,flavor-tagged jets
■ A DAQ/ TPC FEE Upgrade	new architecture / FEE → 1 khz of 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 × 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





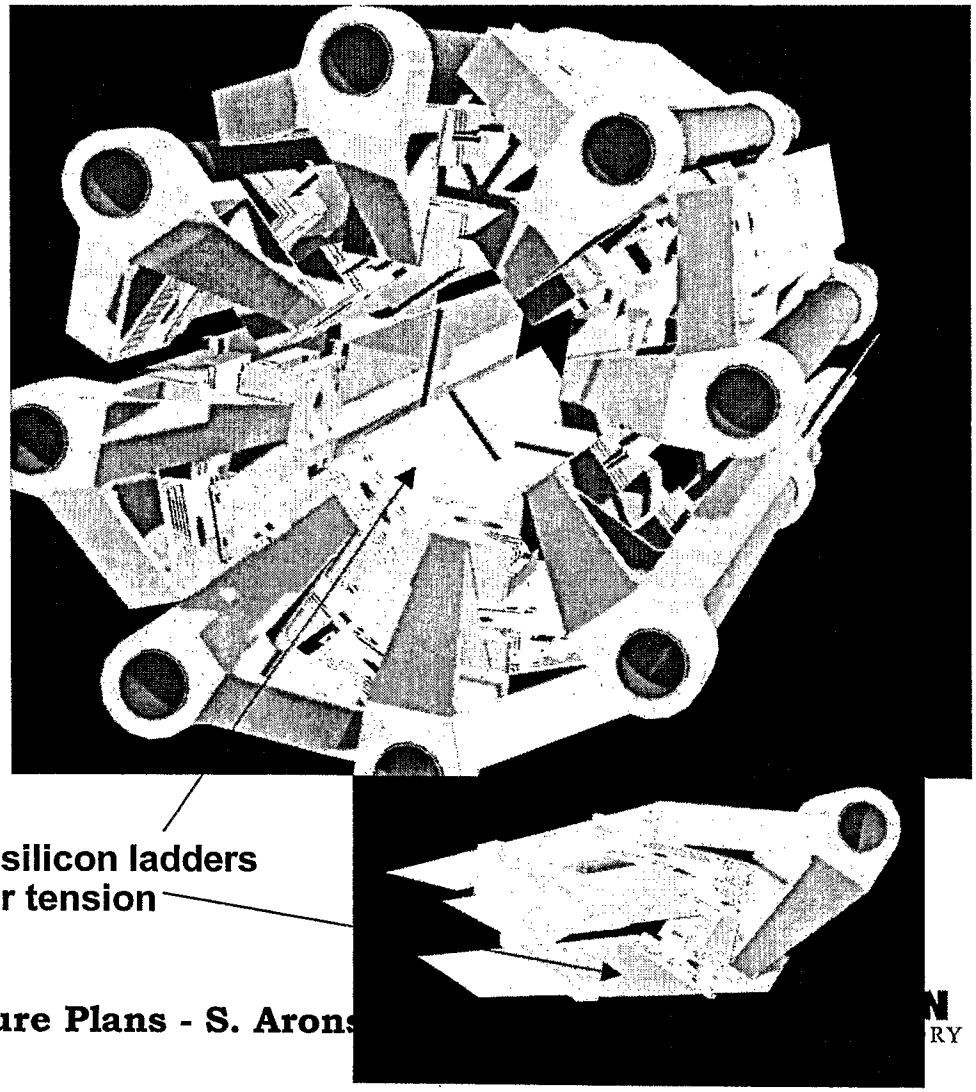


$\sigma \sim 70$ ps, 2 meter path
Strong team including 6 Chinese Institutions in place

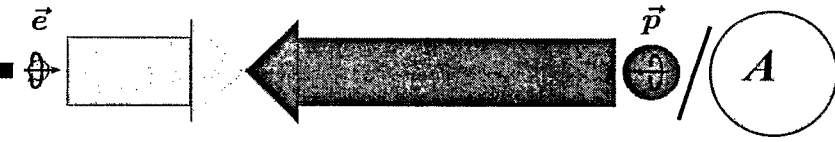
Completed Prototype 28 module MRPC TOF Tray installed in STAR Oct. ' 02 in place of existing central trigger barrel tray

The STAR μVertex detector

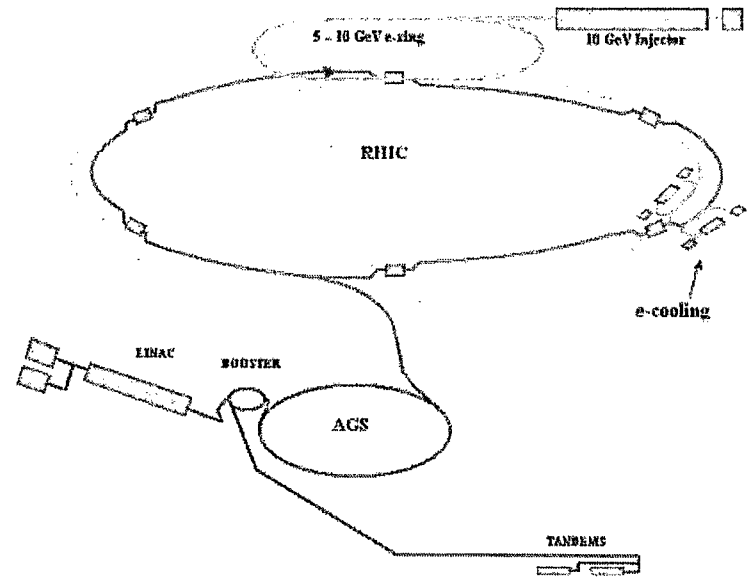
- Open charm
  - Charm quark yield
    - Reconstructing D0
  - Charm hadron chemistry
    - Reconstructing D^+, D_s^+, … decays
  - Charm hadron flow
    - Constructing D^0 spectra
- Open beauty
  - Identifying B mesons
- Identifying heavy quark jets



