J/ψ pair production and J/ψ production in jets in pp collisions

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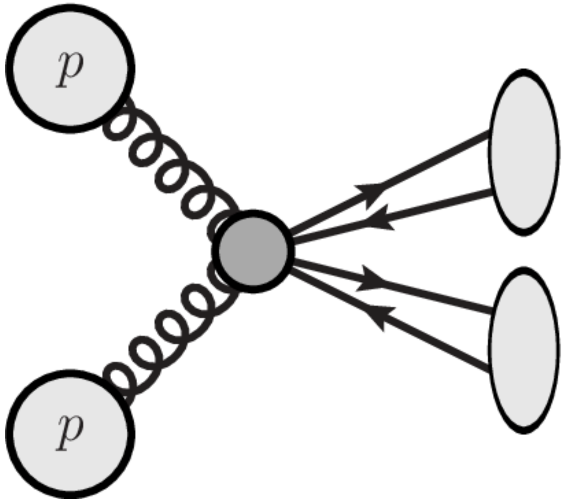
Outline

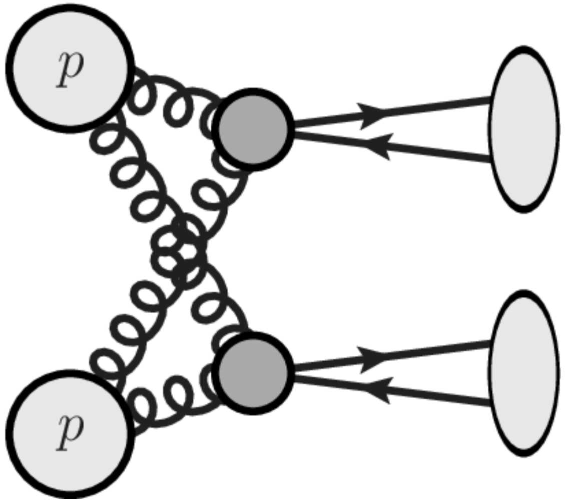
J/ψ pair production

Motivation

J/ψ pair production



Single-Parton Scattering



Double-Parton Scattering

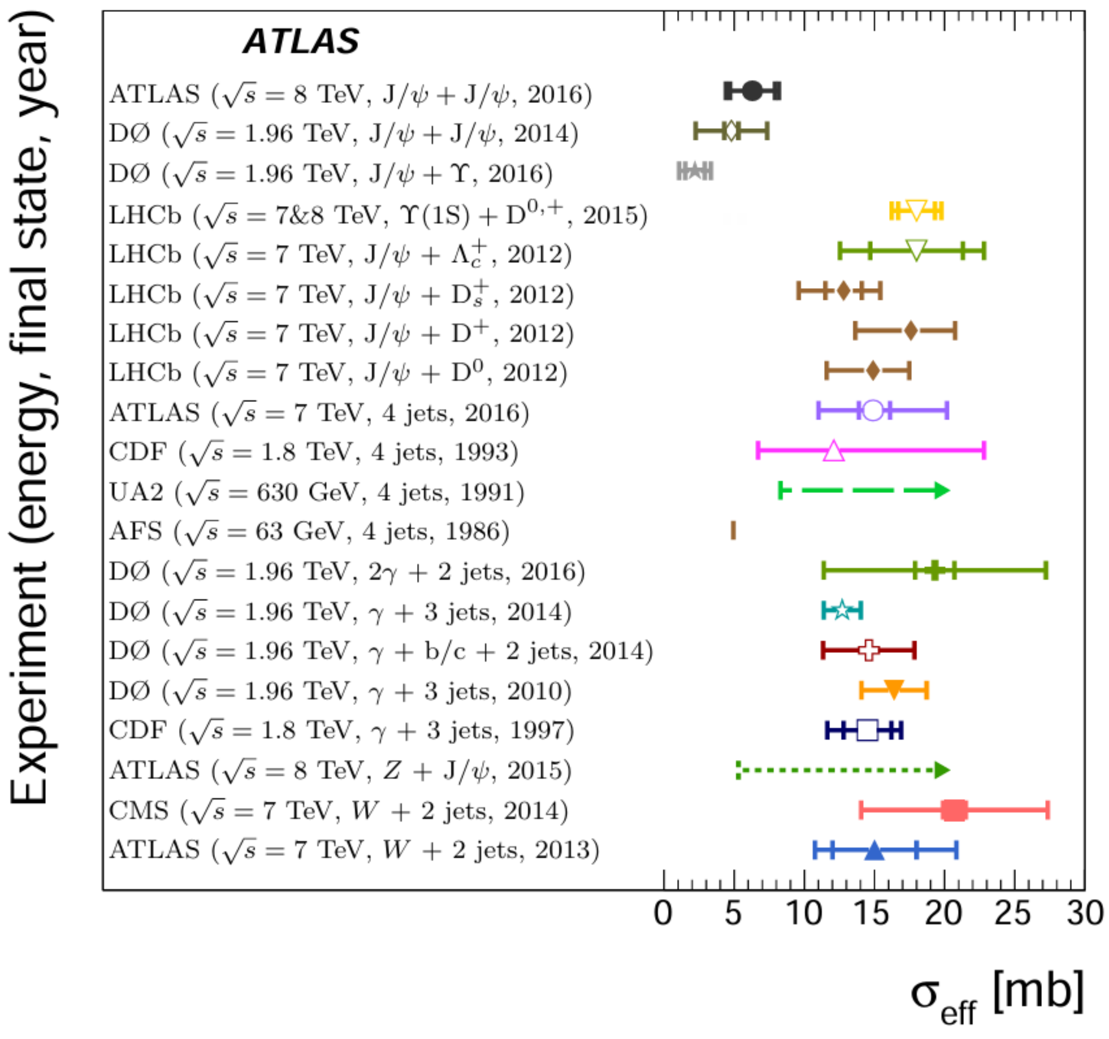
- J/ψ pair production is a golden probe for the production mechanism of heavy quarkonia.
- Exploring the hard energy scale part of Multiple Parton Interactions (MPIs).
- Providing constraints on Long Distance Matrix Elements (LDMEs) appearing in pair production.

