

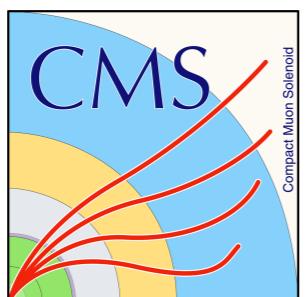
Fragmentation of J/ ψ in jets in PbPb collisions with CMS

Batoul Diab

On behalf of the CMS Collaboration

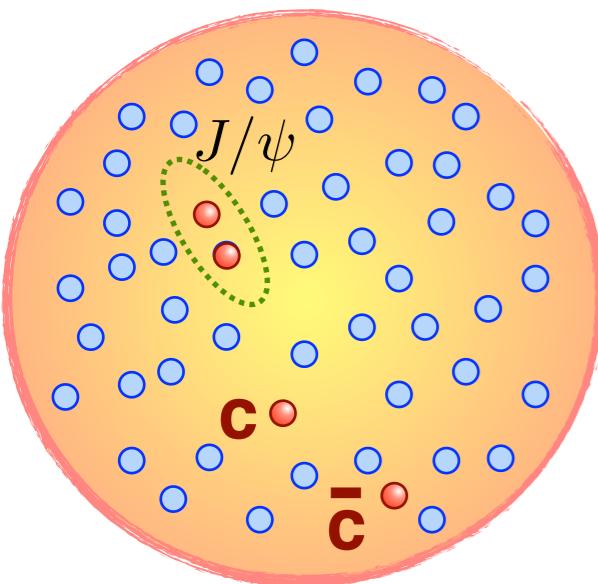
Laboratoire Leprince-Ringuet, École Polytechnique, France

04/06/2020

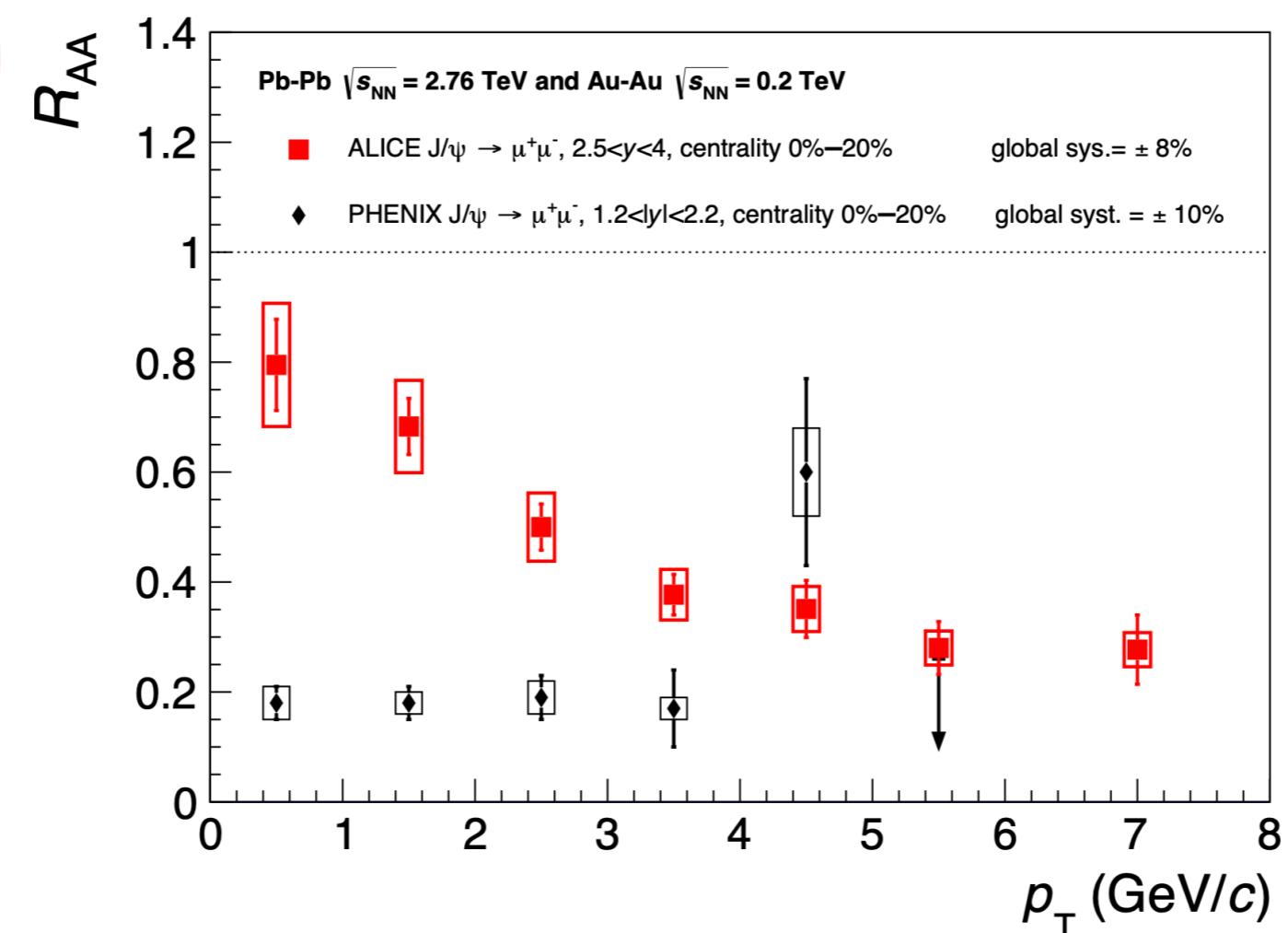


CMS-PAS-HIN-19-007

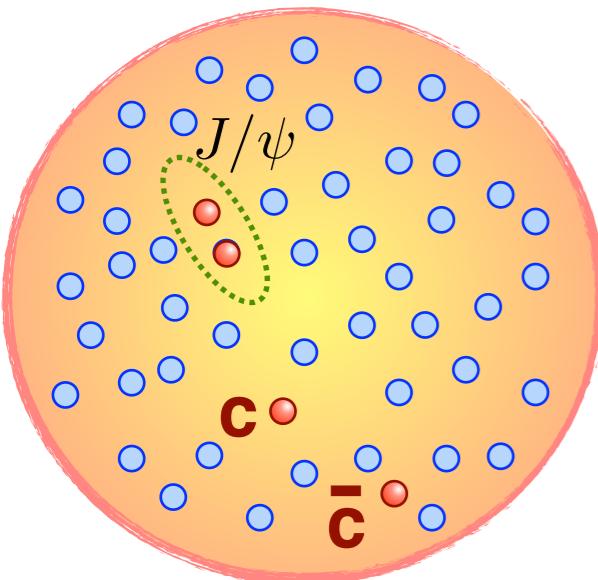
J/ ψ in HI collisions



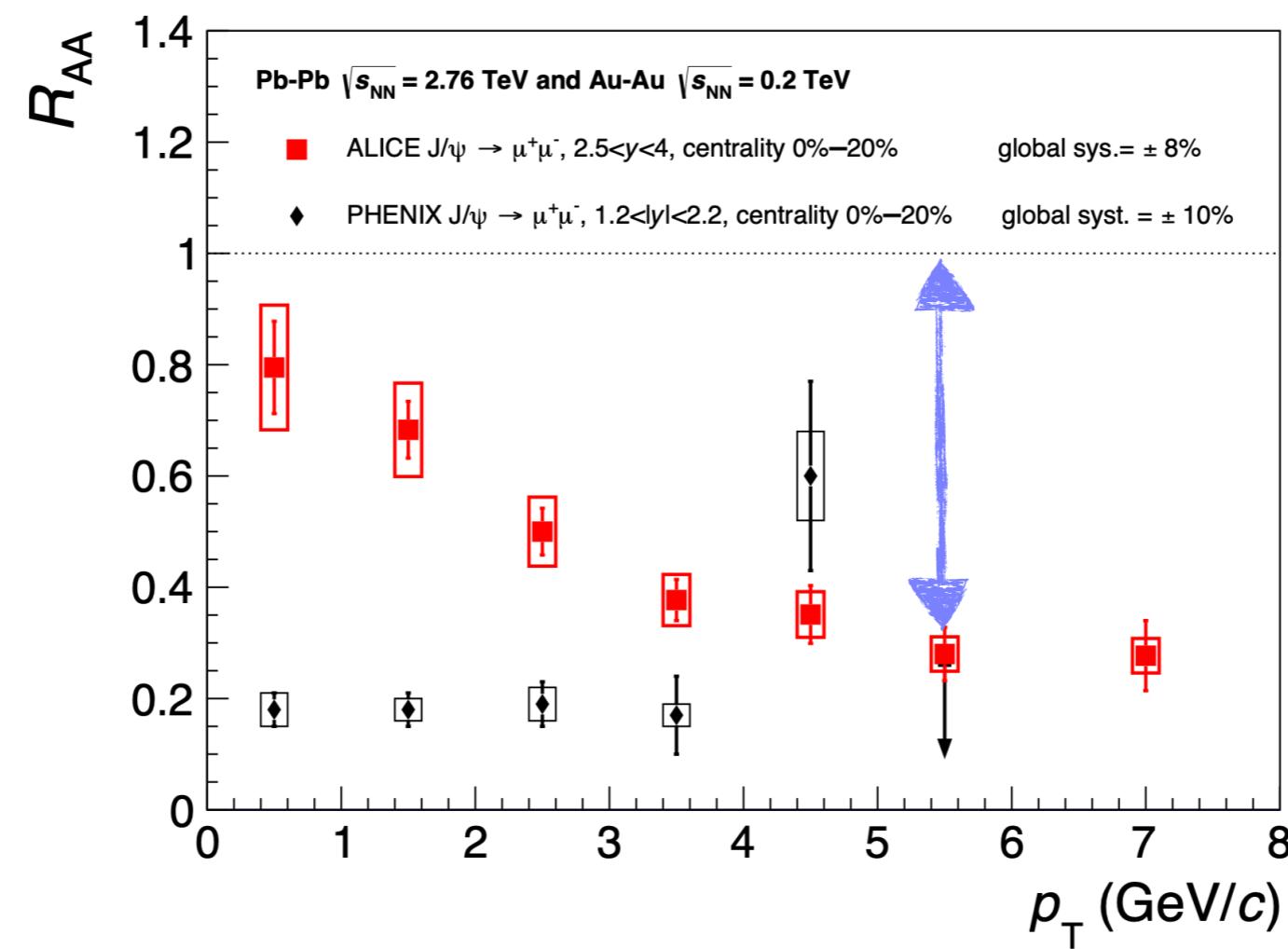
J/ ψ in HI: one of the classic probes of the QGP



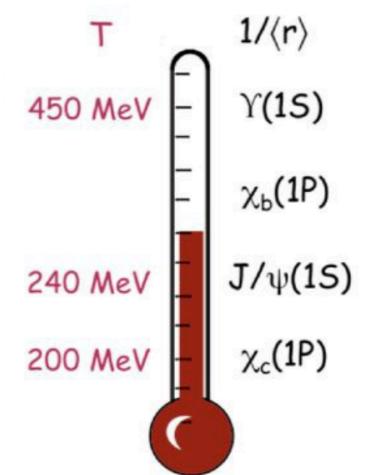
J/ ψ in PbPb collisions

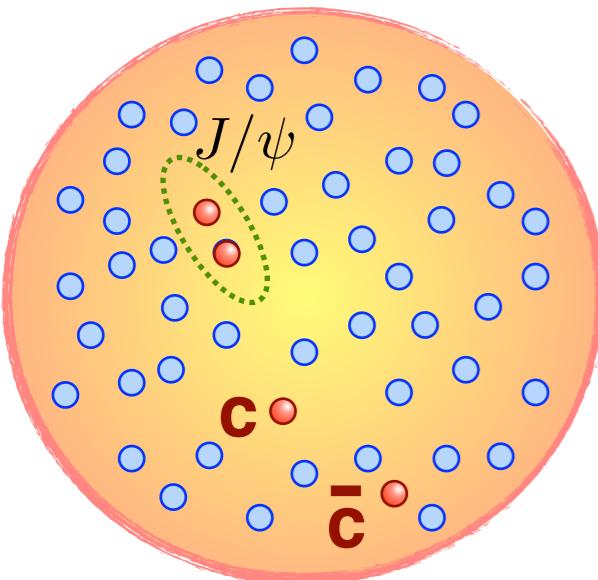


J/ ψ in HI: one of the classic probes of the QGP



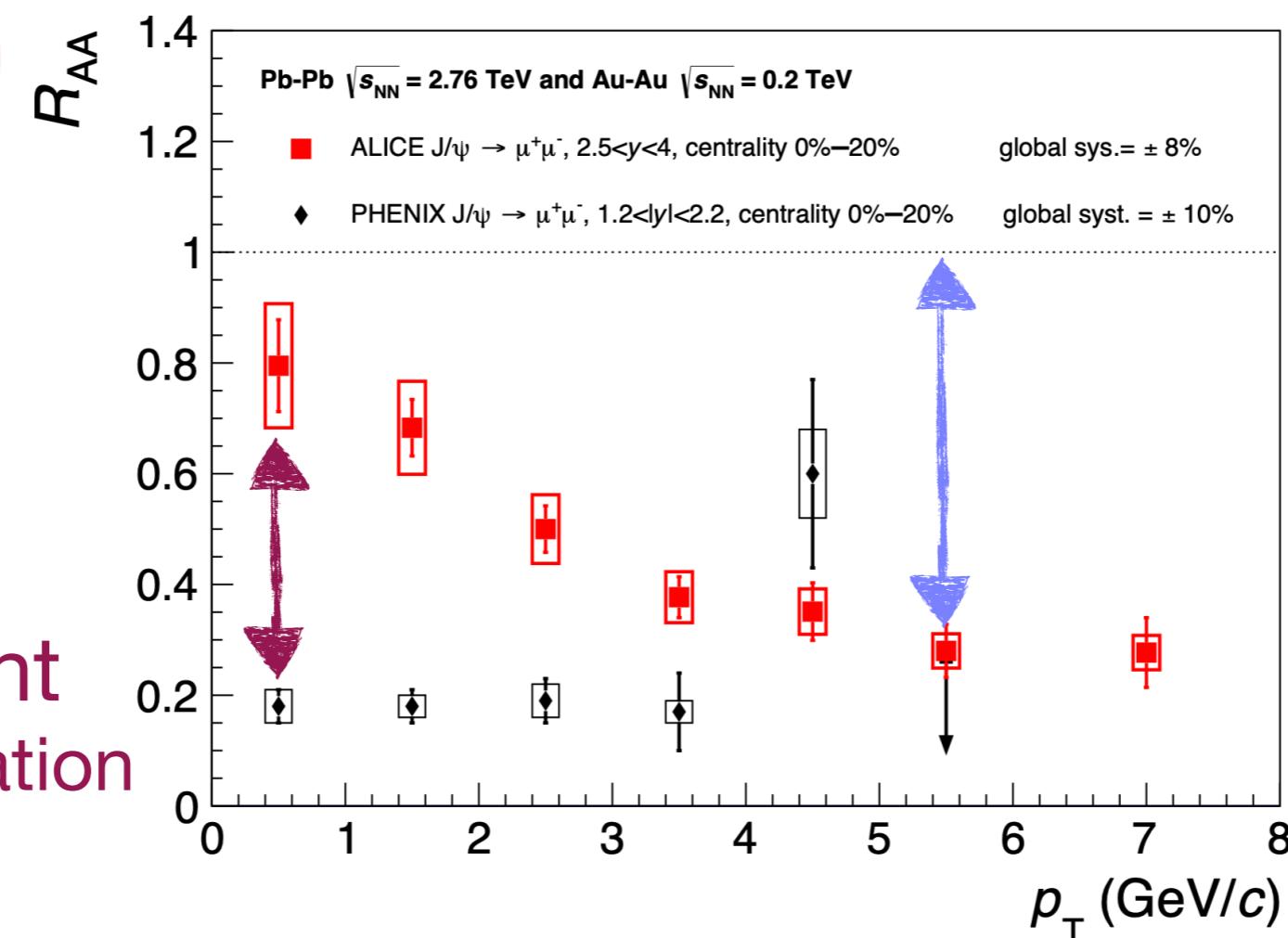
Suppression
→ Debye screening



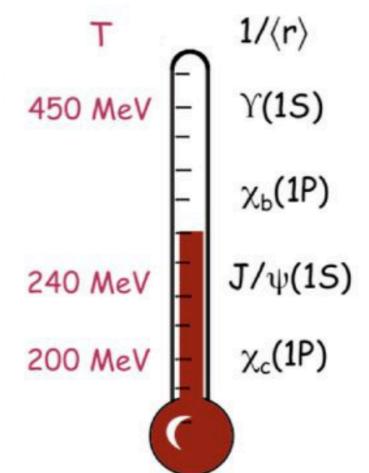


J/ ψ in HI: one of the classic probes of the QGP

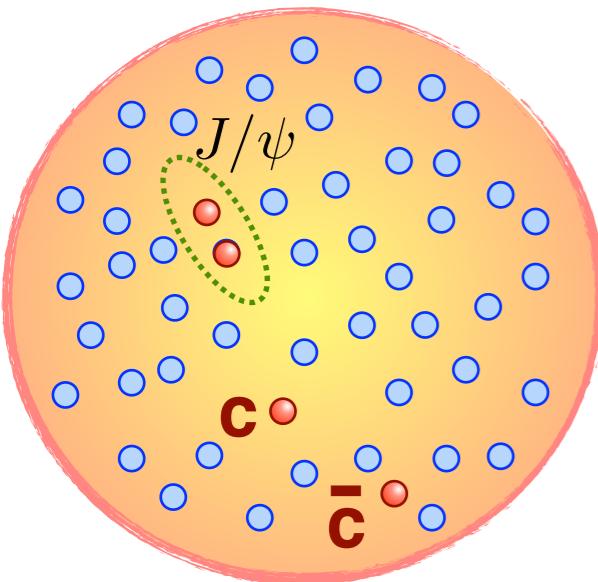
Enhancement
↳ Recombination



Suppression
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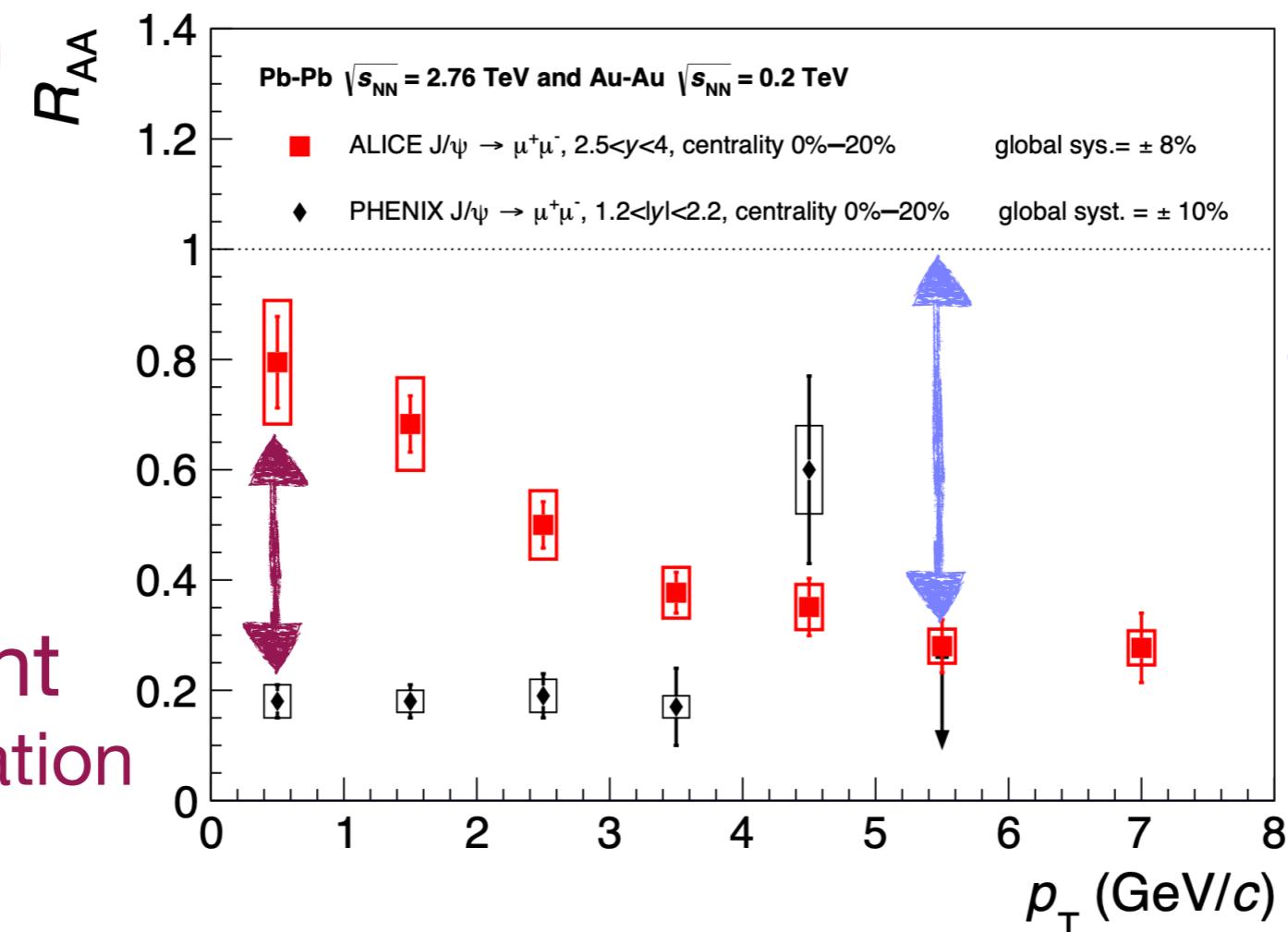


