Charmonium production in pp and Pb-Pb collisions with ALICE

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for the ALICE Collaboration

GSI

EMMI

XX International Workshop on Deep-Inelastic Scattering and Related Subjects

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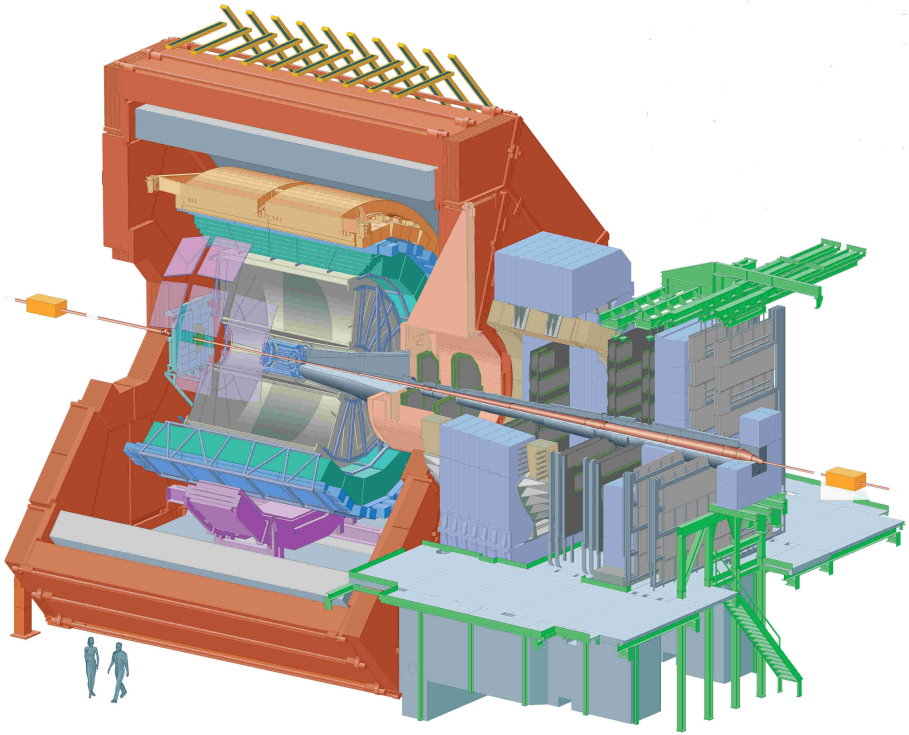
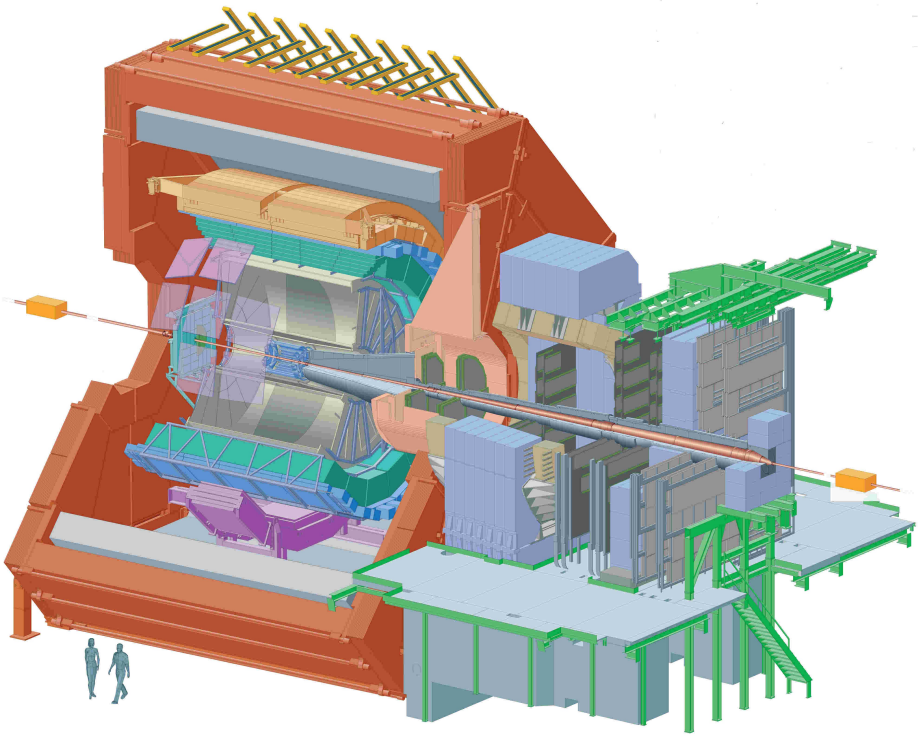
Charmonium measurements in ALICE

- J/ψ measurements in e^+e^- and $\mu^+\mu^-$ decay channels
- Systems: pp, Pb-Pb and p+Pb (soon)
- Collision energy: 2.76 and 7 TeV
- Kinematical coverage
  - $|y|<0.9$, $2.5<y<4.0$
  - $p_T > 0$ GeV/c



Charmonium measurements in ALICE

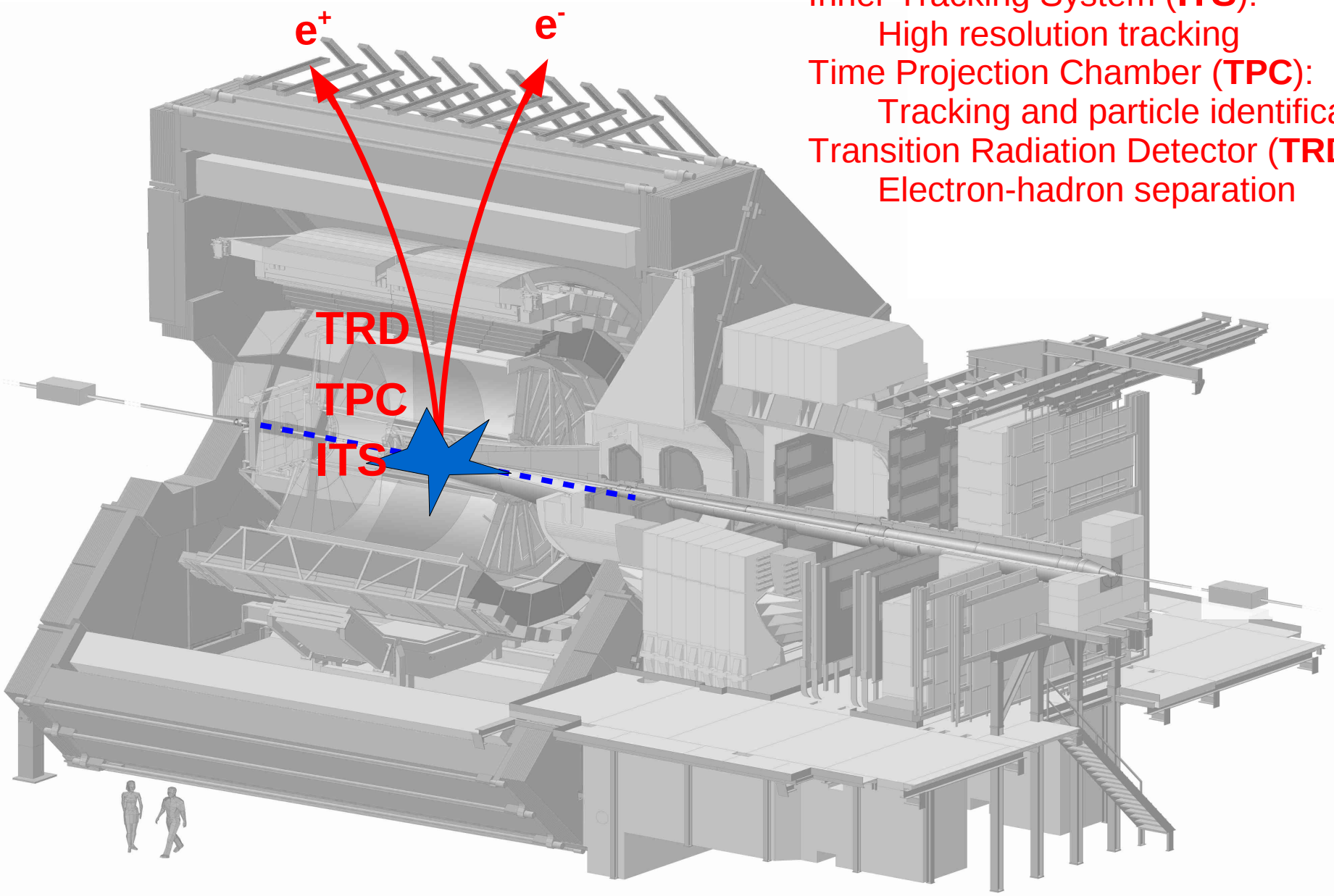
- J/ψ measurements in pp collisions:
  - Rapidity and p_T dependent inclusive cross-sections
  - Feed-down from beauty
  - Polarization
  - Correlation with the event multiplicity



