# Charmonium production measured in PbPb and pp collisions by CMS

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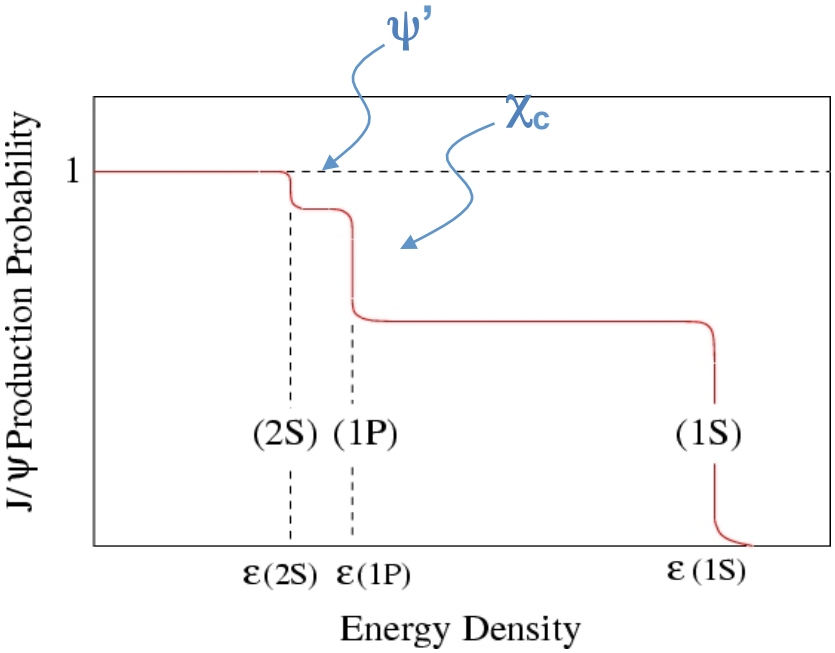
(for the CMS collaboration)

# Why to study charmonia?

In PbPb collisions:

- Debye screening in deconfined phase leads to melting of charmonia
- Different binding energy of bound states and feed down from higher states lead to sequential suppression of J/ψ with increasing temperature
- Measure charmonium yields in PbPb collisions as function of $p_T$ and collision centrality

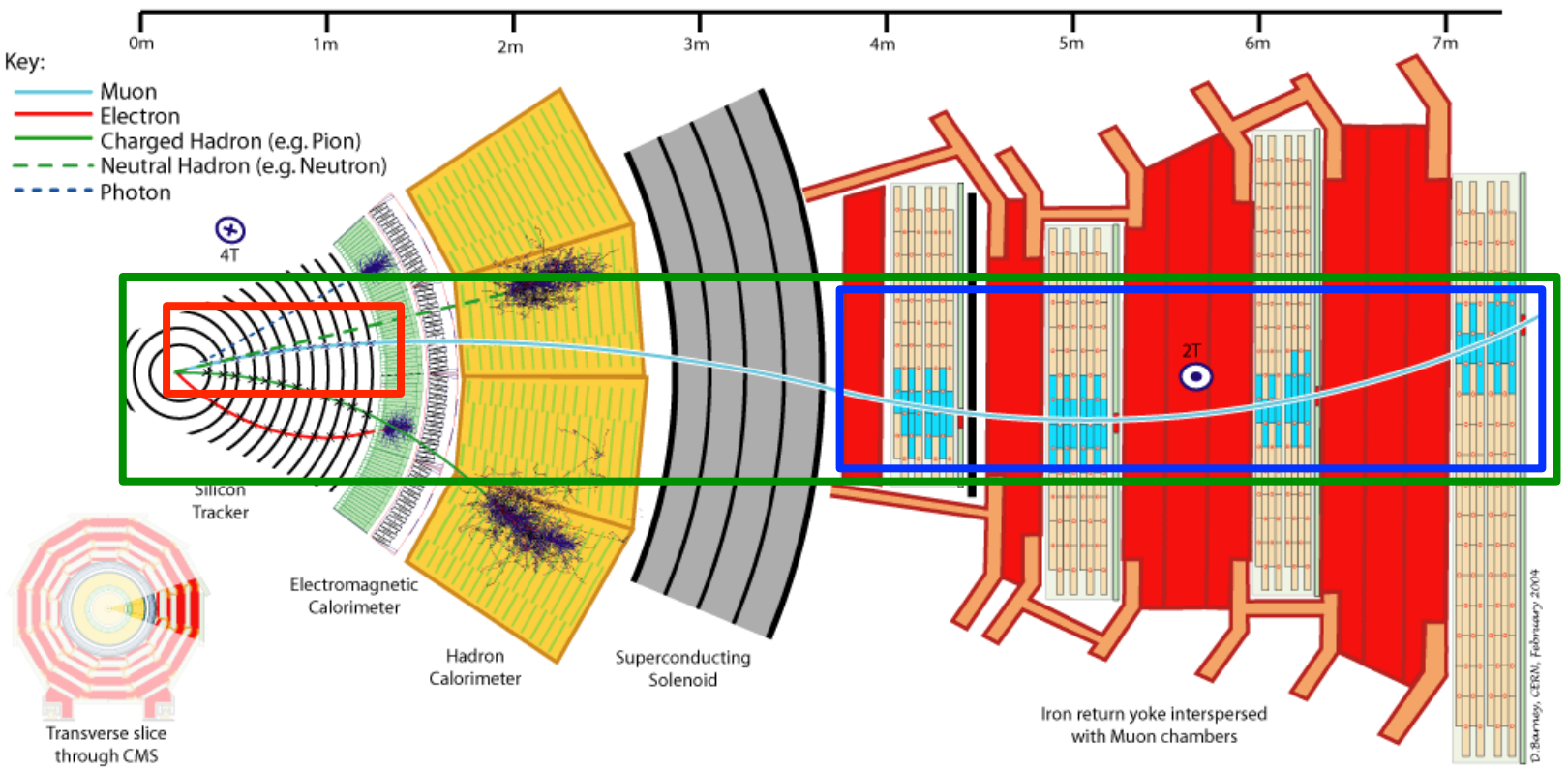
→ characterize QGP




In pp collisions:

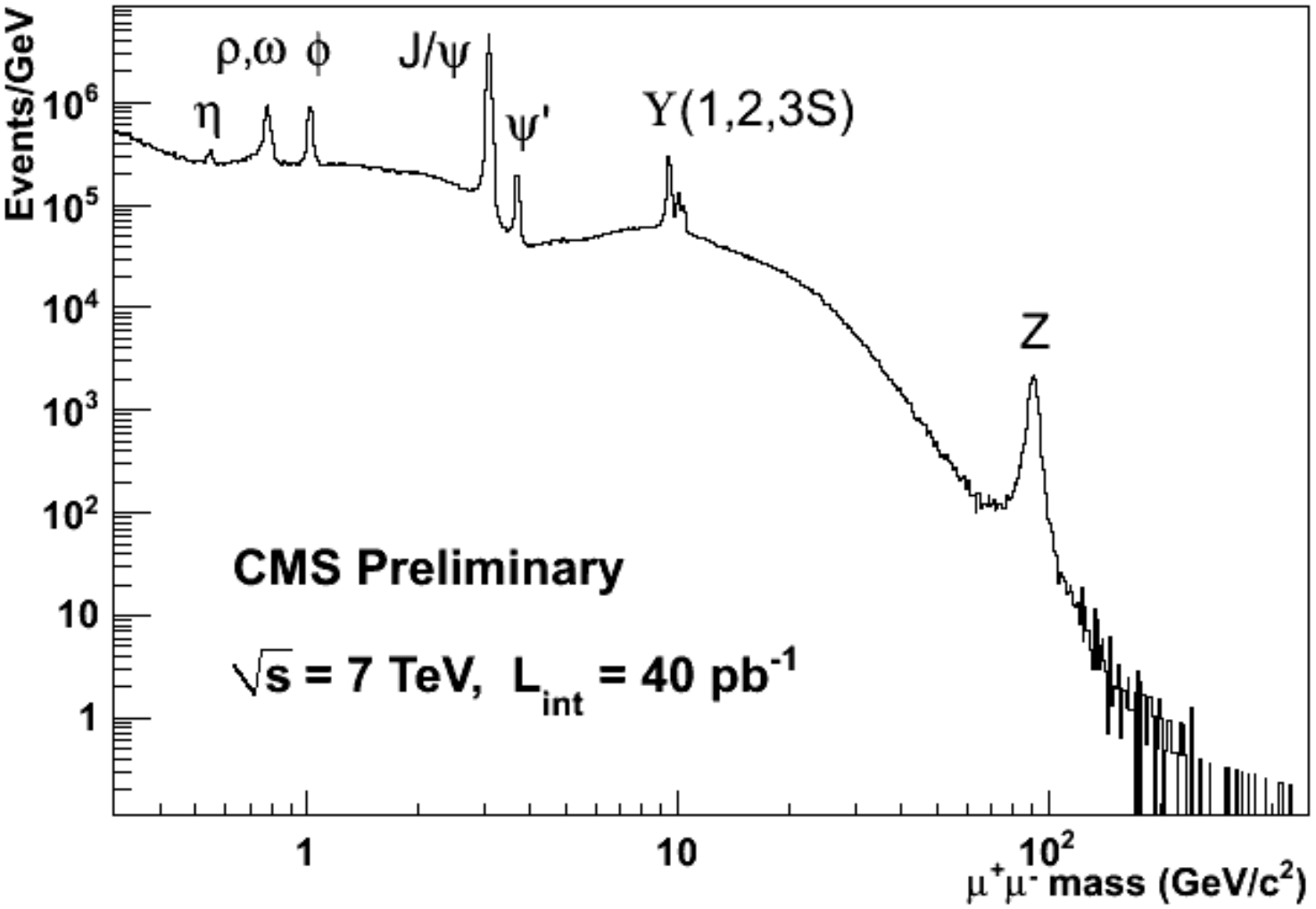
- Baseline for heavy ion collisions
- Cross section measurements
- Polarization

# Muon reconstruction in CMS




- Global muons reconstructed with information from inner tracker and muon stations
- Further muon ID based on track quality ($\chi^2$, # hits,…)

