

# **Study J/Psi Production Mechanisms in p+p and p+Au Collisions in PHENIX**

Ming X. Liu

Los Alamos National Laboratory

**For the PHENIX Collaboration**

SQM2026

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## Outline

- $B \rightarrow J/\Psi$  in p+p
- $J/\Psi$  vs event multiplicity in p+p and p+Au (NEW!)

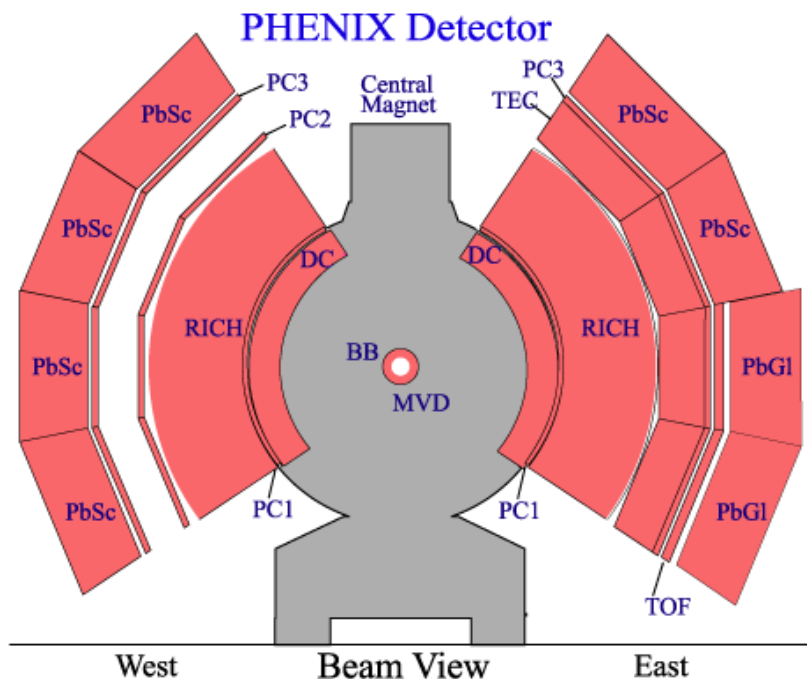
# PHENIX Experiment at RHIC: 2001-2016



# PHENIX Detector Setup

Central arms for di-electrons and forward muon arms for dimuons

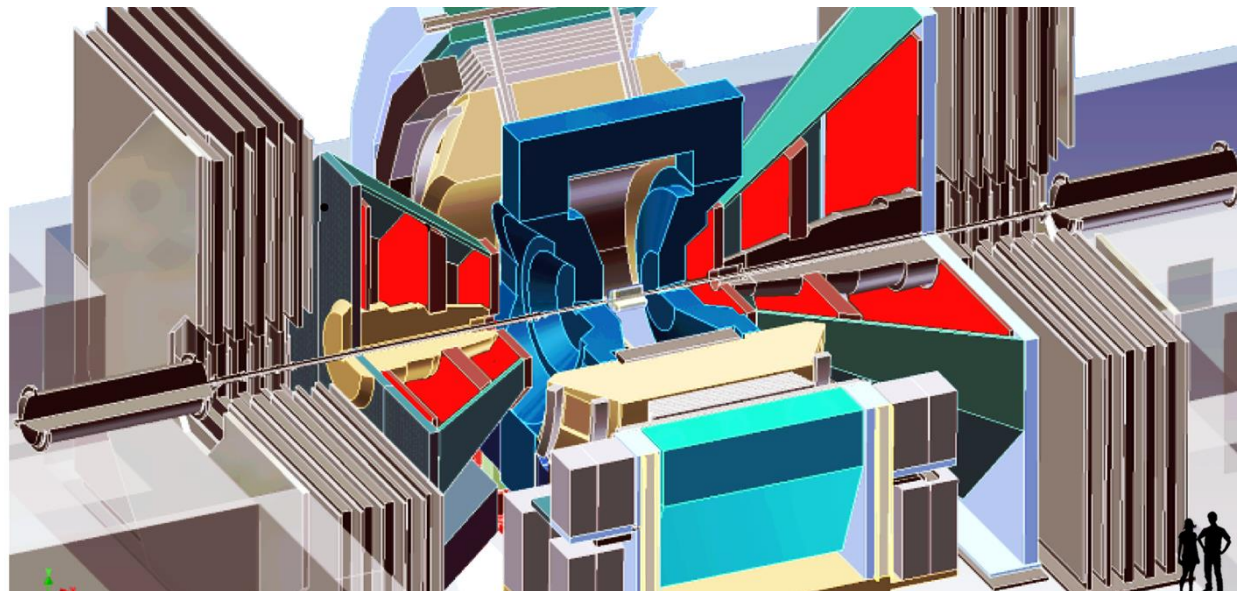
## CENTRAL ARMS + VTX



## Midrapidity $e^+e^-$ capability

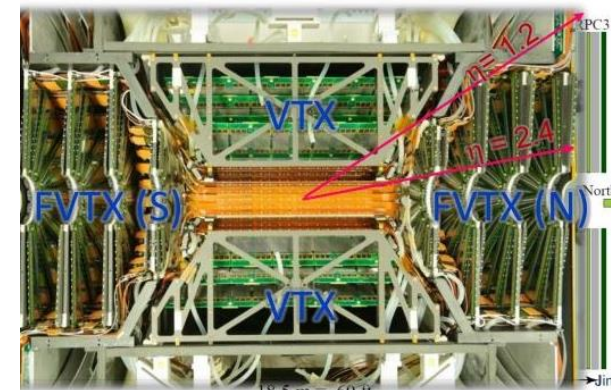
- two  $90^\circ$  spectrometer arms at  $|\eta| < 0.35$
- SVX + DC/PC tracking + RICH + EMCal for electron identification

## FORWARD MUON ARMS + FVTX



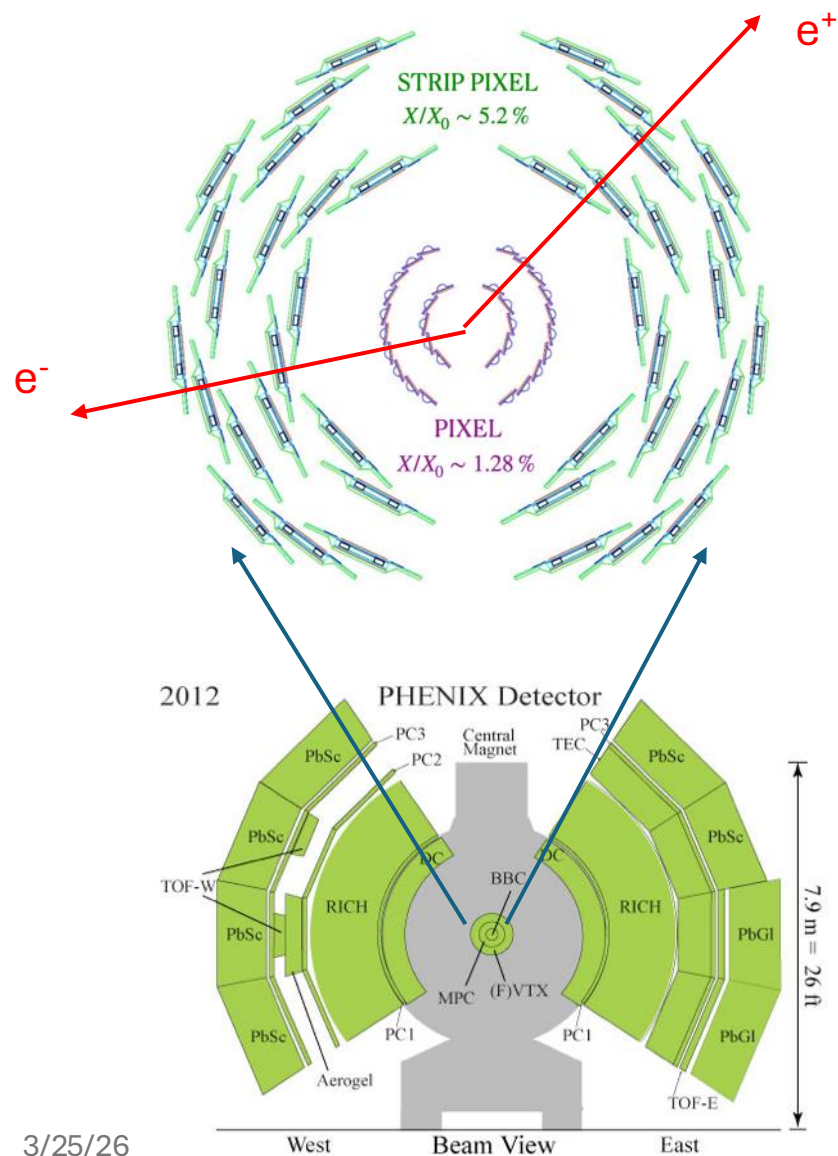
## Forward dimuon spectrometry

- Muon arms:  $1.2 < |\eta| < 2.2$
- MuTr/MuID + FVTX near the IP
- better opening-angle and DCA resolution

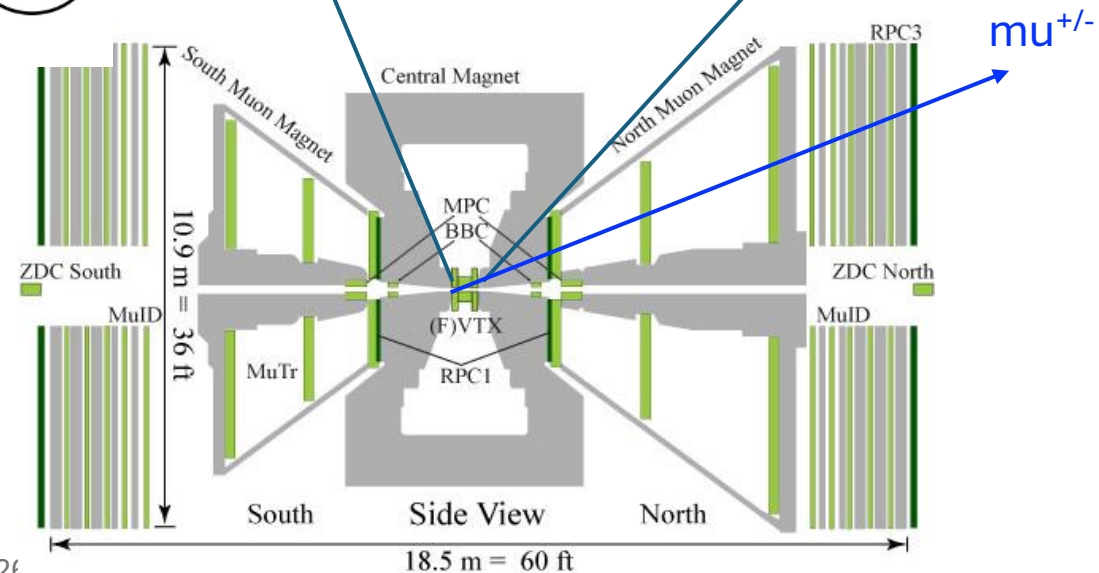
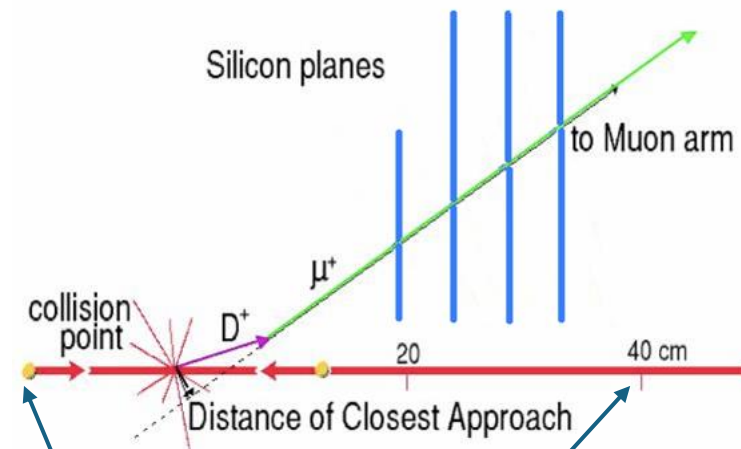
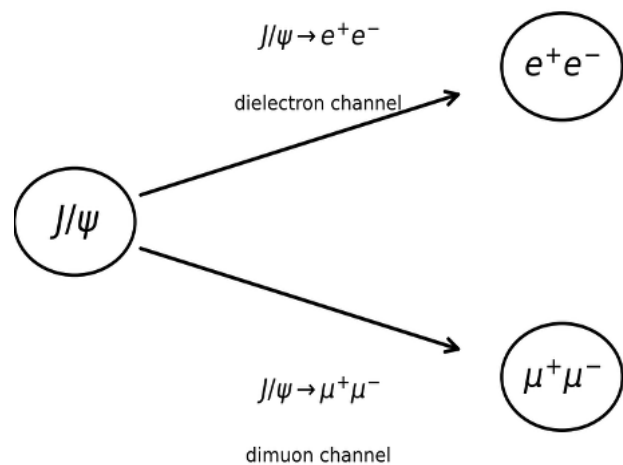


PHENIX combines electron identification at midrapidity with dedicated forward muon spectrometers; VTX/FVTX extend precision tracking and vertexing into the HF physics electron and muon measurements.

