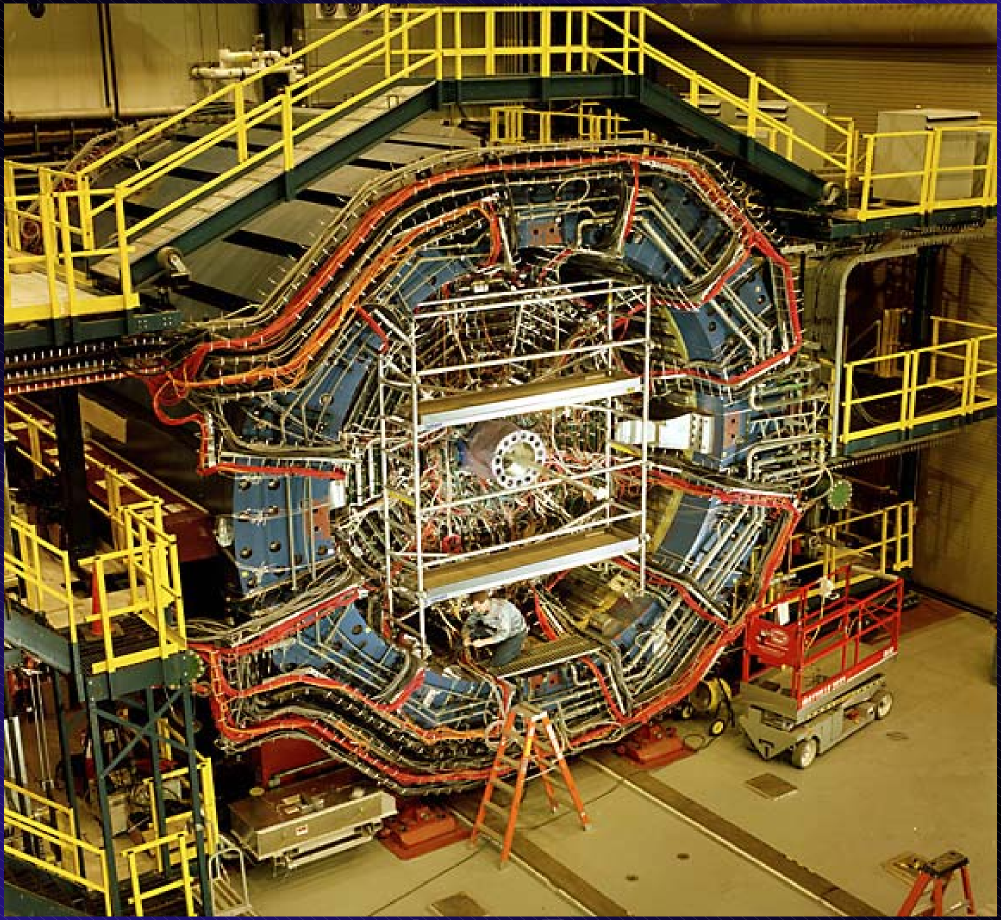
The STAR Experimental Program



Tim Hallman

Brookhaven National Laboratory

RHIC Program Review
July 9-11, 2003

The STAR Collaboration: 48 Institutions, ~ 500 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

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

The STAR Collaboration

There are presently 48 Institutions from 12 Countries in STAR

Additional Letters of Intent or expressions of interest have been received from:

Massachusetts Institute of Technology (Surrow)

University of Bern (Kabana)

Notre Dame (Cason)

Instituto de Ciencias Nucleares (ICN) UNAM,
Instituto de Fisica (IF),UNAM,
Institute for Nuclear Sciences (Ayala)

STAR is a vital, growing, international collaboration

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

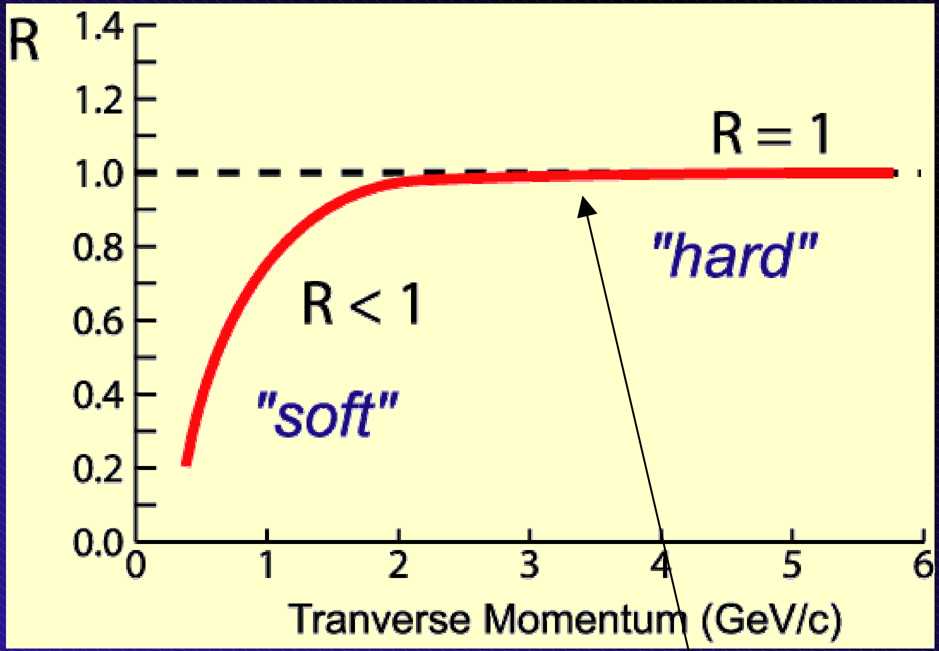
A key probe, new at RHIC: hard scattering of quarks and gluons

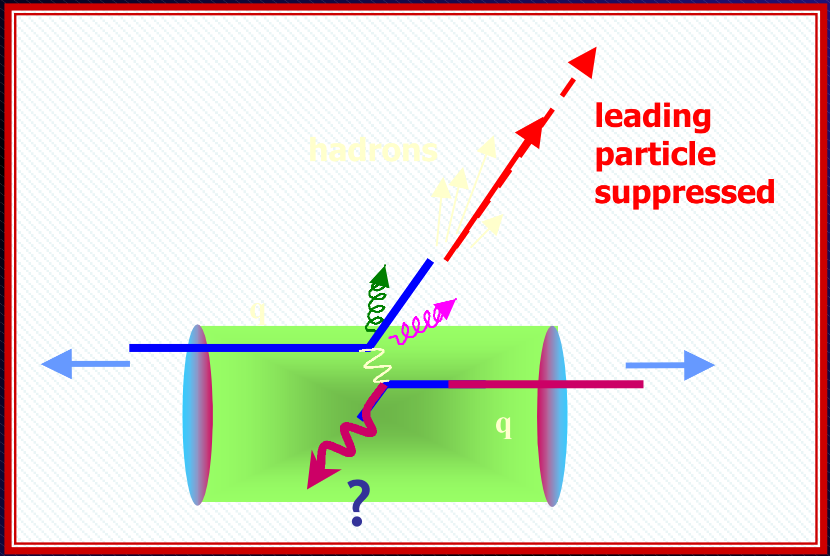
Nuclear Modification Factor:

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

Nucleus-nucleus yield

$<N_{binary}>/\sigma_{inel}^{p+p}$



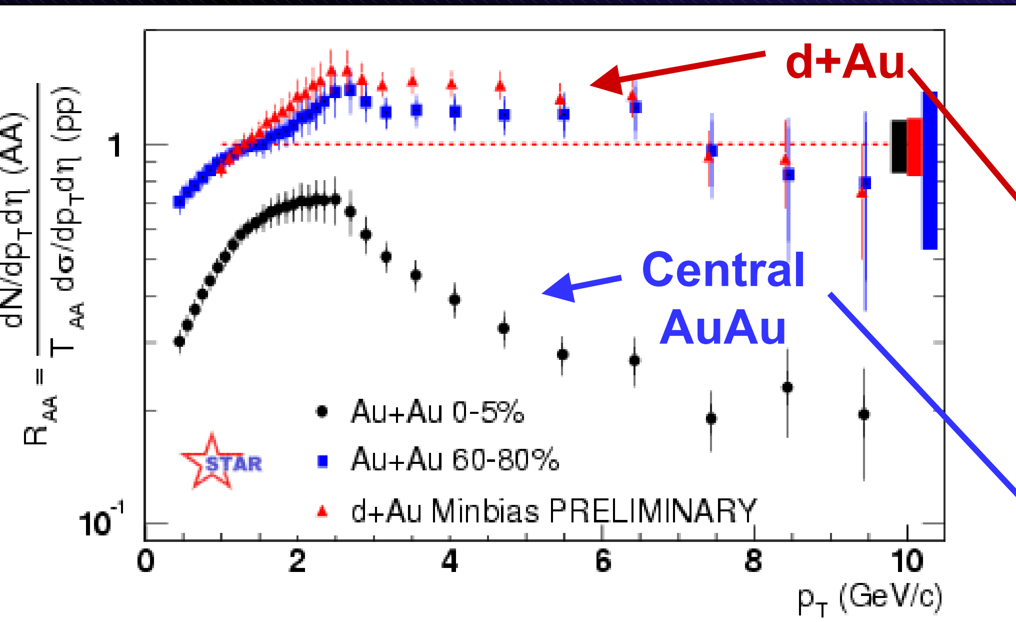


If R = 1 here, nothing "new" going on

BROOKHAVEN NATIONAL LABORATORY

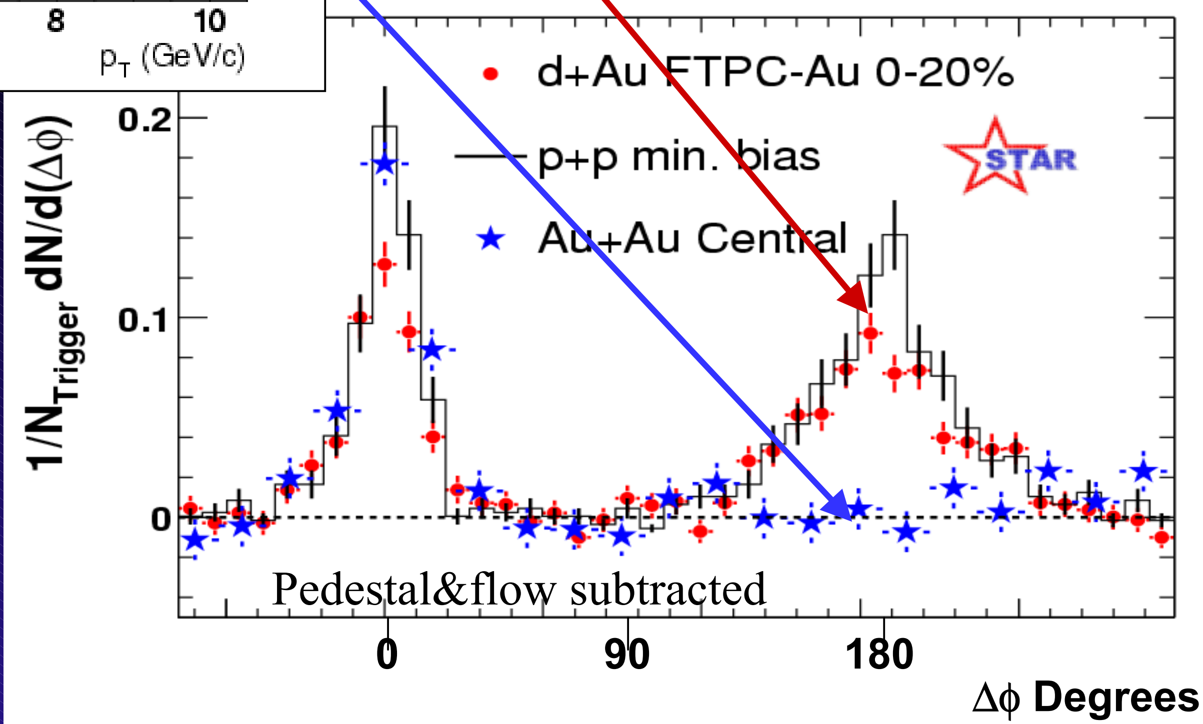
Office of Science U.S. DEPARTMENT OF ENERGY

The d+Au "control" experiment has been performed!



Run II AuAu results at full energy show strong suppression !

d+Au "control" data needed to distinguish between different interpretations



Results show:
Observed suppression due to nature of (new) produced matter !

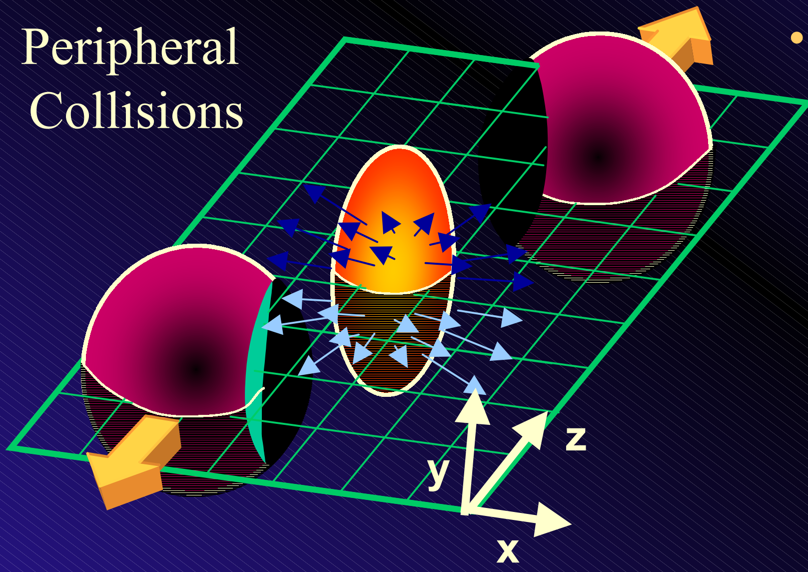
***not* initial state effects**

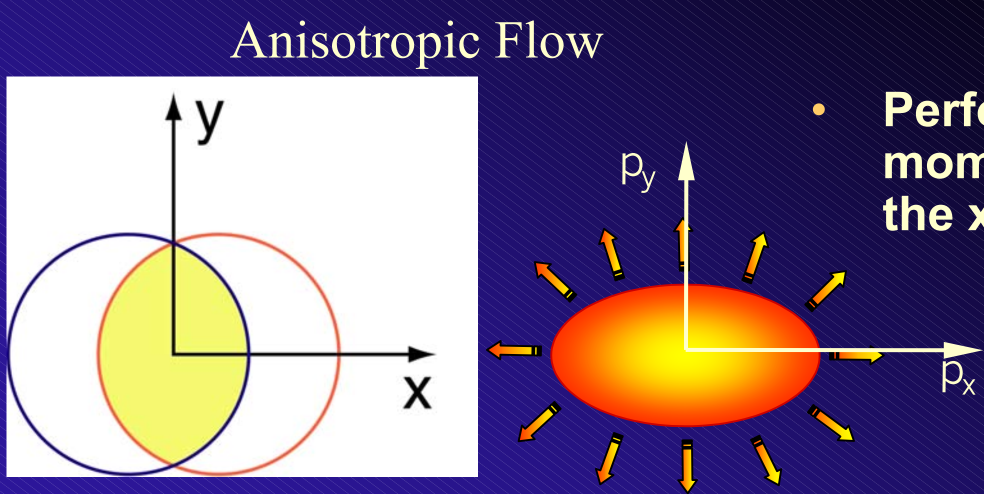
BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

