

LLP searches and Re-Interpretation

LHC BSM WG Meeting

CERN, November 11th 2025

André Lessa

UFABC, São Paulo, Brazil

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(From a theorist's
perspective)

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+ Louie's
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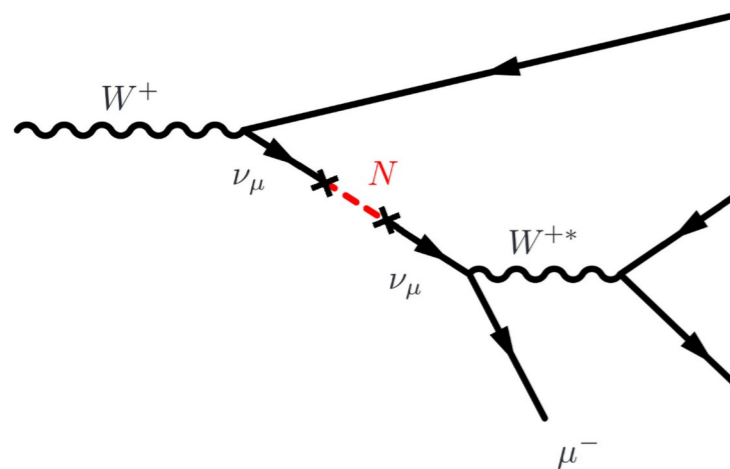
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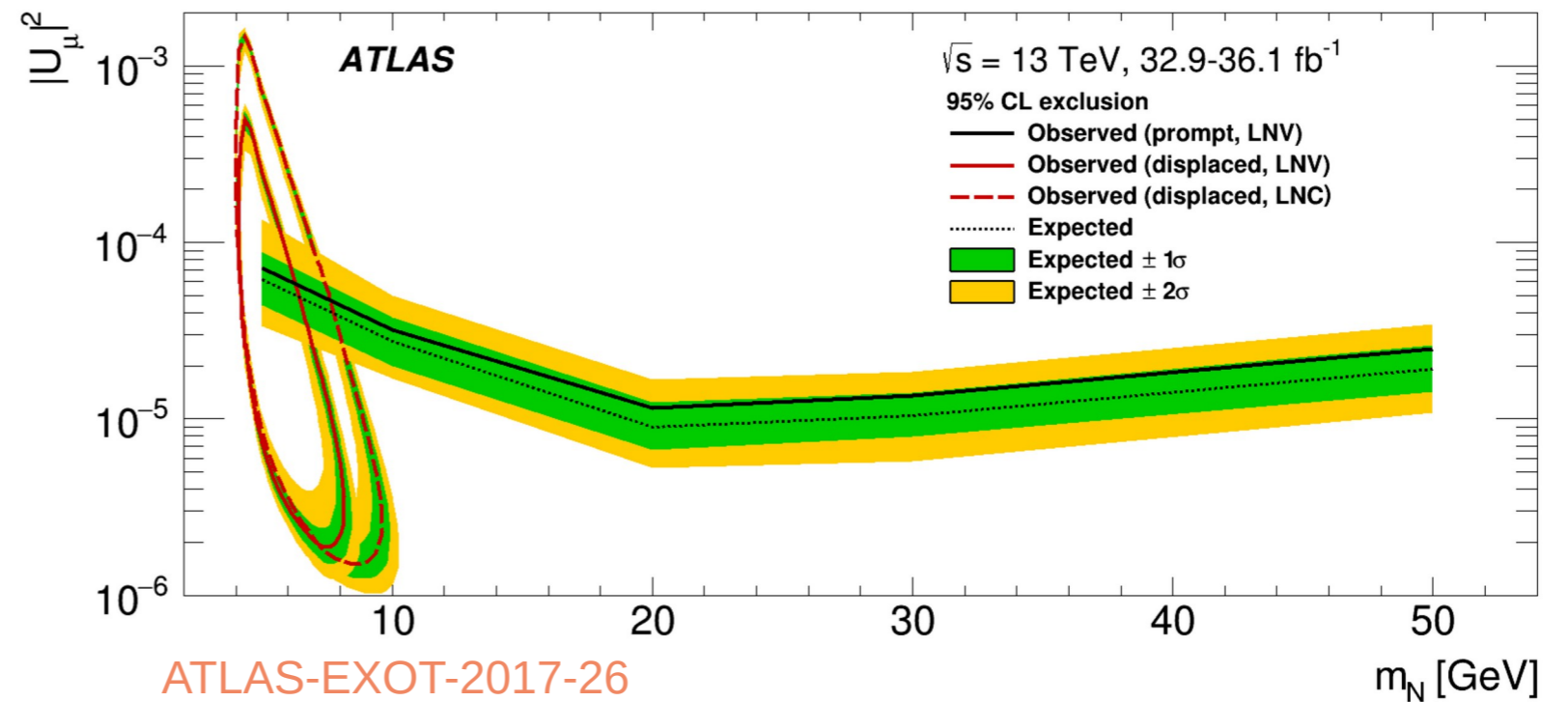
Why *Re-Interpretation*?

- Most searches use benchmark models to present their results



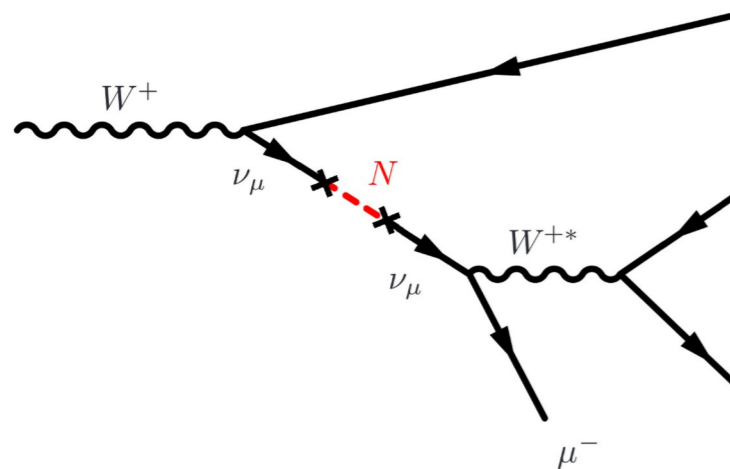
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m_N , $U_{N\mu}$ or U_{Ne}



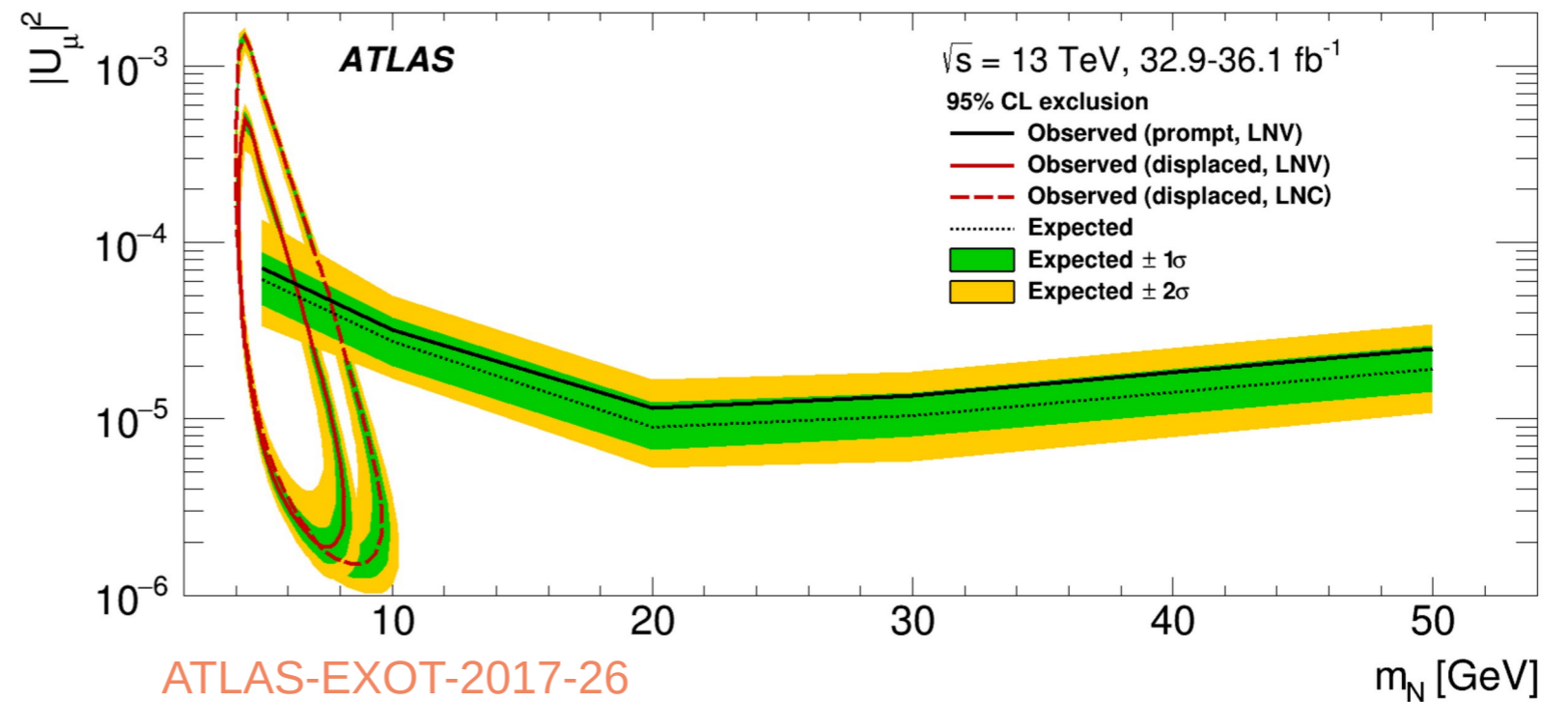
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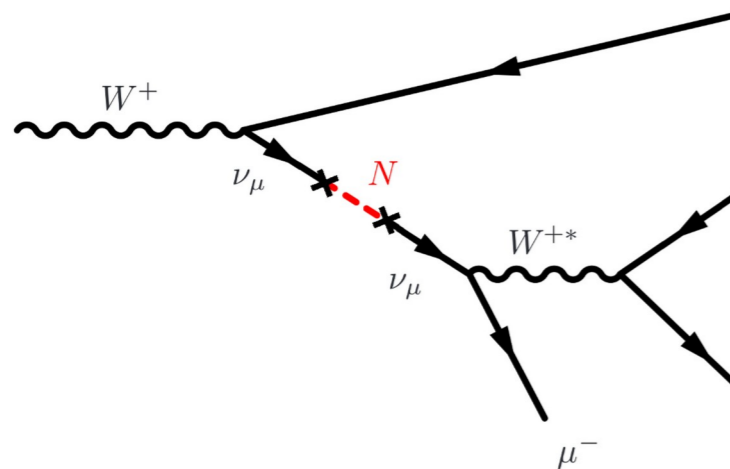
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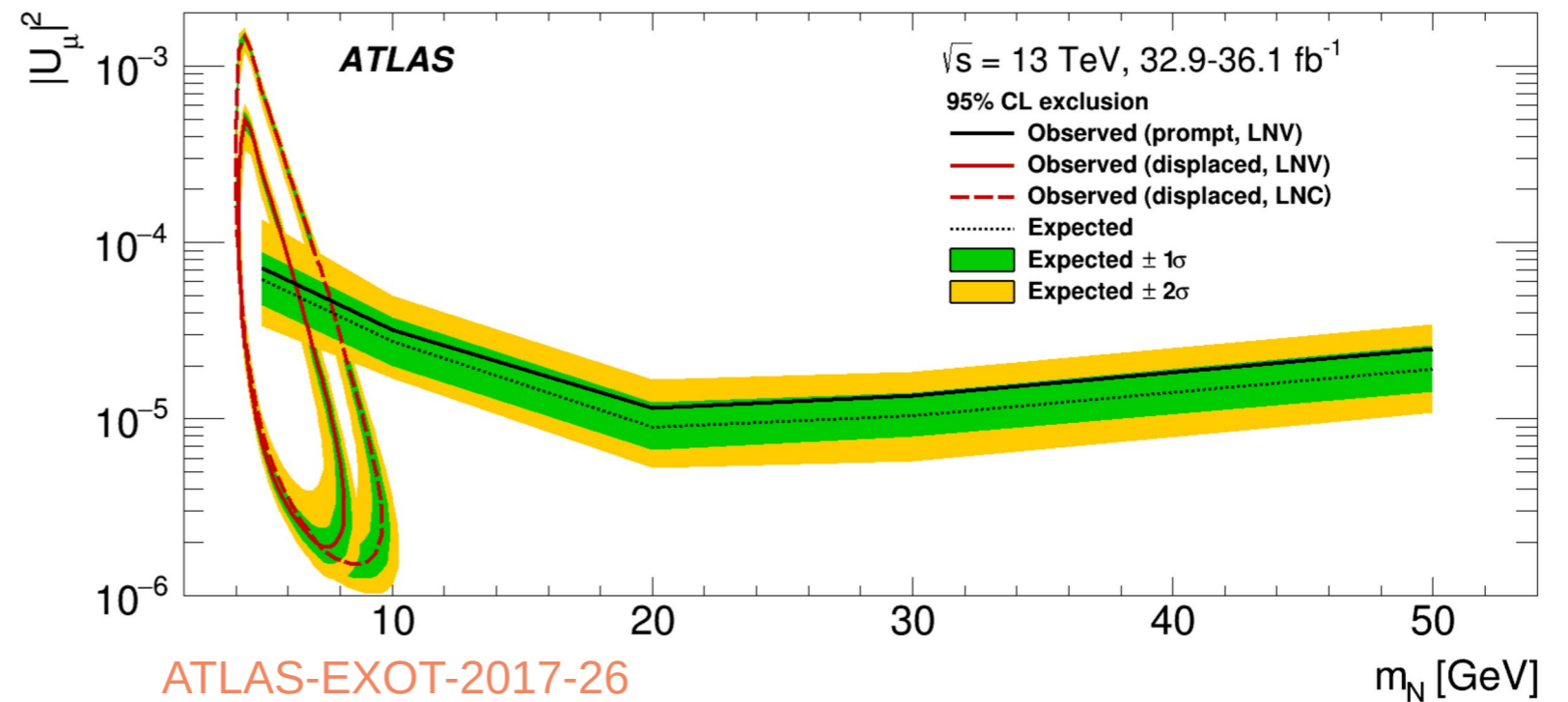
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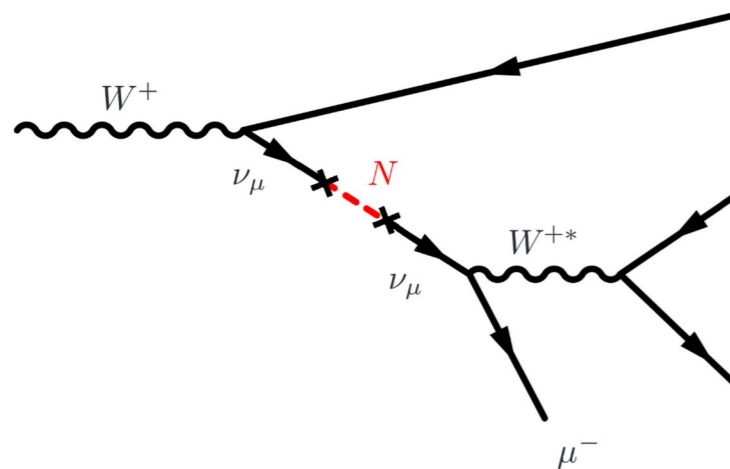
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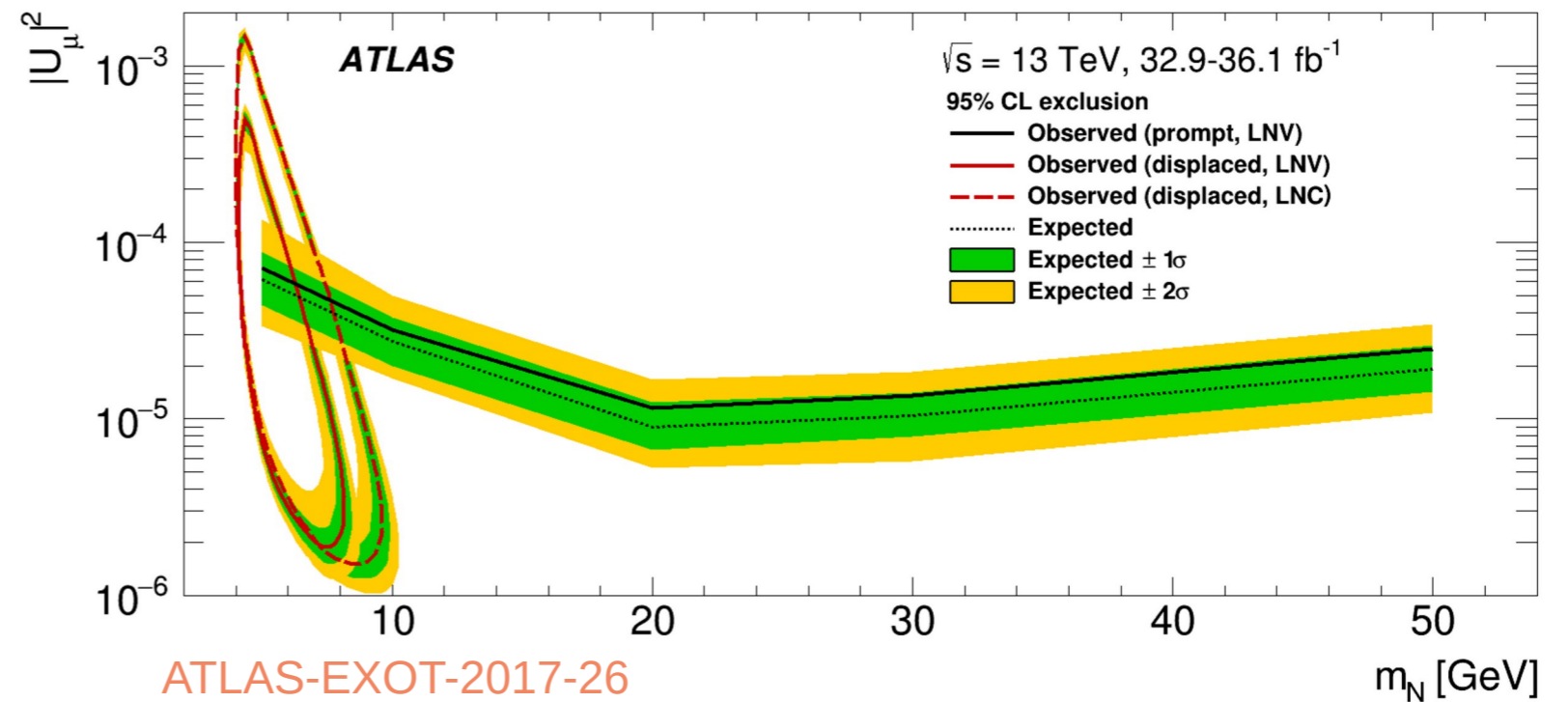
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- *Benchmarks are usually incomplete models*
- *Used mostly to parametrize signal properties and compare sensitivities between searches*
- *They should not be the “final product” of a search!*

Why *Re-Interpretation*?

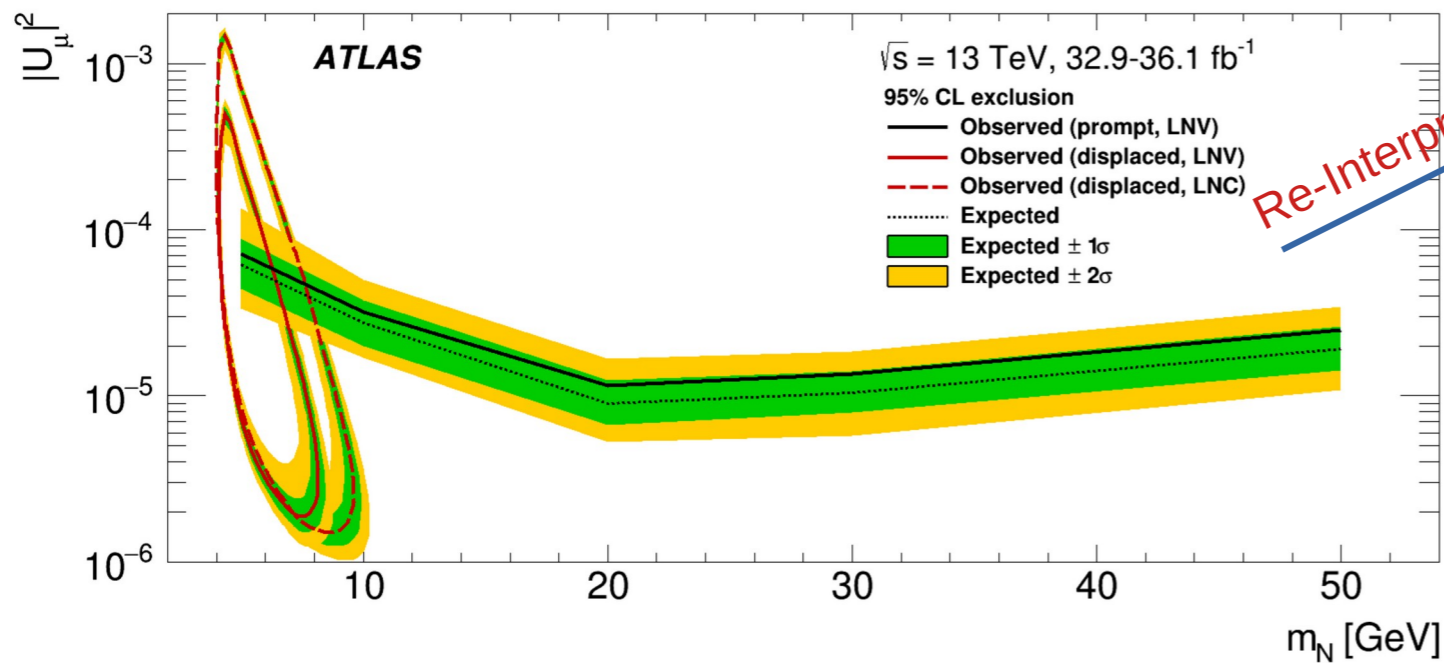
- Indeed, for fitting neutrino masses, *at least two HNLs are needed*:

$$m_{N_I}, U_{I\alpha}, \quad I \geq 2$$

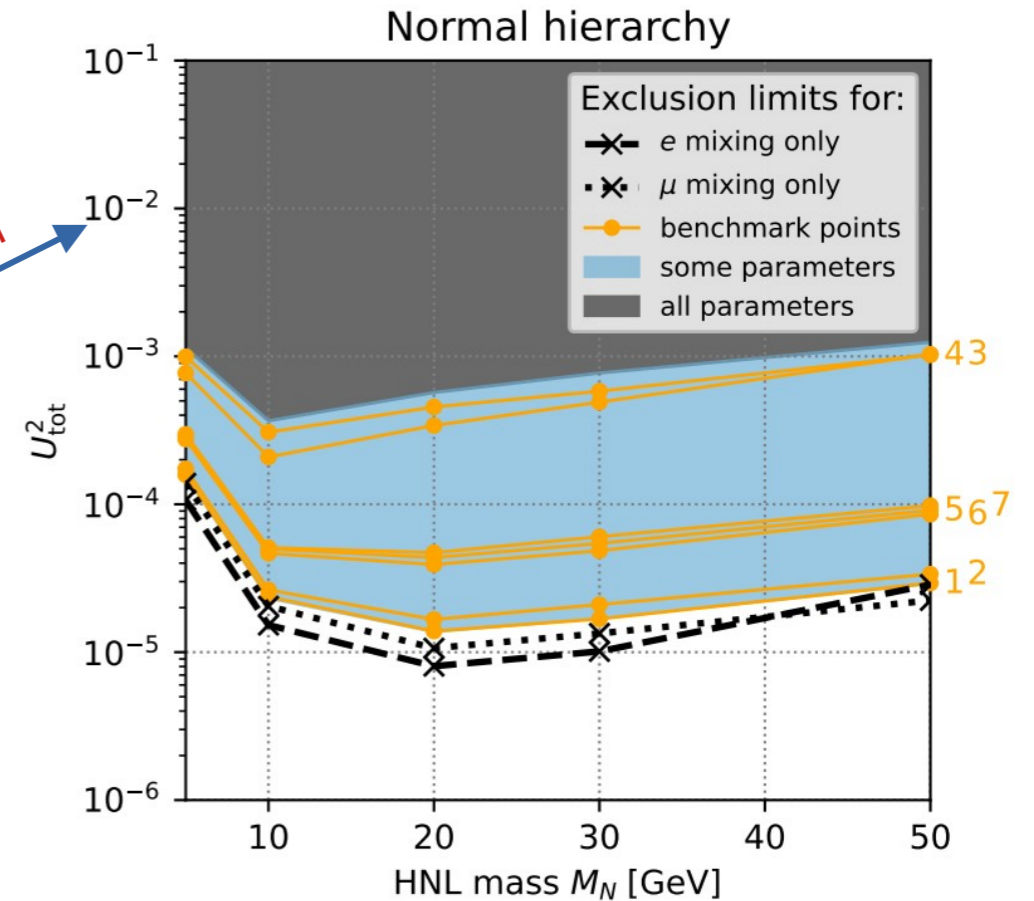
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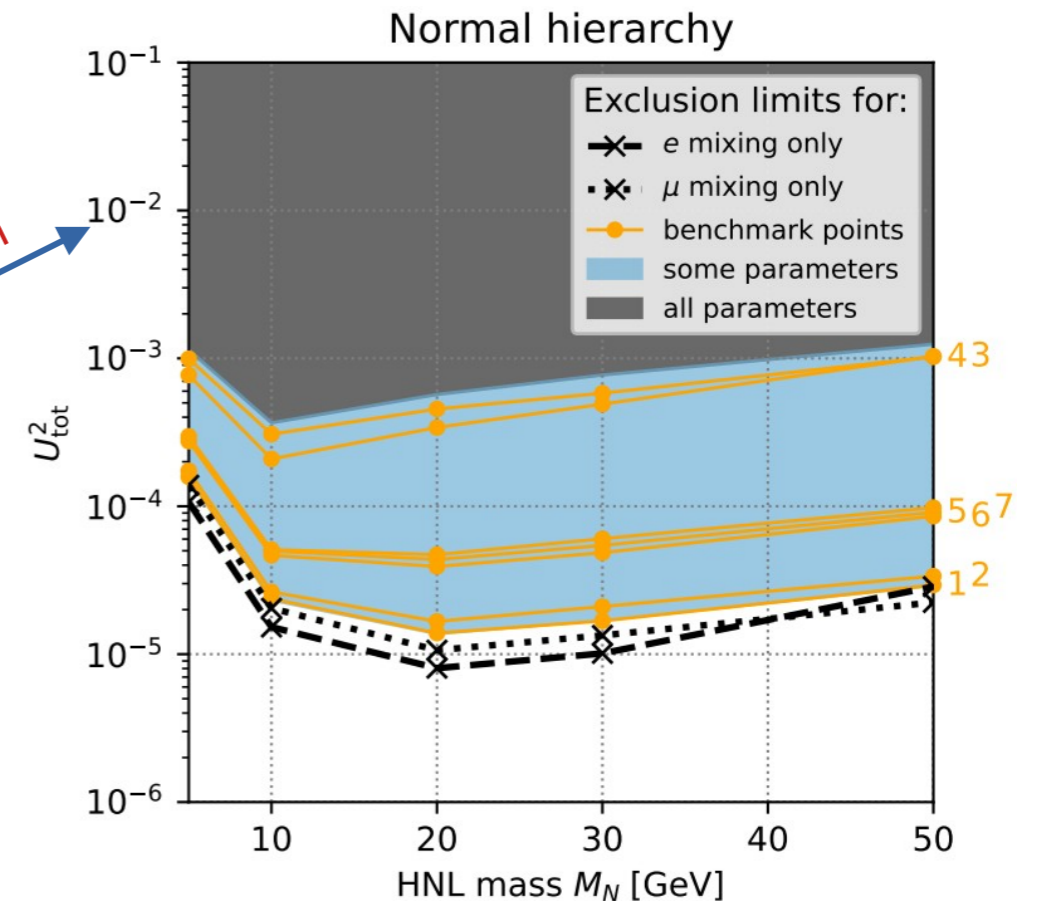
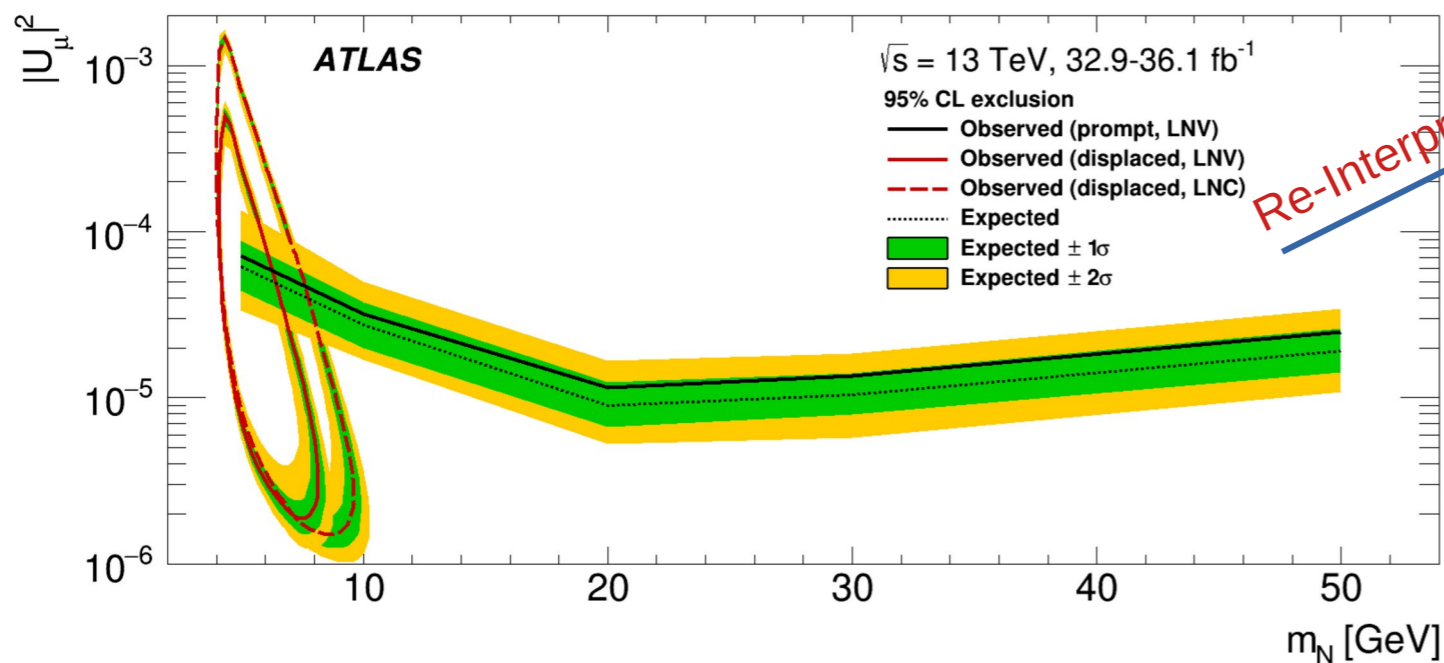


J.-L. Tasteta, O. Ruchayskiy, I. Timiryasov, 2107.12980

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- *Limits can be one order of magnitude weaker!*
- *Re-interpretation motivated new benchmark scenarios for searches*

Why *Re-Interpretation*?

- *Re-Interpretation increases the physics impact of the experimental results*
- *New models can be at the border/edge of the search sensitivity:*
 - *gaps in coverage*
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 - Re-Interpretation is only possible if enough information has been provided by the experimental collaborations.
 - For prompt searches recasting is well-established → use “standard” objects (jets, leptons,...) and observables (H_T , p_T , m_{eff} ,...).
 - But LLP searches typically make use of analysis-specific objects.

Re-Interpretation Material

What has been provided?
(How) can it be used?

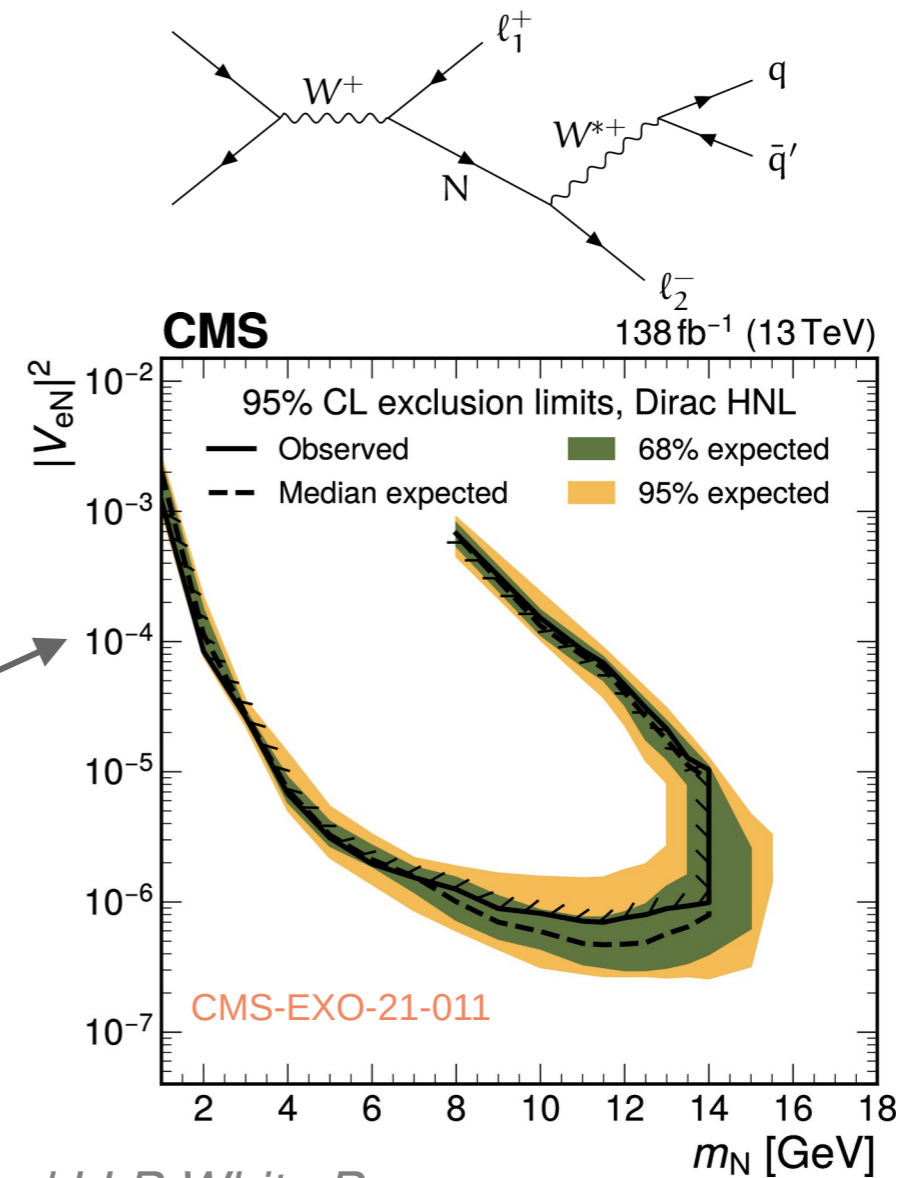
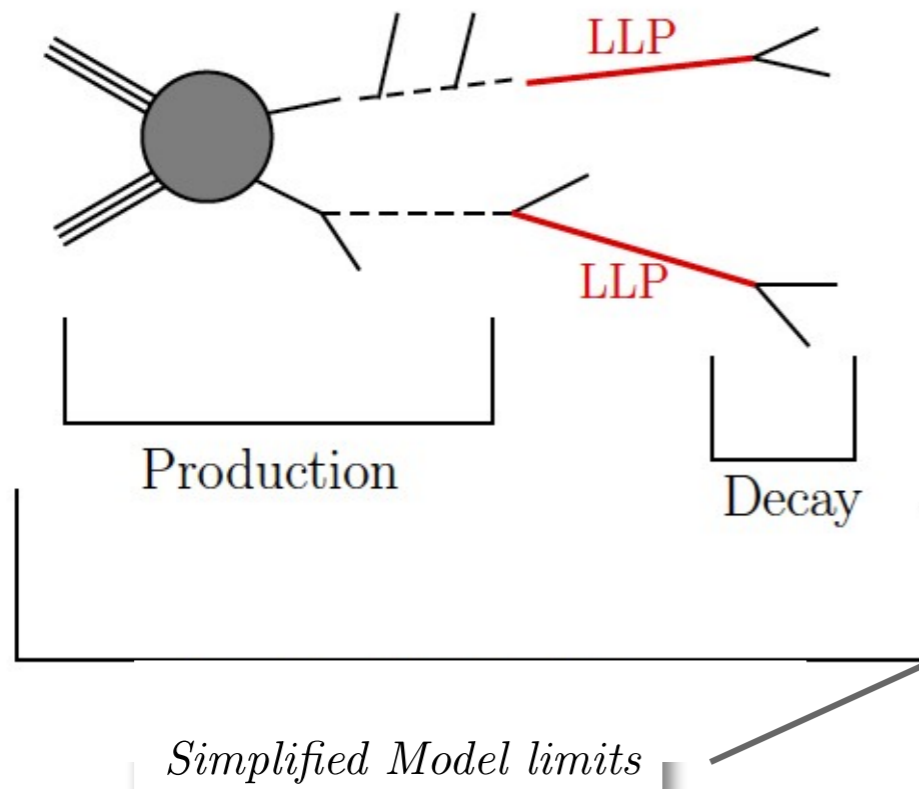
LLP Re-Interpretation

- Auxiliary material for re-interpretation has been provided at various levels of complexity.*

**for a detailed discussion see the Reinterpretation and LLP White Papers (2003.07868 and 1903.04497)*

LLP Re-Interpretation

- Auxiliary material for re-interpretation has been provided at various levels of complexity.*
- Almost every search presents Simplified Model (SMS) limits



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SMS Upper Limits

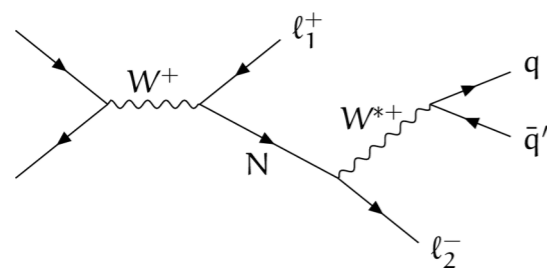
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 - covers all relevant parameter space
 - is provided process by process
 - avoids model assumptions as much as possible!

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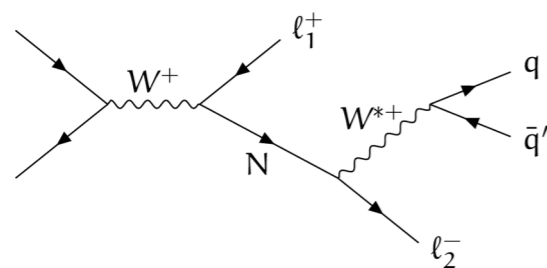
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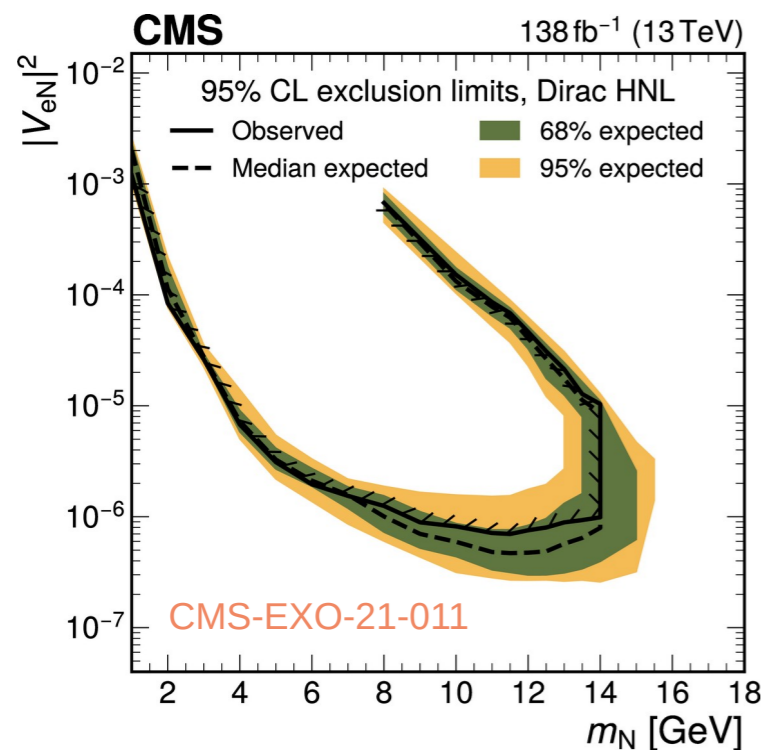
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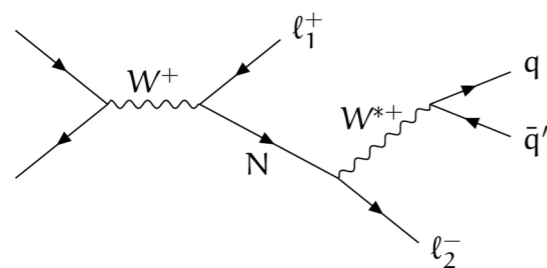
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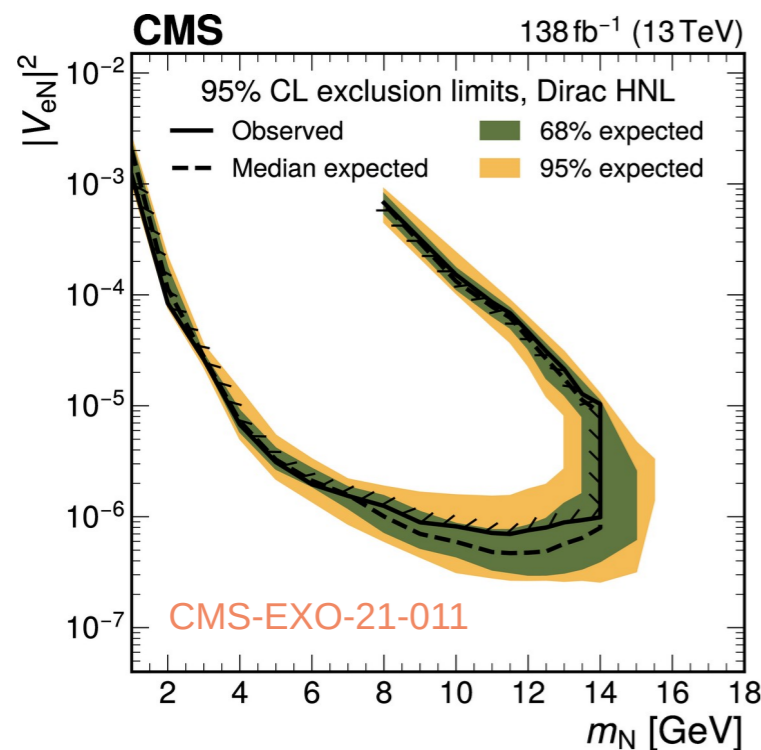
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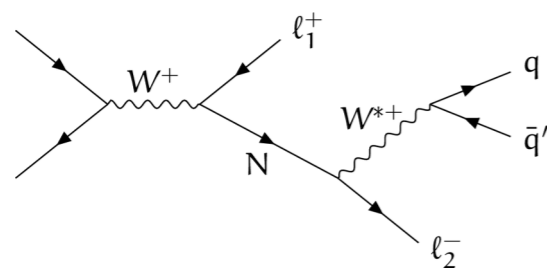
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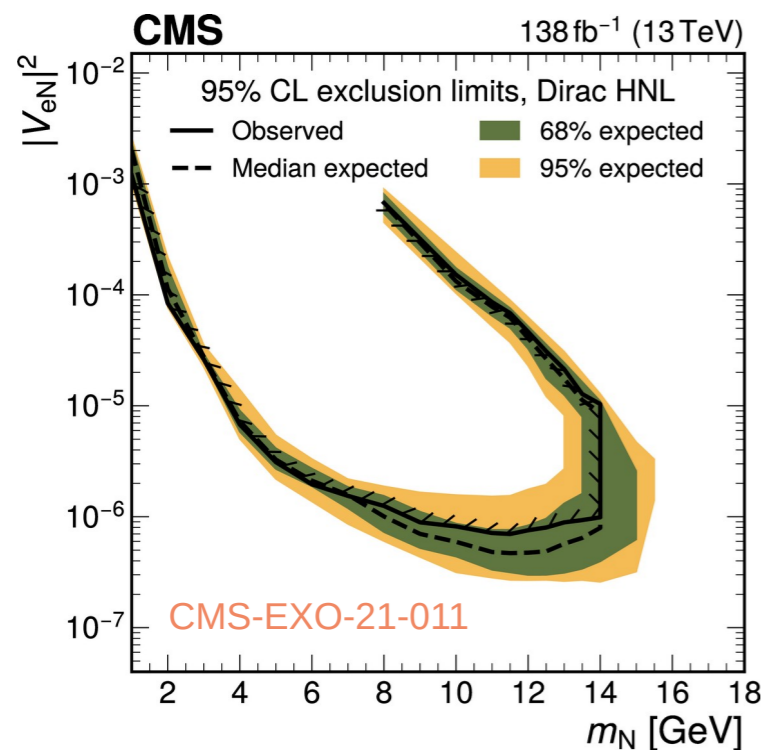
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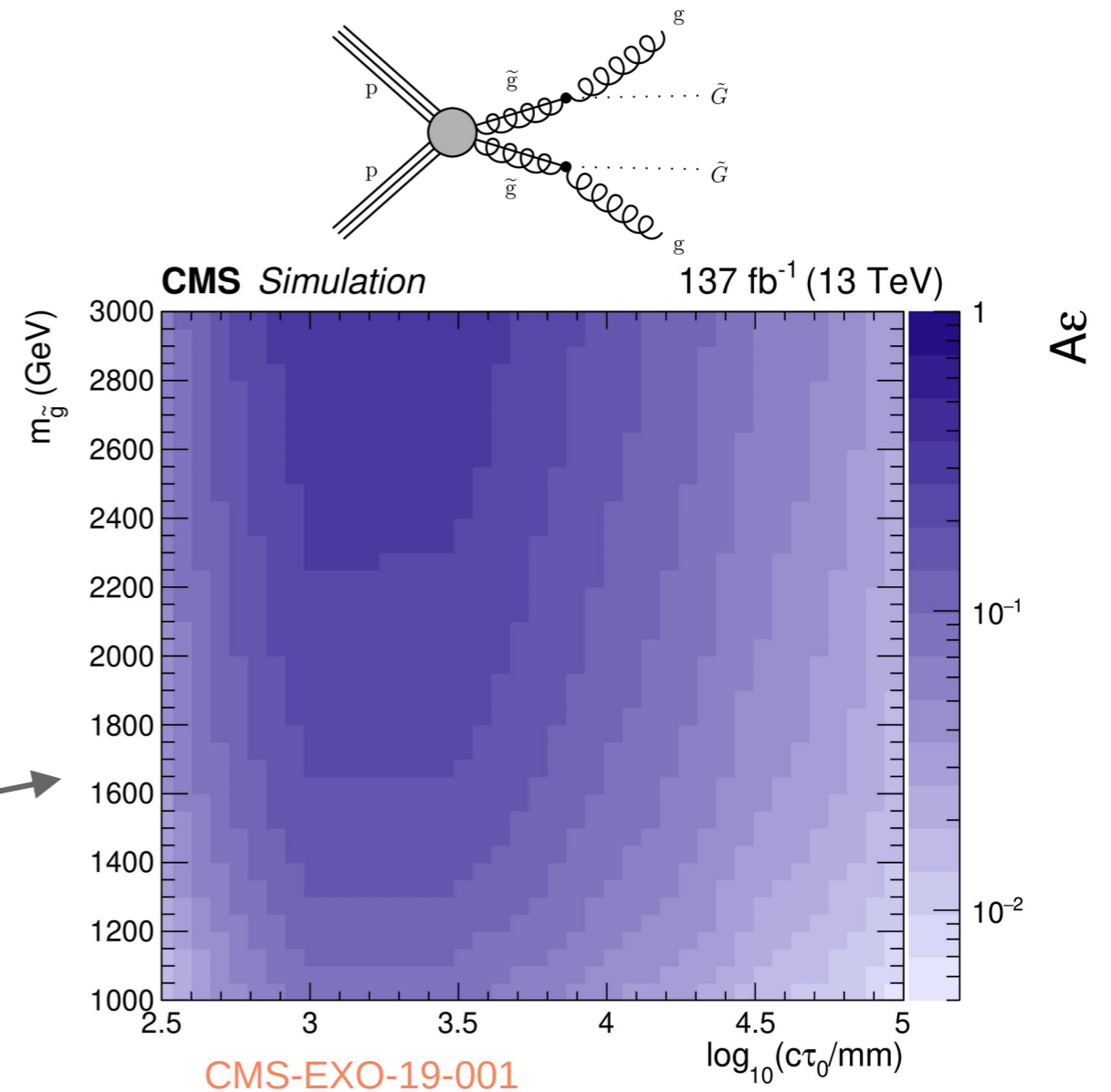
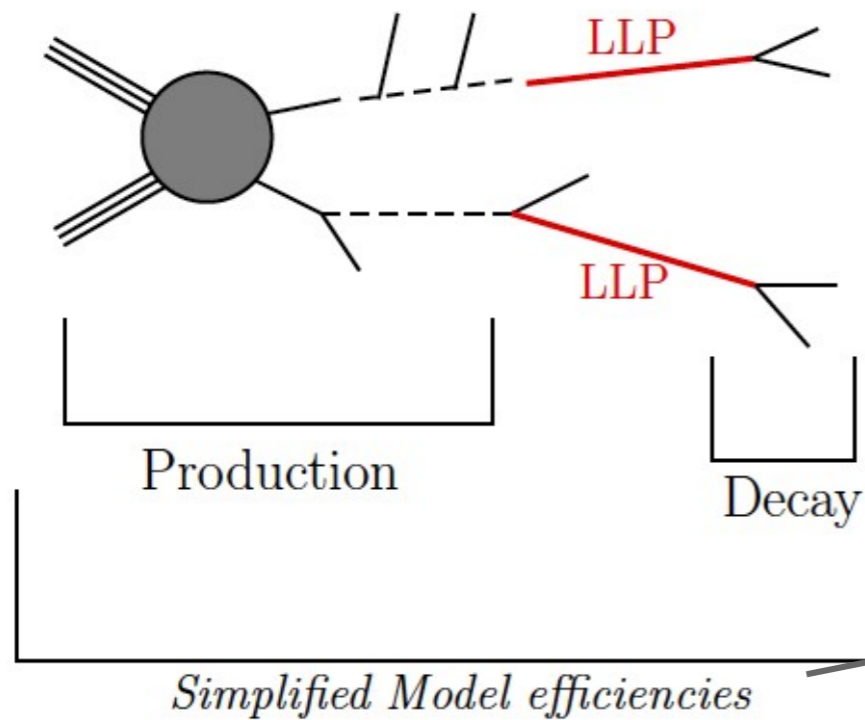
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- ULs \rightarrow “binary statistics” (excluded/not-excluded @ 95%C.L.)
- ULs do not allow for combining signal topologies!
 (If two non-degenerate HNLs \rightarrow can not combine their contributions)

