Upsilon production in p+p collisions at STAR

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Abstract

Measurements of suppression of ϒ states in heavy-ion collisions relative to expectation from p+p collisions is a tool for studying the properties of quark-gluon plasma. Such a suppression is expected to be caused by Debye-like screening of color charges happening at a high temperature in the quark-gluon plasma. In order to correctly interpret this effect, the ϒ production mechanism itself has to be well understood. This is still an open question which can be studied in p+p collisions. Recently, an interesting strong dependence of normalized quarkonium production yields on normalized charged particle multiplicity has been observed. By studying such a dependence for ϒ an insight can be gained into the interplay of hard and soft QCD processes affecting the quarkonium production.

This poster presents the results of ϒ production measurements in p+p collisions from the STAR experiment. The ϒ rapidity distributions are shown both at $\sqrt{s} = 200$ GeV and $\sqrt{s} = 500$ GeV. The available staitistics of the data at $\sqrt{s} = 500$ GeV allowed a separation of ϒ(1S) and ϒ(2S+3S) and to obtain the corresponding transverse momentum spectra. Finally, the normalized ϒ(1S) yield is studied as a function of normalized charged particle multiplicity.

Motivation

Quarkonium production mechanism

Differential cross section measurements provide constraints for quarkonium production models and information about quarkonium production mechanism:

- **Color Evaporation Model** - F_{Υ} a fixed fraction of $q\bar{q}$ pairs forms a particular bound state

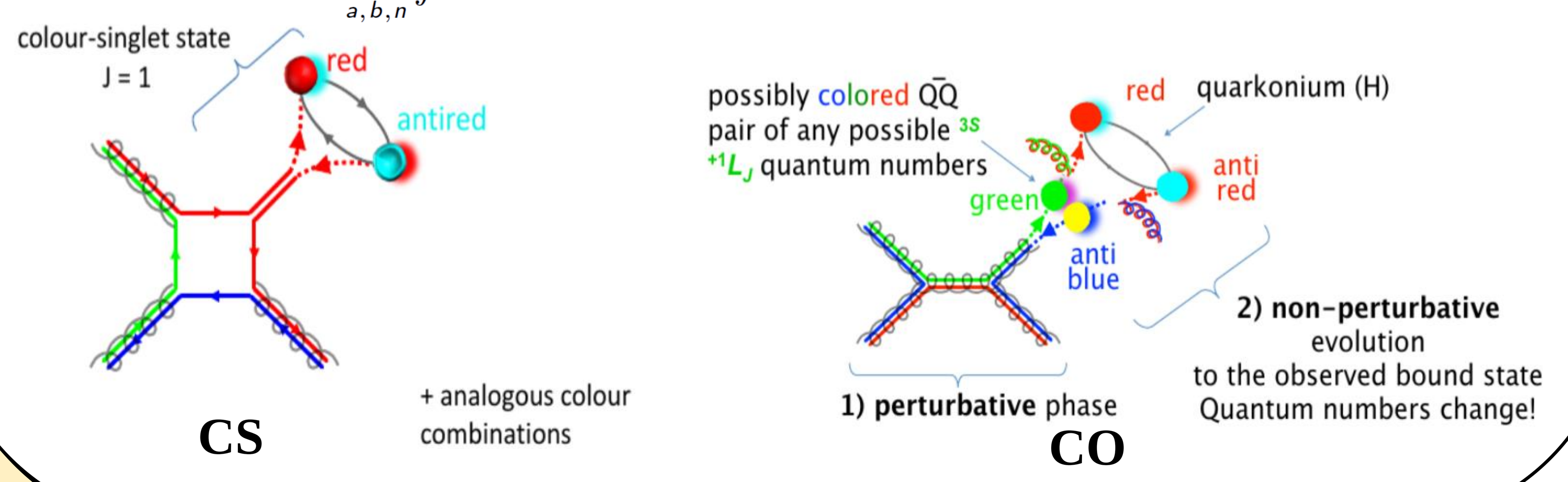
$$d\sigma_{\Upsilon} = F_{\Upsilon}\int_{2m_b}^{2m_B}\frac{d\sigma_{b\bar{b}}}{dm_{b\bar{b}}}dm_{b\bar{b}}$$