Elliptic Flow: the "best barometer" at RHIC

Anisotropic (Elliptic) Transverse Flow

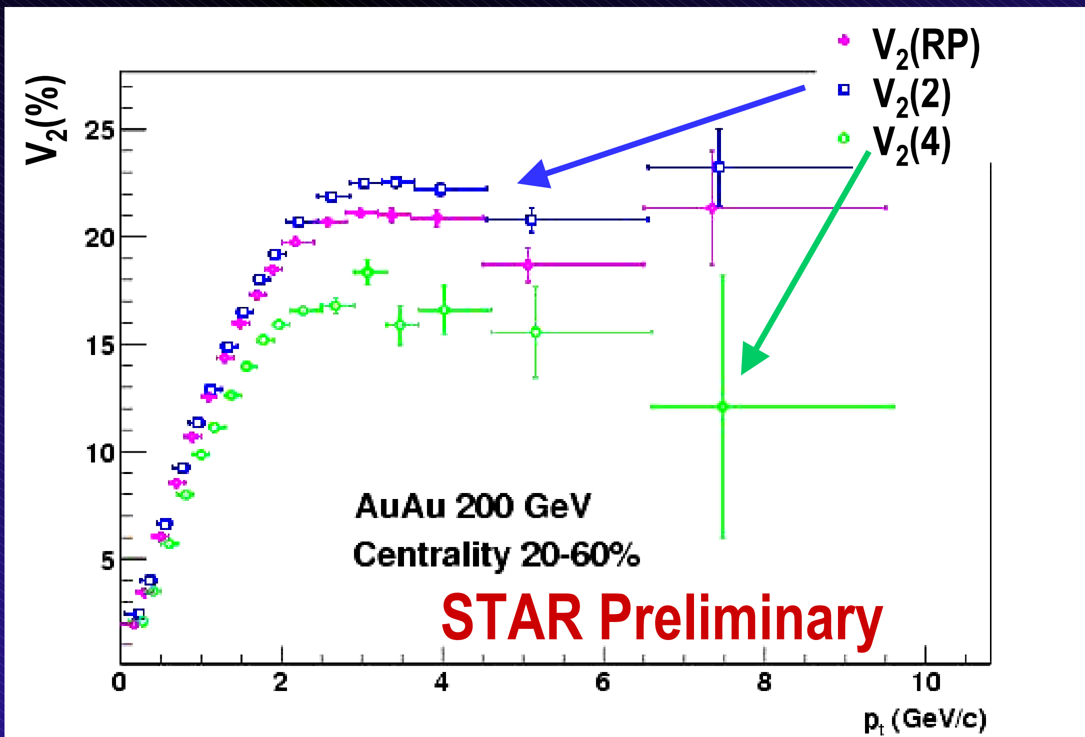




- The overlap region in peripheral collisions is not symmetric in coordinate space
  - Almond shaped overlap region
    - Easier for particles to emerge in the direction of x-z plane
    - Larger area shines to the side
  - Spatial anisotropy → Momentum anisotropy
    - Interactions among constituents generates a pressure gradient which transforms the initial spatial anisotropy into the observed momentum anisotropy

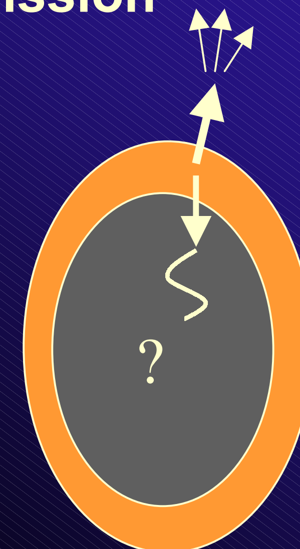
- Perform a Fourier decomposition of the momentum space particle distributions in the x-y plane
    - v_2 is the 2nd harmonic Fourier coefficient of the distribution of particles with respect to the reaction plane

Elliptic flow as a function of transverse momentum



A picture that emerges:
Surface emission

- **The backward going jet is missing in central Au-Au collisions when compared to p-p data + flow**



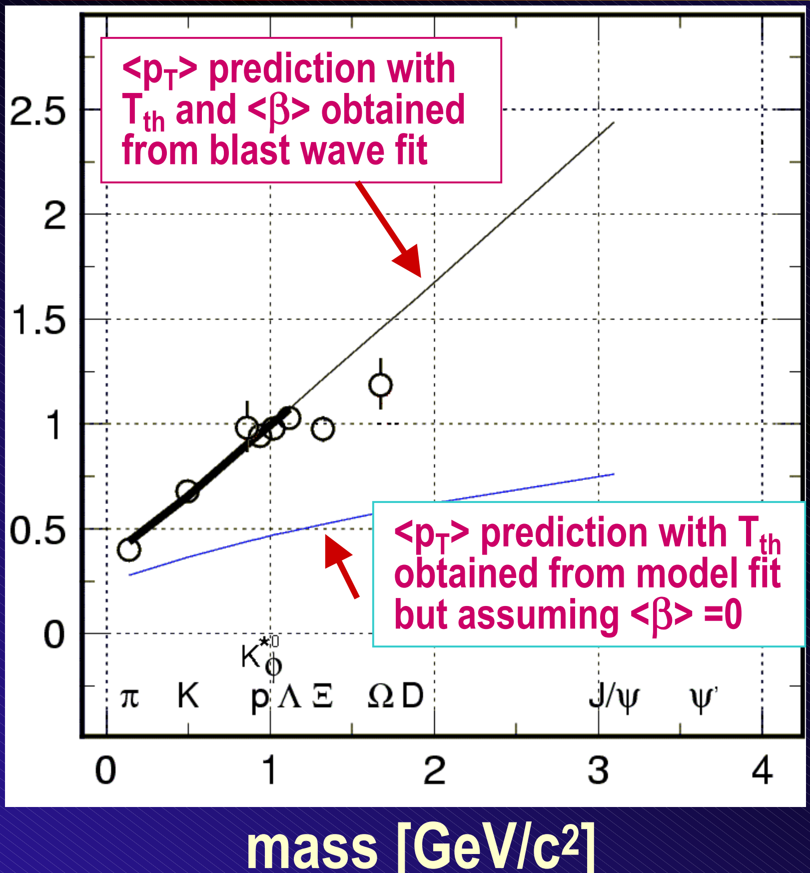
Significant v2 up to ~7 GeV/c in pt, the region where hard scattering begins to dominate.

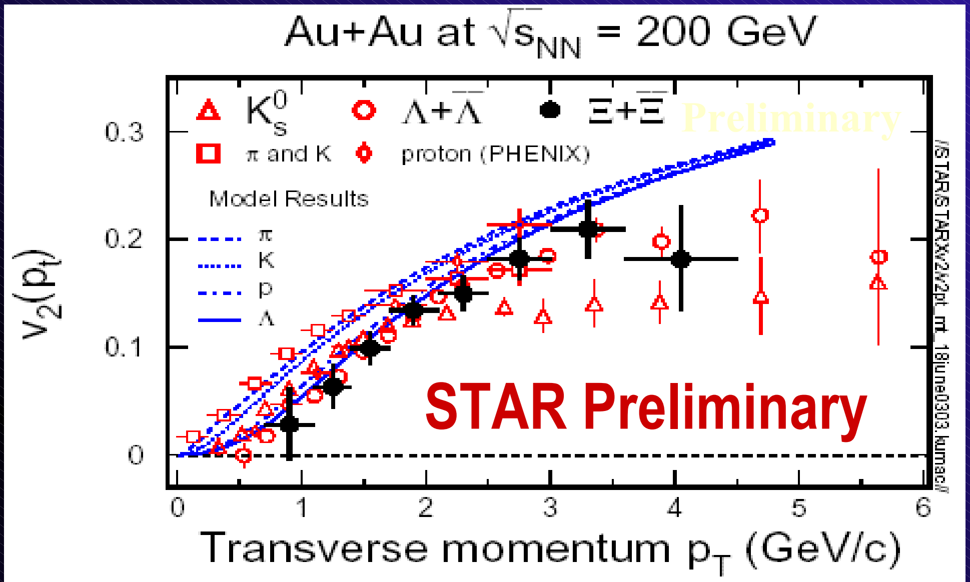
The data support the conclusion that we have produced a medium that is dense, dissipative, and exhibits strong collective behavior

BROOKHAVEN NATIONAL LABORATORY

Office of Science
U.S. DEPARTMENT OF ENERGY

Using the "best barometer" at RHIC to study pressure at early times: new data on the systematics of v2; $\Xi + \bar{\Xi}$ v_2 from min-bias data





Questions on interpretation remain

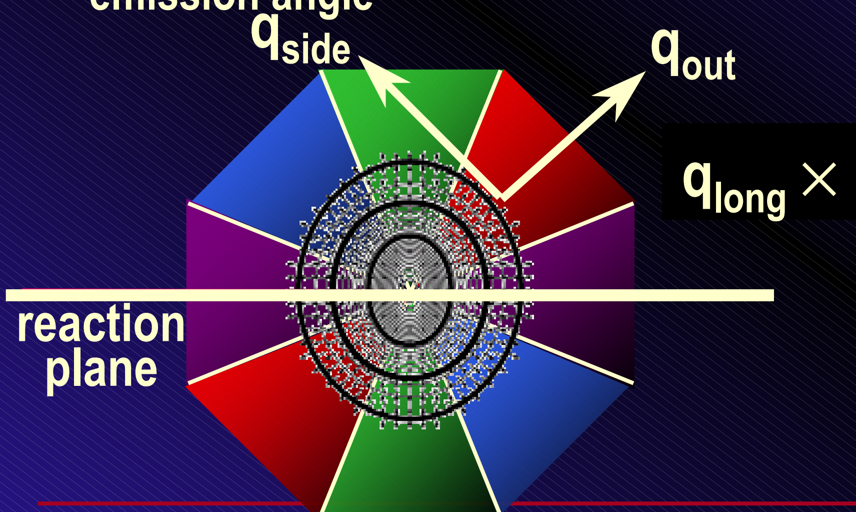
- Earlier decoupling?
- Difference in Feed-down?
- Situation in simpler systems (pp, pA)?

- $\Xi + \bar{\Xi}$ show <u>sizeable</u> elliptic flow!
- Follow hydro behavior at low p_T
- Seems to saturate at $v_2 \sim 20\%$ around $p_\perp \sim 3.0$ GeV
- Ξ $v_2(p_\perp)$ follow Λ evolution

HBT Correlations relative to the reactions plane

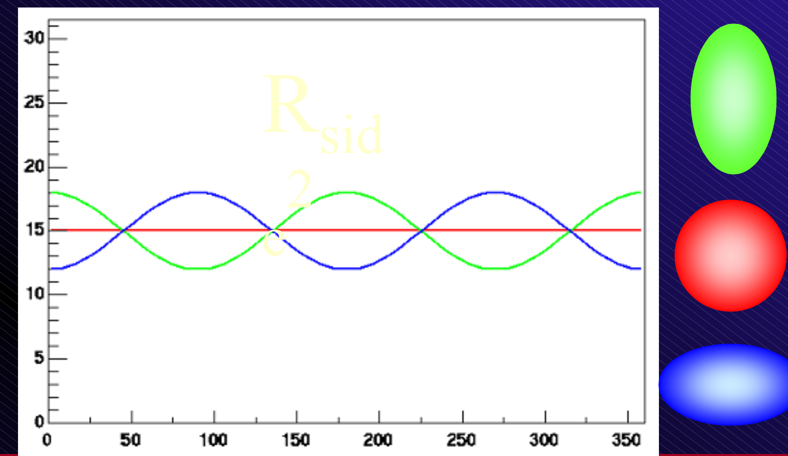
➊ What we measure?

HBT radii as a function of emission angle



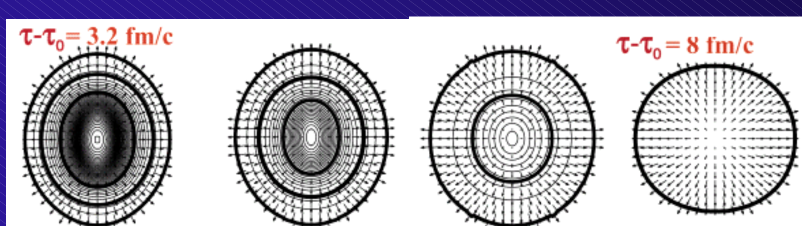
➋ What we expect to see?

2nd-order oscillations in HBT radii



➌ Why we're interested?

The size and orientation of the source at freeze-out places tight constraints on expansion/evolution



➍ What should be remembered

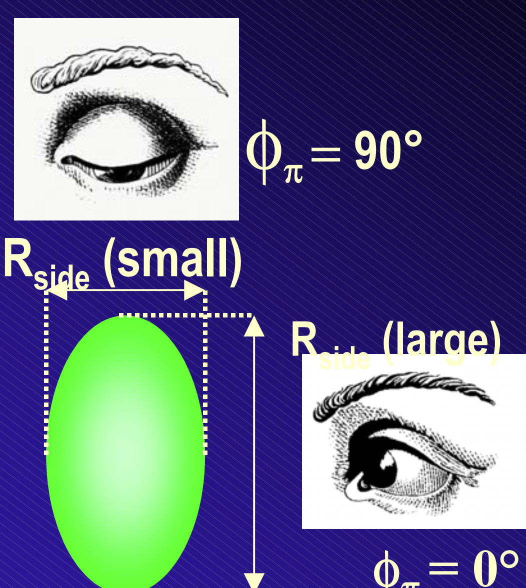
At finite k_T, we don't measure the entire source size. We measure "regions of homogeneity" and relating this to the full source size requires a model dependence.

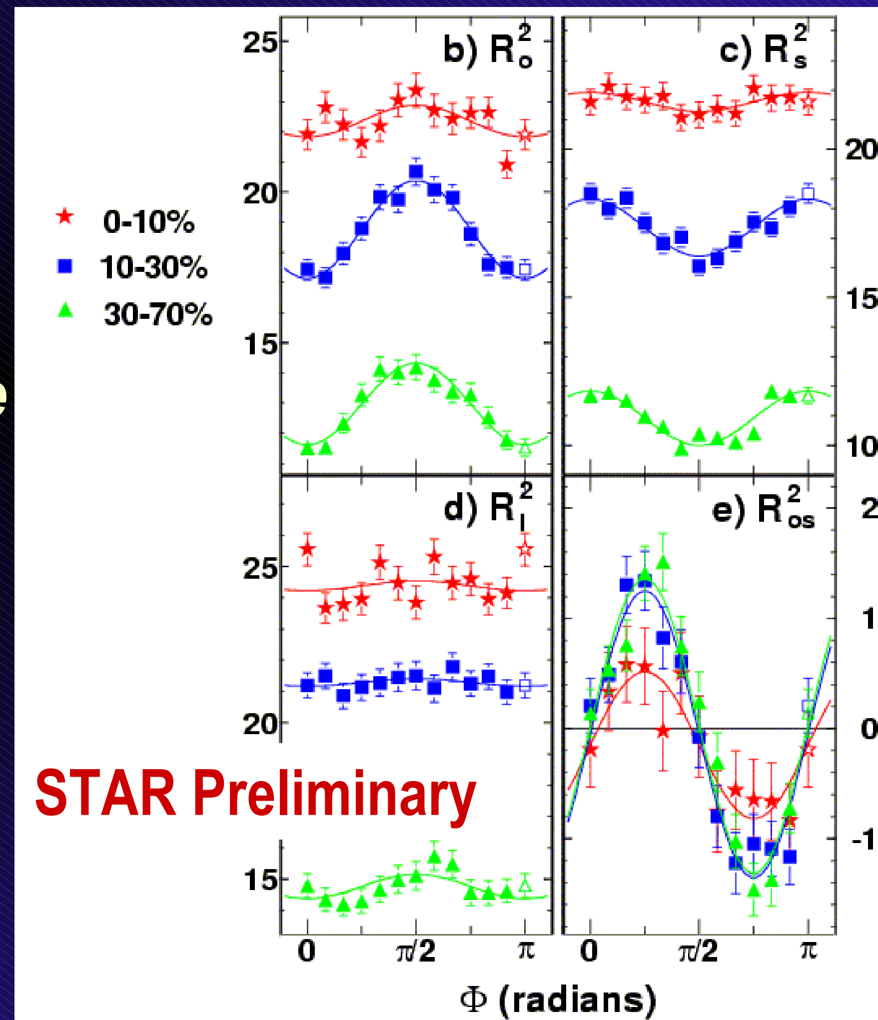
Heinz, Hummel, Lisa, Wiedemann PRC 044903 (2002)

Centrality Dependence of HBT for AuAu at 200 GeV

- 15° bins, 72 CF's total for 12 Φ bins × 3 centrality bins ; × 2 pion signs
- 0.15 < kT < 0.65
- Oscillations exist in transverse radii for all bins

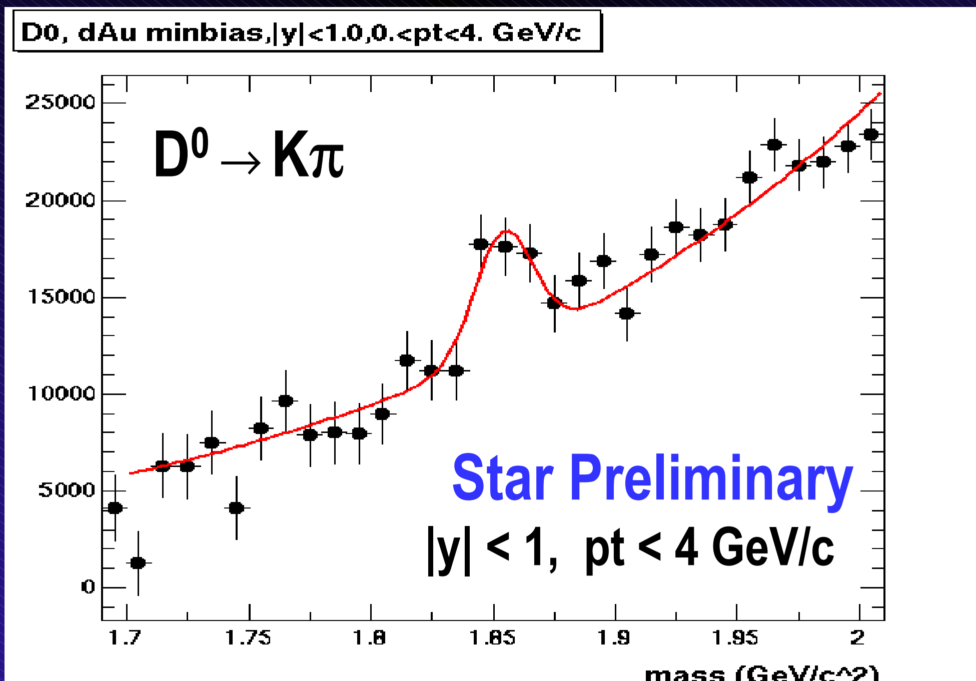
Results show oscillations which indicate out-of-plane extended source and short lifetime!