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



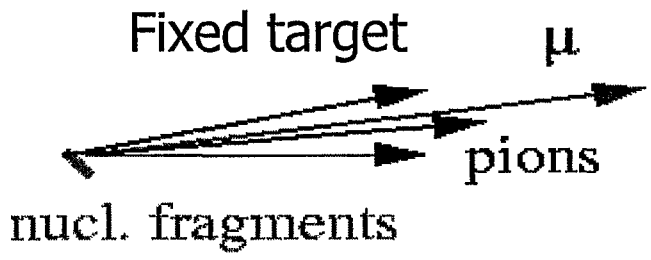
- Why do we need eRHIC?
  - Many fundamental issue in QCD can be addressed with a high energy collider capable of studying polarized deep inelastic scattering

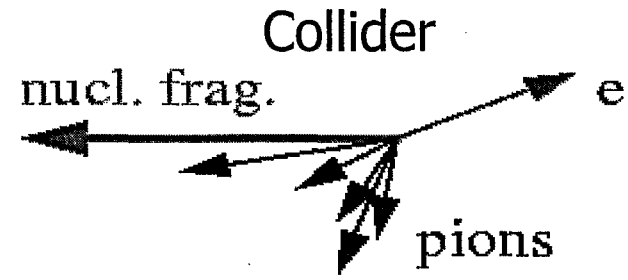
Scientific Frontiers Open to eRHIC

- Nucleon Structure: polarized, unpolarized e-N scattering
  - Role of quarks and gluons in the nucleon
    - –Unpolariz ed quark & gluon distributions, confinement in nucleons
    - –Spin structure: polariz ed quark & gluon distributions
  - Correlation between partons
    - –Hard exclusiv e 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





