STAR Physics Program at RHIC

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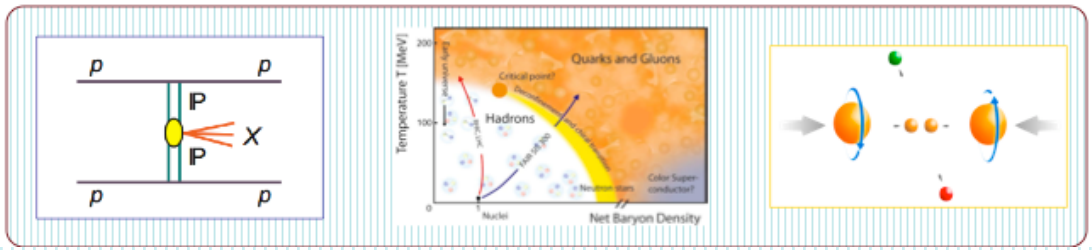
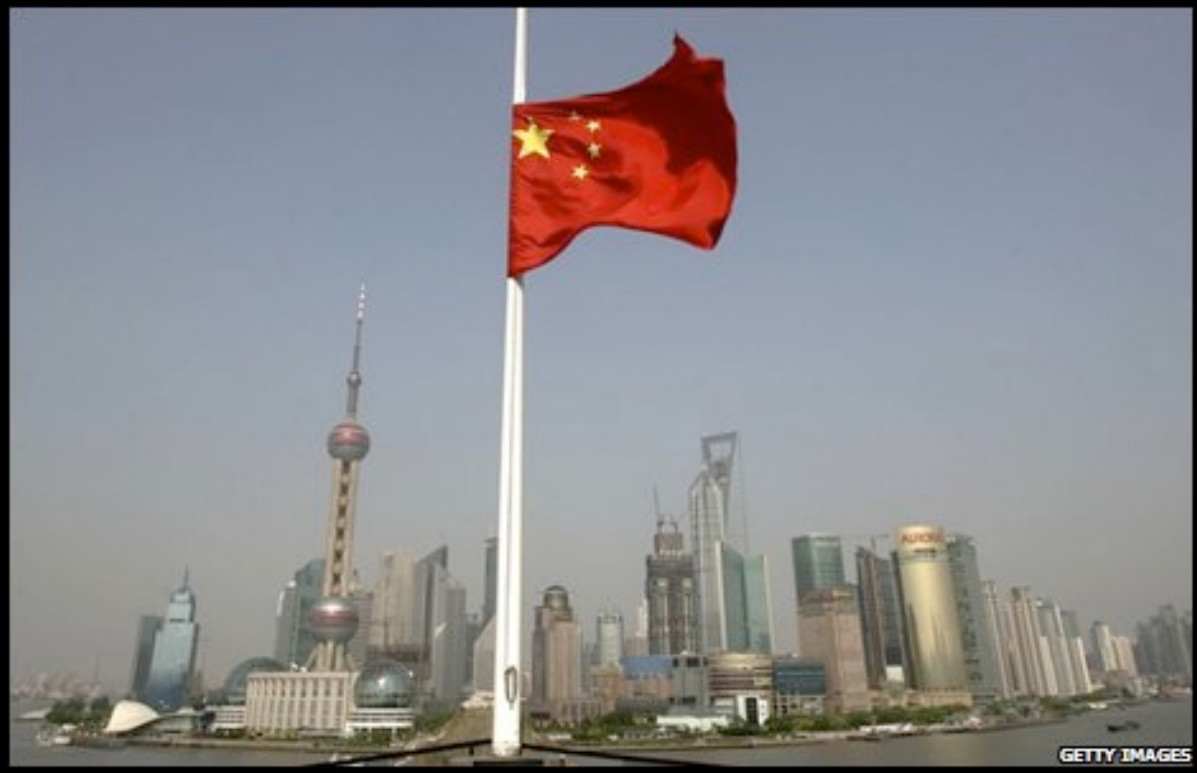


May 22, 2008
Death toll: 41353
Missing: 32666



A new China is emerging

Outline

1) Introduction

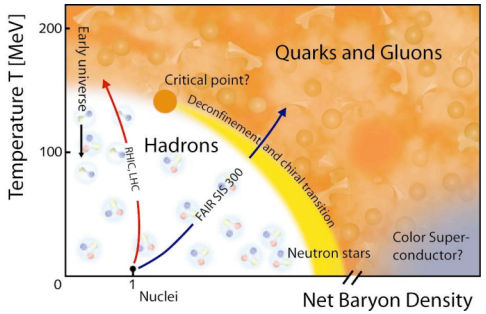
2) STAR Detectors

3) STAR Physics Results

   - *high-energy nuclear collisions*

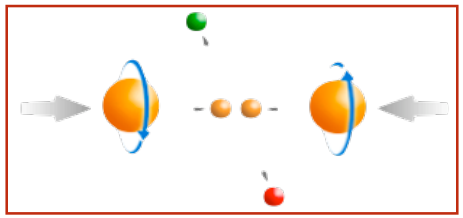
4) Summary

STAR Physics Focus at the QCD Lab



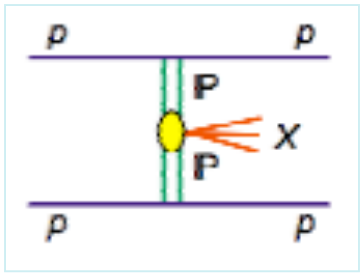
1) Heavy-ion program
   - Study ***medium properties, EoS***
   - pQCD in hot and dense medium

2) RHIC beam energy scan
   - Search for ***critical point***
   - Chiral symmetry restoration

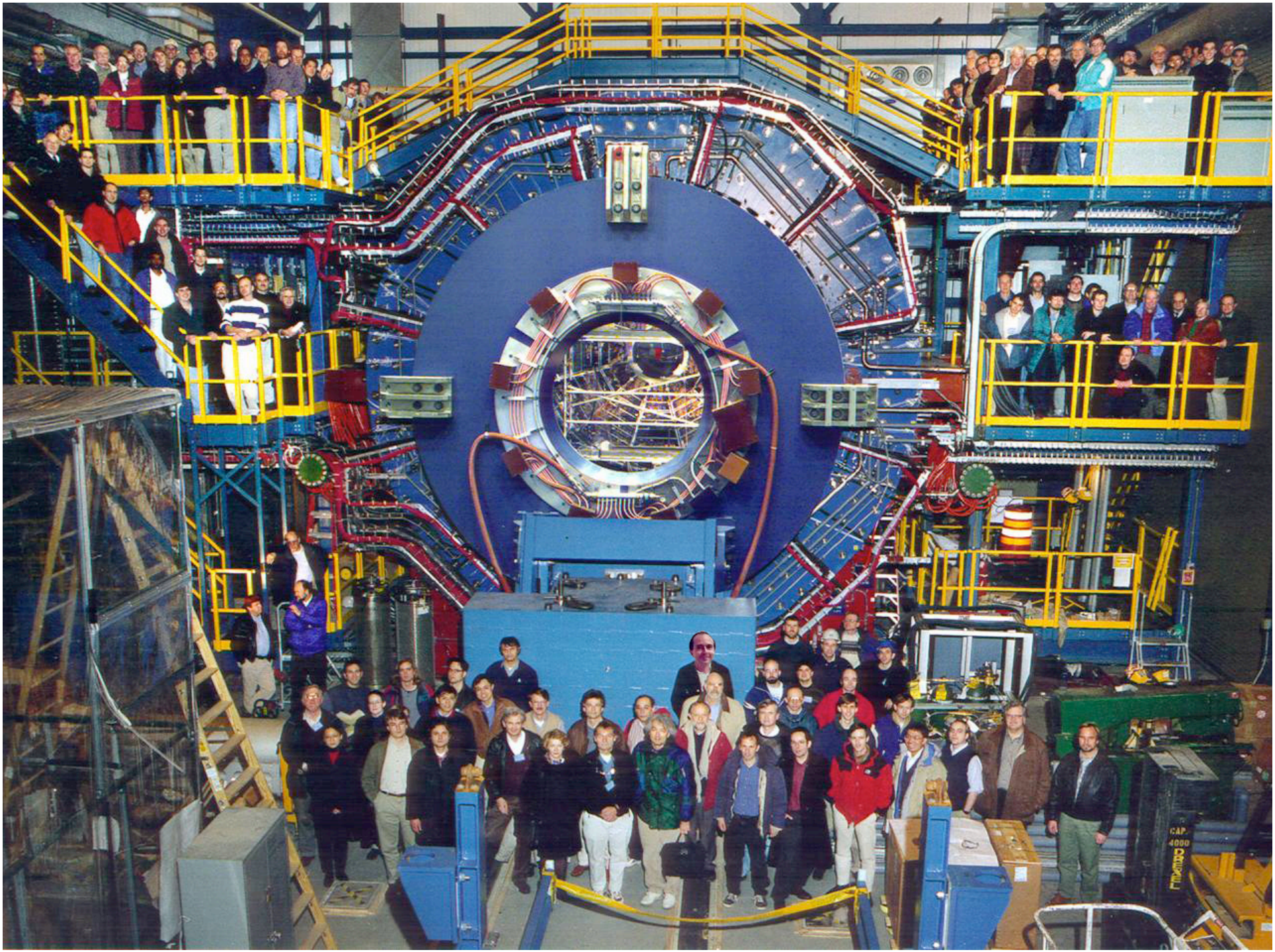


1) Longitudinal and transverse spin programs
   - Study ***proton intrinsic properties***

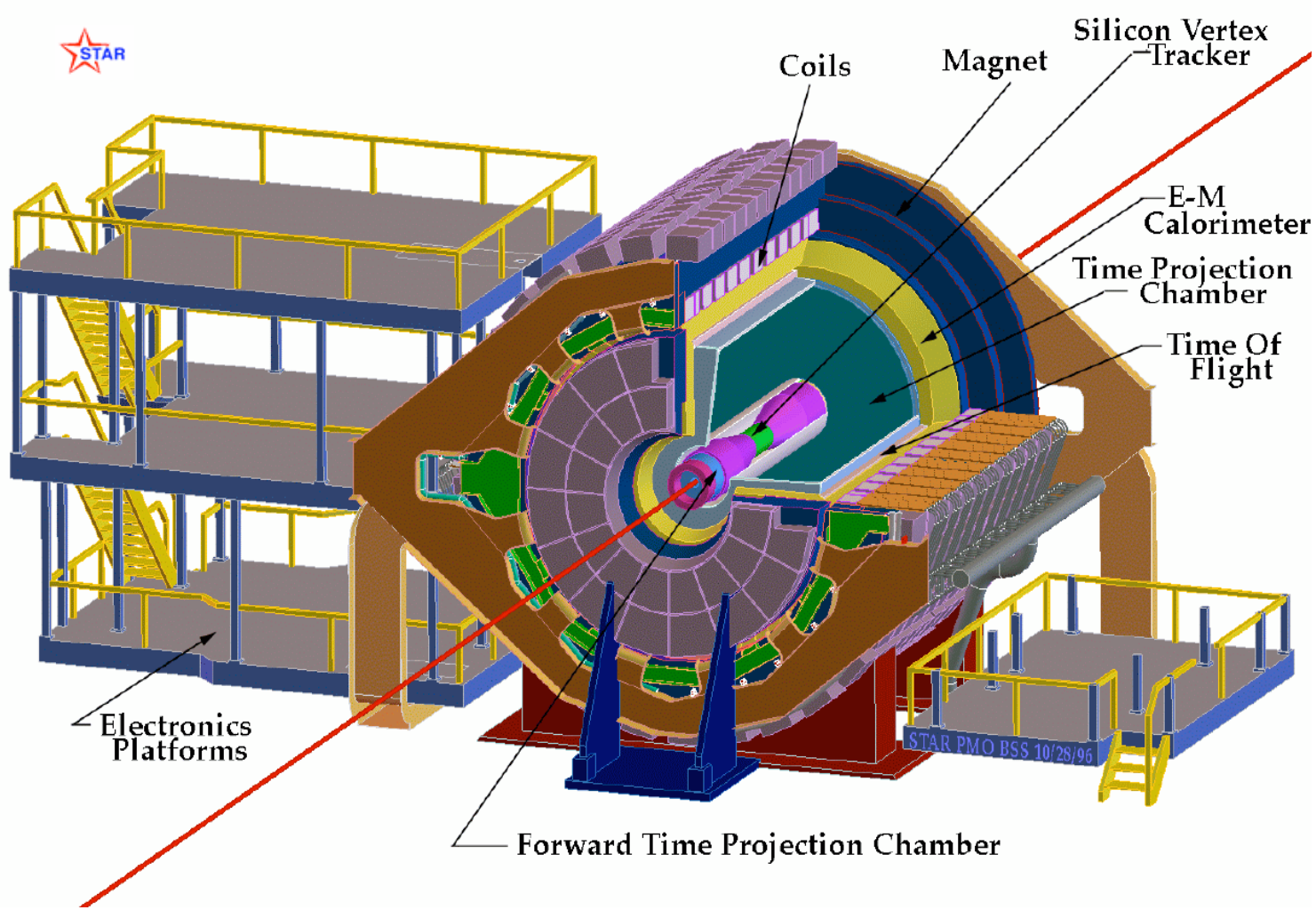
2) Forward programs
   - Study low-x properties and search for ***CGC***



