Event activity dependence of ϒ production in p+p collisions at √s=500 GeV with the STAR experiment

Leszek Kosarzewski, *for the STAR Collaboration*

Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague

Abstract

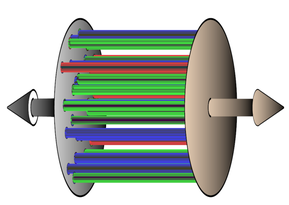
An interesting strong dependence on charged-particle multiplicity (N_{ch}) of J/ψ and ϒ production at the LHC and J/ψ at RHIC has been observed. These measurements provide basic information about particle production mechanisms, especially on an interplay between hard and soft processes (multiple parton interactions, string percolations, color reconnection). In order to better understand this behavior a study of ϒ production as a function of N_{ch} for different p_T ranges and collision energies. Furthermore, by measuring the yield ratios between the excited to ground ϒ states, ϒ(nS)/ϒ(1S), as a function of N_{ch}, the ϒ(nS)-hadron interactions can be studied.

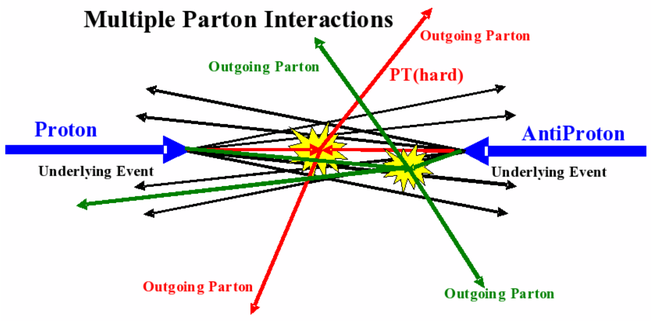
This poster presents STAR results on the self-normalized inclusive ϒ production yield (Υ/<Υ>) measured as a function of self-normalized N_{ch} in $\sqrt{s}$=500 GeV p+p collisions at RHIC. They are compared to results from other experiments and model calculations. The models and the data follow qualitatively similar trend of stronger than linear increase in high multiplicity events. The measured dependence of ϒ(nS)/ϒ(1S) yield ratios on N_{ch} is also presented.

High-multiplicity p+p collisions

Strong increase of Υ/<Υ> and J/ψ/<J/ψ> self-normalized yields with self-normalized multiplicity $N_{ch}/<N_{ch}>$ has been observed in high-multiplicity p+p collisions at LHC. Possible explanations:

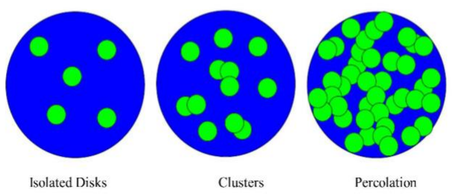
- **MPI** – quarkonium is produced in **multi-parton interactions** [1-3]:



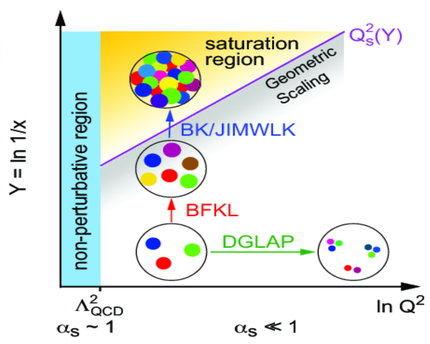


- **String Percolation** – suppression of soft particle production is caused by interactions between overlapping strings of color field [4]:

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



- **CGC-like saturation effects** – density of low-x gluons saturates, influences particle production from soft QCD processes [5,6]

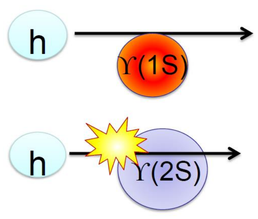


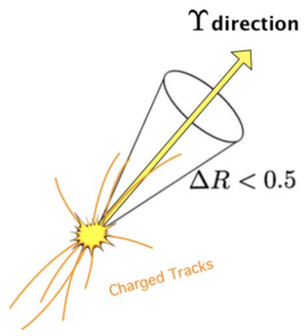
Baseline for A+A comover interaction studies

