J/ψ production as a function of event multiplicity in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE

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Physics motivation

Why to study J/ψ in pp collisions as a function of event multiplicity?

- Important for QCD studies.
- Charm quarks produced in hard process.
- Reference for A-A collisions.
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- High multiplicity pp events:
  - Is charmonium production dependent of event multiplicity?
  - Is there a contribution from Multiple Parton Interactions (MPI) to charmonium production?
  - Interplay between soft and hard process.
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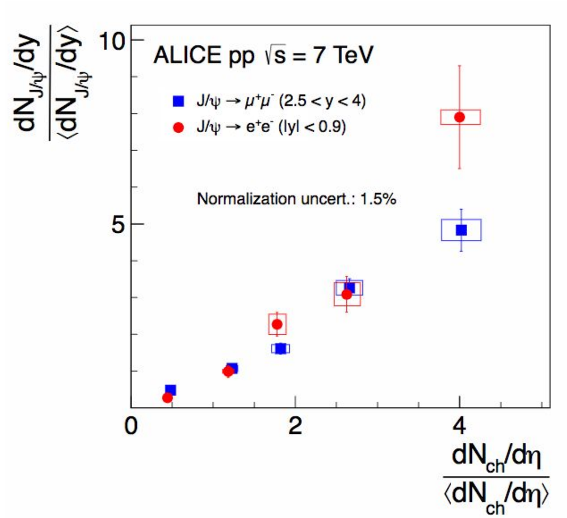
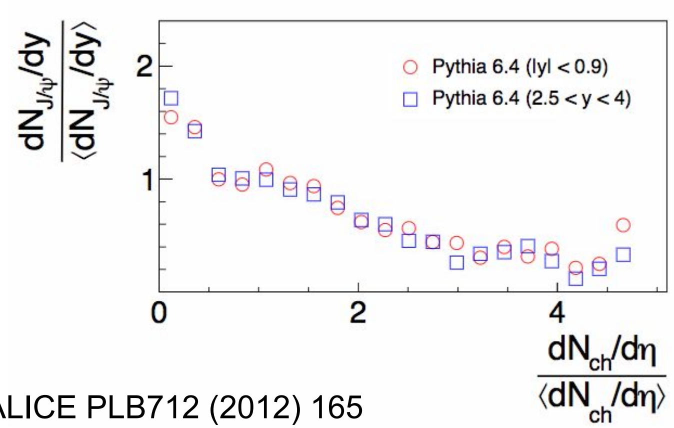
- Is there collective behaviour in high multiplicity pp collisions?
  - Observation of long-range near-side angular correlations in pp collisions (JHEP09 (2010) 091) for charged particles.
  - What about heavy quarks?
    - Charmonium production can give us insights from the hard probes point of view.

Physics motivation

Why to study J/ψ in pp collisions as a function of event multiplicity?





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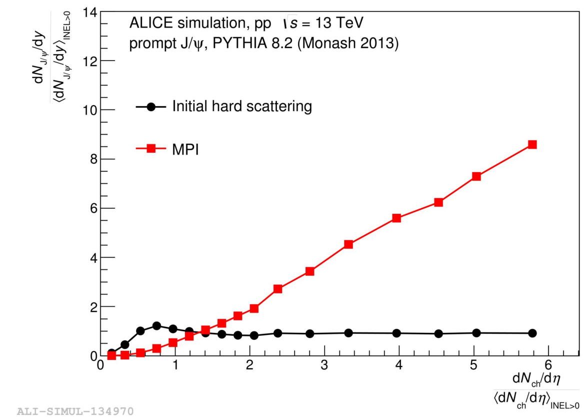
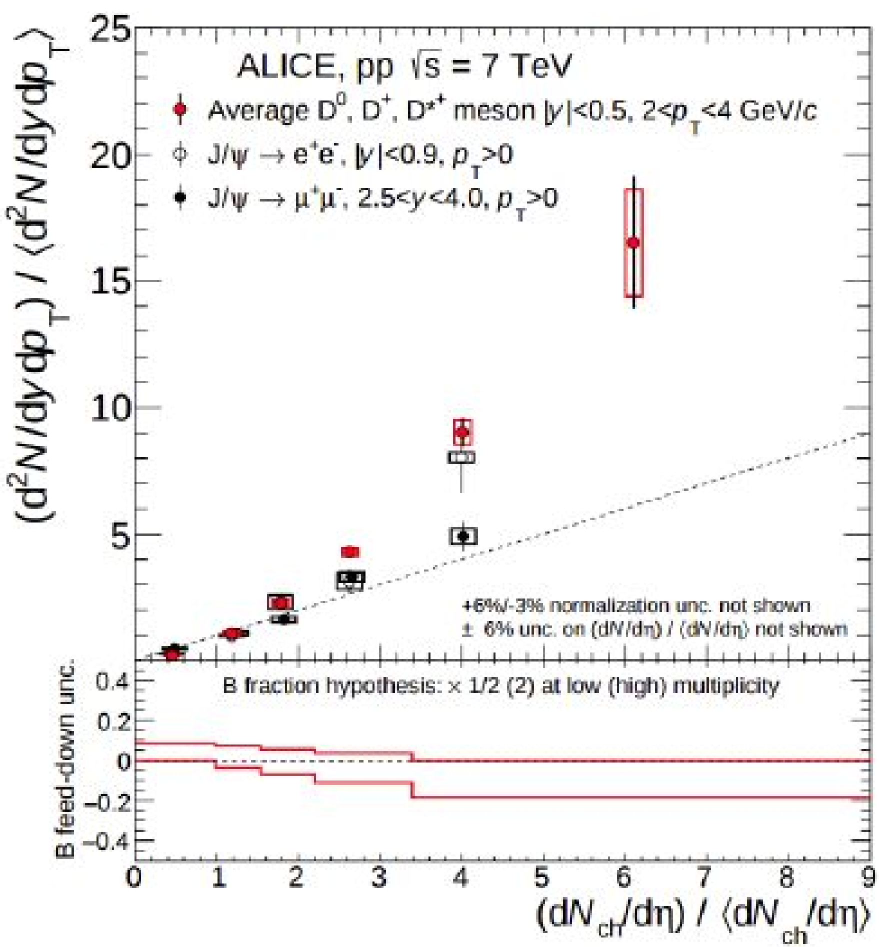


