Event activity dependent quarkonium production in pp collisions with ALICE at the LHC

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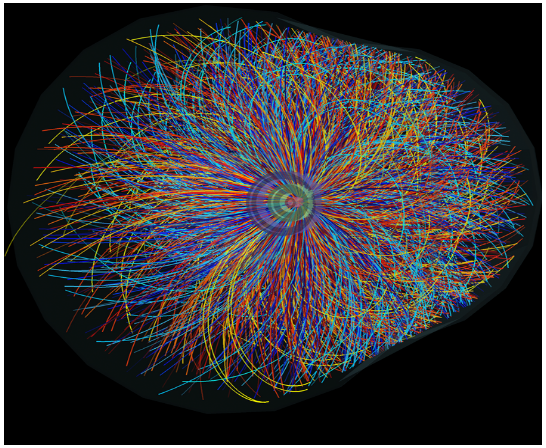
- Physics motivation
- The ALICE Detector
- Results and discussion
- Conclusion



The 4th China LHC Physics Workshop (CLHCP 2018)
Dec. 19-22, Wuhan, China

Physics motivation

Multiplicity dependence of quarkonium production in small systems

- Production mechanism
- Study the role of multiple parton interaction
- Interplay between soft and hard processes

J/ψ yield vs. multiplicity in pp at 13 TeV

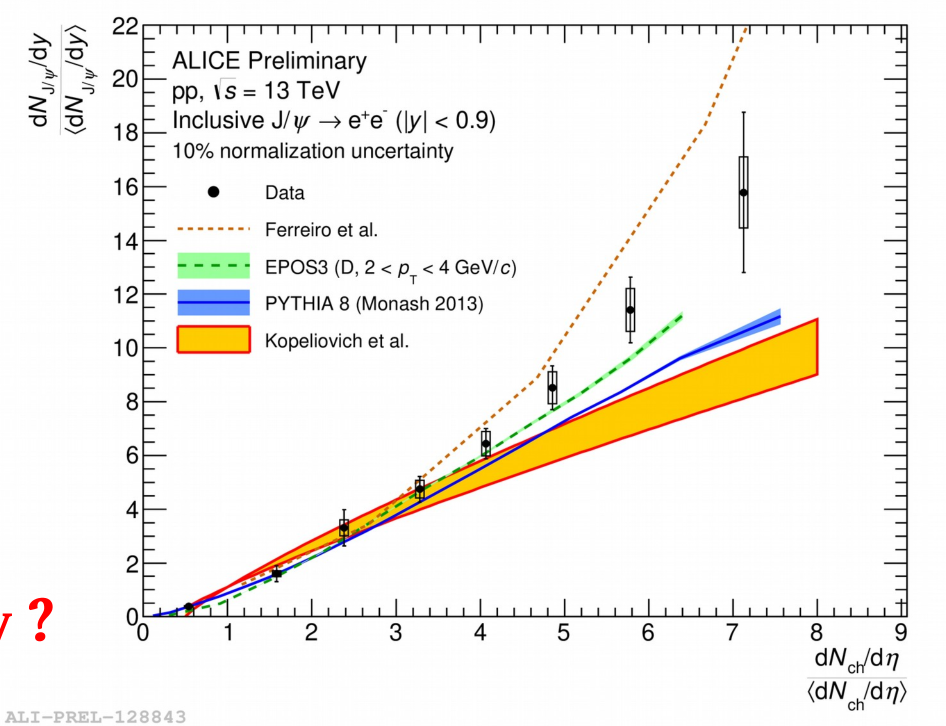
Linear increase:

- Multiple parton interaction

Faster than linear increase:

- Gluon saturation
- Color reconnection

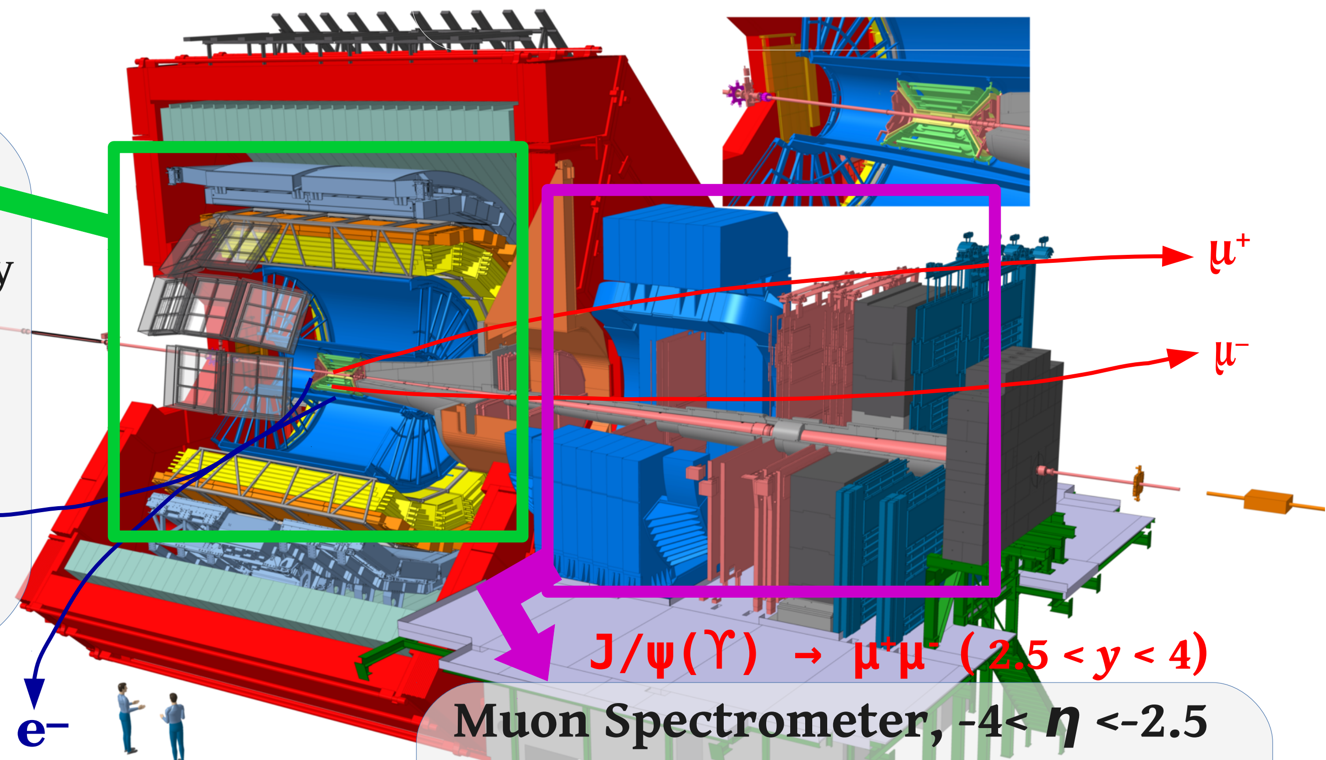
Hint of hot-medium at high multiplicity ?



The ALICE Detector

Charged-particle multiplicity is measured using the number of SPD (the first two layers of the ITS) tracklets in $|\eta| < 1$

Quarkonia are studied at:
Mid-rapidity: $|y| < 0.9$
Forward rapidity: $2.5 < y < 4$



Central barrel, $|\eta| < 0.9$

- ITS:
  - Tracking, vertexing, multiplicity
- TPC:
  - Tracking, PID
- EMCal:
  - High-p_T electrons
  - Triggering
  - PID