[Phys.Rev. C92 034909(2015)]
[Phys.Rev. D 94, 114029(2016)]

- **CGC+NRQCD** model - combines color glass condensate initial conditions with non-relativistic QCD framework including color singlet (**CS**) and color octet (**CO**) contributions

[Phys.Rev. D 94, 014028 (2016)] ,[Phys.Rev. Lett. 113, 192301 (2014)]

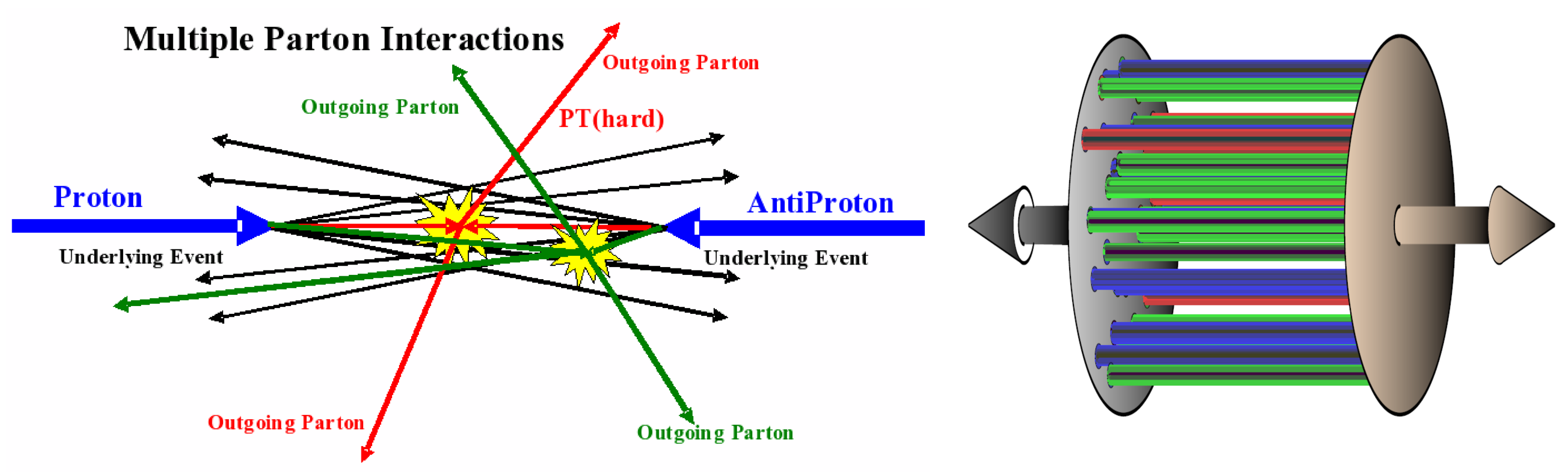
$$d\sigma_{\Upsilon+X} = \sum_{a,b,n}\int f_{a/A}(x_a,\mu_F)f_{b/B}(x_b,\mu_F)d\sigma_{ab\to(b\bar{b})_n+X}(s,\mu_F,\mu_R,\mu_\Lambda,\alpha_s)\langle O_{\Upsilon}^{n}\rangle$$



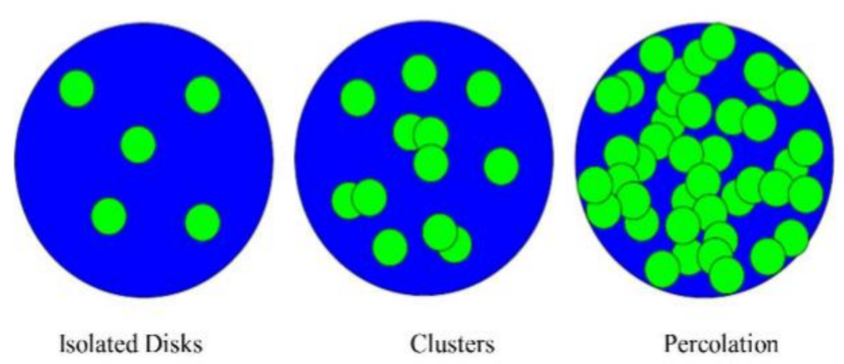
High multiplicity p+p collisions

Enhancement of normalized ϒ production (ϒ/<ϒ>) vs. normalized charged particle multiplicity ($N_{ch}/\langle N_{ch}\rangle$) has been observed in high-multiplicity p+p collisions. Possible explanations:

- **MPI** – quarkonium is produced in multi-parton interactions: [JHEP04,103(2014)],[Phys.Lett.B 712,165-175(2012)], [Phys.Lett. B786 (2018) 87-93]

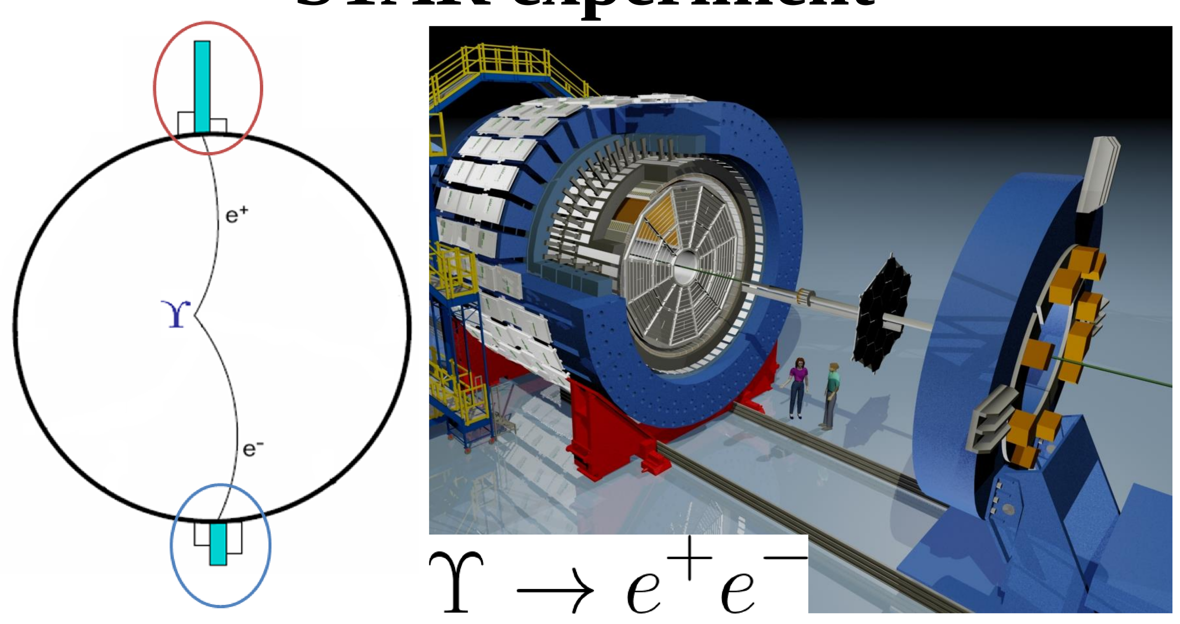


- **String Percolation** – interactions between strings of color field cause suppression of soft particle production: [Phys.Rev. C, 86, 034903 (2012)]



$$\frac{N_{hard}}{\langle N_{hard}\rangle} = \langle\rho\rangle\left(\frac{\frac{dN_{ch}}{d\eta}}{\left\langle\frac{dN_{ch}}{d\eta}\right\rangle}\right)^2$$