Physics Reports Volume 889, Pages 1-106

Motivation

J/ψ pair production

ATLAS: Eur. Phys. J. C77 (2017) 76



DPS contribution to a final state A + B can be evaluated as:

$$\sigma_{A,B}^{DPS} = \frac{m}{2}\frac{\hat{\sigma}^A\,\hat{\sigma}^B}{\sigma_{eff}}$$

m = 1 (2) for identical (different) hadron.

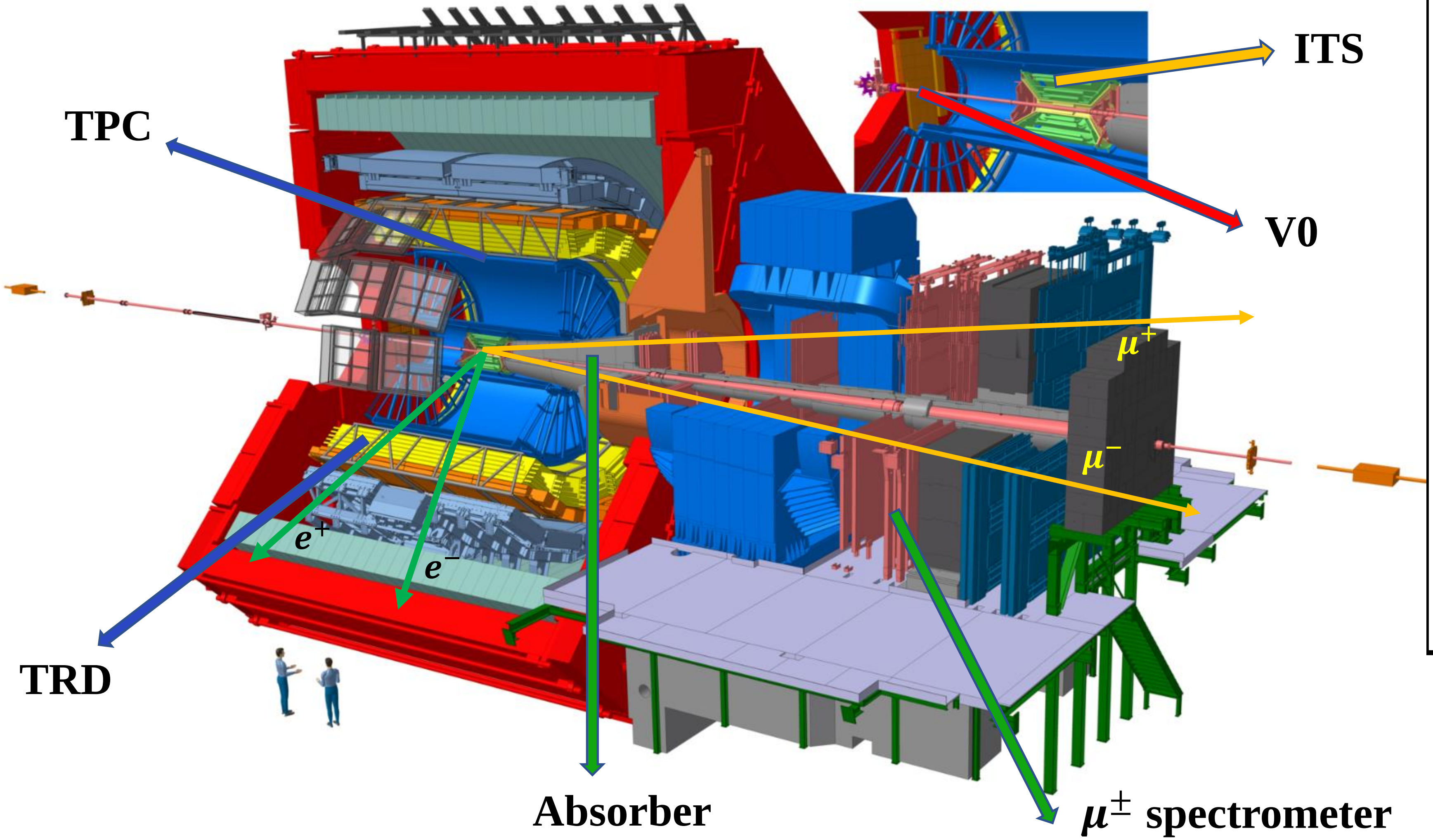
σ_{eff}:effective cross section parameter of DPS.

- Allows the measurements of the effective cross section and the test of its universality.

