

Sabine Kraml

Constraining new physics with SModelS

Based primarily on [arXiv:2112.00769](https://arxiv.org/abs/2112.00769) (SModelS v2) and [arXiv:2306.17676](https://arxiv.org/abs/2306.17676) (SModelS v2.3) in collaboration with *G. Alguero, M. Altakach, J. Heisig, S. Kulkarni, A. Lessa, S. Narasimha, T. Pascal, H. Reyes Gonzalez, W. Waltenberger and A. Wongel* (in bold: people currently active in SModelS)

The XXX International Conference on Supersymmetry and Unification of Fundamental Interactions
Univ. of Southampton, UK
17 - 21 July 2023



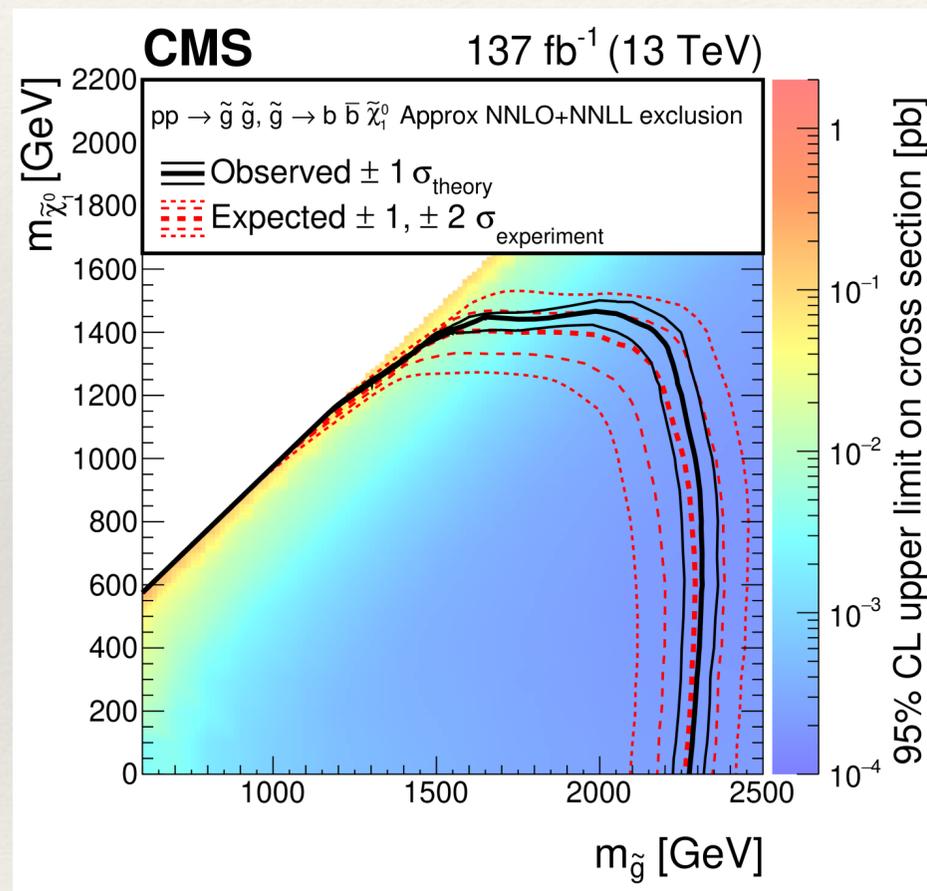
Overview

- ❖ Motivation
- ❖ SModelS working principle
 - ▶ assumptions, caveats
- ❖ Extended simplified model description
 - ▶ treatment of long-lived particles
- ❖ Combination of signal regions and comb. of analyses (new!)
- ❖ Database extension
- ❖ Impact for EW-ino sector of the MSSM
- ❖ Conclusions

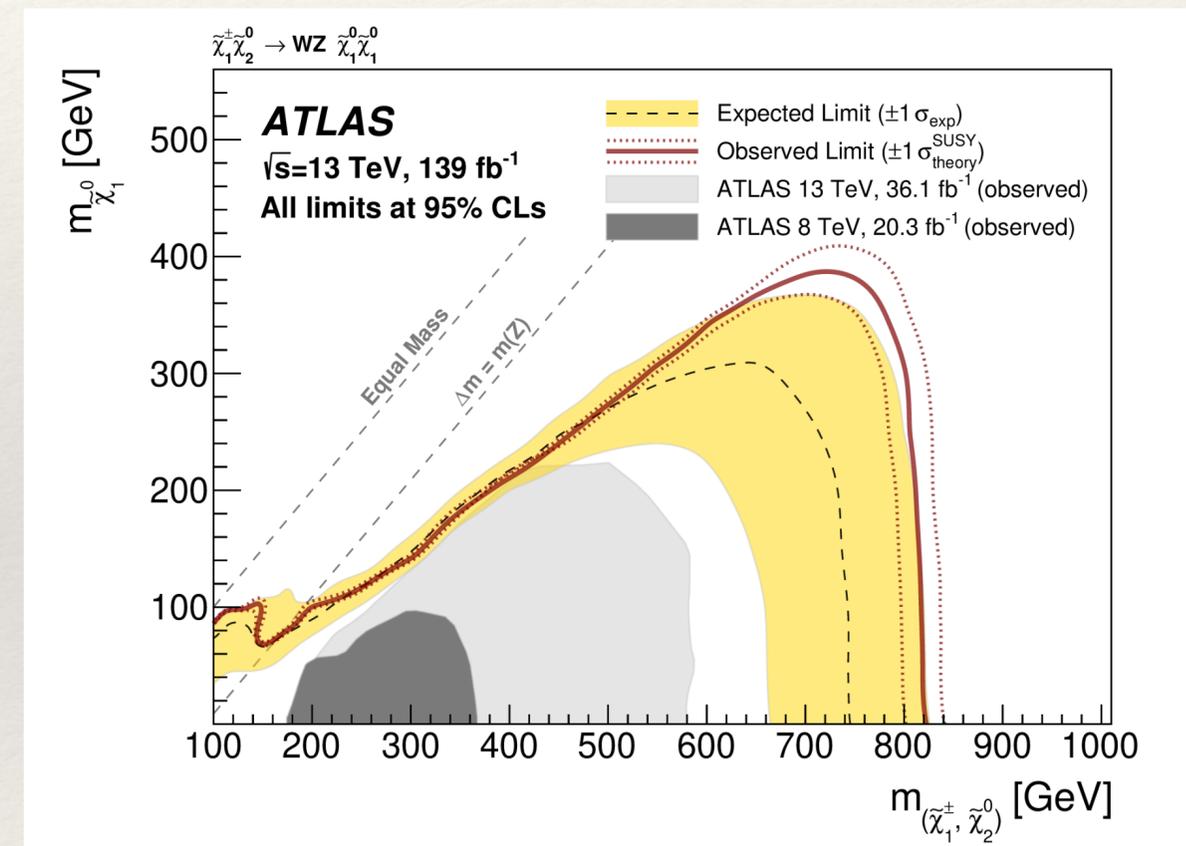


LHC searches for new physics

Pursued on a **channel-by-channel** basis in **specific final states**; results typically presented in the context of simplified models. Examples:



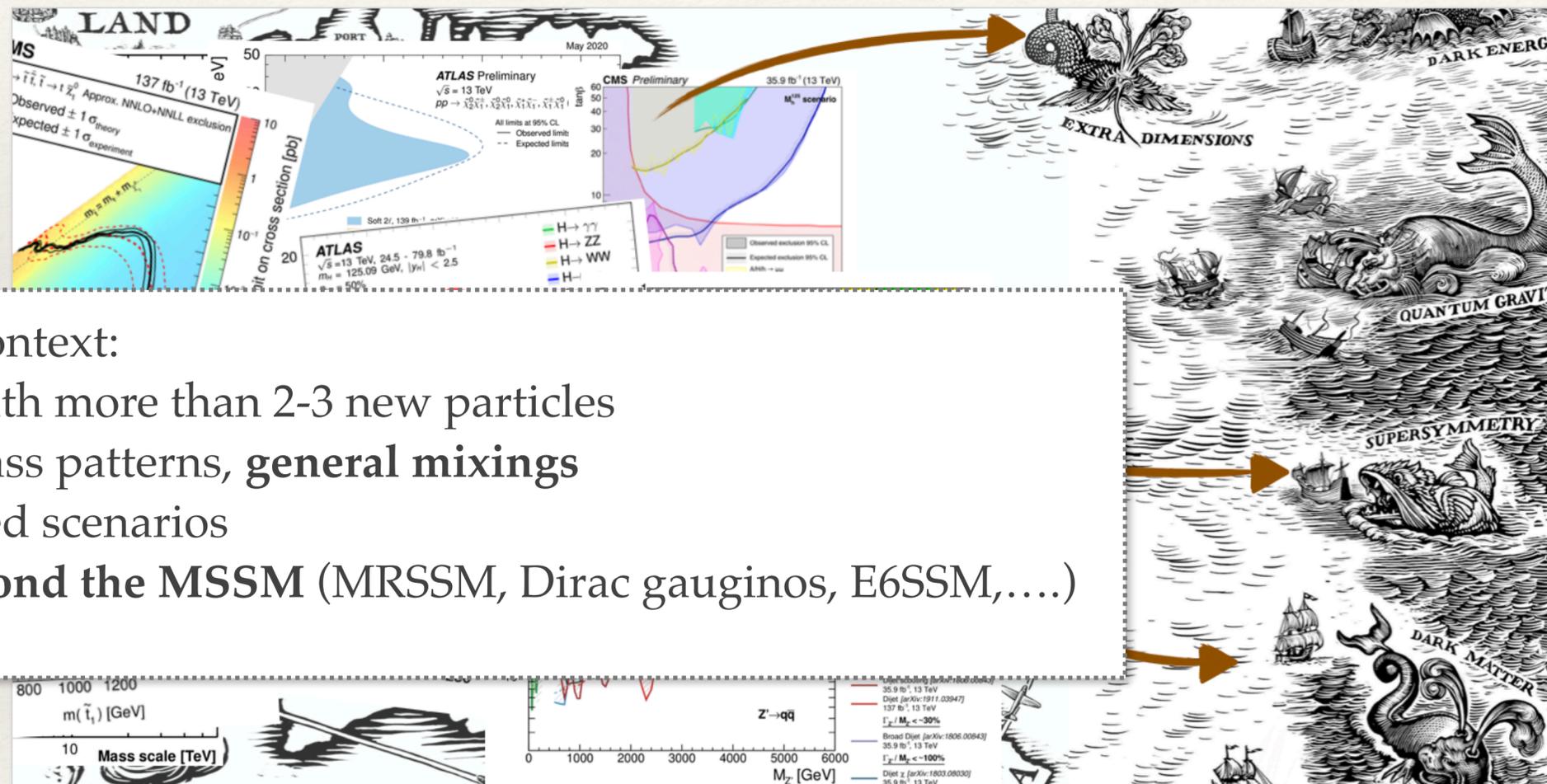
CMS-SUS-19-006: search in final states with multiple jets and large MET



ATLAS-SUSY-2018-05: search in events with two leptons, jets, and MET

... and their (re)interpretation

Aim: obtain a **comprehensive view** of how the plethora of LHC results constrain new physics in the context of **realistic theoretical scenarios** (incl. non-minimal / non-standard ones!)



In the SUSY context:

- scenarios with more than 2-3 new particles
- arbitrary mass patterns, **general mixings**
- GUT-inspired scenarios
- models **beyond the MSSM** (MRSSM, Dirac gauginos, E6SSM,.....)
- ...

Embarrassment of riches ATLAS, CMS and LHCb are sensitive to a far greater set of theories and parameter combinations than have so far been tested.

CERN Courier 28 April 2021

**Reproduce
experimental analysis
in a Monte Carlo simulation**

“recasting”

**Reuse
simplified model results**
(σ_{95} , signal $A \times \epsilon$)

Assumes that $A \times \epsilon$ doesn't change
too much w.r.t. original model

Talk by T. Gonzalo
yesterday pm



(+ATLAS SimpleAnalysis)

**Test of
BSM hypothesis**



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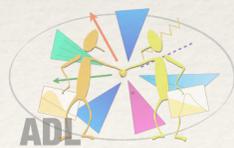
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This Talk

**Test of
BSM hypothesis**



**RIVET
Contur**



(+ATLAS SimpleAnalysis)

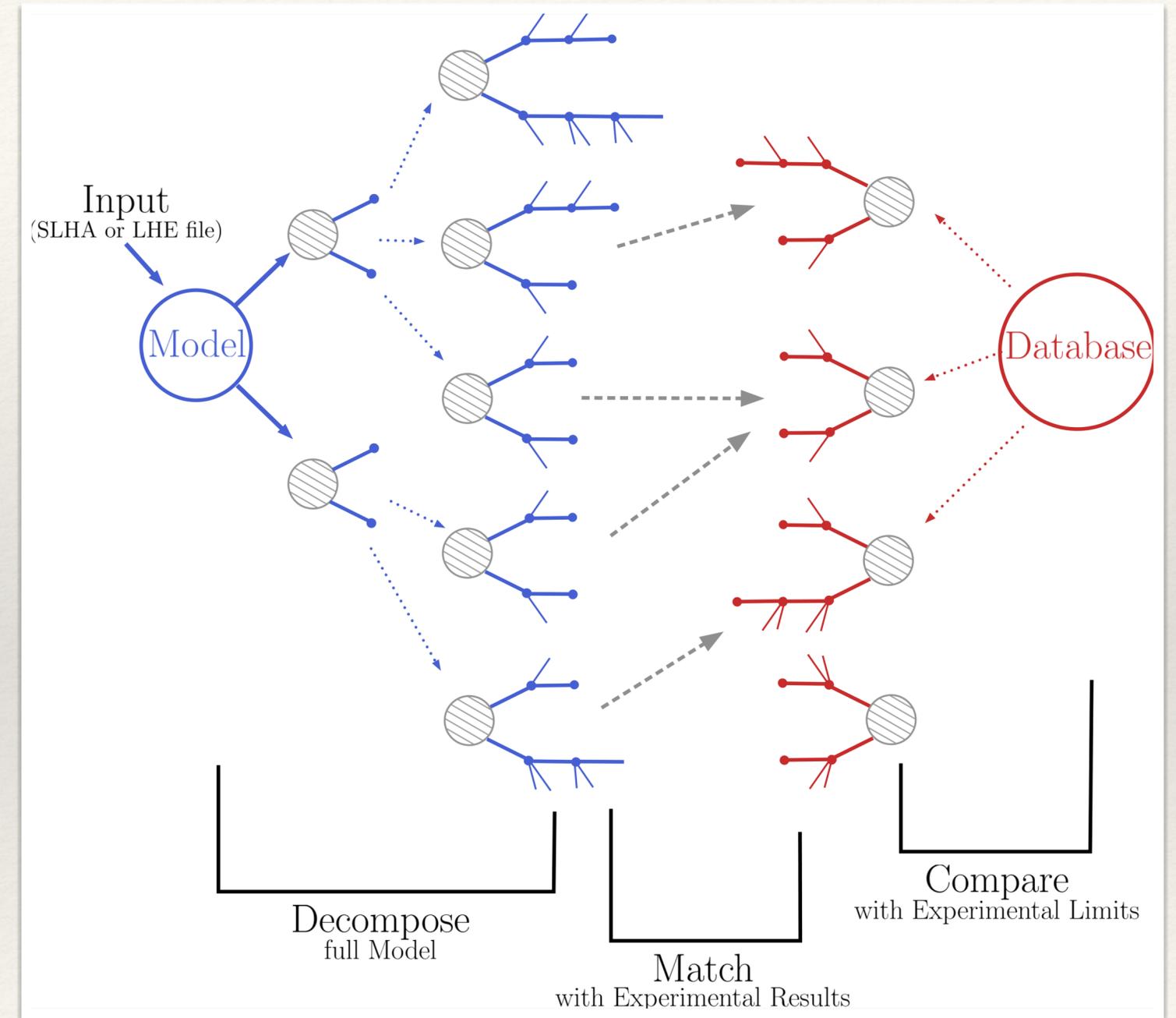


See also talk by T. Pascal yesterday pm

SModels working principle

<https://smodels.github.io>

- ❖ Public tool for the fast reinterpretation of LHC searches on the basis of simplified-model results.
- ❖ Working principle: **decompose** the signatures of **full BSM scenarios into simplified model components**, which are then confronted against the experimental constraints from a **large database of results**.
- ❖ Input: SLHA files with mass spectrum, decay tables and cross sections.
- ❖ Options set in `parameters.ini` file.
- ❖ Any BSM model with a Z_2 -like symmetry!