- ❑ Relative J/ψ yield as a function of relative event multiplicity can give us insight about charmonium production in high multiplicity events compared to charged particles production.
  - ❑ Linear trend is observed for pp collisions at $\sqrt{s}$ = 7 TeV.
  - ❑ PYTHIA 6.4 calculations including only NRQCD do not reproduce the results. Suggests importance of other physics processes.
  - ❑ PYTHIA 8.2 including MPI for charmonium production shows a similar trend as seen in data.

Physics motivation

Why to study J/ψ in pp collisions as a function of event multiplicity?

ALICE, JHEP09 (2015) 148



- Similar trend was also observed:
  - D-mesons in pp collisions at $\sqrt{s}$ = 7 TeV.
  - J/ψ at forward rapidity in pp collisions at $\sqrt{s}$ = 7 TeV.

In this work:

- **Same observable measured in pp collisions at $\sqrt{s}$ = 13 TeV:**
  - **Higher p_T bins:**
    - **Using EMCal trigger.**
  - **Higher multiplicity bins:**
    - **High multiplicity trigger.**

The ALICE detector

Quarkonia are studied in mid-rapidity ($|\eta| < 0.9$) and forward rapidity ($-4 < \eta < -2.5$)

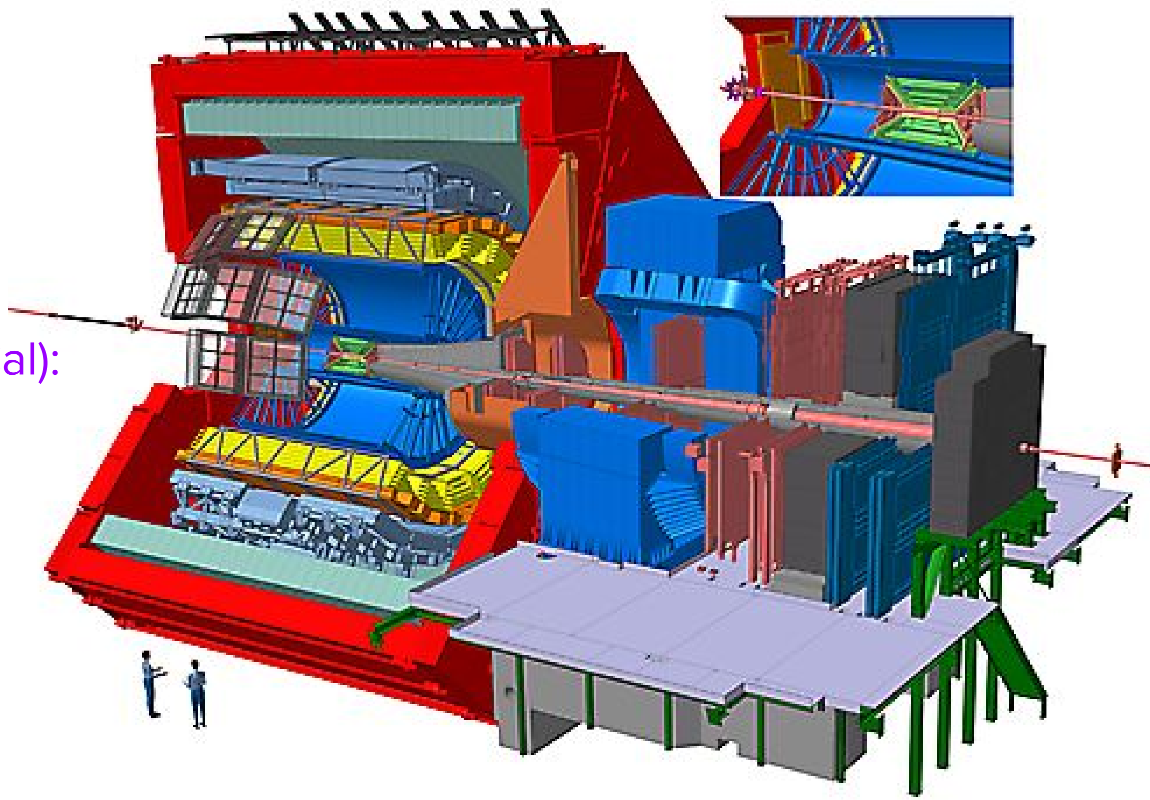
Inner Tracking System (ITS):
- ❑ Vertex determination
- ❑ Tracking
- ❑ Multiplicity estimator (SPD)