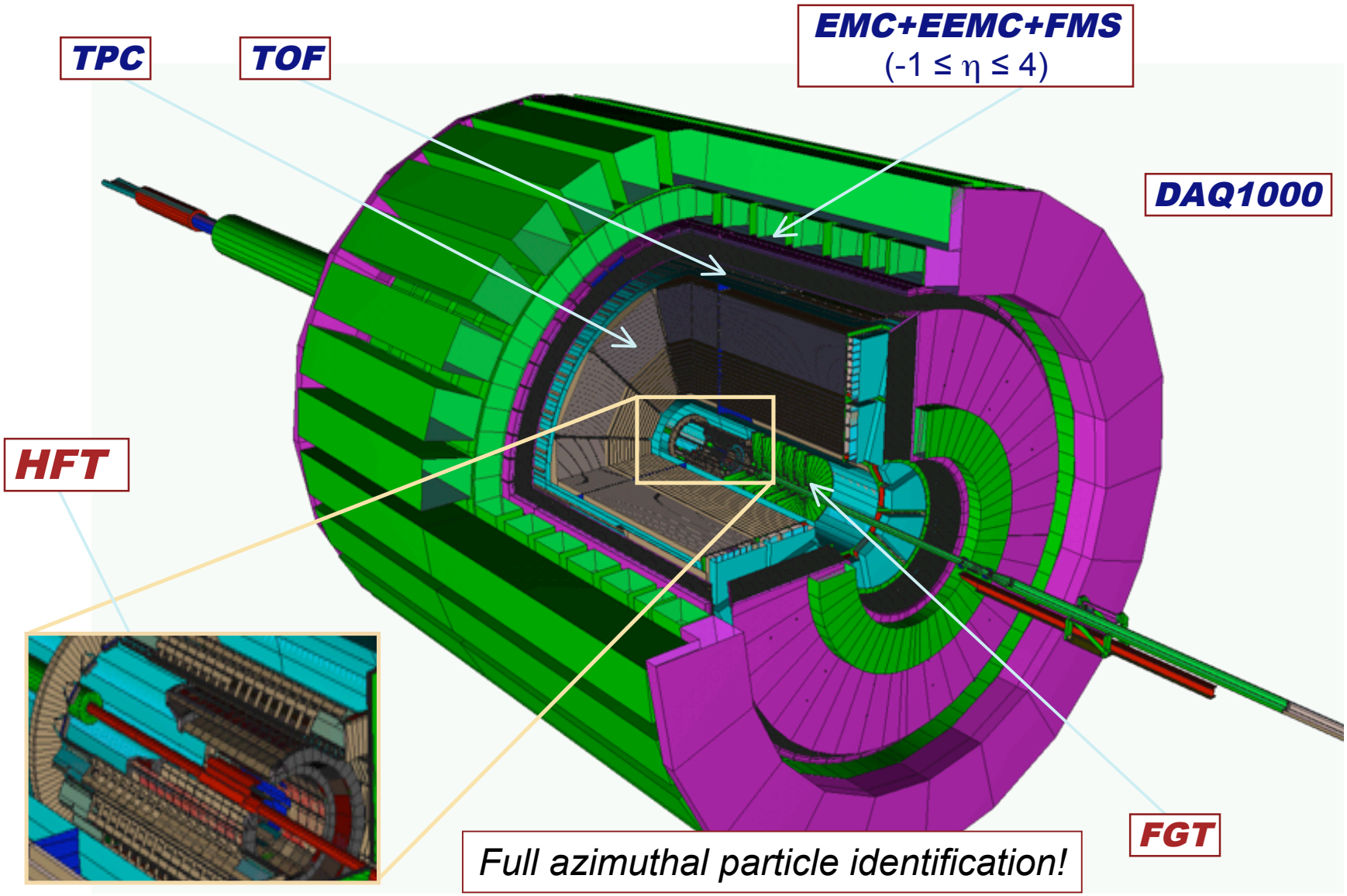
Tagged forward protons
- Study elastic and inelastic processes
- Investigate ***gluonic exchanges*** and search for ***gluonic matter***



