ATLAS measurements of correlations between Υ mesons and inclusive charged particles

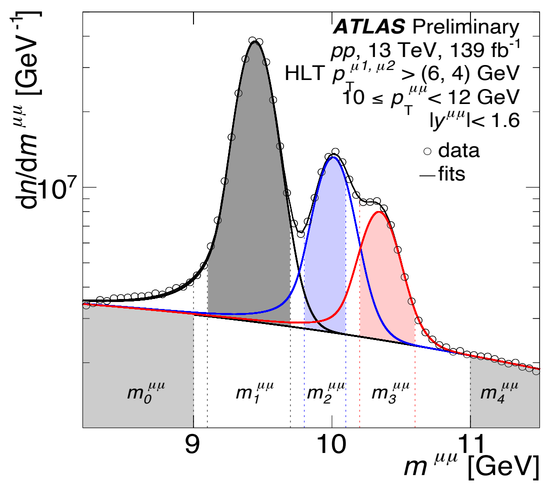
ATLAS-CONF-2022-023

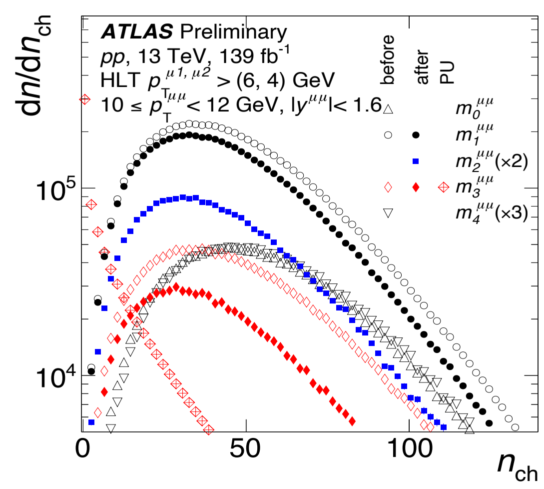
Introduction and Motivation

- Many studies of small systems demonstrate QGP-like signatures that belong to soft physics, but there are not many measurements with hard probes. It motivates a search for new phenomenon in *pp* collisions with hard probes.
- Υ states are most sensitive hard probes of QGP formed in A+A system. $\Upsilon(nS)$ are rare probes that require high statistics which is available at high pileup.
- Pileup evaluation and removal is based on the mixed event technique, that was developed for study of long-range 2PC in *Z*-boson tagged *pp* collisions (EPJC 80 (2020) 64).
- CMS observed a decrease of yields $\Upsilon(n\mathrm{S})$ / $\Upsilon(1\mathrm{S})$ ratios as a function of multiplicity and studied the effect in different sphericity intervals (JHEP04 (2014) 103, JHEP11 (2020) 001). CMS concluded that the effect is related to the underlying event (UE).
- In this analysis, we search for modification of the UE (soft) for different $\Upsilon(nS)$ 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

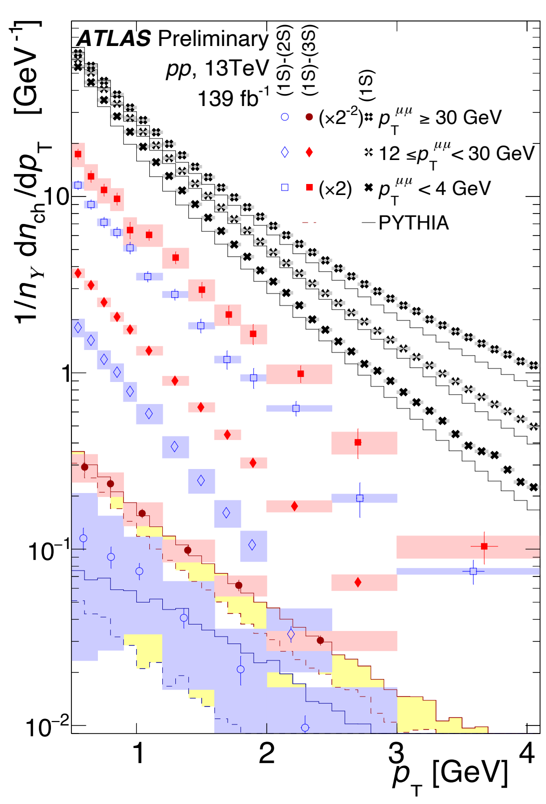
- Full Run-2 13 TeV *pp* collisions data obtained by the ATLAS detector with di-muon triggers.
- $\Upsilon \to \mu\mu$ events with $|y^{\mu\mu}| < 1.6$.
- Charged hadrons: $0.5 < p_T < 10$ GeV, $|\eta| < 2.5$.
- Define $\Upsilon(nS)$ and background rates using fits.
- Extract n_{ch} and all kinematic distributions using the side-band subtraction method by defining five $m^{\mu\mu}$ regions.
- Subtract the pileup using the Mixed Event technique.
- n_{ch} distributions for Υ states are different.
- dn_{ch}/dp_T $dn_{ch}/d\Delta\phi$ are measured using the same procedure.

