Study of multiplicity dependent J/ψ and ψ(2S) production in p+p collisions at PHENIX

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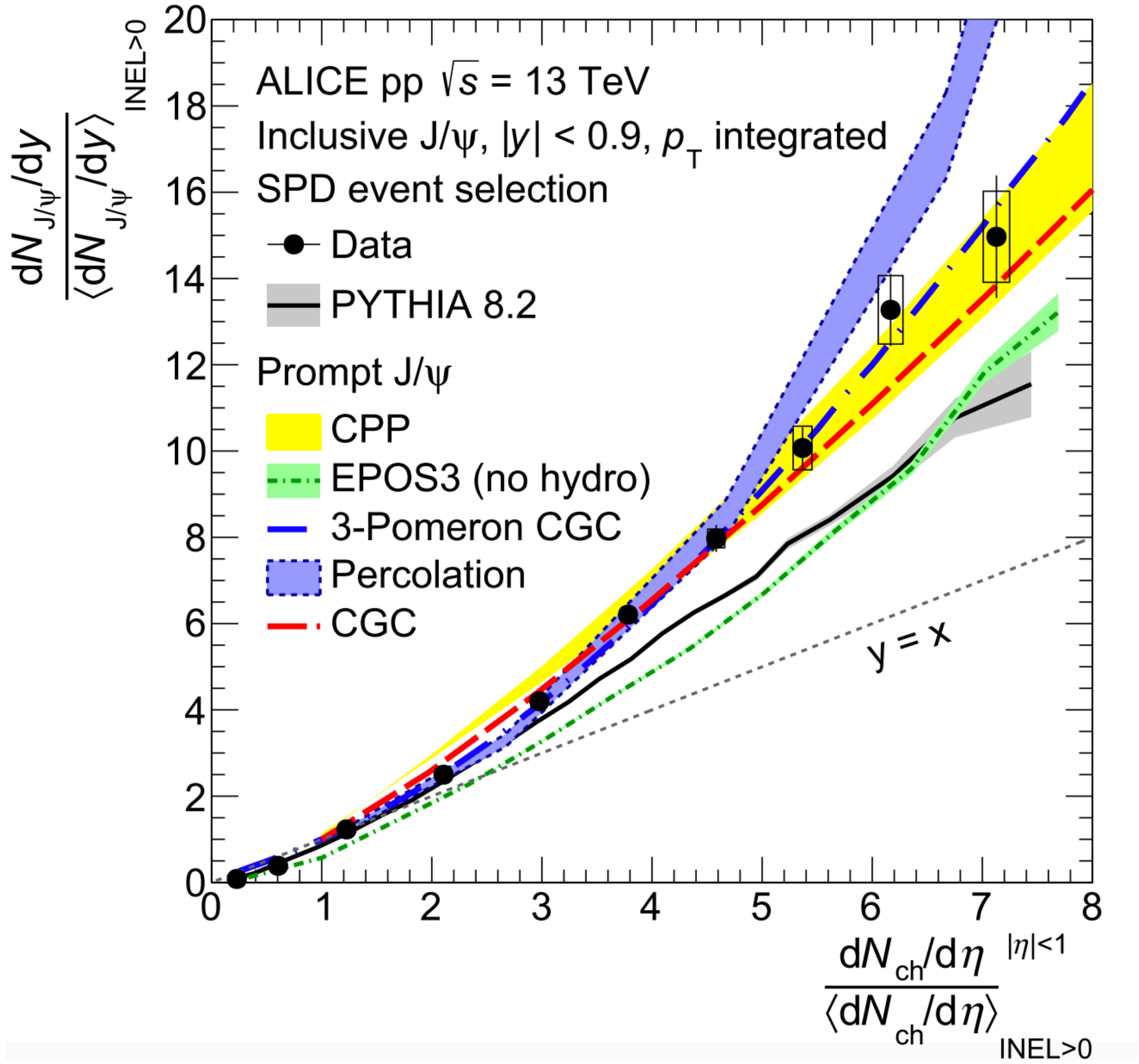
The 38th Winter Workshop on Nuclear Dynamics

1. Introduction

- In the ALICE result, J/ψ yield steeply increases as charged particle multiplicity increases in p+p collisions at 13 TeV



Phys. Lett. B 810 (2020) 135758

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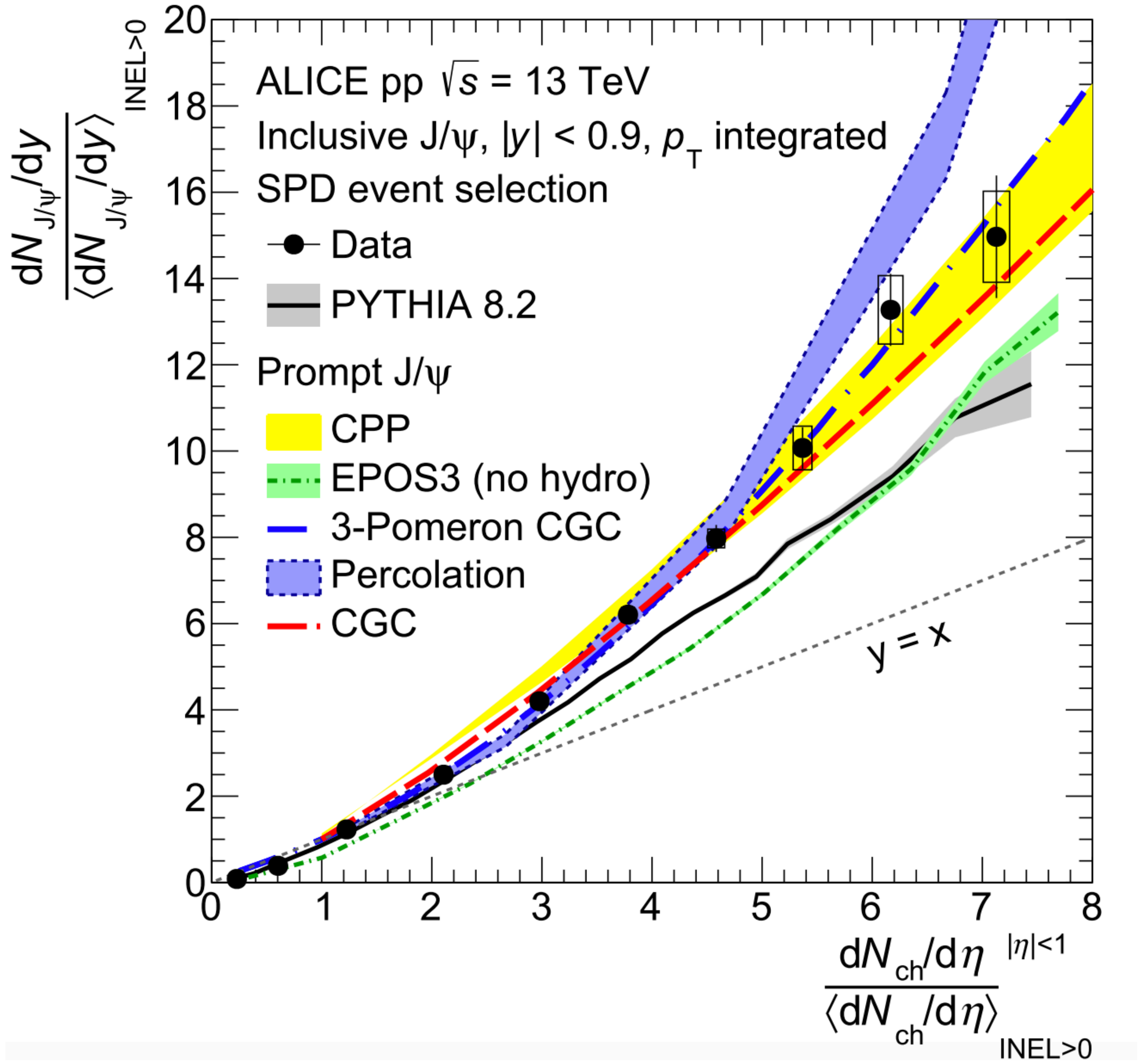
- In STAR* 200 GeV result, similar multiplicity dependency as ALICE* Data (***Tracks from J/ψ are included in multiplicity calculation***)

→ In 200GeV, MPI is important?



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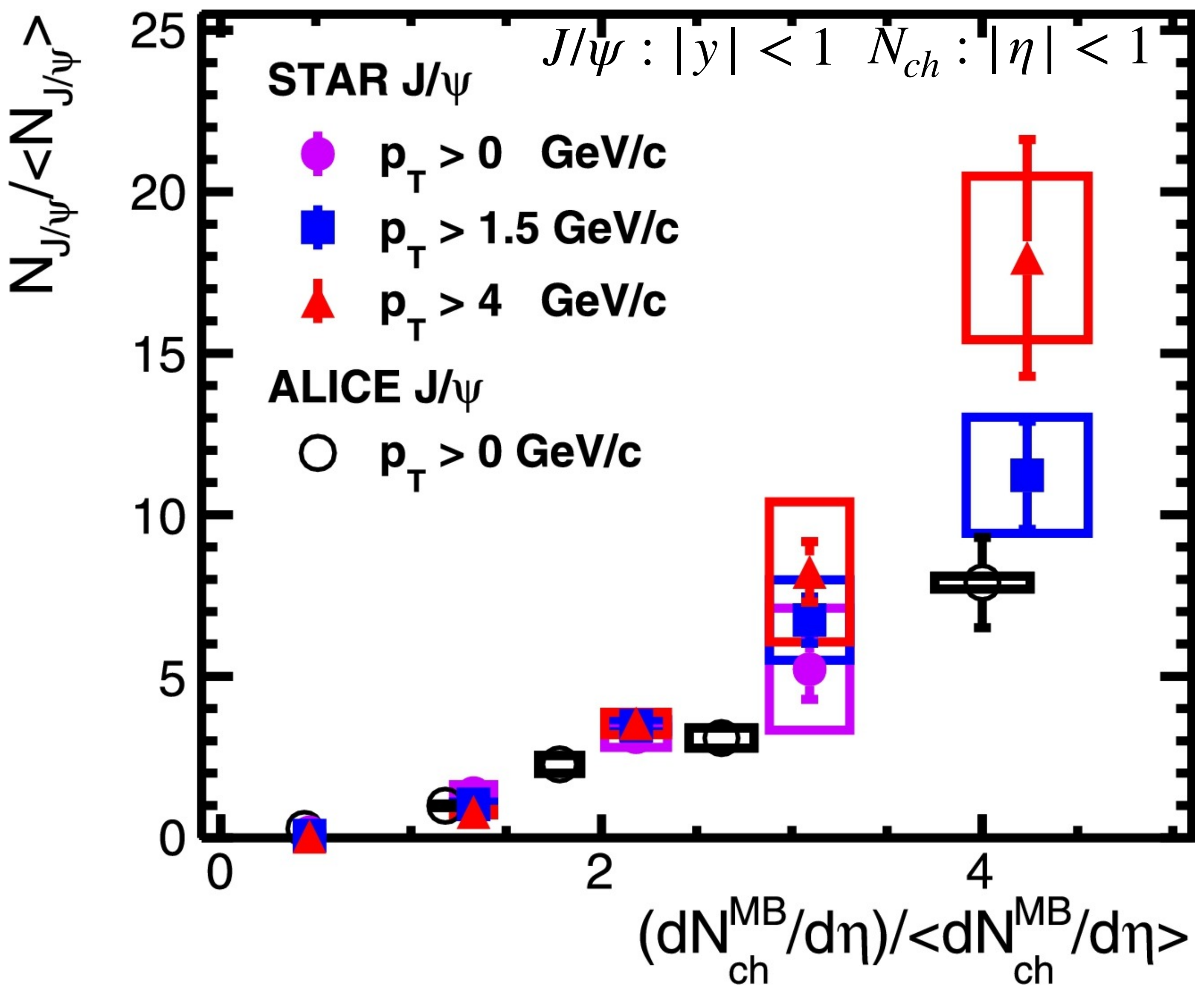

arXiv:1805.03745

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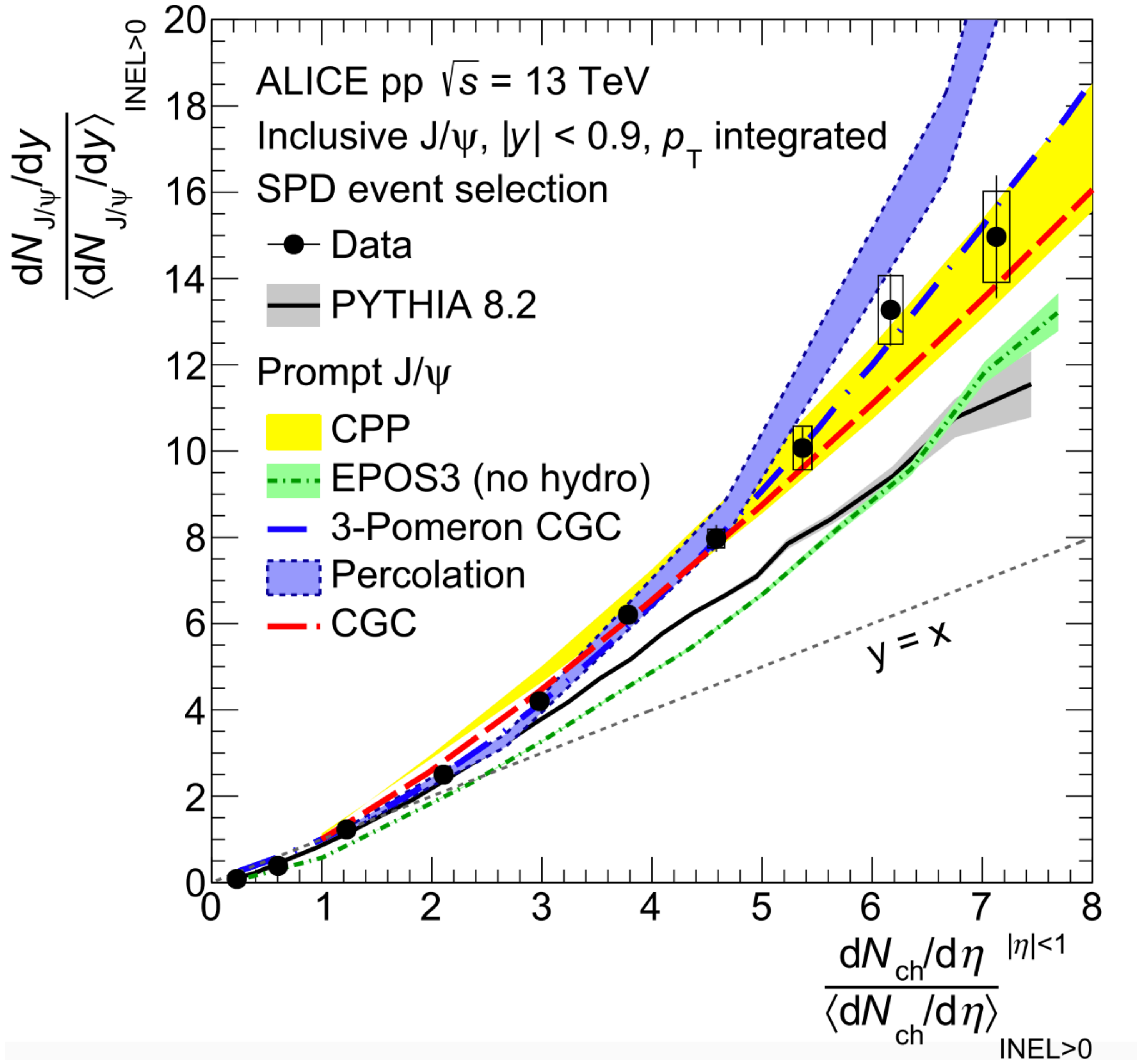
  → In 200GeV, MPI is important?

- In PYTHIA8 $dN_{ch}/d\eta$ distribution, 200 GeV results are lower than 13TeV

  → Effect from J/ψ contribution to the multiplicity calculation?



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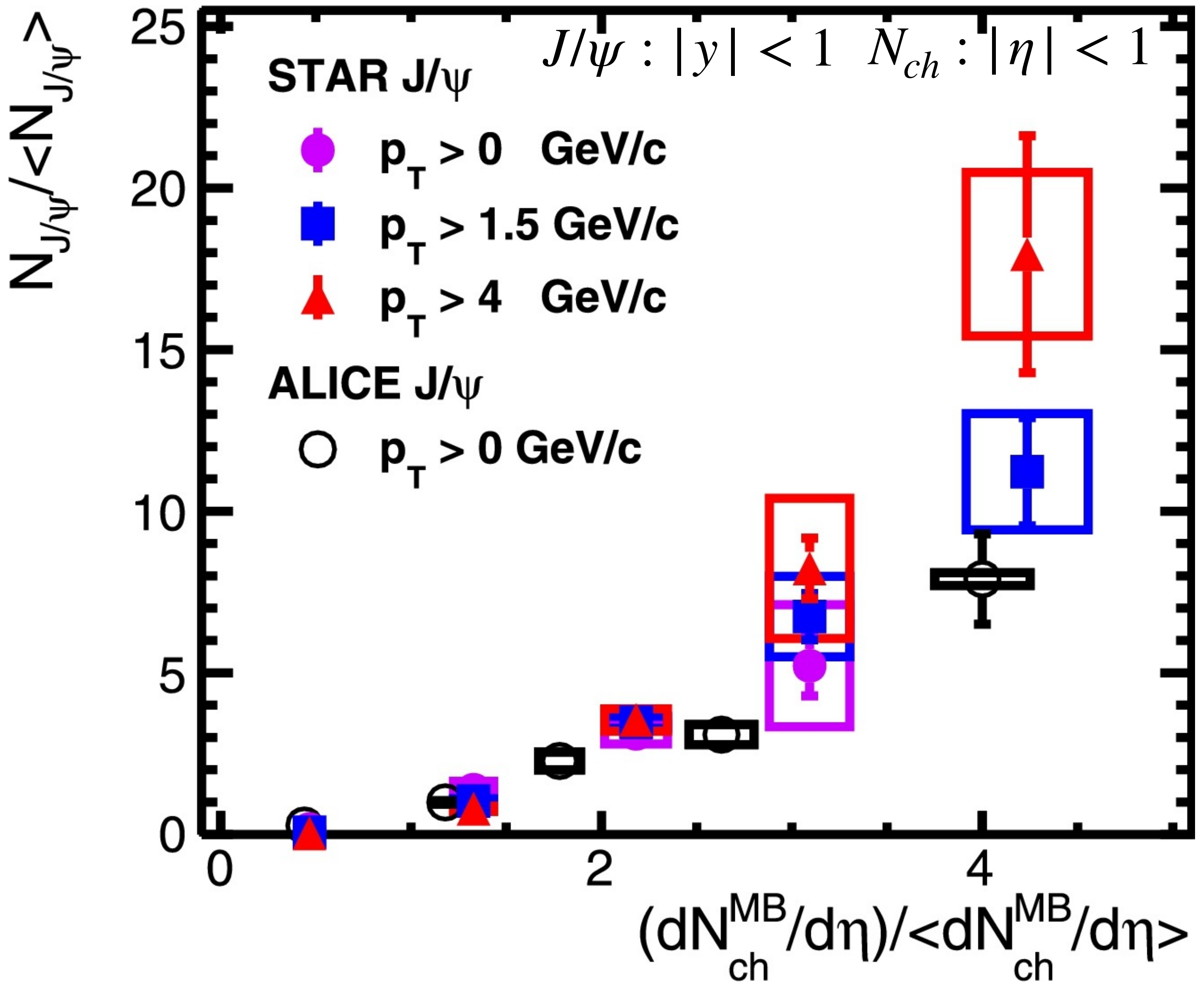

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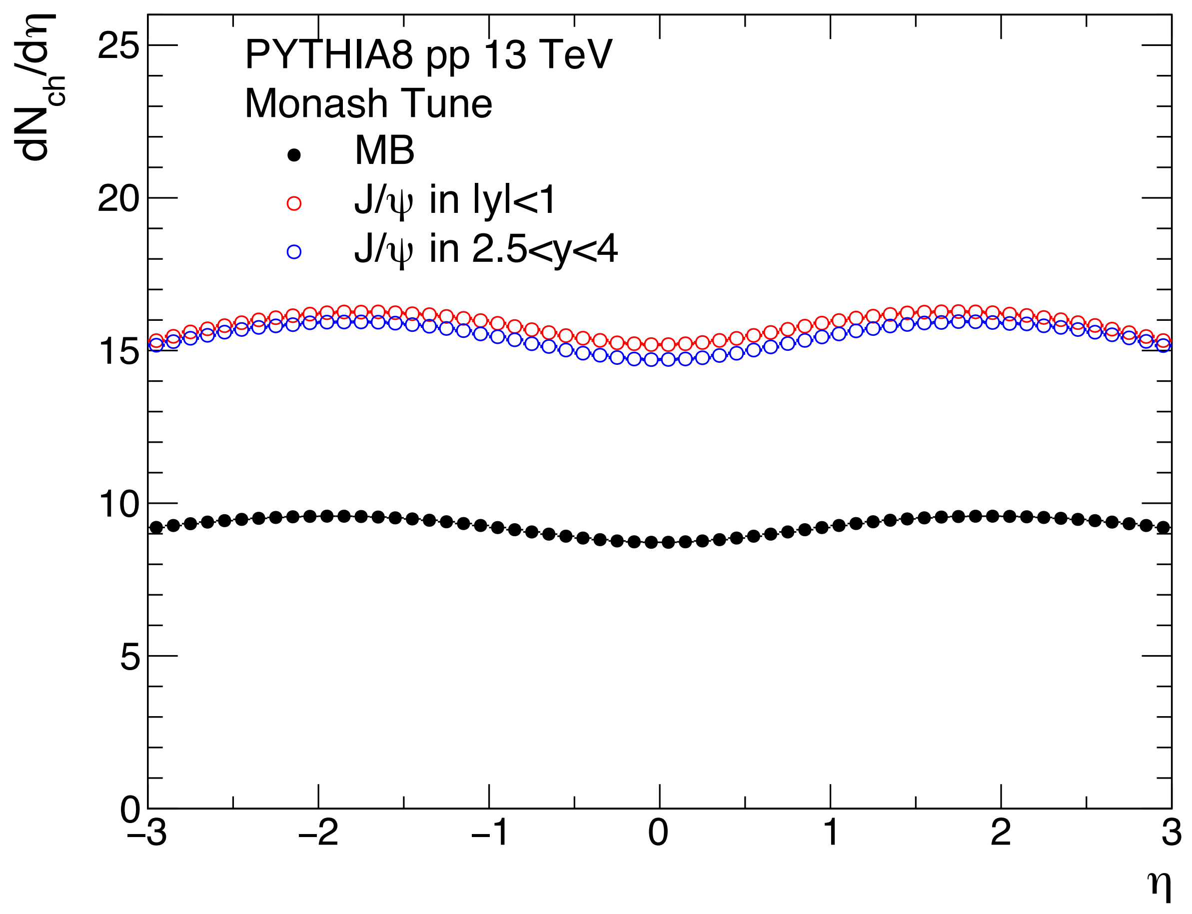