$J/\psi \rightarrow e^+e^-$ $(|y| < 0.9)$

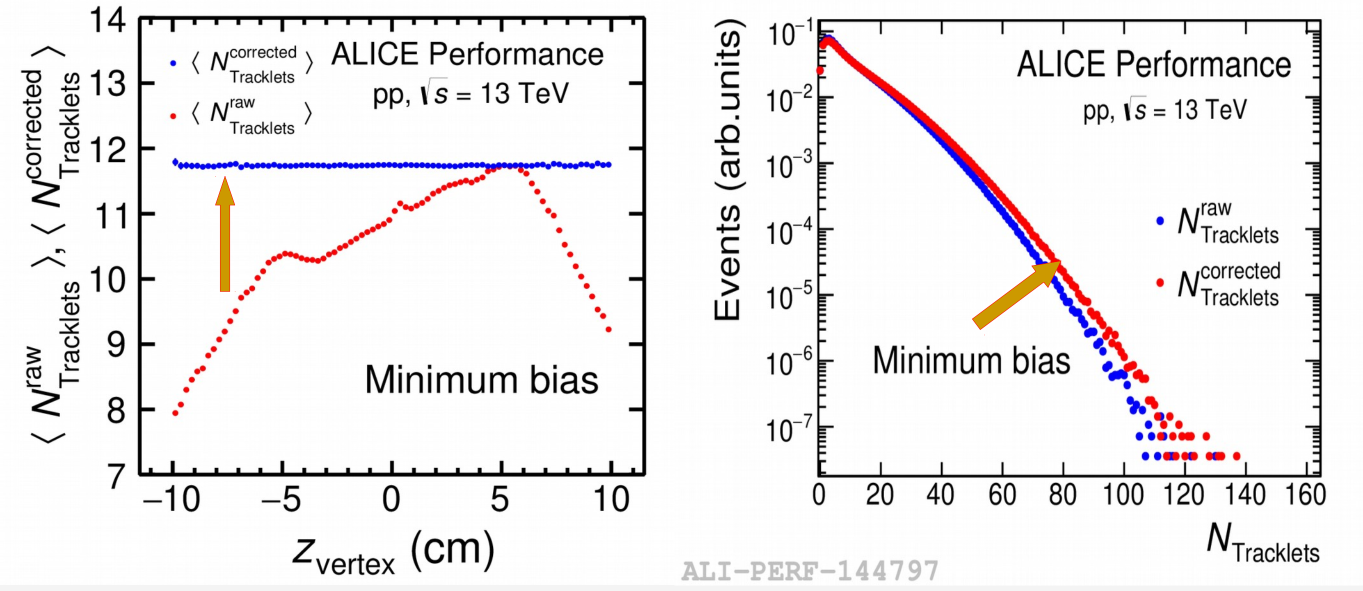
Muon Spectrometer, $-4 < \eta < -2.5$

- Muon Tracker
- Muon Identifier (triggering)
- Open heavy flavours and quarkonia
- W/Z bosons
- Low mass resonances

Smaller detectors

- V0, T0, ZDC...
- Event activity characterization

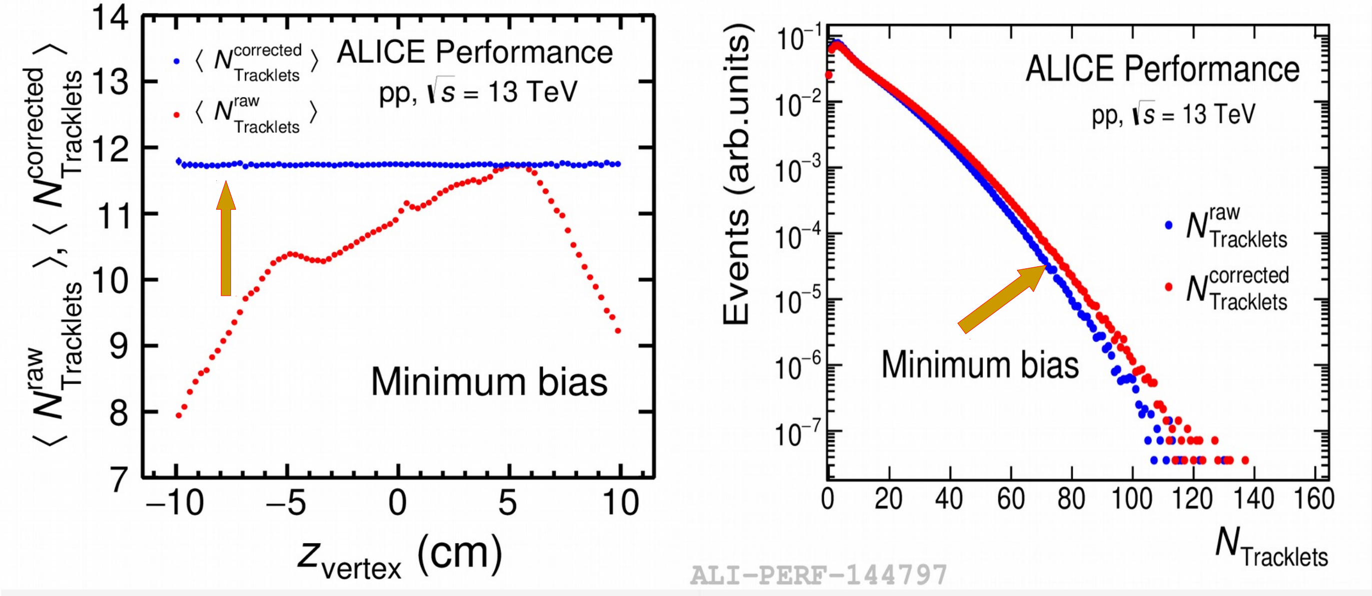
Multiplicity estimation



Correction for detector inefficiency

- Data-driven method
  - ➔ Equalize acceptance× efficiency along the *z*-vertex direction

Multiplicity estimation



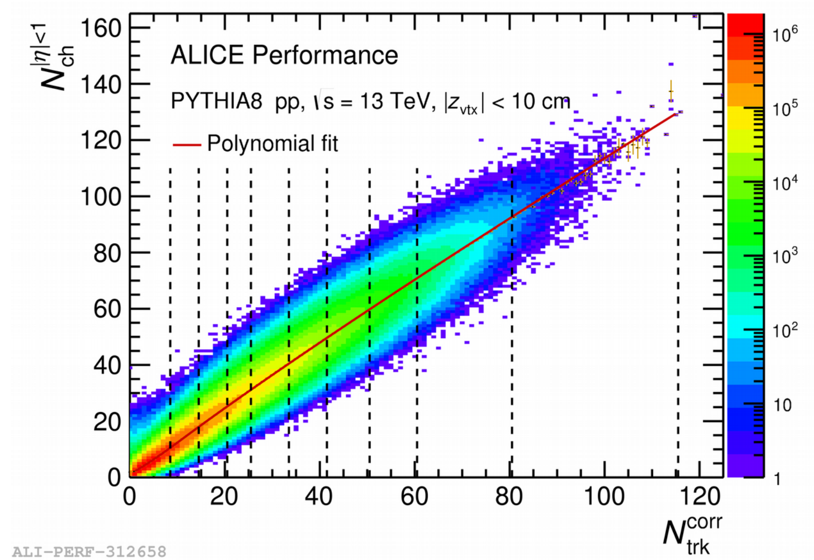
Correction for detector inefficiency

- Data-driven method
  - ➔ Equalize acceptance× efficiency along the *z*-vertex direction

