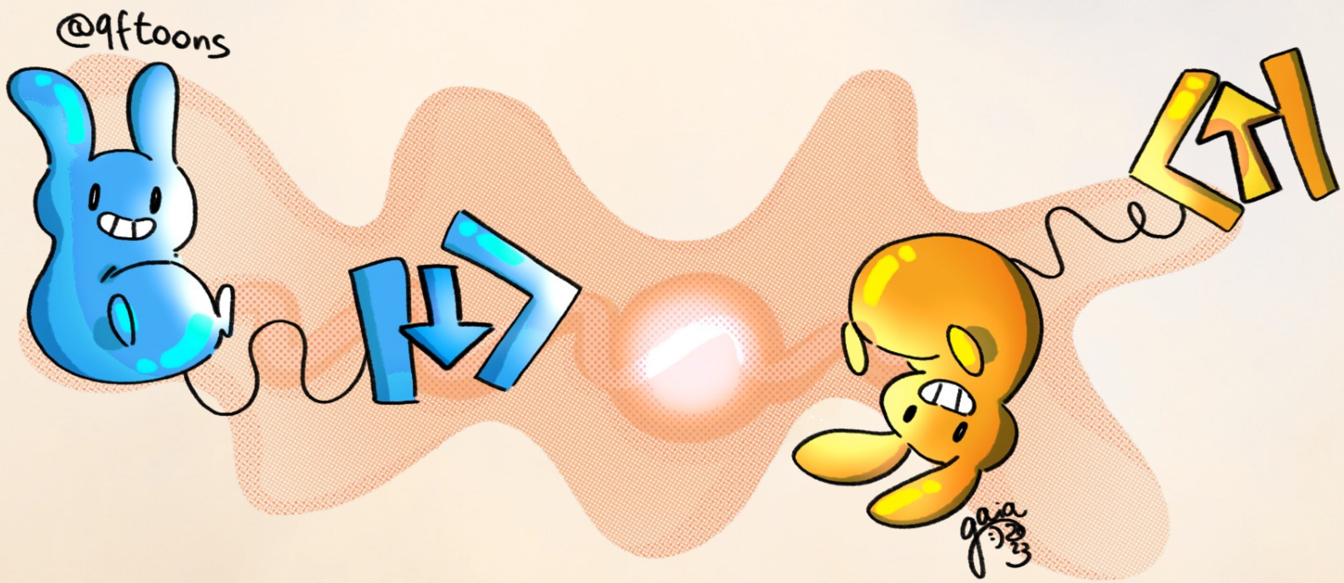
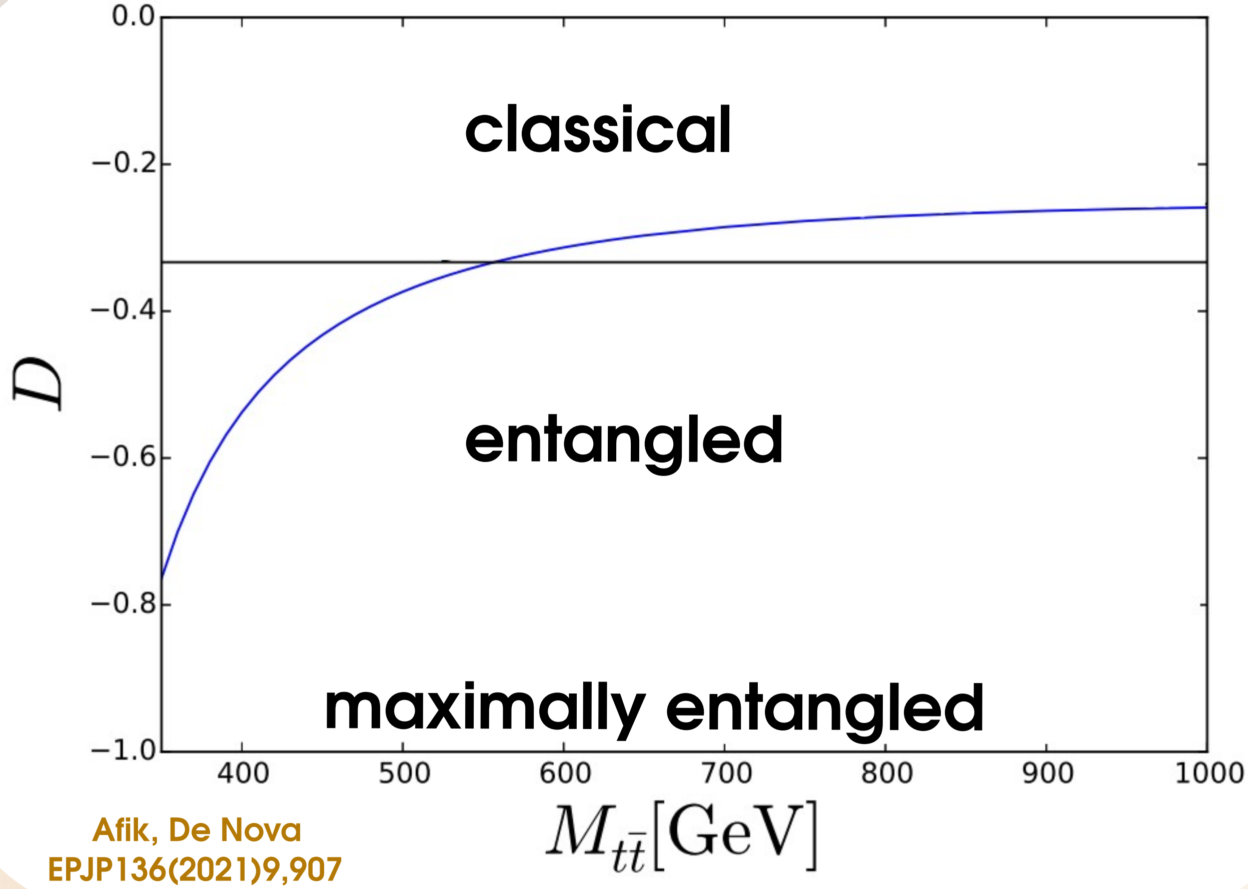
Quantum tomography for BSM



10/3/23 Claudio Severi - U. Manchester

Spin correlations can be so strong they can not be explained classically:



Afik, De Nova
EPJP136(2021)9,907

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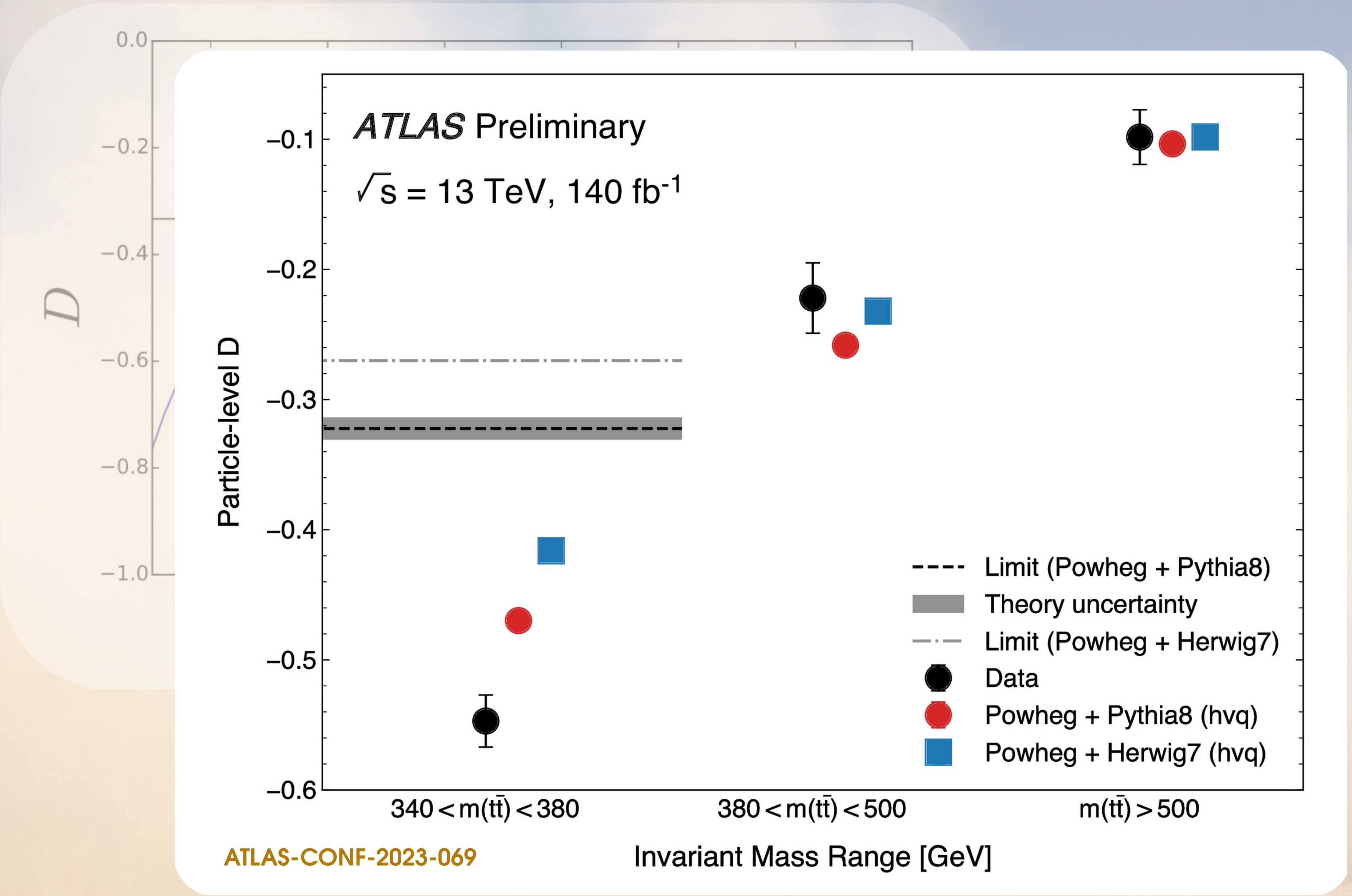

