Quarkonium production in CMS

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For the CMS collaboration

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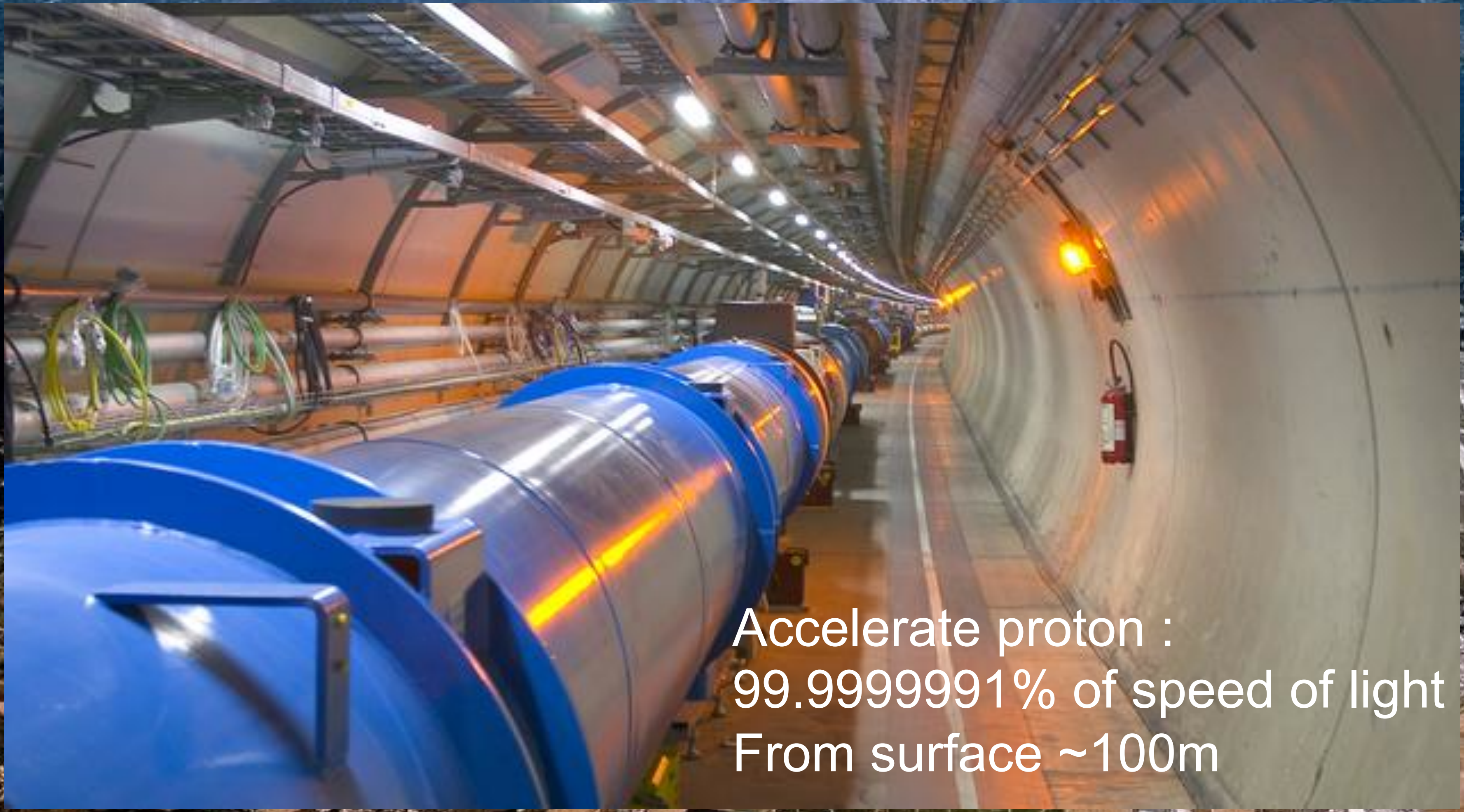
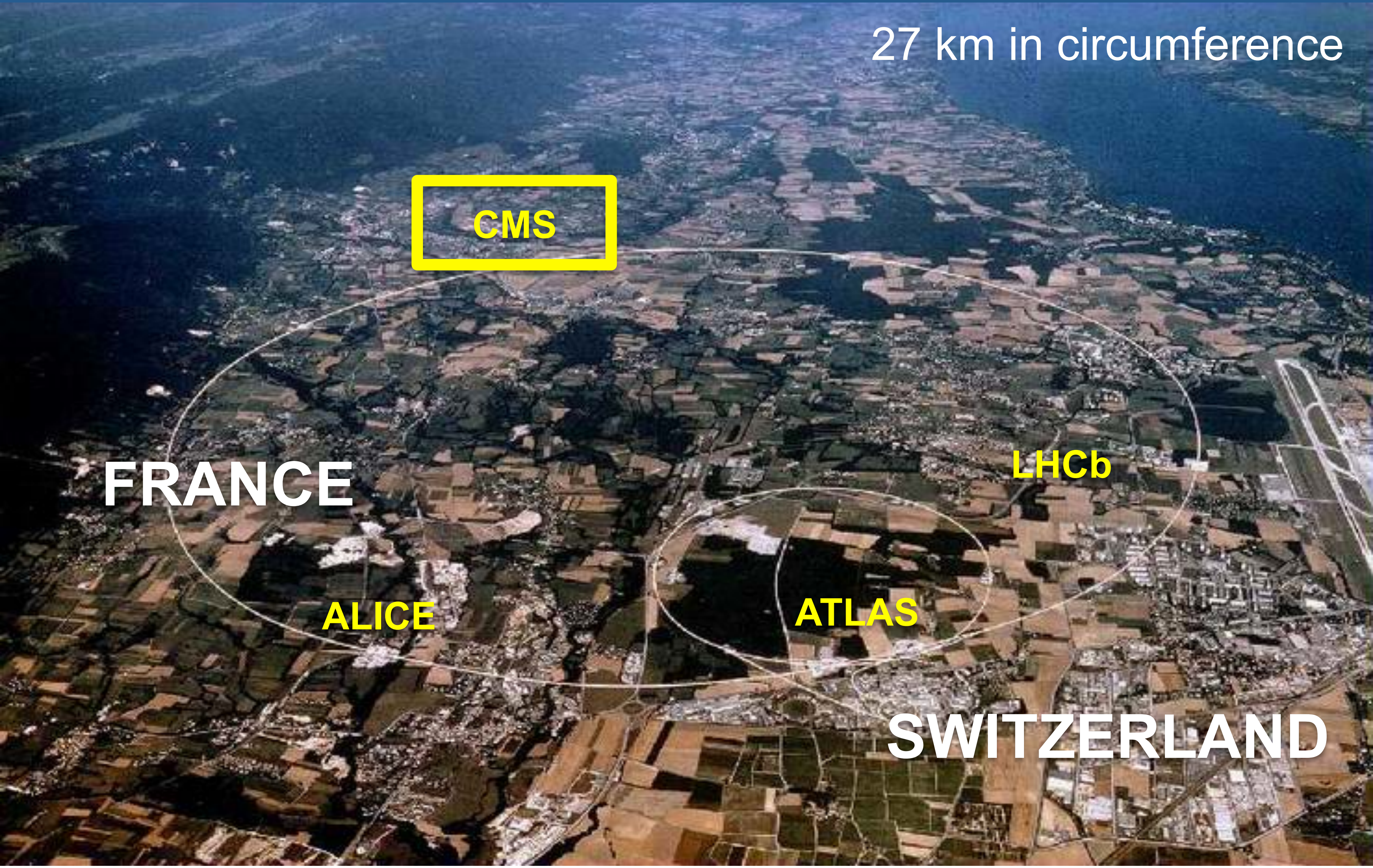
- **CMS detector@LHC**
- **Quarkonia physics motivation**
- **Result from CMS**
  - Charmonia : J/ψ
  - Bottomonia : ϒ
- **Summary**

LHC (Large Hadron Collider)



Accelerate proton :
99.9999991% of speed of light
From surface ~100m

LHC (Large Hadron Collider)

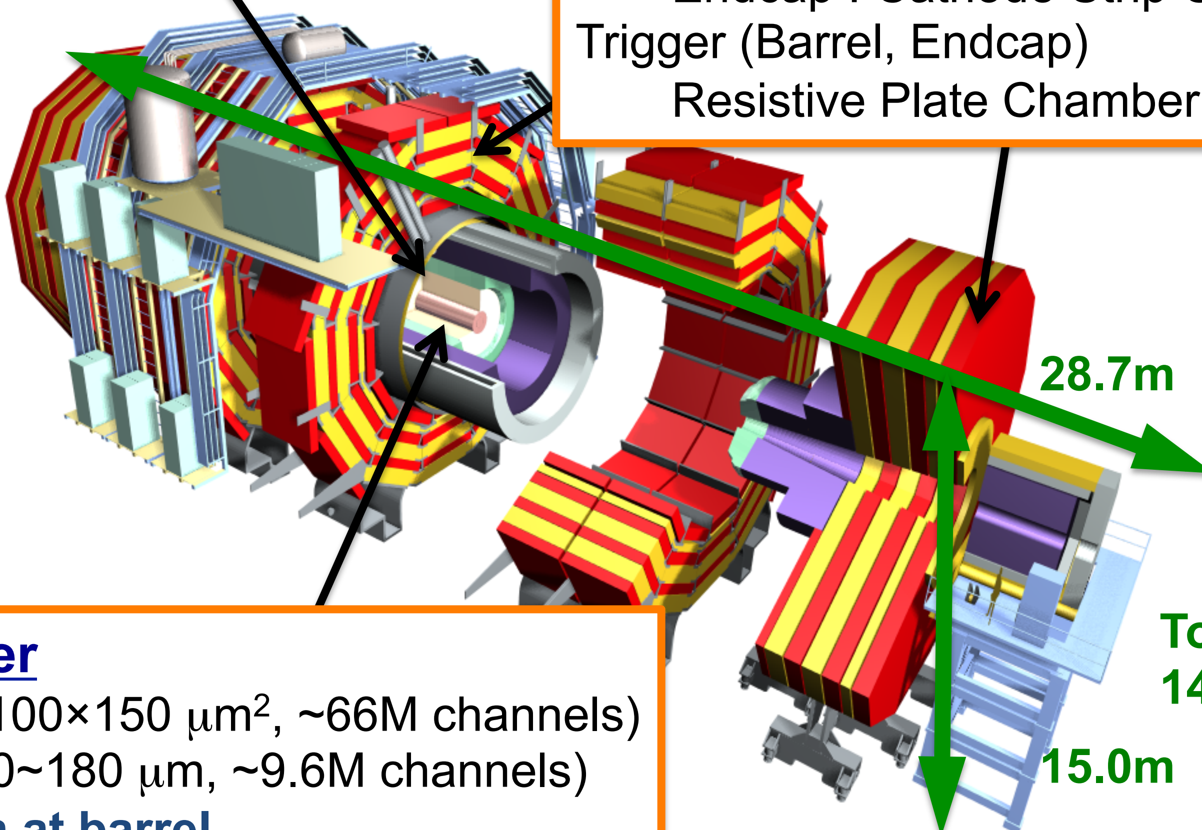


CMS (Compact Muon Solenoid) detector

Superconducting Solenoid
B=3.8T, 6m internal diameter

Muon system
Tracking
- Barrel : Drift Tube (DT)
- Endcap : Cathode Strip Chamber (CSC)

