

Electroweak-inos in the pMSSM with SModelS v3.2

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SUMMARY

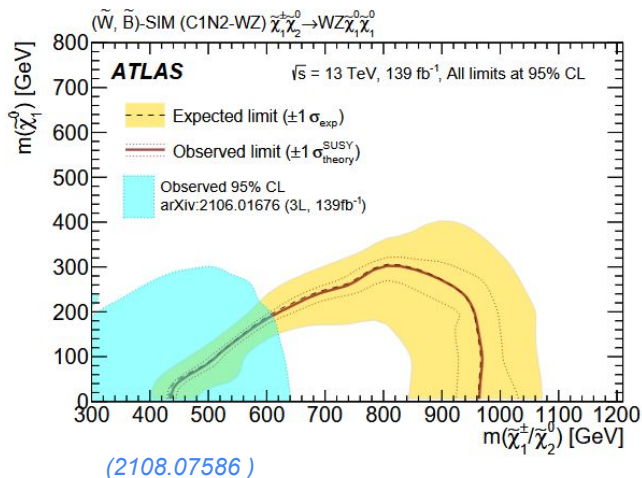
- SModelS working principle
- Recent development in SModelS
- Application : update on the status of pMSSM at LHC

Probing new physics at colliders



Different final states can be investigated to probe SUSY at LHC.

Experiments interpret their results as Simplified Model Spectra (SMS) : effective model assuming for a handful of particles and decay modes.



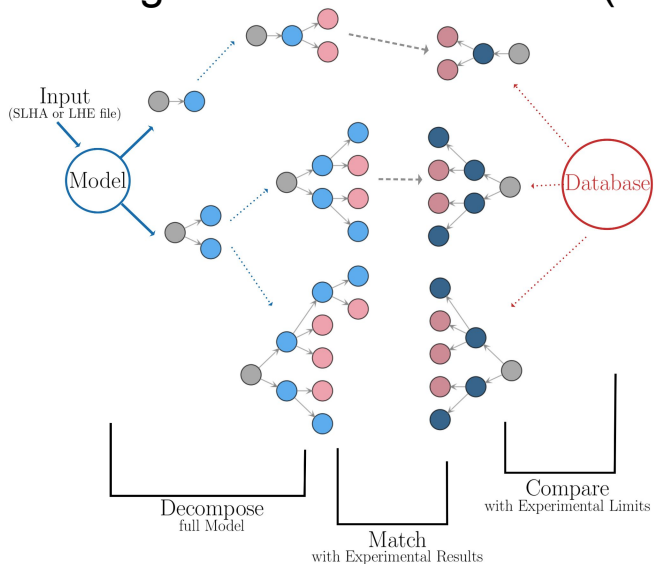
SMS example : production of 2 superpartners decaying in a specific channel

$$\tilde{W}/\tilde{B} (\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow WZ)$$

- Two strategies to constrain a model :
 - Recast experimental analysis, Monte Carlo involved (MadAnalysis,...)
 - Direct use of SMS : SModelS

SModelS : public tool for reinterpreting SMS results from the LHC. Uses CMS and ATLAS results

- Fast (no event simulation / no recast !), thus well suited for parameter scans.
- Not as precise as recasting (interpolation of efficiencies, conservative results).
- Large collection of results (limited by the available SMS results)



Latest version 3.2 :
135 SMS topologies
131 analyses (36 Run 1, 95 Run 2)
67 CMS, 64 ATLAS

Input :

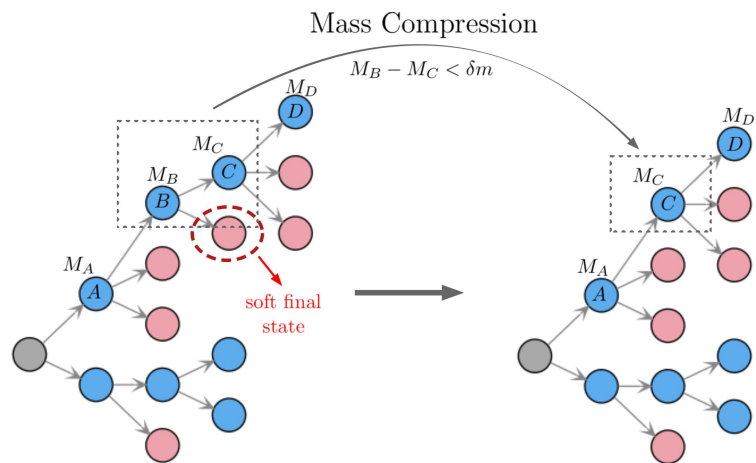
- Mass spectrum
- Decay tables
- Production cross sections at LHC

What's new ?

