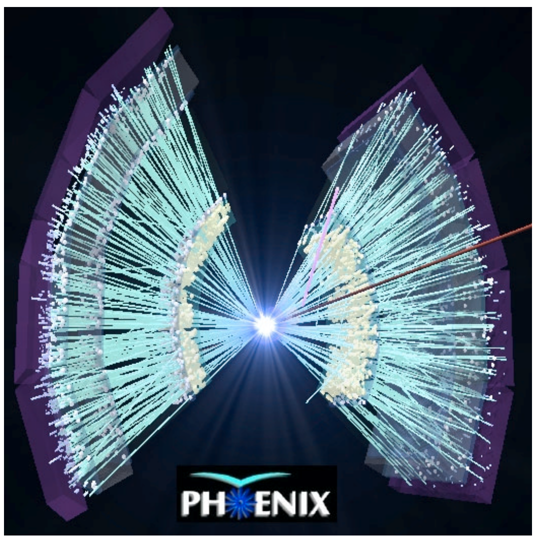
x_T scaling in Au+Au collisions at $\sqrt{s_{NN}}$=130 and 200 GeV for π^0 and charged hadrons from PHENIX

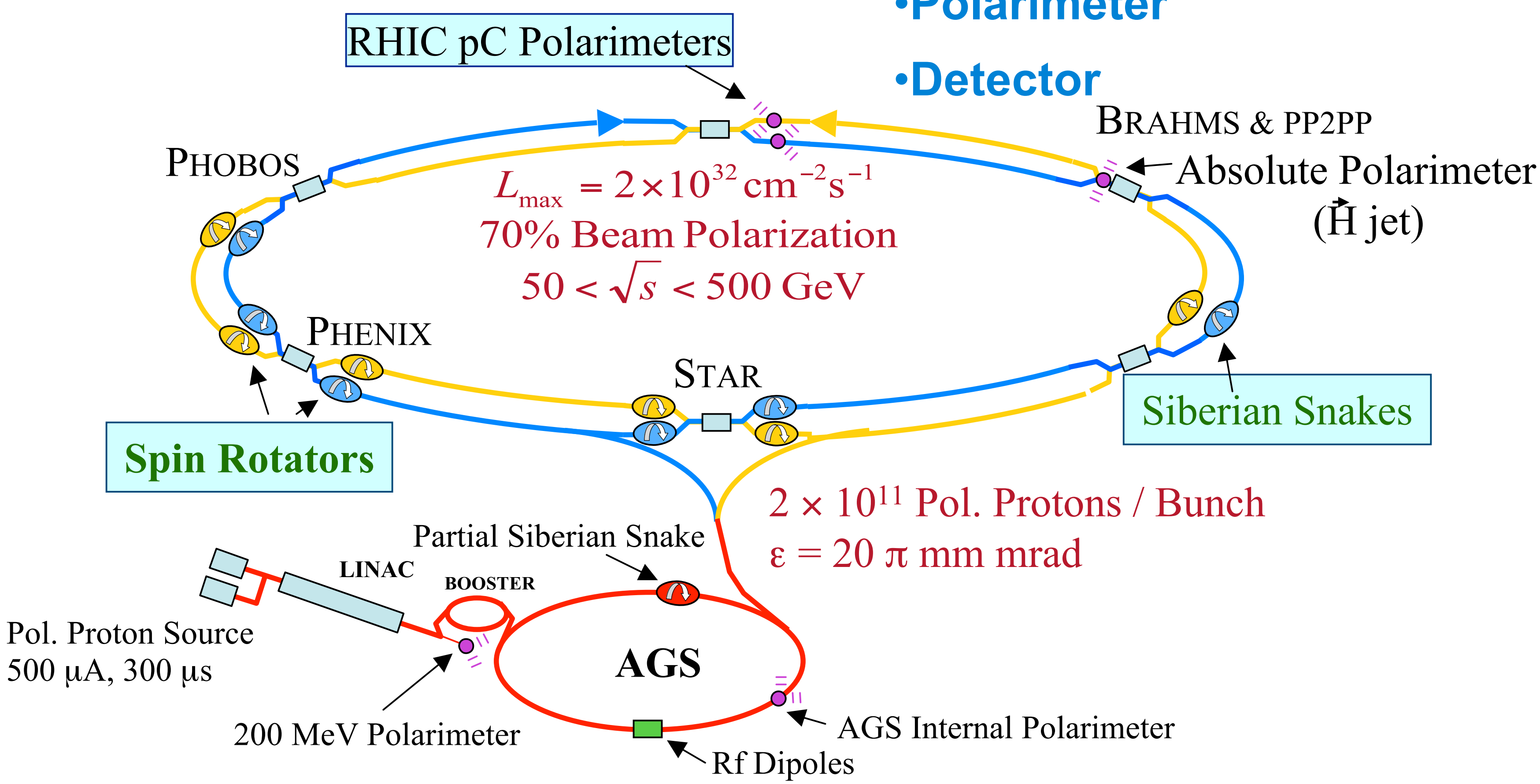


M. J. Tannenbaum
Brookhaven National Laboratory
Upton, NY 11973 USA

nucl-ex/0308006 to appear in PRC

RHIC: RHI+polarized p-p collider

- **Accelerator**
- **Polarimeter**
- **Detector**



PHENIX = **Pioneering High Energy Nuclear Interaction eXperiment**

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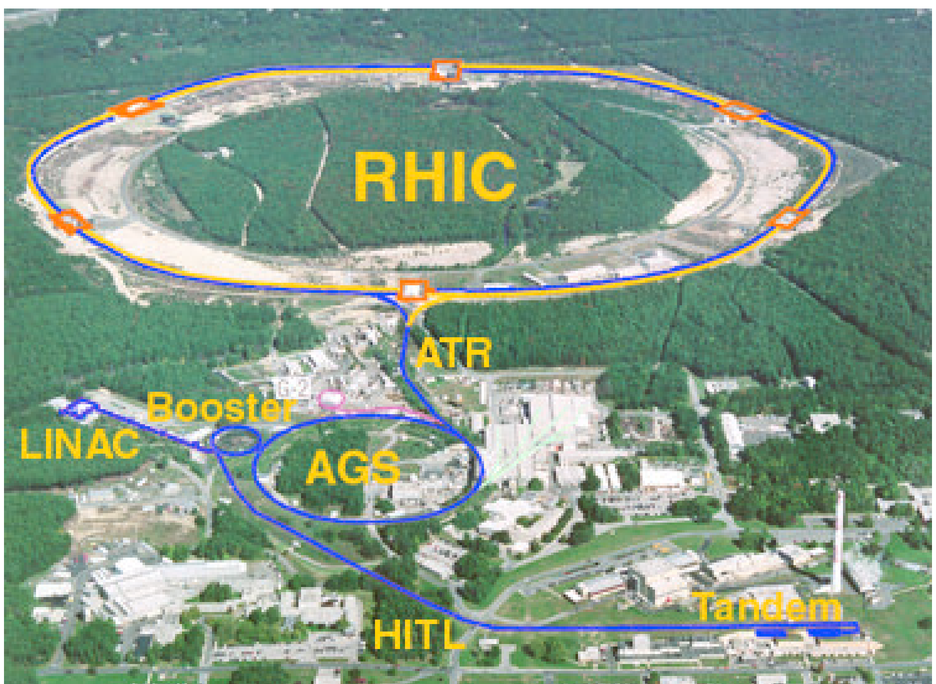
A large, multi-purpose nuclear physics experiment at the Relativistic Heavy-Ion Collider (RHIC)

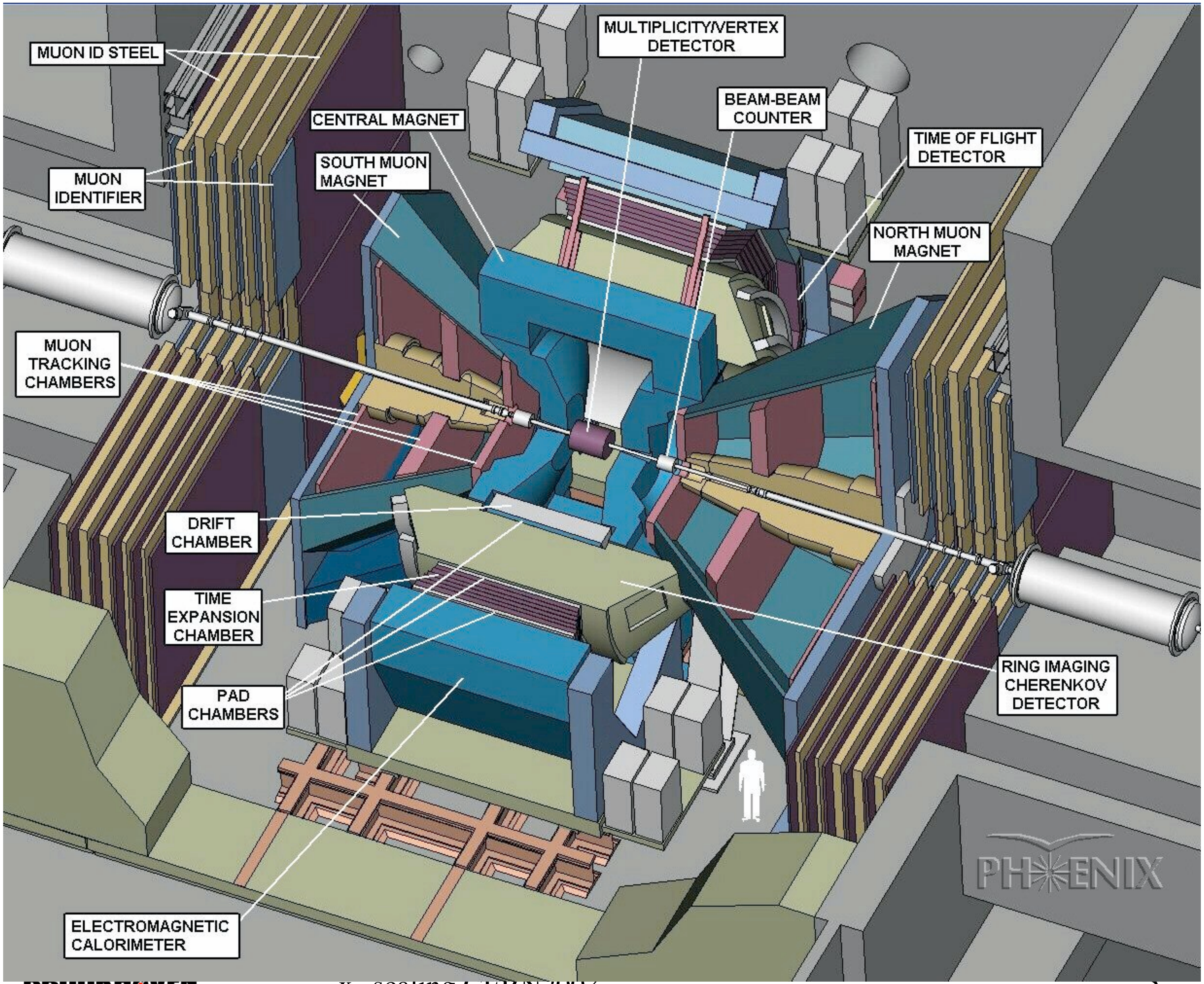


The PHENIX collaboration

A world-wide collaboration of ≈ 500 physicists from 51 Institutions in 12 countries

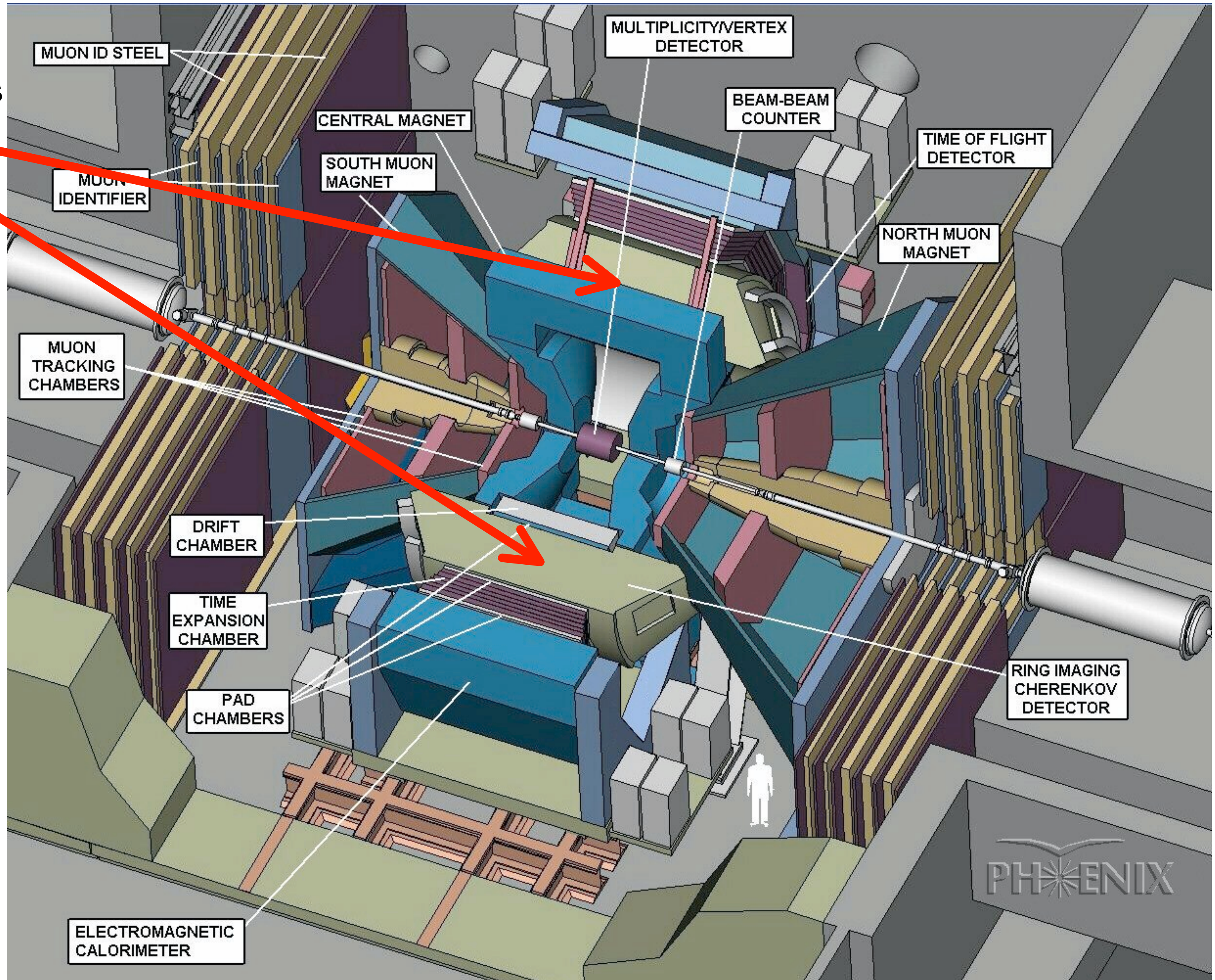
The PHENIX collaboration

The PHENIX detector



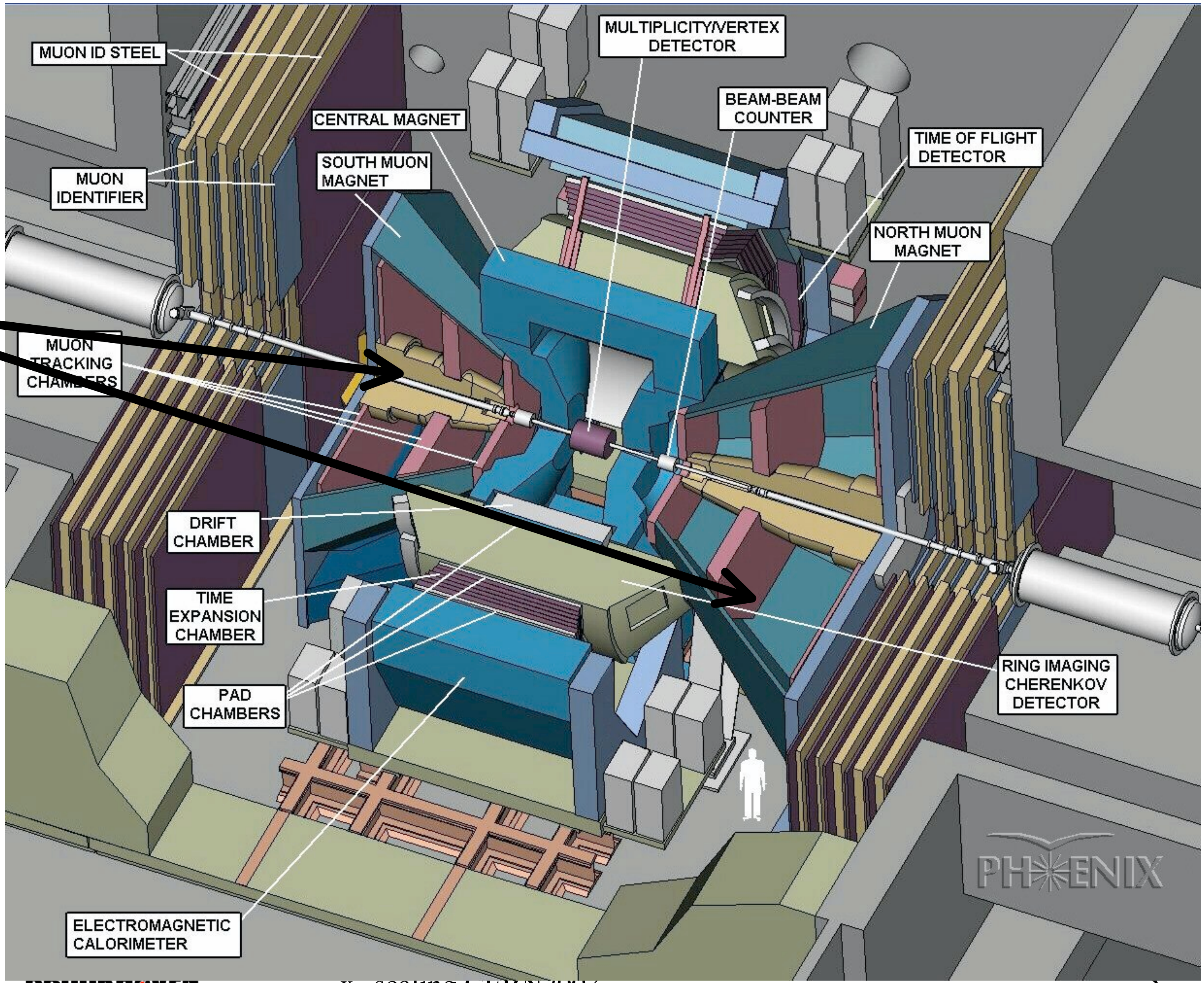
The PHENIX detector

2 Central
Tracking arms



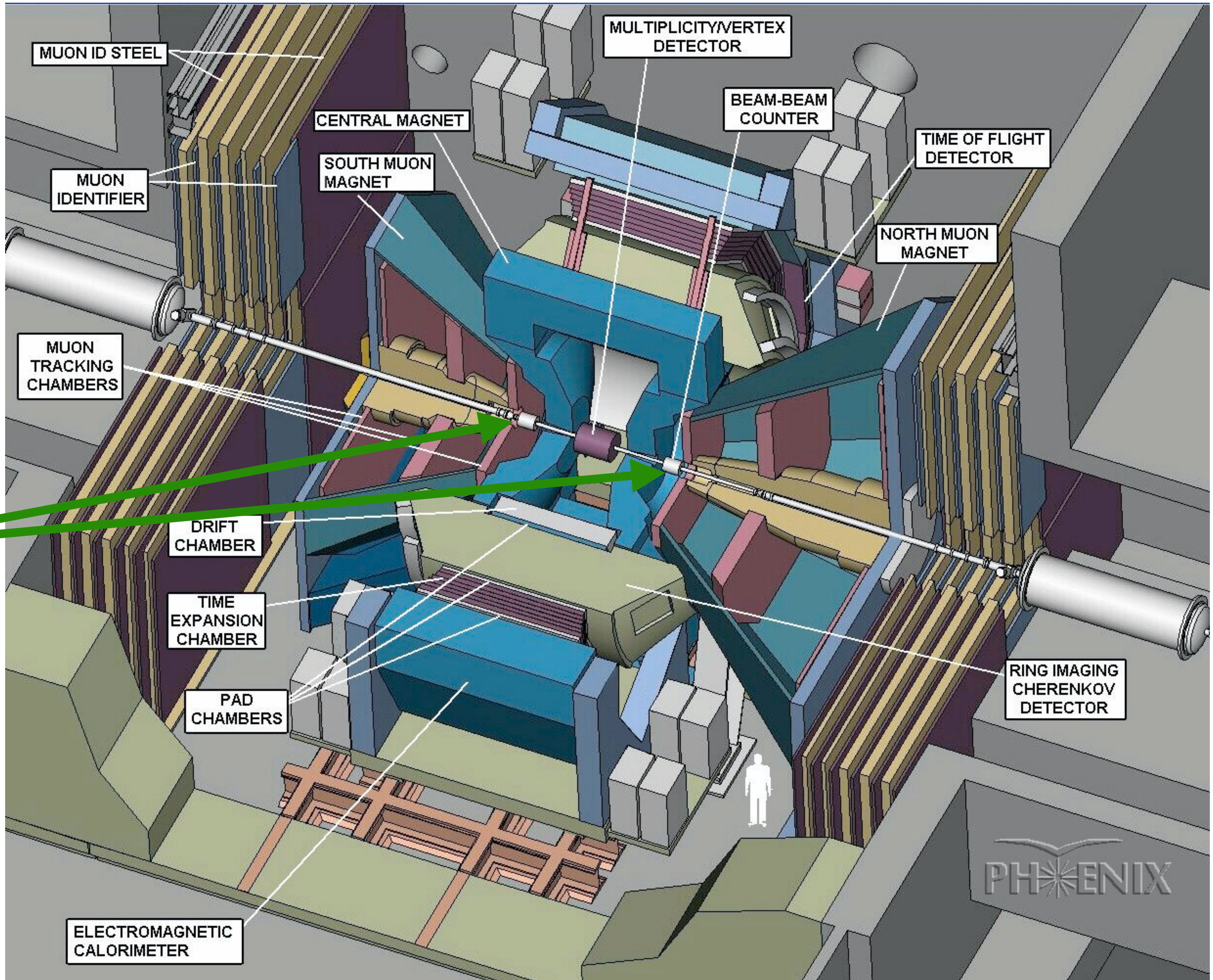
The PHENIX detector

2 Muon arms



The PHENIX detector

Beam-beam counters



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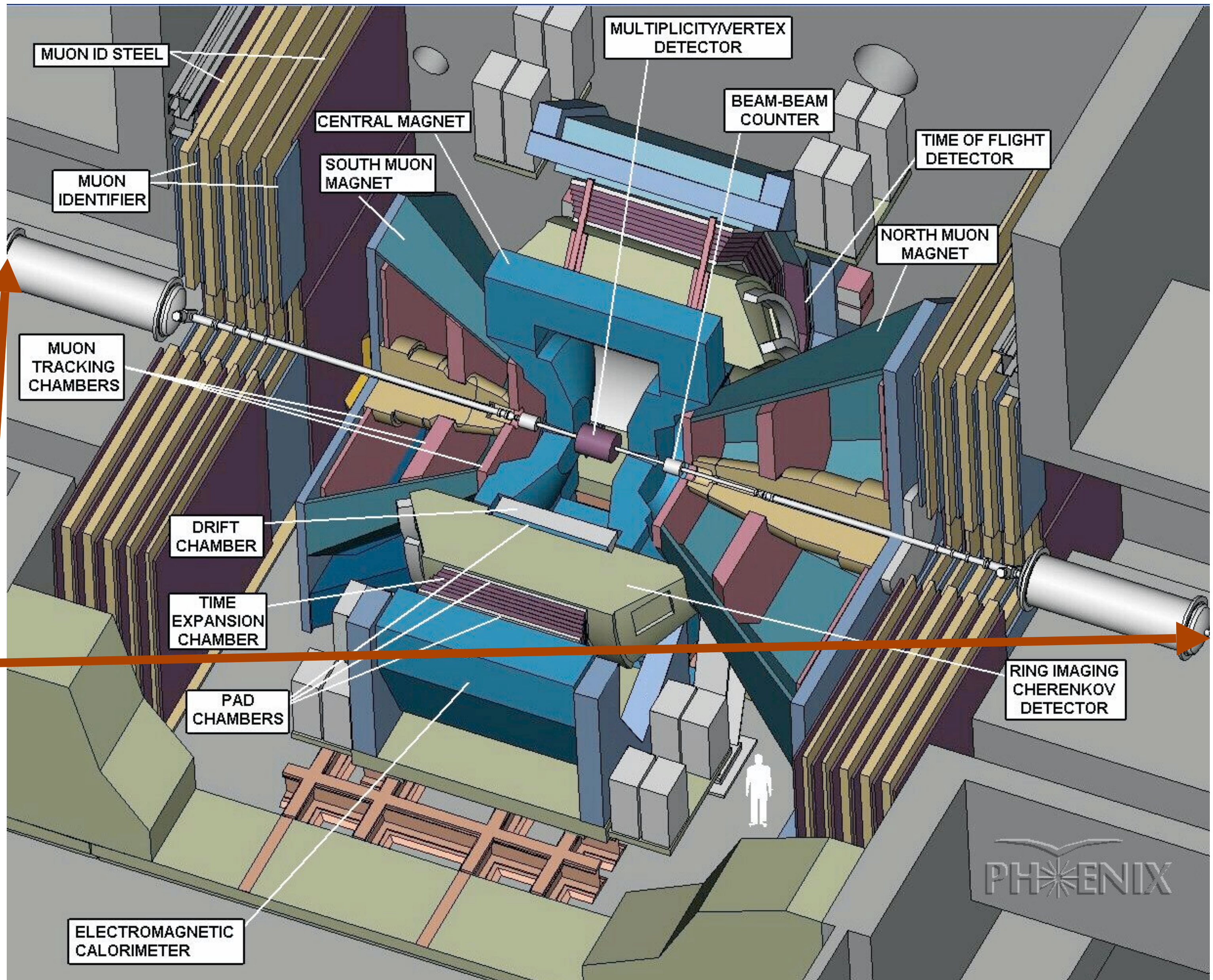

Zero-degree calorimeters (not seen)

Detectors in the central spectrometer arms (pseudorapidity $|\eta| < 0.35$)

- Charged Particle Tracking:
  - Drift-Chambers (DC)
  - Pad-Chambers (PC)
- Identification of charged hadrons:
  - Time-of-Flight (TOF) with start signal from the Beam-Beam-Counters (BBC)
- Electron Identification
  - Ring Imaging Cherenkov Detector (RICH)
- π^0 via $\pi^0 \rightarrow \gamma\gamma$:
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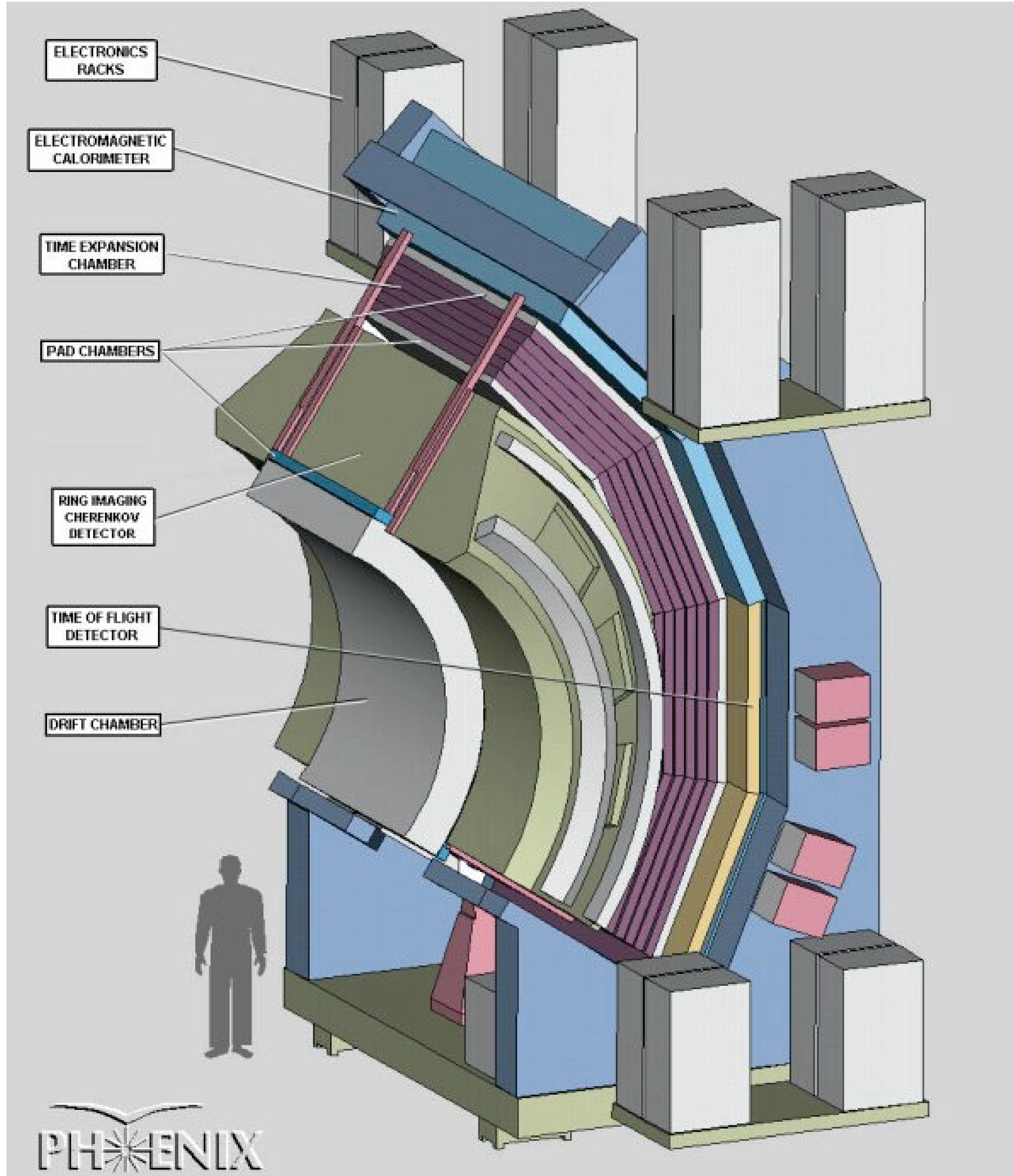

