

# PH KENIX Status and Recent Results

Matthias Grosse Perdekamp, UIUC and RBRC

- PHENIX status and run 2003 performance
- High sensitivity to rare processes  $J/\psi$  and high pT hadrons in Au-Au, d-Au and p-p collisions
- Brief review of run 2002 results
- Hadron production at high transverse momenta charged hadrons and  $\pi^0$  in Au-Au and p-p First look at PHENIX d-Au data





Brazil University of São Paulo, São Paulo China Academia Sinica, Taipei, Taiwan

China Institute of Atomic Energy, Beijing

**Peking University, Beijing** 

France LPC, University de Clermont-Ferrand, Clermont-Ferrand

Dapnia, CEA Saclay, Gif-sur-Yvette

IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, Orsay LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau SUBATECH, Ecòle des Mines at Nantes, Nantes

Germany University of Münster, Münster

Hungary Central Research Institute for Physics (KFKI), Budapest

**Debrecen University, Debrecen** 

Eötvös Loránd University (ELTE), Budapest

India Banaras Hindu University, Banaras

**Bhabha Atomic Research Centre, Bombay** 

Israel Weizmann Institute, Rehovot

Japan Center for Nuclear Study, University of Tokyo, Tokyo

Hiroshima University, Higashi-Hiroshima

KEK, Institute for High Energy Physics, Tsukuba

**Kyoto University, Kyoto** 

Nagasaki Institute of Applied Science, Nagasaki

RIKEN, Institute for Physical and Chemical Research, Wako

**RIKEN-BNL Research Center, Upton, NY** 

University of Tokyo, Bunkyo-ku, Tokyo Tokyo Institute of Technology, Tokyo University of Tsukuba, Tsukuba

Waseda University, Tokyo

S. Korea Cyclotron Application Laboratory, KAERI, Seoul

Kangnung National University, Kangnung

Korea University, Seoul

Myong Ji University, Yongin City

System Electronics Laboratory, Seoul Nat. University, Seoul

Yonsei University, Seoul

Russia Institute of High Energy Physics, Protovino

Joint Institute for Nuclear Research, Dubna

**Kurchatov Institute, Moscow** 

PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg

St. Petersburg State Technical University, St. Petersburg

Sweden Lund University, Lund



#### 12 Countries; 57 Institutions; 460 Participants

**USA** Abilene Christian University, Abilene, TX

Brookhaven National Laboratory, Upton, NY University of California - Riverside, Riverside, CA

University of Colorado, Boulder, CO

Columbia University, Nevis Laboratories, Irvington, NY

Florida State University, Tallahassee, FL Georgia State University, Atlanta, GA

University of Illinois Urbana Champaign, IL lowa State University and Ames Laboratory, Ames, IA

Los Alamos National Laboratory, Los Alamos, NM

Lawrence Livermore National Laboratory, Livermore, CA

University of New Mexico, Albuquerque, NM New Mexico State University, Las Cruces, NM

Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY

Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY

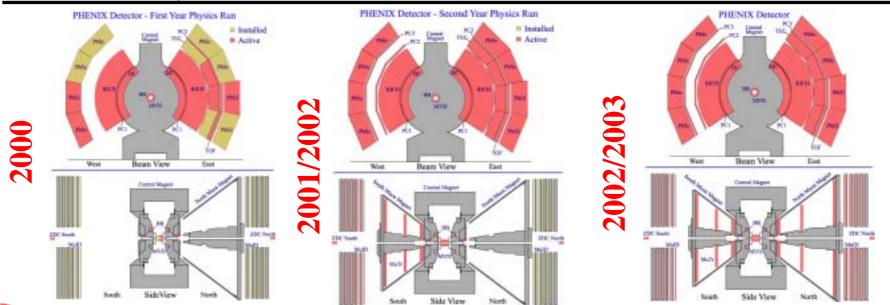
Oak Ridge National Laboratory, Oak Ridge, TN

University of Tennessee, Knoxville, TN Vanderbilt University, Nashville, TN



### PHENIX: Run History

Ru	ın	Year	Species	s <sup>1/2</sup> [GeV]	∫Ldt	$N_{tot}$
0.2	[	2000	Au-Au	130	1 μb <sup>-1</sup>	10M
02	2	2001/2002	Au-Au	200	$24~\mu b^{-1}$	170M
			p-p	200	0.15 pb <sup>-1</sup>	3.7G
03	3	2002/2003	d-Au	200	2.74 nb <sup>-1</sup>	5.5G
			p-p	200	ongo	ing