ALICE detector

Forward ($2.5 < y < 4.0$)

Central barrel ($|y| < 0.9$)



- **V0 detector**
  - ✓ Centrality determination
  - ✓ Trigger
  - ✓ Background rejection
- $\mu^\pm$ **spectrometer**
  - ✓ Trigger
  - ✓ $\mu^\pm$ tracking
- **T**ime **P**rojection **C**hamber
  - ✓ Tracking, Particle identification
- **I**nner **T**racking **S**ystem
  - ✓ Tracking, Vertex reconstruction
- **T**ransition **R**adiation **D**etector
  - ✓ Trigger

Analysis strategy

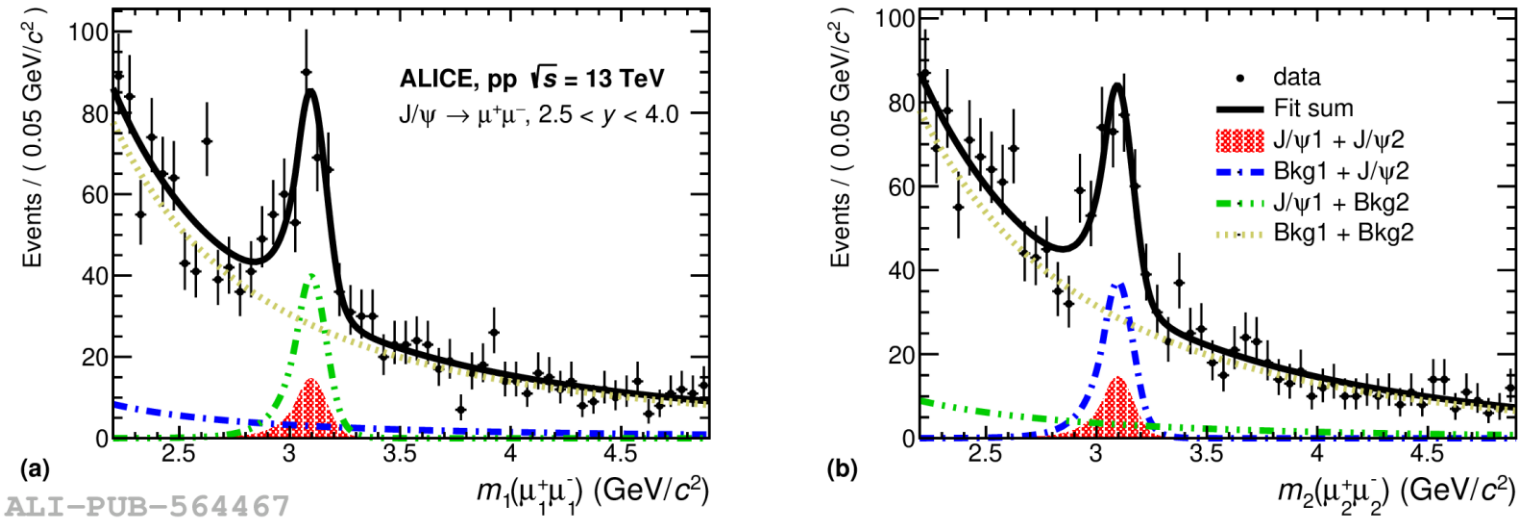
J/ψ pair production

1. Fit the 1D dimuon invariant mass spectrum.
2. Model the 2D spectrum.

$$F(m_1,m_2) = N \times S_1(m_1) \times S_2(m_2) + R_{B_1,S_2} \times B_1(m_1) \times S_2(m_2) + R_{S_1,B_2} \times S_1(m_1) \times B_2(m_2) + R_{B_1,B_2} \times B_1(m_1) \times B_2(m_2),$$

3. Signal extraction by 2D fitting.

ALICE (13 TeV): PRC 108, 045203 (2023)



