LPSC GRENOBLE | MODANE

cnrs IN2P3 Les deux infinis

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SModelS v3

beyond Z_2 topologies

In collaboration with:

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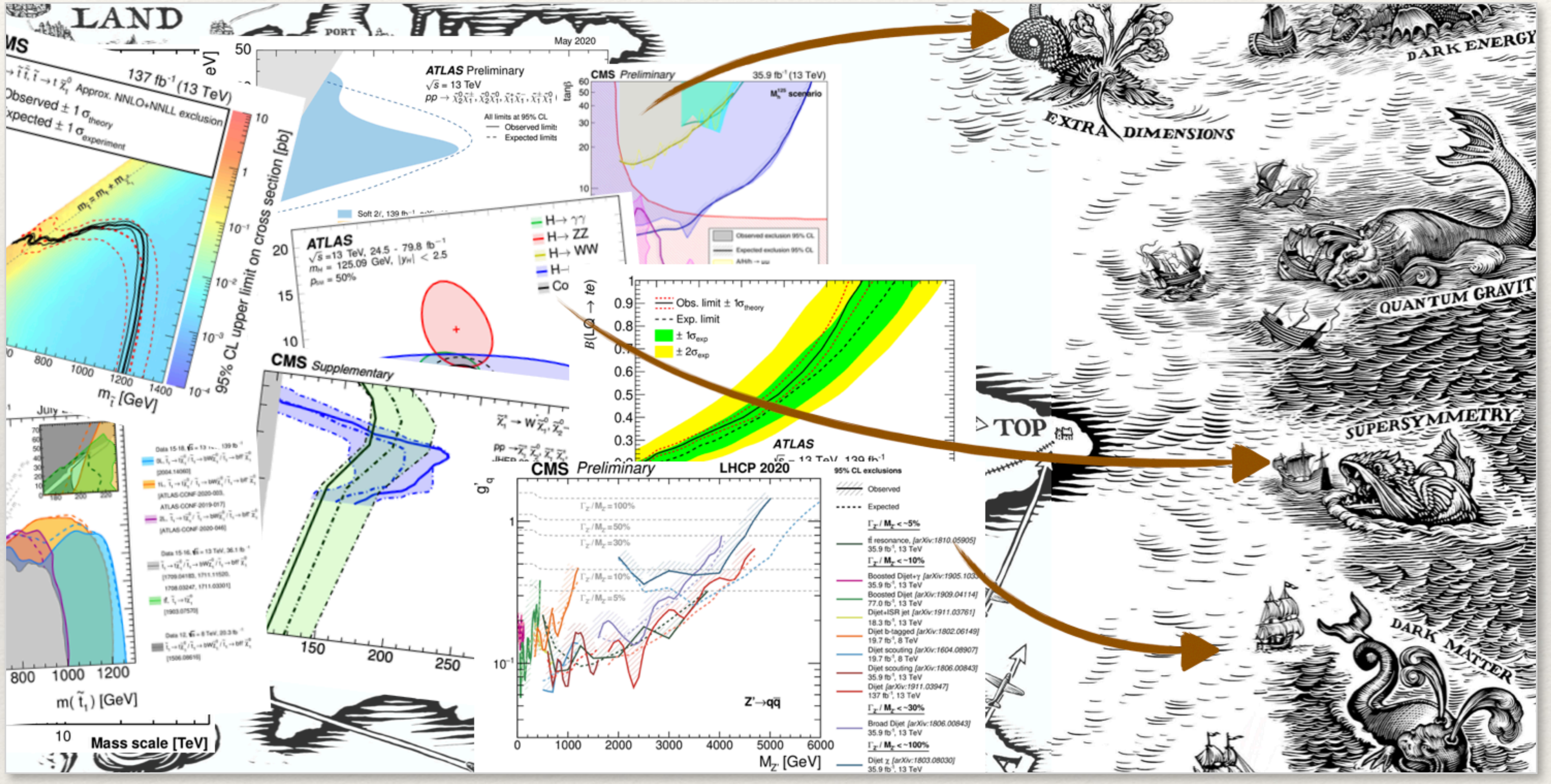
bold: involved in v3 code/database development

Motivation

see also Dipan's talk on Mon. pm.

Experimental analyses are sensitive to a far greater set of theories and parameter combinations than have so far been tested (or even been thought of).



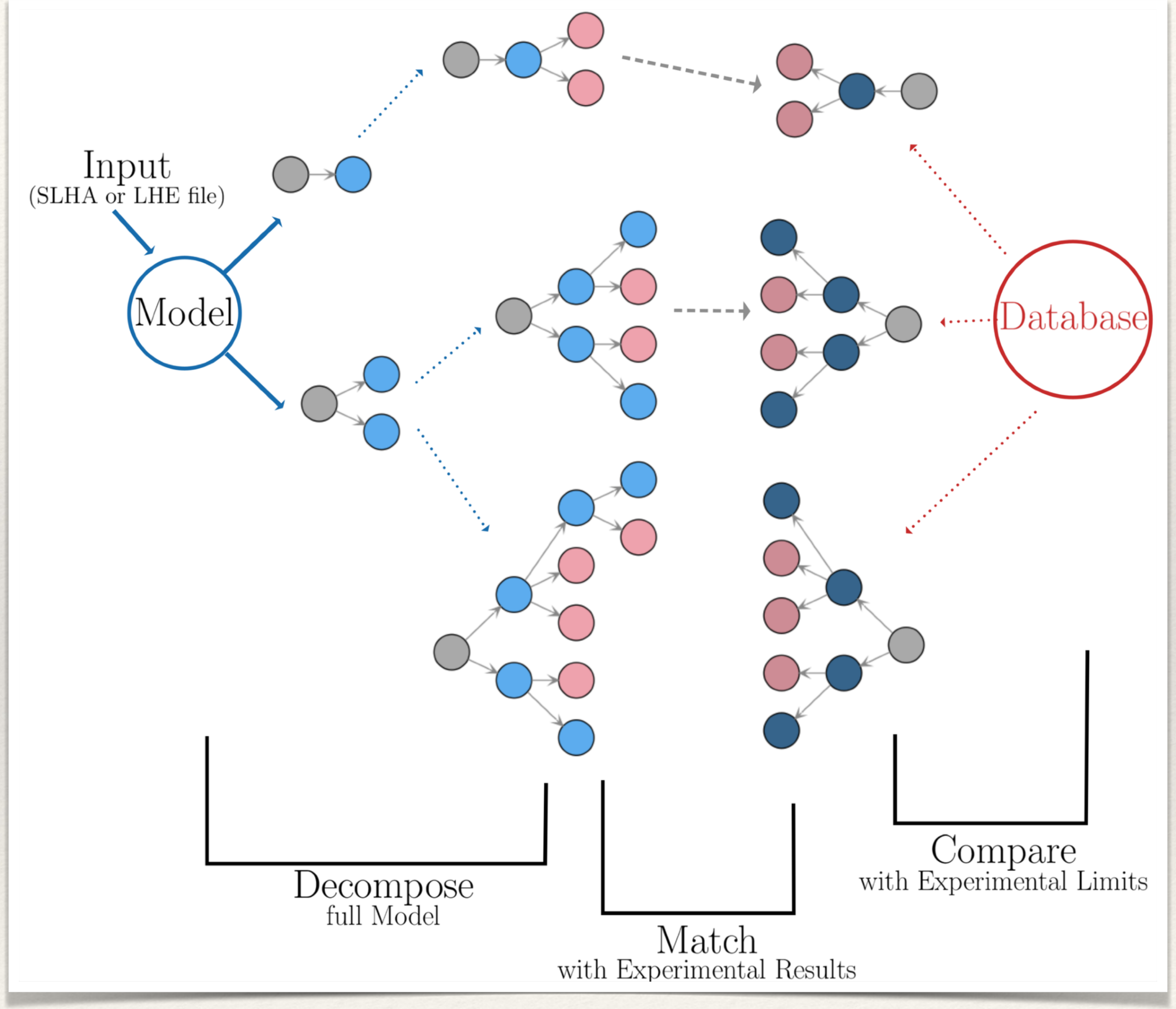
CERN Courier 28 April 2021

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

Meet SModelS

https://smodels.github.io

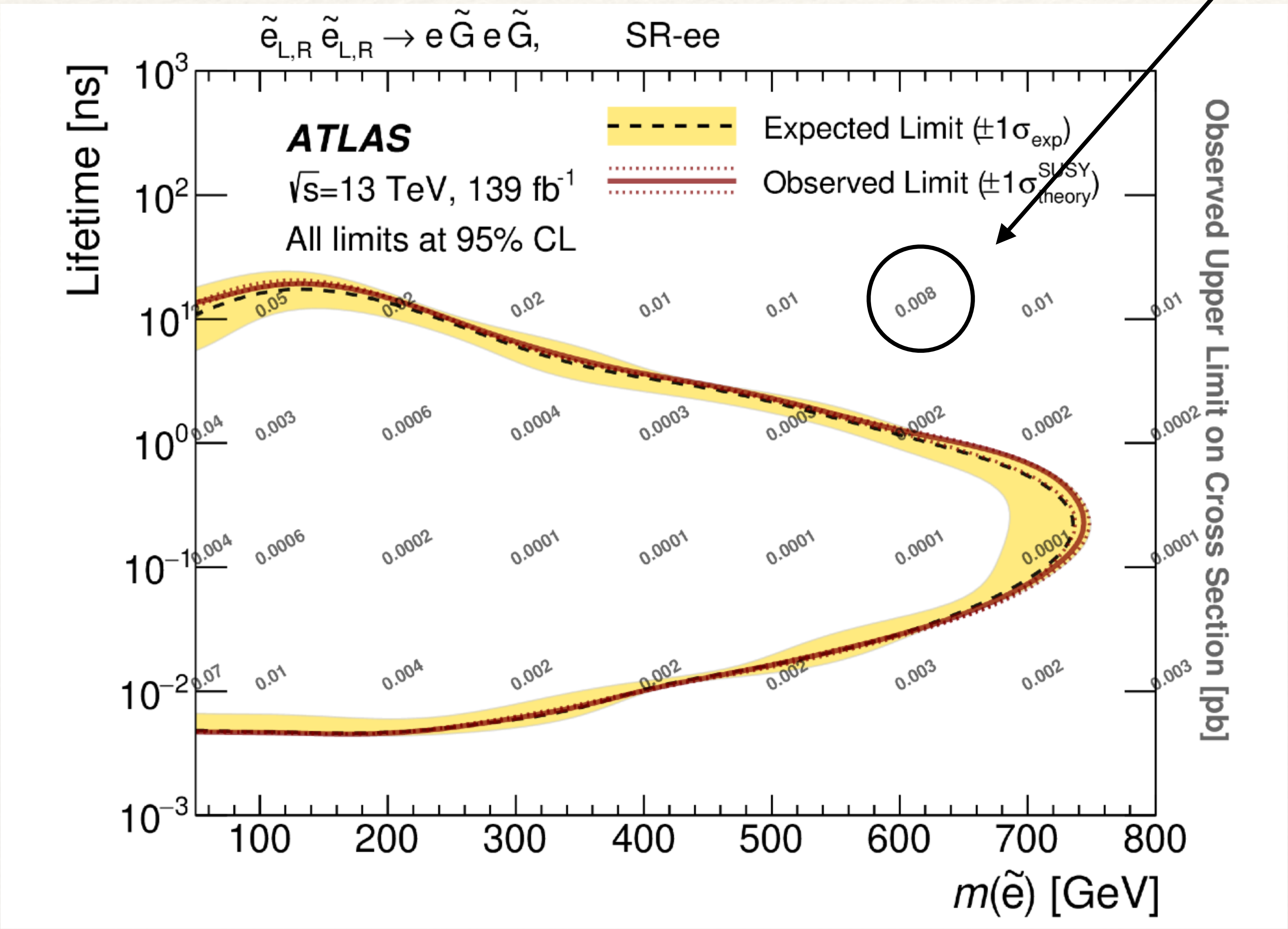
- Public tool for the **fast reinterpretation** of LHC searches on the basis of simplified-model results (no MC simulation).
- Working principle: **decompose** the signatures of **full BSM scenarios into simplified model components**, which are then confronted against the experimental constraints from a **large database of results**.
- Prompt and long-lived signatures are treated simultaneously and at the same footing.
- