

# **Neutral Pion Production in Heavy Ion Reactions at SPS and RHIC**

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# High- $p_T$ Neutral Pion Production

- here: focus on possible energy loss of fast partons in the QGP (**jet quenching**)
- Observable consequence: suppression of high- $p_T$  hadrons
- How to calculate the expected yield in the absence of jet-quenching?
  - Where does hard scattering regime start?
  - Amount of intrinsic parton transverse momentum
  - Effect of  $p_T$ -broadening (**Cronin effect**)

# Nuclear Modification Factor

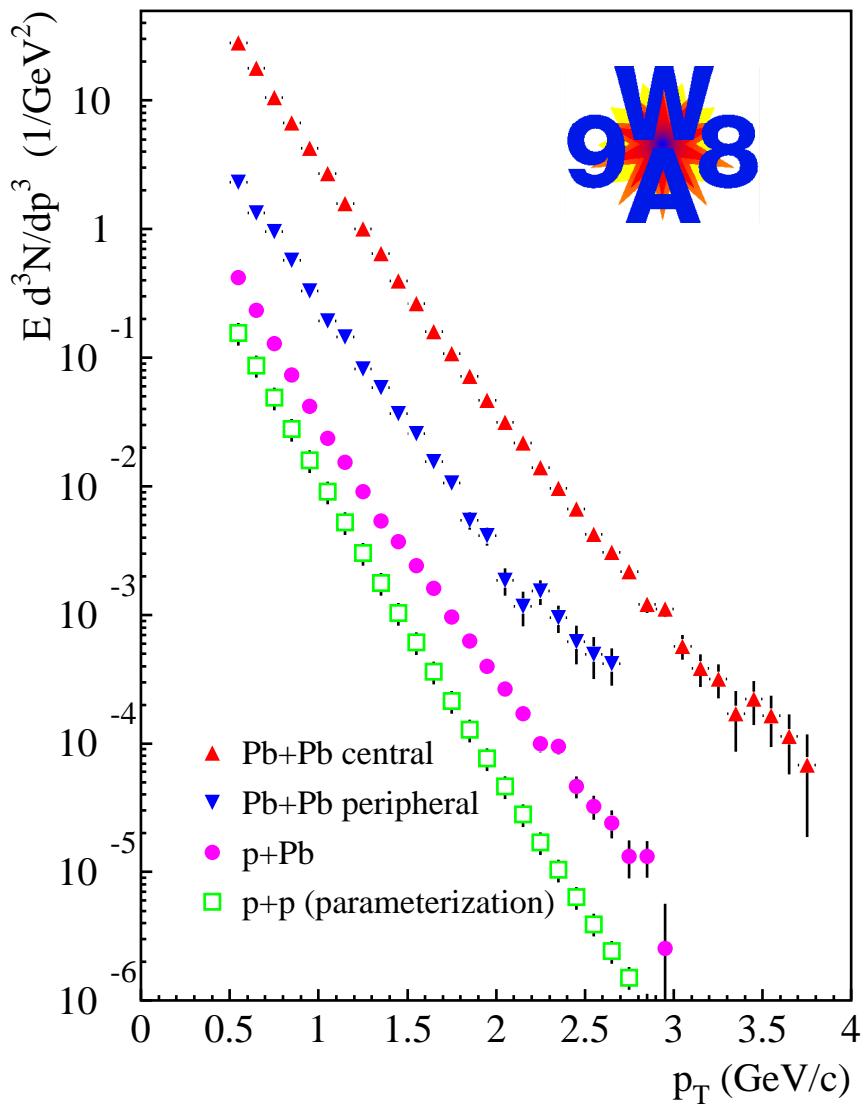
$$R_{AB} = \frac{\frac{d\sigma}{dp_T}(A+B)}{\left[ \int d^2 b T_{AB}(\vec{b}) \right] \times \frac{d\sigma}{dp_T}(p+p)} = \frac{\frac{dN}{dp_T}(A+B)}{N_{coll}^{nn} \times \frac{dN}{dp_T}(p+p)}$$

A·B for min. bias reactions

# inel. nucleon–nucleon collisions

- $R_{AB} = 1$  for point-like scaling
- In that case particle *yields* scale with the number of inelastic nucleon–nucleon collisions

# Neutral Pions at SPS Energies



- p+Pb, Pb+Pb at  $\sqrt{s}_{nn}=17.3 \text{ GeV}$
- p+A data useful to study the strength of the Cronin effect at the given energy