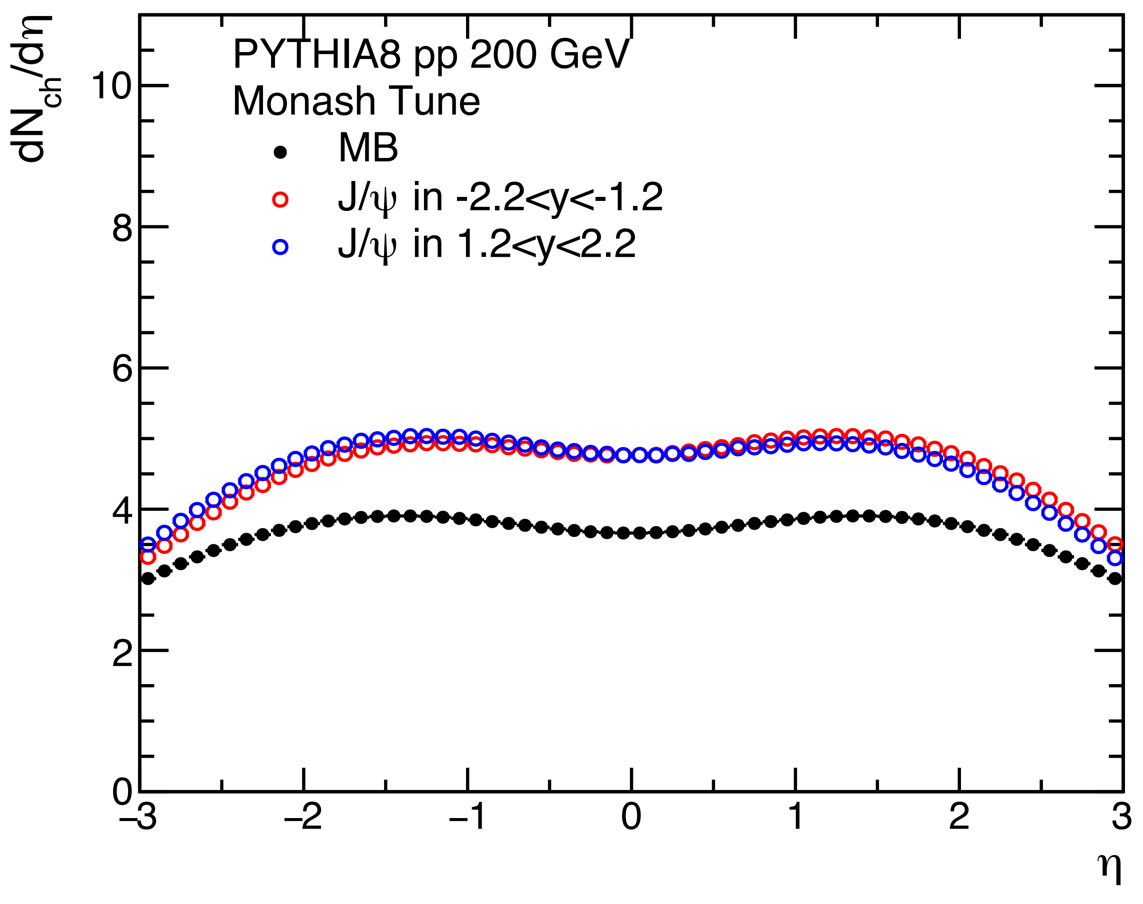

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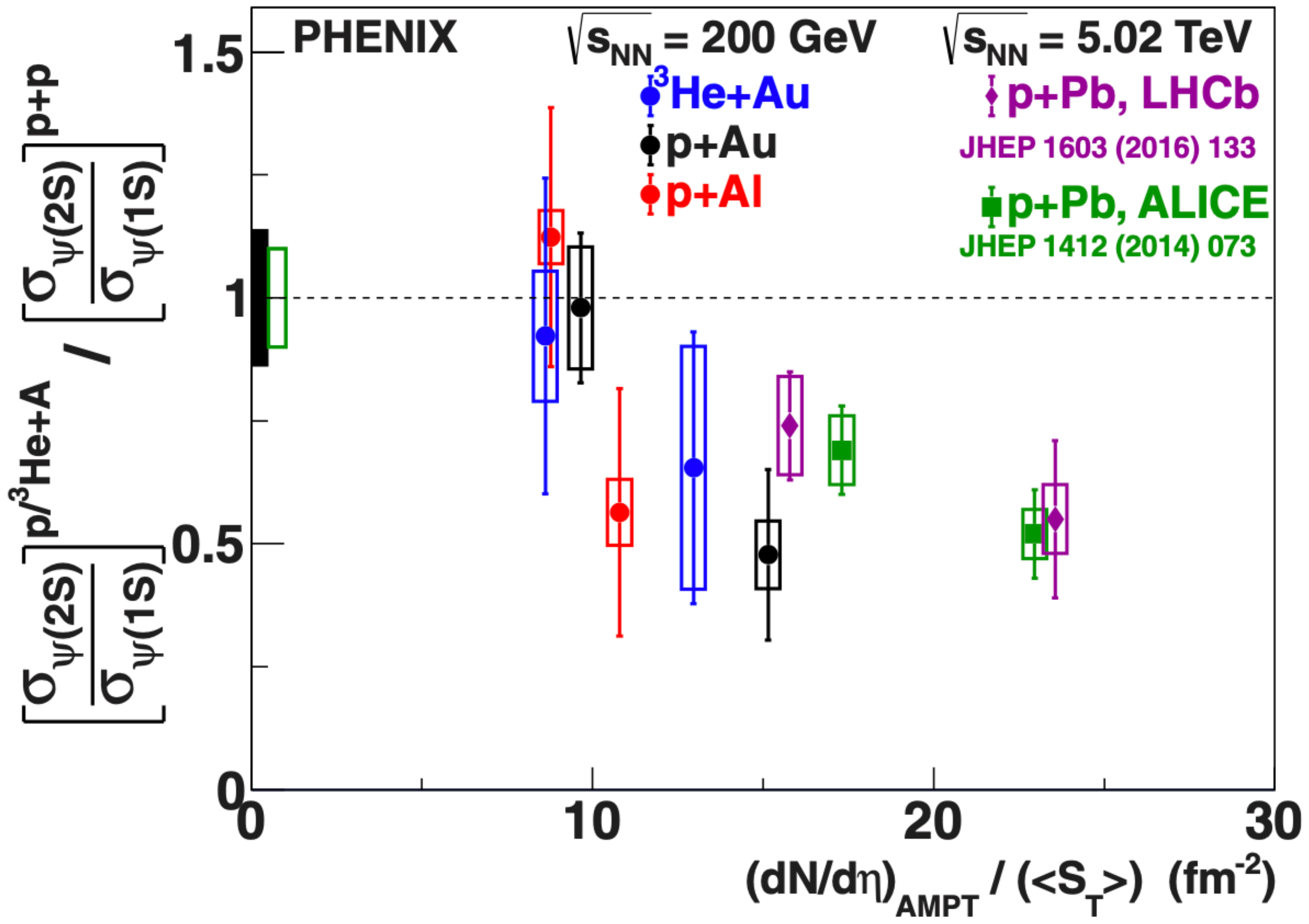
- J/ψ and ψ(2S) ratio decreases
  as charged particle multiplicity increases in p+A collisions

  → Final-state effects such as the co-mover effect
  are also important for quarkonia yields



Phys. Rev. C 95, 034904

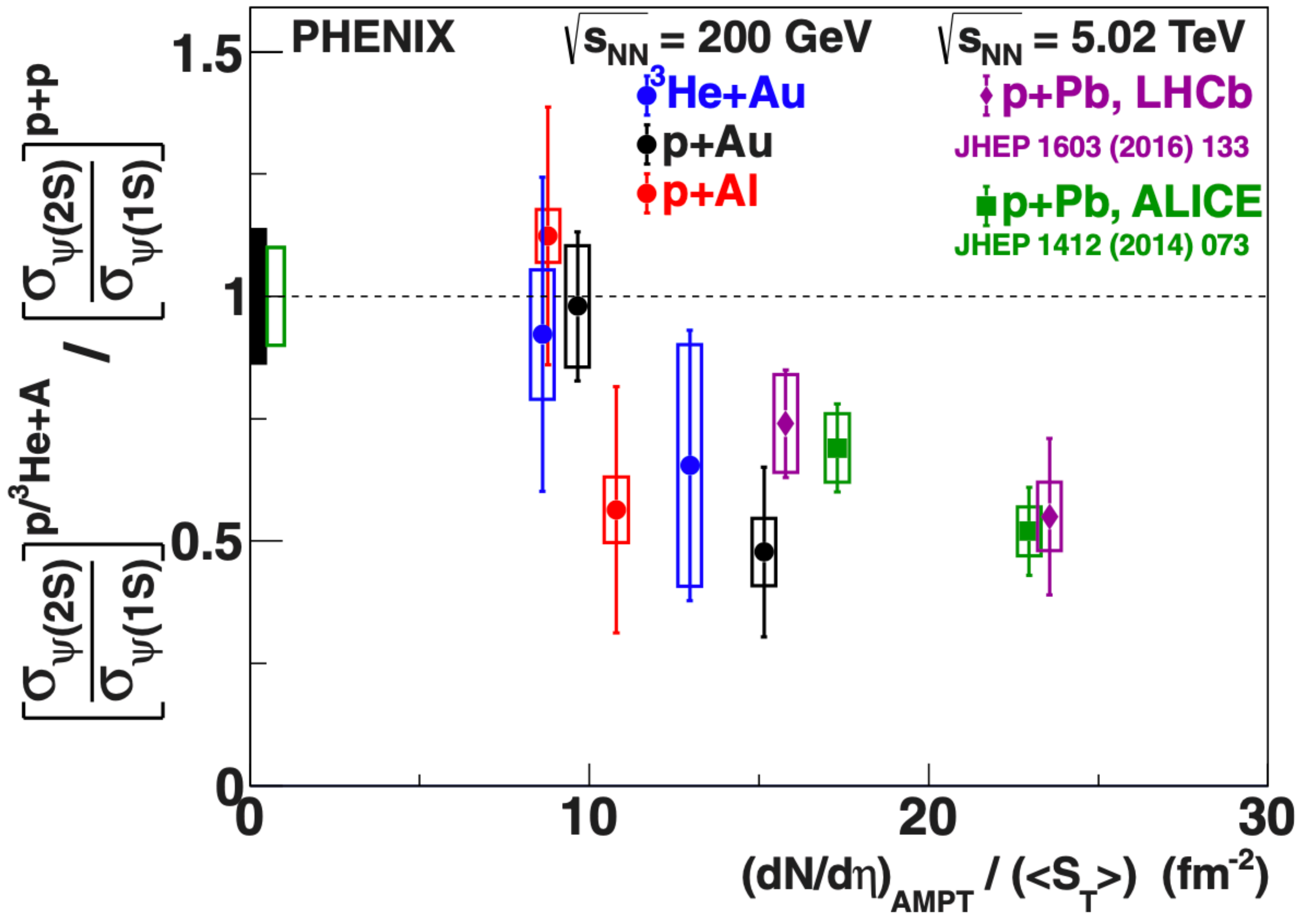
1. Introduction

- J/ψ and ψ(2S) ratio decreases as charged particle multiplicity increases in p+A collisions

  → Final-state effects such as the co-mover effect are also important for quarkonia yields

- In the recent ALICE results in p+p and p+Pb collisions, no significant multiplicity dependence is observed

How about pp 200 GeV?



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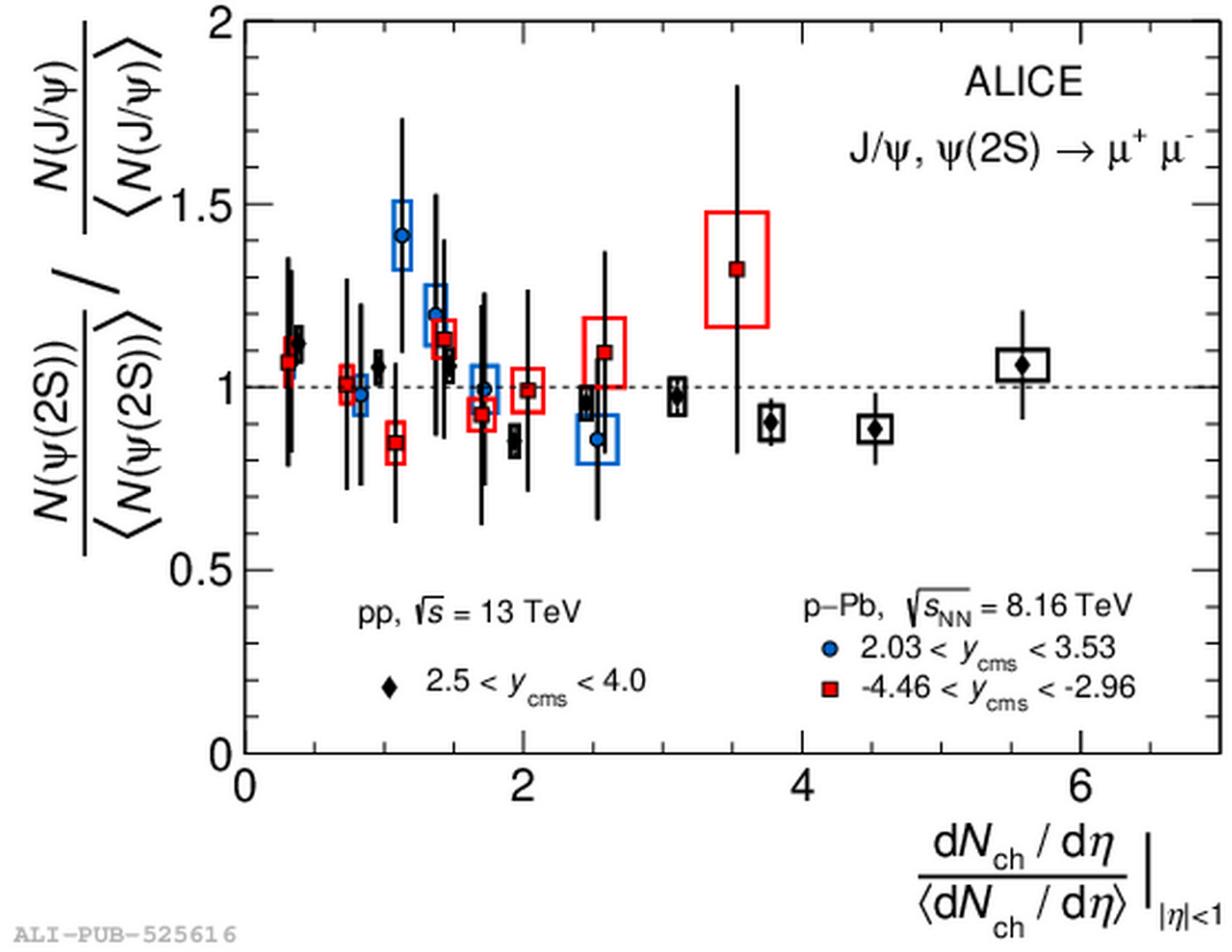
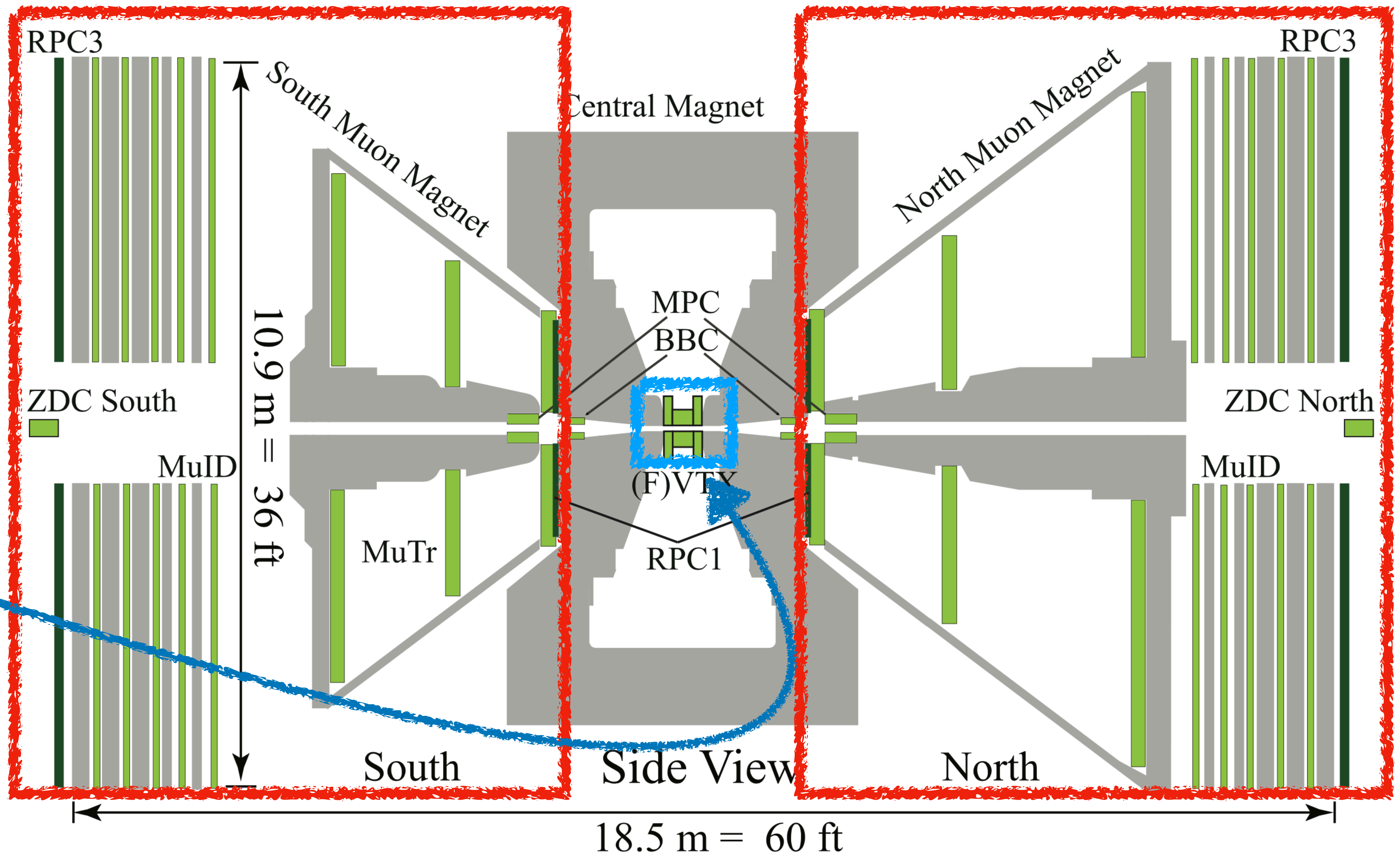


arXiv:2204.10253

2. Analysis in PHENIX

- Acceptance for J/ψ measurement:
  (1)-2.2<y<-1.2, (2)1.2<y<2.2
- MuTr only:
  For high statistics of J/ψ
- MuTr+FVTX:
  For J/ψ and ψ(2S) ratio
- Acceptance for multiplicity measurement:
  (1)|η|<1, (2)-3<η<-1, (3)1<η<3
- Multiplicity can be measured with various detectors at different pseudo-rapidity
  → We can have a detailed look at the correlation between J/ψ production and multiplicity



