

$Y(nS)$ -UE correlations in pp collisions

Baidyanath Sahoo for the *ATLAS* Collaboration



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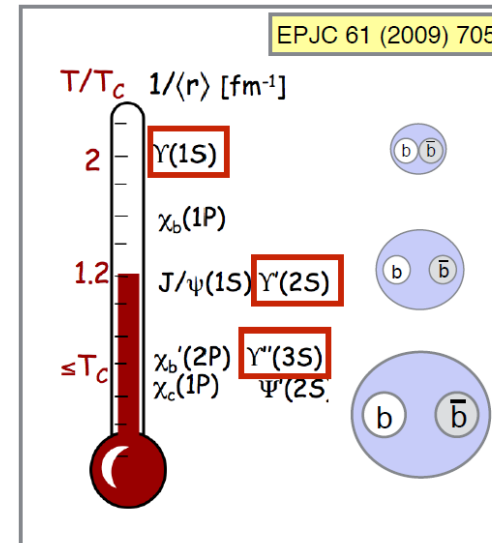
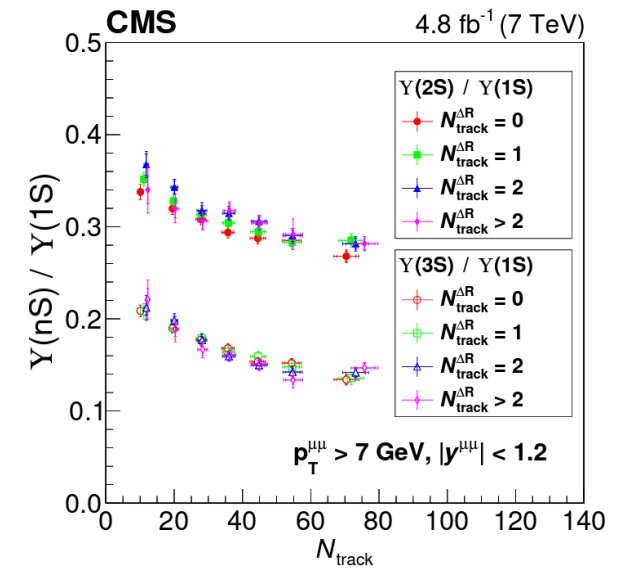
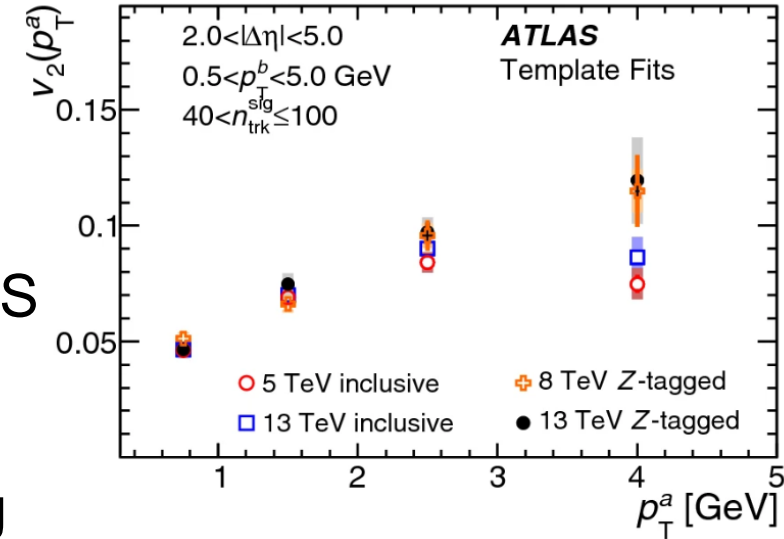
33rd INTERNATIONAL WORKSHOP ON

DEEP INELASTIC SCATTERING

AND RELATED SUBJECTS

Introduction

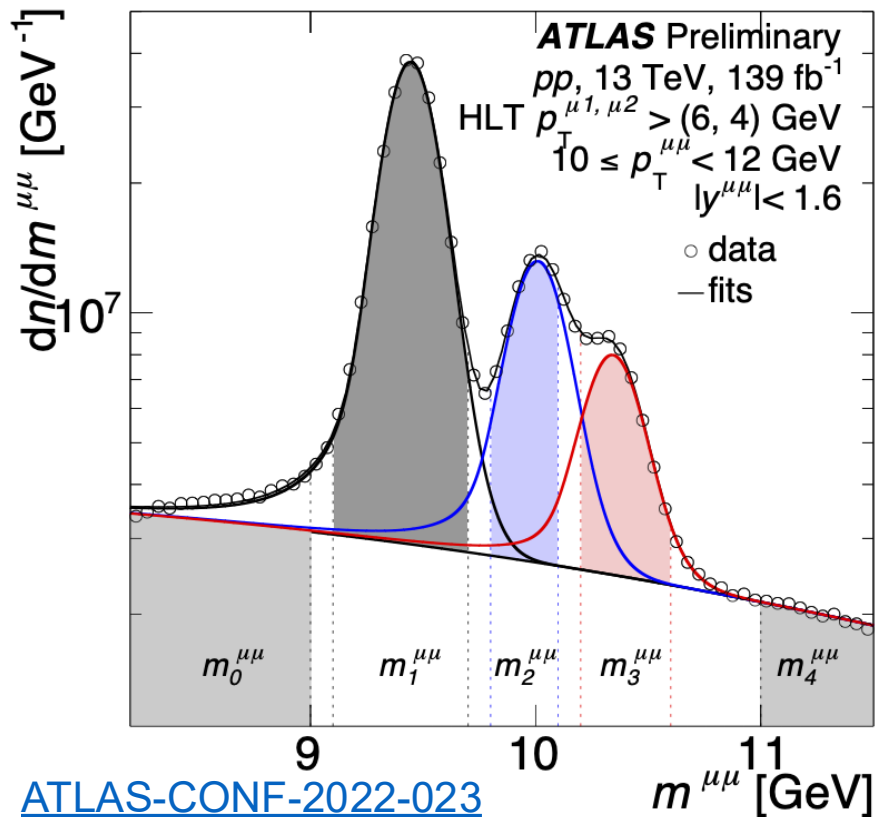
- Heavy ion features have been observed in pp
 - Flow in Z tagged pp events by *ATLAS* [[Eur. Phys. J C80 \(2020\) 64](#)],
 - Y double ratios decreasing with multiplicity pp events by *CMS* [[JHEP 11 \(2020\) 001](#)]
- We search for QGP-like signatures by looking at how underlying event changes in events with Upsilon states
 - Measure charged particle multiplicity, p_T and $\Delta\phi$ distributions in events with different Y states.



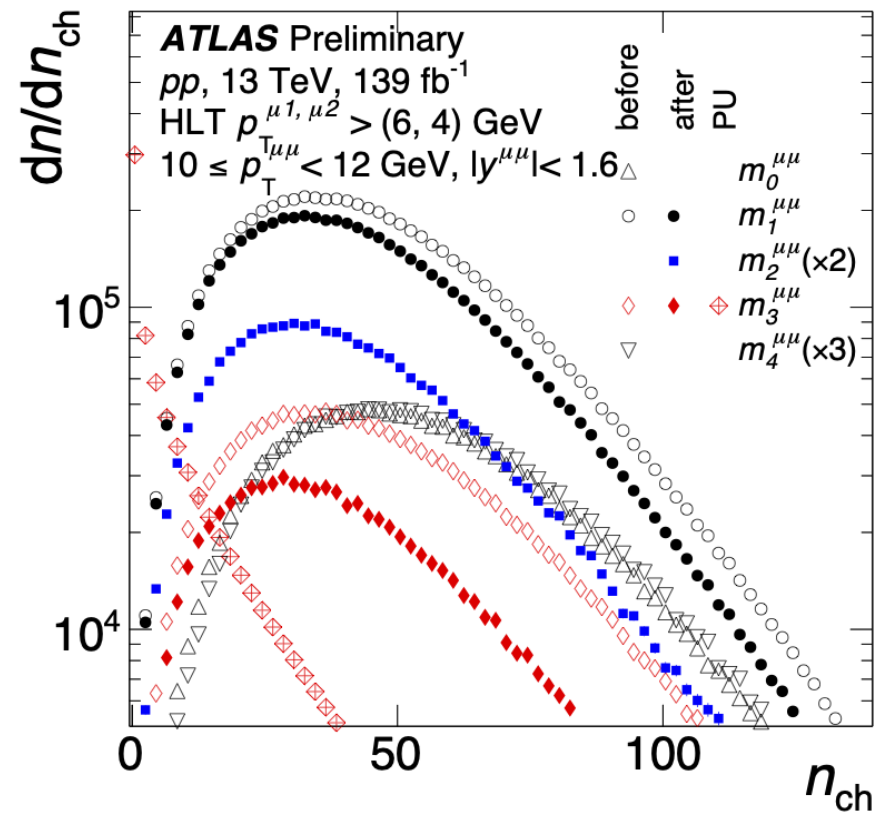
Upsilon States	Mass [GeV]	Binding Radius [fm]	QGP Melting Temp.
Y(1S)	9.46	~0.28	~2 T_c
Y(2S)	10.02	~0.56	1.2 T_c
Y(3S)	10.36	~0.78	$\leq T_c$

Analysis details

- Entire Run-2 pp 13 TeV collisions, 139 fb^{-1}
- Combined average no. of interactions per bunch crossing ($\langle \mu \rangle$): ≈ 33.7
- Events with $Y(nS) \rightarrow \mu\mu$, $|y| < 1.6$, dimuon triggers, all p_T
- Charged hadron n_{ch} , dn_{ch}/dp_T and $dn_{ch}/d\Delta\phi$. $\Delta\phi = \phi^Y - \phi^h$
- Fully corrected, including pileup

