PROBING THE INITIAL STAGES OF HEAVY ION COLLISIONS WITH DIRECT PHOTONS AT PHENIX

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OUTLINE

- Introduction
- Methodology
- Results
- Summary

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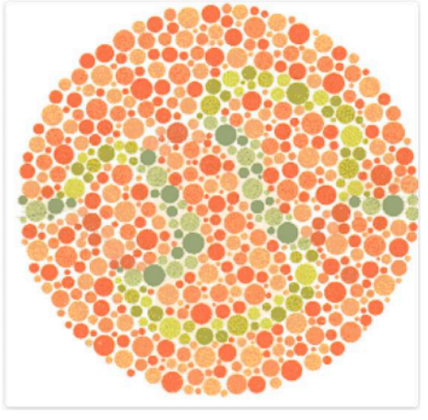
INITIAL STAGES
OF HIGH-ENERGY NUCLEAR
COLLISIONS

Introduction

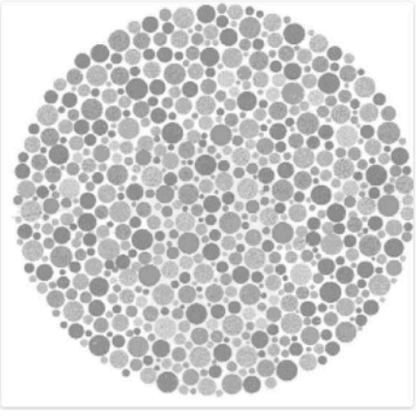
Photons are "color blind" probe of Quark Gluon Plasma

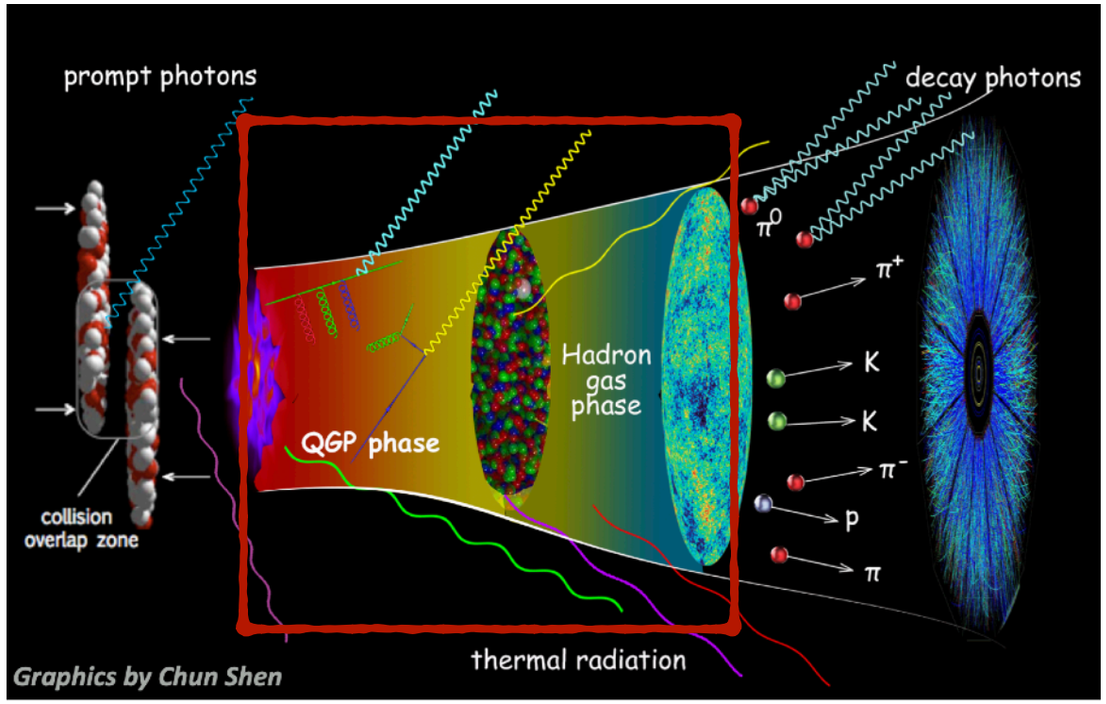
- information about the space-time evolution of matter produced in relativistic heavy-ion collisions
- evidence of thermal radiations from QGP and Hadron Gas

QGP as seen by partons



QGP as seen by photons

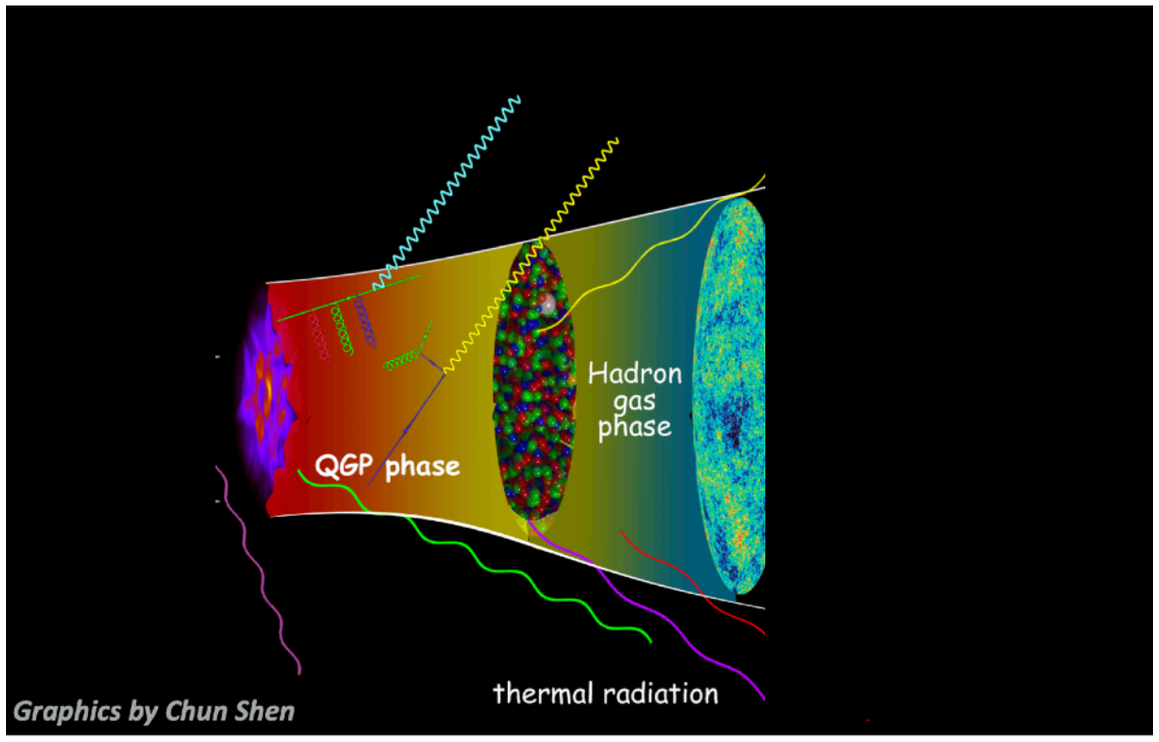




Direct photons = Inclusive photons — Hadronic decay photons

- 80-90% photons are decay photons
- Prompt photons estimated using the p+p baseline

Introduction



If there is a hot and dense medium created in heavy-ion collisions, it will radiate thermal radiation in form of photons or low mass dileptons

