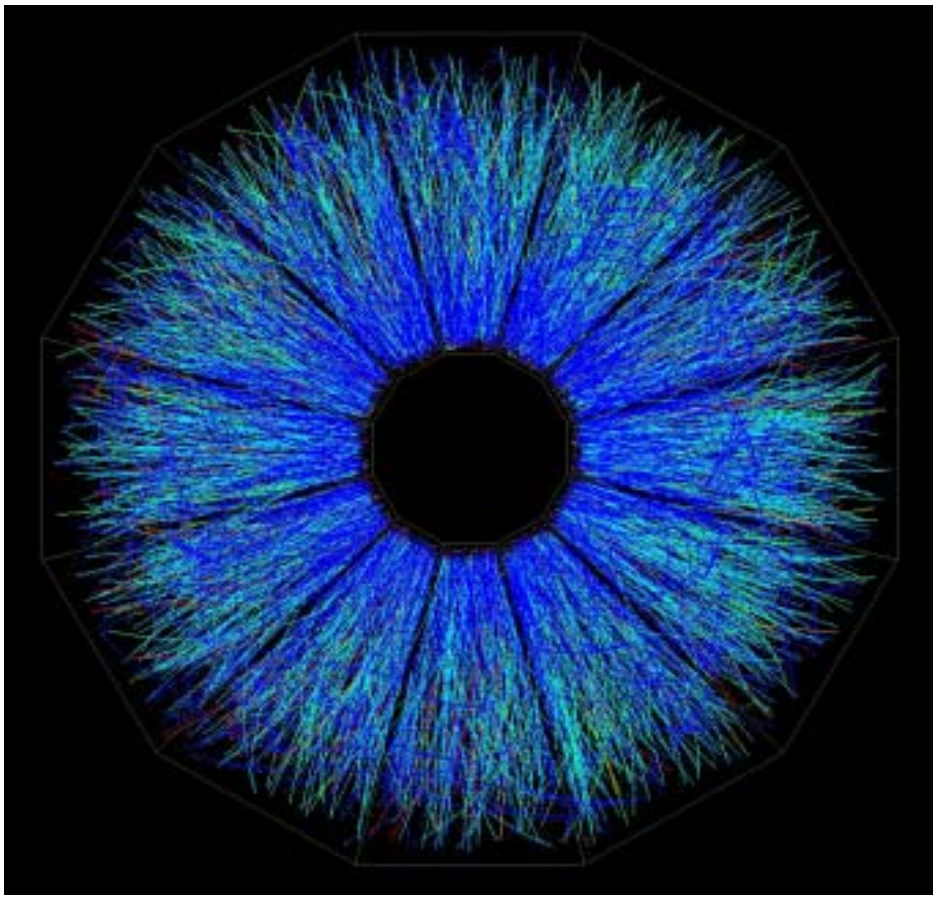
Status of the STAR Experiment



Tim Hallman for the STAR Collaboration
DOE S&T Review
July 6, 2005

Status of the STAR Experiment

Outline of this Talk:

Status of the STAR Collaboration

Report on Run V

Recent and “expected soon” physics results

Future Plans

Concerns

Conclusions

The STAR Collaboration: 51 Institutions, 14 countries, ~ 550 People

U.S. Labs:
Argonne, Berkeley, and Brookhaven National Labs

U.S. Universities:
UC Berkeley, UC Davis, UCLA, Caltech, Carnegie Mellon, Creighton, Indiana, Kent State, MSU, CCNY, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale, MIT

Brazil:
Universidade de Sao Paolo

China:
IHEP - Beijing, IPP - Wuhan, USTC, Tsinghua, SINR, IMP Lanzhou

Croatia:
Zagreb University

Czech Republic:
Institute of Nuclear Physics

England:
University of Birmingham

France:
Institut de Recherches Subatomiques Strasbourg, SUBATECH – Nantes

Germany:
Max Planck Institute – Munich University of Frankfurt

India:
Bhubaneswar, Jammu, IIT-Mumbai, Panjab, Rajasthan, VECC

Netherlands:
NIKHEF

Poland:
Warsaw University of Technology

Russia:
MEPHI – Moscow, LPP/LHE JINR – Dubna, IHEP – Protvino

South Korea:
Pusan National University

Switzerland:
University of Bern

STAR is a vital, growing, international collaboration

Status of the STAR Collaboration: Educating the next generation of Nuclear Scientists

Lastname	Firstname	Inst Id	Institute	Thesis Type	Date of completion	
Gross	Jeffrey	10	Creighton	Masters	1995-00-00	English
Meier	John	10	Creighton	Masters	1996-00-00	English
Bittl	Xaver	22	MPI Munich	Diploma	1997-01-00	German
Konrad	Michael	22	MPI Munich	Ph.D.	1997-07-30	German
Adler	Clemens	13	Frankfurt University	Diploma	1998-00-00	German
Berger	Jens	13	Frankfurt University	Diploma	1998-00-00	German
Jones	Quinn	10	Creighton	Masters	1998-00-00	English
Marstaller	Rainer	22	MPI Munich	Diploma	1998-12-00	German
Lin	Jie	10	Creighton	Masters	1999-00-00	English
Pinganaud	Walter	38	Subatech	Ph.D.	2000-00-00	French
Retiere	Fabrice	38	Subatech	Ph.D.	2000-00-00	French
Eggert	Tobias	22	MPI Munich	Diploma	2000-03-00	German
Hümmler	Holm	22	MPI Munich	Ph.D.	2000-07-00	English
DeMello	Martin	33	Rice University	Masters	2001-00-00	English
Suire	Christophe	15	Strasbourg	Ph.D.	2001-00-00	French
Yamamoto	Eugene	7	UCLA	Ph.D.	2001-00-00	English
Caldron	Manuel	49	Yale Unversity	Ph.D.	2001-12-00	English
Cardenas	Alex	31	Purdue University	Ph.D.	2002-00-00	English
Chaloupka	Petr	26	Nuclear Physics Inst., Prague	Masters	2002-00-00	English
Lansdell	Curtis	40	Texas University	Ph.D.	2002-00-00	English
Long	Hui	7	UCLA	Ph.D.	2002-00-00	English

Status of the STAR Collaboration: Educating the next generation of Nuclear Scientists

Lastname	Firstname	Inst Id	Institute	Thesis Type	Date of completion	
Reid	Jeffrey	46	Washington	Ph.D.	2002-00-00	English
Tonjes	Marguerite	23	MSU	Ph.D.	2002-00-00	English
Gaertner	Andreas	22	MPI Munich	Diploma	2002-01-00	German
Lamont	Matthew	4	Birmingham	Ph.D.	2002-01-00	English
Oldenburg	Markus	22	MPI Munich	Ph.D.	2002-01-10	German
Deng	Wensheng	17	Kent State	Ph.D.	2002-05-00	English
Tang	Aihong	17	Kent State	Ph.D.	2002-05-00	English
Willson	Robert	27	Ohio	Ph.D.	2002-06-00	English
Hippolyte	Boris	15	Strasbourg	Ph.D.	2002-07-00	French
Castillo	Javier	38	Subatech	Ph.D.	2002-07-05	French
Fu	Jinghua	48	Huazhong Normal University	Ph.D.	2002-08-26	English
Johnson	Ian	6	Davis	Ph.D.	2002-09-00	English
Horsley	Matthew	49	Yale Unversity	Ph.D.	2002-12-00	English
Adler	Clemens	13	Frankfurt University	Ph.D.	2003-00-00	German
Berger	Jens	13	Frankfurt University	Ph.D.	2003-00-00	English
Chen	Yu	7	UCLA	Ph.D.	2003-00-00	English
Choi	Bum	40	Texas University	Ph.D.	2003-00-00	English
Flierl	Dominik	13	Frankfurt University	Ph.D.	2003-00-00	English
Gaudichet	Ludovic	38	Subatech	Ph.D.	2003-00-00	French
Gronstal	Steven	10	Creighton	Masters	2003-00-00	English

Status of the STAR Collaboration: Educating the next generation of Nuclear Scientists

Lastname	Firstname	Inst Id	Institute	Thesis Type	Date of completion	
Herston	Timothy	31	Purdue University	Masters	2003-00-00	English
Kunz	Christopher	8	Carnegy	Ph.D.	2003-00-00	English
Morozov	Vladimir	20	LBL	Ph.D.	2003-00-00	English
Norman	Ben E.	17	Kent State	Ph.D.	2003-00-00	English
Parks	Sarah	10	Creighton	Masters	2003-00-00	English
Sorensen	Paul	7	UCLA	Ph.D.	2003-00-00	English
Struck	Christof	13	Frankfurt University	Ph.D.	2003-00-00	English
Warnasooriya	Nilanthi	10	Creighton	Masters	2003-00-00	English
Wells	Randall	27	Ohio State University	Ph.D.	2003-00-00	English
Maierbeck	Peter	22	MPI Munich	Diploma	2003-04-00	German
Miller	Mike	49	Yale Unversity	Ph.D.	2003-12-00	English
Zhang	Haibin	49	Yale Unversity	Ph.D.	2003-12-18	English
Bekele	Selemon	27	Ohio State University	Ph.D.	2004-00-00	English
Chajecki	Zbigniew	45	Warsaw University	Masters	2004-00-00	Polish
Wang	Yiqun	40	Texas University	Ph.D.	2004-00-00	English
Gans	Jon	49	Yale Unversity	Ph.D.	2004-05-00	English
Ishihara	Aya	40	Texas University	Ph.D.	2004-05-00	English
Huang	Shengli	35	USTC	Ph.D.	2004-06-00	Chinese
Lopez-Noriega	Mercedes	27	Ohio State University	Ph.D.	2004-07-00	English
Renault	Gael	38	Subatech	Ph.D.	2004-09-24	French

Status of the STAR Collaboration: Educating the next generation of Nuclear Scientists

Lastname	Firstname	Inst Id	Institute	Thesis Type	Date of completion	
Faivre	Julien	15	Institut de Recherches Subatomiques de Strasbourg	Ph.D.	2004-10-01	French
Ruan	Lijuan	35	USTC	Ph.D.	2004-10-19	English
Putschke	Joern	22	MPI Munich	Ph.D.	2004-11-18	German
Kisiel	Adam	45	Warsaw University	Ph.D.	2004-12-09	English
Simon	Frank	22	MPI Munich	Ph.D.	2005-02-28	English
Estienne	Magali	38	Subatech	Ph.D.	2005-04	French
Adams	John	4	University of Birmingham	Ph.D.	2005-05-18	English
Guo	Ying	47	Wayne State University	Ph.D.	2005-06	English
Wood	Jeffrey	7	UCLA	Ph.D.	2005-06-03	English
Dong	Xin	35	USTC	Ph.D.	2005-06-06	English
Liu	Zhixu	48	Institute of Particle Physics	Ph.D.	2005-06-10	English
Heinz	Mark	51	University of Bern	Ph.D.	2005-06-23	English

Thus far, 73 advanced degrees awarded on STAR work:

55 Ph.D.'s
11 Master's
7 Diploma

Status of the STAR Collaboration: Scientific Productivity

Incident Energy Dependence of pt Correlations at RHIC
Submitted April 29, 2005 e-Print Archives (nucl-ex/0504031)

Multi-strange baryon elliptic flow in Au+Au collisions at sqrt(sNN)= 200 GeV
Submitted April 22, 2005 e-Print Archives (nucl-ex/0504022)

Multiplicity and Pseudorapidity Distributions of Photons in Au + Au Collisions at sqrt(sNN) = 62.4 GeV
Submitted February 4, 2005 e-Print Archives (nucl-ex/0502008)

Distributions of Charged Hadrons Associated with High Transverse Momentum Particles in pp and Au+Au Collisions at sqrt(sNN) = 200 GeV *Submitted January 20, 2005* e-Print Archives (nucl-ex/0501016)

Experimental and Theoretical Challenges in the Search for the Quark Gluon Plasma: The STAR Collaboration's Critical Assessment of the Evidence from RHIC Collisions *Submitted January 13, 2005*, *published May 17, 2005* Nucl. Phys. A 757 (2005) 102

K(892)* Resonance Production in Au+Au and p+p Collisions at sqrt(sNN) = 200 GeV at STAR
Submitted December 9, 2004, *published June 6, 2005* Phys. Rev. C 71 (2005) 064902

Pion interferometry in Au+Au collisions at sqrt(sNN) = 200 GeV *Submitted November 18, 2004*, *published April 28, 2005*
Phys. Rev. C 71 (2005) 044906

Minijet deformation and charge-independent two-particle correlations on momentum subspace (eta,phi) in Au-Au collisions at sqrt(sNN) = 130 GeV *Submitted November 5, 2004* e-Print Archives (nucl-ex/0411003)

Azimuthal Anisotropy in Au+Au Collisions at sqrt(sNN) = 200 GeV
Submitted September 29, 2004 e-Print Archives (nucl-ex/0409033)

Status of the STAR Collaboration: Scientific Productivity

Pseudorapidity Asymmetry and Centrality Dependence of Charged Hadron Spectra in d+Au Collisions at sqrt(sNN) = 200 GeV
Submitted August 16, 2004, published December 23, 2004 Phys. Rev. C 70 (2004) 064907

Transverse momentum correlations and minijet dissipation in Au-Au collisions at sqrt(sNN) = 130 GeV
Submitted August 11, 2004 e-Print Archives (nucl-ex/0408012)

Azimuthal anisotropy and correlations at large transverse momenta in p+p and Au+Au collisions at sqrt(sNN)= 200 GeV
Submitted July 9, 2004, published December 15, 2004 Phys. Rev. Lett. 93 (2004) 252301

Open charm yields in d+Au collisions at sqrt(sNN) = 200 GeV *Submitted July 6, 2004, published February 18, 2005*
Phys. Rev. Lett. 94 (2005) 062301

Measurements of transverse energy distributions in Au+Au collisions at sqrt(sNN) = 200 GeV
Submitted July 2, 2004, published November 23, 2004 Phys. Rev. C 70 (2004) 054907

28 PRL, 15 PRC, 4 PLB published

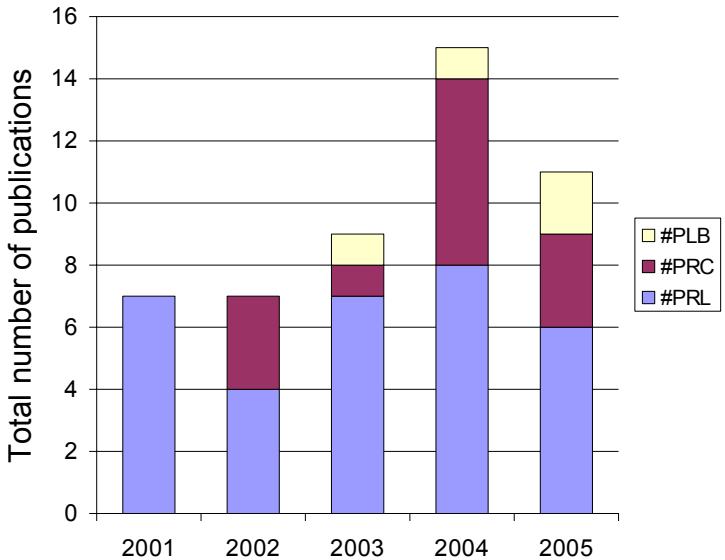
1 PRC, 5 PRL submitted

2692 citations,

11 papers on top cite 100+

18 papers with > 50 citations

1st STAR PRL most cited paper at RHIC



Other Achievements by STAR Collaborators

Zhangbu Xu (BNL):
2005 Presidential Early Career Scientist Award

Jinghua Fu
(IOPP/Tsinghua U.):
2005 Top 100
Thesis in China Award

Paul Sorensen (LBNL):
2004 RHIC/AGS
Thesis Award; 2005
BNL Goldhaber Fellow

Fuqiang Wang (Purdue):
2002 DOE Outstanding
Junior Investigator Award

Xin Dong (USTC):
CAS Early Career Scientist Award

Mike Lisa: 2004 Sambamurti Lecture

Status of STAR Collaboration

Long term visitors at BNL working on STAR

Aggarwal	Panjab	Ahammed	VECC	Arkhipkin	PPL, Dubna
Averichev	LHE, Dubna	Bai	NIKHEF/Utrecht	Baudot	IReS
Bekele	Ohio State	Bhardwaj	University of Rajasthan	Bhati	Panjab
Bonnet	IReS	Bouchet	SUBATECH	Brandin	MEPhI
Bystersky	NPI	Calderon	IUCF	Castillo	LBNL
Crawford	SSL	Das, D.	VECC	Das, S.	VECC
De Moura	Sao Paulo	Derevschchikov	IHEP, Protvino	Dietel	Frankfurt
Dogra	Jammu	Dong, X.	USTC	Dong, W.	UCLA
Efimov	LHE, Dubna	Engelage	SSL	Fedorisin	LHE, Dubna
Filip	NPI	Filippov	Wayne State	Fu	Tsinghua University
Ganti	VECC	Gos	Warsaw	Grebenyuk	NIKHEF/Utrecht
Guilloux	SUBATECH	Gupta	Jammu	Hippolyte	Yale
Igo	UCLA	Heinz	Bern	Hu	MIT
Ignatenko	Wayne State	Jang	MIT	Janik	Warsaw
Jacobs	IUCF	Jakl	NPI	Jedynak	Warsaw
Jones	Birmingham	Kechechyan	LHE, Dubna	Kiryluk	MIT
Kisiel	Warsaw	Koetke	Valpariso	Kolleger	Frankfurt
Kopytine	Kent State	Kotchenda	MEPhI	Kravtsov	MEPhI
Kulikov	LHE, Dubna	Kurnadi	UCLA	Lamont	Yale
Lebedev	Wayne State	Liu, F.	IPP, Wuhan	Liu, H.	USTC
Long	UCLA	Ma, J.	UCLA	Ma, G.	SIAP, Shanghai
Magestro	Ohio State	Mahaptra	Bhubaneswar	Markert	Kent

