The RHIC Beam Energy Scan Program (BES)

5th Polish Workshop on Relativistic Heavy-Ion Collisions SHIN(E)ing Physics

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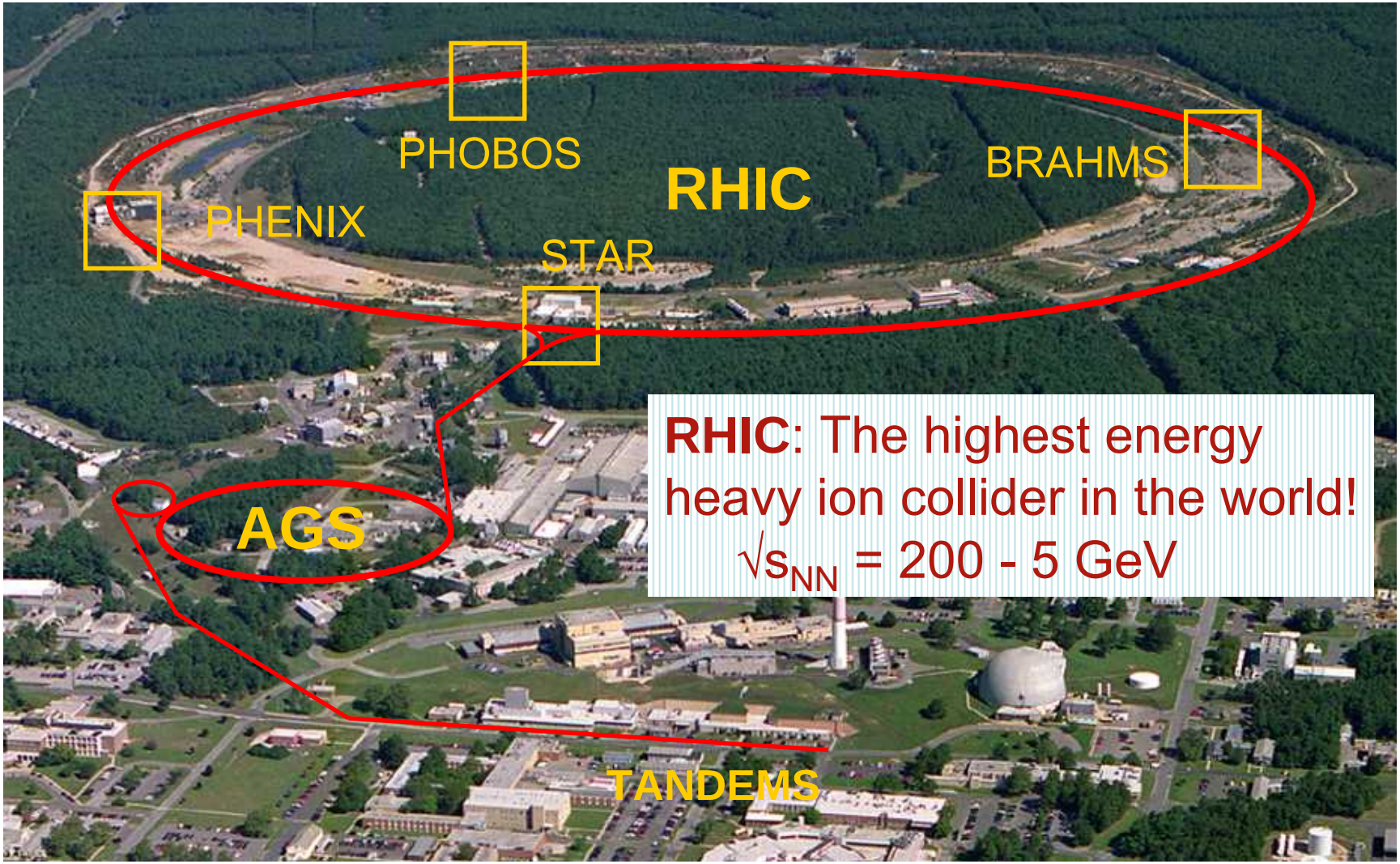
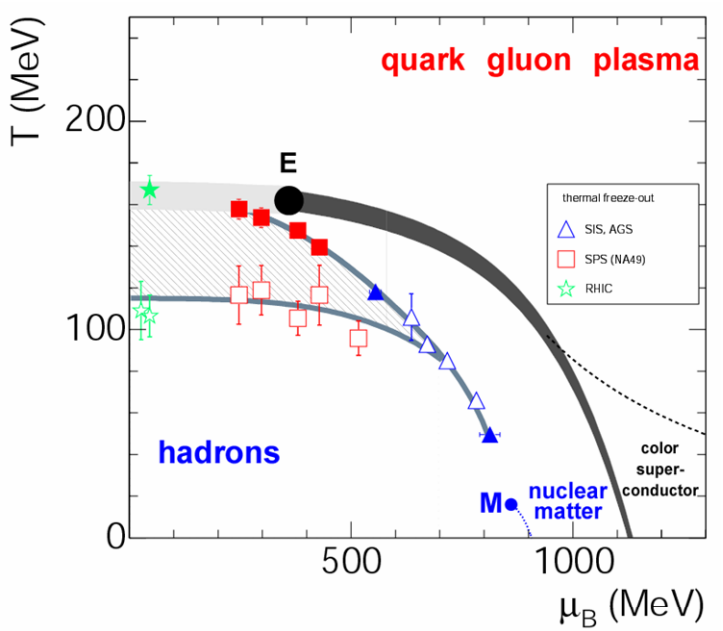
RHIC at Brookhaven Natlional Laboratory



RHIC beam energy scan

experimental knowledge of freeze-out conditions

hydro predicts that evolution of the system is attracted to critical point



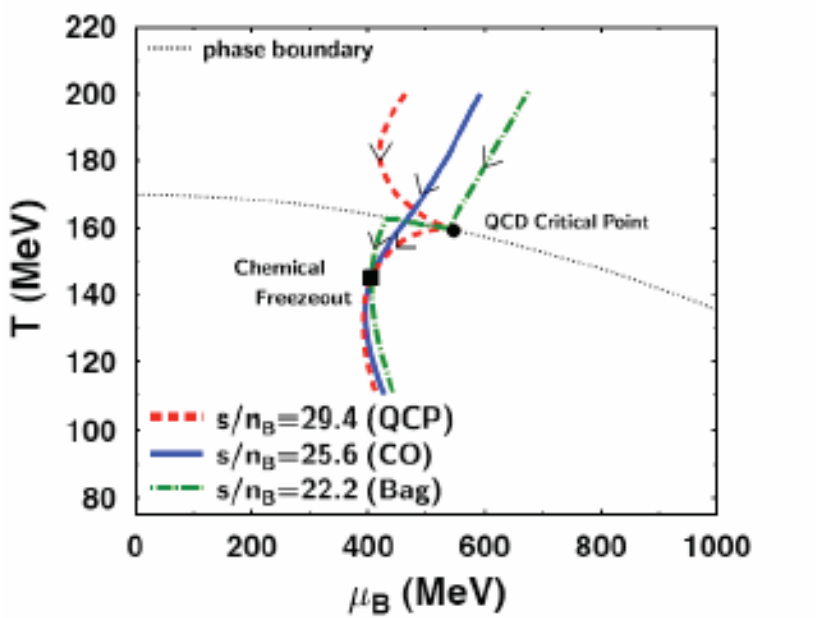


Image courtesy of M.Asakawa

RHIC low energy program:

- search for signals of 1st order transition and CP at low energies
  strategy: vary energy, centrality of Au+Au collisions to scan T,μ_B
- study onset of parton energy loss (opacity) at intermediate energies

RHIC at low energies

injection below standard energy, coasting and colliding beams

2001: collisions at 19.6 GeV Au+Au (standard injection energy)