# Muon pairs in pp at √s = 7 TeV



# J/ψ in pp at √s = 7 TeV

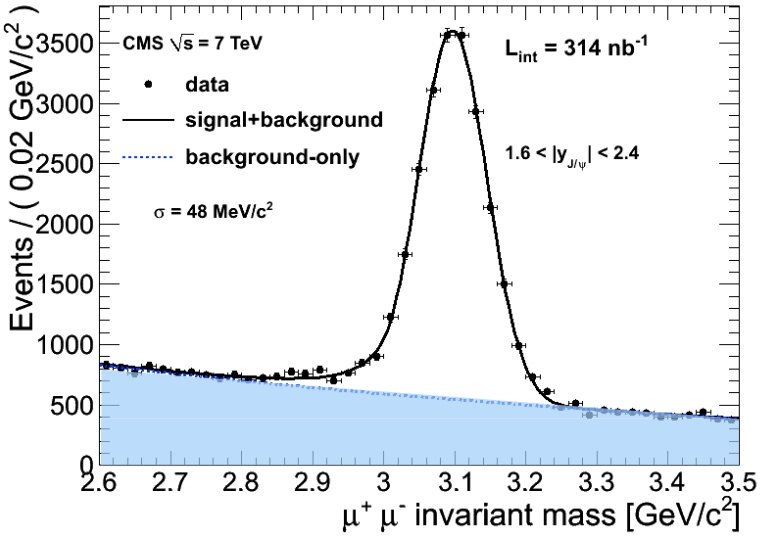
Inclusive J/ψ

Prompt J/ψ

Non-Prompt J/ψ from B decays

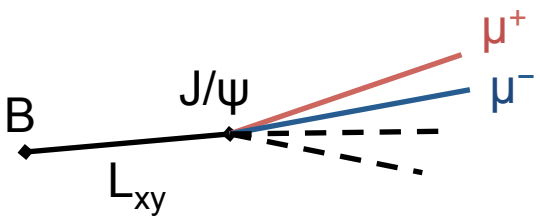
Direct J/ψ

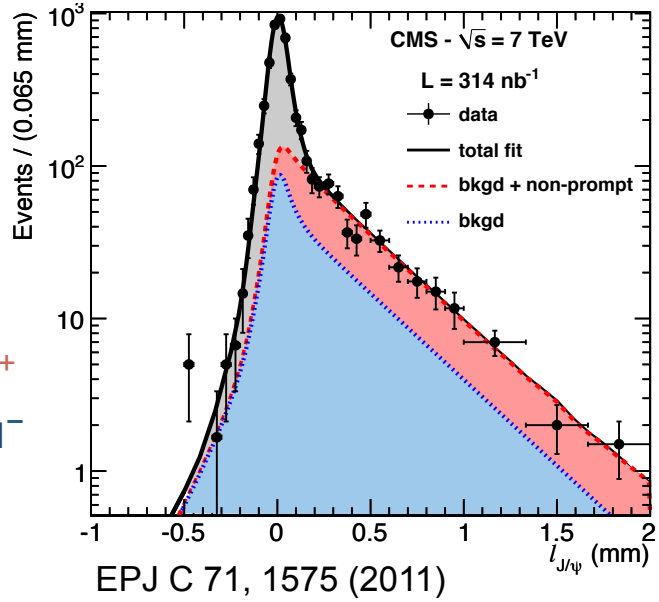
Feed-down from ψ' and $\chi_c$




- Reconstruct $\mu^+\mu^-$ vertex
- Simultaneous fit of $\mu^+\mu^-$ mass and pseudo-proper decay length

$$\ell_{J/\psi} = L_{xy}\frac{m_{J/\psi}}{p_T}$$

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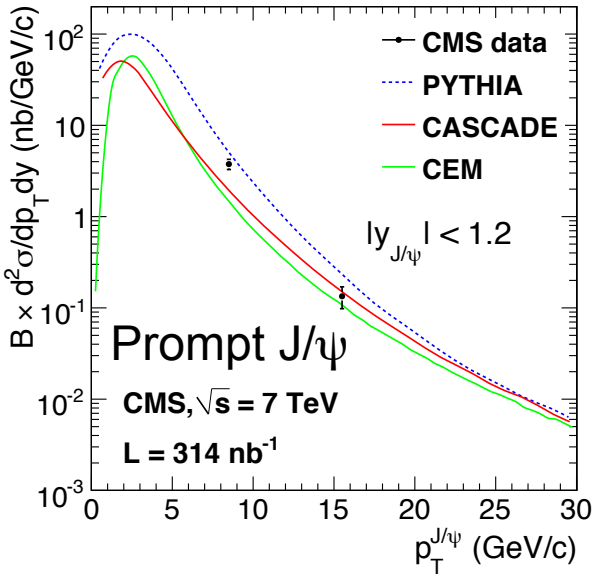
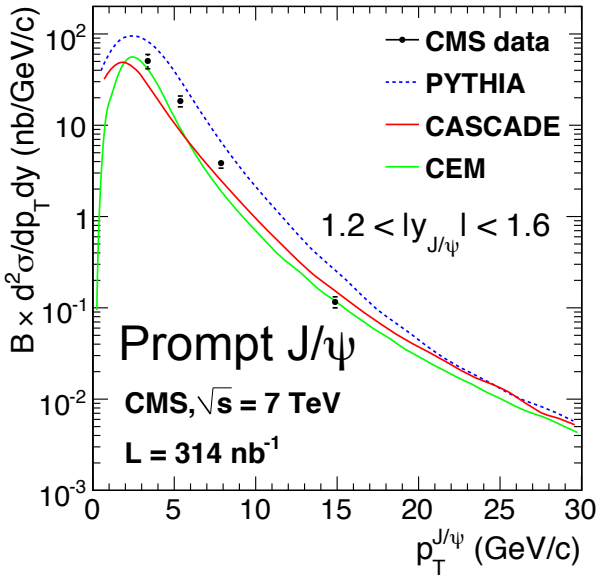
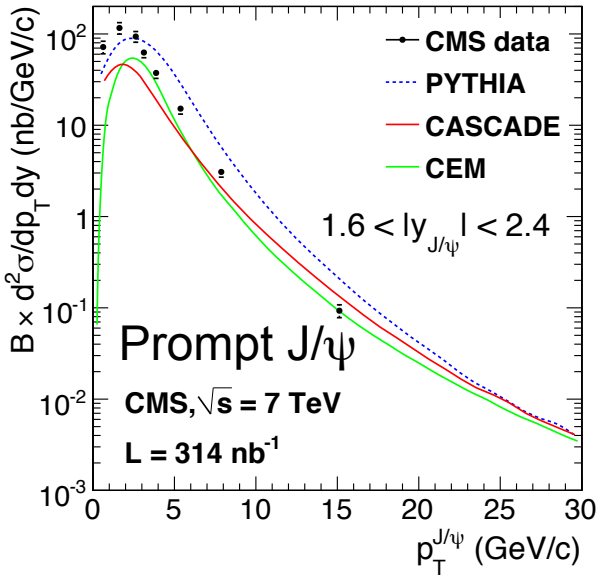
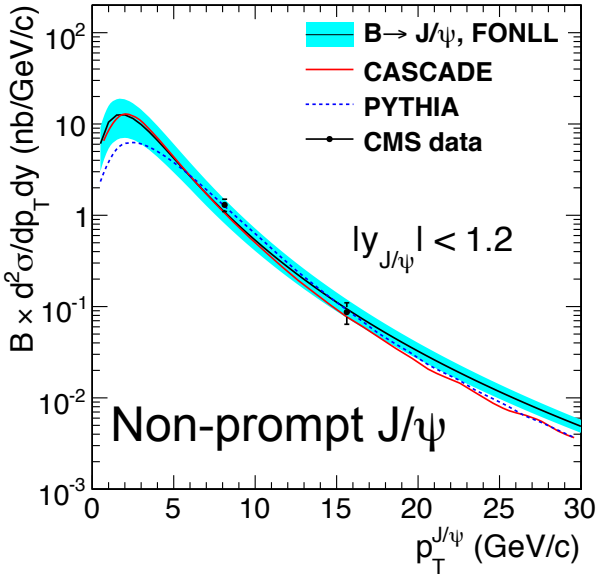
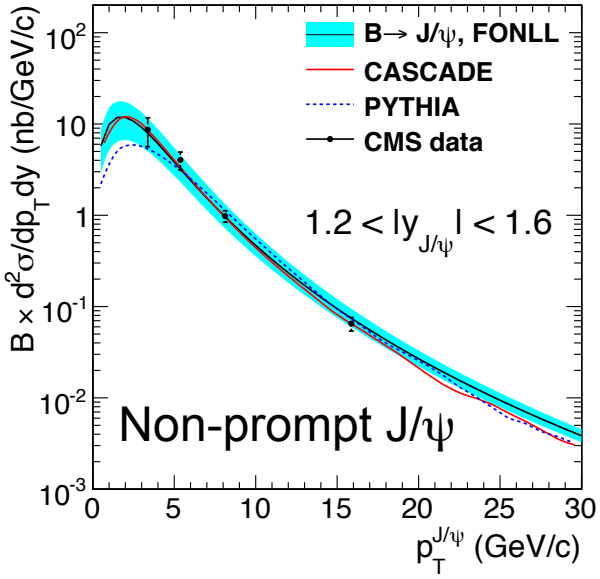
# J/ψ in pp at √s = 7 TeV