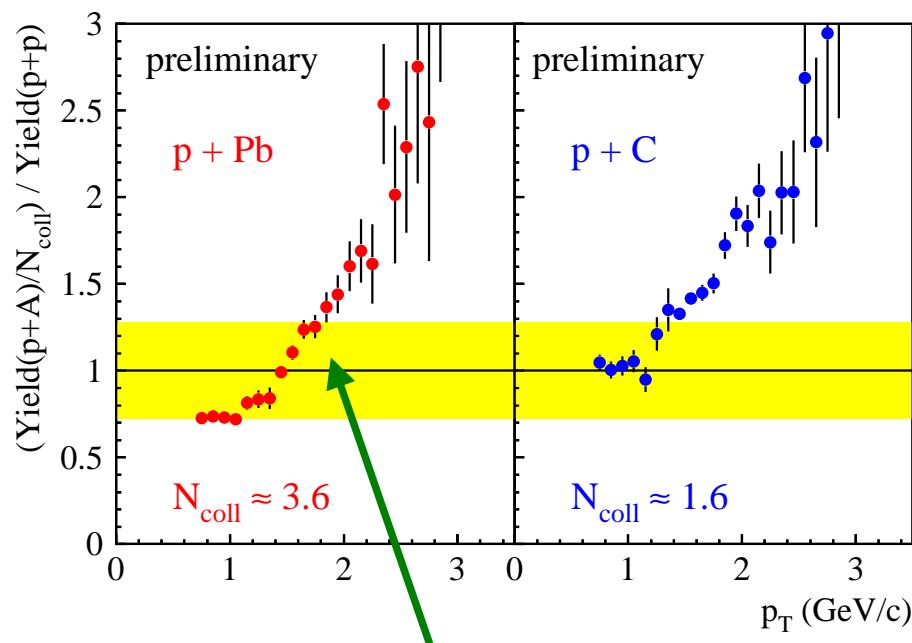
p+p parameterization:

$$E \frac{d^3 N}{dp^3} = C \cdot \left( \frac{p_0}{p_T + p_0} \right)^n$$

$$C = 4.125 \text{ } c^3/\text{GeV}^2, p_0 = 9.02 \text{ GeV}, n = 55.77$$

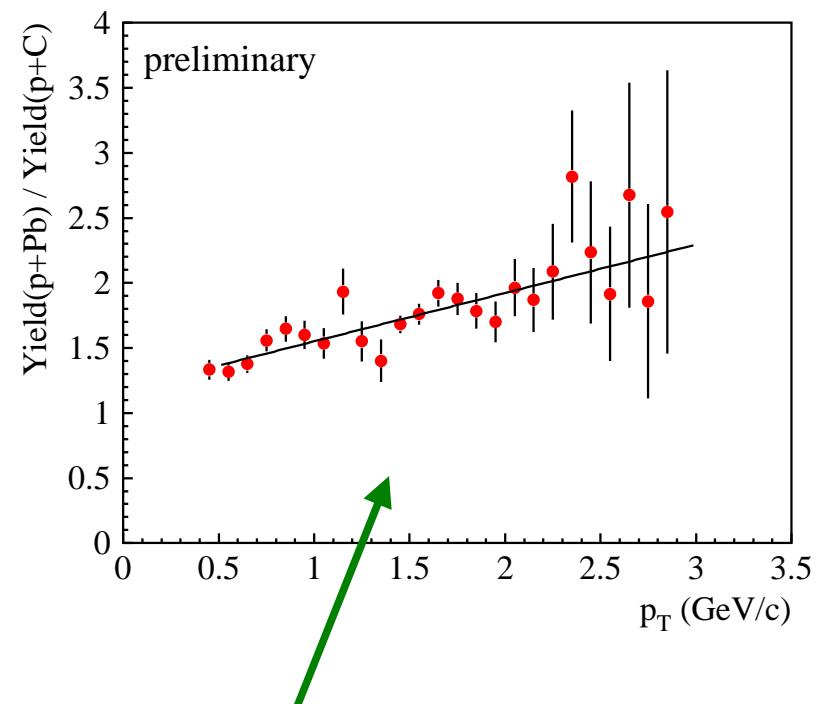
# $\pi^0$ in p+C and p+Pb at $\sqrt{s_{nn}} = 17.3$ GeV

- Comparison p+A / p+p



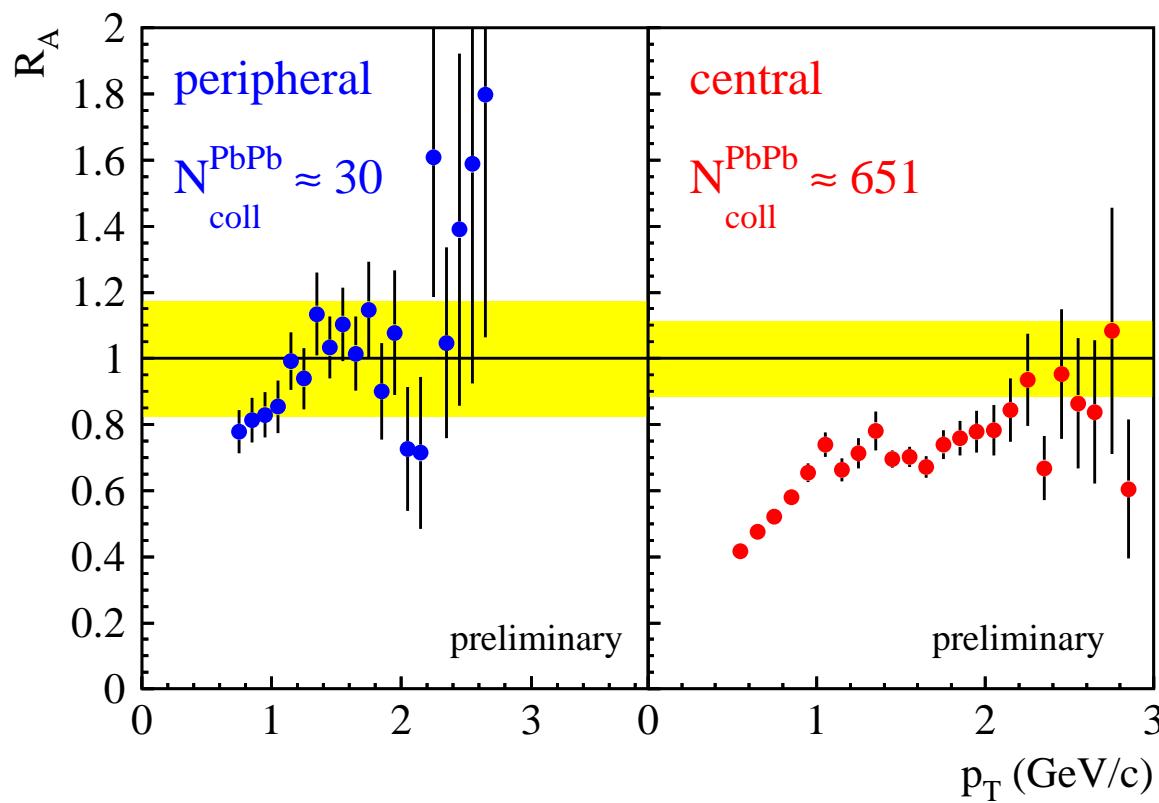
anomalous nuclear enhancement  
above  $p_T=1.5$ –2.0 GeV in p+Pb  
(Cronin effect)