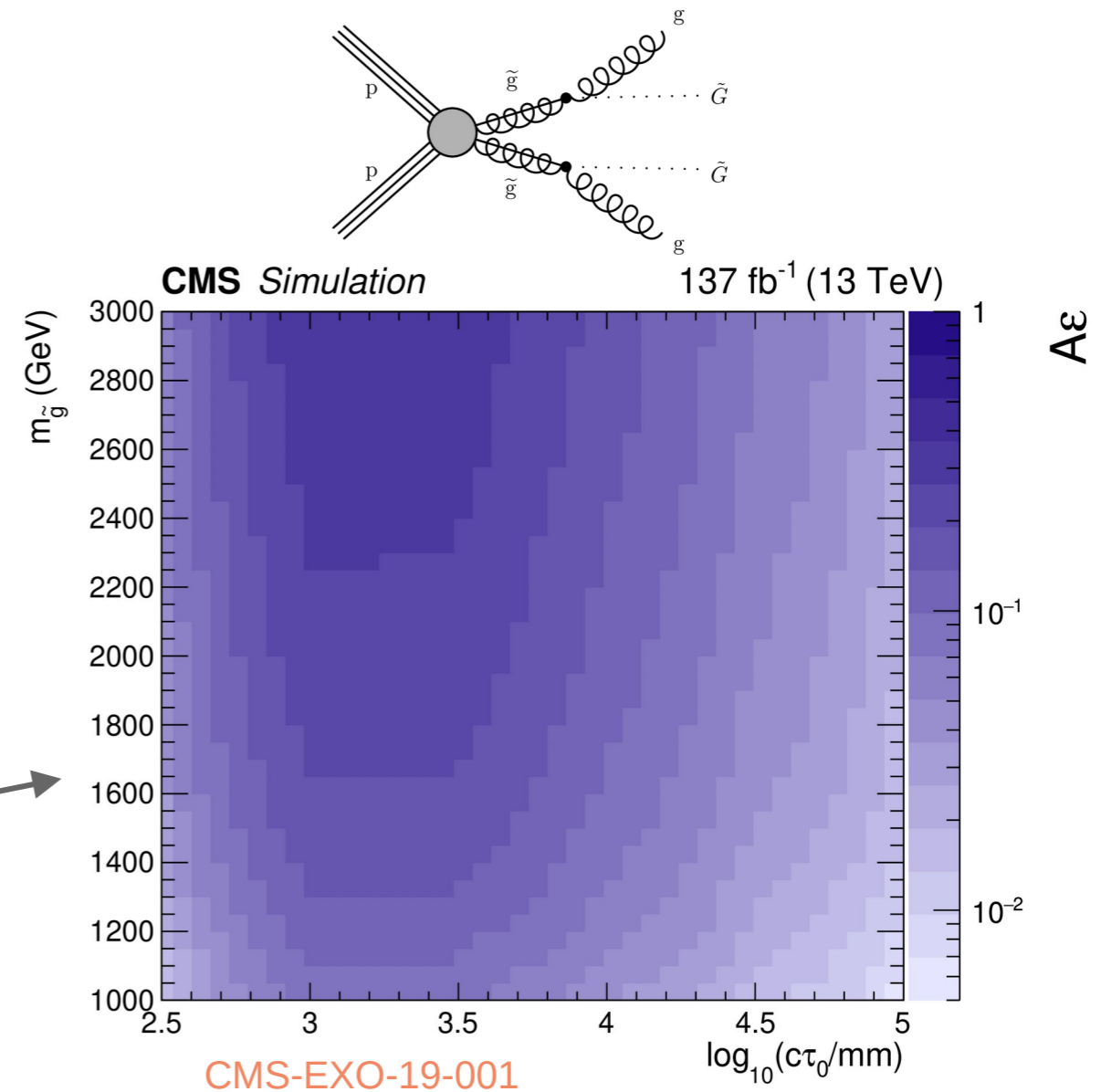
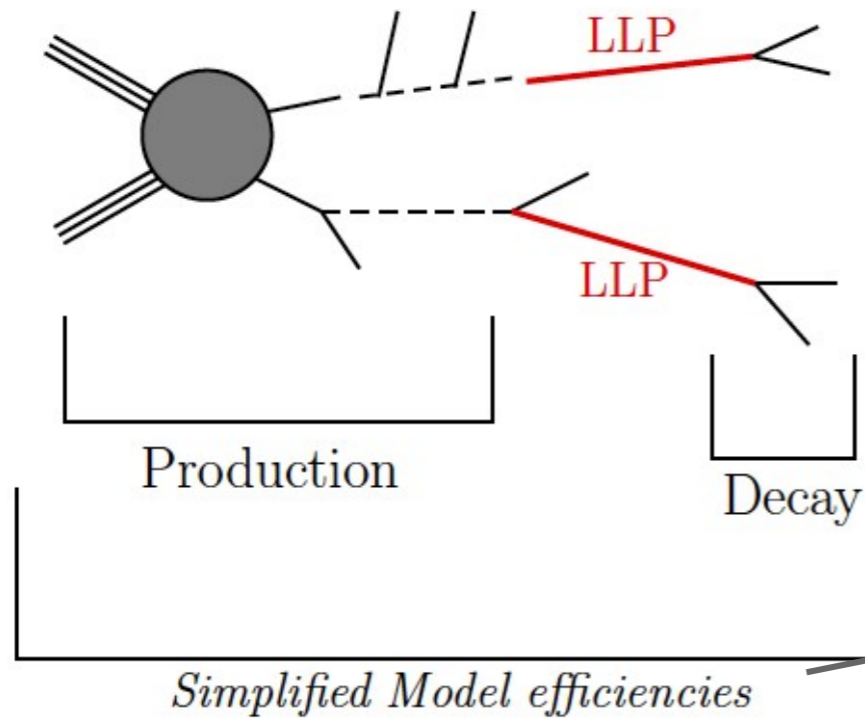
SMS Efficiencies

- Some of these issues can be ameliorated by providing simplified model efficiencies:



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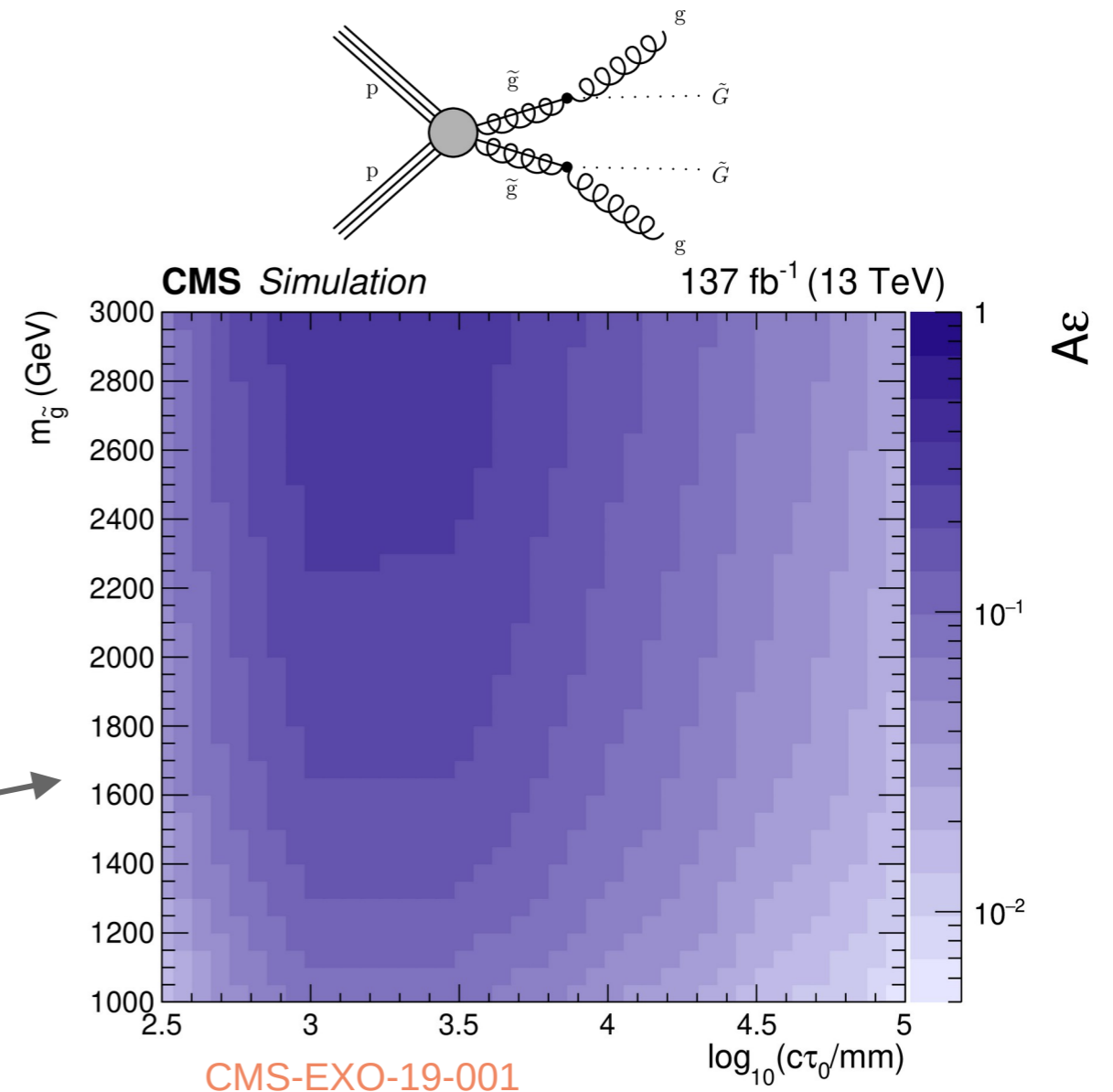
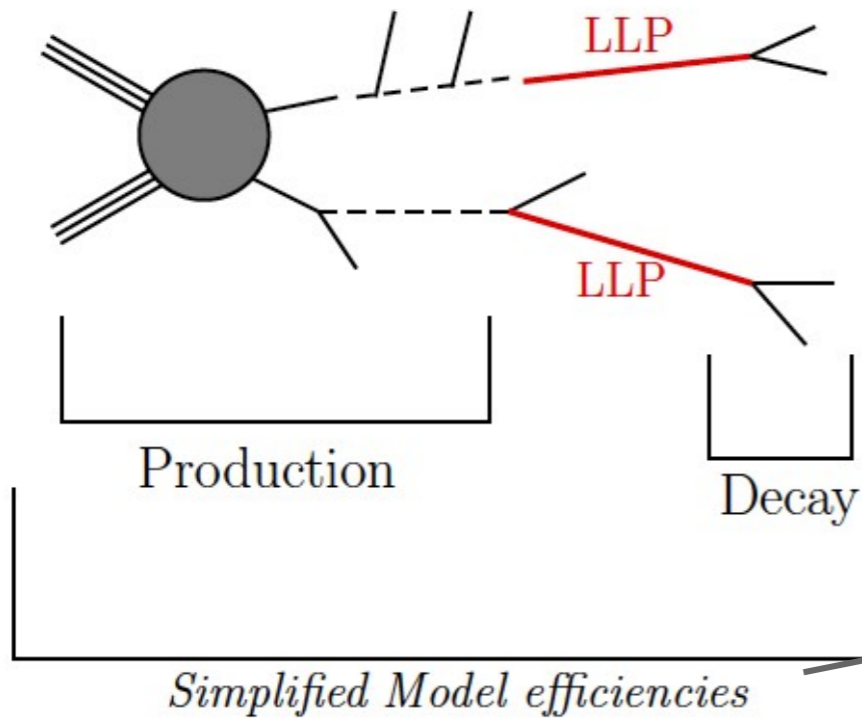
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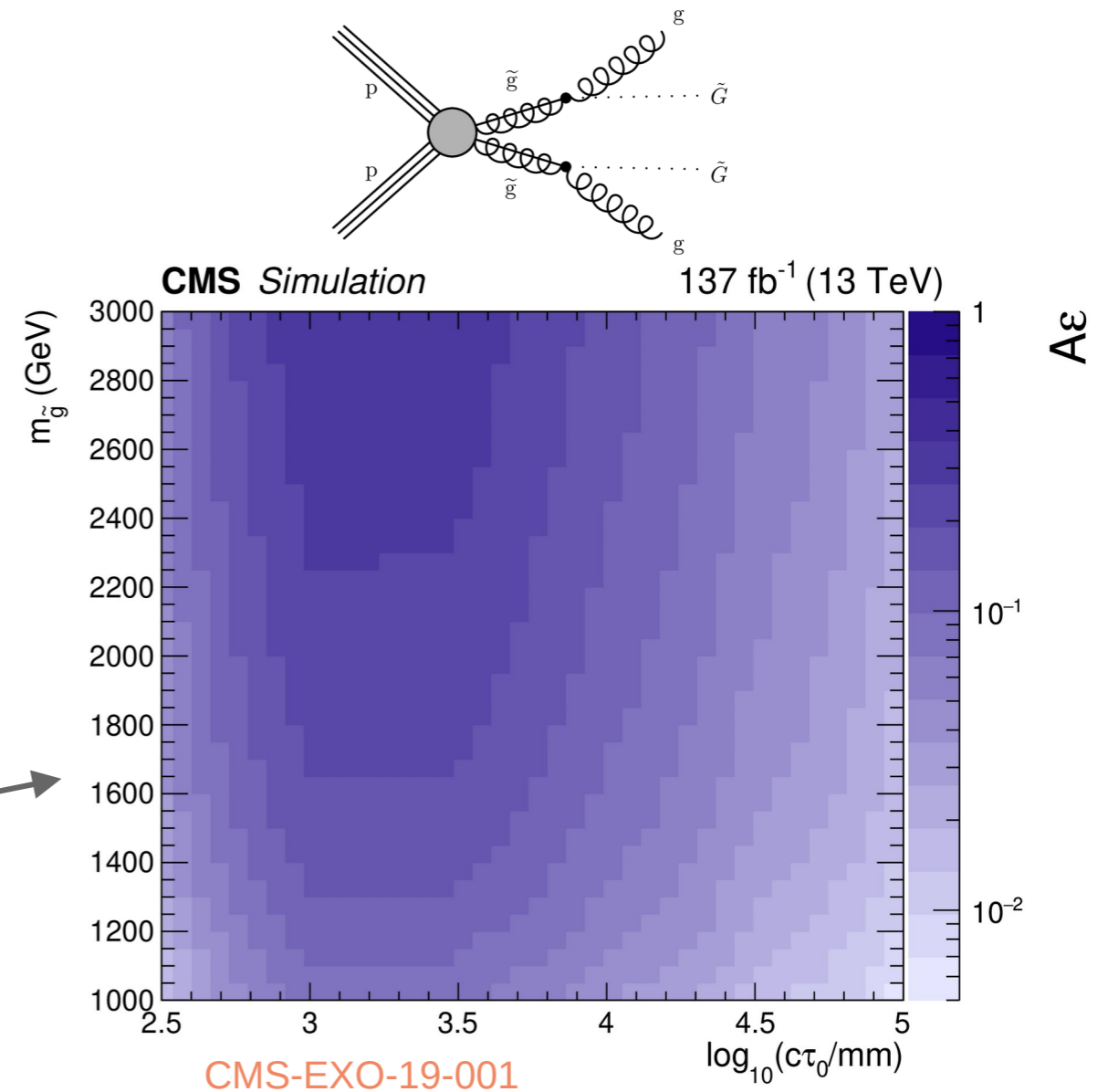
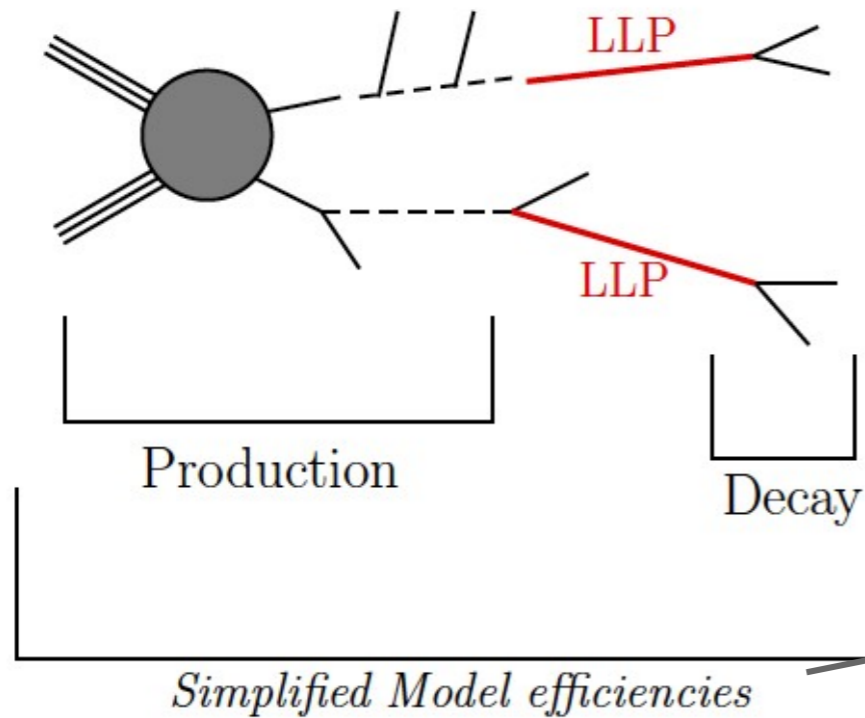
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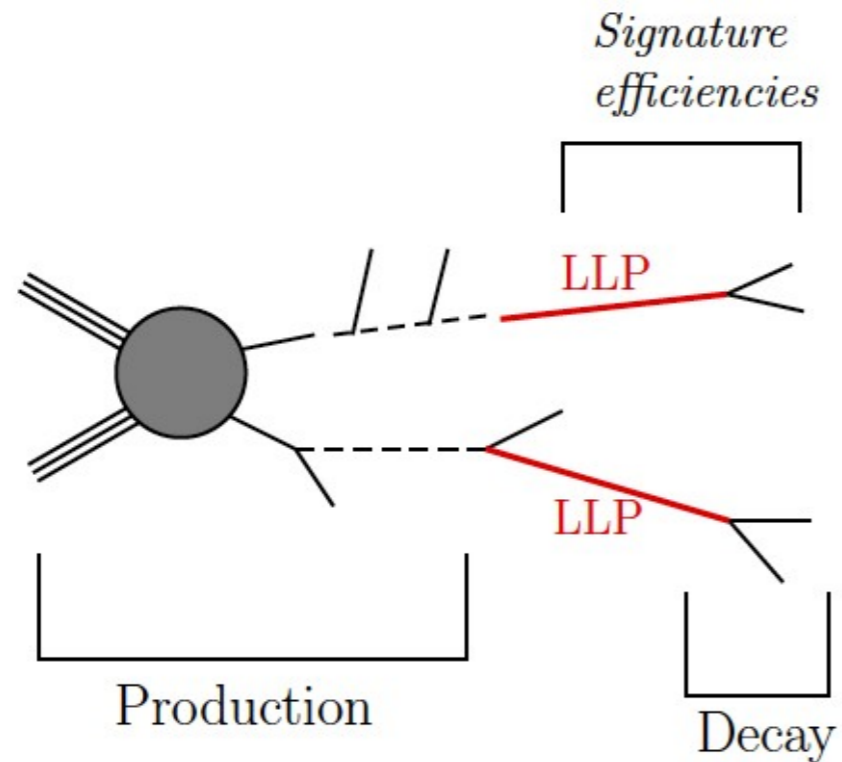
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- Still requires the BSM to match the SMS

