Forward dihadron correlation in pA collisions at RHIC

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RBRC workshop, December 15-17, 2021

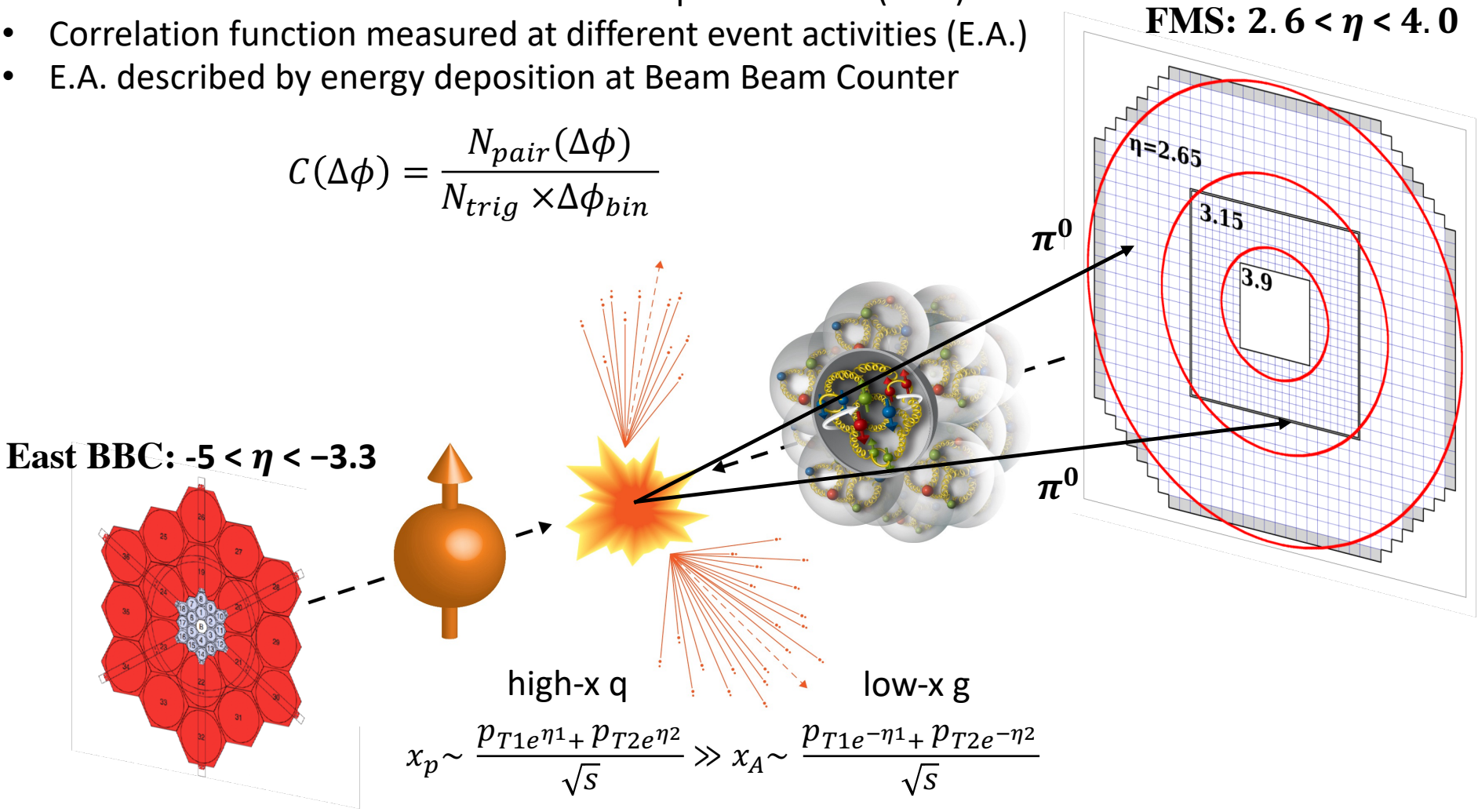
STAR Collaboration: 2111.10396

Forward di-π^0 correlation at STAR

2015 p+p, p+Al and p+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

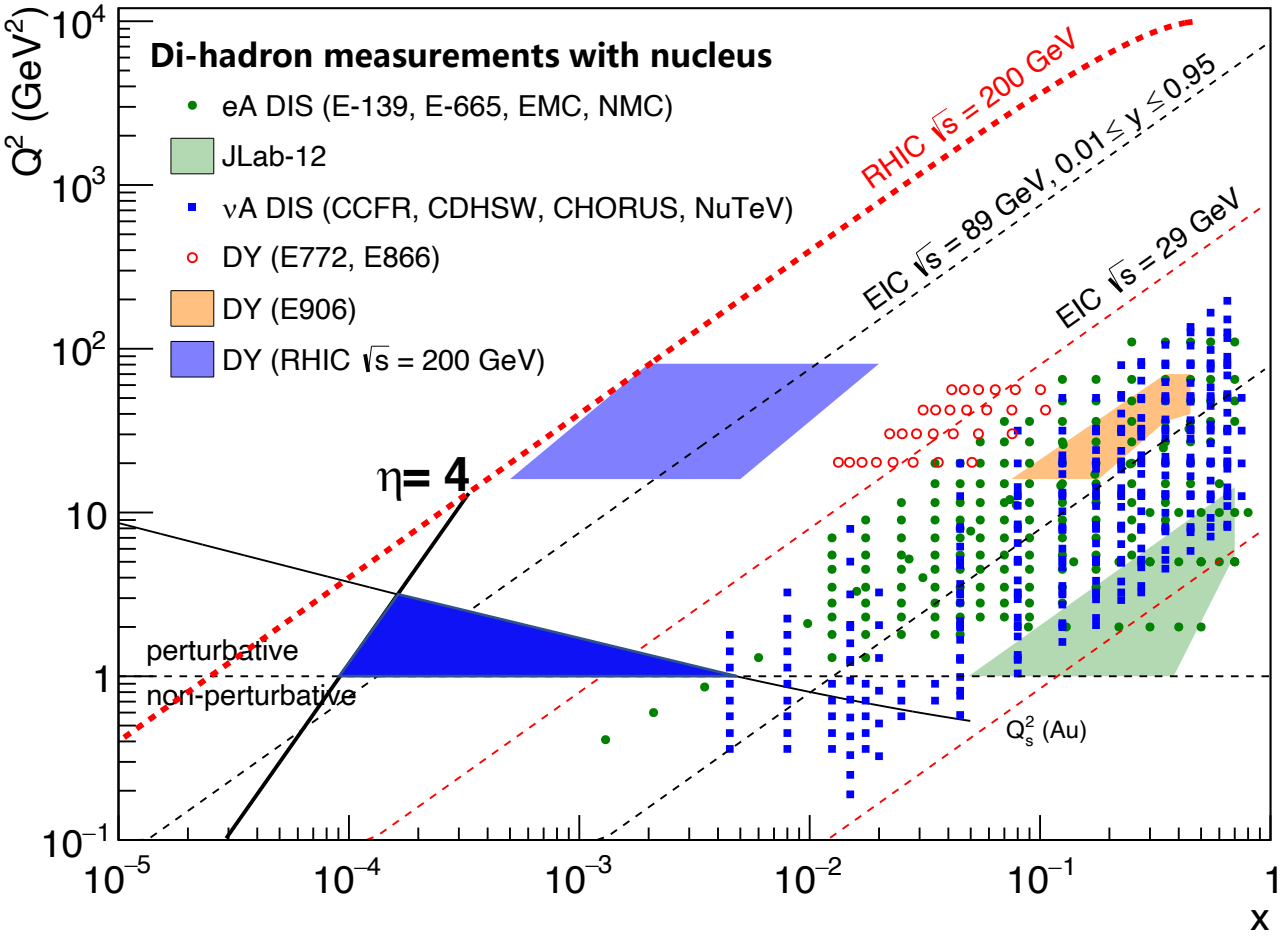
- π^0 reconstructed at the Forward Meson Spectrometer (FMS)
- Correlation function measured at different event activities (E.A.)
- E.A. described by energy deposition at Beam Beam Counter

$$C(\Delta\phi) = \frac{N_{pair}(\Delta\phi)}{N_{trig} \times \Delta\phi_{bin}}$$



x-Q^2 coverage of RHIC data

R. Abdul Khalek et al., arXiv:2103.05419



- STAR FMS data ($\sqrt{s_{NN}}$ = 200 GeV) can probe the saturation region
- Different ion beams → test dependence on Q_s:

$$Q_s^2(x) \sim A^{\frac{1}{3}}\left(\frac{1}{x}\right)^{\lambda}$$

- Correlation measured in various p_T bins: one can study the evolution on x and Q^2 through scanning p_T

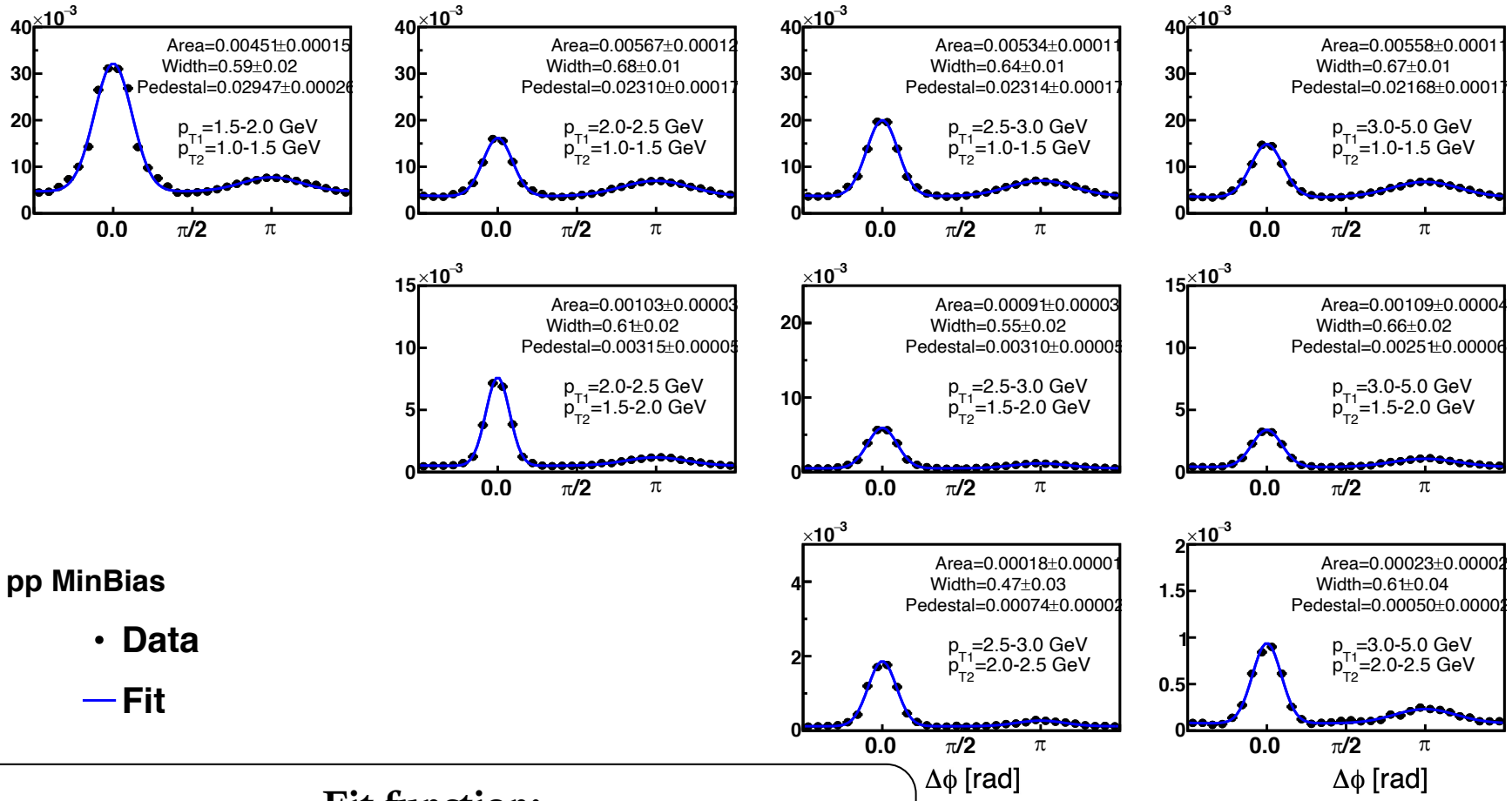
$$x_A \sim \frac{p_{T1}e^{-\eta 1} + p_{T2}e^{-\eta 2}}{\sqrt{s}}$$

$$Q \sim \frac{p_{T1} + p_{T2}}{2}$$

Di-π^0 correlations in pp

trigger π^0: p_{T1}

associated π^0: p_{T2}



pp MinBias

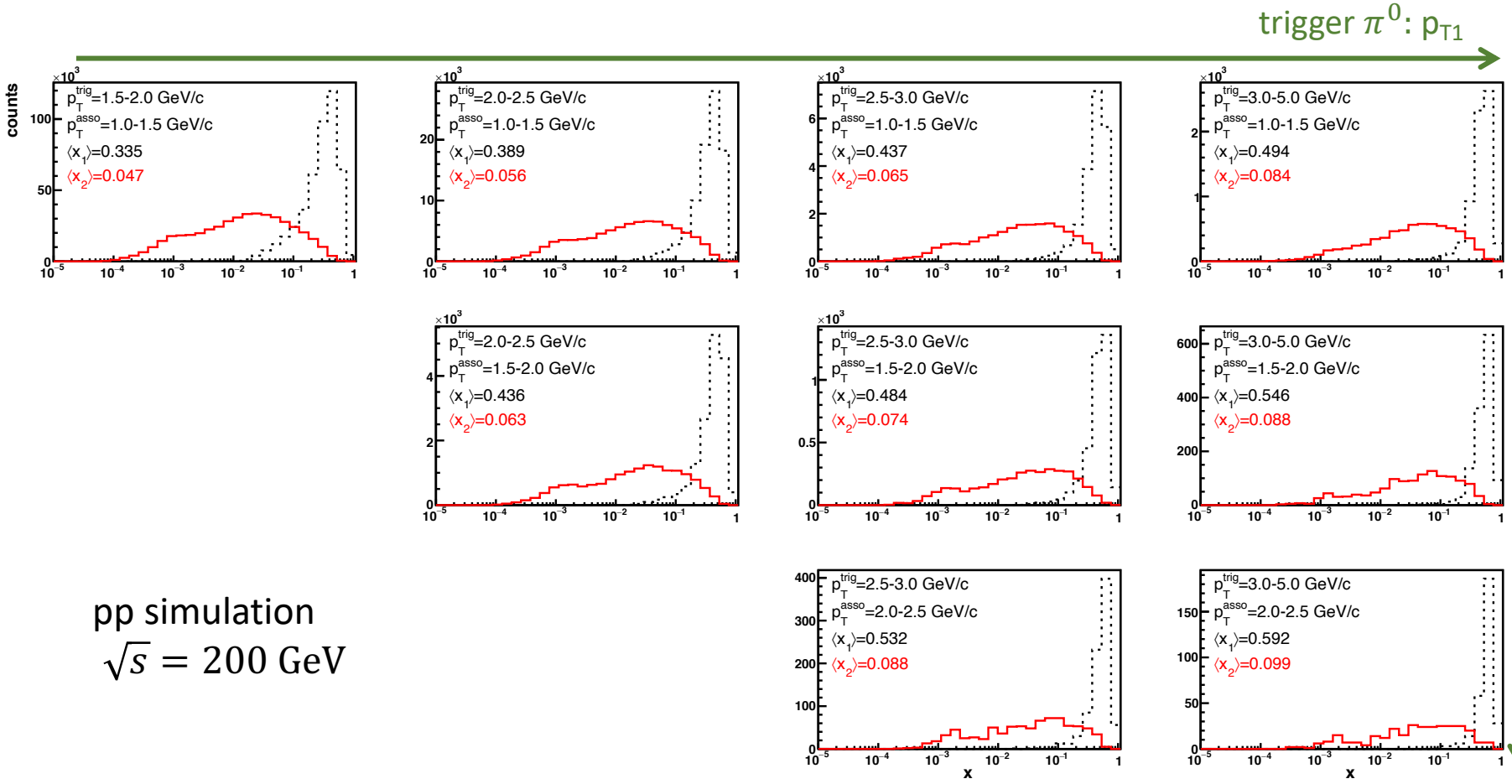
- **Data**
- **Fit**

Fit function:

$\Delta\phi = 0$ $\Delta\phi = \pi$

Pedestal/2π + Gaussian + Gaussian (Area and width)

x region in various p_T bins

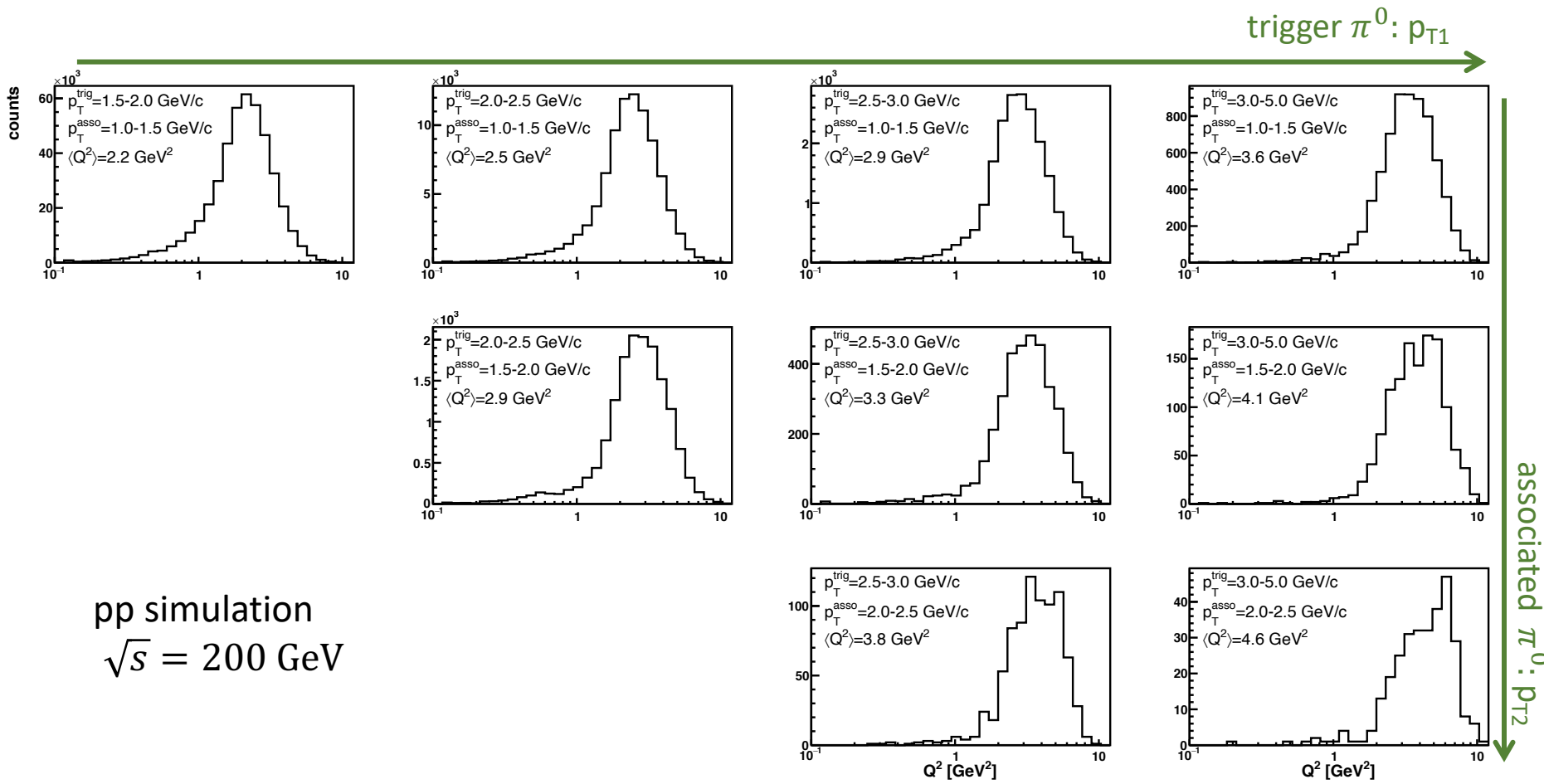


pp simulation

$\sqrt{s} = 200$ GeV

Large $p_T \rightarrow$ small p_T: Large x $\rightarrow$ small x

Q^2 region in various p_T bins



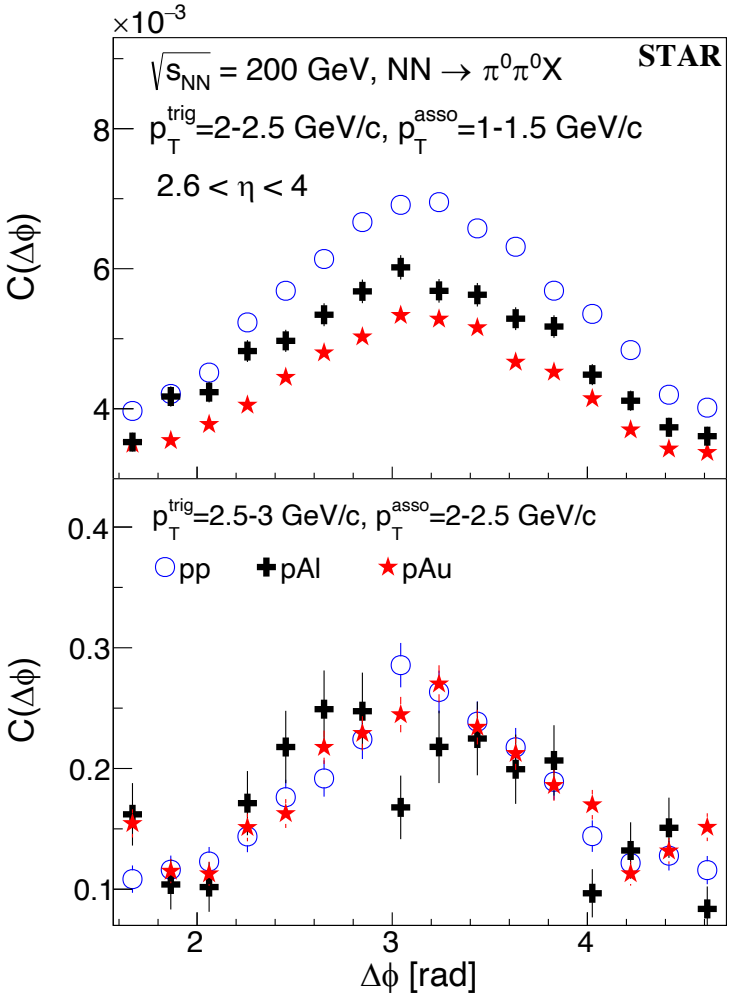
pp simulation

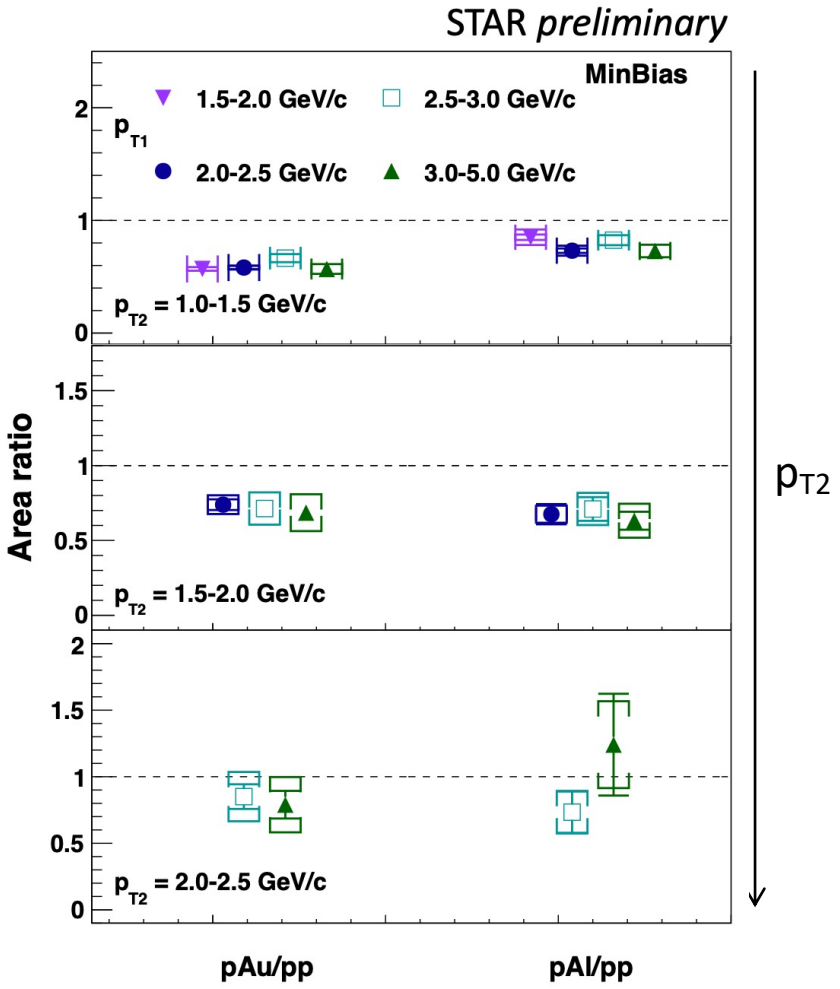
$\sqrt{s} = 200$ GeV

Large $p_T \rightarrow$ small p_T: Large $Q^2 \rightarrow$ small Q^2

STAR data: linear $\rightarrow$ nonlinear region

Di-π^0 correlations at STAR

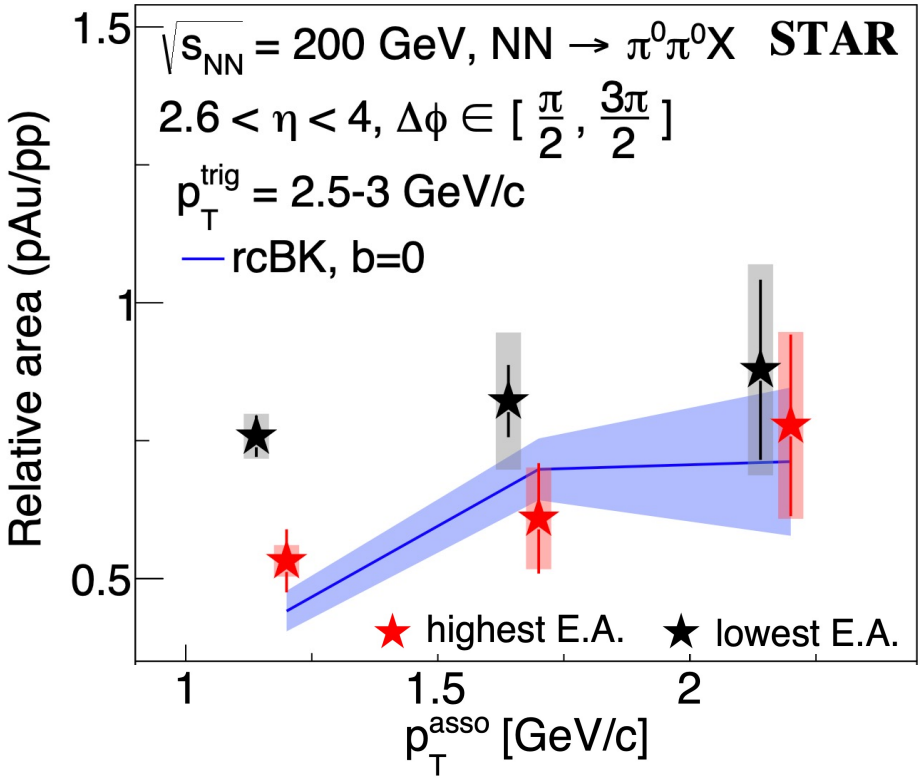


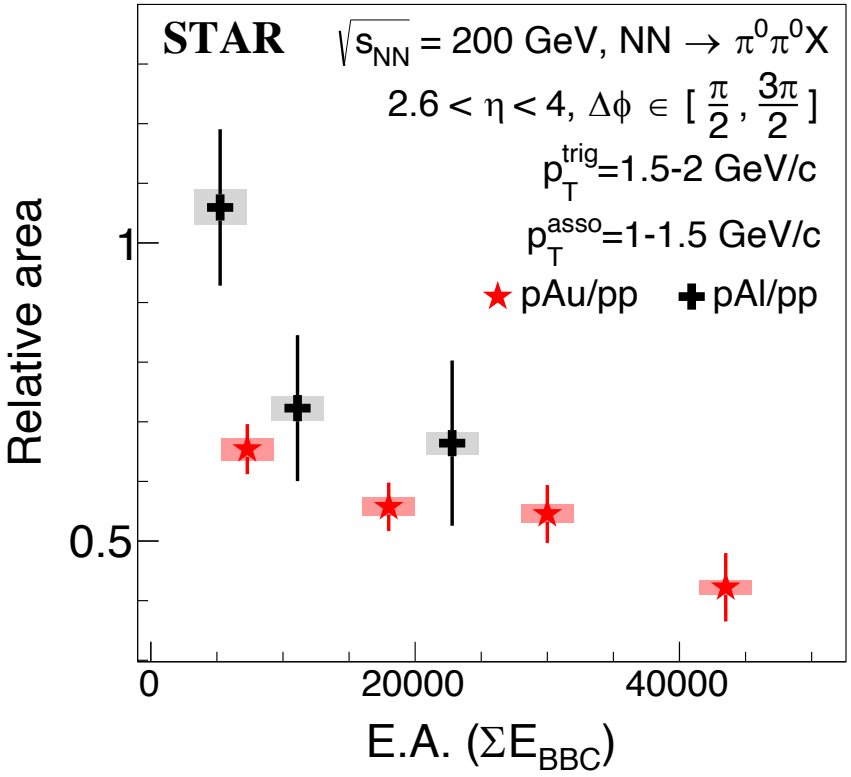


- p_T dependence: suppression observed at low p_T in pA but not high p_T

Di-π^0 correlations at different E.A.s

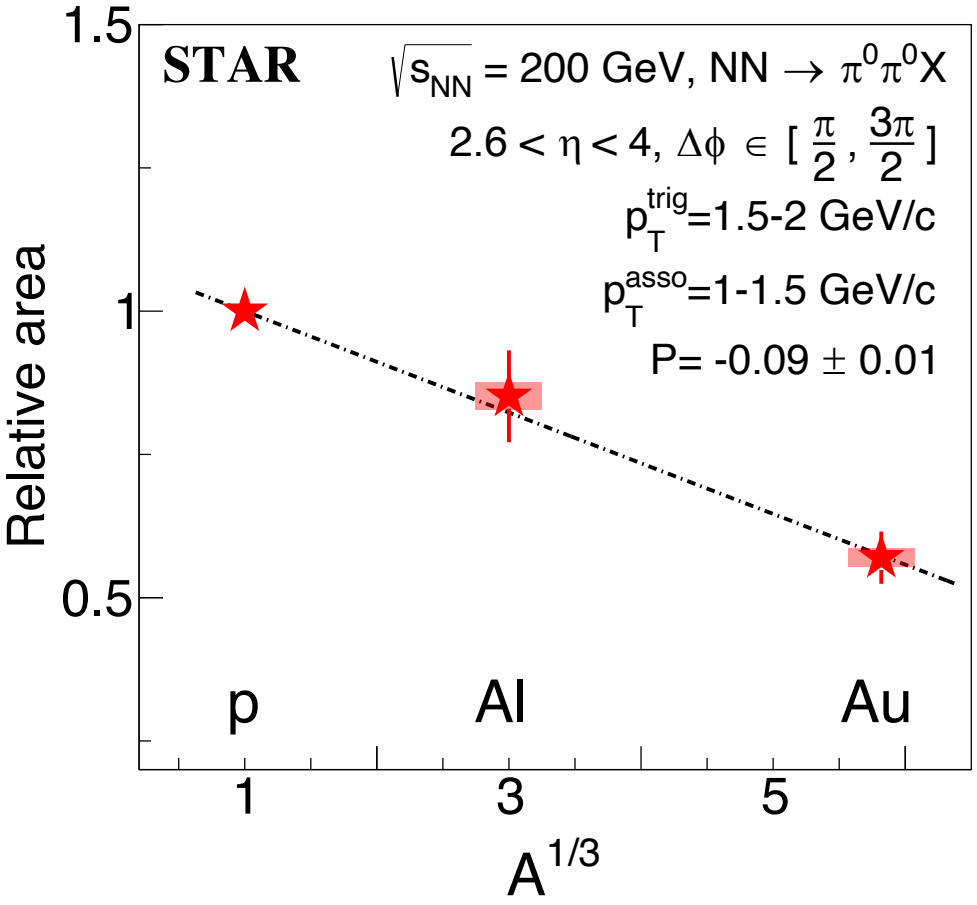
rcBK: Phys. Rev. D 99, (2019) 014002





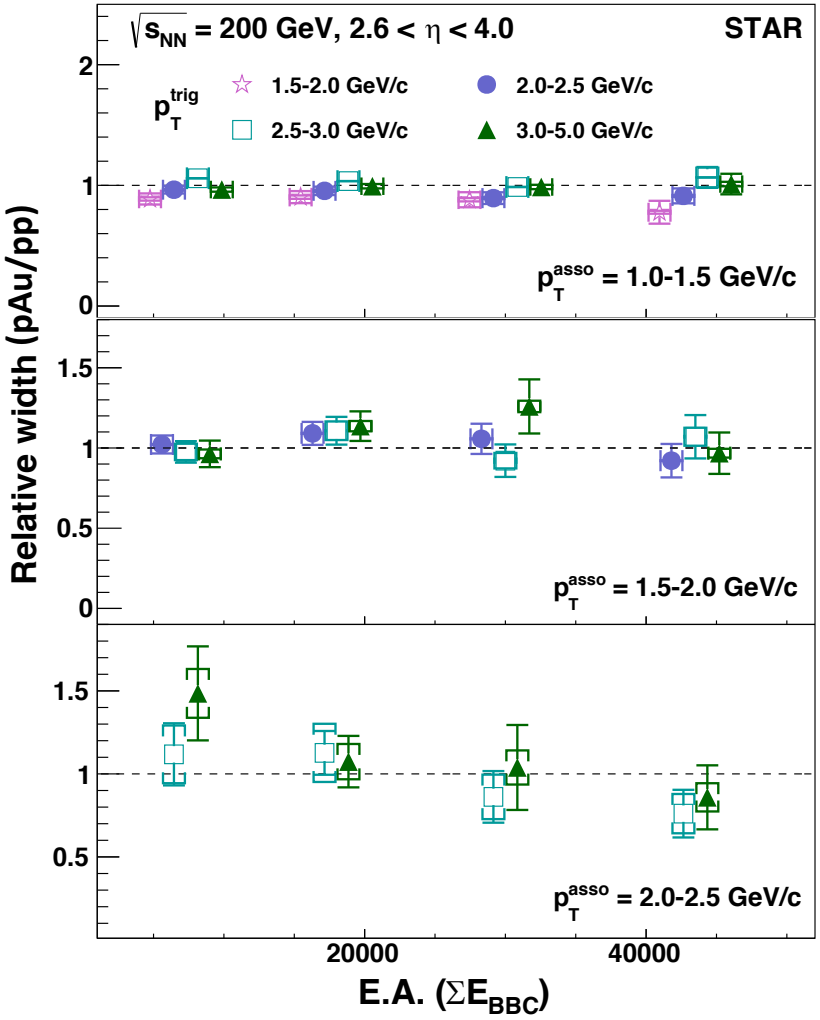
- Suppression in highest E.A. pAu agrees with predictions integrating gluon saturation
- Similar trend of event activity dependence in pAu and pAl: larger suppression at high E.A.
- Nucleus dependence: larger suppression in pAu collisions with respect to pAl collisions

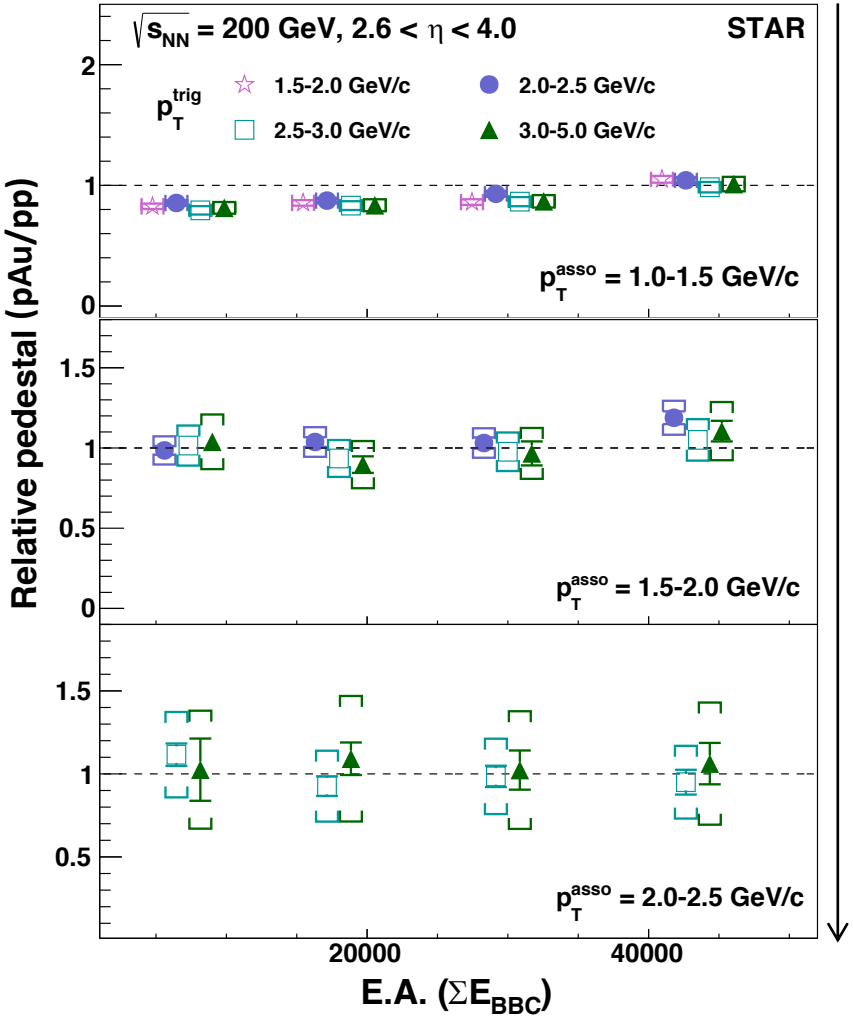
A dependence at STAR



- A linear dependence of the suppression as a function of $A^{1/3}$ is observed
- The slope (*P*) is found to be −0.09 ± 0.01

Width and pedestal in pp and pAu





- Width unchanged between pp and pAu collisions: no broadening
- Stable pedestal: information for double parton interactions in dAu?

Summary and outlook

- The evidence of a novel universal regime of non-linear gluon dynamics in nuclei is very important to help us understand QCD processes in Cold Nuclear Matter:
  - Understand the collective dynamics of gluons
  - Investigate inner landscape of nuclei: initial state input to eA/pA/AA

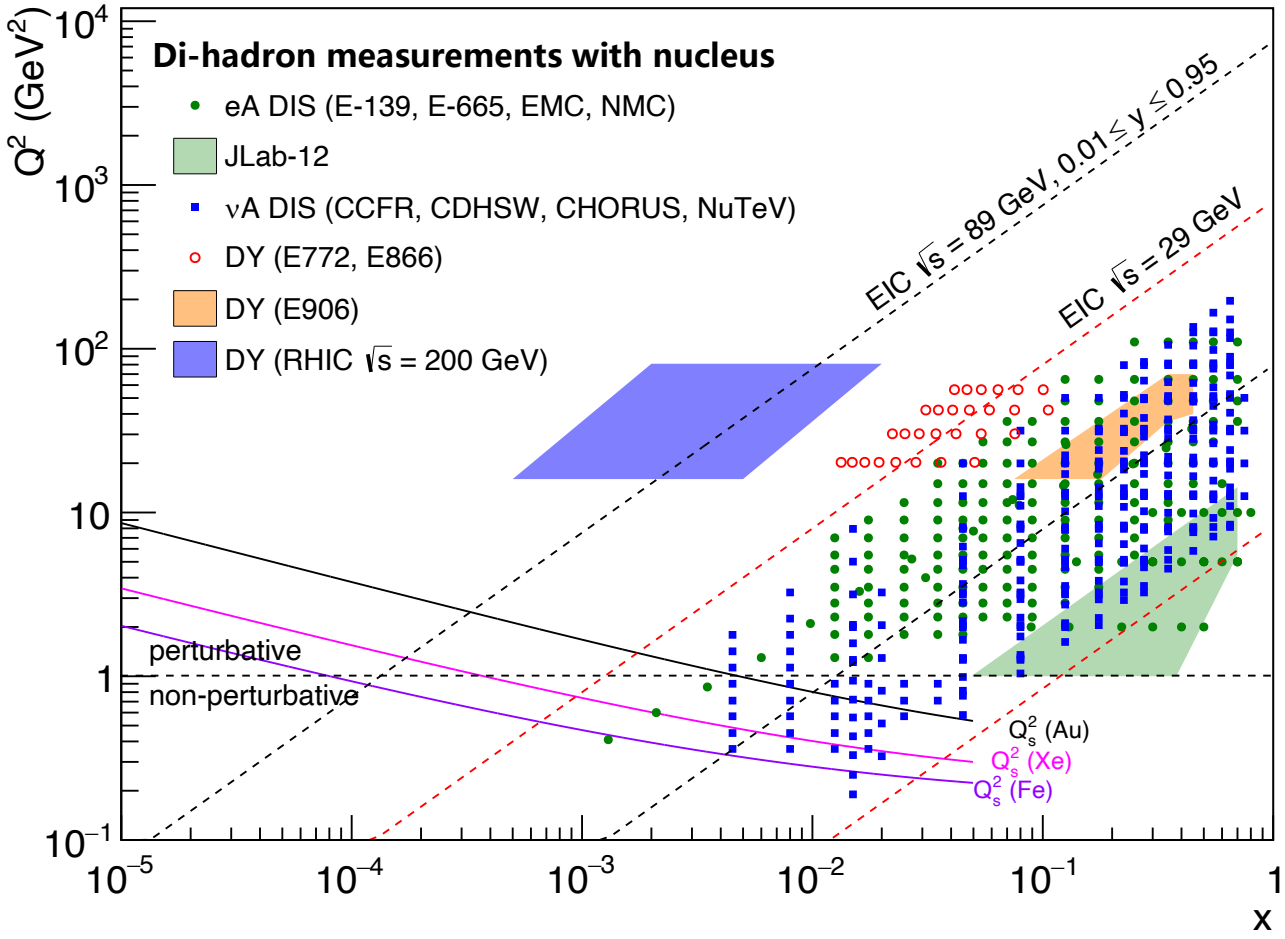
- Di-hadron correlation is a key measurement in the pA physics program at STAR
  - STAR shows a clear signature of non-linear gluon dynamics with di-hadron correlation measurement
  - First measurement of nuclear effect dependence on A: stronger suppression in pAu than pAl
  - Event activity dependence: suppression enhanced in “high activity” collisions at low p_T

- Future high precision measurements at STAR with forward upgrade for more observables: γ-hadron/jet, di-charged hadron, di-jet…

Back up

Q_s^2 dependence on A

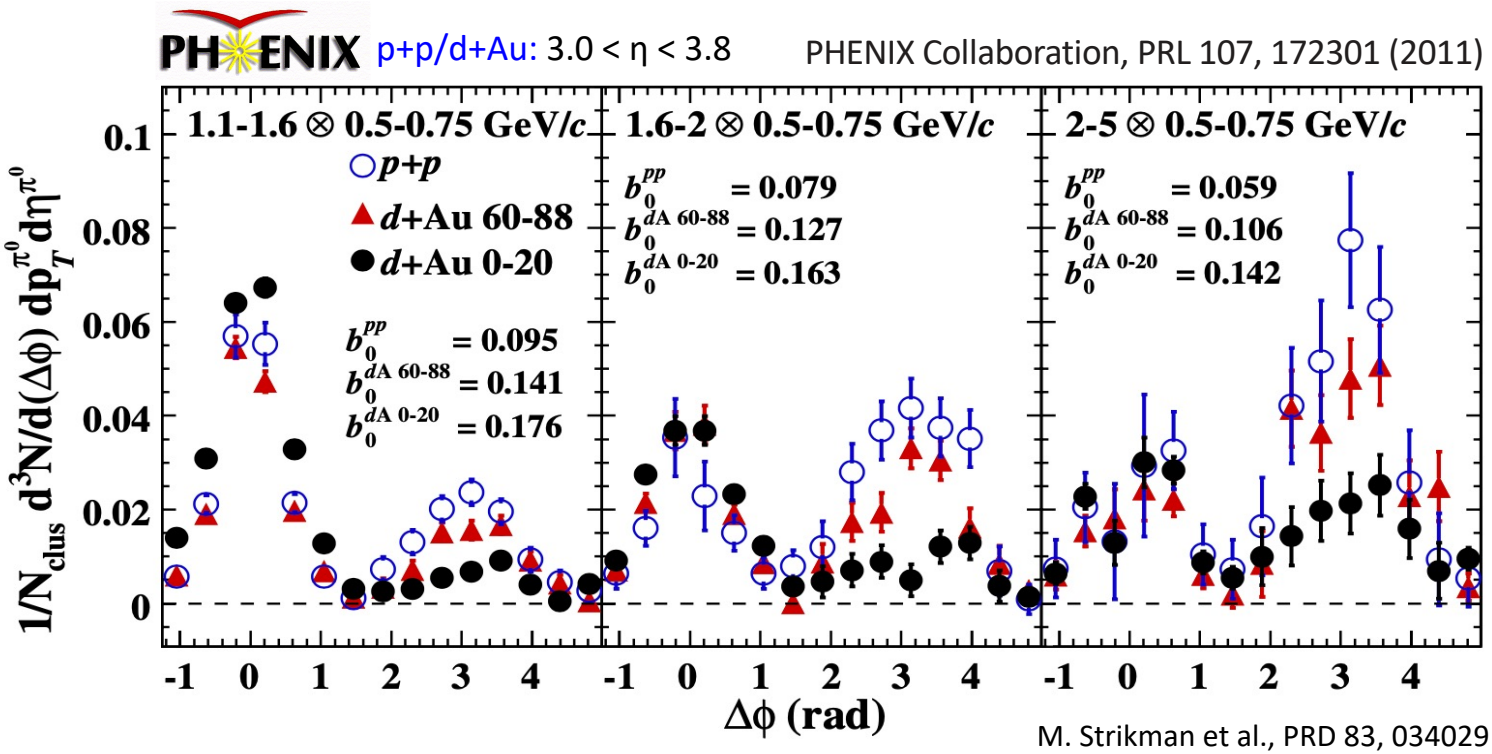
R. Abdul Khalek et al., arXiv:2103.05419



- Different ion beams → test dependence on Q_s
- Saturation scale Q_s: the inverse of transverse distance between partons; grows with A and decreases with x

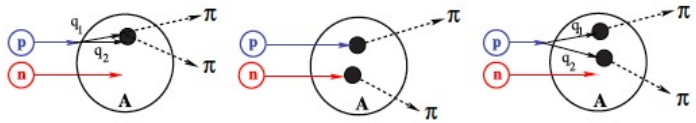
$$Q_s^2(x) \sim A^{\frac{1}{3}} \left(\frac{1}{x}\right)^{\lambda}$$

Di-π^0 correlations in dAu



M. Strikman et al., PRD 83, 034029 (2011)

Possible contribution from double parton interaction to the cross section? →



- dAu: interpretation of the suppression complicated by alternative explanation; much higher pedestal in dAu than in pp

→ pAu collisions are theoretically and experimentally cleaner

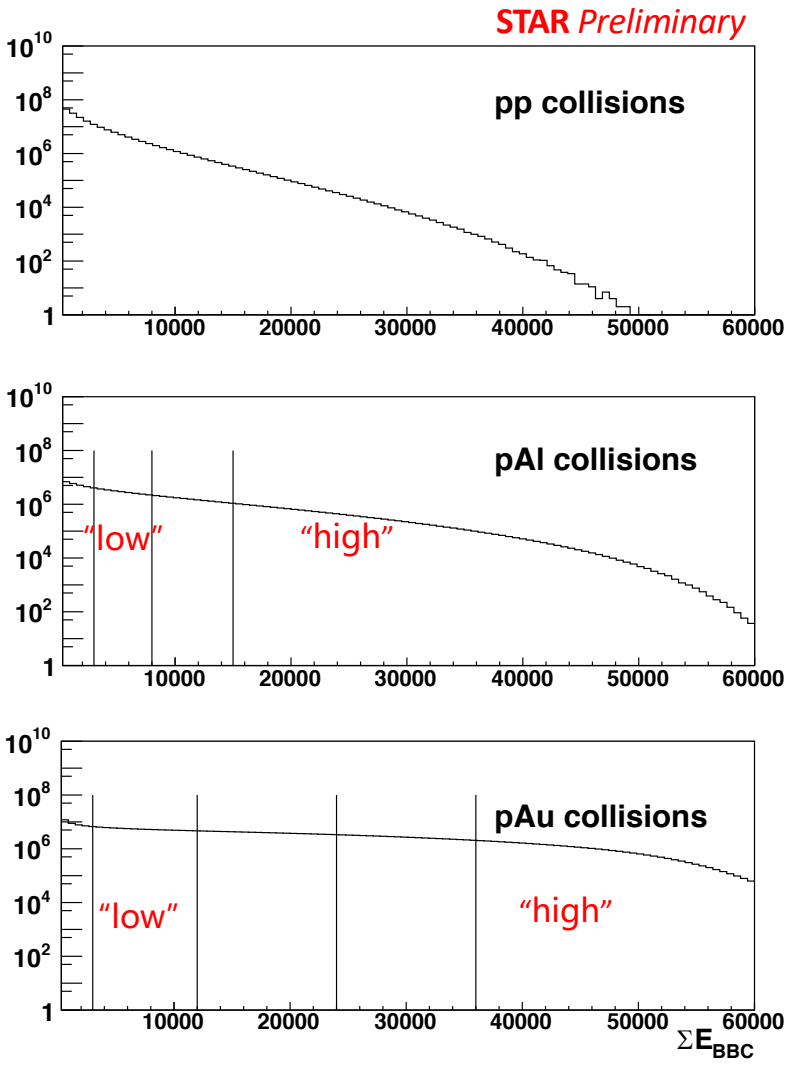
Event activity (E.A.)

Energy deposited at EAST BBC (ΣE_{BBC}) quantifies "event activity"

- East: nucleus beam going direction; backward rapidity
- High energy deposition refers to "high activity" collisions

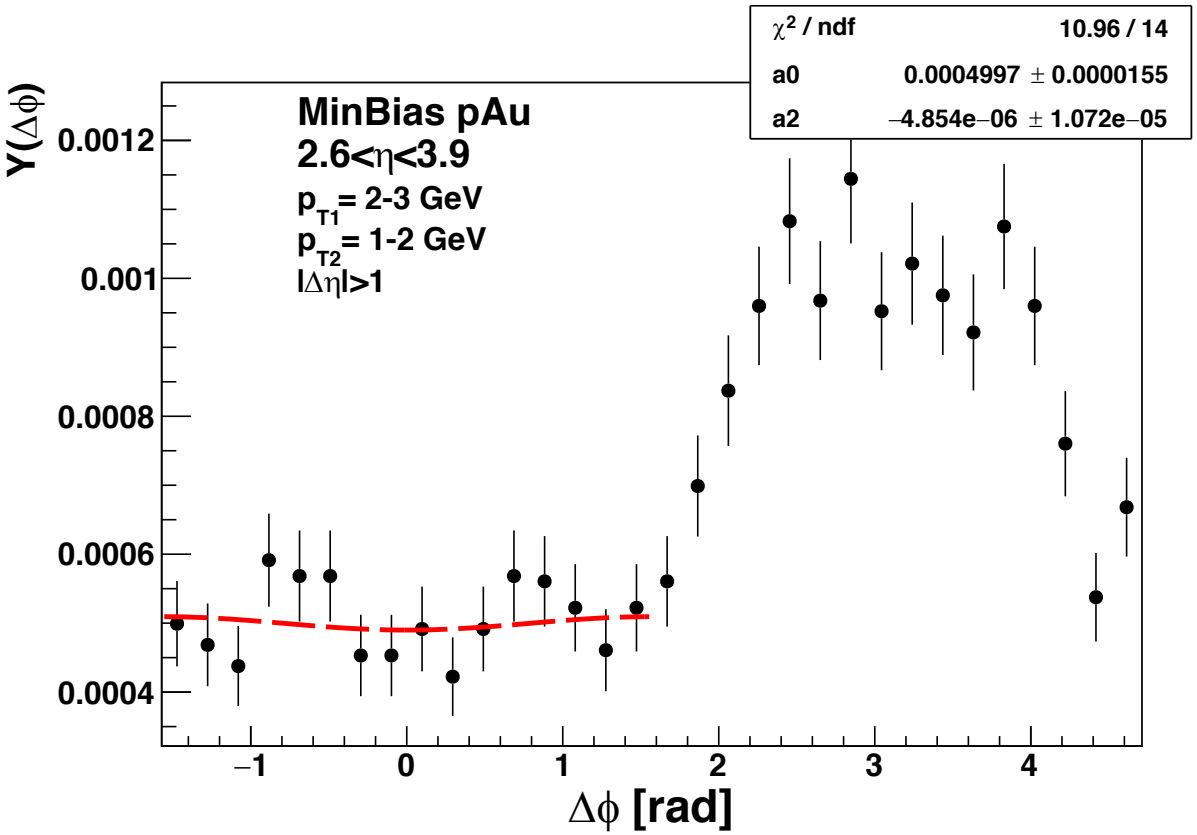
Event activity in pAl and pAu

Beam species	Event activity	ΣE_{BBC} range ($\times 10^3$)	Class
p+Al	Lowest	3-8	31%-60%
	Medium	8-15	60%-81%
	Highest	>15	81%-100%
p+Au	Lowest	3-12	15%-43%
	Medium low	12-24	43%-69%
	Medium high	24-36	69%-88%
	Highest	>36	88%-100%



Flow-like correlation

Fit function: Y(Δϕ) = a0 + 2*a2 cos(2Δϕ)



- Flow signal from near side is negligible for the current measurement
- π^0s at FMS have very high energy; hard to require those two π^0s not come from the same jet
- Due to limited rapidity coverage of FMS, it's challenging to accurately estimate long range correlation. Even if there is flow,
  → makes suppression stronger
- Saturation stays after flow-like correlation subtraction in pPt at LHCb (Nuclear Physics A 00 (2018) 1–4)