
Constraining new physics with SModelS v2.0: long-lived particles

in collaboration with

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Philipp Neuhuber, Humberto Reyes-Gonzalez, Wolfgang Waltenberger, Alicia Wongel

Jan Heisig



PHENO 2021
AFTER WINTER COMES SPRING

Latest topics in Particle Physics
and related issues in
Astrophysics and Cosmology

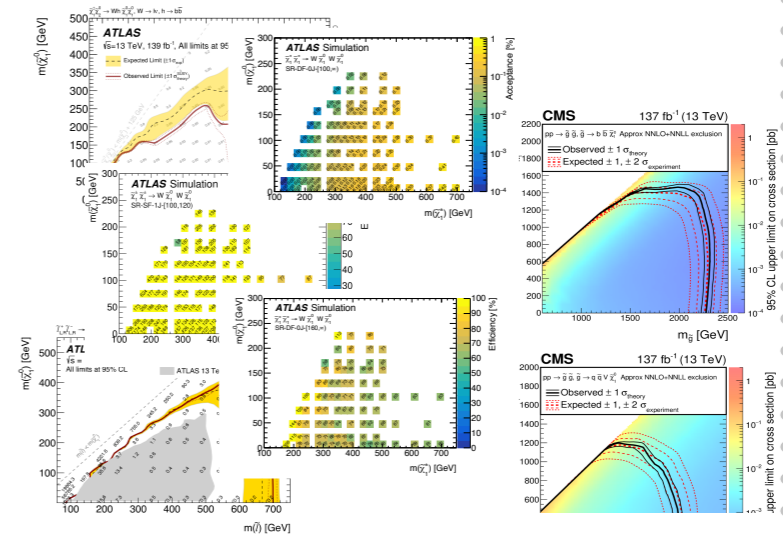
Reinterpretation of new physics searches

Model

$$\mathcal{L} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + i\bar{\Psi}(\not{D} - m)\Psi + (D^\mu\phi)^*D_\mu\phi + \dots$$



Experiment



Event
Generation

Detector
Simulation

Recasting

Result

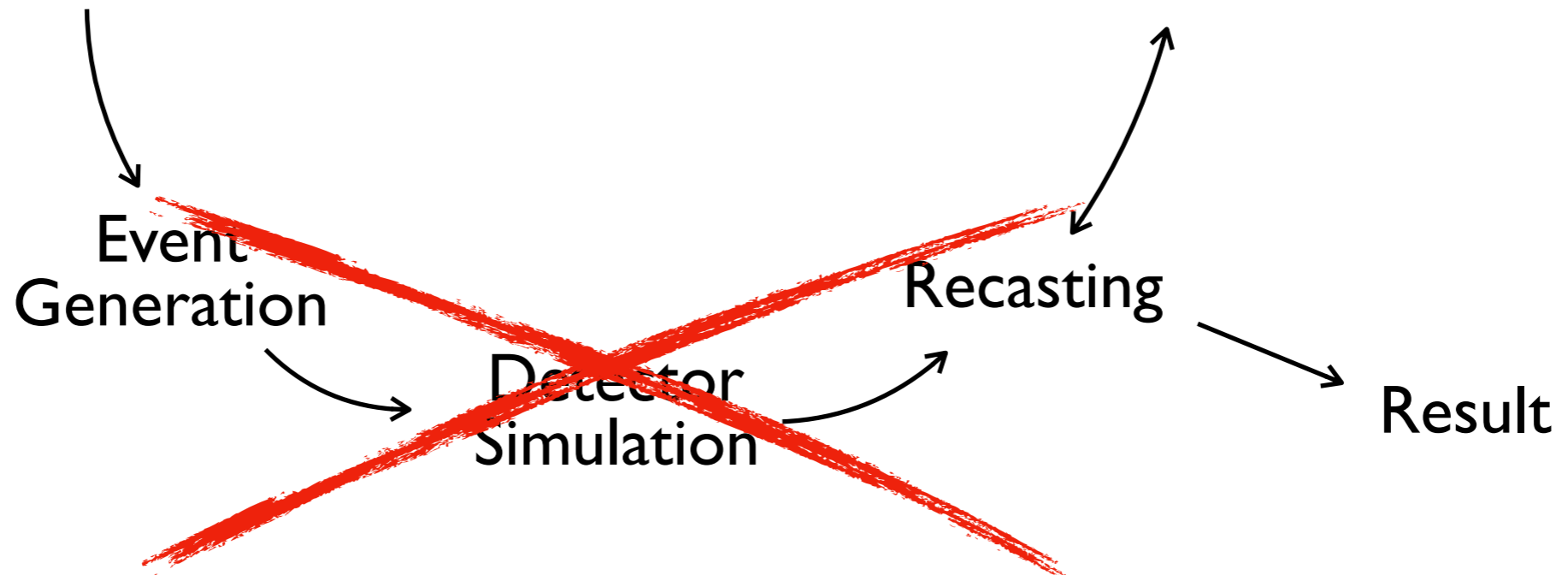
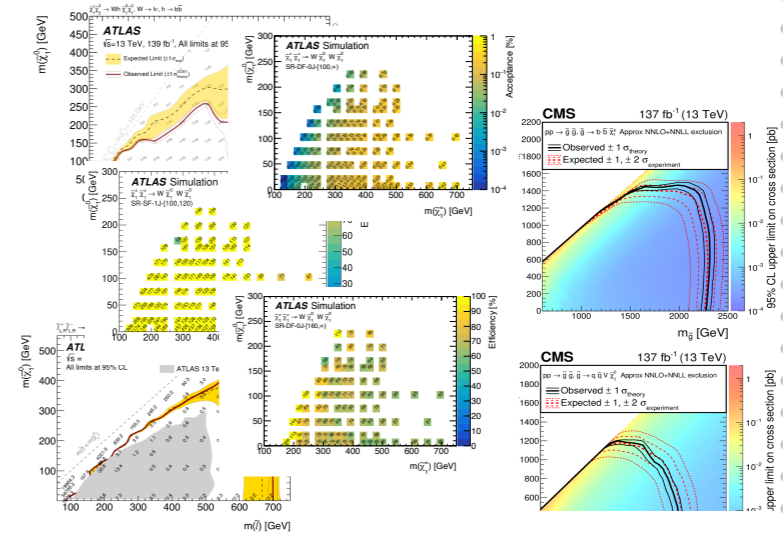
Reinterpretation of new physics searches

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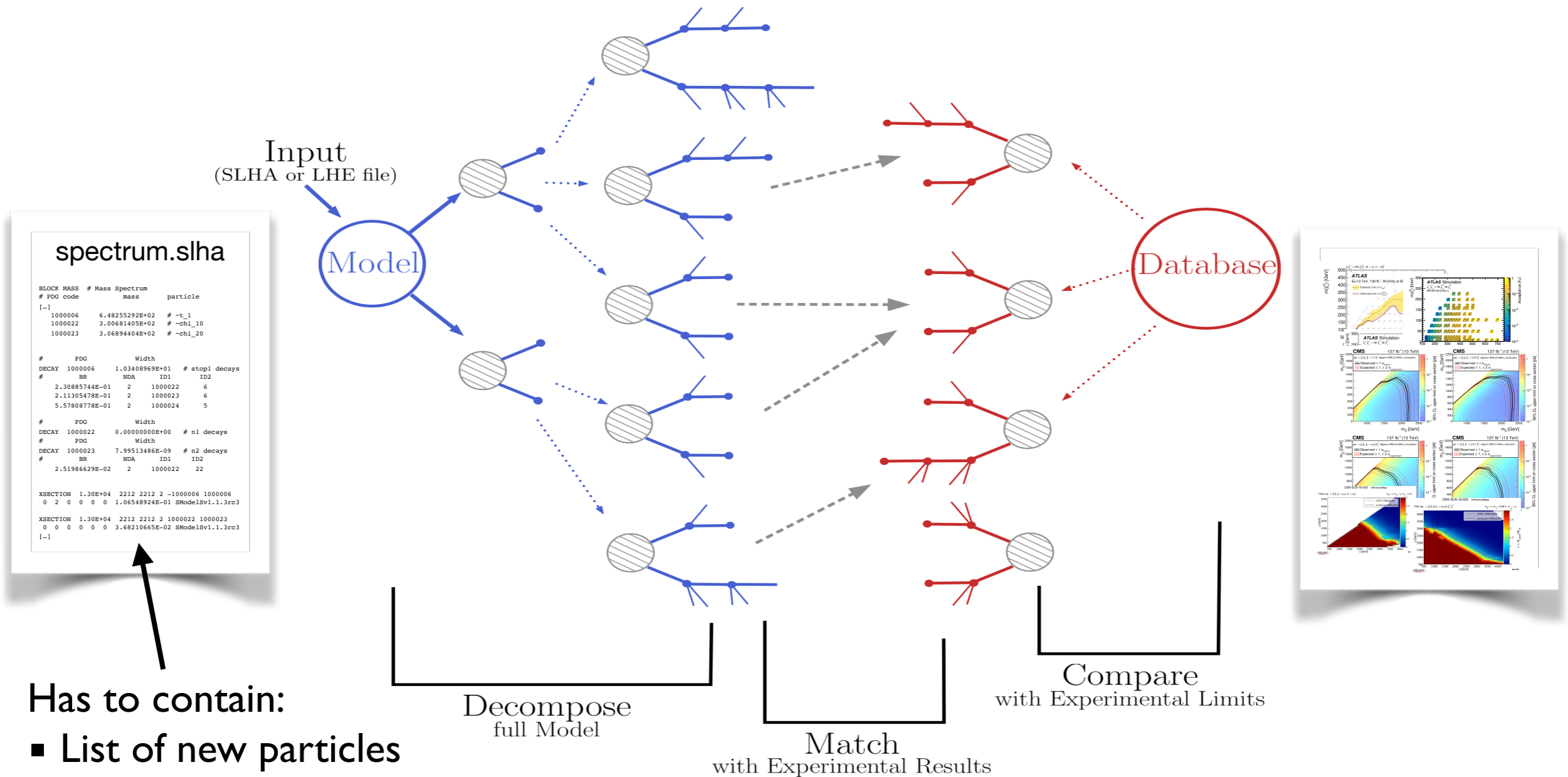