Time Projection Chamber (TPC):
- ❑ Tracking
- ❑ PID

ElectroMagnetic Calorimeter (EMCal):
- ❑ PID
- ❑ Trigger

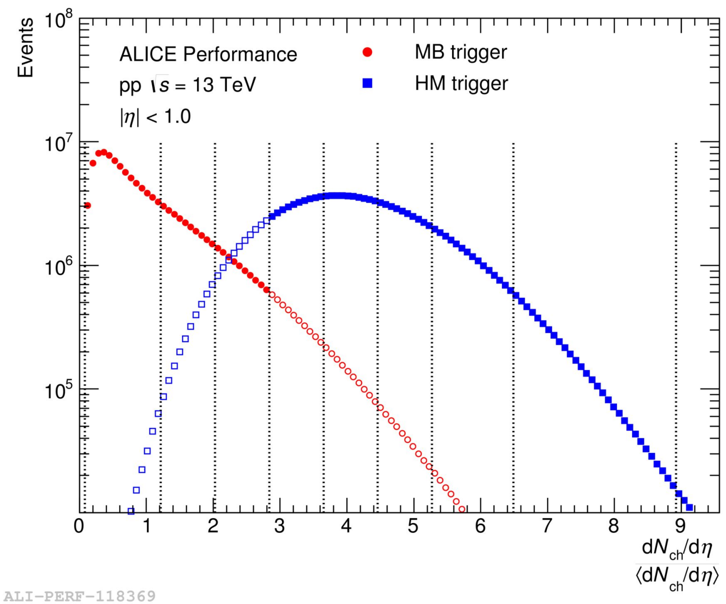
V0:
- ❑ Trigger

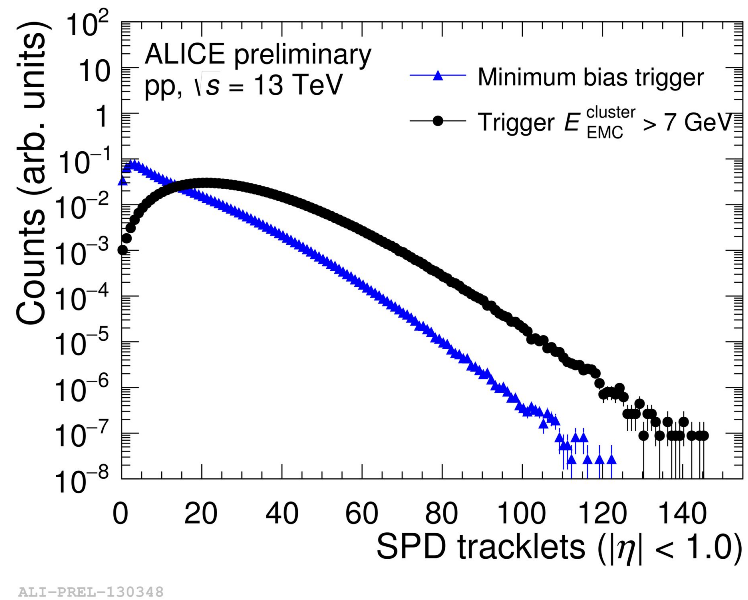
Muon arm:
- ❑ Tracking
- ❑ Trigger



Multiplicity distribution

Multiplicity based on number of tracklets in the innermost layers of ITS.





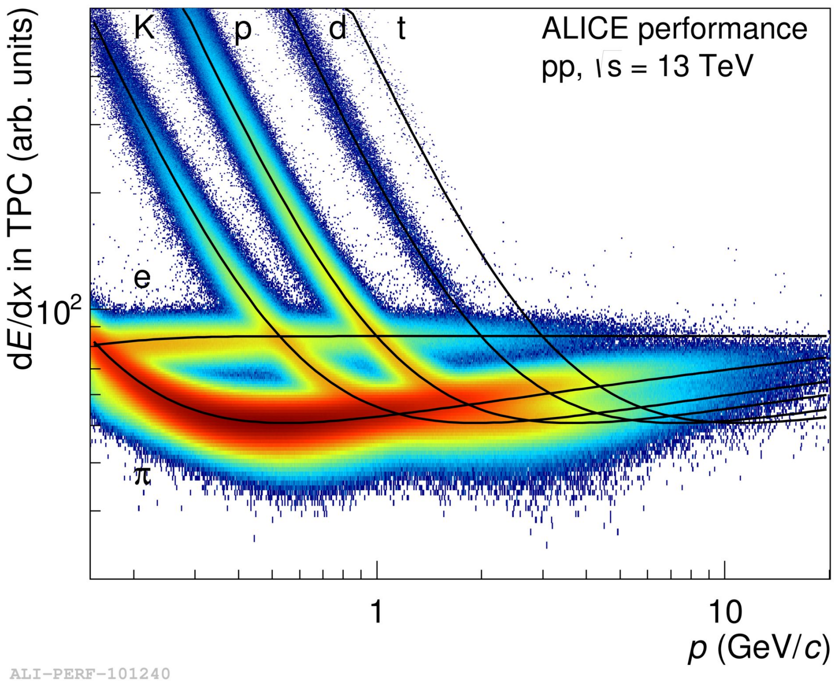
High-Multiplicity (HM) trigger:

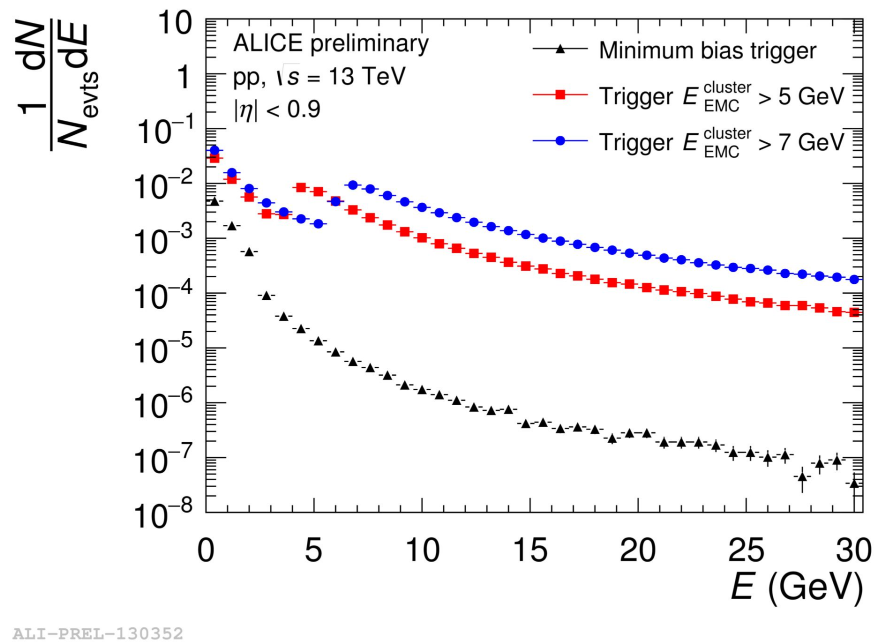
- Based on forward scintillators (V0) to select events with high number of produced particles.
- Extend the multiplicity reach compared to MB.

EMCal trigger:

- Based on energy deposited on EMCal.
- Select high-p_T electrons extending the p_T reach of the measurements.

Electron identification



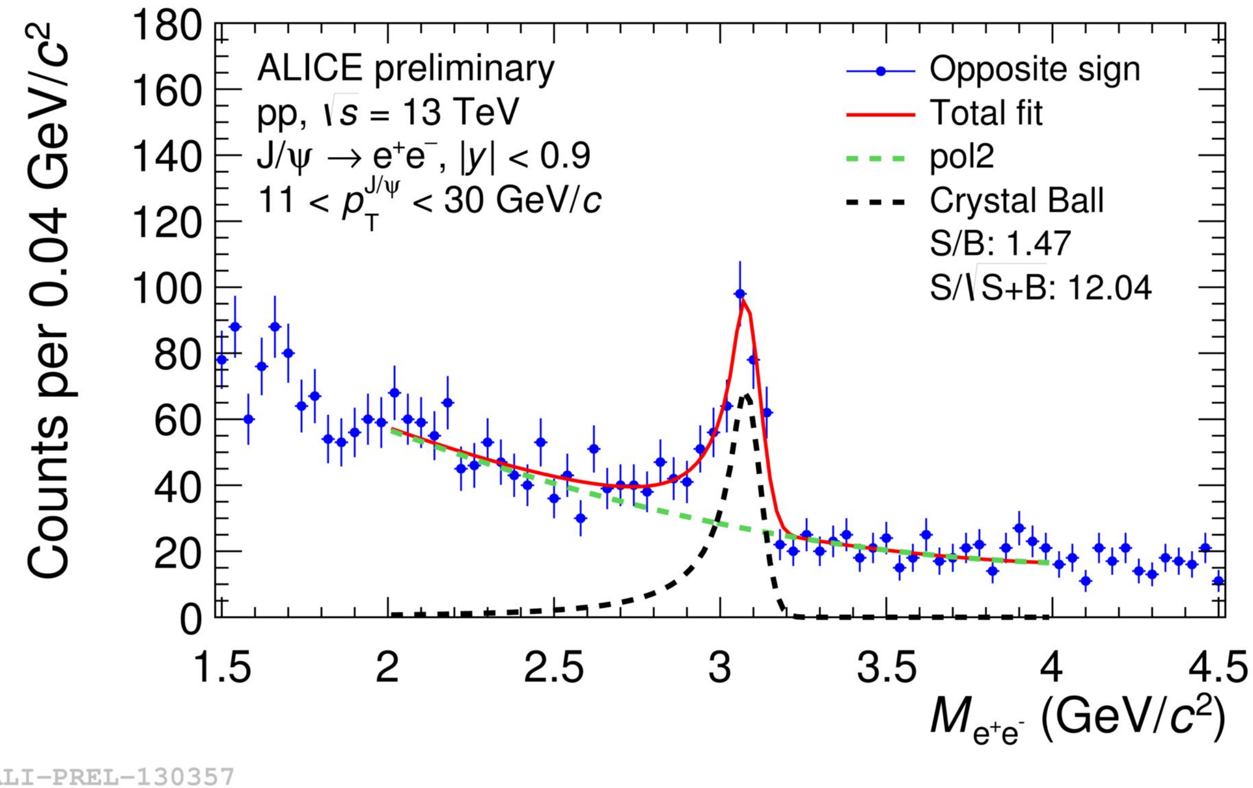


Two different strategies were used:

- ❑ HM trigger and eID using TPC-only (energy loss in the gas).
- ❑ EMCal trigger and eID using TPC+EMCal.

- ❑ EMCal trigger selects events with high-p_T electrons.
- ❑ Two trigger thresholds were used:
  - ❑ $E > 5$ GeV
  - ❑ $E > 7$ GeV
- ❑ Energy in EMCal divided by p from tracks (E/p) is used to separate electrons and hadrons.