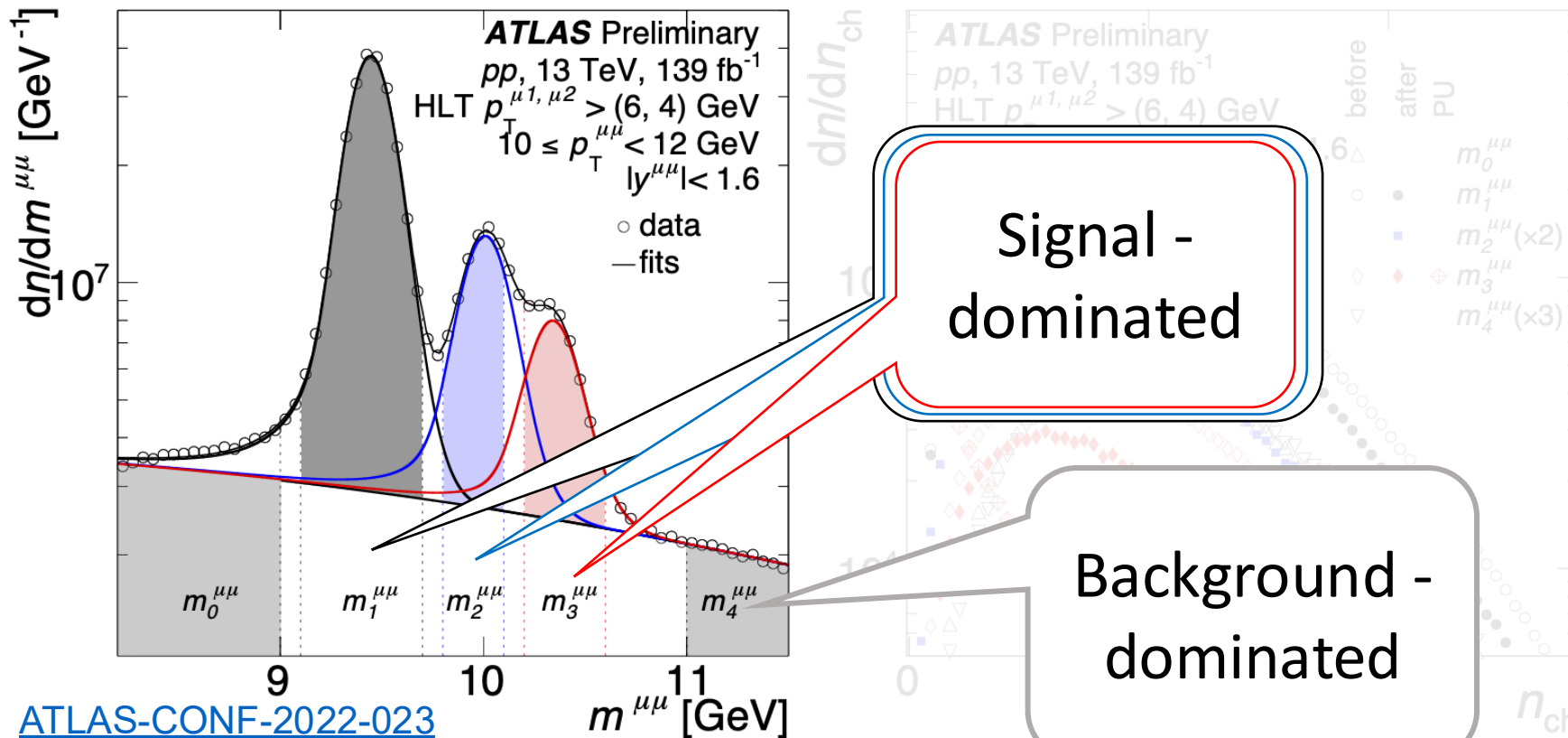


[ATLAS-CONF-2022-023](#)



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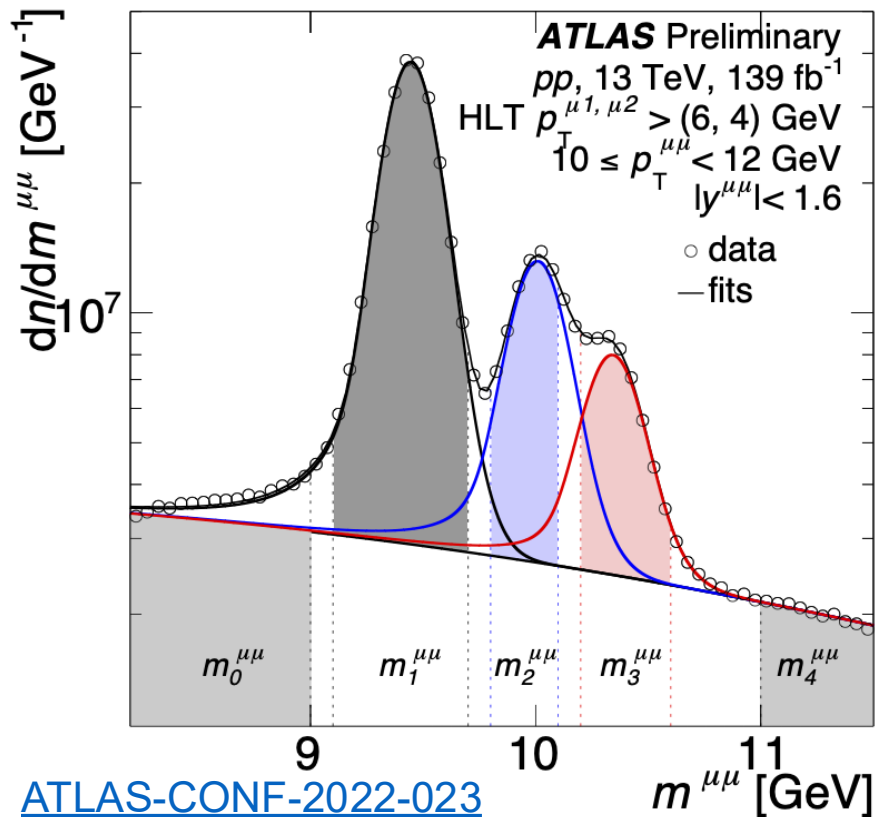
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- Select 5 mass regions



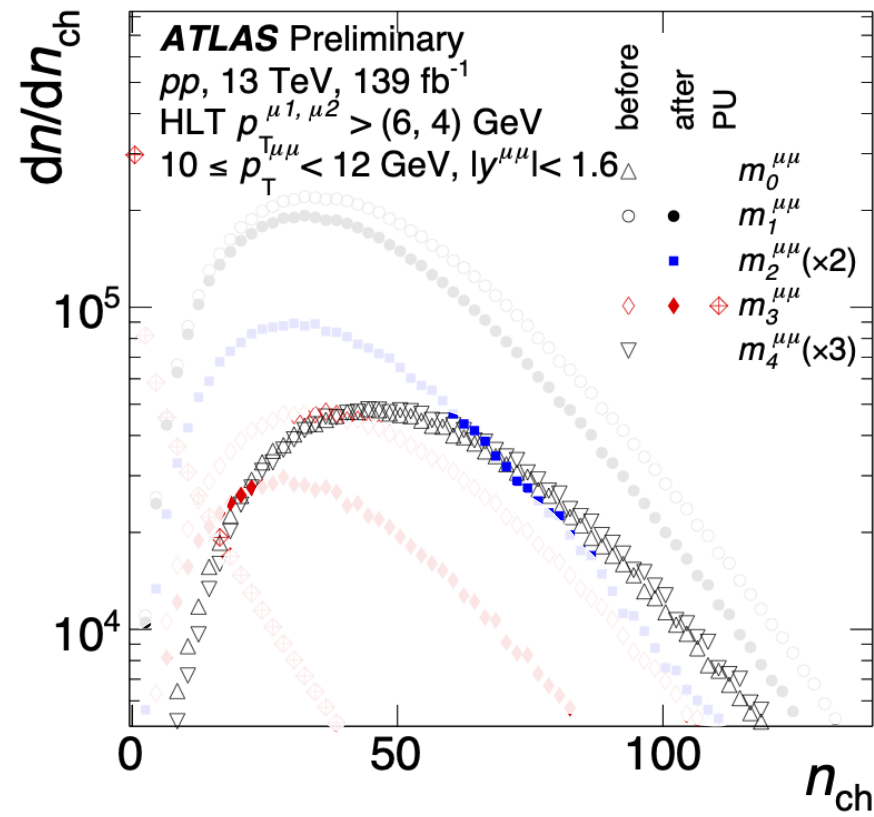
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- Bkg shapes are similar – interpolate