Experiment



Working principle

[13|2.4|75]



```

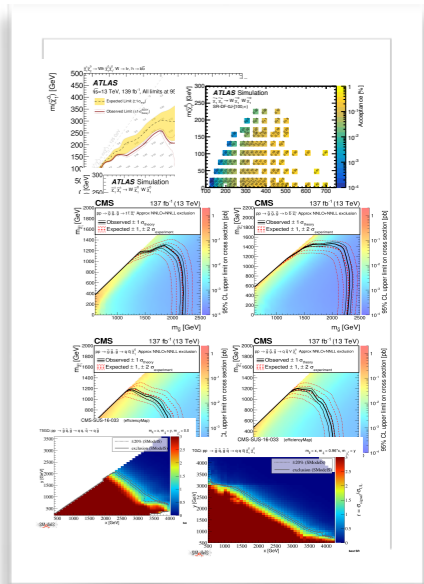
spectrum.ssha
BLOCK MASS # Mass Spectrum
# PDG code mass particle
[-]
1000006 6.48255292E+02 #-t_1
1000022 3.00681405E+02 #-chi_10
1000023 3.06894404E+02 #-chi_20

# PDG Width
DECAY 1000006 1.03408969E+01 # stop1 decays
# BR NDA ID1 ID2
2.30885744E-01 2 1000022 6
2.11305478E-01 2 1000023 6
5.57808778E-01 2 1000024 5

# PDG Width
DECAY 1000022 0.00000000E+00 # n1 decays
# PDG Width
DECAY 1000023 7.99513486E-09 # n2 decays
# BR NDA ID1 ID2
2.51986629E-02 2 1000022 22

XSECTION 1.30E+04 2212 2212 2 -1000006 1000006
0 2 0 0 0 0 1.06548924E-01 SModelsv1.1.3rc3

XSECTION 1.30E+04 2212 2212 2 1000022 1000023
0 0 0 0 0 0 3.68210665E-02 SModelsv1.1.3rc3
[-]
    
```

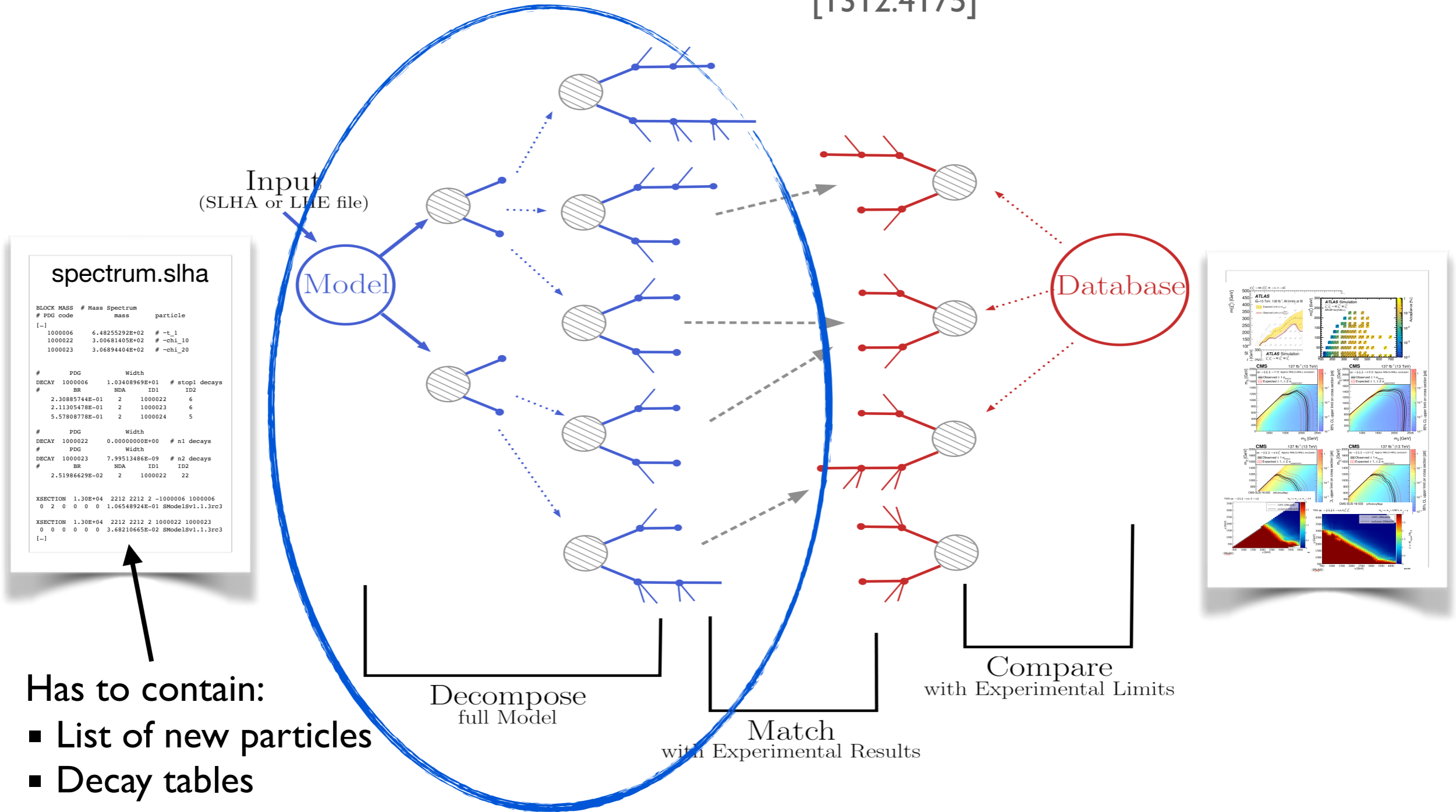


- Has to contain:
- List of new particles
 - Decay tables
 - Production cross sections

[see also Fastlim, |402.0492]

Working principle

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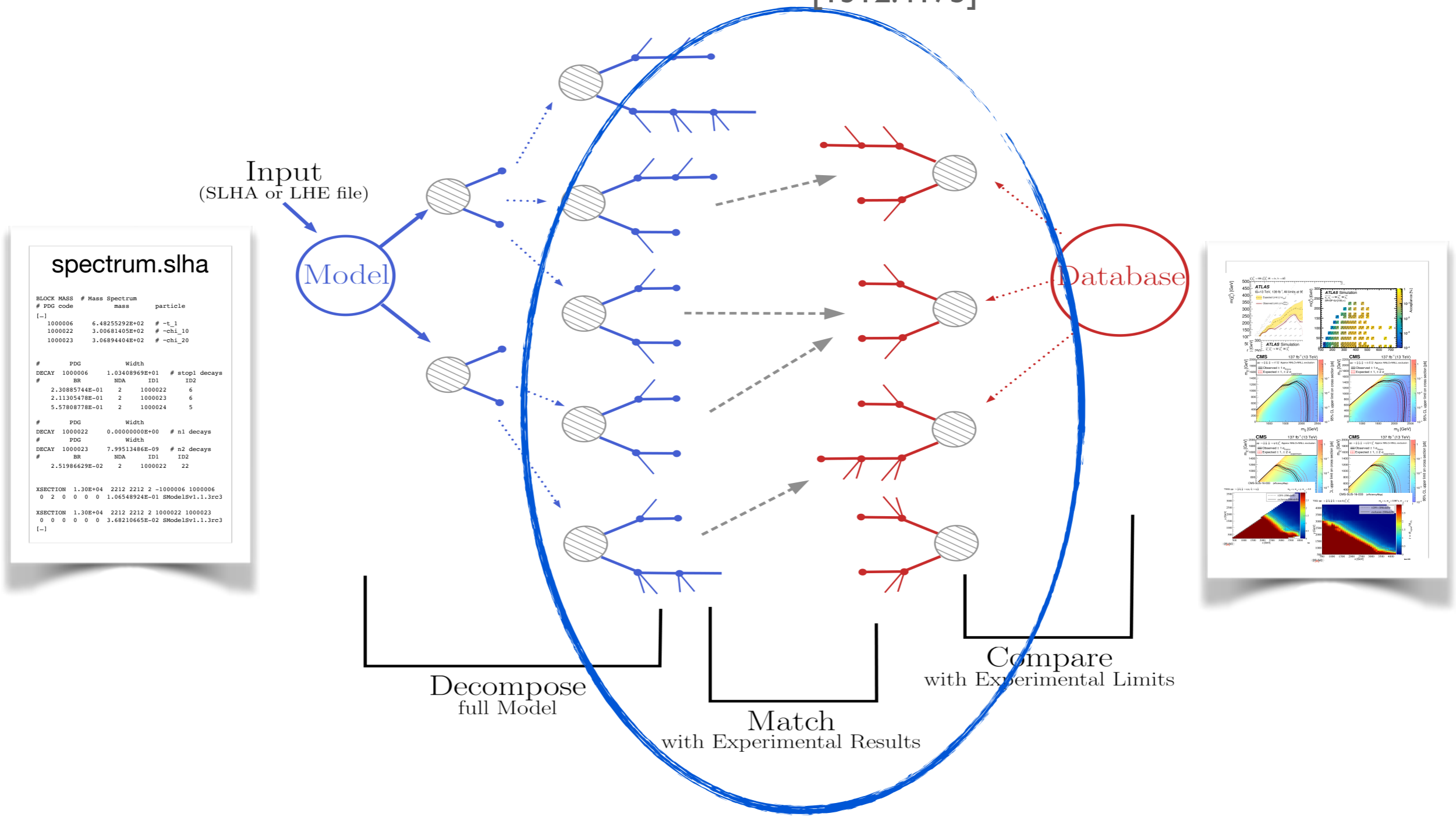
Compare with Experimental Limits