### PHENIX Status in 2003: Design Configuration!

#### **Central Arm Tracking**

**Drift Chamber** 

**Pad Chambers** 

Time Expansion Chamber

#### **Muon Arm Tracking**

Muon Tracker: North Muon Tracker

#### **Calorimetry**

**PbGl** 

PbSc

#### **Particle Id**

Muon Identifier: North Muon Identifier

**RICH** 

**TOF** 

**TEC** 

#### **Global Detectors**

**BBC** 

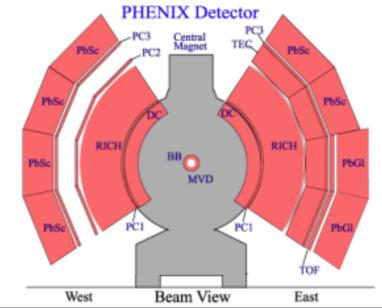
**ZDC/SMD Local Polarimeter** 

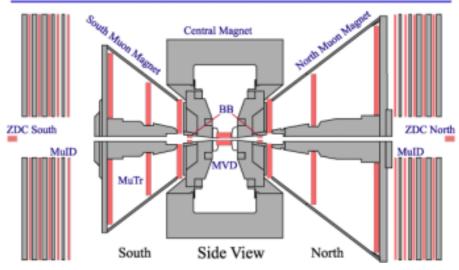
**Forward Hadron Calorimeters** 

**NTC** 

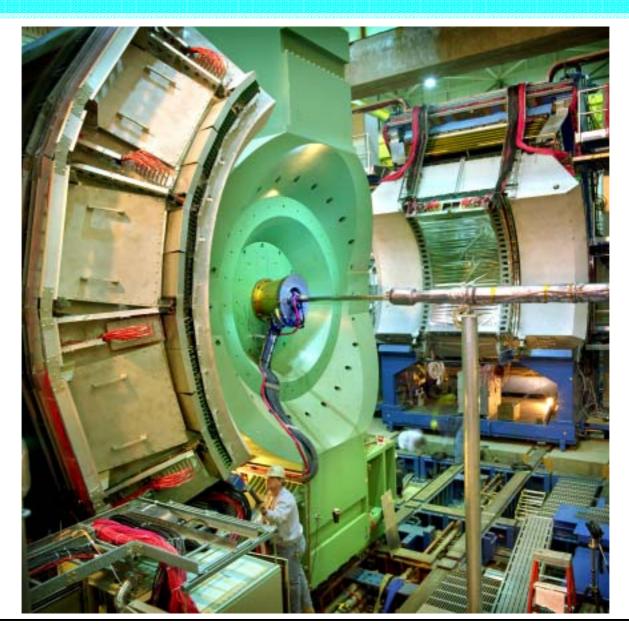
**MVD** 

#### **Online Calibration and Production**



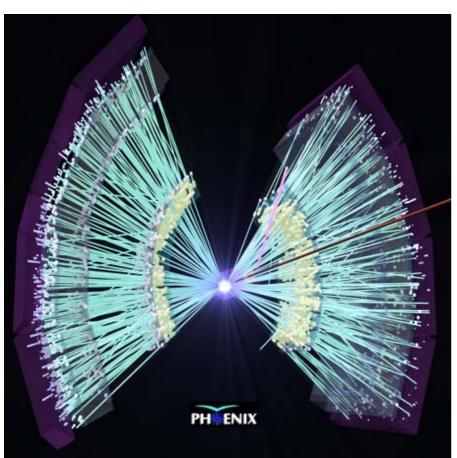


### The PHENIX Detector: Central Arms

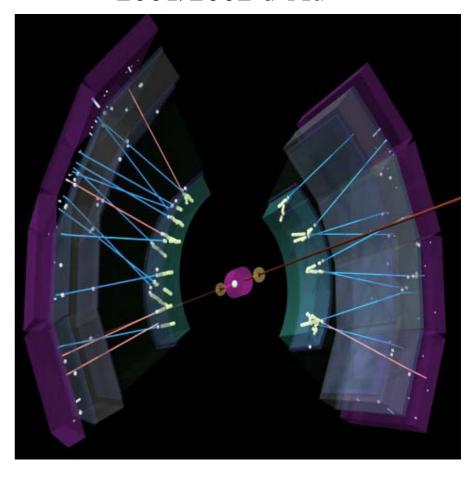


### Two Collisions as seen by the PHENIX Central Arms

2001/2002 Au-Au



2001/2002 d-Au



### DAQ and Trigger System: Rare Event Capability

#### Trigger configuration in d-Au

o Raw rate < 50 kHz

#### o First level trigger:

3 minimum bias

1 single electron  $(J/\psi)$ 

1electron pair (♦)

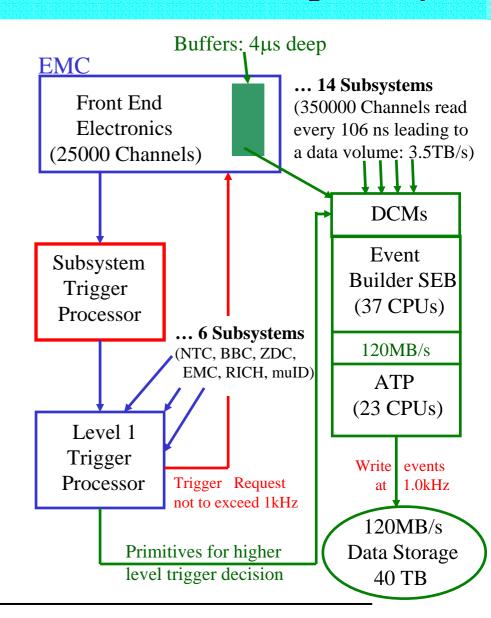
4 photon (0.8, 2.1, 2.8, 3.5 GeV)

