Correlation of Upsilon states with underlying event activity in 13 TeV pp collisions measured by the ATLAS experiment

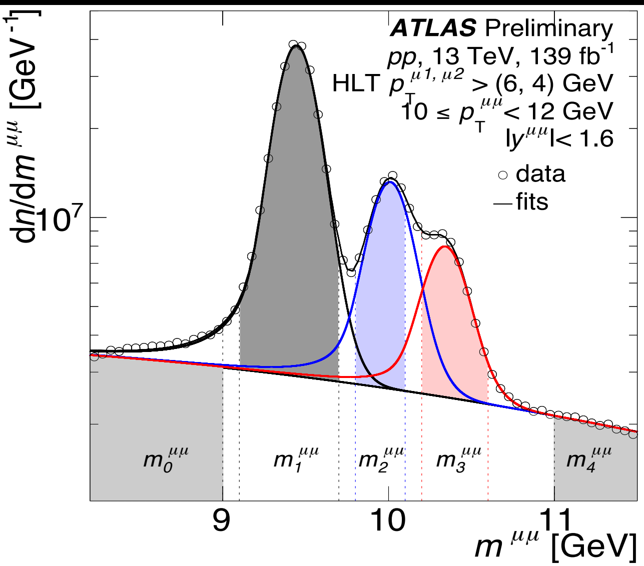
Iakov Aizenberg on behalf of the ATLAS Collaboration

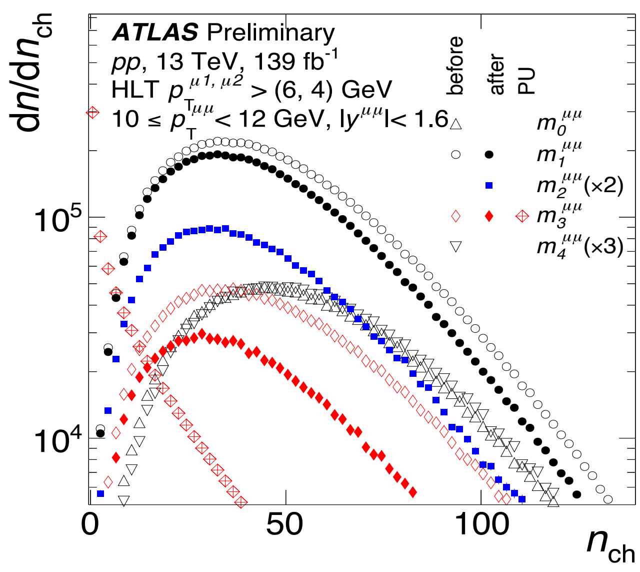
Strangeness in Quark Matter 2022, Poster Session

Introduction and Motivation

- There are many studies of small systems demonstrating QGP-like signatures that belong to soft physics, but there are not many measurements in hard probes. It motivates a search for unexpected features of hard probes in pp collisions.
- Among hard probes, Upsilon states are most sensitive to QGP in A+A systems. Upsilons are rare probes → we need high statistics. High statistics is available, but it was obtained at $\mu < 80$ (μ = pileup).
- Pileup evaluation technology based on the mixed event technique was developed in previous study of long-range 2PC in Z-boson tagged pp collisions (*Eur. Phys. J. C* **80**, 64 (2020)).
- CMS observed a decrease of the ratio of yields Υ(nS) / Υ(1S) as a function of multiplicity and studied the effect in different sphericity intervals (JHEP04(2014)103, JHEP11 (2020) 001). It was suggested that the decrease in the ratios is an UE effect.
- Search for modification of the UE (soft) for different Upsilon states (hard) in pp collisions by measuring $n_{ch}, dn_{ch}/dp_T$ and $dn_{ch}/d\Delta\phi$, where $\Delta\phi = \phi^{\Upsilon} - \phi^{h}$

