Prompt J/ψ in the CMS Experiment

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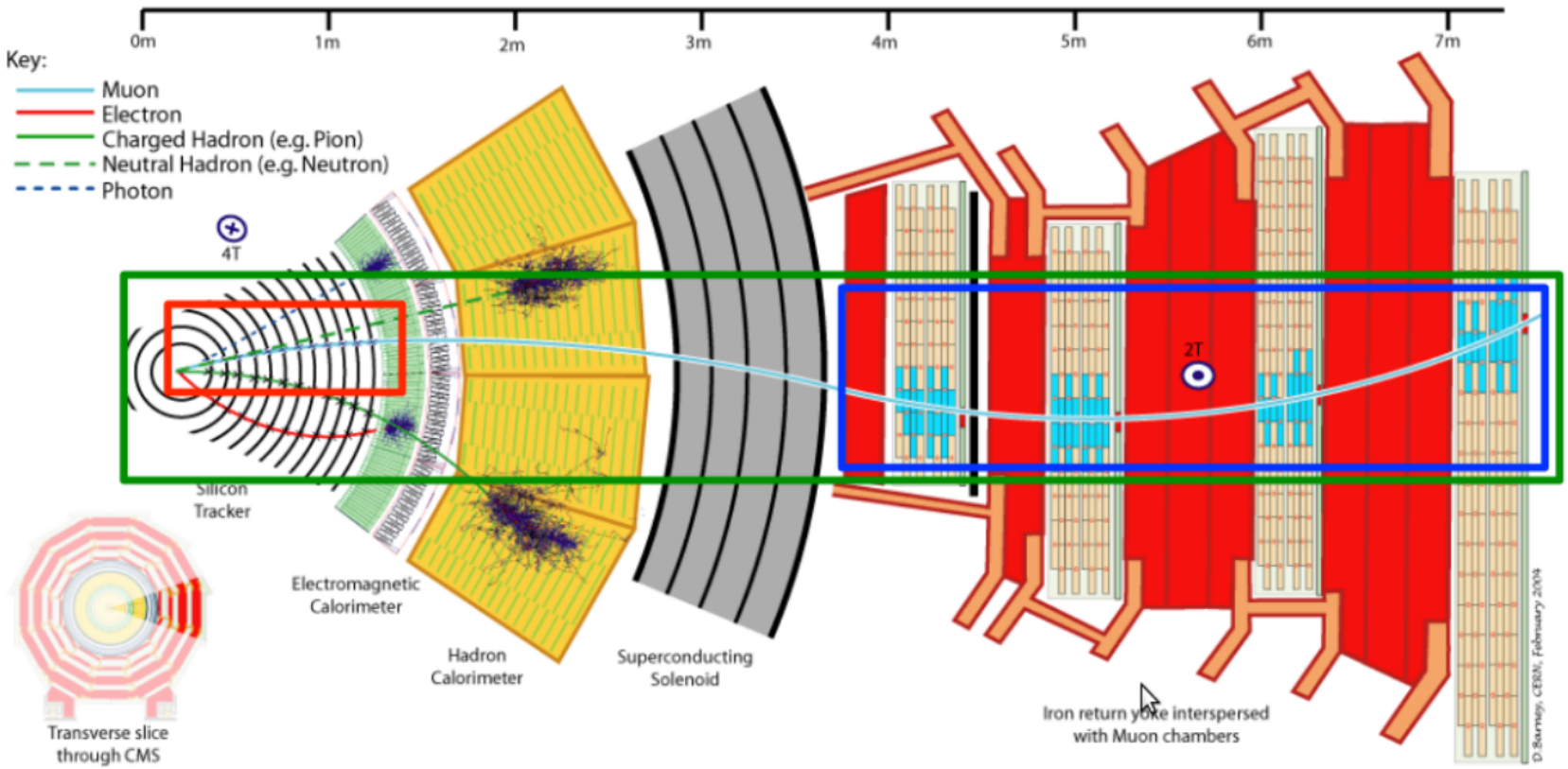
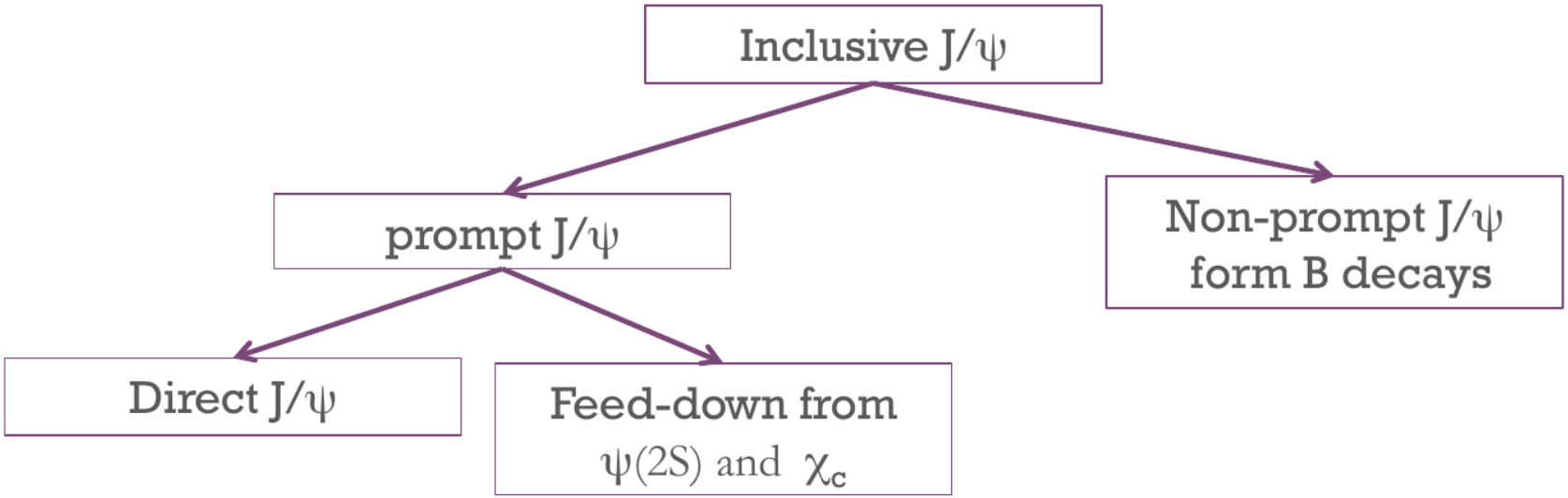
Sept. 15-18, 2014

Muons in CMS



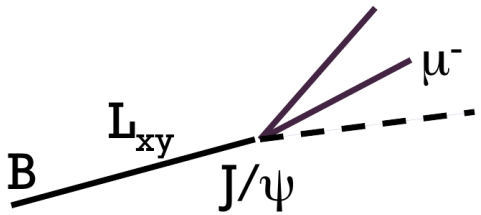
- Excellent muon momentum resolution
  - Combination of muon detectors and inner silicon tracking (1-2% momentum resolution up to p_T 100 GeV)
- J/ψ acceptance
  - In PbPb: mid-y ($p_T > 6.5$ GeV) and forward Y ($p_T > 3$ GeV)
  - In pp and pPb: goes down to $p_T = 0$ GeV at forward rapidity with softer muon ID