- Comparison p+Pb / p+C



flattening of the  $p_T$ -spectrum  
in p+Pb stronger than in p+C

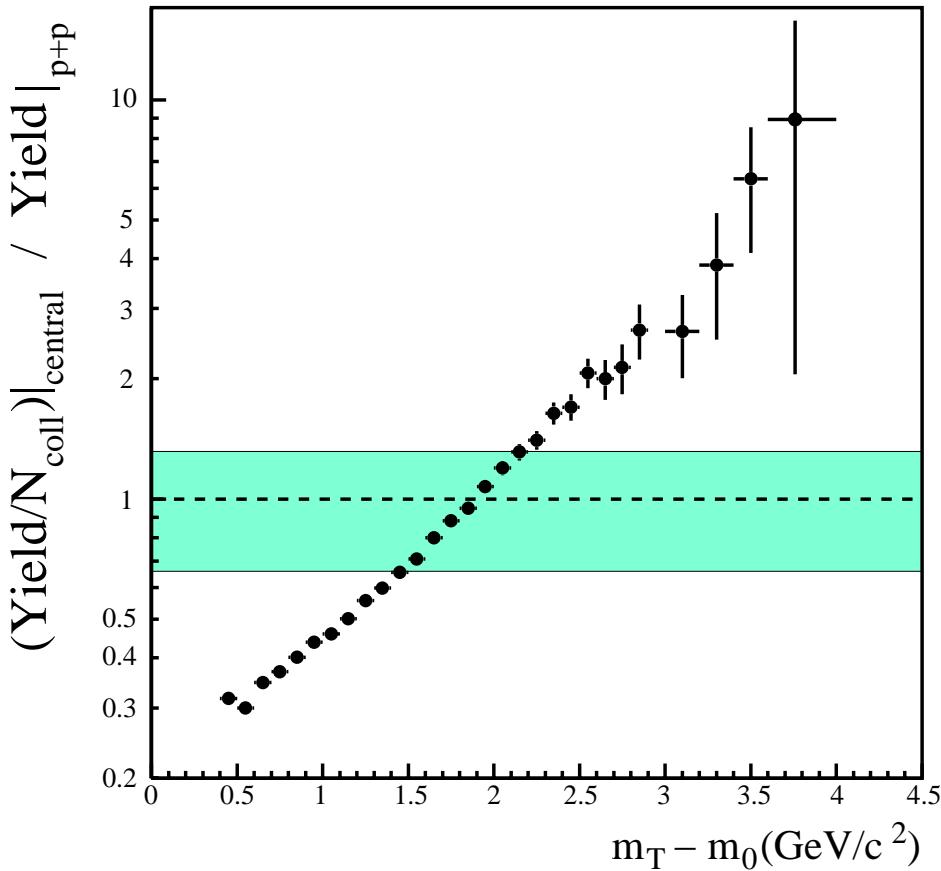
# Comparison between Pb+Pb and p+Pb



- peripheral Pb+Pb:
  - shape rather similar to p+Pb
  - $N_{coll}$  -scaling works
- central Pb+Pb:
  - flatter than p+Pb
  - scaling with  $N_{coll}$  at  $p_T \approx 2.5$  GeV/c