Trigger (Barrel, Endcap)
- Resistive Plate Chamber (RPC)

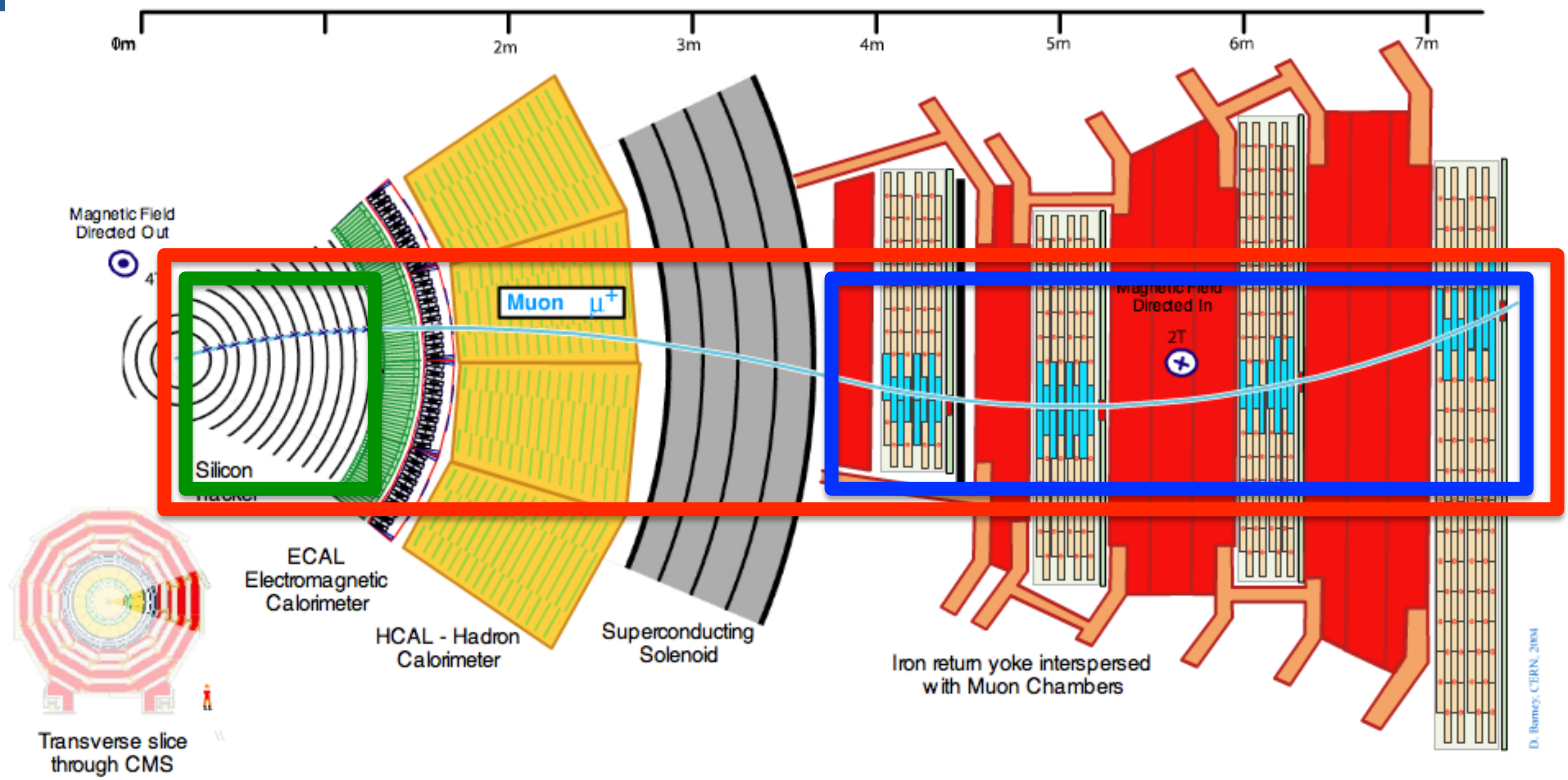


Total weight : 14000 t

Inner tracker
Silicon pixel(100×150 μm^2, ~66M channels)
Microstrips(80~180 μm, ~9.6M channels)

p_T resolution at barrel
$\leq$ 1.5%, p_T<100GeV/c

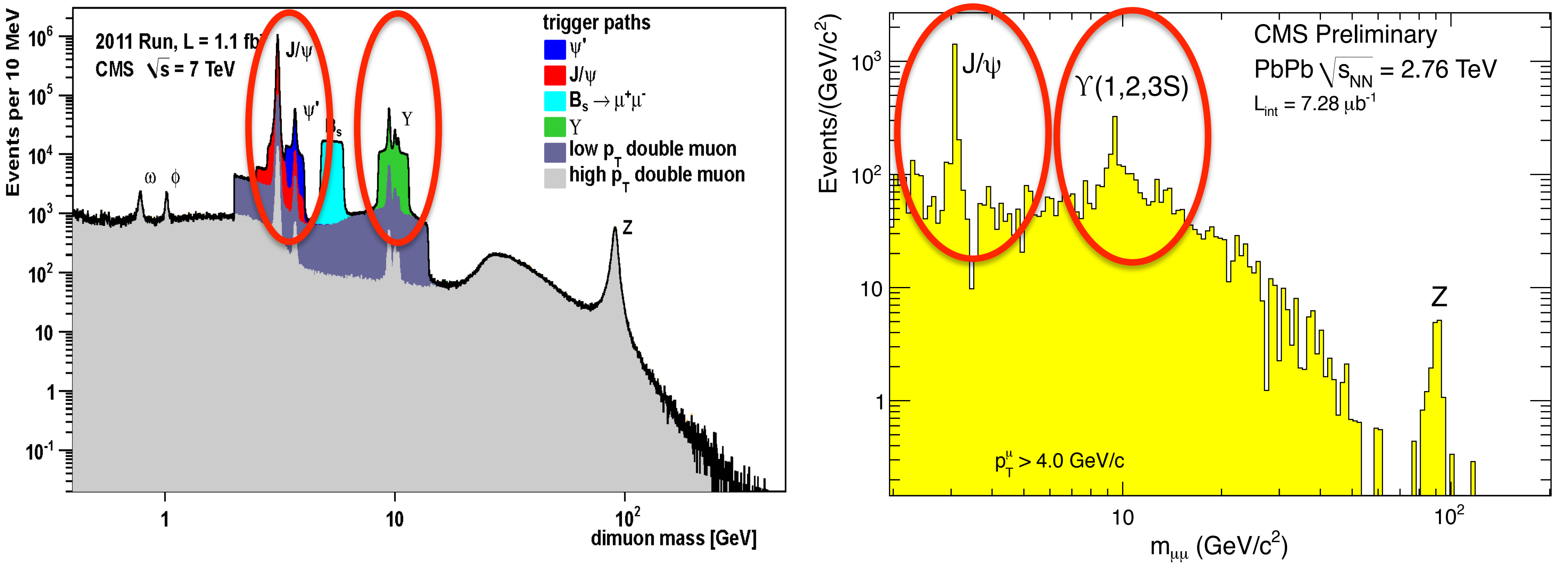
Muon reconstruction mechanism in CMS



- With information from inner tracker and muon stations, global muons reconstructed
- Because of the magnetic field and energy loss(2~3 GeV) in the iron yoke, Global muons need p ≥ 3~5 GeV to reach the muon stations, (depending on eta)
- Further muon ID based on track quality (χ^2, # of hits,…)