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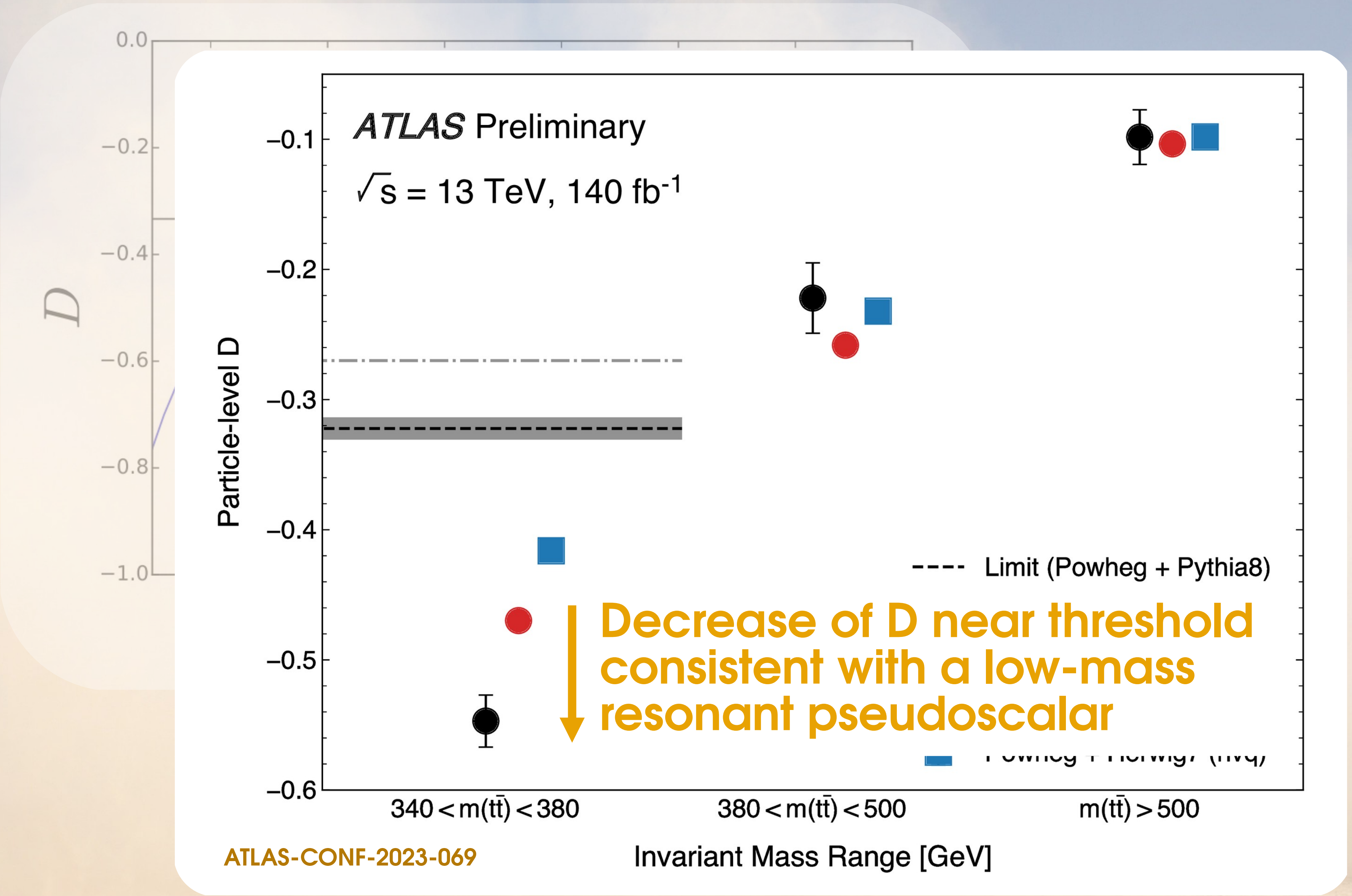
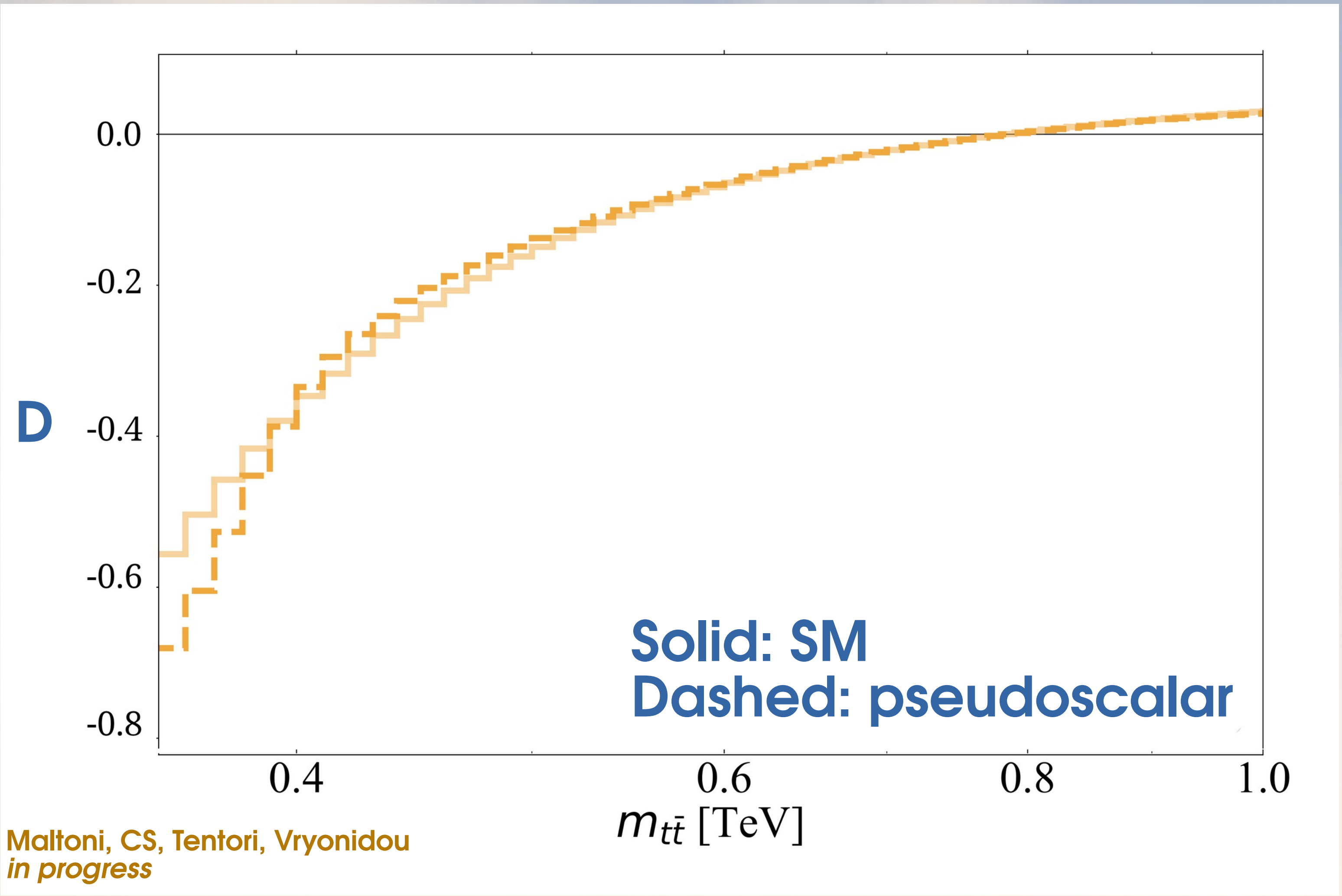
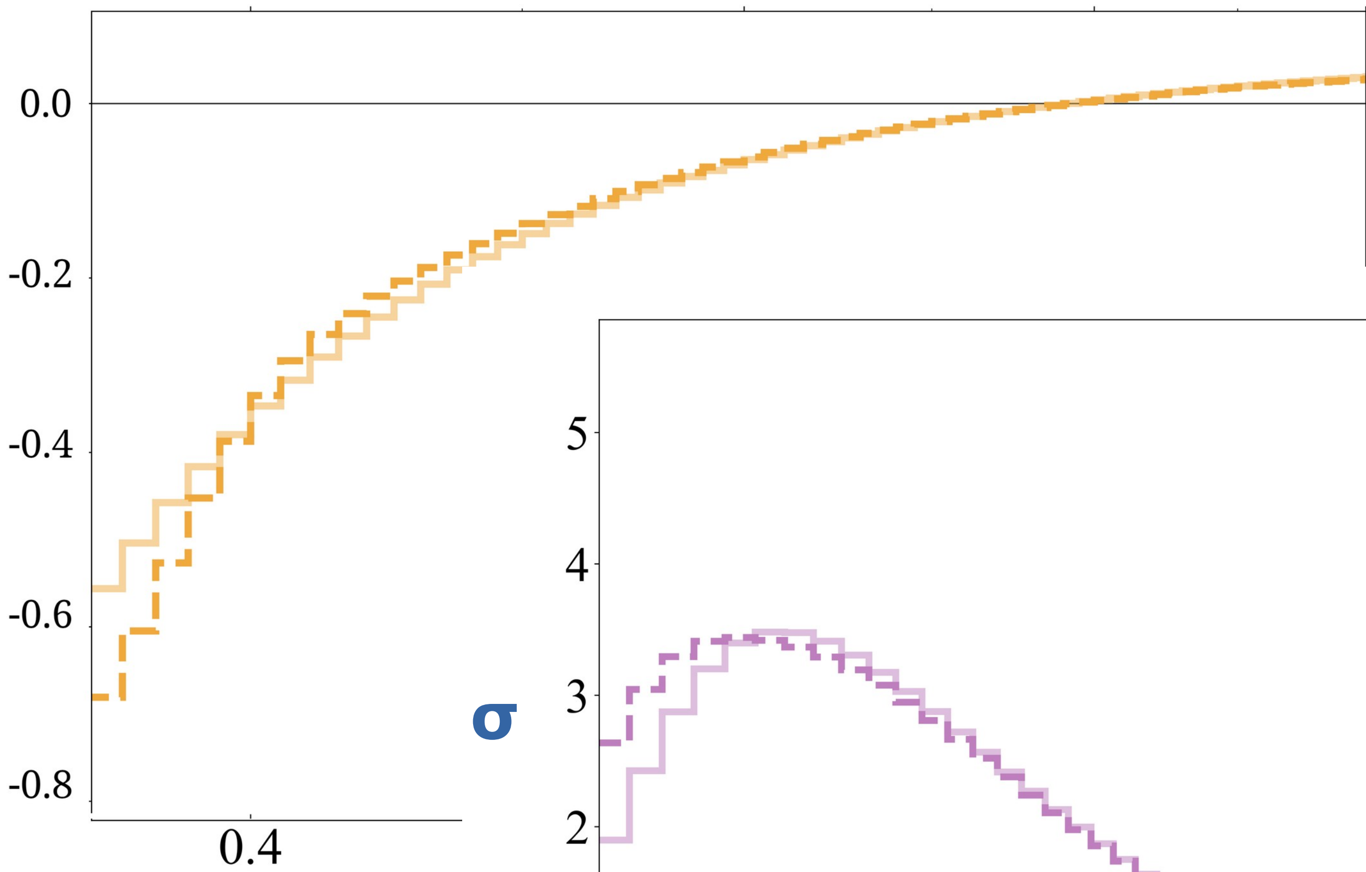


Resonant pseudoscalar at m = 2mt



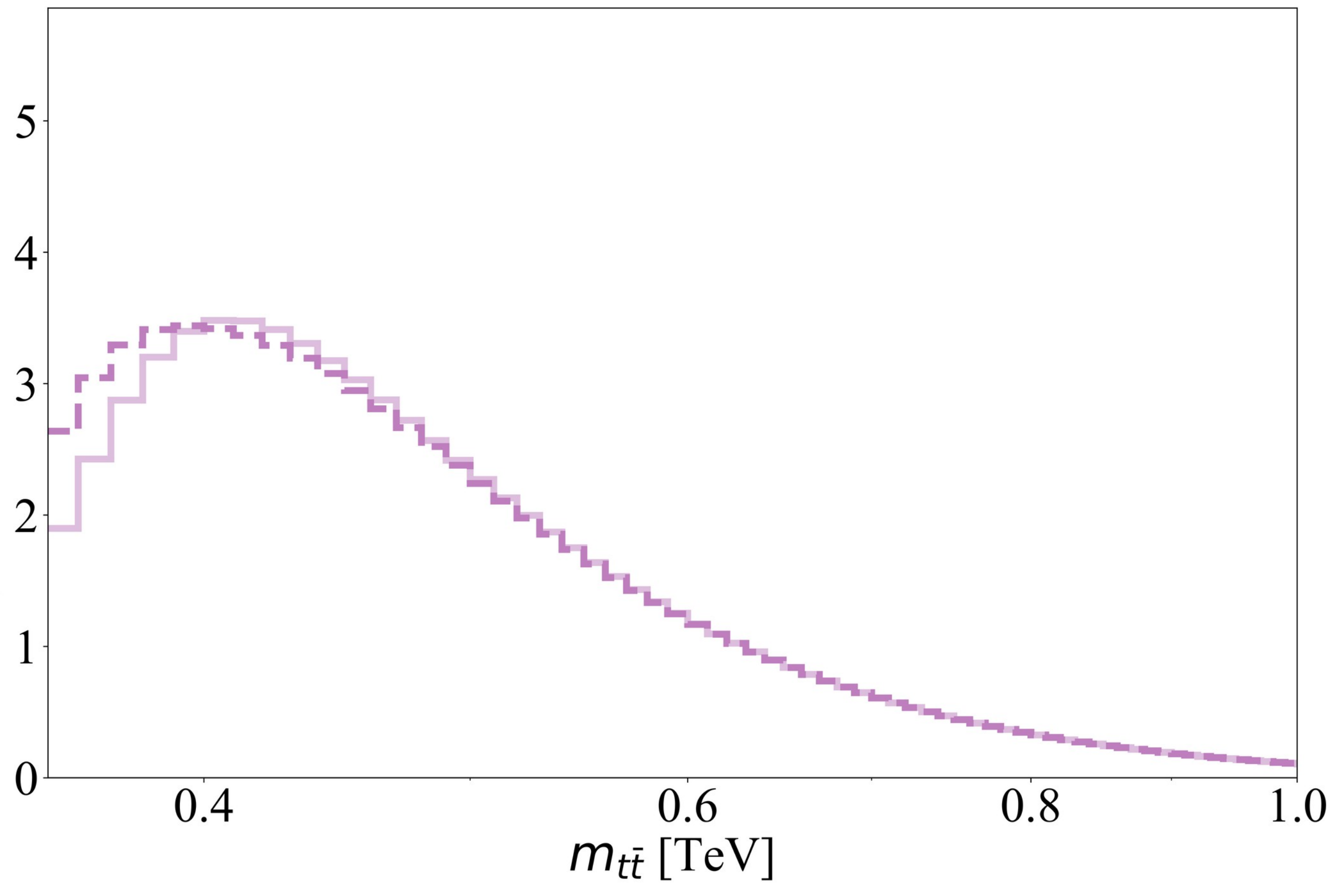
Resonant pseudoscalar at m = 2mt

D



Maltoni, CS, Tentori, Vryonidou
in progress

σ



This would imply a large effect on the cross-section

There is a variety of spin/entanglement observables, apart from D...