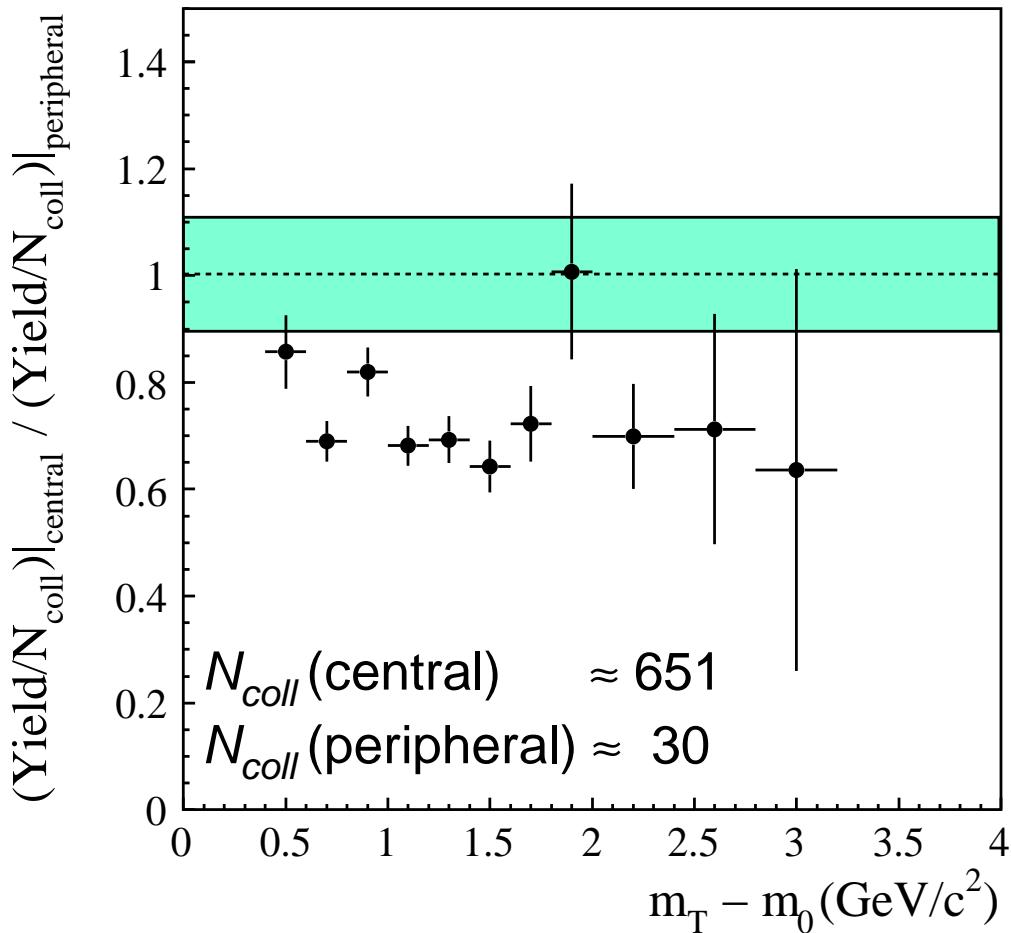
$$R_A = \frac{\frac{dN}{dp_T}(Pb+Pb) / N_{coll}^{Pb+Pb}}{\frac{dN}{dp_T}(p+Pb) / N_{coll}^{p+Pb}}$$

# Comparison of Pb+Pb and p+p $\pi^0$ Spectra



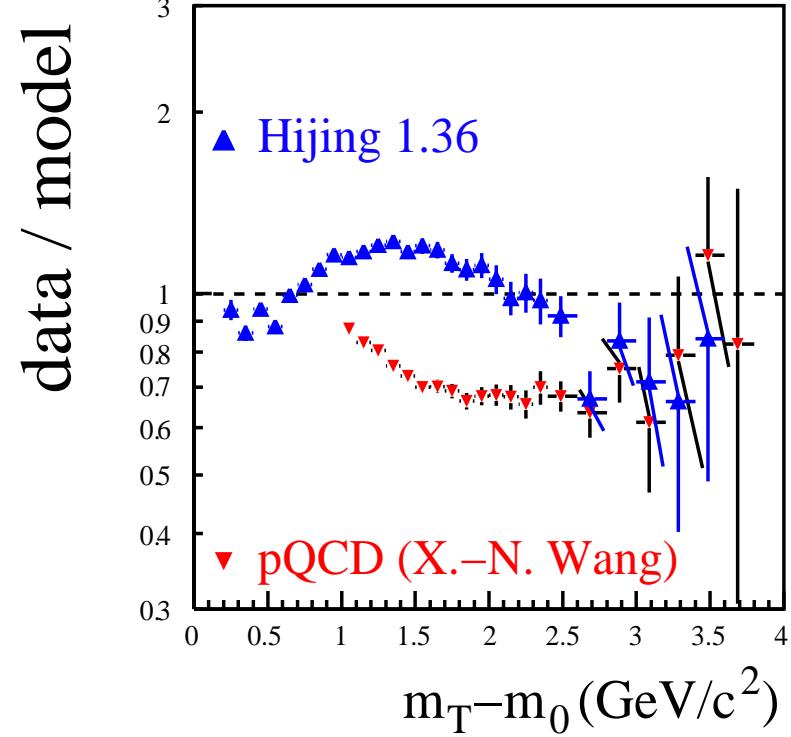
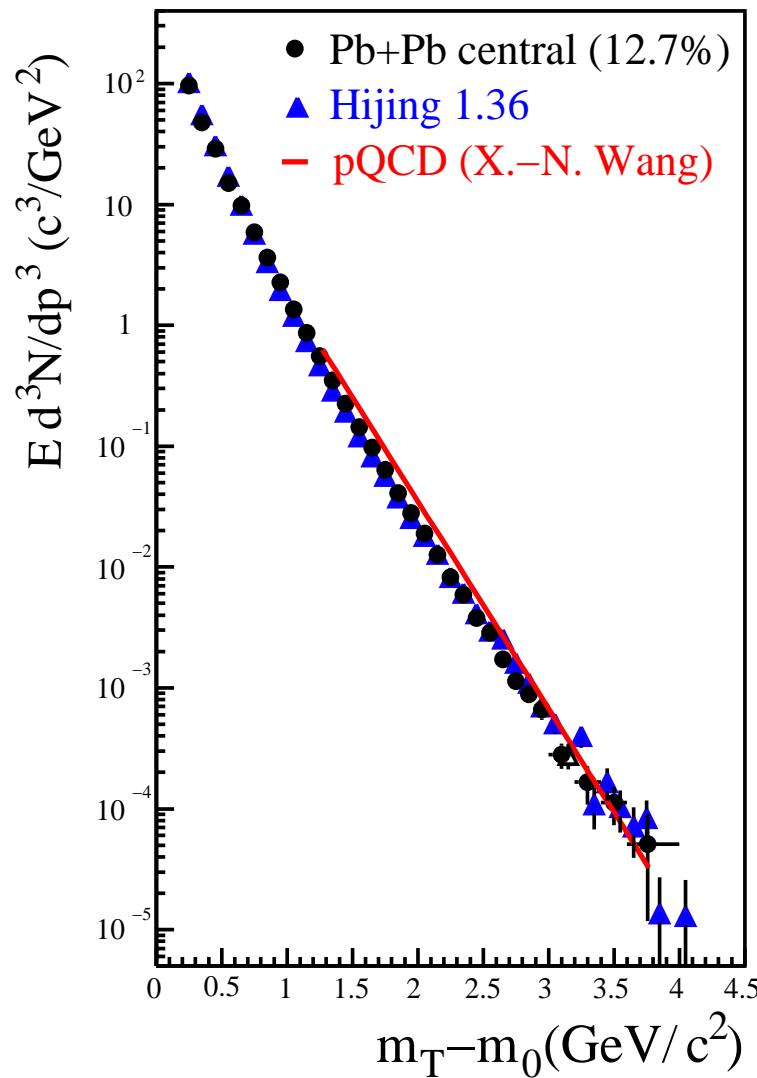
- $\pi^0$  yield scales with  $N_{\text{coll}}$  at  $m_T - m_0 \approx 2 \text{ GeV}/c^2$
- Cronin enhancement above  $m_T - m_0 \approx 2 \text{ GeV}/c^2$