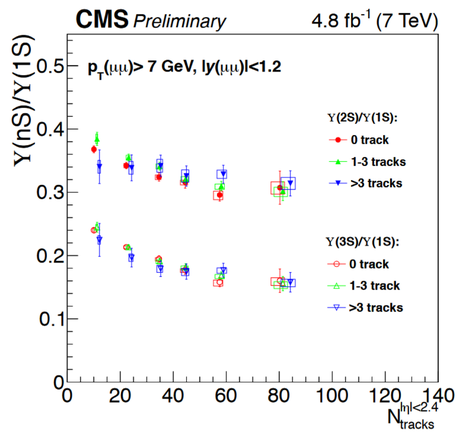
Upsilons may be broken up in collisions with hadrons. This contributes to the observed suppression in A+A collisions and needs to be disentangled from the effect of high temperature QGP. Studies of N_{ch} dependence of ϒ(nS)/ϒ(1S) ratios in p+p collisions provide a baseline reference.

Comover interaction models – include following effects on quarkonium production [7-9]:

- Comoving medium (+hadrons)
- Shadowing
- Regeneration

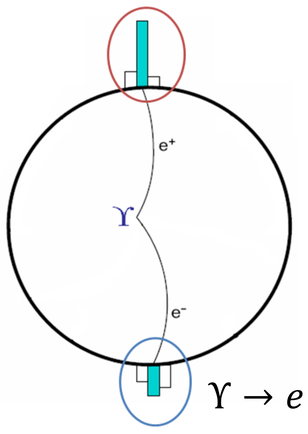




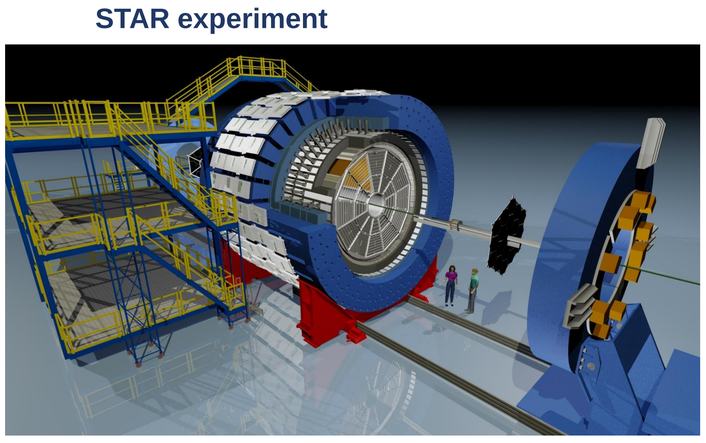


- **For ϒ(1S)**, it is expected to be a small effect [10]
- When **measured inside a cone** of radius $\Delta R < 0.5$ [11]:
  - No strong dependence on localized multiplicity at LHC