Prompt vs non-prompt J/ψ



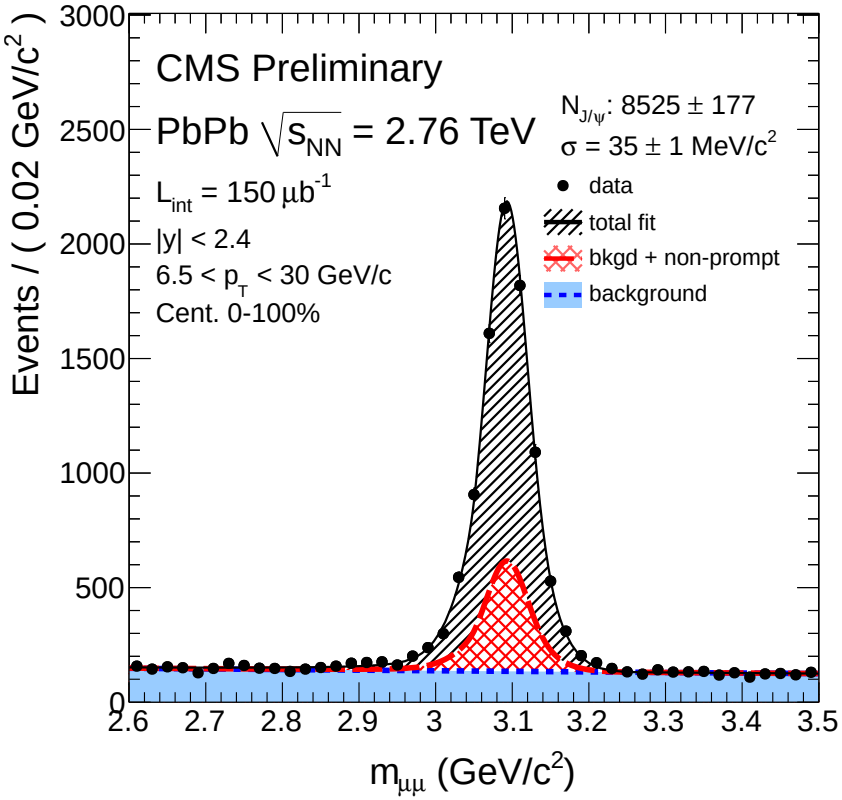
- Long B lifetime ($c\tau \sim 500\,\mu m$)
- $B \to J/\psi$ characterized by displaced muon tracks in the silicon tracker.
- Base on the b-hadron pseudo-proper decay length $\ell_{J/\psi}$:

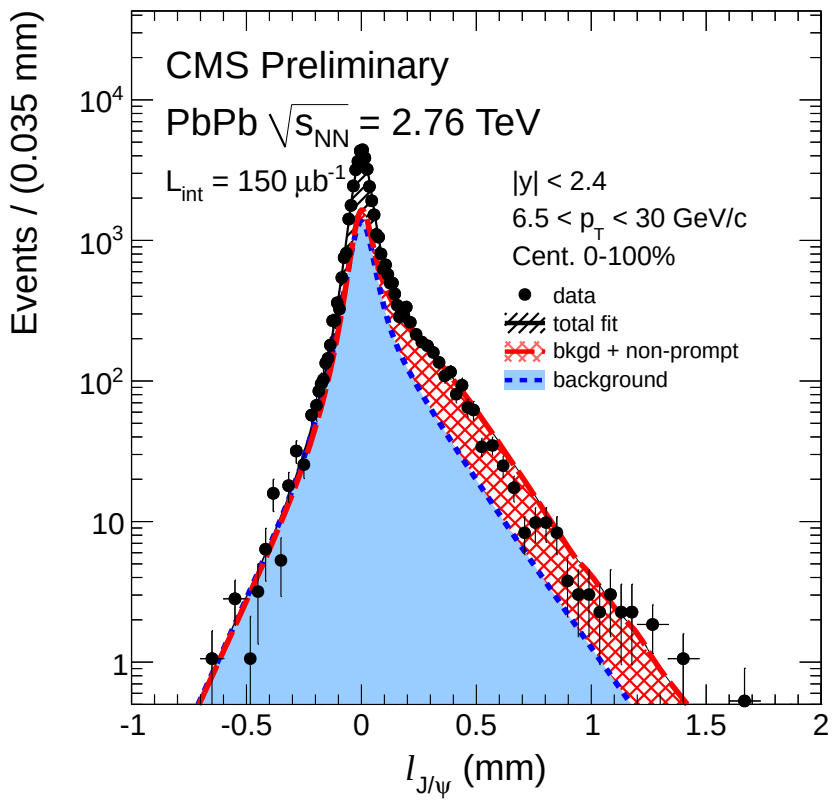
$$\ell_{J/\psi} = L_{xy} \frac{m_{J/\psi}}{p_T}$$



Kinematics

CMS-HIN-12-014





- Simultaneous fit of the dimuon mass $m_{\mu\mu}$ and the pseudo-proper decay length $\ell_{J/\psi}$.

Prompt J/ψ in PbPb: nuclear modification factor

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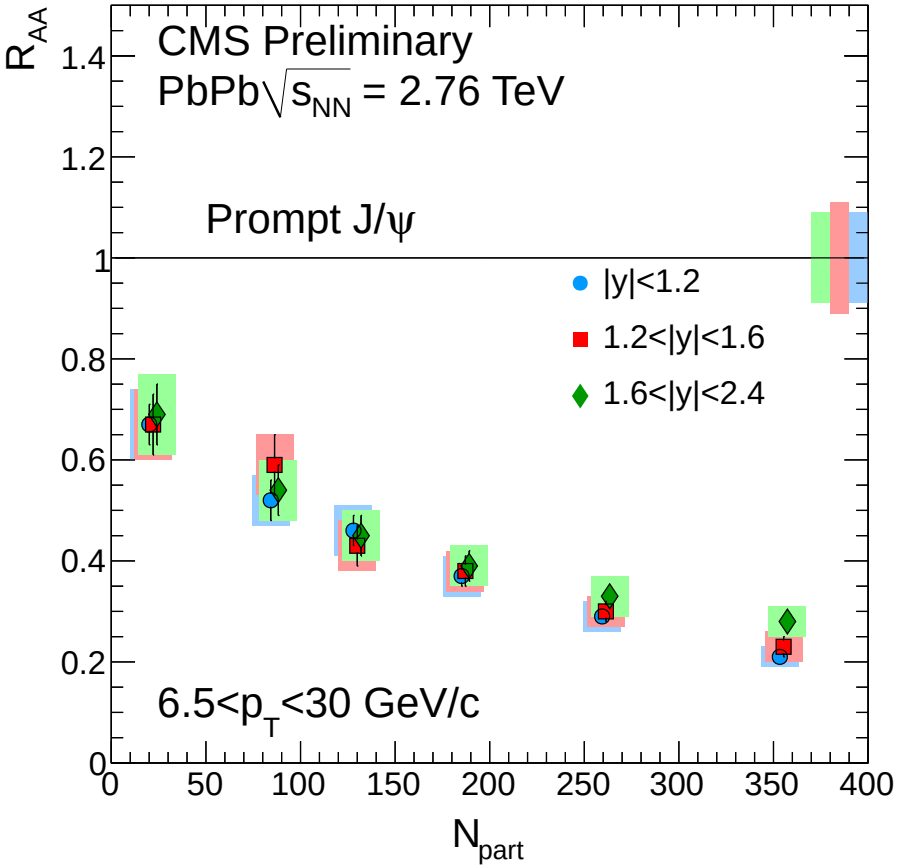
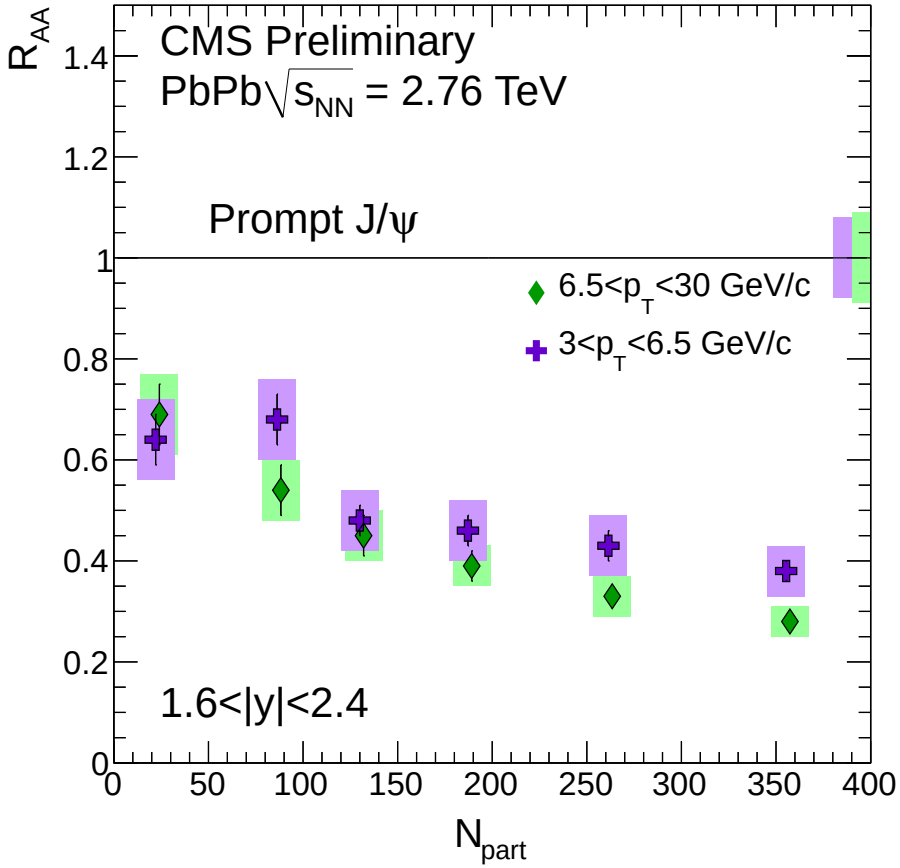