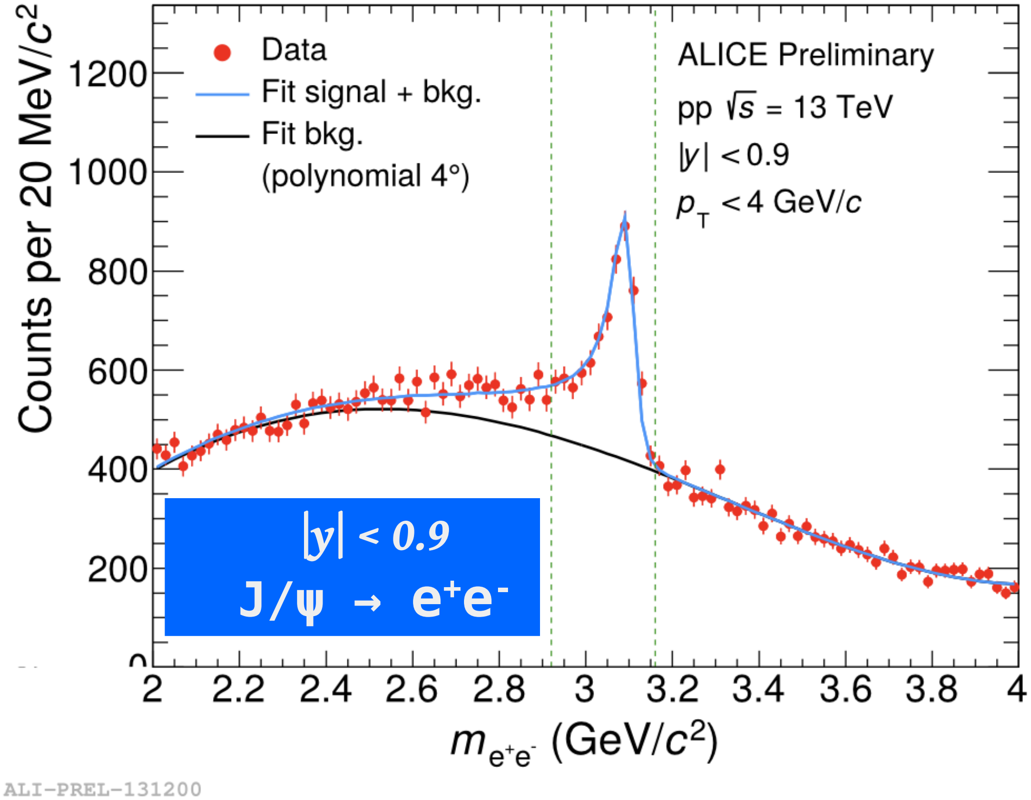
Tracklet-to-charged-particle conversion

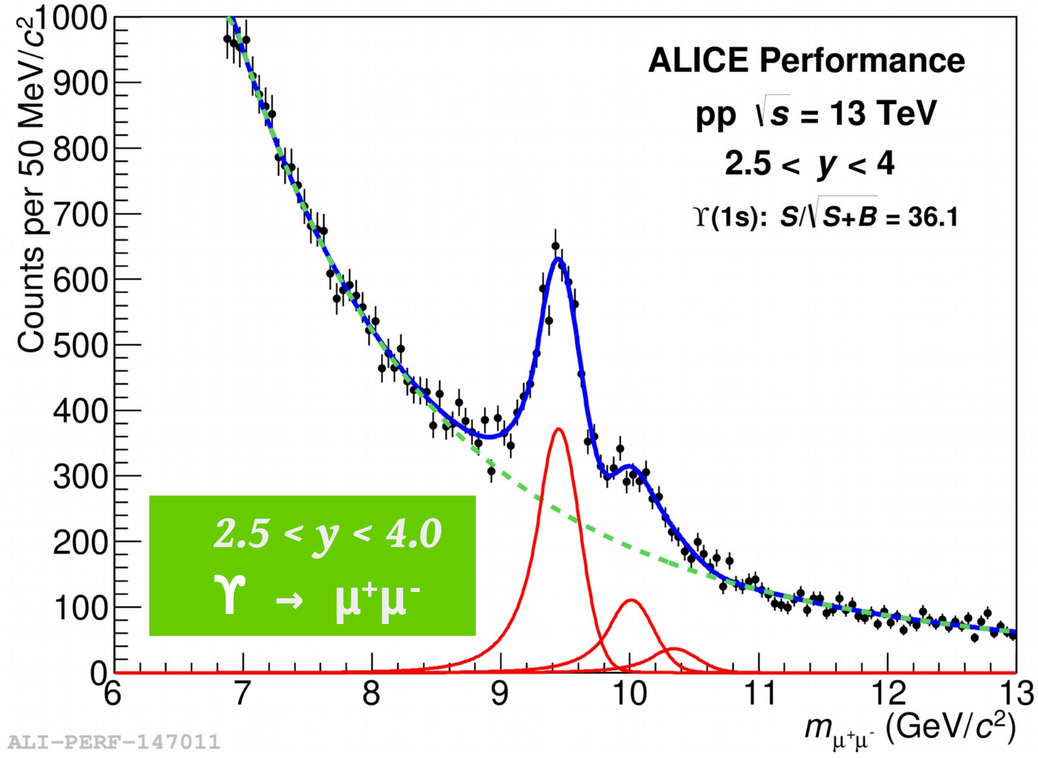
$$\langle N^{i}_{ch} \rangle = \alpha_i \times \langle N^{cor,i}_{trk} \rangle$$

- Based on simulations which reproduce the realistic detector transport



Signal extraction

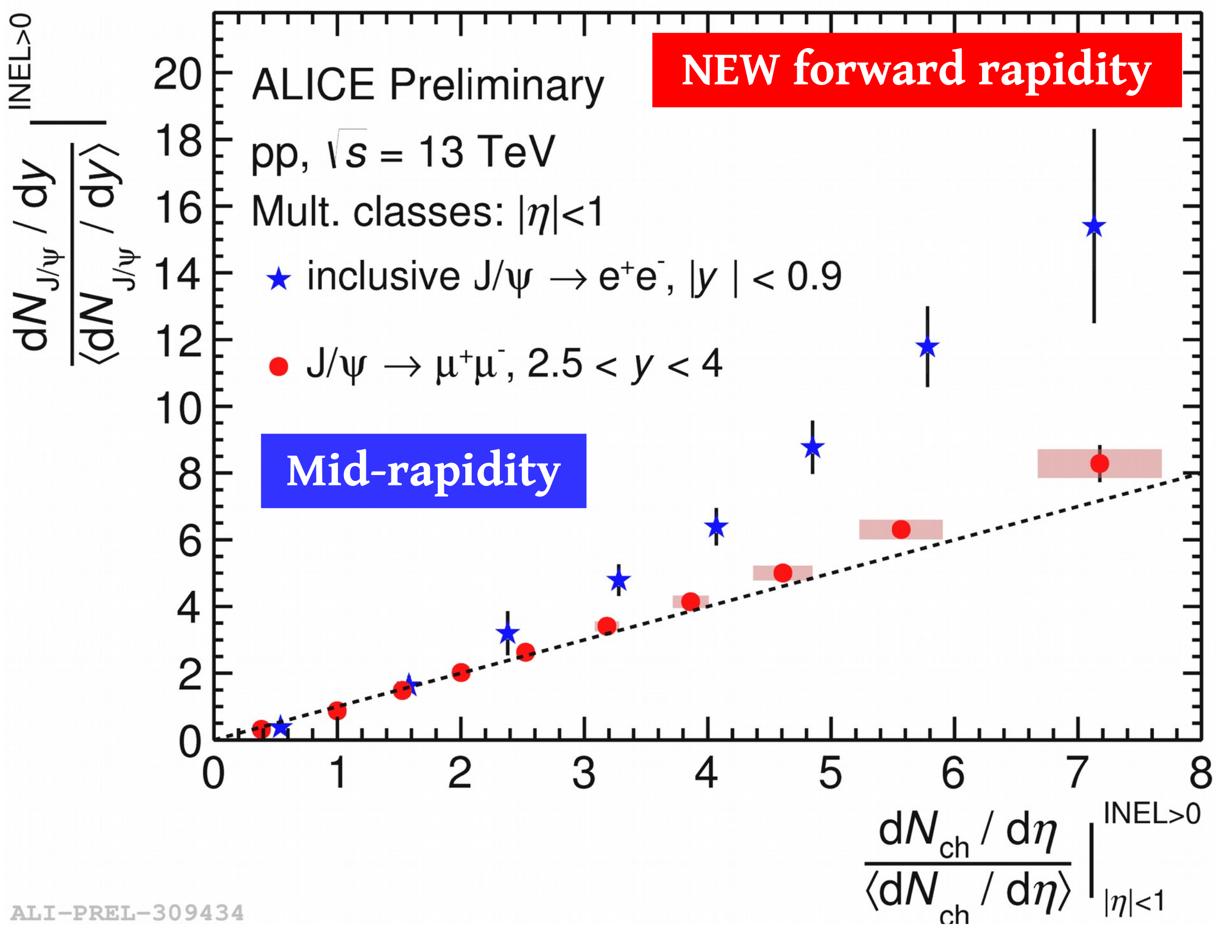


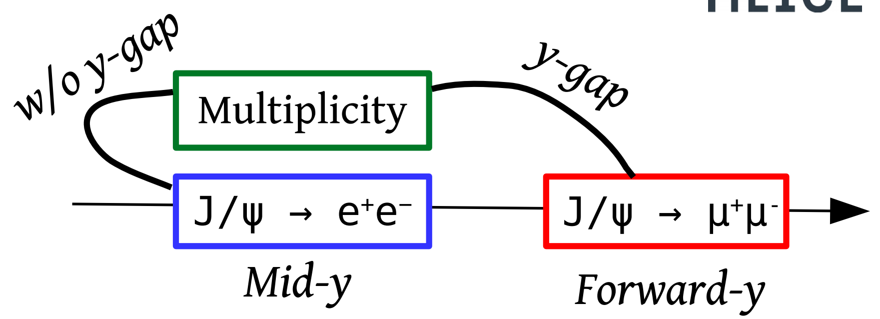


- Clear signal peak at both mid-rapidity and forward rapidity
- A combined fit is applied to disentangle signal and background