# J/ψ Measurements in Central and Muon Arms

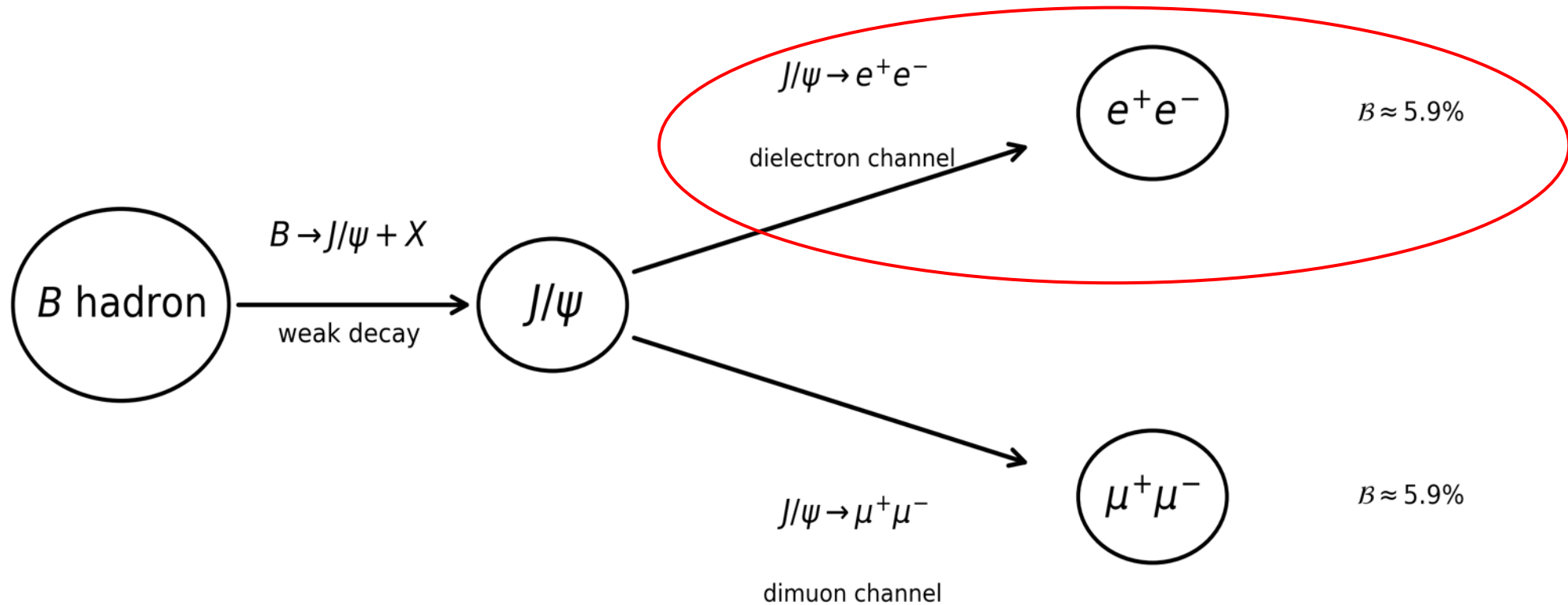


- $e^+e^-$   $|\eta| < 0.35$
- $\mu^+\mu^-$ ,  $1.2 < |\eta| < 2.2$



# (I) Study of $B \rightarrow J/\psi$ Production in p+p at 200GeV

$B$ -hadron feed-down to  $J/\psi$  with dilepton reconstruction

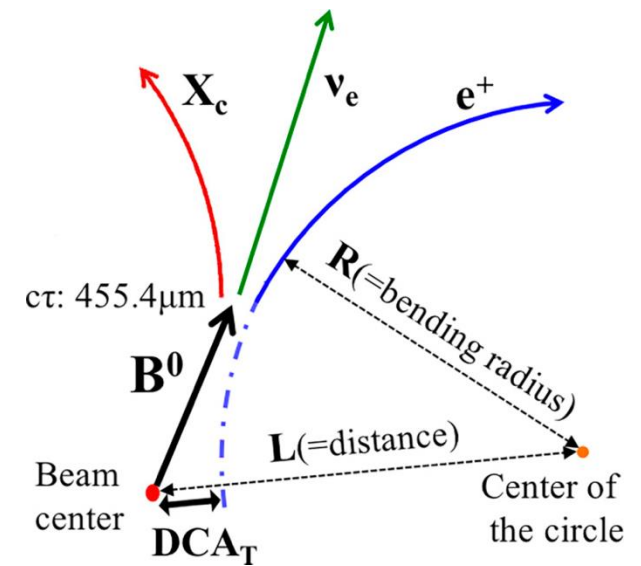
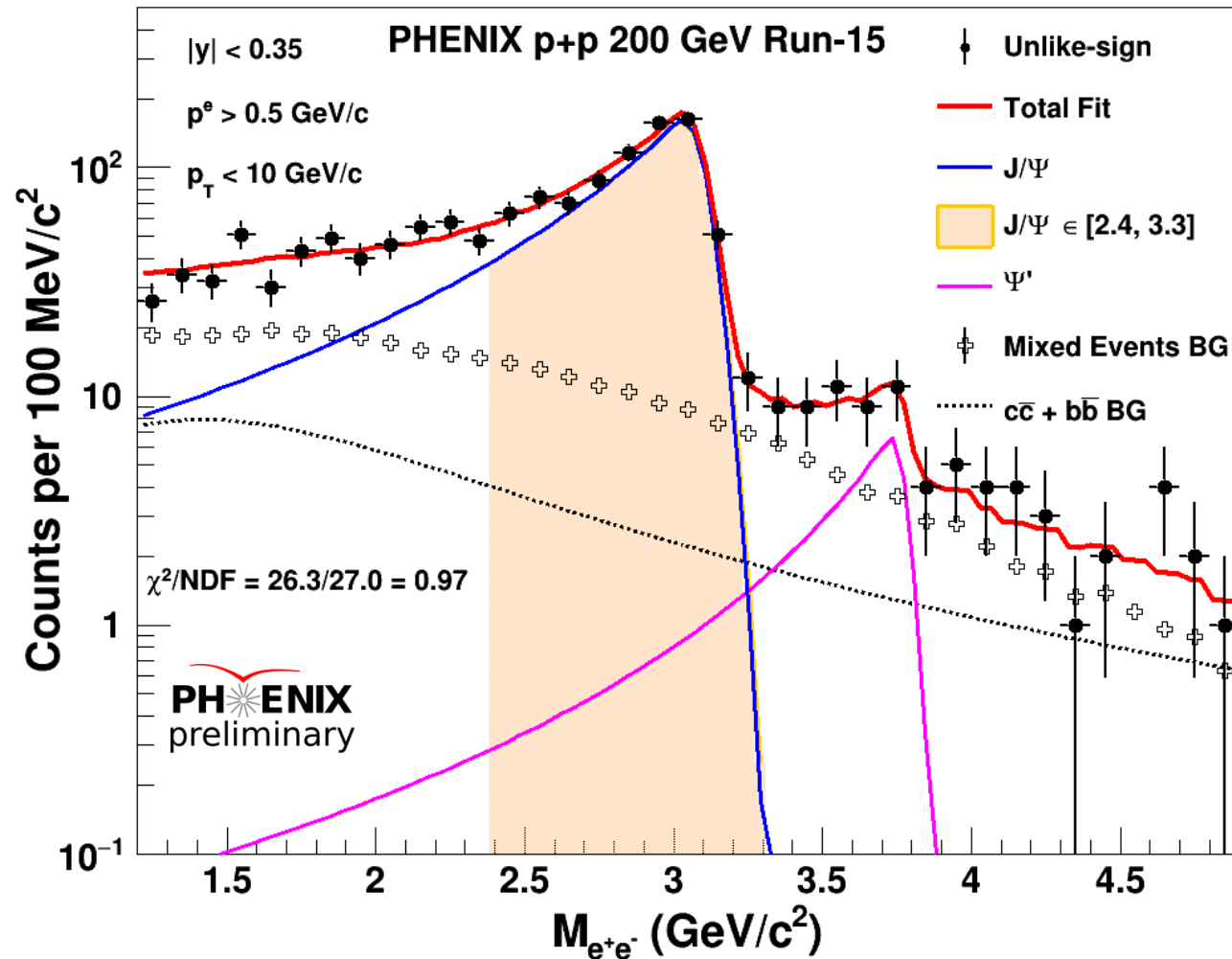


Useful for PHENIX central-arm  $e^+e^-$  and forward-muon  $\mu^+\mu^-$  measurements

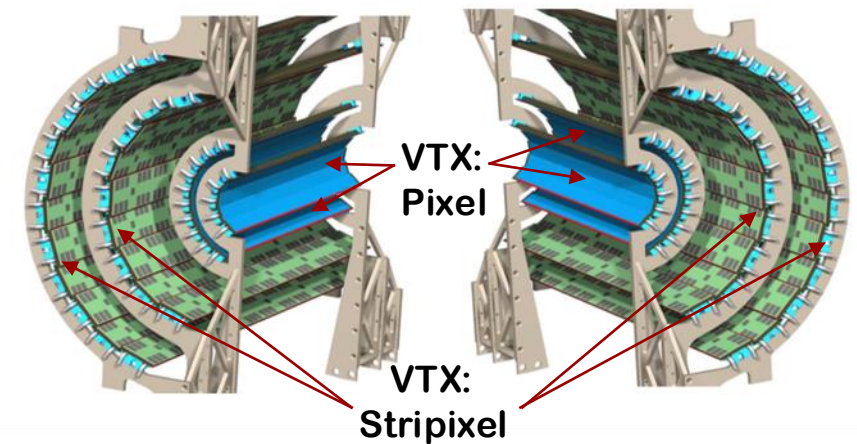


# $(B \rightarrow) J/\psi \rightarrow e^+ e^-$ : prompt vs displaced

## Crystall Ball Function for $J/\psi$ and $\psi$ (2S)

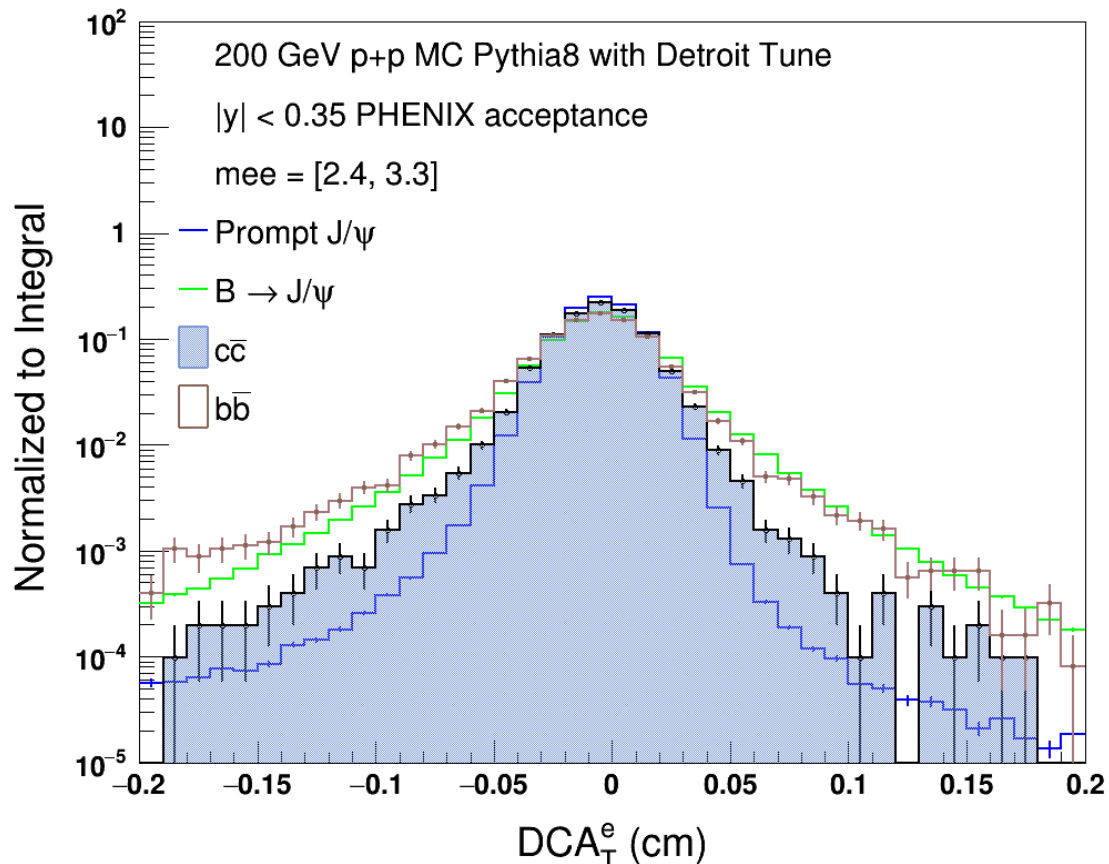


## VTX: silicon VerTeX barrel tracker



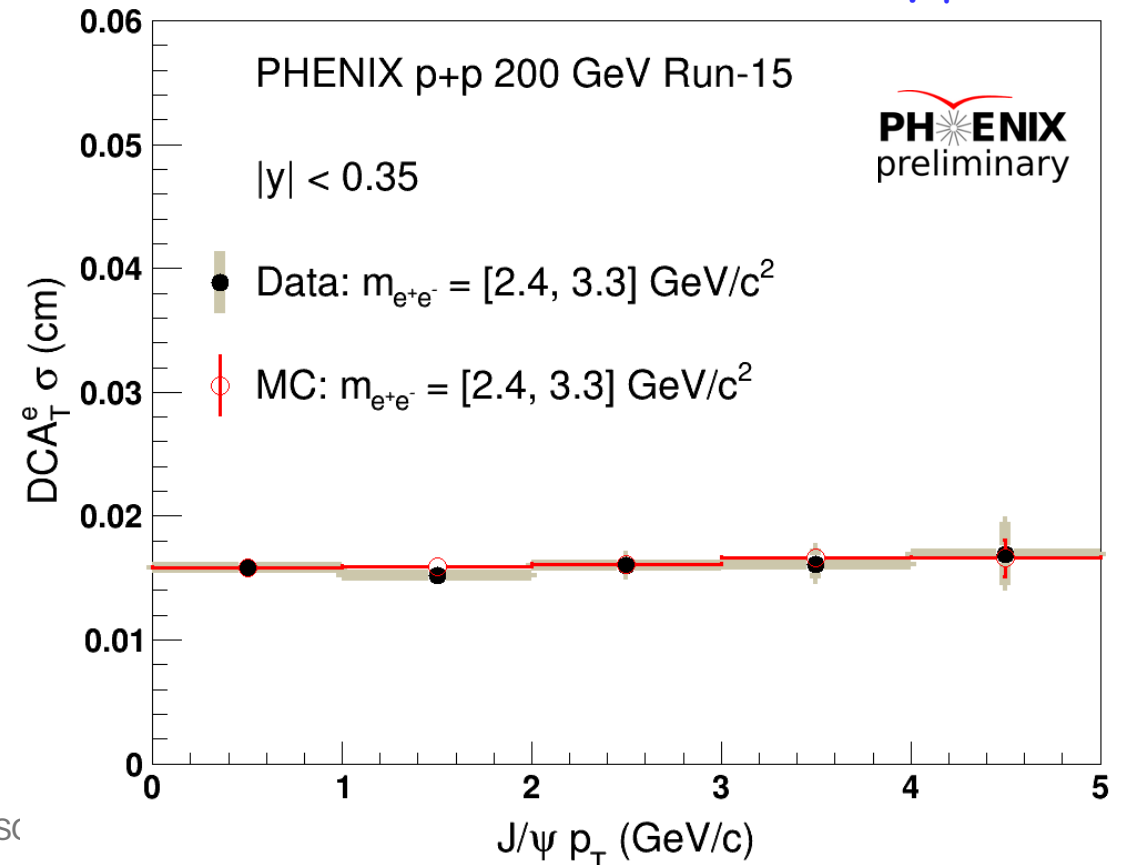
# B → J/ψ Fraction Extraction from Electron DCA<sub>T</sub> Distributions

$$f_{\text{total}}(\text{DCA}_T) - f_{\text{combinatorial}}(\text{DCA}_T) = \text{Yield}_{\text{incl. } J/\psi} \times [\mathbf{F}_{B \rightarrow J/\psi} \times f_{B \rightarrow J/\psi}(\text{DCA}_T) + (1 - \mathbf{F}_{B \rightarrow J/\psi}) \times f_{\text{prompt } J/\psi}(\text{DCA}_T)] \\ + \text{Yield}_{c\bar{c}+b\bar{b}} \times [(1 - R_b) \times f_{c\bar{c}}(\text{DCA}_T) + R_b \times f_{b\bar{b}}(\text{DCA}_T)]$$



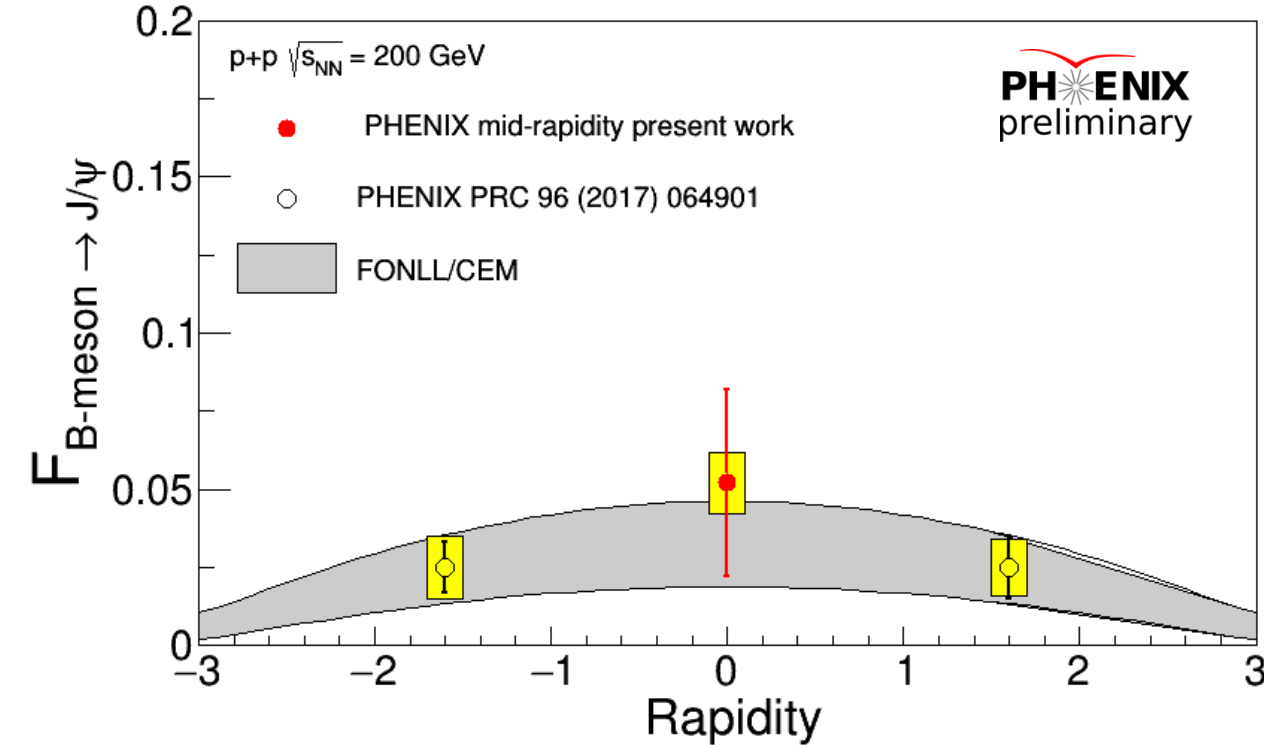
PHENIX @SC

## DCA resolution Data and MC vs p<sub>T</sub>

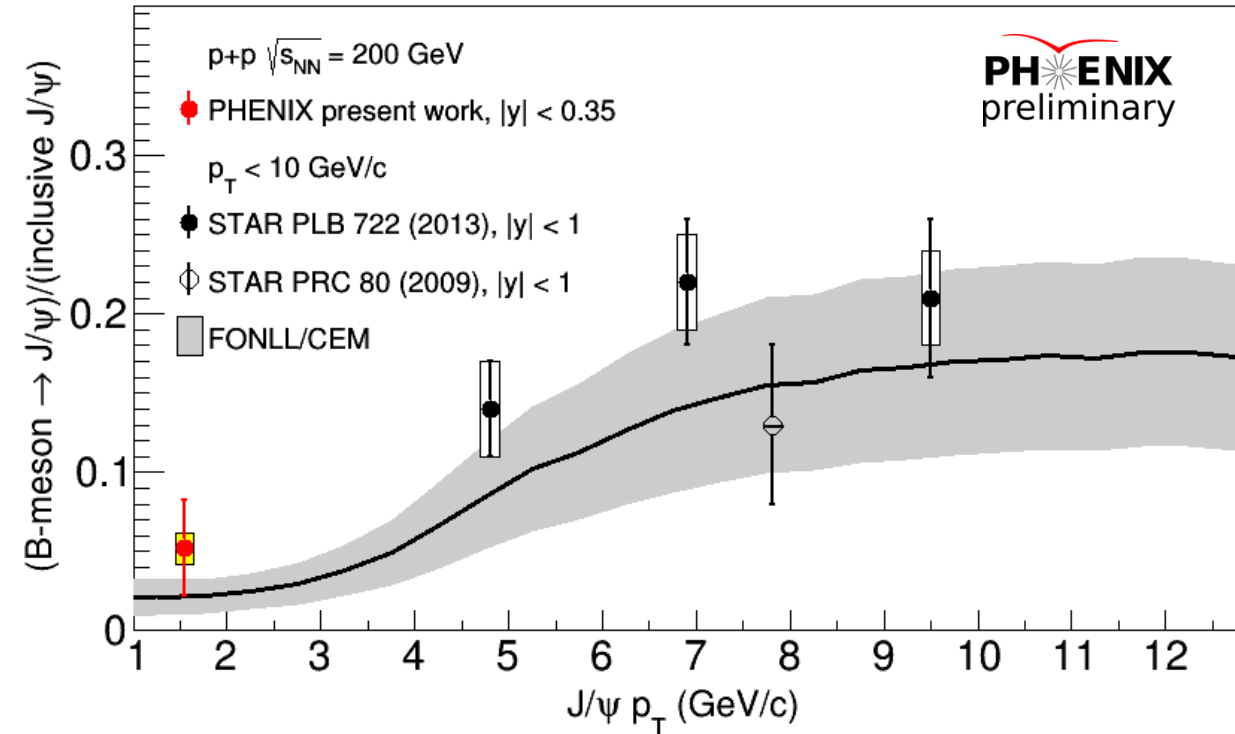


# B $\rightarrow$ J/ $\psi$ Fraction in p+p at RHIC

Fraction of B-meson  $\rightarrow$  J/ $\psi$  versus rapidity



PHENIX and STAR results versus  $p_T$

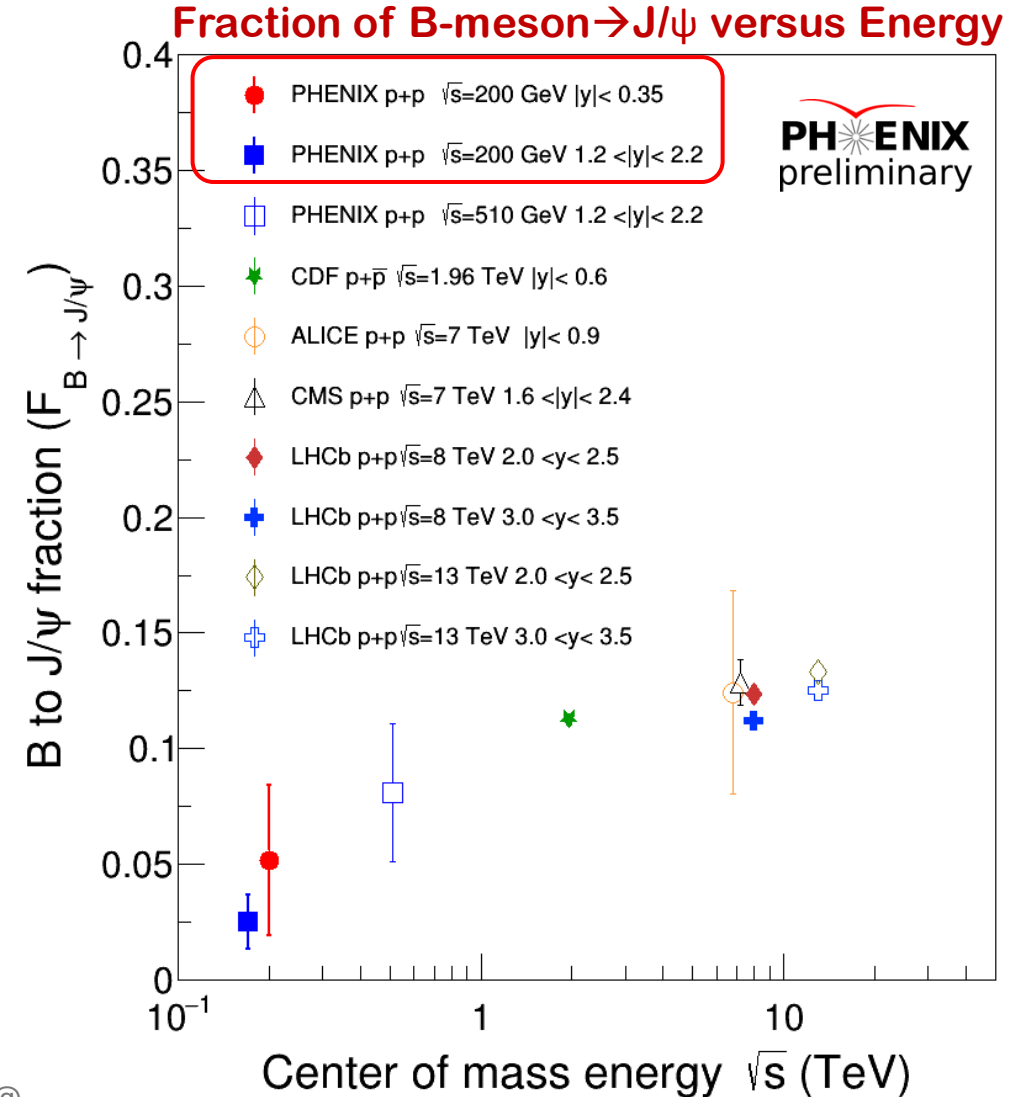
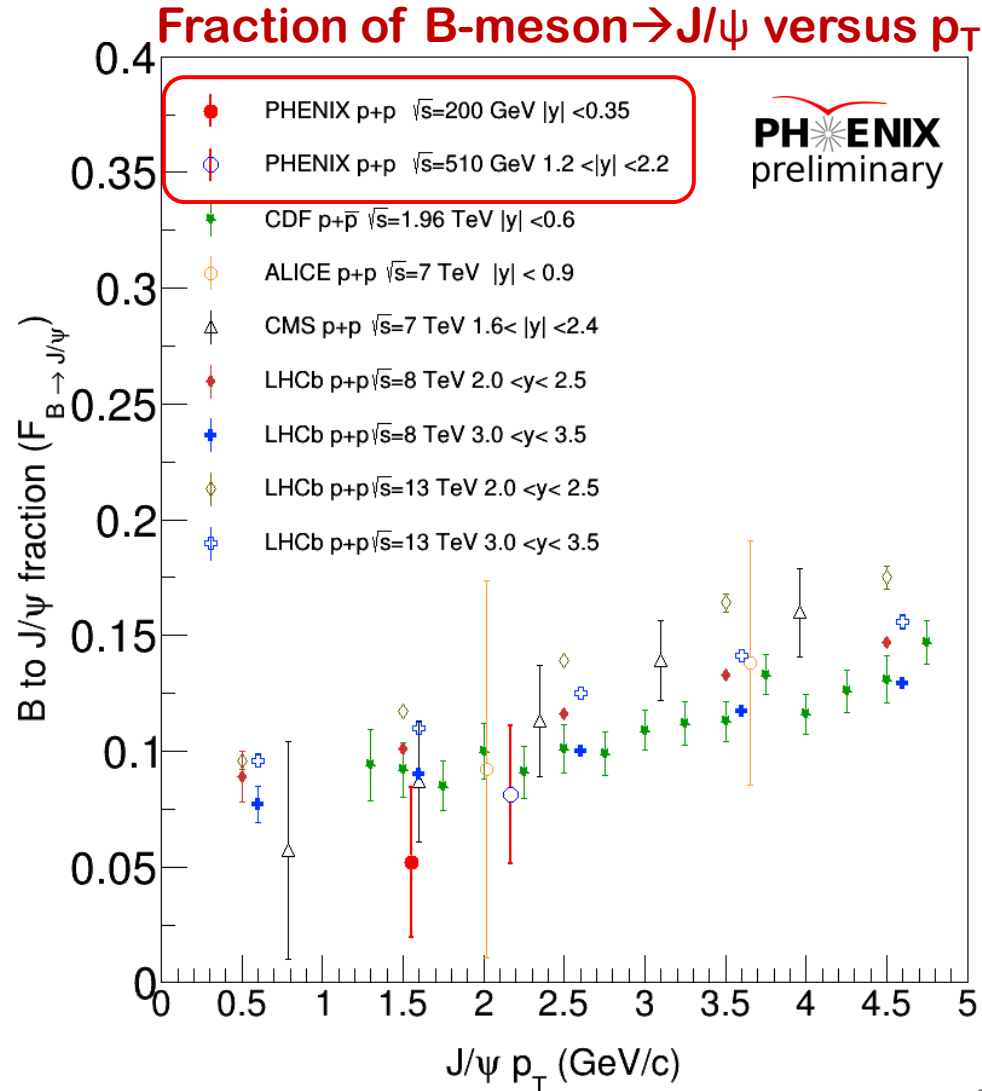


Excellent agreement with Fixed-Order-Next-to-Leading-Logarithm plus Color-Evaporation Model (FONLL+CEM) predictions across large rapidity range.



# B $\rightarrow$ J/ $\psi$ Fraction: Collision Energy and pT Dependence

- Excellent agreement with CDF/ALICE/CMS/LHCb measurements

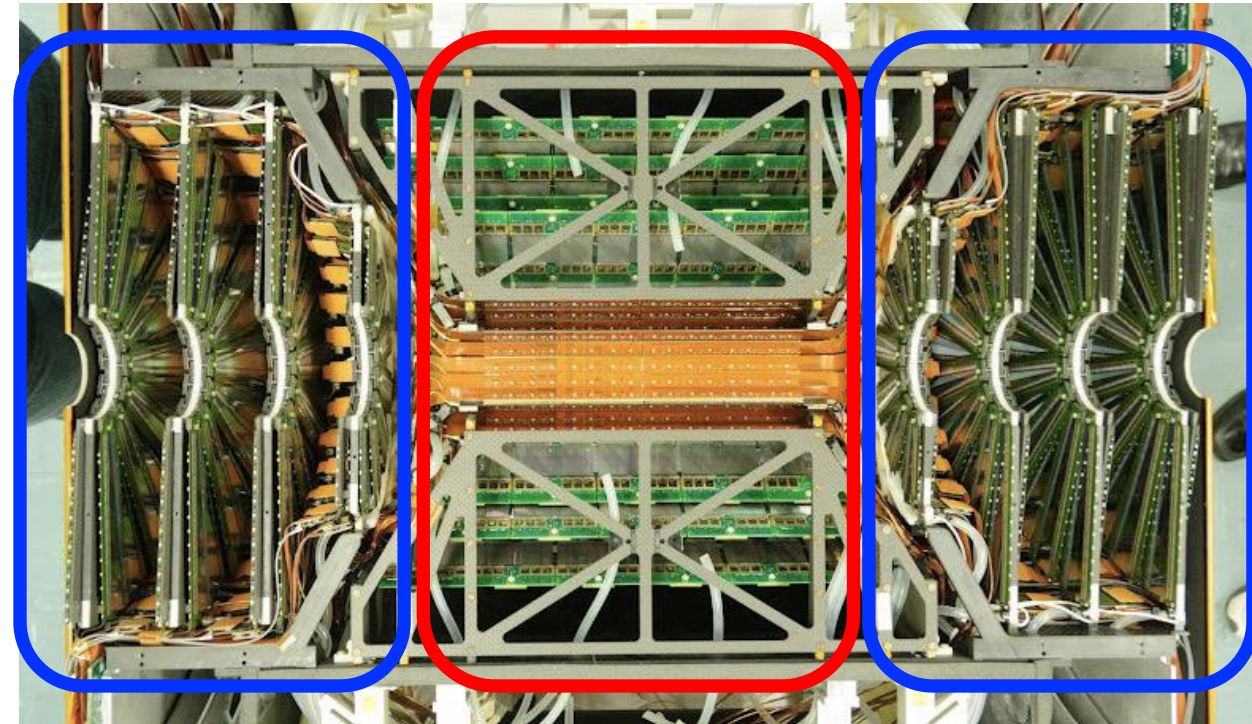
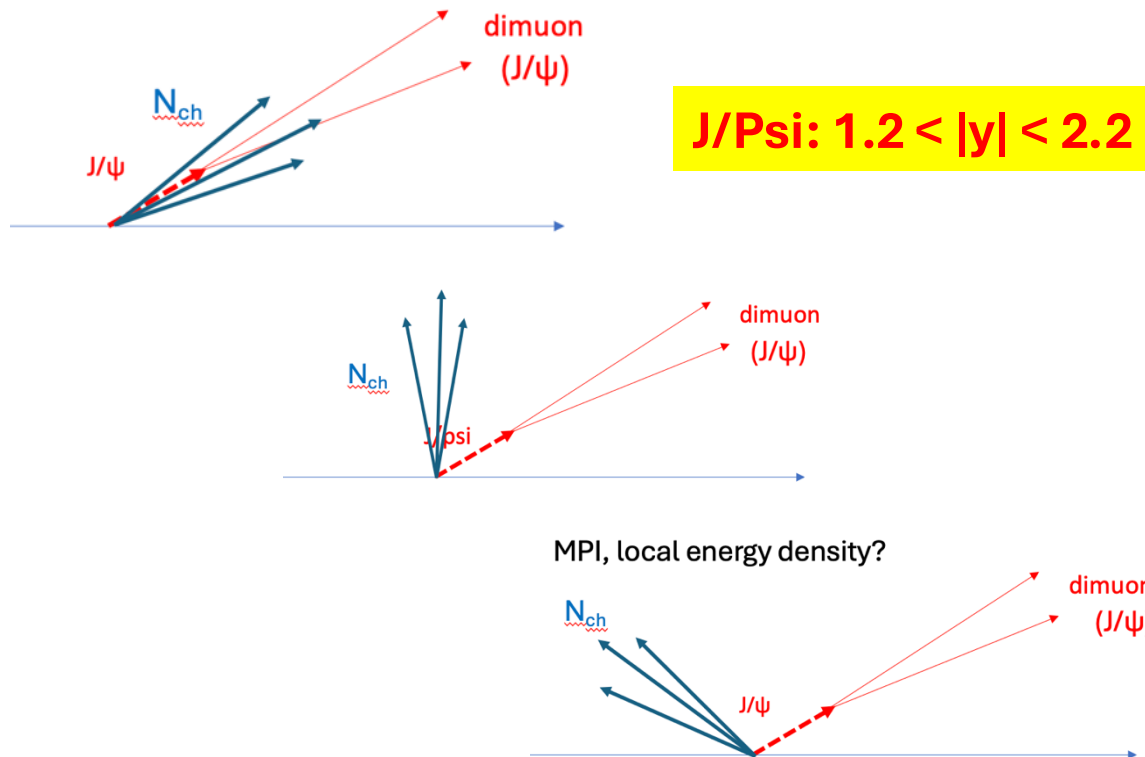


# (II) Study of $J/\psi$ Production vs $N_{ch}$ in p+p and p+Au at 200GeV

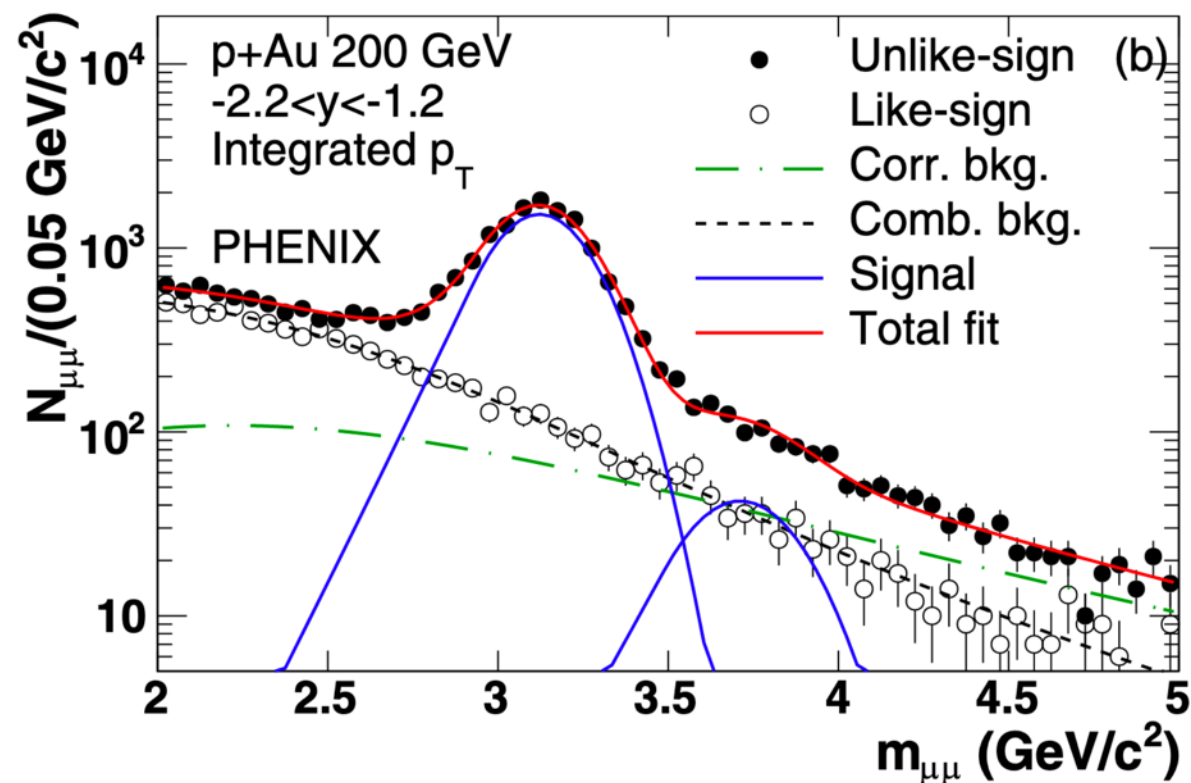
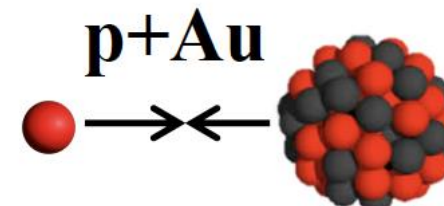
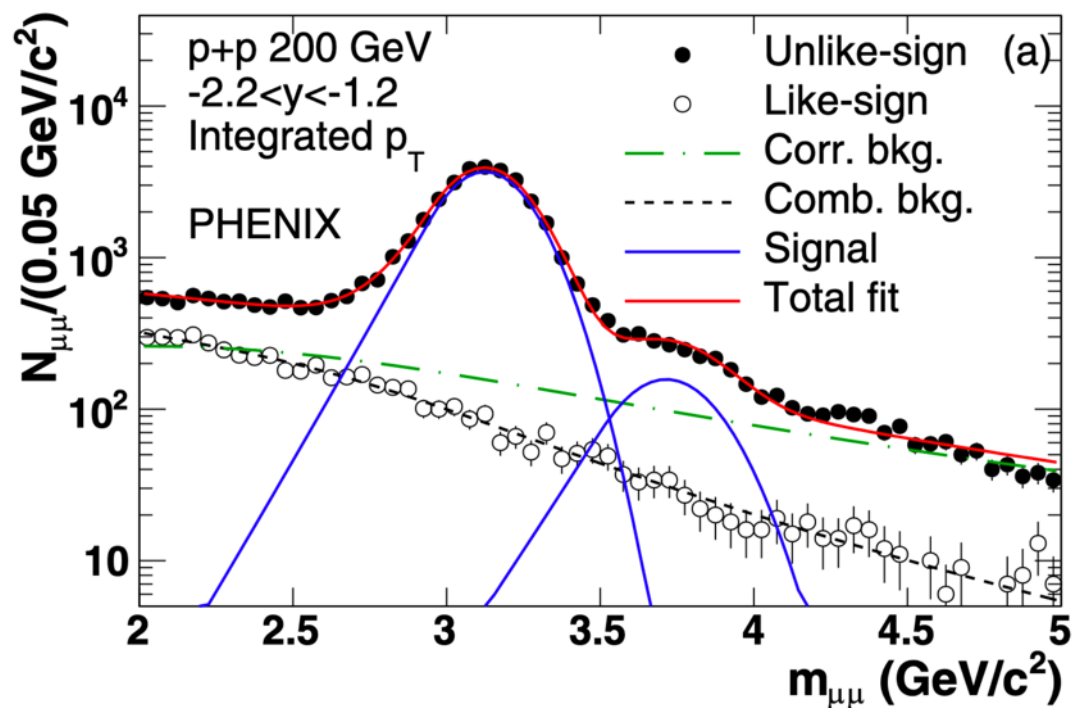
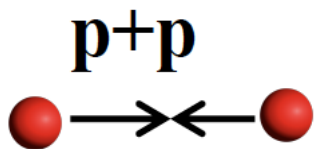
- Final State Interactions (FSI), CNM, QGP
- Local event multiplicity:  $N_{ch}$
- Multi-Parton Interactions (MPI)
- Long-range particle correlations

Event track multiplicity:  $N_{ch}$

- SVX,  $|\eta| < 1$
- FVTX,  $1 < |\eta| < 3$



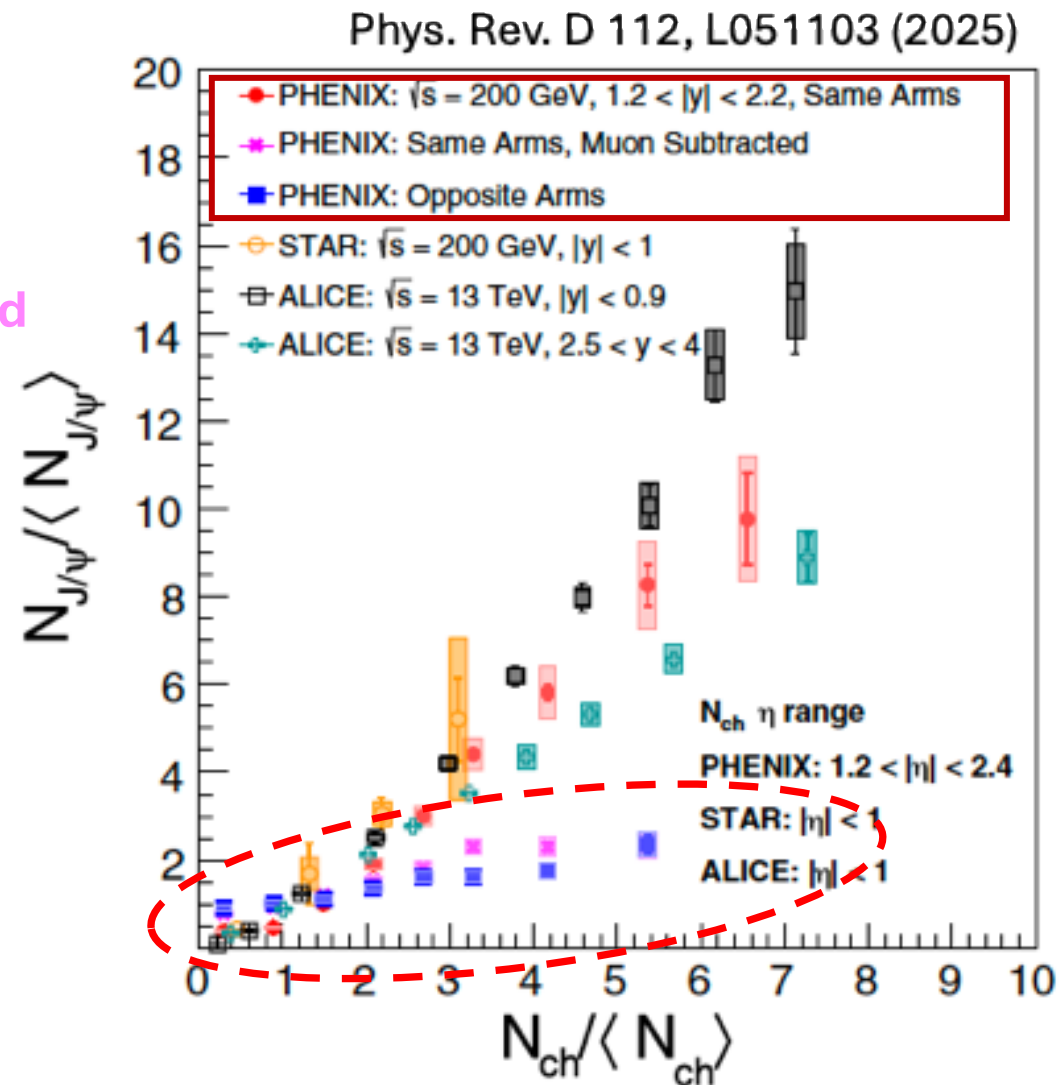
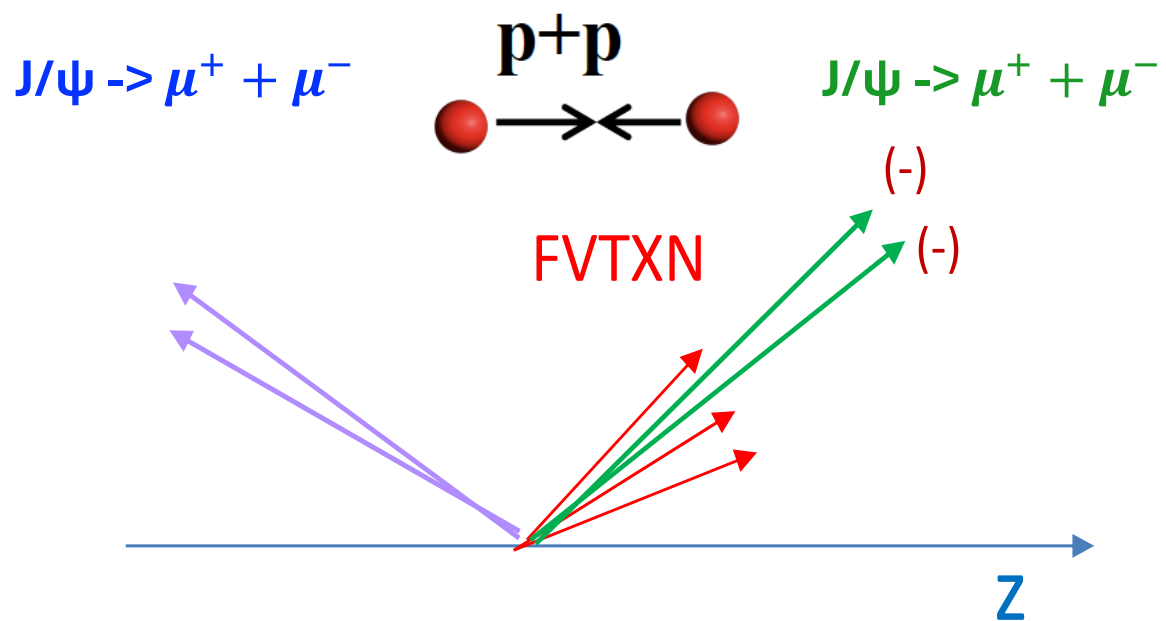
# J/ $\psi$ , $\Psi(2S)$ Measurements in Dimuon Channel





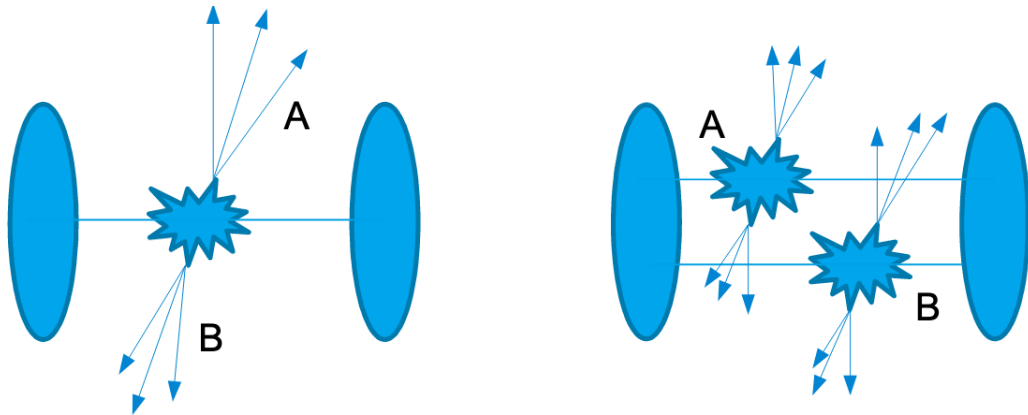
# $J/\psi$ Yield vs $N_{ch}$ in p+p Collisions

1.  $J/\psi$  yields increase vs  $N_{ch}$
2. Similar trend as others, same-arm “inclusive”  $N_{ch}$
3. **Apparent clear difference** in long-range  $\langle J/\psi - N_{ch} \rangle$  correlations, **same arm** vs **opposite arm**
4. **Consistent once same-arm auto-correlation removed**
  - Long range correlation in p+p

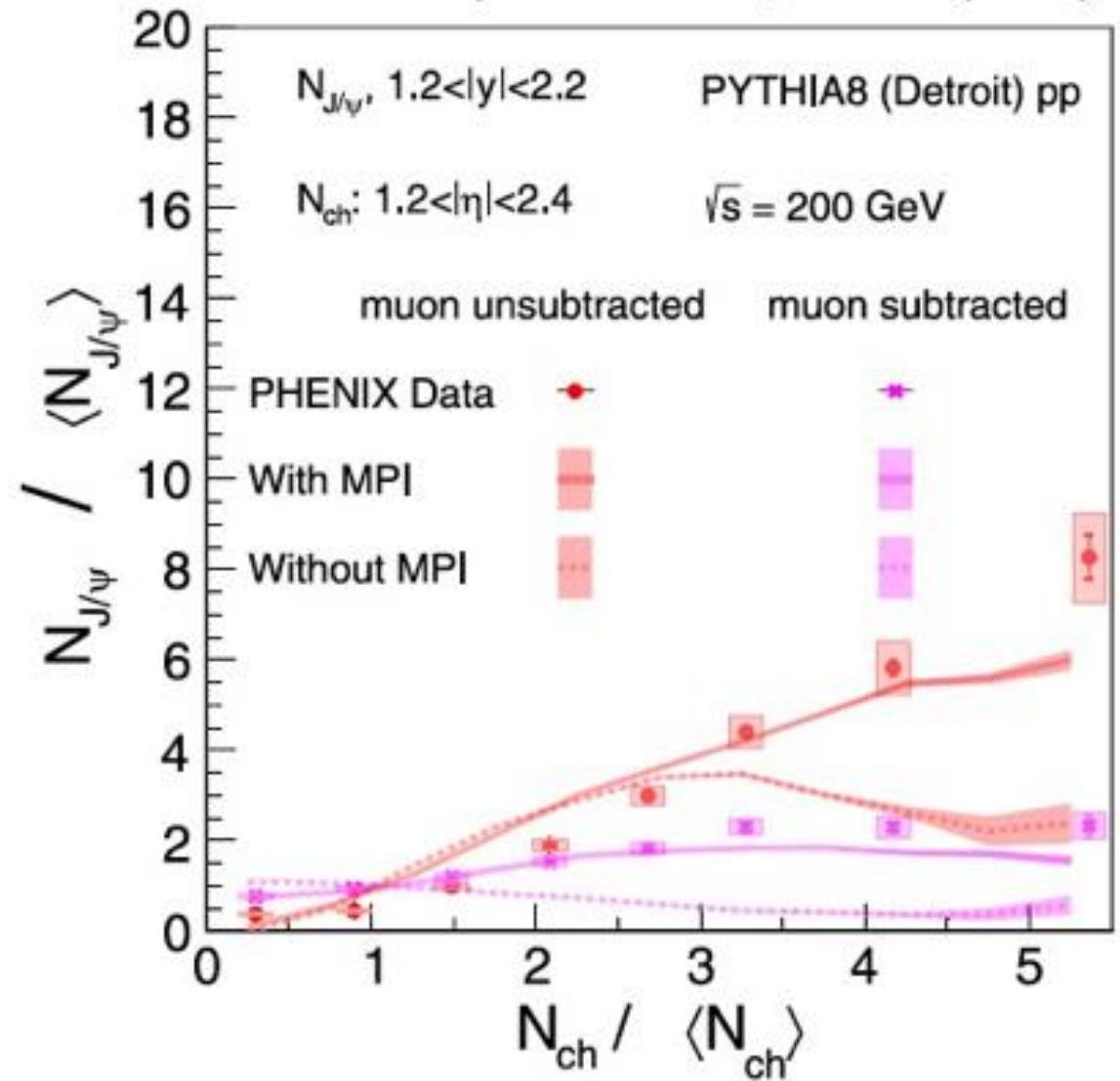


# MPI and CR in PYTHIA8

- **PYTHIA8 Detroit tune reasonably agrees with PHENIX data, with MPI**
  - w/o MPI, fit failed badly
- **Understanding of the underline event activity and correlation is important**



Phys. Rev. D 112, L05113 (2025)



# $J/\psi$ Yield vs $N_{ch}$ in p+Au Collisions

## Unique collision event topology:

- Study correlations over wide rapidity gaps
- Small-x vs large-x in Au
- Core-corona, QGP, CNM, MPI

$-2.2 < y < -1.2$   
 $J/\psi \rightarrow \mu^+ + \mu^-$

$1.2 < y < 2.2$   
 $J/\psi \rightarrow \mu^+ + \mu^-$

FVTXN

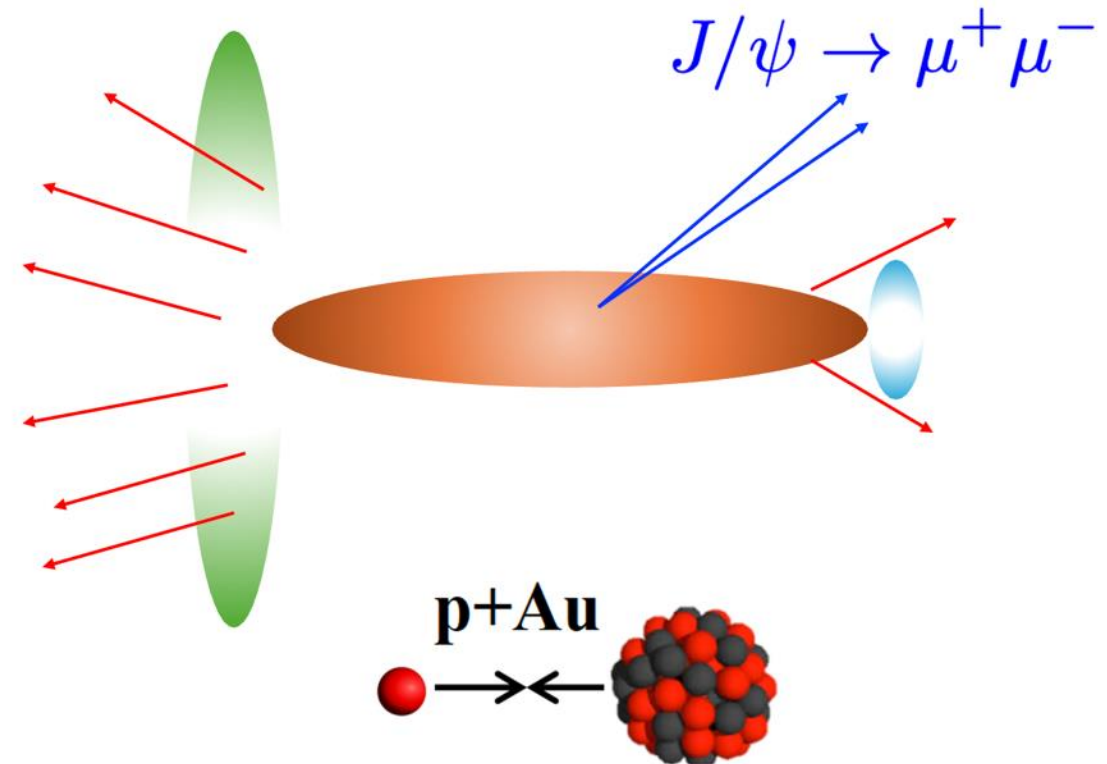
(-)  
 (-)



$y_{beam} = 5.36$  @100GeV (LHC pp @13TeV: 9.54 )

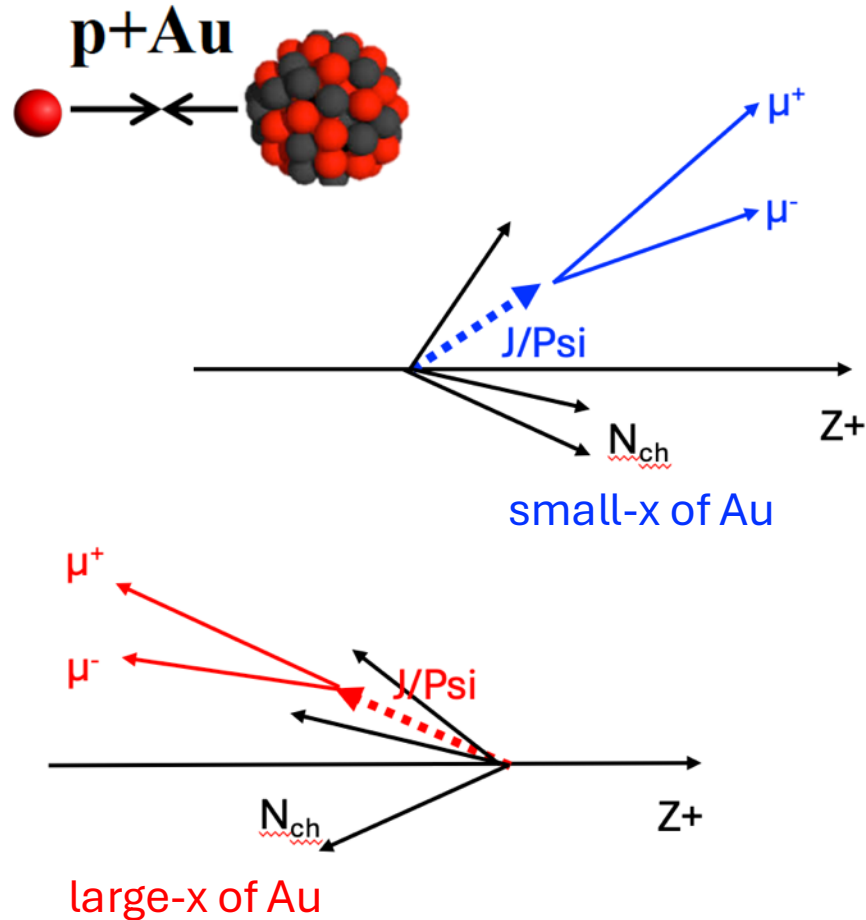
large-x of Au

small-x of Au

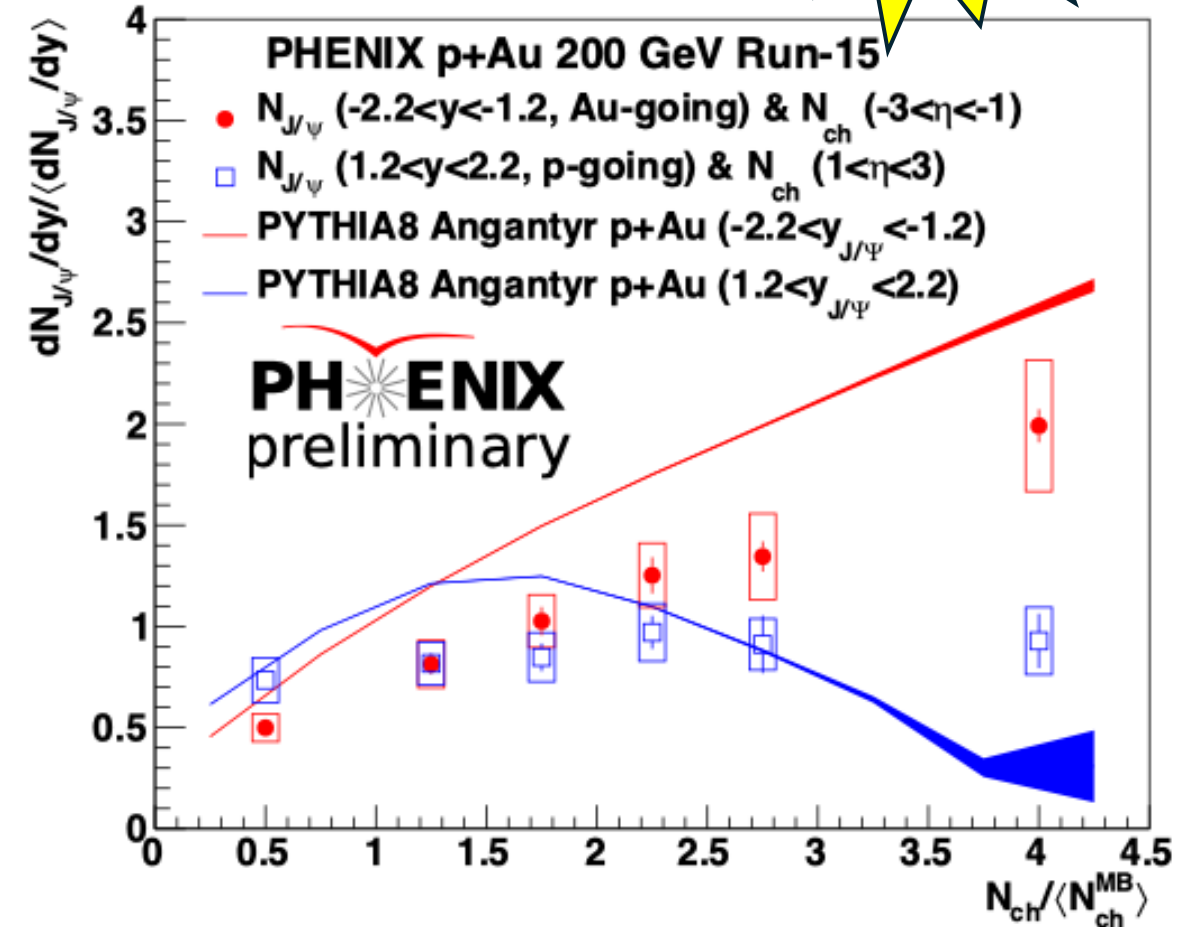




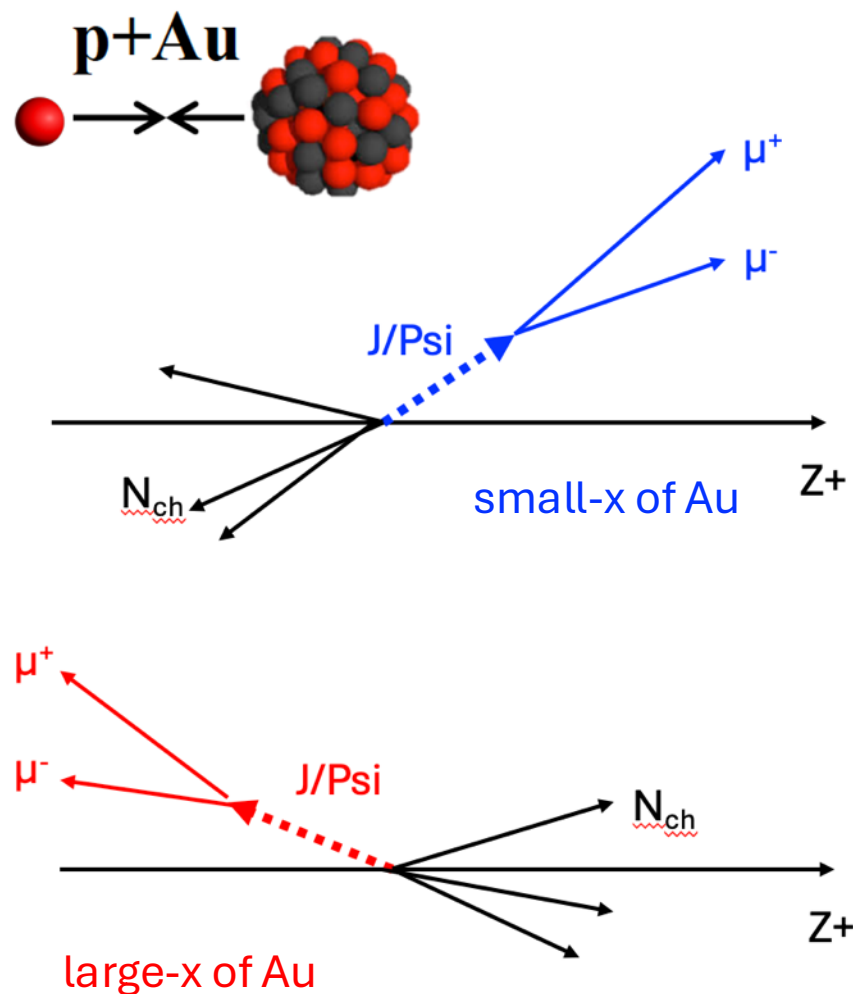
# $J/\psi$ and $N_{ch}$ Correlation: Same Arm



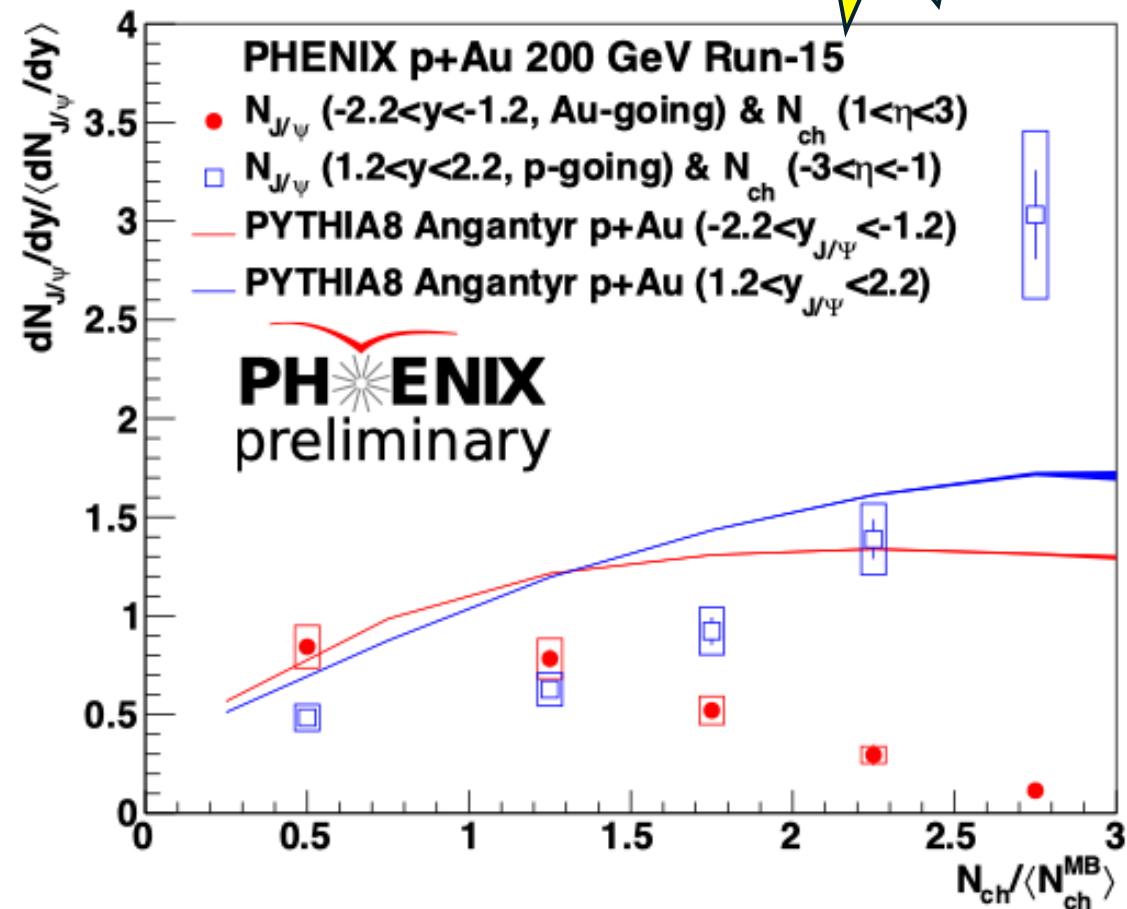
muon subtracted



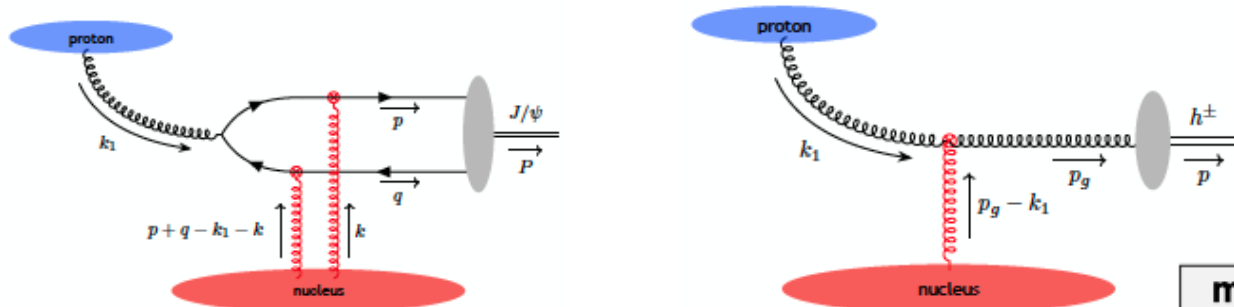
# $J/\psi$ and $N_{ch}$ Correlation: Opposite Arm



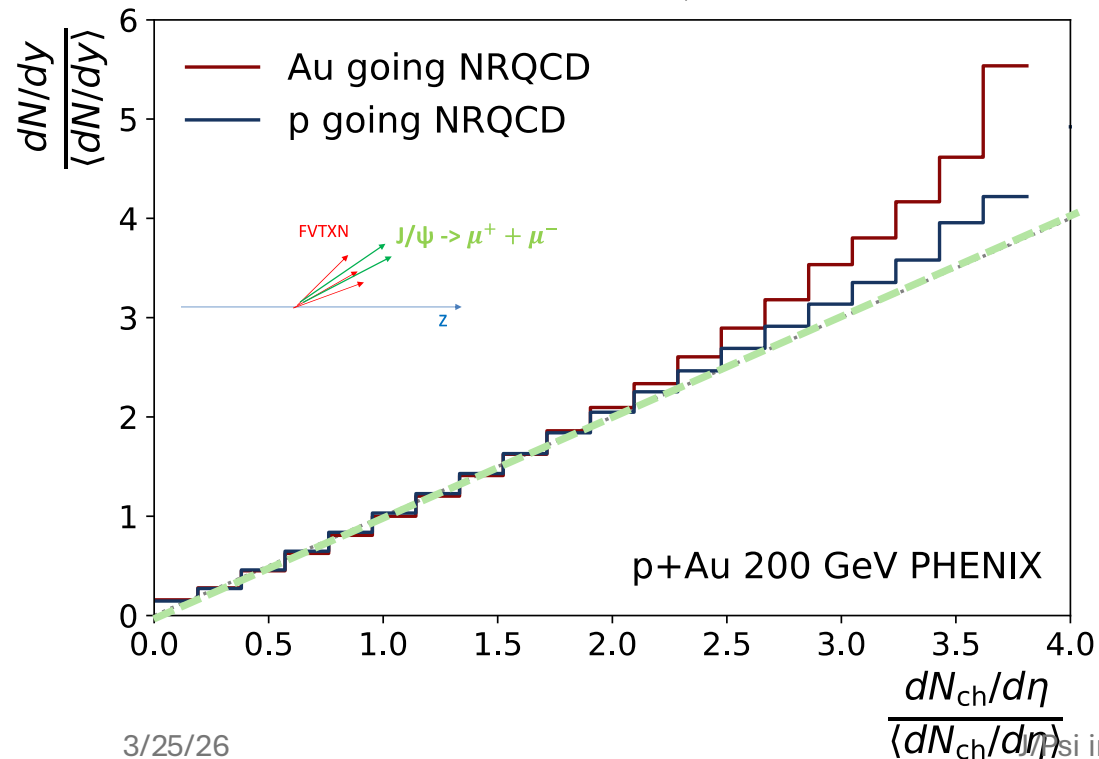
muon subtracted



# Probe CGC in p+Au?



Farid Salazar, Bjorn Schenke and Alba Soto-Ontoso  
arXiv:2112.04611; Private Comm.



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psi in PHENIX @SQM

Run15 (2015)

100GeV/nucleon **PHENIX**

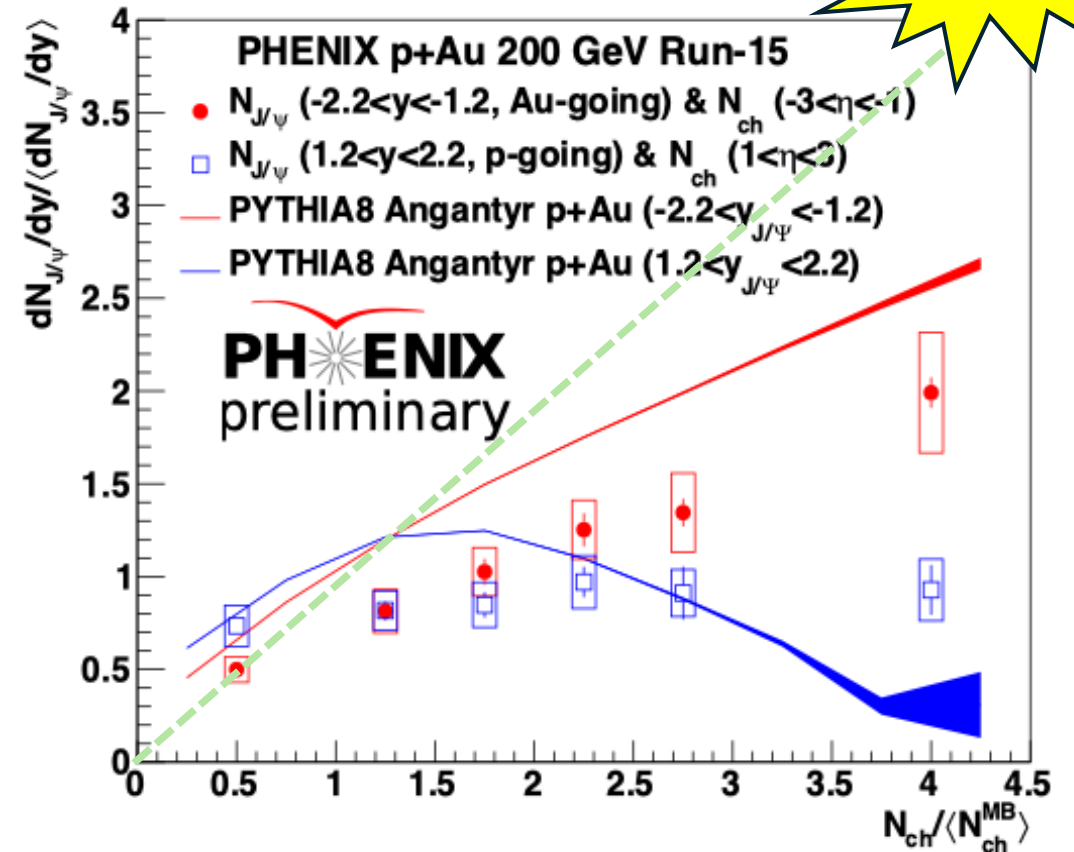
100GeV

Au, Al

Polarized Proton

muon subtracted

**NEW**



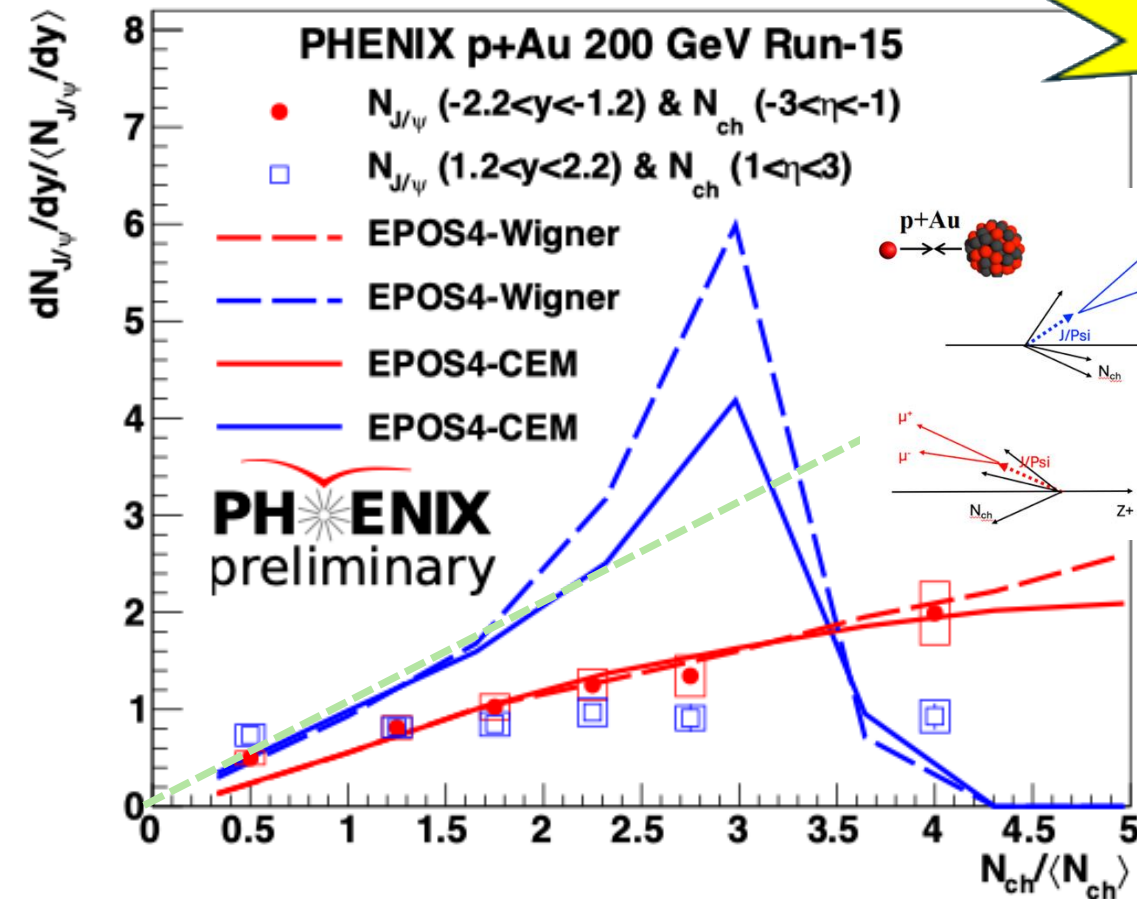


# EPOS-4 and PHENIX Data

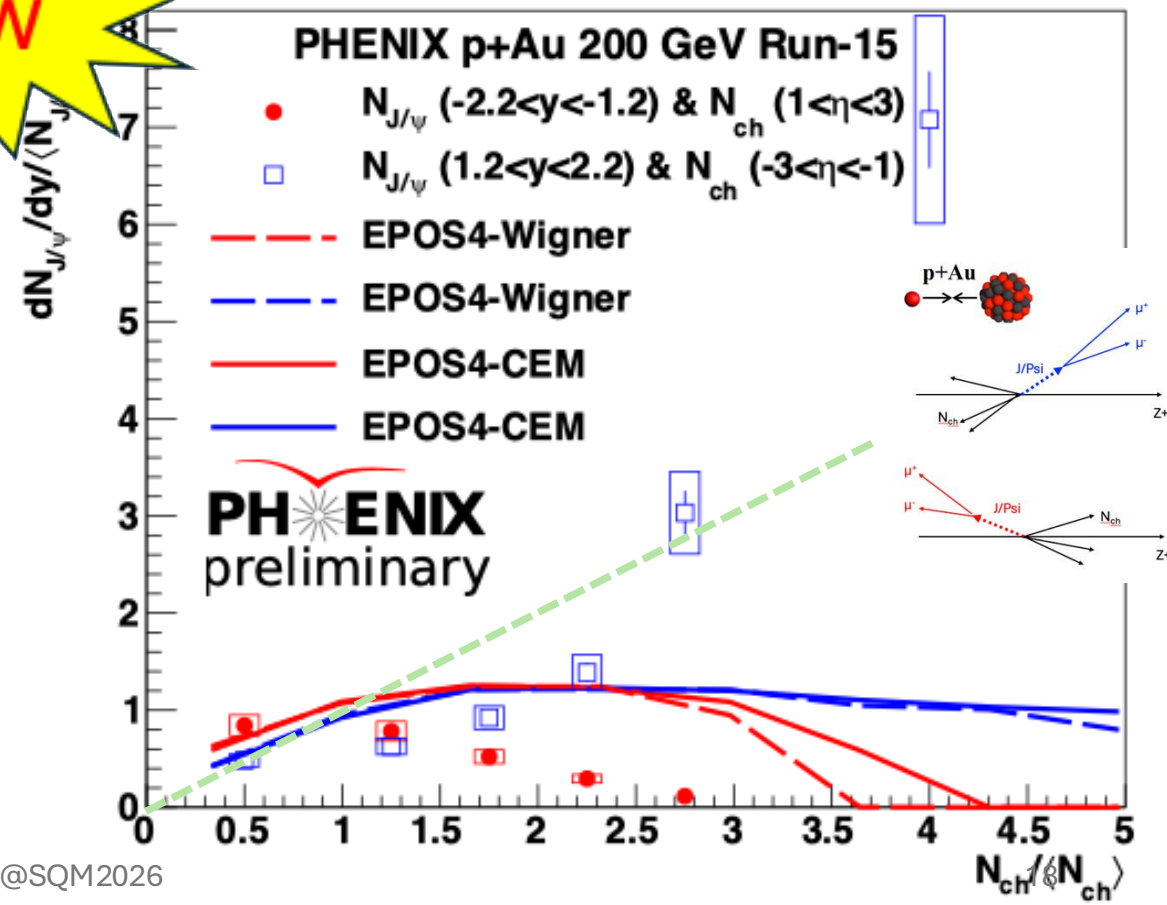
- Excellent agreement with “same-arm” data in **Au-going direction**
- Failed **p-going direction**

- Challenging for “opposite -arm” data in both **Au-going direction** and **p-going direction**

muon subtracted



muon subtracted

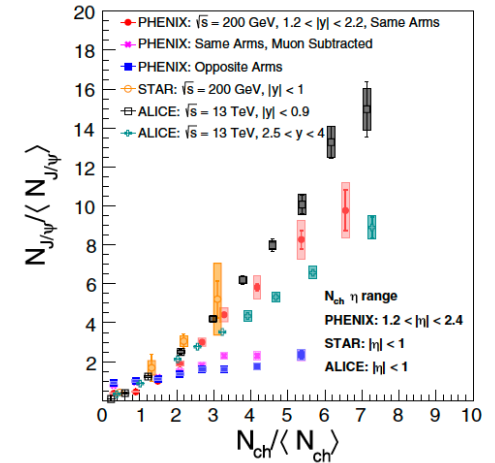
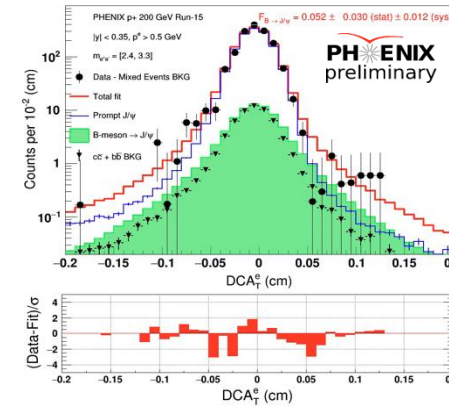


# Summary and Outlook

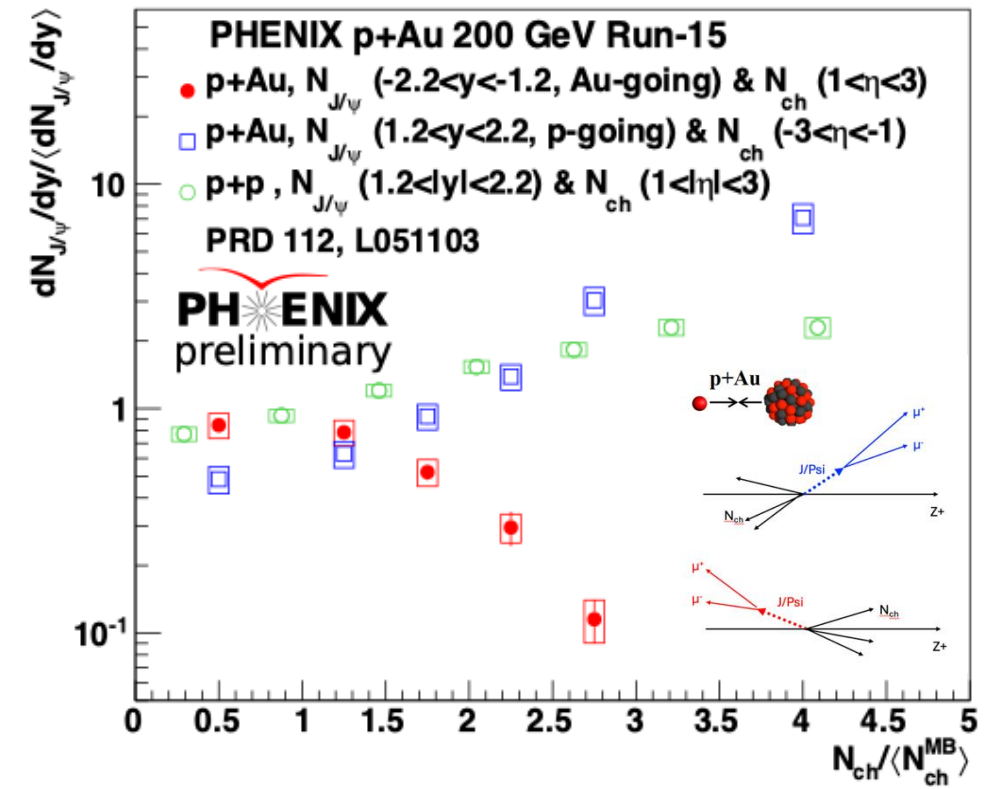
- **B- $\rightarrow$ J/Psi fraction in p+p at 200GeV**
  - excellent agreement with FONLL + CEM prediction
- **Inclusive J/Psi yields vs event multiplicity in p+p and p+Au**
  - pp results consistent with other observations at RHIC and LHC
  - **Novel effects observed in p+Au in large rapidity gap correlation**

## Additional studies needed to understand the physics of p+Au collisions

- Event geometry, short and long range correlation
- QGP, CNM, CGC
- Centrality determination of pAu etc ...



muon subtracted



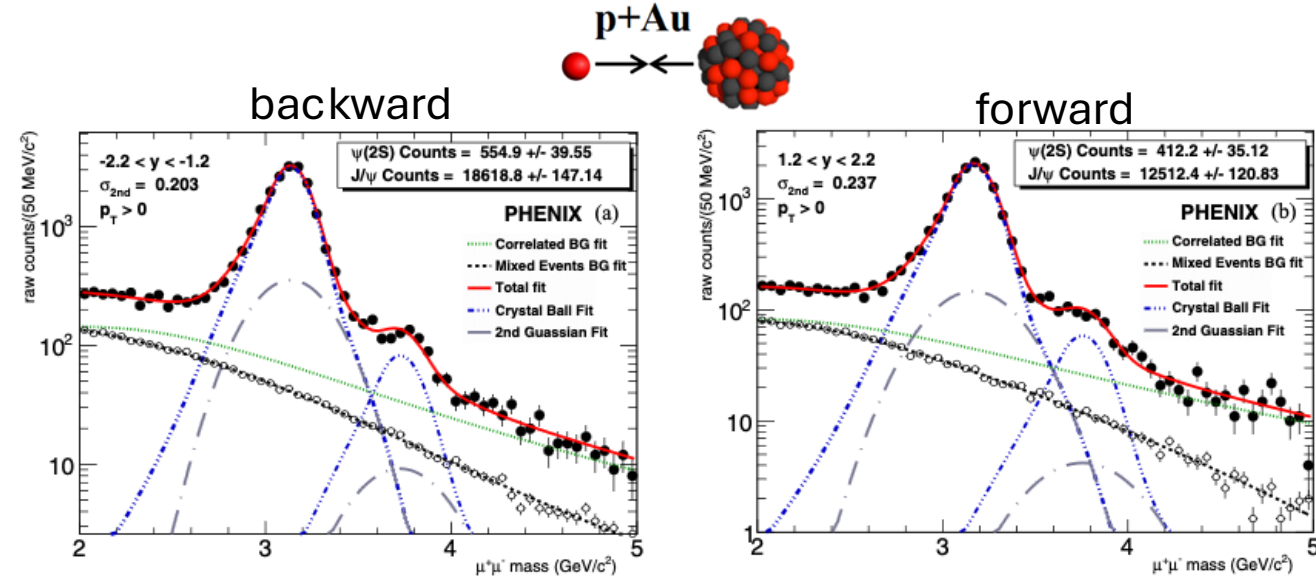
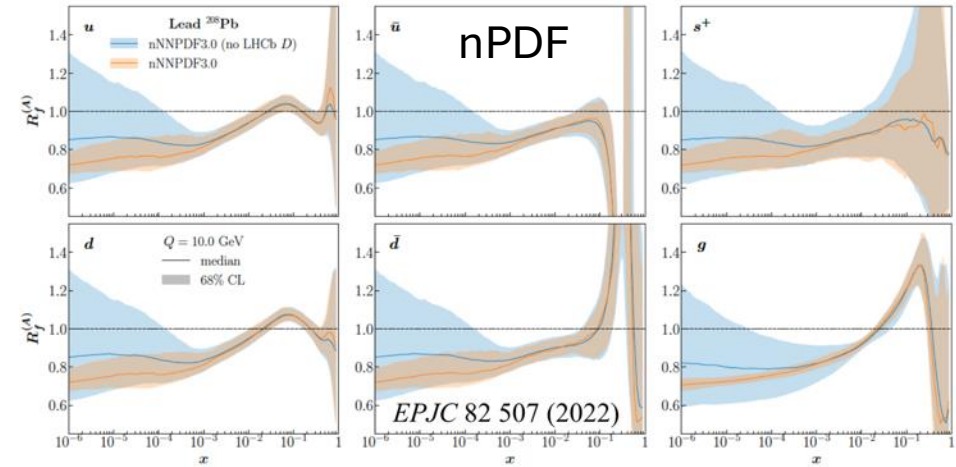
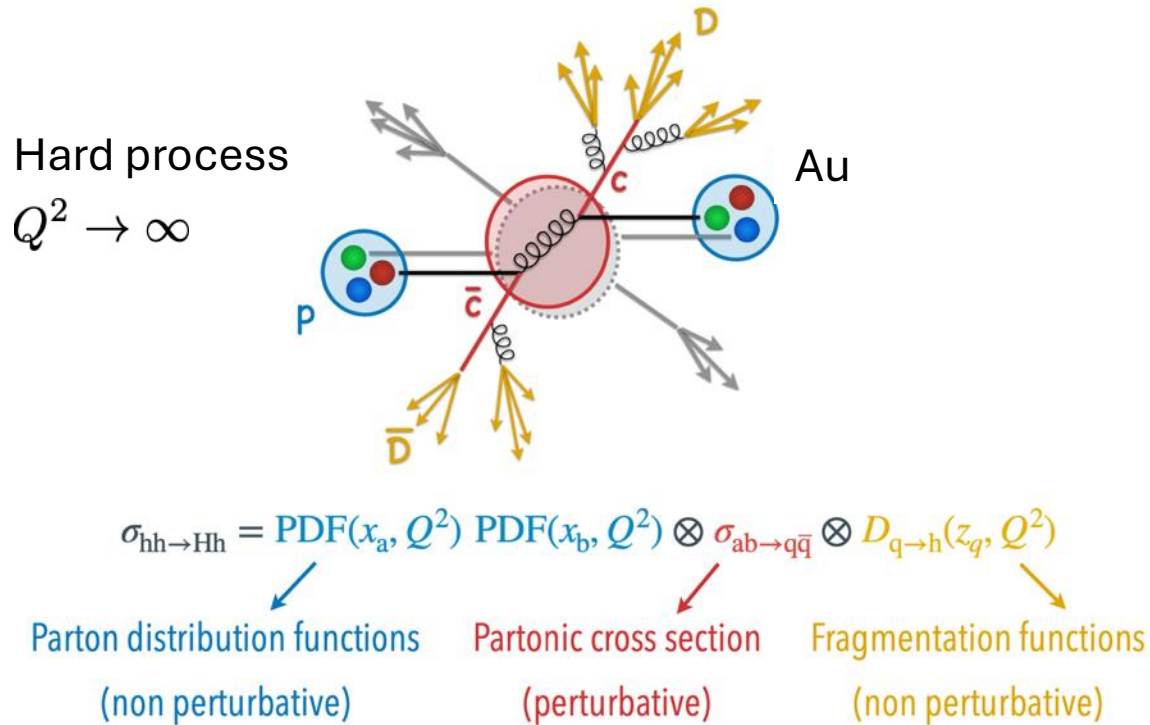
# Backup slides



# HF Production in p+p and p+Au

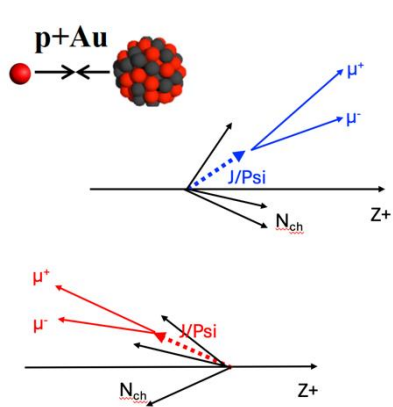
- Initial state, nPDF
- Final state, hadronization
- Multi-parton interactions

(None)universality of PDF and FF and QCD factorization

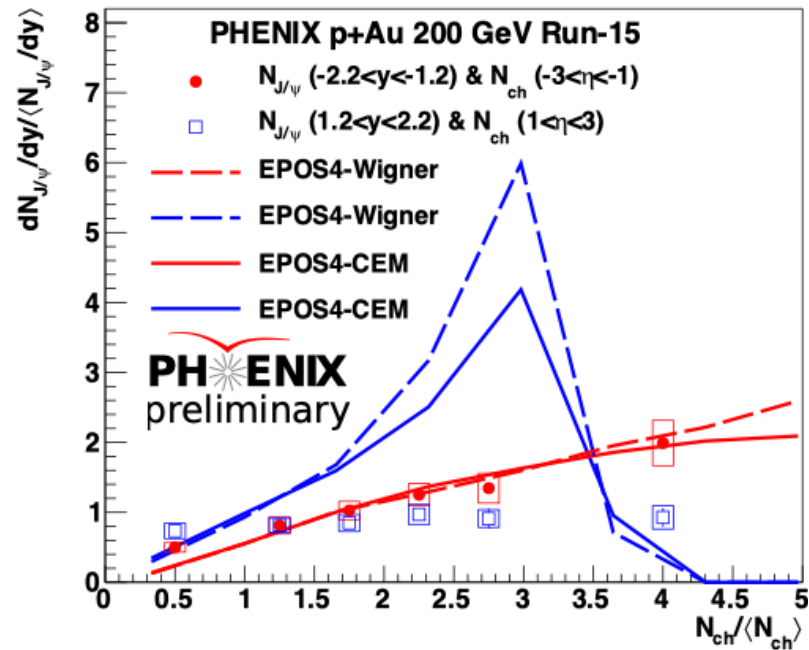


# Physics Discussions

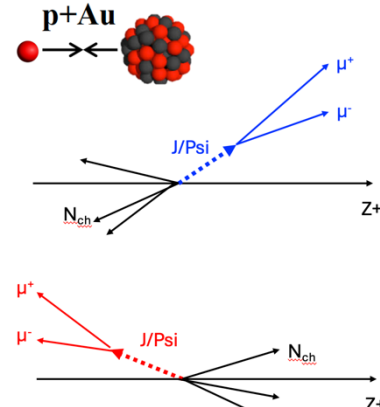
p+p



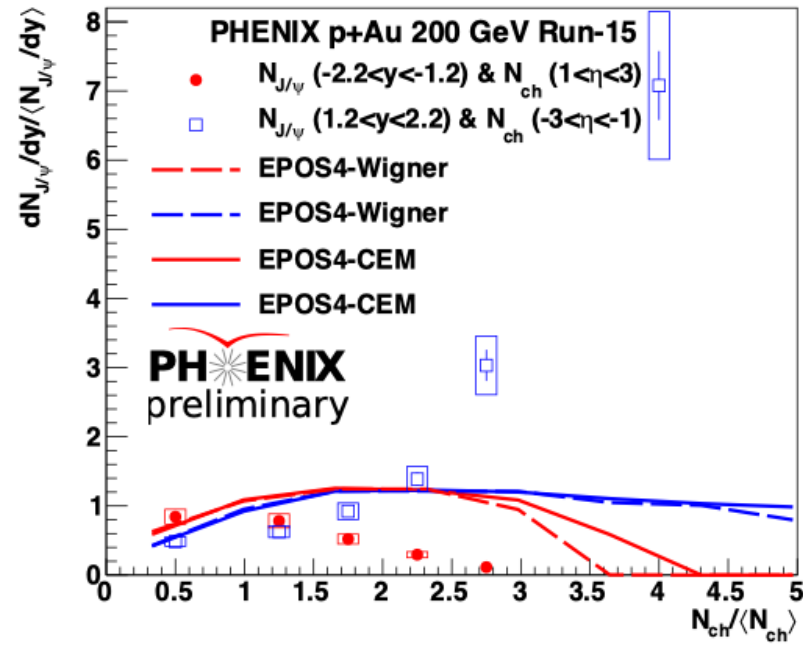
muon subtracted



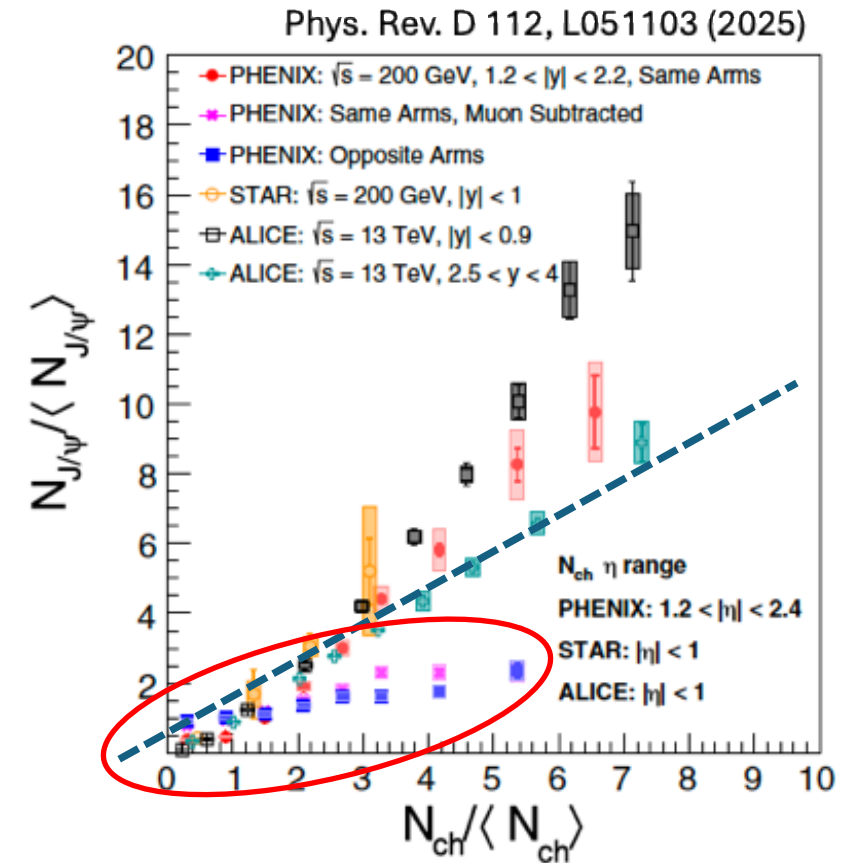
3/25/26



muon subtracted

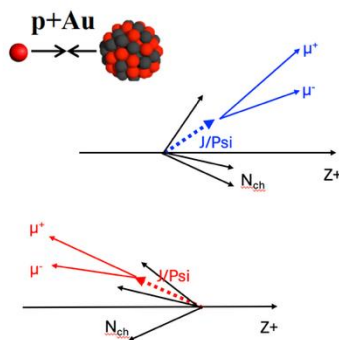


J/Psi in PHENIX @SQM2026

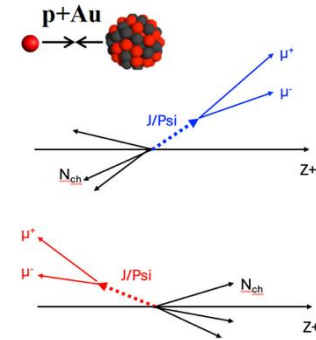
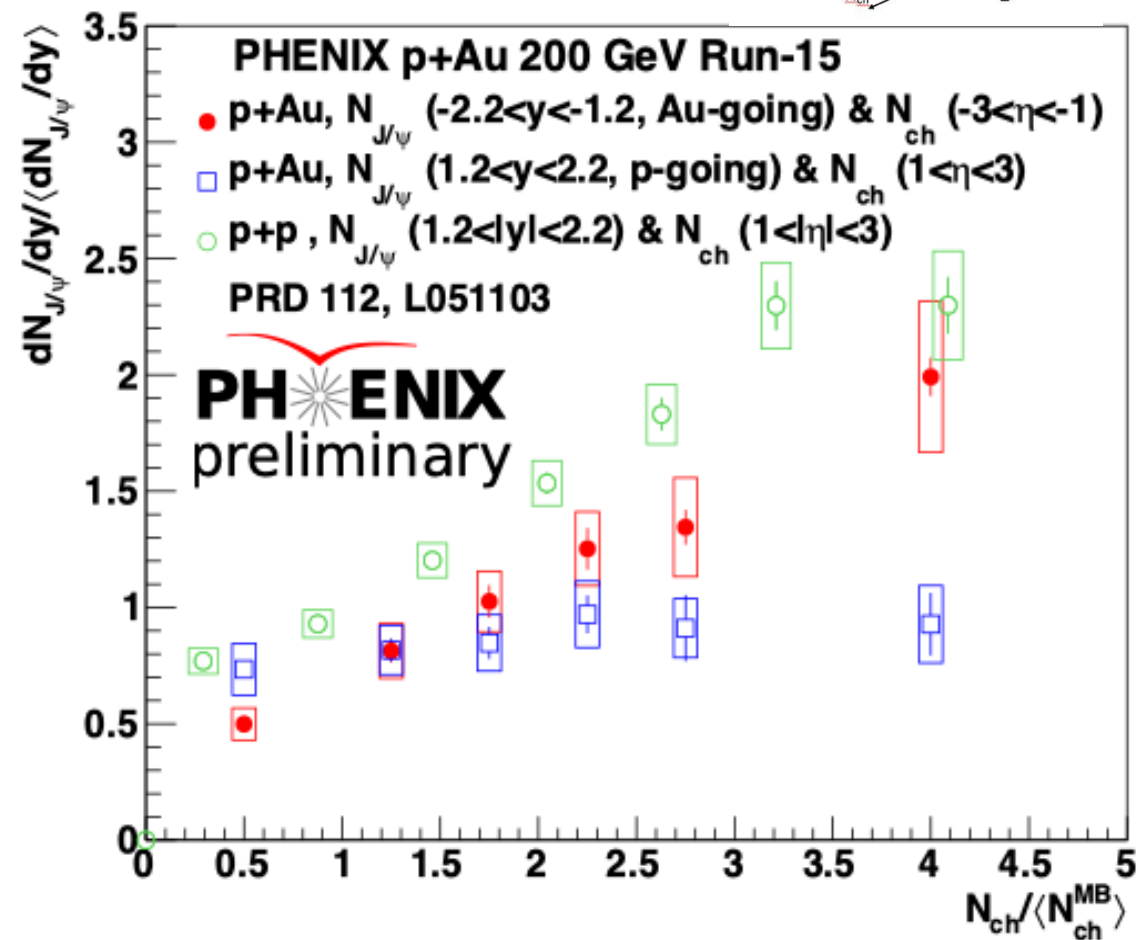


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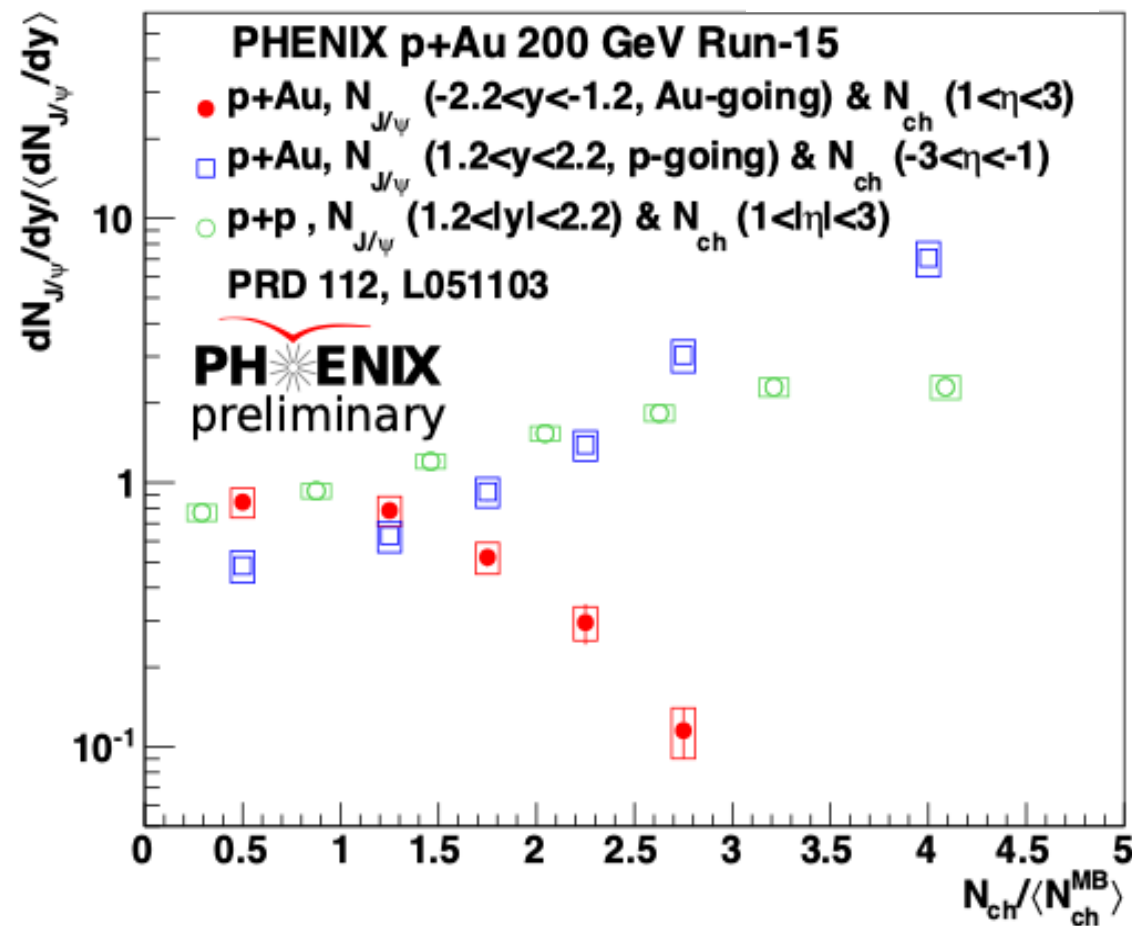
# Physics Discussions: **p+p** and **p+Au**



muon subtracted



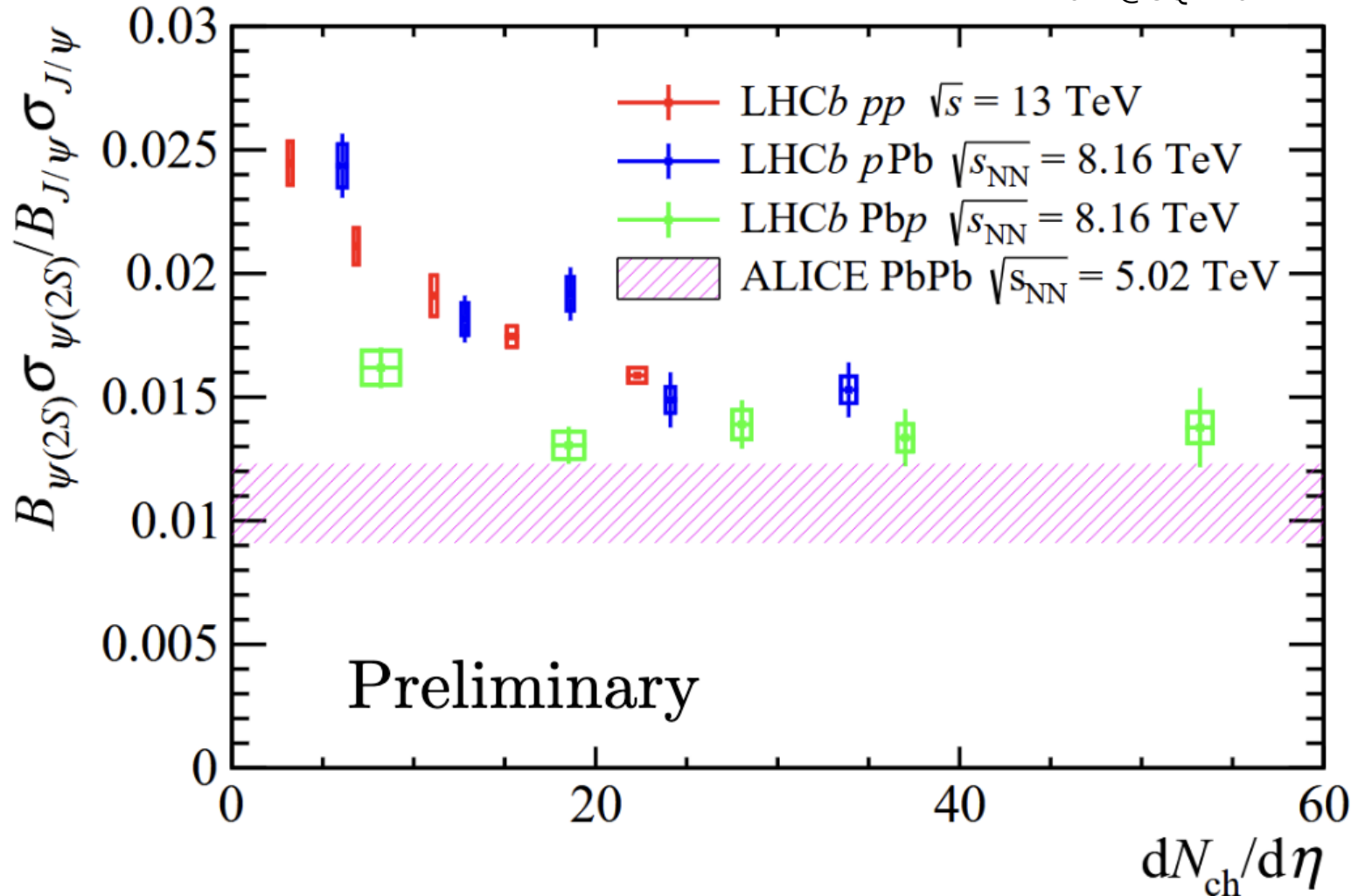
muon subtracted



# LHCb p+Pb: $\psi(2S)/J/\psi$

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T. Boettcher's talk,  
Mon. @SQM26



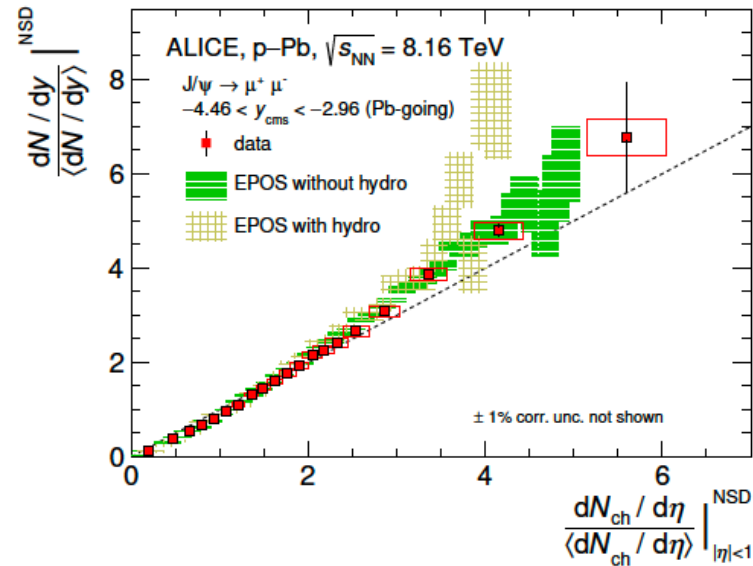
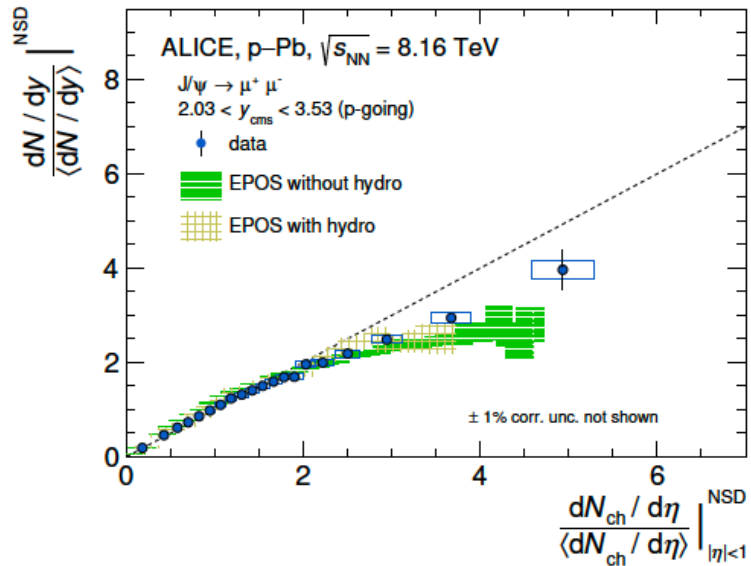
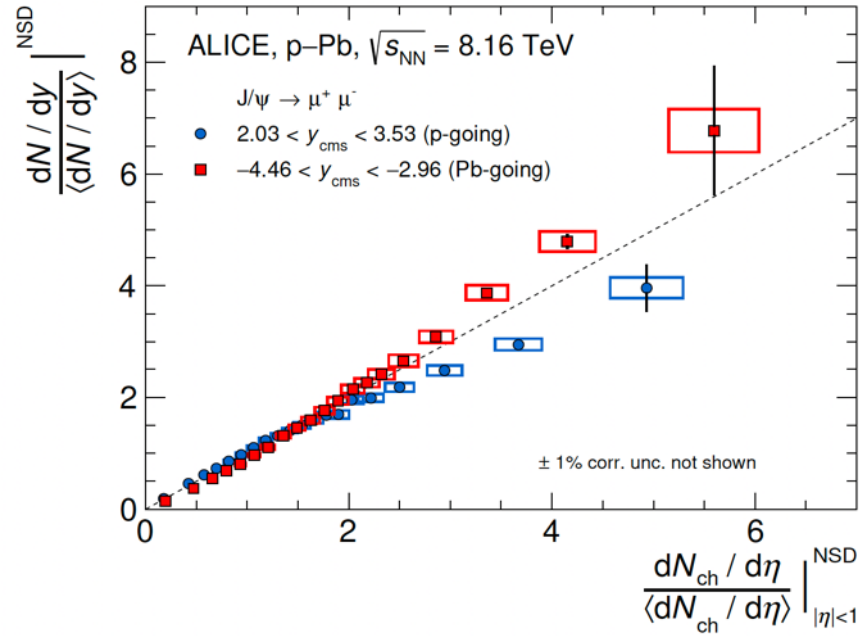
- Pb-going

- p-going

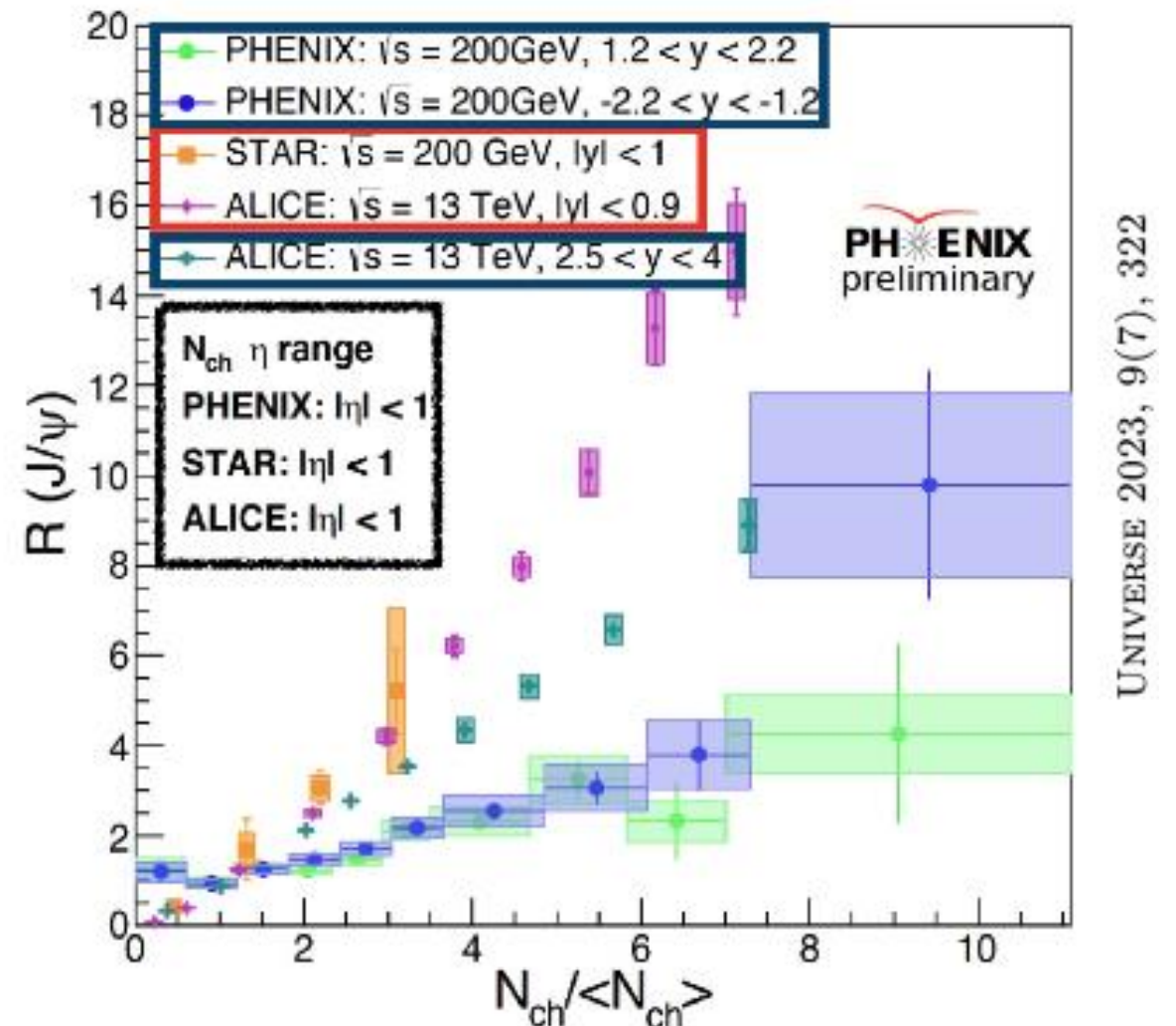
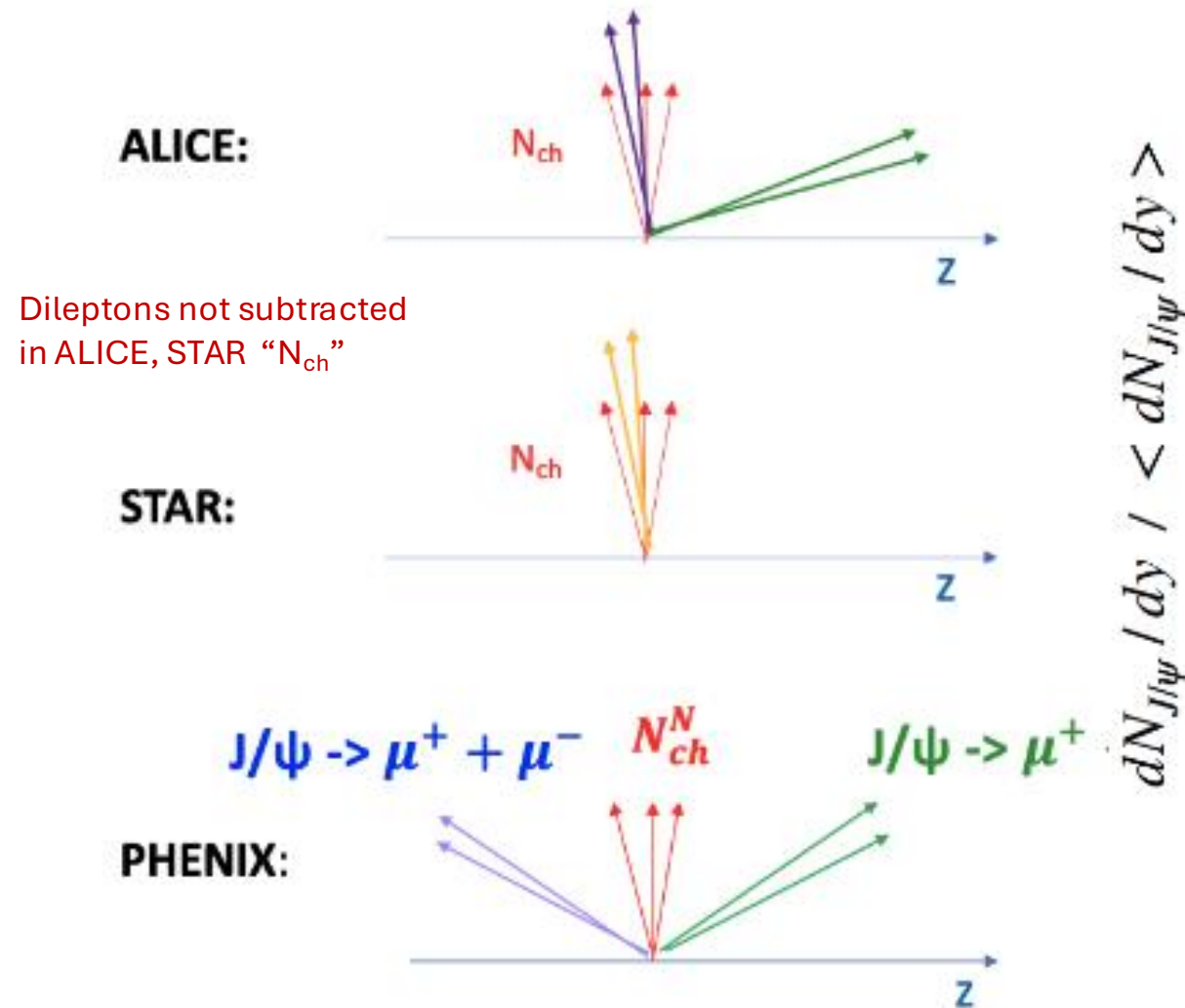
More suppression in the  
Pb-going direction:

$$\psi(2S)/J/\psi$$

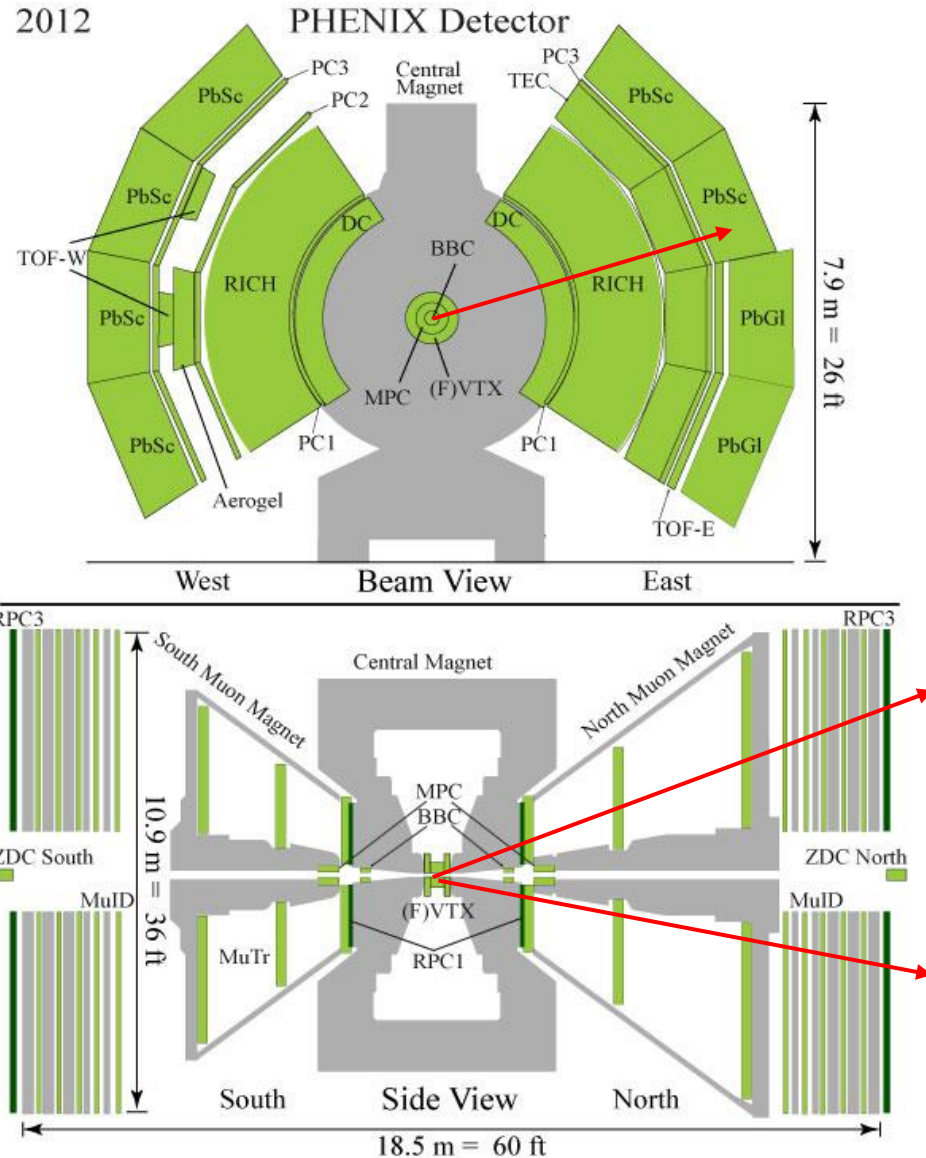




# J/Psi Multiplicity Dependence: RHIC vs LHC



# PHENIX Detector & Measurements



## Central Arms $|\eta| < 0.35$

- Identified charged hadrons
- Neutral Pions/Etas
- Direct Photon
- $J/\psi$  ( $e^+e^-$ )
- Heavy Flavor (VTX),  $e^+/e^-$

## Muon Arms $1.2 < |\eta| < 2.4$

- $J/\psi$
- Unidentified charged hadrons
- Heavy Flavor (FVTX)

## BBC/MPC $3.1 < |\eta| < 3.9$

- Neutral Pion's, Eta's
- Charged particles

## ZDC $|\eta| \sim 5.9$

- Neutrons

## Electron ID:

- VTX
- Tracking
- RICH
- EMCal

## Muon ID:

- FVTX
- MuTraker
- MuID