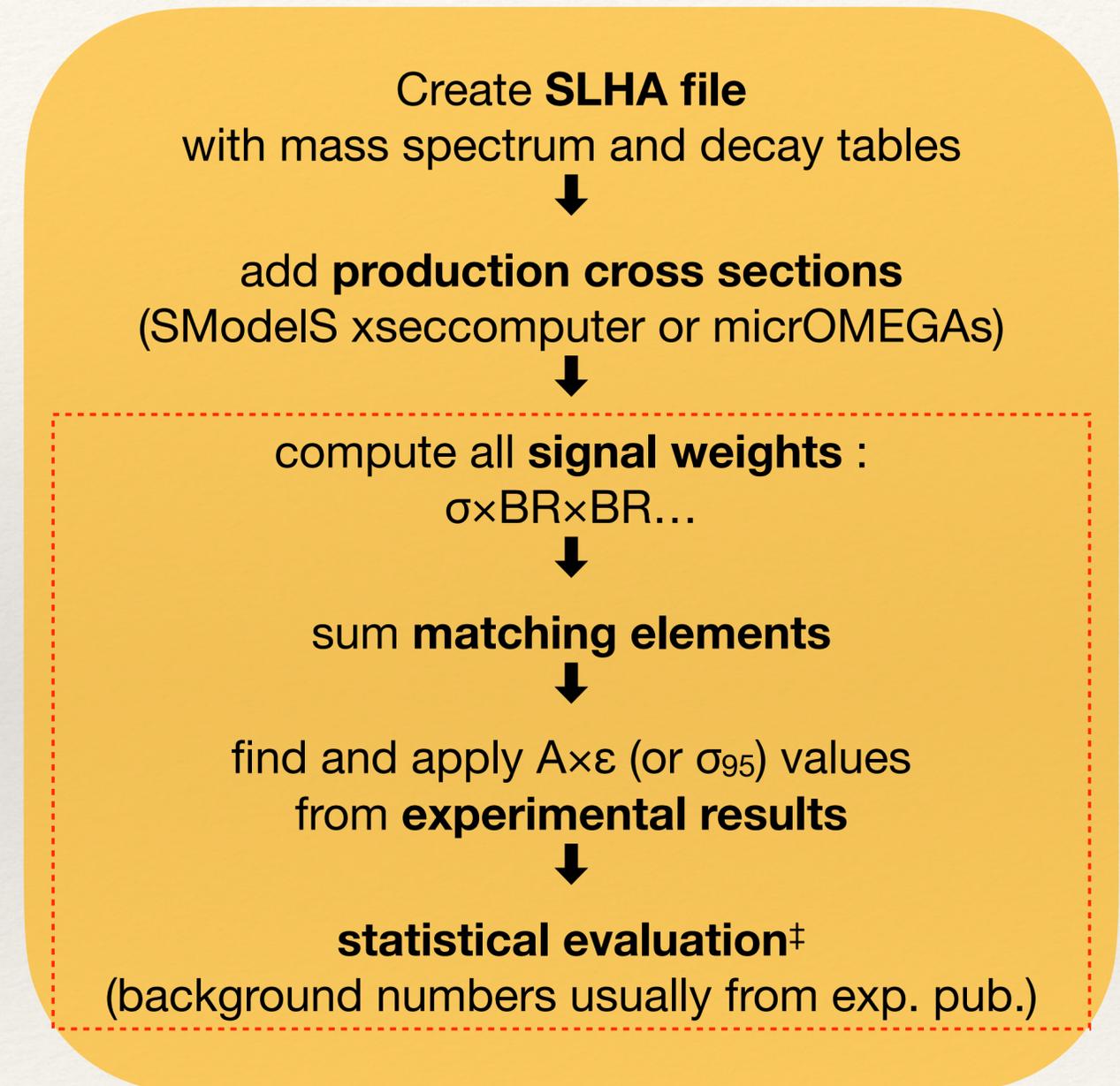
Pros and cons

- Assumes that **signal acceptances** are to good approximation **the same** as in original experimental result.

Valid for **simple rescaling** of production and decay rates ($\sigma \times BR$); other cases need to be **verified**, e.g. spin or production mode dependence.

- Applicable also for ML-based analyses (difficult to impossible to recast)
- Advantages are simplicity and **speed!**
 - **very fast** b/c no MC simulation needed
 - well suited for large scans and model surveys
- Large database** of experimental results
- ATLAS and CMS, Run1 and Run2, **prompt and long-lived results** all **treated simultaneously**
- Easy **classification** of unconstrained cross section, **missing topologies**
- Often conservative:** coverage depends on variety of available simplified-model results

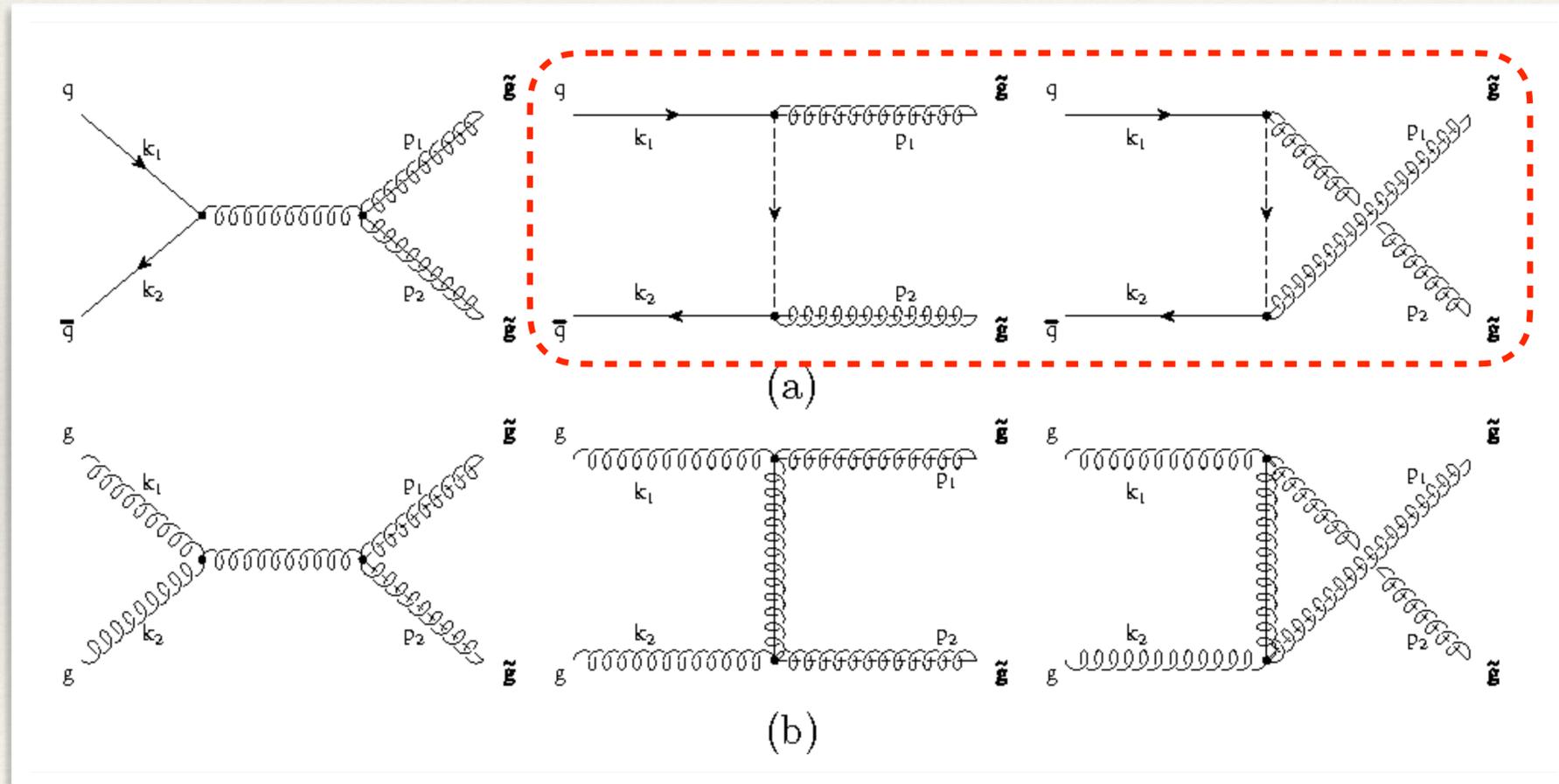
simplified model approach (SModelS)



‡ in case exp. result is σ_{95} : only allowed/excluded

Signal acceptances to good approximation the same ?

- ❖ SModelS ignores details of the production modes (s - or t -channel, intermediate states, ...)
- ❖ Example: experimental results for gluinos usually assume decoupled squarks and vice-versa



SModelS assumes that presence of squark contribution won't significantly change gluino kinematic distributions

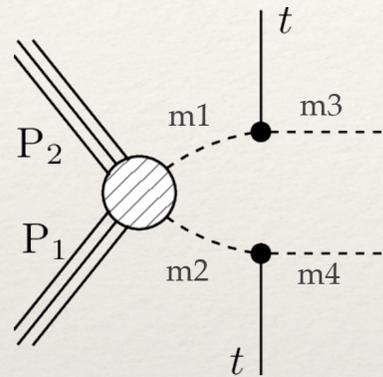
→ signal acceptances and limits on cross sections remain valid

[see arXiv:1312.4175](https://arxiv.org/abs/1312.4175)

Feynman diagrams for gluino pair production: (a) quark-antiquark initial states, (b) gluon-gluon initial states.
Figure credit: Gehrman, Maitre, Wyler, NPB 2004

Signal acceptances to good approximation the same ?

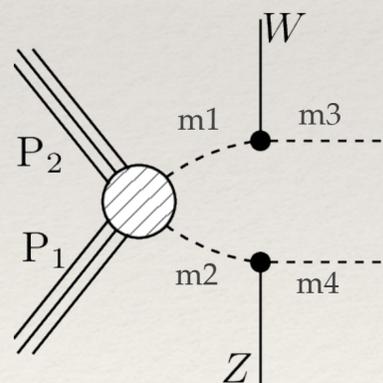
- ❖ For “prompt” signatures, SModelS ignores quantum numbers of BSM particles other than their masses



topology: [[[t]], [[t]]] ... “T2tt”
 masses: (m1,m3), (m2,m4)
 final states: (MET, MET)

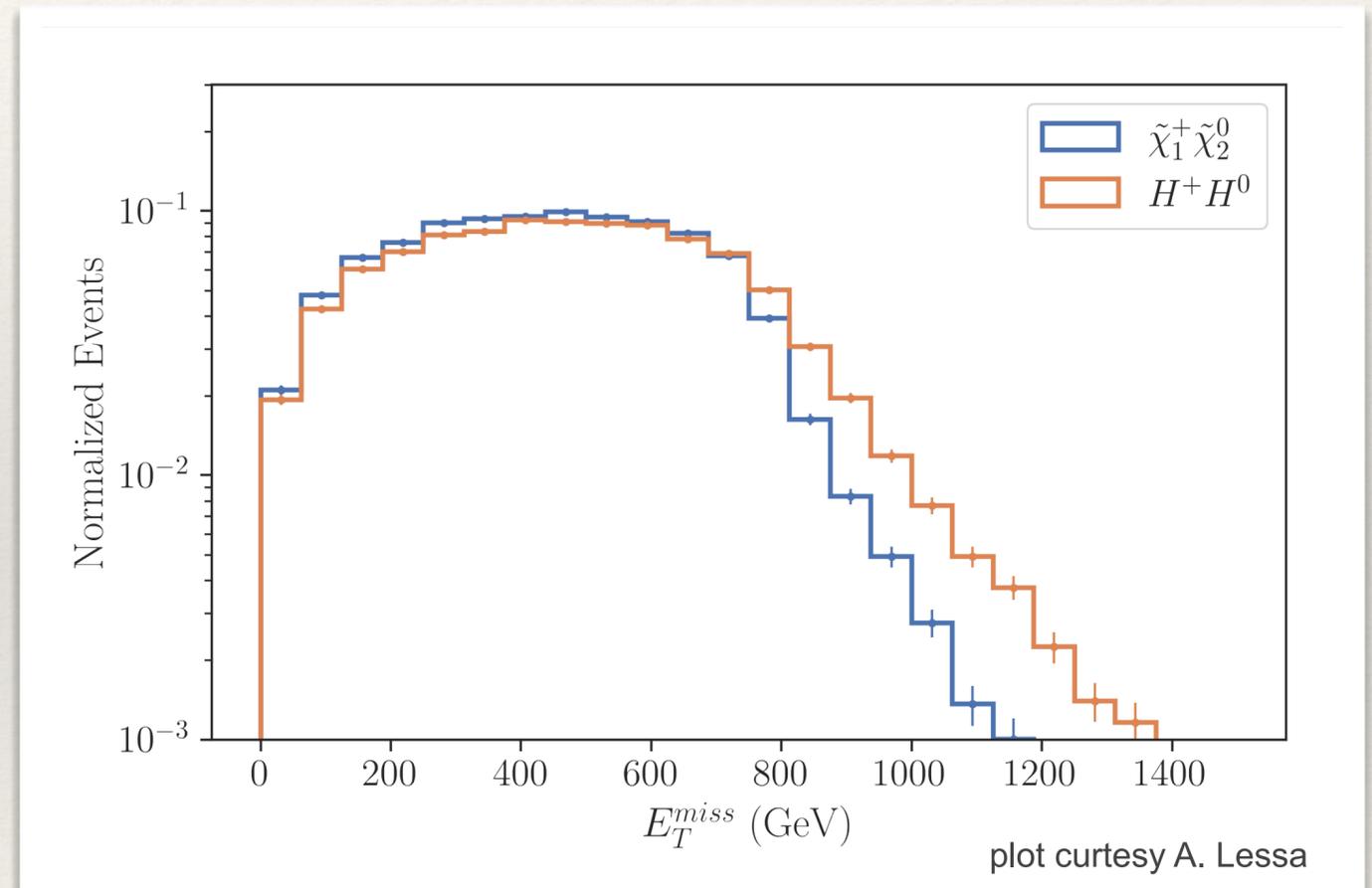
Typically stop → top +LSP, but same signature from fermionic top partner

validity studied in [arXiv:1607.02050](https://arxiv.org/abs/1607.02050)



topology: [[[W]], [[Z]]] ... “TChiWZ”
 masses: (m1,m3), (m2,m4)
 final states: (MET, MET)

A priori chargino/neutralino,
 but also $H^\pm H^0$ in inert doublet model



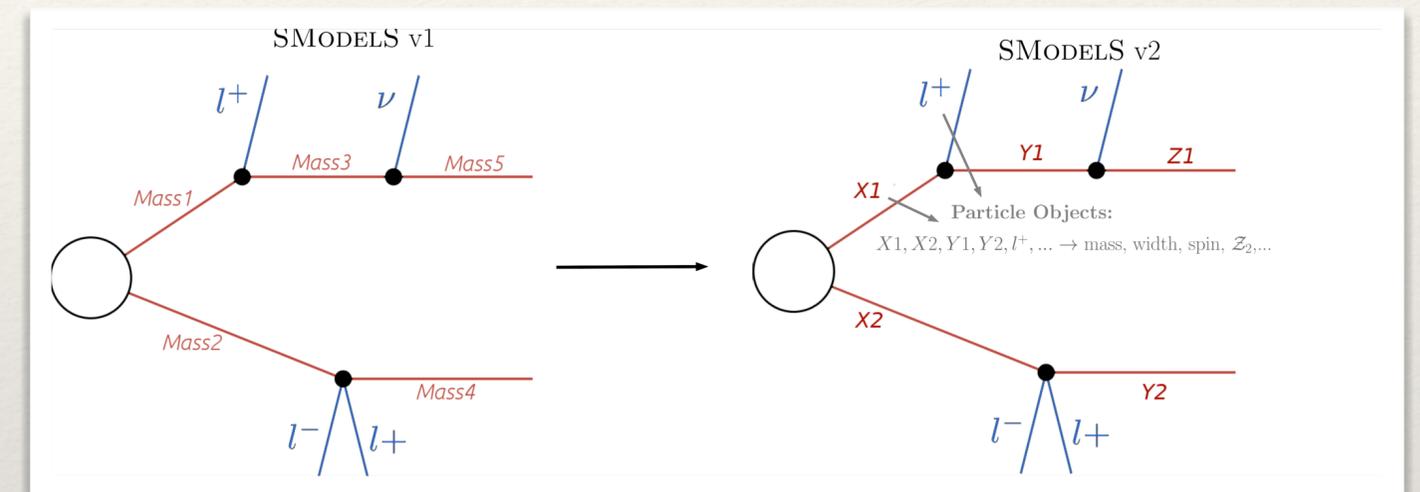
$pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W^\pm Z \tilde{\chi}_1^0 \tilde{\chi}_1^0$ versus $pp \rightarrow H^\pm H^0 \rightarrow W^\pm Z A^0 A^0$
 $m(\text{mothers}) = 800 \text{ GeV}, m(\text{daughters}) = 100 \text{ GeV}$

Extended topology description in v2 series

arXiv:2112.00769

- ❖ So far, the simplified model description involved only the structure of the topology (number of vertices in each branch, and number and type of SM final states in each vertex) and the masses of the BSM particles

- ❖ Now extended by flexible number of attributes for the BSM particles, such as spin, charge, decay width, etc.



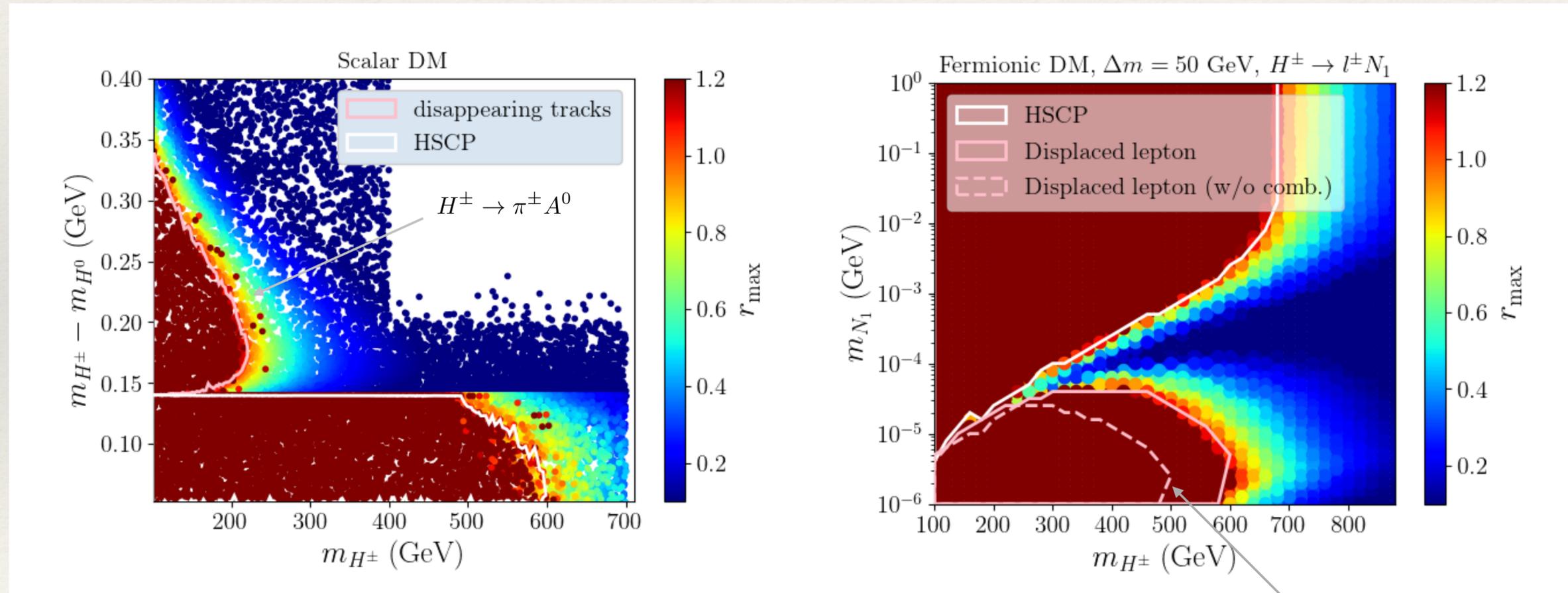
- ❖ Allows in particular for a better treatment of long-lived particle (LLP) signatures.