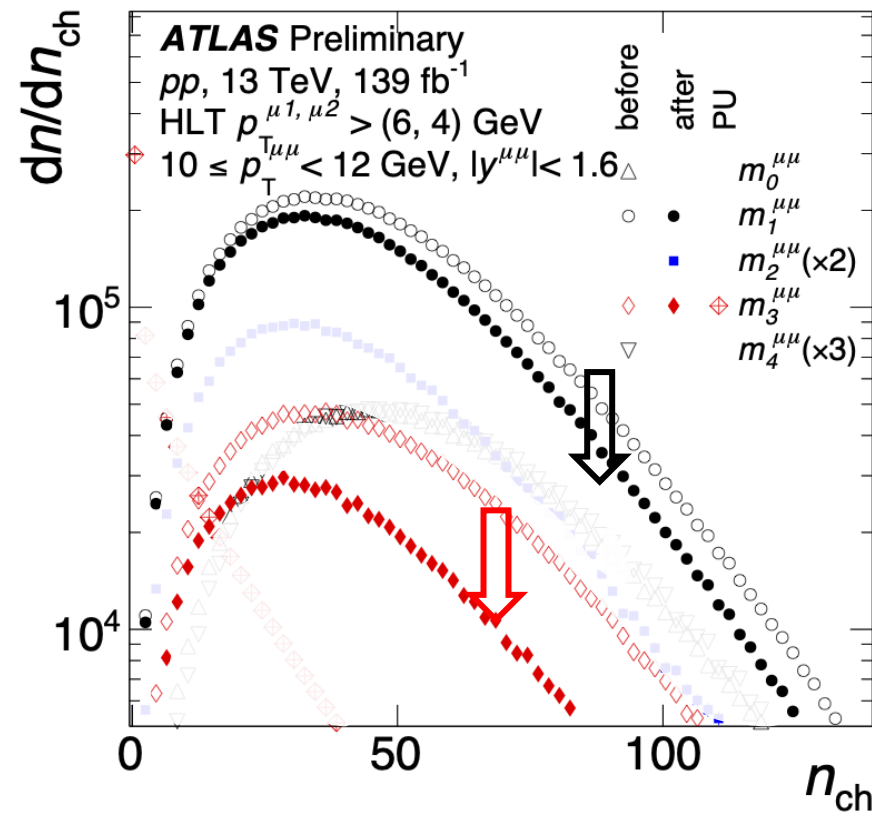
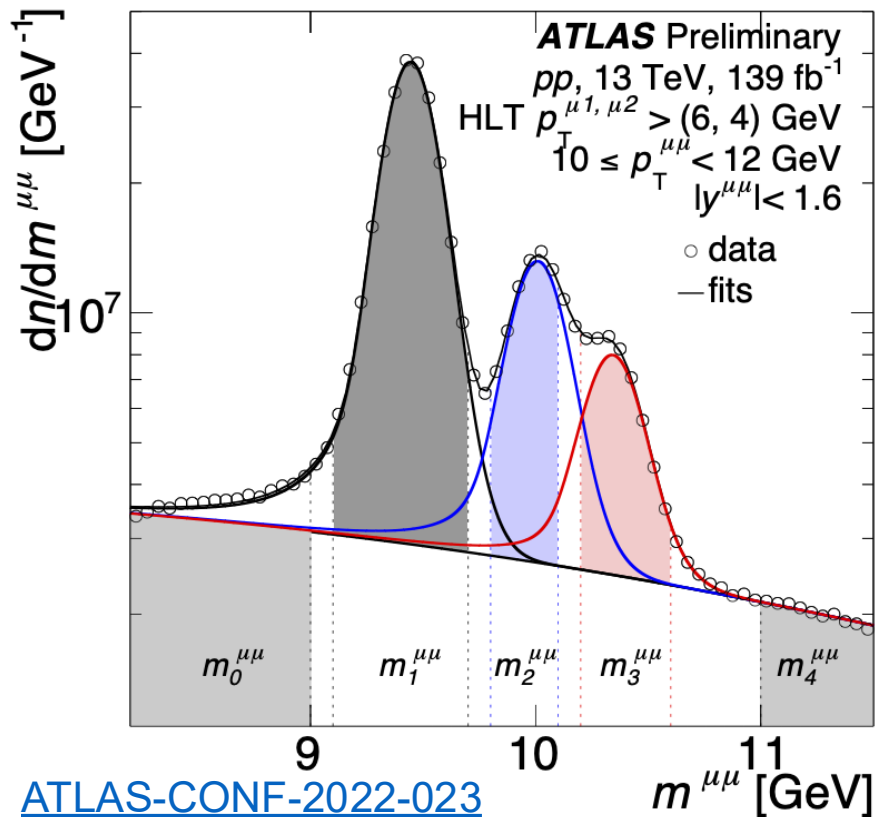
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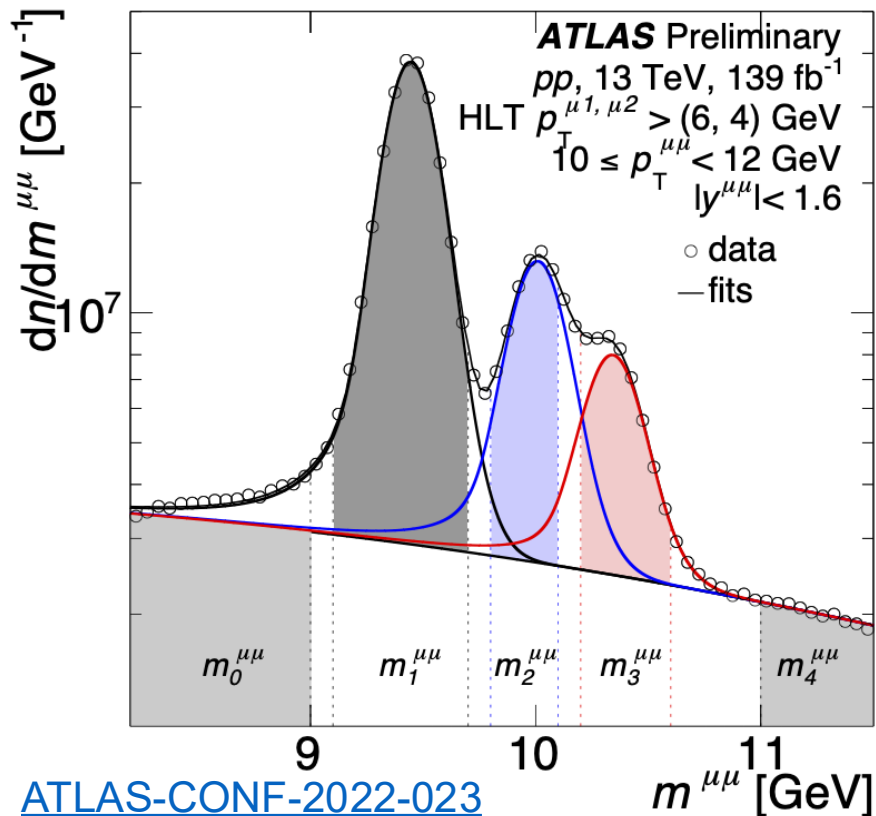
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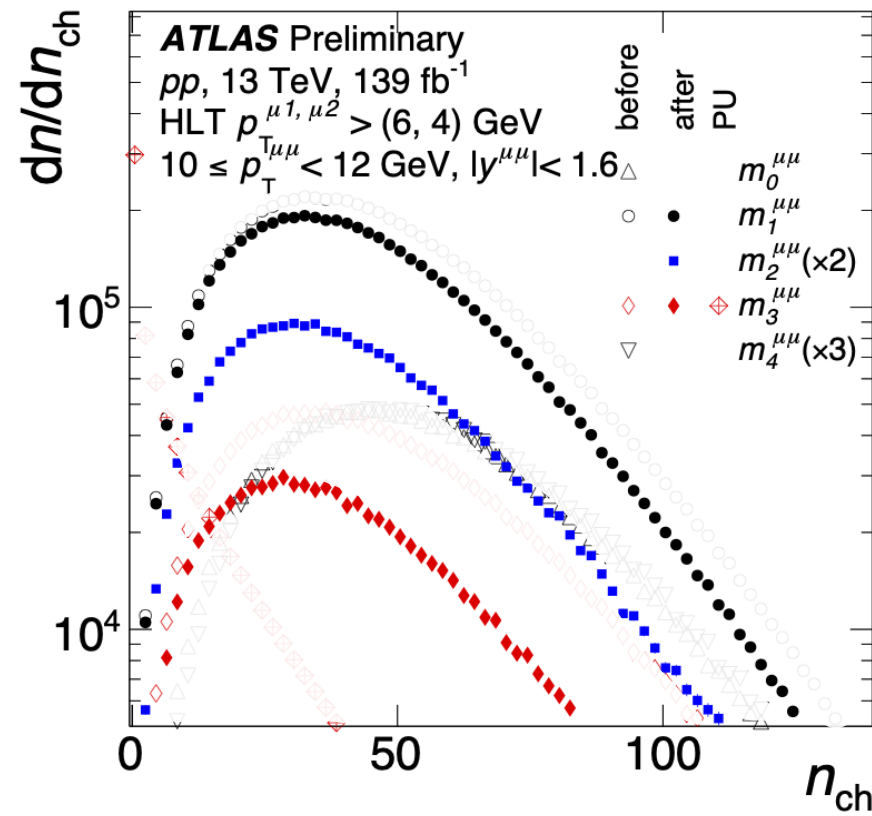
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- After subtraction n_{ch} look different



