Monte Carlo Simulations of Upsilon Meson Production

Jaroslav Bielcik, **Jakub Ceska***, Leszek Kosarzewski, Miroslav Myska
Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague (CZ)

Motivation

Υ in QGP

Υ mesons are a quark-gluon plasma (QGP) probe. The observed production suppression at higher temperatures is caused by:

- Debeye - like colour screening of diquark potential [1];
- cold nuclear matter effects, such as shadowing, comover interaction or nuclear absorption [2];
- feed-down contributions.

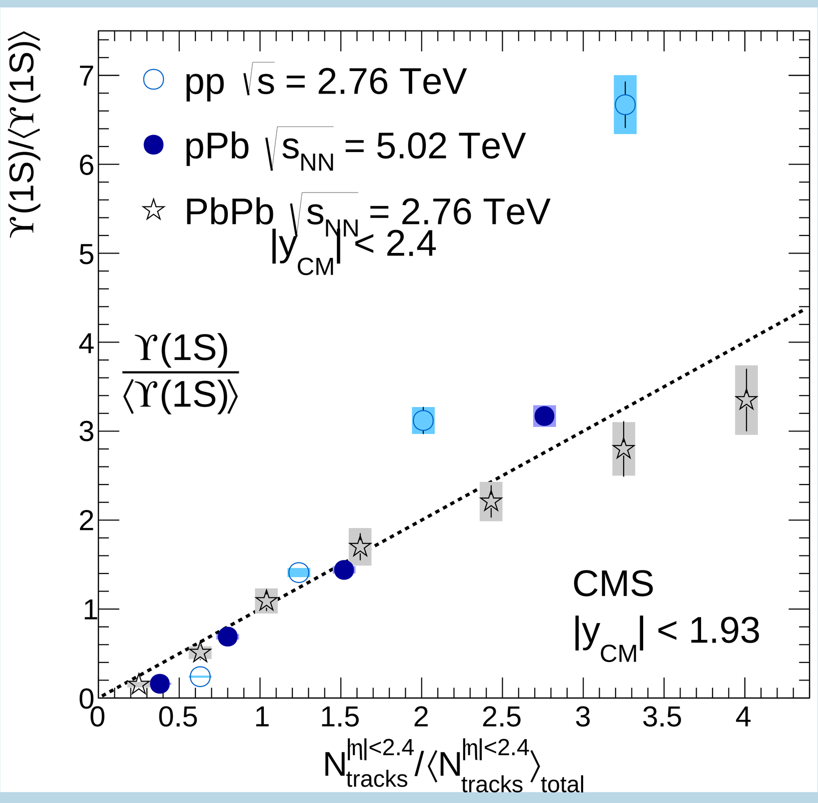
Production mechanisms

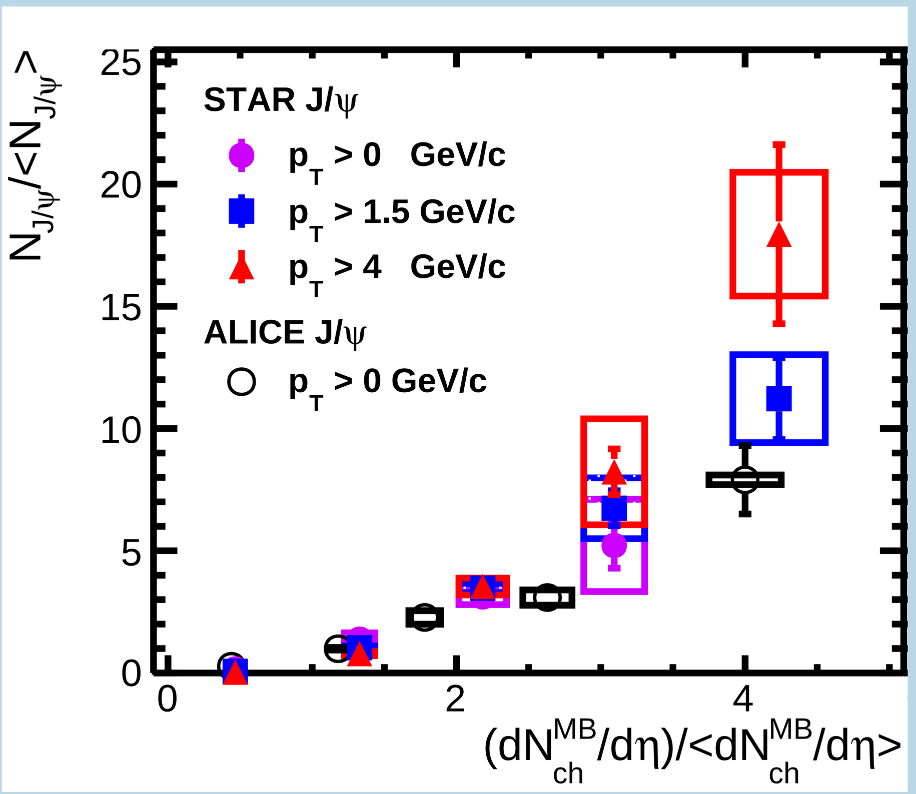
Υ production mechanism is not yet well understood. The important ingredients are:

- hard scattering - $b\bar{b}$ production;
- bound state formation - colour singlet, colour octet channels.

