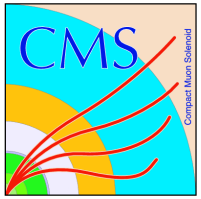
Suppression of open bottom at high p_T via non-prompt J/ψ decays in PbPb collisions at 2.76 TeV with CMS



Mihee Jo
(Korea University)
for the CMS Collaboration

Quark Matter conference, Washington DC
17 August, 2012

Outline

- Introduction
- Compact muon solenoid
- Signal extraction
  - Prompt and non-prompt J/ψ separation
- Acceptance and efficiency
- Results
  - Non-prompt J/ψ R_{AA}
  - b-jet R_{AA}
- Summary

Bottom quark in hot and dense medium

- Bottom quark is a sensitive probe of the medium energy loss
  - Created at an early stage of collision and has long lifetime
    → Interacts with medium and loses energy

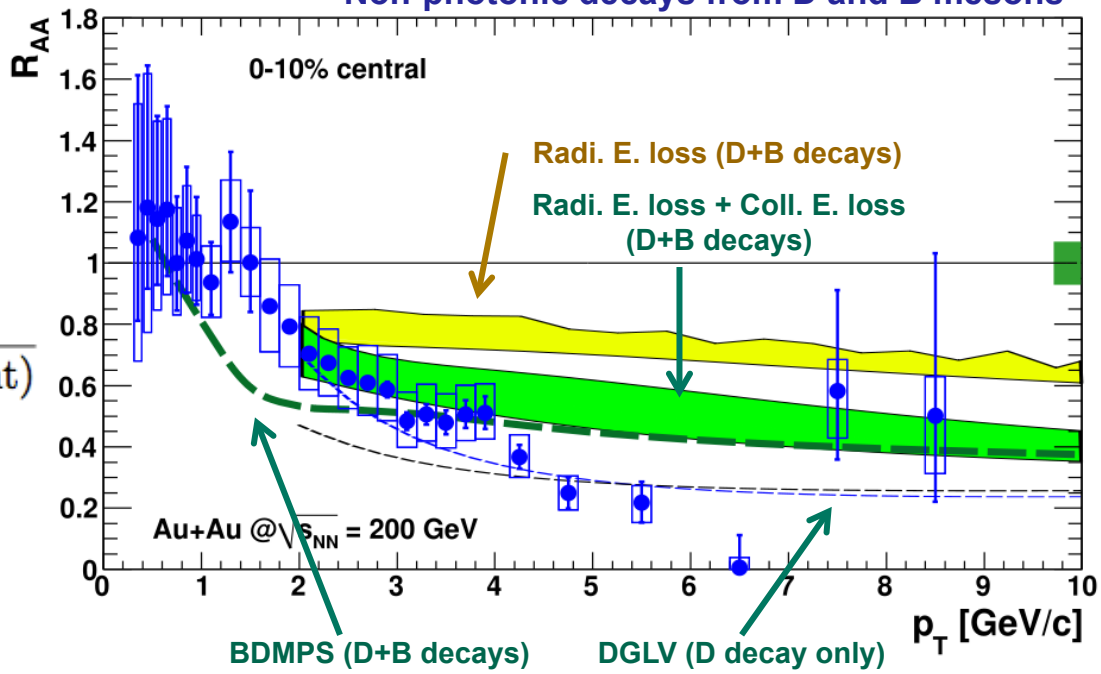
Y.L. Dokshitzer, D.E. Kharzeev, Phys. Lett. B 519 (2001) 199

- Inelastic scattering - radiative energy loss
- Elastic scattering - collisional energy loss
- Dead-cone effect
  - Reduces small-angle gluon radiation for heavy quarks with moderate energy-over-mass values

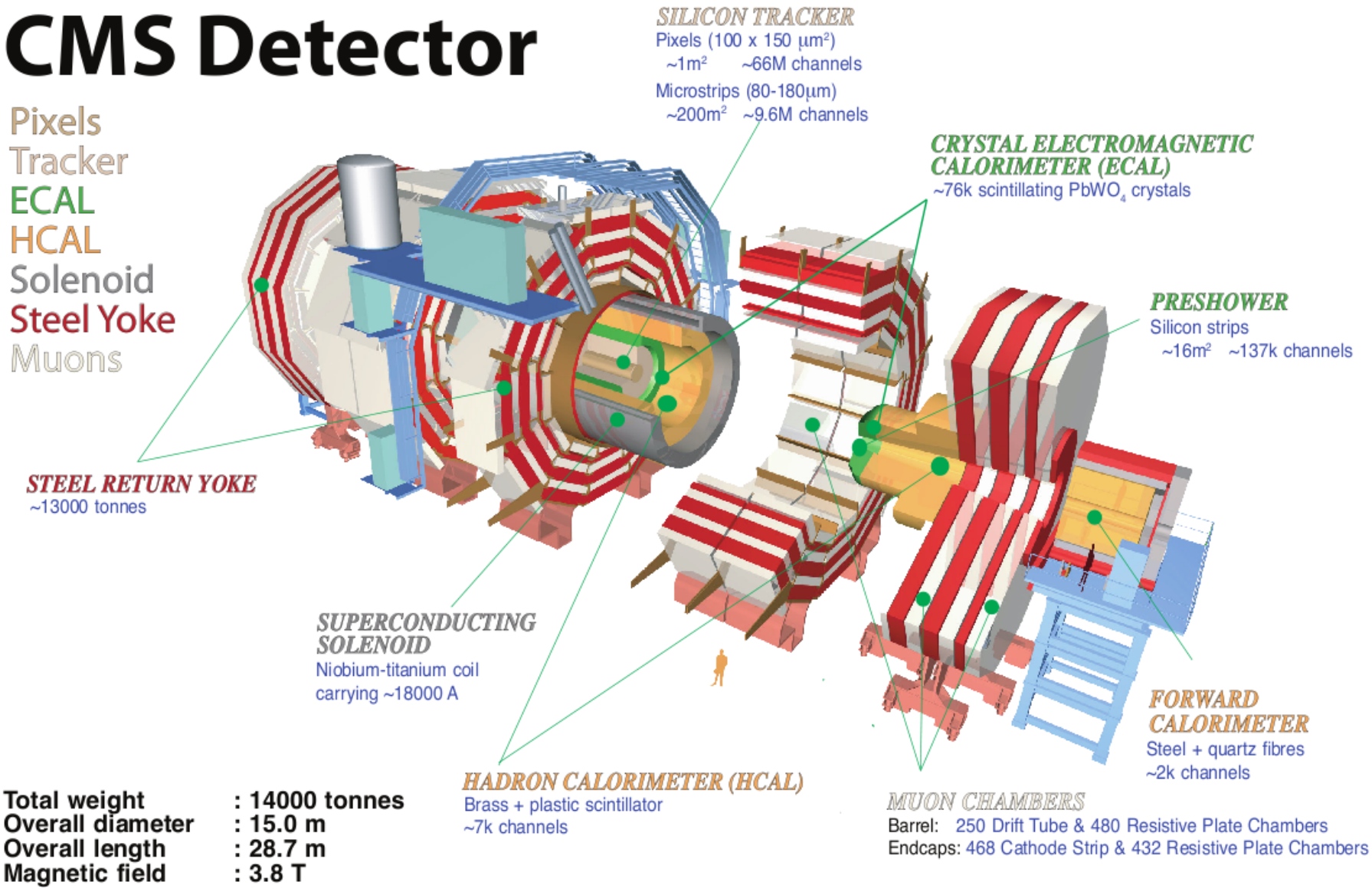
$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{\mathrm{MB}}} \frac{N_{\mathrm{PbPb}}(J/\psi)}{N_{pp}(J/\psi)} \frac{\varepsilon_{pp}}{\varepsilon_{\mathrm{PbPb}}(\mathrm{cent})}$$

R_{AA}(light hadrons) < R_{AA}(D) < R_{AA}(B)

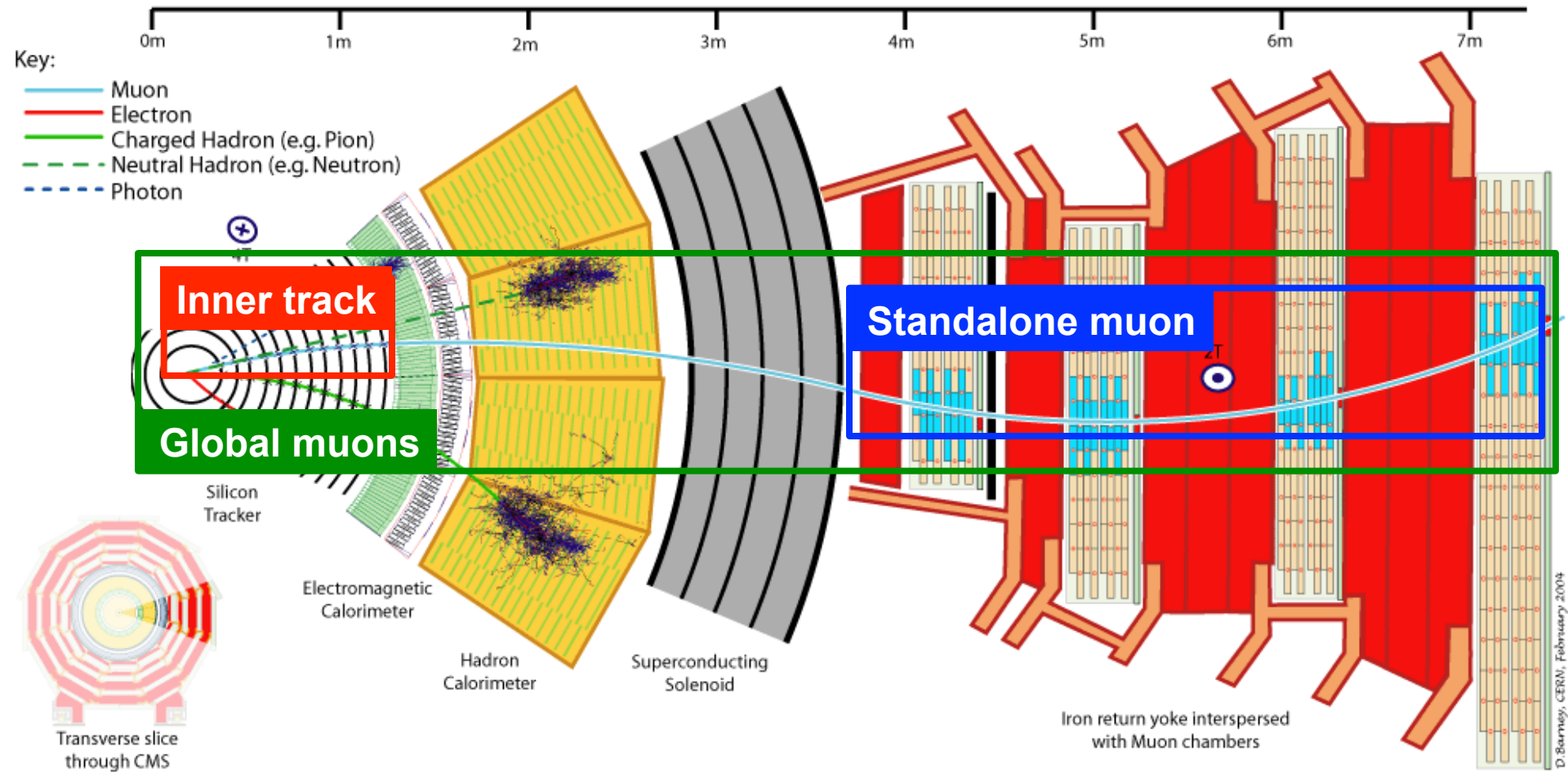
PHENIX Collaboration, Phys. Rev. C 84, 044905 (2011)
Non-photonic decays from D and B mesons