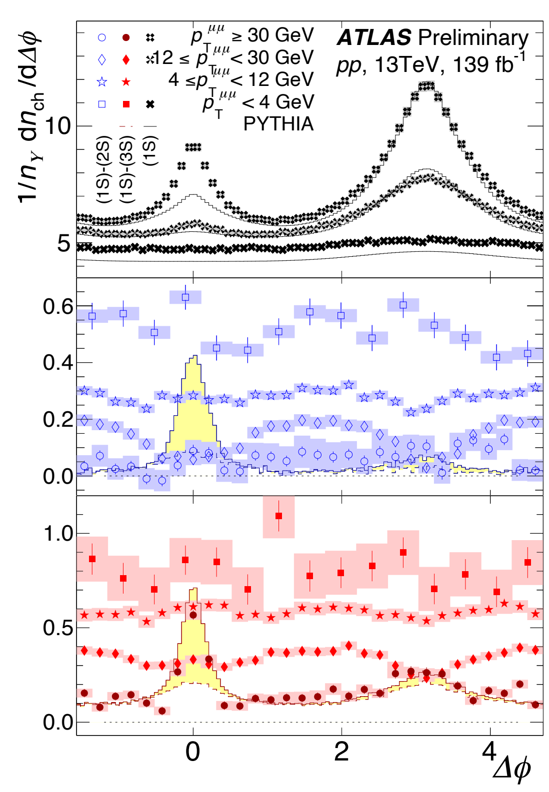




Kinematic Distributions of $\Upsilon(1S)$ and $\Upsilon(1S)$ - $\Upsilon(nS)$

- Subtracted p_T distributions are consistent in shape with the UE and not jets.
- Left panel shows p_T distributions of charged particles for $\Upsilon(1S)$ and subtracted distributions for $\Upsilon(1S)$ - $\Upsilon(2S)$ and $\Upsilon(1S)$ - $\Upsilon(3S)$ for several $p_T^{\mu\mu}$ intervals. Markers – data, lines – Pythia.
- $\Upsilon(1S)$ distribution for $p_T^{\mu\mu}$ < 4 GeV represents the UE.
- For $p_T^{\mu\mu}$ < 30 GeV, subtracted distributions are consistent in shape with $\Upsilon(1S)$ distribution measured in the lowest $p_T^{\mu\mu}$.
- Above 30 GeV, subtracted distributions gets harder, which is partially explained by feed-down decay processes (yellow from Pythia).