J/ψ production vs. event multiplicity

Mid-rapidity vs. forward rapidity

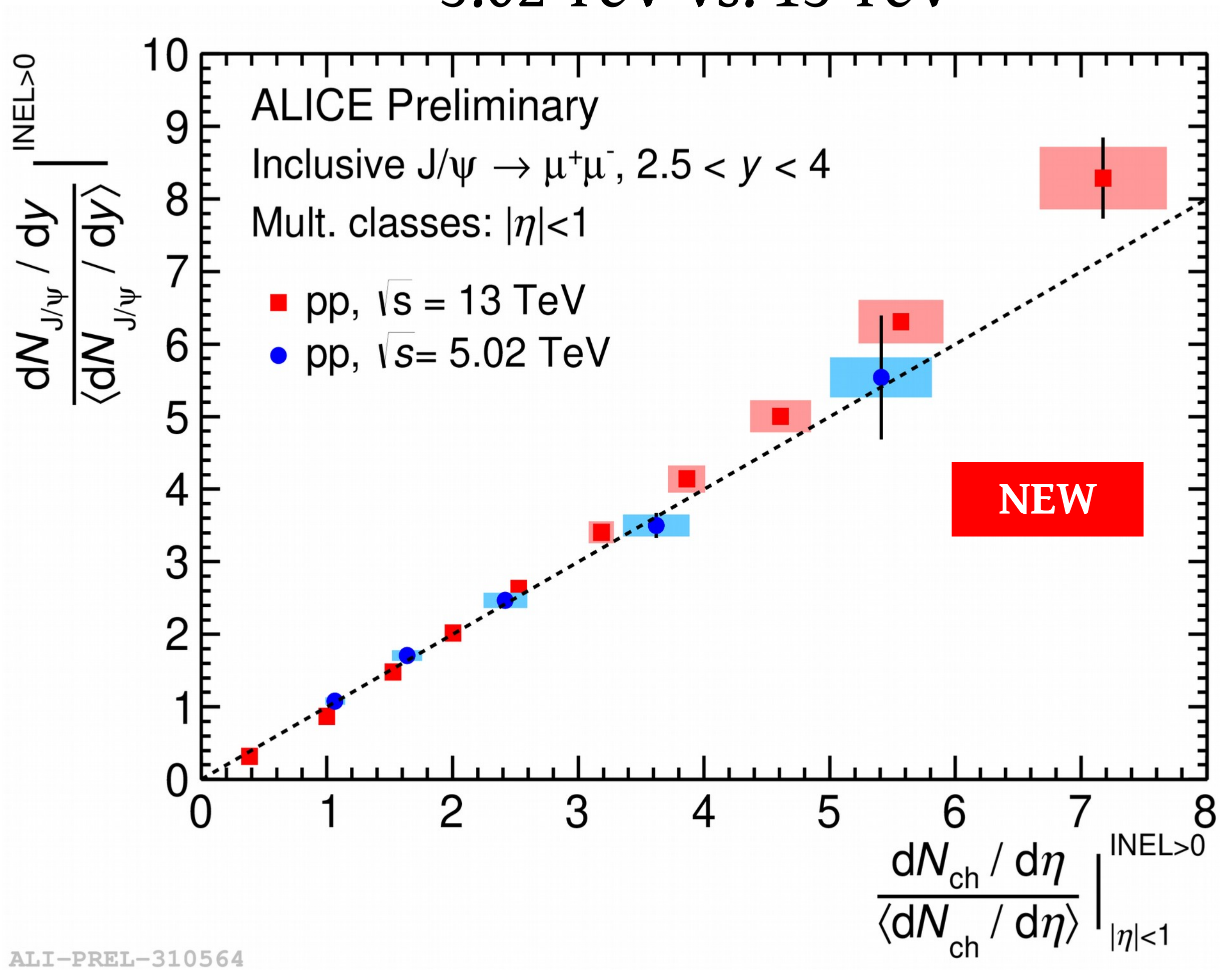




- Faster than linear scaling with multiplicity at mid-rapidity
  - ➔ w/o rapidity gap between signal and multiplicity estimator
- Linear increase at forward rapidity
  - ➔ rapidity gap
- **Hint of auto-correlation bias**

