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Production of Direct Photons in p+Pb and p+C Collisions at $\sqrt{s_{NN}} = 17.4 \text{ GeV}$

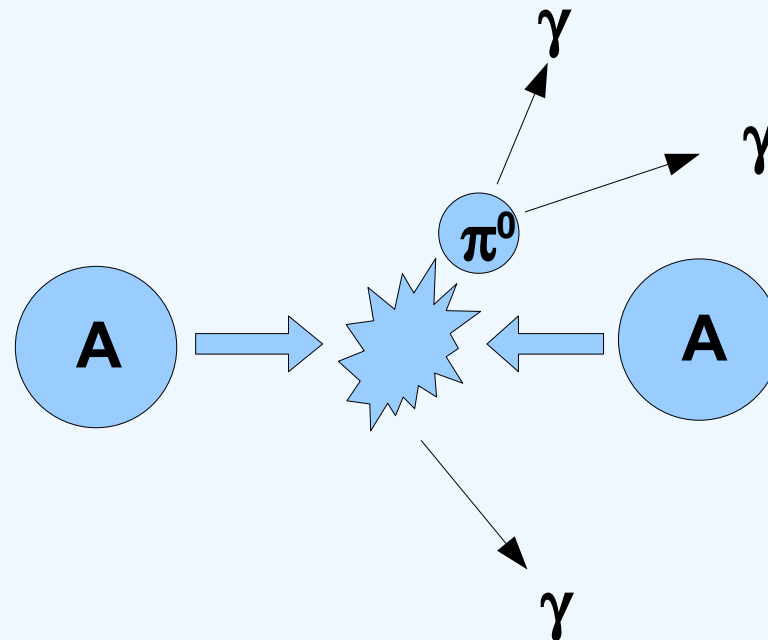
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Germany
for the WA98 Collaboration



- Production of photons in heavy ion collisions
 - Decay photons from meson decays
 - Direct photons

$$\mathcal{Y}_{\text{inclusive}} = \mathcal{Y}_{\text{decay}} + \mathcal{Y}_{\text{direct}}$$

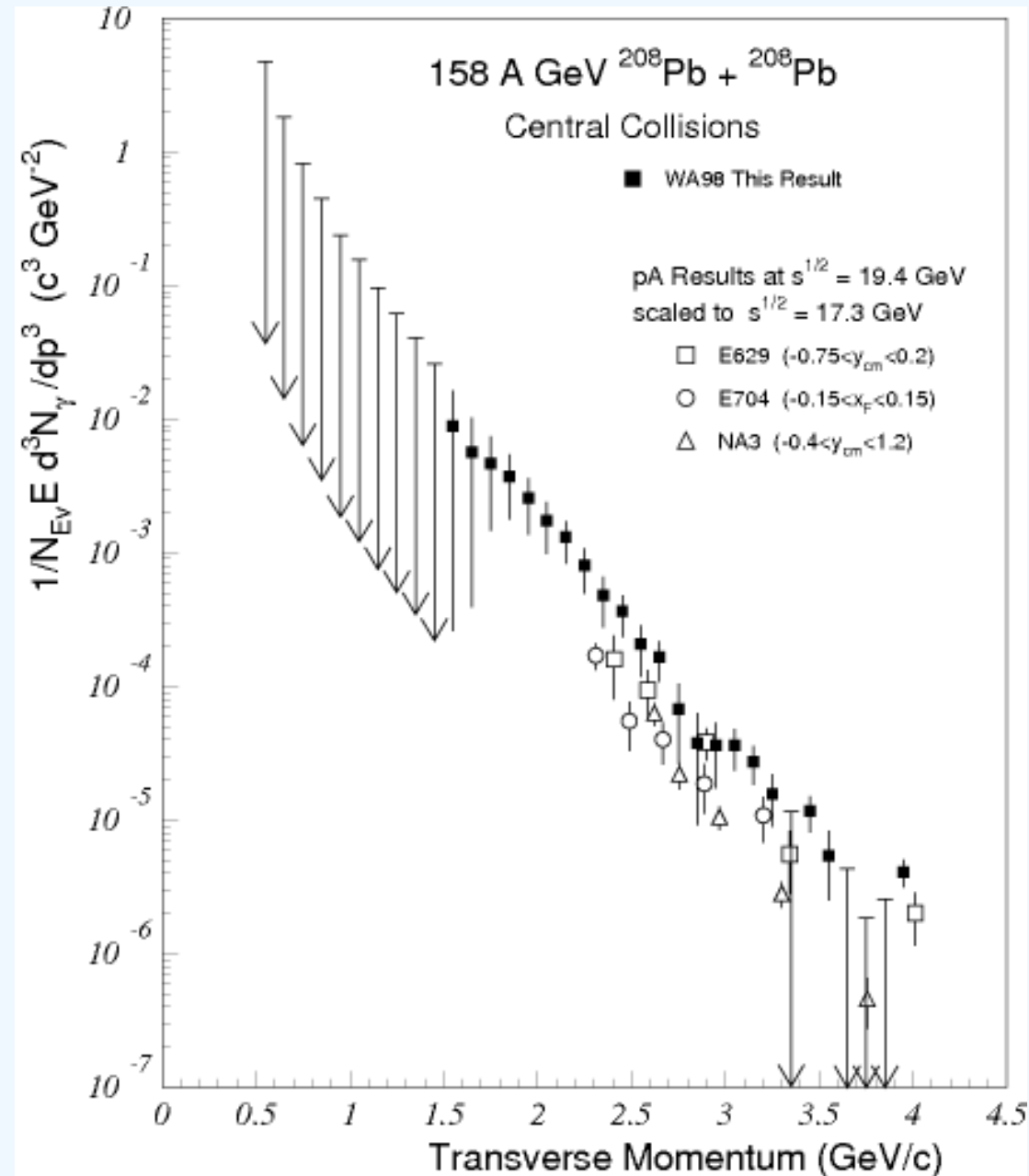
All photons not originating from decays



- Significant direct photon signal for $p_T > 1.5$ GeV

Is there a thermal contribution to the direct photon spectrum?

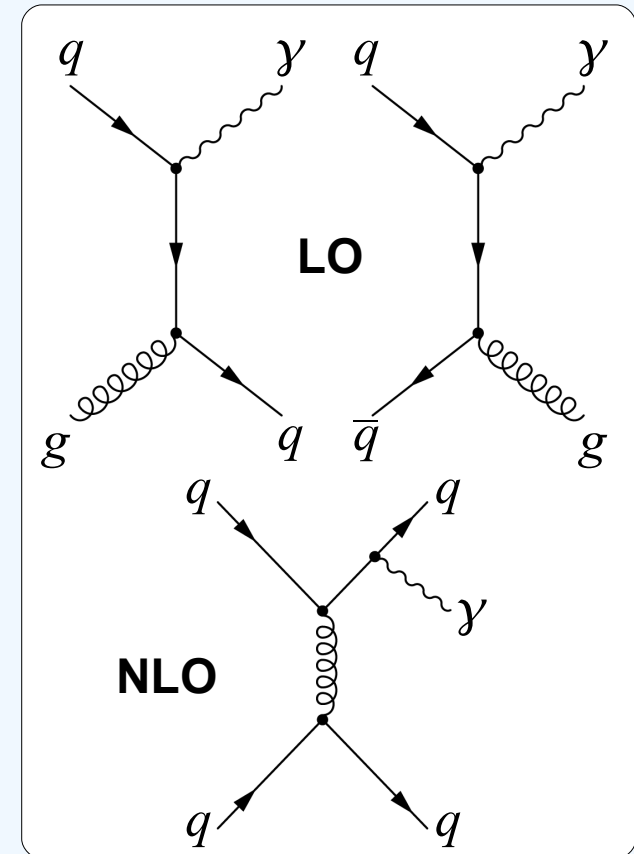
- pQCD has large uncertainties at these energies
- Previously available p+A data at 19.4 GeV
 - only for $p_T > 2$ GeV
 - deviations between data sets
 - large additional uncertainty due to x_T -scaling to 17.3 GeV



Basic picture of direct photon production:

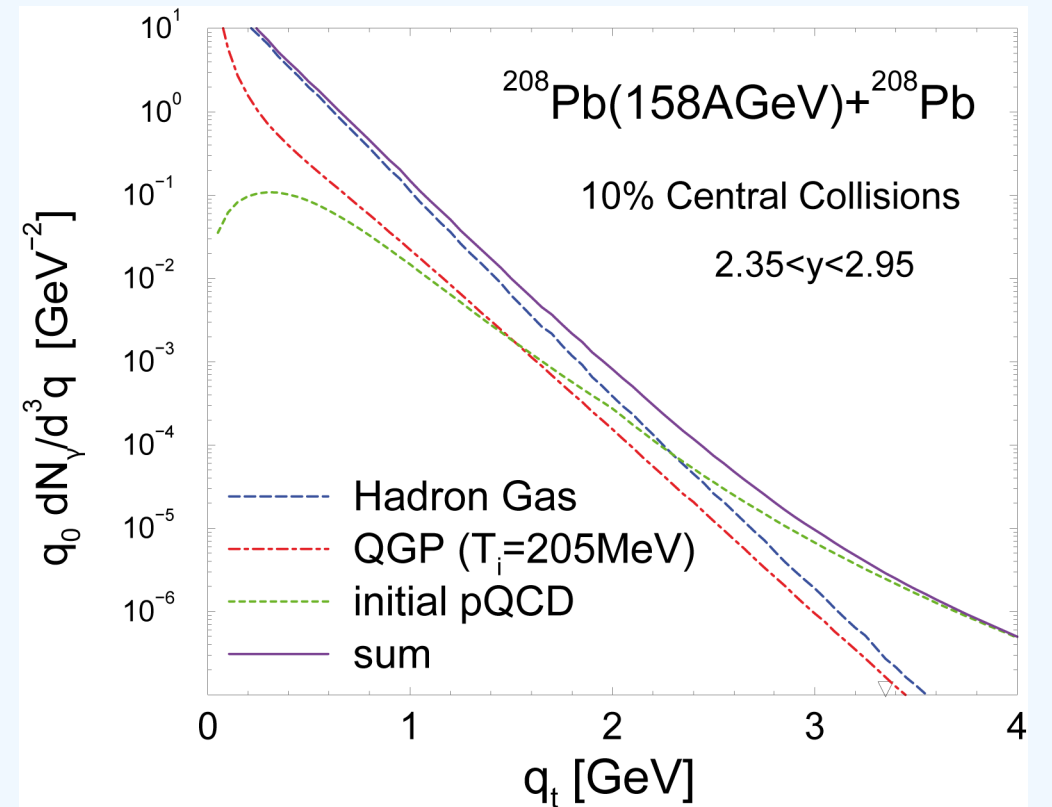
$$\frac{d^2\sigma}{dp_T dy} = \int \text{PDF} \times \text{pQCD} \times \delta$$