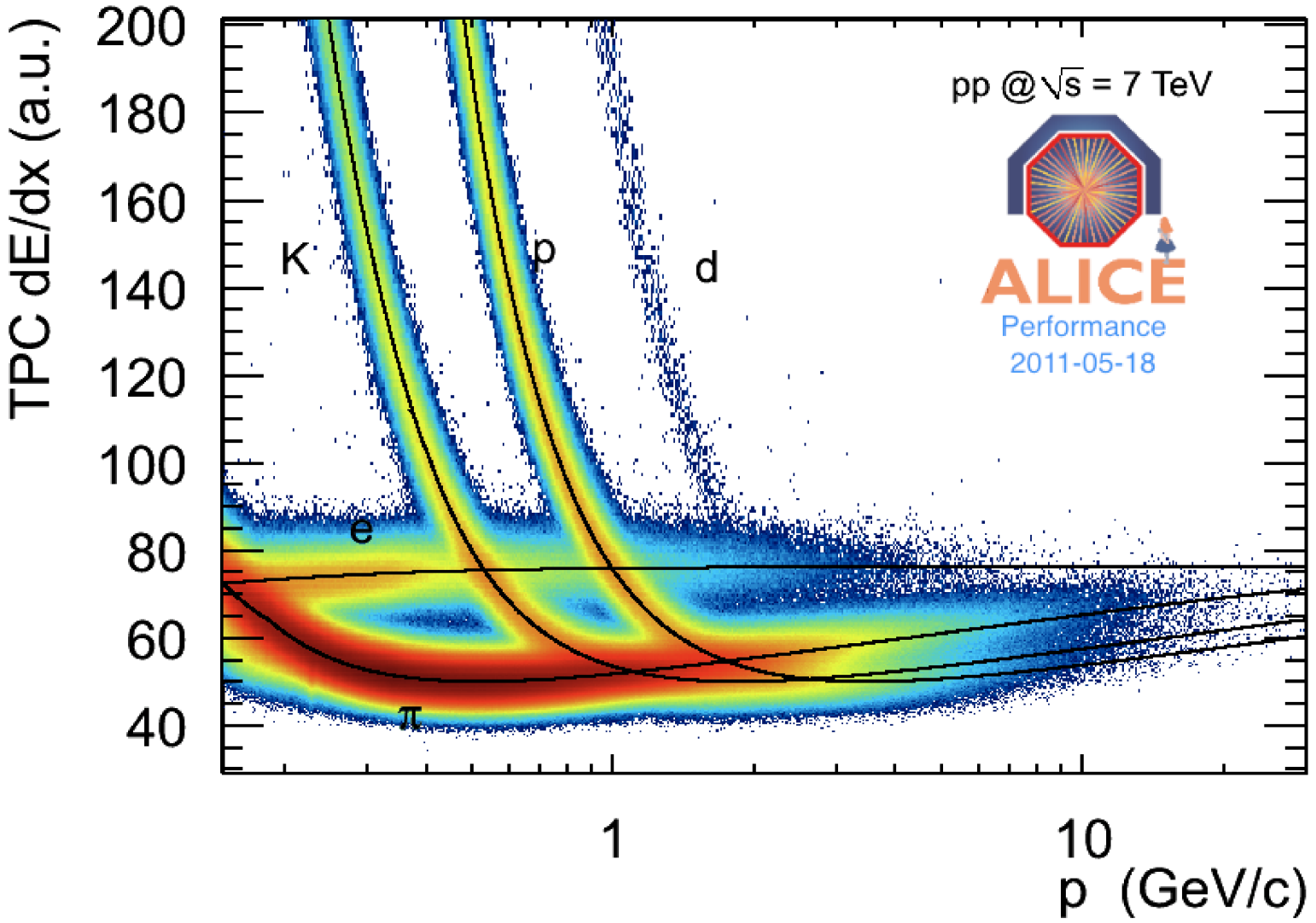
- J/ψ nuclear modification factor in Pb-Pb collisions

ALICE setup

Inner Tracking System (**ITS**):
High resolution tracking
Time Projection Chamber (**TPC**):
Tracking and particle identification
Transition Radiation Detector (**TRD**):
Electron-hadron separation



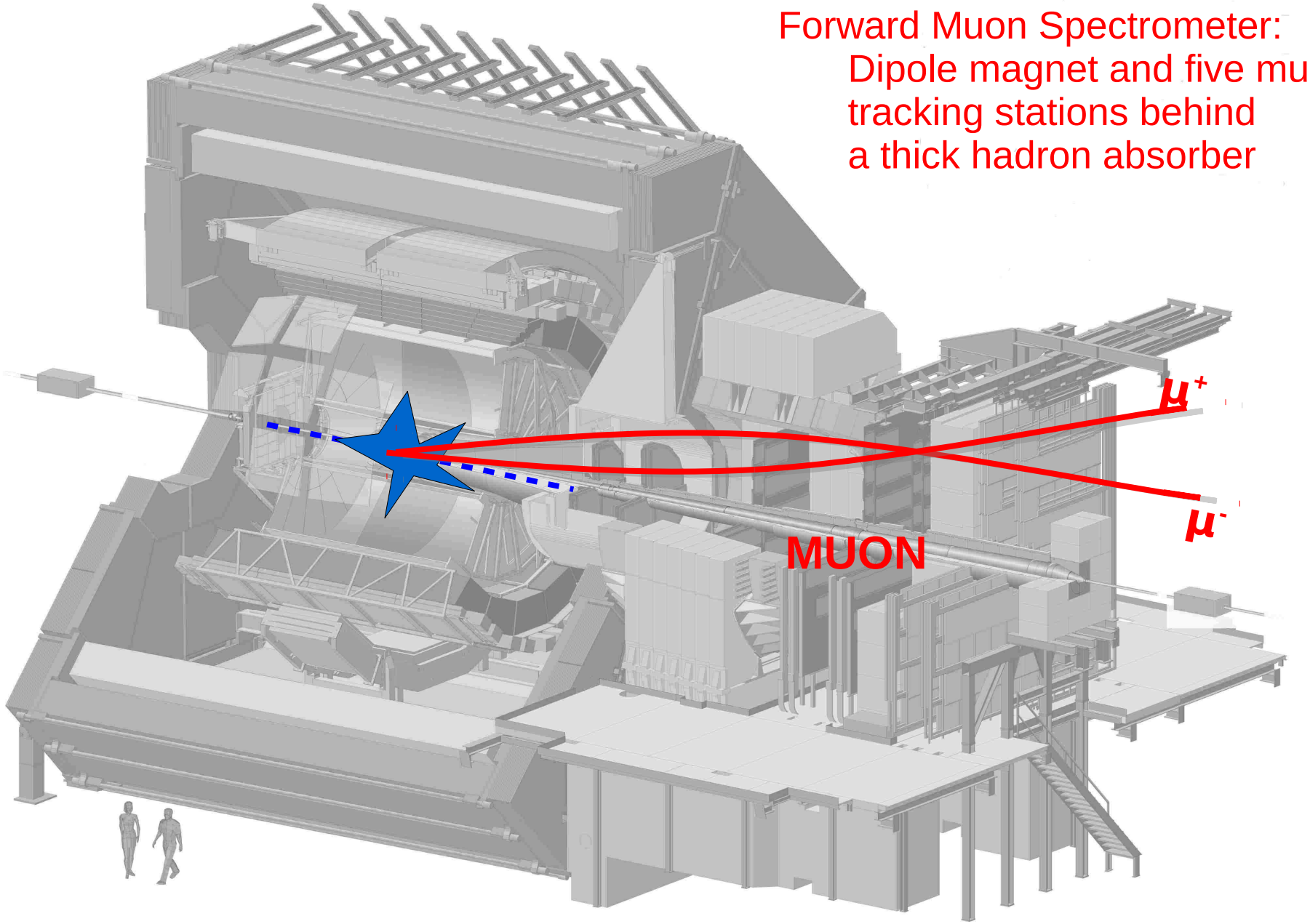
Particle identification in ALICE



Particle identification done using high resolution energy loss measurements with the TPC detector

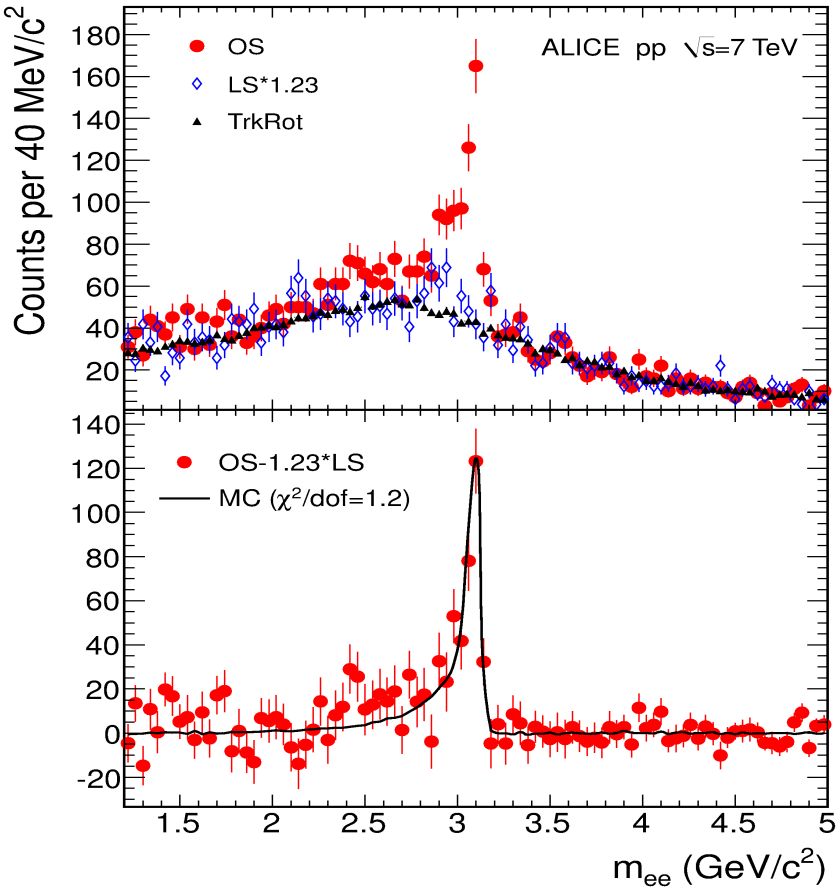
ALICE setup

Forward Muon Spectrometer:
Dipole magnet and five muon tracking stations behind a thick hadron absorber