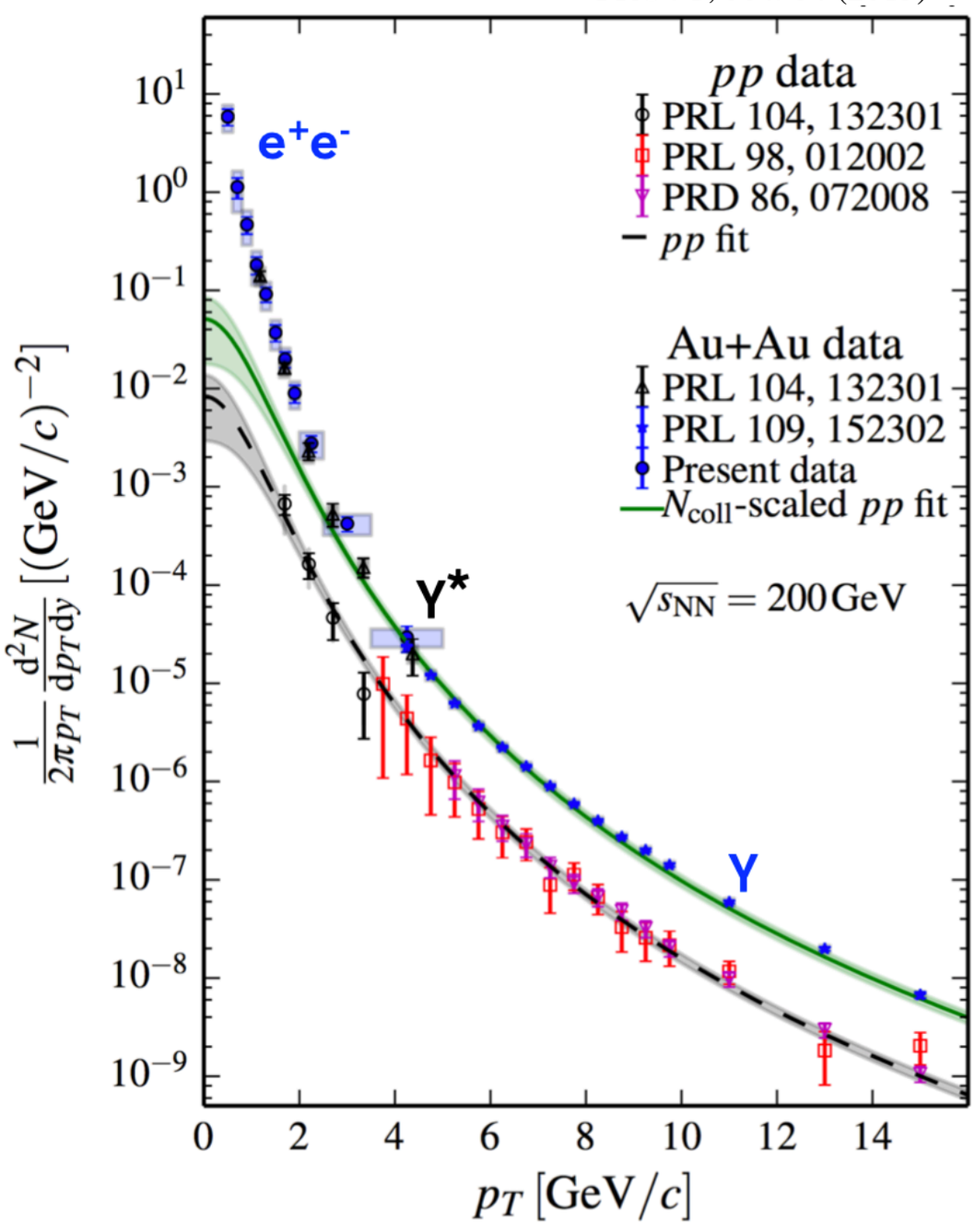
The direct photon spectrum and yield are sensitive to temperature (Rate$\propto T^4$) and the space-time evolution of matter (Doppler shift)

Measurement of yield will constrain initial conditions, sources, emission rates and space-time evolution

Thermal photons in Au+Au collisions

Direct photon yields for p+p collisions at 200 GeV are consistent with pQCD calculations

PRC 91, 064904 (2015)



Thermal photon yield = Direct photon yield of Au+Au − Hard scattering contribution (N_{coll}-scaled p+p)

The Au+Au yield is consistent with N_{coll}-scaled p+p yield above 4 GeV

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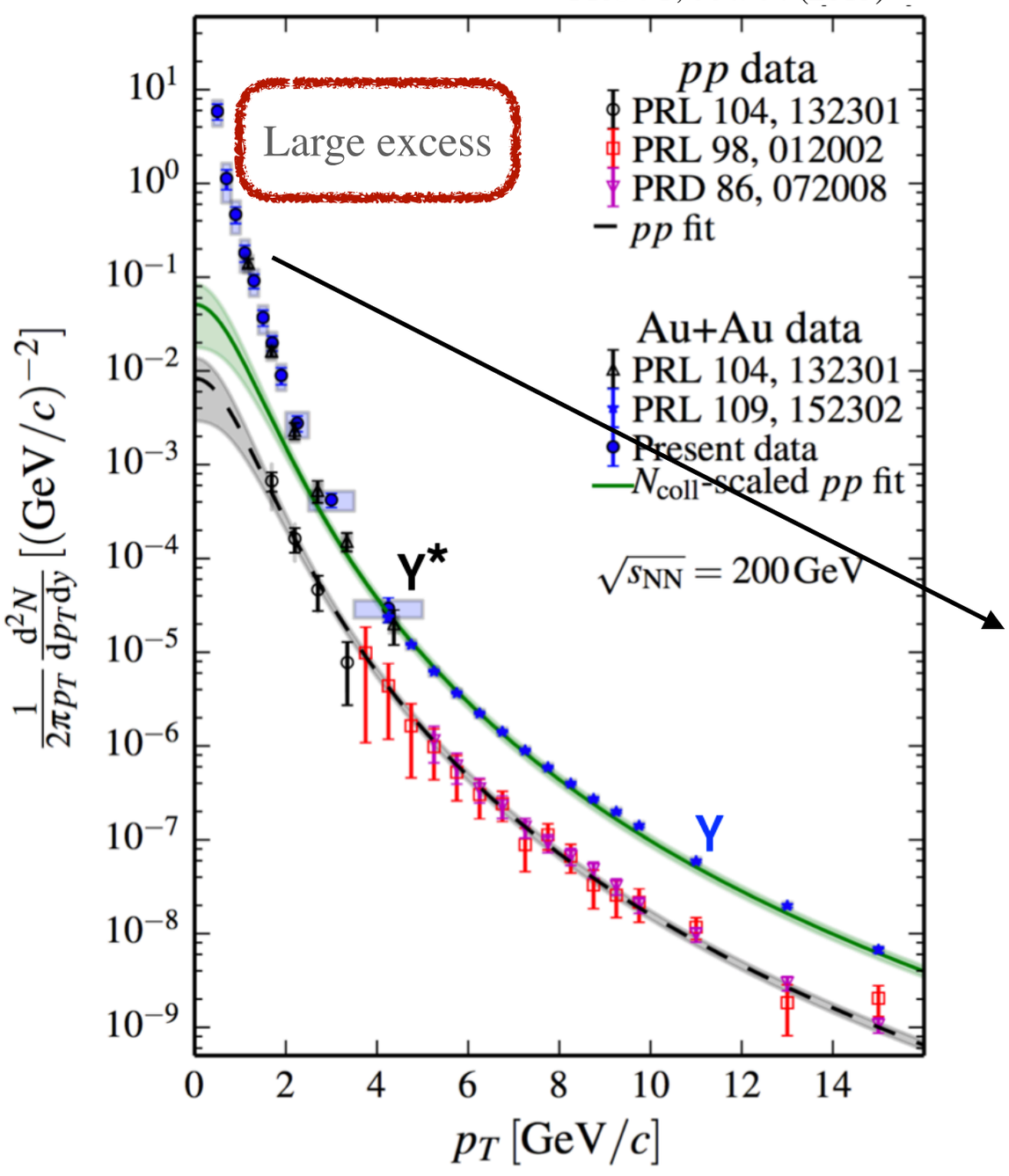

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Significant excess of thermal photons below 3 GeV

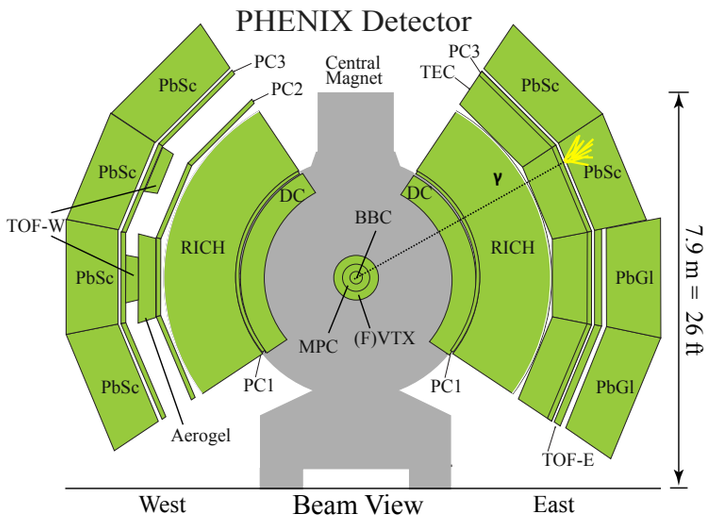
Exponential fit $Aexp(-p_T/T_{eff})$ gives $T_{eff} \sim 240$ MeV