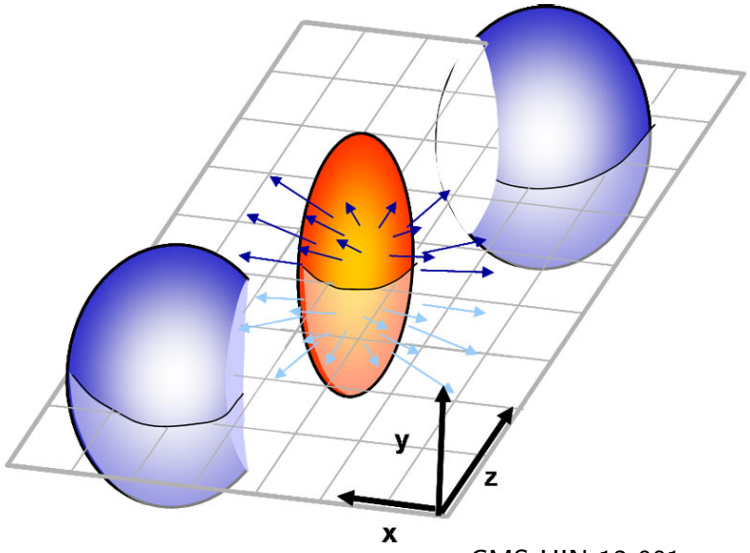
- $p_T > 3\,\mathrm{GeV}/c$ ($p_T > 6.5\,\mathrm{GeV}/c$ for $|\eta| < 1.6$).
- No dependence on rapidity.
- Slightly more suppression at high p_T.
- Factor up to ~ 5 suppression in most central events.

v_2 definition

- Asymmetric particle production w.r.t. the event plane because of pressure gradients.

$$\frac{1}{N}\frac{dN}{d\phi} \sim 1 + 2 \times v_2 \cos(2(\phi - \psi)) + \ldots$$

- Connected with the dynamics of the hot medium.
- J/ψ: correlation with regeneration.



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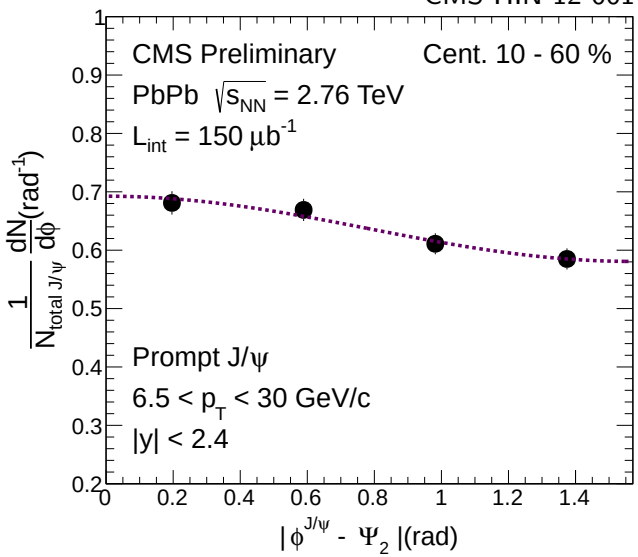
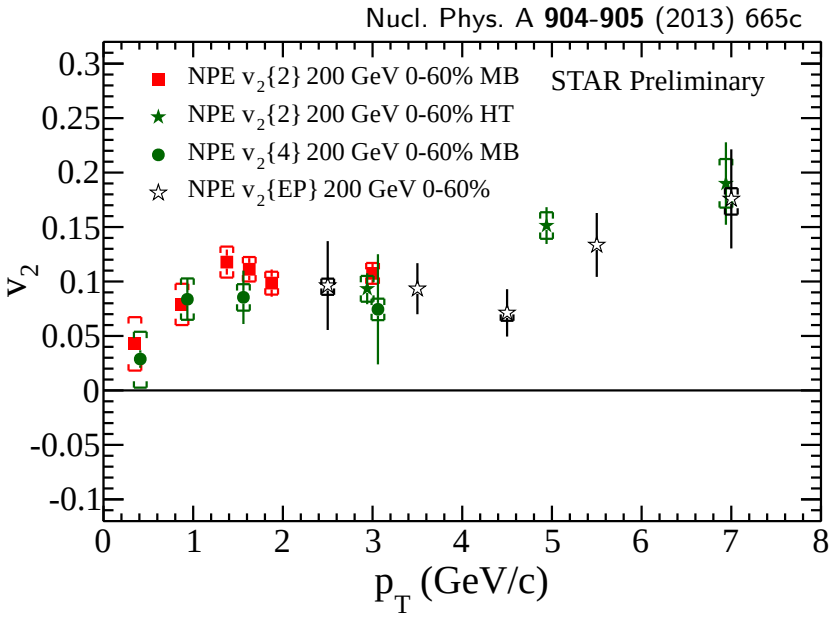
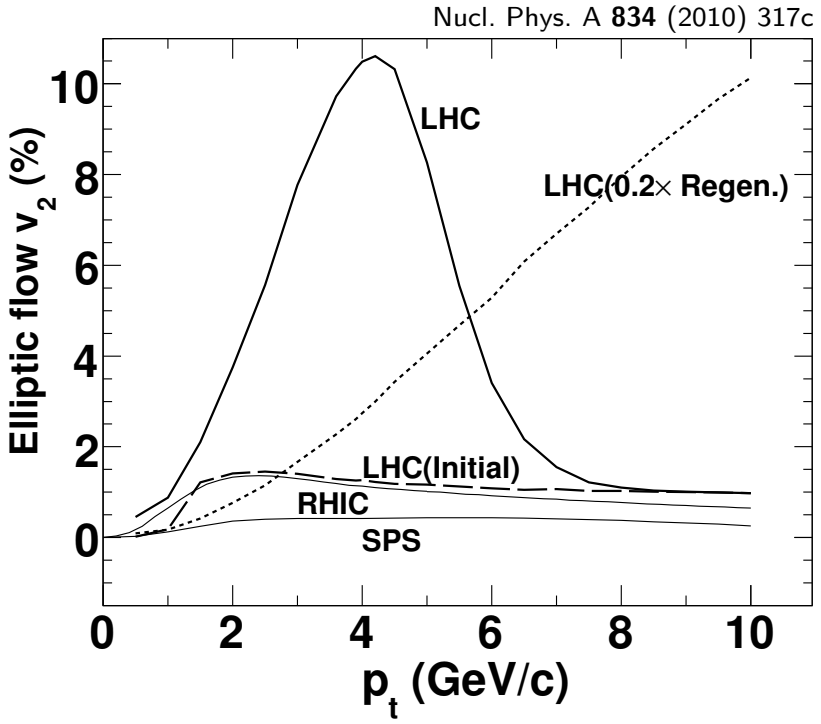


