High-p_T π^0 suppression in Au+Au collisions. Results at $\sqrt{s_{NN}}$ = 200 GeV

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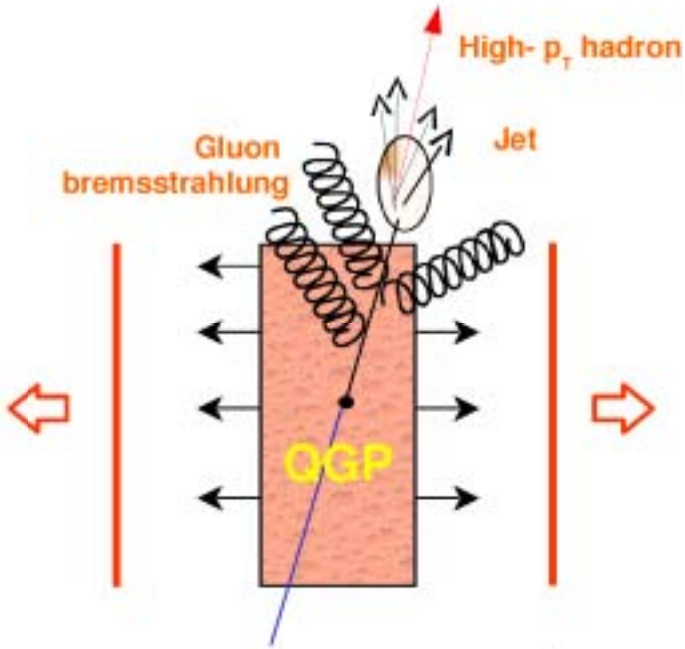
The challenge: "To prove partonic energy loss onset in high-energy HI collisions"

- "*Jet quenching*" : Signature of high-density partonic medium formation.
- Estimate of reached initial gluon density:

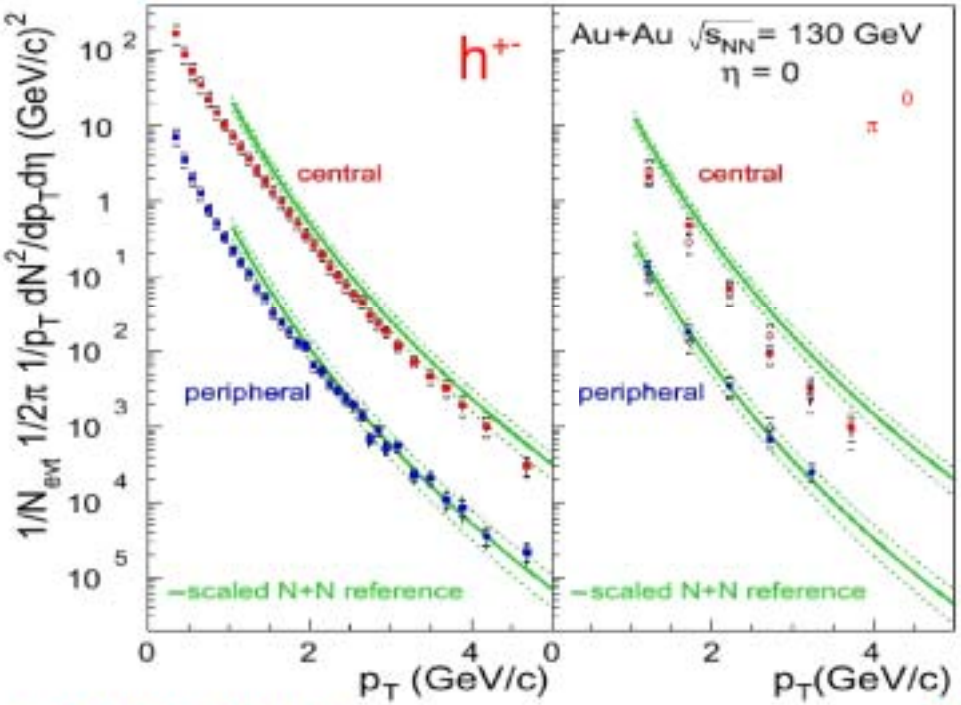
$$\Delta E_{loss} \sim \alpha_s^3 \cdot C_R \cdot \rho_{gluon} \cdot \Delta L^{(2)}$$

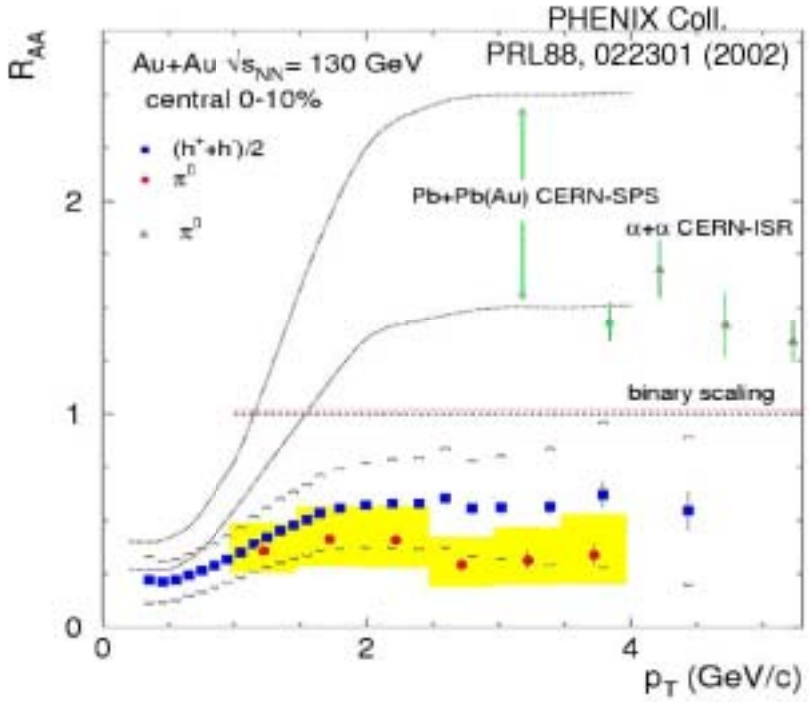


- How ... ?
- Measuring high transv. mom. hadrons (p_T>2 GeV/c) ⇒ parton fragmentation products ("leading particle"):
  - Early production ($\tau \sim 1/p_T \sim 0.1$ fm/c) in parton- parton scatterings with large Q^2.
  - Direct probes of partonic phases ⇒ Sensitive to hot/dense medium.
  - Comparison to available set of baseline "vacuum" data (*pp* ↔ AA) via N_{coll} (# of binary inelastic collisions) scaling.
  - Elementary processes calculable, in principle, from pQCD.

The fact: "High-p_T hadron suppression observed at RHIC @ $\sqrt{s_{NN}}$ = 130 GeV"

- Clear hint of medium effects at work ! (especially π^0)