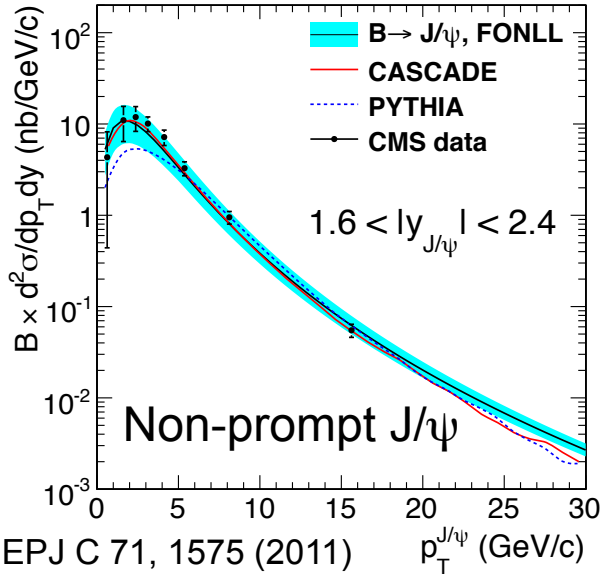


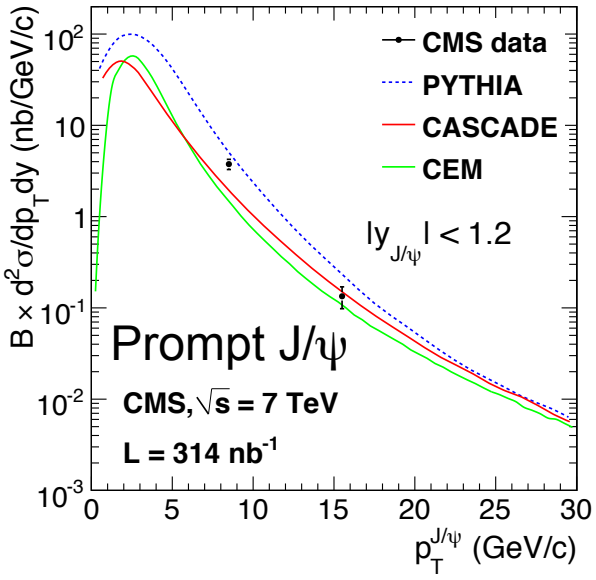



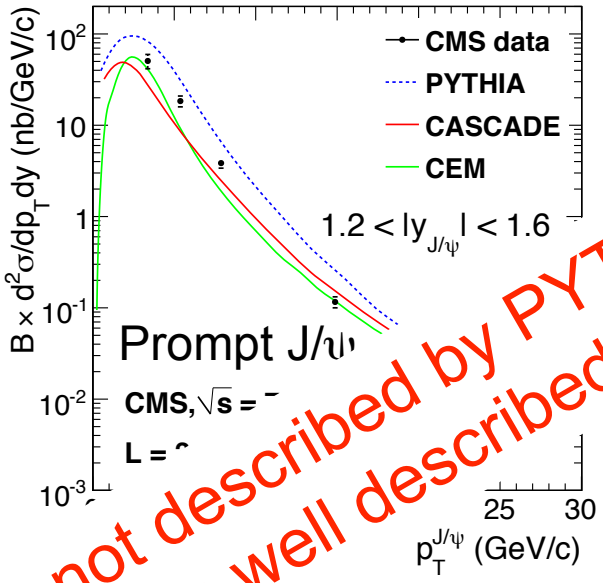



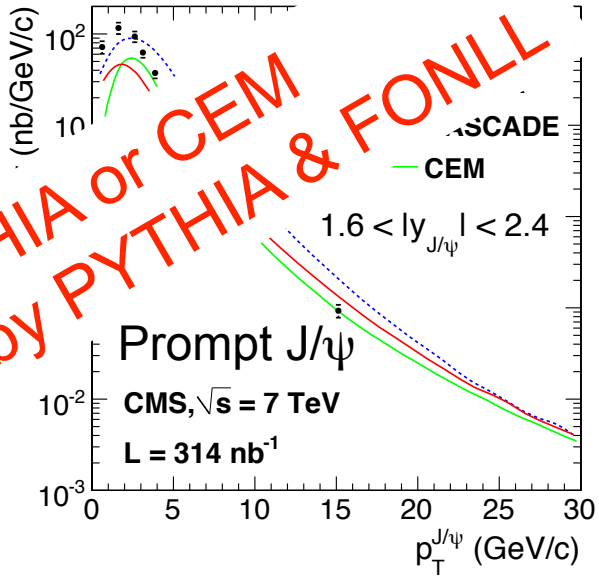



# J/ψ in pp at √s = 7 TeV

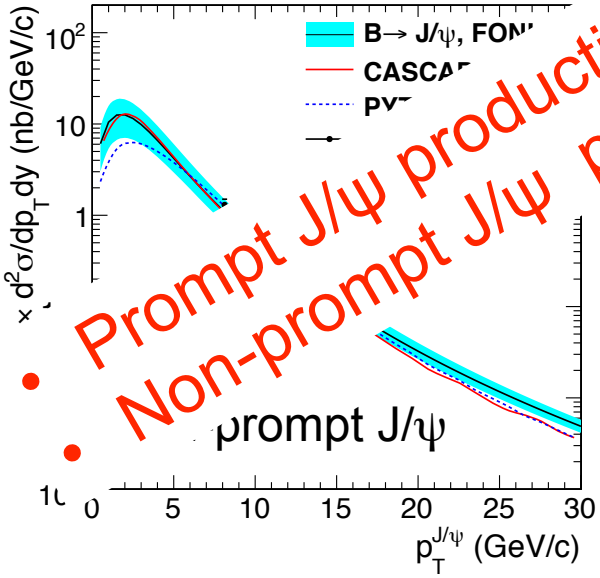


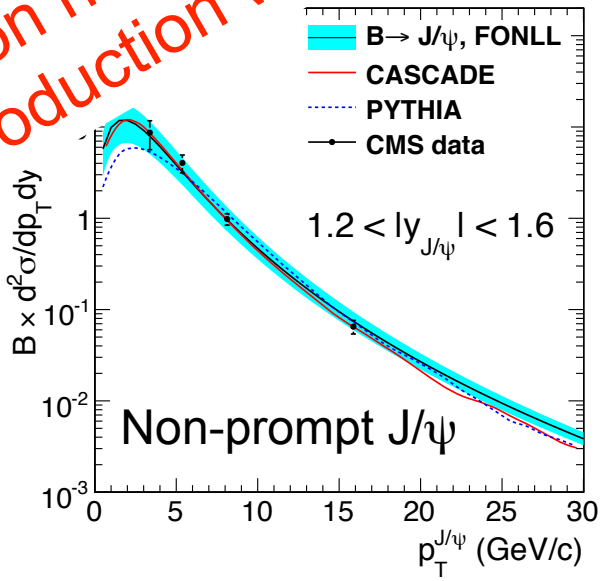



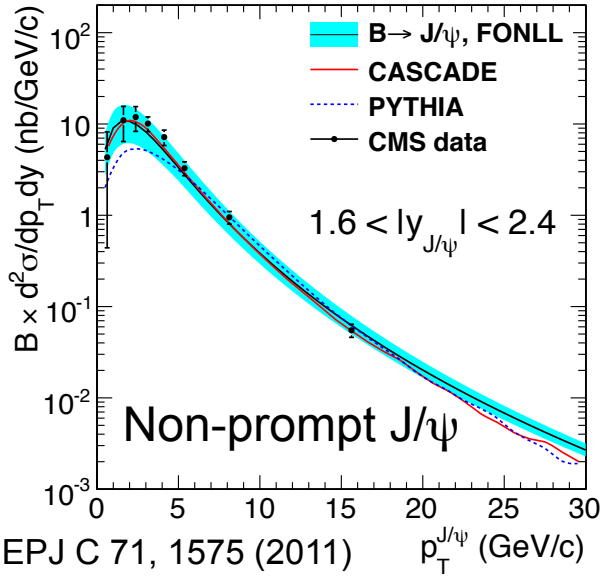




Prompt J/ψ production not described by PYTHIA or CEM

Non-prompt J/ψ production well described by PYTHIA & FONLL

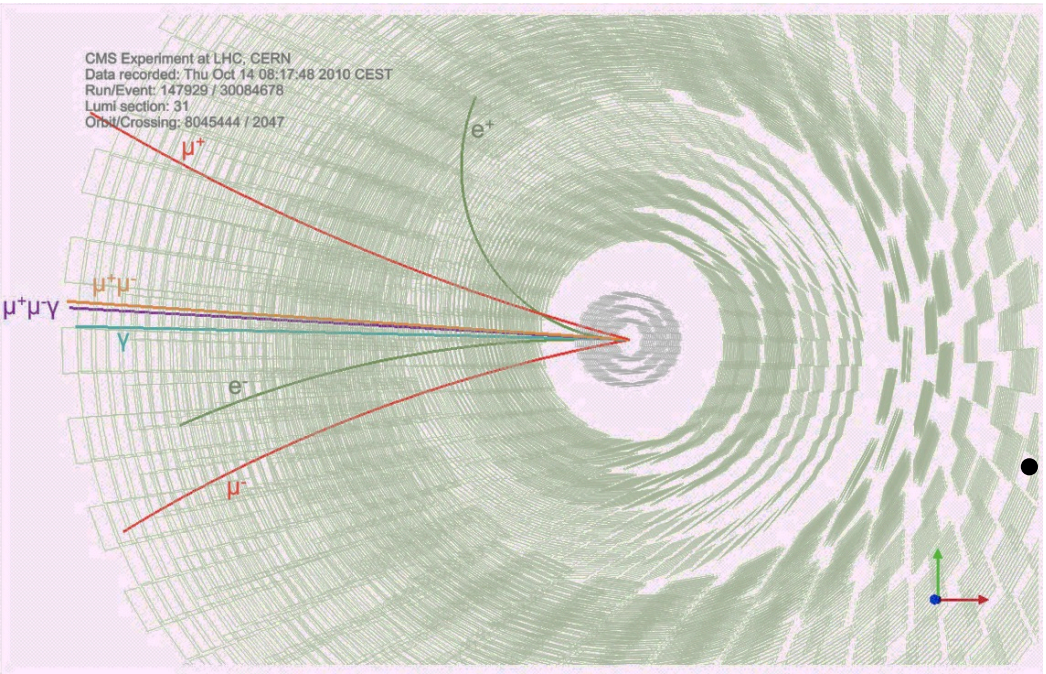


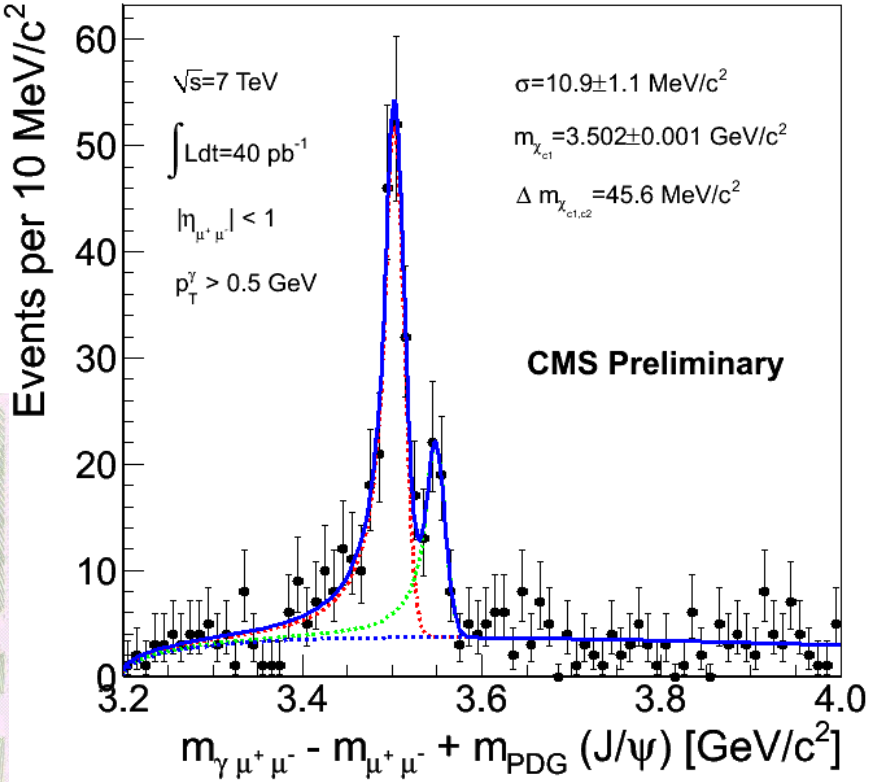



# Excited charmonium states in pp

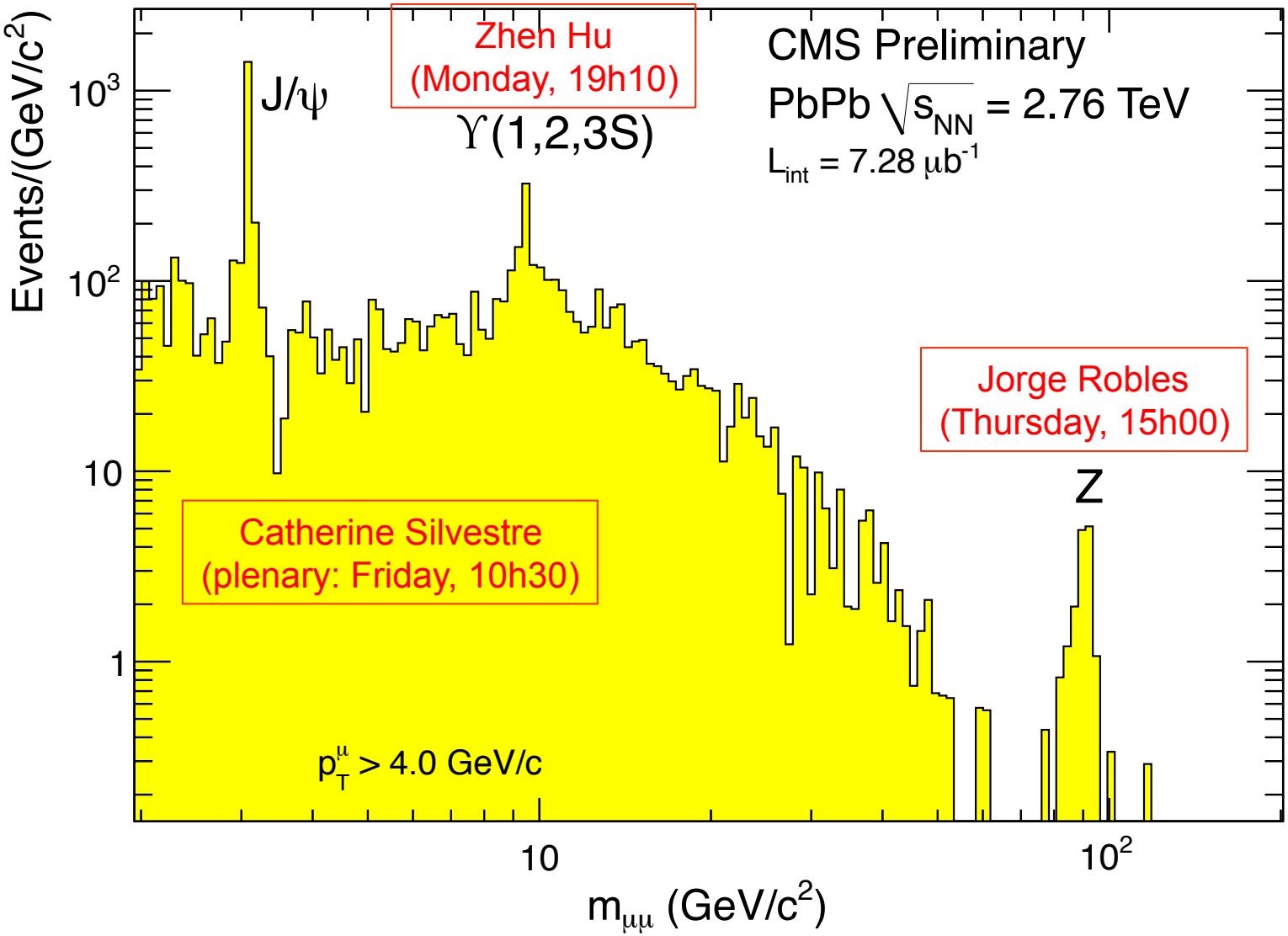
- Feed-down to prompt J/ψ from ψ' and $\chi_c$
- Measured radiative decay of: $\chi_c \rightarrow J/\psi\ \gamma$




- Reconstruct γ conversions:
  - Excellent mass resolution
  - Separate $\chi_{c,1}$ and $\chi_{c,2}$

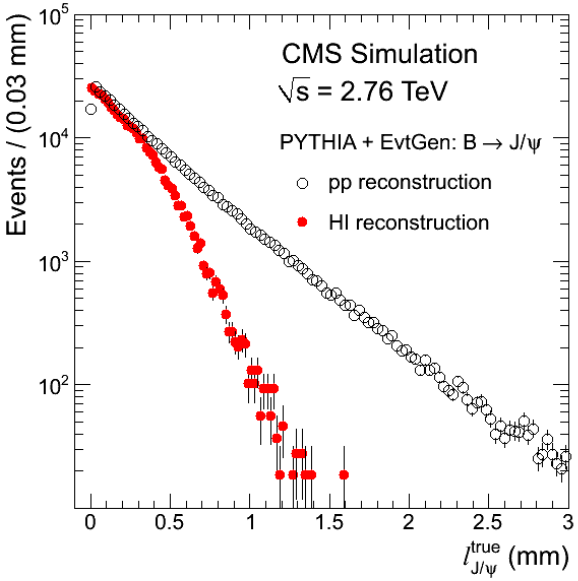
# Muon pairs in PbPb

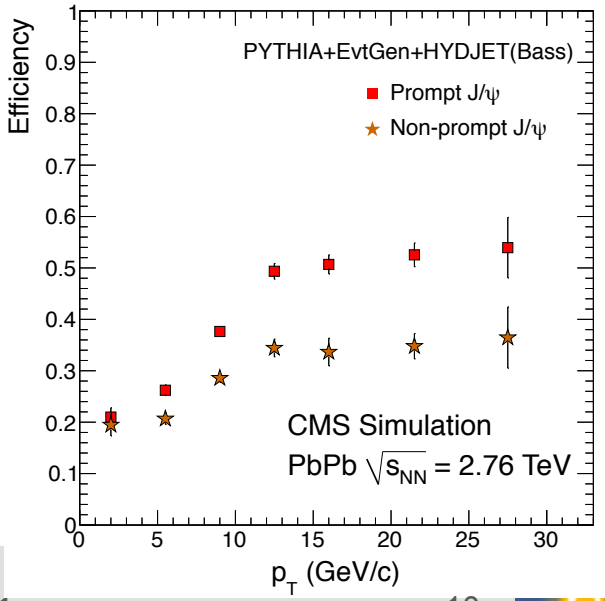


# J/ψ in PbPb at $\sqrt{s_{NN}}$ = 2.76 TeV

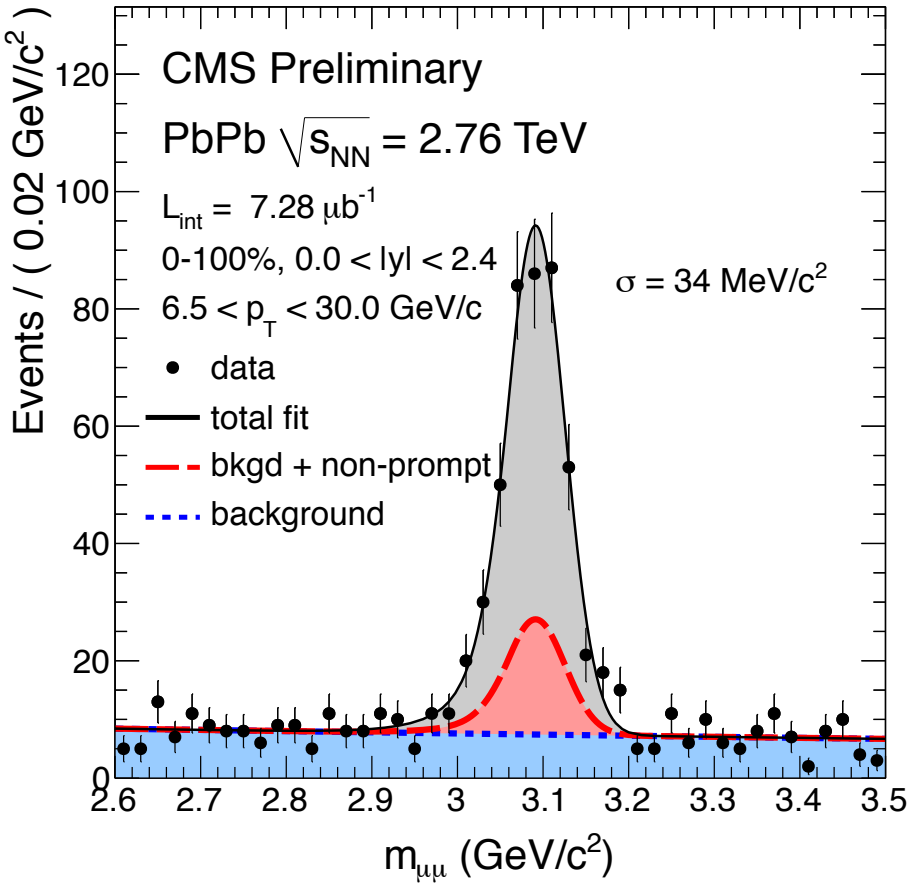
- Separate prompt & non-prompt J/ψ
- HI tracking algorithm less efficient at large decay length
  - Smaller efficiency for non-prompt than for prompt J/ψ
  - Effect increases with $p_T$
- Efficiencies from Monte Carlo
  - Simulate signal with "realistic" PYTHIA
  - Embed signal in min. bias event simulated with HYDJET (also in data)
  - Validated MC by comparing efficiencies measured with "Tag & Probe" in MC and data

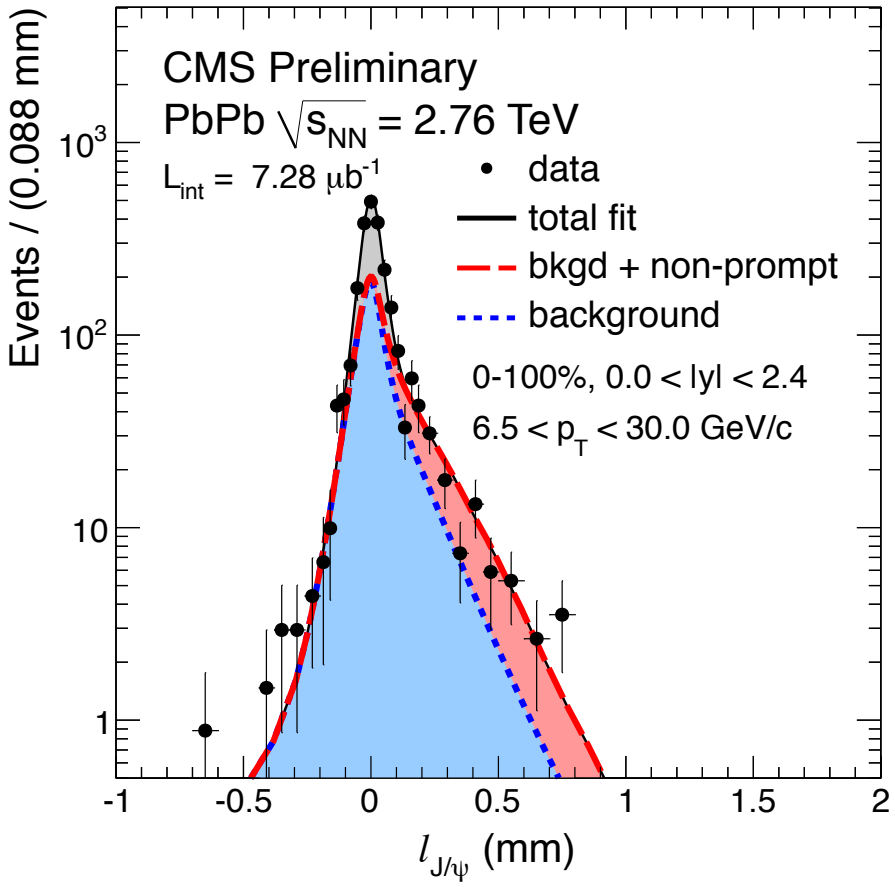
Dongho Moon (Poster)



