RHIC program and machine performances

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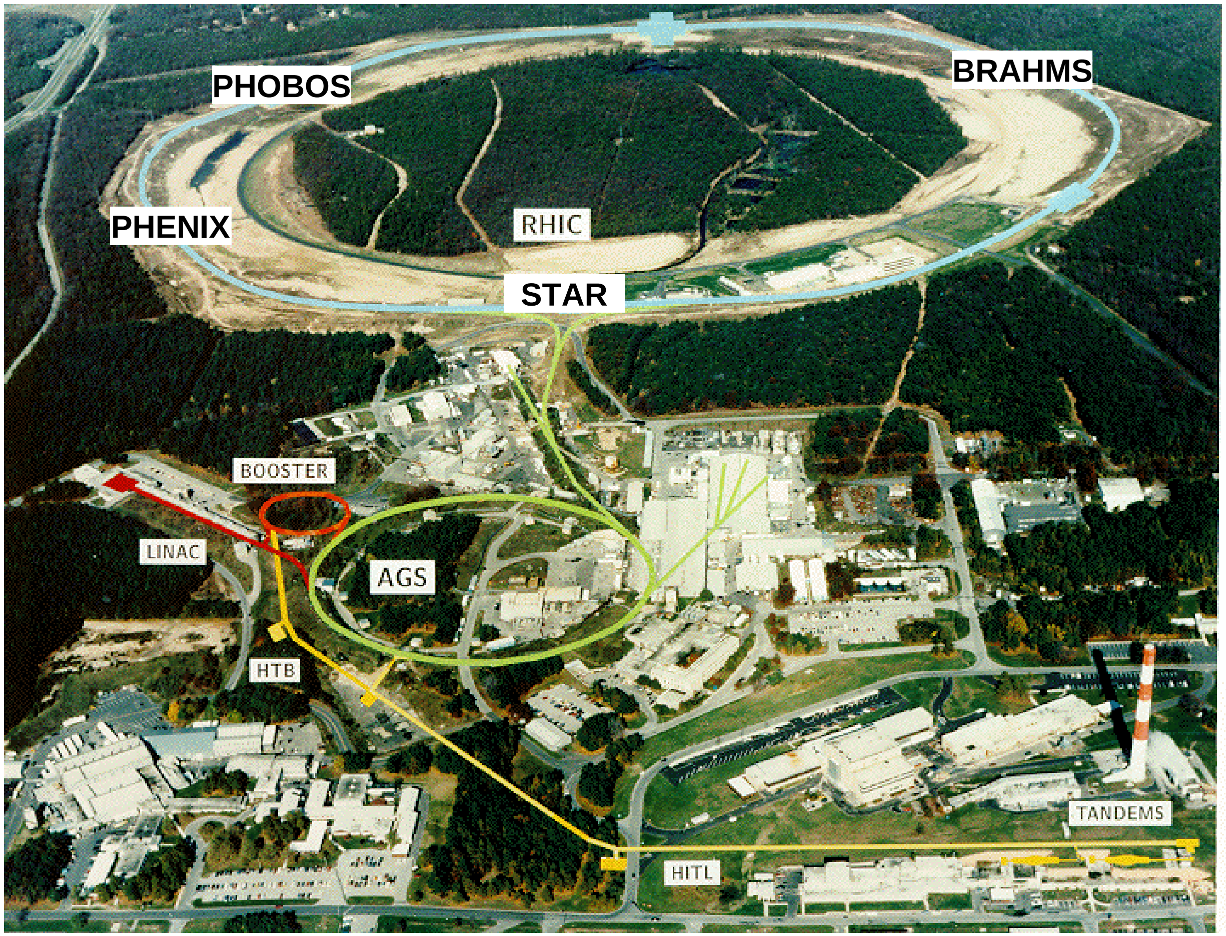
Outline

- the RHIC collider
- the experiments
- selected results
- collider and detector upgrades

The RHIC collider

BNL facility



3.83 km

Capable of colliding *any* nuclear species

Energy:

500 GeV for p-p

200 GeV for Au-Au (per N-N collision)

protons: Linac → Booster → AGS → RHIC

ions: Tandems → Booster → AGS → RHIC

Physics program

Study the formation of a quark gluon plasma in high energy high density nuclear matter

p+p collisions for reference

light ions to study *cold* nuclear matter effects

heavy ions to form a quark gluon plasma

use as many different probes as possible because of a lack of decisive proof for a phase transition

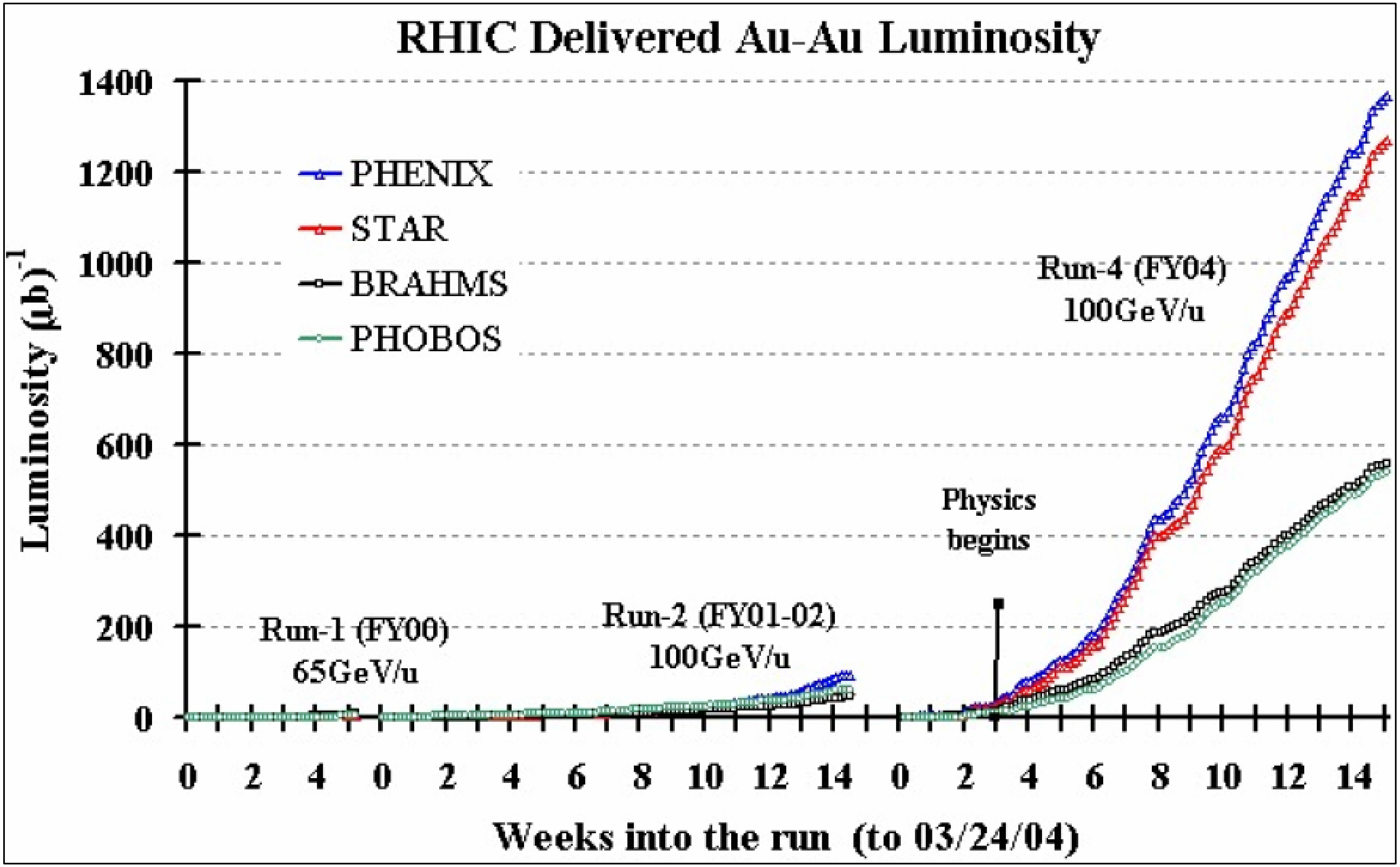
Polarized p+p program :