Match with Experimental Results

[see also Fastlim, |402.0492]

Working principle

[13|2.4|75]



```

spectrum.slh

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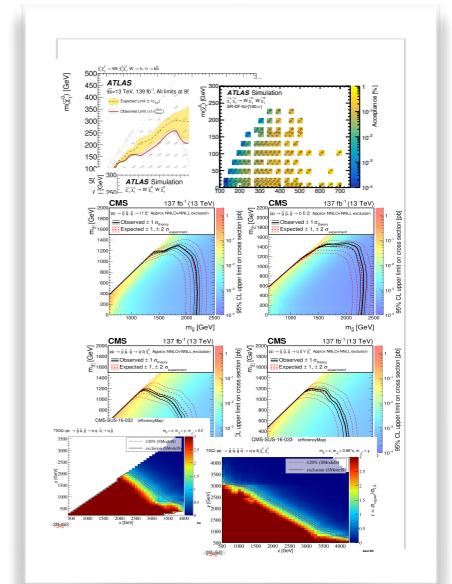
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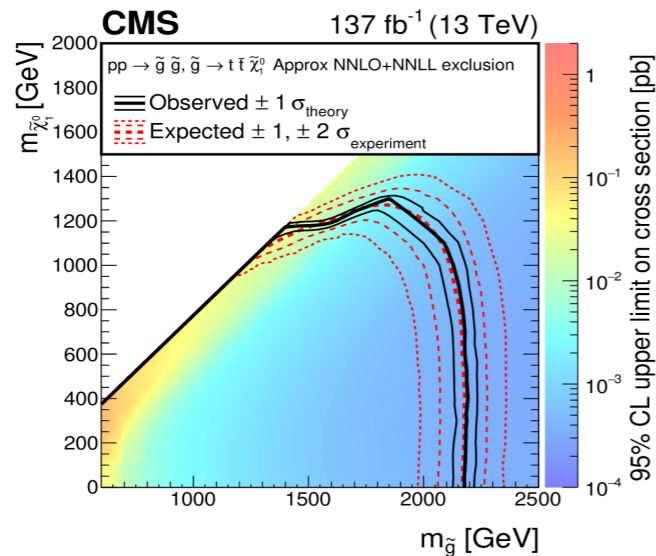
XSECTION 1.30E+04 2212 2212 2 1000022 1000023
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[ - ]

```



SModelS Database: result types

Upper limits (UL)



$$\sigma_{\text{prod}} \times \prod_i \text{BR}_i \times \prod_j \text{BR}_j \leq \underline{\sigma_{\text{prod}}^{\text{UL}}}$$

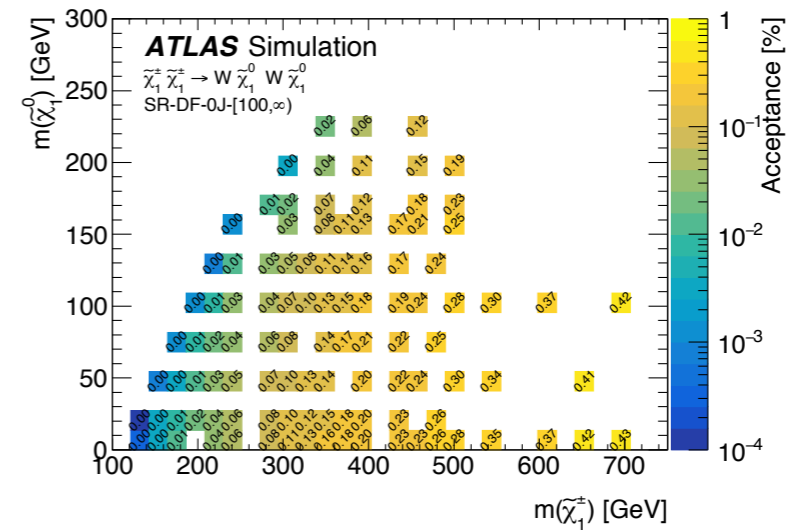
Pros:

- Signal regions usually combined

Cons:

- No combinations of topologies

Efficiency maps (EM)



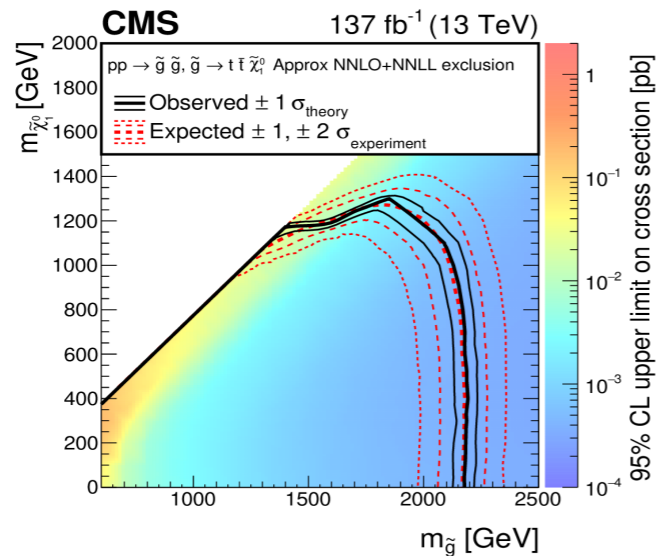
$$\sum_t \left(\sigma_{\text{prod}} \times \prod_i \text{BR}_i \times \prod_j \text{BR}_j \right)_t \underline{\epsilon_{s,t}} \leq \underline{\sigma_{\text{fid},s}^{\text{UL}}}$$

Pros:

- Topologies (t) easily combined (within given signal region, s)
- Likelihoods can be computed
- Combination of signal region if covariance/full likelihood supplied

