Study of multiplicity-dependent charmonia production in p+p collisions at PHENIX

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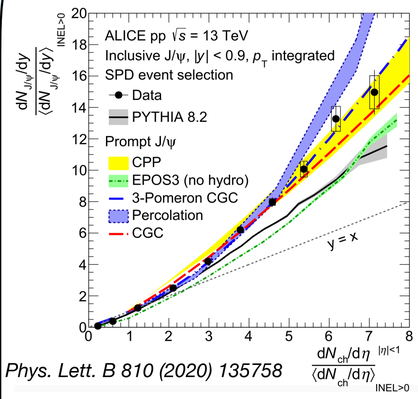
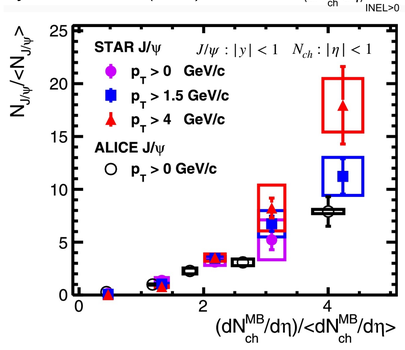
1. Physics motivation



Phys. Lett. B 810 (2020) 135758

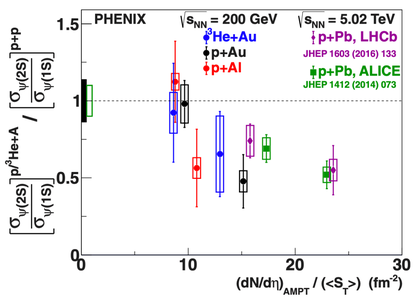


Phys. Lett. B 786 (2018) 87

Initial state effect

- In the ALICE and STAR results,
  J/ψ yield steeply increases
  as <u>charged particle multiplicity increases</u>
  in p+p collisions at 13 TeV and 200 GeV
  → **Multi-parton Interaction is important** for J/ψ production in both energies

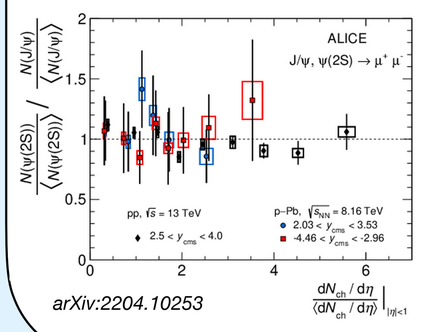
- J/ψ and multiplicity were measured at mid-rapidity in both experiments, and the <u>charged particle multiplicity includes charged tracks of the J/ψ decay products</u>
  →<u>Multiplicity dependence is possibly affected</u> depending on $dN_{ch}/d\eta$ values



Phys. Rev. C 95, 034904 (2017)

Final state effect

- In the left figure *(Phys. Rev. C 95, 034904 (2017))*,
  <u>relative suppression of $\psi(2S)$ than J/ψ</u>
  becomes stronger as the multiplicity density increases in $p/^3He + A$ collisions
  → **Final state effect is also important** for quarkonia production

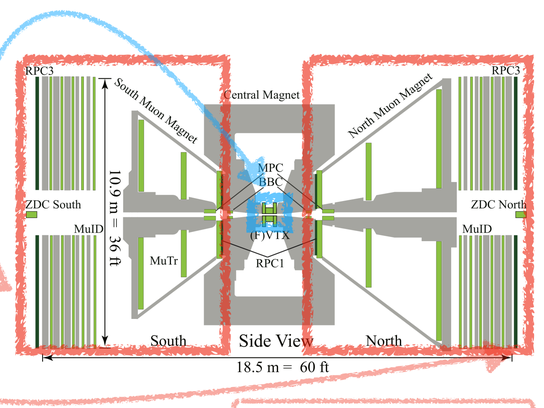


arXiv:2204.10253

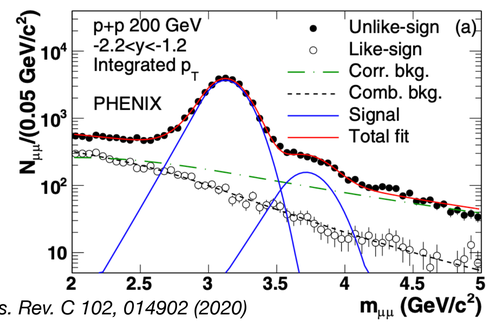
- In the recent ALICE results in $p+p$ and $p+Pb$ collisions, no significant multiplicity dependence is observed