2008: collisions at 9.2 GeV Au+Au and test at 5.0 GeV

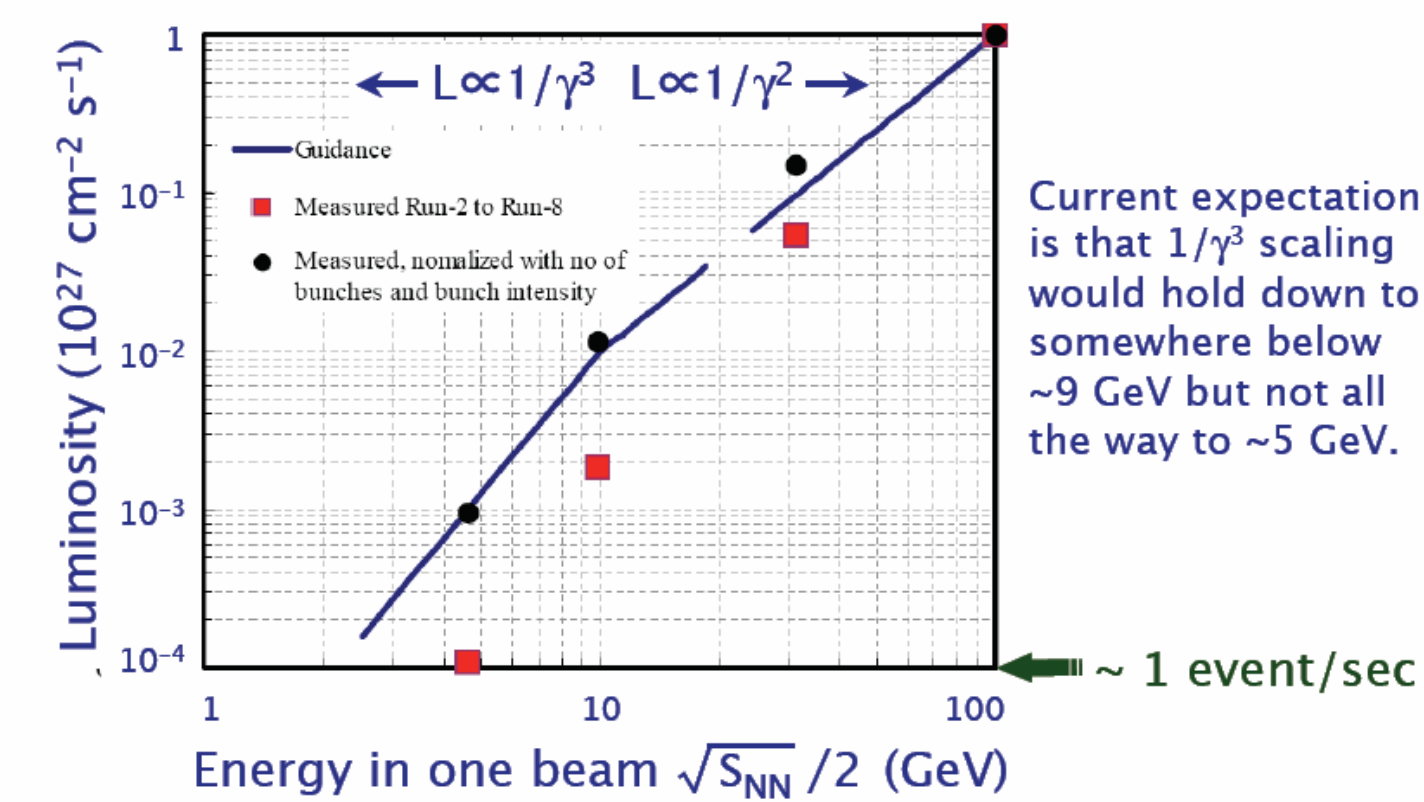
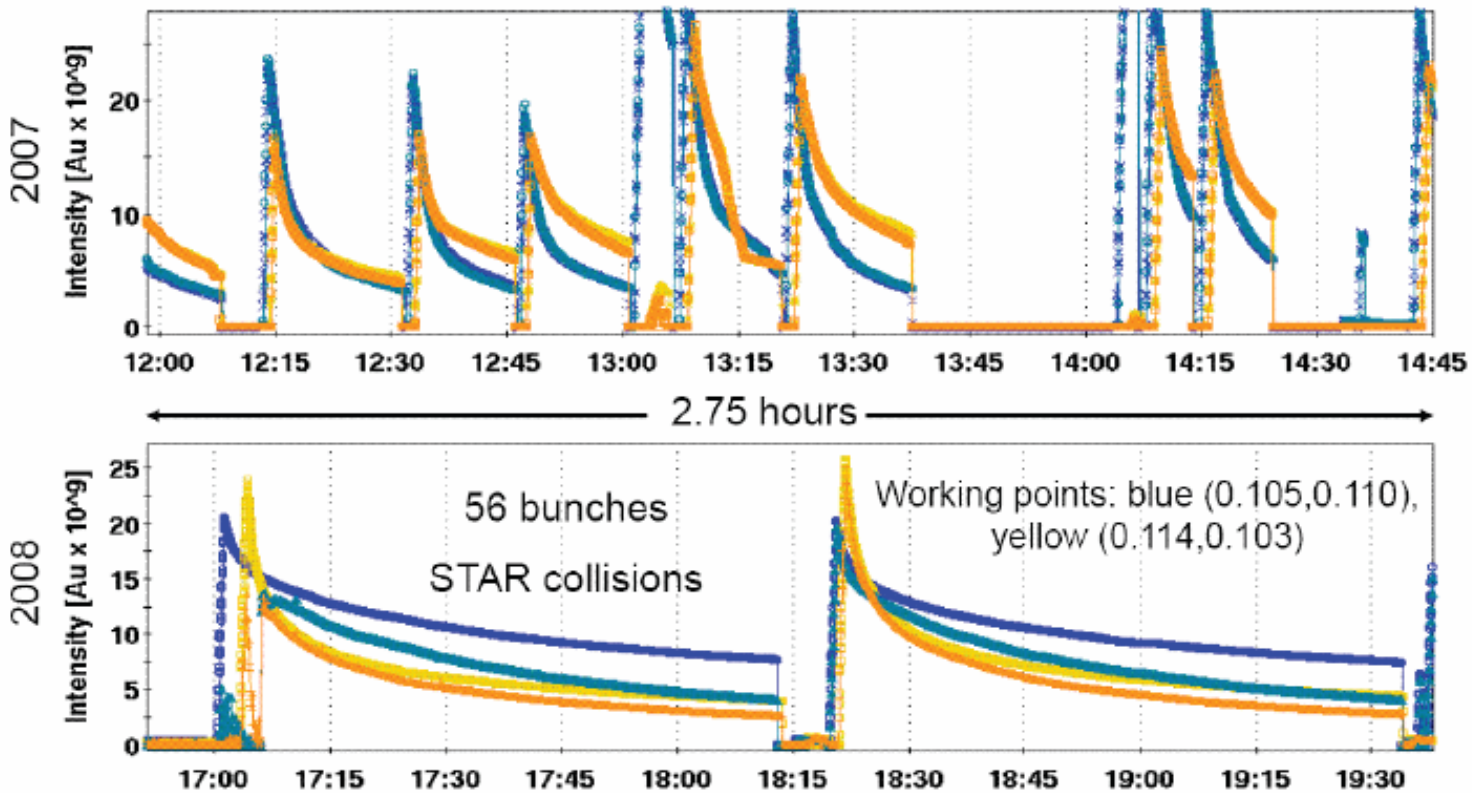