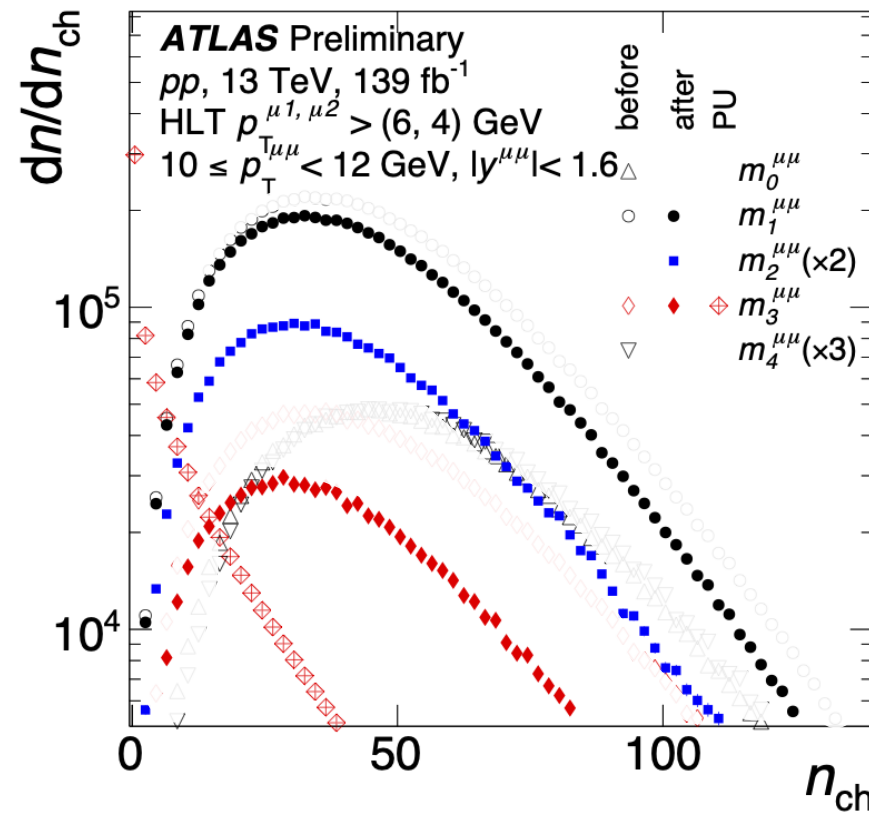
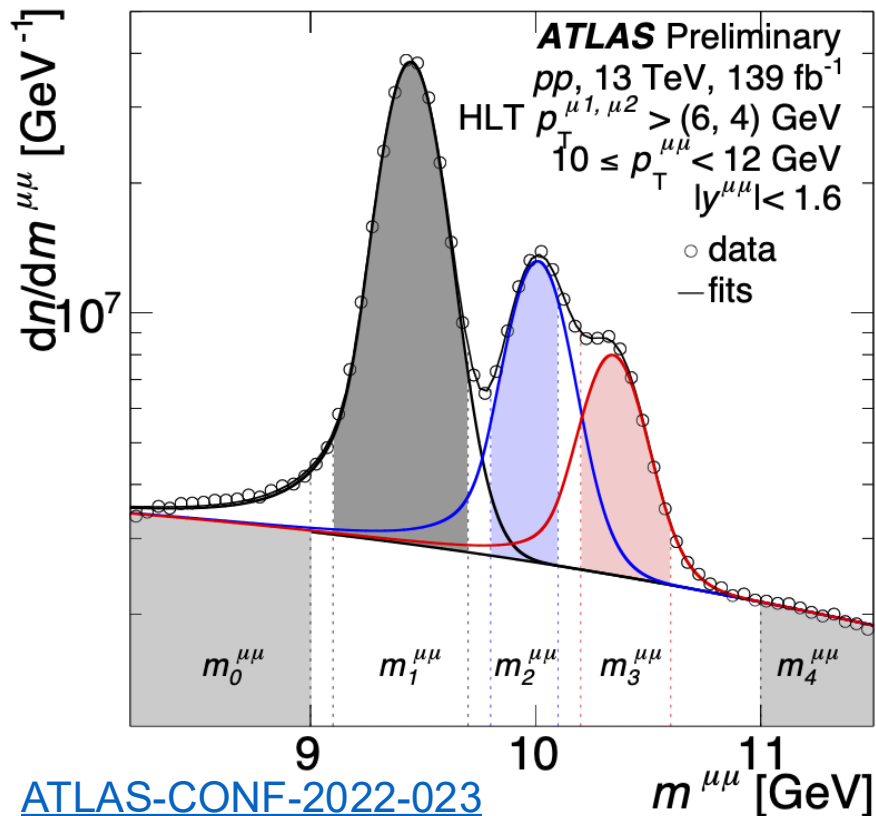
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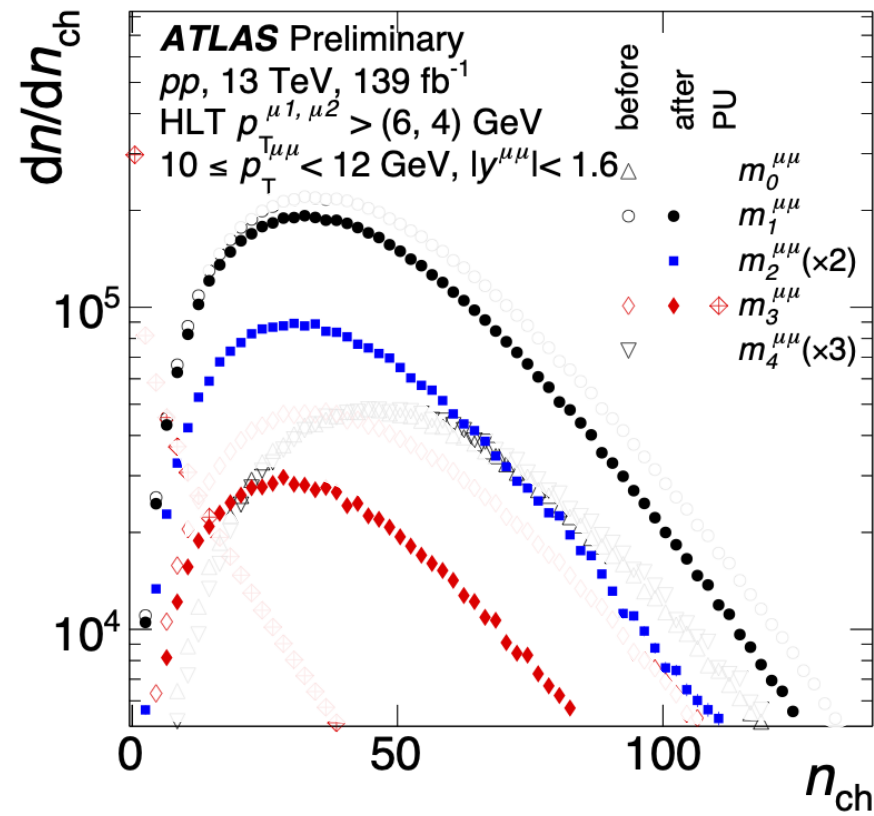
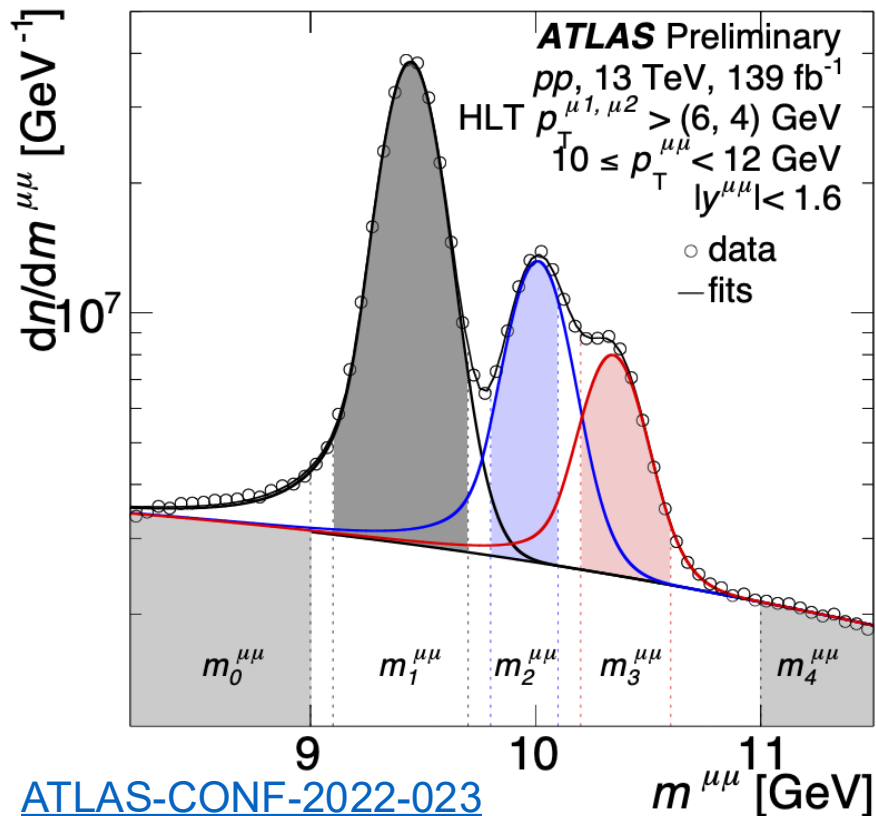