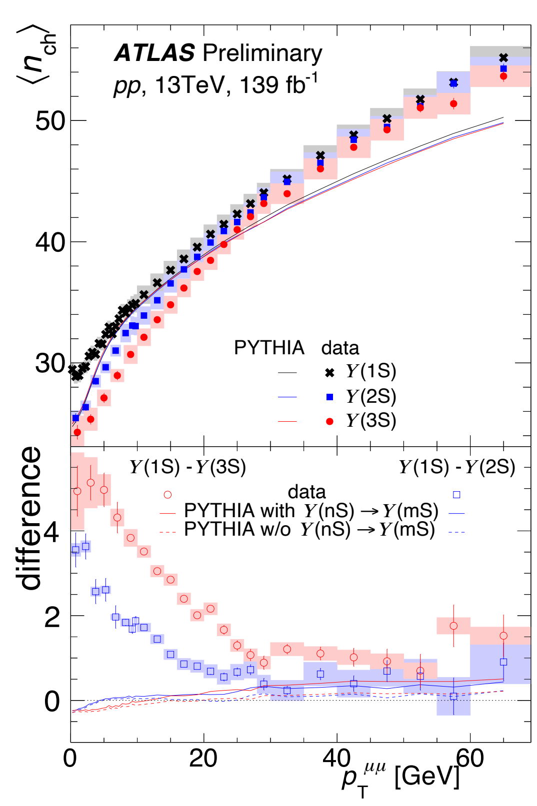
- Subtracted $\Delta\phi$ distributions resemble UE
- Subtracted distributions are always positive reaching almost one particle per unit of $\Delta\phi$.
- The effect is stronger for $\Upsilon(3S)$ than for $\Upsilon(2S)$
- Subtracted distributions display some residual non-uniformity presumably due to $\chi_b(mP) \to \Upsilon(nS)$decays which are not well studied.
- For $\Upsilon(3S)$ at $p_T^{\mu\mu}$ > 30 GeV, peaks appear around $\Delta\phi = 0$ and $\Delta\phi = \pi$ that can be explained by feed-downs $\Upsilon(nS) \to \Upsilon(1S)$.

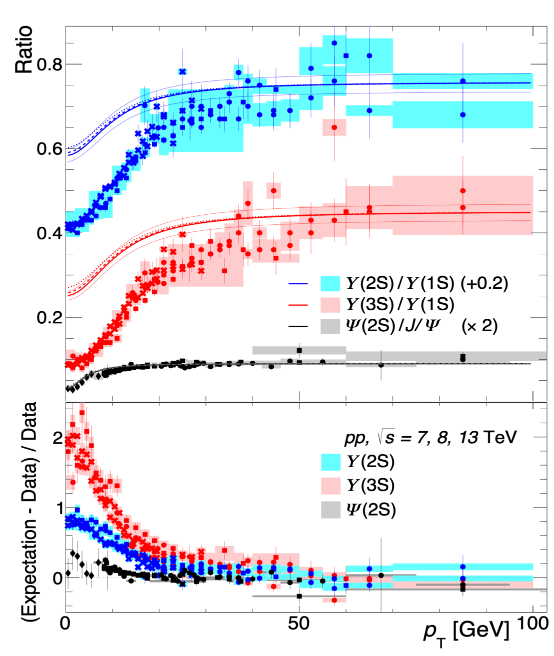
Multiplicity dependence on Υ momentum

- Strong difference in the multiplicity of the UE for different $\Upsilon(nS)$ 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 $\Upsilon(nS)$ states, mass differences, systematic uncertainties cannot explain the effect.
- Pythia does not describe the effect.
- At the lowest $p_T^{\mu\mu}$

$\Upsilon(1S) - \Upsilon(2S)$ $\Delta\langle n_{ch}\rangle = 3.6 \pm 0.4$ 12% of $\langle n_{ch}^{\Upsilon(1S)}\rangle$

$\Upsilon(1S) - \Upsilon(3S)$ $\Delta\langle n_{ch}\rangle = 4.9 \pm 1.1$ 17% of $\langle n_{ch}^{\Upsilon(1S)}\rangle$