study the polarized structure functions of the nucleon, notably DeltaG/G

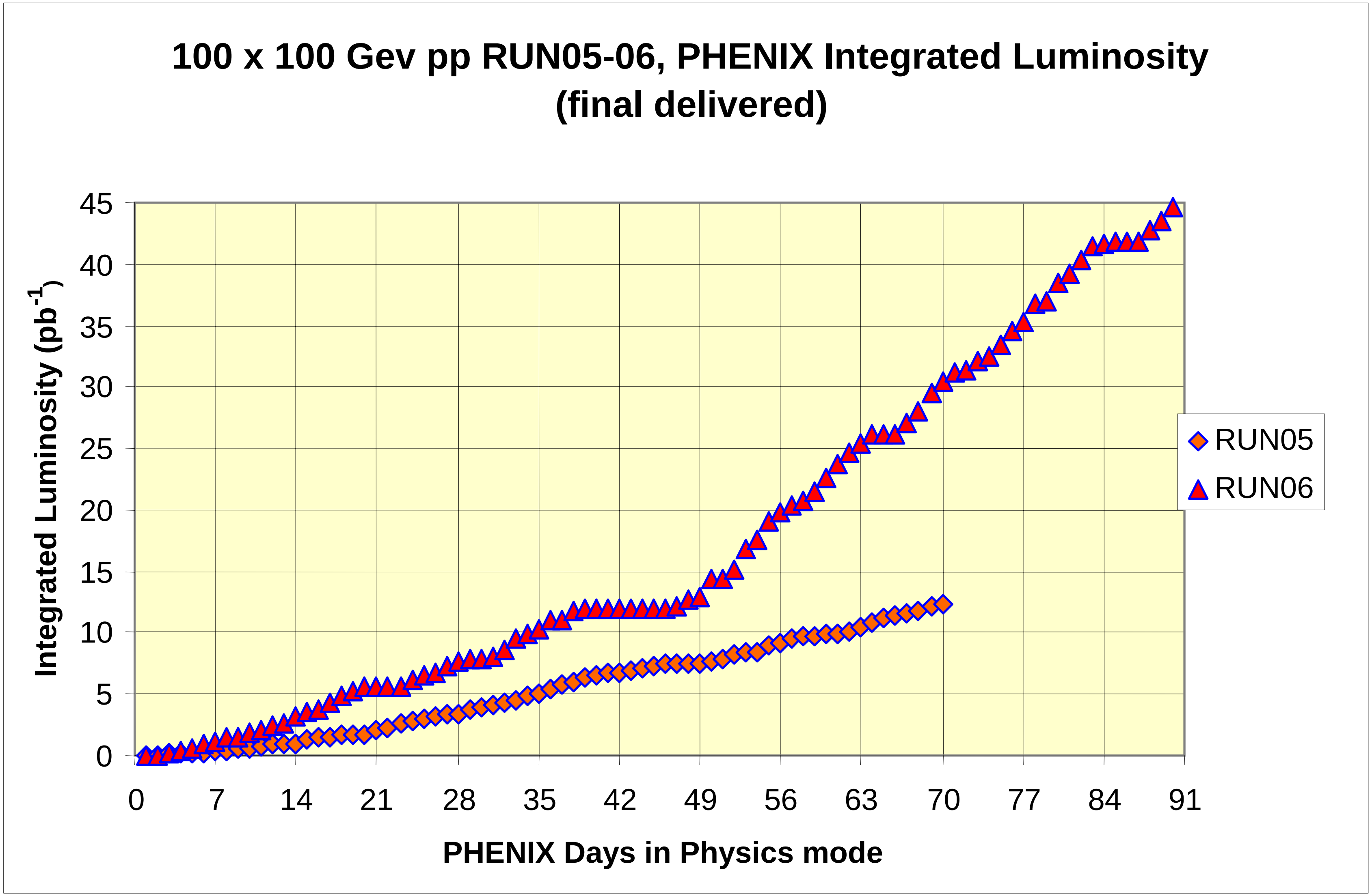
Collision species and energy

Run	Year	Species	Energy (GeV)
01	2000	Au+Au	130
02	2001/2002	Au+Au	200
		p+p	200
03	2002/2003	d+Au	200
		p+p	200
04	2003/2004	Au+Au	200
		Au+Au	62
05	2004/2005	Cu+Cu	200
		Cu+Cu	62
		Cu+Cu	22.5
		p+p	200
06	2006	p+p	200
		p+p	62
		p+p	500

Integrated luminosity (Au+Au)

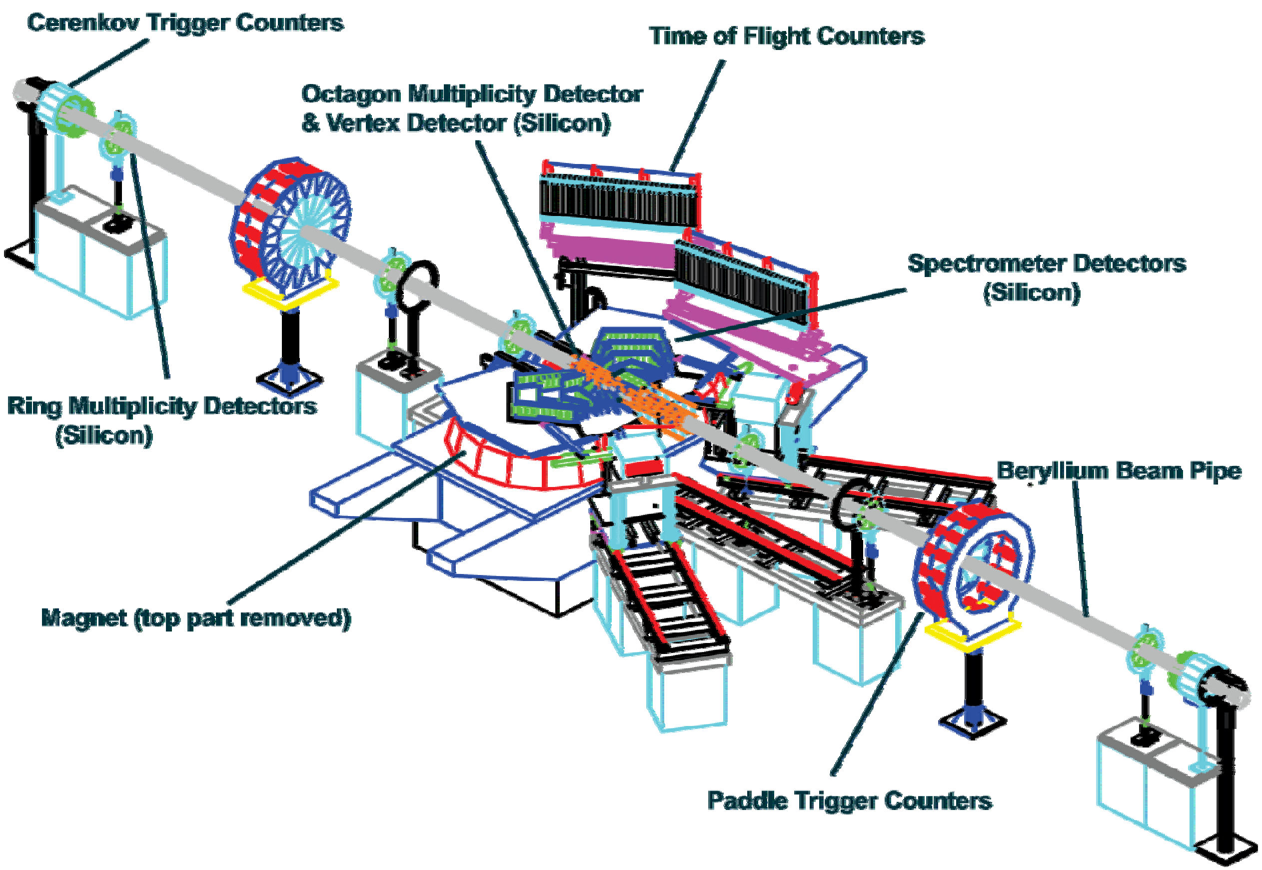


Integrated luminosity (p+p)