STAR Detector

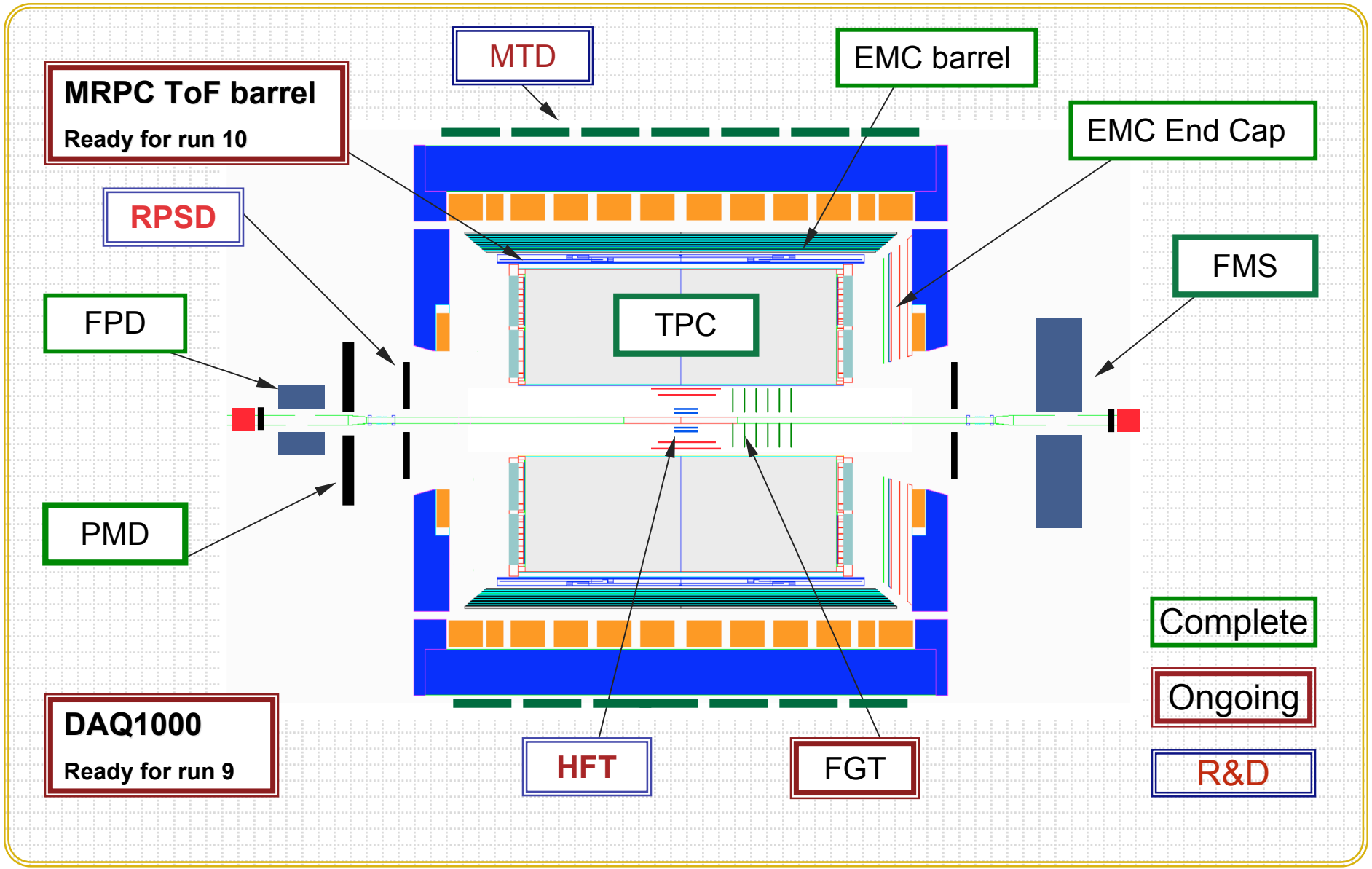


STAR Detectors

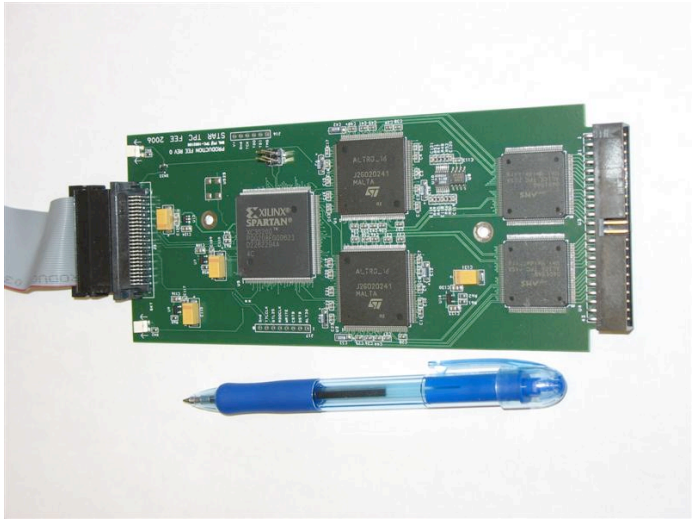


STAR Upgrades

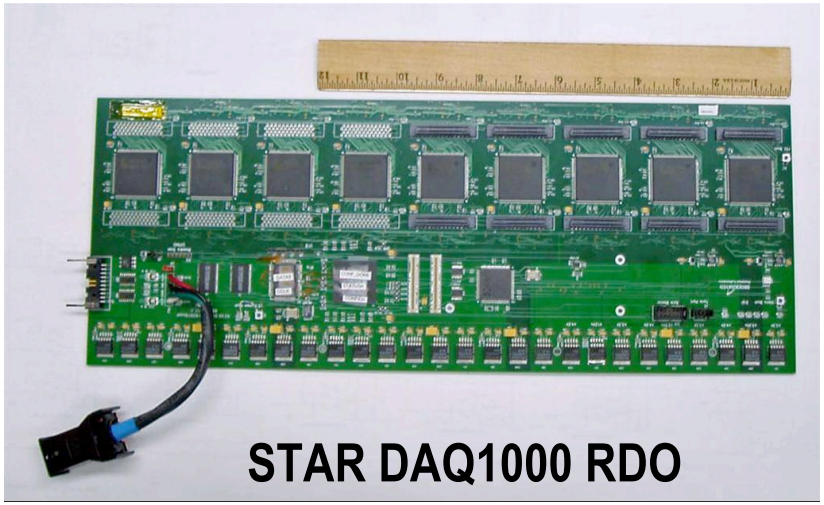
STAR Detector

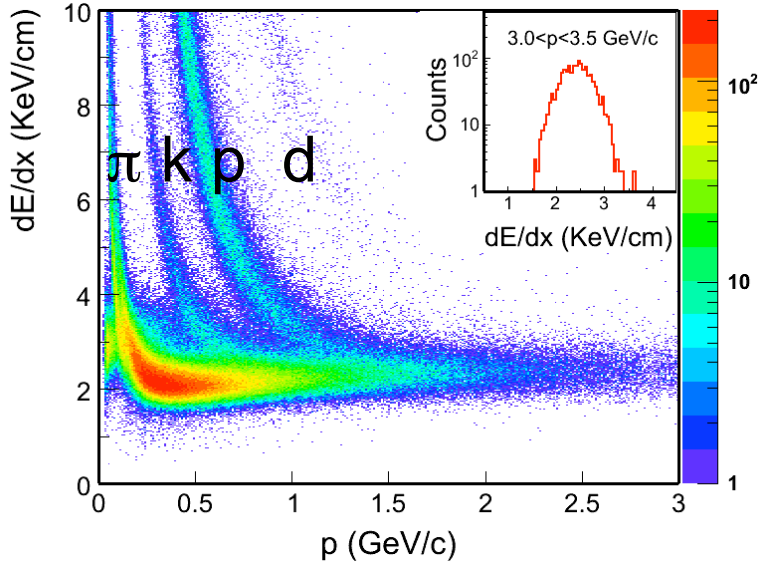


STAR DAQ1000



CERN/ALICE Altro chip development

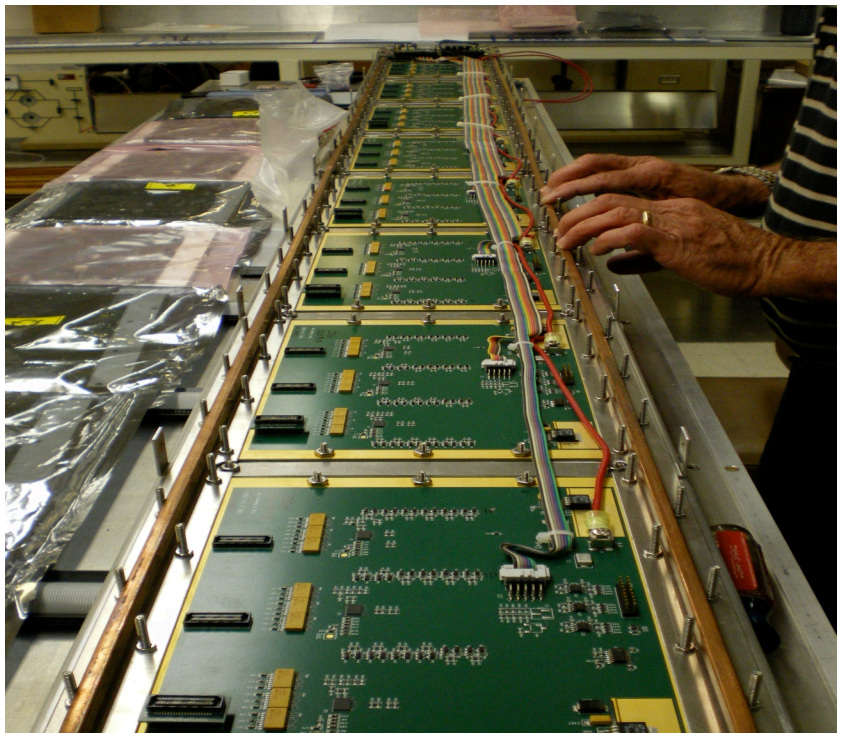


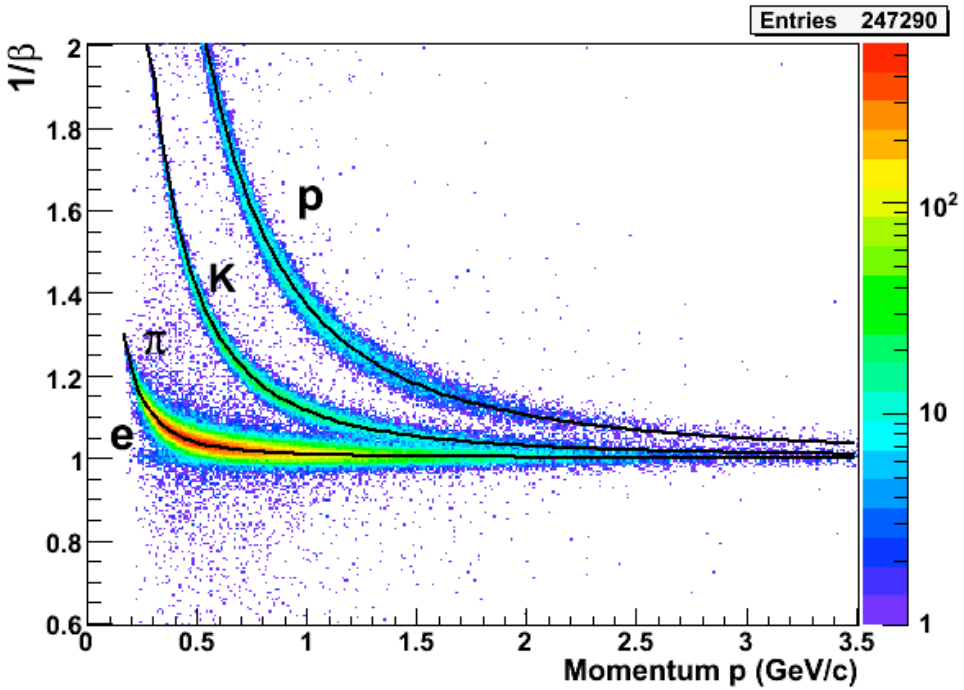


Run 8 tests:

- One sector of the TPC (1/24) instrumented with DAQ1000 electronics
- Routine operation for physics.
- Speed test: operated at 1 kHz with only 5-7% dead time
- Full TPC will be instrumented before Run 9

STAR MRPC ToF





Run 8 test:

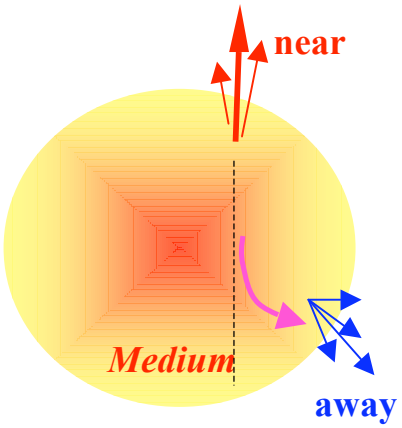
- Five trays of ToF system installed, commissioned, and used for physics
- Behind sector with DAQ1000 TPC electronics. Routine operation for physics.
- **90 (of 120) ToF trays to be installed for Run 9 and the full ToF (120) will be completed before Run 10**

Selected STAR Heavy Ion Results

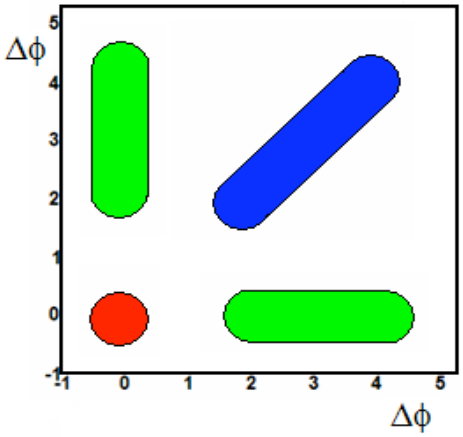
Search for Mach Cone

with Three Particle Correlations

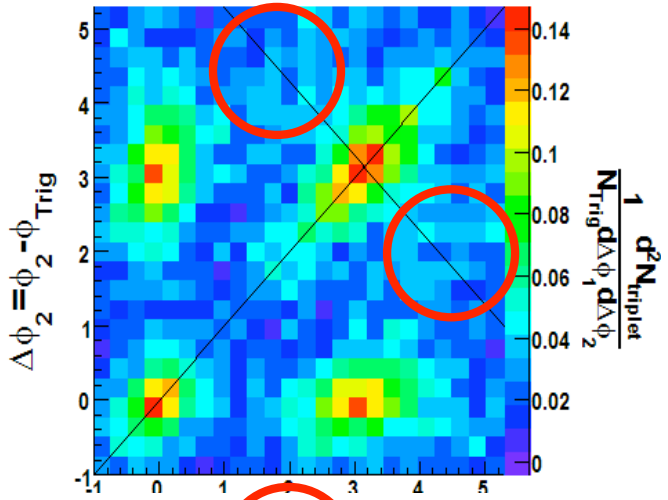
STAR: sub. to PRL, arXiv: 0805.0622

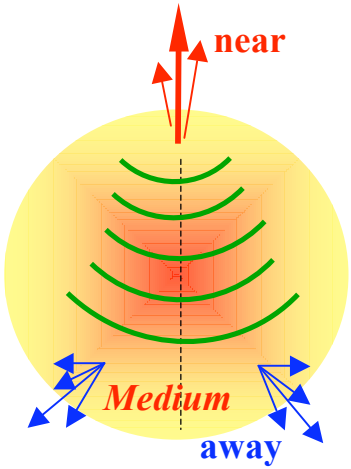


deflected jets

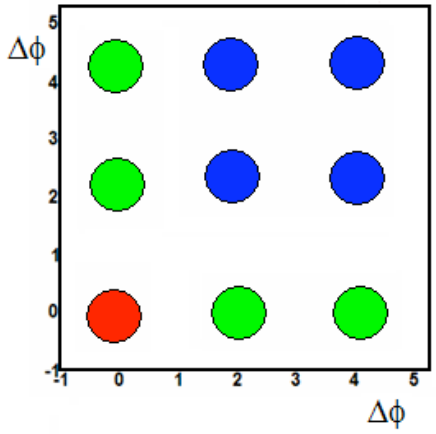


d+Au

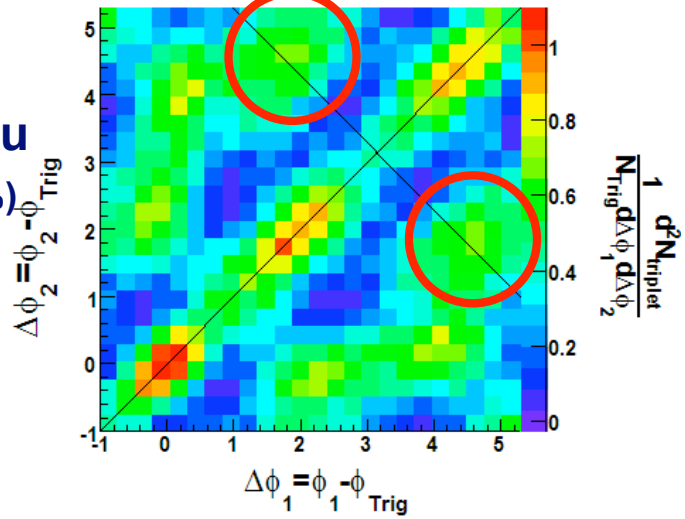




Conical Emission



Au+Au (0-12%)



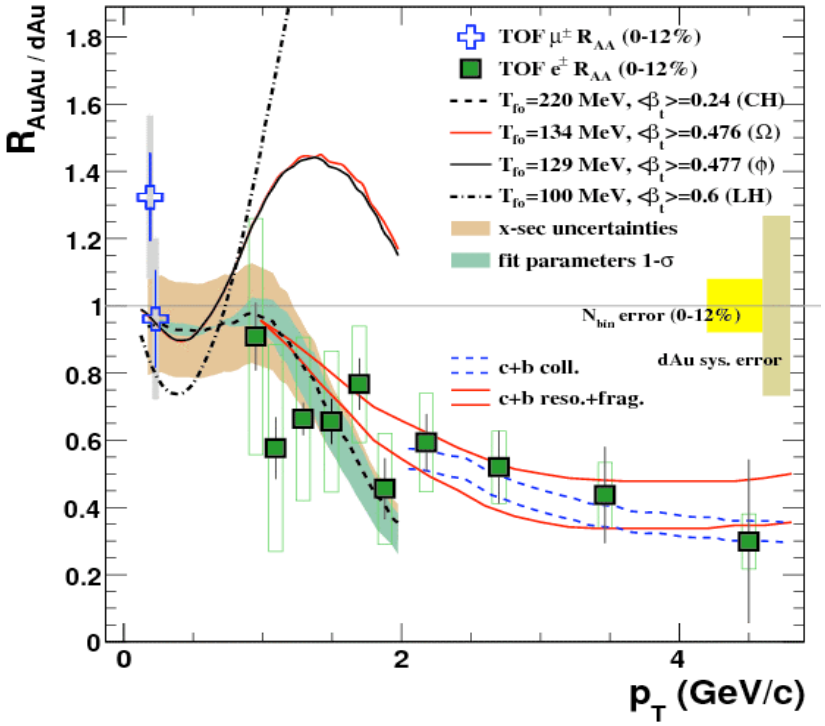
$$\cos\vartheta^{Mach} = \sqrt{p/\varepsilon}$$

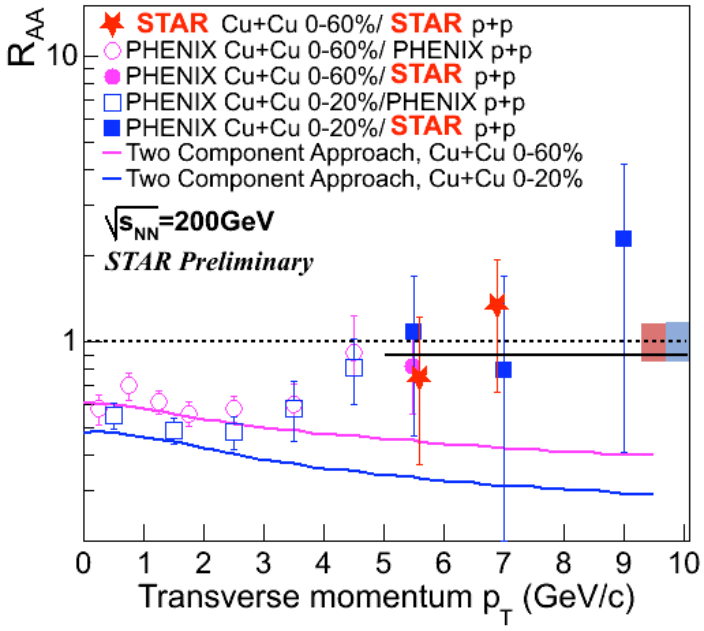
"Evidence of conical emission …"

Open Charm and J/ψ $R_{AA}(p_T)$

STAR: sub. to PRL, arXiv: 0805.0364

Heavy flavor hadrons freeze-out earlier than light flavor (*u,d,s*) hadrons



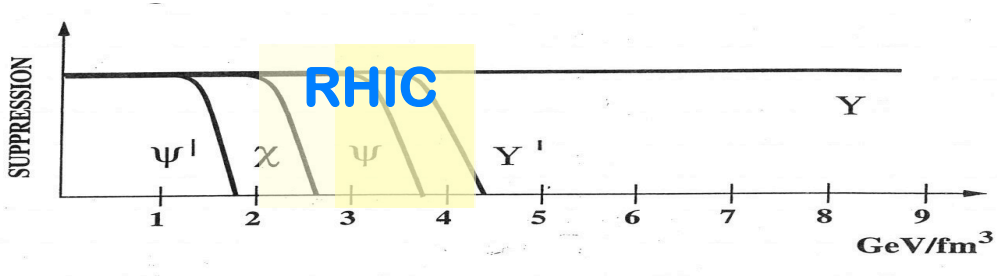


STAR Preliminary:

The Cu+Cu data consistent with no suppression at high p_T:
$R_{AA}(p_T > 5$ GeV/c) = 0.9 ± 0.2

- Low-p_T R_{AA} ~ 0.5-0.6 (PHENIX)
- Most models expect R_{AA} to decrease at high p_T.

