Prompt/non-prompt J/Ψ separation in pp at $\sqrt{s}$ = 13.6 TeV with ALICE

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Quarkonia as probe of the QGP

The **quark-gluon plasma** (QGP) is a state of matter in which quarks and gluons are no more confined inside hadrons and can be produced in ultrarelativistic heavy-ion collisions. Heavy quarkonia, bound states of quark/antiquark pairs, are a valuable tool to investigate the properties of the QGP.

Quarkonia production in nuclear collisions is affected by different mechanisms:
- **suppression** through color screening and dynamical dissociation
- **(re)generation**: recombination of uncorrelated $c\bar{c}$ pairs, produced with high multiplicity at the LHC energies, expected to be almost negligible for beauty quarks

This study : focus on J/Ψ production in small and large collision systems

The nuclear modification factor R_{AA} is the key observable to study quarkonium modification in presence of the QGP:
- R_{AA} = 1 : no modification with respect to pp collisions
- R_{AA} < 1 : suppression

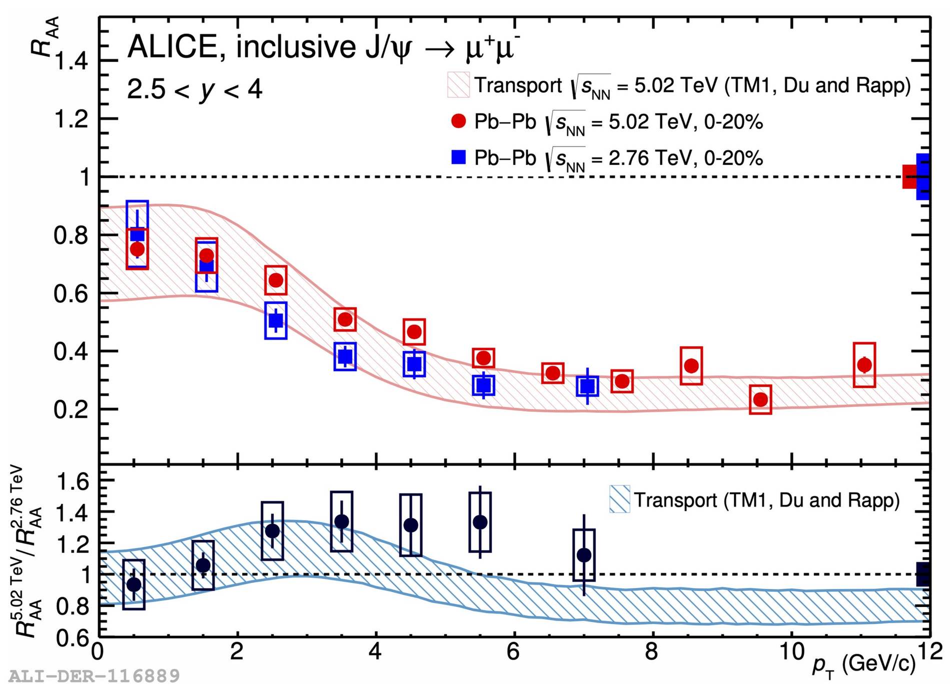
$$R_{AA} = \frac{N^{AA}_{J/\psi}}{<T_{AA}> \cdot \sigma^{J/\psi}_{pp}} \quad (1)$$

J/Ψ inclusive production can be separated into **two contributions** :

prompt J/Ψ:
- produced at the primary vertex (PV)
- interacts with the QGP
- probe for charm sector