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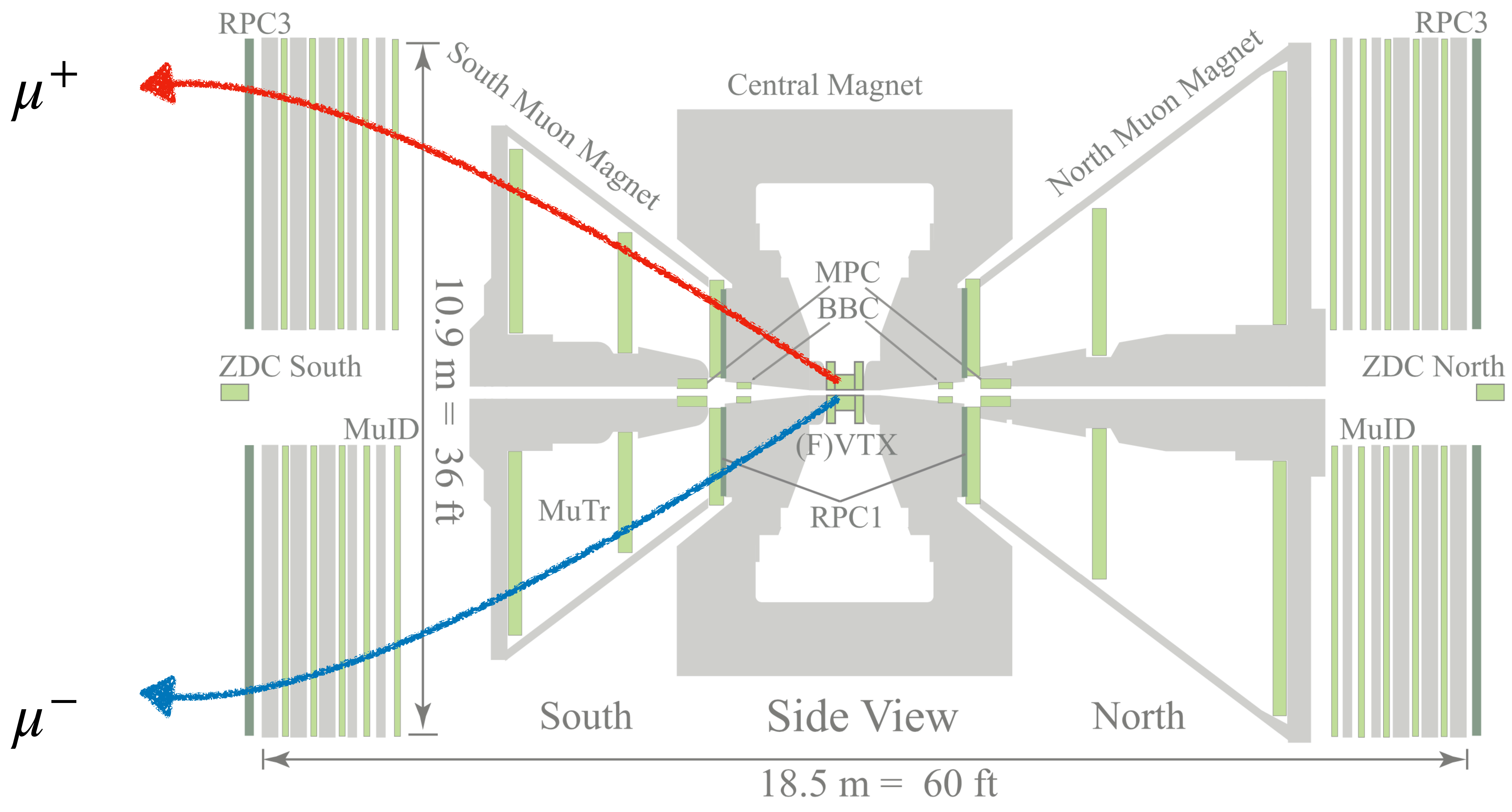
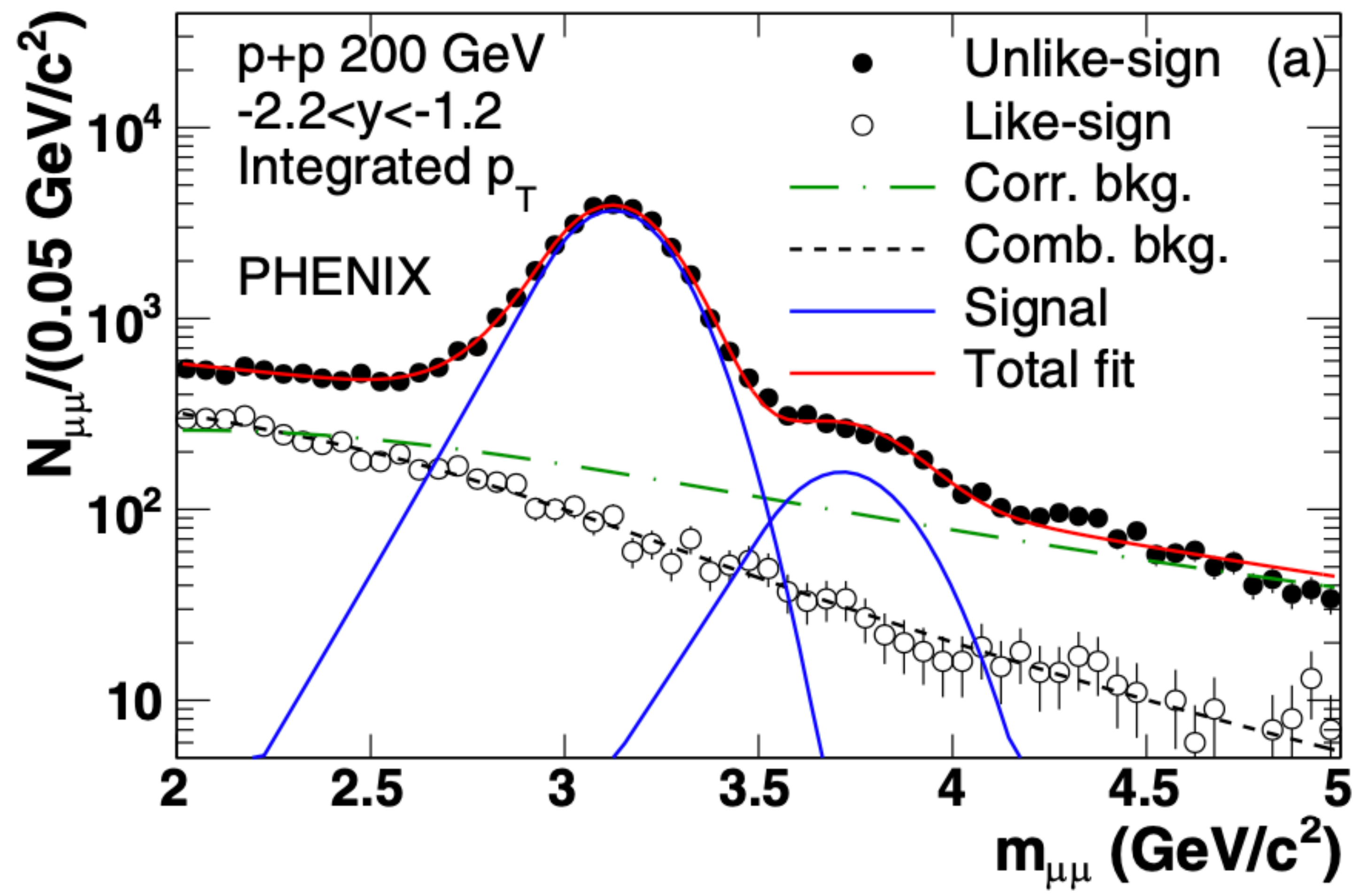
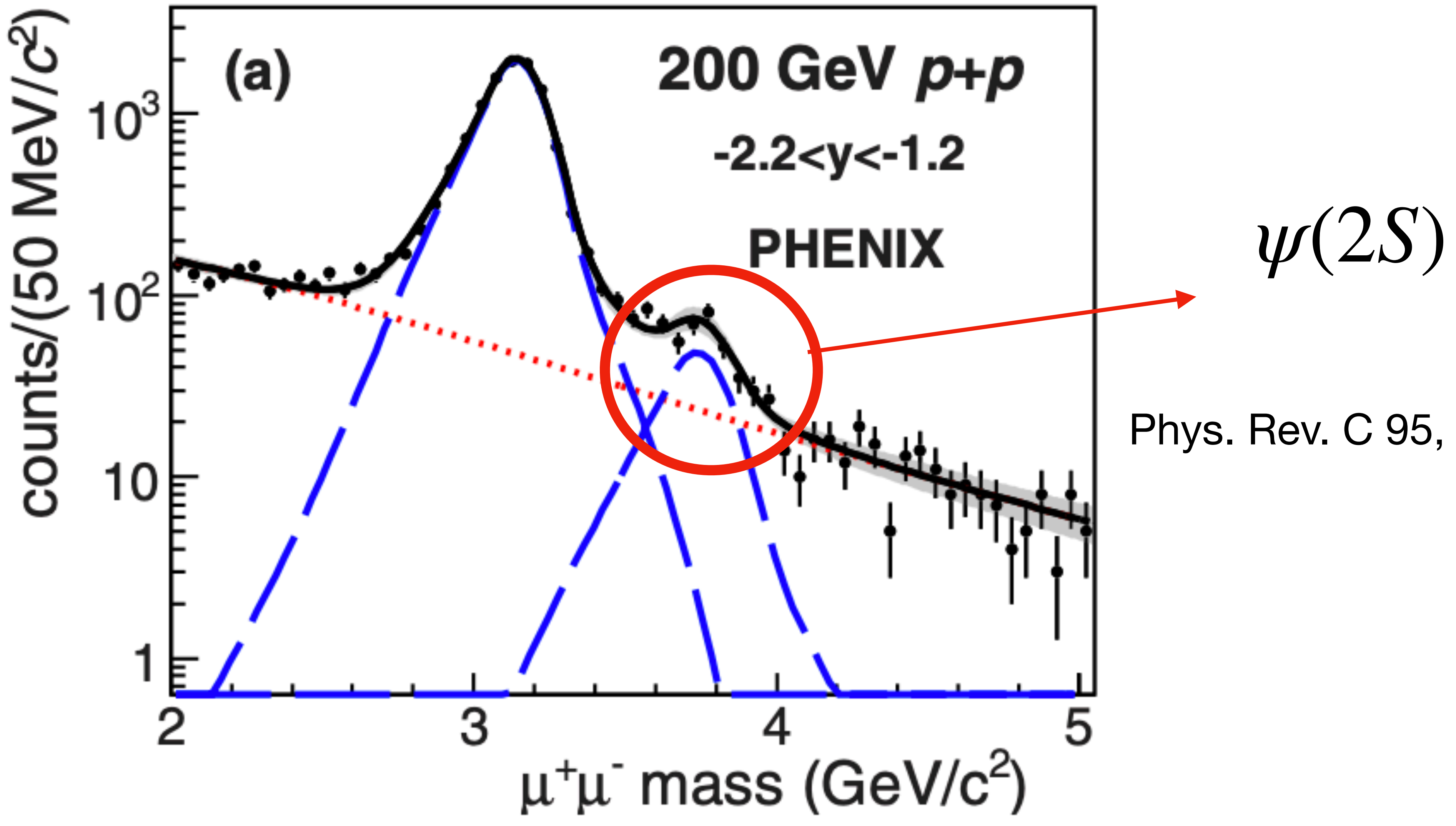


MuTr only



Phys. Rev. C 102, 014902

MuTr+FVTX



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- Dimuons that the single muons associated with FVTX tracks show a good mass resolution for $\psi(2S)$ measurement

→ But, statistics become low

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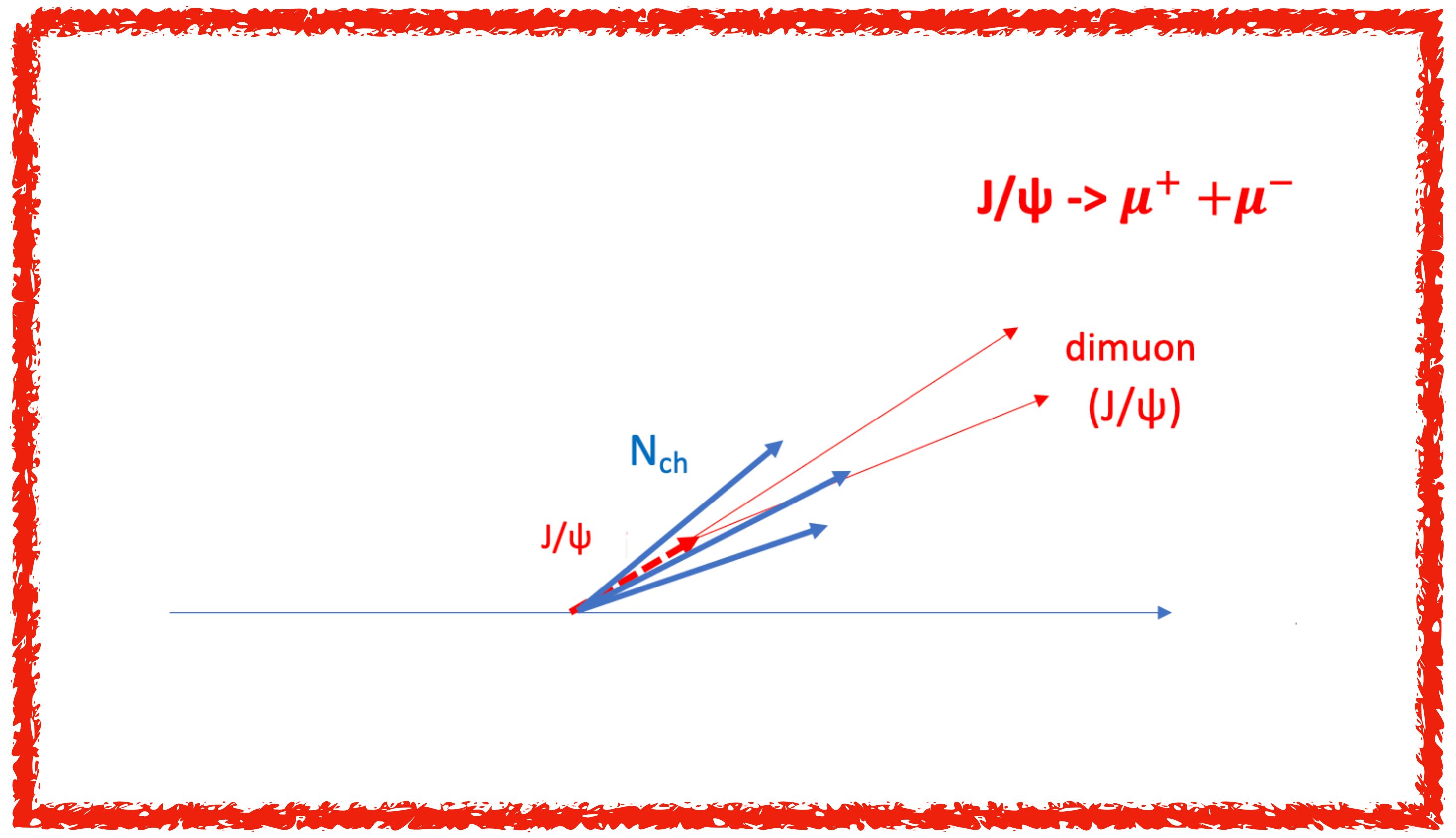
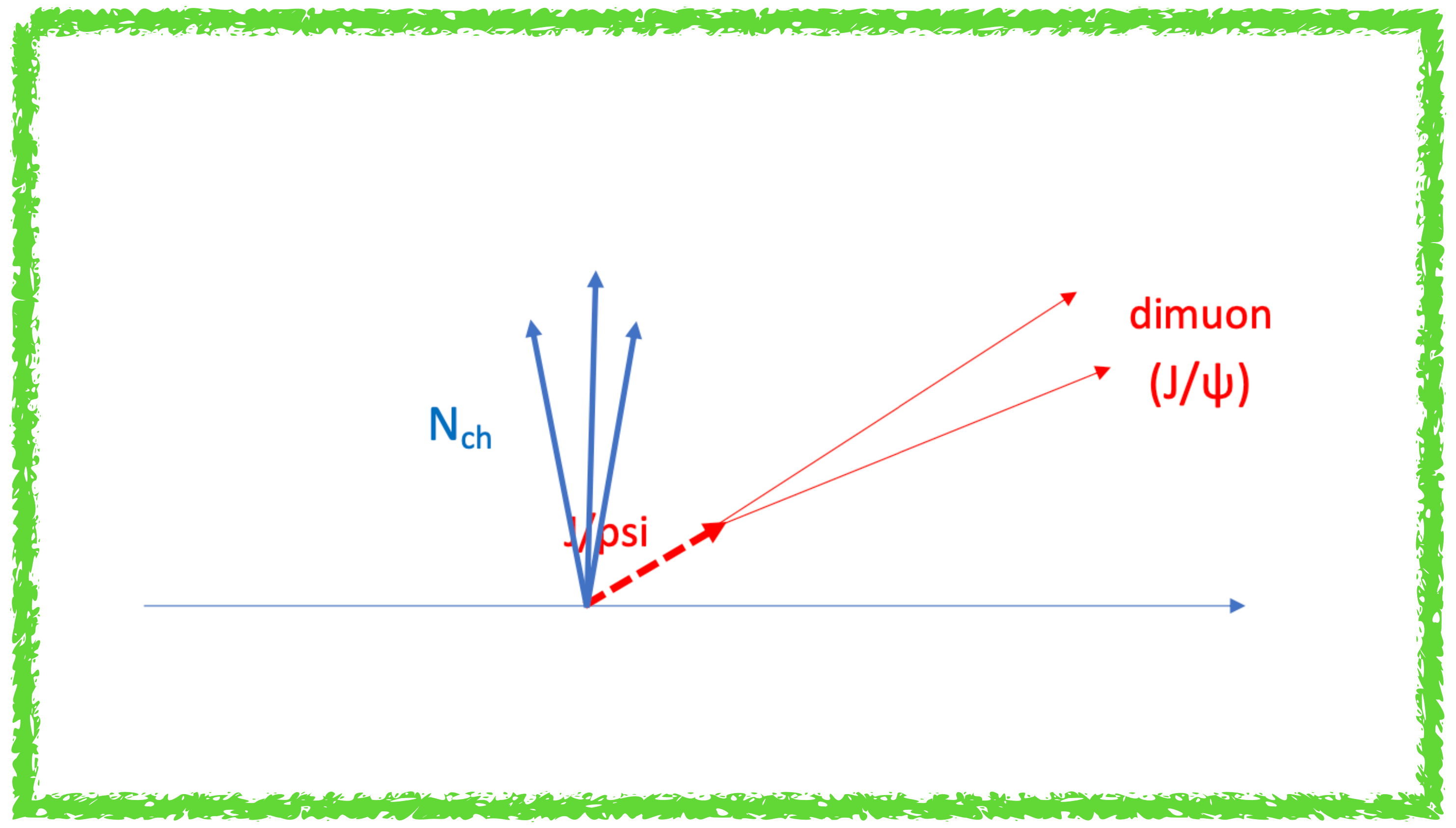
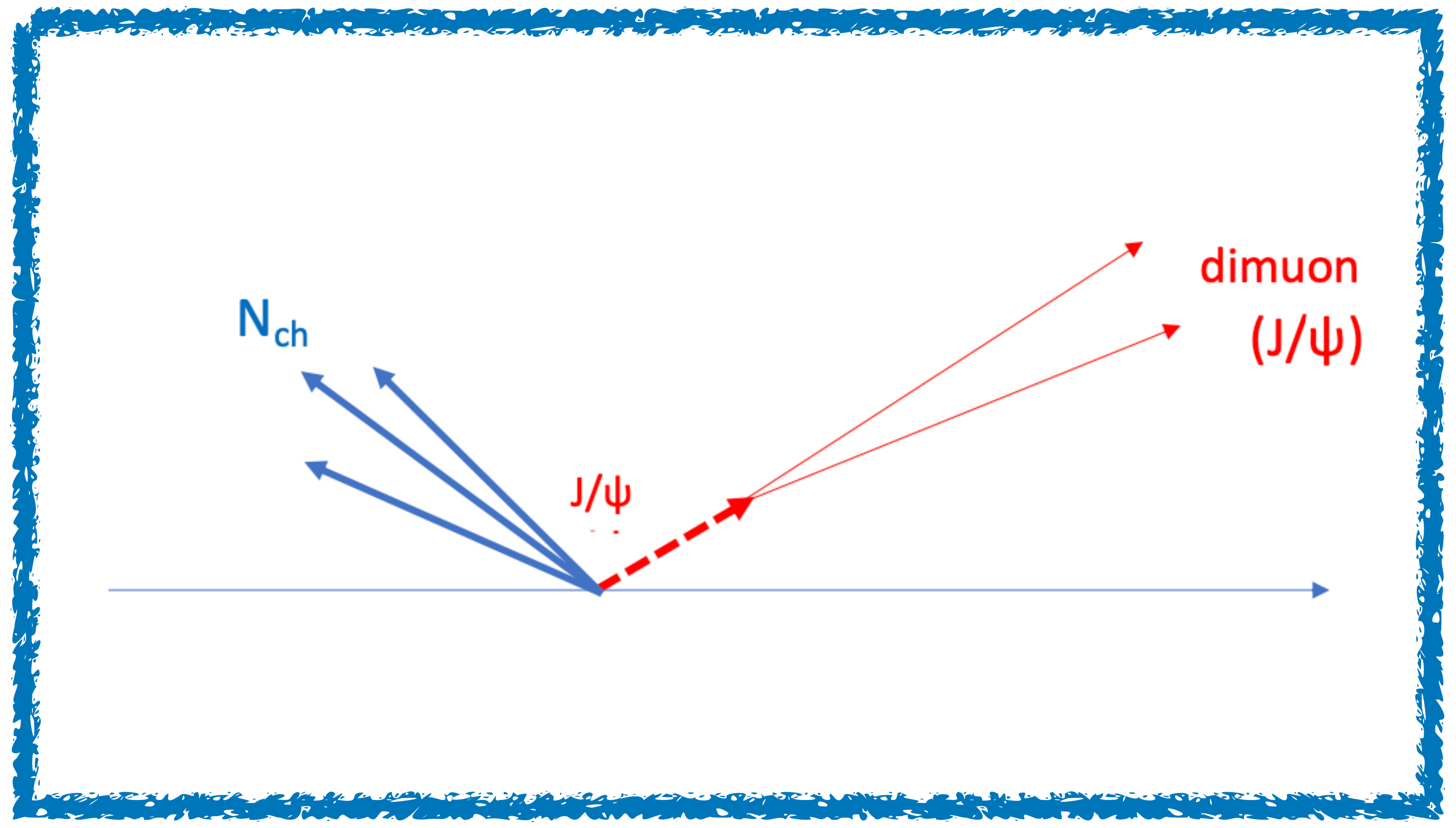


Case 1
(North Muon Arm and FVTX North)



Case 2
(North Muon Arm and VTX)



Case 3
(North Muon Arm and FVTX South)

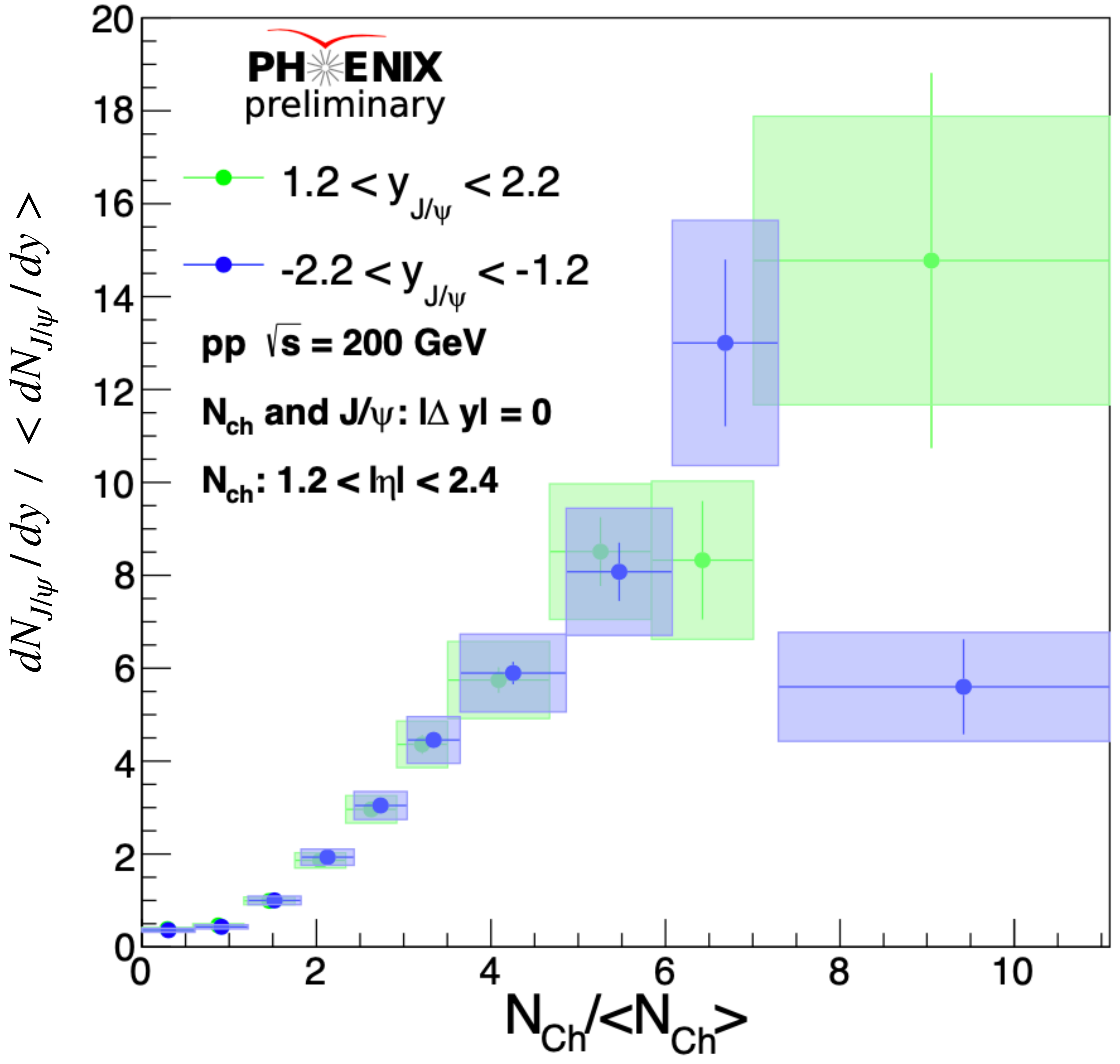
- Case 1) Measure J/ψ and multiplicity at the same direction,
  Can observe MPI effect and final-state effect
  → But the multiplicity is affected by the dimuons from J/ψ

- Case 2,3) Measure J/ψ and multiplicity at the different direction,
  Can check how the correlation changes with the rapidity

3. PHENIX Results

Same direction

RED = Tracklets N_{ch} (1.2 < |η| < 2.4)
Green = J/ψ (1.2 < y < 2.2)
Blue = J/ψ (-2.2 < y < -1.2)



