

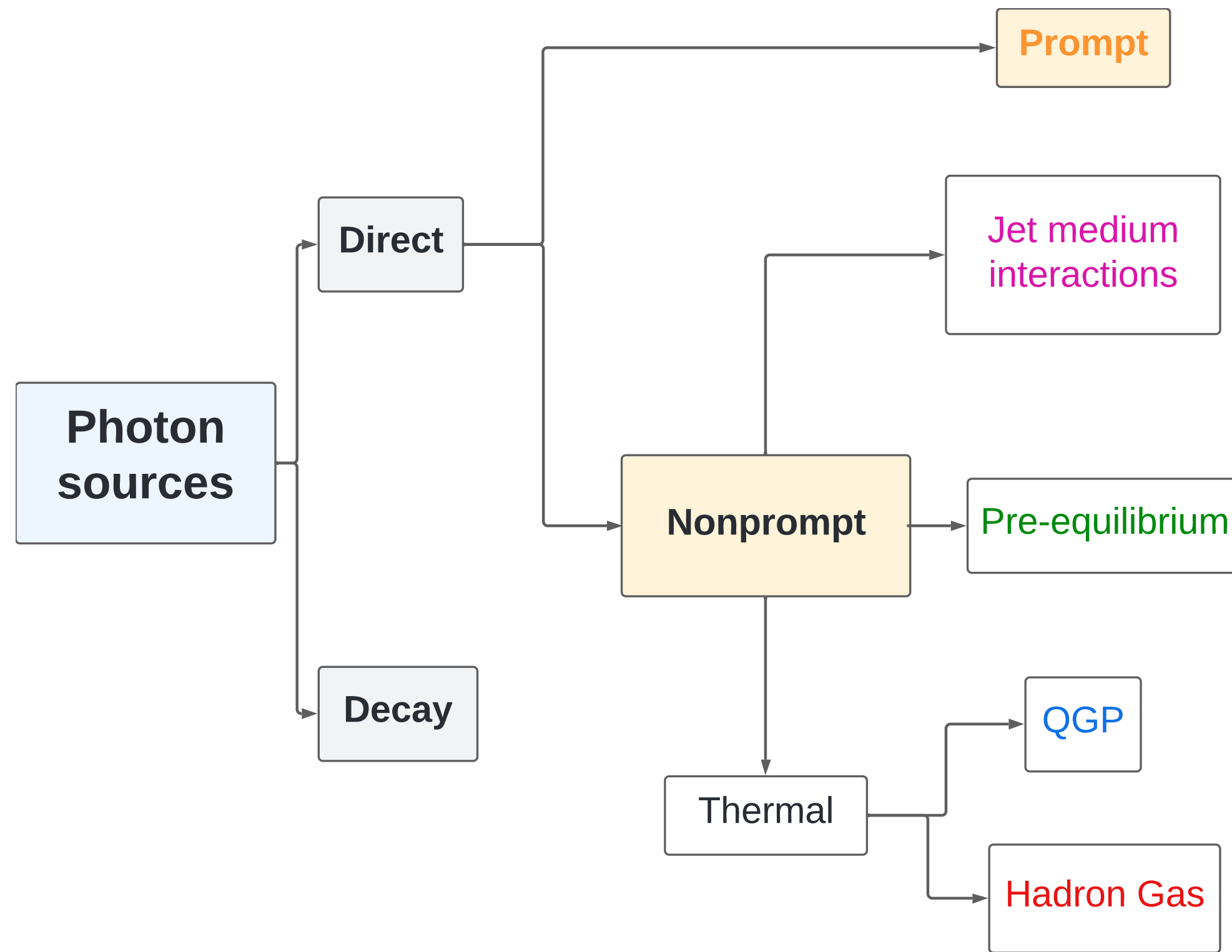


Measurement of low p_T direct photons with PHENIX

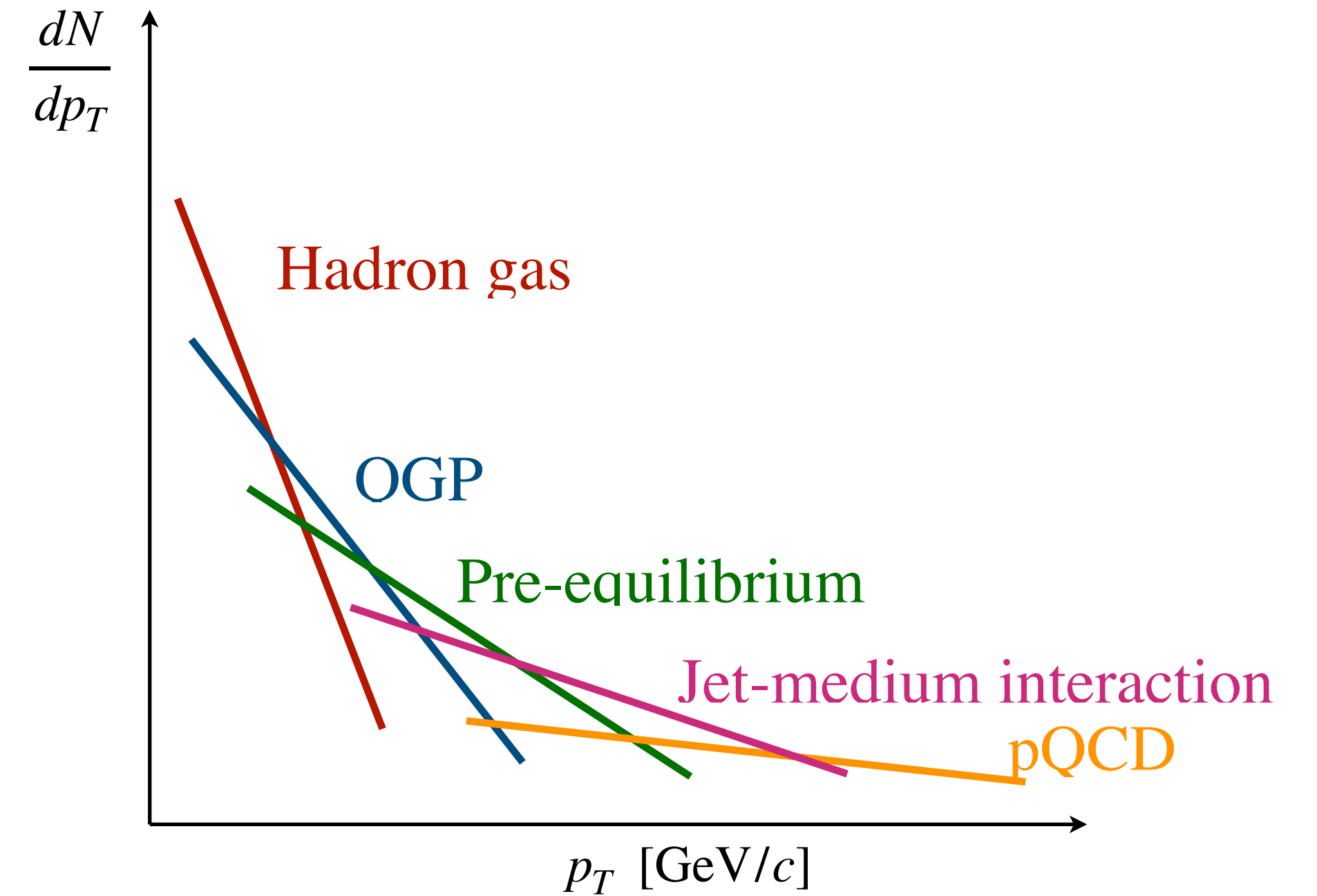
Roli Esha

Center for Frontiers in Nuclear Science
Stony Brook University





Photons are “color blind” probe of Quark Gluon Plasma

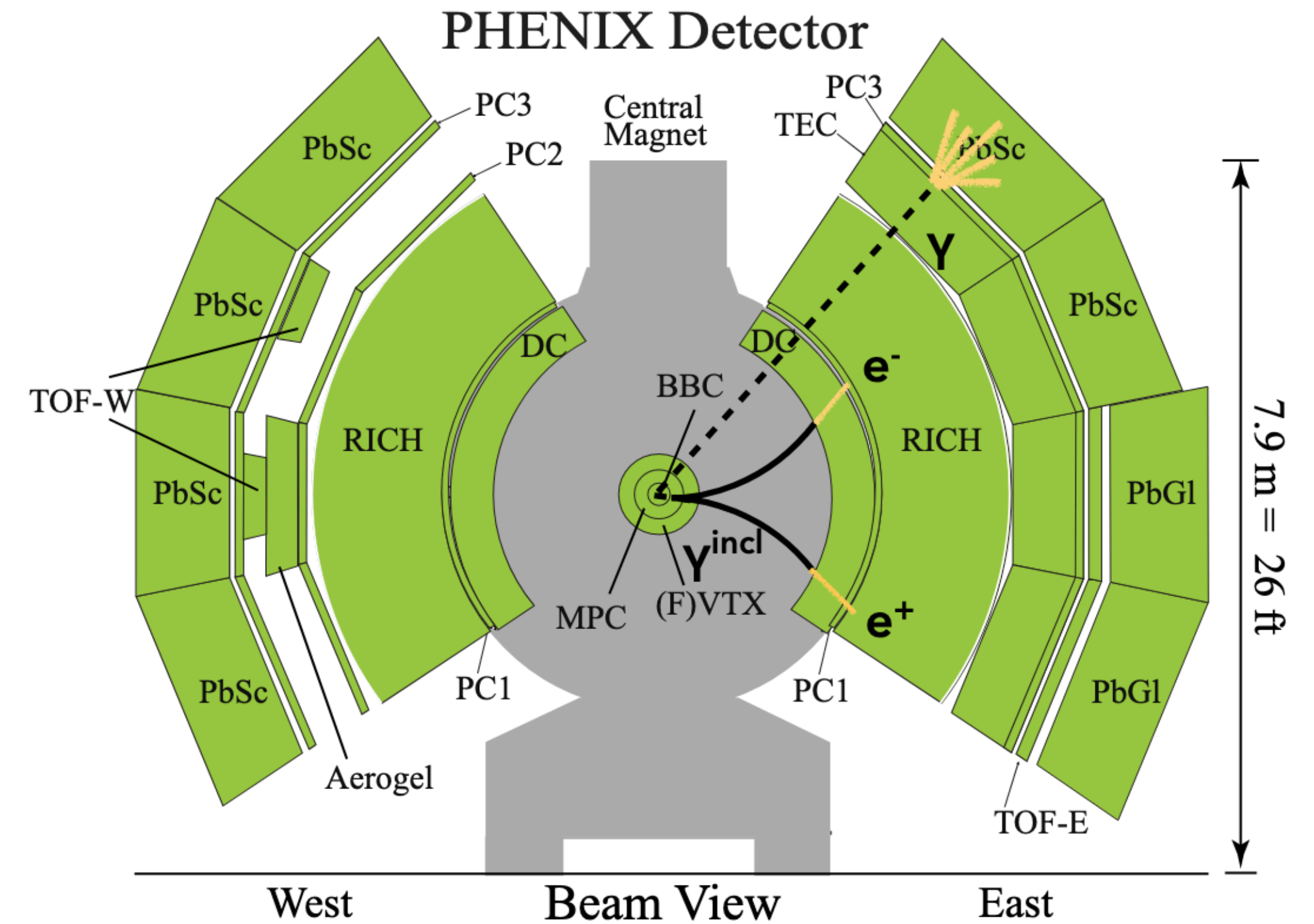
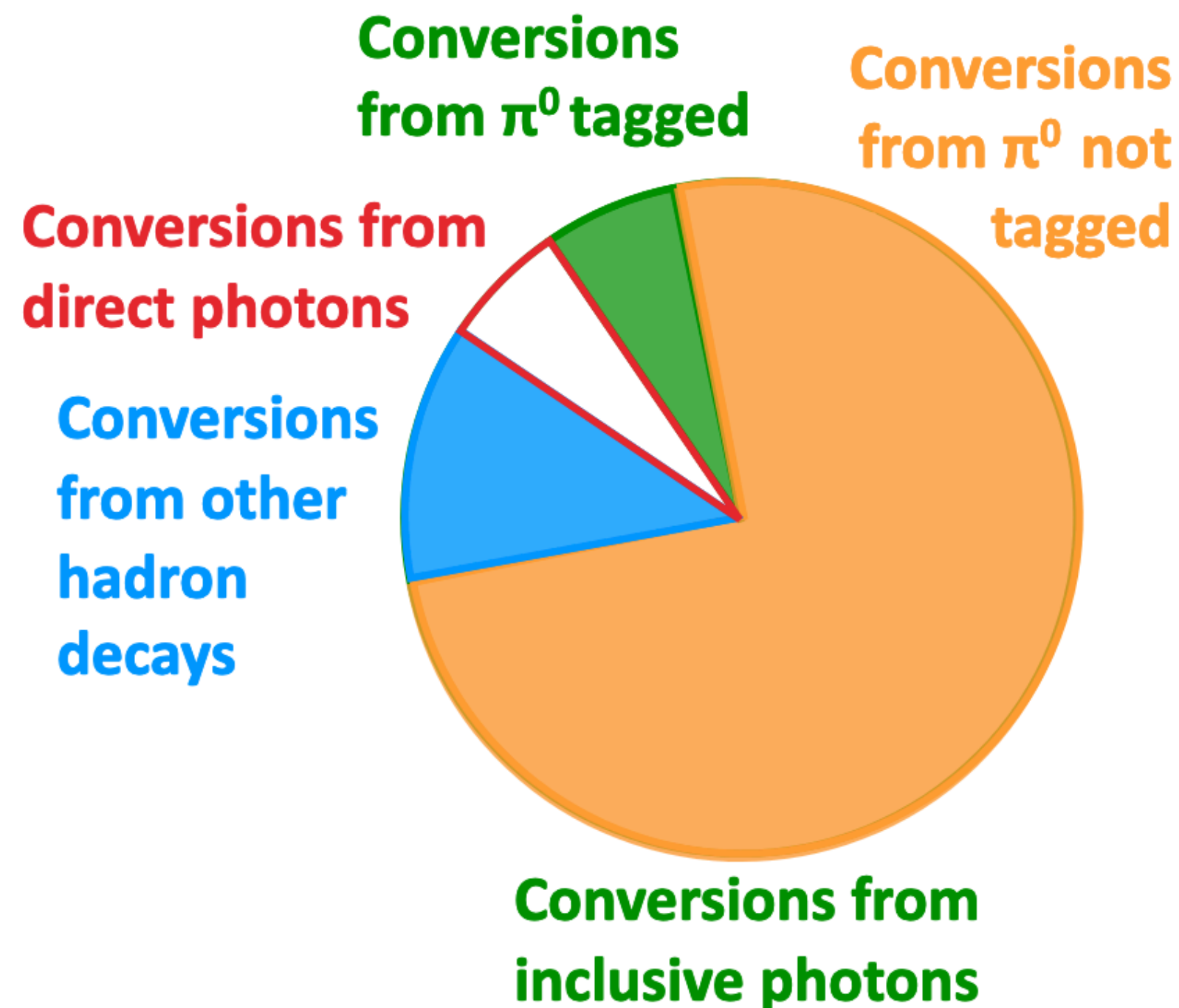


- Sensitive to **space-time evolution** and **temperature** of matter produced in relativistic heavy-ion collisions
- Evidence of thermal radiations from QGP and Hadron Gas

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

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

$$\gamma_{\text{direct}} = (R_\gamma - 1) \gamma_{\text{hadron}}$$

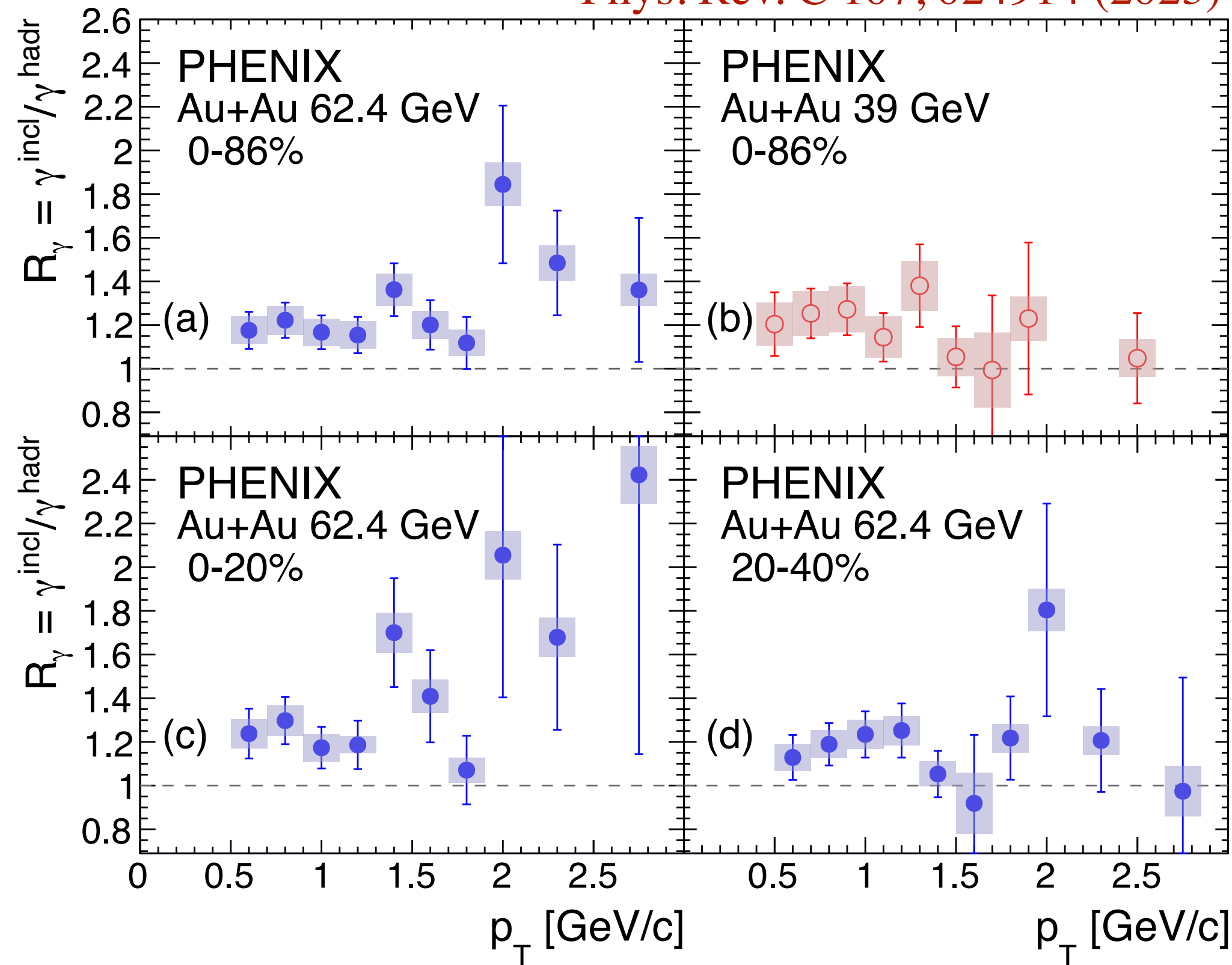


Double ratio tagging method reduces systematic uncertainties

PHENIX Direct γ for Au+Au at 39 and 62.4 GeV

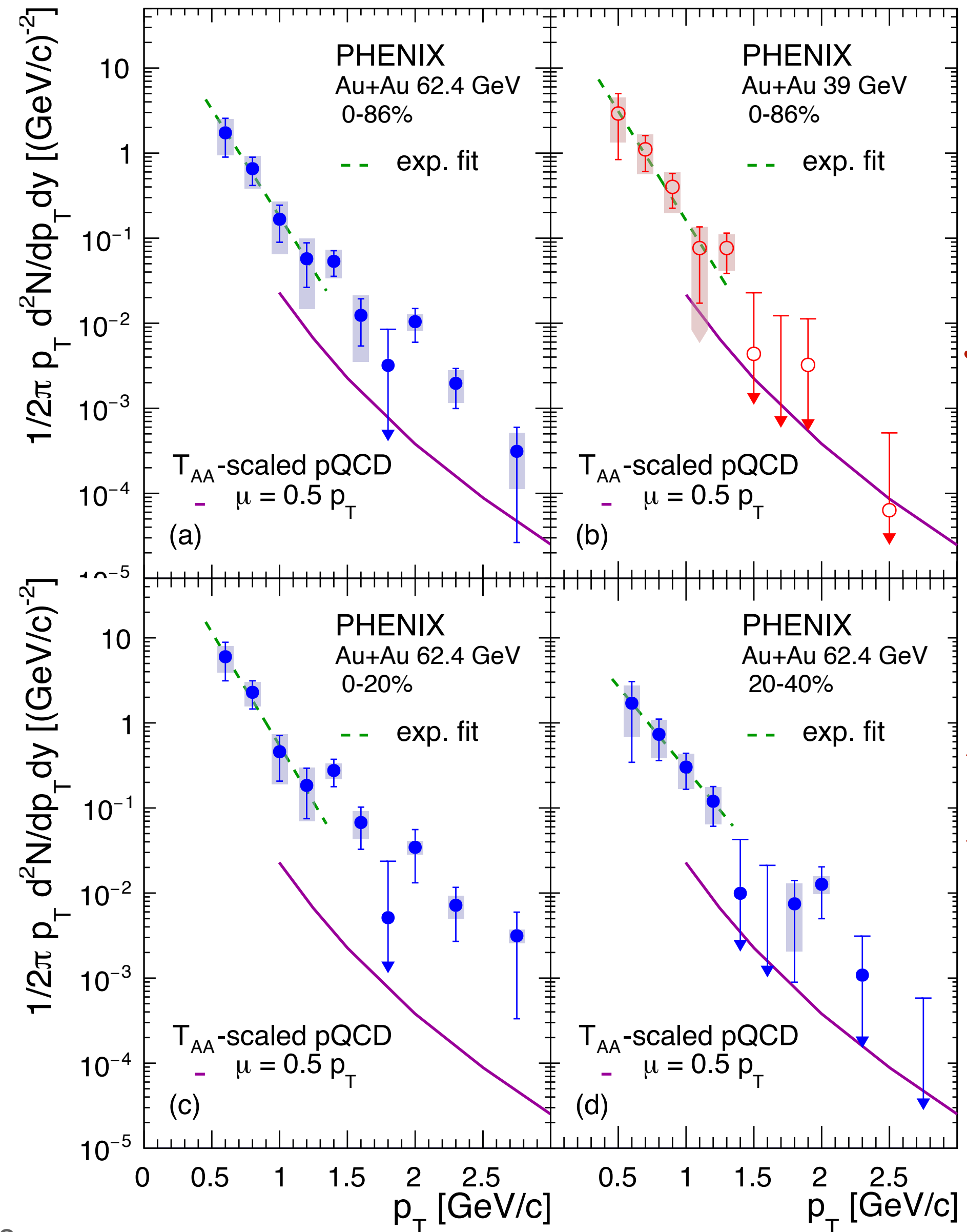


Phys. Rev. C 107, 024914 (2023)