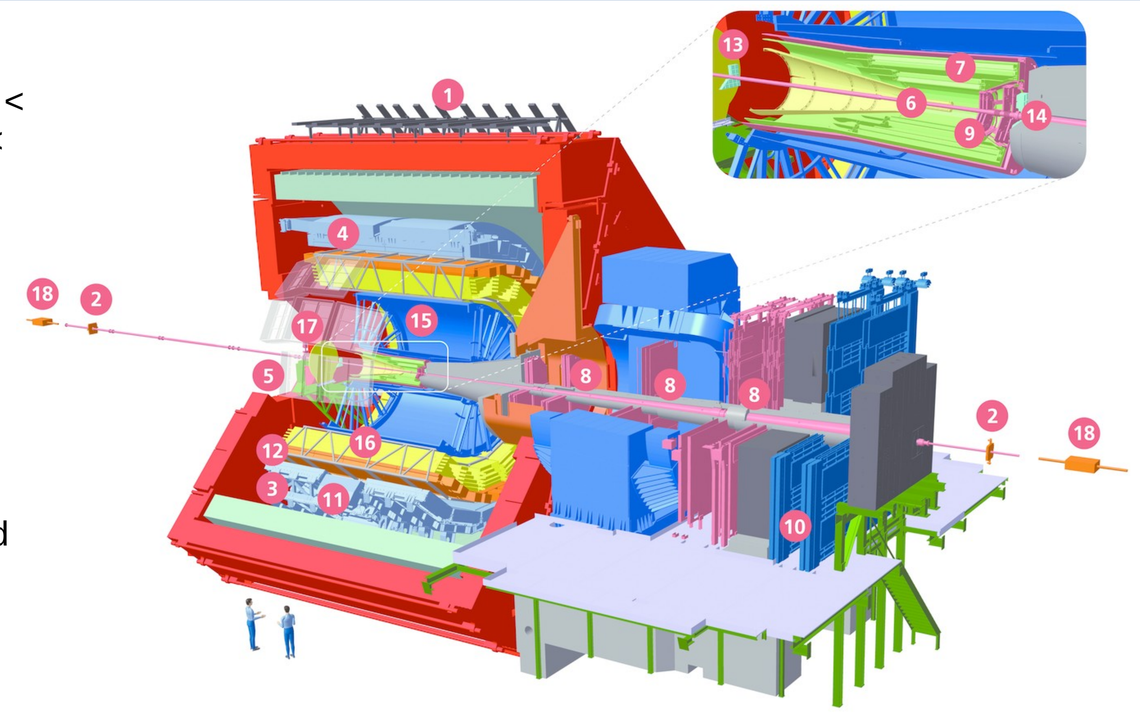
non-prompt J/Ψ:
- from B hadron decays
- vertex topology
- probe for beauty sector

Motivation for prompt/non-prompt J/Ψ separation :
- access another channel for b-hadron studies
- precise study of the **regeneration mechanism**



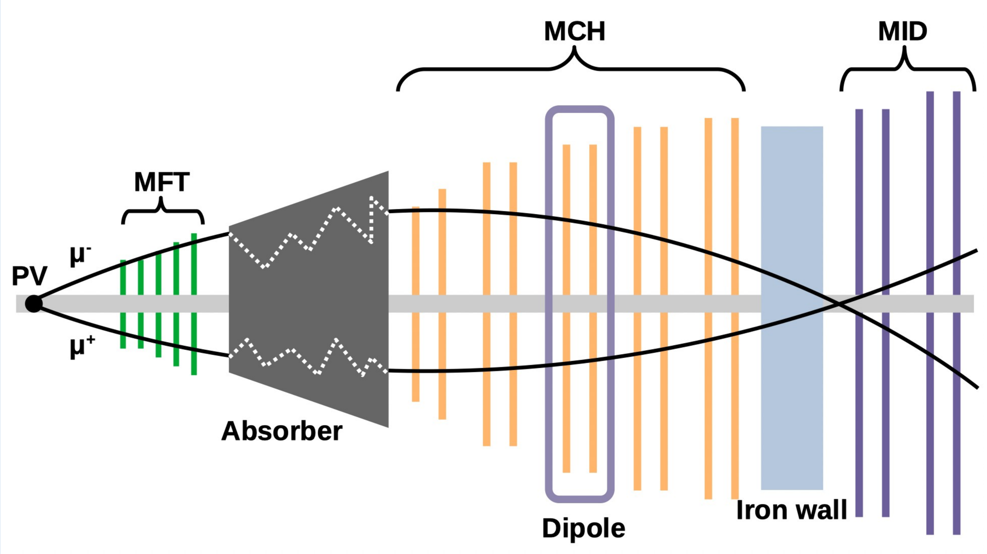
The ALICE experiment

The ALICE experiment is designed for the study of heavy-ion collisions. It consists of a central barrel (|y| < 0.9) and Muon Spectrometer (2.5 < y < 4).



