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

Wenda Guo
for the ALICE Collaboration

Central China Normal University & University of Bergen

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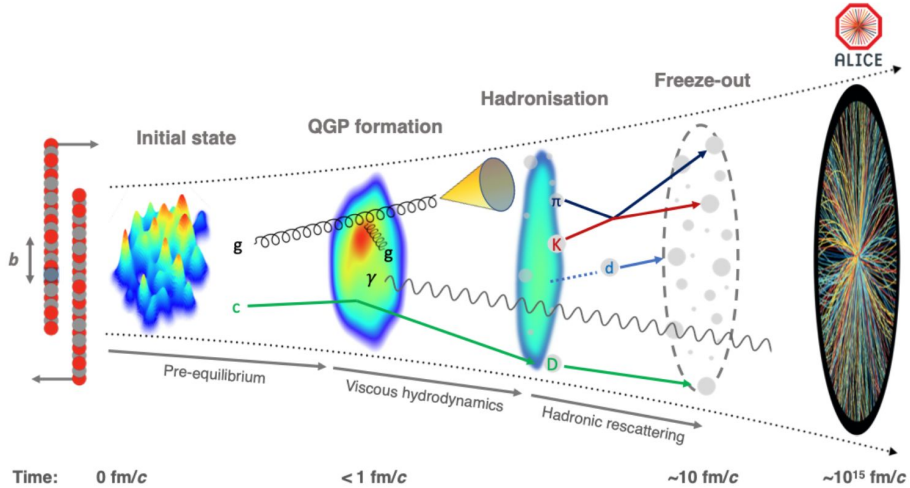
Quarkonium production in pp collisions

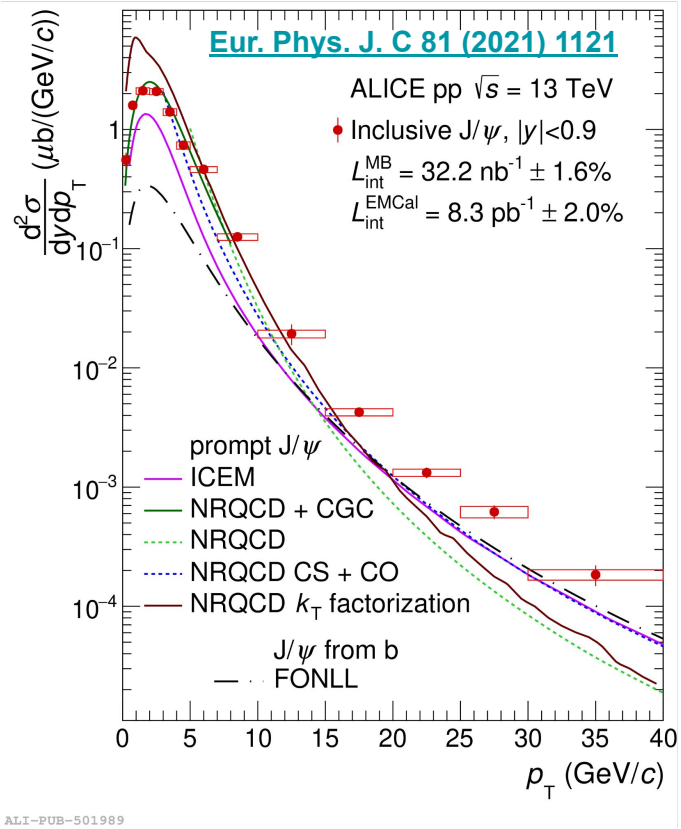
arXiv:2211.04384



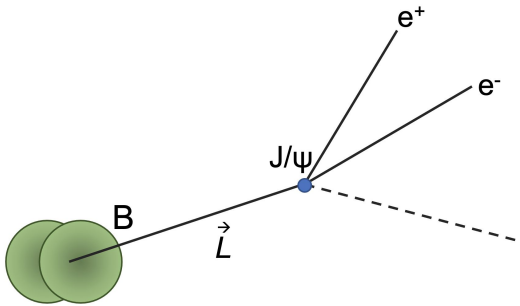
- J/ψ, ψ(nS), Υ(nS)
  - bound state of heavy-quark pair
- Heavy-quarks are produced in initial hard partonic scattering
  - Experience full evolution of heavy-ion collision
  - Probes to study properties of hot and dense medium, i.e. quark-gluon plasma (QGP)

- A meaningful interpretation of heavy-ion collisions relies on the study of small systems (as pp and p–Pb collisions)
  - To understand production mechanism
  - Reference for Pb–Pb collisions

Prompt and non-prompt J/ψ



- The inclusive J/ψ yield can be separated between prompt and non-prompt charmonium.



