Particle multiplicity-dependent charmonia production in p+p collisions by the PHENIX experiment

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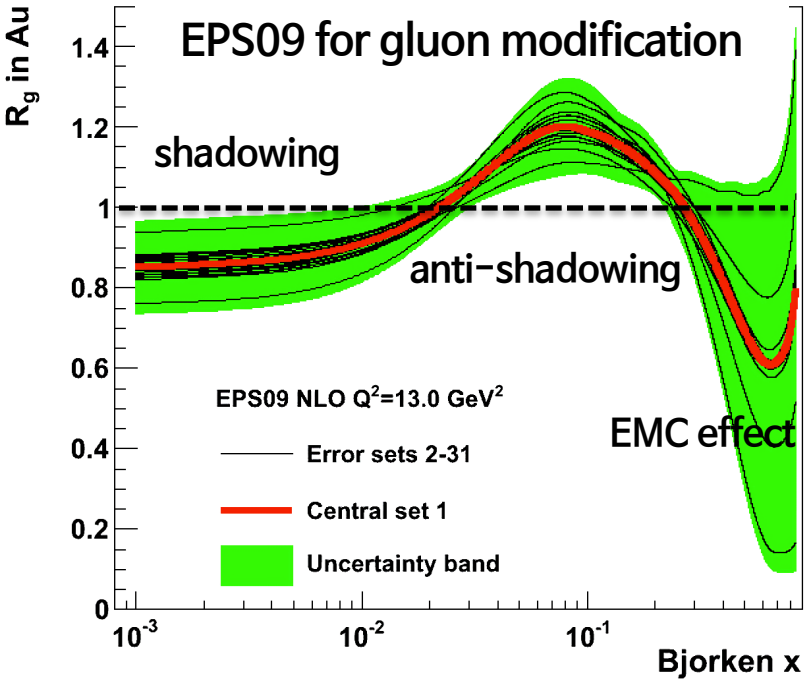
PHENIX

PHYSICS IN COLLISION

42nd International Conference on Physics in Collision

October 10 – 13, 2023 | Universidad de Tarapacá, Arica, Chile

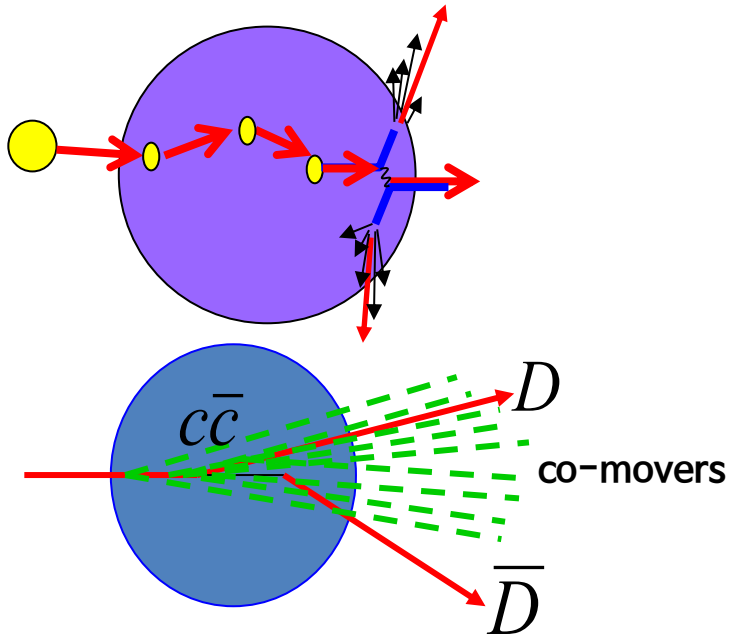
Various effects on charmonia production in small systems



Modified parton distribution functions in nuclei compared to those in nucleon

Scattering with nuclear matter:
(Initial-state and/or final-state interaction)

- Transverse momentum broadening
- Energy loss
- Break-up of bound states



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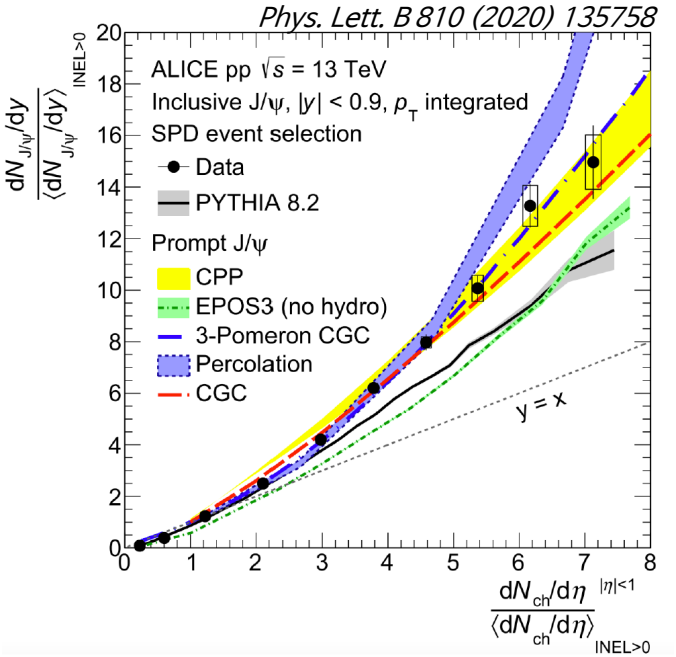
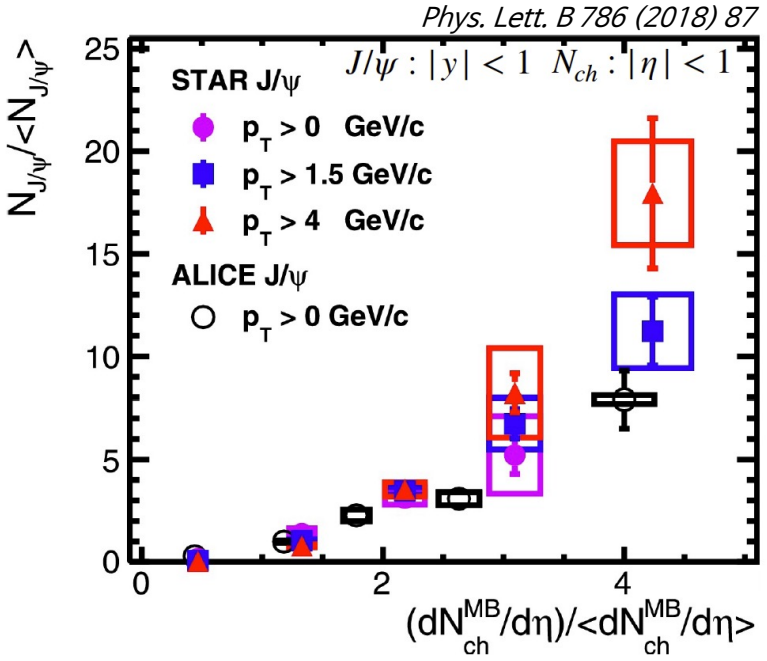
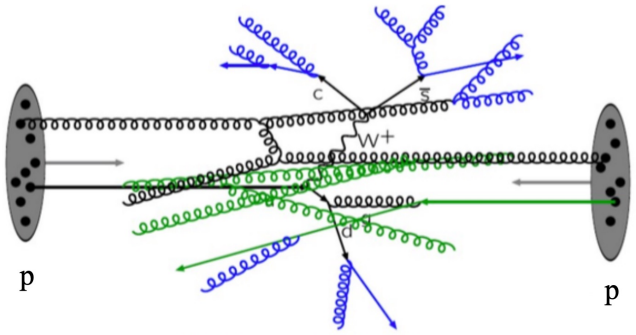
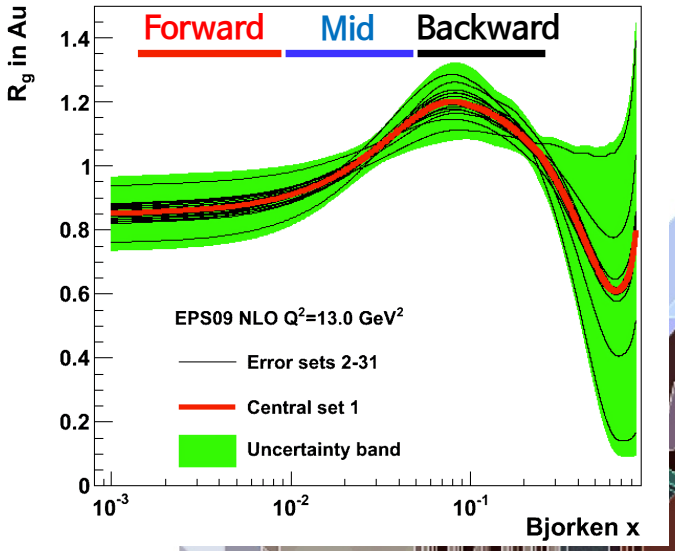


