PHENIX at RHIC

Ju Hwan Kang
Department of Physics
Yonsei University

Him Meeting
ChunNam University, Korea
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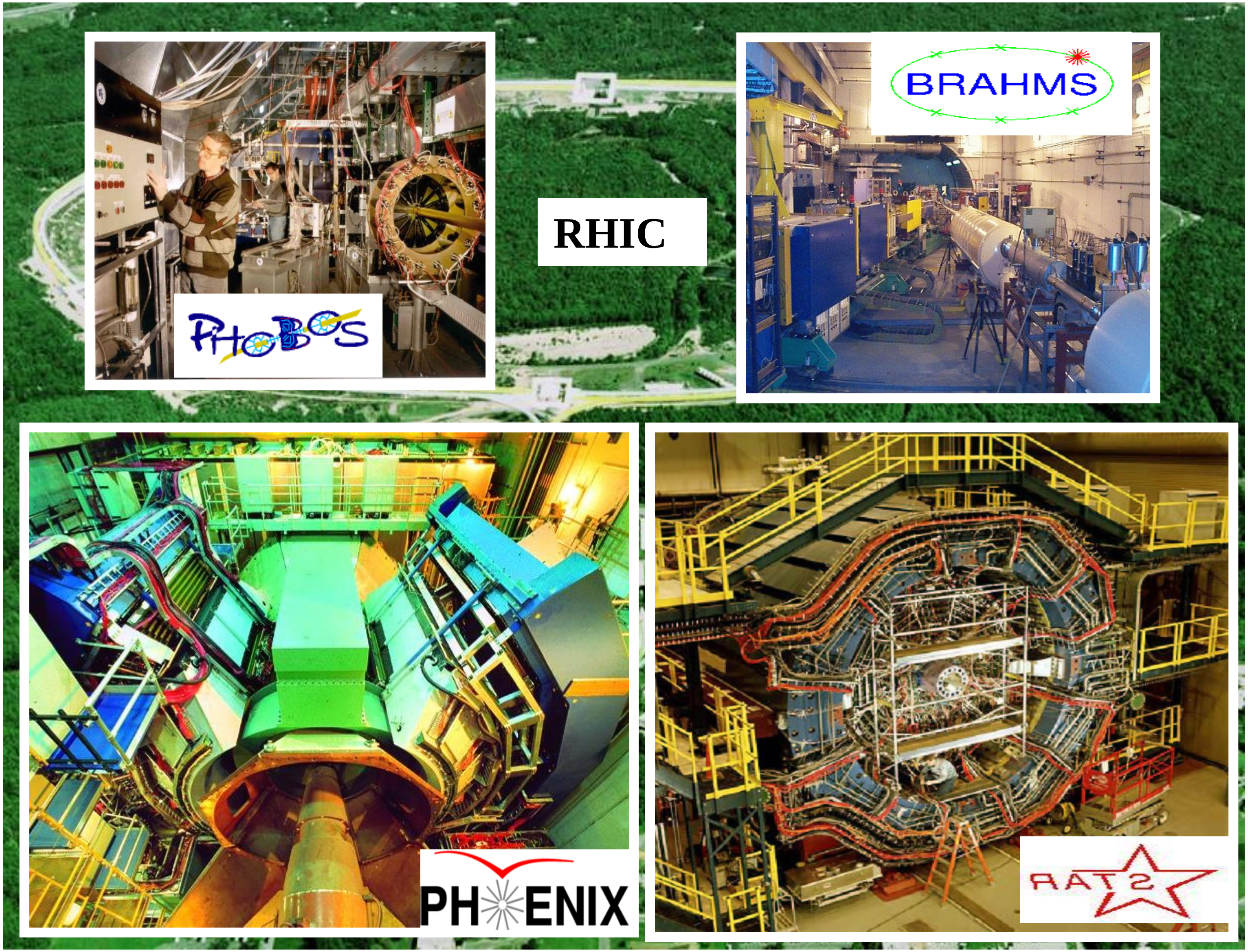
The Relativistic Heavy Ion Collider at BNL

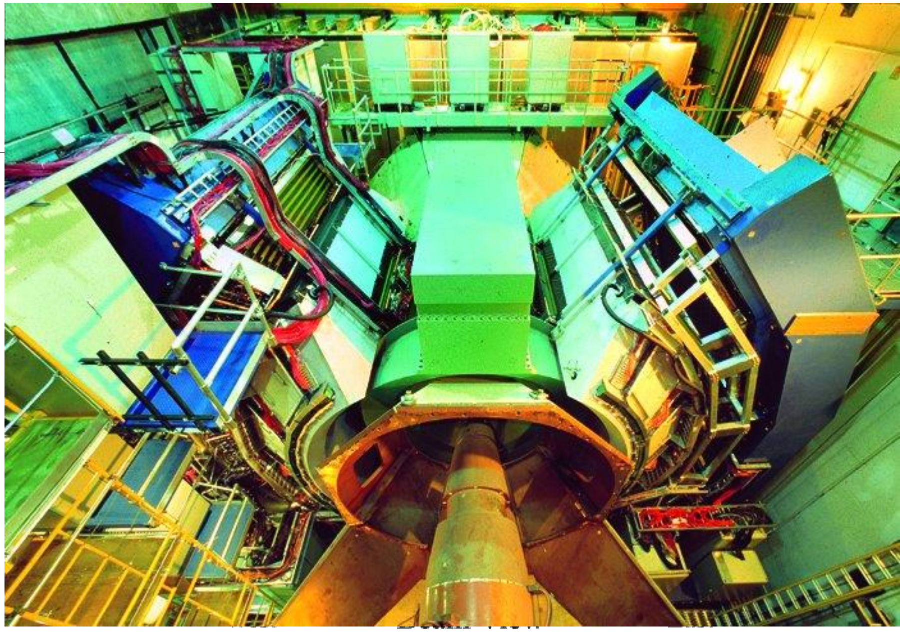
- **Two independent rings 3.83 km in circumference**
  - **120 bunches/ring**
  - **106 ns crossing time**
- **Maximum Energy**
  - **$s^{1/2}$ = 500 GeV p-p**
  - **$s^{1/2}$ = 200 GeV/N-N Au-Au**
- **Design Luminosity**
  - **Au-Au 2×10^{26} $cm^{-2}s^{-1}$**
  - **p - p 2×10^{32} $cm^{-2}s^{-1}$ (polarized)**
- **Capable of colliding any nuclear species on any other nuclear species**

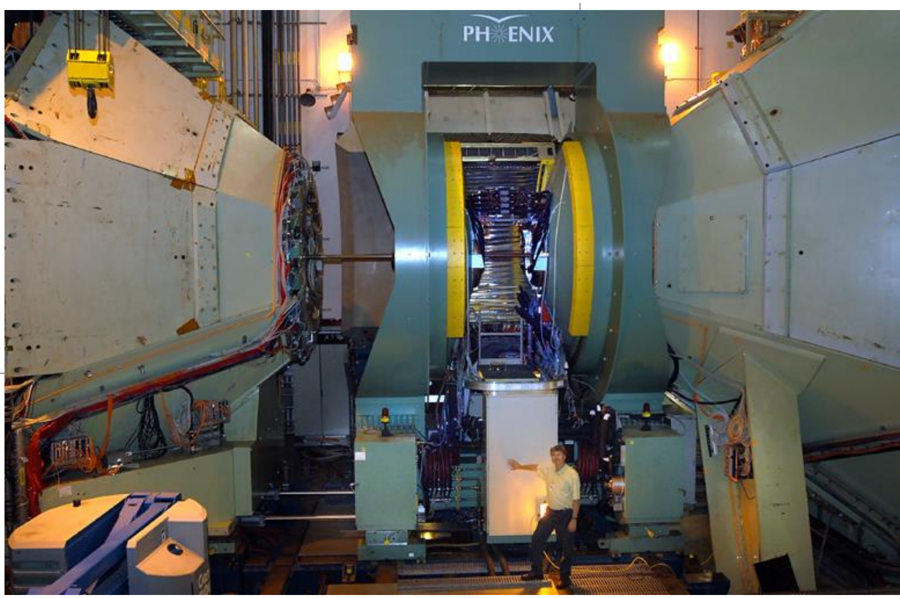
The RHIC Experiments



The PHENIX Detector

Detector Redundancy
Fine Granularity, Mass Resolution
High Data Rate
Good Particle ID
Limited Acceptance





Charged Particle Tracking:

- **Drift Chamber**
- **Pad Chamber**
- **Time Expansion Chamber/TRD**
- **Cathode Strip Chambers**

Particle ID:

- **Time of Flight**
- **Ring Imaging Cerenkov Counter**
- **TEC/TRD**
- **Muon ID (PDT's)**

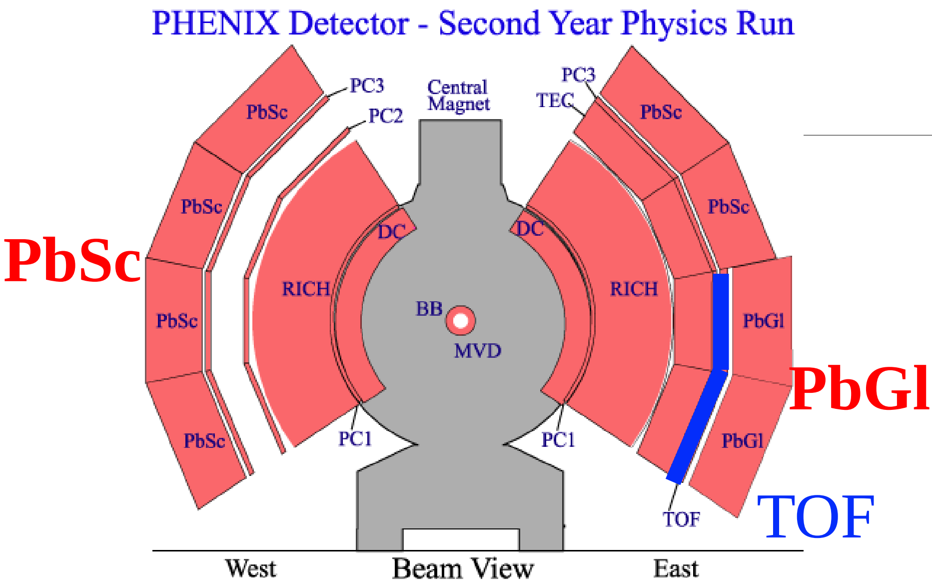
Calorimetry:

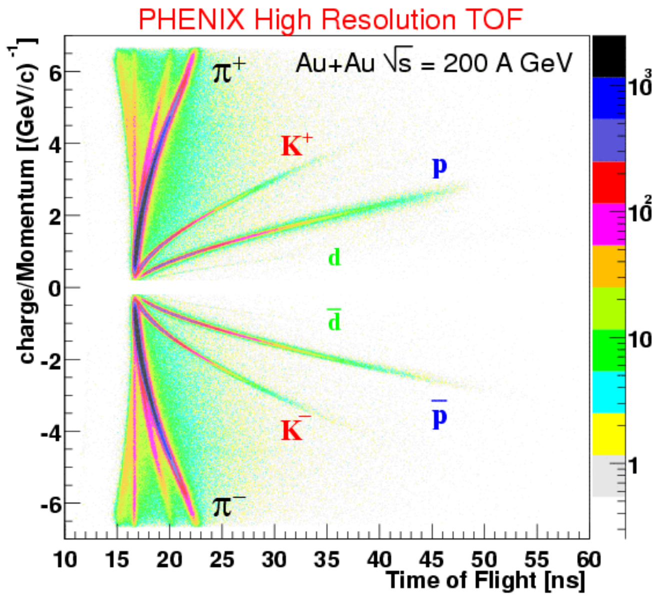
- **Pb Scintillator**
- **Pb Glass**

Event Characterization:

- **Multiplicity Vertex Detector (Si Strip,Pad)**
- **Beam-Beam Counter**
- **Zero Degree Calorimeter/Shower Max Detector**
- **Forward Calorimeter**

PHENIX Central Arm





PID by high resolution TOF

- π, K < 2 GeV/c
- proton, anti-proton < 4 GeV/c
- $\Delta\phi = \pi/4$

π^0 measurement by EMCal

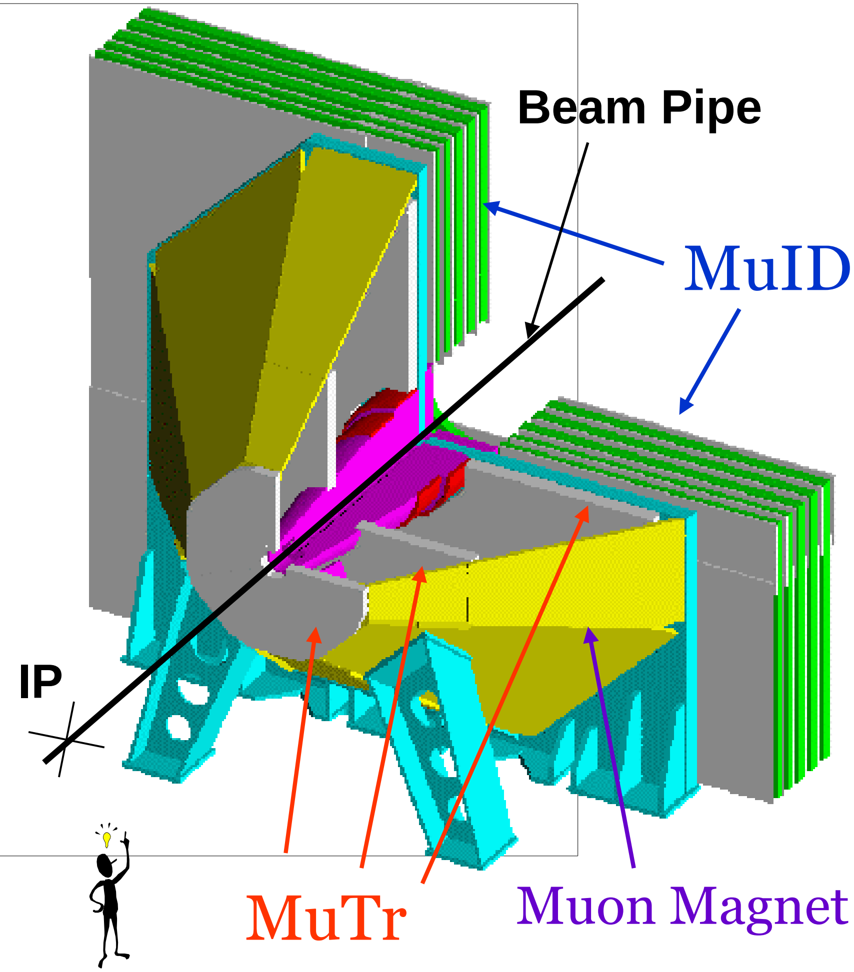
- 1<pt<10GeV/c (possibly ~20GeV)
- 6 lead- scintillator (PbSc) sectors
- 2 lead- glass (PbGl) sectors
- $|\eta|$<0.38 at midrapidity, $\Delta\phi = \pi$