$$R \propto \tilde{A}\mathbb{1} \otimes \mathbb{1} + \tilde{B}_i^{+}\sigma^i \otimes \mathbb{1} + \tilde{B}_i^{-}\mathbb{1} \otimes \sigma^i + \tilde{C}_{ij}\sigma^i \otimes \sigma^j,$$

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In the tops' reference frames:

$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta_1^i} = \frac{1}{2}\left(1 + B_1^i \cos\theta_1^i\right),$$

$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta_2^i} = \frac{1}{2}\left(1 + B_2^i \cos\theta_2^i\right),$$

$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta_1^i \cos\theta_2^j} = \frac{1}{2}\left(1 - C_{ij}\cos\theta_1^i \cos\theta_2^j\right) \ln\left(\frac{1}{|\cos\theta_1^i \cos\theta_2^j|}\right).$$

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Dedicated observables can be directly sensitive to particular variables of interest:

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\varphi} = \frac{1}{2}(1 - D\cos\varphi).$$

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and in the lab frame:

$\cos\varphi_{\text{lab}} = \hat{\ell}_1^{\text{lab}} \cdot \hat{\ell}_2^{\text{lab}},$ $|\Delta\phi_{\ell\ell}|,$ $|\Delta\eta_{\ell\ell}|,$

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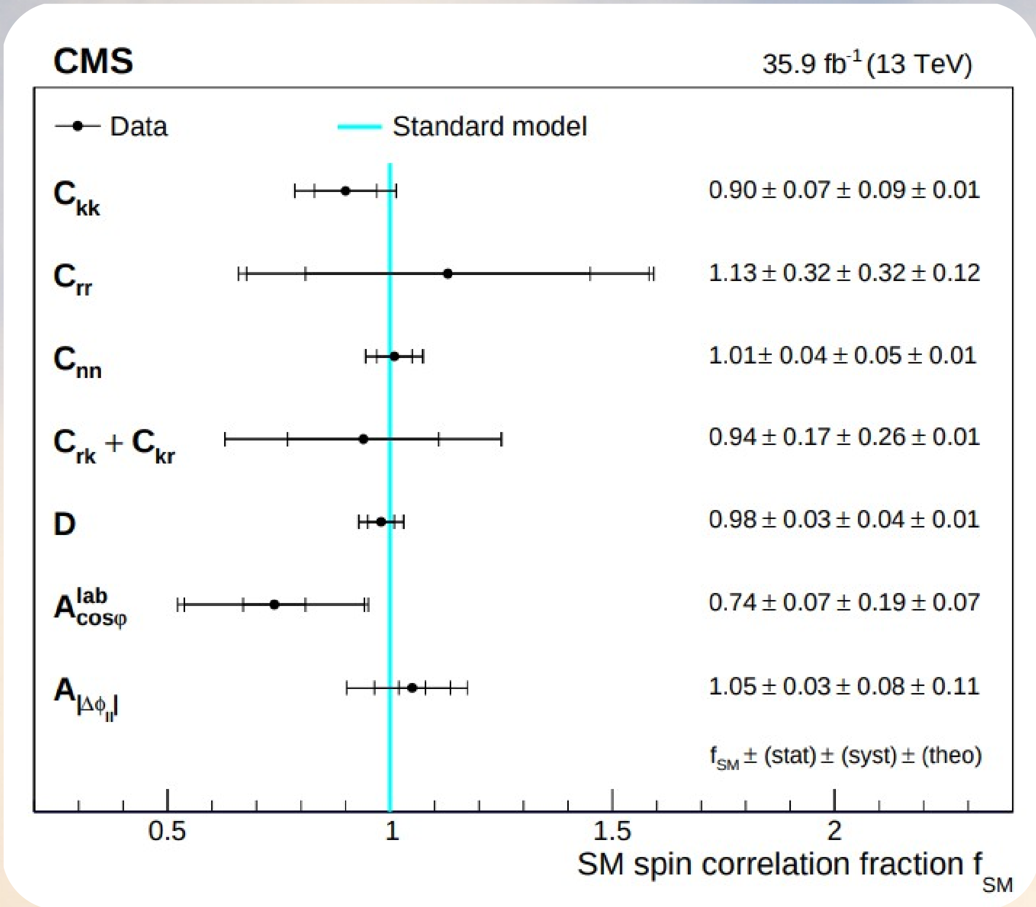
These variables give a convolution of spin and kinematics, but their resolution is excellent:

The motivation for using some of these variables can be found in [25]. The highest ranked variables are the angular variables $\Delta\eta_{\ell\ell}$, $\cos\varphi_{\text{lab}}$, and $\Delta\phi_{\ell\ell}$. In principle, adding additional kinematic variables to the DNN will improve the sensitivity further. However, by adding basic

CMS-PAS-FTR-18-034

Several measurements have already been done:



CMS PRD 100, 072002 (2019)

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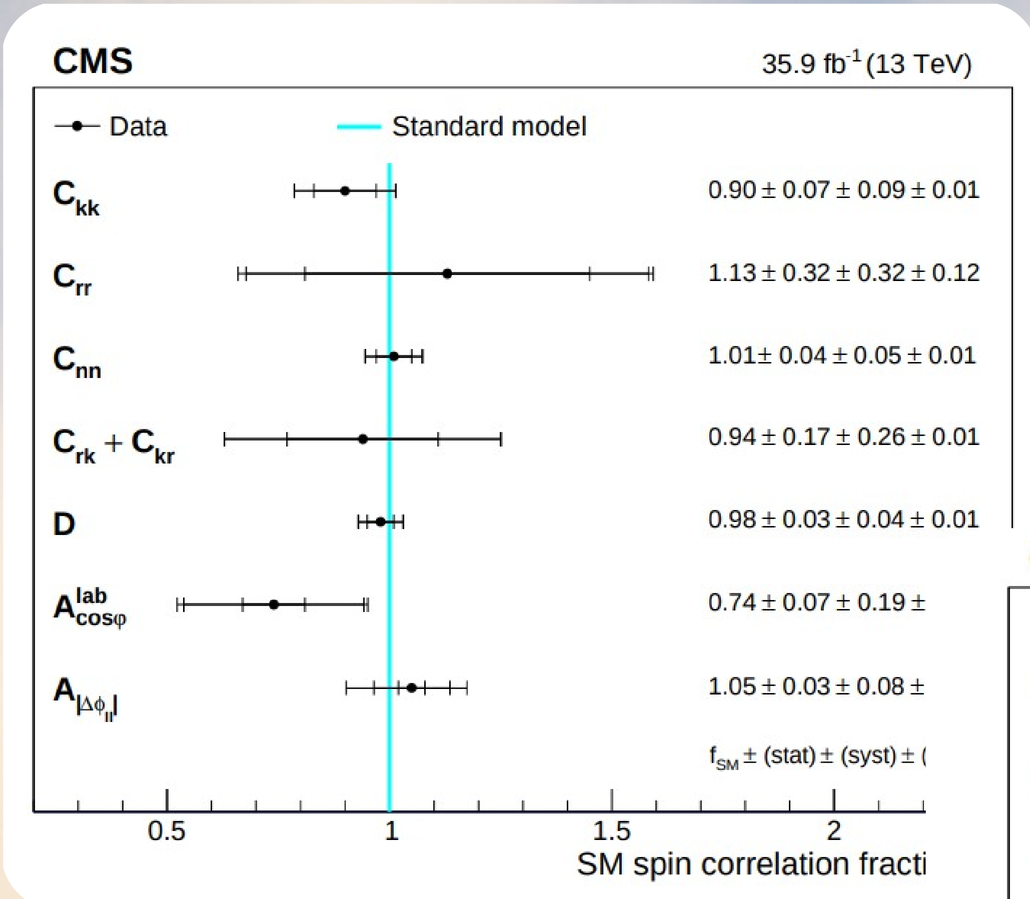