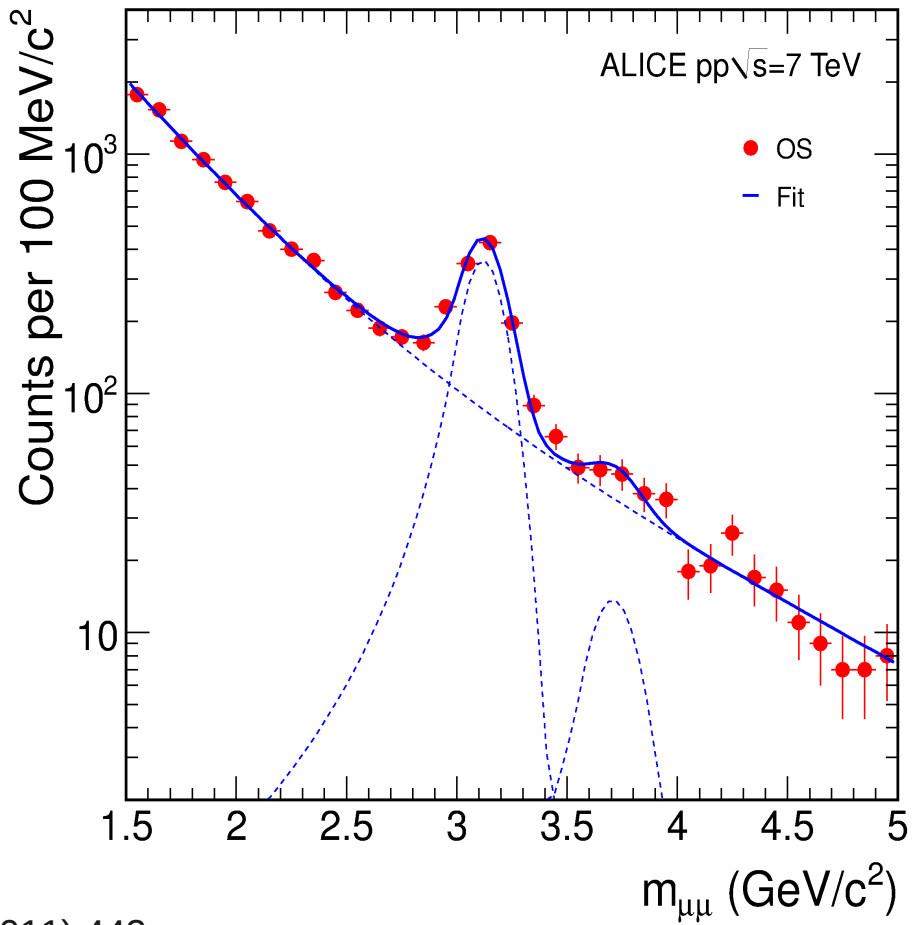


J/ψ reconstruction

$J/\psi \rightarrow e^+ e^-$



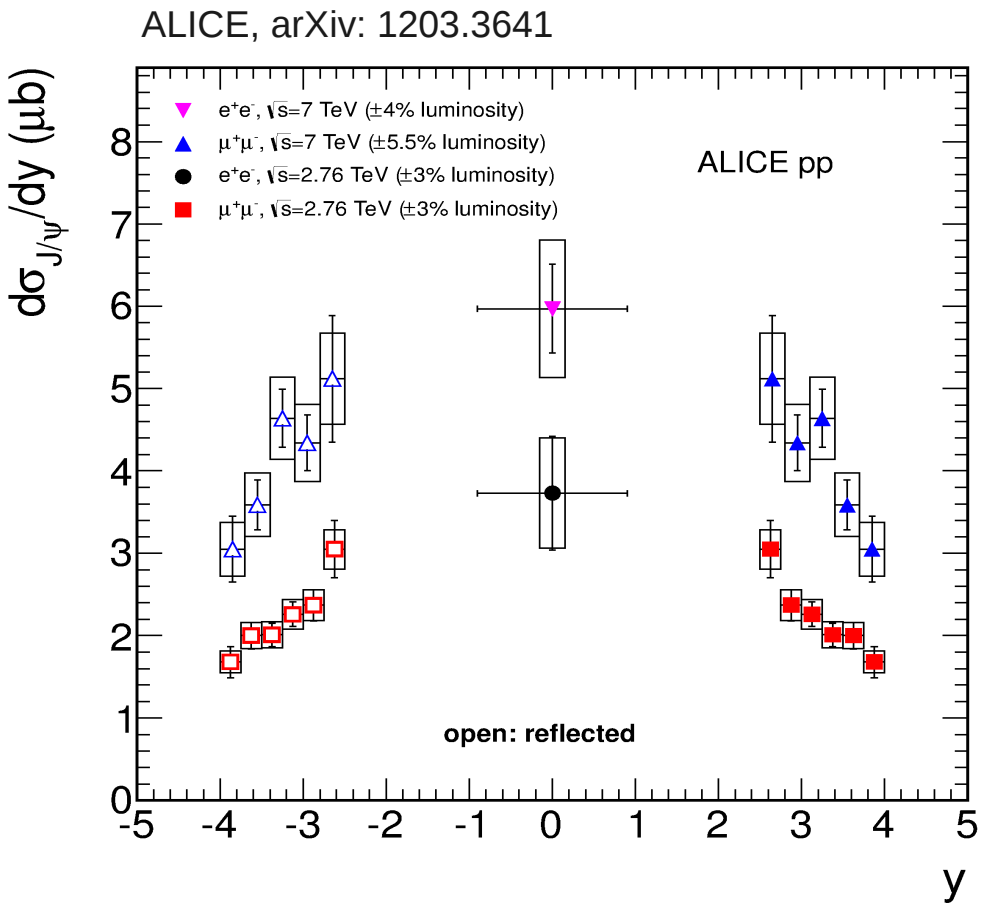
$J/\psi \rightarrow \mu^+ \mu^-$

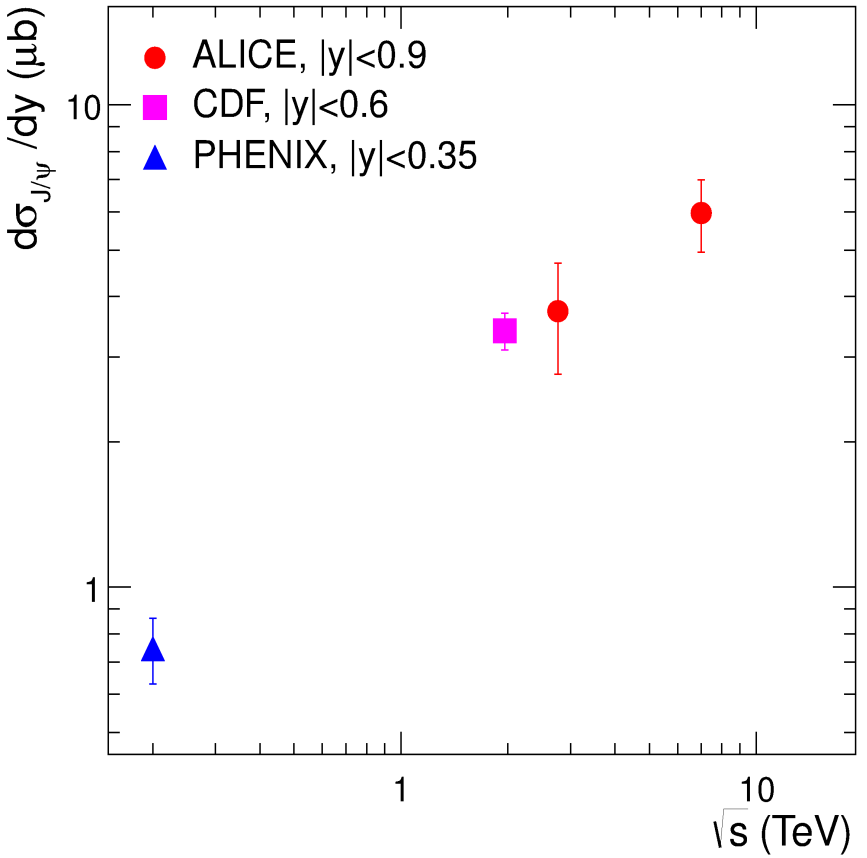


ALICE, PLB704 (2011) 442

- J/ψ extracted by bin-counting (fits) of the e^+e^- ($\mu^+\mu^-$) invariant mass
- Background estimated using like-sign, track rotation or fitting
- Signal shape shows good agreement between data and MC