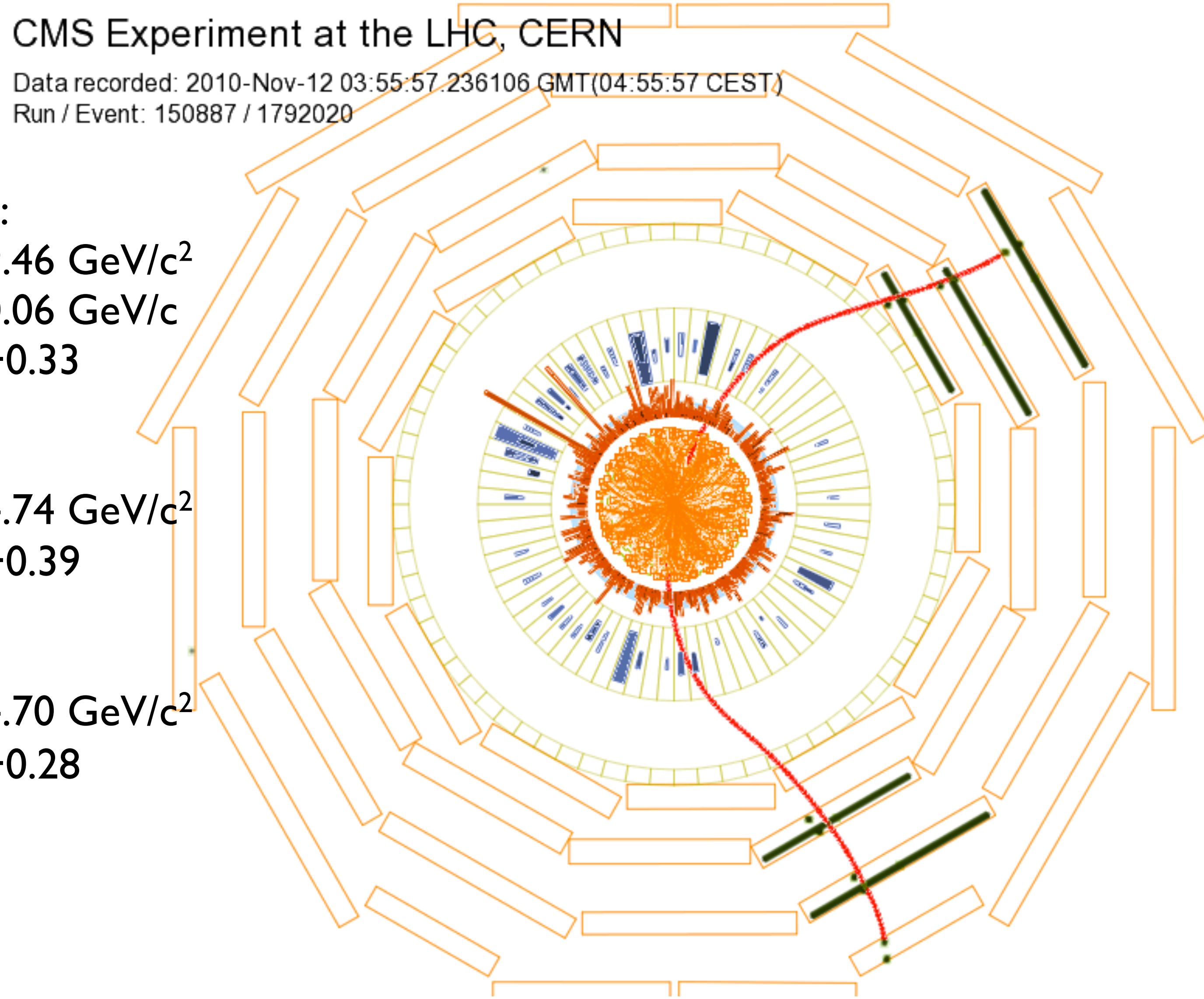
Dimuon mass plot by the CMS experiment

- At 2010, the integrated luminosity used in the HI analysis corresponds to 7.28 μb^{-1} for 2.76 TeV PbPb and 225 nb^{-1} for 2.76 TeV pp collisions



- Cover from low mass to high mass region
- Good dimuon resolution thanks to the tracking
- $p_T > 4.0$ GeV/c : to remove background around the upsilon mass region

Quarkonia candidate in PbPb at CMS



$\mu^+\mu^-$ pair:
mass: 9.46 GeV/c^2
p_T: 0.06 GeV/c
rapidity: −0.33

μ^+:
p_T = 4.74 GeV/c^2
η = −0.39

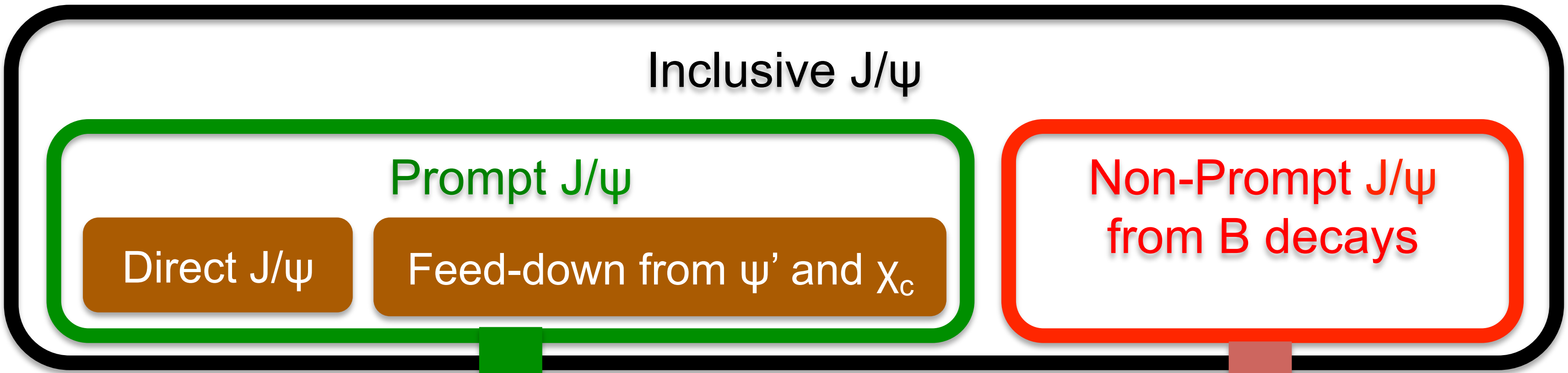
μ^-:
p_T = 4.70 GeV/c^2
η = −0.28

Physics motivation of quarkonia study (1)

- **Quarkonium : flavorless meson whose constituents are a quark and its own antiquark**
  - Charmonium(c-cbar), Bottomonium(b-bbar)
- **Suppression of quarkonium states : Good candidates to probe the QGP in Heavy-Ion collisions**
  - Because of their large mass (mc~1.27 GeV, mb~4.19 GeV), heavy quarks are produced in parton-parton collisions with large momentum transfer Q^2, at the initial stage of the reaction.
  - $T<T_d$, heavy quark pair make strongly bound resonance.
  - $T>T_d$, by Debye screening of the heavy quark binding potential no resonance can be formed.
  - T_d is depend on the binding energy and radius of the resonance.
  - Sequential suppression of the resonances thermometer for the temperature reached in the HI collisions.

State	Υ (1S)	J/Ψ (1S)	X_b' (2P)	X_c (1P)	Υ (3S)	Ψ' (2S)
ΔE (GeV/c^2)	9.46	3.10	10.26	3.53	10.36	3.68
R_0 (fm)	0.28	0.50	0.68	0.72	0.78	0.90

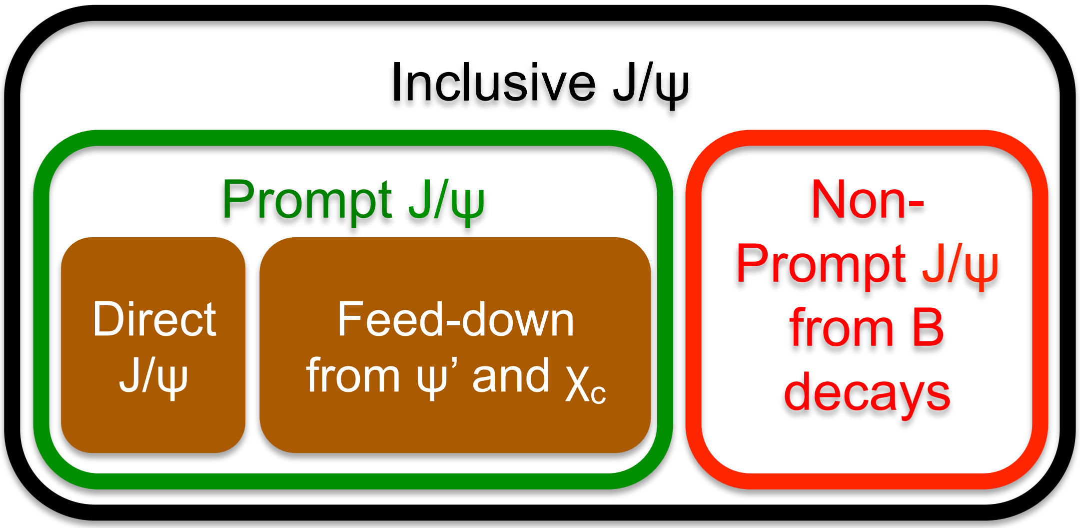
Physics motivation of quarkonia study (2)



- Prompt J/ψ includes the information of the **initial state** of hot-dense matter.

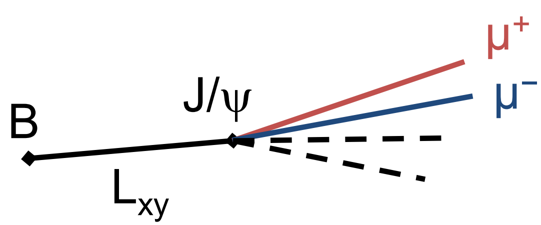
- Owing to the long lifetime of the b hadrons, compared to the QGP lifetime, non-prompt J/ψ should **not suffer from color screening**, but instead may **reflect the b-quark energy loss in the medium**.
- Energy loss would lead to a reduction of the b-hadron yield at high p_T in PbPb collisions compared to the binary-collision-scaled pp yield.

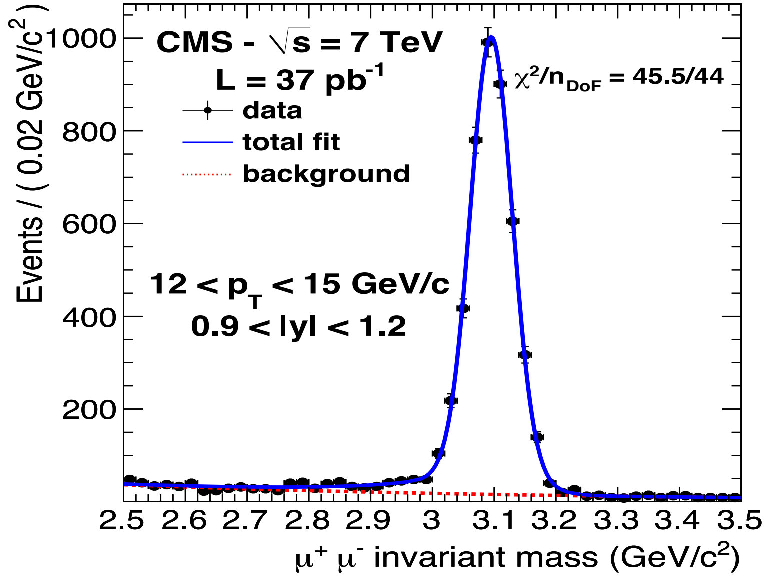
J/ψ in pp at $\sqrt{s}$ = 7 TeV

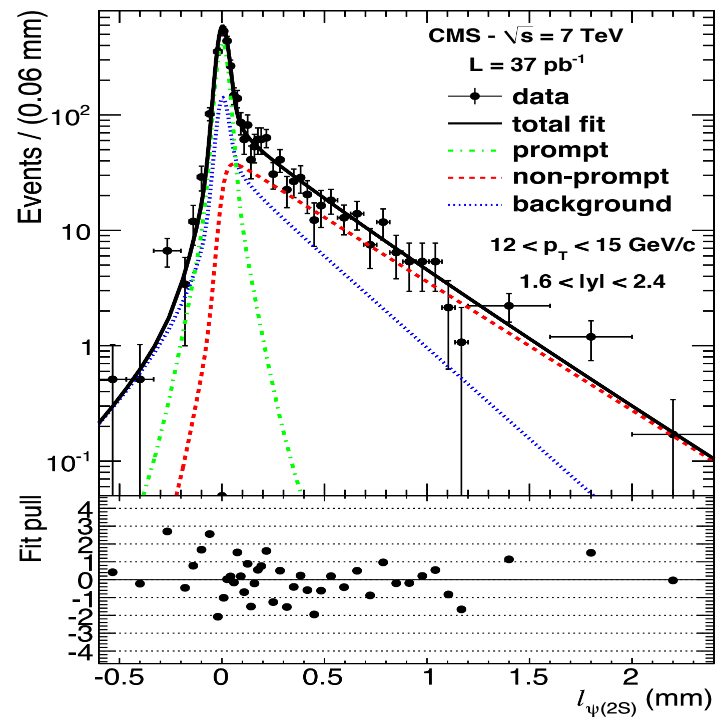


- Reconstruct $\mu^+\mu^-$ vertex
- Simultaneous 2D unbinned maximum likelihood fit of $\mu^+\mu^-$ mass and pseudo-proper decay length ($l_{J/\psi}$)