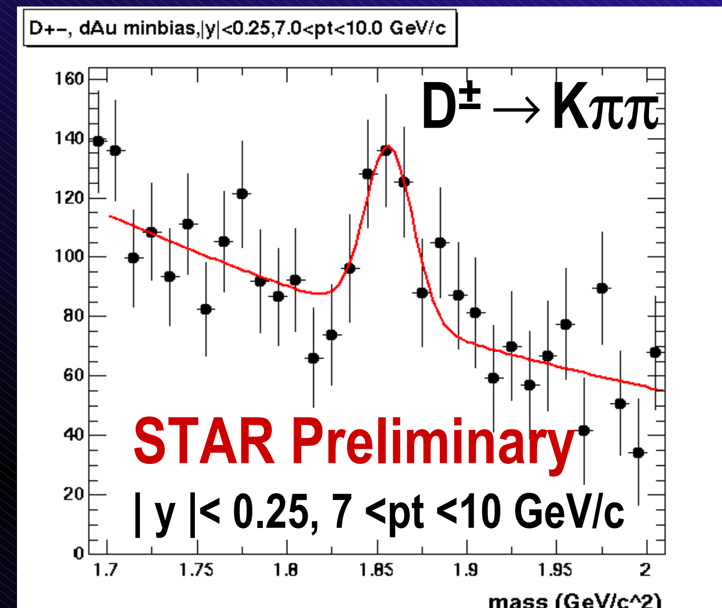




Pressing the search with heavy flavor: first direct observation at RHIC of open charm in d+Au collisions

Open Charm: a probe of initial conditions, and possible equilibration at early times





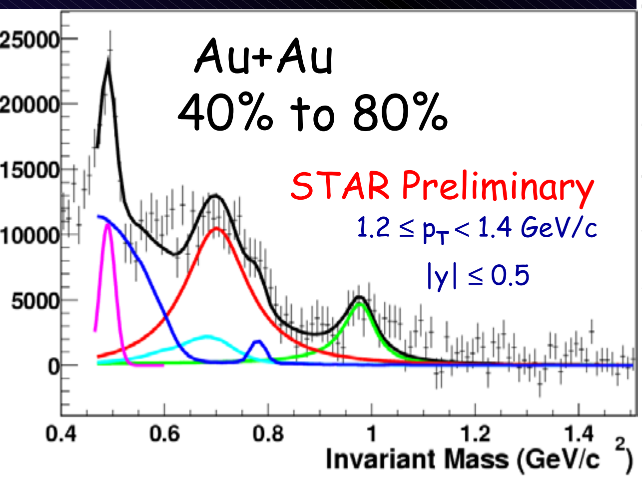
Do c quarks thermalize?

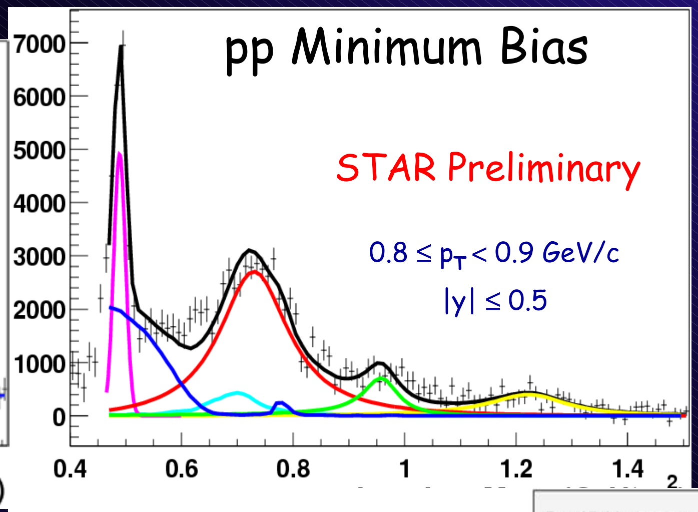
If yes, ratio of charm hadrons yield changes from p-p to Au-Au ; D_s^+ most sensitive.

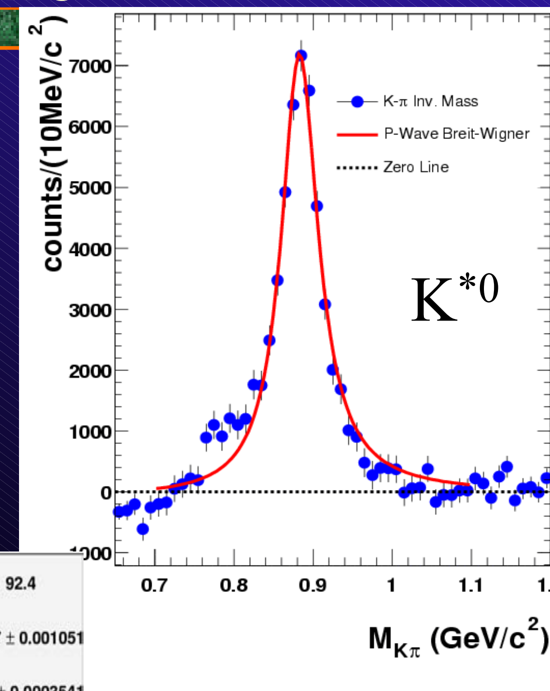
* A.Andronic, P.Braun-Munzinger, K.Redlich, J.Stachel (nucl-th/0209035)

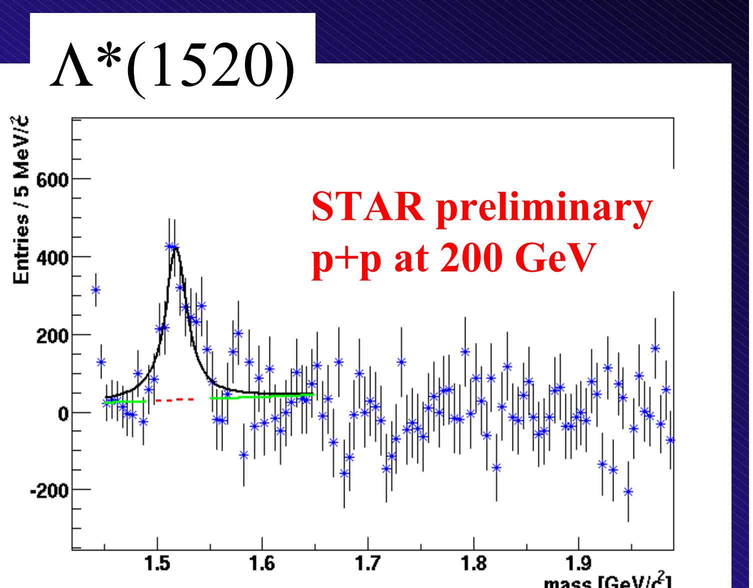
	Pythia p-p 200 GeV	Au-Au Thermal*
D^+/D^0	0.33	0.455
D_s^+/D^0	0.20	0.393
Λ_c^+/D^0	0.14	0.173
$J/\Psi/D^0$	0.0003	0.013

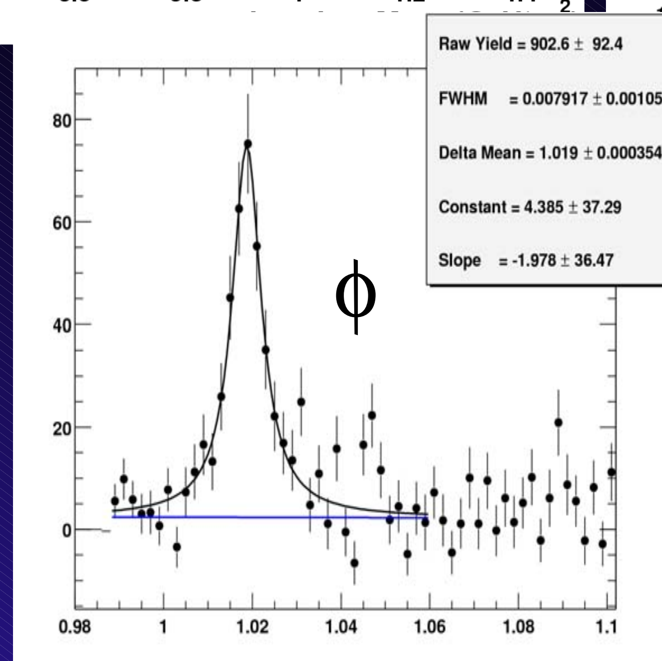
Resonance production: a tool for precision studies of the late stages of the collision at RHIC





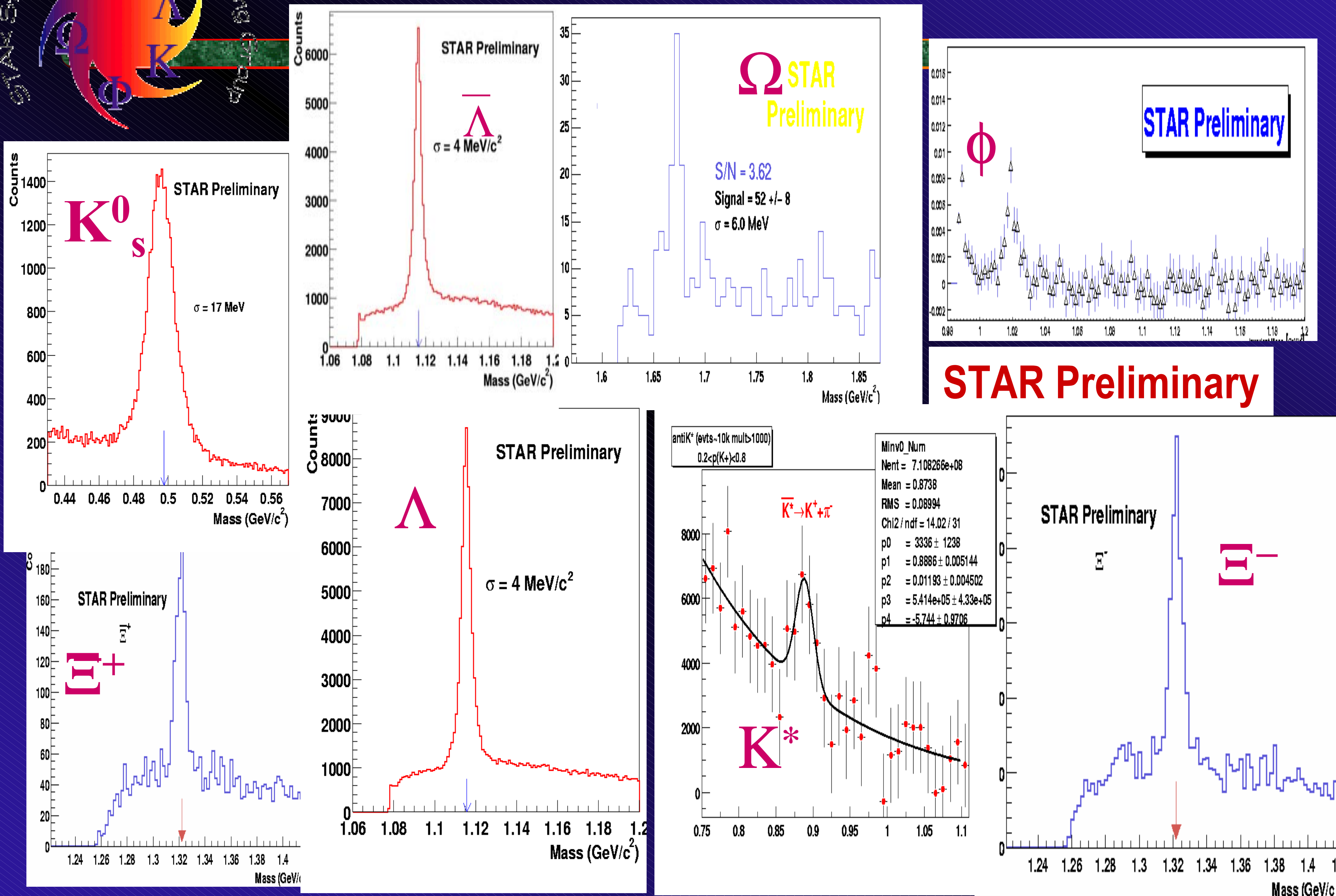






ρ, Δ, K*(892), Σ*(1385), Λ*(1520) φ, D*

The full spectrum of strange particles is available in STAR



Conclusions About Matter Produced at RHIC:

We have produced matter which exhibits features qualitatively different than has been observed before !

- **The evolution is fast**
  - Transverse expansion with an average velocity of 0.55 c
  - Large amounts of anisotropic flow (v_2) suggest hydrodynamic expansion and high pressure at early times in the collision history
  - The duration of hadronic particle emission appears to be very short
- **The produced matter appears to be opaque**
  - Saturation of v_2 at high p_T
  - Suppression of high p_T particle yields relative to p-p
  - Suppression of the away side jet
- **Statistical models describe the final state well**
  - Excellent fits to particle ratio data with equilibrium thermal models
  - Excellent fits to flow data with hydrodynamic models that assume equilibrated systems
  - Chemical freeze-out at about 175 MeV; thermal freeze-out at 100 MeV

Conclusions About Matter at RHIC:

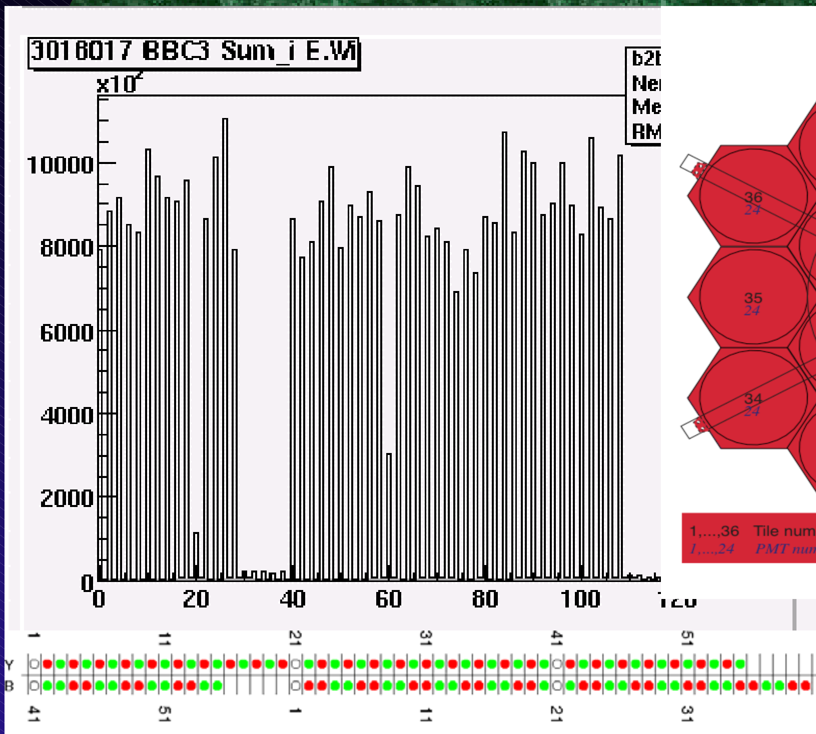
Is there a phase with bulk properties which are Partonic ?