Compact Muon Solenoid

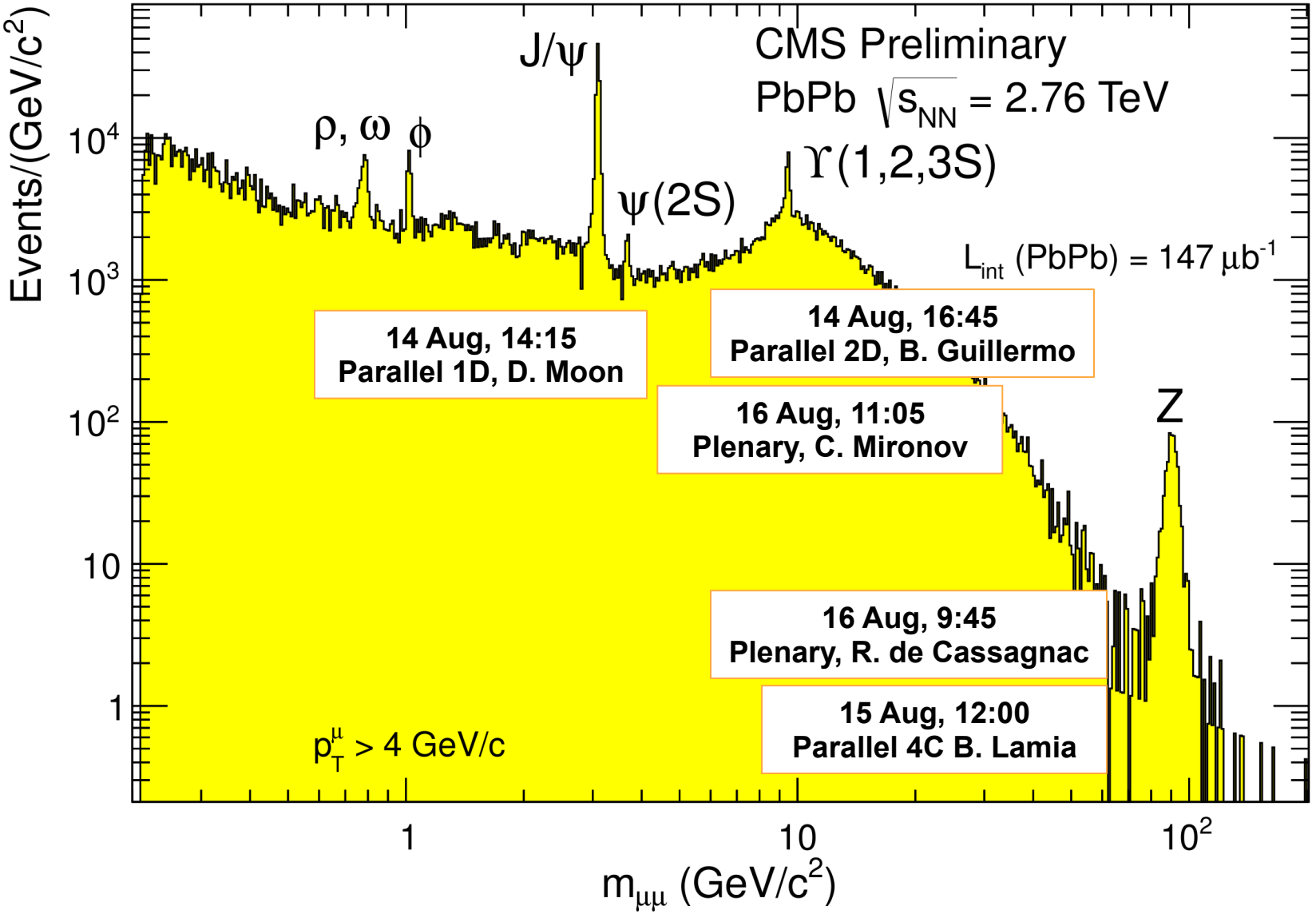


Muon reconstruction in CMS



- Excellent muon identification and triggering (Muon system)
- High mass/momentum resolution (Tracker)

Dimuon spectrum in 2011 PbPb



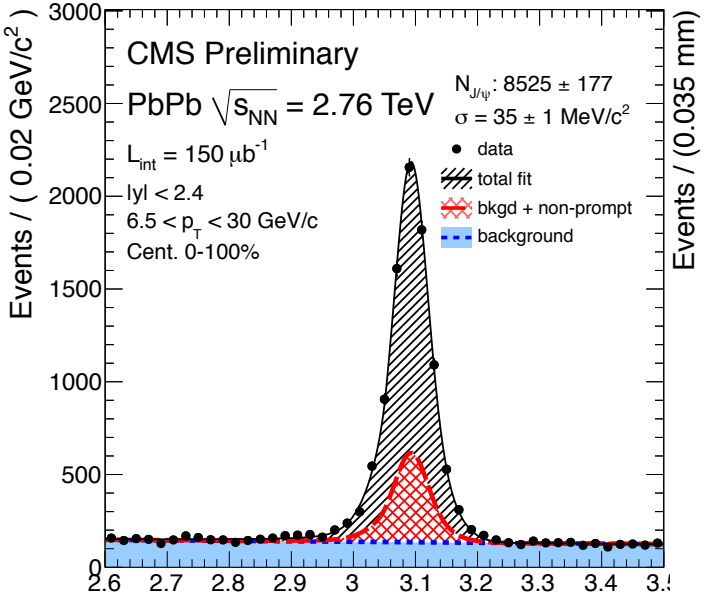
J/ψ separation

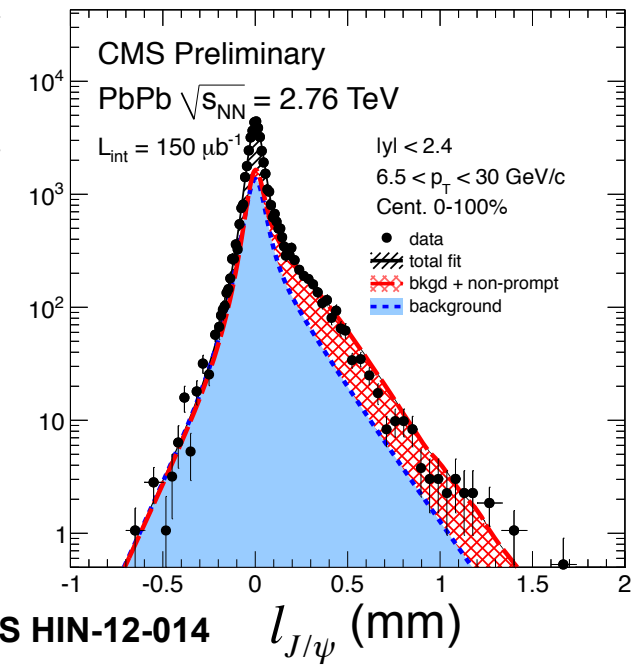
CMS collaboration, JHEP 1205 (2012) 063

Inclusive J/ψ

- **Prompt J/ψ**
  - Direct J/ψ
  - Feed-down from ψ(2S) and χ_c
- **Non-Prompt J/ψ from B decays**

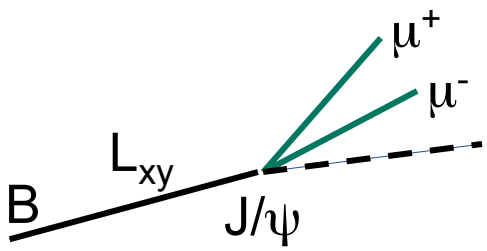
- Reconstruct $\mu^+\mu^-$ vertex
- 2-D unbinned maximum likelihood fit of $\mu^+\mu^-$ mass and pseudo-proper decay length $l_{J/\psi}$





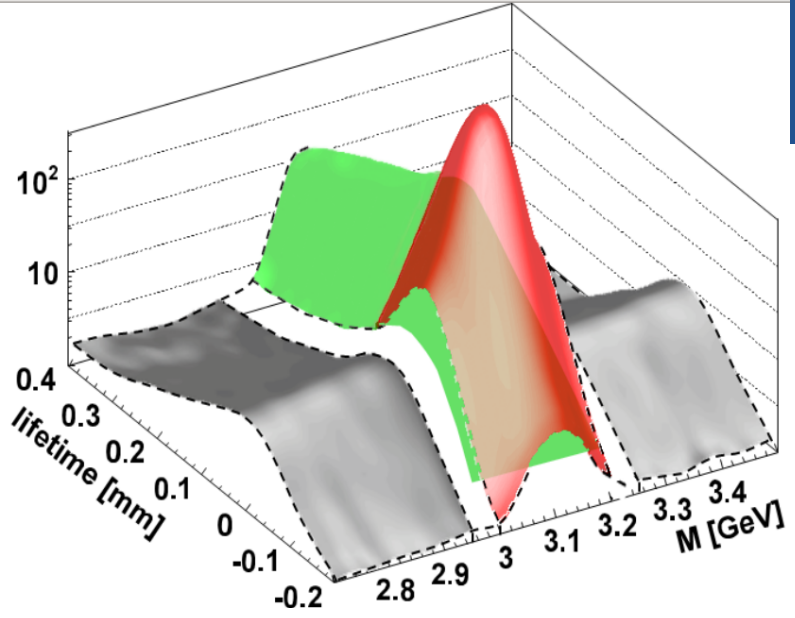
CMS PAS HIN-12-014

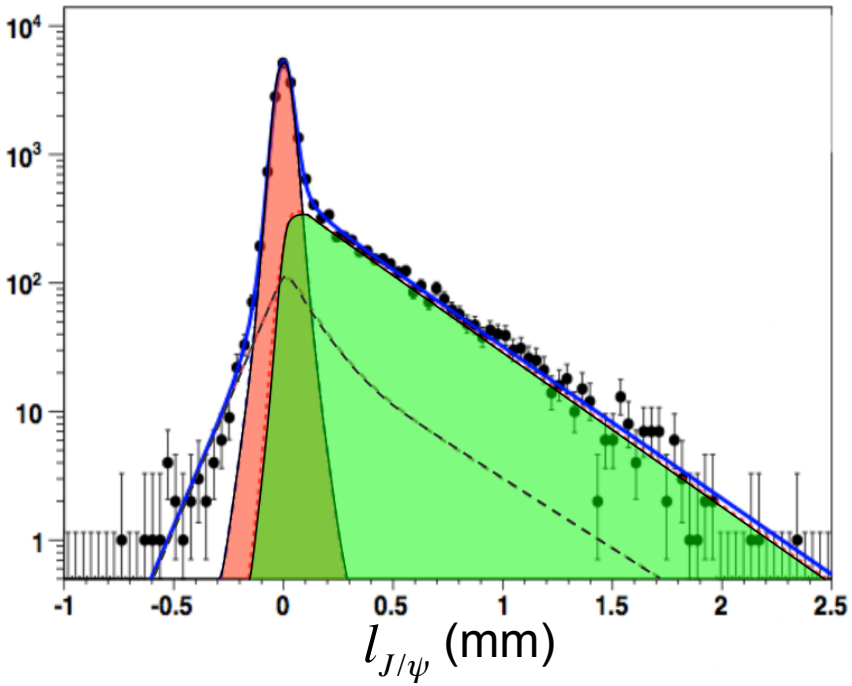
$$\ell_{J/\psi} = L_{xy}\frac{m_{J/\psi}}{p_T}$$



|y| < 2.4
6.5 < p_T < 30 GeV/c
0-100%

Signal Extraction in PbPb





CMS PAS HIN-12-014

- Dimuon mass distributions
  - Signal shape: Crystal Ball + Gaussian
  - Background shape: Exponential
- Dimuon $l_{J/\psi}$ distributions
  - Prompt J/ψ component

Prompt J/ψ MC template modeled with resolution function includes the event-by-event uncertainty of $l_{J/\psi}$

  - Non-prompt J/ψ component

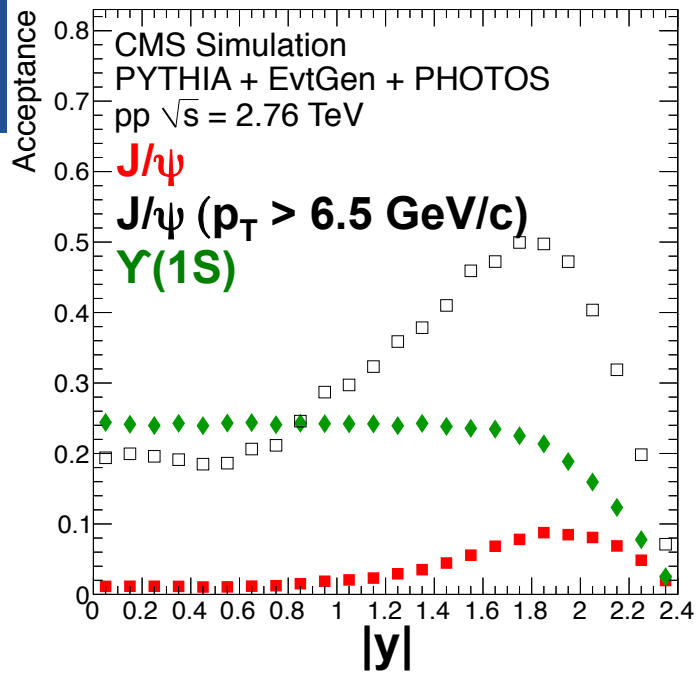
Non-prompt J/ψ MC template uses $l_{J/\psi}$ distribution as a shape