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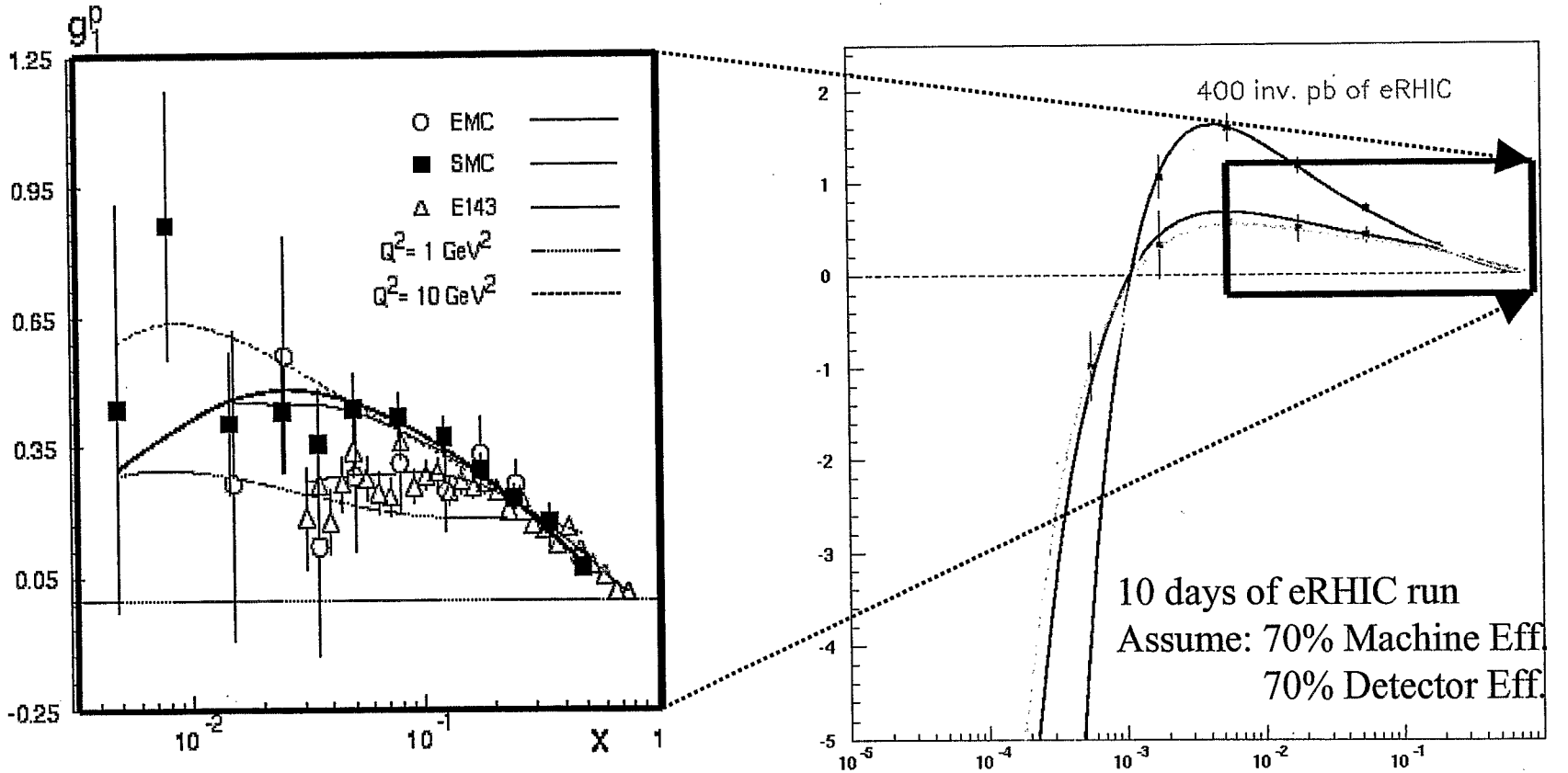
- Better angular separation between scattered lepton & nuclear fragments
  - → Better resolution of electromagnetic probe
  - → Recognition of rapidity gap events (recent diffractive physics)
- Better measurement of nuclear fragments
- Higher center of mass energies reachable
- BUT: tricky integration 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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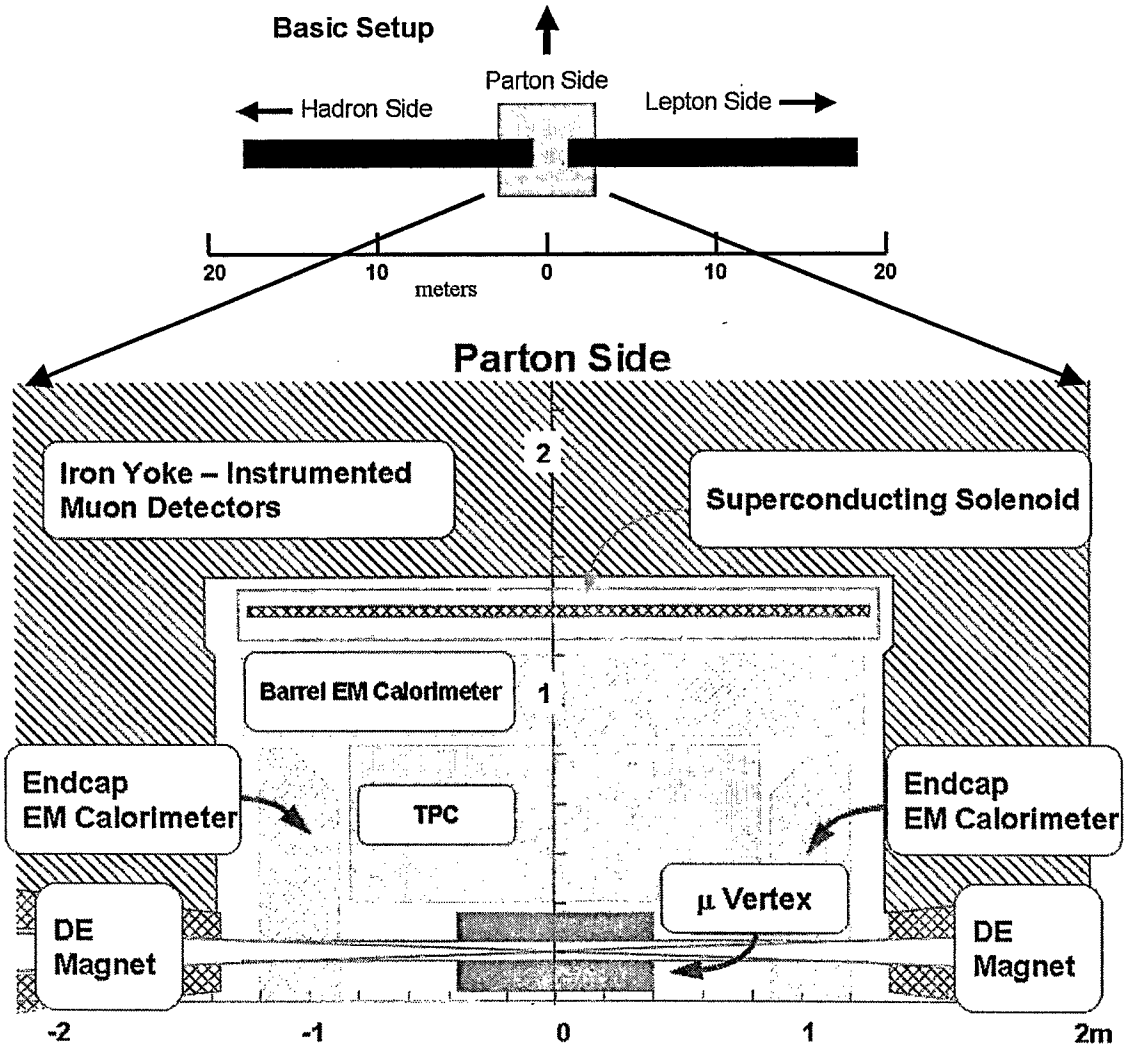
Polarized Gluon Measurement at eRHIC

- 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 $\rightarrow$
  - 2-high p_T hadron production in PGF $\rightarrow$