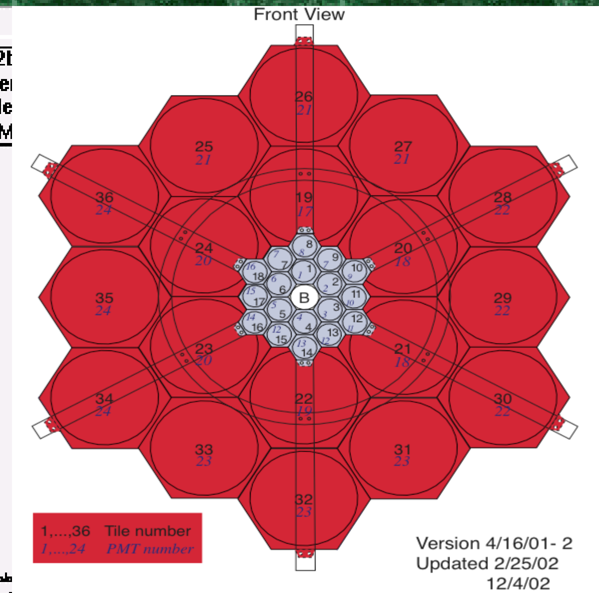
- The data on high pt suppression and v2 support the conclusion that we have produced a medium that:
  - is dense; (pQCD theory $\rightarrow$ many times cold nuclear matter density)
  - is dissipative (very strongly interacting)
- We need to show that:
  - dissipation and collective behavior occur at the partonic stage
  - the system is deconfined and thermalized
  - a transition occurs: can we turn the effects off ?
- We need:
  - extended AuAu run needed to address several important probes that need large data sets (e.g., differential energy loss for quarks, gluons, heavy quarks; J/ψ, open charm, heavy baryon / meson flow); also species and energy scans to map the evolution of key observables.
  - more guidance from theory (!) particularly on what to expect from hadronic scenarios

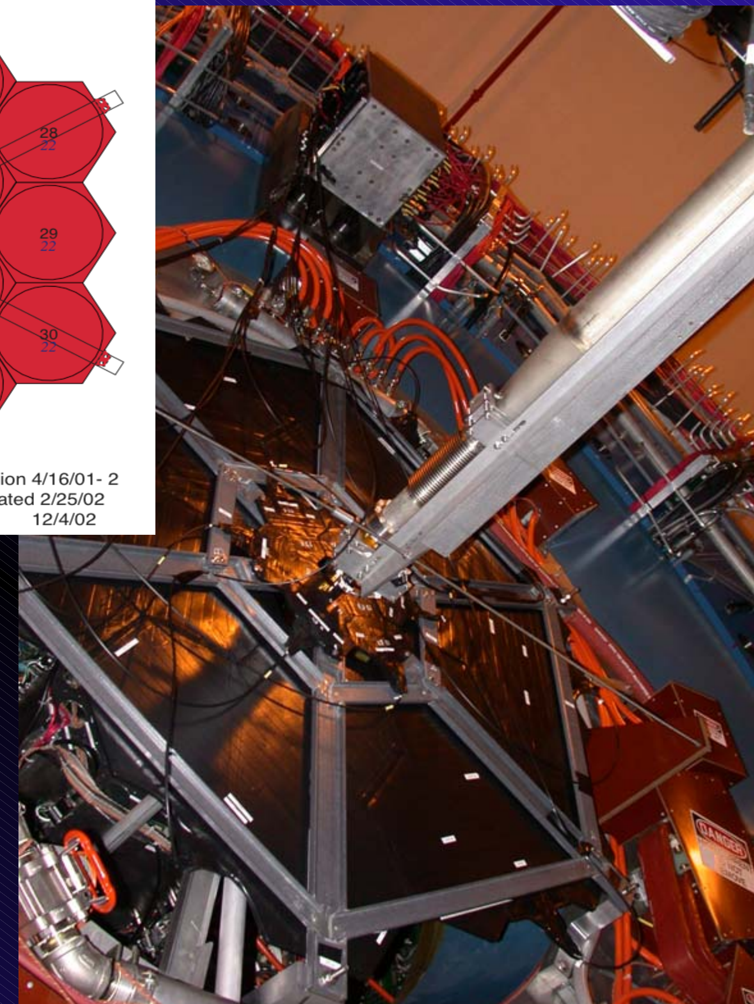
BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

Completion of STAR Beam-Beam Counters (BBC)







Scintillator annuli for each side of STAR (East and West):

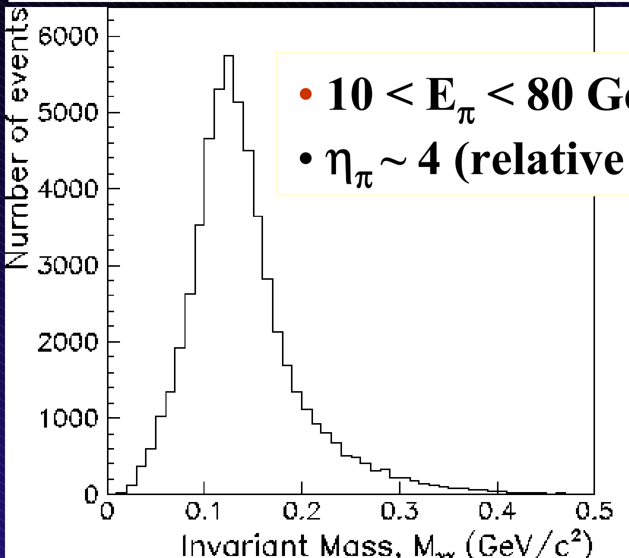
for *pp* collisions serves as ...

- **minimum-bias trigger**
- **absolute luminosity measure**
- **spin-dependent relative luminosity monitor**
- **local polarimeter**
- **background monitor**

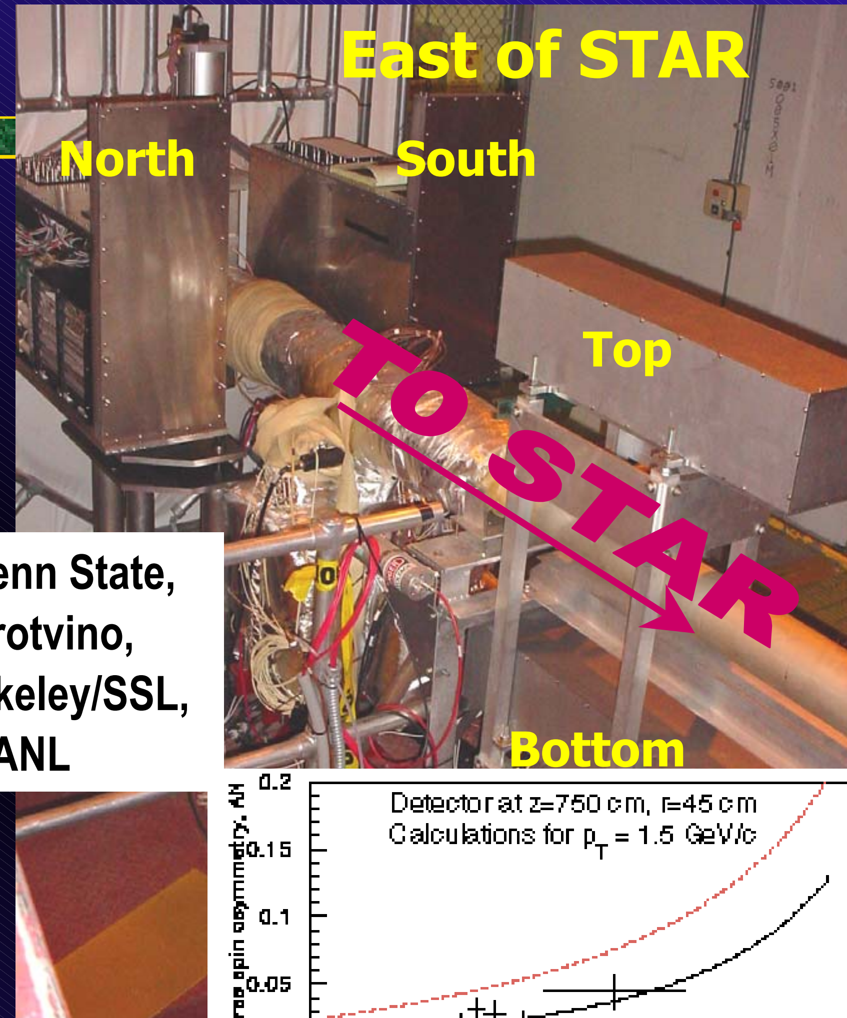
BNL, UCLA, IHEP-Protvino, UC Berkeley/SSL

The STAR Forward Pion Detector

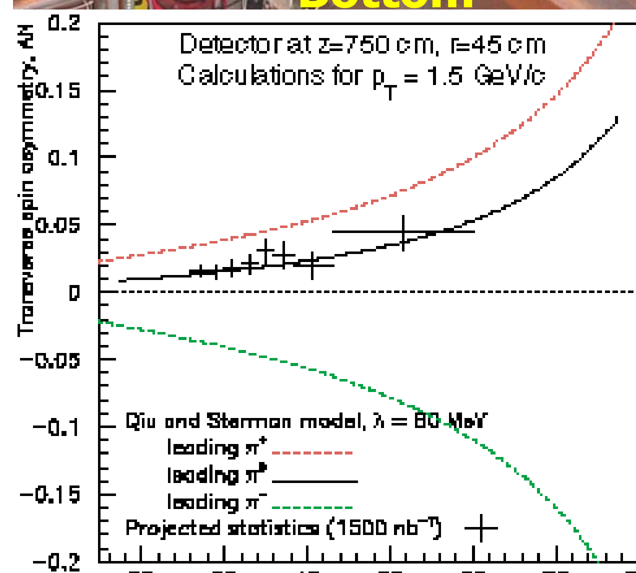
d+Au → π^0+*X*, $\sqrt{s_{NN}}$ = 200 GeV



- $10 < E_\pi < 80$ GeV
- $\eta_\pi \sim 4$ (relative to d)



BNL, Penn State, IHEP-Protvino, UC Berkeley/SSL, UCLA, ANL

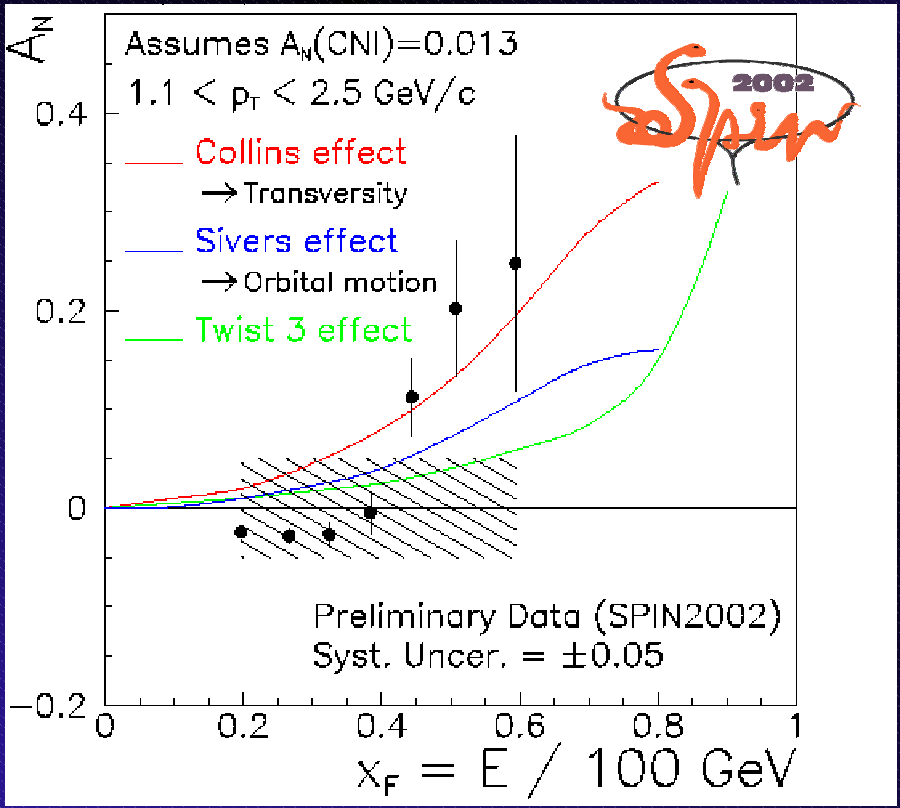


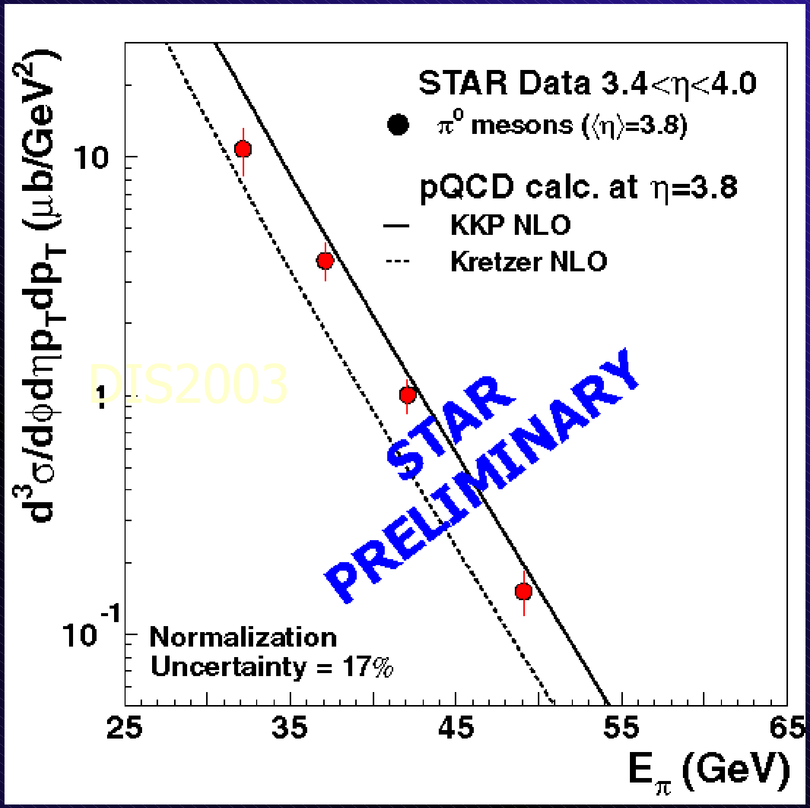
Run 3 Objectives:

- Probe of Color Glass Condensate in d+Au
  ⇒ p_T dependence of large η yield
- Improve understanding of dynamical origin of A_N in $p_\uparrow$+p → π^0 +*X* ⇒
  - Collins effect → sensitivity to transversity
  - Sivers effect → sensitivity to orbital motion
  - twist-3 effect → quark/gluon correlations
- Serve as local polarimeter at STAR IR