STAR experiment

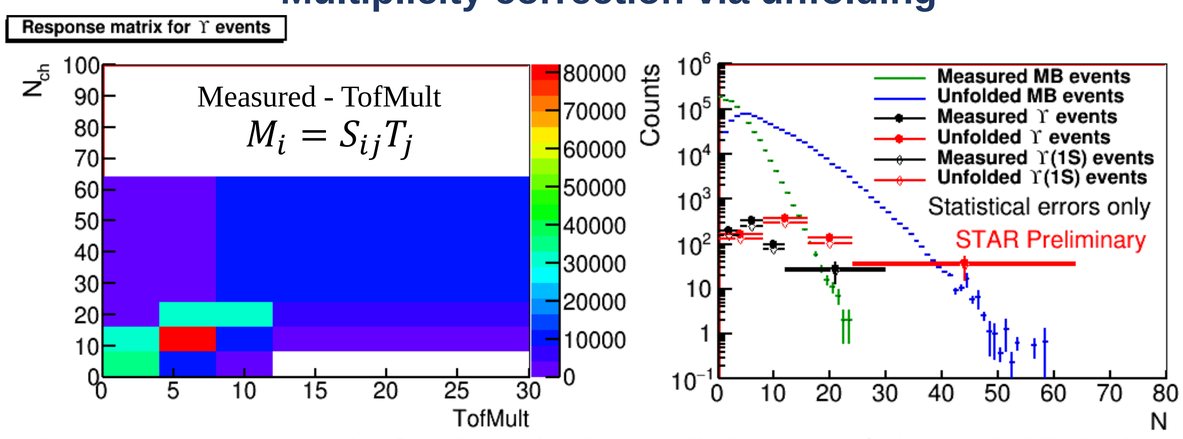


$\Upsilon \rightarrow e^+e^-$



- **TPC**-tracking and particle identification at midrapidity (p, dE/dx)
- **BEMC**-electron identification and triggering on high-p_T electrons (E)
- **TOF**-measures particle velocity, TPC tracks matched to TOF to reject pile-up for measuring N_{ch}

Multiplicity correction via unfolding

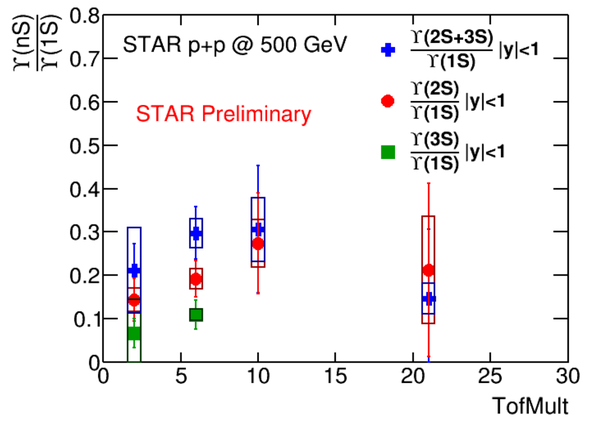


- Detector response matrix S_{ij} determined from PYTHIA simulation and STAR detector simulation
- Measured distributions M_i are unfolded in order to obtain the corrected ones T_j using a Bayesian unfolding method [12]