# $\pi^0$ Central/Peripheral Ratio



- Yields at high  $m_T - m_0$  scale weaker than  $N_{\text{coll}}$
- Shape of peripheral Pb+Pb ( $N_{\text{coll}} \approx 30$ ) and p+p  $\pi^0$  spectrum at  $s^{1/2} \approx 20 \text{ GeV}$  differ significantly
- The latter is not observed for  $\pi^0$ 's in Au+Au at  $s^{1/2} \approx 130 \text{ GeV}$

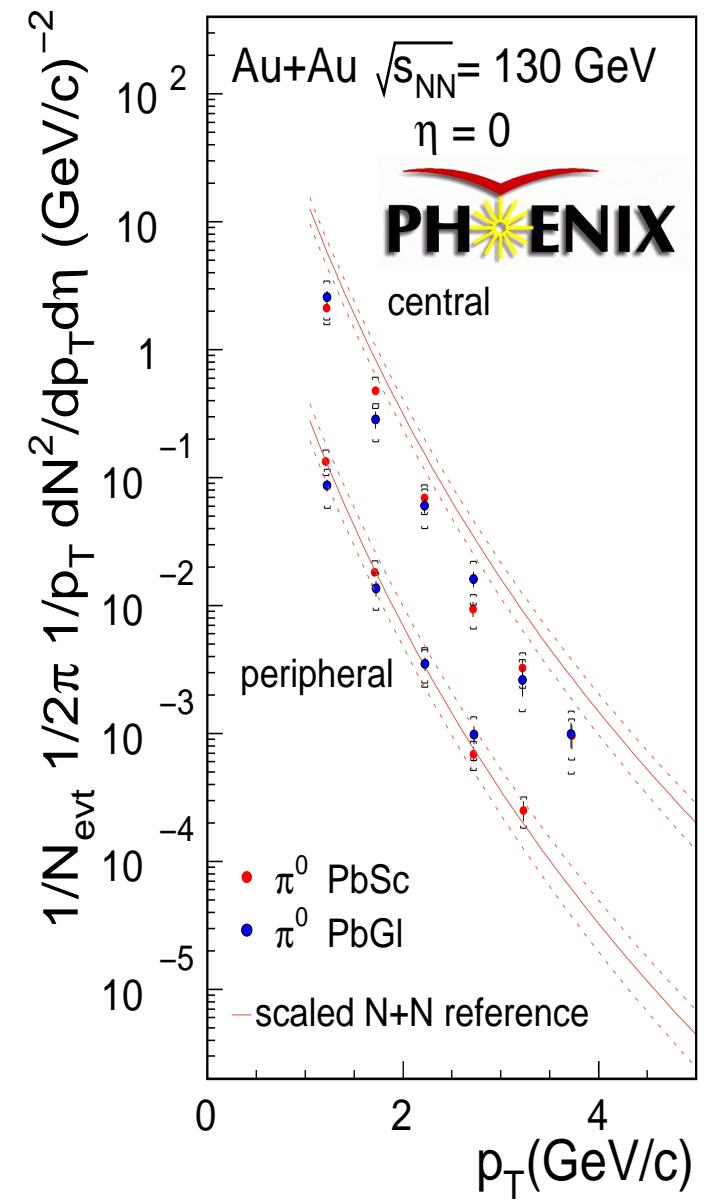
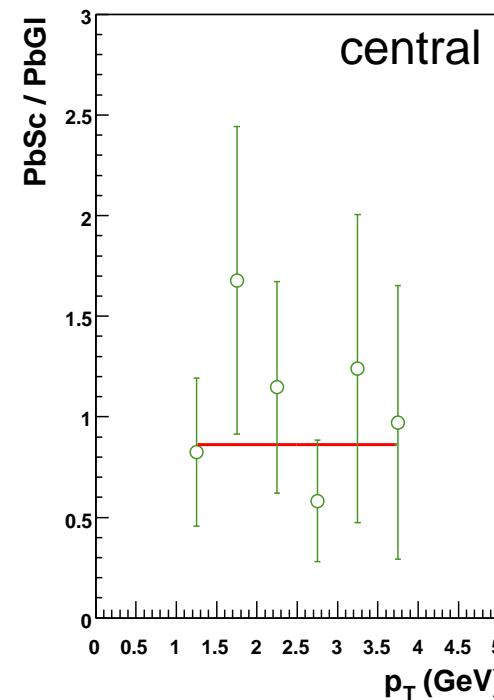
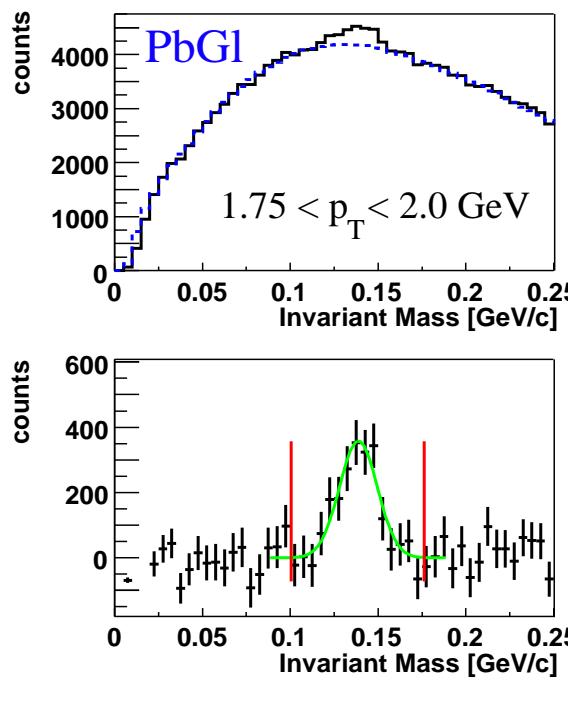
# Comparison to pQCD Calculations



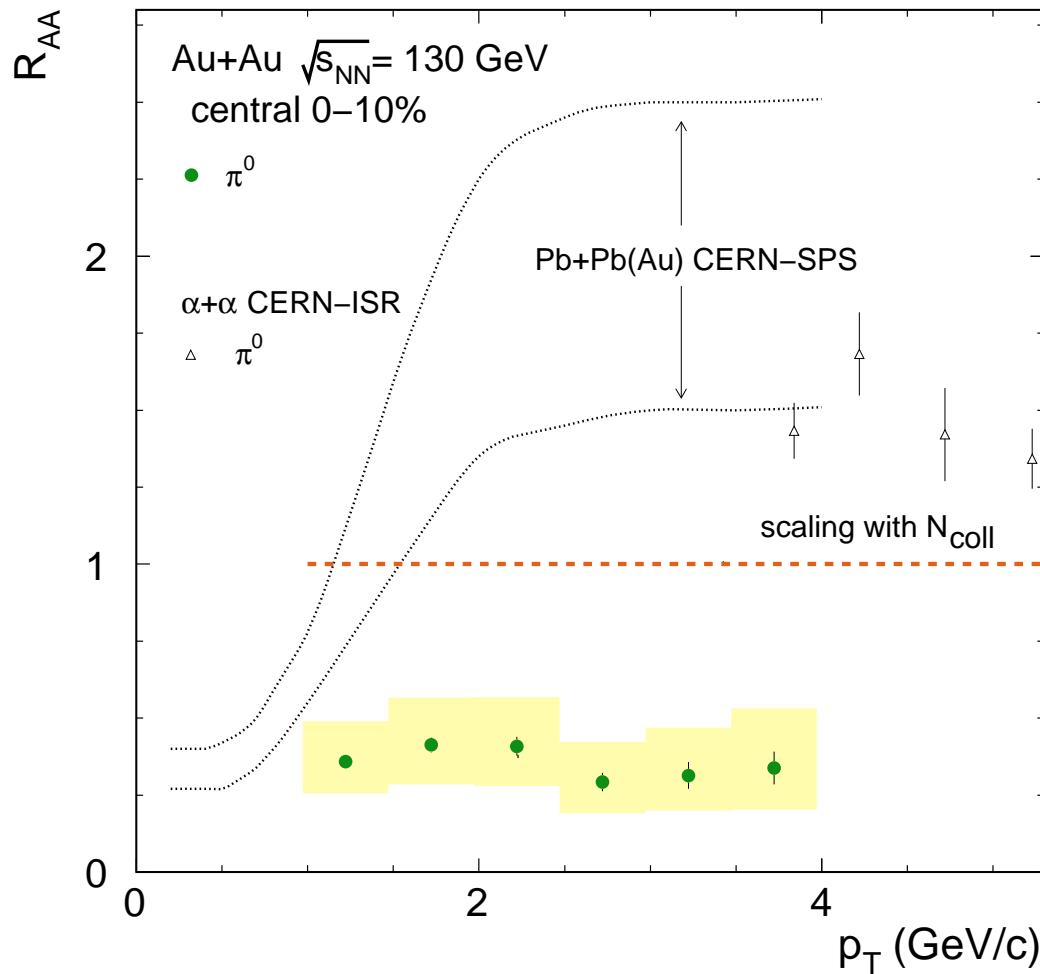
- Jet-quenching not ruled out at SPS energies