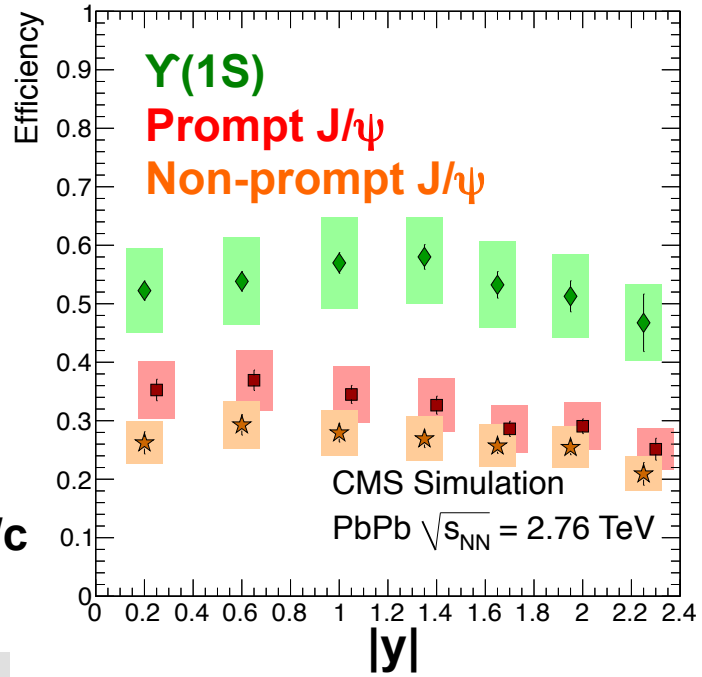
  - Background component

Fit events in mass sidebands to sum of 3 exponential decay functions

Efficiency and acceptance

- MC simulations with PYTHIA
- Acceptance
  - No acceptance for J/ψ at mid-rapidity with $p_T < 6.5$ GeV/c
  - At forward rapidity, acceptance for J/ψ with $p_T > 3$ GeV/c
- Efficiencies
  - Embedded signal in min-bias events simulated with HYDJET
  - Validated MC by comparing efficiencies measured with "Tag & Probe" in MC and data

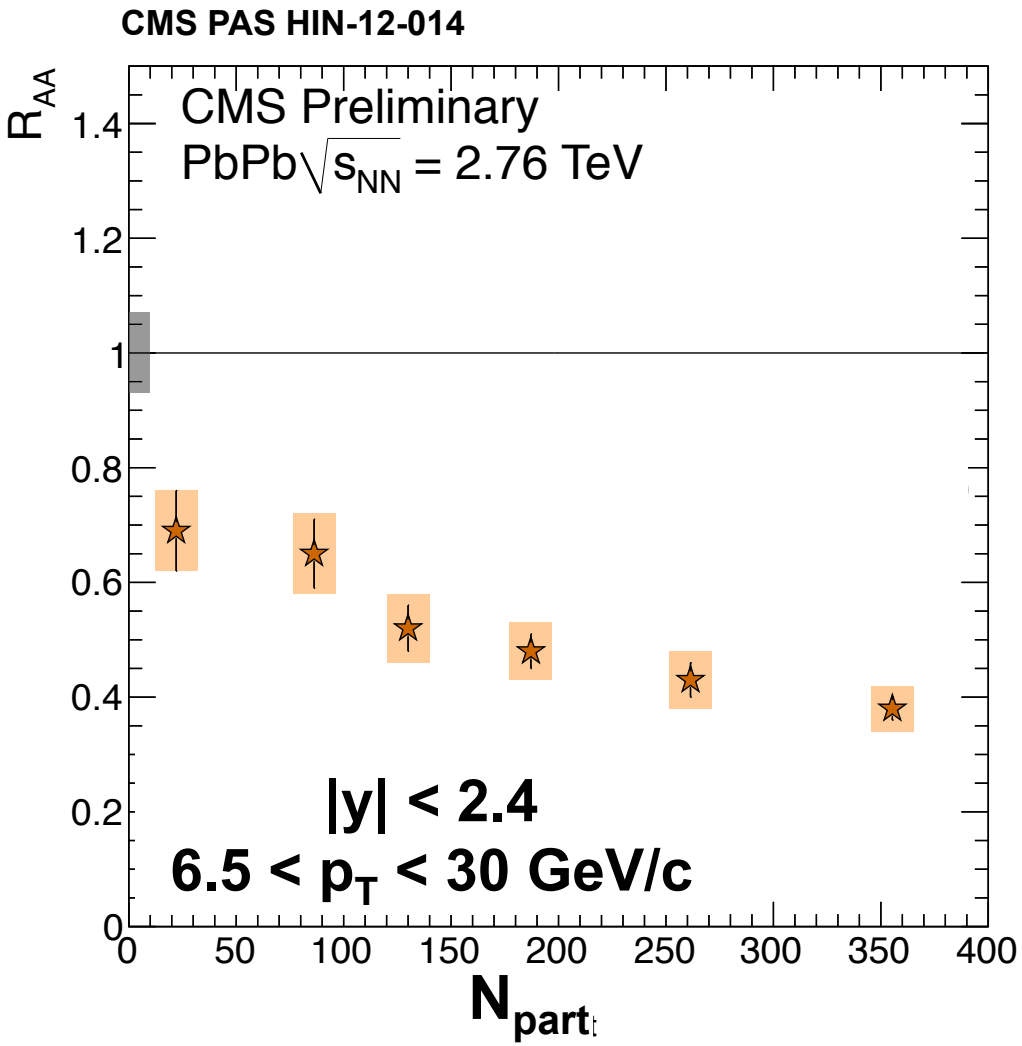




Cent. 0-100%
$6.5 < p_T < 30$ GeV/c

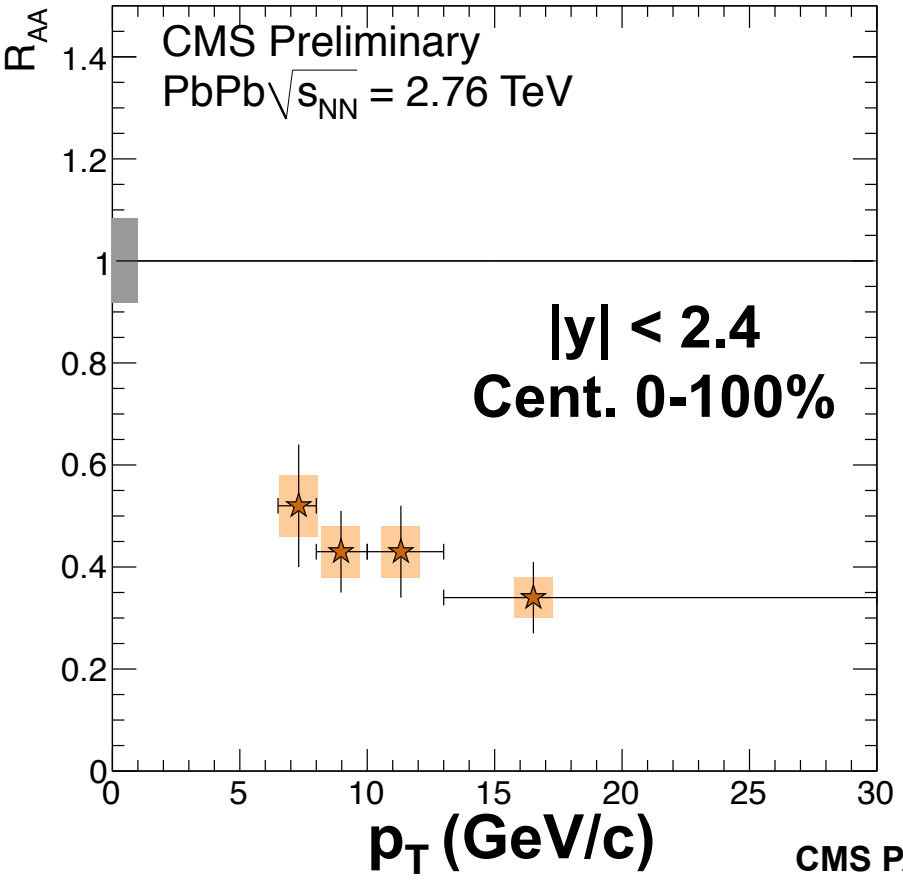
CMS collaboration, JHEP 1205 (2012) 063

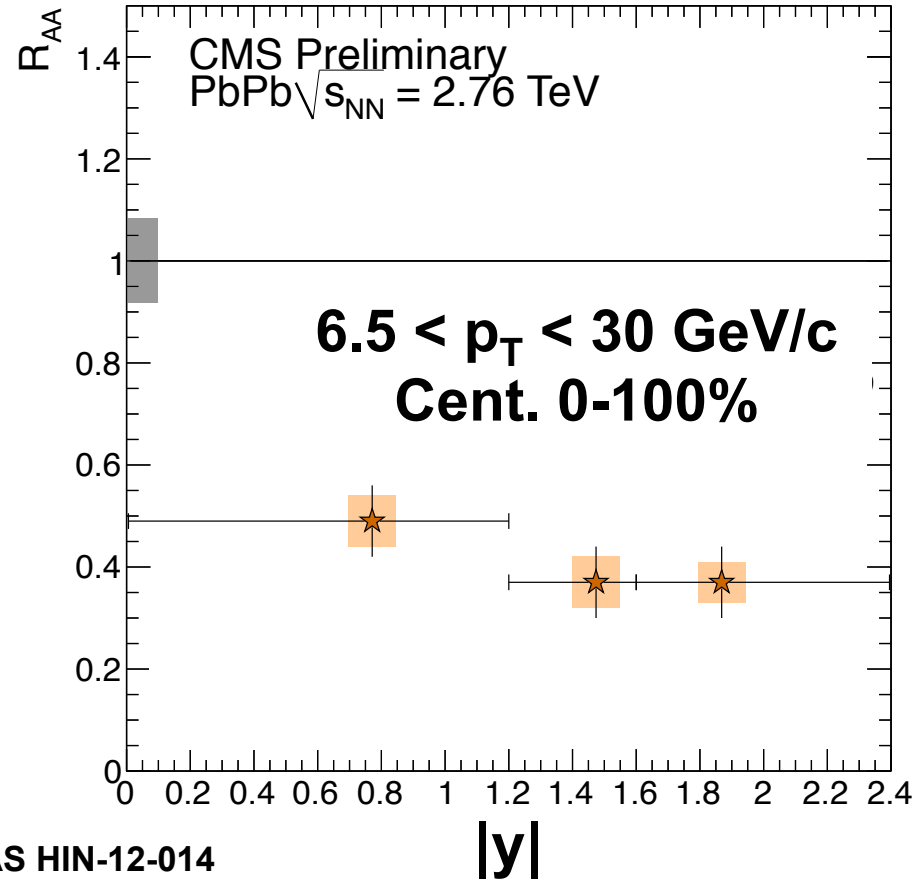
Non-prompt J/ψ R_{AA} vs. N_{part}



- Centrality dependent suppression of non-prompt J/ψ is observed
- Non-prompt J/ψ in the most central collision (0-10%) is suppressed by a factor of 2.5