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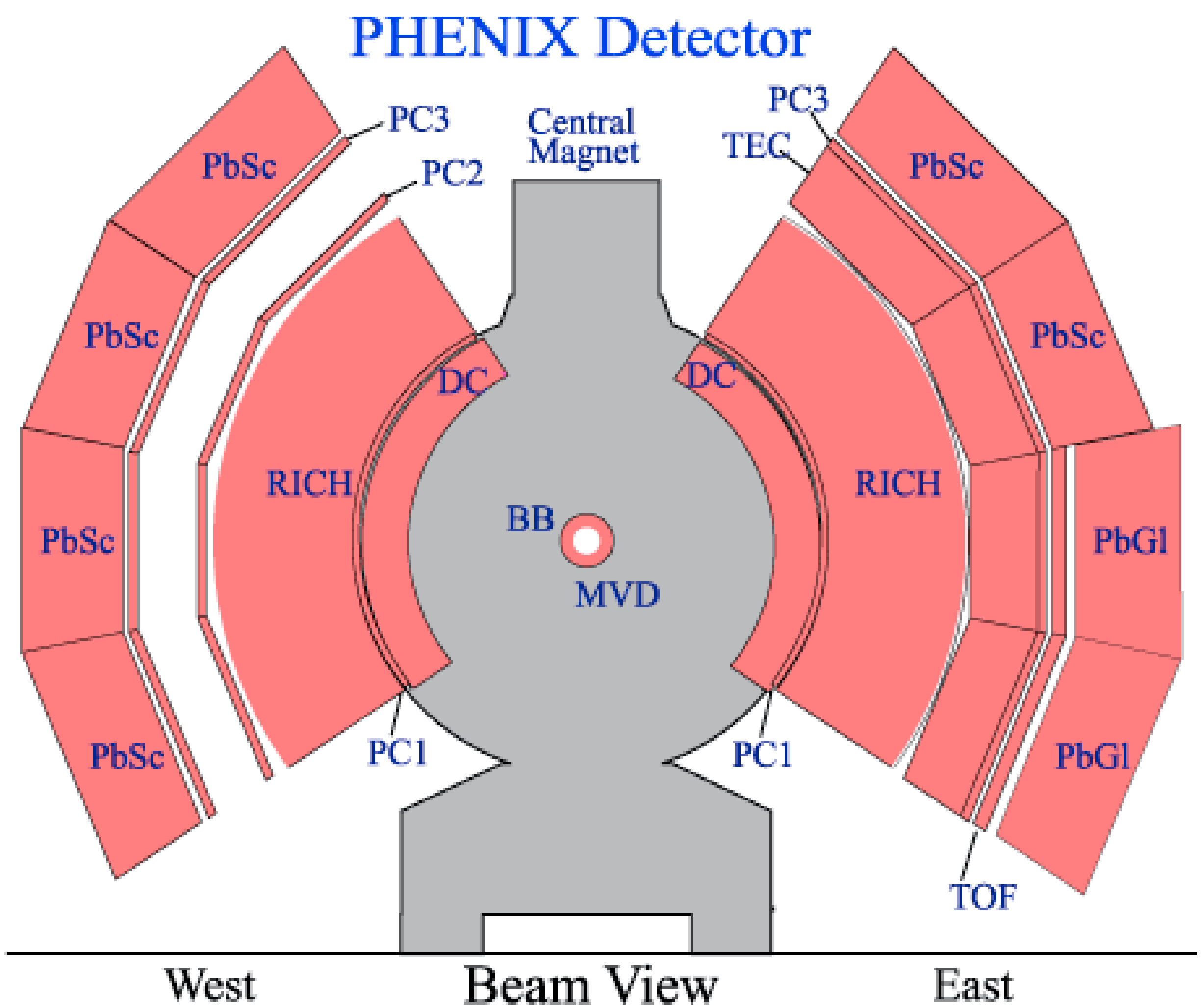
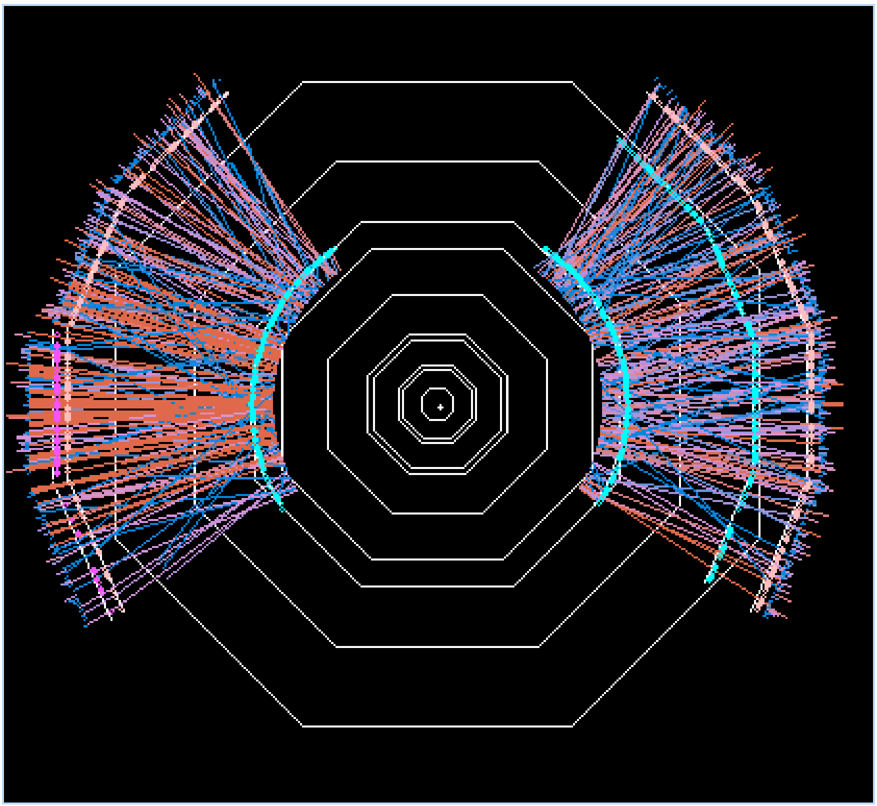
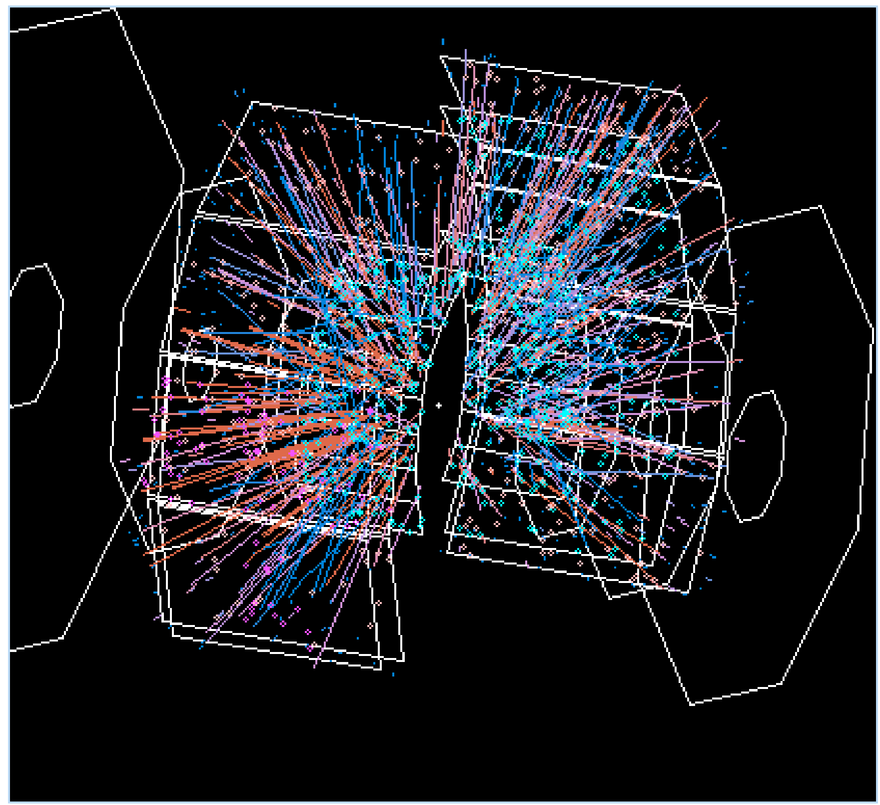


Example of a central Au+Au event at $\sqrt{s_{nn}}$ =200 GeV



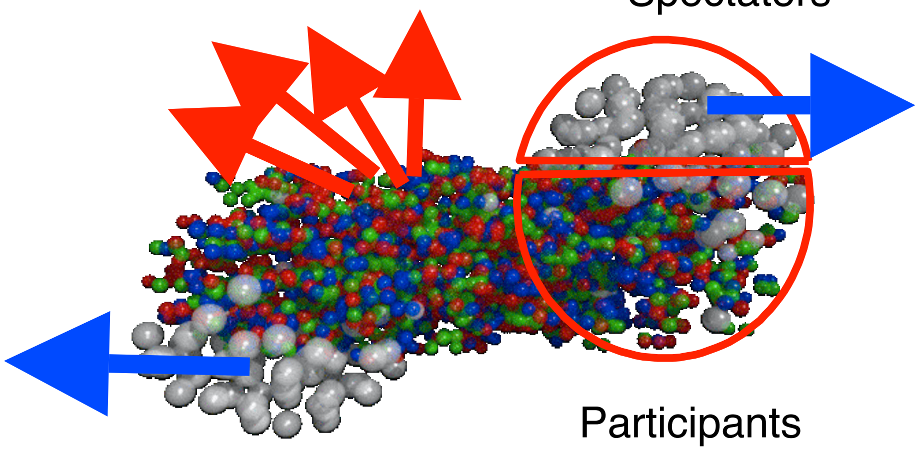


RHIC Run Summary

<table>
<tr><th>RUN</th><th>SPECIES</th><th>ENERGY</th><th>LUMINOSITY</th><th>POLARIZATION</th></tr>
<tr><td>RUN 1
2000</td><td>Au + Au</td><td>130 GeV</td><td>1.0/μb</td><td></td></tr>
<tr><td rowspan="2">RUN 2
2001-2002</td><td>Au + Au</td><td>200 GeV</td><td>24/μb</td><td></td></tr>
<tr><td>P + P</td><td>200 GeV</td><td>150/nb</td><td>Transverse</td></tr>
<tr><td rowspan="3">RUN 3
2002-2003</td><td>d + Au</td><td>200 GeV</td><td>2.7/nb</td><td></td></tr>
<tr><td rowspan="2">P + P</td><td>200 GeV</td><td>17/nb</td><td>Transverse</td></tr>
<tr><td>200 GeV</td><td>350/nb</td><td>Longitudinal</td></tr>
</table>

Recorded on tape at PHENIX

Collision Centrality Determination



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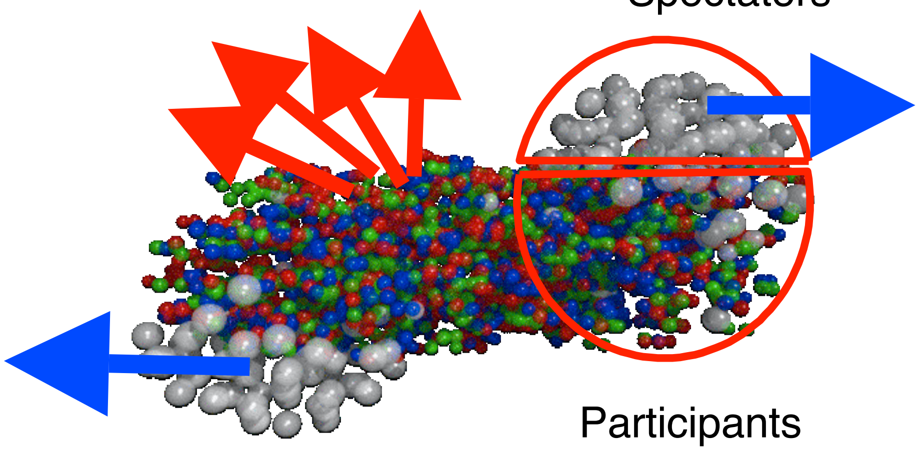

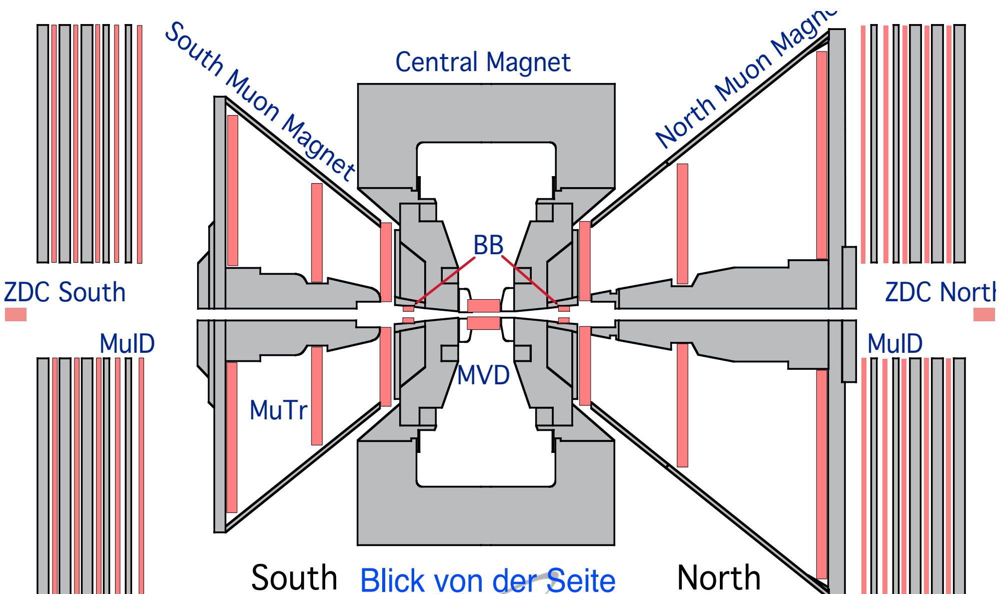

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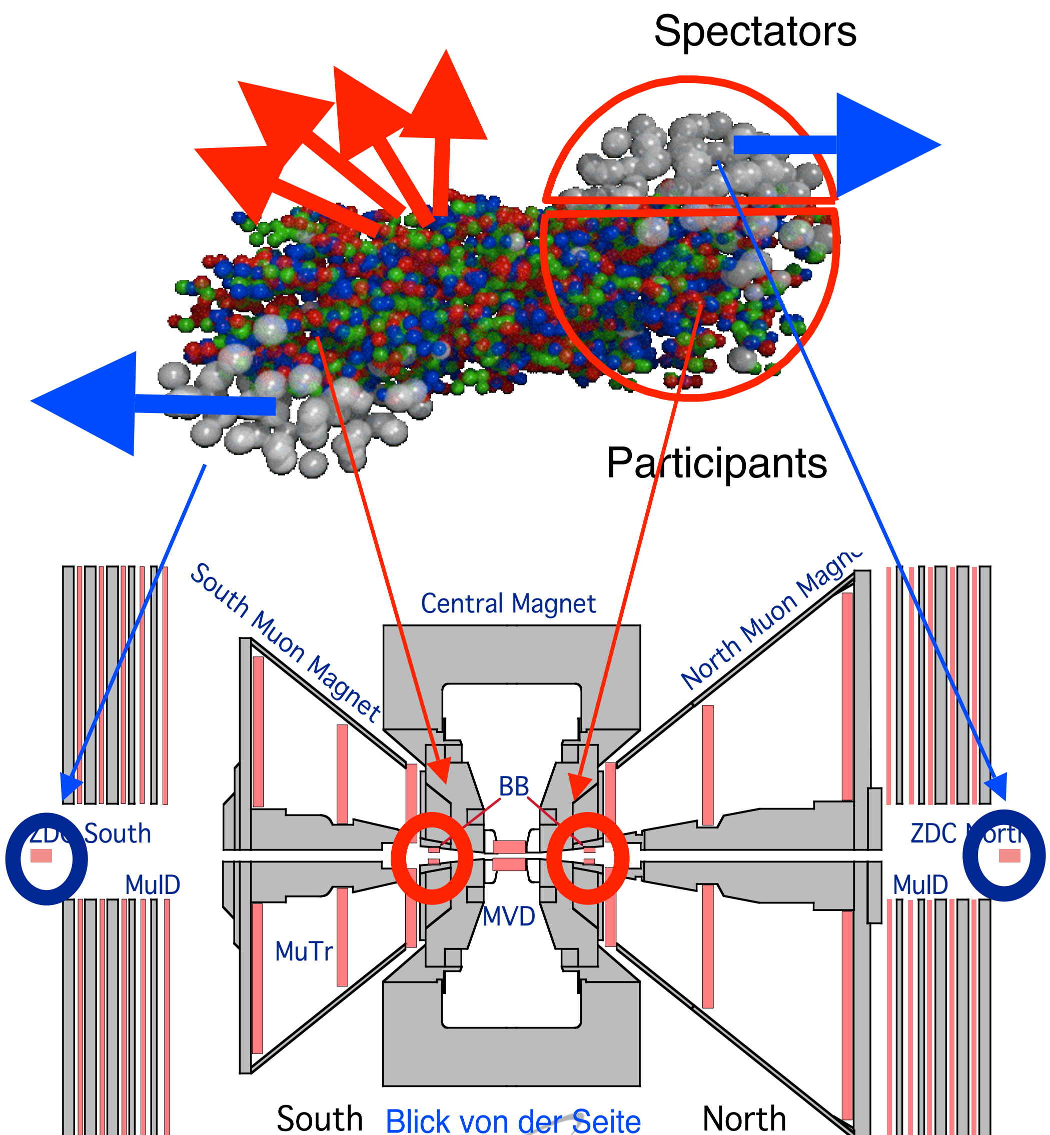

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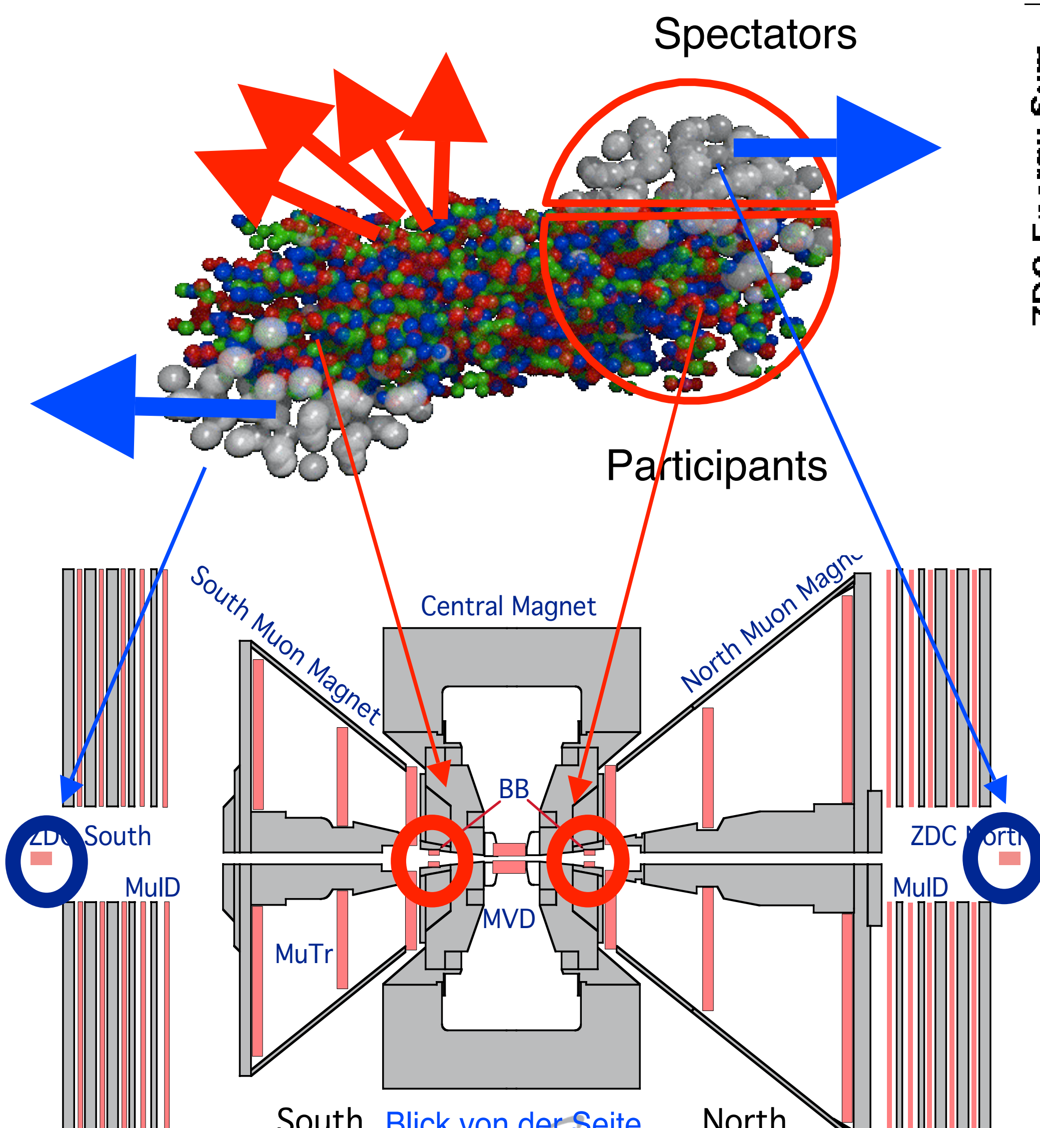
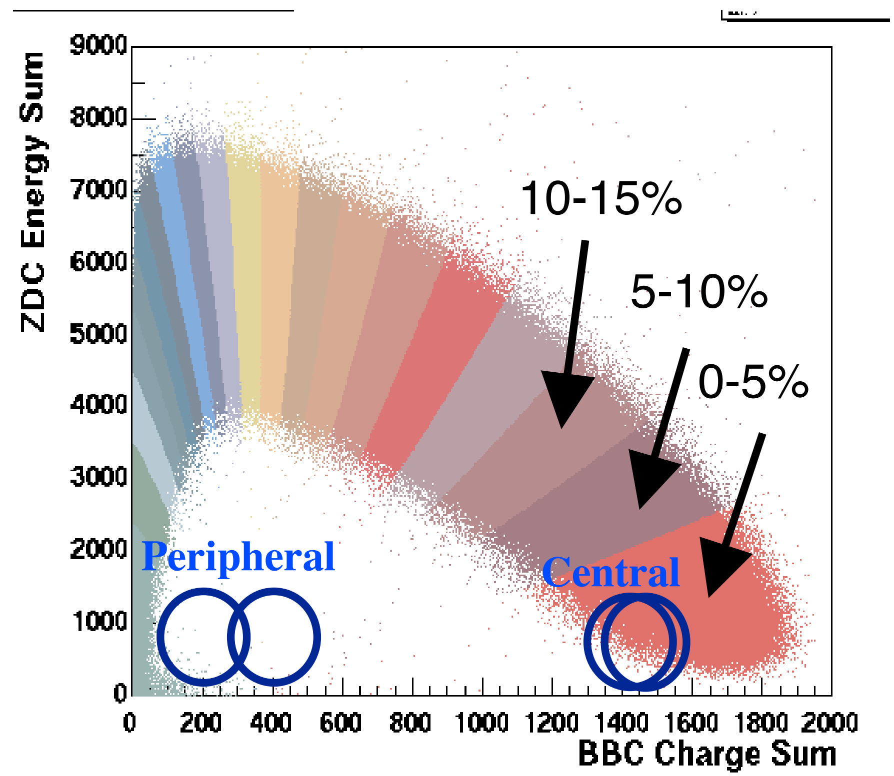
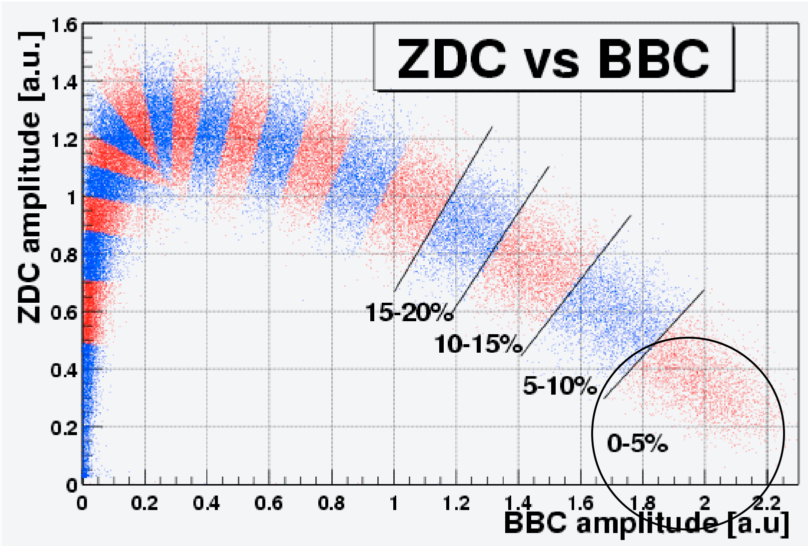


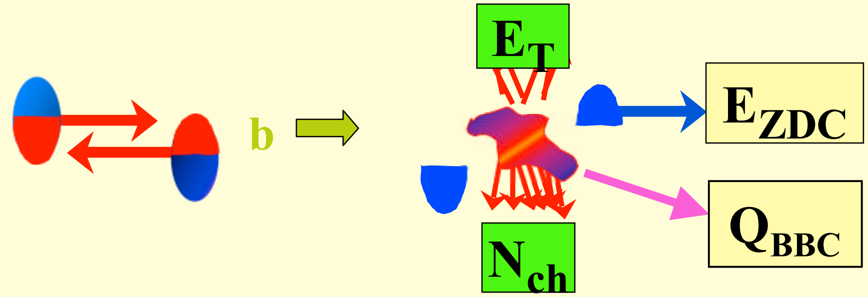


- Centrality selection : Sum of Beam-Beam Counter (**BBC**, $|\eta|$=3~4) and energy of Zero-degree calorimeter (**ZDC**)
- Extracted N_{coll} and N_{part} based on Glauber model.

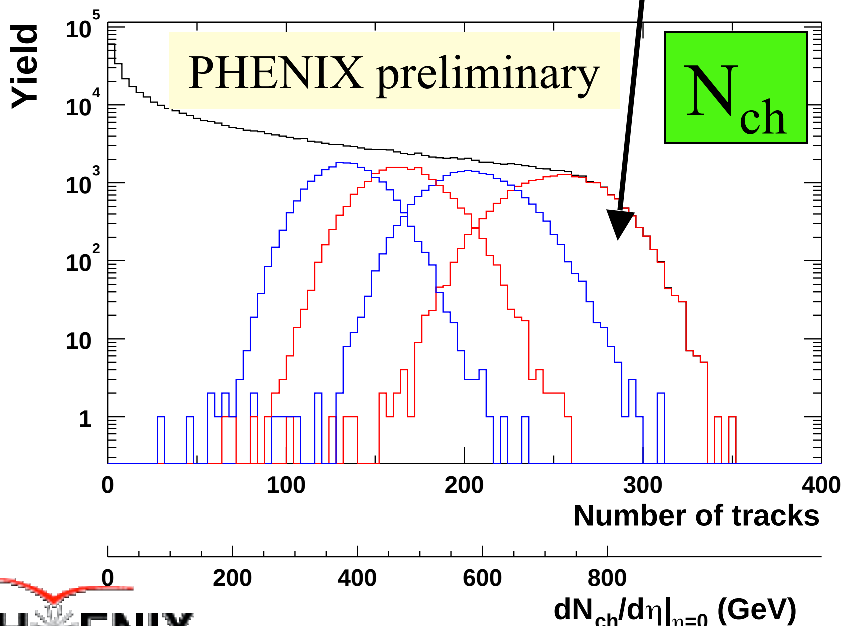
$N_{charged}$ and E_T illustrate the excellent centrality definition

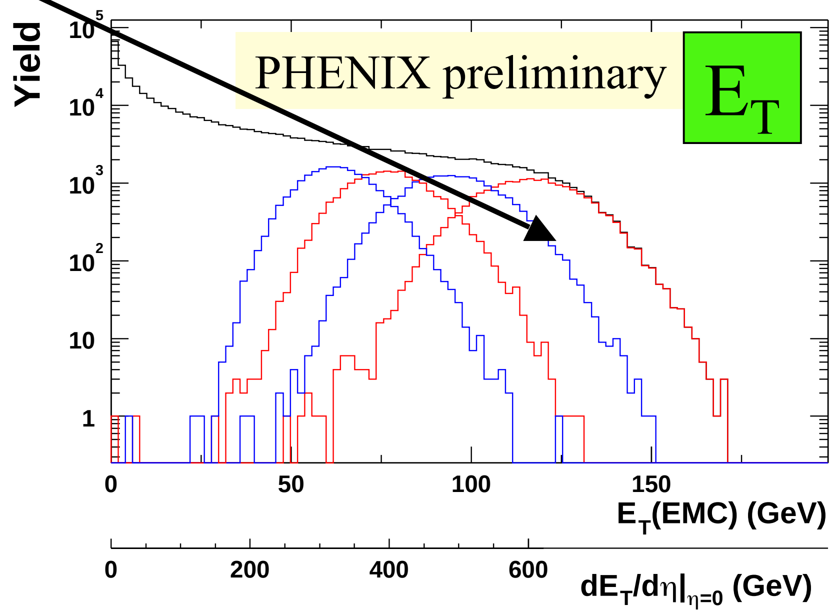


Define centrality classes: ZDC vs BBC



Extract N participants: Glauber model



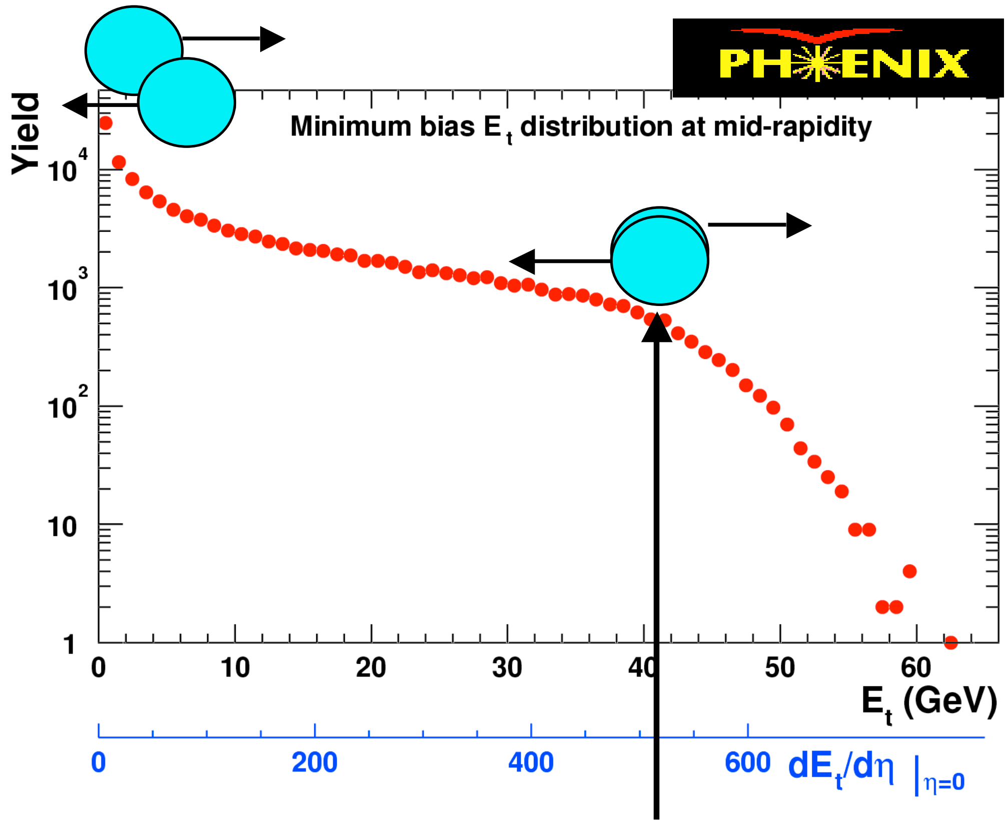


:aling

)

Is the energy density high enough?