2. Analysis method

- 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
- Acceptance for multiplicity measurement:
  (1)$|\eta|$<1, (2)-3<η<-1, (3)1<η<3
- Acceptance for J/ψ measurement:
  (1)-2.2<y<-1.2, (2)1.2<y<2.2

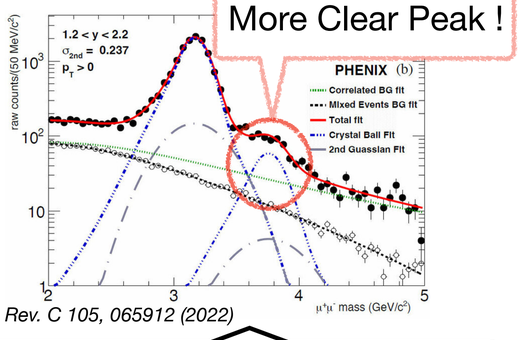


Muon Tracker only:
For high statistics of J/ψ



Phys. Rev. C 102, 014902 (2020)

More Clear Peak !



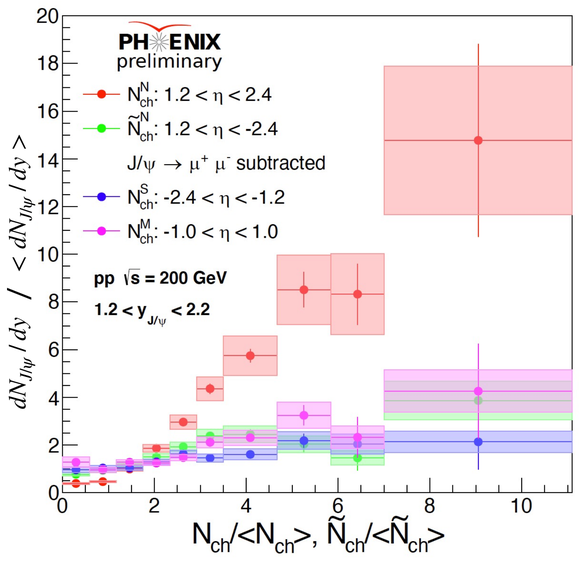
Phys. Rev. C 105, 065912 (2022)

FVTX + Muon tracker : For J/ψ and ψ(2S) ratio

- At lest one MuTr-FVTX matching is required to separate J/ψ and $\psi(2S)$
- Signal shape:
  Crystal ball function and 2nd Gaussian function
- Combinatorial background:
  Mixed events normalized with like-sign
- Correlated background:
  Modified Hagedorn function based on the measurements of correlated dimuons *Phys. Rev. D 99, 072003 (2019)*