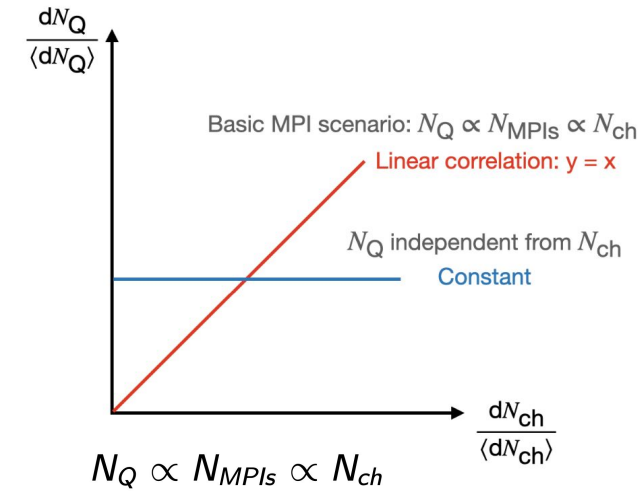
- Prompt :
  - produced in the collision
- Non-prompt :
  - decayed from B hadron

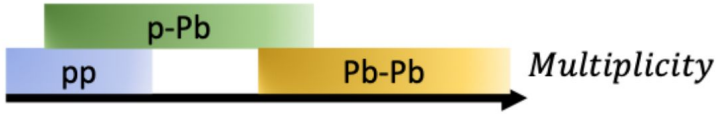
- Non-prompt J/ψ production allows:
  - Separation of prompt/non-prompt charmonium production
  - Access beauty hadron production.

ICEM: V. Cheung et al, Phys. Rev. D 98 (2018) 114029
NRQCD: Ma et al, Phys. Rev. Lett. 106 (2011) 042002
NRQCD+CGC: Ma et al, Phys. Rev. Lett. 113(19) (2014) 192301
NRQCD CS+CO: Butenschoen et al, Phys. Rev. Lett. 106 (2011) 022003
NRQCD kT factorisation: Lipatov et al, Eur. Phys. J. C 80(4) (2020) 330
FONLL: M. Cacciari et al, JHEP 10 (2012) 137

Multiplicity dependence of J/ψ production

- Multiplicity dependent analysis can give insights into
  - Multiparton Interactions (MPI)
  - Interplay of hard components (NQ) and underlying event (Nch)
- Key observable to disentangle initial and final state effects
- Prompt and non-prompt J/ψ vs multiplicity measurements
  - possible estimation of B-hadron production vs multiplicity
  - more accurate calculation on prompt J/ψ