3.1 : Handling initial state radiation and enabling monojet searches in SModelS

Introduced minmassgapISR parameter for controlling the mass compression for ISR topologies

Mass compression introduced in v 2.3:



Database extension (blue):

Need of a new parameter, minmassgapISR to handle the compression to topologies with only MET final states.

Now a MET only topology can only be obtained when the mass differences are all smaller than minmassgapISR

Recommended value ~1 GeV

Analysis ID	Short description	UL	EM
ATLAS-EXOT-2018-06	monojet	✓	✓
ATLAS-SUSY-2019-04	1 l or 2 SS l + multi-jets	✓	
ATLAS-SUSY-2018-19	disappearing track		✓
ATLAS-SUSY-2018-22	multi-jets	✓	✓
CMS-EXO-20-004	monojet		✓

What's new ?

3.2 : Machine learned likelihoods

- **First support for NN surrogate statistical models (ONNX format):**

Database extension ([blue](#)):

Analysis ID	Short description	UL	EM
ATLAS-SUSY-2018-09	2 SS l	✓	✓
ATLAS-SUSY-2019-04	1 l or 2 SS l + multi-jets	✓	✓
ATLAS-SUSY-2020-27	jets + ≥ 1 l, RPV	✓	✓
CMS-SUS-18-004	2-3 soft l	✓	✓
CMS-EXO-19-019	di-lepton resonance	✓	
CMS-SUS-21-008	EWK comb.	✓	
CMS-SUS-23-003	high-pT ISR, multi-l + multi-jets	✓	



github.com/OpenML-LHClkelihoods

Added ONNX models to :