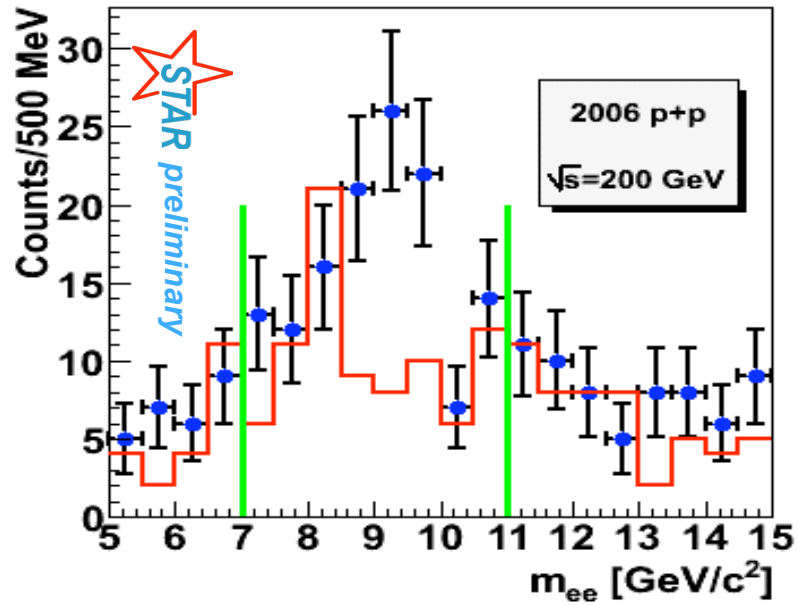
Extending to Higher Mass: ϒ



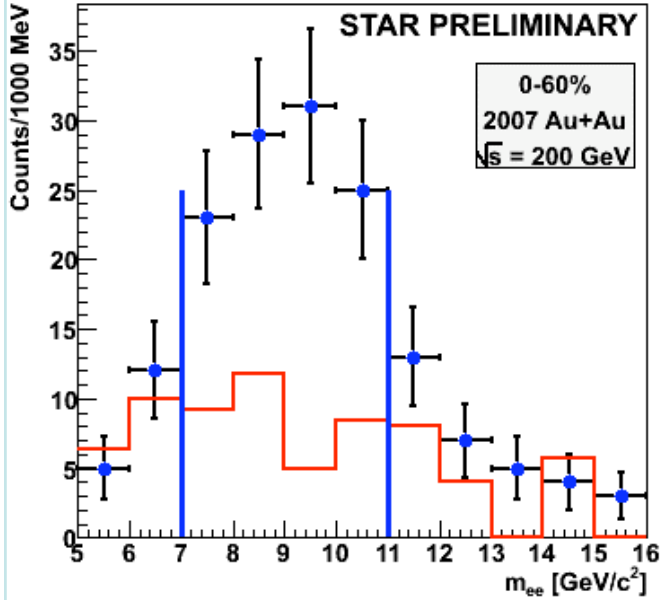
Sequential dissociation of quarkonia is sensitive to energy density of plasma

ϒ (1S+2S+3S) ⟶ e^+e^-

Run 6: 200 GeV p+p

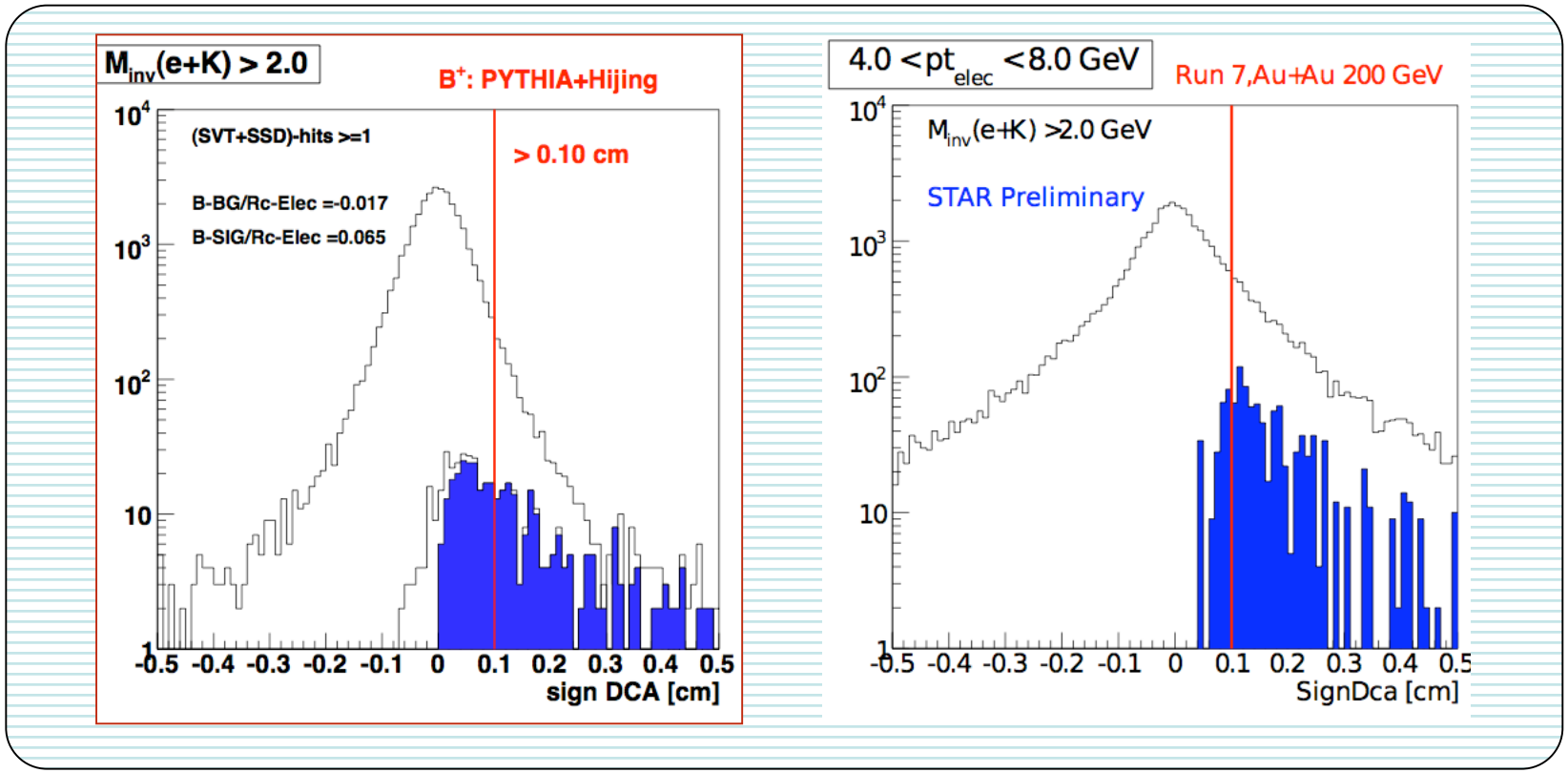


Run 7: 200 GeV Au+Au



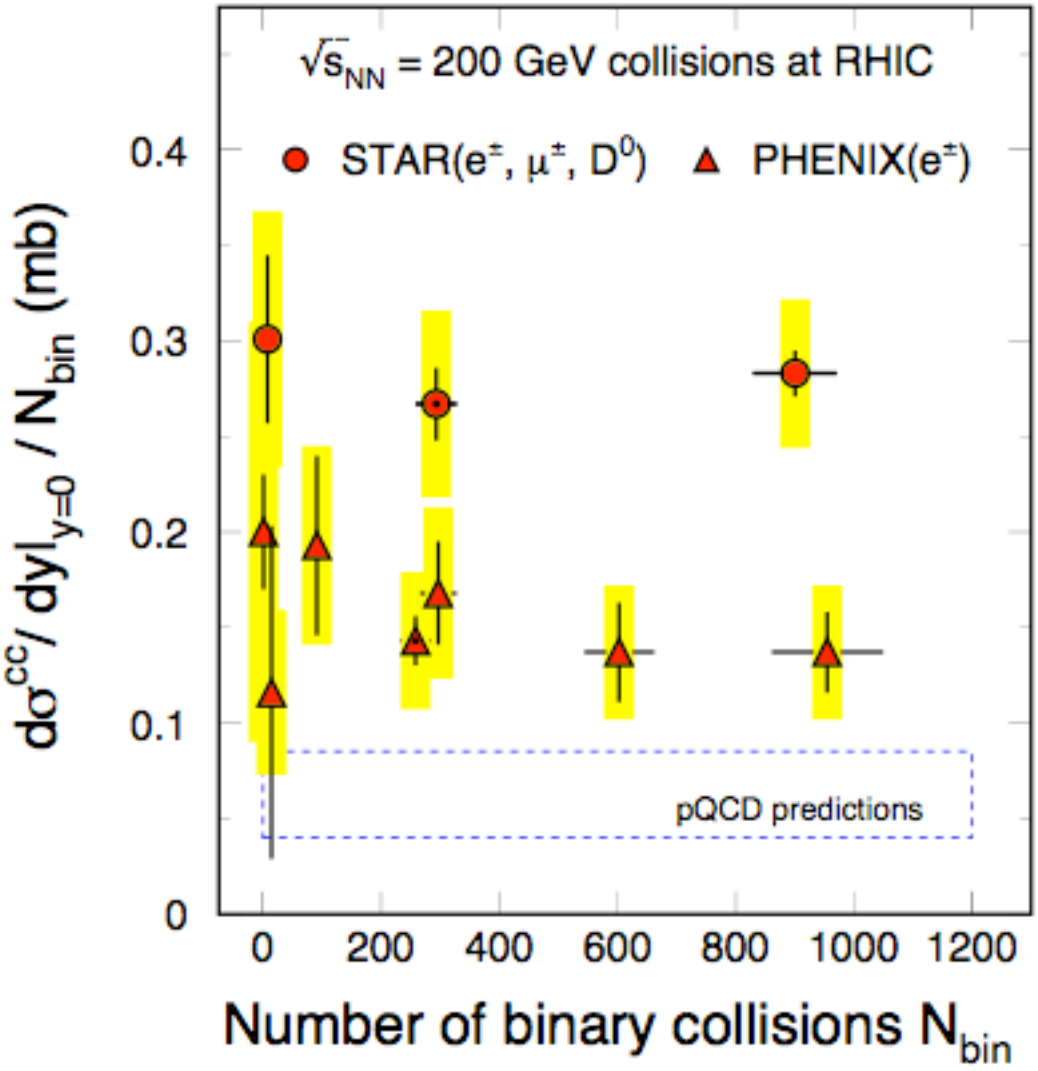
STAR high p_T topological electron trigger works!

Bottom Decay Electron Study



- EMC trigger + SSD+SVT vertex cuts: high energy electrons from Bottom
- In the future: HFT will provide a much more powerful tool for studying heavy flavor hadrons

Charm Cross-section



dσ(cc)/dy at RHIC

1) Within error bars, N_{bin}-scaling is observed!