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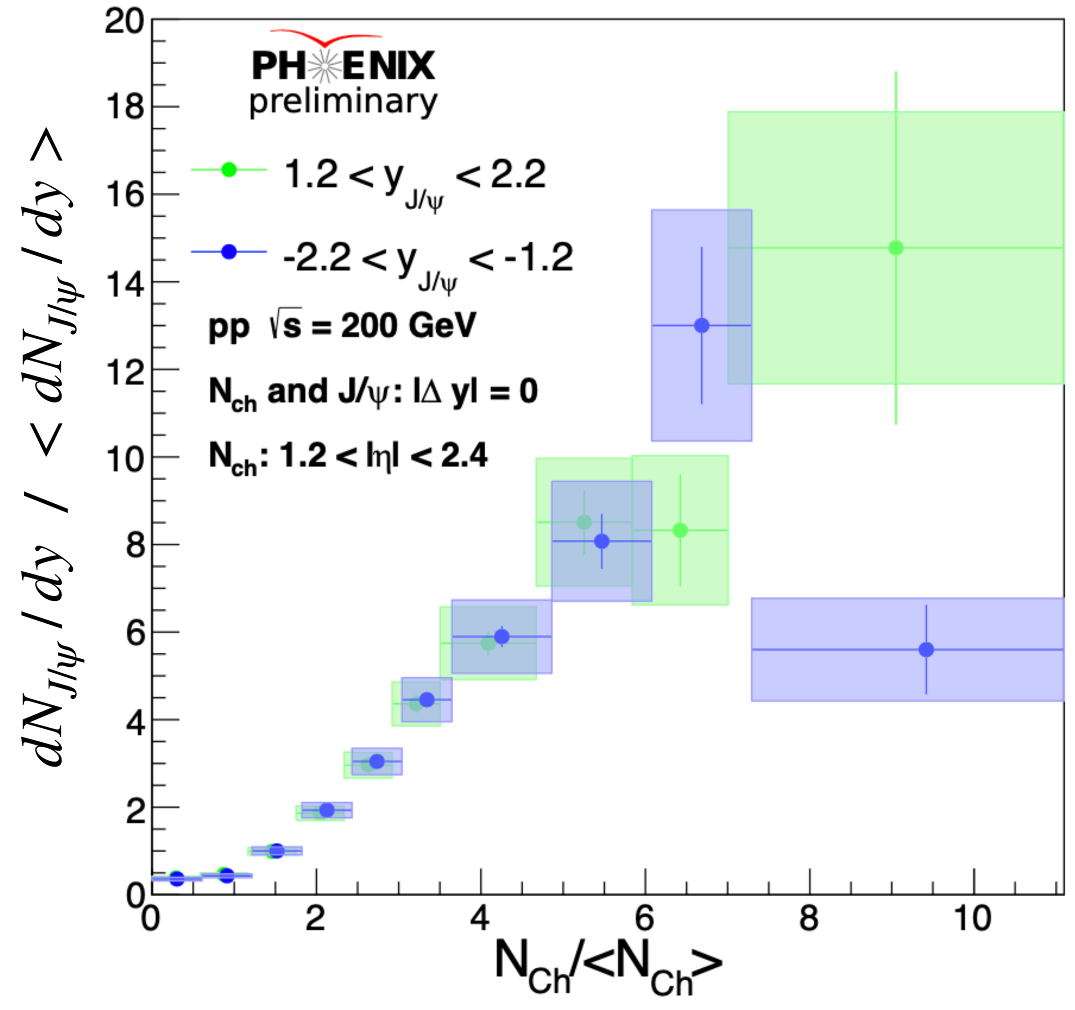
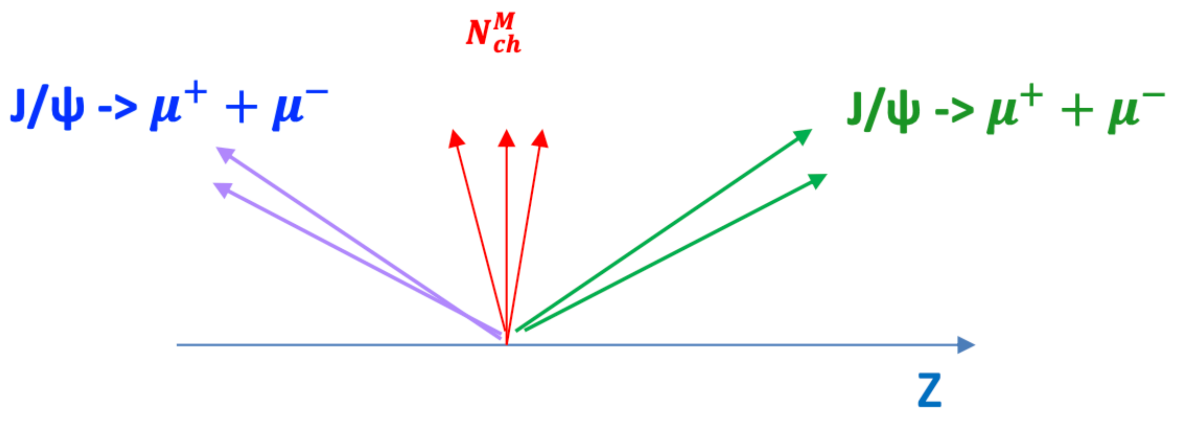
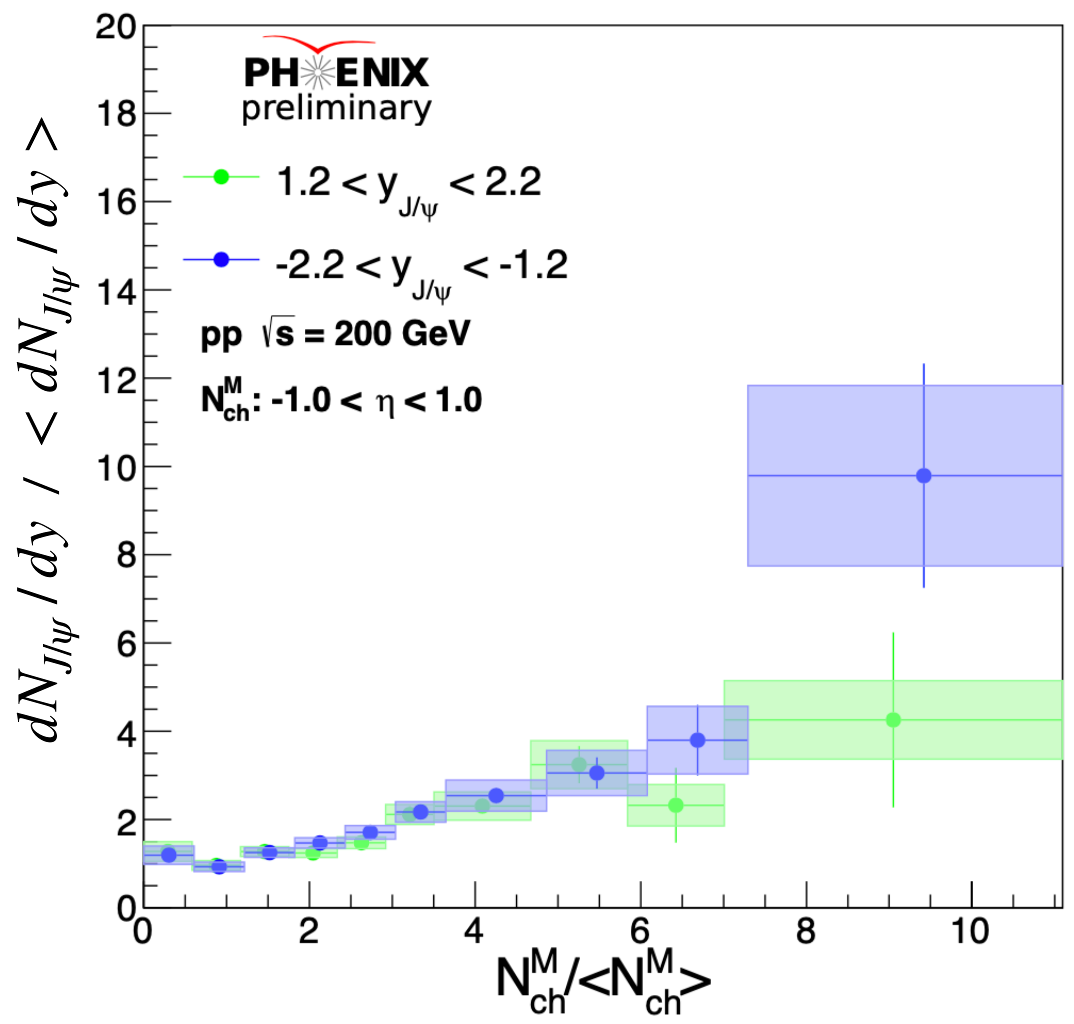


Mid-rap direction

RED = Tracklets N^M_{ch}(|η| < 1.0)
Green = J/ψ (1.2 < y < 2.2)
Blue = J/ψ (-2.2 < y < -1.2)



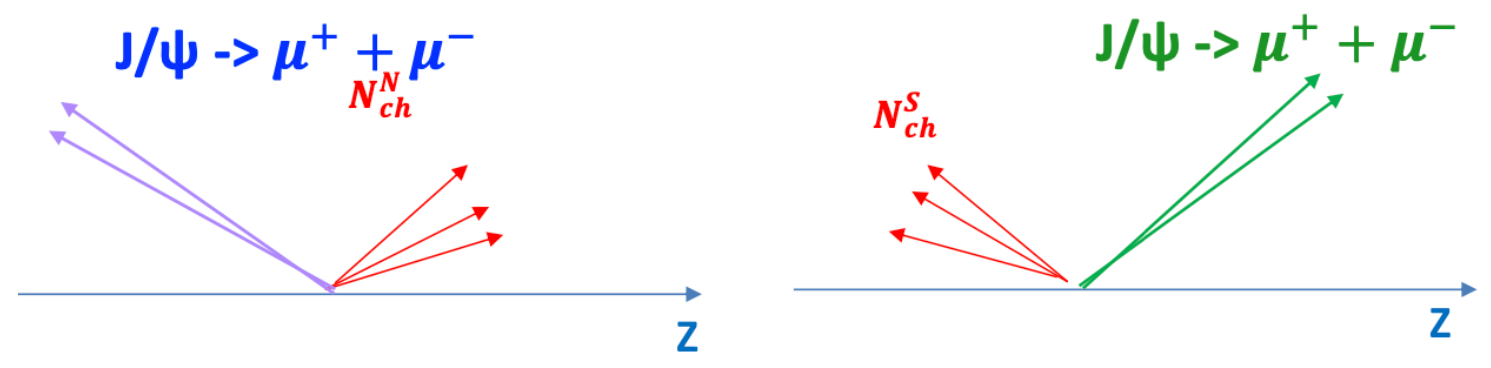


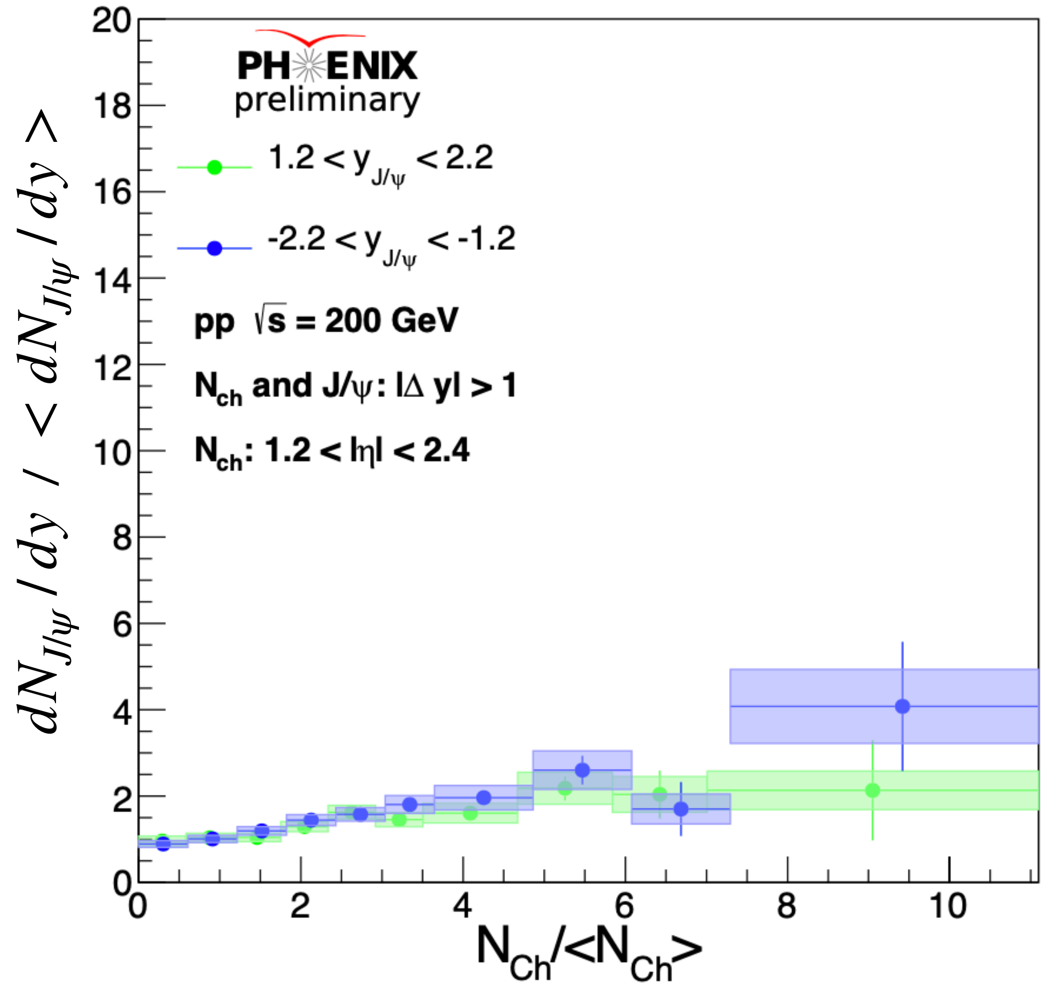
- In the same direction, the MPI effect and final-state effects can be observed,
  When the multiplicity increases, J/ψ yields increase steeply, and the multiplicity dependency is stronger for the same direction case.
  → Different effects between mid- and forward rapidity?
  → Effect from the dimuon contribution to the multiplicity calculation?

3. PHENIX Results

Opposite direction

RED = Tracklets N_{ch} (1.2 < |η| < 2.4)
Green = J/ψ : 1.2 < y < 2.2)
Blue = J/ψ (-2.2 < y < -1.2)





Mid-rap direction

RED = Tracklets N_{ch}^M(|η| < 1.0)
Green = J/ψ (1.2 < y < 2.2)
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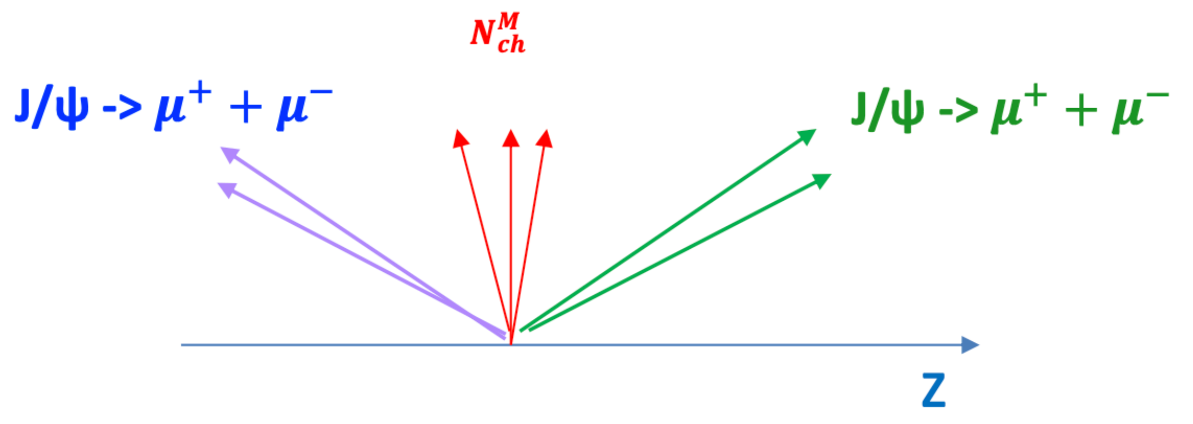

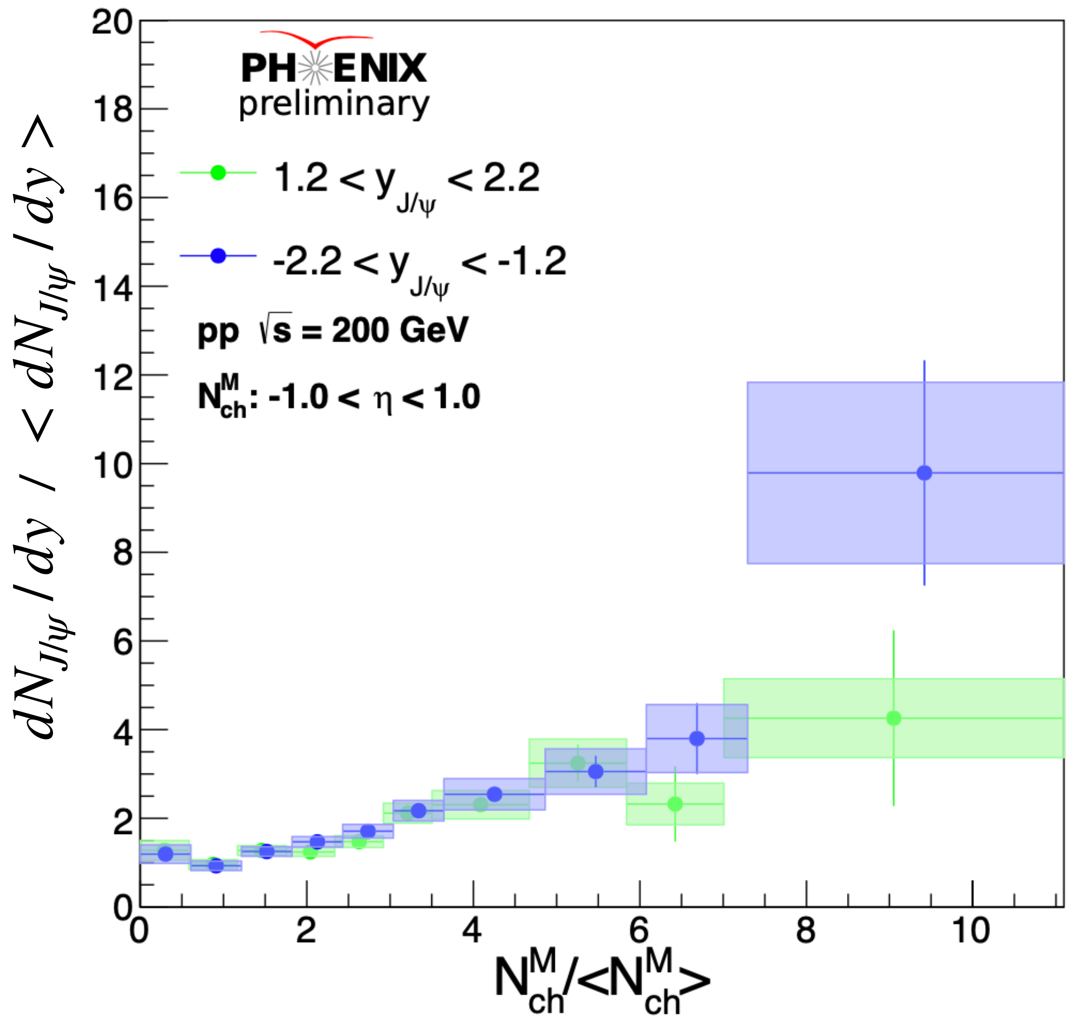

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  → Different effects between mid- and forward rapidity?
  → Effect from the dimuon contribution to the multiplicity calculation?

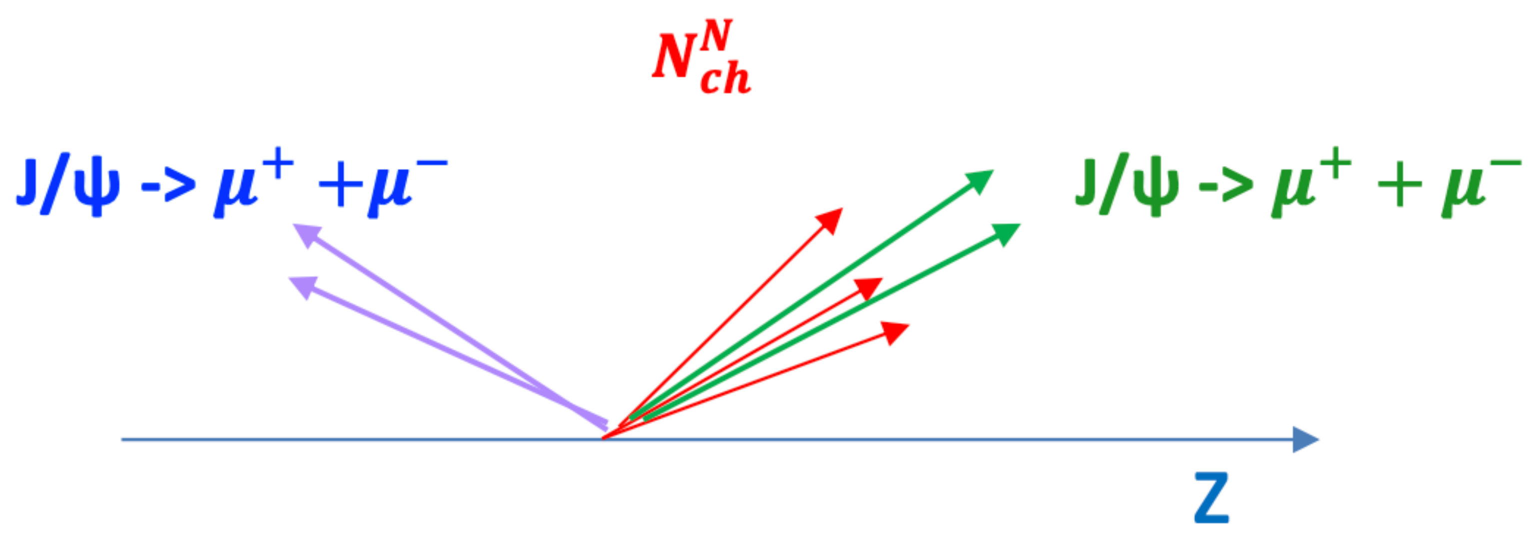
- When J/ψ going to south or north and measuring multiplicity at mid-rapidity or the opposite side,
  Similar dependency has been observed

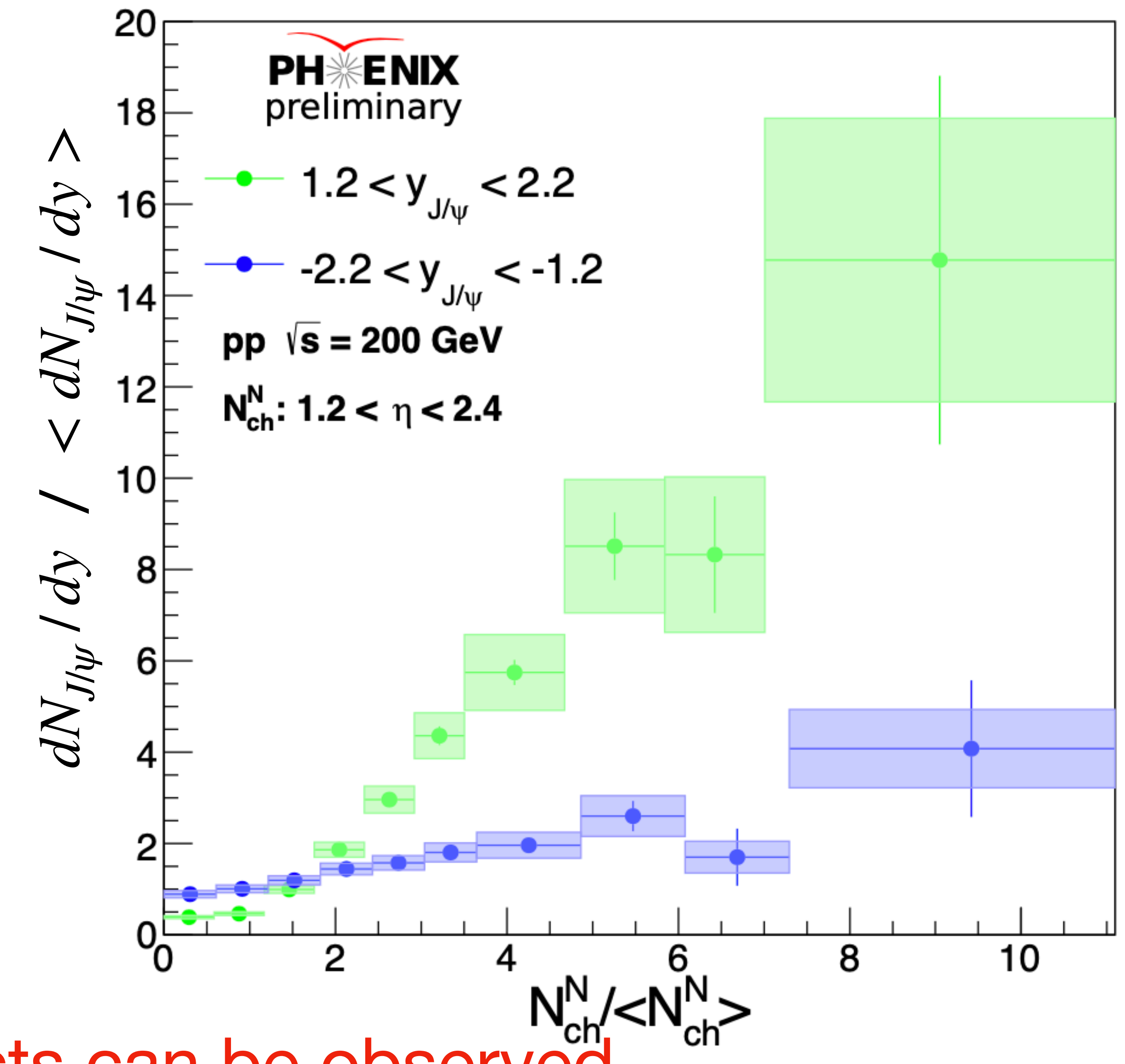
3. PHENIX Results

RED = Tracklets N_{ch}^{N} ($1.2 < \eta < 2.4$)

Green = J/ψ (1.2 < y < 2.2)

Blue = J/ψ (-2.2 < y < -1.2)





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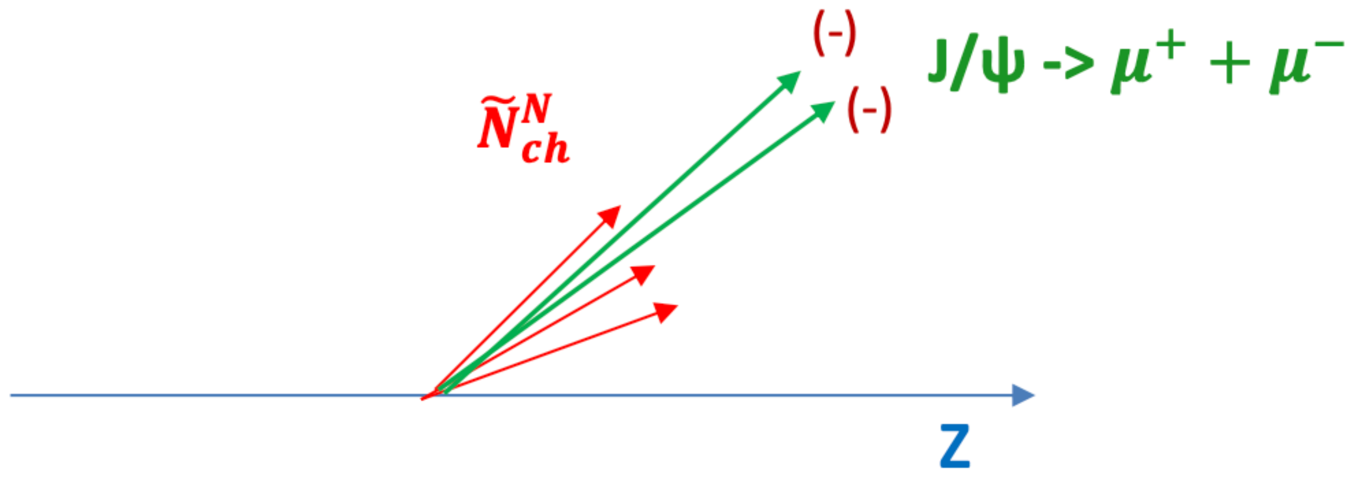
- When J/ψ going to south or north and measuring multiplicity at mid-rapidity or the opposite side, Similar dependency has been observed

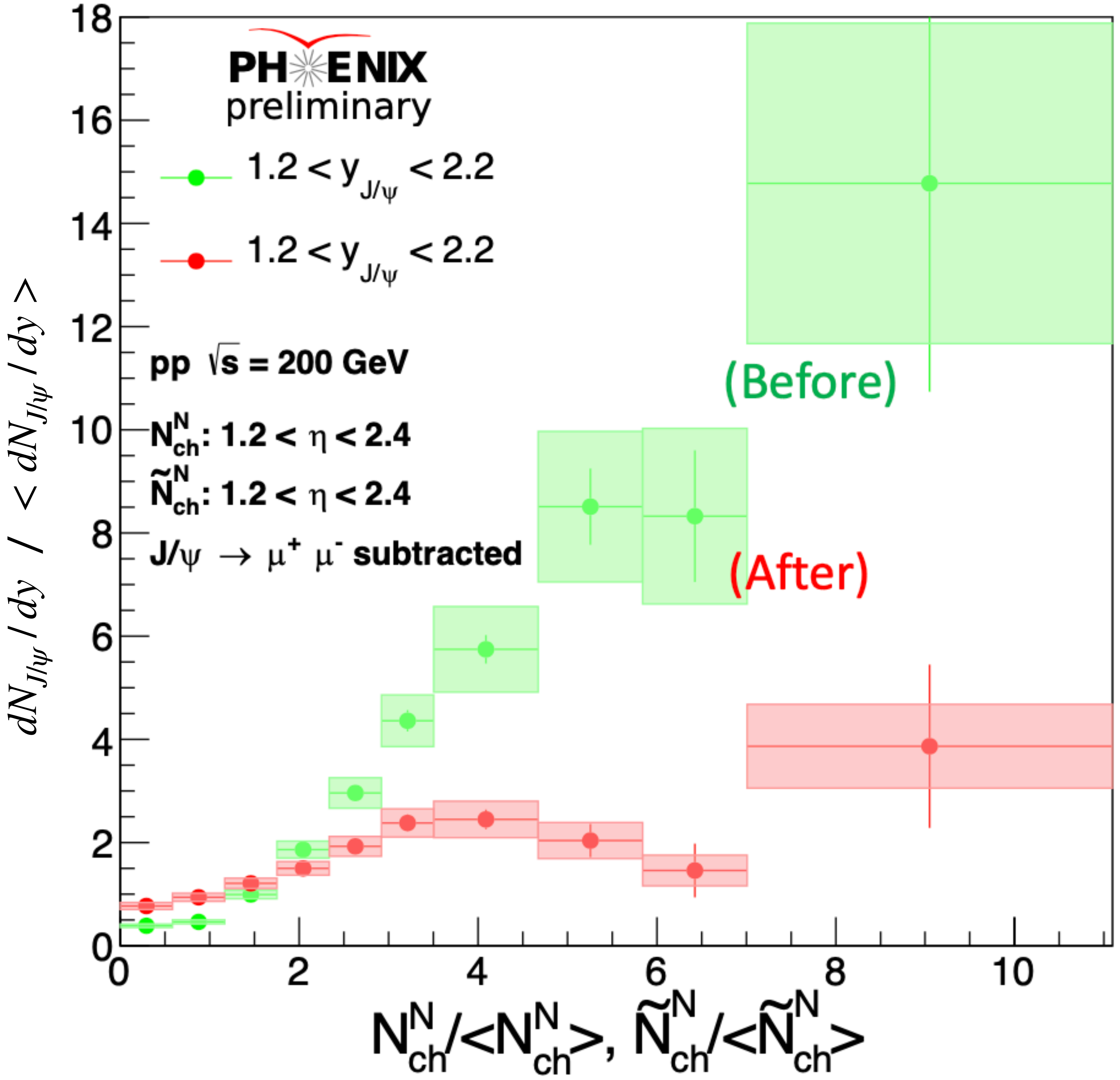
- Very different multiplicity dependence between the same direction case and opposite direction case
  → Note that multiplicity at the same direction includes the dimuon contribution

3. PHENIX Results

RED = Tracklets $\tilde{N}^{N}_{ch}$ (1.2 < η < 2.4) [dimuon subtracted]

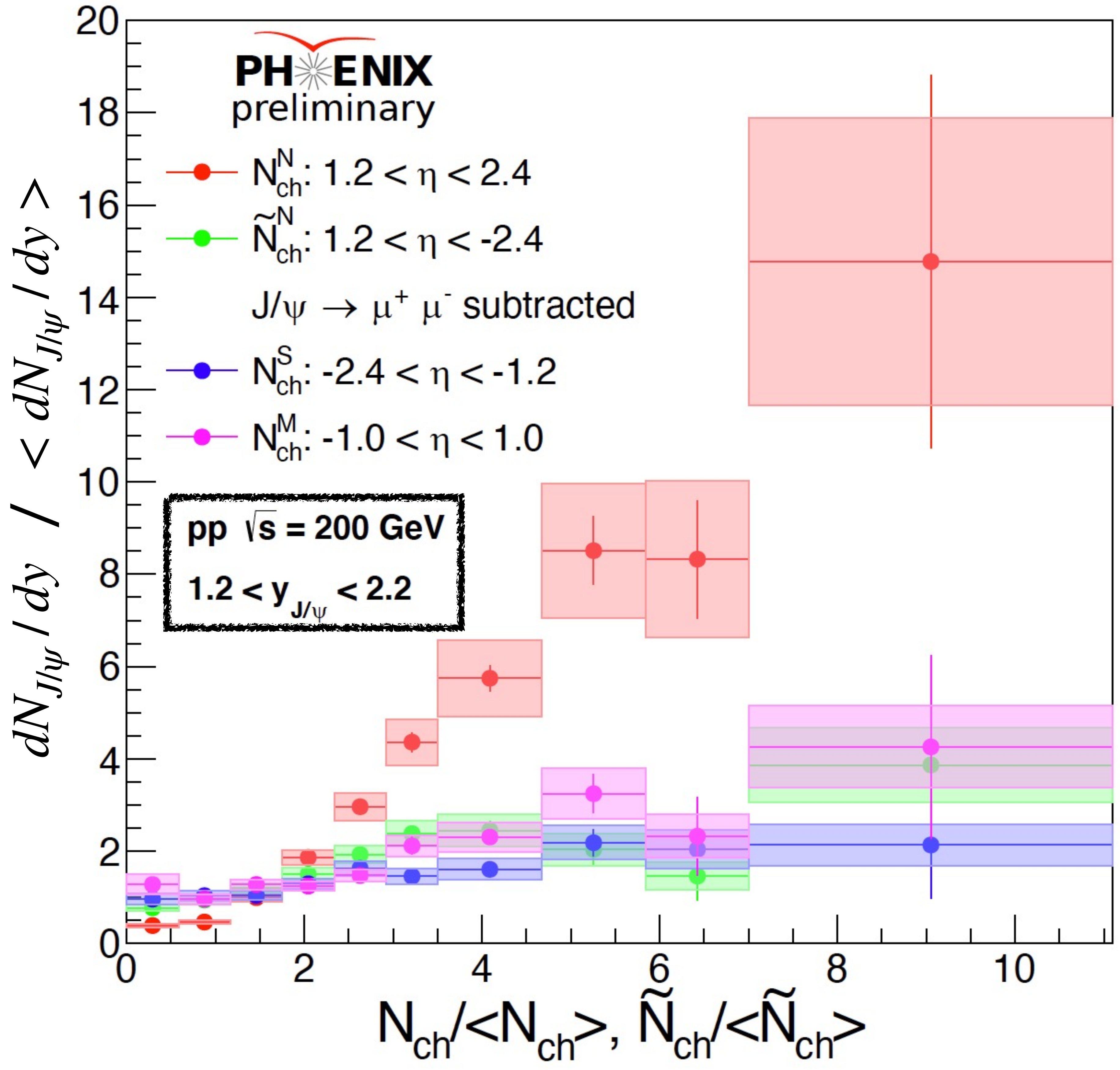
Green = J/ψ (1.2 < y < 2.2)





- After <u>subtraction of the dimuon contribution</u>, multiplicity dependency becomes weaker (Subtracting dimuon contribution when FVTX-MuTr matched)

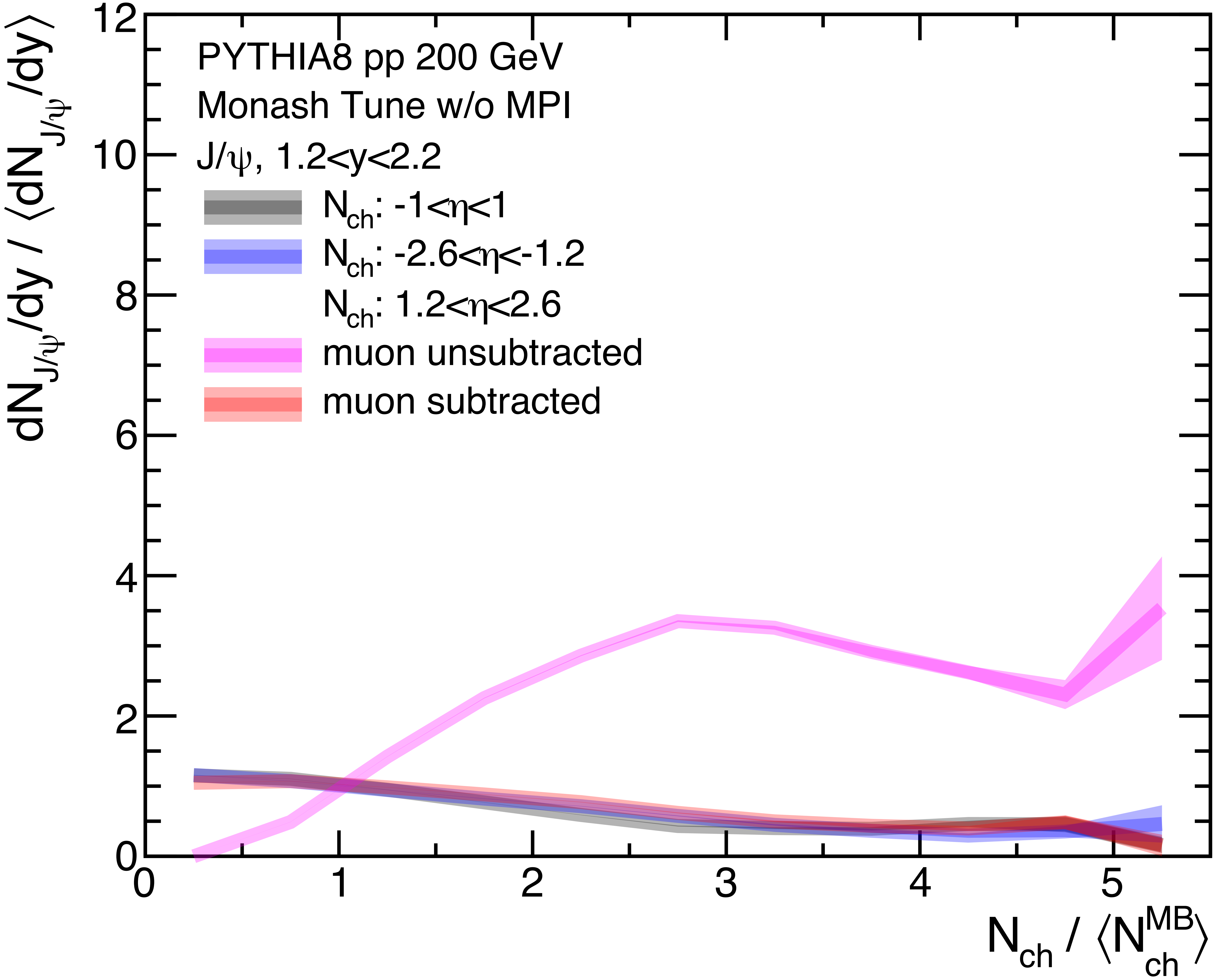
3. PHENIX Results



- After subtraction of the dimuon contribution, multiplicity dependency becomes weaker (Subtracting dimuon contribution when FVTX-MuTr matched)
- Compare results with subtraction to the mid-rapidity and opposite direction cases, similar dependence observed

→ Check PYTHIA8 for more discussion

3. PHENIX Results - Comparison with PYTHIA8



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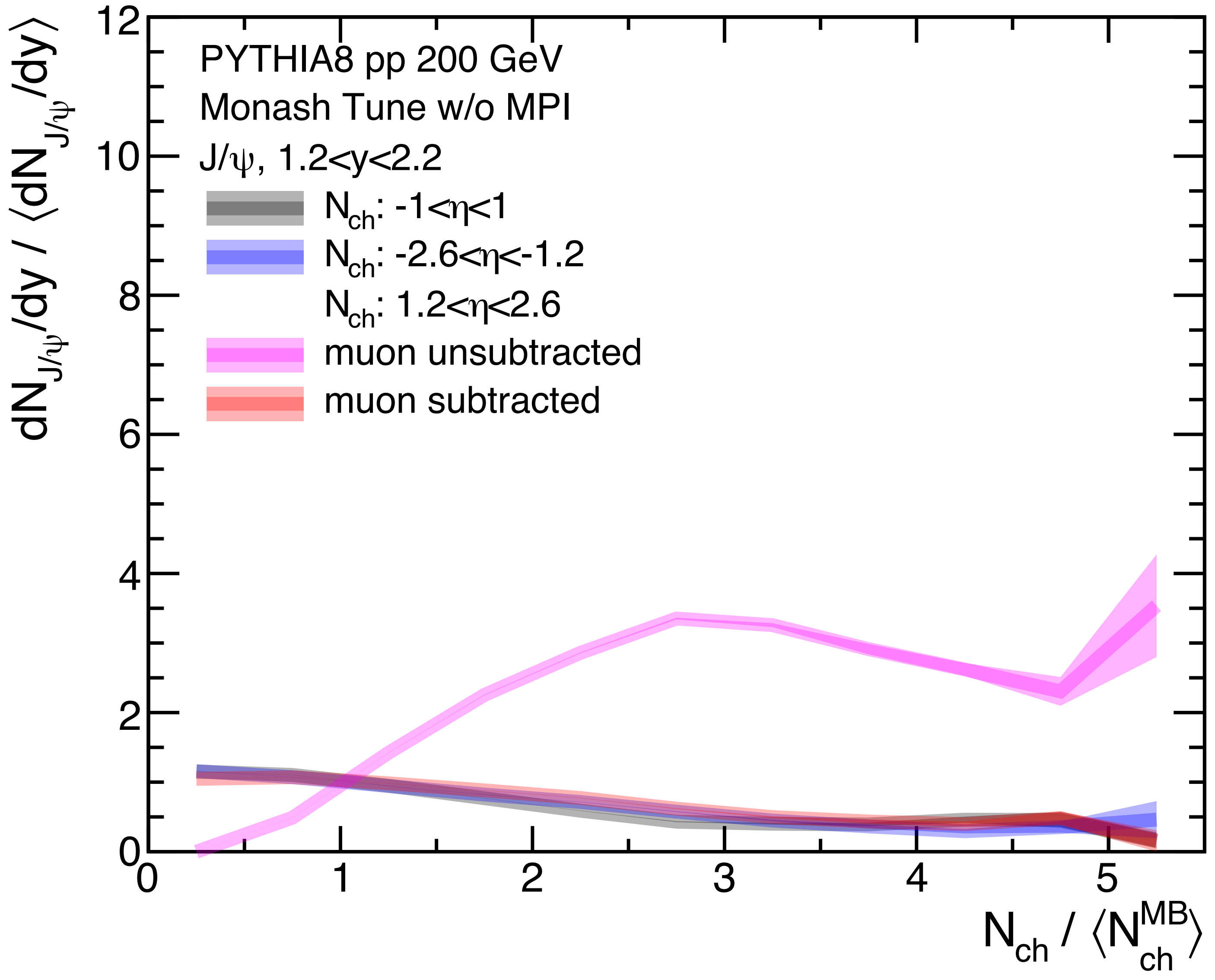
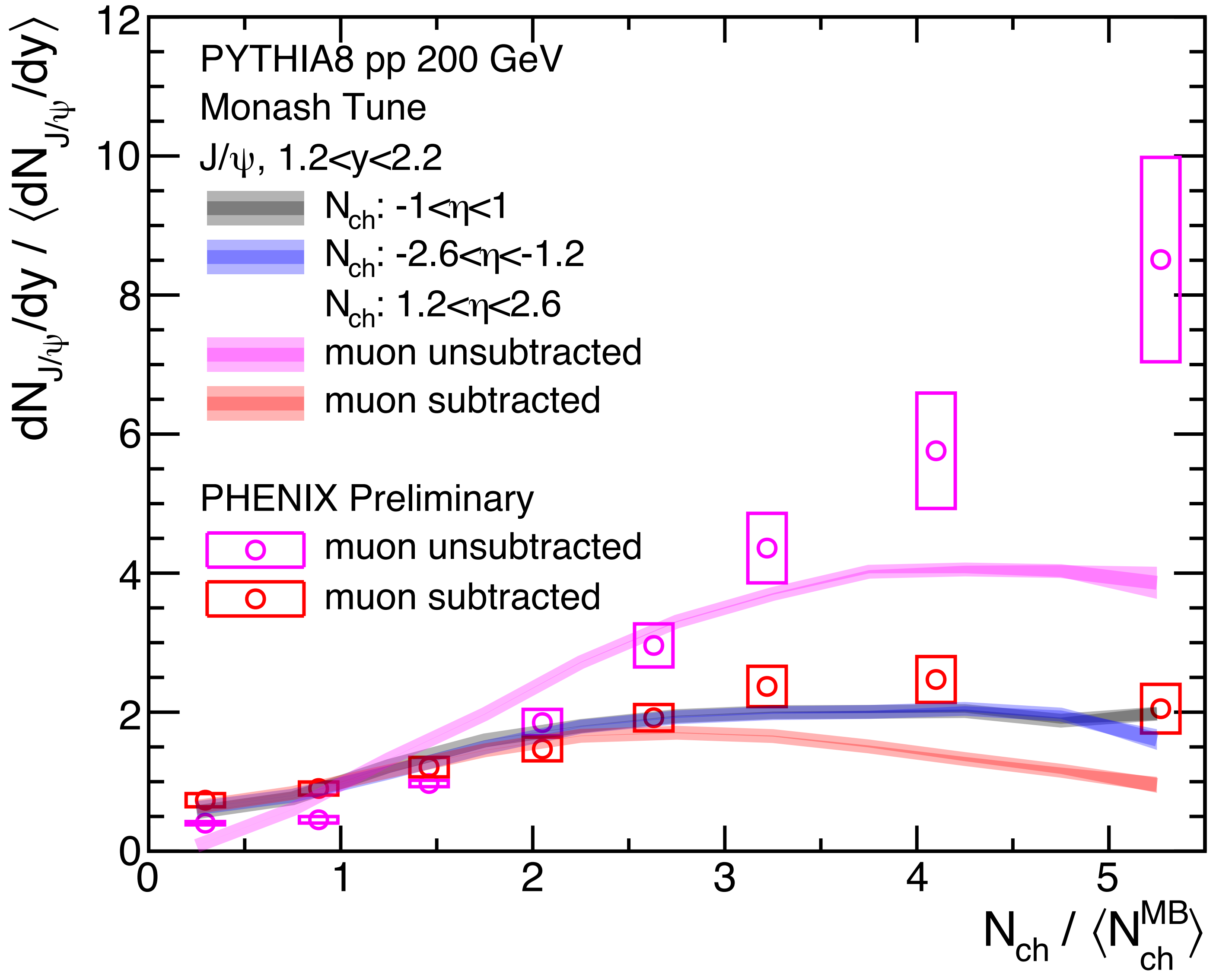