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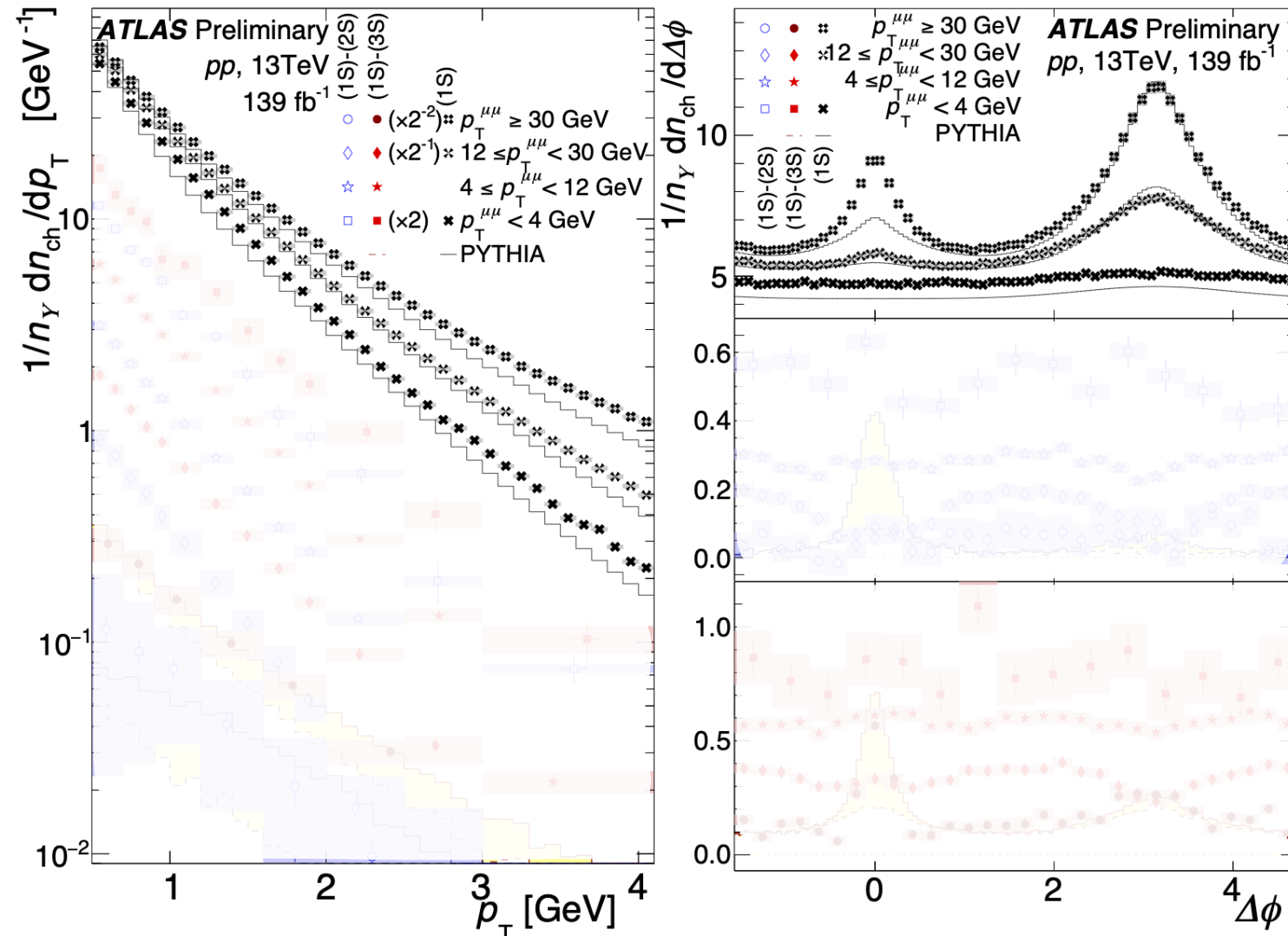
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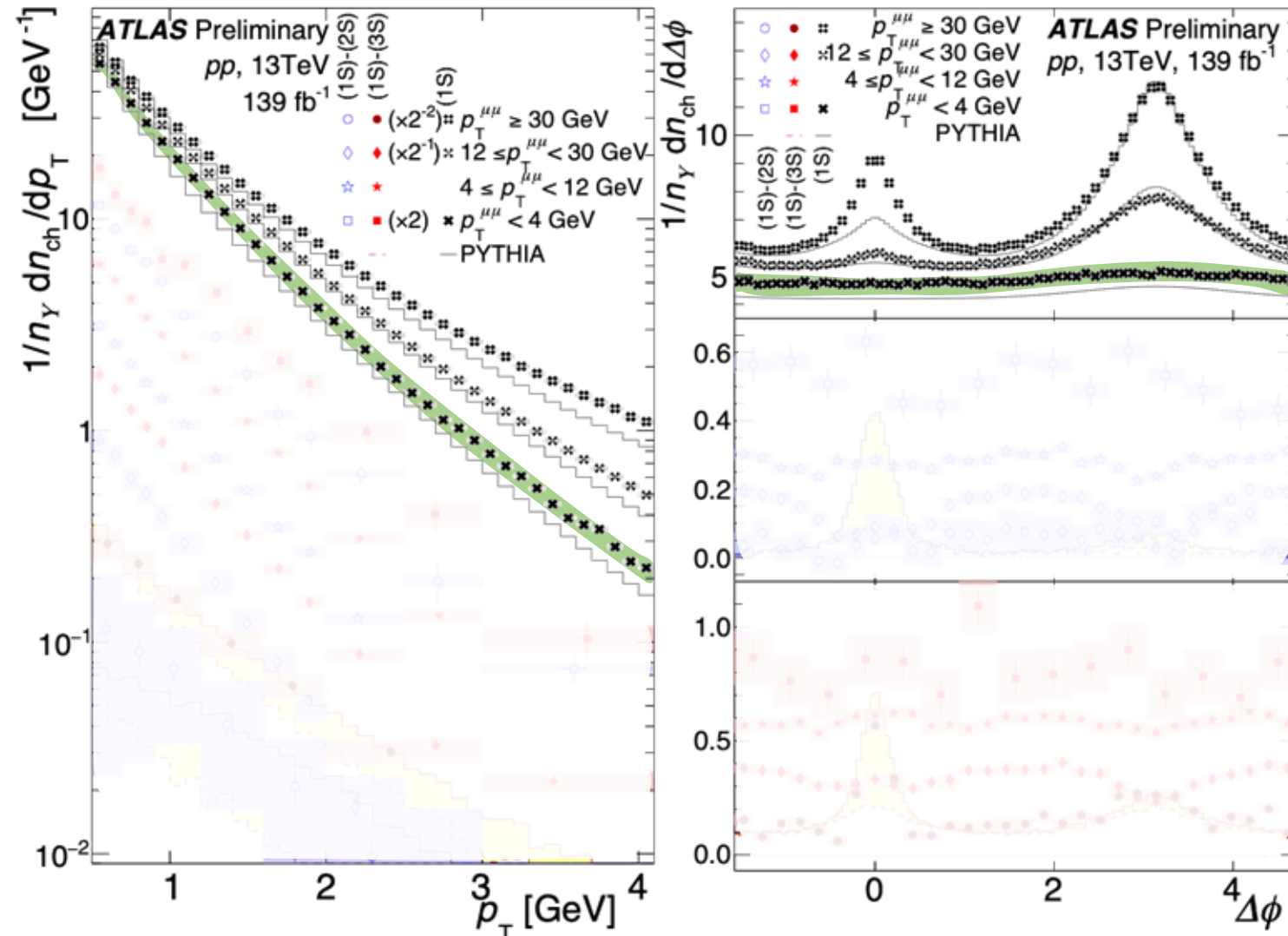
• Direct measurement of n_{ch} , dn_{ch}/dp_T and $dn_{ch}/d\Delta\phi$