Status of STAR Collaboration

Long term visitors at BNL working on STAR

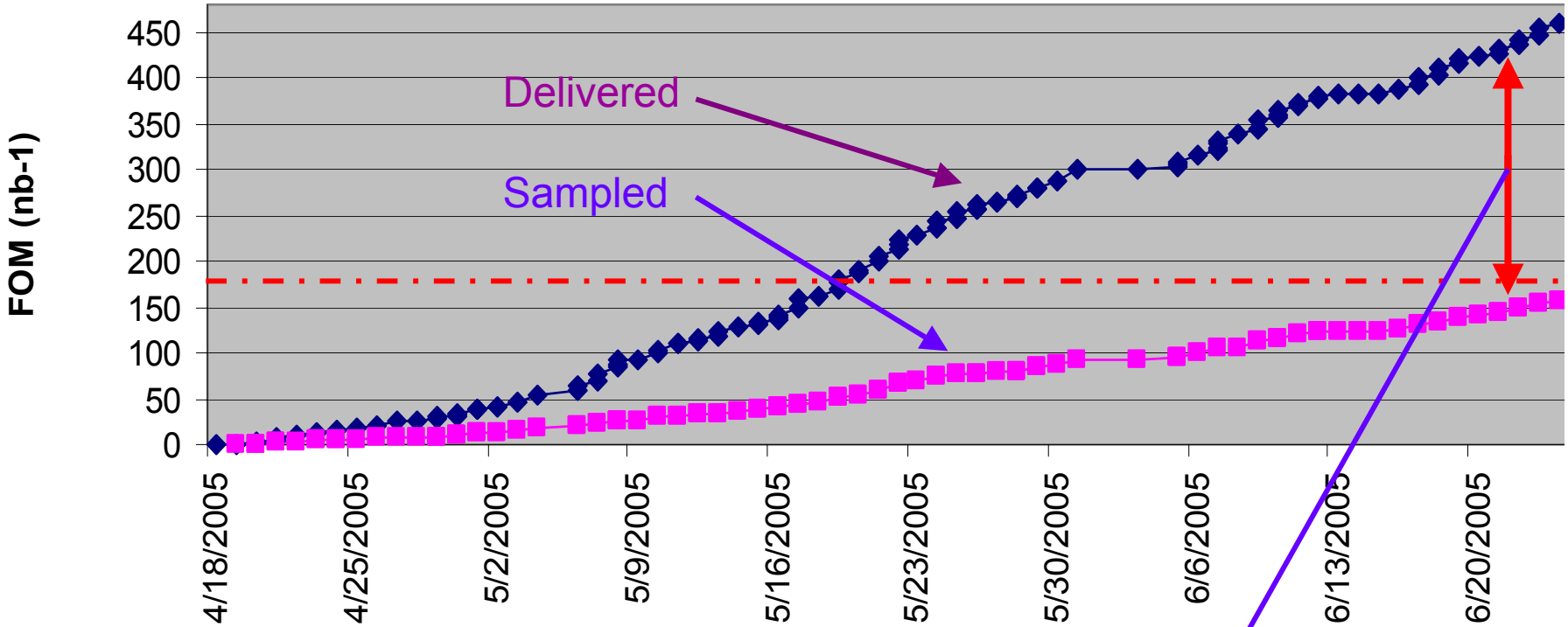
Martin	SUBATECH	Matulenko	IHEP, Protvino	McShane	Creighton
Mironov	Kent State	Mishra	Bhubaneswar	Mohanty	VECC
Morozov	IHEP, Protvino	Munhoz	Sao Paulo	Nandi	VECC
Nayak	VECC	Nelson	Birmingham	Netrakanti	VECC
Nogach	IHEP, Protvino	Okorokov	MEPhI	Pachr	NPI
Pal	VECC	Panebratsev	LHE, Dubna	Petrov	Wayne State
Potukuchi	Jammu	Rakness	Penn State	Raniwala	Rajasthan
Reinnarth	SUBATECH	Retiere	LBNL	Rogatchevsky	LHE, Dubna
Rzepkowski	Warsaw	Sahoo	Bhubaneswar	Sazhin	LHE, Dubna
Seyboth, J.	MPI	Seyboth, P.	MPI	Shao	USTC
Sharma	Panjab	Shimanskiy	LHE, Dubna	Smirnov	Yale
Sowinski	IUCF	Stadnik	LHE, Dubna	Stringfellow	Purdue
Sood	Valpariso	Speltz	IReS	Suaide	Sao Paulo
Sumbera	NPI	Sun	IMP, Lanzhou	Surrow	MIT
Tai	UCLA	Takahashi	Sao Paulo	Taluc	Warsaw
Thomas	LBNL	Timoshenko	MEPhI	Tokarev	LHE, Dubna
Trentalange	UCLA	Tsai	UCLA	Varma	IIT, Mumbai
Vernet	IReS	Viyogi	VECC, Calcutta	Vokal	LHE, Dubna
Wang	IMP, Lanzhou	Whitten	UCLA	Wieman	LBNL
Witt	Bern	Yi	Tsinghua	Zawisza	Warsaw
Zhang	USTC	Zhong	SIAP, Shanghai	Zulkarneeva	PPL, Dubna

Overall, ~500 STAR visitors per year for data taking, operations reviews, workshops, collaboration meetings etc. STAR depends on continuing strong participation

Summary of STAR data sets for FY05 Physics run

Species	$s^{1/2}$ (GeV)	Goal	Achieved
CuCu	200	> 50 Mevts of min-bias	65 Mevts
CuCu	200	1 - 2 nb^{-1} sampled with HT trigger	~ 1.05 nb^{-1} sampled
CuCu	62	> 10 Mevts of min-bias	37 Mevts
CuCu	22	Not requested	3.5 Mevts
pp (long.)	200	Sample 7 pb^{-1} @ 40% P FOM = 180 nb^{-1}	FOM ~ 156 nb^{-1} (~ 87 % of goal)
pp (trans.)	200	Sample 4 pb^{-1} @ 40% P	Few % of goal
pp	200	20 Mevts of min-bias	17 Mevts
pp (trans.)	410	Not requested	~ 6 hrs of data

Longitudinal FOM achieved for FY05 pp Run



Goal = 180 nb^{-1} Sampled FOM

Achieved: 156/180 ~ 87%

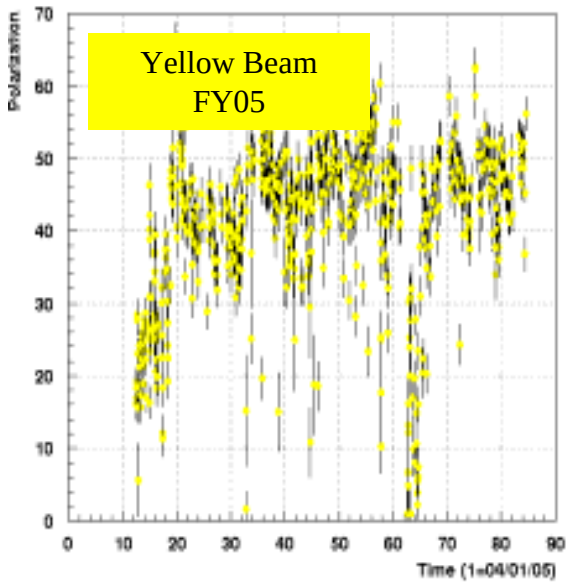
Largest single factor: DAQ deadtime
(⇒ zero with proposed DAQ1000 upgrade)

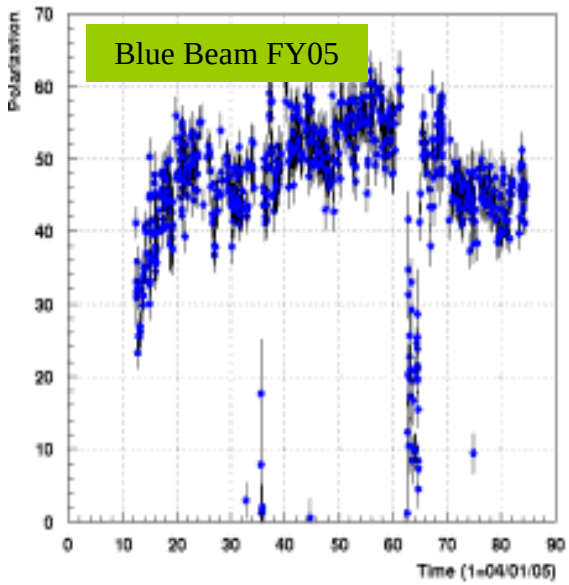
RHIC as a (the only) polarized proton collider
Machine performance overview (FY02-FY05)

- Overview of performance parameters

	√s [GeV]	Lpeak [10^{30}] cm^{-2} s^{-1}	L [pb^{-1}]	Polarization [%]
FY02	200	2	0.35	15
FY03	200	6	1	30
FY04	200	6	0.4	40
FY05	200 (410)	9	9	50

- Status
  - ☑ Siberian snake and spin rotator magnets
  - ☑ Fast polarimeters in AGS/RHIC
  - ☑ Local polarimeters at STAR/PHENIX
  - ☑ Spin transfer AGS to RHIC
  - ☑ Polarized gas-jet target
  - ☑ Warm AGS Siberian snake
  - ☑ Installation of cold AGS Siberian snake magnet and commissioning started
  - ☑ Commissioning towards 250GeV ramp started (At 205GeV)





Blue and Yellow Beam polarization

Recent Collaboration Accomplishments

Two **Major** upgrades of STAR's scientific reach:

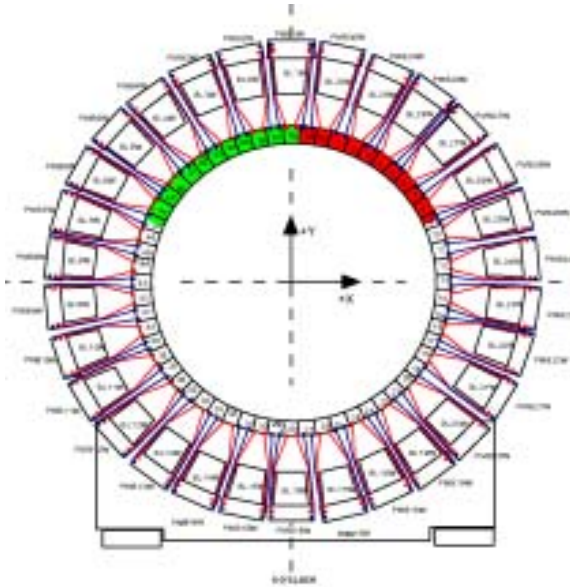
Commissioning of the STAR Barrel and Endcap Electromagnetic Calorimeters
(Task force leader: Will Jacobs, Indiana University Cyclotron Center, UCLA, ANL, MIT, BNL, NIKHEF, WSU, JINR, Sao Paolo)

Development of extended PID combining TPC and MRPC TOF
(Zhangbu Xu, O. Barannikova, et al.)

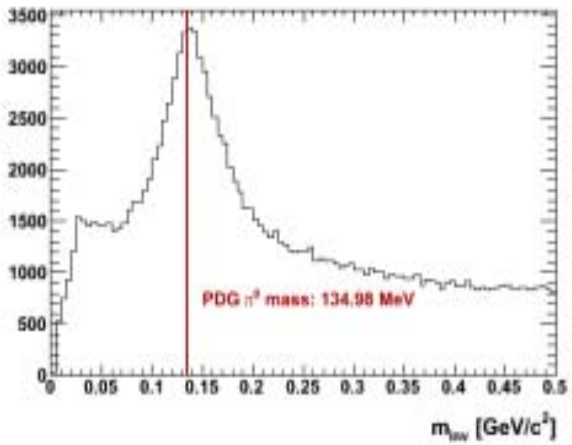
Thank you DOE, NSF, BNL Management, and C-AD !

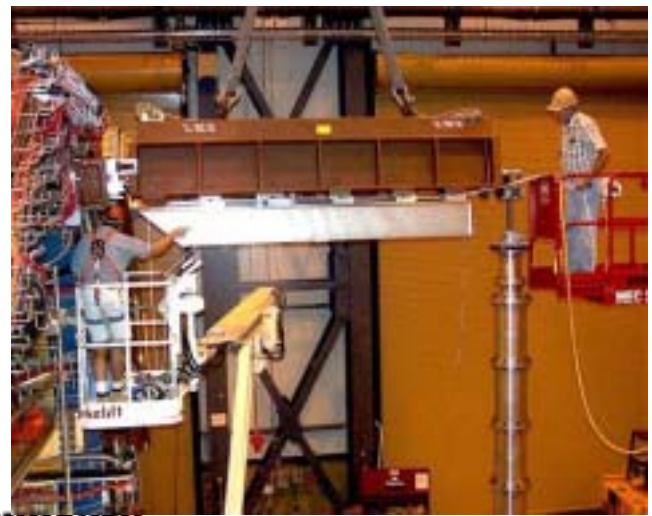
Other important recent additions: Silicon Strip Detector, Photon Mult. detector

STAR calorimeter system: Barrel EMC (BEMC)



F. Simon

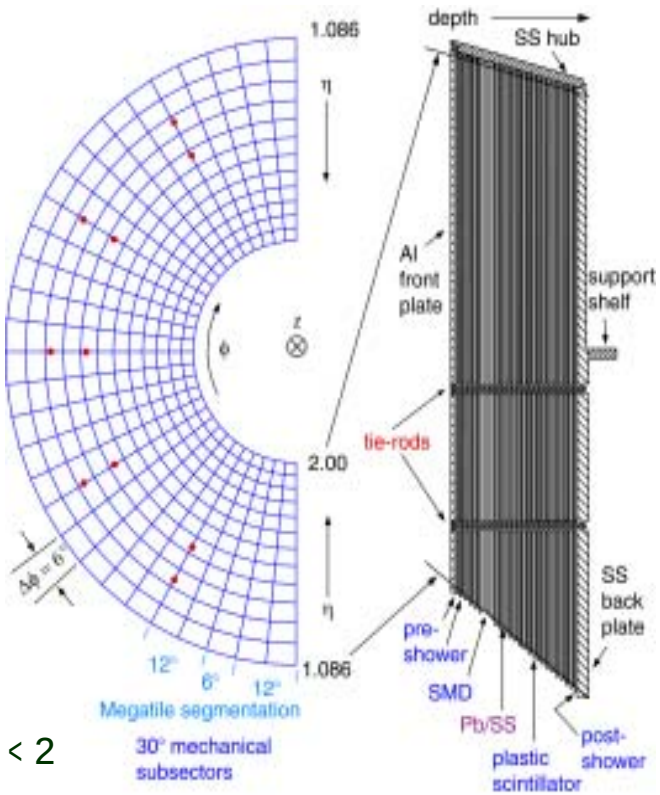




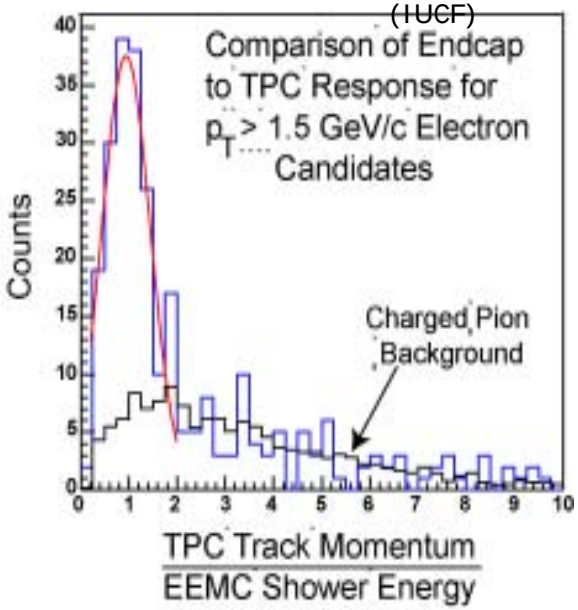
- Barrel Calorimeter: $-1 < \eta < 1$

- Lead-scintillator EM calorimeter (~20 X_0)
- 120 modules with: $\Delta\eta \times \Delta\varphi = 0.1 \times 1.0$
- 40 towers per module: $\Delta\eta \times \Delta\varphi = 0.05 \times 0.05$
- Shower max. detector (SMD): wire proportional counter (π^0/γ discrimination)
- Pre-shower layers
- Module installation completed

STAR calorimeter system: Endcap EMC (EEMC)



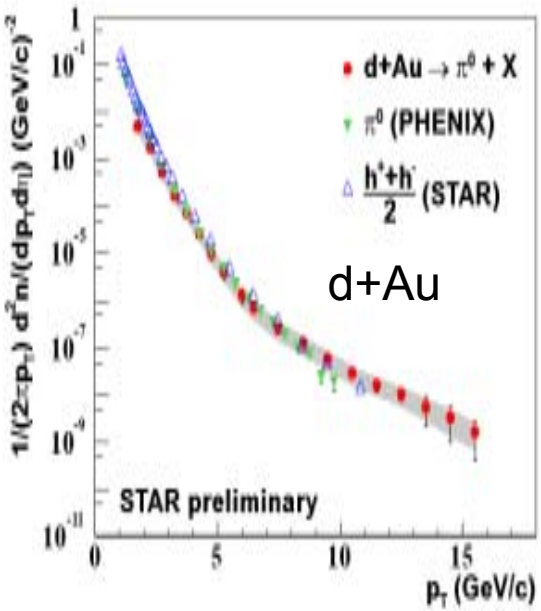
J. Balewski (IUCF)

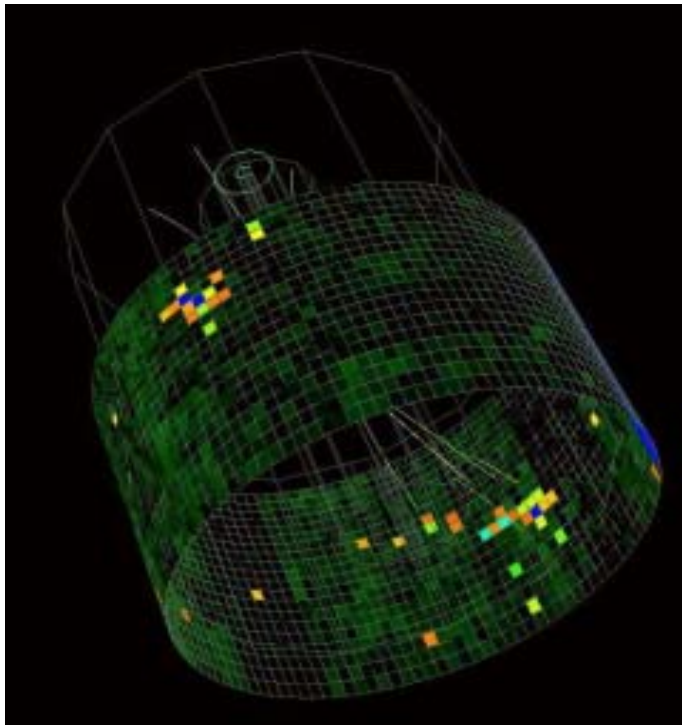


- Endcap calorimeter: $1.086 < \eta < 2$
  - Lead-scintillator calorimeter (~24 X_0)
  - 720 towers with: $\Delta\varphi = 0.1$, $\Delta\eta = 0.057$ at $\eta = 1.086$ to 0.099 at $\eta = 2$
  - Shower max. detector (SMD): scintillator strip layers (π^0/γ discrimination)
  - Pre-shower and post-shower layers
  - EEMC installation completed and fully instrumented!

