Multiplicity dependence of Υ meson production in p+p collisions at $\sqrt{s} = 510$ GeV

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Abstract

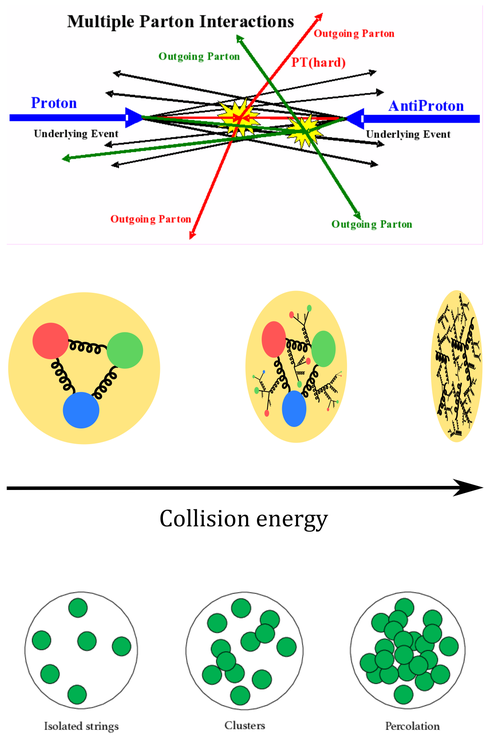
Measurements of Υ meson production in heavy-ion collisions allow the study of the properties of the quark-gluon plasma, such as in-medium modifications to the strong interaction and the medium's thermodynamic properties. However, the quarkonium production mechanism is not completely understood even in vacuum, which is of great interest on its own. It could also have significant consequences for interpreting Υ measurements in heavy-ion collisions.

In this poster, we present the status of the latest measurements of Υ meson production via the dielectron channel in p+p collisions at $\sqrt{s} = 510$ GeV recorded by the STAR experiment in 2017. The transverse momentum and rapidity spectra of three Υ states combined will be calculated. We will also measure the dependence of self-normalised Υ meson yield on self-normalised charged-particle multiplicity to probe the interplay between soft and hard processes. The presented analysis utilises a data sample with a significant increase in statistics compared to previous measurements, which results in improved precision and extended multiplicity reach.

Motivation

A significant increase of the dependence of the self-normalised quarkonium yield on the self-normalised charged-particle multiplicity has been observed in high-multiplicity p+p collisions at the RHIC and the LHC. Possible explanations for this phenomenon include:

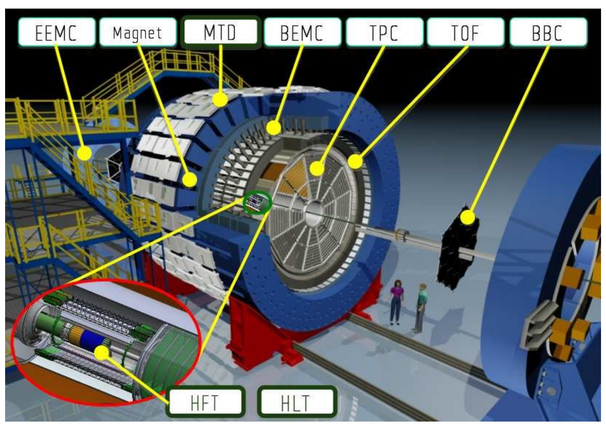
- **Multi-parton interactions (MPIs)** [1, 2, 3, 4]
  - quarkonia produced predominantly in MPIs
  - quarkonium yield proportional to #MPIs
  - multiplicity proportional to energy density
- **CGC saturation effects** [5, 6]
  - low-x gluon density saturates → soft-QCD particle production influenced
- **String percolation** [7]
  - soft-QCD production suppression due to interactions of overlapping colour field strings



STAR

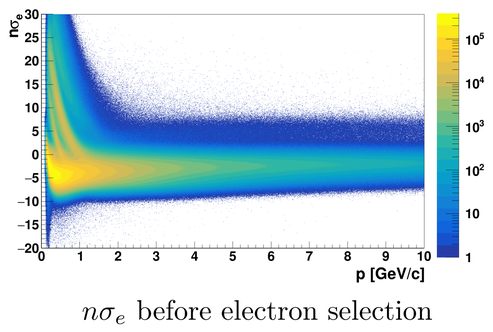
The STAR experiment is located at the RHIC collider in BNL. Subdetectors primarily used in this analysis are:

- **TPC** - tracking and PID (p, dE/dx)
- **BEMC** - electron ID, high-p_{T} electron trigger (E)
- **TOF** - precise multiplicity measurement due to pile-up removal (TofMult)
- **BBC** - instantaneous luminosity determination to correct for TPC tracking efficiency