# Prompt vs. non-prompt J/ψ in PbPb

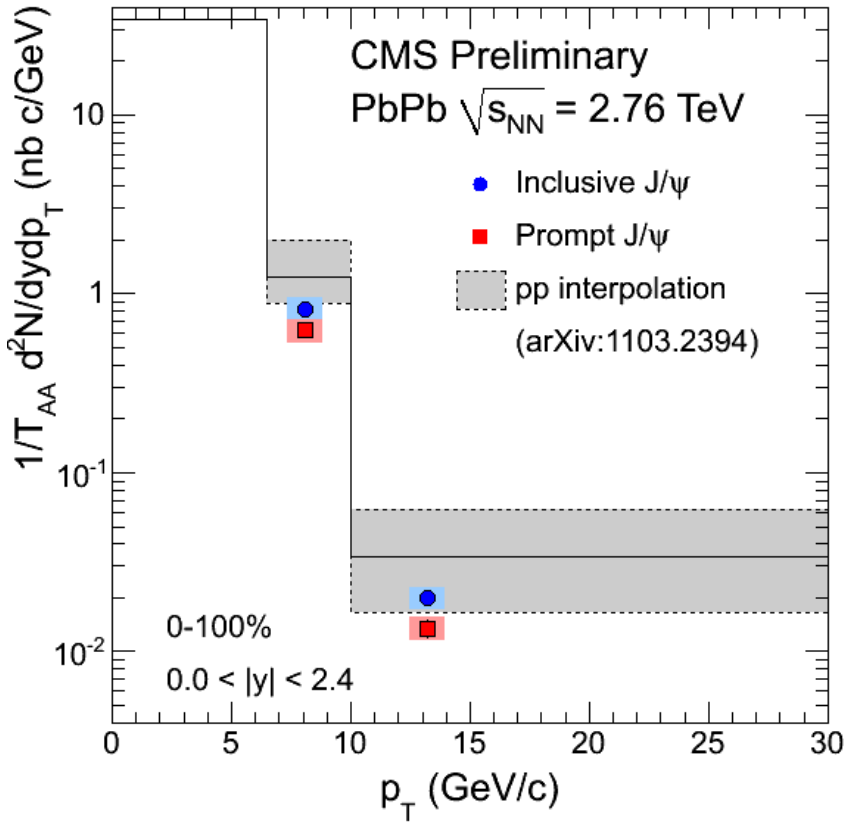


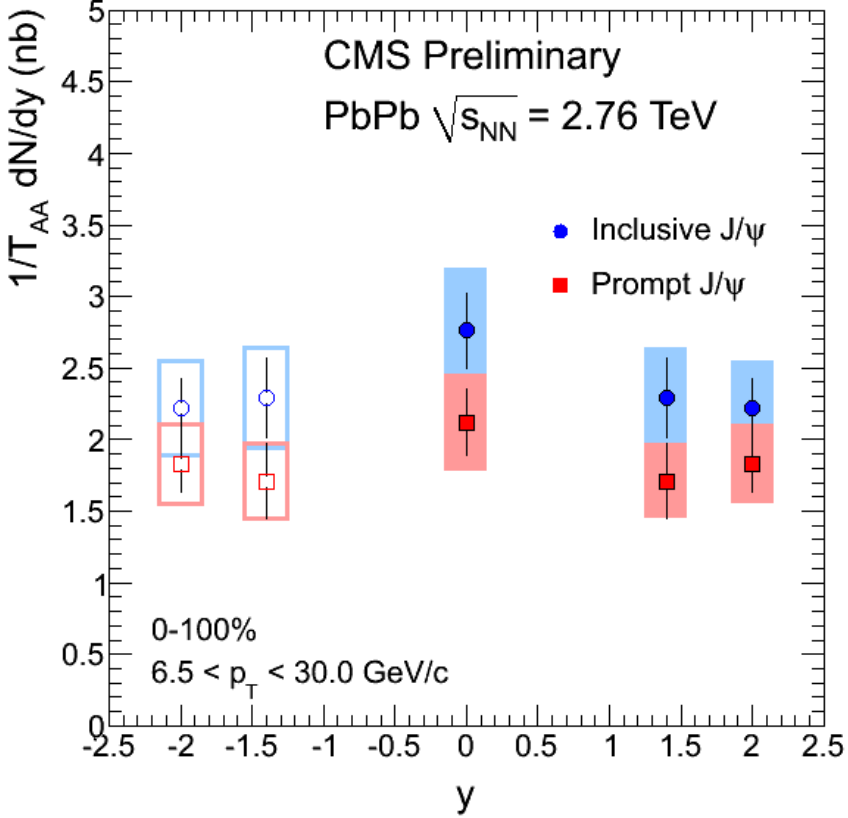




First time that prompt and non-prompt J/ψ have been separated in heavy ion collisions

# Prompt J/ψ yield vs. $p_T$ and y

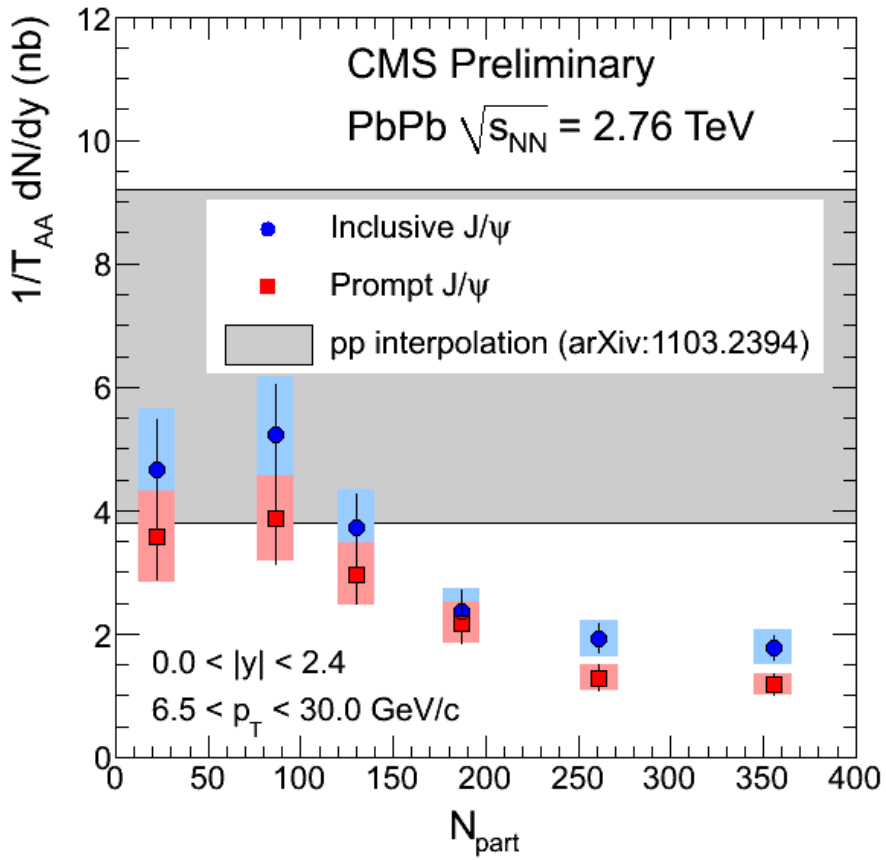
$$T_{AA} = N_{\mathrm{coll}} / \sigma_{pp}$$




- pp from interpolation of RHIC, Tevatron and LHC data
- Large uncertainty on pp interpolation does not allow definite conclusion: Need a real pp reference!