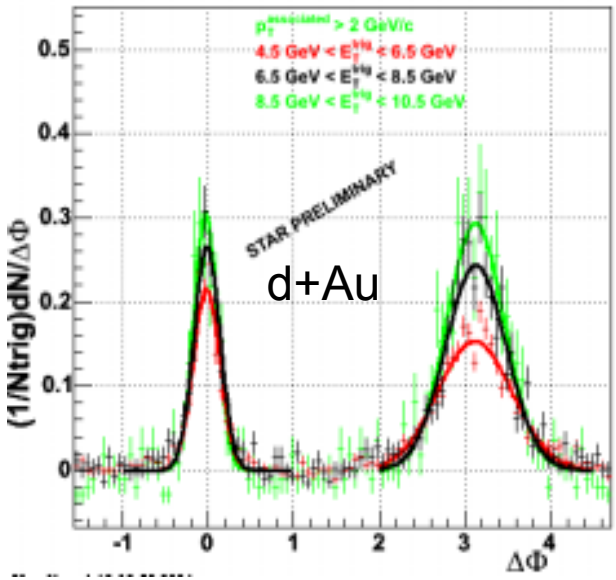
High P_T with Calorimetry

π^0 to high p_T



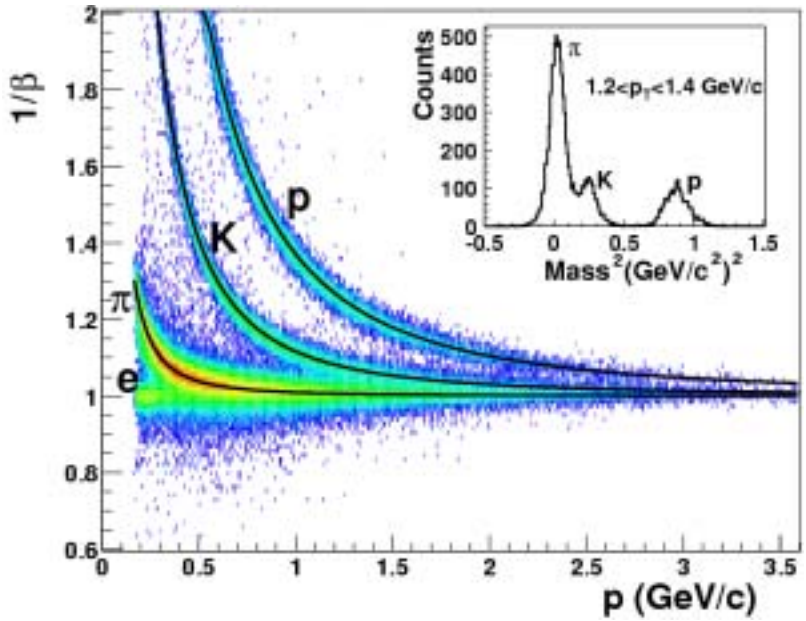


γ-tagged Correlations

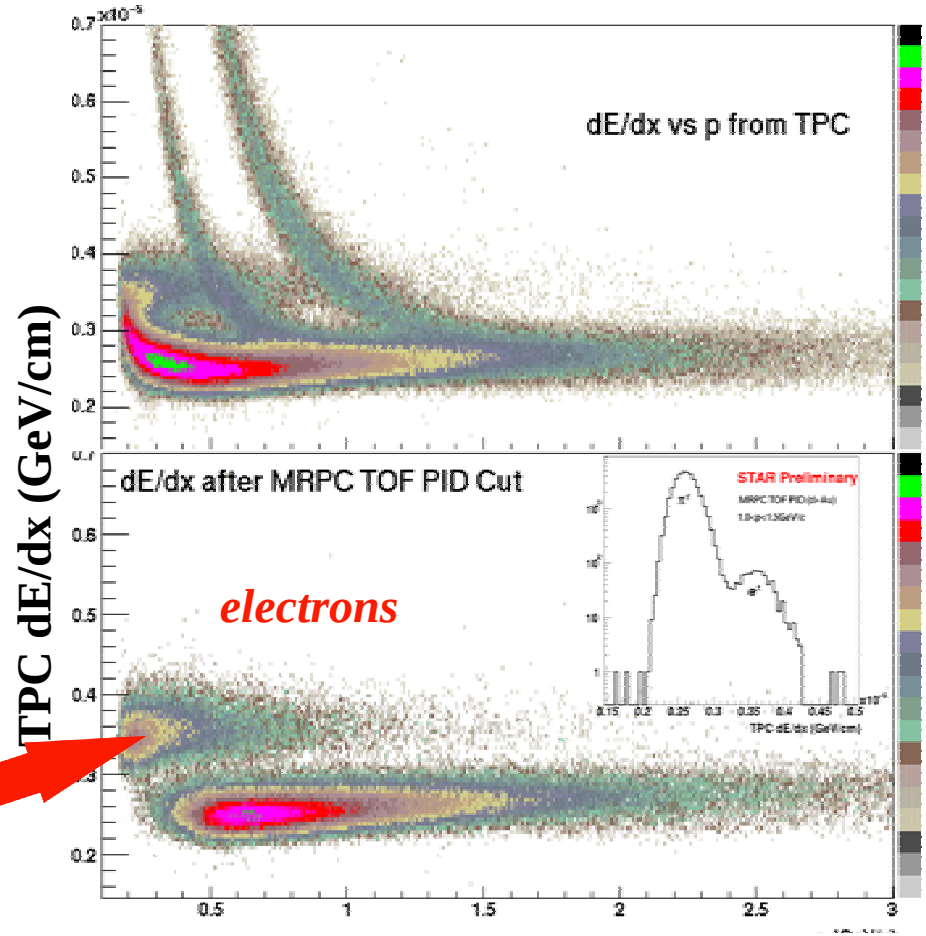


- Triggered datasets allow for full utilization of Luminosity for rare probes
- Central to the spin program
- Results on correlations (γ-tagged vs. charged-tagged) in Au for QM05
  - Dietel, Magestro

New Electron Identification Capability in STAR: MRPC ToF



Phys. Rev. Lett. 94 (2005) 062301
Phys. Lett. B 616 (2005) 8.



Electron identification:

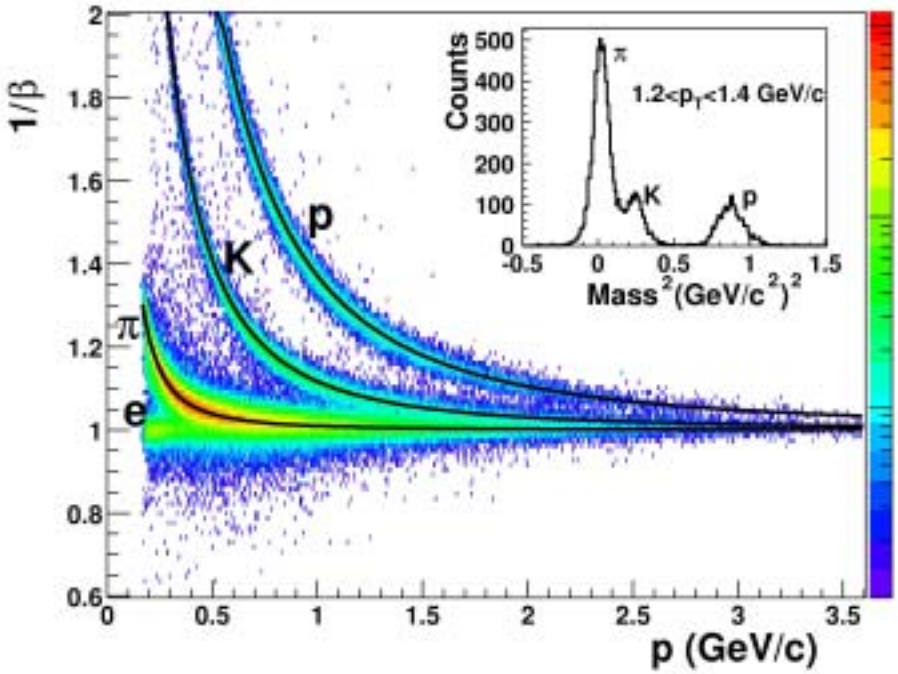
TOFr $|1/\beta-1| < 0.03$

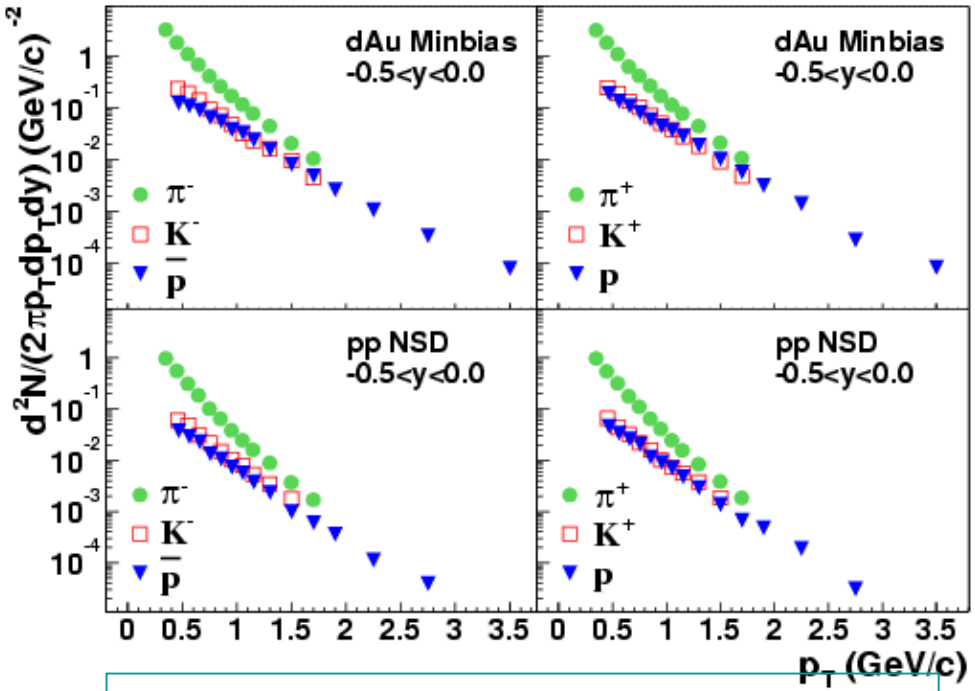
TPC dE/dx electrons!!!

Particle momentum p (GeV/c)

MRPC TOF

Beyond unidentified hadrons: PID Capabilities with TOF

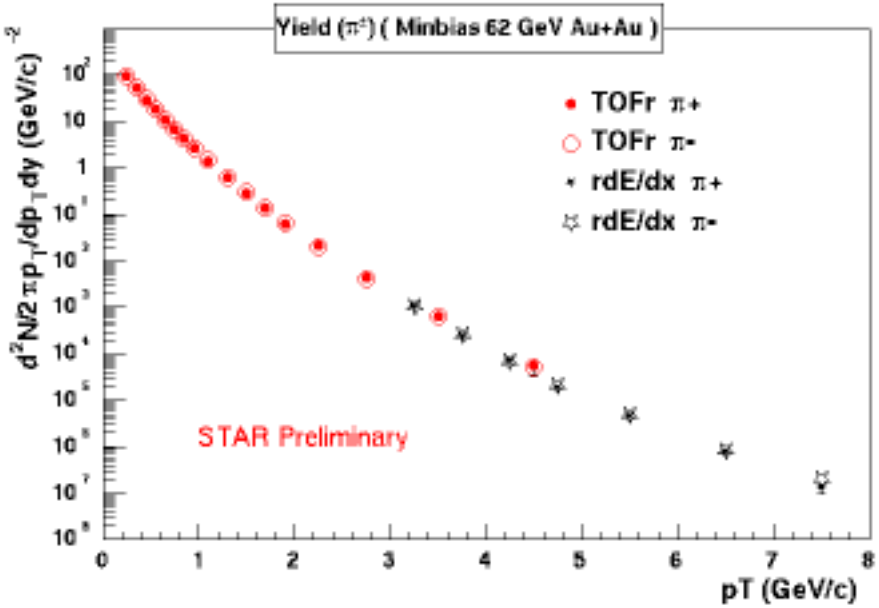


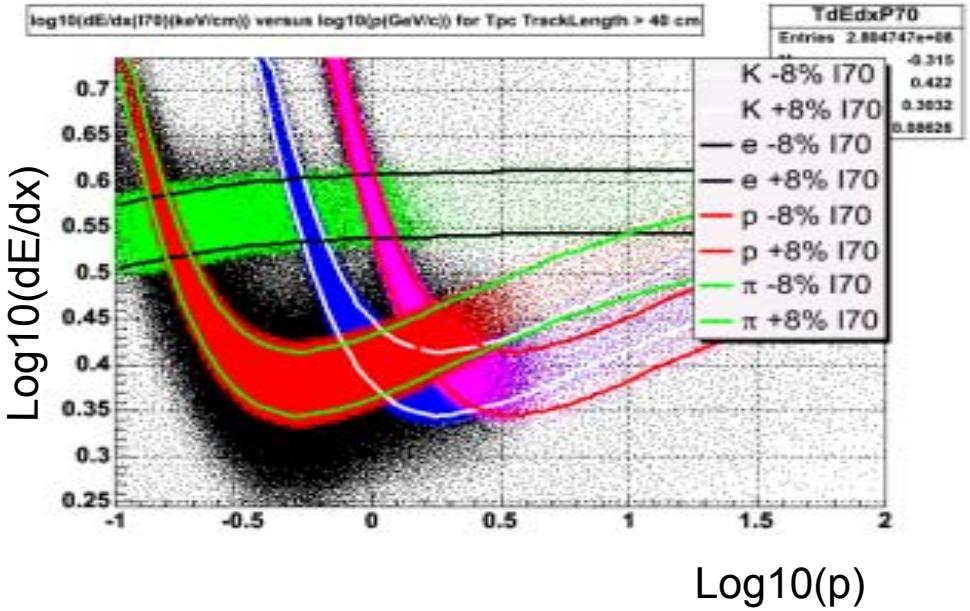


Phys. Lett. B 616 (2005) 8

- MRPC TOF is a cost-effective solution for large area time-of-flight system
- Spectra from p+p, d+Au obtained with first-year prototype

Extending STAR Particle ID



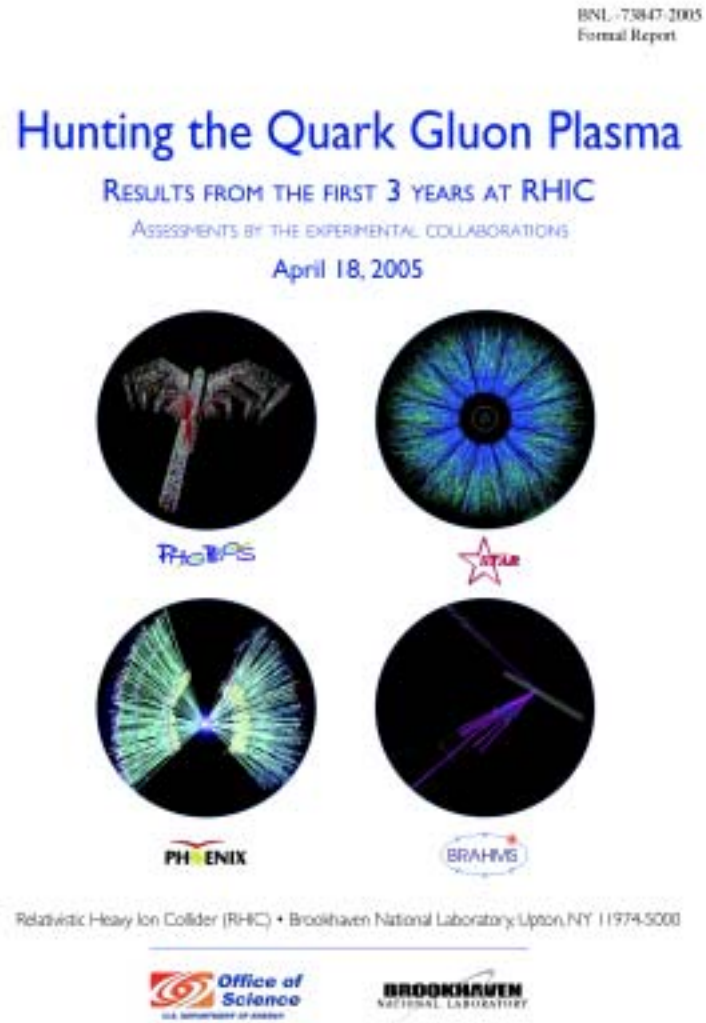


Methods paper submitted to NIM A, nucl-ex/0505026.