Inclusive J/ψ cross-section

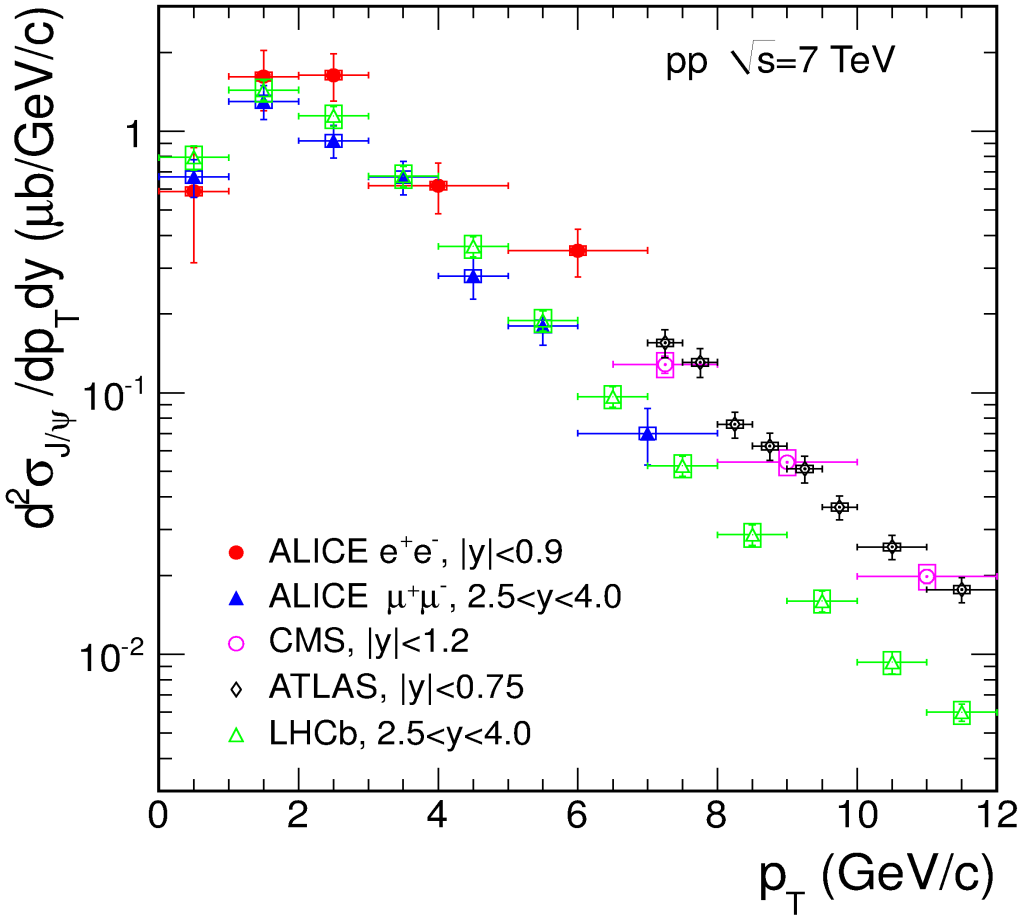




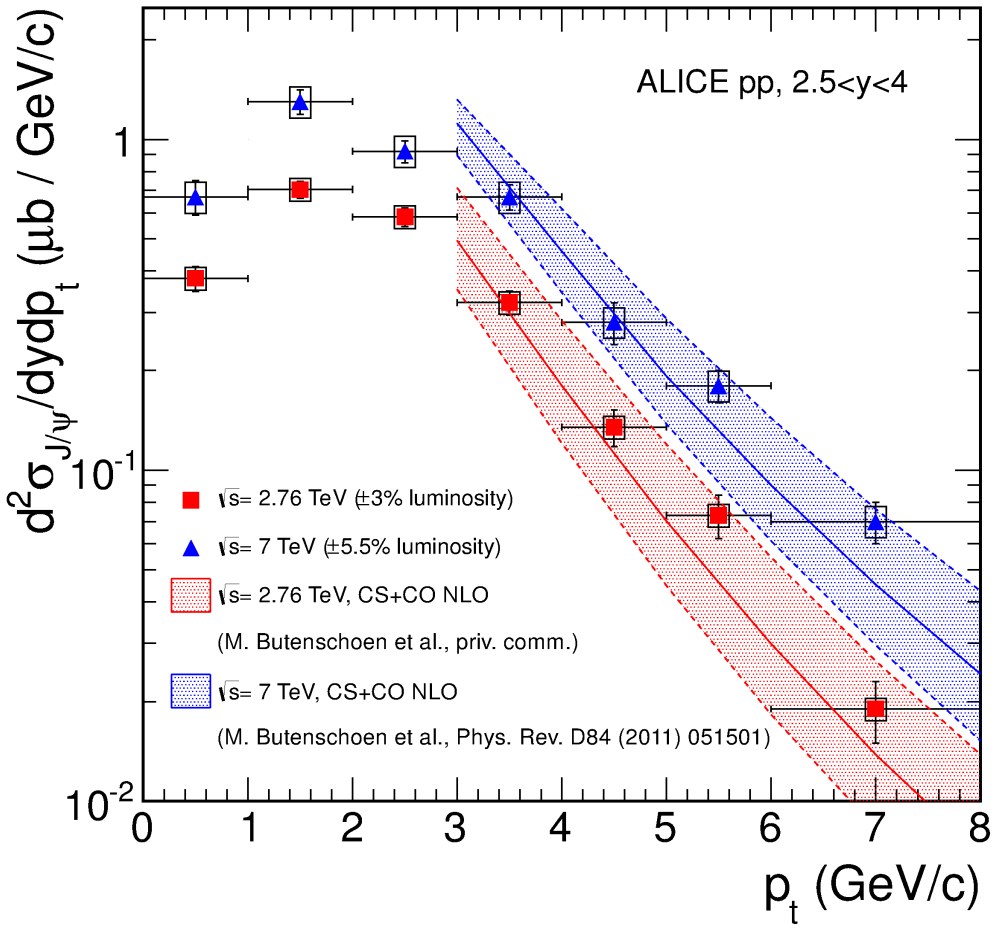
- J/ψ measured down to p_T=0 (no extrapolation on the integrated cross-sections)
- Measurement at 2.76 TeV required as a reference for the Pb-Pb measurements

P_T differential J/ψ inclusive cross-section

ALICE, PLB704 (2011) 442



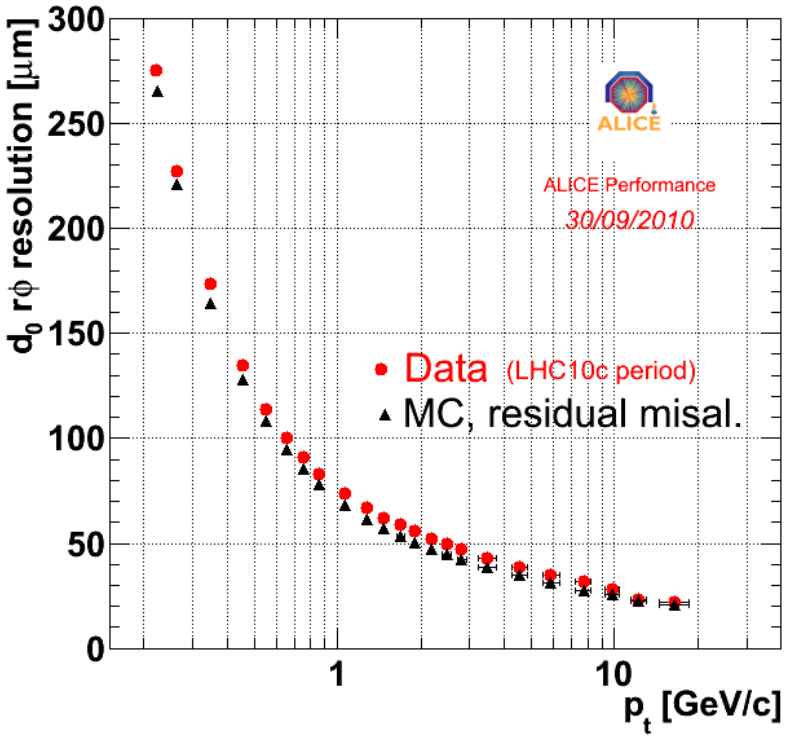
ALICE, arXiv: 1203.3641



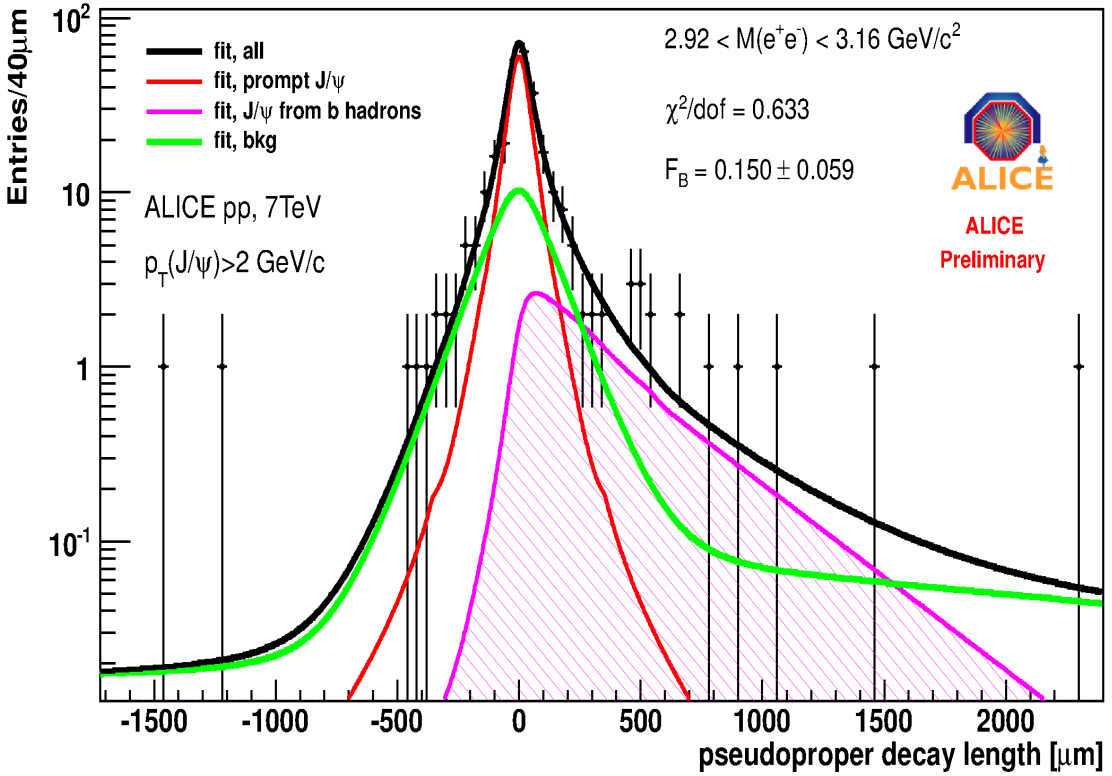
- Good agreement with the other LHC experiments in the common kinematical regions
- p_T dependence reproduced down to p_T=3.0GeV/c within the NRQCD factorization calculations

