Correlation of Y meson production with the underlying event in pp collisions measured by the ATLAS experiment

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Introduction and Motivation

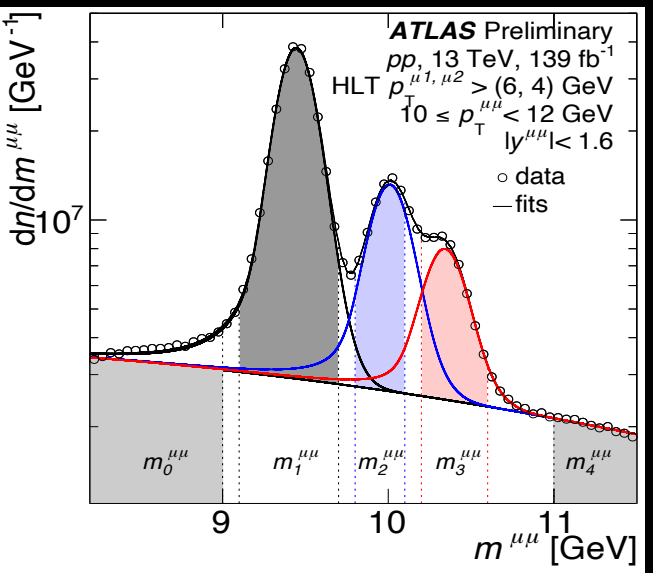
- There are many studies of small systems demonstrating QGP-like signatures that belong to soft physics, but there are not many measurements in hard probes.

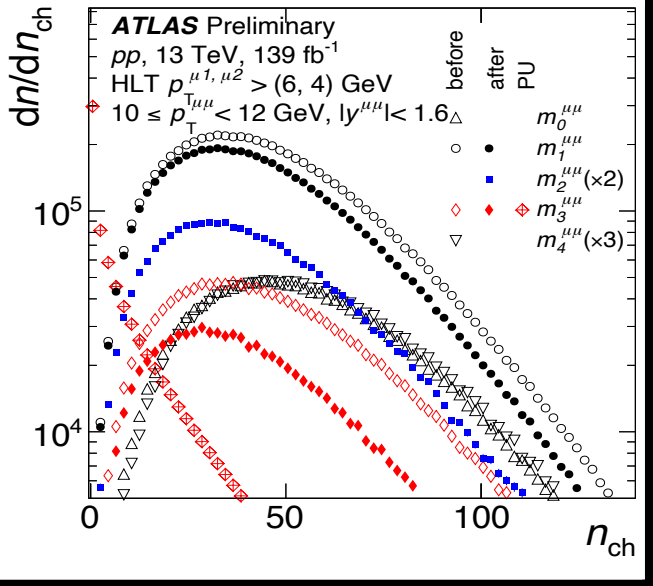
- Previous study of long-range 2PC in Z-boson tagged pp collisions (*Eur. Phys. J. C* **80,** 64 (2020)) → Hard + soft in pp collisions, comprehensive pileup technology developed

- 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 $\Delta\phi = \phi^Y - \phi^h$

- CMS observed a decrease of the ratio of yields Y(nS) / Y(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.