2 muon

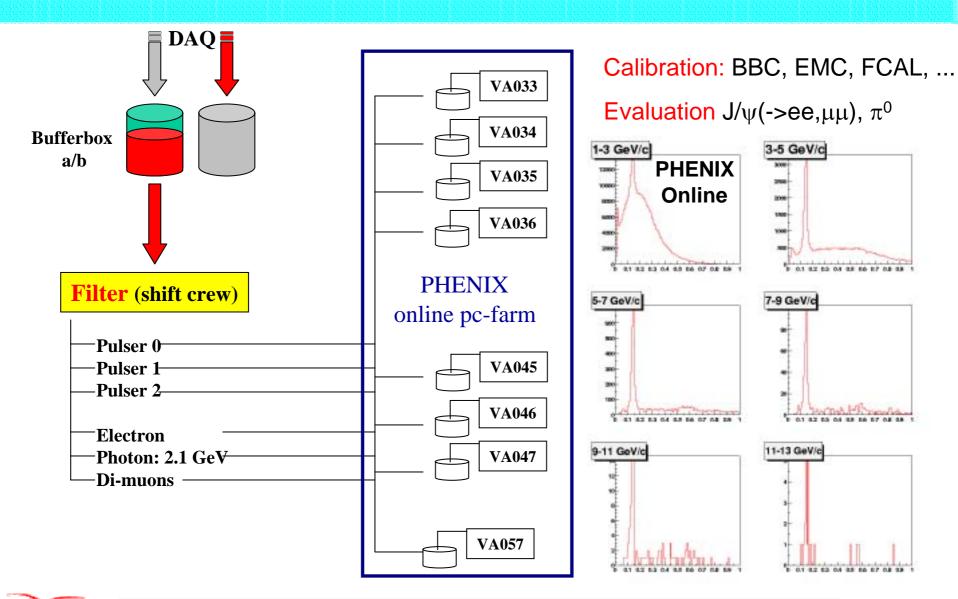
2 di-muon  $(J/\psi)$ 

o Level 2: off

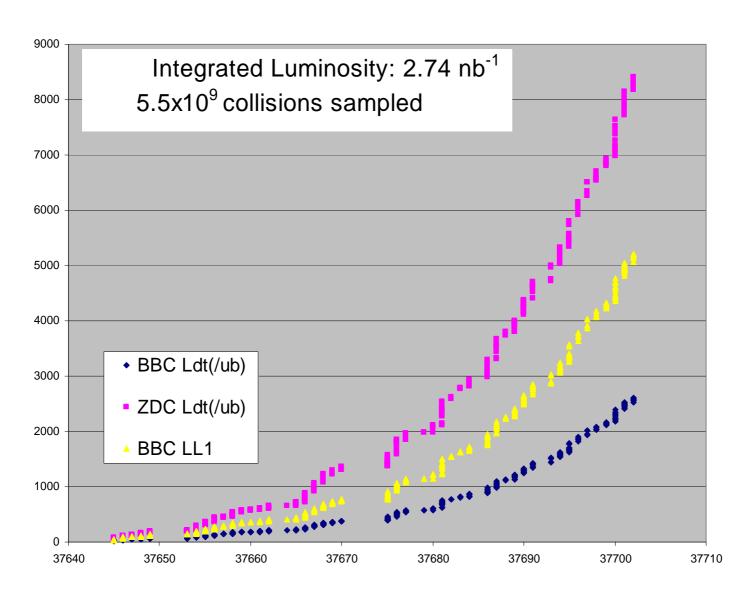
o Extend to 300kHz in p-p



#### Online Calibration, Evaluation and Production



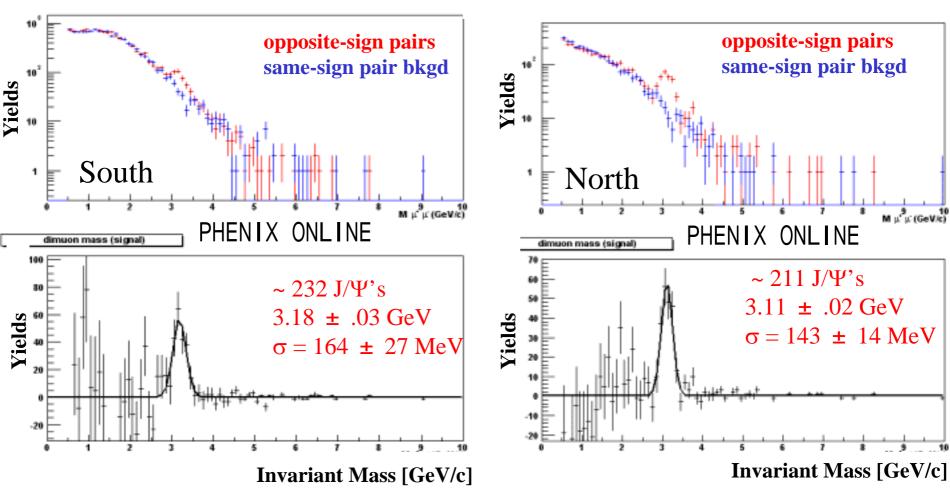
### Run 2003 d-Au $\sqrt{s} = 200 \text{ GeV}$



### Run 2003 d-Au $\sqrt{s} = 200 \text{ GeV}$ :

### **Performance of the Muon Spectrometers**

Di-muon invariant mass spectra —



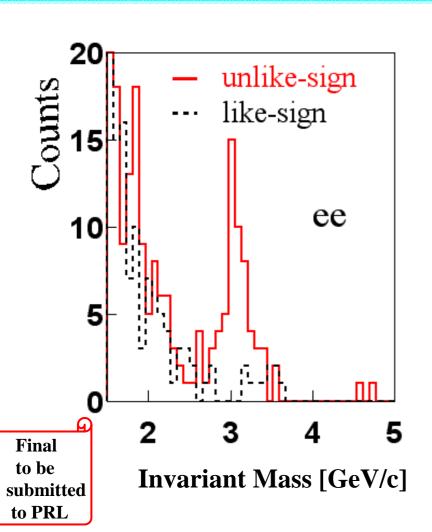


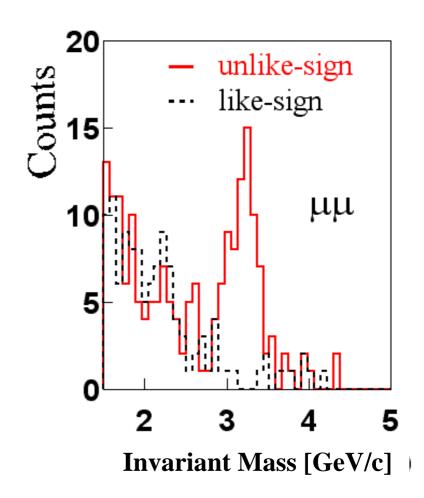
#### PHENIX results

- Run -2 <u>final</u> results:
  - High pT pi0 (Au+Au @ 200 GeV): submitted to PRL nucl-ex/0304022
  - High pT pi0 (p+p @ 200 GeV): submitted to PRL hep-ex/0304038
  - Elliptic flow of identified particles (Au+Au @ 200 GeV): to be submitted to PRL
  - J/Psi yields (Au+Au @ 200 GeV) to be submitted to PRC
  - J/Psi yields (p+p @ 200 GeV) to be submitted to PRL
  - p,pbar high pT enhancement (Au+Au @ 200 GeV) to be submitted to PRL
- Run-2 <u>preliminary</u> results:
  - dN/dy and dE\_T/dy (Au+Au @ 200 GeV)
  - Identified charged particle spectra and yields (Au+Au @ 200 GeV)
  - Inclusive charged particle at high pT (Au+Au @ 200 GeV)
  - phi -> KK (Au+Au @ 200 GeV)
  - Event-by-event fluctuations (Au+Au @ 200 GeV)
  - Di-Lepton continuum (Au+Au @ 200 GeV)
  - Two-pion correlations (Au+Au @ 200 GeV)
  - d and dbars (Au+Au @ 200 GeV)
- Run-3 <u>preliminary</u> results:
  - High pT pi0 (d+Au @ 200 GeV)
  - High pT inclusive charged particles (d+Au @ 200 GeV)

