Measurements of $J/\psi \rightarrow e^+e^-$ with ALICE at the LHC

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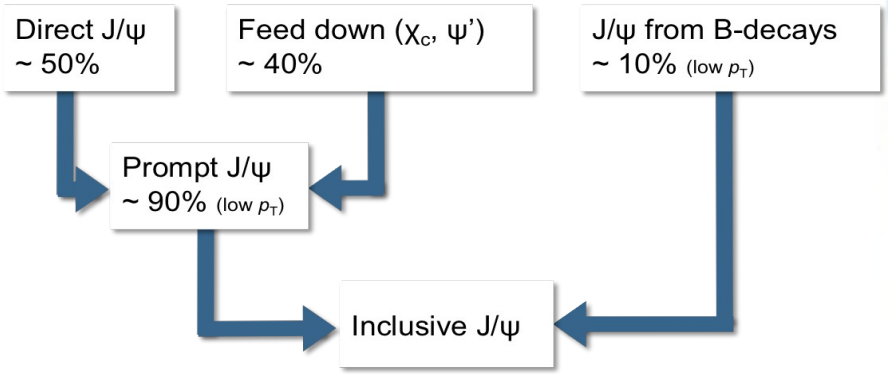
***Strangeness in Quark Matter**, 21-27 July 2013*

Outline

- Motivation
- The ALICE detector at the LHC
  - $J/\psi \rightarrow e^+e^-$ reconstruction
- Results:
  - pp collisions at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76 TeV
  - Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
  - Prospects for p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
- Conclusions

Motivation (1)

- pp collisions:
  - Test of QCD-based models (CEM, CSM, NRQCD) in a new energy domain
  - Measure the beauty production cross section (J/ψ ← B) at low p_T
  - Reference for Pb-Pb collisions



- p-Pb collisions:
  - Understand Cold Nuclear Matter (CNM) effects (e.g. Nuclear Parton Shadowing)

Motivation (2)

- Pb-Pb collisions:
  - $c\bar{c}$ pairs produced at the early stage of the collision
    → sensitive to the full QGP history
  - J/ψ suppression via Colour Debye Screening

    T. Matsui and H. Satz, Phys. Lett. **B178**, 416 (1986).
    → historical QGP signature
  - Regeneration mechanisms

    P. Braun-Munzinger and J. Stachel, Phys. Lett. **B490,** 196 (2000)

    R.L. Thews, M. Schroedter, and J. Rafelski, Phys. Rev. **C63**, 054905 (2001).
    new QGP signature at LHC energies → can counteract suppression
  - Study of beauty production via displaced J/ψ