Contributed talk at QM05: Barannikova. Results to 12 GeV (!) in Au+Au

- TPC:
  - Pion: 0-~0.6GeV/c
  - Kaon: 0.2-~0.6GeV/c
  - Proton: 0.2-~1 GeV/c
- TOF:
  - Pion: 0.2-~1.6GeV/c
  - Kaon: 0.2-~1.6GeV/c
  - Proton: 0.2-~3 GeV/c
- TPC+TOF:
  - Pion: 0.-~10 GeV/c
  - Kaon: 0.2-~3GeV/c
  - Proton: 0.2-~? GeV/c

Recent Collaboration Achievements


BNL-73847-2005
Formal Report

Hunting the Quark Gluon Plasma

RESULTS FROM THE FIRST 3 YEARS AT RHIC

ASSESSMENTS BY THE EXPERIMENTAL COLLABORATIONS

April 18, 2005

Relativistic Heavy Ion Collider (RHIC) • Brookhaven National Laboratory, Upton, NY 11974-5000

Office of Science

BROOKHAVEN NATIONAL LABORATORY

Experimental and Theoretical Challenges in the Search for the Quark Gluon Plasma:

The STAR Collaboration's Critical Assessment of the Evidence from RHIC Collisions ,
Nucl. Phys. A 757 (2005) 102

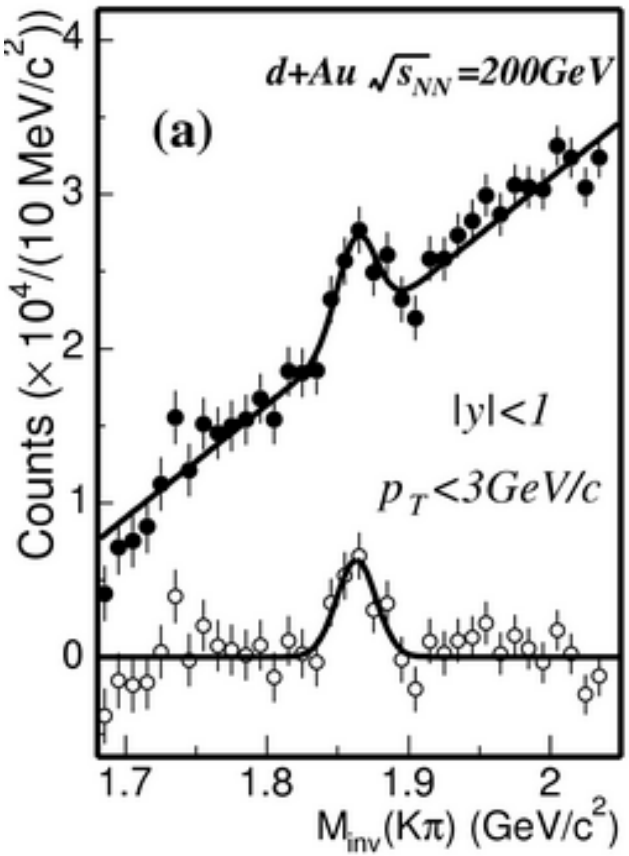
Strong evidence pointing to a "dense, opaque, non-viscous, pre-hadronic liquid state of matter not anticipated before RHIC"

Question: do the quarks and gluons in this matter reach thermal equilibrium with each other before confinement ?

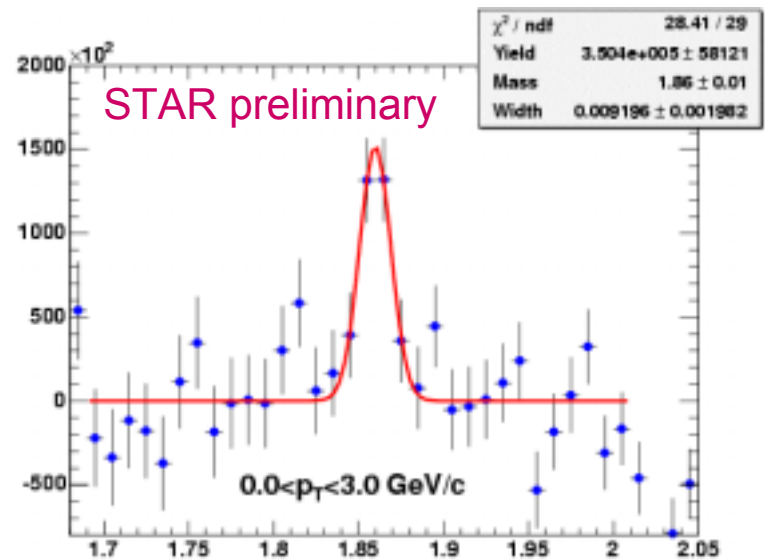
Direct Open Charm Reconstruction

No secondary vertex, Treated as “heavy K*”

d+Au: Phys. Rev. Lett. 94 (2005) 062301

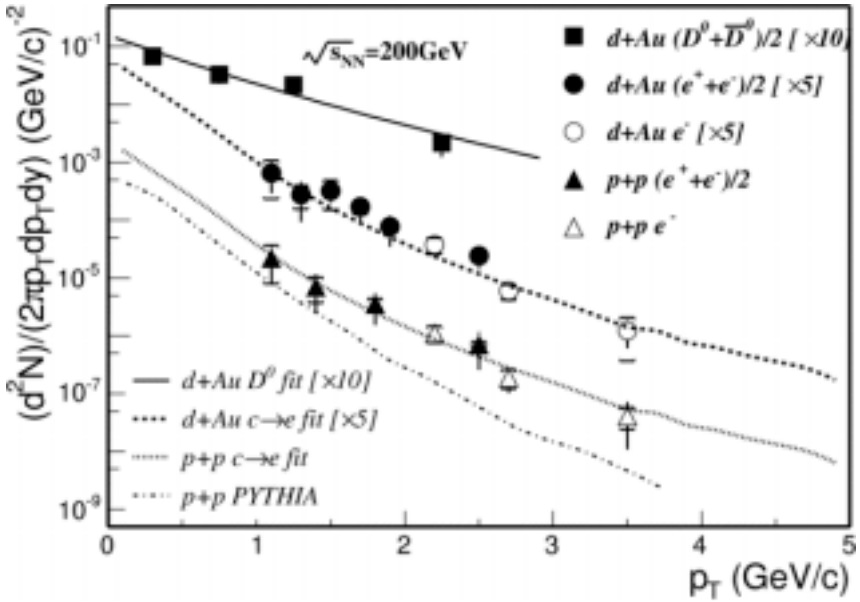


Au+Au: Clear signal for QM05, Zhang

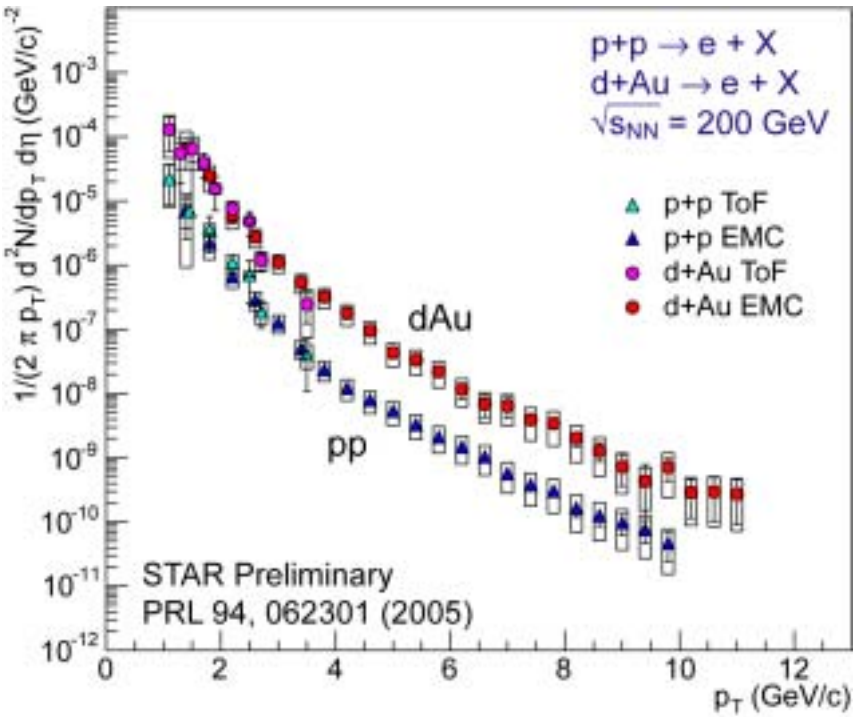


hadronic channel: $D^0 \rightarrow K^- \pi^+$
(B.R. 3.80%±0.09%)

D Meson and Electron Spectra from STAR



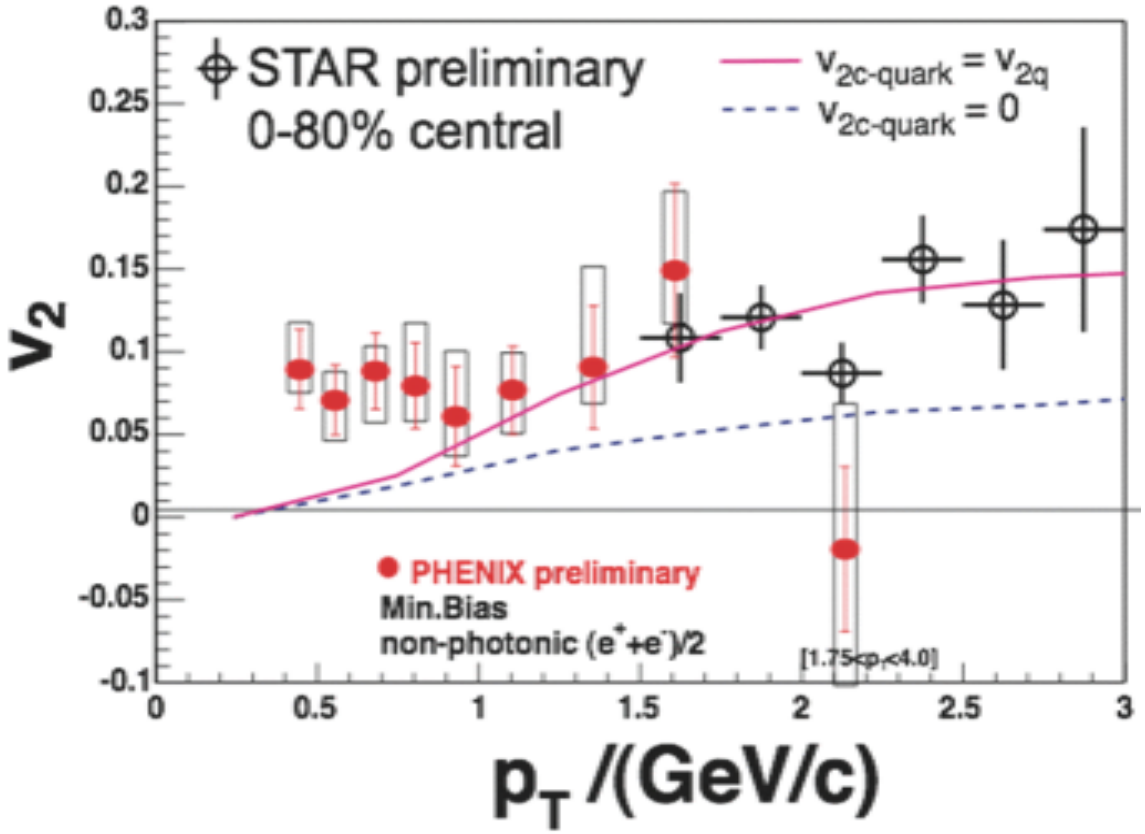
Phys. Rev. Lett. 94 (2005) 062301



Consistency in d+Au between three methods of electron ID and direct reconstruction of D mesons

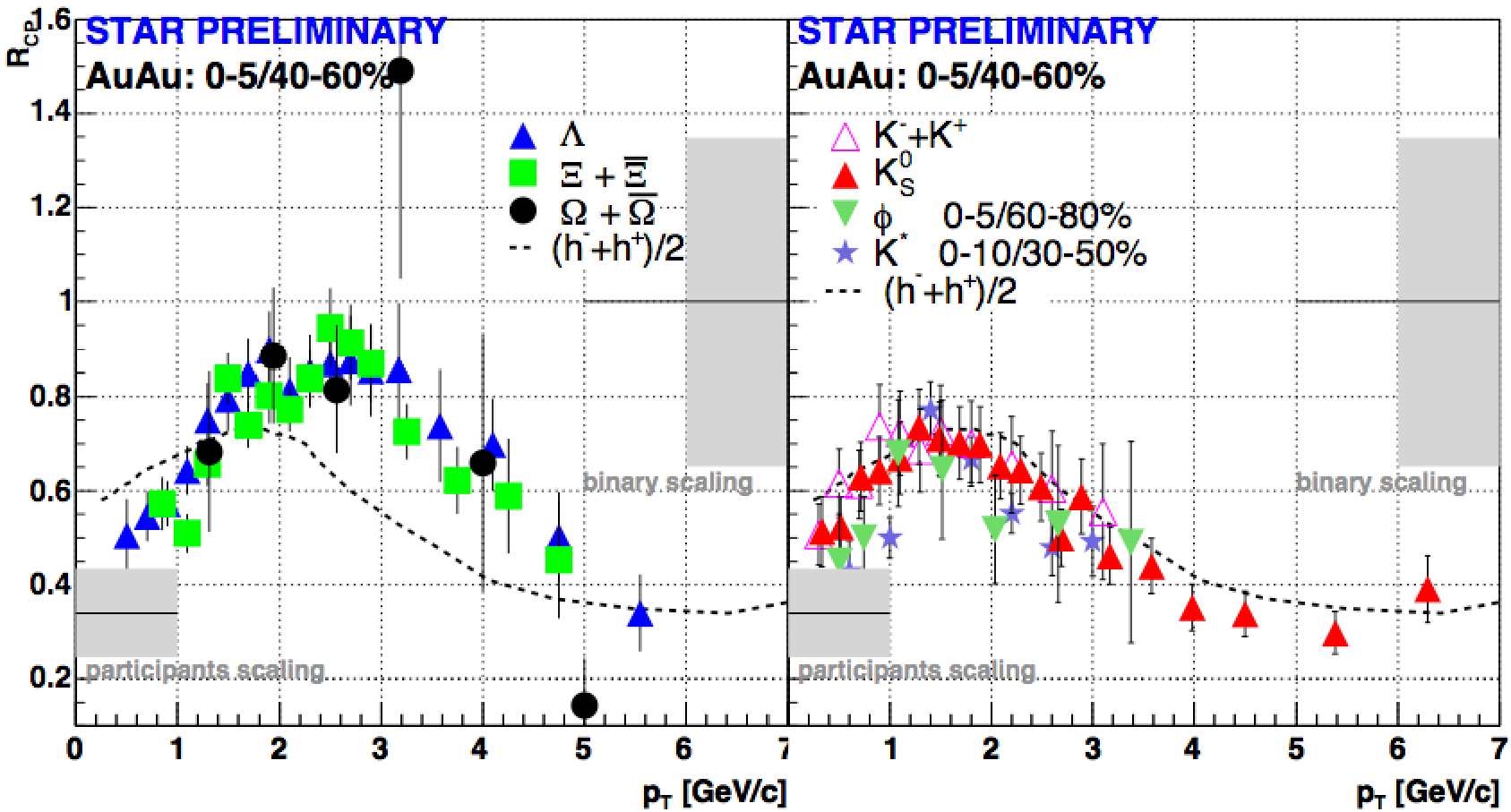
QM05: Bielcik, Zhang results from Au+Au

Elliptic Flow of Charm



Indications that charm quark flows as others: high degree of collectivity
QM05: Laue