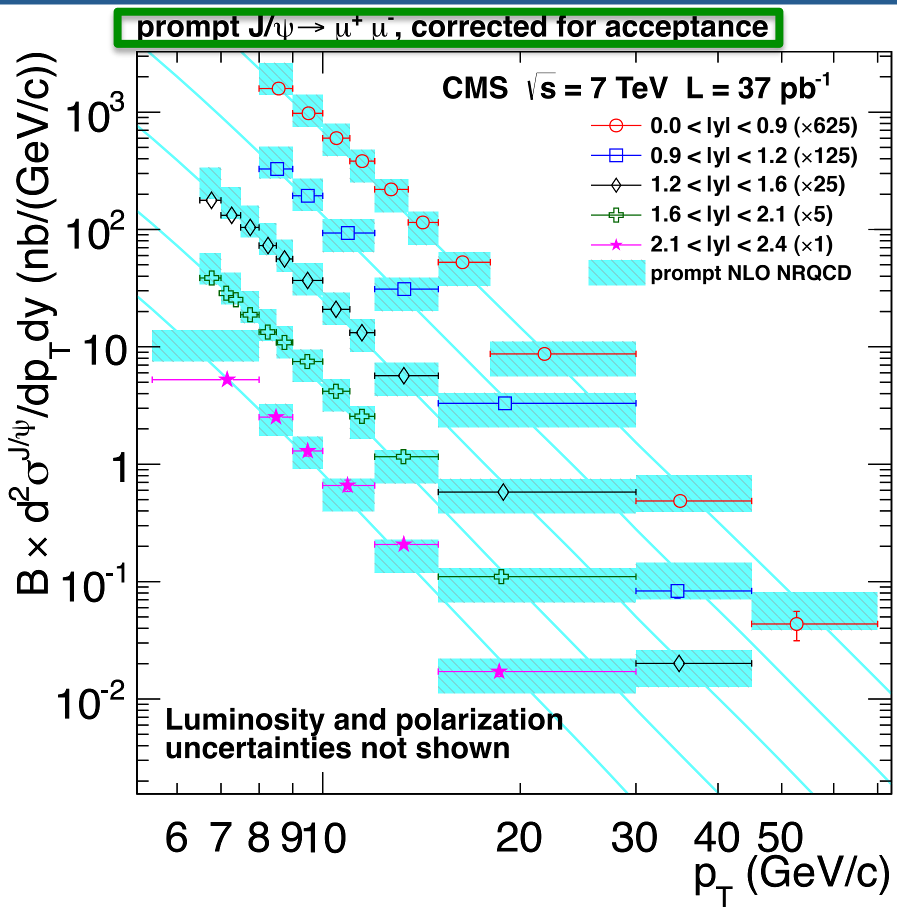
$$\ell_{J/\psi} = L_{xy}\frac{m_{J/\psi}}{p_T}$$

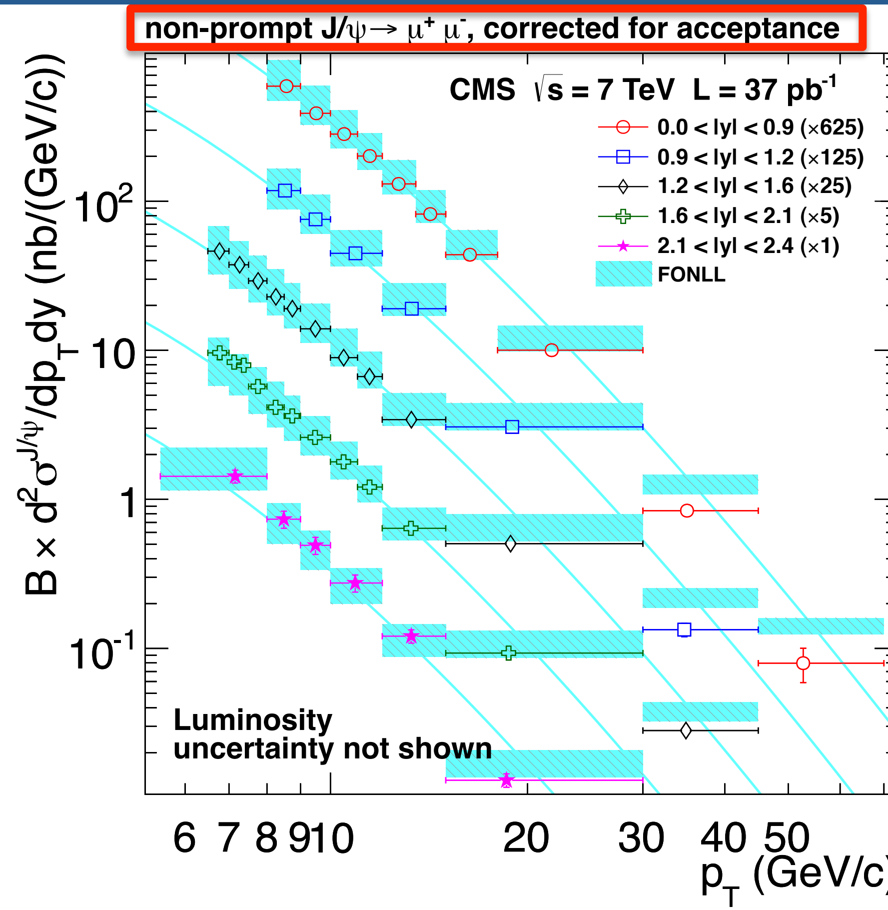






J/ψ in pp at √s = 7 TeV

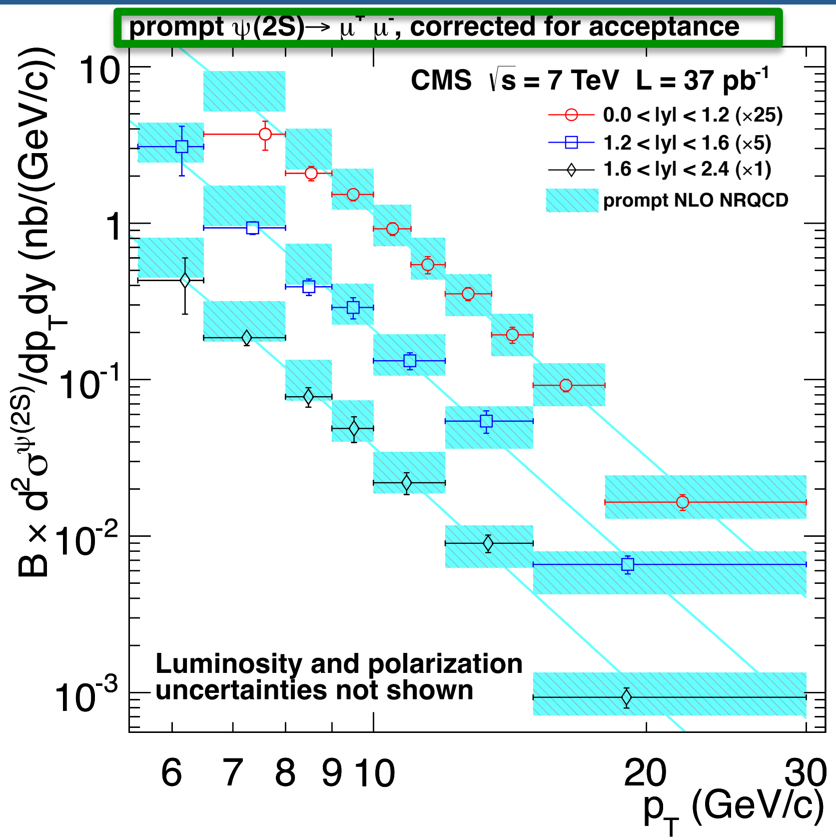


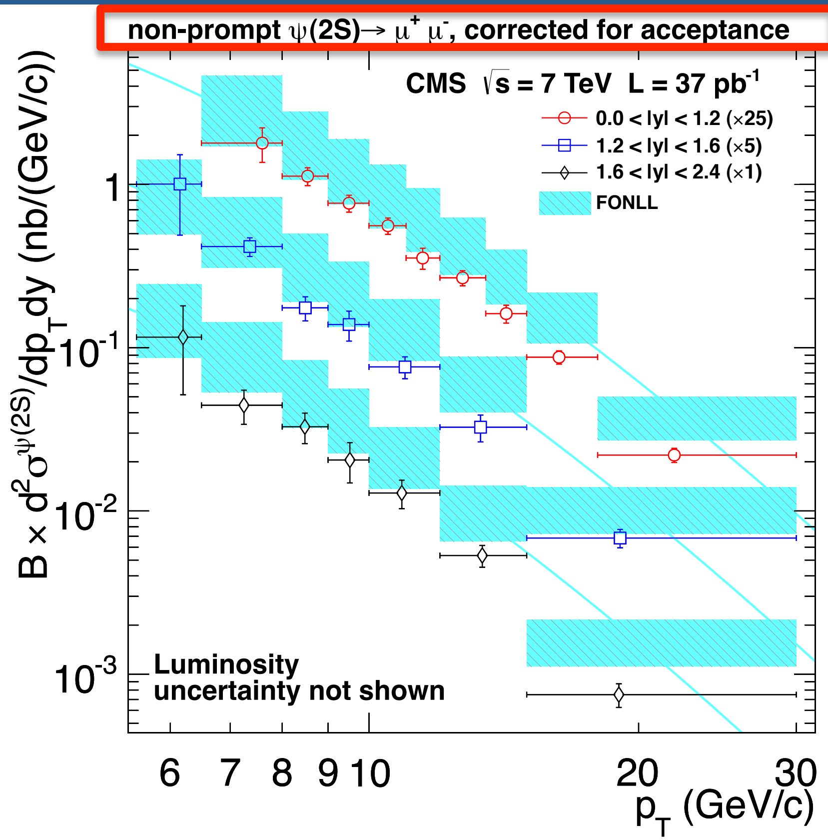


arXiv : 1111.1557
(accepted by JHEP)