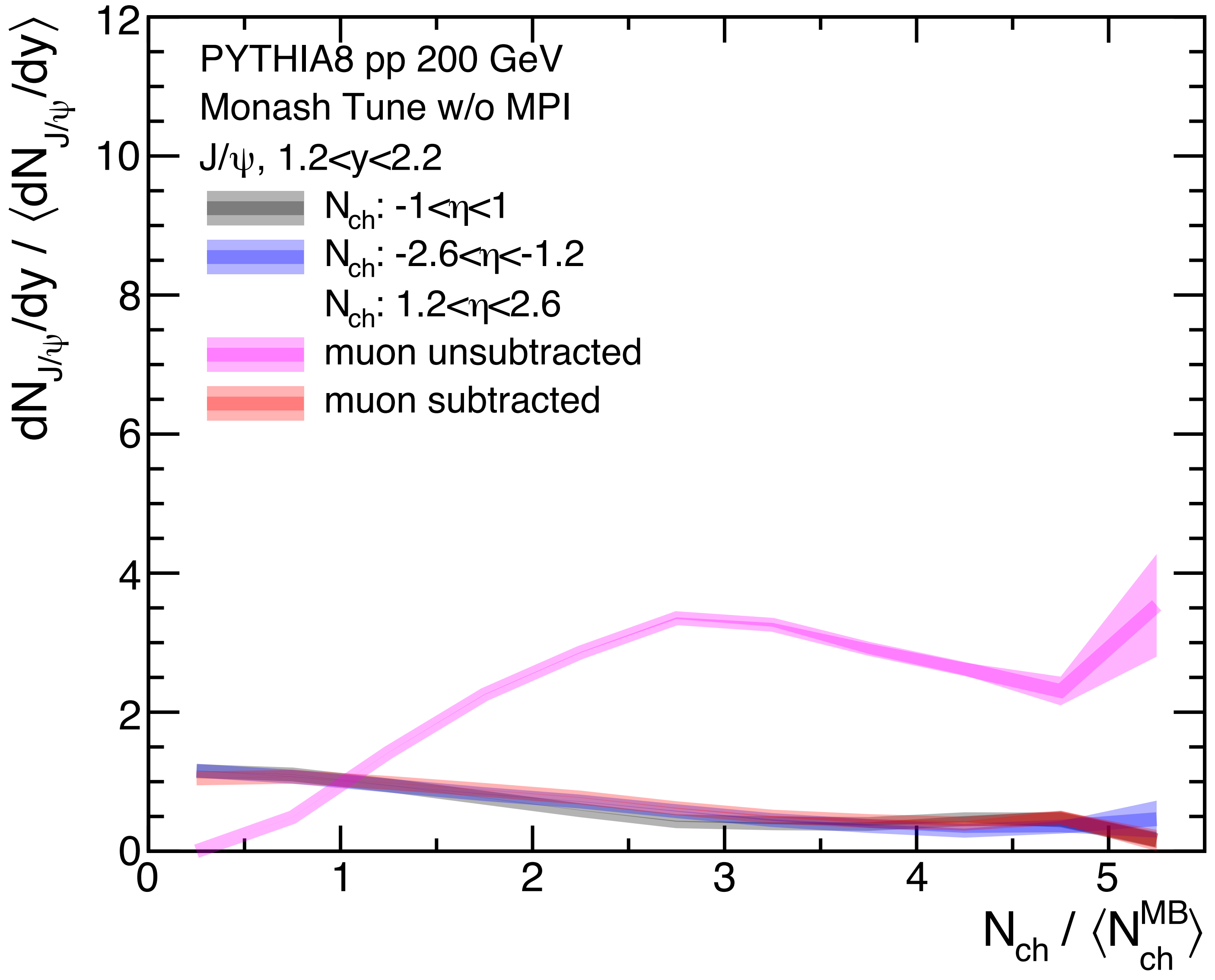


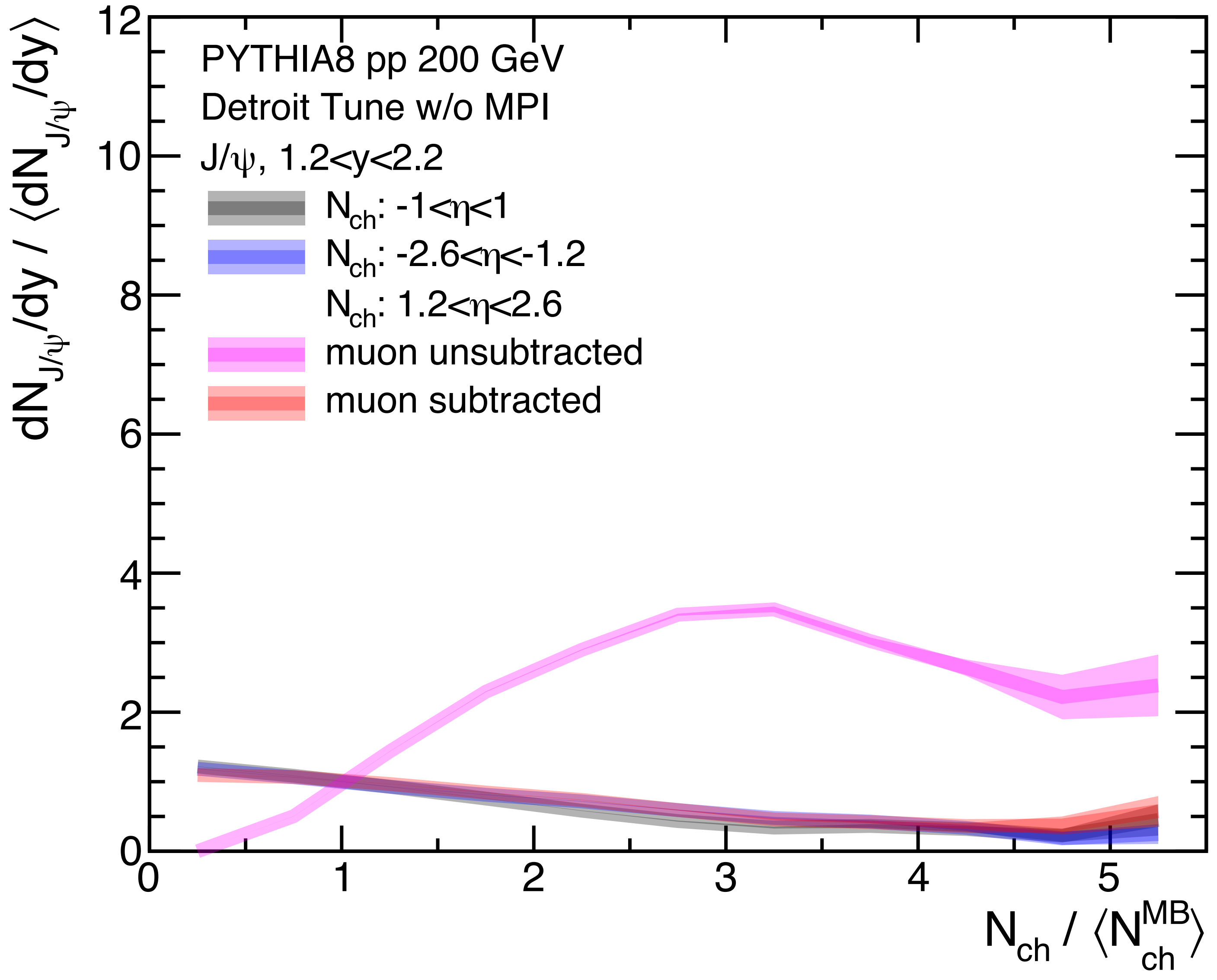
Turn off the MPI effect

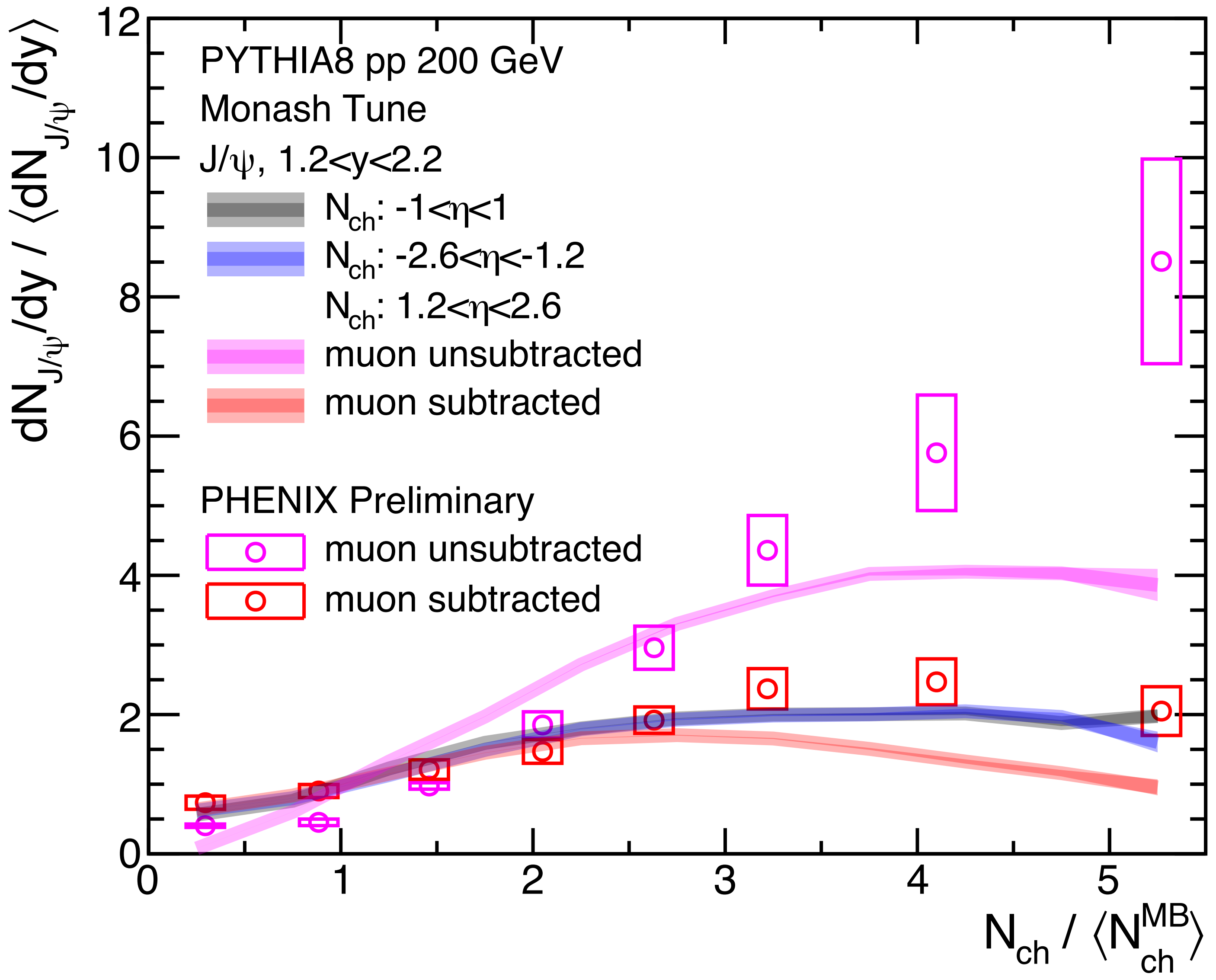
- Multiplicity at different acceptances and the same acceptance with subtraction (red): show a decreasing trend
- PYTHIA with MPI can better describe the data

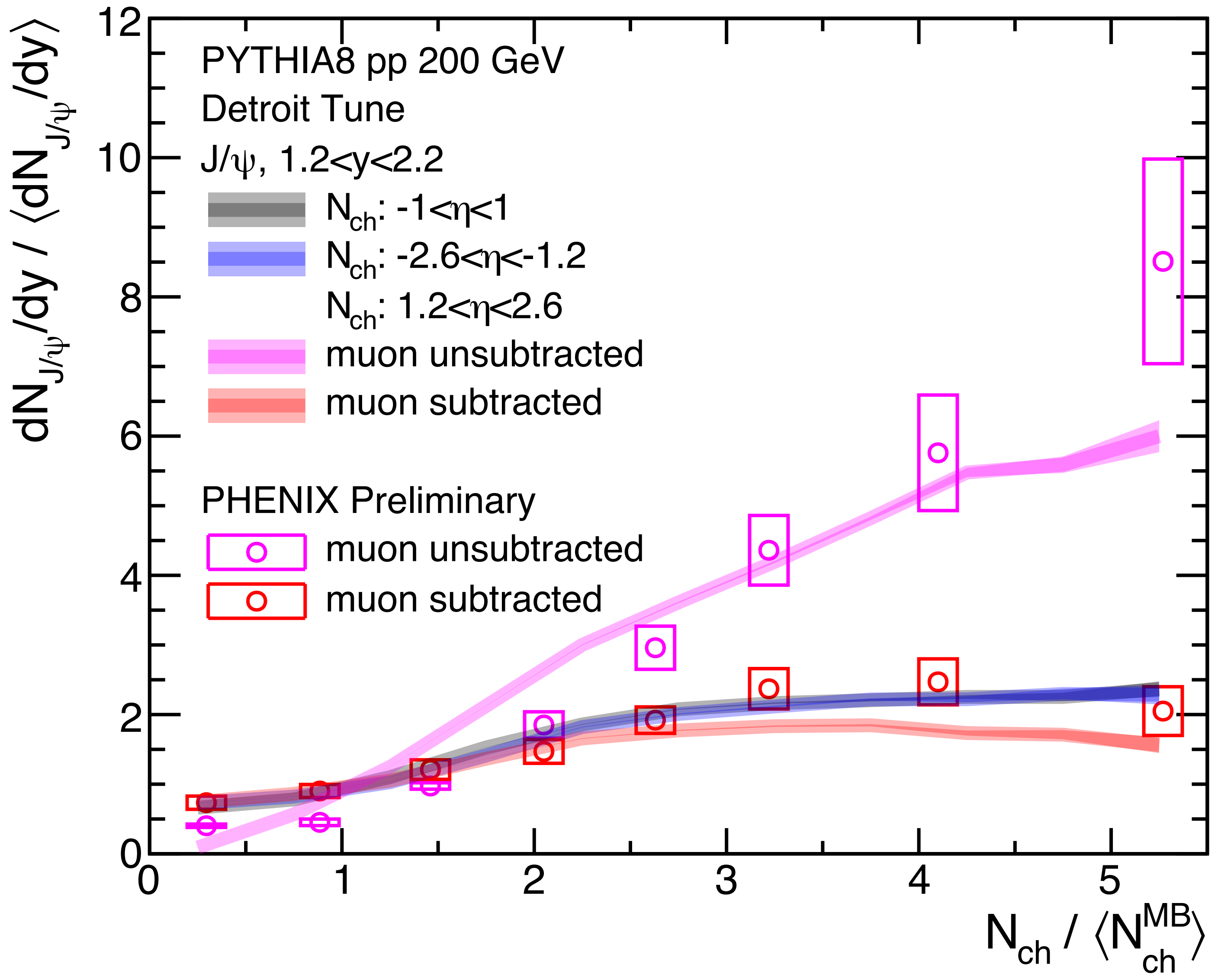
MPI effect is important at 200 GeV

3. PHENIX Results - Comparison with PYTHIA8









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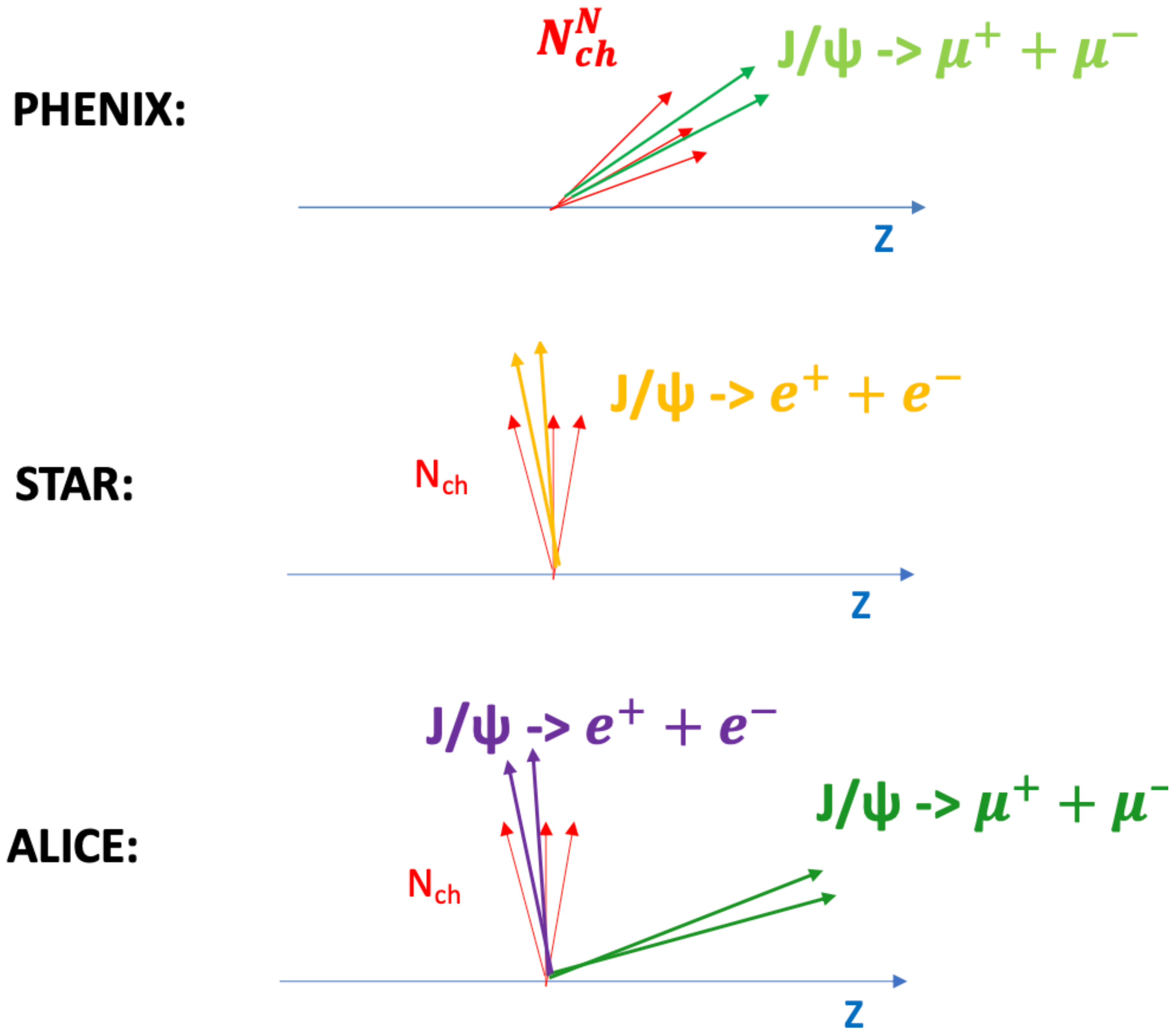
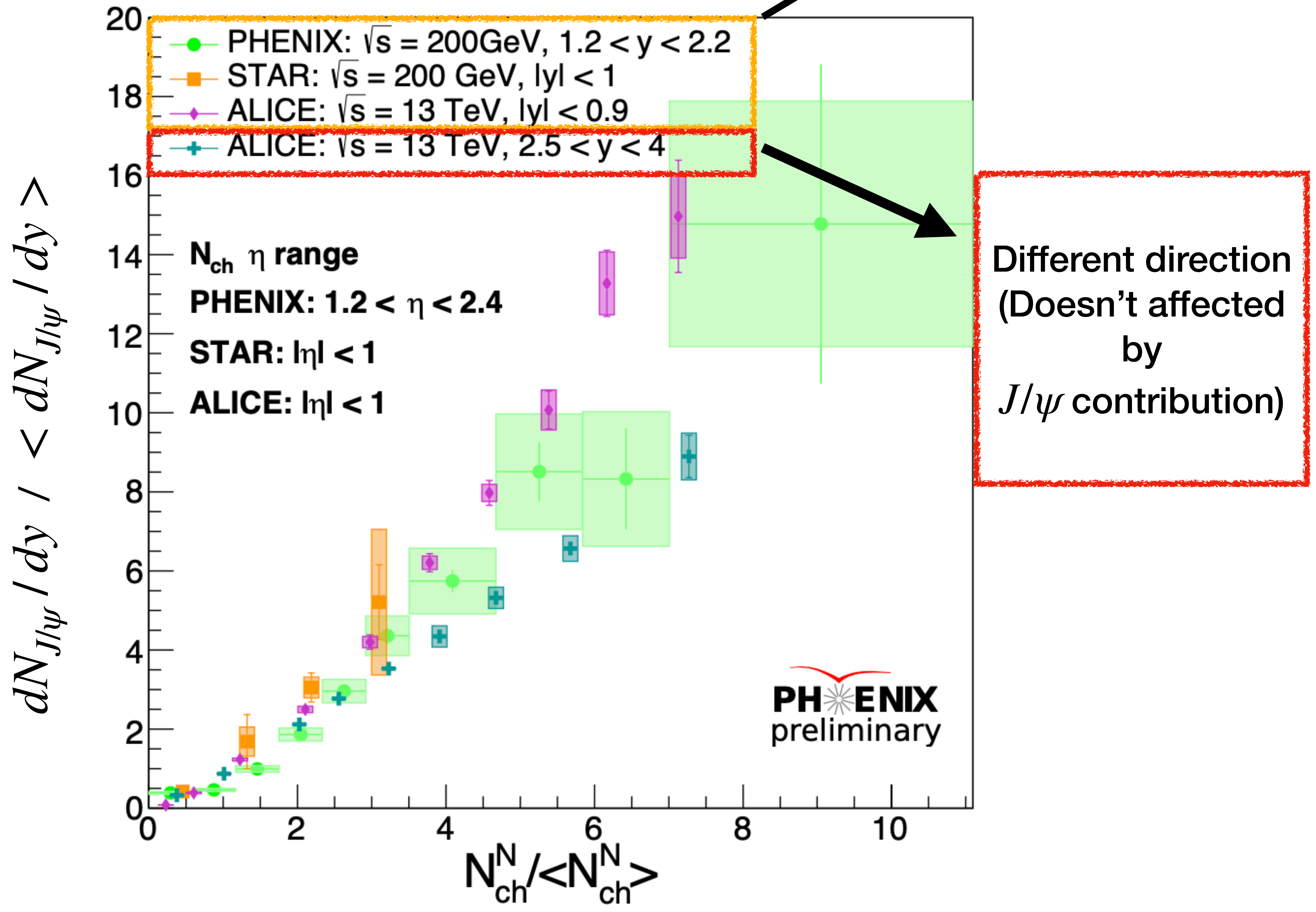
MPI effect is important at 200 GeV

- Monash Tune for the LHC energies
  Detroit Tune for the RHIC energies (*arXiv:2110.09447)
- J/ψ at forward rapidity ($1.2<y<2.2$)
  Multiplicity at different (other) acceptance:
  similar multiplicity dependence between two tunes

  Multiplicity at same acceptance:
  slightly stronger dependence in Detroit Tune at high multiplicity
- Detroit Tune shows a better agreement with the PHENIX results