Charged particle multiplicity dependence

- CMS: strong Υ production dependence on charged particle multiplicity in pp @ $\sqrt{s} = 2.76$ TeV [3]
- STAR: similar trend for J/Ψ in pp @ $\sqrt{s} = 200$ GeV [4]





This dependence is sensitive to:

- interplay between soft and hard processes;
- multiple parton interaction influence;
- possible parton saturation signatures.

Normalised multiplicity dependence

Experimental observable $N_\Upsilon / \langle N_\Upsilon \rangle$ defined as:

$$N_\Upsilon / \langle N_\Upsilon \rangle = (N_{\mathrm{MB}}/N_{\mathrm{MB}}^{\mathrm{bin}})(N_\Upsilon^{\mathrm{bin}}/N_\Upsilon) \qquad (1)$$

$N_{\mathrm{ch}} / \langle N_{\mathrm{ch}} \rangle$ ... self-normalised particle multiplicity
N_Υ ... total number of events containing Upsilon meson
$N_\Upsilon^{\mathrm{bin}}$ ... number of Upsilon events in corresponding multiplicity bin
N_{MB} ... total number of minimum bias (MB) events
$N_{\mathrm{MB}}^{\mathrm{bin}}$ ... number of MB events in corresponding $N_{\mathrm{ch}} / \langle N_{\mathrm{ch}} \rangle$ bin

References

* speaker, ceskajak@fjfi.cvut.cz

[1] S. Chatrchyan *et al.* [CMS], Phys. Rev. Lett. **109** (2012), 222301
[2] Ziwei Lin and C.M. Ko, Phys. Lett. B **503** (2001), 104 - 112
[3] S. Chatrchyan *et al.* [CMS], JHEP **04** (2014), 103
[4] J. Adam, *et al.* [STAR], Phys. Lett. B **786** (2018), 87-93
[5] L. Kosarzewski [STAR]: *Overview of quarkonium production studies in the STAR experiment*, Presented at FAIRness 2019
[6] J. Adam *et al.* [ALICE], JHEP **09** (2015), 148

Acknowledgements

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PYTHIA

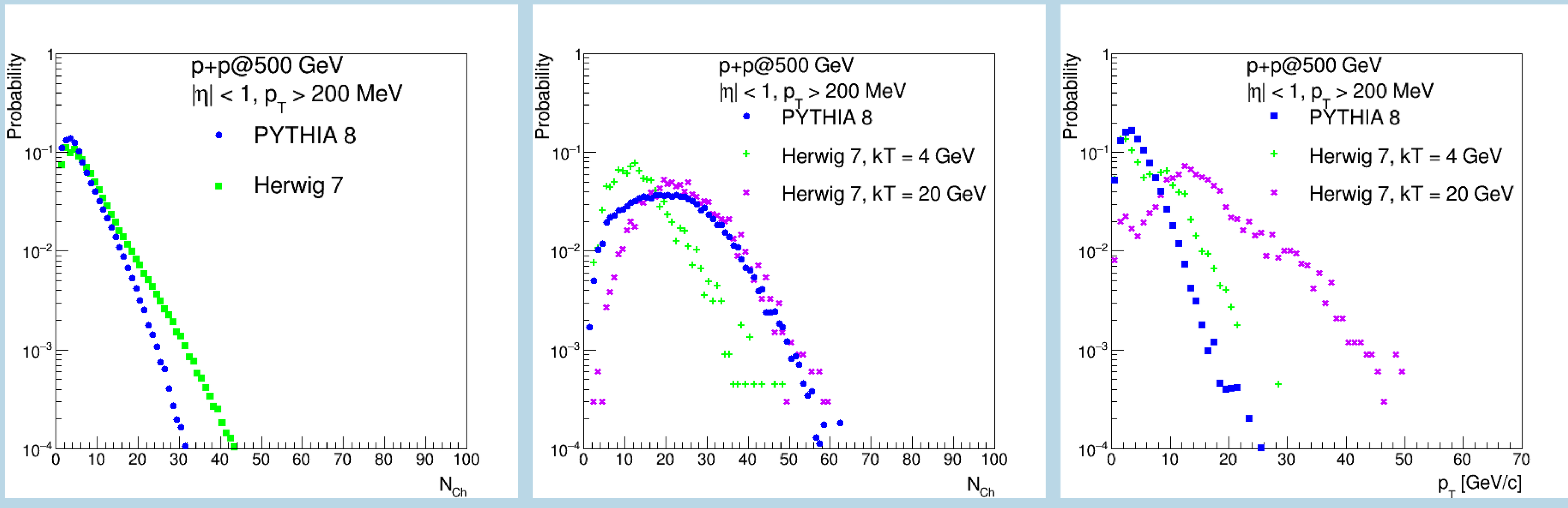
- p_T ordered showers
- Lund string hadronisation
- direct Upsilon production (matrix elements for Bottomonia)