- Prompt direct photons
 - Hard parton-parton collisions
 - Depend on PDF of nuclei
 - Can be understood by pQCD at high p_T
 - But: Large systematic uncertainties at low p_T
- Thermal direct photons
 - Produced in thermally equilibrated phase (HG, QGP)
 - Depend on thermal momentum distribution of thermalized medium
 - Expected to be dominant at low p_T
- Other contributions: Pre-equilibrium photons, fragmentation ...



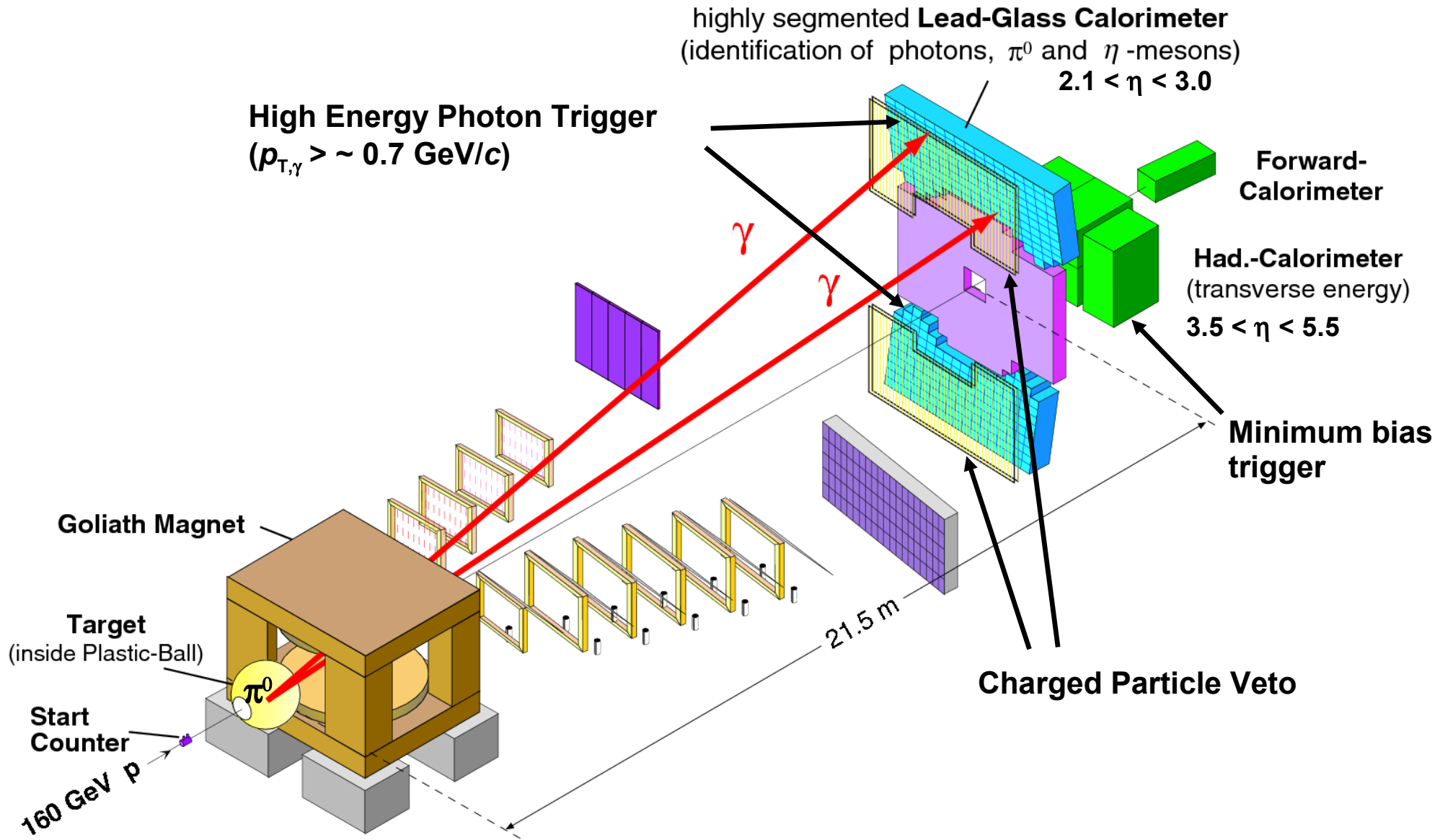
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Turbide, Rapp, Gale
Phys.Rev. C69 (2004) 014903

- **Cannot be separated in A+A measurement**
- **A direct photon measurement in p+A collisions can help to set limits on prompt photon contribution in A+A**

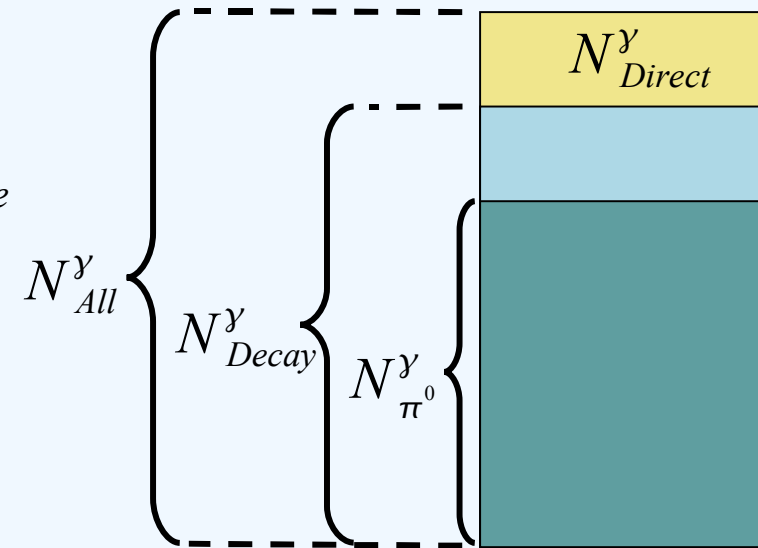


- Inclusive photons: $\gamma_{\text{inclusive}} = \gamma_{\text{direct}} + \gamma_{\text{decay}}$
- $\gamma_{\text{direct}} \ll \gamma_{\text{decay}}$: Difficult to extract significant signal

- Extraction of direct photons:

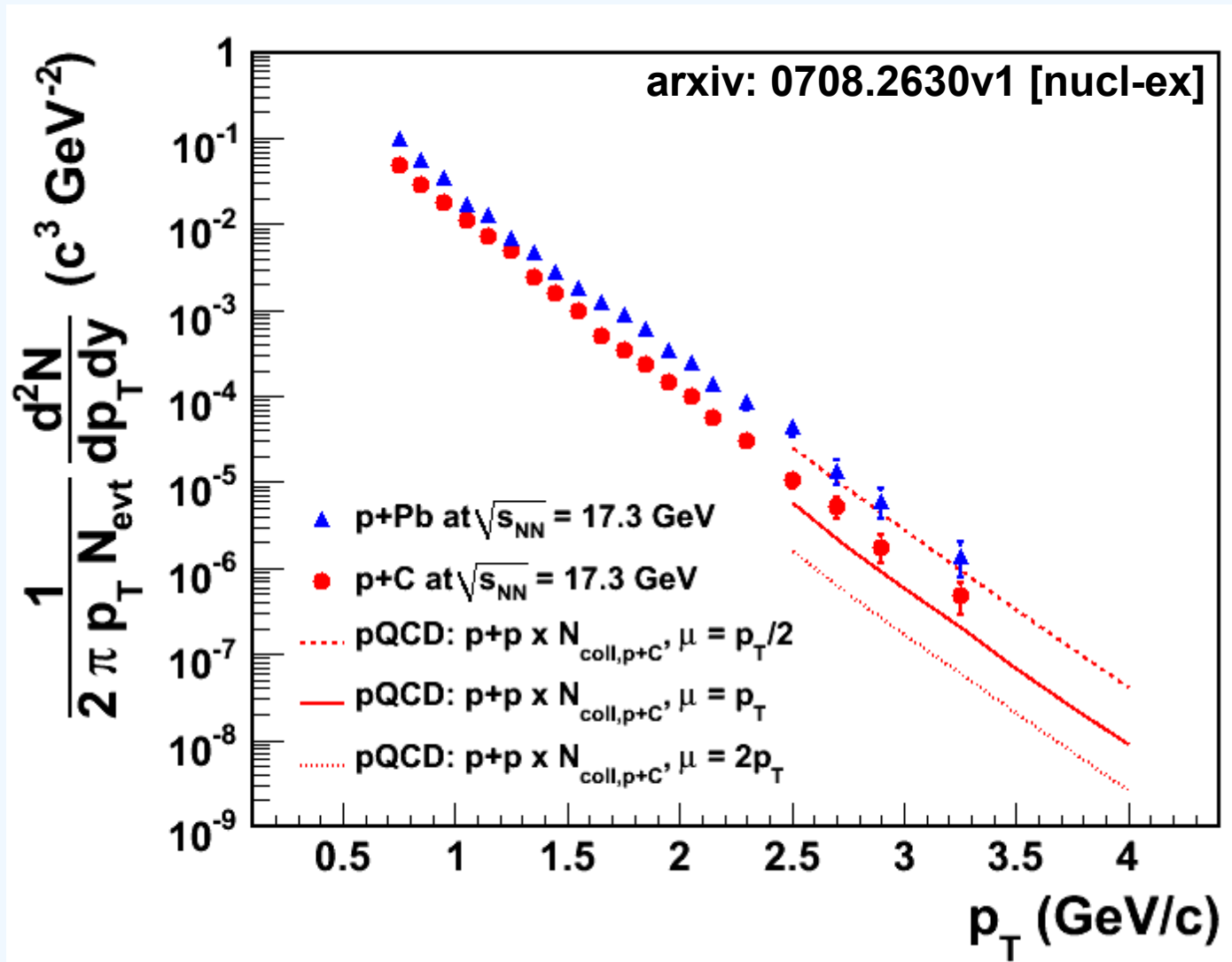
$$\gamma_{\text{direct}} = \gamma_{\text{inclusive}} - \gamma_{\text{decay}} = \left(1 - \frac{1}{R_\gamma}\right) \gamma_{\text{inclusive}}$$