Electron measurement

- Charged tracks: DC & PC
- RICH rings
- EM Calorimeter clusters

The PHENIX Muon Arms

- Detect muons with
  - $p_{tot} > 2$ GeV/c
  - $-1.2 > \eta > -2.2$ (South Arm) or $1.2 < \eta < 2.4$ (North Arm)
- Muon Tracker (MuTr)
  - Measure momentum of muons with cathode-readout strip chambers at 3 stations inside Muon Magnet
- Muon Identifier (MuID)
  - π/μ separation with 5-layer sandwich of chambers (Iarocci tubes) and steel
  - Trigger muons



PHENIX

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, Urbana-Champaign, IL
Iowa 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

*as of July 2002

The RHIC Run History

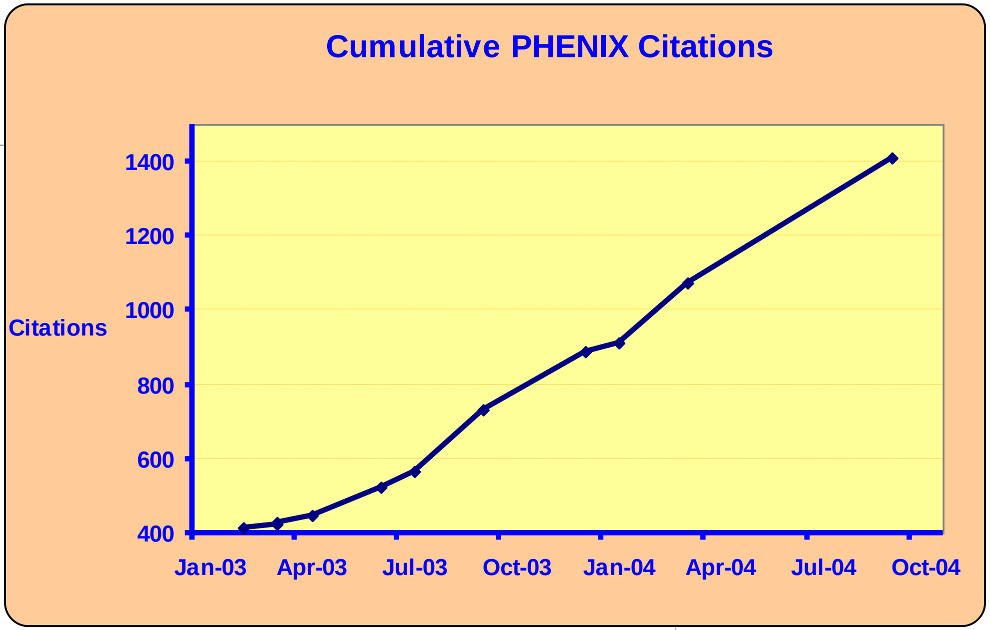
The RHIC machine performance has been very impressive:

- Machine is delivering design luminosity(+) for AuAu
- Collided 3 different species in 4 years
  - AuAu, dAu, pp
- 4 energies run
  - 19 GeV, 64 GeV, 130 GeV, 200 GeV
- 1st operation of a polarized hadron collider

PHENIX	Year	Species	$s^{1/2}$ [GeV]	$\int L dt$	N_{tot} (sampled)	Data Size
Run1	2000	Au-Au	130	1 μb^{-1}	10M	3 TB
Run2	2001/02	Au-Au	200	24 μb^{-1}	170M	10 TB
		Au-Au	19	------	<1M	
		p-p	200	0.15 pb^{-1}	3.7G	20 TB
Run3	2002/03	d-Au	200	2.74 nb^{-1}	5.5G	46 TB
		p-p	200	0.35 pb^{-1}	6.6G	35 TB
Run4	2003/04	Au-Au	200(64)	241 μb^{-1}(9.1)	1.5G(58M)	200 TB
		p-p	200	352 μb^{-1}	360M	10 TB

Publication Summary

- Run-1
  - 12 publications
  - 8 are "TopCites"
    - 3 of these are "famous"
  - One "archival" summary
- Run-2
  - 12 publications to date
  - 4 are "TopCites"
    - 1 of these is "famous"
  - One "archival" summary
  - Several more nearing completion
    - Direct photons, open charm, energy survey…
- Run-3
  - 2 publications
    - d+Au suppression (a TopCite/famous)
    - First result on $A_{LL}(\pi^0)$ for spin study
  - Several in progress
- Run-4: > x 10 *data-size compared to Run-2 Au+Au*



PHENIX White Paper (I)

PHENIX just released White Paper which is an extensive review of its results up to Run3 (http://arXiv.org/abs/nucl-ex/0410003).

- Energy density; $\varepsilon_{Bj}=(1/\tau A)(dE_T/dy)$
  - For the created particles at proper time (τ_{Form}=0.35fm/c); 15 GeV/fm^3.
  - Hydrodynamical calculation using elliptic flow (τ_{Therm}=1fm/c); 5.4 GeV/fm^3.
- Thermalization
  - Measured yields/spectra are consistent with thermal emission (T_{Therm}=157MeV, μ_B=23MeV, β=0.5).
  - Elliptic flow (v_2) is stronger at RHIC than at SPS, and $v_2(p) < v_2(\pi)$.
  - Currently do not have a consistent picture of the space-time dynamics of reactions at RHIC as revealed by p_t spectra, v_2 vs p_t for proton and pion; not yet possible to extract quantitative properties of QGP or mixed phase using those observables.
- Fluctuations
  - Net charge fluctuations has ruled out the most naïve model in a QGP by showing non-random fluctuations expected from high-p_t jets only.
  - A severe constraint on the critical fluctuations expected for a sharp phase transition but is consistent with the expectation from lattice QCD having a smooth transition.

PHENIX White Paper (II)

- Binary Scaling
  - To exclude final state medium effect, π from d+Au, γ/total charm yields from Au+Au collisions were used.
  - Experimental evidence for the binary scaling of point-like pQCD process in AuAu collisions.
  - Initial condition for hard-scattering at RHIC is an incoherent superposition of nucleon structure functions.
- High-P_t Suppression
  - The observed suppression of high-pt particle production at RHIC is a unique phenomenon not having been produced previously.
  - Medium induced energy lose is the only currently known physical mechanism that can fully explain the observed high-p_t suppression.
- Hadron production
  - The large (anti) baryon to pion excess relative to expectations from parton fragmentation functions at p_t=2-5GeV/c remains one of the most striking unpredicted experimental observations at RHIC.
  - At present, no theoretical framework provides a complete understanding of hadron formation in the intermediate P_t region.

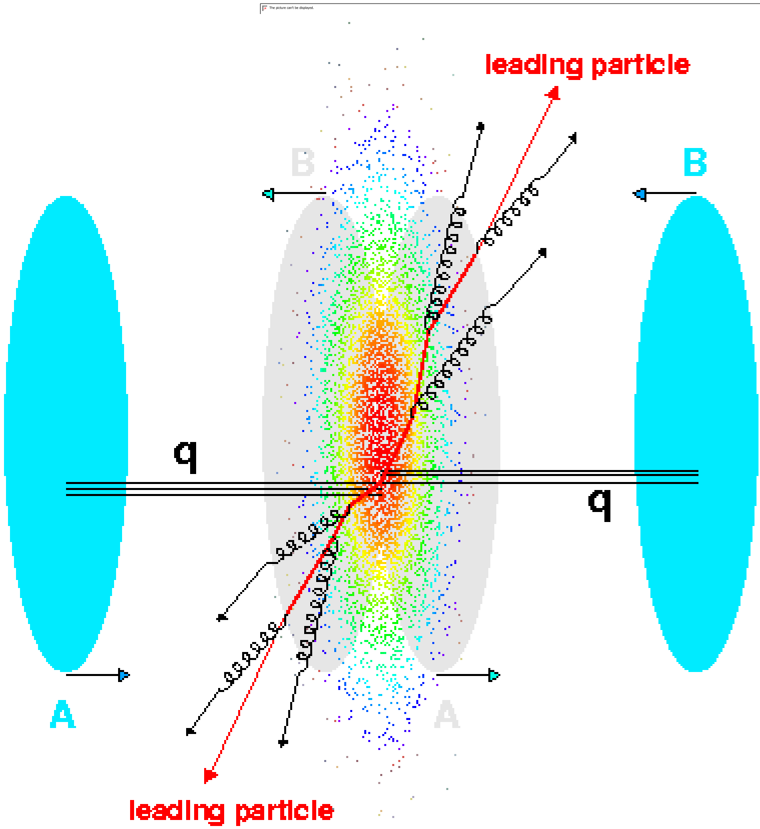
PHENIX White Paper (III) ;
Future Measurements

To further define and characterize the state of matter formed at RHIC, PHENIX is just starting the study of penetrating probes not experiencing strong interactions in the produced medium. By their very nature, penetrating probes are also rare probes and consequently require large value of the integrated luminosity.

- High-P_t Suppression and Jet Physics
  - Trace the suppression to much higher P_t to determine whether it disappears.
  - High momentum jet correlations using π, K, p to beyond 8GeV/c in P_t and γ.
- J/ψ Production
  - $\mu^+\mu^-$ decay channel at forward and backward rapidities, and e^+e^- decay channel in mid-rapidity for p+p, d+A/p+A, and A+A systems.
- Charm Production
  - Produced in the initial hard collisions between the incoming partons. Measure indirectly using high-p_t single leptons and directly with upgraded detector.
- Low-Mass dileptons
  - Sensitive prove of chiral symmetry restoration.
- Thermal Radiation
  - Through real photons or dileptons, a direct fingerprint of the matter formed.

Hard scattering in Heavy Ion collisions

schematic view of jet production



Jets:

- primarily from gluons at RHIC
- produced early (τ<1fm)
- sensitive to the QCD medium (dE/dx)

Observed via:

- fast leading (high pt) particles or
- azimuthal correlations between them

Mechanisms of energy loss in vacuum (*pp*) is understood in terms of formation time and static chromoelectric field regeneration* . Any nuclear modification of this process could provide a hint of QGP formation.

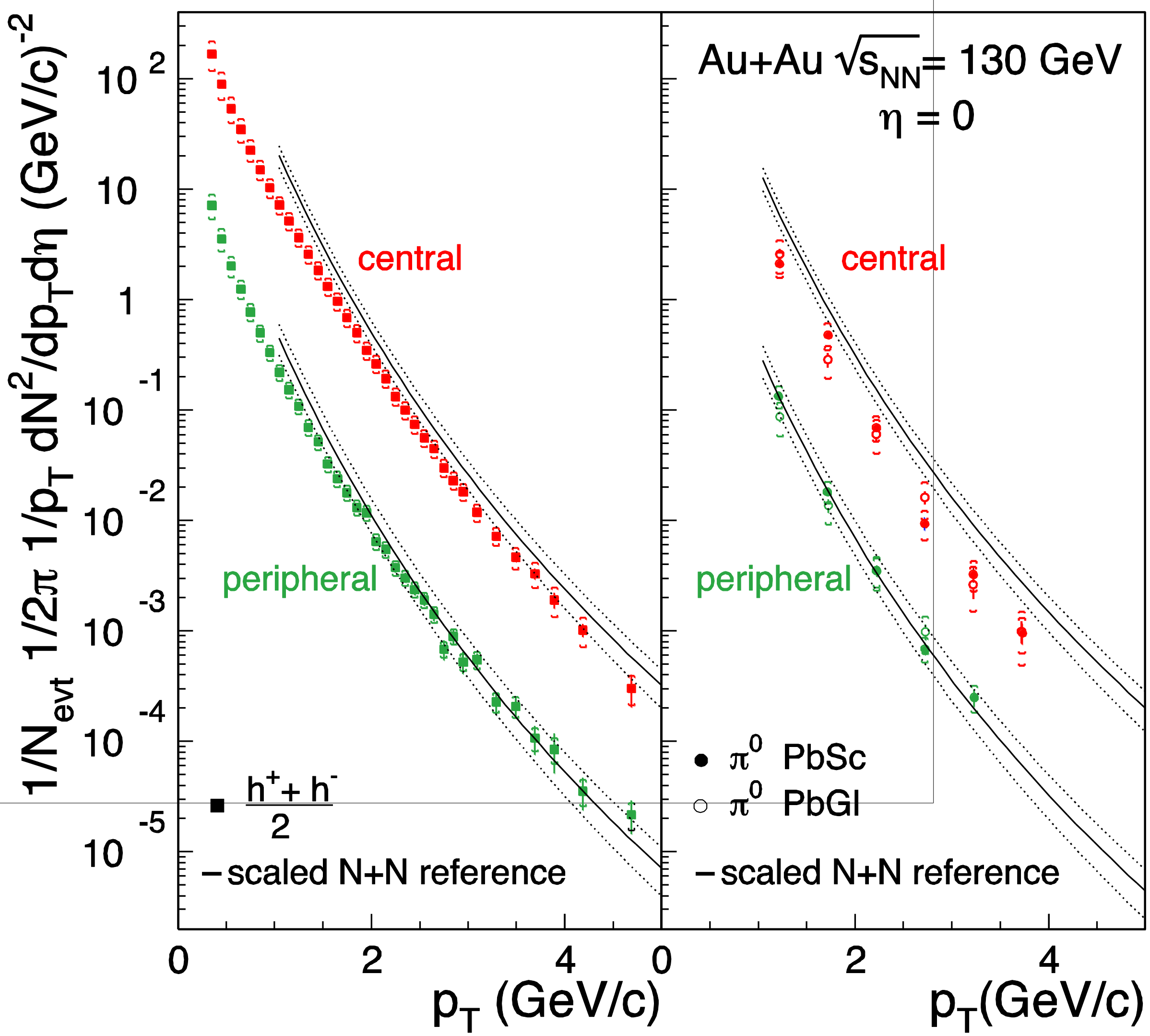
* *F.Niedermayer, Phys.Rev.D34:3494,1986.*

RHIC Year-1 High-PT Hadrons

Hadron spectra out to p_T~4-5 GeV/c

Nominally high p_T hardrons are from hard scattering; scale spectra from N+N by number of binary collisions

Peripheral reasonably well reproduced; but central significantly below binary scaling

