Medium effects on Upsilon production in pp collisions

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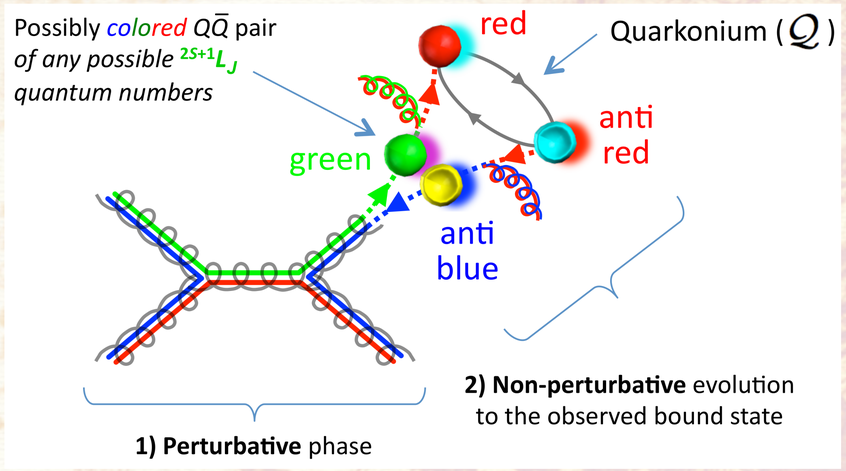
Quarkonium Production

Non-relativistic quantum chromodynamics (NRQCD) factorizes quarkonium production in two steps:



1) Creation of a (**colored**, octet) QQ̄ by "short-distance" processes
2) Binding into the singlet quarkonium state, ***changing quantum numbers*** by emitting/absorbing gluons

Binding probability set by "long-distance matrix elements" (LDMEs), fit to ***cross section*** and ***polarization*** data

Open Questions

- **Is color neutralization affected by the medium?**
- **Are LDMEs constant and universal (NRQCD conjecture)?**
- **What are the implications for heavy-ion physics?**

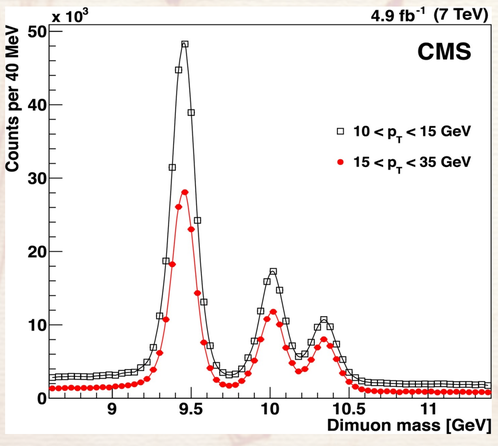
We seek answers through the study of $\Upsilon(nS)$ cross sections and polarizations in proton-proton collisions as a function of charged particle multiplicity ("collision centrality")

Analyzed Data

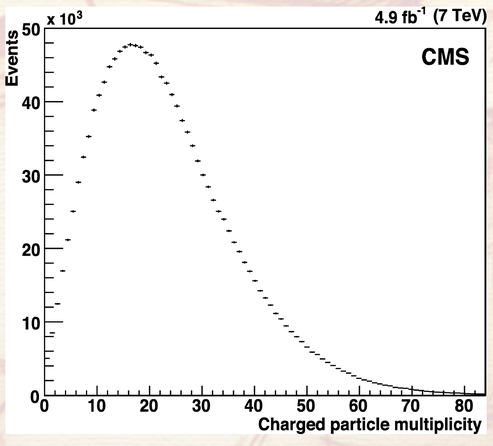
[CMS, PLB 761 (2016) 31]

We use the 2011 pp data sample: 7 TeV; L = 4.9 fb^{-1}

Phase space: $|y| < 1.2$ and $0 < p_T < 50$ GeV (yields) or $10 < p_T < 35$ GeV (polarizations)



The $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ peaks are very well resolved in the dimuon mass distribution



Multiplicity bins

N_{ch} (polarization): charged tracks with $p_T > 500$ MeV

N_{tracks} (yields): charged tracks with $p_T > 400$ MeV

Polarization

[CMS, PLB 761 (2016) 31]