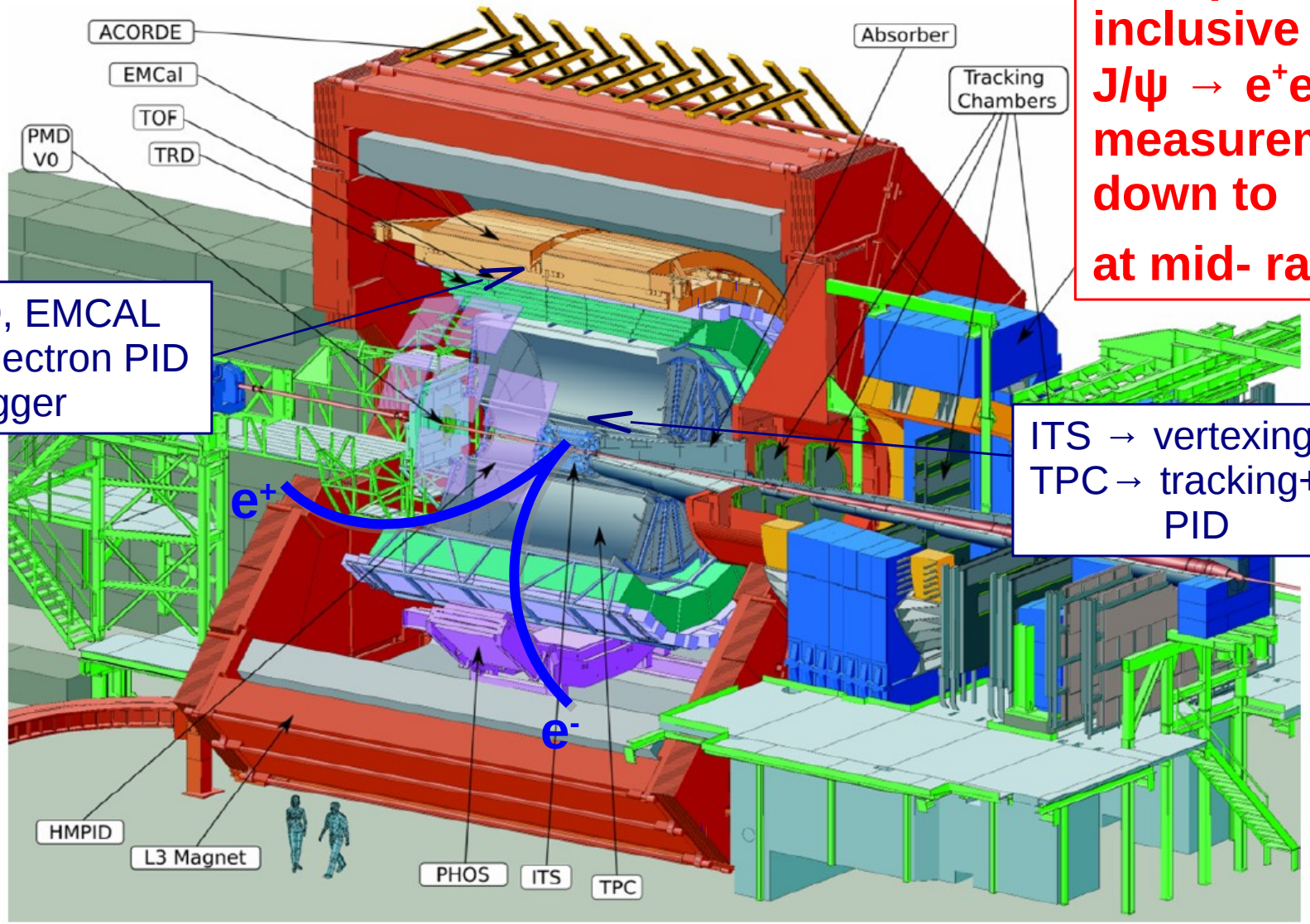
The ALICE detector at the LHC

J/ψ → μ+μ- at forward rapidity → see L. Palomo's talk

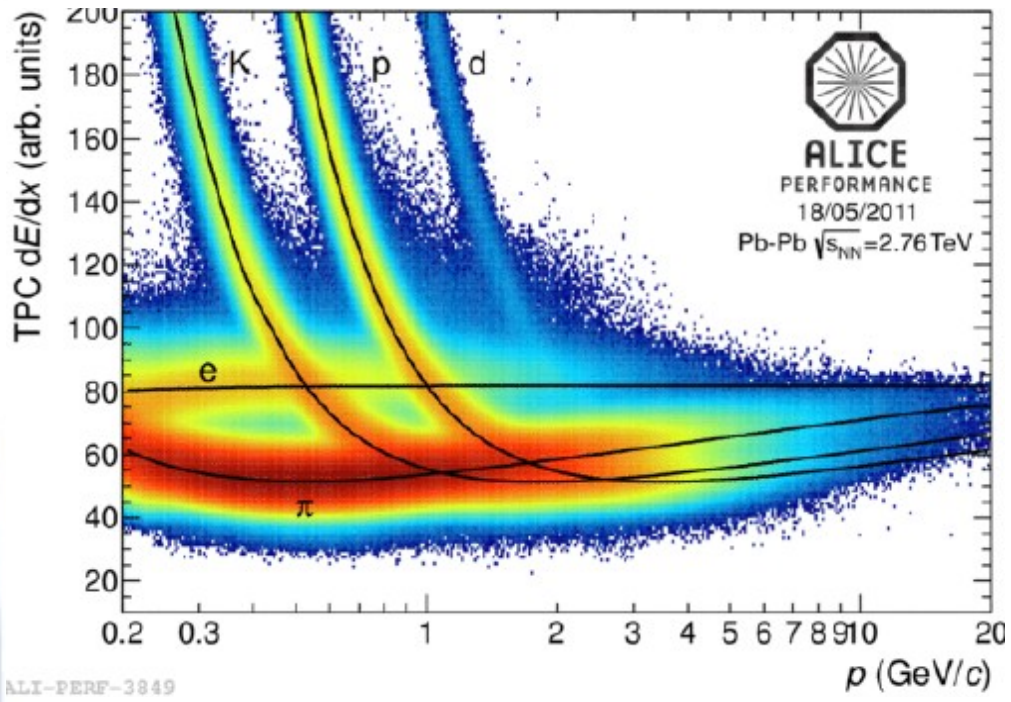
Acceptance for inclusive J/ψ → e^+e^- measurements: down to $p_T = 0$ at mid- rapidity

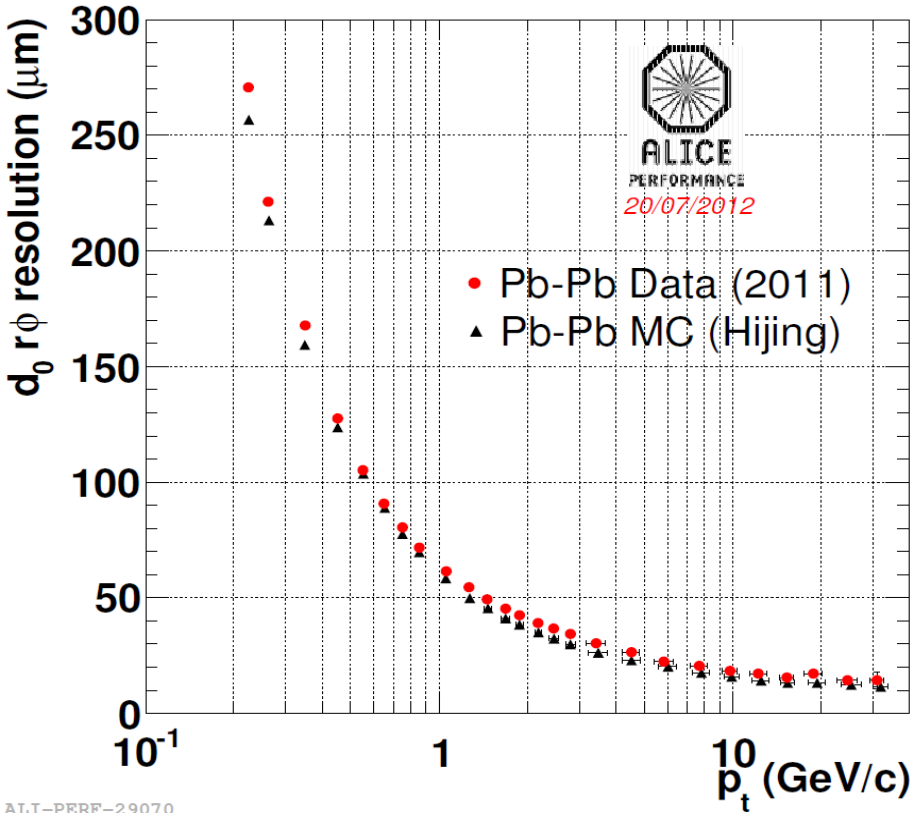
TRD, EMCAL → electron PID + trigger

ITS → vertexing + tracking
TPC → tracking+electron PID



J/ψ → e^+e^- reconstruction





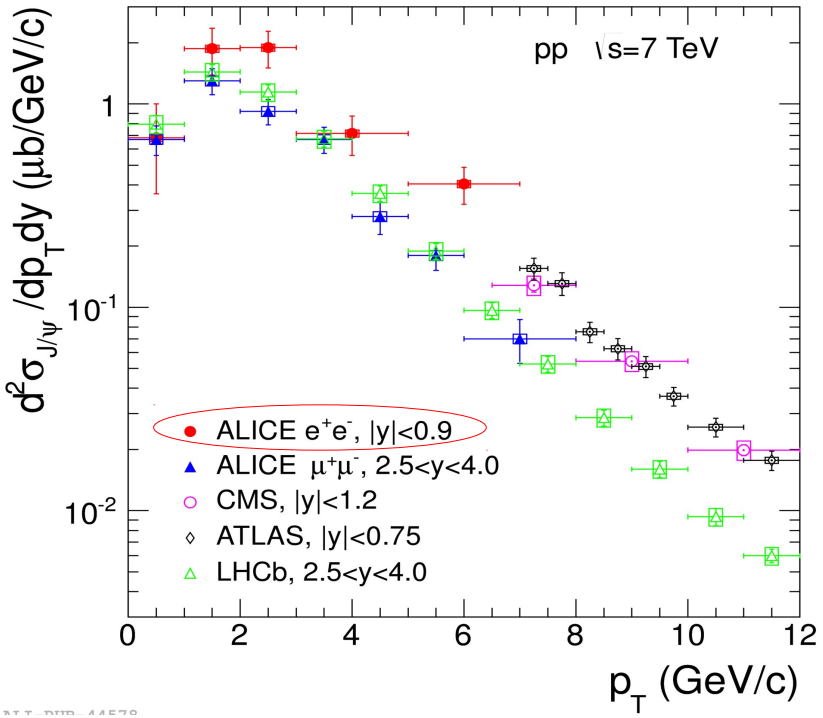
- Kinematic cuts: $|y^{J/\psi}|<0.9$, $p_T>0.85$ - 1.0 GeV/c, $|\eta^e|<0.9$
- Tracking: Inner Tracking System (ITS) + Time Projection Chamber (TPC)
  - Removal of electrons from gamma conversion
- PID:
  - Energy loss measurements dE/dx in TPC

- Good impact parameter resolution in the transverse plane (~60μm for p_T=1 GeV/c)
  - allows the study of J/ψ detached from primary vertex, coming from B hadrons decays ($c\tau_B$ ~ 500μm)