STAR-Spin Results from Run 2

$$p_{\uparrow} + p \rightarrow \pi^0 + X, \sqrt{s} = 200 \text{ GeV}$$





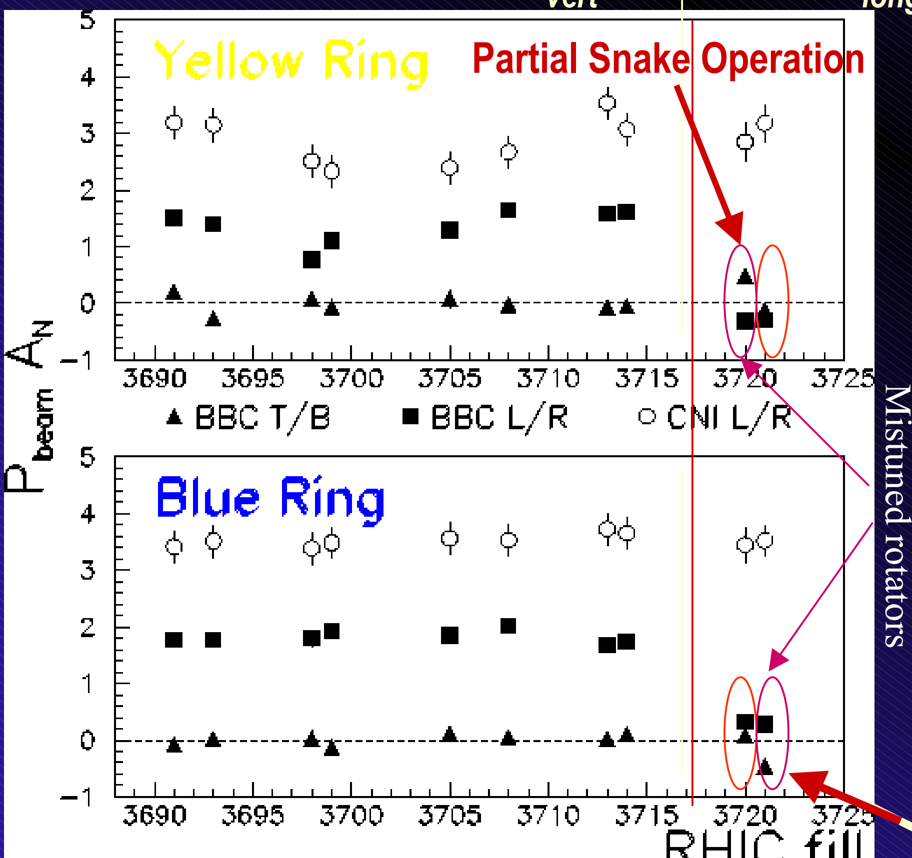
- Measured cross sections consistent with pQCD calculations
- Large spin effects observed for $\sqrt{s}$ = 200 GeV *pp* collisions

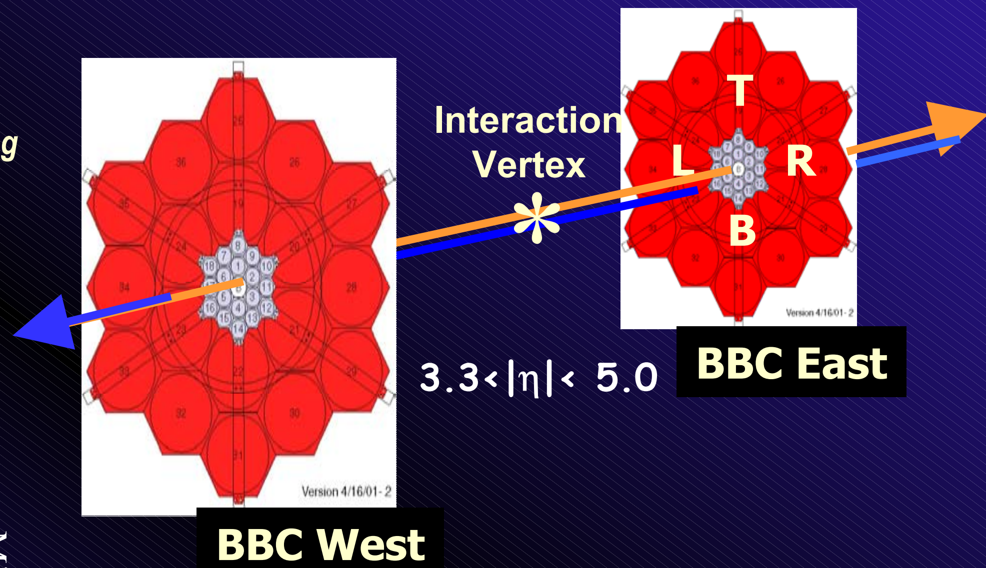
Status: final analysis complete / paper in final preparation

STAR Spin Rotator Magnet Tuning (Run 3 result)

RHIC polarimeter **(CNI) establishes polarization** ***magnitude;***
Local polarimeter **(BBC) establishes polarization** ***direction*** **at STAR.**

STAR spin rotator: **OFF ← ⇒ P_{vert}** | **ON → ⇒ P_{long}**



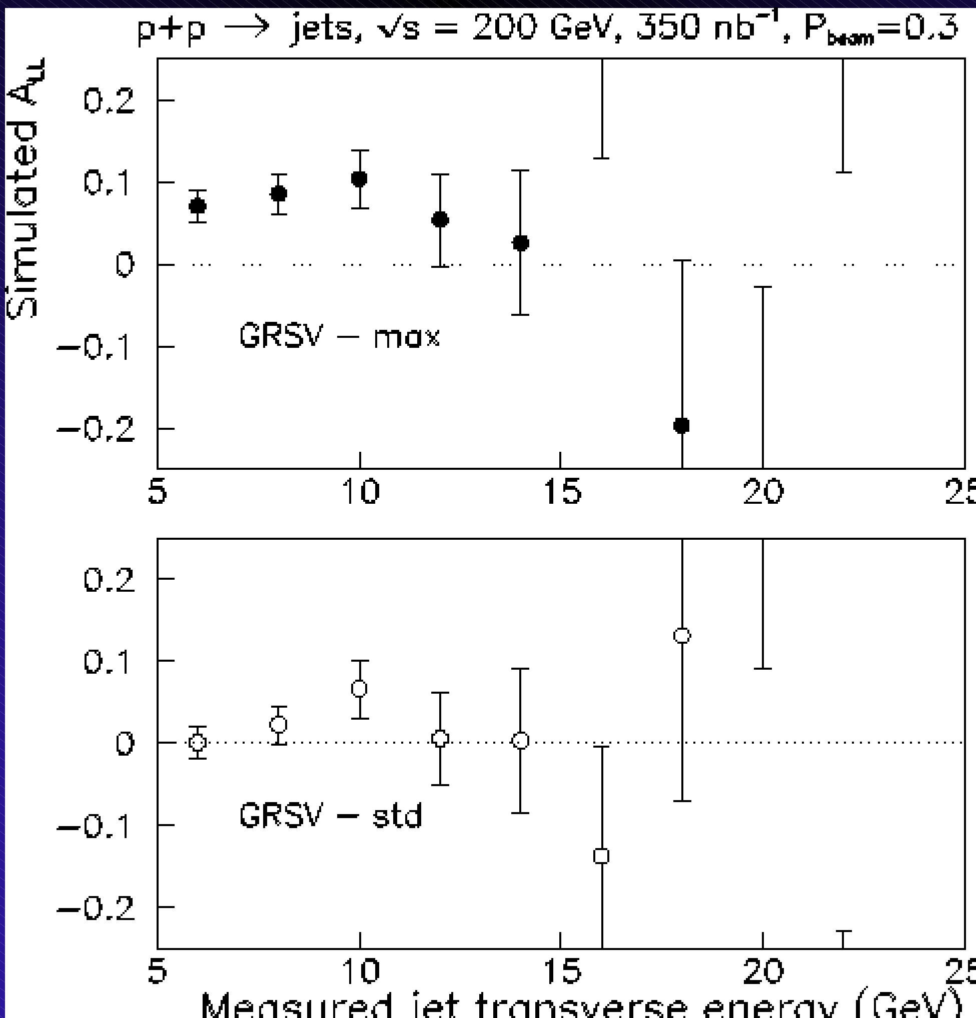


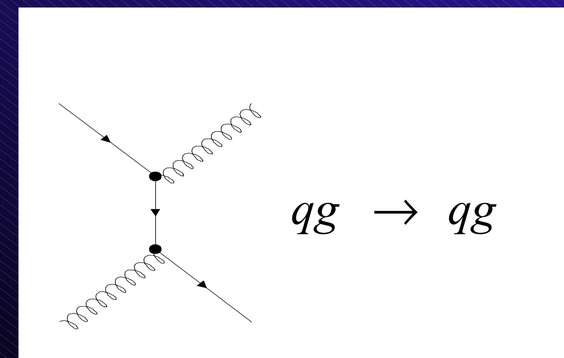
- **Use inner tiles of BBC as a *Local Polarimeter* monitoring *pp* collisions.**
- **Rotators OFF ⇒ BBC L/R spin asymmetries comparable to RHIC polarimeter (CNI).**
- **Rotators ON ⇒ adjust rotator currents to minimize BBC L/R and T/B spin asymmetries.**

"Double-blind" intentional mis-tune check

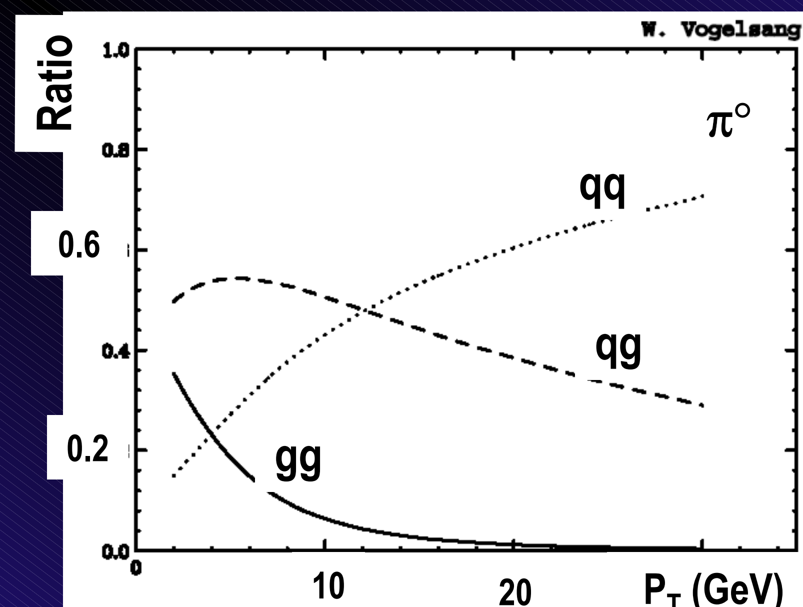
Projections for Sensitivity to ΔG from Run 3

Longitudinal spin asymmetry (A_{LL}) for mid-rapidity jet production
⇒ may be first measurements directly sensitive to gluon polarization.





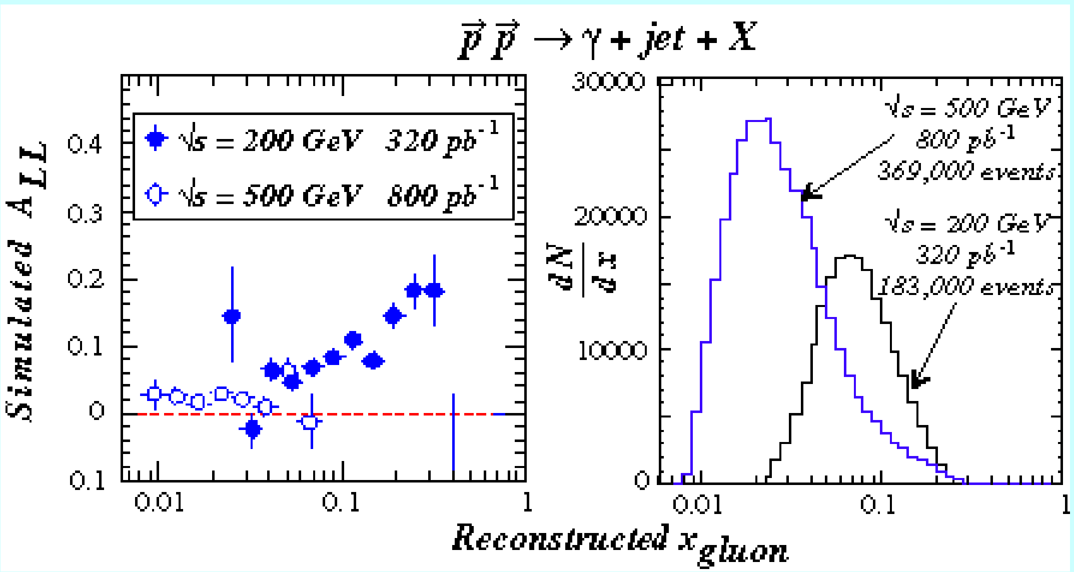
gg + *qq'* contributions



Future STAR Spin Physics Goals

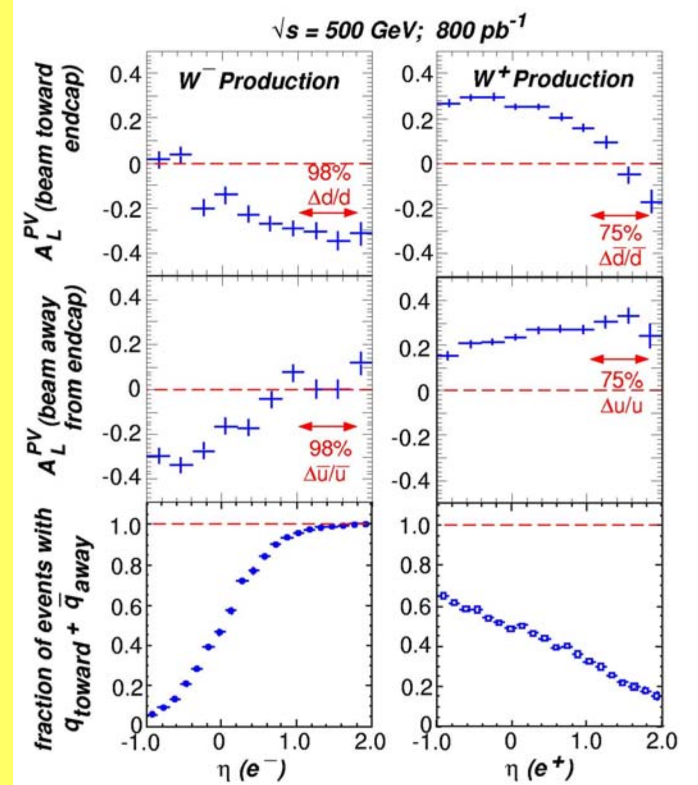
ΔG (x) determination via A_{LL} in

$$\vec{p} + \vec{p} \rightarrow \gamma + jet + X$$



Δu , Δd determination via A_L^{PV} in

$$p + p \rightarrow W^{\pm} + X \ @ \sqrt{s} = 500 \ GeV$$



At design luminosity, a 10-week runs (with ≈ 50% RHIC•STAR efficiency) apiece would yield:

- $\sqrt{s} = 200\ GeV,\ P = 0.7,\ \mathscr{L} = 8 \times 10^{31} \Rightarrow P^4 \int \mathscr{L} \bullet eff\ dt \approx 60\ pb^{-1}$
- $\sqrt{s} = 500\ GeV,\ P = 0.7,\ \mathscr{L} = 2 \times 10^{32} \Rightarrow P^4 \int \mathscr{L} \bullet eff\ dt \approx 150\ pb^{-1}$

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

Conclusions About STAR Spin Physics at RHIC:

- Successful second run overall for the first polarized collider:

  Spin Physics Measurement Goals from Run 3 BUR:

  - Complete measurement of the analyzing power A_N for neutral pions produced at large Feynman x and moderate transverse momentum. ✓
  - Establish a robust means to commissioning and tune the spin rotators. ✓
  - Study transverse single spin effects for high-pt particle production at mid rapidity. ✓
  - Establish the level of the systematics for a first measurement of ΔG in $p\uparrow + p\uparrow$; if sufficient precision can be achieved and a significant non-zero A_{LL} is observed, make a first measurement of(ΔG) — data being analyzed.
- There is clearly work to do (and a lot of work ongoing)
  - Within STAR there is a focused strategic plan for the near term as well as for the longer term future once the endcap and barrel electromagnetic calorimeters are complete
- Even though these are early days, there are already exciting results
- Luminosity is a concern (10's of pb^{-1}/week needed). (Continued progress on polarization also necessary)

Impact of the STAR Experimental Program

STAR Publications

17 papers published or submitted since the last program review:

Multiplicity Fluctuations in Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV"
J. Adams et al, submitted to Physical Review C, July 3, 2003