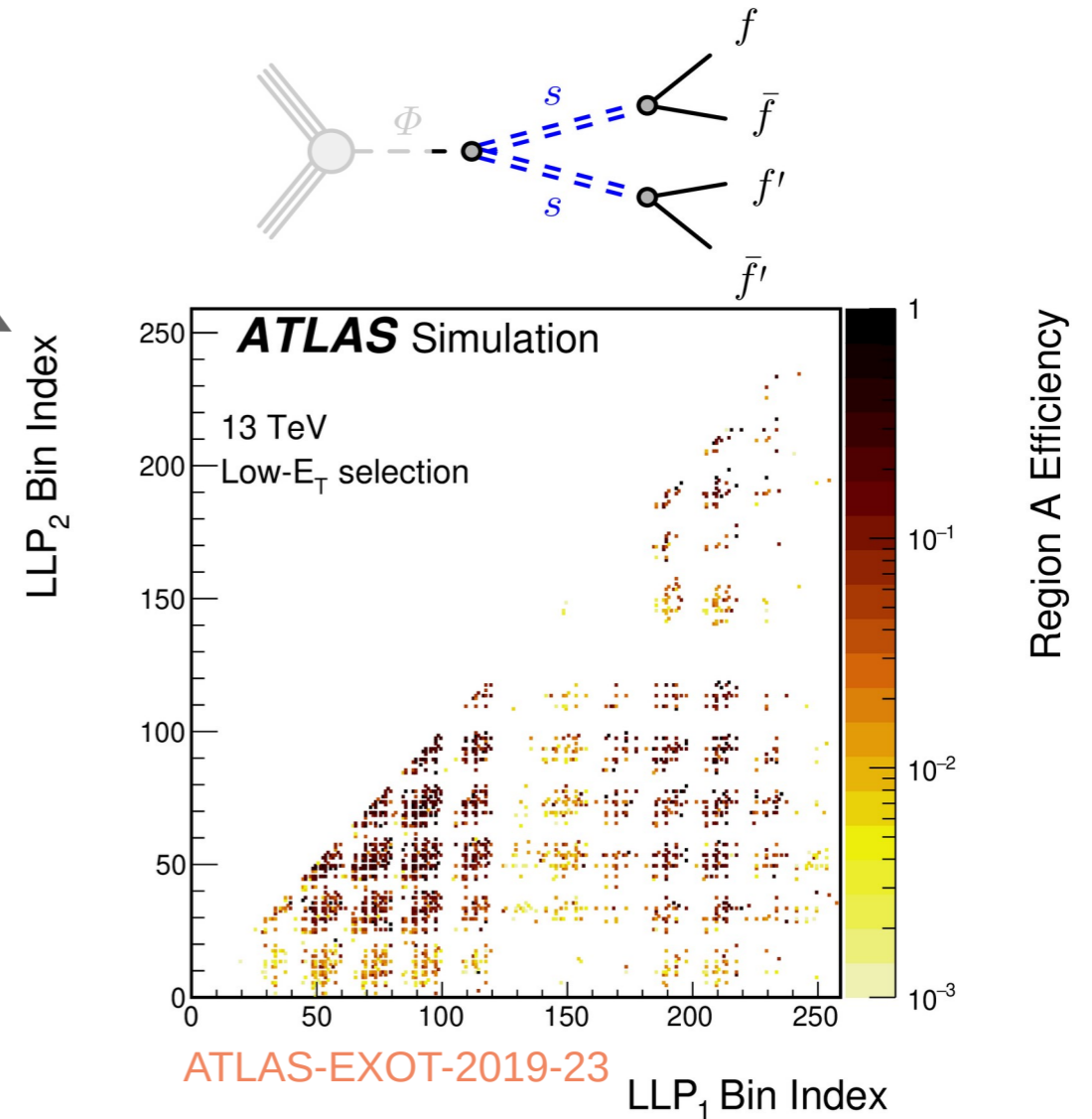
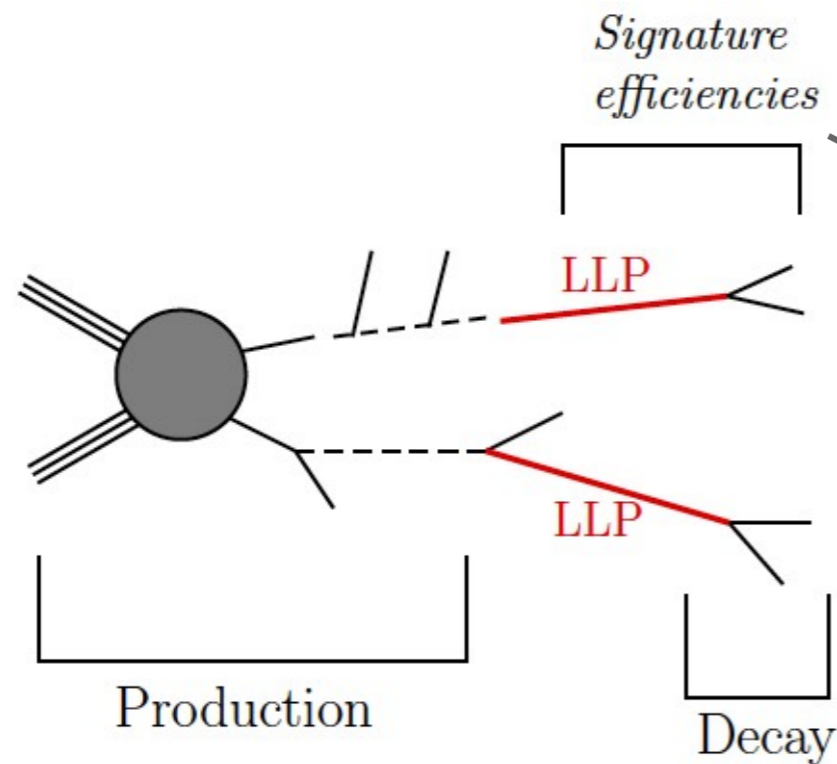
Signature **Efficiencies**

- Model dependence can be greatly reduced with efficiencies for reconstructing/tagging/selecting LLPs:



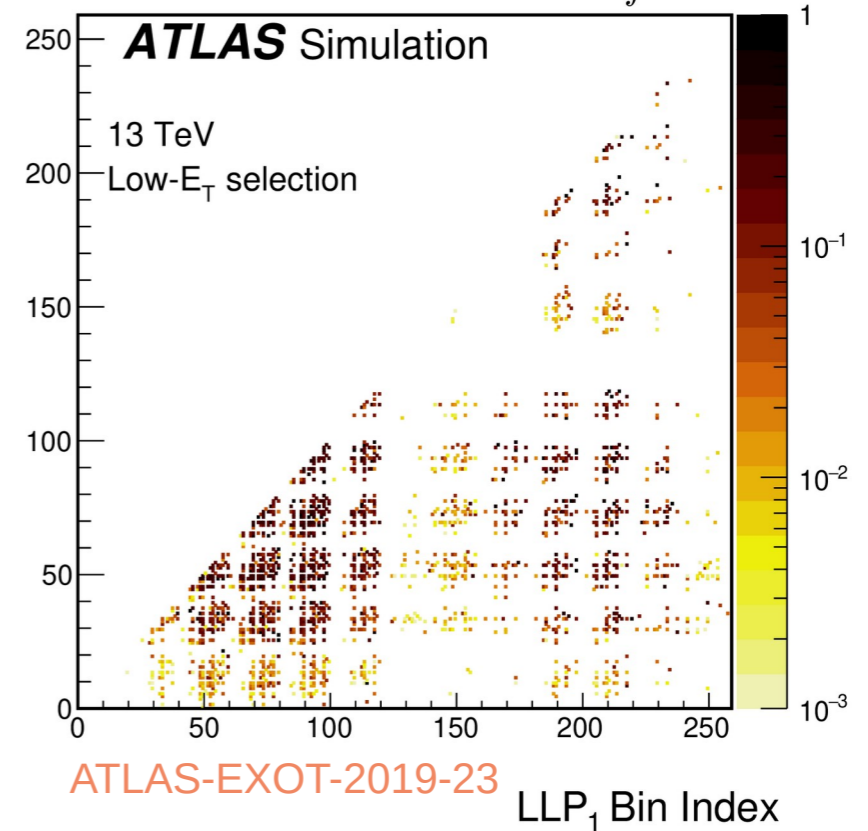
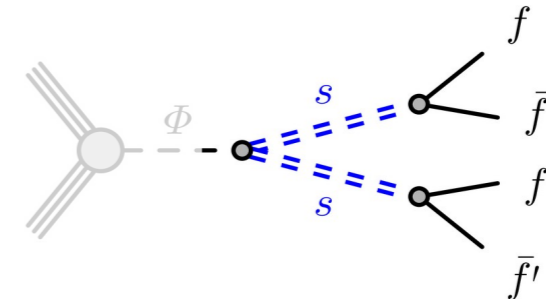
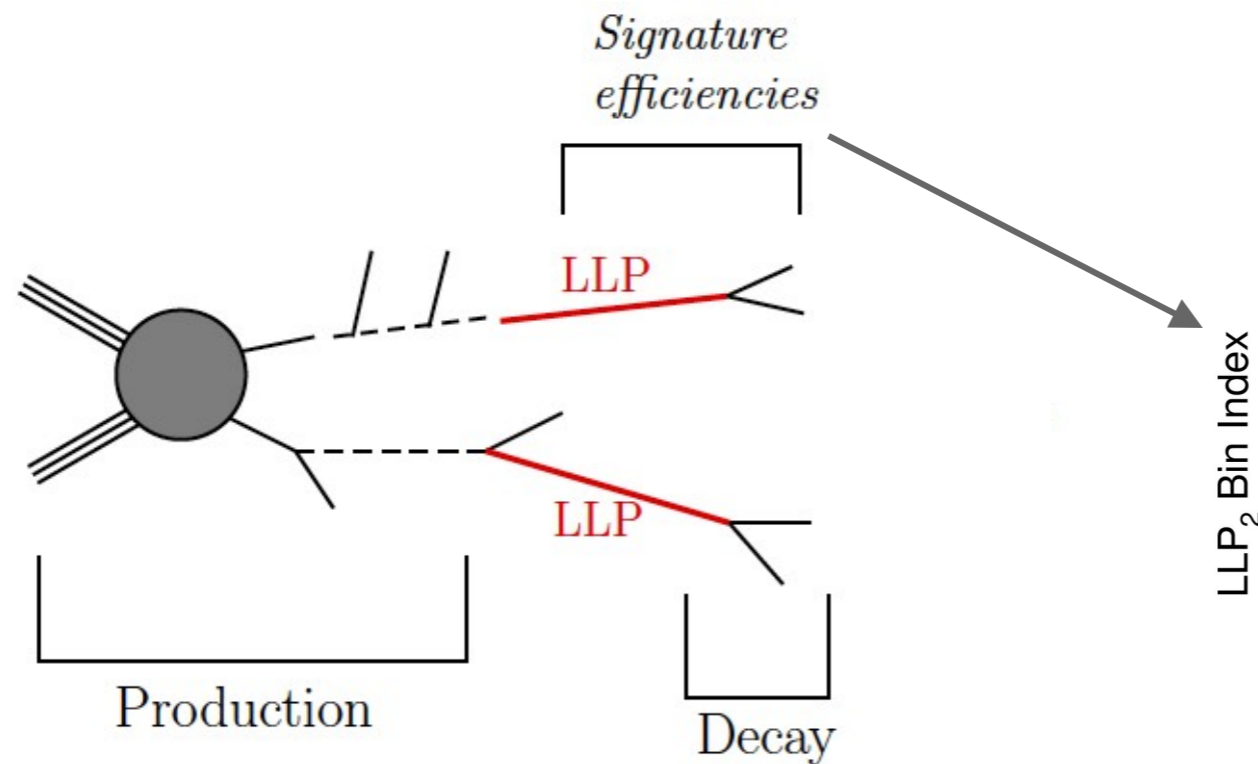
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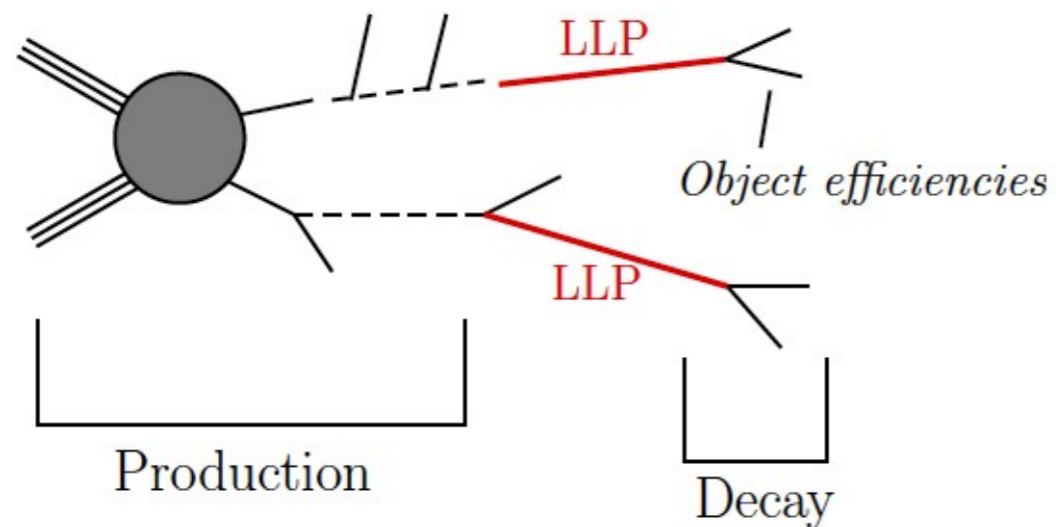


Region A Efficiency

- Limited to a specific LLP decay
- Efficiencies depend on a small set of LLP properties (decay length, p_T , ...)

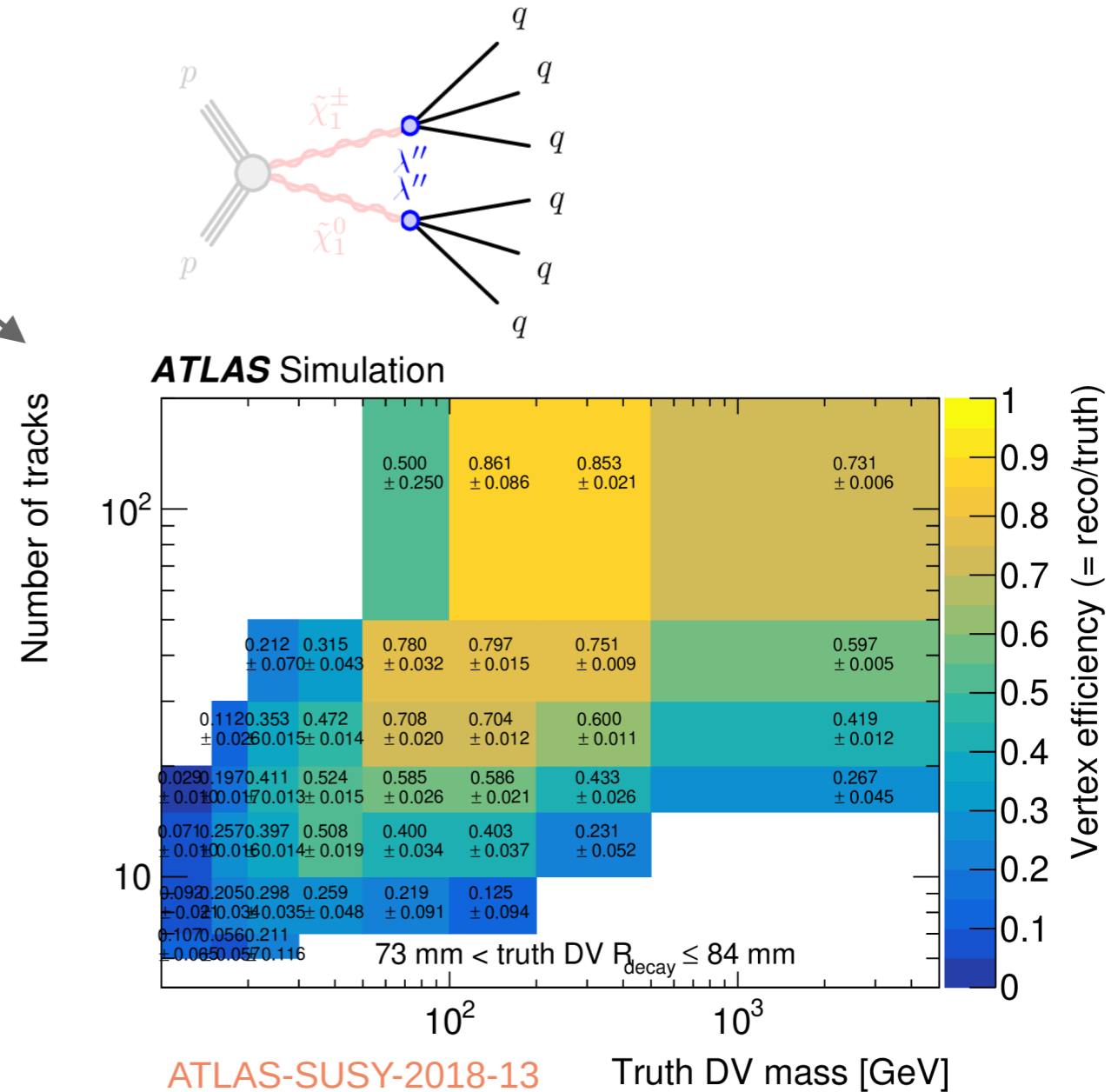
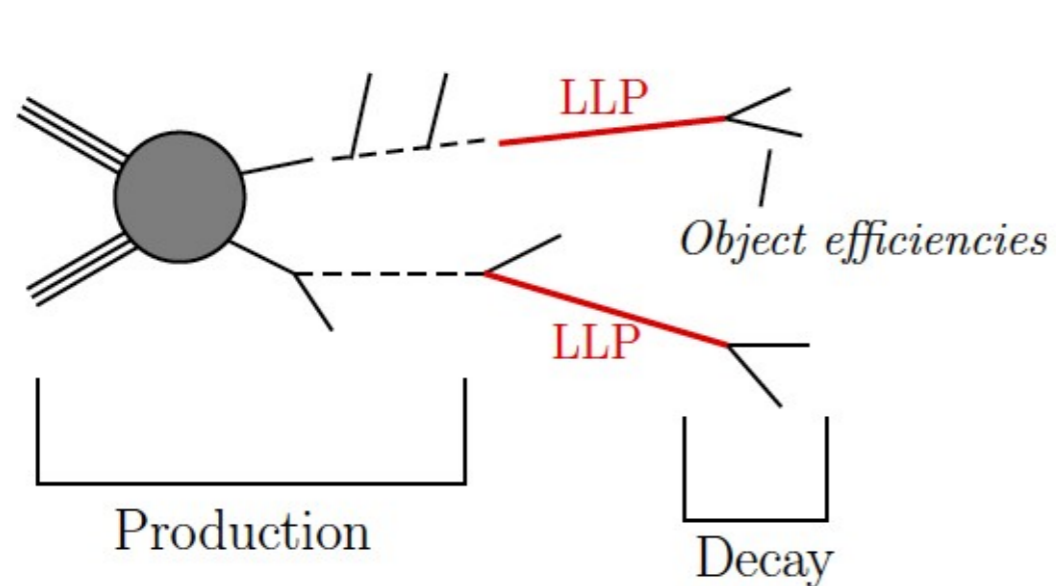
Object Efficiencies

- Finally, **model independence** can be (almost) achieved with **object-level efficiencies**:



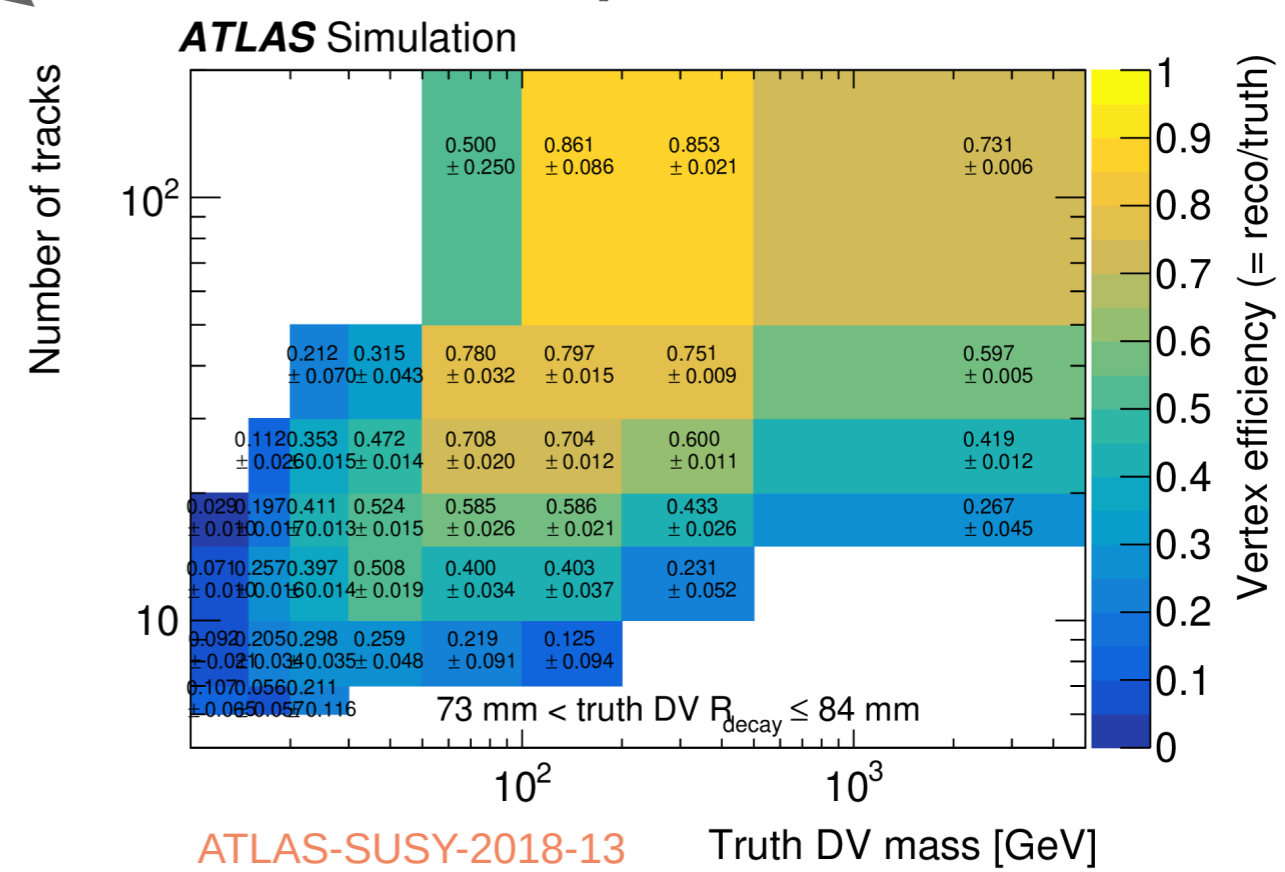
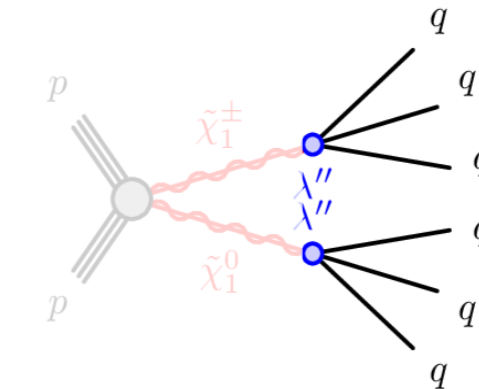
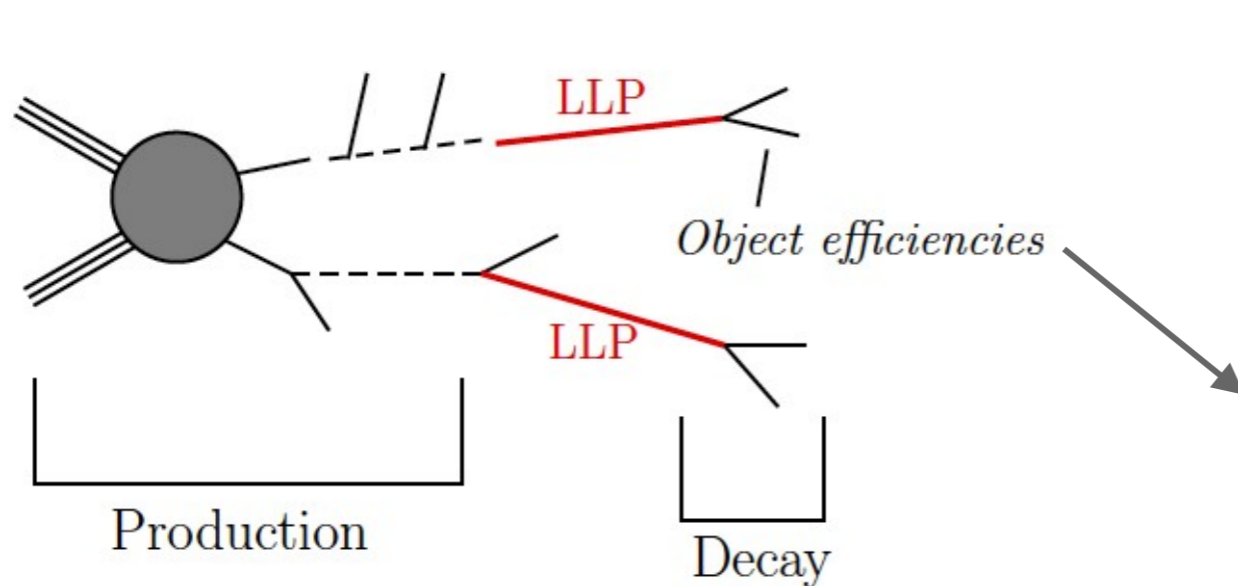
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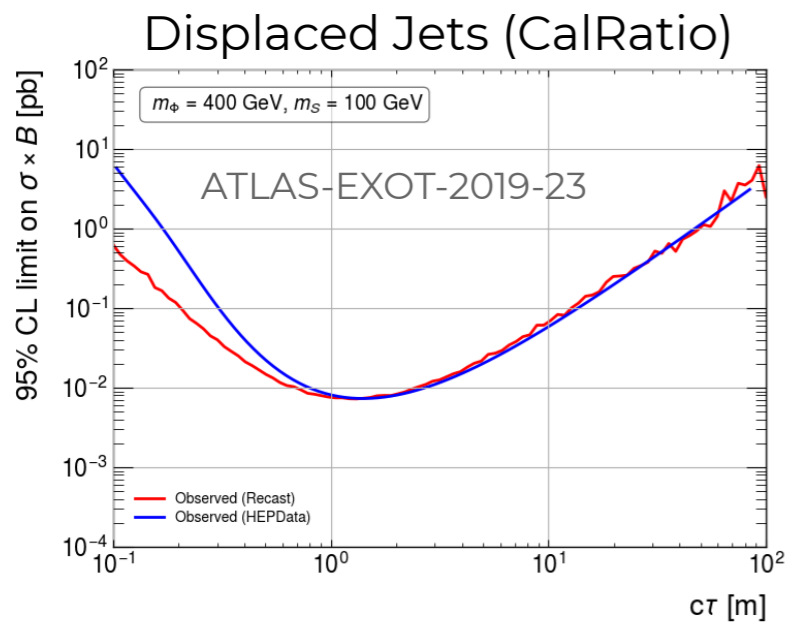
- Can only be used if given for “pheno-level” variables
- Not always easy to parametrize
→ surrogate models?