Non-prompt J/ψ R_{AA} vs. p_T and y

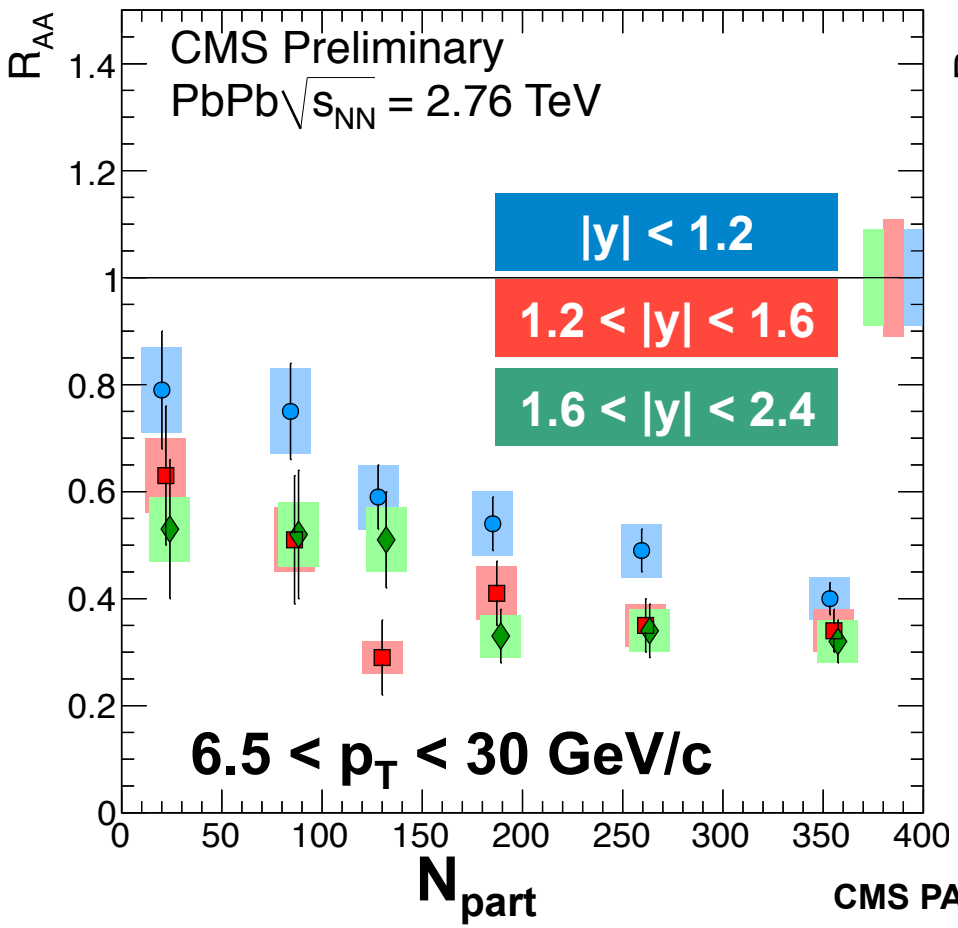


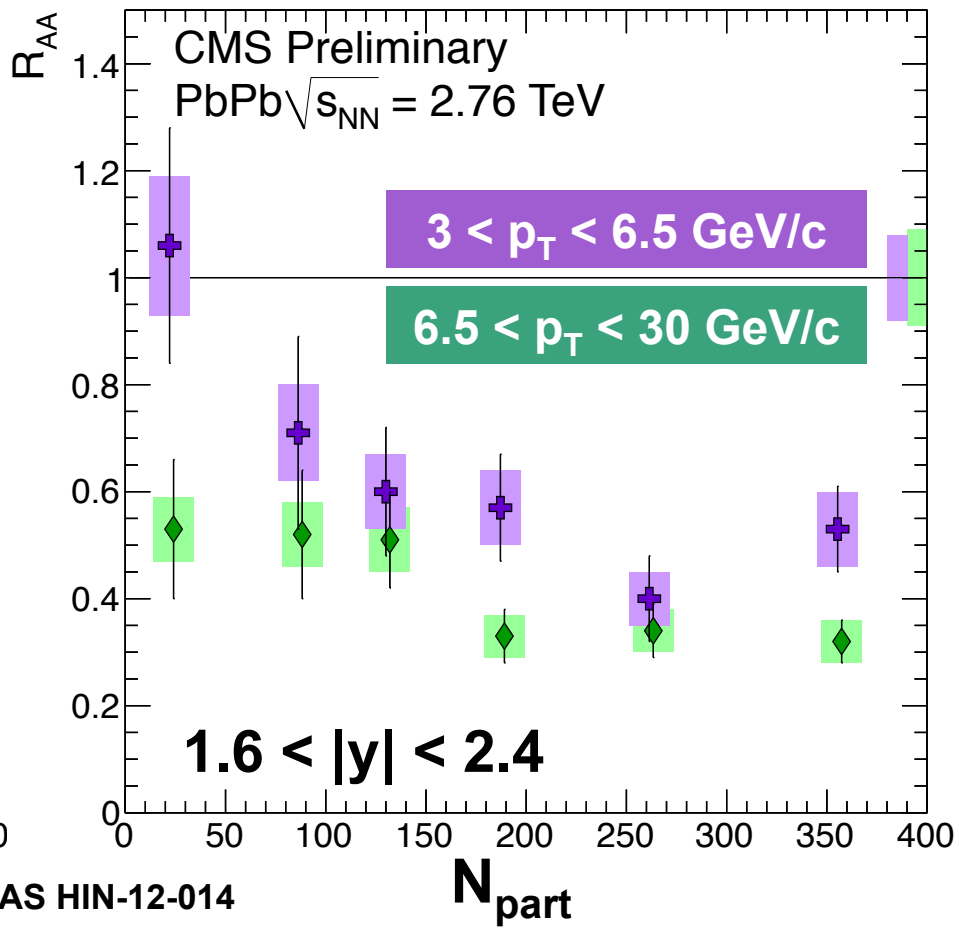


CMS PAS HIN-12-014

- Low-p_T J/ψ is slightly less suppressed than high-p_T J/ψ
- Mid-rapidity J/ψ is slightly less suppressed than in forward rapidity

Non-prompt J/ψ R_{AA} vs. N_{part} & p_T , N_{part} & y

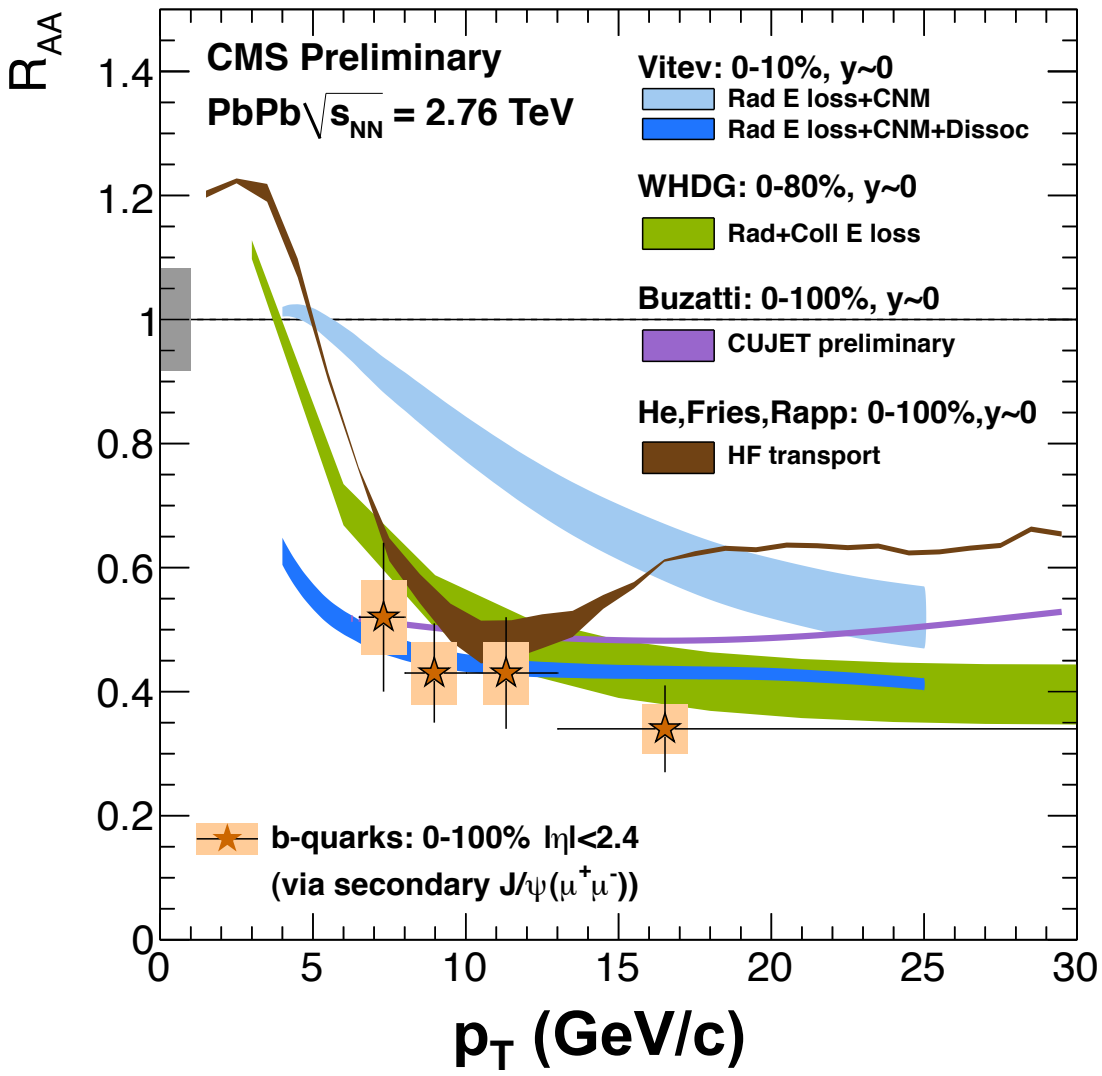


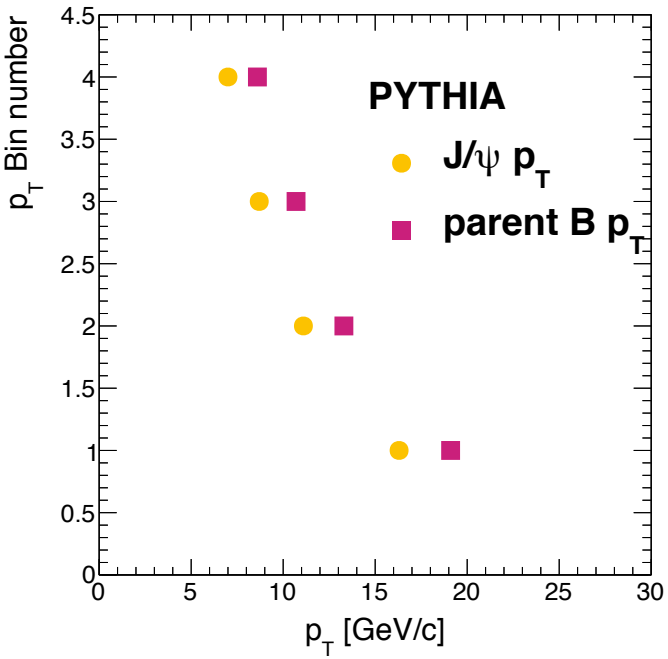


CMS PAS HIN-12-014

- All rapidity bins show centrality dependent suppression
- Low-p_T J/ψ is less suppressed than high-p_T J/ψ