J/ ψ in PbPb collisions

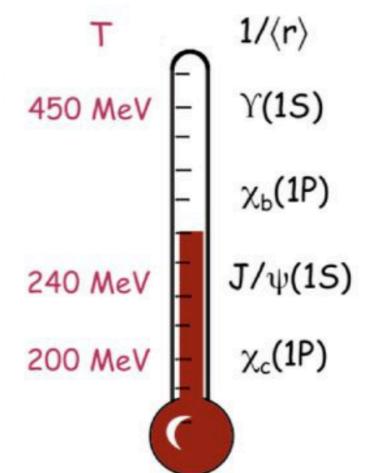


J/ ψ in HI: one of the classic probes of the QGP

Enhancement
↳ Recombination

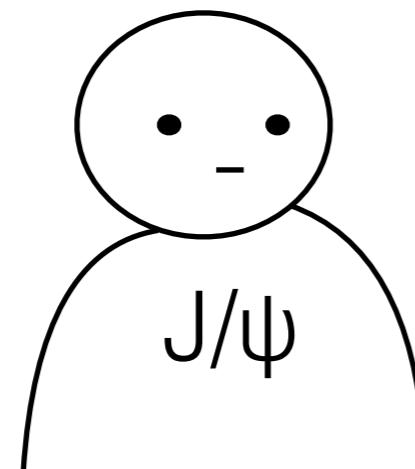


Suppression
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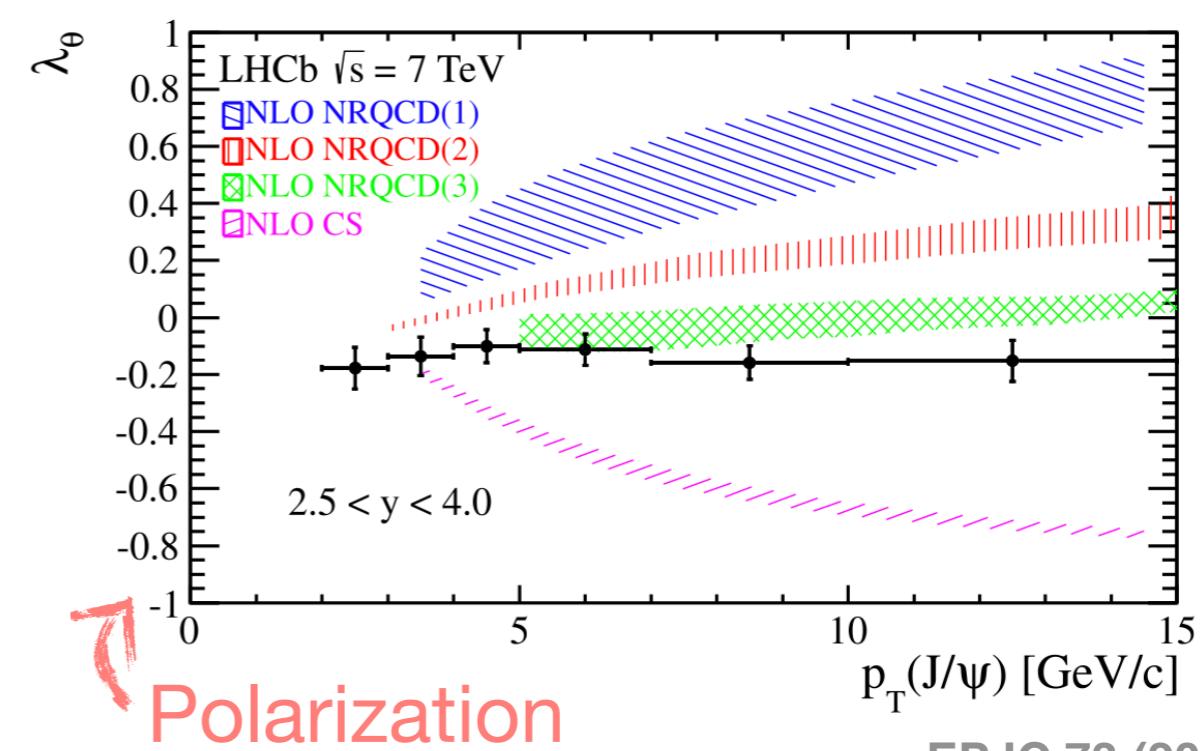
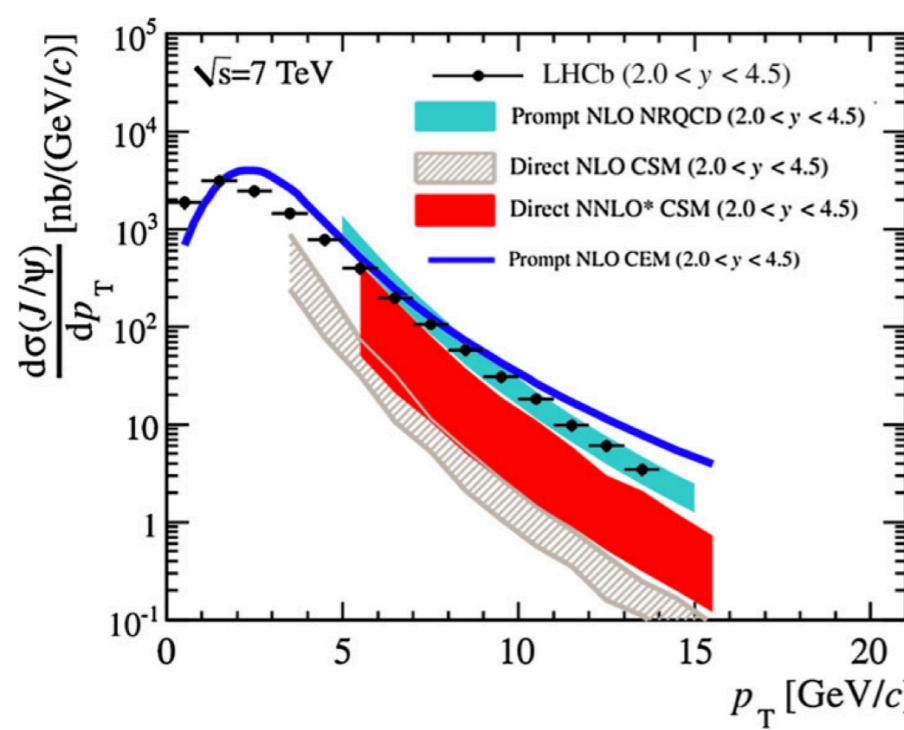
This picture assumes the production of the $c\bar{c}$ pair at early times

J/ ψ production in pp

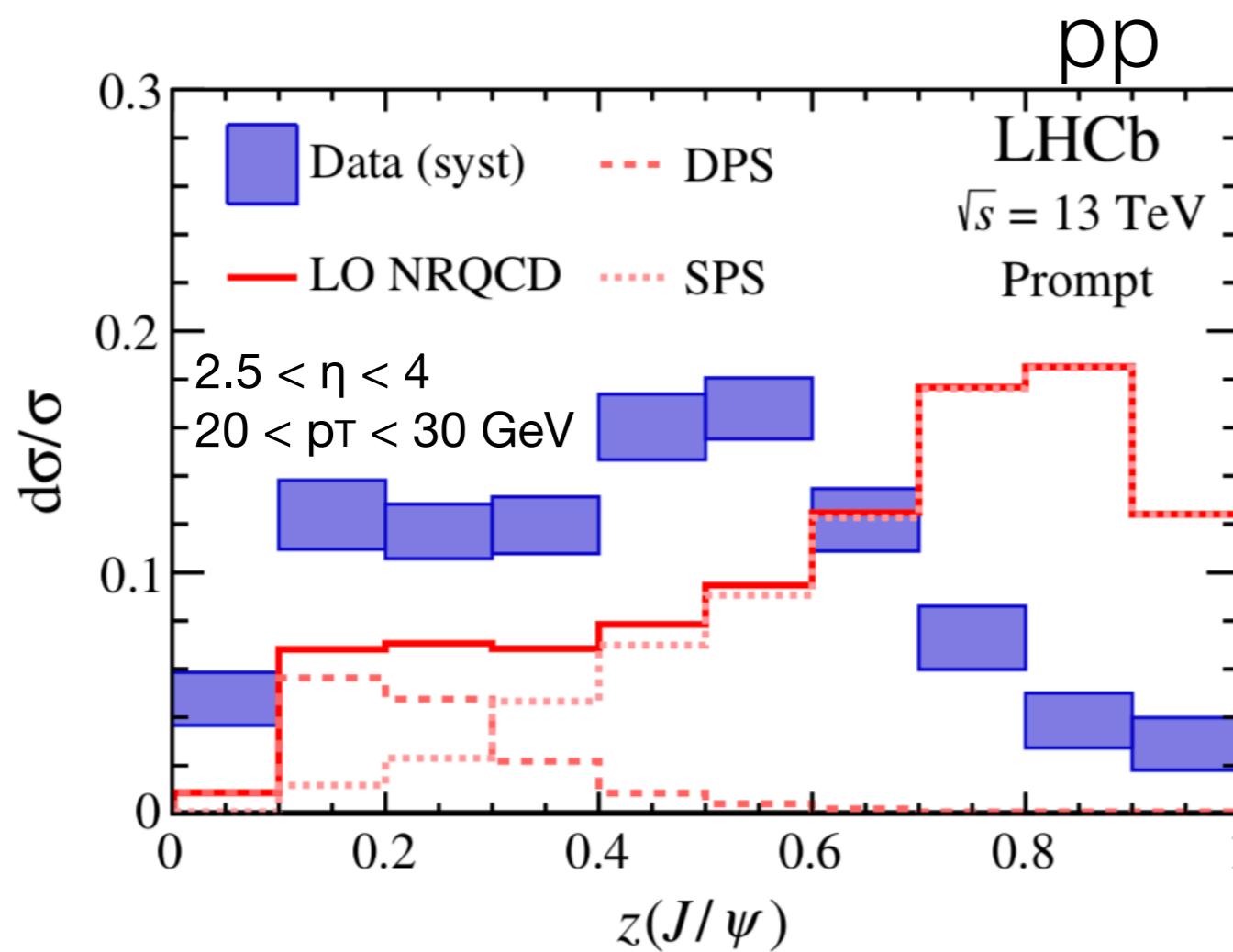
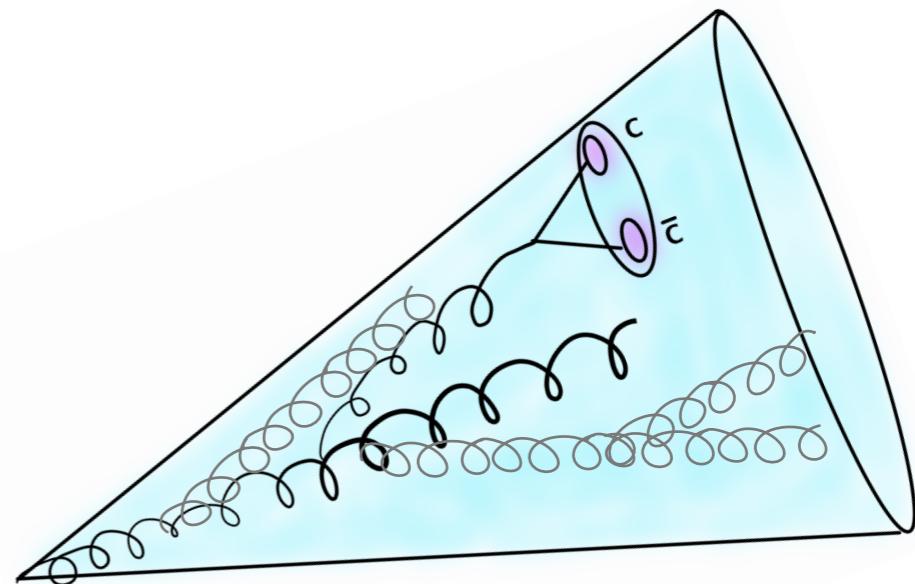
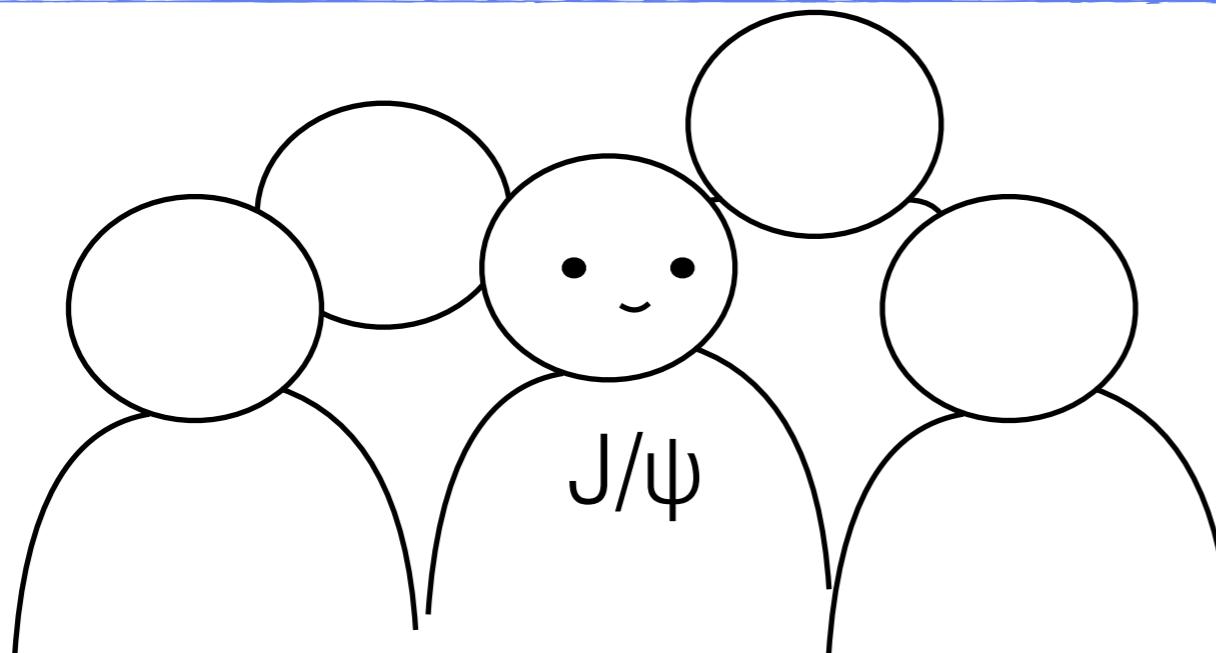


J/ ψ production is not
fully understood

Models can't reproduce both
cross section and polarization



J/ ψ in jets in pp

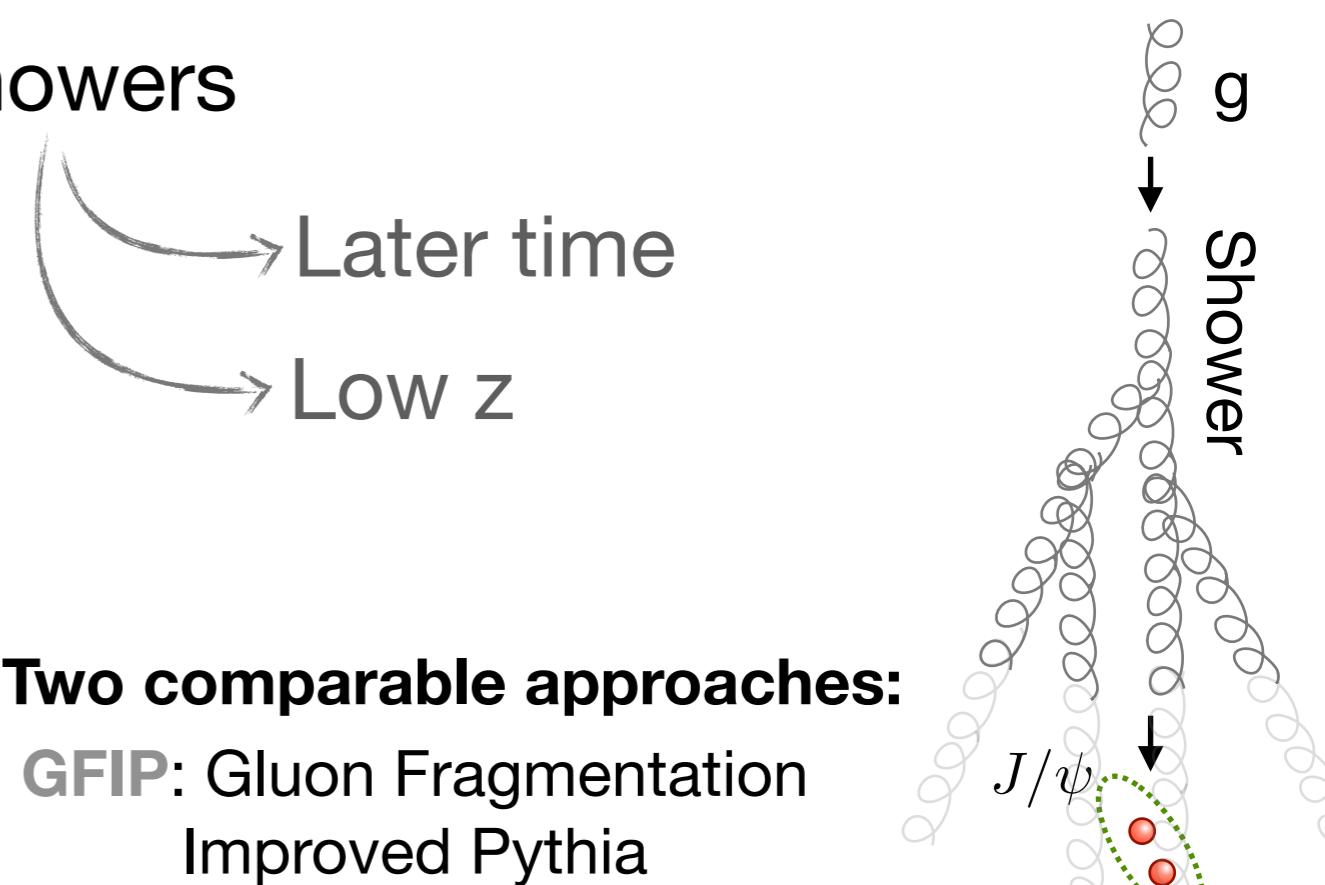
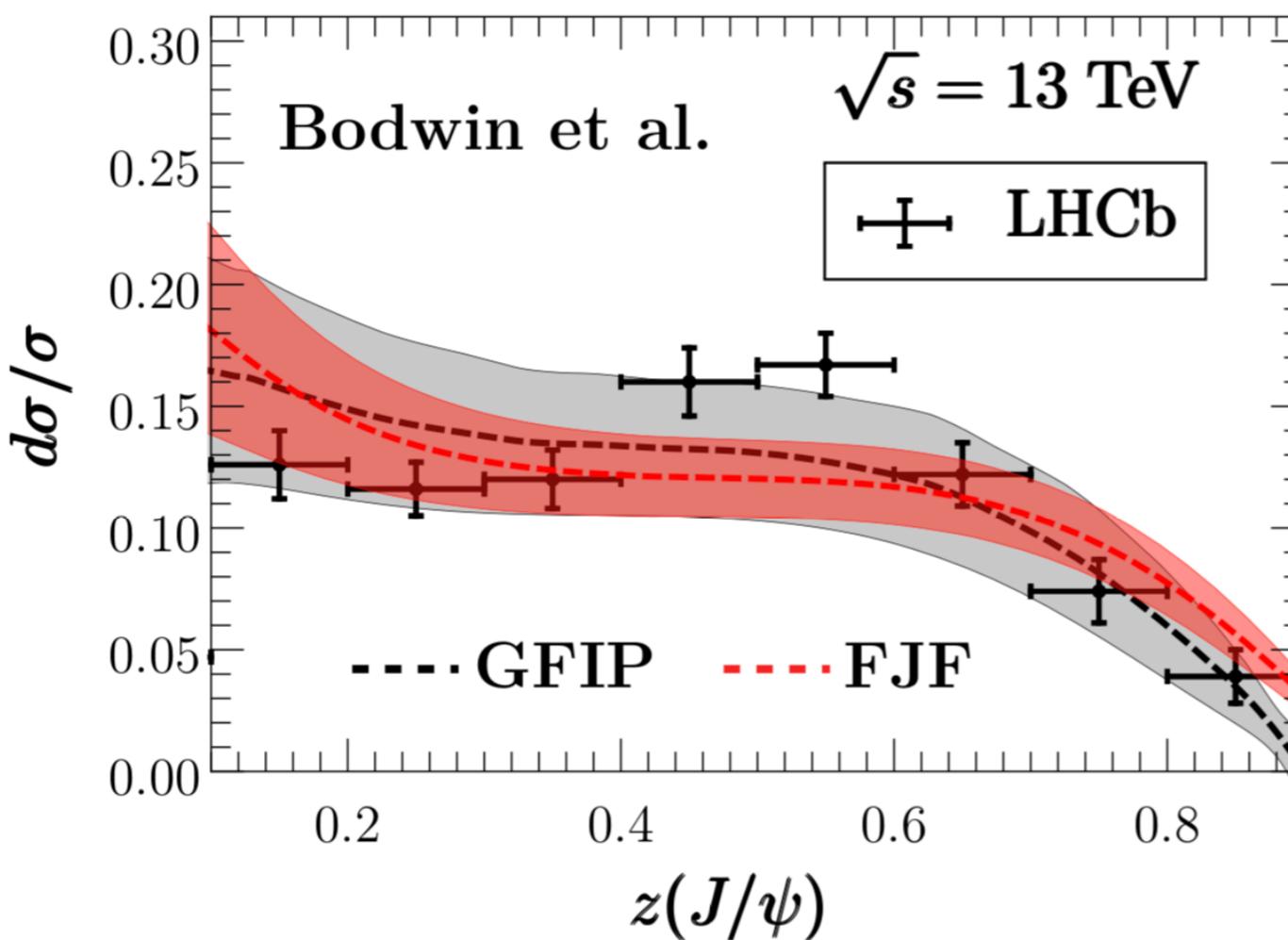