4. Acceptance and efficiency correction.

Cross section of J/ψ pair production

J/ψ pair production

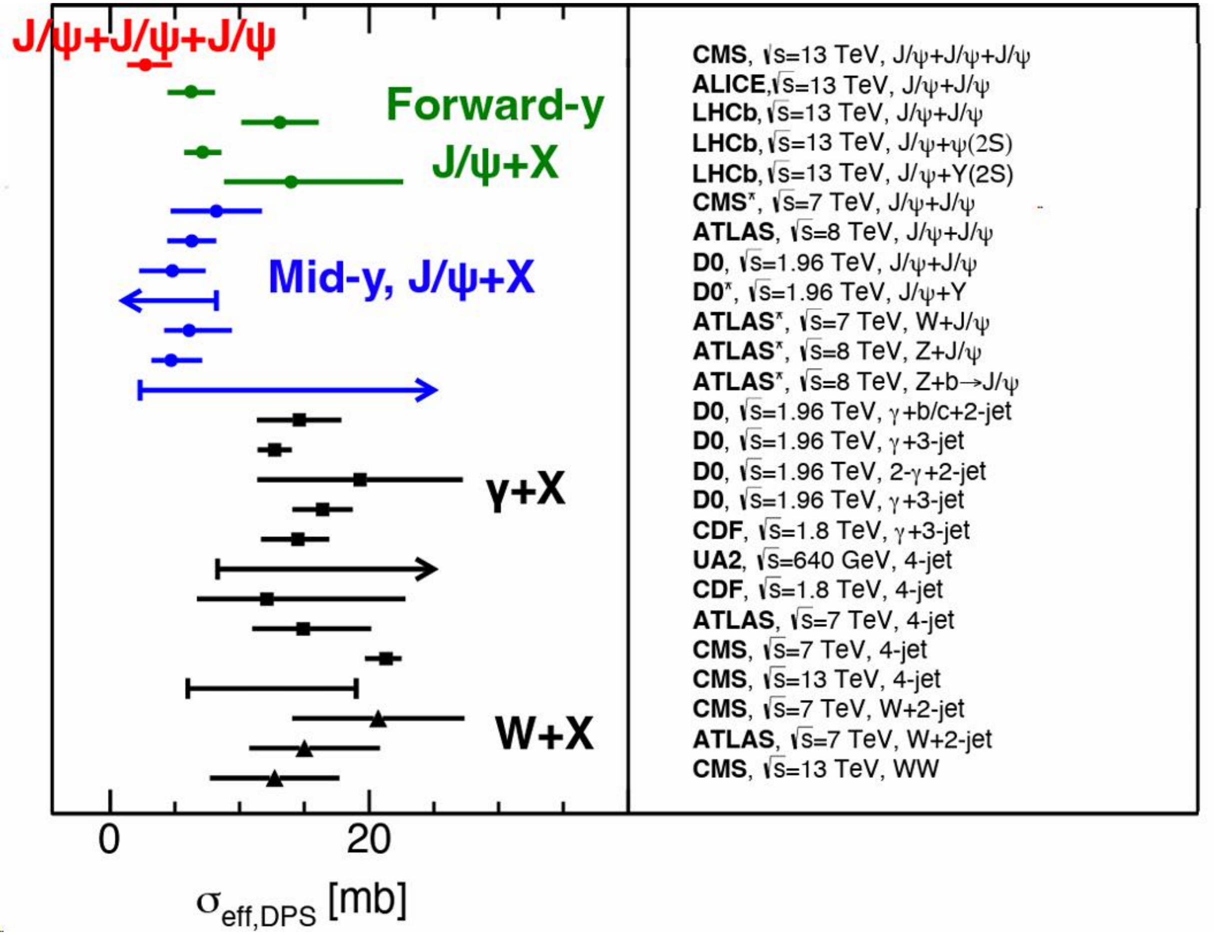
	σ(J/ψJ/ψ)	
ALICE (13 TeV)	10.3 ± 2.3(stat.) ± 1.3 (syst.) nb	$2.5 < y < 4.0$, $p_T > 0$
LHCb (13 TeV)	15.2 ±1.0 (stat.) ± 0.9 (syst.) nb	$2 < y < 4.5$, $p_T < 10$ GeV/c
LHCb (7 TeV)	5.1 ± 1.0 (stat.) ± 1.1 (syst.) nb	$2 < y < 4.5$, $p_T < 10$ GeV/c
D0 (1.96 TeV)	129 ± 11 (stat.) ± 37 (syst.) fb	$\|y\| < 2$, $p_T > 4$ GeV/c
CMS (7 TeV)	1.49 ± 0.07 (stat.) ± 0.13 (syst.) nb	$\|y\| < 2.2$, $p_T > 4.5$ GeV/c (*)
ATLAS (8 TeV)	15.6 ± 1.3 (stat.) ± 1.2 (syst.) pb	$\|y\| < 1.05$, $p_T > 8.5$ GeV/c
ATLAS (8 TeV)	13.5 ± 1.3 (stat.) ± 1.1 (syst.) pb	$1.05 < \|y\| < 2.1$, $p_T > 8.5$ GeV/c

ALICE (13 TeV): PRC 108, 045203 (2023)
LHCb (13 TeV): JHEP 06 (2017) 047
LHCb (7 TeV): PLB 707 (2012), pp. 52-59
D0 (1.96 TeV): PRD 90, 111101(R) (2014)
CMS (7 TeV): JHEP 09 (2014) 094
ATLAS (8 TeV): EPJC **77**, 76 (2017)

- The cross-section of J/ψ pair production measured by ALICE differs from that of other experiments, but due to their different phase spaces, the differences can be understood.

Effective DPS cross section

J/ψ pair production



	effective DPS cross section
ALICE (13 TeV)	6.7 ± 1.6 (stat.) ± 2.7 (syst.) mb
LHCb (13 TeV)	7.3 ± 0.5 (stat.) ± 1.0 (syst.) mb
D0 (1.96 TeV)	4.8 ± 0.5 (stat.) ± 2.5 (syst.) mb
CMS (7 TeV)	—
ATLAS (8 TeV)	6.3 ± 1.6 (stat.) ± 1.0 (syst.) ± 0.1 (BF) ± 0.1 (lumi) mb

ALICE (13 TeV): PRC 108, 045203 (2023)
LHCb (13 TeV): JHEP 06 (2017) 047
D0 (1.96 TeV): PRD 90, 111101(R) (2014)
CMS (7 TeV): JHEP 09 (2014) 094
ATLAS (8 TeV): EPJC **77**, 76 (2017)

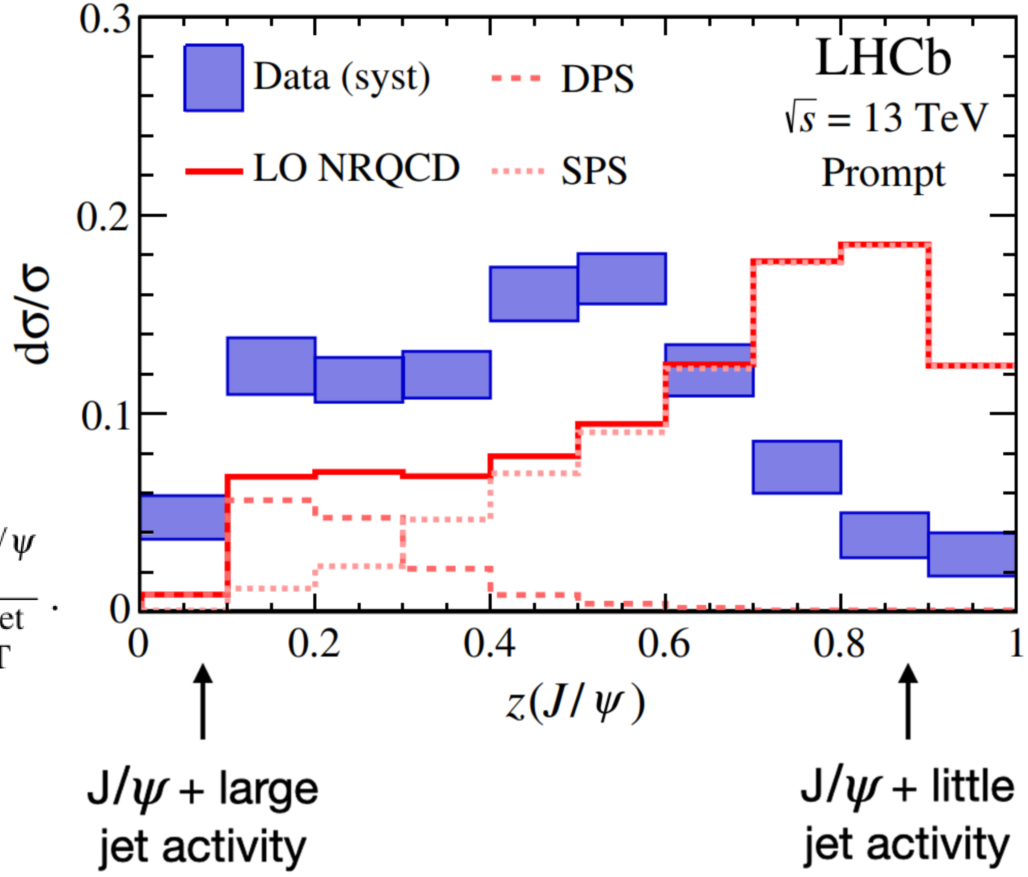
- The effective DPS cross-section measured by ALICE also agrees with the results from other experiments.