Theory / RHIC / prediction

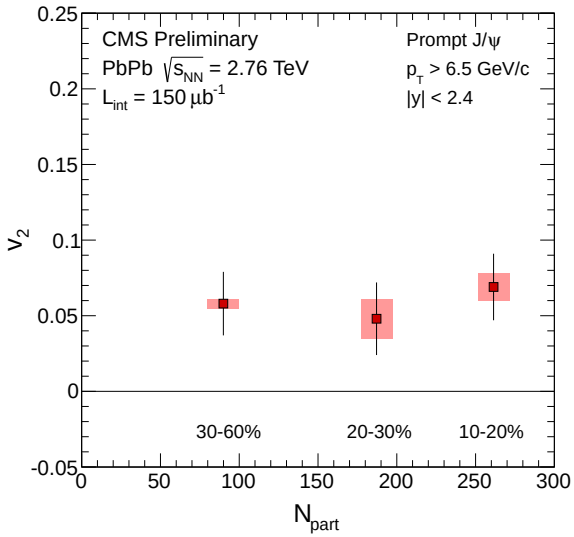


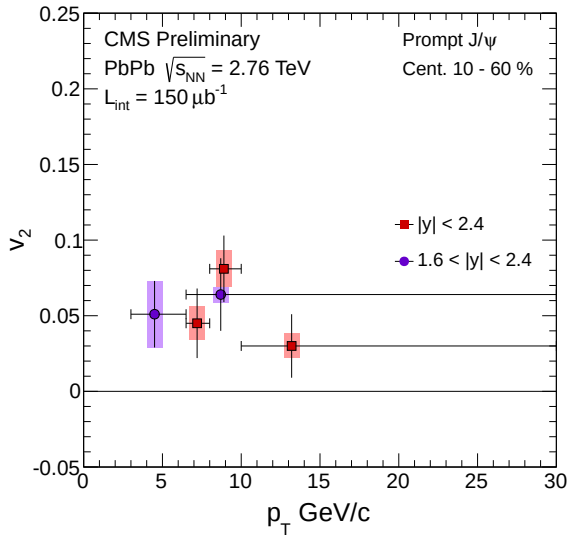


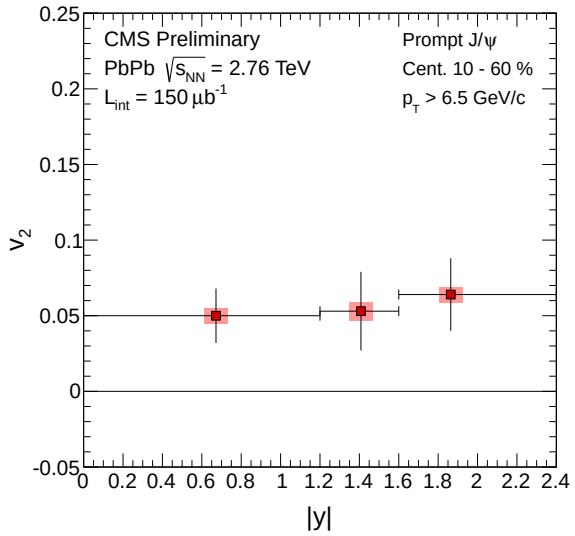
- Charm quarks flow as can be seen from the v_2. Strong indication of some form of thermalized charm
  - If there is (re)generation of J/ψ they should inherit this flow as well
  - In contrast to primordial J/ψ that survived the QGP phase, J/ψ v_2 should discriminate between (re)generated J/ψ and primordial J/ψ

v_2 results

CMS-HIN-12-001







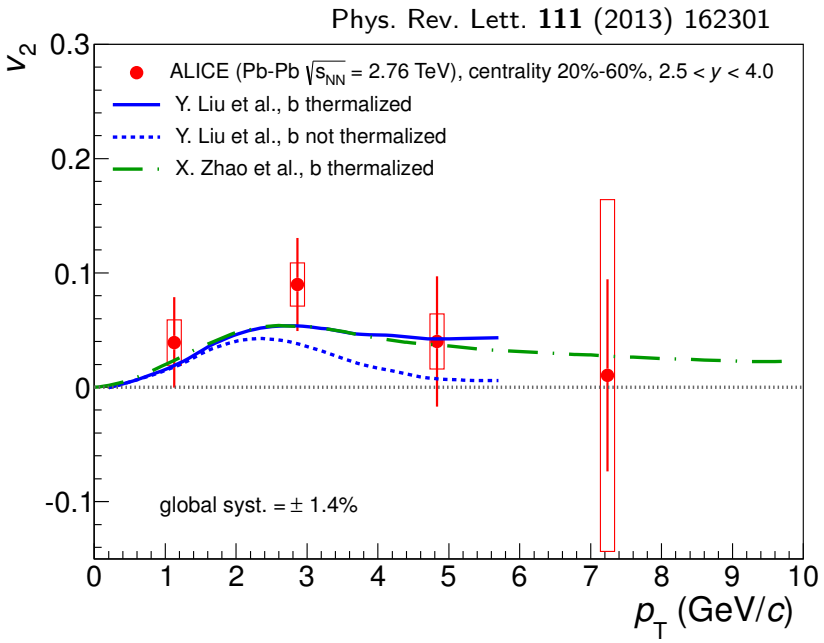
Significant non-zero v_2

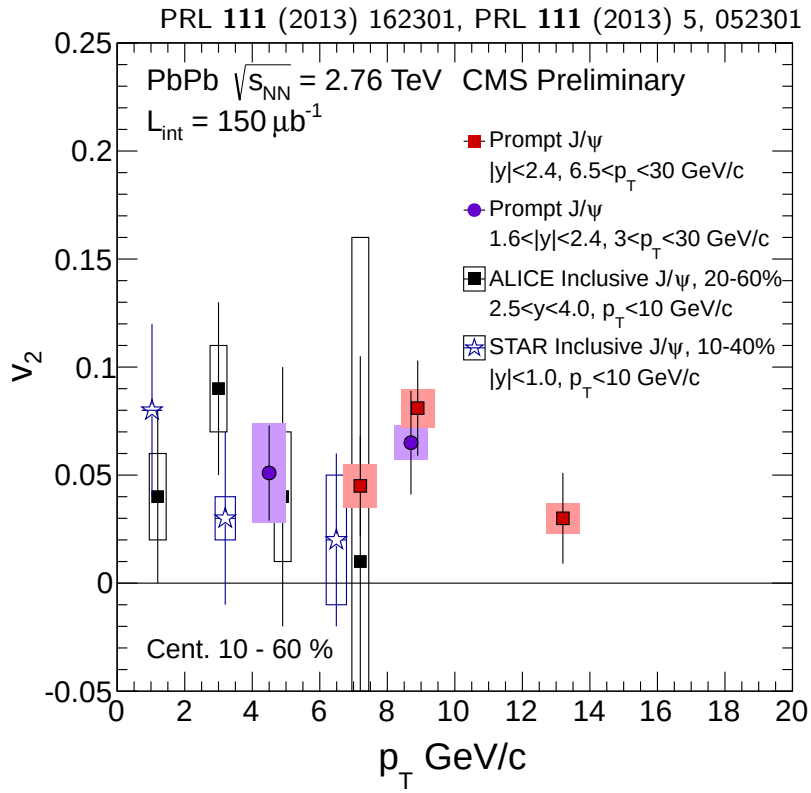
$$v_2(p_T > 6.5\,\mathrm{GeV}/c,\ |y| < 2.4,\ 10-60\%) = 0.054 \pm 0.013 \pm 0.006\ (3.8\sigma)$$

- No strong dependence on centrality, p_T or rapidity.