- Prompt J/ψ well described by NRQCD
- Non-prompt J/ψ fall faster at high p_T than expected from FONLL

ψ(2S) in pp at √s = 7 TeV

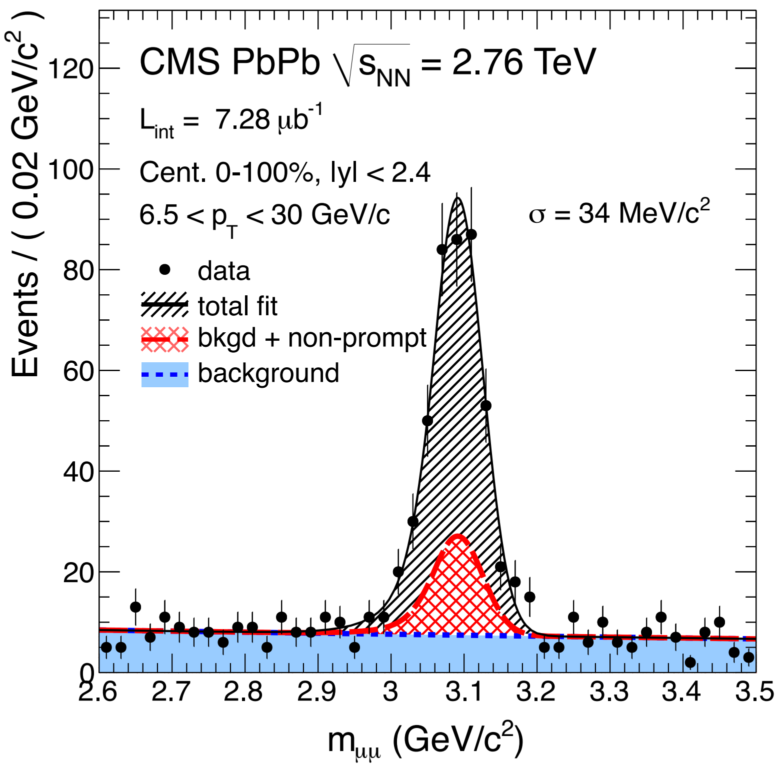


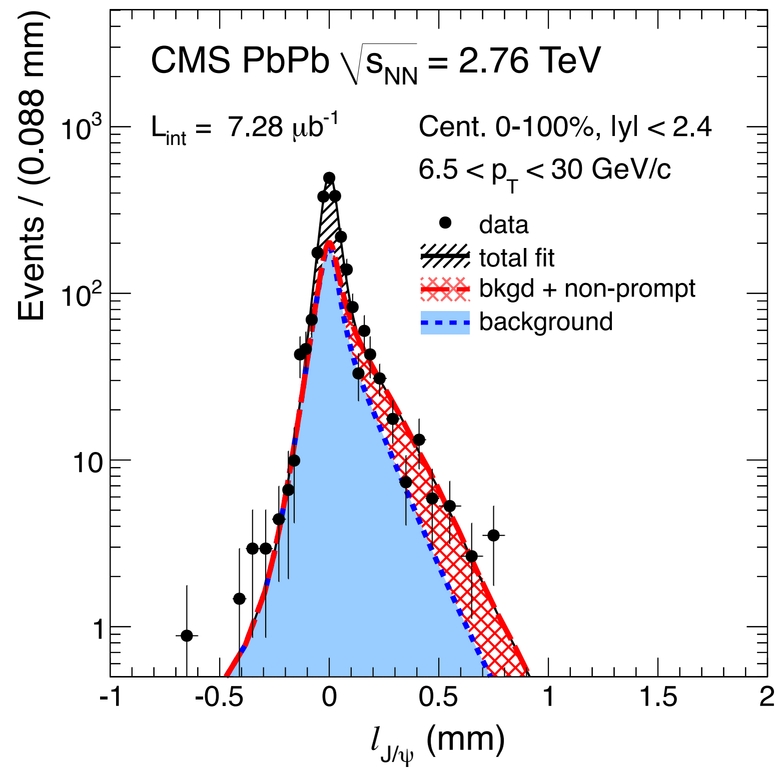


arXiv : 1111.1557
(accepted by JHEP)

- Prompt ψ(2S) well described by NRQCD
- Non-prompt ψ(2S) overestimated by FONLL (however, large uncertainty on BR(B→ψ(2S)X)
  - falls faster with pT than expected from FONLL

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



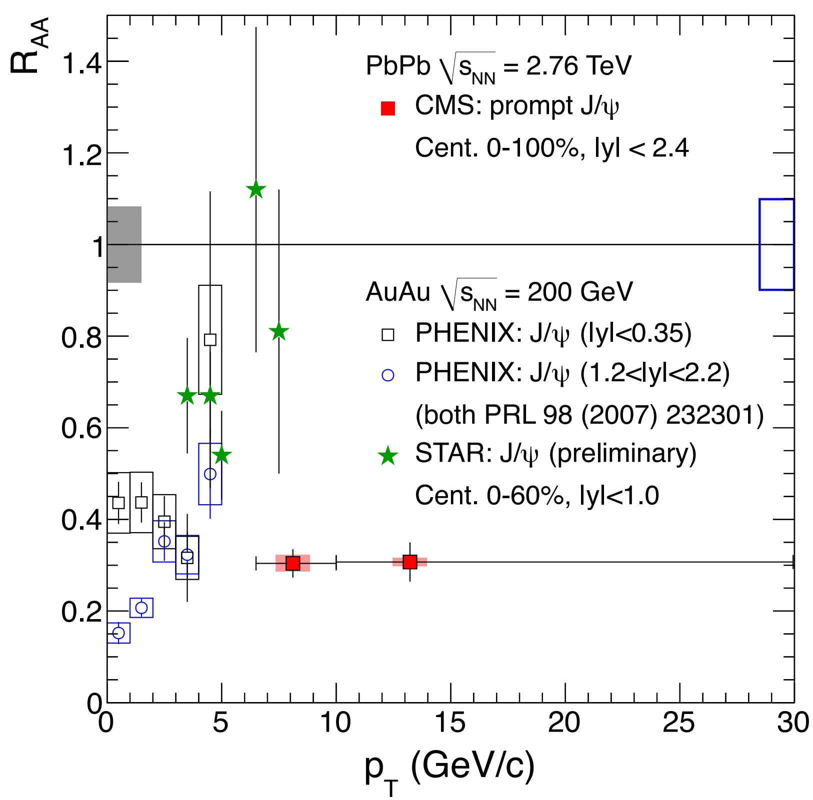


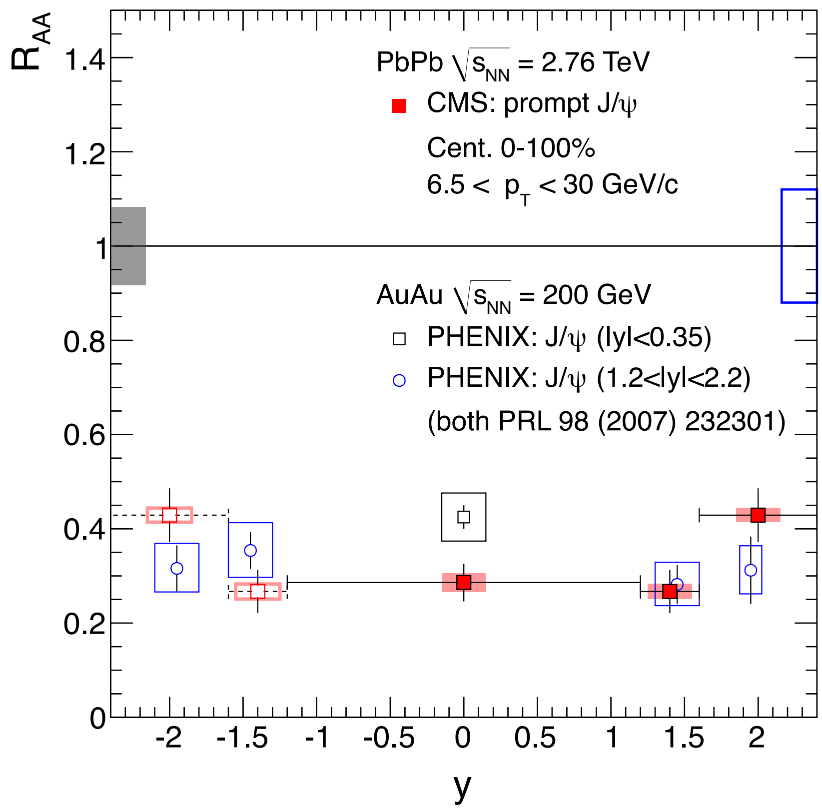
arXiv : 1201.5069
(submitted by JHEP)

- Same mechanism used as in pp
- **For the first time, prompt and non-prompt J/ψ have been separated in heavy-ion collisions**

Prompt J/ψ R_{AA} vs p_T, y

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





- RHIC : lower p_T, but R_{AA} increase with p_T
- CMS : factor 3 suppression for p_T > 6.5 GeV/c
  almost no p_T dependence