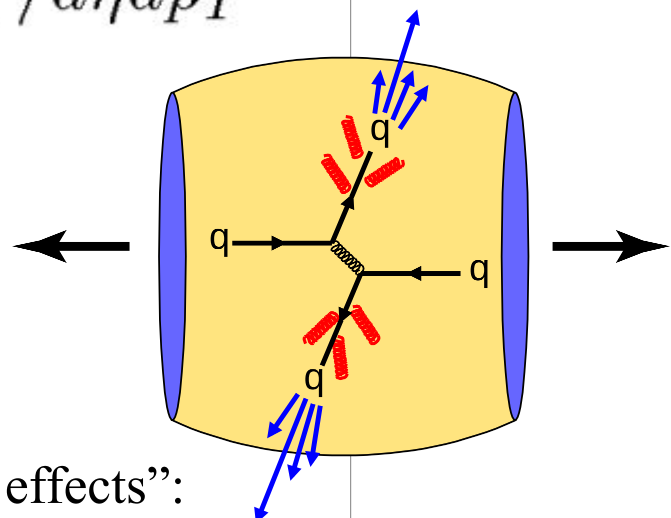


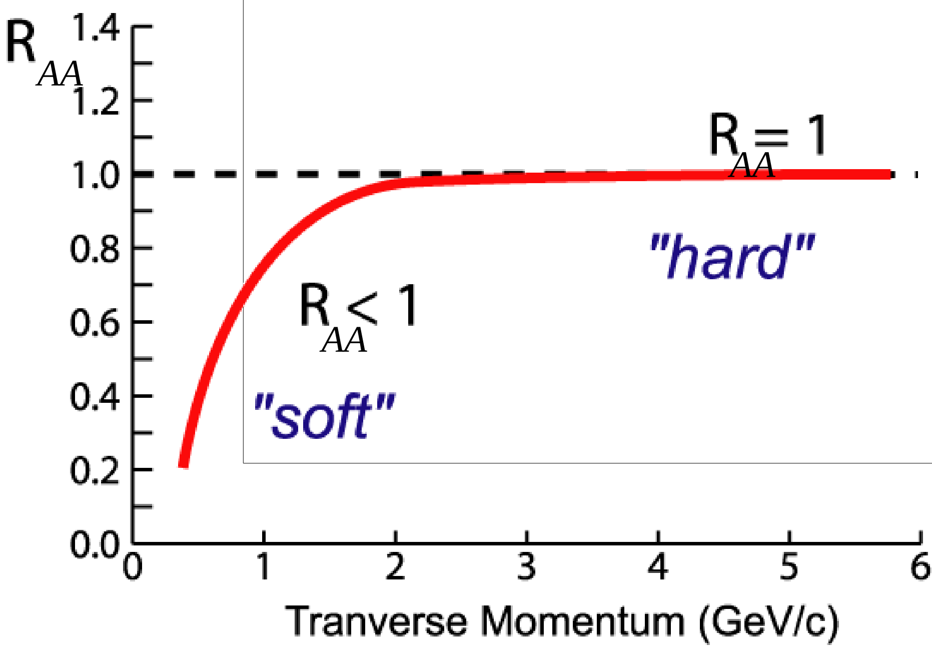
Closer look using the Nuclear Modification Factor RAA

Nuclear Modification Factor:

$$R_{AA}(p_T) = \frac{d^2N_{AA}/d\eta dp_T}{\langle N_{coll}\rangle\, d^2N_{pp}/d\eta dp_T}$$

Compare A+A to p-p cross sections





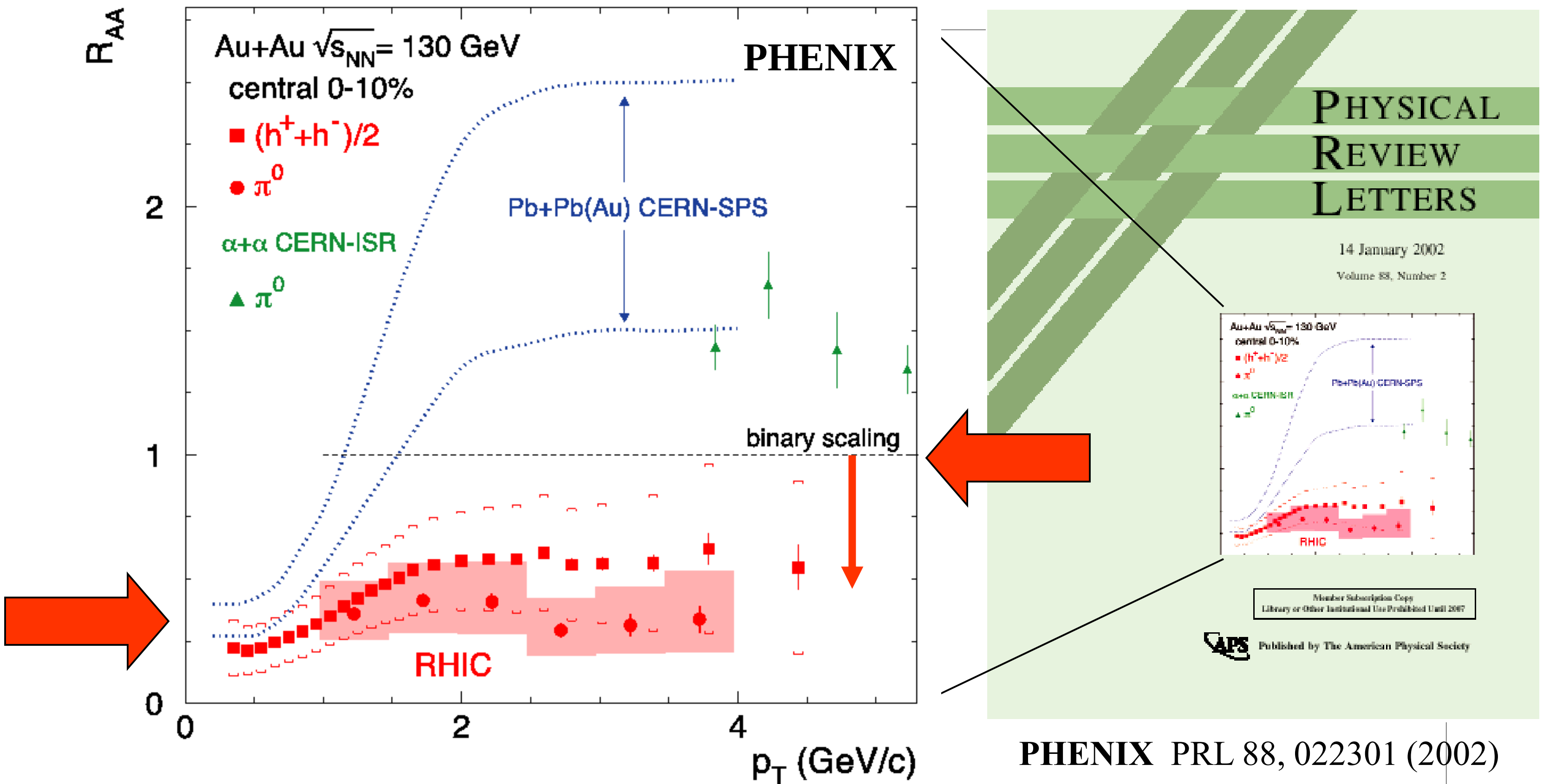
"Nominal effects":

- $R_{AA} < 1$ in regime of soft physics
- $R_{AA} = 1$ at high-p_T where hard scattering dominates
- $R_{AA} > 1$ due to k_T broadening (Cronin)

Suppression:

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

RHIC Headline News… January 2002



PHENIX PRL 88, 022301 (2002)

First observation of *large* suppression of high p_T hadron yields

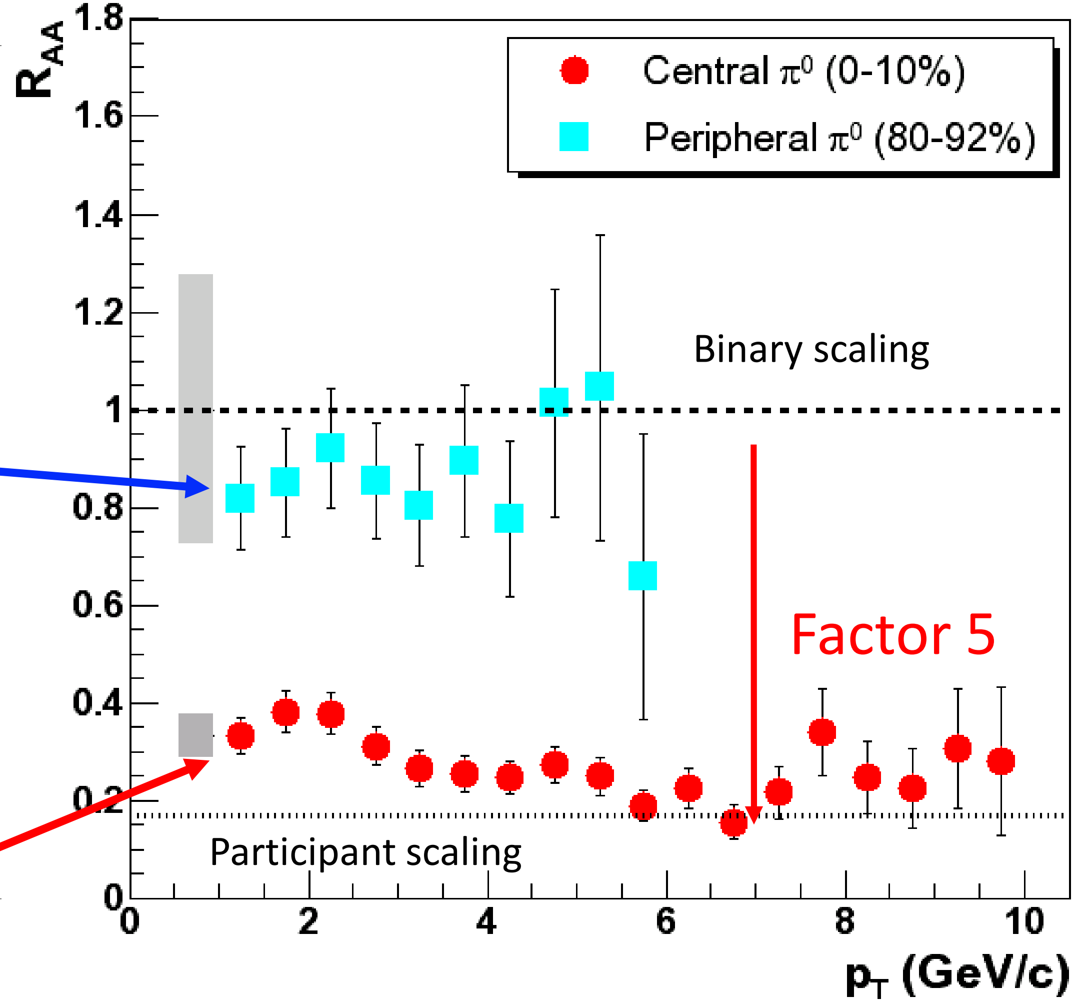
"Jet Quenching"? == Quark Gluon Plasma?

R_{AA} : High P_T Suppression to at least 10 GeV/c

$$R_{AA} = \frac{Yield_{AuAu} / \langle N_{binary} \rangle_{AuAu}}{Yield_{pp}}$$

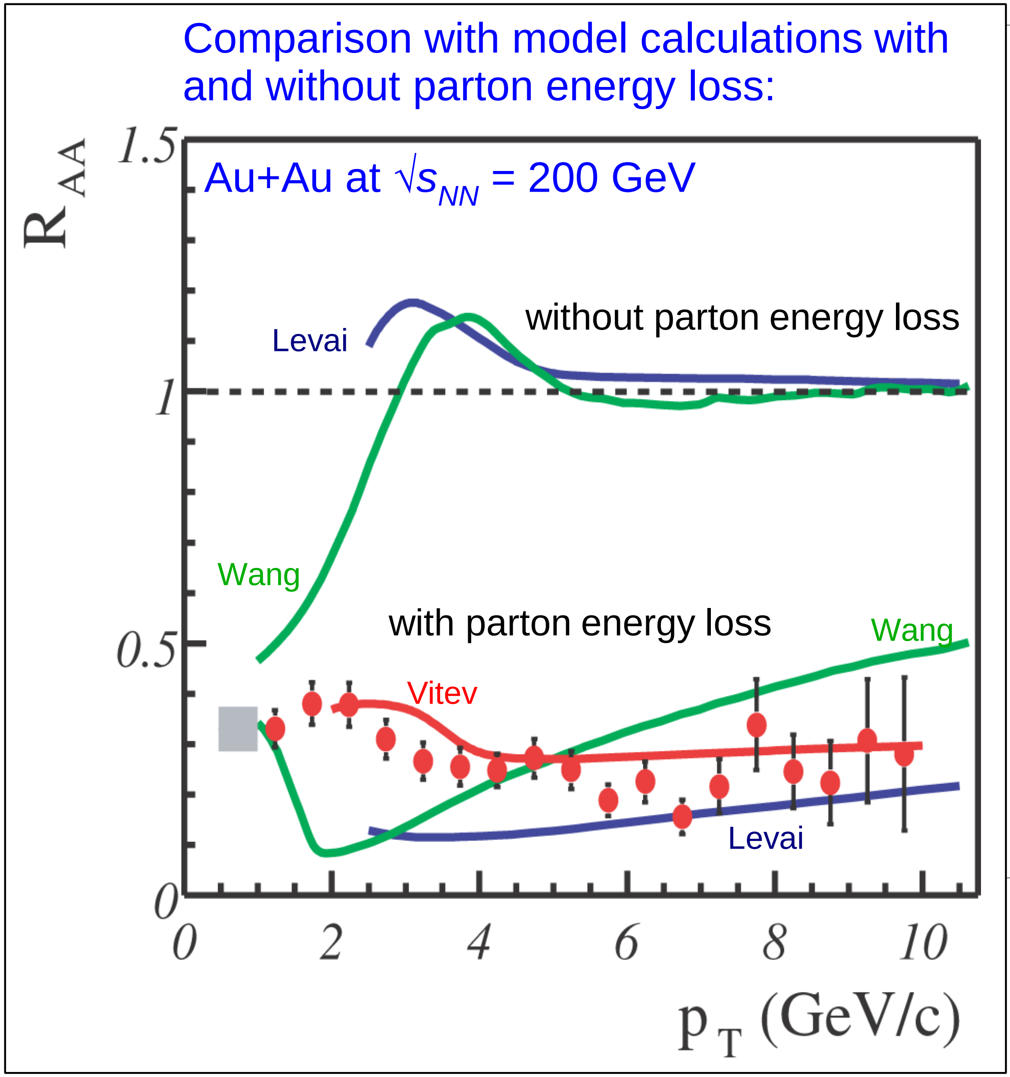
Peripheral AuAu - consistent with N_{coll} scaling (large systematic error)

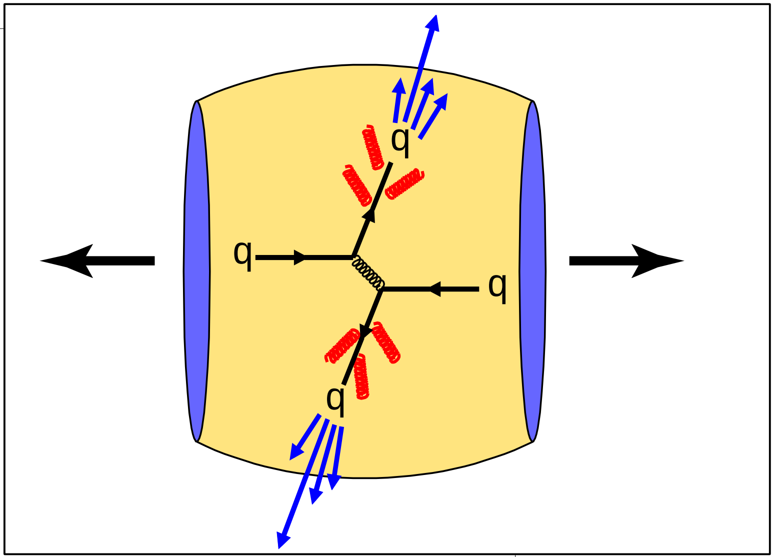
Large suppression in central AuAu - close to participant scaling at high P_T



PRL 91 (2003) 072301

Jet-Quenching?