Humberto Reyes-Gonzalez, Joaquin Iturriza Ramirez and Rafal Maselek

ATLAS-SUSY-2018-04 : 2 hadronic taus + MET

ATLAS-SUSY-2018-16 : 2 soft l + jets + MET

ATLAS-SUSY-2018-32 : 2 OS l + MET

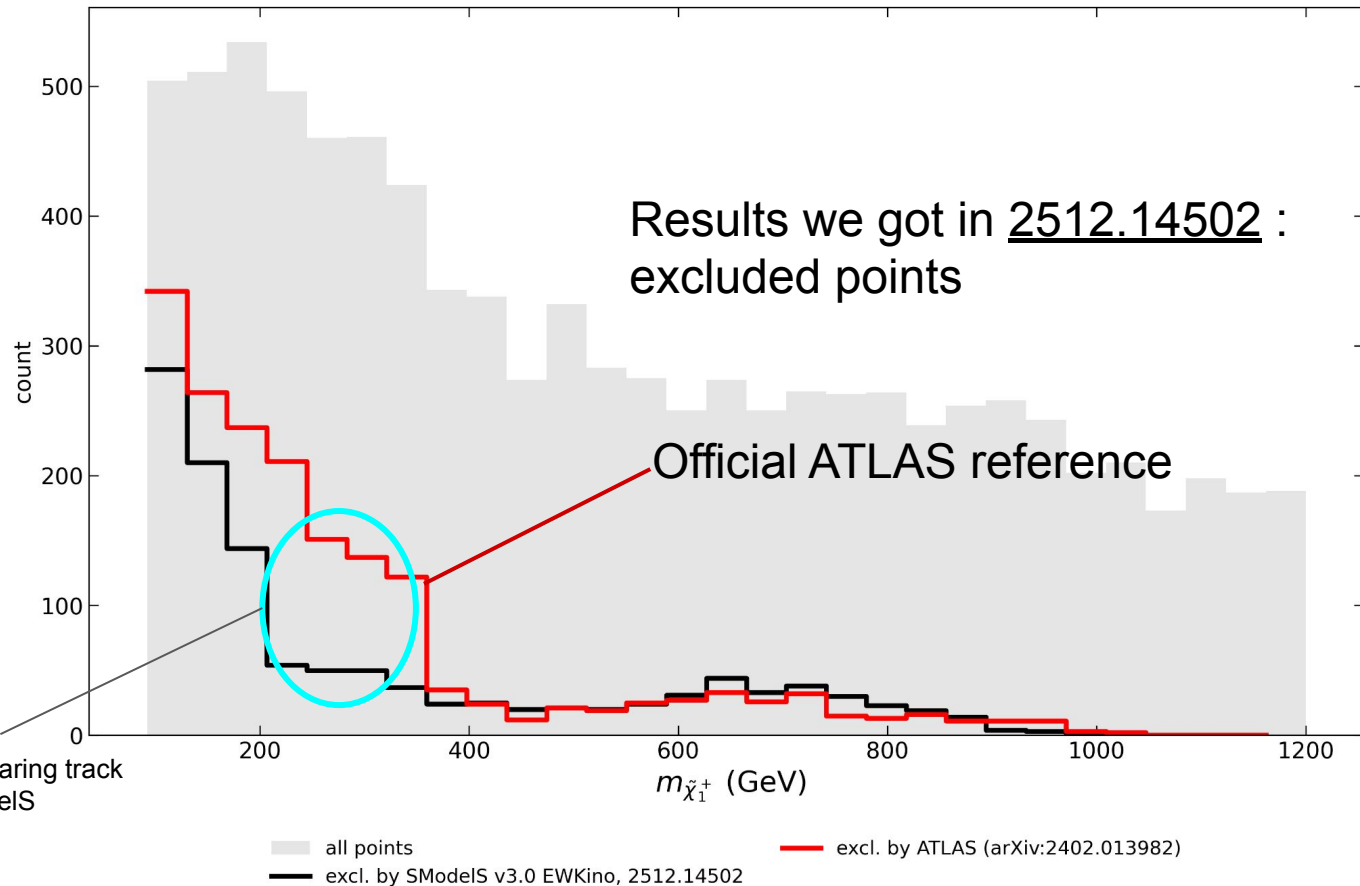
ATLAS-SUSY-2019-08 : 1l + h(bb) + MET

ATLAS-SUSY-2019-09 : 3l + MET

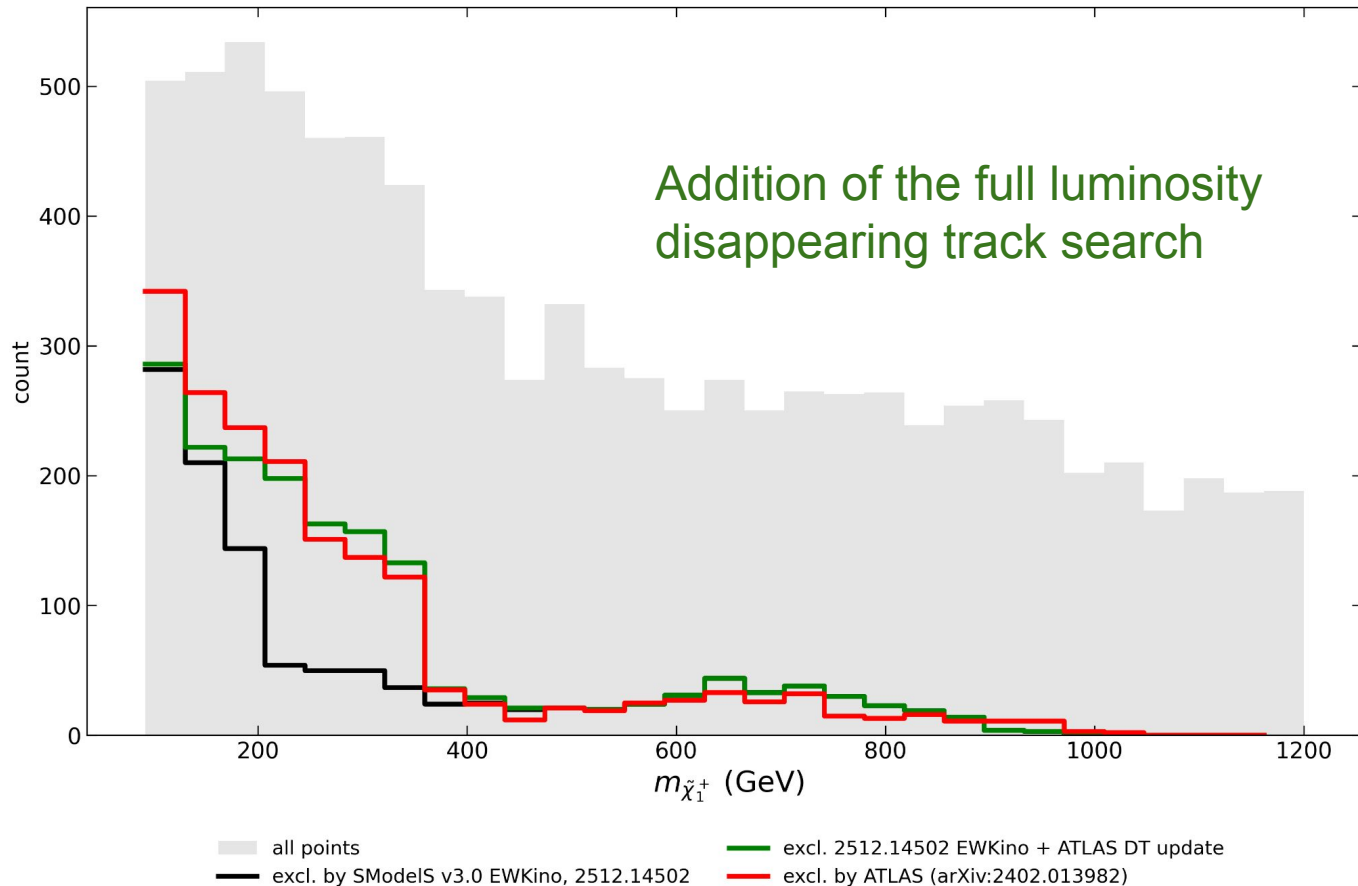
Application : update on the status of pMSSM at LHC