# Neutral Pions at RHIC

- Two e.m. calorimeters in PHENIX
  - lead-glass (PbGI)
  - lead-scintillator (PbSc)
- Good cross check:  
PbGI and PbSc data analyzed by two different teams



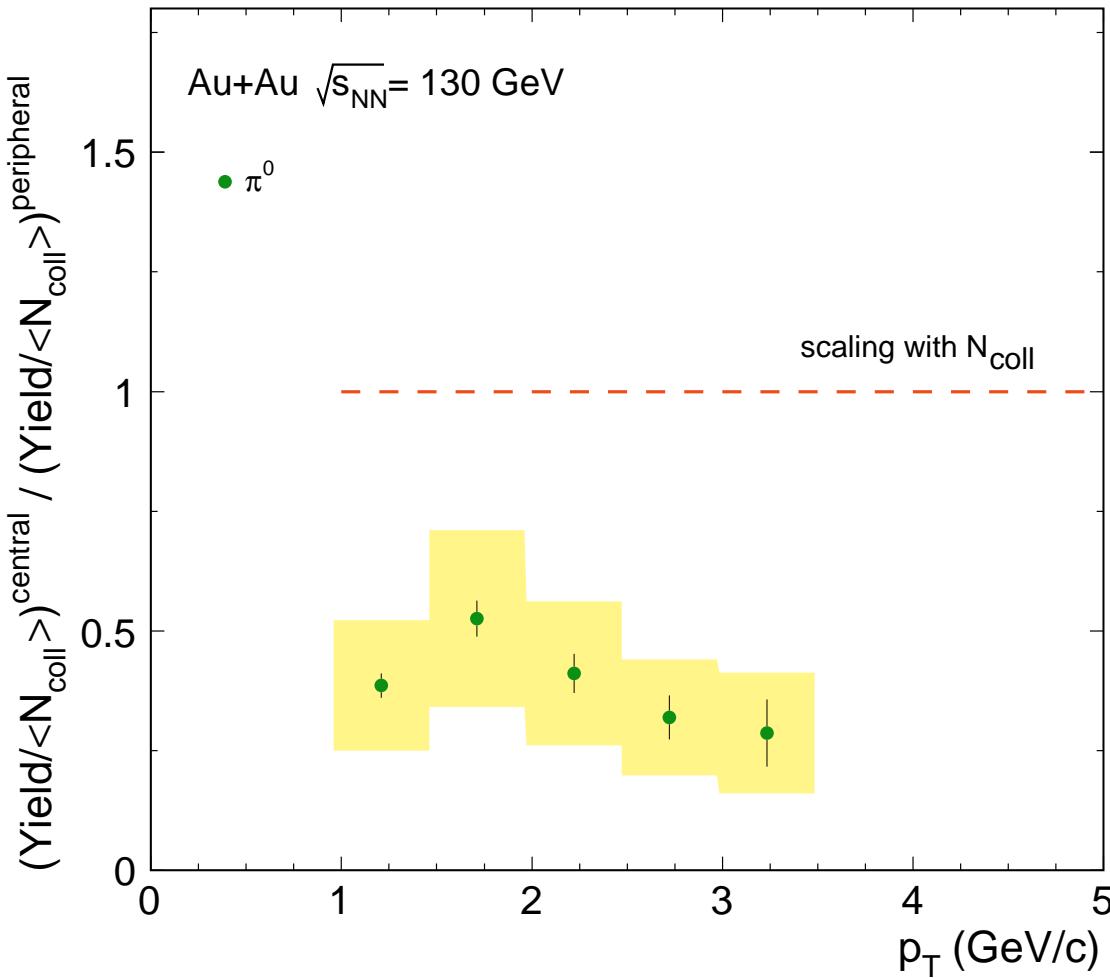
# $\pi^0$ in Central Au+Au Compared to p+p



- p+p reference:  
interpolated to  $\sqrt{s_{nn}}=130$  GeV  
based on existing data
- Expectation from Cronin–effect:  
 $R_{AA} > 1$  at high  $p_T$
- Observed:  $R_{AA} < 1$