  } ***Shape of $\Delta G(x)$***
- Photo-production (real photon) kinematics at eRHIC
  - Single and di-jet production in PGF
  - Open charm production in PGF

Detector Design (I)... others expected



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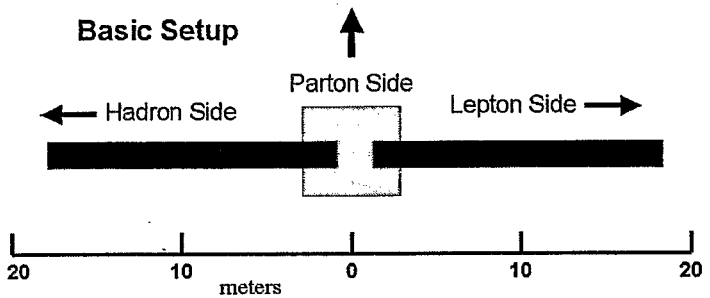
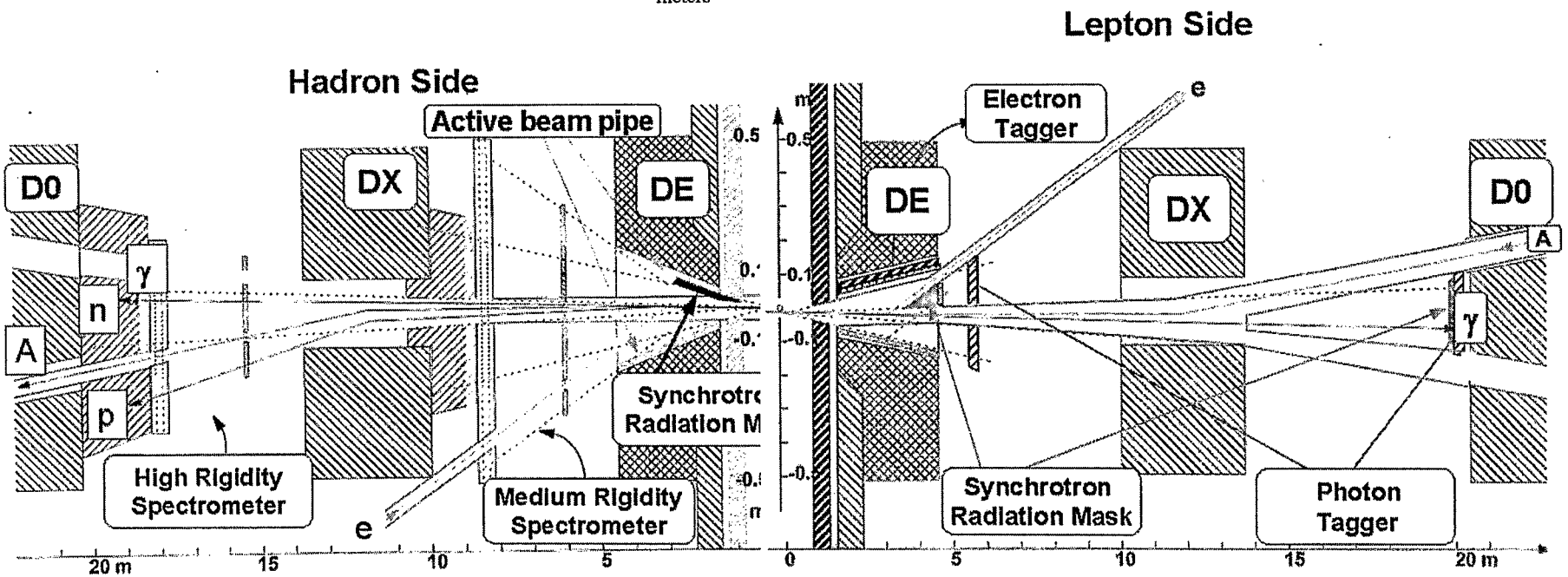
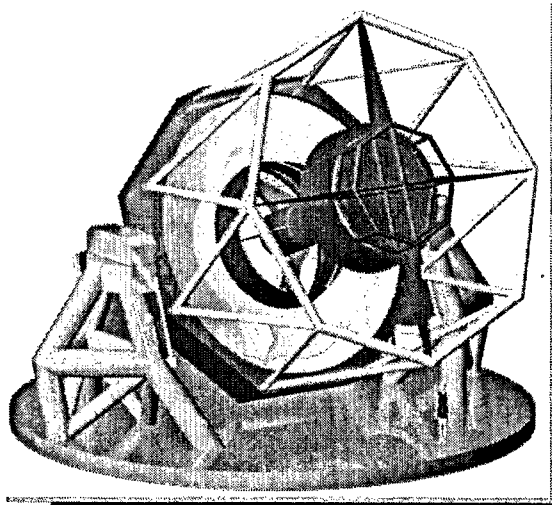
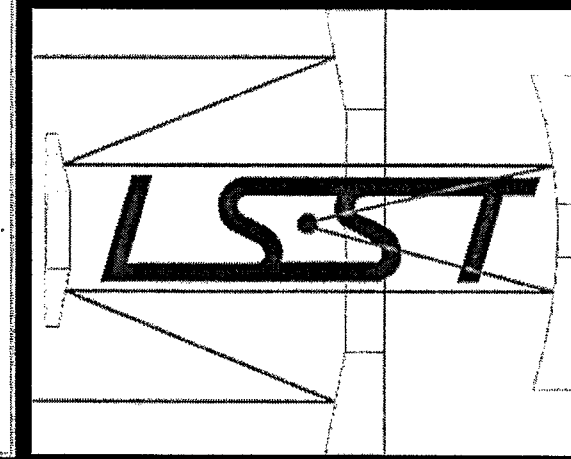
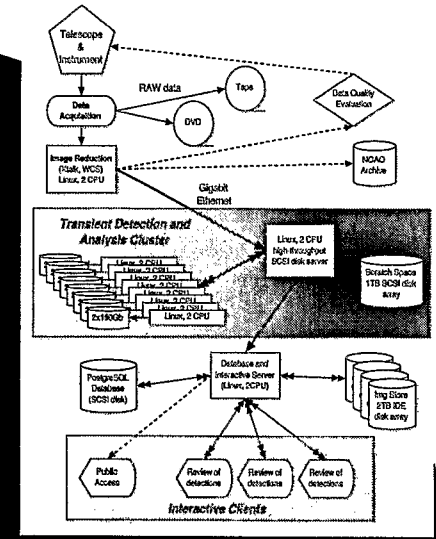