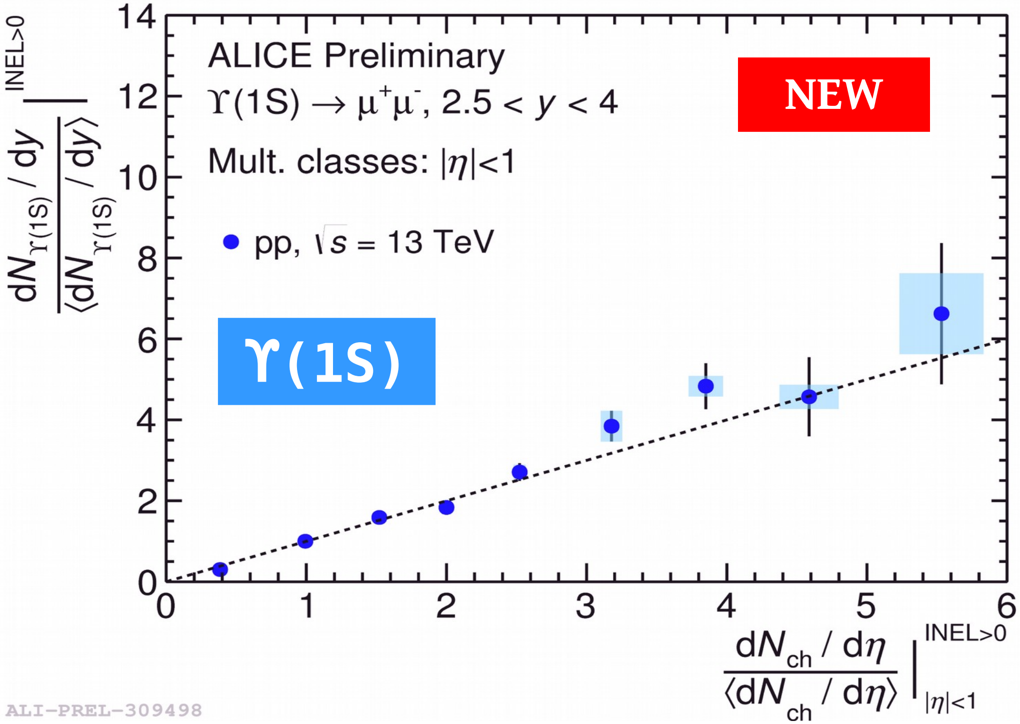
J/ψ production vs. event multiplicity

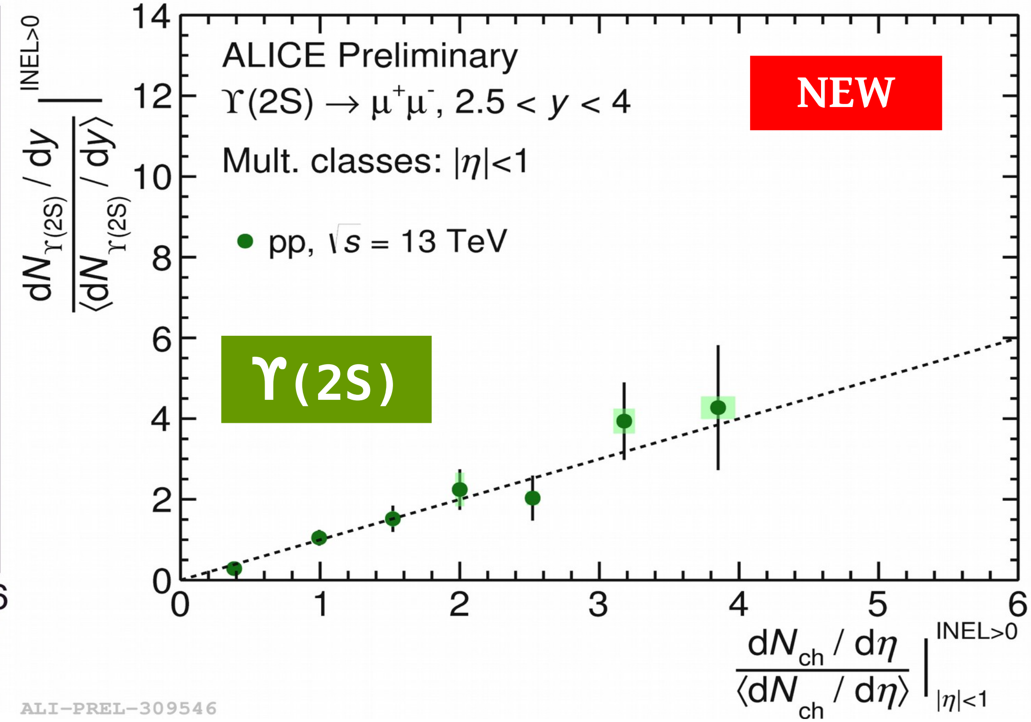
5.02 TeV vs. 13 TeV



- **No colliding energy dependence**

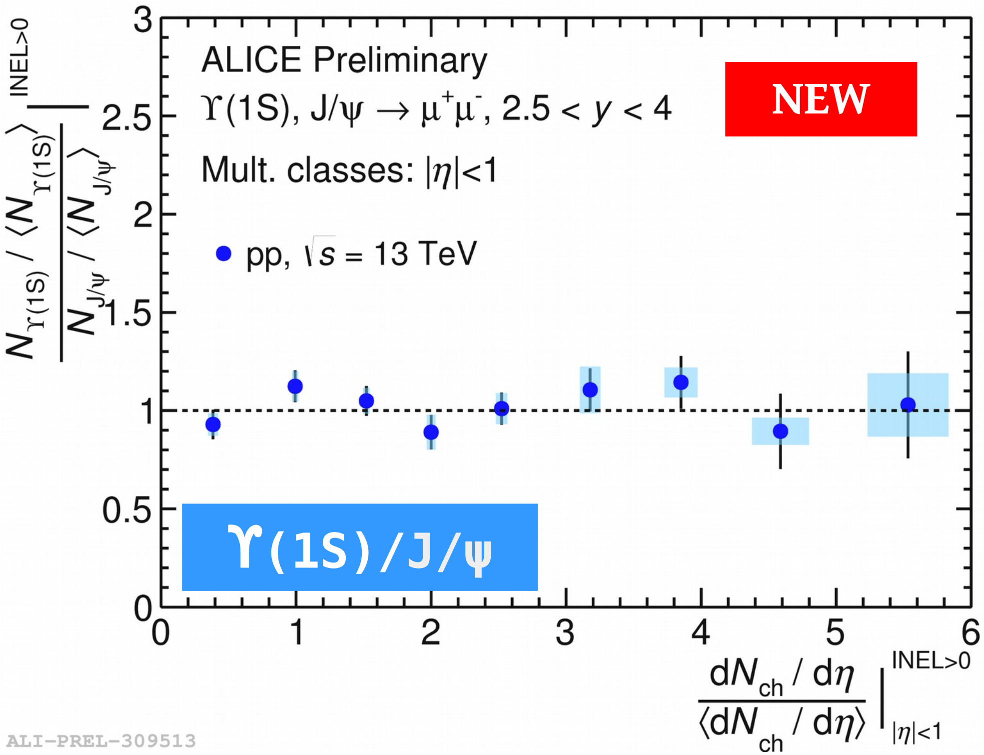
Υ production vs. event multiplicity

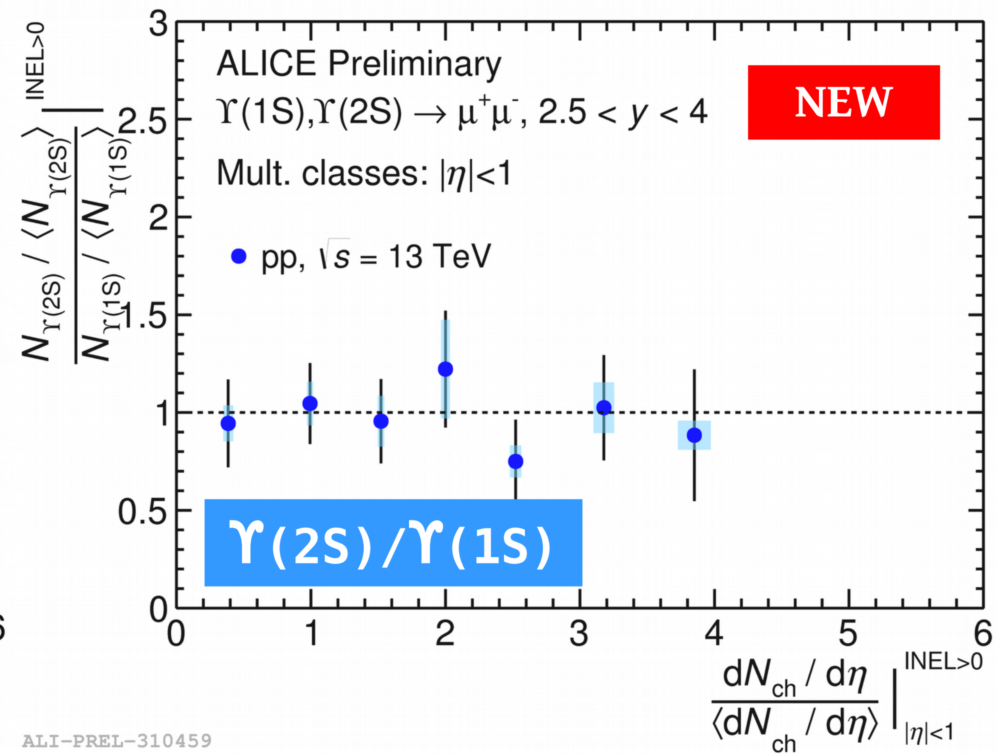




- **First measurement of Υ production vs. charged-particle multiplicity with ALICE**
- Similar trend between Υ(1S) and Υ(2S): linear increase with the charged-particle multiplicity

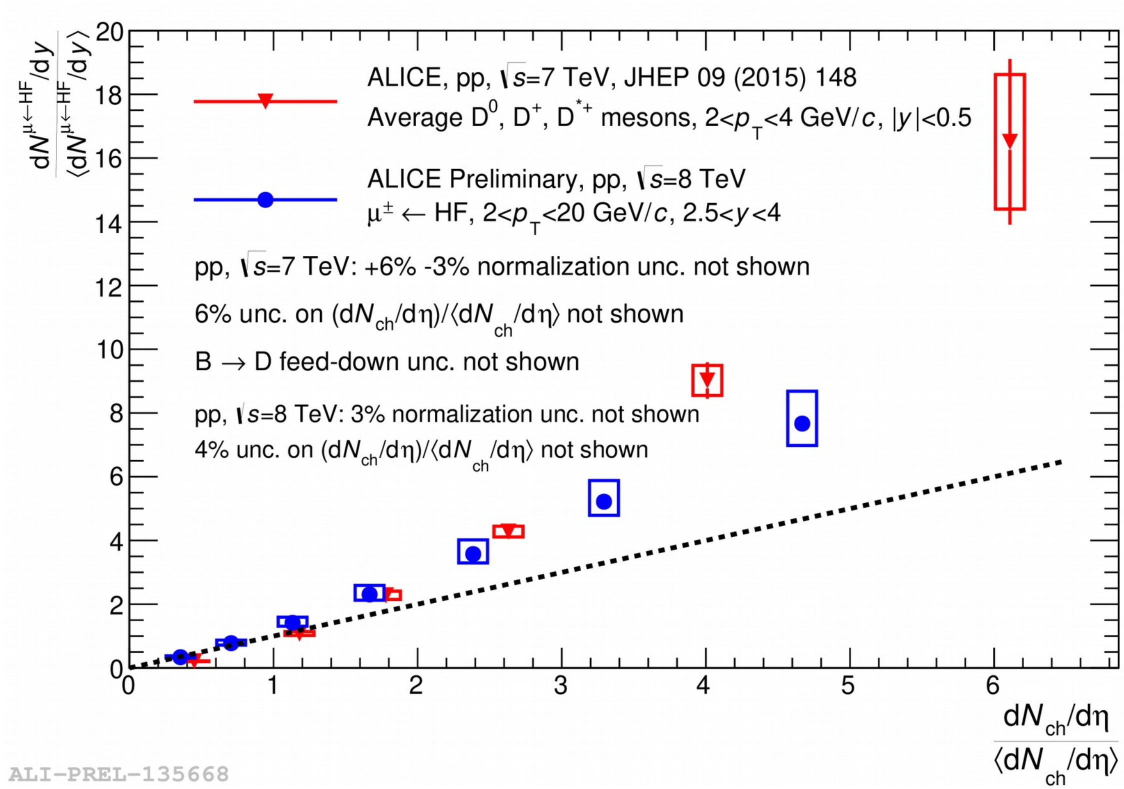
$\Upsilon(1S)/J/\psi$ and $\Upsilon(2S)/\Upsilon(1S)$ vs. event multiplicity

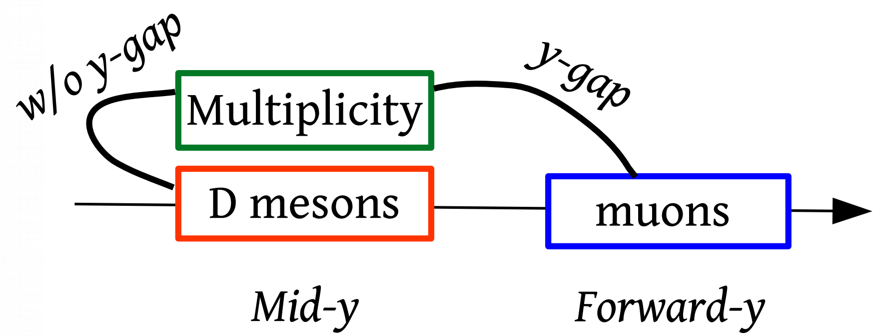




- The double ratios of $\Upsilon(1S)/J/\psi$ and $\Upsilon(2S)/\Upsilon(1S)$:
  - The double ratio is found to be unity irrespective of charged-particle multiplicity
  - The multiplicity dependence production is the same within uncertainties for J/ψ, $\Upsilon(1S)$ and $\Upsilon(2S)$

D mesons and muons from HF vs. event multiplicity





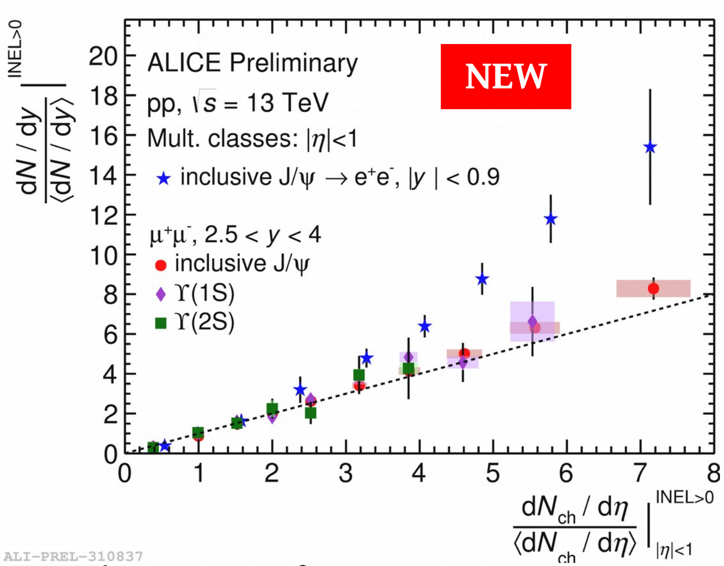
- Similar multiplicity dependence as J/ψ and ϒ at low multiplicity
- Stronger than linear increase at high multiplicity
- The increase appears slightly faster at mid-rapidity than at forward, which is similar to what is observed in J/ψ
- Need to study the role of jet fragmentation in J/ψ production

Conclusion

ALICE has measured the correlation of quarkonia and open heavy-flavours production with charged particles in pp collisions

Quarkonia:

- J/ψ :
  - Faster than linear increase at high multiplicity and mid-rapidity
  - Linear increase observed at forward rapidity
  - Indication of auto-correlation bias
  - No colliding energy dependence
- ϒ: Linear increase observed at forward rapidity
- ϒ(1S)/J/ψ and ϒ(2S)/ϒ(1S) ratios:
  - Consistent with unity, for all multiplicities
  - No dependence on quarkonium state



Open heavy flavours:

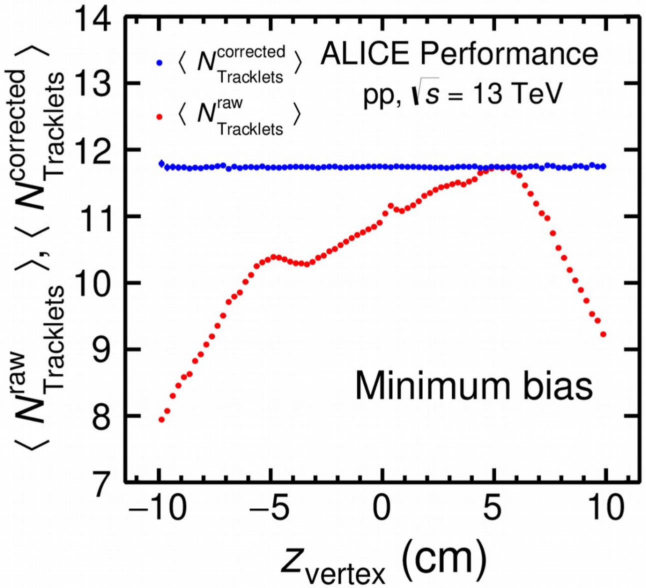
- Enhancement at high multiplicity for both D-meson and muons from HF

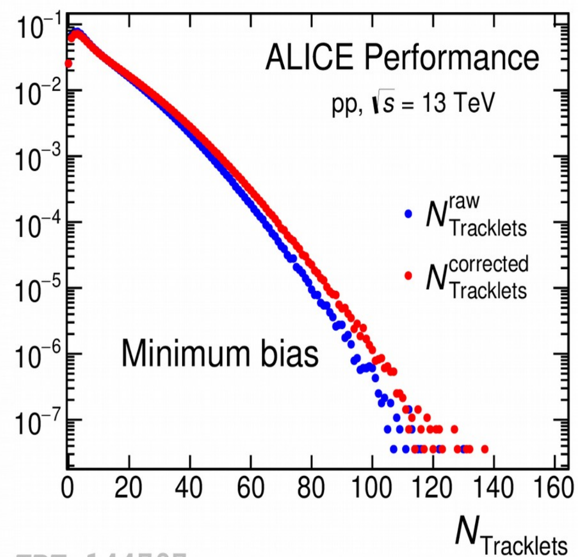
Thank you

Back up

Analysis strategy

Mid-rapidity multiplicity estimation





1) Data-driven method:
→ Flatten <N_{trk}(v_z)> distribution

$$N^{cor}_{trk}(v_z) = N_{trk}(v_z) + Poisson(\Delta N)$$

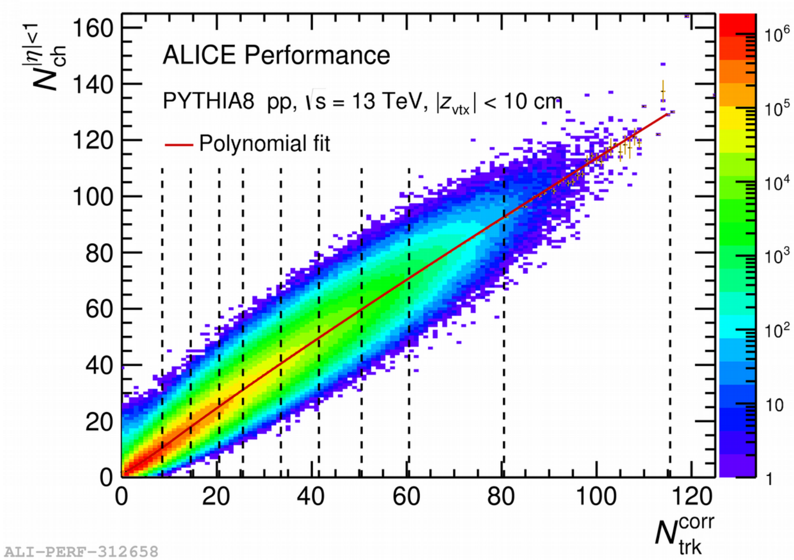
$$\Delta N = N_{trk}(v_z)\frac{\langle N_{trk}(v_z^0)\rangle - \langle N_{trk}(v_z)\rangle}{\langle N_{trk}(v_z)\rangle}$$