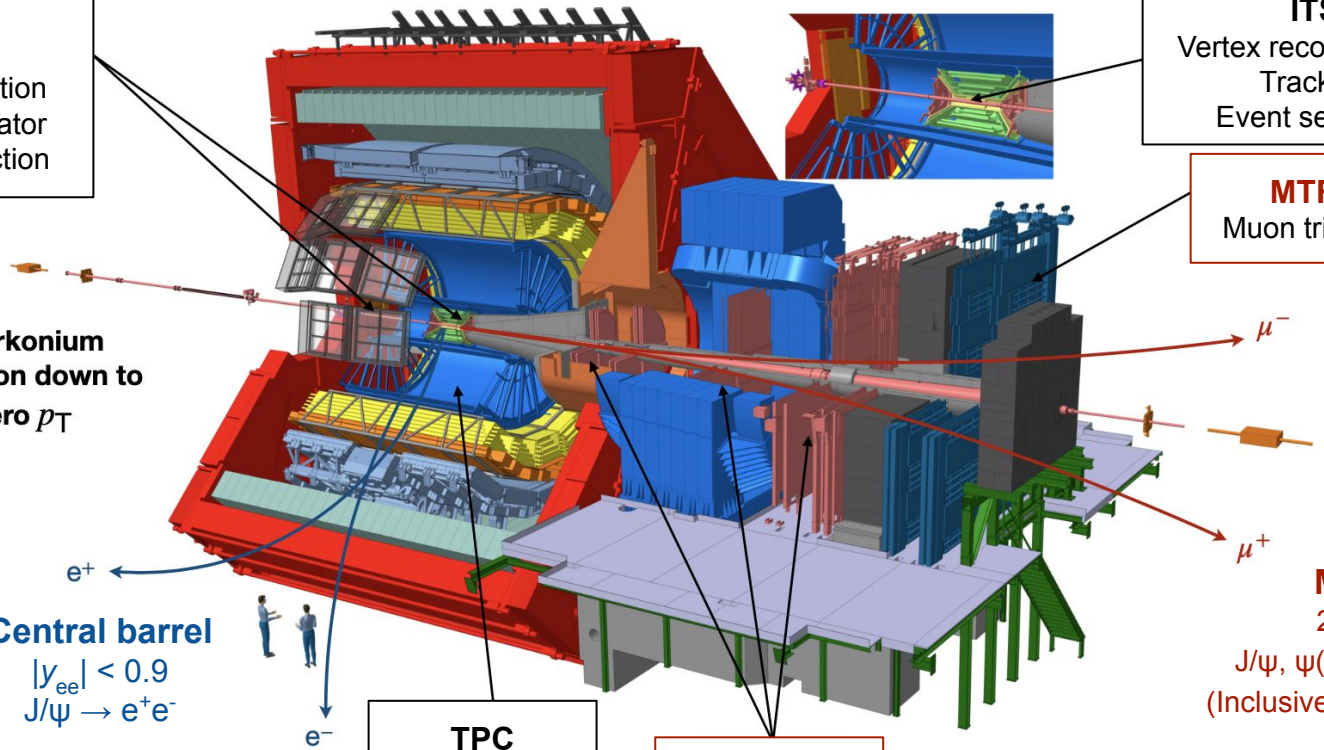


ALICE detector (Run 1 and Run 2)

V0
Trigger
Beam-gas rejection
Centrality estimator
Multiplicity selection

ITS
Vertex reconstruction
Tracking
Event selection

MTR
Muon trigger



Quarkonium detection down to zero p_T

Central barrel
$|y_{ee}| < 0.9$
$J/\psi \rightarrow e^+e^-$

Prompt and non-prompt J/ψ can be separated at midrapidity

TPC
Tracking
PID via d*E*/d*x*

MCH
Muon tracking

Muon arm
$2.5 < y_{\mu\mu} < 4$
J/ψ, $\psi(2S)$, $\Upsilon(nS) \rightarrow \mu^+\mu^-$
(Inclusive quarkonium states)

Separation of prompt and non-prompt J/ψ

- Analysis technique: based on maximization of 2D likelihood function, on invariant mass and pseudoproper decay length (x) fitted simultaneously

Signal Background

$$F(x, m_{ee}) = f_{Sig} \times F_{Sig}(x) \times M_{Sig}(m_{ee}) + (1 - f_{Sig}) \times F_{Bkg}(x) \times M_{Bkg}(m_{ee})$$

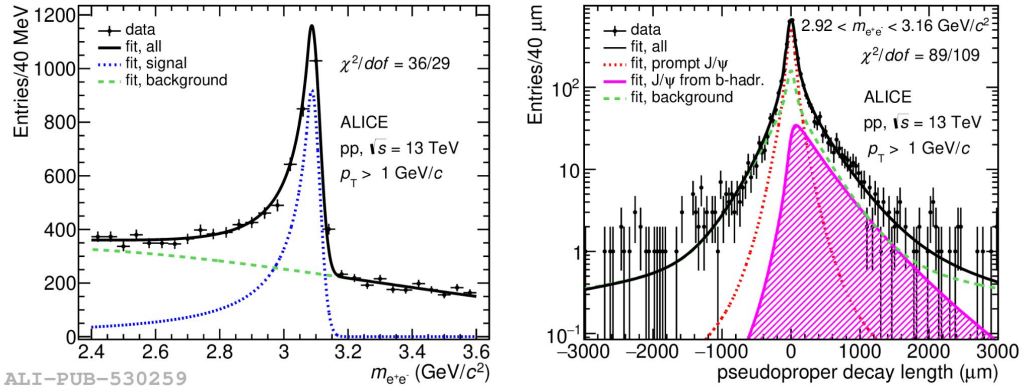
$$F_{Sig}(x) = f_B \times T(x) + (1 - f'_B) \times R(x)$$

non-prompt prompt

Likelihood function:

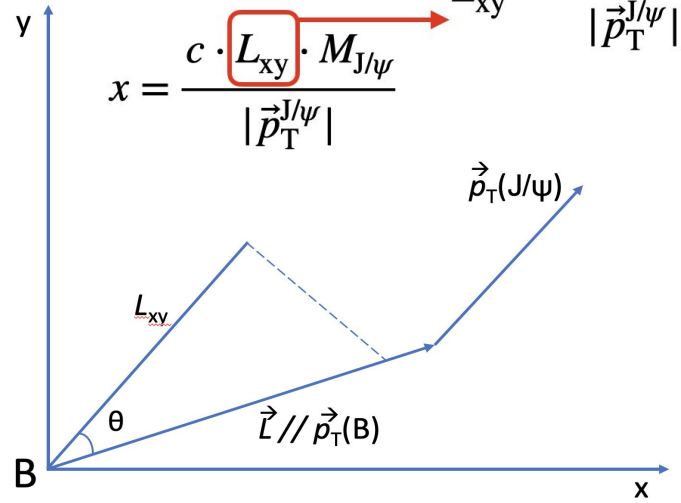
$$\ln\{L\} = \sum \ln\{F(x, m_{ee})\}$$

Likelihood fit performance



x is defined as

$$x = \frac{c \cdot L_{xy} \cdot M_{J/\psi}}{|\vec{p}_T^{J/\psi}|} \qquad L_{xy} = \frac{\vec{L} \times \vec{p}_T^{J/\psi}}{|\vec{p}_T^{J/\psi}|}$$



JHEP 03 (2022) 190

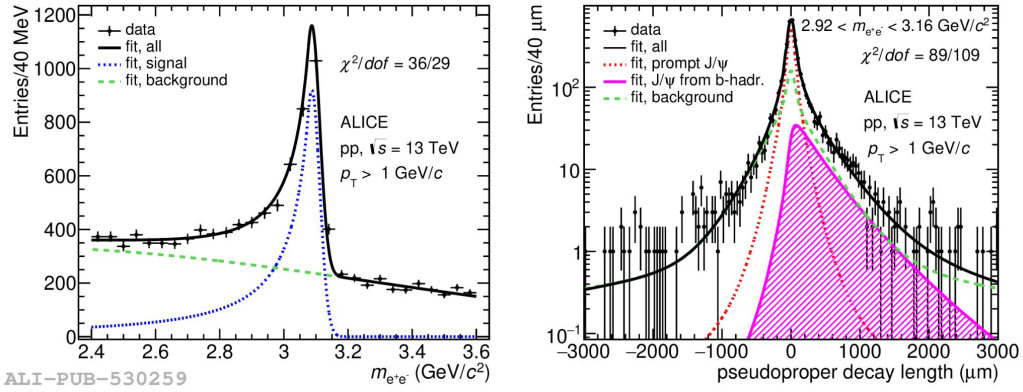
Separation of prompt and non-prompt J/ψ

- Analysis technique: based on maximization of 2D likelihood function, on invariant mass and pseudoproper decay length (x) fitted simultaneously

$$F(x, m_{ee}) = \underbrace{f_{Sig} \times F_{Sig}(x) \times M_{Sig}(m_{ee})}_{\text{Signal}} + \underbrace{(1 - f_{Sig}) \times F_{Bkg}(x) \times M_{Bkg}(m_{ee})}_{\text{Background}}$$

$$F_{Sig}(x) = \underbrace{f_B \times T(x)}_{\text{non-prompt}} + \underbrace{(1 - f_B') \times R(x)}_{\text{prompt}}$$

Likelihood fit performance



- f_B' is the raw fraction of non-prompt J/ψ, which is extracted from the likelihood fit, needs to be corrected by acceptance times efficiency which could be slightly different for prompt and non-prompt J/ψ
- Efficiency and acceptance correction formula:

$$f_B = \left(1 + \frac{1 - f_B'}{f_B'} \cdot \frac{\langle A \times \varepsilon \rangle_B}{\langle A \times \varepsilon \rangle_{Prompt}}\right)^{-1}$$