Recent measurement by
LHCb: **J/ ψ in jets**

$$z = J/\psi p_T / \text{jet } p_T$$

prompt J/ ψ are produced
with far more jet activity
than predicted by models

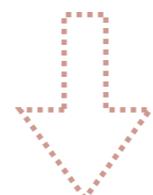
Fixed order calculations are not enough to understand the J/ψ puzzle
 J/ψ could be produced in parton showers



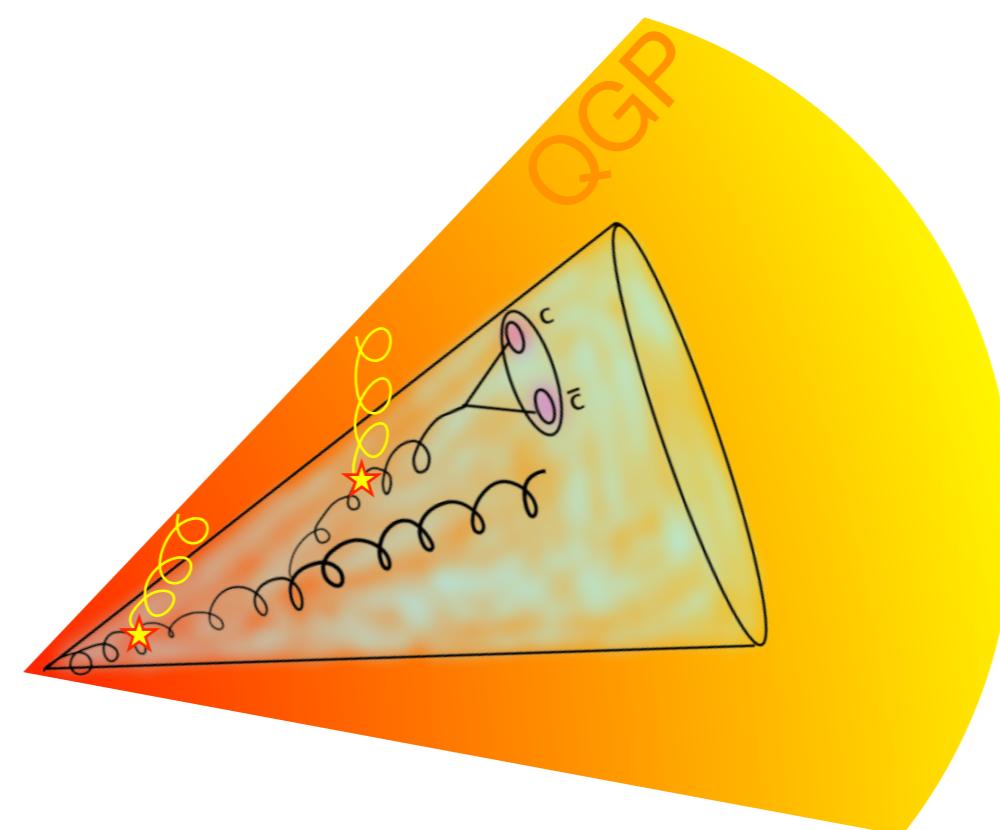
Better agreement with LHCb results than LO NRQCD

J/ ψ production in AA collisions

J/ ψ may also be produced in parton showers



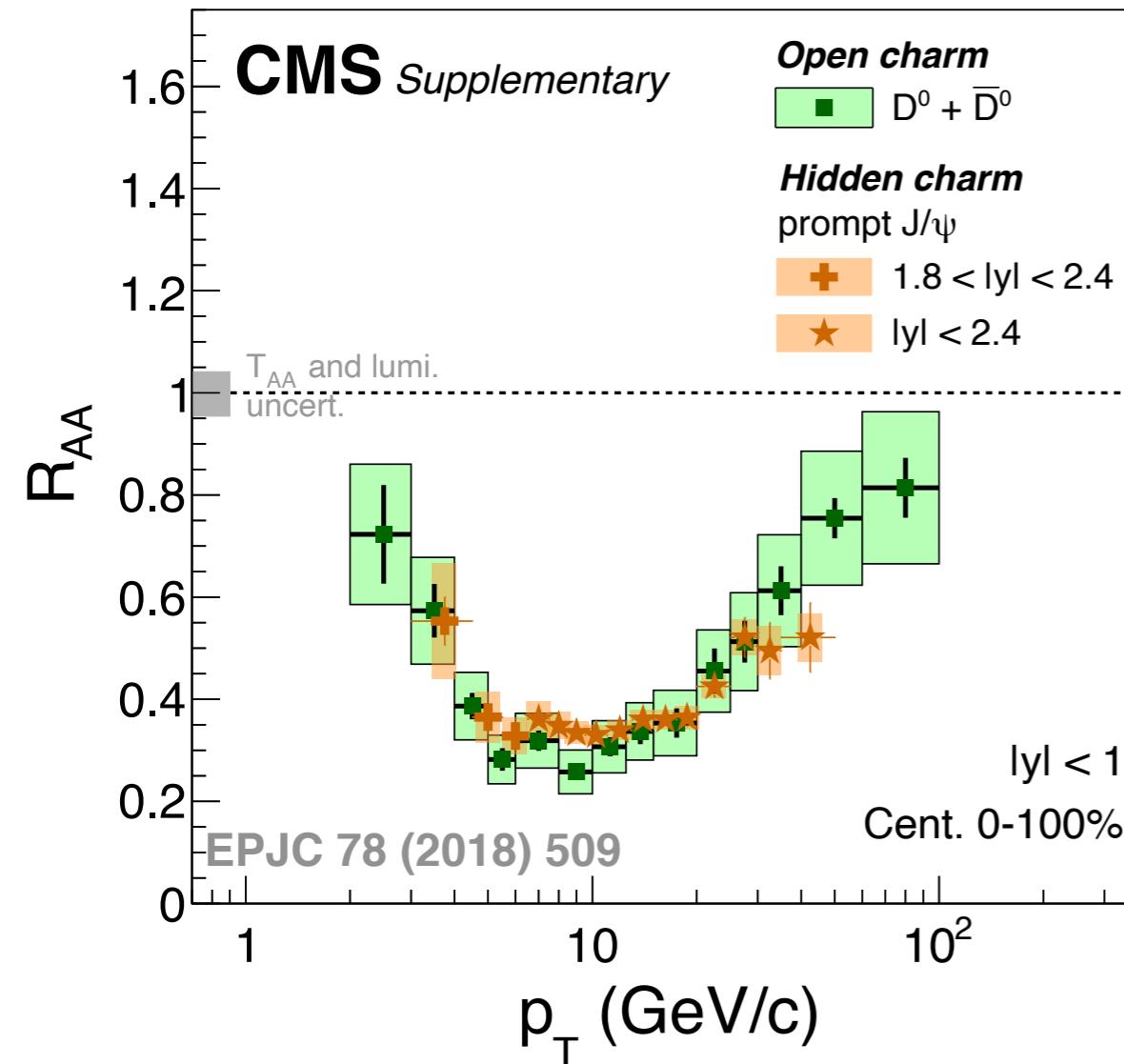
In the course of the interaction of the partons with the QGP



Important implications for the interpretation of J/ ψ in HI

Another look at RAA

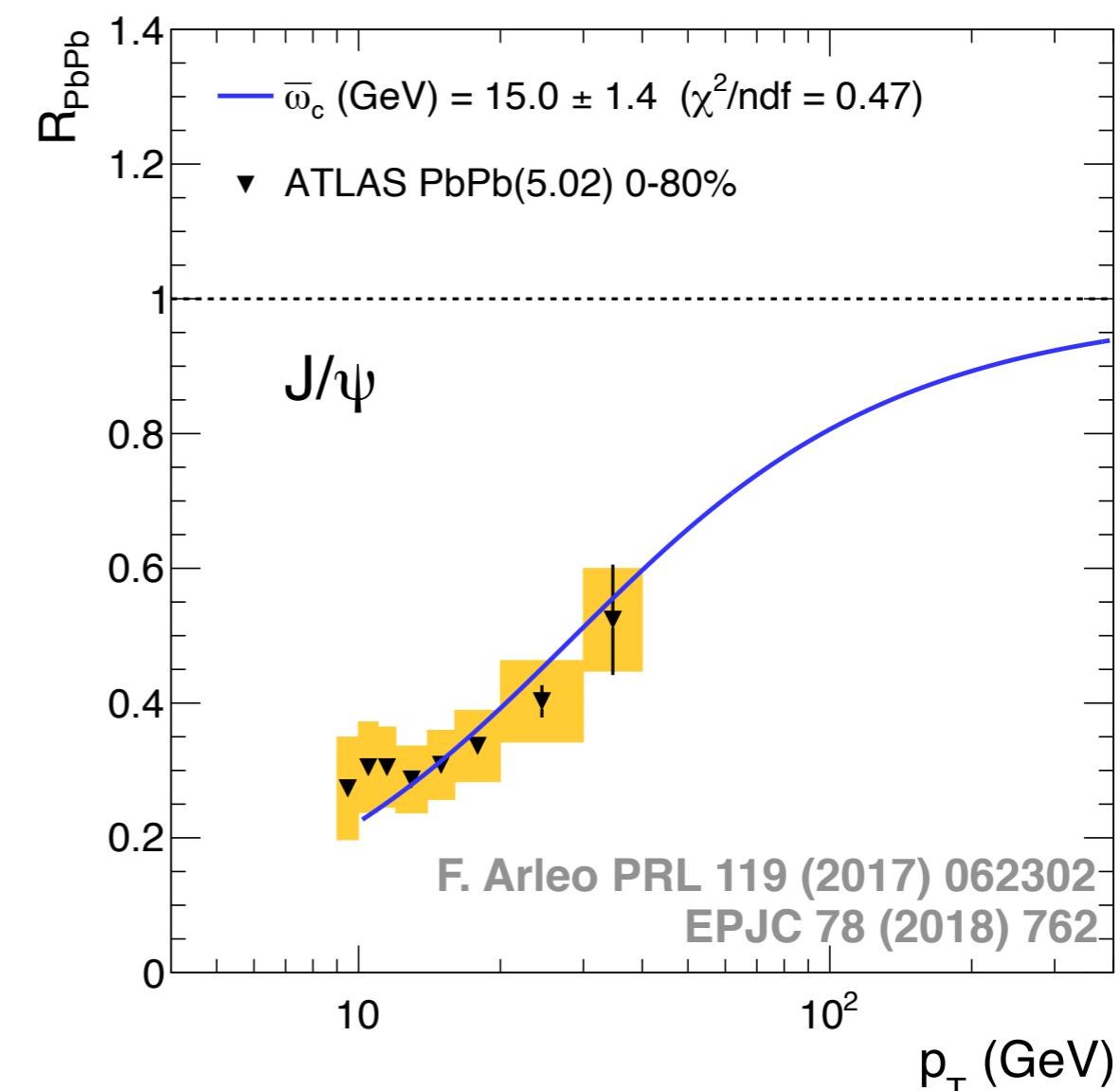
5.02 TeV pp (27.4 pb^{-1}) + PbPb ($530/368 \mu\text{b}^{-1}$)



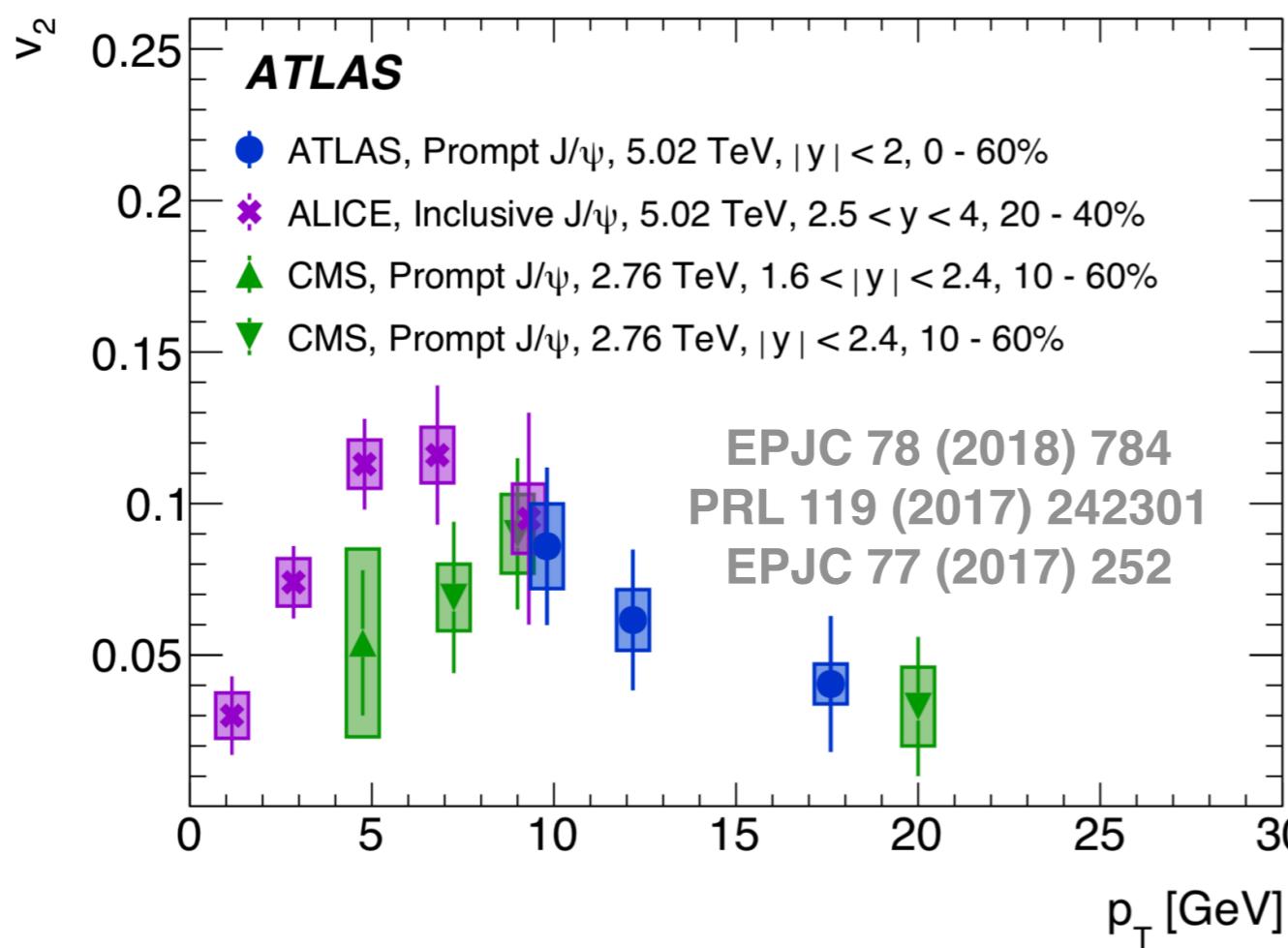
Well described by calculations of parton energy loss