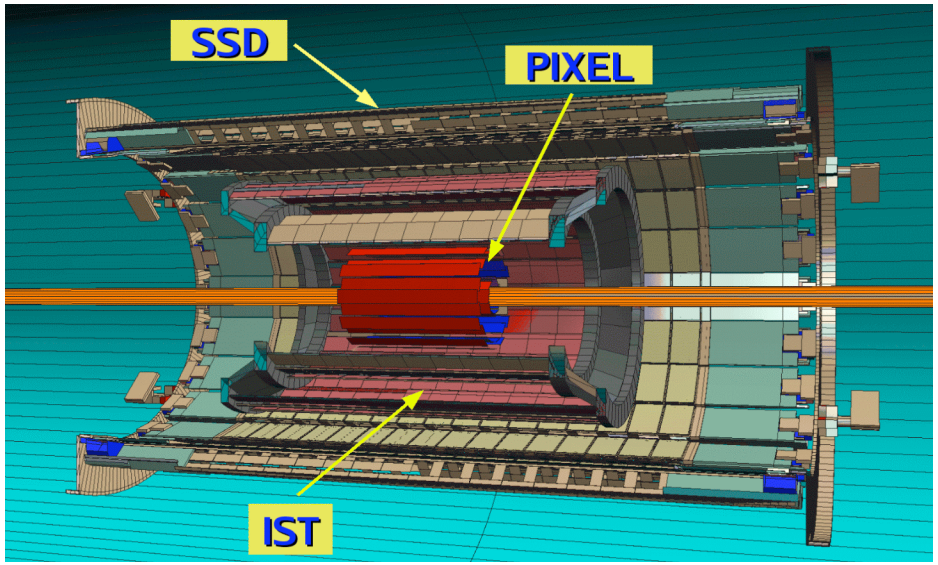
2) Large systematic uncertainties

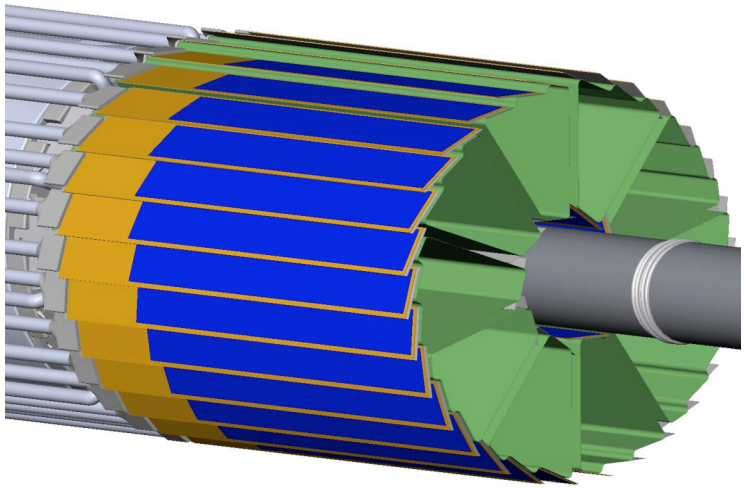
3) Theory under predict

4) dσ(cc)/dy at RHIC:

   STAR ~ 2 x PHENIX

The Future of Charm





Direct reconstruction of charm hadrons:

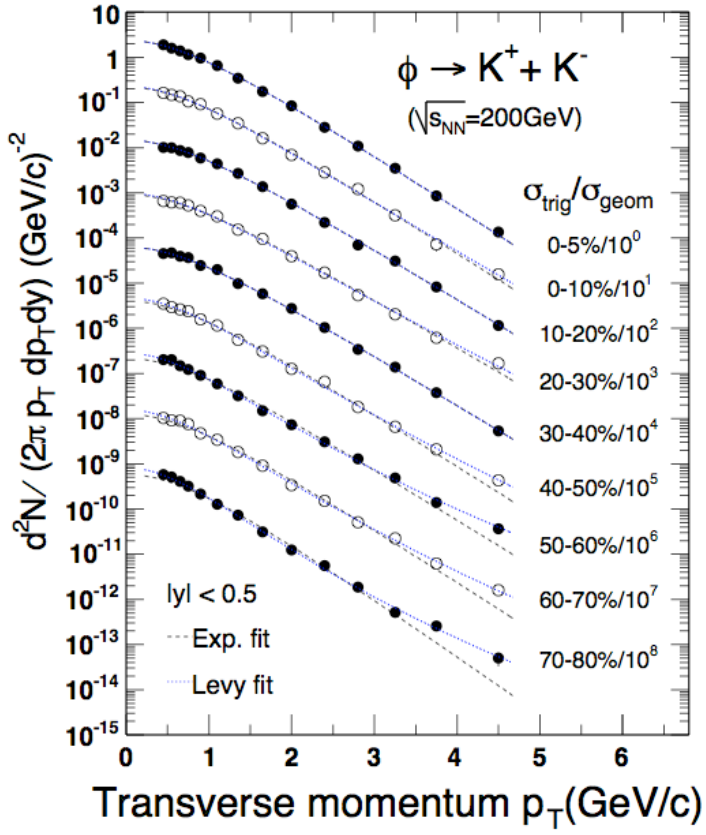
D^0, D^*, $D^{\pm}$, Λ_C

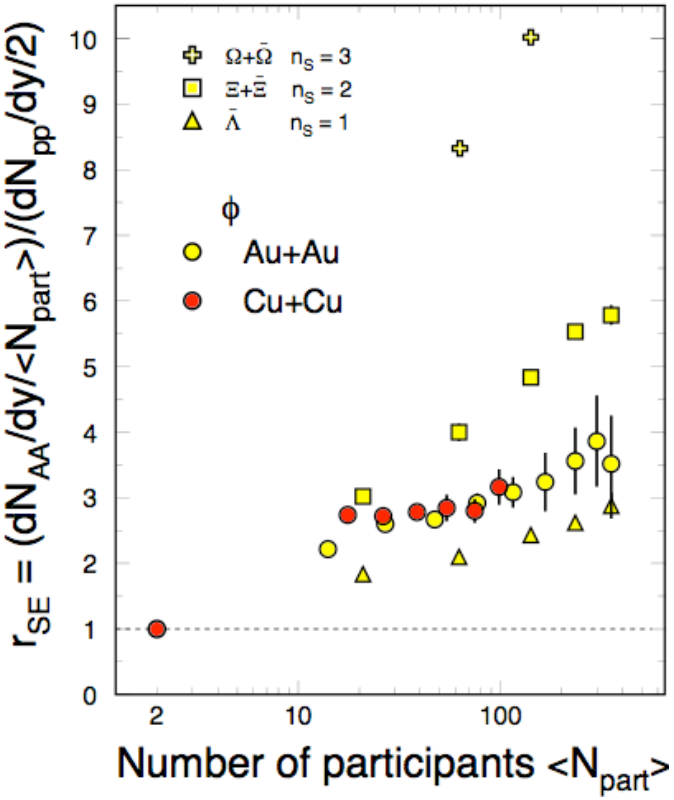
- Cross-sections
- R_{AA}
- v_2

Essential for future RHIC Heavy ion program!

ϕ-mesons from Au+Au Collisions

STAR: *PRL. **98** (2007) 062301; nucl-ex/0703033*





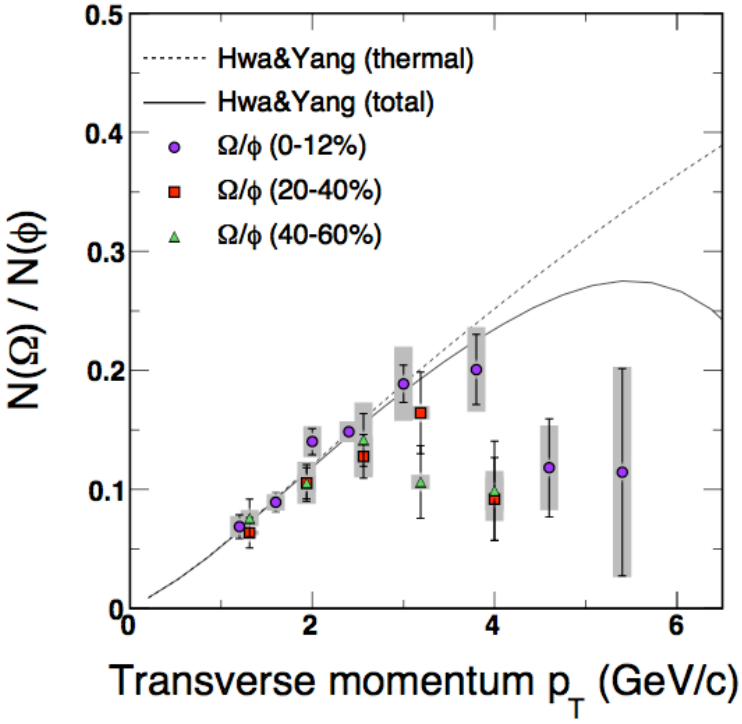
ssbar fusion ⇨ ϕ-meson formation!

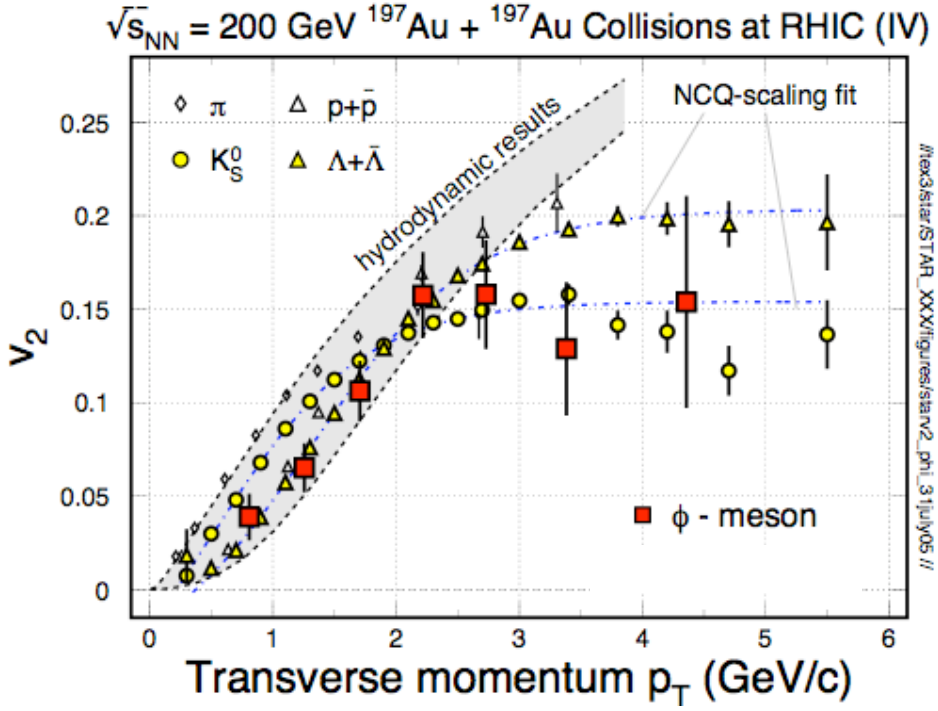
STAR: Phys. Lett. *B612*, 81(2005)

The observed strangeness enhancement is NOT due to the Canonical suppression!

STAR: Preliminary

ϕ -meson Flow: Partonic Flow



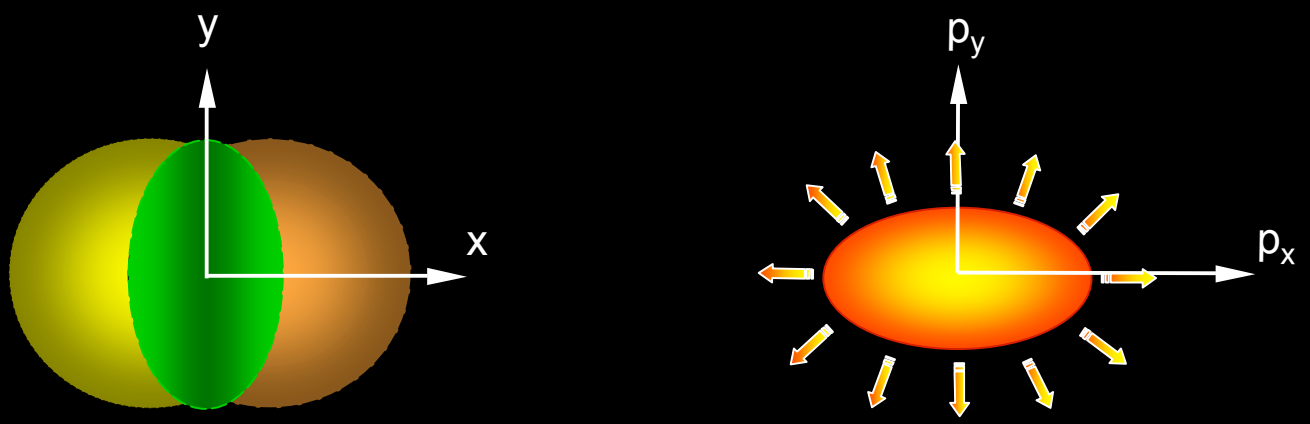


"φ-mesons are produced via coalescence of seemingly thermalized quarks in central Au+Au collisions. This observation implies *hot and dense matter with partonic collectivity* has been formed at RHIC"