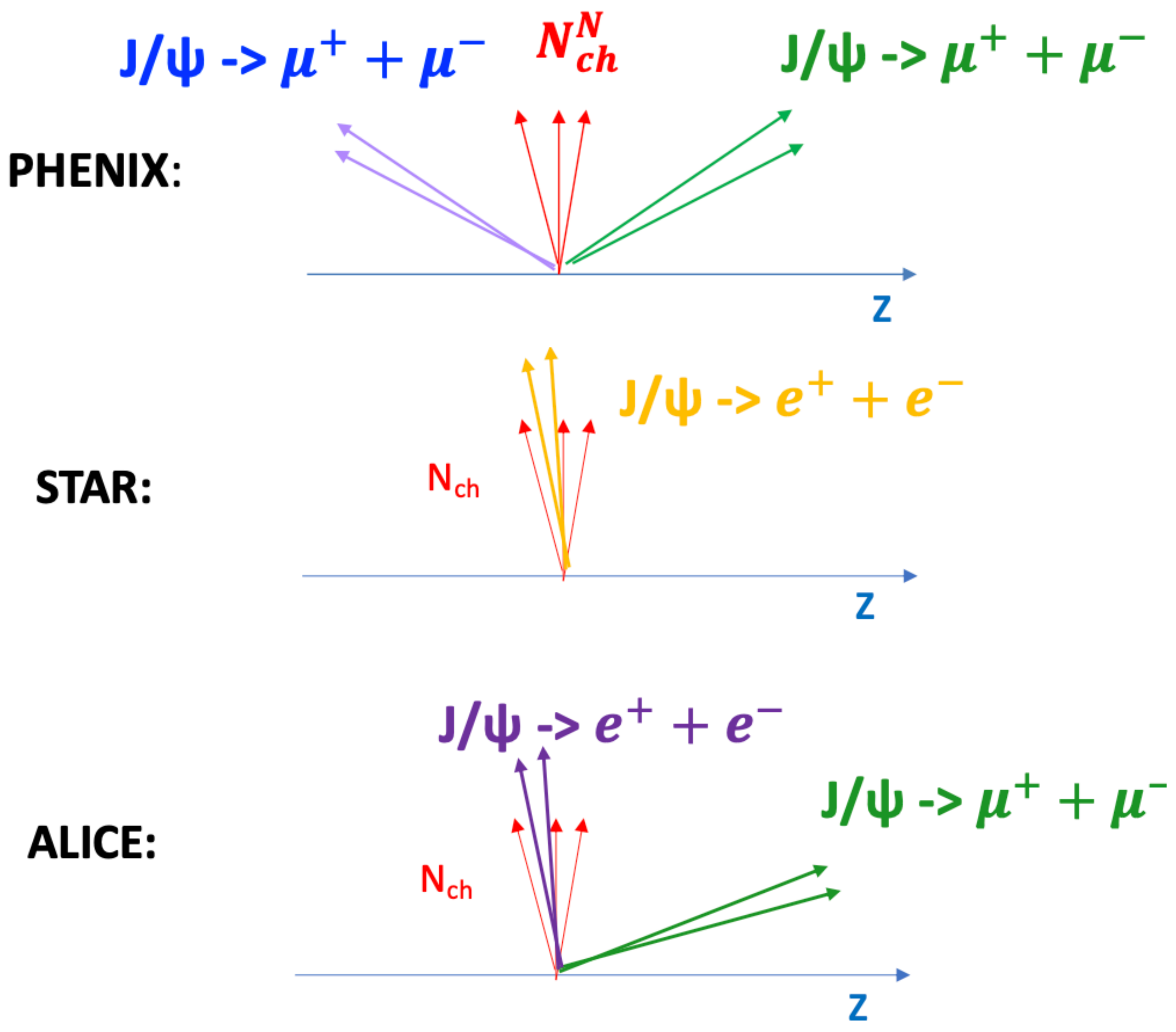
3. PHENIX Results

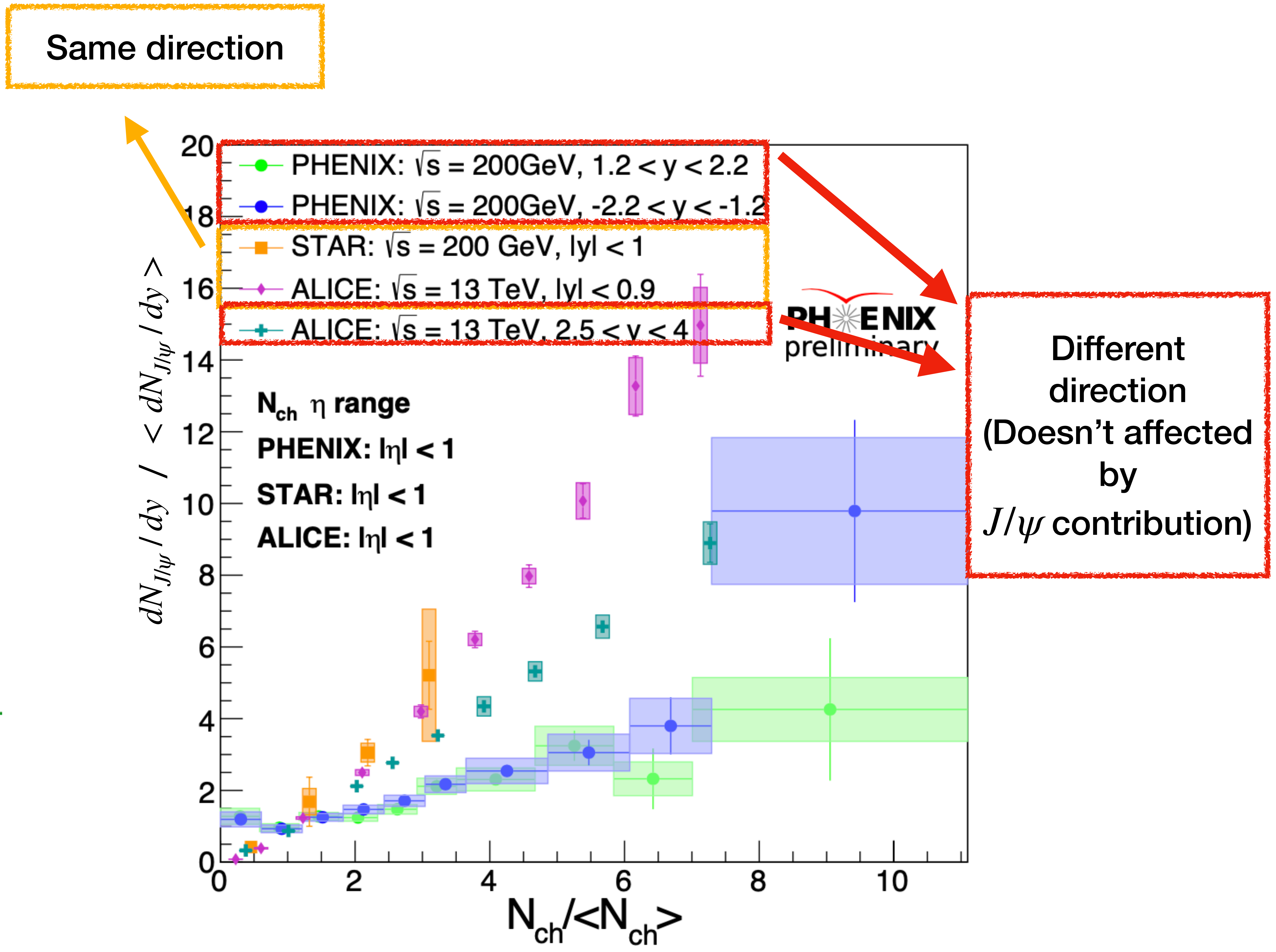




- PHENIX, STAR, ALICE (Measuring multiplicity at the same acceptance with J/ψ)
  → Similar multiplicity dependence despite different center-of-mass energy

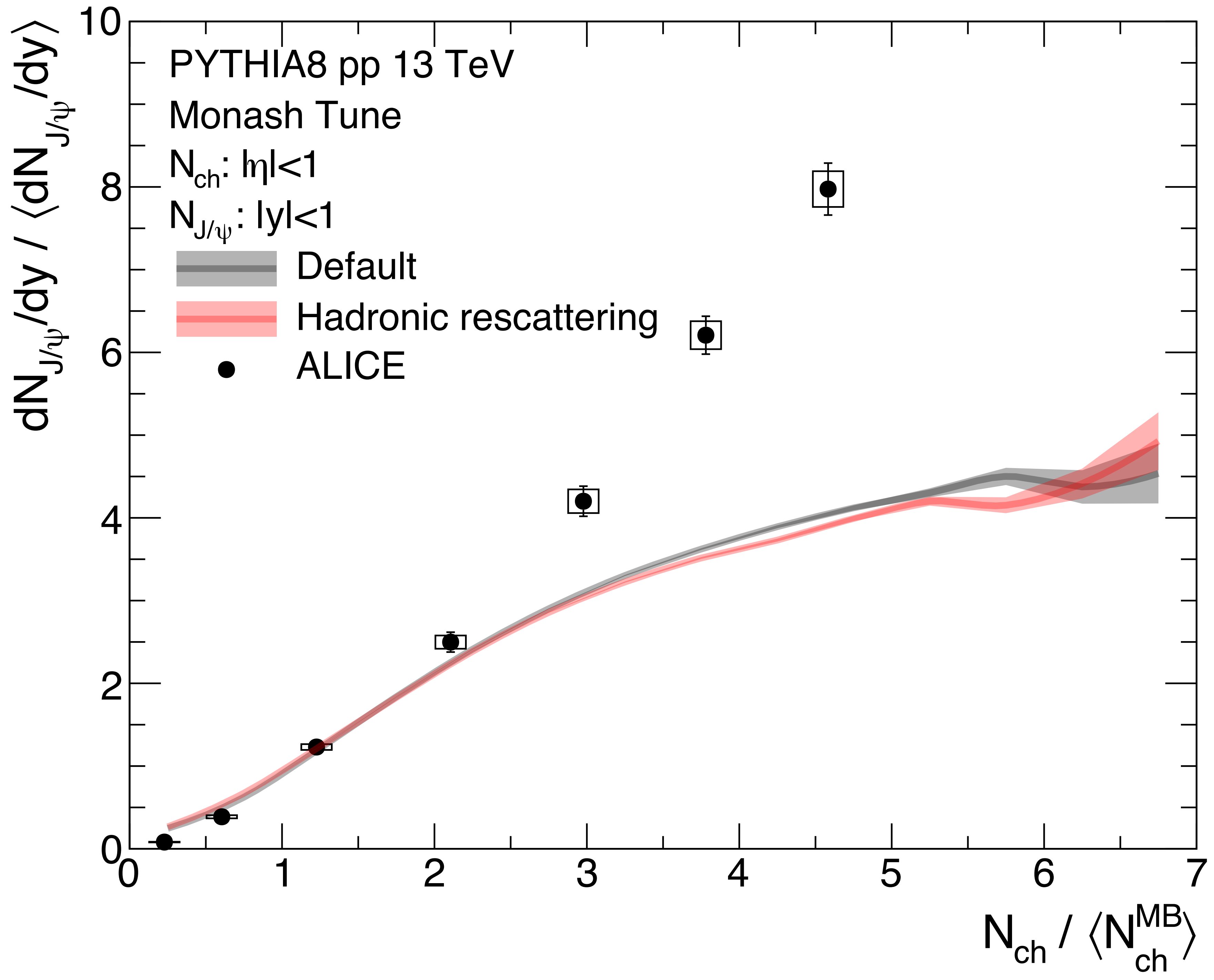
3. PHENIX Results

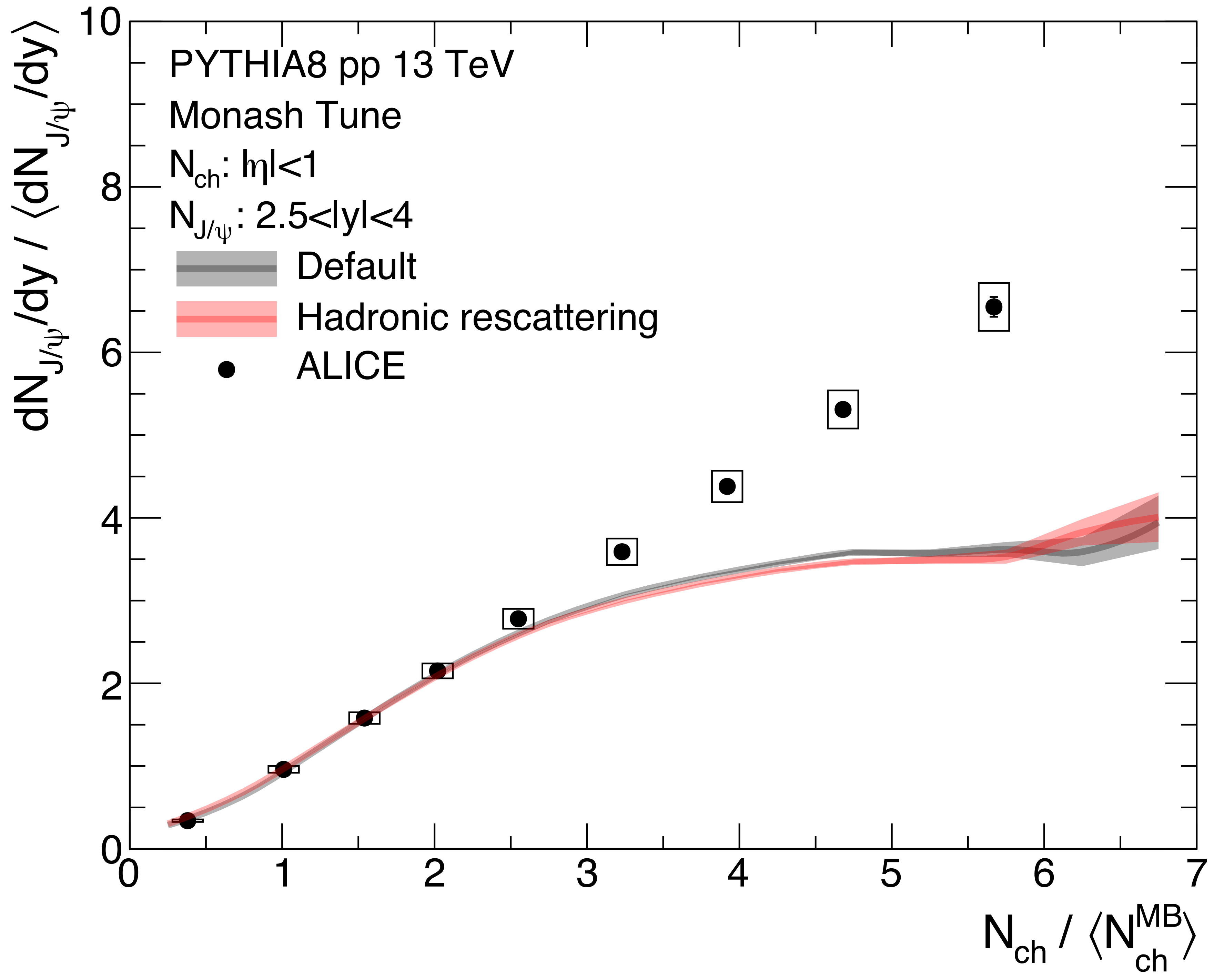




- Compare the **PHENIX result with multiplicity measure at mid-** to STAR* and ALICE*, a weaker dependency is observed
  (***Tracks from J/ψ are included in multiplicity calculation**)
  → Dimuon subtraction is important for multiplicity calculation

4. Discussion - Final-state effect

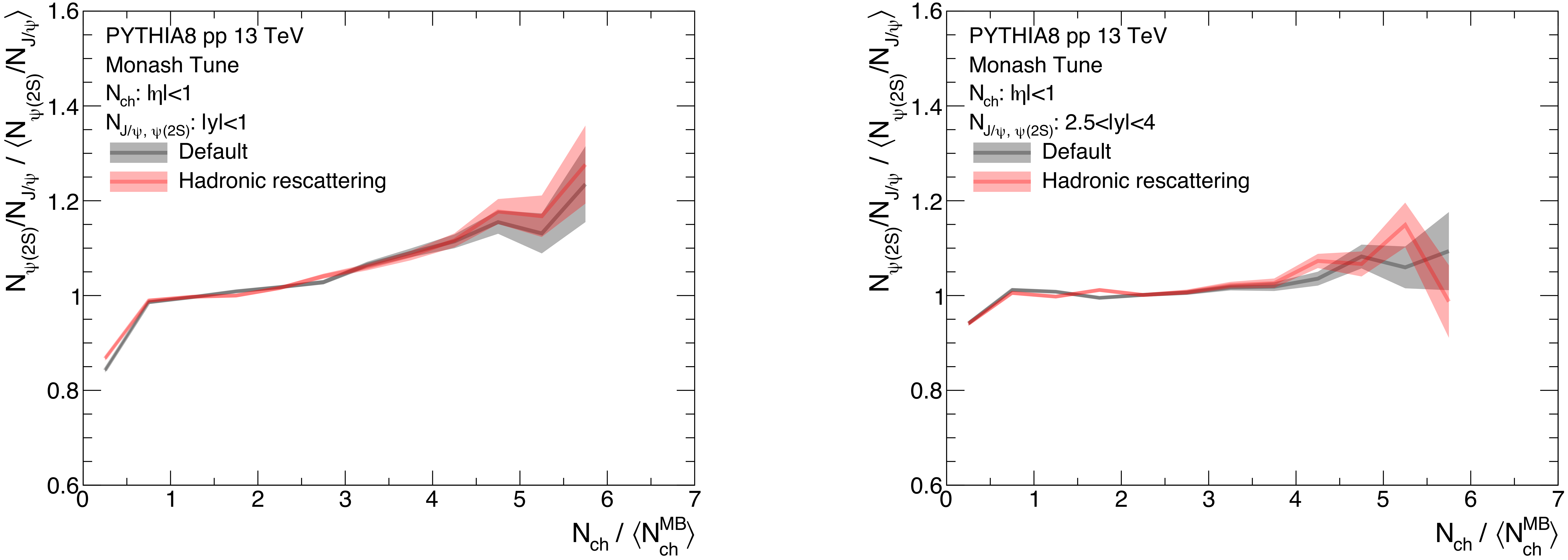




- Recently, an option for the <u>hadronic rescattering</u> was added to PYTHIA8
  → Use this option to check the final-state effect

- In pp at 13 TeV, turn on the hadronic rescattering, a <u>little decrease is seen</u> at high multiplicity

4. Discussion - Final-state effect

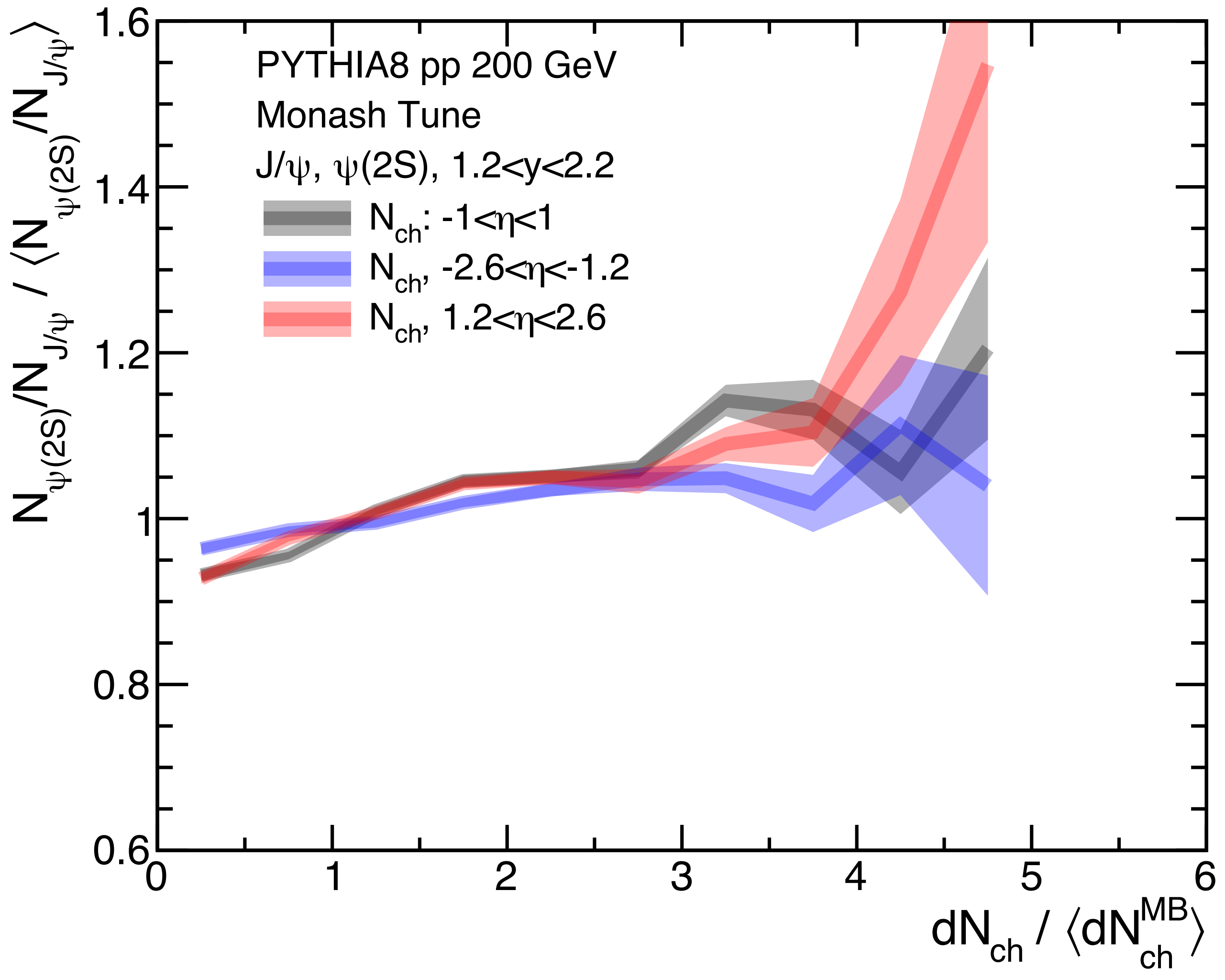


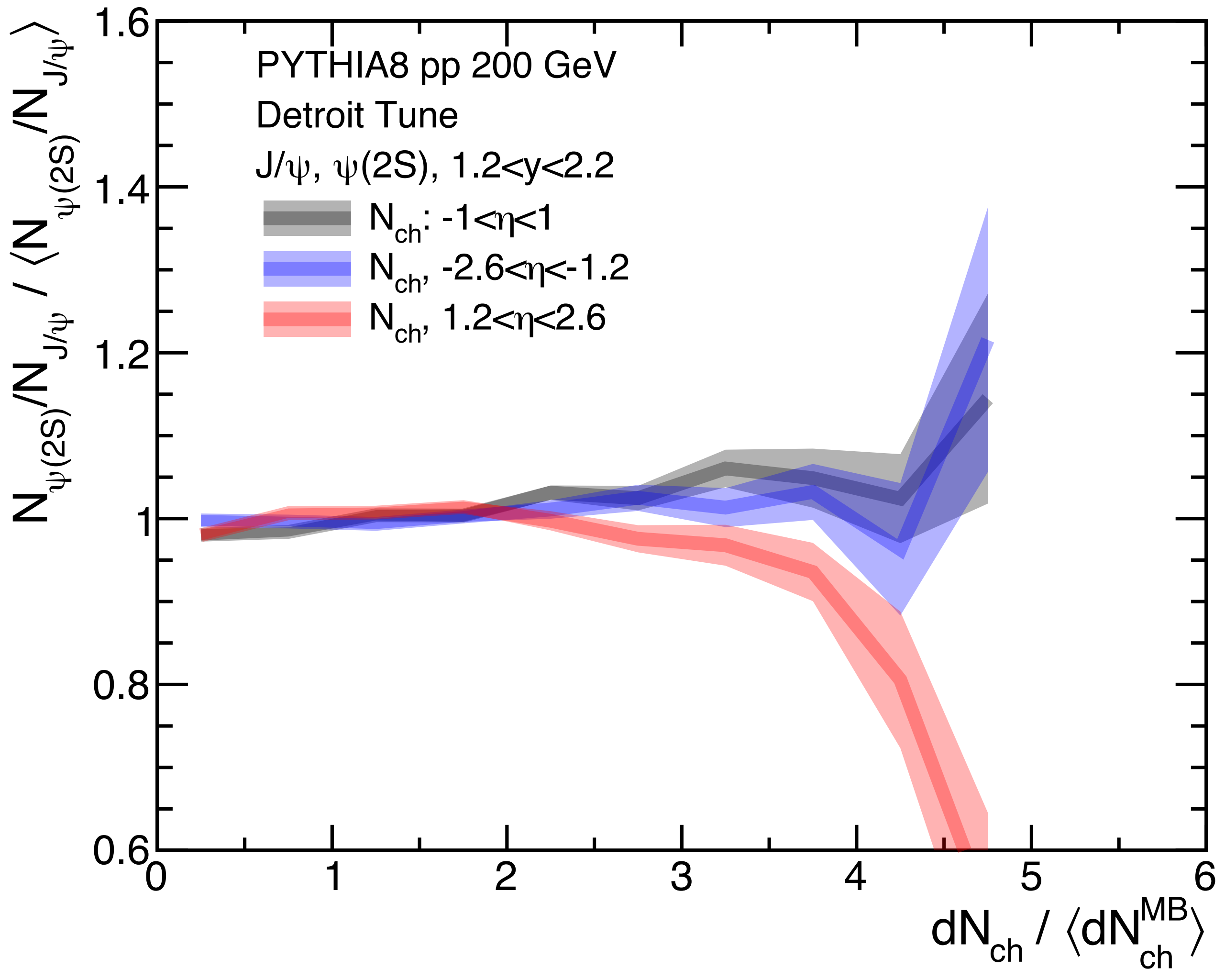
- ψ(2S) is expected to be more easily broken by final-state effects.