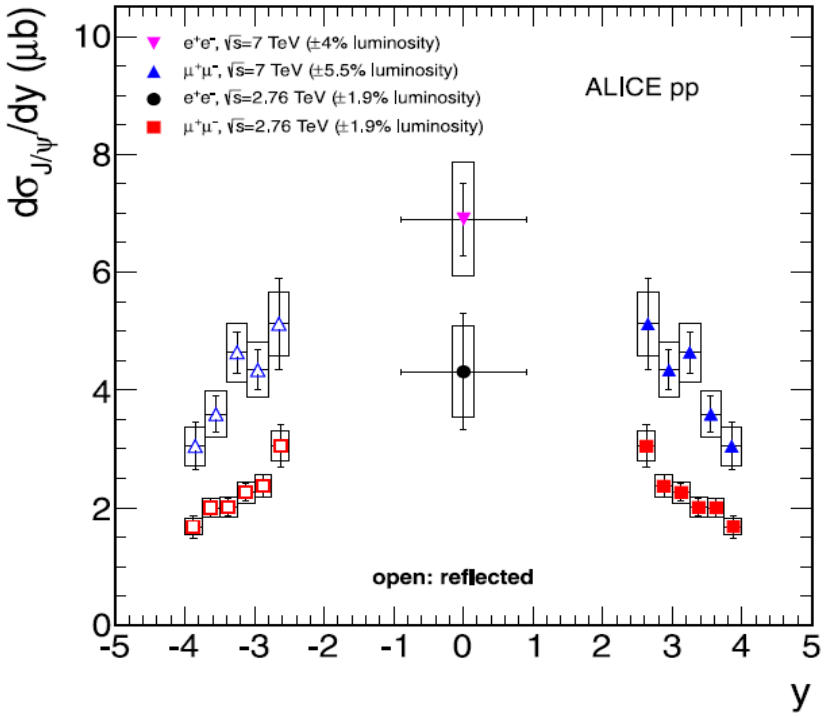
Results in proton-proton collisions

Inclusive J/ψ cross section in pp

ALICE: Phys. Lett. **B718**, 692 (2012).



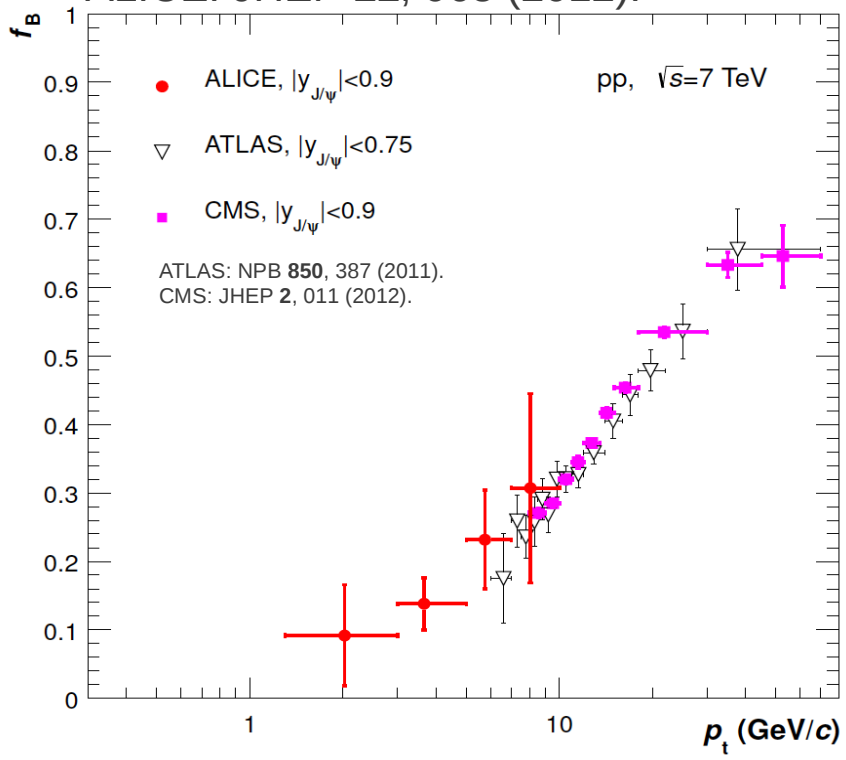
ALICE: Phys. Lett. **B718**, 295 (2012).

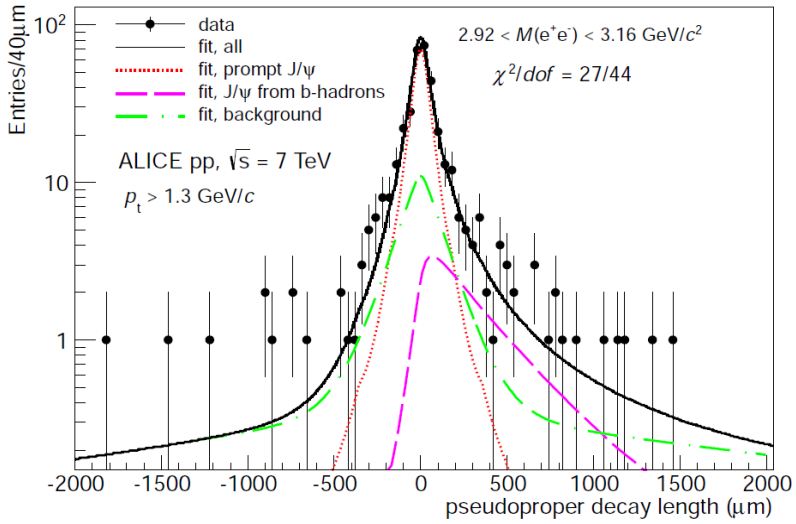


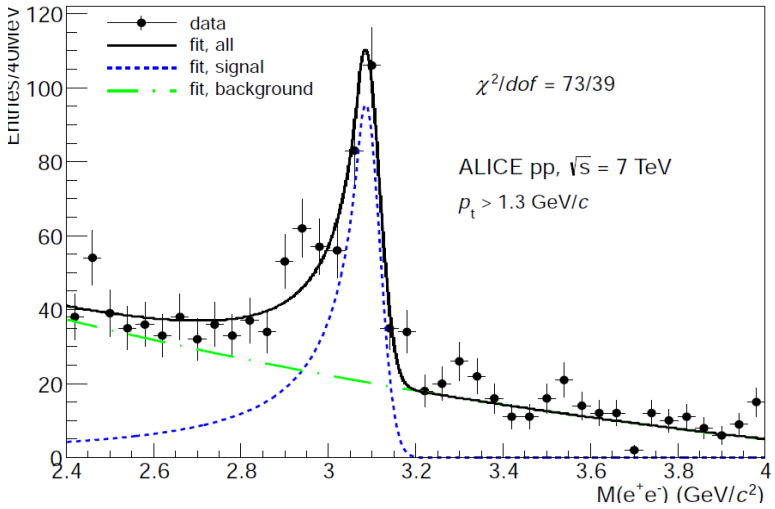
- down to $p_T = 0$
- kinematical coverage complementary to the one of CMS and ATLAS
- pp at $\sqrt{s}$ = 2.76 TeV → reference for Pb-Pb analyses

Non-prompt J/ψ fraction in pp at √s =7 TeV

ALICE: JHEP **11**, 065 (2012).







- Separation of prompt and non-prompt J/ψ in 4 p_T bins using the pseudoproper decay length:

$$x = \frac{c \cdot L_{xy} \cdot m_{J/\psi}}{p_t^{J/\psi}}, \quad L_{xy} = \vec{L} \cdot \vec{p}_t^{J/\psi} / p_t^{J/\psi}$$