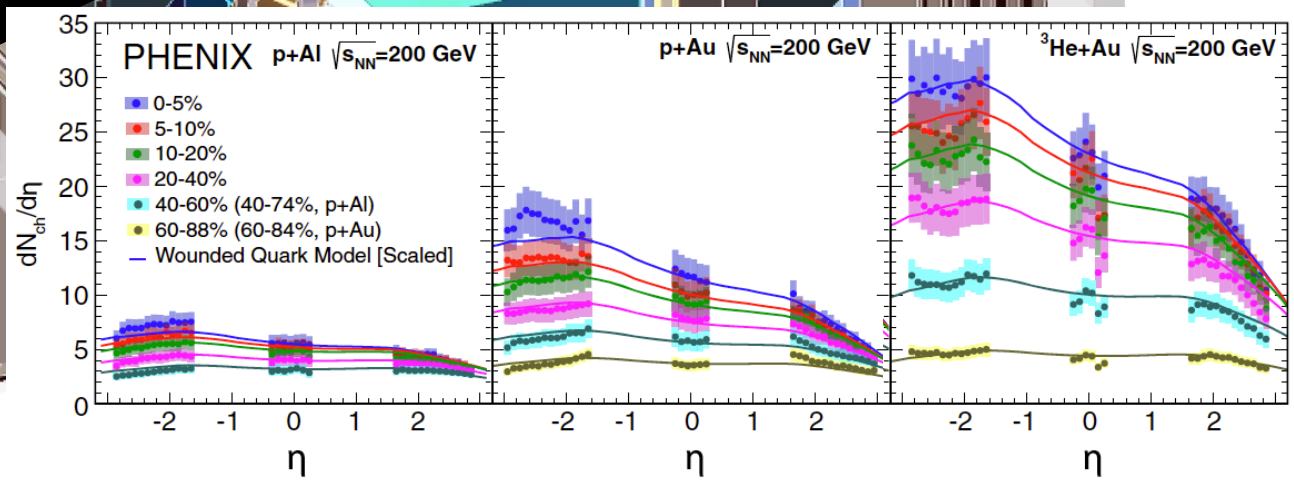


- Inclusive J/ψ yield increases with particle multiplicity in p+p collisions at 13 TeV and 200 GeV
  - Similar multiplicity dependence at two energies
  - Multiparton interaction is important for J/ψ production in both energies



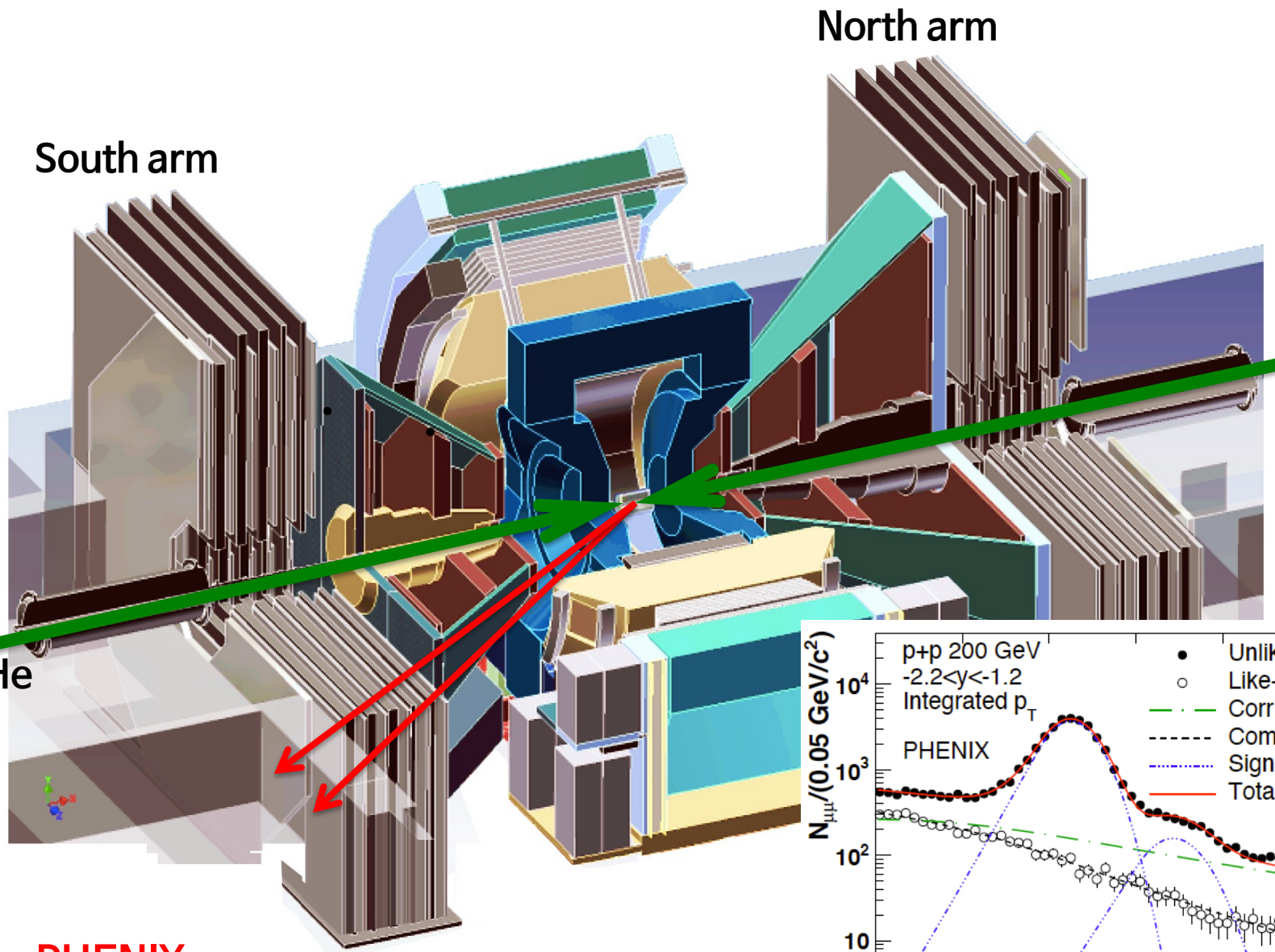
Charmonia measurements at PHENIX





Phys. Rev. Lett. 121, 222301 (2018)

Charmonia measurements at PHENIX



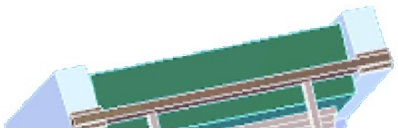
PHENIX muon arms
$1.2 < |\eta| < 2.2$, $\Delta\varphi = 2\pi$

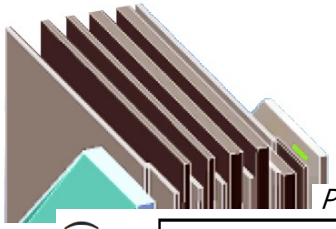
Phys. Rev. C 102, 014902 (2020)