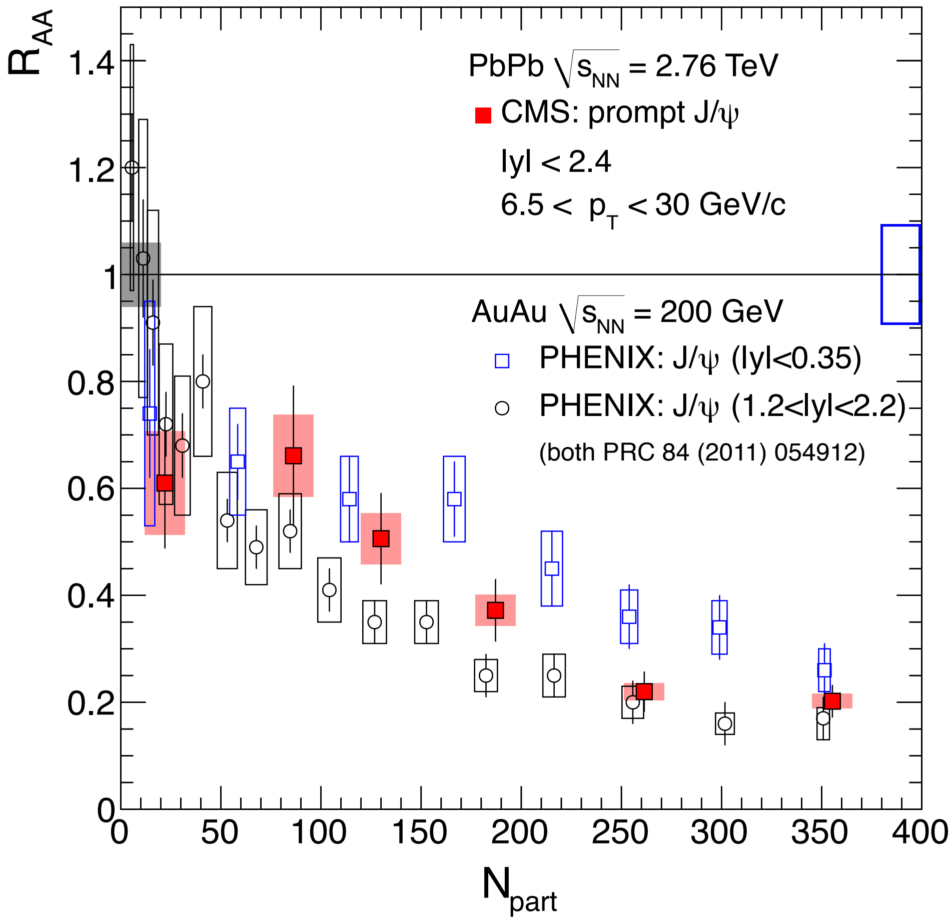
(do not seem to be observed by RHIC)

- PHENIX : stronger suppression in forward range
- CMS : less suppression in forward range
- Increasing R_{AA} going towards ALICE y range

arXiv : 1201.5069 (submitted by JHEP)

Prompt J/ψ R_{AA} vs N_{part}

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

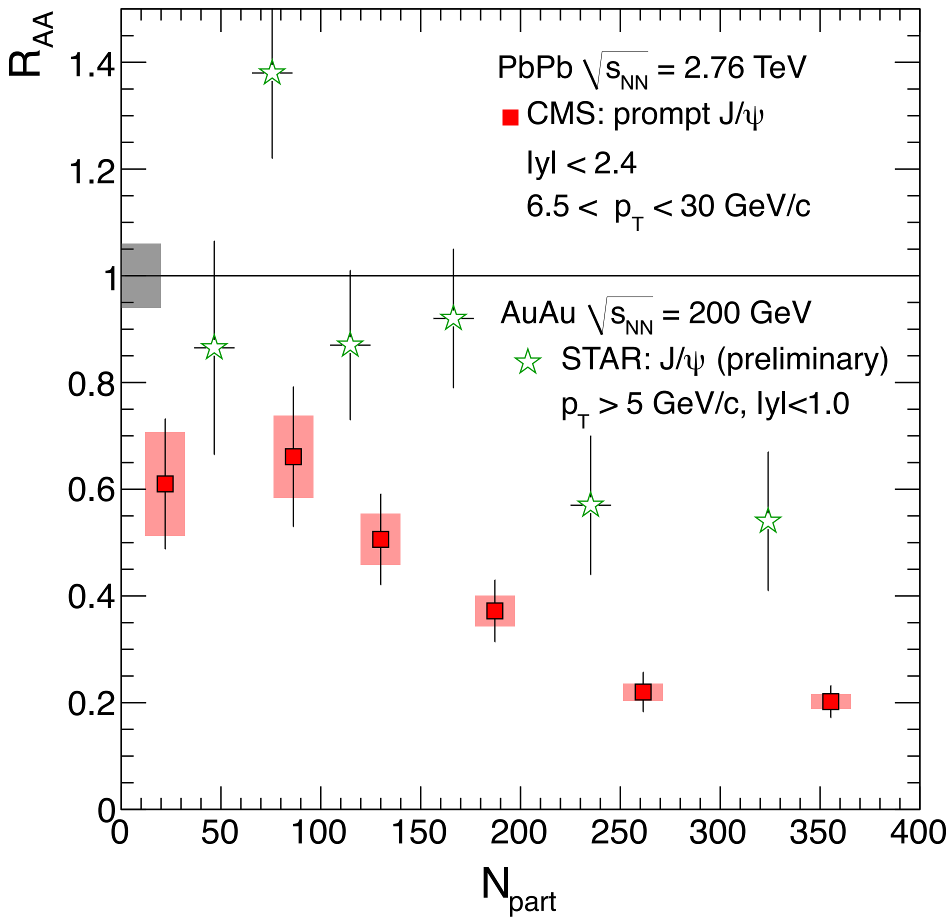


- 0~10% : suppressed by factor 5 with respect to pp
- 50~100% : suppressed by factor 1.6 remains
- Similar suppression seen at PHENIX though CMS is high p_T while PHENIX is low p_T

arXiv : 1201.5069 (submitted by JHEP)

Prompt J/ψ R_{AA} vs N_{part}

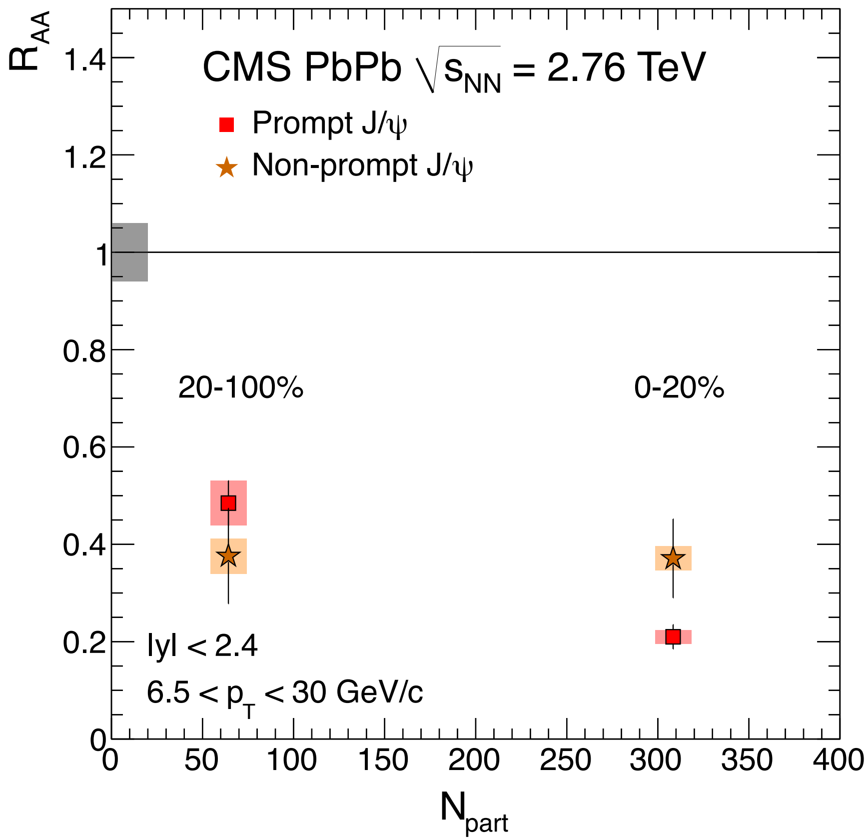
$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{\text{MB}}} \frac{N_{\text{PbPb}}(J/\psi)}{N_{pp}(J/\psi)} \frac{\varepsilon_{pp}}{\varepsilon_{\text{PbPb}}(\text{cent})}$$

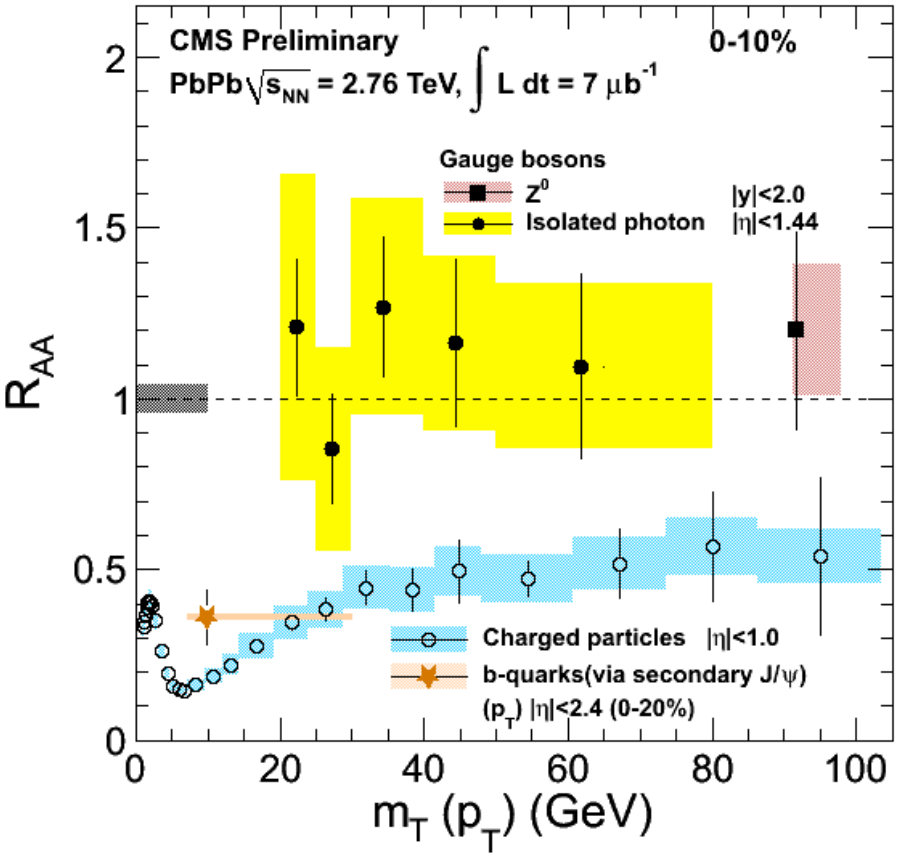


- 0~10% : suppressed by factor 5 with respect to pp
- 50~100% : suppressed by factor 1.6 remains
- Similar suppression seen at PHENIX though CMS is high p_T while PHENIX is low p_T
- STAR measured less suppression at high p_T

arXiv : 1201.5069 (submitted by JHEP)