Prompt J/ψ R_{AA} has a similar behaviour to other hadrons

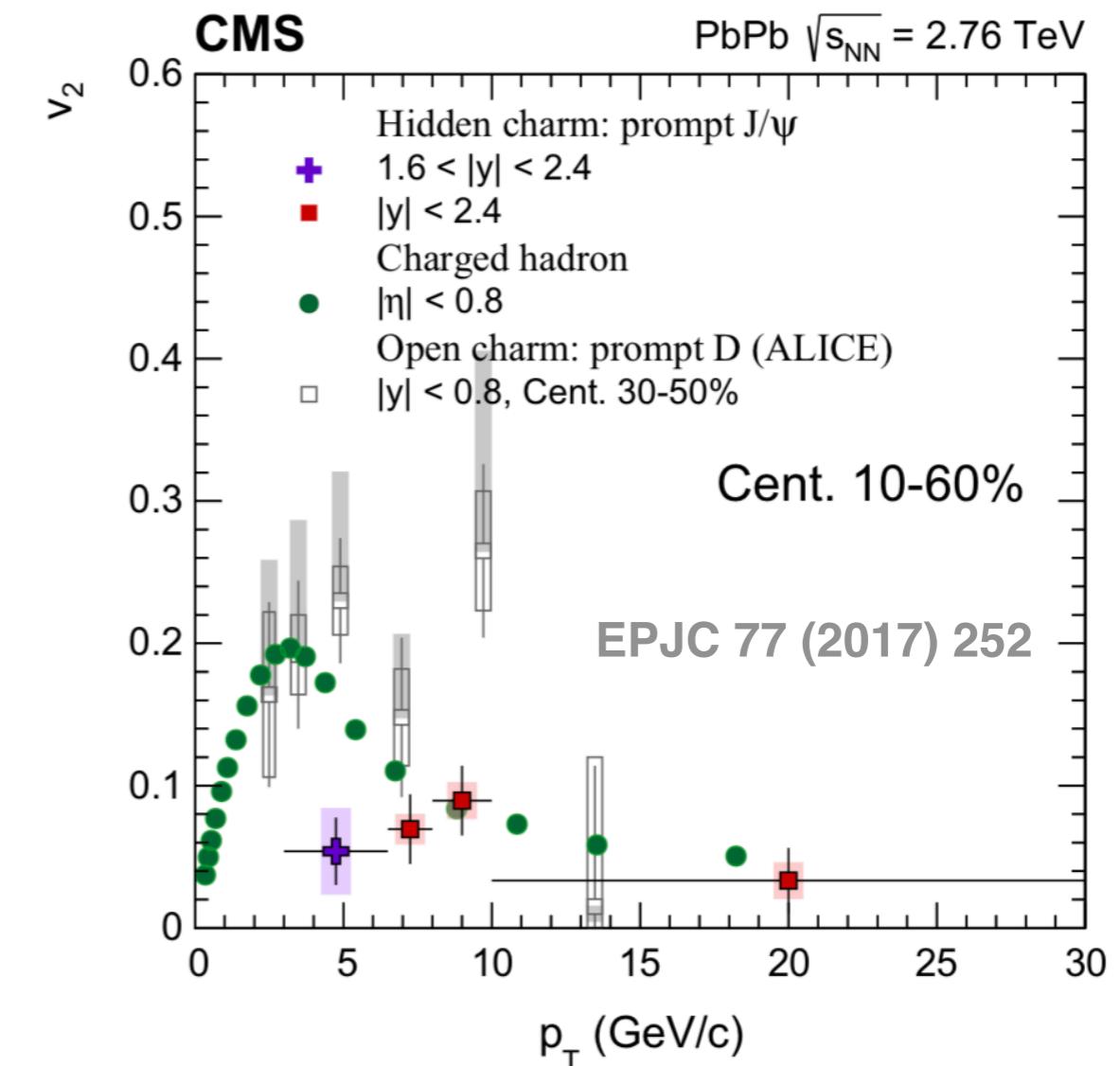
Universal behavior



Elliptic flow in PbPb



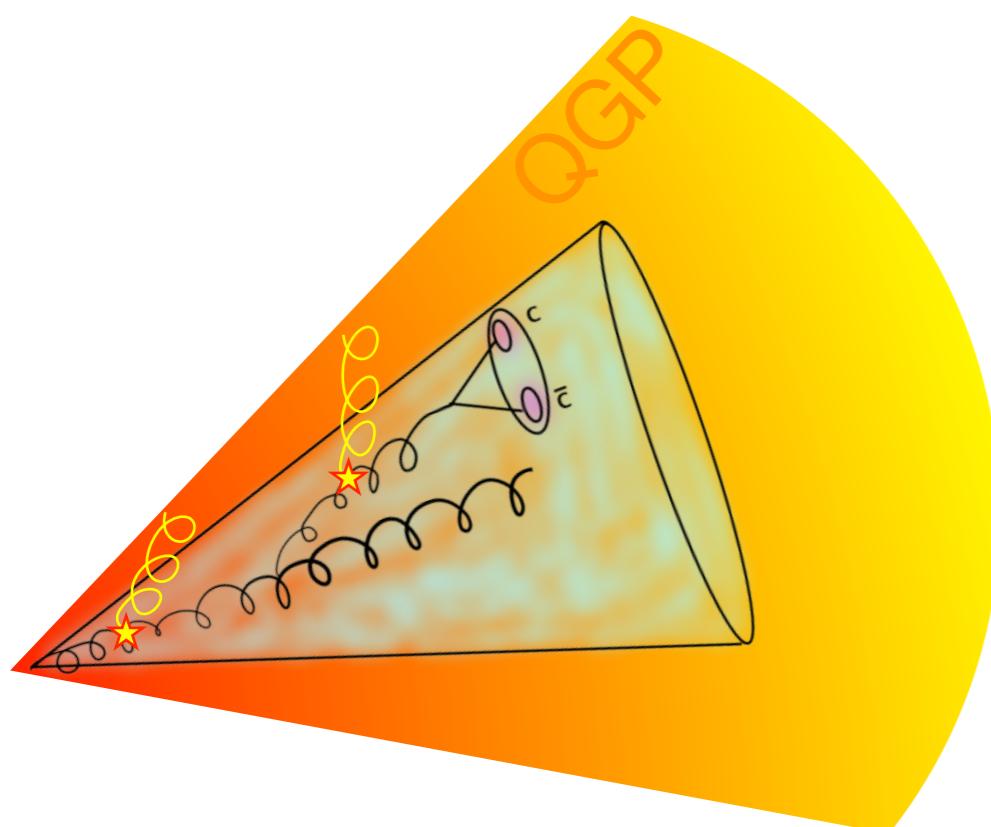
Unexpected non zero v_2
for prompt J/ ψ at high p_T



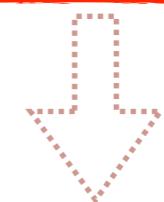
Similar to other
hadrons at high p_T

Path-length dependence of energy loss

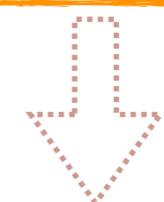
J/ ψ production in AA collisions



Jet quenching might be relevant in J/ ψ suppression

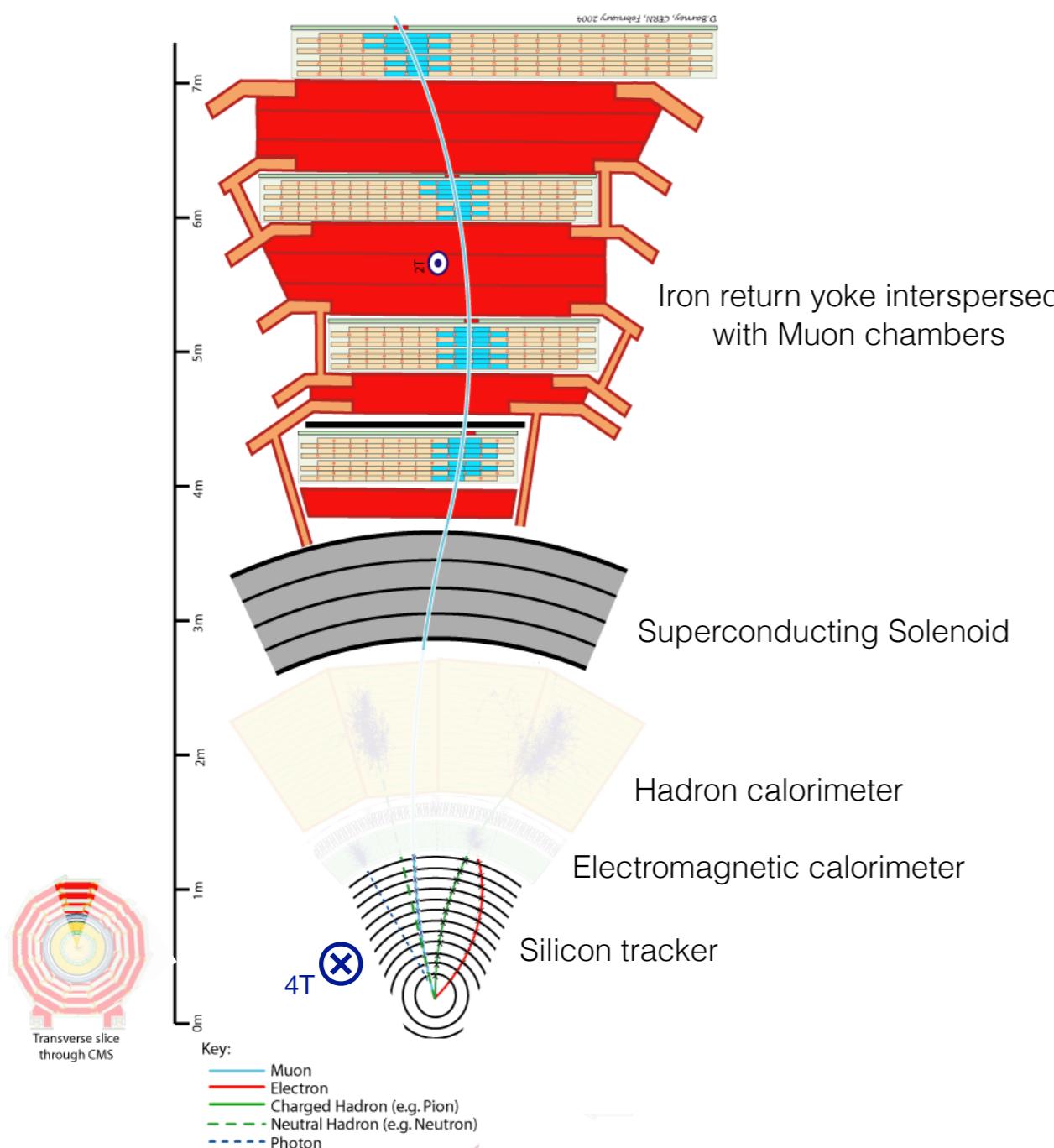


Measure the fragmentation function in PbPb collisions



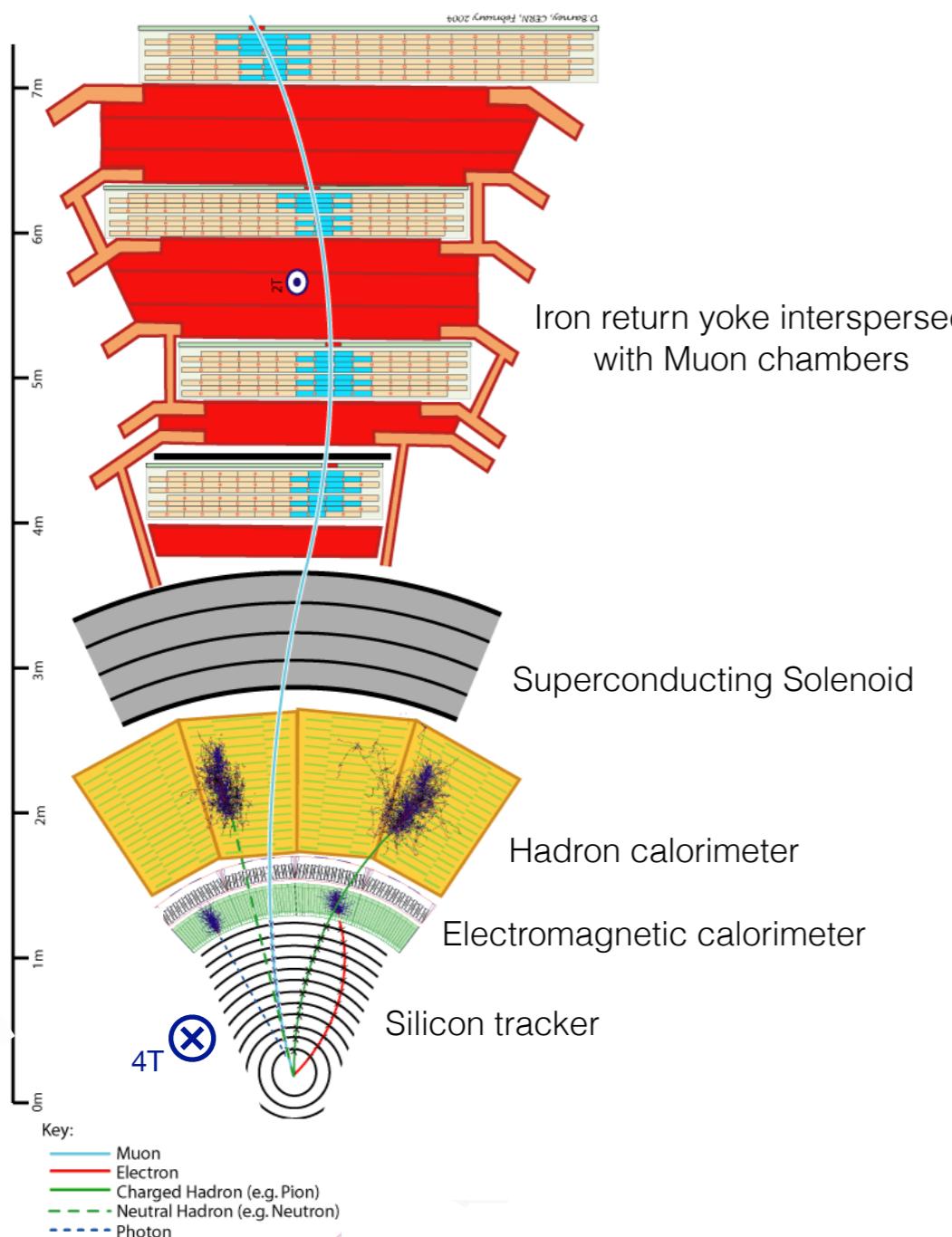
$$z = p_{\text{T},J/\psi} / p_{\text{T},\text{Jet}}$$

Analysis workflow



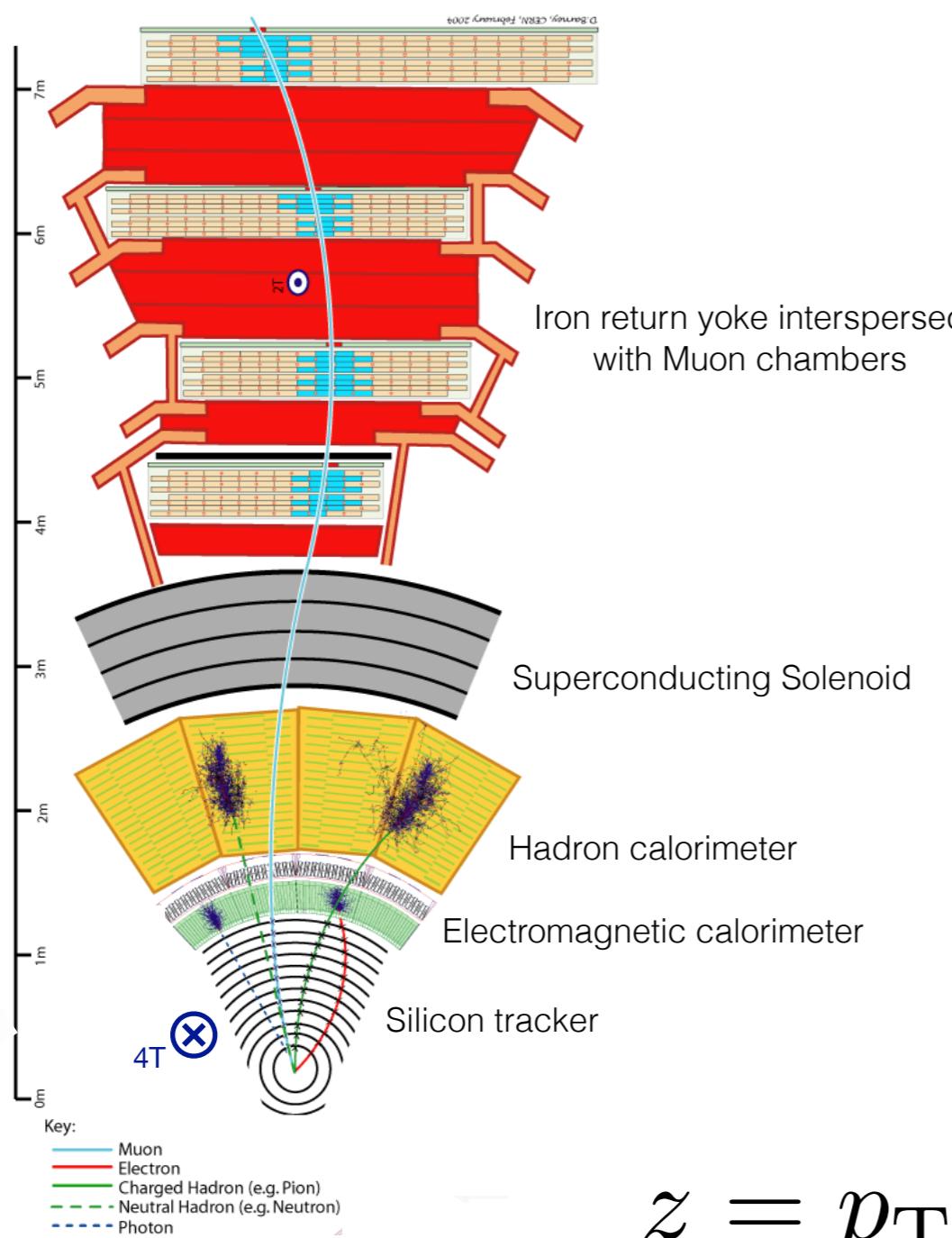
Decay channel: $J/\psi \rightarrow \mu\mu$
 $J/\psi p_T > 6.5 \text{ GeV}$

Analysis workflow



Decay channel: $J/\psi \rightarrow \mu\mu$
 $J/\psi p_T > 6.5 \text{ GeV}$
anti- k_T algorithm ($R=0.3$)
 J/ψ used as a constituent in
the clustering, replacing
decay muons
 $30 < \text{jet } p_T < 40 \text{ GeV}$
 $|\eta_{\text{Jet}}| < 2$

Analysis workflow



Decay channel: $J/\psi \rightarrow \mu\mu$

$J/\psi p_T > 6.5 \text{ GeV}$

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$$z = p_{T,J/\psi}/p_{T,\text{Jet}}$$

J/ ψ signal extraction

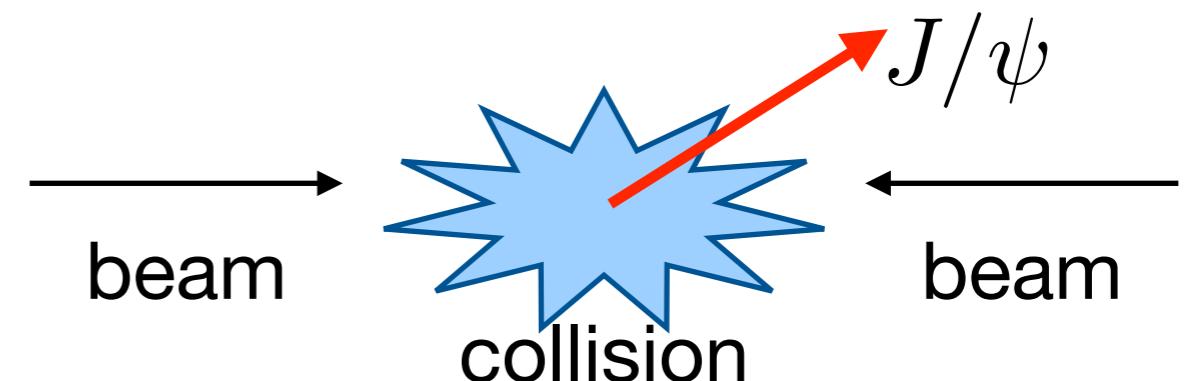
Unfolding

Results

Prompt vs nonprompt charmonia

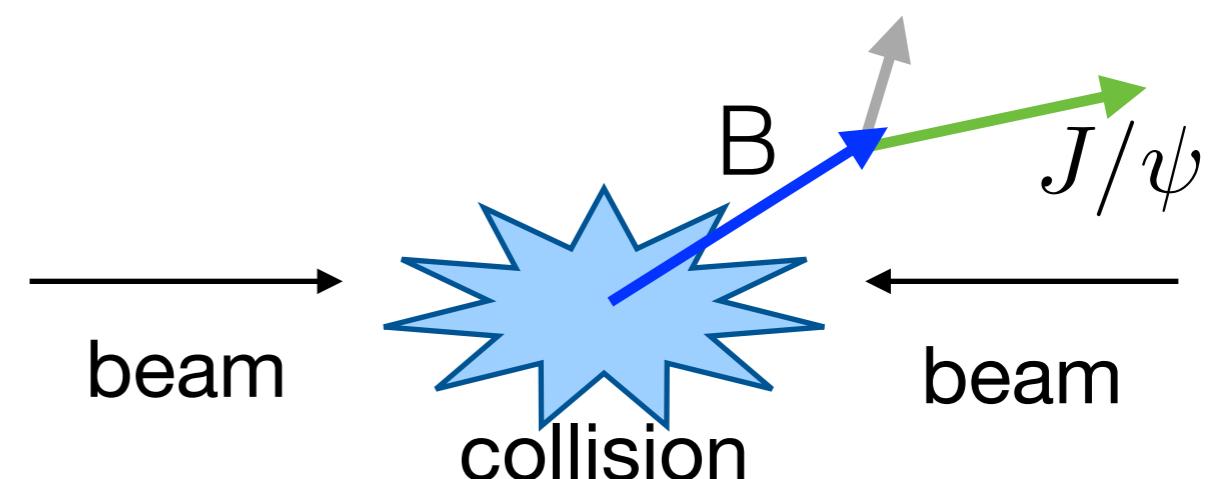
Prompt:

Directly in the collision
Decay of heavier charmonium states



Nonprompt:

Decay of b hadrons



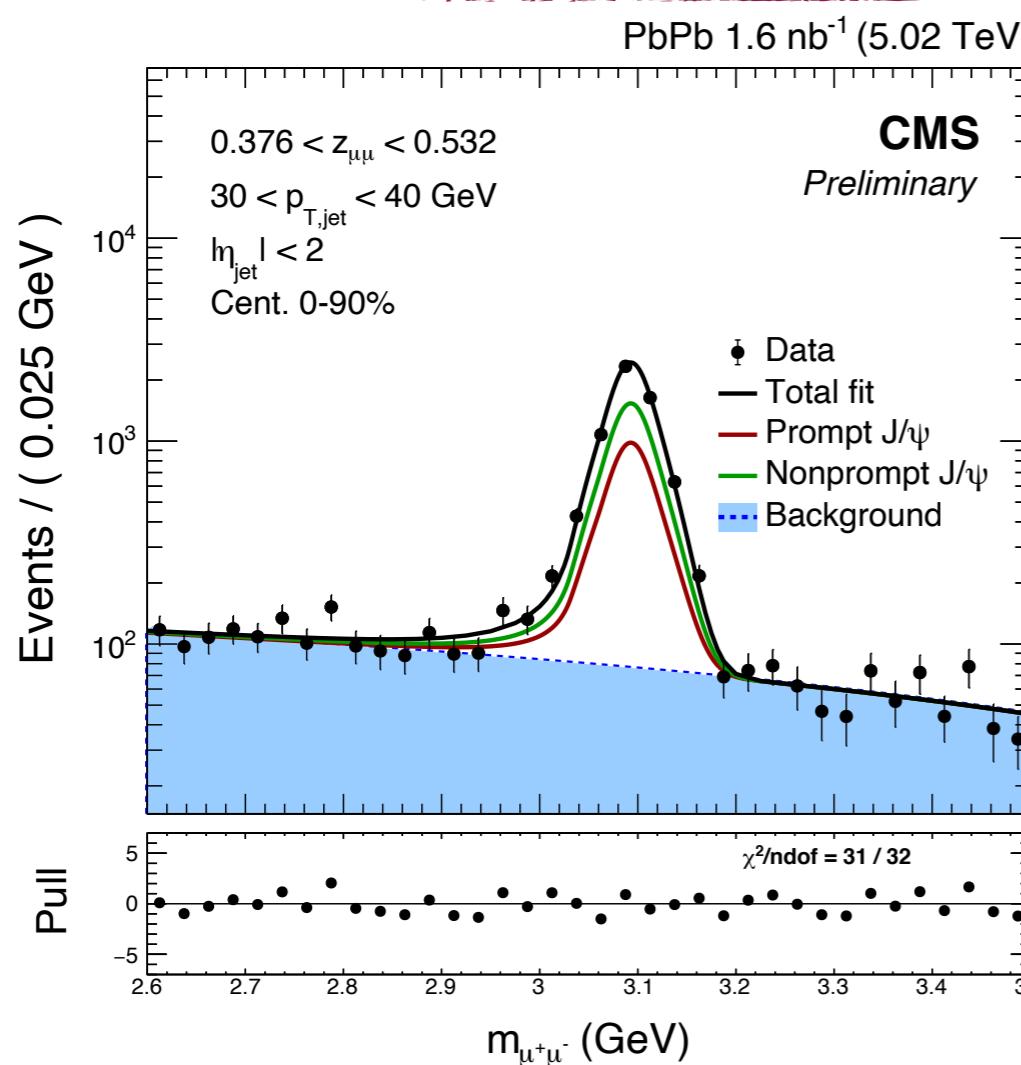
Separation based on the
pseudo-proper decay length $l_{J/\psi}$

A diagram showing a particle B decaying at a "Primary vertex" into a J/ψ particle and another particle. The J/ψ particle then decays at a "Secondary vertex" into an electron (μ^-) and a positron (μ^+). A dashed line extends from the primary vertex to the secondary vertex. The distance between these vertices is labeled L . The formula for the pseudo-proper decay length is given as
$$l_{J/\psi} = L \cdot \frac{m}{p_T}$$

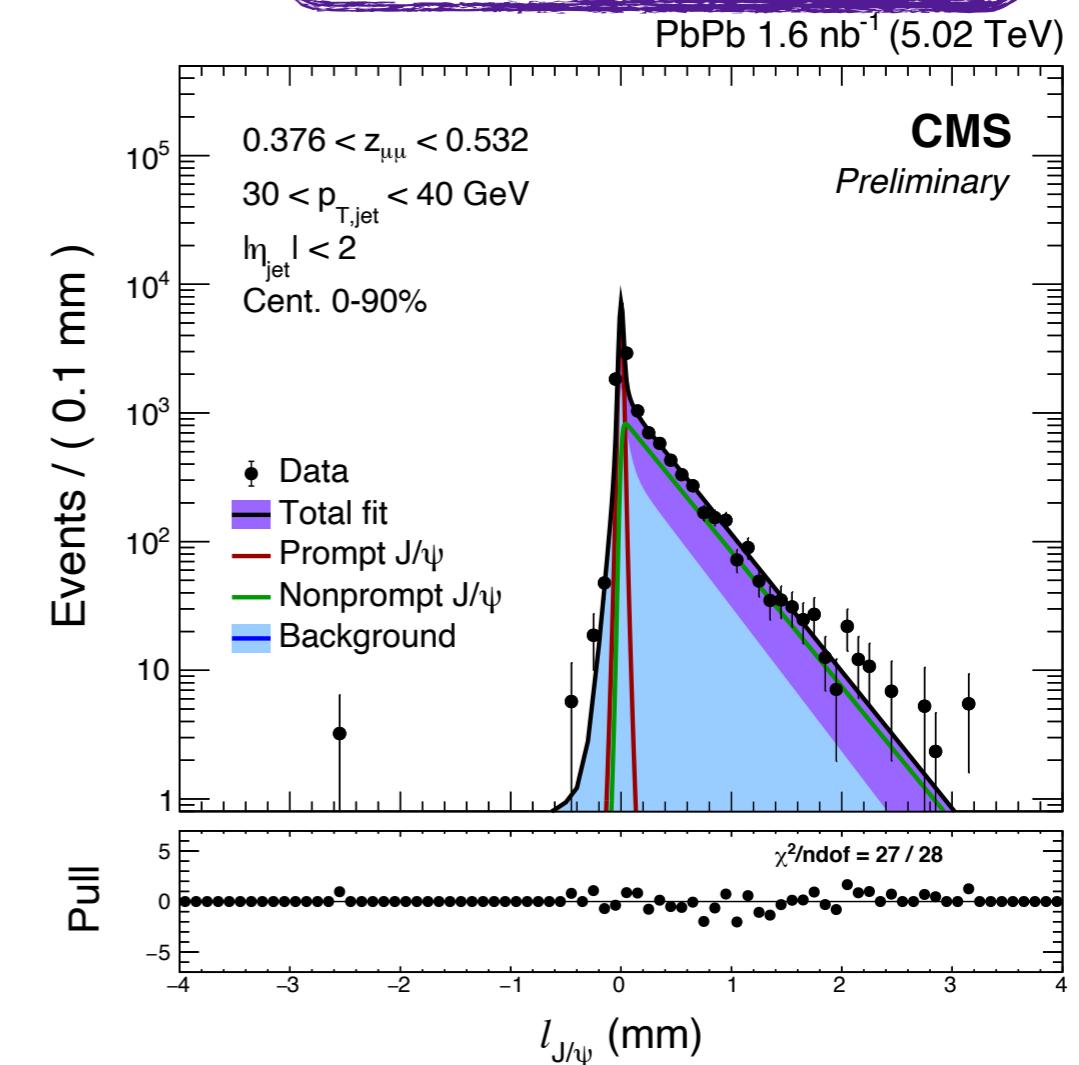
Signal extraction

2D fitting procedure is used

Invariant mass



Pseudo-proper decay length



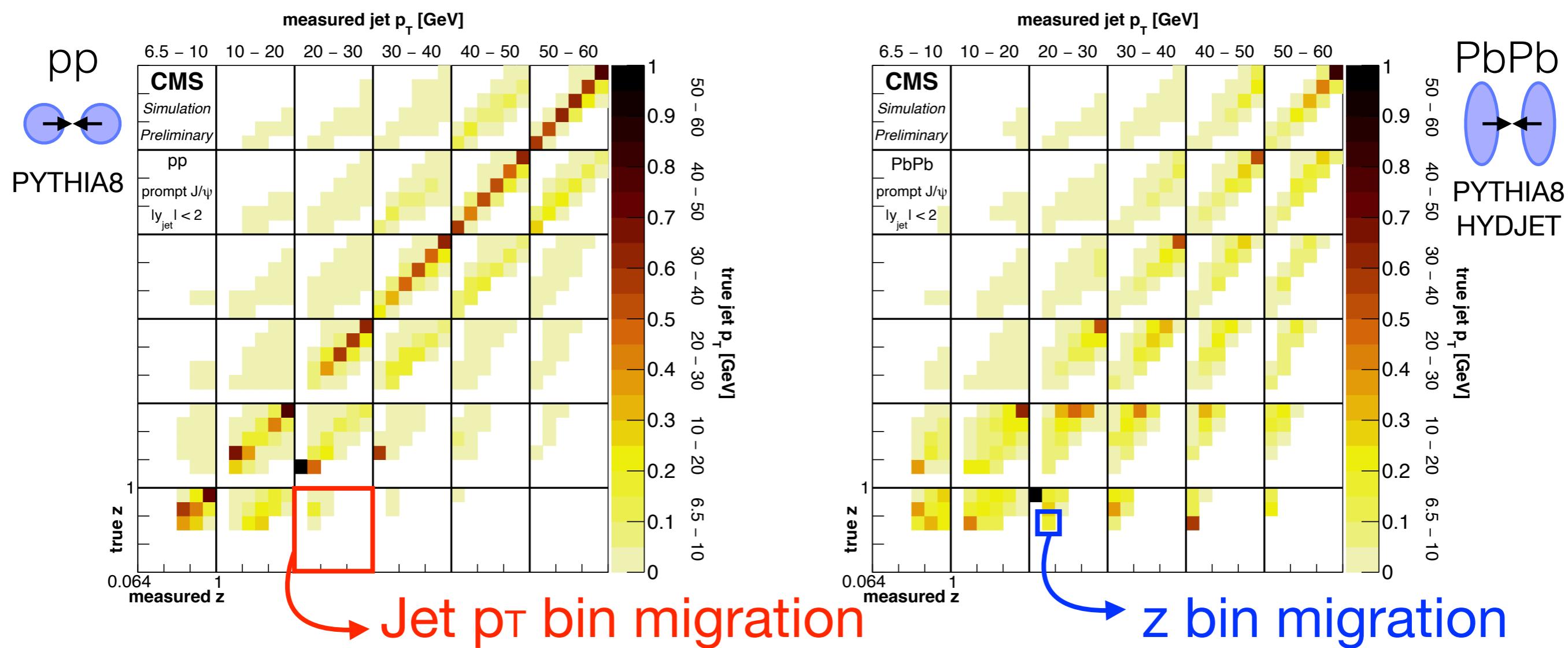
The fits are performed in z and jet p_T bins to extract the yields

Unfolding of jet resolution

Wide jet p_T resolution of jets \rightarrow unfolding is needed

Iterative D'Agostini method, RooUnfold package

The z prior is flattened in the transfer matrix to avoid MC bias



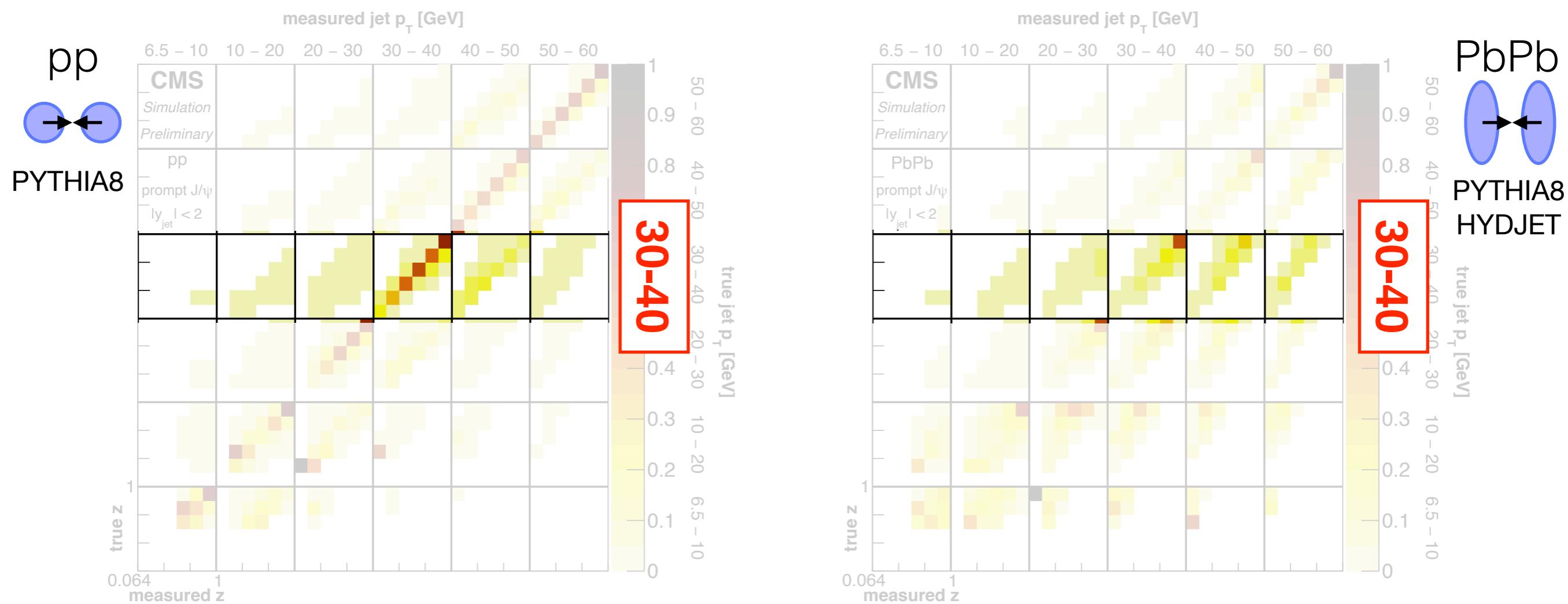
The response matrices show the relationship between the truth-level and measured values in the simulation

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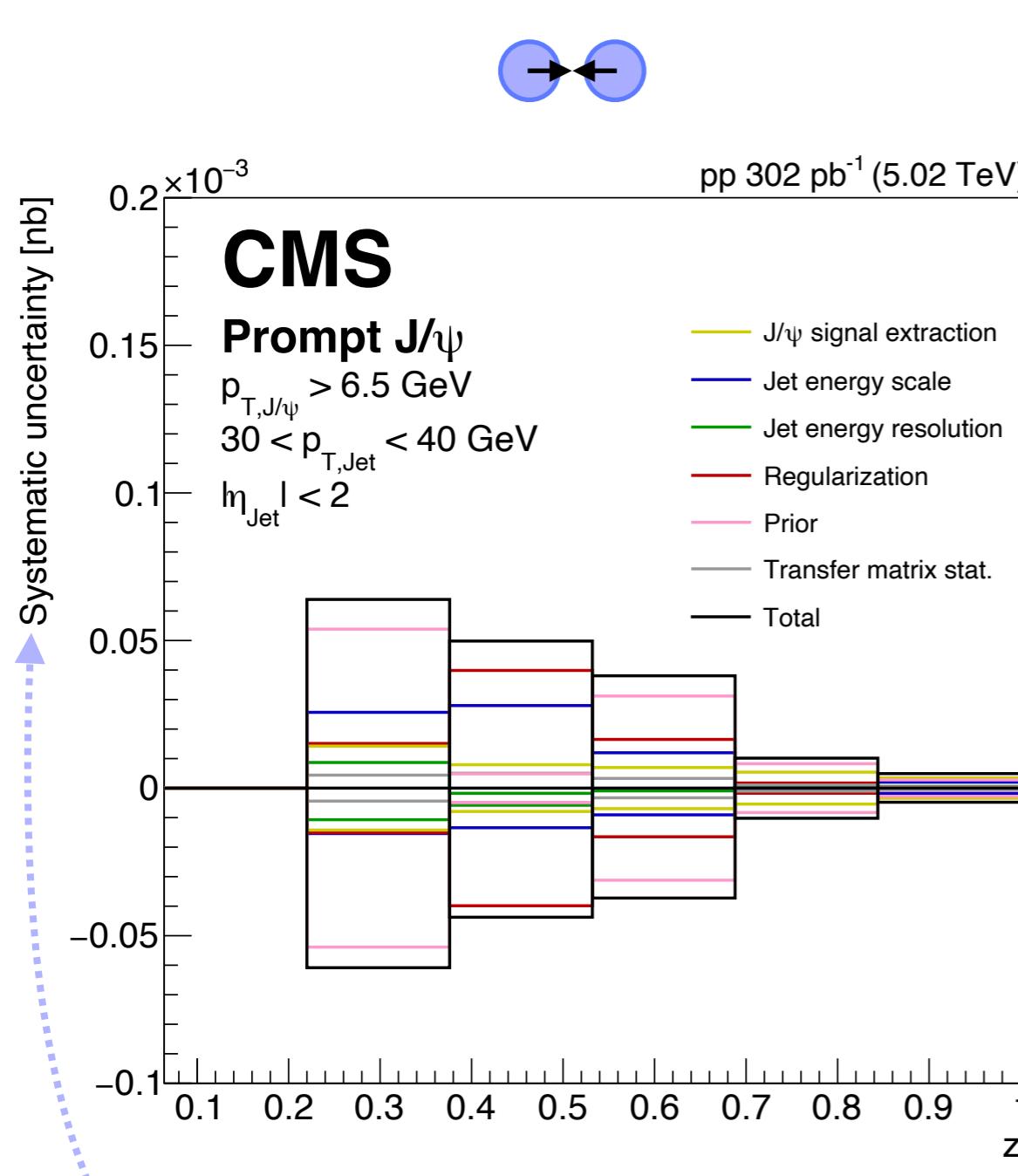
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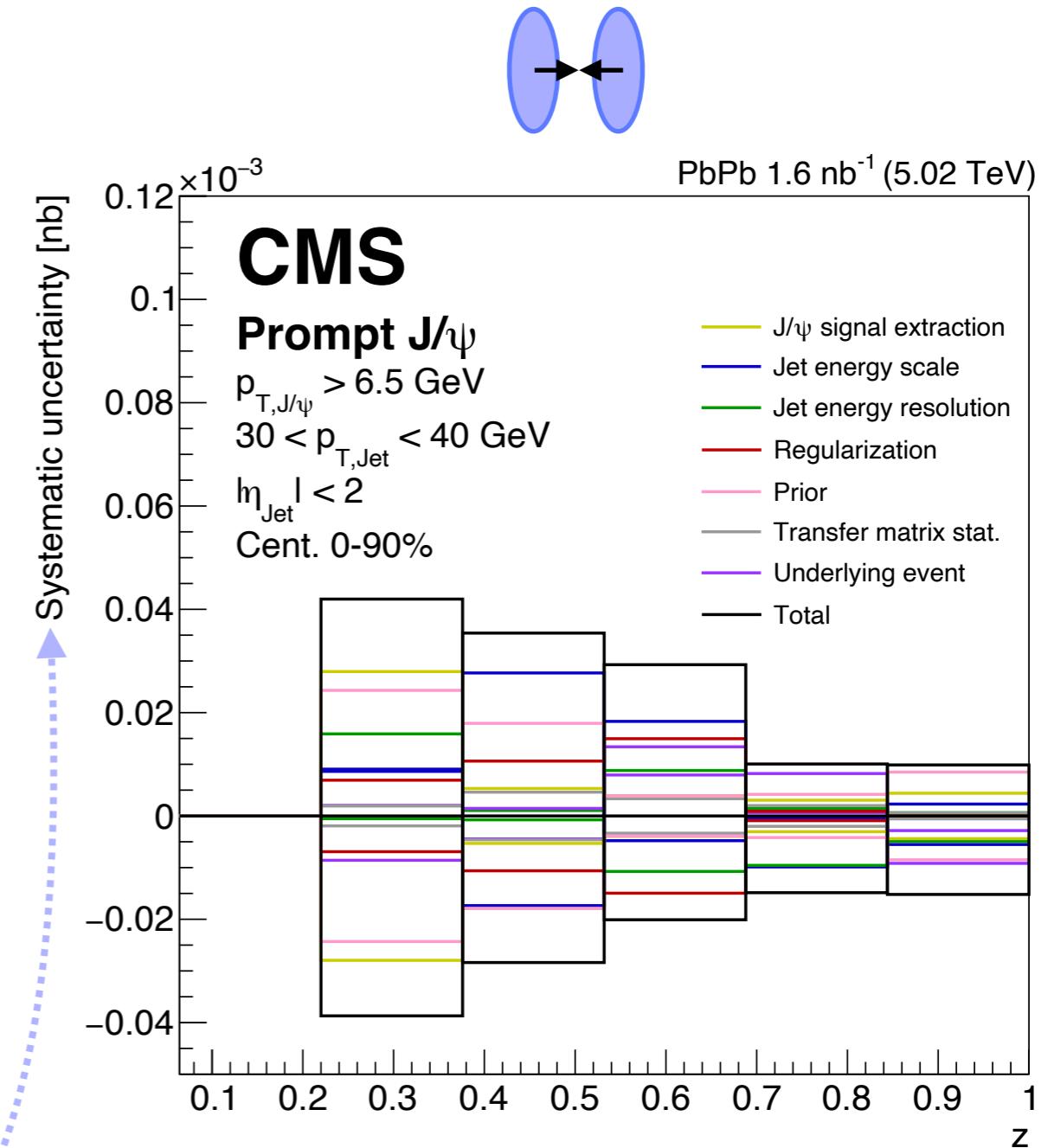