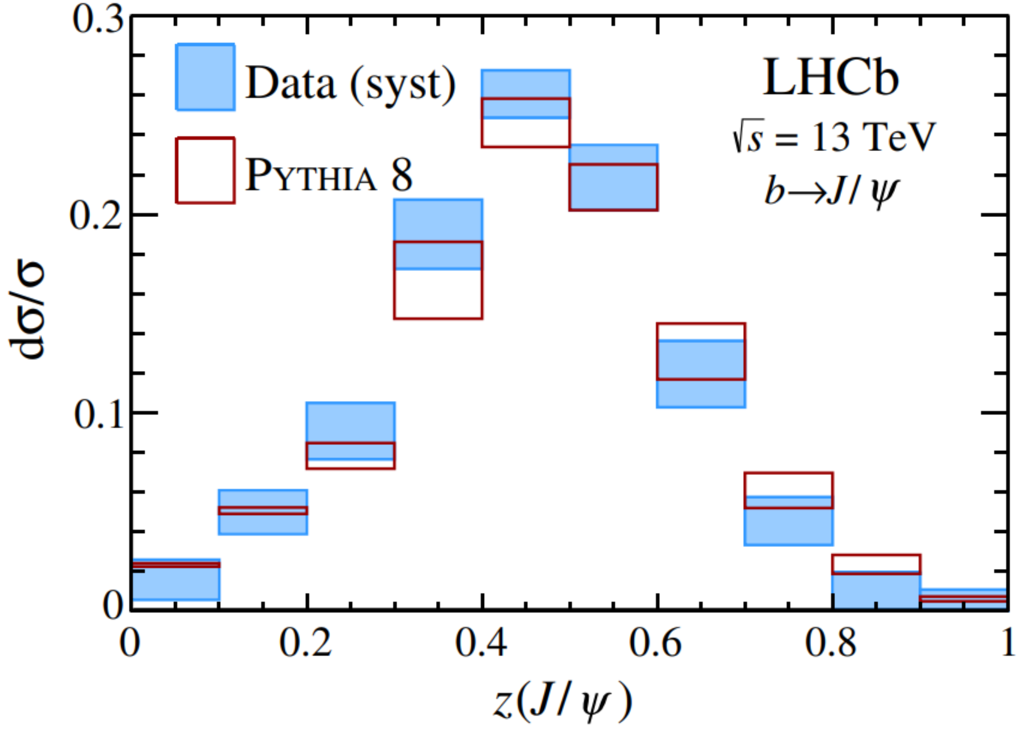
J/ψ production in jets

J/ψ production in jets

LHCb: Phys. Rev. Lett. 118, 192001

$$z \equiv \frac{p_T^{J/\psi}}{p_T^{jet}}.$$



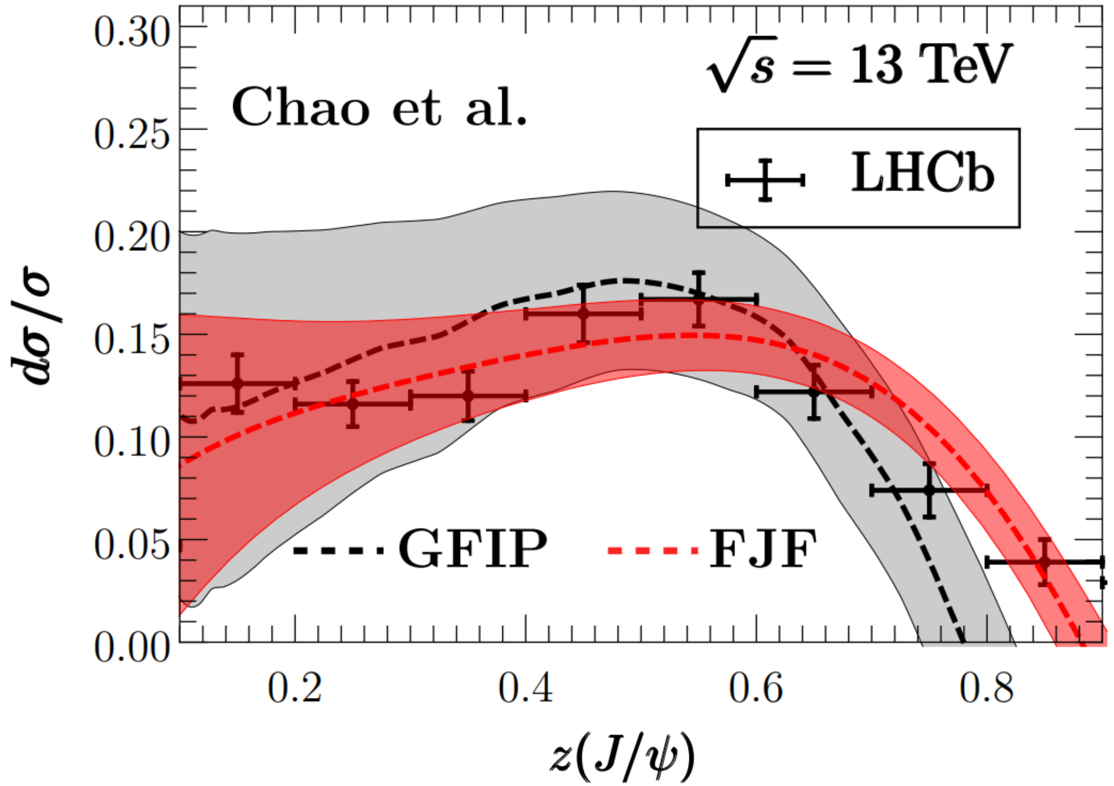


- Prompt J/ψ produced with larger jet activity than NRQCD, DPS and SPS predicted.
- The fragmentation function of non-prompt J/ψ agree with PYTHIA 8 prediction.

Motivation

J/ψ production in jets

LHCb: Phys. Rev. Lett. 119, 032002

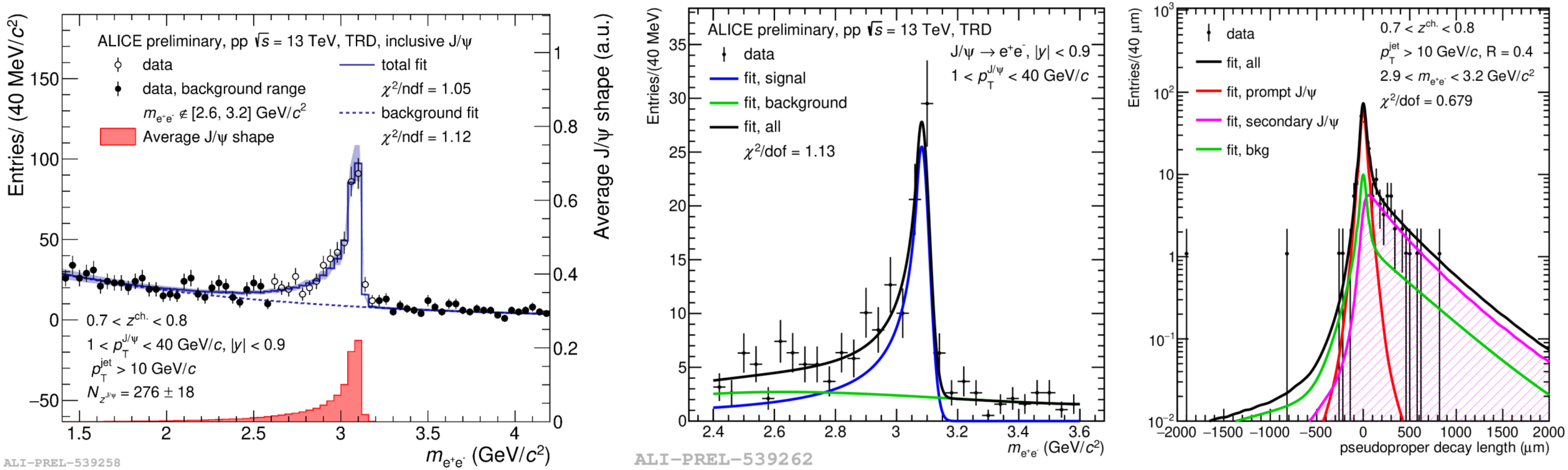


GFIP: **G**luon **F**ragmentation **I**mproved **P**YTHIA
FJF: **F**ragmenting **J**et **F**unctions

- Models including parton showers describe data.