Feed-down from beauty decays

Vertex spatial resolution

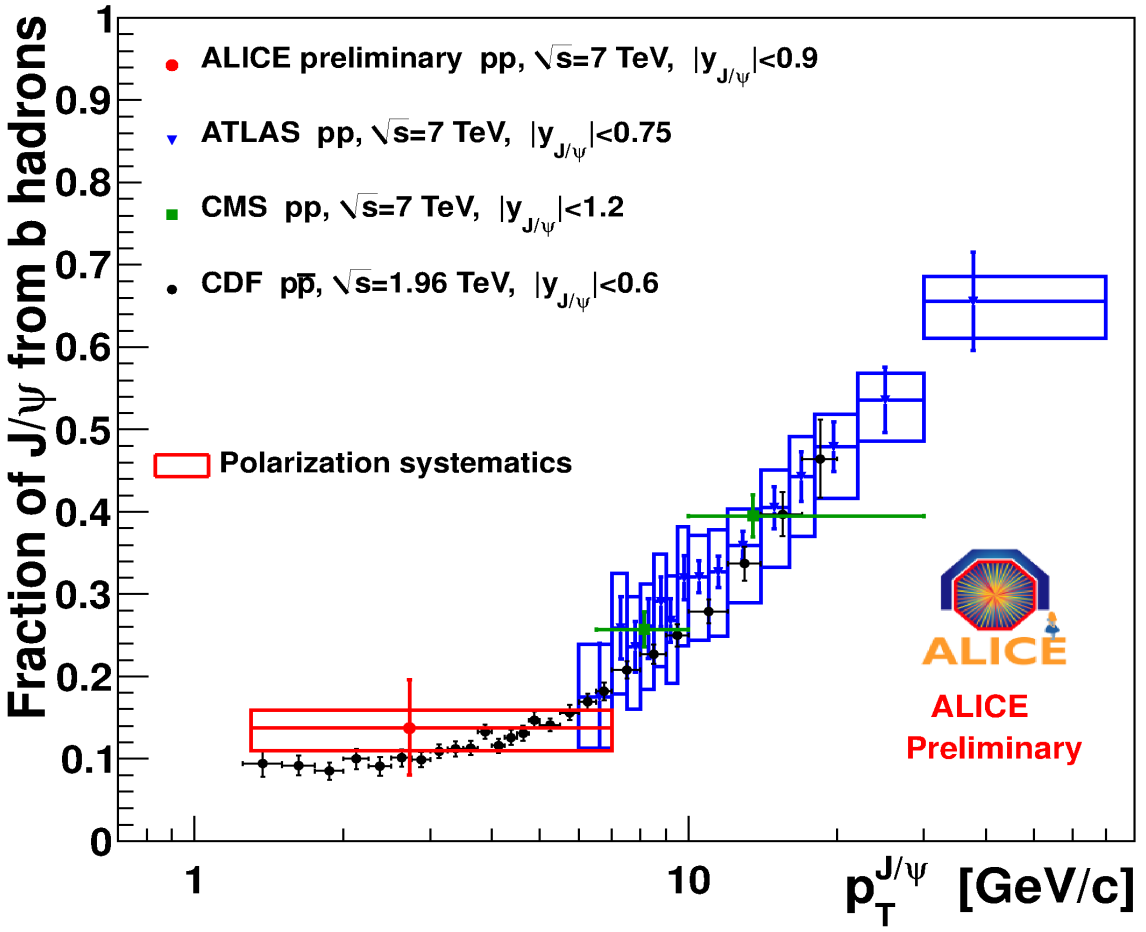


Secondary vertices analysis



- Spatial resolution below 100 μm for tracks with p_T>1 GeV/c
- Fraction of beauty obtained by reconstructing the decay vertex of the secondary J/ψ candidates

Feed-down from beauty decays

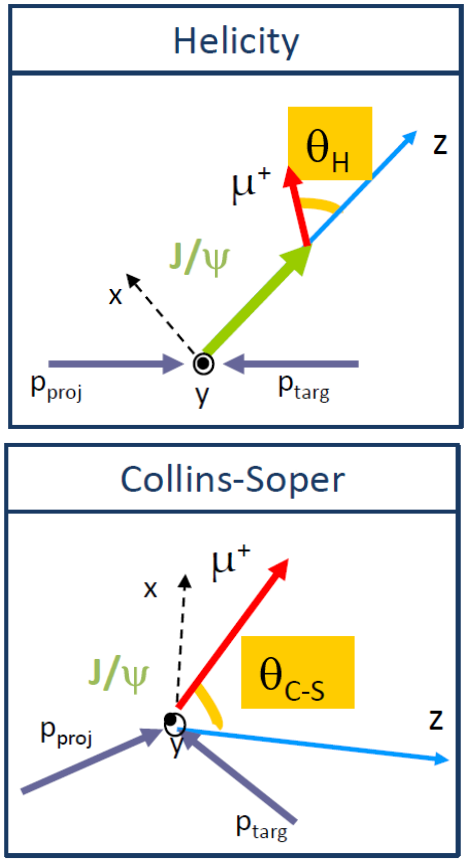


$$\frac{d\sigma_{J/\psi \leftarrow b}}{dy}(y=0, p_T>2.0\,GeV/c) = 0.56 \pm 0.16\,(stat.) \pm 0.12\,(syst.)\,\mu b$$ (ALICE preliminary)

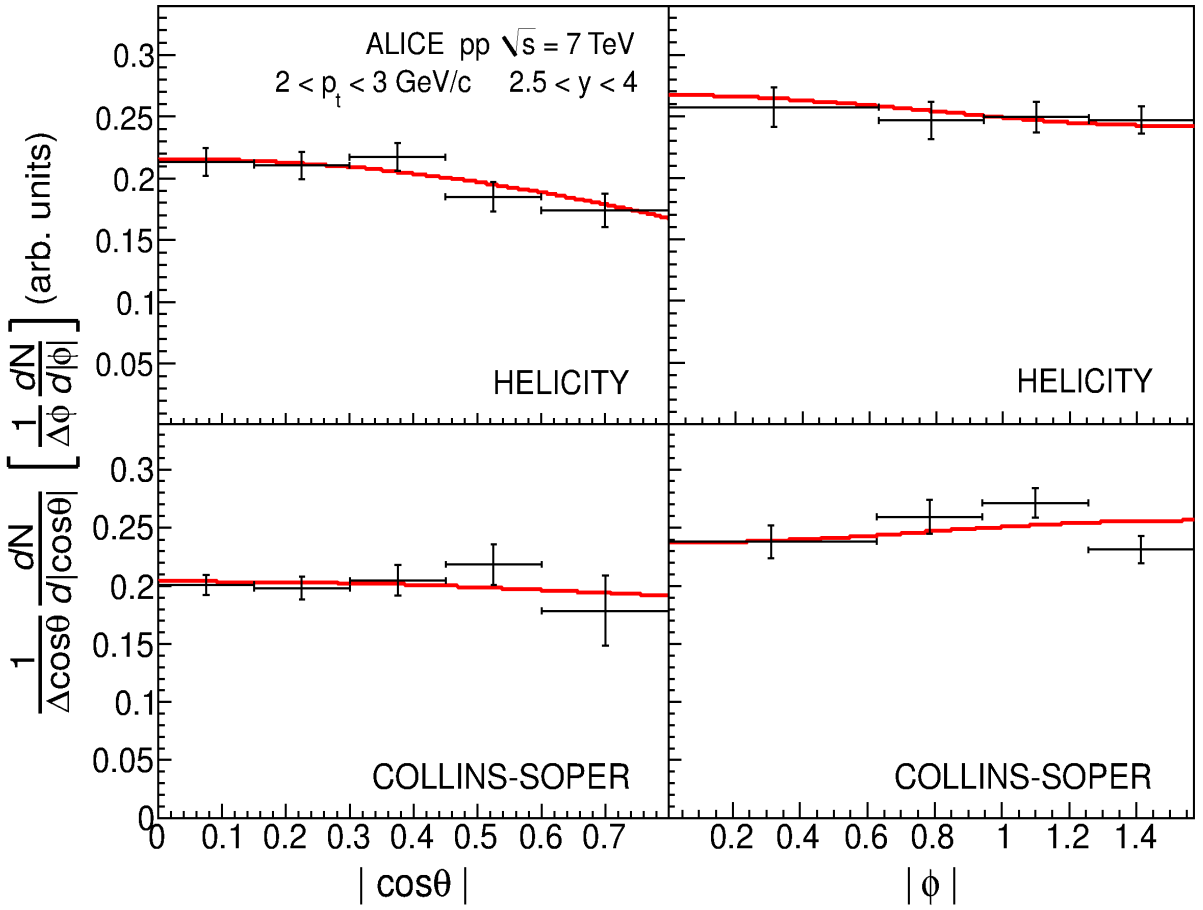
$$\frac{d\sigma_{J/\psi \leftarrow b}}{dy}(y=0, p_T>2.0\,GeV/c) = 0.60^{+0.25}_{-0.19}\,\mu b$$ (FONLL)