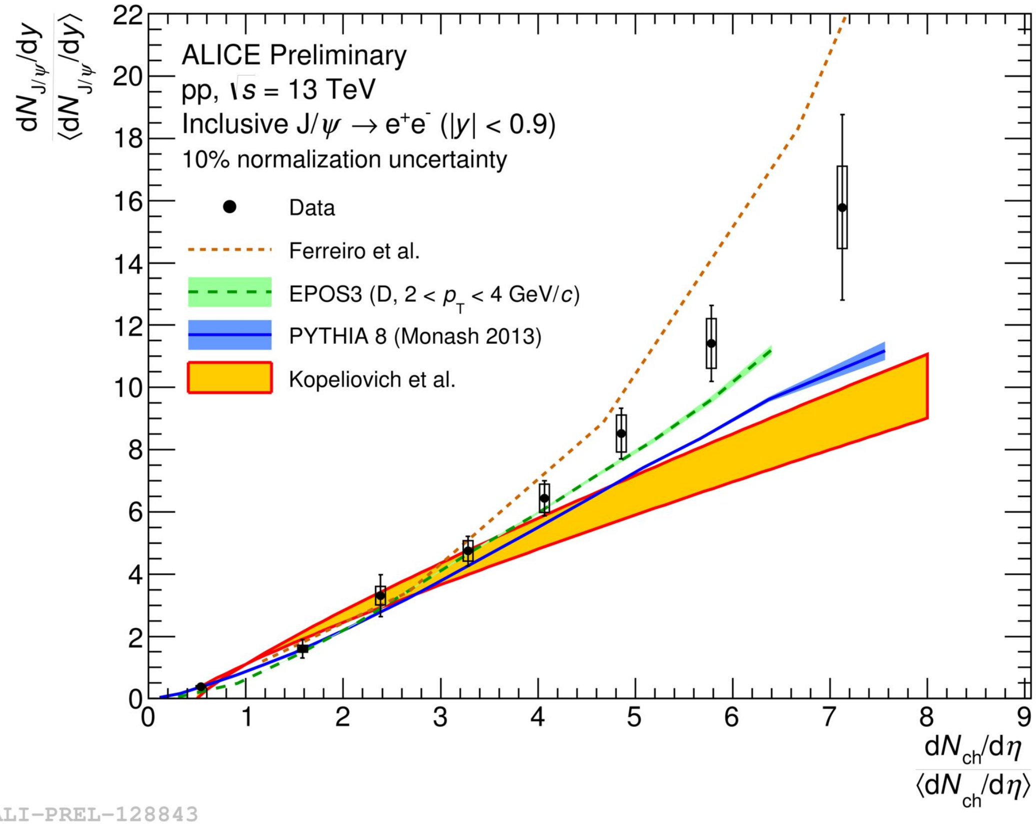
J/ψ reconstruction



- J/ψ reconstructed in the dielectron channel at mid-rapidity.
- Signal extraction based on invariant mass distribution of unlike-sign pairs.
- Background described by event-mixing at low p_T and by a pol2 at high p_T.

J/ψ yield as a function of multiplicity

Relative J/ψ yield as a function of relative charged-particle multiplicity (p_T integrated).



J/ψ yield grows faster than linear. Enhancement qualitatively predicted by different models:

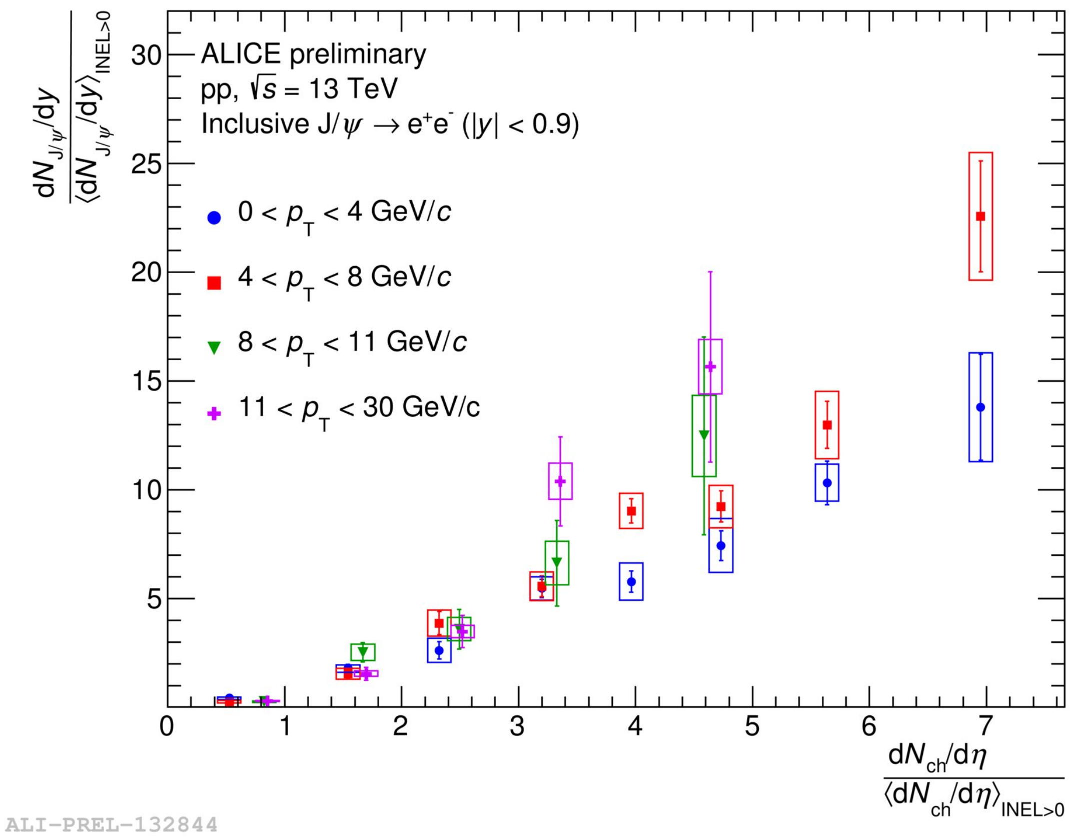
Ferreiro et al: Saturation of soft particle production.
(Ferreiro, Pajares, PRC86 (2012) 034903)