Baryon vs. Meson R_{CP}: Constituent Quarks

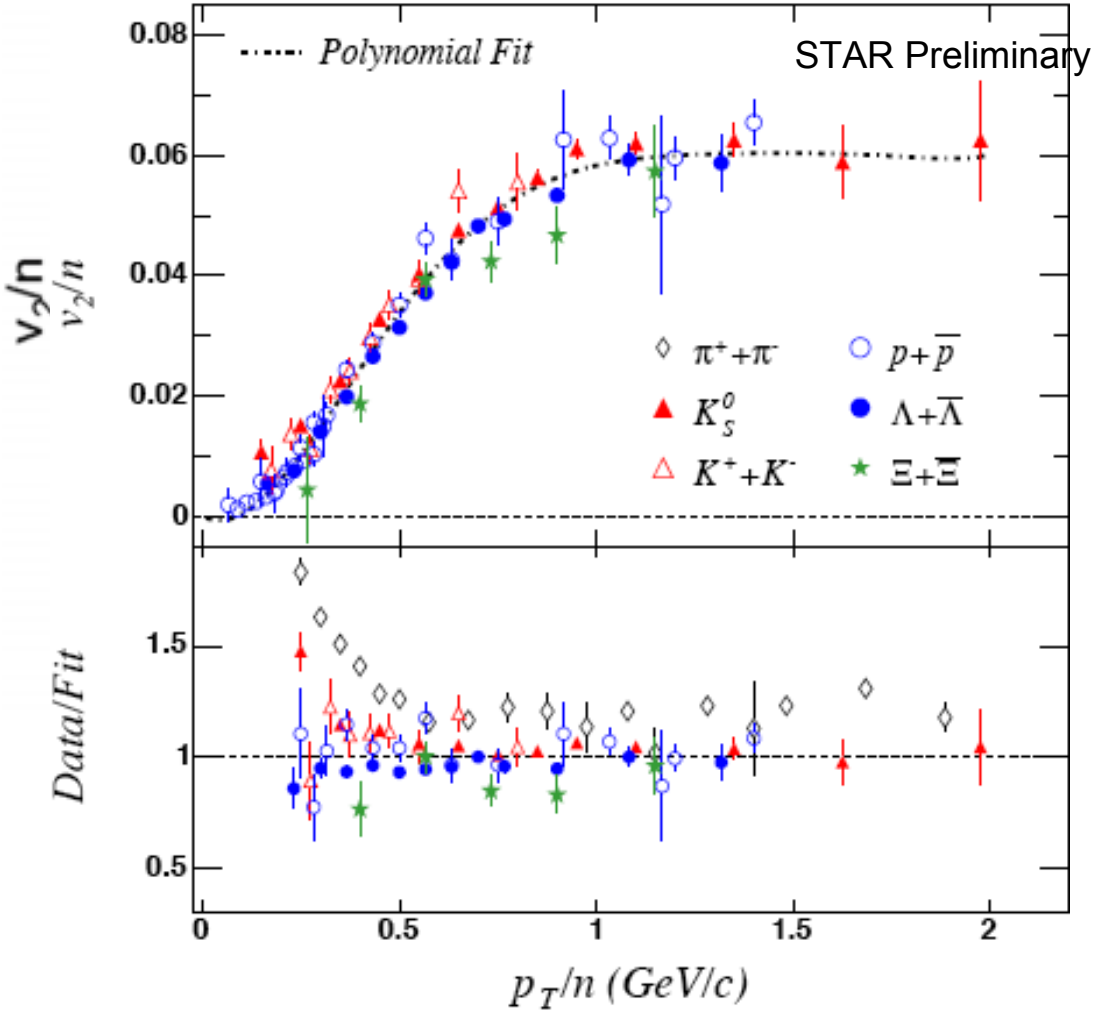


Clear separation between baryons and mesons: K*, ϕ follow mesons

QM05: Barannikova (to 12 GeV), Cai (ϕ)

Constituent Quark scaling of Elliptic Flow

62 GeV AuAu



Constituent quark scaling of elliptic flow seen both at 200 and 62 GeV at intermediate p_T

Extended particle identification for p, π

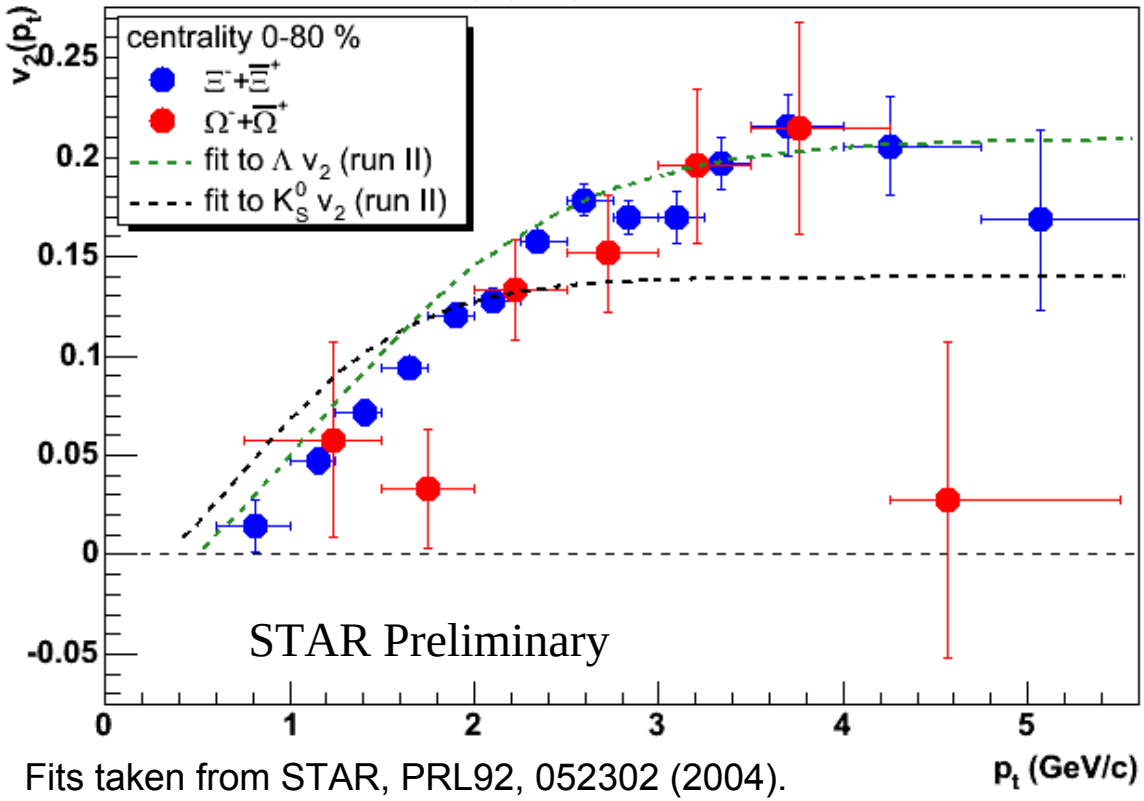
Indicator of relevant degrees of freedom?

QM05: Oldenburg

0-80% central

Elliptic Flow of Multiply Strange Baryons

AuAu 200 GeV from run 4



Fits taken from STAR, PRL92, 052302 (2004).

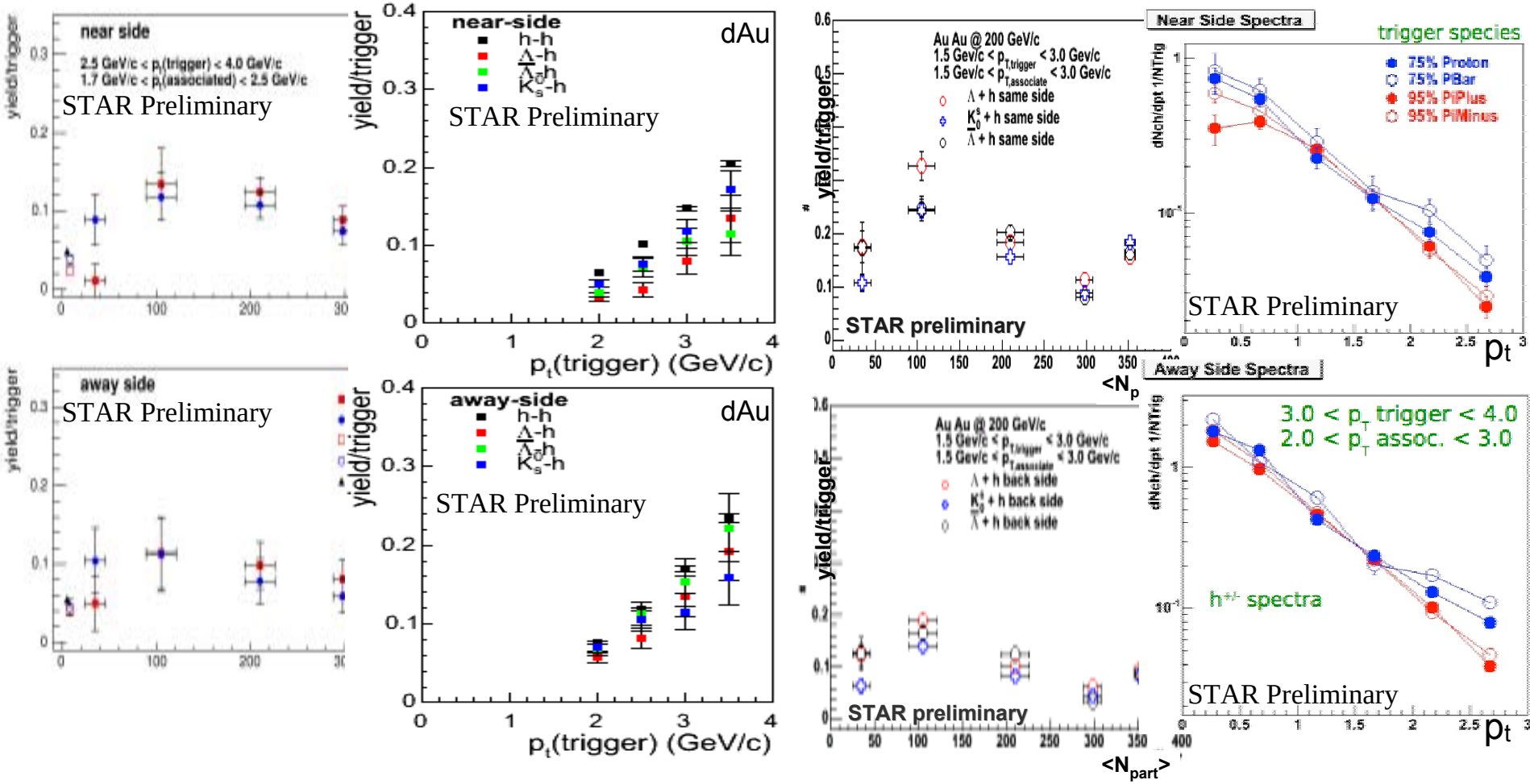
High statistics from year 4

At low p_T, mass splitting as in hydrodynamics

At intermediate p_T, constituent quark scaling: s quark flows

QM05: Oldenburg

Correlations with Identified Trigger Particles



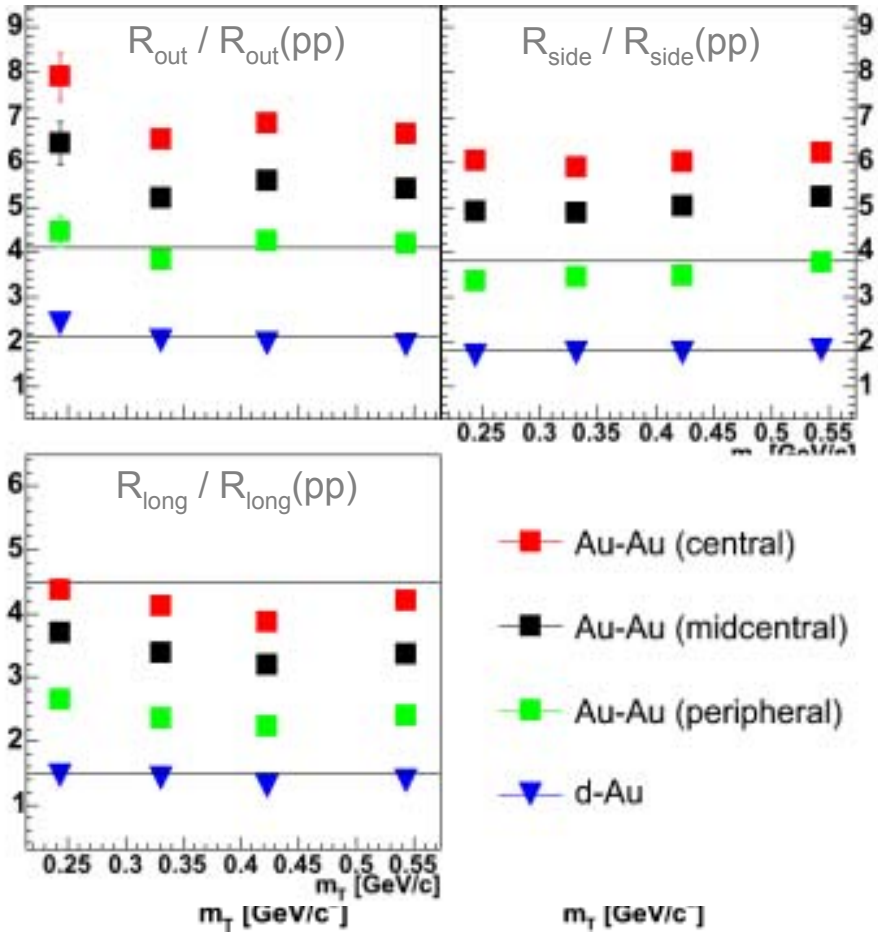
No indication in any quantity for difference between meson or baryon triggers

Significant questions for coalescence picture: thermal+shower, or remnant correlations?

QM05: Ulery

A puzzle in HBT: p+p → d+Au → Cu+Cu → Au+Au

preliminary



All four systems exhibit similar kT dependence. Why?

Is the standard Interpretation of the m_T dependence in terms of flow mistaken?

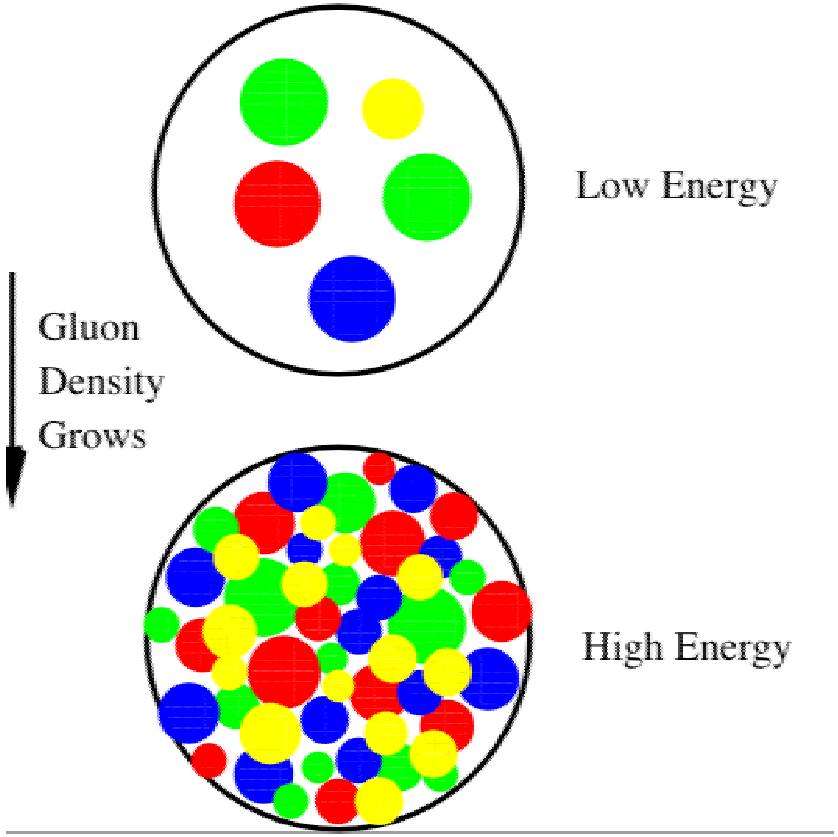
- Rapid turnaround analysis of Cu+Cu @62, 200 GeV, Au+Au @62 GeV
- QM05: Chajecki

Results that will be reported at QM05

Parallel talks

- M. Oldenburg: Event-wise azimuthal anisotropy (v_2) for identified hadrons
- C.A. Pruneau: Probing collision dynamics with fluctuation and correlation studies
- Z. Chajecki: Identified particle correlations in STAR
- P. Chaloupka: Non-identical particle correlations in STAR
- J. Bielcik: Heavy flavor production from single electrons in Au+Au
- F. Laue: Non-photonic single electron v_2
- H. Zhang: Open charm production in Au+Au
- T. Dietel: Azimuthal correlations of high pT photons and hadrons
- D. Magestro: High pT $\Delta\phi$ correlations with increased statistics
- O. Barannikova: Results of identified pions, kaons, (anti-) protons up to p_T 12 GeV/c
- X. Cai: Nuclear Modification Factor R_{CP} and v_2 for ϕ
- B. Mohanty: Particle production at forward rapidity in d+Au and Au+Au collisions
- J. Ulery: Full reconstruction of hadrons correlated with high pt PID'd particles
- S. Salur: System size dependence of strangeness production

A central, related question: the initial condition



D. Kharzeev, E. Levin and L. McLerran, Phys. Lett. B 561 (2003) 93

- Parton dynamics in a dense system of gluons differs from pQCD
- Saturated gluon density (CGC) $\Rightarrow$ effective field theory of dense gluon systems provides an appropriate description of the initial condition

Large nucleus (A) at low momentum fraction $x \rightarrow$ gluon distribution saturates ~ $1/\alpha_s(Q_S^2)$ with $Q_S^2 \sim A^{1/3}$

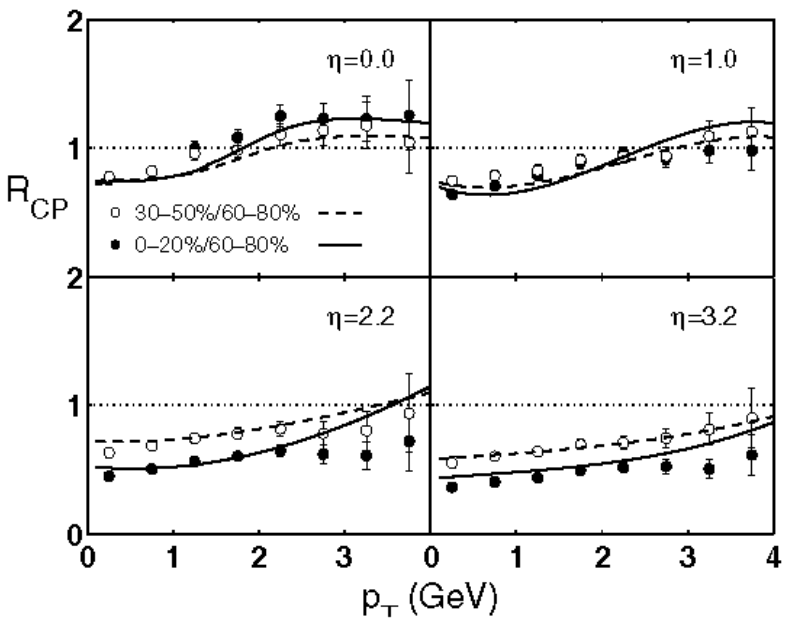
A collision puts these gluons 'on-shell' $\rho \sim A\, xg(x,Q^2) / \pi R^2$