- Secondary J/ψ from beauty measured down to pt=1.3 GeV/c

J/ψ polarization



ALICE, PRL108 (2012) 082001



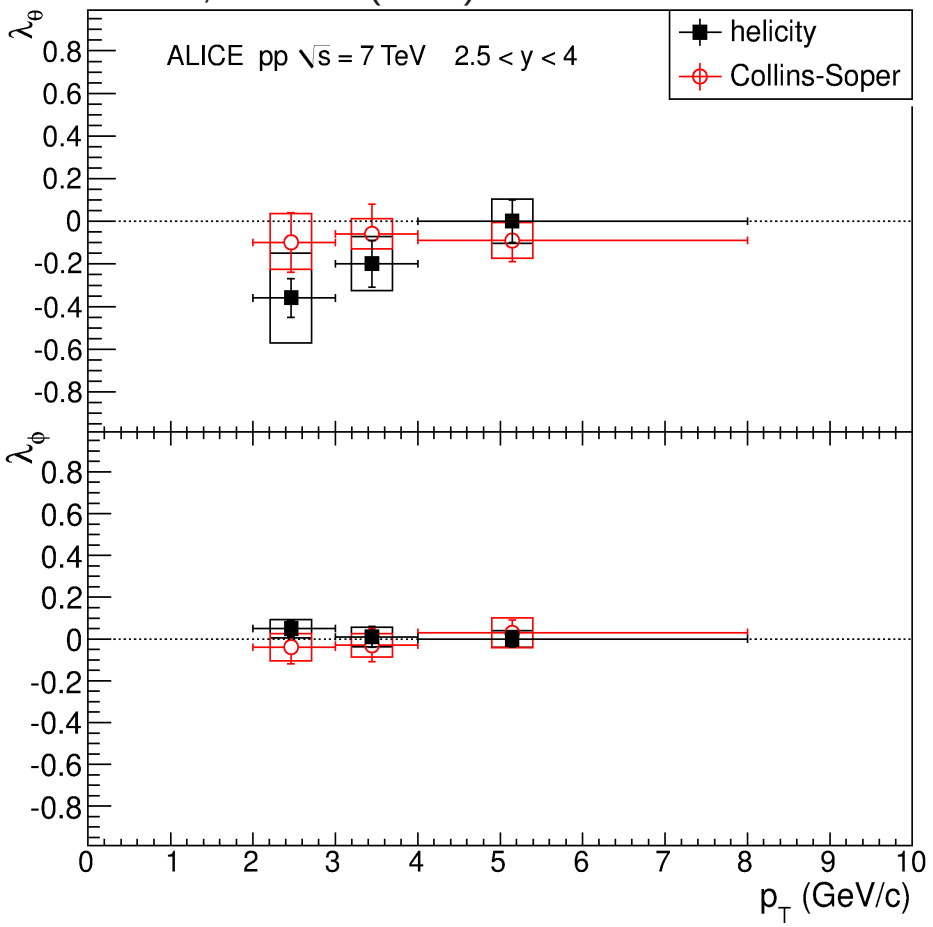
$$W(\cos\theta,\varphi)\approx 1+\lambda_\theta\cos^2\theta+\lambda_\varphi\sin^2\theta\, cos2\,\varphi+\lambda_{\theta\varphi}\, sin2\,\theta\cos\varphi$$

$\lambda_\theta > 0 \rightarrow$ Transversal polarization

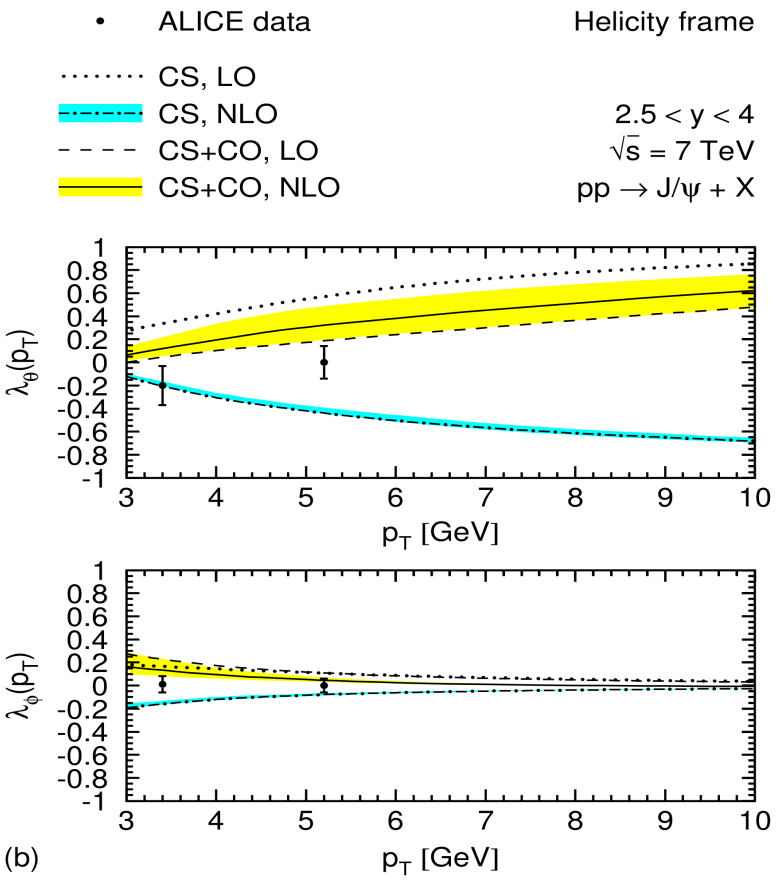
$\lambda_\theta < 0 \rightarrow$ Longitudinal polarization