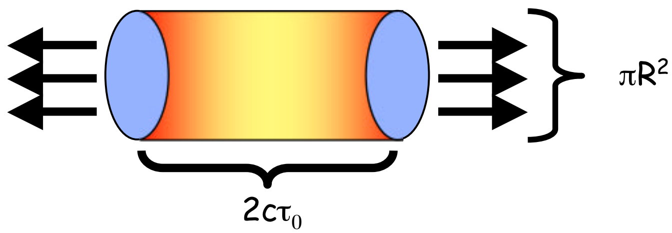
PRL87, 052301 (2001)



Is the energy density high enough?

PRL87, 052301 (2001)

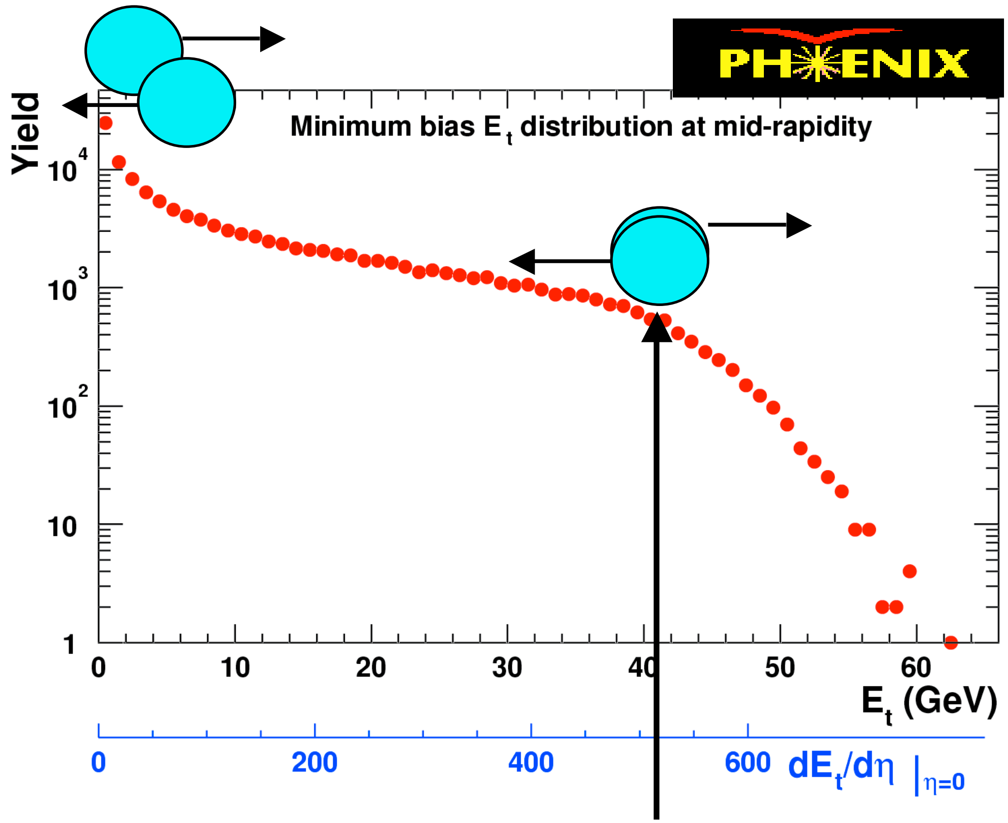
Colliding system expands:



Energy ⊥ to beam direction

$$\varepsilon_{Bj} = \frac{1}{\pi R^2}\frac{1}{2c\tau_0}\left(2\frac{dE_T}{dy}\right)$$

per unit velocity || to beam



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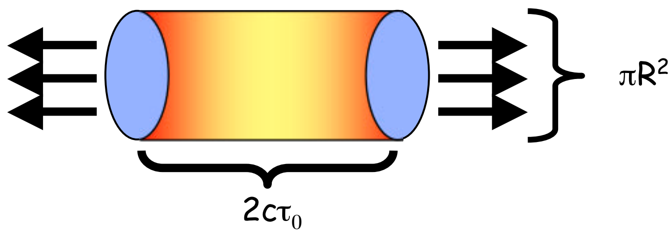

Energy $\perp$ to beam direction

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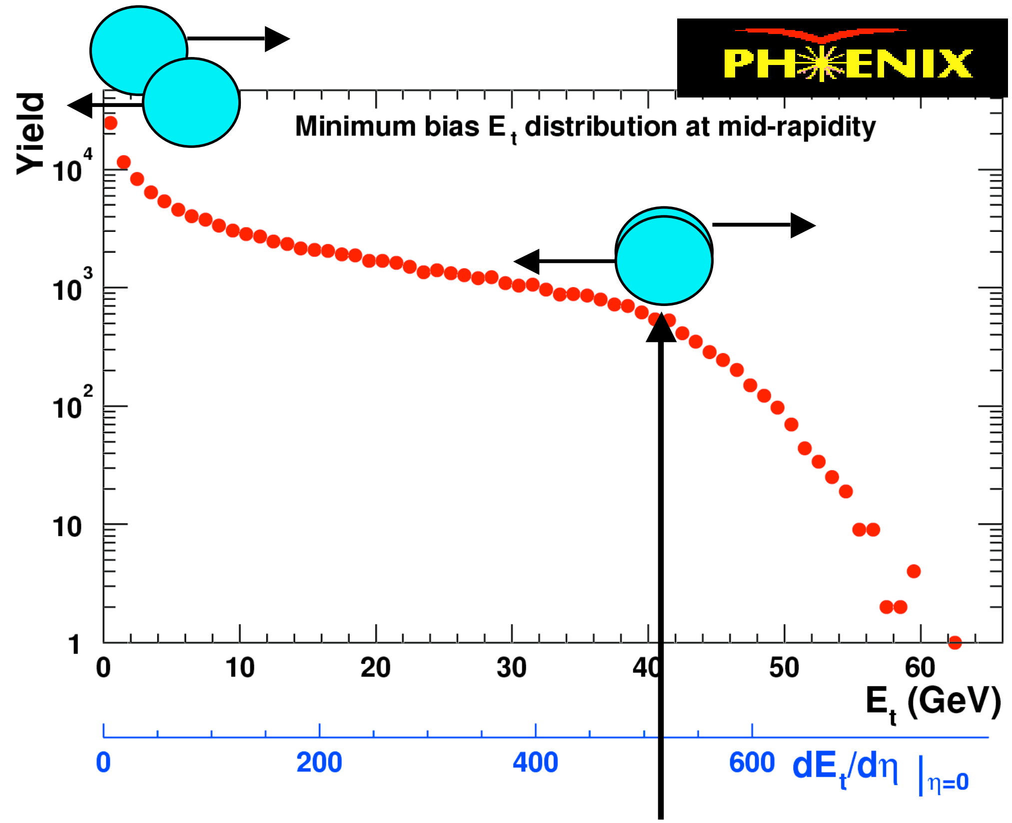
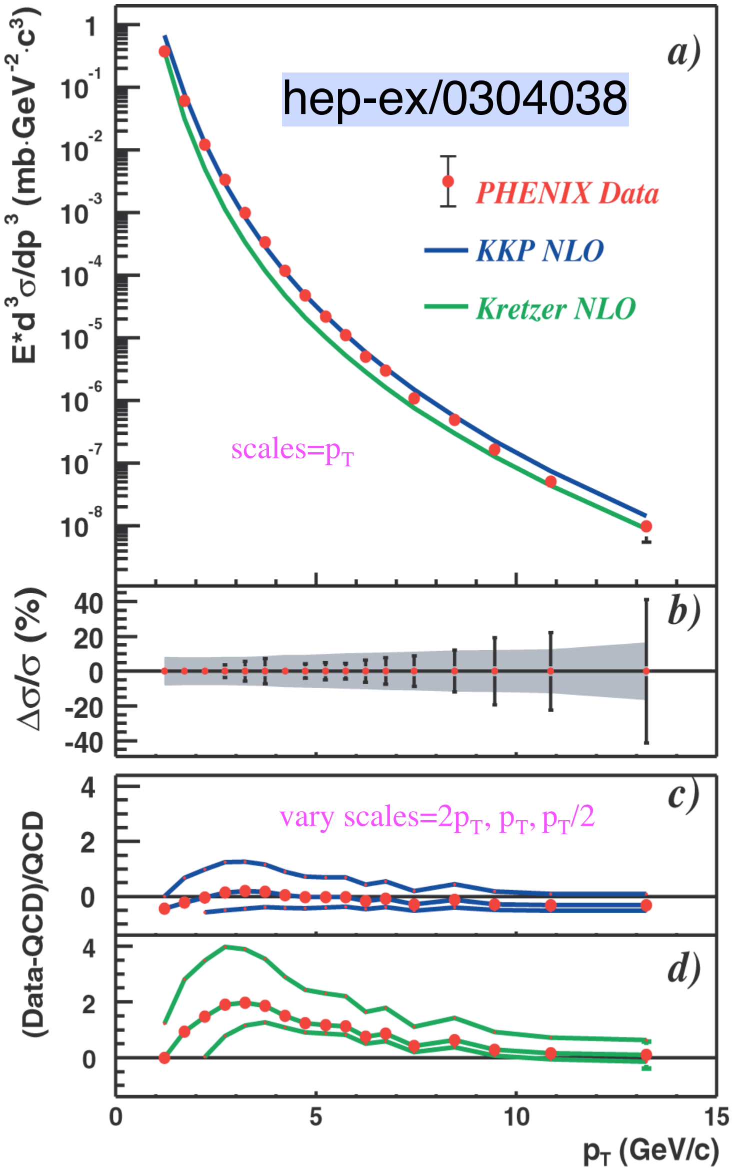


→ε ≥ *4.6 GeV/fm³* (130 GeV Au+Au)

***5.5 GeV/fm³* (200 GeV Au+Au)**

well above predicted transition!

π^0-Production in p+p at $\sqrt{s}$ = 200 GeV



- π^0 spectrum is absolutely normalized.
- **Trigger-Counter is BBC which is biased against counts in central spectrometer**
- $f_{\pi 0}$ ~75% of the total number of π^0 from inelastic events are also registered in BBC- this is measured and corrected for.
- **BBC-also used as luminosity counter**
- absolutely calibrated with vanderMeer scan: σ_{BBC}=21.8mb±9.6%
  - intLums=N_{BBC}/σ_{BBC}

$$E\frac{d^3\sigma}{dp^3} = \frac{1}{\hat{\mathcal{L}}} \cdot \frac{1}{2\pi p_T^*} \cdot \frac{C_{\mathtt{reco}}}{f_{\pi^0}} \cdot \frac{N_{\pi^0}}{\Delta p_T \Delta y},$$

- Physics:
  - Good agreement with NLO pQCD
  - Spectrum constrains *D*(Gluon→π) fragmentation function
  - Result needed as reference for interpretation of Au+Au-Spectra

Hard Scattering is Point-Like—From DIS

E. Gabathuler, Total cross-section

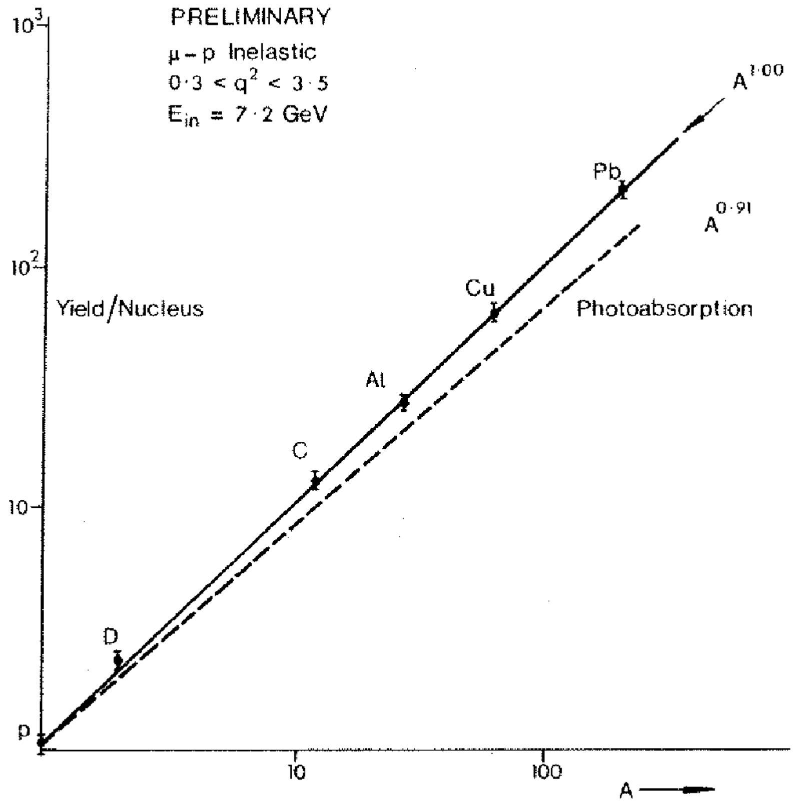


Fig. 14. The A dependence of the inelastic muon cross-section as presented by Tannenbaum (see discussion).

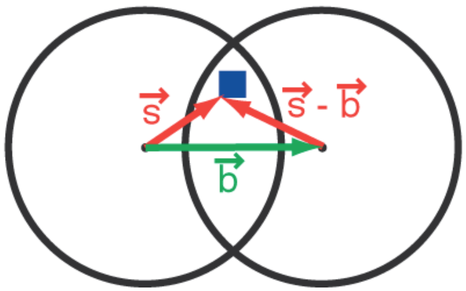
AGS $\mu - A$ scattering data, from E. Gabathuler's talk, [Proc. 6th Int. Symposium on Electron and Photon Interactions at High Energies, Bonn (1973)].

- ♡ DIS is pointlike $A^{1.00}$ even at modest q^2—no shadowing.
- ♡ Photoproduction is shadowed—$A^{0.91}$

High p_T in A+B—T_{AB} Scaling

Hard-scattering is a point-like process, with excellent PQCD predictions $\sim 10\%$ for $p-p$ and $\bar{p}-p$ collisions. For p+A or A+A collisions the cross sections should scale by the number of point sources, A for p+A or A^2 for A+A.

As a function of impact parameter, the profile function for a nucleus A



$$T_A(\vec{s}) = \int dz \rho_A(z, \vec{s})$$

is the number of nucleons per unit area along a direction z at a point from the center of the nucleus represented by a 2-d vector $\vec{s}$, where z is perpendicular to $\vec{s}$. For an interaction of nucleus A with nucleus B at impact parameter $\vec{b}$, the nuclear overlap integral $T_{AB}(\vec{b})$ is defined:

$$T_{AB}(\vec{b}) = \int d^2 s T_A(\vec{s}) T_B(\vec{b} - \vec{s}) \quad ,$$

where $d^2 s = 2\pi s ds$ is the 2-dimensional area element. Simply:

$$N^{AB}_{hard-coll}(\vec{b}, \sigma) = T_{AB}(\vec{b}) \times \sigma^{p-p}_{hard-coll}$$

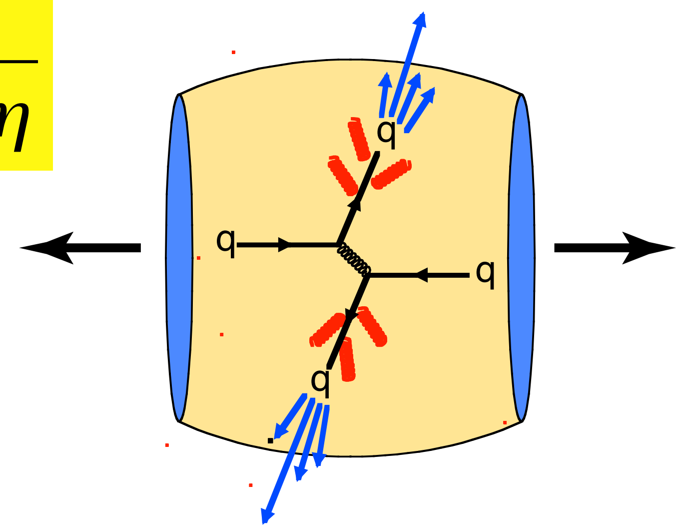
More precisely, for a certain fraction f of the nuclear interaction cross section for A+B collisions, the semi-inclusive yield is related to the $p-p$ inclusive cross section:

$$\frac{1}{N_f} \frac{d^3 N^{A+A}_f}{p_T dp_T dy d\phi} = \frac{d^3 \sigma^{p-p}}{p_T dp_T dy d\phi} \times \langle T_{AB} \rangle_f$$

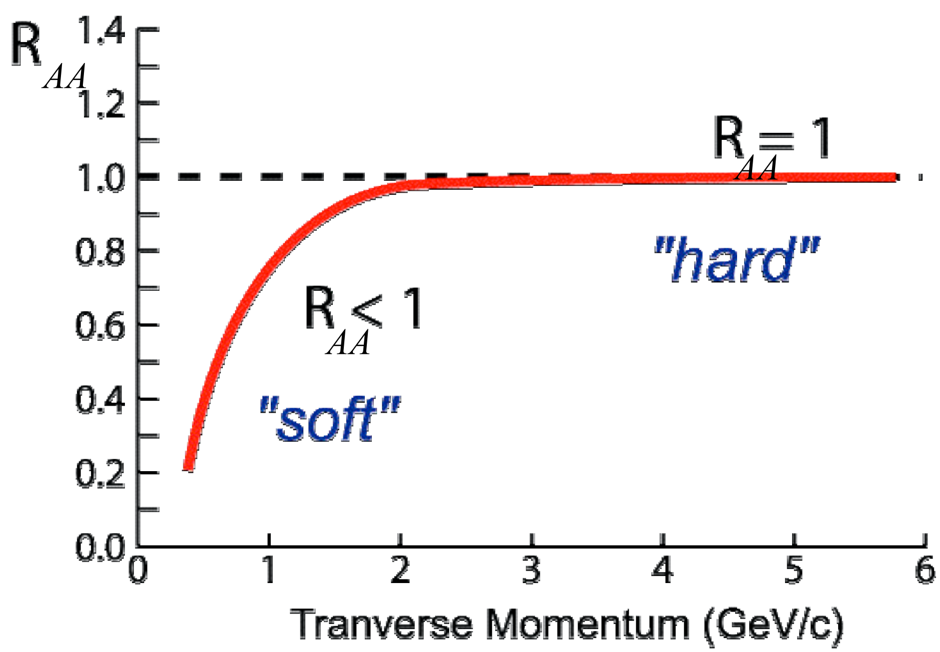
We use the Nuclear Modification Factor R_{AA} for pointlike scaling of an AA measurement from p-p

Nuclear Modification Factor:

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



Compare A+A to p-p cross sections



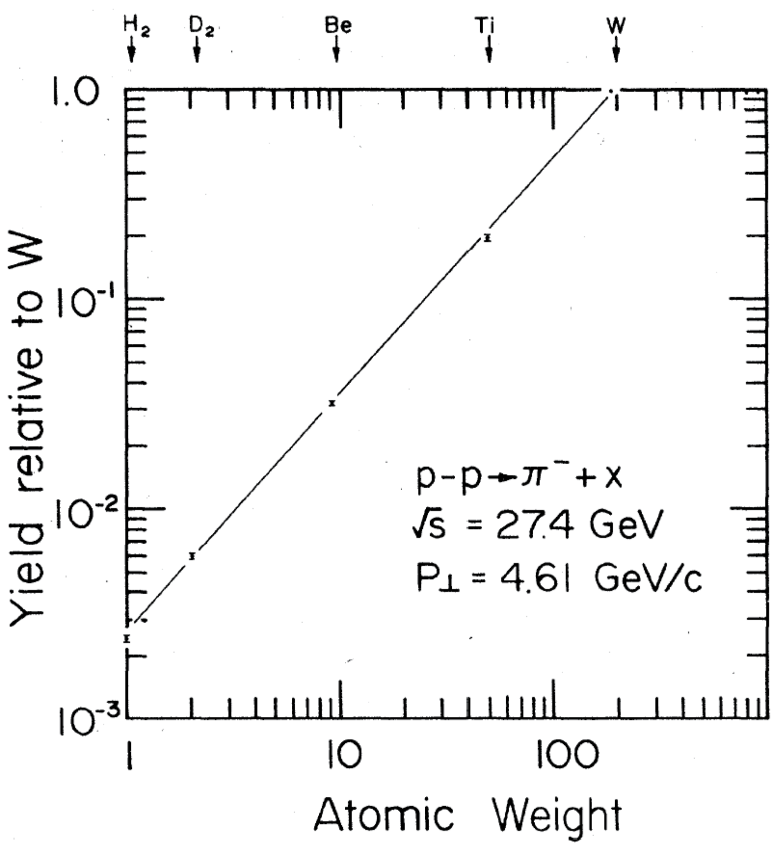
"Nominal effects":

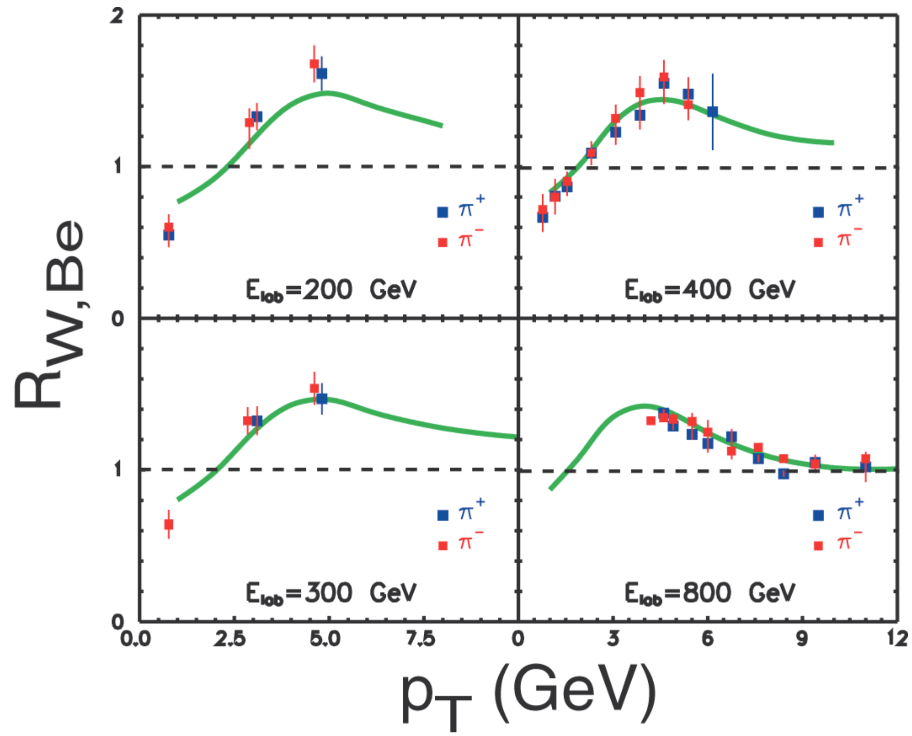
- $R_{AA} < 1$ in regime of soft physics
- $R_{AA} = 1$ at high-p_T where hard scattering dominates
- $R_{AA} > 1$ due to k_T broadening (Cronin)

What really Happens ($R_A > 1$) for p+A

The anomalous nuclear enhancement a.k.a. the Cronin effect due to multiple scattering of initial nucleons (or constituents)

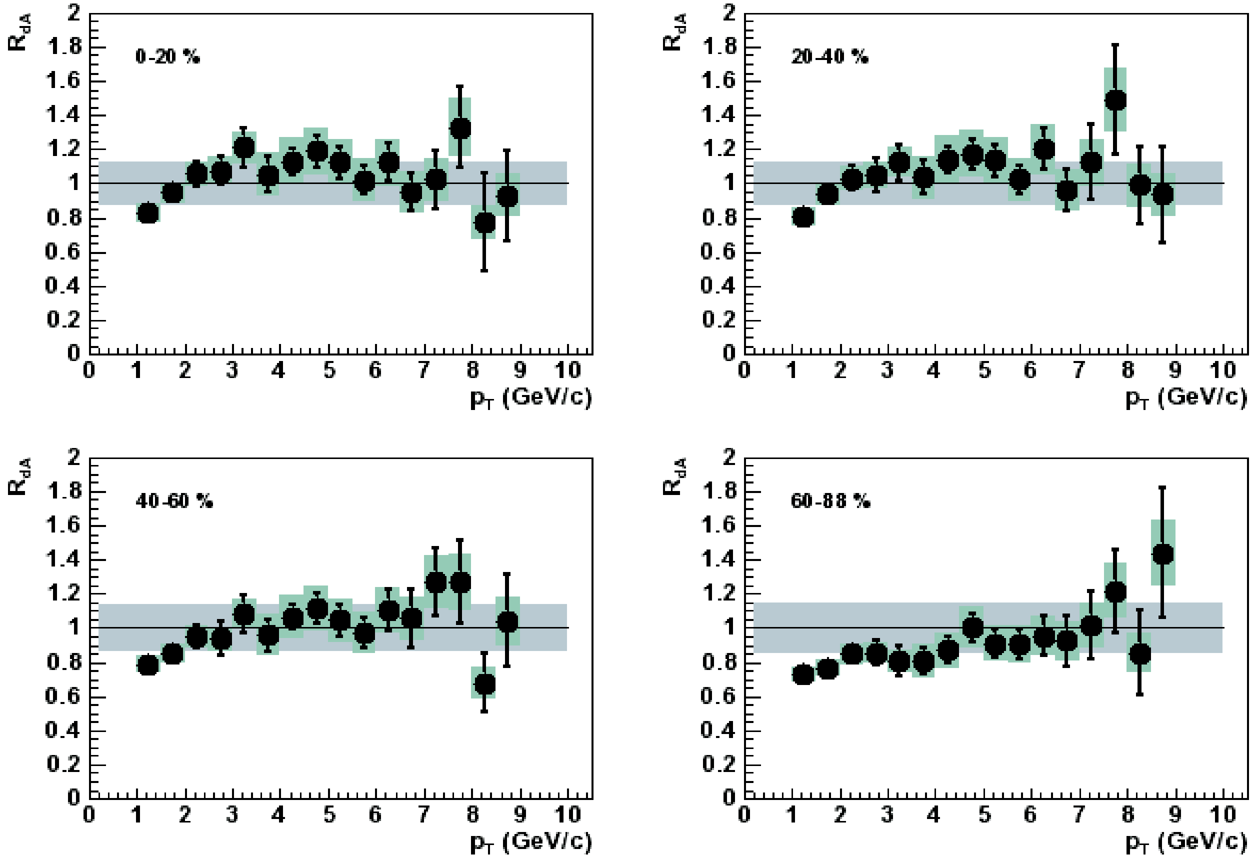
- Known since 1975 that yields increase as A^{α}, $\alpha > 1$