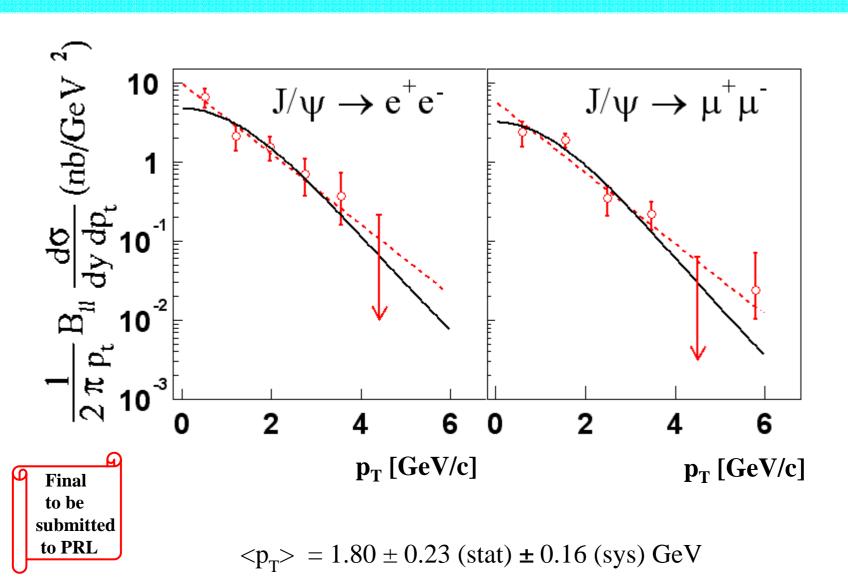


### Run 2002 p-p $\sqrt{s}$ = 200 GeV: $J/\psi$ Invariant Mass Distribution



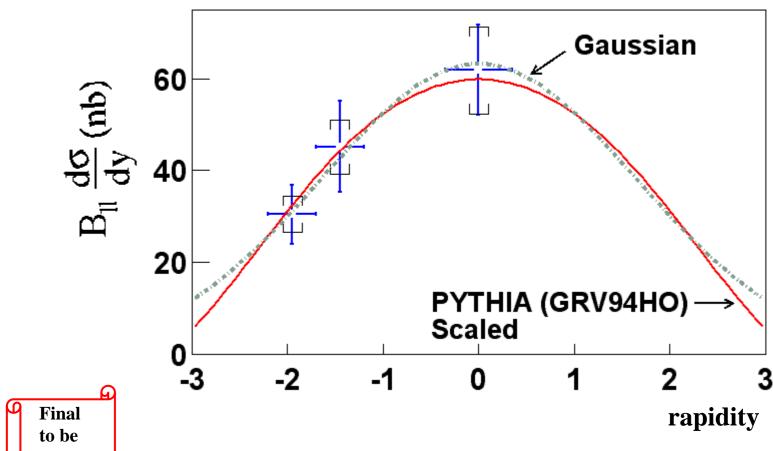


### Run 2002 p-p $\sqrt{s}$ = 200 GeV: J/ $\psi$ p<sub>T</sub> Distribution



# Run 2002 p-p $\sqrt{s}$ = 200 GeV:

### J/ψ Rapidity Distribution

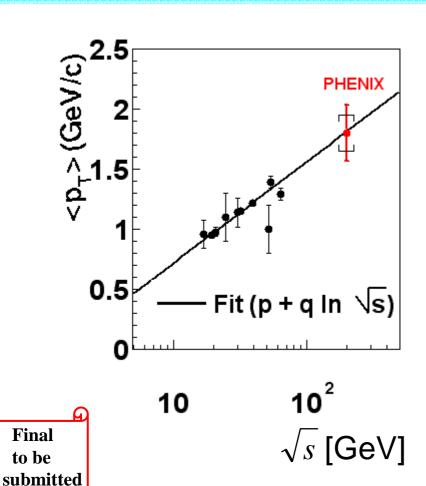


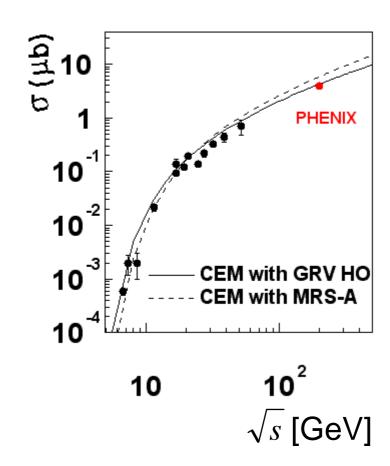
to be submitted to PRL

 $\sigma = 3.98 \pm 0.62 \text{ (stat)} \pm 0.56 \text{ (sys)} \pm 0.41 \text{(abs)} \text{ } \mu\text{b}$ 

### Run 2002 p-p $\sqrt{s}$ = 200 GeV:

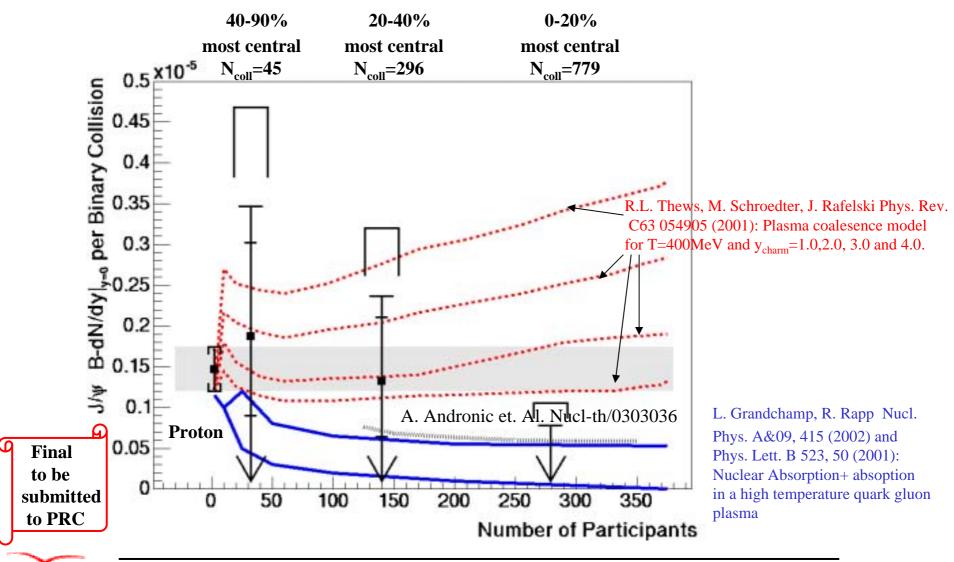
### **Comparison with Previous Experiments**





to PRL

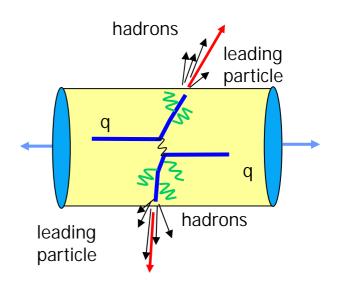
### Run 2002 Au-Au $\sqrt{s}$ = 200GeV: J/ $\psi$ Production Centrality Dependence