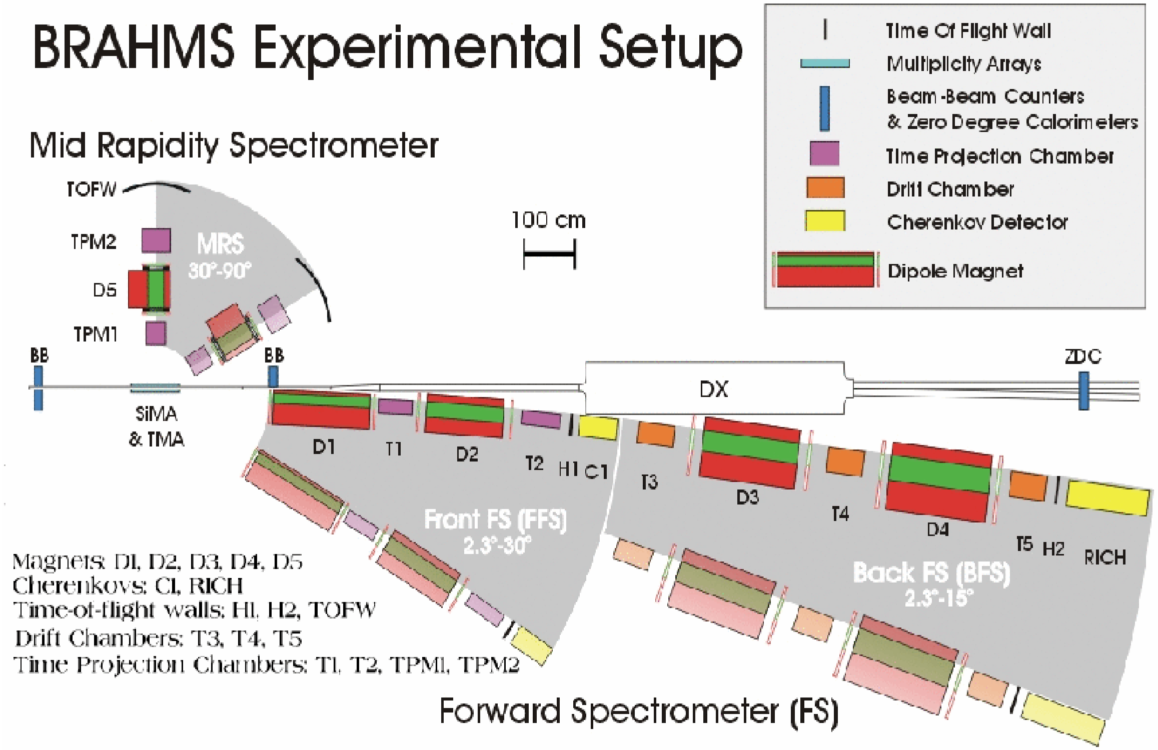
The experiments

PHOBOS



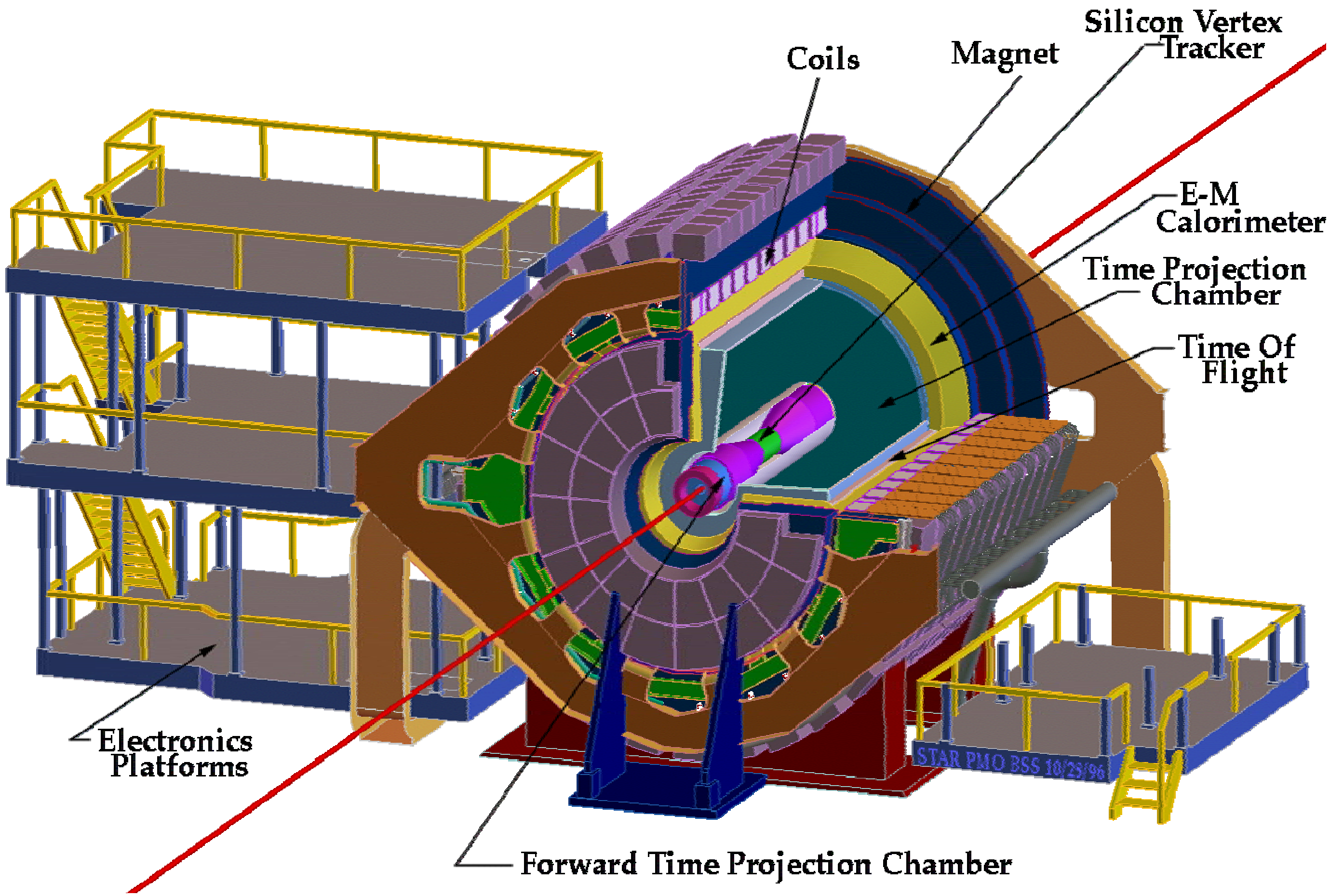
- Multiplicity of charged particles for $|\eta| < 5.4$
- Particles down to low p_t (~100MeV) near $y = 0$
- Particle ratios, spectra, and correlations

BRAHMS



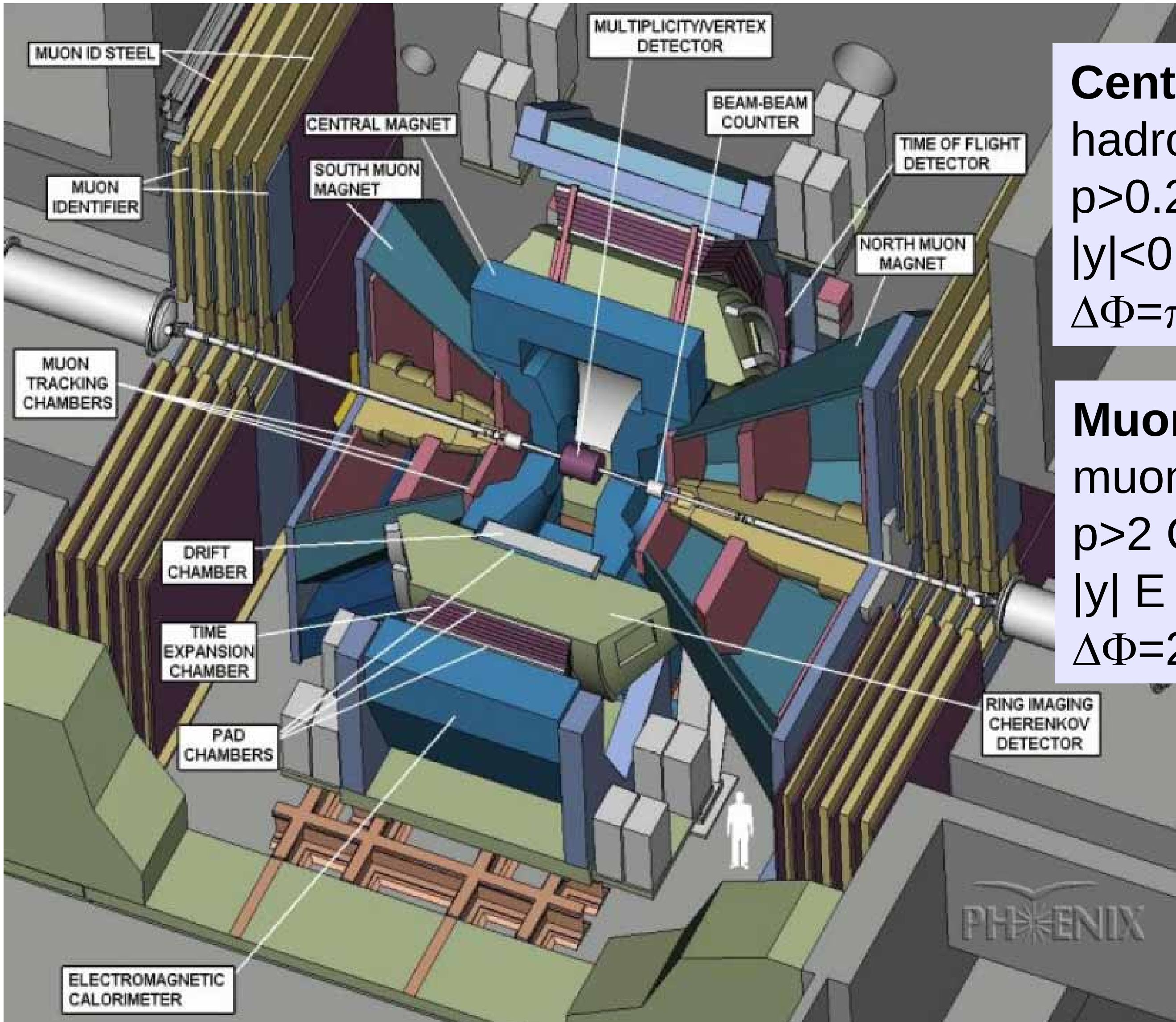
Measures momentum, energy of charged hadrons at forward rapidity (up to η=3.2). Low *x* physics, saturation physics.

STAR



Hadrons, electrons and jets at mid rapidity over $\Delta\Phi=2\pi$

PHENIX



Central arm
hadrons; photons; electrons
p>0.2 GeV/c
|y|<0.35
$\Delta\Phi=\pi$

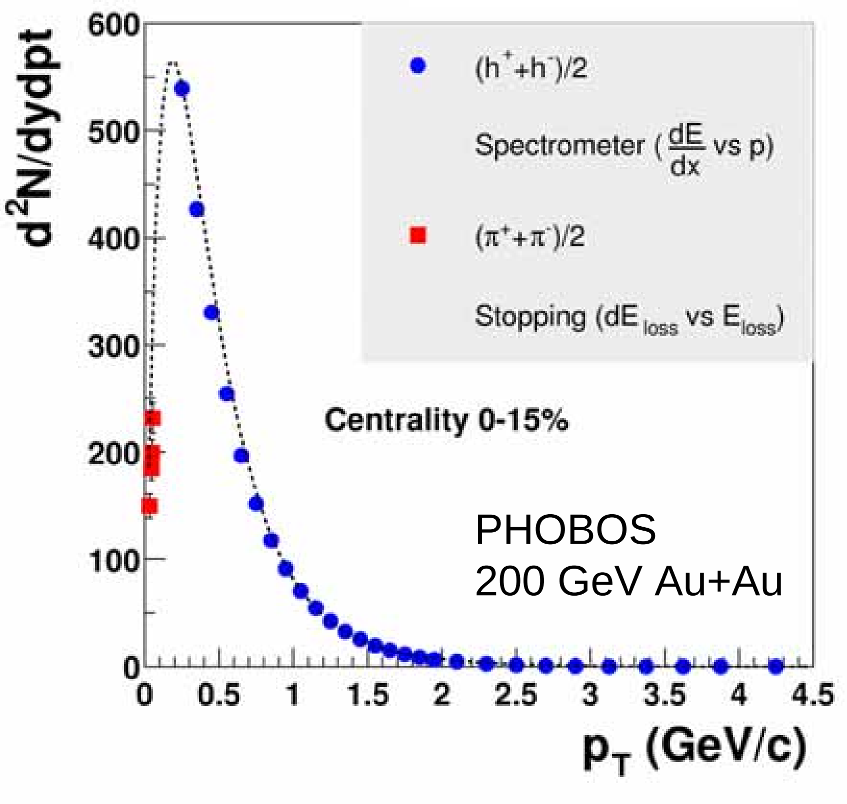
Muon arms
muons; stopped hadrons
p>2 GeV/c
|y| E [1.2,2.4]
$\Delta\Phi=2\pi$