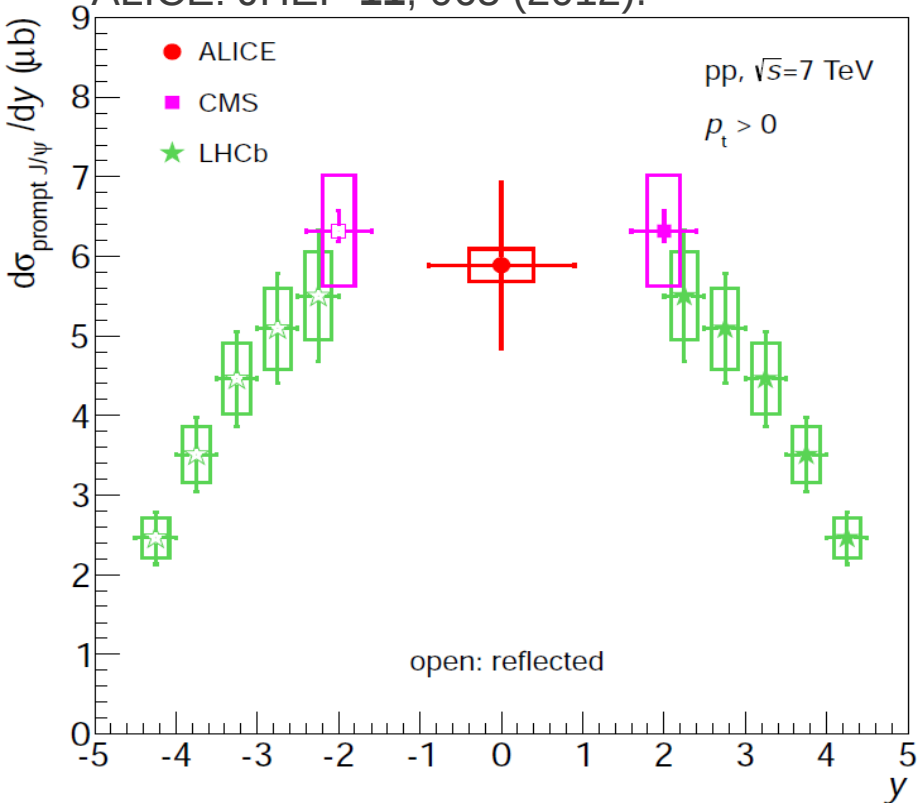
- Prompt and non-prompt J/ψ yields measured also as a function of charged particle multiplicity (→see Renu Bala's talk on Thursday)

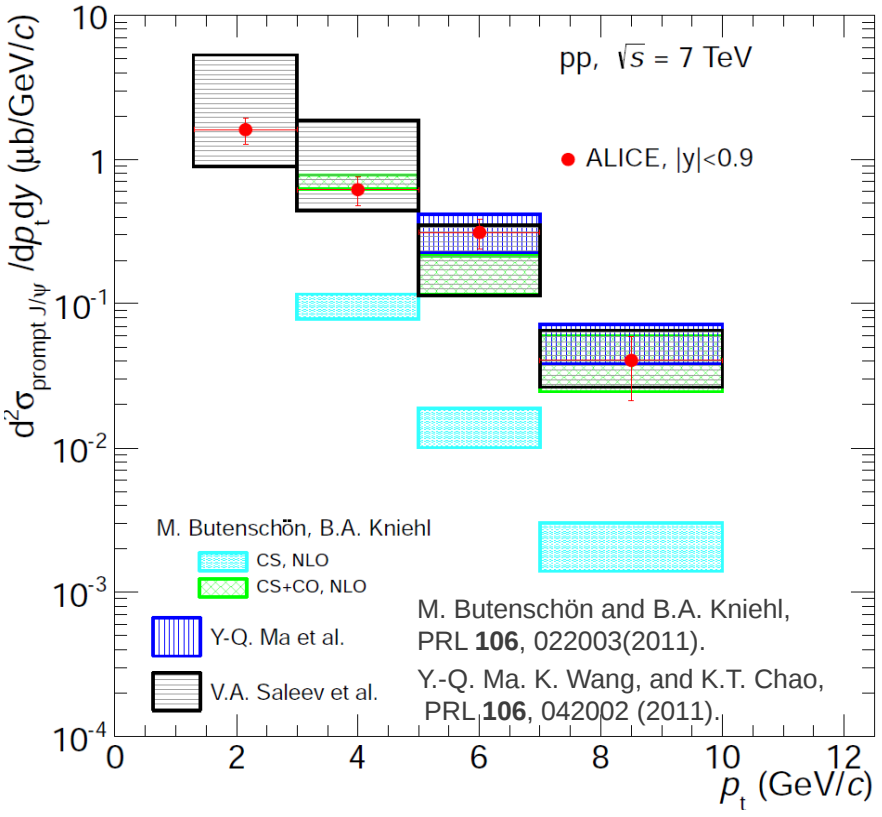
- Non-prompt J/ψ fraction f_B measured for p_T>1.3 GeV/c

$$f_B = 0.149 \pm 0.037\,(\text{stat.})^{+0.018}_{-0.027}\,(\text{syst.})^{+0.025\,(\lambda_{HE}=1)}_{-0.021\,(\lambda_{HE}=-1)}\,(\text{syst.pol.})$$

Prompt J/ψ in pp at √s =7 TeV

ALICE: JHEP **11**, 065 (2012).





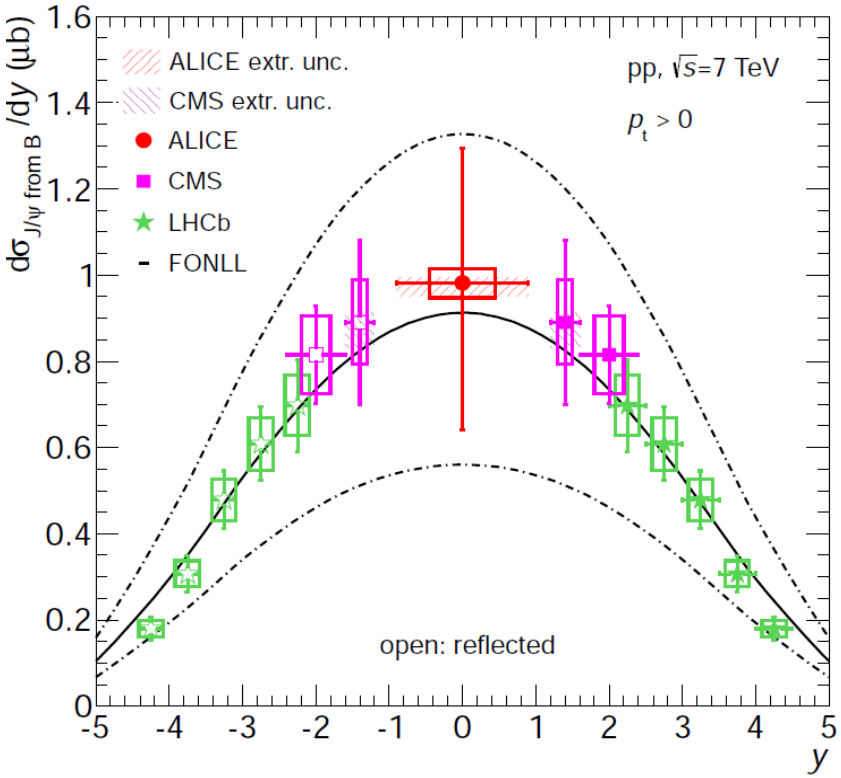
- prompt J/ψ cross section measured for $p_T > 0$:

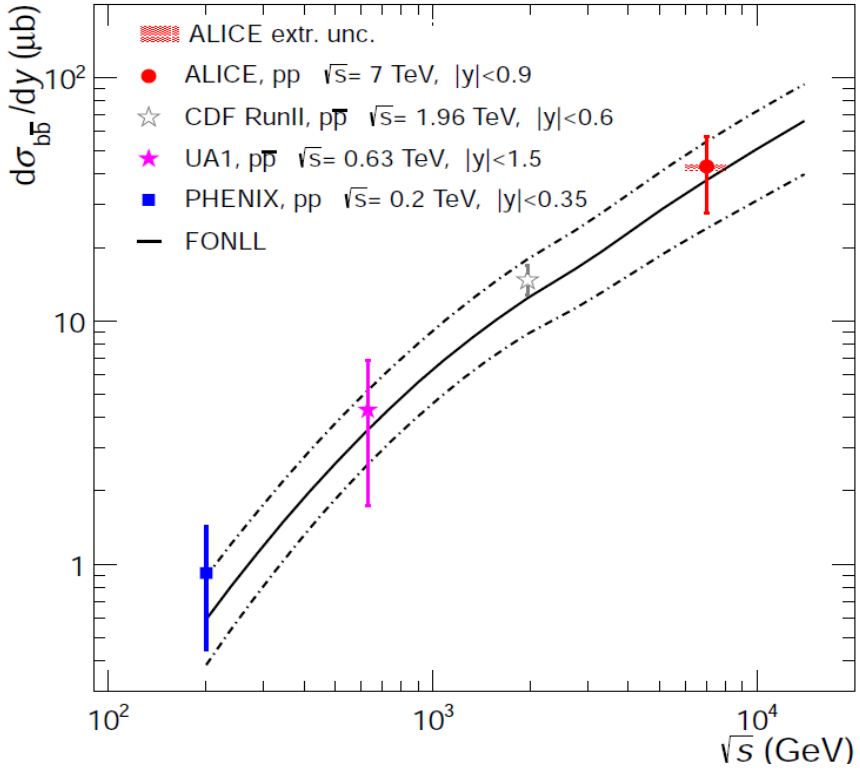
$$\frac{d\sigma_{\text{prompt J}/\psi}}{dy} = 5.89 \pm 0.60(\text{stat.})^{+0.88}_{-0.90}(\text{syst.})^{+0.03}_{-0.01}(\text{extr.})^{+1.01(\lambda_{HE}=1)}_{-0.99(\lambda_{HE}=-1)}\ \mu\text{b}$$

- Good agreement for prompt J/ψ cross section with NRQCD calculations

Non-prompt J/ψ in pp at $\sqrt{s}$ = 7 TeV

ALICE: JHEP **11**, 065 (2012).



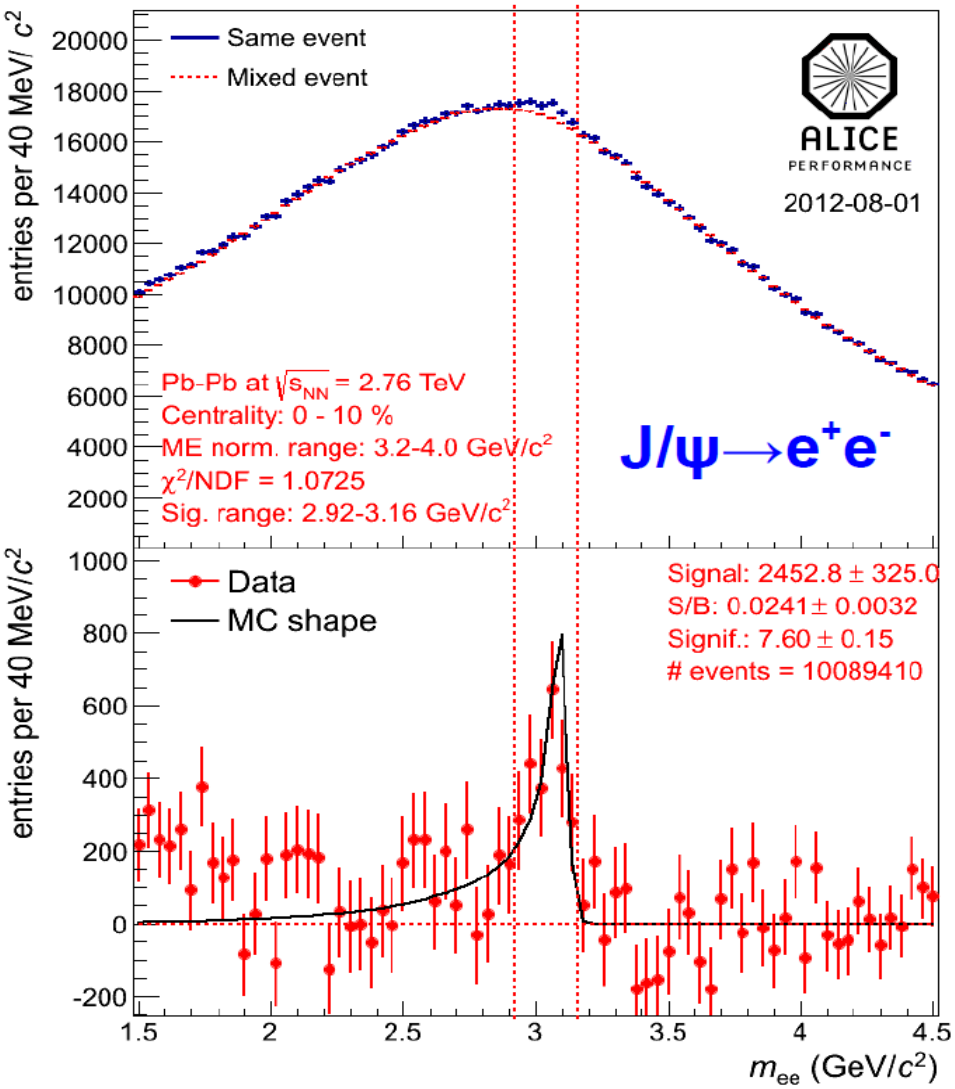


- Non-prompt J/ψ and beauty production cross sections extrapolated down to p_T = 0 at mid-rapidity, using FONLL predictions [M. Cacciari et al., JHEP **07**, 033 (2004).]
  - total beauty cross section from FONLL extrap.:

$$\sigma(\mathrm{pp} \to \mathrm{b\bar{b}} + X) = 282 \pm 74(\mathrm{stat.})^{+58}_{-68}(\mathrm{syst.})^{+8}_{-7}(\mathrm{extr.})\ \mu\mathrm{b}$$