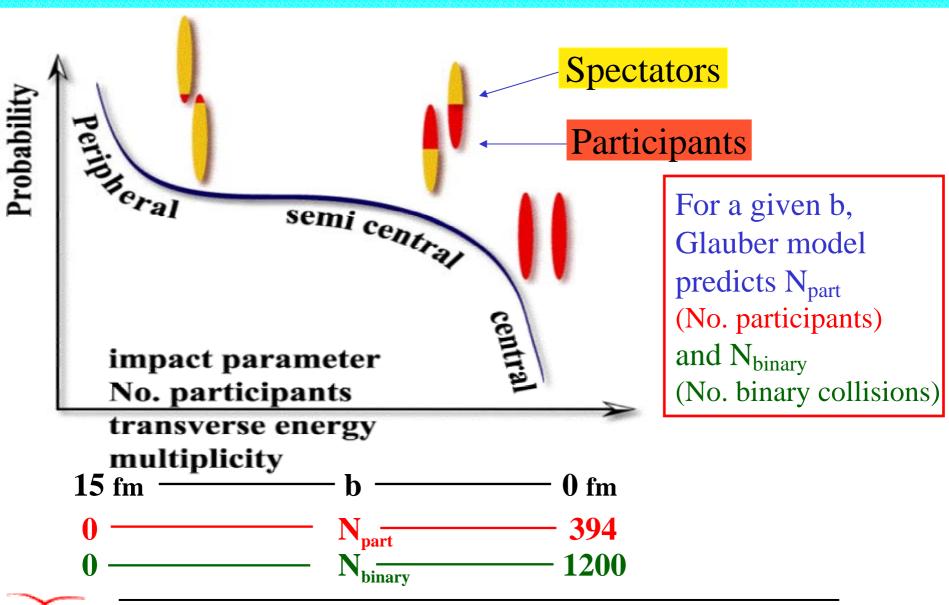
### Hadron Production at Large Transverse Momenta

- in colored "quark matter"
  partons expected to loose
  significant energy via gluon
  bremsstrahlung
  - attenuation or absorption of jets "jet quenching"
  - suppression of high p<sub>T</sub> hadrons
  - modification of angular correlation
  - changes of particle composition

jet production in quark matter



## Collision Geometry -- "Centrality"



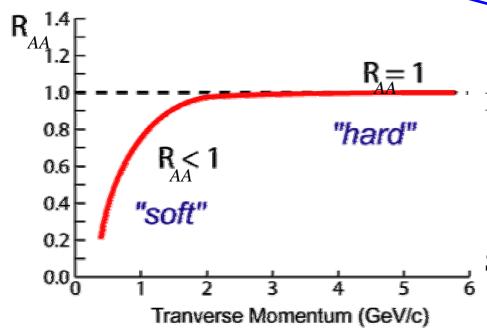
### Quantify Nuclear Modification of Hadron Spectra

- 1. Compare Au+Au to nucleon-nucleon cross sections
- 2. Compare Au+Au central/peripheral

Nuclear Modification Factor:

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

nucleon-nucleon cross section





If no "effects":

 $R_{AA} = 1$  in regime of soft physics  $R_{AA} = 1$  at high- $p_T$  where hard scattering dominates

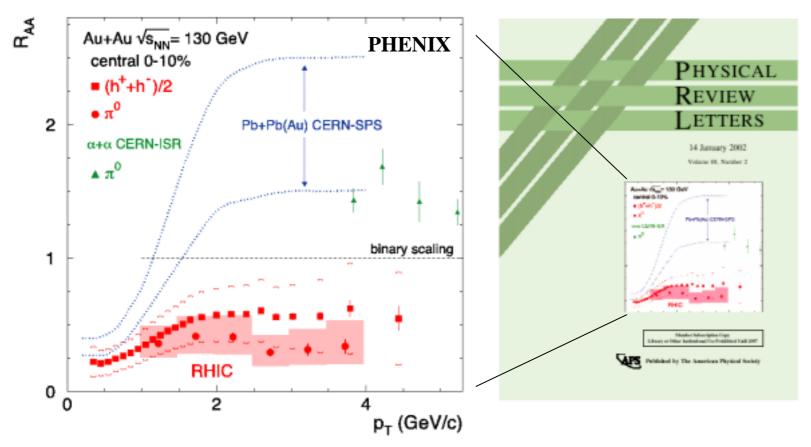
Suppression:

 $R_{AA} < 1$  at high- $p_T$ 



### Run 2000 p-p $\sqrt{s}$ = 130 GeV:

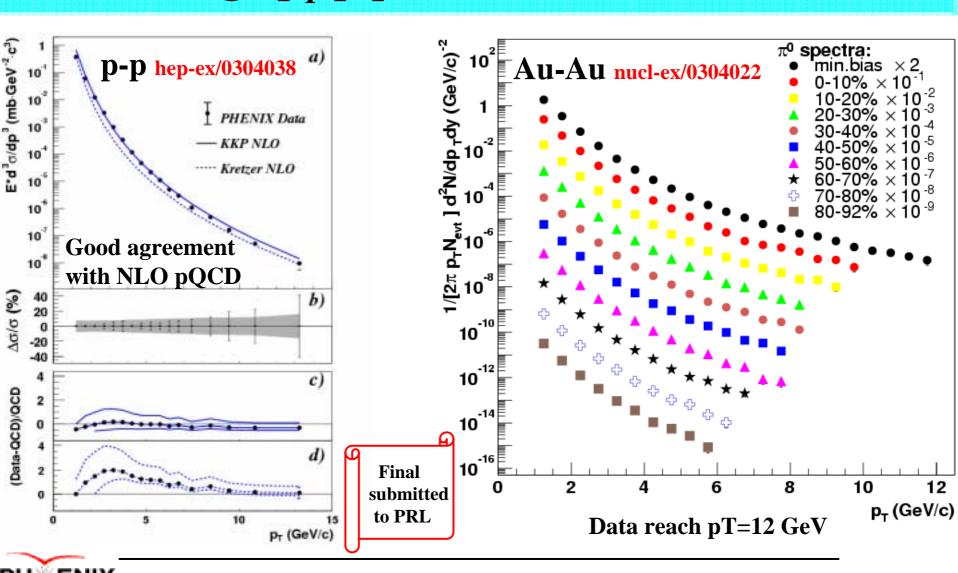
### Discovery of High p<sub>T</sub> Hadron Suppression at RHIC



- o Charged hadron and neutral pion results with independent systematic errors!
- o Extrapolation from UA1 as proton reference.