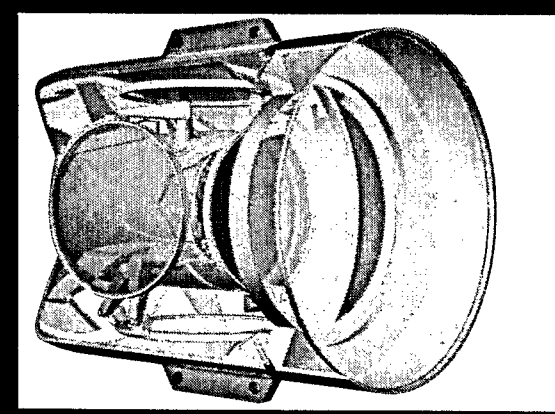


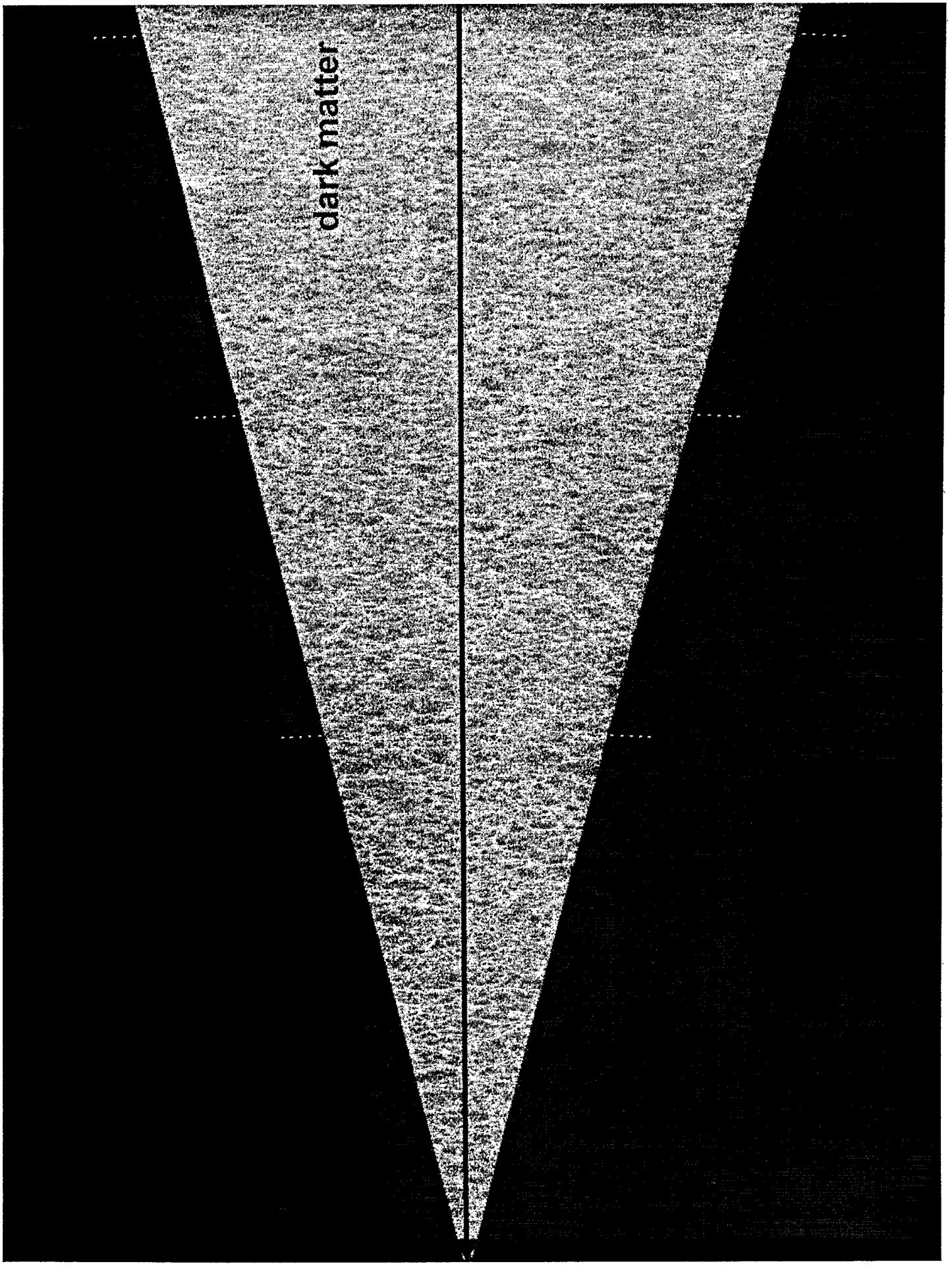
LSST Major subsystems










dark matter

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, ATLA S, 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 mi xture of LDRD funded and unfunded efforts**