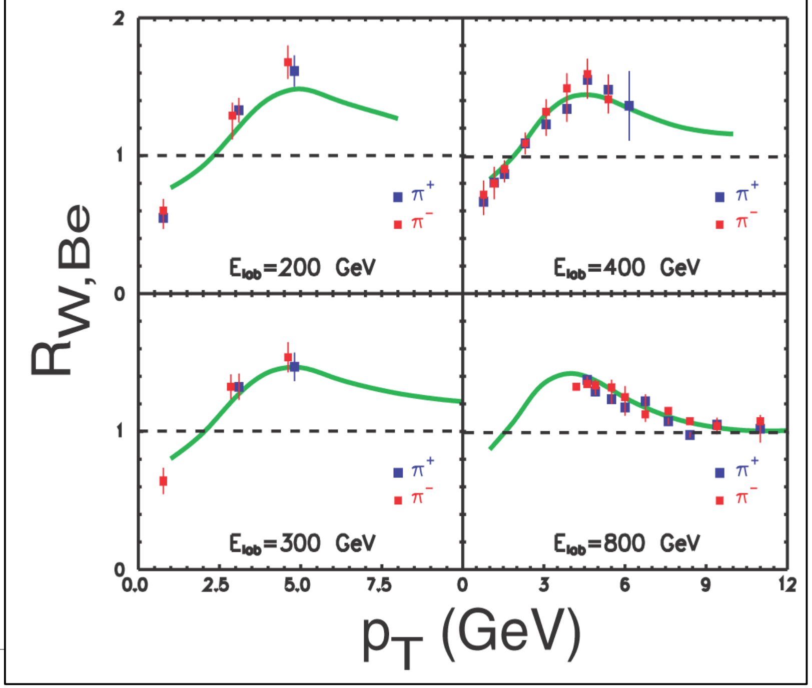
- Pion-suppression reproduced by models with parton energy loss
- p_T-dependence not well described

Initial State Effects

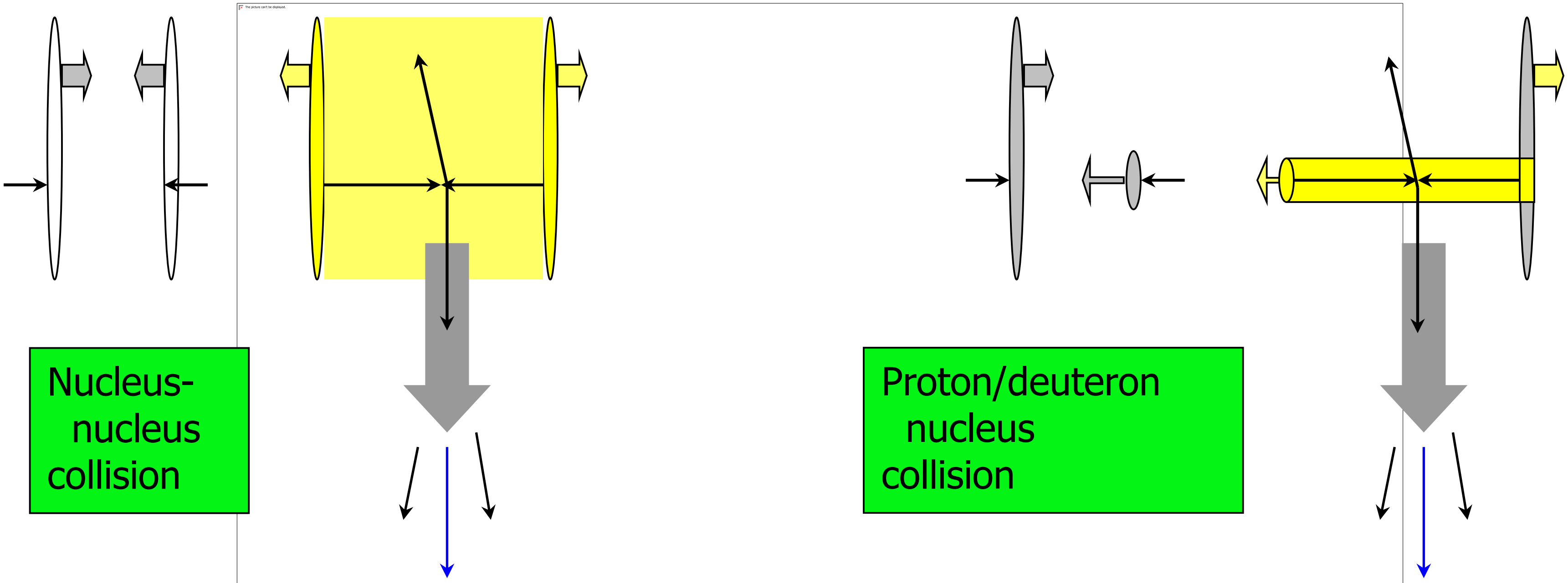
- Initial State Effects:
  Effects which lead to $R_{AA} \neq 1$ at high p_T but which are not related to properties of the hot and dense nuclear matter

- Candidates:
  Initial state multiple soft scatterings (Cronin Effect): increases R_{AA}
  Modification of the nucleon structure functions in nuclei (Shadowing): decreases R_{AA}
  Gluon saturation (Color Glass Condensate): decreases R_{AA} (?)

Cronin-Effect observed in p+A experiments:



p+A (or d+A): The control experiment



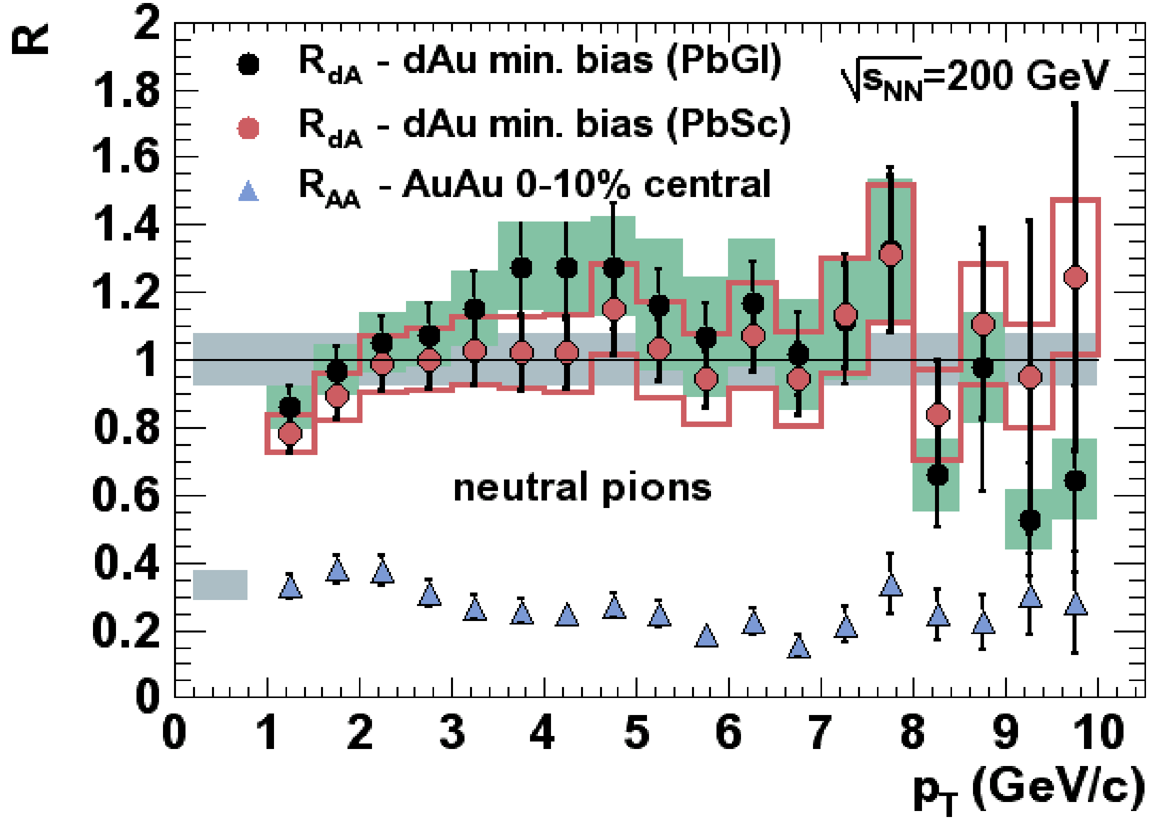
- **Jet Quenching interpretation; interaction with medium produced in final state suppresses jet.**
- **Gluon Saturation interpretation, gluons are suppressed in initial state resulting in suppression of initial jet production rate.**
- **If these initial state effects are causing the suppression of high-P_T hadrons in Au+Au collisions, we should see suppression of high-P_T hadrons in d+Au collisions.**

R_{AA} vs. R_{dA} for Identified π^0

Neutral pions are measured with 2 independent Calorimeters – PbSc and PbGl: Consistency check.

d+Au

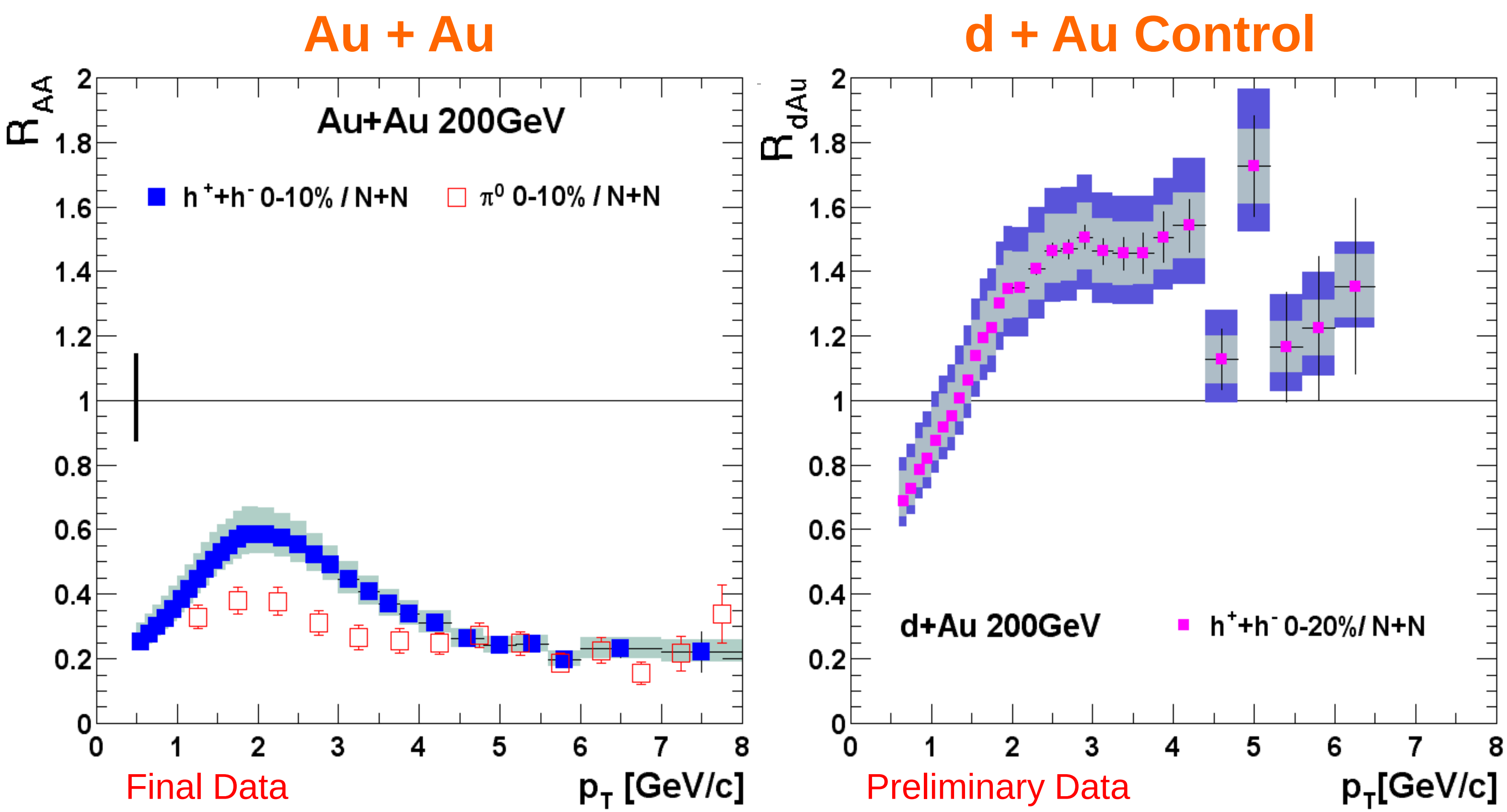
Au+Au



The dAu results (initial state effects only) suggest that the created medium is responsible for high p_T suppression in Au+Au.

PHENIX, PRL91 (2003) 072303.

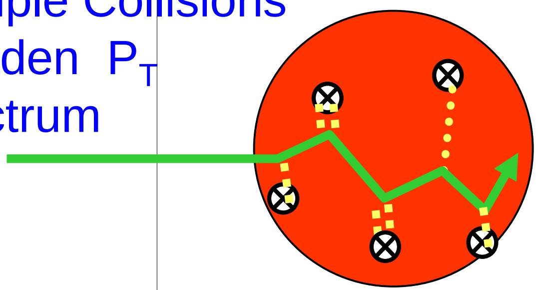
Centrality Dependence

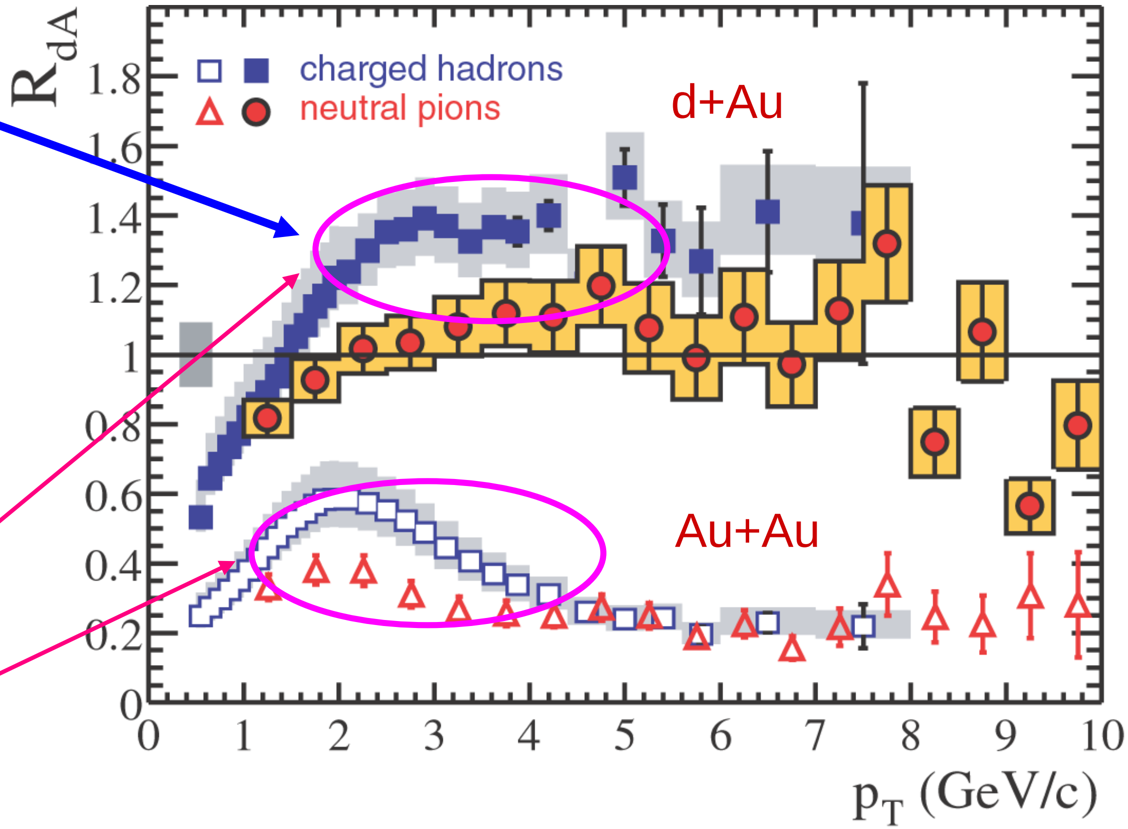


- Opposite centrality evolution of Au+Au compared to d+Au control.
- **Initial state enhancement ("Cronin effect") in d+Au is suppressed by final state effect in Au+Au.**
- **Notice difference between π^0 and $h^+ + h^-$ (more later).**