Wealth of PHENIX data

√s [GeV]	p+p	p+Al	p+Au	d+Au	^{3}He+Au	Cu+Cu	Cu+Au	Au+Au	U+U
510	✓								
200	✓	✓	✓	✓	✓	✓	✓	✓	✓
130								✓	
62.4	✓			✓		✓		✓	
39				✓				✓	
27								✓	
20				✓		✓		✓	
14.5								✓	
7.7								✓	

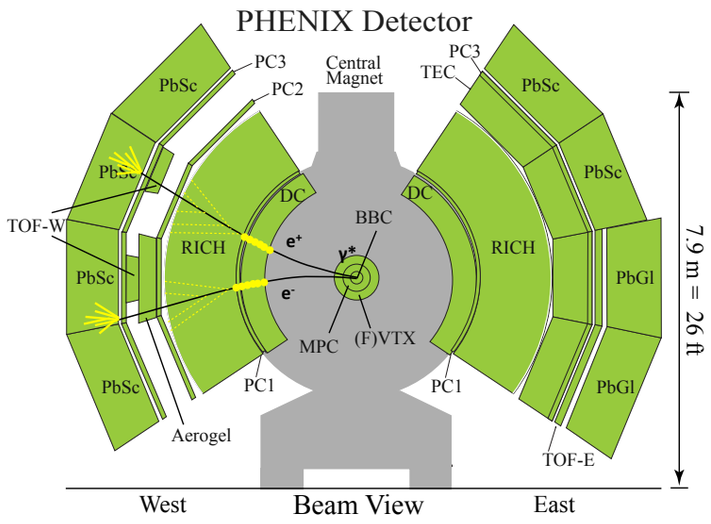
9 collision species
9 collision energies

Calorimeter method



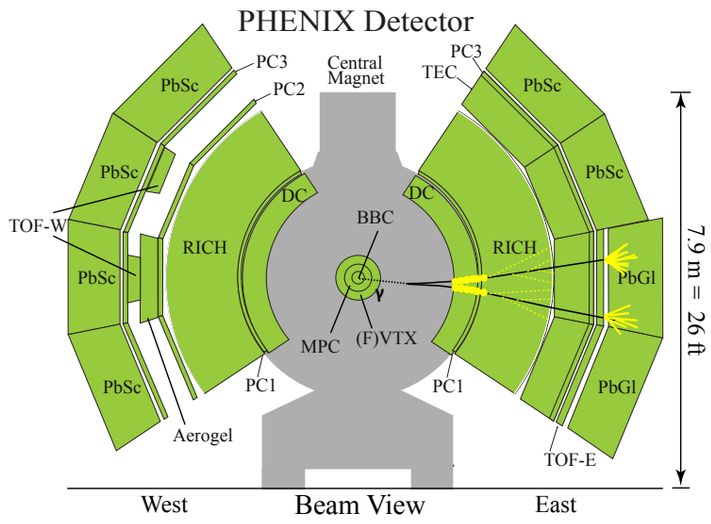
Virtual photon method

$$\gamma^* \rightarrow e^+ + e^-$$



External conversion method

$$\gamma \rightarrow e^+ + e^-$$



Universal scaling of low p_T direct photons

Using $dN_{ch}/d\eta$ at midrapidity to compare data from different beam energies, collisions species, and collision centralities

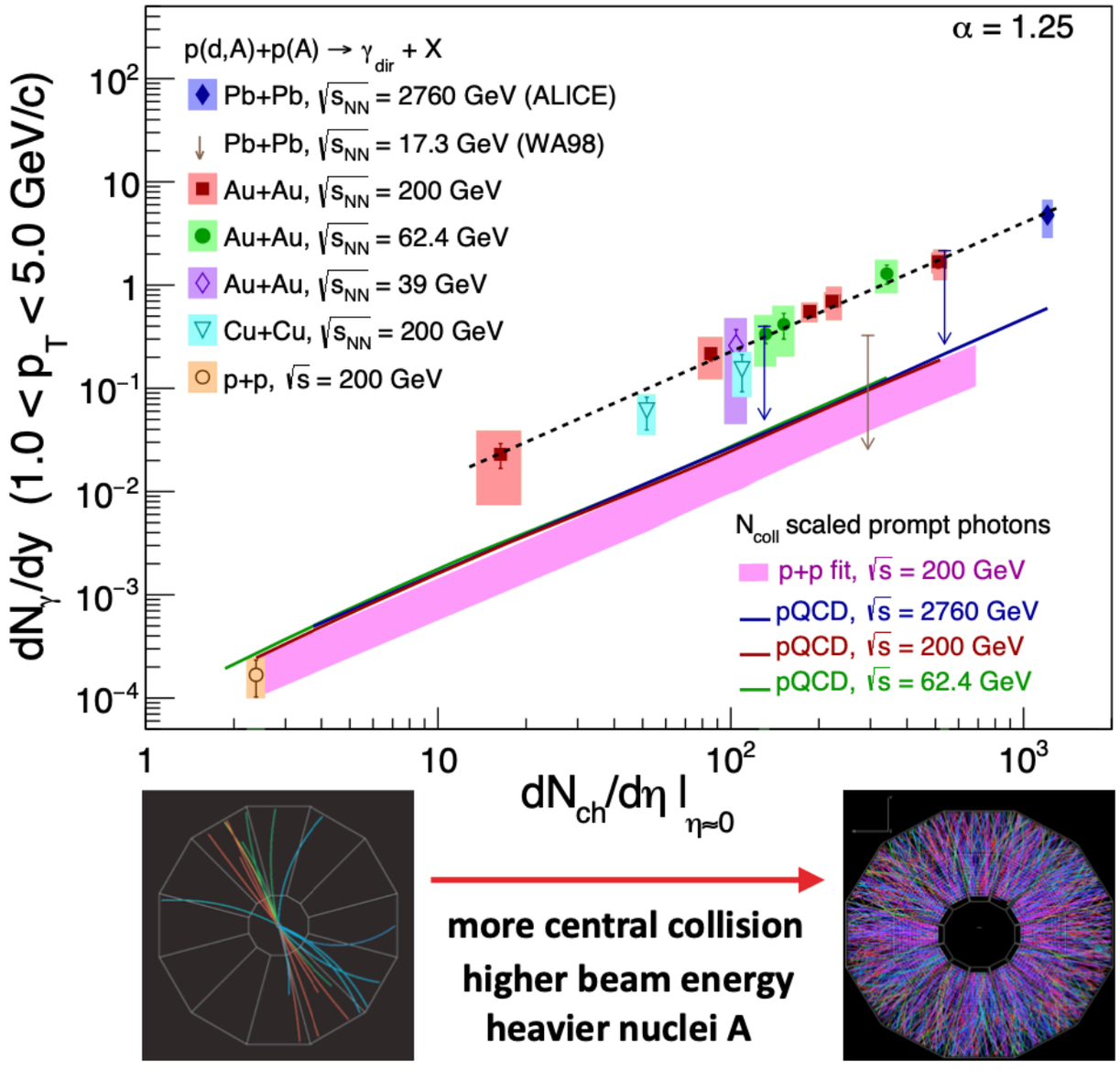
Universal scaling behavior in all A+A systems

$$dN_\gamma/dy = A \times (dN_{ch}/d\eta)^\alpha$$

N_{coll} x pQCD and N_{coll} x p+p follow same scaling at 0.1 of yield

Implies similar sources for low-p_T photon production

PRL 123, 022301 (2019)