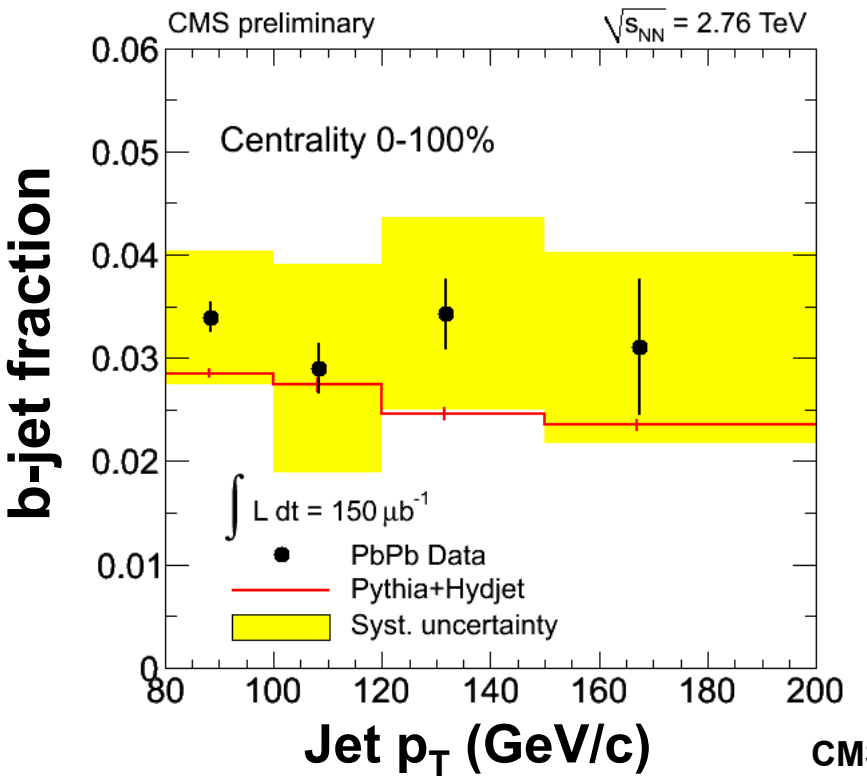
Non-prompt J/ψ R_{AA} comparison

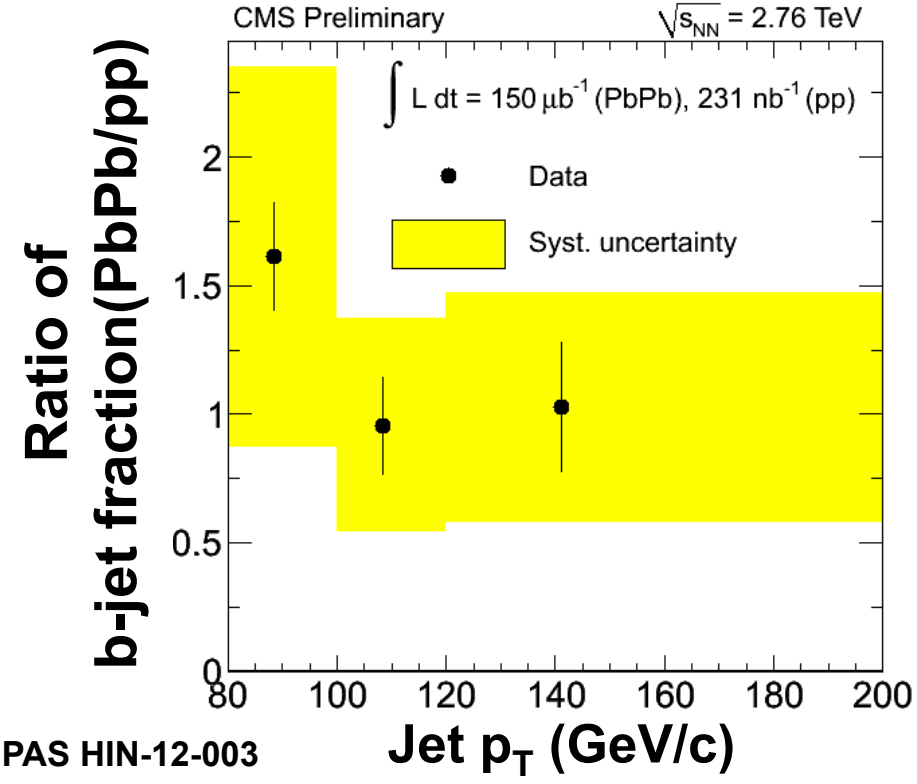




- R_{AA} of non-prompt J/ψ is described with theory calculations
  - Non-prompt J/ψ p_T for measurement and B p_T for theory curves

b-jets in heavy-ion collisions



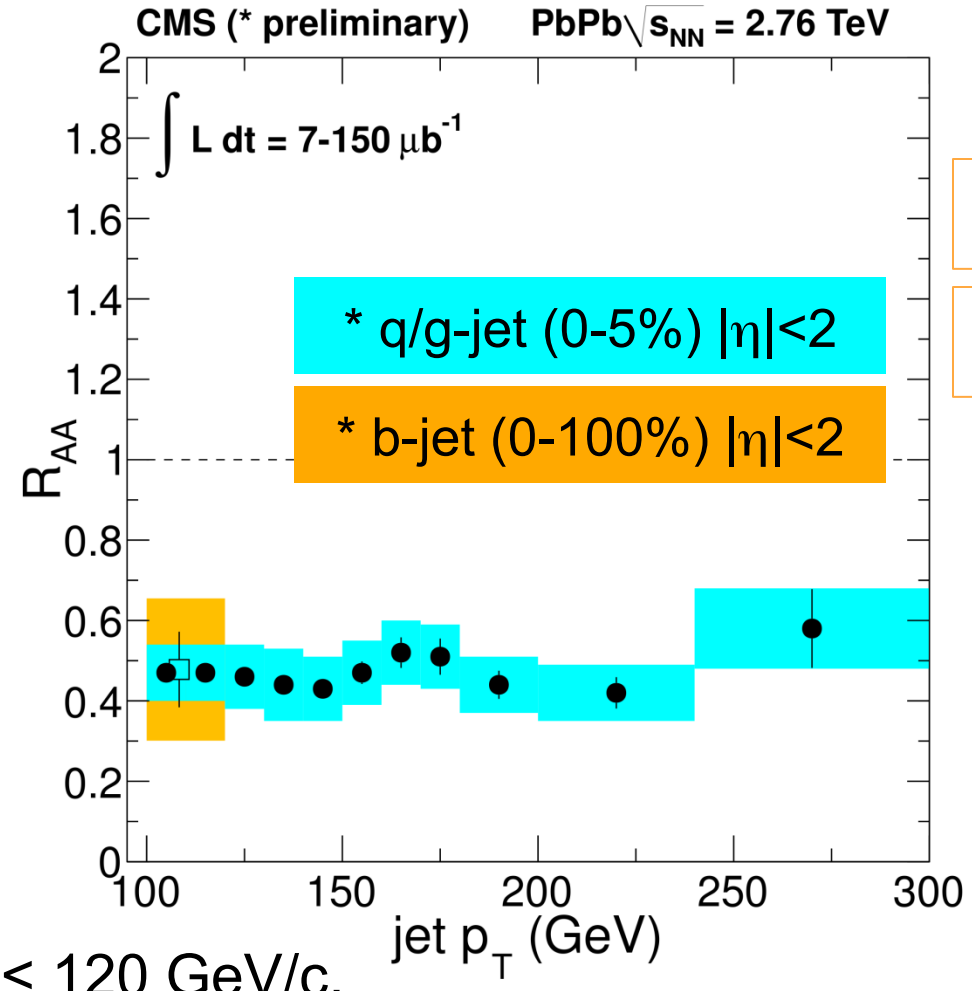


CMS PAS HIN-12-003

- Jets from b-quark fragmentation are identified for the first time in heavy ion collisions
  - Jets are tagged by their secondary vertices
  - b-quark contribution is extracted using template fits to their secondary vertex mass distributions

b-jets in heavy-ion collisions

CMS PAS HIN-12-003



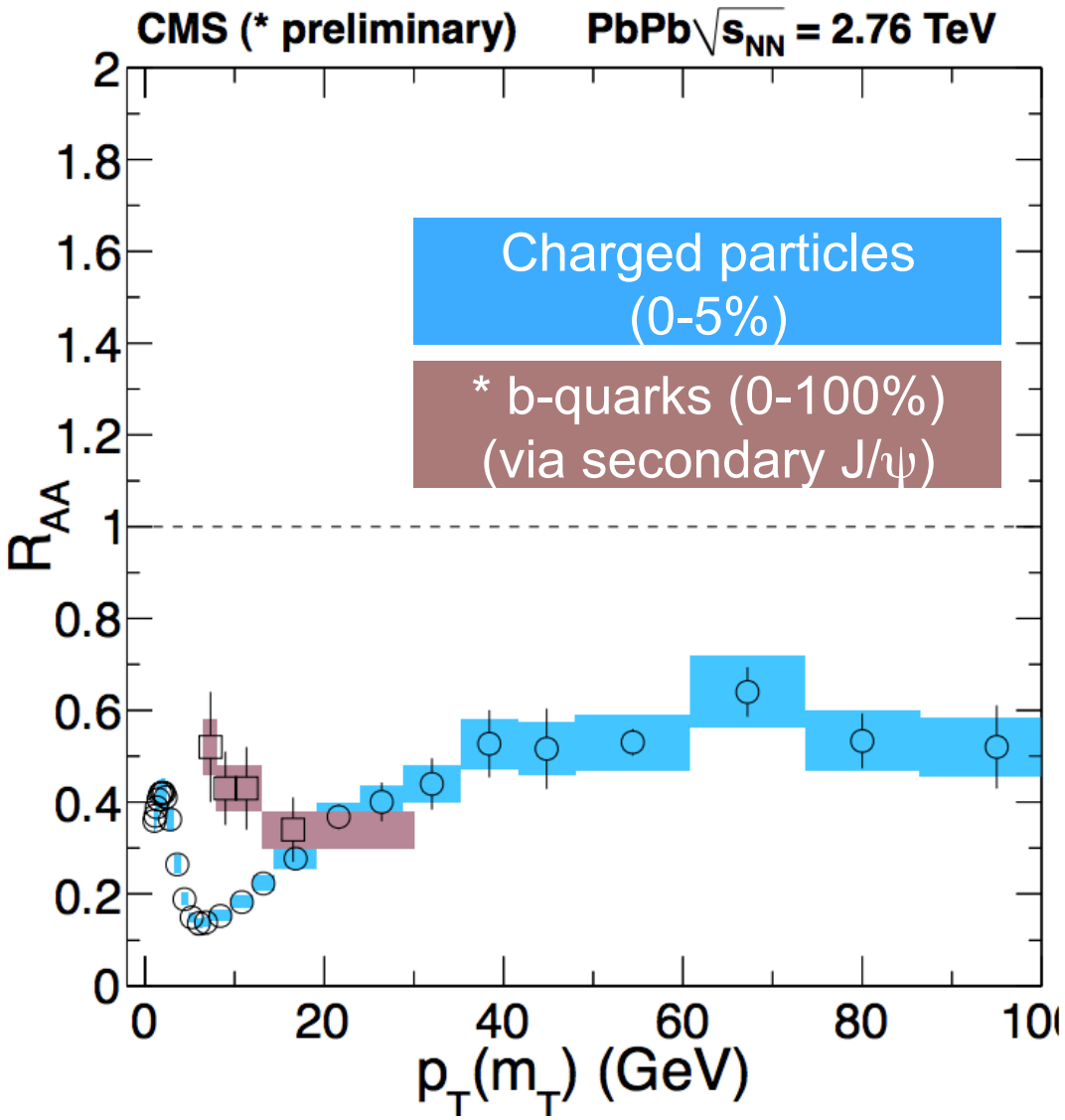
14 Aug, 16:45
Parallel 2B, M. Nguyen

18 Aug, 09:20
Flash talk, J. Robles

At 100 < jet p_T < 120 GeV/c,

- Inclusive jet R_{AA} = 0.50 ± 0.01(stat.) ± 0.06(syst.)
- b-jet R_{AA} = 0.48 ± 0.09(stat.) ± 0.18(syst.)