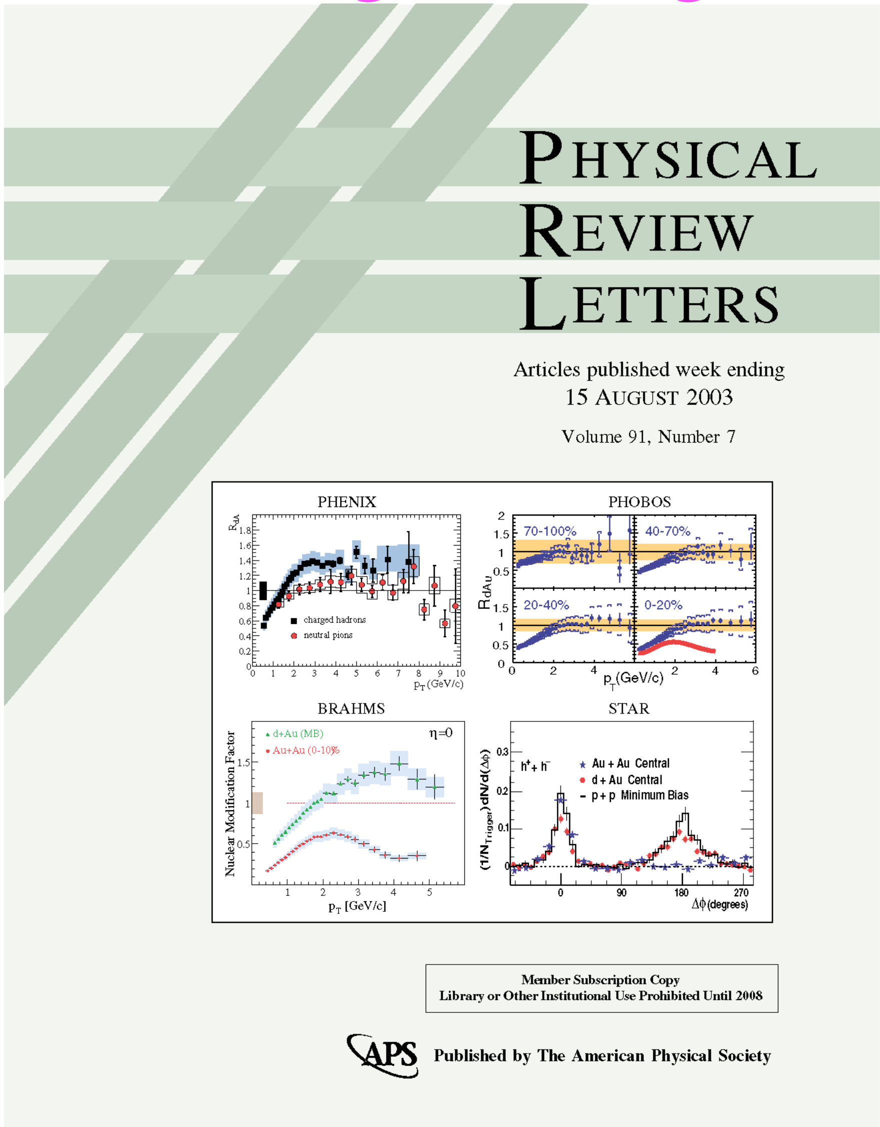
- J.W. Cronin et al., Phys. Rev. **D11**, 3105 (1975)
- D. Antreasyan et al., Phys. Rev. **D19**, 764 (1979)

Cronin effect observed in d+Au at RHIC $\sqrt{s_{NN}}$=200 GeV



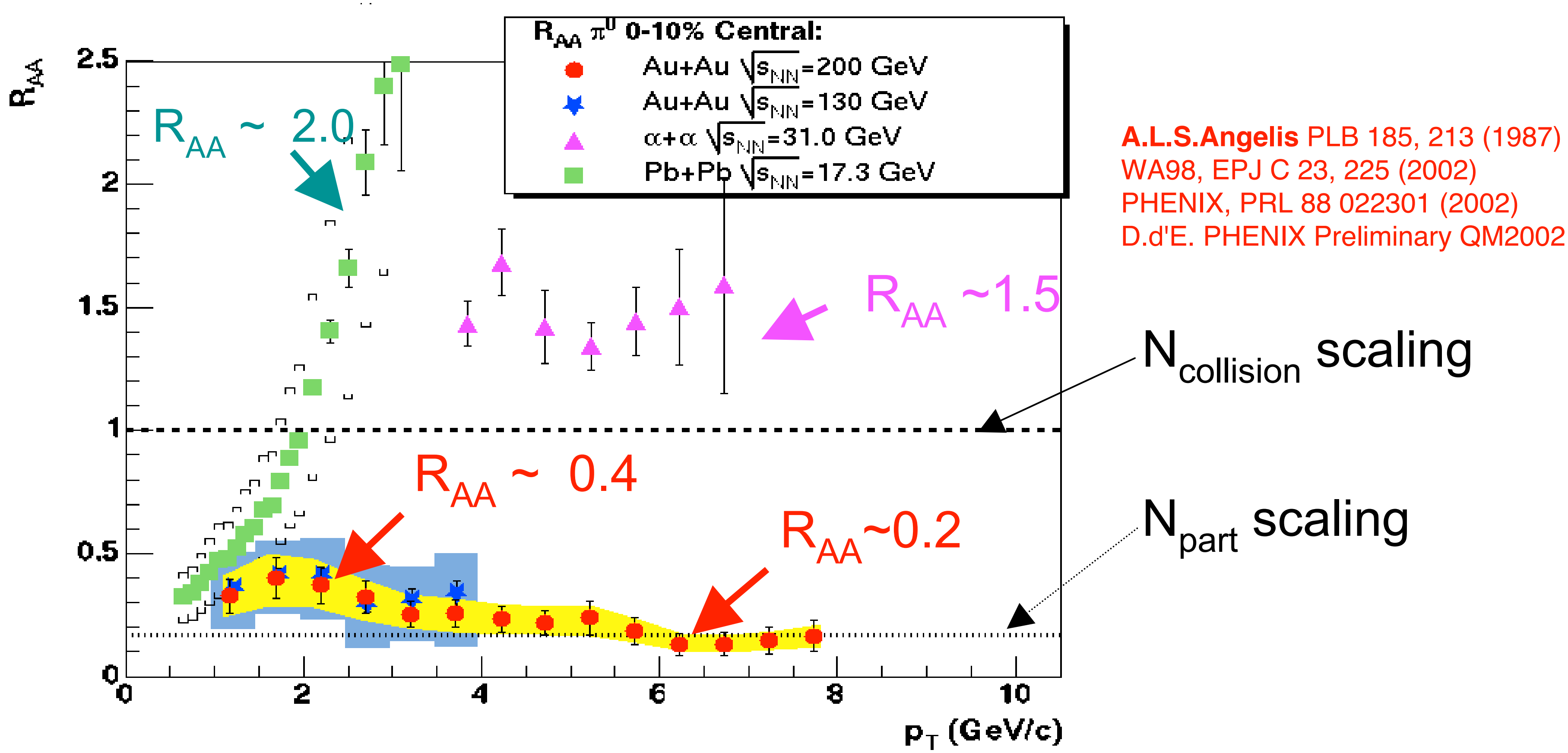
PHENIX preliminary π^0 d+Au vs centrality for DNP2003

This leads to our second PRL cover, our first being the original Au+Au discovery



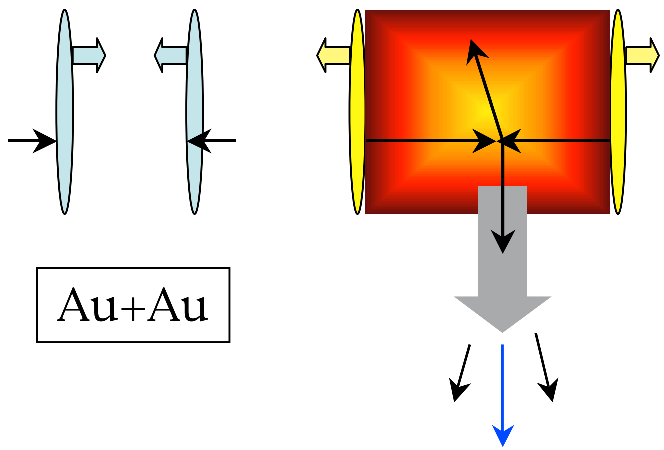
Nuclear modification factor: $\sqrt{s_{NN}}$ dependence for A+A collisions

CERN: Pb+Pb ($\sqrt{s_{NN}}$ ~ 17 GeV), α+α ($\sqrt{s_{NN}}$ ~31 GeV): all previous msmts-Cronin enhancement



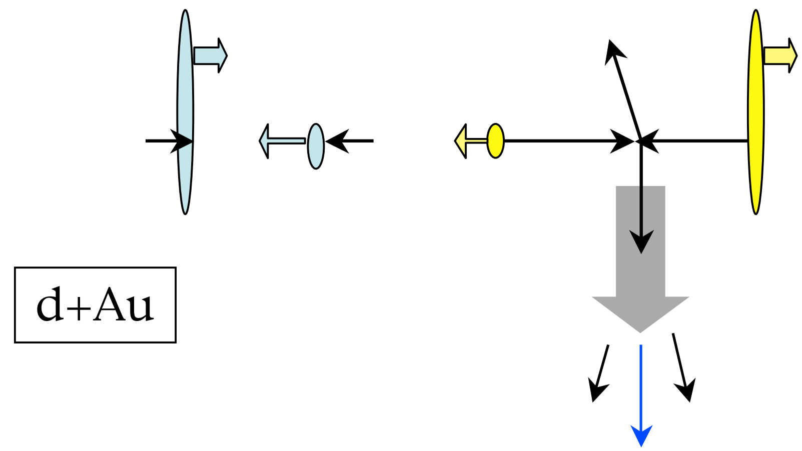
RHIC Au+Au $\sqrt{s_{NN}}$=130 and 200 GeV HUGE SUPPRESSION---Major Discovery 2001-2

d+Au: Control Experiment proves the Au+Au discovery



= hot and dense medium

Initial + Final State Effects



= cold medium

Initial State Effects Only

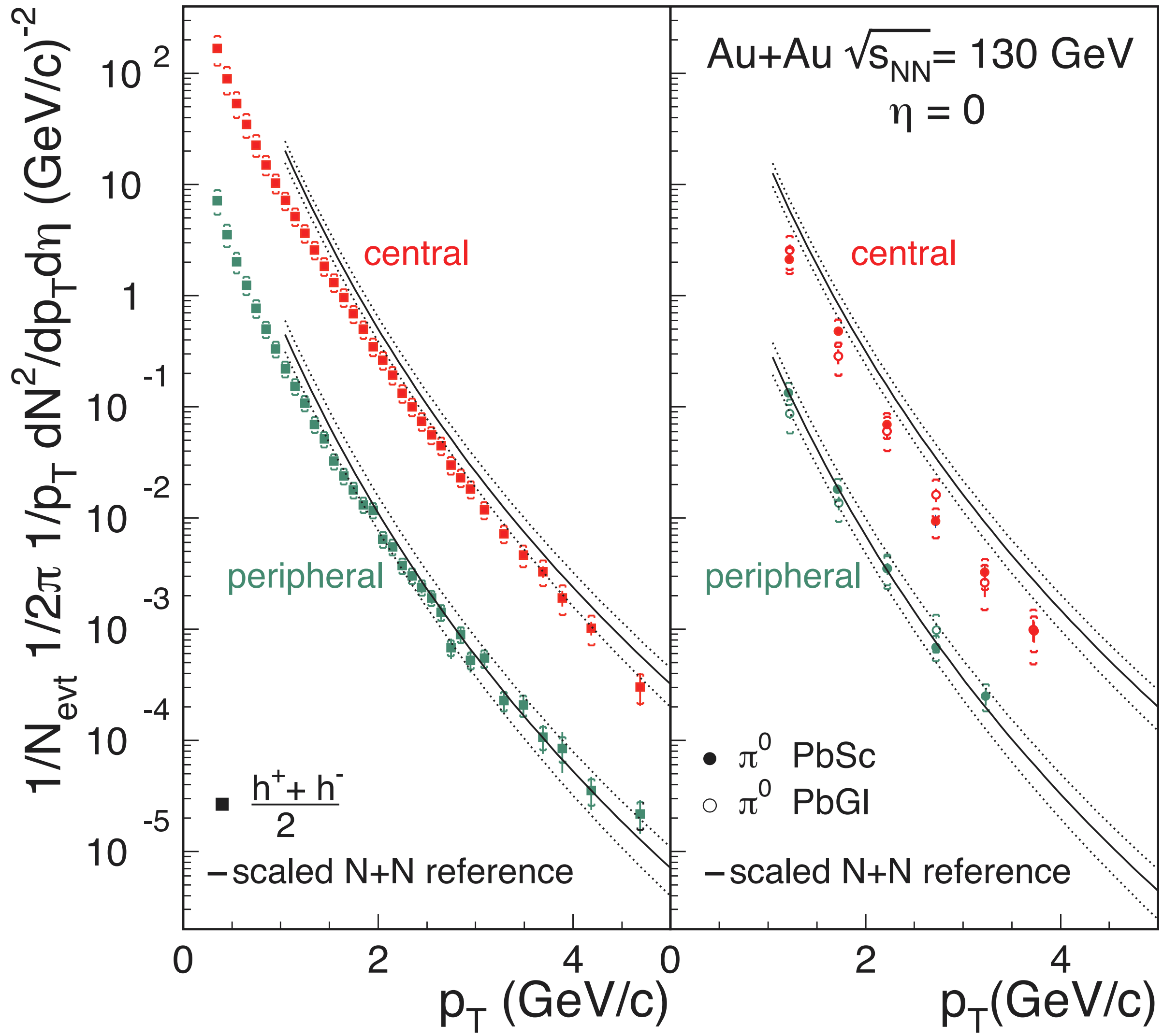
- The "Color Glass Condensate" model predicts the suppression in **both Au+Au and d+Au** (due to the initial state effect).
- **The d+Au experiment tells us that the observed hadron suppression at high p_T central Au+A is a final state effect.**
- However the clever "Color Glass Condensate" people still have a few hoops for us to jump through.

RHIC Year-1 High-P_T Hadrons

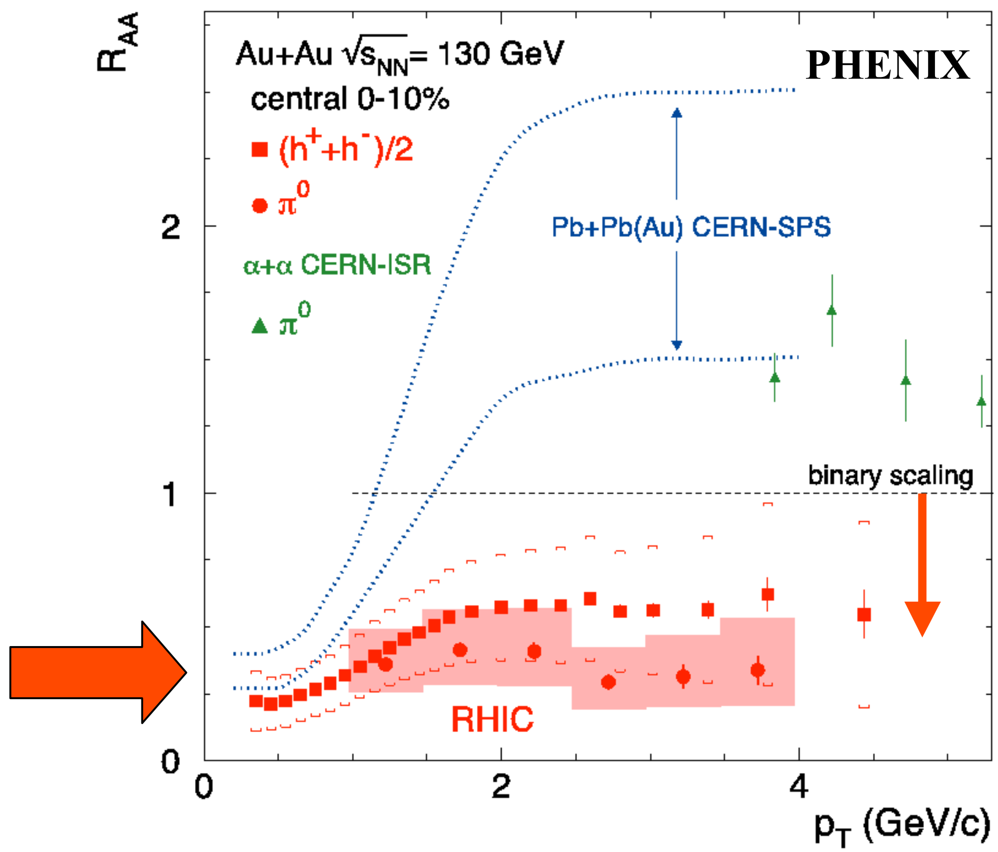
Hadron spectra out to
p_T~4-5 GeV/c

Nominally expect production through hard scattering, scale spectra from N+N by number of binary collisions

Peripheral reasonably well reproduced; but central significantly below binary scaling



RHIC Headline News… January 2002

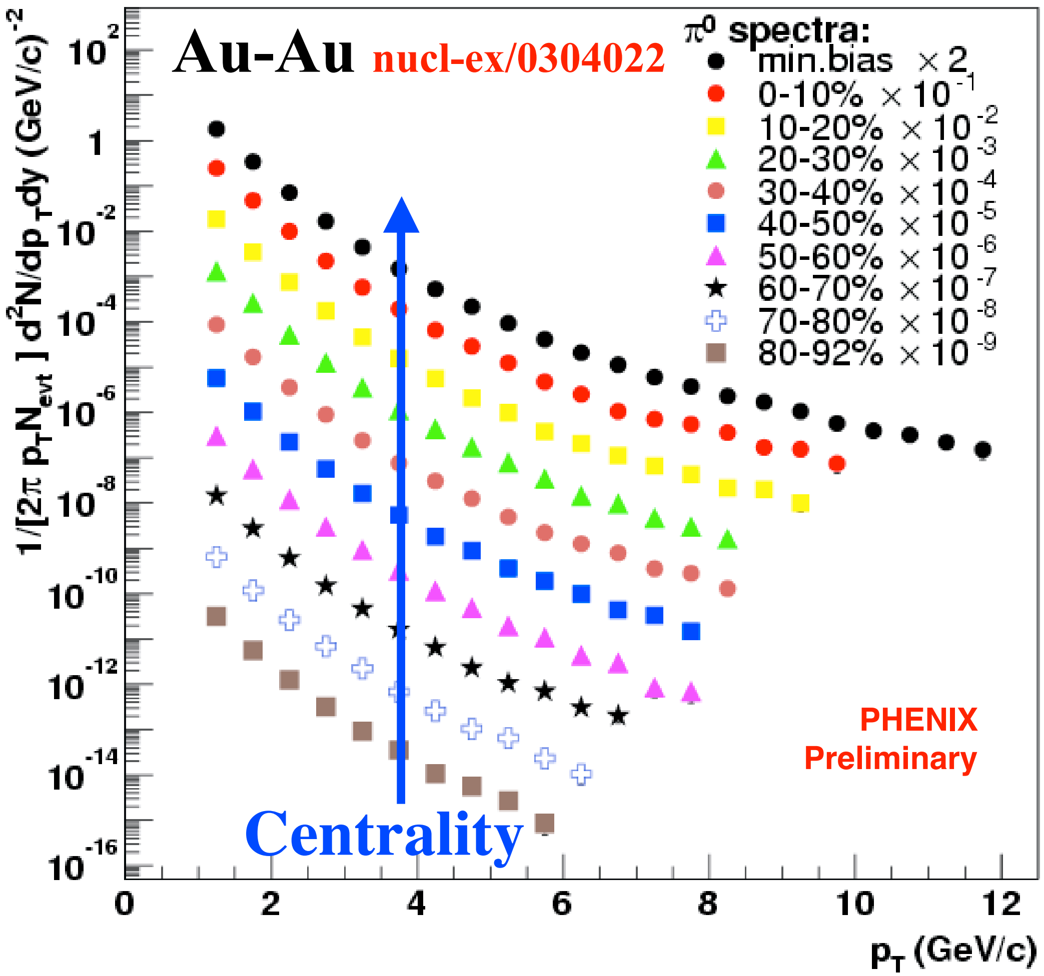


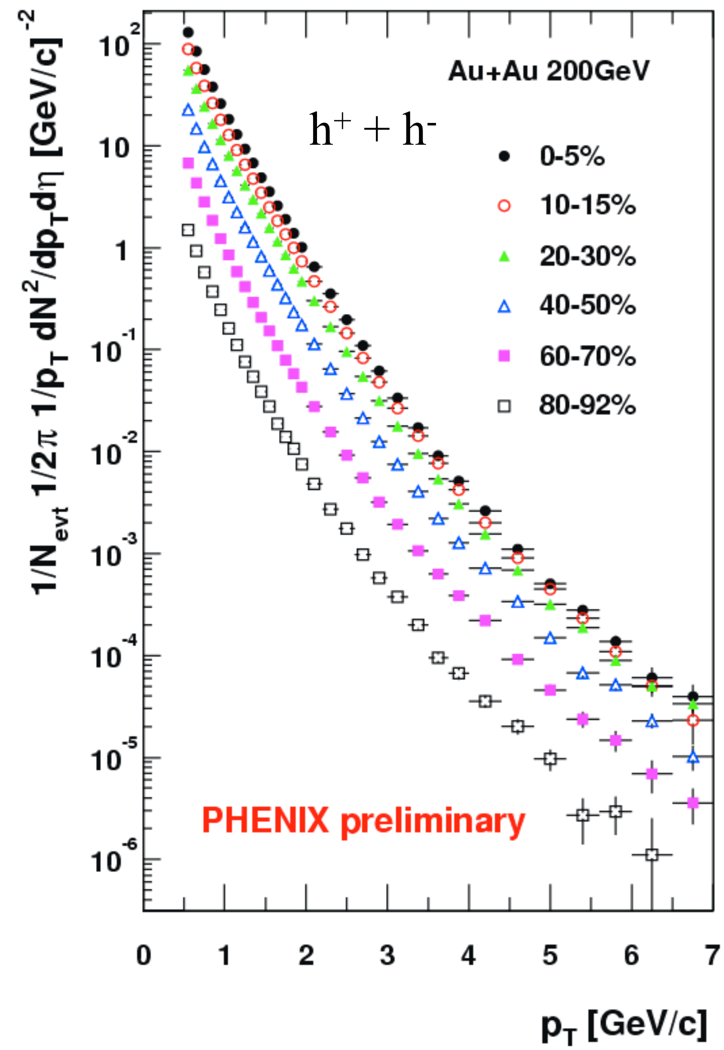
PHENIX PRL 88, 022301 (2002)

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

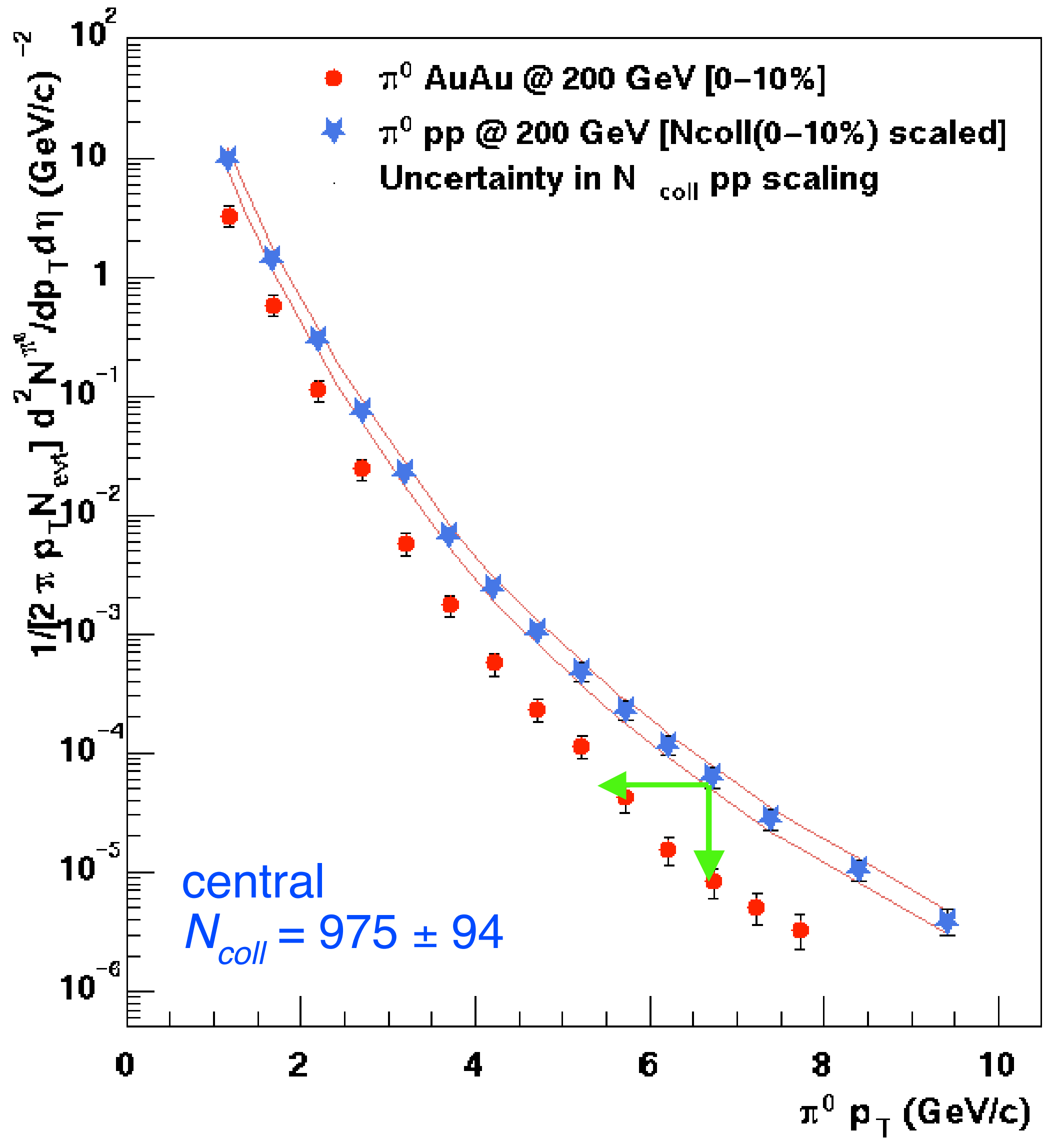
"Jet Quenching"? == Quark Gluon Plasma?