Kinematic distributions



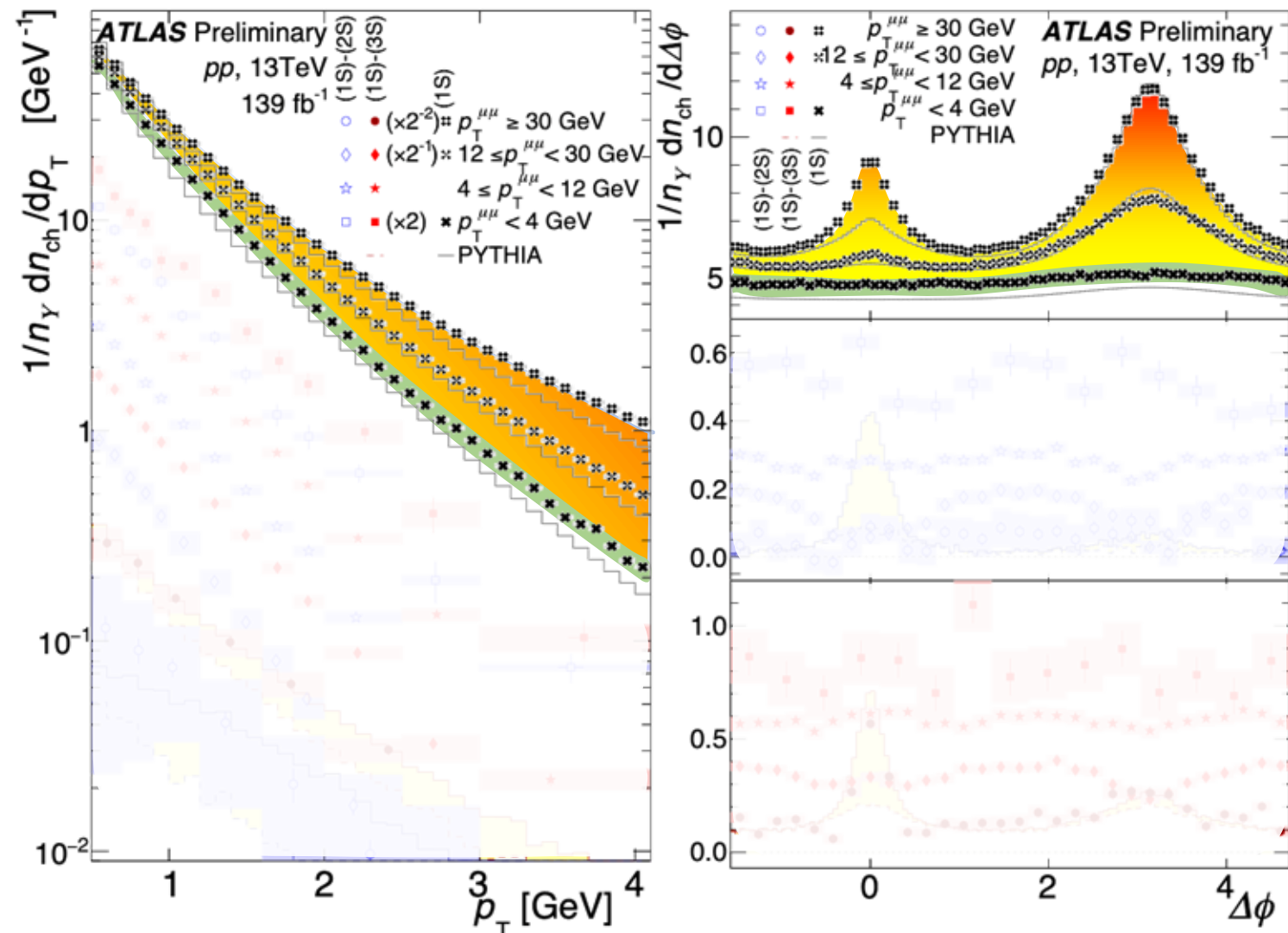
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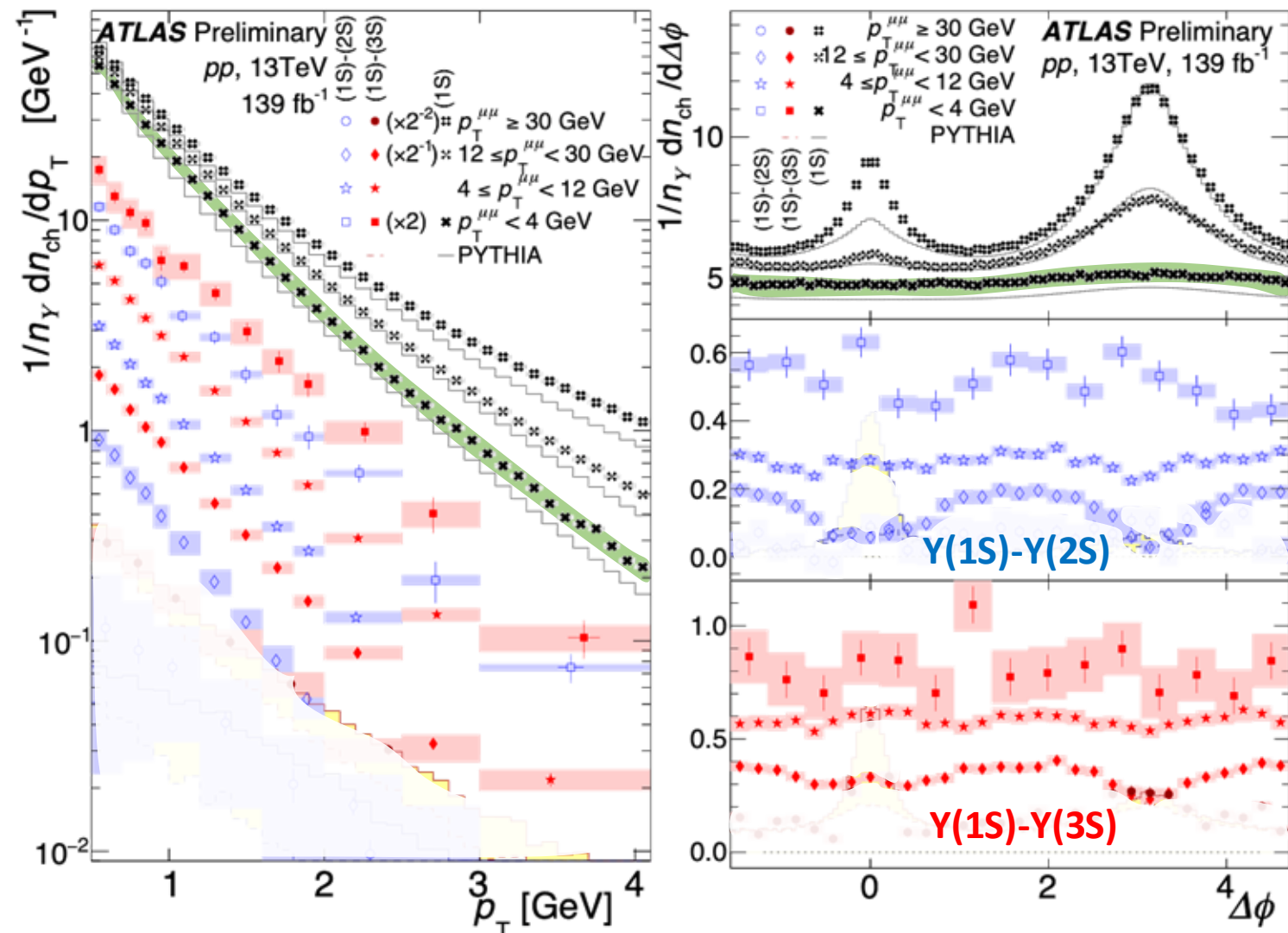
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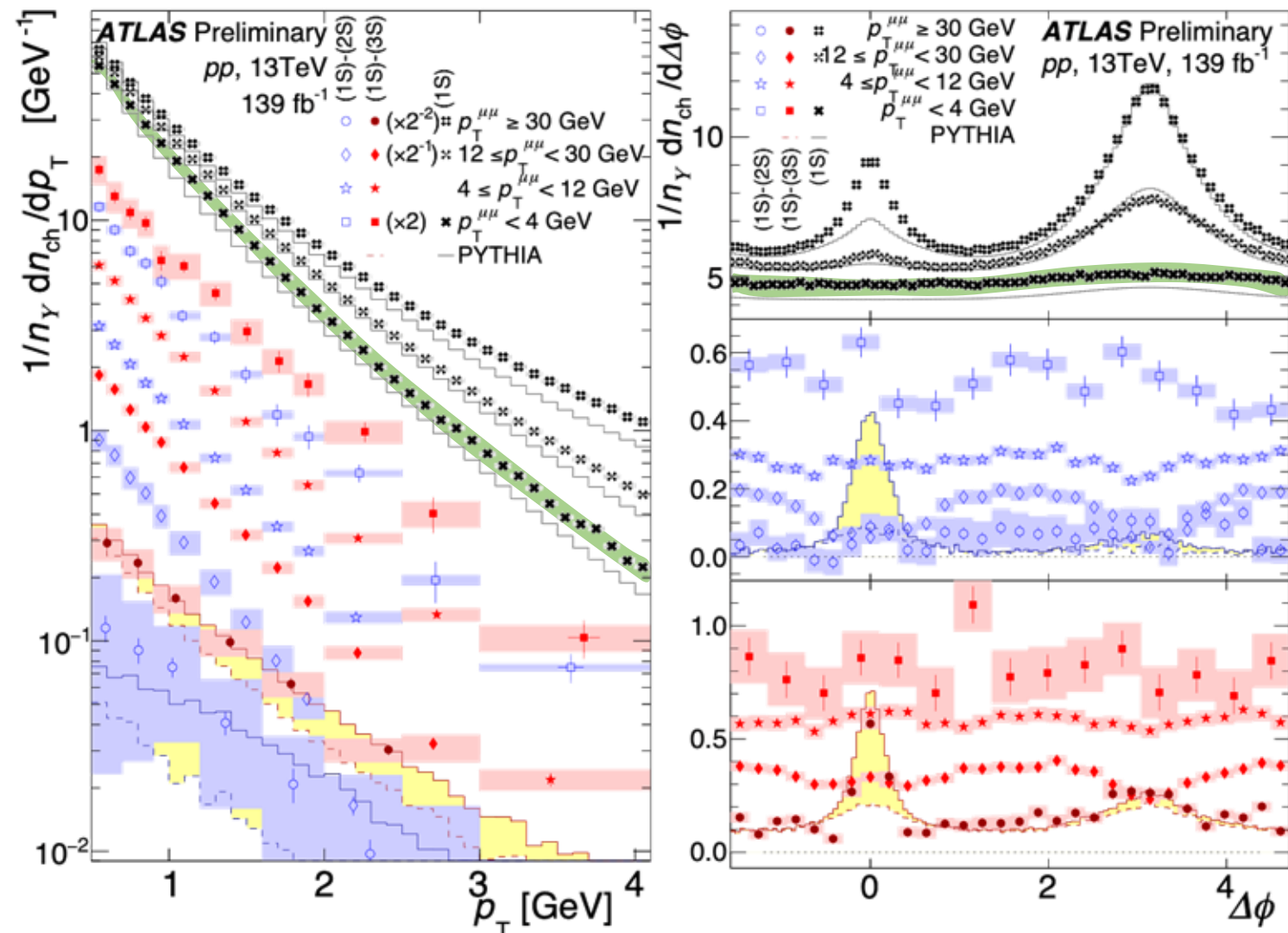
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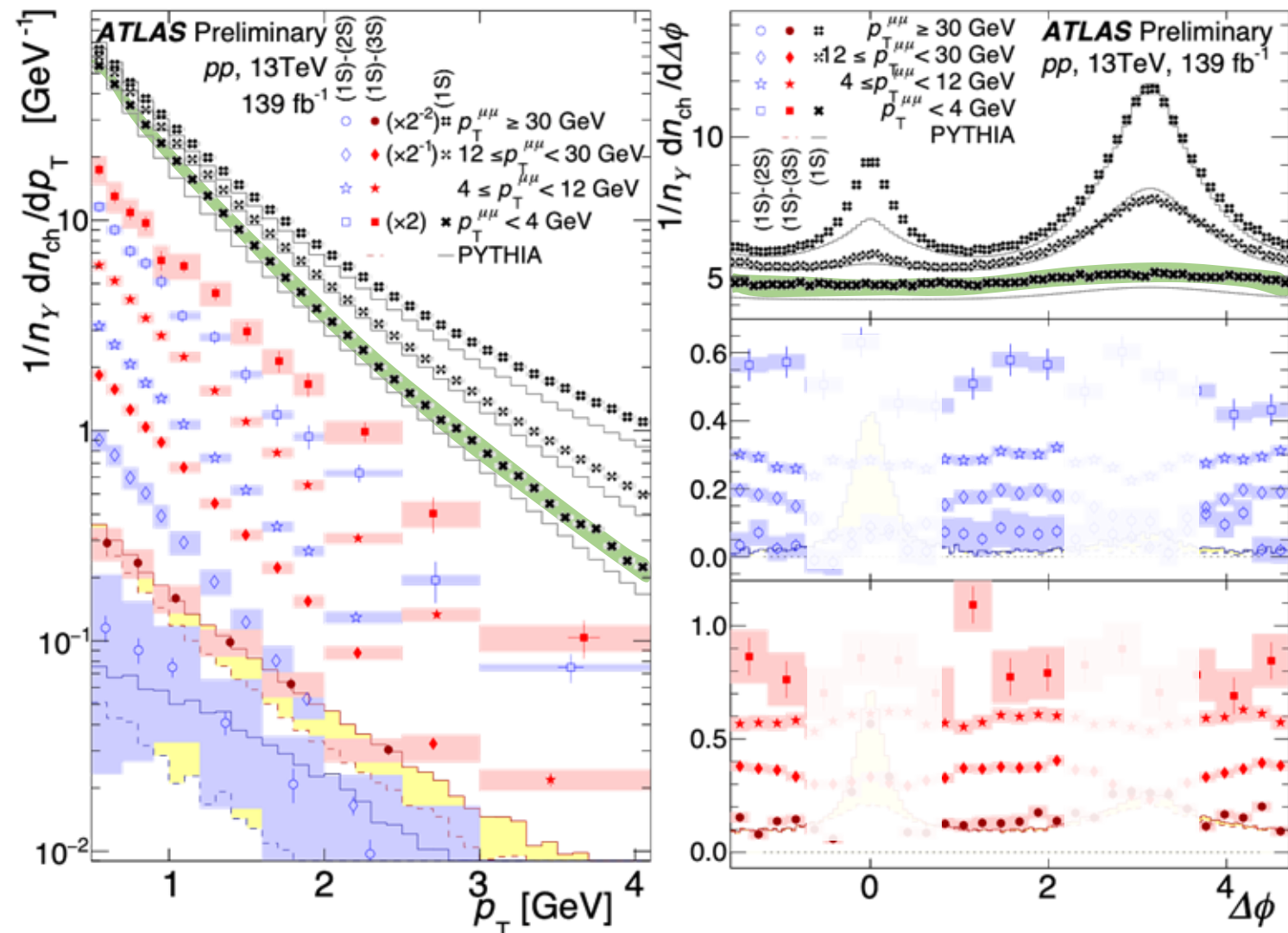