Summary



- Non-prompt J/ψ is suppressed in PbPb collisions
- Distinct b-quark suppression pattern at low p_T is observed
- b-jets at high-p_T shows similar suppression

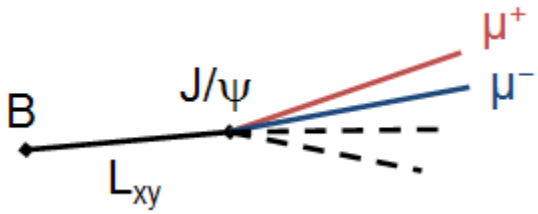
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN

BACK UP

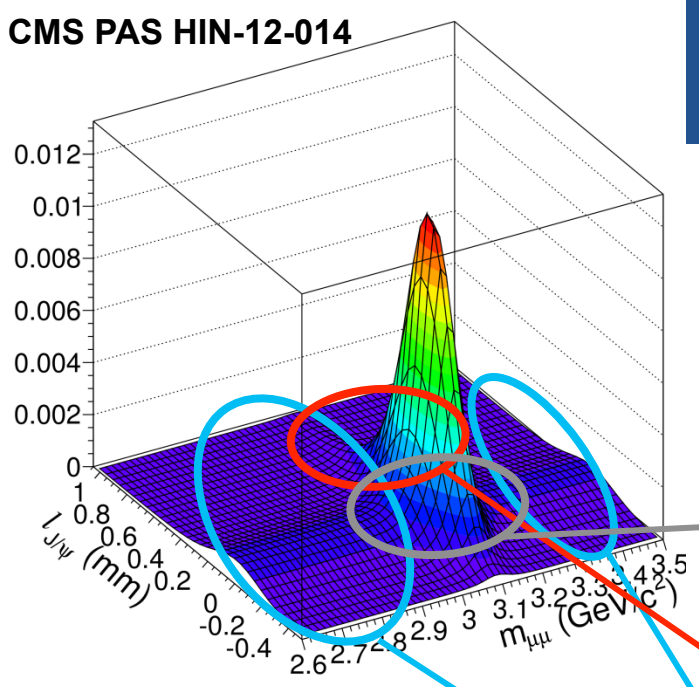
J/ψ separation

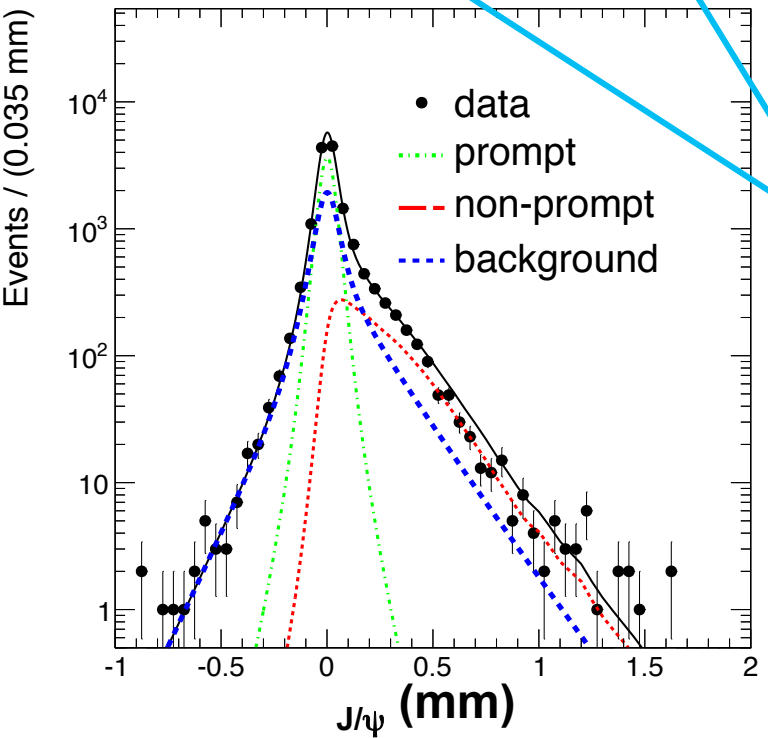
- L_{xy}: The most probable transverse b-hadron decay length in the laboratory frame
  - u: the unit vector in the direction of the J/ψ meson p_T
  - S: the sum of the primary and secondary vertex covariance matrices

$$L_{xy} = \frac{\hat{u}^T S^{-1} \vec{r}}{\hat{u}^T S^{-1} \hat{u}} \qquad \ell_{J/\psi} = L_{xy} \frac{m_{J/\psi}}{p_T}$$



Signal Extraction in PbPb





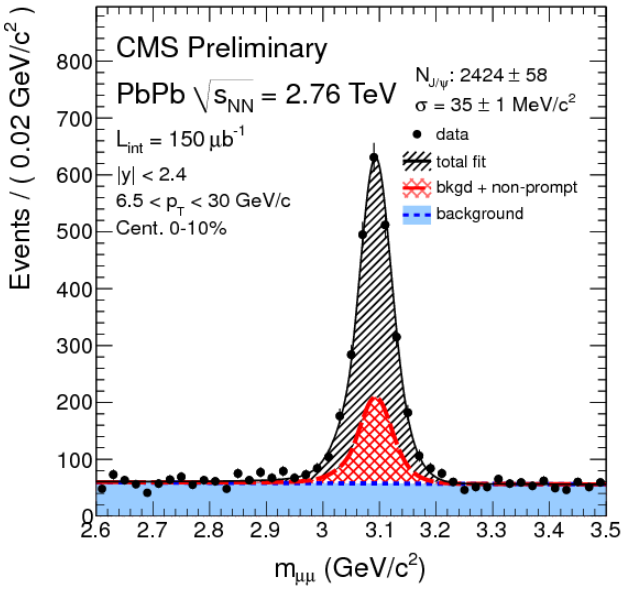
- Dimuon **mass** distributions consist of
  - **Signal shape**: Crystal Ball + Gaussian
  - **Background shape**: Exponential
- Dimuon $\ell_{J/\psi}$ distributions consist of
  - **Prompt J/ψ component**

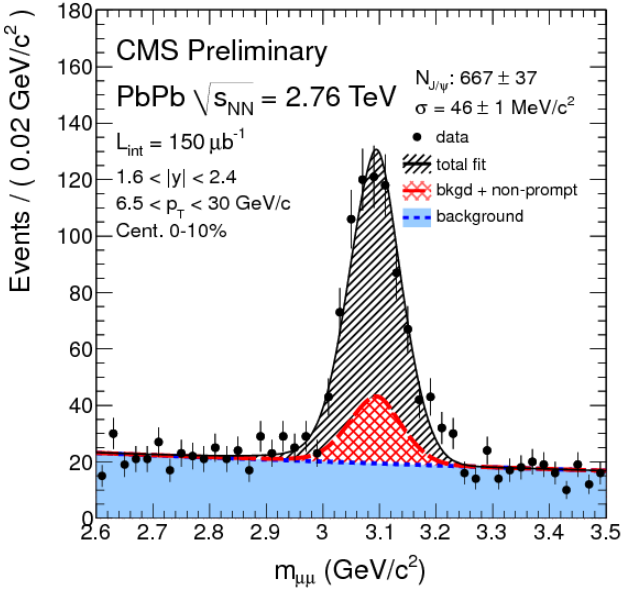
    Prompt J/ψ MC template modeled with resolution function includes the event-by-event uncertainty of $\ell_{J/\psi}$
  - **Non-prompt J/ψ component**

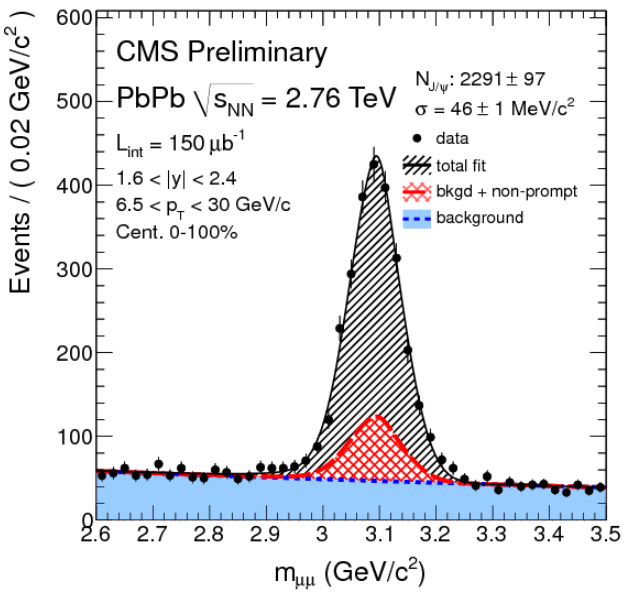
    Non-prompt J/ψ MC template $\ell_{J/\psi}$ distribution as a shape
  - **Background component**

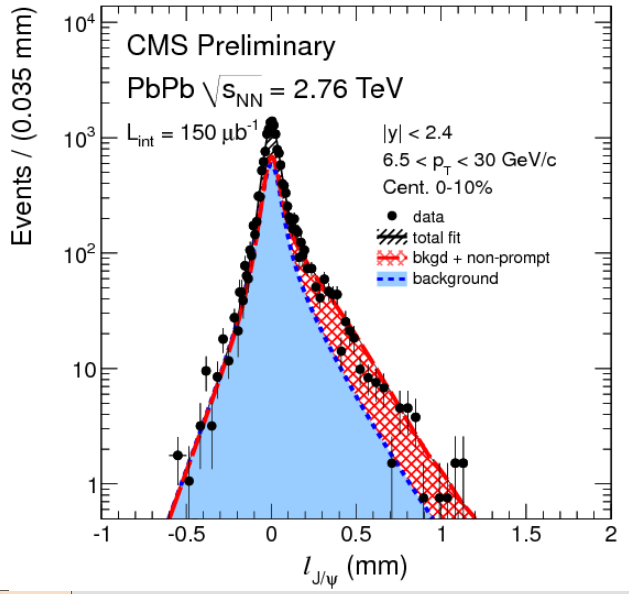
    Fit events in mass sidebands to sum of 3 exponential decay functions