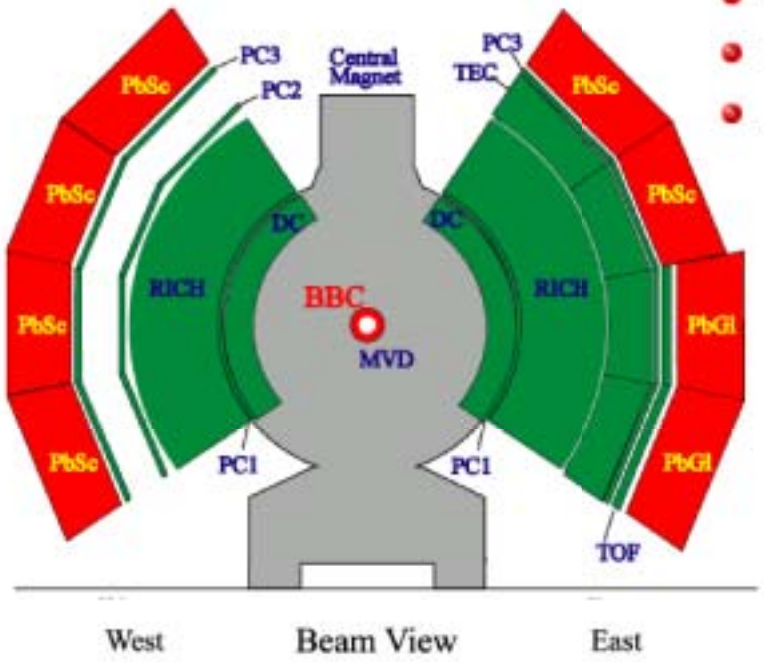




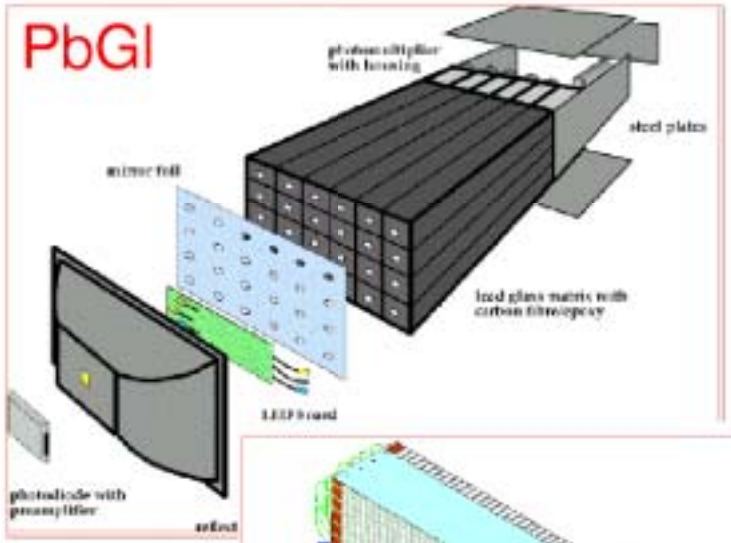
- Initial-state nuclear ? final-state hadronic ? final-state partonic ?

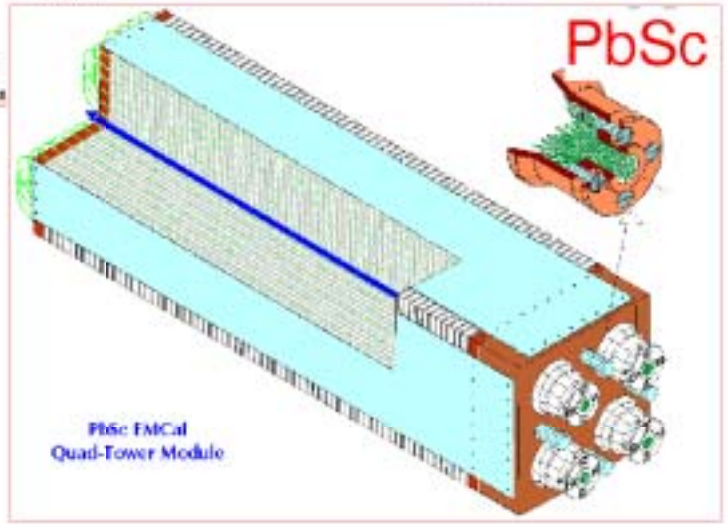
The goal: "Let's see what happens at higher energy (200 GeV), with much higher statistics, for much larger p_T values, and for finer centrality classes

The device: "PHENIX Run- 2 EMCal"



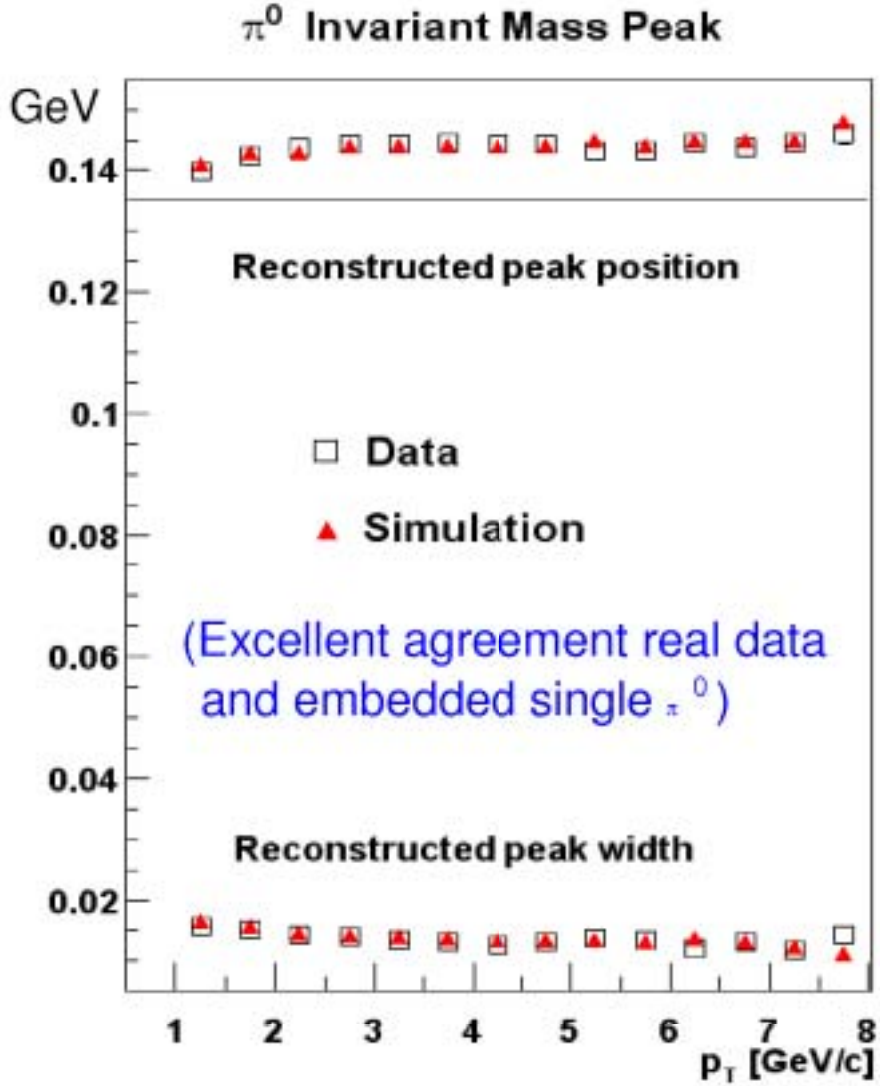
- 6 lead- scintillator (PbSc) sectors (15500 towers)
- 2 lead- glass (PbGl) sectors (9200 towers)
- Acceptance: $|\eta|<0.37$ at midrapidity, $\phi = \pi$