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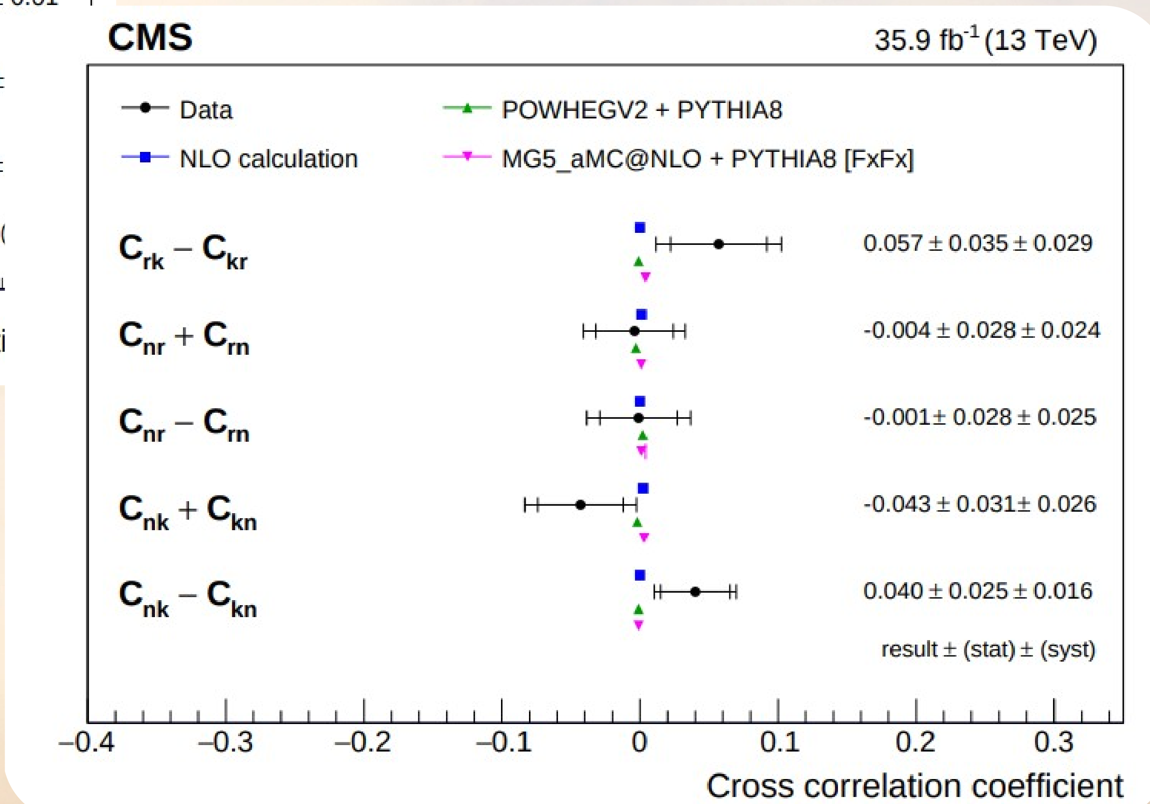
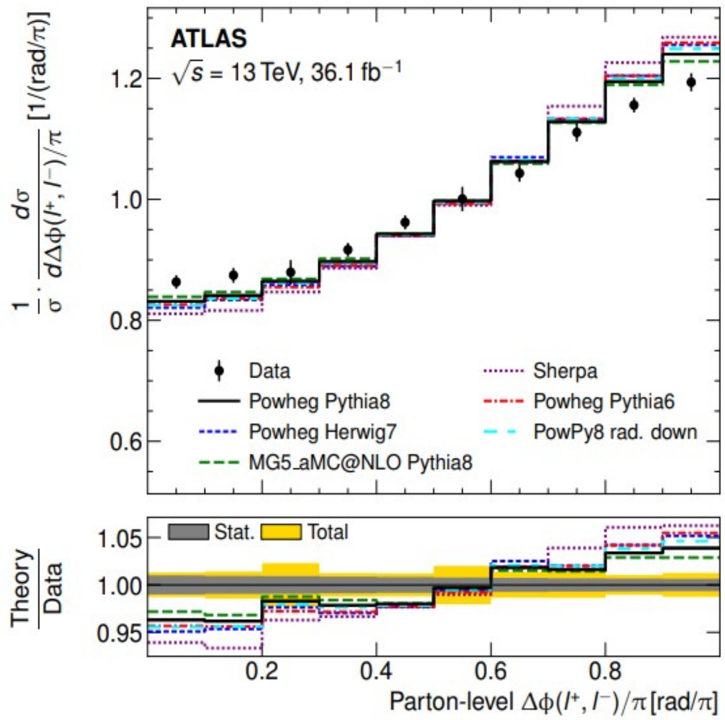
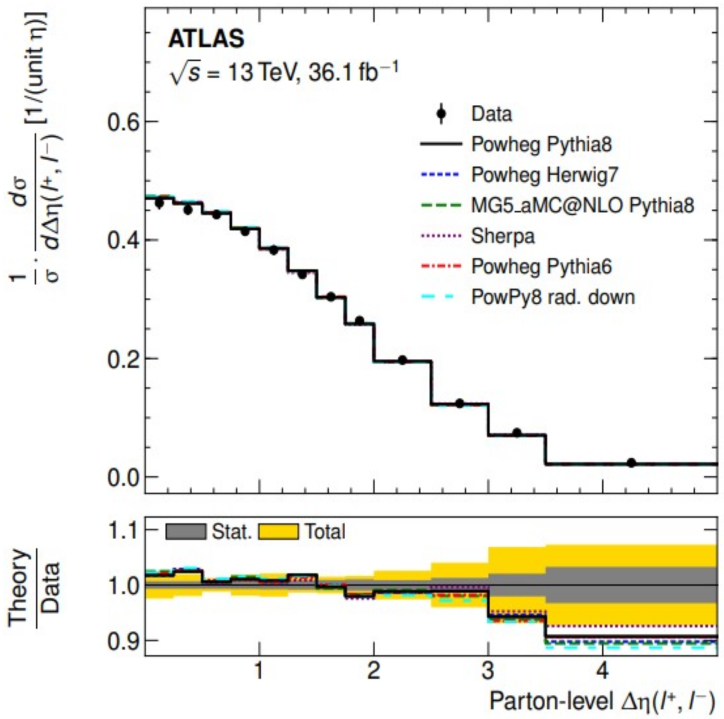


ATLAS EPJC 80 (2020) 754





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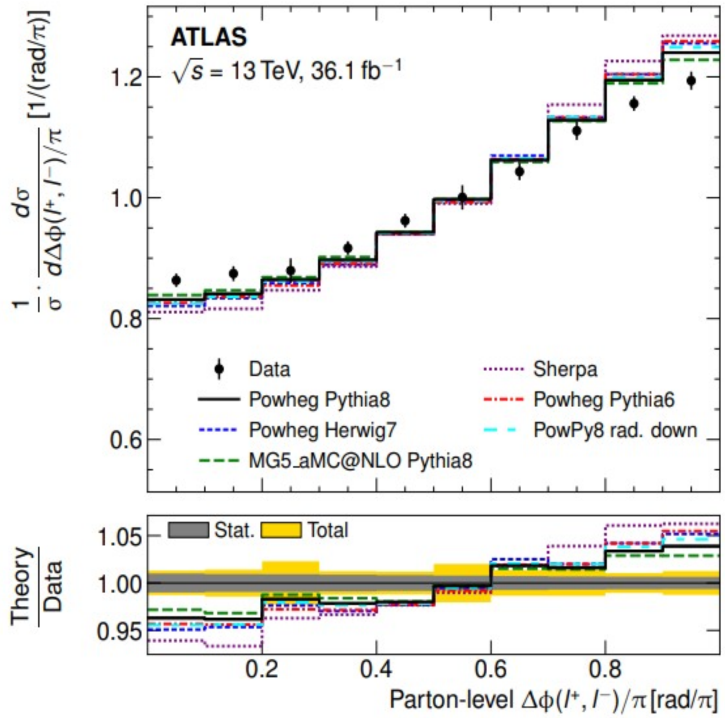

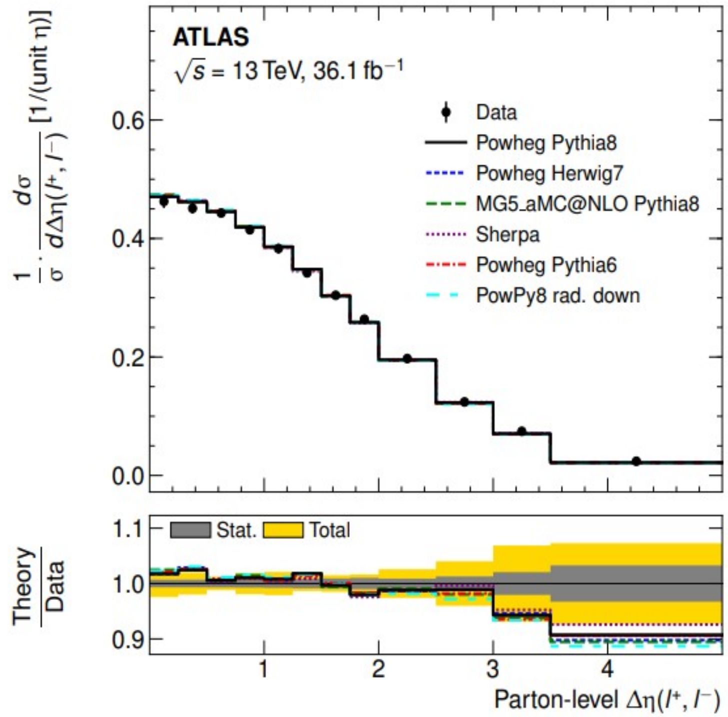

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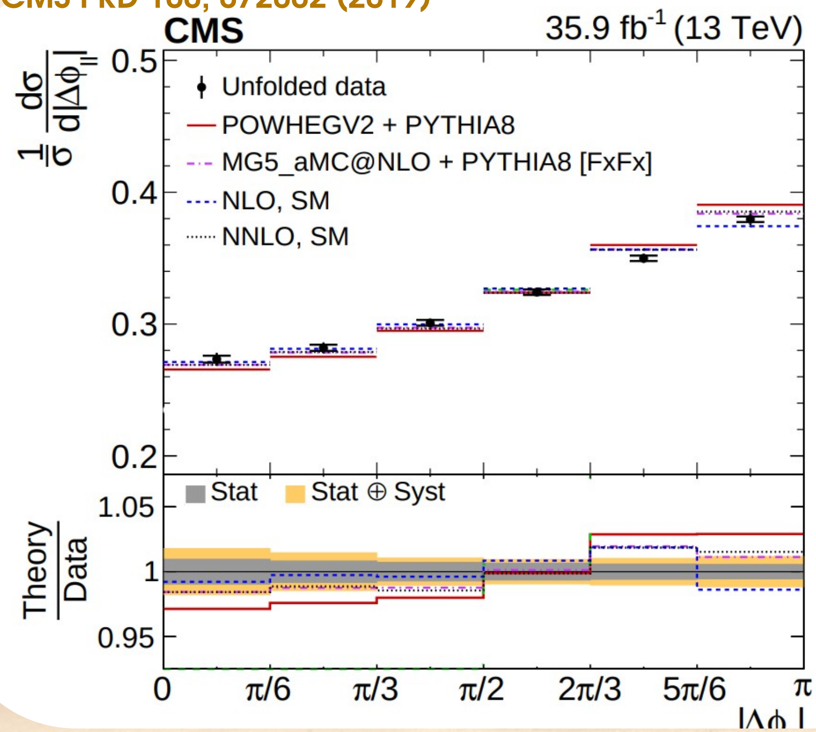

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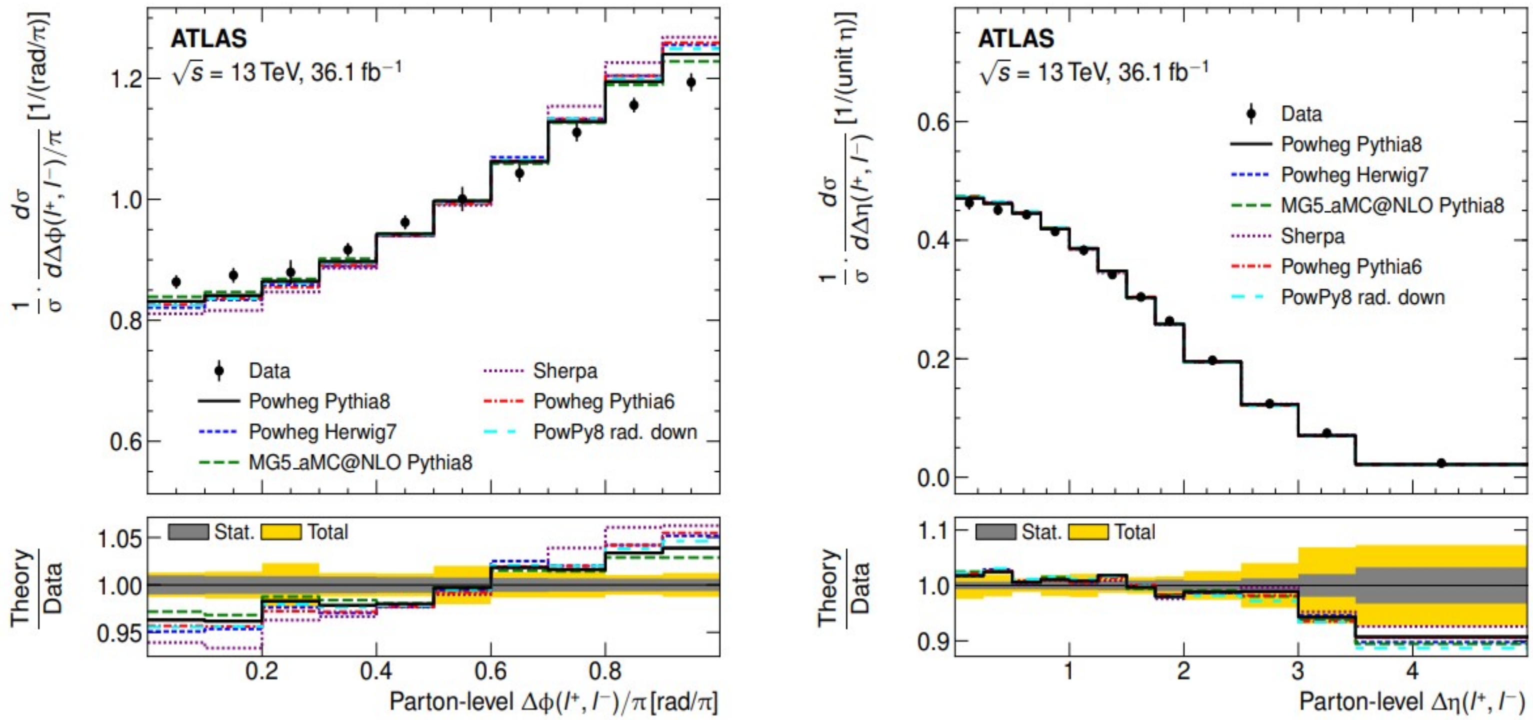