Three-Pion HBT Correlations in Relativistic Heavy-Ion Collisions from the STAR Experiment
J. Adams et al, submitted to Phys. Rev. Lett. on June 20, 2003 [nucl-ex 0306028]

Rapidity and Centrality Dependence of Proton and Anti-proton Production from ^{197}Au+ ^{197}Au Collisions at $\sqrt{s_{NN}}$ = 130 GeV
J. Adams et al, submitted to Phys. Rev. Lett. on June 19, 2003 [nucl-ex0306029]

Evidence from d+Au measurements for final-state suppression of high p_T hadrons in Au+Au collisions at RHIC
J. Adams et al, submitted to Phys. Rev. Lett. on June 18, 2003 [nucl-ex/0306024]

Particle dependence of azimuthal anisotropy and nuclear modification of particle production at moderate p_T in Au+Au collisions at sqrt(s_{nn}) = 200 GeV
J. Adams et al, submitted to Phys. Rev. Lett. [nucl-ex/0306007]

Transverse momentum and collision energy dependence of high p_T hadron suppression in Au+Au collisions at ultrarelativistic energies
J. Adams et al, submitted to Phys. Rev. Lett. [nucl-ex/0305015]

Impact of the STAR Experimental Program

STAR Publications (cont'd)

Narrowing of the Balance Function with Centrality in Au+Au Collisions at sqrt(s_{nn}) = 130 GeV
J. Adams *et al.* Phys. Rev. Lett. 90, 172301 (2003)

Strange anti-particle to particle ratios at mid-rapidity in sqrt(s_{nn}) = 130 GeV Au + Au collisions
accepted for publication by Phys. Letts. B on June 5, 2003

Disappearance of back-to-back high p_T hadron correlations in central Au + Au collisions at sqrt(s_{nn}) = 200 GeV
C. Adler *et al.* Phys. Rev. Lett. 90, 082302 (2003)

Centrality Dependence of High p_T Hadron Suppression in Au + Au Collisions at sqrt(s_{nn}) = 130 GeV
C. Adler *et al.* Phys. Rev. Lett. 89, 202301 (2002)

Azimuthal Anisotropy and Correlations in the Hard Scattering Regime at RHIC
C. Adler *et al.*Phys. Rev. Lett. 90, 032301 (2003)

Kaon Production and Kaon to Pion Ratio in Au + Au Collisions at sqrt(s_{nn}) = 130 GeV
submitted to Phys. Letts. B [nucl-ex/0206008]

Coherent Rho-zero Production in Ultra-Peripheral Heavy Ion Collisions
C. Adler *et al.*Phys. Rev. Lett. 89, 272302 (2002) [nucl-ex/0206004]

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

Impact of the STAR Experimental Program

STAR Publications (cont'd)

Elliptic flow from two- and four-particle correlations in Au + Au collisions at sqrt(s_{nn}) = 130 GeV
C. Adler *et al.* Phys. Rev. C66, 034904 (2002) [nucl-ex/0206001]

K*(892)^0 Production in Relativistic Heavy Ion Collisions at sqrt(s_{nn}) = 130 GeV
C. Adler *et al.* Phys. Rev. C66, 061901(R) (2002) [nucl-ex/0205015]

Azimuthal anisotropy of K0s and Lambda + Lambdabar production at mid-rapidity from Au+Au collisions at sqrt(s_{nn}) = 130 GeV
C. Adler *et al.* Phys. Rev. Lett. 89, 132301 (2002)

Mid-rapidity Lambda and Lambda bar Production in Au + Au Collisions at sqrt(s_{nn}) = 130 GeV
C. Adler *et al.* Phys. Rev. Lett. 89, 092301 (2002) [nucl-ex/0203016]

Total Papers Published or Submitted:
25 scientific, 18 technical
(19 PRL, 4 PRC, 2 PLB, 18 NIM)

Citations (Source is Spires):
758 total, 179 published in Phys Rev, Phys Rev Lett, or Phys Lett B

Impact of the STAR Experimental Program

STAR Publications

Total Papers Published or Submitted:

25 scientific, 18 technical

(19 PRL, 4 PRC, 2 PLB, 18 NIM)

Citations (Source is Spires):

758 total, 179 published in Phys Rev, Phys Rev Lett, or Phys Lett B

Educating the next generation of scientists in STAR

23 students have received degrees on STAR ; 3 more in the near future

Year	Student	Institution	Country	Topic
2003	Norman	Kent State	U.S.	Strangeness Production in AuAu
2003	Pinganuad	Subatech	France	Reconstruction of multi-strange particles with SSD
2003	Chen	UCLA	China	Charged hadron production at intermediate pt
2003	Wells	Ohio State	U.S.	HBT Correlations in AuAu collisions at RHIC
2003	Choi	U. Texas	U.S.	High pt hadron production in AuAu collisions
2003	Struck	Frankfurt	Germany	Anti-Nuclei Production
2002	Reid	U. Washington	U.S.	E-by-E Methods in RHIC data
2002	Lansdell	U. Texas	U.S.	Charged Xi Production in 130 GeV Au+Au
2002	Horsley	Yale	U.S.	Charge Particle Ratios as a function of p_T
2002	Johnson	U.C. Davis	U.S.	Photon and Neutral Pion Production
2002	Cardenas	Purdue	Panama	Charged Kaon Production
2002	Hippolyte	IReS	France	Study of Strangelet Production at RHIC
2002	Castillo	Subatech	France	Doubly Strange Particle Production at RHIC
2002	Willson	Ohio State	U.S.	Three-Pion HBT with STAR
2002	Tang	Kent State	China	Elliptic Flow in Au + Au at sqrt(s_{nn}) = 130 GeV
2002	Deng	Kent State	China	Charged K prod. in Au-Au at sqrt(s_{nn}) = 130 GeV
2002	Belt Tonjes	Mich. State	U.S.	Balance Function to search for late hadronization
2002	Long	UCLA	China	Mid-rapidity Lambda and Lambda bar Production
2002	Oldenburg	MPI	Germany	Anisotropic Flow with the STAR Forward TPCs
2002	Lamont	Birrmingham	U.K.	Neutral Strange Particle Production
2001	Calderon	Yale	Mexico	Charged Hadron Spectra in Au-Au Collisions
2001	Yamamoto	UCLA	U.S.	Phi Meson Production in Au-Au
2001	Suire	IReS	France	Silicon Strip Tracking for use in STAR

There are 60 students in STAR and 120 “juniors” (< 5 years since Ph.D.) overall

Impact of the STAR Experimental Program: Talks

Talks Distributed by STAR Talks Committee

Keane (Chair), Cebra, Laue, Nelson, Sandweiss, Schweda, Spinka

CONFERENCE		TALK TOPIC	SPEAKER & INSTITUTION	
Jul 02	Wigner Cent., Budapest	STAR overview	Fabrice Retiere	LBNL
Jul 02	VHE Cosmic Rays, CERN	Heavy Ion overview	Spencer Klein	LBNL
Jul 02	Prague Spin	Symm & Spin	Joanna Kiryluk	UCLA
Aug 02	Feynman Festival, MD	Partons at RHIC	Steve Vigdor	Iindiana U
Aug 02	HEP & QCD, Dubna	STAR overview	Gary Westfall	MSU
Aug 02	Nuclei & Cosmos, Japan	STAR overview	Soeren Lange	Frankfurt
Aug 02	High En Phy, Amsterdam	STAR overview	Jim Thomas	LBNL
Sep 02	Multipart. Dyn, Crimea	STAR overview	Jamie Dunlop	Yale
Sep 02	RHIC/AGS Users Mtg, BNL	Hard Phys in AA	Peter Jacobs	LBNL
Sep 02	RHIC/AGS Users Mtg, BNL	Soft Phys in AA	Rene Bellwied	Wayne State
Sep 02	RHIC/AGS Users Mtg, BNL	Spin	Geary Eppley	Rice
Octl 02	QCD WS, Kanpur, India	STAR QGP review	Subhasis Chattop.	VECC
Oct 02	Hadron struct, Slovakia	STAR Summary	Kai Schweda	LBNL
Oct 02	Had Coll Phy, Karlsruhe	Overview, HEP emphasis	Markus Oldenburg	Munich
Oct 02	LHC days, Croatia	STAR overview	Jamie Dunlop	Yale
Nov 02	CFIF WS, Lisbon	Quarks to nuclei	Will Jacobs	Indiana U
Nov 02	RIKEN WS, BNL	Future Plans for Spin	Les Bland	BNL
Nov 02	Early Universe, Mexico	Overview of STAR	Manuel Calderon	BNL
Nov 02	Vertex2002, Hawaii	SVT vertexing	Helen Caines	Yale
Dec 02	INT WS, Seattle	K0 & Lambda	Paul Sorensen	UCLA
Jan 03	Pomeranchuk, Moscow	STAR overview	Kirill Filimonov	LBNL

Impact of the STAR Experimental Program: Talks

Talks Distributed by STAR Talks Committee

CONFERENCE	TALK TOPIC	SPEAKER & INSTITUTION
Jan 03 Bormio 03, Italy	STAR overview	Matt Lamont Birmingham
Feb 03 Lake Louise WS, Alberta	STAR spin + UPC	Carl Gagliardi TAMU
Feb 03 Lake Louise WS, Alberta	STAR heavy ion o'view	Jenn Klay LBNL
Mar 03 SQM 03, N Carolina (ple)	STAR Strangeness	Helen Caines Yale
Mar 03 EMC WS, Juelich, Germany	STAR EMC	Frank Simon MPI Munich
Apr 03 DIS 03, St Pete, Russia	spin (parallel)	Greg Rakness Indiana
May 03 Trends in HEP, Crimea	Overview	Frank Laue BNL
May 03 Intersections, NYC	Intermediate/High Pt	Peter Jacobs LBNL
May 03 Intersections, NYC	Global Observables	Zhangbu Xu BNL
May 03 Intersections, NYC	STAR detector	Jun Takahashi Sao Paulo
May 03 RHIC/AGS Users Mtg, BNL	STAR overview	Nu Xu LBNL
May 03 RHIC/AGS Users Mtg, BNL	STAR spin overview	Steve Trentalange UCLA
May 03 RHIC/AGS Users Mtg, BNL	STAR upgrades	Dick Majka Yale
May 03 Pheno 03, Madison, WI	RHIC, esp. high Pt	Tom Ludlam BNL
May 03 8th Wigner, CUNY, NYC	Correlations	Mercedes Noriega Ohio State
May 03 8th Wigner, CUNY, NYC	Soft physics	Ben Norman Kent
May 03 8th Wigner, CUNY, NYC	Hard probes	Jon Gans Yale
Jun 03 NN 03, Moscow (ple)	STAR overview	Sergey Panitkin BNL
Jun 03 HEP & Cosm., Australia	STAR overview	Soeren Lange Frankfurt
Jun 03 Beyond Std Model, Germany	RHIC overview	Raimond Snellings NIKHEF
Jun 03 LHC & RHIC WS, Greece	UPC	Janet Seger Creighton
Jun 03 12th Mod Phy, Dubna	STAR overview	Igor Savin PPL Dubna
Jul 03 Gordon, Waterville, ME	RHIC spin	Akio Ogawa Penn State

Impact of the STAR Experimental Program: Talks

Talks Distributed by STAR Talks Committee (Cont'd)

CONFERENCE	TALK TOPIC	SPEAKER & INSTITUTION	
Jul 03 Spin-Praha-03, Czech Rep	Spin	Hal Spinka	Argonne
Jul 03 Spin-Praha-03, Czech Rep	Spin	Misha Tokarev	LHE Dubna
Jul 03 Spin-Praha-03, Czech Rep	Spin	Larisa Nogach	Protvino
Aug 03 Symmetry 03, Budapest	O'view, esp. CP viol.	Evan Finch	Yale
Aug 03 Lepton-Photon 03, FNAL	RHIC HI overview	Dave Hardtke	LBNL
Aug 03 Balkan Phy 03, Serbia	Overview	Mike Lisa	Ohio State
Aug 03 11th Lomonosov, Moscow	Overview	Daniel Cebra	U.C. Davis
Aug 03 Light Cone WS, Durham, UK	RHIC overview	Ron Longacre	BNL
Aug 03 Pan-Pacific Spin, Seattle	Gluon polarization	Jim Sowinski	Indiana
Aug 03 5th MNMP, Samarkand	STAR overview	Richard Lednicky	LHE, Dubna
Sep 03 Vertex03 Lake District UK	SVT/SSD/microvertex	Stephane Bouvier	Subatech
Oct 03 Transversity WS, Athens	STAR spin	Steve Heppelmann	Penn State
Oct 03 Hypernuc & Strange...JLab	RHIC strangeness	Hui Long	UCLA
Sep 03 Hadron 03, Germany	STAR spin	Bernd Surrow	MIT
Sep 03 Vertex03 Lake District UK	STAR tracking	Claude Pruneau	Wayne State

59 invited talks (above) Plus 12 contributed Talks at SQM2003,
7 Talks at Spin 2002 (2 plenary, 5 contributed)
Total of 78 Talks since DOE Program Review, 2002

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

The BNL STAR Group's Mission

Research Effort

- To perform forefront research and advance the state of knowledge in relativistic heavy ion physics
  - Form a core effort to strengthen STAR overall scientific program
  - Tie analysis strongly to knowledge of detector performance
  - Optimize the physics performance of the detector

Operations Team

- To insure quality operation of the STAR detector and provide an environment strongly supportive of STAR users

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

Role of the BNL STAR Group

Lead responsibilities of the local BNL group

Research:

- STAR Physics Analysis Coordinator
- STAR HBT Co-convenor
- STAR Spectra Physics Co-convenor
- STAR Heavy Flavor Co-convenor
- STAR Spokesperson

Operations:

- STAR Operations Leader
- STAR Technical Support Group Leader
- STAR Software and Computing Leader
- STAR Data Acquisition Leader
- STAR Simulations Leader
- STAR SVT Sub-system Manager
- STAR FTPC Sub-system Manager
- STAR Chief Electronics Engineer
- STAR Data Production Manager
- STAR Magnet sub-system Manager
- STAR Safety Representative
- STAR ZDC Sub-system Manager
- STAR Conventional Systems / Global Interlocks Manager

The STAR Council Chair-Elect
is also a member of the BNL STAR Group
(W. Christie)

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

BNL STAR Group Operations Responsibilities

- **STAR Systems (The Overall Scope of Operations in STAR) -**
  - ***TPC, Magnet, SVT, Slow Controls, EEMC, BEMC, Trigger, FTPC, SSD, TOFp, TOFr, ZDC, FPD, PMD, BBC, Soft& Comp, DAQ, LVL III, Run Control, Conventional Systems***
- **Coordination of all detector operation and maintenance.**
  - *Coordination of Detector commissioning*
  - *Scheduling*
  - *Budget preparation and tracking*
  - *Coordination with C-AD*
  - *Safety & environmental compliance*
  - *Allocation and tracking of User Support*
- **Coordination of STAR Software effort**
  - *Offline Software*
  - *Maintenance of Software libraries*
  - *Design and maintenance of databases*
  - *Design, maintenance, and running of data production*
  - *Computer support for operations*
  - *Coordination with RCF*
  - *Development of next generation tracker*

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

BNL STAR Group Operations Responsibilities

- **Engineering and Technical Support ***
  - *Engineering oversight and design reviews for new and upgraded systems*
  - *Designer support and archiving of existing and new system engineering drawings*
  - *Installation management for new systems*
  - *Technical support for operations*
  - *Sub system procurement support*
- **Subsystem responsibility for:**

  DAQ, Run Control, SVT, Magnet, Online and Offline software, Conventional* systems, STAR Global Interlock System, ZDCs, BBC, FPD, FTPC
- **Recent accomplishments:**
  - ***Record breaking production of d+Au data for analysis***
  - ***maintenance/support for quality operation in Run 3***
  - ***new user-friendly run control/DAQ interface***
  - ***installation / integration of 1/4 EMC barrel; 1/2 EEMC Mechanical Structure; PMD; FPD; TOFr;***

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

* *In collaboration with C-AD EF&S*

BNL STAR Operations Group

Concerns

- The local group is finding it necessary to take on additional scope:

    Forward Time Projection Chambers (Lebedev now subsystem lead)

    Barrel EMC (need for resident expert stressed by Subsystem Manager , Tom Cormier)

    Local Trigger expert needed to help cover LVL III and to augment present trigger and DAQ efforts which have minimal staffing.