Comparison with ALICE

CMS-HIN-12-001

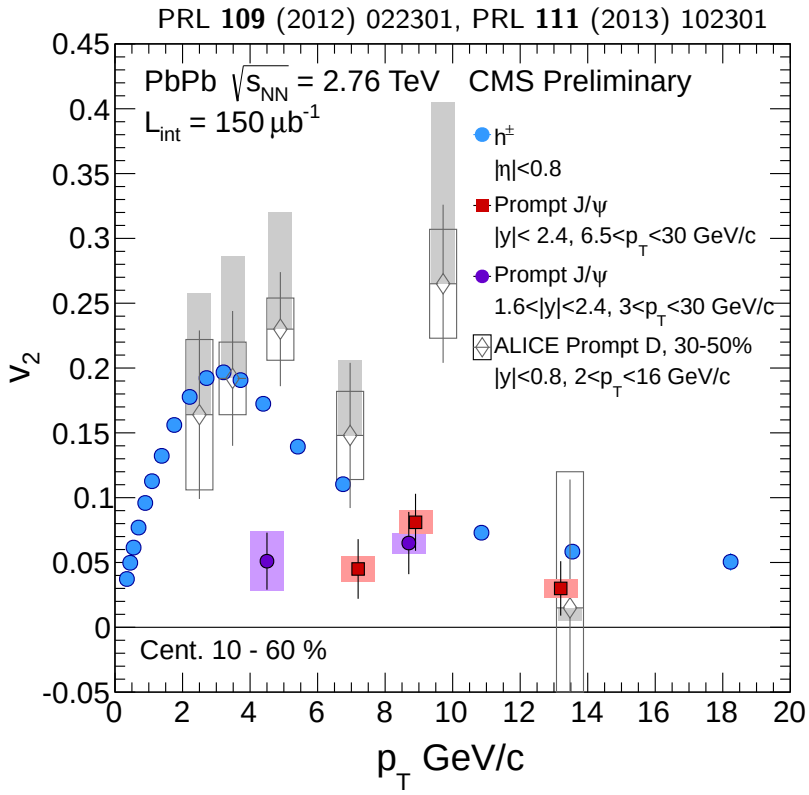




- Confirm non-zero J/ψ v_2.
- Extend to high p_T region ($6.5 < p_T < 30\,\mathrm{GeV}/c$).
- No significant dependence on p_T in CMS data.

Comparison to charged hadrons and D mesons

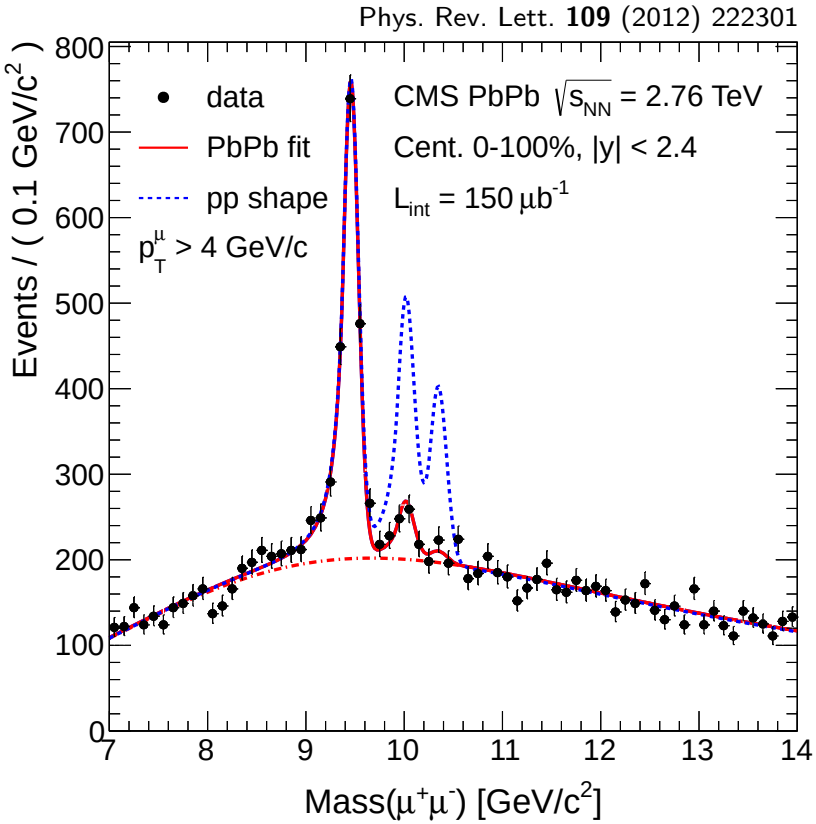
CMS-HIN-12-001



- low p_T: v_2(light quark) $\approx$ v_2(open c) $>$ v_2(closed c)
- high p_T: v_2(light quark) $\approx$ v_2(open c) $\approx$ v_2(closed c)
  - pure path-length dependence?

Excited states suppression in PbPb

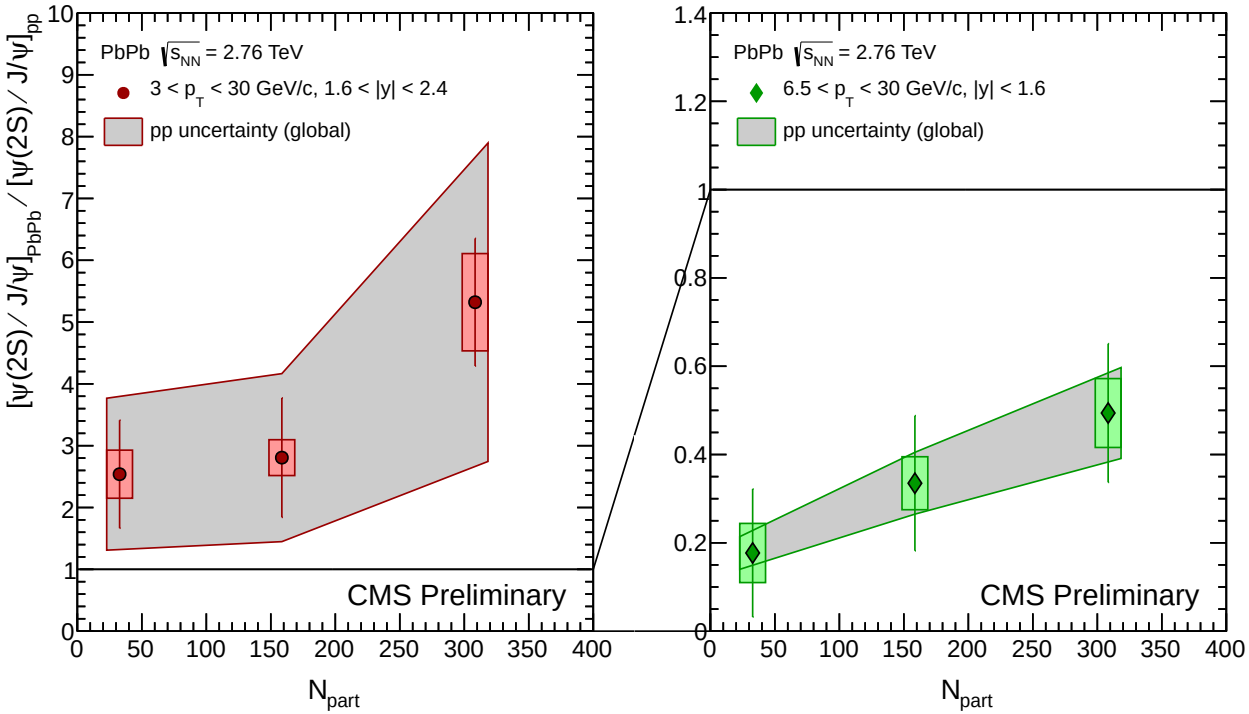
Observed stronger suppression of excited states than ground state in bottomnia measurement. What about charmonia ?