- Double ratio: $R_\gamma = \frac{(\gamma/\pi^0)_{\text{meas}}}{(\gamma/\pi^0)_{\text{decay}}}$



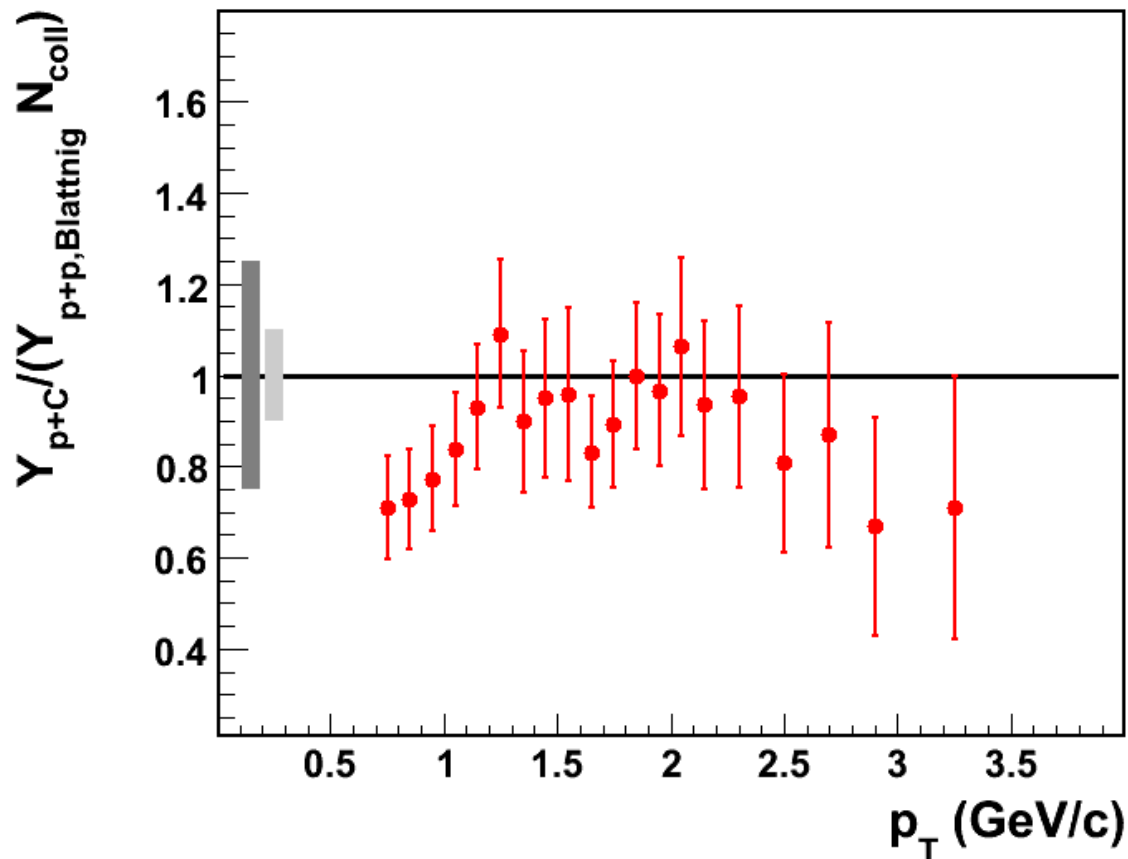
- **Advantage:**
Systematic uncertainties in γ/π^0 -ratio cancel out partially

- **Final** WA98 neutral pion spectra for p+Pb and p+C
- p+C data compatible with scaled p+p pQCD calculation
 - but: large pQCD uncertainties: need **measured** reference



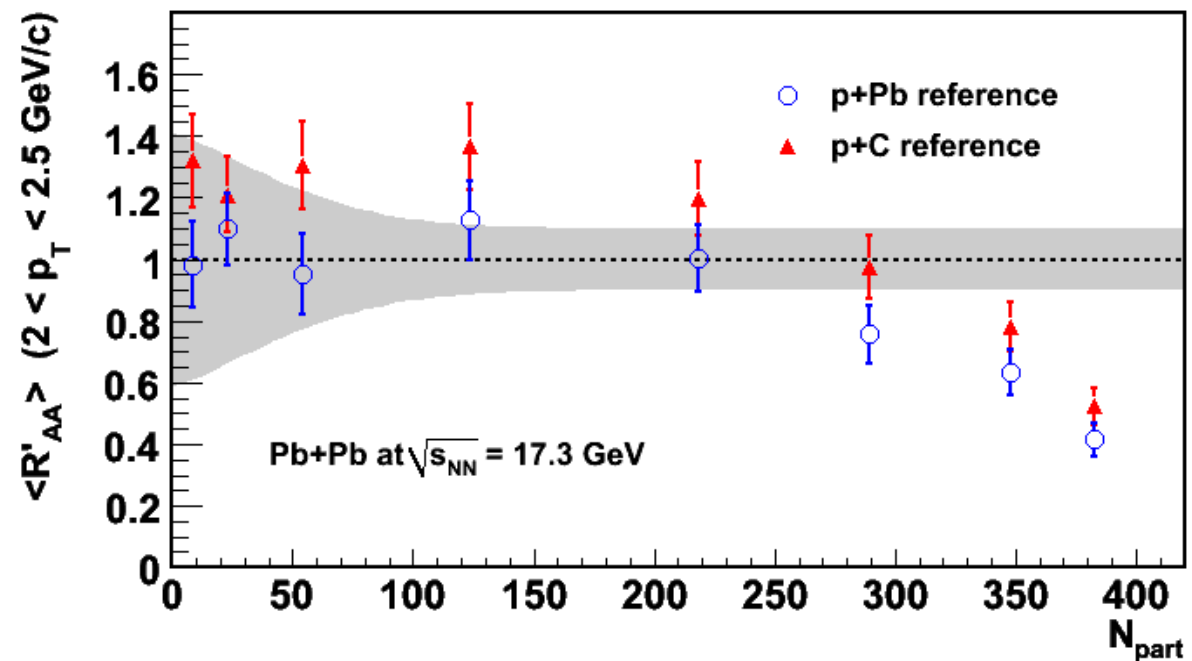
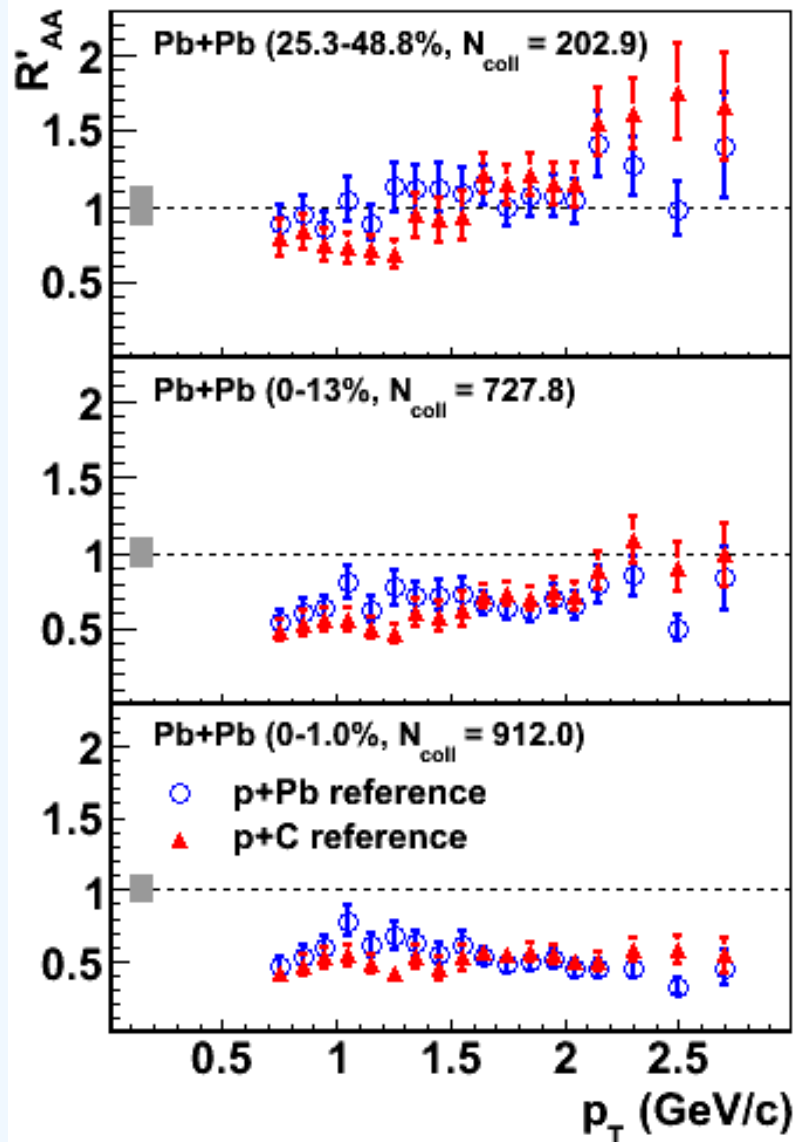
R_{pC} : Compared to p+p parameterization by Blattnig et.al.
(Phys. Rev. D62, 094030(2000))