Validation Material

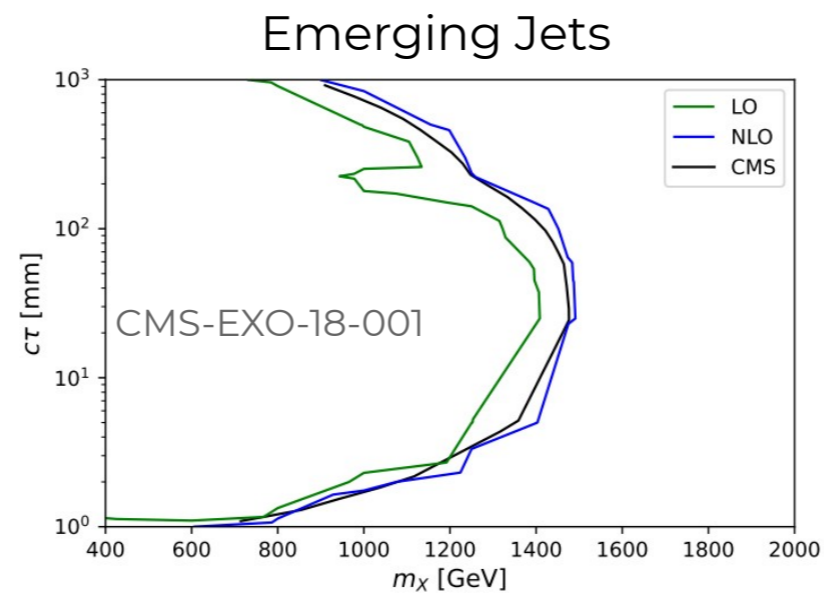
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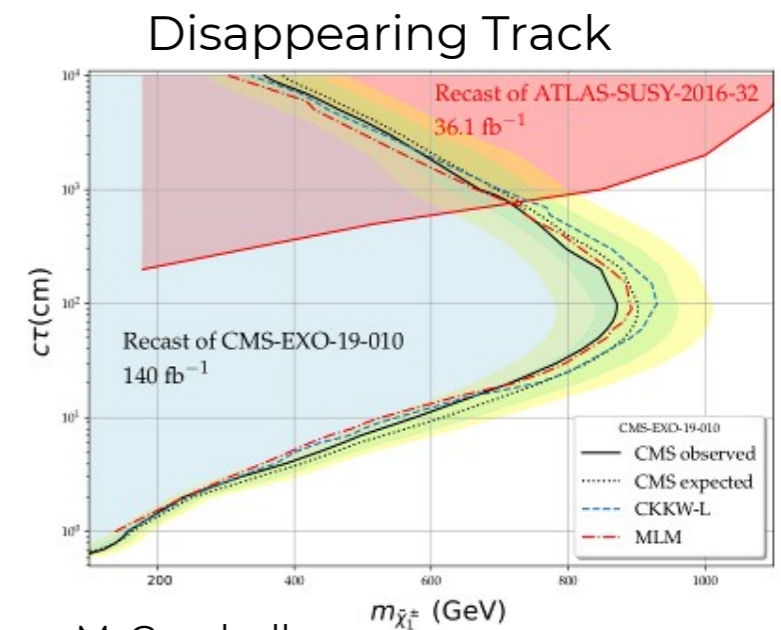
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- Some “successful” recasting examples:



L. Corpe, T. Chehab, A. Goudelis, 2412.13976



J. Carrasco, J. Zurita, 2307.04847

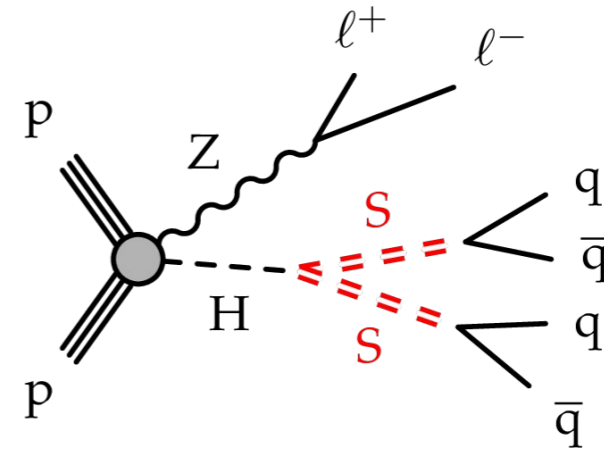


M. Goodsell

Re-Interpretation “Failures”

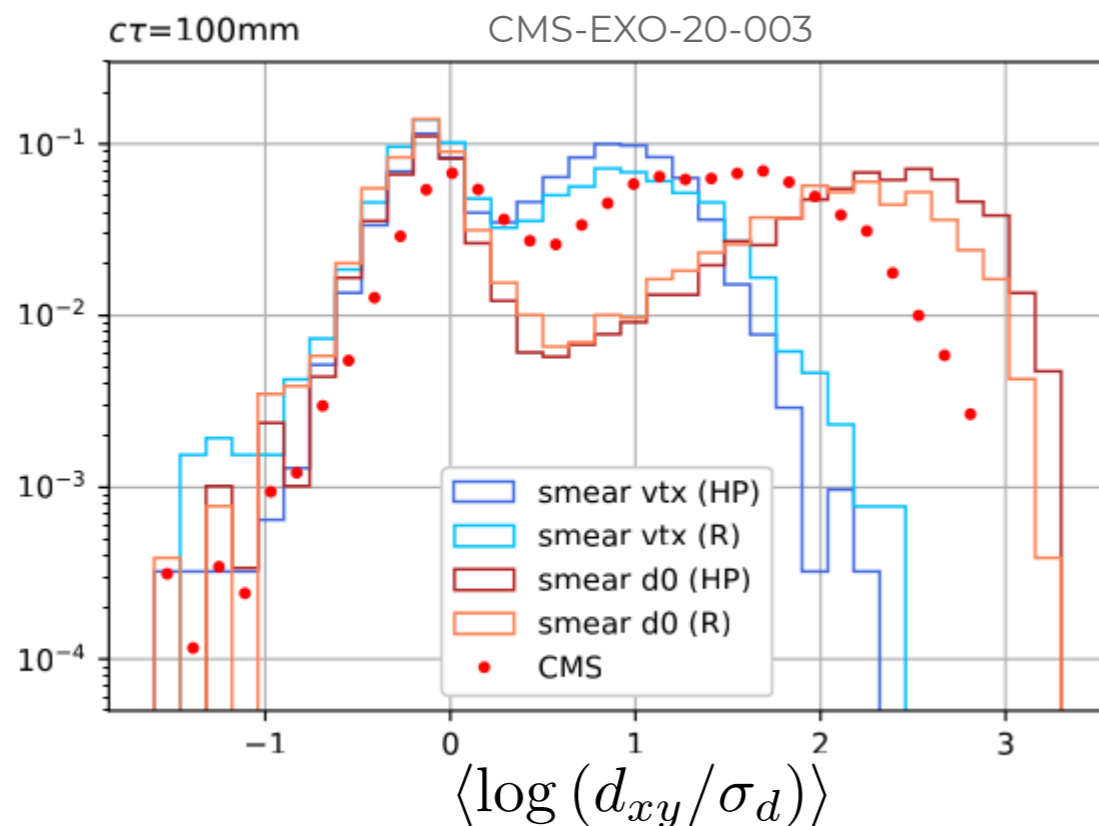
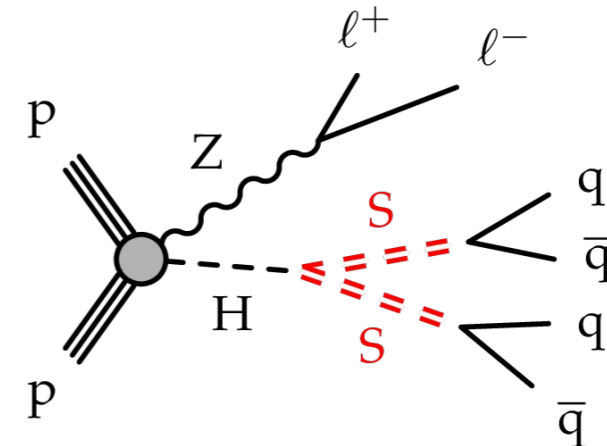
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 - Some variables are too hard to reproduce! (IP^{2D})
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J. Carrasco, J. Zurita

- Potential impact on $H \rightarrow$ Dark Sector
- Required information was not kept by the analysis
- Project got stuck due to the lack of re-interpretation material!

Re-Interpretation “Failures”

- **Example:** ATLAS-SUSY-2018-19 (Disappearing Track)
 - No HepData entry
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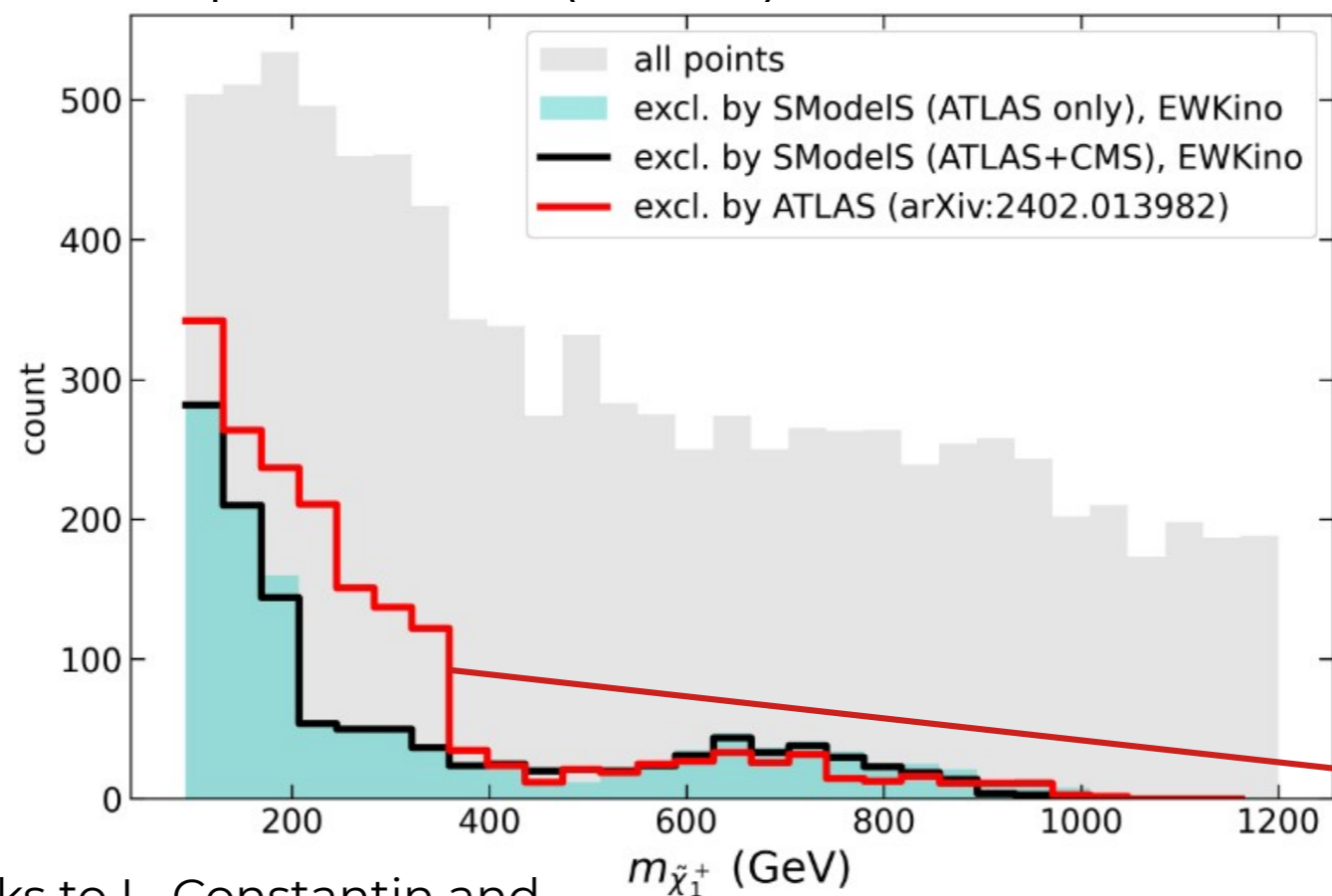
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Thanks to L. Constantin and
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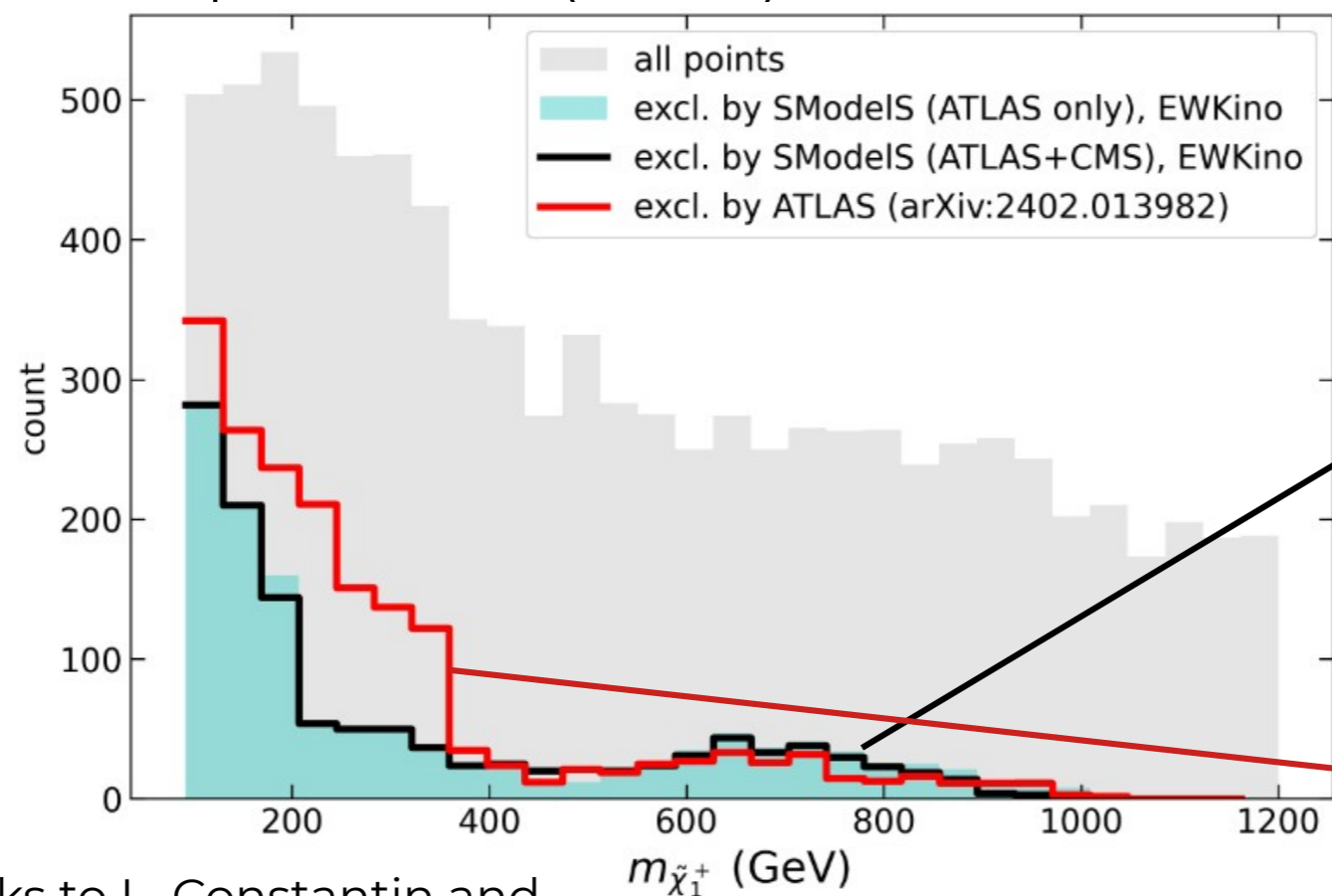
ATLAS pMSSM results
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ATLAS-EXOT-2020-15

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Re-Interpretation

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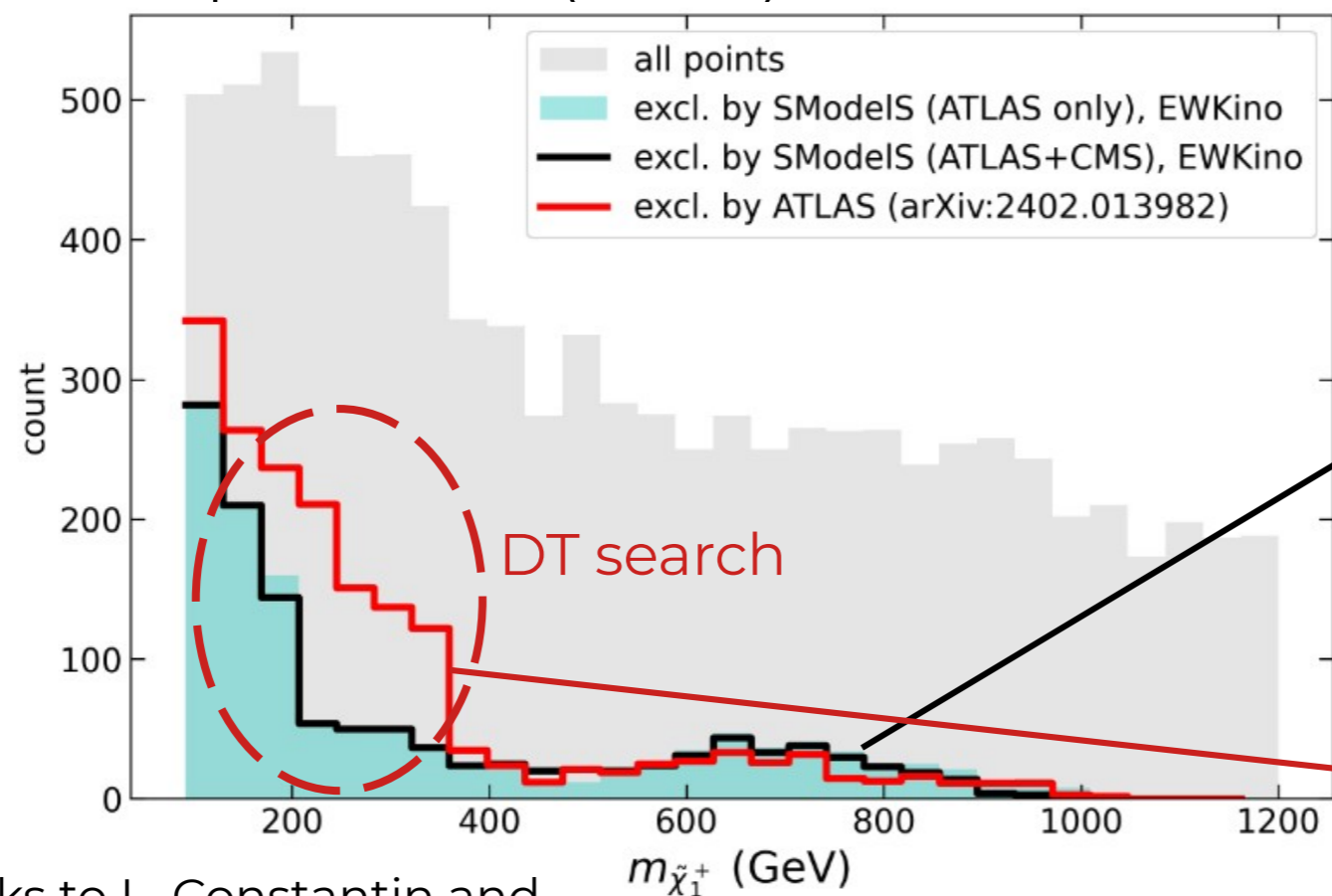
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Physics Impact

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with the material provided?

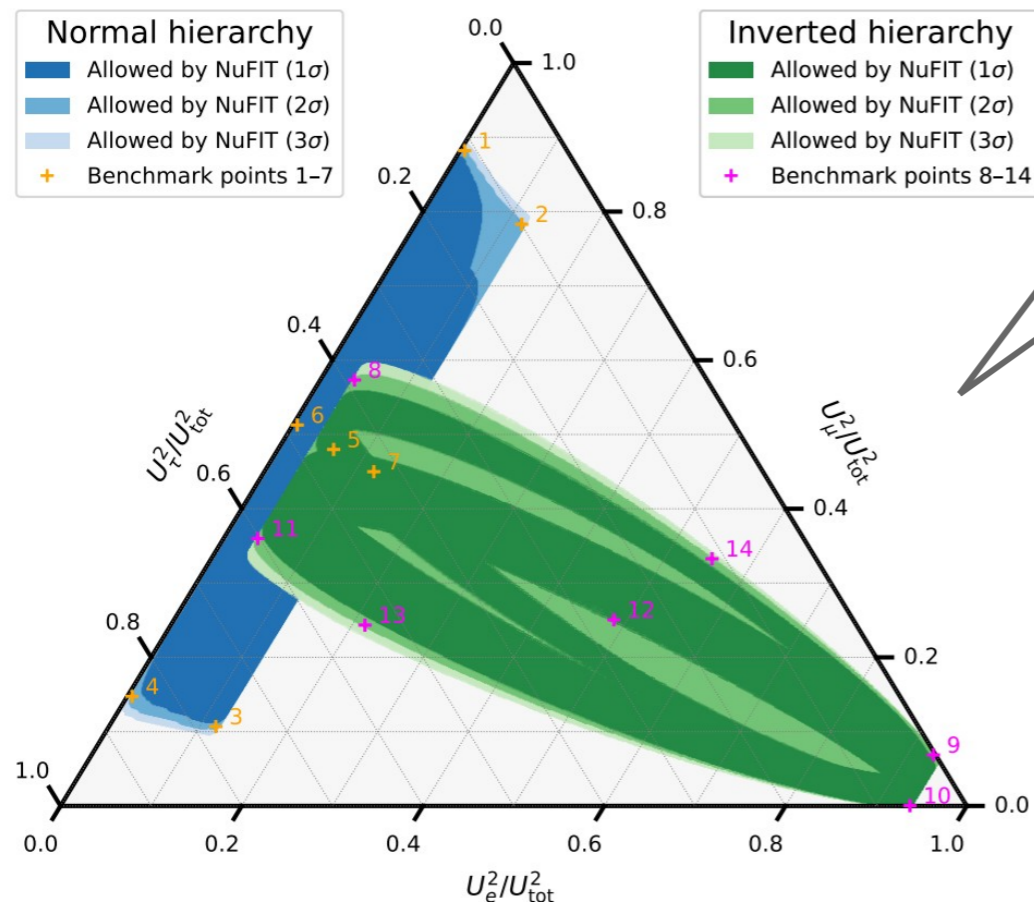
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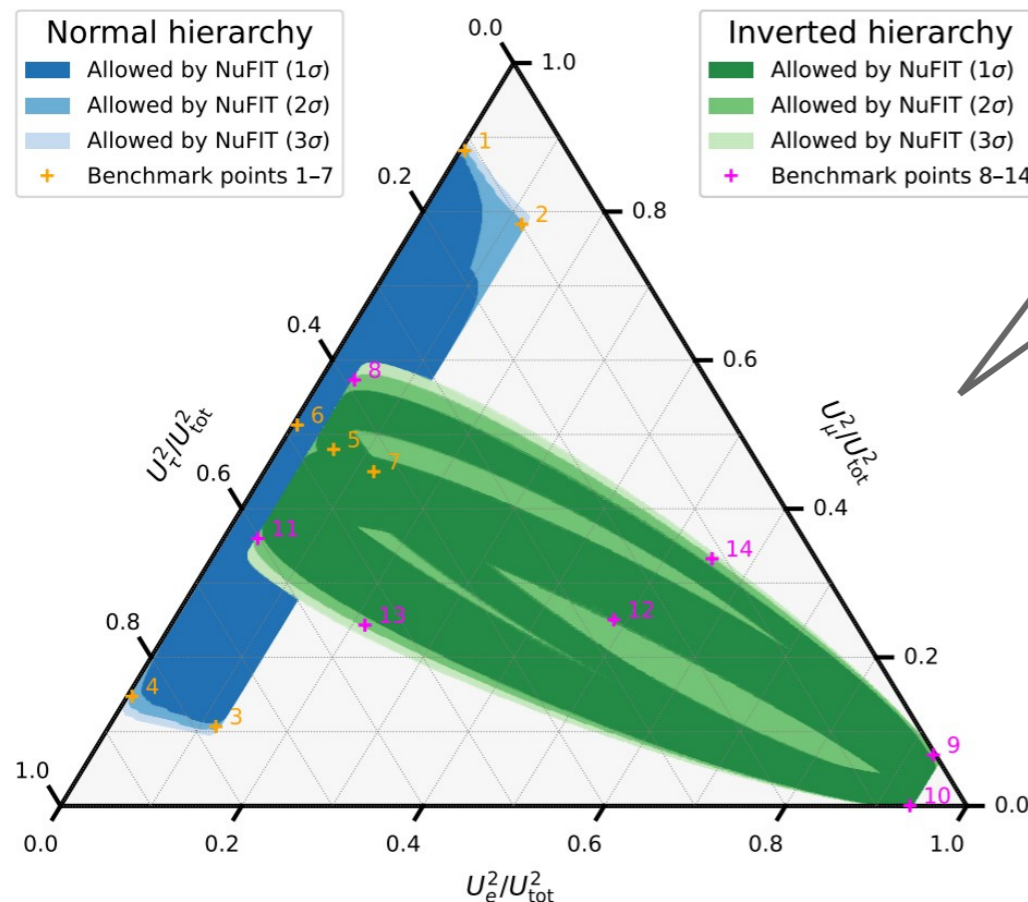