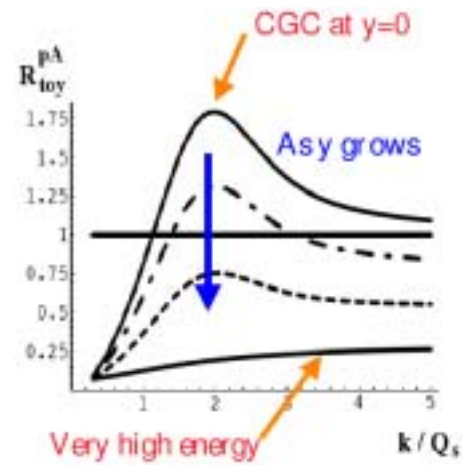
Parton-hadron duality maps gluons directly to charged hadrons

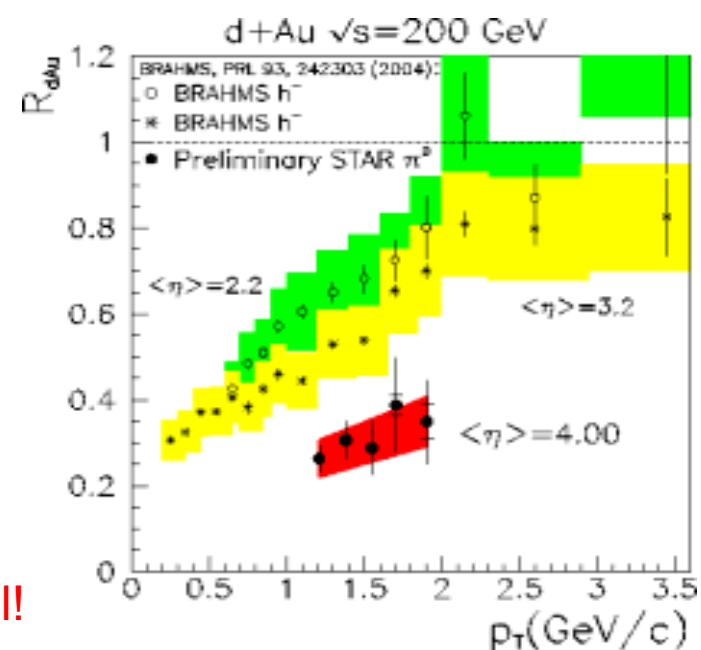
A prediction of the CGC: η dependence of R_{dAu}

Suppression of R_{dAu} at forward η

Disagreement with expectations based on incoherent multiple scattering in the initial state (i.e. standard factorized pQCD explanation for Cronin enhancement) → suppression of high p_T in d+Au at small x



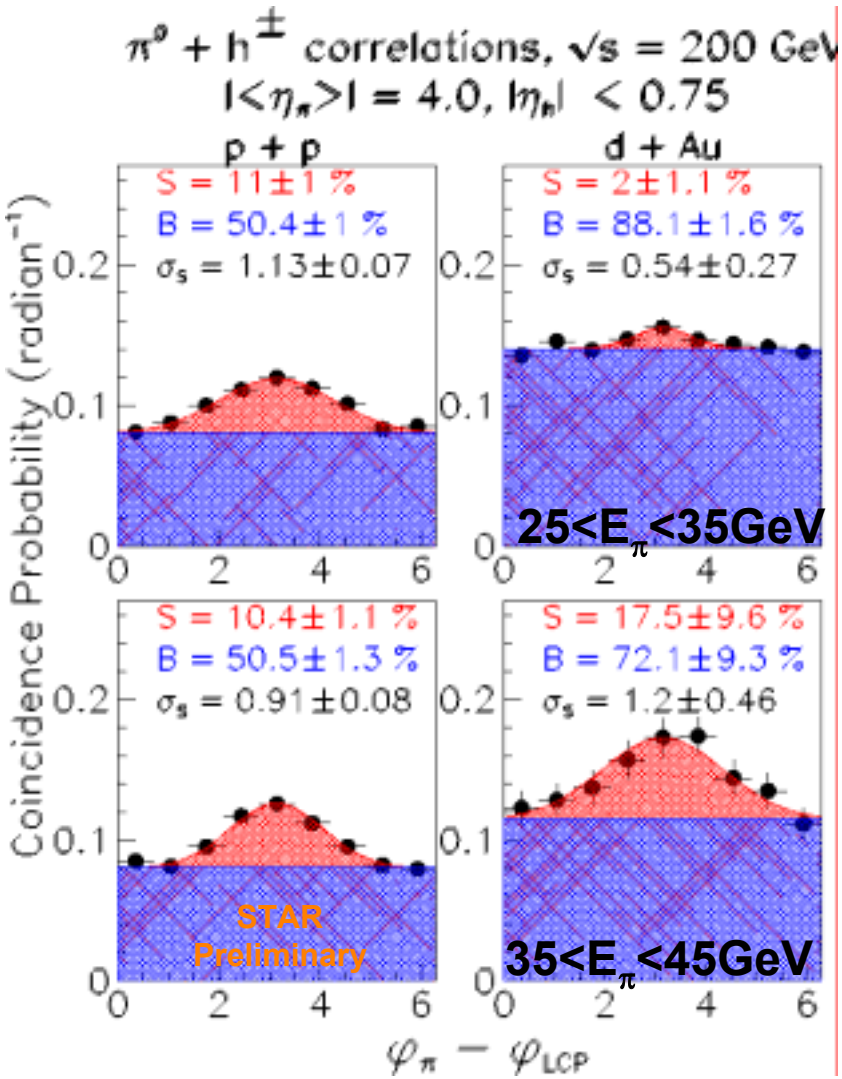




$$R_{dAu} \approx \frac{1}{2\times 197}\frac{\sigma_{dAu}}{\sigma_{pp}}$$

But this interpretation is not unique:
Recombination versus BRAHMS data does as well!

A definitive measurement: correlations at low x in d+Au

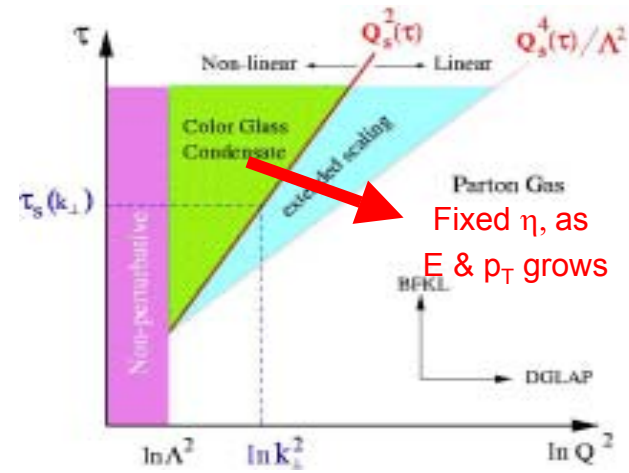


Statistical errors only

Large $\Delta\eta$ π^0+h$^\pm$ correlations

- **Suppressed at small $\langle x_F \rangle$, $\langle p_{T,\pi} \rangle$**

Consistent with CGC picture



- **Consistent in d+Au and p+p at larger $\langle x_F \rangle$ and $\langle p_{T,\pi} \rangle$**

as expected by HIJING

The Detector Upgrade Planned to do it: STAR Forward Meson Spectrometer

Located at tunnel exit on west side

Inner: 684 blocks, 3.8^2 x 45 cm

Outer 756 blocks, 5.82 x 60 cm

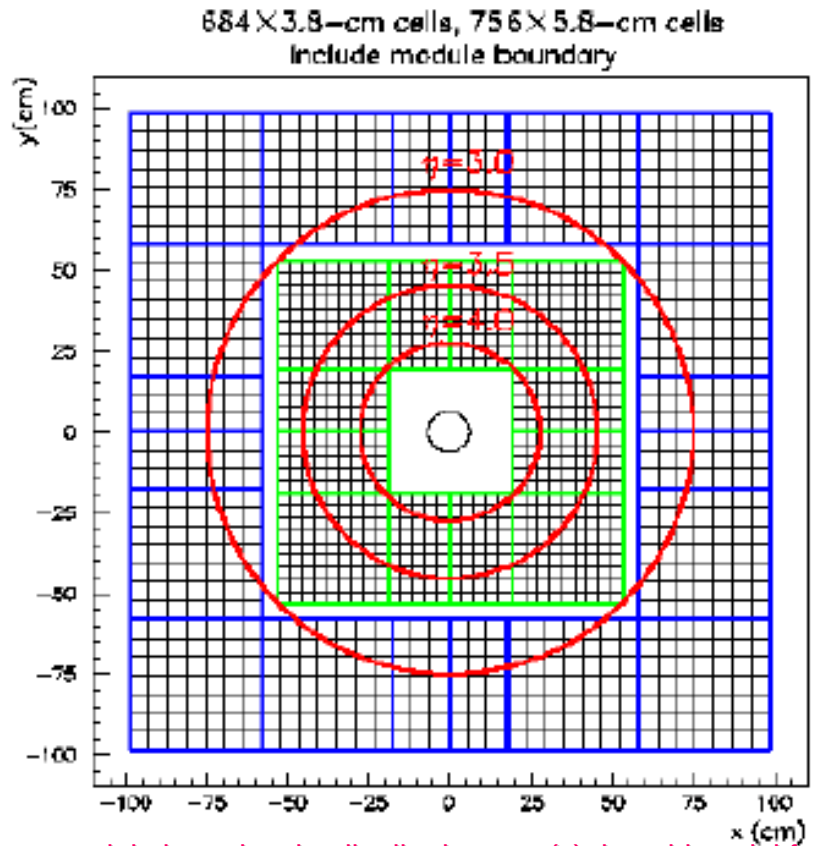
Uses existing PbGlass, PMTs, bases.

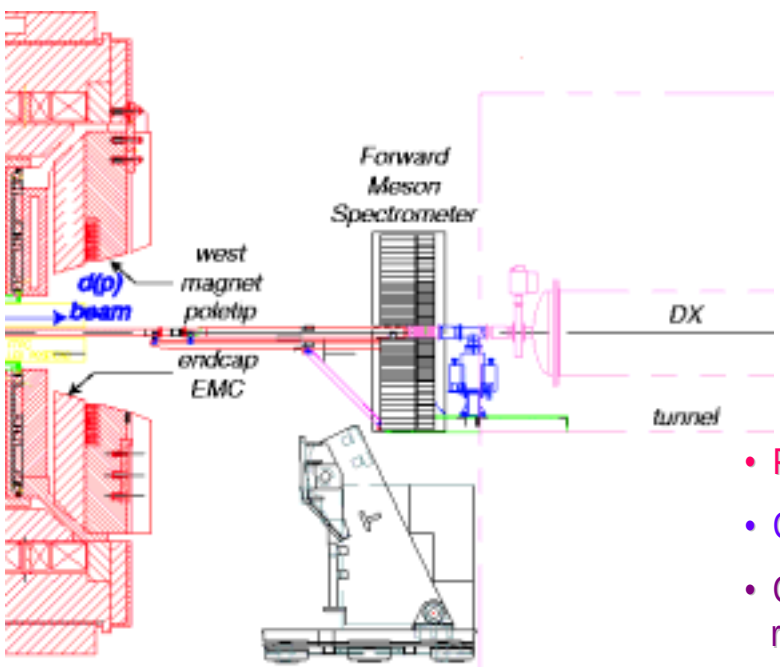
In hand, being refurbished

- Support platform being modified
- Readout Electronics being designed
- Goal: ready for a run in 2007

Full azimuthal coverage for $2.5 < \eta < 4.0$

Good efficiency for photons and mesons (π, K, D)



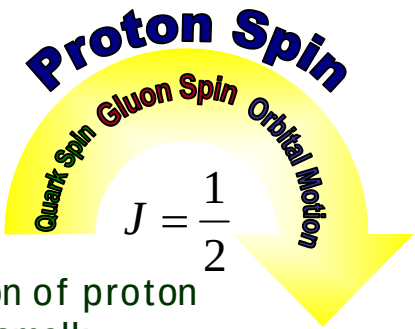


- Parton model gluon density distributions, $xg(x)$, in gold nuclei for $0.001<x<0.1$
- Characterization of expected gluon saturation effects
- Origin of very large transverse spin asymmetries in $p_{\uparrow} + p \rightarrow p^0 + X$ reactions initiated by transversely polarized proton beams

RHIC SPIN Program

- Fundamental question: How is the proton spin made up?

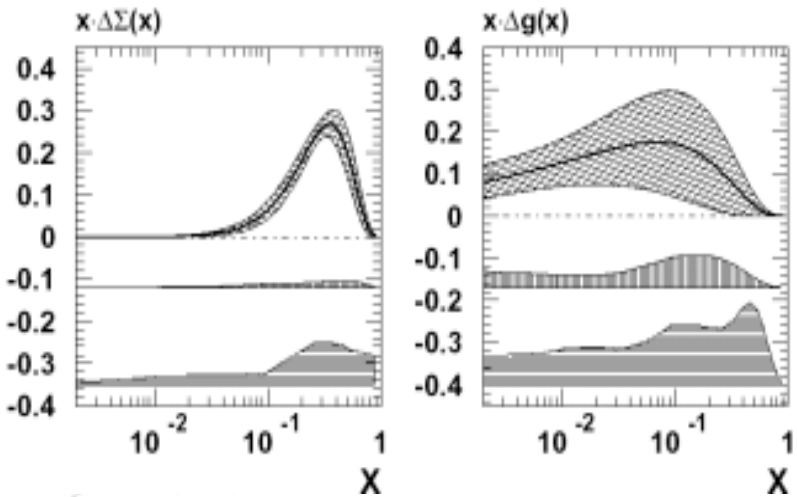
$$J = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z^q + L_z^g$$



- EMC/SMC result: Fraction of proton spin carried by quarks is small:

$$\Delta\Sigma_{(AB)} = 0.38^{+0.03}_{-0.03} \text{ at } Q_i^2 = 1\text{GeV}^2$$

- Where is the spin of the proton? ΔG and $(L_z^q + L_z^g)$
- SMC QCD-analysis:



- At present: ΔG is only poorly constrained from scaling violations in fixed target DIS experiments

$$\Delta G_{(AB)}\left(Q^2 = 1GeV^2\right) = 0.99^{+1.17}_{-0.31} \text{ at } Q_i^2 = 1\text{GeV}^2$$

B. Adeva et al., SMC Collaboration, Phys. Rev. D58 (1998) 112002.

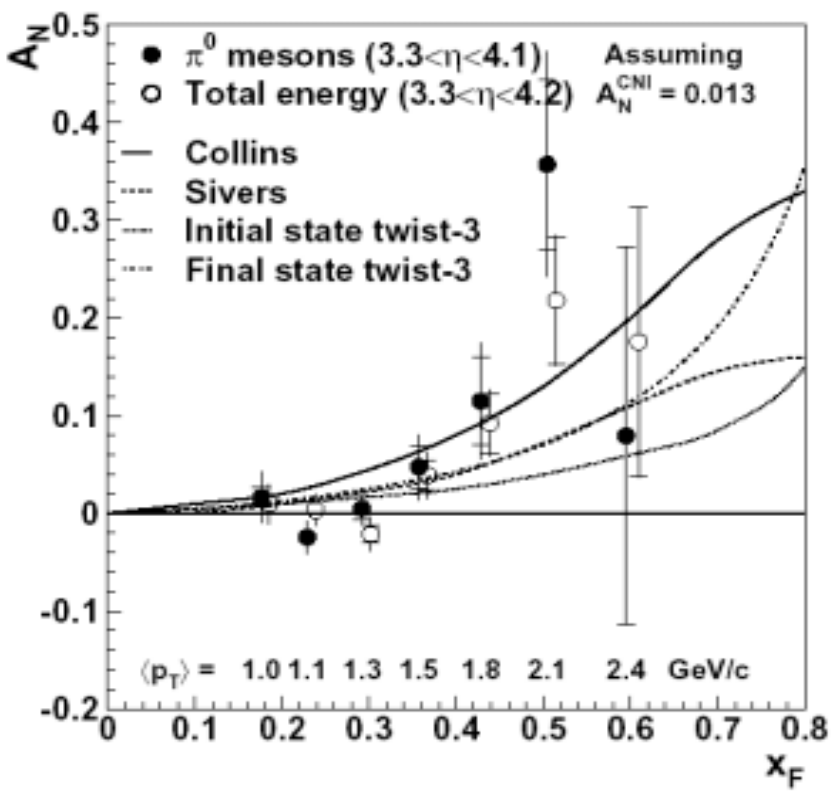
- Need: New generation of experiments to explore the spin structure of the proton: polarized proton collisions at RHIC

RHIC spin program:

- Unique multi-year program which has just started…!
- Explore various aspects on the spin structure and dynamics of the proton in a new domain:
  - Spin structure of the proton (gluon polarization, flavor decomposition of quark/anti-quark polarization, transverse spin dynamics and transversity)
  - Spin dependence of fundamental interactions
  - Spin dependence of fragmentation
  - Spin dependence in elastic polarized pp collisions