EPOS3: MPI and hydrodynamic expansion of the system.
(Werner et al., Phys.Rept.350 (2001) 93)

PYTHIA8: MPI and saturation of soft particle production via color reconnection.
(Sjostrand et al.,Comput.Phys.Commun.178(2008)852)

Kopeliovich et al: higher Fock states.
(Kopeliovich et al., PRD88 (2013) 116002)

J/ψ yield as a function of multiplicity



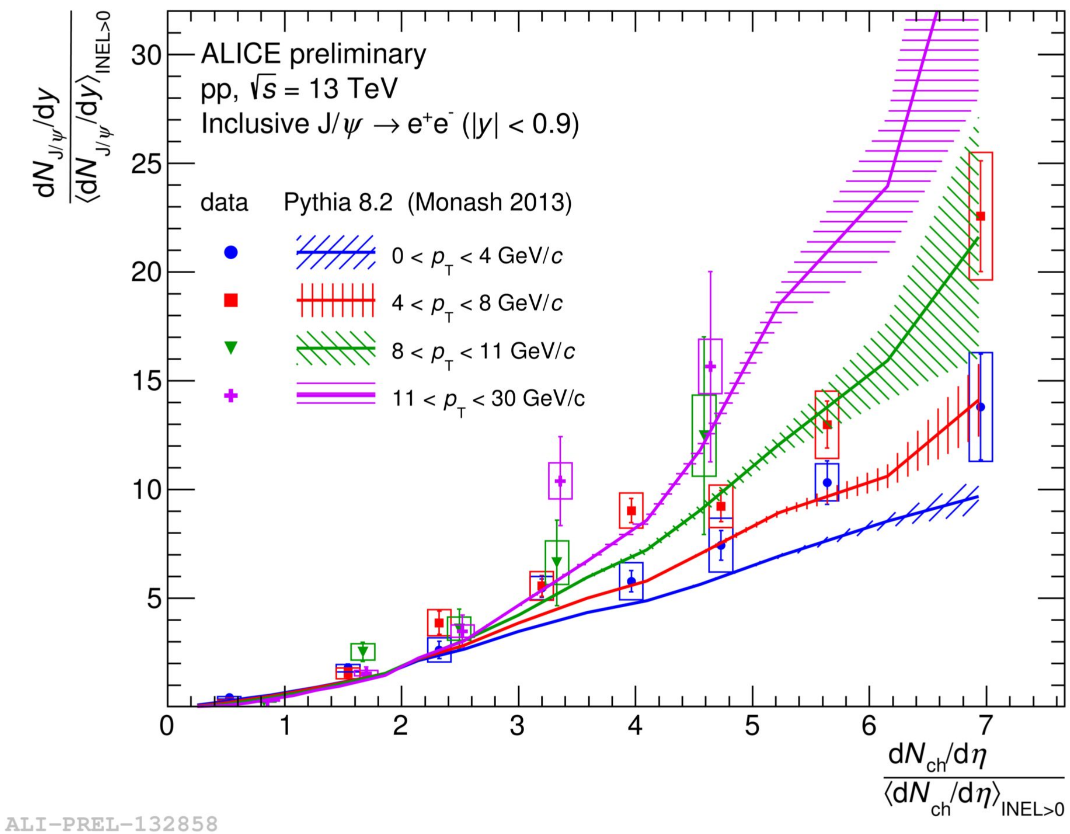
Relative J/ψ yield as a function of relative charged-particle multiplicity measured in four p_T bins.

- Low p_T: HM trigger and TPC-only for eID.
- High p_T: EMCal trigger and TPC+EMCal for eID.

J/ψ yield grows faster than linear

Indication that the enhancement is stronger for high p_T intervals.