- J/ψ and ψ(2S) measured at the same direction or mid-rapidity seems similar results between with and without hadronic rescatterings
  → Same amount effect for J/ψ and ψ(2S)?
  → Hadronic rescattering has a very small effect?

How about pp 200 GeV?

4. Discussion - Final-state effect





J/ψ and ψ(2S) ratio at forward rapidity (1.2<y<2.2)

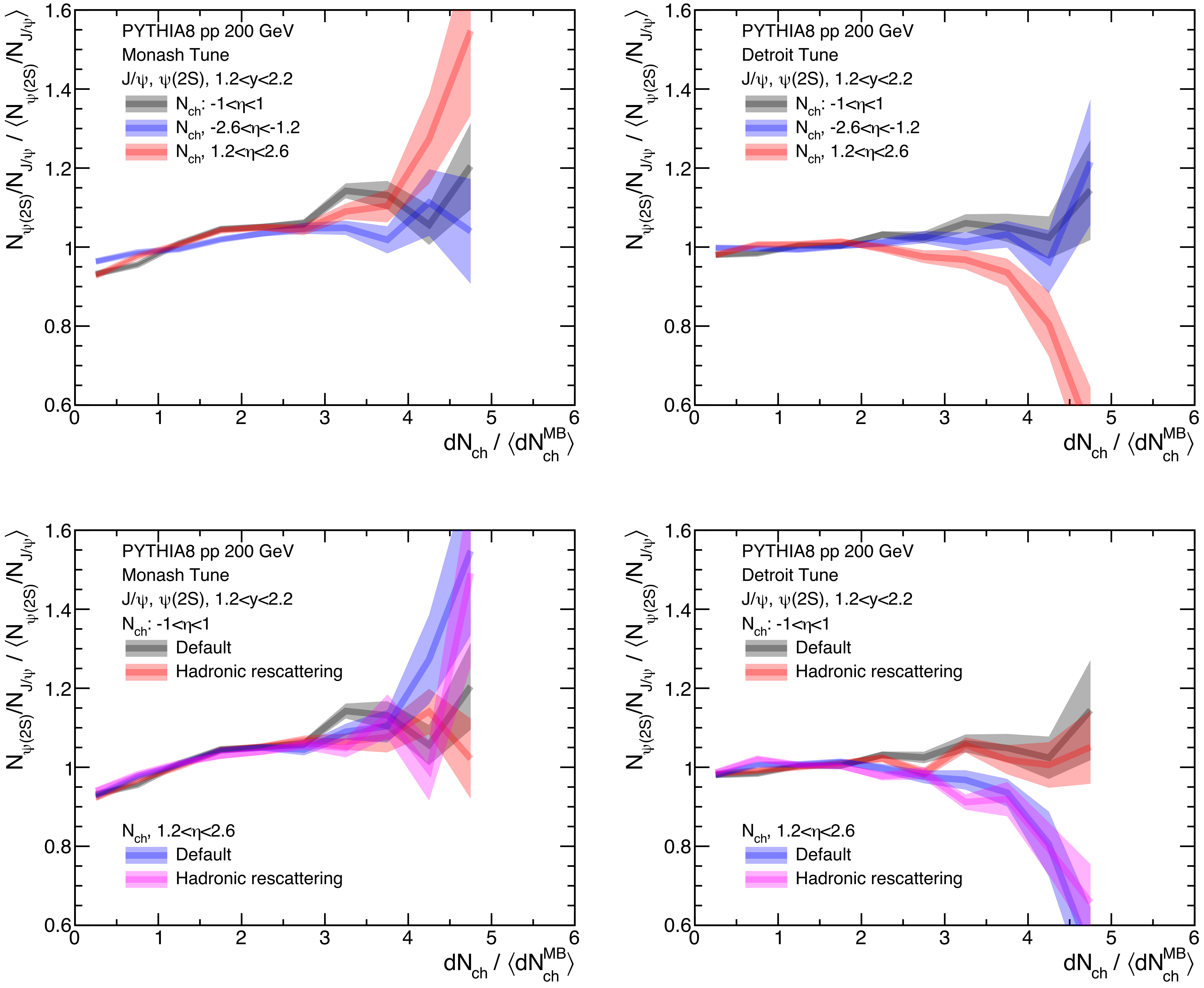
- Monash Tune:

  Slightly increasing J/ψ and ψ(2S) ratio as multiplicity increases

- Detroit Tune:

  Weak multiplicity at mid-rapidity and opposite direction, but a decreasing trend at the high multiplicity for the same direction case

4. Discussion - Final-state effect



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- Monash Tune:
  Slightly increasing J/ψ and ψ(2S) ratio as multiplicity increases

- Detroit Tune:
  Weak multiplicity at mid-rapidity and opposite direction, but a decreasing trend at the high multiplicity for the same direction case

Hadronic rescattering

- Both tunes show no difference with and without the hadronic rescattering option.

5. Summary

1. The study of multiplicity-dependent J/ψ and ψ(2S) production in p+p collisions can provide information on the contribution of MPI processes and final-state effects on quarkonia production

2. J/ψ yield as a function of multiplicity at various acceptances in p+p at 200 GeV has been measured at PHENIX
→ Similar multiplicity dependence with STAR and ALICE when including dimuon contribution to the multiplicity
→ When subtracting the dimuon contribution, the multiplicity dependence decrease and become similar to results with multiplicity calculated at other acceptances Detroit Tune shows a better agreement with the PHENIX data

3. In the comparison with PYTHIA8, the Detroit tune shows a better agreement with the PHENIX results than the Monash tune
→ Hadronic rescatterings in PYTHIA shows no effect at 200 GeV (only small effect at 13 TeV)
→ MPI Effect is important at 200GeV

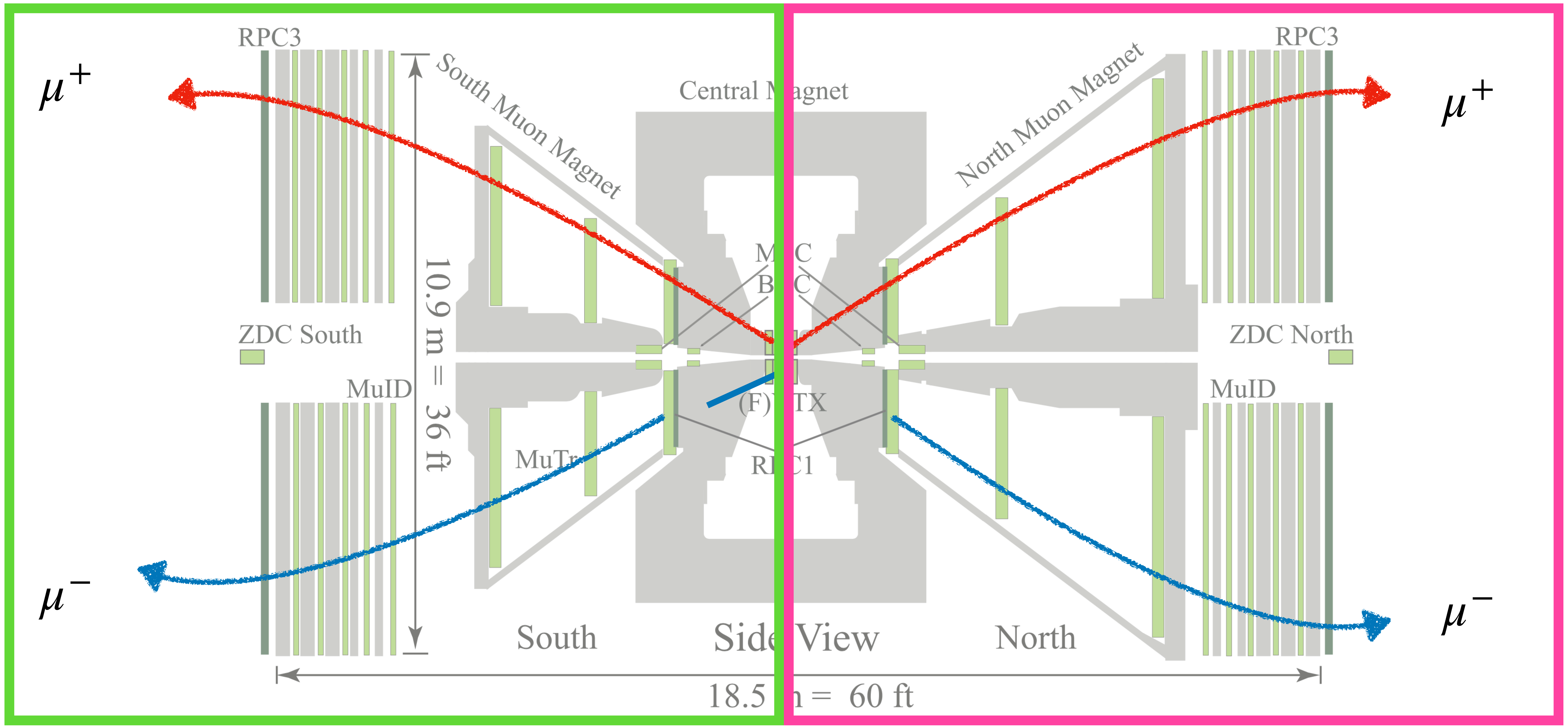
4. Further study can be done with ψ(2S)/J/ψ ratio as a function of multiplicity

Thanks for listening

Back up

Backup - Analysis in PHENIX - ψ(2S) analysis

Case 1

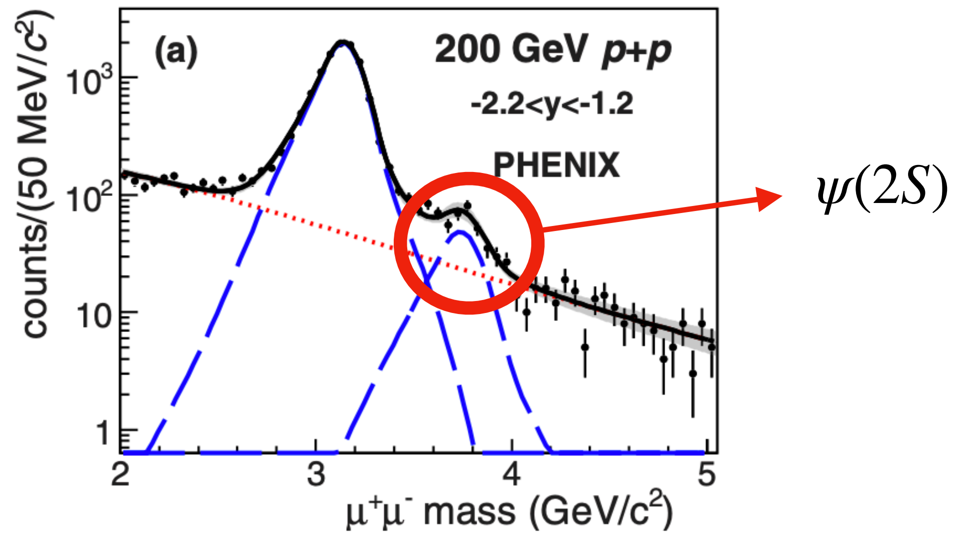


Case 2

- Dimuons that the single muons associated with FVTX tracks show a good mass resolution for $\psi(2S)$ measurement
→ But, statistics become low

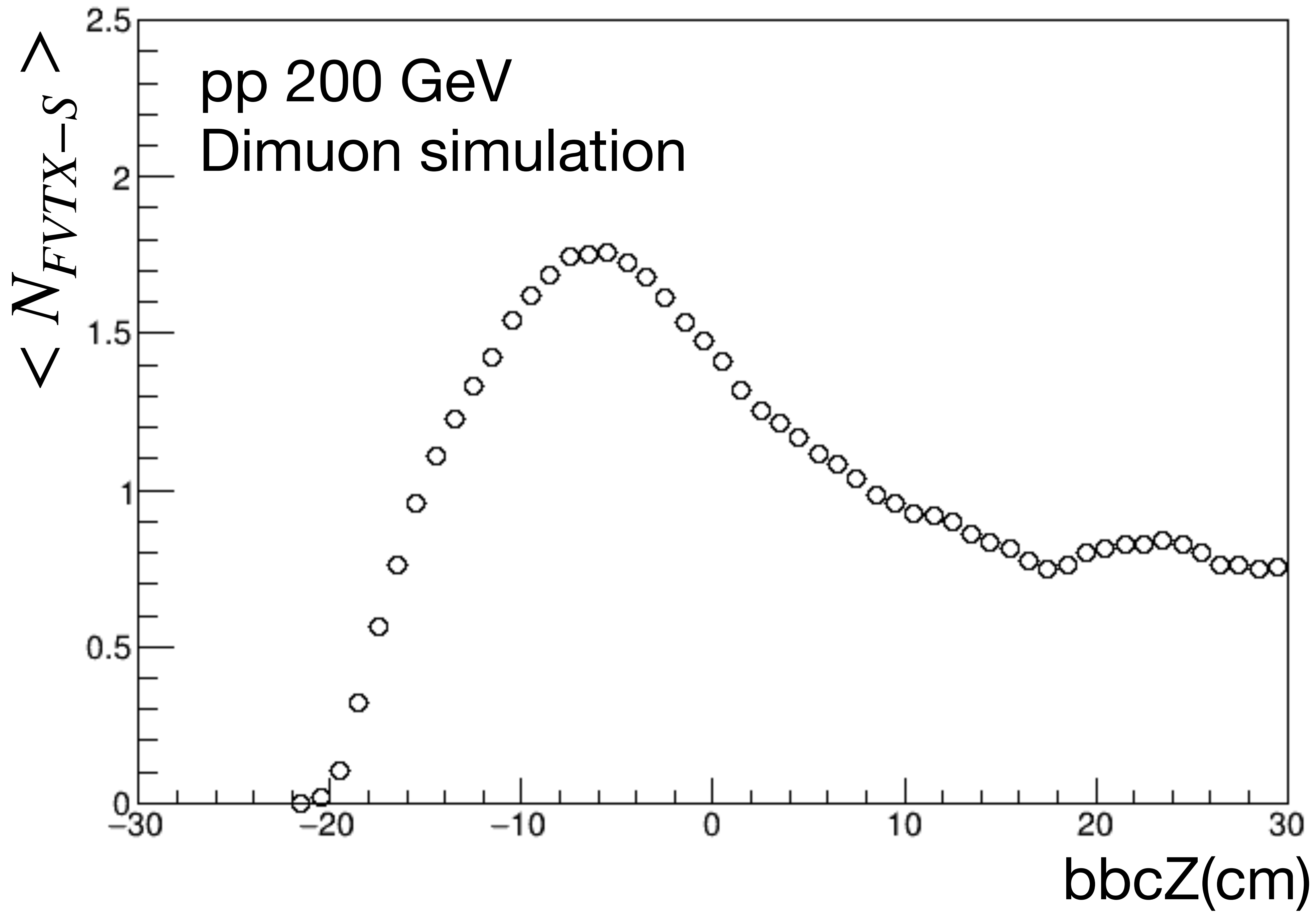
- Recent PHENIX analysis (Phys. Rev. C 95, 034904) showed dimuons of single FVTX matching can be used for ψ(2S) analysis
→ Need to be careful to calculate the multiplicity when subtracting the dimuon contribution

MuTr+FVTX



Phys. Rev. C 95, 034904

Backup - Analysis in PHENIX - Multiplicity calculation



- To subtract the J/ψ (ψ(2S)) contribution from multiplicity in the same direction, use simulation results from the full GEANT4+reconstruction simulation to consider the z-dependent FVTX acceptance and reconstruction efficiency.

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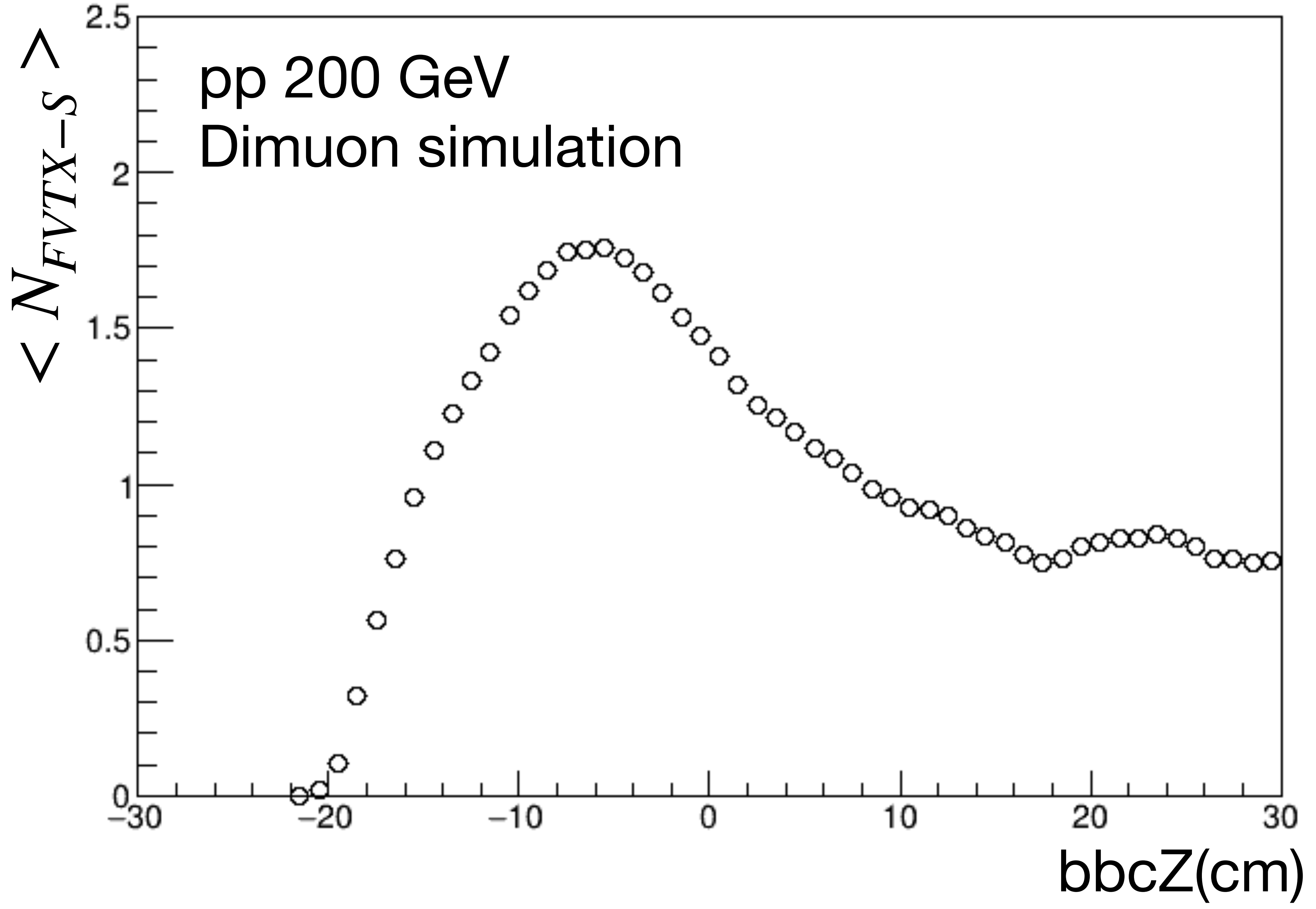

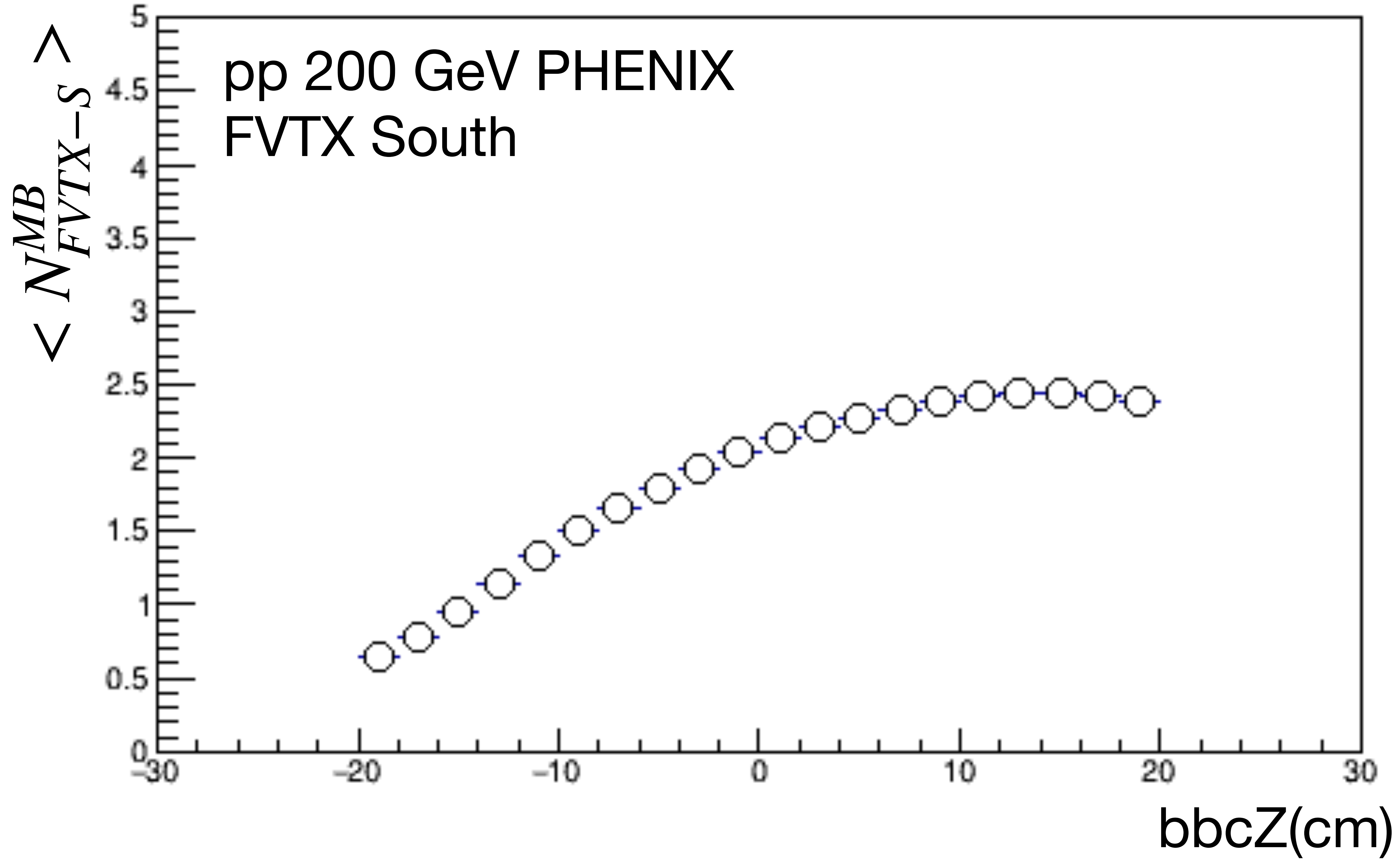

- To subtract the J/ψ (ψ(2S)) contribution from multiplicity in the same direction, use simulation results from the full GEANT4+reconstruction simulation to consider the z-dependent FVTX acceptance and reconstruction efficiency.
- $<N_{MB}>$ in each detector shows a z-vertex dependence
- bbcZ closer to the FVTX's first station (z=-20 cm for South and z=+20 cm for North), <u>the acceptance and reconstruction efficiency decreases</u>

The z-dependent $<N_{MB}>$ will be used to calculate event-by-event N_{MB} / $<N_{MB}>$