External conversion method

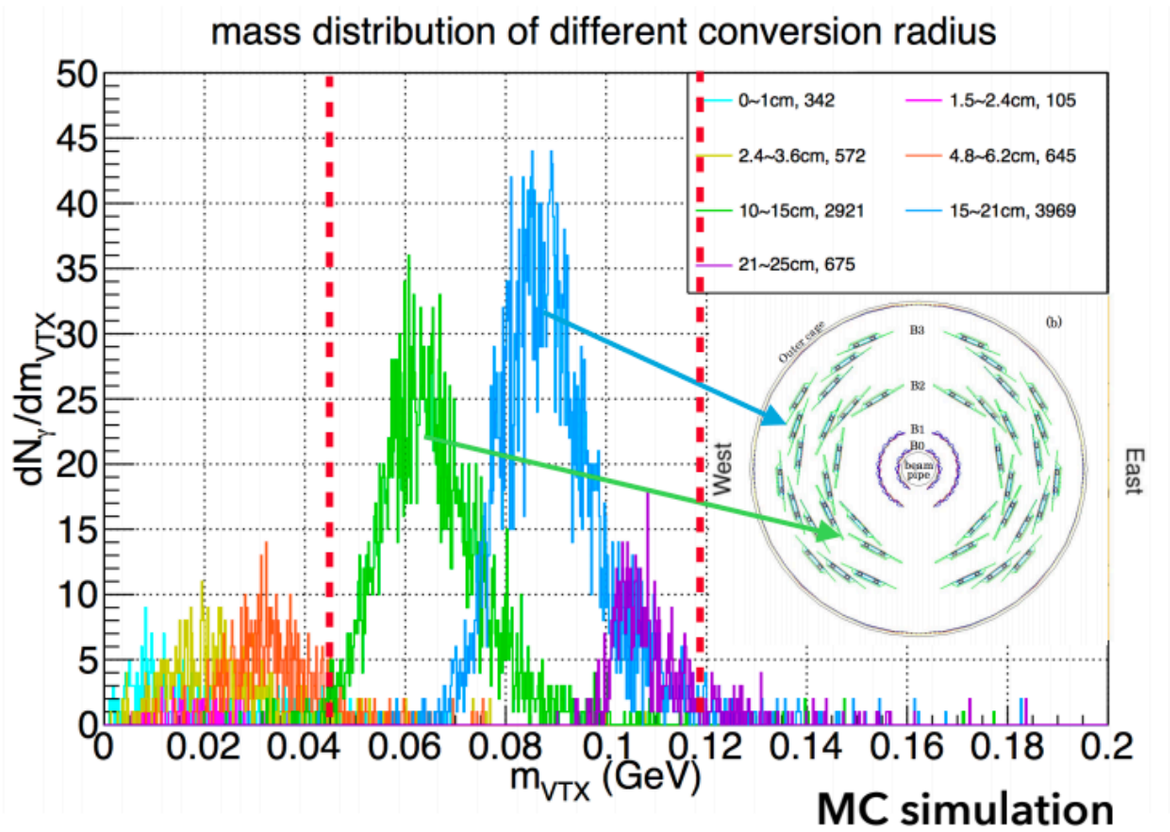
$$R_\gamma = \frac{\gamma_{inclusive}}{\gamma_{decay}} = \frac{\frac{\gamma_{inclusive}}{\gamma_{\pi^0}}}{\frac{\gamma_{hadron}}{\gamma_{\pi^0}}} = \frac{\langle \epsilon f \rangle \frac{N_\gamma^{inclusive}}{N_\gamma^{\pi^0}}}{\frac{\gamma_{hadron}}{\gamma_{\pi^0}}}$$

$N_{inclusive}$: number of photons that convert to e^+e^- pair within the detector acceptance

N_{π^0} : number of converted photons that can be tagged as a π^0 decay

<εf> : detector efficiency and acceptance

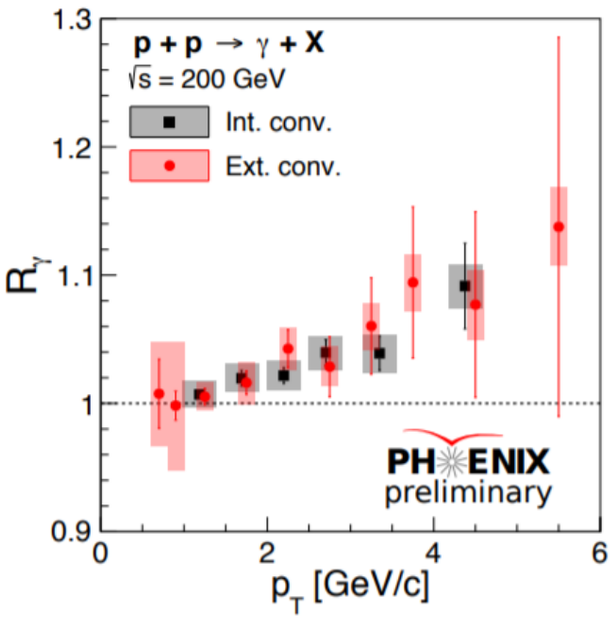
Cocktail ratio : ratio of photons coming from all hadrons to those coming only from π^0 decays

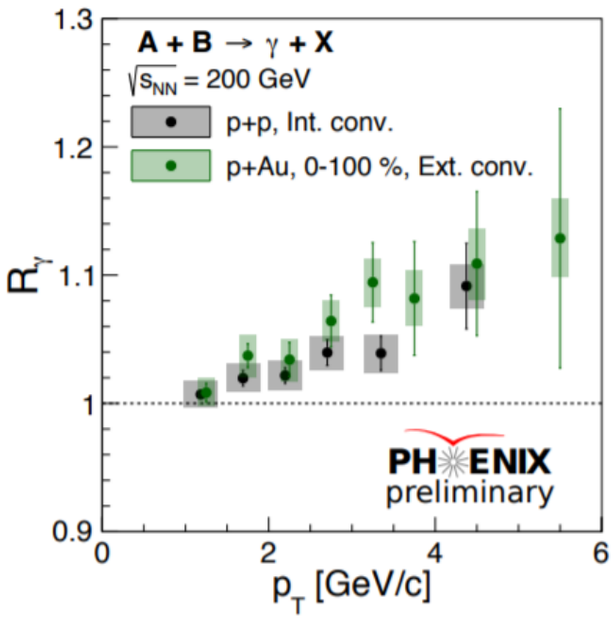


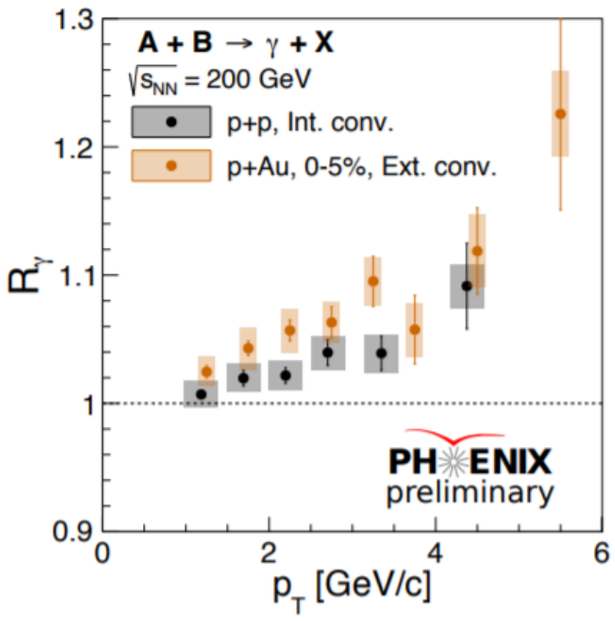
Double ratio tagging method reduces systematics