STAR: Phys. Rev. Lett. ***99*** (2007) 112301// * STAR, Duke, TAMU,

Anisotropy Parameter v_2

coordinate-space-anisotropy ⇨ momentum-space-anisotropy

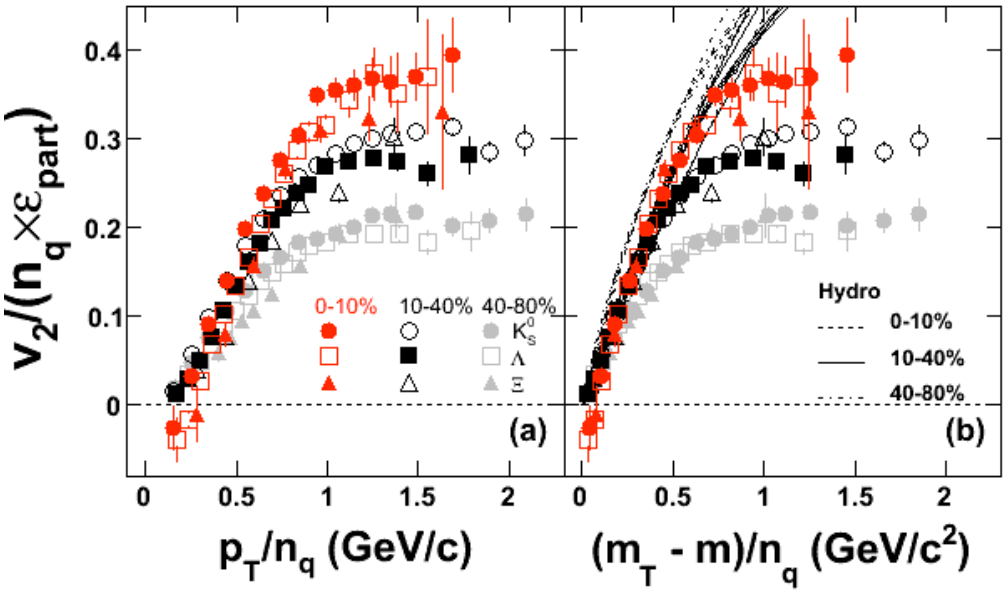


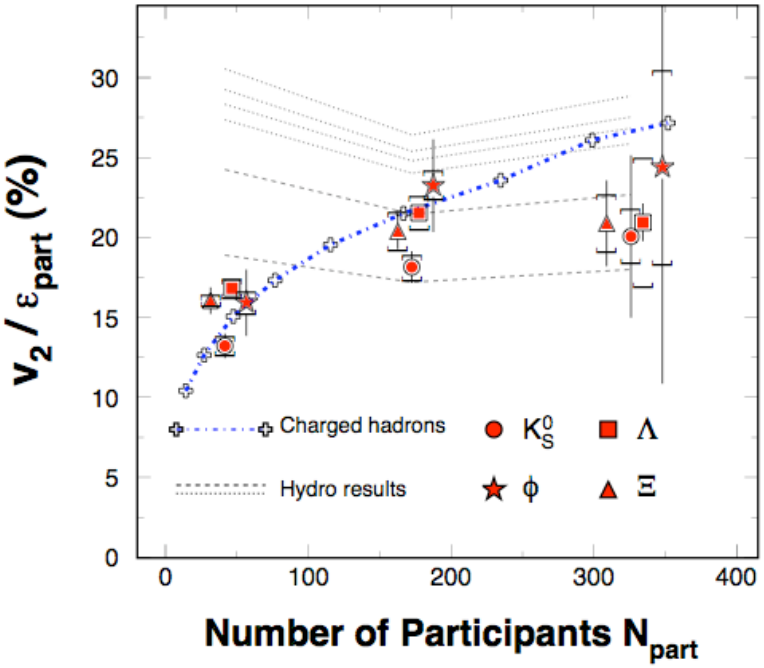
$$\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle} \qquad v_2 = \langle \cos 2\varphi \rangle, \quad \varphi = \tan^{-1}\left(\frac{p_y}{p_x}\right)$$

Initial/final conditions, EoS, degrees of freedom

Eccentricity Scaling (?)

STAR: PRC, in print, arXiv:0801.3466v1



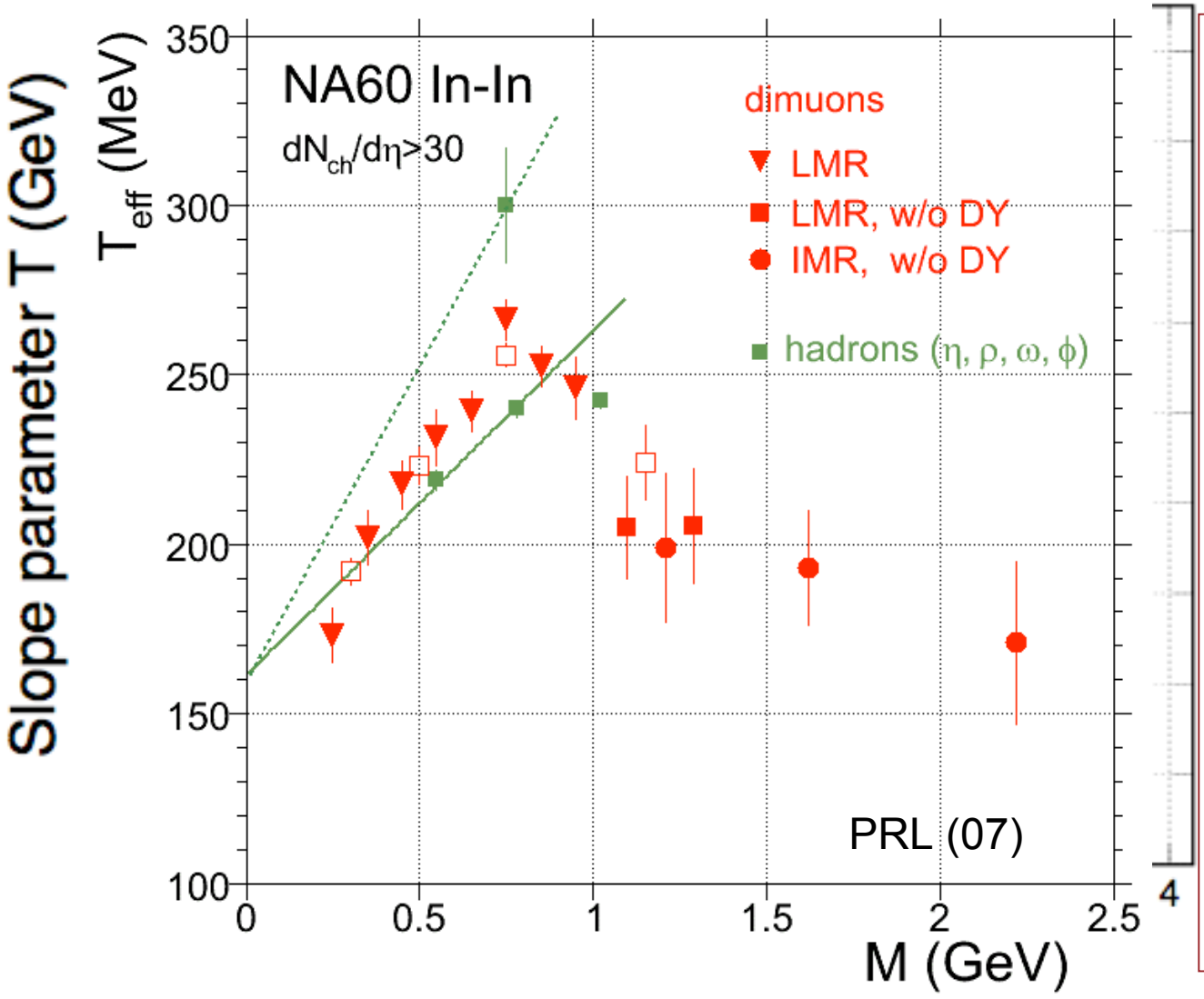


200 GeV Au+Au

*S. Voloshin, A. Poskanzer, PL **B474**, 27(00).*
D. Teaney, et. al., nucl-th/0110037

- Larger v_2/ε_{part} indicates stronger flow in more central collisions.
- Clearly, no ε_{part} scaling.
- **The observed n_q-scaling does not necessarily mean thermalization.**

Direct Radiation



Di-leptons allow us to measure the direct radiation from the matter with partonic degrees of freedom, no hadronization!

- Low mass region:
  $\rho, \omega, \phi \Rightarrow \mathbf{e^-e^+}$
  $m_{inv} \Rightarrow \mathbf{e^-e^+}$

  medium effect
  Chiral symmetry

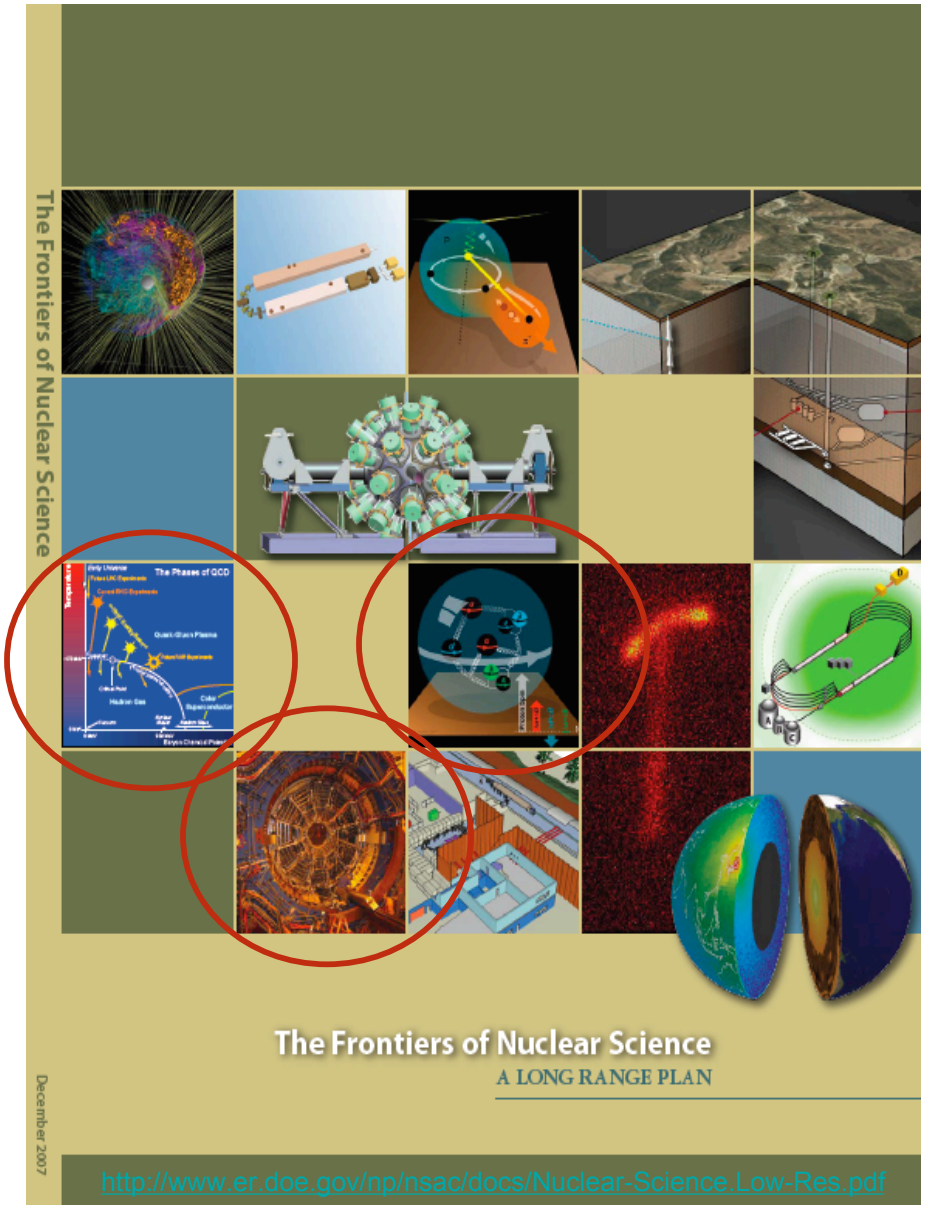
- High mass region:
  $\mathbf{J/\psi \Rightarrow e^-e^+}$
  $m_{inv} \Rightarrow \mathbf{e^-e^+}$

  Direct radiation

Search for the Hadronic Shore

- *in high-energy nuclear collisions*

The Frontiers of Nuclear Science

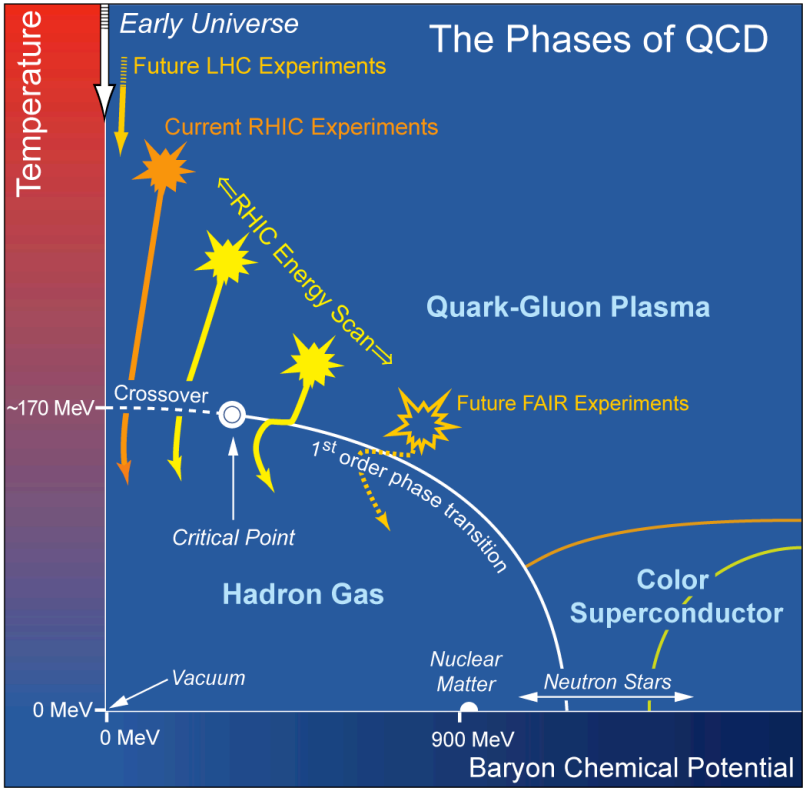


(I) **Systematically study the partonic medium properties at RHIC**

(II) **Search for QCD critical point**

(III) **Study proton intrinsic structure**

Search for QCD Critical Point



STAR Beam User Request FY10

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

Key measurements:

(1) All PID hadron spectra and v_2
(2) K/π, $\langle p_T \rangle$ … fluctuations

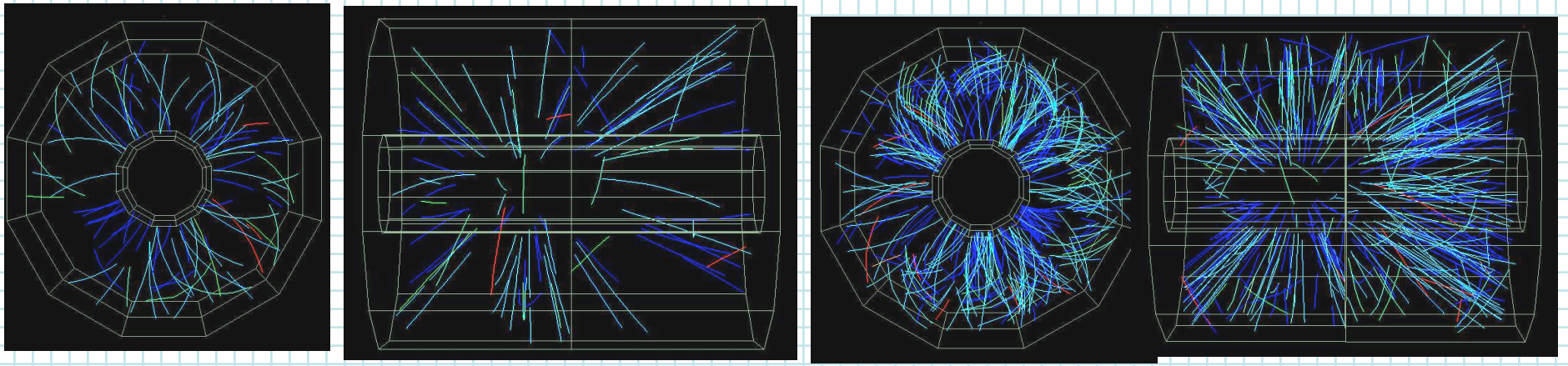
Strategy:

(1) From high to low energy, disappearance of high energy density phenomena (controlled experiment)

(2) Cover SPS range $\sqrt{s_{NN}}$ = 5 - 20 GeV, look for the onset of de-confinement

Low Energy Test Run (9 GeV)

Au + Au Collisions!

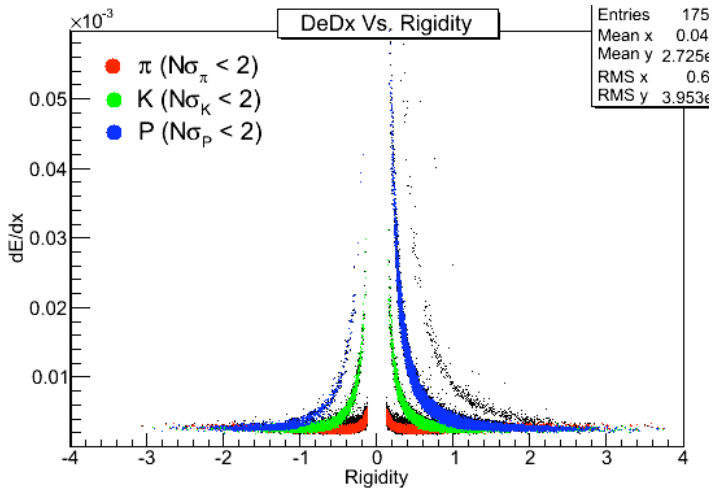


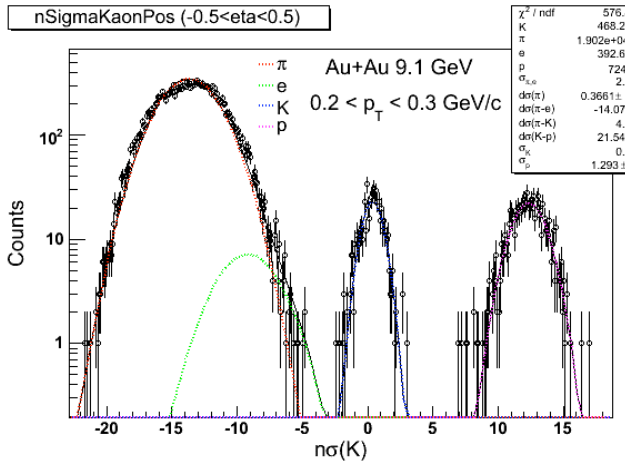
1) **~ 3500 collisions collected**
2) **Gain understanding of triggering issues**
3) **Determine Luminosity: rate ~ 0.6 Hz at 9 GeV**
4) **STAR studying the following:**

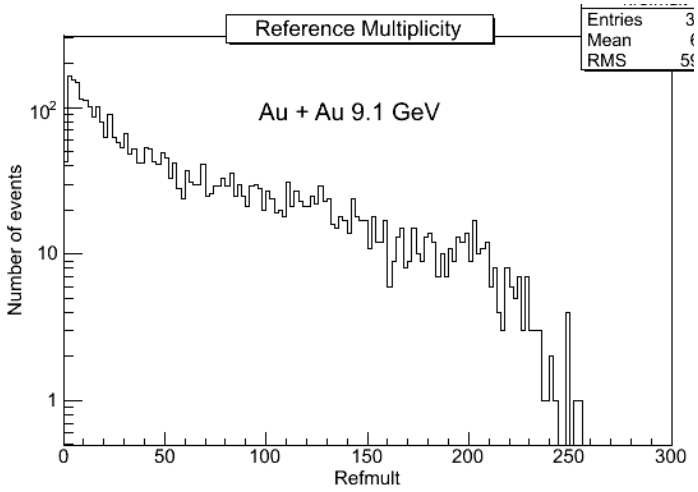
   Particle identification in TPC; total charged multiplicity

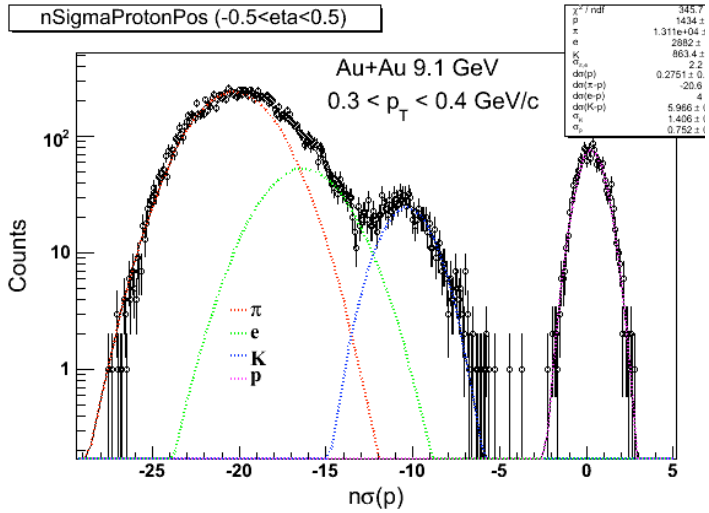
   π-π interferometry, particle ratios; v_1 and v_2
5) **Physics ready with 2 - 4 Hz collisions**

Ready for Physics at Energy Scan



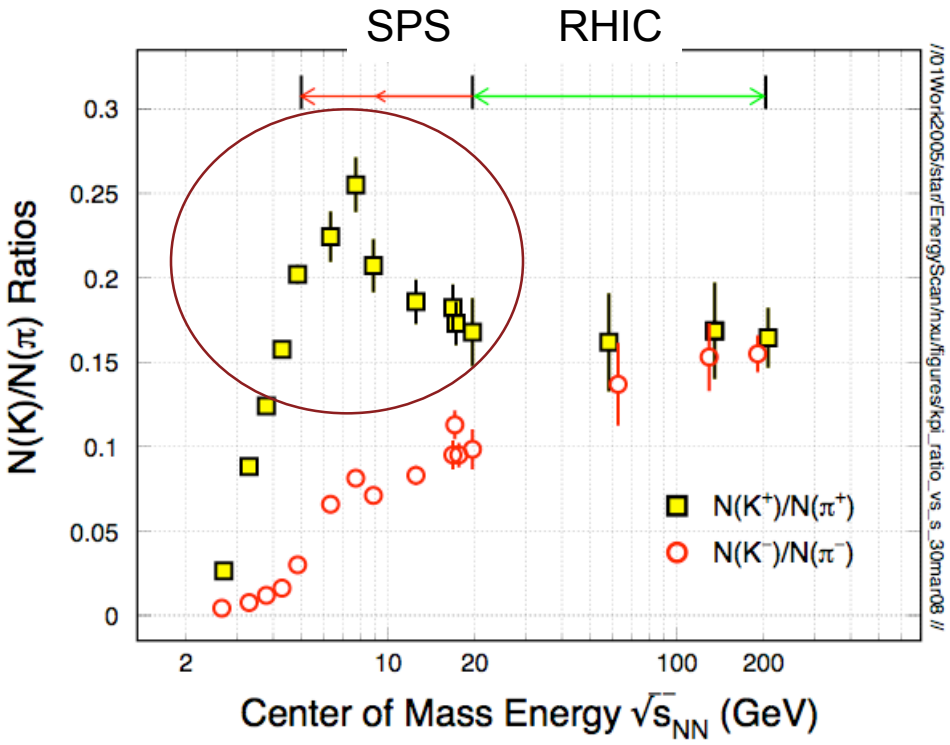


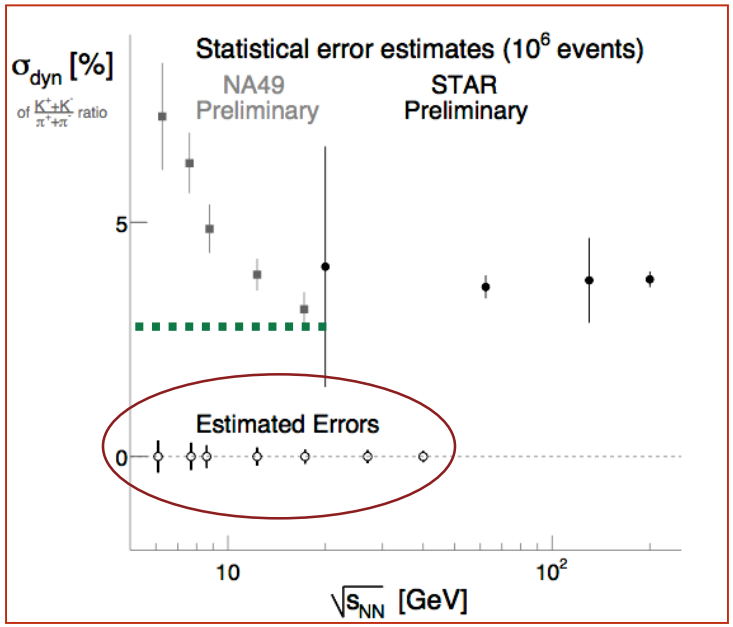




PID will be significantly extended using TOF

Observables and Advantages





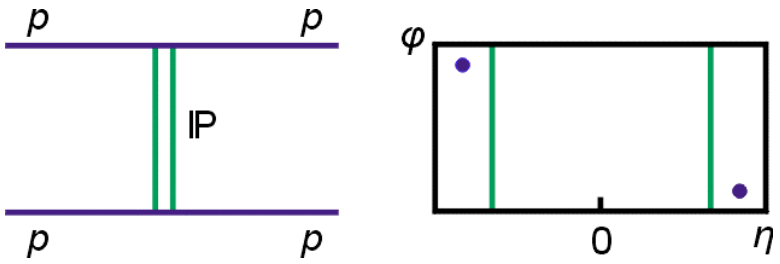
Torrieri

Advantages at STAR:

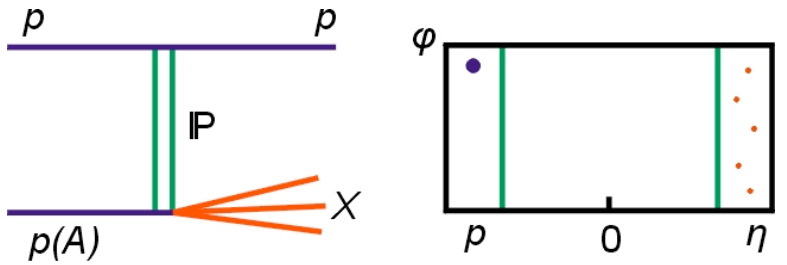
- Large acceptance: full azimuthal coverage and |y| < 1.0
- Clean particle identification: (TPC, ToF, EMC)
- Acceptance does ***not*** change with beam energy, systematic errors under control
- High potential for discovery