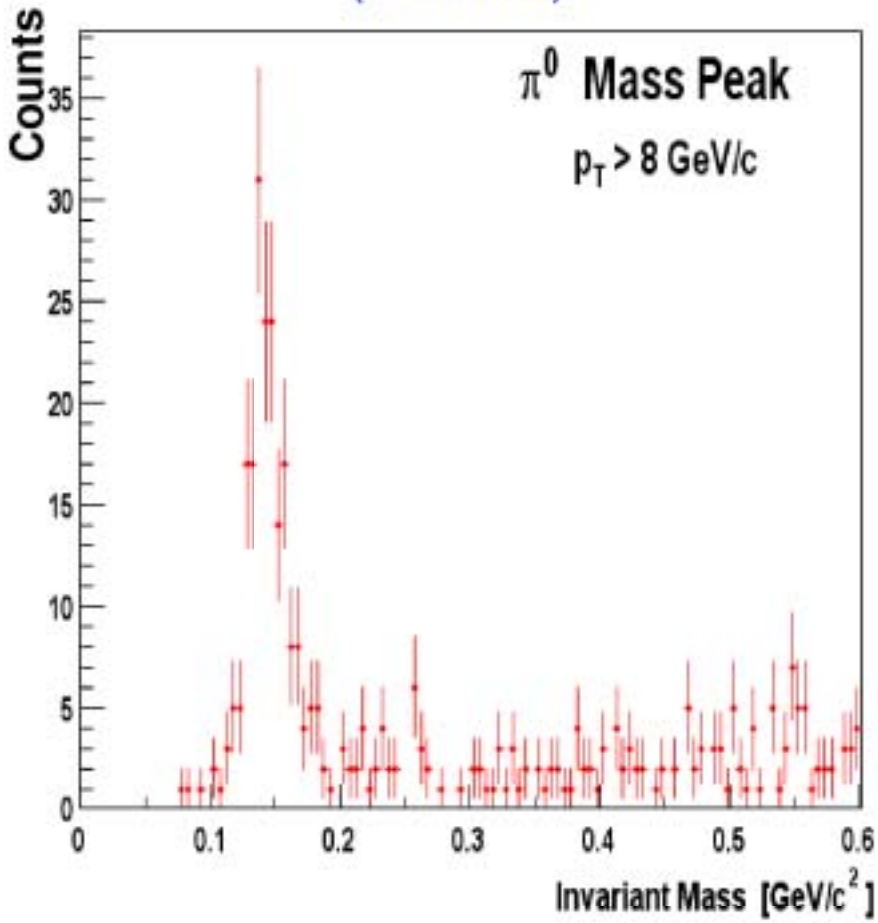
The probe : π^0

- Energy scale and resolution:



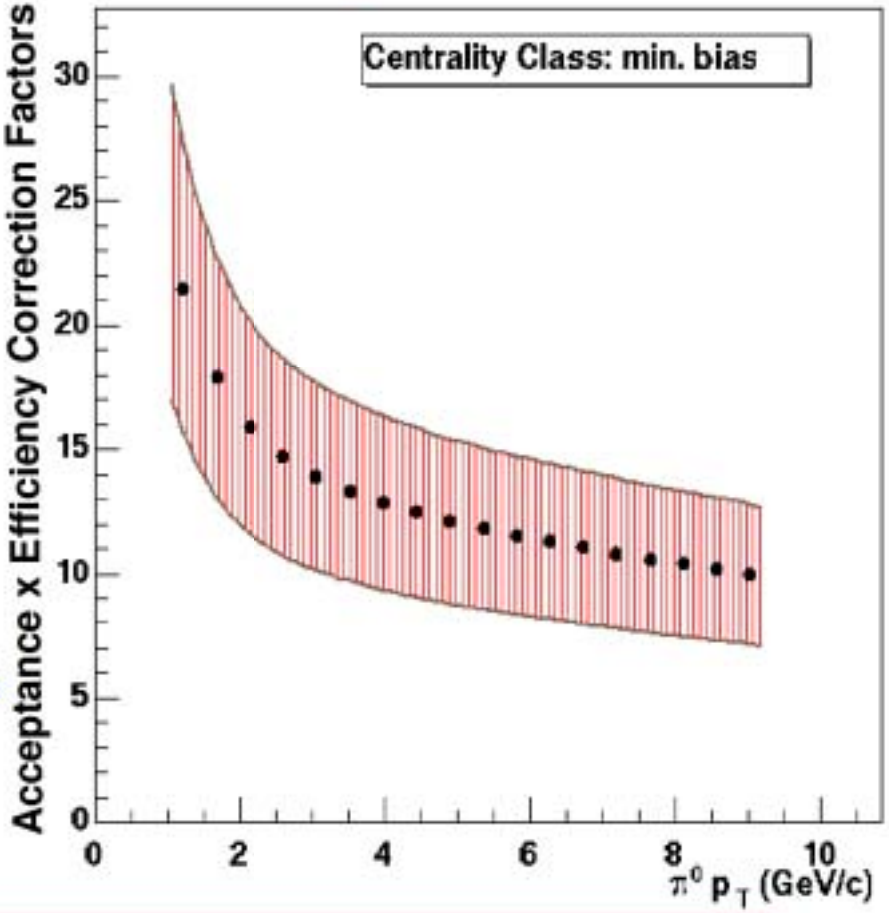
$\gamma\gamma$ invariant- mass analysis:

π^0 peak at $p_T > 8$ GeV/c (min.bias)



The systematics (1): Correction factors & syst. errors

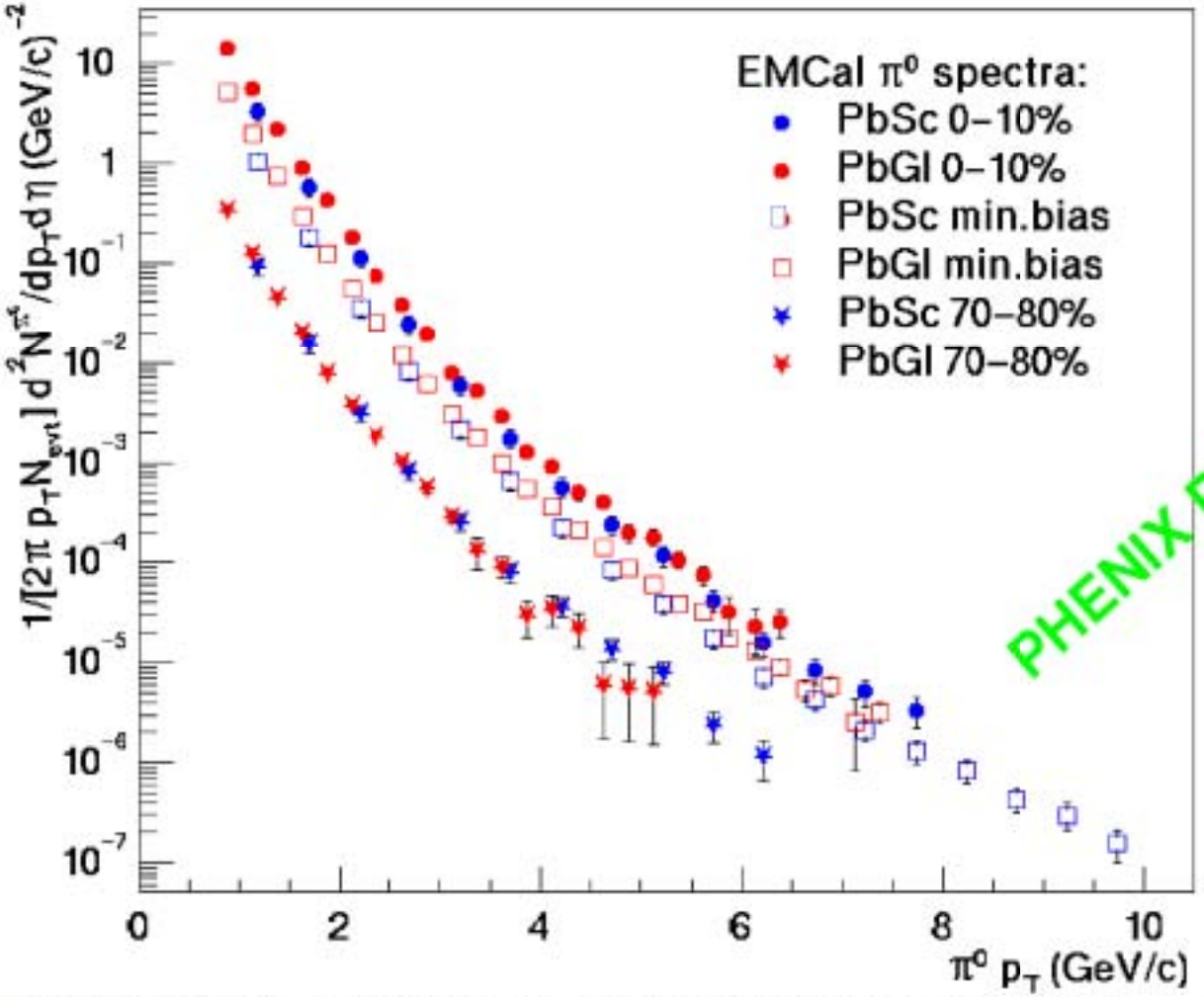
- Efficiency losses calculated with 2M simulated single π^0 embedded in real data
- Correction factors: x20.- x10.
  - Acceptance: ~1/0.25
  - Efficiency: ~1/[0.20- 0.30]
- Systematic errors (% yield):
  - π^0 extraction: ~15%
  - p_T smearing: ~10%
  - TOF cut : ~10%
  - Fiduc., asym., hot towers cuts: ~5%
  - Acceptance: ~3%
  - Off-vertex π^0 contribution: ~3%



- Final systematic error: ~20%- 30% (periph), ~23%- 33% (central) increasing with p_T

The systematics (2): PbGl vs PbSc π^0 spectra

- Two different detectors, analysis, and systematics ...