Image courtesy of T. Roser

Au-Au operation in RHIC @ $\sqrt{s_{NN}}$=9 GeV

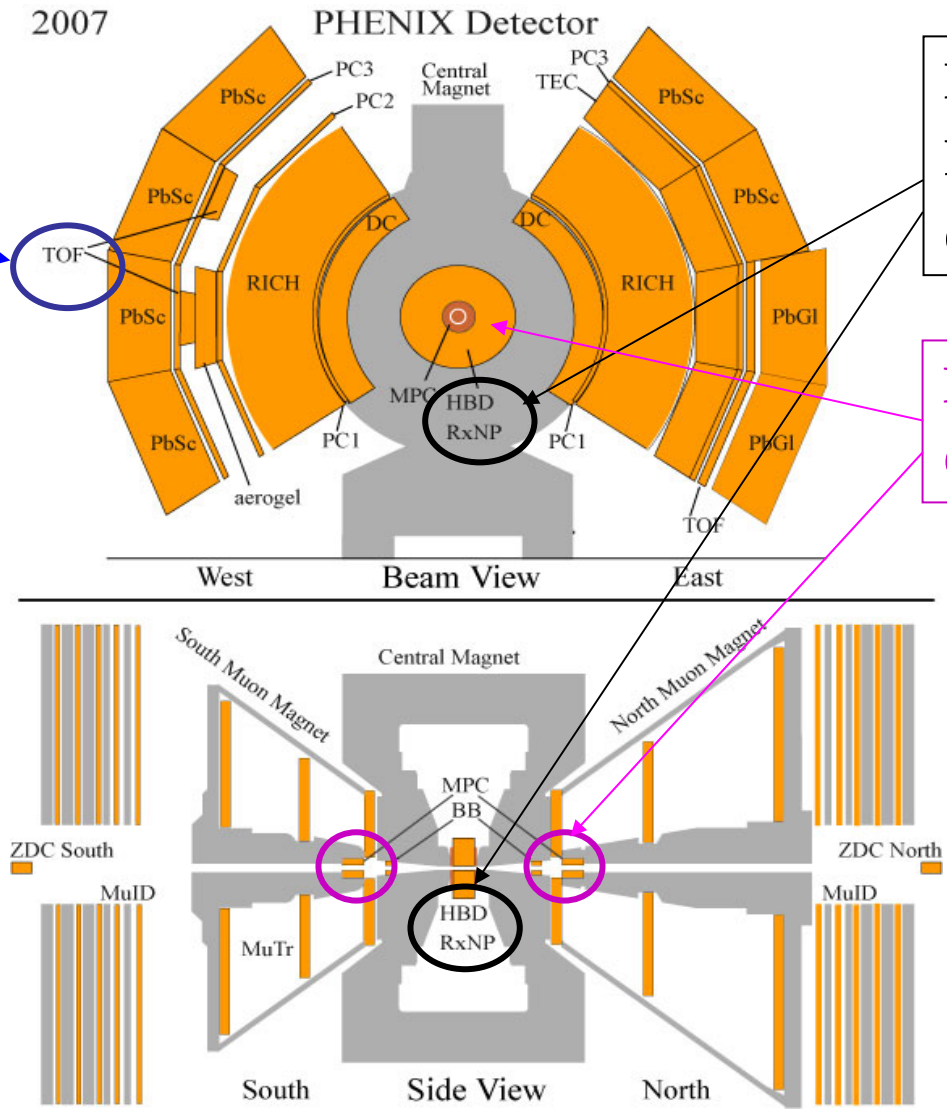


- 2008 blue beam lifetime: 3.5 minutes (fast), 50 minutes (slow)
- Sextupole reversal and elimination of octupoles clearly helped beam lifetime
- Injection efficiency and yellow beam lifetime can clearly benefit from further tuning

Image courtesy of T.Satogata

PHENIX experiment

TOF-W (PID)



Hadron Blind, Reaction Plane detectors

Muon Piston Calorimeter (N & S)

Good PID
Fast

Small acceptance

PHENIX plans

Summary

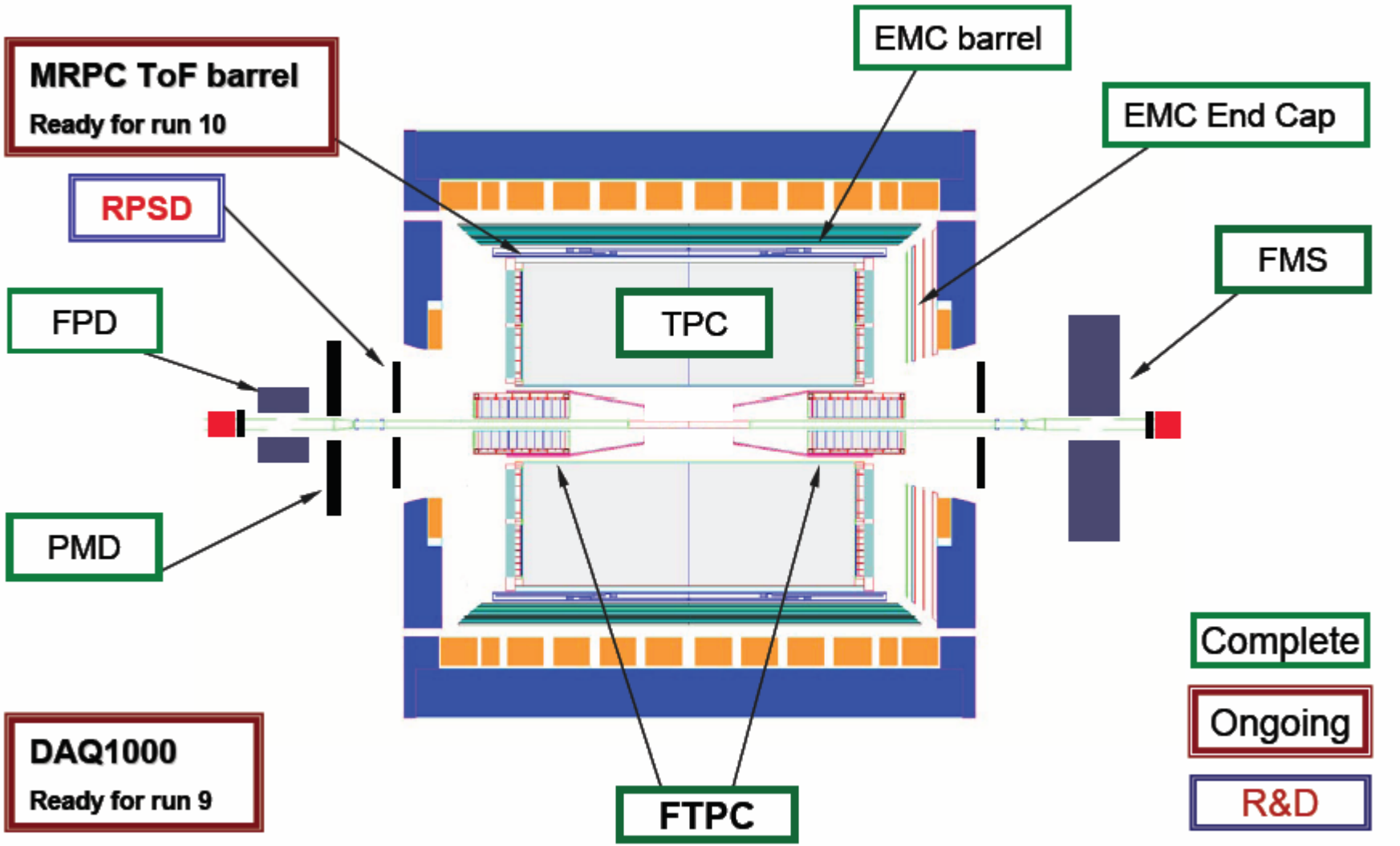
For $20 \le \sqrt{s_{NN}} \le 100$ GeV RHIC can make an immediate and unique contribution to:

- The low-μ_B end of the critical point search
- Quantification of the onset of light-quark and heavy-quark opacities.
- Quantification of the onset of QNO scaling
- Constraining the Hadronic EOS

This is achievable within realistic running periods of ~ 20-25 weeks:

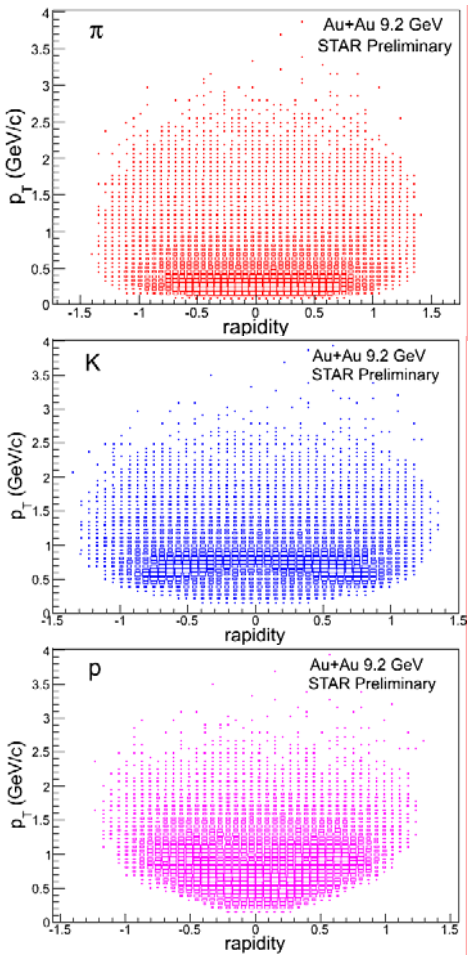
Roy A. Lacey, Stony Brook; INT Workshop on the QCD Critical Point, July 28 - Aug. 22, 2008