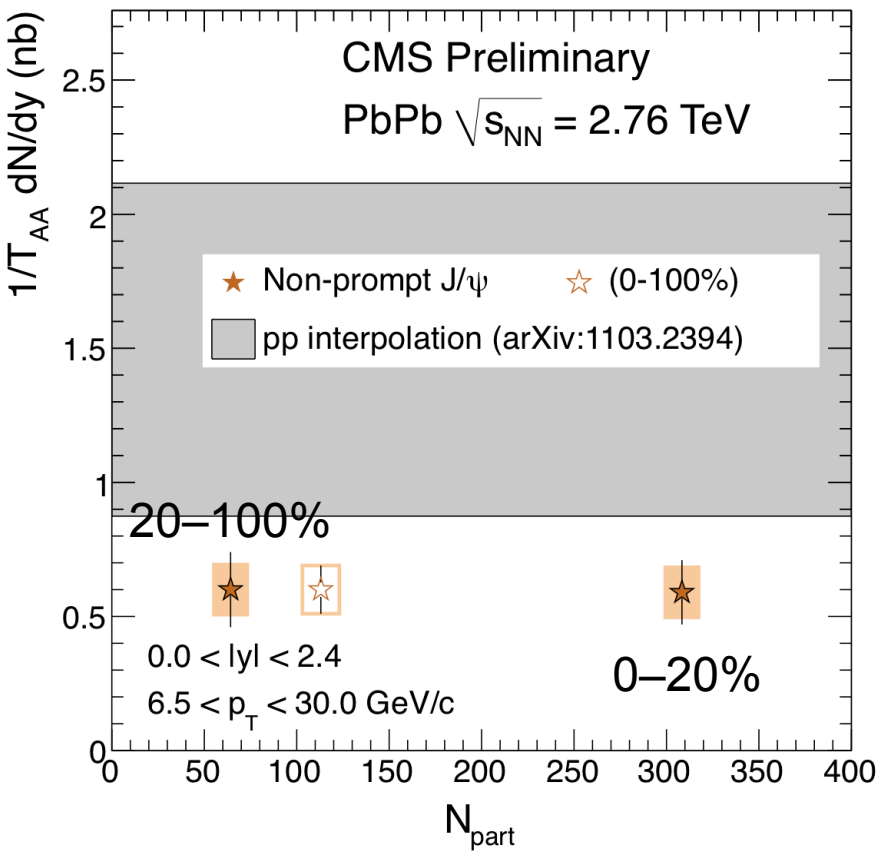
# Prompt J/ψ yield vs. centrality




- pp from interpolation of RHIC, Tevatron and LHC data

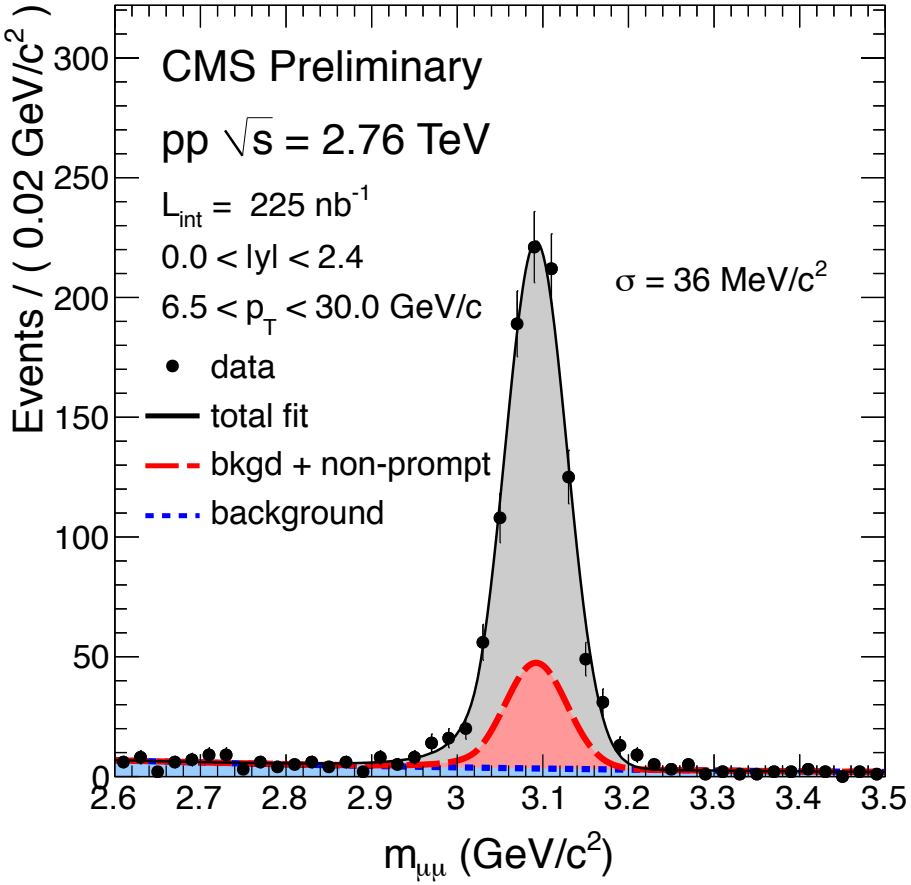
- Large uncertainty on pp interpolation due to a $p_T > 6.5$ GeV/c cut
- Prompt J/ψ: Suppression by factor of 3 in central (0-10%) compared to peripheral (50-100%)
- Peripheral collisions in agreement with lower limit of interpolation
- Need a real pp reference!

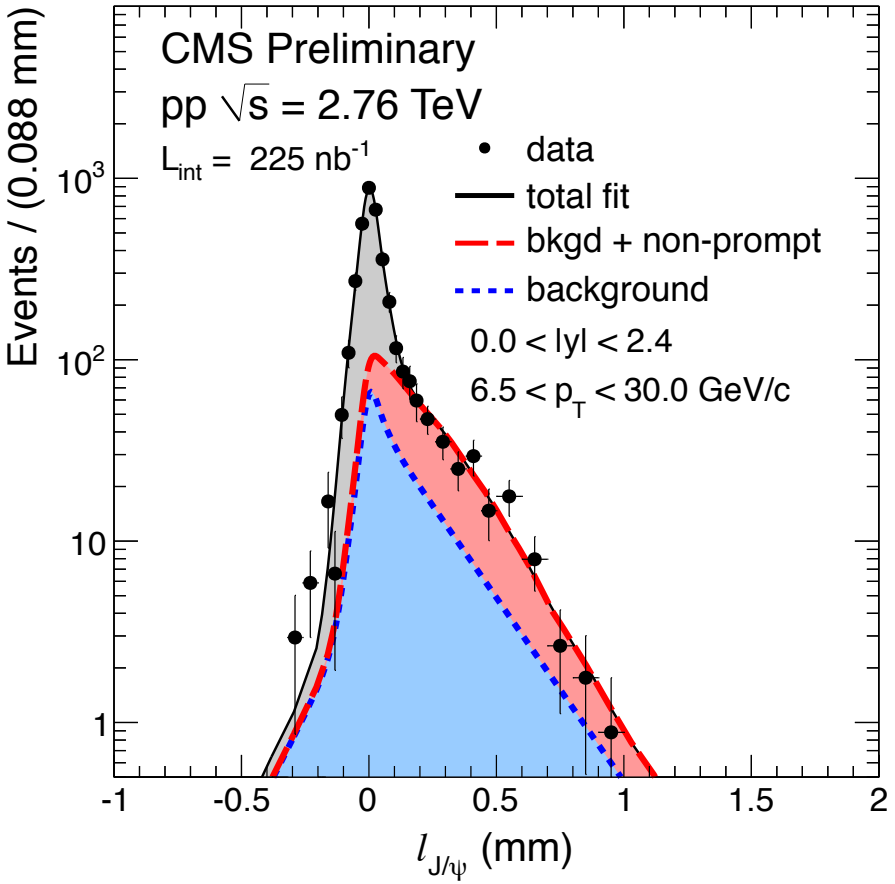
# Non-prompt J/ψ yield vs. centrality




- Scaled pp interpolation by measured B-fraction
- Non-prompt J/ψ: Suppression with respect to interpolation
- Need a real pp reference!

# Reference: J/ψ in pp at √s = 2.76 TeV

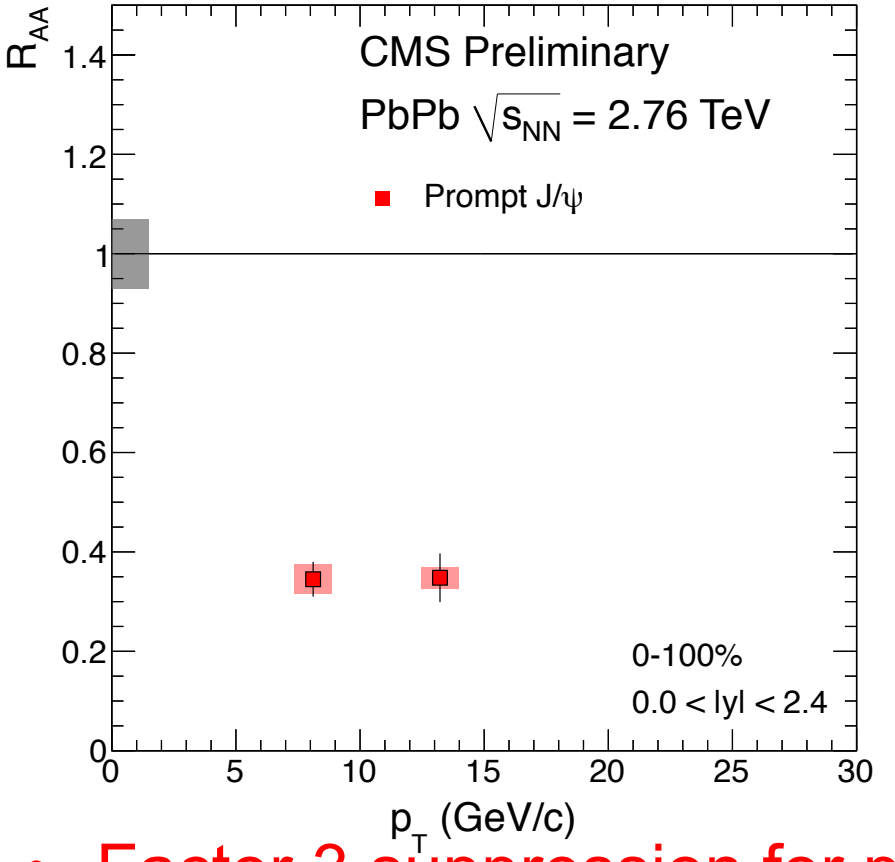


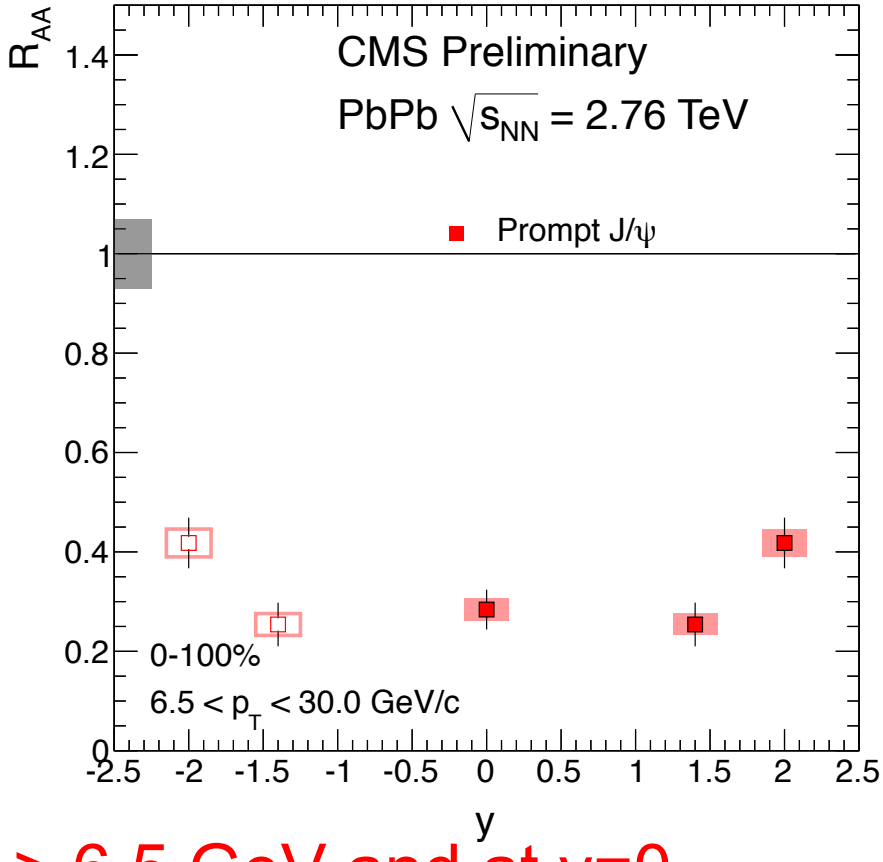




- 1 week long run at √s = 2.76 TeV in March 2011
- pp data reconstructed with heavy ion algorithm
- Identical cuts used as in heavy ion analysis