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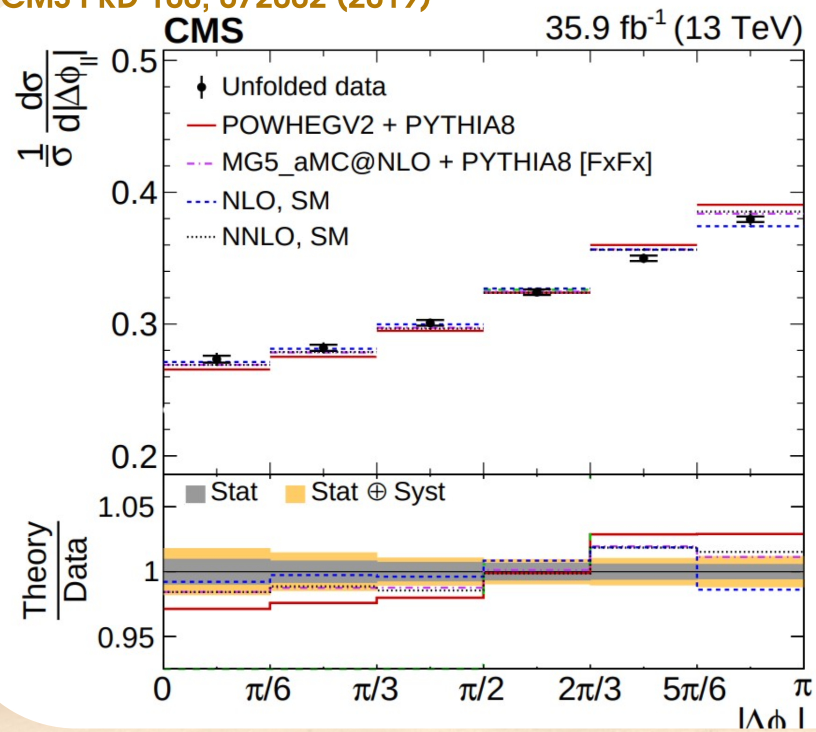
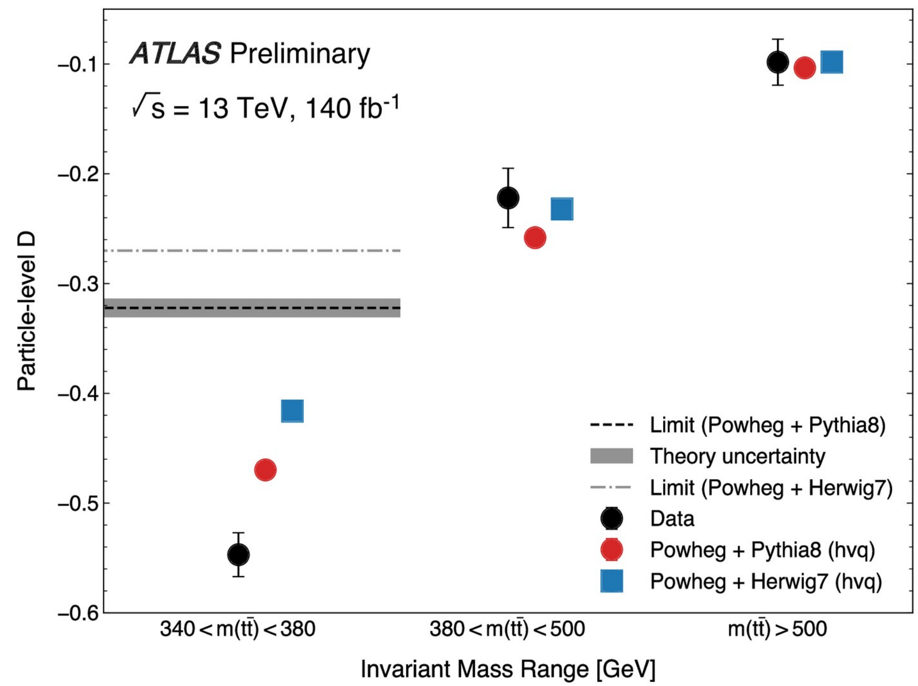


ATLAS-CONF-2023-069



Do these deviations paint a consistent picture?

NO

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NOt yet

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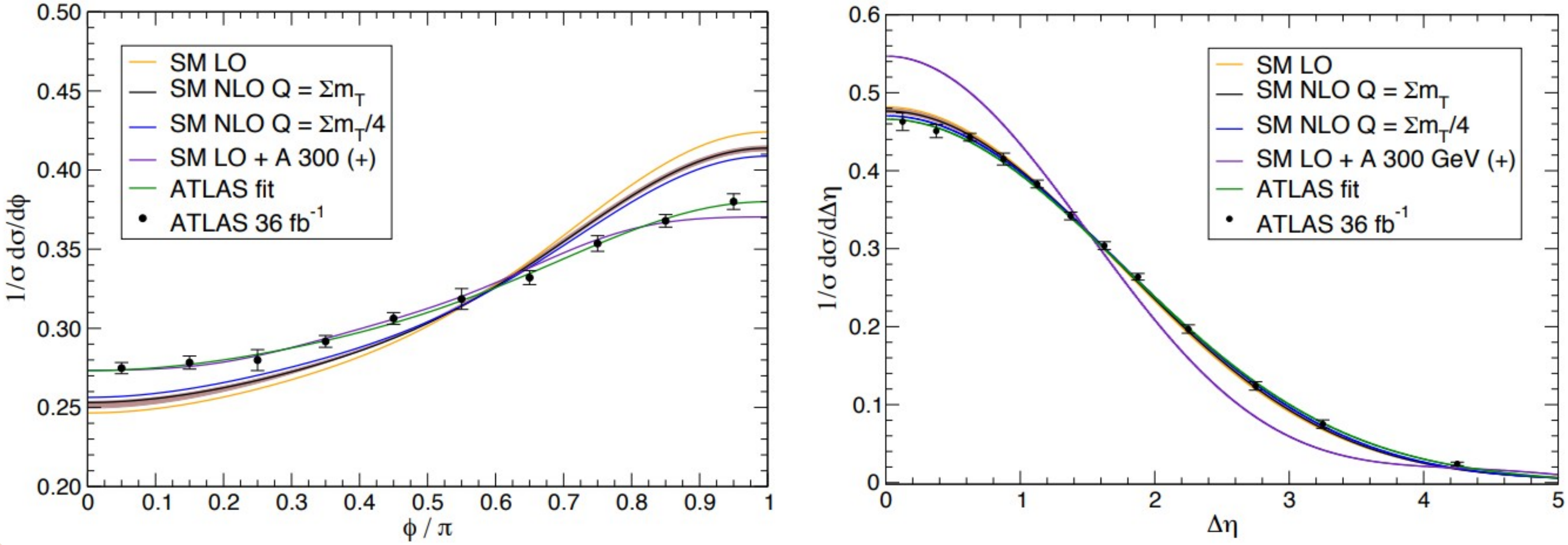
Example: resonant pseudoscalar gg → A → tt



Aguilar-Saavedra
TOP LHC WG, 14/11/19

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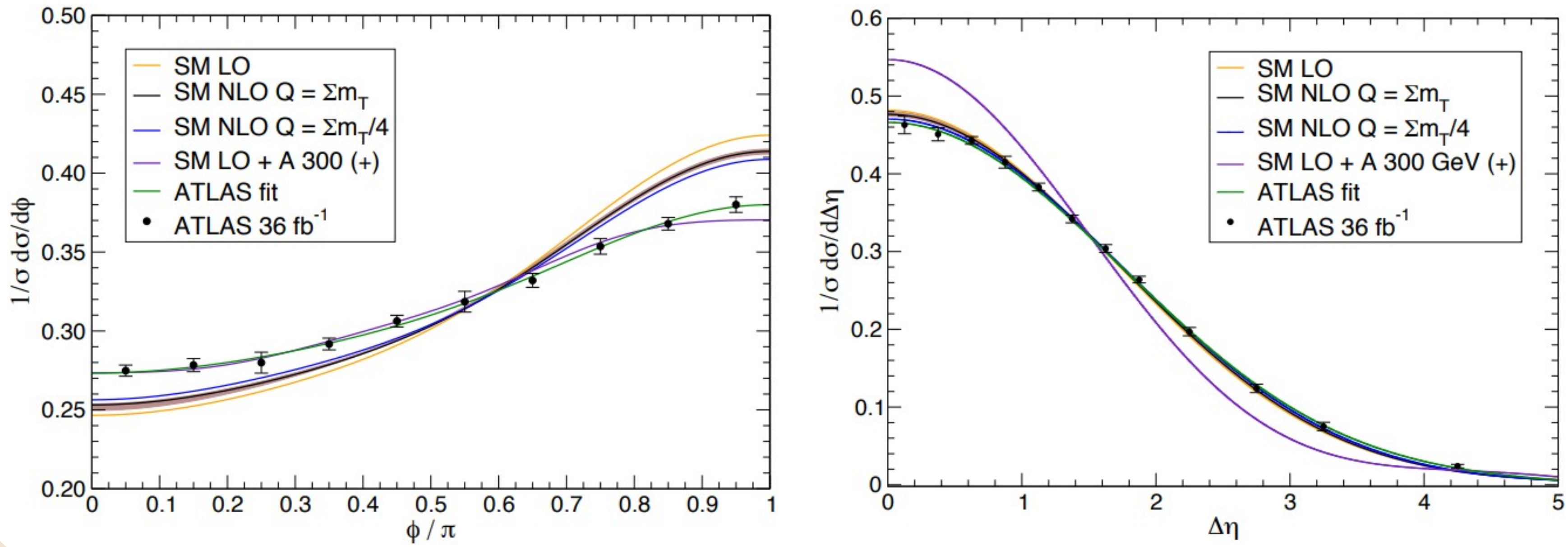
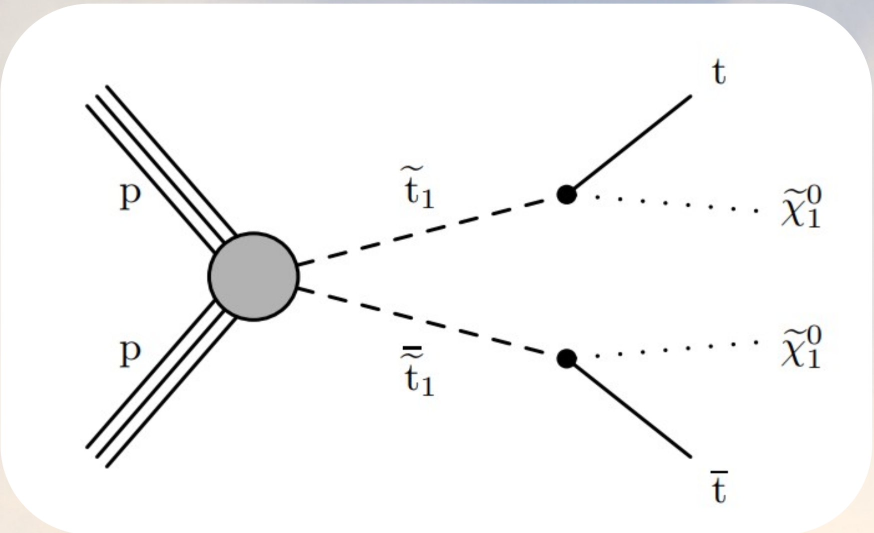


Aguilar-Saavedra
TOP LHC WG, 14/11/19

The amount of signal needed to explain Δϕ is immediately excluded by Δη.