STAR detector (2010)

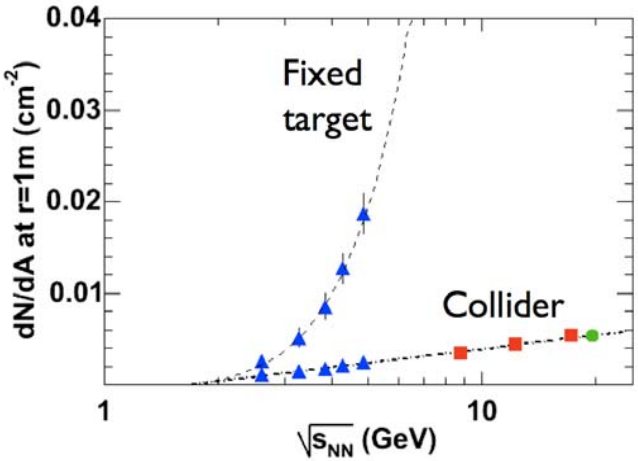


advantage of STAR and collider geometry

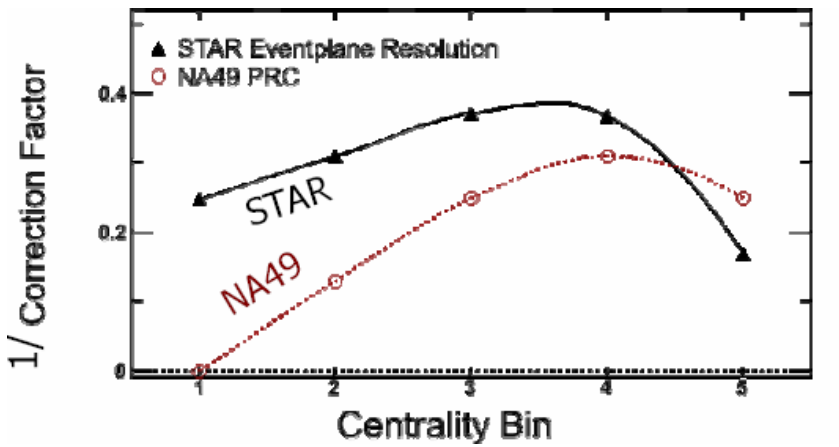
uniform, energy independent
large acceptance



modest increase of track
density with energy at collider

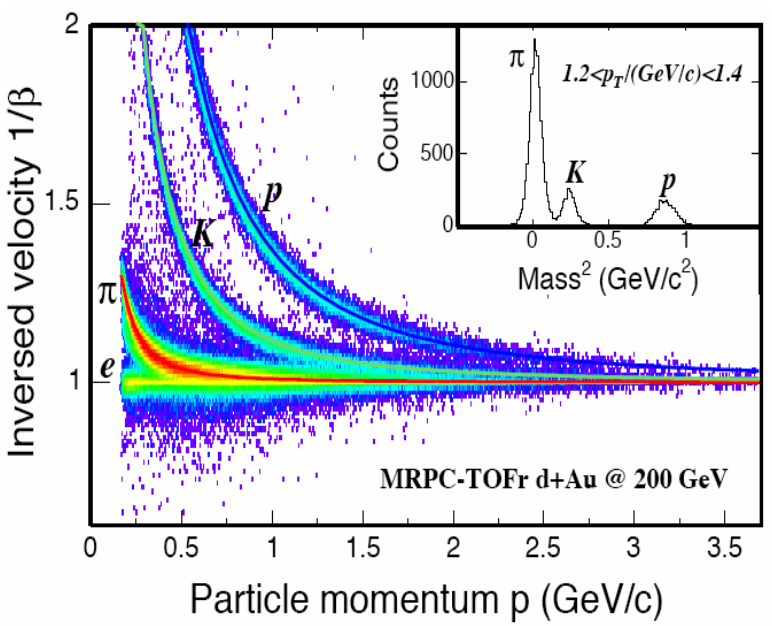


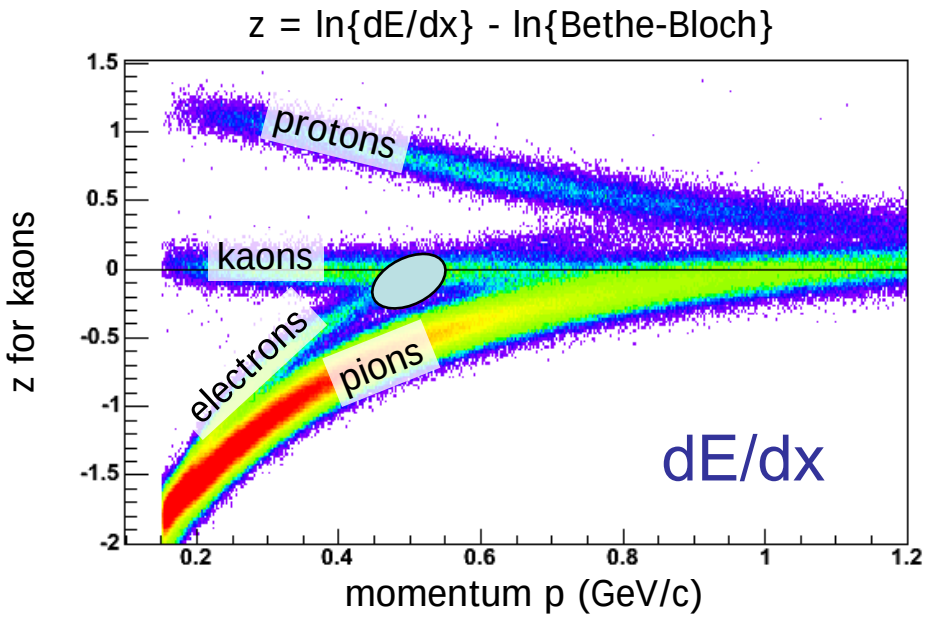
much better event plane resolution



Particle identification

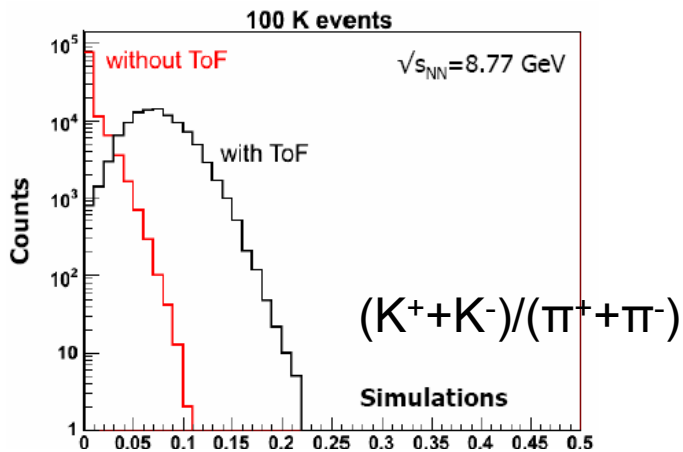
TOF



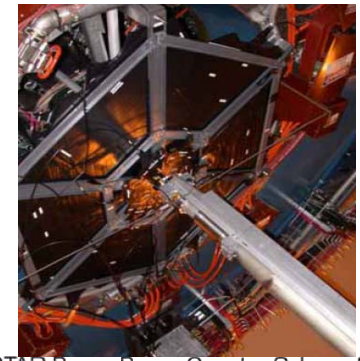


- TOF: π,K up to 1.6 GeV/c, p to 3 GeV/c
- dE/dx only: π,K below 0.6 GeV/c

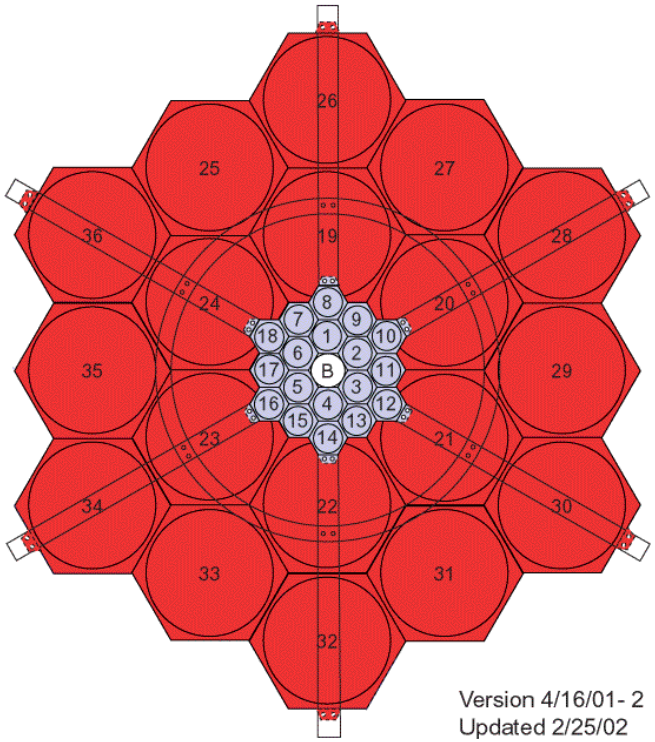
combined TOF+dE/dx essential for precise fluctuation measurements