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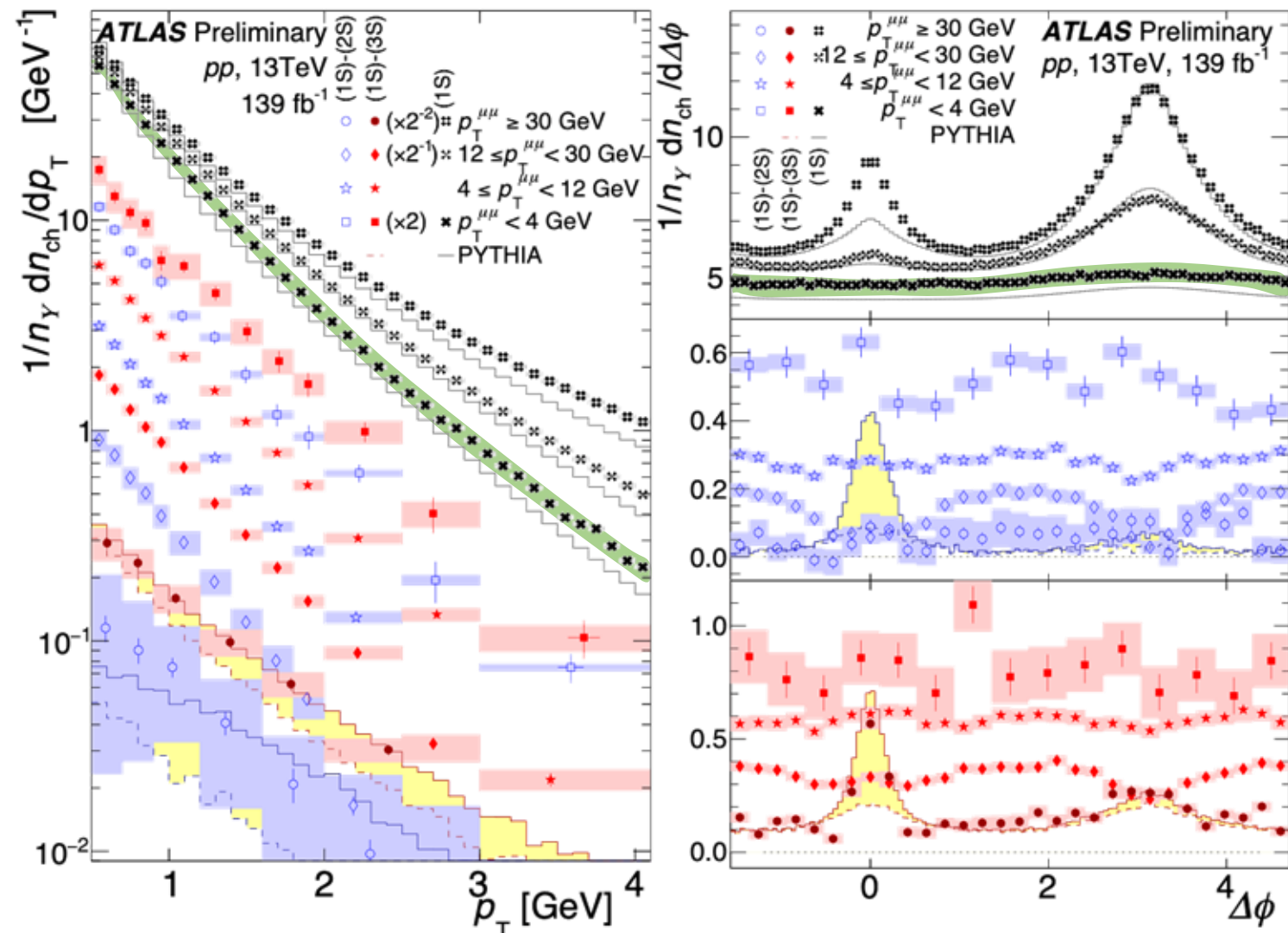
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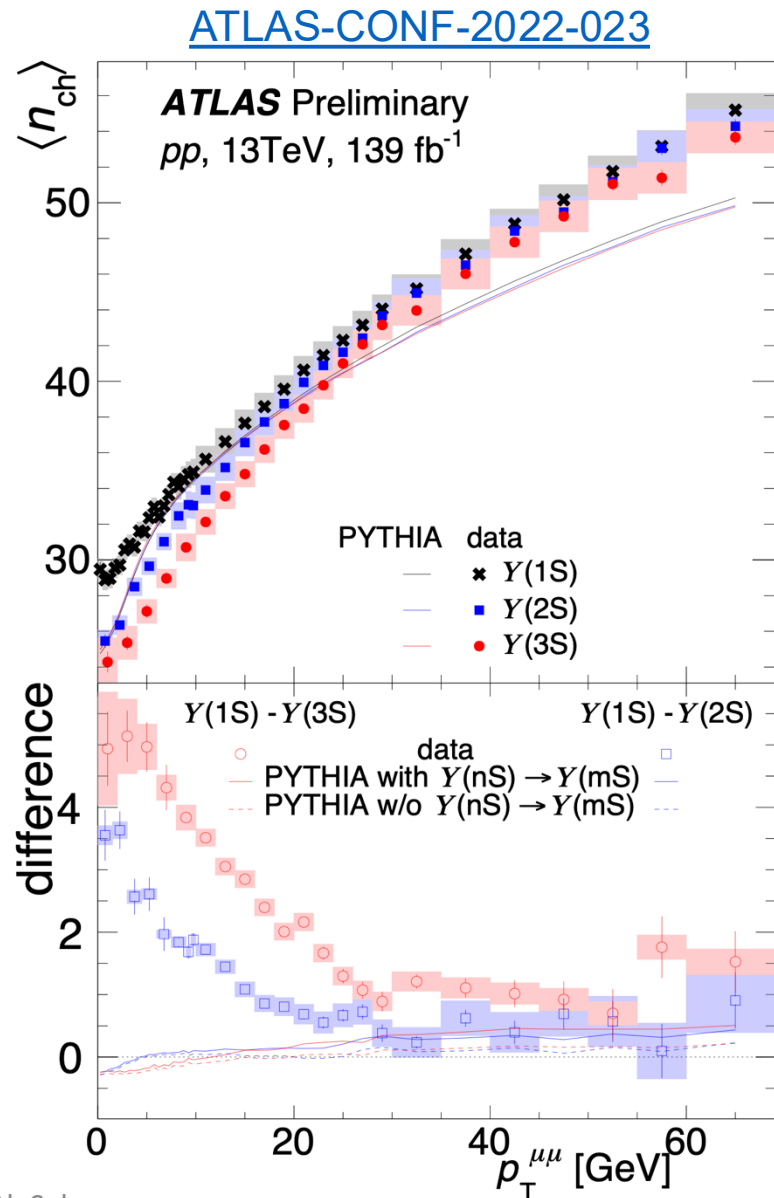
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- Away from jets there are regions with charged particles.
- The Y(1S) vs Y(nS) charged-particle difference comes from the UE, not from the hard scattering producing the Y.