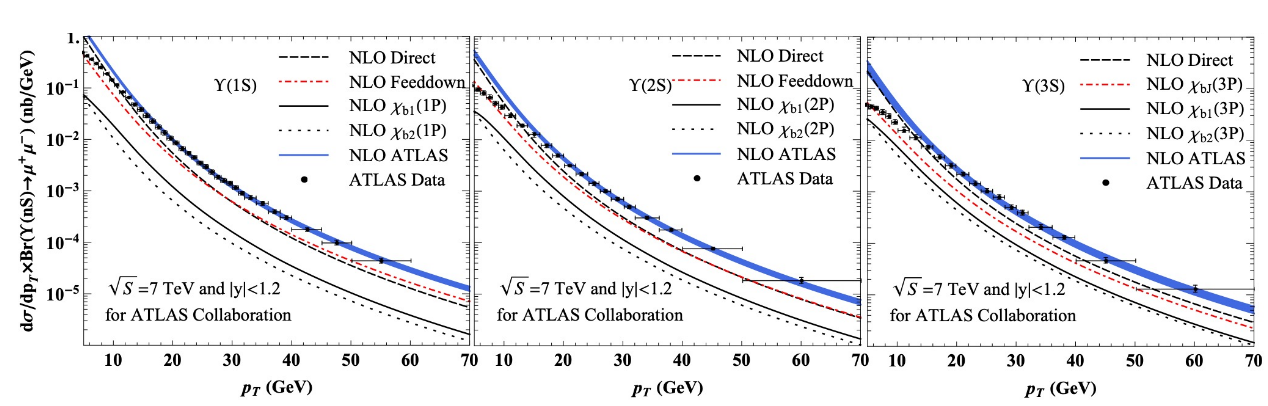


Global Analysis

Ref [arXiv:2203.11831] performs the global analysis of quarkonia yields at LHC energies. Deficit of tracks, observed in the analysis, can be related to unusual $\Upsilon(nS)$ / $\Upsilon(1S)$ ratios.

Theoretical Calculations

Calculations of Υ yields, e.g. Ref [PRD94, 014028 (2016)], at low-$p_T^{\mu\mu}$ show clear differences with the data



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Iakov Aizenberg on behalf of the ATLAS Collaboration

ATLAS EXPERIMENT

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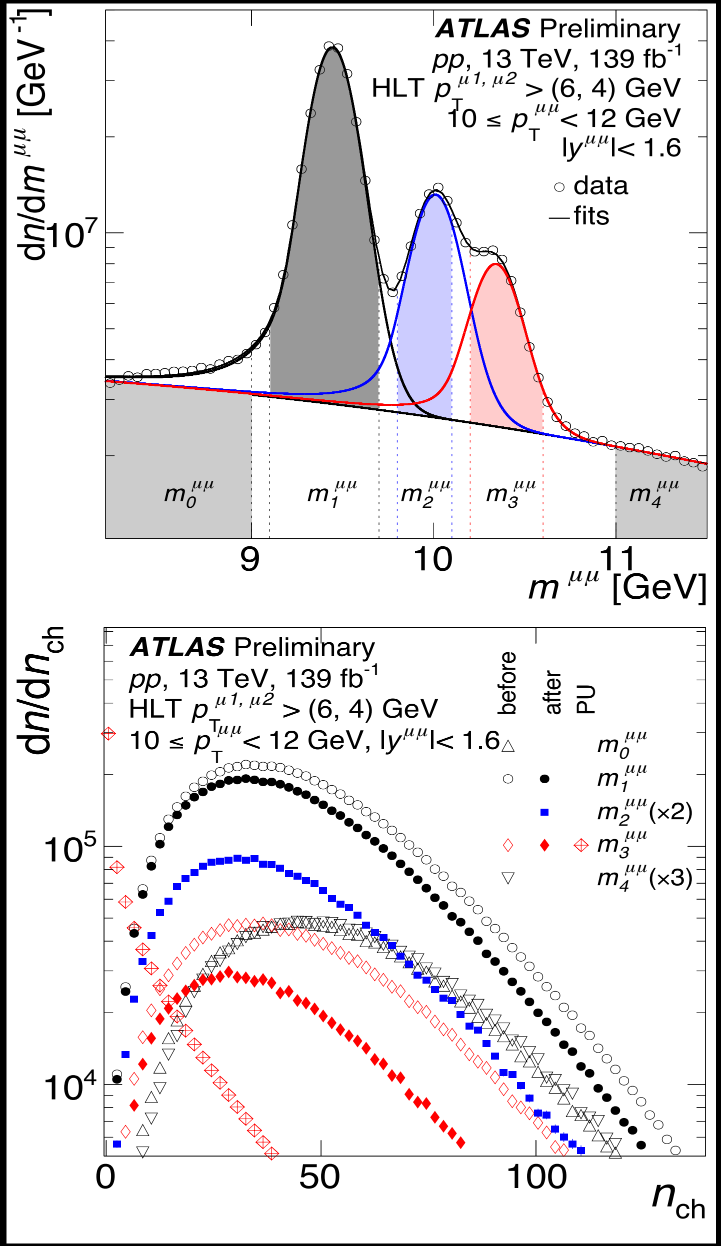