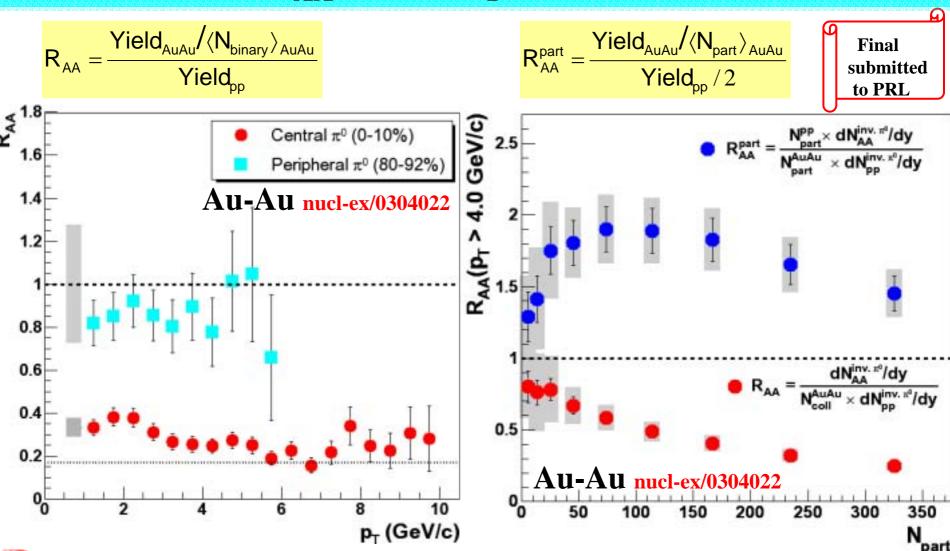


# Run 2001/2002 p-p + Au-Au $\sqrt{s}$ = 200 GeV: High p<sub>T</sub> p-p and Au-Au $\pi^0$ Results



#### Run 2001/2002 Au-Au $\sqrt{s} = 200 \text{ GeV}$ :

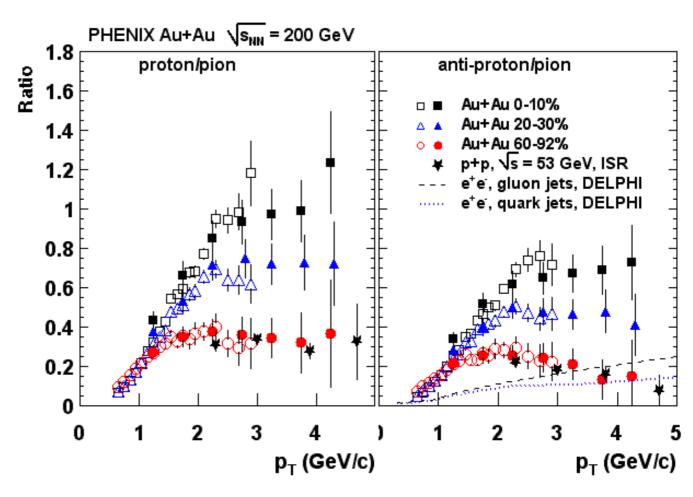
### R<sub>AA</sub>: High p<sub>T</sub> Suppression



### Run 2001/2002 Au-Au $\sqrt{s}$ = 200 GeV: Particle Composition at High p<sub>T</sub>

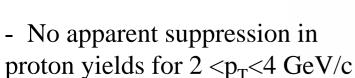
- $p/\pi \sim 1$  at high  $p_T$  for central collisions
- In peripheral collisions,  $p/\pi \sim 0.4$

Final to be submitted to PRL

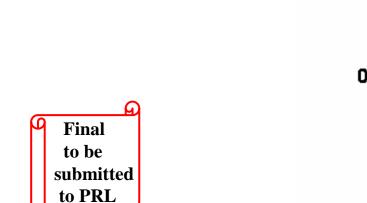


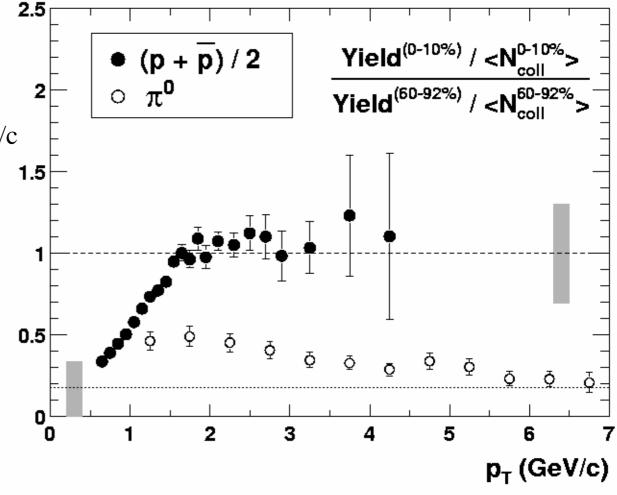
#### Run 2001/2002 Au-Au $\sqrt{s} = 200 \text{ GeV}$ :

### Central to Peripheral Ratio for Protons and Pions



- Different production mechanism for protons?





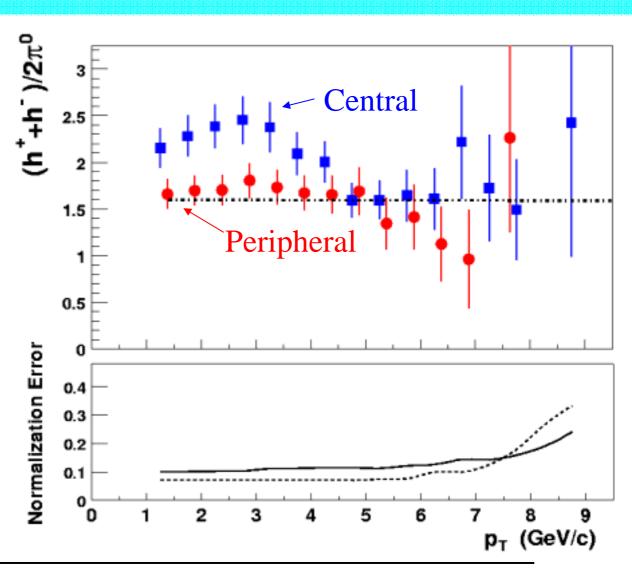
#### Run 2001/2002 Au-Au $\sqrt{s} = 200 \text{ GeV}$ :