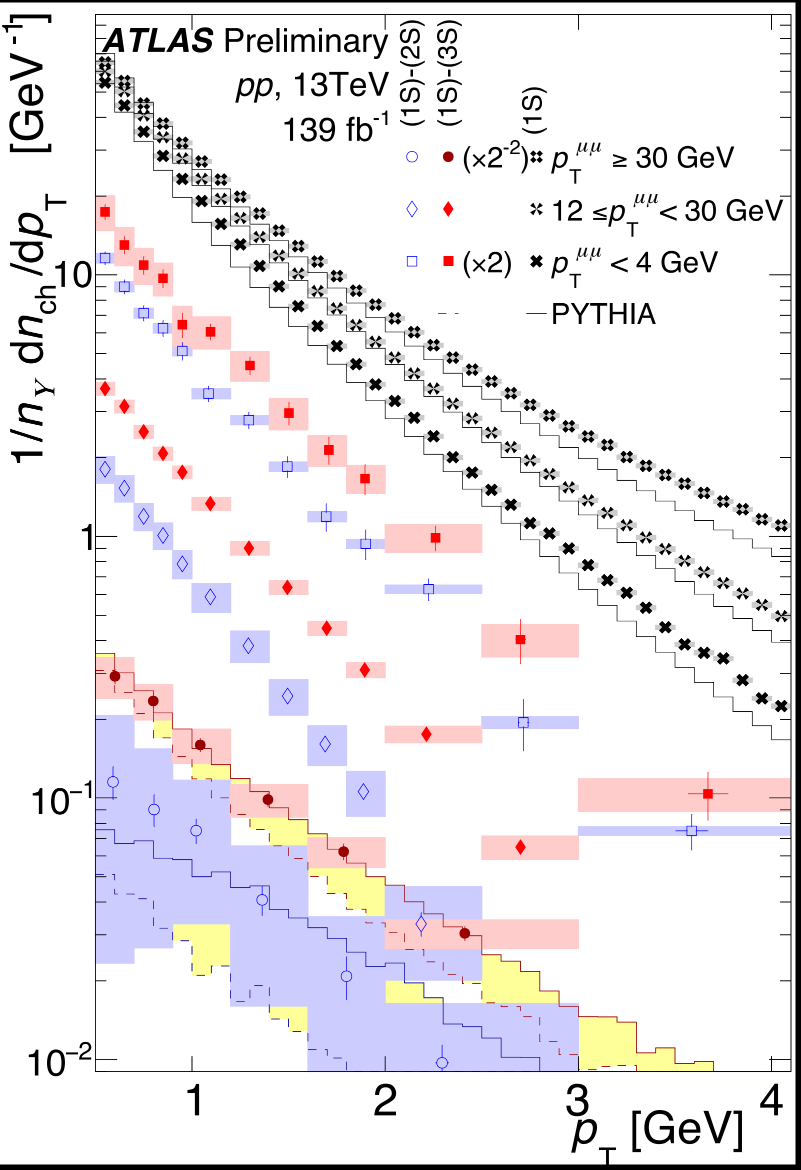
Analysis





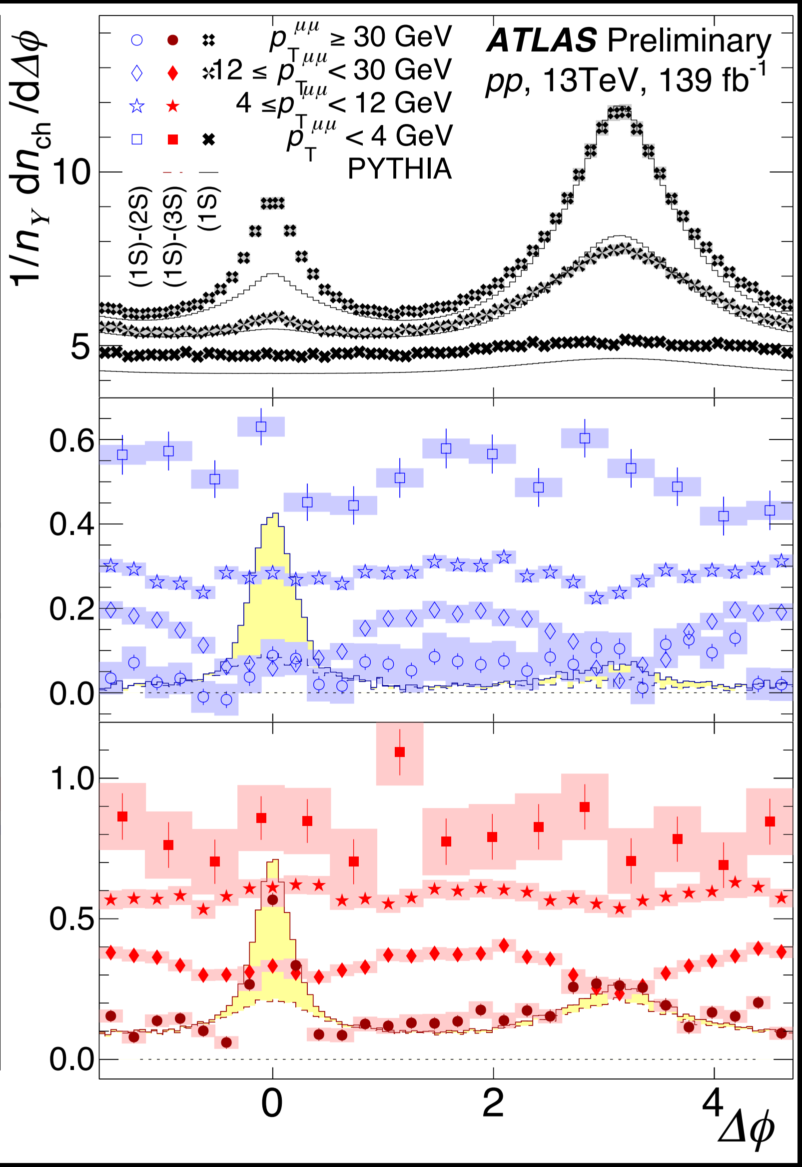
- Full Run 2 13 TeV pp collisions data as sampled by ATLAS detector di-muon triggers.
- $\Upsilon \to \mu\mu$ events with $|y^{\mu\mu}| < 1.6$.
- Charged particles: 0.5 < p_T < 10 GeV, and $|\eta| < 2.5$.
- Analyze Υ candidates in 5 mass regions, use fits to disentangle signal & background.
- Extracting n_{ch} distributions for these 5 mass regions, one can see that the background in the 'upper-mass' and 'lower-mass' regions are quite similar in shape → side-band subtraction works well!
- Pileup is controlled.
- n_{ch} distributions for Y states are different.
- dn_{ch}/dp_T $dn_{ch}/d\Delta\phi$ are measured using the same procedure.

Kinematic Distributions of Υ(1S)-Υ(nS)



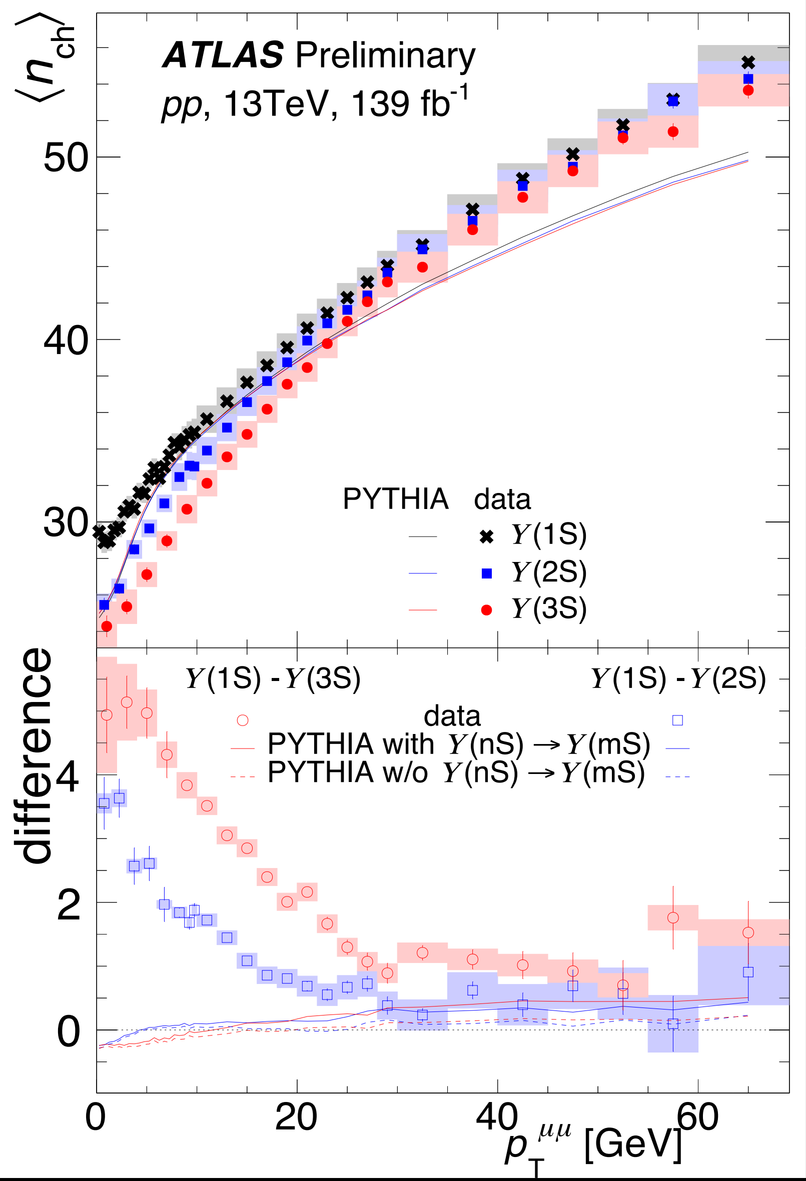
- **Subtracted p_T distributions are consistent in shape with the UE and not jets.**
- Figure shows p_T distributions of charged particles for Υ(1S) and subtracted distributions for Υ(1S)-Υ(nS) for several $p_T^{\mu\mu}$ intervals. Markers – data, lines – Pythia.
- For $p_T^{\mu\mu}$ < 4 GeV, the distribution resembles particles coming from the UE.
- For $p_T^{\mu\mu}$ < 30 GeV, subtracted distributions are consistent in shape with Υ(1S) distribution measured in the lowest $p_T^{\mu\mu}$.
- Above 30 GeV, subtracted distributions gets harder, which is explained by feed-down decay processes.

Kinematic Distributions of Y(1S)-Y(nS)



- **Subtracted $\Delta\phi$ distributions resemble UE**
- Subtracted distributions start to display some non-uniformity in the interval $p_T^{\mu\mu} \geq 12$ GeV.
- For Y(3S) at $p_T^{\mu\mu}$ > 30 GeV, peaks appear around $\Delta\phi = 0$ and $\Delta\phi = \pi$. Likely explained by feed-down decays (Y(nS)→Y(1S), χ_b(mP)→Y(nS))
  - Pythia shows effect of Y(nS)→Y(1S)

Mean Values of n_{ch} Distribution



Strong difference in the multiplicity of the UE for different Υ(nS) states is observed.

The effect is strongest at $p_T^{\mu\mu} = 0$ and diminishes with increasing $p_T^{\mu\mu}$, but still visible at 20-30 GeV.

Feed-down of Υ(nS) states, mass differences, systematic uncertainties cannot explain the effect.

At the lowest measured $p_T^{\mu\mu}$, for Υ(1S)-Υ(2S) the difference is 3.6±0.4 and for Υ(1S)-Υ(3S) the difference is 4.9±1.1

Similarity

In Ref [arXiv:2203.11831v1], the transverse mass scaling of heavy mesons is studied using all available LHC data at $\sqrt{s} = 7$, 8 and 13 TeV. Analysis reveals significant difference in the yield ratios of Υ(nS)/Υ(1S) between expectations from m_T-scaling and the measurements. This difference has similar $p_T^{\mu\mu}$ shape as the difference in $\langle n_{ch} \rangle$ between Υ-states measured by ATLAS, suggesting the possibility that these are two manifestations of the same physics mechanism.

ATLAS-CONF-2022-023 arXiv:2203.11831v1