Central barrel :
- Inner Tracking System (ITS) : Si-pixel sensors used for vertex reconstruction
- Fast Interaction Trigger (FIT) : provides timing indications
- Time Projection Chamber (TPC) : used for vertexing, tracking and PID

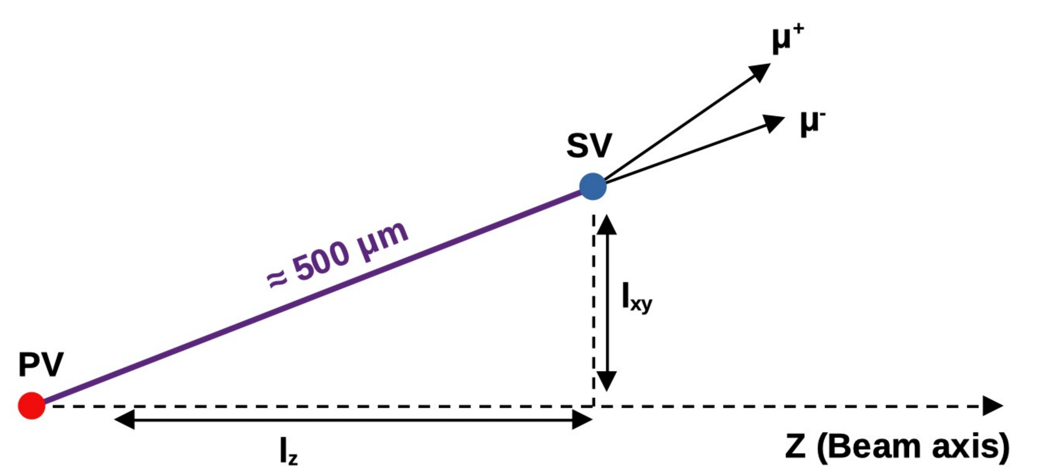
Muon Spectrometer :
- Muon Forward Tracker (MFT) (9) :
  - **installed in Run 3**
  - five disks made of Si-pixel sensors (CMOS based)
  - measures charged tracks with high spatial resolution
  - provides vertex capability, allowing to measure non-prompt decay
- Absorber :
  - suppresses hadronic contributions
- Muon Chambers (MCH) (8) :
  - ten multiwire sensor chambers for muon tracking
  - momentum determination thanks to the dipole magnet
- iron wall :
  - filter for low momentum muons (p<4 GeV/c) coming from π and K decay
- Muon Identifier (MID) (10) :
  - four RPC chambers arranged in two stations
  - select high momentum muons



MCH-MID tracks matched to MFT tracks : **global tracks**

Prompt/non-prompt J/Ψ separation : analysis strategy

J/Ψ from b-hadron decays are characterized by displaced topology :