Charmonia measurements at PHENIX

North arm

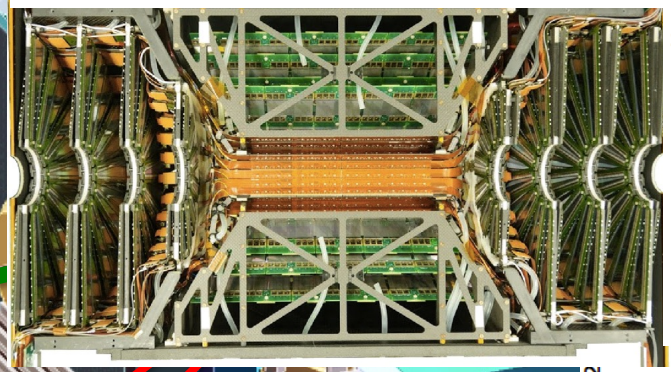
South arm

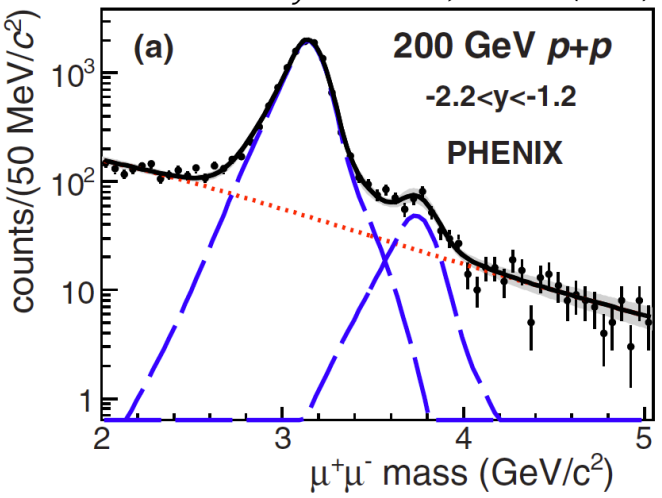




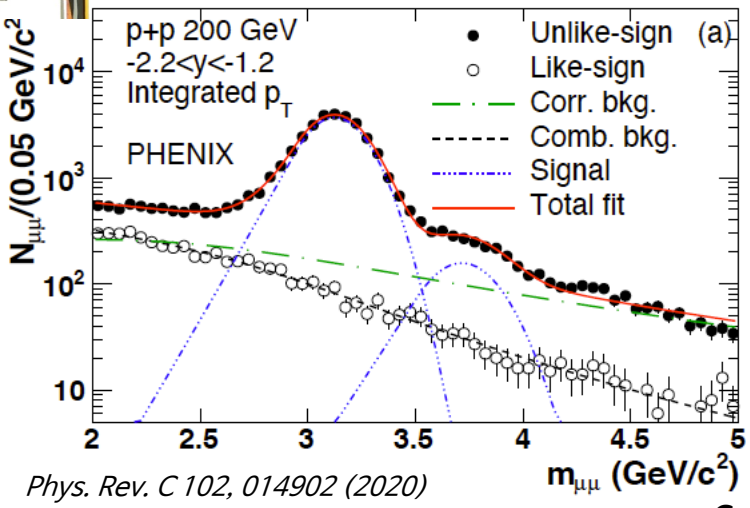
Phys. Rev. C 95, 034904 (2017)

VTX and FVTX provide precise vertex/tracking





p/d/^{3}He

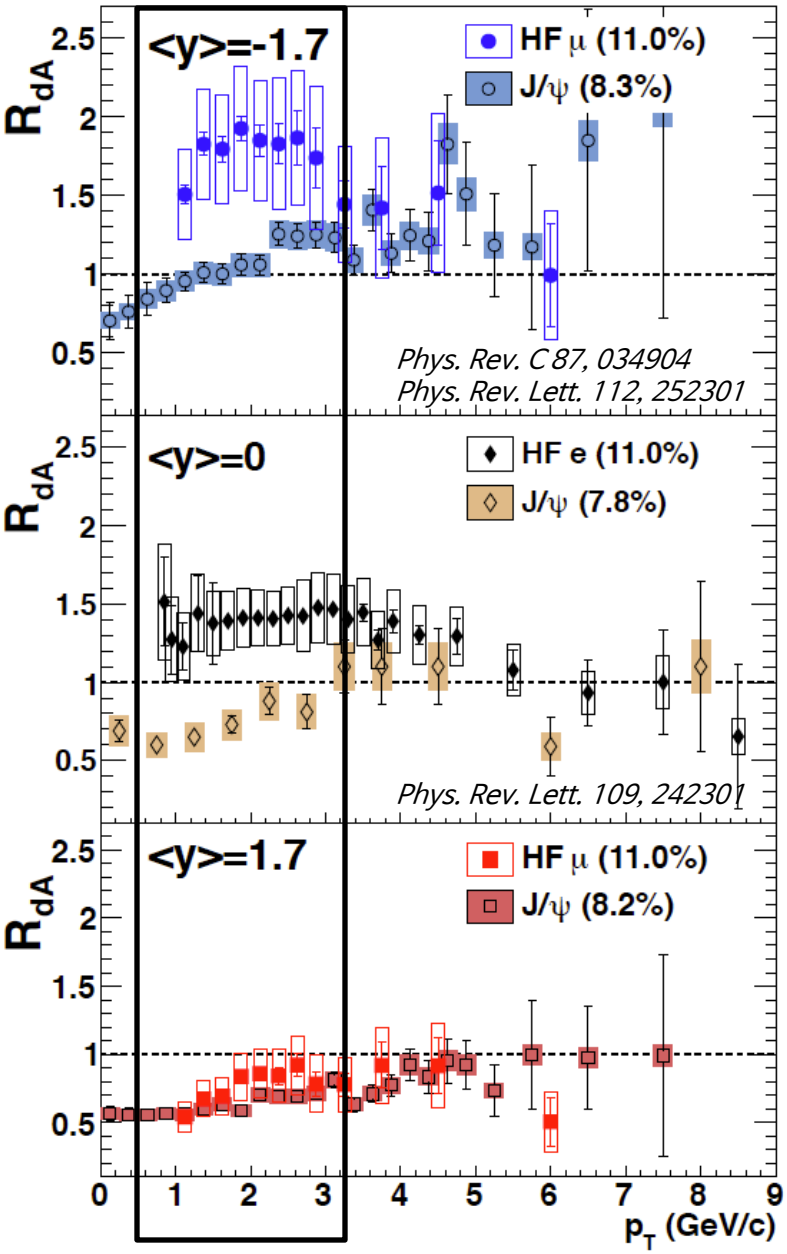


Phys. Rev. C 102, 014902 (2020)

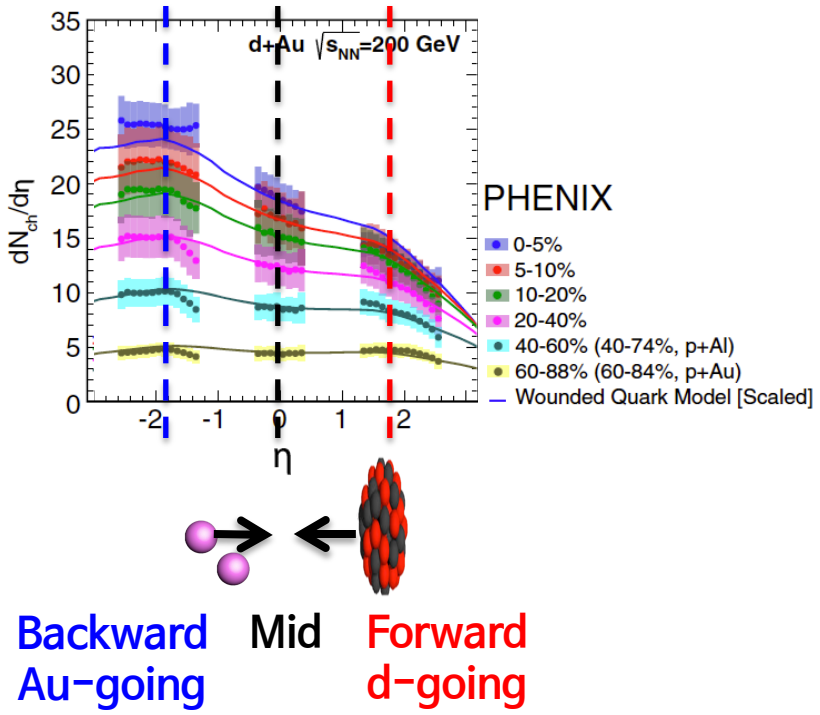
PHENIX muon arms

$1.2 < |\eta| < 2.2$, $\Delta\varphi = 2\pi$

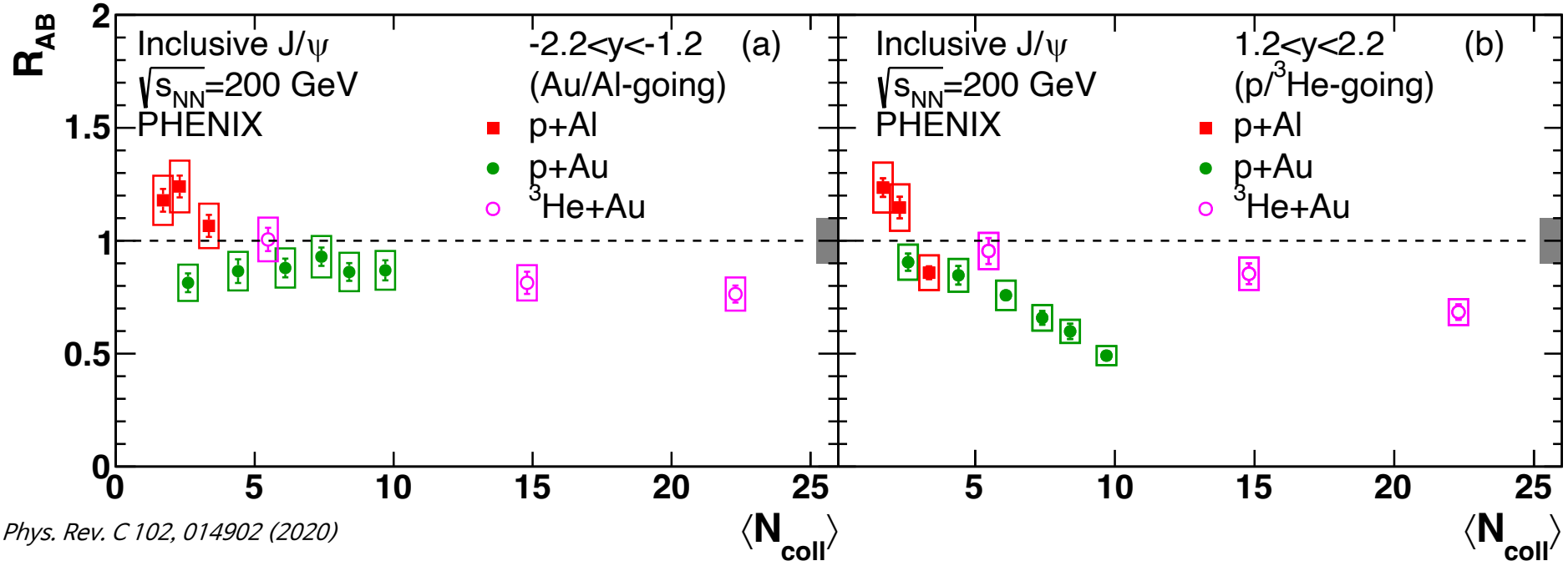
Final-state effects in small systems: HF muon and J/ψ



