Measurements of suppression of Y 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 Y 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 Y in an insight can be gained into the interplay of hard and soft QCD processes affecting the quarkonium production.

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

**Abstract**

**Quarkonium production mechanism**

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

- **Color Evaporation Model** - \( F_\text{C} \) a fixed fraction of quark-antiquark pairs forms a particular bound state

\[
dx = F_\text{C} \int_{0}^{\frac{1}{T}} \frac{d^3k}{d\Lambda} (k_{+}, k_{-}) \left( \frac{e^{k_{+}T} - 1}{e^{k_{+}T} + 1} \right)
\]

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

\[
dx = \sum_{\text{colour-singlet state}} \left( \alpha_{s}(x_{Q}) \right)^{2} \left( k_{\perp}^{2} \right)^{-2} e^{-\frac{x_{Q}}{x_{0}}}
\]

- **TOF - particle velocity measurement, TPC tracks matched to TOF to reject pile-up for measuring \( N_{\text{ch}} \)**

- **TPC - tracking and particle identification at midrapidity**

- **BEMC - electron identification and triggering on high-\( p_{T} \) electrons**

**Results**

1. **Spectra**

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

2. **Multiplicity dependence and ratios**

- Similar trend observed for \( \Upsilon \) and J/\( \Psi \) 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
- \( \Upsilon(1S)/\Upsilon(1S) \) ratios below world data average, but within 2σ

**Motivation**

The enhanced production of \( \Upsilon \) states in heavy-ion collisions at RHIC is well understood. The simulation models based on parton distribution function (PDF) and transport models, such as the UrQMD model, are used to describe the measured data. However, the transport models are limited in describing the reactions at RHIC energies.

**High multiplicity p+p collisions**

Enhancement of normalized \( \Upsilon \) production \( (\Upsilon)/n_{\text{ch}} \) vs. normalized charged particle multiplicity \( (N_{\text{ch}})/n_{\text{ch}} \) has been observed in high-multiplicity p+p collisions. Possible explanations:

- **MPI - quarkonium is produced in multi-parton interactions:**
  - \( \Upsilon \) production is initiated by multi-parton interactions, leading to an enhancement in \( \Upsilon \) yield.
  - \( \Upsilon \) production is not directly correlated with the number of charged particles.

- **String Percolation - interactions between strings of color field cause suppression of soft particle production:**
  - String percolation occurs when strings of color field create a network that suppresses the production of soft particles.
  - This mechanism leads to a decrease in the yield of \( \Upsilon \) states at high multiplicities.

**Conclusions**

- \( \Upsilon(1S) \) spectra are reasonably well described by CEM model, but CGC+NRQCD overestimates the data especially at low-\( p_{T} \).
- Indication of a strong rise in \( \Upsilon \) yield with multiplicity, similar to that seen for J/\( \Psi \) at RHIC and LHC.
- Measured \( \Upsilon(1S)/\Upsilon(1S) \) ratios are below world data average, however within 2σ.