- [2512.14502](#) : We compared the coverage in SModelS of electroweakinos in the phenomenological Minimal Supersymmetric Standard Model (pMSSM) with the official coverage of [ATLAS](#) with v3.0 on a scan of ~9000 points
- Neutral and charged sparticles : $(\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0)$
 $(\tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm)$ mixing wino, higgsino and bino component.
- In v3.2 : We now have the full luminosity ATLAS disappearing track, as well as monojet searches and new electroweakino constraining results.
- The machine learned likelihood evaluation is much faster, allowing us to update the results in no time : 4h30 to run the full scan against ~2 days in 3.0. Up to an order of magnitude gained on some points !

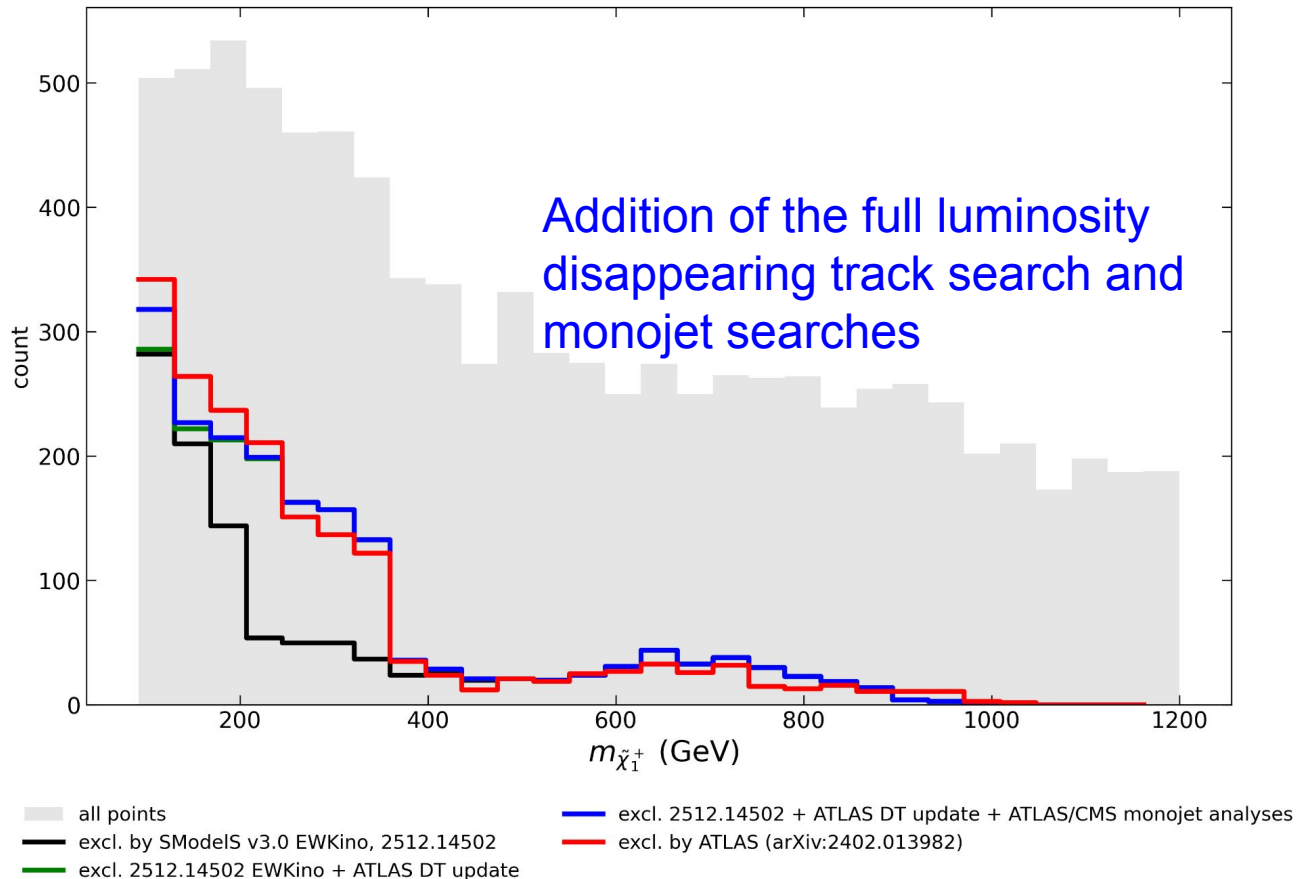
Single analysis level update



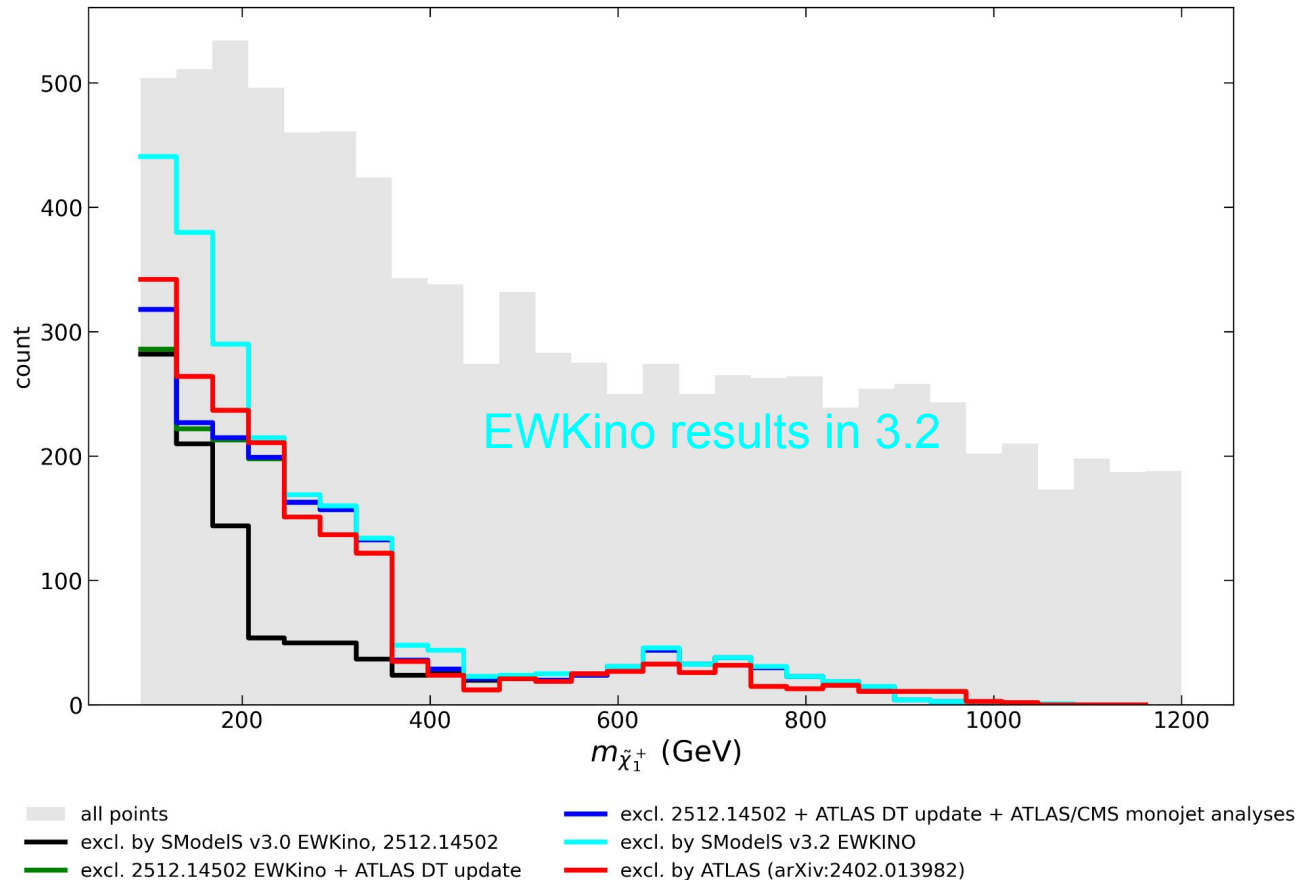
Single analysis level update