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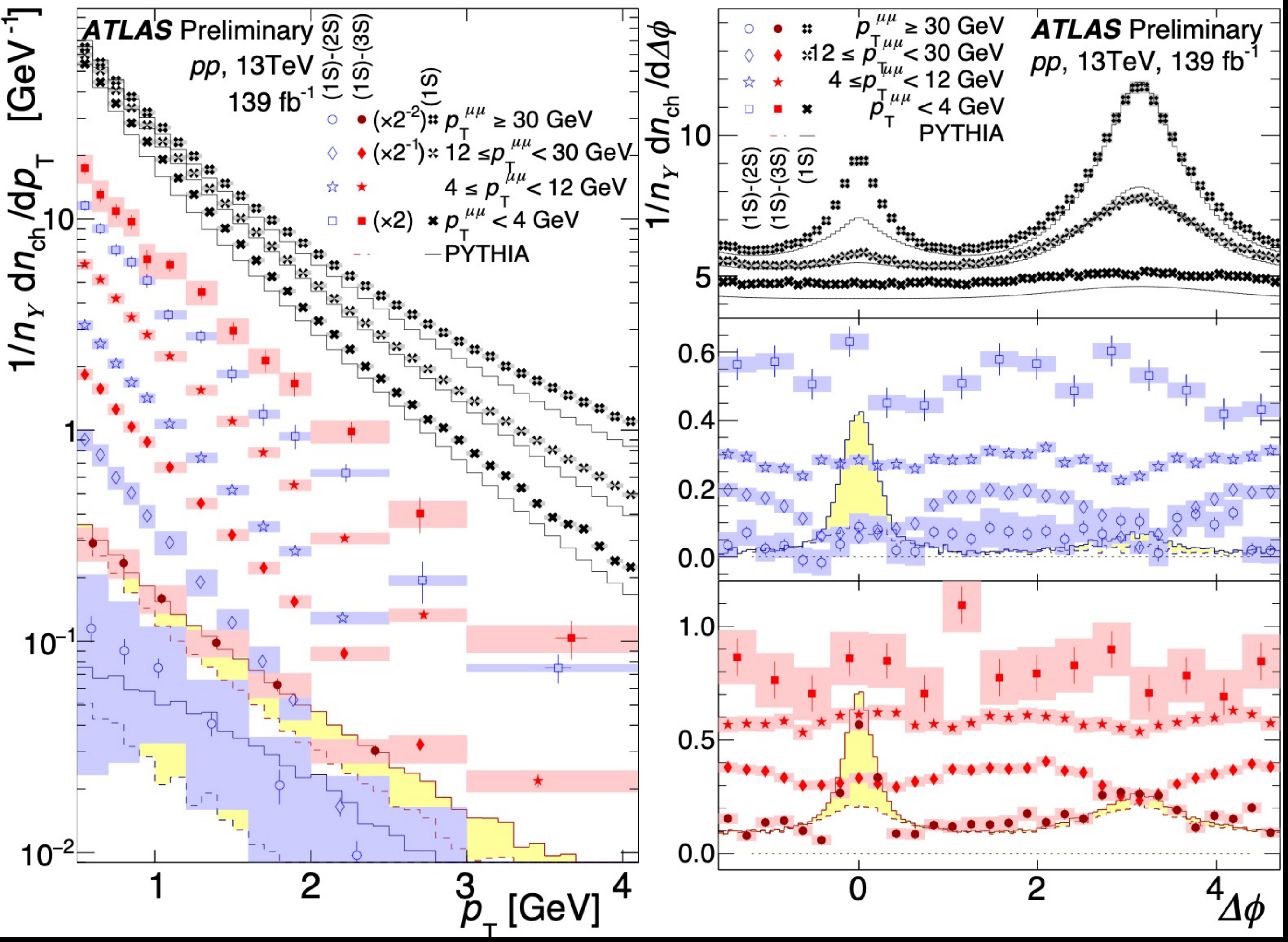