  - f_B is the fraction of non-prompt J/ψ after efficiency and acceptance correction

JHEP 03 (2022) 190

Separation of prompt and non-prompt J/ψ

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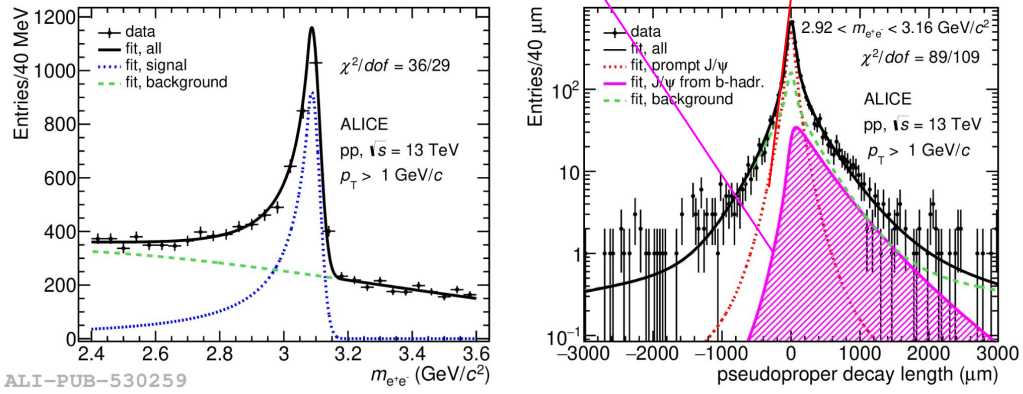
non-prompt prompt

Likelihood fit performance



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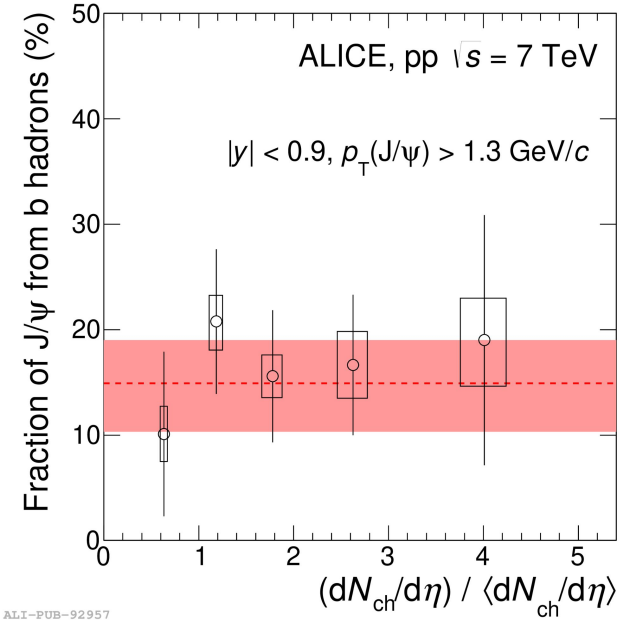
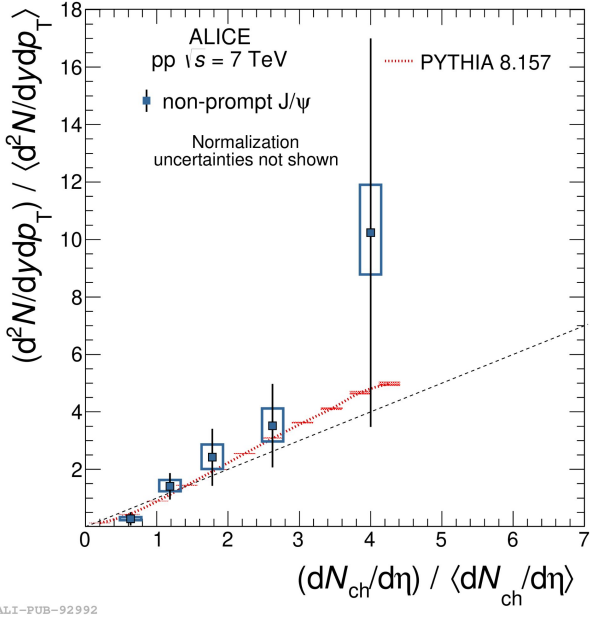
JHEP 03 (2022) 190