R_{AA} of $\Upsilon(1S) > \Upsilon(2S) > \Upsilon(3S)$

Previous $\psi(2S)$ results

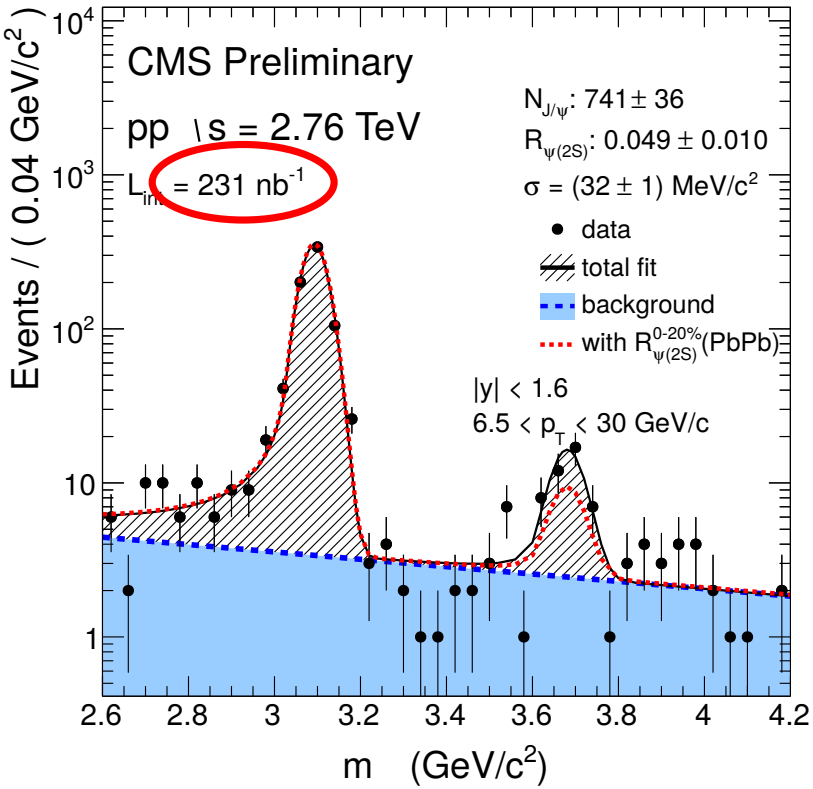
CMS-HIN-12-007

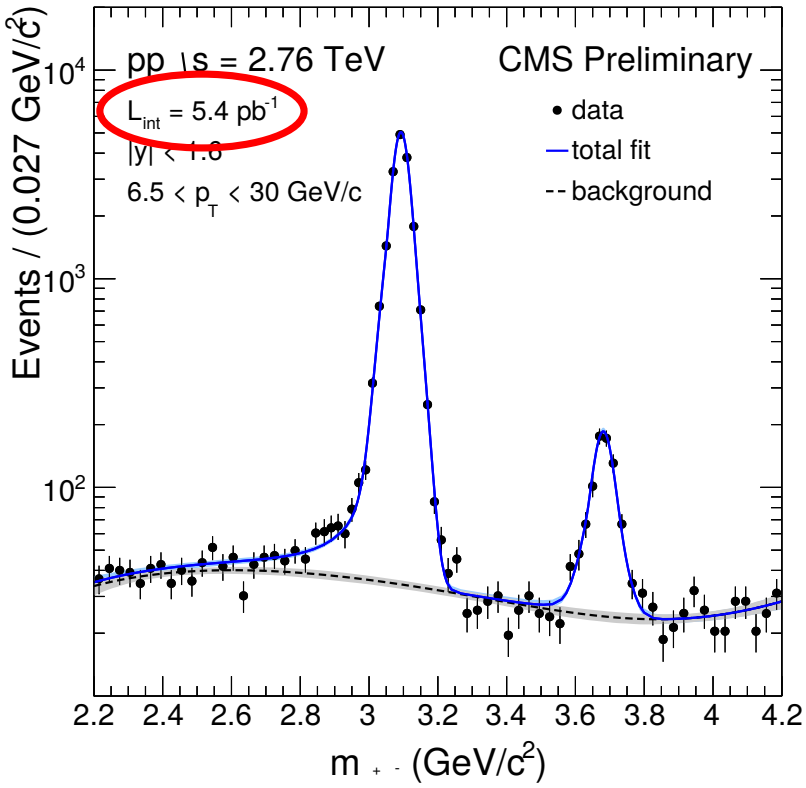


- Double ratio of inclusive $\psi(2S)$ to J/ψ
- Stronger suppression of $\psi(2S)$ than J/ψ in mid-rapidity and high p_T (as predicted from sequential melting)
- Hint of $\psi(2S)$ enhancement relative to J/ψ in central PbPb at low p_T and forward rapidity, however, severely limited by large pp uncertainty

More pp data

CMS-HIN-12-007

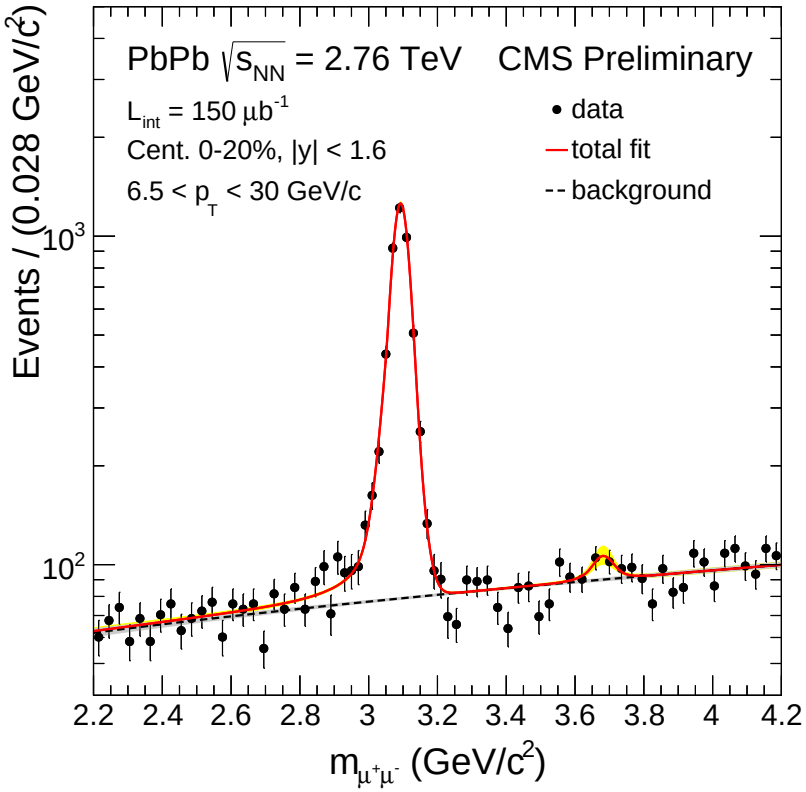


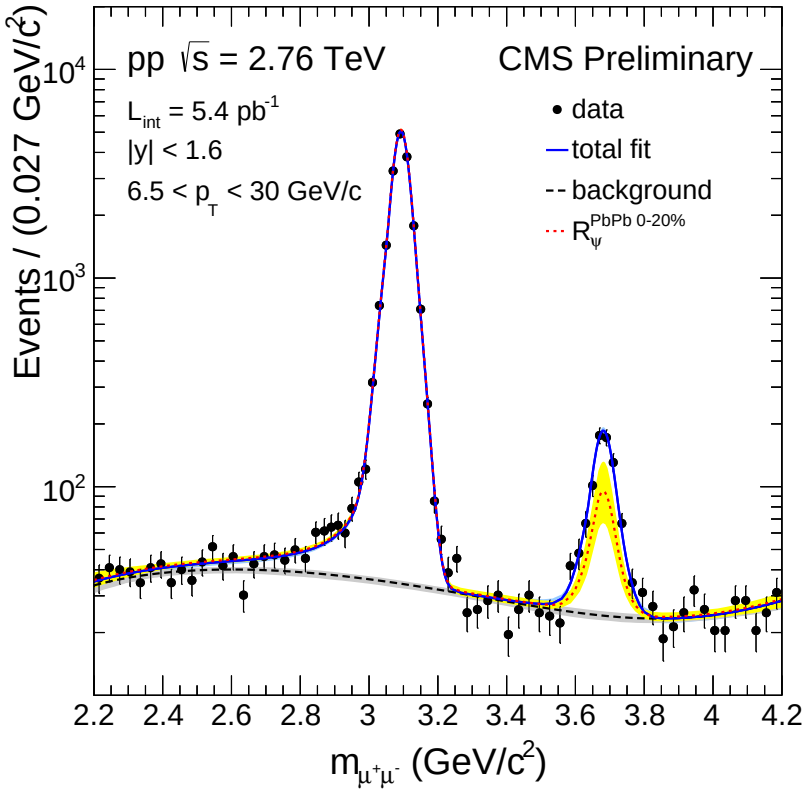


- Thanks to pp run in 2013: $\sim$ 20 times larger data sample
- Reject non-prompt contribution by cut on pseudo-decay length
  - Non-prompt contamination $\sim$ 5%: included in systematic uncertainties