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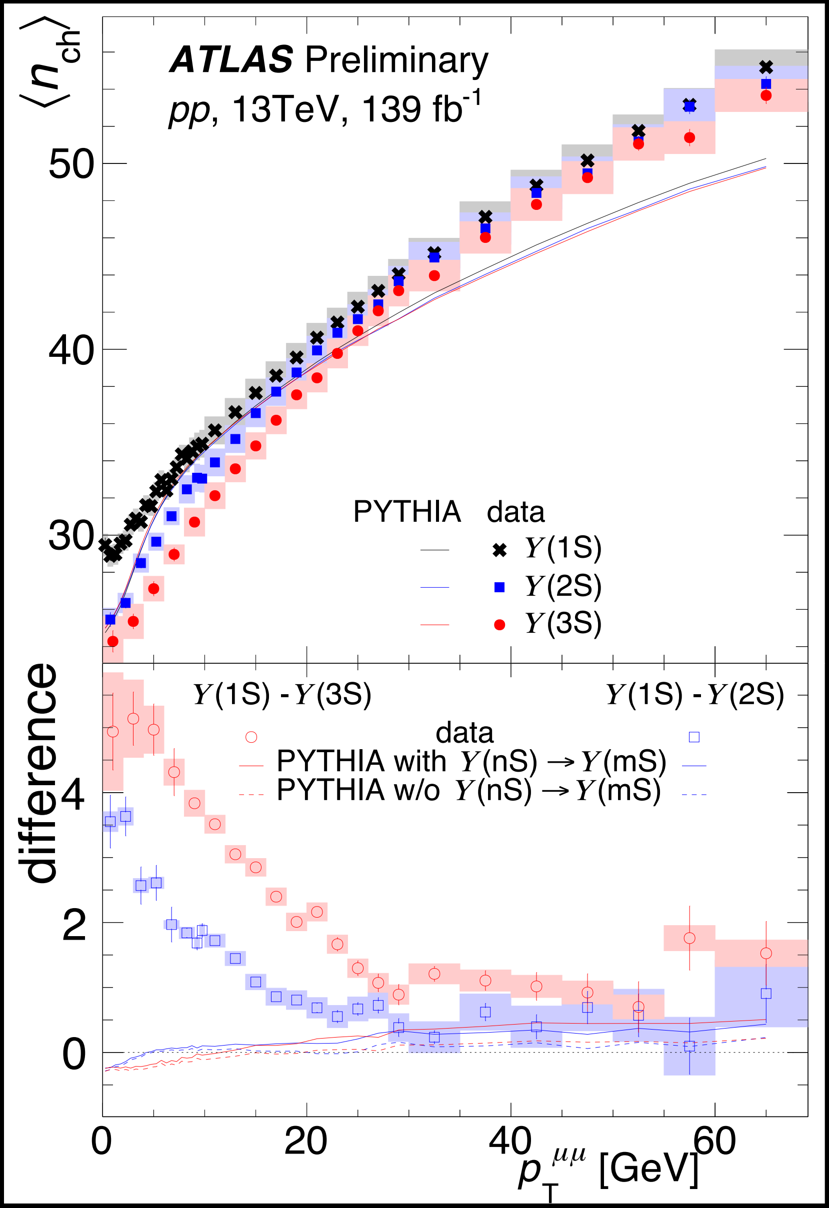