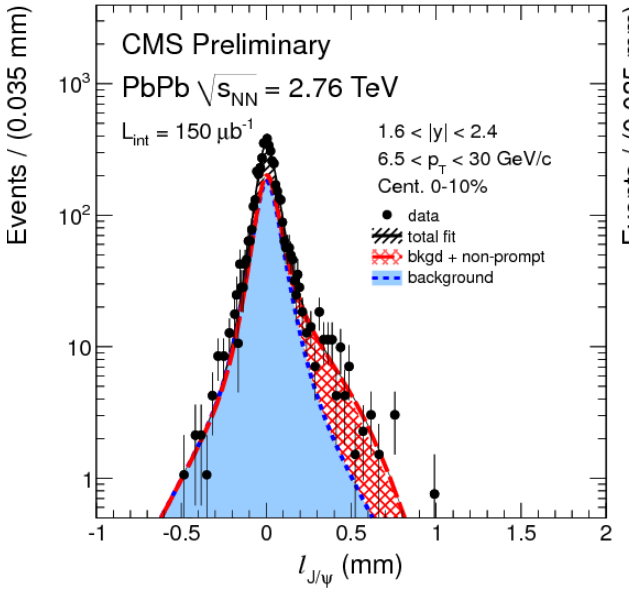
Signal Extraction

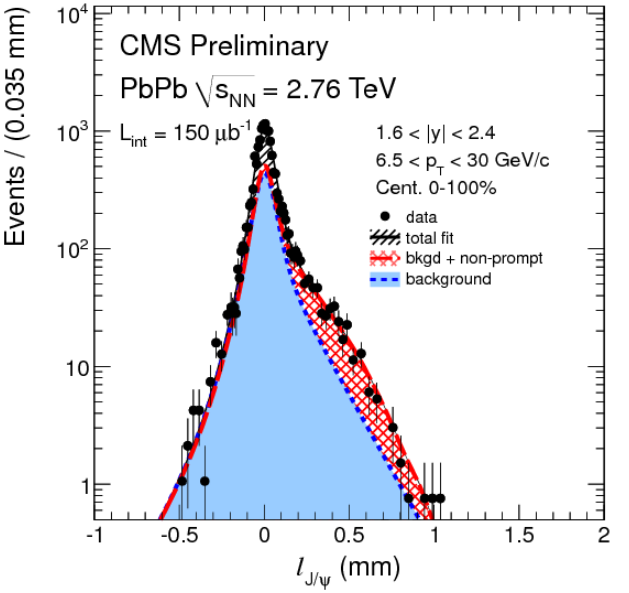




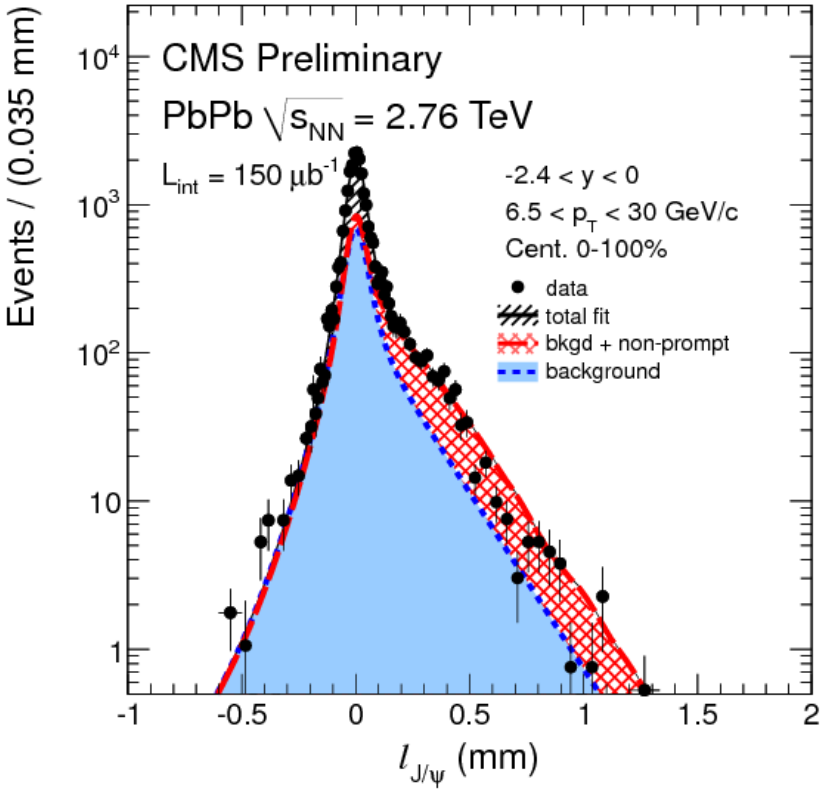




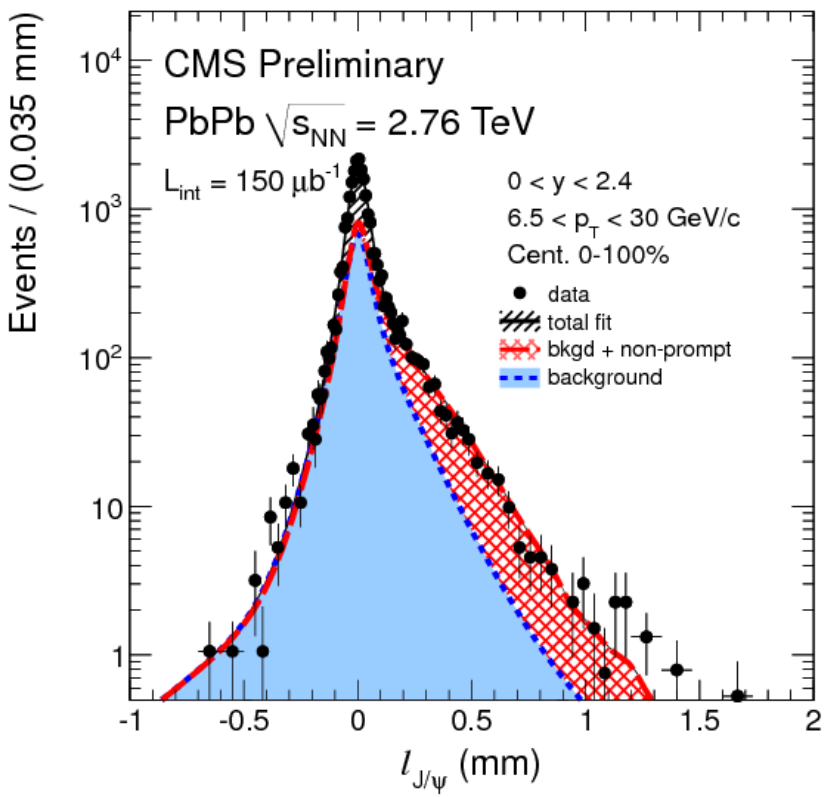




Signal Extraction in separated rapidity



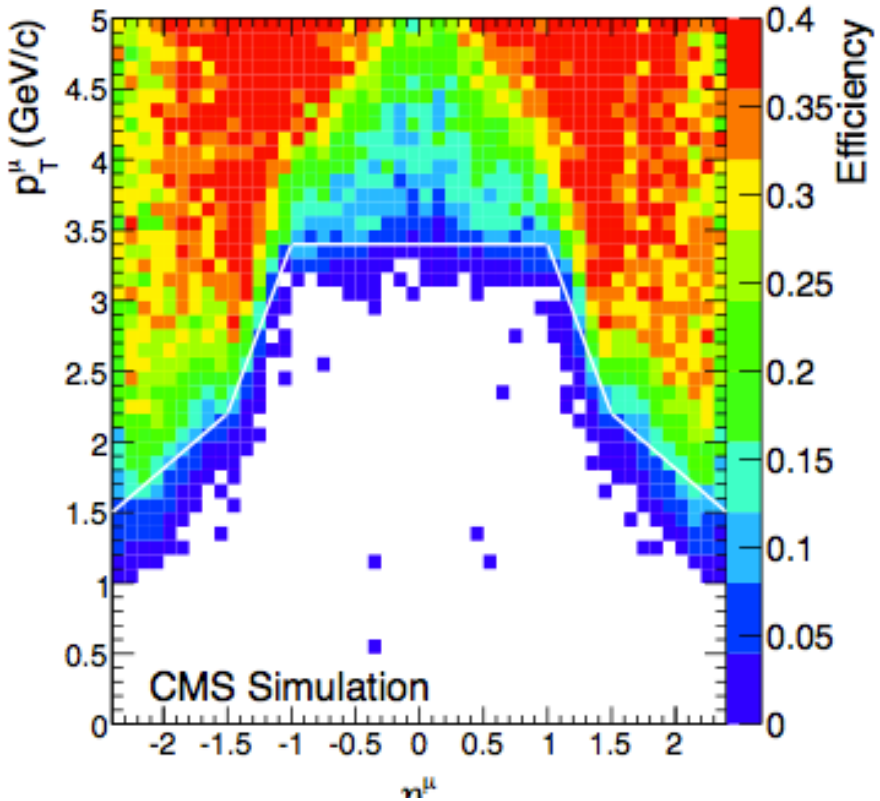
B-fraction = 0.233 ± 0.008



B-fraction = 0.234 ± 0.009

- Poor pseudo-proper decay length distribution originates from y<0
  - B-fraction does not affected

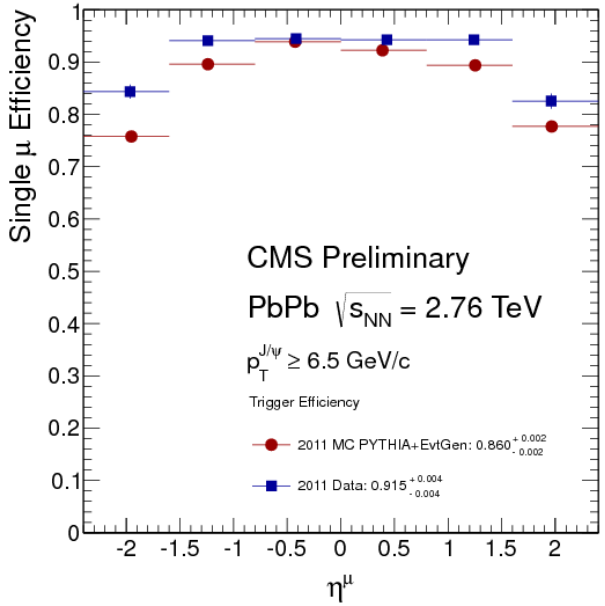
Single muon acceptance

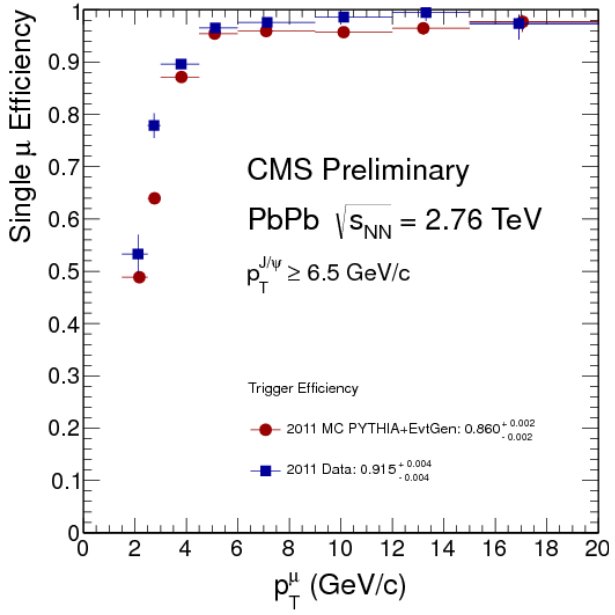


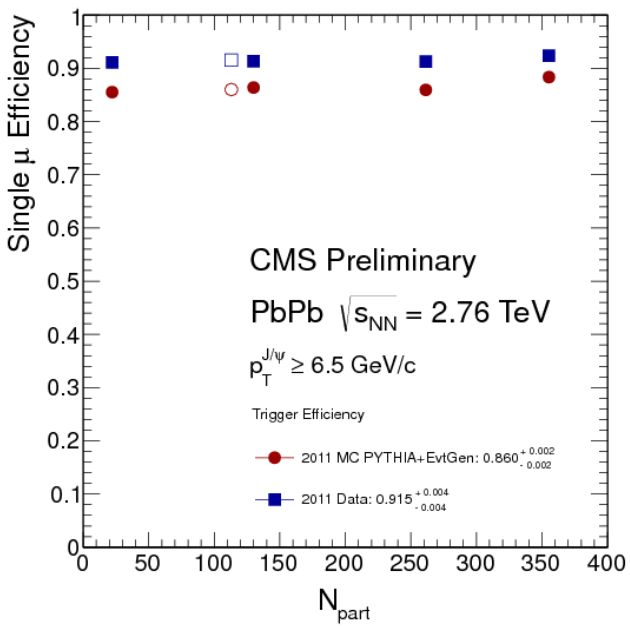
$$p_T^\mu > 3.4\,\text{GeV}/c \quad \text{for } |\eta^\mu| < 1.0,$$
$$p_T^\mu > (5.8 - 2.4 \times |\eta^\mu|)\,\text{GeV}/c \quad \text{for } 1.0 < |\eta^\mu| < 1.5,$$
$$p_T^\mu > (3.4 - 0.78 \times |\eta^\mu|)\,\text{GeV}/c \quad \text{for } 1.5 < |\eta^\mu| < 2.4.$$

Trigger efficiency correction

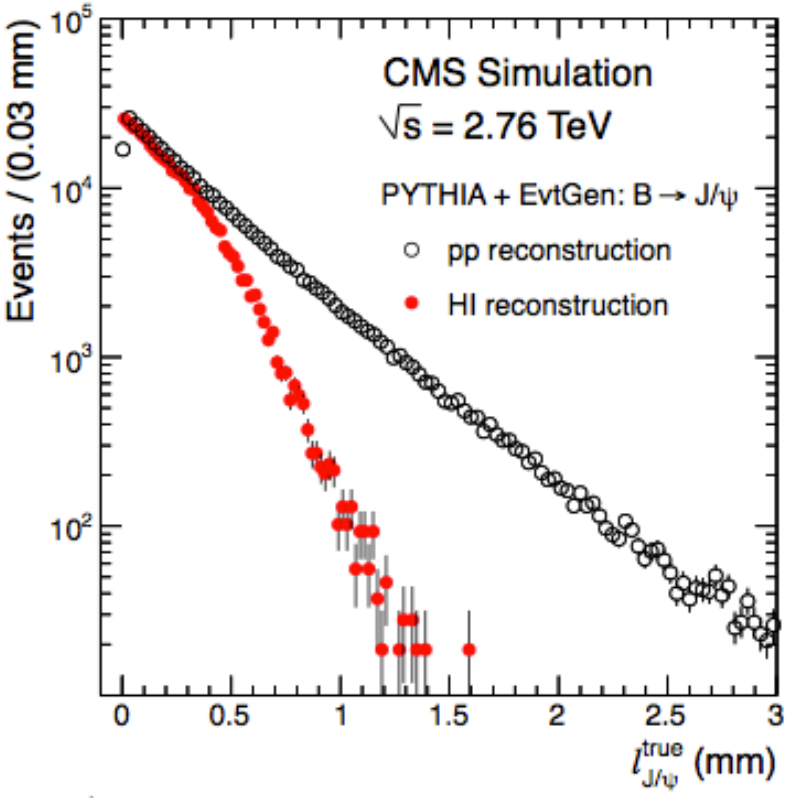
- Different dimuon trigger was used in 2011 PbPb collisions because of High luminosity
- Difference between MC and data is corrected with Tag & Probe method