Non-prompt J/ψ R_{AA}

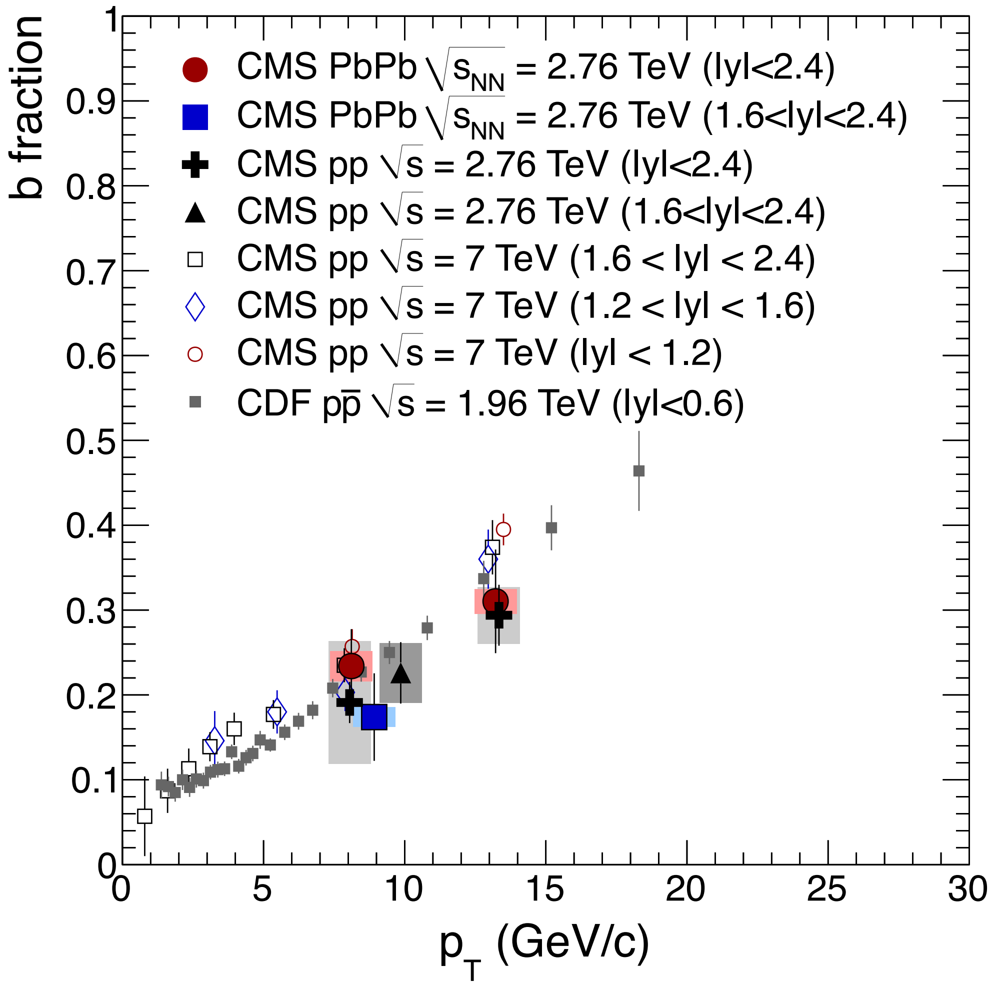




- Suppression of non-prompt J/ψ observed in minimum bias and central PbPb collisions, no centrality dependence
- **First indications of high-p_T b-quark quenching like light quarks**

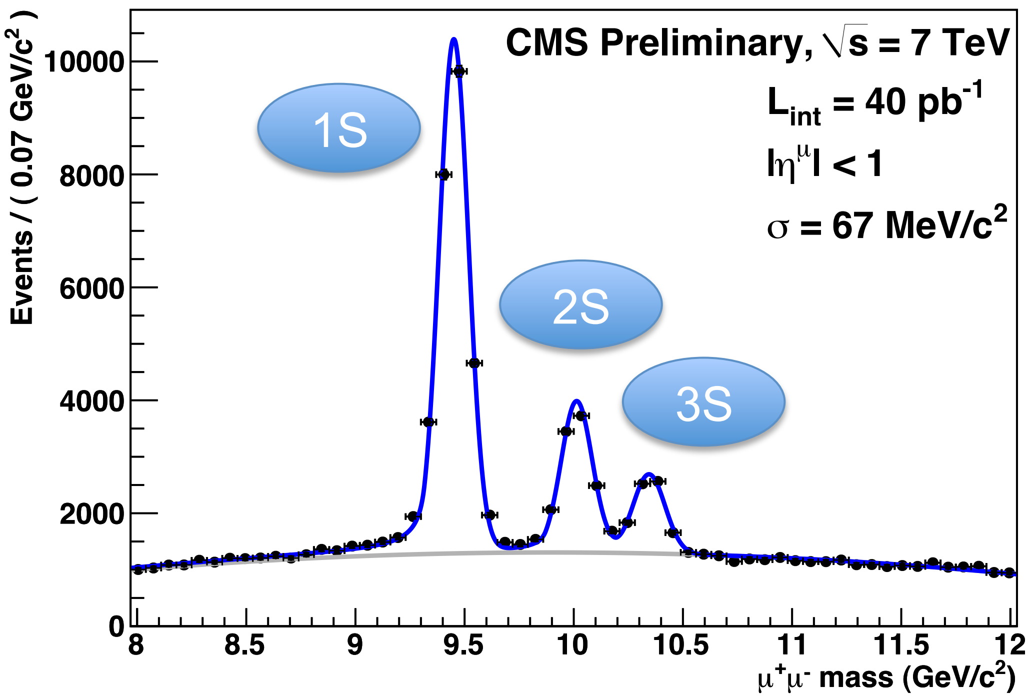
arXiv : 1201.5069 (submitted by JHEP)

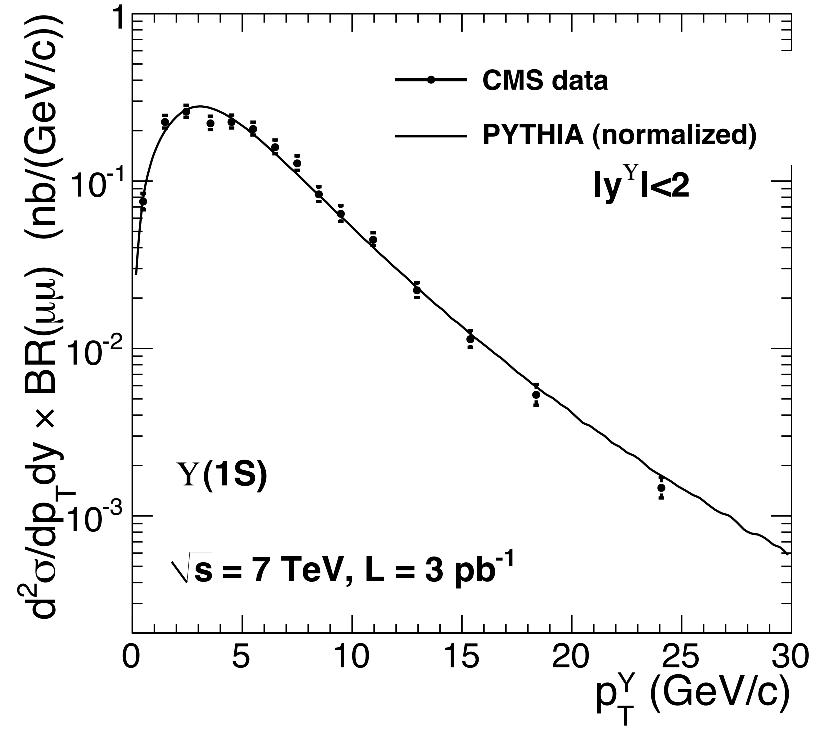
b fraction compared with earlier results



- **Good agreement within uncertainties, between the earlier results at other collision energies and the present measurements.**

Υ(nS) in pp at $\sqrt{s}$ = 7 TeV

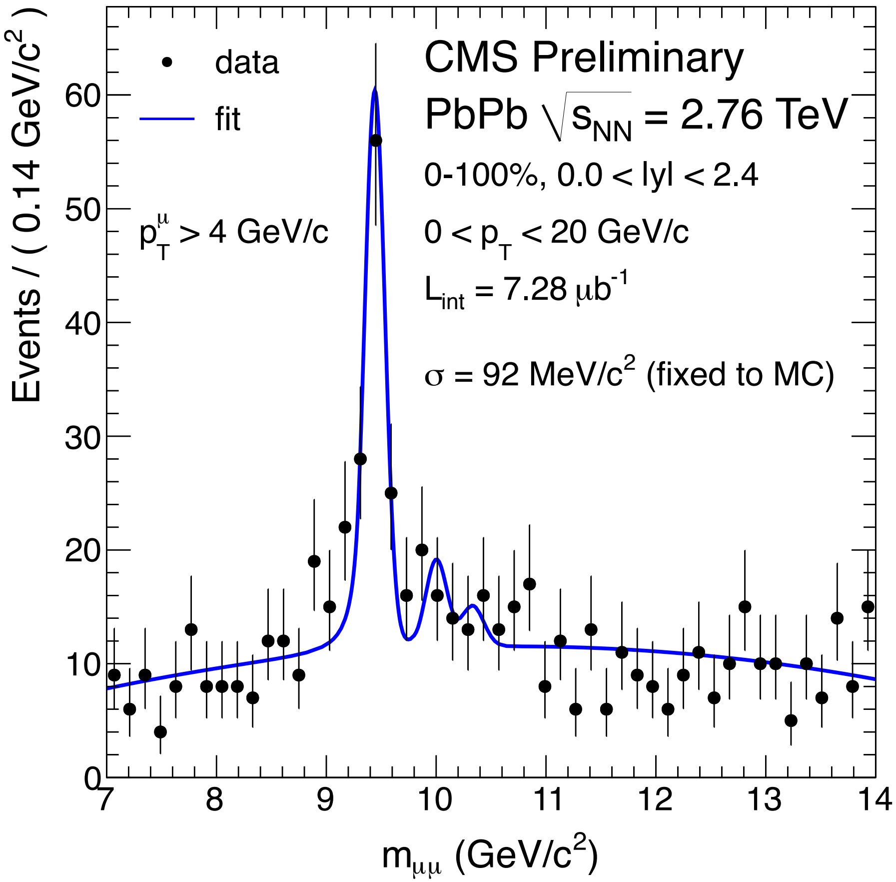




- Separation of the 3 Υ states with good mass resolution
- The normalized p_T-spectrum prediction from PYTHIA is consistent with the measurements