$\psi(2S)$ mass shape at high p_T

CMS-HIN-12-007



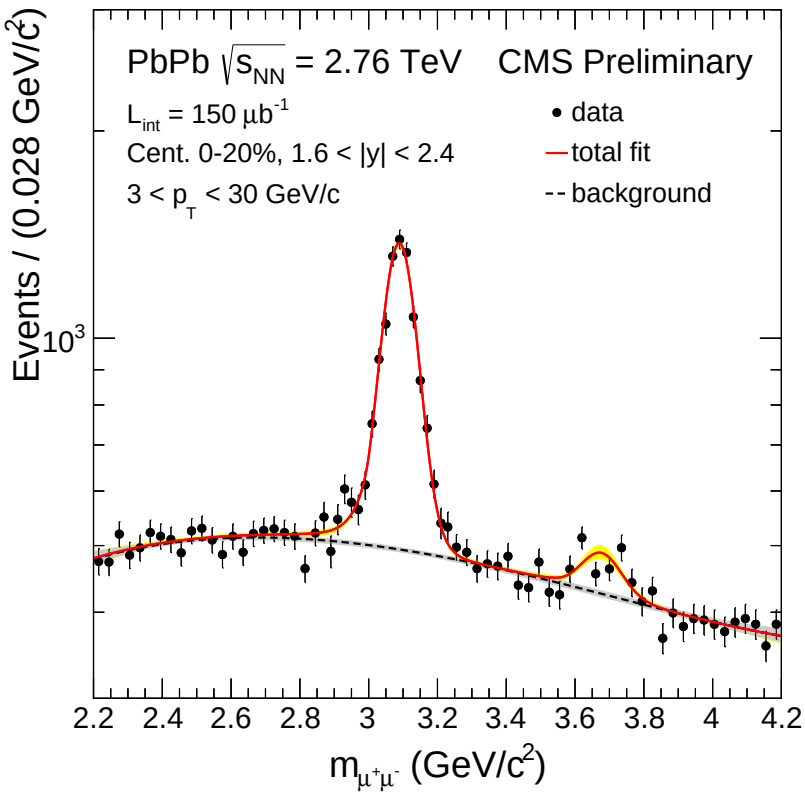


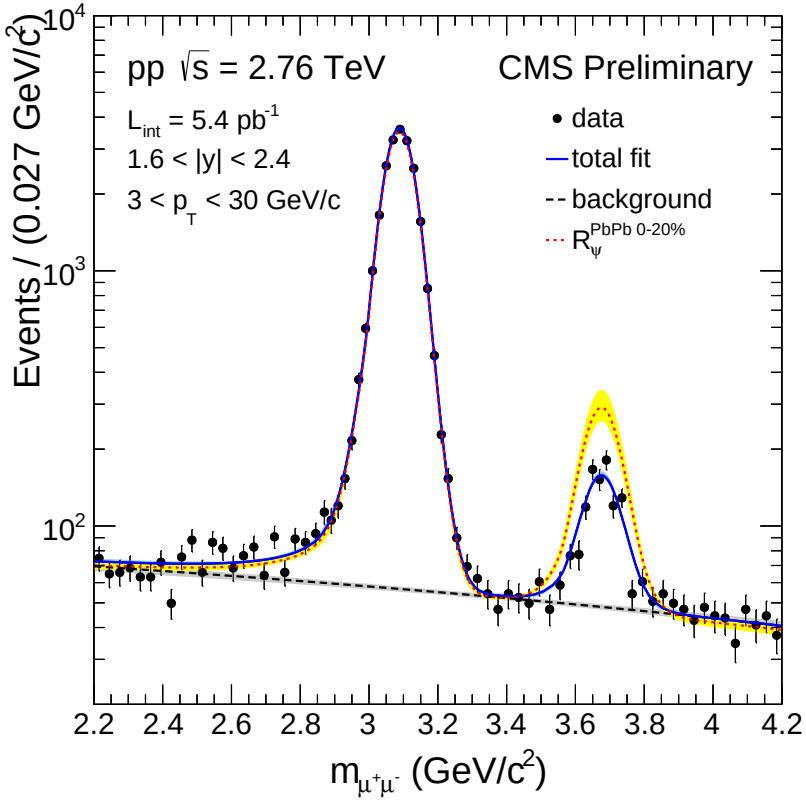
High p_T (mid-rapidity)

$\psi(2S)$ in PbPb is smaller than in pp with respect to the J/ψ.

$\psi(2S)$ mass shape at low p_T

CMS-HIN-12-007



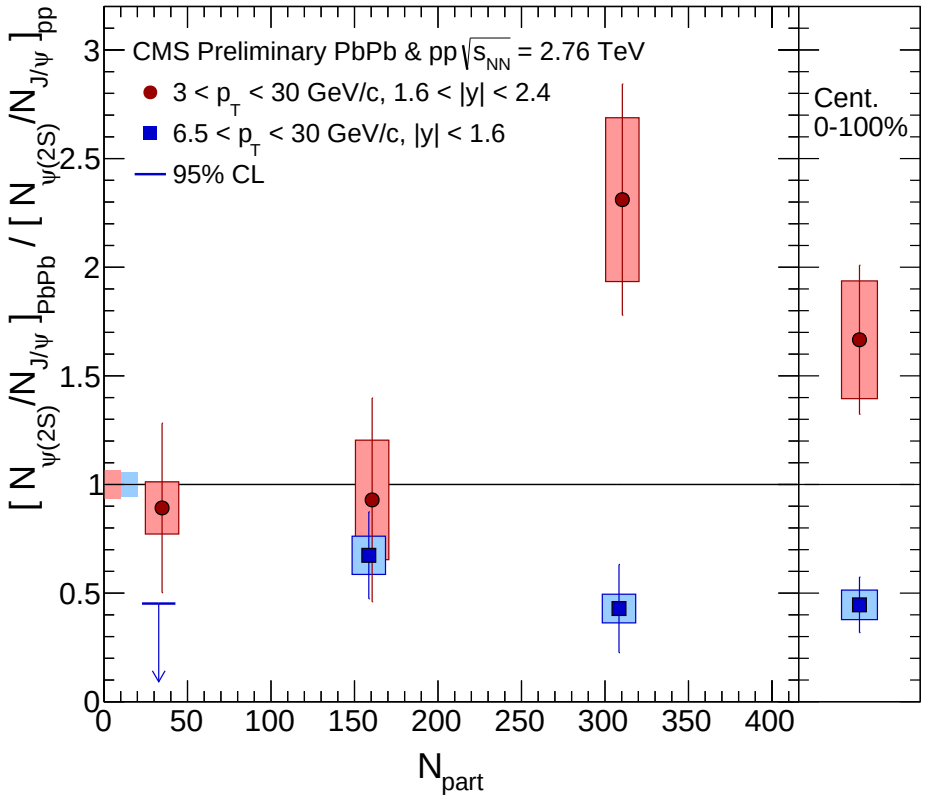


Low p_T (forward rapidity)

$\psi(2S)$ in PbPb is higher than in pp with respect to the J/ψ.