Triggering using BBCs



STAR Beam-Beam Counter Schematic
Front View



Version 4/16/01- 2
Updated 2/25/02

Studies indicate BBCs can be used for triggering during BES

Multiplicity larger than that for p+p

	AuAu @ 5 GeV		AuAu @ 8.75 GeV	
impact parameter	BBC Inner	BBC Outer	BBC Inner	BBC Outer
0<b<3	5	27	12	54
3<b<6	11	30	21	57
6<b<9	22	35	39	40
b>9	44	30	66	8

BBC is sensitive down to single MIP hitting the detector

→ Triggering is not a problem

Precise determination of participants may be problematic

STAR plans: search for QCD critical point

Au+Au collisions

STAR Beam User Request FY10

E_{lab}	$\sqrt{s_{NN}}$ [GeV]	μ_B [MeV]	Rate [Hz]	Goal [Events]	Duration [Days]
13	5.0	550	0.5		7
20	6.1	491	1.4	1M	20
30	7.7	410	2.7	2M	20
40	8.6	385	4	2M	15
80	12.3	300	10	5M	15
158	17.3	229	25	10M	12
400	27	151	30	10M	7
800	39	112	50	10M	6

Key measurements:

(1) All PID hadron spectra and v_2

(2) K/π, $\langle p_T \rangle$ … fluctuations

(3) Correlations of baryons (kurtosis of N_p-N_{pbar} mult.distribution)

better precision and sensitivity to CP than NA49

BNL PAC recommendations (May 8 – 9, 2008)

Run 09-10:

1. Longitudinally polarized proton-proton collisions at $\sqrt{s}$ = 200 GeV with 60% average polarization for 10-12 weeks, sufficient to record an integrated luminosity of about 25 pb^{-1} in PHENIX and about 50 pb^{-1} in STAR.

2. High luminosity Au+Au collisions at $\sqrt{s}$ = 200 GeV for 8-10 weeks, corresponding to an integrated luminosity of 1.2-1.4 nb^{-1} in PHENIX, to exploit the capabilities of its Hadron Blind Detector (HBD). This will allow both a high precision measurement of the low mass di-lepton spectrum in PHENIX and STAR, and development of transverse stochastic cooling of the Au beams. In addition, it will enable STAR to exploit its new DAQ capability in a high statistics run.

3. Longitudinally polarized proton-proton collisions at $\sqrt{s}$ = 500 GeV for 5 weeks to allow beam development and commissioning by C-AD, a first measurement of W boson production in PHENIX, and background studies in STAR.

Run 11-13:

2.2.3. Heavy ion collisions at lower energies

There are multiple compelling motivations for running RHIC at lower energies. The search for the QCD critical point is a "must do" experiment. Beyond this specific search, the collision energy dependence of various signature characteristics such as quasi-ideal hydrodynamic flow and jet-quenching should be determined. To date, however, the PAC has not seen a compelling presentation of the key observables and their potential physics impact for this measurement program.

In the view of the PAC, the experiments must define a strategic approach to the energy scan program, with a first exploratory run of order 8-10 weeks that will indicate whether and how to further explore this region with additional running in later years. For both experiments, the essential set of energies and the details of the physics implications (beyond projected statistical uncertainties) from different data sets need to be developed. This will require input from the theory community. The upcoming INT workshop provides a timely opportunity for the experimental and theoretical communities to work together toward this goal. This input is required to determine the future run duration, energy range, and number of energy points as correlated with physics potential (both for discovery and for further quantification).

Two Step Approach

$\sqrt{s_{NN}}$ (GeV)	PHENIX	STAR	
62.4	✓		
39	✓	✓	
28	✓	✓	
22.4*	✓		future
17.3		✓	
12.3		✓	
8.6		✓	
7.7		✓	
6.1		✓	
5.0		✓	

Step I: First RHIC energy scan: FY10, 8-10 weeks.
4 weeks above the injection energy and 5-6 week below.

Two Step Approach

Step I:

First RHIC Energy Scan: FY10, 8-10 weeks.
4 weeks above the injection energy and 5-6 week below.

Strategy: (a) disappearance of sQGP signal
(b) appearance of critical behavior

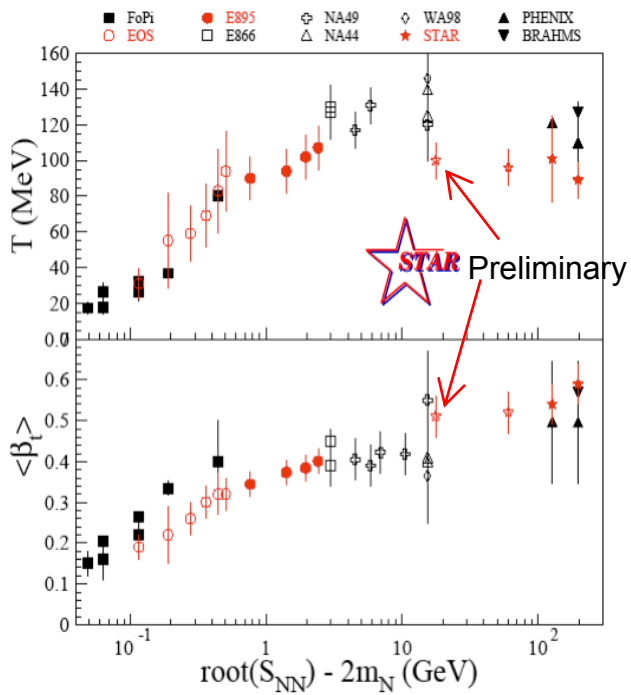
Step II: FY12 (or later)

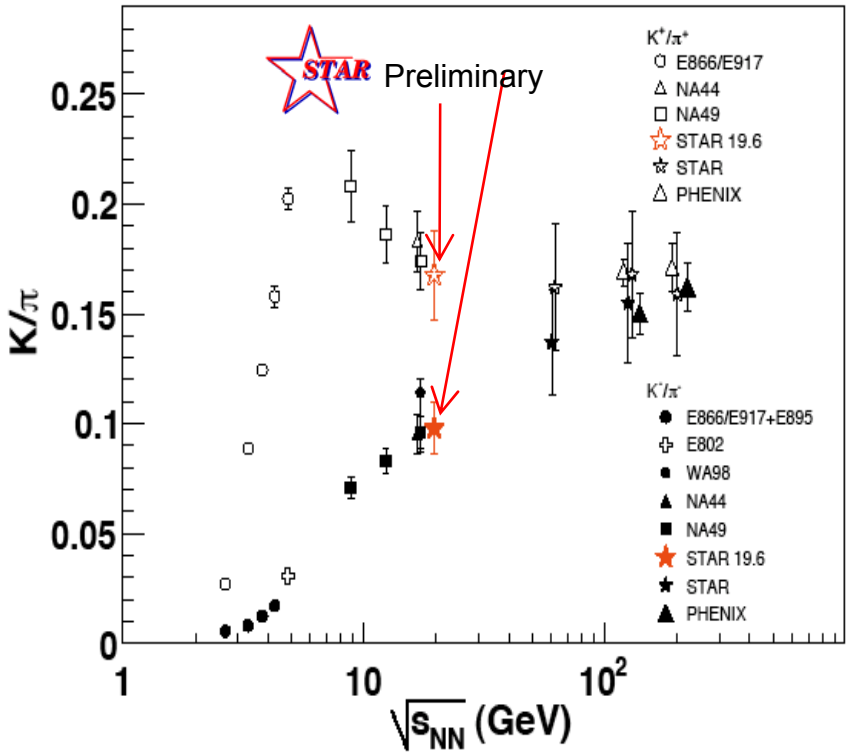
Strategy: Focus on the region where the (a) and (b) cross each other.