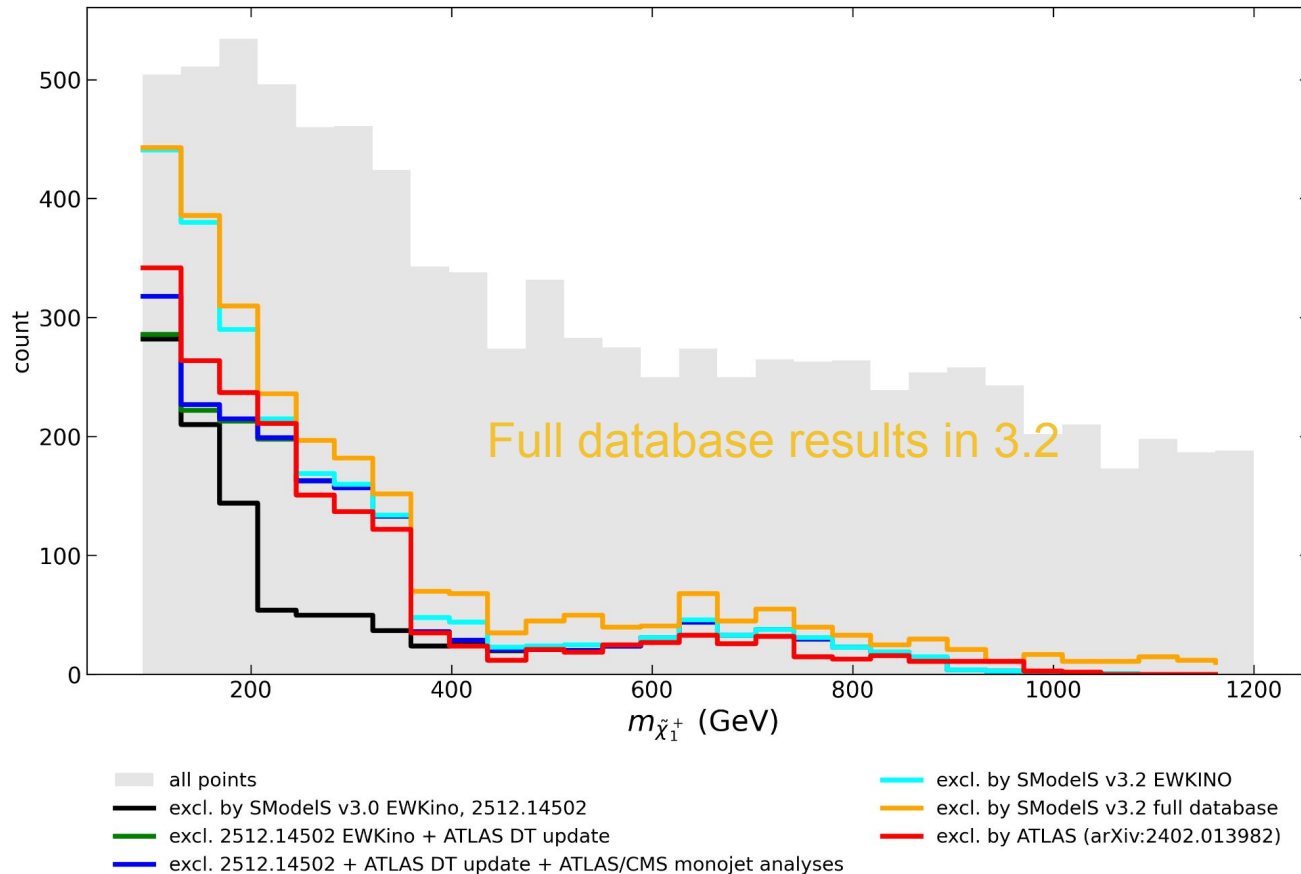
Single analysis level update



Single analysis level update

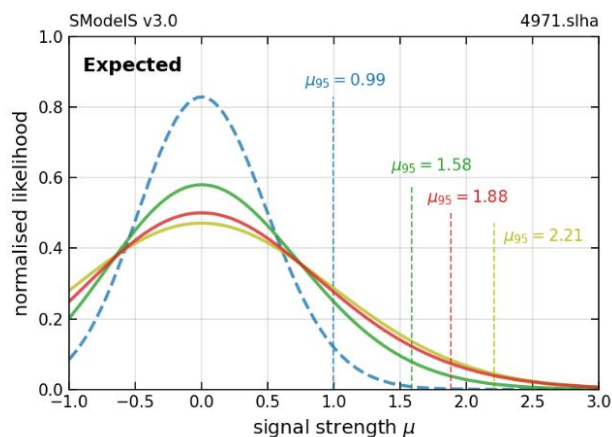
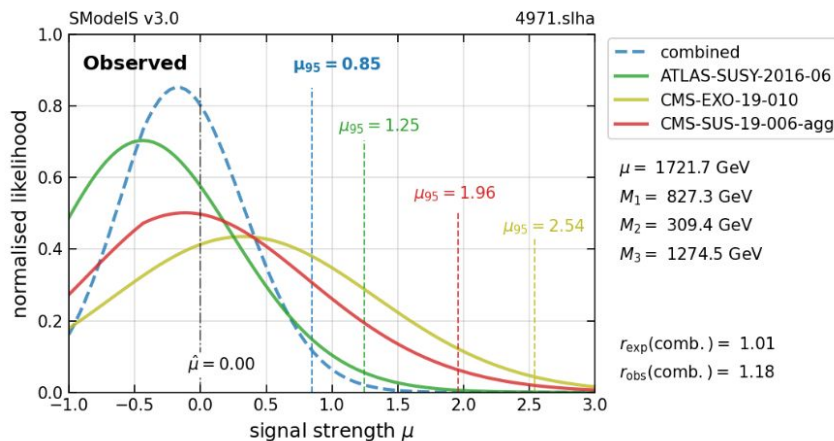


Single analysis level update



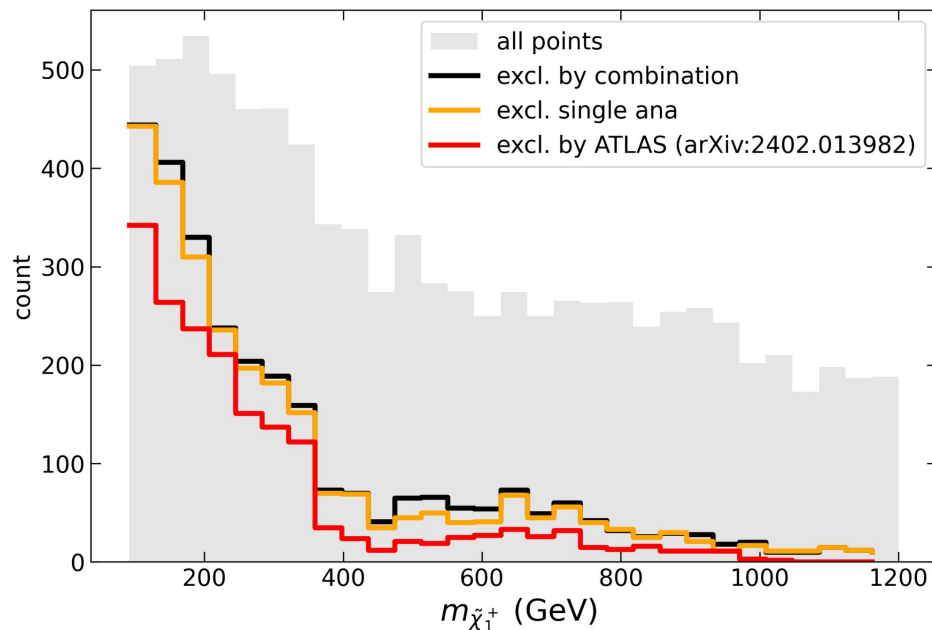
Going further : analysis combination and full database use

We can combine uncorrelated analyses in SModelS to reduce statistical fluctuations and include different topologies.