Other example: SUSY in the top mass corridor



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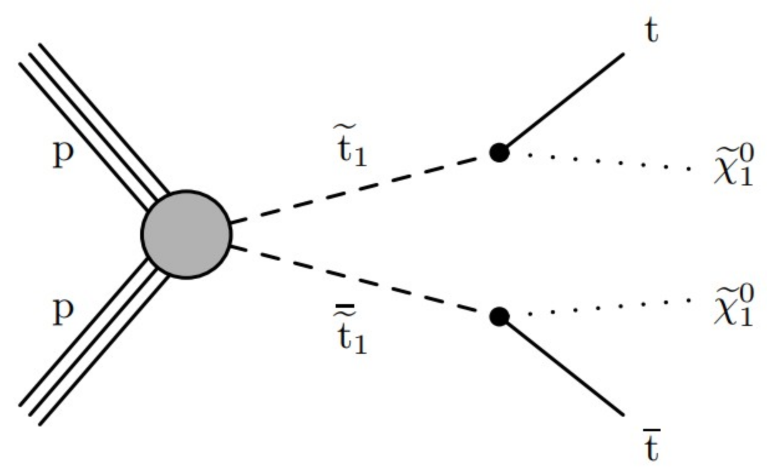

$$m_{\tilde{t}_1} \approx m_t + m_{\tilde{\chi}_1^0}.$$

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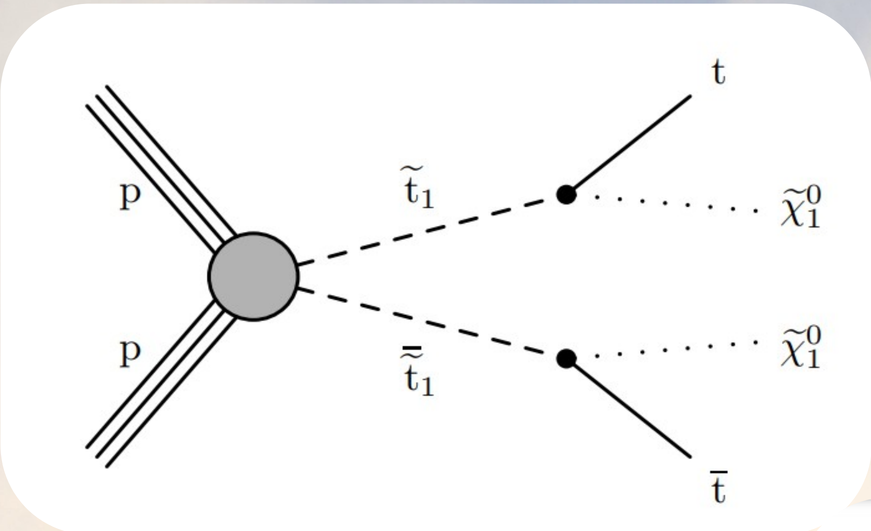

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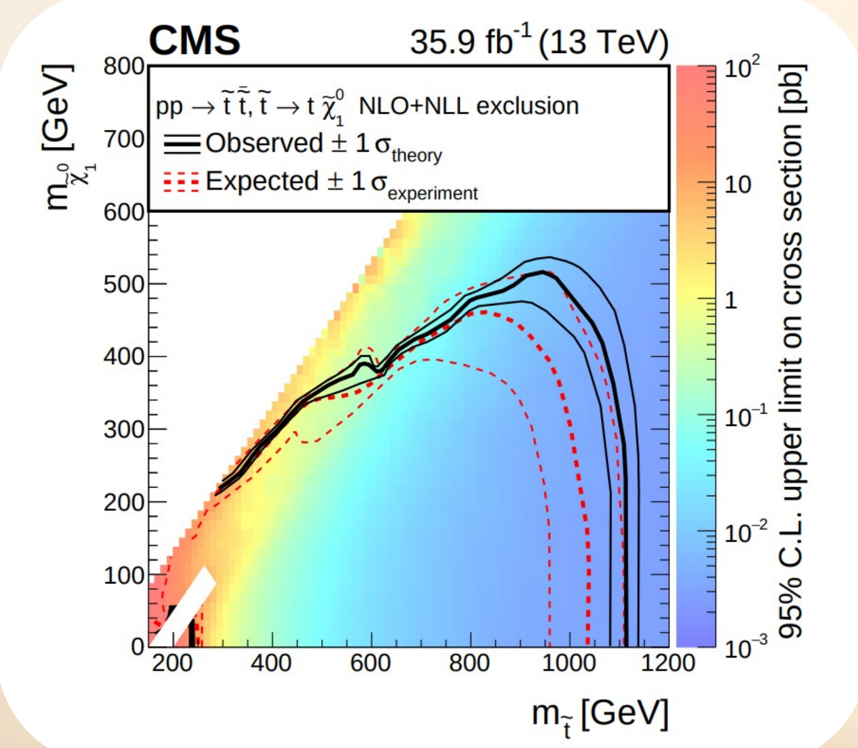

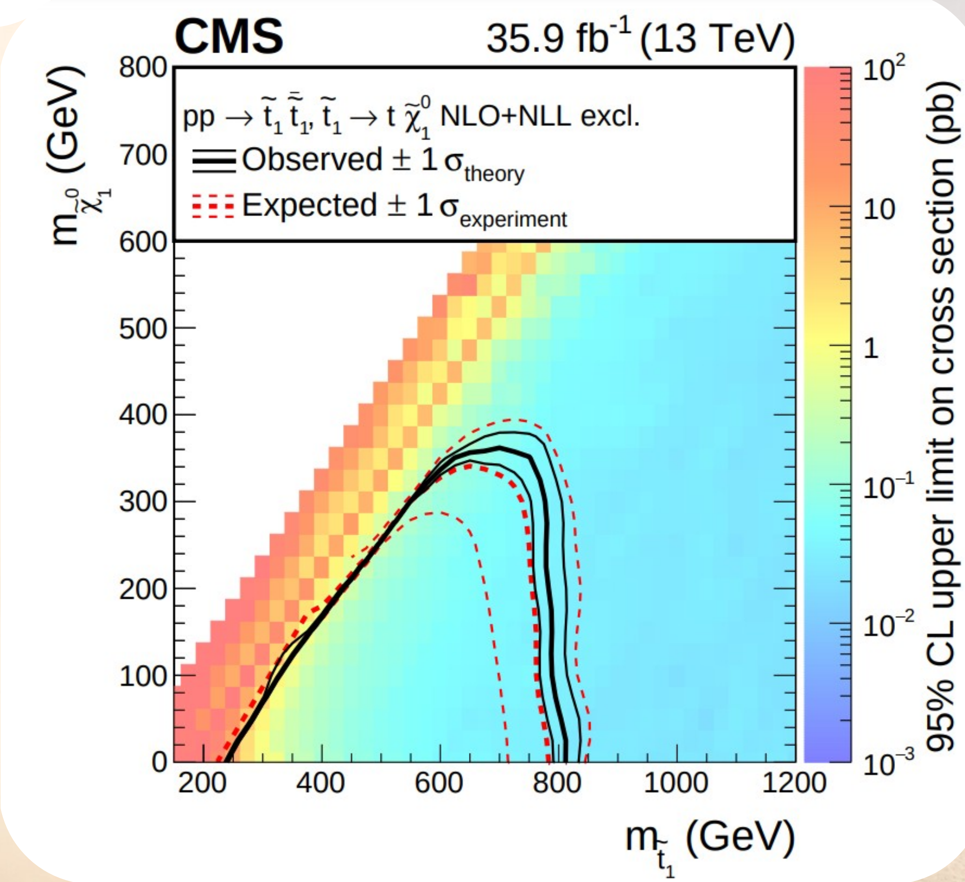

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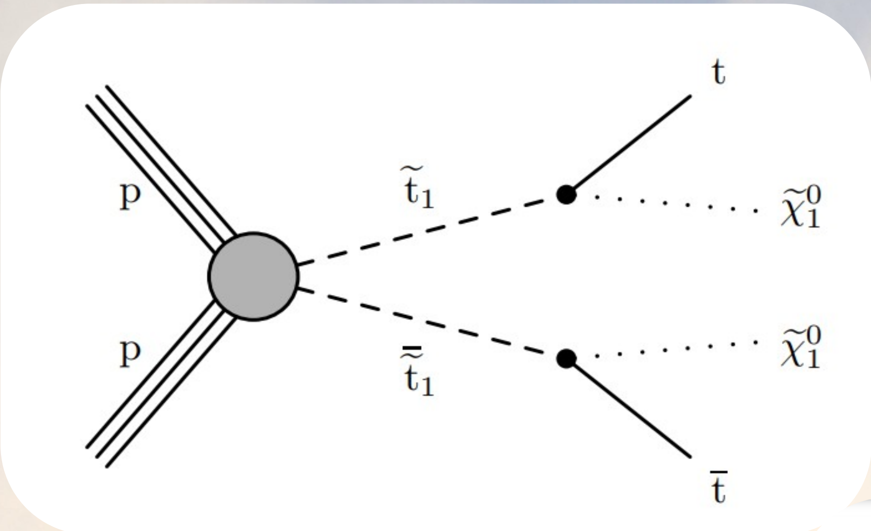

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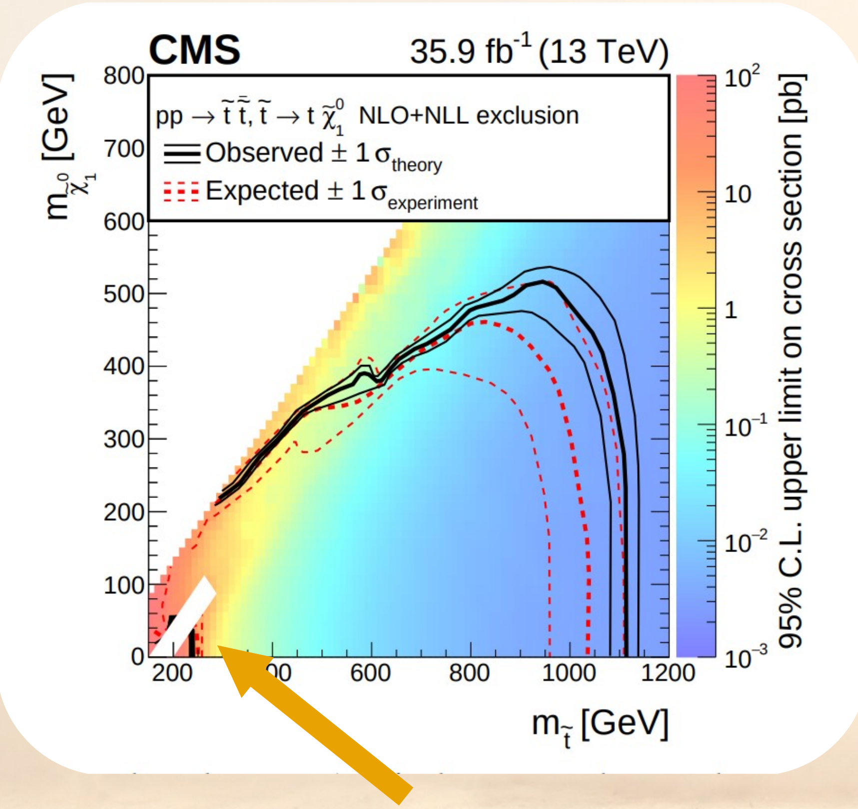