- Has been used for search for jet-quenching at SPS
- Agreement between N_{coll} -scaled p+C and Blattnig
→ supports use of Blattnig as reference

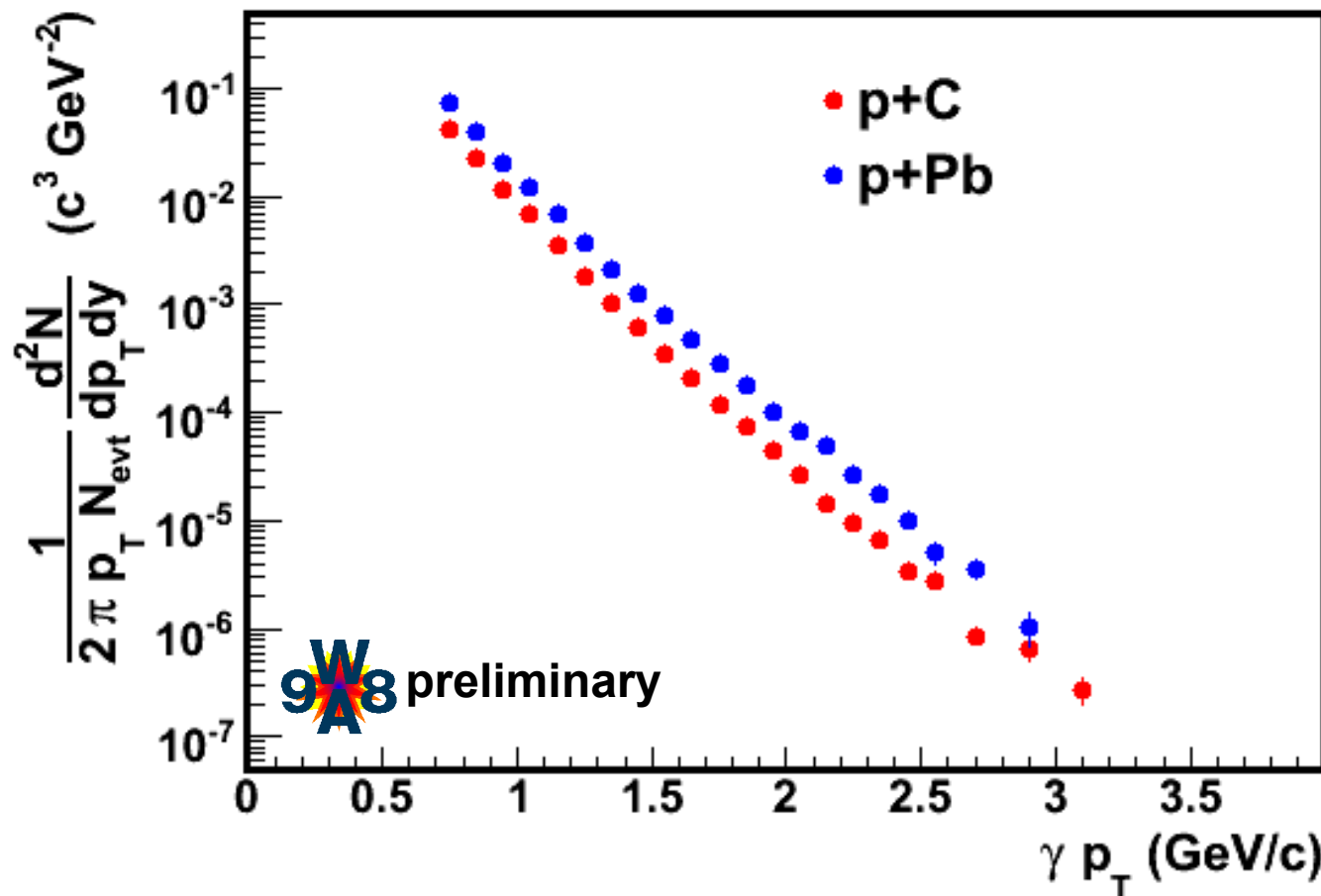


R_{AA} of the WA98 Pb+Pb data
with p+Pb and p+C reference:
Neutral pion suppression for
 $N_{part} > \sim 300!$

$$R'_{AA} = \frac{N_{coll,pA} Y_{Pb+Pb}}{N_{coll,Pb+Pb} Y_{p+A}}$$



- back to direct photons: inclusive photon spectra

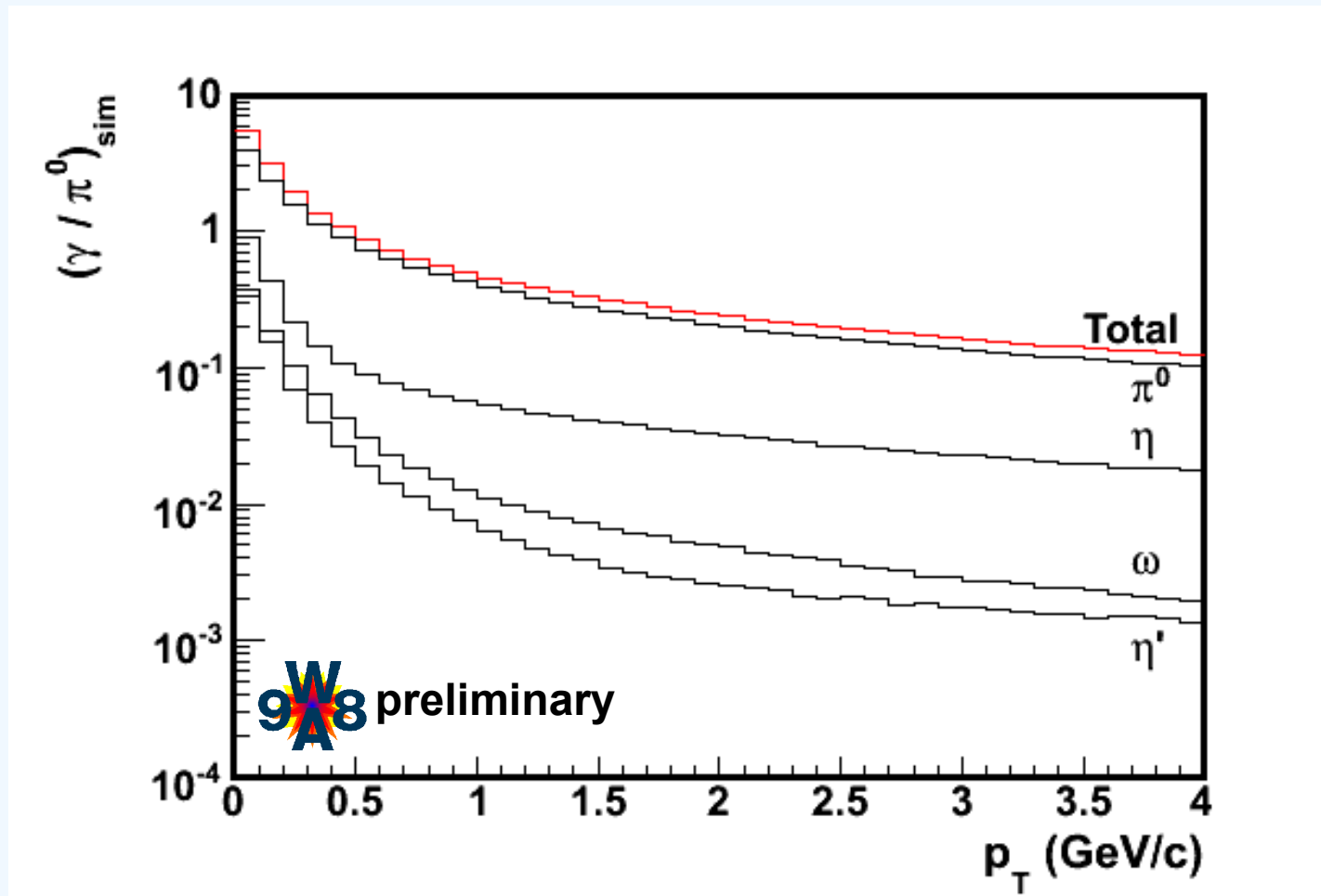


Triggered data from
 $p_T > 1.2 \text{ GeV}$

Corrected for:

- Acceptance
- Efficiency
- Conversion
- Contaminations:
 - Charged Particles
 - Neutrons

- Decay photon spectra from monte carlo
- Input: π^0 spectrum
- Simulated mesons: π^0 , η , ω , η'
- $\eta/\pi^0 = 0.48 \pm 0.02$



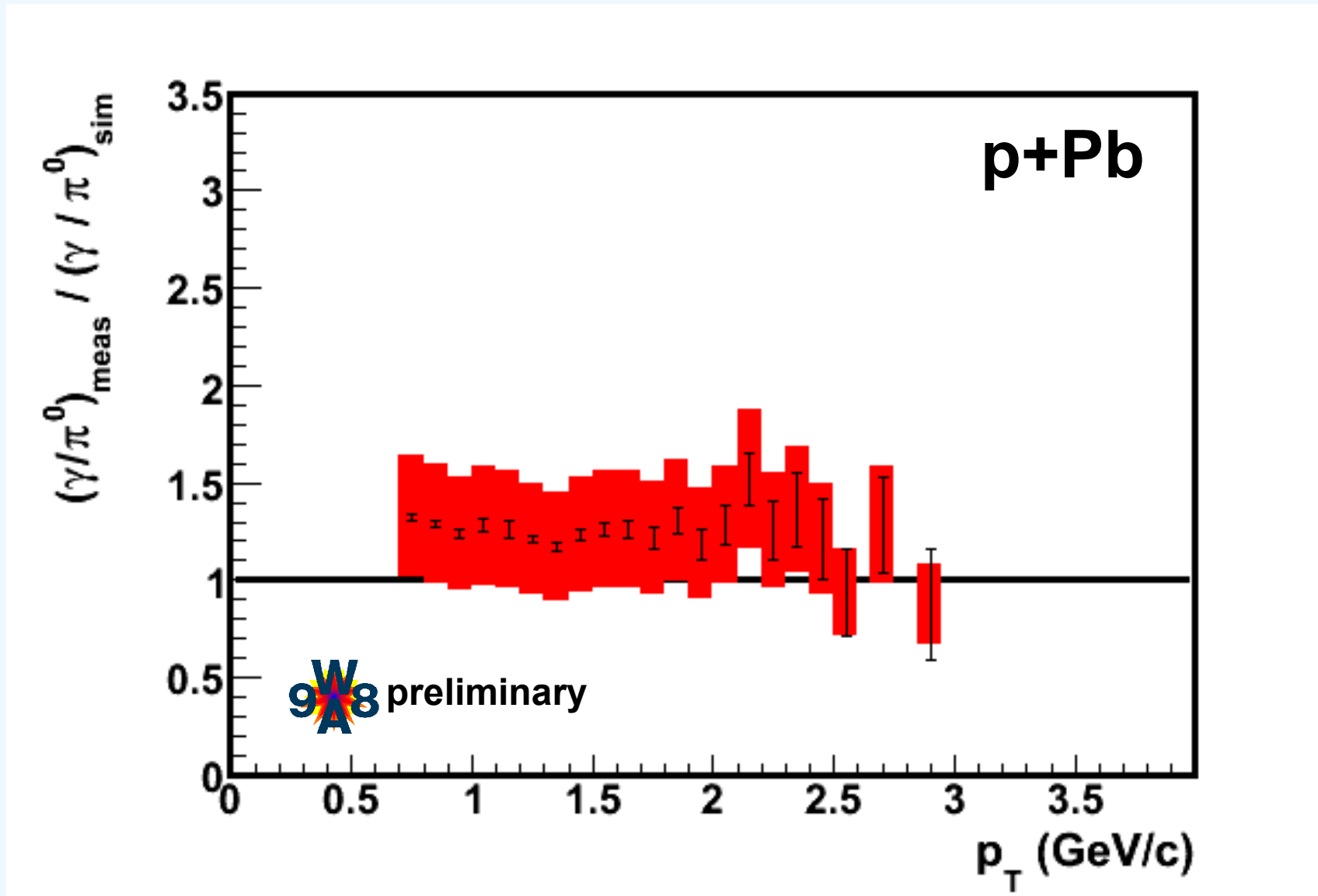
Systematic Uncertainties

p_T	2 GeV	
Inclusive Photon Spectrum	5%	} $(\gamma/\pi^0)_{\text{meas}}$
Pion Spectrum	10%	
No-Target Correction	2%	
Energy Scale	5%	
Acceptance	2%	} $(\gamma/\pi^0)_{\text{backg}}$
m_T -Scaling	3%	
Unaccounted Decays	1%	
Fit to Pions, p+Pb	20%	} $(\gamma/\pi^0)_{\text{meas}} / (\gamma/\pi^0)_{\text{backg}}$
Fit to Pions, p+C	10%	

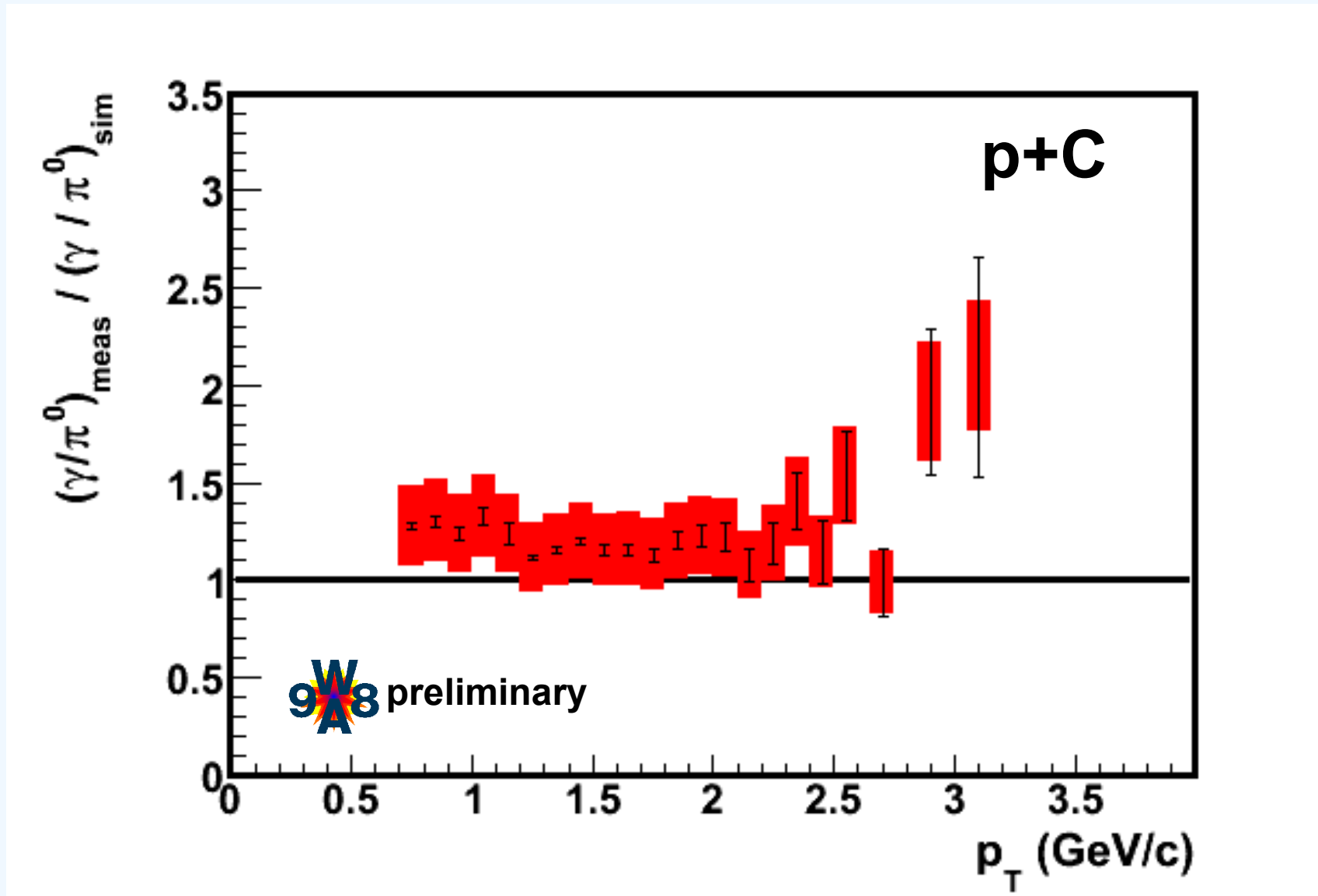
Individual errors are added in quadrature

Analyzed Events

	p+C	p+Pb
Pb+Pb Data, MB:		
Central:	$6.7 \cdot 10^6$	
Peripheral:	$4.3 \cdot 10^6$	
MB Events	$1.2 \cdot 10^6$	$1.0 \cdot 10^6$
HEP Events	$1.5 \cdot 10^6$	$0.5 \cdot 10^6$
Corresponding MB	$3.9 \cdot 10^7$	$8.2 \cdot 10^6$