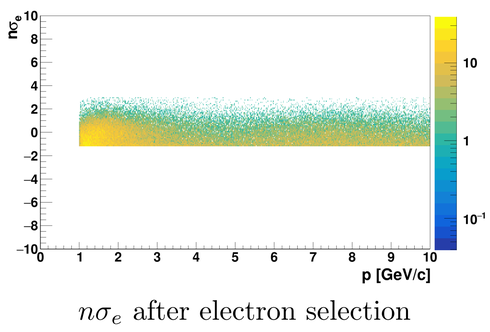


Electron selection

$\mathbf{n\sigma_e}$ (based on dE/dx)	**-1.2 - 3.0**
$\mathbf{E_{TOW}/E_{CLU}}$	$> \mathbf{0.5}$
$\mathbf{E_{CLU}/p}$	**0.45 - 1.45**
$\mathbf{\lvert\Delta Z\rvert}$	$< \mathbf{5}$ **cm**
$\mathbf{\lvert\Delta\varphi\rvert}$	$< \mathbf{0.020}$ **rad**



$n\sigma_e$ before electron selection



$n\sigma_e$ after electron selection

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

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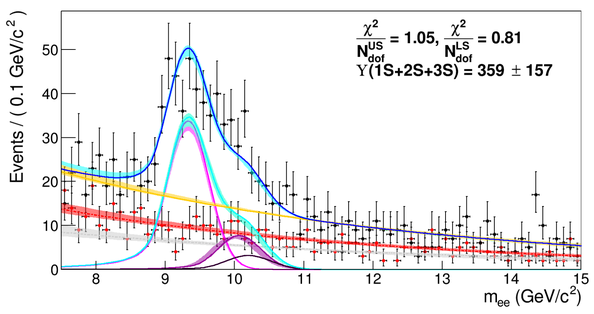
Analysis

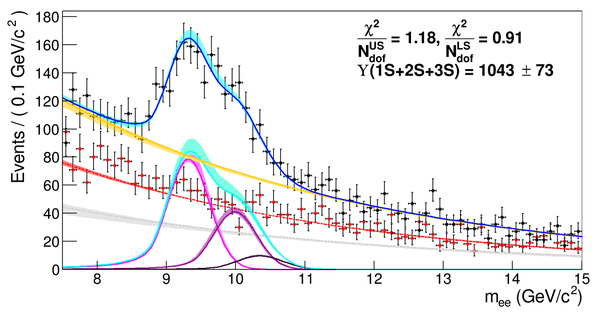
The signal extraction procedure utilises both the unlike-sign (US) and like-sign (LS) dielectron mass spectra. The components of the **total fit** include:

- **background**
  - **combinatorial background** - exponential, LS mass spectrum used
  - **residual background** - exponential
- **signal** - 3 one-sided Crystal Ball functions (**Υ(1S)**, **Υ(2S)**, **Υ(3S)**)

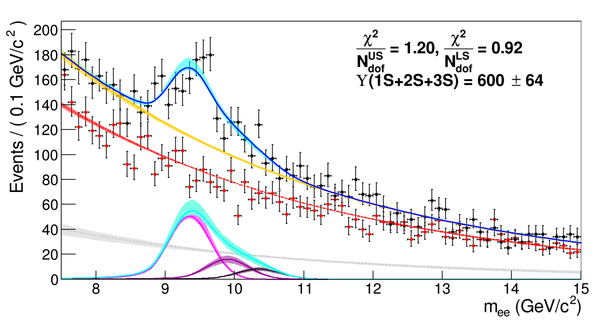
The model is implemented using unbinned likelihood method and uses simultaneous fitting of both of the mass spectra via recursive fractions.
The constraints used include mass separation of 500 MeV/c^2 and 400 MeV/c^2 for Υ(1S), Υ(2S) and Υ(3S) respectively. The widths and their constraints were chosen to correspond linearly with the state's invariant mass
The fit is performed in several normalised TofMult bins (0-1, 1-2, 2-3, 3-7), which will be then used to obtain the dependence of the self-normalised Υ meson multiplicity on the self-normalised charged-particle multiplicity.



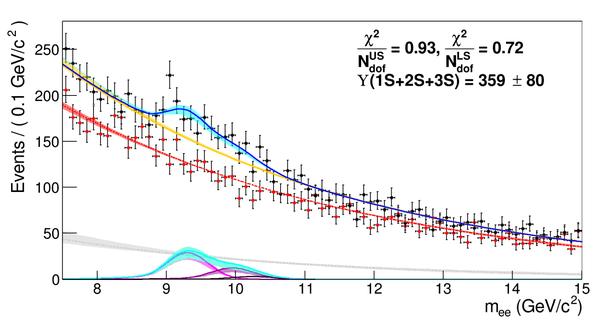
0-1 ⟨TofMult⟩



1-2 ⟨TofMult⟩



2-3 ⟨TofMult⟩



3-7 ⟨TofMult⟩

Fits can be improved by using constraints from embedding simulations - ongoing.

Conclusion

The analysis is currently in progress. The signal extraction procedure is set up and provides results, which agree with expectations.
Work continues on the embedding to constrain the lineshapes and unfolding to obtain a measure of event multiplicity independent of luminosity and detector effects. More effort is needed in estimating the Υ reconstruction efficiency.
The dataset should provide the largest Υ signal ever observed at RHIC. This will allow for high precision high-p_{T} measurement. The results will provide additional constraints to models of Υ production and its dependence on the charged-particle multiplicity.

References

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