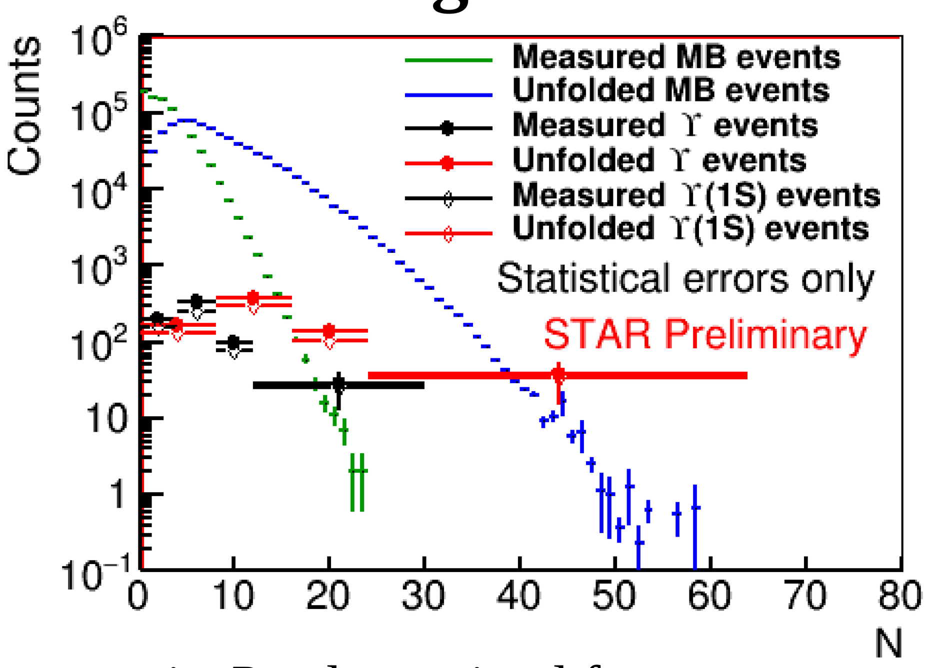
STAR experiment



- **TPC** – tracking and particle identification at midrapidity
- **BEMC** – electron identification and triggering on high-p_T electrons
- **TOF** – particle velocity measurement, TPC tracks matched to TOF to reject pile-up for measuring N_{ch}

Multiplicity correction via unfolding

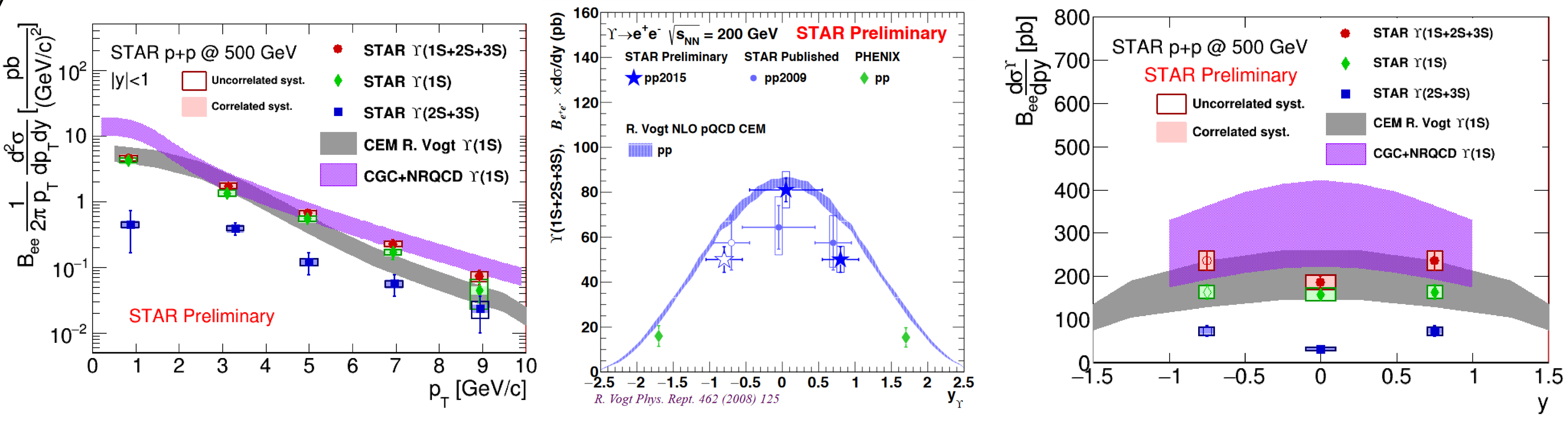
$M_i = R_{ij}T_j$
Measured
↓
Unfolded
$T_j = R_{ji}^{-1}M_i$
[arXiv:1105.1160]