- ▶ width-dependent results
- ▶ spin often matters (e.g. disappearing tracks: trigger on ISR jet)

- heavy stable charged particles
- disappearing tracks
- displaced leptons
- displaced jets

LLP example: charged scalars in scotogenic model

- ❖ Supplements the SM by an additional SU(2) scalar doublet, Φ , (“inert doublet”) and three sterile neutrinos, N . The new fields are taken to be odd under a new Z_2 -parity, while the SM fields are even.
- ❖ Lightest new state is stable and a dark matter (DM) candidate; can be neutral scalar or sterile neutrino (fermion).

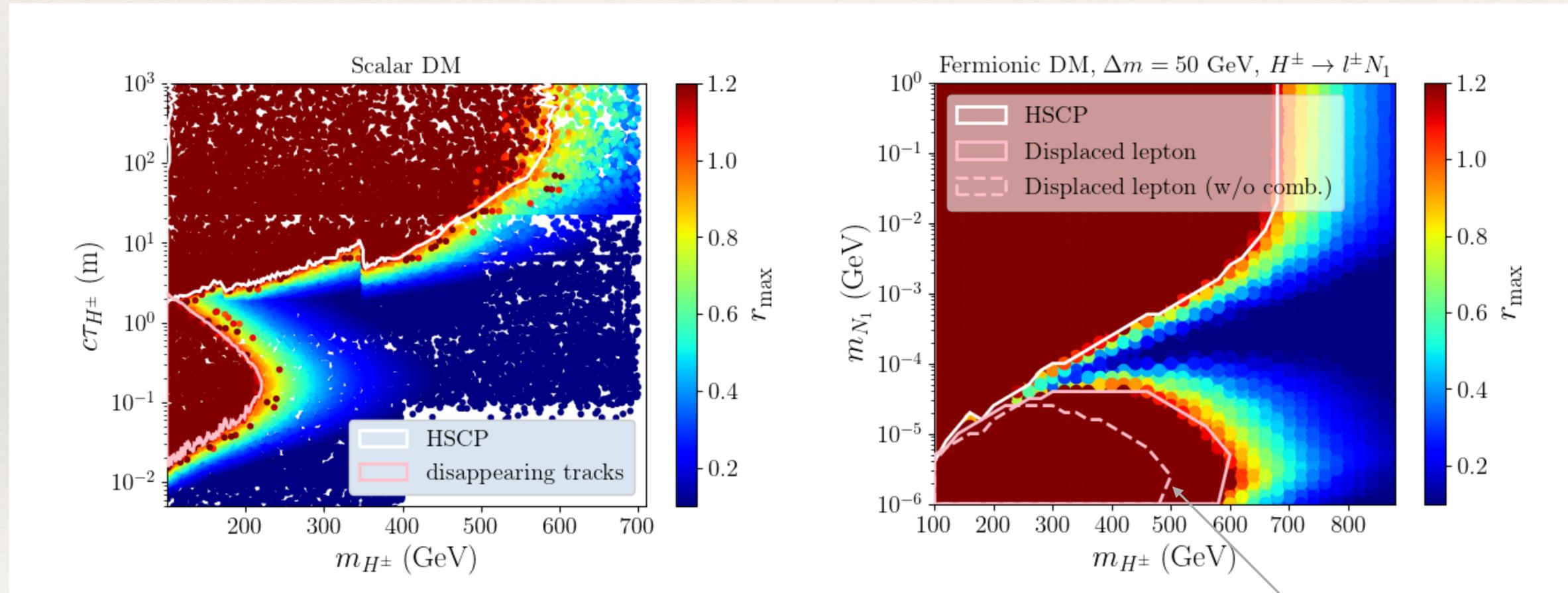


$$r = \frac{\text{theory prediction}}{\text{experimental limit}}$$

Limit without signal region combination;
>100 GeV weaker

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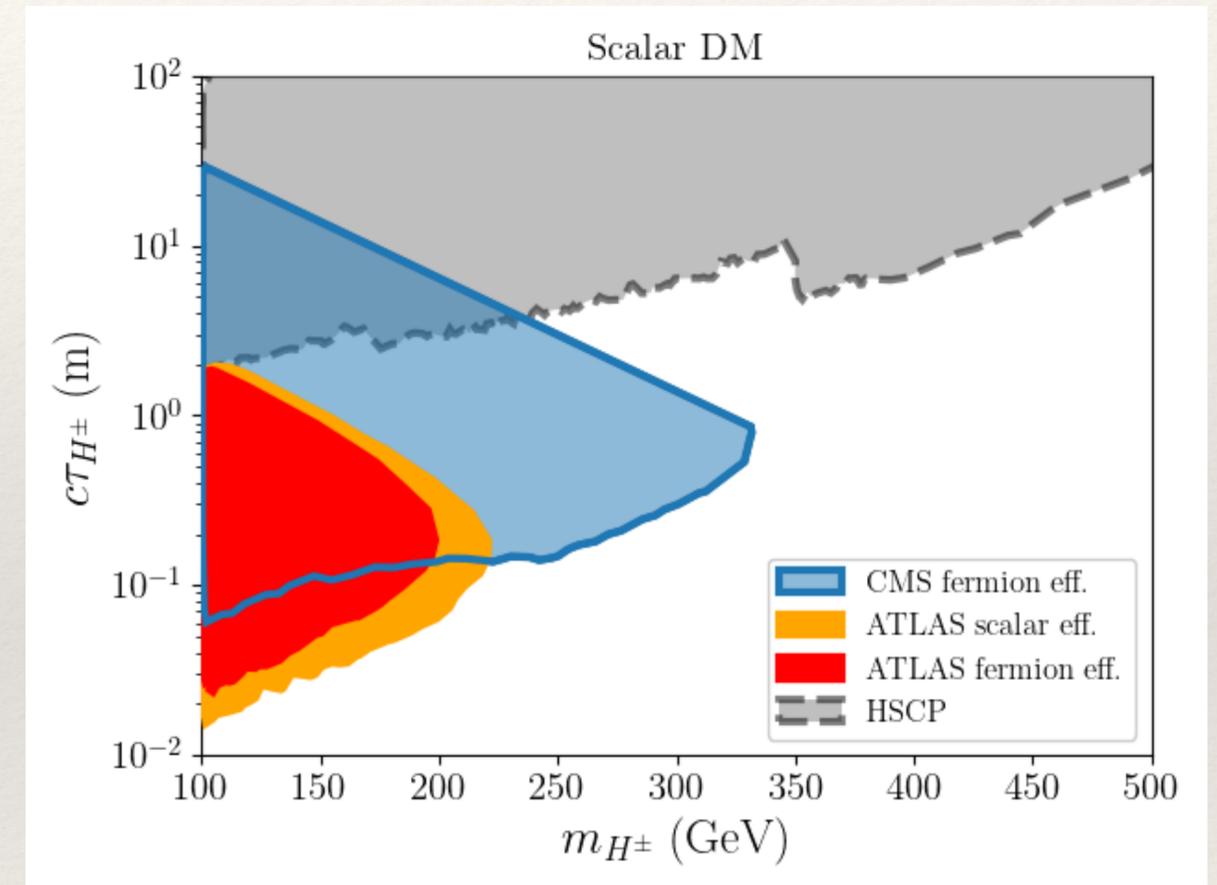
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Spin dependence

- ❖ LLP decay length depends on the LLP boost and consequently on its spin
- ❖ Disappearing track analyses: pursued as searches for long-lived charginos
 - ❖ ATLAS-SUSY-2016-06, 36 / fb: we use efficiencies recasted by *Belyaev et al.* for both the fermion (chargino) and the scalar (charged Higgs) LLP cases. [arXiv:2008.08581](https://arxiv.org/abs/2008.08581), Zenodo dataset
 - ❖ CMS-EXO-19-010, 101 / fb: use official results from CMS; only the fermion (chargino) case is available.

[arXiv:2112.00769](https://arxiv.org/abs/2112.00769)



Note: ATLAS-SUSY-2018-42, 139 / fb: official chargino results not reusable; not pure topologies but sum of 1 and 2 charged tracks (C1N2 and C1C1 prod.); recast in progress.

[A. Lessa, talk at LLP workshop, June 2023](#)

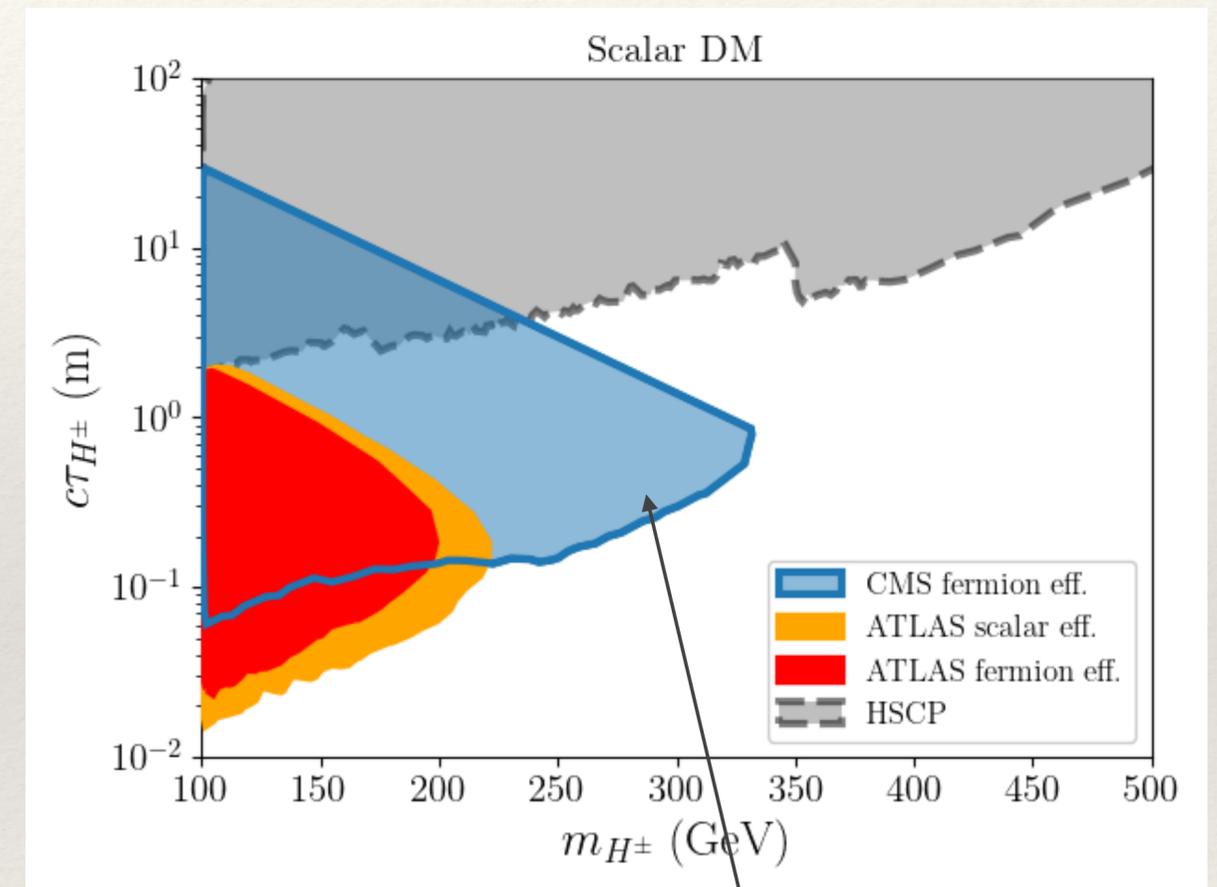
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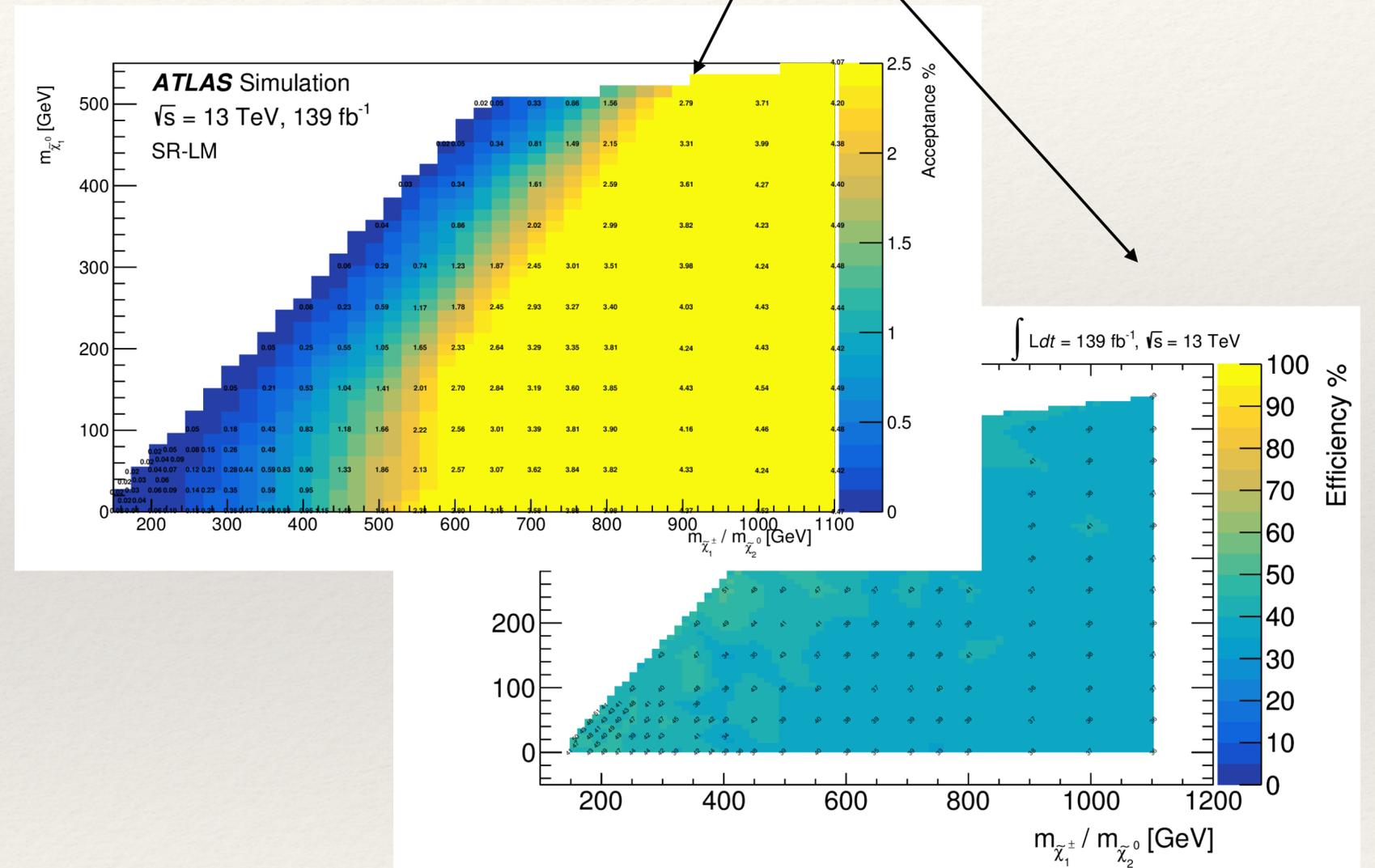
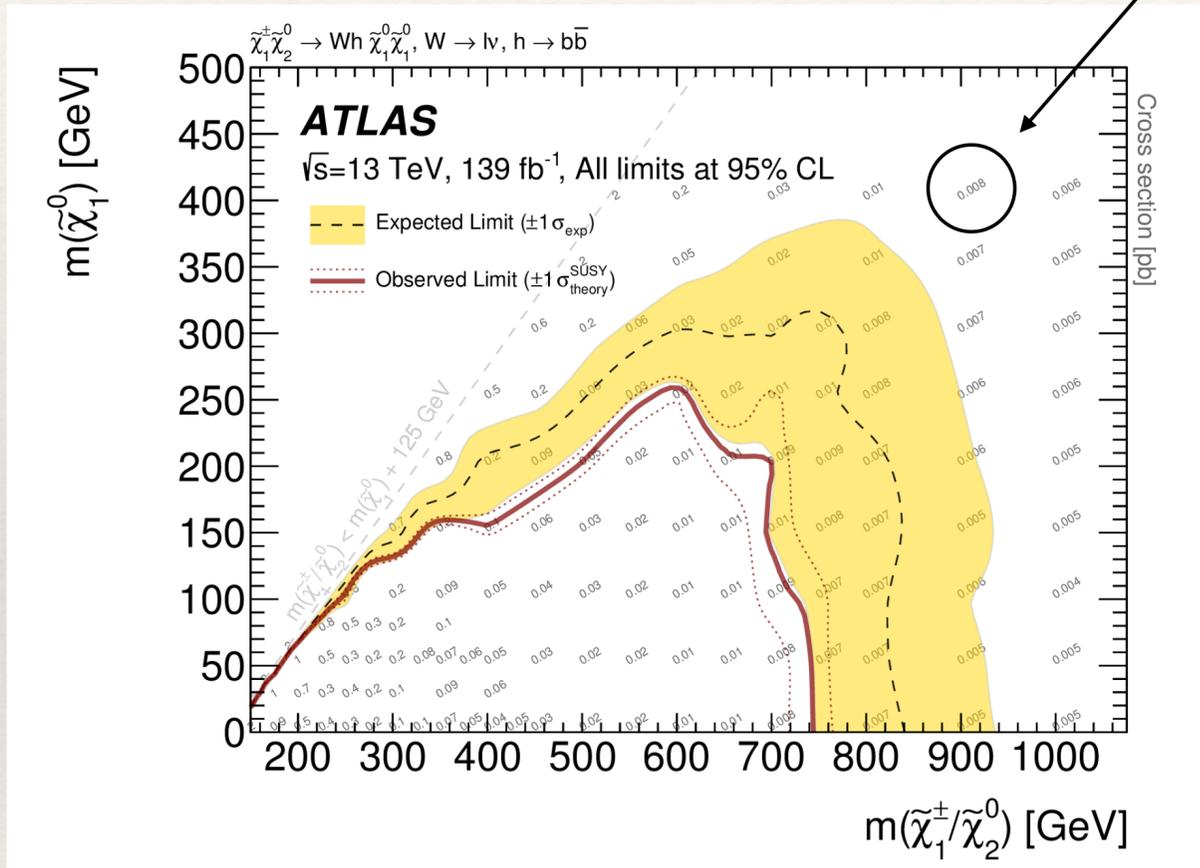
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Users who want to use the CMS result for scalar LLPs, have to “trick” SModelS into it; e.g. change qnumbers in model input, or download text database and change spin assignment for the CMS-EXO-19-010 maps.