Cronin Effect (R_{AA}>1) : h_ch vs. π^0

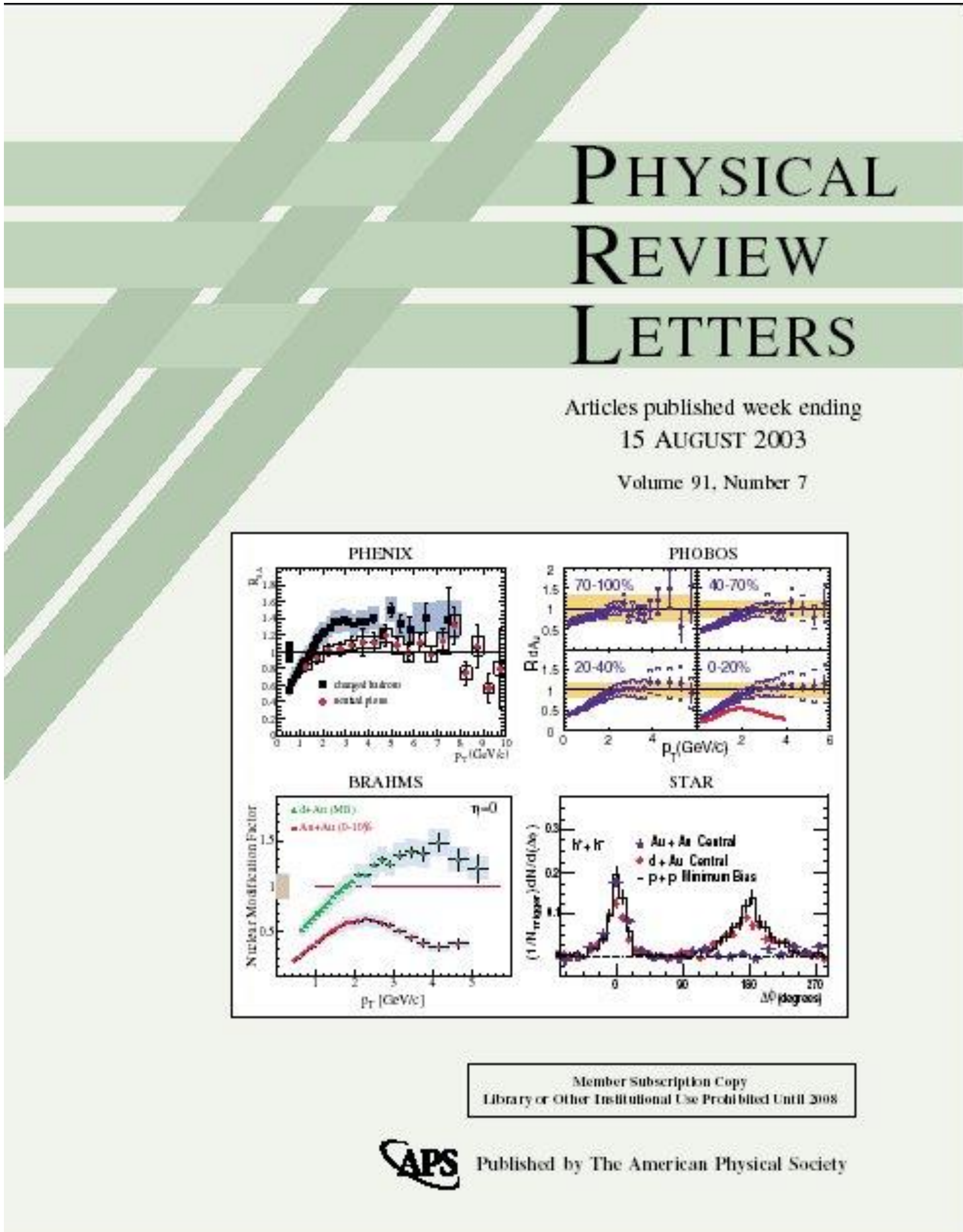
d+Au: Cronin Effect (R_{dA}>1): Initial Multiple Collisions broaden P_T spectrum





PHENIX
PRL 91 072303 (2003)
nucl-ex/0306021

- Different behavior between p^0 and charged hadrons at p_T = 1.5 - 5.0 GeV/c!
- d+Au data suggests the flavor dependent Cronin effect.



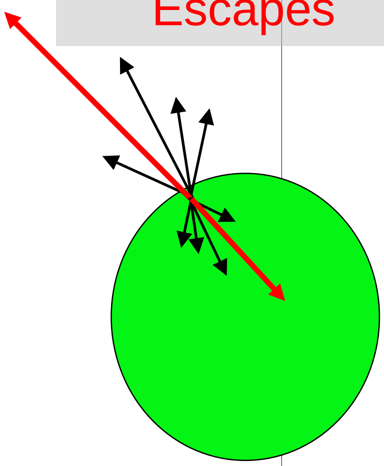
RHIC headline news… August 2003

BNL Press Release, June 2003:

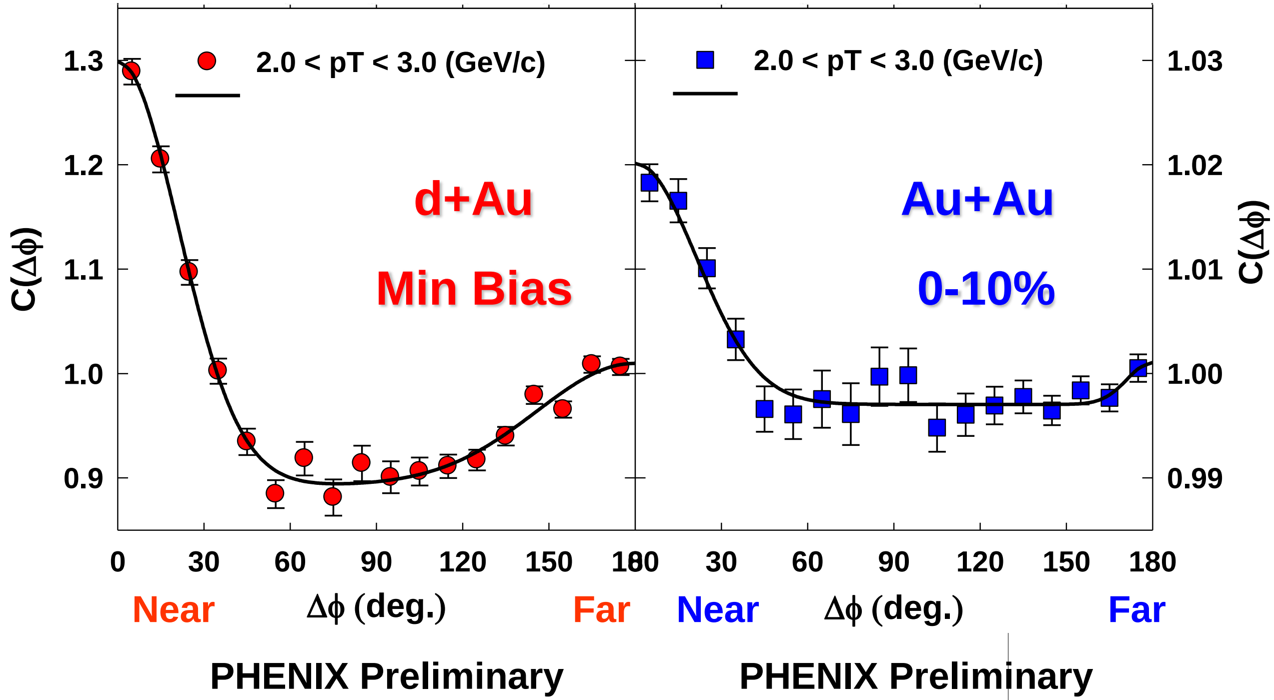
Lack of high p_T hadron suppression in d+Au strongly suggests that the large suppression in Au+Au is a final state effect of the produced matter (QGP?!)

Jet Correlations: 2-Particle Correlations

“Near Side Jet” Escapes



“Far Side Jet” Lost

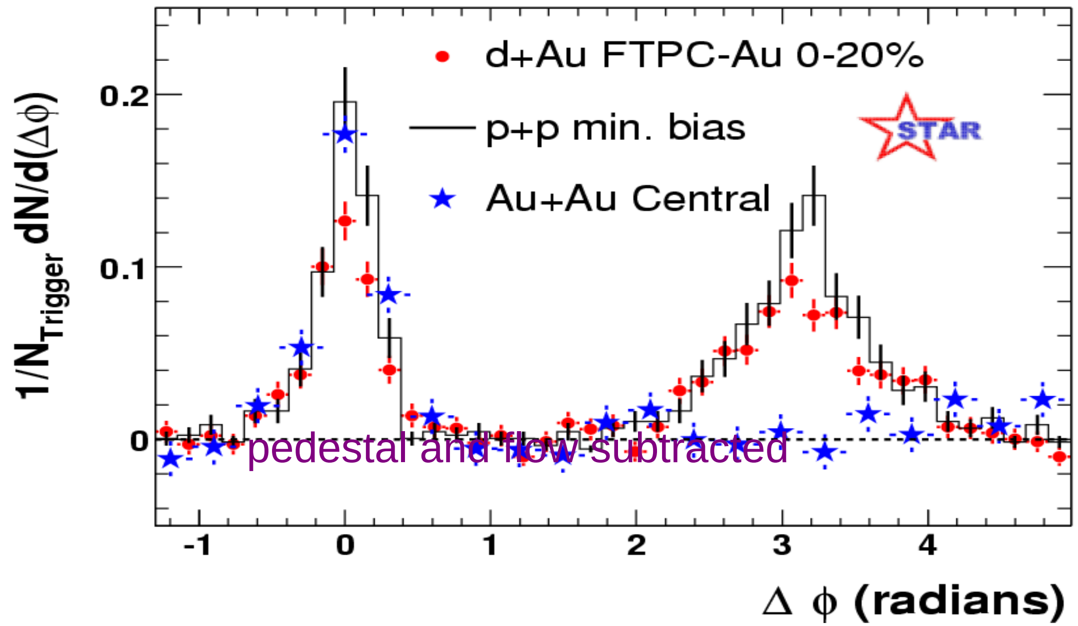


Parton exiting on the periphery of the collision zone should survive while partner parton propagating through the collision zone is more likely to be absorbed if Jet-Quenching is the correct theory.

Far-side Jet is suppressed in Central Au+Au : Further indication of suppression by produced medium.

Two Particle Azimuthal Distribution

The previous PHENIX result is consistent with published STAR result
(PRL 91, 072304, 2003)



- Azimuthal distribution similar in p+p and d+Au
- Strong suppression of the far-side jet in central Au+Au

Summary of high-pt Suppression

- There is a massive suppression of high-pt hadron yield in Central AuAu collisions.
- No high-pt suppression in dAu collisions is observed and the initial state effect such as gluon condensation (CGC) can not explain the above suppression.
- The high-pt suppression in Central AuAu is consistent with the final state effect; partonic energy-loss (Jet Quenching) in produced matter (QGP?).
- Far-side Jet is suppressed in Central AuAu : Further indication of suppression by produced medium.

The RHIC Upgrade Program

- **Resent long range RHIC planning exercise at BNL**
  - five year beam use proposals and decadal plans from all experiments
  - Twenty year planning study for the RHIC facility
- **Introduction: executive summary of plans for RHIC future**
  - Schedule, projected luminosity development, detector upgrades
- **Details of "near and medium term" detector upgrades**
  - Particle identification for jet tomography (PHENIX, STAR)
  - Dalitz pair rejection for electron pair continuum (PHENIX)
  - Precision vertex tracking (PHENIX, STAR)
  - Enhanced forward instrumentation (PHENIX)
- **Longer term upgrades for RHIC II area**
  - Upgrades of readout electronics, DAQ and triggers (STAR)
  - Large acceptance micro TPC for fast tracking (PHENIX, STAR)
- **Summary**

documents can be found at http://www.bnl.gov/henp

Long Term RHIC Operation and Upgrade Plans

2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

RHIC operation at and beyond design luminosity

eRHIC
e-ion collider

RHIC II 40x design luminosity for Au-Au via electron cooling

RHIC baseline program
- Au-Au ~ 1 nb^{-1} at 200 GeV
- Species scan at 200 GeV
- Au-Au energy scan
- Polarized protons ≥ 150 nb^{-1}

Completion of
- BRAHMS & PHOBOS

Studies of dense nuclear matter
with rare probes: jet tomography, open flavor,
J/ψ, ψ', χc, $\Upsilon(1s)$, $\Upsilon(2s)$, $\Upsilon(3s)$
Polarized protons at 500 GeV
p-A physics

Near & medium term detector upgrades
of PHENIX and STAR
Proposals submitted or in preparation

New eRHIC experiment

Long term upgrades
of PHENIX and STAR
related to RHIC II

new RHIC experiments ?