RHIC Run 2: √s=200 GeV/c Au+Au collisions now extend to higher P_T



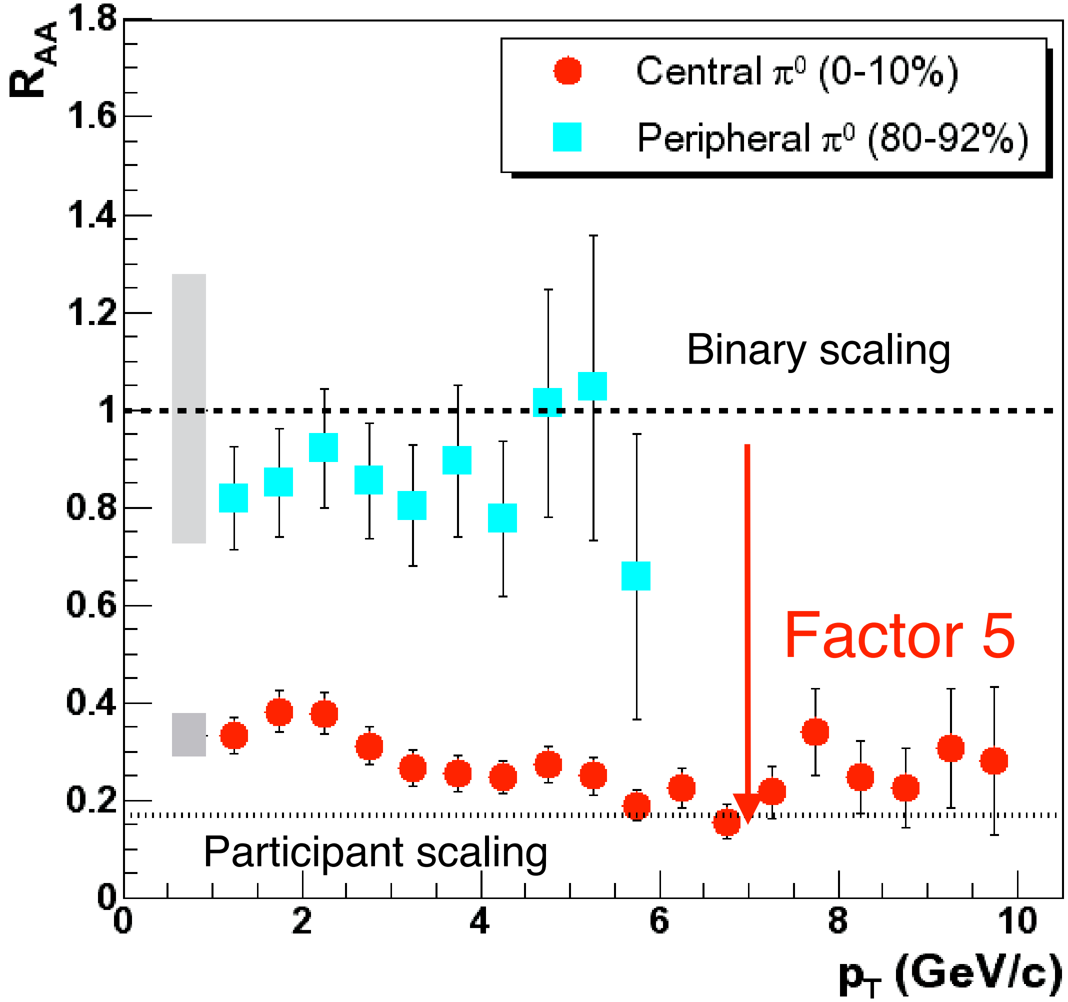


Central Spectrum is suppressed---is this due to a shift caused by energy loss



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

$$R_{AA} = \frac{\mathrm{Yield}_{AuAu} / \langle N_{binary} \rangle_{AuAu}}{\mathrm{Yield}_{pp}}$$

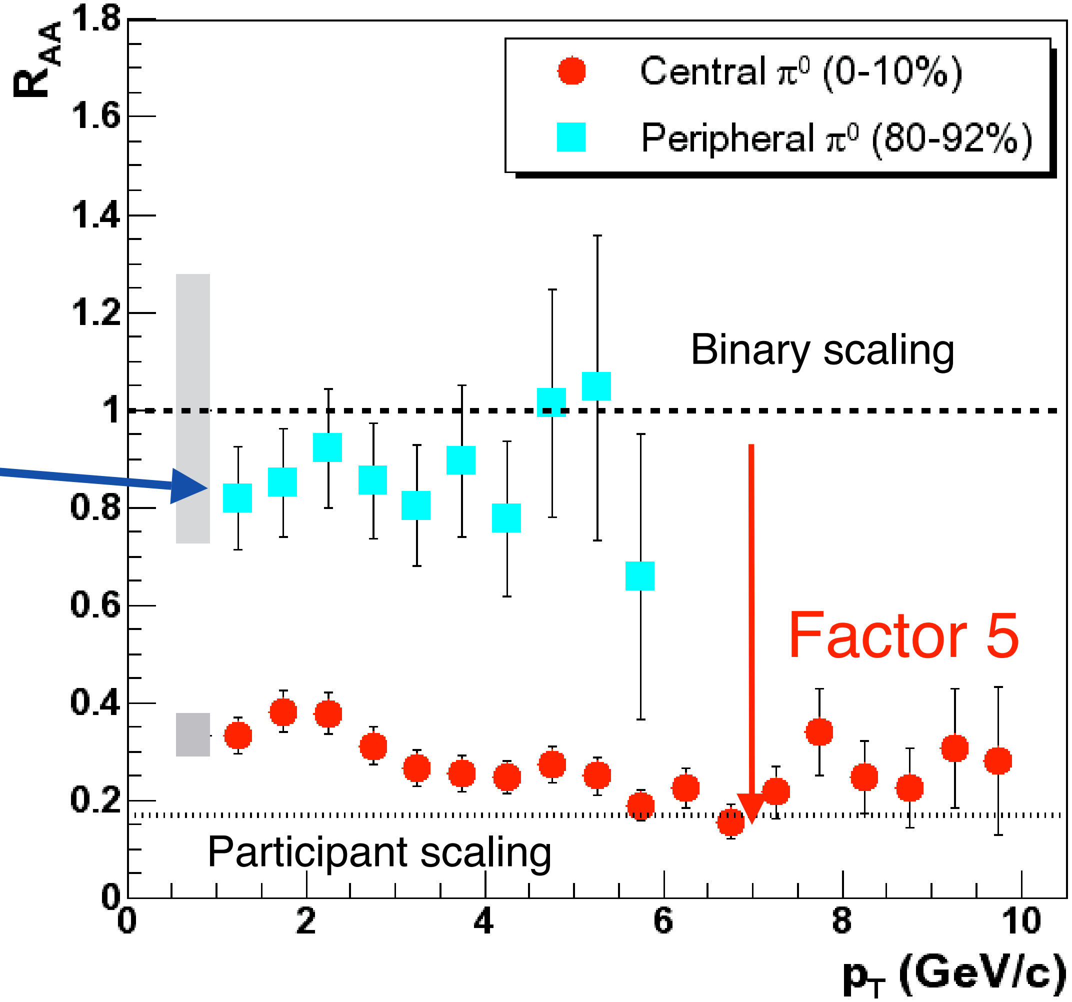


PRL 91 (2003) 072301

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

$$R_{AA} = \frac{\text{Yield}_{AuAu}/\langle N_{binary}\rangle_{AuAu}}{\text{Yield}_{pp}}$$

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



PRL 91 (2003) 072301

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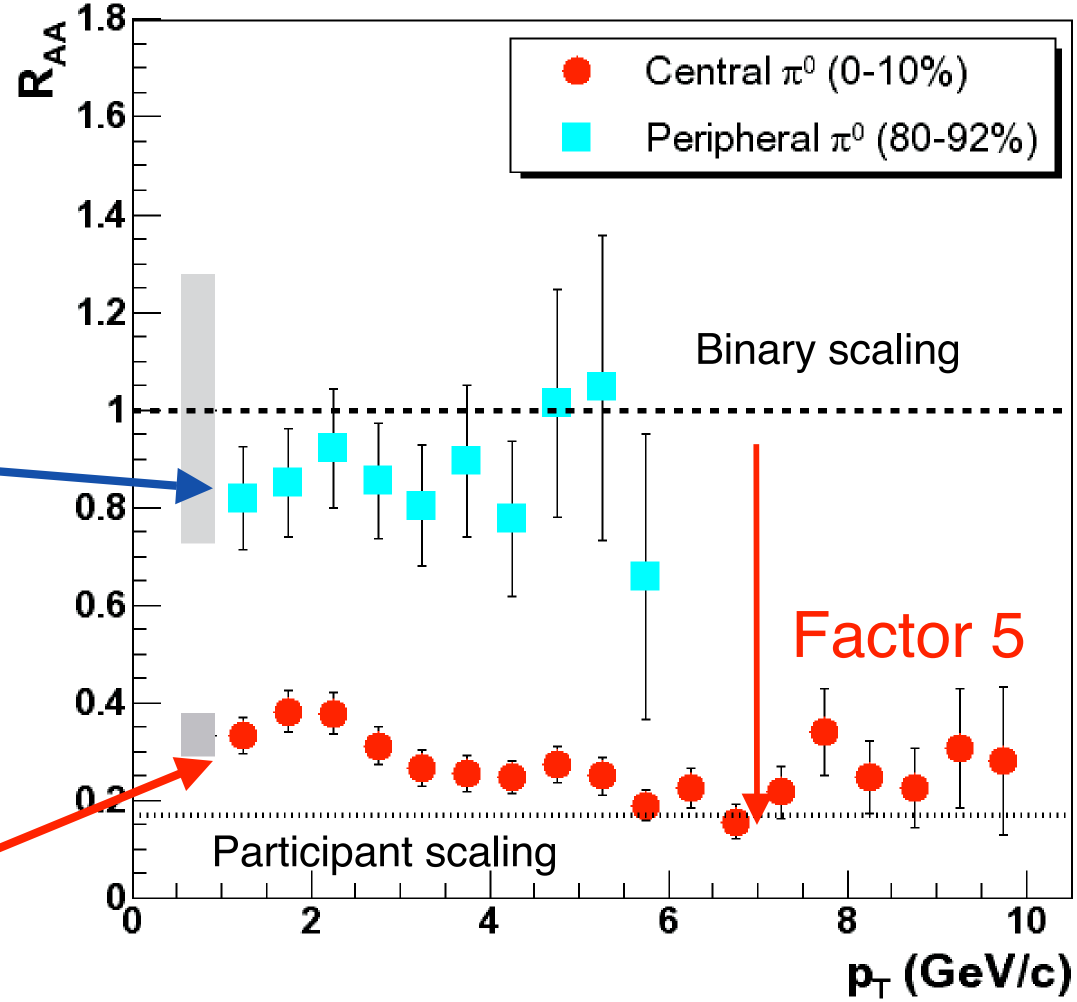
Peripheral AuAu - consistent with N_{coll} scaling (large systematic error)

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

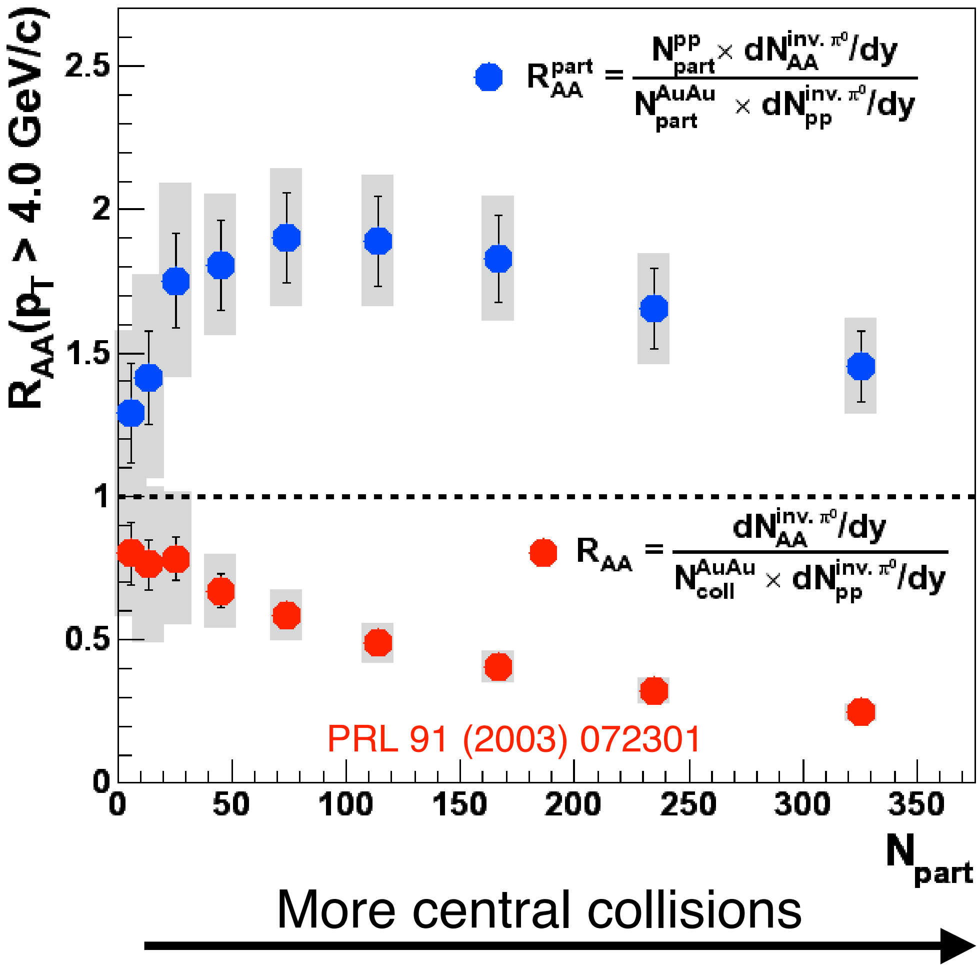


PRL 91 (2003) 072301

Centrality Dependence of R_{AA}

The suppression increases smoothly with centrality

- approximate N_{part} scaling.



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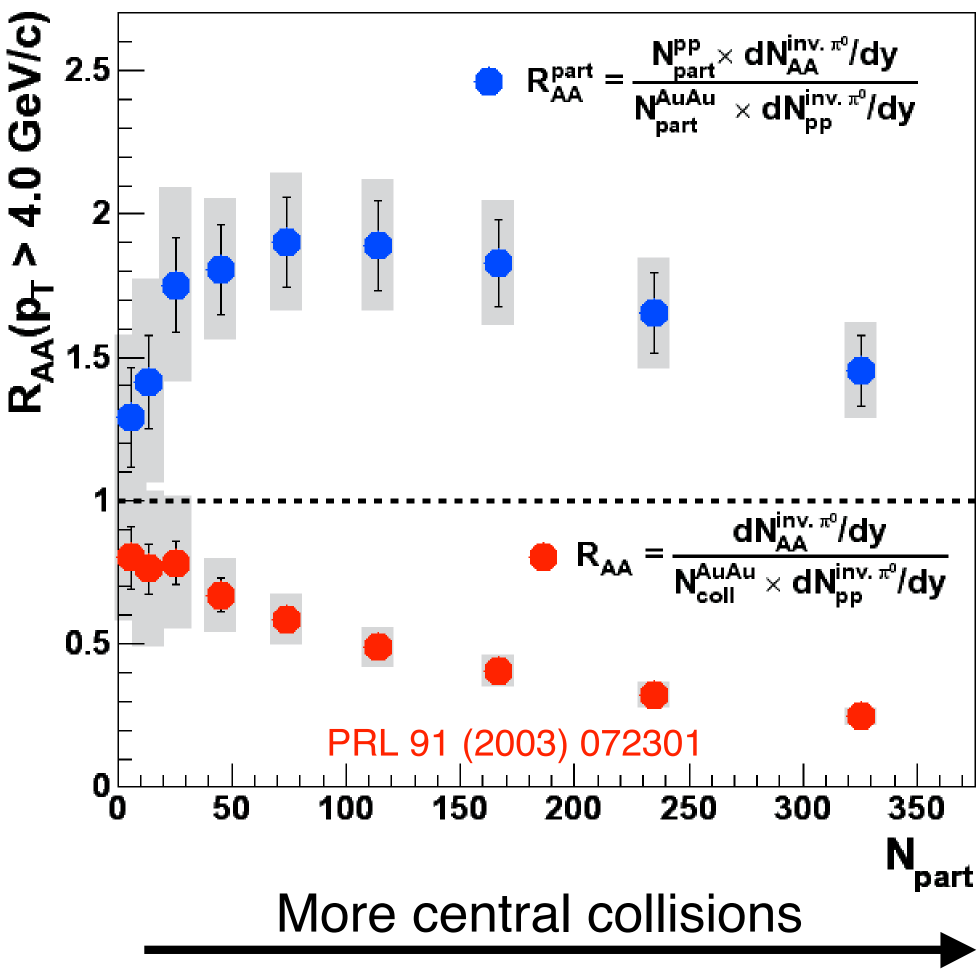
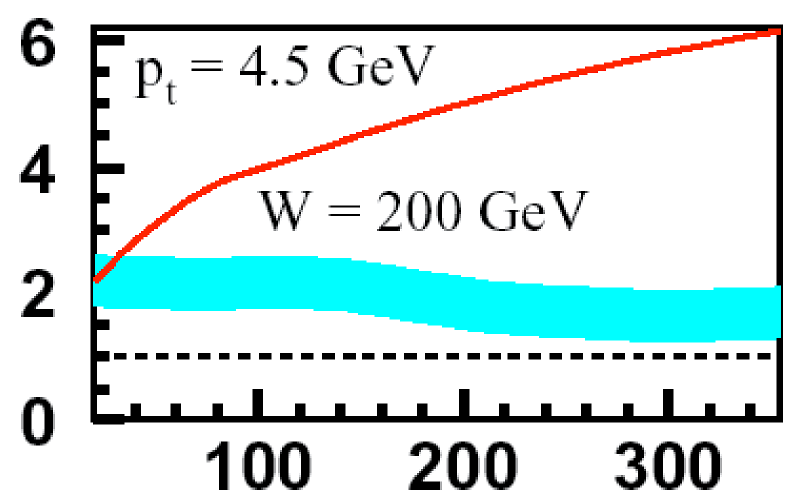


Centrality dependence similar to predictions of Color Glass Condensate (AKA Gluon Saturation)

- Suggests Initial state effect!?!



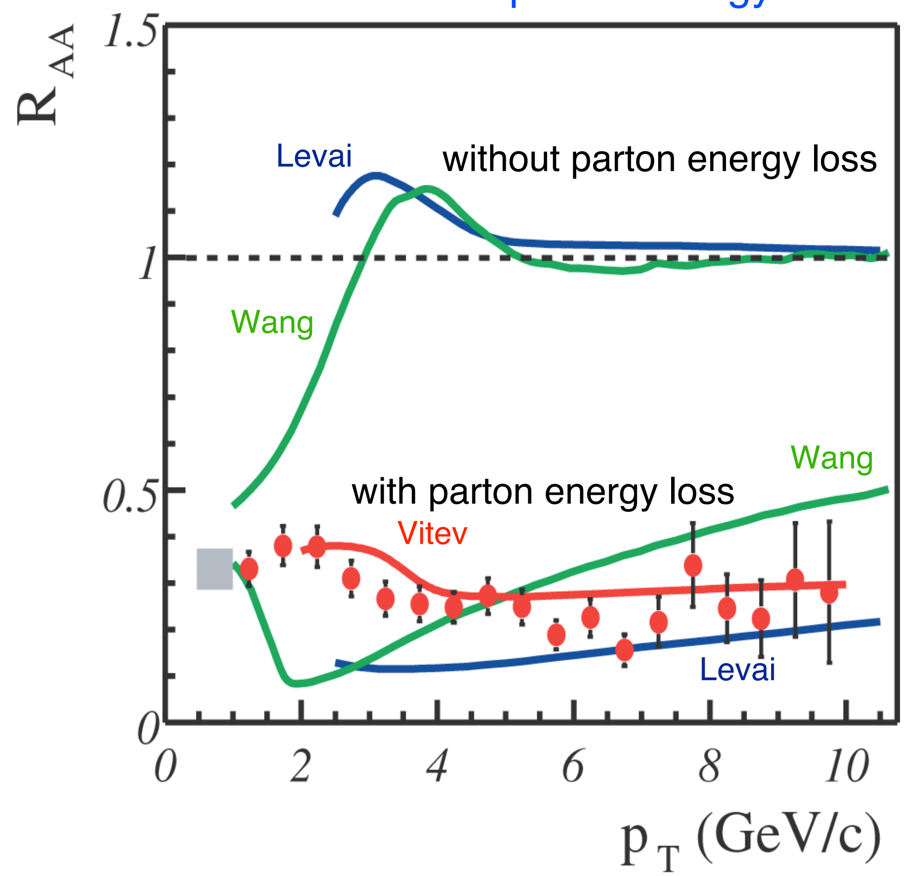
D.Kharzeev, E.Levin, L.McLerran
hep-ph/0210332

Jet Quenching?

- pion suppression reproduced by models with parton energy loss
- other explanations not ruled out

  (at this stage)

Comparison with model calculations with and without parton energy loss



Au+Au→π^0+X at $\sqrt{s_{NN}}$ = 200 GeV

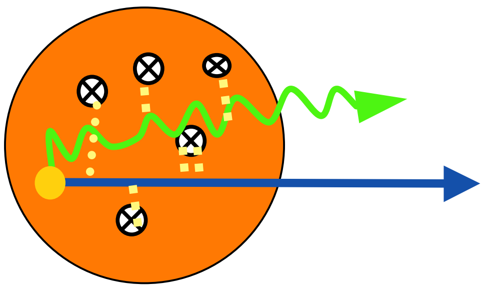
Can x_T scaling reveal the nature of the physics processes in jet suppression?

Suppression: Final State Effect?

- **Hadronic absorption of fragments:**
  - Gallmeister, et al. PRC67,044905(2003)
  - Fragments formed inside hadronic medium

- **Parton recombination (up to moderate p_T)**
  - Fries, Muller, Nonaka, Bass nucl-th/0301078
  - Lin & Ko, PRL89,202302(2002)

- **Energy loss of partons in dense matter**
  - Gyulassy, Wang, Vitev, Baier, Wiedemann…



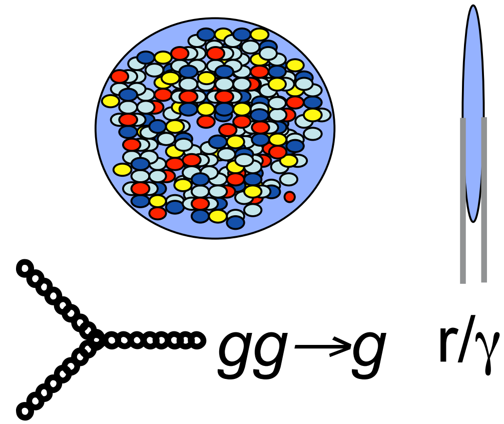
Alternative: Initial Effects

- **Gluon Saturation**
  - **(color glass condensate: CGC)**

  Wave function of low x gluons overlap; the self-coupling gluons fuse, saturating the density of gluons in the initial state.

  (gets N_{ch} right!)

  hep-ph/0212316; D. Kharzeev, E. Levin, M. Nardi

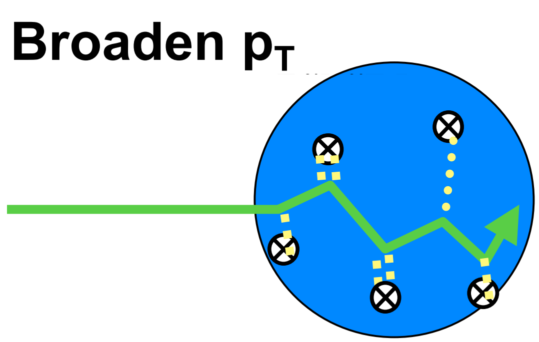


D.Kharzeev et al., PLB 561 (2003) 93

- **Multiple elastic scatterings**

  (Cronin effect)

  Wang, Kopeliovich, Levai, Accardi



- **Nuclear shadowing**

High p_T physics in PHENIX at RHIC
M. J. Tannenbaum, BNL, June 11, 2001

- Hard Scattering in p-p collisions was discovered at the CERN ISR in 1972 by the method of leading particles.
- A very large flux of high p_T pions was observed with a power-law tail which varied systematically with $\sqrt{s}$, the c.m. energy of the collision.
- The huge flux of high p_T particles proved that the partons of DIS strongly interacted with each other.
- Scaling arguments allowed the form of the force law between 'partons' to be determined but there was some early confusion caused by initial transverse momentum k_T which distorted the spectra.
- Further ISR measurements utilizing inclusive single or pairs of hadrons established that high transverse momentum particles are produced from states with two roughly back-to-back jets which are the result of scattering of constituents of the nucleons as described by Quantum Chromodynamics.
- In the region of hard scattering ($p_T > 2$ GeV/c) scaling from p-p to nuclear collisions should be simply proportional to the relative number of point-like sources in each, corresponding to A (p+A), $A \times B$ (A+B) for the total rate and to T_{AB} the overlap integral of the nuclear profile functions, as a function of centrality.
- In stark contrast to results at lower c.m. energies, measurements of high p_T π^0 and $h^+ + h^-$ production at $\sqrt{s_{NN}} = 130$ GeV from PHENIX at RHIC show a huge suppression compared to point-like scaling...

CCOR 1978—Discovery of "REALLY High $p_T > 7$ GeV/c"

A. L. S. Angelis, et al., Phys. Lett. **79B**, 505 (1978)

See also, A. G. Clark, et al., Phys. Lett. **74B**, 267 (1978)

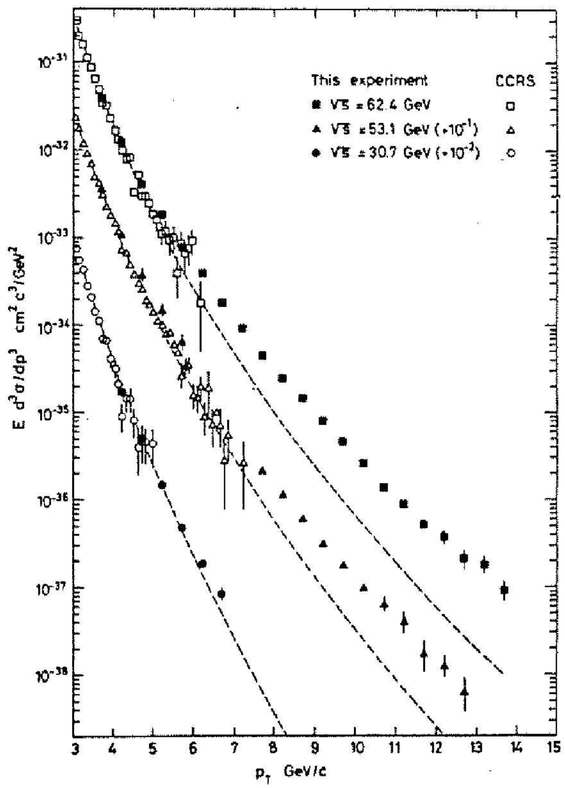
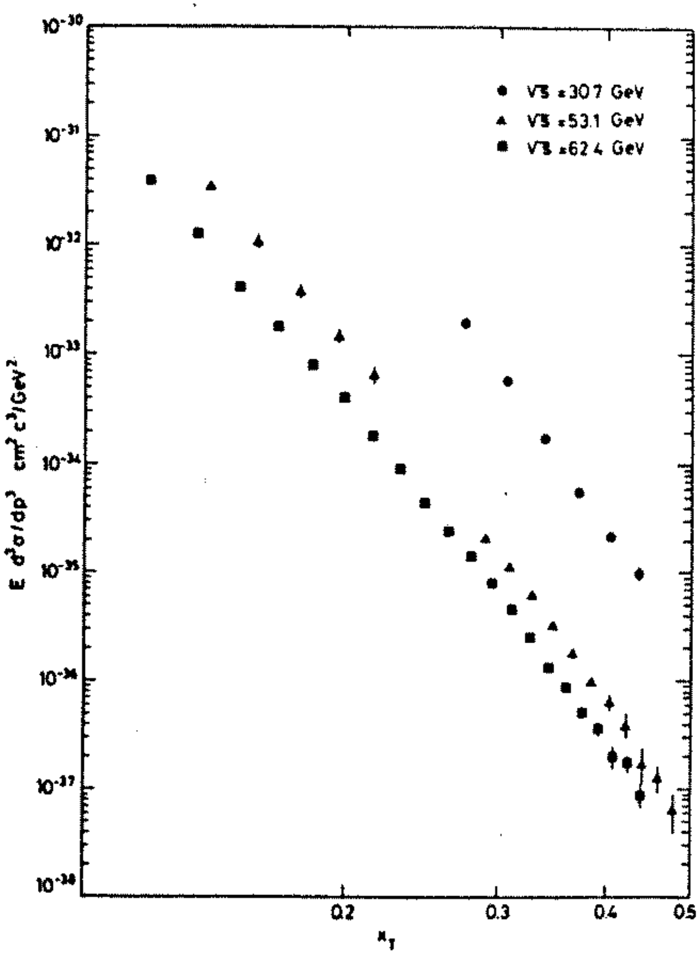


Figure 4: CCOR transverse momentum dependence of the invariant cross section for $p + p \to \pi^0 + X$ at three center of mass energies. Cross sections are offset by the factors noted. Open points and dashed fit are from a previous experiment, CCRS, F. W. Büsser, et al., Nucl. Phys. **B106**, 1 (1976).

♡ $Ed^3\sigma/dp^3 \simeq p_T^{-5.1\pm0.4}(1 - x_T)^{12.1\pm0.6}$, for $7.5 \leq p_T \leq 14.0$ GeV/c, $53.1 \leq \sqrt{s} \leq 62.4$ GeV (including *all* systematic errors).

