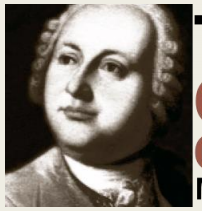


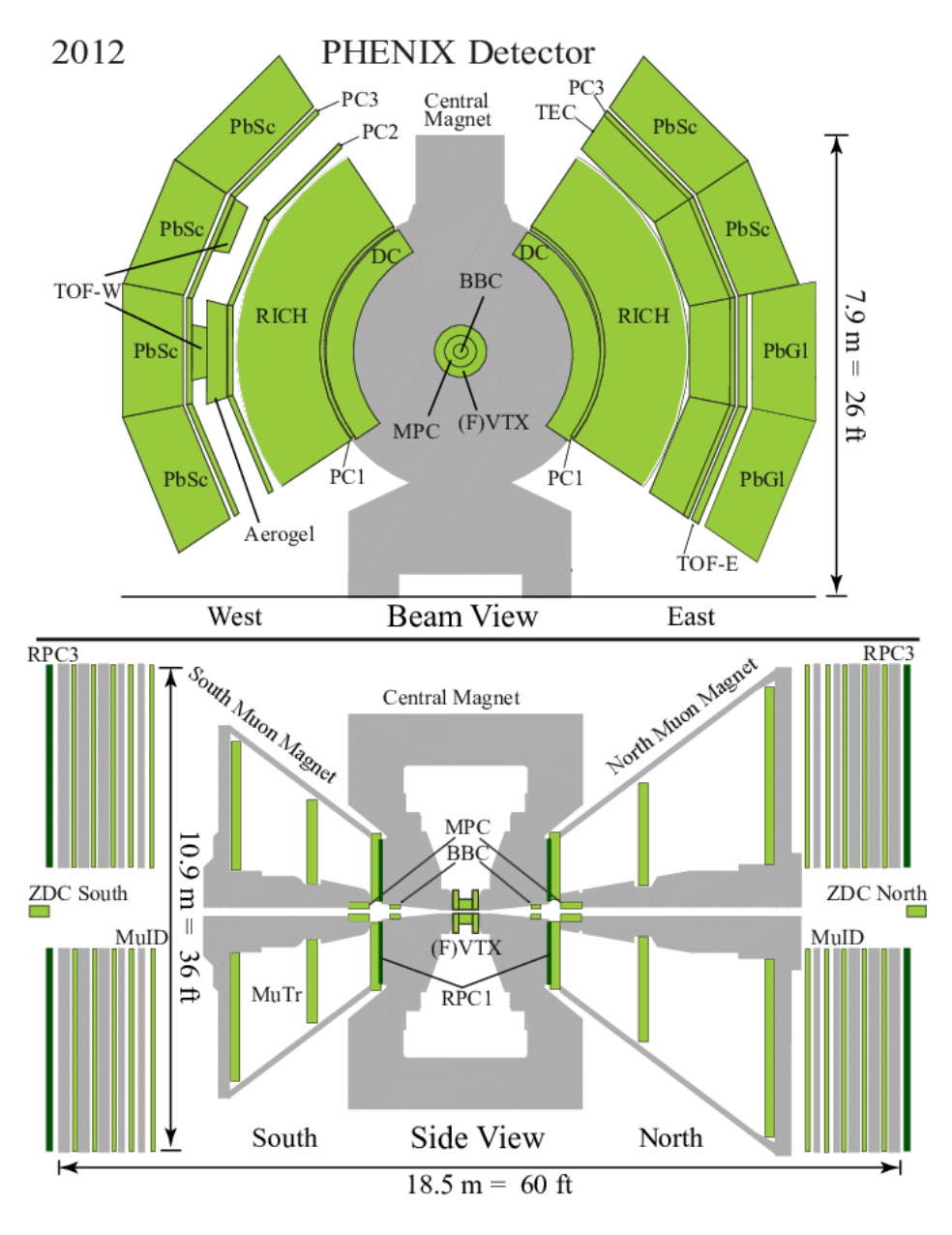
TWENTIETH LOMONOSOV CONFERENCE August, 19-25, 2021
ON ELEMENTARY PARTICLE PHYSICS
MOSCOW STATE UNIVERSITY

STUDY OF HIGH-PT DIRECT PHOTONS IN SMALL SYSTEMS AT PHENIX

Zhandong Sun for the PHENIX collaboration
University of Debrecen, Hungary

DEBRECENI EGYETEM

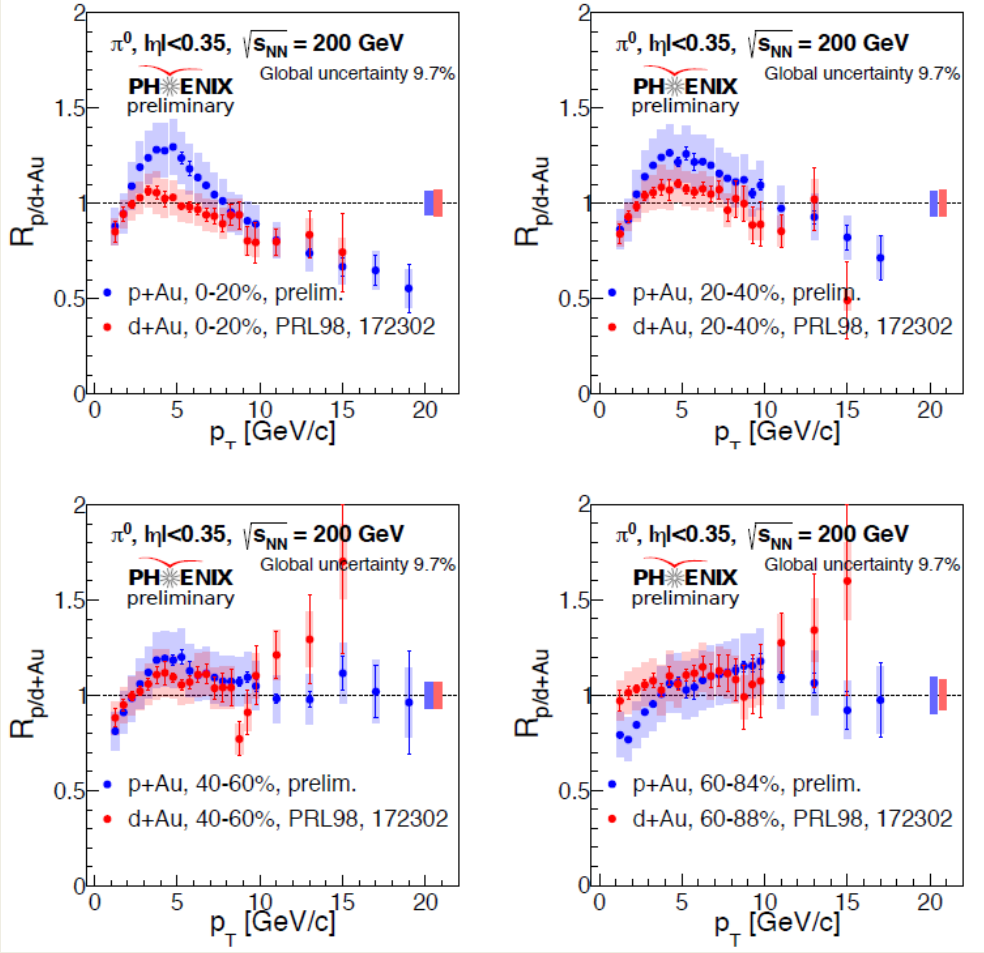
PHENIX



Outline

- Motivation
- Extraction of π^0
- 2D-matrix Method
- Uncertainty study
- Decay photons
- Corrected π^0 and raw direct photons
- Summary

Nuclear modification factor for π^0 in p/d+Au collisions



Reading the plot…

$$R_{AA}(pt) = \frac{\frac{dN_{AA}}{dp_T}}{\langle N_{coll} \rangle \frac{dN_{pp}}{dp_T}}$$

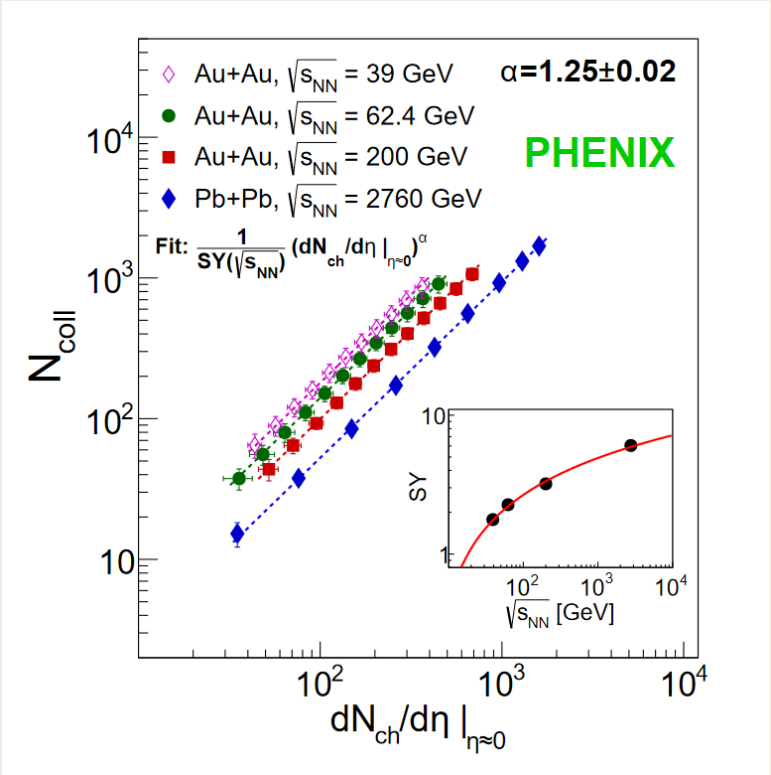
- Both p+Au and d+Au show large centrality dependence.
- In high p_T we observe suppression in central events and enhancement in peripheral events.

Conclusion:
Something interesting is behind the centrality dependence !

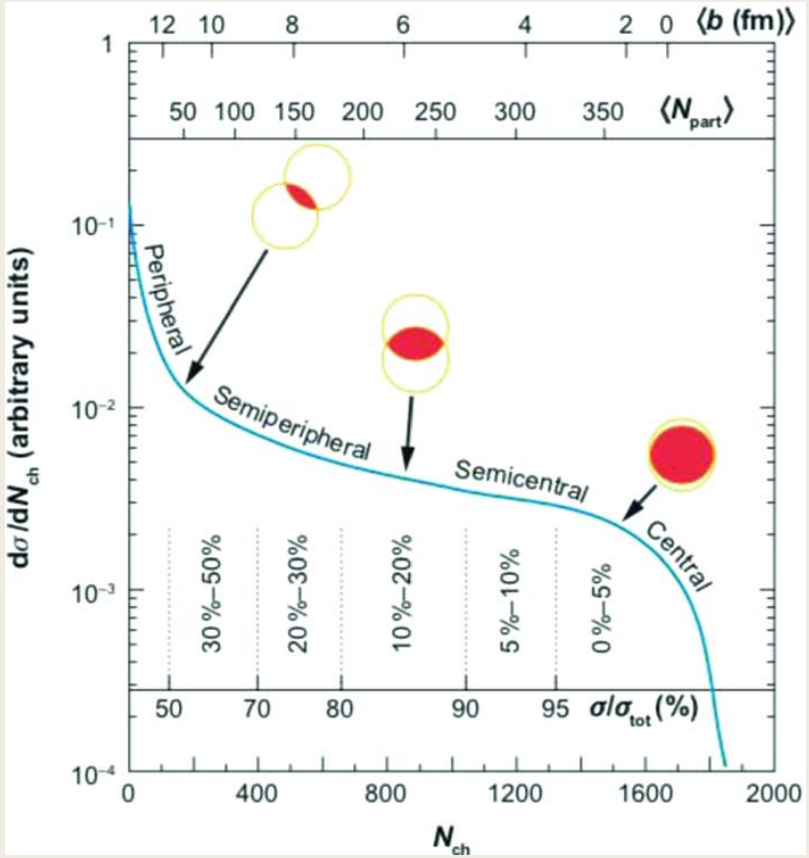
(possible) Mis-binning of centrality?

$$R_{AA}(pt) = \frac{\frac{dN_{AA}}{dp_T}(N_{ch})}{\langle N_{coll}\rangle \frac{dN_{pp}}{dp_T}}$$

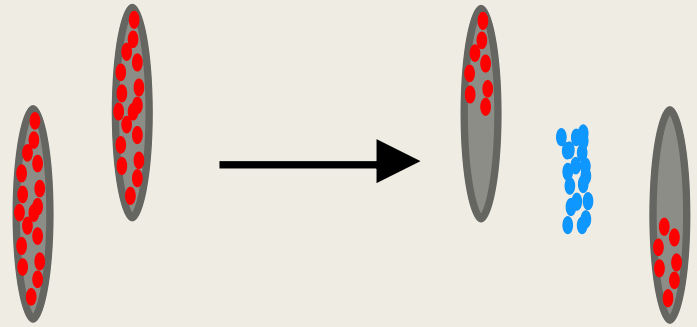
N_{coll}: Average number of binary collisions in a type of event according to Glauber Model.



Phys. Rev. Lett. 123.022301



Annu. Rev. Nucl. Part. Phys. Vol. 57:205-243



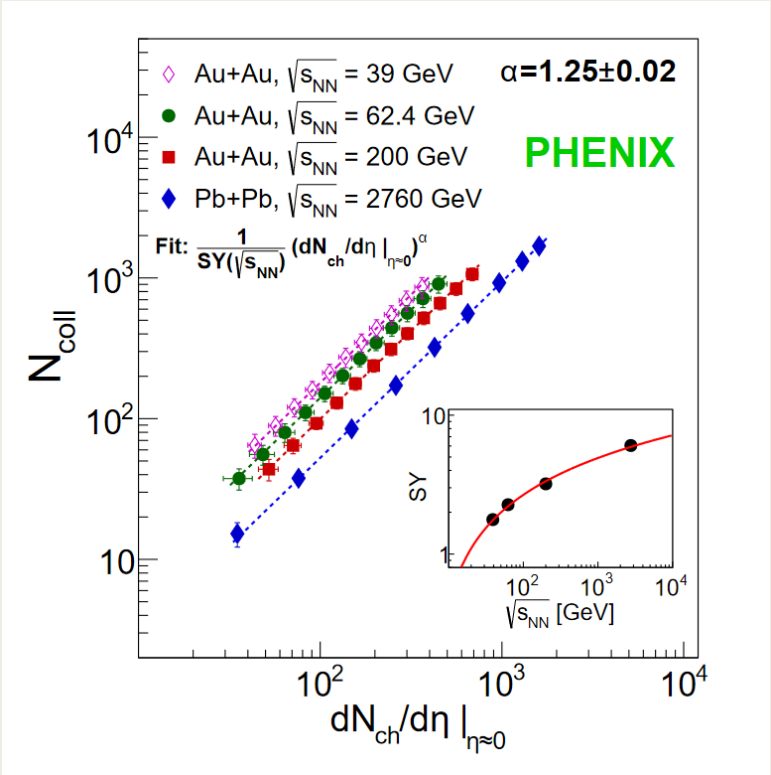
This works well when two large ions collide

- $N_{charge} \leftrightarrow N_{coll}$

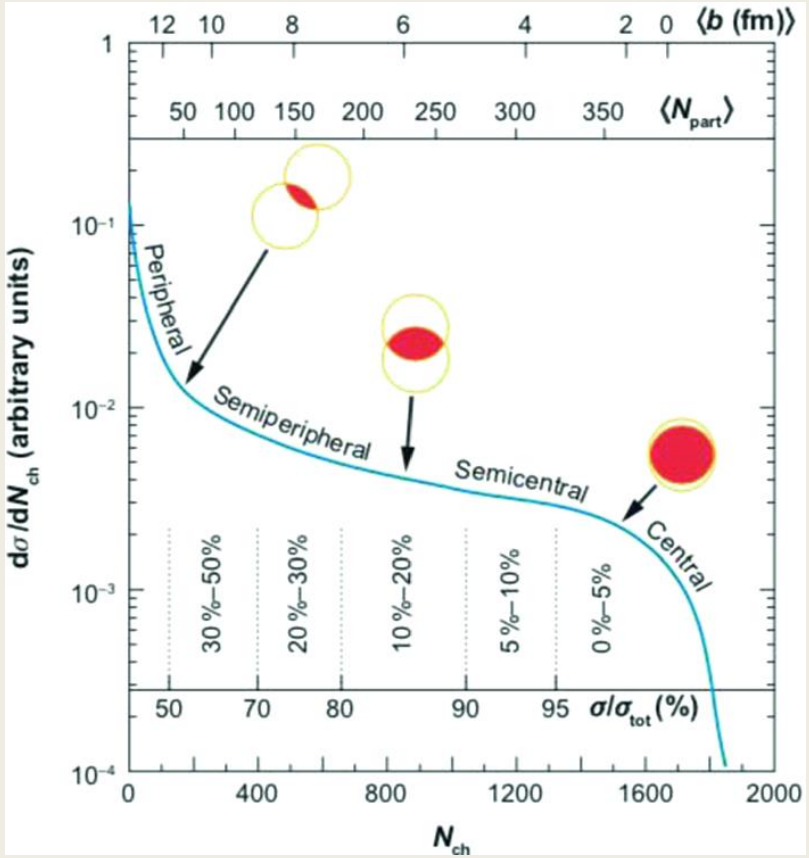
(possible) Mis-binning of centrality?

$$R_{AA}(pt) = \frac{\frac{dN_{AA}}{dp_T}(N_{ch})}{\langle N_{coll}\rangle \frac{dN_{pp}}{dp_T}}$$

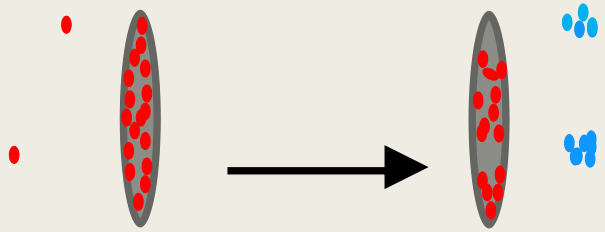
N_{coll}: Average number of binary collisions in a type of event according to Glauber Model.



Phys. Rev. Lett. 123.022301



Annu. Rev. Nucl. Part. Phys. Vol. 57:205-243

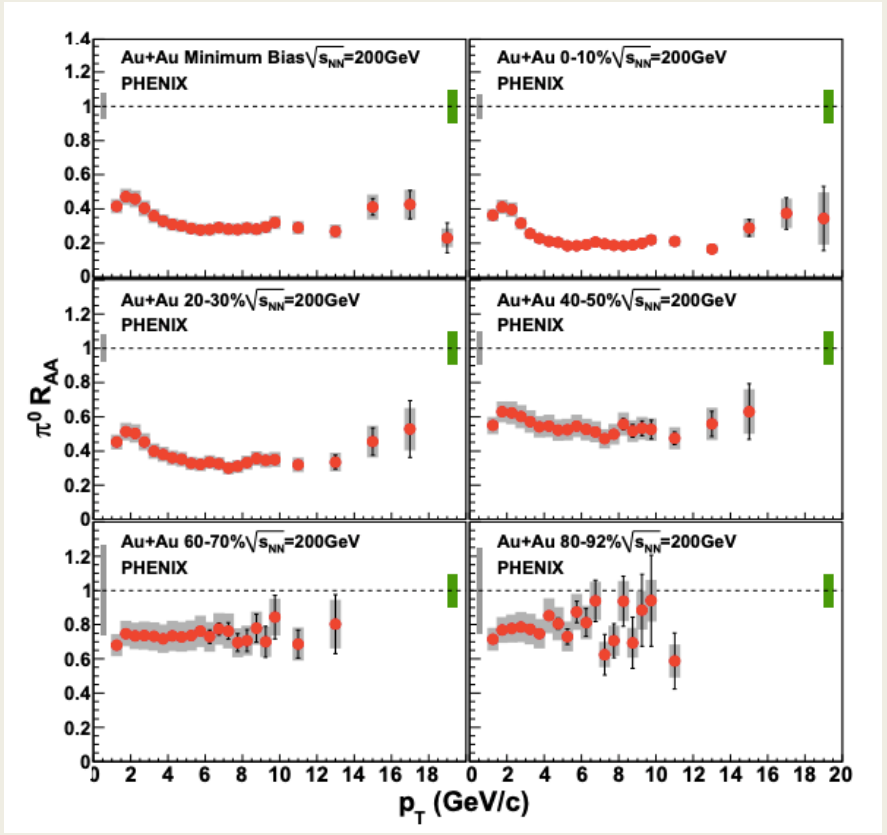


However, in small systems...

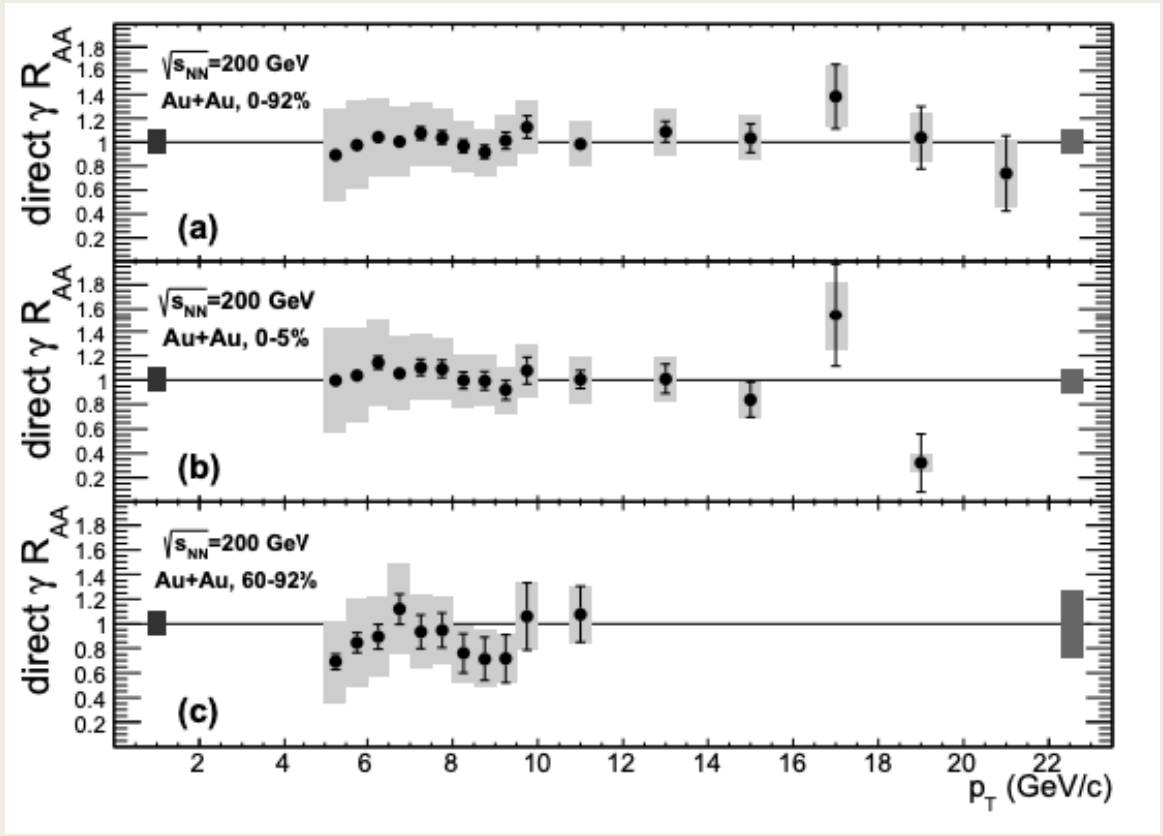
- $N_{charge} \leftrightarrow N_{coll}$

Direct photons

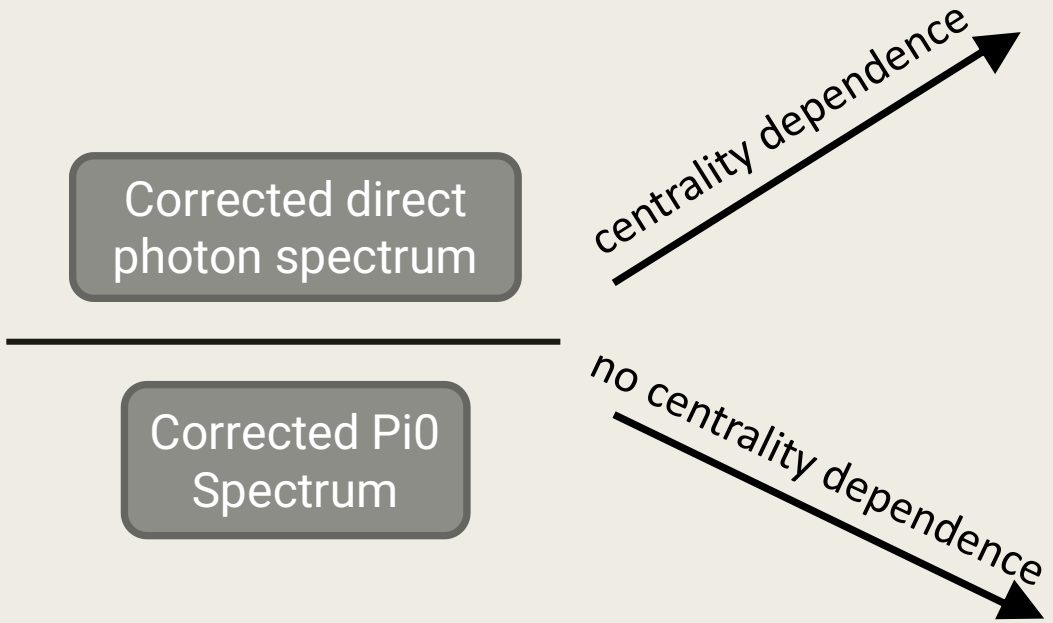
Au+Au
Suppression in π^0 and non-suppression in direct γ R_{AA}



Phys. Rev. L 101 (2008) 232301



Phys. Rev. L 109 (2012) 152302

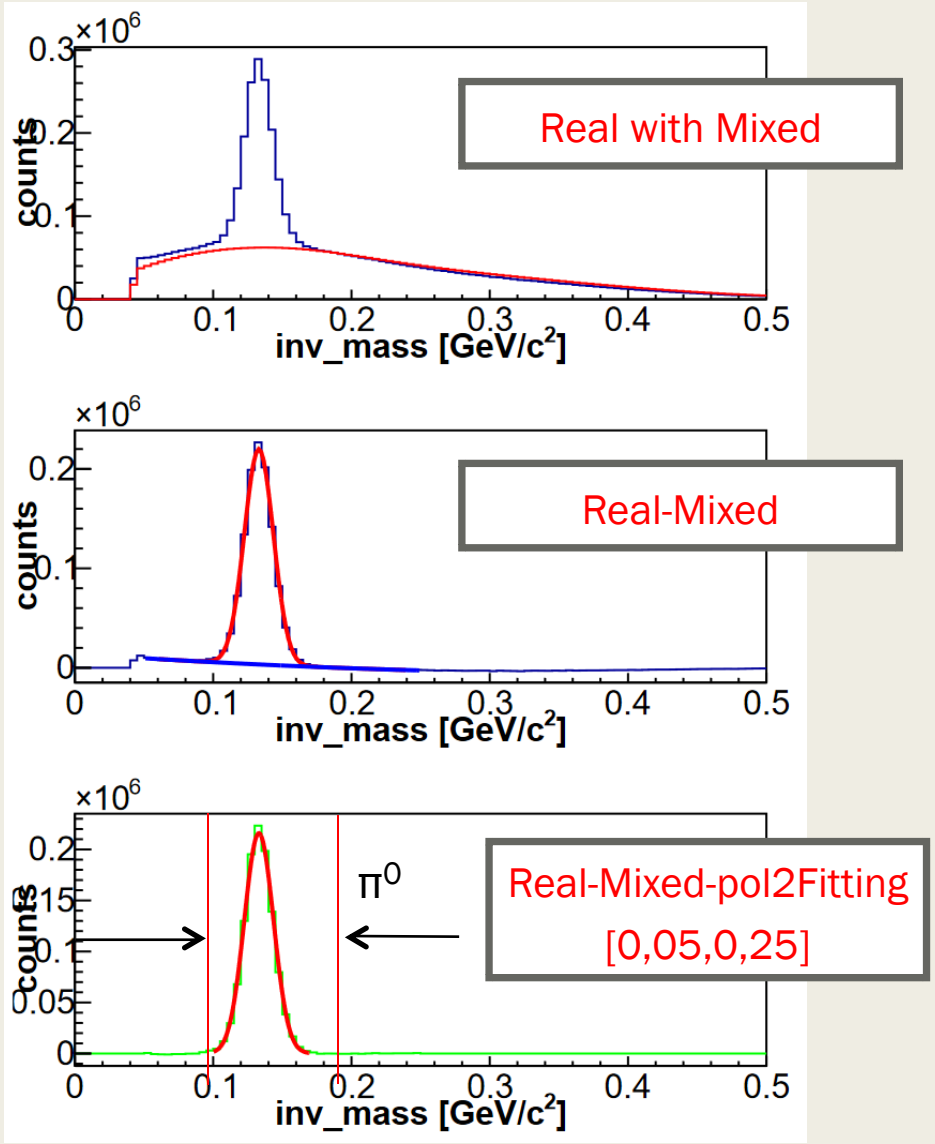


The centrality dependence that we see in π^0 spectrum is because of true physics effects. And it should not affect direct photon.

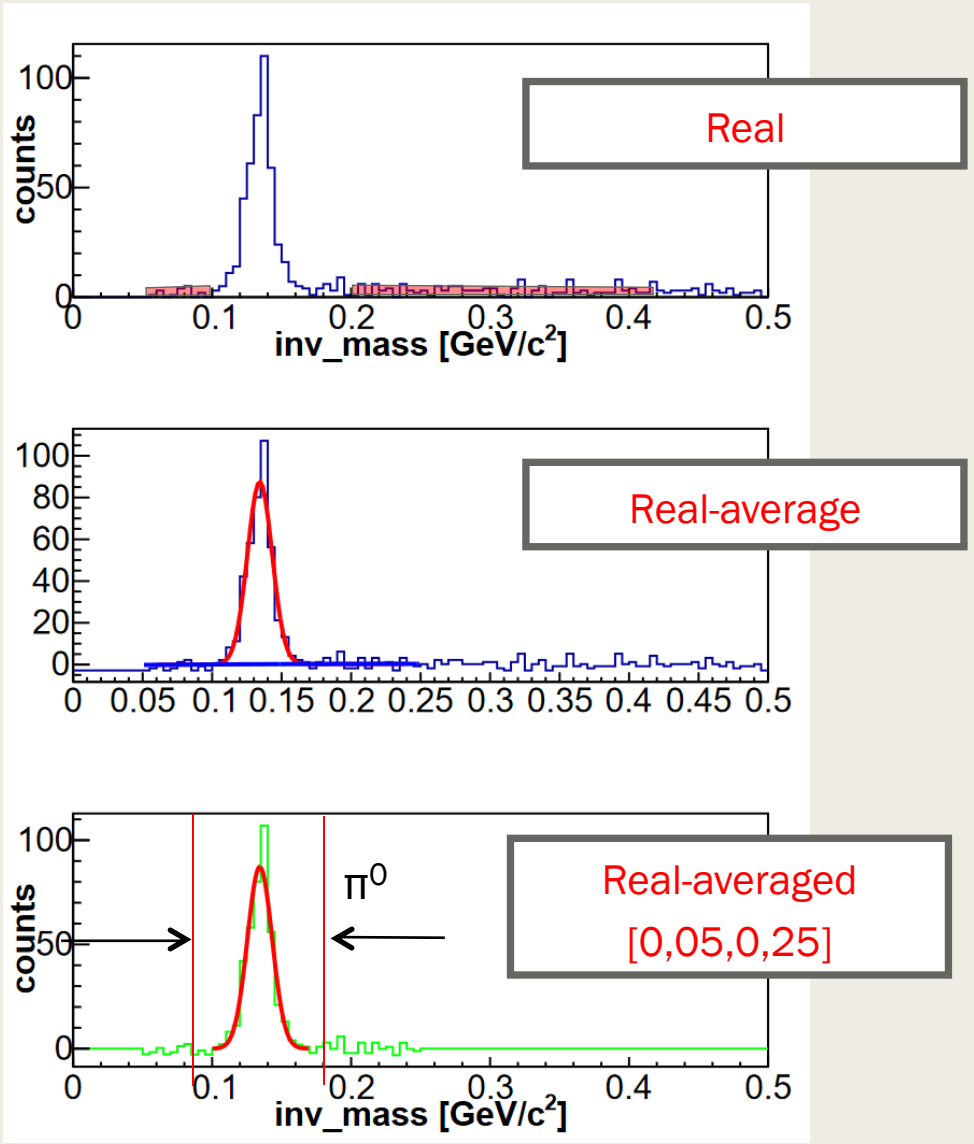
The centrality dependence that we see in π^0 spectrum is because of mis-binning of centrality. This should affect direct photon equally.

$$m_{\gamma\gamma} = \sqrt{2E_1E_2(1-\cos\emptyset)}$$

Mixed event method at low-p_T



Average bkg. subtraction method at high-p_T



What should be corrected ?

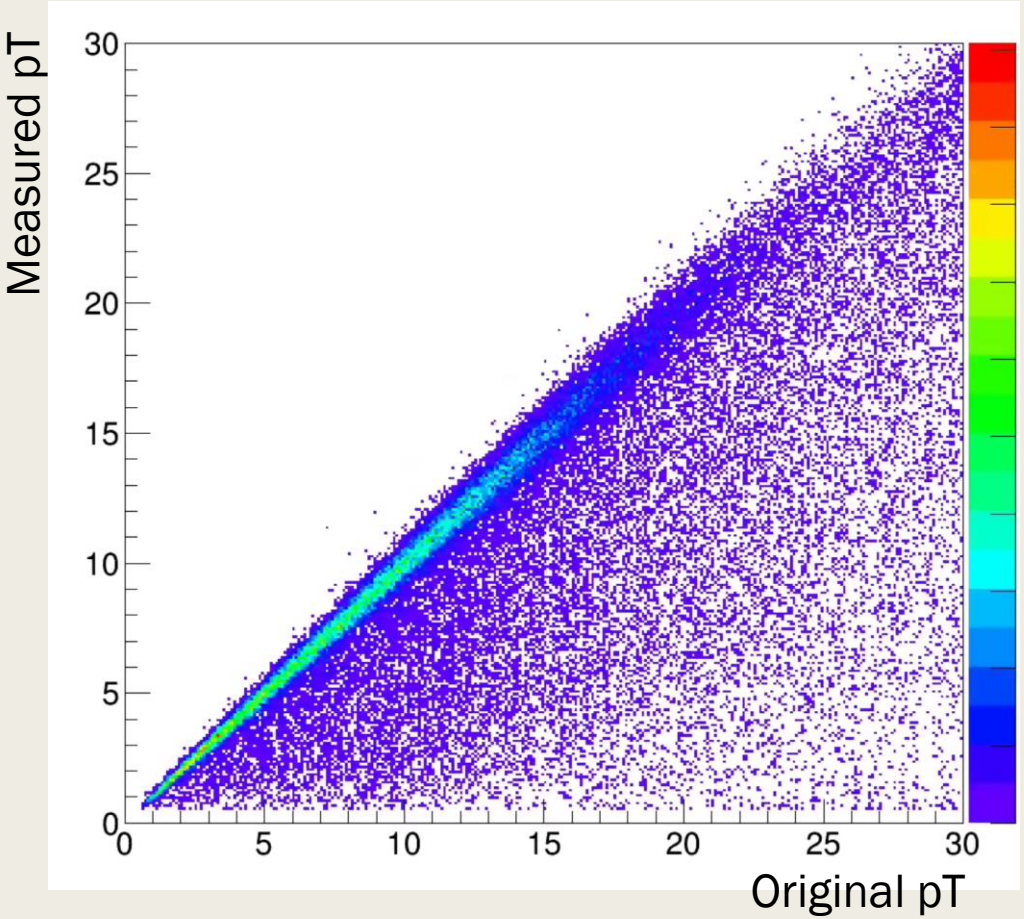
Acceptance:
- Coverage of rapidity $|\eta|<0.35$
- Dead/hot towers in EMCal
- Cluster selection geometrically for analysis

Efficiency:
- PID efficiency
- Merging effect at high p_T
- Cluster break-up at high p_T

Smearing:
- The p_T of the reconstructed π^0 might be different from the true p_T

Migration takes place between p_T bins.
True p_T is steep , so migration is mostly to lower p_T.

Inverting this response matrix is problematic due to the small, fluctuating off-diagonal elements.



Simulated response matrix -- true -> measured

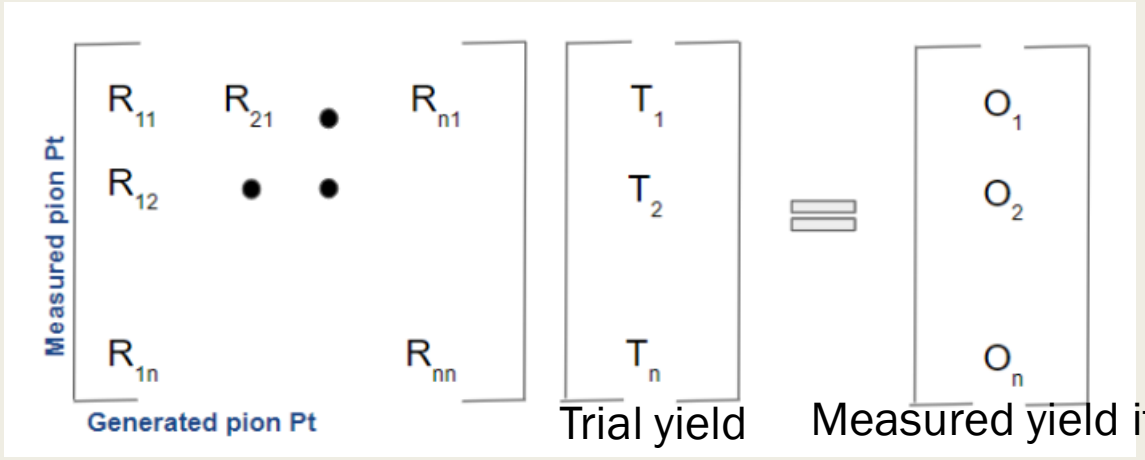
$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ . & . & \cdots & . \\ . & . & \cdots & . \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \; elements\ divided\ with \begin{bmatrix} n_1 & n_2 & . & . & n_n \end{bmatrix}$$

n_n is the number of π^0 generated at p_T n

x_{mn} is the number of π^0 generated at p_T *n* but reconstructed as p_T *m*

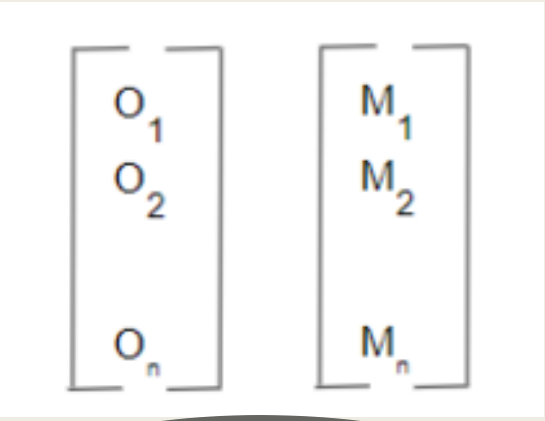
$$\longrightarrow \begin{bmatrix} \frac{x_{11}}{n_1} & \frac{x_{12}}{n_2} & \cdots & \frac{x_{1n}}{n_n} \\ \frac{x_{21}}{n_1} & \frac{x_{22}}{n_2} & \cdots & \frac{x_{2n}}{n_n} \\ . & . & \cdots & . \\ . & . & \cdots & . \\ \frac{x_{m1}}{n_1} & \frac{x_{m2}}{n_2} & \cdots & \frac{x_{mn}}{n_n} \end{bmatrix}$$

How to use the response matrix without inverting it



Trial yield

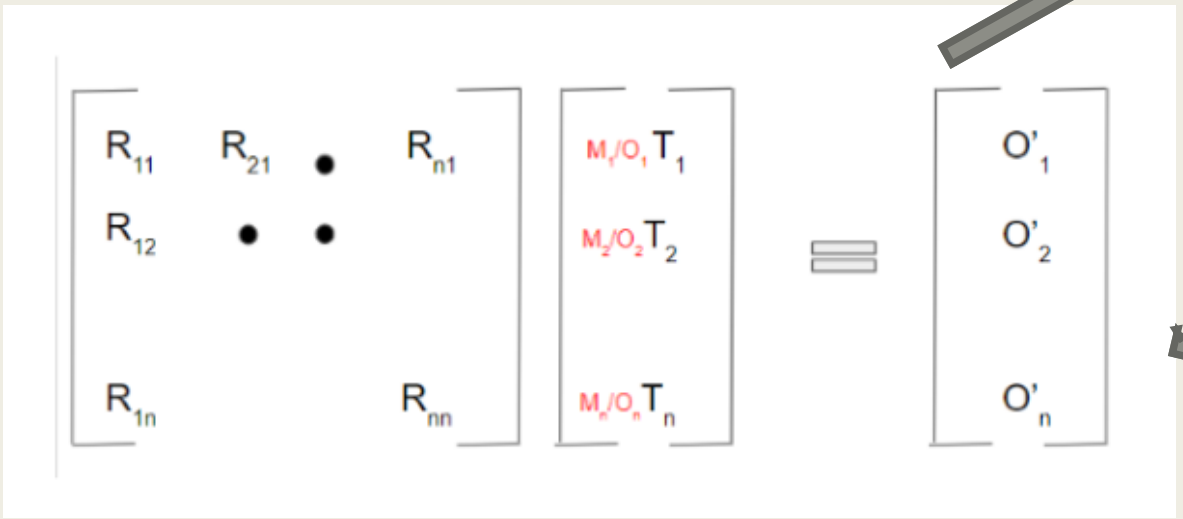
Measured yield if trial yield is the input



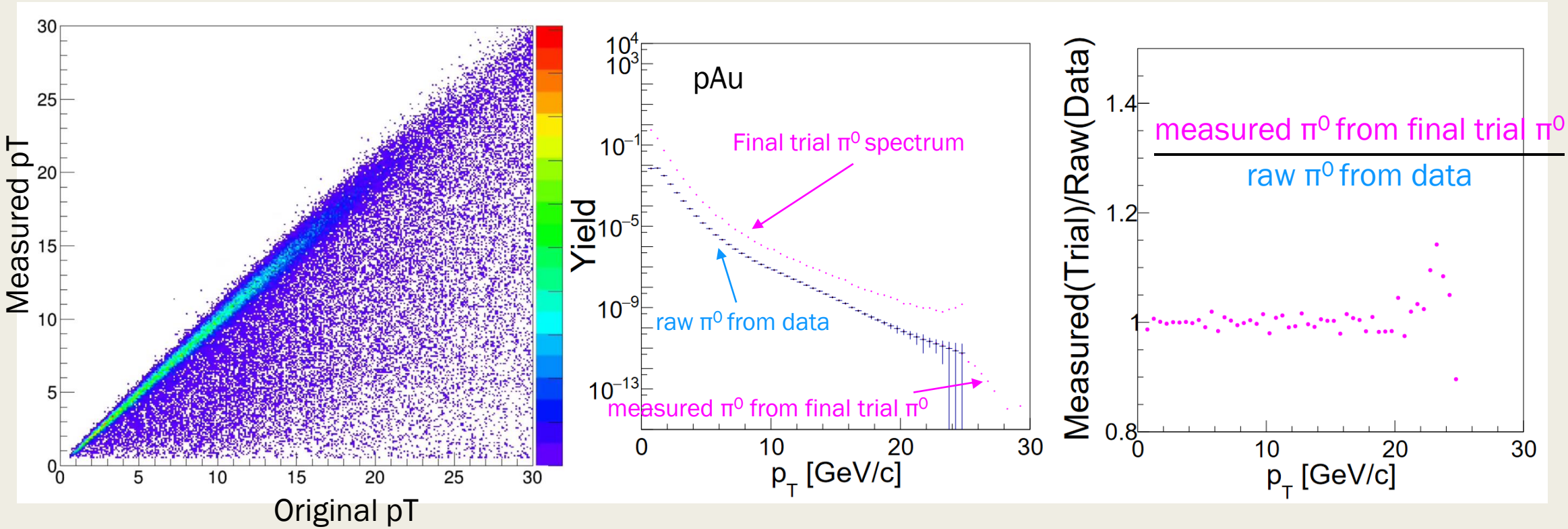
Compare to raw yield from data

Disagree

Agree

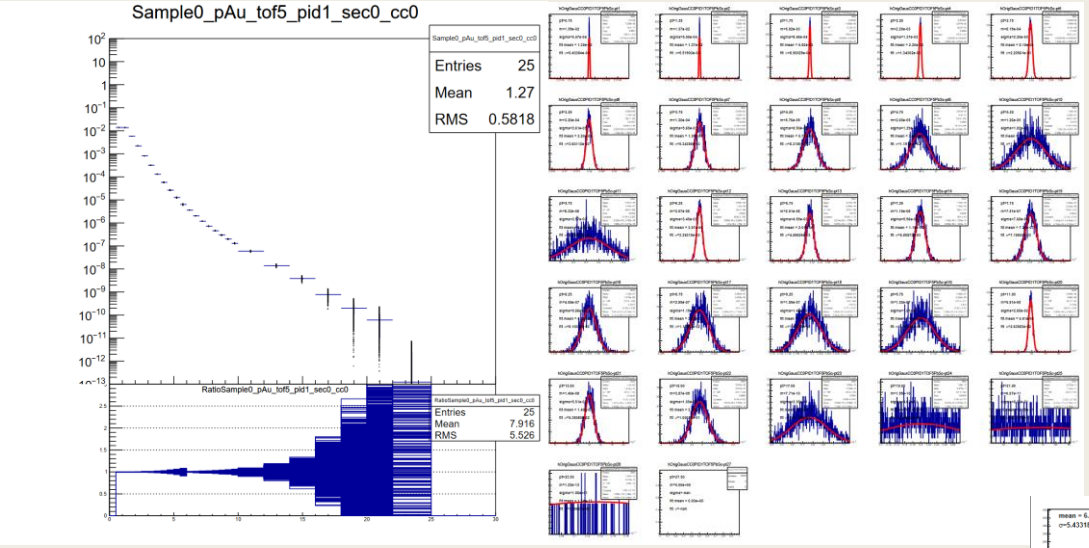


Final trial function is the corrected yield



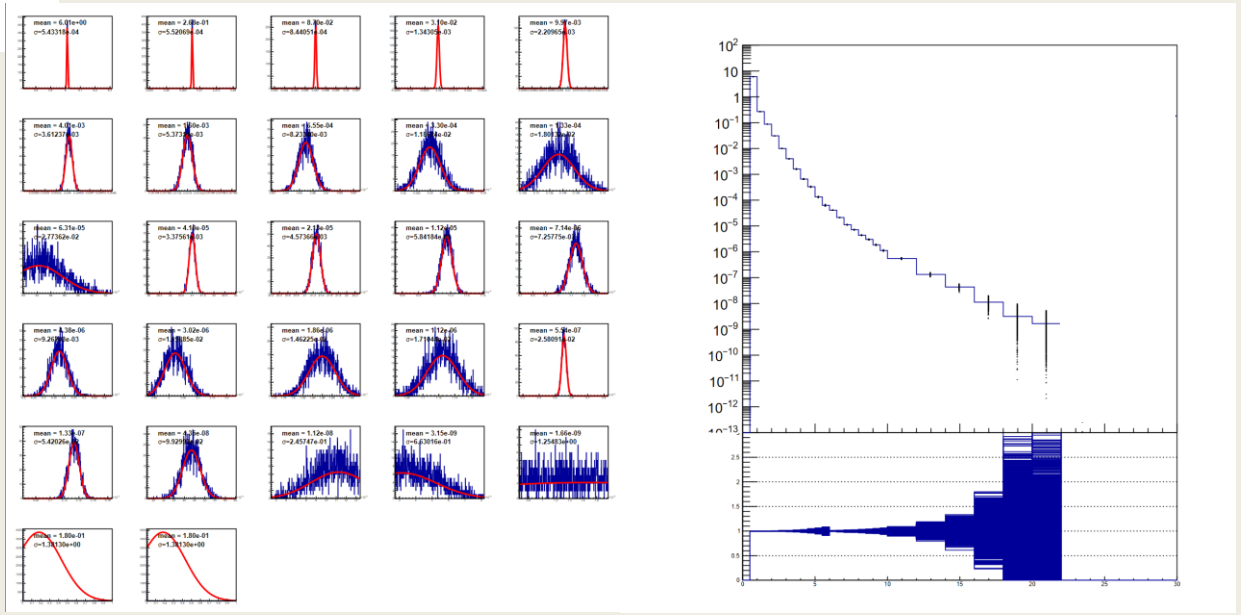
The blue curve is the raw spectrum extracted from data.
The magenta is the trial spectrum after 4 iterations.

Propagation of statistical uncertainty



Randomizing from raw spectra in p_T bins for 3000 sample spectra

1) 3000 sample spectra are generated using the value and original uncertainty at each p_T.
2) Correct all sample spectra by 2-D response matrix.
3) Plot all corrected spectra together and fill histograms for each p_T.
4) A Gaussian fit tells us about the stat. uncertainty of the corrected spectra.



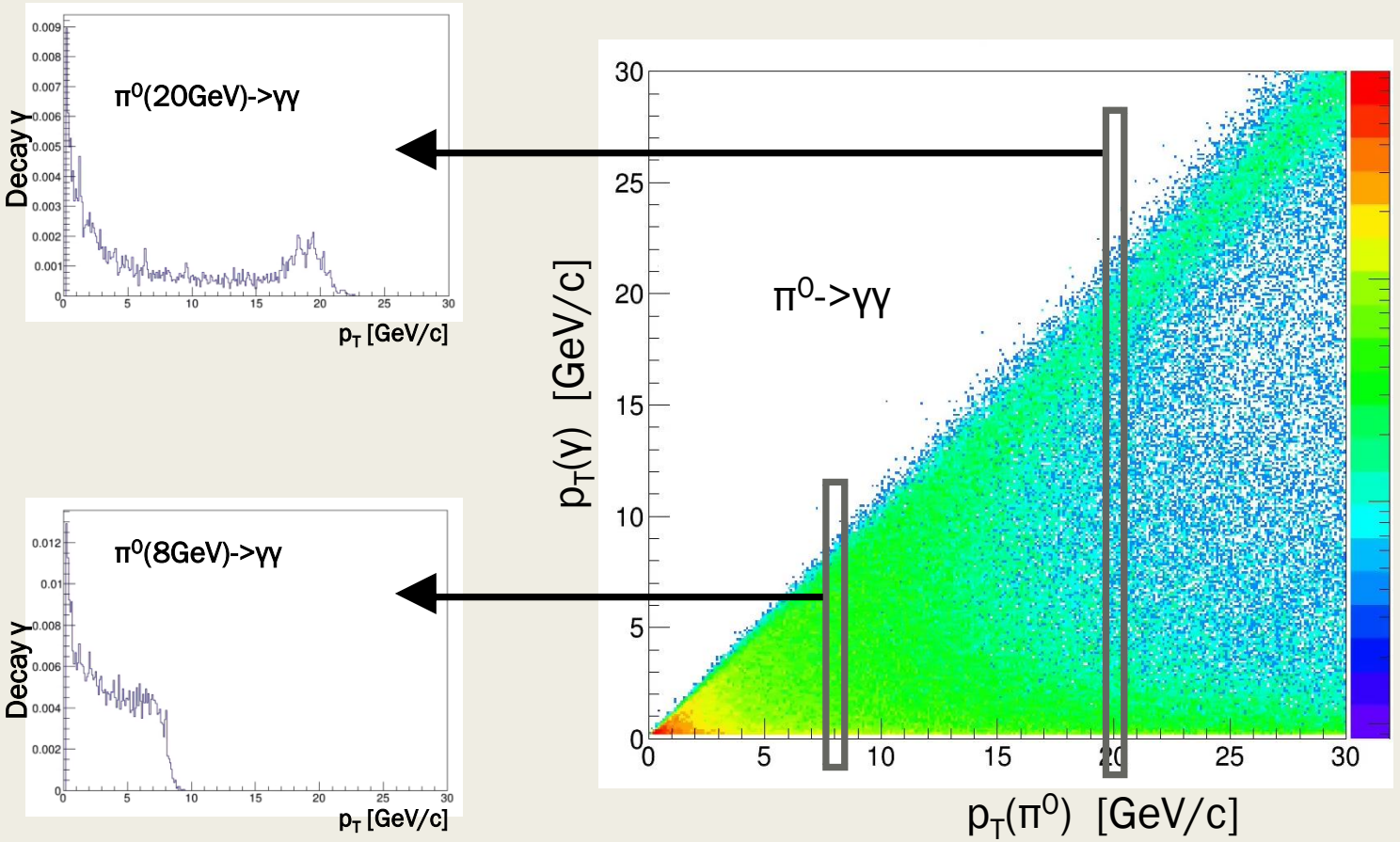
Fit randomized corrected spectra in p_T bins, mean and sigma go to the final corrected spectrum

Inclusive photons can't by corrected by one single matrix.

Kinematically, the 2γ distribution should be flat, but when actually measured in the detector, it isn't flat.

Inclusive photons

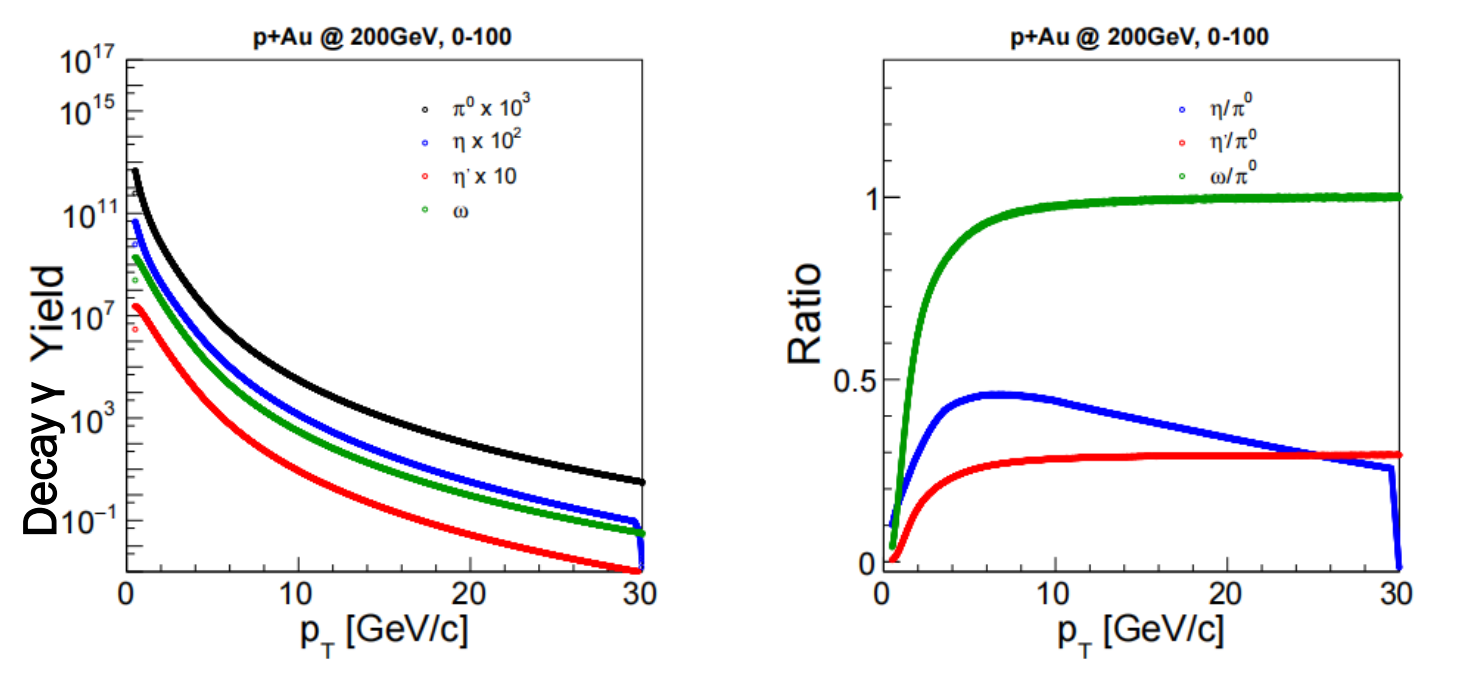
Decay photons Direct photons



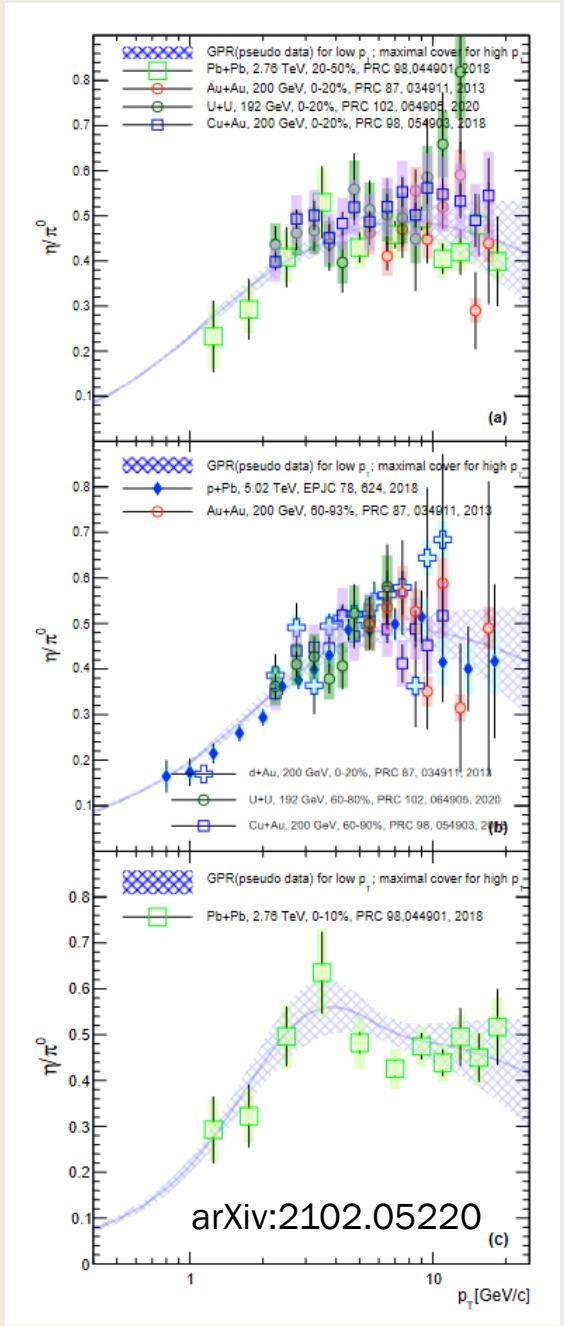
Direct photons don't have the merging effect, nor do they exhibit wrong energy sharing of separate, but close-by clusters as seen in decay photons.

Other sources of decay photons : *η, η', ω, etc.*

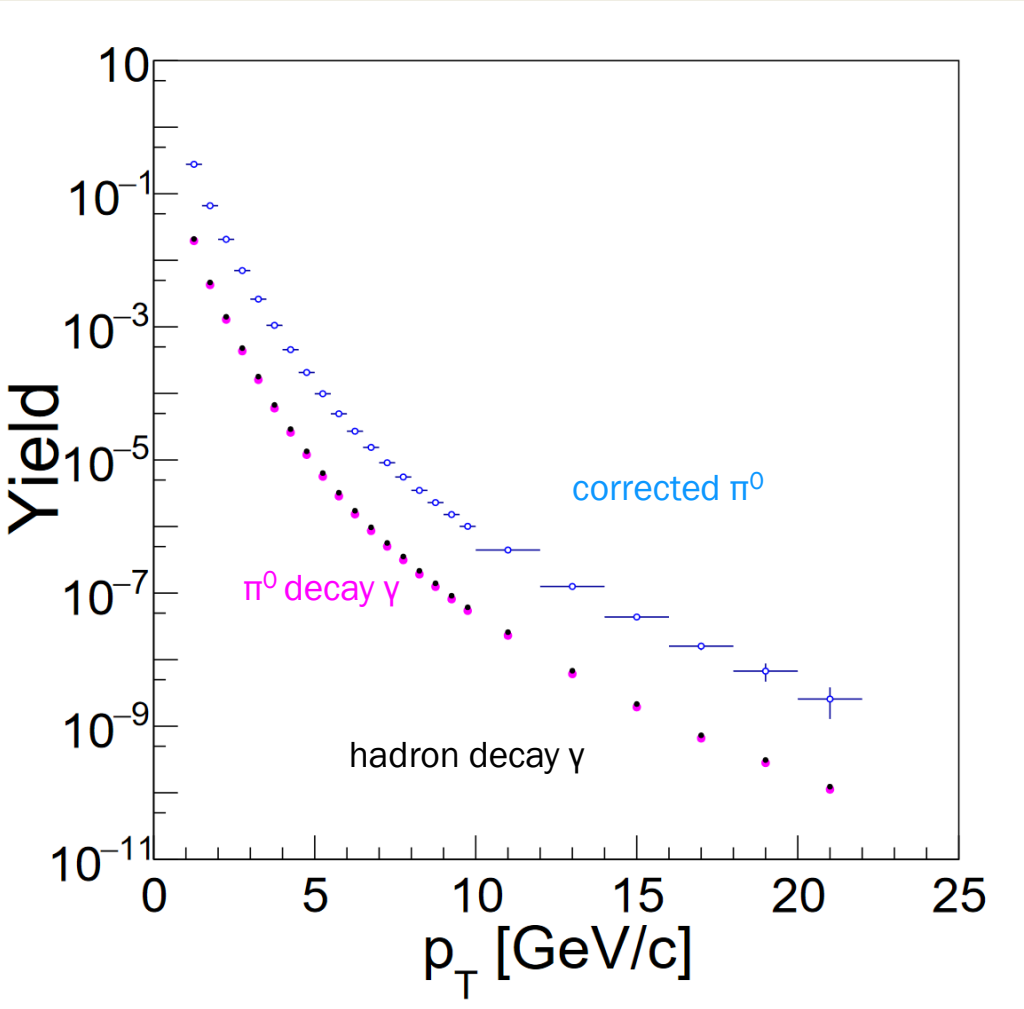
From cocktail ratio calculation using m_T scaling ,



Usually η/π^0 ratio is considered as asymptotically constant, but according to a recent study arXiv:2102.05220, we see the decreasing of η/π^0 with increasing p_T.

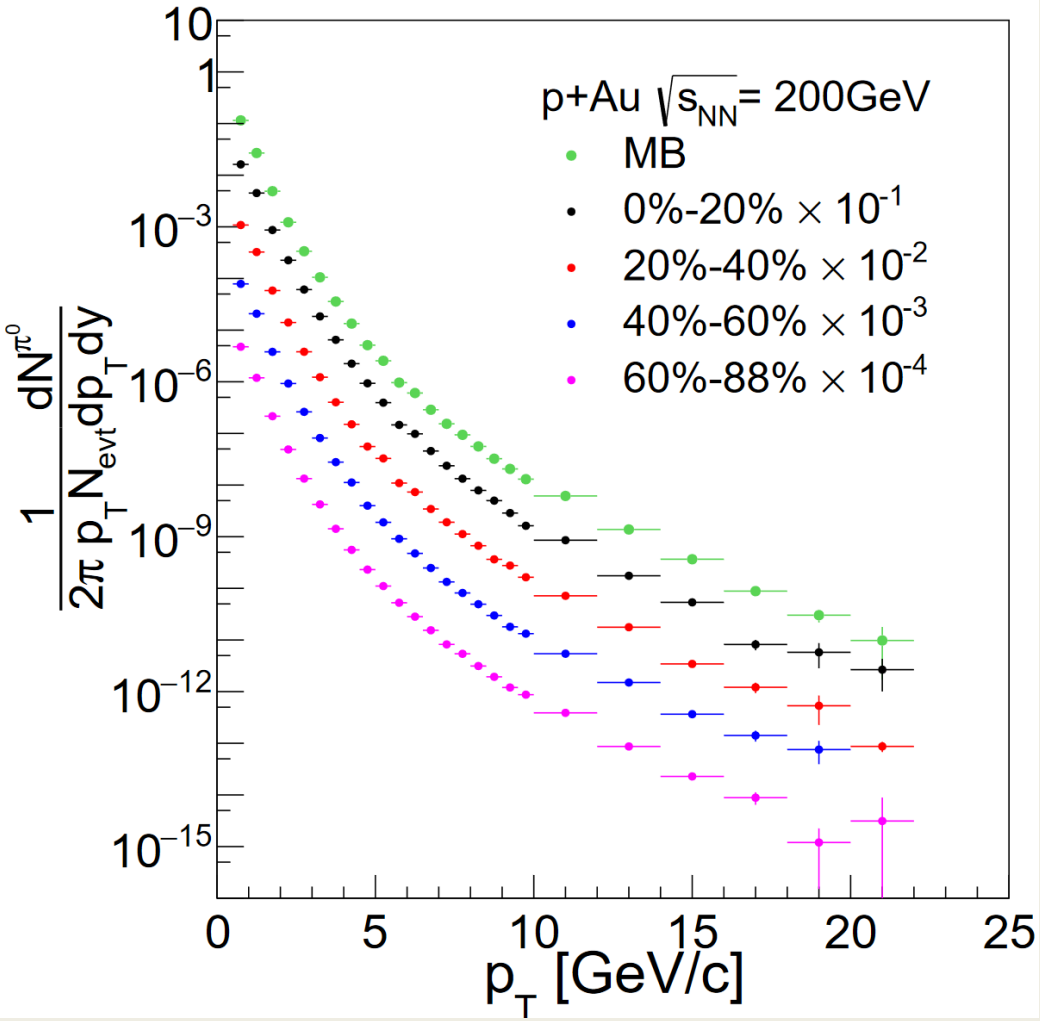


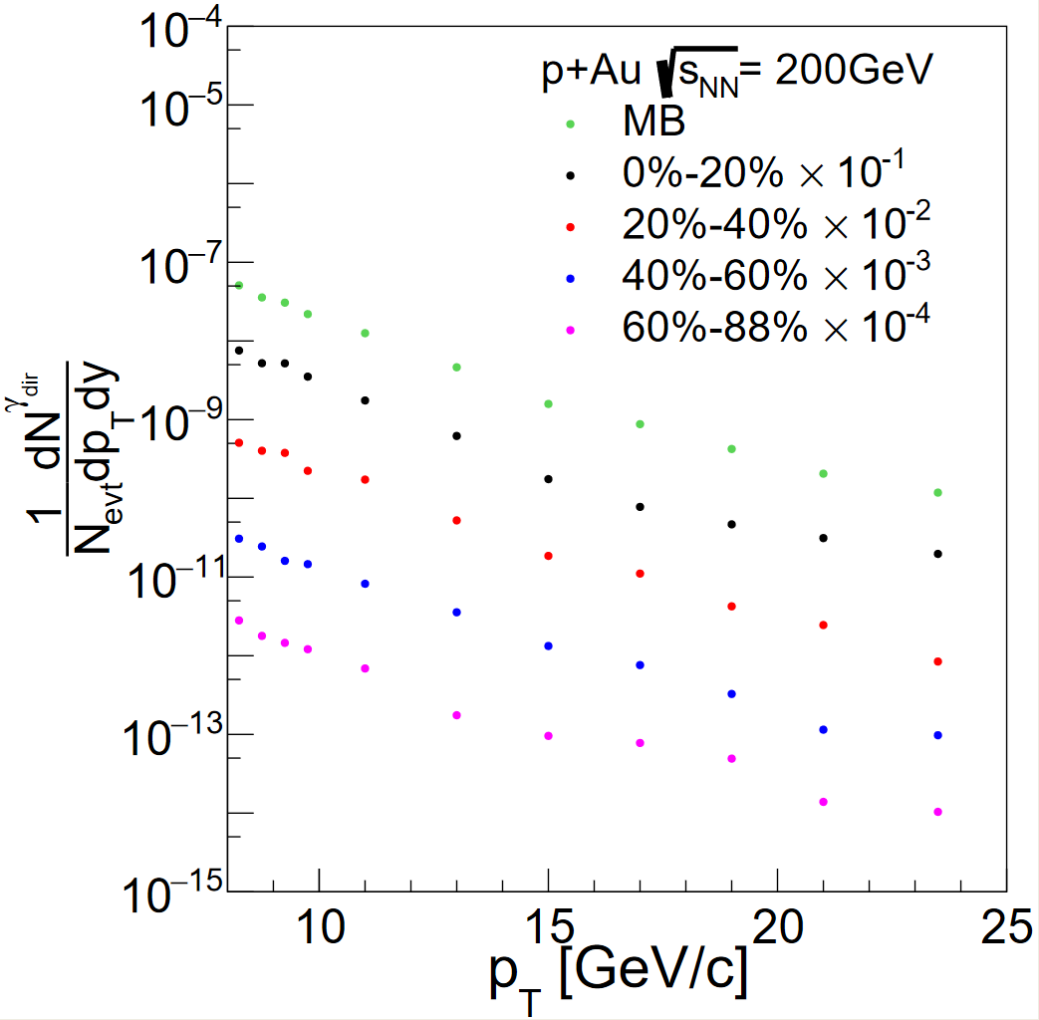
Decay photons are calculated using 2-D response matrix for π^0 decay and then scaled by cocktail ratio.



Only the stat. uncertainty is shown.
Currently, we are working on the Sys. uncertainty.

First spectra of raw direct photons.
There is a significant contamination by hadrons in the EMCal at lower energies, which is currently under study.





Summary

- Centrality dependence in nuclear modification factor of π^0 in p/d+Au collisions
- 2-D response matrix method is introduced for corrections
- Statistical uncertainty propagation in the yield of π^0
- Invariant yield of pion and raw direct photon spectra
- The ratio direct γ/π^0 is the ultimate goal

THANK YOU FOR YOUR ATTENTION !