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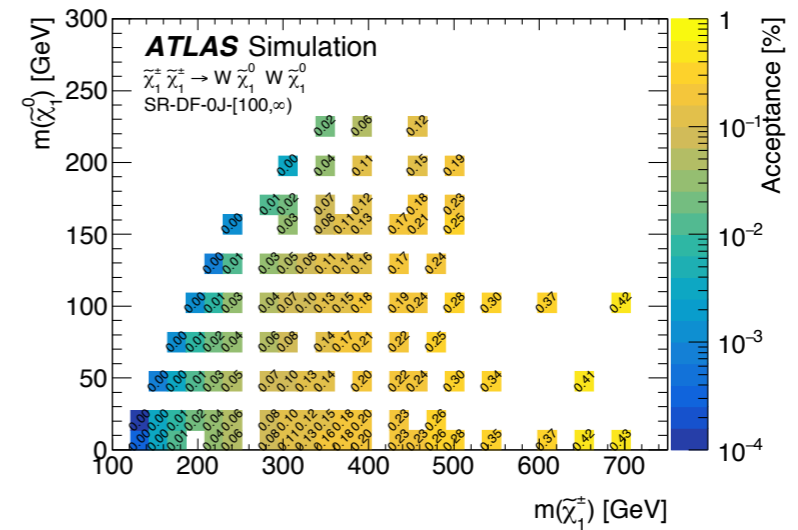
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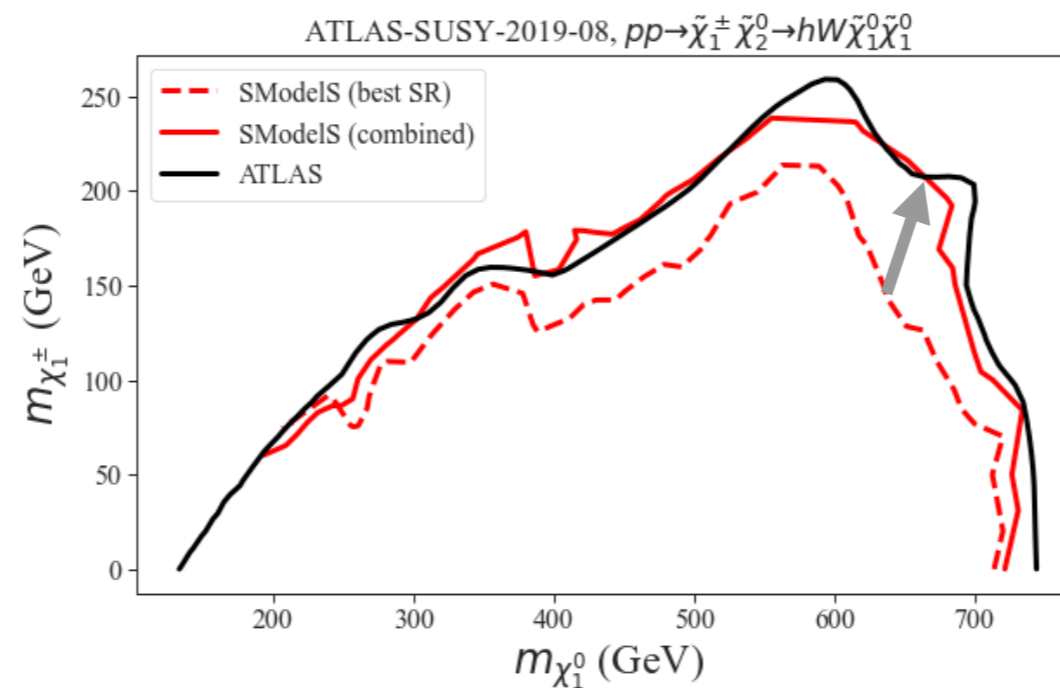
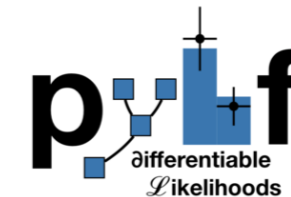
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SModelS Database: result types

- Covariance matrix \Rightarrow simplified likelihood
[CMS-NOTE-2017-001] (cov.)
- Full background model \Rightarrow full likelihood
[ATLAS-PHYS-PUB-2019-029] (json)

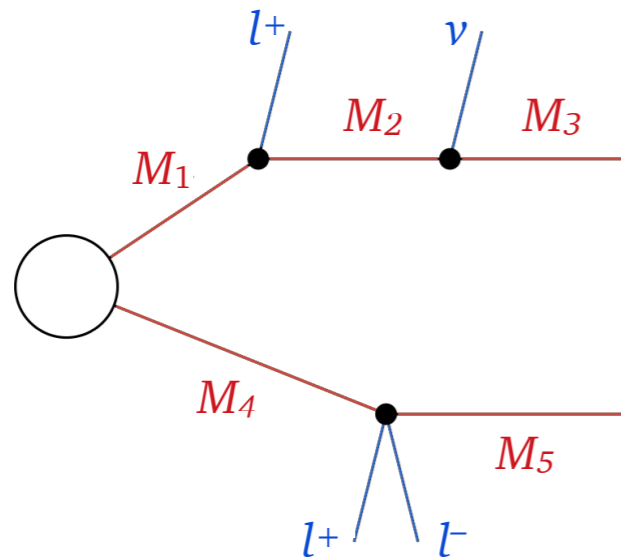


[see 2009.01809]

if covariance/full likelihood supplied

New features in SModelS 2.0

version 1.X



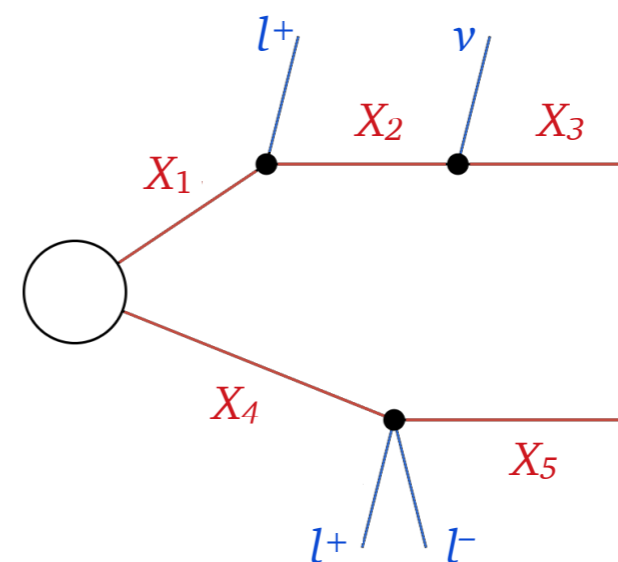
Simplified model topology contains:

- Structure
- Weight
- Final state particles
- Masses M_i

Only detector-stable BSM final states
(some reweighting for finite lifetimes)

[see 1808.05229, 1811.10624]

version 2.0



X_i = Particle object

- Containing mass, width, charges, spin, ...

Enables:

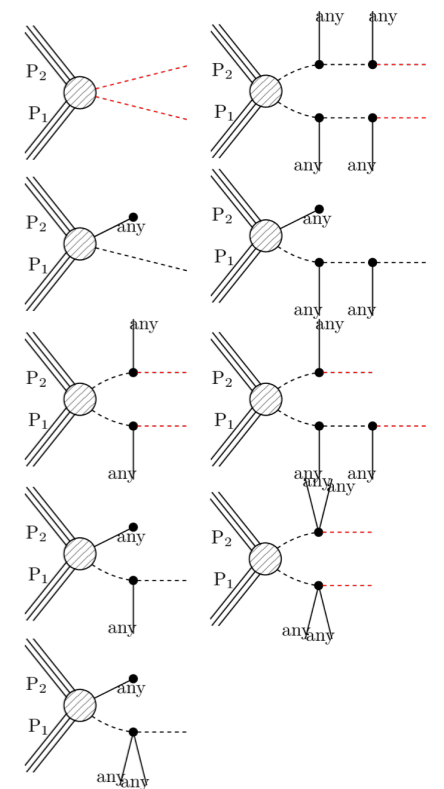
- Width-dependent results
⇒ General long-lived particle searches
- Drop SMS approximations
e.g. specify spin, if search sensitive

Long-lived particle results in SModelS 2.0

Validated:

1. CMS-EXO-19-001: delayed jets + MET (EM)
2. ATLAS-SUSY-2016-08: displaced vertices + MET (UL)
3. ATLAS-SUSY-2016-32: HSCPs, R -hadrons (EM)
4. CMS-EXO-13-006: HSPCs, R -hadrons (EM)
5. ATLAS-SUSY-2016-06 disappearing tracks (EM)*

} home-made EMs:



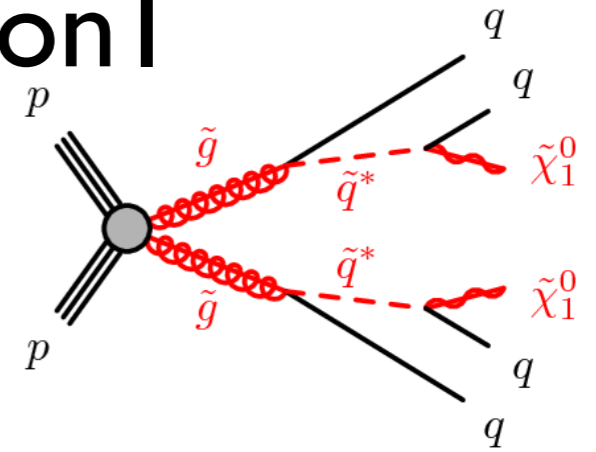
On its way:

6. ATLAS-SUSY-2018-14: displaced leptons
7. CMS-EXO-19-010: disappearing tracks

*) Efficiency maps provided by A. Belyaev, S. Prestel, F. Rojas-Abbate, J. Zurita [2008.08581]