Selected results

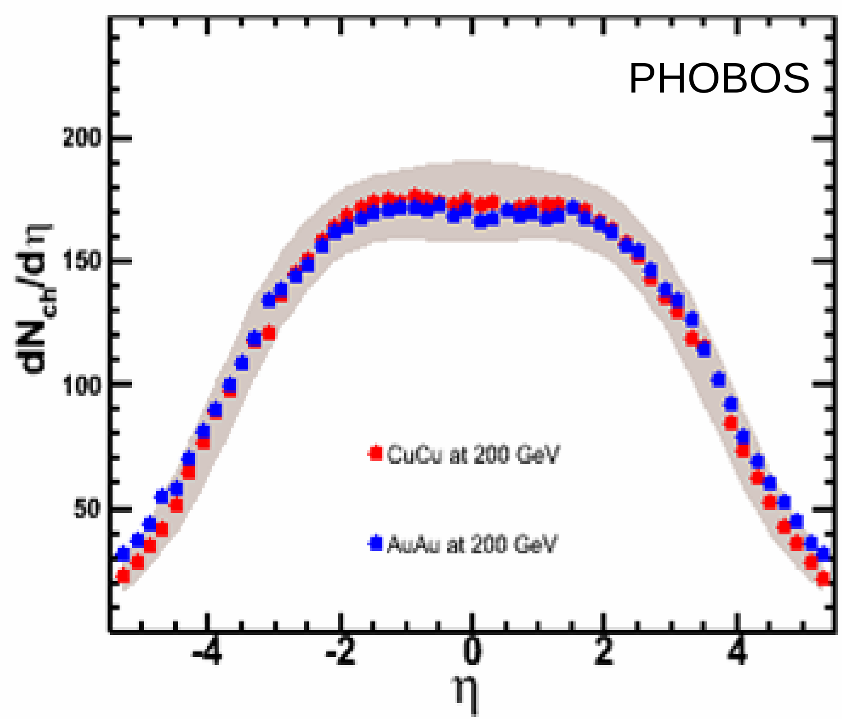
Particle production

Total charged particle production

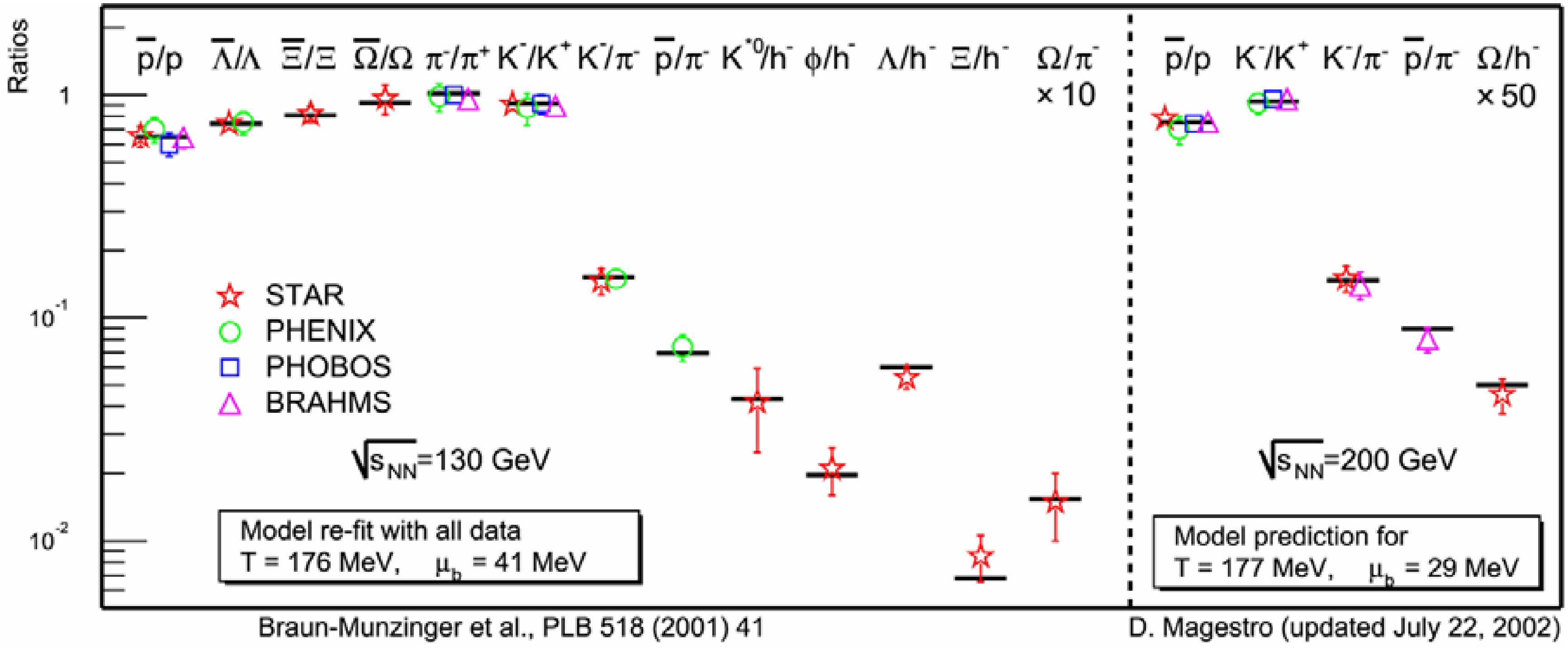
D. Hofman (Moriond '04)



G. Roland (QM'05)



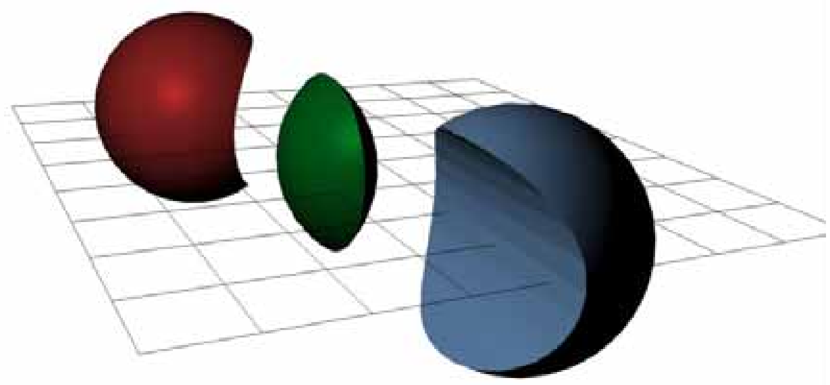
Particle ratio



Elliptic flow (1)

Study the Φ distributions of the particles with respect to the reaction plane.

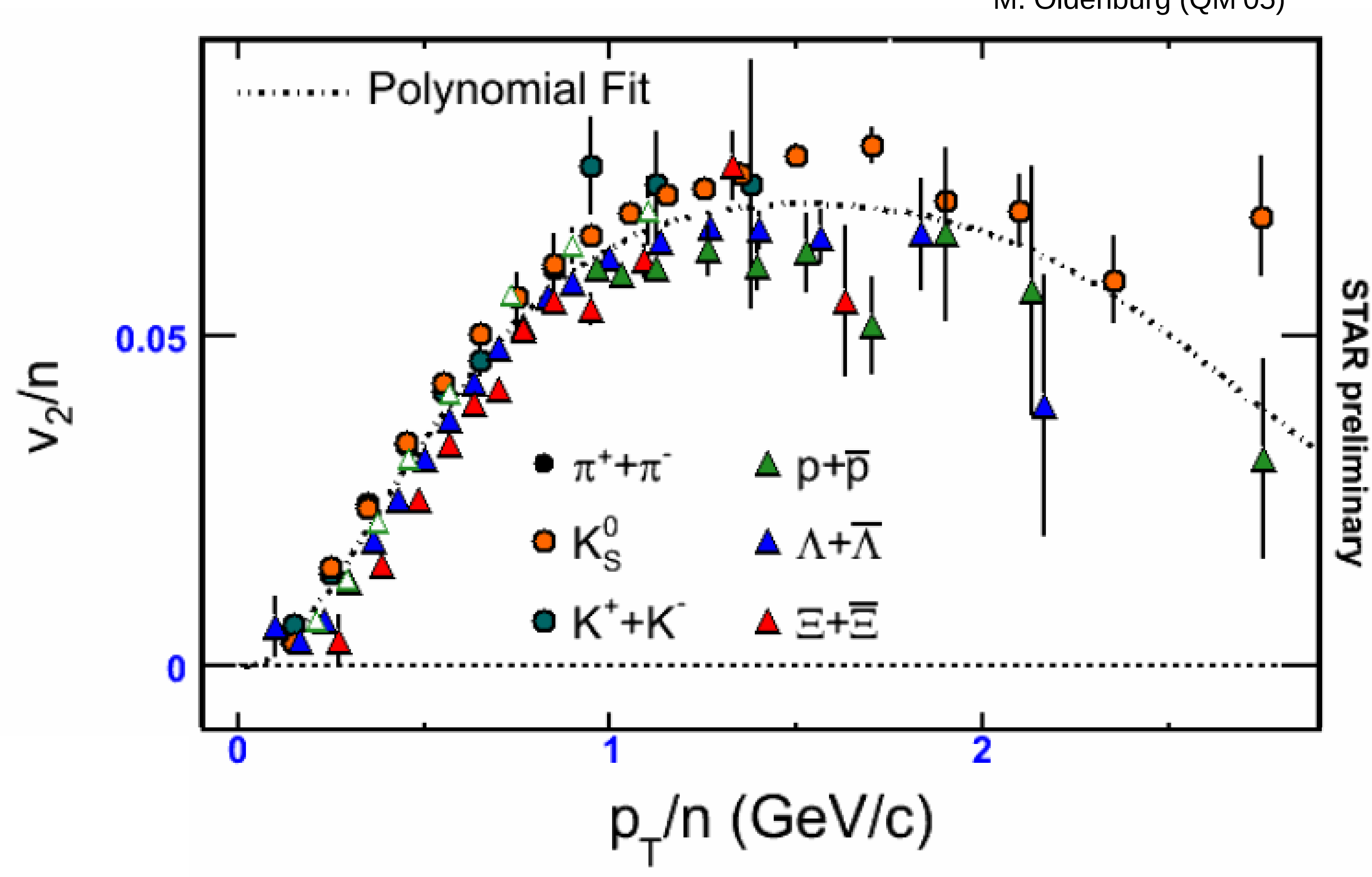
Use v_2, the second coefficient of the Fourrier transform to study the anisotropy related to the pressure gradient in the overlapping area.