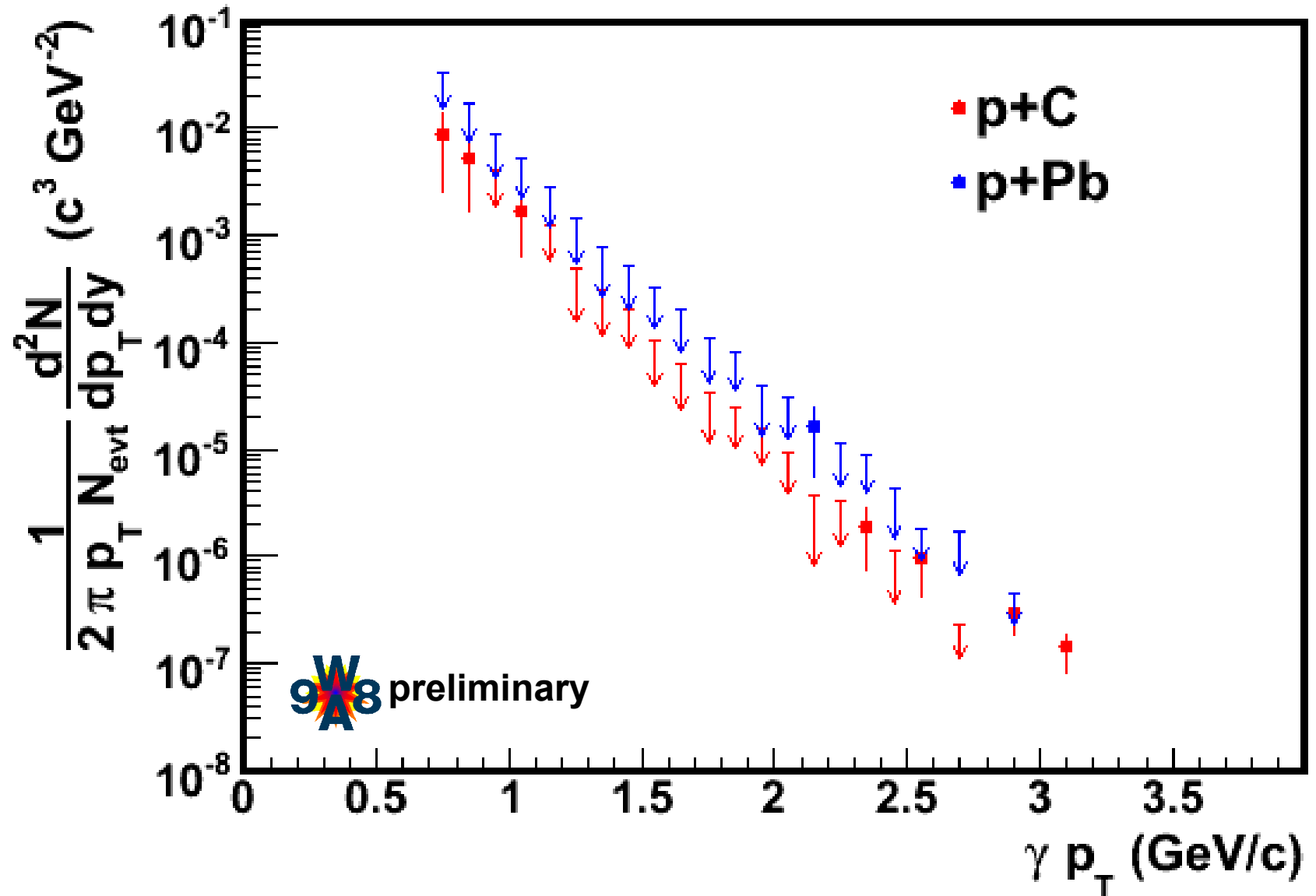


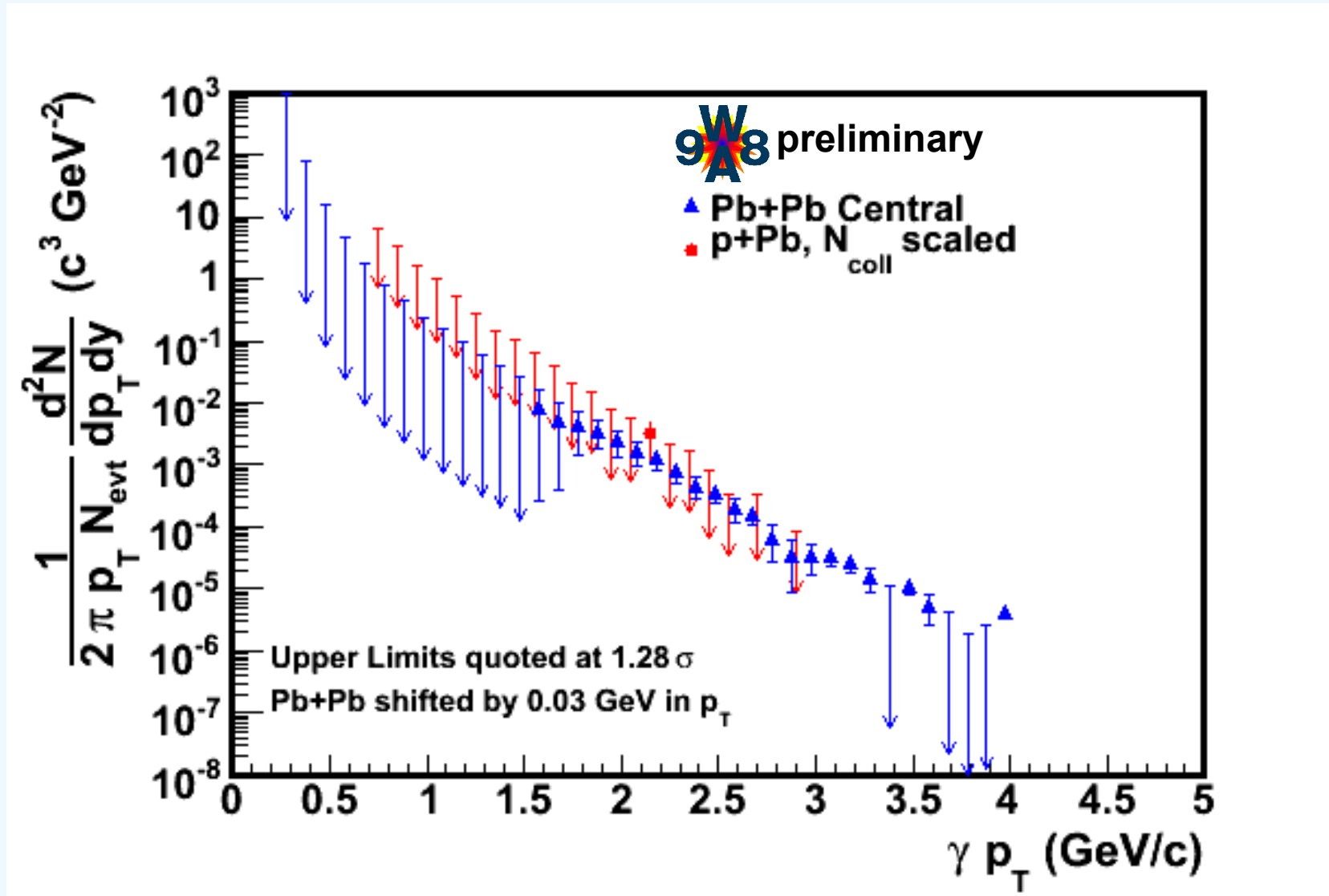
No significant excess in double ratio within errors



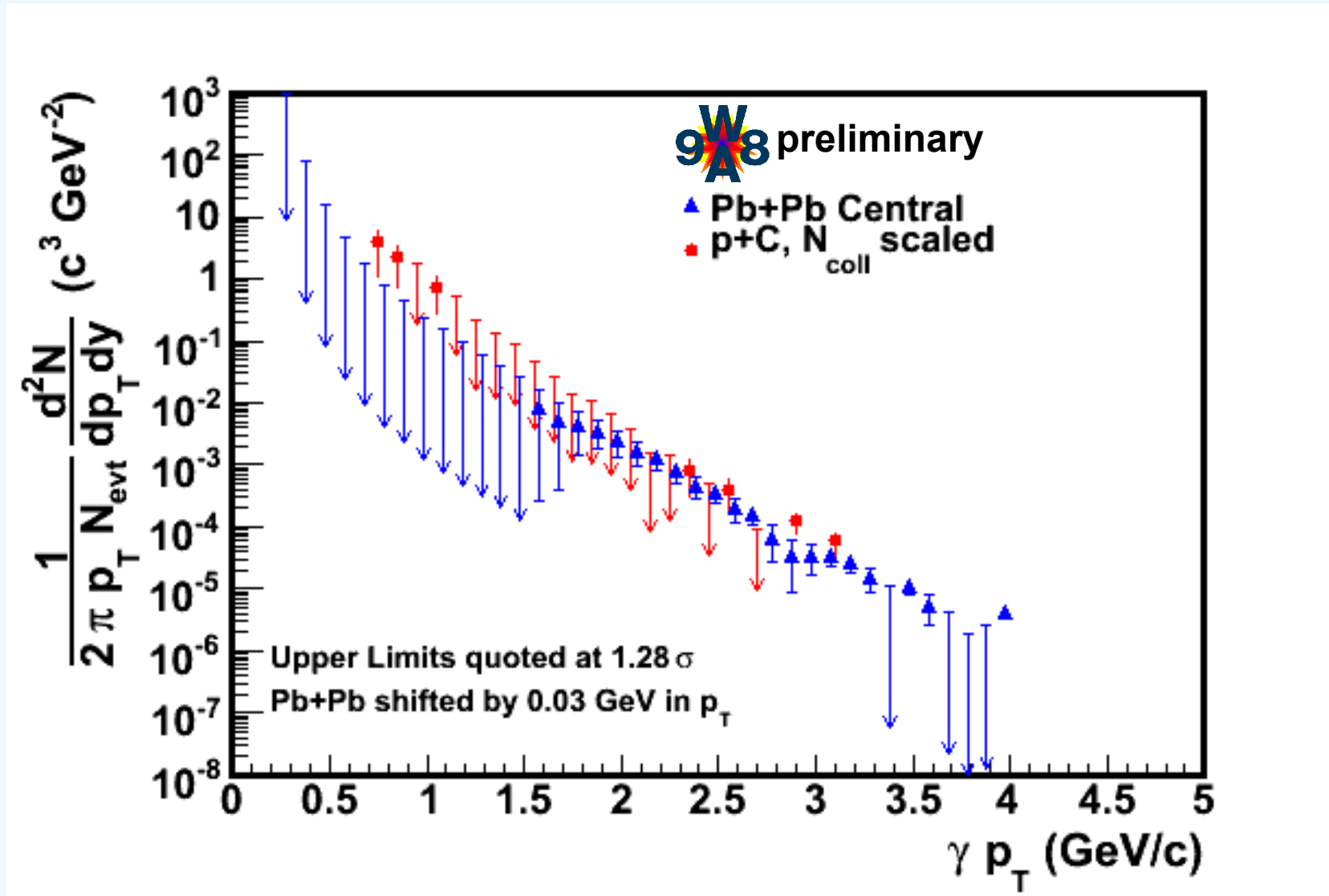
No significant photon excess in p_T region relevant for thermal contribution