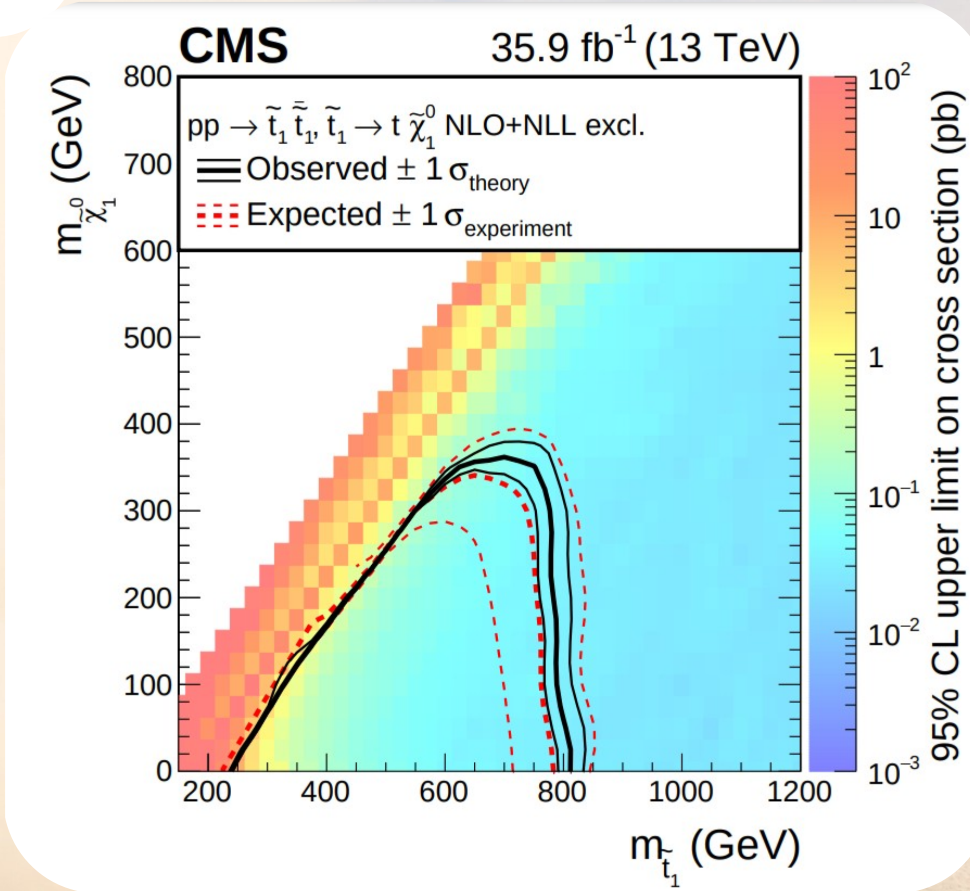

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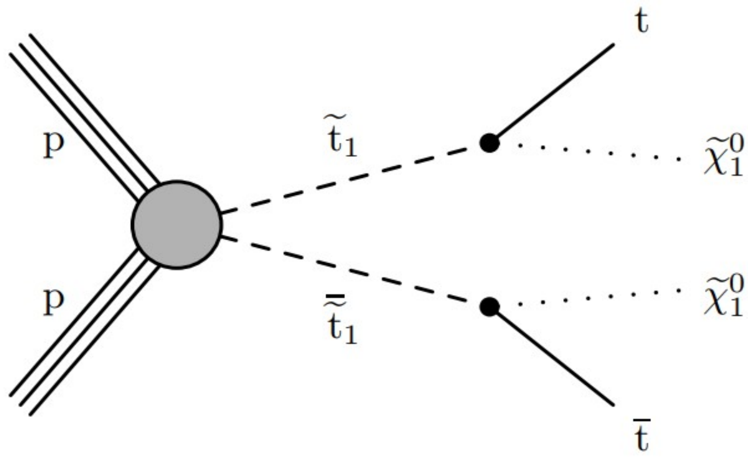

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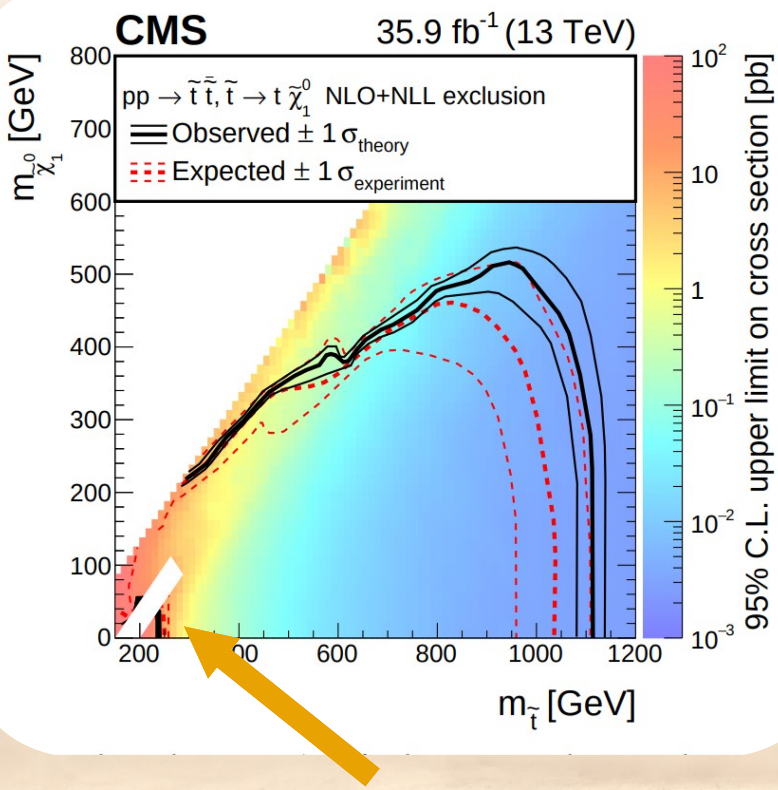

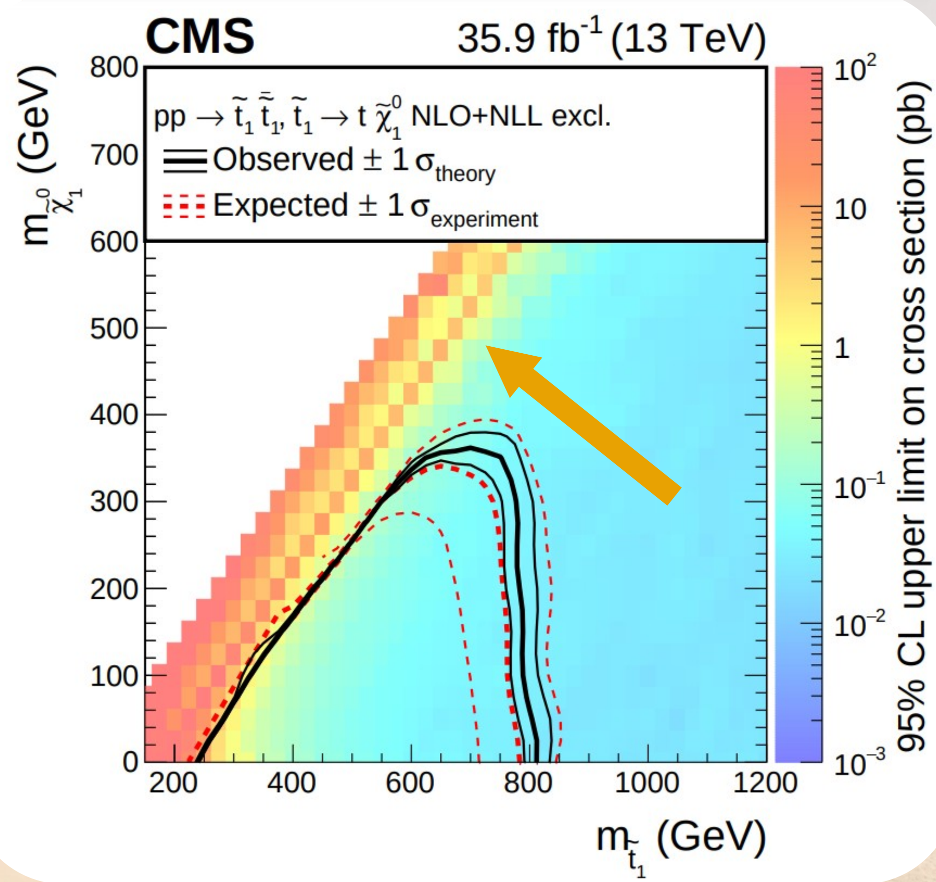

Other example: SUSY in the top mass corridor

Sensitivity from kinematical distributions is very small. Spin on the other hand...

$$B_i = \frac{\sigma_{\text{SM}}}{\sigma} B_{i\,\text{SM}} + \frac{\sigma_{\text{SUSY}}}{\sigma} B_{i\,\text{SUSY}} \approx \frac{\sigma_{\text{SUSY}}}{\sigma} B_{i\,\text{SUSY}}.$$

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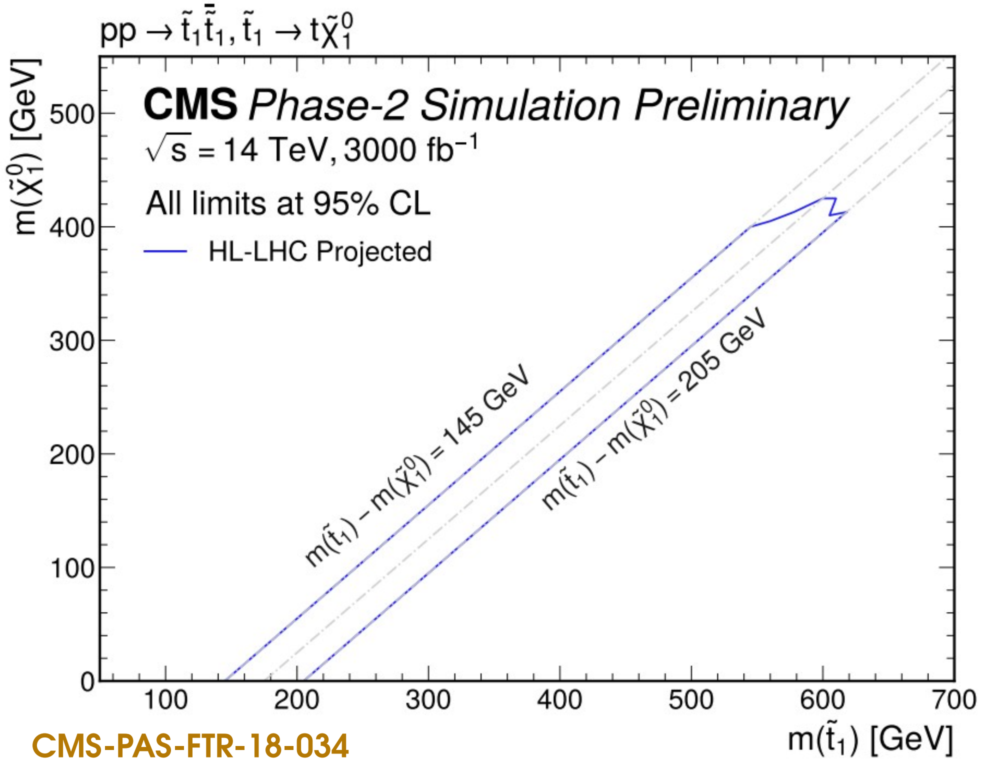

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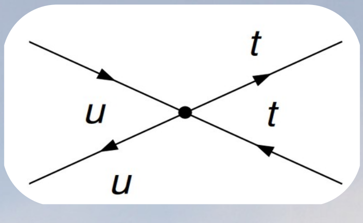
all spin density matrix and Δφlab, Δϕ, Δη

Last example: Heavy new physics (SMEFT) contact interaction between light quarks and tops.