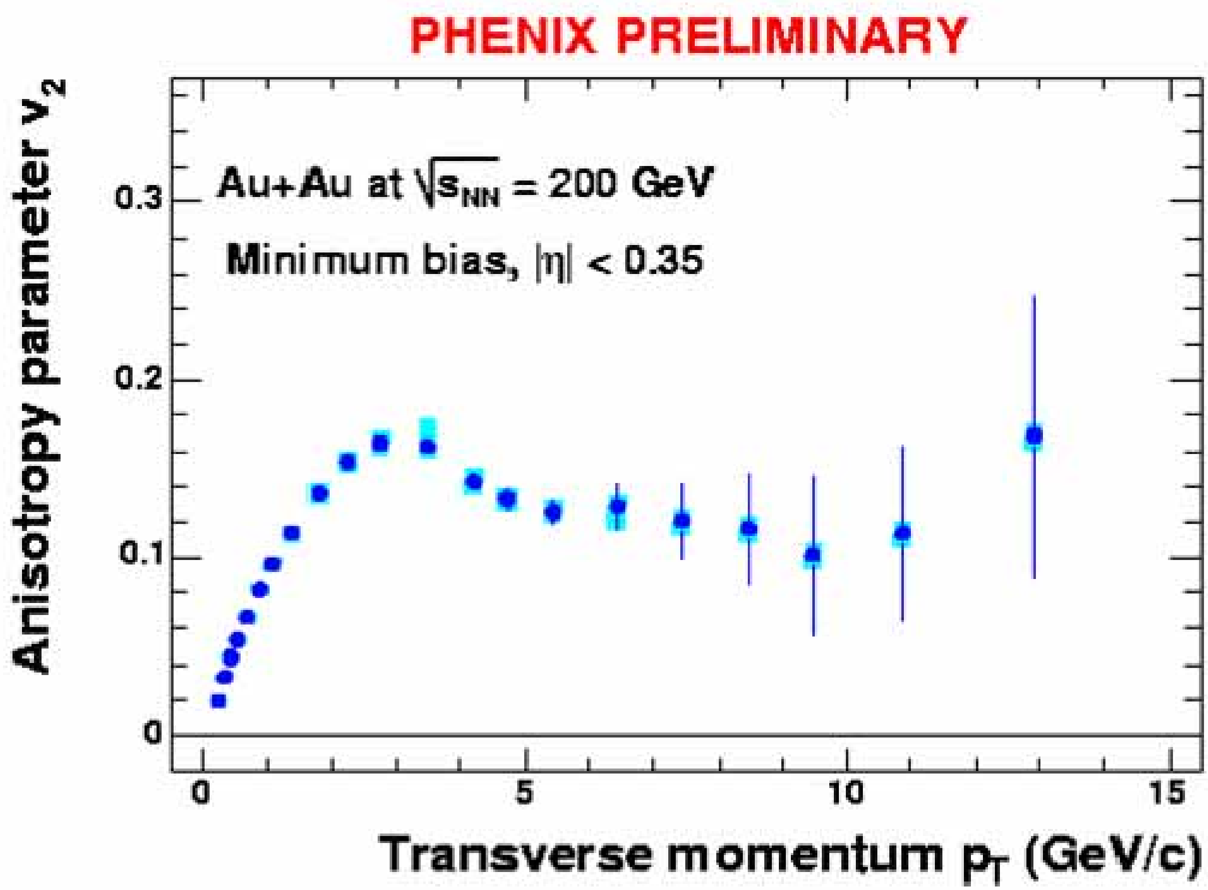
Positive v2 means that the particles are emitted preferentially in the reaction plan as opposed to perpendicular to it.

Elliptic flow (2)

M. Oldenburg (QM'05)



Elliptic flow (3)



Jet Quenching (1)

No direct Jet reconstruction at RHIC.

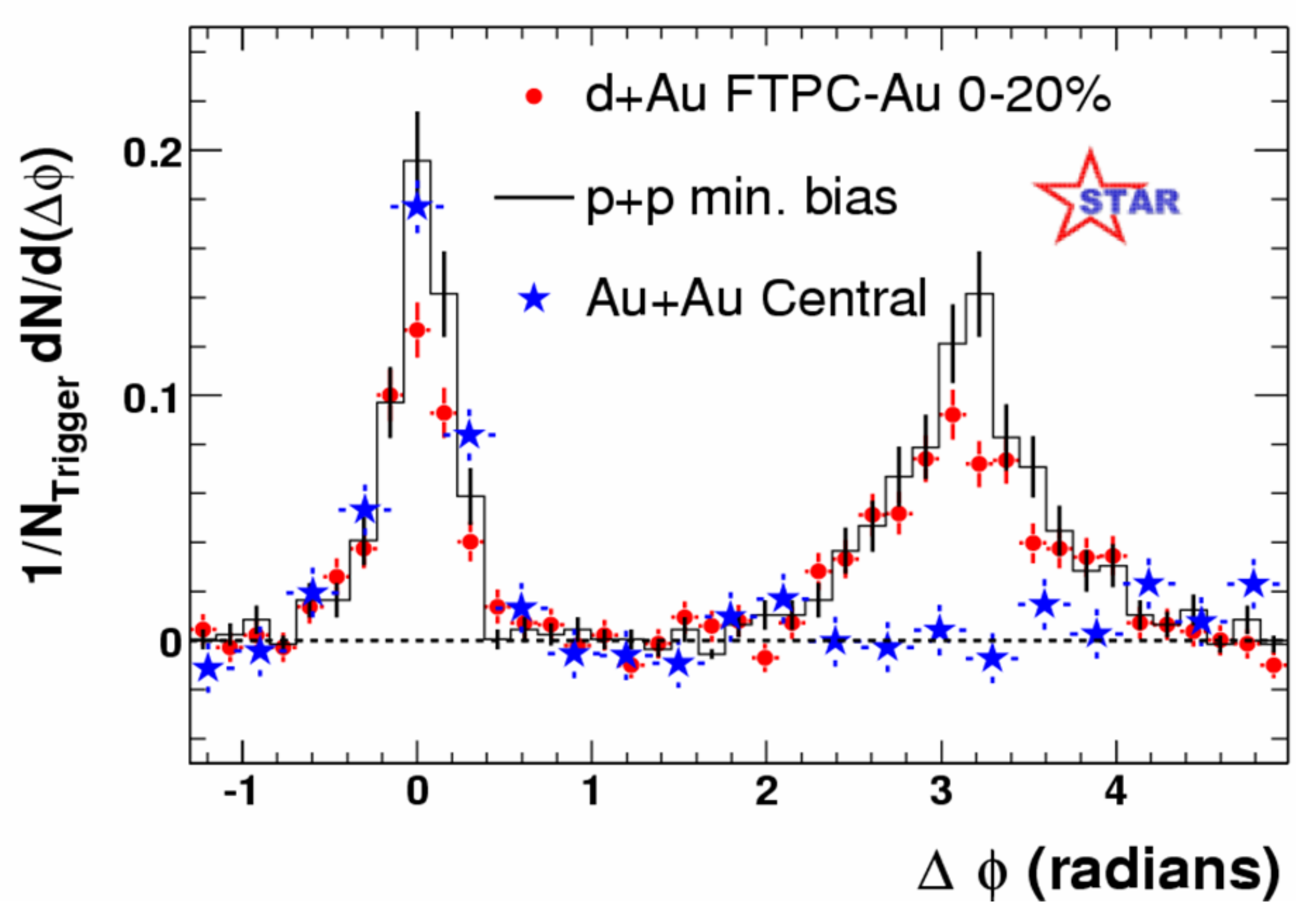
Study back to back jets by looking at Φ correlations between particles.