J/ψ yield as a function of multiplicity

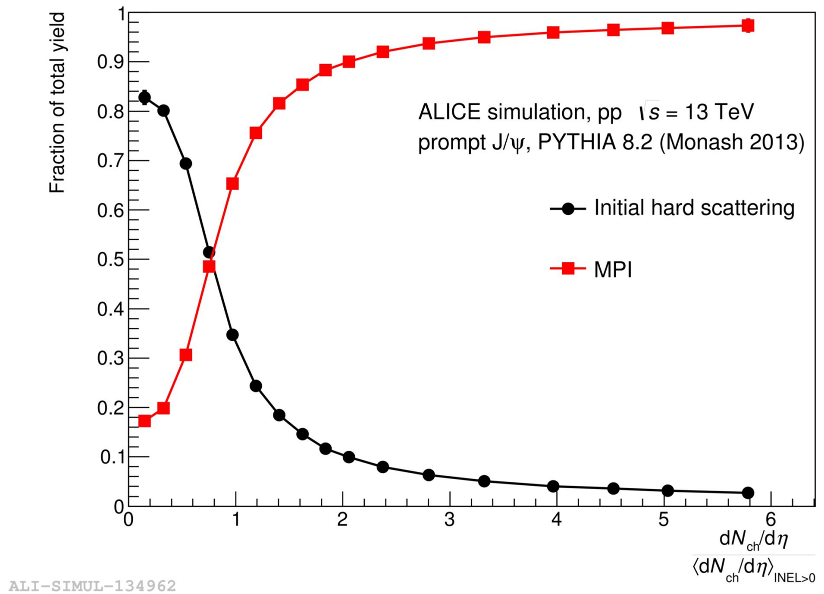


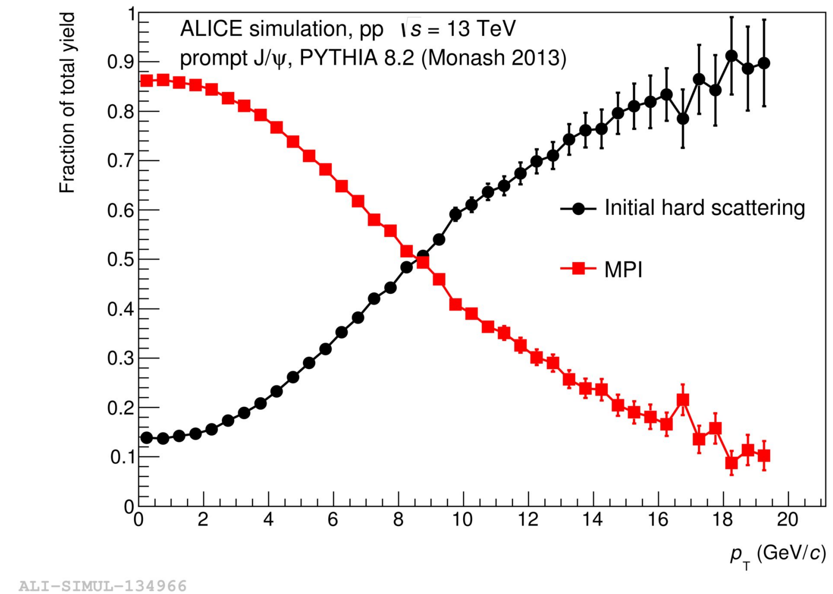
Relative J/ψ yield as a function of relative charged-particle multiplicity measured in four p_T bins: comparison with PYTHIA8.2 predictions.

PYTHIA8.2 shows similar trend as observed in data.

Hint that MPI plays a role in charmonium production.

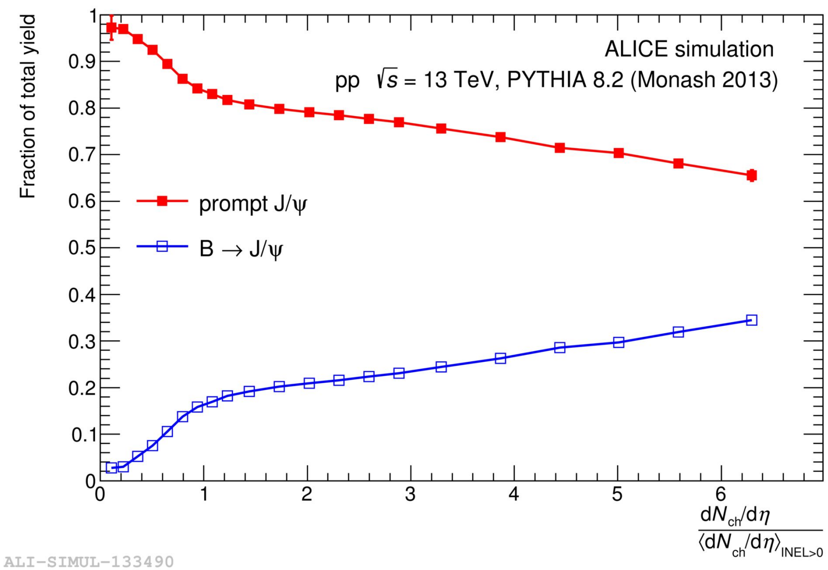
J/ψ yield in PYTHIA8.2 simulations

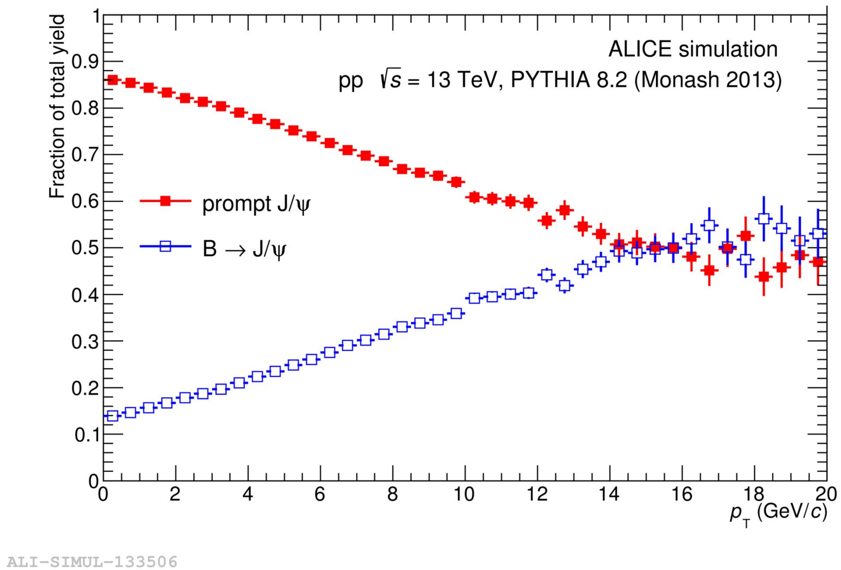




- MPI is the dominant process for J/ψ production at high multiplicity and at low p_T.
- Initial hard scattering is dominant for low multiplicity and high p_T.