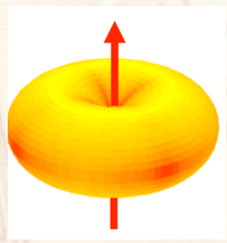
Quarkonium polarizations are measured using the angular distribution of the $\Upsilon \rightarrow$ dimuon decay mode:

$$W(cos\vartheta, \varphi|\vec{\lambda}) \propto \frac{1}{3+\lambda_\vartheta}(1 + \lambda_\vartheta\ cos^2\vartheta + \lambda_\varphi\ sin^2\vartheta\ cos2\varphi + \lambda_{\vartheta\varphi}\ sin2\vartheta\ cos\varphi)$$

Extreme polarizations: transverse and longitudinal

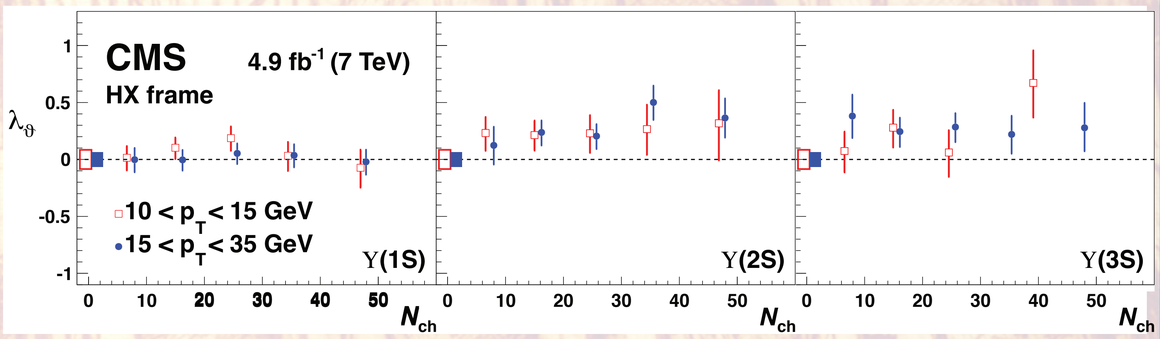
Transverse
$J_z = \pm 1$
$\lambda_\theta = +1$

Chicago
$J_z = ???$
$\lambda_\theta = ???$



Longitudinal
$J_z = 0$
$\lambda_\theta = -1$

We measured the N_{ch} dependence of the λ parameters for the three $\Upsilon(nS)$ states:

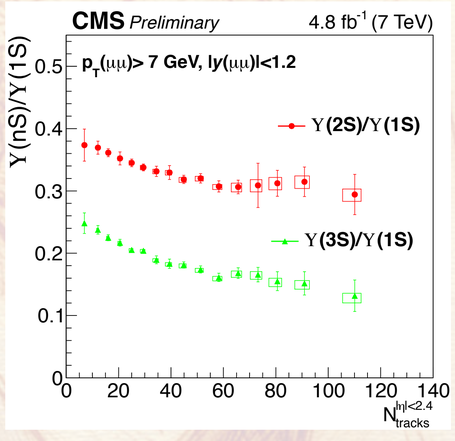


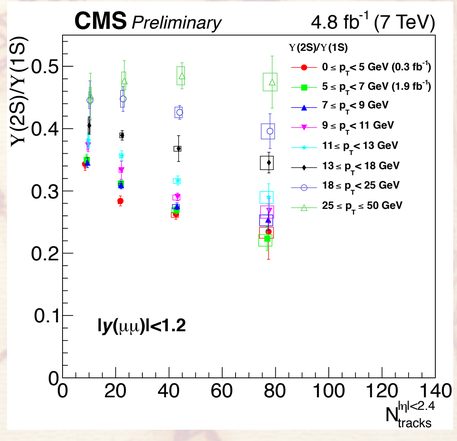
- No significant variations are seen for the $\Upsilon(1S)$, the state most affected by feed-down decays
- Statistical uncertainties prevent definitive statements for the $\Upsilon(2S)$ and $\Upsilon(3S)$ states

Cross Section Ratios

[CMS PAS, BPH-14-009]

The $\Upsilon(2S)/\Upsilon(1S)$ and $\Upsilon(3S)/\Upsilon(1S)$ ***cross section ratios decrease with increasing N_{tracks}***





The decreasing trend is more pronounced for low p_T quarkonia; the ratio becomes flat for $p_T > 20$ GeV

Summary

- Upsilon polarizations and cross section ratios were measured versus event multiplicity
- ***No significant polarization changes were seen, but better precision is needed, especially for the excited states***
- ***Cross section ratios decrease significantly*** with multiplicity with a strong dependence on p_T