Analysis strategy

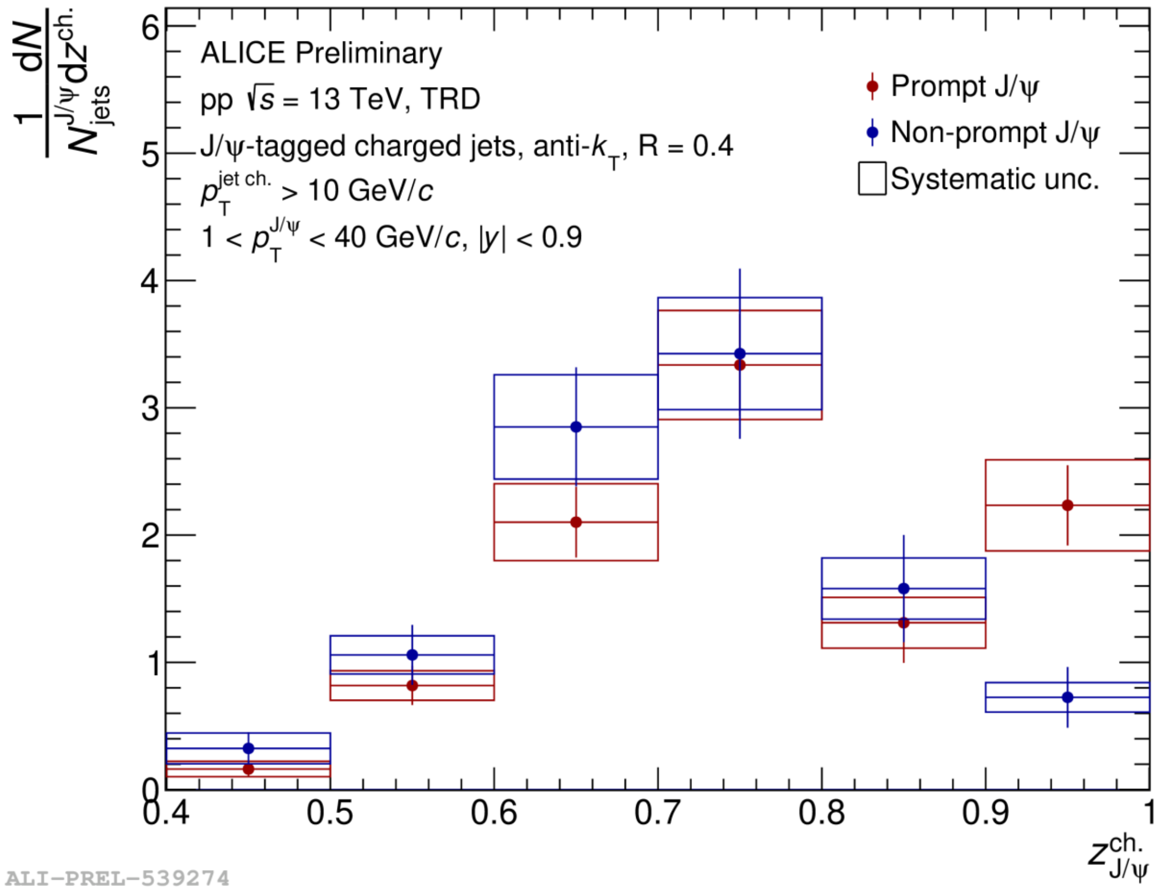
J/ψ production in jets



1. Jet reconstruction by using anti-kT algorithm with the FASTJET package.
2. Extract J/ψ signal in jets with different z(J/ψ).
3. Separation of prompt and non-prompt J/ψ.
4. Acceptance, efficiency and detector effect correction.