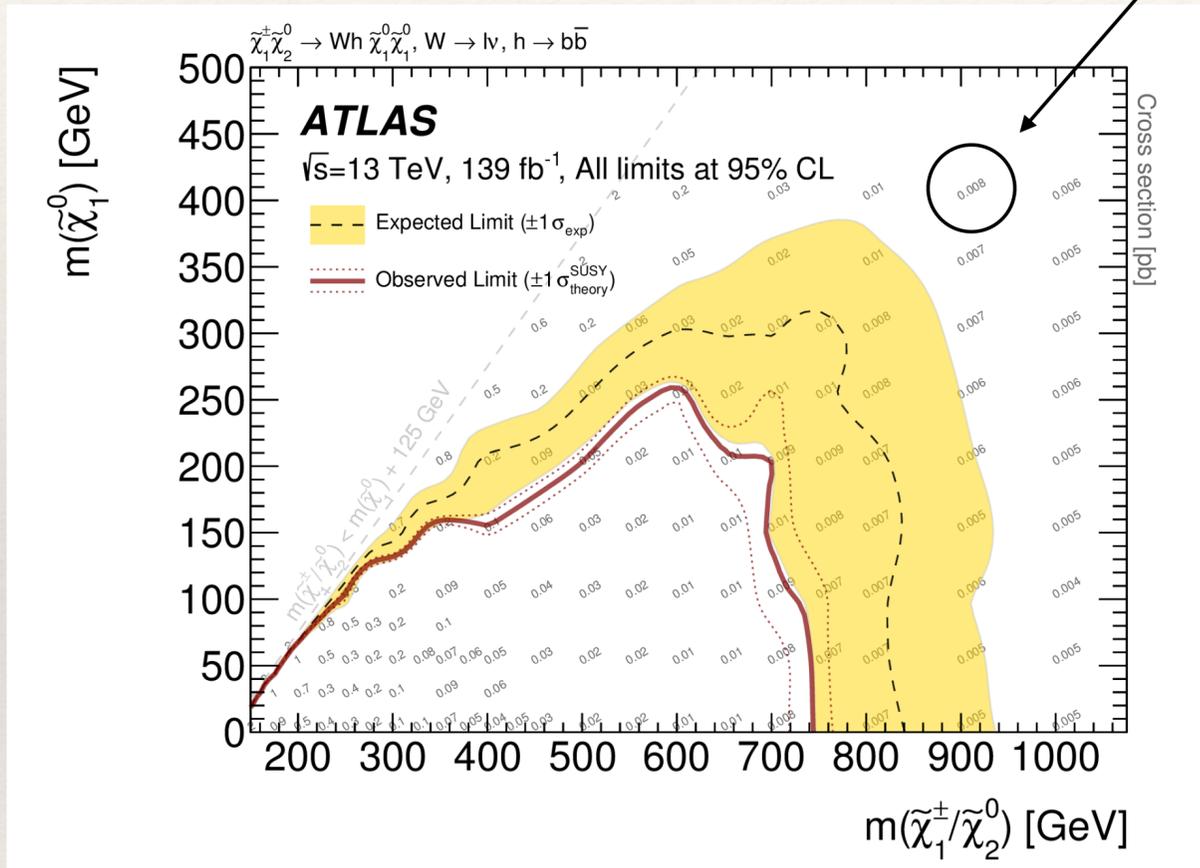
Experimental results used in SModelS

upper limit (UL) maps and $A \times \epsilon$ 'efficiency' maps (EM)



Experimental results used in SModelS

upper limit (UL) maps and $A \times \epsilon$ 'efficiency' maps (EM)



- ❖ Maps of 95% CL upper limits on the signal cross section (σ_{95}) as function of the simplified model parameters

$$r = \frac{[\sigma \times \text{BR} \times \text{BR}]}{\sigma_{95}} \quad \leftarrow \text{theory prediction for the signal}$$

- ❖ Excluded if $r \geq 1$
- ❖ Binary decision: excluded or not

Experimental results used in SModelS

upper limit (UL) maps and **A×ε ‘efficiency’ maps (EM)**

Maps of $A\varepsilon$ for the signal regions of an analysis allow us

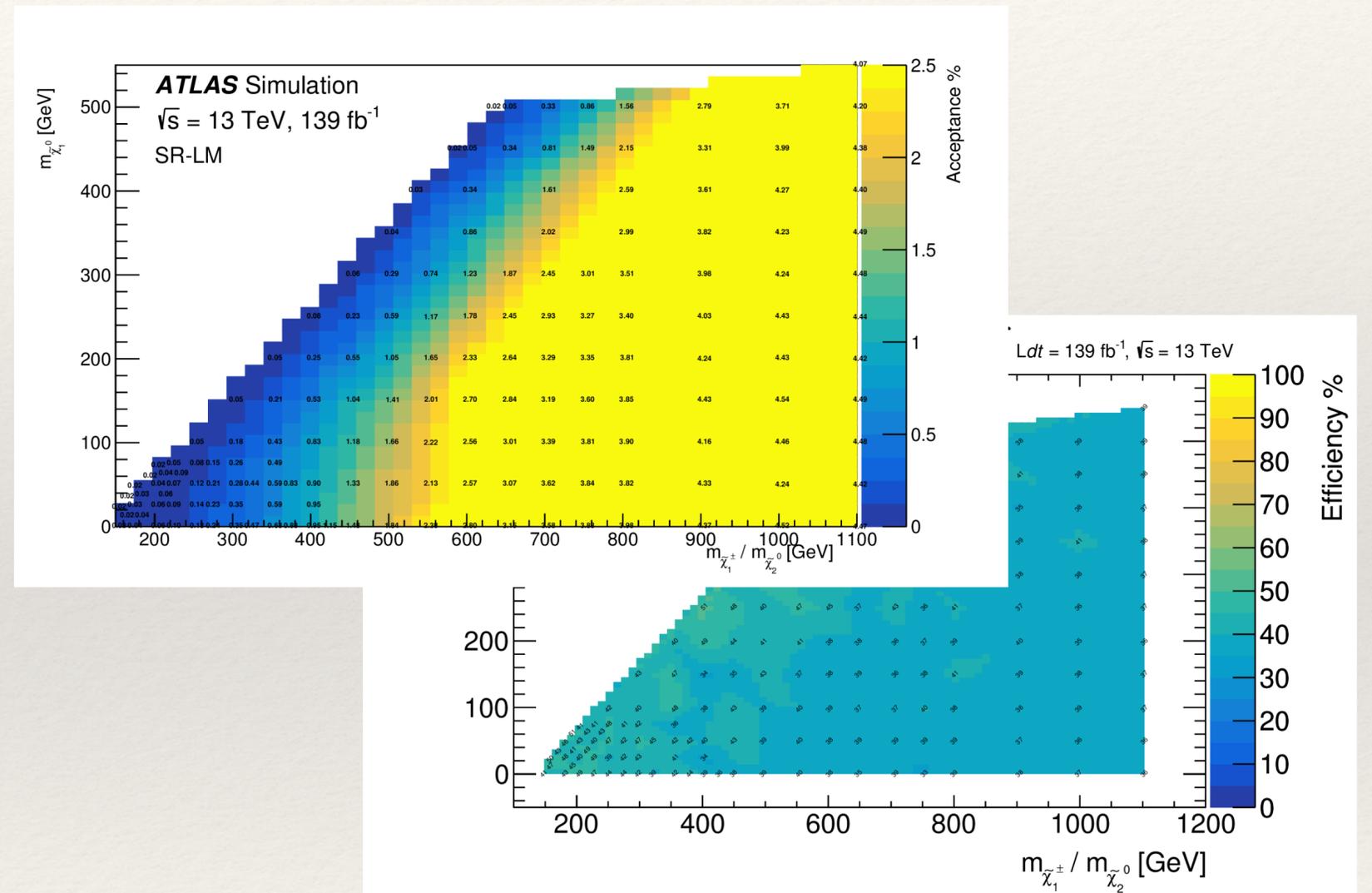
- ▶ to sum different contributions to the same signal region

$$n_{\text{sig}} = \sum A\varepsilon [\sigma \times \text{BR} \times \text{BR}] \times \mathcal{L}$$

- ▶ given expected and observed numbers of events, **compute a likelihood** for the hypothesised signal *)

$$\mathcal{L}(\mu, \theta | D) = P(D | \mu s + b + \theta) p(\theta)$$

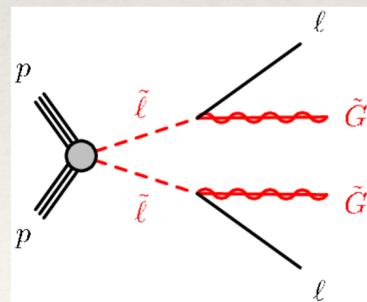
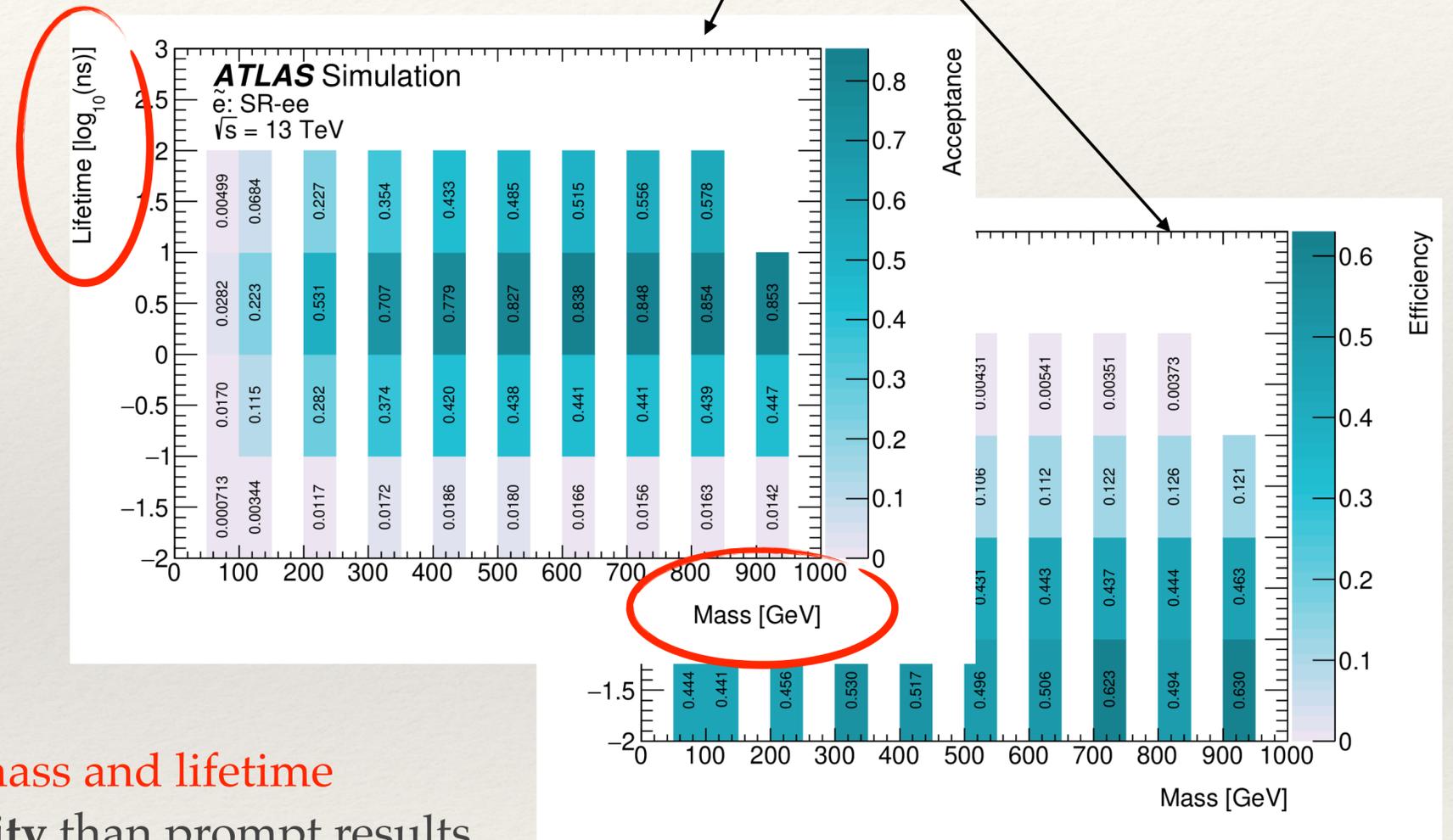
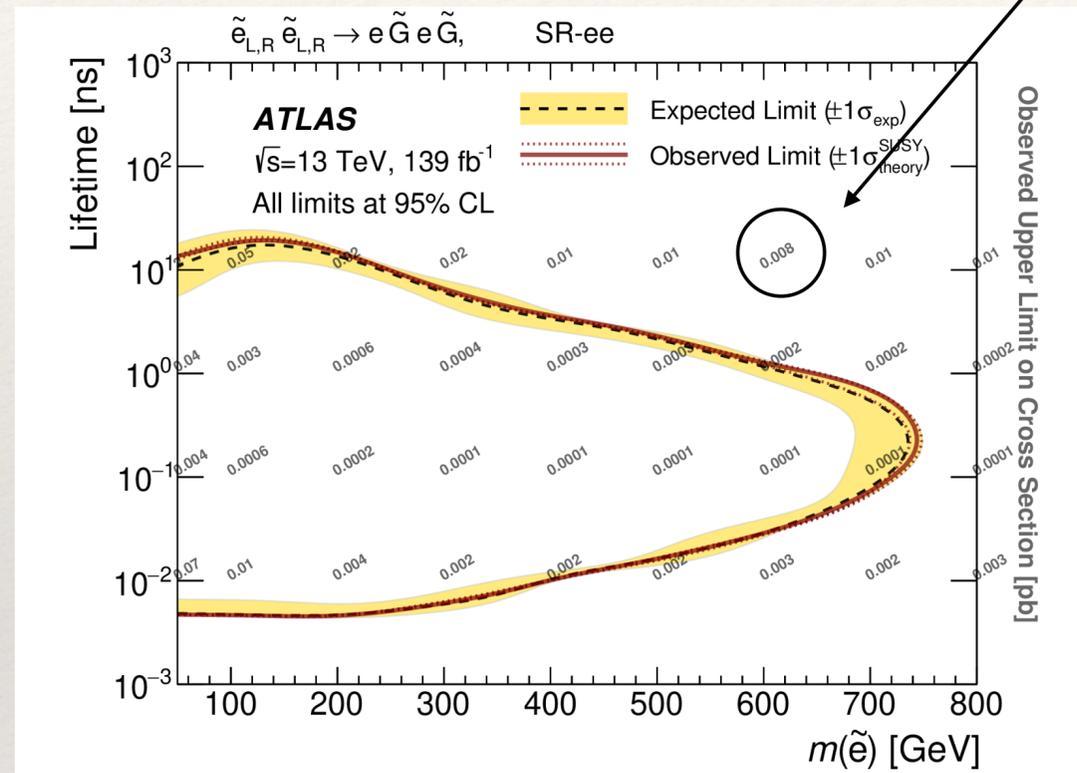
- ▶ do sophisticated statistical evaluations (likelihood ratio tests, confidence levels, p-values, etc.)