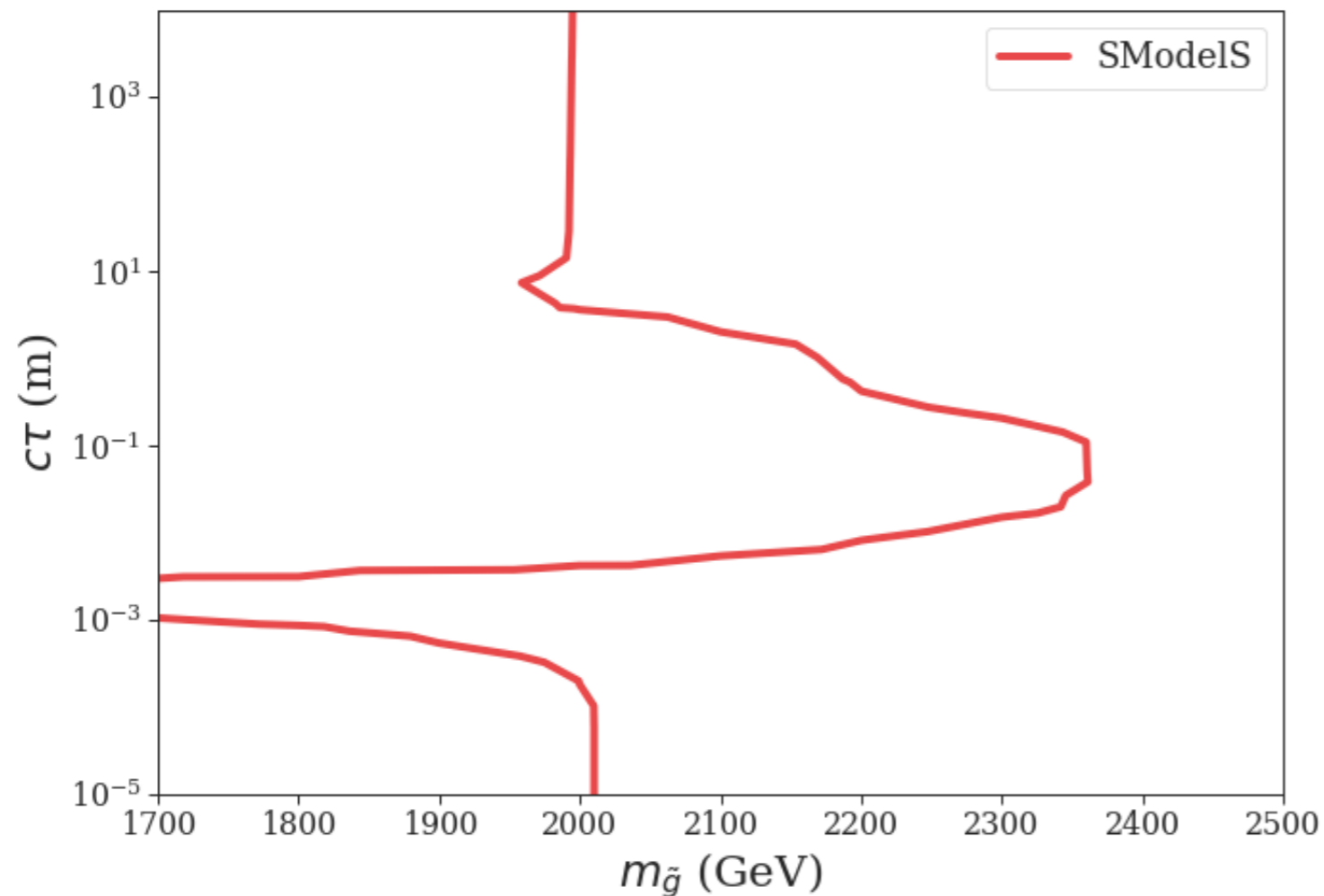
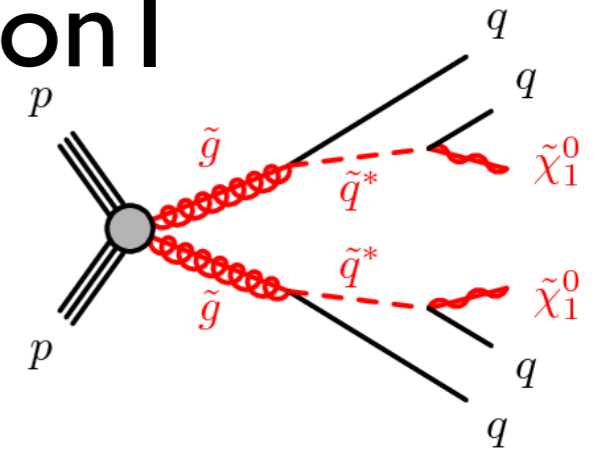
Long-lived particles: Application I

- Illustrative example: Simplified model gluino production:
- Vary squark masses (*i.e.* lifetime):