Use a trigger particle of high enough p_t;

Look at $\Delta\Phi$ between partner and trigger particle

- $\Delta\Phi \sim 0$ same jet
- $\Delta\Phi \sim \pi$ back to back jet

Jet Quenching (2)



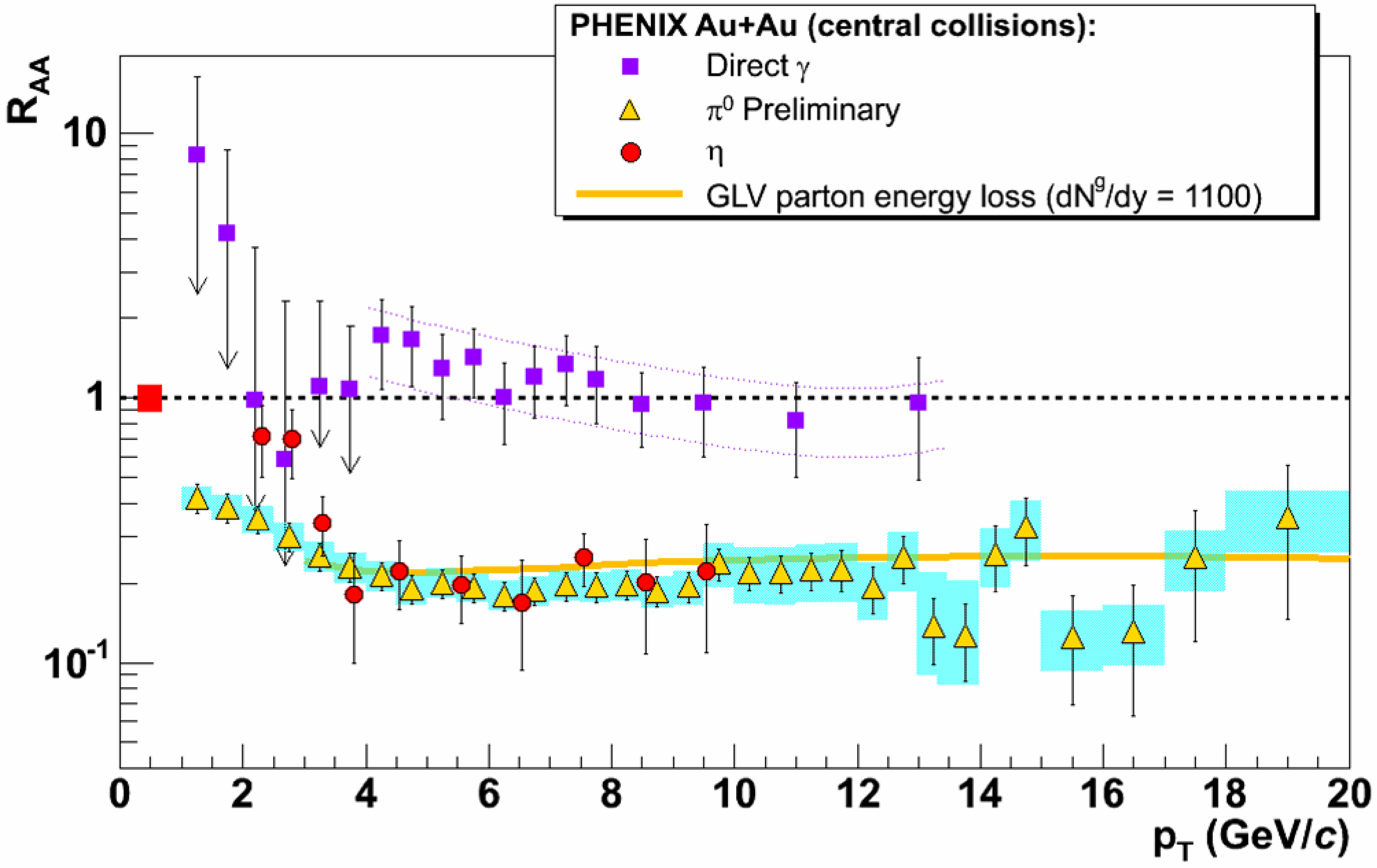
Nuclear modification factor (1)

$$R_{AA} = \frac{\text{yield in A+A}}{N_{col}\text{. yield in p+p}}$$

N_{col} = number of equivalent p+p collisions

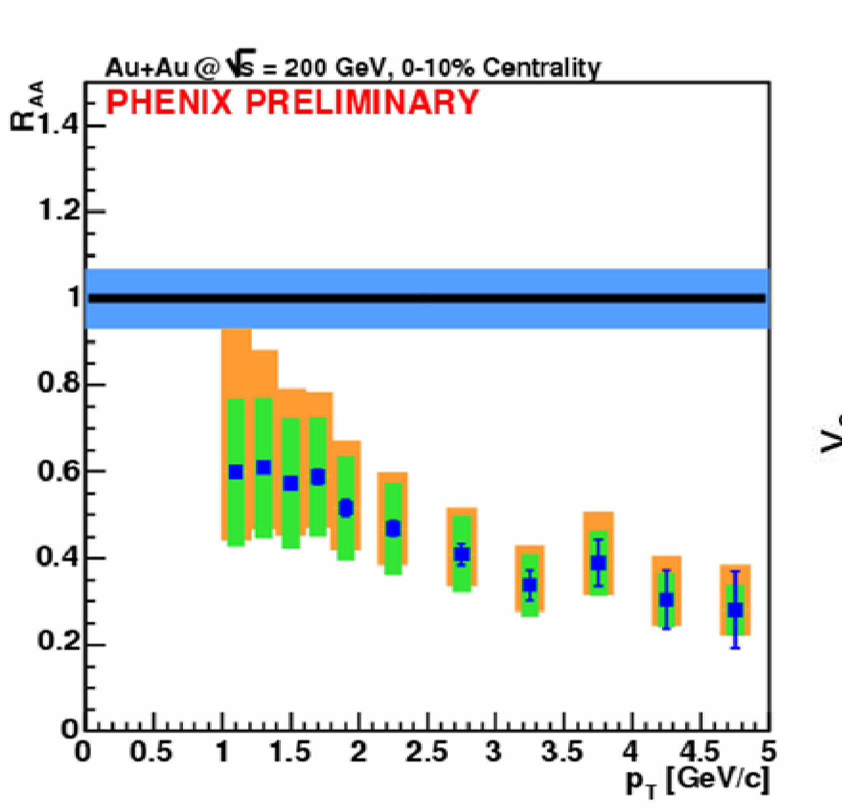
N_{part} = number of participant nucleons