Physics Beyond Reach of Current RHIC Program

- Comprehensive study of QCD at high T with heavy ion, p-nucleus, and pp
  - high p_T phenomena (identified particle, p_T>20 GeV/c and γ-jet)
  - electron pair continuum (low masses to Drell-Yan)
  - heavy flavor production (c- and b-physics)
  - charmonium spectroscopy (J/ψ, ψ', χ_c and Υ(1s),Υ(2s),Υ(3s))

requires highest AA luminosity

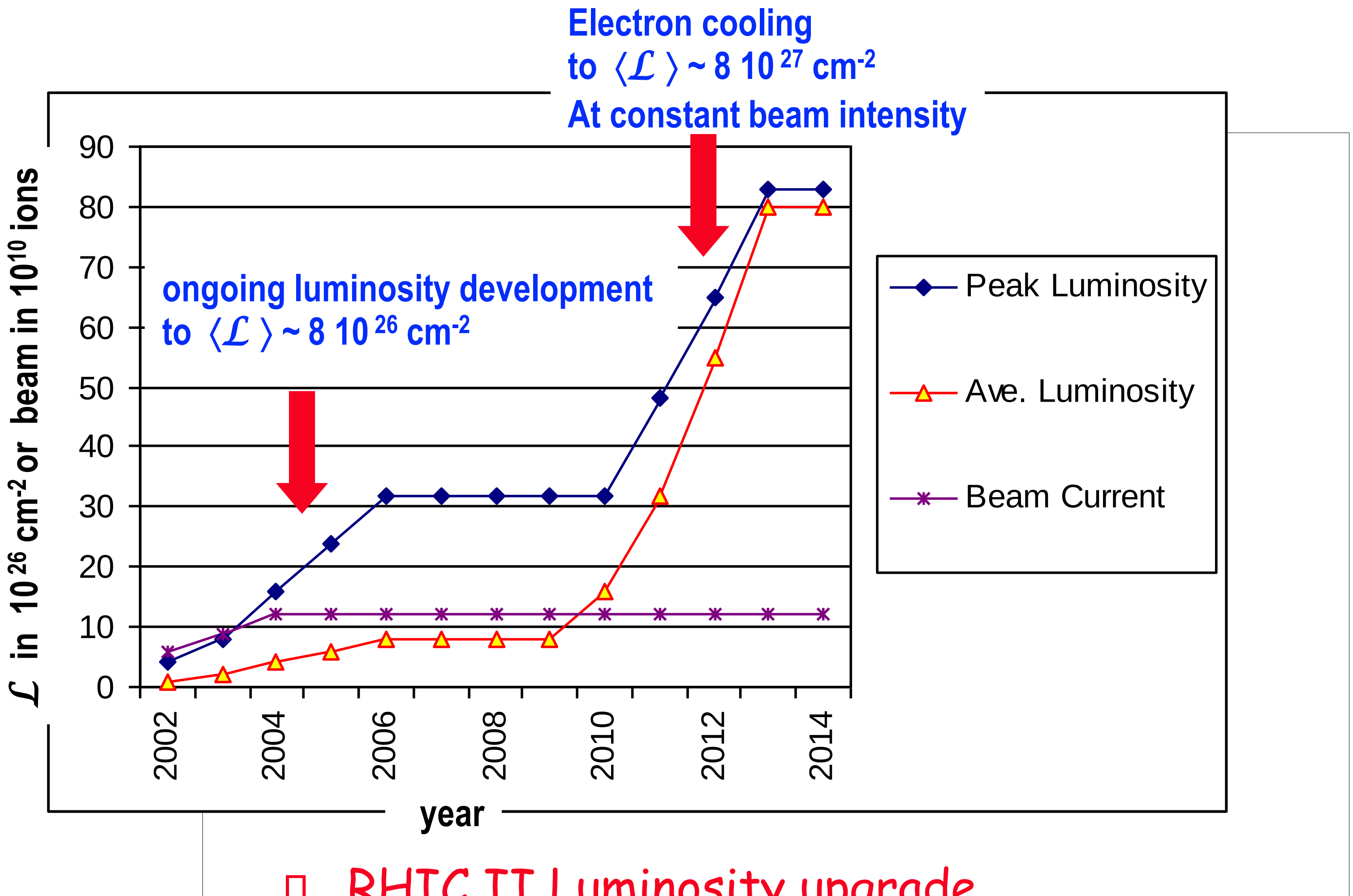
- Extended exploration of the spin structure of the nucleon
  - gluon spin structure ($\Delta G/G$) with heavy flavor and γ-jet correlations
  - quark spin structure ($\Delta q/q$) with W-production
  - Transversity

requires highest polarization and luminosity

- Exploration of the nucleon structure in nuclei
  - A-, p_T-, x-dependence of the parton structure of nuclei
  - gluon saturation and the color glass condensate at low x

Requires not only upgrade of RHIC luminosity
But also of the experiments
Corresponding plans developed over the last 2 years

RHIC Au-Au Luminosity Development



- RHIC II Luminosity upgrade

  Ongoing R&D for electron cooling

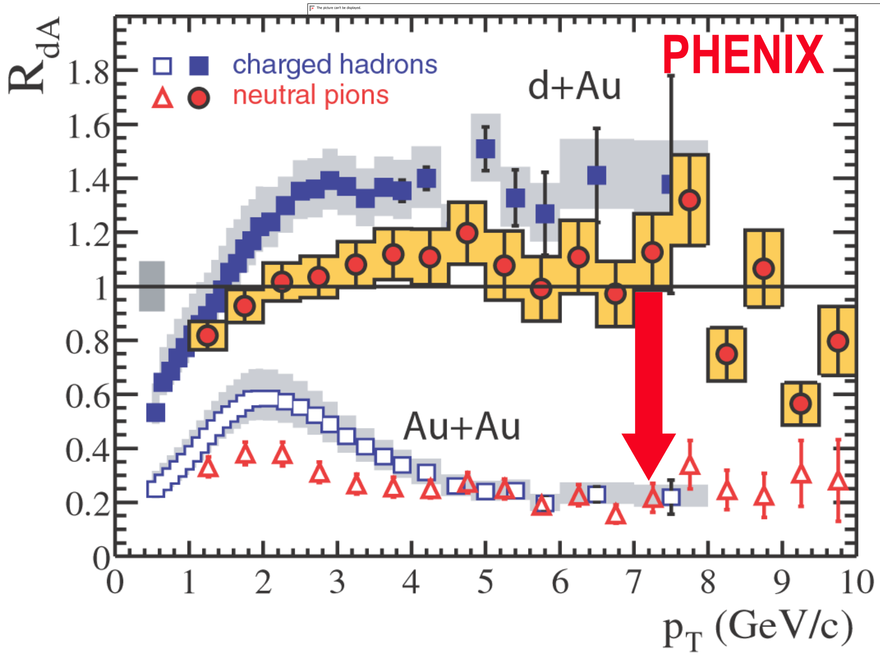
  Hope for full implementation by 2010

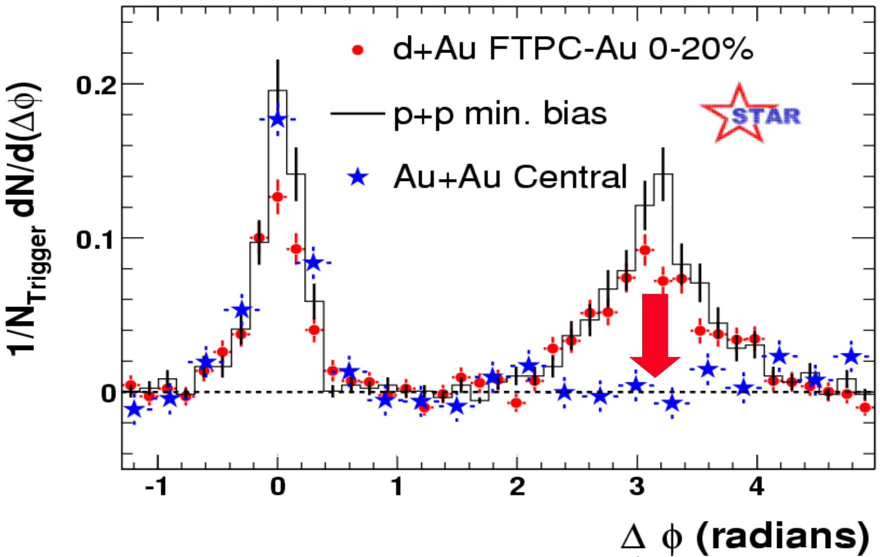
  Expect ramp up of luminosity over 3 years

  Full Au-Au Luminosity by 2013

High p_T Phenomena

Jet quenching: one of the most interesting discoveries at RHIC





Next steps require more detailed studies:

Near future: better PID

- Extend K, π, p p_T range to 10 GeV/c → PHENIX
- Large solid angle PID → STAR

Future steps: γ-jet tomography → RHIC II

PHENIX High p_T Particle Identification

		Pion-Kaon separation	Kaon-Proton separation
TOF	σ~100 ps	0 - 2.5	- 5
RICH	n=1.00044 γth~34	5 - 17	17 -
Aerogel	n=1.01 γth~8.5	1 - 5	5 - 9

Combination of three PID detectors

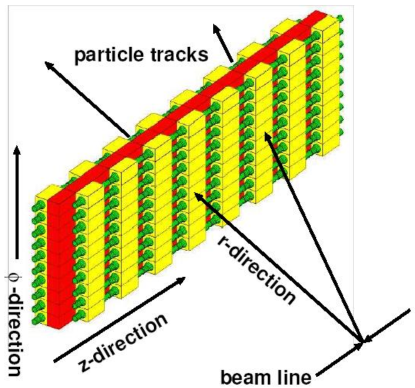
TOF σ ~ 100 ps

RICH with CO_2 γ_{th} ~ 34

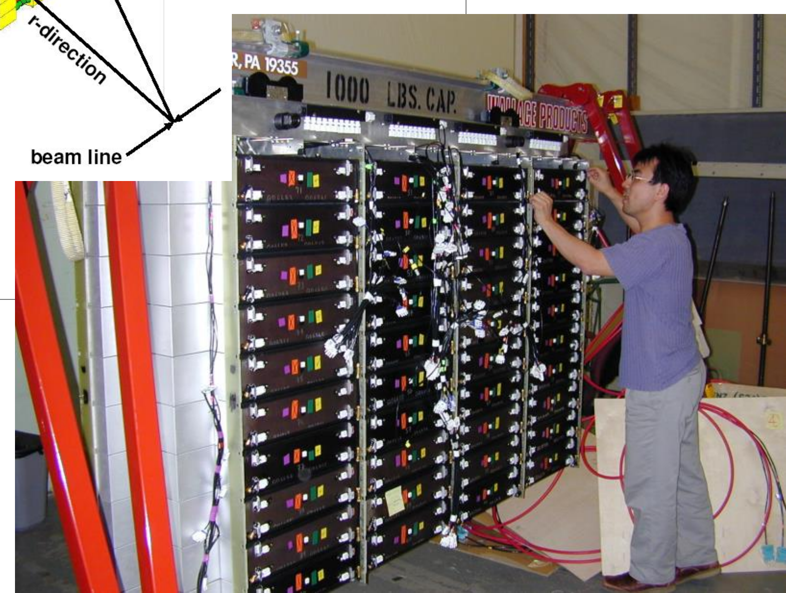
Aerogel Č, γ_{th} ~ 8.5

π, K, p separation out to ~ 10 GeV/c

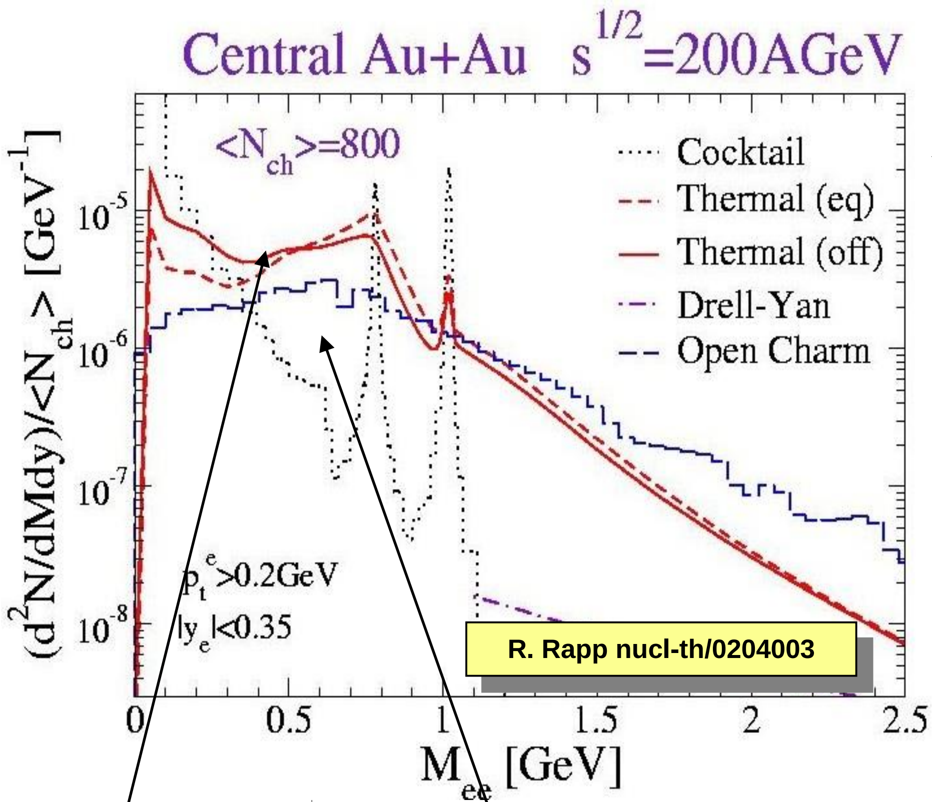
coverage ~ 4-8 m^2 in west arm

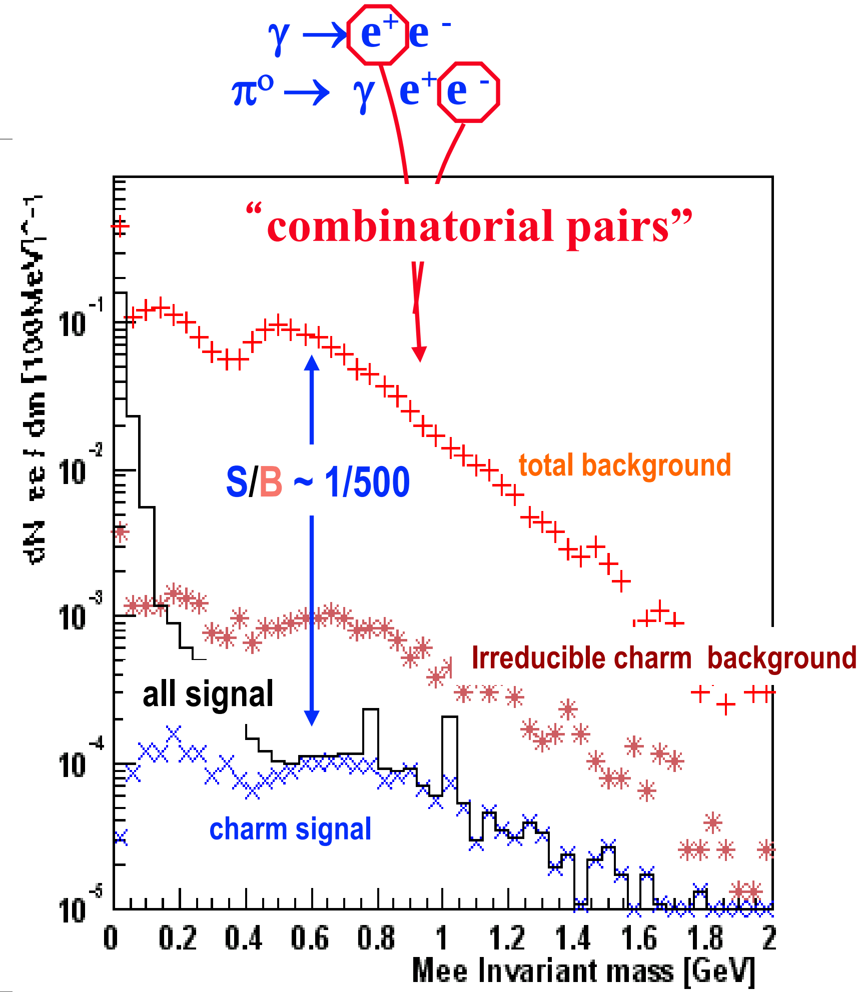


- 2 m^2 Aerogel Cherenkov installed
- Future plans:
  4 m^2 of aerogel detectors by 2005
  Develop matching TOF detector
  based on RPC's



