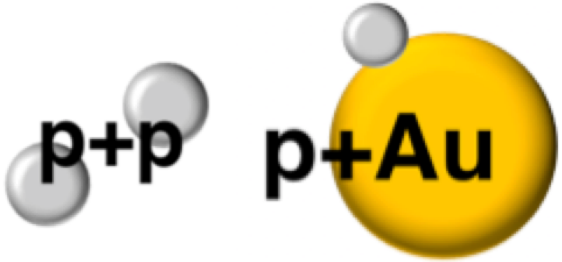
筑波大学
University of Tsukuba

PHENIX



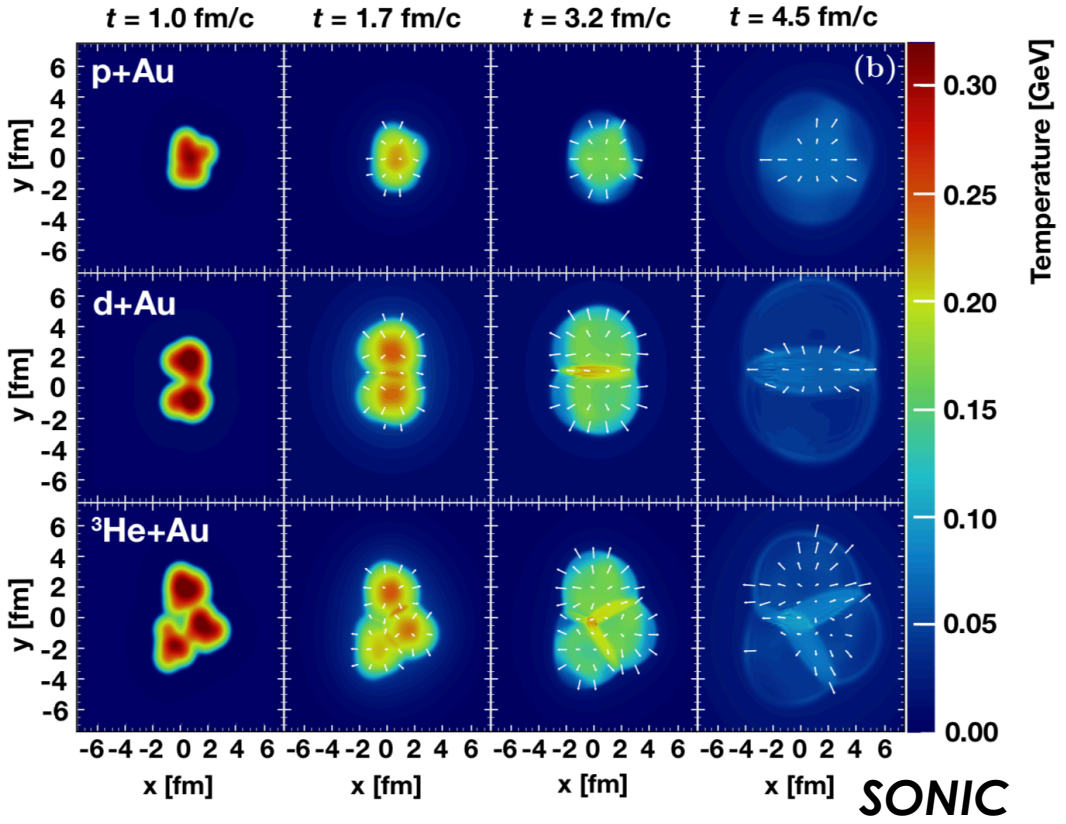
PHENIX measurement of direct photon radiation from p+p and p+Au collisions

Norbert Novitzky (Tsukuba University)

Why small systems?

The small system collisions look similar to the very peripheral heavy ion collisions:

- Theory models show that in small collisions can reach temperatures above the critical point – creating QGP
- Variety of small system collisions at RHIC



Several heavy ion observables show a smooth transition between the p+p and A+A collisions.

High multiplicity p+p and p+A collisions could answer some of the remaining questions about the mechanism to create a strongly interacting medium

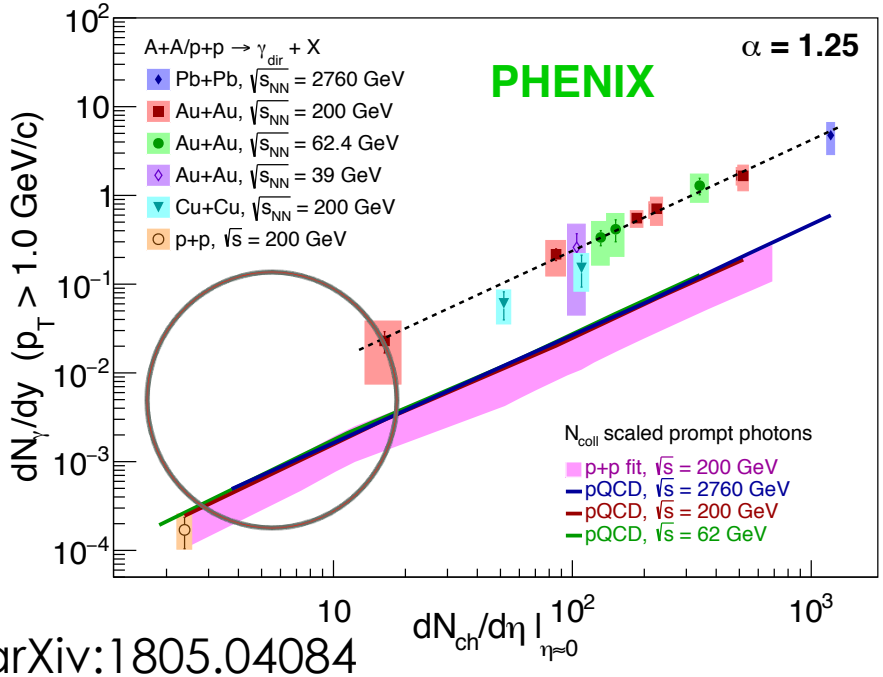
Why direct photons?

Thermal photons were **predicted** and **measured** in the heavy ion collisions:

- There are still open questions about the hadron gas vs quark gluon plasma contributions → see

A. Drees Wed 10h45

If there is a medium created in "high multiplicity small collision systems" → they should emit thermal radiation in form of photons & di-leptons



arXiv:1805.04084

All the available A+A

- Scales with the slope of 1.25
- Gap between 2 to 20 multiplicities

Does the 'thermal photon' production turn on?

Direct photon excess

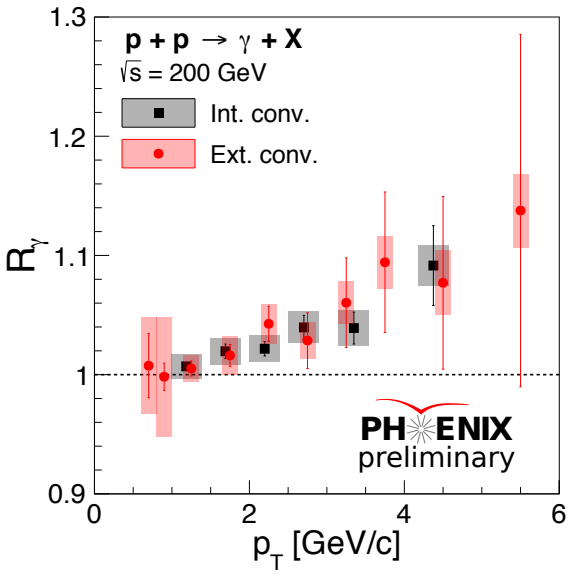
R_γ measurement from p+p at 200 GeV:

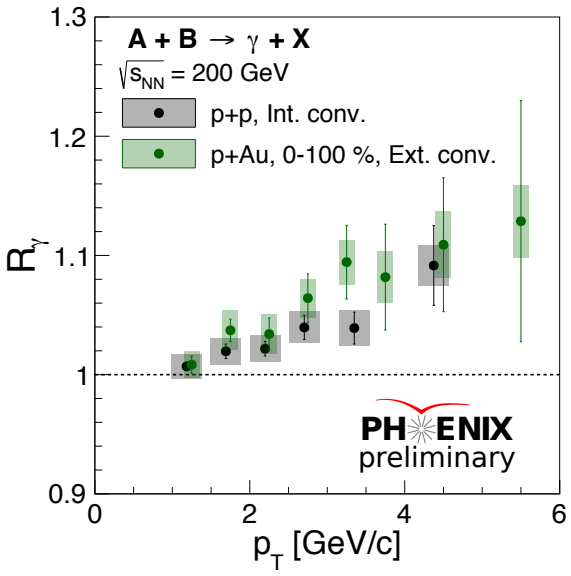
- Consistent with the previous measurement

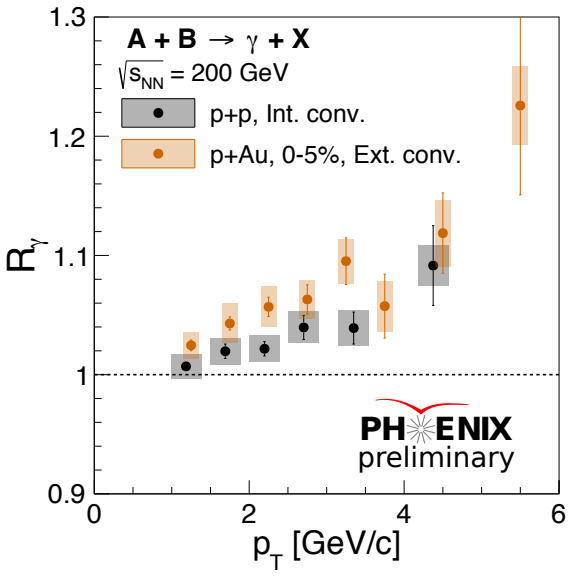
Rγ measurement in p+Au at 200 GeV:

- New measurement in minimum bias collisions
- New measurement in the very central (high multiplicity) 0-5% collisions

$$R_\gamma = \frac{inclusive}{decay}$$







Small, positive signal observed in all collision systems

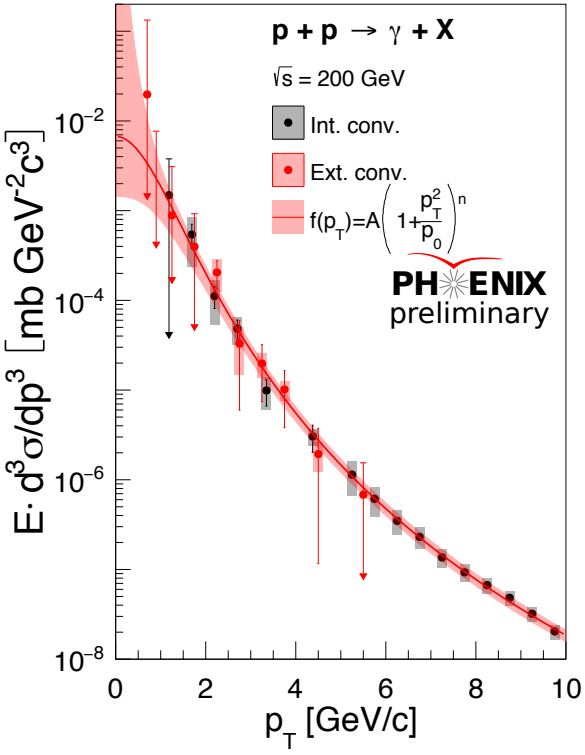
Direct photon invariant yields

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

Fit function, inspired from pQCD
Systematic errors include the fit errors, different functional forms

$$f(p_T) = A\left(1 + \frac{p_T^2}{p_0}\right)^n$$

A = 6.74e-03
p_0 = 2.1
n = -3.3



Systematic error estimation of the fit:

- The uncertainties from individual data points
- New results not included (yet)
- Different functional forms (all pQCD inspired)

Direct photon invariant yields

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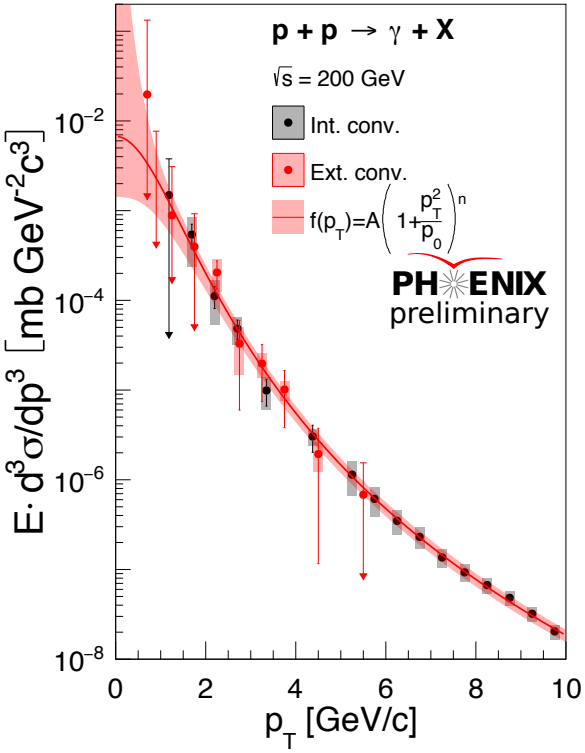
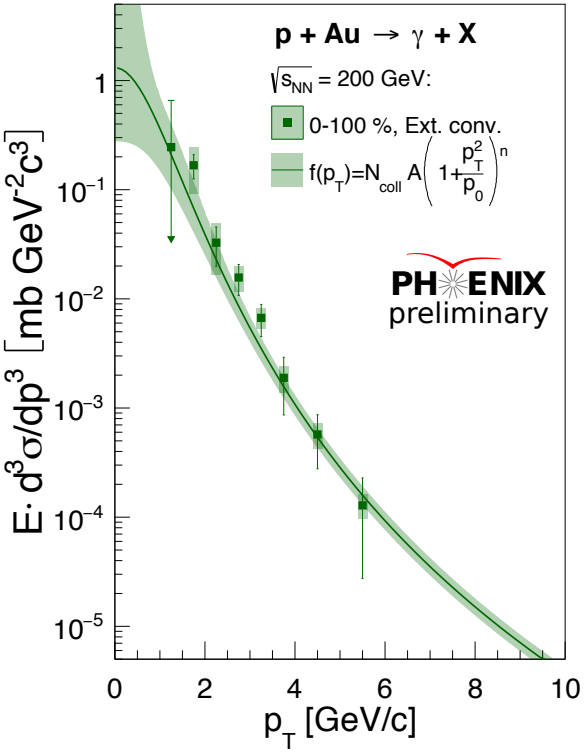
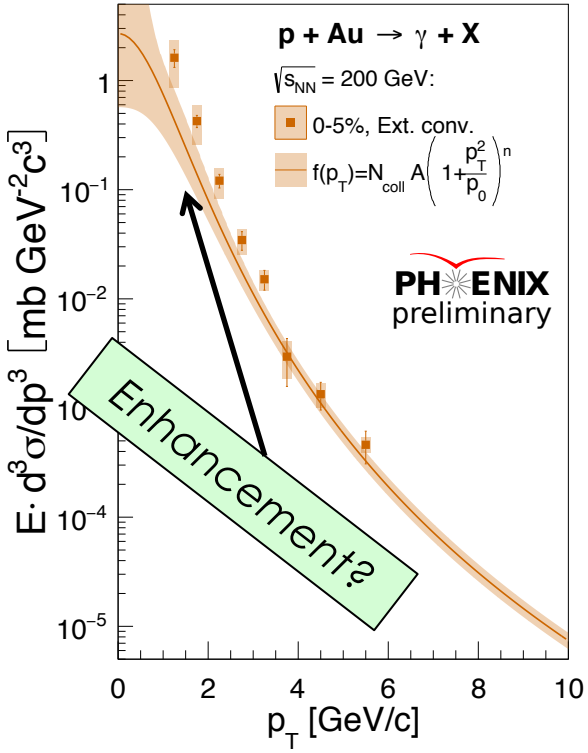


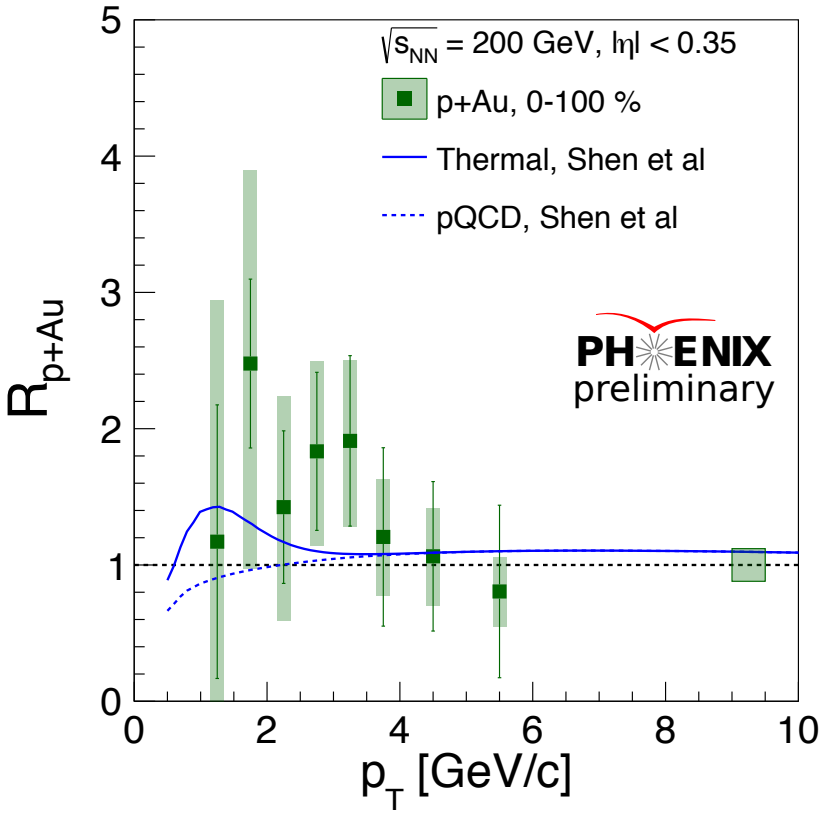


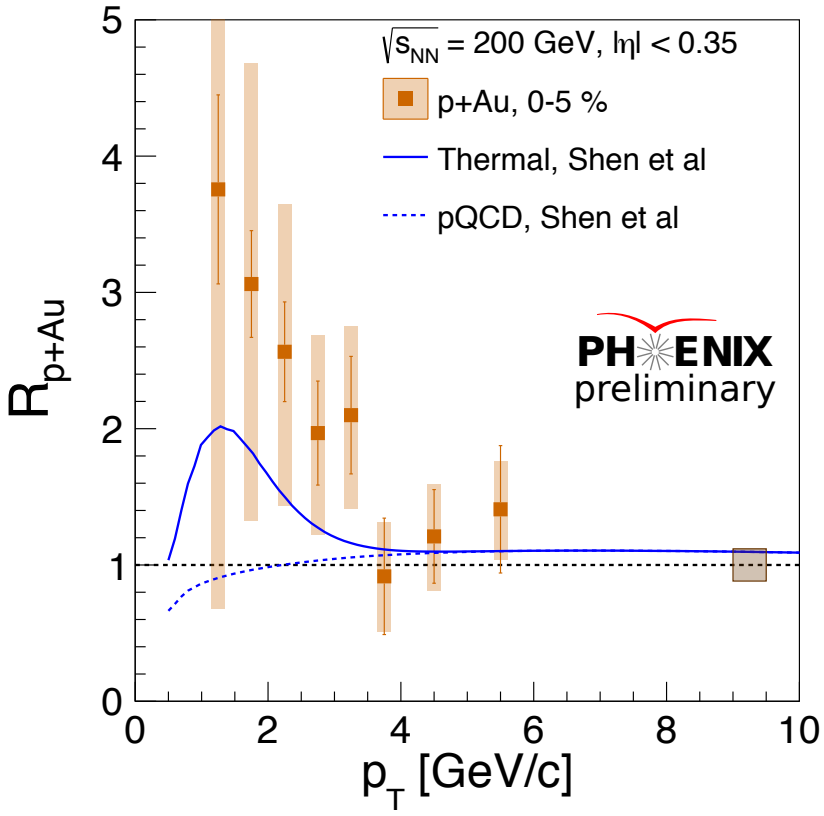
N_{coll} = 4.667



N_{coll} = 9.59

Excess photon in p+Au collisions?

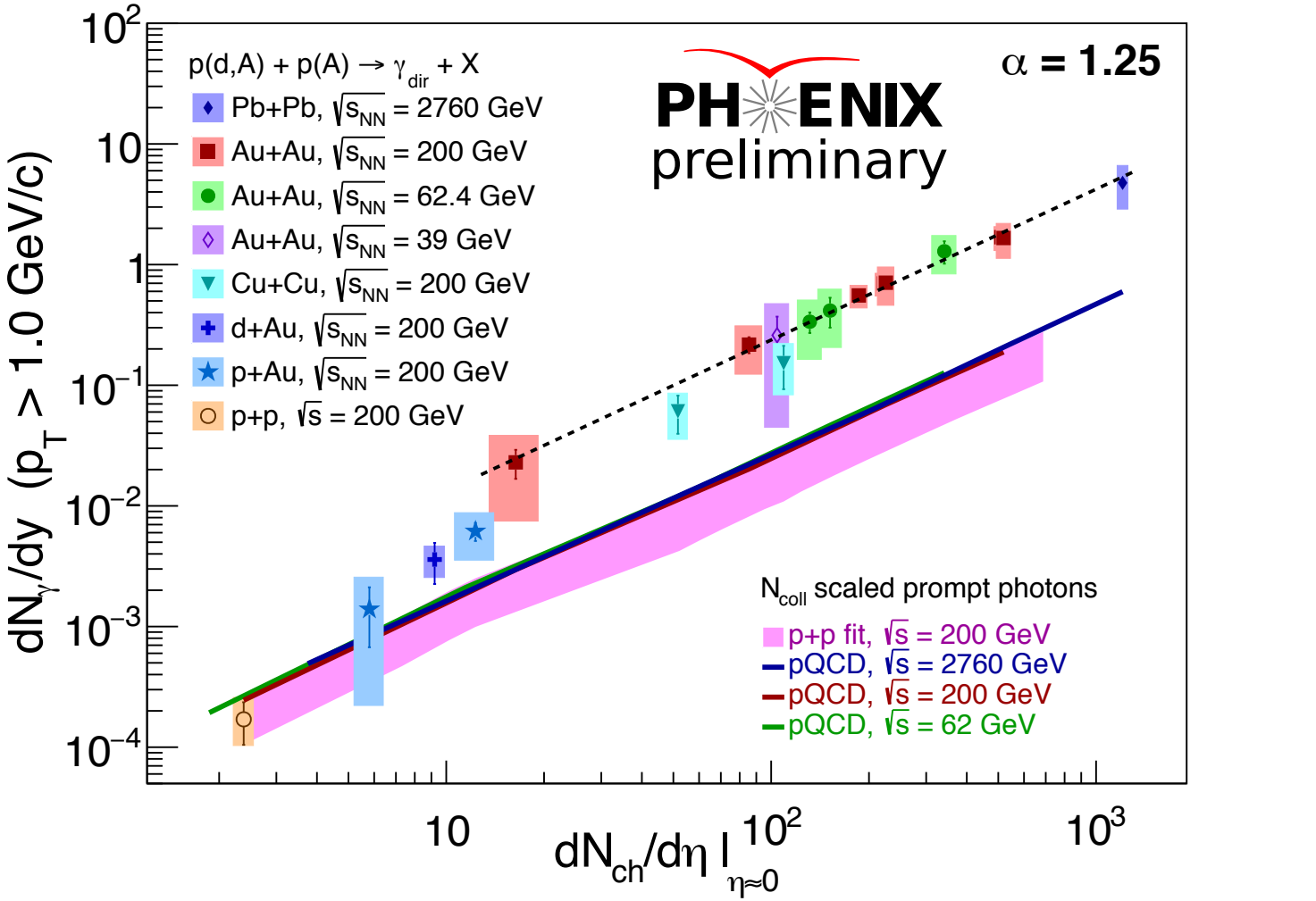




The direct photon R_{p+Au} is consistent with unity in the minimum bias collisions and shows a hint of small enhancement in the high multiplicity collisions.

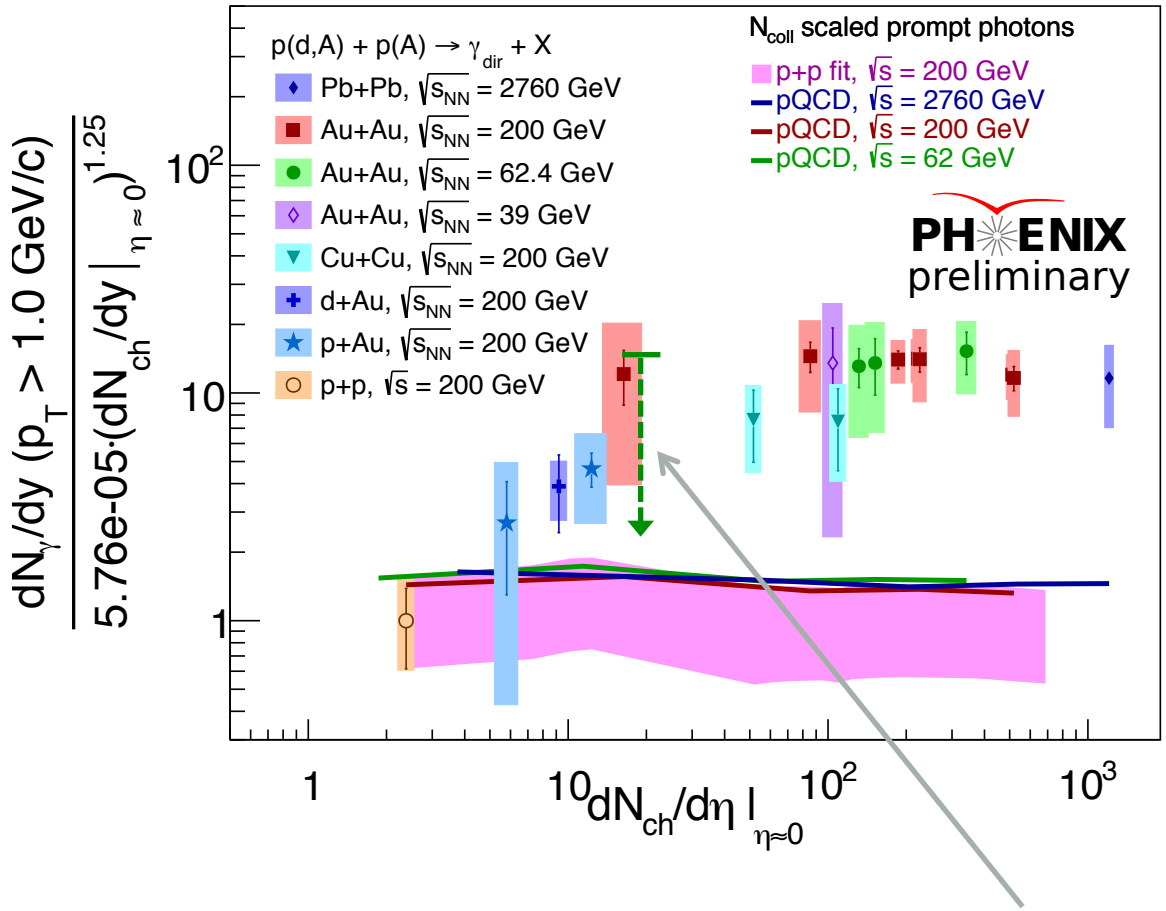
Hint of small enhancement in high multiplicity events

Filling up the multiplicity gap



The new data fill up the gap!

Integrated yield divided with pQCD expectation



Yield divided with the N_{coll} scaled pQCD expectation

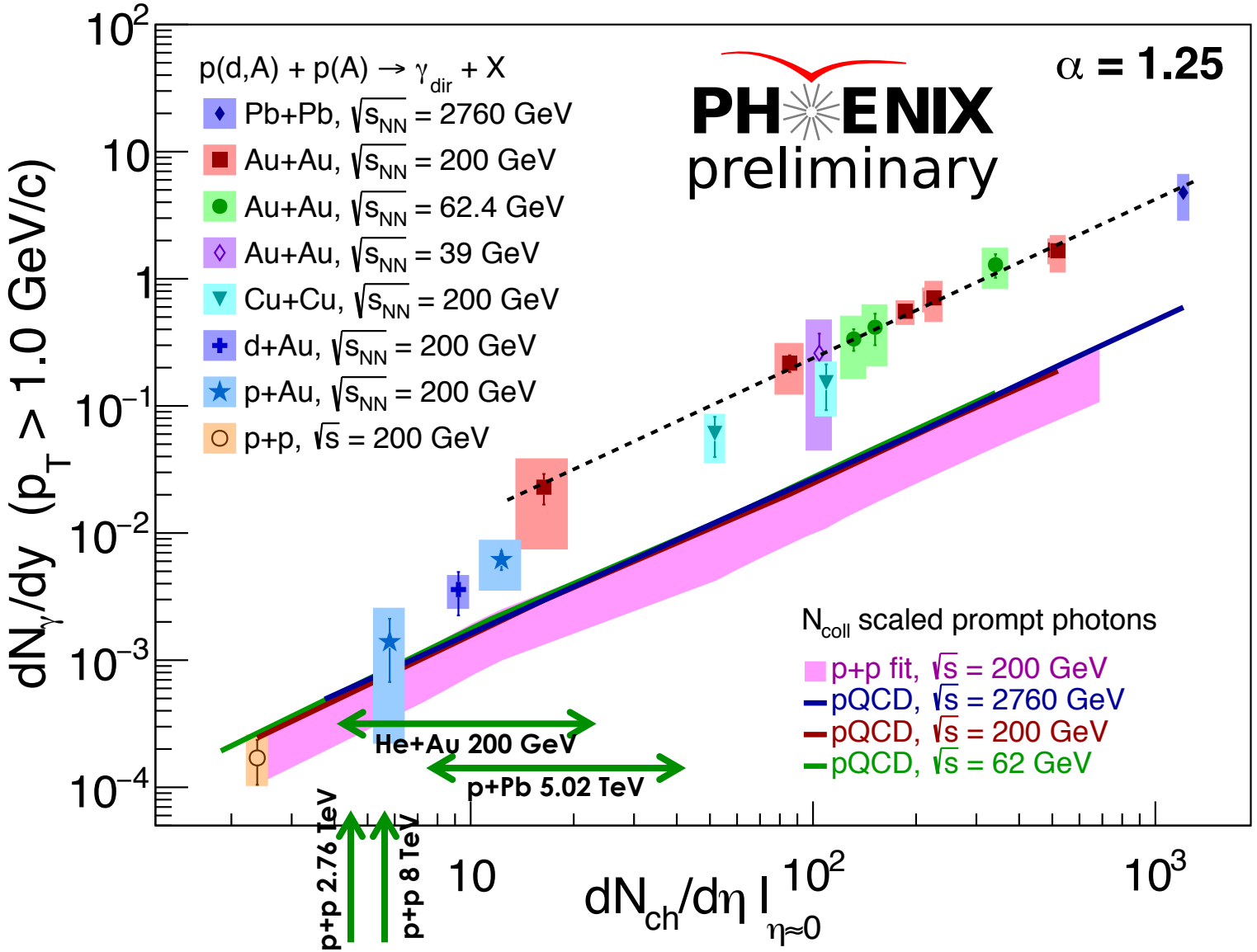
Transition observed between the p+p to A+A collisions

ALICE data (upper limit) in minimum bias p+Pb collisions

Summary

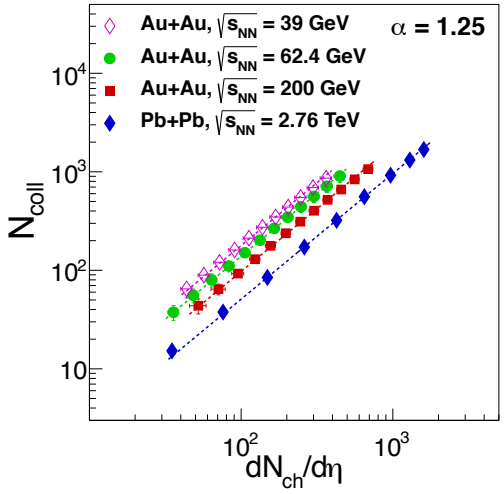
- PHENIX measured the low-p_T direct photon yields via external photon method in p+p collisions at 200 GeV:
  - The result is very consistent with the previous measurement
  - It is extended to $p_T > 0.6$ GeV/c
- PHENIX measured the low-p_T direct photon yields in minimum bias and high multiplicity p+Au collisions at 200 GeV:
  - The minimum bias collisions are consistent with the N_{coll} scaled p+p collisions
  - There is a hint of some small enhancement in the high multiplicity p+Au collisions compared to the expected N_{coll} scaled p+p baseline
- Integrated yield from various heavy ion measurements suggest a 'transition phase' between 2-20 multiplicities:
  - p+Au and d+Au measurements are consistent with the transition

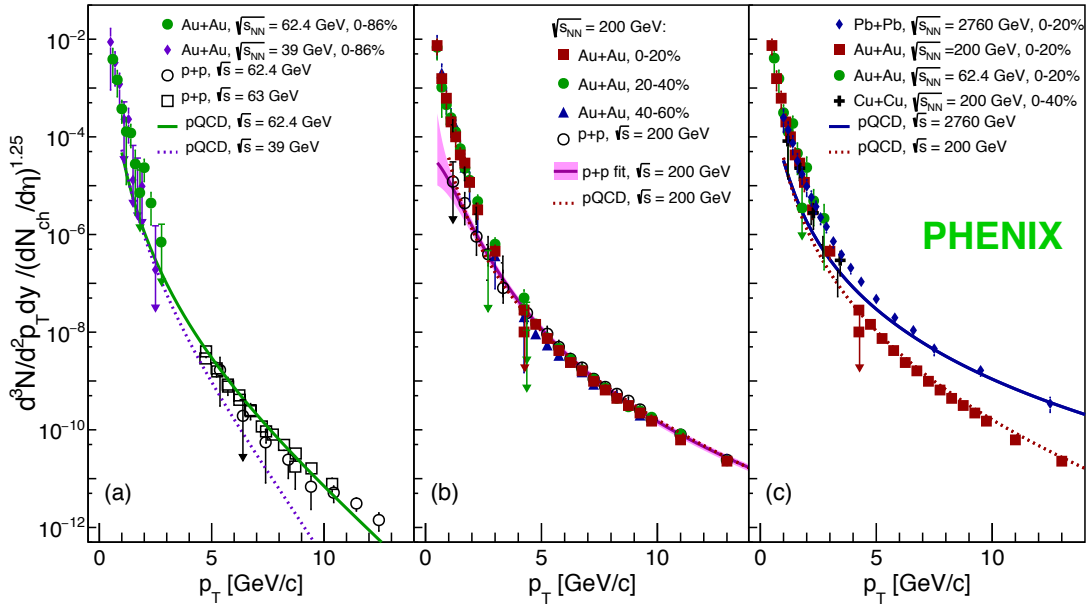
Outlook


p(d,A) + p(A) → γ dir + X
Pb+Pb, √sNN = 2760 GeV
Au+Au, √sNN = 200 GeV
Au+Au, √sNN = 62.4 GeV
Au+Au, √sNN = 39 GeV
Cu+Cu, √sNN = 200 GeV
d+Au, √sNN = 200 GeV
p+Au, √sNN = 200 GeV
p+p, √s = 200 GeV
PHENIX
preliminary
α = 1.25
Ncoll scaled prompt photons
p+p fit, √s = 200 GeV
pQCD, √s = 2760 GeV
pQCD, √s = 200 GeV
pQCD, √s = 62 GeV
He+Au 200 GeV
p+Pb 5.02 TeV
p+p 2.76 TeV
p+p 8 TeV
dNγ/dy (pT > 1.0 GeV/c)
dNch/dη |η≈0

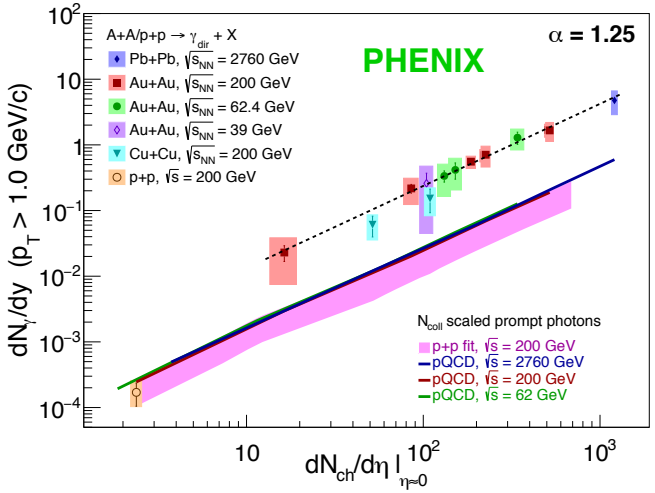
BACKUP

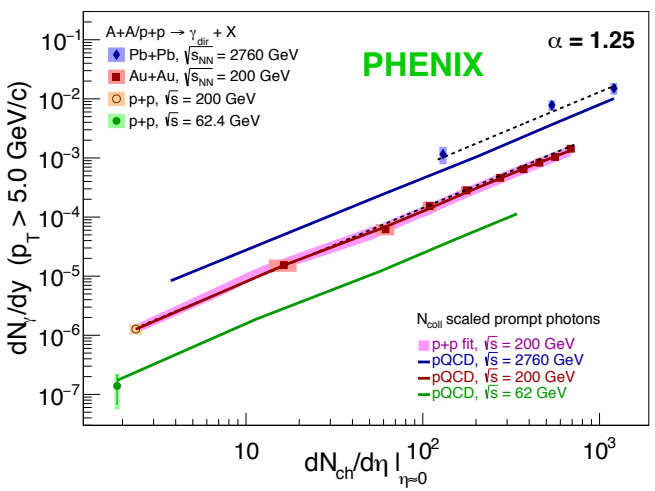
Direct photon scaling plots





Plots from:
arXiv:1805.04084

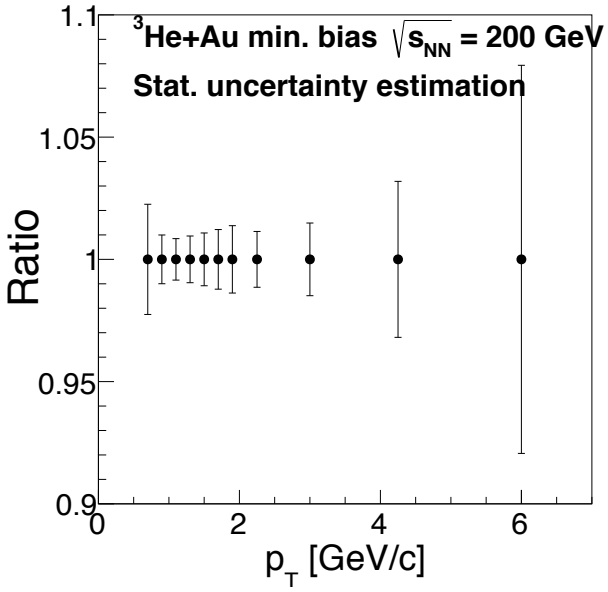


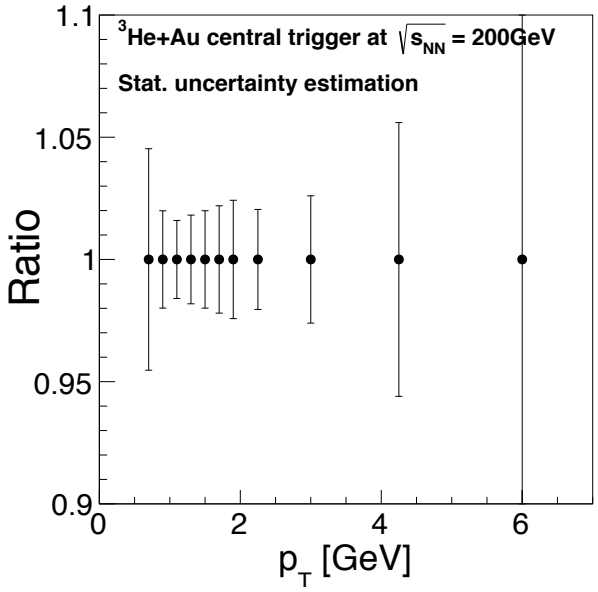


^{3}He+Au already under way

Estimation of the statistical significance:

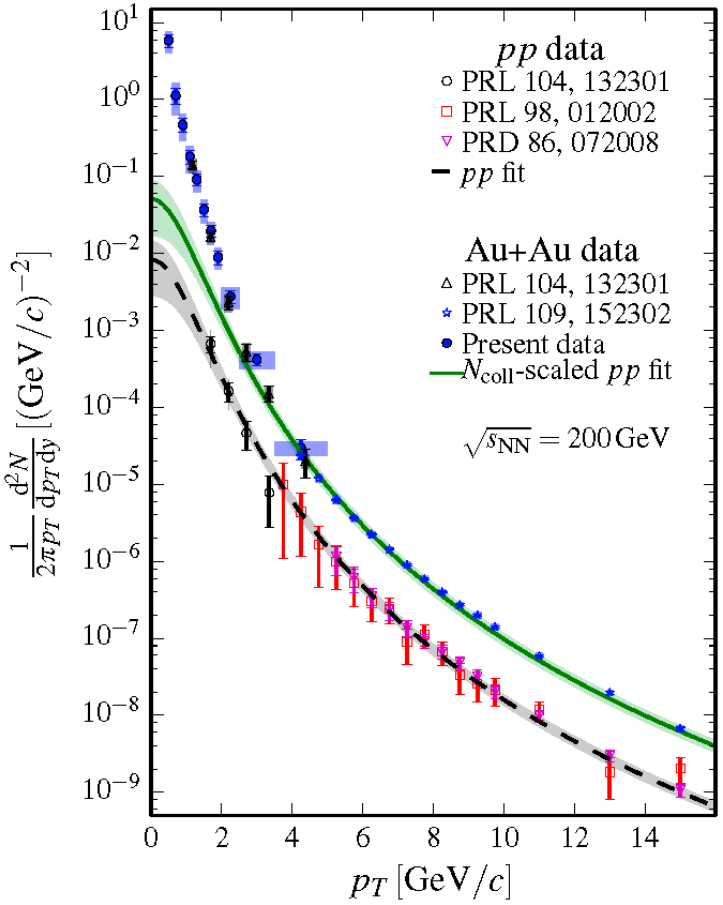
- >1-2 % signal should be able to see
- Important addition to the excess yield investigation



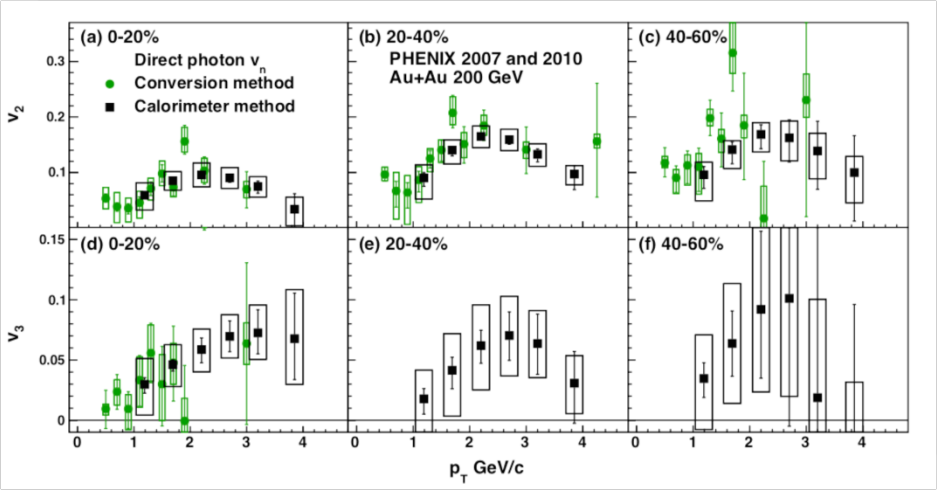


Direct photon puzzle

PRC91, 064904 (2015)



PRC 94, 064901

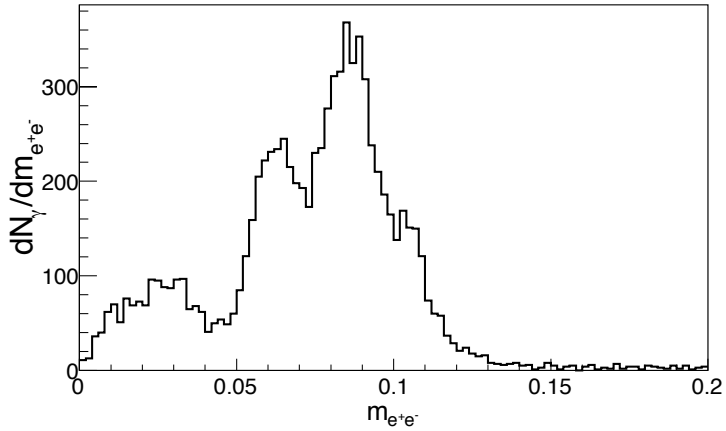


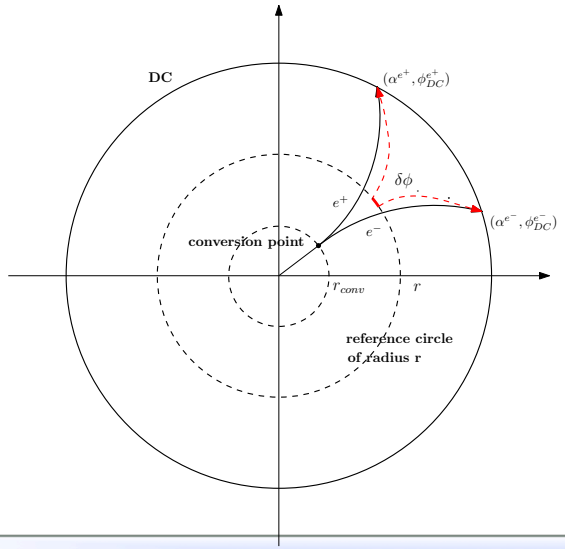
- **Large yield**
  - Emission from the early stage where temperature is high
- **Large elliptic flow (v_2)**
  - Emission from the late stage where the collectivity is sufficiently built up

Reconstruction method

- Identify and reconstruct photons via external conversions to e^+e^- pairs. The method depend on the conversion geometry.
- Previous method used **single e^+/e^- tracks** (2010):
  - thick conversion radius at 60cm
- New method uses **e^+e^- pairs** (>2011):
  - Reconstruction of the true conversion radius

simulation result





- Solve the equation of motions for both tracks to the their intersection
- Once the conversion radius is found, reconstruct the true momentum of the photon