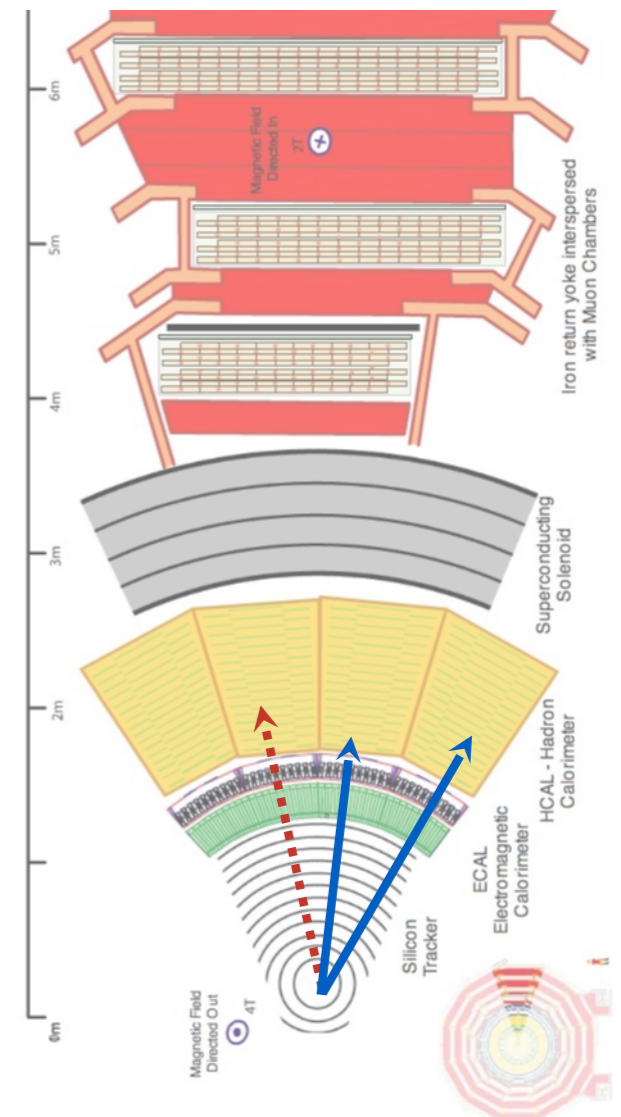
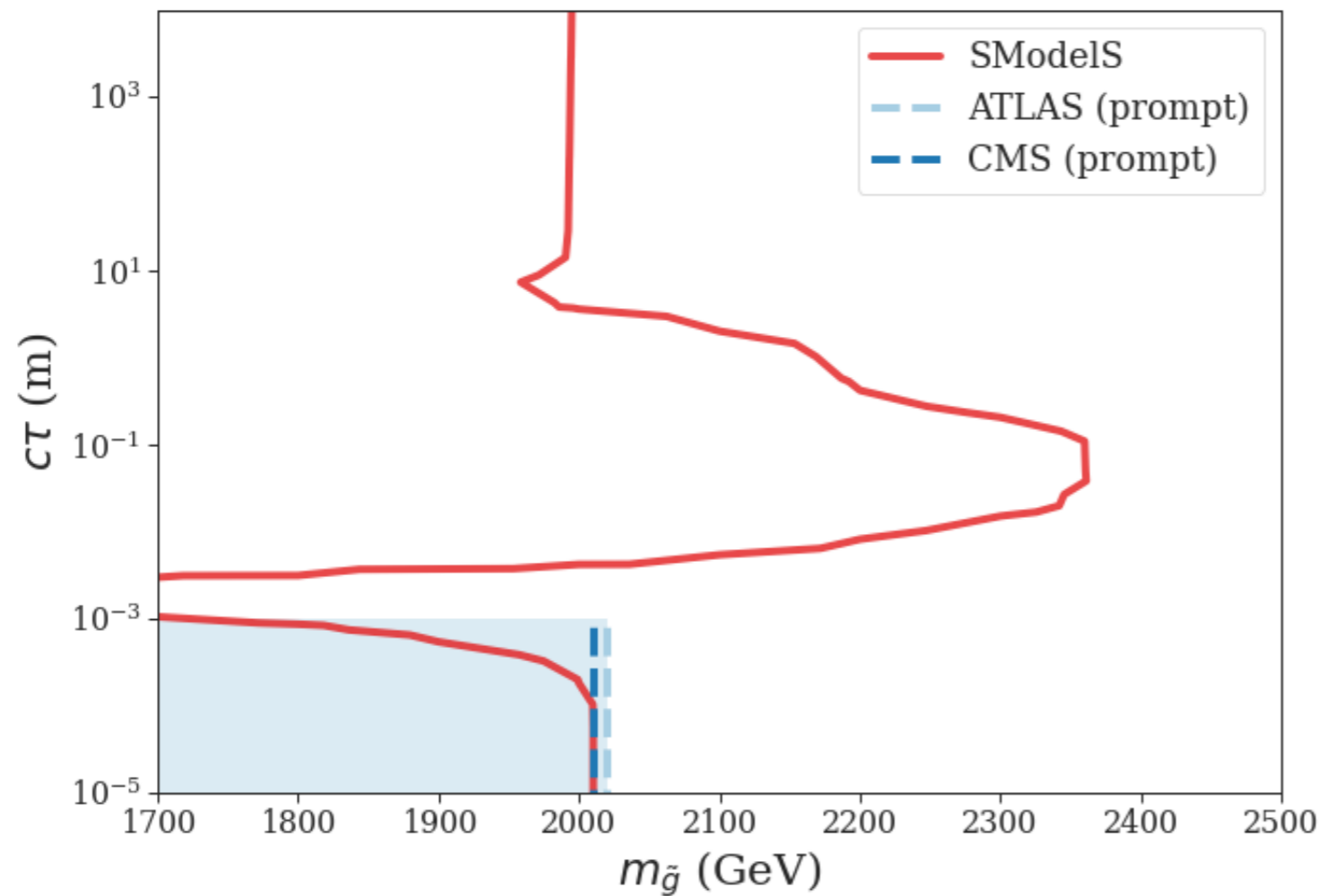
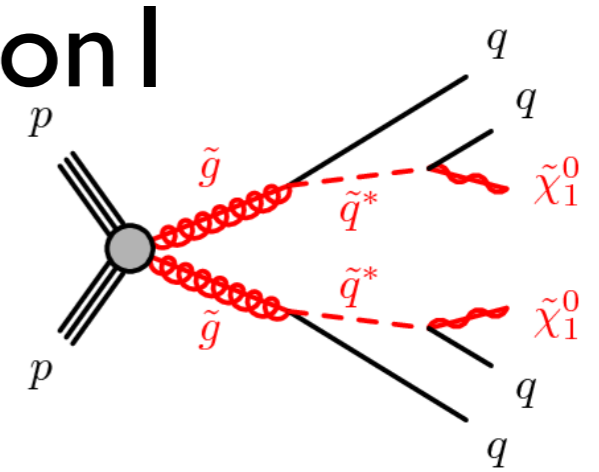
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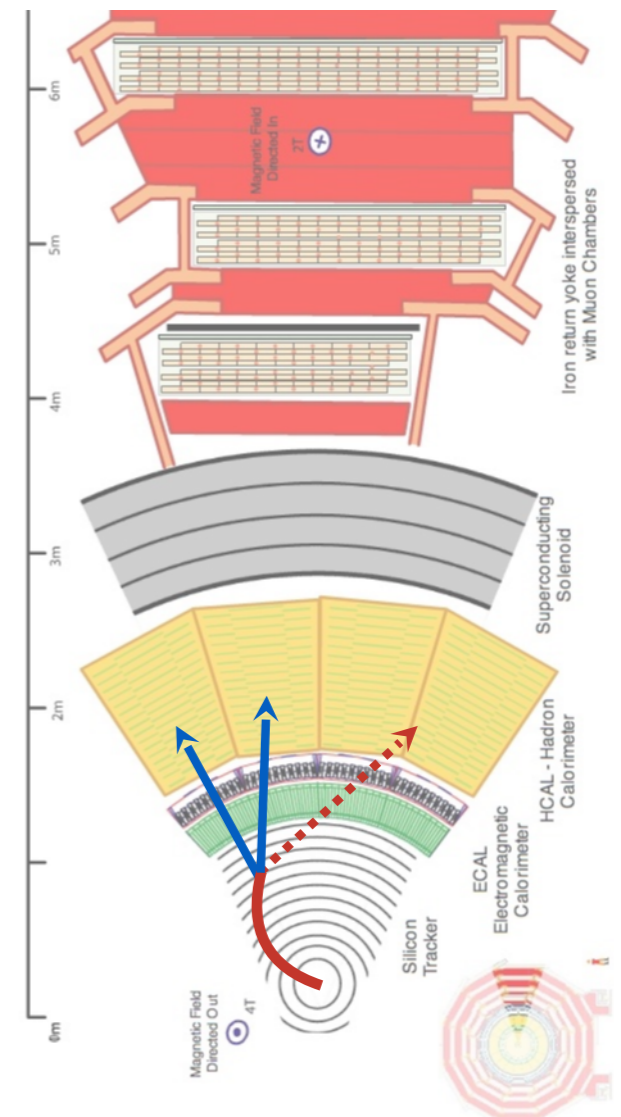
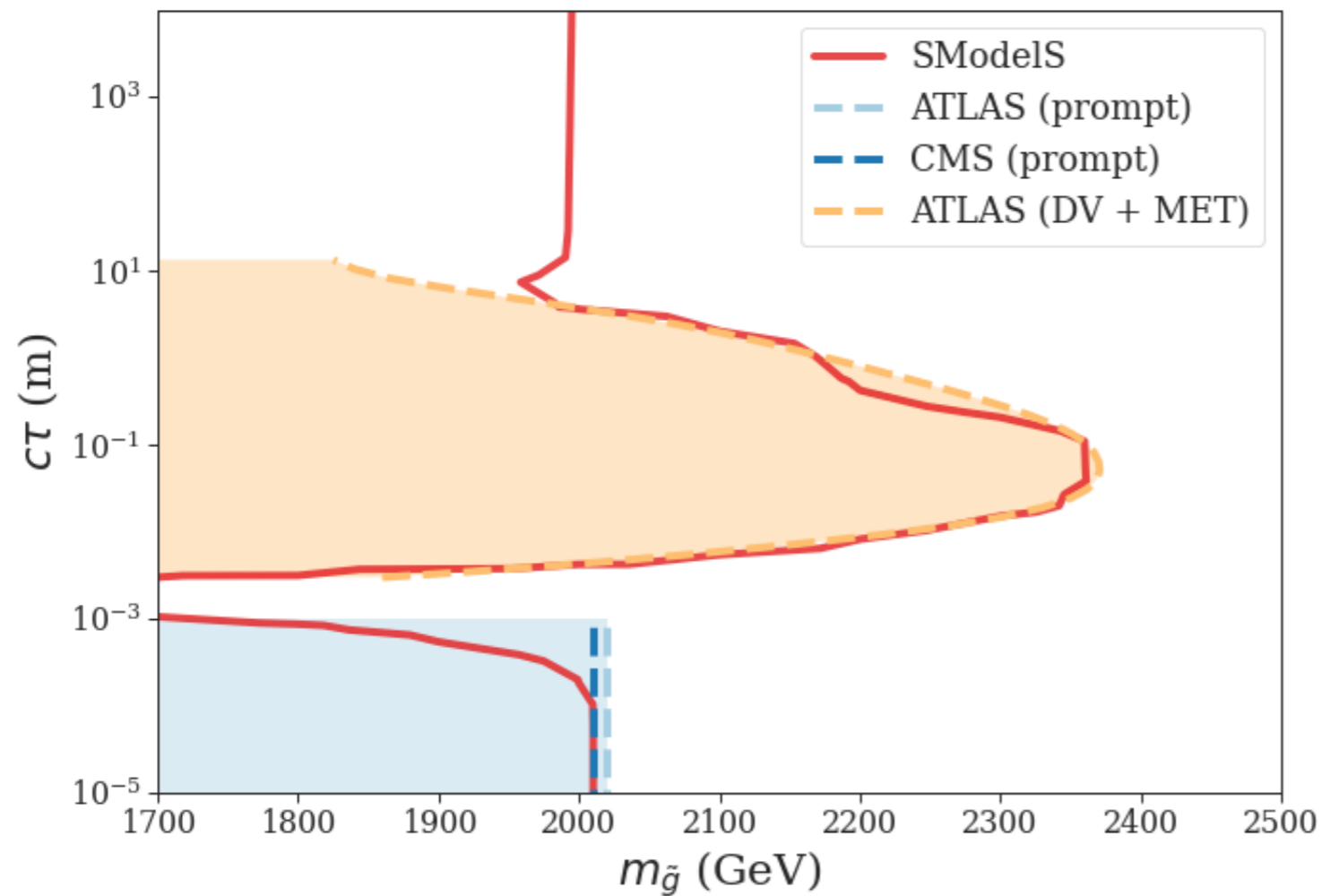
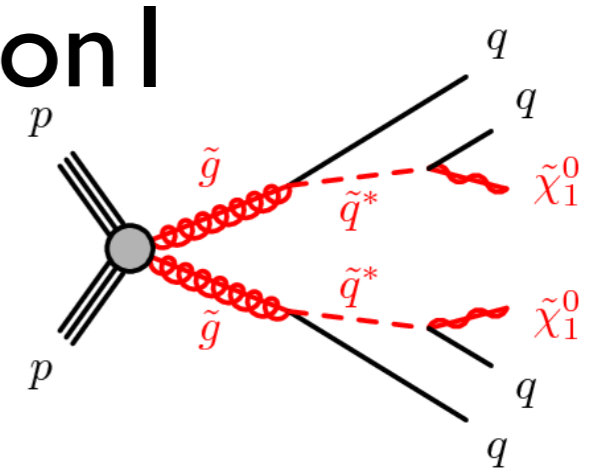
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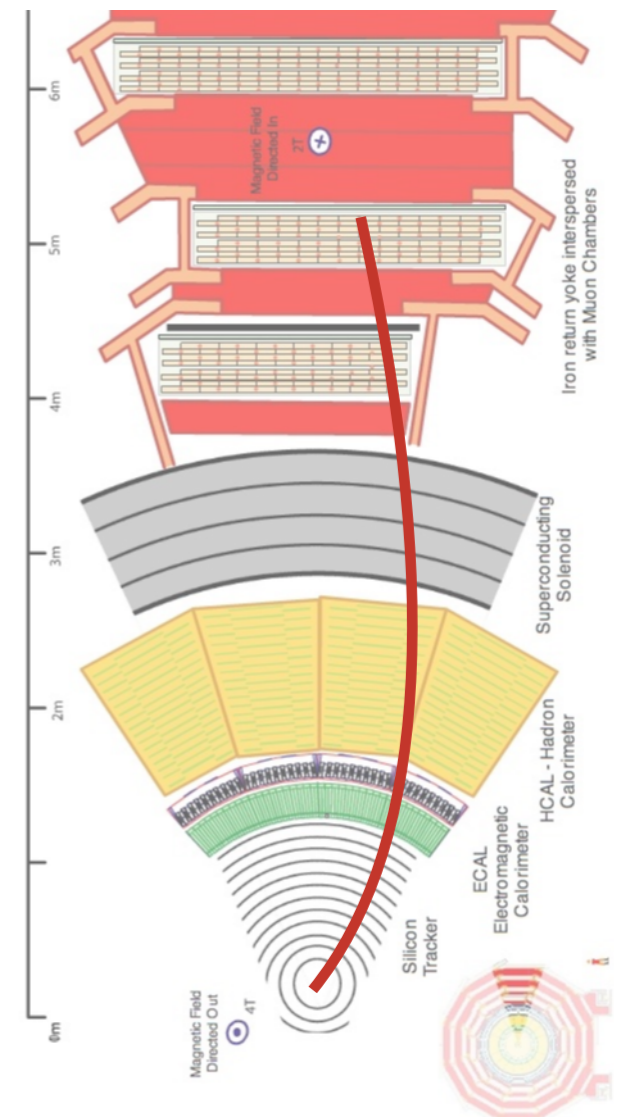
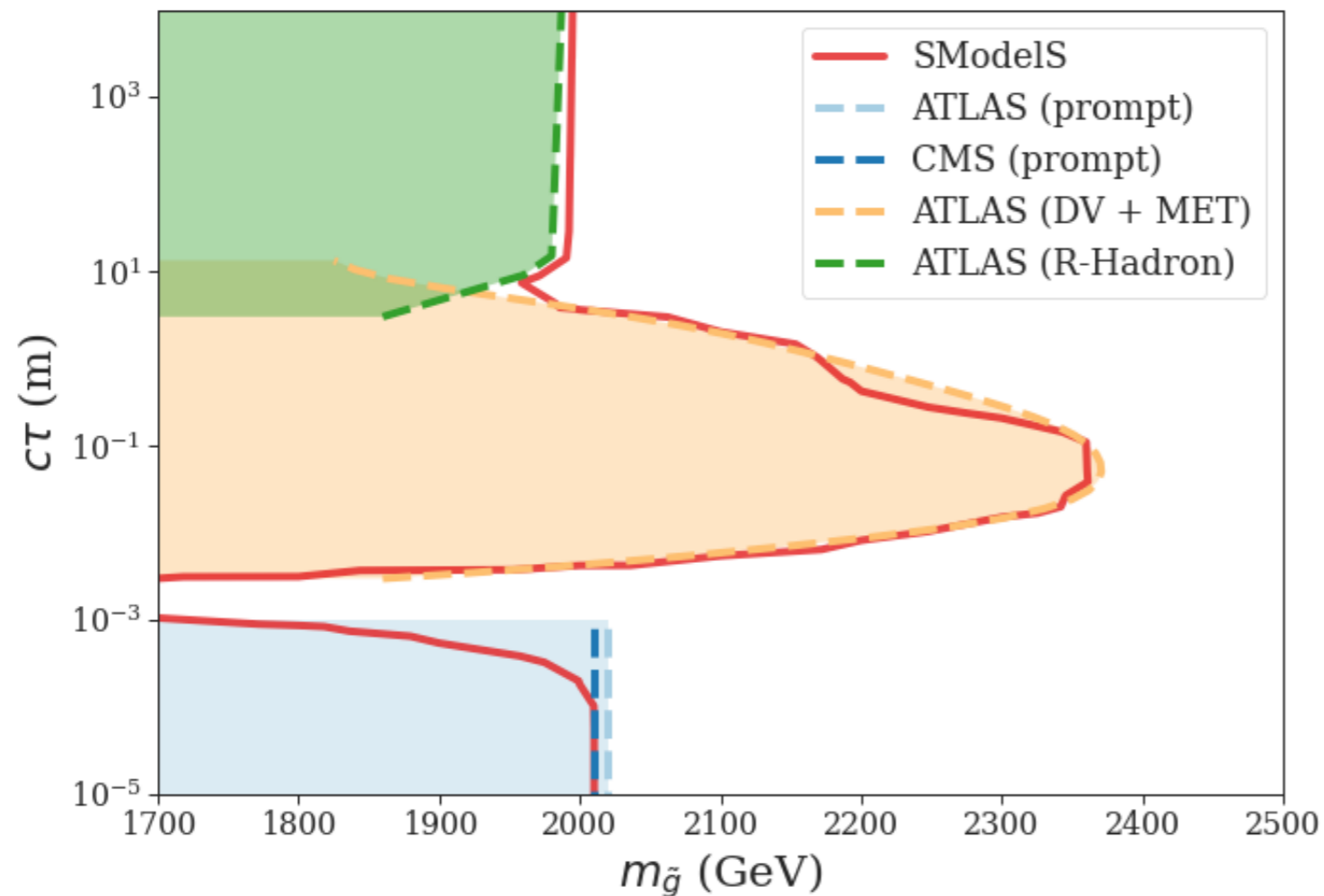
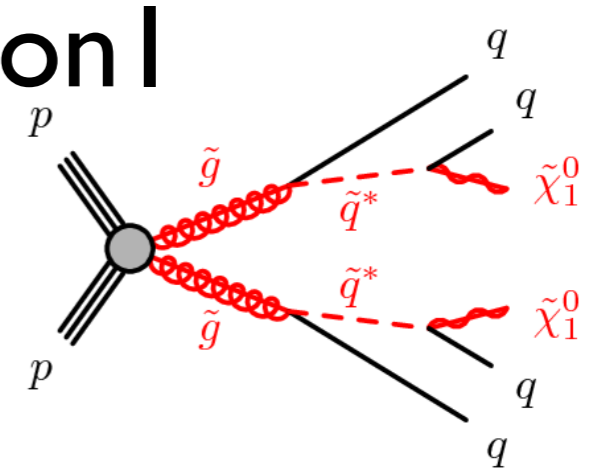
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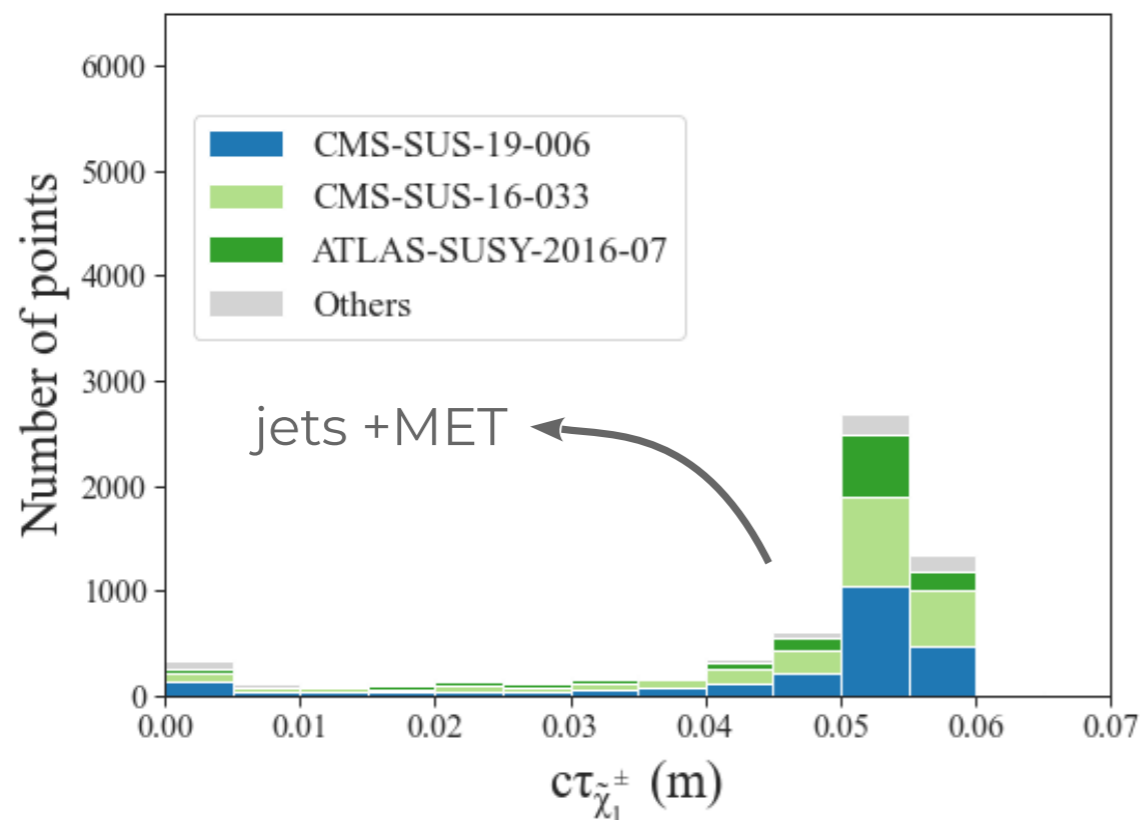