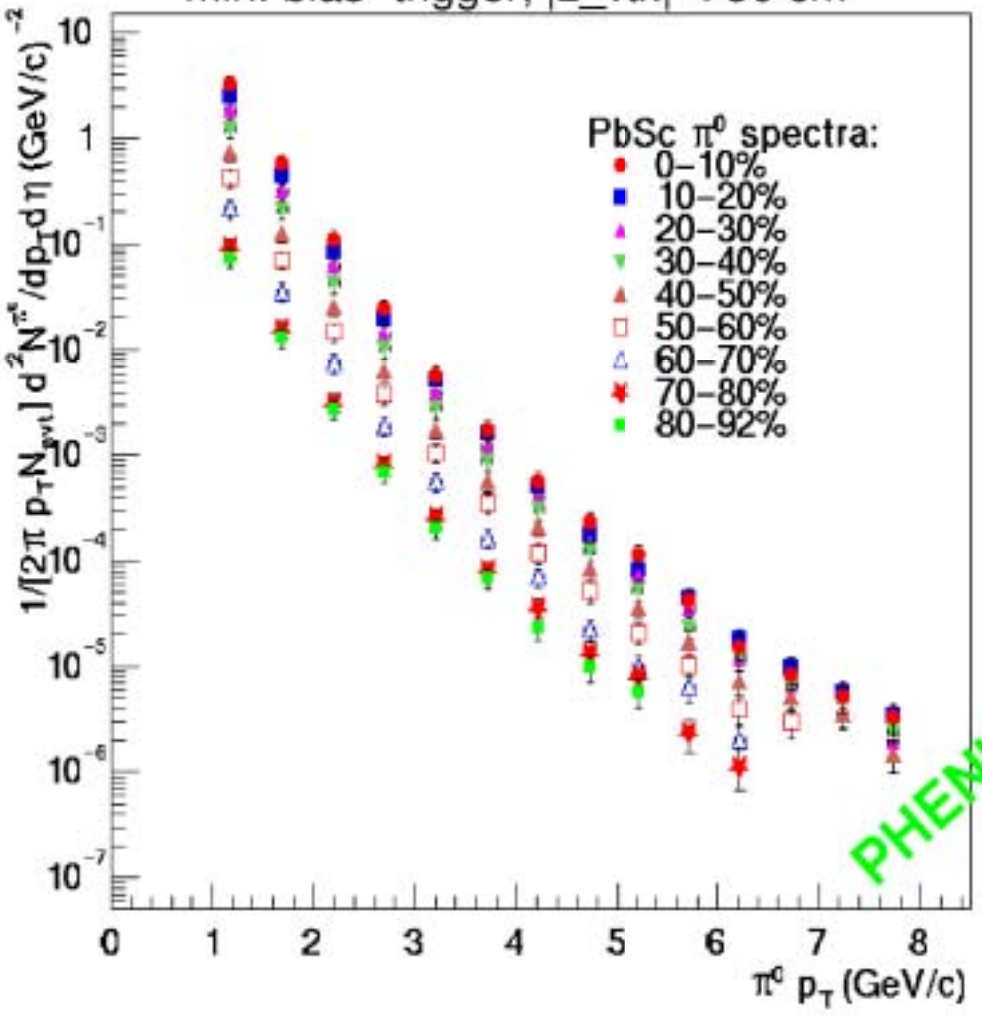
See also Christian Klein-Boesing poster

- Differences PbSc/PbGl consistent with systematic errors: <25%

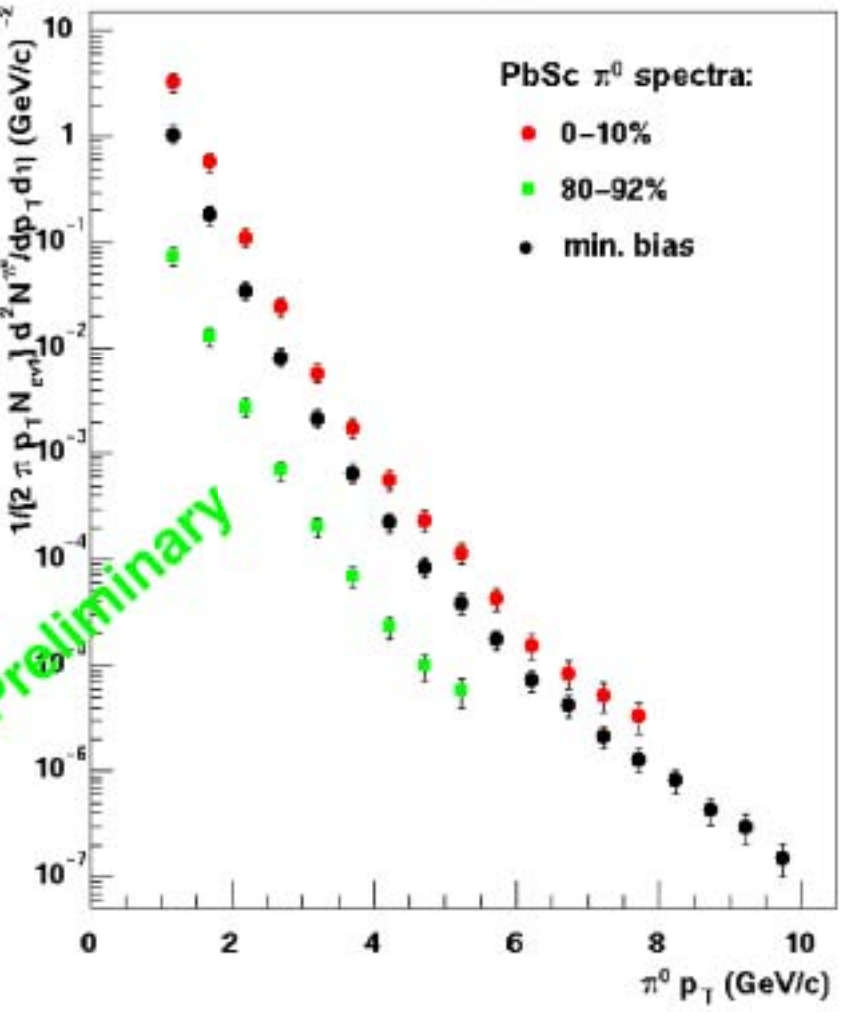
The results (1): High-p_T π^0 spectra

- 30 Million events analyzed.