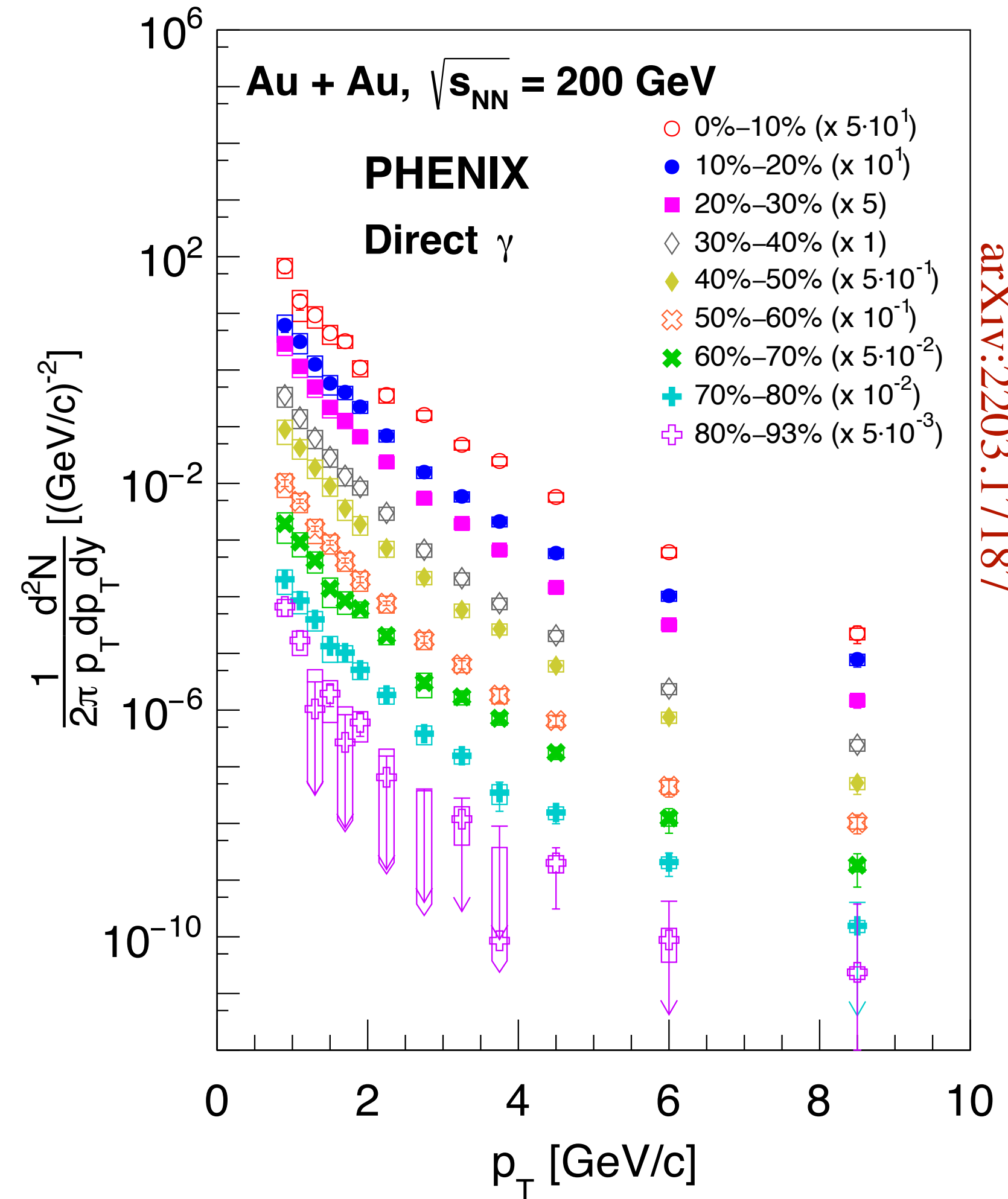
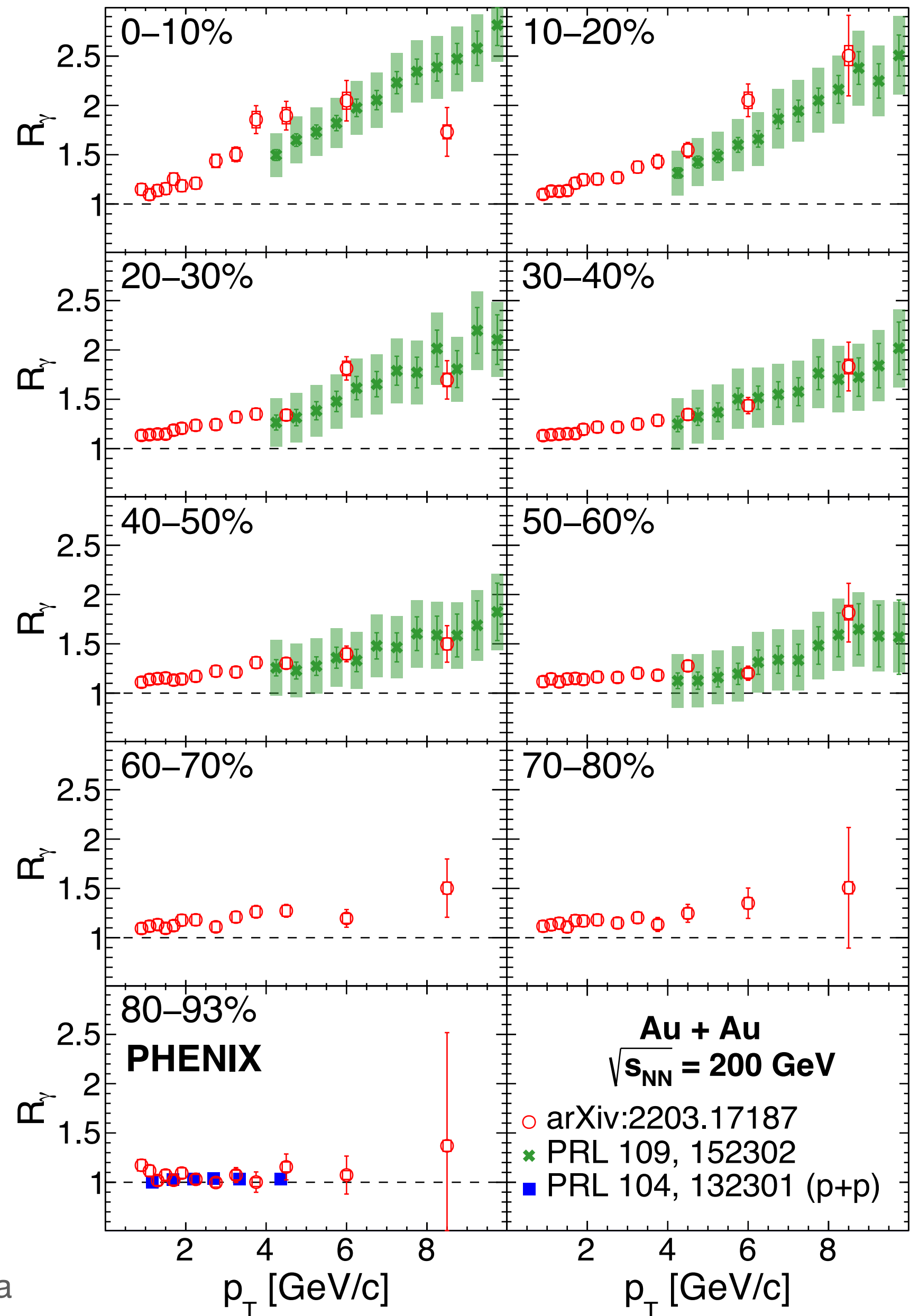


Conversions on the backplane of Hadron Blind detector

Significant direct photon component relative to those from hadron decays



Phys. Rev. C 107, 024914 (2023)

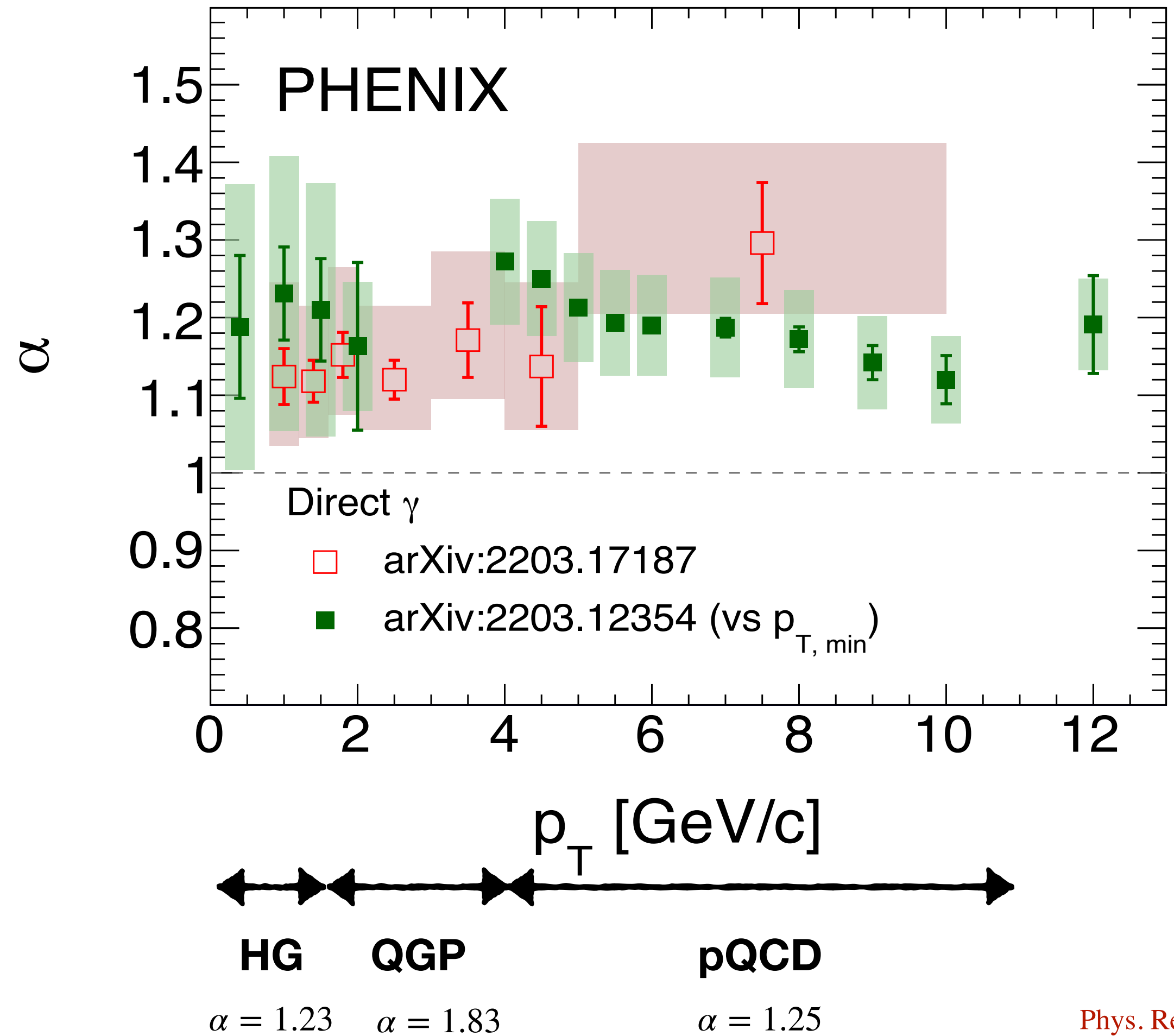
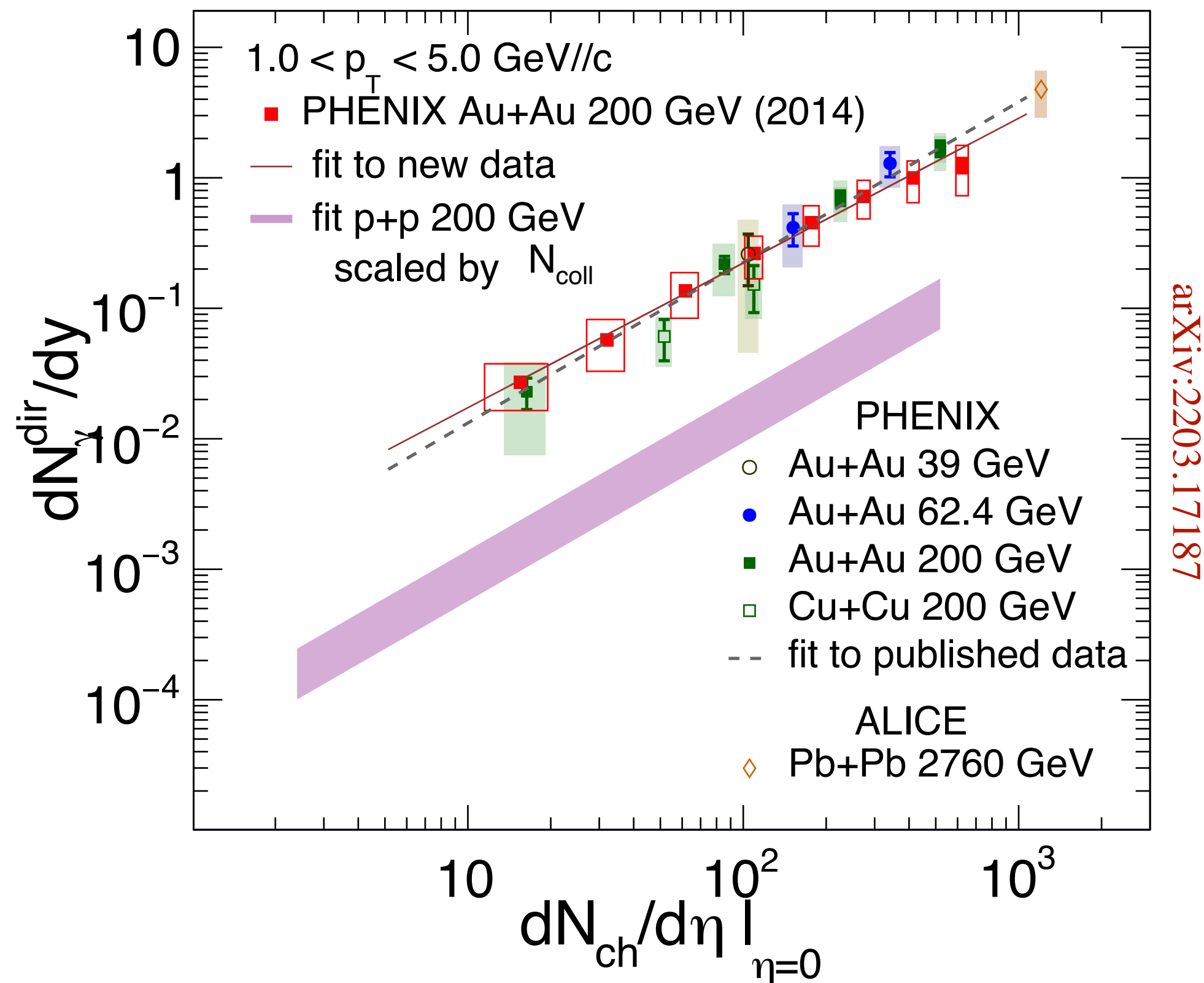


Conversions in the layers of the Silicon Vertex detectors

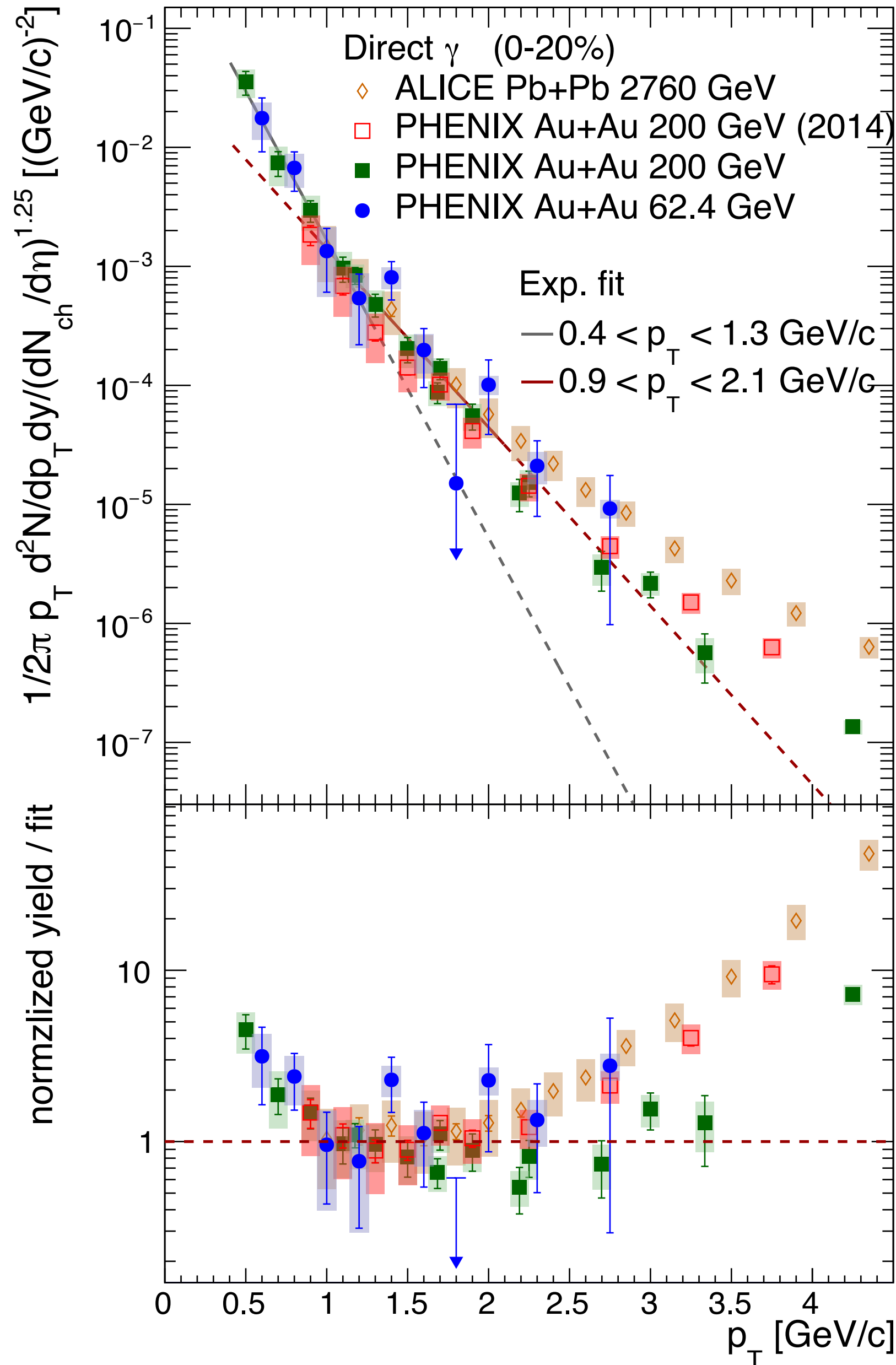


$$dN_\gamma/dy = A \times (dN_{ch}/d\eta)^\alpha$$

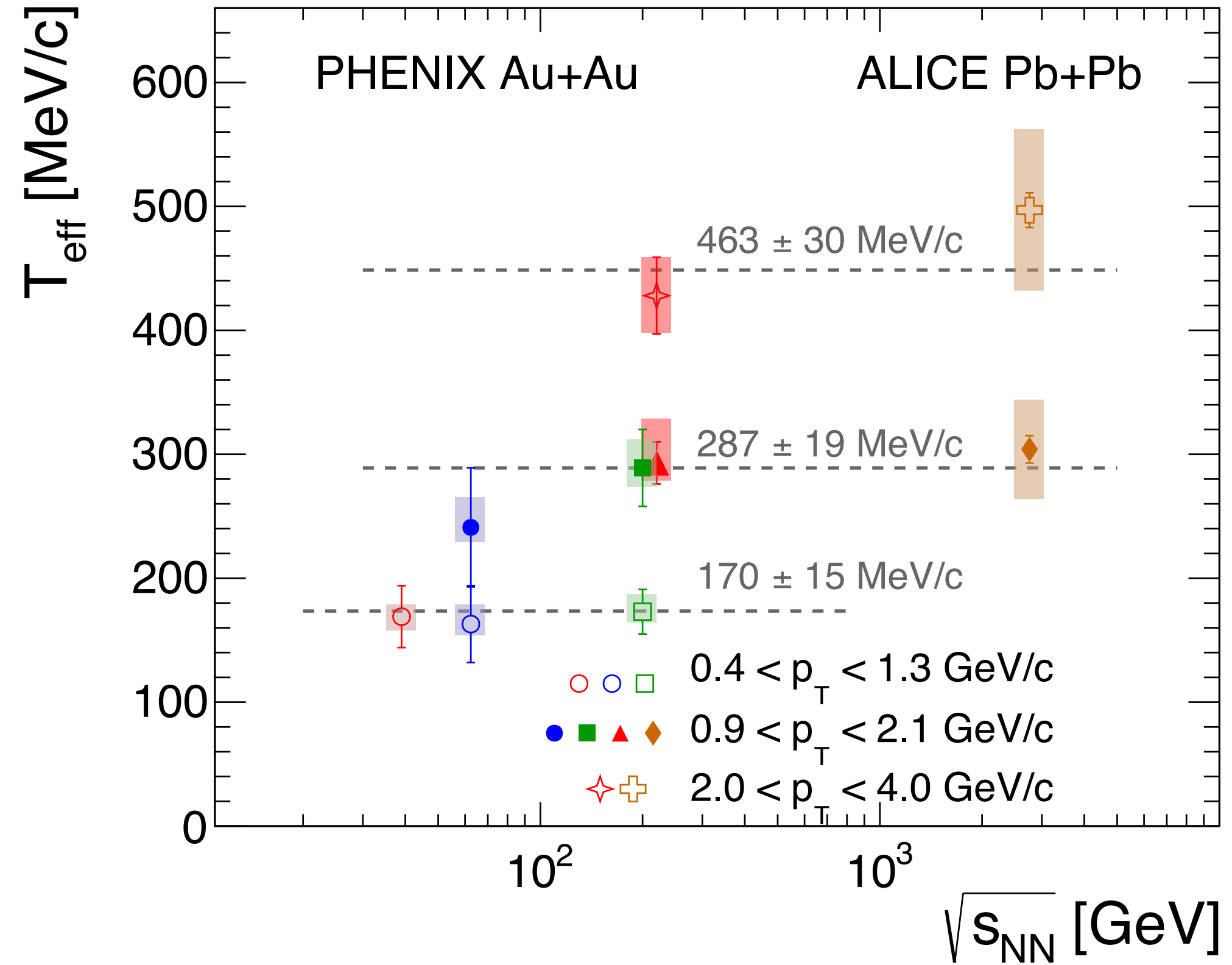
Universal scaling behavior in all A+A systems



$\alpha > 1$ and independent of p_T

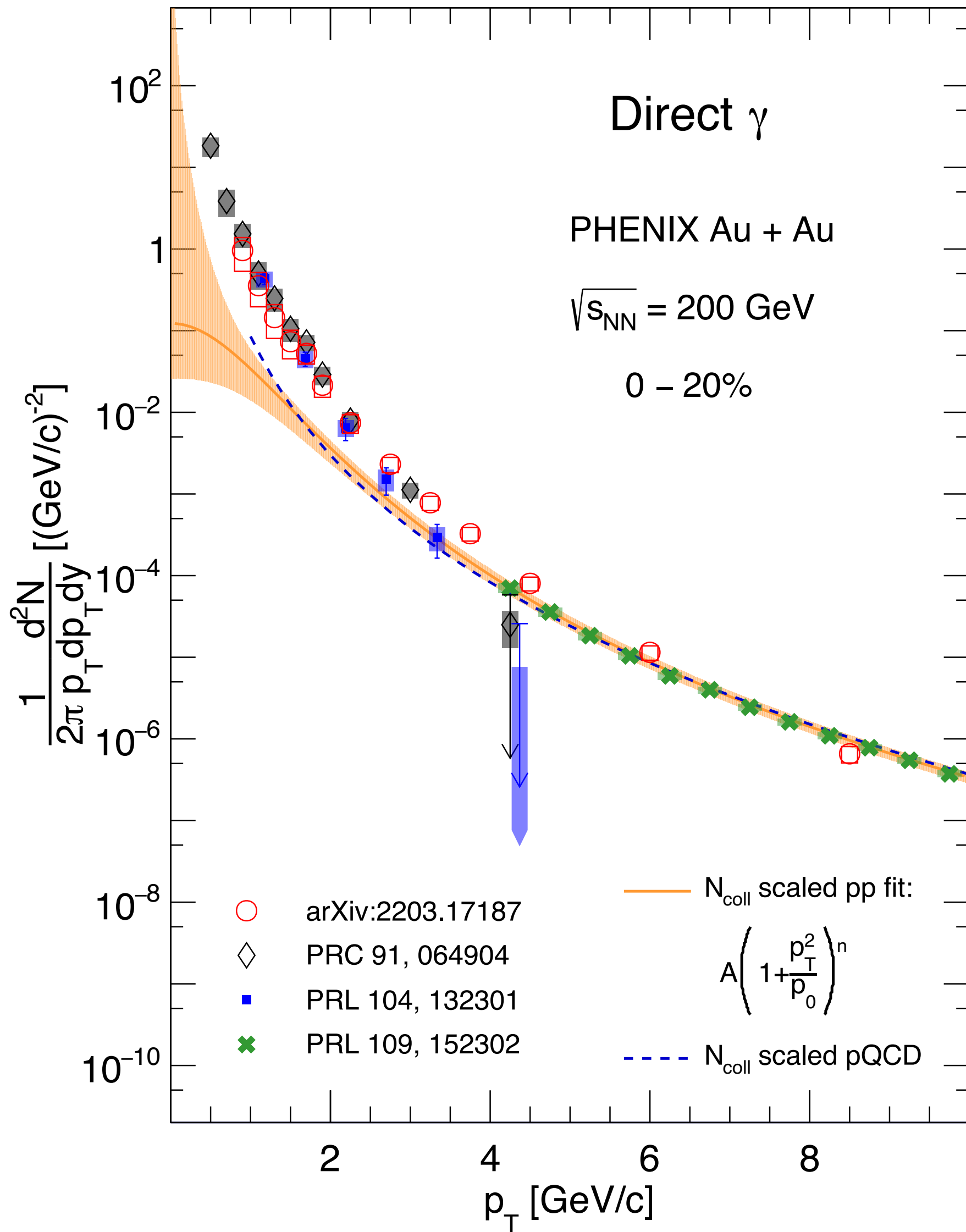


Phys. Rev. C 107, 024914 (2023), arXiv:2203.17187



Phys. Rev. C 107, 024914 (2023)
arXiv:2203.17187

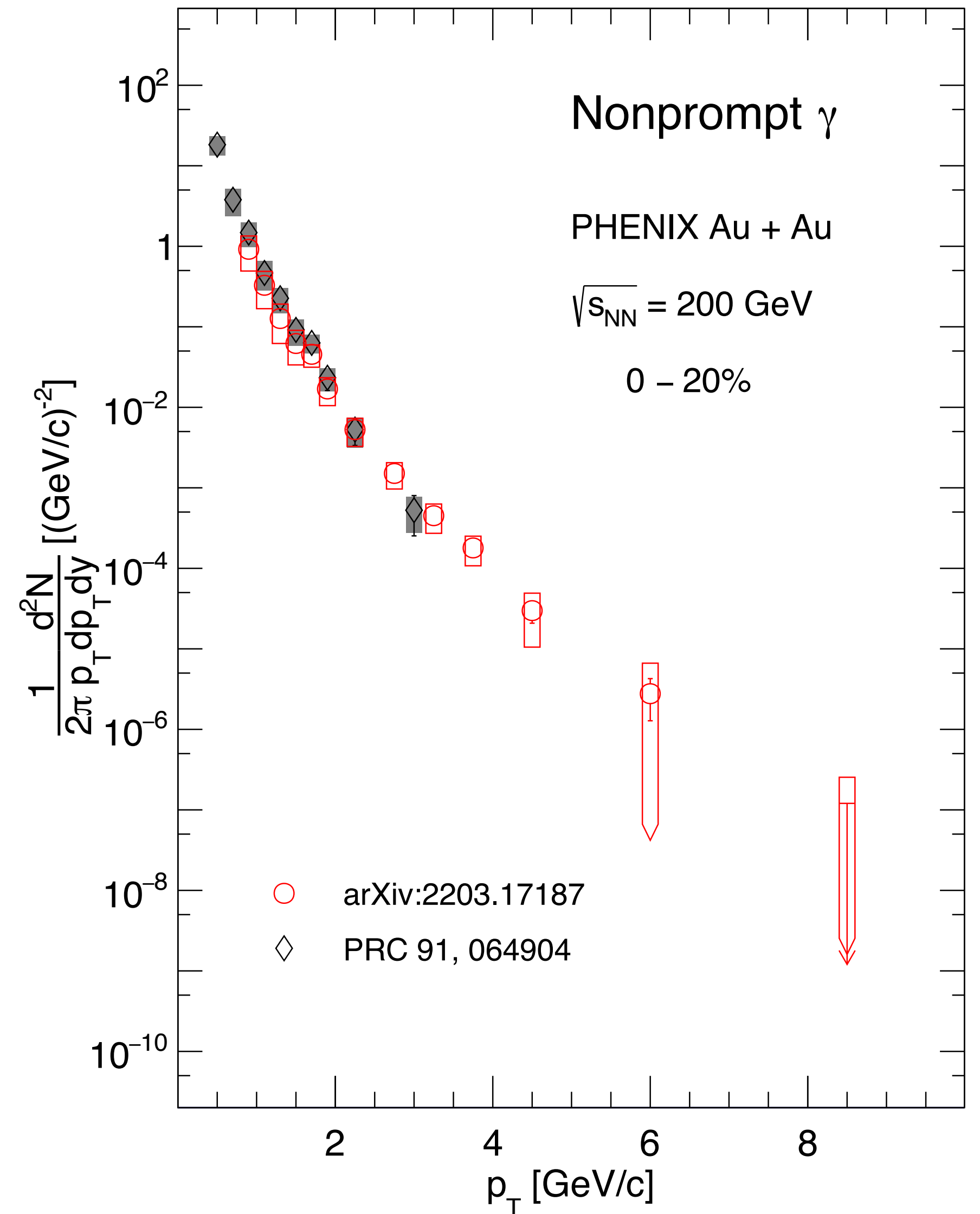
Similar spectra around 2 GeV/c — common source of photon production independent of $\sqrt{s_{NN}}$

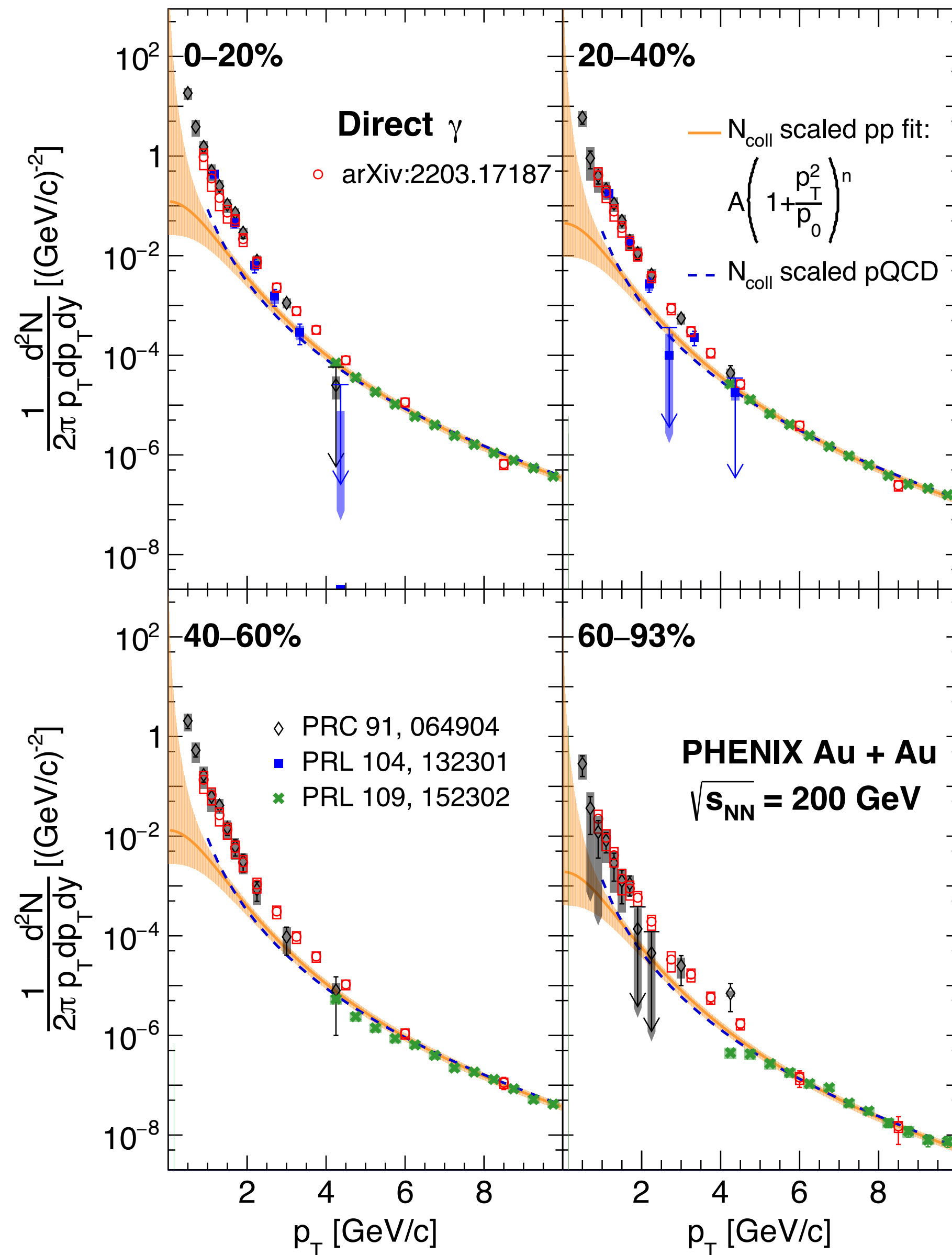


Direct photon

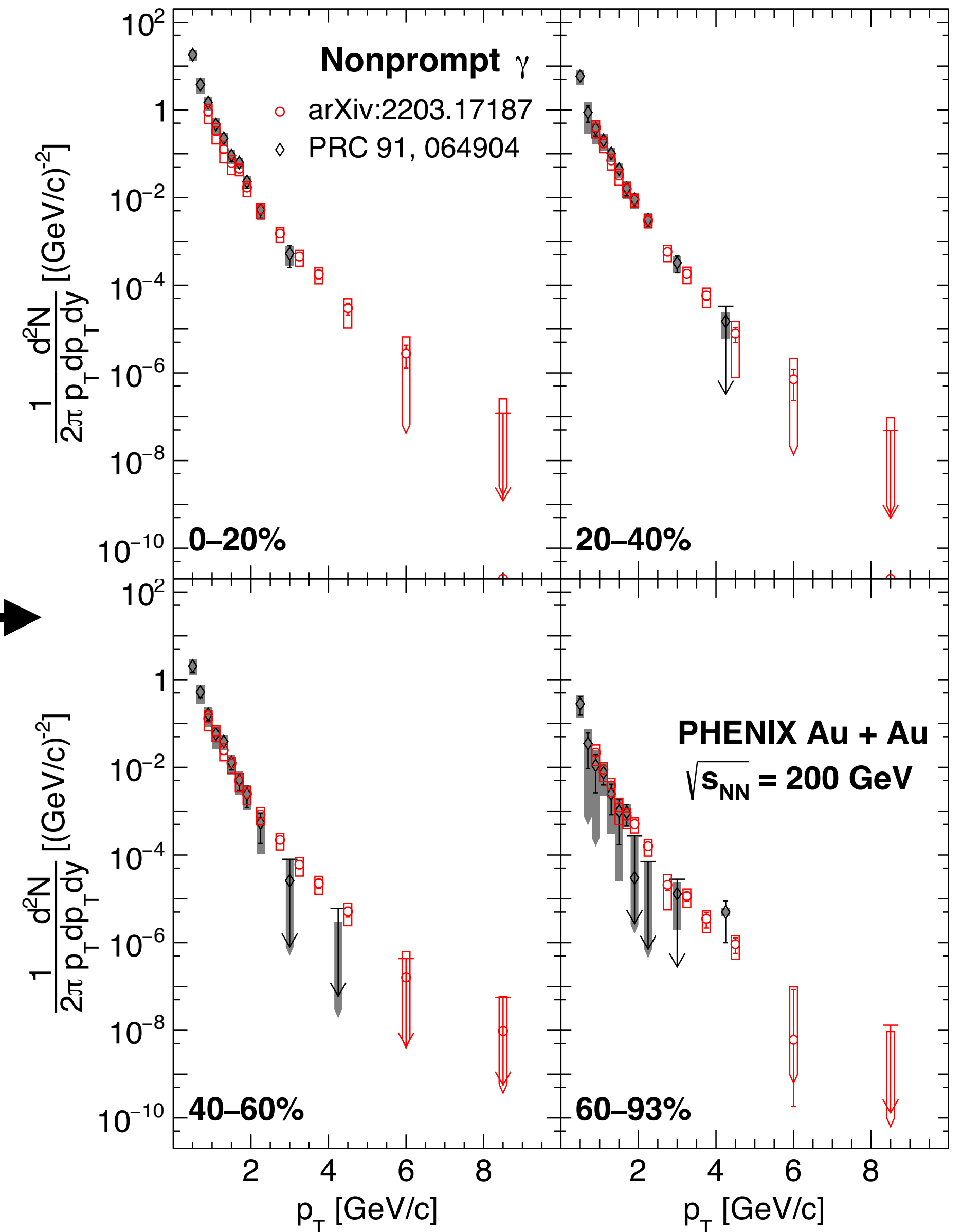
— N_{coll} scaled
p+p fit

**Non-prompt
direct photon**





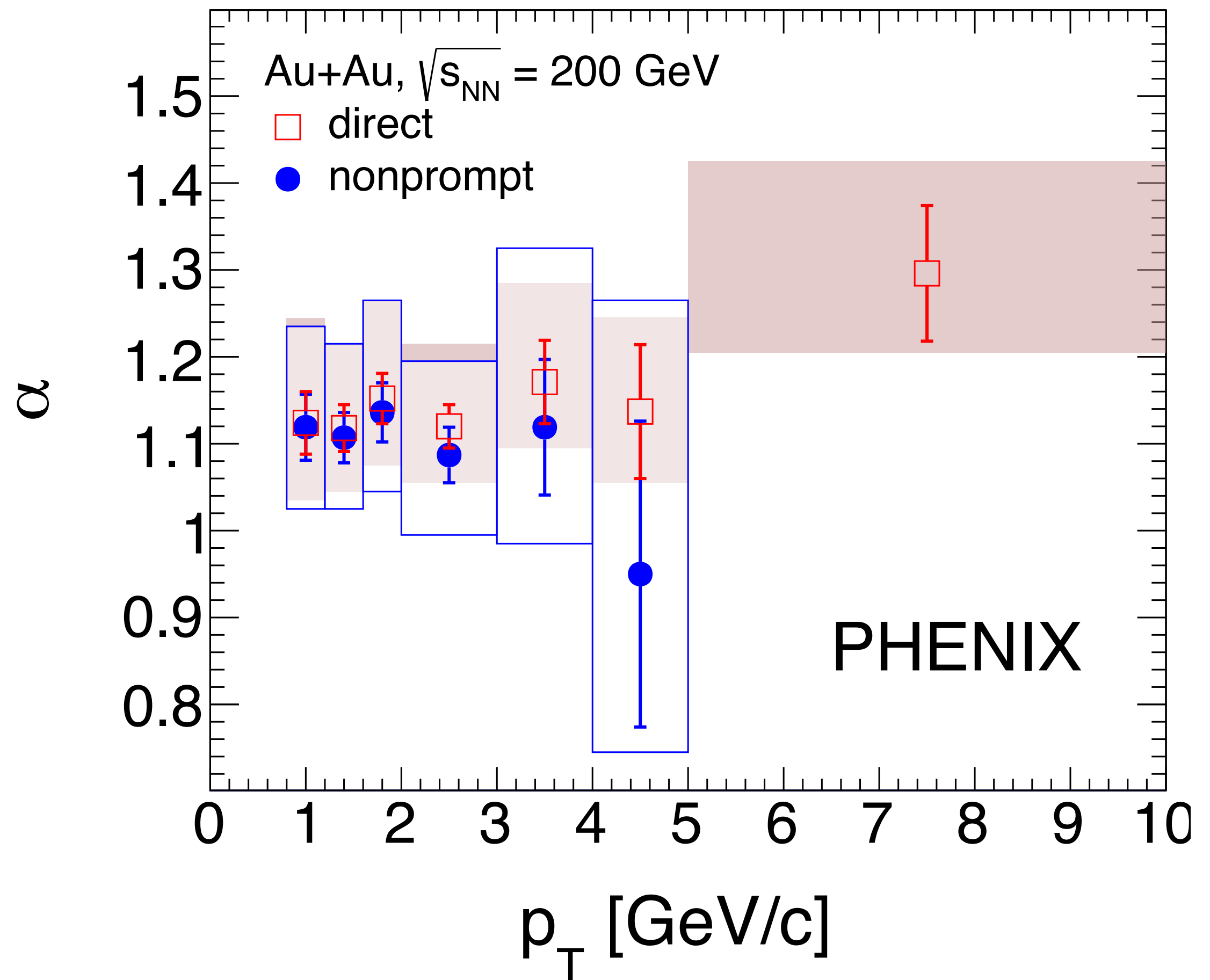
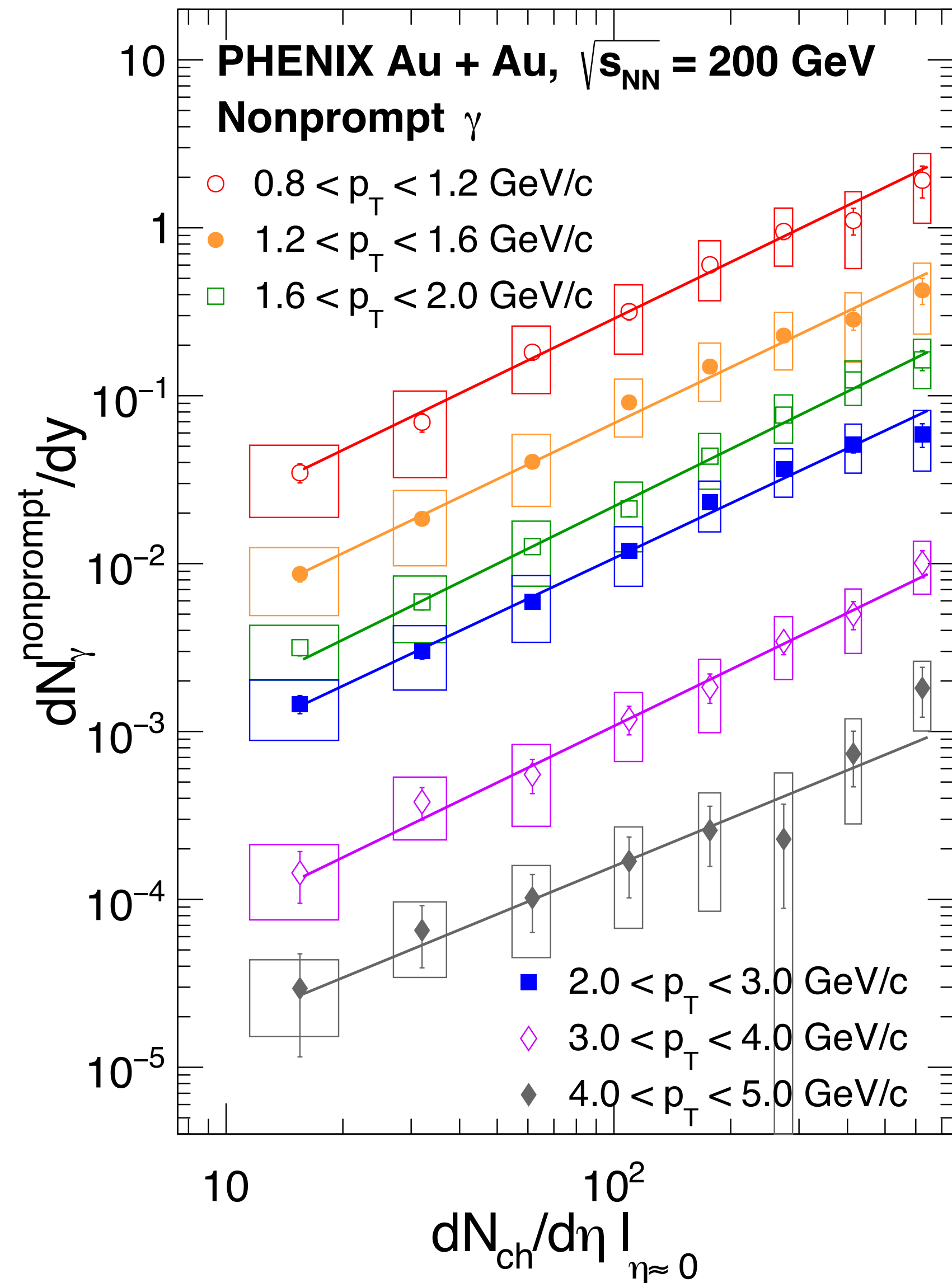
— N_{coll} scaled
p+p fit



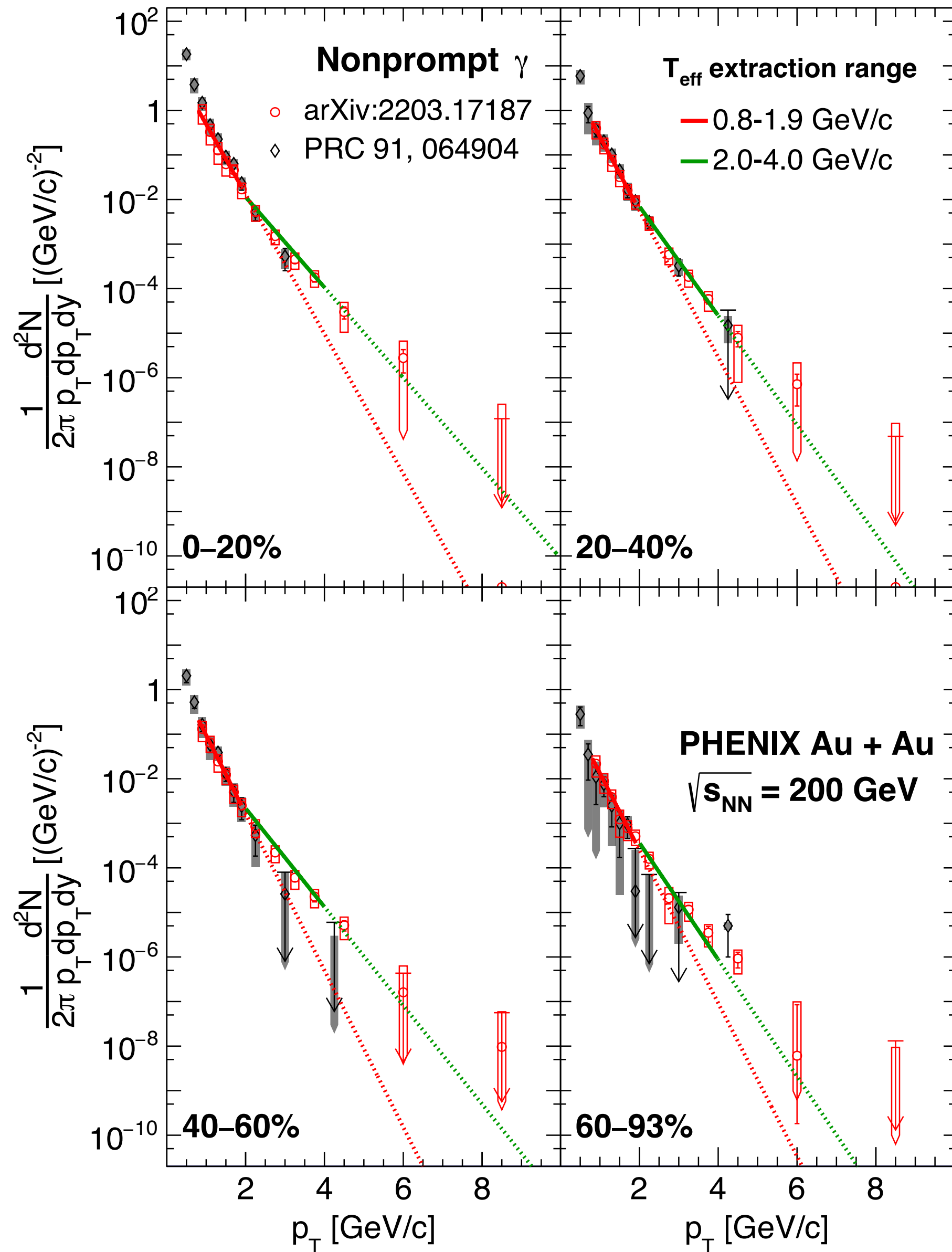


arXiv:2203.17187

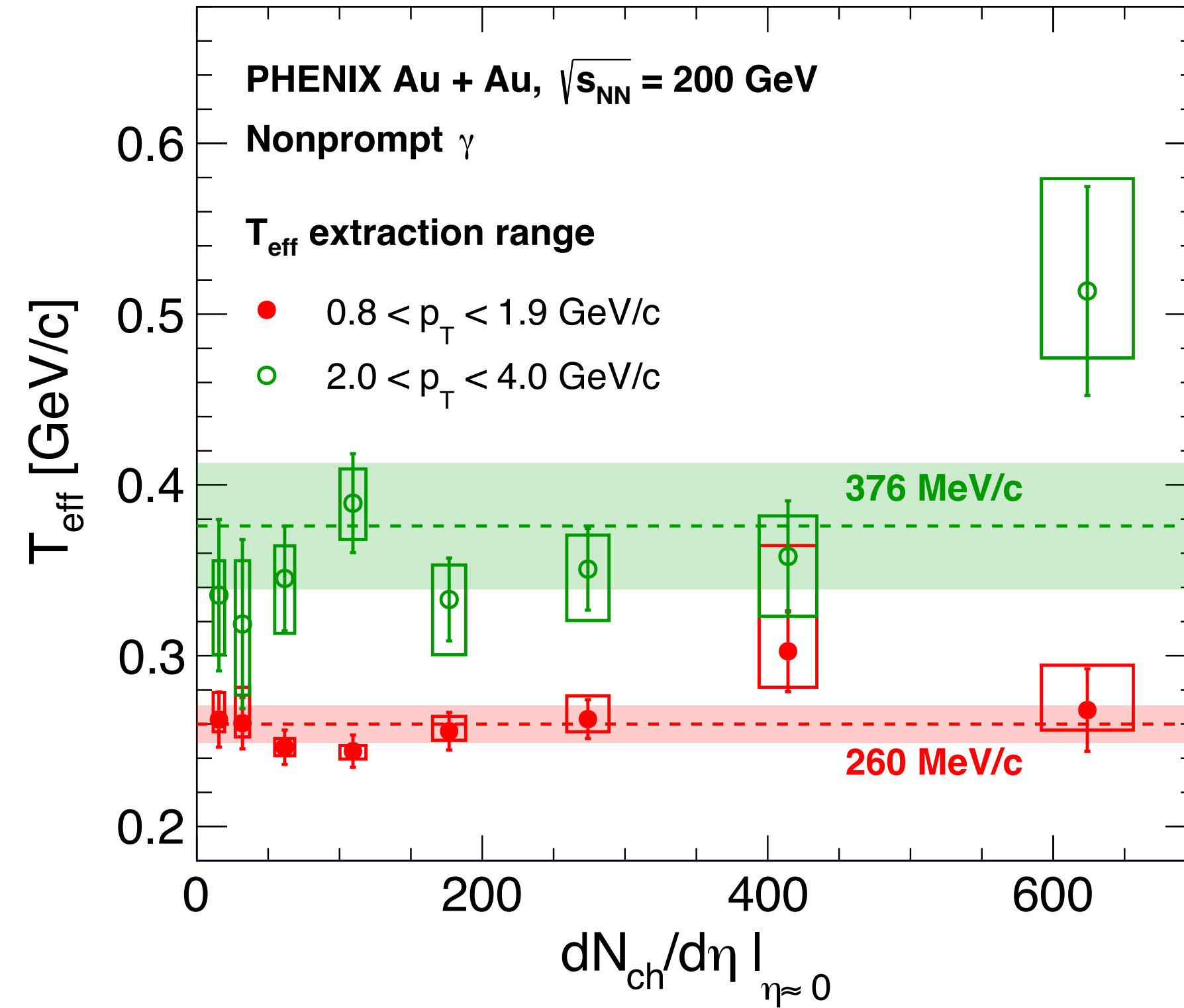
arXiv:2203.17187



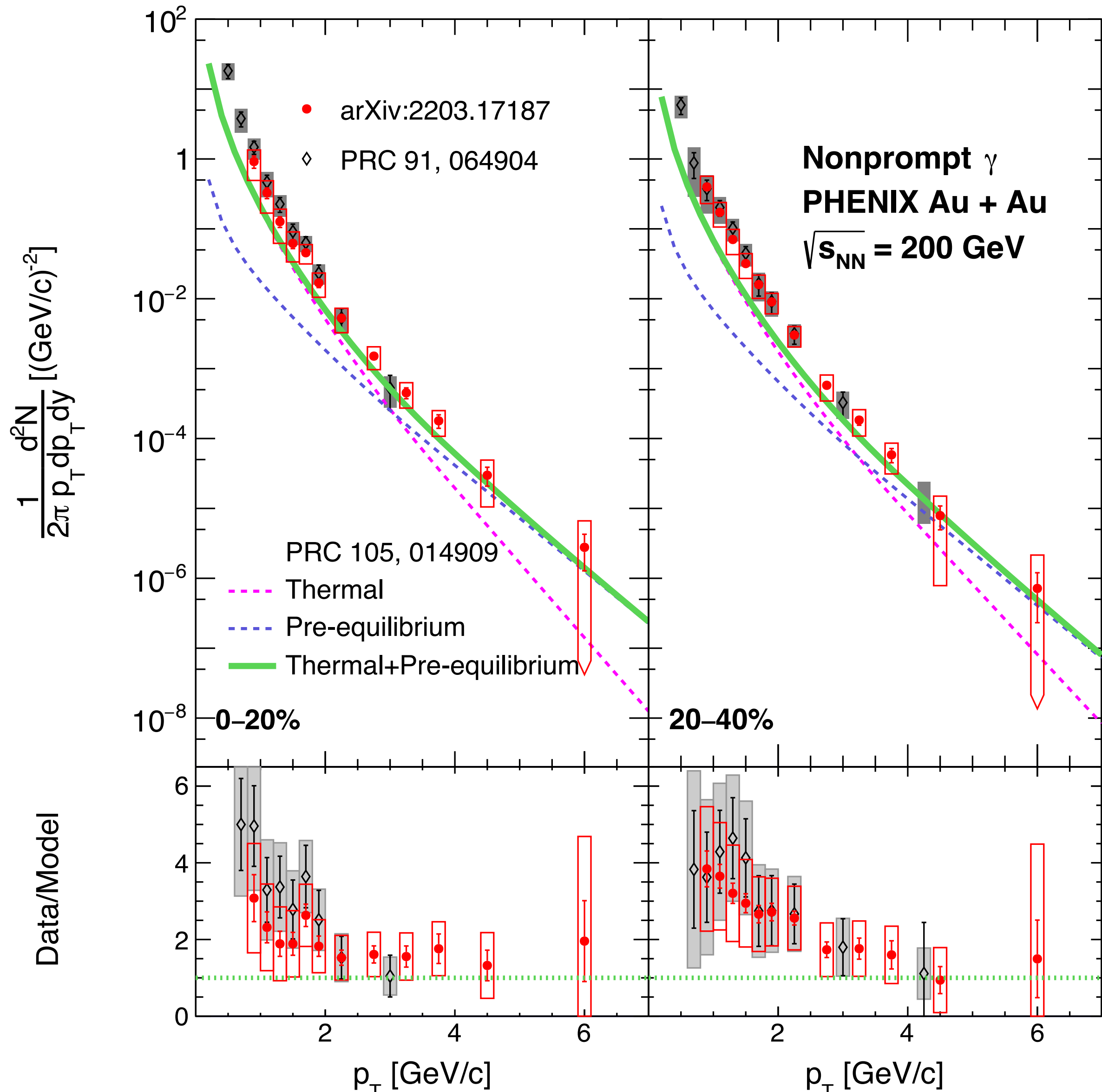
α independent of p_T for direct and nonprompt photons



arXiv:2203.17187



Increasing inverse slope with p_T to above 350 MeV/c suggests contributions from sources beyond those from Hadron Gas



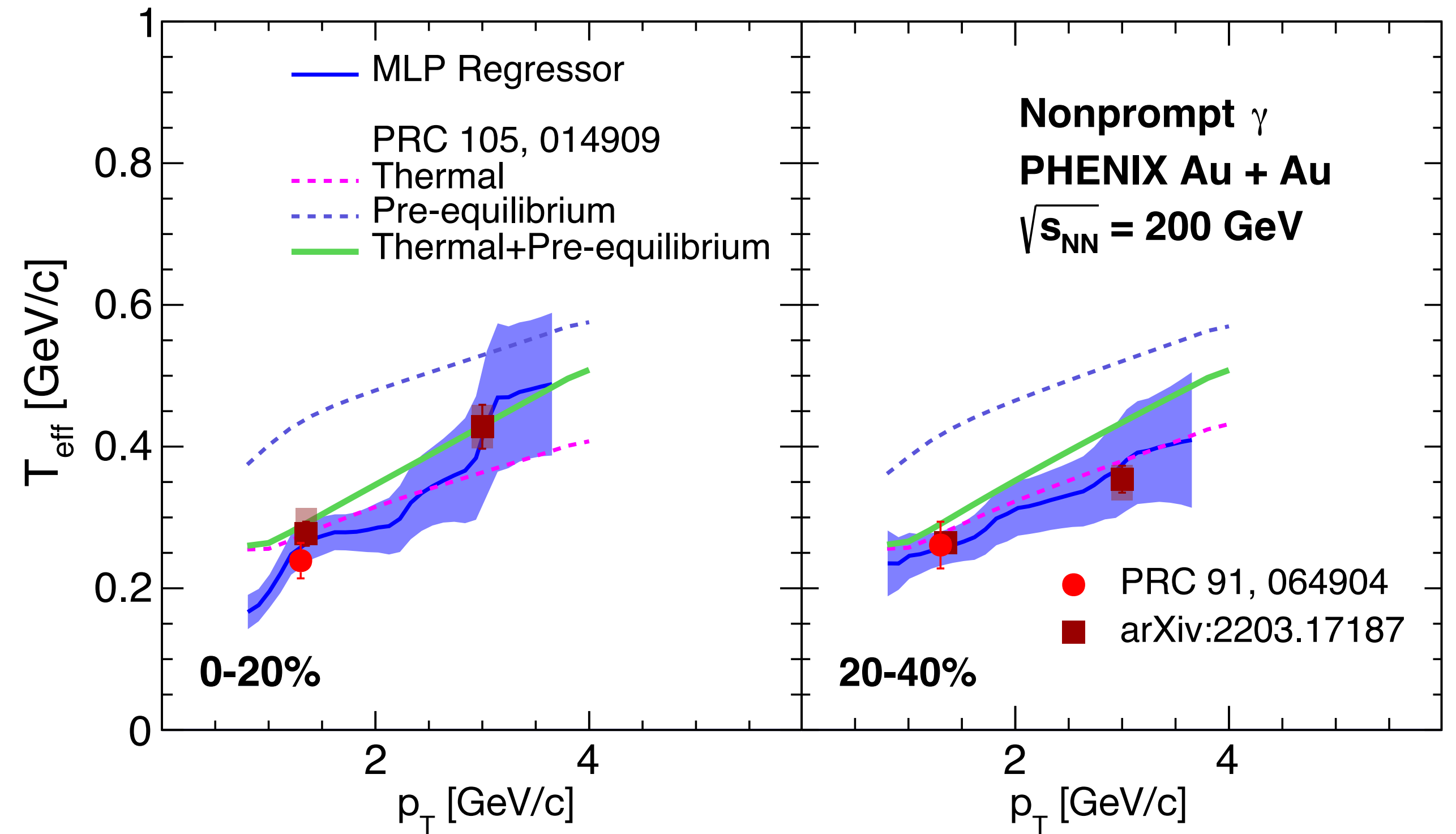
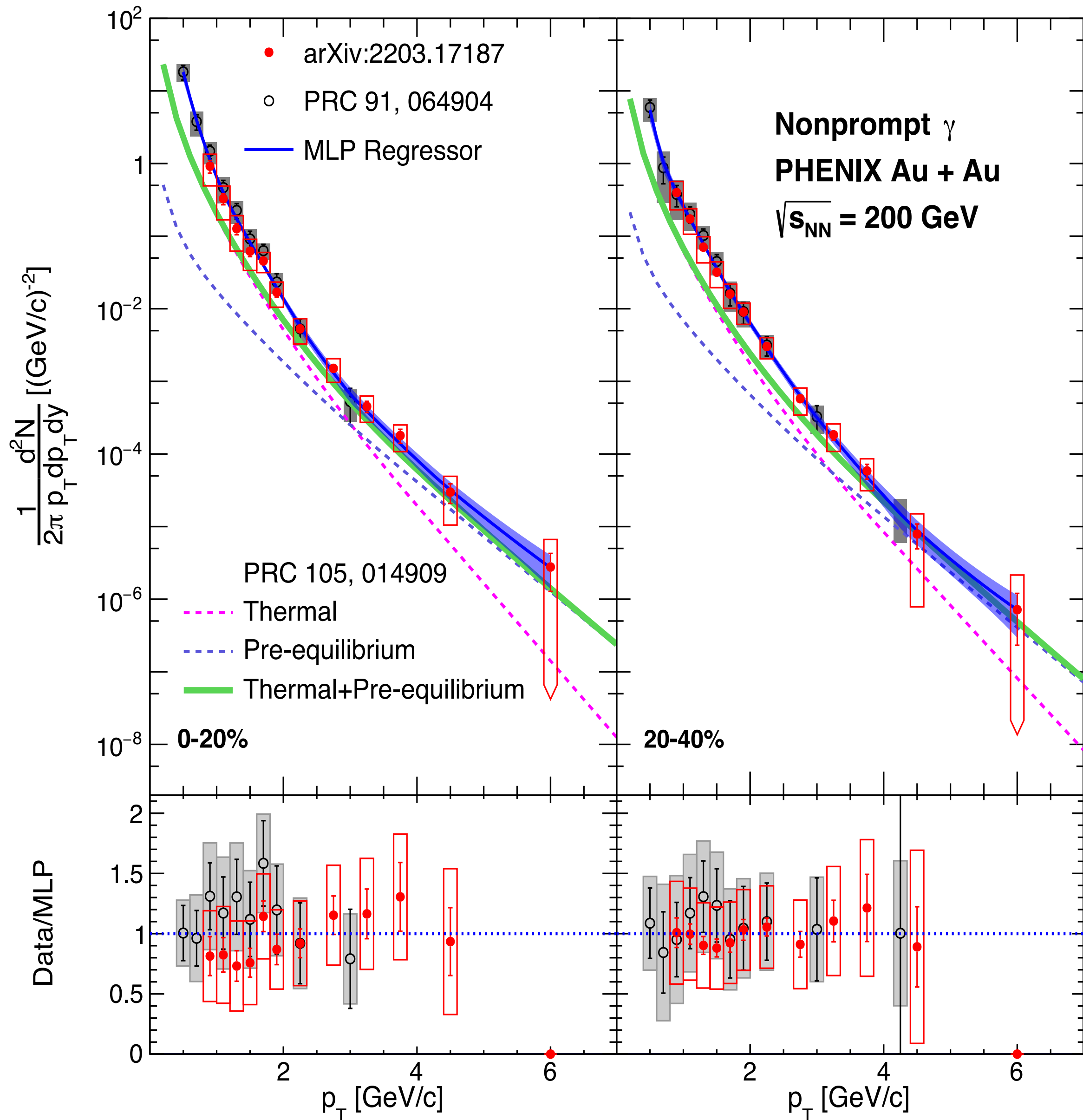
C. Gale, J.-F. Paquet, B. Schenke & C. Shen,
 Phys. Rev. C **105** (2022) 014909

Multi-messenger heavy-ion physics

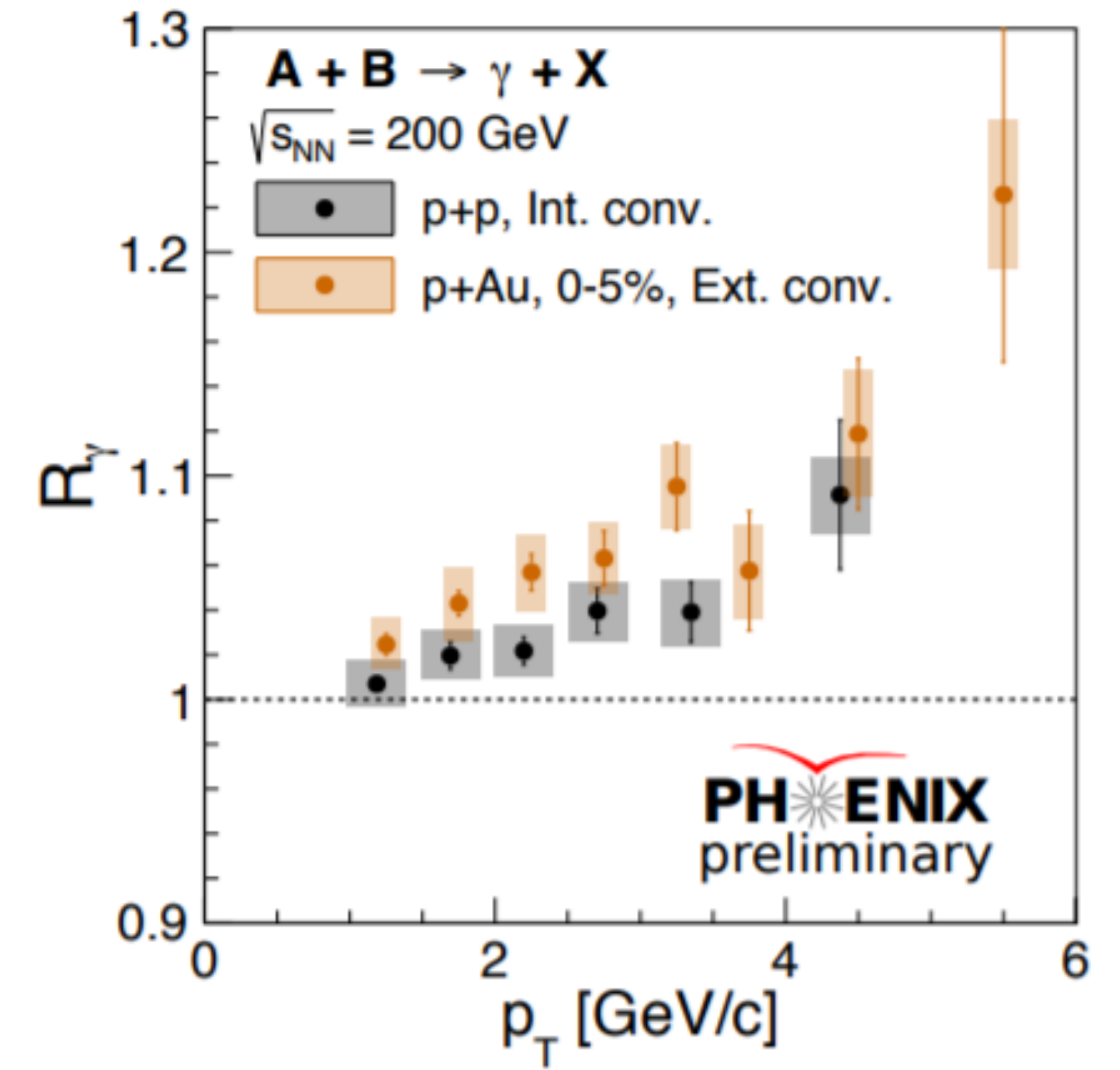
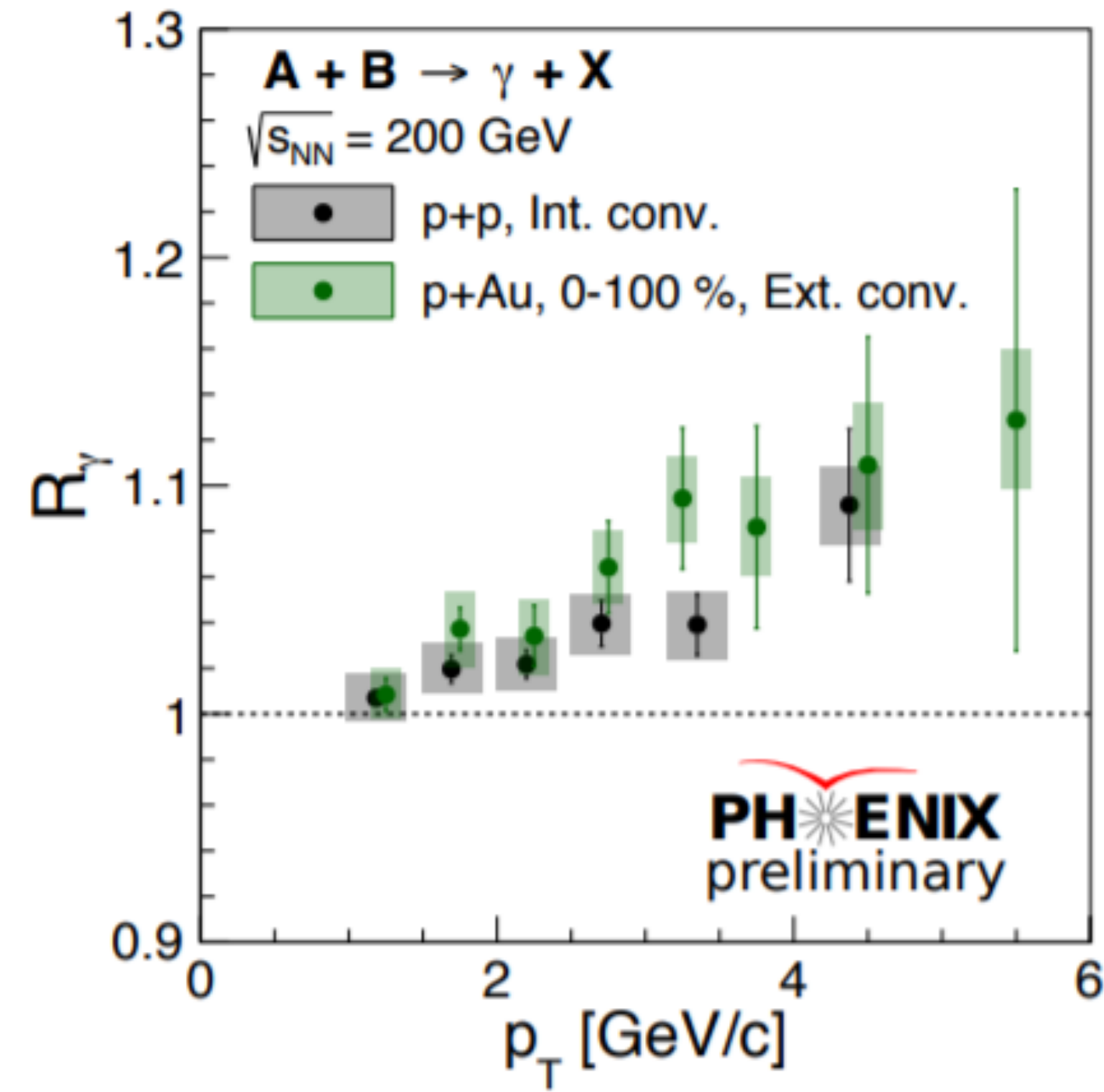
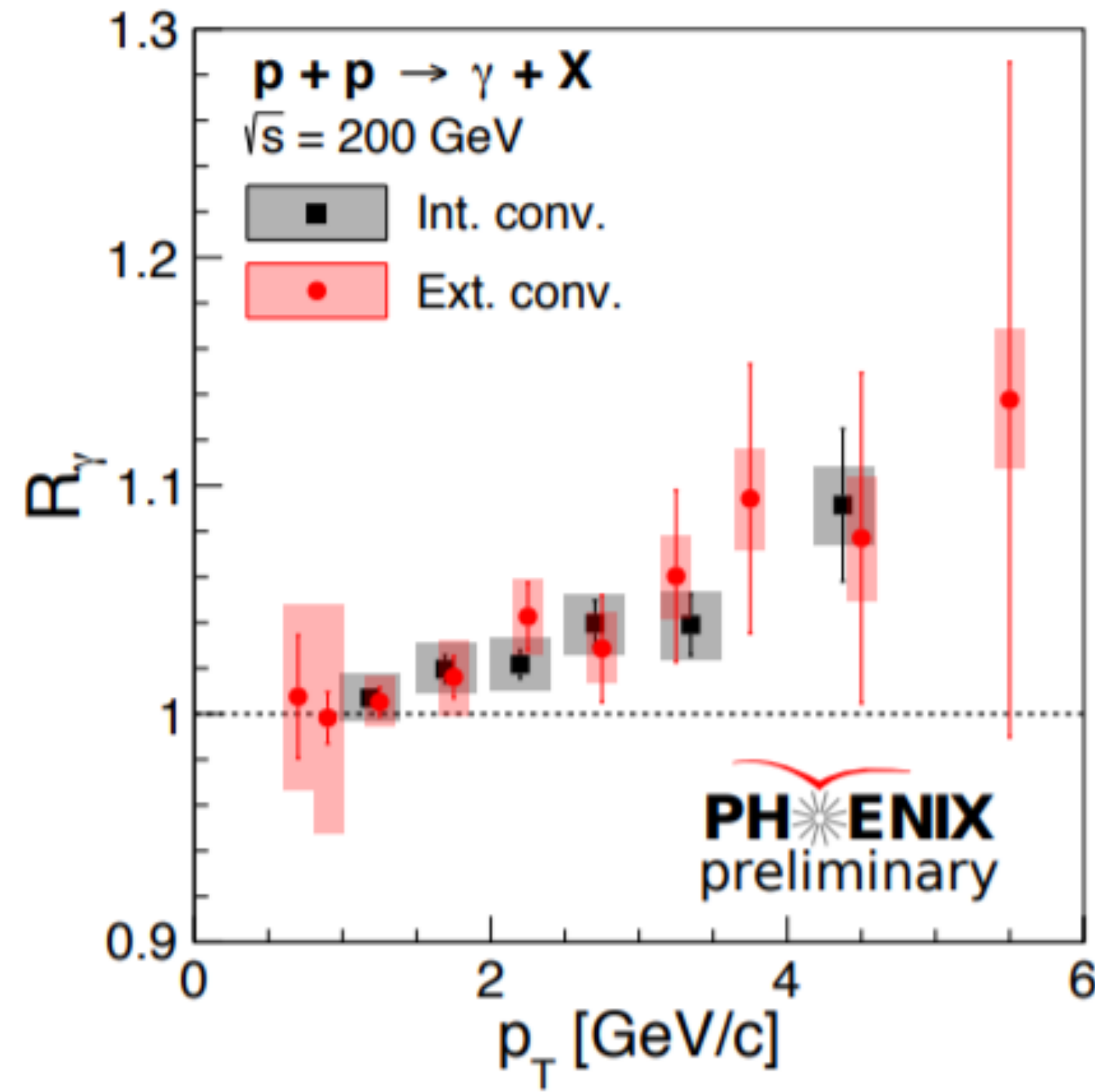
- Hybrid model that describes all stages of relativistic heavy-ion collisions
- Effect of the pre-equilibrium phase on both photonic and hadronic observables highlighted

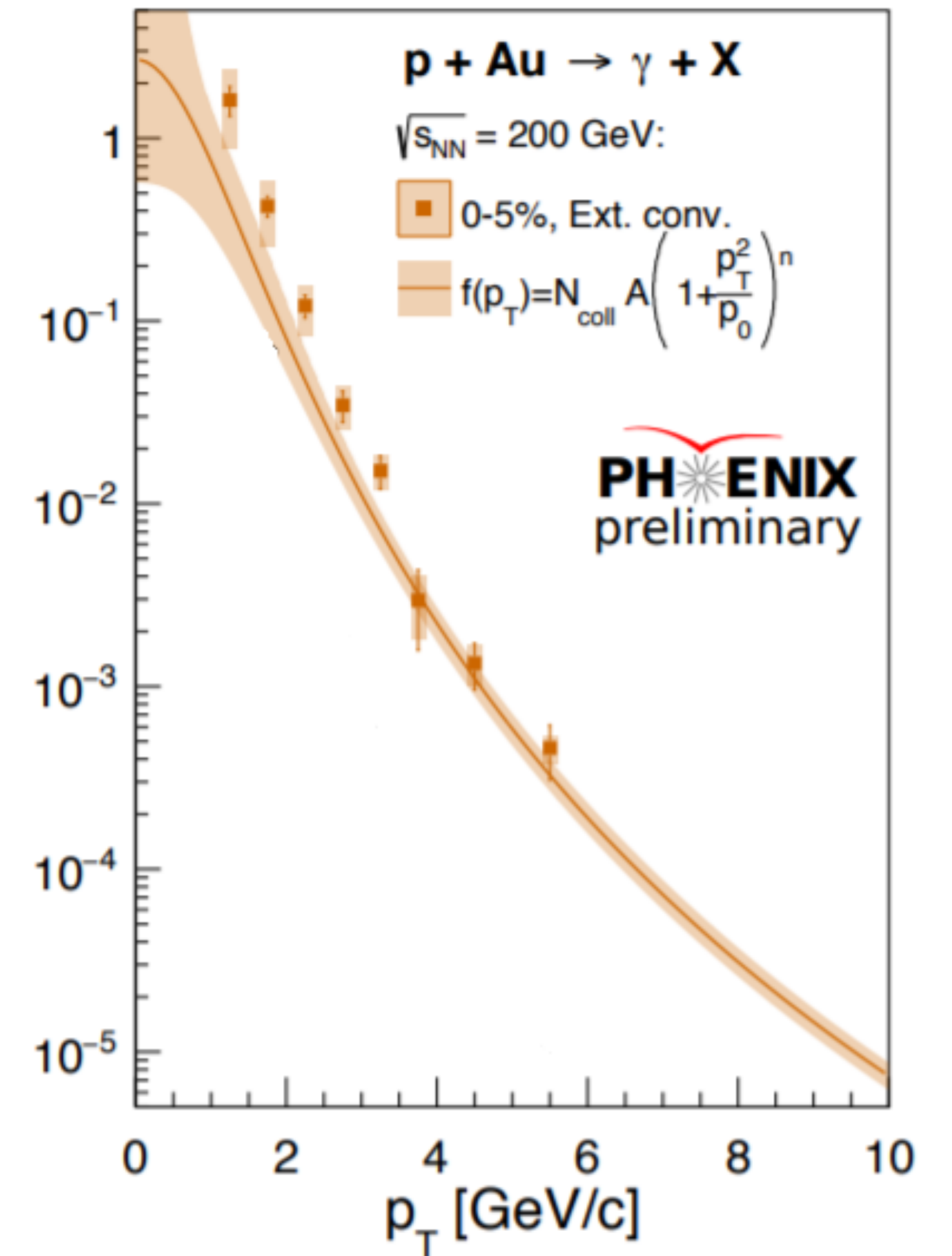
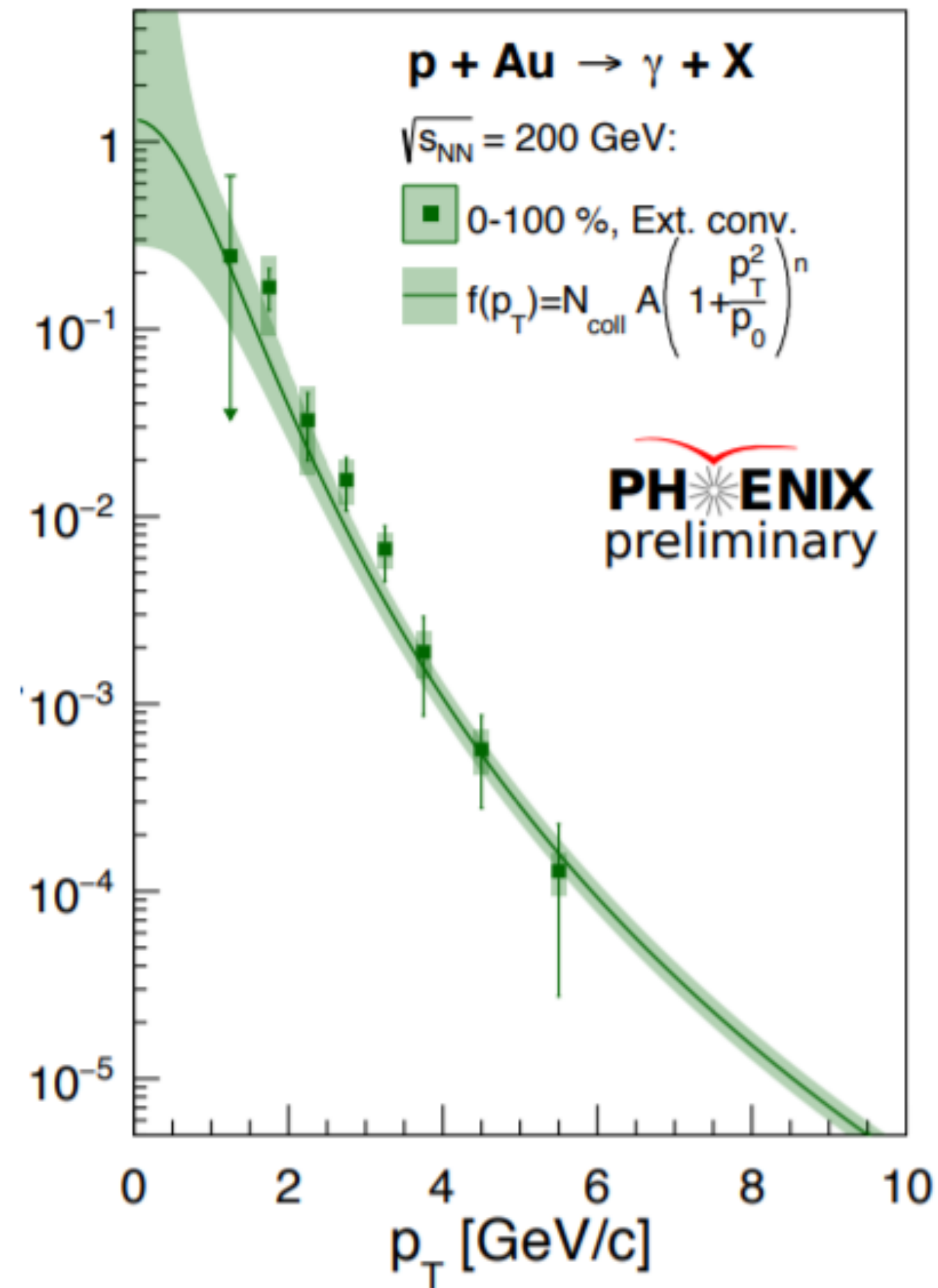
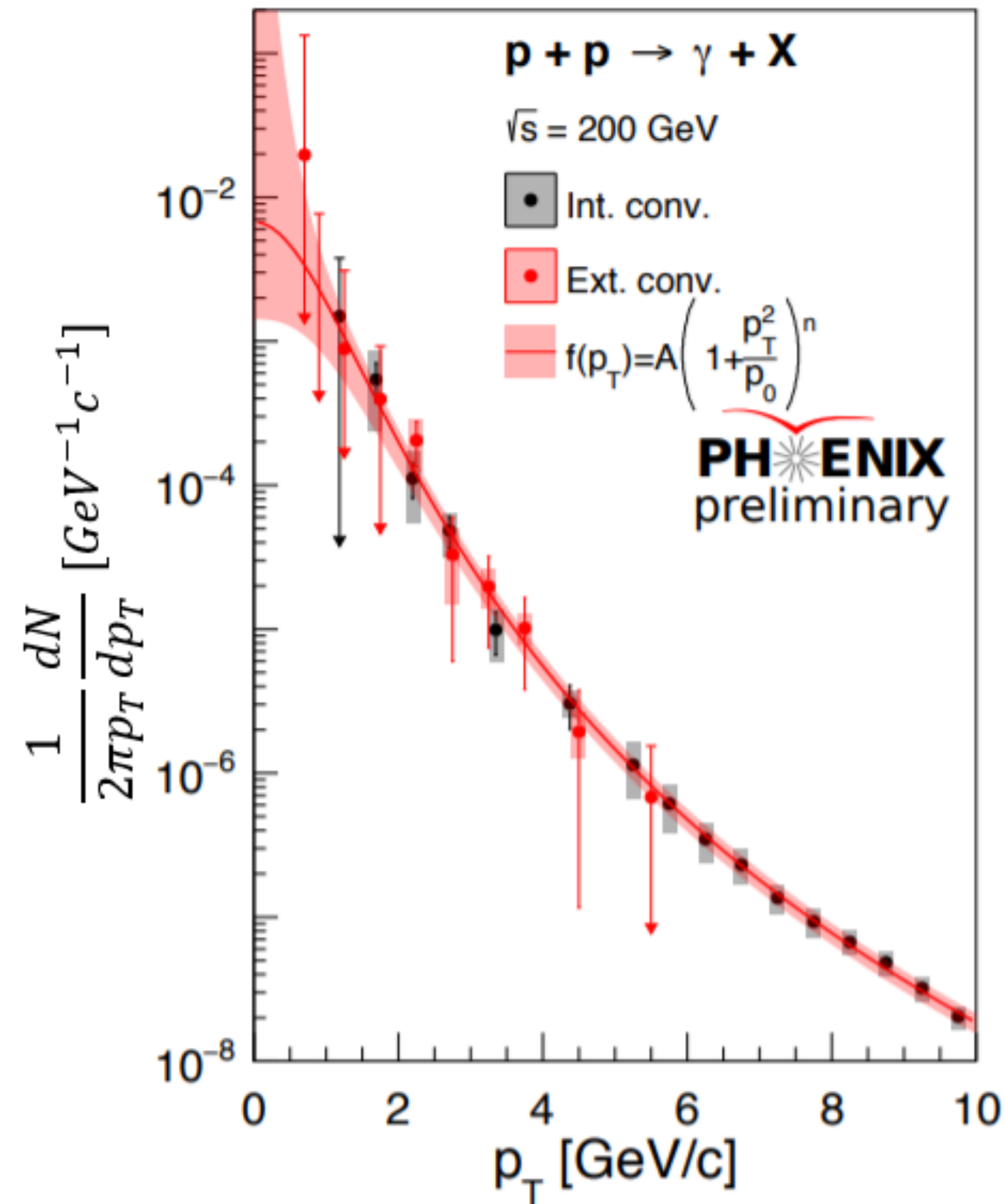
Dominant contribution from pre-equilibrium above 3 GeV/c in the model seems to align well with the data

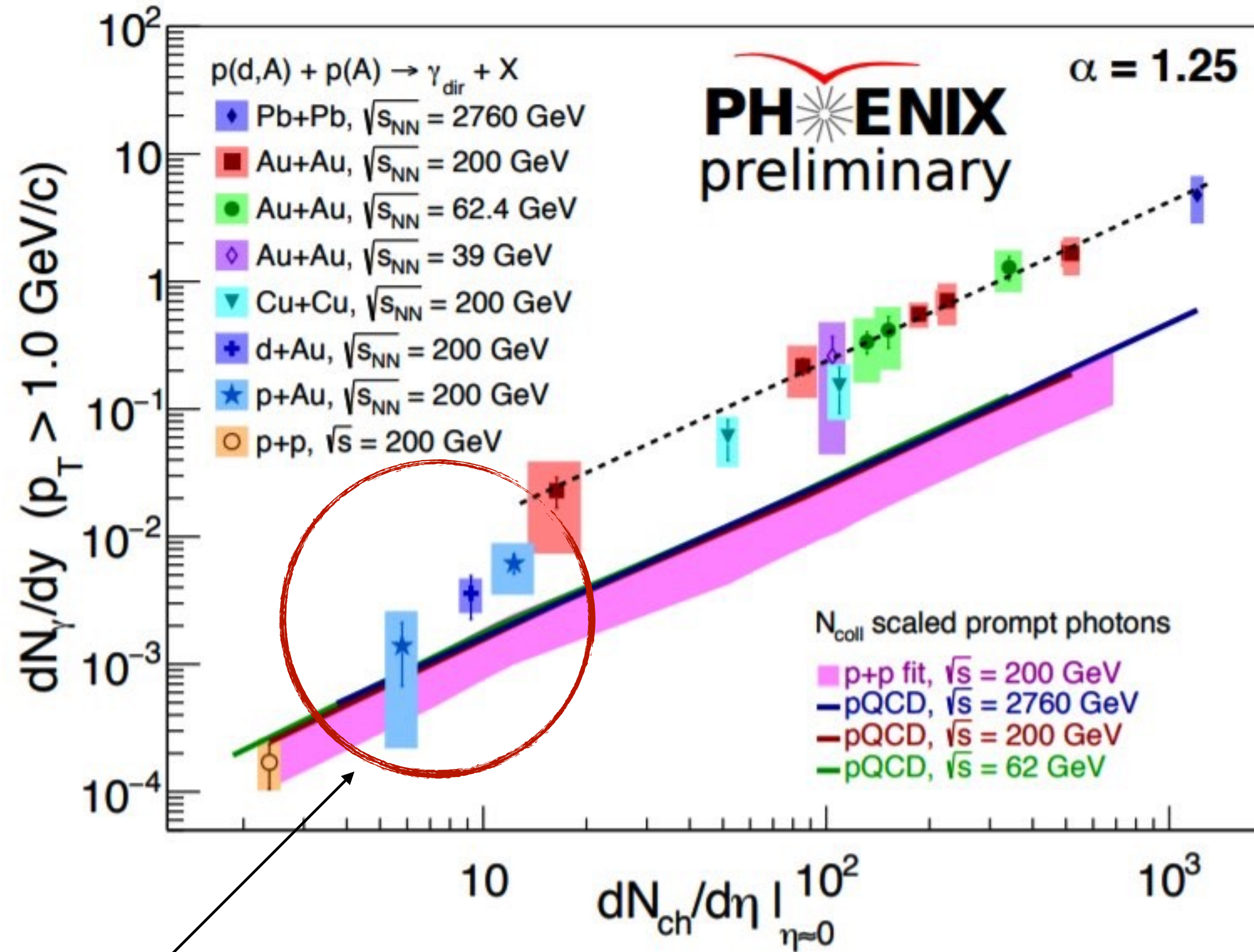
Overall yield falls short, especially below 2 GeV



**Contributions from pre-equilibrium
may be important at intermediate p_T**



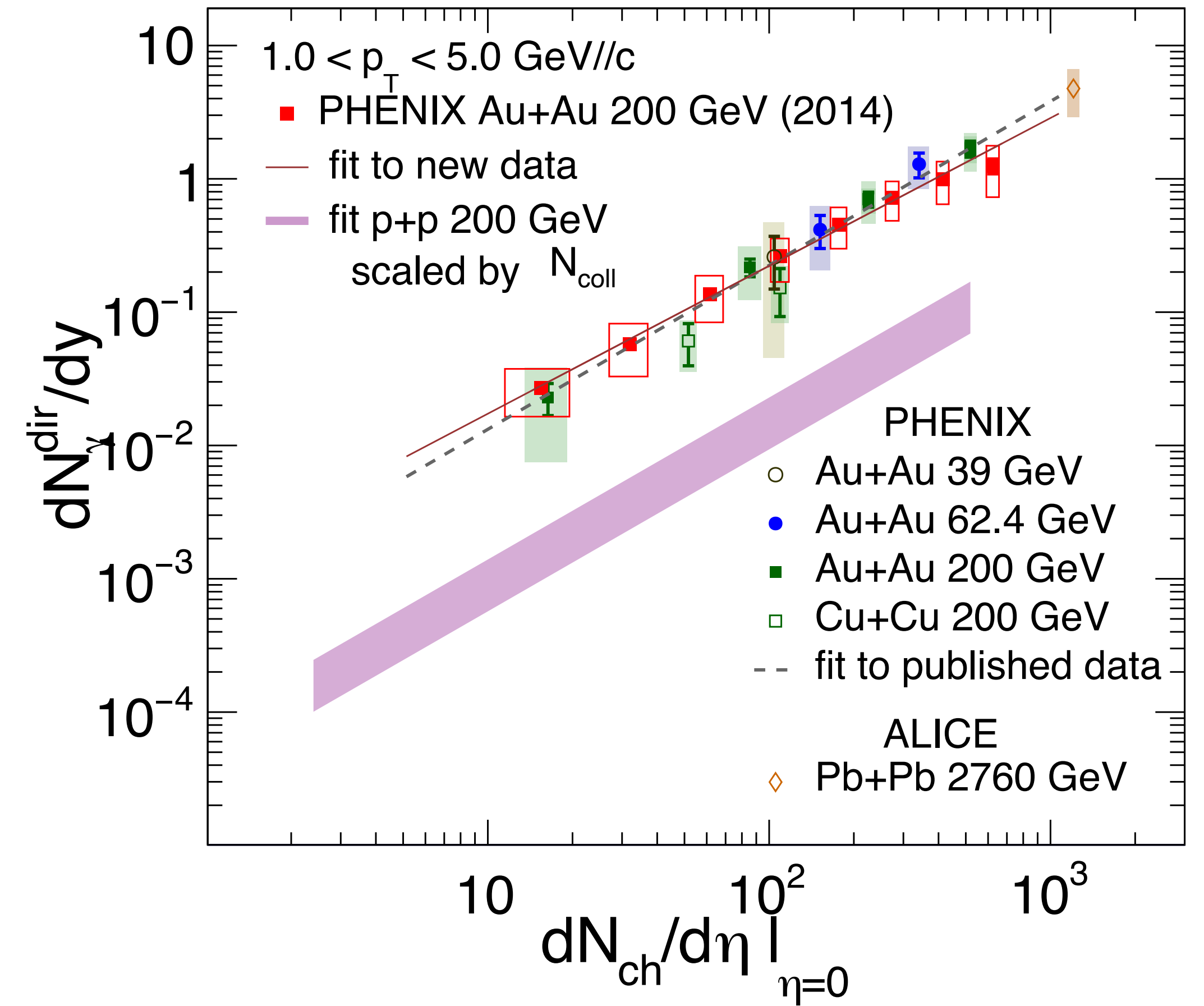




Onset of QGP (?)

arXiv : 2203.17187

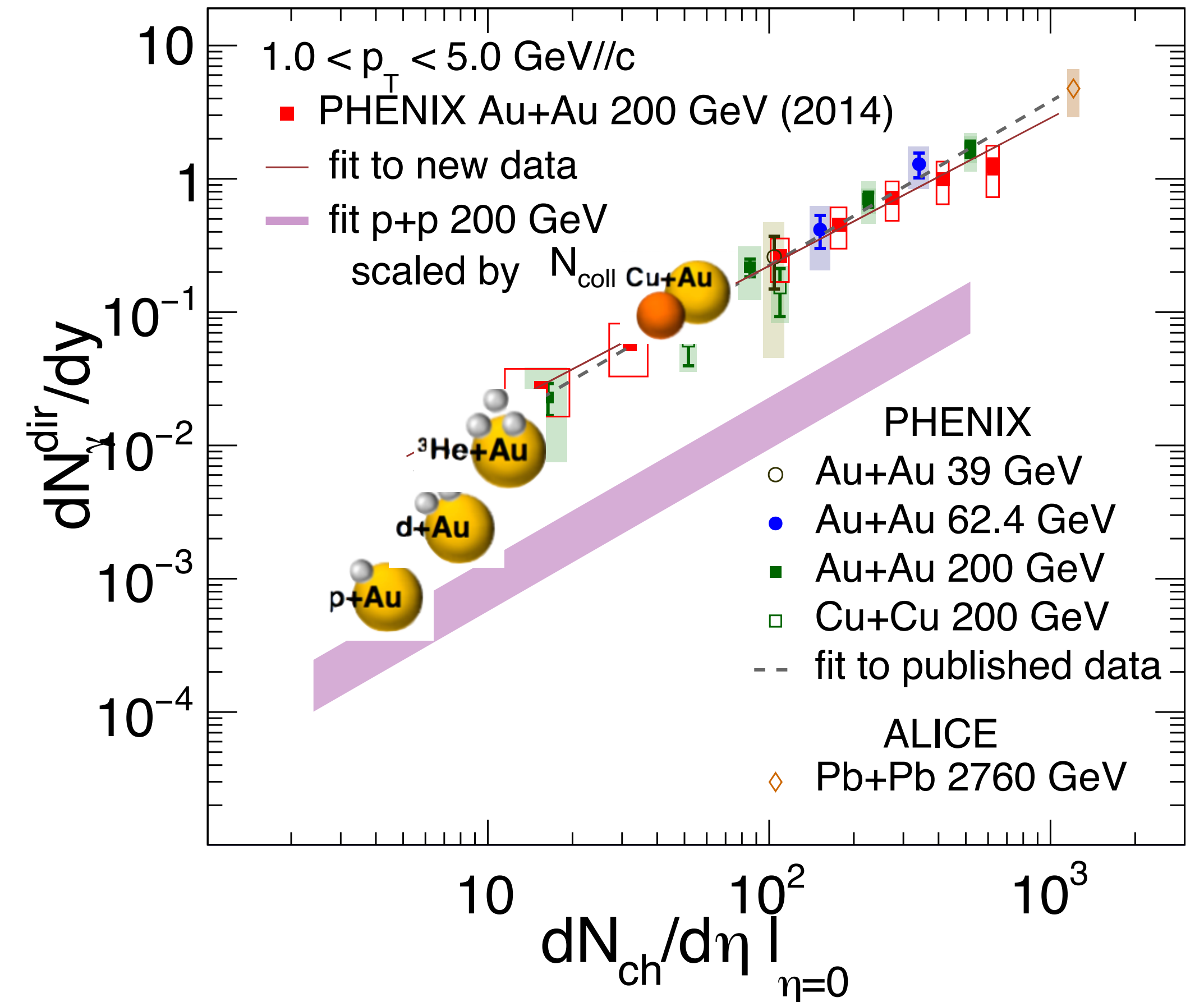
Double differential analysis of the shape of the momentum spectra of direct and non-prompt direct photons and the rapidity density, dN_γ/dy , in p_T and $dN_{ch}/d\eta$



arXiv : 2203.17187

Double differential analysis of the shape of the momentum spectra of direct and non-prompt direct photons and the rapidity density, dN_γ/dy , in p_T and $dN_{ch}/d\eta$

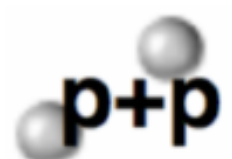
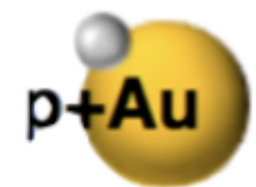
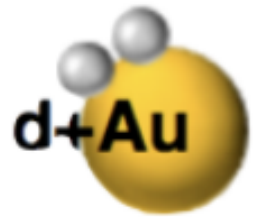

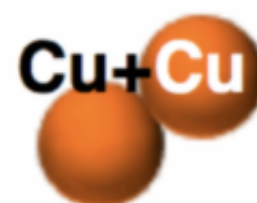
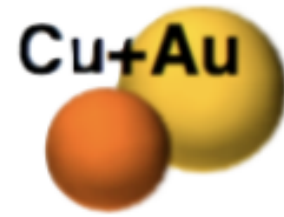
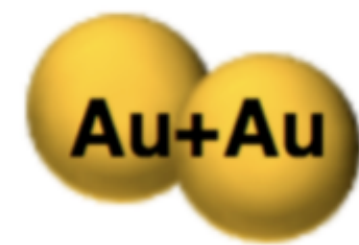
More results coming soon from small system collisions and Cu+Au at $\sqrt{s_{NN}} = 200$ GeV



Thank you for your attention!

Back-up



									
$\sqrt{s_{NN}}$ [GeV]	200	200	200	200	200	200	39	62.4	200
Calorimeter	2003		2003						2004
Virtual $\gamma^* \rightarrow e^+ + e^-$	2005/6		2008		2005				2004
Conversion $\gamma \rightarrow e^+ + e^-$	2015	2015	2016	2014		2012	2010	2010	2007/10 2014

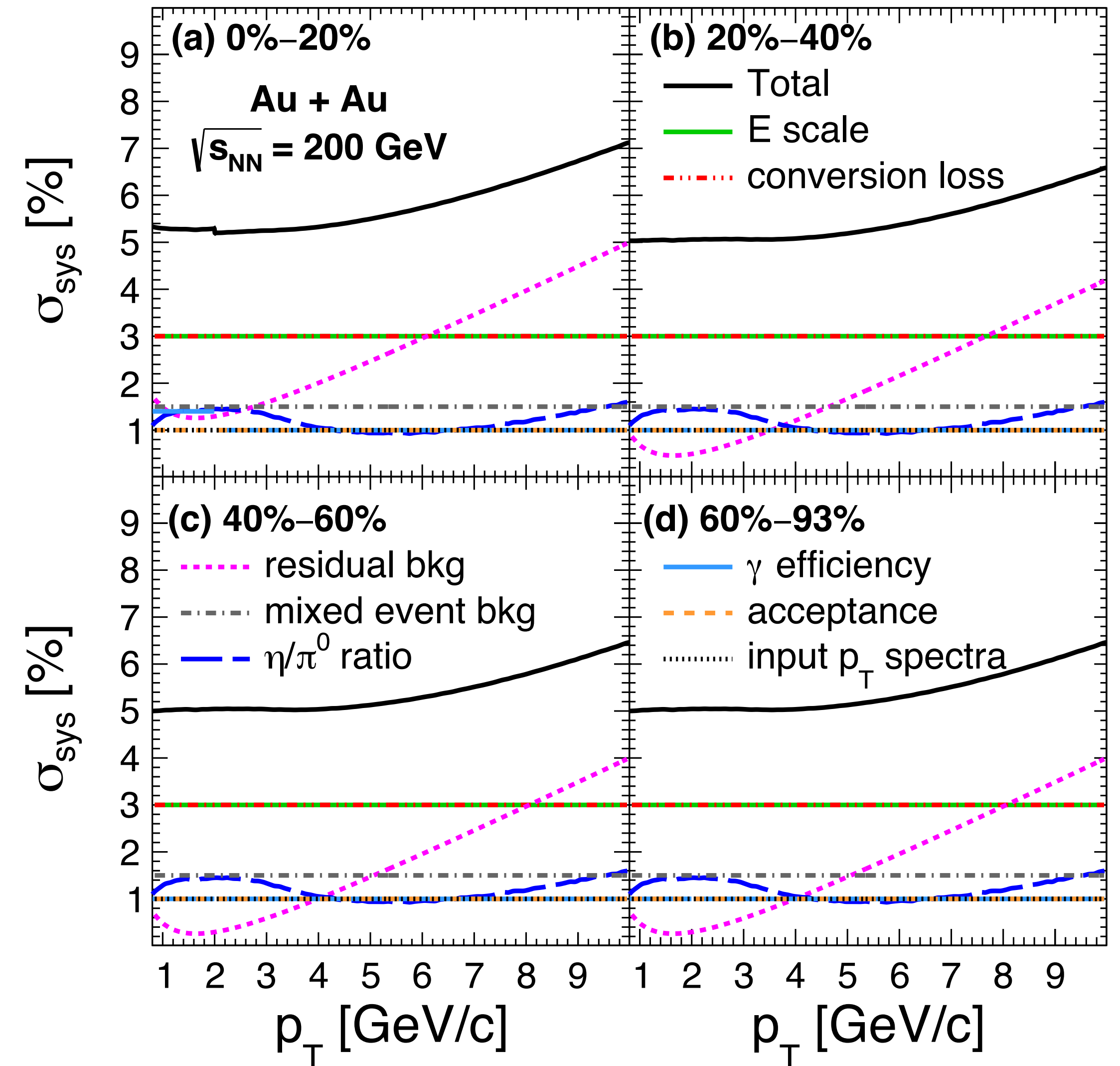
Published

Recently submitted

Ongoing

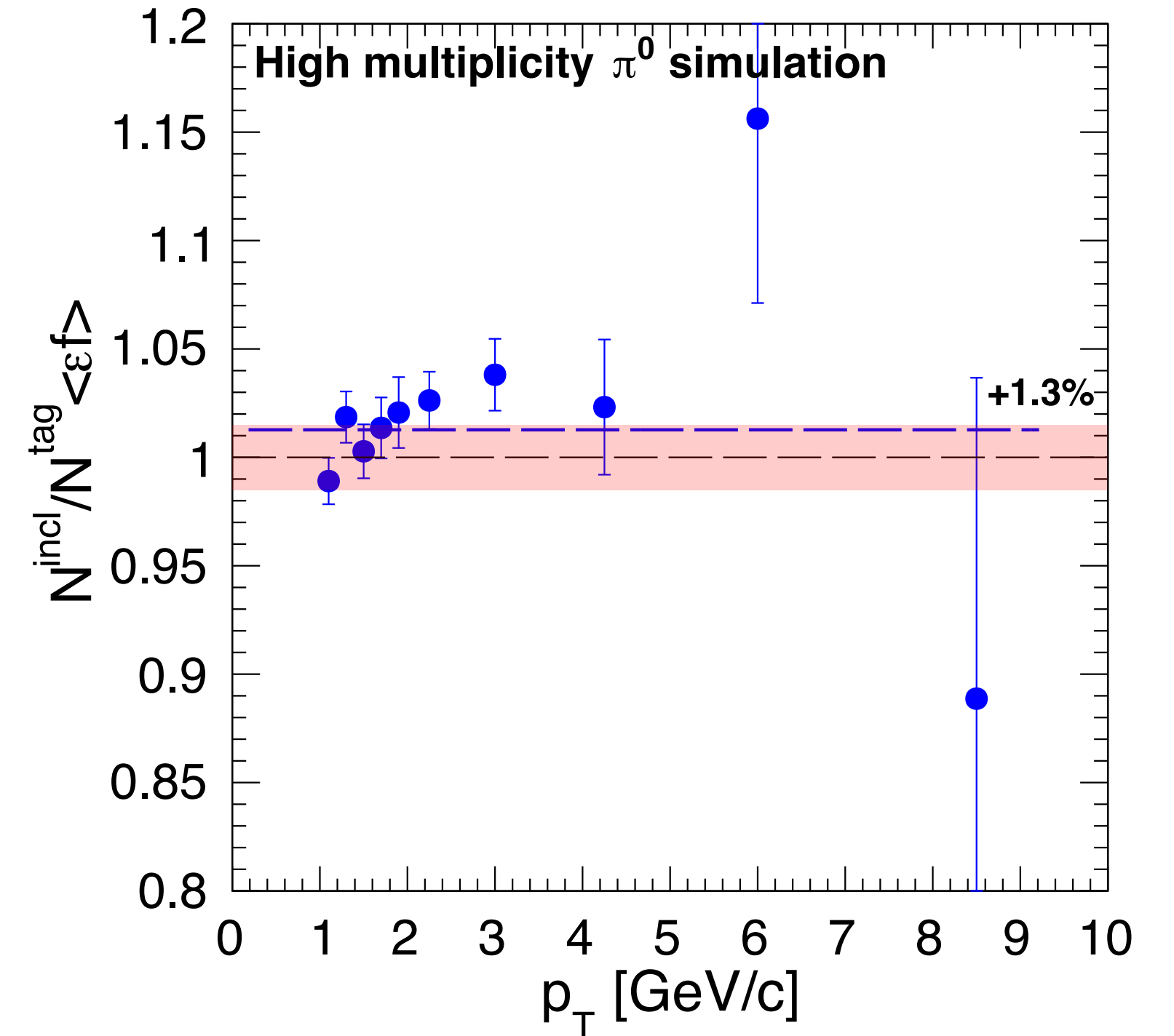
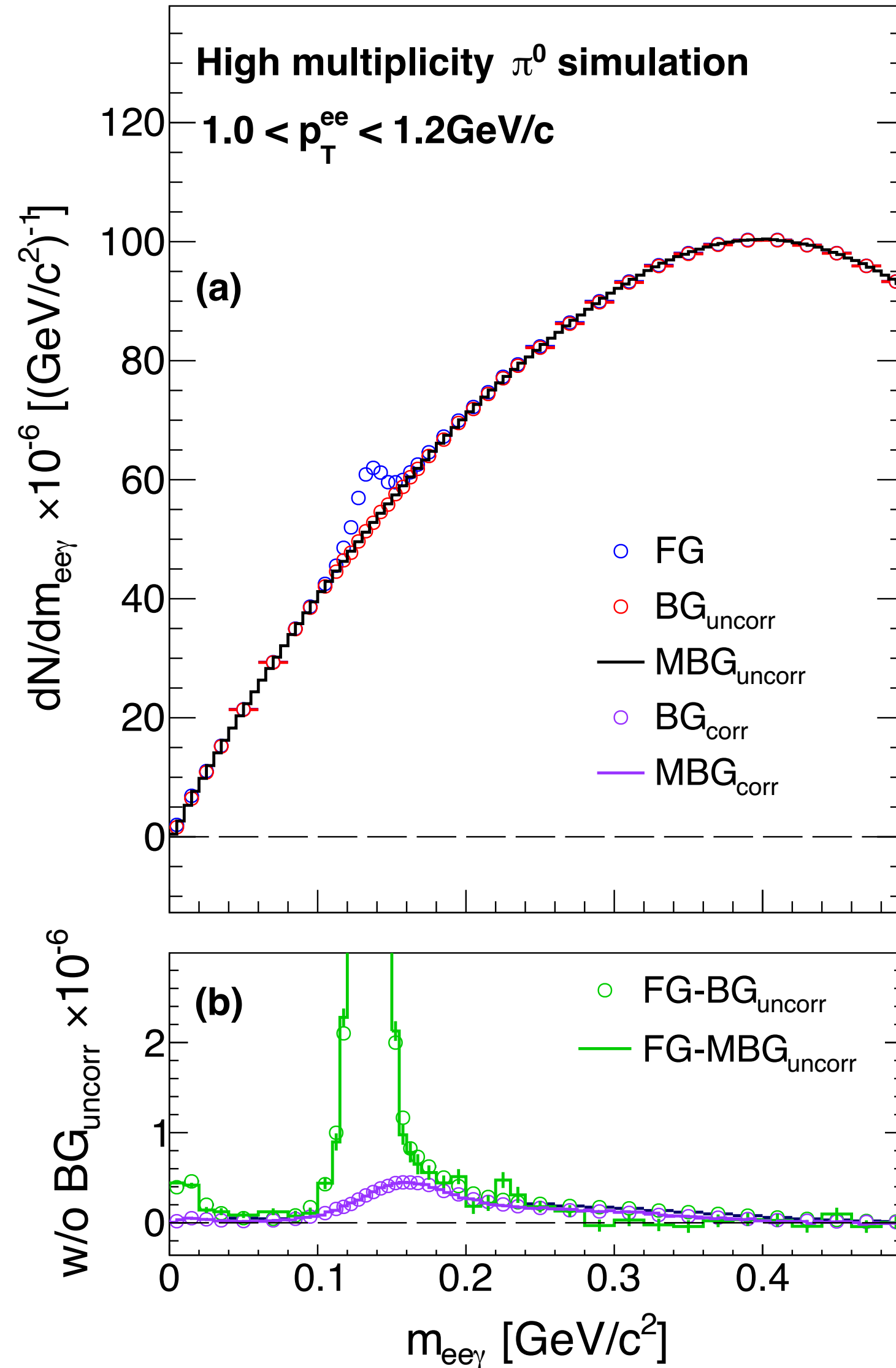
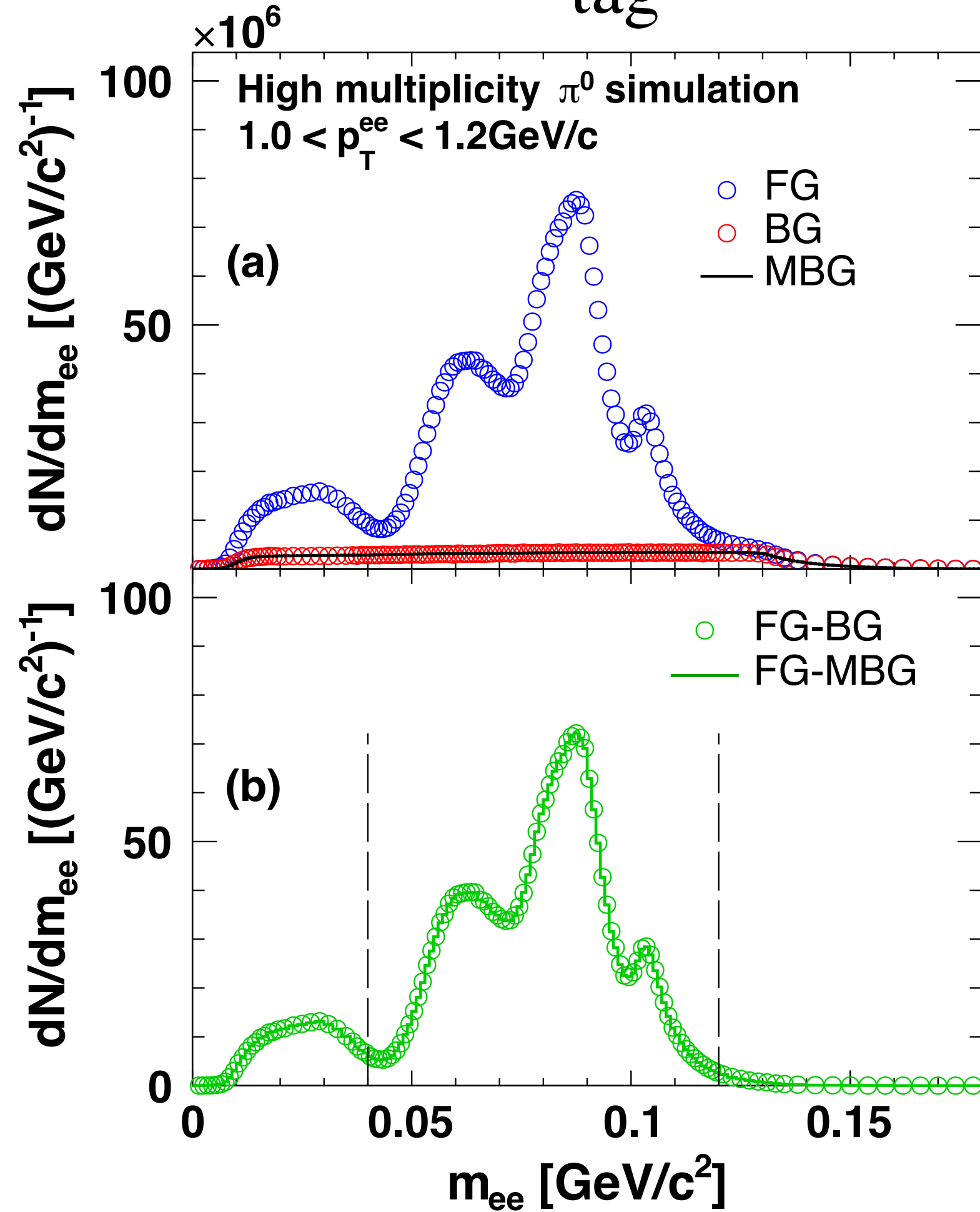
Systematic uncertainty source (39 GeV)	σ_{sys}/R_γ	Type
π^0 reconstruction		
tagged photon yield	8%	A
<i>Conditional acceptance</i>		
input Hagedorn p_T spectra and energy scale	8%	B
<i>Cocktail ratio</i>		
γ^{hadron}/π^0	2%	B

Systematic uncertainty source (62.4 GeV)	σ_{sys}/R_γ	Type
π^0 reconstruction		
tagged photon yield	5%	A
<i>Conditional acceptance</i>		
input Hagedorn p_T spectra and energy scale	5%	B
<i>Cocktail ratio</i>		
γ^{hadron}/π^0	2%	B



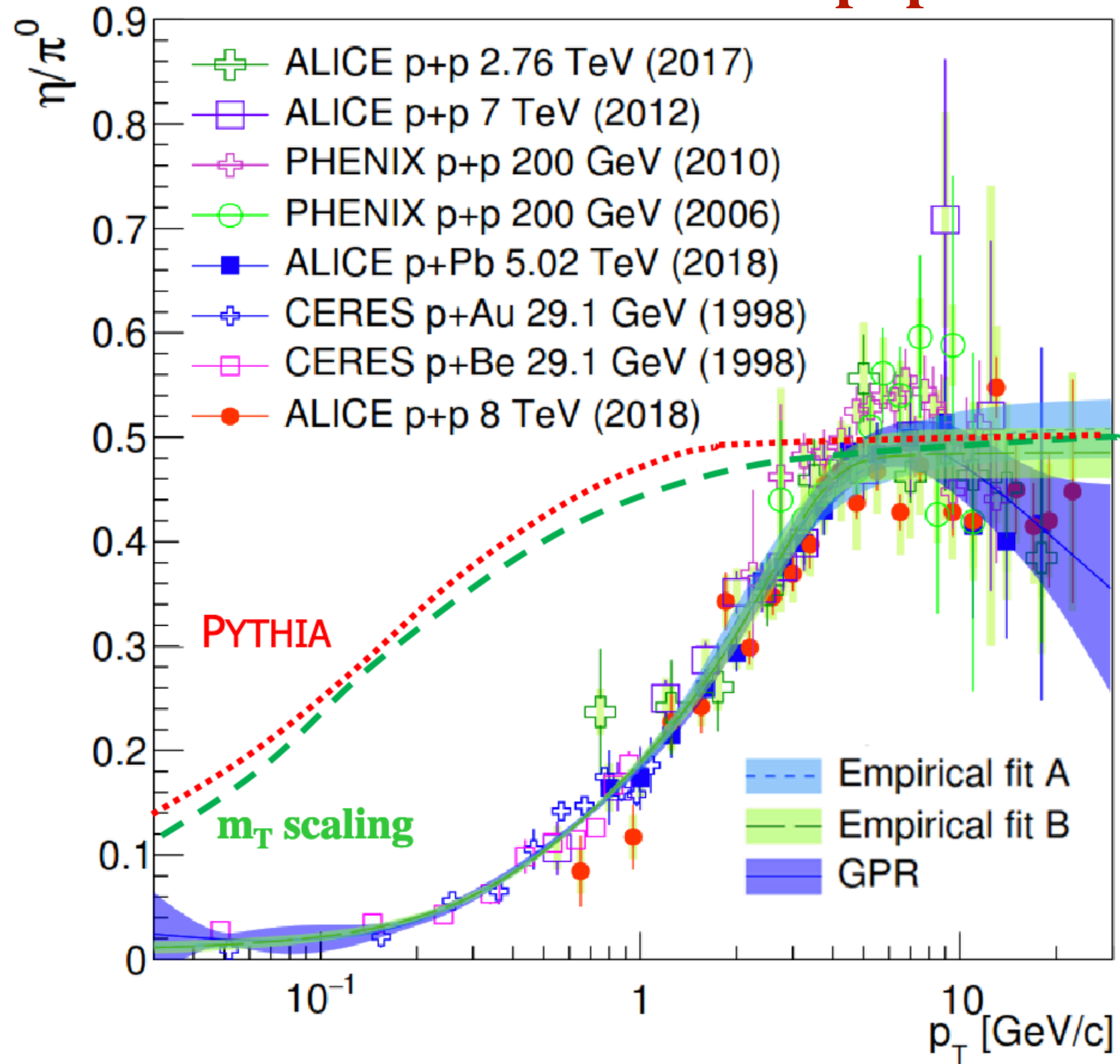


$$R_\gamma = \frac{N_{\text{inc}}}{N_{\text{tag}} \pi^0} \langle \epsilon f \rangle$$



Simulating 280 π^0 per event through the PHENIX reconstruction and analysis framework

Universal ratio for p+p

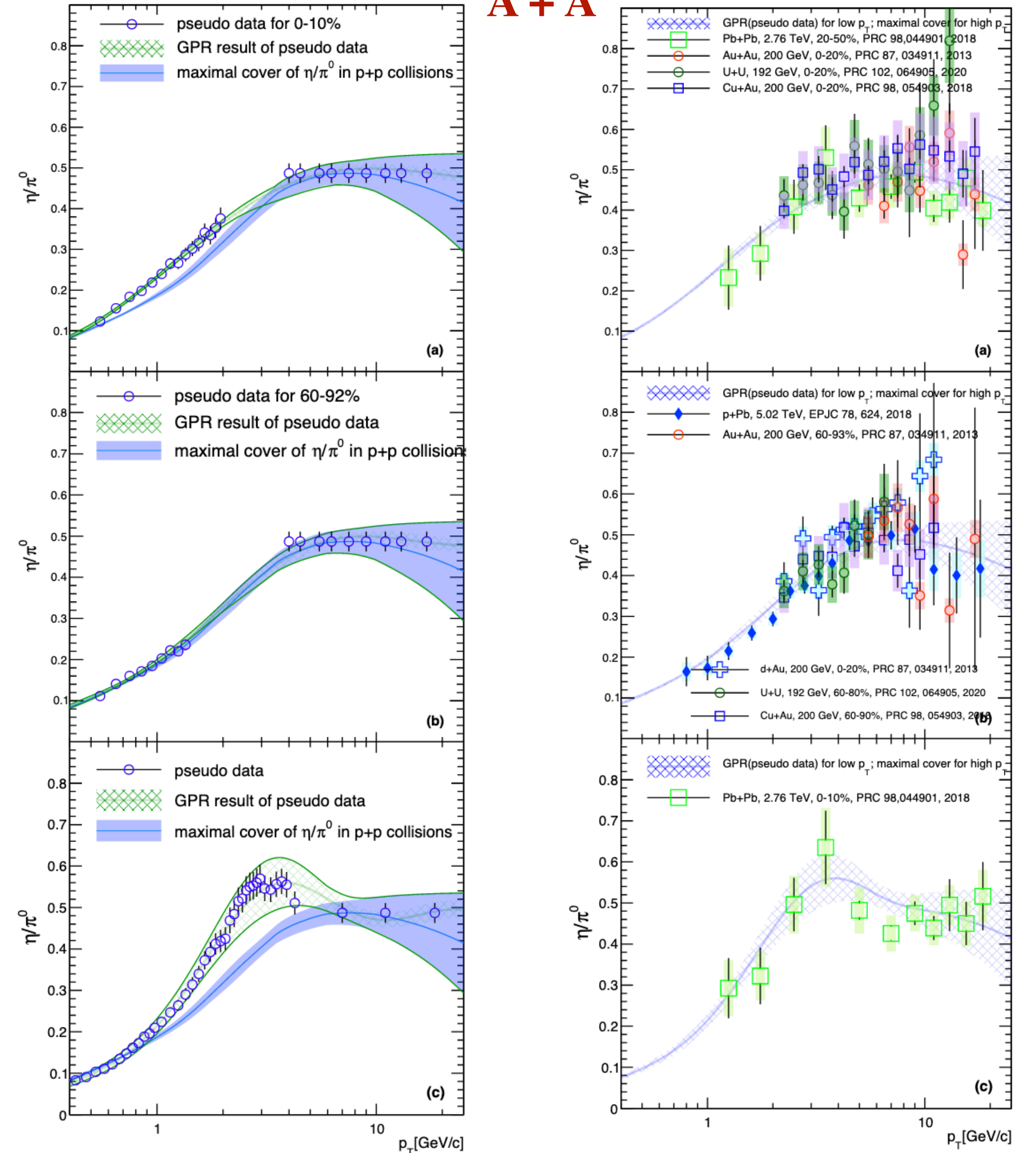


arXiv : 2102.05220

Accounting for effects of radial flow



A + A



Functional form inspired by pQCD

Fit below 1 GeV/c motivated by Drell Yan measurements [Ito, et al, PRD23, 604 (1981)]

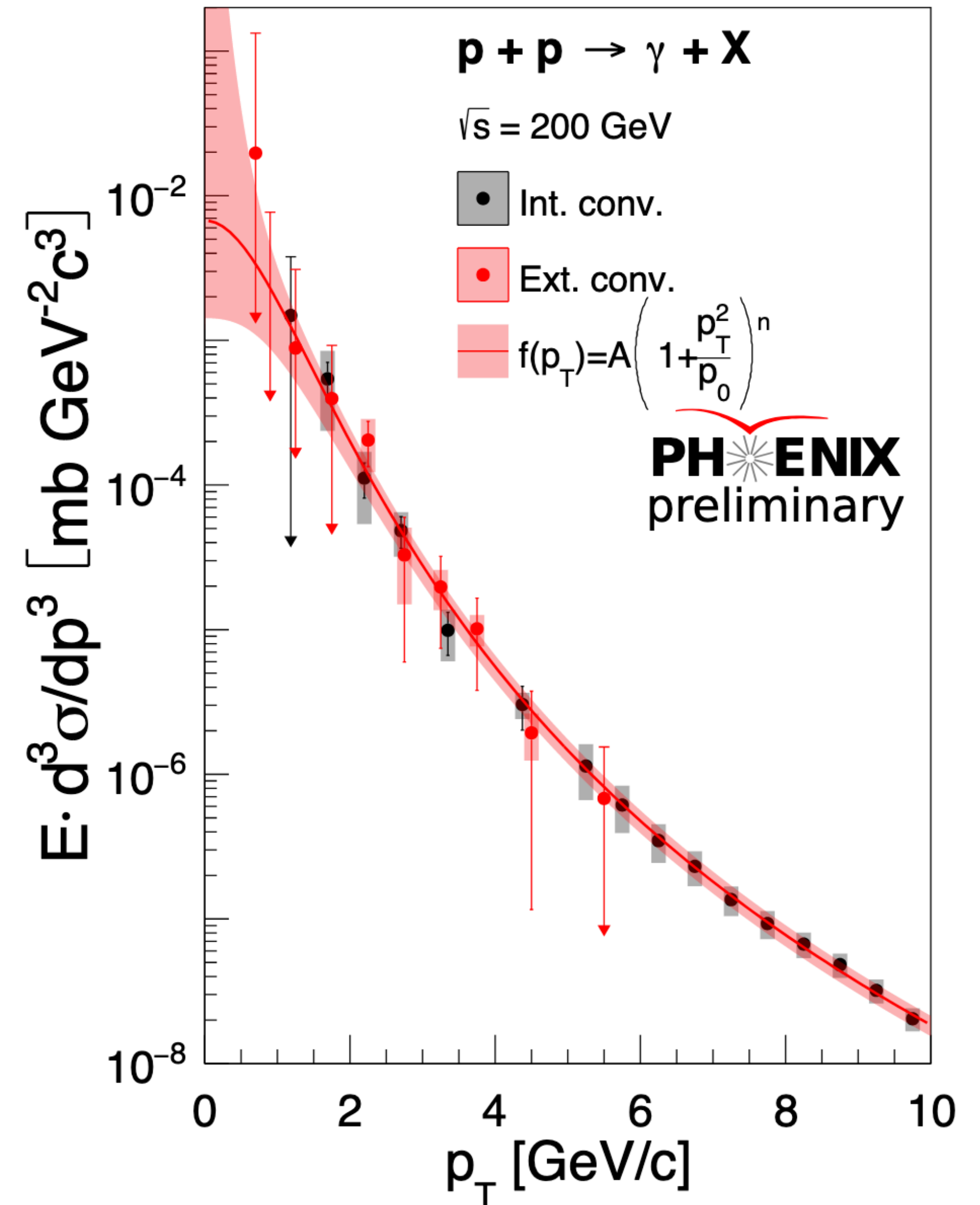
Systematic errors include the fit errors, different functional forms

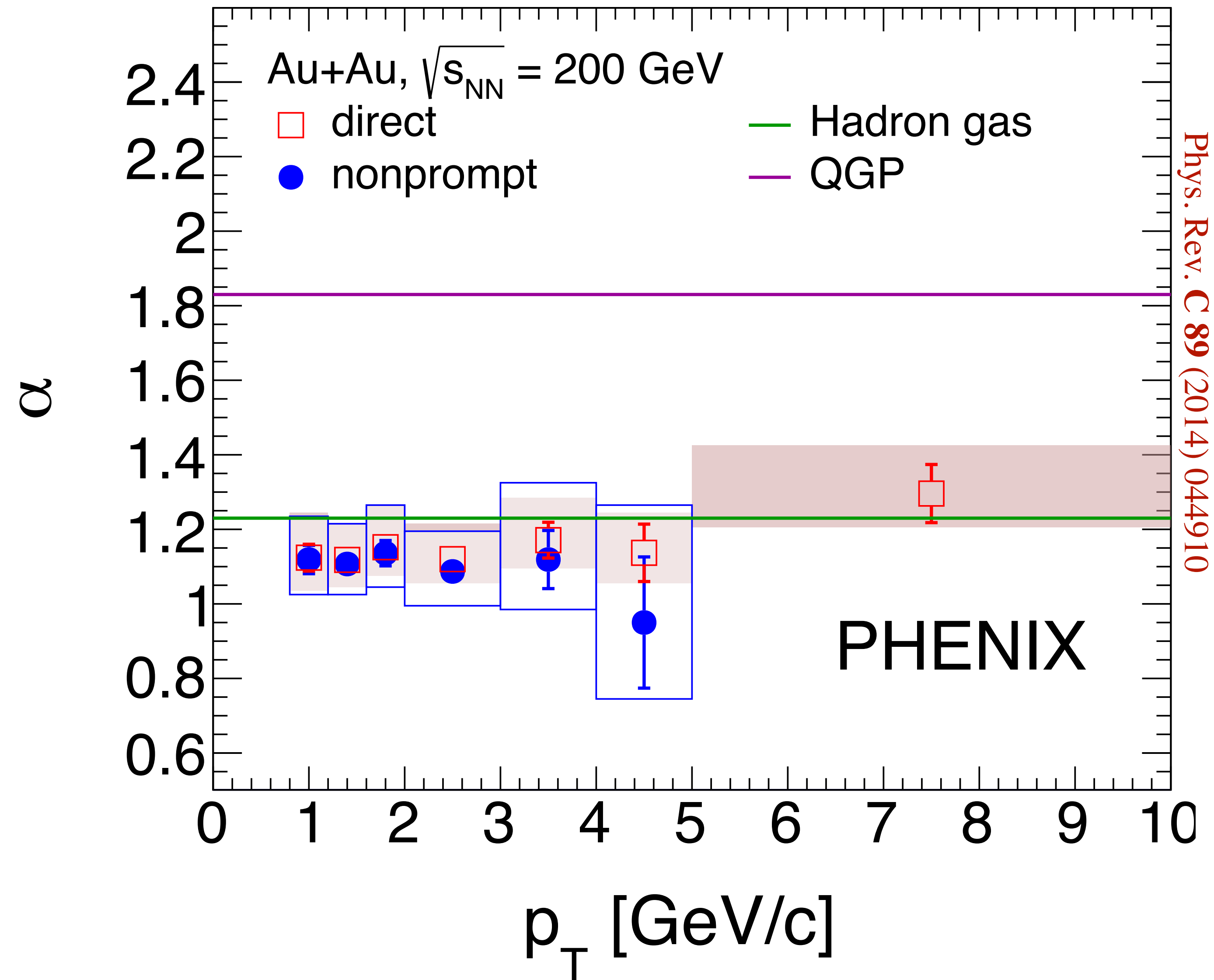
$$\frac{dN}{dy} = a \left(1 + \frac{p_T^2}{b^2} \right)^c$$

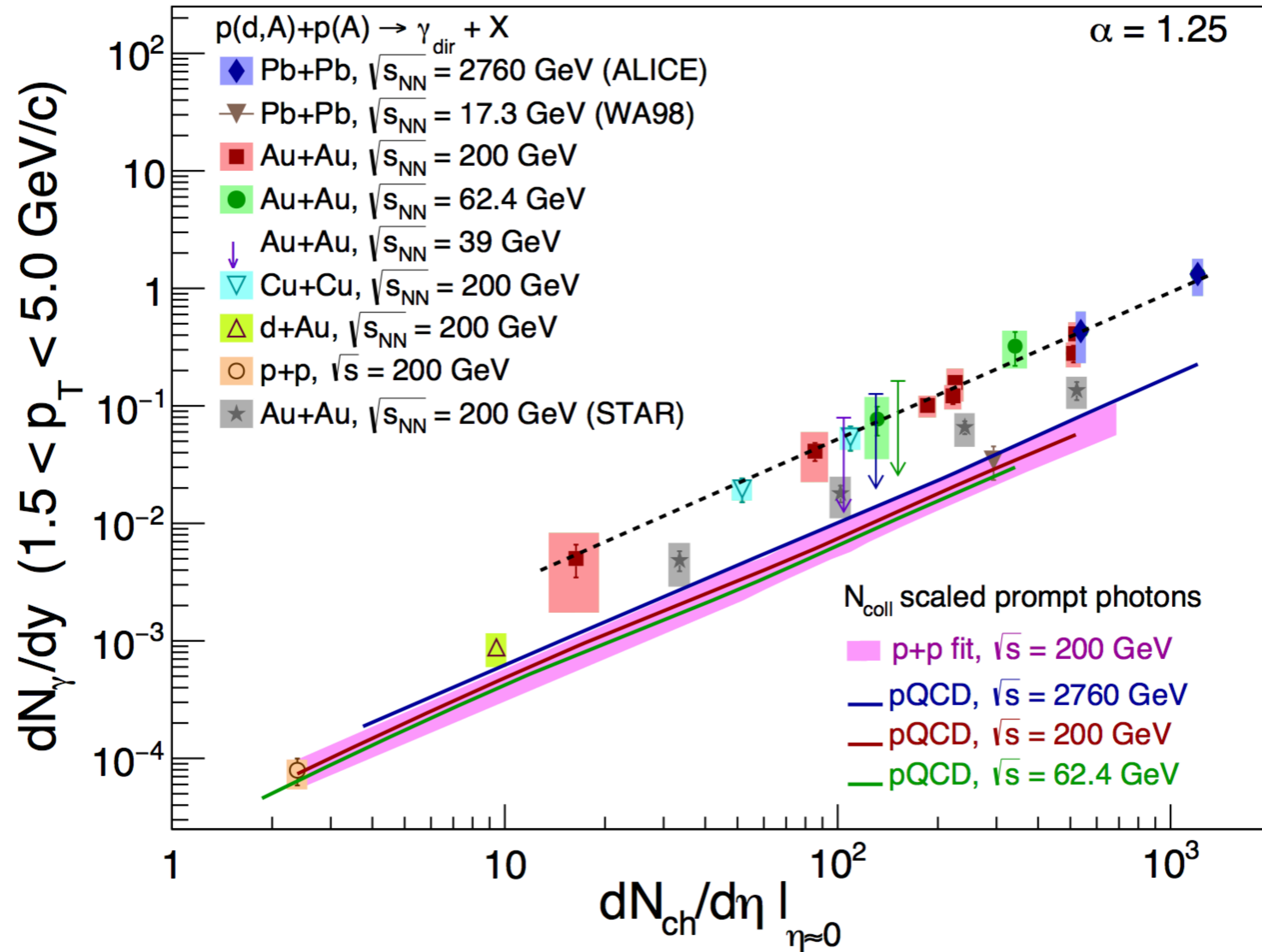
$$a = 6.4 \times 10^3$$

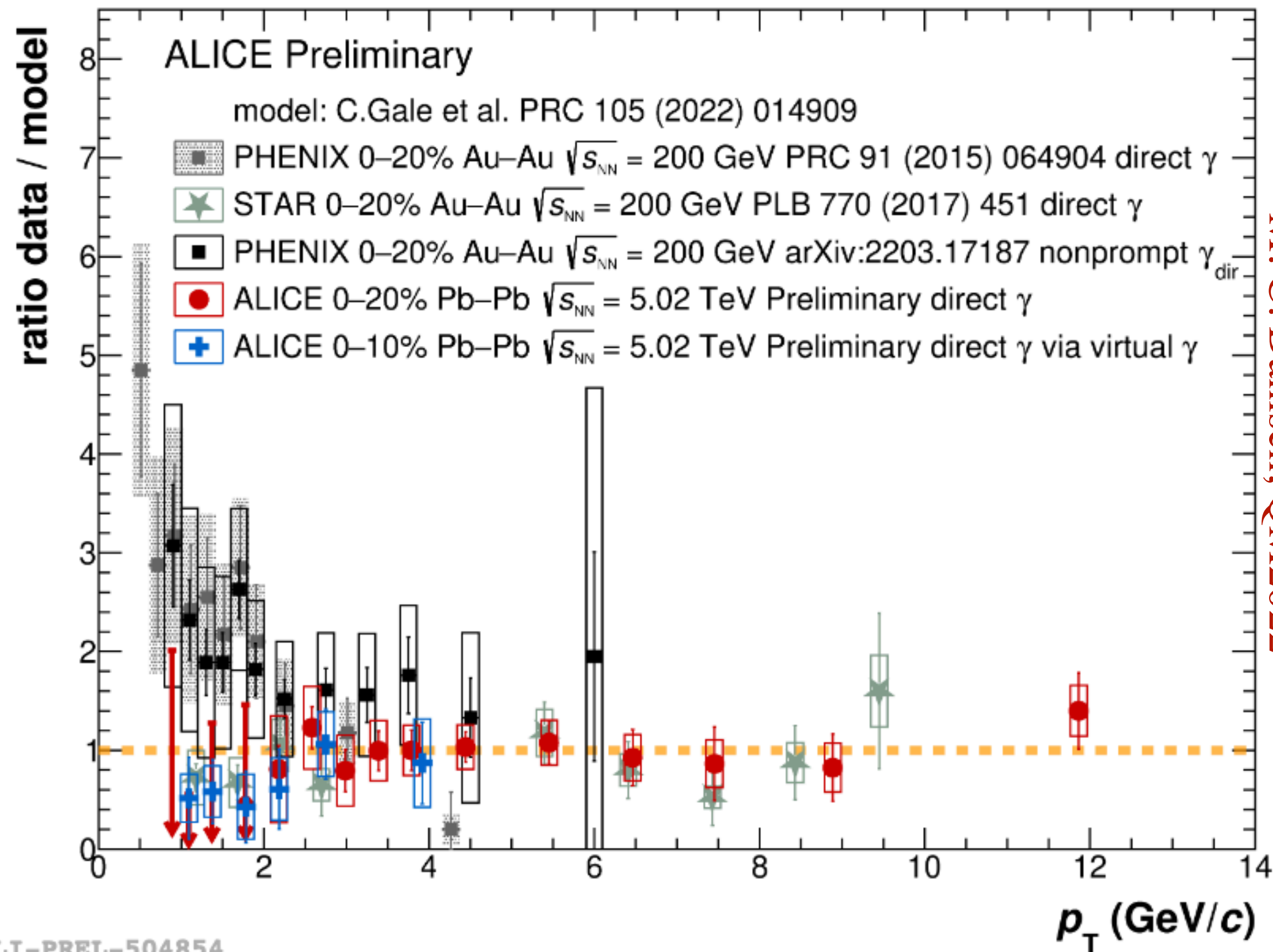
$$b = 1.45$$

$$c = -3.30$$

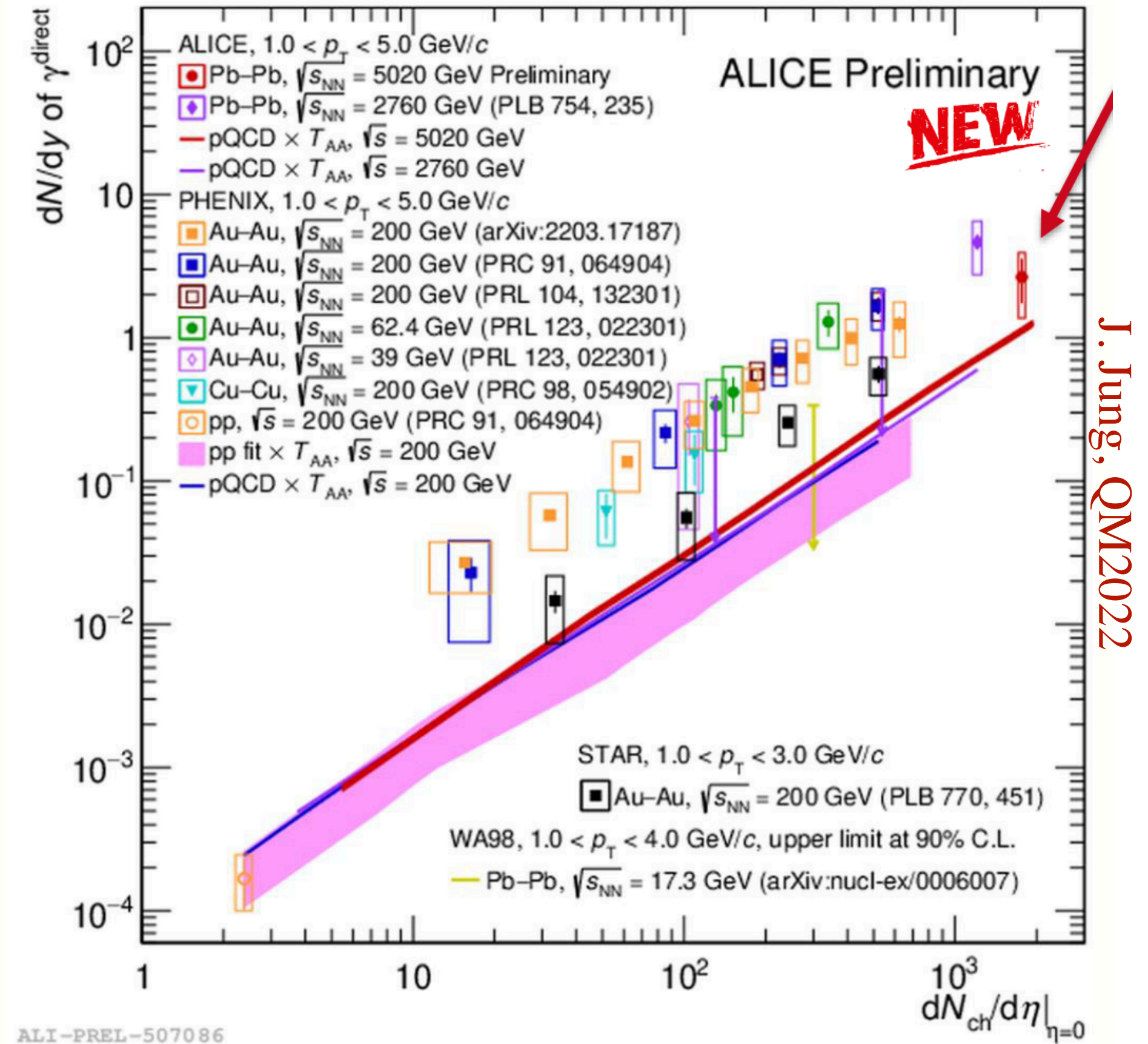




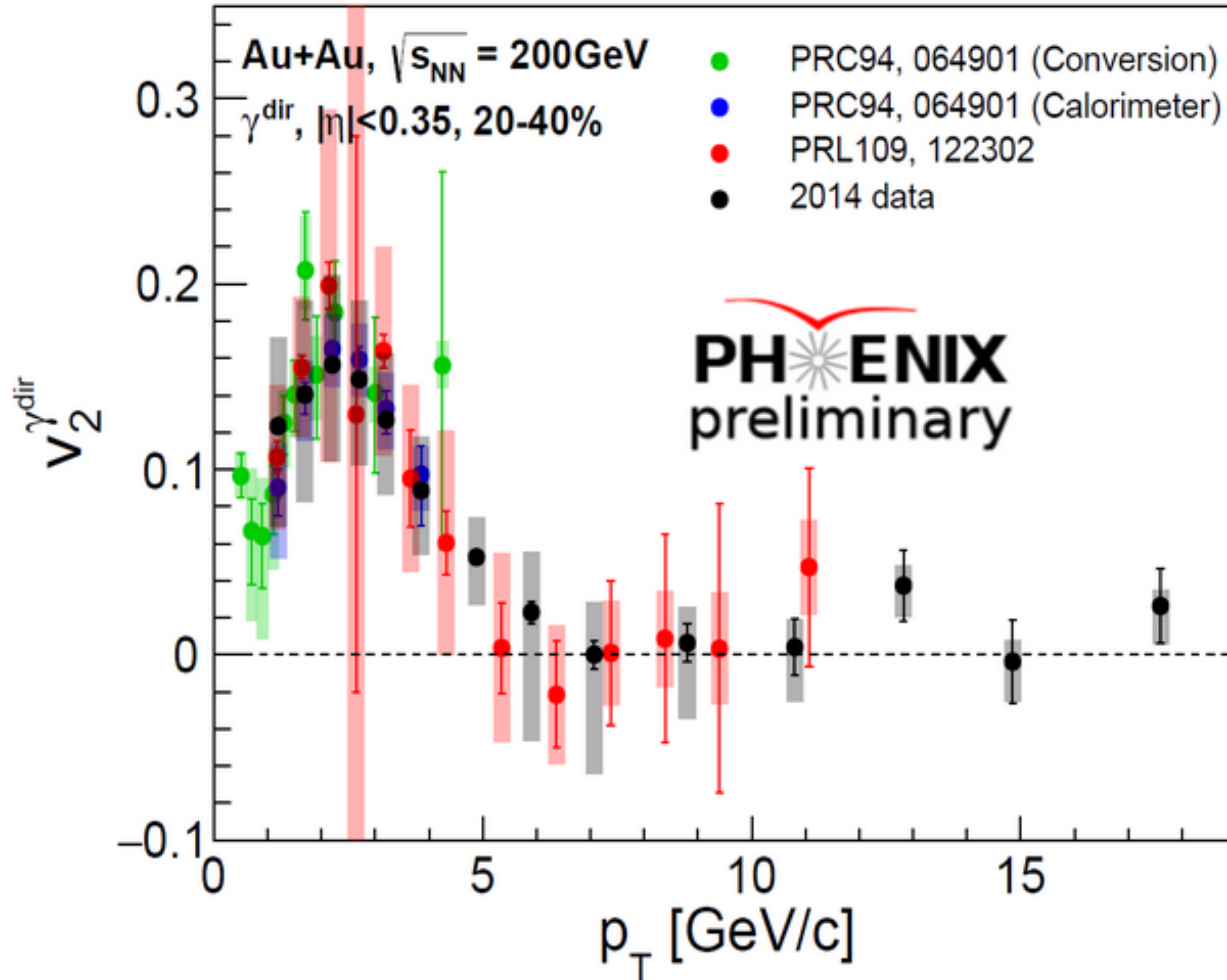




M. C. Danisch, QM2022



J. Jung, QM2022



$$v_n^{dir} = \frac{R_\gamma v_n^{inc} - v_n^{dec}}{R_\gamma - 1}$$