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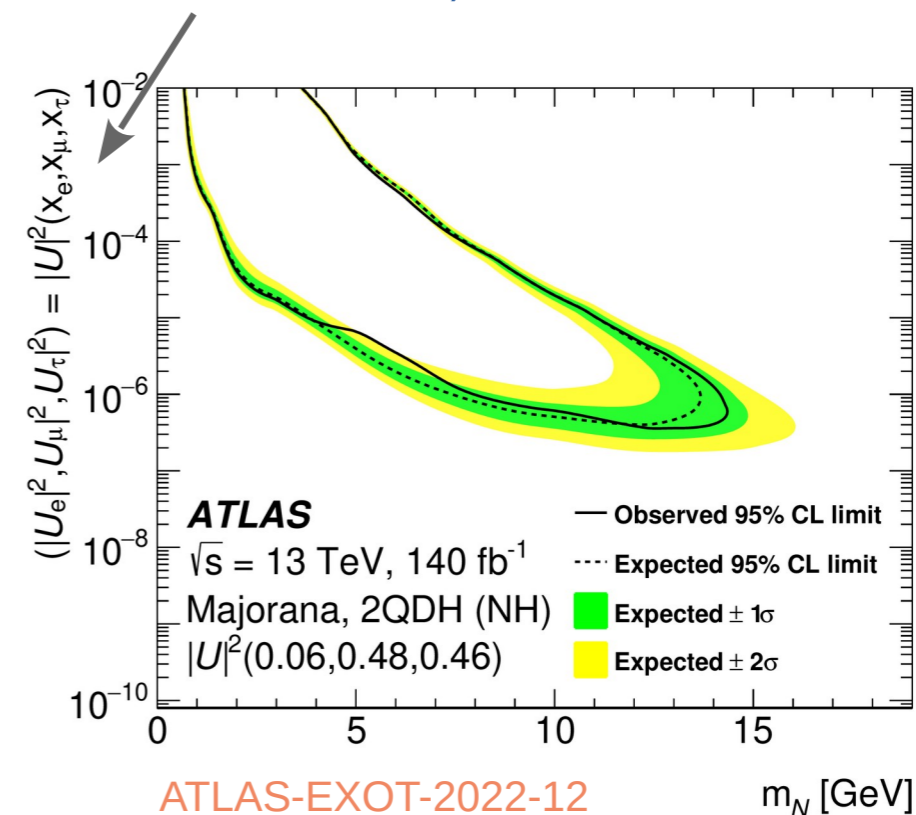
- **Example: HNLs**



J.-L. Tasteta, O. Ruchayskiy, I. Timiryasov, 2107.12980

Displaced taus can be dominant!
(new signature)

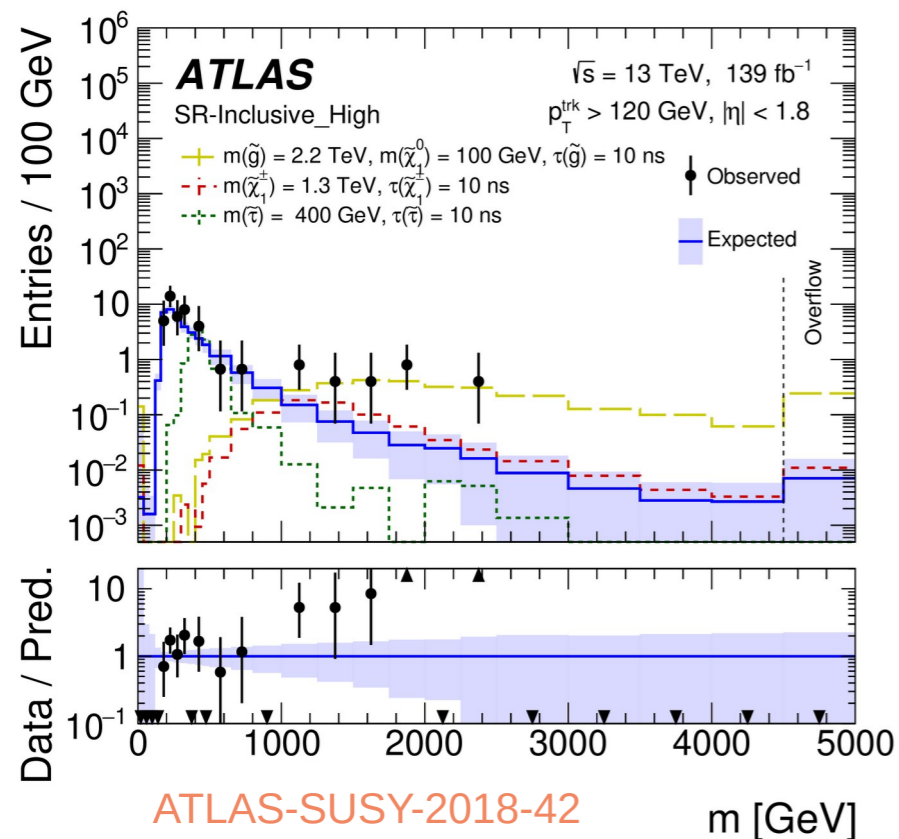
Combination of lepton flavors
(new benchmarks)



ATLAS-EXOT-2022-12

Physics Impact: Examples

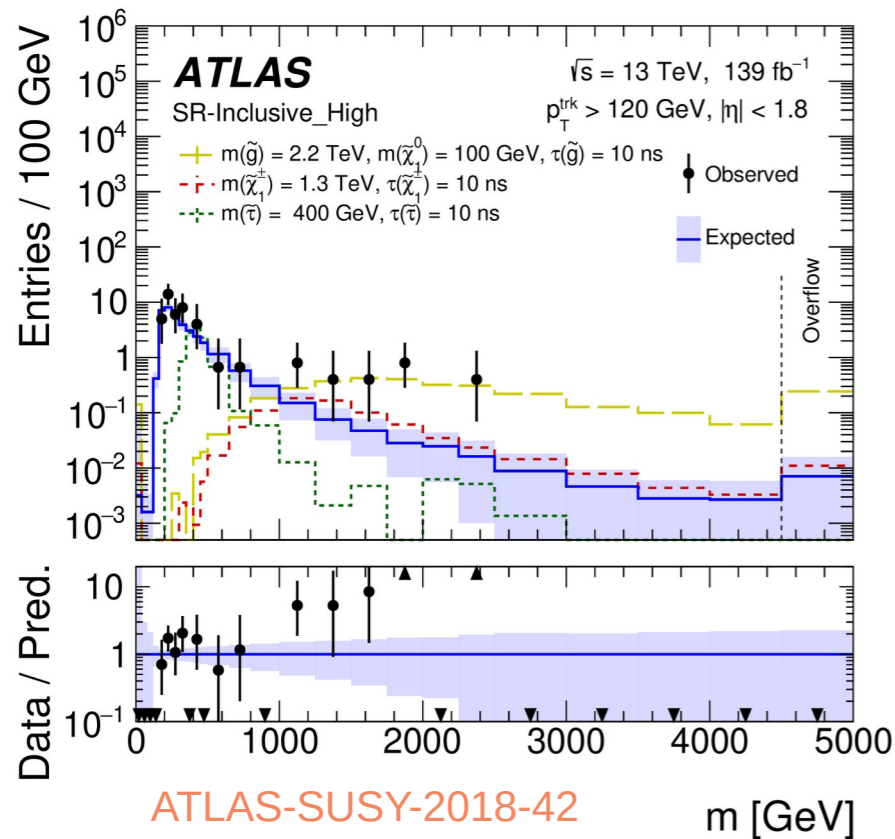
- **Example:** Heavy Stable Charged Particles:



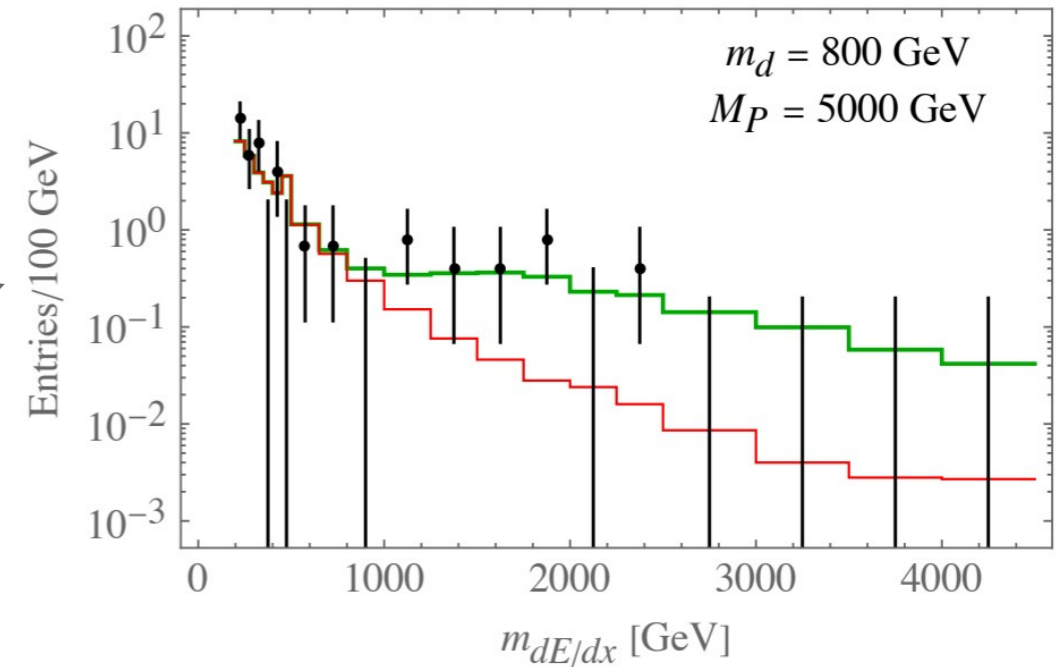
ATLAS: excess is not consistent with slow moving $Q=1$ tracks

Physics Impact: Examples

- **Example:** Heavy Stable Charged Particles:



Re-Interpretation →



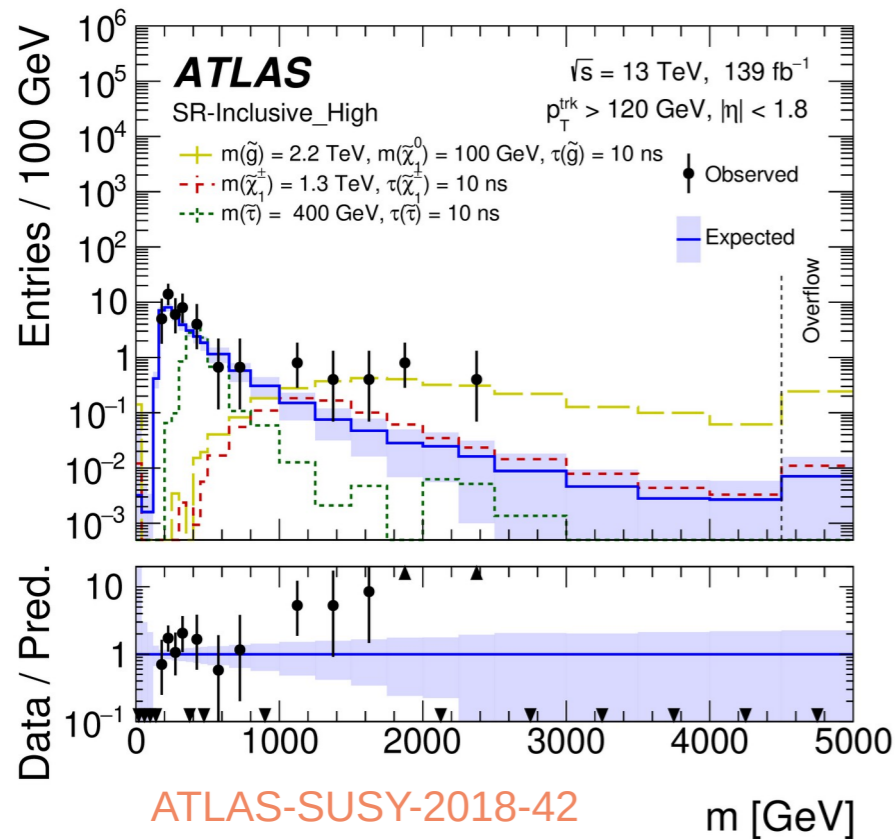
G. Giudice, M. McCullough and D. Teresi, 2205.04473

Signal consistent with boosted ($Q > 1$) HSCPs

ATLAS: excess is not consistent with slow moving $Q=1$ tracks

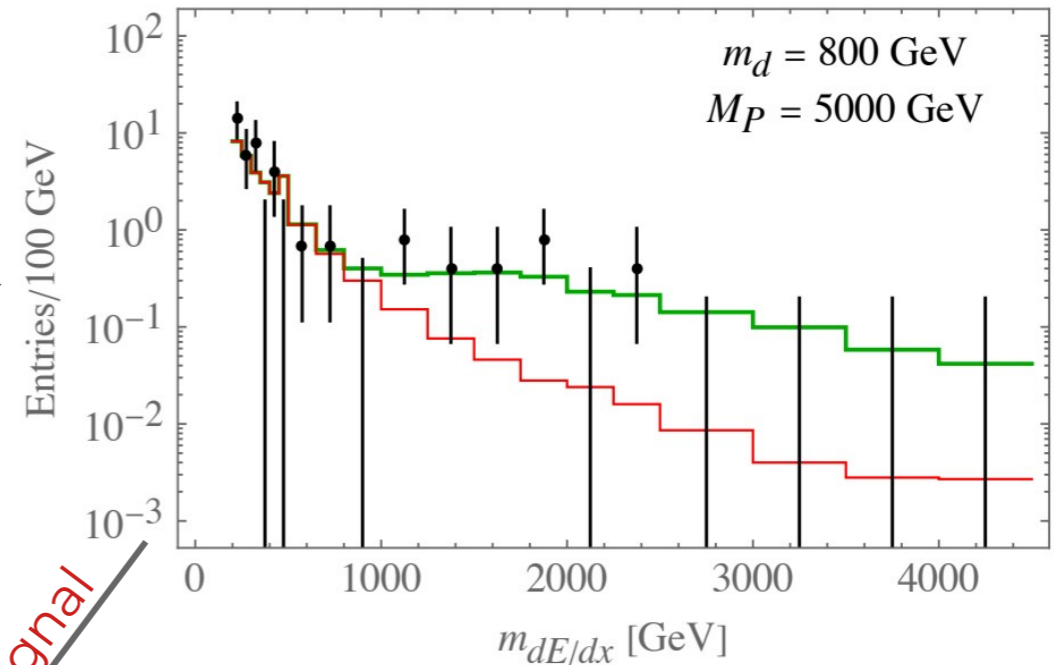
Physics Impact: Examples

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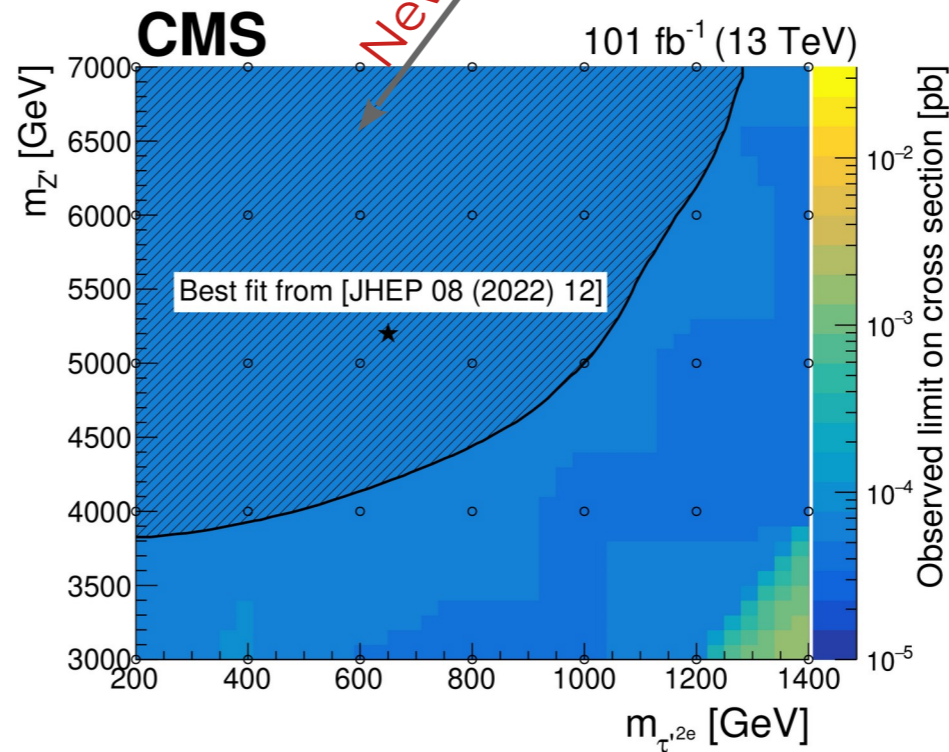


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Re-Interpretation



G. Giudice, M. McCullough and D. Teresi, 2205.04473

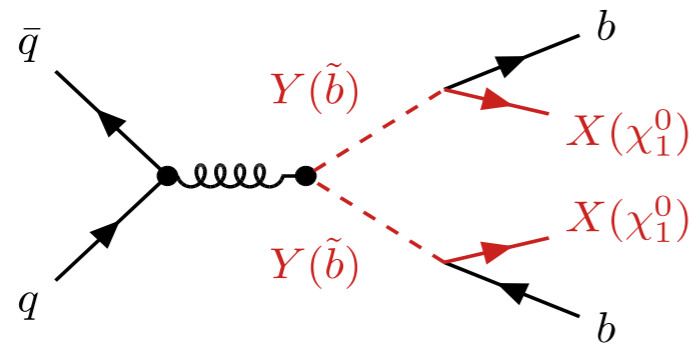


Signal consistent with boosted ($Q > 1$) HSCPs

Proposed signal tested by CMS

Physics Impact: Examples

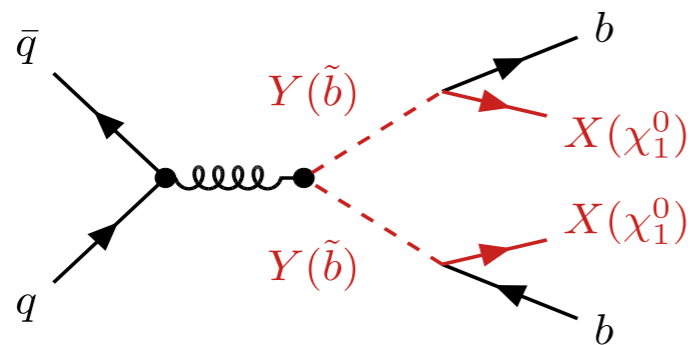
- **Example:** Minimal Conversion-Driven Freeze-out



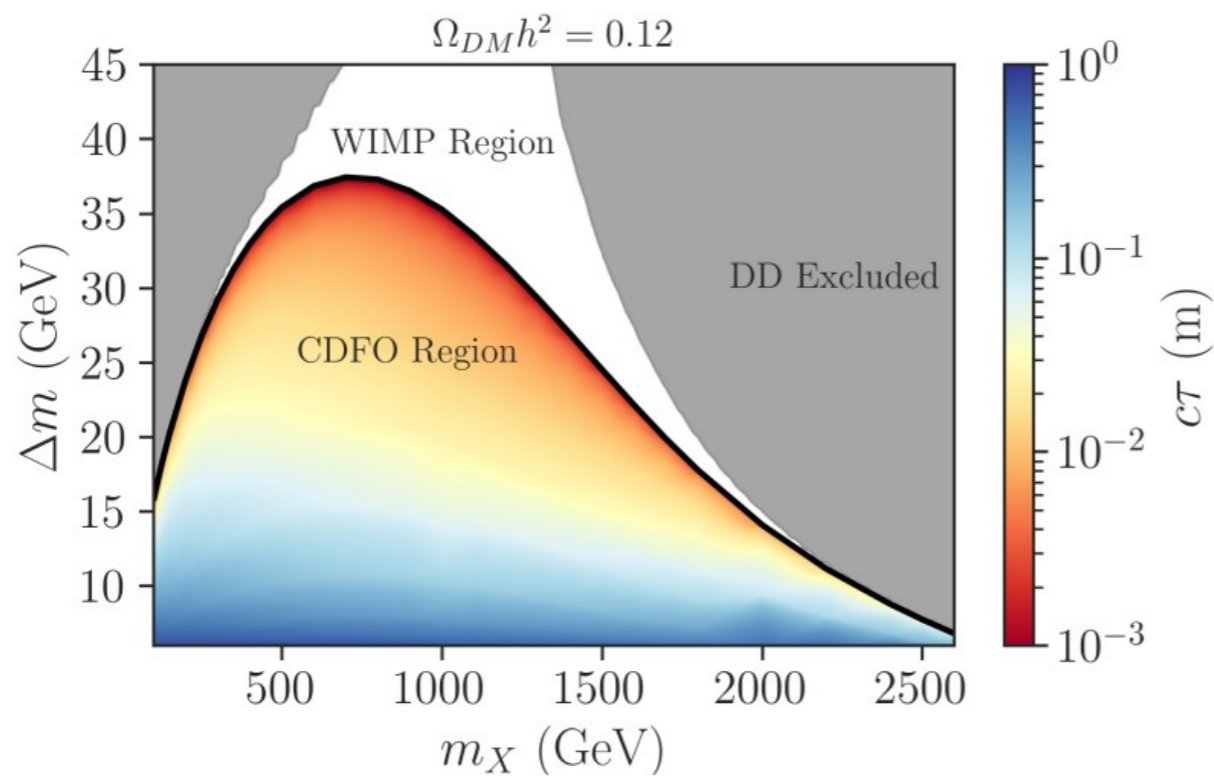
$$\lambda_b \sim 10^{-4}, m_Y \gtrsim m_X \Rightarrow \Omega_{DM} h^2 = 0.12$$