"min. bias" trigger, |z_vtx| < 30 cm



- Spectra up to p_T~10 GeV/c



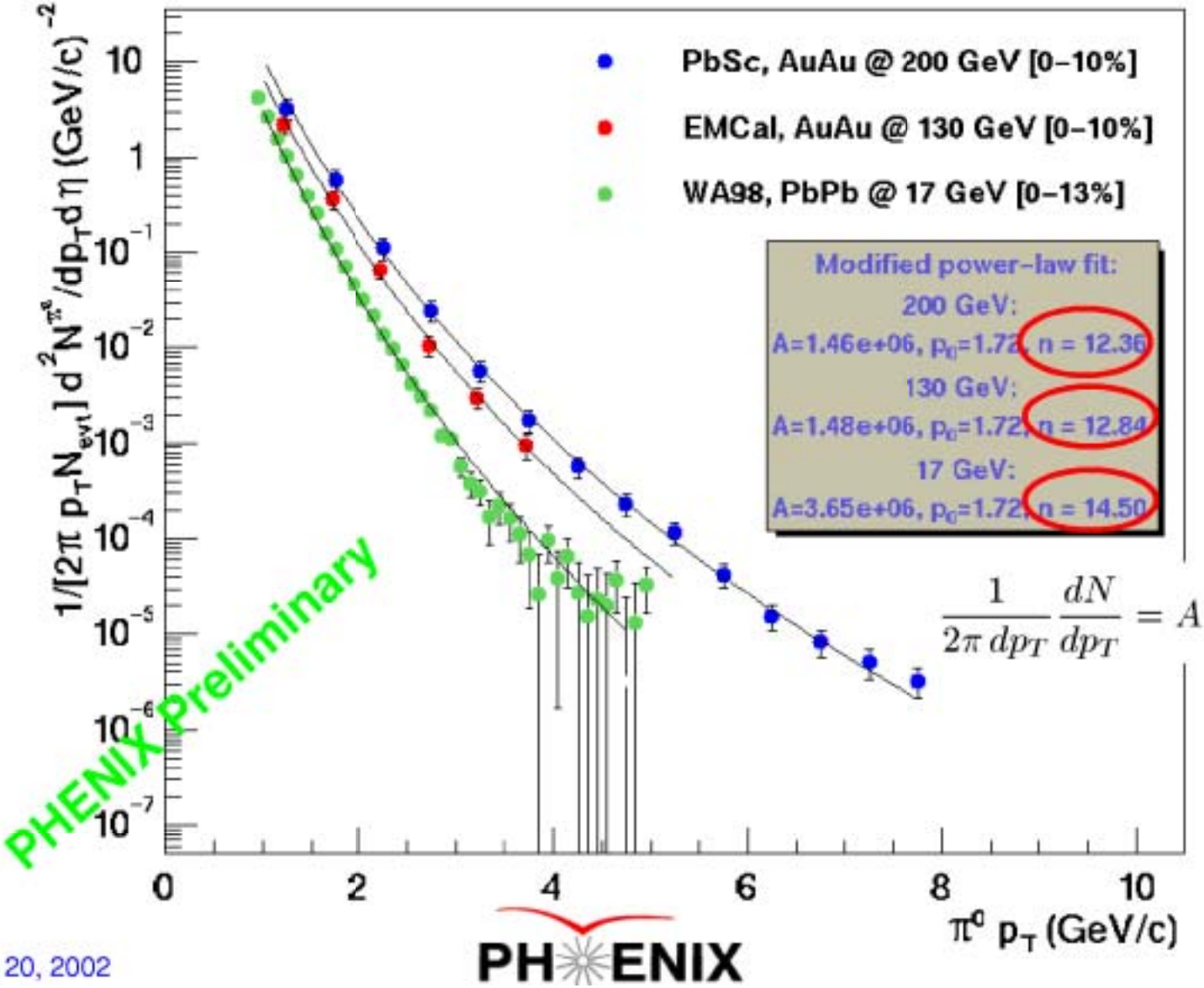
PHENIX Preliminary

- 9 different centrality classes

Min. bias, most central & periph.

The results (2): Central π^0 SPS $\leftrightarrow$ RHIC 130 $\leftrightarrow$ RHIC 200

- Slow increase of power- law slopes with sqrt(s)



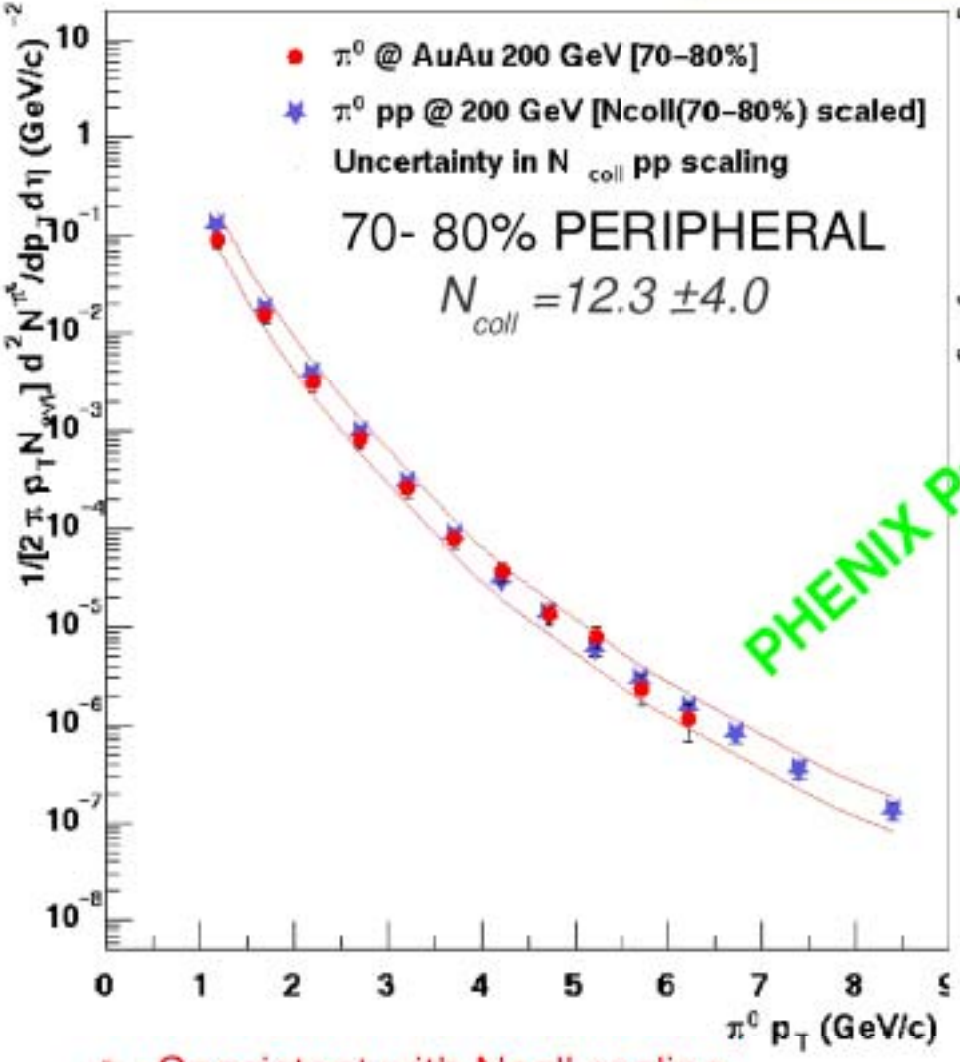
PHENIX

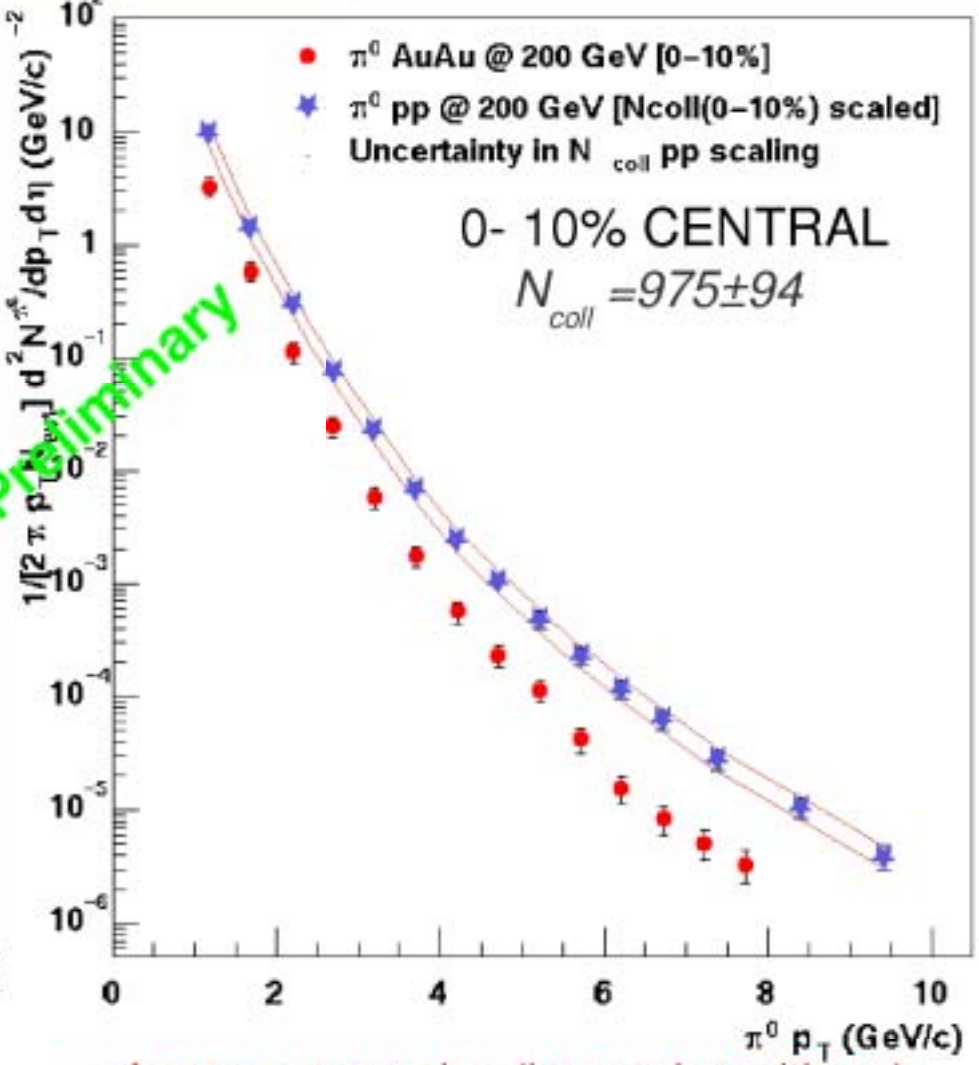
The results (3): pp vs AuAu (peripheral & central)

- Peripheral:

π^0 from PHENIX pp @ 200 GeV
(Hisa Torii's talk)

- Central:





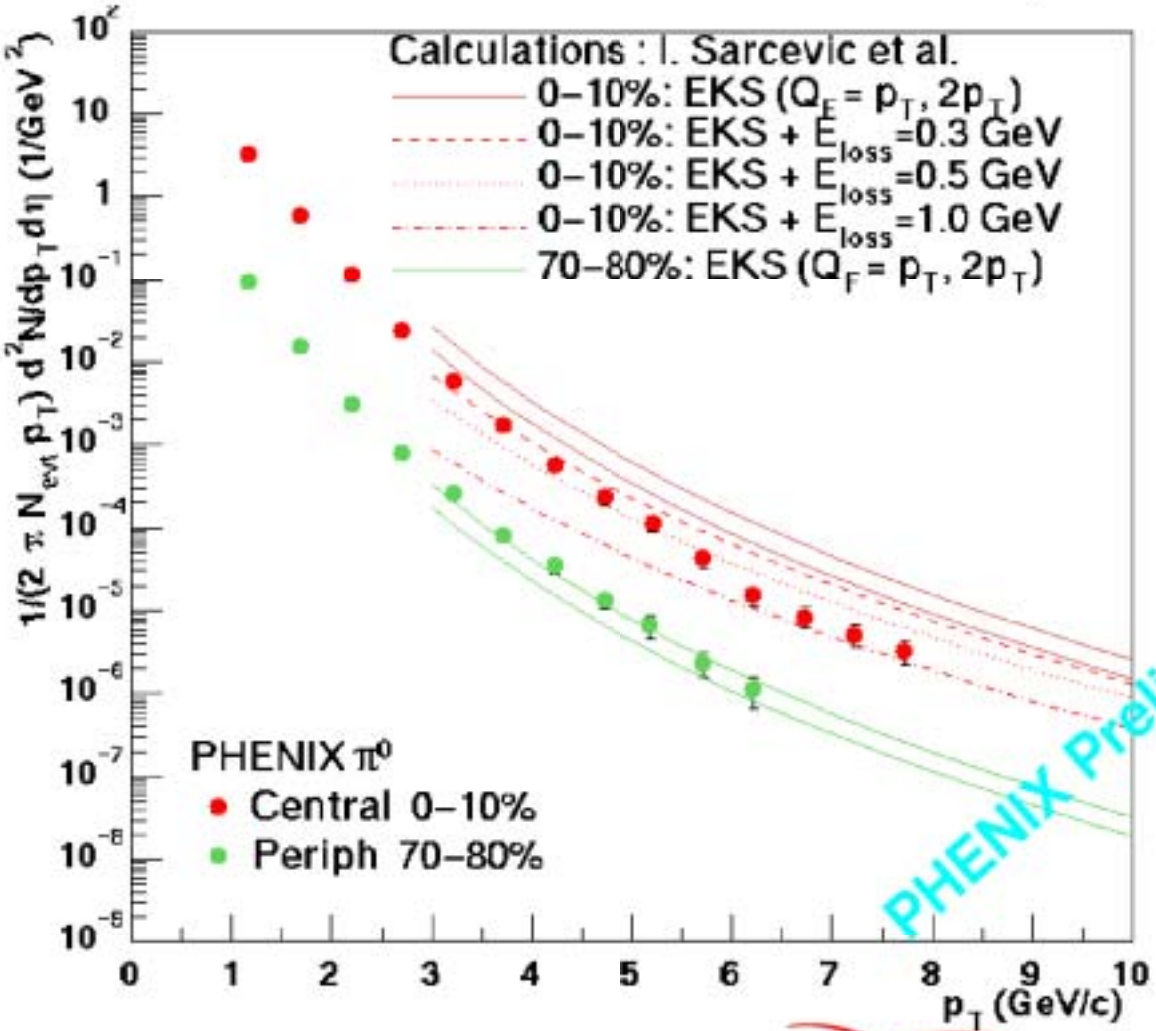
PHENIX Preliminary

- Consistent with Ncoll scaling
- Large suppression (increasing with p_T) above p_T~1 GeV/c compared to scaled pp.

The results (4): Comparison to pQCD [1] calculations

- Peripheral: Reproduced with no significant nuclear effects.
- Central: Well below predictions without energy loss.
  Increasing suppression with p_T:

$\langle E_{loss} \rangle$ ~0.3 GeV (p_T=3 GeV/c)
$\langle E_{loss} \rangle$ ~1.0 GeV (p_T=8 GeV/c)

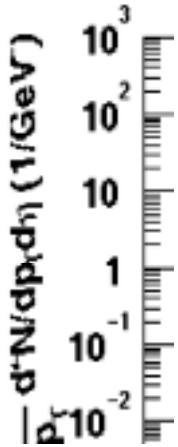


NLO pQCD
- Parton Distrib. Functions: MRS99
- Fragmentation Functions: BKK

Medium effects:
- Shadowing: EKS98
- E_{loss}: Wang,Huang,Sarcevic (E_{loss} per parton collision, Poisson scatt. probab.)