<N_{trk}(v_z^0)>: reference value

2) Tracklet-to-charged particle conversion
- Based on MC information
- Reproduce data well

$$\boxed{\langle N^i_{ch}\rangle = \frac{\sum N_j \times f \to Eval(N^{cor,j}_{trk})}{\sum N_j}}$$

$$\boxed{\frac{dN^i_{ch}/d\eta}{<dN_{ch}/d\eta>} = \frac{<N^i_{ch}>/\Delta\eta}{<dN_{ch}/d\eta>}}$$



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Analysis strategy

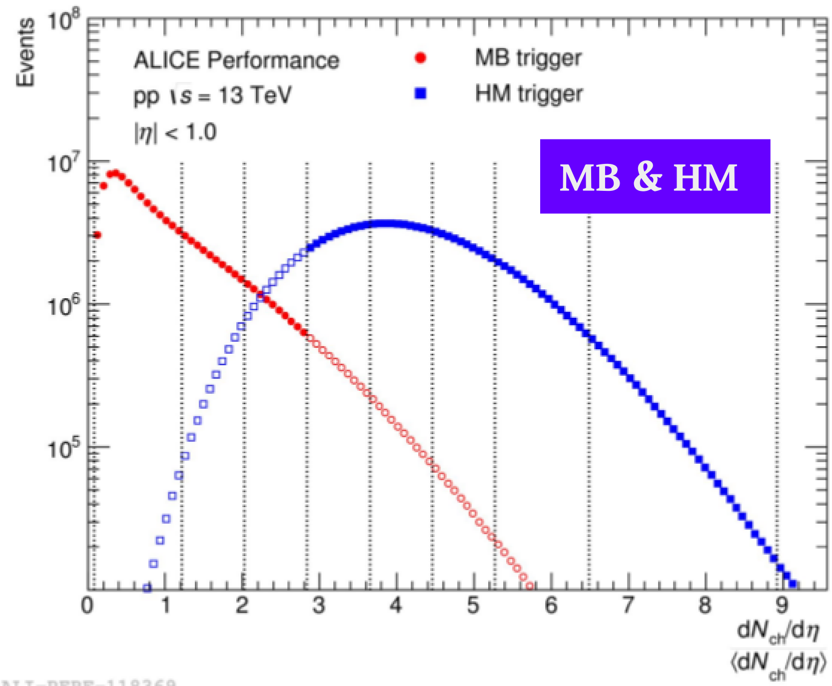
- **Data sample**
  - Minimum bias triggered events: baseline
  - High multiplicity triggered events: $J/\psi \rightarrow e^+e^-$
  - Di-muon triggered events: $J/\psi \rightarrow \mu^+\mu^-$, $\Upsilon \rightarrow \mu^+\mu^-$
- **Multiplicity estimators**
  - Mid-rapidity: $1.4 < |\eta| < 2.0$
  - Forward-rapidity: $2.8 < \eta < 5.1$, $-3.7 < \eta < -1.7$
- **Observables:**
  - Relative charged-particle pseudo rapidity density:

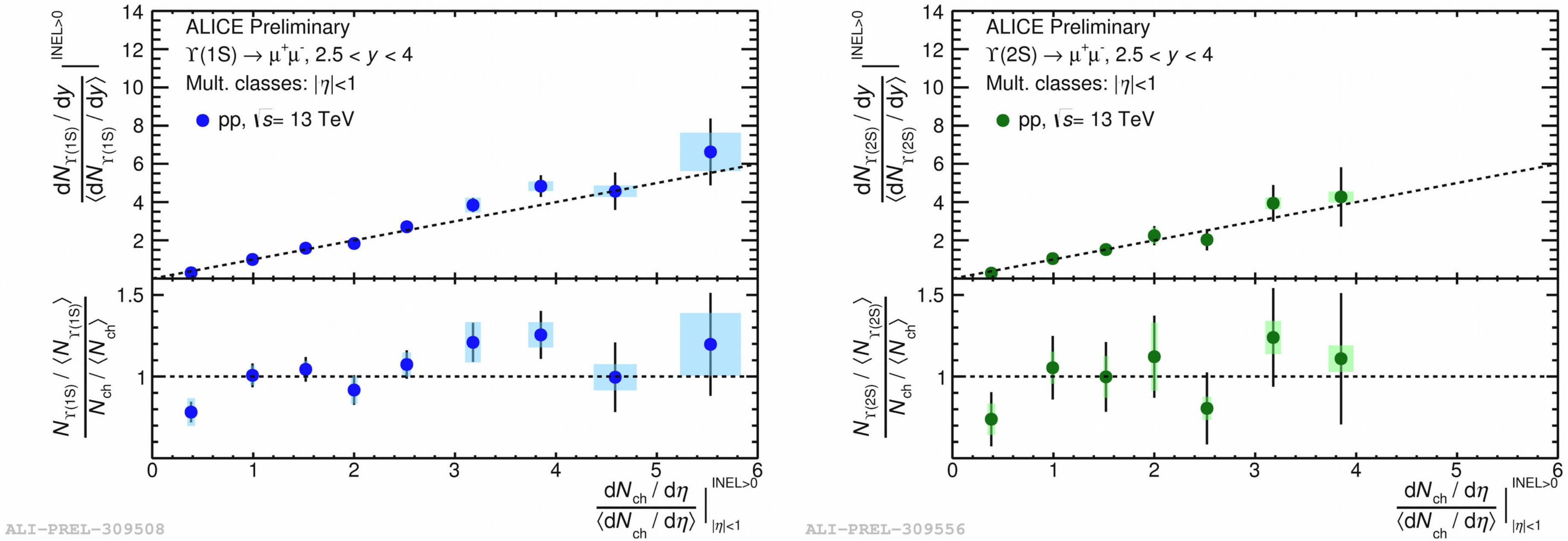
$$\frac{<dN_{ch}/d\eta>_i}{<dN_{ch}/d\eta>} = \frac{<N^i_{ch}>/\Delta\eta}{<dN_{ch}/d\eta>} = \frac{f(N^{cor,i}_{trk})/\Delta\eta}{<dN_{ch}/d\eta>_{INEL>0}}$$

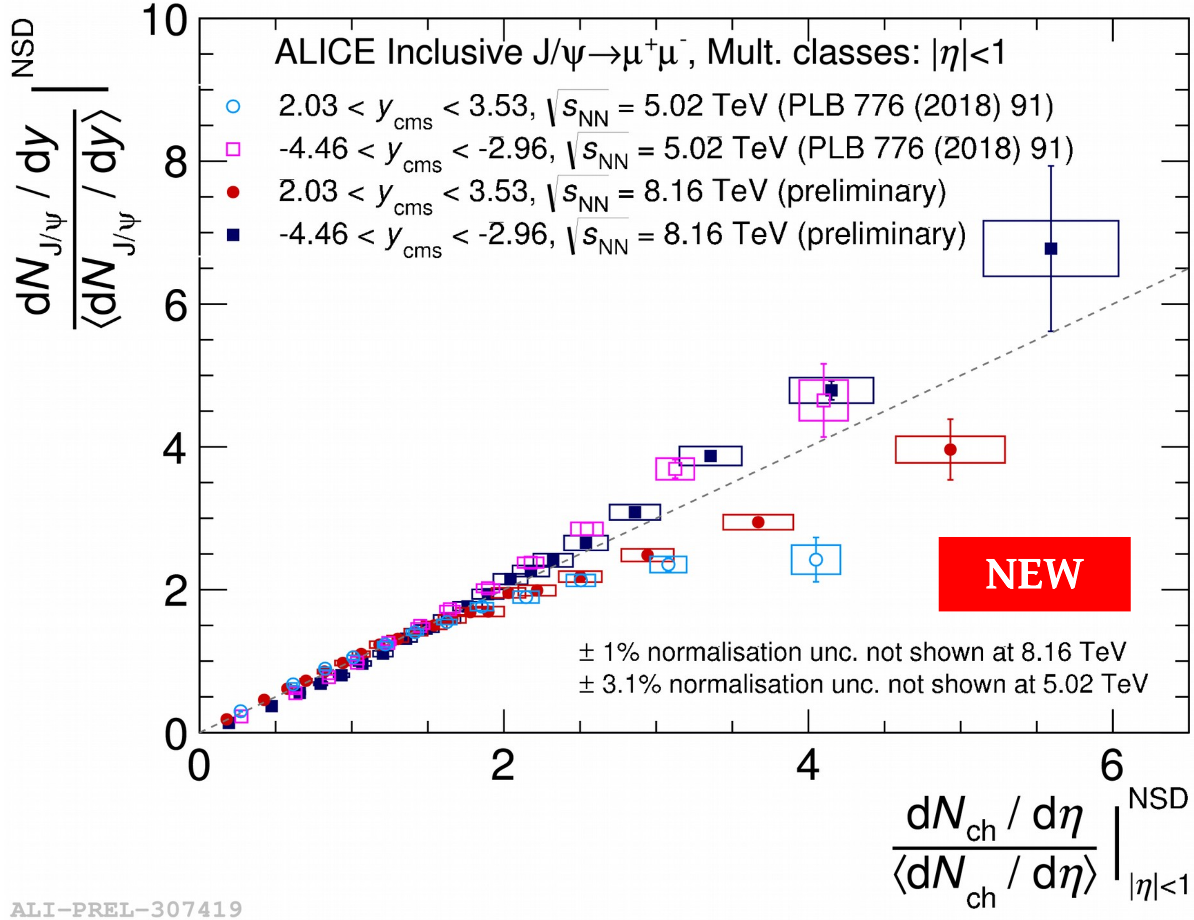
  - Relative J/ψ or Υ yield:

$$\frac{<dN_S/dy>_i}{<dN_S/dy>} = \frac{<Y_S>_i}{<Y_S>} = \frac{N^i_S}{N^{tot}_S} \times \frac{N^{tot}_{MB}}{N^i_{MB}} \times \frac{\varepsilon^i_{MB}}{\varepsilon_{MB}} \times \frac{\varepsilon_S}{\varepsilon^i_S}$$

S: J/ψ or Υ

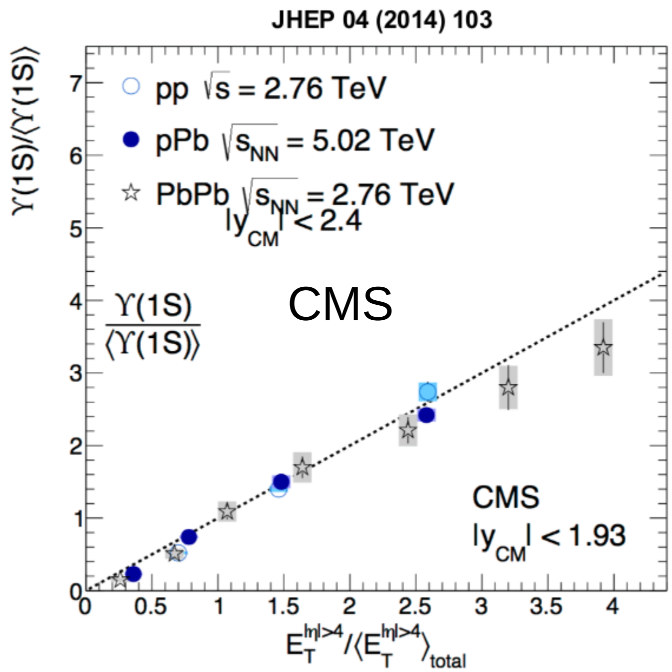


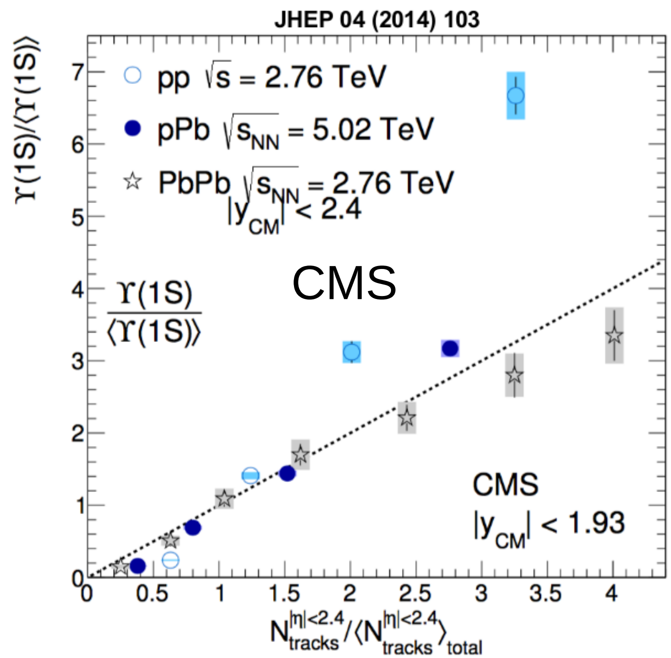

ALICE Preliminary
ϒ(1S) → μ⁺μ⁻, 2.5 < y < 4
Mult. classes: |η|<1
pp, √s= 13 TeV
ALI-PREL-309508
ALICE Preliminary
ϒ(2S) → μ⁺μ⁻, 2.5 < y < 4
Mult. classes: |η|<1
pp, √s= 13 TeV
ALI-PREL-309556



- Independent of colliding energy

Υ production vs. multiplicity



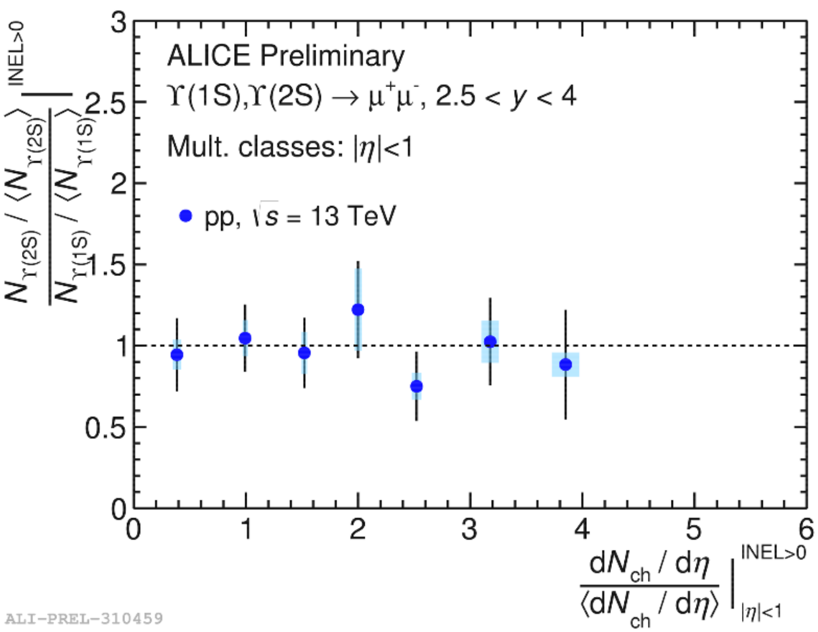


Linear behavior measured for forward E_T (with y-gap)

Qualitatively similar to what we observe for J/ψ and D mesons in similar rapidity region (without y-gap)

Υ excited to ground state ratio

ALICE: with *y*-gap



CMS: without *y*-gap

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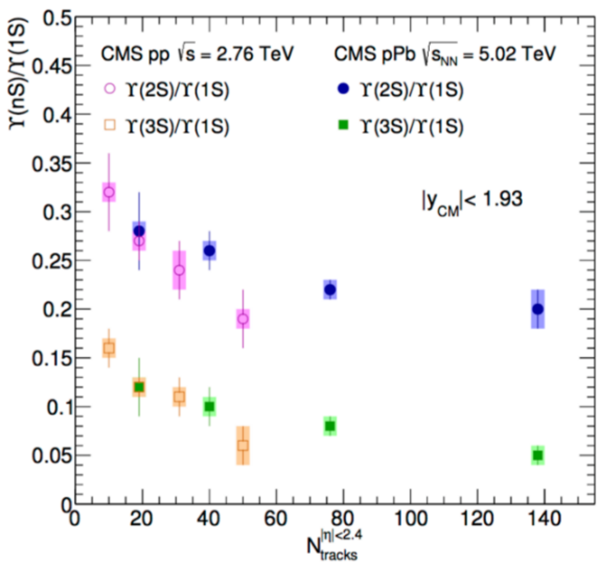

CMS: with *y*-gap