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Systematic uncertainties



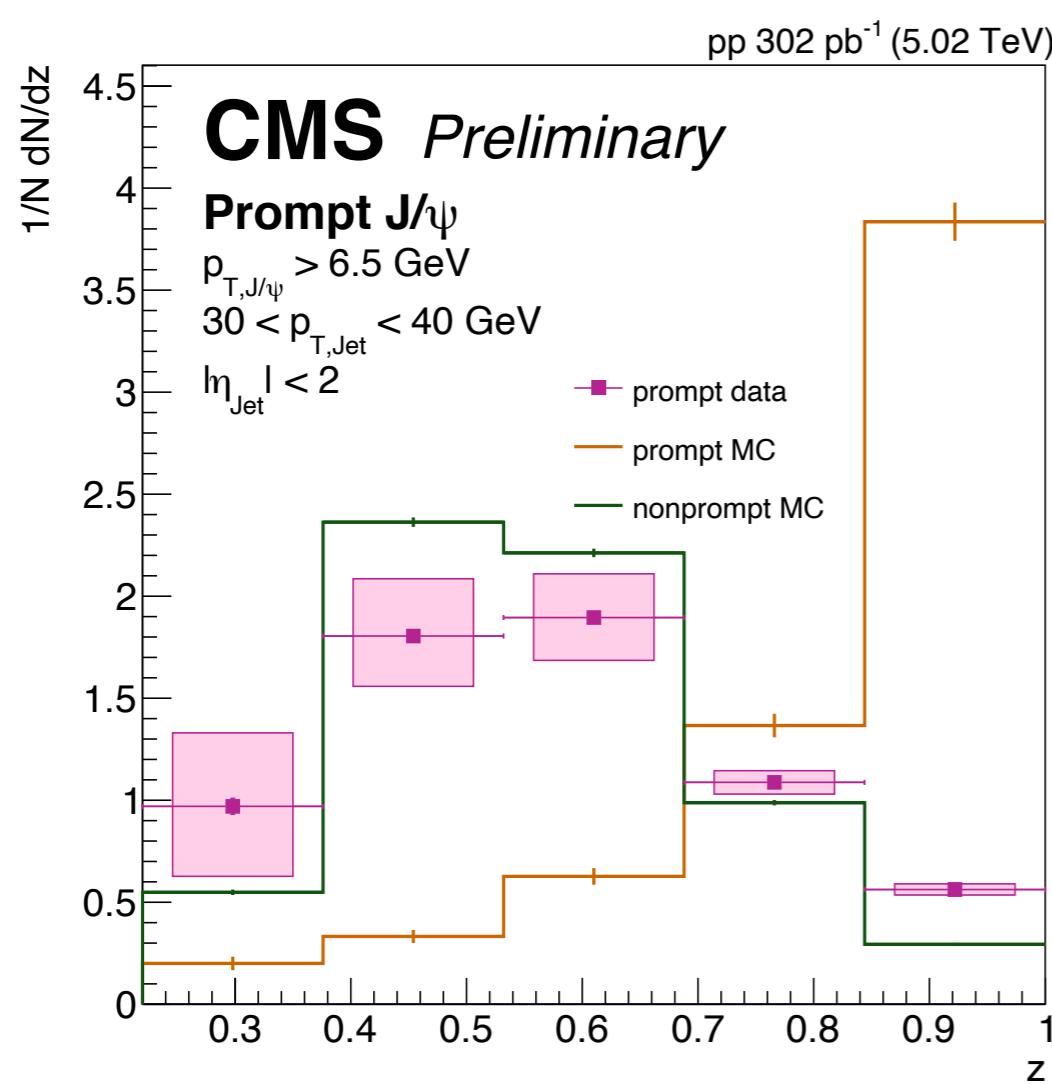
Absolute uncertainties





Results

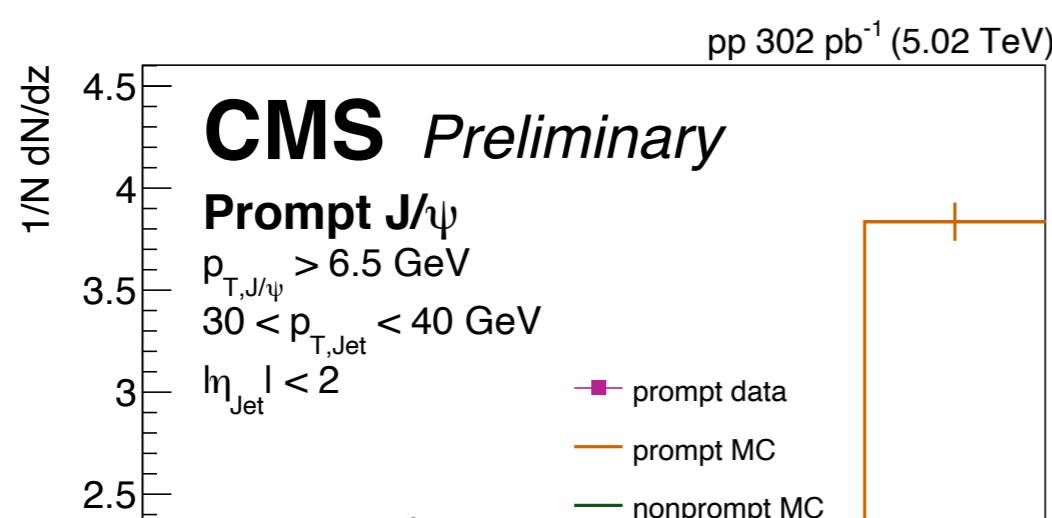
Self-normalised z distributions in pp data and simulation
Sizable jet component, as opposed to isolated J/ ψ



Prompt data more similar to
nonprompt PYTHIA8 than
prompt PYTHIA8

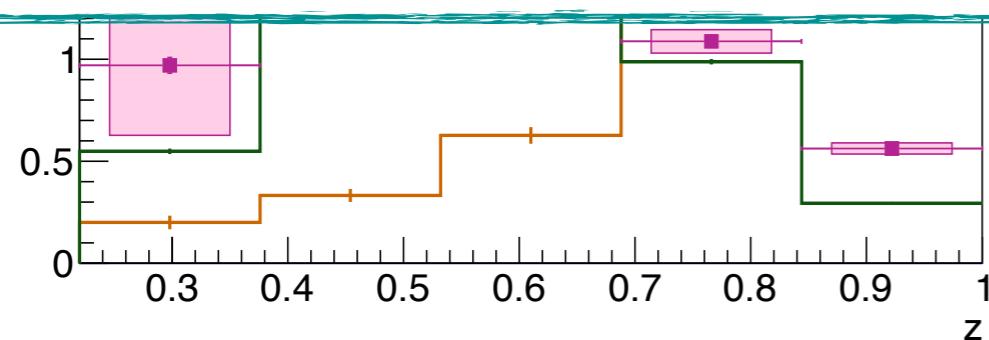


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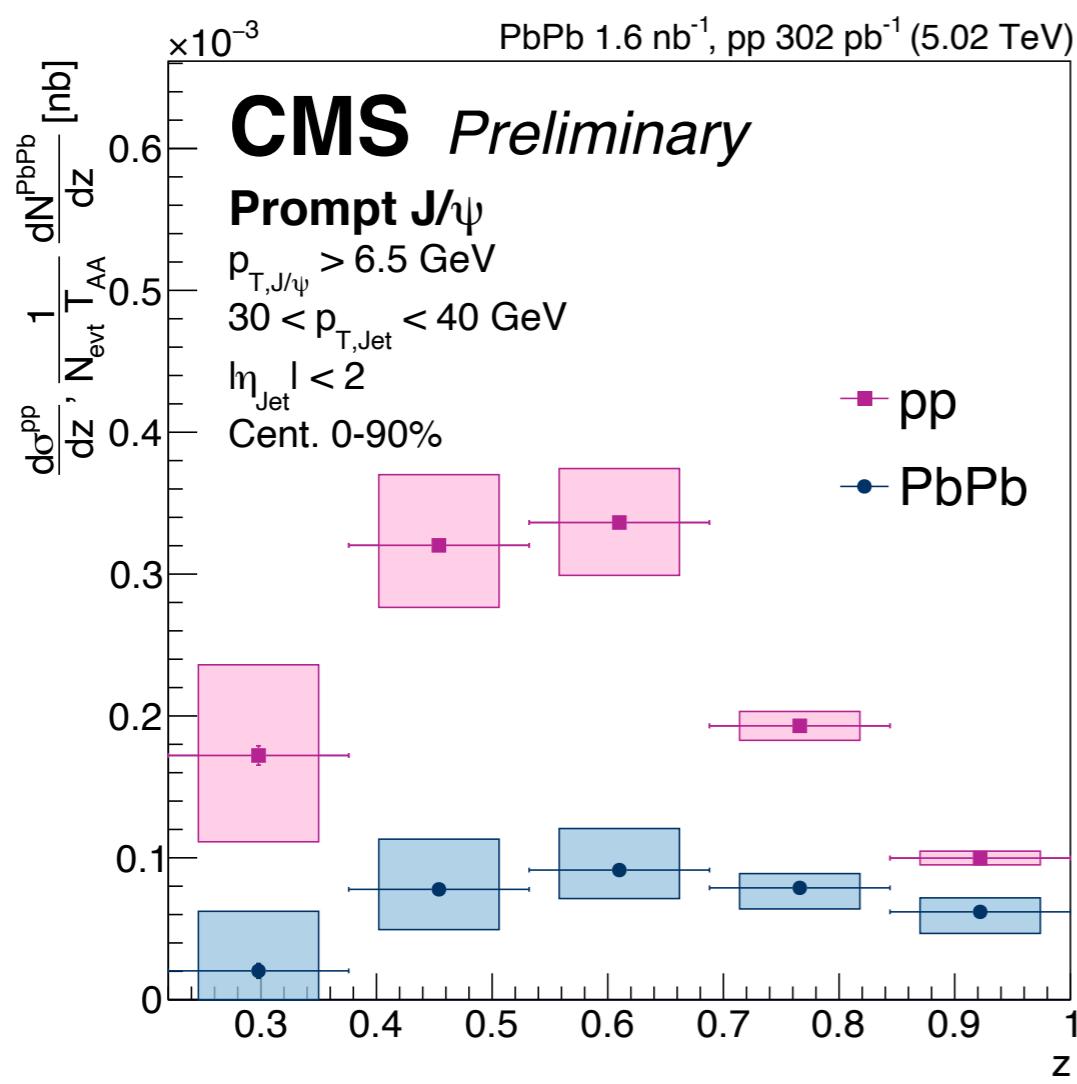


Prompt data more similar to
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prompt PYTHIA8

CMS measurement at 8 TeV:
PLB 804 (2020) 135409
 $(85 \pm 3(\text{stat}) \pm 7(\text{syst}))\%$ of J/ ψ ($E_{J/\psi} > 15 \text{ GeV}$) are produced with a jet ($E_{\text{jet}} > 19 \text{ GeV}$)



Per-event yield of prompt J/ ψ mesons in PbPb collisions and the cross section in pp collisions, as a function of the fragmentation variable z



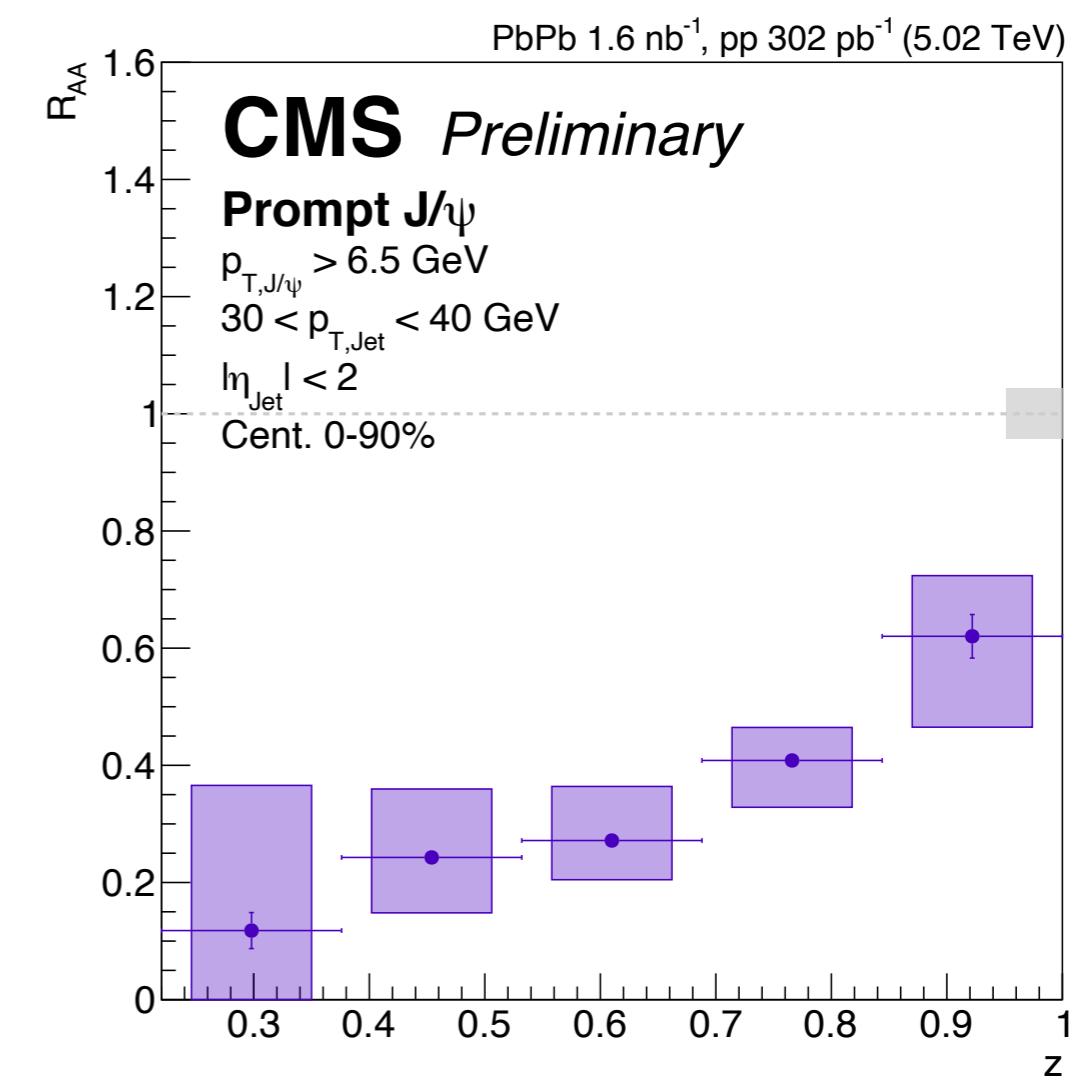
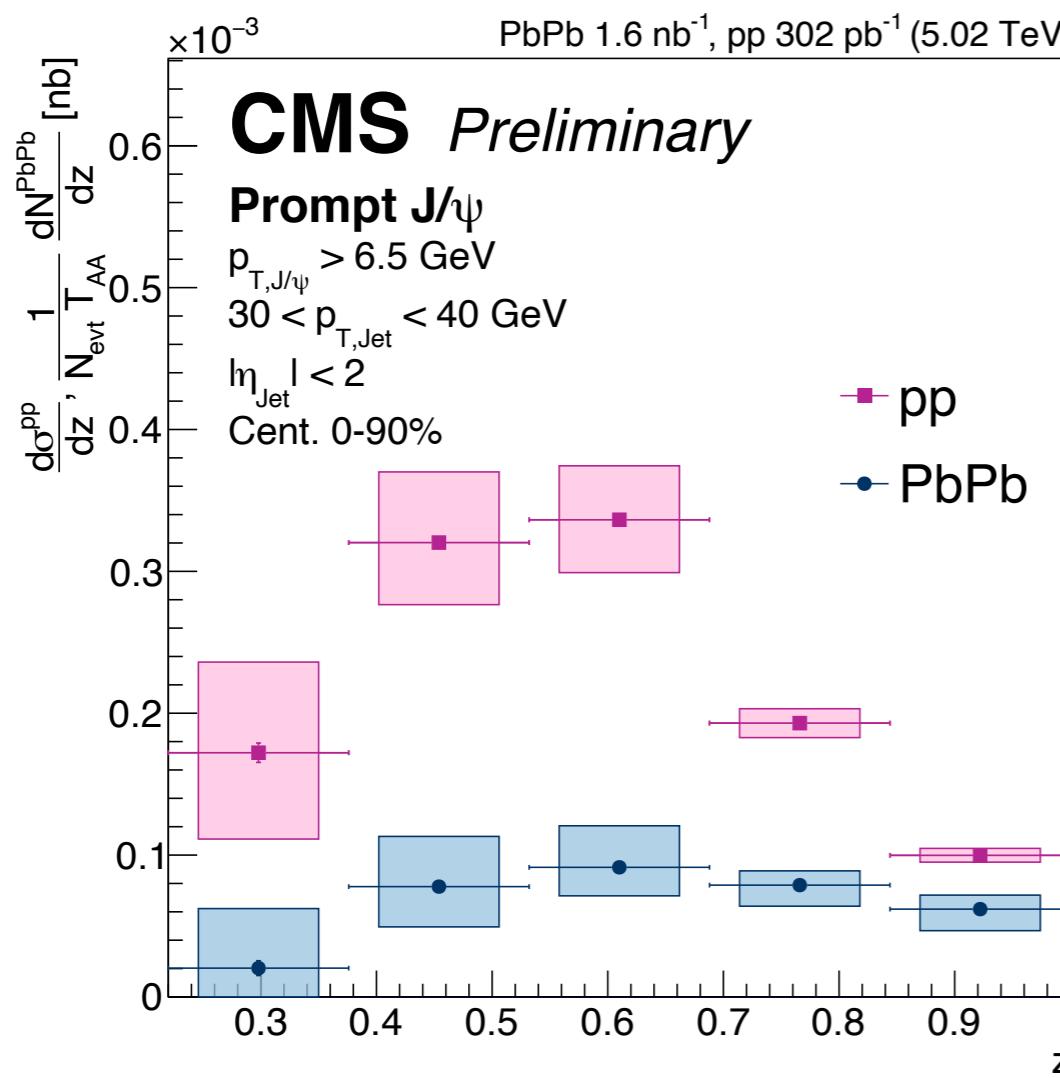
pp and PbPb have similar trends
Suppression in PbPb in all z bins



Rising trend as a function of z



Less suppression for isolated J/ ψ compared to J/ ψ with larger jet activity



Rising trend as a function of z



Less suppression for isolated J/ ψ compared to J/ ψ with larger jet activity

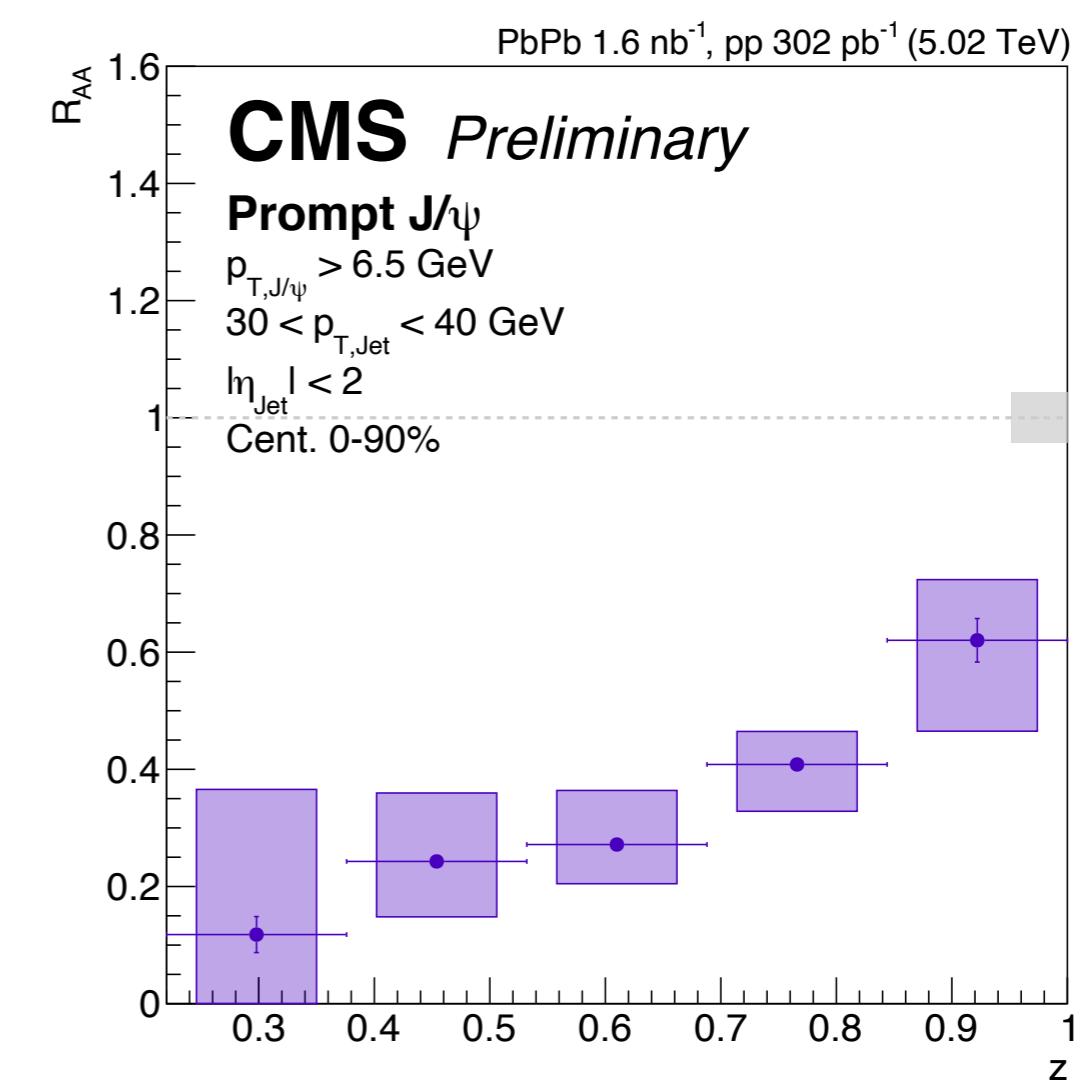
Lower z



J/ ψ produced later in parton shower



Larger degree of interaction with the QGP

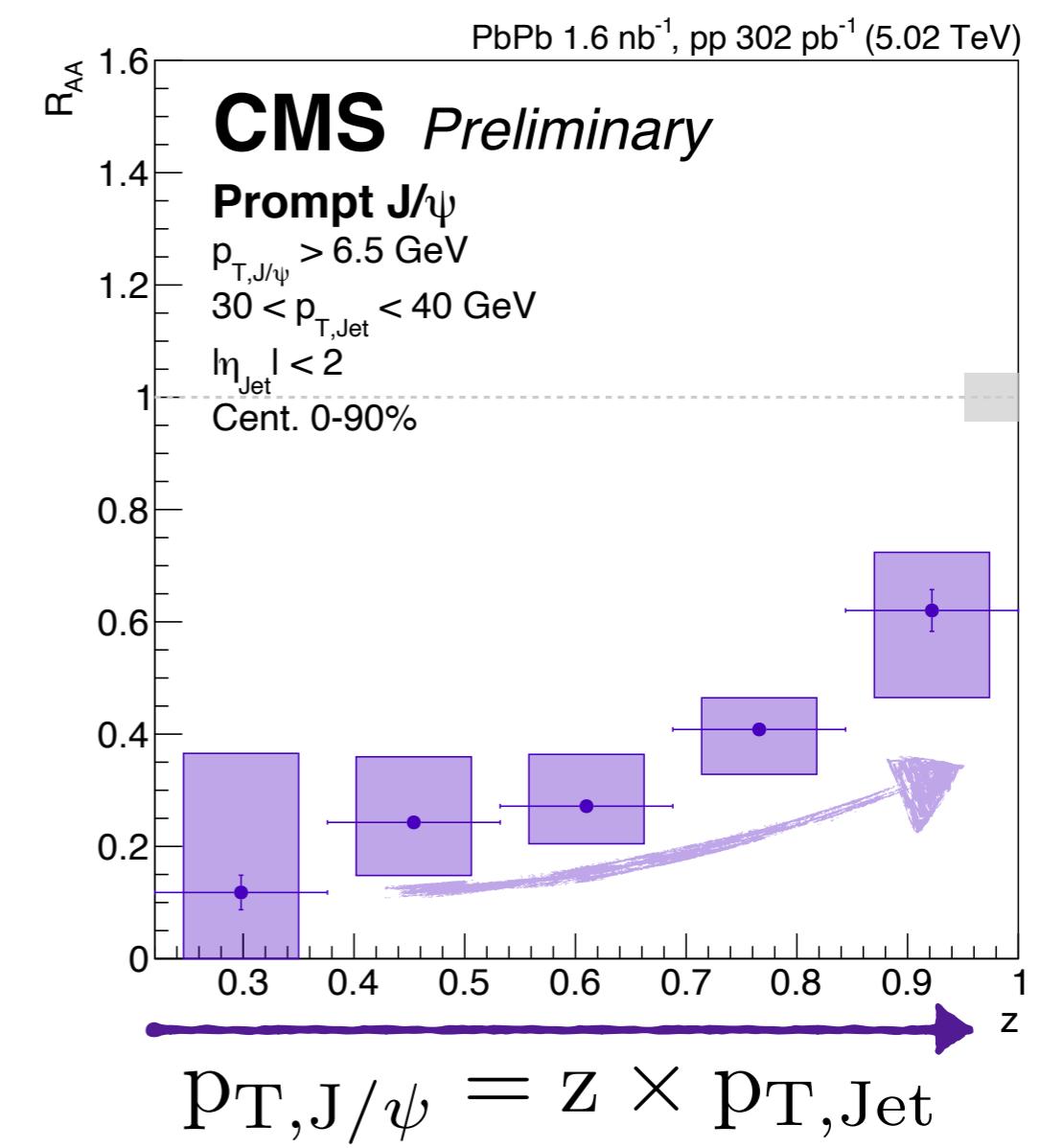
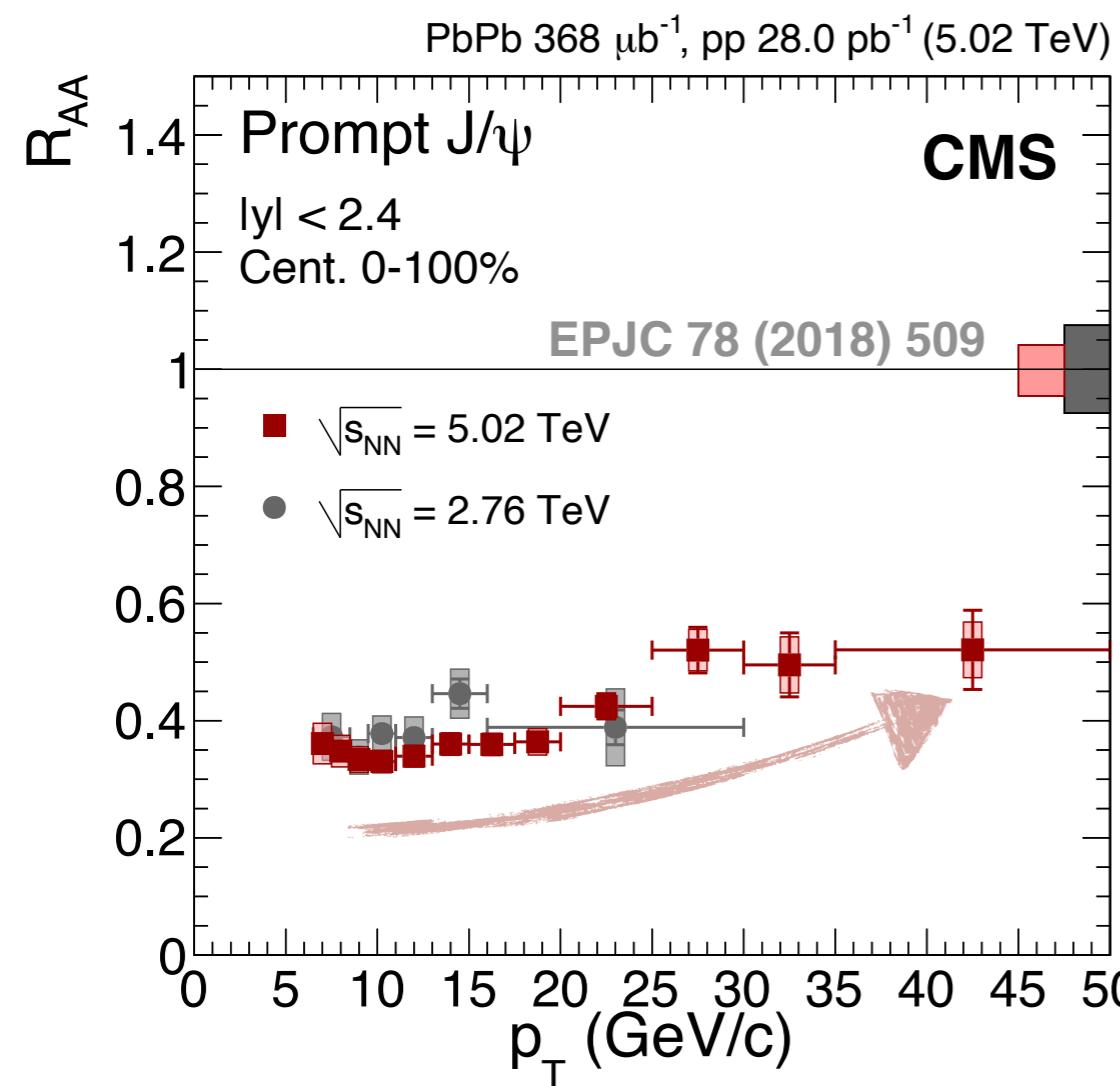


RAA of J/ ψ in jets vs RAA

z increases with increasing p_T



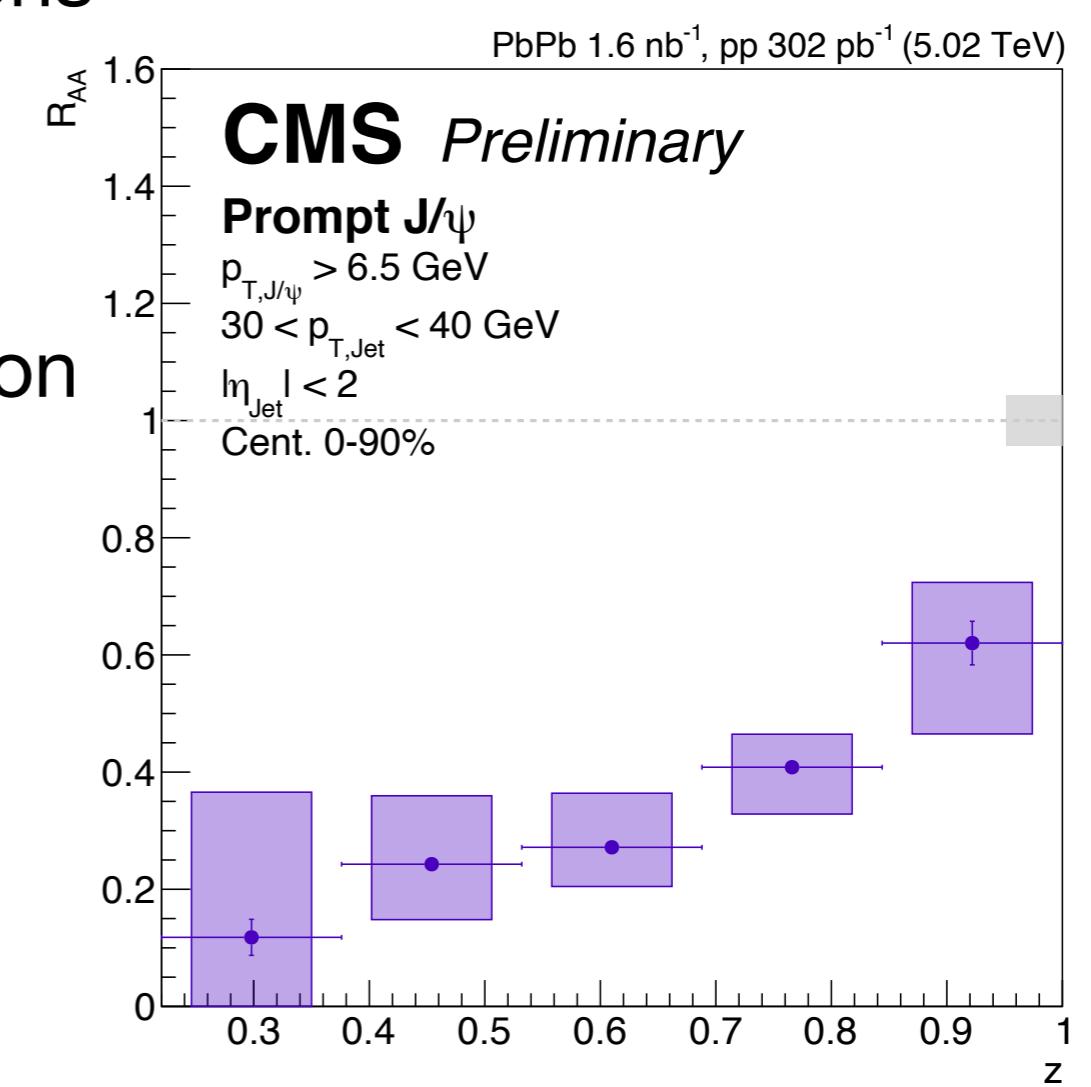
Rising trend in inclusive prompt RAA might be explained by jet quenching



We measured the jet fragmentation function of prompt J/ ψ in pp and PbPb collisions

RAA showed a rising trend with z

These results support an interpretation of jet quenching as a relevant mechanism for J/ ψ suppression

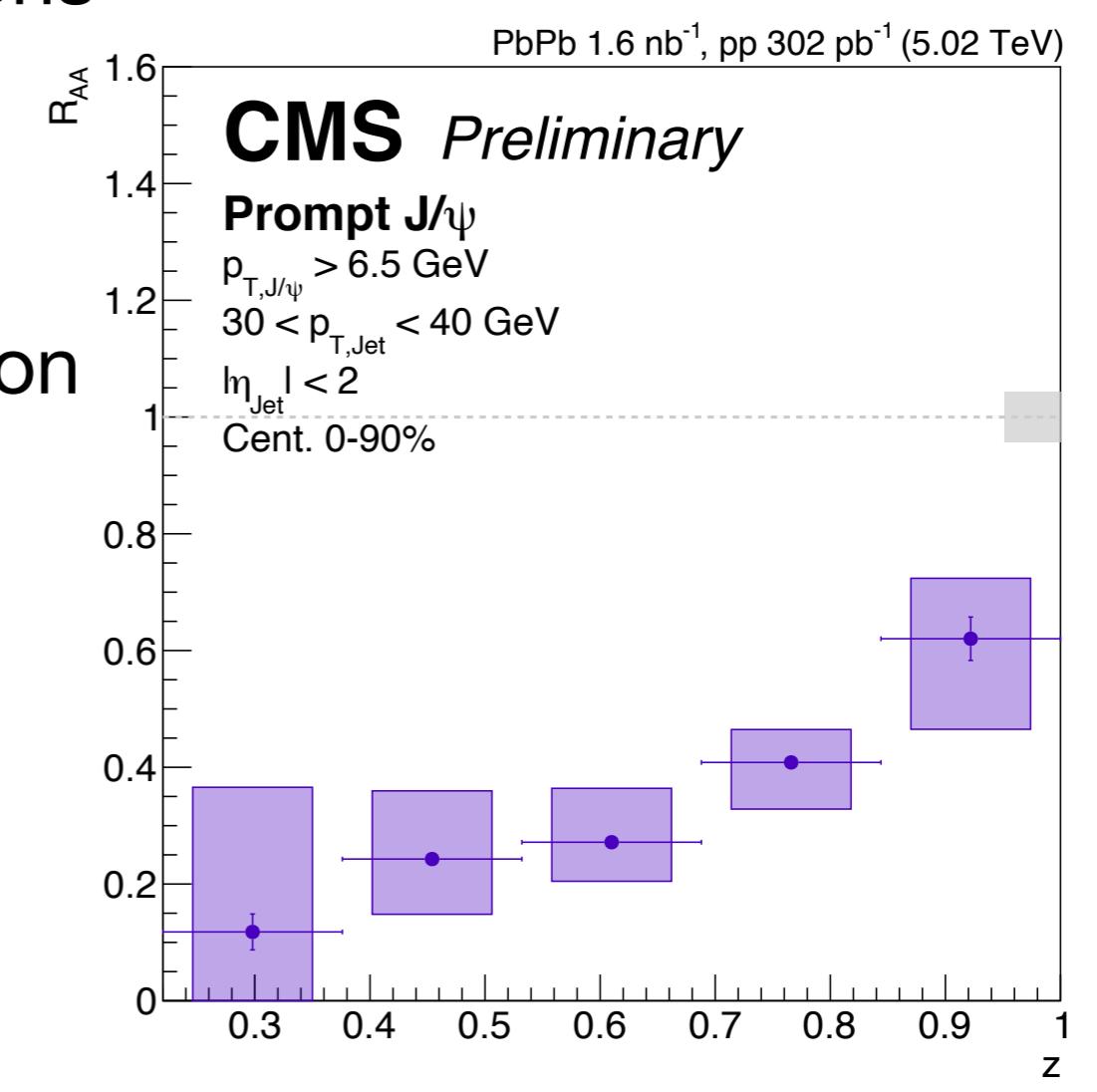


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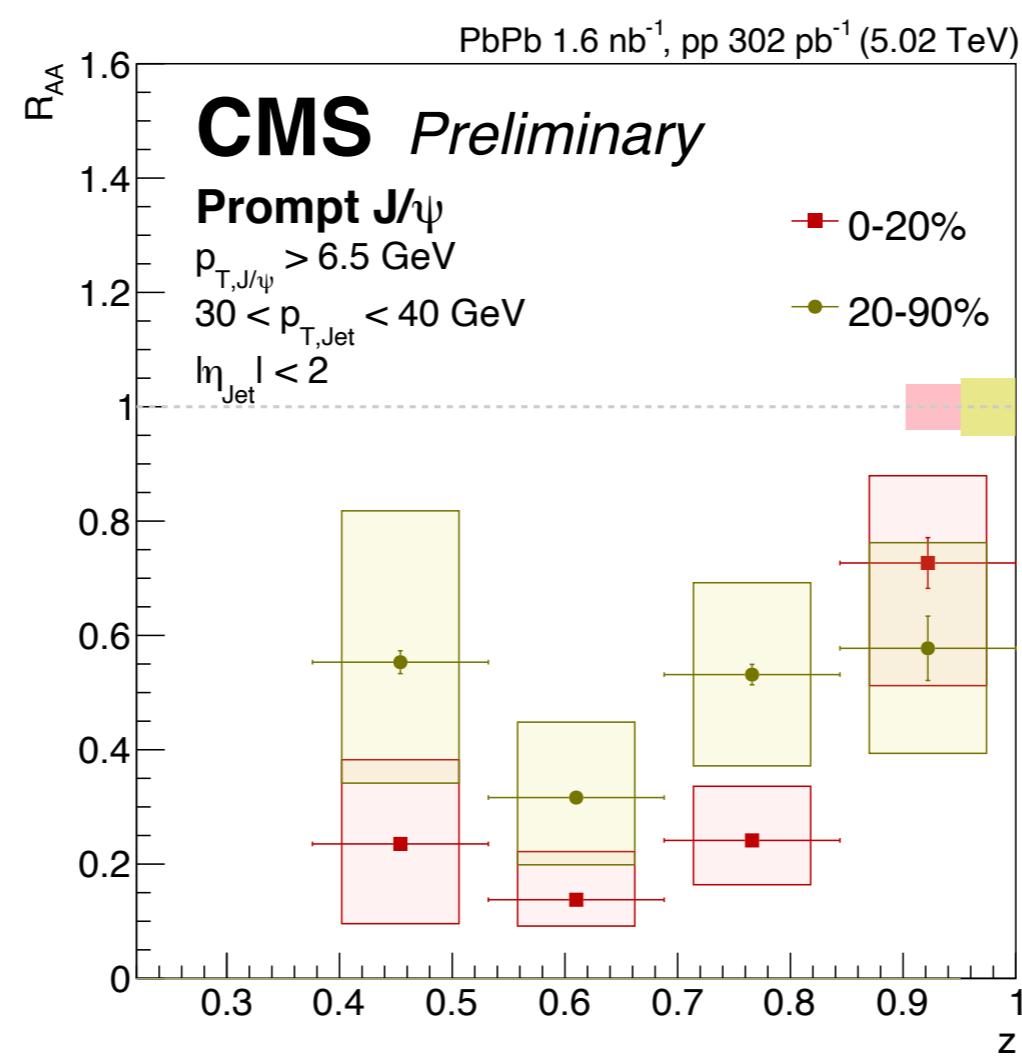
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Thank you