3. Results

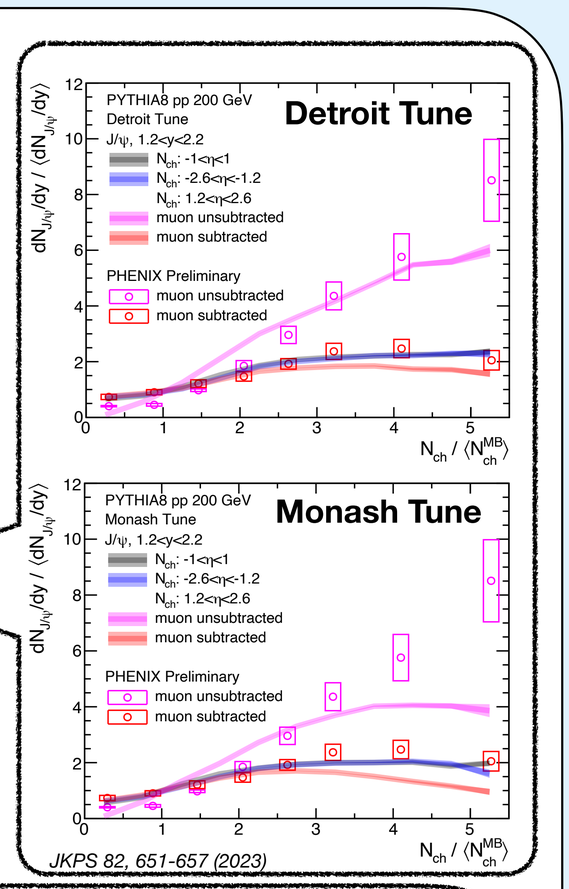
Multiplicity-dependent J/ψ production



- J/ψ and multiplicity at same rapidity (forward rapidity) multiplicity without subtraction of muons from J/ψ
  → <u>More steeply increasing</u> than other results
- Multiplicity with subtraction of muons from J/ψ
  → <u>Weaker multiplicity dependence</u> and similar trend with other results

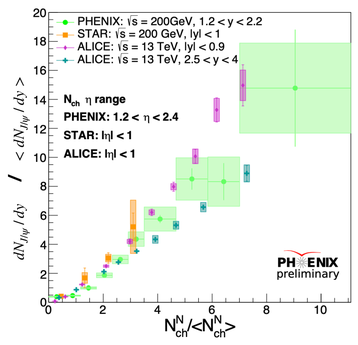
Comparison with PYTHIA8

- PYTHIA with multi-parton interactions can better describe the data
  → **Multi-parton interaction effect is important at 200 GeV**
- Comparison of two tunes:
  Slightly stronger dependence in the Detroit Tune *(Phys. Rev. D 105,016011(2022))*
  for the same acceptance of N_{ch} and J/ψ
- → A better agreement with the Detroit Tune for RHIC energies than the Monash Tune

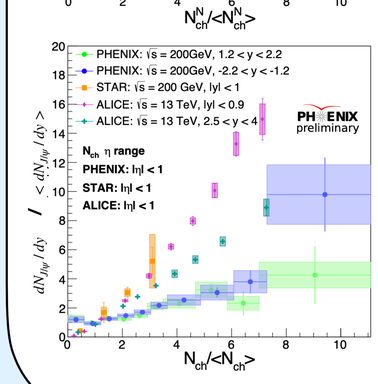


JKPS 82, 651-657 (2023)

Comparison with other results

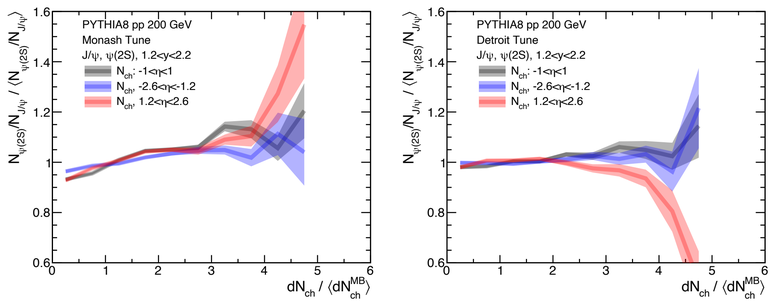


- J/ψ and multiplicity at mid-rapidity
  → <u>A similar dependence</u> is observed in 200 GeV and 13 TeV
  <u>Tracks from J/ψ are included in both results</u> (STAR and ALICE),
  But more <u>significant impact in 200 GeV</u> due to smaller multiplicity
- PHENIX results without subtraction of muons from J/ψ
  → A similar multiplicity dependence with the LHC energies



- After the subtraction of muons from J/ψ
  → Significantly <u>lower multiplicity dependence</u> than
  STAR results (same collision energy, $J/\psi: |y|<1, N_{ch}: |\eta|<1$)
  Considering the muon contribution is very important to interpret the multiplicity dependence
  ALICE results (higher collision energy, $J/\psi: 2.5<y<4, N_{ch}: |\eta|<1$)
  The multiplicity dependence due to multi-parton interaction effect varies with collision energy.

4. Outlook



- Analysis to measure multiplicity-dependent J/ψ and $\psi(2S)$ ratio is ongoing to study final-state effects in p+p collisions
- Two PYTHIA tunes show different multiplicity dependence in the J/ψ and $\psi(2S)$ ratio
  → Another check of the underlying event description