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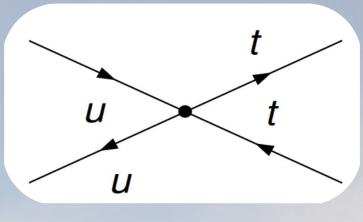
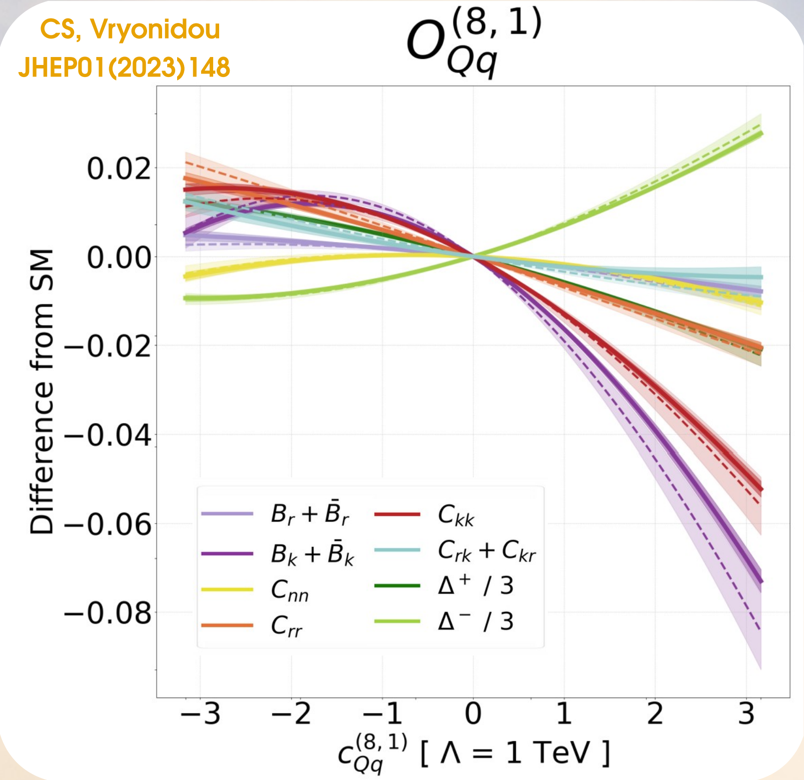


Inclusive measurement



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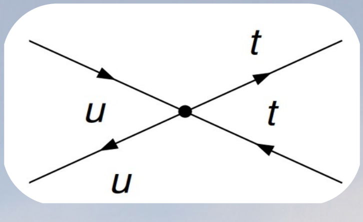

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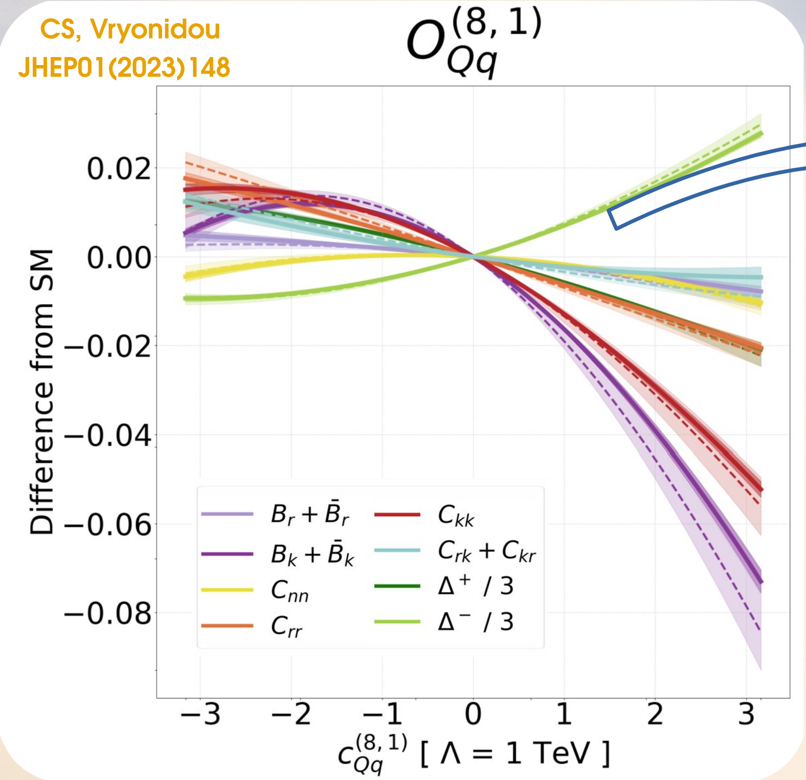
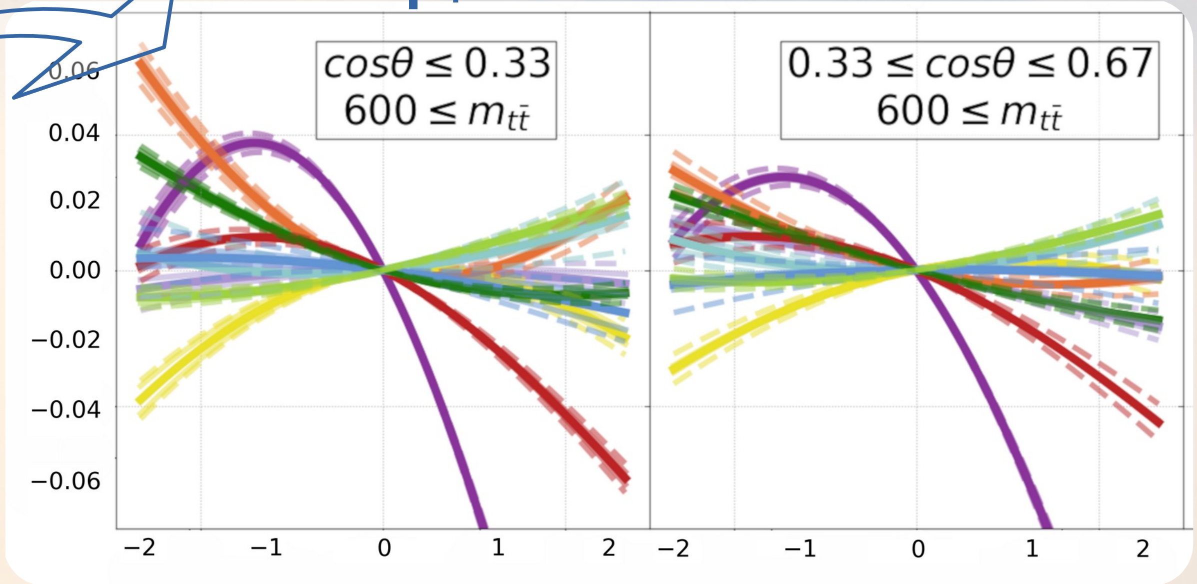


Measurement with p_T cuts



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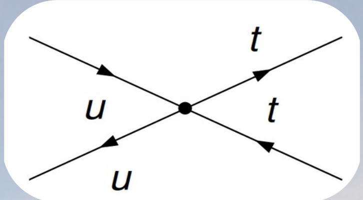

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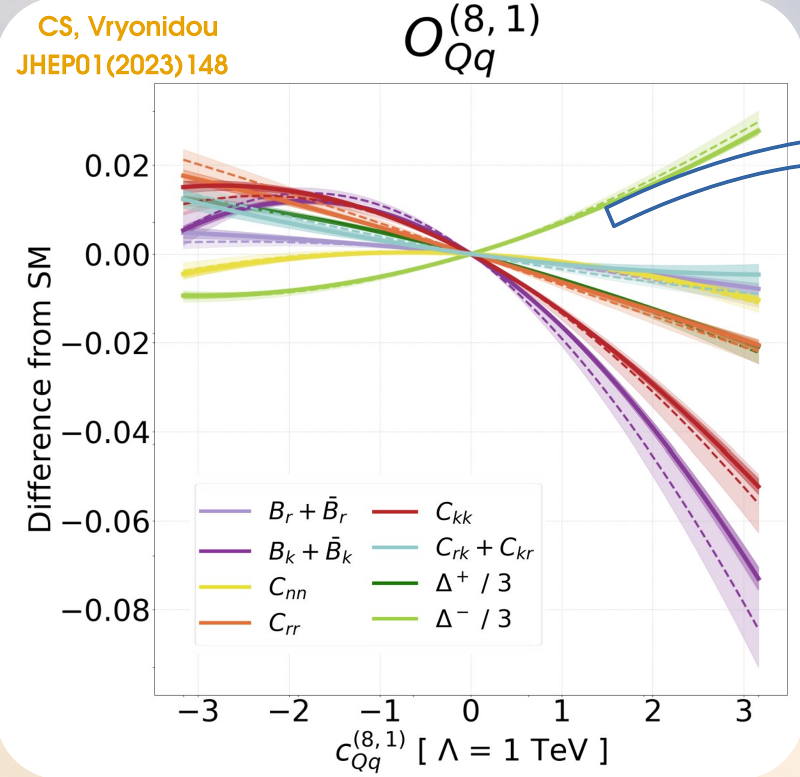

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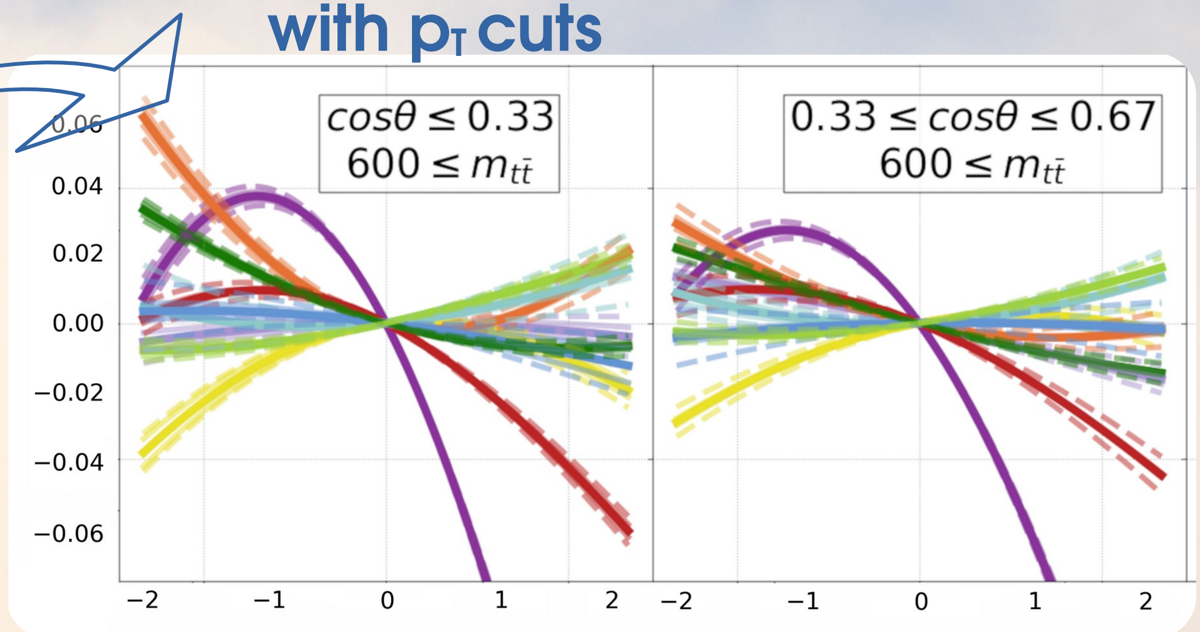

Our simulations show that <u>one</u> differential measurement will be competitive with the <u>global fits</u> to all top data.

Operator	Run III Projection 300 fb^{-1} Differential	Current Global Fit
$\mathcal{O}^8_{Qu}$	$[-0.7, 0.6]$	$[-1.0, 0.5]$
$\mathcal{O}^8_{Qd}$	$[-0.9, 0.8]$	$[-1.6, 0.9]$
$\mathcal{O}^{(1,8)}_{Qq}$	$[-0.4, 0.3]$	$[-0.4, 0.3]$
$\mathcal{O}^{(3,8)}_{Qq}$	$[-1.1, 0.8]$	$[-0.5, 0.4]$


Thank you :D

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Highest-Energy Detection Of Quantum Entanglement Achieved Yet

The energy scale is a thousand billion times higher than typical laboratory experiments.

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Senior Staff Writer & Space Correspondent

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and allows physicists to test indirectly many properties of the standard model of particle physics, such as the mass of the Higgs boson.

All of those tests are done by looking at the decay products, the particles that are created in the aftermath of the top-quark pairs coming into existence. The team managed to measure a degree of entanglement that could not be explained if the quarks were not entangled, with a precision that exceeded the golden standard for particle physics.

The results were presented at the ATLAS conference on September 28.