J/ψ polarization

ALICE, PRL108 (2012) 082001

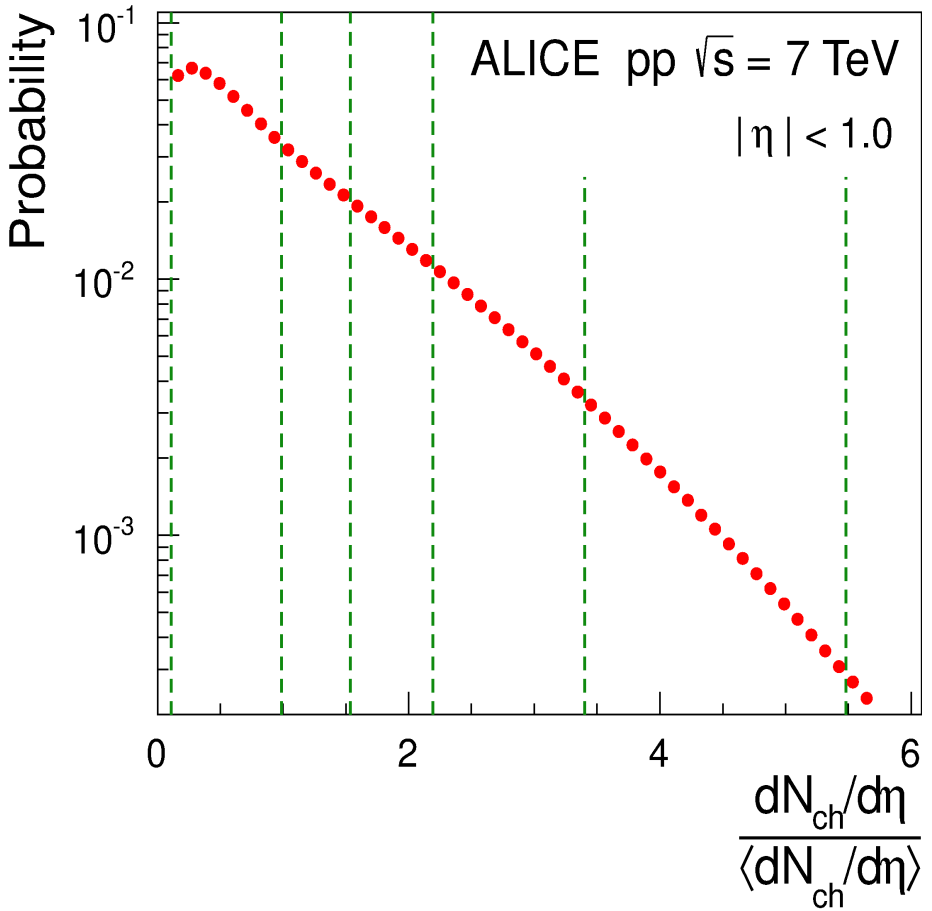


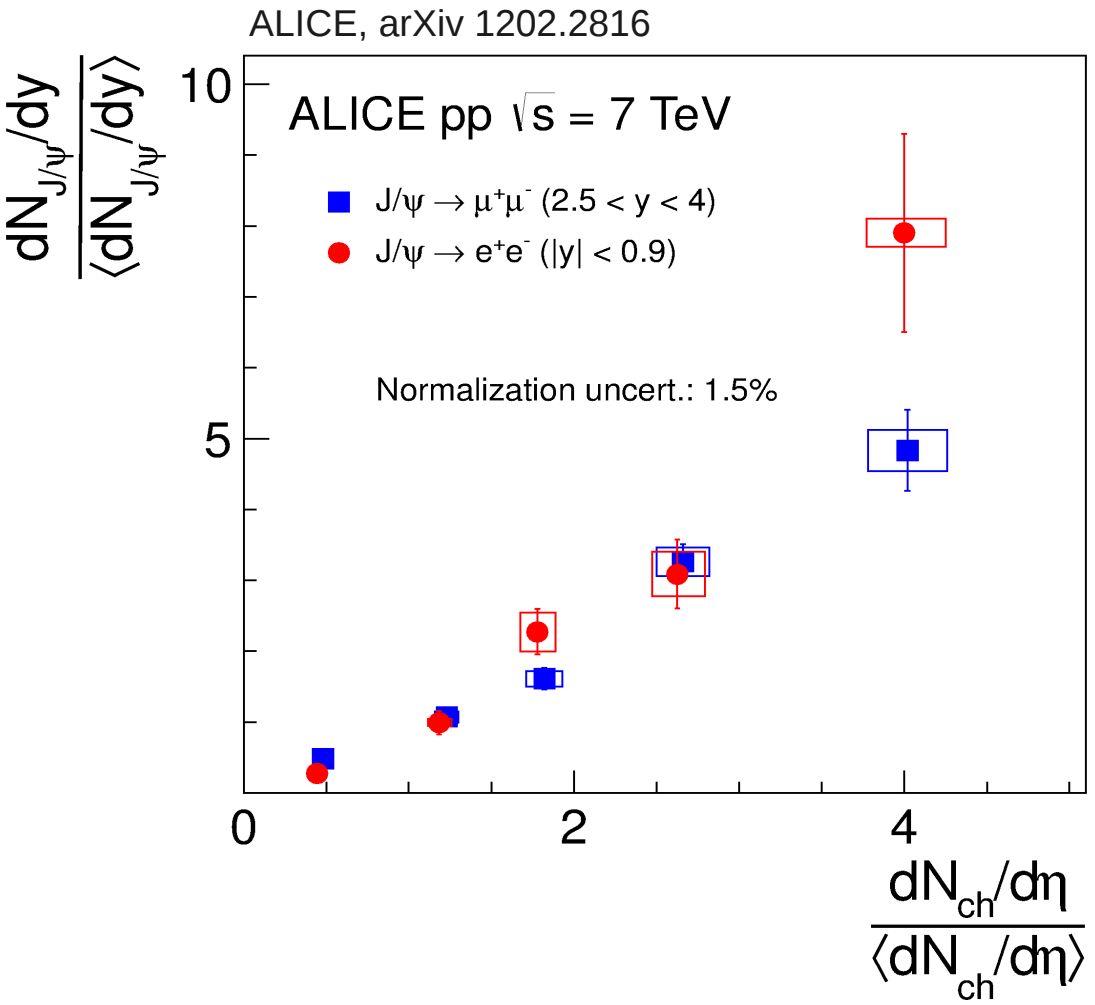
Butenschoen, Kniehl, arXiv: 1201.3862



- Within the statistics, the anisotropy of the J/ψ decay in both θ and φ is consistent with zero in both considered frames
- NRQCD calculations seem to improve the agreement with data when both color octet and color singlet channels are considered.

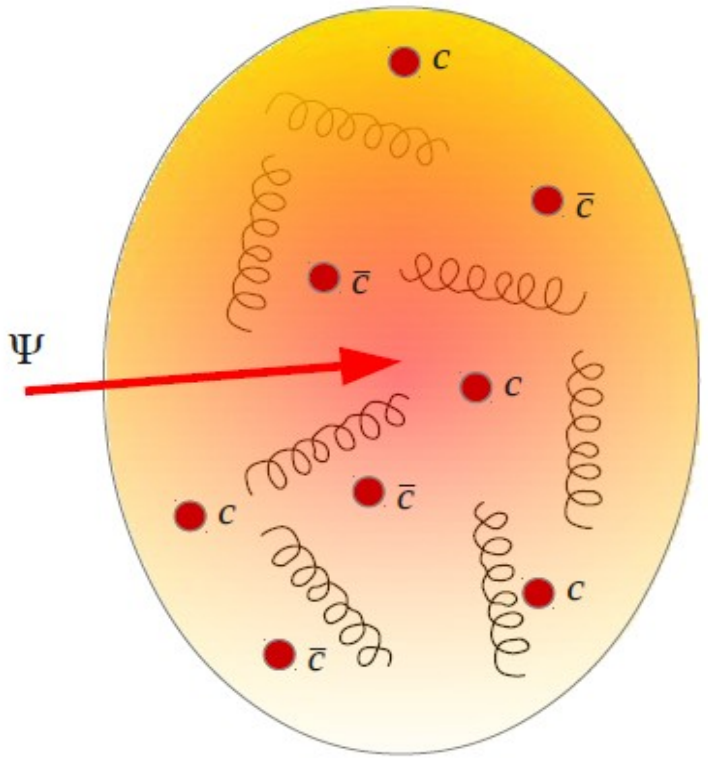
J/ψ vs event multiplicity





- J/ψ rapidity density approximately proportional to the charged particle density
- Posible explanation via multi-parton interactions?

J/ψ in heavy-ion collisions

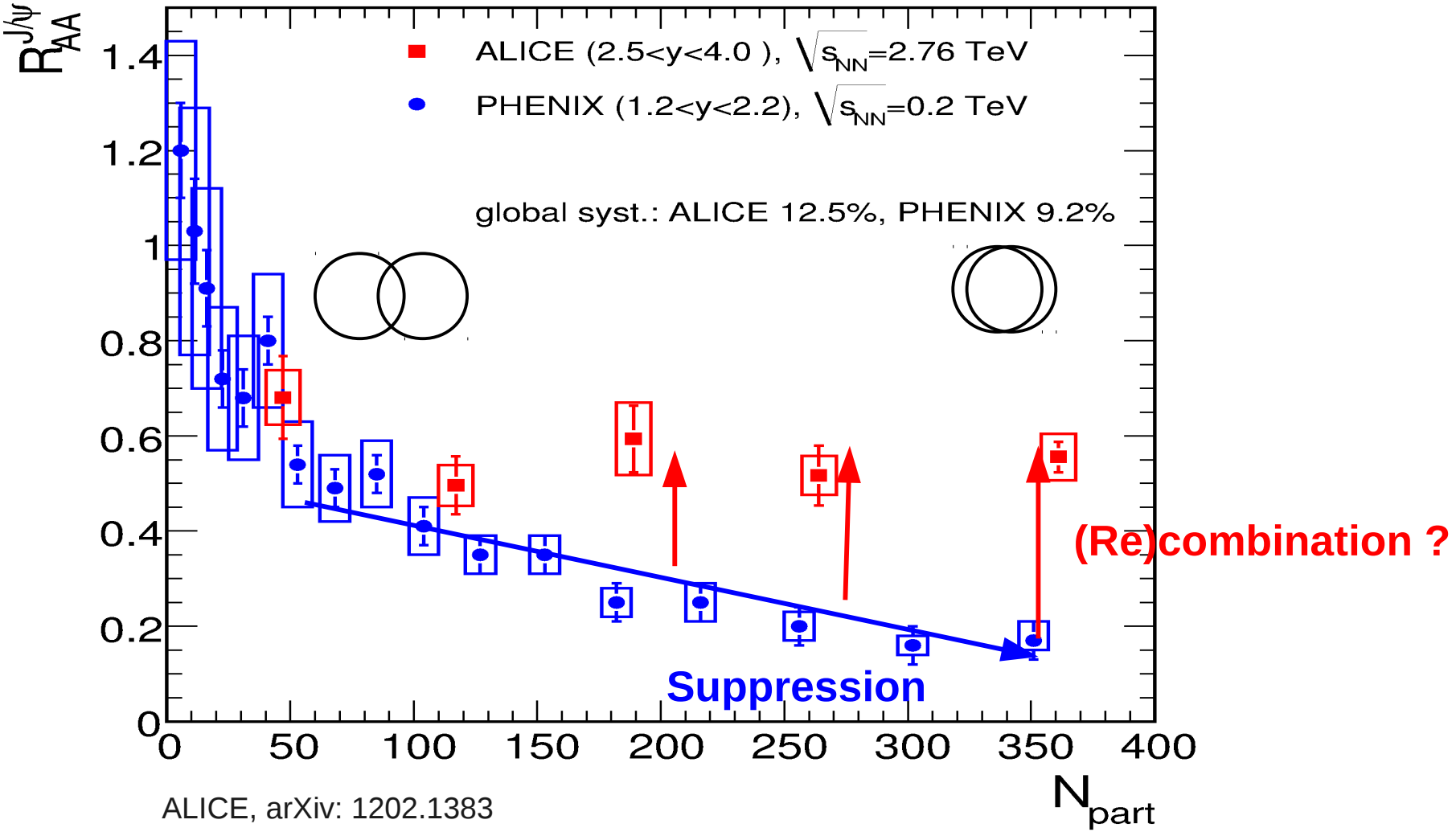


$$R_{AA}^{J/\psi} = \frac{Y_{AA}^{J/\psi}}{\langle T_{AA} \rangle \times \sigma_{pp}^{J/\psi}}$$

$R_{AA}^{J/\psi}$	Nuclear modification factor
$Y_{AA}^{J/\psi}$	Yield in Pb-Pb collisions
$\langle T_{AA} \rangle$	Nuclear overlap function (Glauber)
$\sigma_{pp}^{J/\psi}$	Inclusive cross-section in pp collisions