### Particle Composition at high p<sub>T</sub>

 $(h^++h^-)/2\pi^0 \sim 50\%$ greater in central than peripheral at mid p<sub>T</sub>

similar again for pT>5 GeV/c

Final to be submitted to PRL

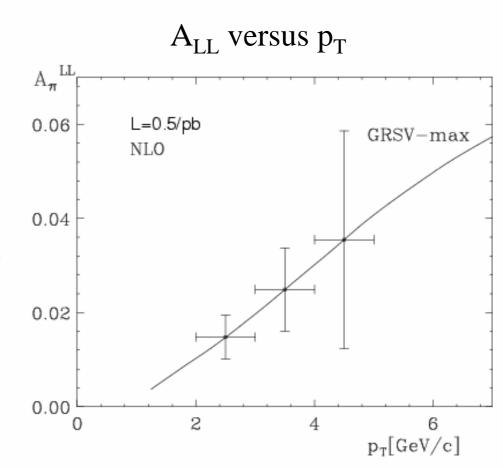


# Run 2002/2003: d-Au and p-p at $\sqrt{s} = 200$ GeV

p-p run goal:

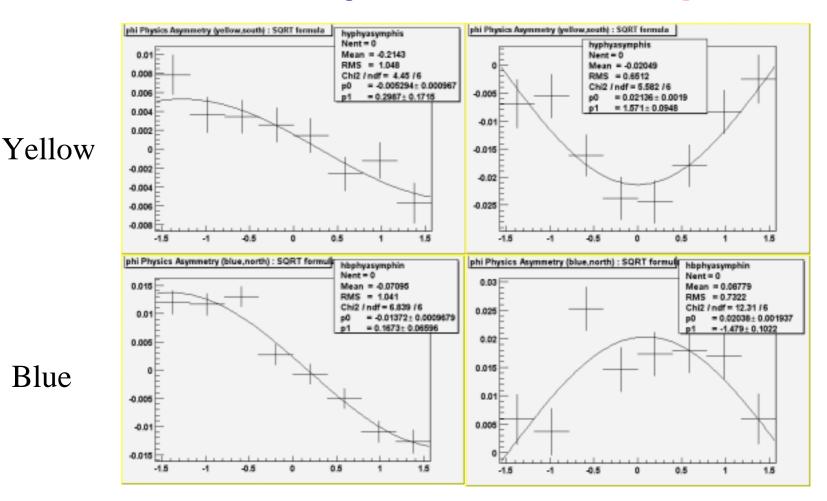
Access gluon polarization through double spin asymmetries  $A_{LL}$  inclusive  $\pi^0$  production

Required: 30% Polarization and JLdt=500nb<sup>-1</sup>



### Successful Rotator Commissioning/Local Polarimetry

Rotators on --> vertical polarization Rotators on--> radial polarization



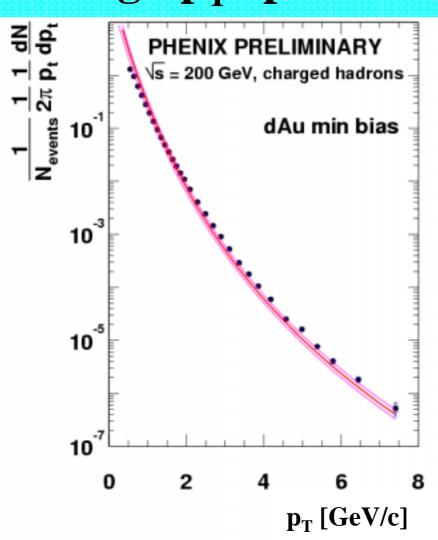
See Kiyoshi Tanida's talk Friday!

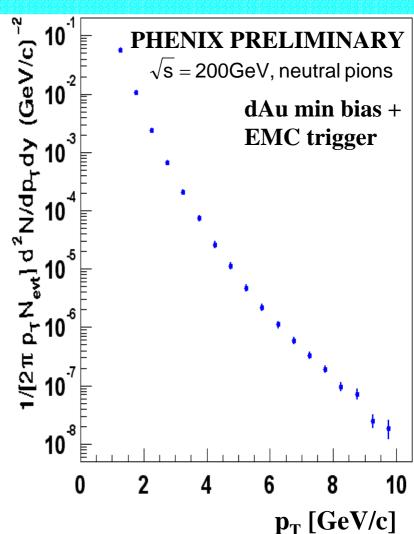


Blue

### Run 2002/2003:

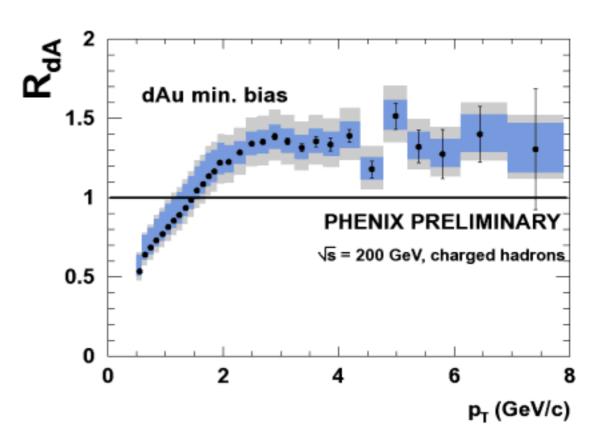
## High $p_T$ Spectra in d-Au at $\sqrt{s} = 200$ GeV





## Charged Hadrons R<sub>AA</sub> for d+Au: R<sub>dA</sub>

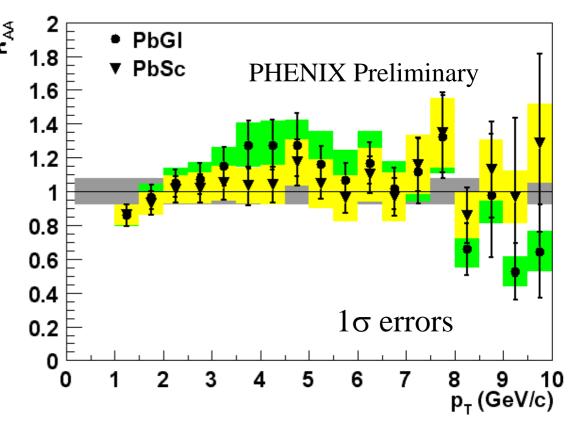
- Charged hadron are measured with tracking detectors in two independent arms
- Cronin type enhancement relative to binary scaling