Low-Mass e^+e^- Pairs: Prospects at RHIC



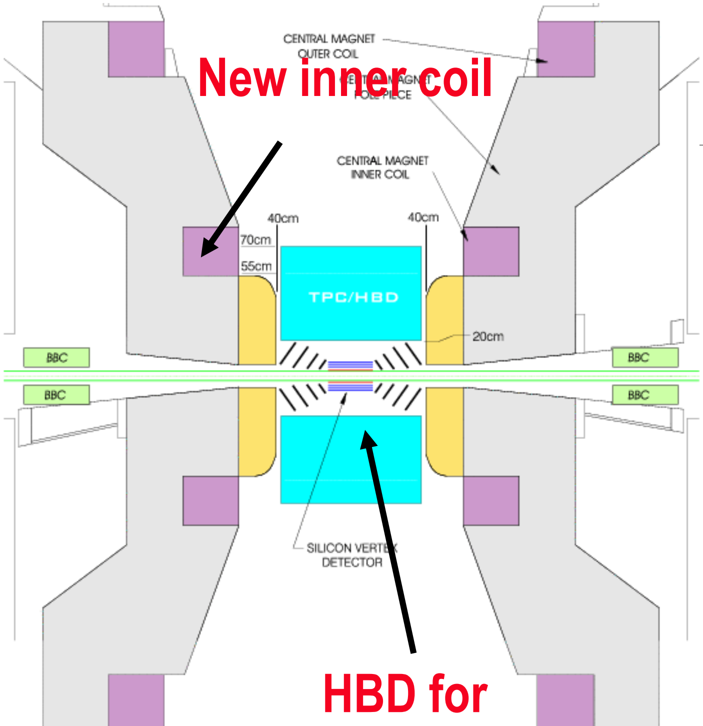


Strong enhancement of low-mass pairs persists at RHIC

Significant contribution from open charm

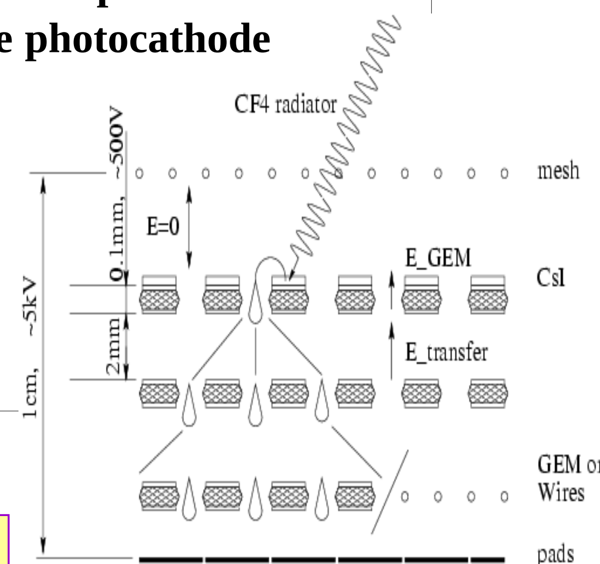
Need Dalitz rejection
& accurate charm measurement → PHENIX

PHENIX Dalitz Rejection with a HBD



- **Dalitz rejection via opening angle**
  - **Field free region to maintain opening angle**
  - **HBD for electron ID**
    - **Proximity focused RICH with 50 cm radiator**
    - **Provides minimal signals for charged particle**

- **HBD concept:**
  - **windowless Cherenkov detector**
  - **CF_4 as radiator and detector gas**
  - **Triple GEM with pad readout**
  - **CsI reflective photocathode**



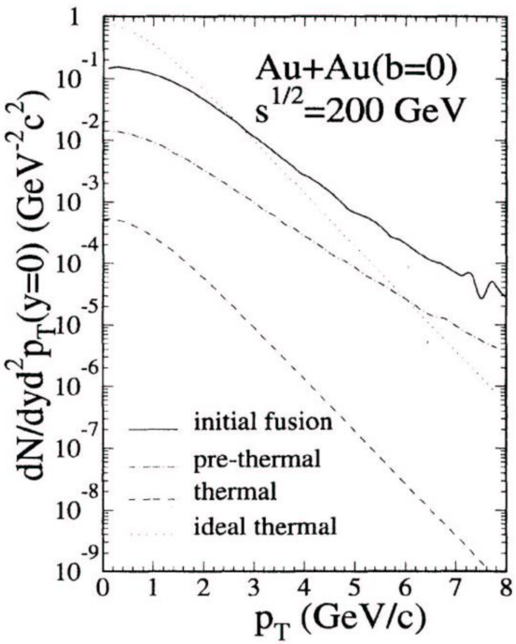
R&D at Weizmann Institute

- **Bandwidth 6-11eV, $N_0 \approx 940 cm^{-1}$ $N_{pe} \approx 40$!**
- **No photon feedback**
- **Low granularity, relatively low gain**
- **Hadron blind**

Proposal expected during 2004
Earliest implementation by 2006

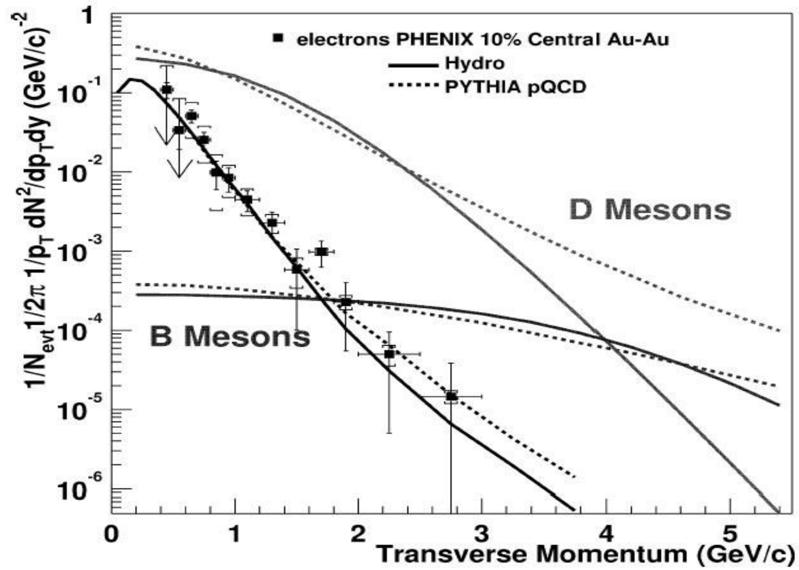
Physics from Precise Charm Measurements in Au-Au

Is there pre-thermal charm production?



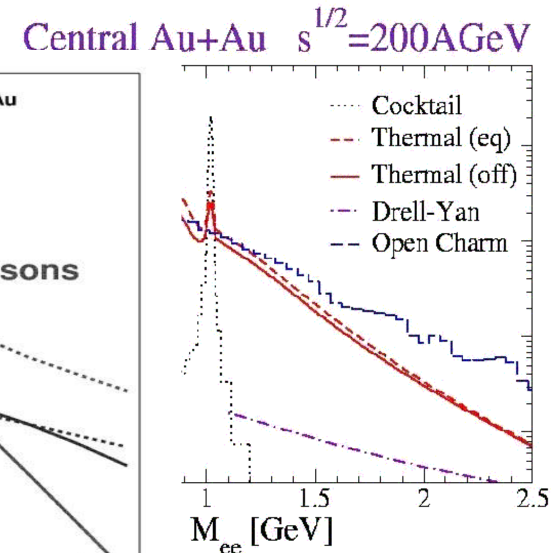
Precision measurement

Does charm flow? Does charm suffer energy loss?



Charm out to p_T > 4 GeV/c

Thermal dileptons from the QGP



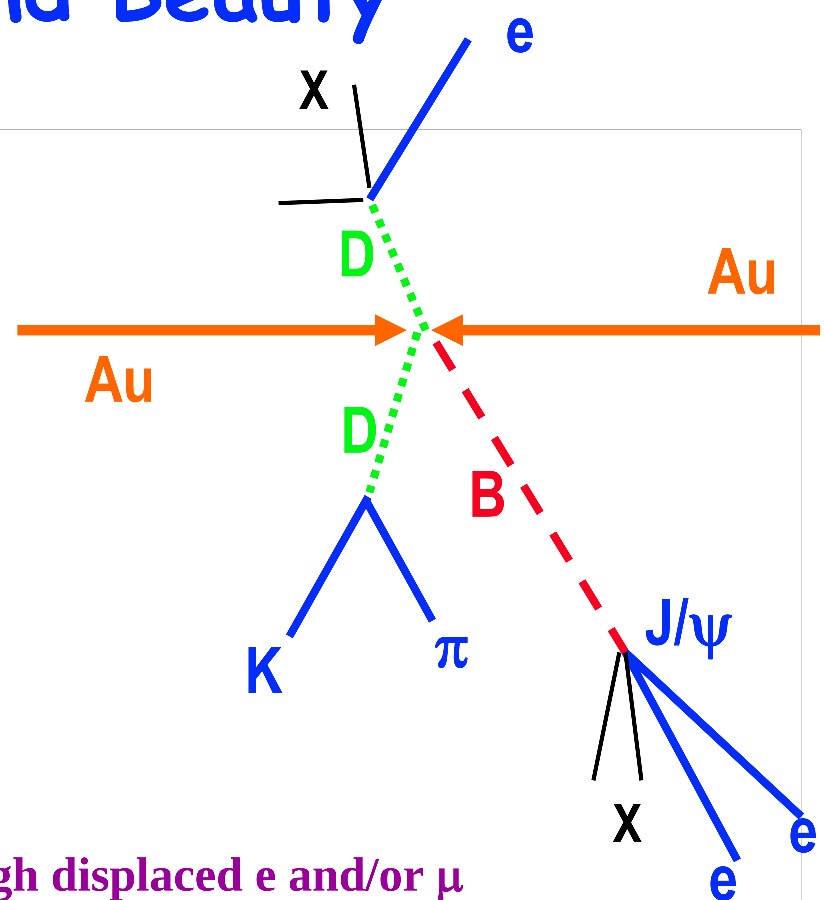
Accurate measurement of correlated e+e- pairs

These measurements are not possible or very limited without micro vertex tracking

Direct Observation of Open Charm and Beauty

Detection of decay vertex will allow a clean identifications of charm and bottom decays

	m GeV	cτ μm
D^0	1865	125
$D^\pm$	1869	317
B^0	5279	464
$B^\pm$	5279	496



Detection options:

- Beauty and low p_T charm through displaced e and/or μ
- Beauty via displaced J/ψ
- High p_T charm through $D \rightarrow \pi K$

Need secondary vertex resolution < 50 μm

Beauty and high p_T charm will require high luminosity

PHENIX Barrel VTX Detector Proposal

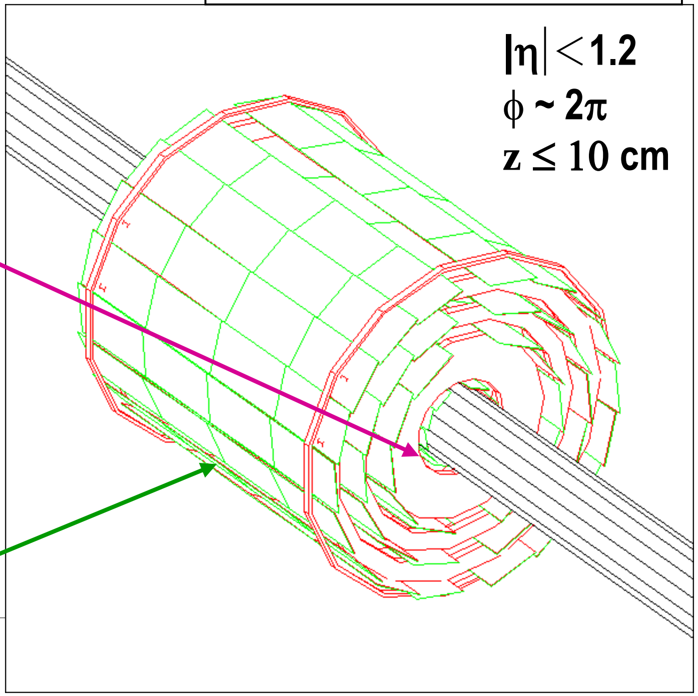
- Proposal submitted to BNL

  Detector system based on established technology

  Extensive ongoing R&D program

  Seek construction funds FY05 through FY07

Barrel detector (GEANT model)



Inner layer:

Hybrid Pixel Detector (50 μm x 425 μm) at R ~ 2.5 cm

Alice hybrid pixel technology:

32 x 256 channels / chip

bump bonded to pixel sensor

talks by V.Manzari and A.David

Three outer layers:

Strip Detectors (80 μm x 3 cm) at R ~ 6, 8, 10 cm

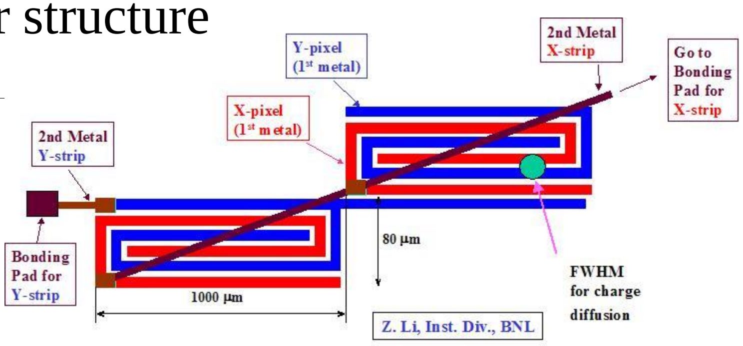
novel strip sensors with FNAL SVX4 readout

details on next slide

PHENIX Silicon Strips Detectors

- Sensor technology choice:
  - Single sided, two dimensional read-out sensor developed by Z. Li of BNL Inst. Division
  - 80 m x 3 cm strip
  - X/U stereo read-out

Sensor structure



- Readout chip technology choice:
  - SVX4 chip developed by FNAL/LBNL
  - 128 ch/chip

SVX4 chip

- Ongoing R&D
  - Prototypes sensors tested in beam at KEK
  - 2nd generation prototype in production
  - Will be tested with SVX4 readout
  - Plan to purchase SVX4 from FNAL