Mean n_{ch} values associated with different Y states



- Strong difference in the multiplicity of the UE for different Y(nS) states is observed.
- It does not exist in Pythia and Pythia needs to be improved to better model Y production.
- The effect is strongest at $p_T = 0$ and diminishes with increasing p_T , but still visible at 20-30 GeV.
- Feed-down of Y(nS) states, mass differences, systematic uncertainties cannot explain the effect.
- At the lowest p_T ,
 - For Y(1S) – Y(2S) the difference is 3.6 ± 0.4
 - For Y(1S) – Y(3S) the difference is 4.9 ± 1.1

Independent check from m_T -scaling

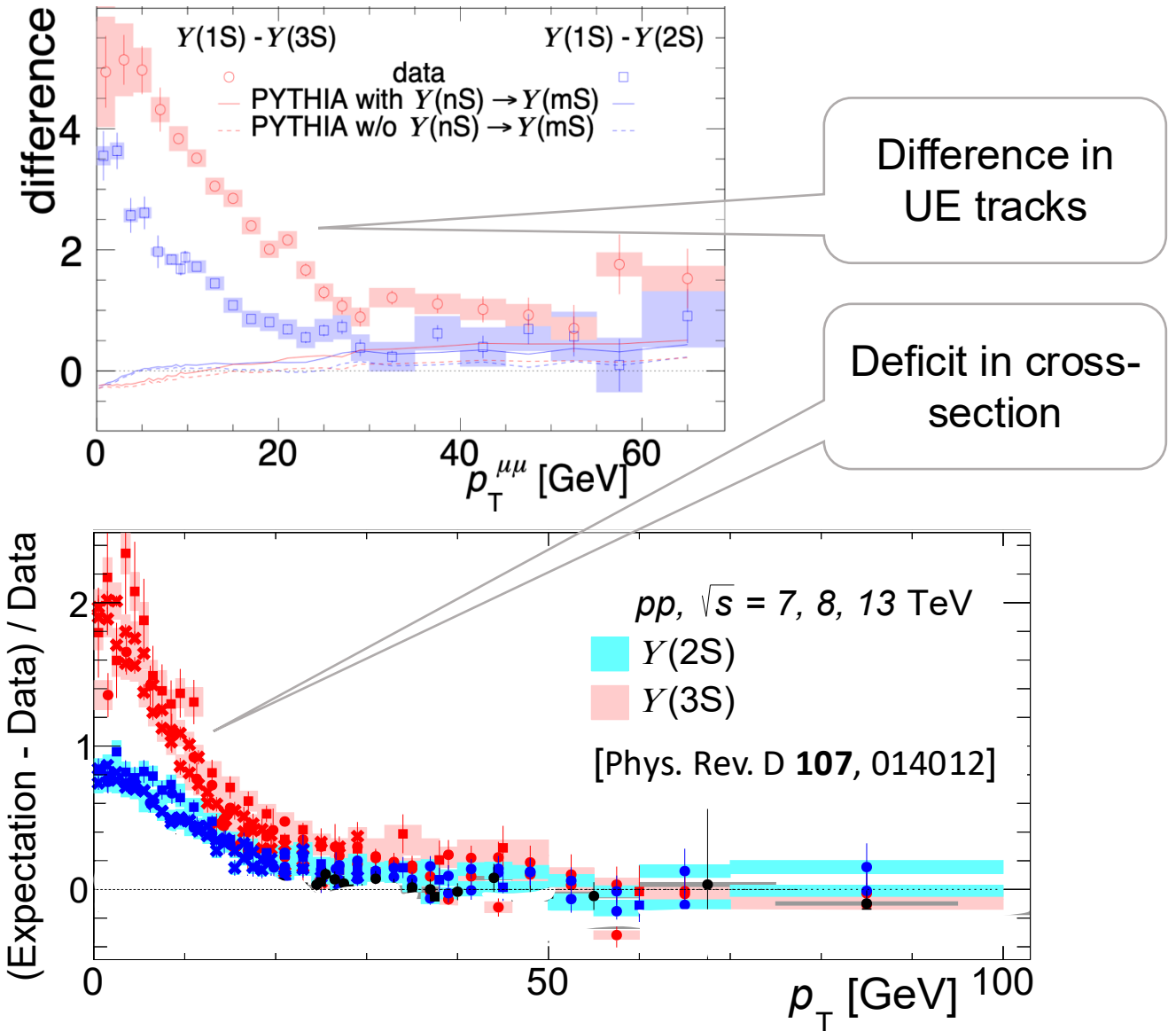
Assumption:
particles with same quark content and similar masses have similar kinematics

The extent of similarity can be tested with the m_T - scaling

Extending it to $Y(2S)$ and $Y(3S)$ → measured spectra fall below expectation at low- p_T

Deficit is larger for $Y(3S)$ than $Y(2S)$ and disappears at high- p_T

Same hierarchy and p_T dependence as the UE-track difference: two independent measurements, consistent picture



Summary

Measured charged-hadron multiplicity and kinematic distributions in events tagged with $Y(nS)$ using full Run 2 pp data at 13 TeV.

Events with excited Y states have lower charged-particle multiplicity than the events with $Y(1S)$.

The effect is strongest at low Y p_T and diminishes with increasing p_T .

Subtracted distributions suggest the effect is related to the underlying event, not to the hard scattering producing the Y .

PYTHIA does not reproduce the effect, improvements needed to better model Y production in pp .

Similarities with the m_T – scaling analysis results.

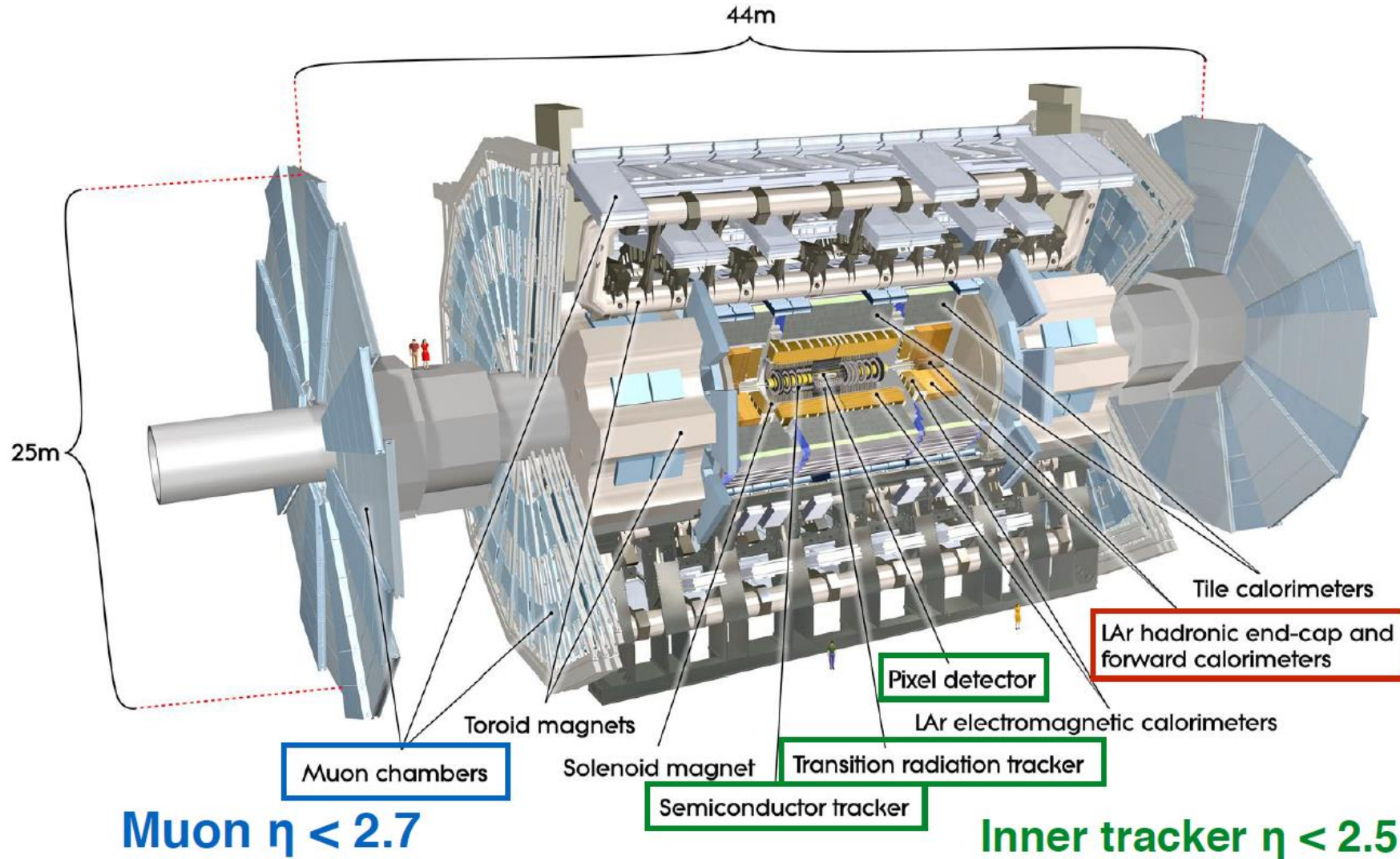
Picture supported by recent LHCb ([JHEP 05 \(2025\) 011](#)) and ALICE ([Nucl. Phys. B 1011 \(2025\) 116786](#)) multiplicity-dependent Y measurements.

Thank you for your attention!

Backup

ATLAS detector

$Y(nS)$ are measured via dimuon decay channel at midrapidity.



**FCal $3.1 < \eta < 4.9$
(for centrality)**

Number of interactions per bunch crossing