Approach

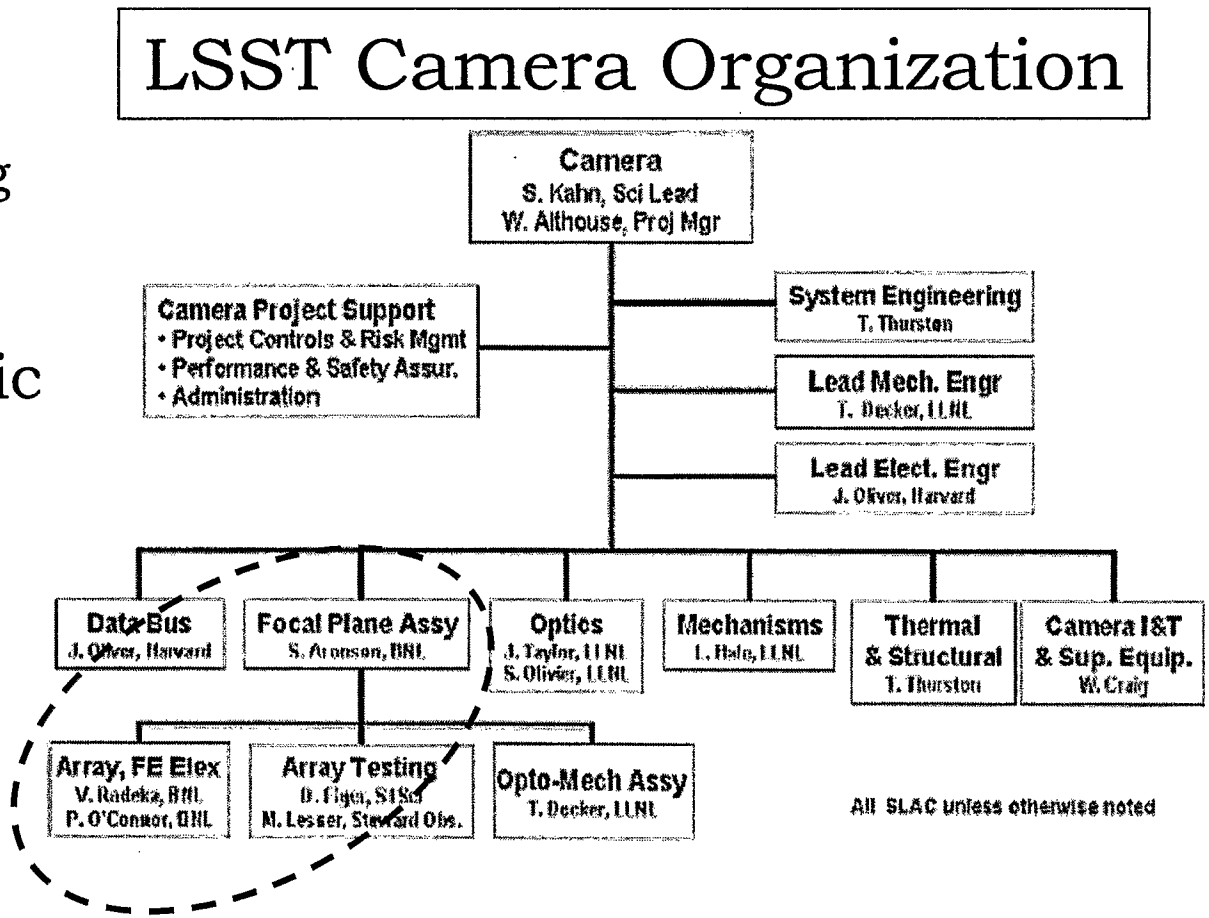
- Scientific
  - BNL's interest within the broad science scope of LSST is centered on the exploration and characterization of **Dark Energy**
  - We are developing the capability to perform this research primarily through weak gravitational lensing
    - Map of galactic shear → map of the mass which 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