PHENIX Forward Upgrade Components

- **Endcap Vertex Tracker**

  silicon pixel detectors

- **Nosecone EM Calorimeter**

  W-silicon (20-50 X/X0)

  shower max

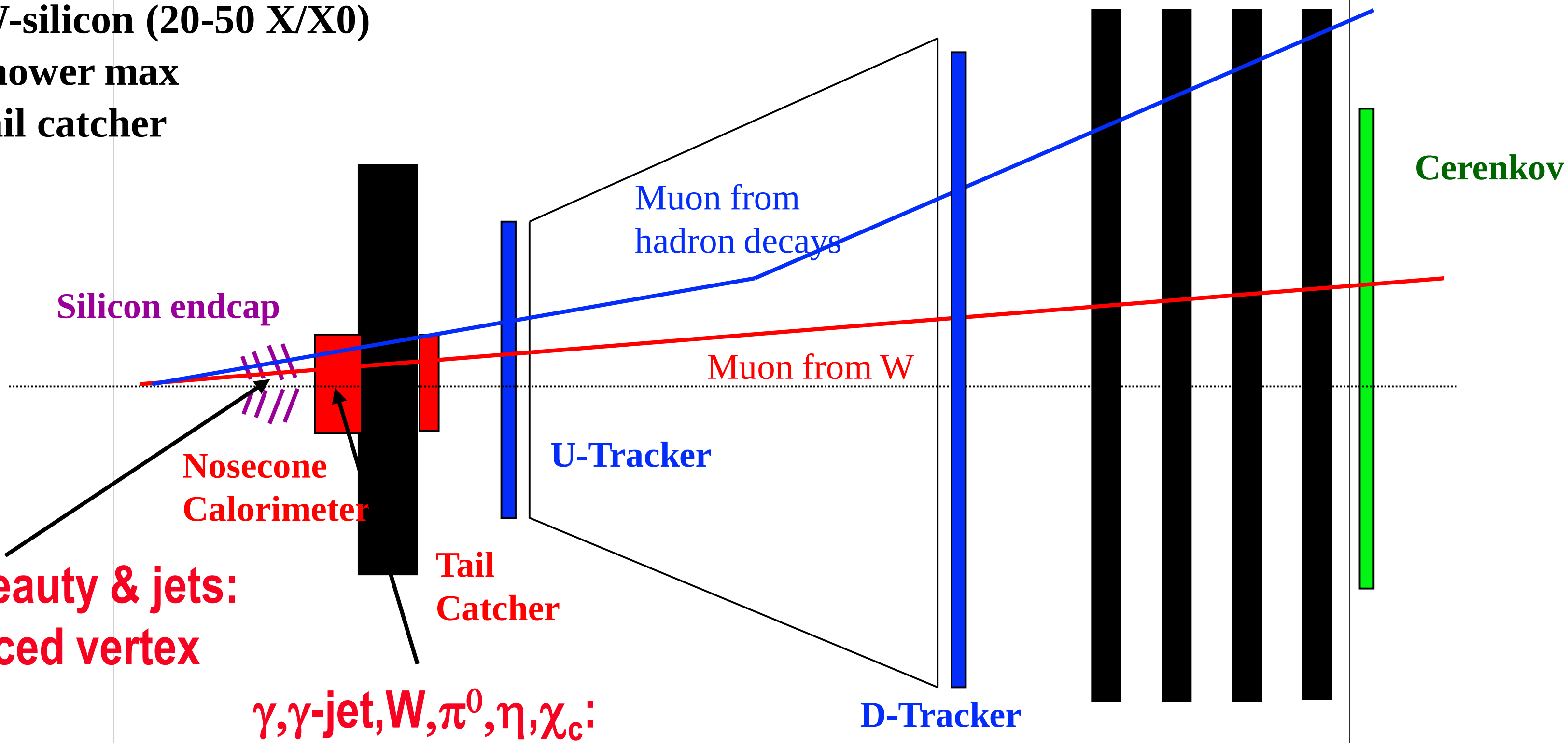
  tail catcher

- Muon trigger

  U-tracker (MuTr or new)

  D-tracker (timing with RPC's?)

  Cerenkov



charm/beauty & jets: displaced vertex

γ,γ-jet,W,π^0,η,χ_c: calorimeter

W and quarkonium: improved μ-trigger rejection

Proposal expected in 2004
Staged implementation 2005++

Possible Contributions (PHENIX)

- Silicon Vertex Detector (VTX): vertexing with 50 μm of resolution for heavy quark and lower mass e^+e^- measurements

  Still R&D stage, seek construction funds FY05 through FY07
- Endcap Vertex Tracker (silicon pixel) and Nosecone EM Calorimeter (W-silicon): γ, γ-jet, W, pizero, eta

  Staged implementation 2005++
- Hadron Blind Detector (HBD): Dalitz rejection to remove electron backgrounds

  Still R&D stage, earliest implementation by 2006
- Data analysis and production

  In 2004, PHENIX produced about 300TB of raw data plus a couple of times of reconstructed data and analysis files.

  A typical Heavy Ion experiment produces too much data each year and needs manpower and computing resources outside of RHIC/LHC.

  Such efforts can be of more interest for theorists also.

Current Analysis Status in Yonsei

- We already have been analyzing the followings "locally":
  RUN2(PP) : single muon
  RUN3(dAu) : single muon
  RUN4(PP) : single muon as well as j/ψ

- Additionally, our group just have started official data reproduction for muon portion of RUN3(dAu) after installing every PHENIX software into our local cluster.

- Currently, our local linux cluster have 20 CPU's and 20 TB of storage and still expanding hardware resources every year. Soon (this month) we will have gigabit network connection also. Not many groups in PHENIX have such resources and experiences related to the analysis.

Possible Contributions (ALICE)

- Personally, I think ALICE is a good experiment for us to work together as long as we can obtain the appropriate fund.

- If Korean group is interested in Aerogel detector in ALICE, we can get "any" level of support from Tsukuba group.

- If not many good hardware activities are left in ALICE, I think analysis and computing activities would be a good place to consider because it is not too early for people to prepare for the ALICE data analysis by generating simulation data and developing the analysis software.

- To be familiar with ALICE computing and communicate with ALICE software group in CERN, people may have to visit CERN for some extended period once we deicide this. Also, we need money to build good local computing facilities.

The picture can't be displayed.

Backup

More on High P_T Suppression

I would like to pick the most famous result for the rest of my talk. The following are topics related to the High P_T Suppression.

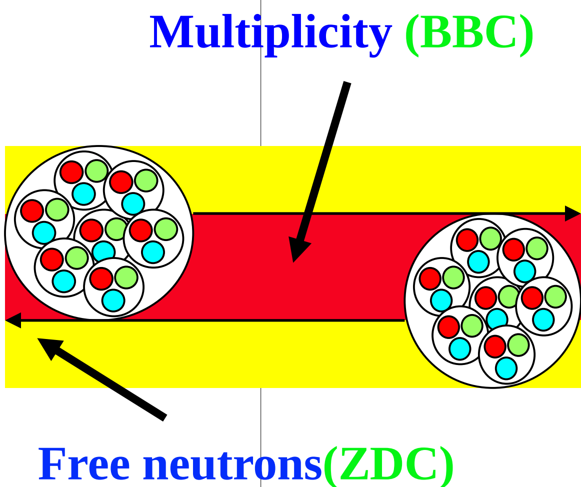
- Event Characterization in PHENIX
- Collision centrality, N_participants, N_collisions
- High p_T hadron suppression in Au+Au
- High p_T hadron suppression in d+Au (control exp.)
- Suppression of far-side jet in central Au+Au

Event characterization

AA collisions are not all the same, centrality (or impact parameter b) can be determined by measuring multiplicity (or transverse energy) near collision point combined with the number of free neutrons into beam directions.

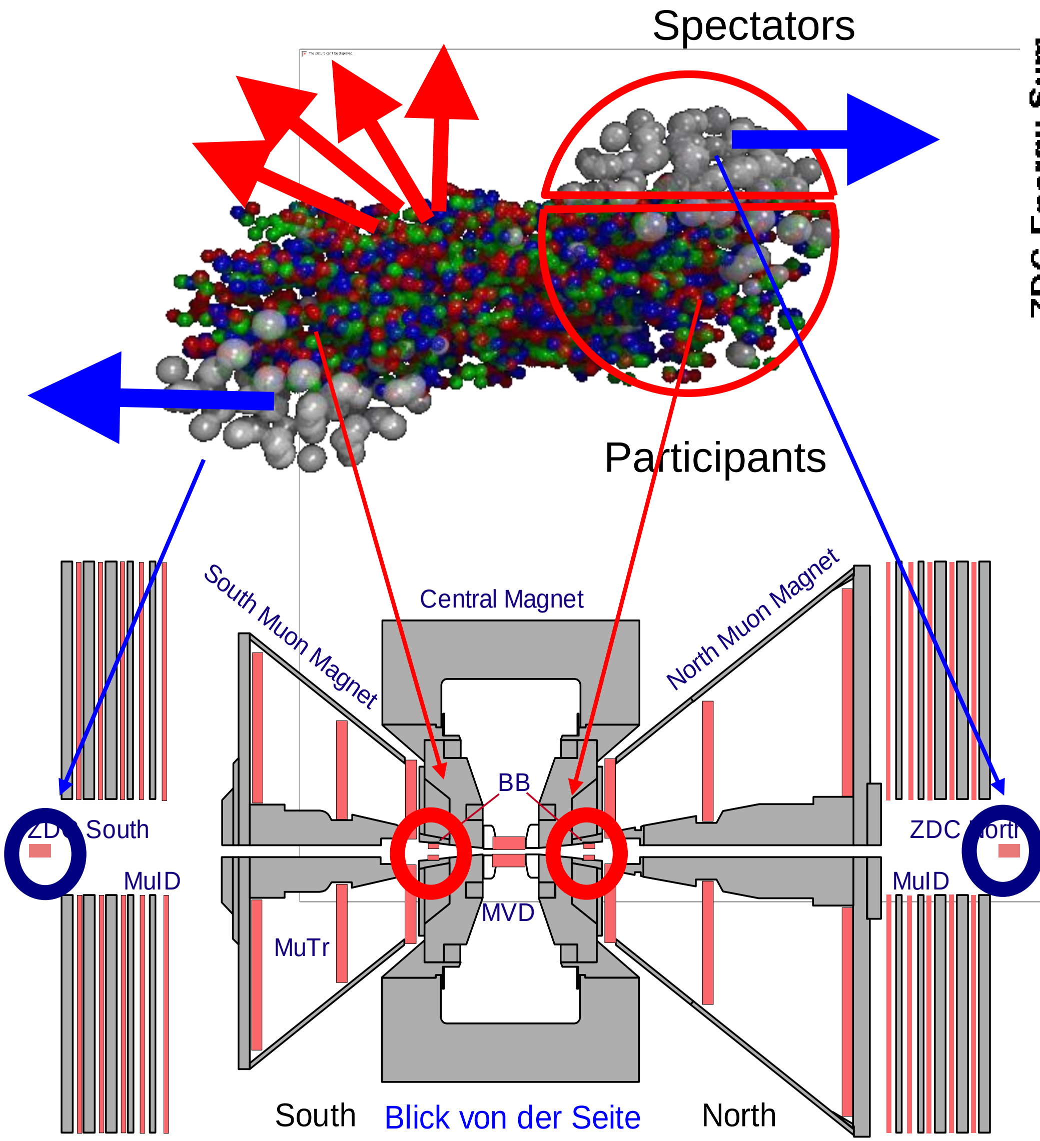
- *Npart*: Number of nucleons which suffered at least one inelastic nucleon-nucleon collision

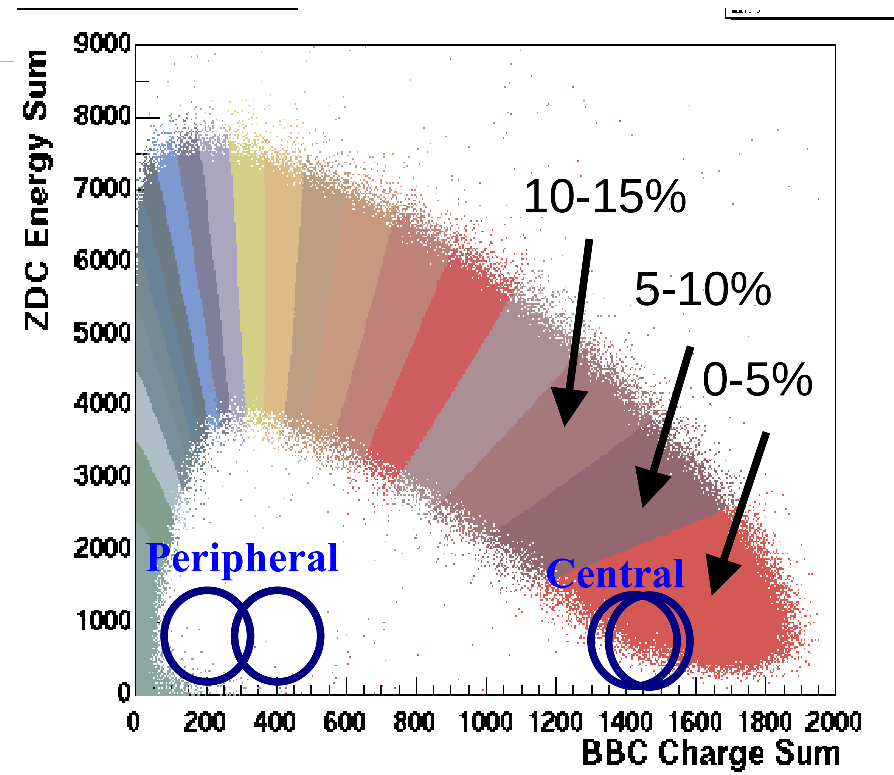
- *Ncoll*: Number of inelastic nucleon-nucleon collisions



Knowing the centrality using multiplicity of charged particles (BBC) and, number of free neutrons (ZDC), we can determine *Npart* and *Ncoll* from Glauber calculations; **Phys. Rev. 100 (1955) 242.**

Collision Centrality Determination

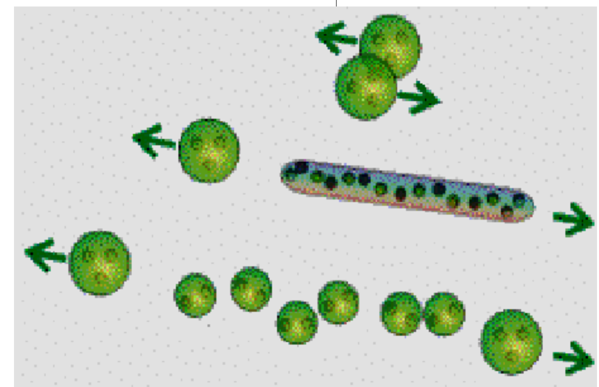




- **Centrality selection : Sum of Beam-Beam Counter (BBC, $|\eta|=3\sim4$) and energy of Zero-degree calorimeter (ZDC)**
- **Extracted N_{coll} and N_{part} based on Glauber model.**

AA as a superposition of pp

Probability for a "soft" collision is large (~99.5%). If it happens, the nucleon is "wounded" and insensitive to additional collisions as it needs some time (~1fm/c) to produce particles, thus yields of soft particles scale from pp to AA as the number of participants(*Npart*).



Probability for a "hard" collision for any two nucleons is small, thus yields of hard particles should scale with the number of binary nucleon-nucleon collisions(*Ncoll*).