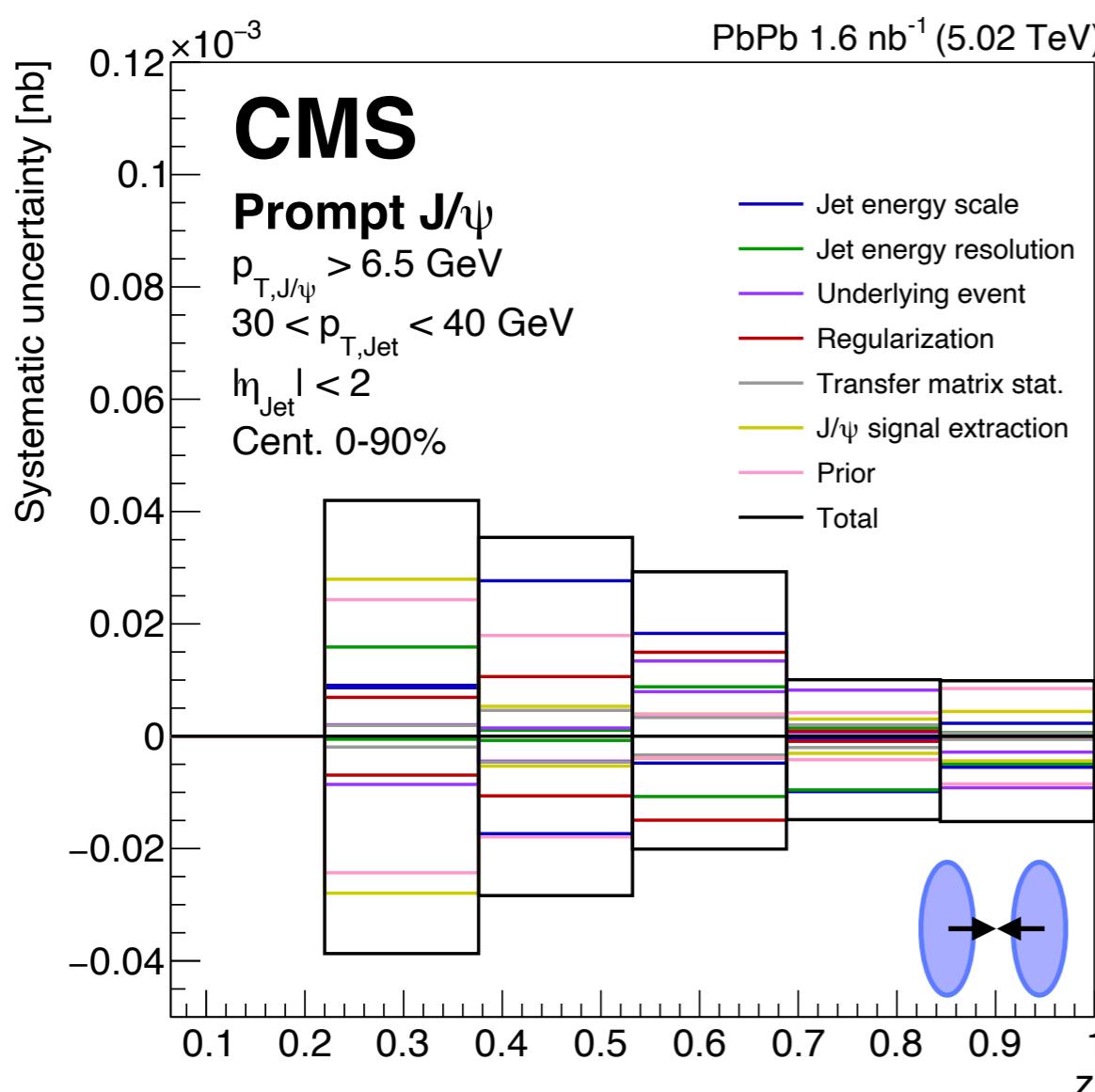
Backup

- Larger suppression for central events

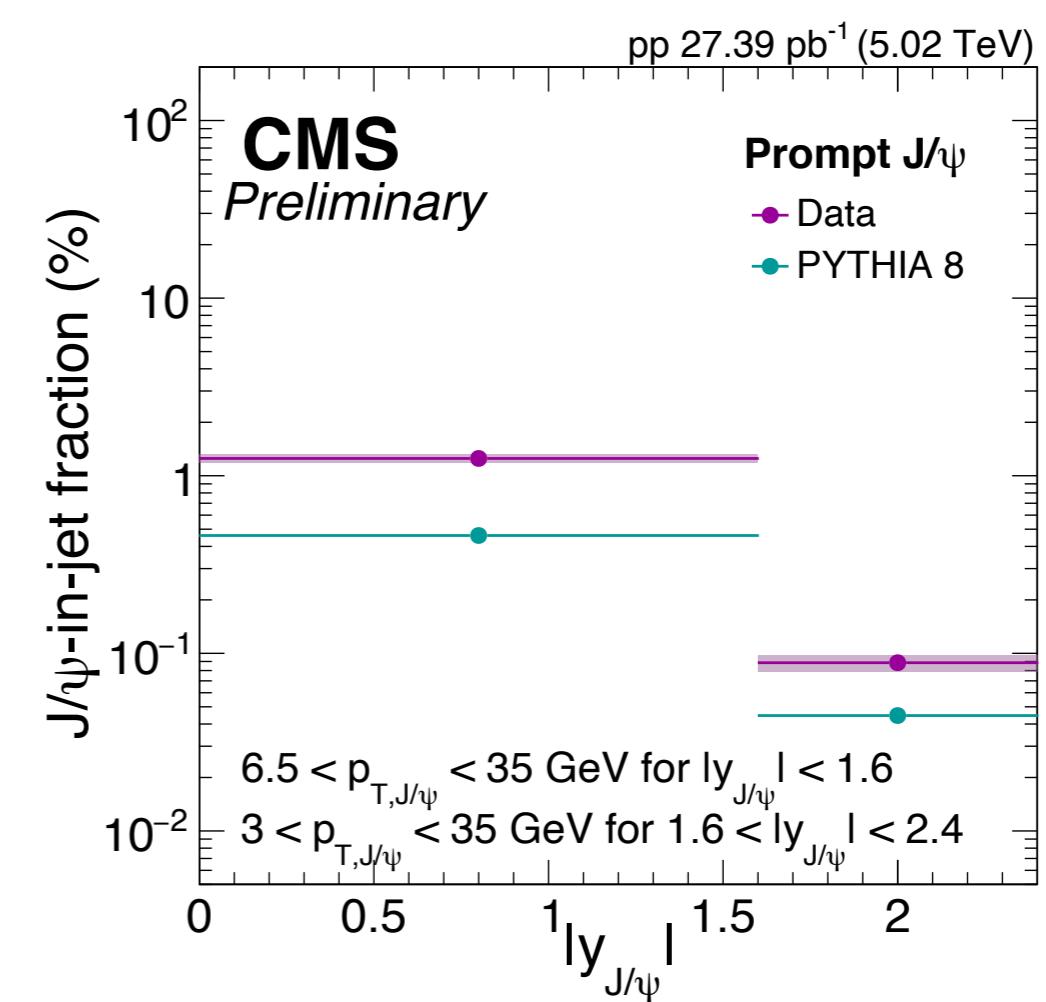
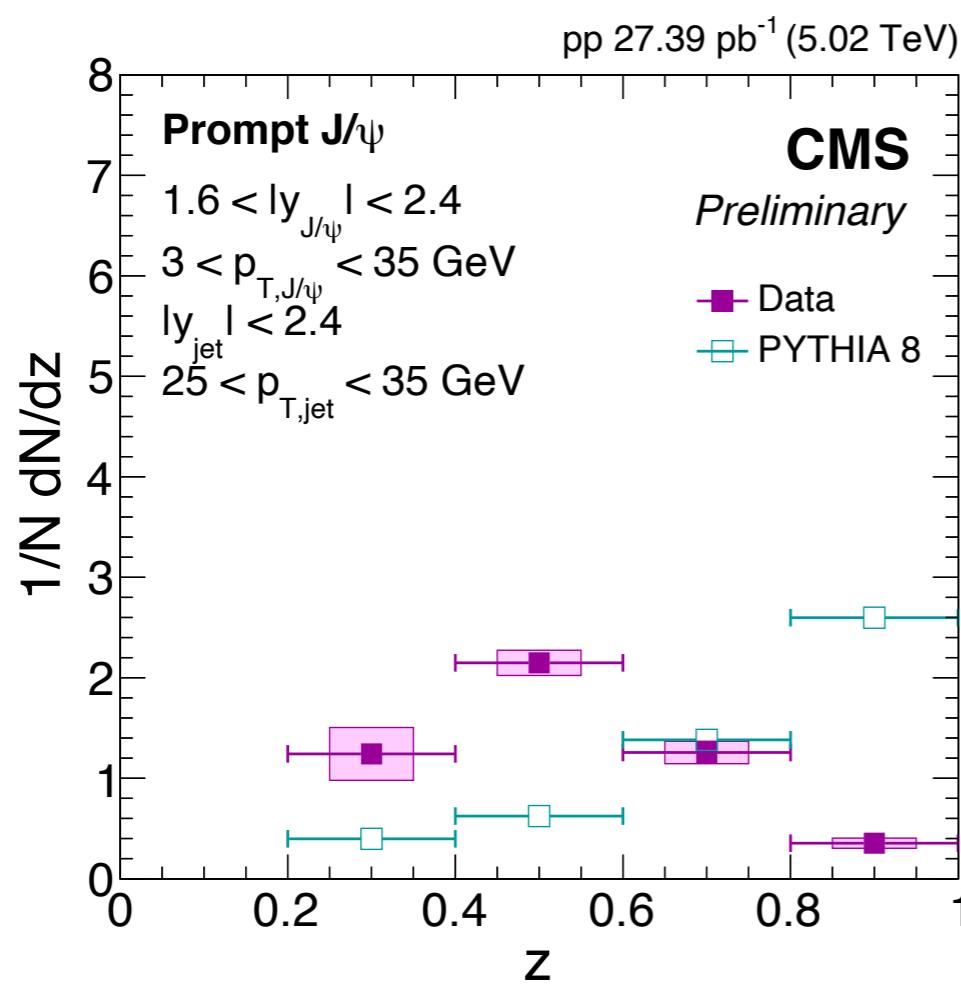


Systematic uncertainties

jet energy scale and resolution is evaluated from dijet and γ +jet balancing methods

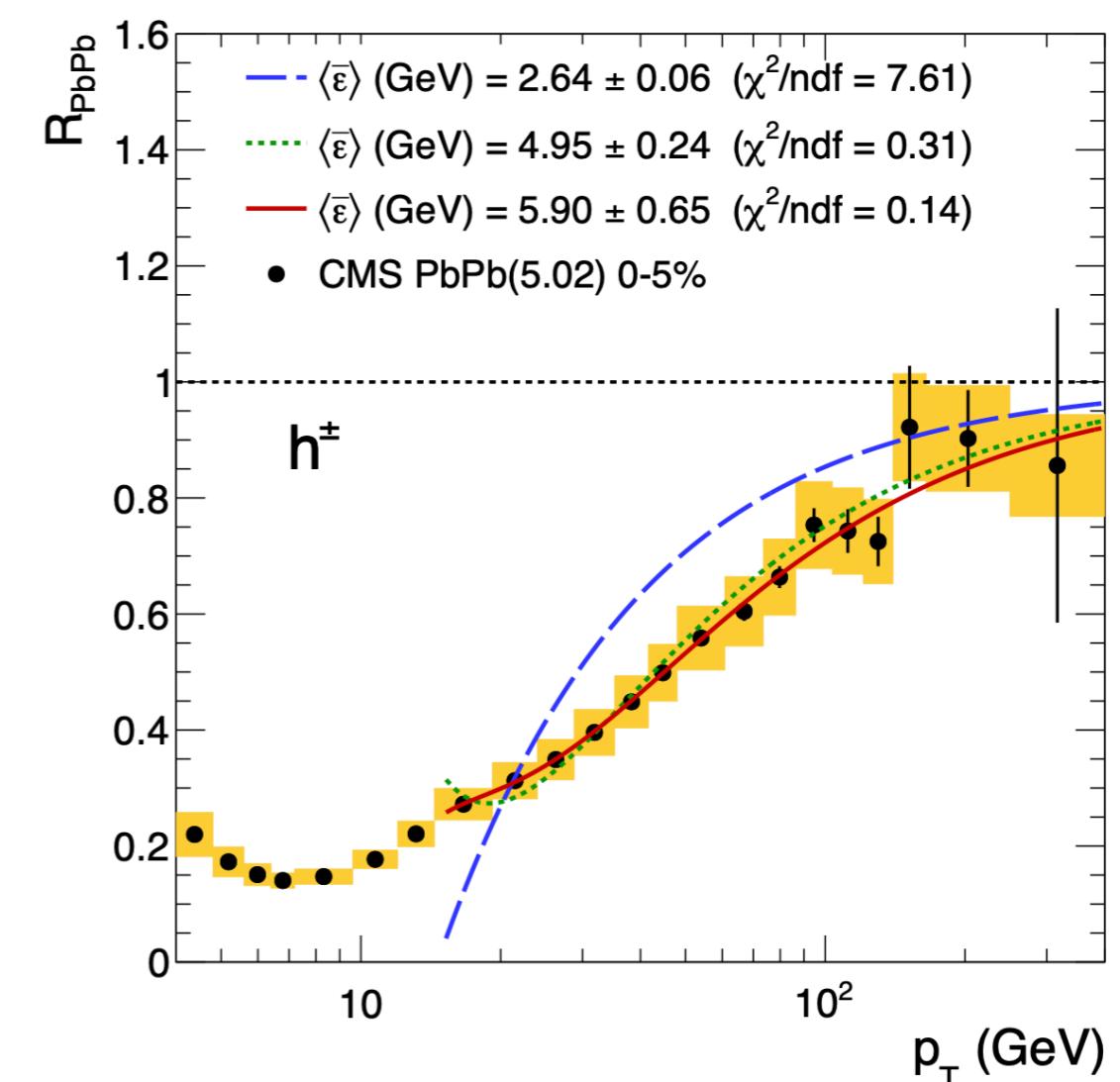
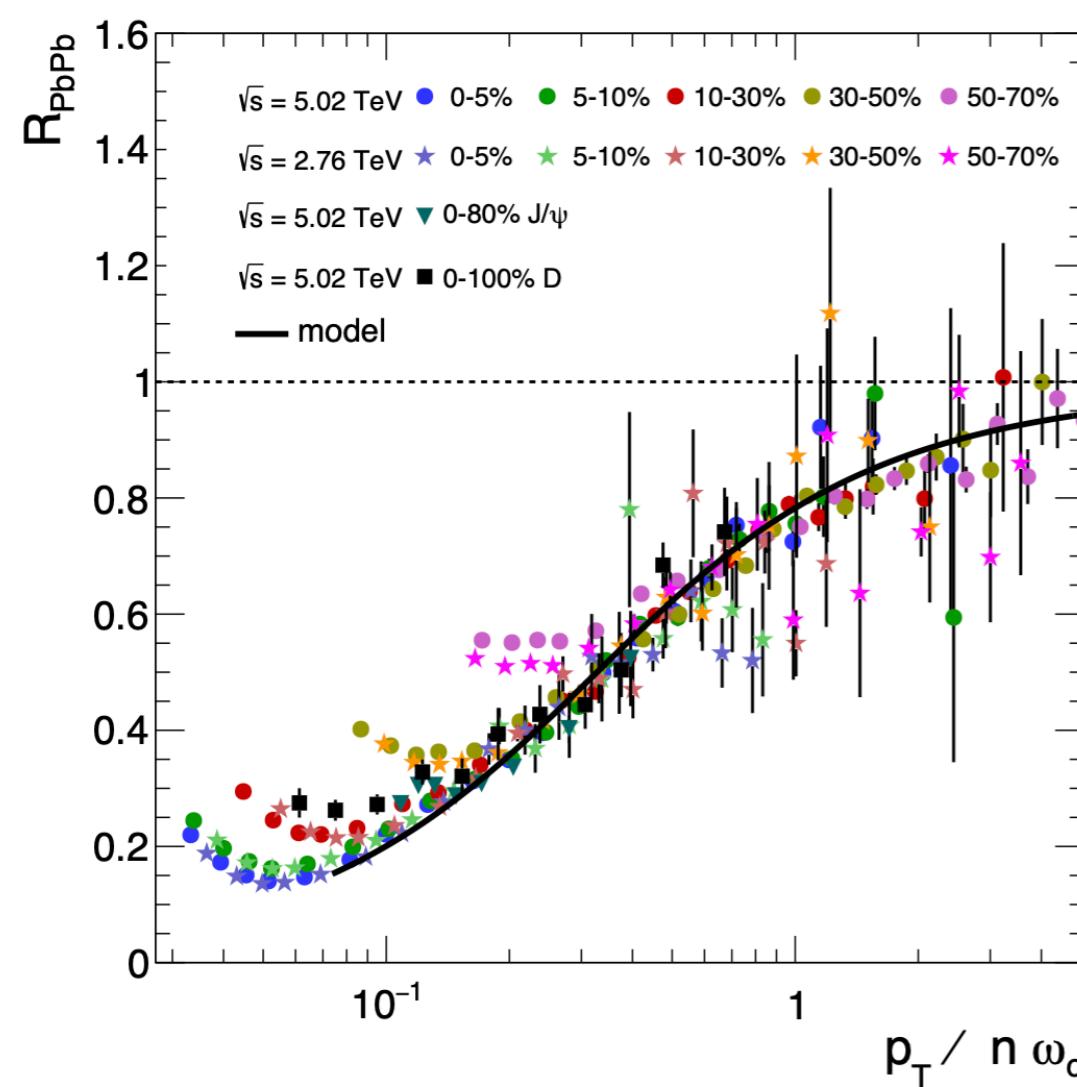


- Similar trend to at forward rapidity with jet p_T range
- Less than 2% of prompt J/ ψ are produced with jets of 25-35 GeV
- CMS measurement at 8 TeV: $84.0 \pm 0.1\%$ of J/ ψ are produced with a jet PLB 804 (2020) 135409



CMS-PAS-HIN-18-012

Universal behavior



F. Arleo PRL 119 (2017) 062302