Other comparisons to calculations (GLV, Wang) see S. Miouduzewski talk

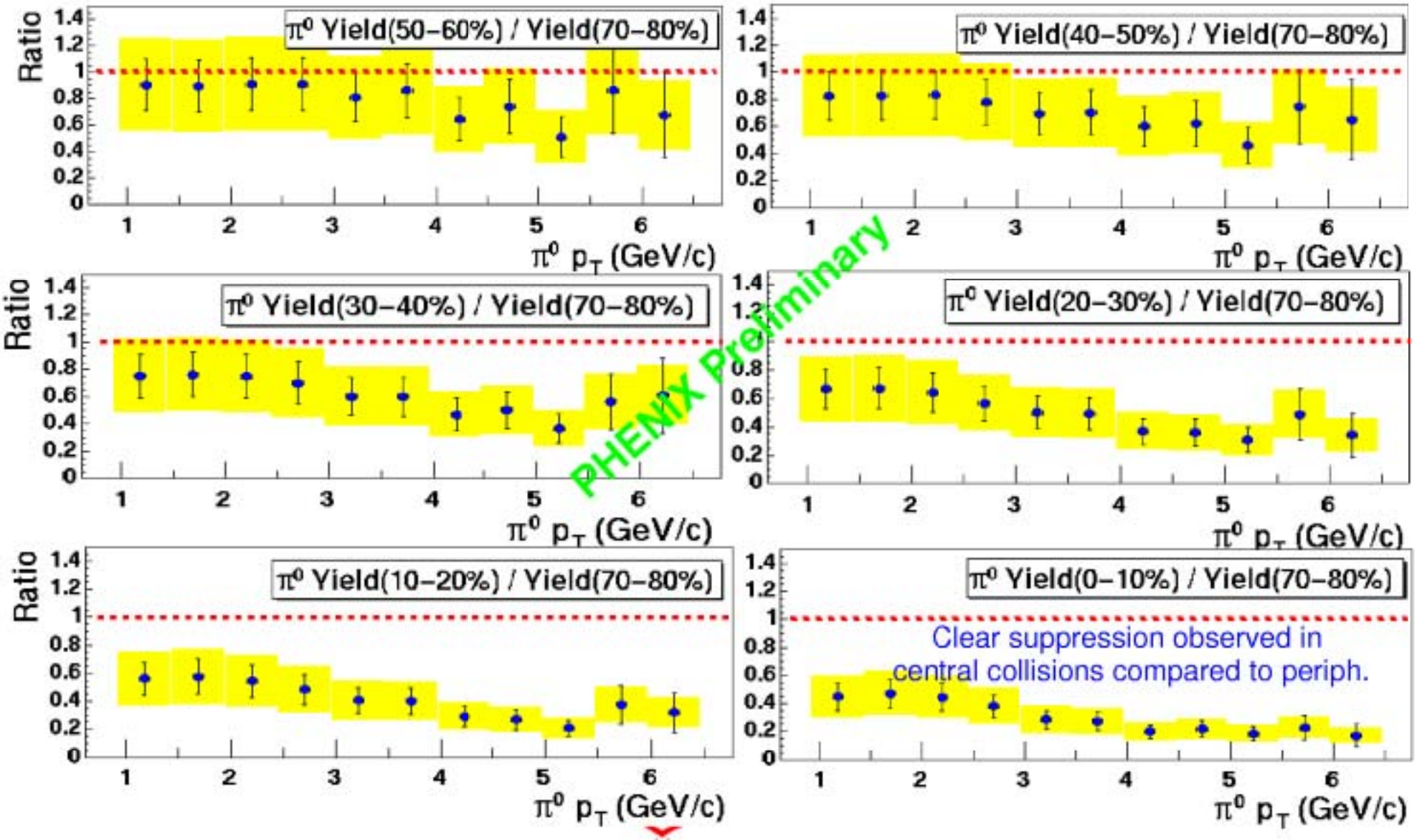
(1) S.Jeon, J. Jalilian- Marian, I.Sarcevic hep- ph/0207120



Results (5): Ratios Central/Peripheral

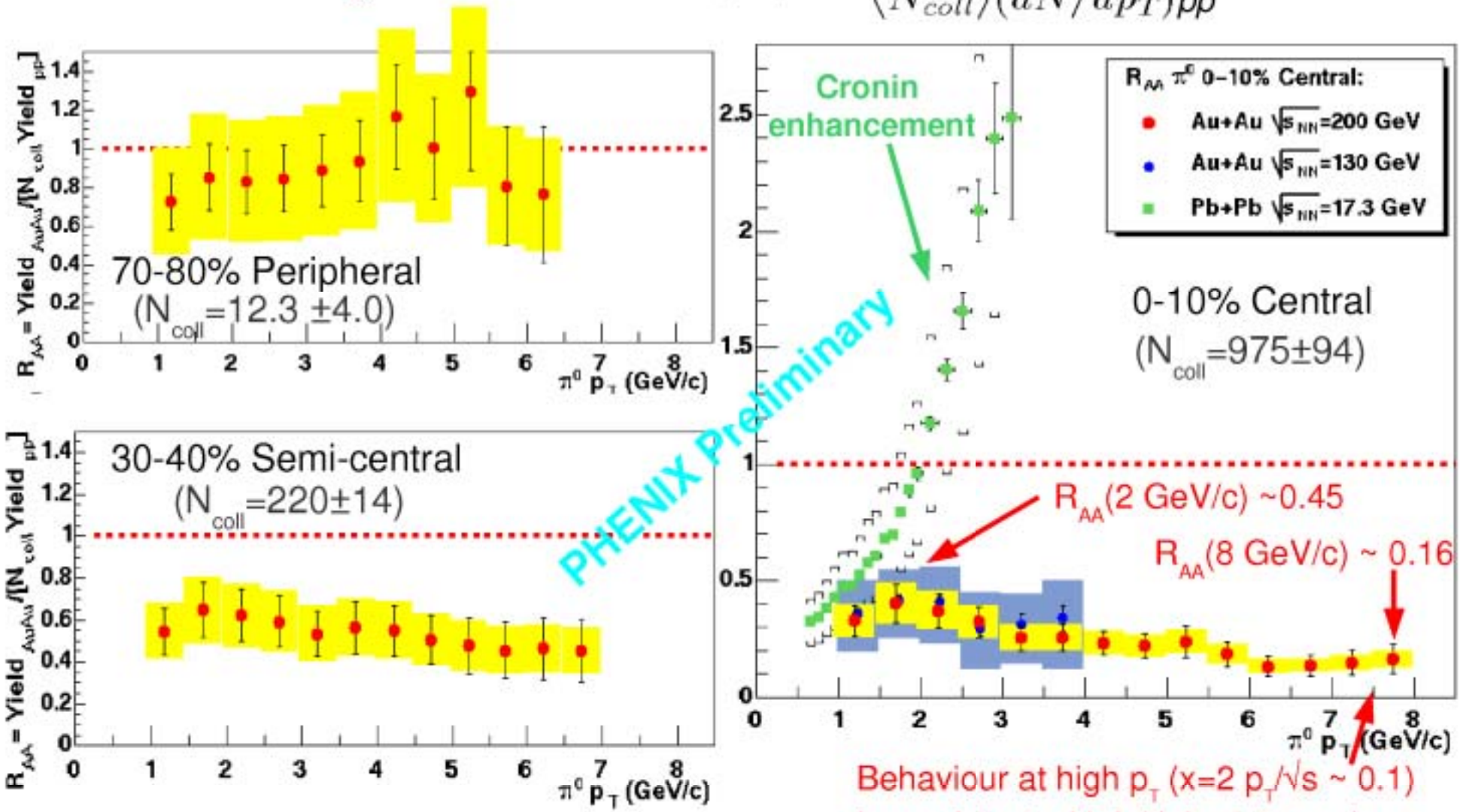
Ratio AuAu(different centralities) / AuAu(70-80%)

(part of the uncertainties cancel out)
(yellow bands: uncertainties in binary scaling)