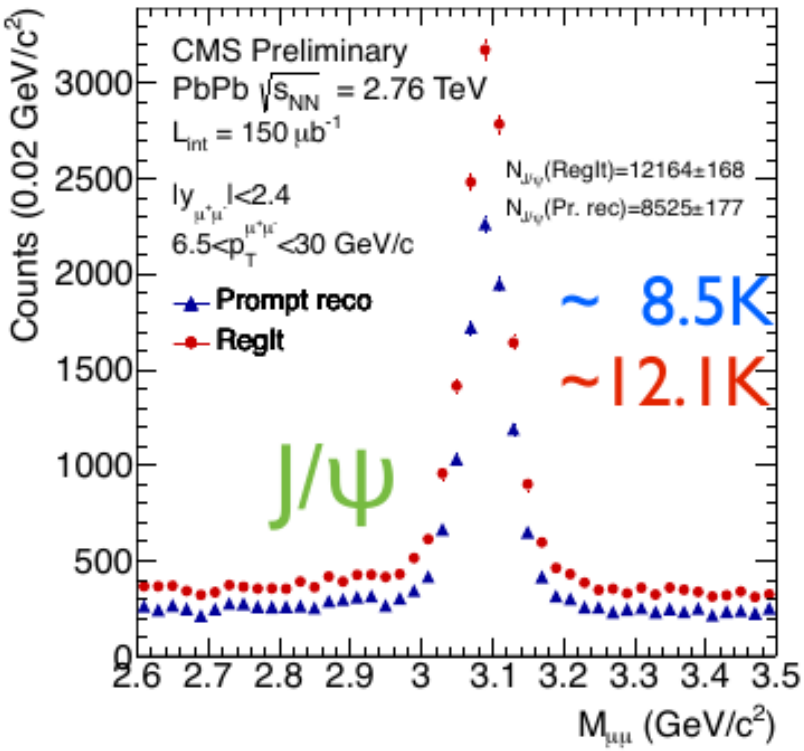
Double ratio of prompt $\psi(2S)$

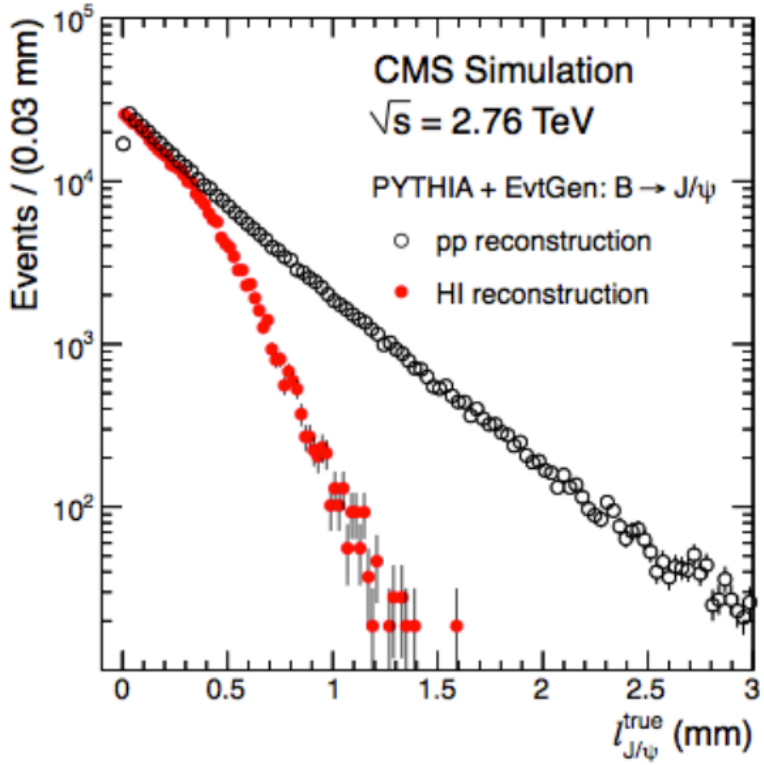
CMS-HIN-12-007



- Difference in $\psi(2S)$ production for both central and peripheral PbPb between high p_T (mid-y) and low p_T (forward y)
- high p_T (mid-y): $\psi(2S)$ more suppressed than J/ψ in PbPb
- low p_T (forward y): $\psi(2S)$ less suppressed than J/ψ in PbPb

Offline muon reconstruction software developments





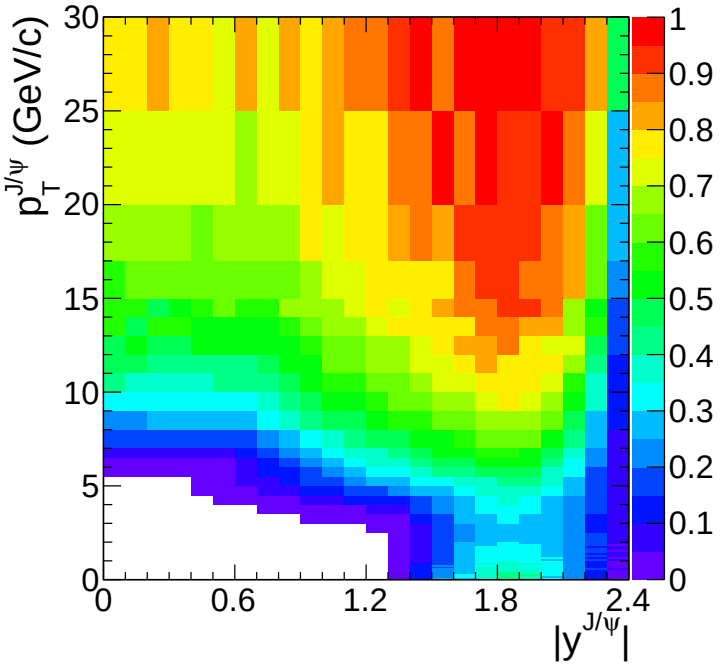
- Prompt reconstruction: inner track + hits in the muon chambers
- Regional Iterative algorithm: inner track + (pp iterative tracking in region around muon hits) + hits in the muon chambers
- $\sim$ 40% increase in dimuon efficiency for prompt J/ψ
- Some improvement still possible for muons with high impact parameter

Offline muon reconstruction software developments

- Working on increasing the reconstruction efficiency for displaced muons
- Also lowering the p_T threshold for J/ψ detection

Offline muon reconstruction software developments

J/ψ acceptance with "pp" cuts



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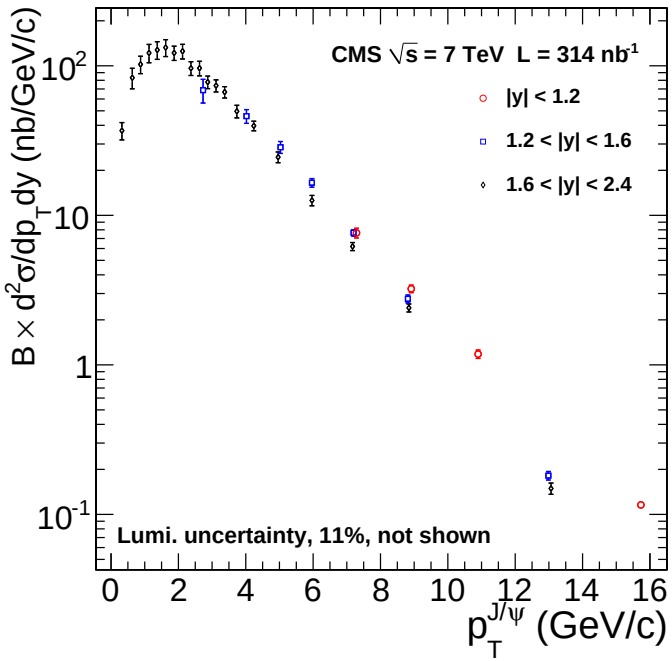

- Working on increasing the reconstruction efficiency for displaced muons
- Also lowering the p_T threshold for J/ψ detection

Summary

Prompt J/ψ v_2

Significant v_2:
$v_2(p_T > 6.5\,\mathrm{GeV}/c,\ |y| < 2.4,\ 10-60\%) = 0.054 \pm 0.013 \pm 0.006$ (3.8σ)

Double ratio of $\psi(2S)$

Clear difference mid-rapidity (high p_T) and forward rapidity (low p_T)

- Mid-rapidity (high p_T) : suppressed as predicted from sequential melting
- Forward rapidity (low p_T) : opposite trend to the mid-rapidity (high p_T) results and also opposite to expectation from sequential melting or regeneration

Reconstruction developments

Enhancing the performance for the next run

Additional material

$\psi(2S)$: comparison with ALICE