Nuclear modification factor (2)
High Pt particle suppression

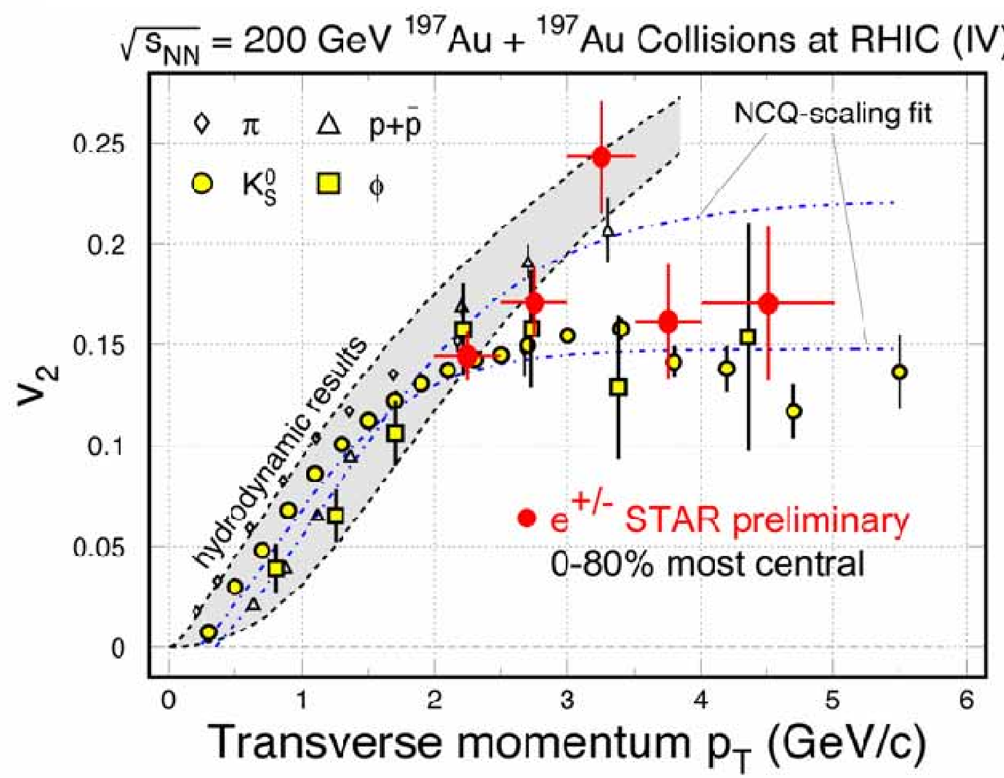


Heavy quarks (1) open charm

Measure open charm via non-photonic single electron spectra



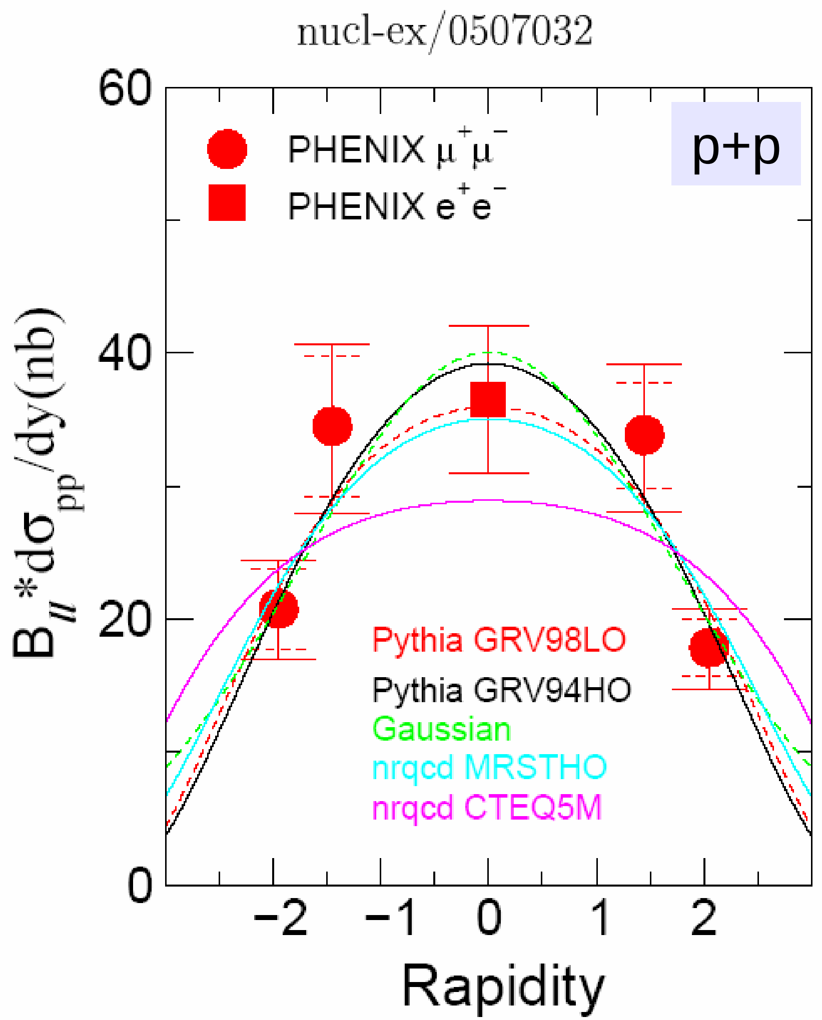
open charm R_{AA}

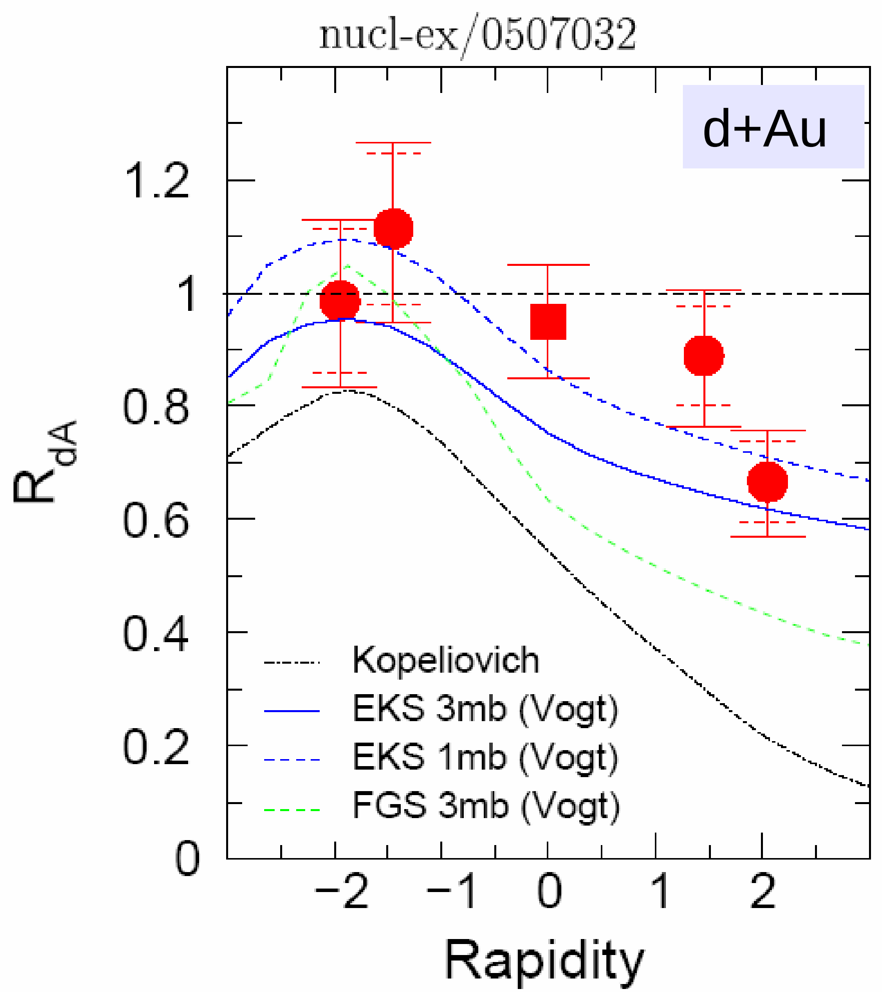


open charm v_2

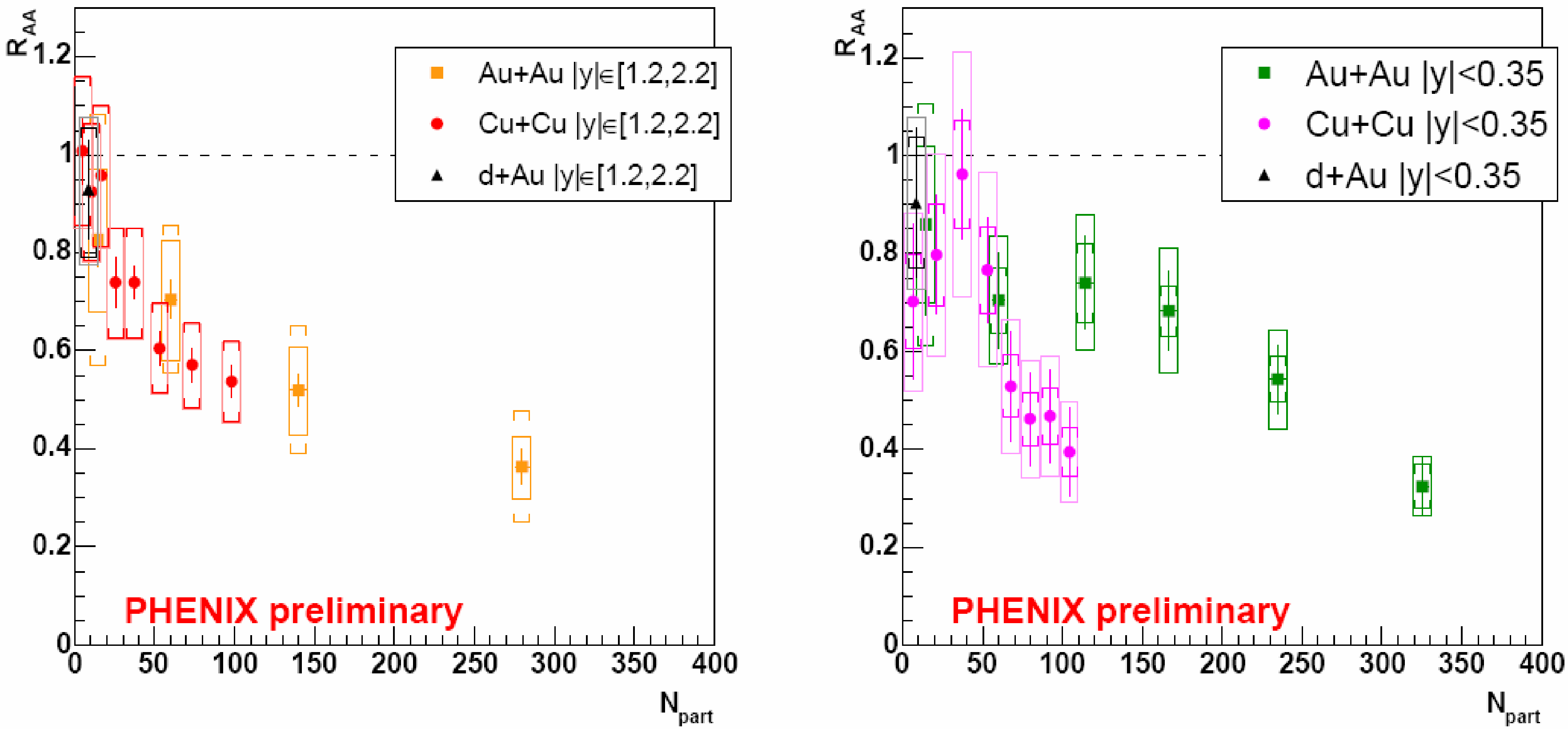
Heavy quarks (2) J/Psi in p+p and d+Au

Measure charmonium via di-lepton pairs





Heavy quarks (3) J/Psi in Cu+Cu and Au+Au



forward rapidity

mid rapidity

Detector upgrades and future RHIC program

Future physics program

Heavy ion
High pT phenomena (identified particle, p_T>20 GeV/c and γ-jet)
Lepton pair continuum (low masses to Drell-Yan)
Heavy flavor production (c and b physics)
Charmonium spectroscopy (J/ψ, ψ' and Υ)

Nucleon structure in nuclei
Gluon saturation and the color glass condensate at low x

Spin structure of the nucleon (p+p)
Gluon spin structure (ΔG/G) with heavy flavor and γ-jet correlations
Quark spin structure (Δq/q) with W-production
Transversity

RHIC II luminosity upgrade

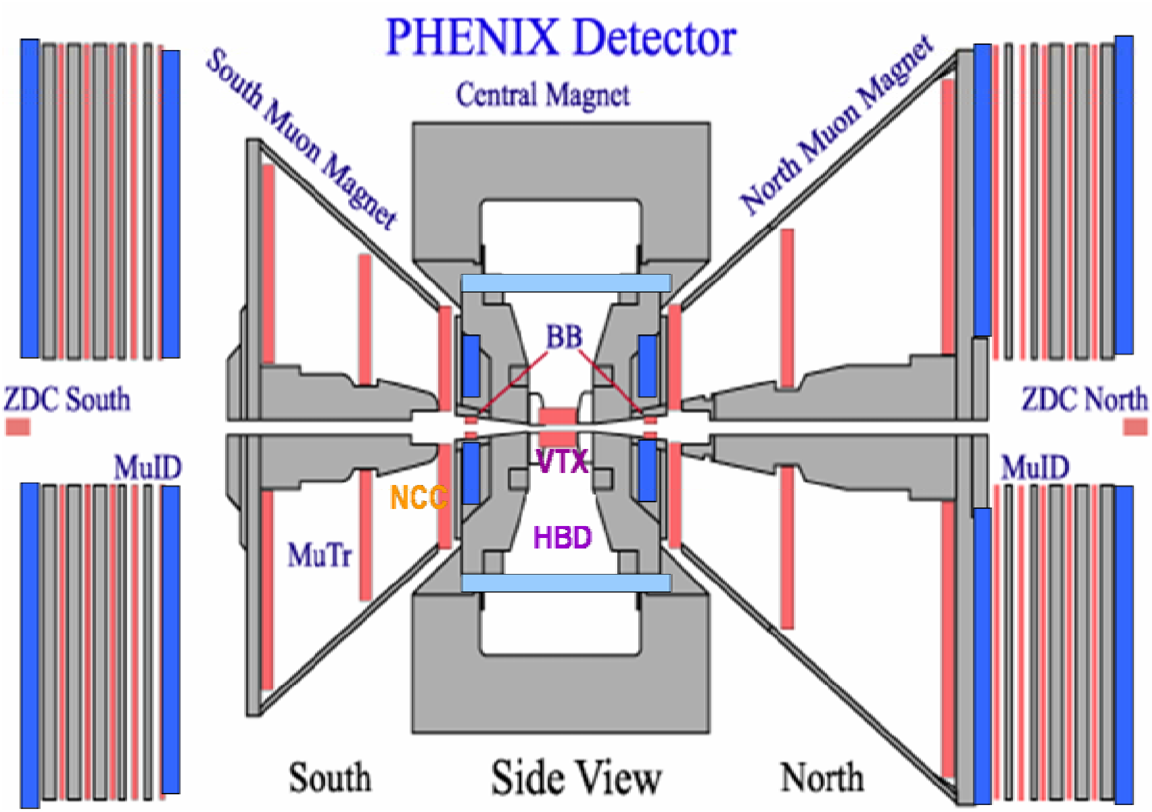
Species	units	Obtained	RHIC II
p+p	pb^{-1}	~6	33
d+Au	nb^{-1}	4.5	62
Cu+Cu	nb^{-1}	2.4	25
Au+Au	mb^{-1}	160	2500

T. Frawley (QWG 06)

STAR upgrades

- Full acceptance time of flight barrel
- Micro vertex detector
- TPC electronic upgrade (faster, higher rate capability)
- Forward tracking upgrade
- Compact fast TPC using GEMS

PHENIX upgrades



- Central and forward Silicon Vertex detector
- Hadron blind detector
- Nose cone calorimeter
- Muon trigger upgrade (resistive plate chambers)
- Reaction plane detector

Conclusion

Conclusion (1)
Heavy flavors at RHIC II and LHC

	RHIC II	**LHC**
Heavy flavor yields/year	similar	
QGP temperature	$2T_c$	$4T_c$
QGP lifetime	~7fm/c	~17fm/c
N_{cc}/collision	10	115
N_{bb}/collision	0.05	5
J/psi mechanism	suppression + coalescence	coalescence
Upsilon mechanism	suppression	suppression + coalescence
Open b		easier ⇐ high cross section
Open c		harder ⇐ high feed down from b

T. Frawley (QWG 06)

Conclusion (2)

http://en.wikipedia.org/wiki/Relativistic_Heavy_Ion_Collider

Fears among the public

Before RHIC started operation, there were fears among the public that the extremely high energy could produce one of the following catastrophic scenarios:

- RHIC creates a black hole
- RHIC creates a transition into a different quantum mechanical vacuum
- RHIC creates strange matter that is more stable than ordinary matter

The main issue in the controversy was the demand by critics for physicists to show an exactly zero probability for such a catastrophic scenario, which physics cannot provide. However, by following the same argument of the critics, and using the same experimental and astrophysical constraints, physicists are also unable to demonstrate a zero probability, but just an upper limit for the likelihood, that tomorrow Earth will be struck with a "doomsday" cosmic ray, resulting in the same destructive scenarios. According to this argument of upper limits, RHIC would still modify the chance for the Earth's survival by an extremely marginal amount.

Additional slides

PHENIX upgrades

- **Aerogel and time-of-flight**
  provide complete p/K/pi separation for momenta up to ~10 GeV/c
- **Hadron-blind detector**
  detects electrons from near the vertex
- **Reaction plane detector**
  measures reaction plane with resolution better by factor 2
  minimum bias trigger for low energy runs
- **Vertex detector**
  detects displaced vertices from the decay of charm or bottom mesons
- **Forward calorimeter**
  provides photon+jet studies over a wide kinematic range
- **Resistive plate chambers**
  triggers on rare probes (J/psi, upsilon, W) at high luminosity

Bibliography

http://www.phenix.bnl.gov/phenix/WWW/publish/dave/colloquia/BNL_colloquium.ppt

http://qm2005.kfki.hu/Talks/Globe/aug9/1100//IT_QM05_Summary.ppt

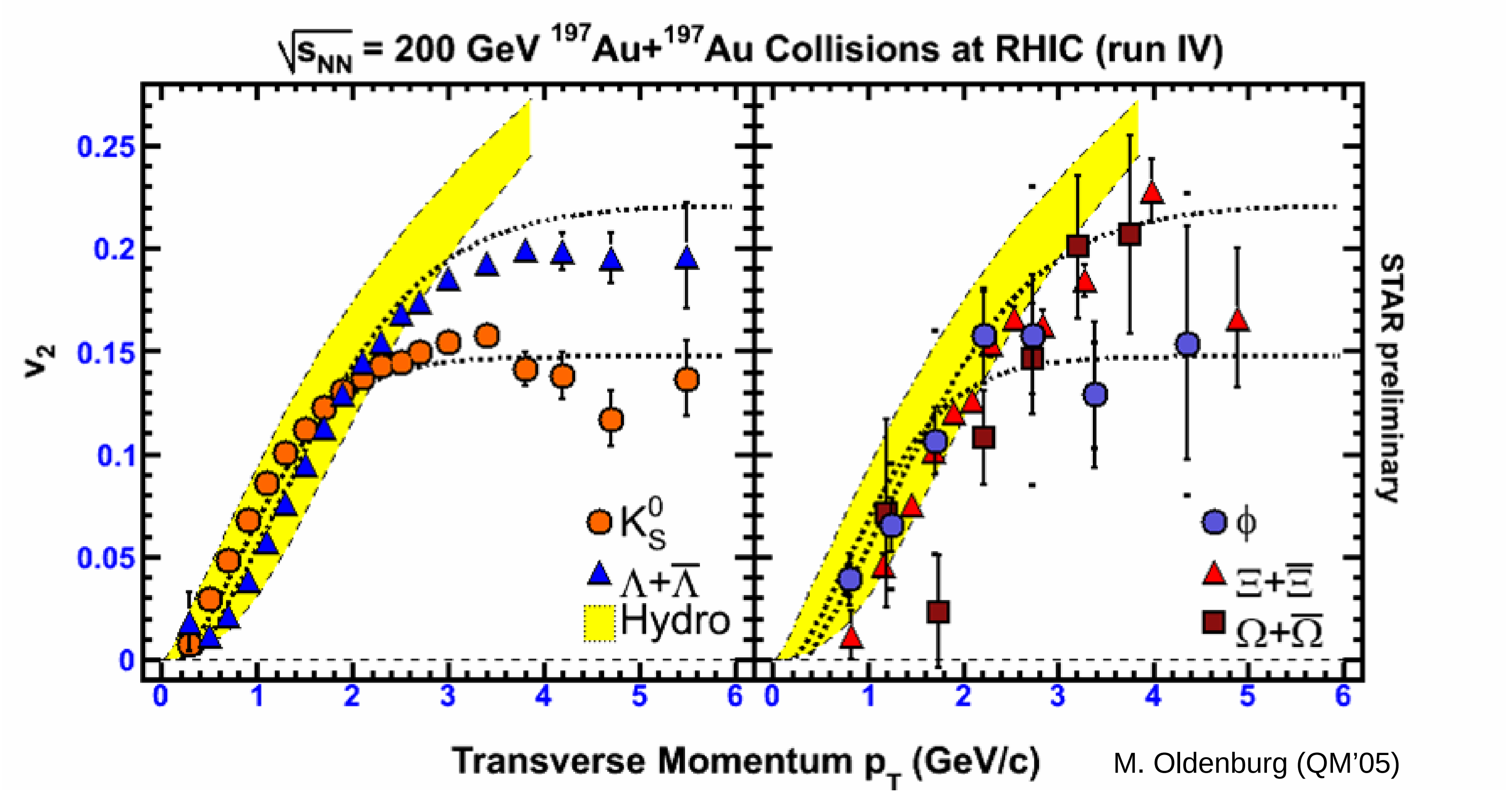
http://www.phenix.bnl.gov/phenix/WWW/publish/zajc/sp/presentations/RBUP05

http://www-rnc.lbl.gov/qm2004/talks/parallel/Tuesday04/ADrees_PPTWin.ppt

https://www.phenix.bnl.gov/phenix/WWW/p/draft/frawley/QWG_phenix_quarkonium_june30_2006.pdf

http://en.wikipedia.org/wiki/Relativistic_Heavy_Ion_Collider

Elliptic flow (1)



M. Oldenburg (QM'05)

Jet quenching (3)

Lower threshold for trigger and partner. The way side jet is here but its shape is affected by the medium.