*) if information on correlations is available, SRs can be combined

Same principle for LLP results, but as maps in terms of mass and lifetime

upper limit (UL) maps and $A \times \epsilon$ 'efficiency' maps (EM)



LLP results are 'maps' in terms of mass and lifetime
 → in principle higher dimensionality than prompt results

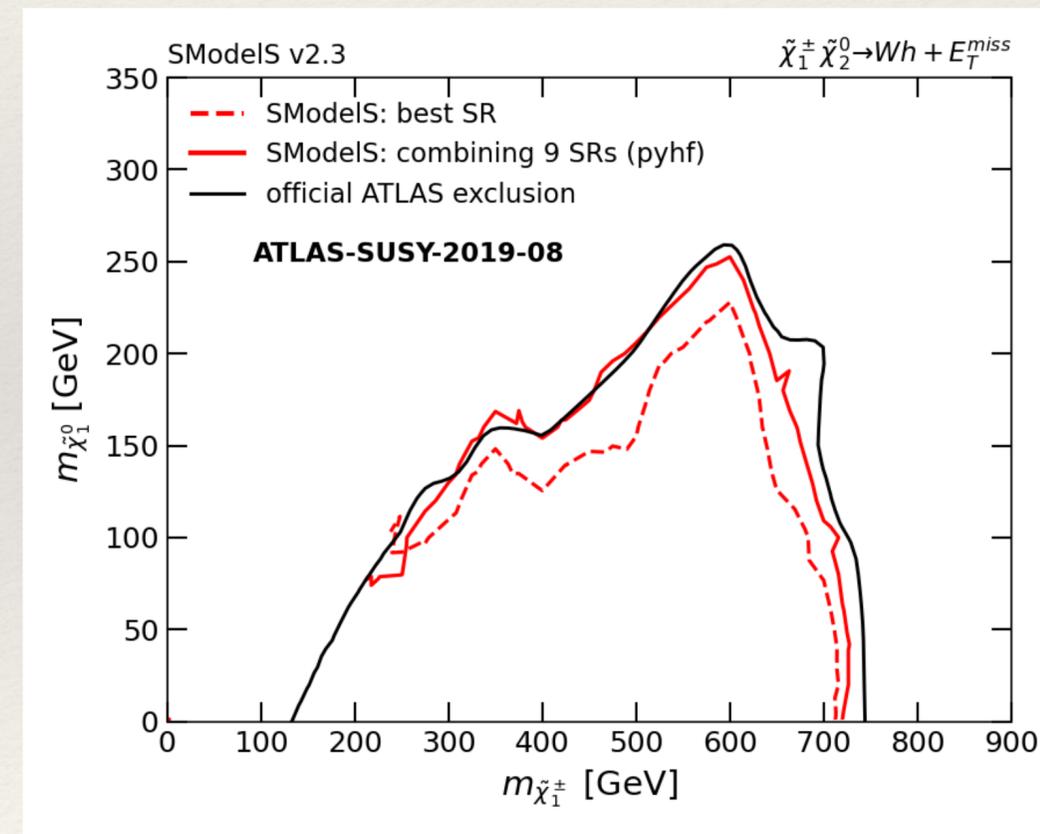
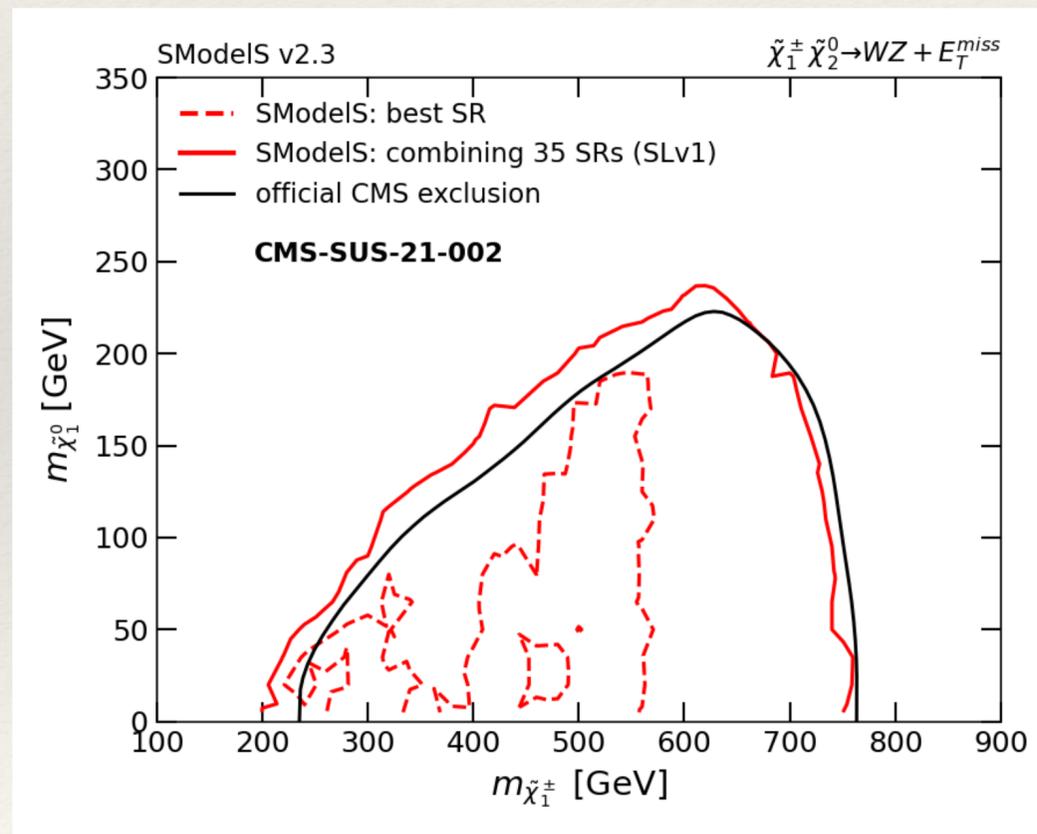
Combination of signal regions

combineSRs = True/False

- ❖ Combination of SRs uses more of the data of an analysis; more reliable constraints
- ❖ Needs correlation info, otherwise we can only use the most sensitive, a.k.a. “best”, SR.
- ❖ Statistical modelling: covariance matrix (CMS) or HistFactory model (ATLAS)

simplified likelihood, SL

full likelihood, pyhf



As of v2.3, SModelS also makes use of the “SLv2” (Gaussian approx. with a skew) |

For HistFactory models, we can now also include control regions!

NEW: combination of analyses

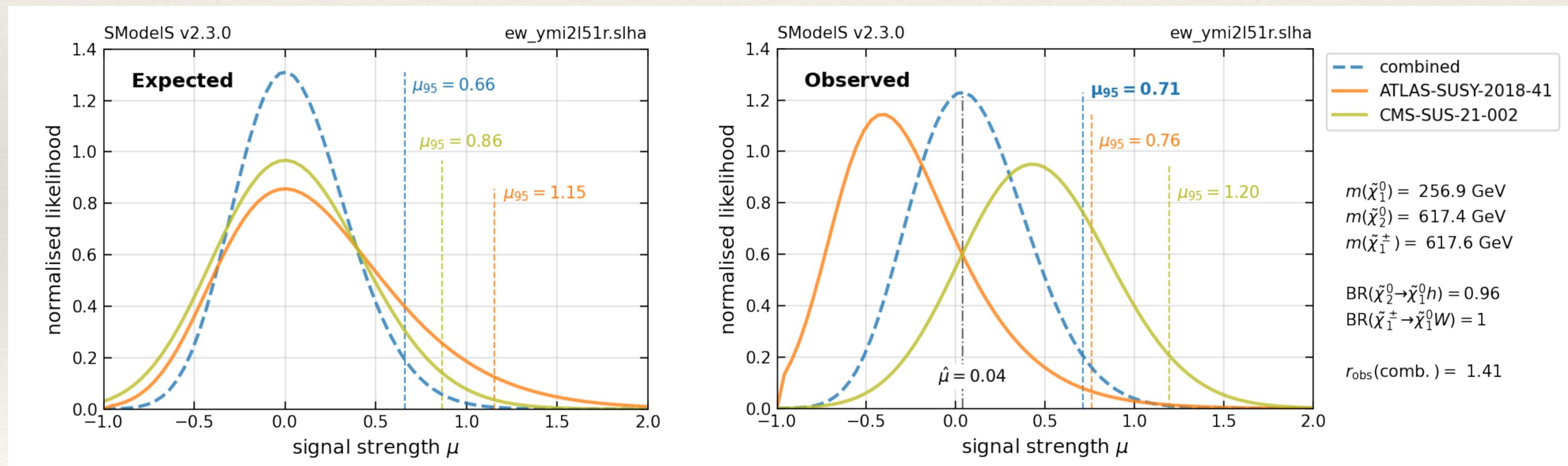
`combineAnas = [user-defined list]`

- ❖ SModelS now also provides the possibility to combine likelihoods from different analyses, under the assumption that they are approximately uncorrelated.
- ❖ Combined likelihood is computed as $\mathcal{L}_C(\mu) = \prod_{i=1} \mathcal{L}_i(\mu s^i)$.
- ❖ Interesting for two reasons:
 - ▶ The signal of a particular BSM scenario may be manifest in different final states, which are constrained by different analyses → want to know the combined effect
 - ▶ Experimental analyses are statistical in nature, so always subject to over- or under-fluctuations (observed limits being weaker or stronger than expected ones).
→ again want to know the combined effect

NEW: combination of analyses

combineAnas = [user-defined list]

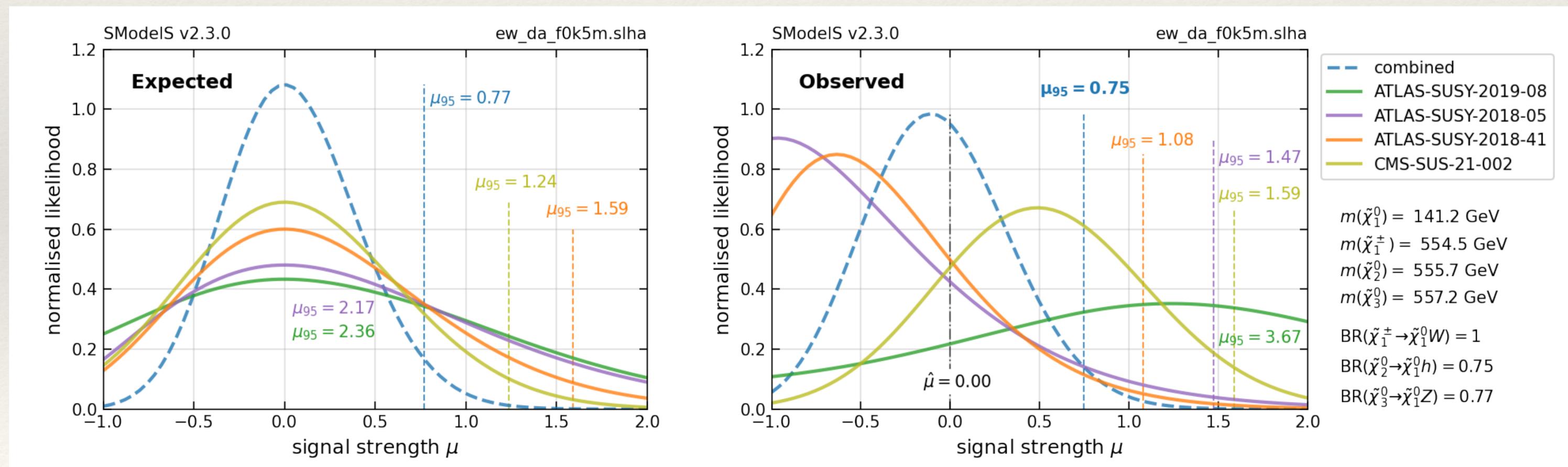
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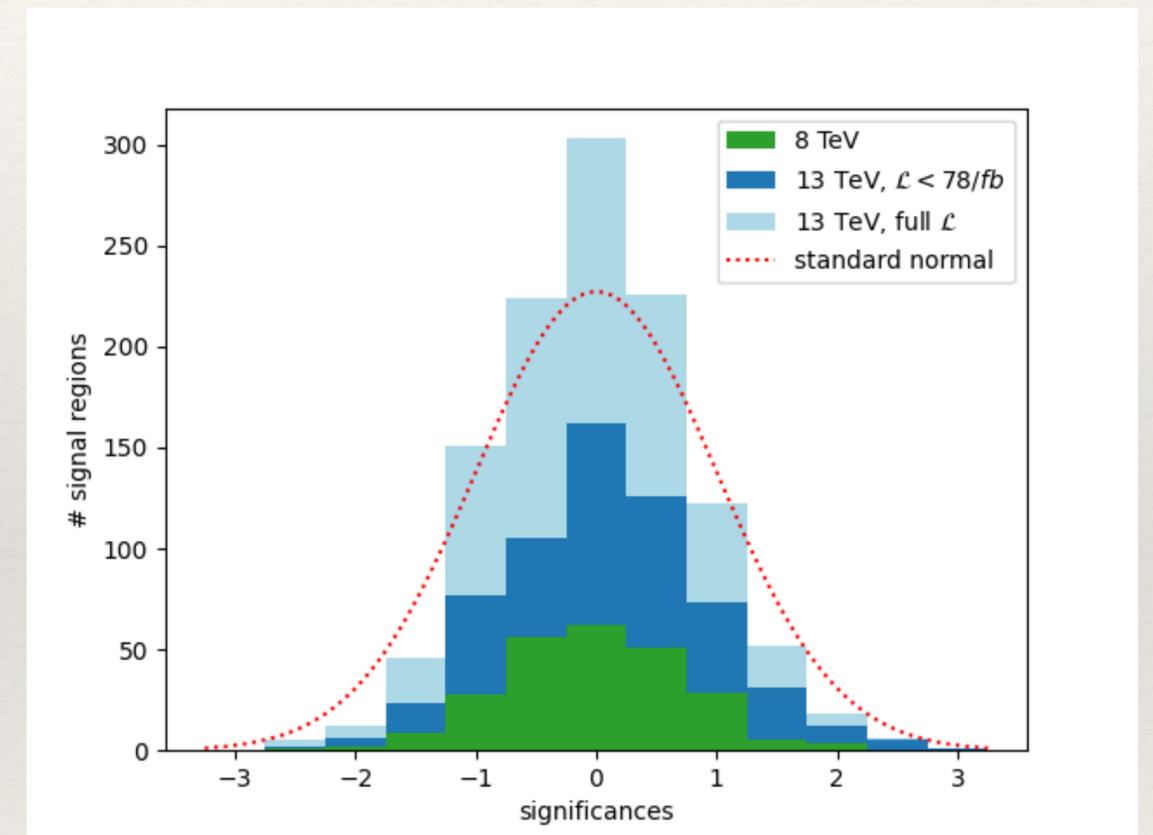
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The Database

- ❖ In total exp. results from **111 ATLAS and CMS publications**
- ❖ Run 1: 15 ATLAS + 18 CMS analyses
- ❖ **Run 2: 38 ATLAS + 40 CMS analyses**
(17 ATLAS+13 CMS for full luminosity)
- ❖ **10 LLP searches:** HSCP, disappearing tracks, displaced vertices
- ❖ New in v2.3.0: 9 ATLAS + 12 CMS;
full set of available EW-ino results



Significances with respect to the SM hypothesis, for all SRs (EM results) in the database. A standard normal distribution is expected if no new physics is in the data. New physics would manifest itself as an overabundance of large significances.

Run 2 analyses in the v2.3.0 database

(ID in bold: new in v2.3.0)

ID	Short Description	\mathcal{L} [fb^{-1}]	UL _{obs}	UL _{exp}	EM	comb.
ATLAS-SUSY-2015-01	2 b -jets	3.2	✓			
ATLAS-SUSY-2015-02	1 l stop	3.2	✓		✓	
ATLAS-SUSY-2015-06	0 l + 2–6 jets	3.2			✓	
ATLAS-SUSY-2015-09	jets + 2 SS or $\geq 3l$	3.2	✓			
ATLAS-SUSY-2016-06	disappearing tracks	36.1			✓	
ATLAS-SUSY-2016-07	0 l + jets	36.1	✓		✓	
ATLAS-SUSY-2016-08	displaced vertices	32.8	✓			
ATLAS-SUSY-2016-14	2 SS or 3 l 's + jets	36.1	✓			
ATLAS-SUSY-2016-15	0 l stop	36.1	✓			
ATLAS-SUSY-2016-16	1 l stop	36.1	✓		✓	
ATLAS-SUSY-2016-17	2 OS l	36.1	✓			
ATLAS-SUSY-2016-19	2 b -jets + τ 's	36.1	✓			
ATLAS-SUSY-2016-24	2–3 l 's, EWK	36.1	✓		✓	
ATLAS-SUSY-2016-26	$\geq 2c$ -jets	36.1	✓			
ATLAS-SUSY-2016-27	jets + γ	36.1	✓		✓	
ATLAS-SUSY-2016-28	2 b -jets	36.1	✓			
ATLAS-SUSY-2016-32	HSCP	31.6	✓	✓	✓	
ATLAS-SUSY-2016-33	2 SFOS l 's	36.1	✓			
ATLAS-SUSY-2017-01	$Wh(bb)$, EWK	36.1	✓			
ATLAS-SUSY-2017-02	0 l + jets	36.1	✓	✓		
ATLAS-SUSY-2017-03	multi- l EWK	36.1	✓		✓	
ATLAS-SUSY-2018-04	2 hadronic taus	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-05	2 l + jets, EWK	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-05	2 l + jets, strong	139.0			✓	
ATLAS-SUSY-2018-06	3 l , EWK	139.0	✓	✓	✓	
ATLAS-SUSY-2018-08	2 OS l	139.0	✓		✓	
ATLAS-SUSY-2018-10	1 l + jets	139.0	✓		✓	
ATLAS-SUSY-2018-12	0 l + jets	139.0	✓	✓	✓	
ATLAS-SUSY-2018-14	displaced vertices	139.0			✓	PYHF
ATLAS-SUSY-2018-22	multi-jets	139.0	✓		✓	
ATLAS-SUSY-2018-23	$Wh(\gamma\gamma)$, EWK	139.0	✓	✓		
ATLAS-SUSY-2018-31	2 b + 2 $h(bb)$	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-32	2 OS l	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-40	2 b + 2 $h(\tau\tau)$	139.0	✓	✓	✓	
ATLAS-SUSY-2018-41	hadr. EWK search	139.0	✓	✓	✓	SLv1
ATLAS-SUSY-2018-42	charged LLPs, dE/dx	139.0	✓	✓	✓	
ATLAS-SUSY-2019-02	2 soft l 's, EWK	139.0	✓		✓	SLv1
ATLAS-SUSY-2019-08	1 l + $h(bb)$, EWK	139.0	✓		✓	PYHF
ATLAS-SUSY-2019-09	3 l , EWK	139.0	✓	✓	✓	PYHF