Fragmentation function

J/ψ production in jets

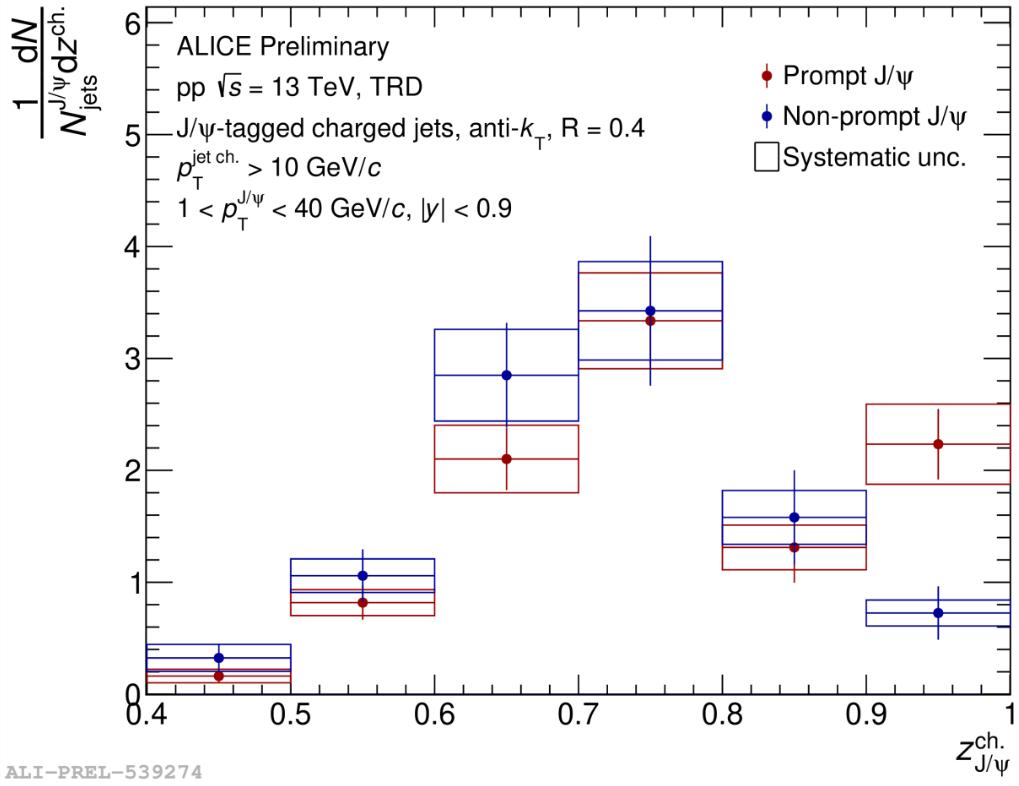


- Prompt and non-prompt J/ψ fragmentation functions similar within uncertainties.

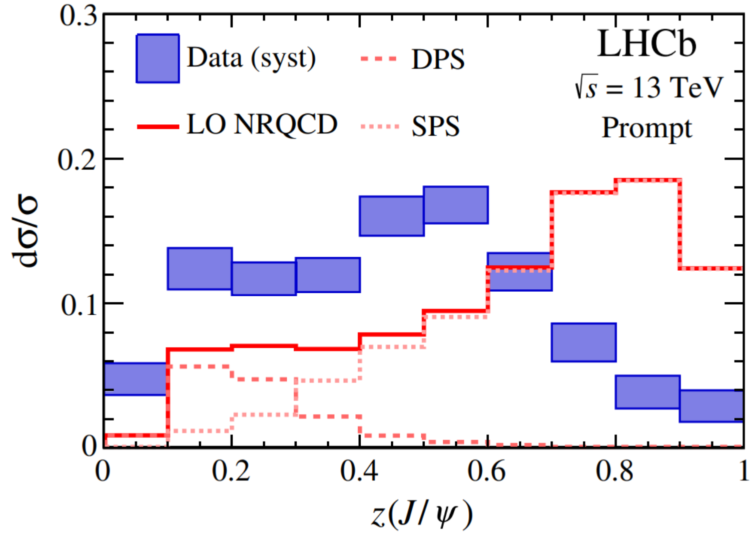
Fragmentation function

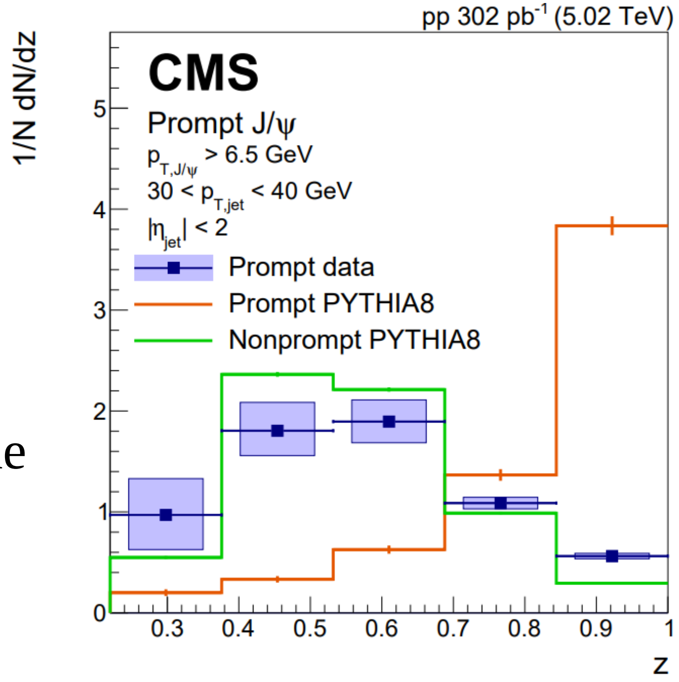
J/ψ production in jets

LHCb: Phys. Rev. Lett. 118, 192001
CMS: Phys. Lett. B 825 (2021) 136842



VS.





- The ALICE results shows the peak between 0.6 to 0.8 differently from the other experiments.
- ALICE explores a lower p_{T} range, enhancing model constraints.
- Model predictions are being preparing.

Summary

J/ψ pair production in pp collisions

- The J/ψ pair production has been measured in the forward rapidity of pp collisions.
- The cross-section of J/ψ pair production measured by ALICE differs from that of other experiments due to their different phase spaces.
- The effective DPS cross-section measured by ALICE agrees with that of other experiments.

J/ψ production in jets in pp collisions

- Prompt and non-prompt J/ψ fragmentation functions agree within uncertainties.

Outlook

- The upgraded ALICE detectors and increased luminosity in Run 3 data-taking will enhance precision. It will bring about more precise measurement.