first STAR experience with Low Energy in 2001

19.6 GeV Au+Au

D. Cebra QM2008





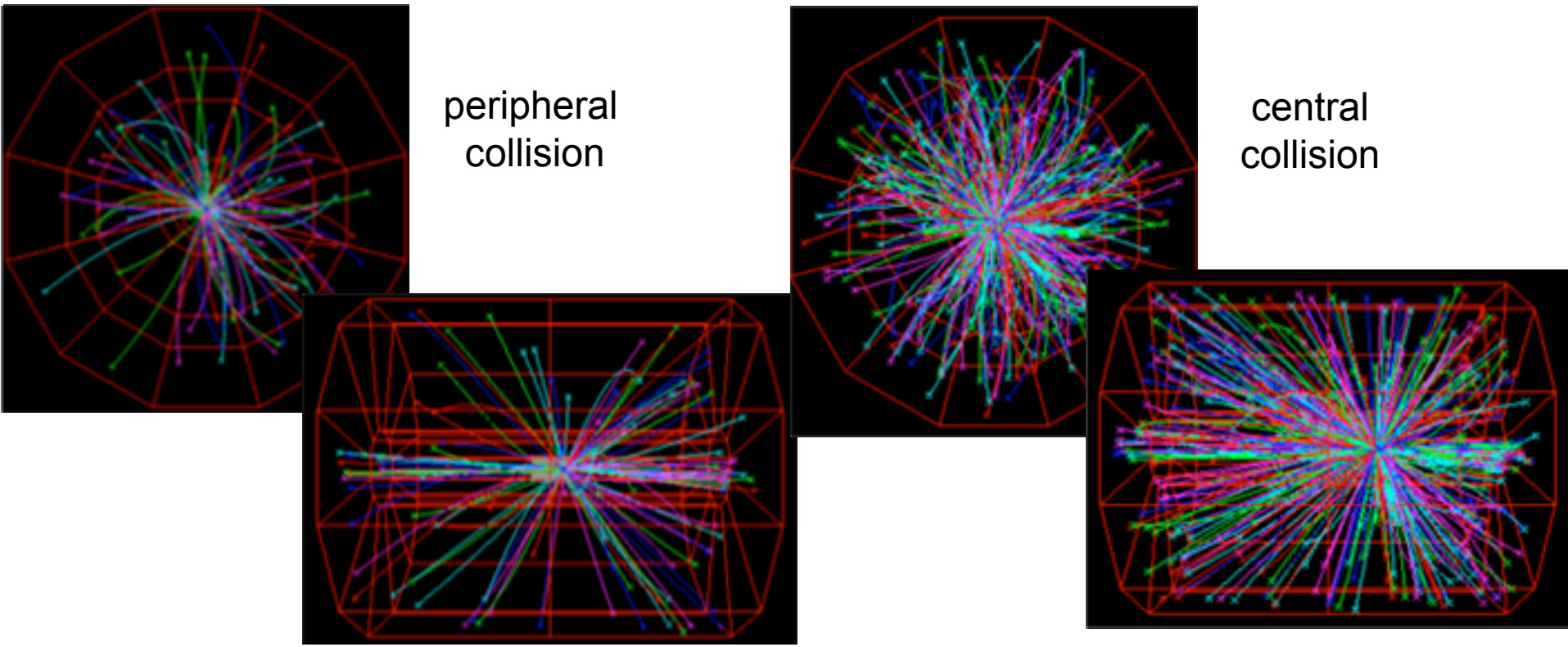
E802 PRL81, 2650 (1998)
E866 PLB476, 1 (2000)
E917 PLB490, 53 (2000)
NA44 PLB471, 6 (1999)
WA98 PRC67, 104906 (2003)
NA49 PRC66, 054902 (2002)
NA49 EPJC33, S621 (2004)
NA49 arXiv:0710.0118v2
PHENIX PRC69, 034909 (2004)
PHENIX PRL88, 242301 (2002)
STAR PRL92, 112301 (2003)
STAR PLB595, 143 (2004)

Sufficient data to extract ratios, flow velocity, HBT radii, v_2

Data fit into systematics

2008: low energy run with 9.2 GeV Au+Au

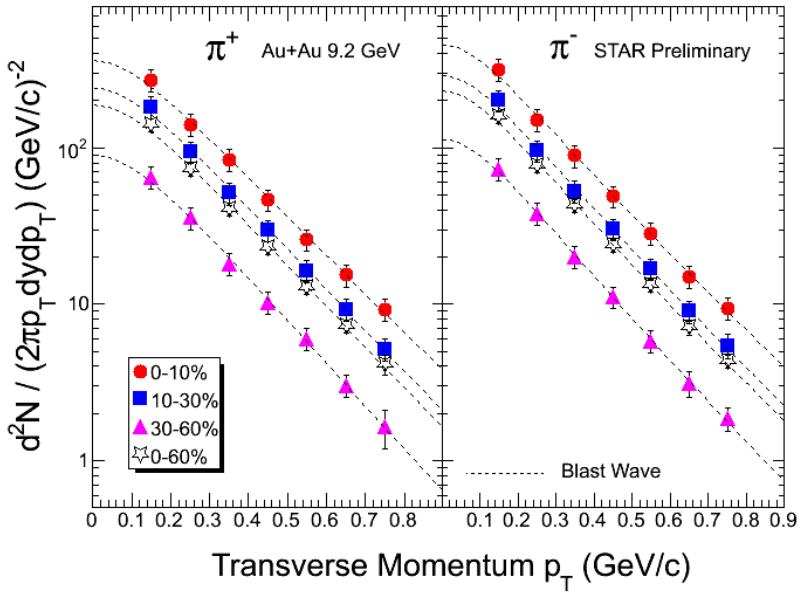
Injecting and colliding Au+Au $\sqrt{s_{NN}}$ = 9.2 GeV, a few hours -> 4K good events !

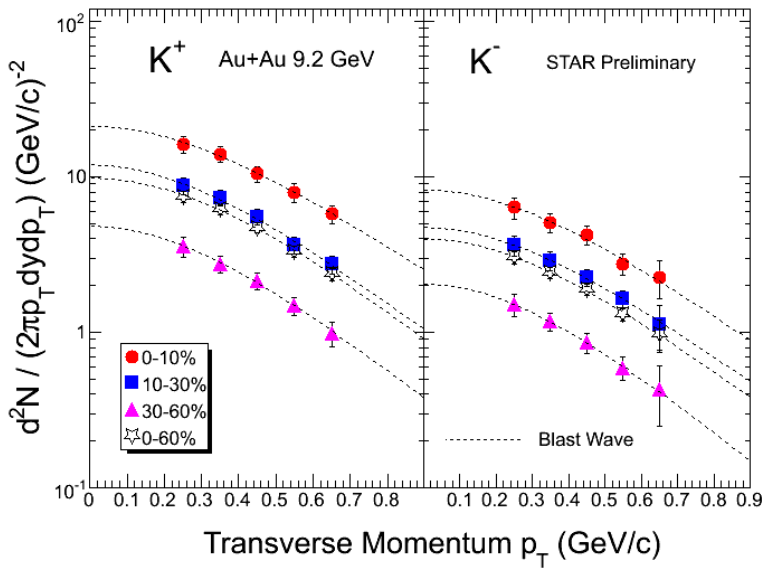


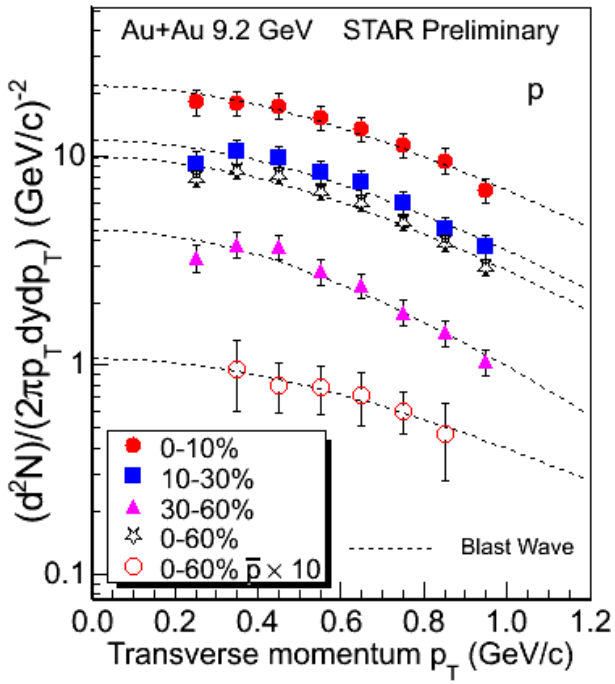
Short test @ $\sqrt{s_{NN}}$ = 5 GeV allowed study of beam optics