Physics Impact: Examples

- **Example:** Minimal Conversion-Driven Freeze-out



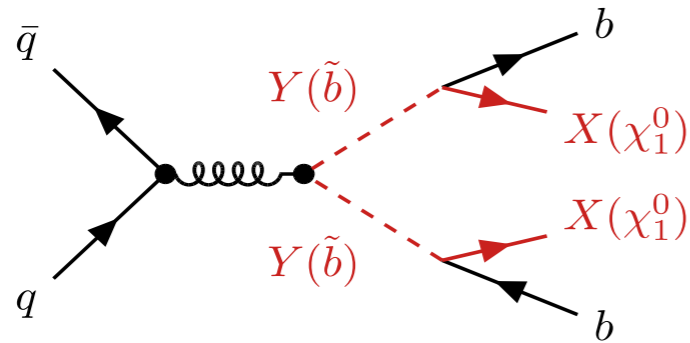
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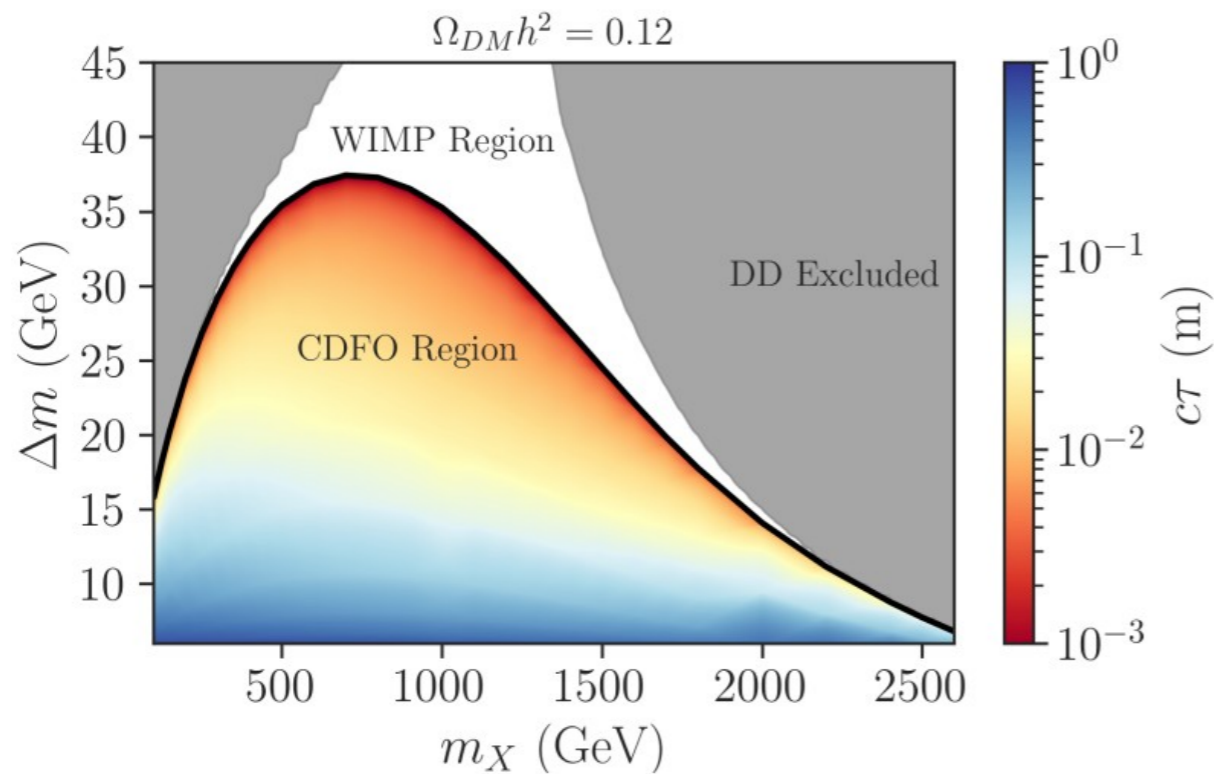
J. Heisig, AL, L. Ramos, 2404.16086

Physics Impact: Examples

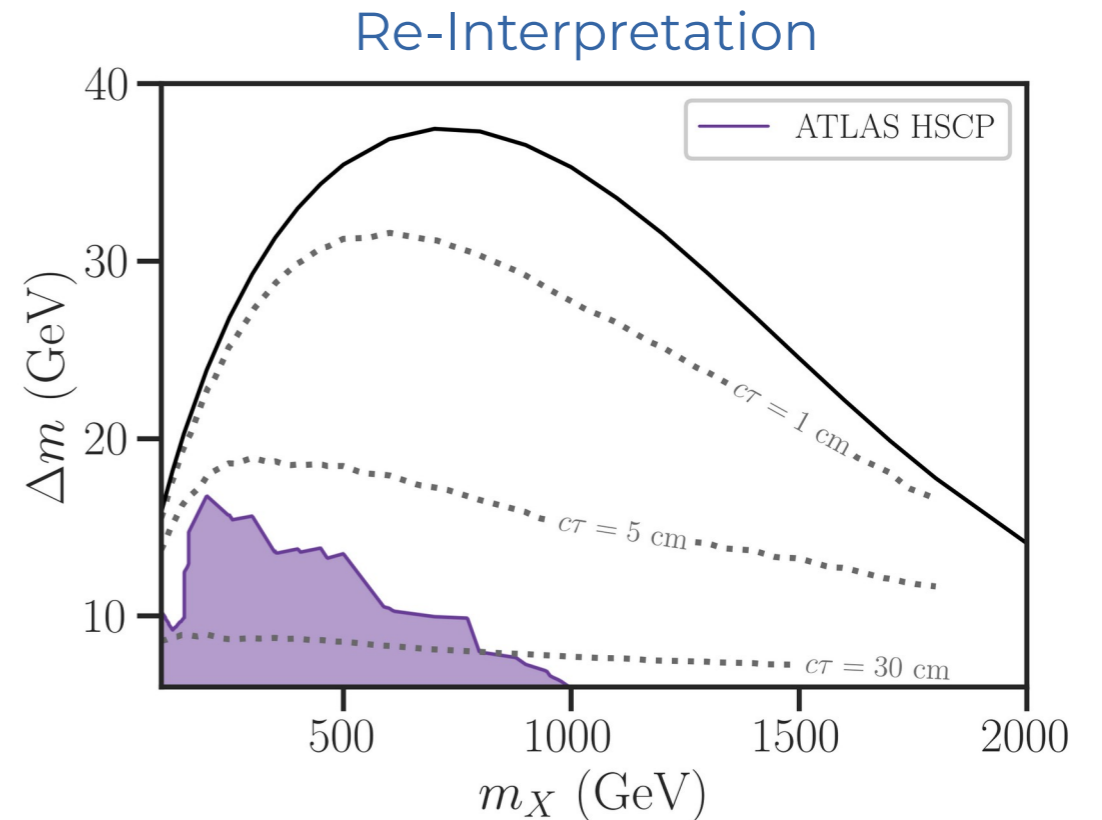
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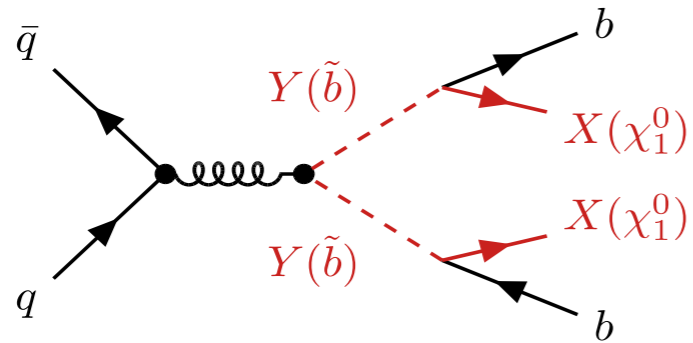


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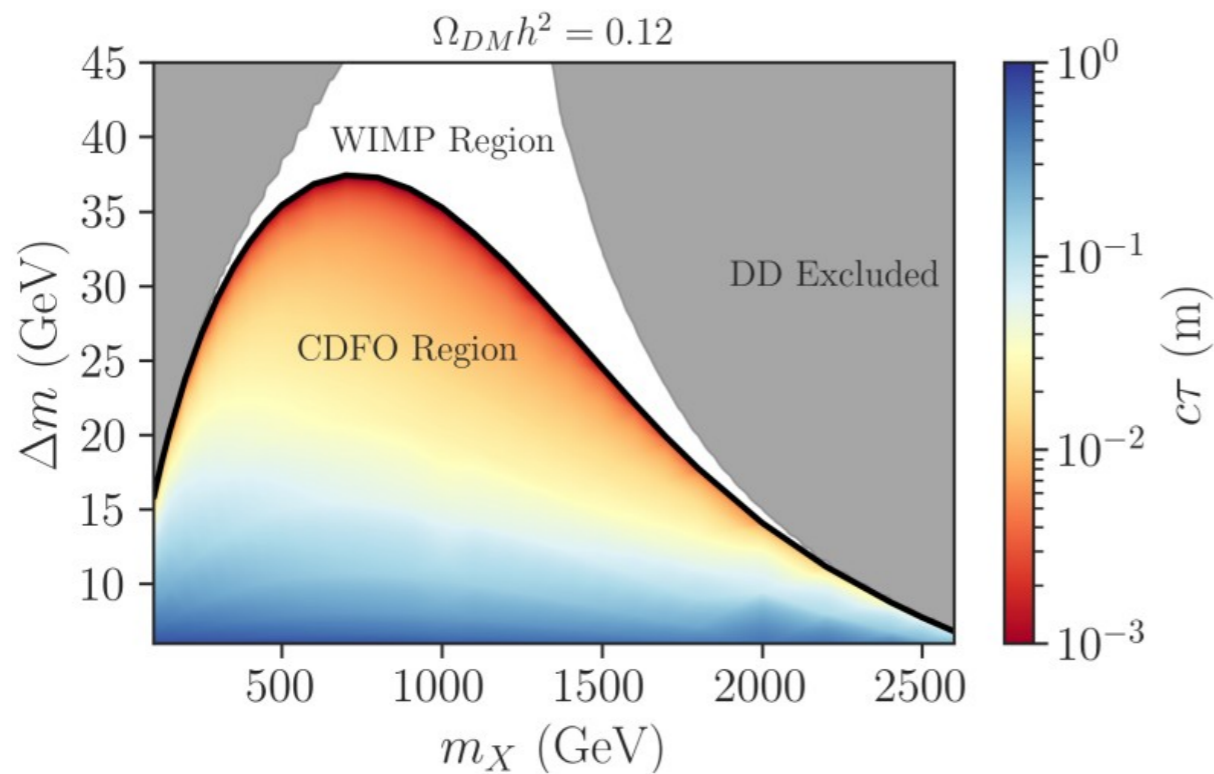


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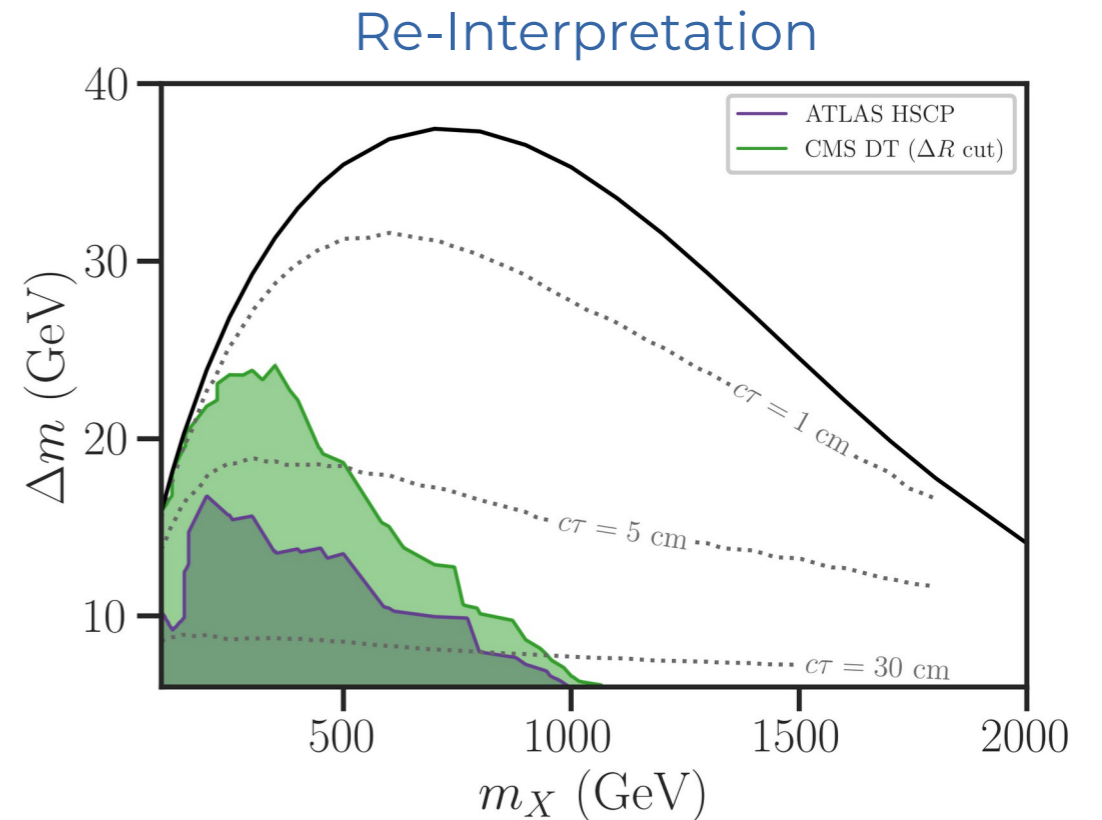
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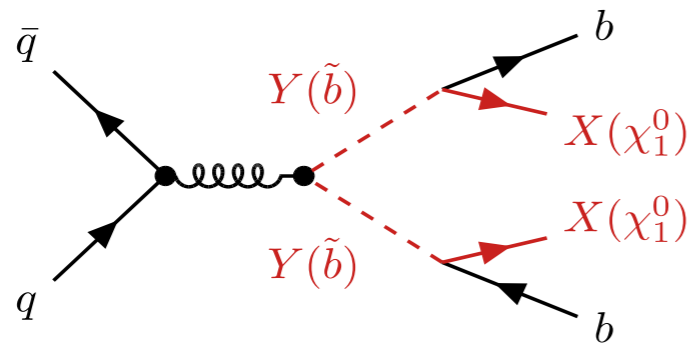


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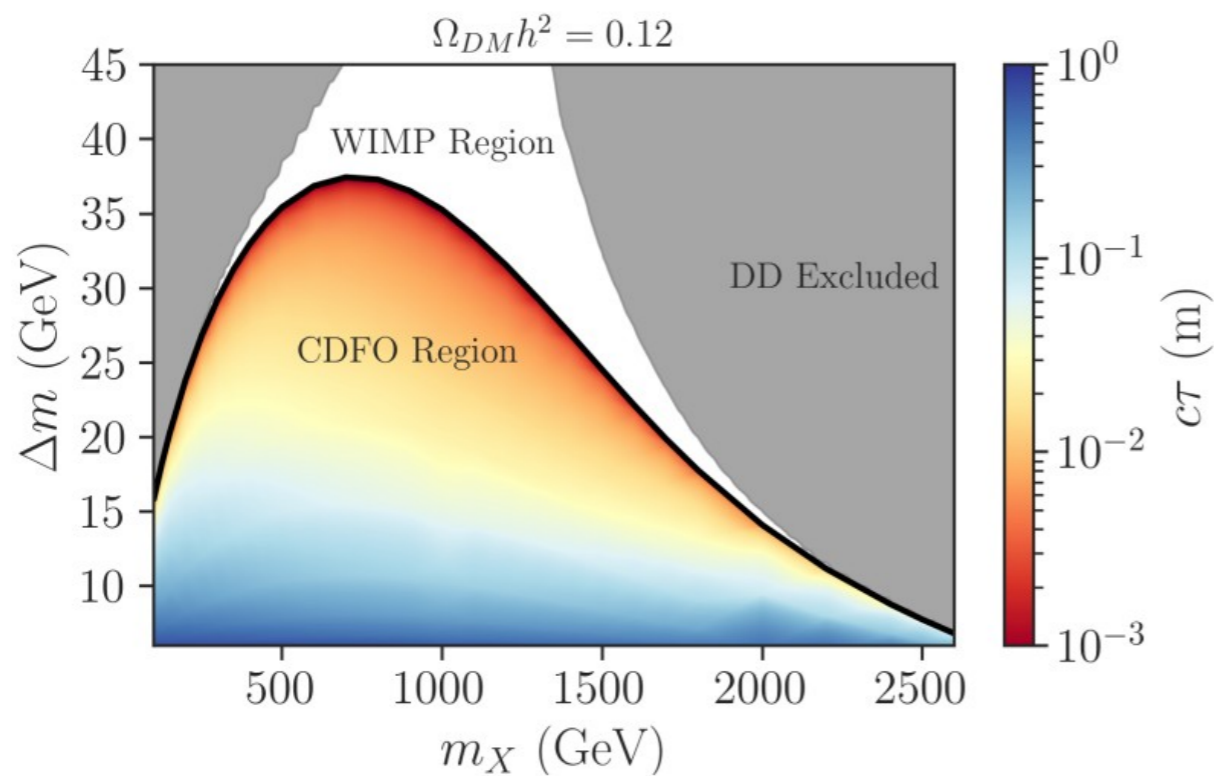


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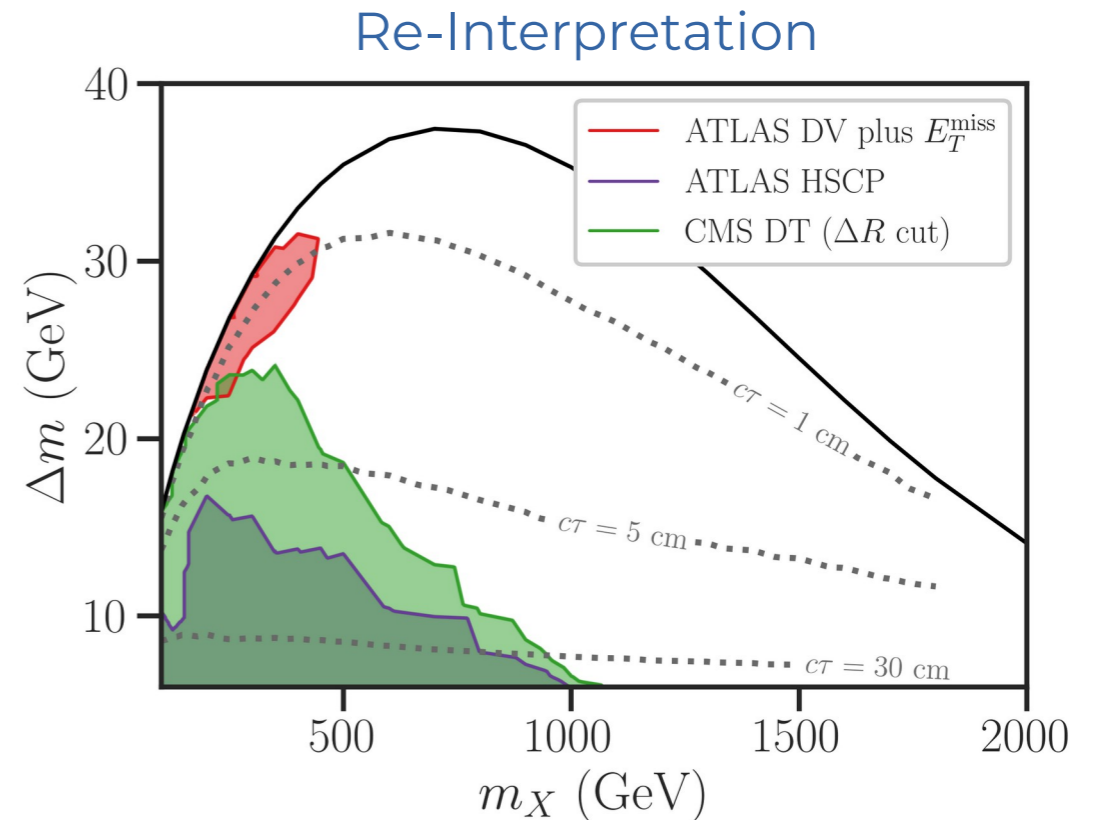
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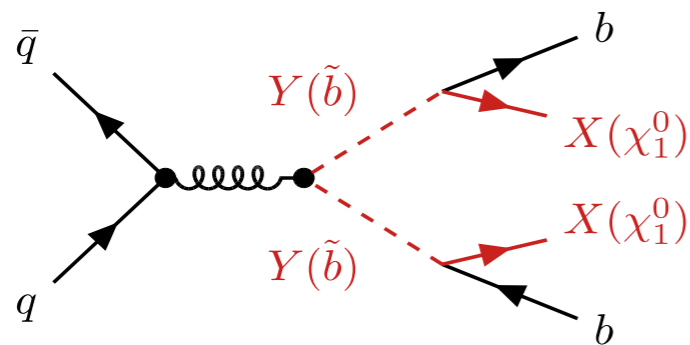


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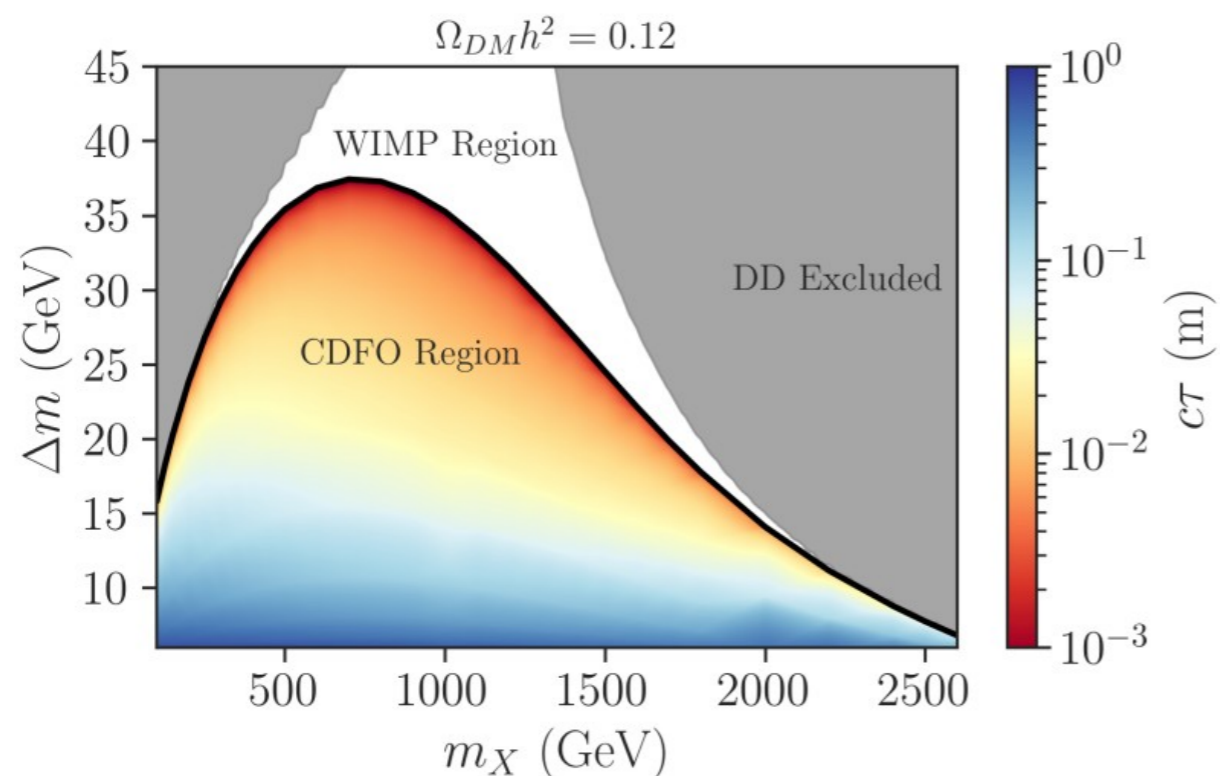