    Software effort needs some re-building after attrition at BNL and elsewhere

- A flat budget in FY04 ⇒

    Reduction in staff to try to maintain adequate MST

    Inability to meet the needs above

    Operations crew stretched thinner; reduced response time; less efficient use of beam time.

The BNL STAR Group's Role as Host:
STAR users at BNL for an extended period of time

Name	Institution	Task
Barnby	Kent State	Software/Analysis
Bekele	Ohio Strate	HBT Analysis
Berger	Frankfurt	Level III support
Castillo	LBNL	Strangeness Analysis
Chajecki	Warsaw TU	Software Development
Chattopadhyay	VECC	BEMC/PMD Support
Crawford	SSL	Trigger Support
Das	VECC	PMD Support
De Moura	Sao Paolo	BEMC support
Dietel	Frankfurt	Level III support
Dong	USTC	TOFr Support
Eckardt	MPI	FTPC Support
Engelage	SSL	Trigger Support
Gonzalez	UCLA	Spectra Analysis
Heinz	Bern	Strangeness/SVT supp
Henry	Texas A&M	BEMC Software dev.
Ishihara	U. Texas	E-by-E Analysis
Ivanshin	PPL, Dubna	BEMC support
Judd	SSL	Trigger Support
Kiryluk	UCLA	Spin analysis/dev.
Klay	LBNL	High pt analysis
Kolleger	Frankfurt	Level III support
Kopytine	Kent State	E-by-E Analysis

Name	Institution	Task
Kotchenda	PNPI	TPC Gas System
Kulikov	LHE, Dubna	Slow Controls
Lange	Frankfurt	Level III support
Noriega	Ohio State	HBT Analysis
McShane	Creighton	Undergrad Student training
Meissner	LBNL	Trigger Support
Mironov	Kent State	Software Development
Nayak	VECC	PMD support
Nelson	Birmingham	DAQ/Trigger support
Nogach	IHEP, Protvino	FPD Development
Oldenburg	MPI	FTPC Suppoer
Panebratsev	LHE, Dubna	EEMC Support
Putschke	MPI	FTPC Support
Rakness	IUCF	Spin development
Ruan	USTC	TOFr Development
Shestermanov	IHEP, Protvino	FPD Development
Simon	MPI	FTPC Development
Smirnov	Yale	GEM Development
Sowinski	IUCF	EEMC installation
Stringfellow	Purdue	TPC support
Suaide	Sao Paolo	BEMC support
Struck	Frankfurt/Yale	Anti-nucleus analysis
Szarwas	Warsaw TU	Software Development
Takahashi	Sao Paolo	SVT Support

The BNL STAR Group's Role as Host:

STAR users at BNL for an extended period of time

(Cont'd)

Name	Institution	Task
Thomas	LBNL	STAR Management
Trentalange	UCLA	BEMC Support
Ward	U. Texas	Trigger Support
Whitten	UCLA	Shift Sign-up Coord
Wieman	LBNL	Micro-Vertex Development
Witt	BERN	Strangeness Analysis
Wood	UCLA	Polarimeter Development
Zhang	Yale	Resonance analysis

Overall, the STAR Group hosted 240 STAR users for a total of 498 visits to BNL for data taking, reviews, workshops, collaboration meetings etc. since the last review

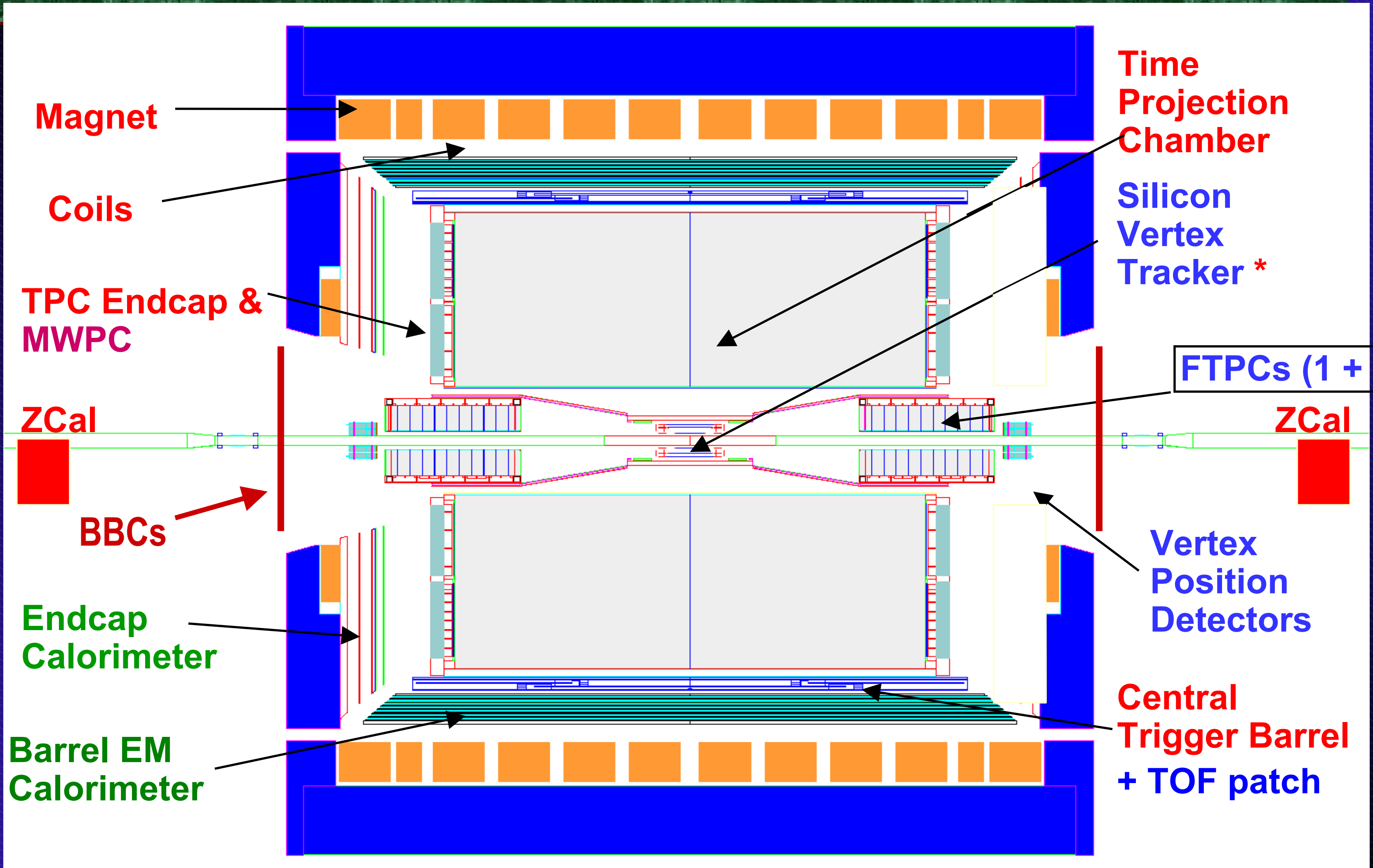
The local BNL STAR Group has also helped co-sponsor

Strange Quark Matter (SQM) 2003

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

The STAR Detector



BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

Near-term STAR Upgrades (2002-2004)

- **2002 installation:**
  - ***Complete west half of barrel EMC ✓***
  - ***1/3 of endcap EMC ✓***
  - ***completed BBC ✓***
  - ***Photon Multiplicity Detector ✓ (partial)***
  - ***Start on FPD ✓***
  - ***Start on SSD ✓***
  - ***1 prototype tray of MRPC TOF ✓***
  - ***Level 1+2 trigger algorithms ✓***
  - ***DAQ100 (deferred)***

- **2003 installation:**
  - ***¾ of barrel EMC***
  - ***endcap EMC mechanical done; 5 sectors fully instrumented***
  - ***complete Forward Pion Detector***
  - ***complete 11 ladders SSD***
  - ***Finish PMD installation***
  - ***implement DAQ100 & ITTF***

- **2004 installation:**
  - ***complete SSD***
  - ***complete barrel EMC***
  - ***complete endcap EMC***
  - ***start (?) on barrel TOF (SBIR II)***

Physics program requires medium-term (pre-RHIC II) detector upgrades to begin to be incorporated in 2005 and beyond.

Near Term STAR Upgrades

Summary

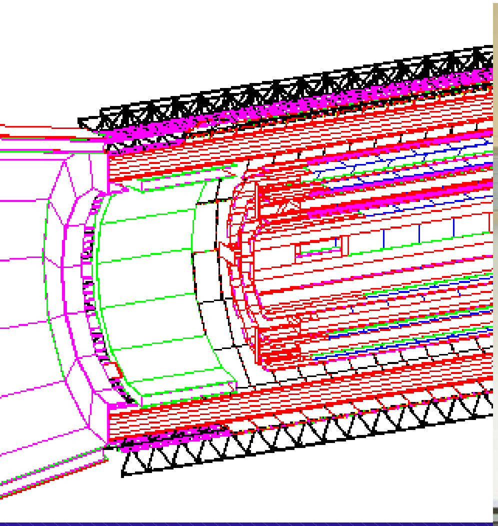
Detector / Interest	Status by 11/03	Completion
Barrel Electromagnetic Calorimeter (high pt, photons, π°, jets)	90 modules of 120 installed	2004
Endcap Electromagnetic Calorimeter (reach in x_{BJ}, high pt, photons, π°, jets)	mech structure installed; 40% instr.	2004
Silicon Strip Detector (x 1.5 efficiency for hyperon reconstr.)	11 ladders installed for Run 4	2004
Photon Multiplicity Detector $\langle m_\gamma \rangle$ (π°) fluctuations, Chiral Condensate	Detector Mechanical and some readout installed	2003
TOFr (< 100 ps TOF PID with MRPC Modules)	New prototype Tray	2003
DAQ 100 ($\rightarrow$ Event Rates ~ 100 Hz)	Completed for Run 4	2003
Forward Pi Zero Detector (A_N for leading π°, G(x) in d + Au)	Complete	2003
Level I, II Trigger Aborts (Rare Trigger Selection e.g. J/Ψ)	Commissioning	Ongoing Dev.

The STAR Experimental Program - Near Term Upgrades

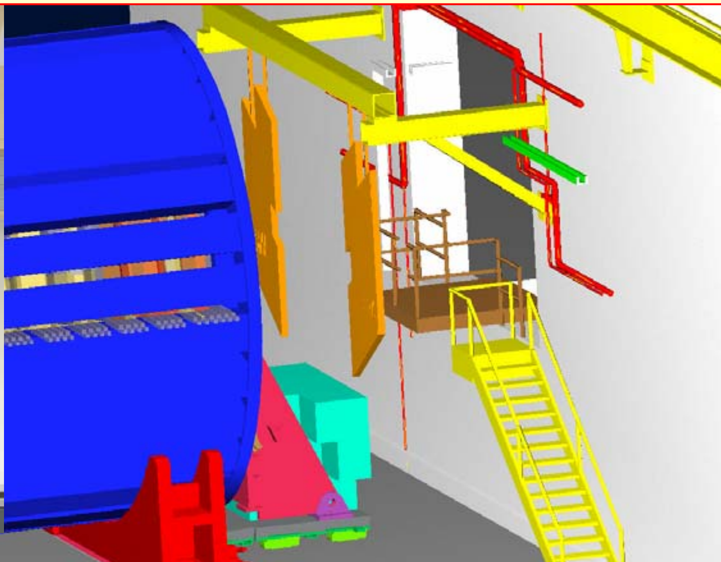
The STAR Barrel EMC

The STAR Endcap EMC

The STAR Silicon Strip Detector (SSD)

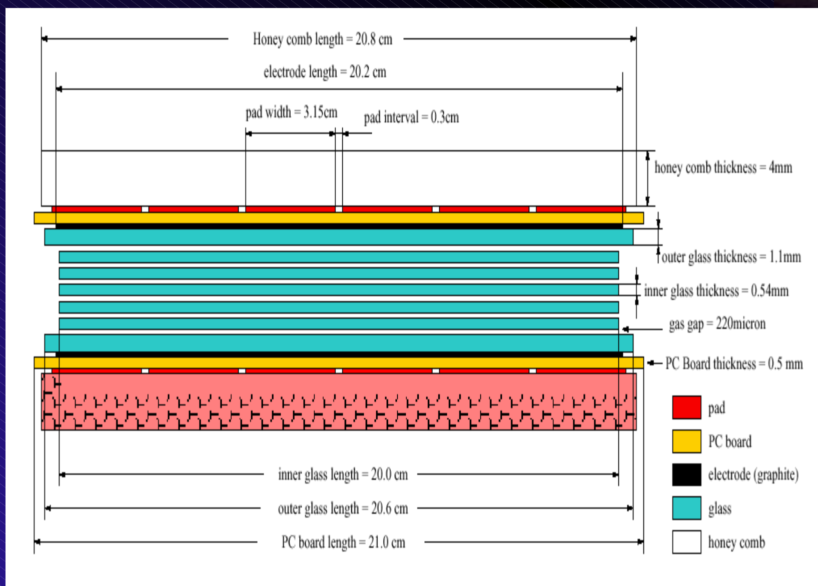


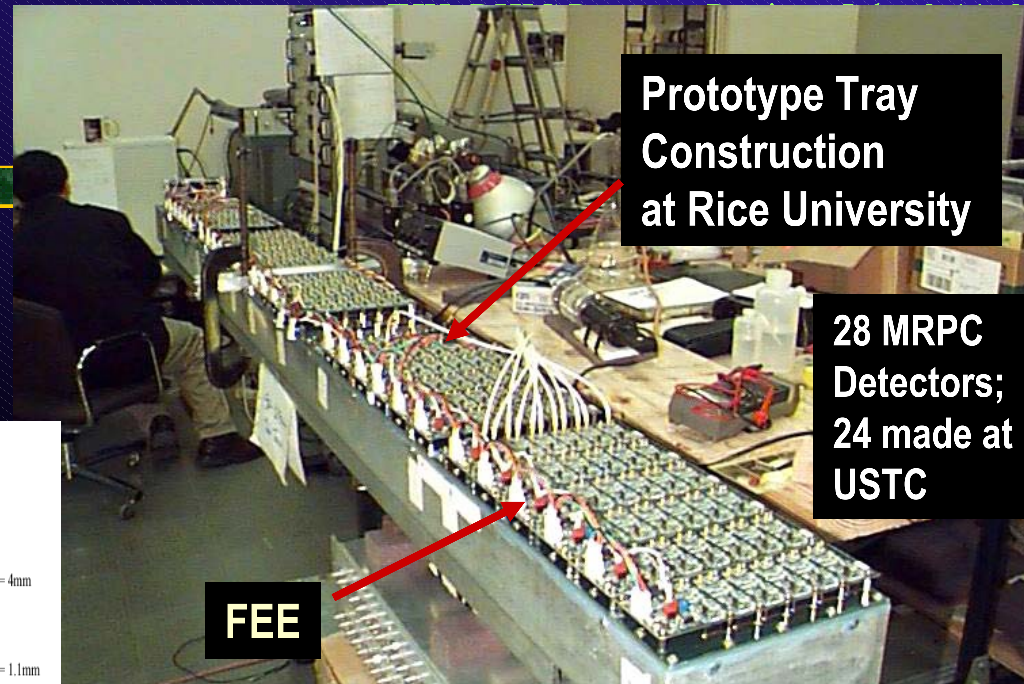
STAR Photon Multiplicity Detector (PMD)

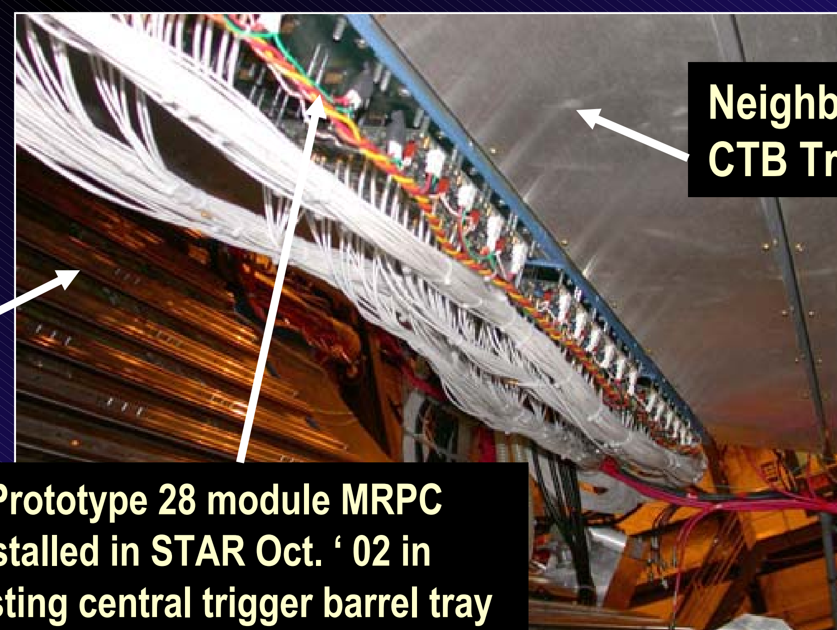


The STAR Barrel TOF MRPC Prototype

MRPC design developed at CERN, built in China





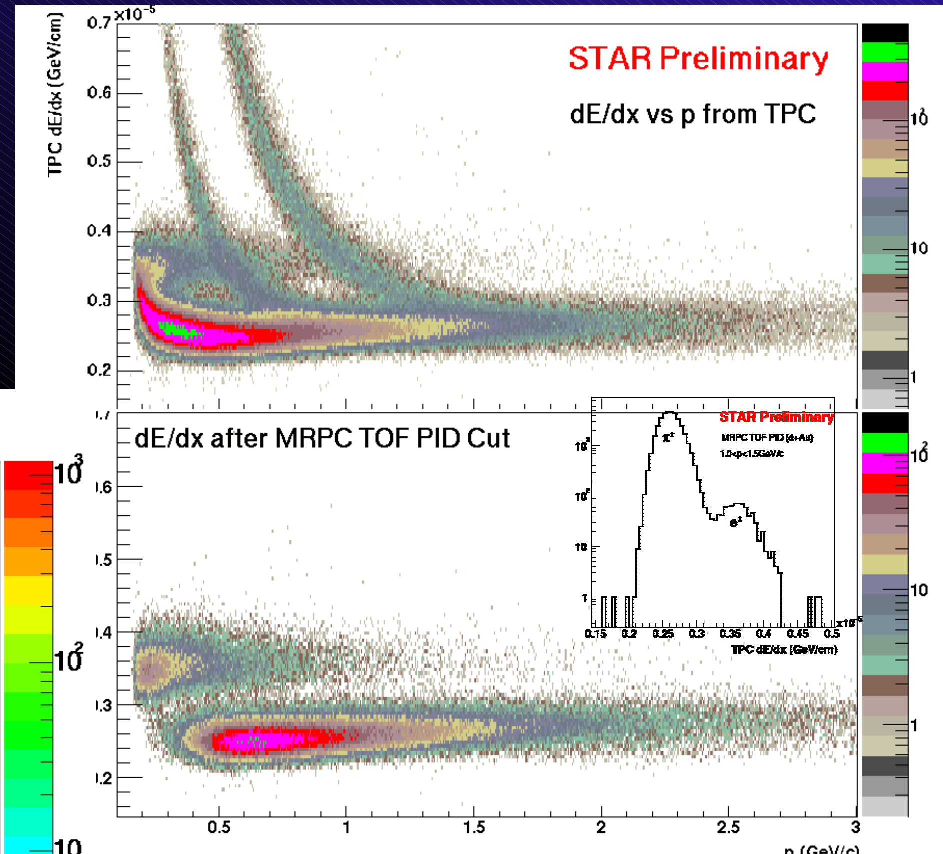


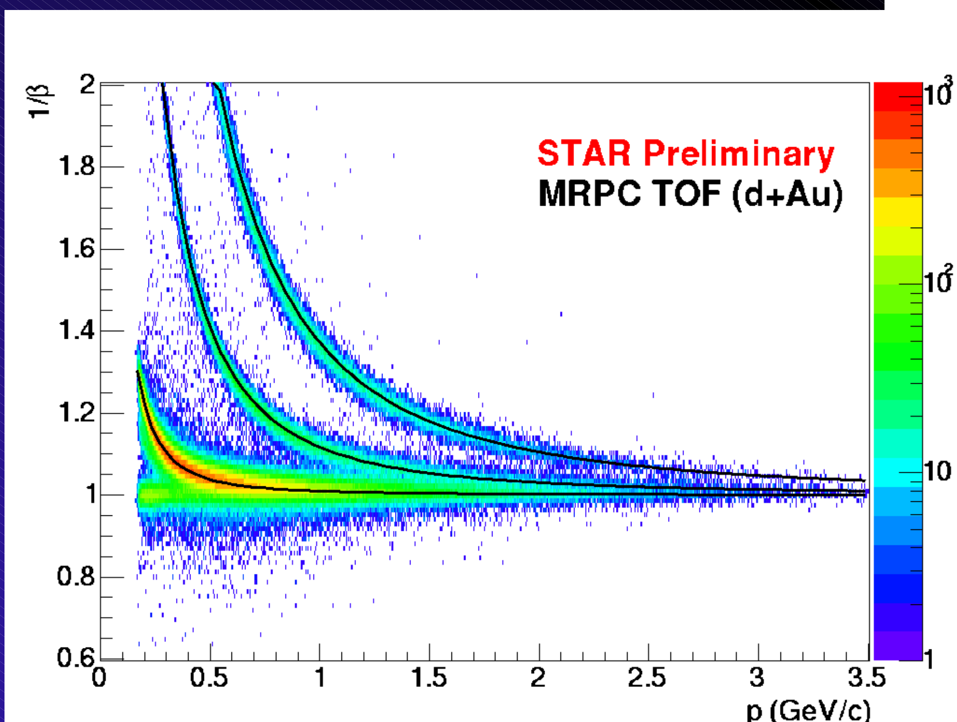
σ ~ 50 ps, 2 meter path

Strong team including 6 Chinese Institutions in place

The STAR Barrel TOF MRPC Prototype

Prototype modules met all performance specs in the STAR environment and produced important physics on PID'd Cronin Effect





Proposal reviewed and approved by STAR and has been submitted to BNL Management

High Luminosity RHIC Physics

Detector upgrade requirements developed from

- Two years of discussions beginning with RHIC Detector R&D Workshop at BNL in 2001
- Dedicated detector study workshops at Montauk (PHENIX) and Bar Harbor (STAR)

Leading to:

- Detector upgrades proposal submitted and reviewed in December 2002 by independent Detector Advisory Committee (P. Braun Munzinger, Chair)

The proposed R&D program is sound; should begin now to be ready for "phase where emphasis will shift towards studies with improved sensitivity for rare phenomena as well as studies requiring very large data samples."

The Most Effective Approach:

Evolutionary upgrades to the existing PHENIX and STAR detectors, maintaining a strong physics program with each throughout the remainder of this decade.

New components phased in during annual shut-downs.

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

STAR Future Physics and Planned Upgrades

Present Status of the Heavy Ion Program:

We are producing matter which exhibits features qualitatively different than previously observed!

- The evolution is clearly that of highly dynamic, strongly interacting matter
  - (high radial flow (β ~ 0.6) and v2, HBT $\rightarrow \tau$ for emission ~ 1 fm/c)
- The produced matter appears to be opaque
  - (Suppression of high p_T inclusives, suppression of back-to-back correlations)

The program must (still) answer definitively:

Is there a phase with bulk- matter properties which are partonic ?

What are those properties in detail?

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

STAR Future Physics and Planned Upgrades

In STAR these questions will be attacked

- using hard probes such as
  - Inclusive jets and direct photons
  - back to back jets (correlation of leading particles)
  - direct gamma + leading hadron from jet
  - flavor tagged jets

  to measure the differential energy loss for gluon, light quark, and heavy quark probes which couple differently to the medium

- with very large samples of "soft physics" events to unfold the bulk properties of the produced matter, studying e.g.
  - heavy quark thermalization
  - heavy baryon / meson elliptic flow
  - spectrum of extended hadronic matter (resonances)
  - broken / restored symmetries (e.g., cp violation, chiral restoration)

To carry out its future program STAR needs:

- **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
- **A Barrel MRPC TOF** — 4 vector information for an additional 60% of the hadrons in final state; extended scientific reach for key observables
- **Development of GEM tech.** — Preparation for a compact, fast, next generation TPC needed for 40 x L
- **High Luminosity** — 10 - 50 times the luminosity (10 nb^{-1}) integrated at RHIC up to 2010 (Thomas Roser will provide)

STAR Future Physics and Planned Upgrades

To be ready, the R&D must start <u>now</u>

Proposal for FY2003 - FY2005

Project	Principal Investigator	Collaborating Institutions	Requested Funds (K$) FY 2003	FY 2004	FY 2005
TPC FEE Upgrade	J. Marx	LBNL	79.8	166.5	0.0
DAQ Upgrade	T. Ljubicic	BNL	207.0	716.0	850.0
MRPC Time-of-Flight Development	G. Eppley	Rice, Texas	128.0	134.0	0.0
High Resolution Vertex Detector Development	H. Wieman	LBNL, BNL	133.3	336.5	495.0
Micropattern Readout Development for Gas Detetectors	N. Smirnov	Yale, BNL, LBNL	210.0	347.0	347.0
		Totals	758.1	1700.0	1692.0

STAR Future Physics and Planned Upgrades

The Scope & Scientific Merit of Proposed R&D / Upgrade Plan

System	R&D	Constr/Cost	Benefit to STAR
Inner μvtx	'03 → '05 $ 965K	' 06 → '07 $4M	D's , flavor- tagged jets
DAQ Upgrade	'03 → '05 $1.77M	' 06 → '08 $5M	1 kz → L3; D's; Ω & D, v2, cp, D thermalization
FEE Upgrade	'03 → '04 $250k	' 04 → '06 $2.5M	1 kz → L3; D's; Ω, D, v2, cp, D thermalization
Barrel MRPC TOF	' 03 → '04 $260k	' 04 → '05 $4.5M + $2.5M in- kind	4 vector information for all charged hadrons; extended p_T for resonances Ω v2; D's; ebe correlations; anti-nuclei
GEM DeV	' 03 → '05 $900k	'08 - '10 ?	Compact, fast TPC;robust tracking for high Q^2 physics at 40 x L

Addressing STAR's Future Needs

- **Future Physics / Upgrade Working Group (Vigdor, Majka Co-Chairs)**
- **Crystallize the central major physics questions that an upgraded STAR can address crisply over the next ten years, utilizing A-A, p-A and polarized p-p collisions**
- **Identify the STAR measurements most likely to lead to progress in answering the above questions, and the precision goals needed to provide qualitatively new information.**
- **Build on the work of the STAR Upgrades Steering Committee and the preparations for the December 2002 R&D review by the DAC, to develop the case that the proposed upgrades are essential determine the RHIC luminosity that will be needed**
- **Identify specific simulation studies needed to demonstrate the technical feasibility and interpretability of the proposed core measurements, and assemble a team to carry out these simulations.**
- **On the basis of continuing (past June 2003) discussions and simulations, define the physics-driven requirements that should be imposed on detailed designs for new STAR subsystems. Monitor progress on these designs, and on the R&D underlying them, to make sure these requirements will be met.**

Addressing STAR's Future Needs

New Detector Development and Oversight (Jim Thomas)

- oversight of progress on new detector developments once they begin construction after their R&D phase, until they are fully integrated, productive elements of the standard STAR detector system and DAQ stream.
- STAR Point of Contact for DOE and BNL
- Facilitator to insure steady progress and address needs (manpower, funding)

STAR Software and Computing

- STAR Software and Computing will face several major challenges in the coming months (years):
  - Very large data sets will take over a year to analyze with present resources
  - Implementation and quality assurance of new STAR Tracker (ITTF)
  - Quality assurance on DAQ 100 implementation
  - Preparing for "next generation" computing architectures (e.g GRID)
  - Re-staffing to address attrition at BNL and elsewhere (sofi, reco, calibration)

Preparation of the STAR Run IV Beam Use Request

The "ground rules: Run IV performance projections (T. Roser, July 7, 2003)

- 2 weeks required to cool down from 80 Kelvin to 4 Kelvin.
- Each mode projected to take 2 weeks of machine set-up to establish collisions and 3-weeks of machine development ("ramp-up") to reach "final" luminosity for the subsequent data taking period.
- During ramp-up period detector set-up can occur, but priority is given to machine development. No significant machine development will be scheduled during the data taking period.
- An example of how the expected 27 weeks of RHIC refrigerator operation during FY2003 would be scheduled for two RHIC operating modes:

Cool-Down: 4 weeks; Warm-up: 1 week

Set-up mode 1	2 weeks	Set-up mode 2	2 weeks
Ramp-up mode 1	3 weeks	Ramp-up mode 2	3 weeks
Data taking mode 1	7 weeks	Data taking mode 2	7 weeks

Projected Performance

Mode	# bunches	Ions/bunch [´10^9]	β*[m]	Emittance [mm]	L_{peak} [$cm^{-2}s^{-1}$]	L_{ave}(store) [$cm^{-2}s^{-1}$]	L_{ave} (week) [$week^{-1}$]
Au-Au	56	1	1	15-40	14×10^{2}	3×10^{26}	70 $(mb)^{-1}$
(p↑-p↑)	56	100	1	20	8×10^{30}	5×10^{30}	1.8 $(pb)^{-1}$
Si-Si	56	7	1	20	5×10^{28}	22×10^{28}	5 $(nb)^{-1}$

STAR Physics Working Group (and any other) beam use proposals due to Spokesperson July 15th

Draft Beam Use Request to STAR Collaboration by July 31

Decision at STAR Collaboration meeting August 11-16; proposal sent to Tom Kirk by August 29th.

Concerns

- A flat budget in FY04 ⇒
  - 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.
- A second year without real support for R&D will kill the "ongoing" detector developments; these will have to be re-started in the future. This could have <u>very</u> serious consequences for the future RHIC program
- Adequate computing resources and progress to "keep up"
- Strategic optimization of use of resources to "run the program"
- Finding career positions for those people ready to "take the next step"
- Visa's Issues -- in many cases these have prevented individuals from carrying out planned activities (LVL III, TOF, PMD, EEMC, EMC)
- Maintaining momentum and steady progress towards the future

The STAR Experiment

Conclusions

- Overall, the STAR (RHIC) scientific program has thus far been an *outstanding success,* meeting every challenge and delivering exciting, important new scientific results
- To continue to be successful, in a future view where resources will be very tight, it is necessary to arrive at a strategic optimization of the use of resources across the program, taking into account the needs, e.g. of research (at BNL and other STAR (RHIC) institutions), beam time, operations, and future development of the program
- The “RHIC story” has just begun. If the first 3 years are any indication, there is a lot of exciting science to look forward to.

The STAR Experiment

Backup Slides

EEMC Status

1) Installed and successfully commissioned for 2003 run:

- lower half mechanical structure
- 4 30-degree sectors of active elements
- tower readout for 4 sectors
- rudimentary slow controls
- EEMC contribution to Level 0 trigger
- stand-alone DAQ for testing independent of STAR, as well as integration into STAR DAQ
- software for analyzing tracked MIP's, tracked electrons, and pi0's for EEMC calibration purposes

2) Installation goals for summer 2003 shutdown:

- upper half mechanical structure
- all 12 30-degree sectors of active elements, including towers, SMD, preshower and postshower layers and readout fibers
- complete tower readout of 12 sectors
- multi-anode PMT readout and state-of-the-art FEE for 5 sectors of SMD, preshower and postshower.

EEMC Status

3) Committed funding from NSF, IUCF, IU and STAR capital equipment ($60K) now extends a total of ~$600K beyond the original projected construction cost, and will allow completion of: 8 full sectors of MAPMT readout (configurable as 8 sectors of SMD only, or as 6 sectors of SMD plus preshower plus postshower); small spare capacity for megatiles, PMT and MAPMT boxes and readout channels.

4) Additional funding needed to complete 12 full sectors of MAPMT readout for SMD, preshower and postshower is $500K (for tubes, FEE, boxes, etc.). There are ongoing discussions with possible sources of such funds. The detector will be ready to add this readout when and if it becomes available. With suitable funding timelines, it could be added during the 2004 shutdown.