Identified hadron spectra at mid-rapidity

(4k events)



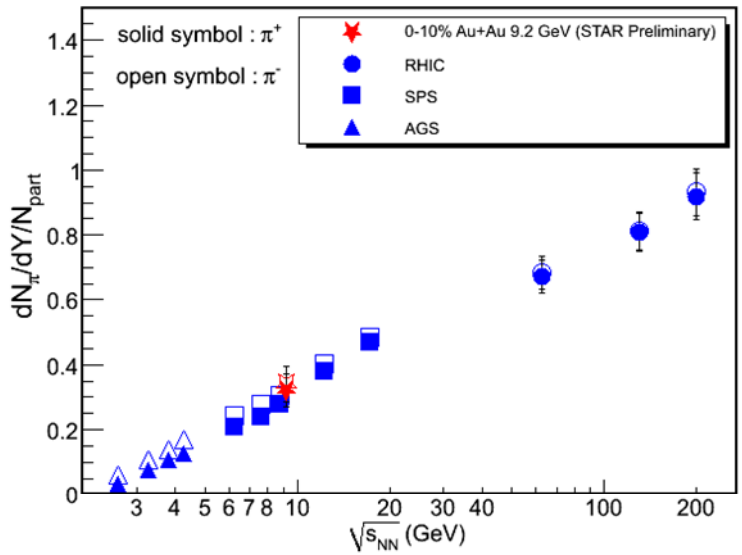


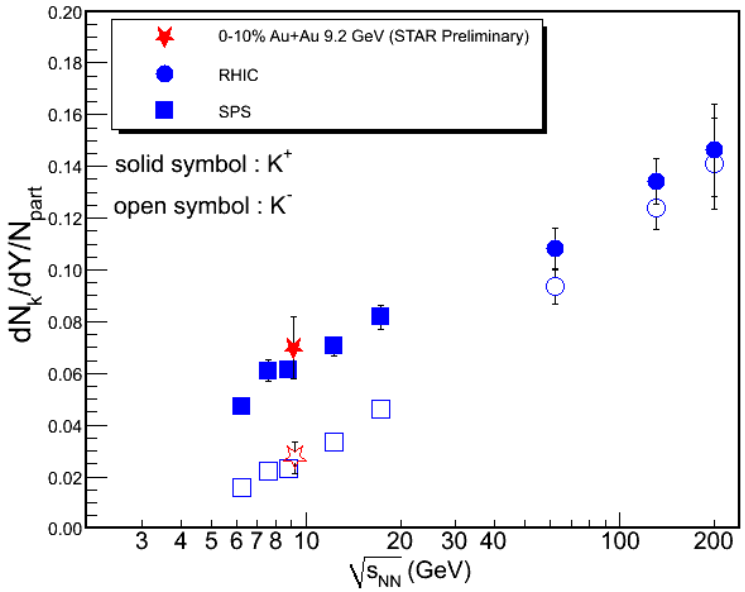


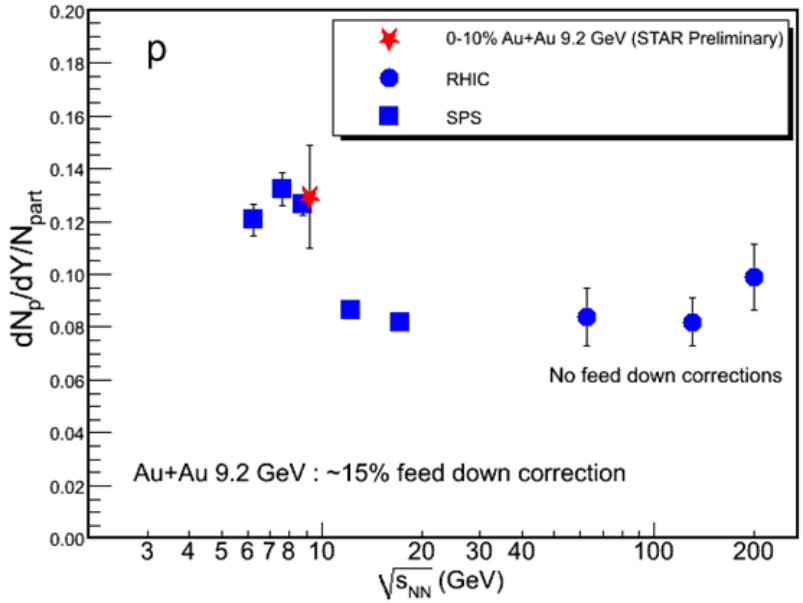
slope of the spectra follows
$p < K < \pi$

Yield and Slope – at mid-rapidity

(4k events)



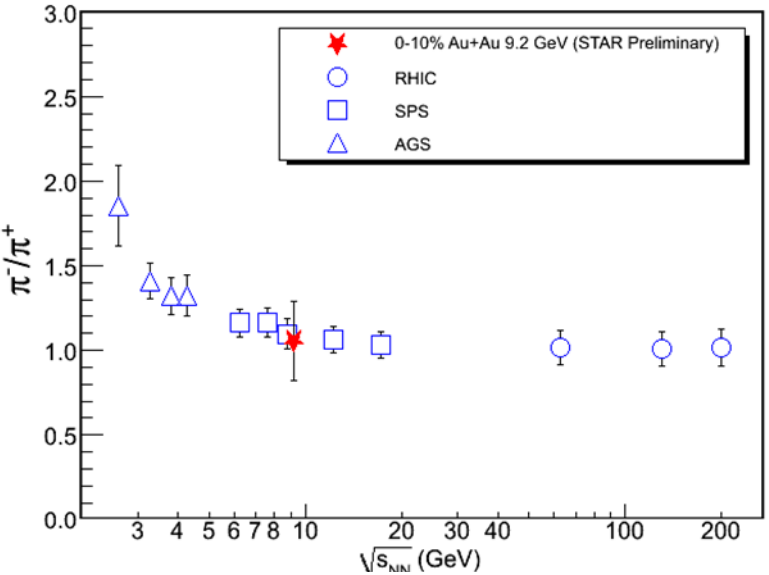


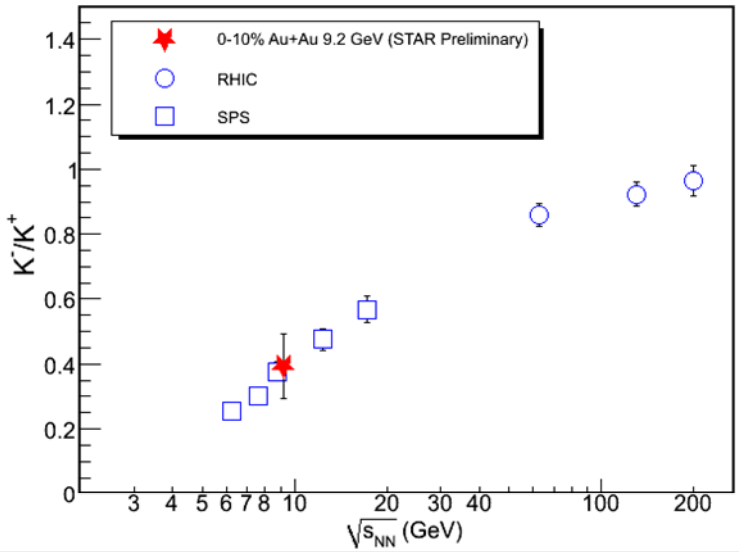


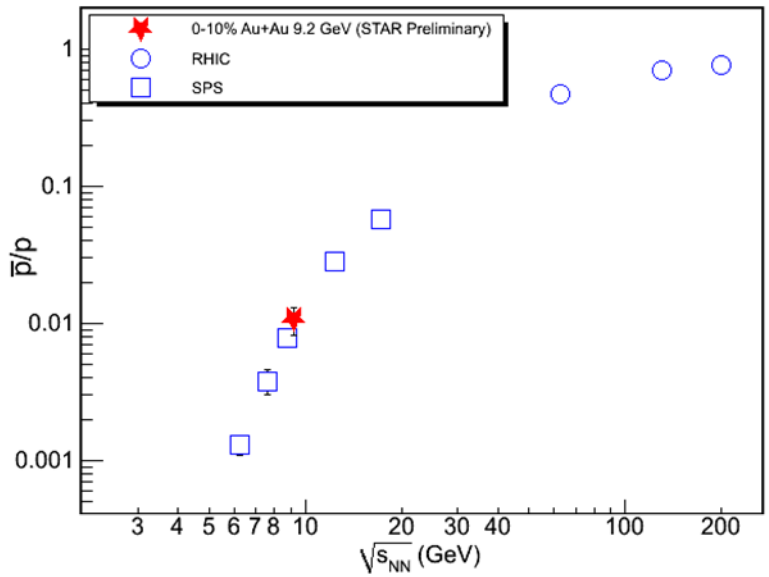
yields and slopes consistent with the published data at similar energy

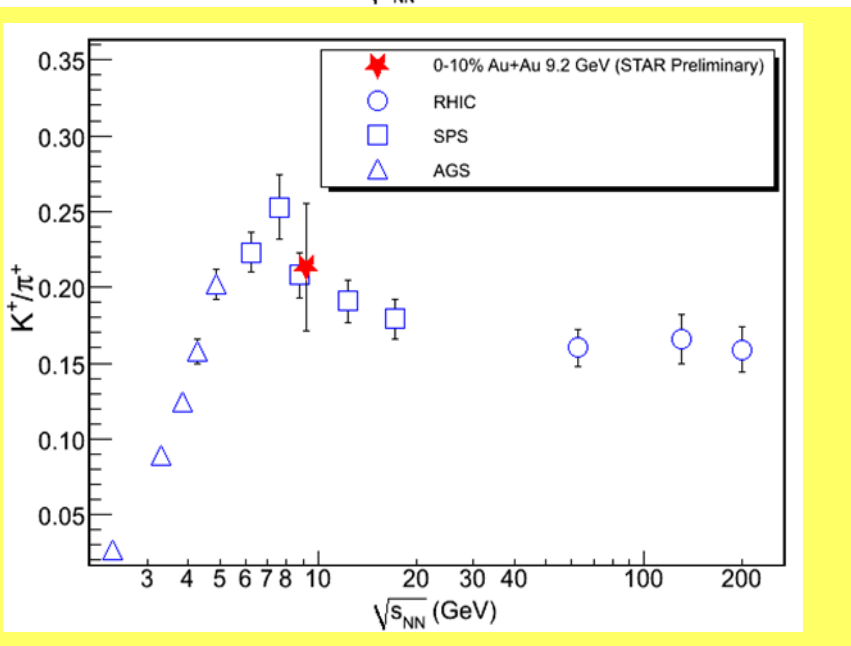
L.Kumar/STAR SQM2008

ratios at mid-rapidity (4k events)





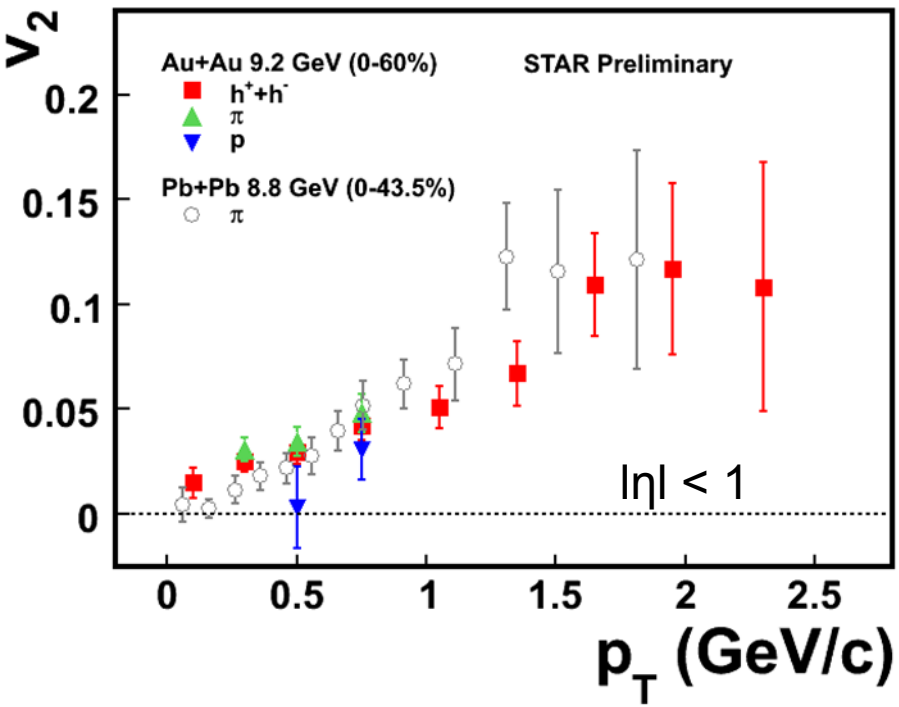




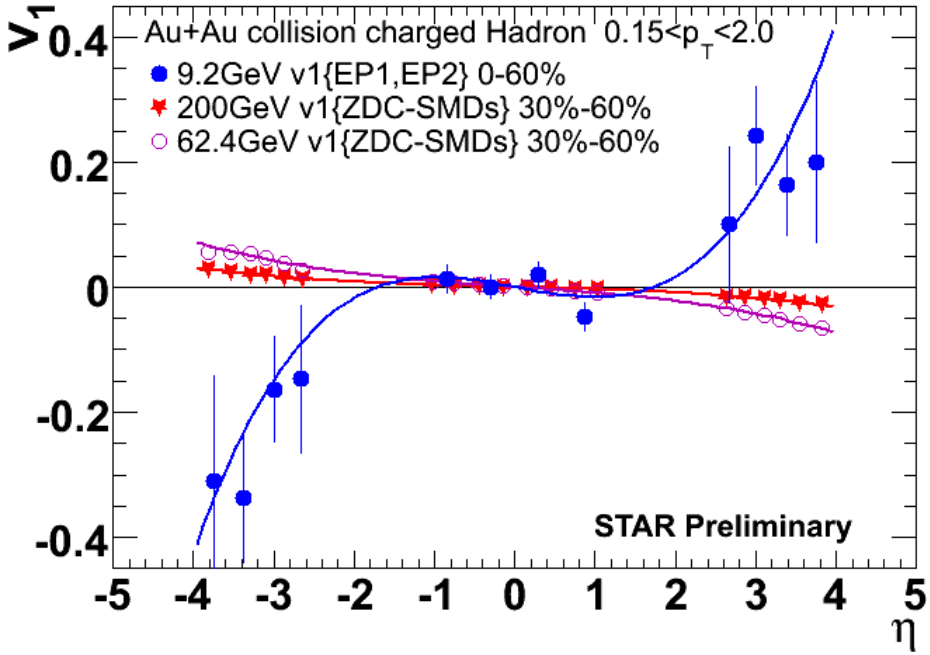
Azimuthal Anisotropy

(4k events)

elliptic flow



directed flow



Summary

- STAR is strongly interested in the low-energy search for the critical point of QCD
- PHENIX data taking at lower energies may be hindered by detector limitations
- PAC recognizes importance but needs more convincing on signatures
- envisaged start of data taking in 2010 subject to favorable PAC decision in summer 2009

- successful test runs of RHIC and STAR at $\sqrt{s_{NN}}$= 19.6 and 9.0 GeV
- significant physics results were obtained in spite of small statistics
- agreement with SPS NA49 fixed target results
- the MPRC TOF system (last required STAR upgrade) will be completed by May 2009 (75% already installed)

- let us hope that the present economic troubles will not derail this exciting program on both sides of the Atlantic