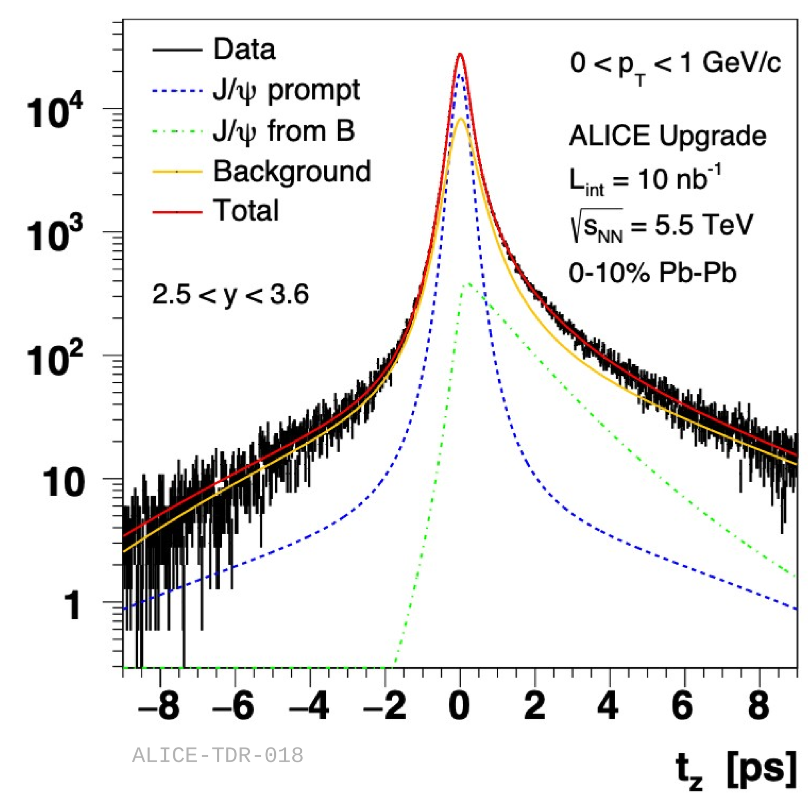
Forward rapidity : longitudinal boost increases time of flight of b hadrons up to mm scale, providing better discrimination power for prompt/non-prompt separation

Run 2 : no information beween vertex and tracking chambers, all muon track reconstructed as coming from PV
Run 3 : now possible to do prompt/non-prompt separation at forward rapidity

Prompt/non-prompt separation is done using **pseudo-proper decay length** $l_{J/\psi}$:
- J/Ψ vertex ($z_{J/\psi}$) along z axis
- primary vertex (z_{vtx}) along z axis
- J/Ψ invariant mass ($M_{J/\psi}$)
- longitudinal momentum (p_z)
- **pseudo-proper decay time** (τ_z)

$$l_{J/\psi} = c.\tau_z = c.\frac{(z_{J/\psi} - z_{vtz}).M_{J/\psi}}{p_z} \quad (2)$$

Analysis procedure: template fit to the pseudo-proper decay time:
- Data : Monte Carlo simulation
- background : mainly composed of combinatorial muon pairs and decay from π and K
- prompt distribution : centered around τ_z = 0, symmetric shape
- non-prompt distribution : right tail for τ_z > 0, asymmetric shape



Extraction of prompt/non-prompt fraction

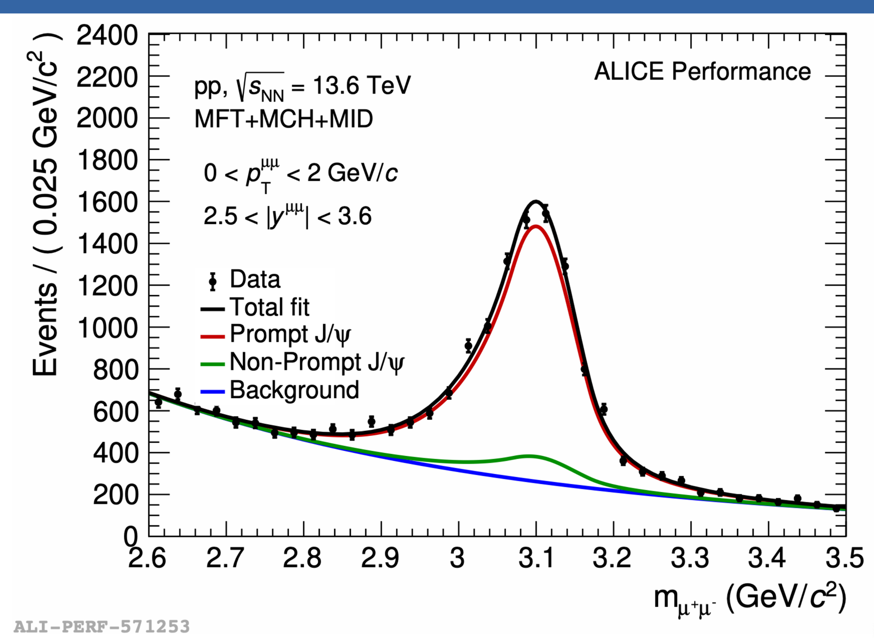
Event selection :
- -10 cm < z_{vertex} < 10 cm
- event quality cuts