Results in Pb-Pb collisions

J/ψ → e^+e^- analysis in Pb-Pb

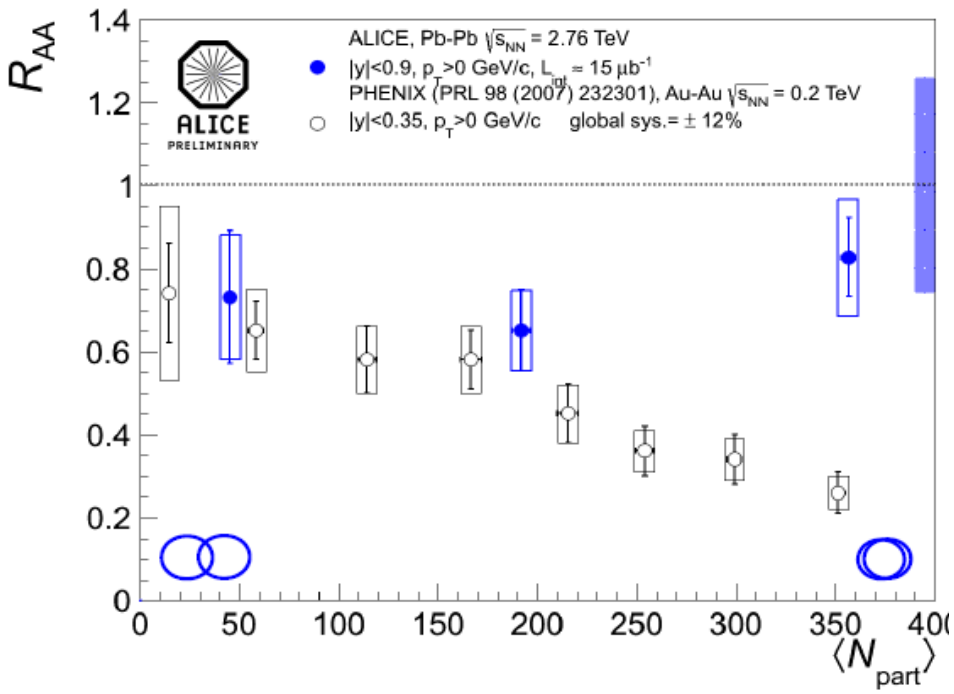


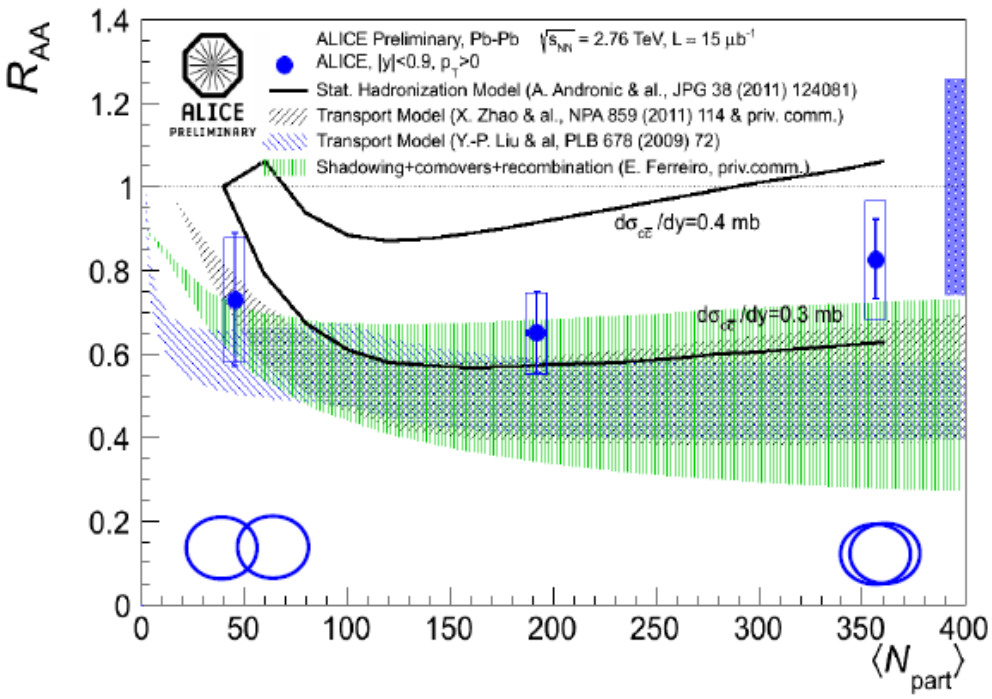
- Inclusive J/ψ analysis:
  - ✔ $|y|<0.9$, $p_T>0$
  - ✔ R_{AA} measured in three centrality classes:

$$R_{AA} = \frac{d^2N_{AA}/dp_T dy}{N_{coll} \times d^2N_{pp}/dp_T dy}$$

- Fraction of non-prompt J/ψ studied for $p_T>2$ GeV/c as a function of centrality
- Outlook:
  - ✔ R_{AA} as a function of transverse momentum
  - ✔ R_{AA} for prompt and non-prompt J/ψ

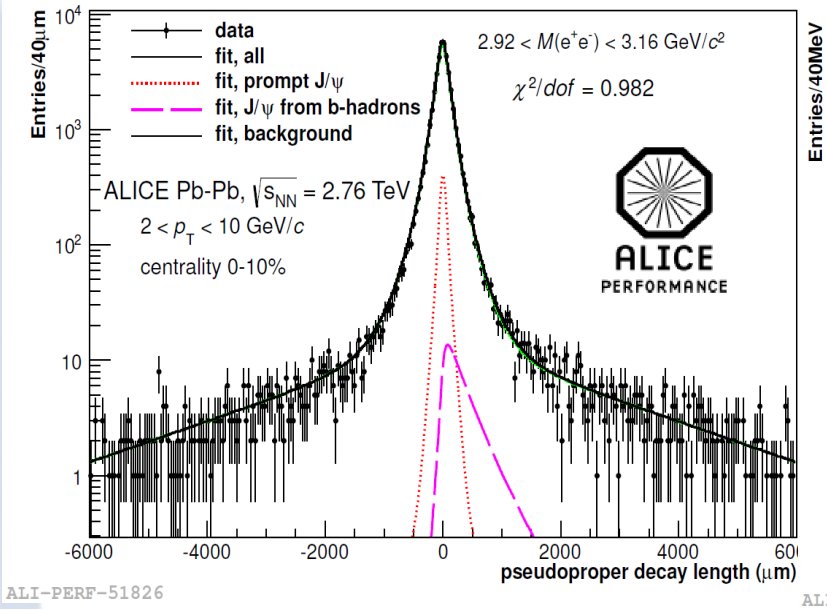
Inclusive J/ψ R_{AA} vs centrality



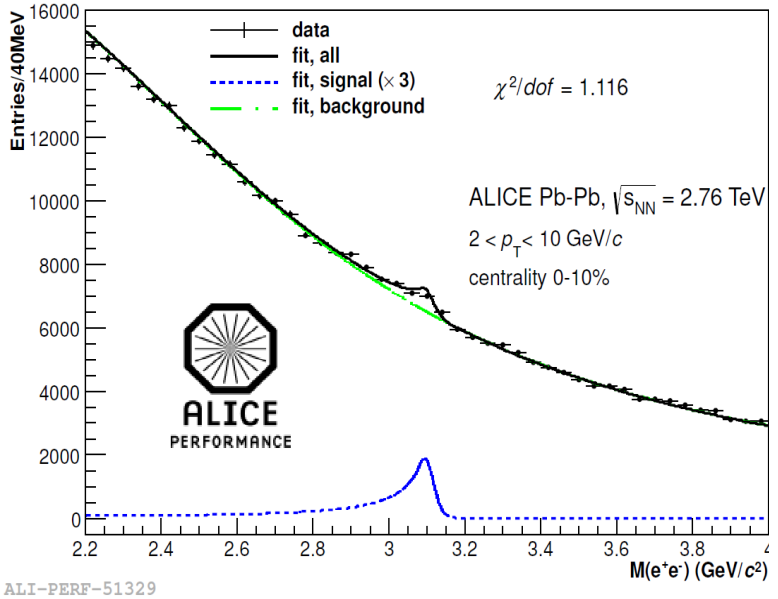


- Indication for reduced suppression for most central collisions w.r.t. PHENIX (similar behaviour at forward rapidity → see Lizardo Palomo's talk)
- Models which consider the (re)combination of deconfined charm pairs from the QGP are in agreement with data albeit with large uncertainties of the charm cross section
- p-Pb results are necessary to measure gluon shadowing in the Pb nucleus