Results (6): Nuclear modification factor

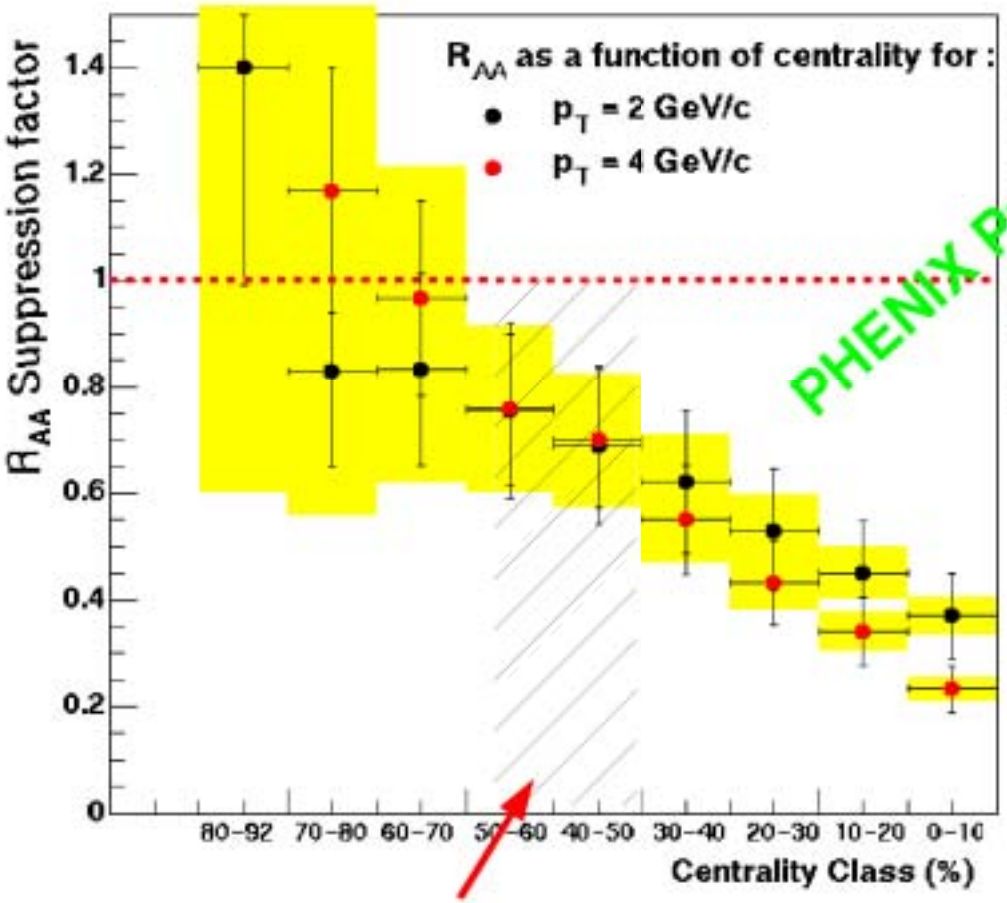
Ratio AuAu / (N_{coll} scaled) *pp* : $R_{AA}(p_T) = \frac{(dN/dp_T)_{AA}}{\langle N_{coll}\rangle (dN/dp_T)pp}$



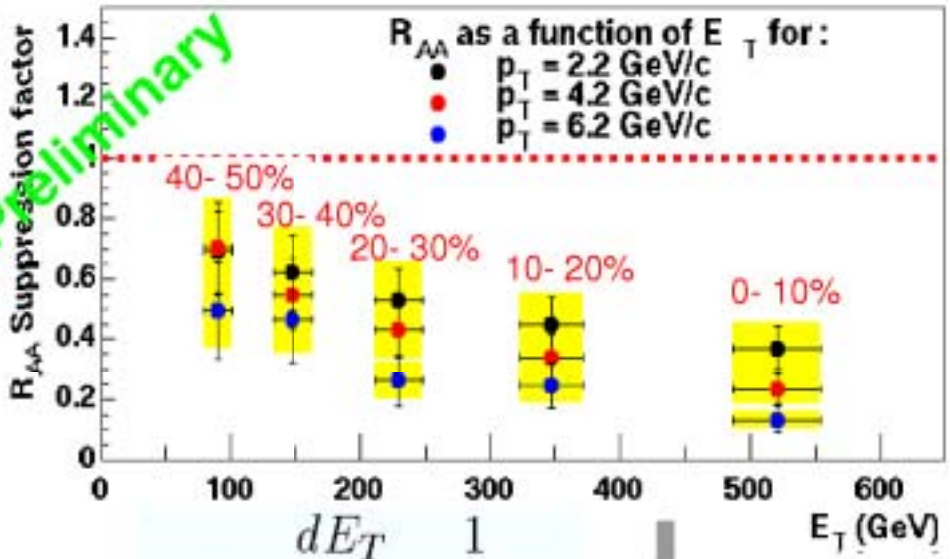
Behaviour at high p_T ($x=2\,p_T/\sqrt{s}$ ~ 0.1) inconsistent with initial- state nuclear effects (shadowing → antishadowing).

Results (7): Onset of suppression ?

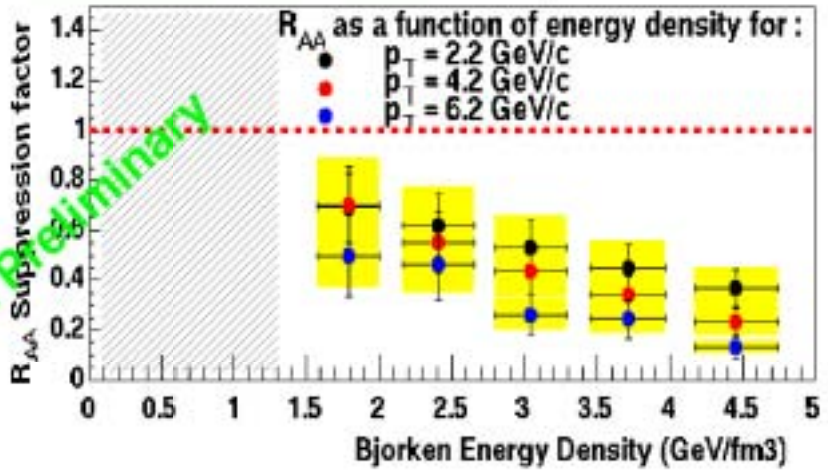
- R_{AA} plotted as a function of centrality ~ transverse energy[(1)] (~ $\epsilon_{Bjorken}$):



Suppression sets in for centrality ~40-60%



$$\epsilon_{Bj} = \frac{dE_T}{dy}\frac{1}{\tau_0 \pi R^2}$$



[(1)] E_T: See S. Bazilevsky talk

The summary & conclusions:

- 30 Million Au+Au events at $\sqrt{s_{NN}}$ = 200 GeV : $d^2N/dp_T d\eta$ for π^0 measured up to p_T~ 8 GeV/c in 9 different centrality classes.
- Peripheral AuAu collisions behave effectively as *pp* collisions.
- Central AuAu spectra significantly below peripheral AuAu and *pp* binary scaling extrapolations:

1. Increasing suppression with p_T and centrality class:
   ~2.5 @ p_T = 2 GeV/c, ~6. @ p_T = 8 GeV/c (for most central bin)
2. Consistent with AuAu data at $\sqrt{s_{NN}}$= 130 GeV.
3. Qualitat. agreement with pQCD calculations + $\langle E_{loss} \rangle$ ~ 0.3 - 1.0 GeV
4. Quenching sets in at ~40-60% centrality.
5. Different behaviour than expected for initial-state nuclear effects:
   - No indication of Cronin-like enhancement (WA98).
   - Different p_T (x_T) dependence than in shadowing → antishadowing.

- *Can the high- p_T depletion be explained within a (dense) hadronic scenario ? Otherwise, probably the only remaining explanation calls for high energy- density partonic medium formation.*

Npart scaling you said ... ?

[Yield AuAu(0-10%) <Npart(pp)>] / [<Npart(AuAu)> Yield pp]