Upper Limits on Direct Photons





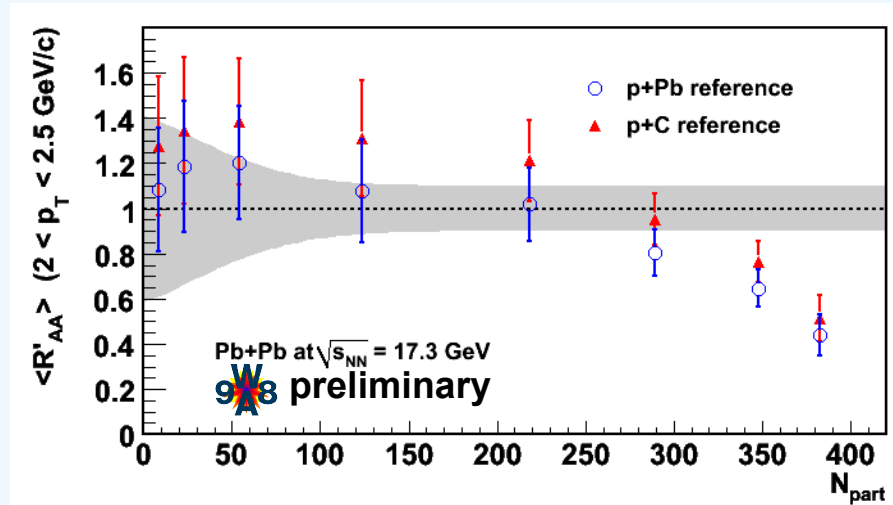
→ N_{coll} scaled p+Pb data consistent with central Pb+Pb data within errors



- N_{coll} scaled p+C data consistent with central Pb+Pb data within errors
- No further limit on prompt photon production can be set

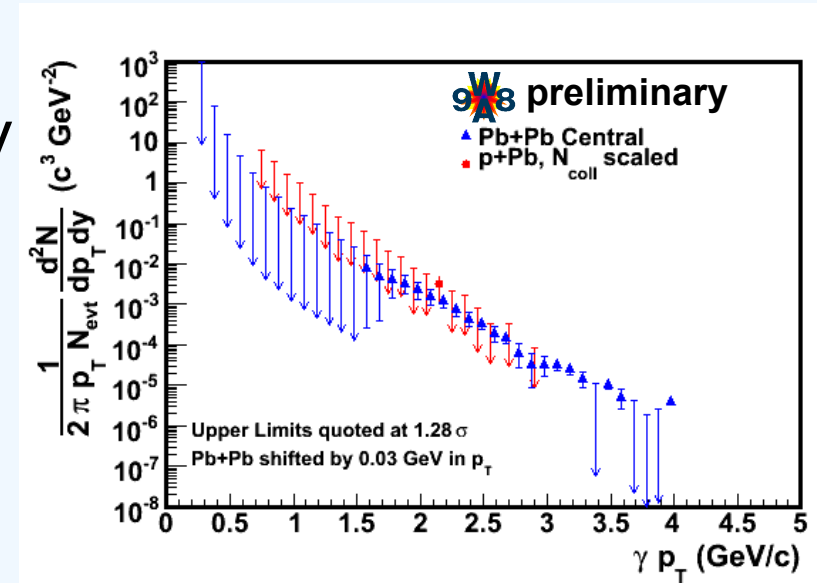
- **Neutral pion production in p+A collisions at $\sqrt{s_{NN}} = 17.4$ GeV**

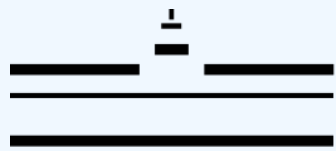
- **Significant suppression** in most central Pb+Pb collisions with both p+A data sets as a reference



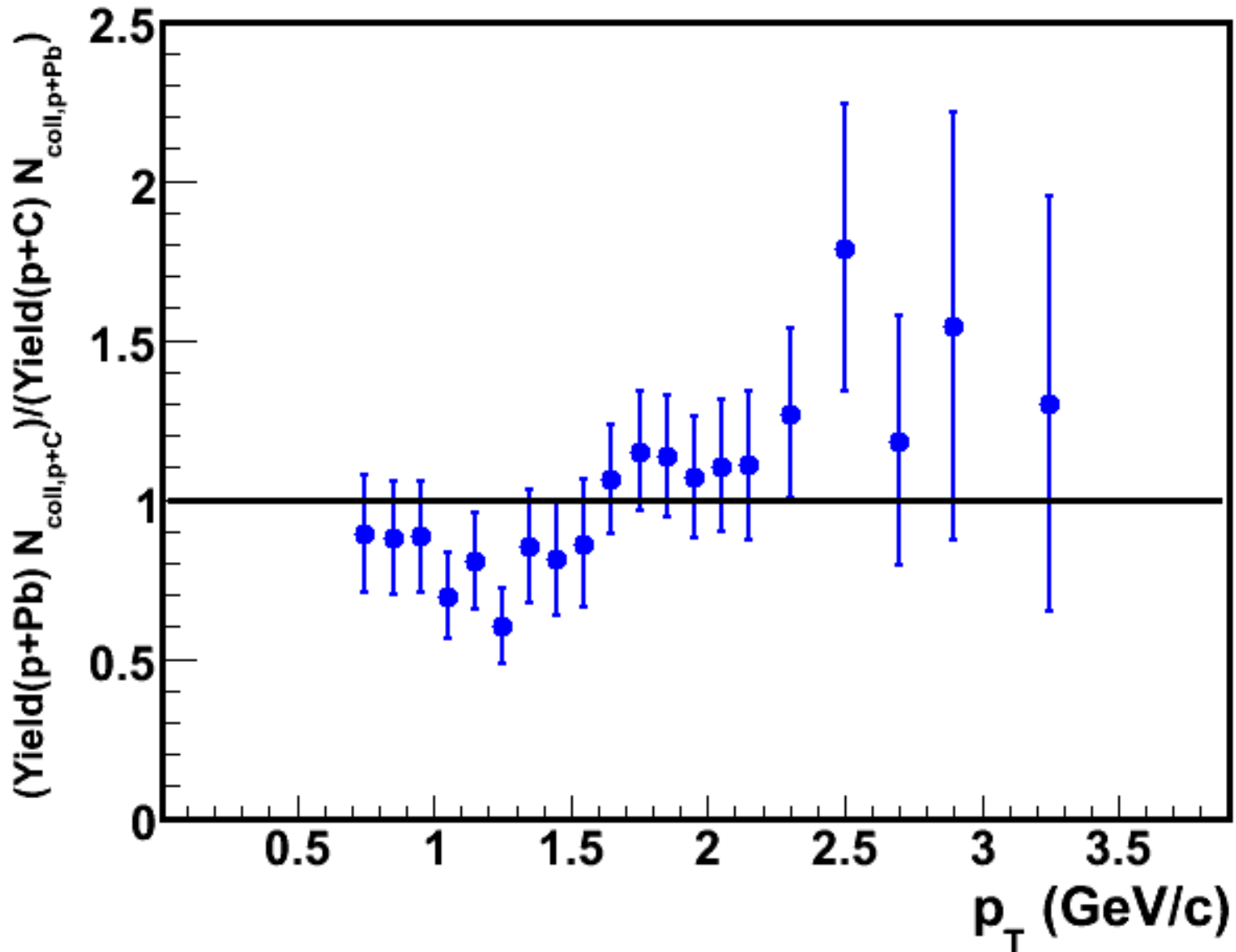
Production of direct photons in same data sets