Tagged Forward Protons

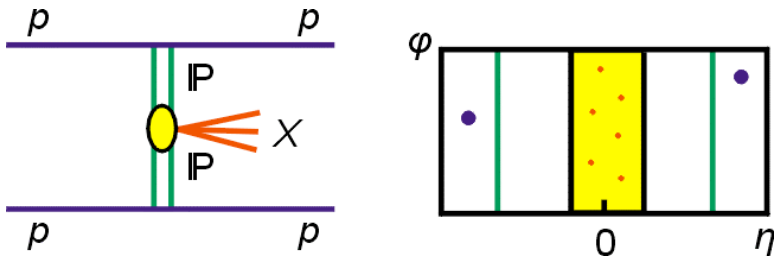
Elastic and Inelastic Processes



Elastic Scattering: Roman Pots only



Single Diffraction: RP + FMS or RP + BBC



For each proton vertex one has

t four-momentum transfer

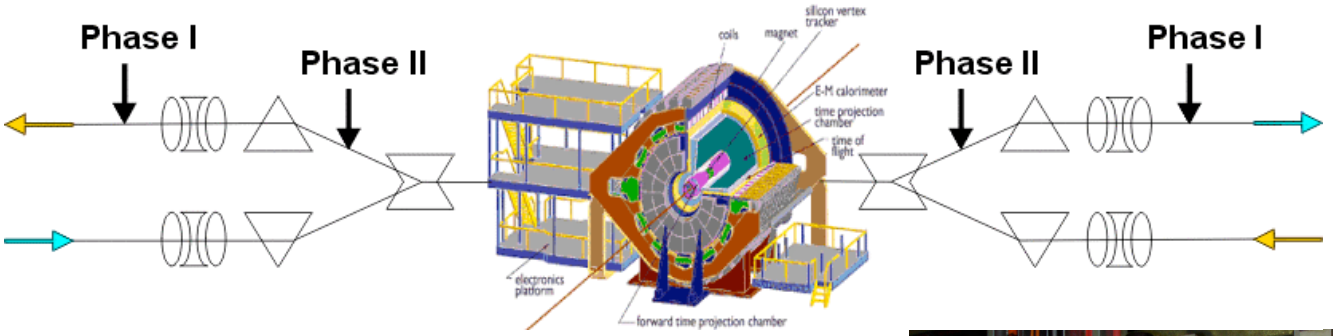
$\xi = \Delta p/p$ - proton momentum loss

M_X invariant mass

Central Production: RP + ToF; Tracks in the TPC ***full azimuthal acceptance***

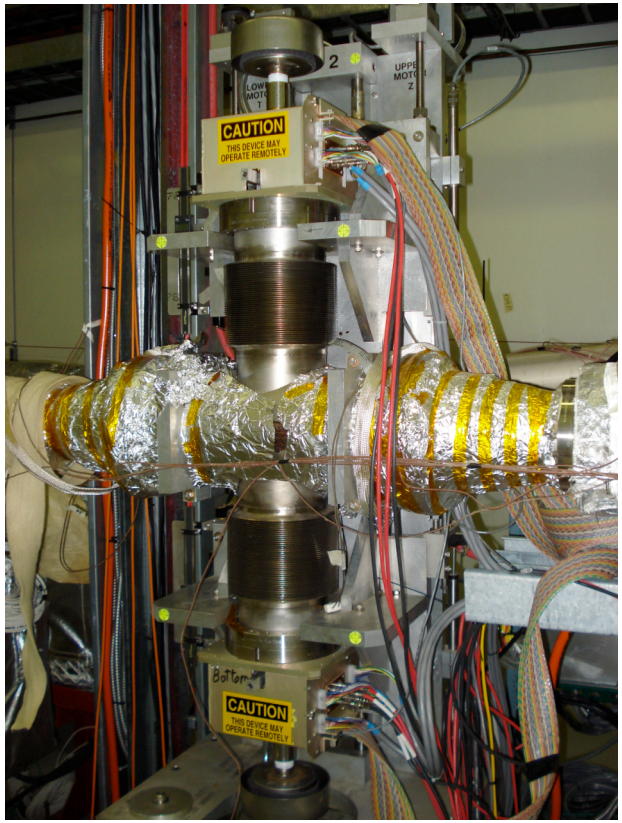
In terms of QCD, Pomeron exchange consists of the exchange of a color singlet combination of gluons. Hence, triggering on forward protons at high (RHIC) energies predominantly selects exchanges mediated by ***gluonic matter***.

Status of pp2pp

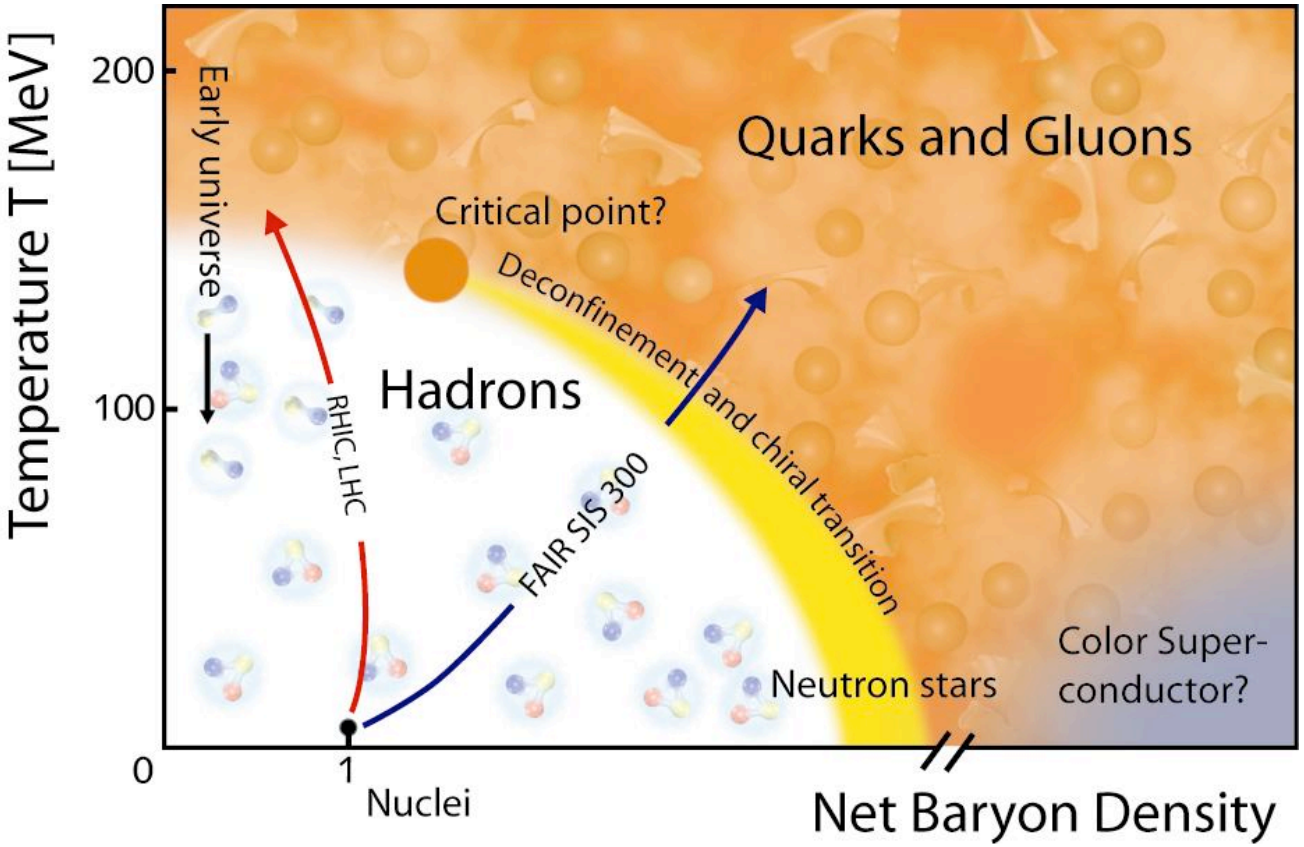


- Roman Pots (RP) were installed East and West of STAR (Phase I);
- pp2pp integrated into trigger and DAQ;
- Inserted pots into the beam pipe during last 2 hours of Run 8 (pp):
  - ***Triggered on elastic and inelastic coincidences in pp2pp RP***
  - ***No impact on background levels in STAR mid-rapidity detectors***

Phase II: Install RP between DX-D0 magnets, allowing to trigger on forward protons with standard tune, hence taking data with STAR without need for dedicated time.



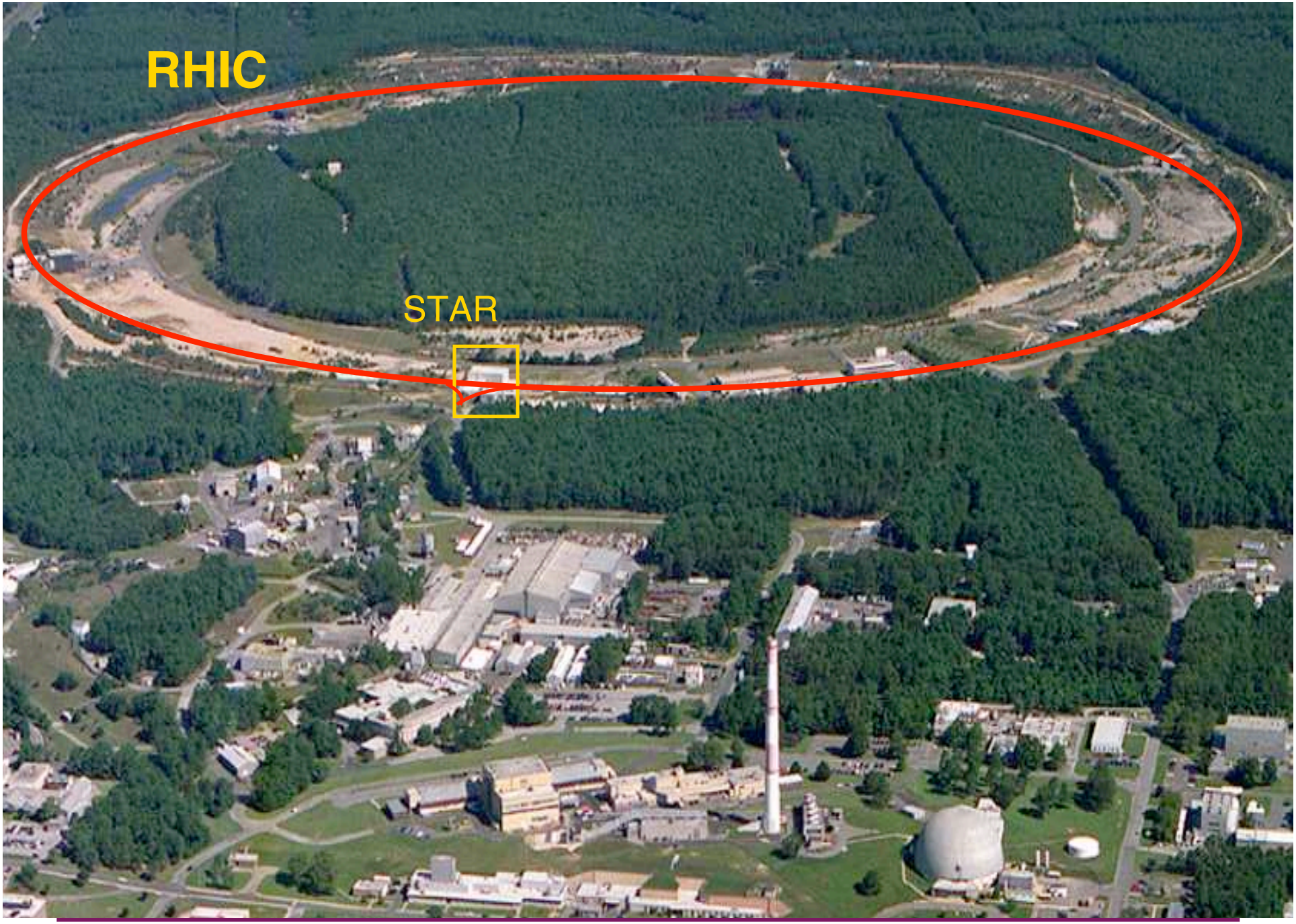
STAR Heavy Ion Physics



1) RHIC heavy-ion program
   - Study ***medium properties*** and pQCD in hot and dense medium

2) RHIC energy scan
   - Search for the ***QCD critical point***


Let us all work together, to make
STAR even brighter!


RHIC
STAR

STAR Upgrade Timeline

Upgrade	Completion	Key physics measurements
FMS	Completed 2008	(a)Transverse asymmetry at forward rapidity (b) CGC
TPC DAQ (DAQ1000)	Summer 2008 Ready for Run 09	Large data set, minimal dead time
MRPC TOF	Summer 2009 Full TOF ready for Run 10	Full PID in full azimuthal acceptance (90/120 trays will be used in Run 9) TOF capability is critical for the energy scan
FGT	Summer 2010 Ready for Run 11	Forward $W^{\pm}$ for flavor separated quark polarization
HFT	Summer 2011 Ready for Run 12	(a) Precision hadronic ID for Charm and Bottom hadrons (b) Charm and Bottom hadron energy loss and flow

1) Physics
2) Upgrades - technically driven schedule
3) Request for new measurements