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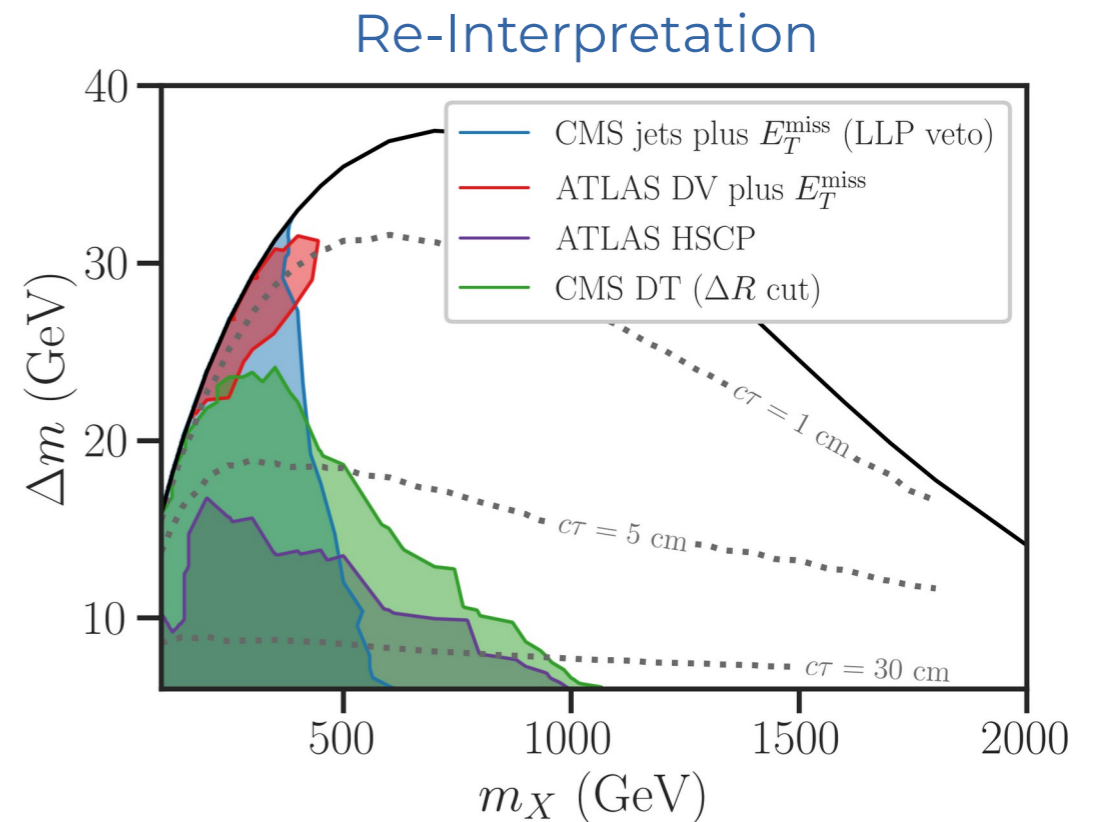
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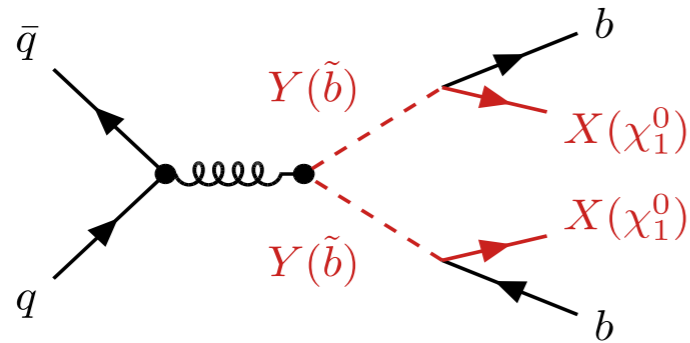


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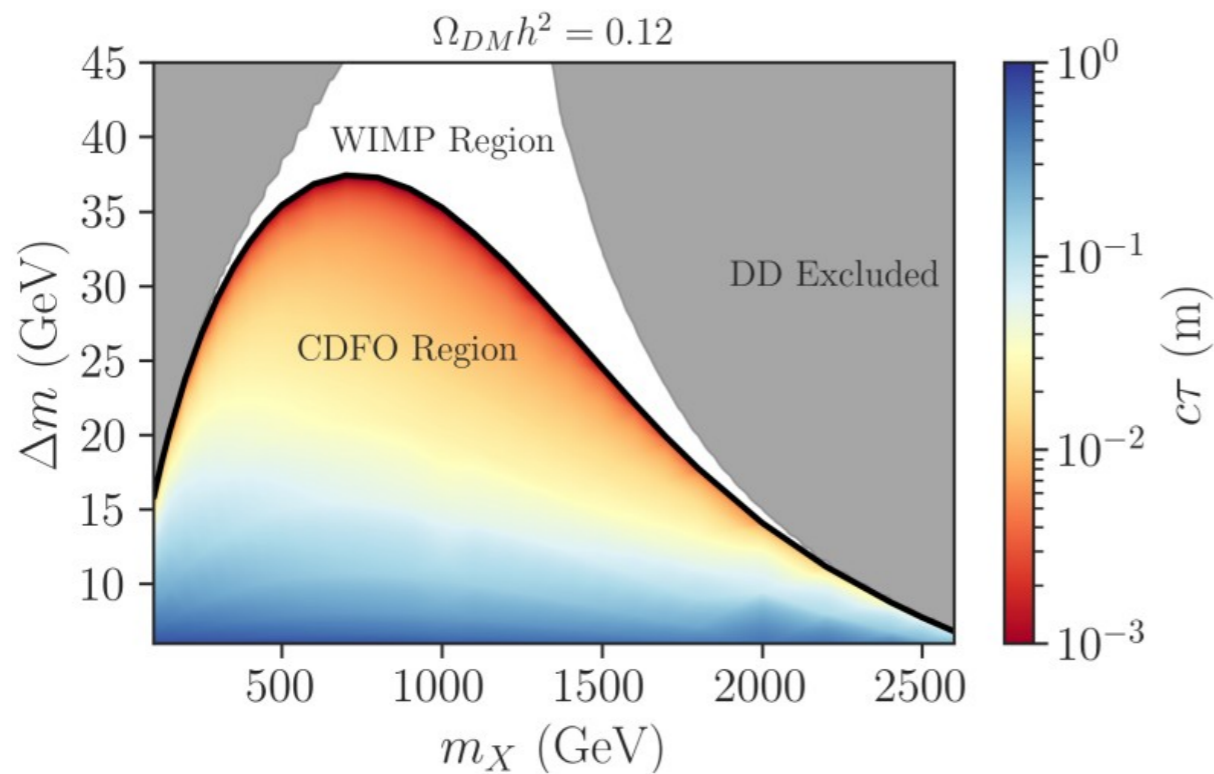


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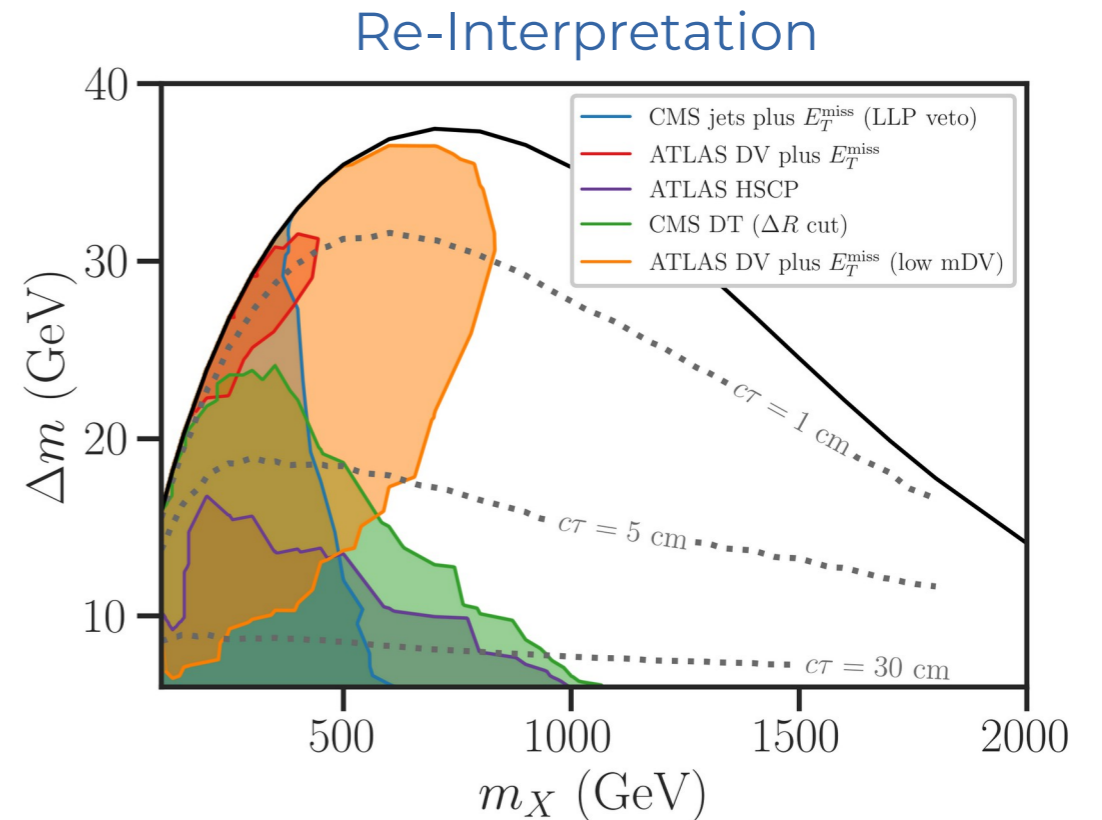
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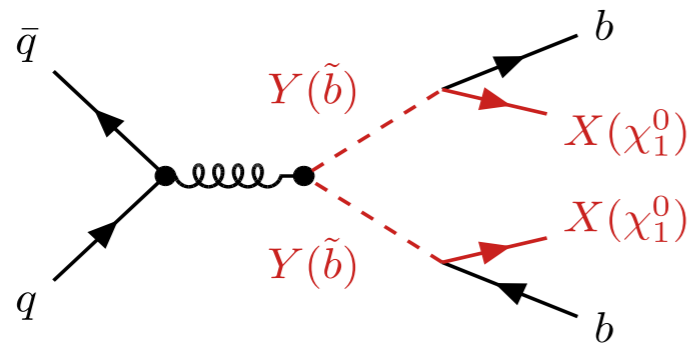


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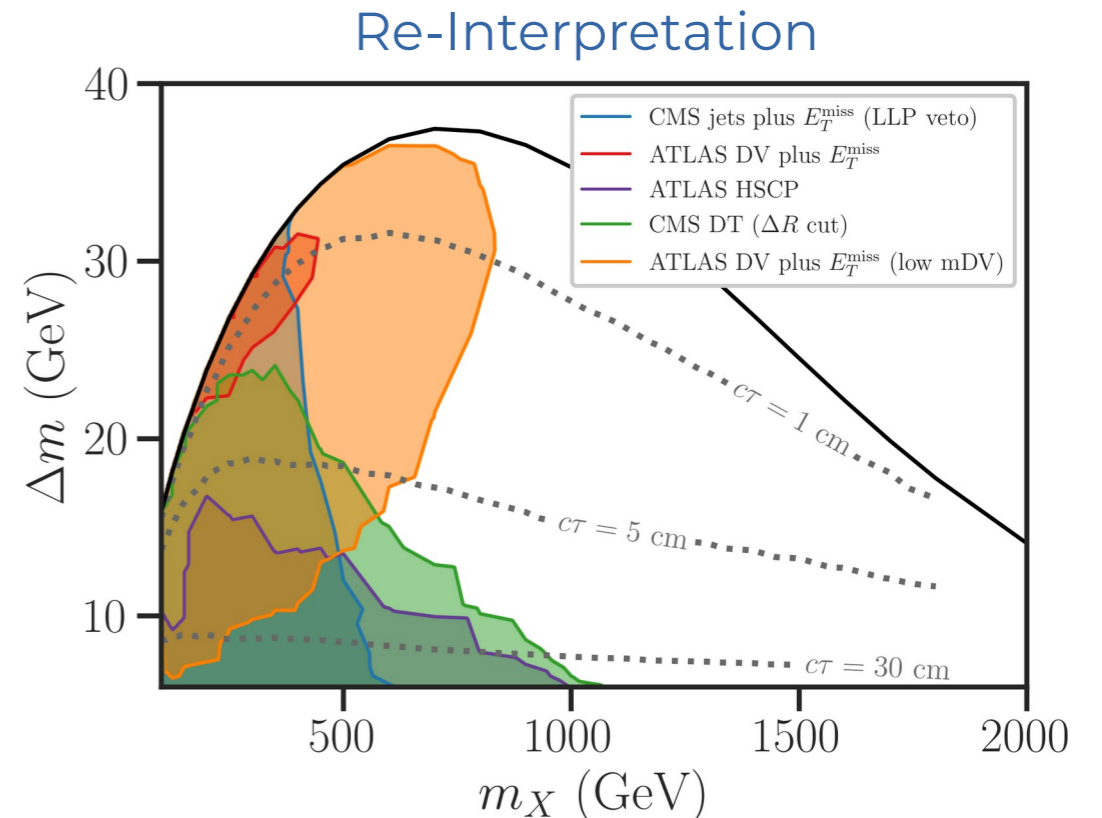
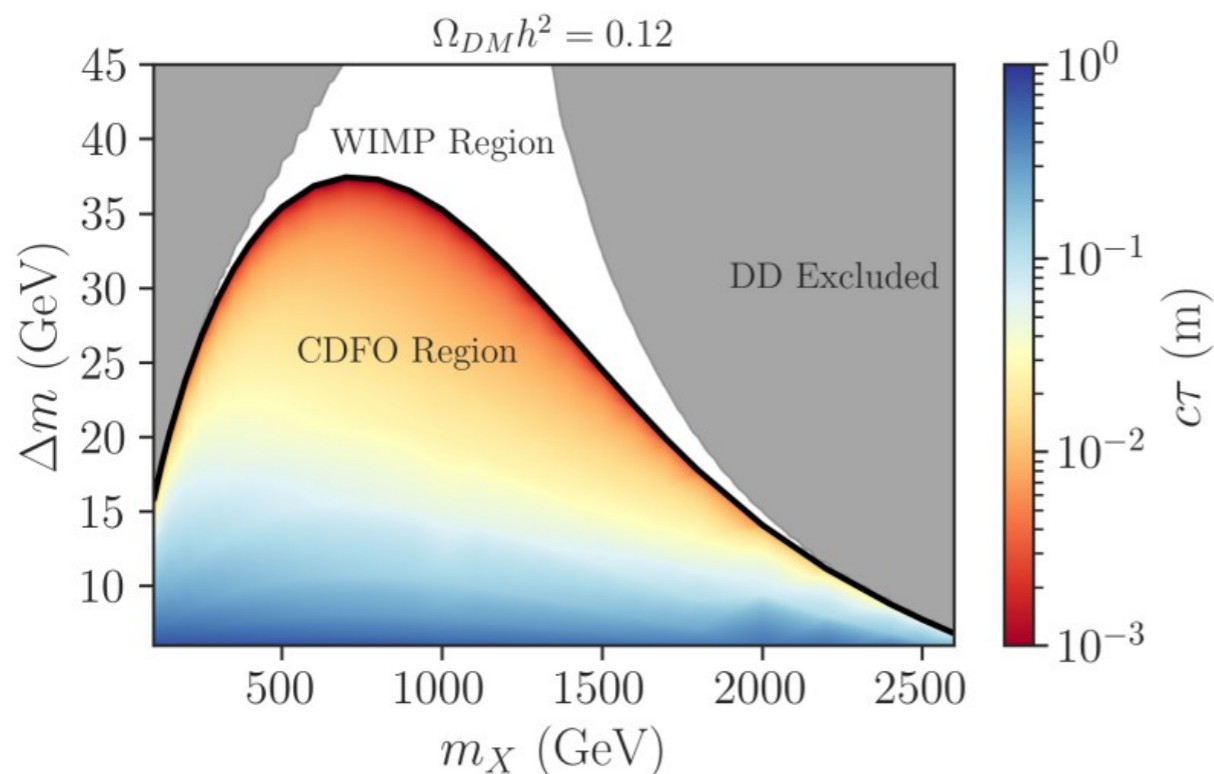


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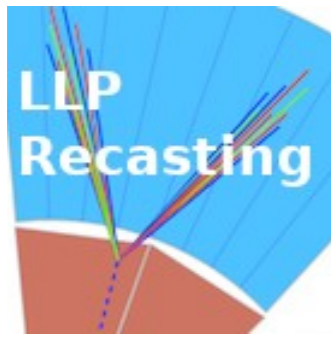


J. Heisig, AL, L. Ramos, 2404.16086

- *New Signal* → soft and mildly displaced objects
- *New strategies* have the potential to greatly enhance the sensitivity

LLP Recasting Repository

- Recasting repo @ GitHub: github.com/llprecasting/recastingCodes
 - contains most of the recasting code for the LLP searches mentioned here



LLP Recasting Repository

This repository holds example codes for recasting long-lived particle (LLP) searches. The code authors and repository maintainers are not responsible for how the code is used and the user should use discretion when applying it to new models.

Adding your recasting code

This is an open repository and if you have developed a code for recasting a LLP analysis, we encourage you to include it here. Please contact llp-recasting@googlegroups.com and we will provide you with the necessary information for including your code.

Repository Structure

The repository folder structure is organized according to the type of LLP signature and the corresponding analysis and authors:

- [Displaced Vertices](#)
 - [13 TeV ATLAS Displaced Jets](#)
 - [13 TeV ATLAS Displaced Vertex plus MET by ALessa](#)
 - [13 TeV ATLAS Displaced Vertex plus MET by GCottin](#)
 - [8 TeV ATLAS Displaced Vertex plus jets by GCottin](#)
- [Displaced Jets \(CalRatio\)](#)
 - [13 TeV ATLAS Displaced Jets in the calorimeter](#)
 - [13 TeV ATLAS Displaced Jets plus X in the calorimeter](#)
- [Emerging Jets](#)
- [Heavy Stable Charged Particles](#)
 - [13 TeV ATLAS HSCP - 139/fb](#)
 - [13 TeV ATLAS HSCP - 31.6/fb](#)
 - [8 TeV CMS HSCP](#)
- [Disappearing Tracks](#)

Contributors 7



Conclusions

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 - *recasting guides, pseudocode and cut-flows are essential!*
 - *public BDTs, NNs,... are welcome! (see 2312.145775)*
 - *always aim for model independence!*
- *Re-interpretation is essential for:*
 - *identifying gaps in coverage!*
 - *increasing the physics impact of searches*

ReInterpretation Checklist

1. **If only simplified model** efficiencies or upper limits are provided:
 - Aim for model independence!
 - Provide results for individual processes
 - Parametrize results in terms of basic parameters (masses, lifetime)
 - Try and cover a relevant part of this parameter space
2. Otherwise...
 - Parametrized efficiencies (signature or object-level)
 - Cutflows (for benchmarks at the bulk and edge of the exclusion curve)
 - Cards for event generation (benchmark models):
 - Process card. Parameters (model) card, Pythia card, ...
 - Signal Distribution for “recasting observables” (benchmarks)
 - Pseudocode
 - Recasting guide

Backup

Re-Interpretation “Failures”

- [Example](#): ATLAS-SUSY-2018-19 (Disappearing Track)

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 - Signature-level efficiencies with NaNs

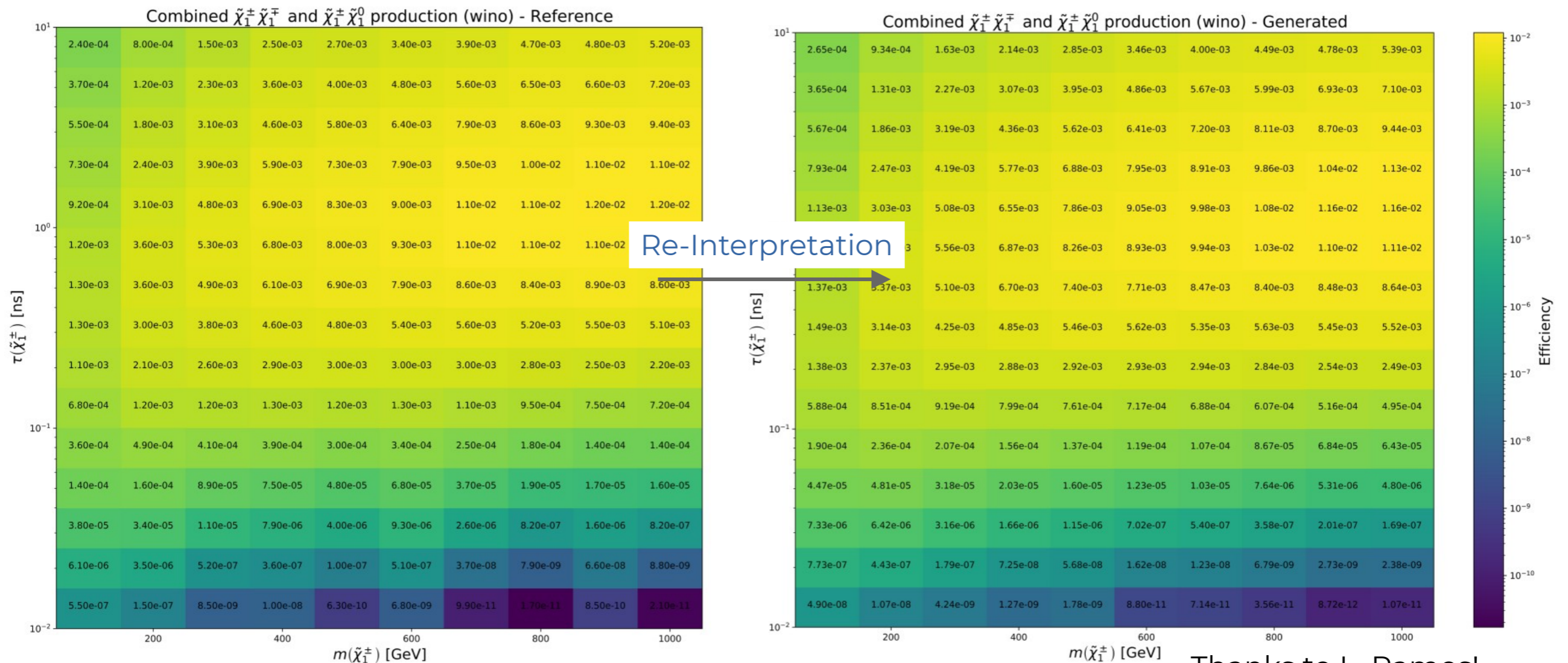
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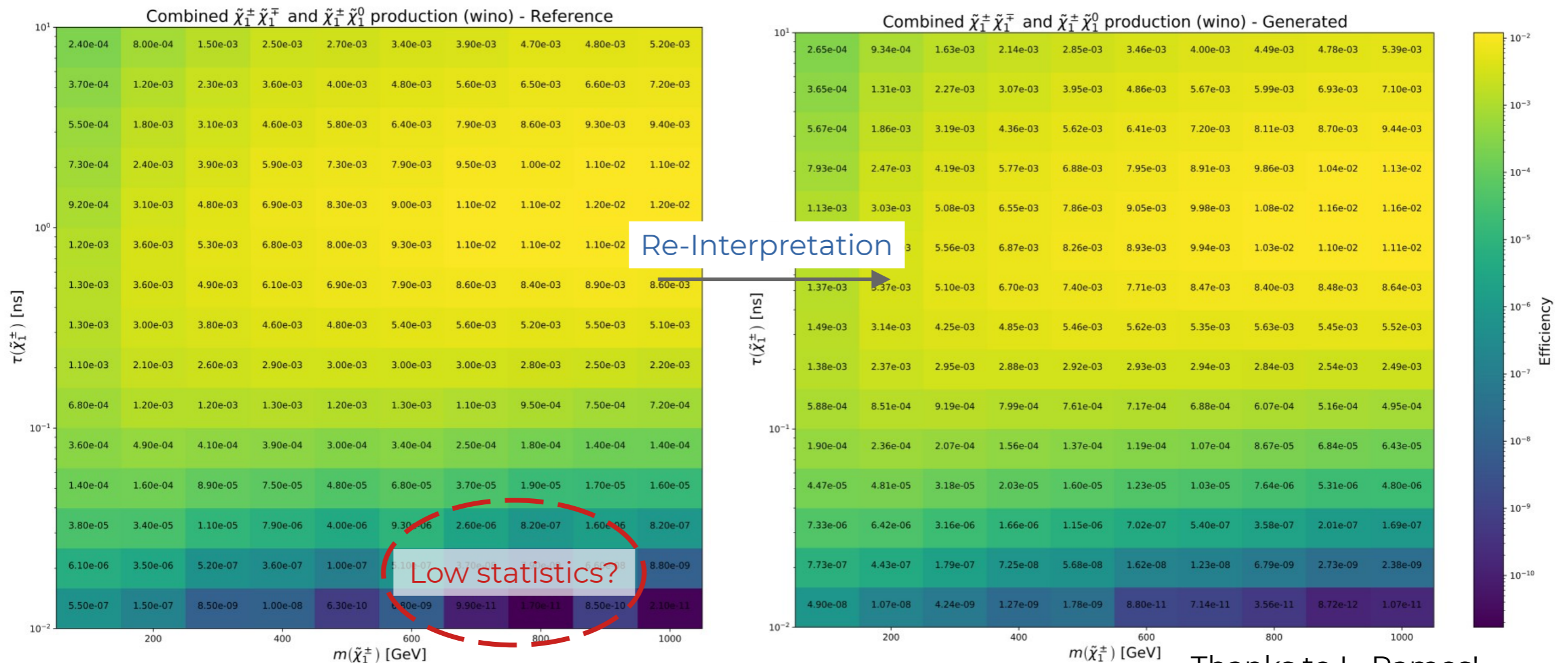
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