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CMS-PAS-EXO-16-036	HSCP	12.9	✓			
CMS-PAS-SUS-16-052	ISR jet + soft l	35.9	✓		✓	SLv1
CMS-SUS-16-009	0 l + jets, top tag	2.3	✓	✓		
CMS-SUS-16-032	2 b - or 2 c -jets	35.9	✓			
CMS-SUS-16-033	0 l + jets	35.9	✓	✓	✓	
CMS-SUS-16-034	2 SFOS l	35.9	✓			
CMS-SUS-16-035	2 SS l	35.9	✓			
CMS-SUS-16-036	0 l + jets	35.9	✓	✓		
CMS-SUS-16-037	1 l + jets with MJ	35.9	✓			
CMS-SUS-16-039	multi- l , EWK	35.9	✓		✓	SLv1
CMS-SUS-16-041	multi- l + jets	35.9	✓			
CMS-SUS-16-042	1 l + jets	35.9	✓			
CMS-SUS-16-043	$Wh(bb)$, EWK	35.9	✓			
CMS-SUS-16-045	2 b + 2 $h(\gamma\gamma)$	35.9	✓			
CMS-SUS-16-046	high- p_T γ	35.9	✓			
CMS-SUS-16-047	γ + jets, high H_T	35.9	✓			
CMS-SUS-16-048	2 OS l , soft	35.9			✓	SLv1
CMS-SUS-16-050	0 l + top tag	35.9	✓	✓	✓	SLv1
CMS-SUS-16-051	1 l stop	35.9	✓	✓		
CMS-SUS-17-003	2 taus	35.9	✓			
CMS-SUS-17-004	EWK combination	35.9	✓			
CMS-SUS-17-005	1 l + jets, top tag	35.9	✓	✓		
CMS-SUS-17-006	jets + boosted $h(bb)$	35.9	✓	✓		
CMS-SUS-17-009	SFOS l	35.9	✓	✓		
CMS-SUS-17-010	2 l stop	35.9	✓	✓		
CMS-SUS-18-002	γ + (b -)jets, top tag	35.9	✓	✓		
CMS-SUS-18-004	2–3 soft l 's	137.0	✓	✓		
CMS-SUS-18-007	2 $h(\gamma\gamma)$, EWK	77.5	✓	✓		
CMS-EXO-19-001	non-prompt jets	137.0			✓	
CMS-EXO-19-010	disappearing tracks	101.0			✓	
CMS-SUS-19-006	0 l + jets, MHT	137.0	✓	✓	✓	SLv1
CMS-SUS-19-008	2–3 l + jets	137.0	✓	✓		
CMS-SUS-19-009	1 l + jets, MHT	137.0	✓	✓		
CMS-SUS-19-010	jets + top and W -tag	137.0	✓	✓		
CMS-SUS-19-011	2 l stop	137.0	✓	✓		
CMS-SUS-19-013	jets + boosted Z 's	137.0	✓	✓		
CMS-SUS-20-001	SFOS l	137.0	✓	✓		
CMS-SUS-20-002	stop combination	137.0	✓	✓		
CMS-SUS-20-004	2 $h(bb)$, EWK	137.0	✓	✓	✓	SLv2
CMS-SUS-21-002	hadr. EWK search	137.0	✓	✓	✓	SLv1

LLP

full Run-2
luminosity:
17 ATLAS,
13 CMS

Run 2 analyses in the v2.3.0 database

(ID in bold: new in v2.3.0)

ID	Short Description	\mathcal{L} [fb^{-1}]	UL _{obs}	UL _{exp}	EM	comb.
ATLAS-SUSY-2015-01	2 <i>b</i> -jets	3.2	✓			
ATLAS-SUSY-2015-02	1 ℓ stop	3.2	✓		✓	
ATLAS-SUSY-2015-06	0 ℓ + 2–6 jets	3.2			✓	
ATLAS-SUSY-2015-09	jets + 2 SS or $\geq 3\ell$	3.2	✓			
ATLAS-SUSY-2016-06	disappearing tracks	36.1			✓	
ATLAS-SUSY-2016-07	0 ℓ + jets	36.1	✓		✓	
ATLAS-SUSY-2016-08	displaced vertices	32.8	✓			
ATLAS-SUSY-2016-14	2 SS or 3 ℓ 's + jets	36.1	✓			
ATLAS-SUSY-2016-15	0 ℓ stop	36.1	✓			
ATLAS-SUSY-2016-16	1 ℓ stop	36.1	✓		✓	
ATLAS-SUSY-2016-17	2 OS ℓ	36.1	✓			
ATLAS-SUSY-2016-19	2 <i>b</i> -jets + τ 's	36.1	✓			
ATLAS-SUSY-2016-24	2–3 ℓ 's, EWK	36.1	✓		✓	
ATLAS-SUSY-2016-26	≥ 2 <i>c</i> -jets	36.1	✓			
ATLAS-SUSY-2016-27	jets + γ	36.1	✓		✓	
ATLAS-SUSY-2016-28	2 <i>b</i> -jets	36.1	✓			
ATLAS-SUSY-2016-32	HSCP	31.6	✓	✓	✓	
ATLAS-SUSY-2016-33	2 SFOS ℓ 's	36.1	✓			
ATLAS-SUSY-2017-01	<i>Wh(bb)</i> , EWK	36.1	✓			
ATLAS-SUSY-2017-02	0 ℓ + jets	36.1	✓	✓		
ATLAS-SUSY-2017-03	multi- ℓ EWK	36.1	✓		✓	
ATLAS-SUSY-2018-04	2 hadronic taus	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-05	2 ℓ + jets, EWK	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-05	2 ℓ + jets, strong	139.0			✓	
ATLAS-SUSY-2018-06	3 ℓ , EWK	139.0	✓	✓	✓	
ATLAS-SUSY-2018-08	2 OS ℓ	139.0	✓		✓	
ATLAS-SUSY-2018-10	1 ℓ + jets	139.0	✓		✓	
ATLAS-SUSY-2018-12	0 ℓ + jets	139.0	✓	✓	✓	
ATLAS-SUSY-2018-14	displaced vertices	139.0			✓	PYHF
ATLAS-SUSY-2018-22	multi-jets	139.0	✓		✓	
ATLAS-SUSY-2018-23	<i>Wh($\gamma\gamma$)</i> , EWK	139.0	✓	✓		
ATLAS-SUSY-2018-31	2 <i>b</i> + 2 <i>h(bb)</i>	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-32	2 OS ℓ	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-40	2 <i>b</i> + 2 <i>h($\tau\tau$)</i>	139.0	✓	✓	✓	
ATLAS-SUSY-2018-41	had. EWK search	139.0	✓	✓	✓	SLv1
ATLAS-SUSY-2018-42	charged LLPs, dE/dx	139.0	✓	✓	✓	
ATLAS-SUSY-2019-02	2 soft ℓ 's, EWK	139.0	✓		✓	SLv1
ATLAS-SUSY-2019-08	1 ℓ + <i>h(bb)</i> , EWK	139.0	✓		✓	PYHF
ATLAS-SUSY-2019-09	3 ℓ , EWK	139.0	✓	✓	✓	PYHF

ID	Short Description	\mathcal{L} [fb^{-1}]	UL _{obs}	UL _{exp}	EM	comb.
CMS-PAS-EXO-16-036	HSCP	12.9	✓			
CMS-PAS-SUS-16-052	ISR jet + soft ℓ	35.9	✓		✓	SLv1
CMS-SUS-16-009	0 ℓ + jets, top tag	2.3	✓	✓		
CMS-SUS-16-032	2 <i>b</i> - or 2 <i>c</i> -jets	35.9	✓			
CMS-SUS-16-033	0 ℓ + jets	35.9	✓	✓	✓	
CMS-SUS-16-034	2 SFOS ℓ	35.9	✓			
CMS-SUS-16-035	2 SS ℓ	35.9	✓			
CMS-SUS-16-036	0 ℓ + jets	35.9	✓	✓		
CMS-SUS-16-037	1 ℓ + jets with MJ	35.9	✓			
CMS-SUS-16-039	multi- ℓ , EWK	35.9	✓		✓	SLv1
CMS-SUS-16-041	multi- ℓ + jets	35.9	✓			
CMS-SUS-16-042	1 ℓ + jets	35.9	✓			
CMS-SUS-16-043	<i>Wh(bb)</i> , EWK	35.9	✓			
CMS-SUS-16-045	2 <i>b</i> + 2 <i>h($\gamma\gamma$)</i>	35.9	✓			
CMS-SUS-16-046	high- p_T γ	35.9	✓			
CMS-SUS-16-047	γ + jets, high H_T	35.9	✓			
CMS-SUS-16-048	2 OS ℓ , soft	35.9			✓	SLv1
CMS-SUS-16-050	0 ℓ + top tag	35.9	✓	✓	✓	SLv1
CMS-SUS-16-051	1 ℓ stop	35.9	✓	✓		
CMS-SUS-17-003	2 taus	35.9	✓			
CMS-SUS-17-004	EWK combination	35.9	✓			
CMS-SUS-17-005	1 ℓ + jets, top tag	35.9	✓	✓		
CMS-SUS-17-006	jets + boosted <i>h(bb)</i>	35.9	✓	✓		
CMS-SUS-17-009	SFOS ℓ	35.9	✓	✓		
CMS-SUS-17-010	2 ℓ stop	35.9	✓	✓		
CMS-SUS-18-002	γ + (<i>b</i> -)jets, top tag	35.9	✓	✓		
CMS-SUS-18-004	2–3 soft ℓ 's	137.0	✓	✓		
CMS-SUS-18-007	2 <i>h($\gamma\gamma$)</i> , EWK	77.5	✓	✓		
CMS-EXO-19-001	non-prompt jets	137.0			✓	
CMS-EXO-19-010	disappearing tracks	101.0			✓	
CMS-SUS-19-006	0 ℓ + jets, MHT	137.0	✓	✓	✓	SLv1
CMS-SUS-19-008	2–3 ℓ + jets	137.0	✓	✓		
CMS-SUS-19-009	1 ℓ + jets, MHT	137.0	✓	✓		
CMS-SUS-19-010	jets + top and <i>W</i> -tag	137.0	✓	✓		
CMS-SUS-19-011	2 ℓ stop	137.0	✓	✓		
CMS-SUS-19-013	jets + boosted <i>Z</i> 's	137.0	✓	✓		
CMS-SUS-20-001	SFOS ℓ	137.0	✓	✓		
CMS-SUS-20-002	stop combination	137.0	✓	✓		
CMS-SUS-20-004	2 <i>h(bb)</i> , EWK	137.0	✓	✓	✓	SLv2
CMS-SUS-21-002	had. EWK search	137.0	✓	✓	✓	SLv1

LLP
EW-ino

full Run-2
luminosity:
17 ATLAS,
13 CMS

(note 16/17 of ATLAS
but only 5/13 of CMS
analyses provide EMs)

Case study for EW-inos (MSSM)

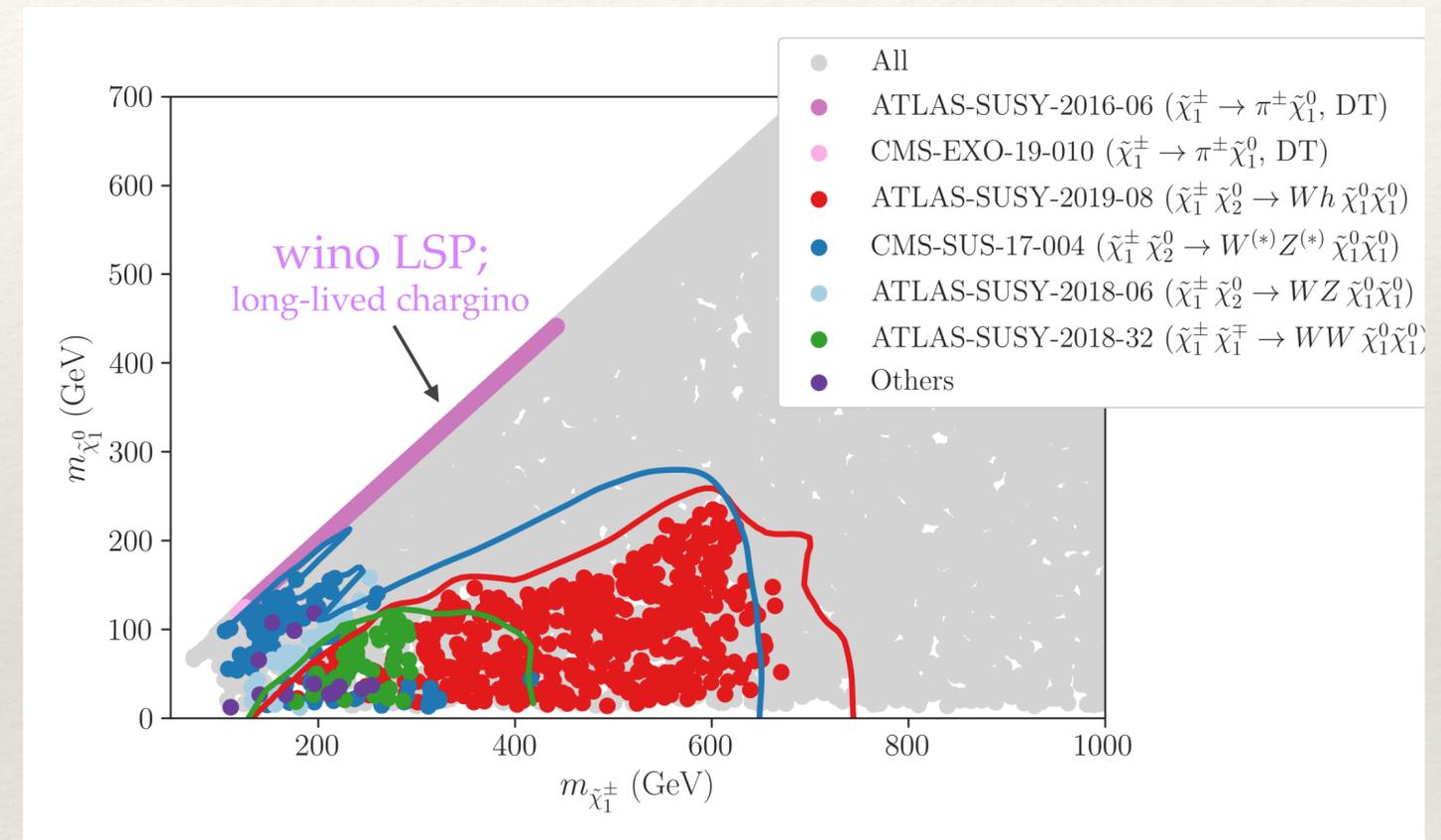
- ❖ Random scan over EW-ino parameters from [arXiv:2112.00769](https://arxiv.org/abs/2112.00769)

$$\begin{aligned}
 10 \text{ GeV} &< M_1 < 3 \text{ TeV}, \\
 100 \text{ GeV} &< M_2 < 3 \text{ TeV}, \\
 100 \text{ GeV} &< \mu < 3 \text{ TeV}, \\
 5 &< \tan \beta < 50
 \end{aligned}$$

All other soft masses set to 10 TeV.

- ❖ Mass spectrum and decays computed with Softsusy 4.1.12, Xsections at LO with Pythia8.
(+NLO with Prospino2 for pts with $r > 0.7$)

SModelS v2.1



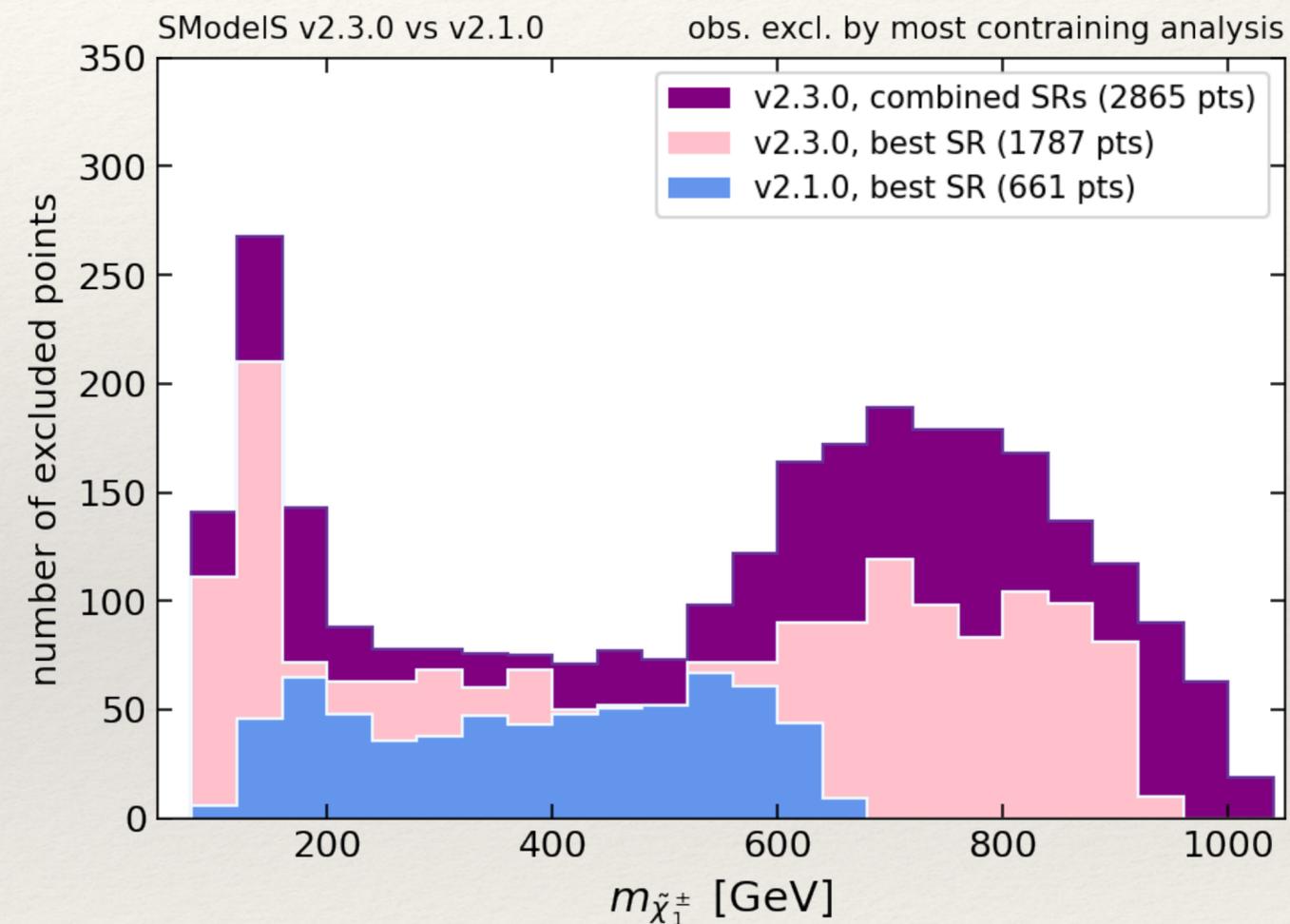
Case study for EW-inos (MSSM)