Herwig

- angular ordered showers
- cluster hadronisation
- Upsilon production during hadronisation ($b\bar{b}$ matrix element)

Simulation

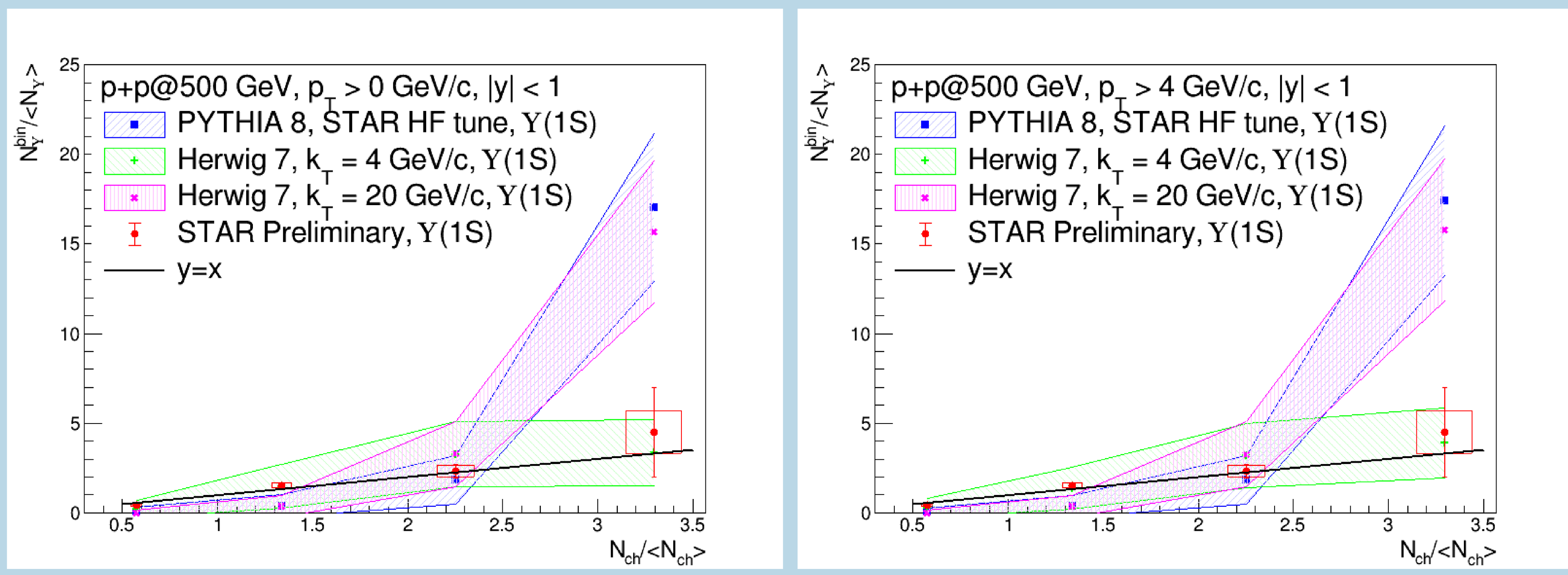
- PYTHIA and Herwig simulations of pp collisions at 500 GeV
- Minimum bias: non-single-diffractive SoftQCD
- Track selection: $|\eta| < 1$, $p_T > 0.2$ GeV/c, stable ($\tau > 10$ mm/c) (STAR cuts)
- Upsilon selection: $p_T > 0$ or 4 GeV/c, electron decay channel only, both electrons within acceptance
- Directly produced Upsilon(1S) - no feed-down contribution
- Herwig production depends on b-parton $k_\perp$ cut (4 or 20 GeV/c) - lower values result in spoiling track multiplicity while improving Upsilon characteristics
- Comparison to STAR preliminary data [5]



Multiplicity distributions for MB (left) and Upsilon(1S) (middle) events and p_T distributions for Upsilon events (right).

Results

- Normalised event multiplicity of Upsilon yield calculated using (1)
- $N_{\mathrm{ch}} / \langle N_{\mathrm{ch}} \rangle$ binning selected according to STAR preliminary data: 0-1, 1-2, 2-3, 3-8 and 8-100 (overflow bin)



Normalised Upsilon(1S) yield dependence on normalised multiplicity for PYTHIA and Herwig compared to STAR preliminary data [5];
left: p_T integrated; right: $p_T > 4$ GeV/c.

Conclusion

- The minimum bias spectra differ significantly for PYTHIA and Herwig in larger multiplicities
- Upsilon production in Herwig has limited validity
- Both PYTHIA and Herwig ($k_\perp = 20$ GeV/c) predict stronger than linear increase in normalised Upsilon yield in dependence on normalised multiplicity
- In comparison to STAR preliminary data [5] both PYTHIA and Herwig ($k_\perp = 20$ GeV/c) predict higher values for larger multiplicities, while underestimating smaller multiplicity values
- The data suggests, that Upsilon mesons are produced in multi-parton collisions [6], due to stronger than linear increase predicted by PYTHIA and Herwig ($k_\perp = 20$ GeV/c)

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