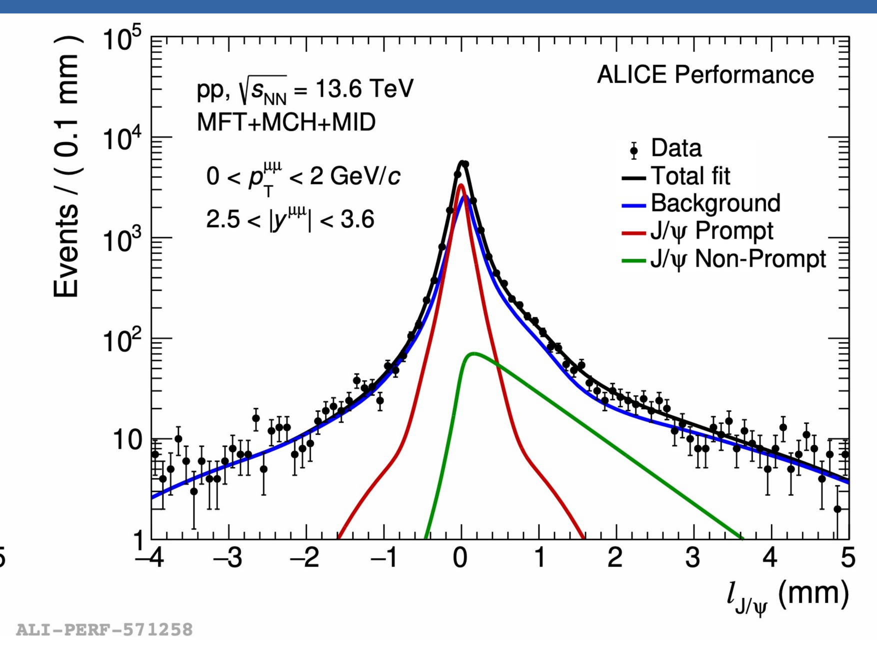
Dimuon pairs selections :
- opposite sign muon pairs
- 2.5 < y < 3.6
- $M_{\mu\mu}$ > 1.8 GeV/c^2

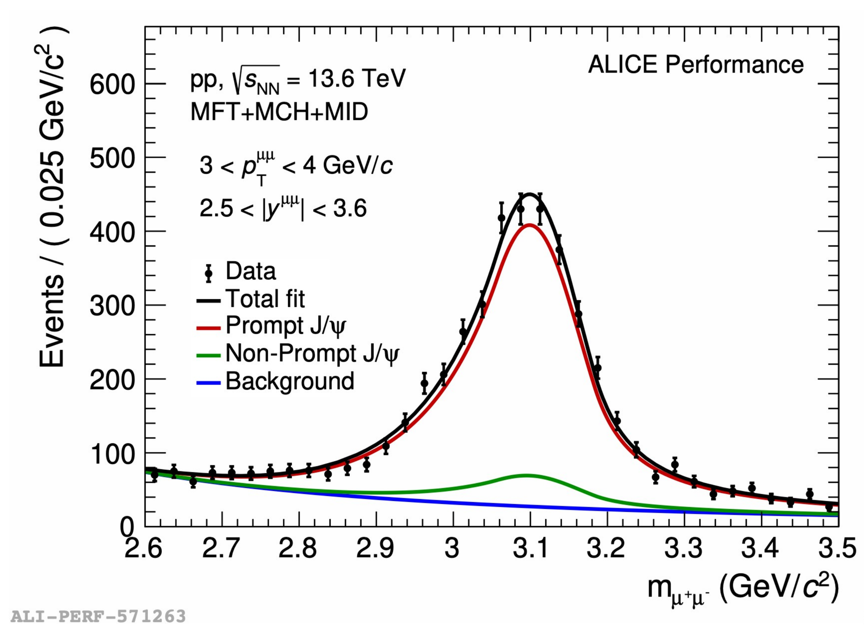
Dataset : pp 13.6 TeV, 2022 sample (60%)