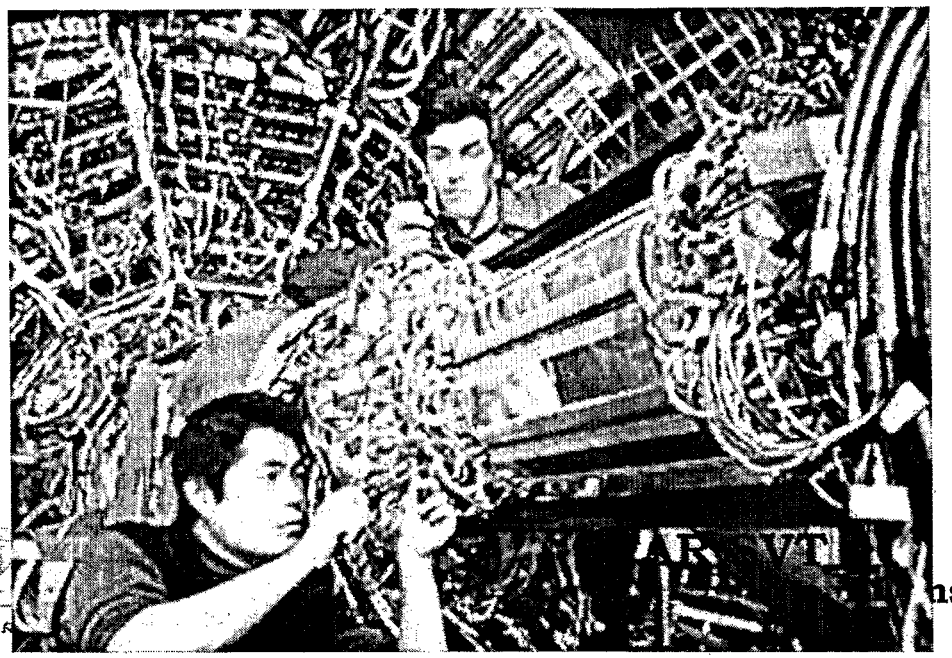
BNL's principal LSST role

- 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

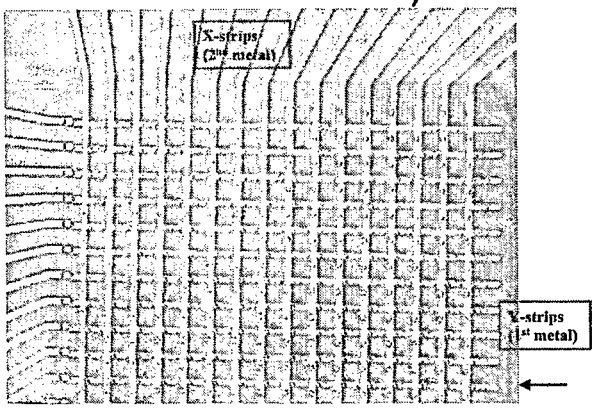
- **Instrumentation Division has**
  - **A unique ability within the DOE labs and US universities to fabricate complex silicon detector devices**
    - **The highest sensitivity low noise ICs**
  - **Experience designing Si pixel detectors with low noise ASIC readout for RHIC and ATLAS**
  - **Experience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



Novel Detectors

- **Stripixel detectors**

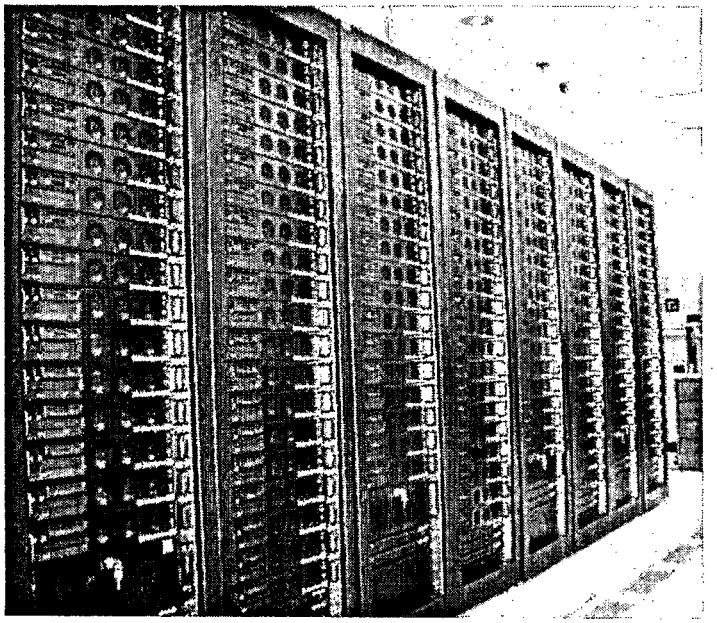
  1-sided 2D position sensing (PHENIX barrel VTX)



- **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



PROCEDURE FOR PROPOSING RENEWAL OF THE COLLABORATION AGREEMENT IN 2007

Chiharu Shimoyamada

Year	2004	2005	2006	2007	2008	2009	2010	2011
Month	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D
JFY		JFY2004	JFY2005	JFY2006	JFY2007	JFY2008	JFY2009	
MoU	MoU #2 -Present 5 years-				MoU #3 -5 Years ?-			
Present Budget Frame	Present Budget Frame RBRC+Spin							
Next Budget Frame	＊Hearing RIKEN ＊Hearing MEXT ＊Settl				Next Budget Frame RBRC+Spin (5 Years)			
MSCs								
	Start Planning	Fix Plan	Approve Actual Plan					
RIKEN Planning Term	#1				#2			
RHIC RUN	4	5	6	7	8	9		

Issues

- Length of the next MoU
- Length of the next Budegt Frame
- Format of the one after (JFY2012)

Procedure for Requesting New Budget

NEW DIRECTION OF RBRC BEYOND JFY 2007

Nicholas P. Samios

New Direction of RBRC Beyond JFY 2007

Nicholas P. Samios

Presentation
11th Meeting of The Management Steering Committee of RIKEN BNL Collaboration