- ❖ Random scan over EW-ino parameters from [arXiv:2112.00769](https://arxiv.org/abs/2112.00769)

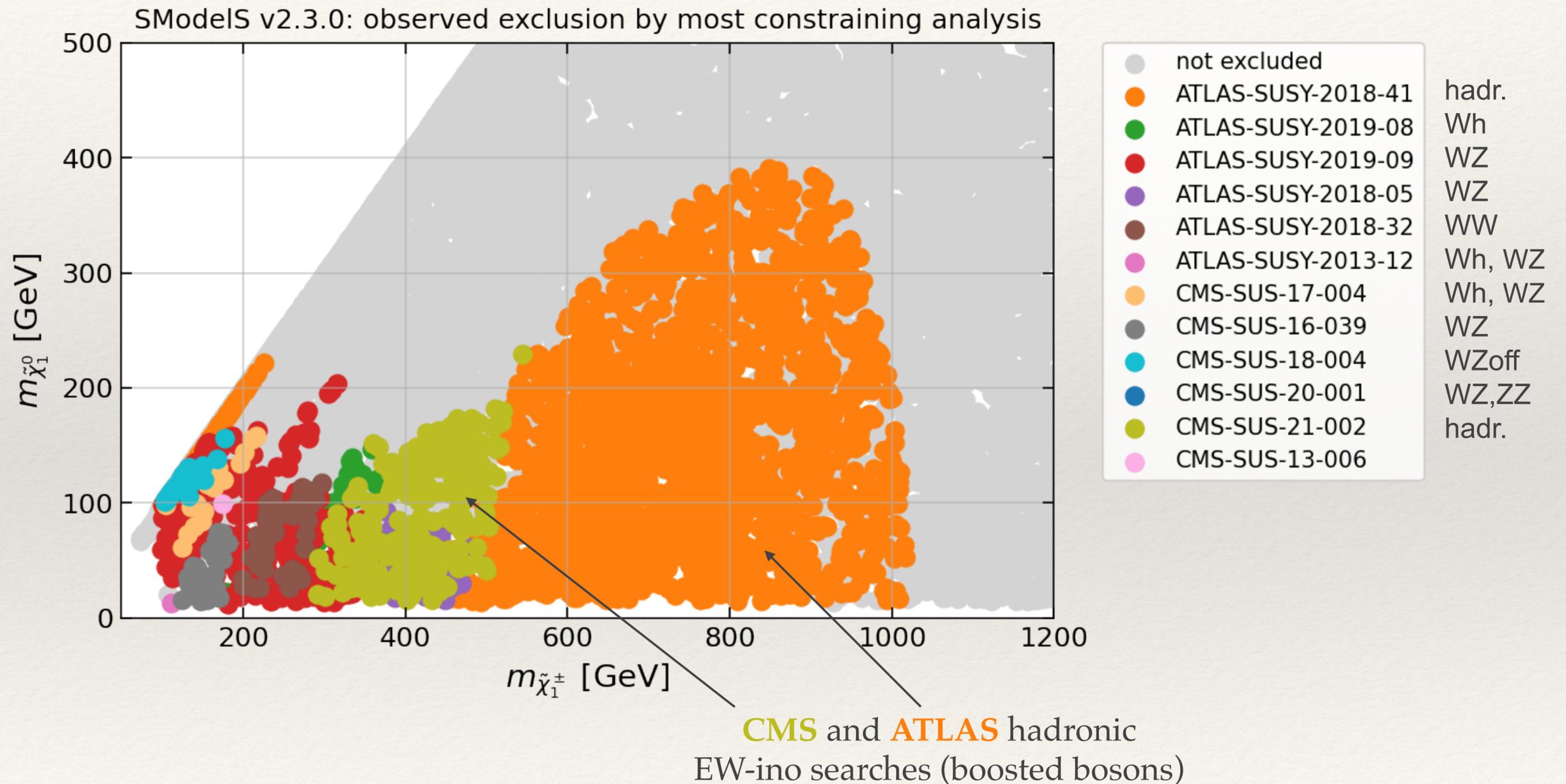
$$\begin{aligned}
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 \end{aligned}$$

All other soft masses set to 10 TeV.

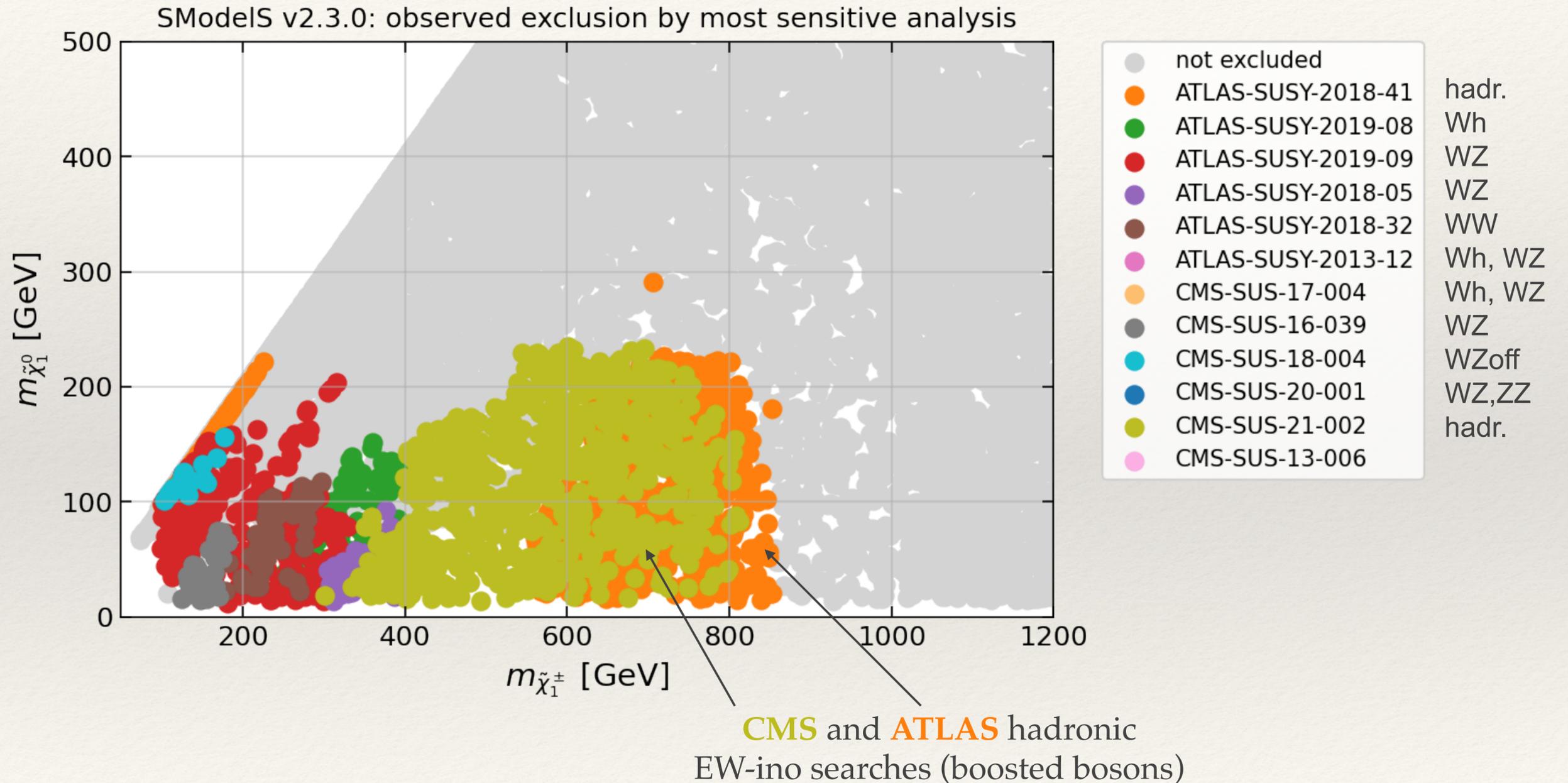
- ❖ Total $\sim 100\text{K}$ points \rightarrow select subset with $m_{\tilde{\chi}_1^0} < 500 \text{ GeV}$, $m_{\tilde{\chi}_1^\pm} < 1200 \text{ GeV}$, and only prompt decays (no wino-LSP): 18.5K points for evaluation with v2.3



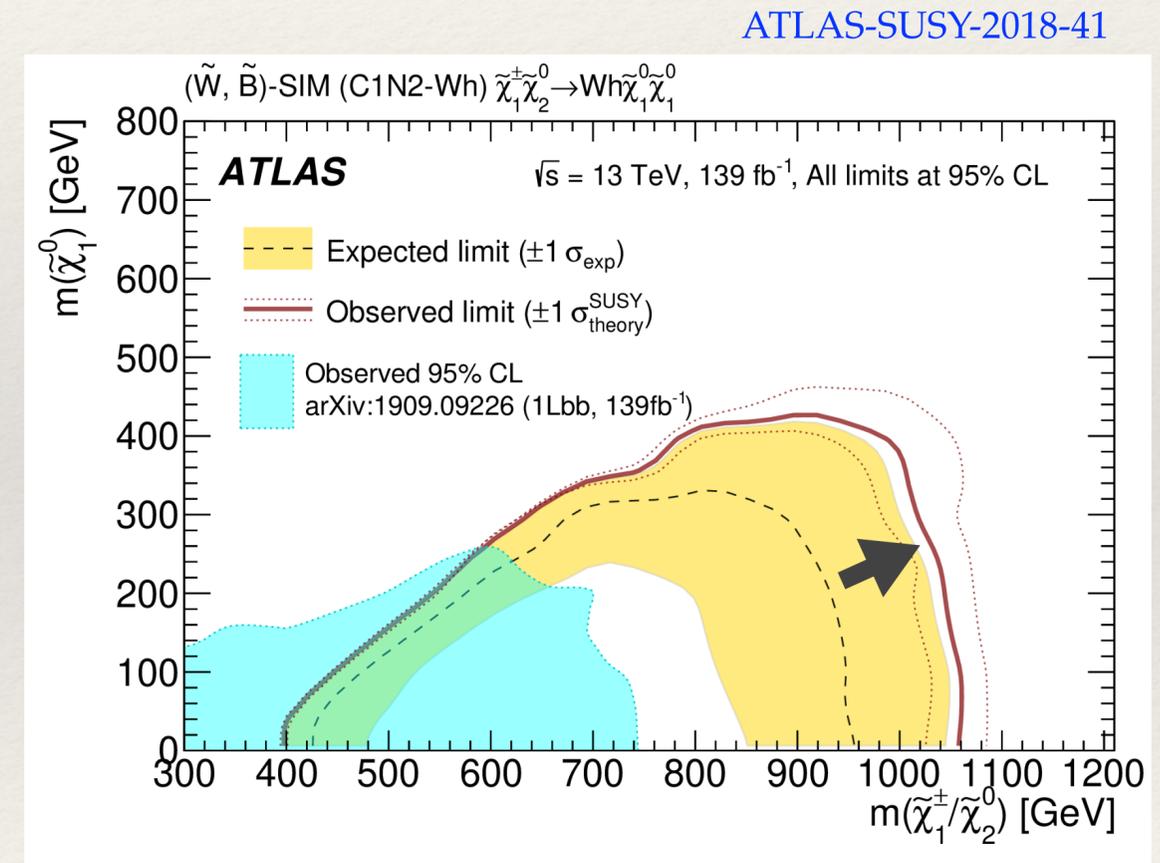
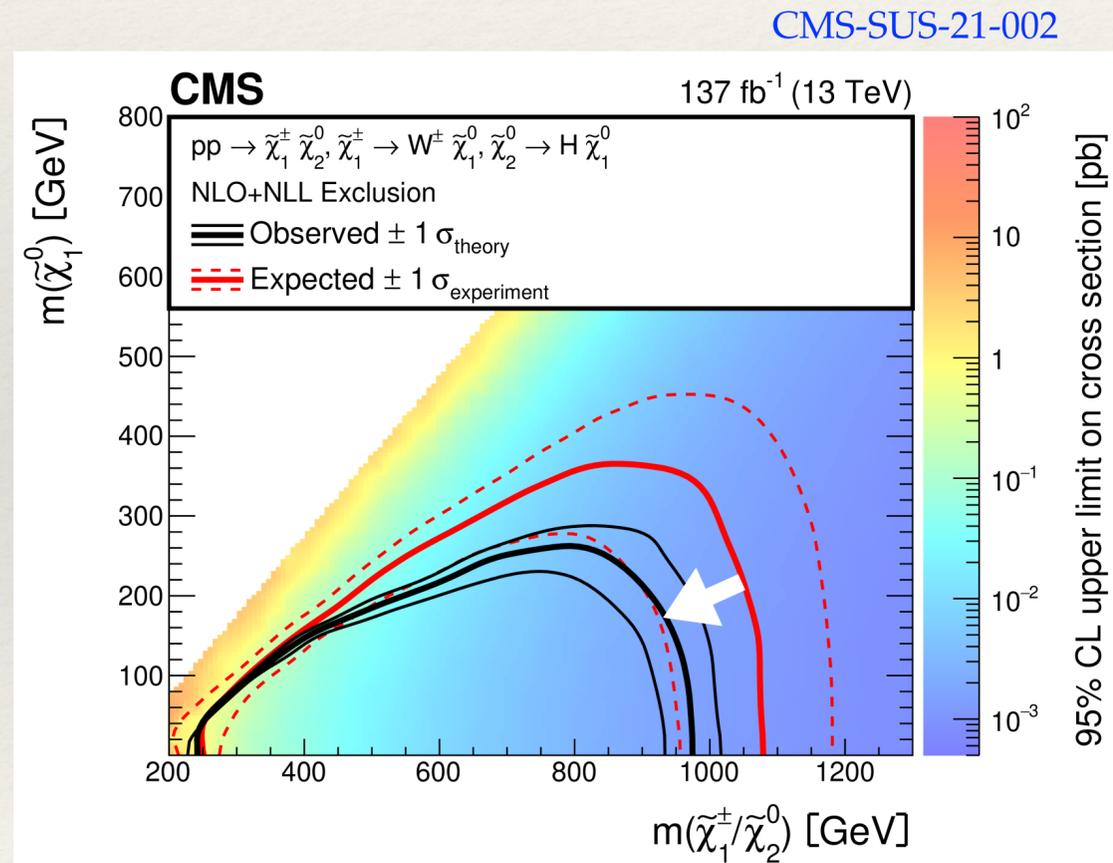
Exclusion by most constraining analysis ...