Υ(nS) in PbPb at $\sqrt{s_{NN}}$ = 2.76 TeV

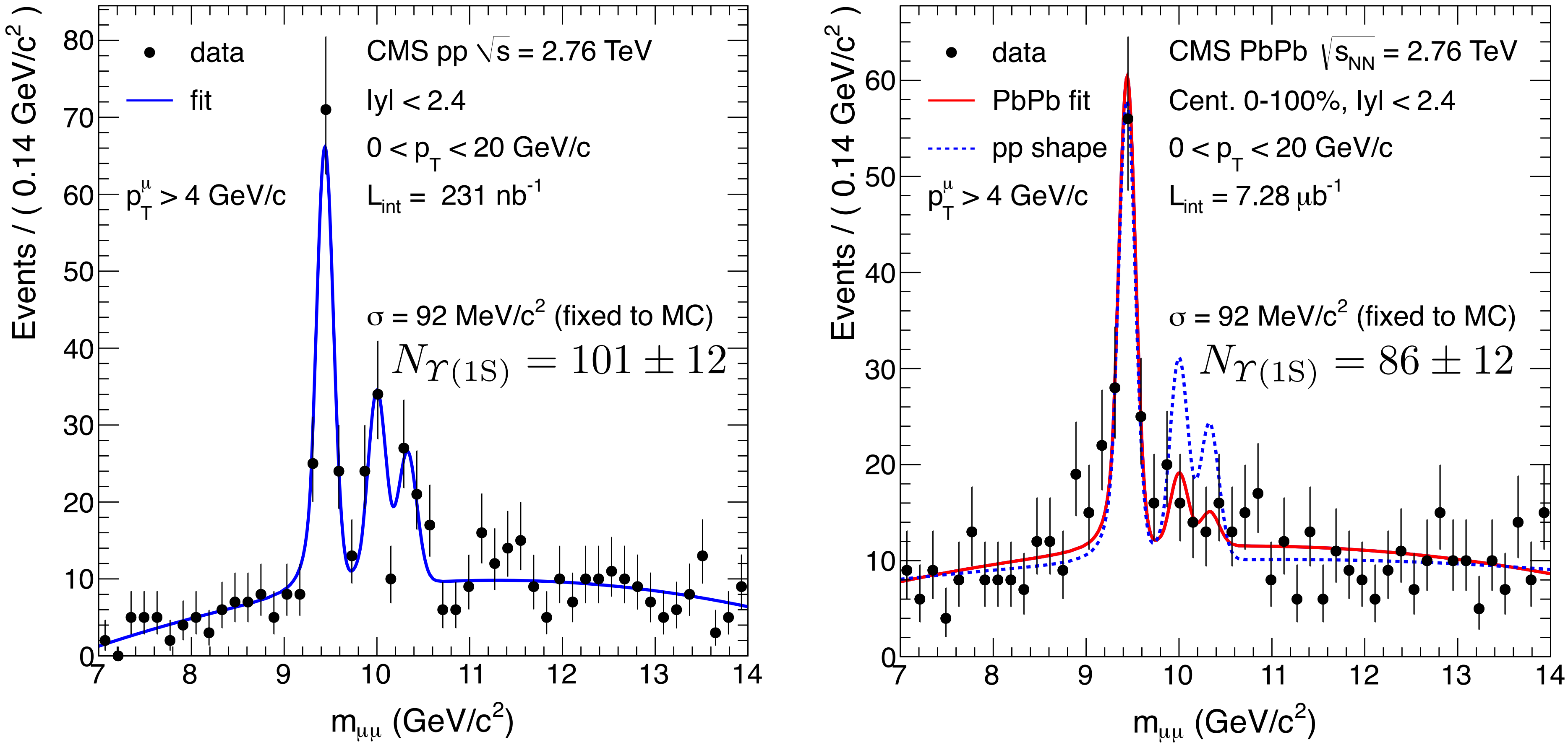
arXiv : 1201.5069 (submitted by JHEP)



- Extended unbinned maximum likelihood fit
  - Signal
    - Resolution fixed from MC simulation
    - Peak separation fixed to PDG
  - Background
    - Second order polynomial
- Obvious Upsilon(1S)

Υ(2S+3S)/Υ(1S) suppression

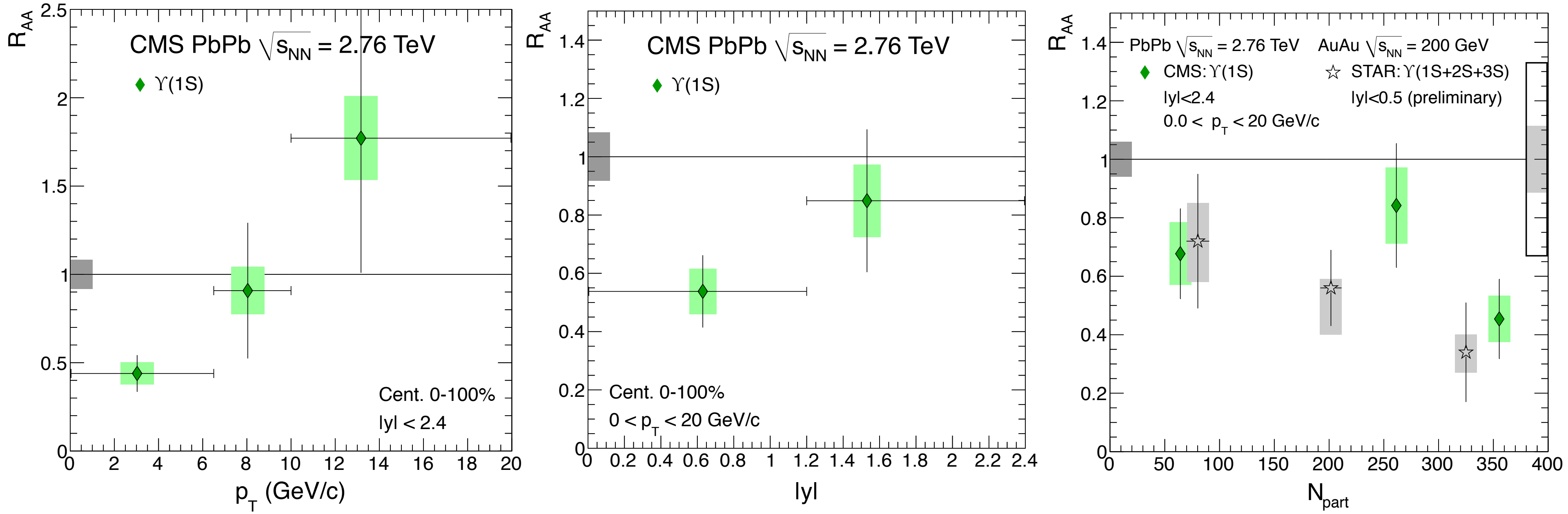
arXiv : 1105.4894
PRL 107 (2011) 052302



- Measure Υ(2S+3S) production relative to Υ(1S) production
- Simultaneous fit to pp and PbPb data at 2.76 TeV

$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)|_{PbPb}}{\Upsilon(2S+3S)/\Upsilon(1S)|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

Υ(1S) R_{AA} vs p_T, y and N_{part}



- Are Υ(1S) suppressed at high p_T?
- No obvious rapidity dependence within the large statistical uncertainties

- In CMS, Υ(1S) suppressed by factor ~2.3 in 0~10%

- STAR measures R_{AA} of Υ(1S+2S+3S) = 0.56
- for CMS (0~100%) calculated R_{AA} of Υ(1S+2S+3S) = 0.43

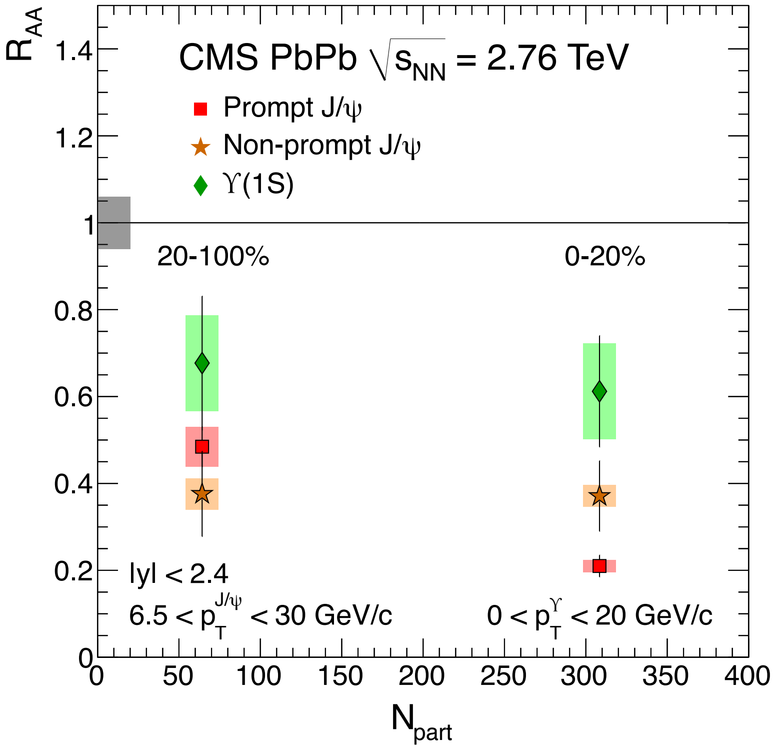
arXiv : 1201.5069 (submitted by JHEP)

Summary of the results

In pp collisions at $\sqrt{s}$ = 7 TeV,

- prompt J/ψ and ϒ(1S) is well described by models within uncertainties
- J/ψ from B decays is overestimated by FONLL model

In PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV,



- prompt J/ψ and J/ψ from B decays suppressed
- ϒ(1S) and ϒ(2S+3S) with respect to ϒ(1S) are suppressed

arXiv : 1201.5069 (submitted by JHEP)

CMS HI group is analyzing with 2011 HI data now !
Expect new excited result !