### π<sup>0</sup> R<sub>AA</sub> for d+Au collisions: R<sub>dA</sub>

Neutral pions are measured with 2 independent Calorimeters – PbSc and PbGl

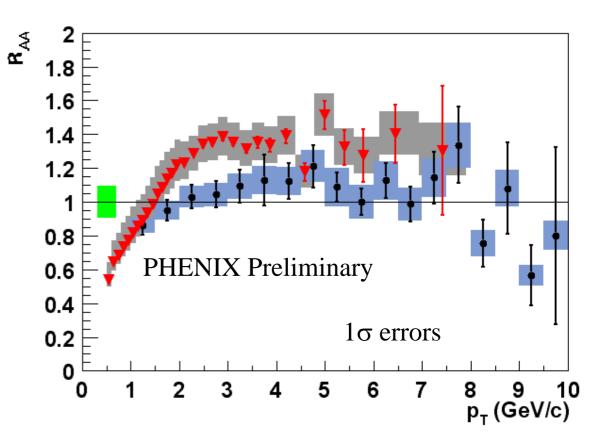
- 2 results agree within errors
- Not suppressed relative to binary scaling



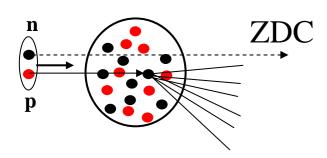
## $R_{dA}$ for charged hadrons compared to $\pi^0$

"Cronin" enhancement more pronounced in the charged hadron measurement

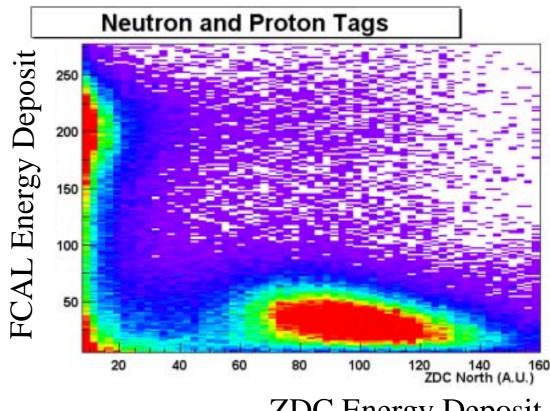
Possibly a larger effect in protons at medium  $p_T$ 



### **Neutron tagged p-A collisions**



Neutron tagged events are enhanced in ultra-peripheral collisions

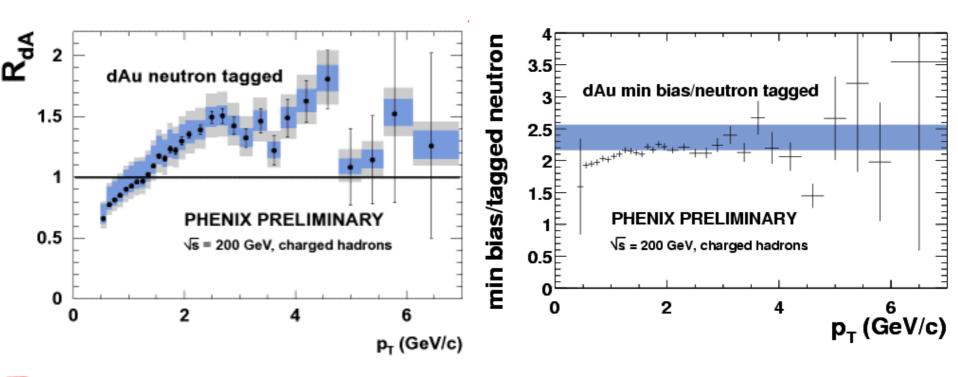


**ZDC** Energy Deposit

### Centrality Dependence of R<sub>dA</sub>

Comparison of ultra-peripheral events (<Ncoll>=3.6+/-0.4) to minimum bias (<Ncoll>=8.5+/-0.7)

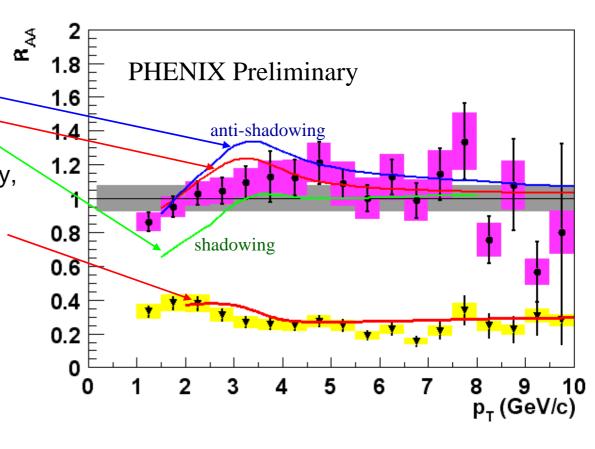
No centrality dependence observed!



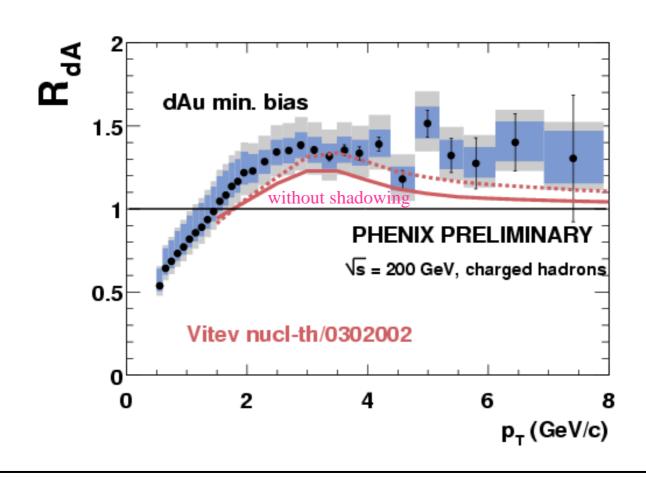
# $\pi^0$ R<sub>AA</sub> Theory and Experiment for central Au+Au and d+Au collisions

d+Au: I. Vitev, nucl-th/0302002 and private communication.

Au+Au: I. Vitev and M. Gyulassy, hep-ph/0208108, to appear in Nucl. Phys. A; M. Gyulassy, P. Levai and I. Vitev, Nucl. Phys. B 594, p. 371 (2001).



# h<sup>+/-</sup> R<sub>AA</sub> Theory and Experiment for central Au+Au and d+Au collisions





# Summary

PHENIX operates in design configuration

Successful d-Au and continuing p-p running

Wealth of results from Run-2 on Au-Au and p-p physics

Cronin like enhancement at high p<sub>T</sub> in d-Au

We live in interesting times, more results in the near future!