- In central (0-20%) d+Au collisions
  - Similar nuclear modifications between HF muon and J/ψ at forward rapidity
  - HF muon yield is enhanced in $1 < p_T < 5$ GeV/c but J/ψ yield is suppressed at mid- and backward rapidity



Final-state effects in small systems: J/ψ



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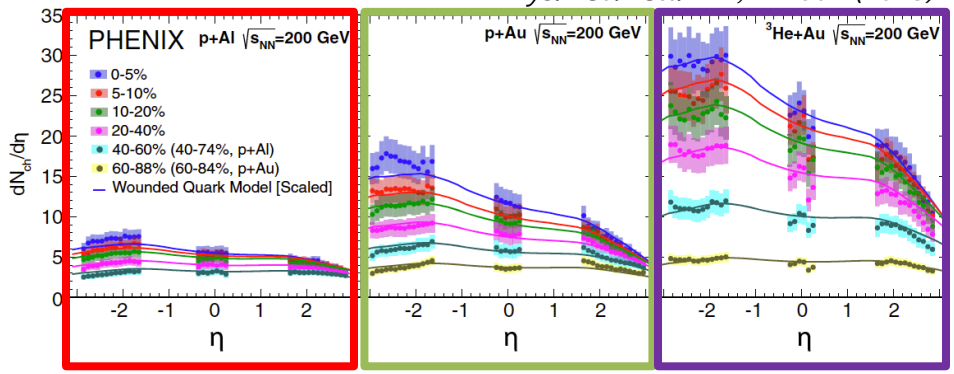
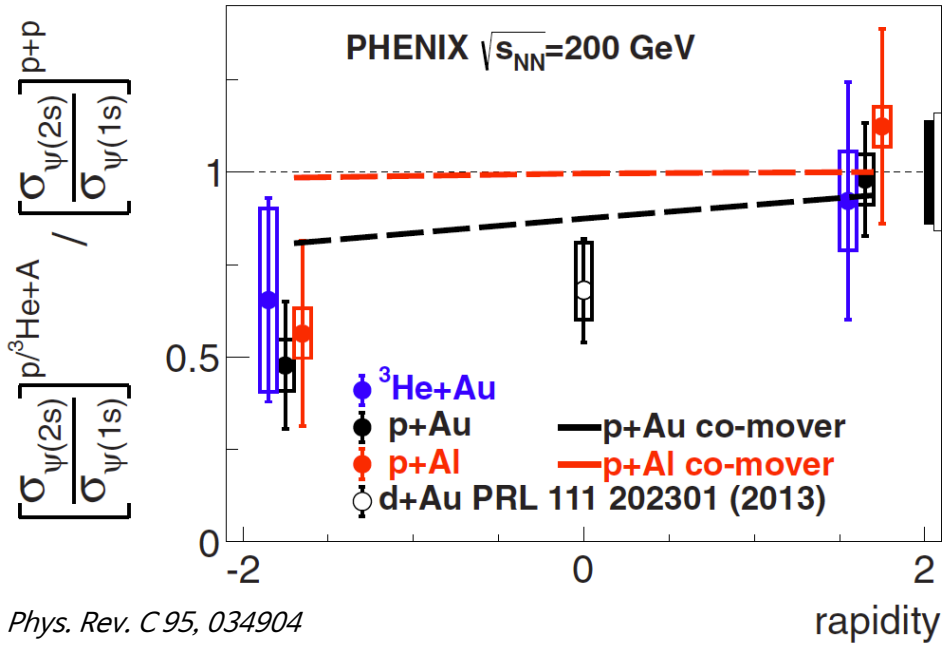
Phys. Rev. Lett. 121, 222301 (2018)

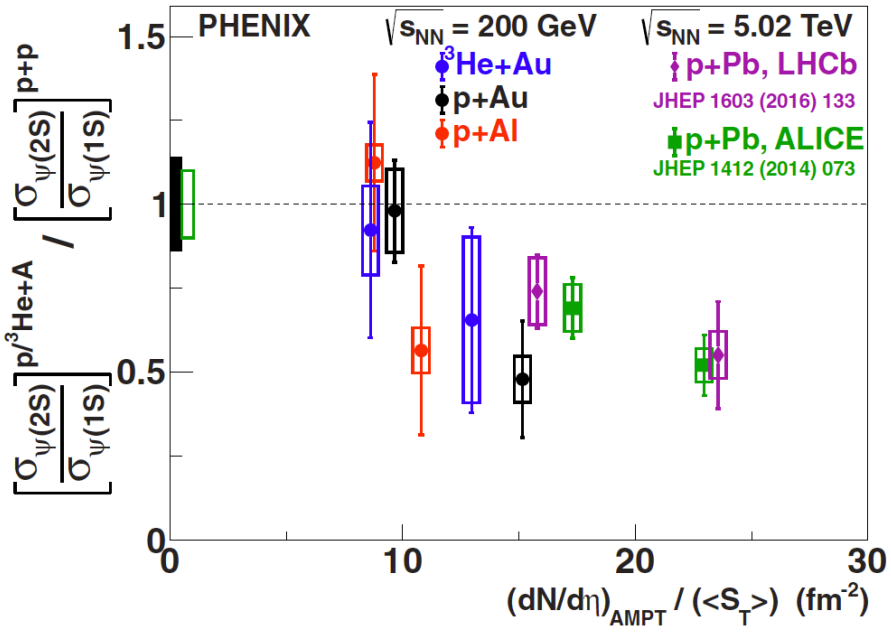


- No strong centrality dependence at backward rapidity, whereas a clear centrality dependence at forward rapidity

Final-state effects in small systems: J/ψ and ψ(2S)