May 27, 2005
Brookhaven National Laboratory, Upton, NY

Propose a 5 year Extension of the RIKEN BNL MOU
JFY 2007-2011

Request budgetary support in RIKEN both in the RBRC Operations and the RHIC Spin Program

Partial History

1995 MOU RIKEN-BNL SPIN Physics Program

1997 Establishment of RIKEN BNL Research Center
1997 QCDSP RIKEN-Columbia Agreement

1998 QCDSP Dedication
1999 RHIC Dedication

1999 Establishment of RBRC RHIC Fellows Program

2001 RHIC – Polarized Protons

2002 MOU Renewal RIKEN-BNL

2002 QCDOC RIKEN-Columbia Agreement

2005 QCDOC Dedication

2005 First Major Spin Run

2006 Request of MOU Renewal

Physics Interests of RBRC:

States of Matter at High Energy Density

Investigate the nature of strongly interacting matter in bulk

Nuclear matter → quark gluon plasma

- Probe the Standard Model
- Spin Structure of Hadrons
- How are strongly interacting particles made from fundamental constituents?
- How does the fundamental interaction of QCD produce mass & confinement?
- Tests of Cabbibo, Kobayashi-Maskawa (CKM) matrix
- Non-Perturbative QCD (Lattice Gauge)
- Measuring and Understanding the Gluon, Quark, Anti-quark Distributions

Activities and Accomplishments:

- Participated in the establishment of the existence of hot, dense matter that is composed of strongly coupled quarks and gluons - the quark gluon plasma. This is matter that existed 10 microseconds after the big bang.

- Developed a theory of matter at small x, the color glass condensate.

- Spin structure functions: First measurements for gluons

- Calculated next to leading order (NLO) production of single pions and photons in proton proton interactions, including spin.

- Calculations of spin structure functions using lattice QCD.

- Explored the thermodynamic properties of a quark-gluon plasma on a lattice.

- Lattice QCD calculations of hadronic masses and hadronic effects associated with extractions of the parameters of CKM matrix.

- CP violation in hadron decays

- QCDSP (0.6 Teraflops) > 99% operational efficiency

- QCDOC (10 Teraflops) constructed and operational

RHIC Accelerator:	Siberian Snakes, Spin Rotators, Polarimeters (AGS & RHIC)
PHENIX Detector:	Muon arm Event selection software Local Polarimeter
Gluons:	Precise measurement with pions, goal accomplished
Orbital Angular Momentum:	Precise measurement of quark spin analyzing power with BELLE data

Role of Spin - Wako

1995-1999+	Snake, Rotator, muon arm construction
1999-2006	Maintenance (snakes, muon arm, AGS-snake)
2002-2003	CCJ construction, personnel & trips
2002-2006	Silicon vertex R&D - construction (ongoing)

Other Achievements

Outstanding Fellows and Post docs
- Permanent Positions - Universities and Laboratories
- RBRC University Fellows Program

Awards: 5 Outstanding Junior Investigators

Publications: 275 Theory/211 Experiment
35 RBRC Proceedings

Workshops: 42

Seminars: 5 per week

Scientific Review Committee Reports
- All very positive on quality of staff and scientific productivity.

Aims and Expected Accomplishments during 5-year Extension

Era of Precise Lattice Gauge Calculations

- Include virtual quark-antiquark pairs
- Larger lattices
- QCD Thermodynamics
- Hadronic and quark masses
- CP violation
- CKM matrix
- Start planning for next generation computer (300 tflop - 1 petaflop)

Precise Studies of High Energy Density Matter

- Strongly Coupled Quark Gluon Plasma
- Relate the properties of matter as extracted from theory and what is seen in experiment
- Examples - jet correlation functions
- hydrodynamics

Physics of Color-glass Condensate

- Understand the gluonic matter, which composes hadrons and dominates the soft gluon part of the hadronic wave function.
- Propose probes of this matter as it pertains to RHIC, eRHIC, and LHC.

Spin of the Proton

Relate computations in perturbative QCD to measurements and extraction of quantities, which measure how spin is distributed amongst the gluons and quarks inside a hadron and extract gluon spin from RHIC experiments.

Era of Precision Spin Physics

Exploit and derive benefits from 10 year investment in spin hardware

Gluons - Precise measurements at smaller momenta functions with pions, direct photons and charm

Quark and anti-quarks - Precise measurements using electron weak parity violation

Detectors: Muon and vertex upgrades

Machine: 500 GeV - high polarization and luminosity

R&D: Extended measurements with RHIC and for eRHIC

5 Year Research Plan for Spin Physics at RHIC - February 11, 2005

Budget & Personnel
RBRC and Spin Program
Mature
Steady State
Personnel Levels - Flat
Budget Levels - Flat

Spin Program
- Maintenance
- CCJ
- Personnel
- Upgrades
- Future R&D

RBRC
- Theory
- Experiment
- Administration

We propose that this plan should be reviewed and suggest that the Management Steering Committee charge the Scientific Review Committee to do such a review prior to submission to RIKEN.

PUBLICATION LIST

RBRC - EXPERIMENT

RBRC Experimental Publications
April 2004 – March 2005

RHIC Spin (and pp) Publications

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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**
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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**
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