$n(x_T, \sqrt{s})$ WORKS, $n \rightarrow 5 = 4^{++}$



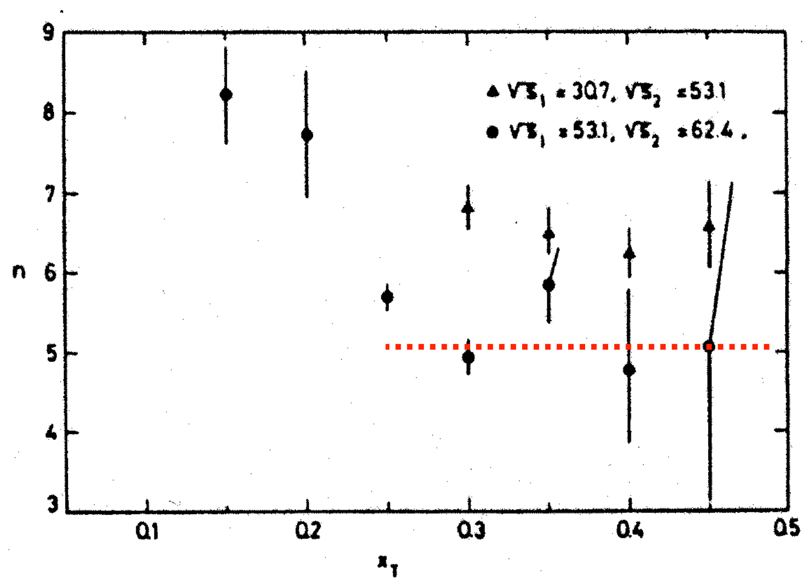
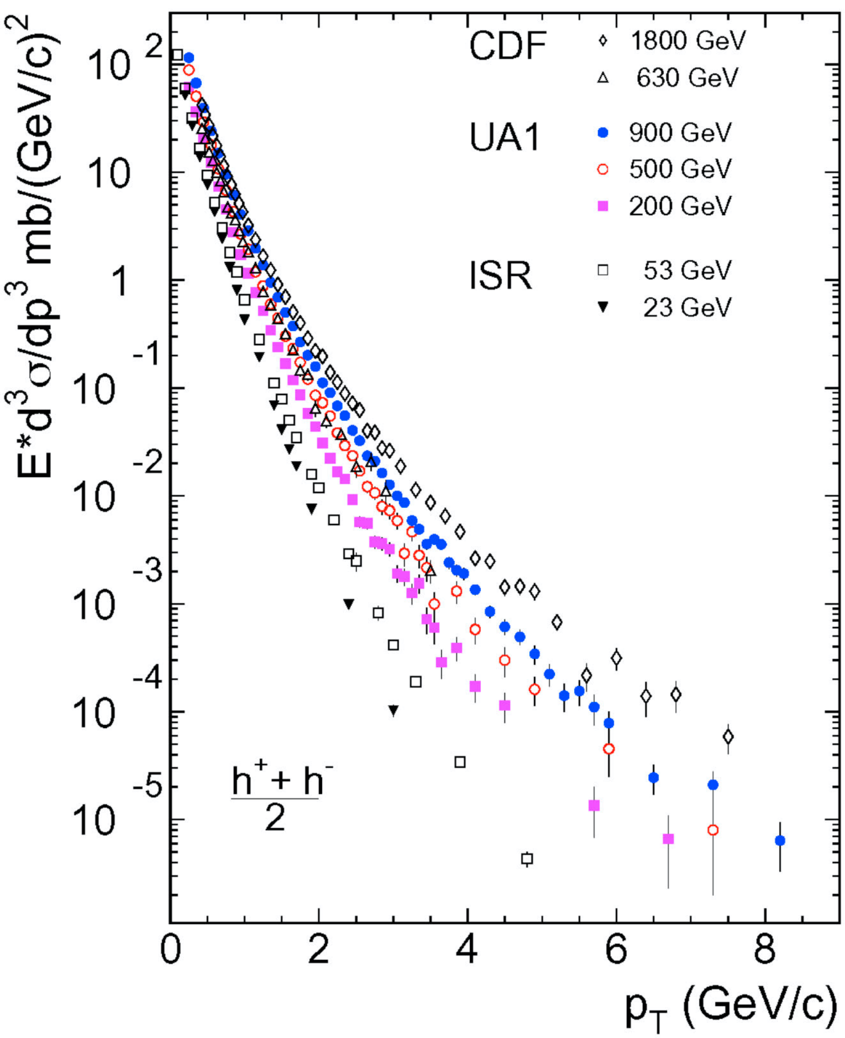
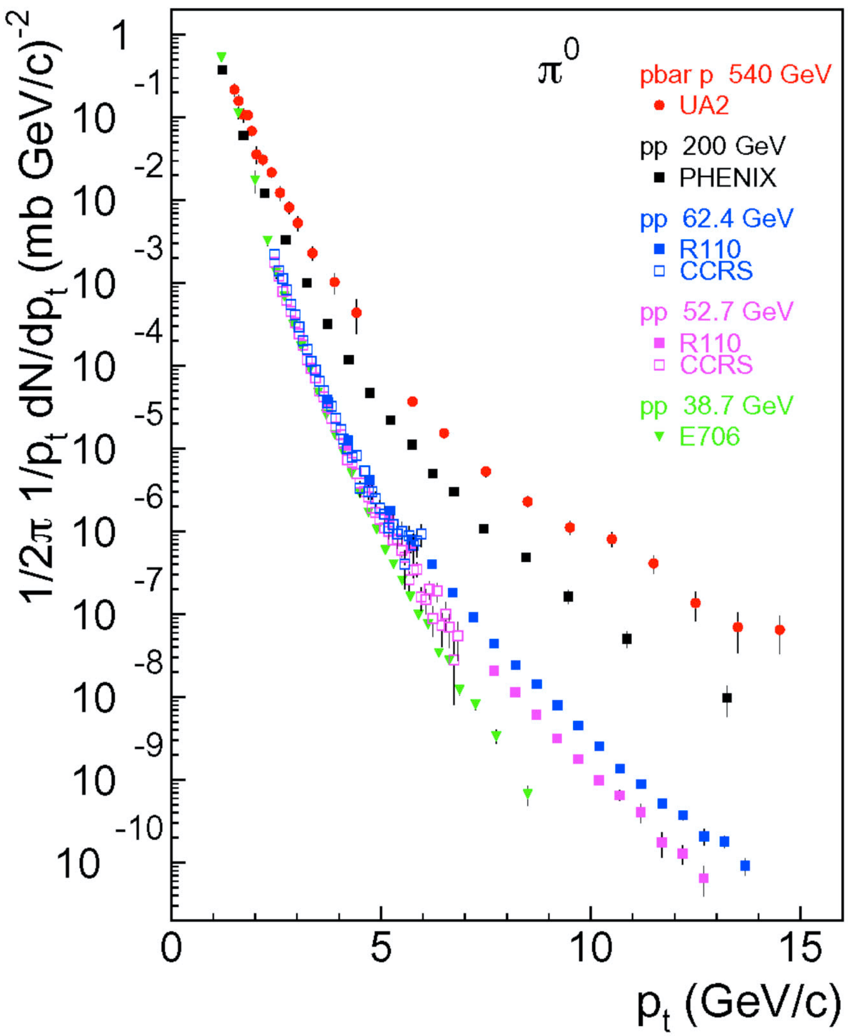


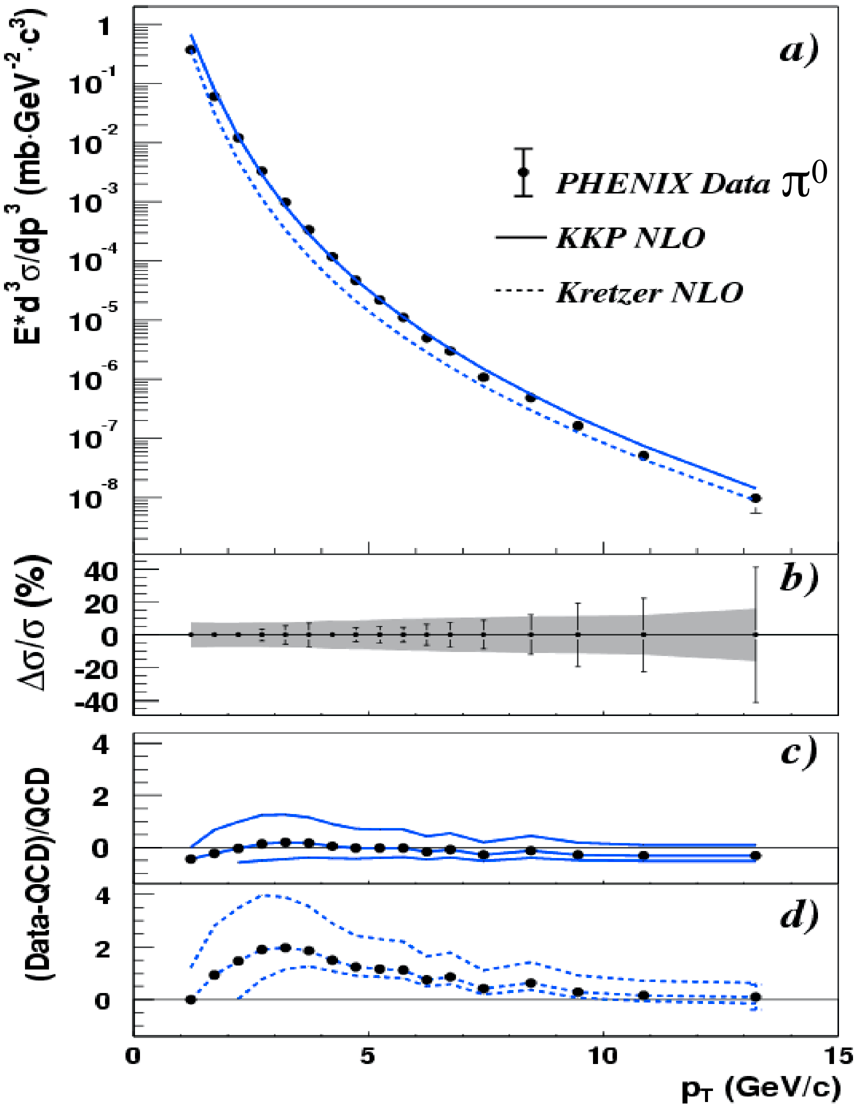
Figure 5: Left: CCOR invariant cross section vs $x_T=2p_T/\sqrt{s}$. Right: $n(x_T, \sqrt{s})$ derived from the combinations indicated. *The systematic normalization at $\sqrt{s}$=30.6 has been added in quadrature. Note that the absolute scale uncertainty cancels!*

Inclusive single hadron high p_T spectra in p-p all $\sqrt{s}$





pp spectra √s=23-1800 GeV illustrate hard scattering phenomenology



- π^0 measurement in same experiment allows us the study of nuclear effect with less systematic uncertainties.

- Good agreement with NLO pQCD
- **Reference for Au+Au spectra**
- **Give us Idea how to analyze whether Au+Au data illustrate hard-scattering by the same mechanism as in p-p collisions**

PHENIX (p+p) hep-ex/0304038

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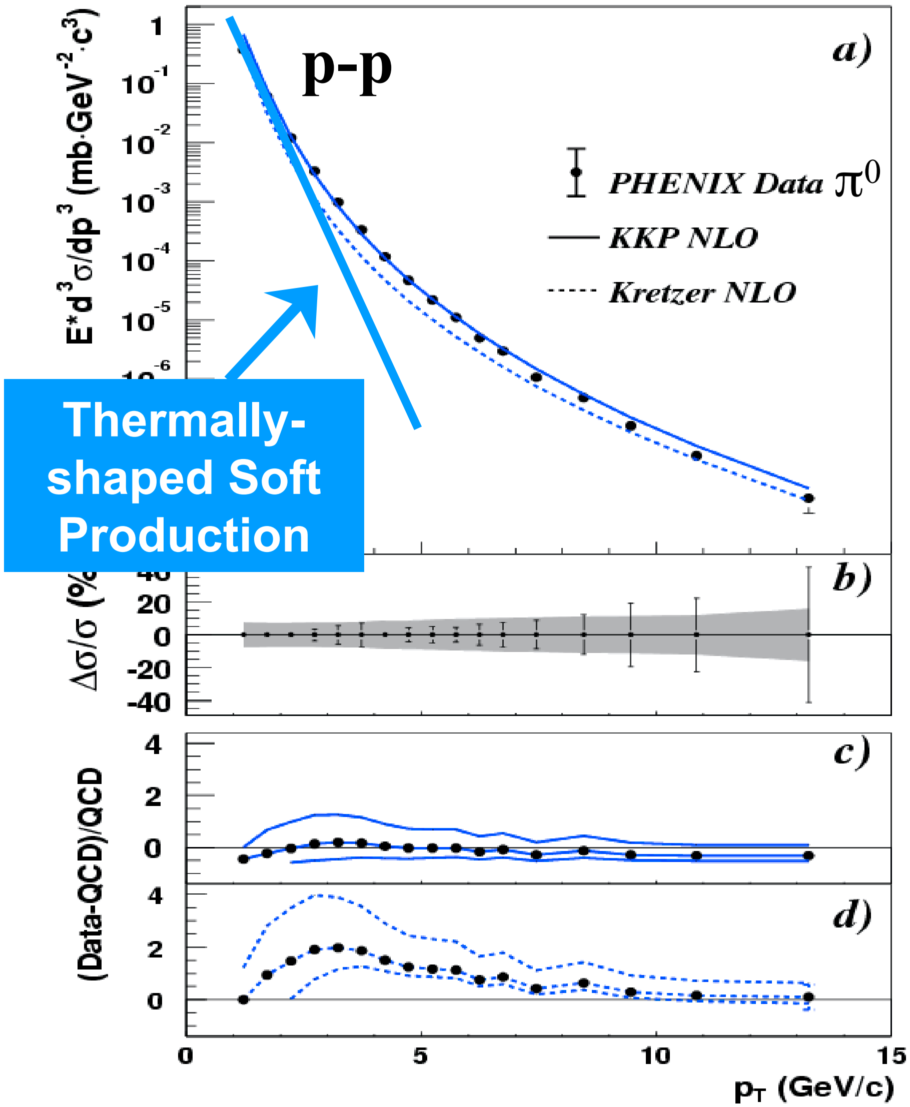

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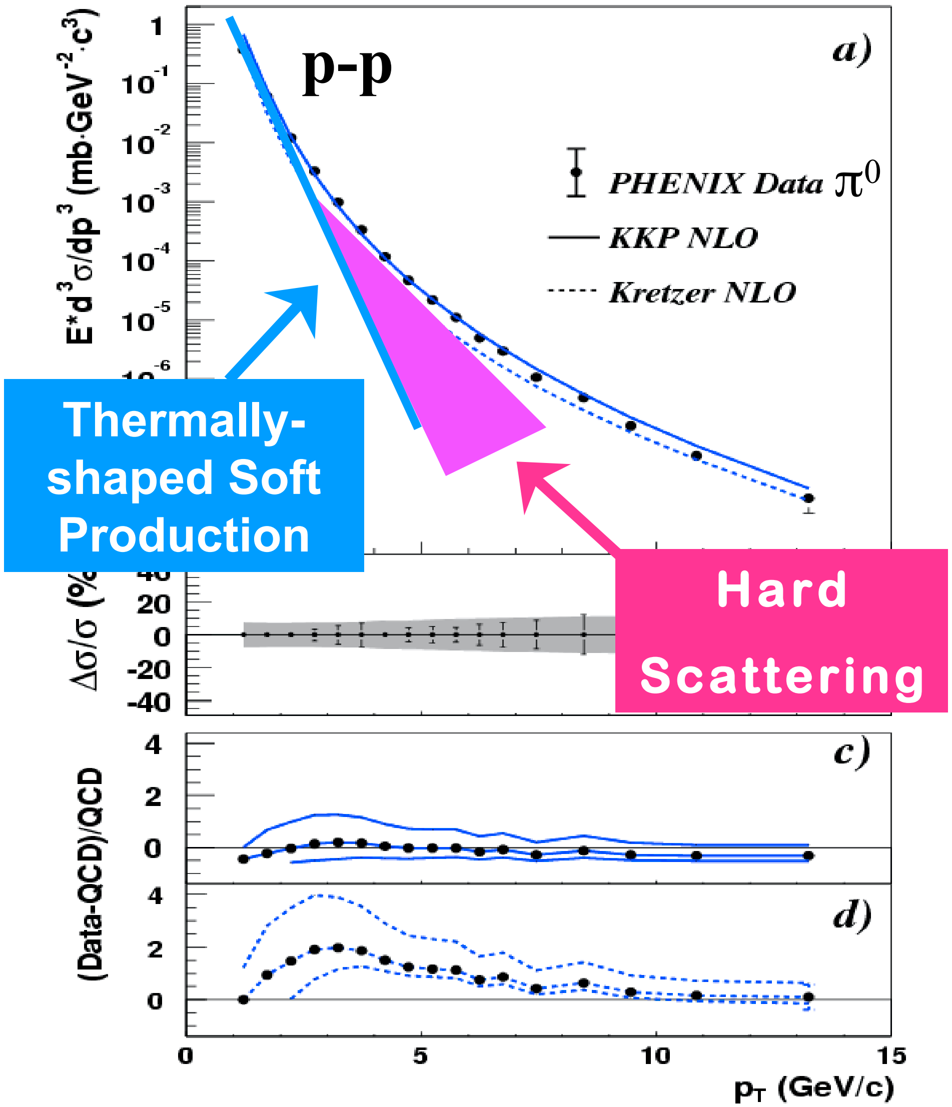

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PHENIX (p+p) hep-ex/0304038

The invariant cross section for the single-particle inclusive reaction $p + p \rightarrow C + X$ where particle C has transverse momentum p_T near mid-rapidity, was given by the general scaling form [54]:

$$\boxed{E\frac{d^3\sigma}{dp^3} = \frac{1}{p_T^n} F\left(\frac{2p_T}{\sqrt{s}}\right) \quad \text{where} \quad x_T = 2p_T/\sqrt{s}}$$

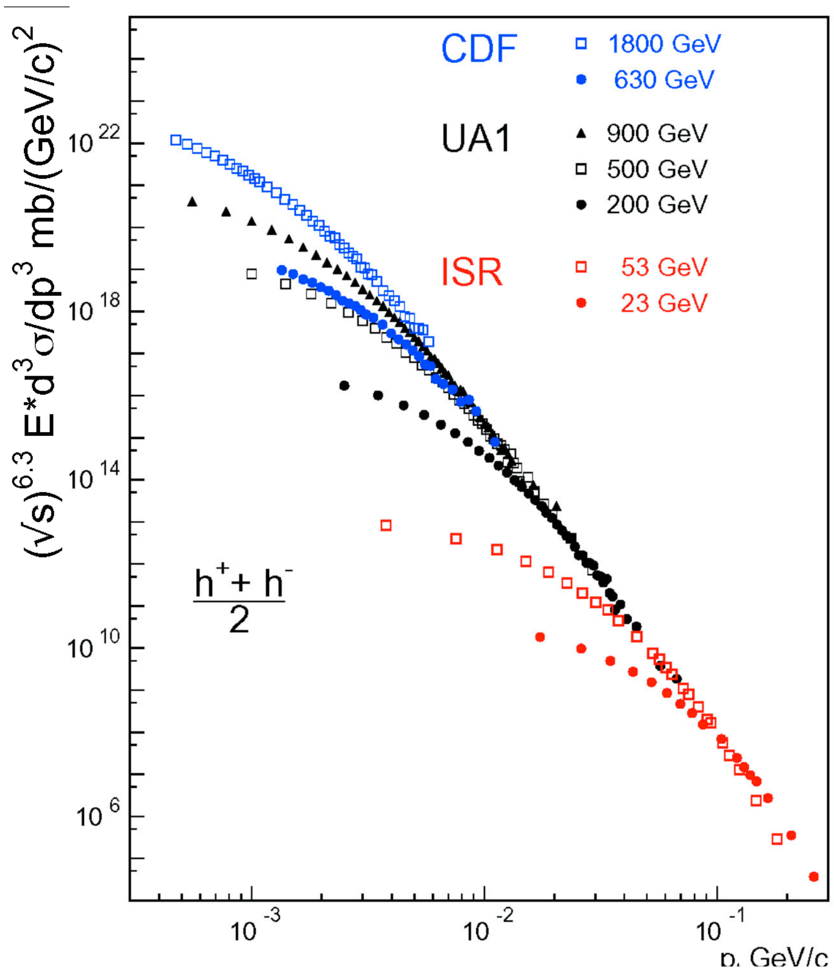
There are 2 factors: a function F which depends only on the ratio of momenta, and a dimensioned factor, p_T^{-n}, where n depends on the quantum exchanged in the hard-scattering. For QED or Vector Gluon exchange [53], $n = 4$. For the case of quark-meson scattering by the exchange of a quark [54], n=8.

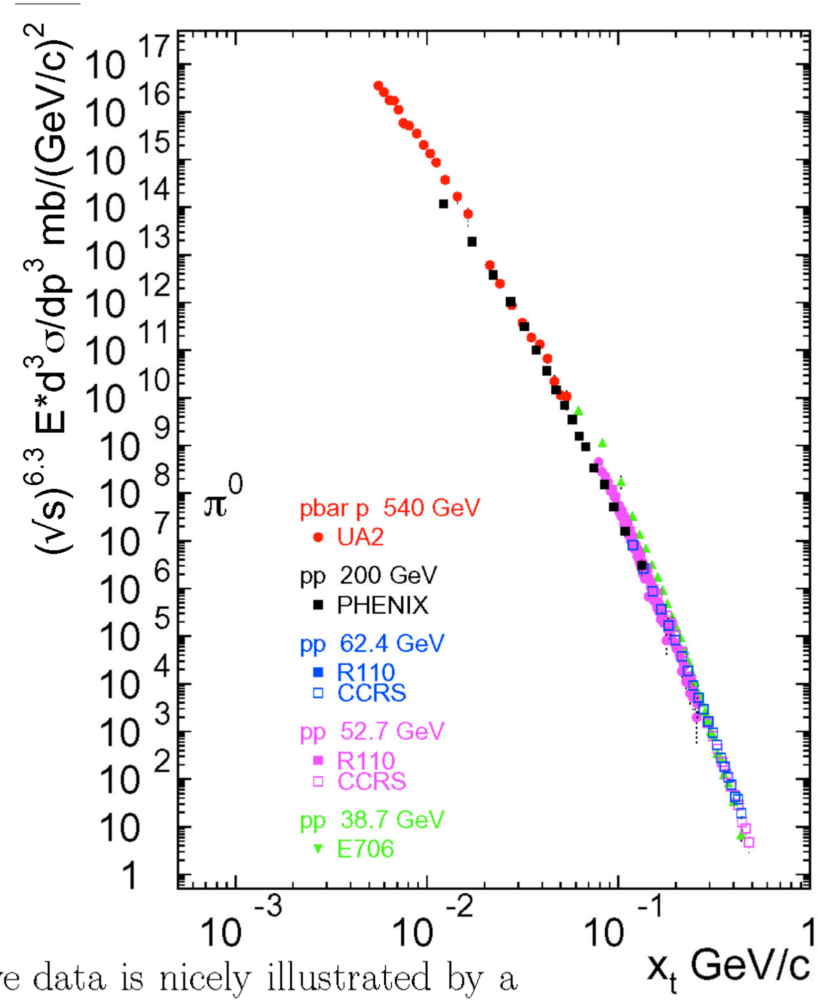
Inclusion of QCD [58] into the scaling form led to the x_T-scaling law

$$\boxed{E\frac{d^3\sigma}{dp^3} = \frac{1}{\sqrt{s}^{\,n(x_T,\sqrt{s})}} G(x_T)}$$

where the "x_T-scaling power" $n(x_T, \sqrt{s})$ should equal 4 in lowest order (LO) calculations, analogous to the $1/q^4$ form of Rutherford Scattering in QED. The structure and fragmentation functions, which scale as the ratios of momenta are all in the $G(x_T)$ term. Due to higher order effects such as the running of the coupling constant, $\alpha_s(Q^2)$, the evolution of the structure and fragmentation functions, and the initial state k_T, measured values of $n(x_T, \sqrt{s})$ in $p+p$ collisions are in the range from 5 to 8.

x_T scaling in p-p collisions x~0.05-0.10

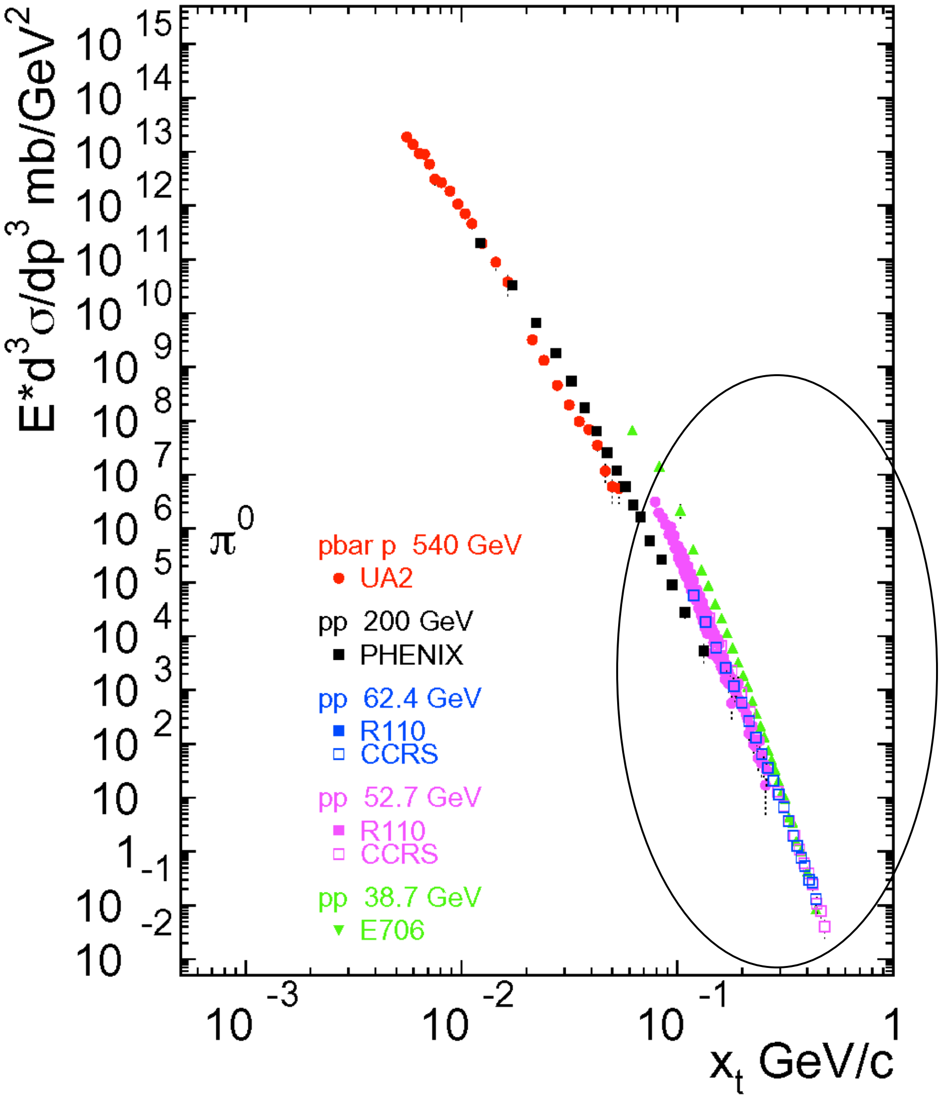


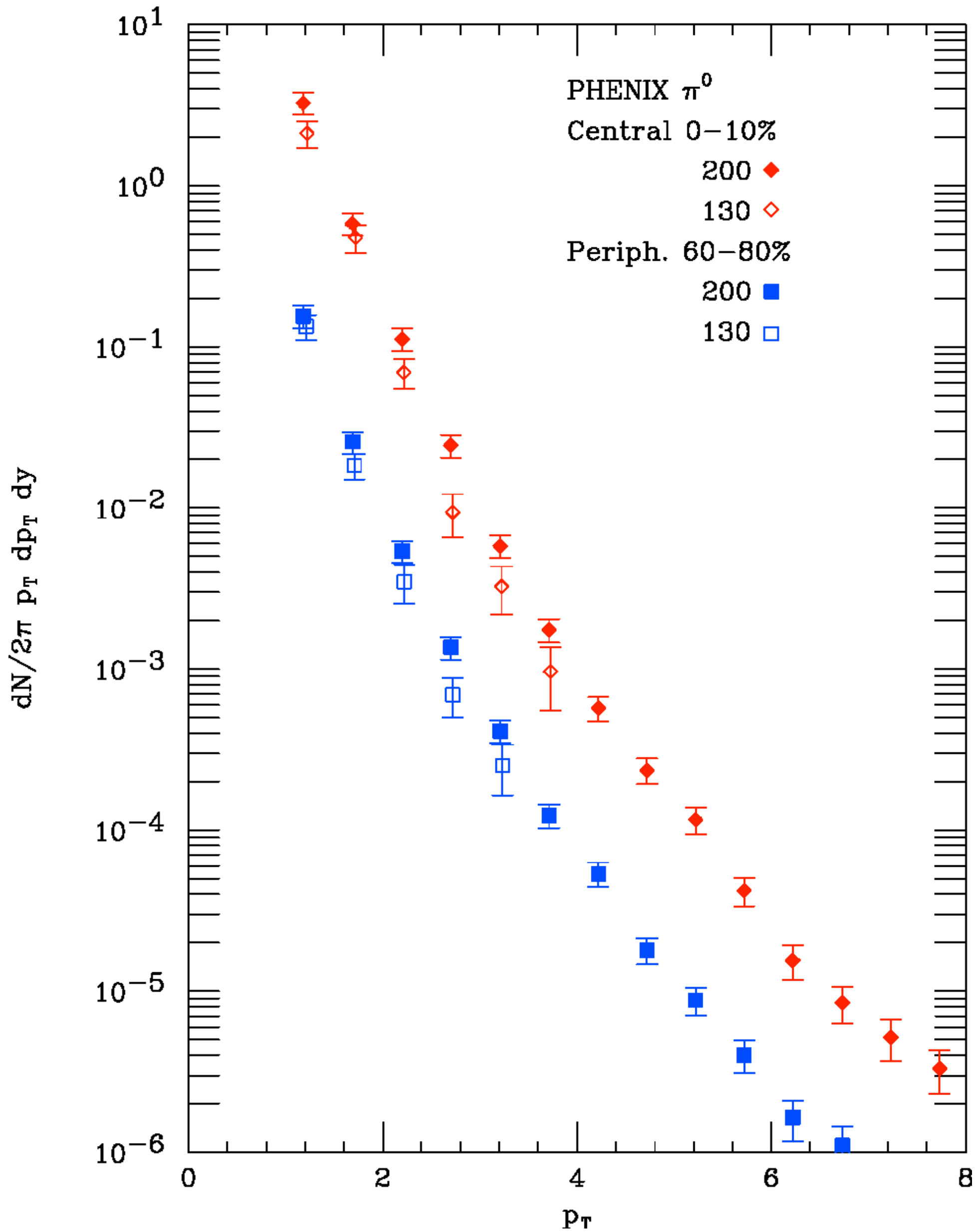


The x_T-scaling of the single particle inclusive data is nicely illustrated by a plot as a function of x_T, with $n(x_T, \sqrt{s}) = 6.3$ of:

$$\sqrt{s}^{\,n(x_T,\sqrt{s})} \times E\frac{d^3\sigma}{dp^3} = G(x_T)$$

As in previous talk scaling at higher x_T is improved with n=5.1



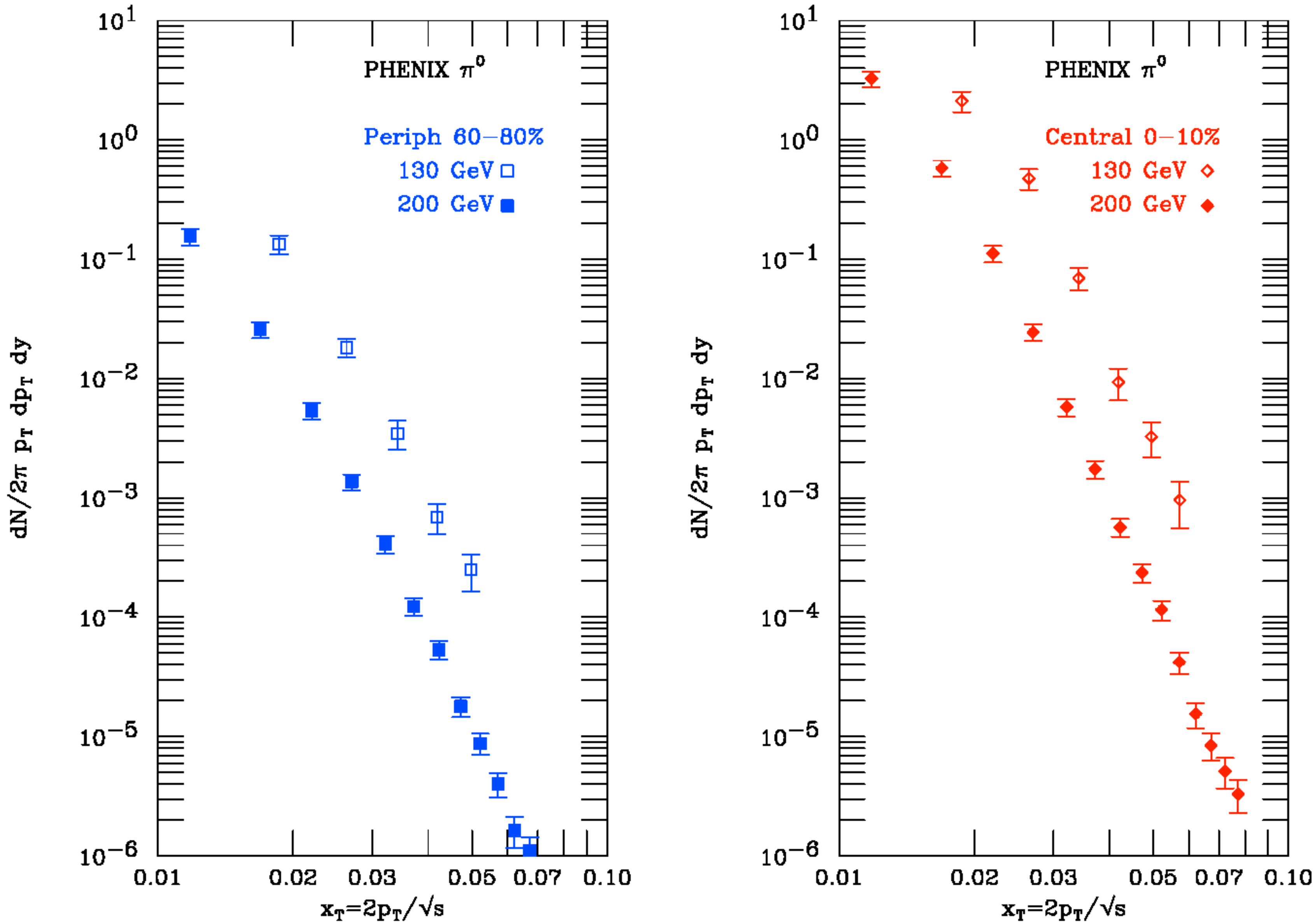


PHENIX Semi-Inclusive π_0 Au+Au $\sqrt{s_{NN}}$=130 and 200 GeV vs p_T

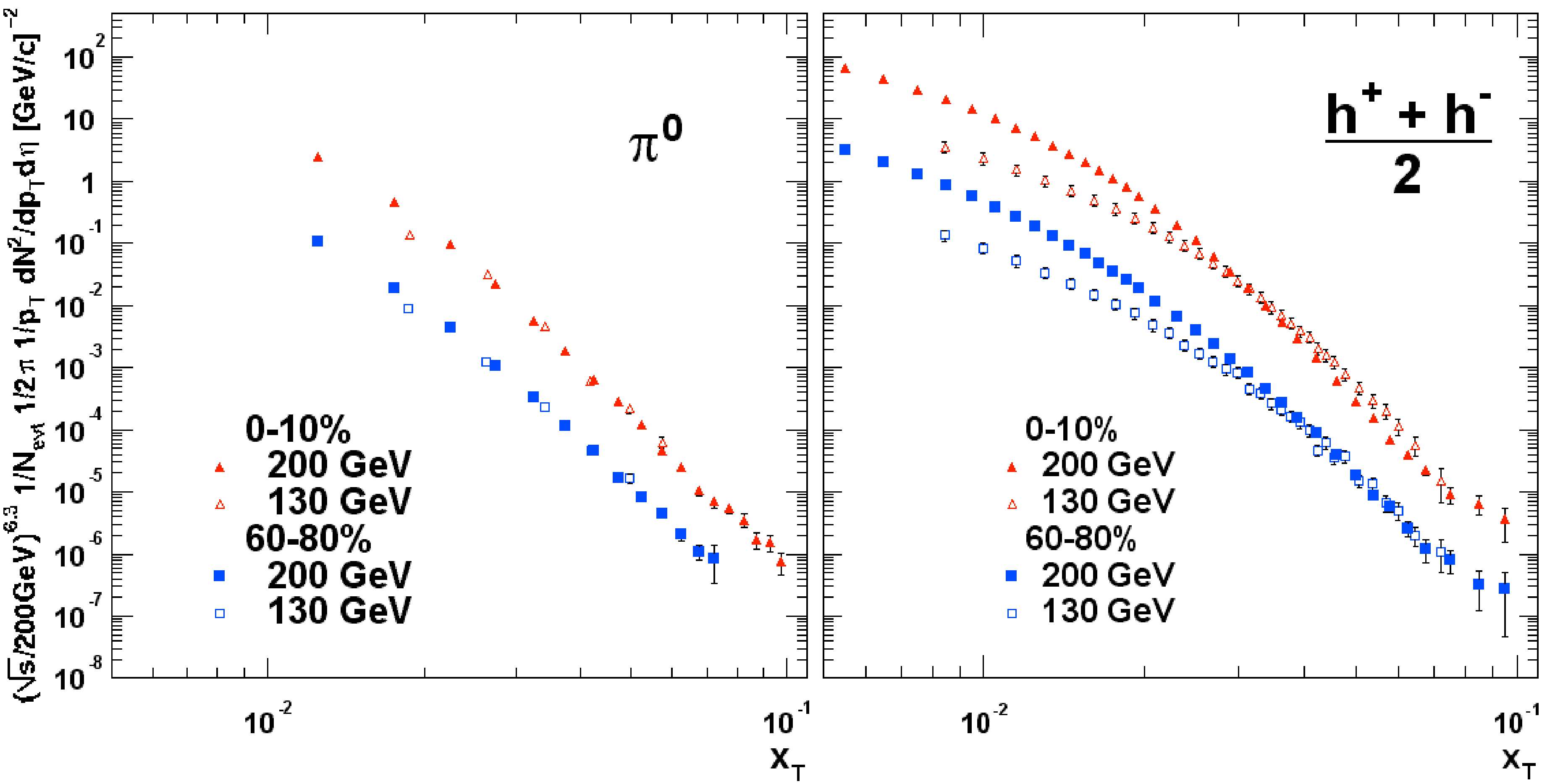
Peripheral 60 -- 80%

Central 0-10%

Same data vs x_T on log-log plot



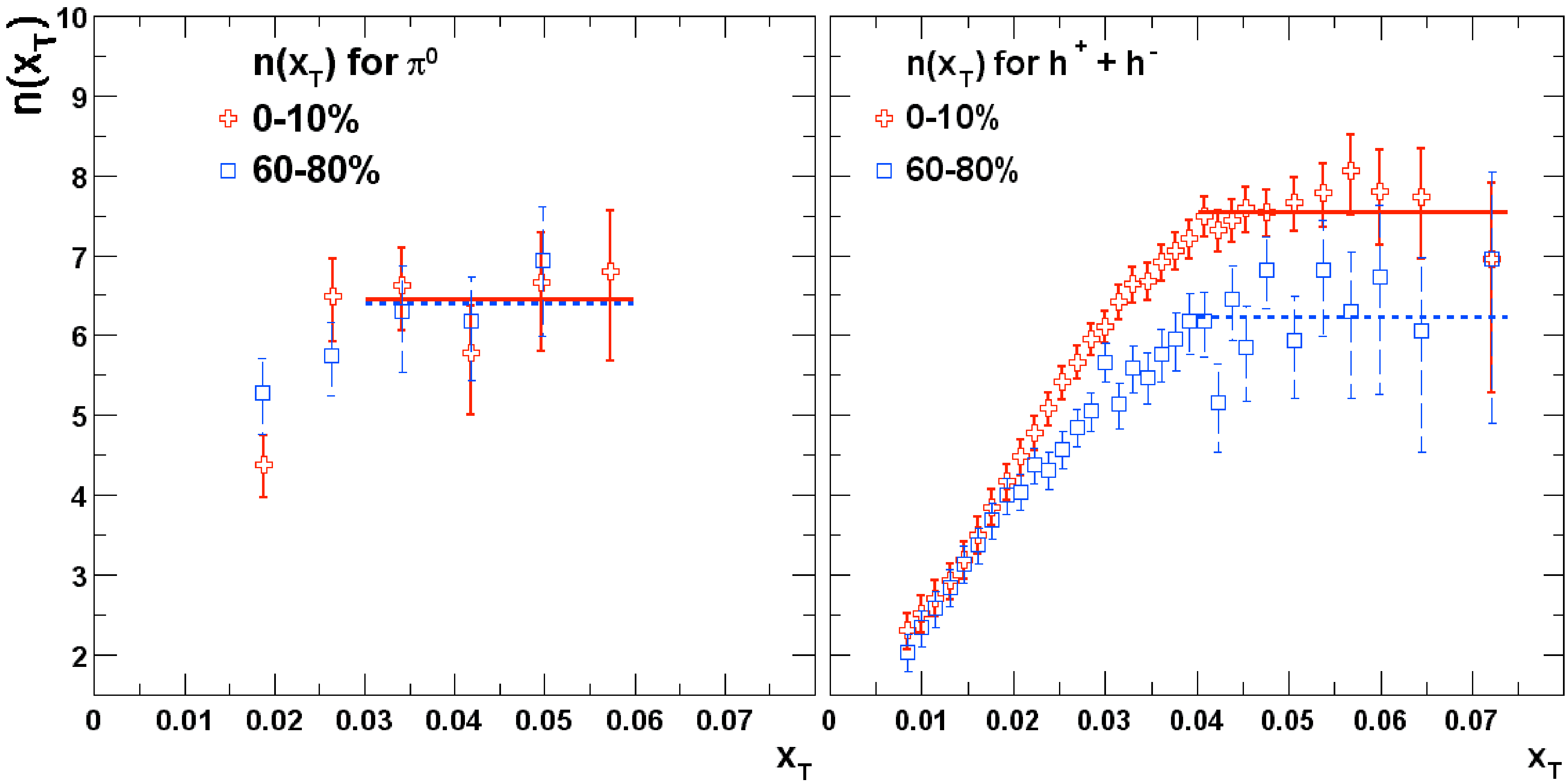
π^0 and $(h^+ + h^-)/2$ x_T scaled n=6.3



- Can calculate $n(x_T)$ point-by-point by the ratio of σ_{inv} at fixed x_T for 2 different $\sqrt{s}$

$$\left(\frac{\sqrt{s_1}}{\sqrt{s_2}}\right)^{n(x_T,\sqrt{s})} = \frac{\frac{Ed^3\sigma}{dp^3}(x_T, \sqrt{s_2})}{\frac{Ed^3\sigma}{dp^3}(x_T, \sqrt{s_1})}$$

$n(x_T)$ point-by-point 200/130



- π^0 x_T scales in both peripheral and central Au+Au with same value of n=6.3 as in p-p
- $(h^+ + h^-)/2$ x_T scales in peripheral same as p-p but difference between central and peripheral is significant

Precision values of $n(x_T)$

For a more quantitative analysis, the $Au + Au$ data for a given centrality and hadron selection are fitted simultaneously for $\sqrt{s_{NN}} = 130$ and 200 GeV to the form,

$$E\frac{d^3\sigma}{dp^3}(x_T, \sqrt{s}) = \left(\frac{A}{\sqrt{s}}\right)^n (x_T)^{-m}$$

Fitting results for π^0 over $0.03 < x_T < 0.06$		
parameters	0-10% centrality bin	60-80% centrality bin
A	0.973 ± 0.232	0.843 ± 0.3
m	8.48 ± 0.17	7.78 ± 0.22
n	$6.41 \pm 0.25(stat)$ $\pm 0.49(sys)$	$6.33 \pm 0.39(stat)$ $\pm 0.37(sys)$
Fitting results for $h^+ + h^-$ over $0.04 < x_T < 0.074$		
A	2.30 ± 0.44	0.62 ± 0.27
m	8.74 ± 0.28	8.40 ± 0.43
n	$7.53 \pm 0.18(stat)$ $\pm 0.40(sys)$	$6.12 \pm 0.33(stat)$ $\pm 0.36(sys)$

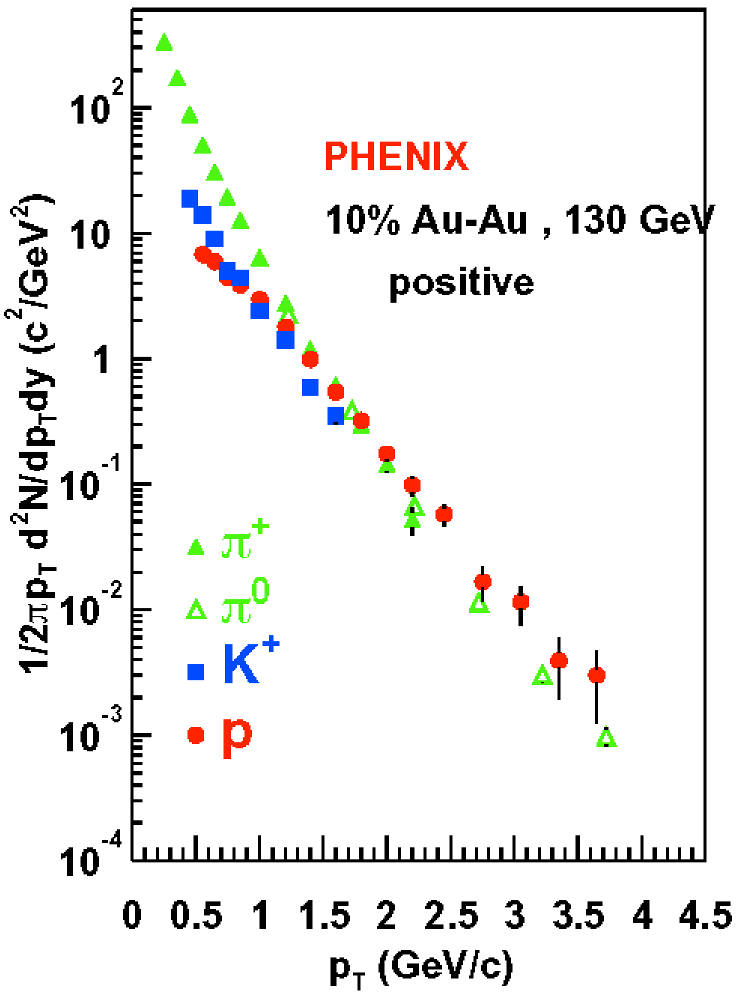
- $\Delta n = n_{cent} - n_{periph} = 1.41 \pm 0.43$ for $(h^+ + h^-)/2$ ***significant***
- $\Delta n = n_{cent} - n_{periph} = 0.09 \pm 0.47$ for π^0

Conclusions

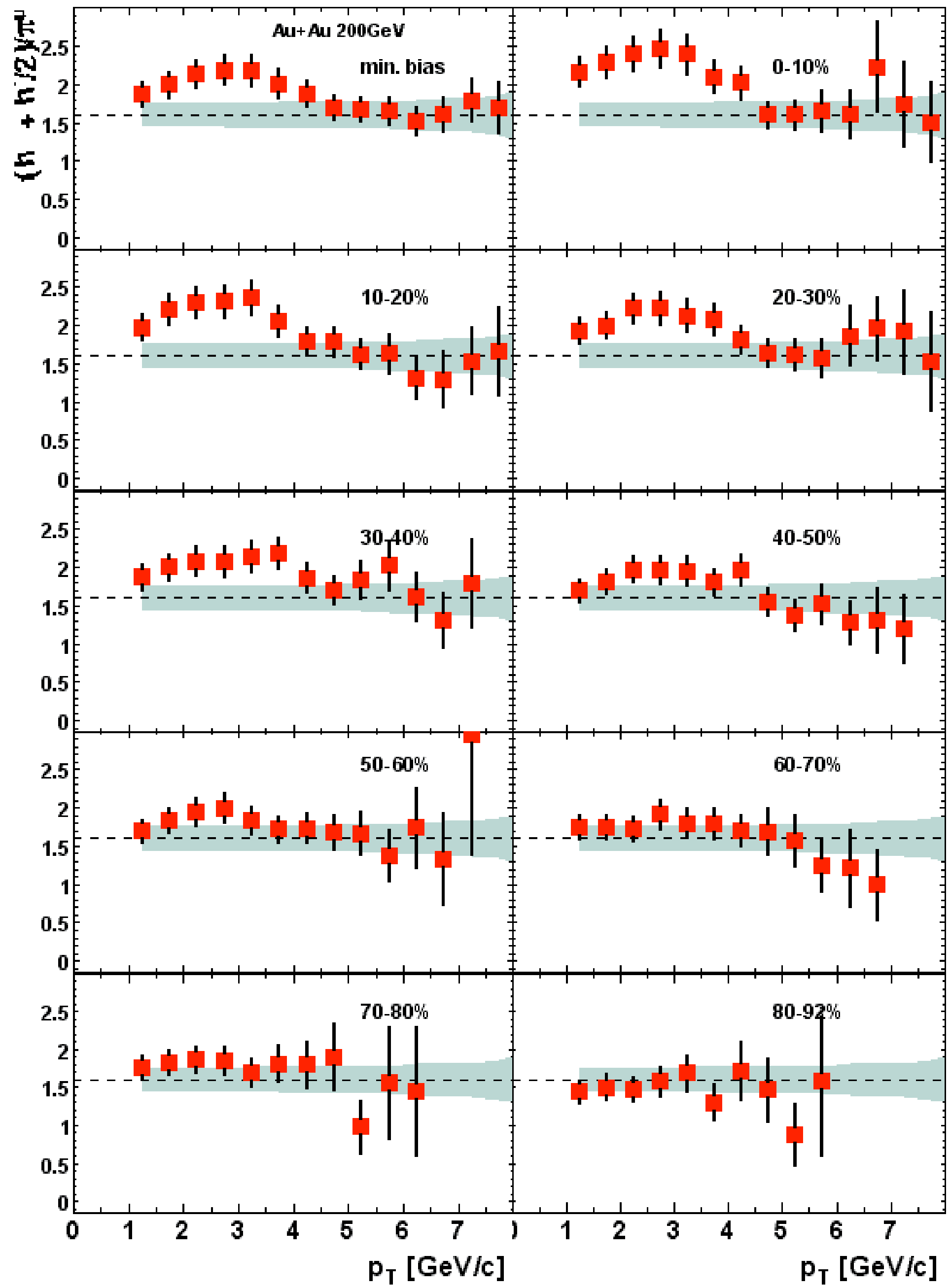
- x_T scaling in peripheral Au+Au collisions at $\sqrt{s_{NN}}$ =130 and 200 GeV for both π^0 and $(h^+ + h^-)/2$ with the same value of n~6.3 as in p-p collisions in this x_T $\sqrt{s}$ range indicates that hard-scattering is the dominant production mechanism for high p_T particles in Au+Au collisions.
- π^0 production exhibits x_T scaling with the same value of n~ 6.3 in both central and peripheral Au+Au collisions
- This implies that the dynamics of suppressed high p_T π^0 production in Au+Au collisions is consistent with hard-scattering according to pQCD with scaling structure and fragmentation functions as in p-p collisions.
- Perhaps a little puzzling since this indicates that the energy loss of the parton scales with its energy, if energy loss. However, scaling is consistent with gluon-saturation.

Conclusions, continued

- For $(h^+ + h^-)/2$ the difference in n between central and peripheral collisions is significant: $\Delta n = 1.41 \pm 0.43$ and is consistent with the large proton and anti-proton enhancement compared to charged pions, which appears to violate x_T scaling from 130 to 200 GeV:
  - » The range $0.04 < x_T < 0.074$ corresponds to $2.6 < p_T < 4.8$GeV/c at 130GeV and $4 < p_T < 7$GeV/c at 200GeV
    But protons are enhanced for the same p_T range $2 < p_T < 4.5$GeV/c for both 130 and 200 GeV



PRL **88**, 242301 (2002)

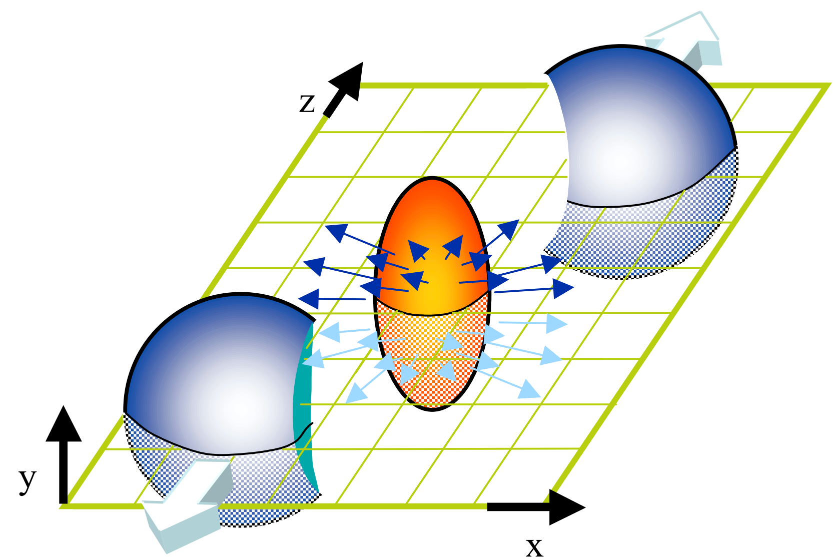


nucl-ex/0308006

Event Anisotropy-M. Kaneta

- Because of sensitive to collision geometry
  - At low p_T (<2 GeV/c)
    - Pressure gradient of early stage
    - Hydrodynamical picture is established
  - At high p_T (>2 GeV/c)
    - Energy loss in dense medium (Jet Quenching)
    - Partonic flow(?)

Here we focus on ellipticity of azimuthal momentum distribution, v_2 (second Fourier coefficient) as physics message



Method of π^0 v_2 Measurement

- Define reaction plane by charged multiplicity on Beam-Beam Counters
- π^0 reconstruction from Electro-Magnetic Calorimeter (EMC)
  - For each p_T, azimuthal angle, centrality
- Combine both information
  - Counting number of π^0 as a function of

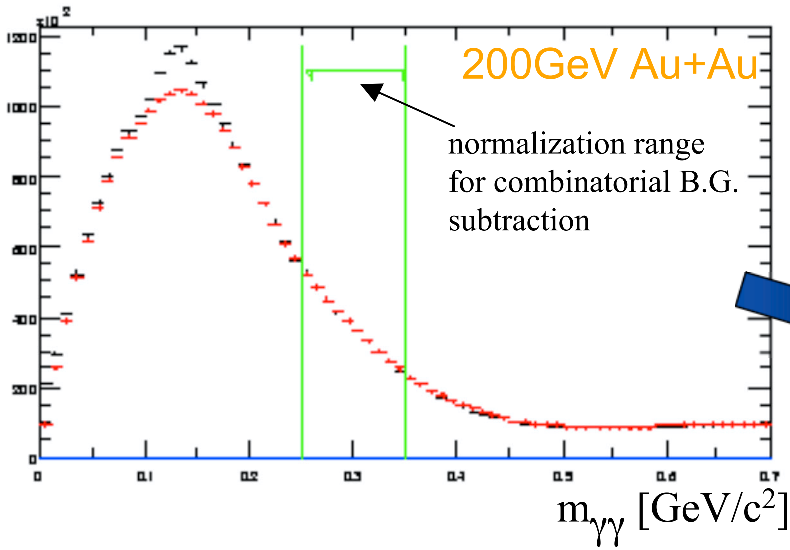
$$E\frac{dN^3}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T\, dp_T\, dy}\left(1 + \sum_{n=1}^{\infty} 2\, \underbrace{v_n^{measured}}_{\text{event anisotropy parameter measured}} \cos[n(\underbrace{\phi}_{\text{azimuthal angle of the particle}} - \underbrace{\Psi_r}_{\text{reaction plane angle}})]\right) \text{where } n = 1,2,3,\ldots$$

$$v_n^{real} = v_n^{measured} / \text{(reaction plane resolution)}_n$$

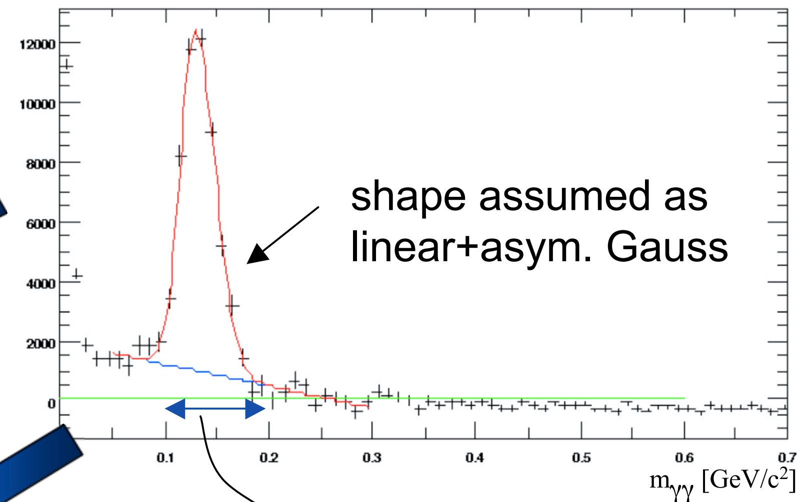
Note: the detail of reaction plane definition will be found in **nucl-ex/0305013**

Some example plots from an analysis procedure

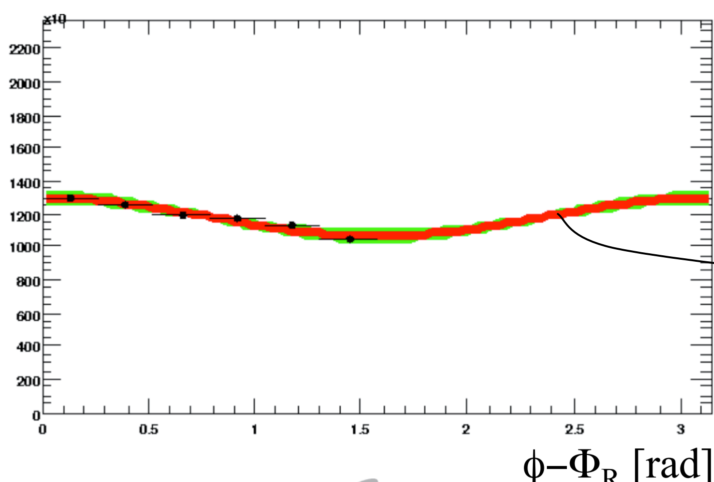
Invariant mass of $\gamma\gamma$ from same event and mixed event (classed by reaction plane, centrality, vertex position)



After subtraction, there is 2nd component of B.G. in p_T<2GeV/c region



count number of π^0 in a range after 2nd B.G. subtraction (not used the fit function)



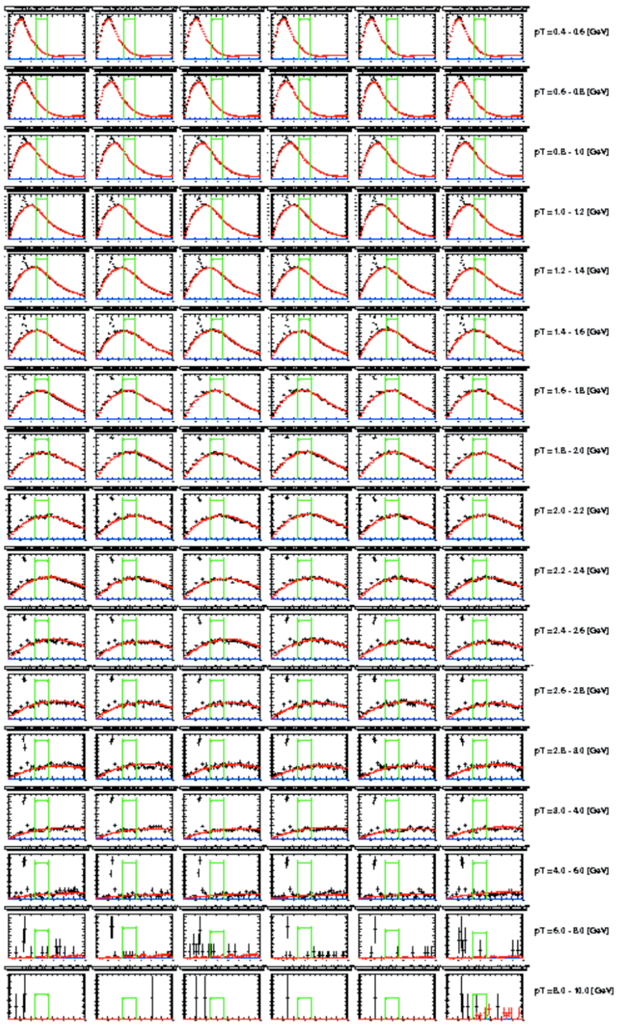
Fit function:
(average of π^0 count) × (1 + 2 v_2 cos[2(ϕ - Φ_R)])
Green lines : deviation by error of v_2