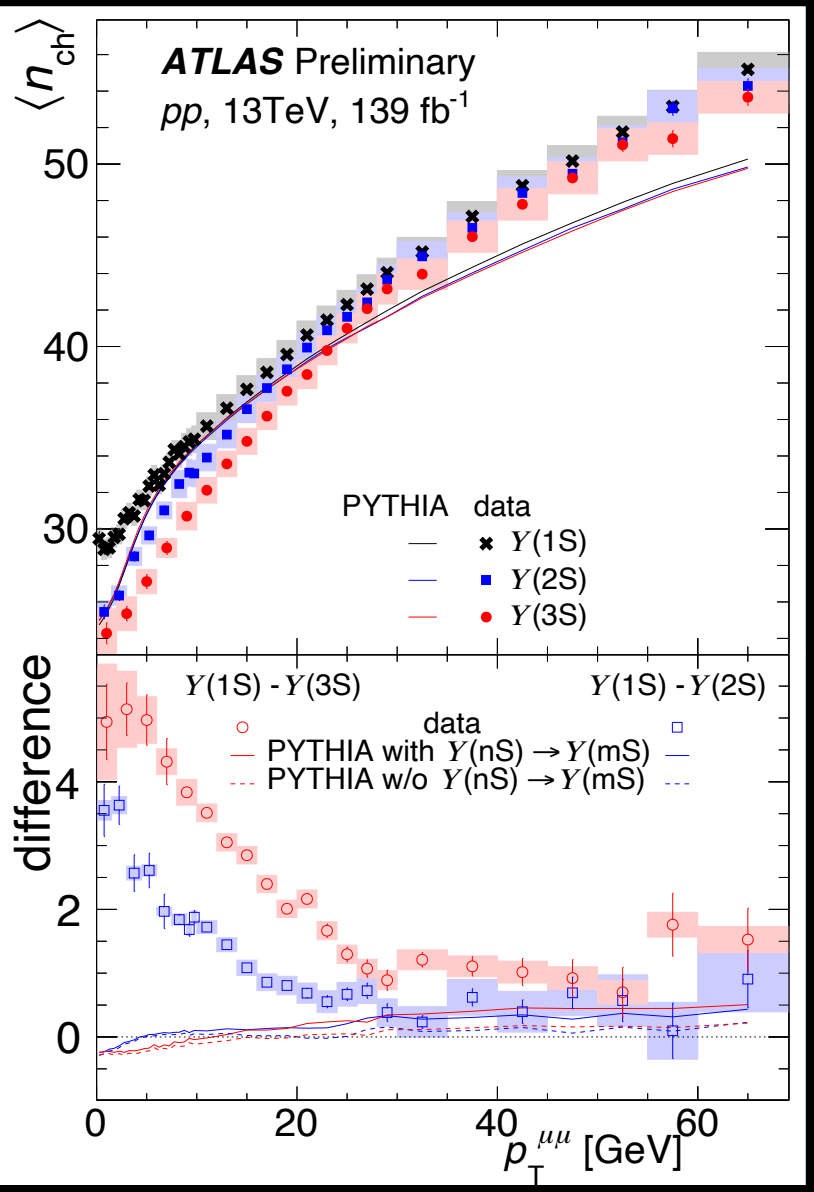
Analysis





- Full Run 2 13 TeV pp collisions data as sampled by ATLAS detector di-muon triggers
- $Y \rightarrow \mu\mu$ events with $|y^{\mu\mu}| < 1.6$.
- Charged particles: $0.5 < p_T < 10$ GeV, and $|\eta| < 2.5$
- Analyze Y 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

Mean Values of n_{ch} Distribution



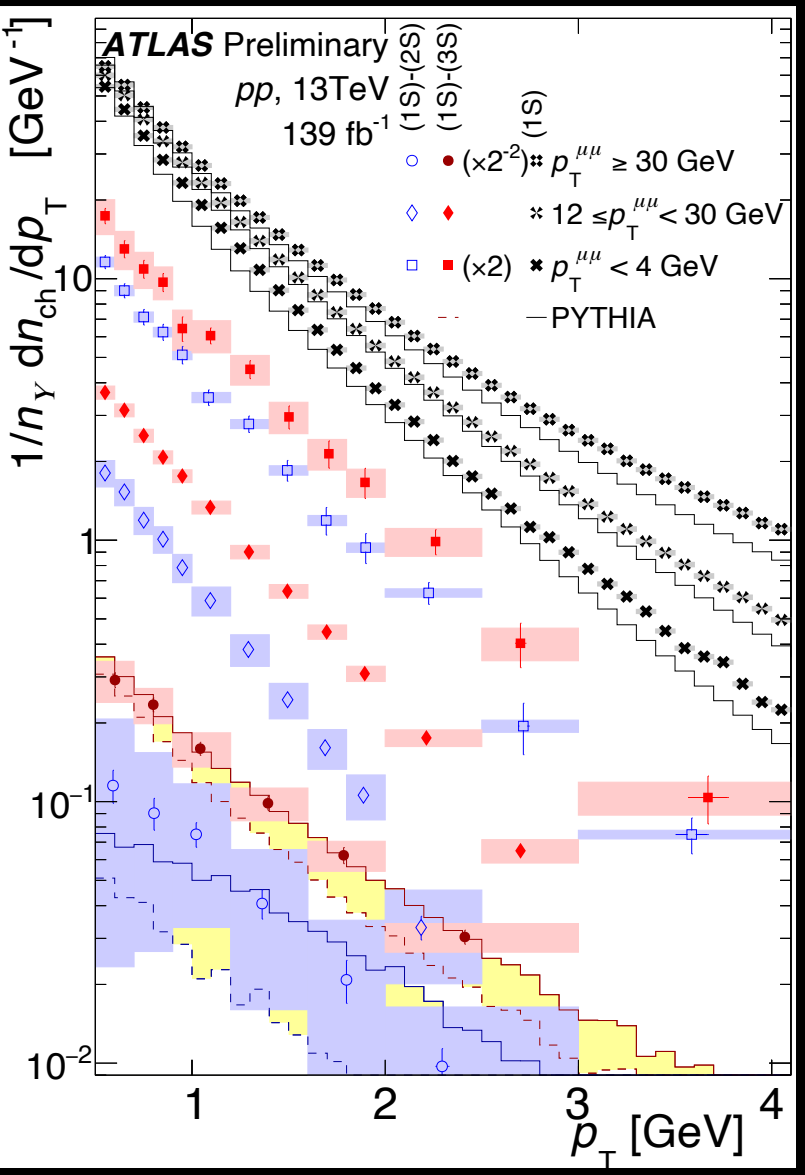
Strong difference in the multiplicity of the UE for different Y(nS) states is observed.