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Long-lived particles: Application 2

- Full model: ATLAS pMSSM scan (wino-like LSP) [1508.06608]
 - 43,680 points allowed by 8TeV results
 - 8,832 points excluded by v1.2.4

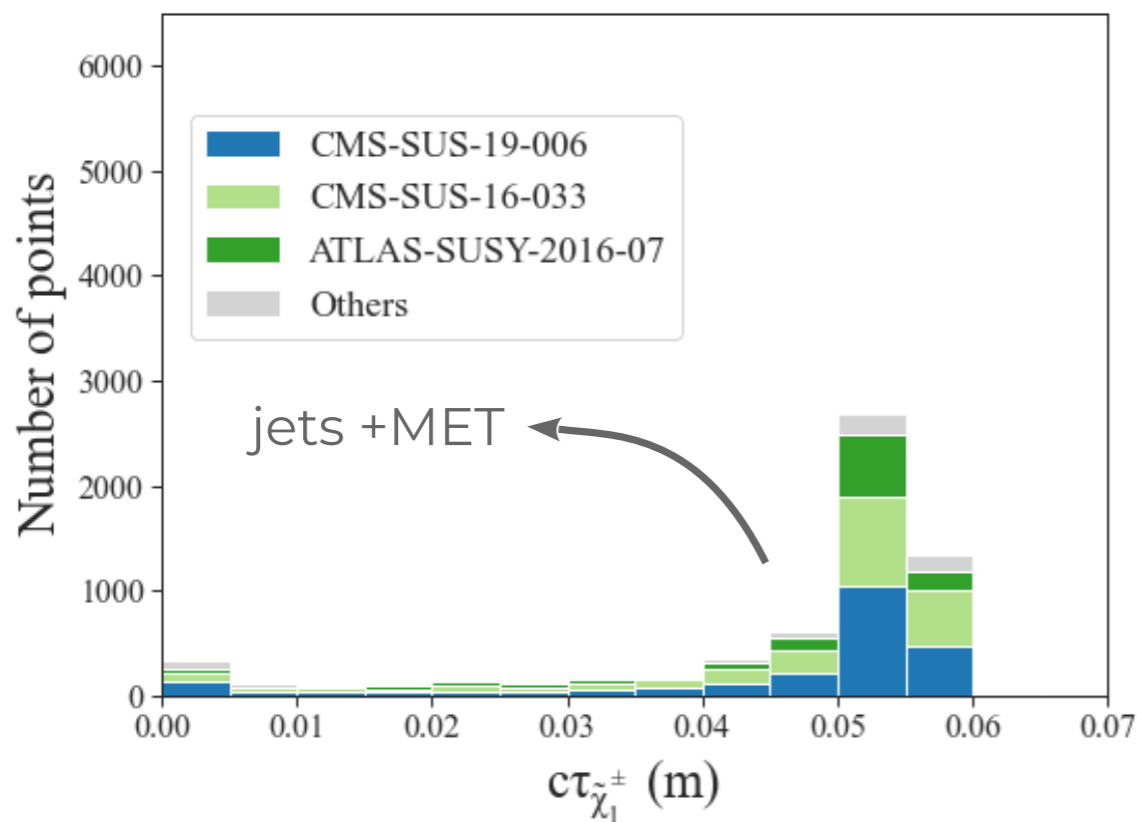
SModelS v1.2.4



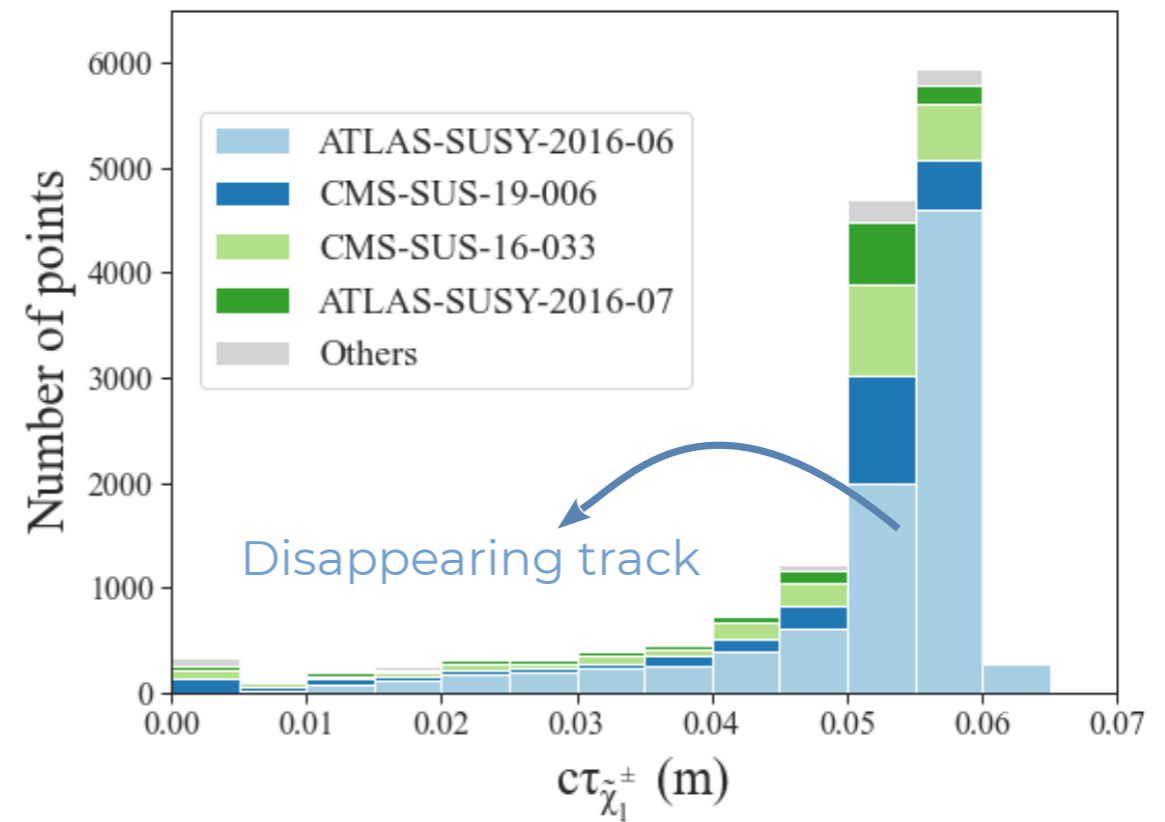
Long-lived particles: Application 2

- Full model: ATLAS pMSSM scan (wino-like LSP) [1508.06608]
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 - 15,474 points excluded by v2.0**

SModelS v1.2.4



SModelS v2.0



Run SModelS 2.0



- Everything you need is explained on smodels.github.io:
 - An [online manual](#)
 - The [installation](#) section
 - The [release notes](#) and [known issues](#)
 - A full [list of analyses](#) of the latest database version, incl. [validation plots](#)
 - An [SMS dictionary](#) explaining the naming scheme used by SModelS
- Useful tools: **SModelS Tools**
 - The [cross section calculator](#)
 - A plotting tool for [interactive plots](#)
 - ...
- Another convenient way to run SModelS: [mircoMEGAs](#) interface
 - Automatic generation of slha files
 - Includes computation of cross sections and decay widths (CalcHEP)

For questions & comments, send us an e-mail: smodels-users@lists.oeaw.ac.at

Conclusions



- SModelS: fast check of new physics models w/o MC simulation
- Direct use simplified-model results from collaborations
- Huge database: 100 searches, ~270 UL results, ~3000 EMs
- Prompt and long-lived searches on same footing
- Growing number of long-lived particle searches
- Particle objects: include widths, charges, spins, ...
- Works beyond cut-and-count analyses (e.g. using ML)
- Missing topologies: detect experimental gaps

<https://smodels.github.io>