First STAR Spin Results

- First measurement of A_N for forward π^0 production at RHIC - STAR

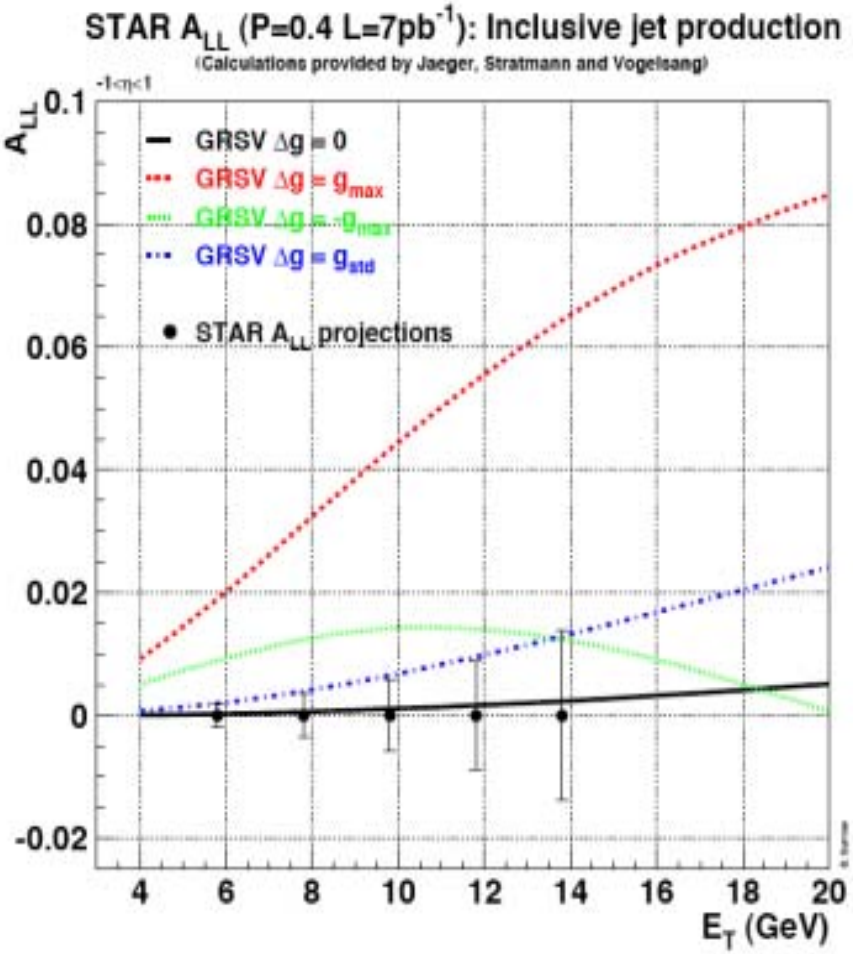


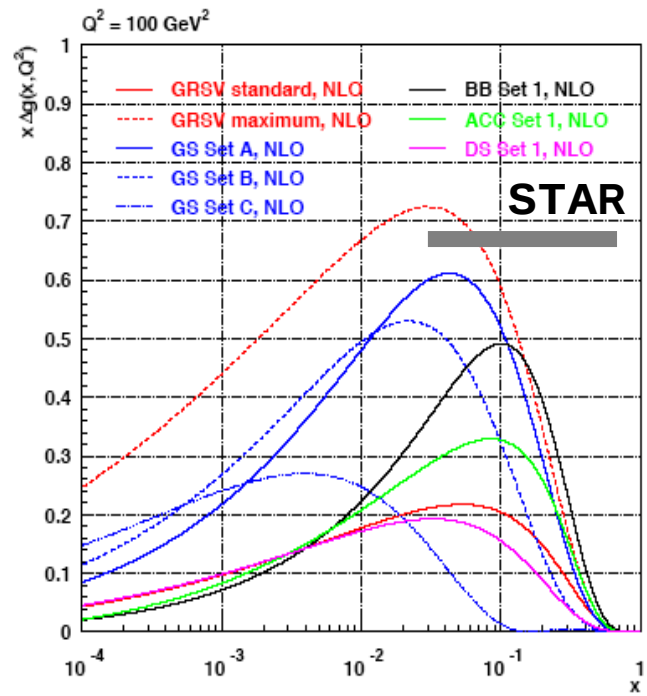
STAR collaboration, Phys. Rev. Lett. 92 (2004) 171801.

- A_N is found to increase with energy similar to E704 result ($\sqrt{s}$ = 20 GeV (10 X smaller than at RHIC), $0.5 < p_T < 2.0$ GeV)
- This behavior is also seen by several models which predict non-zero A_N values
- Several approaches beyond the basic "naive QCD calculations" yield non-zero A_N values at RHIC energies:
  - Sivers: include intrinsic transverse component, $k_\perp$, in initial state (orbital momentum) (before scattering takes place)
  - Collins: include intrinsic transverse component, $k_\perp$, in final state (transversity) (after scattering took place)
  - Qiu and Sterman (Initial-state twist-3)/Koike (final-state twist-3): more "complicated QCD calculations" (higher-twist, multi-parton correlations)

Future STAR spin results

- Prospects on constraining ΔG: Inclusive jet production



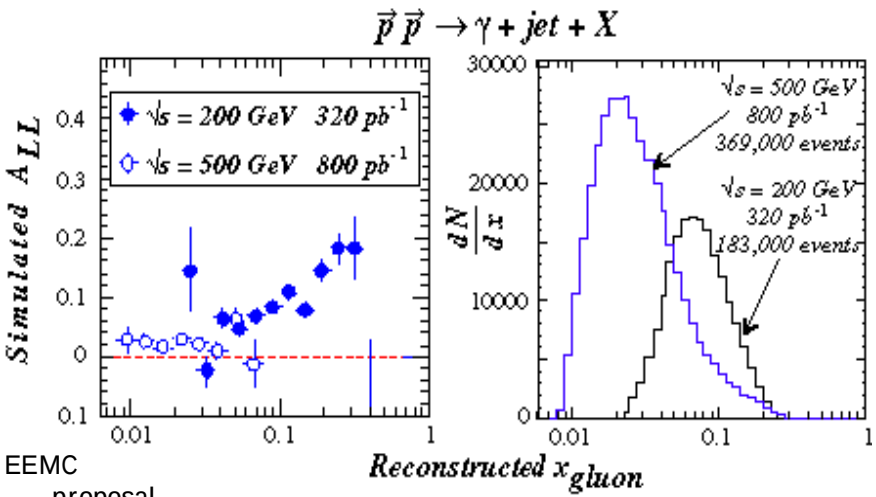


- Potential to discriminate between several of the expectations based on DIS parameterizations (Not all of which are equally probable!)
- BEMC/EEMC: Calibration well under control!

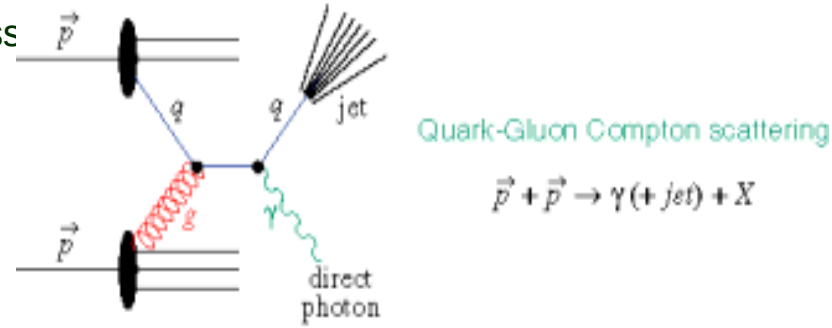
Future STAR Spin physics

Quark-Gluon Compton scattering at STAR

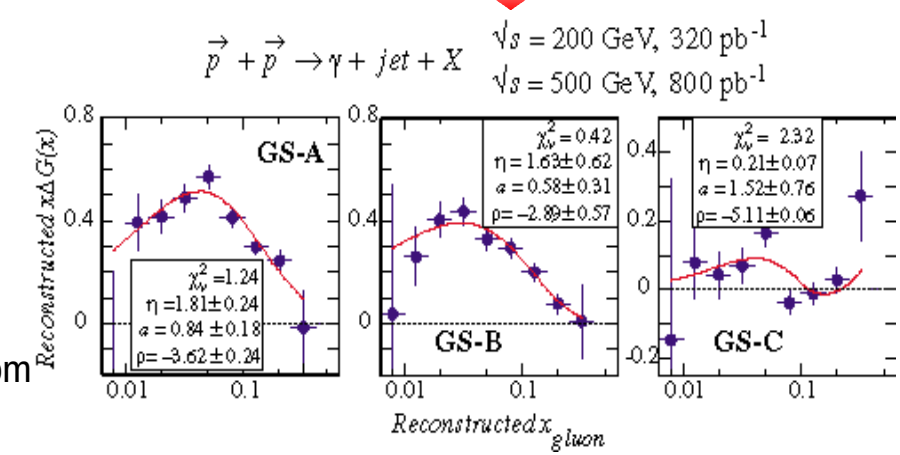
- Simulated A_{LL} at two different RHIC center-of-mass energies::



EEMC proposal



$$A_{LL} \cong \frac{\Delta G(x_g)}{G(x_g)} \cdot A_1^p(x_q) \cdot \hat{a}_{LL}^{(g+q\rightarrow\gamma+q)}(\cos\vartheta^*)$$



- Combined data sample at 200 GeV and 500 GeV is essential to minimize extrapolation errors in determining ΔG:

$$\Delta G(Q^2) = \int_0^1 \Delta g(x, Q^2)\,dx$$

Accuracy: 0.5

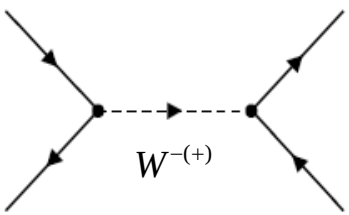
- Ultimately: Global analysis of several data sets from RHIC (STAR, PHENIX) and DIS (HERMES, COMPASS)!

EEMC proposal

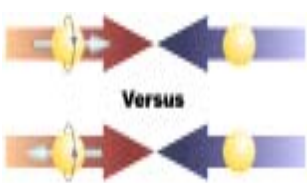
Future STAR spin prospects

W production in polarized pp collisions at RHIC

- Semi-inclusive DIS - sensitivity reduced by fragmentation functions and e^2_q weighting
- $W^{\pm}$ production in pp collisions forms the best means to probe the flavor structure of the proton sea



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



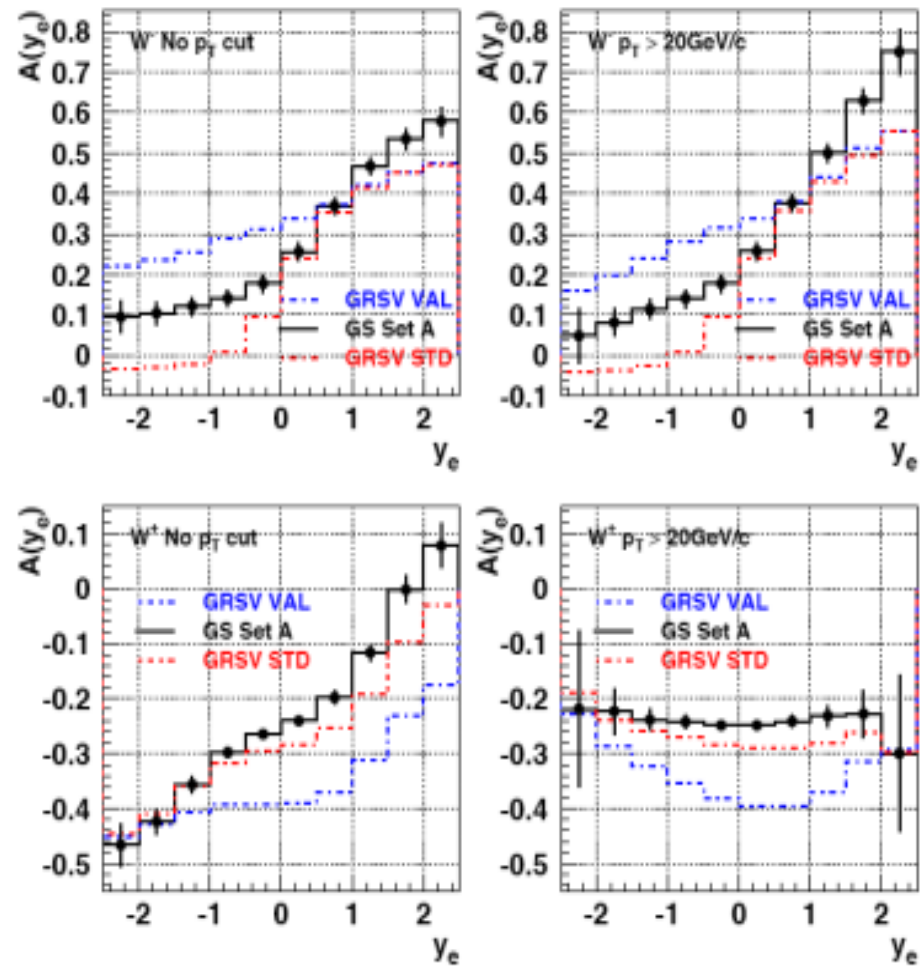
$$A_L^{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

$$A_L^{PV(W^+)}(\vec{p}p) \rightarrow \Delta u/u$$
$$A_L^{PV(W^+)}(\vec{p}p) \rightarrow \Delta \bar{d}/\bar{d}$$

$$A_L^{PV(W^-)}(\vec{p}p) \rightarrow \Delta d/d$$
$$A_L^{PV(W^-)}(\vec{p}p) \rightarrow \Delta \bar{u}/\bar{u}$$

- Parity violating single-spin asymmetries at RHIC provide access to the quark flavor structure of the proton spin (PHENIX/STAR upgrade required!)

RHICBOS W simulation at 500GeV CME (P=0.7 L=800pb^{-1})



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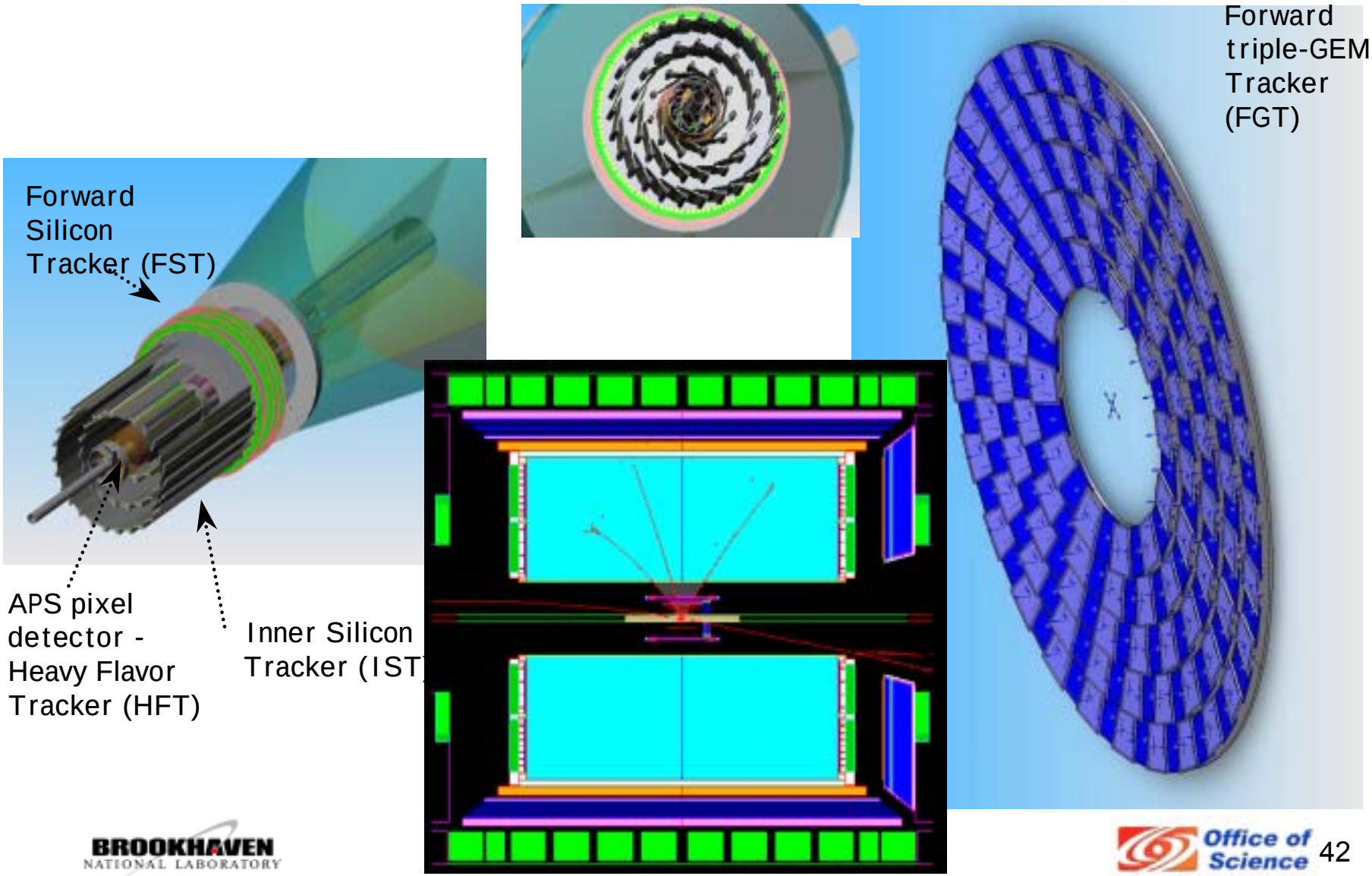
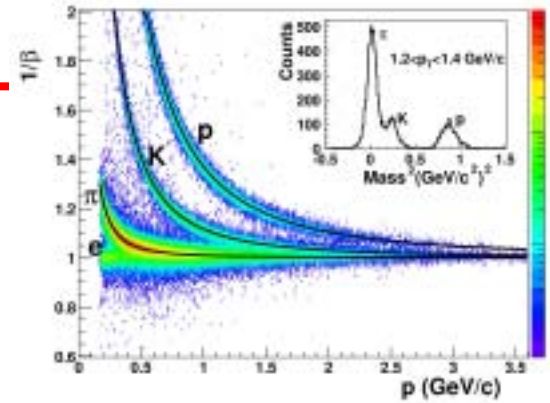
Future STAR physics prospects

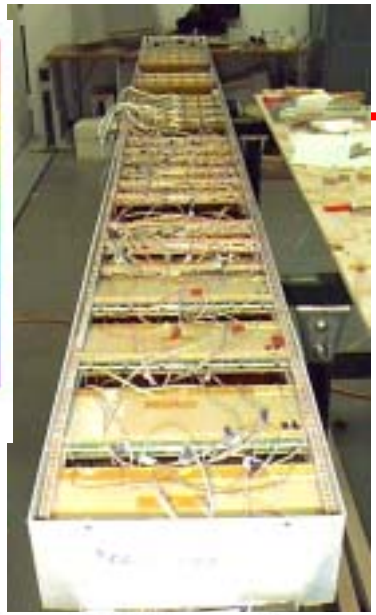
STAR tracking upgrade: conceptual layout

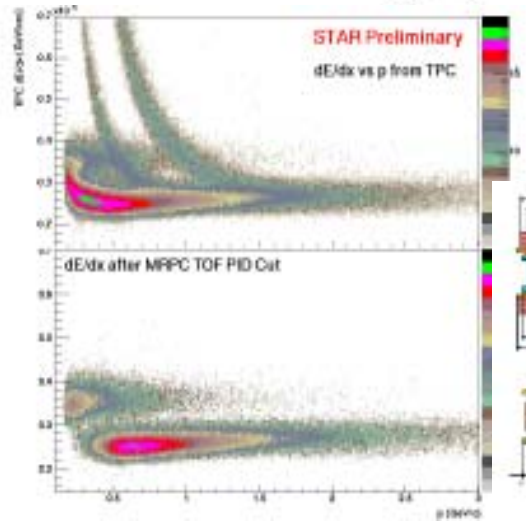


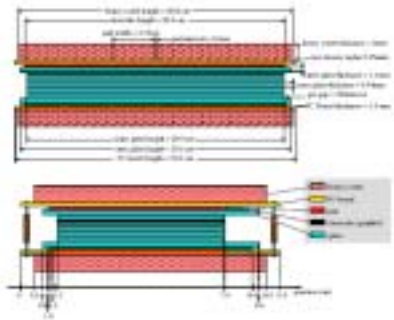
STAR Barrel MRPC TOF

Physics: correlations, fluctuations, partonic collectivity, open charm, vector meson ($\rightarrow e^+e^-$), lepton, di-lepton spectra, away-side jet fragmentation, exotica searches, $\Lambda\Lambda$ helicity correlations, ...









Technique: MRPC technology

- 3800 modules, 23,000 readout chan. to cover full TPC barrel
- Large coverage $-\pi<\phi<\pi$, $-1<\eta<1$
- $R\approx 2.1$ m, $\Delta t < 100$ ps
- 95% of charged particles in acceptance ID'd
- Fast detector with high granularity

Joint US/China project: China – MRPC modules; US - Electronics, trays, integration

This technology has been demonstrated with the prototype tray in STAR yielding nice physics results: spectra, charm yields, ...

STAR TOF Barrel Status

- Project included in President's budget for 2006
- DOE review August 22-23 to "baseline" the project
- Project approved in China subject to DOE approval
- DOE SBIR ($750K) allowed development of generic electronics capability
- Budget: $4.7M US, $2.3M in-kind from China
- Schedule: ~3 years for construction – partial and increasing coverage during construction period
- Prototype tray (TOFr5) with HPTDC readout installed in Run V

First major "next-generation" upgrade of the RHIC detectors

DAQ – TPC Readout Upgrade

- Acquisition of very large data samples for precision and rare process studies: e.g., symmetry restoration/breaking, $\gamma\gamma$ HBT, …
- Triggered data sets benefit - dead time reduced to ~ 0
- Space for end cap tracker for W physics

Goal: Increase data rate for most detectors to ≥ 1kHz

Make use of CERN developments for ALICE/LHC:

PASA (preamp/shaper amp)

ALTRO (digitizer, digital filter, zero suppression, buffer)

SIU (RDO, optical data sender)

D-RORC (PCI receiver board)

DAQ – TPC Readout Upgrade

Cost *Estimate*:

FEE:	$1169k
RDO:	$ 371k
DAQ:	$ 324k
Total:	$1863k

Agreement with CERN to secure chip-set in negotiation

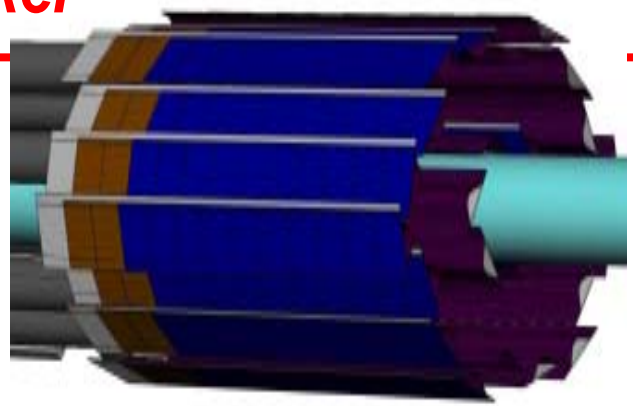
Schedule:

Nov. 2005 Small prototype in STAR

Nov. 2006 Two Sectors in STAR

Nov. 2007 Full TPC readout in STAR

STAR Heavy Flavor Tracker



- Heavy flavor collectivity
- Charm quark kinetic equilibration
- Heavy flavor (c,b) energy loss
- Vector mesons $\rightarrow e^+e^-$

- Two layers of CMOS pixel detector around a new thin (0.5mm) small radius (14 mm) beam pipe
- 10^8 pixels, $(30\ \text{mm})^2$
- 50 mm thick
- 10 mm point resolution

Significant progress on:

- Physics design and vetting with simulations
- Mechanical design
  - integration and installation
  - support
  - alignment
  - calibration
- Sensor prototype
- Readout design

STAR Heavy Flavor Tracker

HFT Proposal now under internal review in STAR:

Stephen Steadman, Chair
Helen Caines
David Lynn
Jana Bielcikova
Spiros Margetis
Gerrit van Nieuwenhuizen
Marcelo Munhoz
Subject experts, various

Schedule:

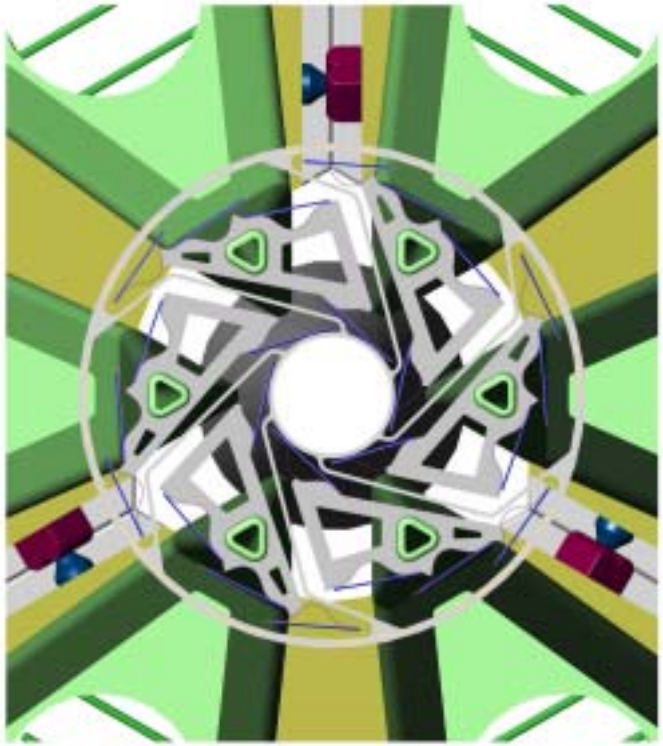
Complete Mechanical Design: Sep. '05

Prototype Ladder: Jan '06

Complete Electrical Design: Jan. '07

Construction: FY08

A Heavy Flavor Tracker for STAR



STAR Tracking Upgrade

Two Parts: Barrel, Forward

Barrel Tracking Upgrade:

- Ultimate pointing device for HFT – compatible with DAQ1000
- Replaces SVT – remove SVT infrastructure in $1<\eta<2$ region for $W^{+(-)} \rightarrow e^{+}(e^{-})$ (sea anti-quark contribution to proton spin), and provide part of the $1<\eta<2$ tracking

Forward Tracking Upgrade:

- High precision Tracking in $1<\eta<2$ to discriminate charge sign in $W^{+(-)} \rightarrow e+(e-)$ - 10's of GeV $e^{\pm}$

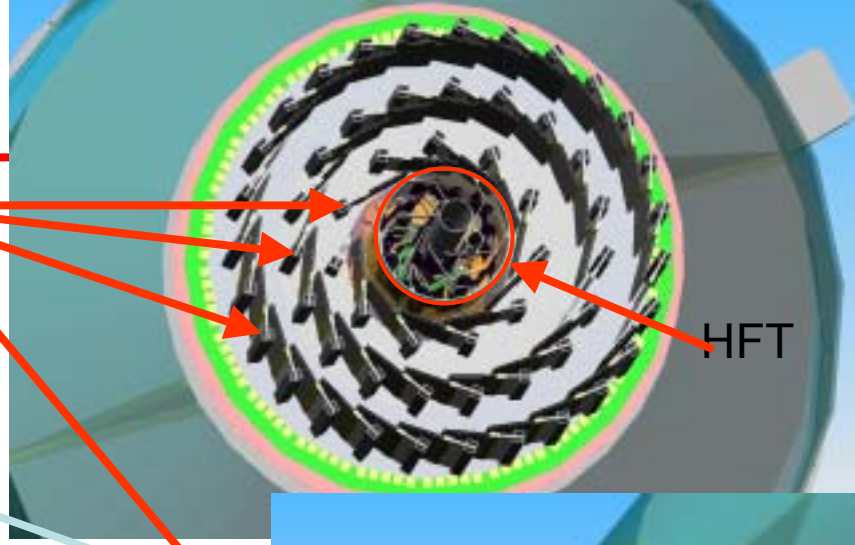
Good progress on mechanical and electronic design for a "working" design
Simulation infrastructure in place
Goals:

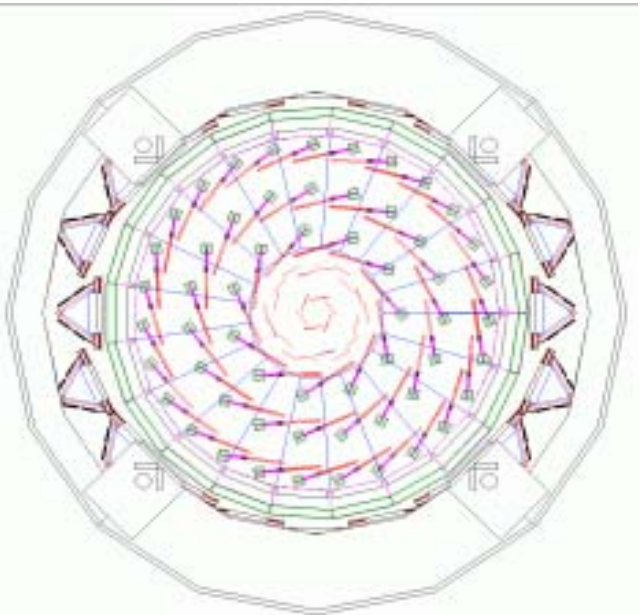
Proposal for Barrel – summer 2005
Barrel installation – for next long AuAu run (? 2008-9)
Proposal for Forward Tracker – summer 2006
Forward tracker installation – before first long polarized pp run at $\sqrt{s}$ = 500 GeV.

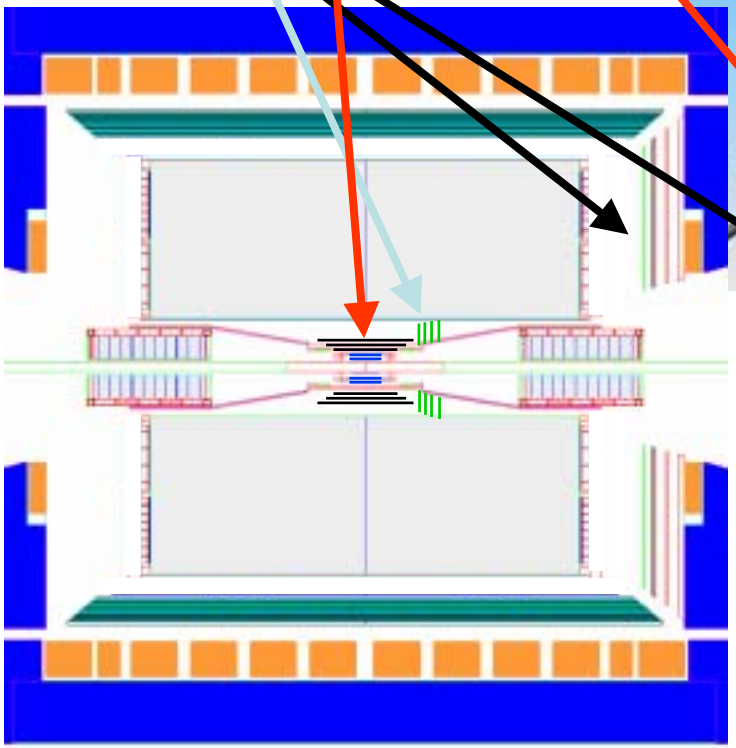
STAR Tracking Upgrade

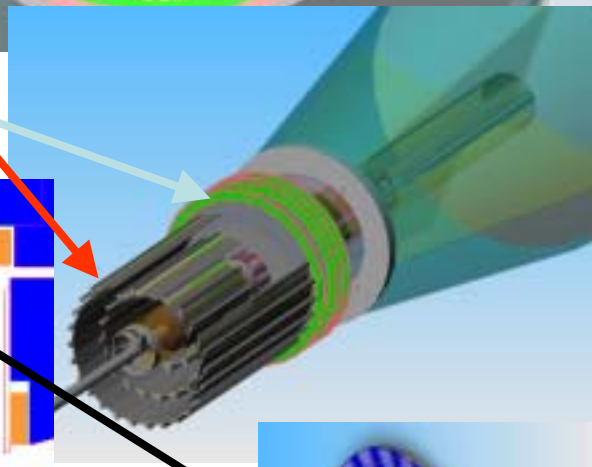
Barrel: Three double layers of single sided silicon strip detectors

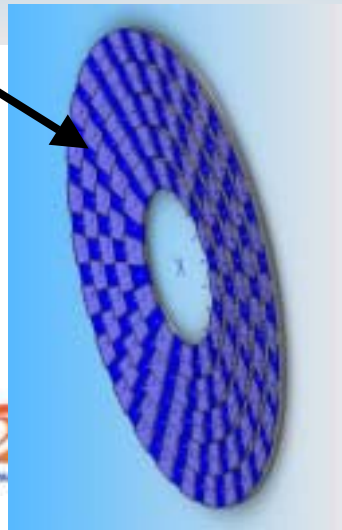
Forward: 4 Silicon strip discs plus GEM layer on End Cap











Challenges for STAR Upgrades

- Capability for major charm measurement program (TOF, uVTX, fast DAQ) for next long Au-Au run: 2008, 2009,…?
- Forward tracking for 500GeV proton run: 2009, 2010, …?
- Very forward instrumentation for next d-Au run: 2007, …?

Upgrades planned to carry out the future STAR program

- A Barrel MRPC TOF — PID information for > 95% of kaons and protons in the STAR acceptance; clean $e^{\pm}$ ID down to 0.2 GeV/c extended scientific reach for key observables
- Heavy Flavor Tracker — Precise hit position close to the primary vtx $\rightarrow$ D's ,flavor- tagged jets
- A DAQ/ TPC FEE Upgrade — New architecture / FEE $\rightarrow$ > 1 khz of events available at L3; effective increase in utilization of luminosity by factor of 10
- Development of GEM tech. — Technology development for forward tracking upgrade
- Forward Tracking Upgrade — W charge sign identification
- Forward Calorimeter Upgrade: — Jet reconstruction at high pseudorapidity: CGC monojet search in d(p) + A; isolation of fragmentation effects in large pp $\rightarrow \pi^0$ production single-spin transverse asymmetries

Concerns

- A flat budget or worse in FY06 ⇒
  - Reduction in staff to try to maintain adequate MST
  - Inability to meet some critical support needs and increased scope
  - Operations crew stretched thinner; reduced response time; less efficient use of beam time.
- Adequate R&D support to maintain steady progress on upgrades
- Adequate computing resources and progress to “keep up”
- Strategic overall optimization of use of resources to “run the program”
- Finding career positions for those people ready to “take the next step”
- Maintaining momentum and steady progress towards the future

Conclusions

- The STAR program is making outstanding progress:
  - New physics and important scientific discoveries
  - Educating the next generation of nuclear scientists
  - Developing new capabilities
  - Quality operation of the detector with increasing efficiency
- With continued strong support, the future is very bright for a unique world-leading program of heavy ion and spin physics studies well into the next decade