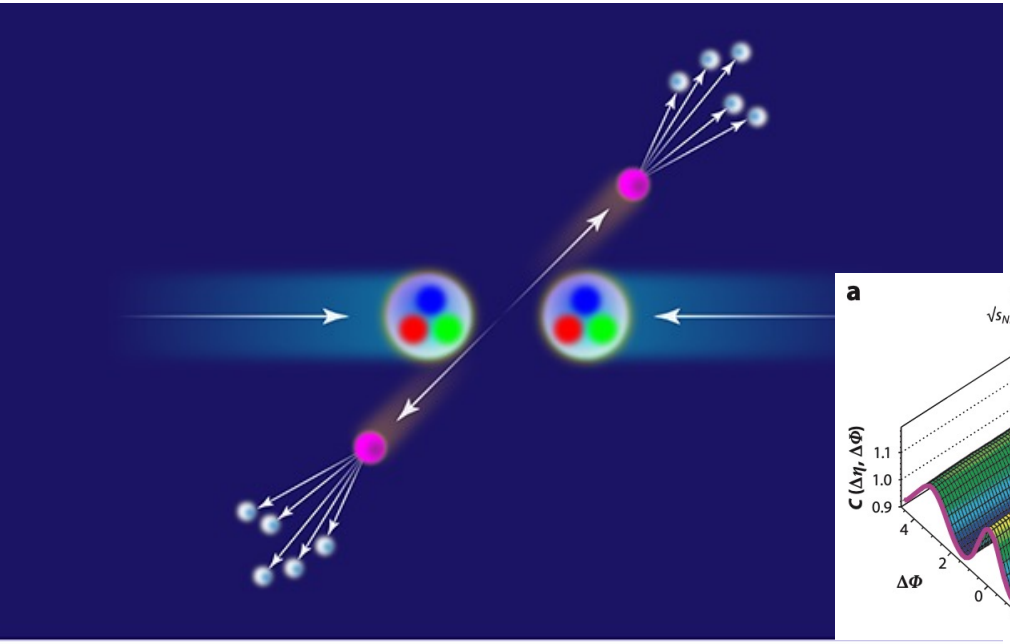
Phys. Rev. C 95, 034904

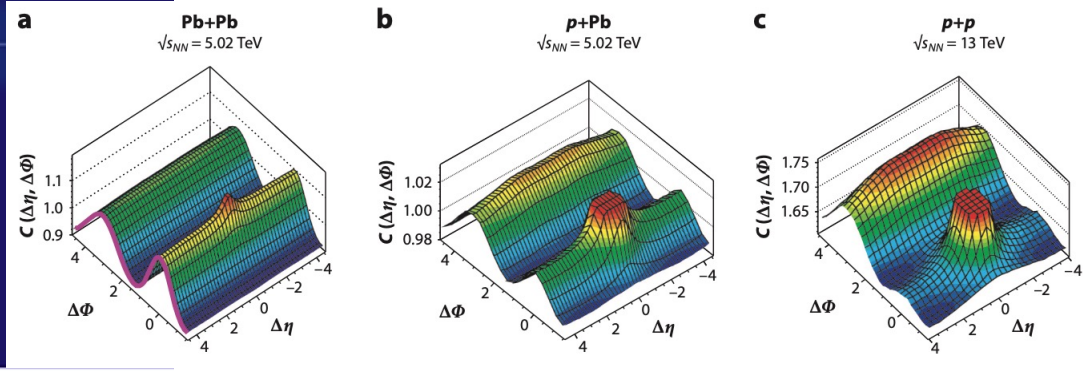


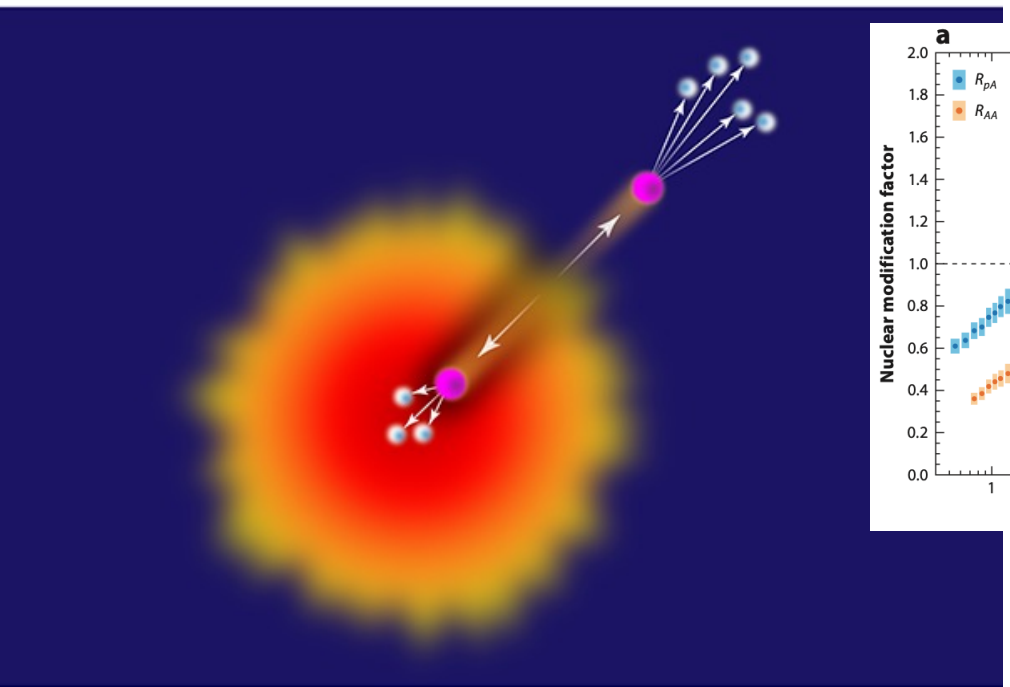
- Stronger suppression of ψ(2S) at backward rapidity (A-going direction)
  - The co-mover disassociation model describes the rapidity dependence in p+Au collisions but little difference in p+Al collisions

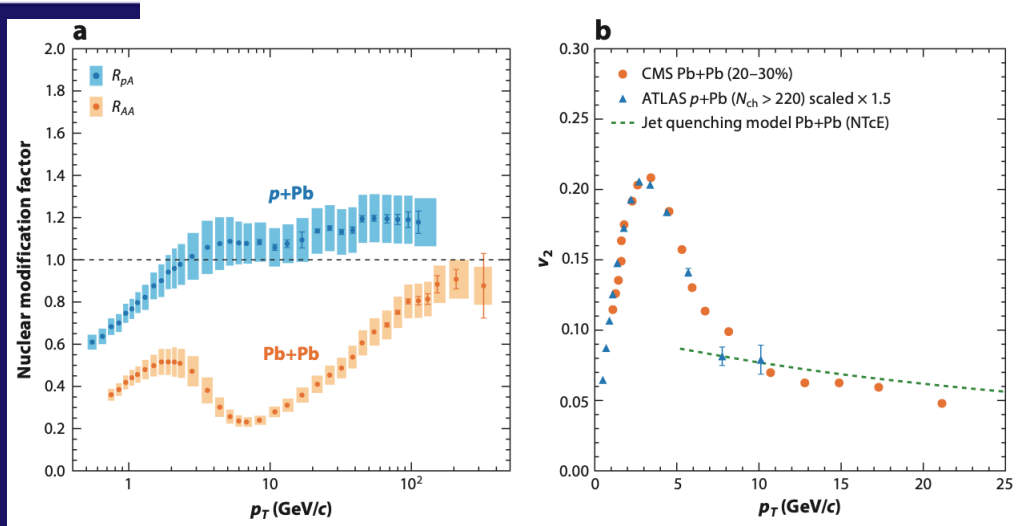
- Relative ψ(2S) suppression increases as the co-moving particle density increases

Searching for a hint of final-state interactions in p+p collisions









Annu. Rev. Nucl. Part. Sci. 2018. 68:211

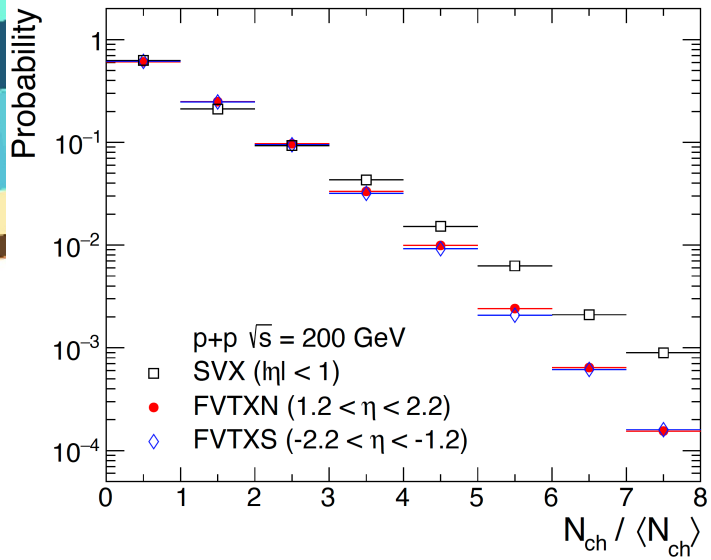
Charmonia and multiplicity measurements at PHENIX

North arm for charmonia

South arm for charmonia

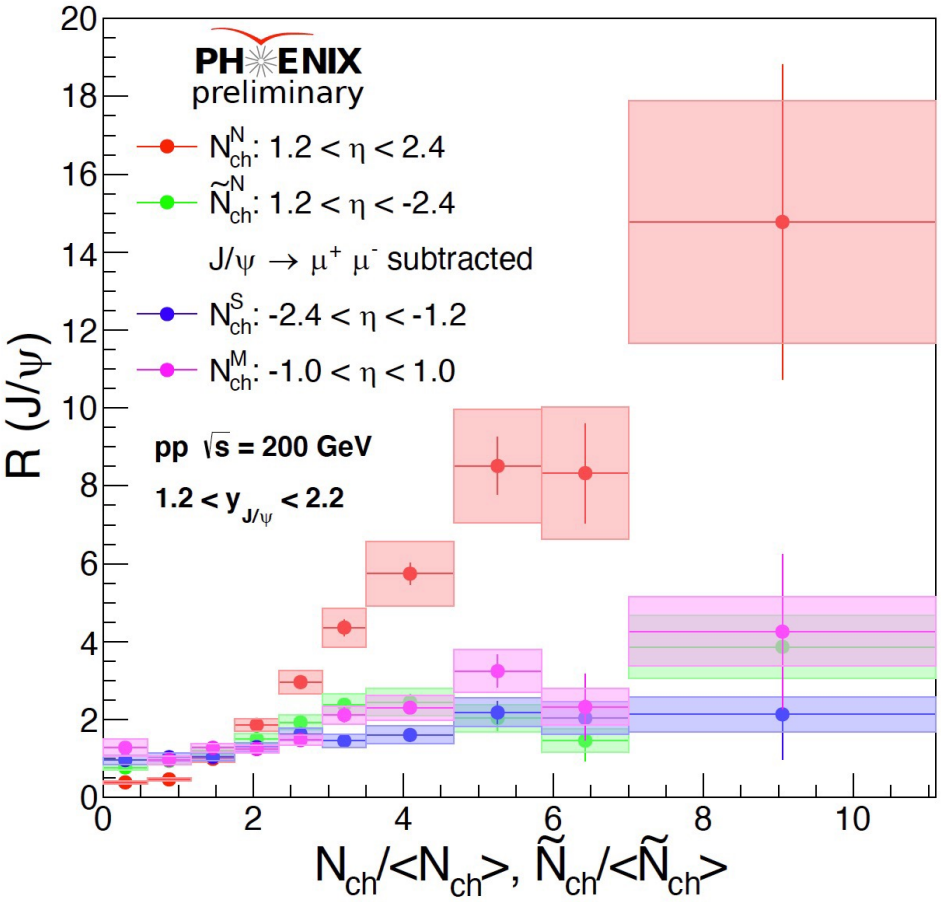
VTX and FVTX
for charged particle multiplicity