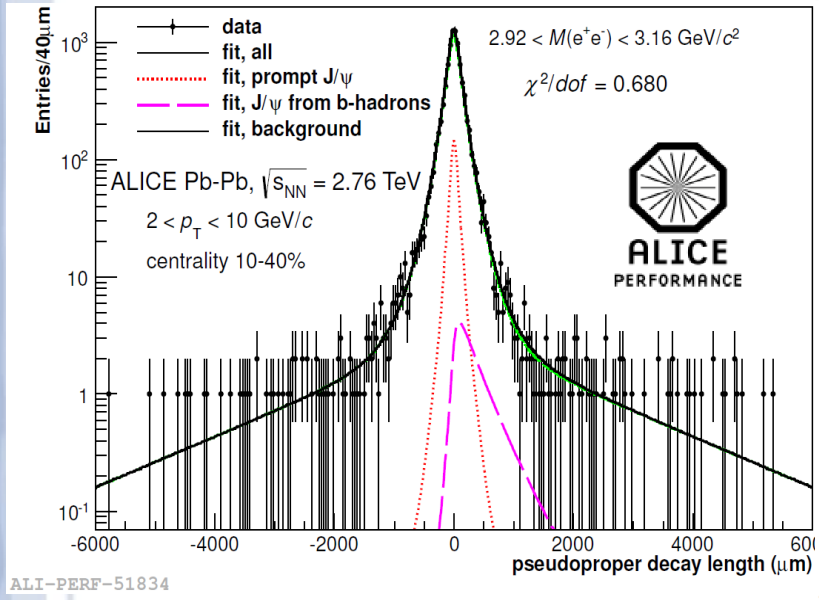
Non-prompt J/ψ fraction (1)



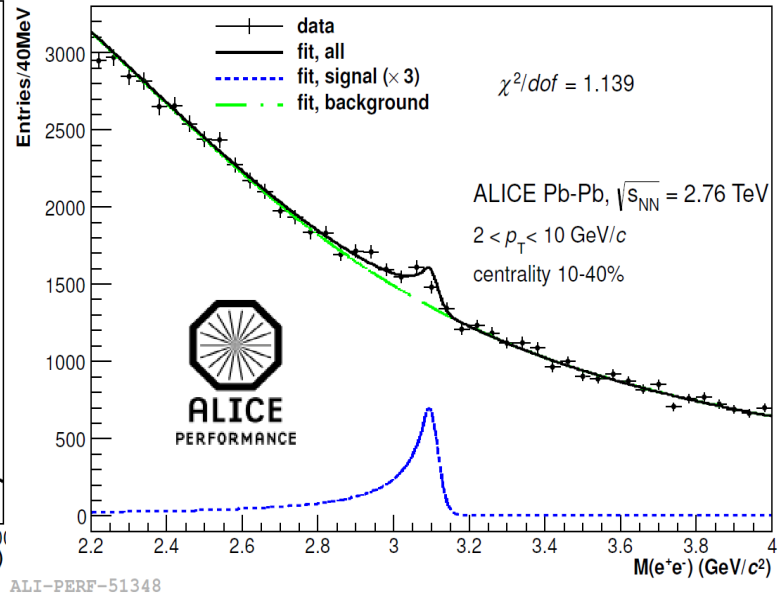
ALI-PERF-51826



ALI-PERF-51329



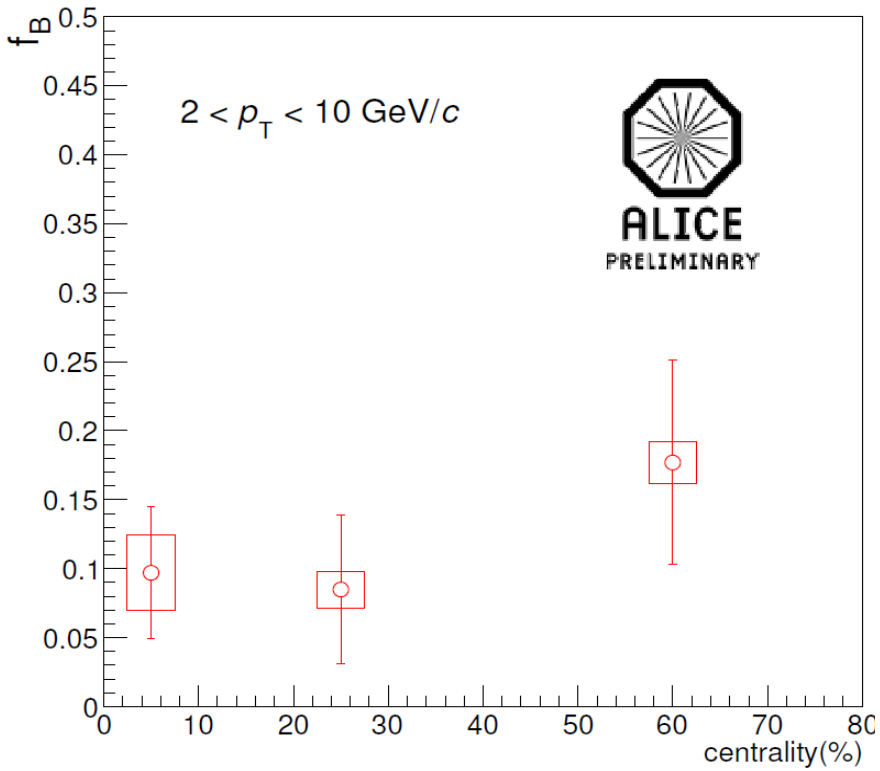
ALI-PERF-51834



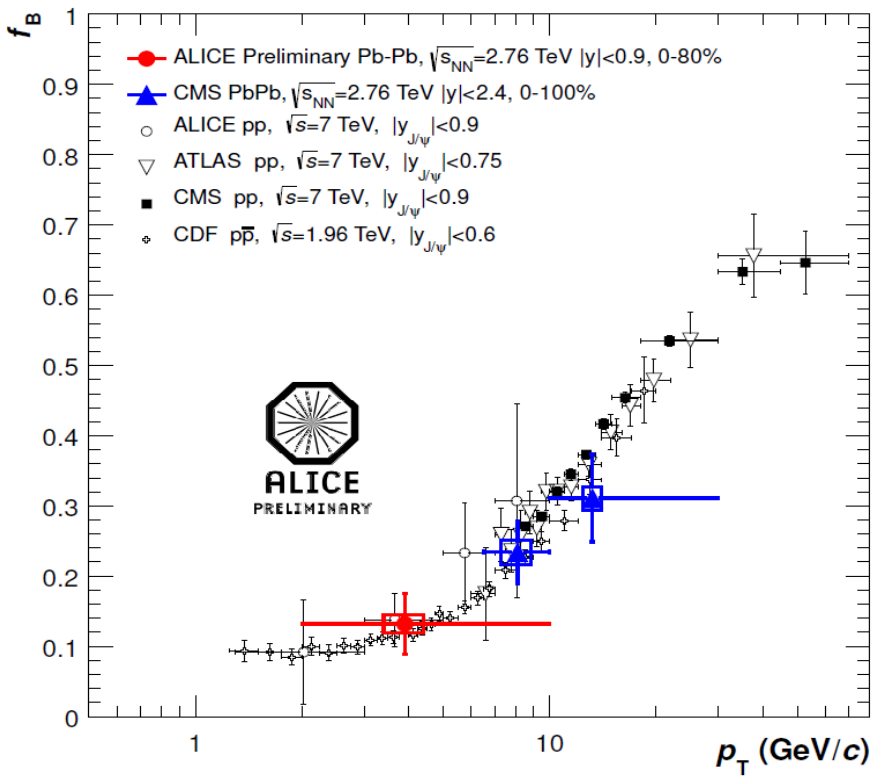
ALI-PERF-51348

- Non-prompt J/ψ fraction measured in Pb-Pb for $2<p_T<10$ GeV/c in three different centrality classes
- Pseudoproper decay length and inv. mass distributions with the projection of the maximum likelihood fit superimposed