# Nuclear Modification Factor

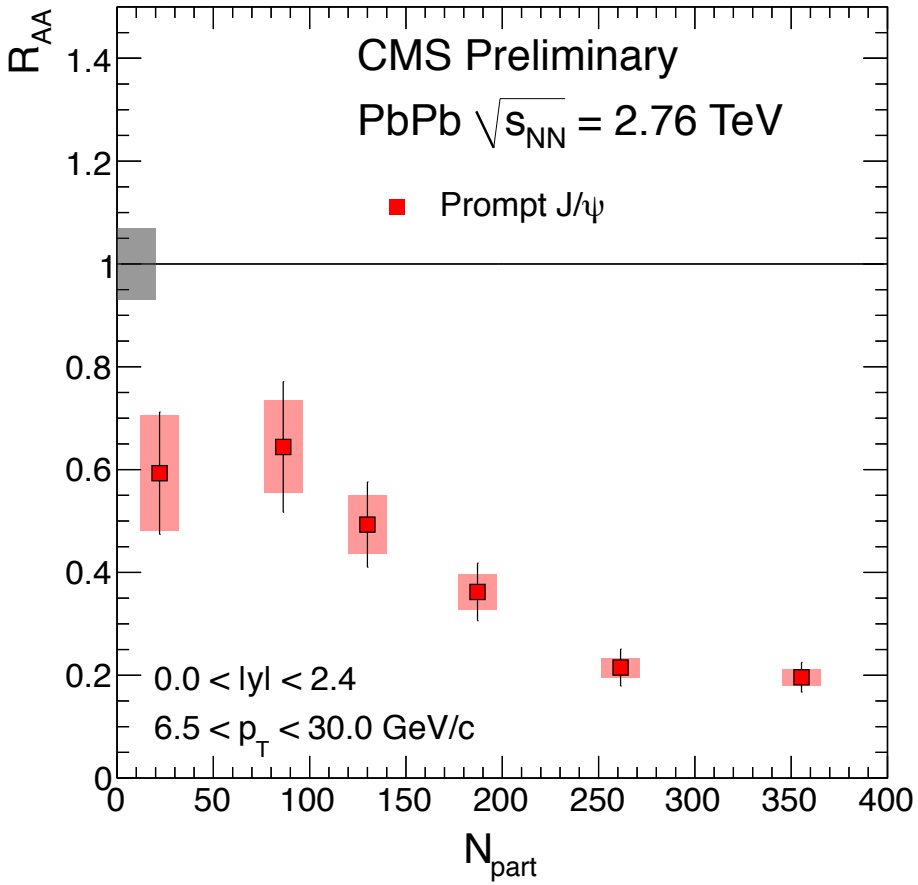
$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{\mathrm{MB}}} \frac{N_{\mathrm{PbPb}}(J/\psi)}{N_{pp}(J/\psi)} \frac{\varepsilon_{pp}}{\varepsilon_{\mathrm{PbPb}}(\mathrm{cent})}$$




- Factor 3 suppression for $p_T$ > 6.5 GeV and at y=0
- Trend to less suppression at forward rapidity

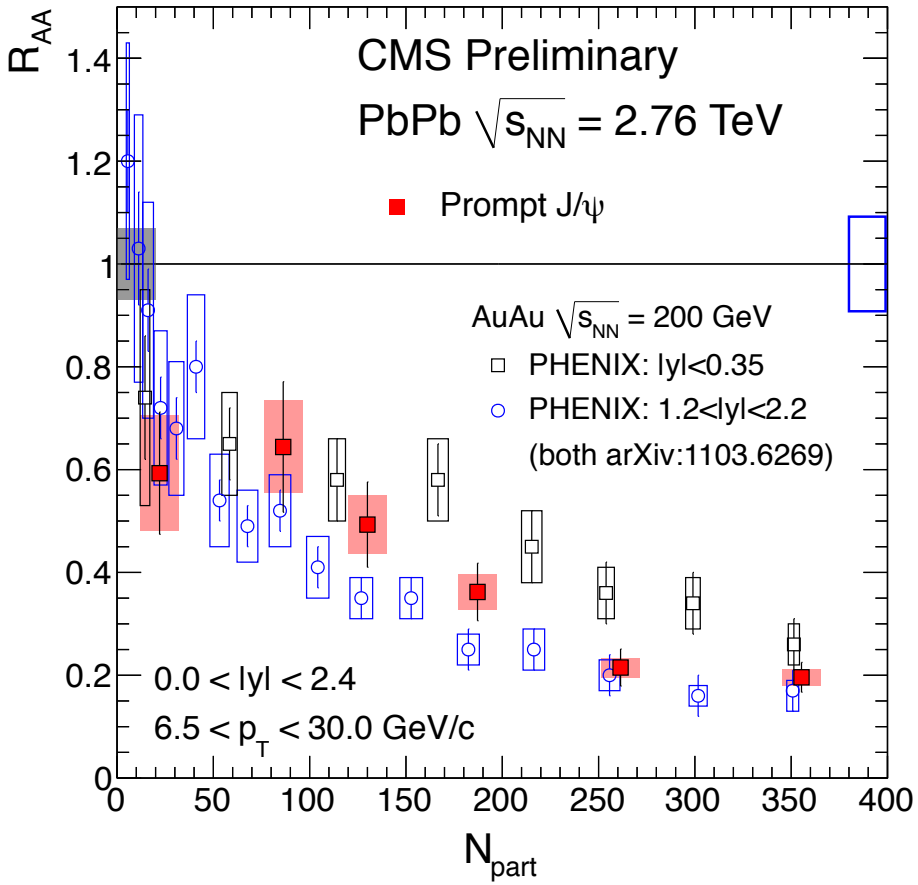
# Nuclear Modification Factor




Prompt J/ψ:

- 0-10% suppressed by factor 5 with respect to pp
- 50-100% suppressed by factor ~1.6

# Nuclear Modification Factor

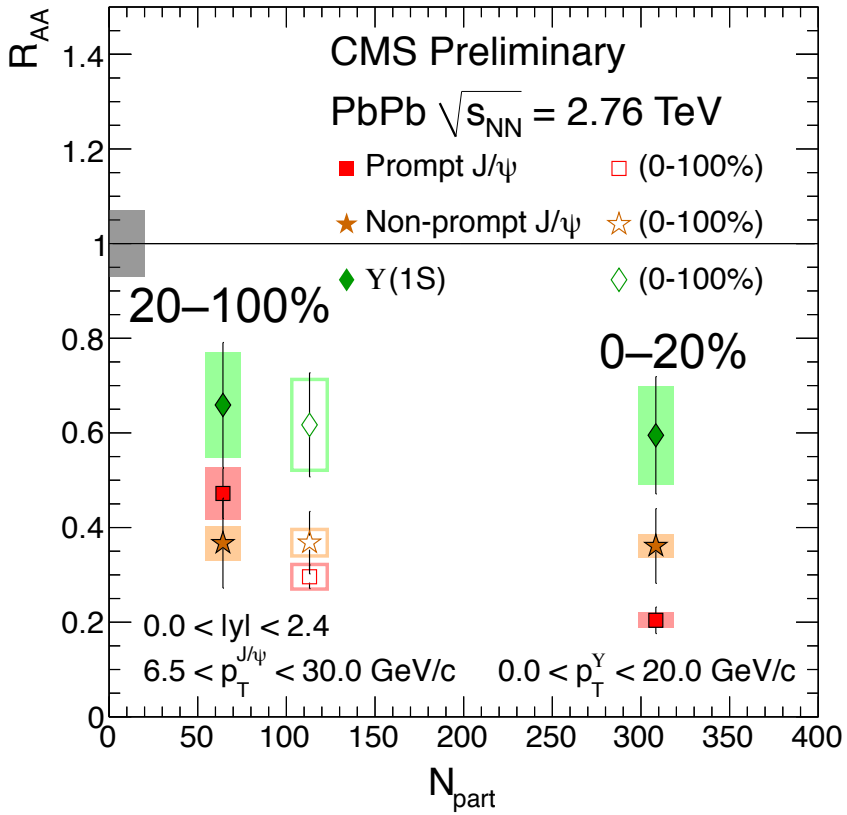



PHENIX data: arXiv:1103.6269

Comparison to J/ψ in AuAu collisions at $\sqrt{s_{NN}}$ = 200 GeV

- Measured at much lower $p_T$
- Surprising qualitative agreement in centrality dependence
- Suppression in the most central collisions seems the same

# Summary




Υ: $p_T$ > 0 GeV/c

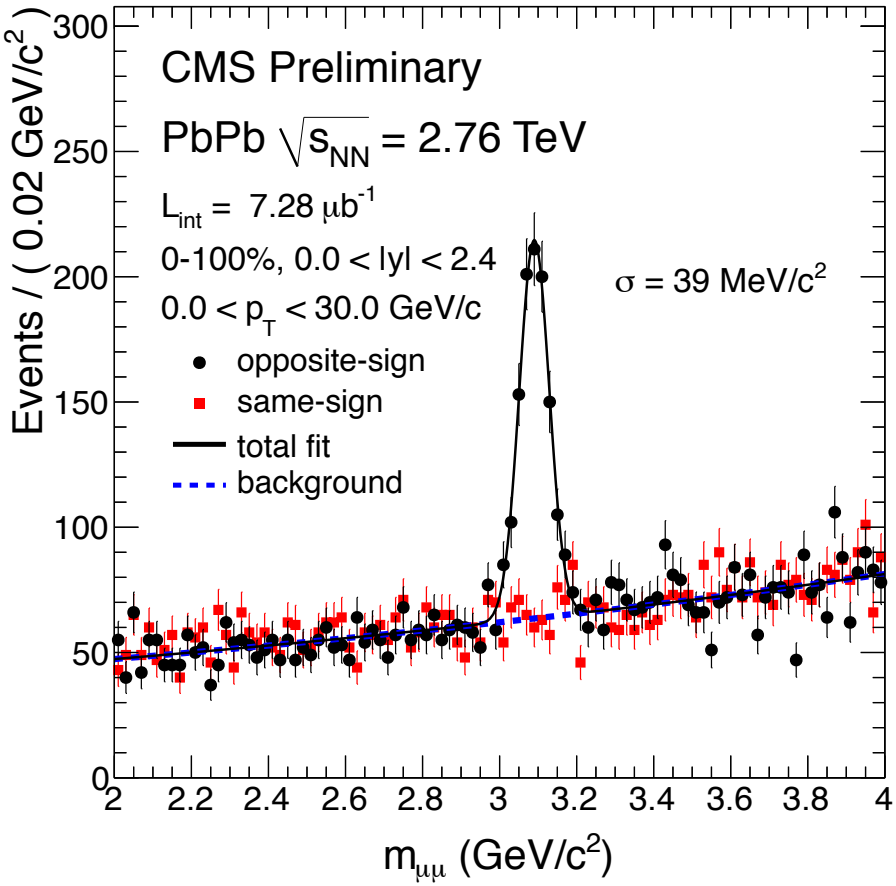
J/ψ: $p_T$ > 6.5 GeVc

- Suppression of prompt and non-prompt J/ψ, and Υ(1S)
- Strength of the suppression varies:
  - Prompt J/ψ suppressed the most, Υ(1S) the least (in 0-20%)
  - Non-prompt J/ψ suppressed due to b-quark quenching?