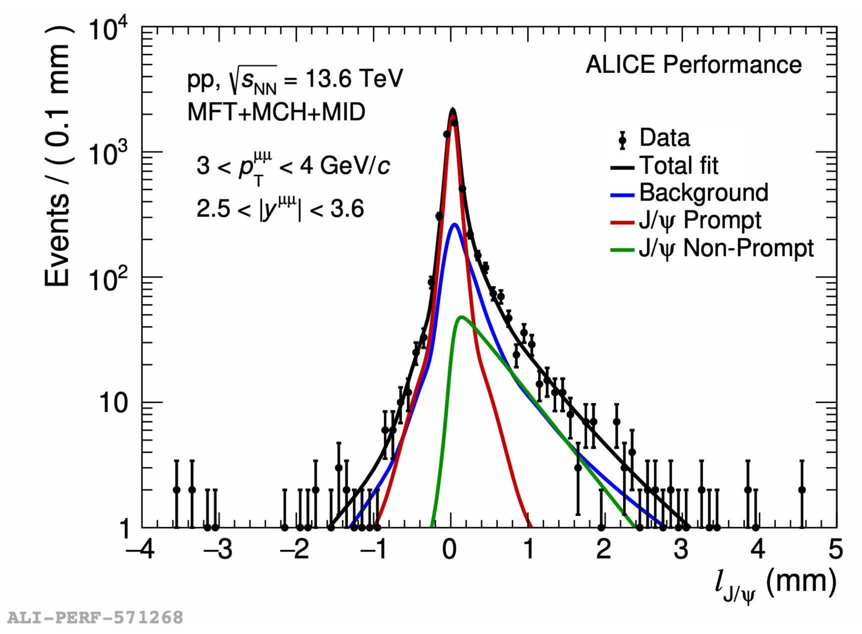
Tracks selections :
- -3.6 < η < -2.5, muon spectrometer + MFT acceptance
- 2° < θ_{abs} < 10° : absorber exit angle, limits multiple scattering in the thickest parts of the absorber
- 0 GeV.cm/c < p.DCA < 594 GeV.cm/c : product of momentum and distance of closest approach, removes beam/gas interaction
- ambiguous tracks from pile-up collisions removed
- Global tracks (MFT+MCH+MID matching)

The extraction of the non-prompt fraction is performed using the sPlot package and it is based on the following steps:
1. Fit to the invariant mass distribution to separate J/Ψ signal from the background
2. Fit to the $l_{J/\psi}$ distribution using the signal and background weights from invariant mass fit (step 1)
   - $l_{J/\psi}$ resolution is extracted fitting the distribution for $l_{J/\psi}$ < 0 (non-prompt contribution excluded)
3. 2D fit of mass and $l_{J/\psi}$ distribution :
   - non-prompt $l_{J/\psi}$ distribution initialized using Monte Carlo input
   - signal and background shapes for the invariant mass and $l_{J/\psi}$ resolution are fixed in the previous steps
   - non-prompt fraction, number of J/Ψ and number of background events are kept free









Results :
- prompt and non-prompt components are well identified : **promising results for prompt/non-prompt separation**

Next step : acceptance-efficiency evaluation via Monte Carlo simulation and correction of the measured non-prompt J/Ψ fraction

Outlook :
The datasets collected for pp collisions at $\sqrt{s}$ = 13.6 TeV will allow a precise differential measurement in p_T and y of the prompt/non-prompt J/Ψ fraction

First step toward prompt/non-prompt J/Ψ R_{AA} study in Pb-Pb

Alice Collaboration. Technical Design Report of Muon Forward Tracker, CERN-LHCC-2015-001, ALICE-TDR-018 (2015)
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M. Coquet. Thesis, https://theses.fr/2023UPASP123 (2023)
Alice Collaboration. ALICE upgrades during the LHC Long Shutdown 2, arXiv:2302.01238 (2023)

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