Non-prompt J/ψ fraction (2)



ALI-PREL-51321



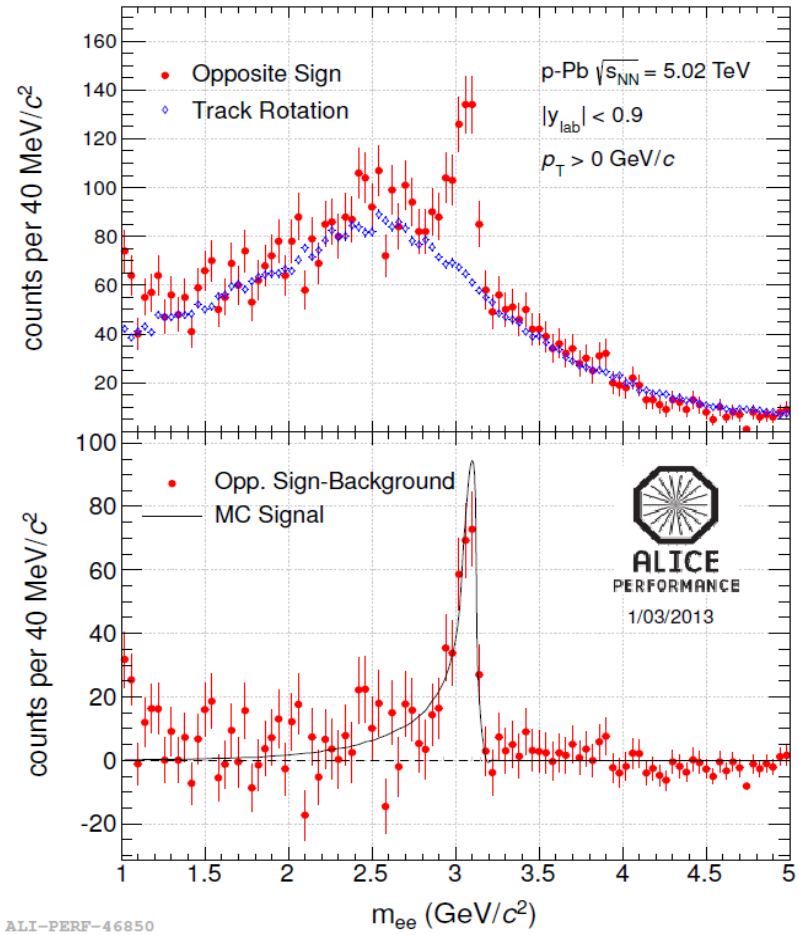
ALI-PREL-51325

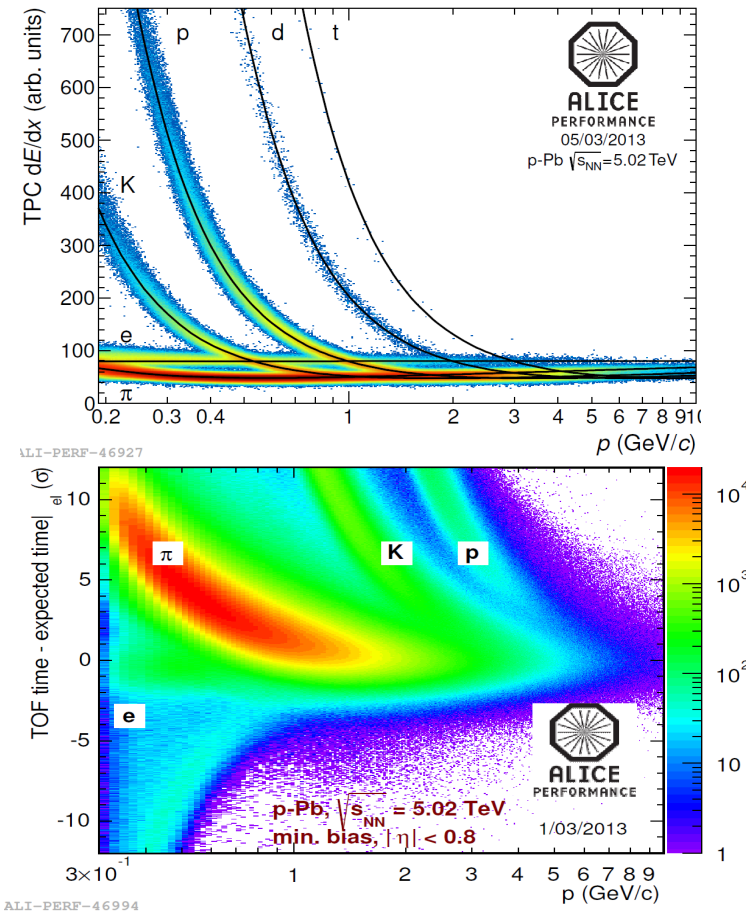
Error bars: statistical uncertainties
Boxes: systematics

- No significant dependence of fraction of non-prompt J/ψ f_B on centrality

- f_B in centrality class 0-80% measured at low p_T → ALICE p_T coverage complementary to the one of CMS
- Evidence of similar trend of f_B as a function of p_T in pp and Pb-Pb

Prospects for p-Pb collisions





- Minimum-bias (~50μb^{-1}) + TRD triggered (trigger on single electron) events (~1.4nb^{-1})
- Good detector performances for both tracking and PID
- Good quality measurements expected soon

Conclusions

- pp collisions:
  - Inclusive J/ψ cross section measured at mid rapidity down to $p_T = 0$ at $\sqrt{s} = 7$ TeV and at $\sqrt{s} = 2.76$ TeV → unique at LHC
    - Cross section measured at $\sqrt{s} = 2.76$ TeV used as reference for Pb-Pb
  - Prompt and non-prompt J/ψ separated down to $p_T = 1.3$ GeV/c at $\sqrt{s} = 7$ TeV; non-prompt J/ψ and beauty production cross sections also measured down to $p_T=0$
- Pb-Pb collisions
  - Nuclear suppression factor R_{AA} measured at mid-rapidity for $p_T>0$ as a function of centrality:
    - Indications of (re)generation of J/ψ from deconfined charm quarks (confirmed also by results at forward rapidity)
    - Analysis of p-Pb collisions will help to understand Pb-Pb results
  - Non-prompt J/ψ fraction measured for $p_T>2$ GeV/c as a function of centrality:
    - No significant dependence on centrality
    - suggestion of a similar trend of non-prompt J/ψ fraction f_B as a function of p_T for pp and Pb-Pb
    - Outlook: R_{AA} for prompt and non-prompt J/ψ at low p_T soon

Back-up

Systematics on non-prompt J/ψ fraction

Centr.	$F_{Bkg}(x)$	(*)R(x)	(*)MC p_T	Mass (Bkg)	(*)Mass (Sig)	(*)$\chi_B(x)$	Tot.
0-10%	±22%	±15%	±4%	±6%	±4%	±4%	28.2%
10-40%	±10%	±10%	±4%	±3%	±3%	±3%	15.6%
40-80%	±5%	±5%	±4%	±1%	±1%	±2%	8.5%

- Pseudoproper decay length background shape $F_{bkg}(x)$ under the signal region
- Resolution function R(x) for prompt J/ψ description
- p_T spectra to describe prompt and non-prompt J/ψ to get the "corrected" f_B
- Invariant mass:
  - m_{ee} signal shape
  - m_{ee} background shape
- MC-truth pseudoproper decay length distribution for non-prompt J/ψ ($\chi_B(x)$)
- Primary vertex (negligible)

(*) contributions correlated with centrality