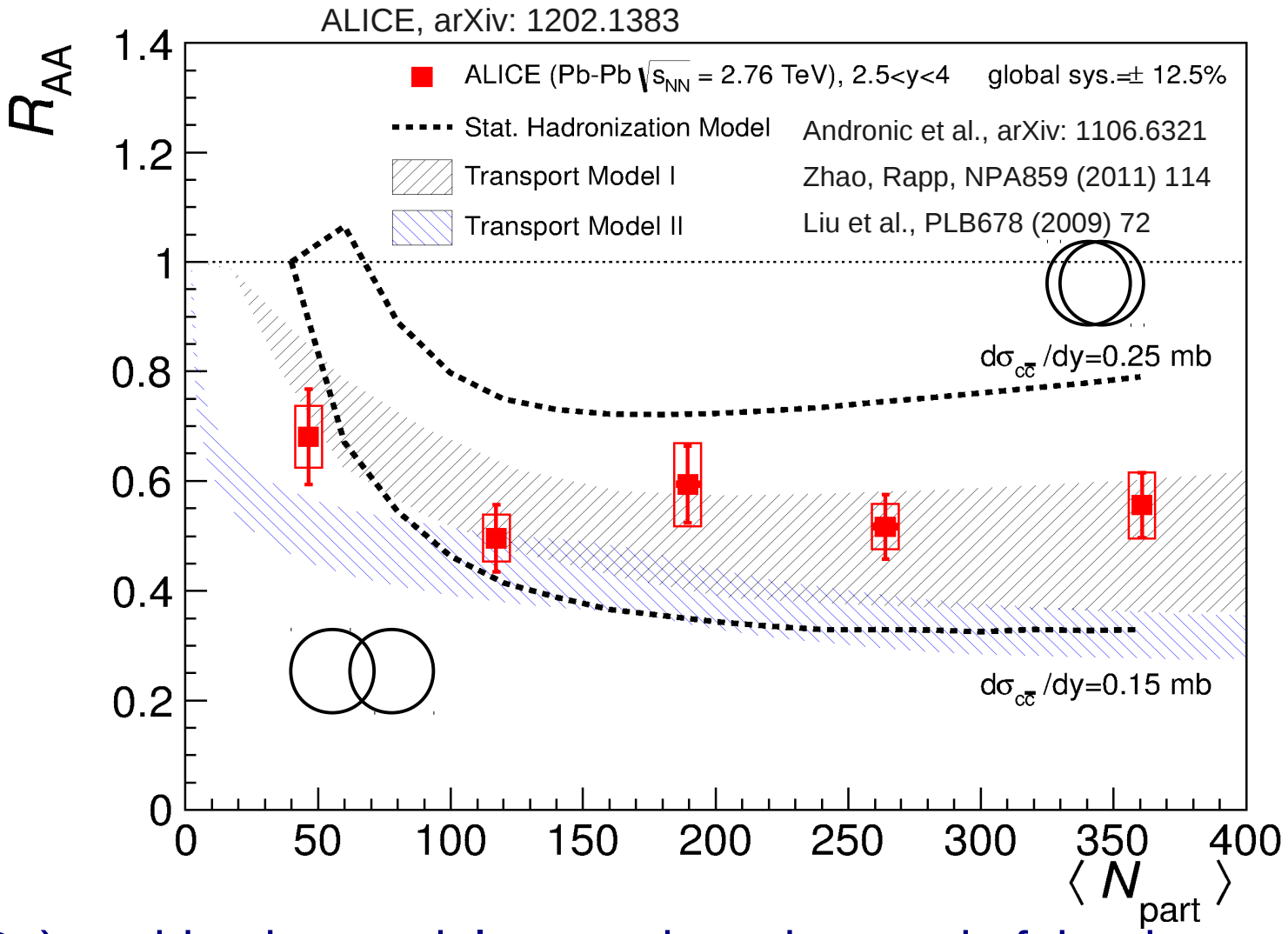
- Probe for the deconfined quark-gluon matter created in relativistic heavy-ion collisions (Matsui & Satz, PLB178 (1986) 416)
- Test of hadronization models (e.g. Andronic et al.,NPA789 (2007) 334-356)

Centrality dependence of the nuclear modification factor



- R_{AA} in central collisions is 3 times higher at LHC compared to RHIC

Comparison to models



- (Re)combination models reproduce the trend of the data
- The c-cbar inclusive cross-section needed to fully constrain the statistical hadronization model

Summary & Conclusions

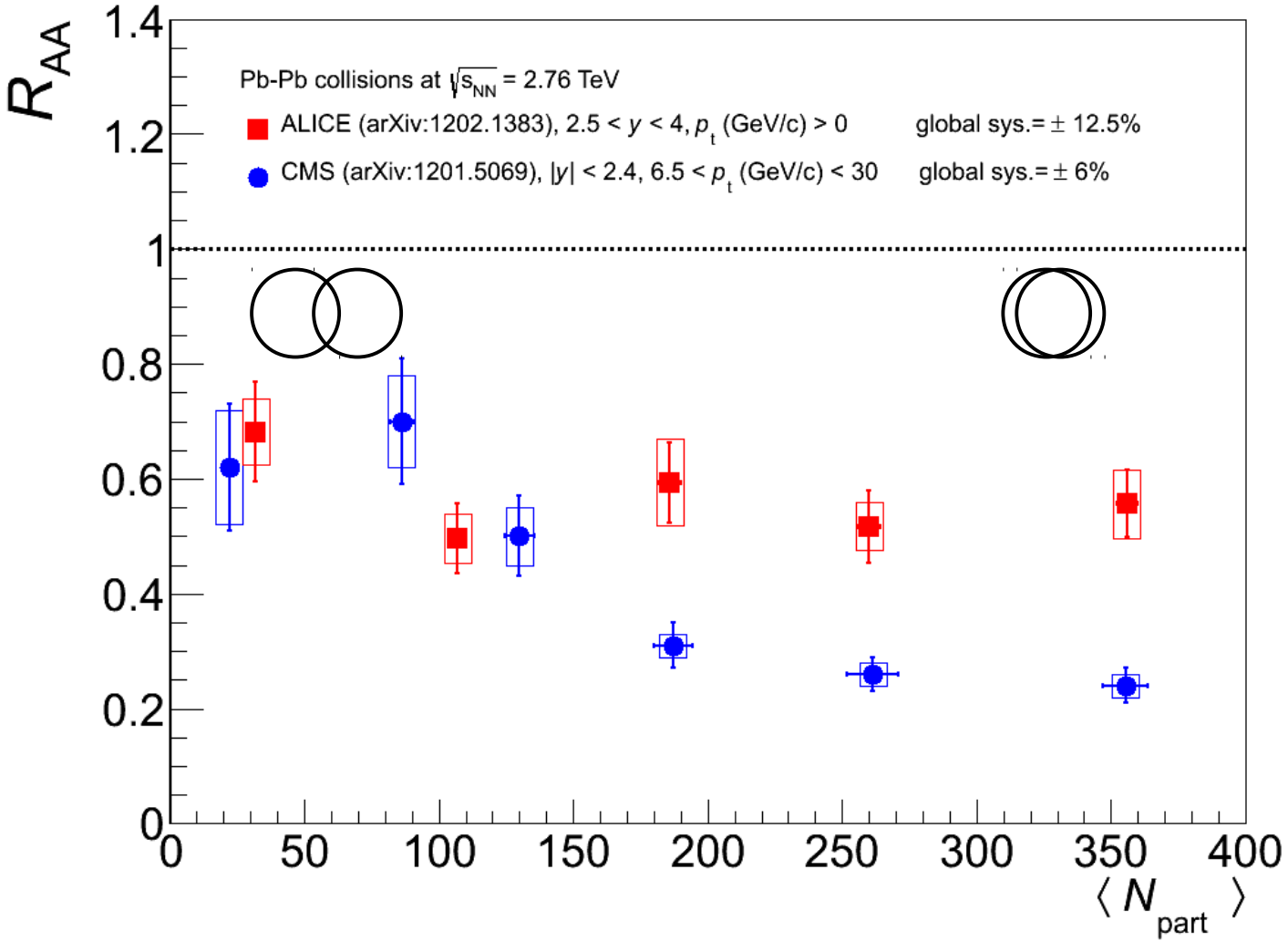
- J/ψ cross-section is measured in pp collisions at 2.76 and 7 TeV by the ALICE Collaboration:
  - The p_T dependent cross-section is well reproduced within NRQCD calculations down to 3 GeV/c
- The fraction of secondary J/ψ from beauty decays is measured down to 1.3 GeV/c
  - FONLL calculations show a very good agreement with the data
- Within the statistics available, the J/ψ polarization measurement is compatible with no polarization in both Collins-Soper and Helicity frames
- ALICE observes an approximately linear increase of the relative J/ψ yields to the pp charged particle multiplicity
- In central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, ALICE observes an enhancement of J/ψ production by a factor 3 compared to the lower energy measurements at RHIC.

Outlook

- In pp collisions:
  - Triggers will enable the measurement of higher mass quarkonium states (ψ', ϒ family)
  - Provide new observables to characterize the J/ψ production context
    - J/ψ-hadron correlations
    - Underlying event, etc.
- In Pb-Pb collisions:
  - J/ψ nuclear modification factor as a function of rapidity and transverse momentum in both decay channels
  - Disentangle initial state effects in Pb-Pb collisions (e.g. shadowing, gluon saturation) using the planned p-Pb collisions
  - Nuclear modification factor for ψ' and Y states
  - J/ψ event plane anisotropy (flow)

Backups

J/ψ in heavy-ion collisions



- Suppression grows with increasing p_T