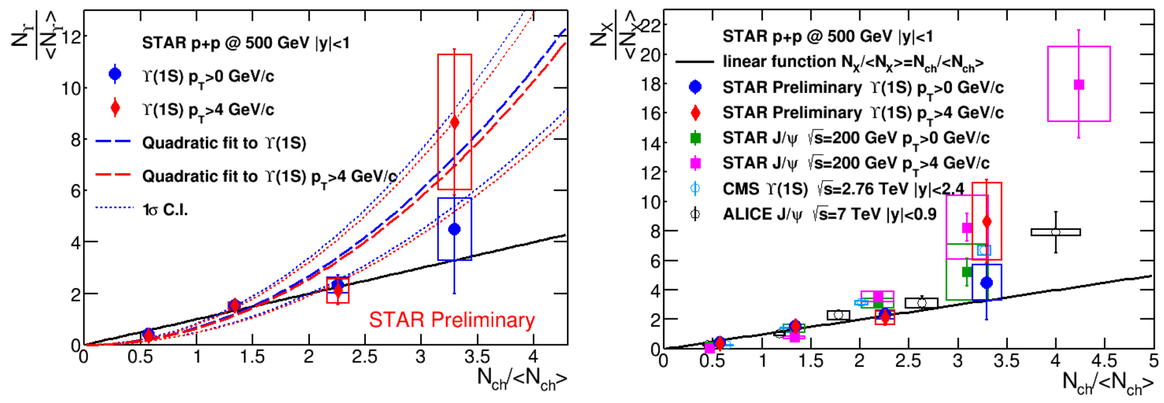
Results

Ratios vs. N_{ch}

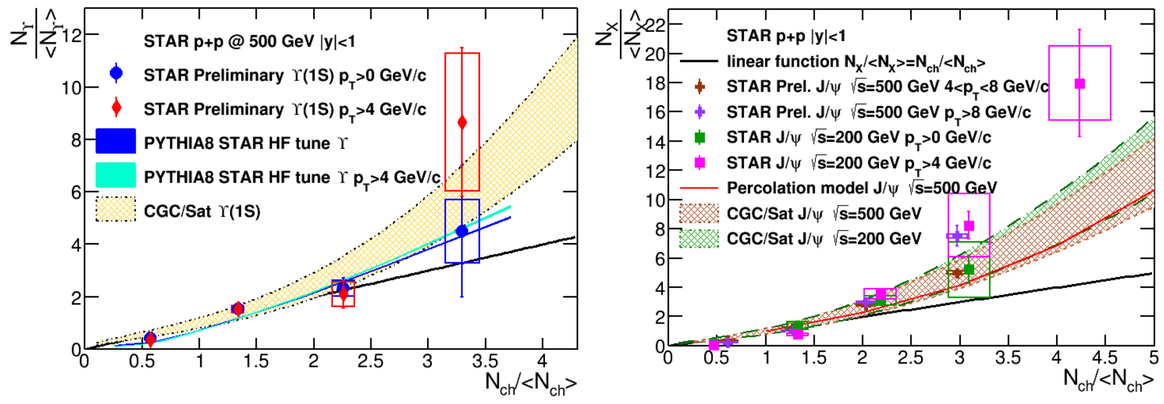
- No significant dependence on uncorrected N_{ch} matched to TOF (TofMult)
  - ϒ(nS)/ϒ(1S) ratios lower than world data average, but within 2σ [13]



Self-normalized ratios vs. self-normalized N_{ch}



- J/ψ and ϒ follow similar trends at RHIC and LHC [1-2,14-15]



- Both PYTHIA8 with MPI and Percolation Model qualitatively describe the trend in the data [4]
  - More precise measurements at high multiplicities are needed in order to distinguish between the models
- CGC/Saturation model describes the data well within uncertainties [5]
  - Consistent with ϒ measurements
  - Describes J/ψ data

Conclusions and outlook

- No significant dependence of ϒ(nS)/ϒ(1S) ratios on Nch observed
- STAR results consistent with strong dependence of Υ/<Υ> on self-normalized N_{ch},but uncertainties are large
- ϒ follows similar trend as J/ψ at RHIC and LHC
- ϒ data are qualitatively described by the PYTHIA and CGC/Saturation, Percolation models
- More precise measurements are needed at high N_{ch} and more differential studies (p_T, forward N_{ch} etc.)
- STAR collected 10x more data in 2017 p+p run for high-p_T quarkonium studies

References

[1] CMS Collaboration, JHEP04,103(2014)
[2] ALICE Collaboration, Phys.Lett.B 712,165-175(2012)
[3] STAR Colaboration, Phys.Lett. B786 (2018) 87-93
[4] Ferreiro, E et al., Phys.Rev. C, 86, 034903 (2012)
[5] Levin E et al., Eur.Phys.J. C79 (2019) no.5, 376
[6] Marquet C. et al., Nucl. Phys. A 904-905 (2013) 294c-301c
[7] Ferreiro E. et al., Phys. Lett. B731 (2014) 57
[8] Capella A. et al., Eur.Phys.J.C58 (2008) 437-444
[9] Capella A. et al., Phys.Rev.Lett. 85 (2000) 2080-2083
[10] Lin Z. et al., Phys.Lett.B503 (2001) 104-112
[11] CMS-PAS-BPH-14-009
[12] Adye T., arXiv:1105.1160
[13] Zha W. et al., Phys. Rev. C 88, 067901(2013)
[14] Ma R., Nucl.and Part.Phys. Proc., 276-278 (2016) 261–264
[15] STAR Collaboration, Phys.Lett.B 786,87-93(2018)

ČVUT ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

Supported by the Ministry of Education, Youth and Sports of the Czech Republic under grant: CZ.02.1.01/0.0/0.0/16_019/0000778

Supported in part by: U.S. DEPARTMENT OF ENERGY | Office of Science

The STAR Collaboration
drupal.star.bnl.gov/STAR/presentations

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research, Development and Education

MINISTRY OF EDUCATION, YOUTH AND SPORTS