New Combination

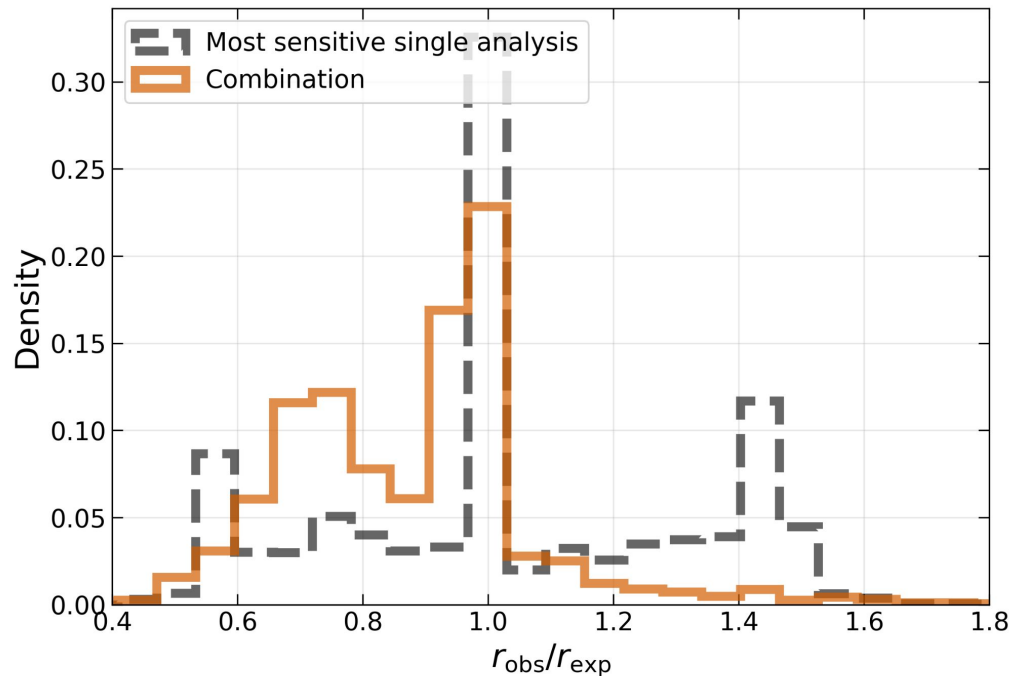
	Single analysis exclusion (expected)	Combination exclusion (expected)
Previous study	1696 (1479)	2031 (2002)
Now	2661 (2683)	2828 (3115)



We had 20% (35%) increase in excl.(expected) in 2512.14502
Now we have 6% (16%) increase in excl. (expected)

CMS-SUS-23-003 UL is very sensitive and compete with the
combination : most sensitive search for 2000 points

New Combination



$$r = \frac{\sigma^{BSM}}{\sigma_{95}}$$

Excess when $r_{obs}/r_{exp} < 1$

In 2512.14502 36% of points have an excess, 52% after combination.
In this update, 32% of points have an excess, 87% after combination.

Summary

- SModelS is a well suited software to go beyond SMS and investigate the coverage of the parameter space of new physics.
- SModelS can now use learned likelihood and is faster than ever !
- New results in the database drastically increased the coverage of SModelS in comparison with previous studies
- Can we identify points with “high” significance ?

Thanks !

Mixing matrix for the electroweakinos

$$\mathcal{M}_N = \begin{pmatrix} M_1 & 0 & -c_\beta s_W m_Z & s_\beta s_W m_Z \\ 0 & M_2 & c_\beta c_W m_Z & -s_\beta c_W m_Z \\ -c_\beta s_W m_Z & c_\beta c_W m_Z & 0 & -\mu \\ s_\beta s_W m_Z & -s_\beta c_W m_Z & -\mu & 0 \end{pmatrix}$$

$$\mathcal{M}_C = \begin{pmatrix} \mathbf{0} & \mathbf{X}^T \\ \mathbf{X} & \mathbf{0} \end{pmatrix}, \quad \mathbf{X} = \begin{pmatrix} M_2 & \sqrt{2} s_\beta m_W \\ \sqrt{2} c_\beta m_W & \mu \end{pmatrix}$$

Neutral eigenstates $(\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0)$

Charged eigenstates $(\tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm)$