Muons from J/ψ



Multiplicity-dependent J/ψ yields

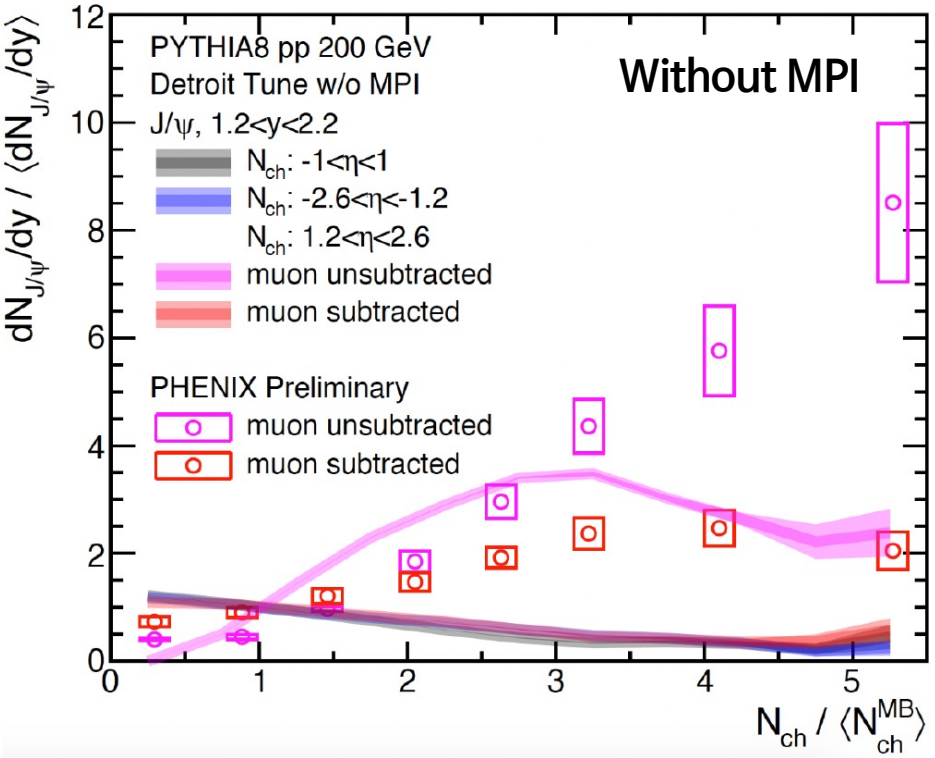
$$R(J/\psi) = \frac{dN_{J/\psi}/dy}{\langle dN_{J/\psi}/dy \rangle}$$

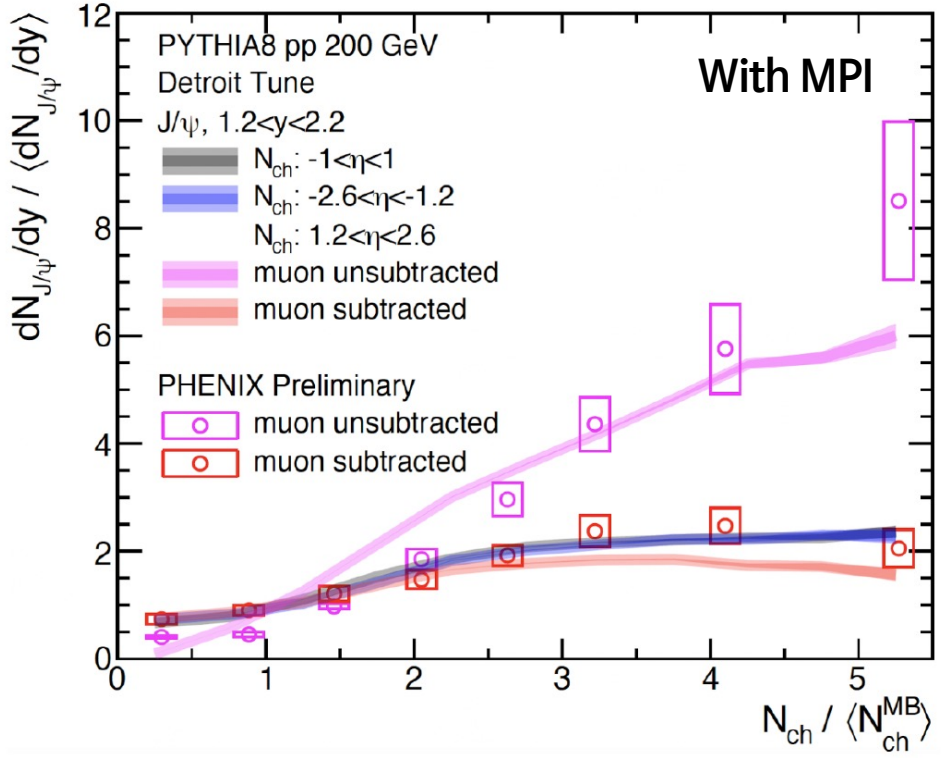


- J/ψ at forward, N_{ch} at mid-rapidity:
  Increasing yield as charged particle multiplicity becomes larger
- J/ψ at forward, N_{ch} at backward:
  A similar trend in the results with the multiplicity at mid-rapidity
- J/ψ at forward, N_{ch} at forward
  N_{ch} including muons from J/ψ:
  More steeply increasing than other results

  N_{ch} with subtraction of muons from J/ψ:
  Weaker multiplicity-dependence
  Similar trend with other results