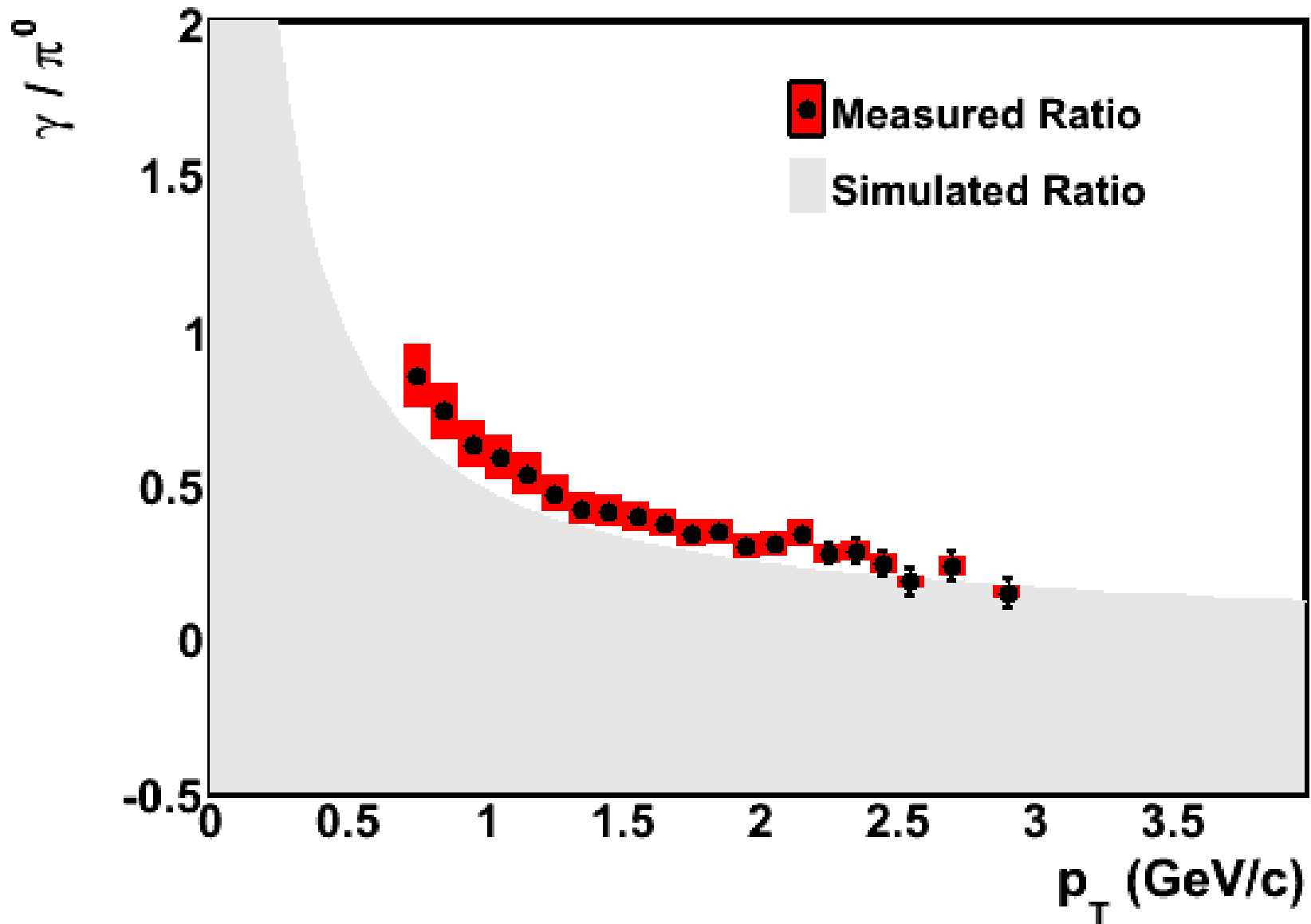
- **Upper limits** could be extracted up to $p_T \approx 3$ GeV
- Upper limits on prompt photons derived from p+A above Pb+Pb data: **No conclusions about thermal component in Pb+Pb**

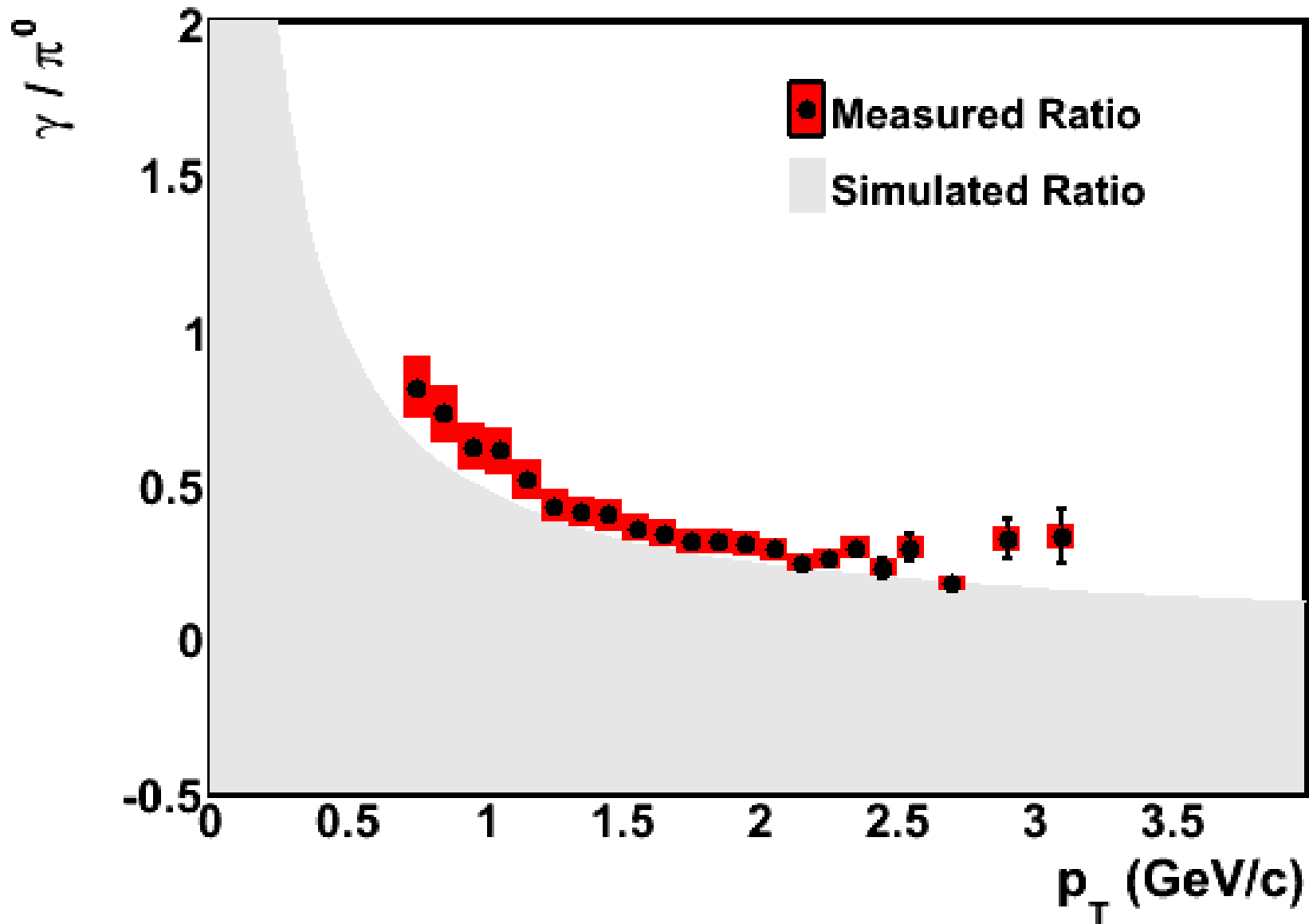


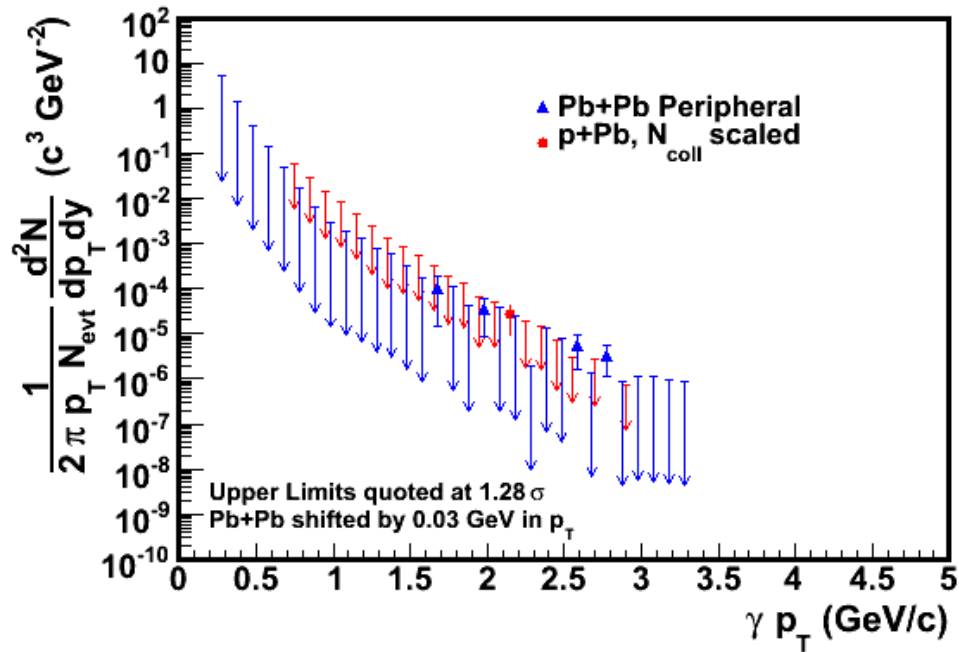


Backup









Similar behaviour of
p+Pb and p+C data

N_{coll} scaled p+A data sets both
consistent with peripheral Pb+Pb
data