To be used for p/d/^{3}He/Au+Au collisions at 200 GeV

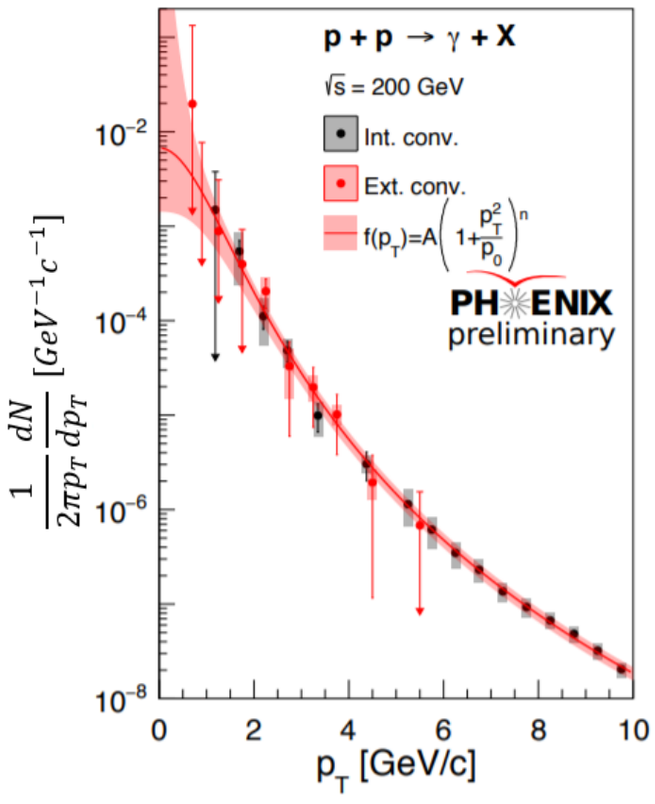
Direct photons in small system collisions

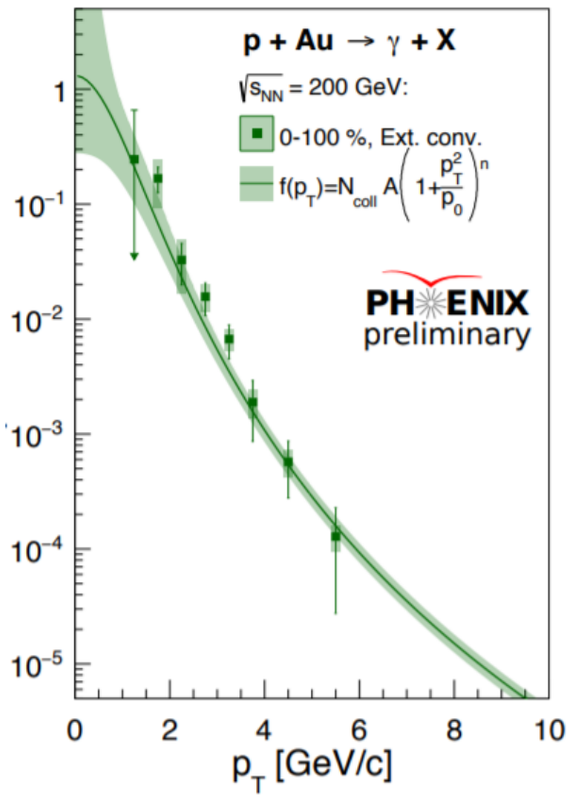


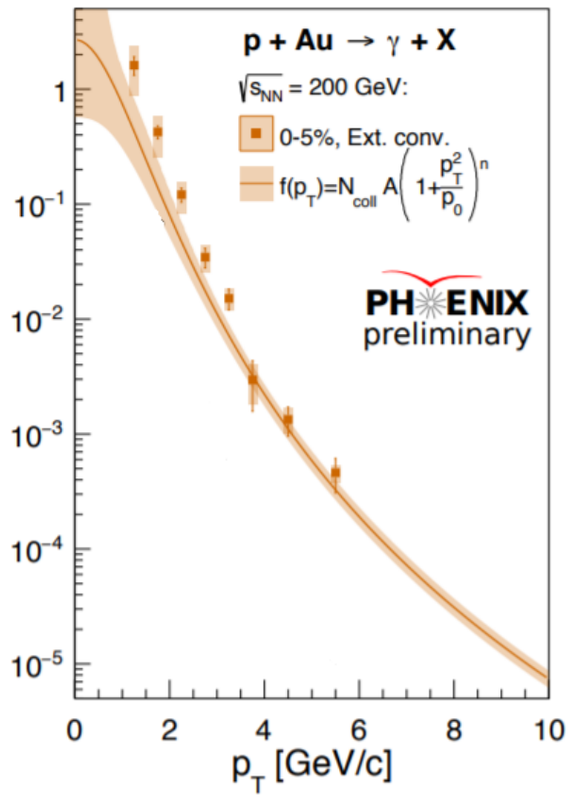




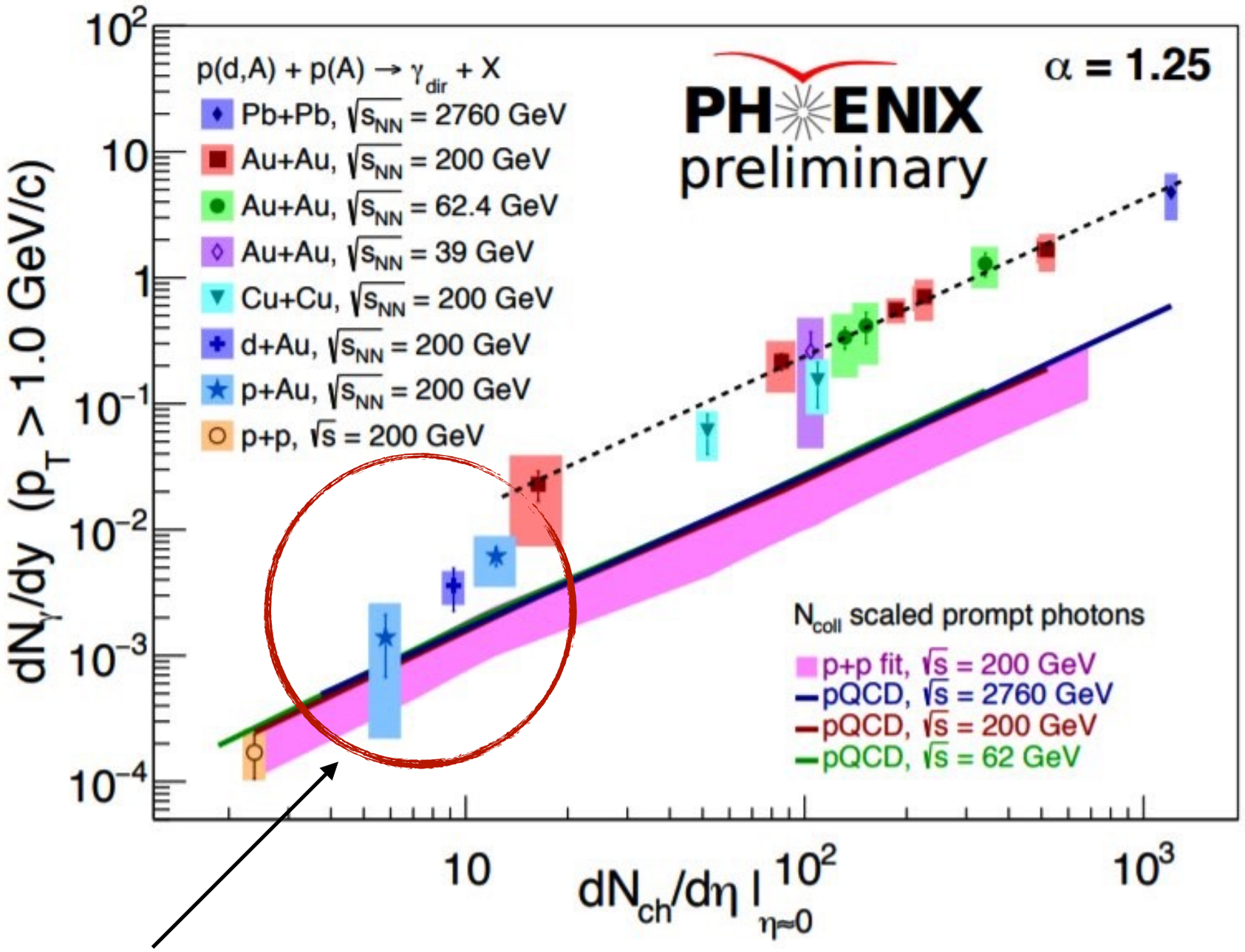
$$\gamma_{direct} = \left(R_\gamma - 1\right) * \gamma_{hadron}$$







Bridging the gap



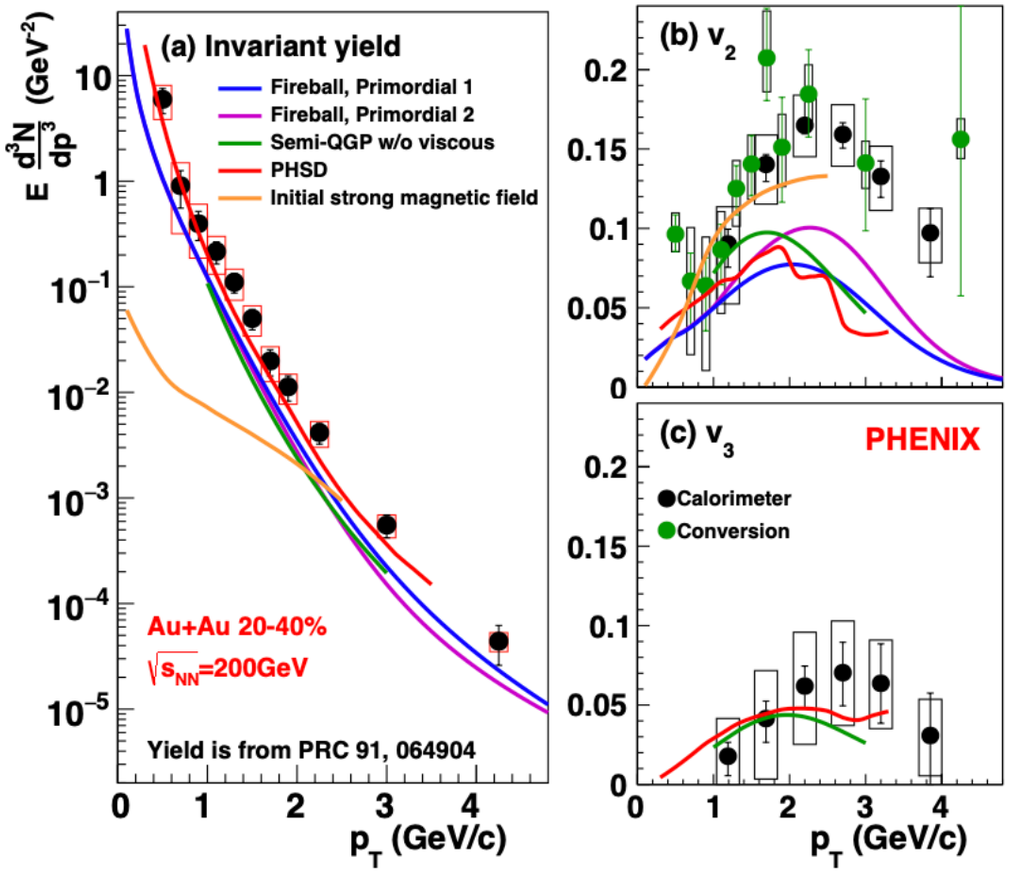
Onset of QGP (?)

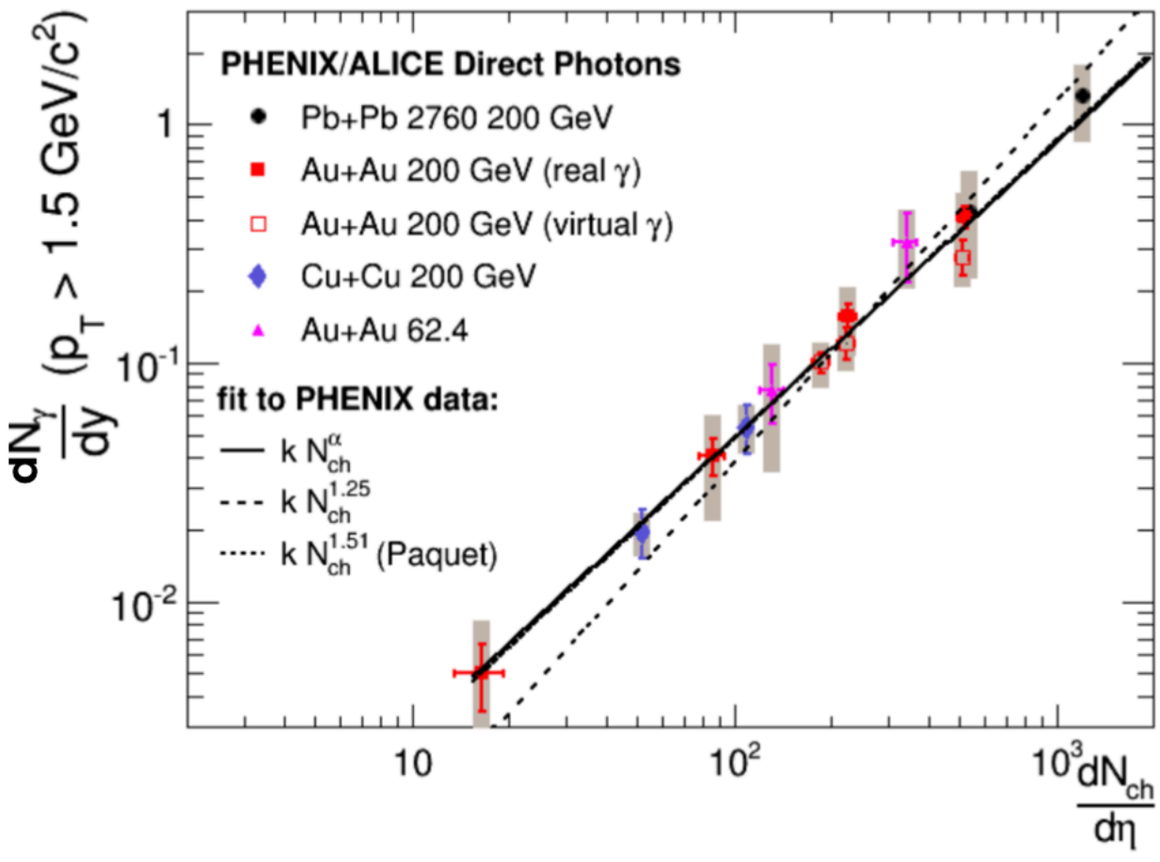
Direct photon puzzle

Experimental observations

- Large yield of low p_T direct photons
- Large anisotropic emissions
- Universal scaling with slope of 1.25

What is the main source of low pT photon emissions ?

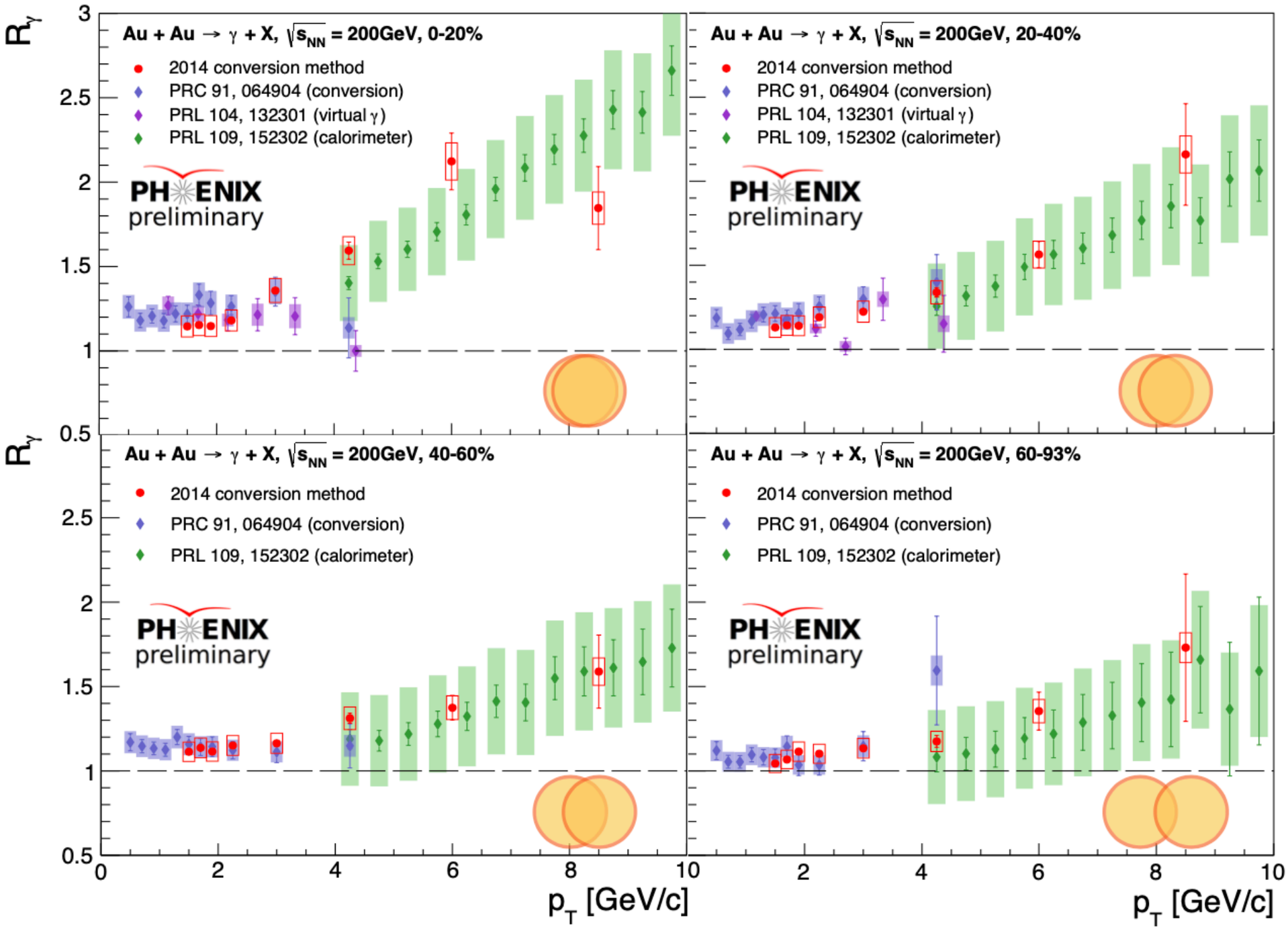




Challenging to explain these by invoking thermal photon emissions

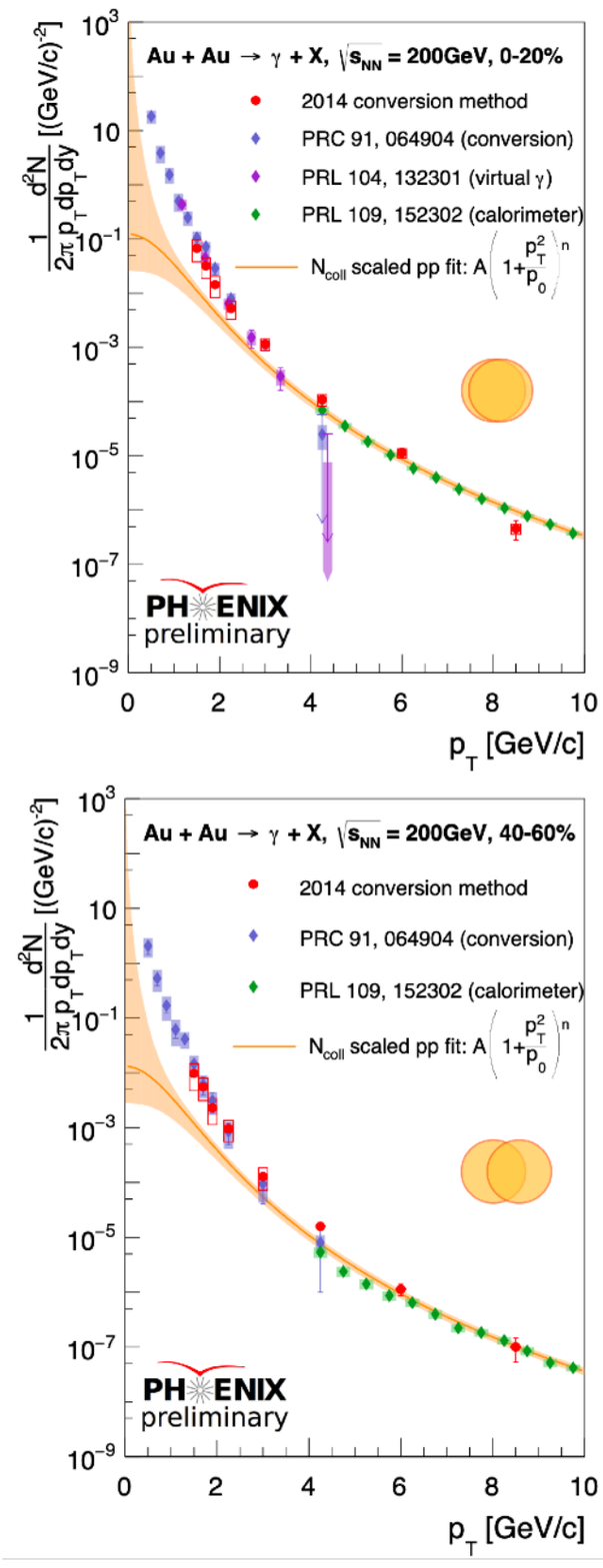
Towards precision measurement

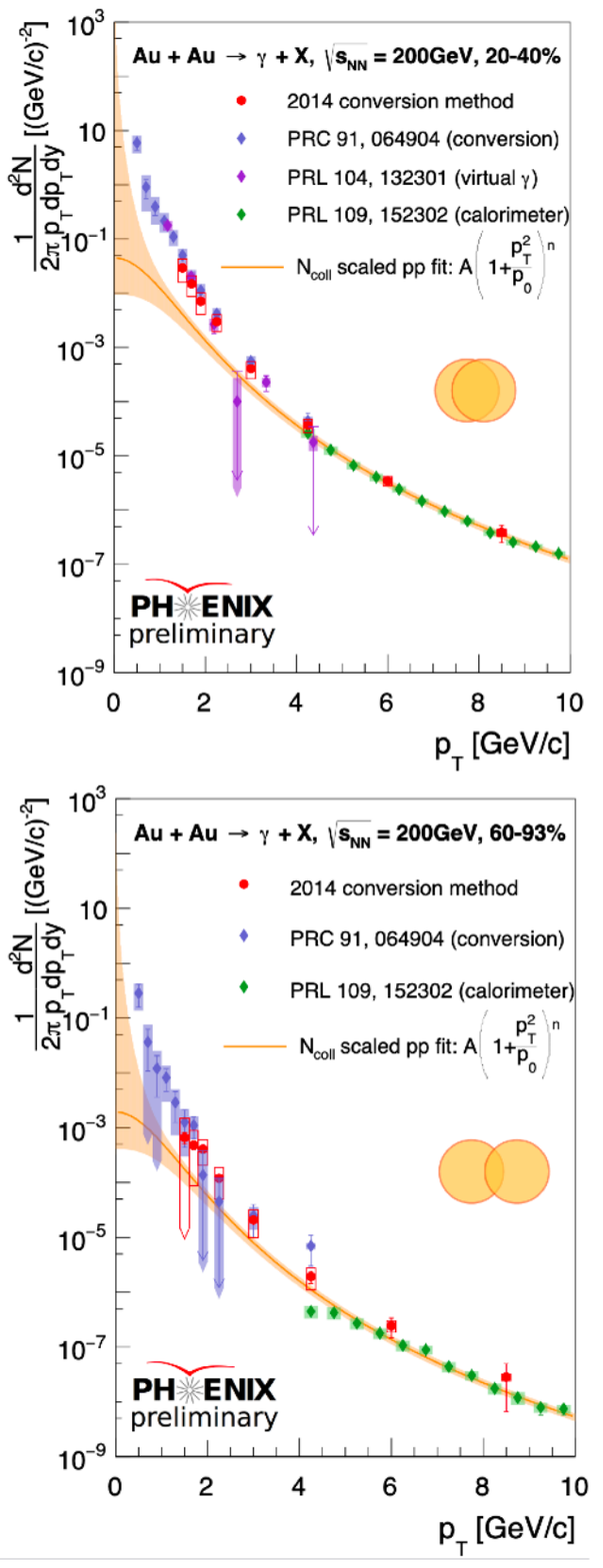
New measurement using 2014 Au+Au dataset having 10X more statistics with external conversions at VTX



Full overlap and consistency with previously published results using different methods

Towards precision measurement



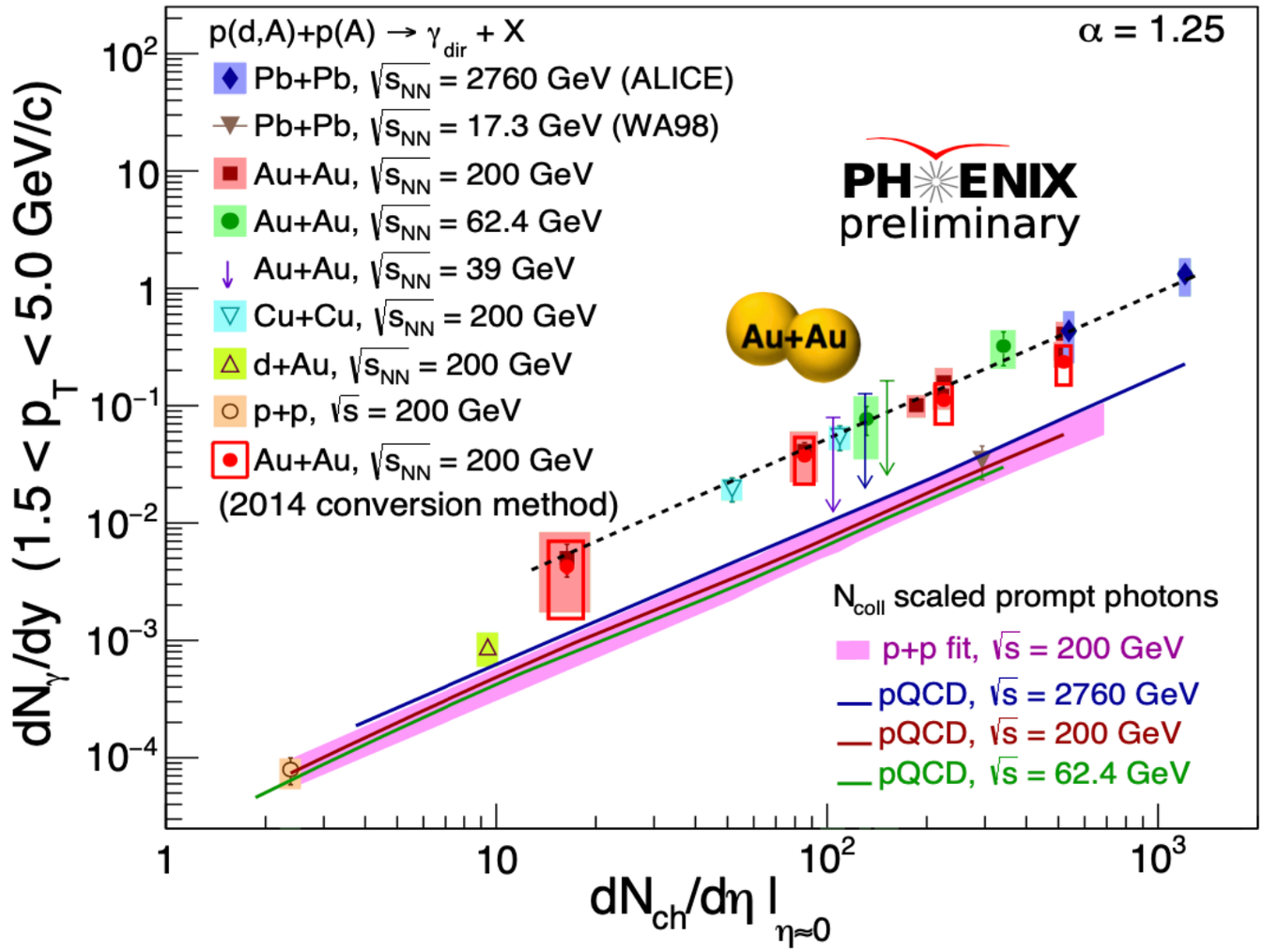


At high p_T, Au+Au data consistent with N_{coll} scaled p+p implying the dominant photon source is hard scattering

At low p_T, Au+Au data shows a clear enhancement with respect to the prompt contribution below 3GeV

Summary and outlook

New Au+Au result are consistent with the observed scaling behavior in A+A systems

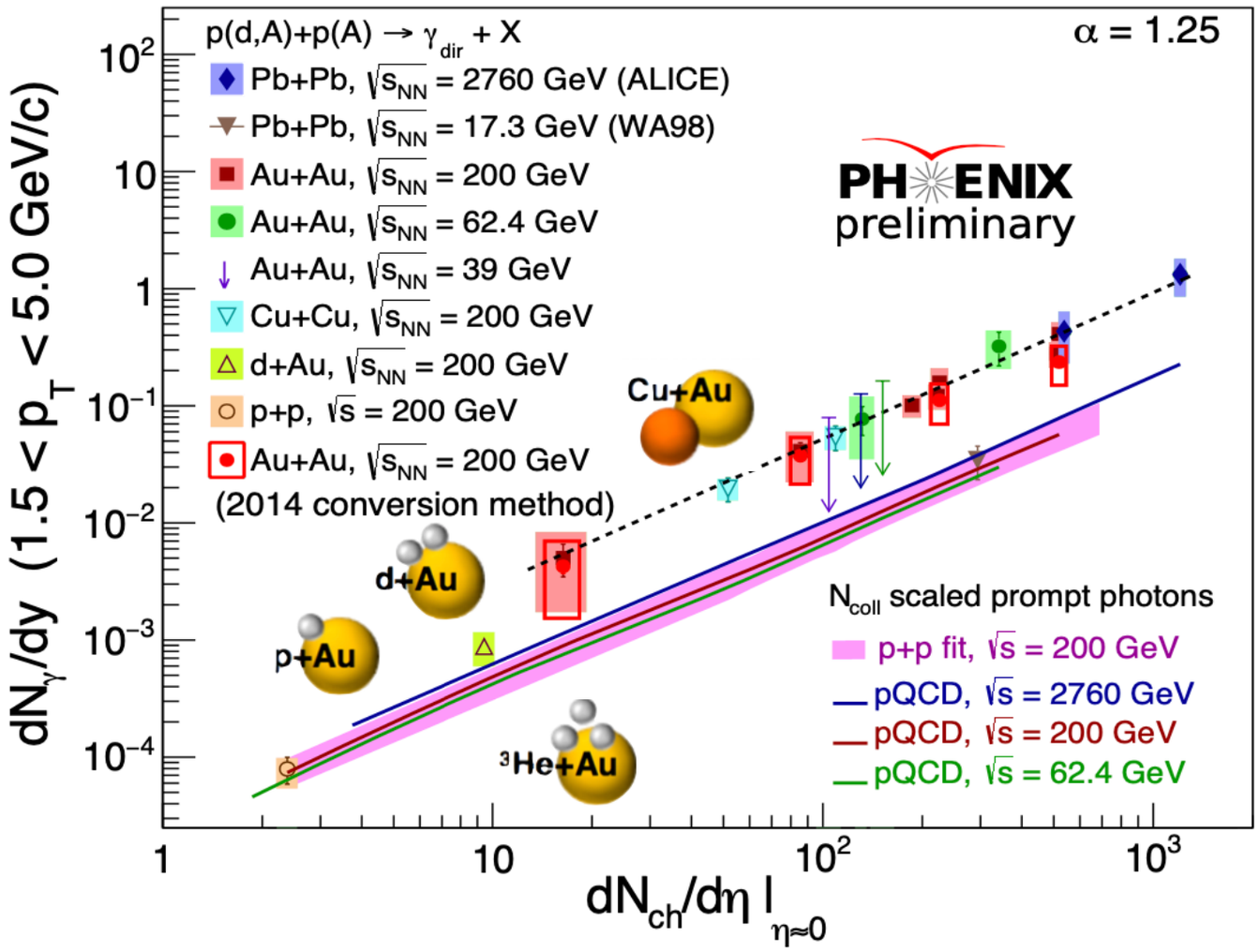


Summary and outlook

New Au+Au result are consistent with the observed scaling behavior in A+A systems

Filling the gaps:

- More peripheral Au+Au collisions
- Other systems are being analyzed/finalized



Thank you!