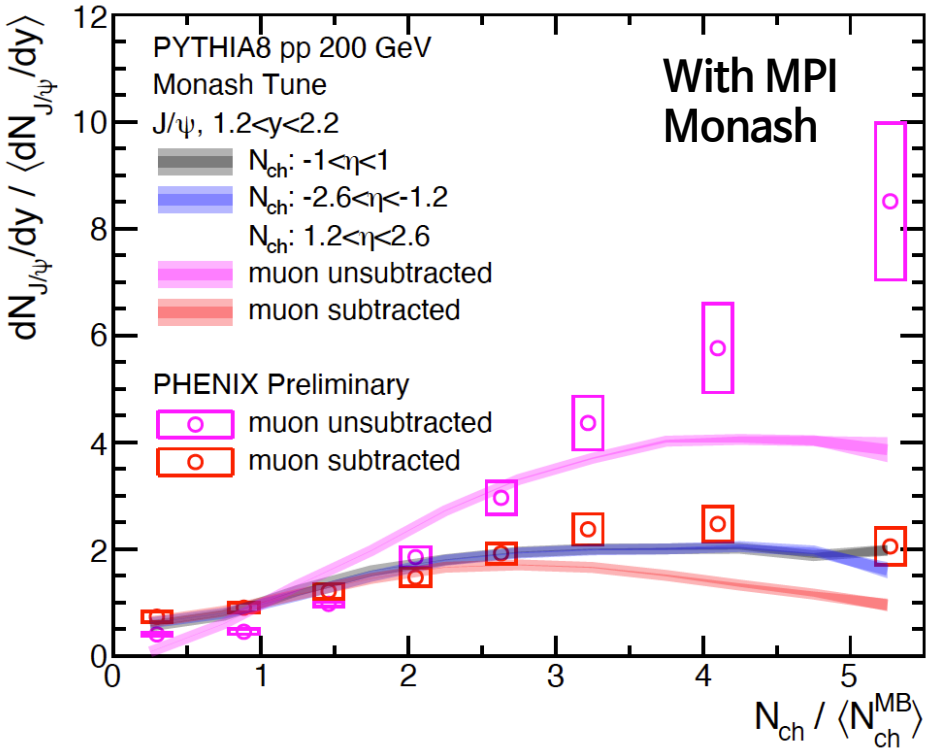
Multiplicity-dependent J/ψ yields

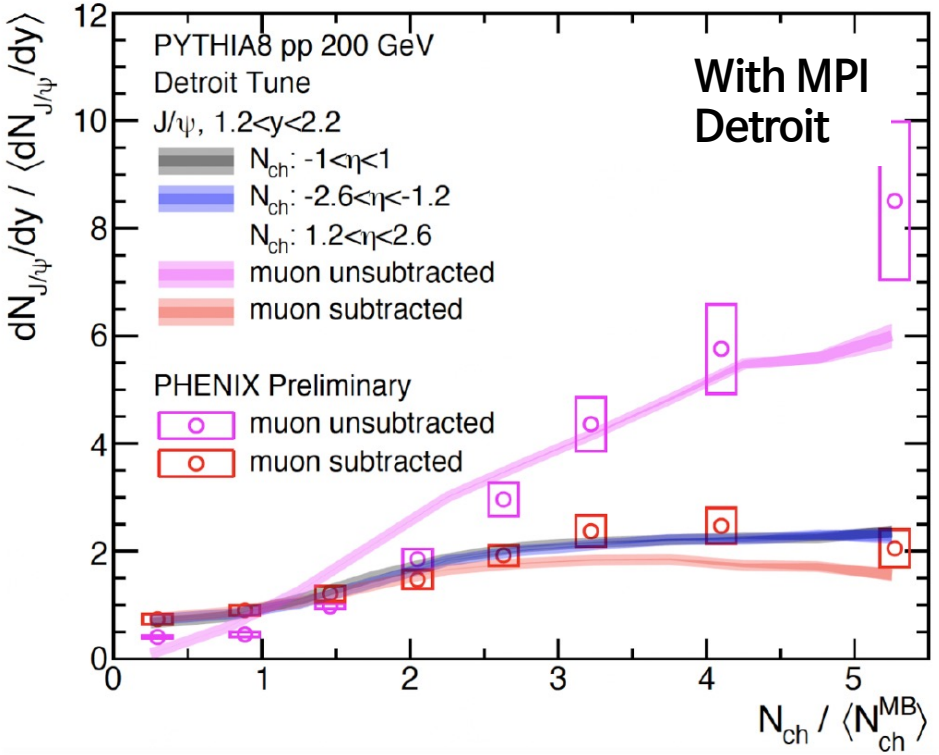




- J/ψ relative yields compared with PYTHIA8 Detroit tune for RHIC energies
- Multiparton interactions are required to reproduce PHENIX data

Multiplicity-dependent J/ψ yields



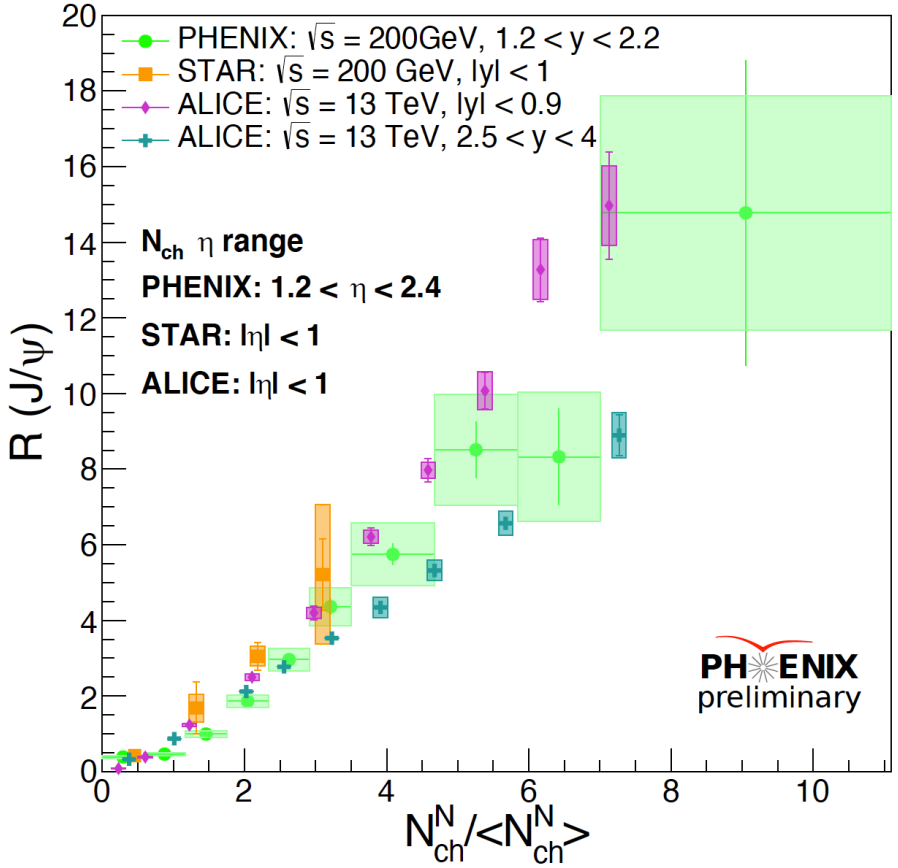


- J/ψ relative yields compared with PYTHIA8 Detroit tune for RHIC energies
- Multiparton interactions are required to reproduce PHENIX data

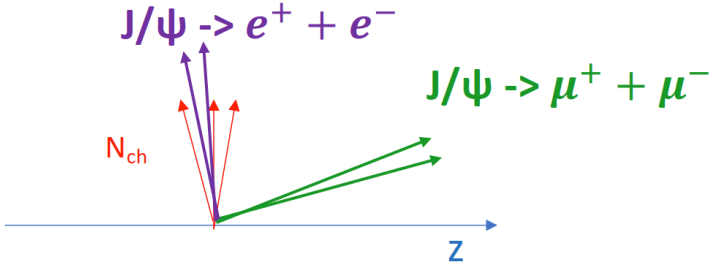
- Detroit tune for RHIC energies shows a better agreement than Monash tune for LHC energies

Comparison with results from other experiments

$$R(J/\psi) = \frac{dN_{J/\psi}/dy}{\langle dN_{J/\psi}/dy \rangle}$$



ALICE:



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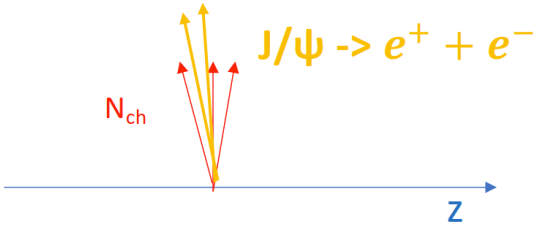
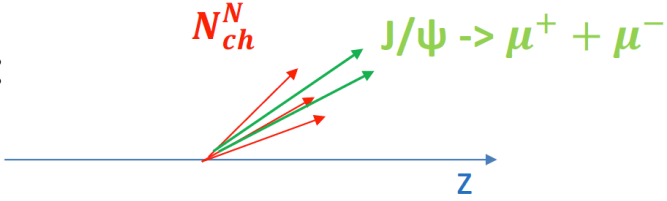


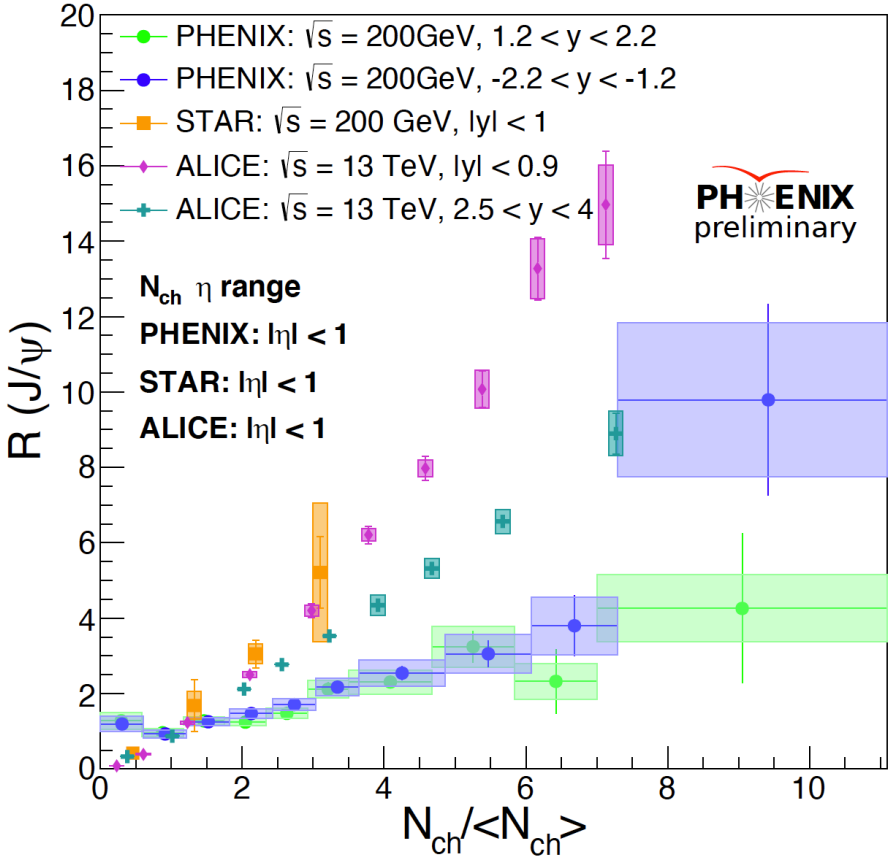
PHENIX:



- **Without subtraction** of muons from J/ψ in N_{ch}:
  Similar multiplicity dependence between RHIC and LHC results

Comparison with results from other experiments

$$R(J/\psi) = \frac{dN_{J/\psi}/dy}{\langle dN_{J/\psi}/dy \rangle}$$



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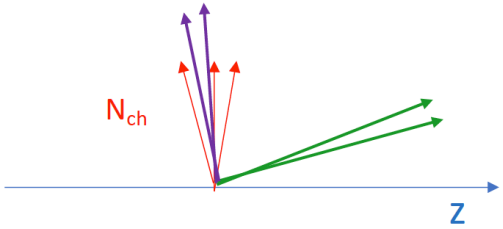

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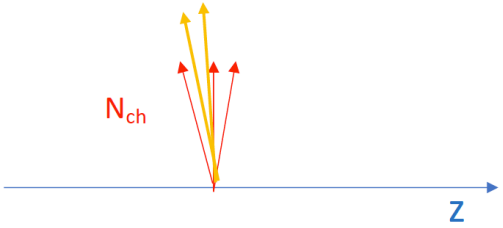
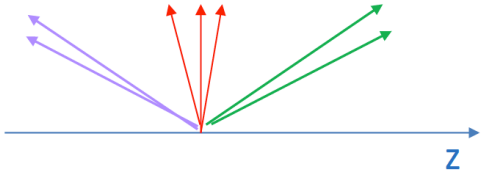


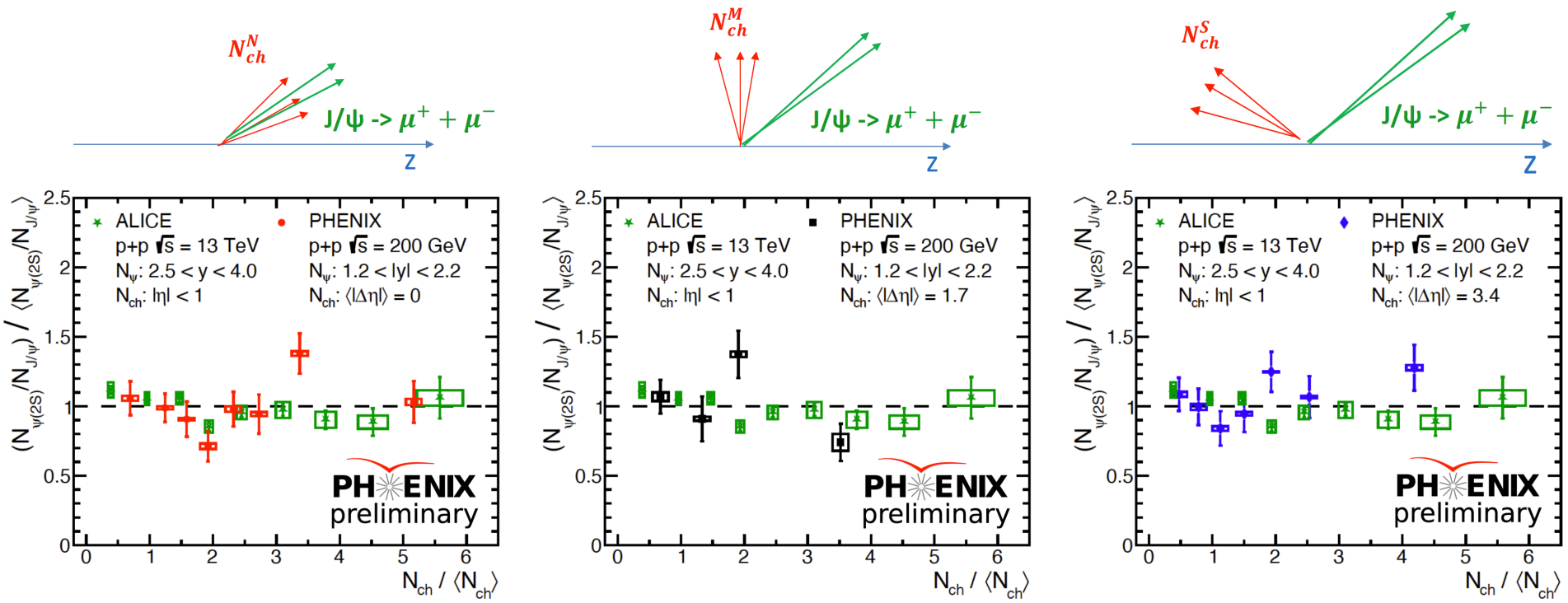
PHENIX:

$J/\psi \rightarrow \mu^+ + \mu^-$ N_{ch}^{N} $J/\psi \rightarrow \mu^+ + \mu^-$



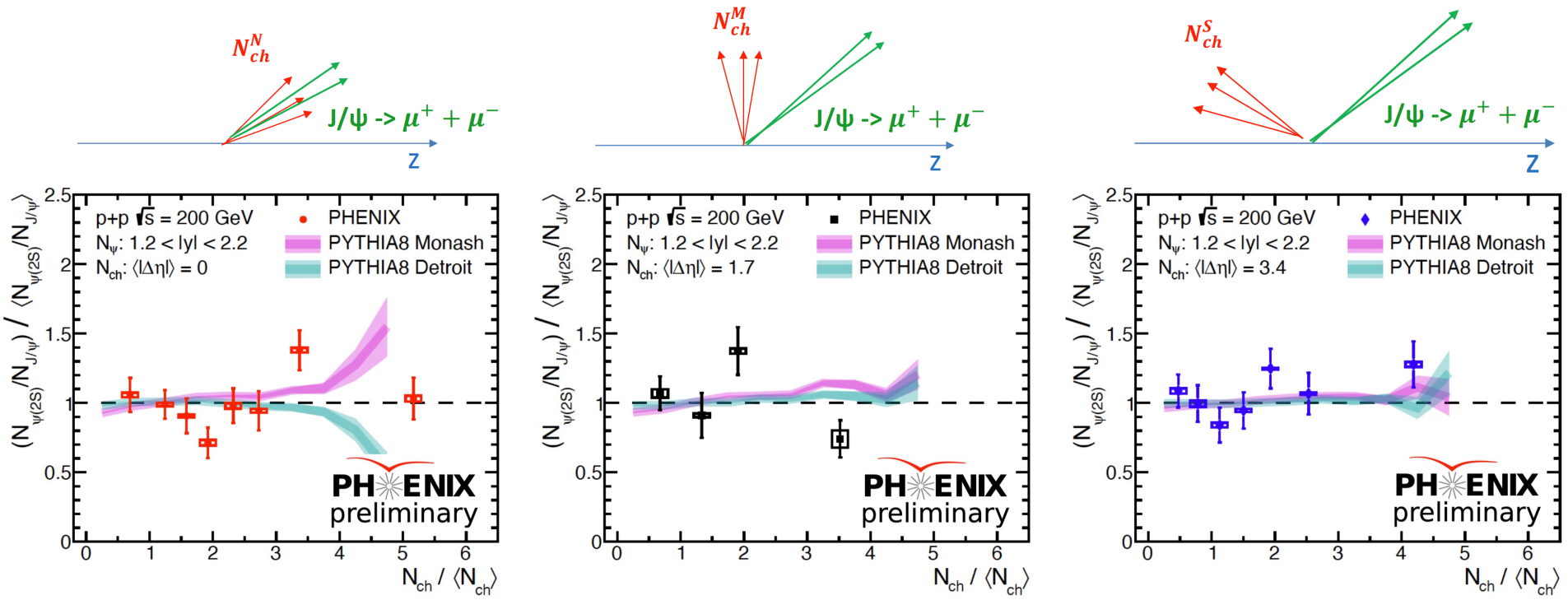
- **With the subtraction** of muons from J/ψ in N_{ch}: Smaller multiplicity dependence at RHIC
- Considering muons from J/ψ in N_{ch} is important, particularly at RHIC

Multiplicity-dependent yield ratio between J/ψ and ψ(2S)



- PHENIX results are consistent with ALICE results at 13 TeV showing a weak multiplicity dependence

Multiplicity-dependent yield ratio between J/ψ and ψ(2S)



- PHENIX results agree with PYTHIA, including no final-state effects

Summary

- PHENIX has studied multiplicity-dependent J/ψ and ψ(2S) production in p+p collisions, which can provide information on
  1) contribution of MPI processes and
  2) final-state effects on quarkonia production

- J/ψ yields as a function of multiplicity:
  Increasing yields as multiplicity increases
  1) PYTHIA8 Detroit tune with MPI can describe the data
  2) multiplicity dependence is smaller than LHC results

- Yield ratio of J/ψ and ψ(2S) as a function of multiplicity
  1) little multiplicity dependence in p+p collisions at 200 GeV
  2) can be described by PYTHIA without final-state effects
  2) consistent with the ALICE results