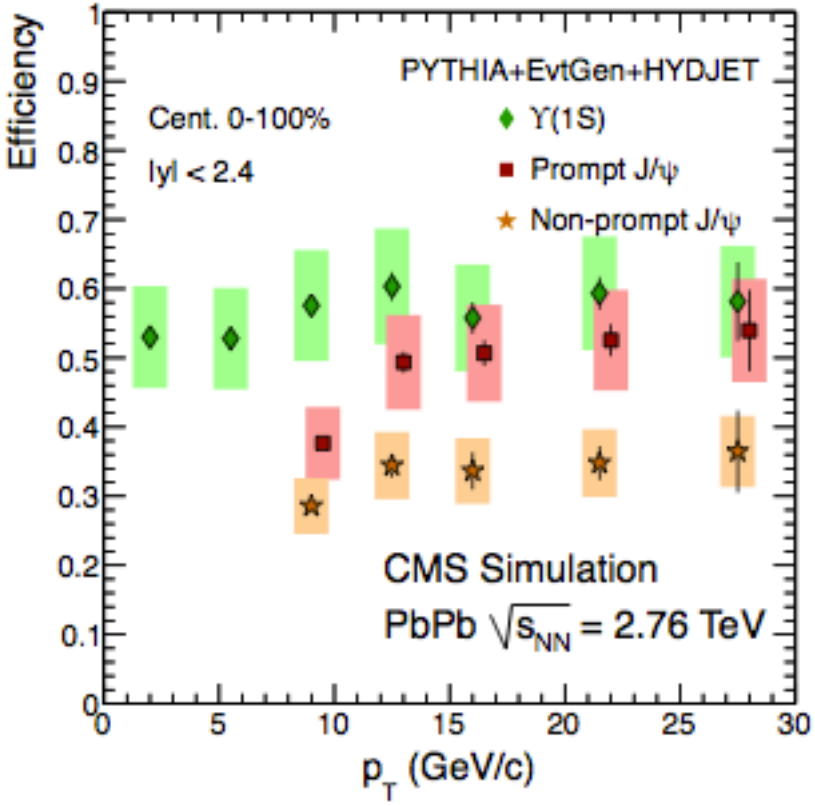






Reconstruction Efficiency





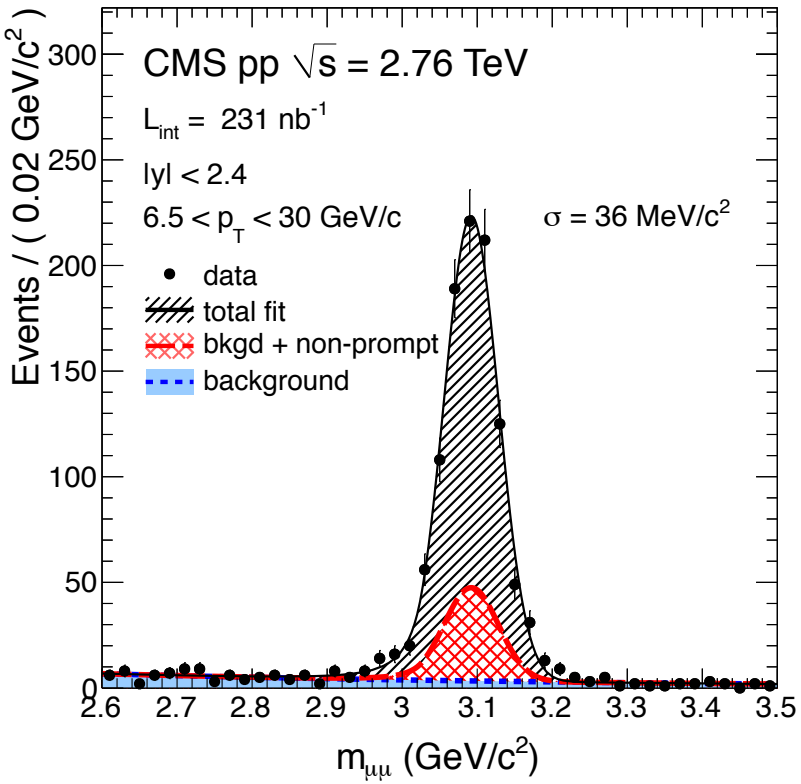
Systematic Uncertainties

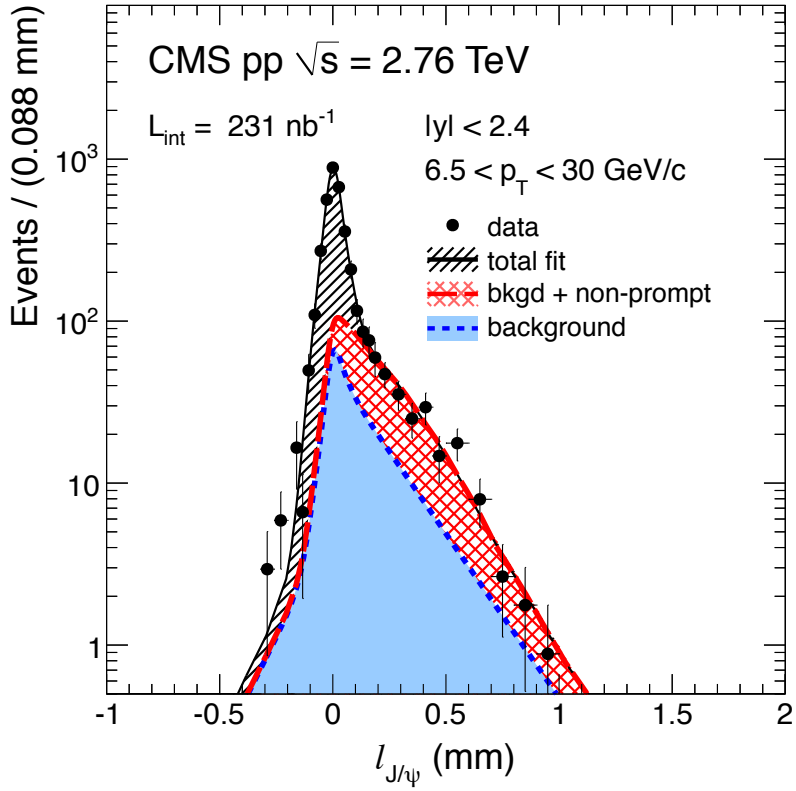
- Signal extraction
  - Mass distribution
    - Alternative shapes for signal, backgrounds are tested
    - Uncertainties of fixed parameters are tested
  - Pseudo-proper decay length distribution
    - Alternative shapes for resolution functions
- Efficiency
  - Tag & probe method for reconstruction efficiency validation
  - Tag & probe method for trigger efficiency correction

	prompt J/ψ (%)	non-prompt J/ψ (%)
PbPb yield extraction	0.2–1.7	0.6–4.5
pp yield extraction	0.3–1.6	1.7–8.4
$\mathrm{T\&P}^{recoValidation} * (1 - \epsilon_{\mathrm{PbPb}}/\epsilon_{\mathrm{pp}})$	1–9	1–10
$\mathrm{T\&P}^{triggerCorrection}$	10	10
T_{AA}	4.1–18	4.3–15
Total	10.8–23	11.1–22.7

pp reference for R_{AA}

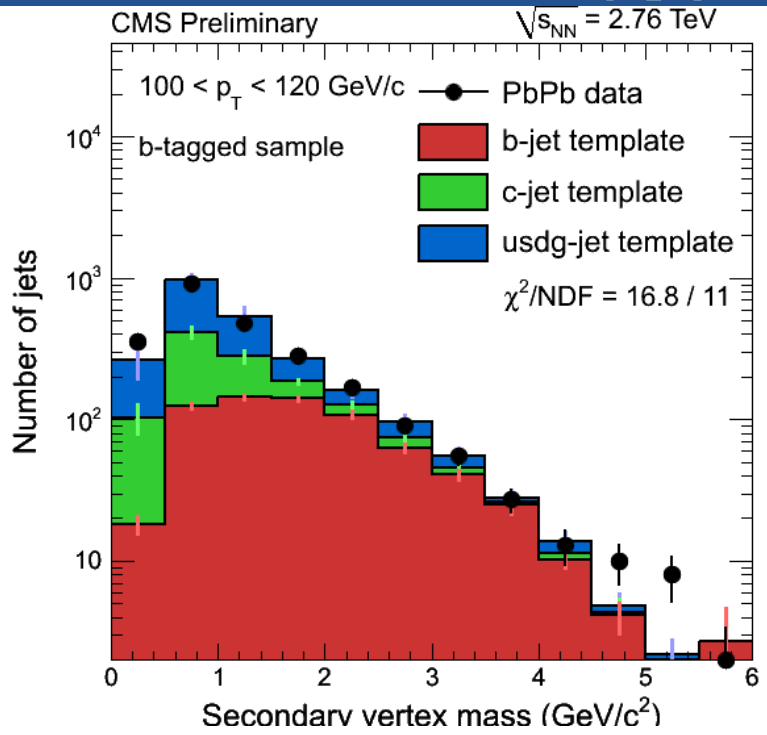
CMS collaboration, JHEP 1205 (2012) 063



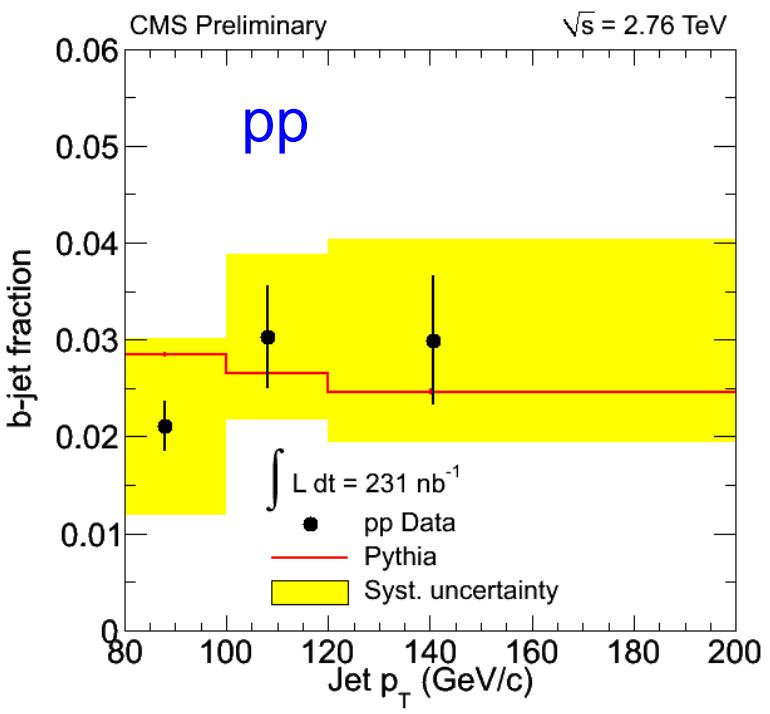


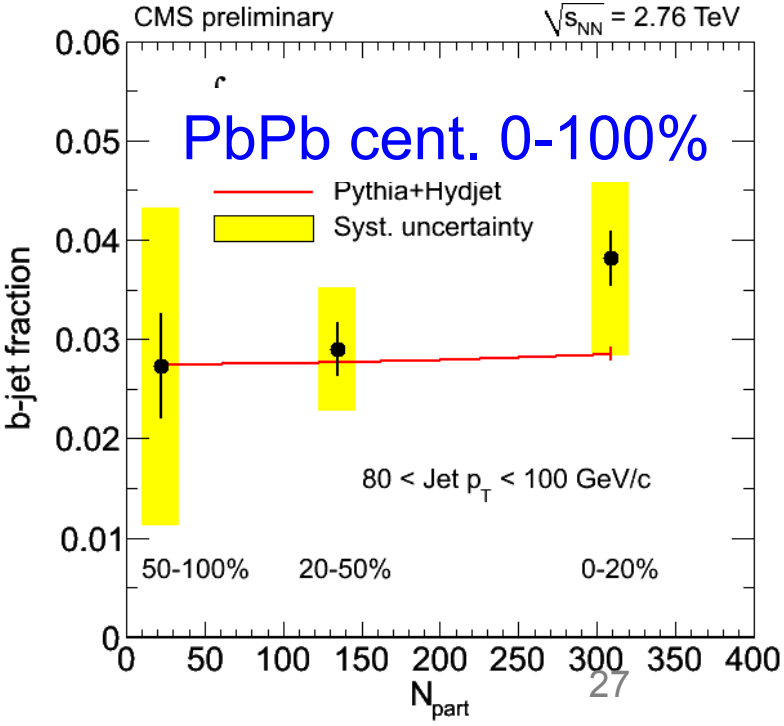
- 231 nb^{-1} data reconstructed by heavy-ion algorithm
- Different trigger condition (HLT_L1DoubleMu0 – slightly higher quality)
- Same acceptance and efficiency condition as heavy-ion analysis

b-jet R_{AA}



100 < p_T < 120 GeV/c





CMS PAS HIN-12-003