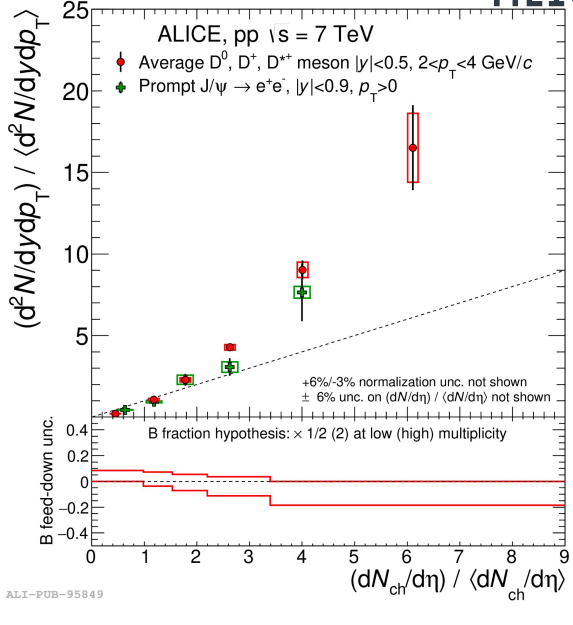
f_B fraction vs multiplicity in pp at $\sqrt{s}$ = 7 TeV

JHEP 09 (2015) 148

D meson production: JHEP 09 (2015) 148
PYTHIA 8.157: T. Sjoestrand et al, Comput. Phys. Commun. 178 (2008) 852



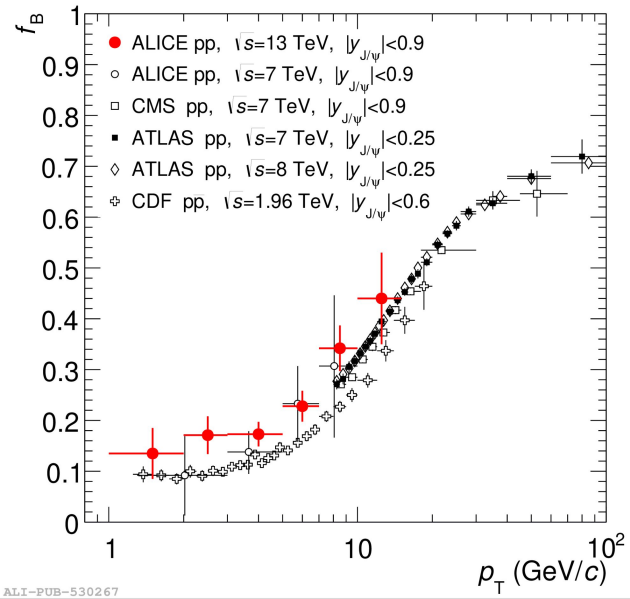


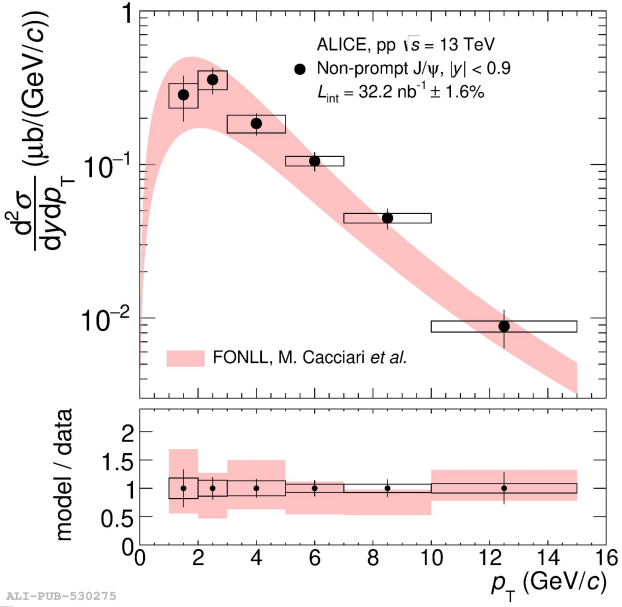


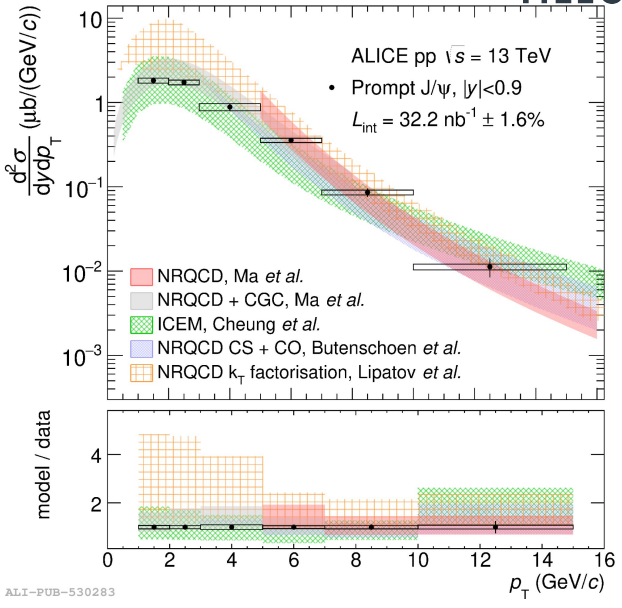
- Fraction of non-prompt J/ψ in pp collisions at $\sqrt{s}$ = 7 TeV shows no multiplicity dependence
- The results at $\sqrt{s}$ = 7 TeV can reach 4 times the average multiplicity (higher multiplicity reach expected at $\sqrt{s}$ = 13 TeV thanks to high-multiplicity triggered data)
- Prompt J/ψ production vs multiplicity shows an increase with charged-particle multiplicity, which is faster than linear
- Hint for similar faster than linear increase of the yields with the multiplicity for non-prompt J/ψ, however uncertainties are large to conclude

f_B fraction vs p_T in pp at $\sqrt{s}$ = 13 TeV

JHEP 03 (2022) 190







- Fraction of non-prompt J/ψ vs p_T at $\sqrt{s}$ = 13 TeV is measured.
- Non-prompt and prompt J/ψ cross sections are computed by combining non-prompt J/ψ fractions and inclusive J/ψ measurements
- The cross sections are consistent with different model calculations.
- Beauty-quark production cross sections can be inferred from non-prompt J/ψ measurements

Inclusive J/ψ production: Eur. Phys. J. C 81 (2021) 1121
FONLL: M. Cacciari et al, JHEP 10 (2012) 137
ICEM: V. Cheung et al, Phys. Rev. D 98 (2018) 114029
NRQCD: Ma et al, Phys. Rev. Lett. 106 (2011) 042002
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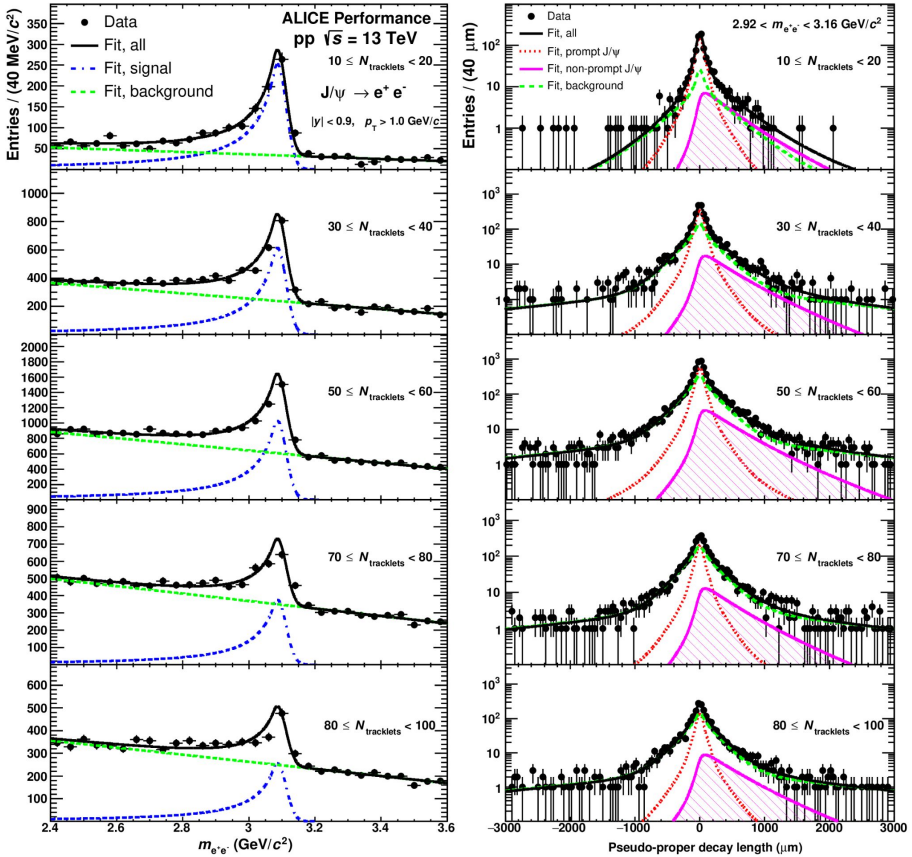
Towards f_B fraction measurement vs multiplicity in pp at $\sqrt{s}$ = 13 TeV



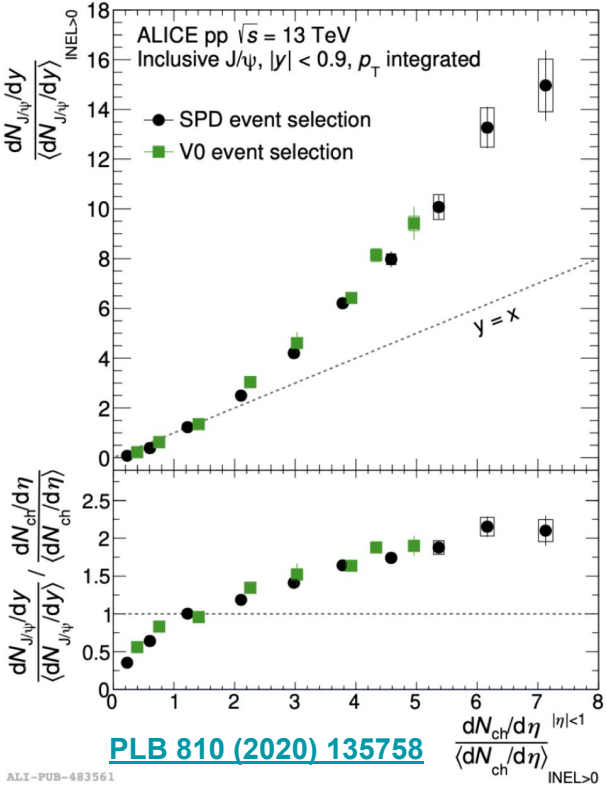
ALI-PERF-539349

- Fraction of non-prompt J/ψ vs multiplicity in pp collisions at $\sqrt{s}$ = 13 TeV is measured with ALICE, via 2D maximum likelihood fit method.
- Significantly higher multiplicity region reach compared to $\sqrt{s}$= 7 TeV thanks to high-multiplicity triggered events, reaching ***7 times*** the average multiplicity (4 times at $\sqrt{s}$ = 7 TeV).

Summary and outlook

- Measurement of the fraction of non-prompt J/ψ vs multiplicity in pp collisions at $\sqrt{s}$ = 13 TeV is ongoing and will be released soon.
- Prompt and non-prompt J/ψ yields vs multiplicity will be evaluated by combining with existing inclusive J/ψ measurements.

Thanks for your attention!



PLB 810 (2020) 135758

Back up

J/ψ reconstruction strategy

- Decay channel : J/ψ → e+e-
- Track selection:
  - track selected via criteria shown in the right table, concerning
    - track kinematics
    - reconstruction quality
    - track PID
- Pair selection
  - $|y| < 0.9$
  - $p_T > 1$ GeV/c

Variables	Cut values
$\|\eta\|$	$<\|0.9\|$
p_T	>1.0 GeV/c
|DCAxy|	<0.5 cm
|DCAz|	<2.0 cm
TPC $n\sigma_e$	[-3,3]
TPC $n\sigma_\pi$	>3.5
TPC $n\sigma_p$	>3.5
reject kinks	yes
request ITS refit	yes
request TPC refit	yes
request SPDany	yes
TPC $\|\chi^2\|$	[0,4]
ITS $\|\chi^2\|$	[0,36]
TPC Ncls.	[70,160]
ITS Ncls. shared	[0,1]