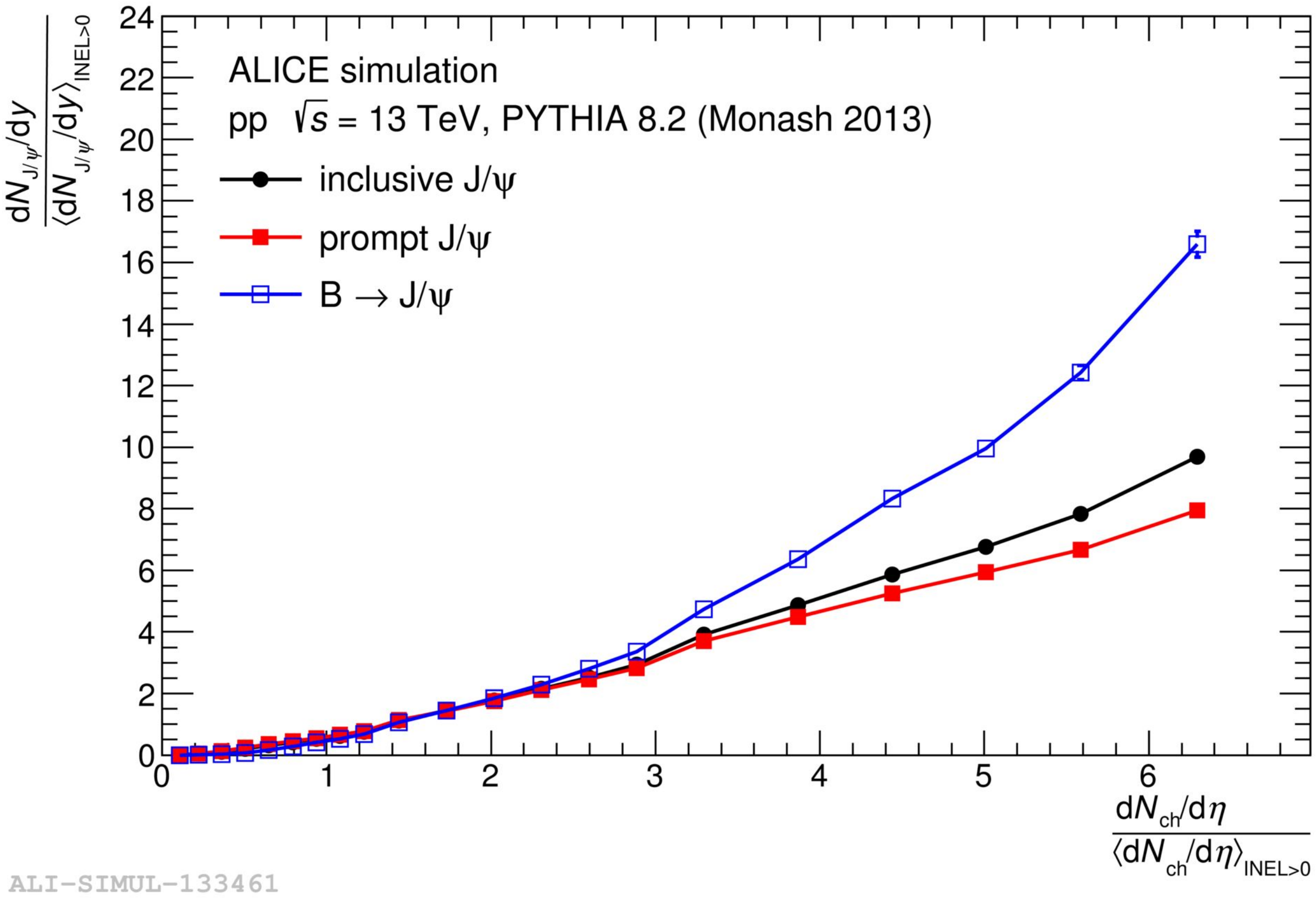
J/ψ yield in PYTHIA8.2 simulations





- Prompt J/ψ yield is dominant for the multiplicity range studied.
- Prompt J/ψ yield is dominant for p_T up to 14 GeV/c.

J/ψ yield in PYTHIA8.2 simulations



- Non-prompt J/ψ yield grows faster than prompt J/ψ.
- Separation of prompt and non-prompt components in data would give a better interpretation of the results.

Conclusions

- The self-normalized inclusive J/ψ yield as a function of self-normalized charged-particle multiplicity was measured in pp collisions at 13 TeV.

- The results indicate an enhancement of J/ψ yield as a function of self-normalized charged-particle multiplicity stronger than linear.

  - Indication of stronger rise at high p_T.
  - Qualitatively predicted by PYTHIA8.

- This hints to an important role of multiple interactions at the parton level for charm production in hadron-hadron collisions.

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Thank you very much!