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 Y(nS) states, mass differences, systematic uncertainties cannot explain the effect.

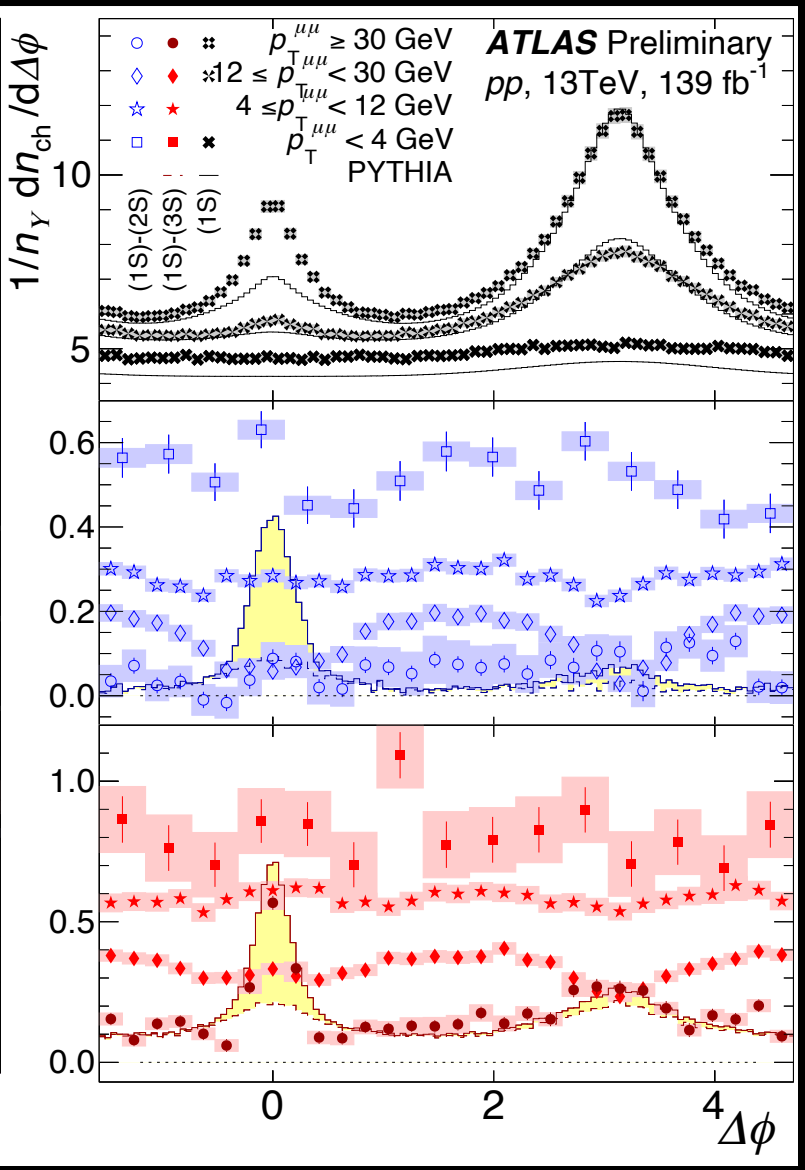
At the lowest measured $p_T^{\mu\mu}$, for Y(1S)-Y(2S) the difference is 3.6±0.4 and for Y(1S)-Y(3S) the difference is 4.9±1.1

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



- **Subtracted p_T distributions are consistent in shape with the UE and not jets.**
- Figure shows p_T distributions of charged particles for Y(1S) and subtracted distributions for Y(1S)-Y(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 Y(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)

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 Y(nS)/Y(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 Y-states measured by ATLAS, suggesting the possibility that these are two manifestations of the same physics mechanism.

ATLAS-CONF-2022-023 *arXiv:2203.11831v1*