Tooooooooooooo many histograms checked

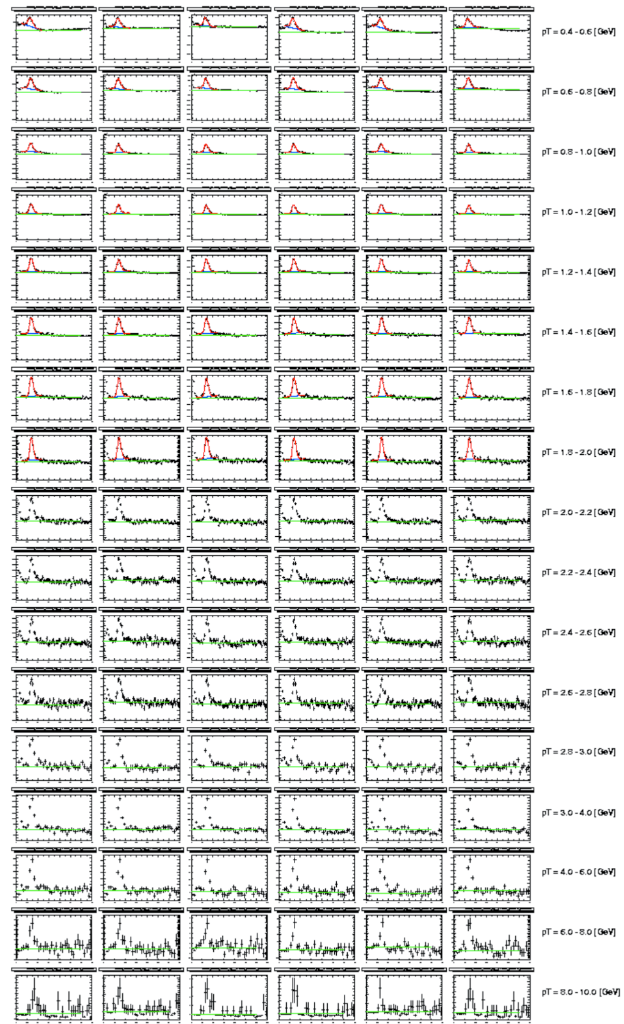
Toooooooooooo many histograms checked

Example of invariant mass distributions for each p_T, ϕ-Φ_R in a centrality bin

Before combinatorial background subtraction

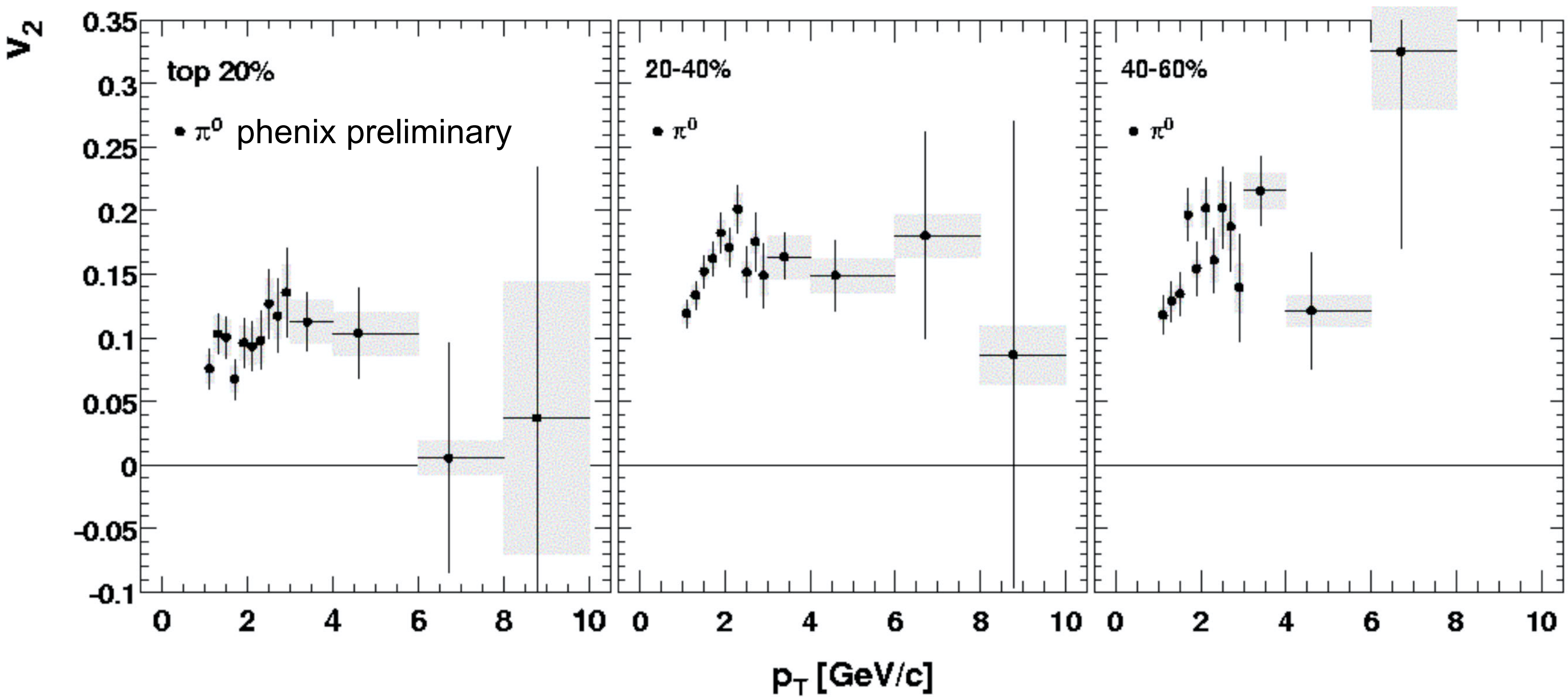


After combinatorial background subtraction



v_2 vs. p_T vs. Centrality from 200GeV Au+Au

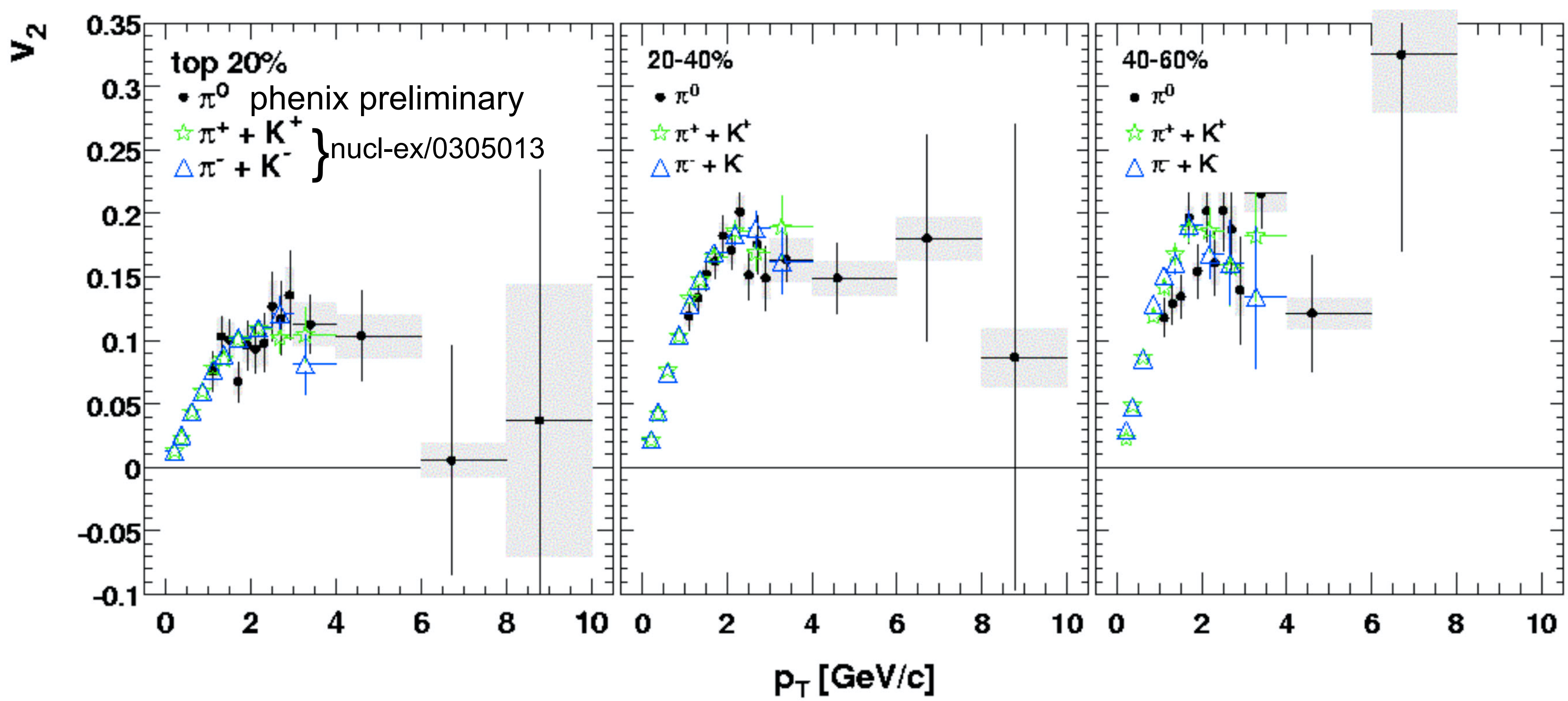
Statistical error is shown by error bar
Systematic error from π^0 count method and reaction plane determination is shown by gray box



v_2 vs. p_T vs. Centrality from 200GeV Au+Au

Statistical error is shown by error bar
Systematic error from π^0 count method and reaction plane determination is shown by gray box

The charged π and K v_2 are shown only with statistical errors



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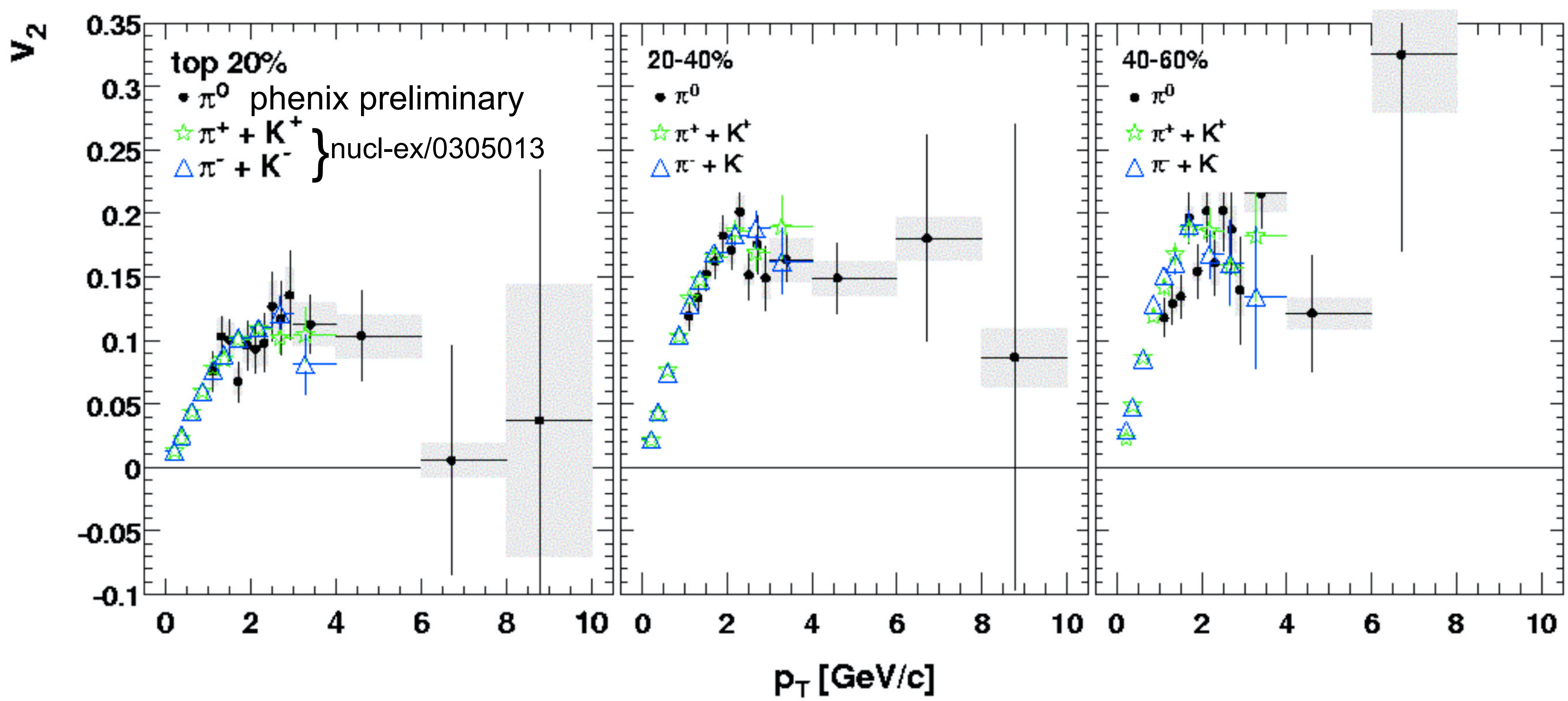
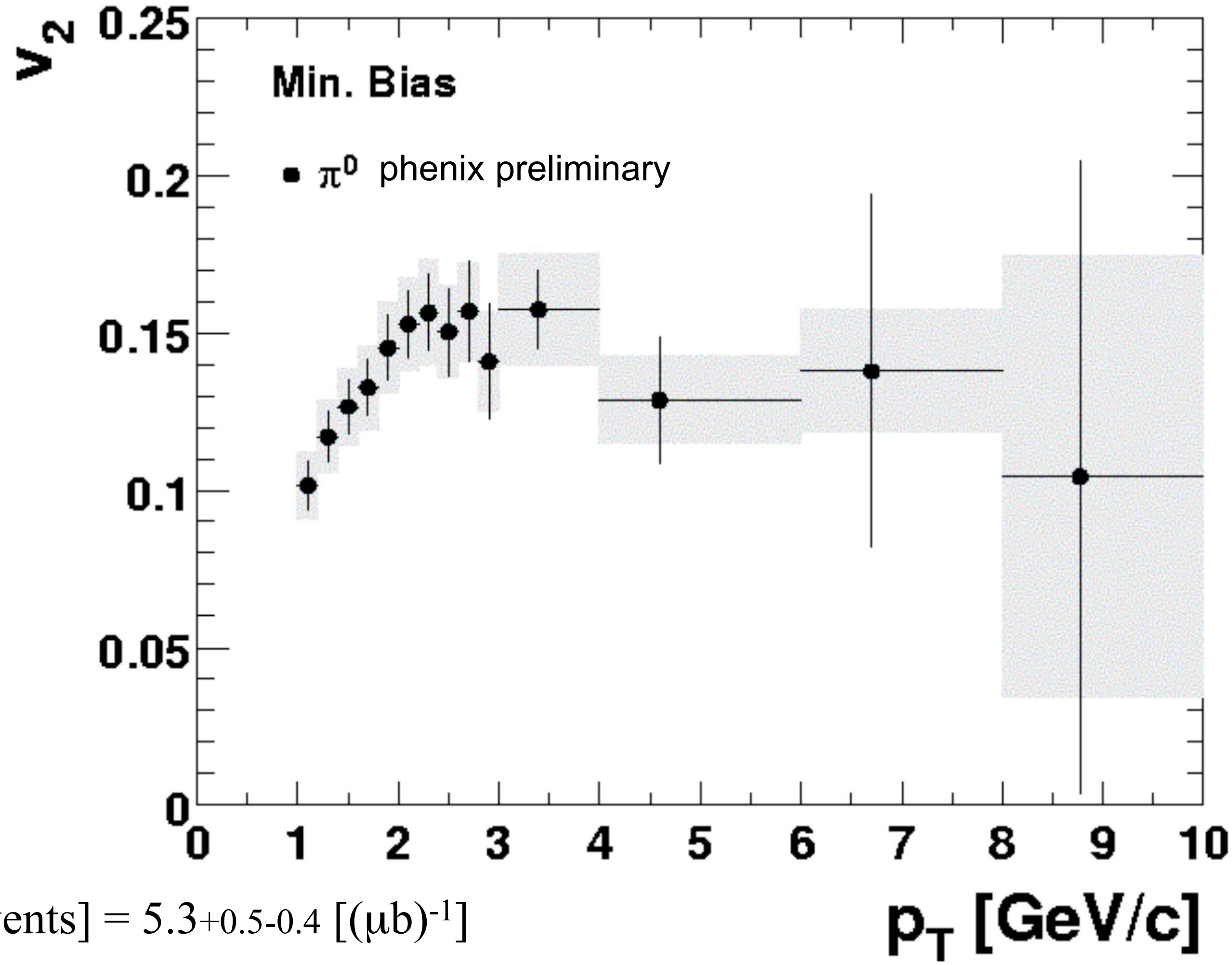


- Charged π+K v_2 consistent with π^0 v_2 in p_T<4GeV/c

v_2 vs. p_T (Minimum Bias) from 200GeV Au+Au

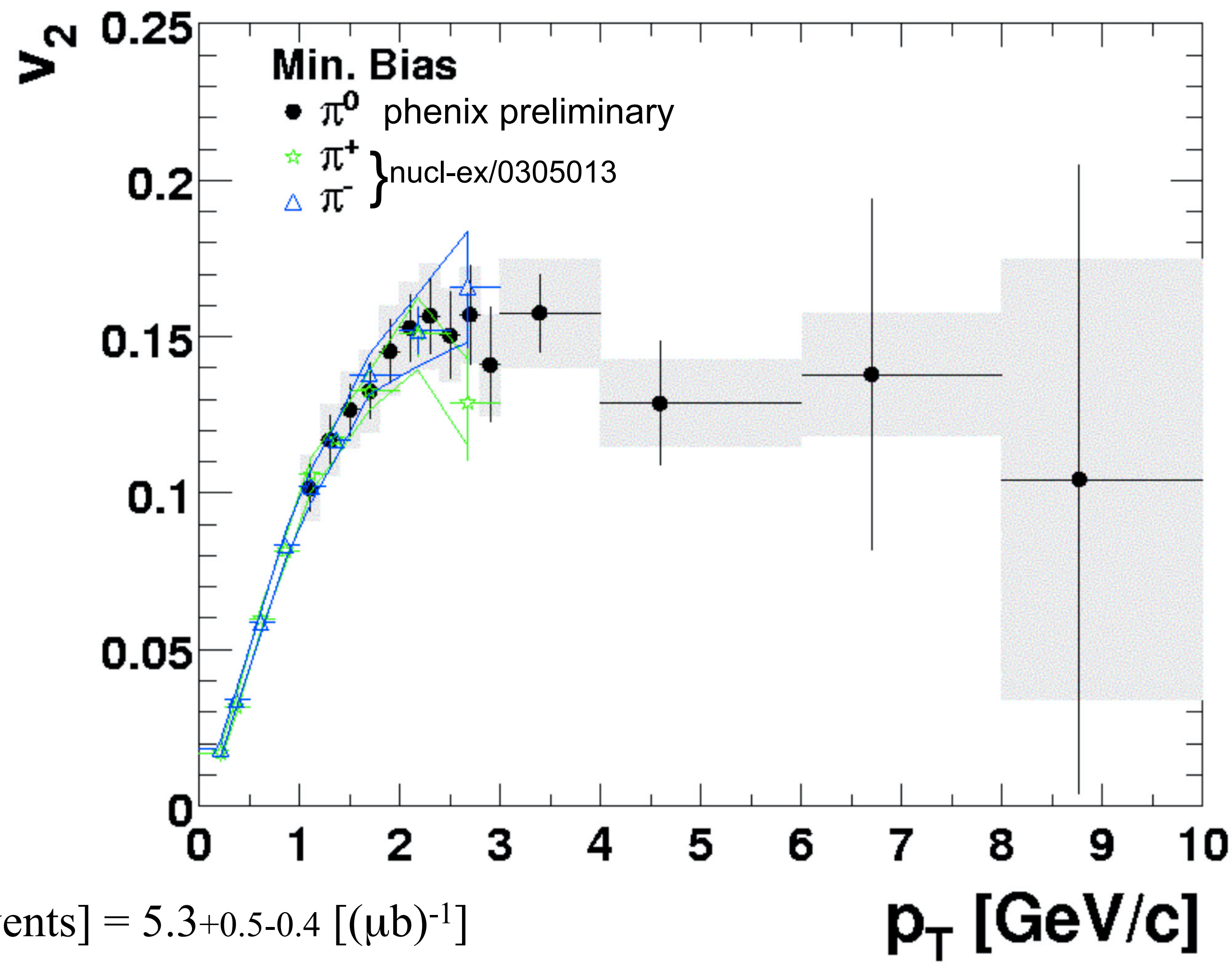
- Identified particle v_2 up to p_T=10GeV/c



36.3×10^6 [events] = $5.3_{+0.5-0.4}$ [(μb)$^{-1}$]

v_2 vs. p_T (Minimum Bias) from 200GeV Au+Au

- Identified particle v_2 up to p_T=10GeV/c



36.3×10^6 [events] = $5.3^{+0.5}_{-0.4}$ [(μb)$^{-1}$]

v_2 vs. p_T (Minimum Bias) from 200GeV Au+Au

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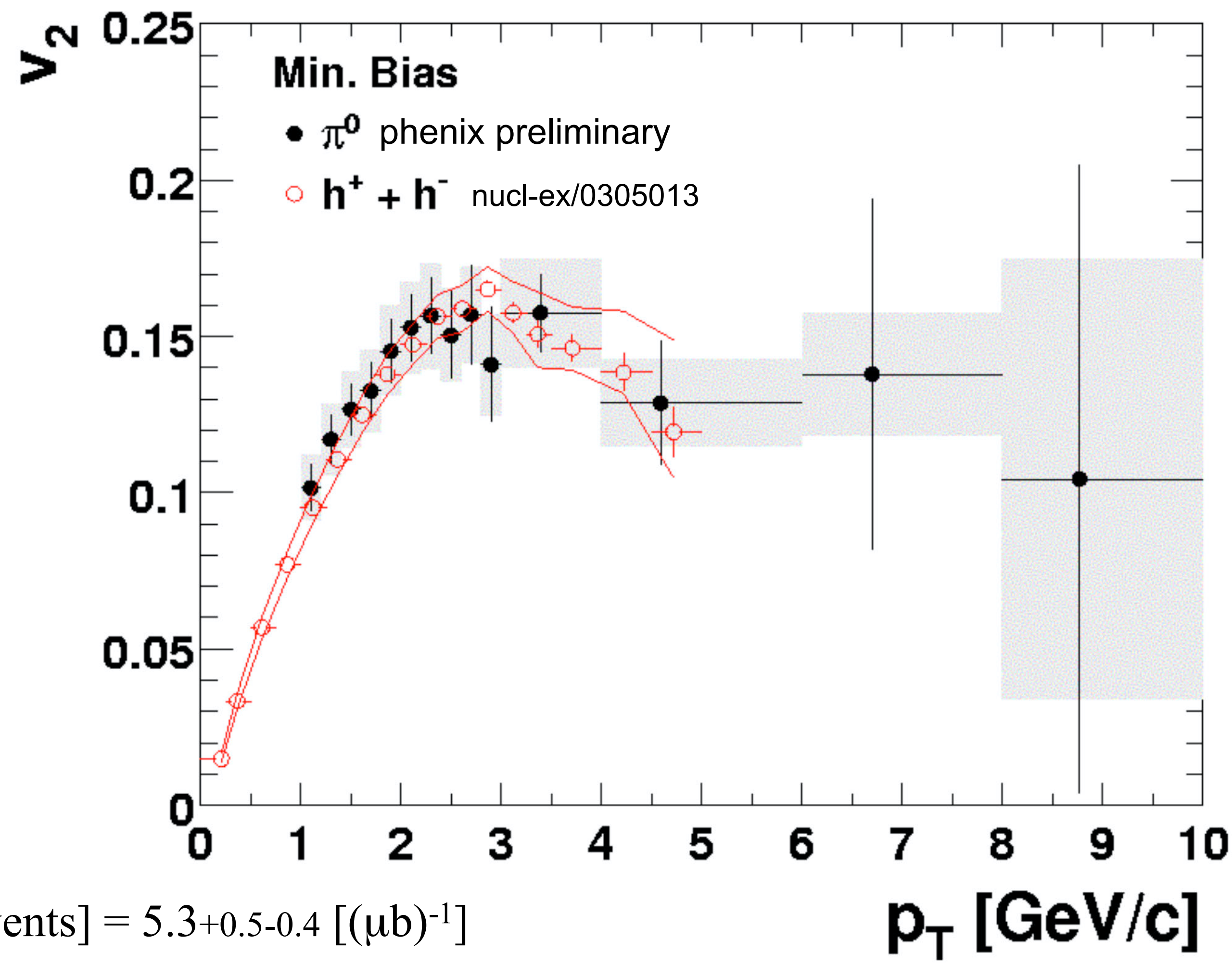
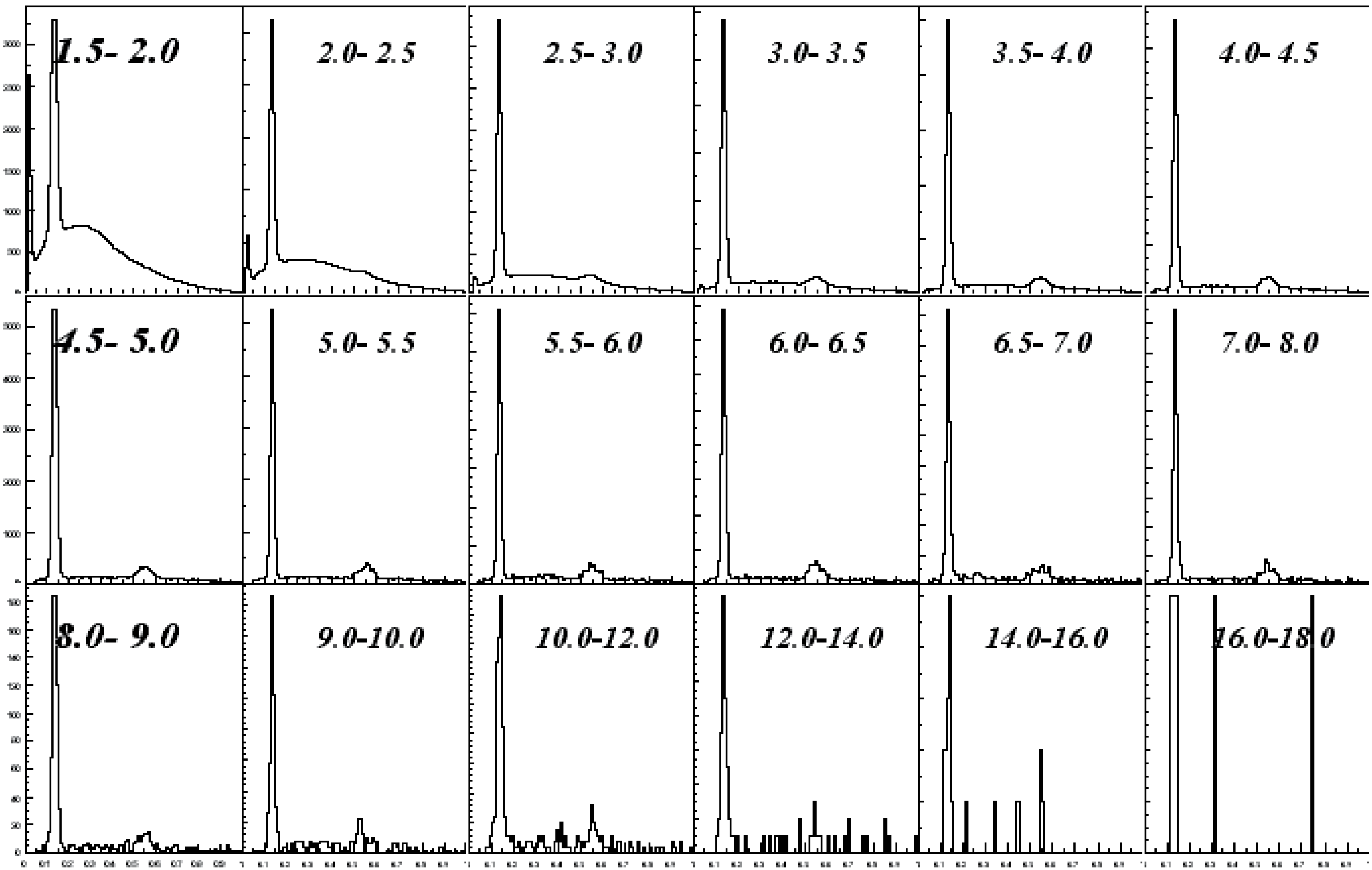


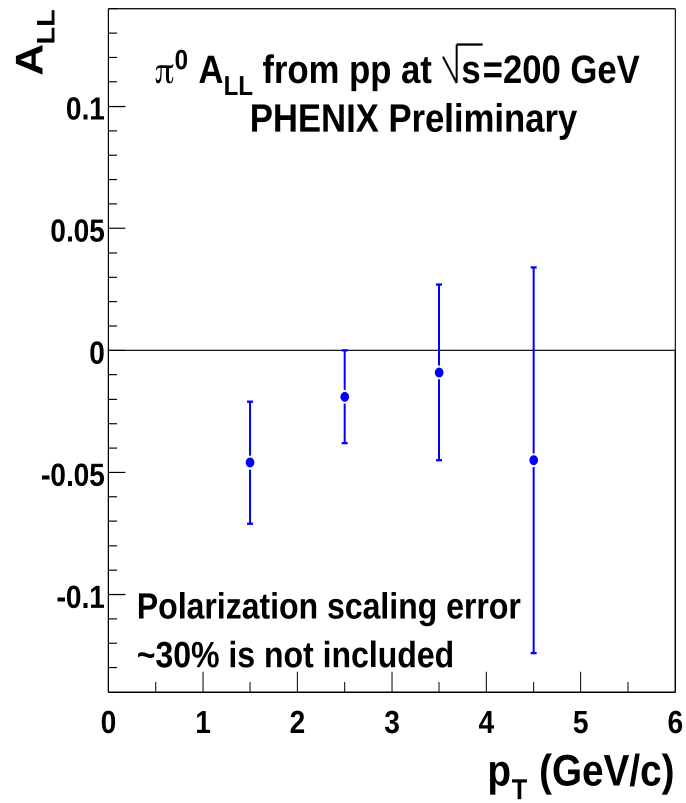
36.3×10^6 [events] = $5.3^{+0.5}_{-0.4}$ [$(\mu b)^{-1}$]

Run3-$\sigma_{\pi 0}$: Pi0 reconstruction



π^0 A_{LL} from pp at 200 GeV-run3

p_T GeV/c	$A_{LL}^{\pi 0+bck}$ (r_{bck})	A_{LL}^{bck}	$A_{LL}^{\pi 0}$ (Background subtracted)
1-2	-0.028±0.012 (45%)	-0.006±0.014	-0.046±0.025
2-3	-0.022±0.015 (17%)	-0.035±0.027	-0.019±0.019
3-4	-0.002±0.033 (7%)	0.094±0.092	-0.009±0.036
4-5	-0.023±0.074 (5%)	0.38±0.24	-0.045±0.079



Polarization scaling error δP ~30%: is not included

- Analyzing power A_N(100 GeV) ~ A_N(22GeV) is assumed
- δP~30%: combined stat. and syst. error for A_N(22GeV) (AGS E950)