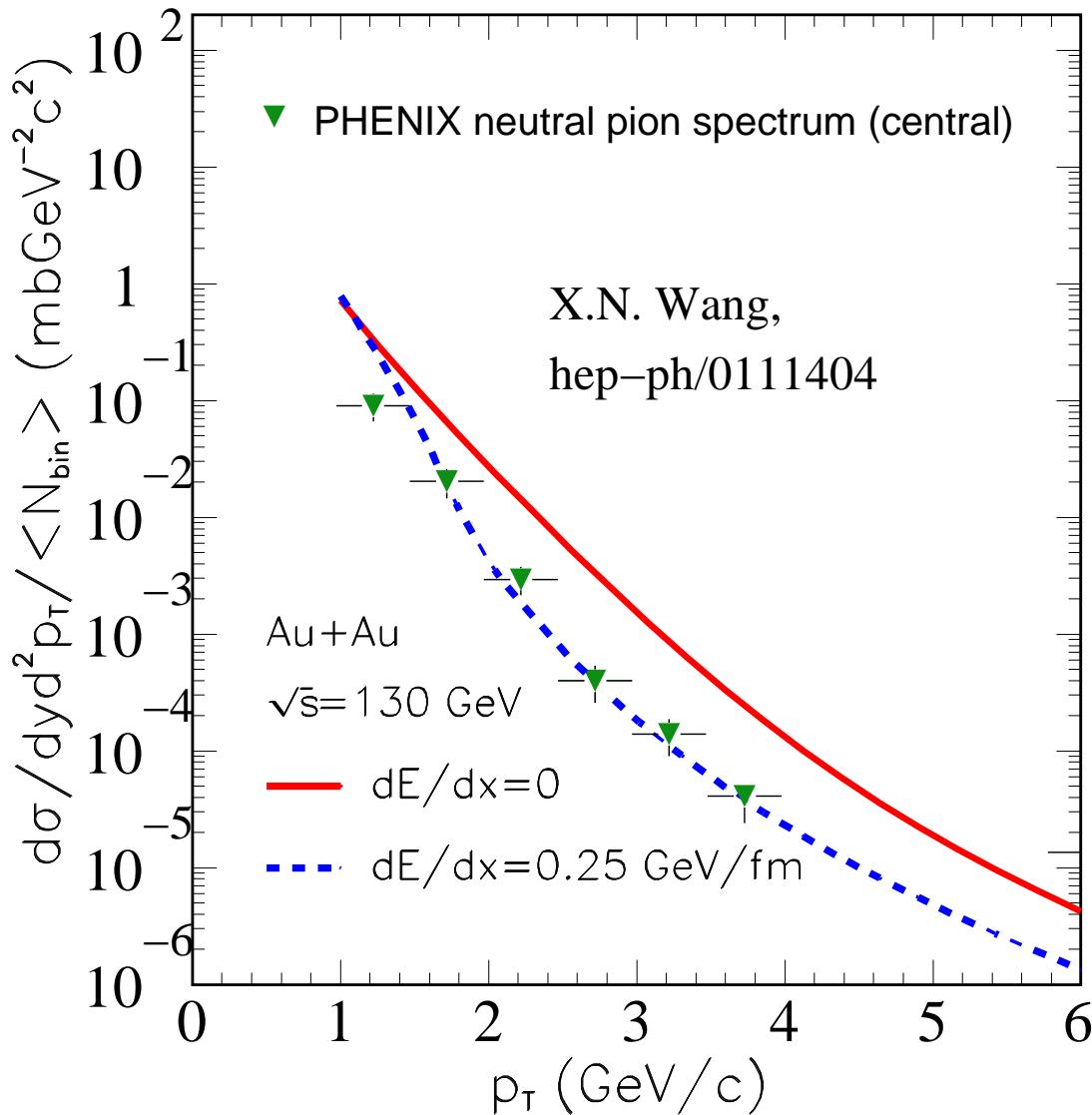
Glauber Monte-Carlo:  
 $N_{coll}$  (central) =  $905 \pm 96$   
 $N_{coll}$  (peripheral) =  $20 \pm 6$

# $\pi^0$ Central/Peripheral Ratio



- Scaling of  $\pi^0$ -yields from peripheral to central weaker than  $N_{coll}$ -scaling
- Ratio smaller than at SPS energies
- Shape of peripheral Au+Au and p+p spectrum rather similar (unlike SPS results)

# Comparison to pQCD Calculations



- Jet–quenching is a possible explanation for the observed suppression of  $\pi^0$ 's at high- $p_T$
- Comparison of energy loss
  - $dE/dx \approx 0.3 \text{ GeV}/\text{fm}$  in cold nuclear matter (Hermes)
  - $dE/dx = 0.25 \text{ GeV}/\text{fm}$  corresponds to an effective energy loss of  $dE/dx \approx 12 \text{ GeV}/\text{fm}$  in a static system
  - energy loss in the initial state of the Au+Au system  $\approx 40$  times higher than in cold nuclear matter

# Summary

- $\pi^0$  production at  $\sqrt{s_{nn}}=17.3 \text{ GeV}$ 
  - p+C, p+Pb:  
Anomalous nuclear enhancement relative to p+p at high  $p_T$
  - Pb+Pb:
    - Anomalous nuclear enhancement relative to p+p at high  $p_T$
    - Scaling from peripheral to central yield weaker than  $N_{coll}$ -scaling
    - Comparison to pQCD calculation:  
Jet-quenching not ruled out
- $\pi^0$  production in Au+Au at  $\sqrt{s_{nn}}=130 \text{ GeV}$ 
  - suppression of high  $p_T \pi^0$ 's in central collisions relative to  $N_{coll}$ -scaled p+p reference
  - Jet-quenching in QGP one possible explanation

# PHENIX Year 2000 Setup

PHENIX Detector - First Year Physics Run