... versus exclusion by most sensitive analysis

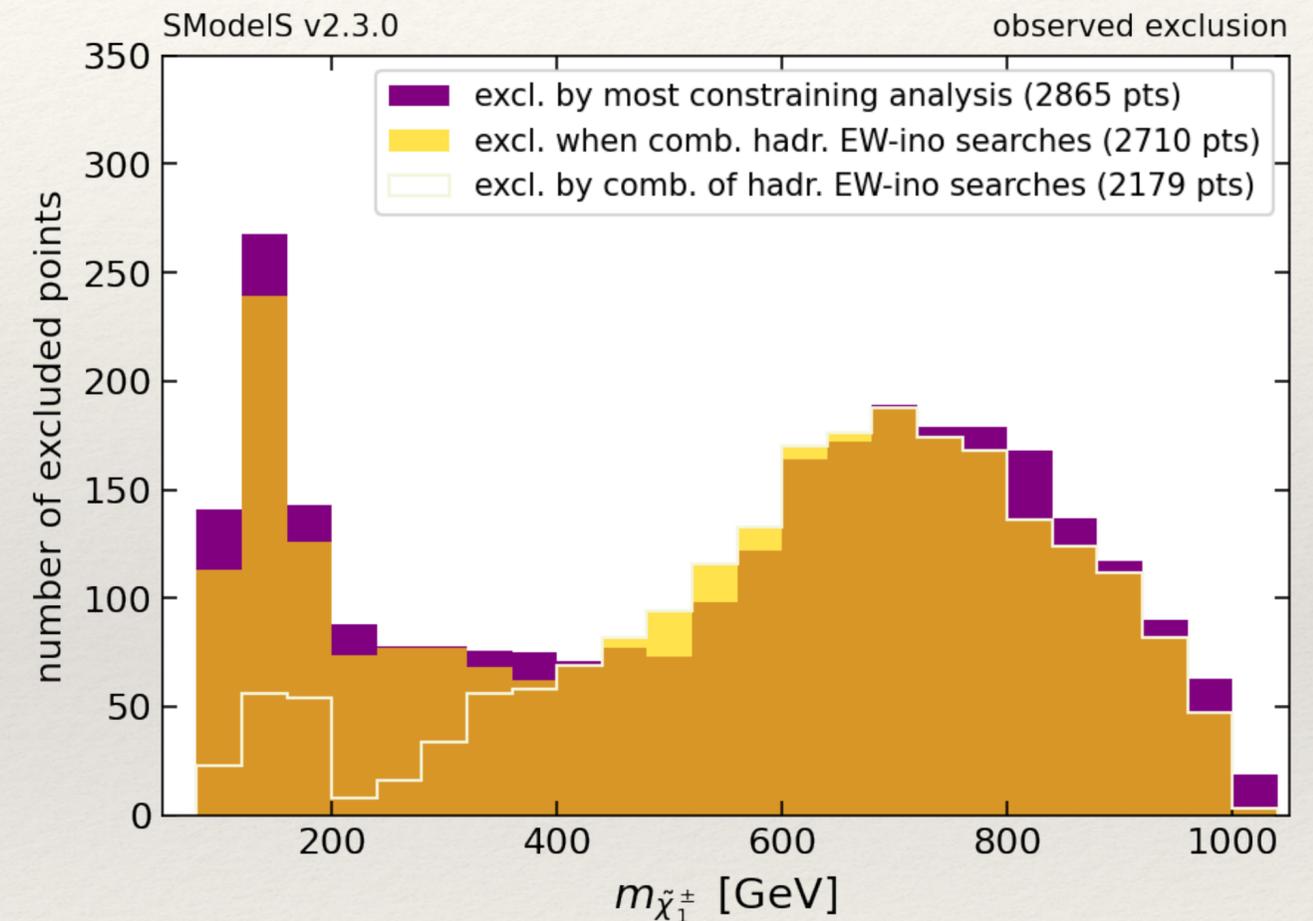
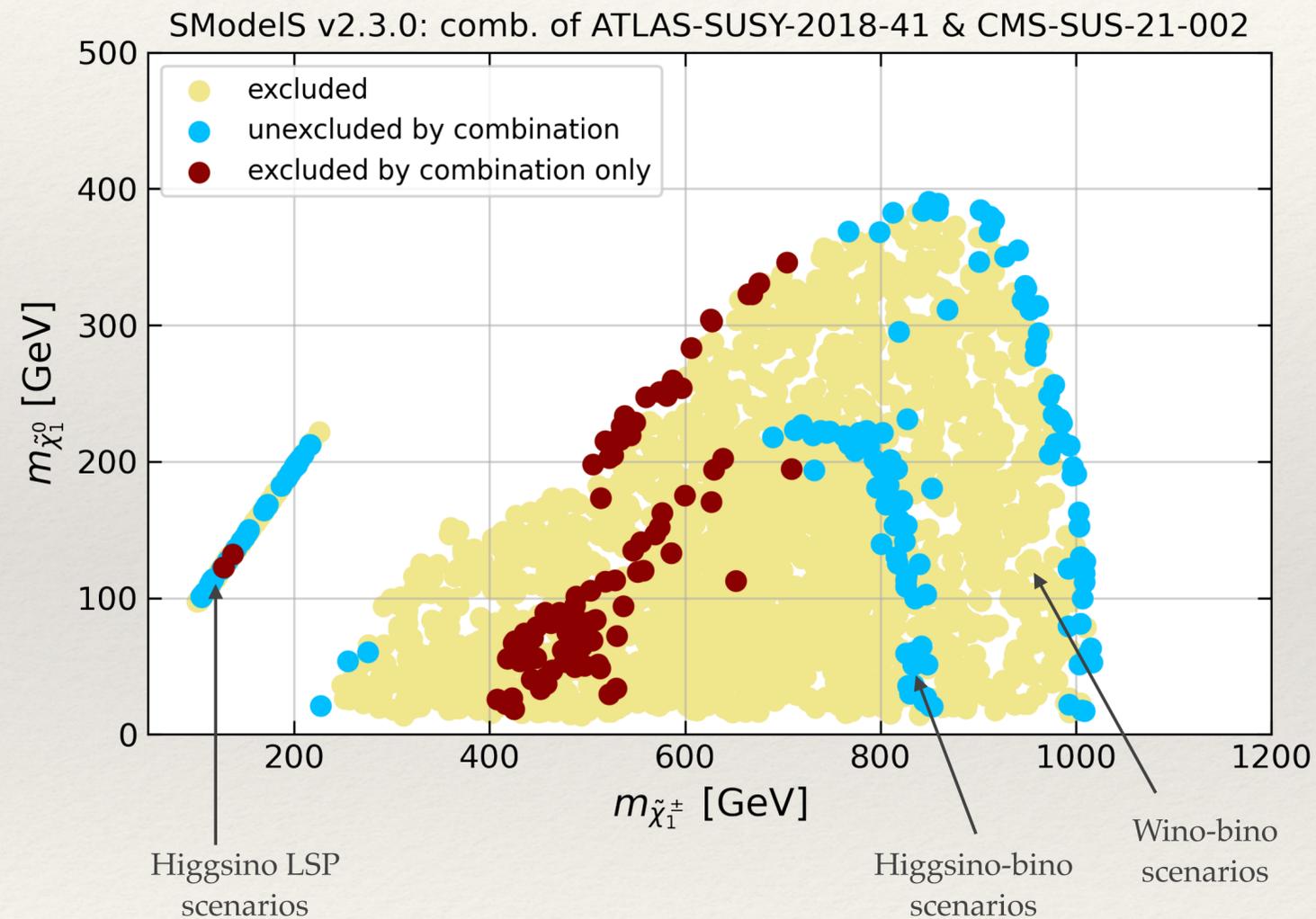


- ❖ Reason: CMS and ATLAS hadronic EW-ino searches have similar sensitivity, but while CMS has a small excess, the ATLAS analysis observes a deficit of events and thus sets a stronger individual limit
- ❖ Strong motivation for combining



Combining ATLAS and CMS hadronic EW-ino searches

`combineAnas = [ATLAS-SUSY-2018-41, CMS-SUS-21-002]`

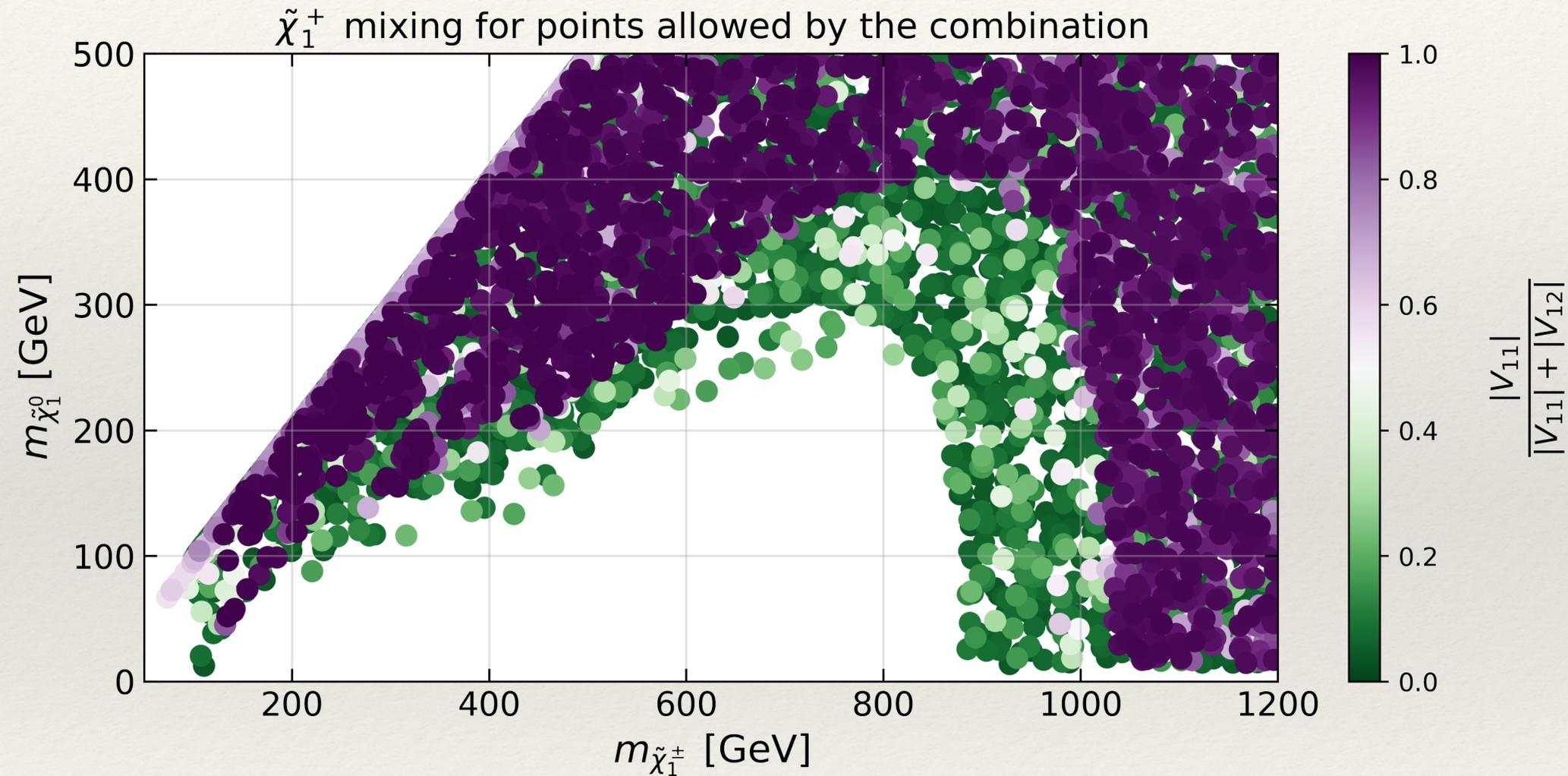


See talk by [Timothée Pascal](#) for dynamic, optimised combination of all orthogonal EW-ino results

Allowed scenarios in global combination

- ❖ Optimised combination of 16 EW-ino searches in SModelS v2.3

Timothée Pascal



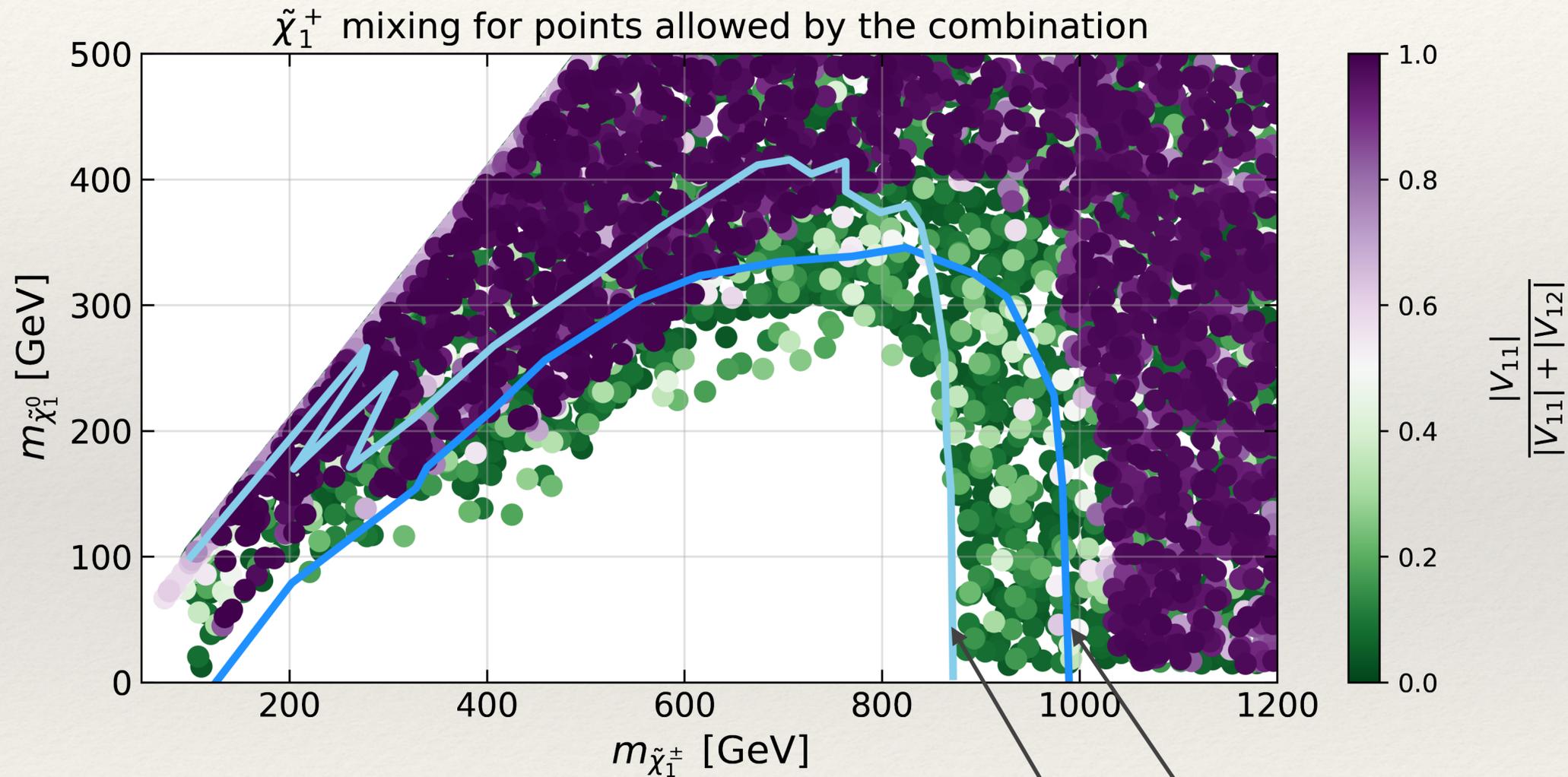
To be compared to simplified-model limits from “official” combinations

ATLAS → Alexander Khanov ; **CMS** → Pablo Matorras-Cuevas

Allowed scenarios in global combination

- Optimised combination of 16 EW-ino searches in SModelS v2.3

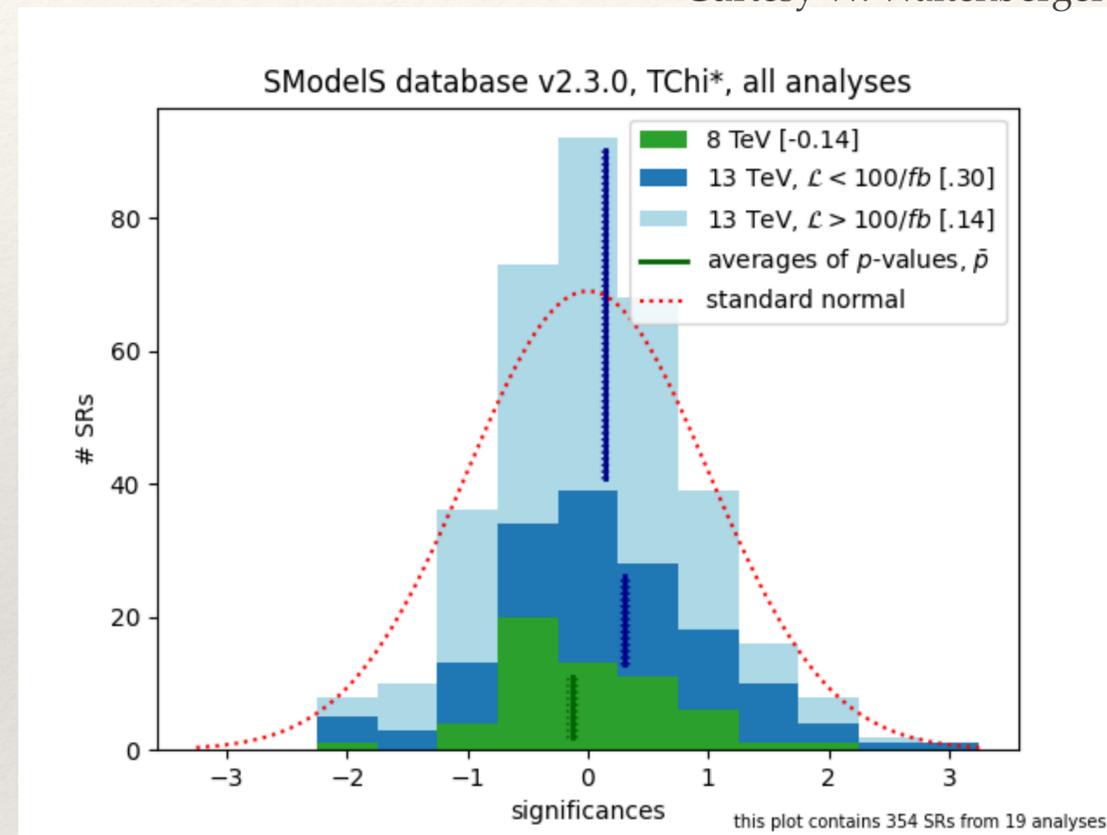
Timothée Pascal



To be compared to simplified-model limits from “official” combinations
ATLAS → Alexander Khanov ; **CMS** → Pablo Matorras-Cuevas

Limit curves from CMS combination; wino-bino scenario with 100% decay into either WZ or Wh (+MET) final states

Courtesy W. Waltenberger



Significances with respect to the SM hypothesis;
EW-ino analyses only.

Conclusions



- ❖ SModelS is an easy-to-use **public tool for the fast reinterpretation** of LHC searches on the basis of simplified-model results. Available from [GitHub](#) and [PyPI](#).
- ❖ **Large database** covering a total of 111 ATLAS and CMS publications
 - ▶ Run 2: 38 ATLAS + 40 CMS analyses (17 ATLAS+13 CMS for full luminosity).
 - ▶ Coverage mostly limited by variety and kind of simplified-model EMs available
- ❖ Simultaneous treatment of **prompt and long-lived** signatures.
- ❖ v2.3 comes with the ability to **combine likelihoods from different analyses**:
 - ▶ statistically more rigorous constraints,
 - ▶ opens the way for DIY global LHC likelihood analyses.
- ✓ All results from [arXiv:2306.17676](#) are available on [Zenodo](#).

Thanks to all ATLAS and CMS analysis teams who take care that their results are reusable !!