- Response matrix R_{ij} determined from PYTHIA simulation and STAR detector simulation
- Measured distributions M_i unfolded with this matrix to obtain corrected ones T_j

Results

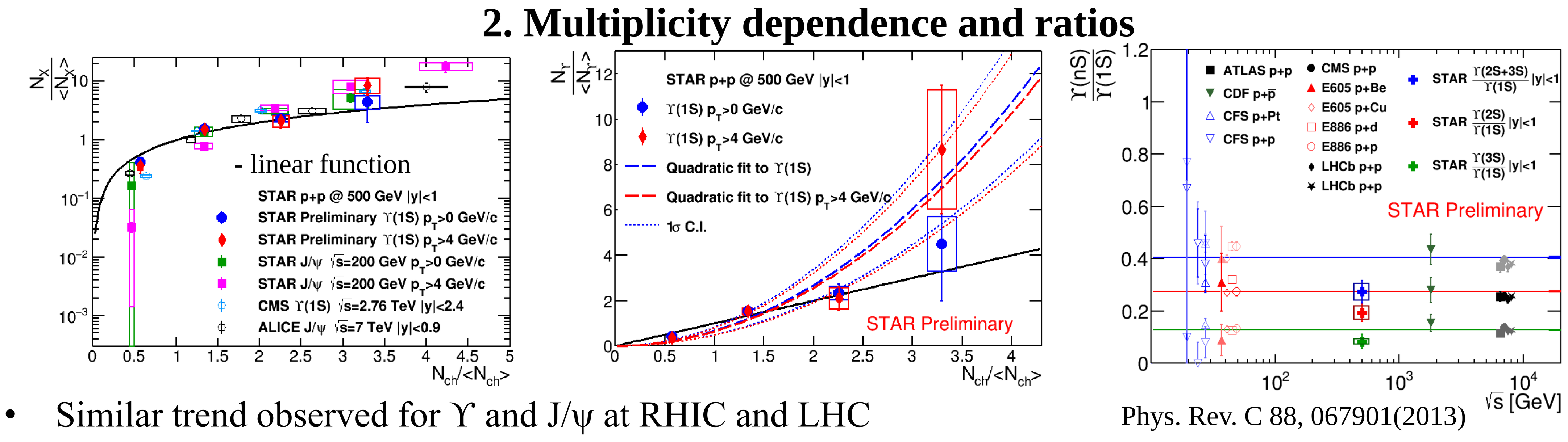
1. Spectra



- CEM for inclusive ϒ(1S) agrees with the data reasonably well
- CGC+NRQCD for direct ϒ(1S) above the data
- Rapidity distribution at $\sqrt{s} = 500$ GeV
  - Flatter than at $\sqrt{s} = 200$ GeV
  - Dip at midrapidity for ϒ(2S+3S) ≈ 2σ from flat

[Phys.Rev. D 94, 014028 (2016)]
[Phys.Rev. Lett. 113,192301 (2014)]
[Phys.Rev. C92 (2015)034909]

2. Multiplicity dependence and ratios



Phys. Rev. C 88, 067901(2013)

- Similar trend observed for ϒ and J/ψ at RHIC and LHC
- Both PYTHIA8 with MPI and Percolation Model qualitatively describe the trend in the data
  - Measurements with better precision at higher multiplicities are needed to distinguish among different models
- ϒ(nS)/ϒ(1S) ratios below world data average, but within 2σ

[JHEP04,103(2014)], [Nucl.and Part.Phys. Proc., 276-278, pp.261-264(2016)], [Phys.Lett.B 712,165-175(2012)], [Phys.Lett.B 786,87-93(2018)]

Conclusions

- ϒ(1S) spectra are reasonably well described by CEM model, but CGC+NRQCD overestimates the data especially at low-p_T
- Indication of a strong rise of ϒ/<ϒ> with multiplicity, similar to that seen for J/ψ at RHIC and LHC
- Measured ϒ(nS)/ϒ(1S) ratios at $\sqrt{s} = 500$ GeV are below world data average, however within 2σ

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