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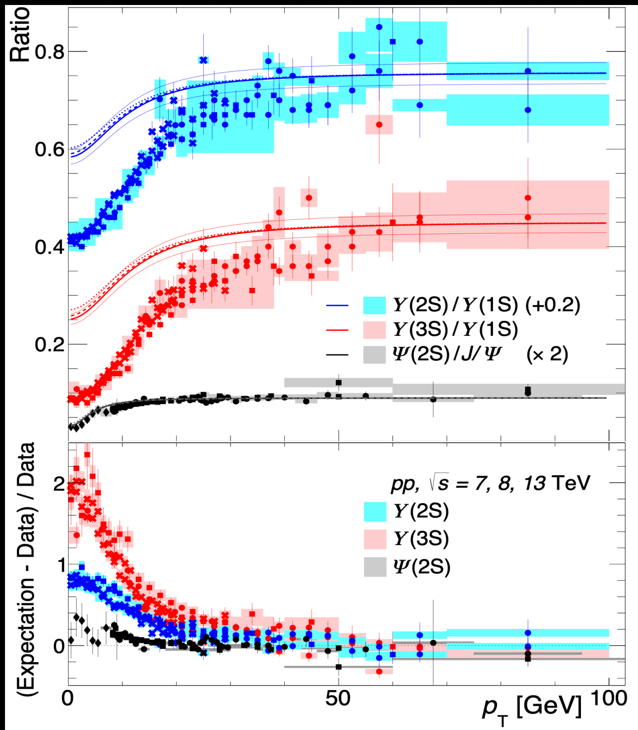

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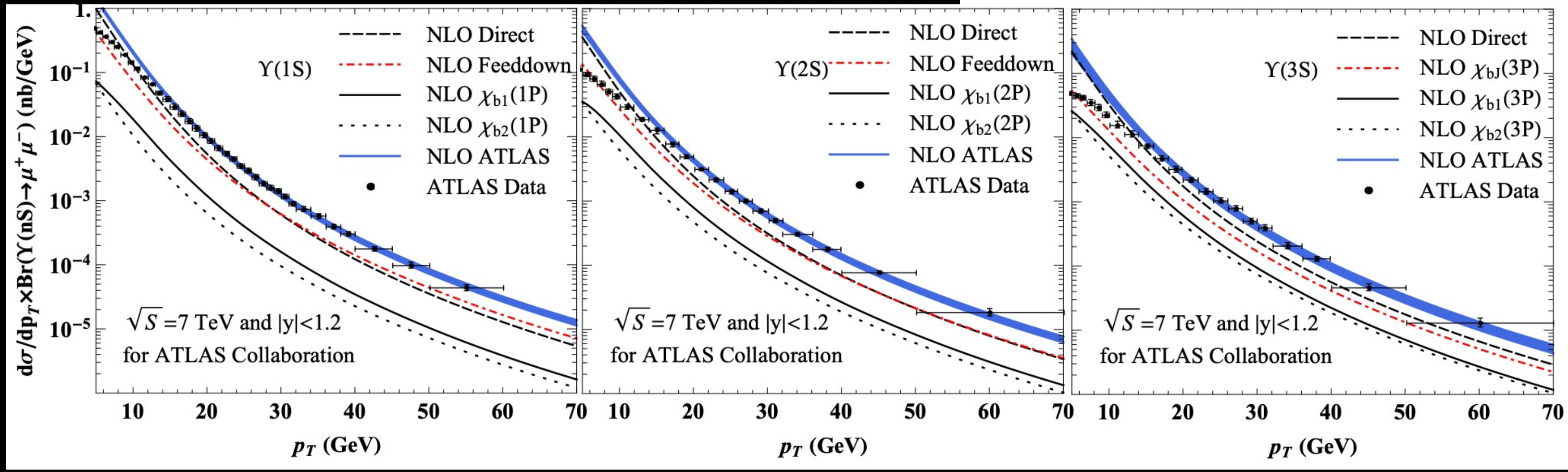

Thank you for your attention