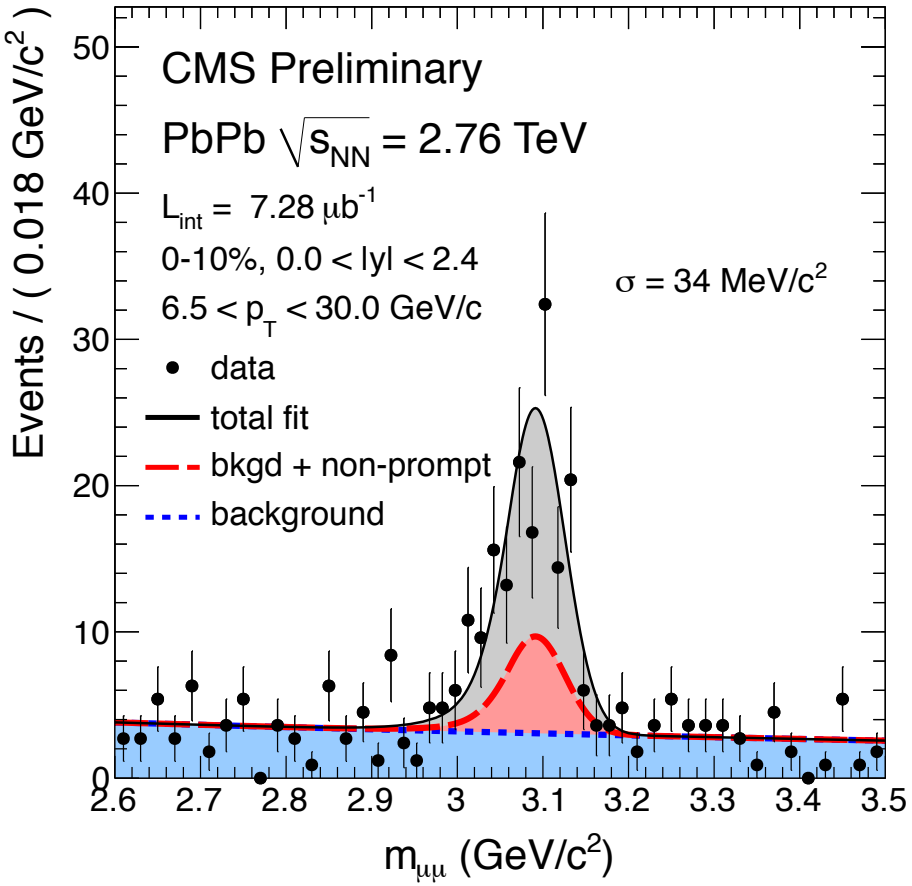
# Backup

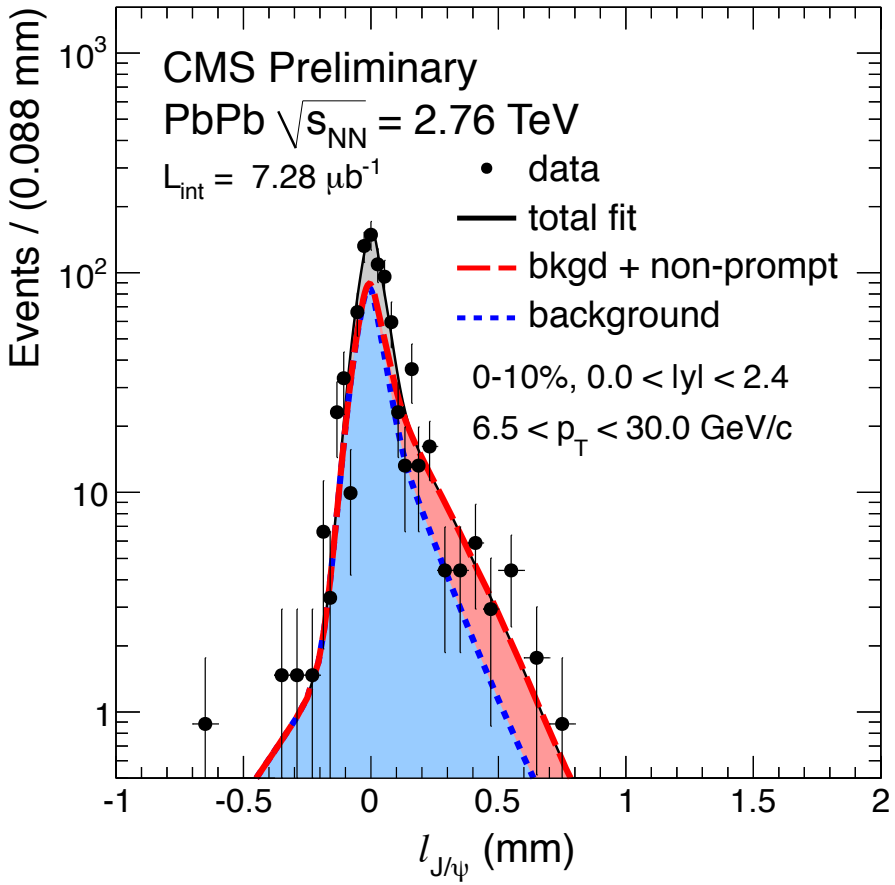
# J/ψ

- 734 ± 54 J/ψ in full acceptance
- 39 MeV/$c^2$ mass resolution
- no sensitivity to ψ' (m=3.686 GeV/$c^2$, expect ~20)
- background well described by same-sign pairs → mostly combinatorial background



# Prompt vs. non-prompt J/ψ in PbPb

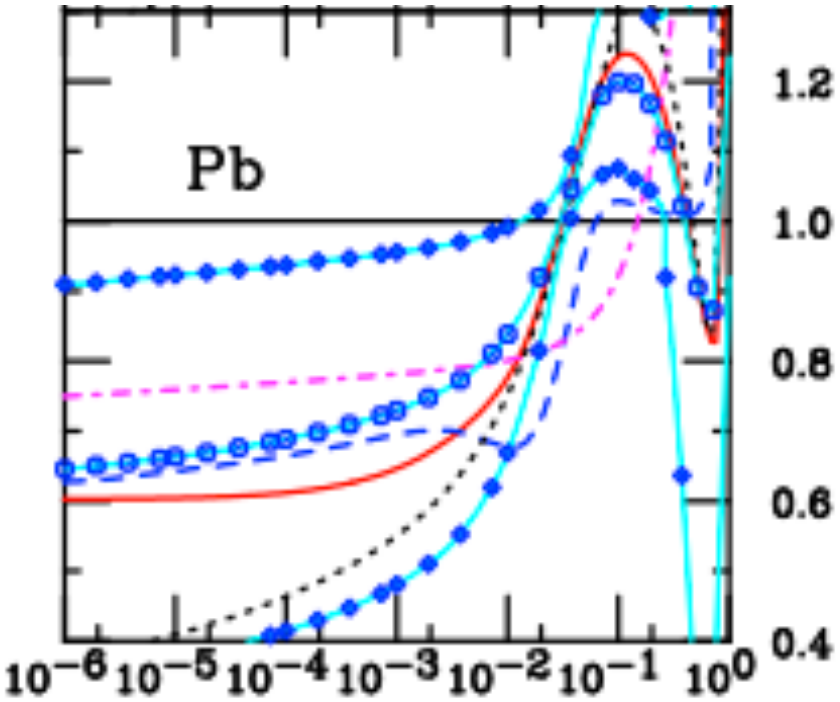


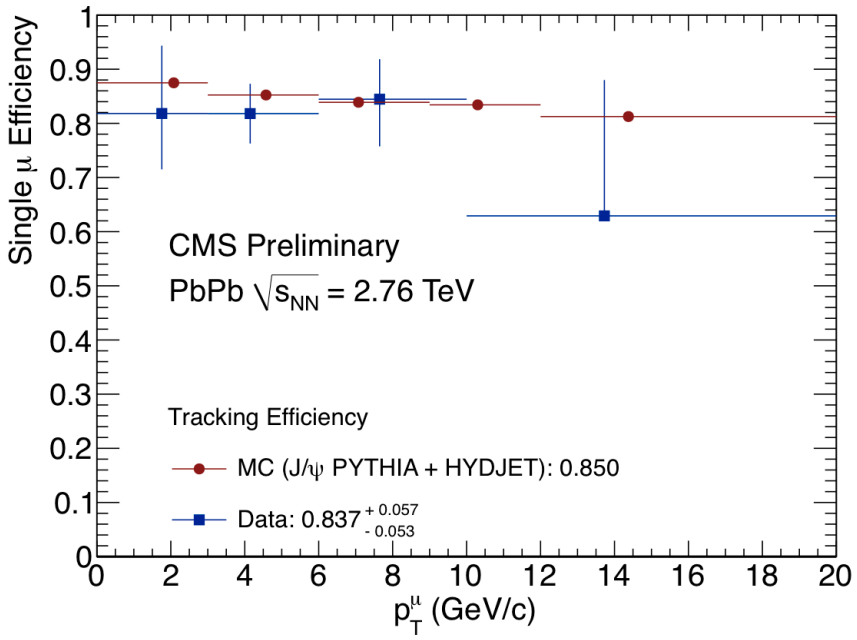

Also works in the 10% most central collisions

# Shadowing

- The parameterizations are:
  - EKS98 (solid)
  - nDSg (dashed)
  - HKN (dot-dashed)
  - EPS08 (dotted)
  - EPS09 (solid lines w/ symbols)
- R. Vogt
  PRC 81, 044903 (2010)



# Tag & Probe




- Tag:
  - High quality muon
- Probe:
  - Track in the muon station
- Passing Probe:
  - Probe that is also reconstructed as global muon (i.e. with a track in the Si-tracker)
- Reconstruct J/psi peak in passing probe-tag pairs and in failing probe-tag pairs
- Simultaneous fit to passing and failing probes allows us to measure the efficiency of the inner track reconstruction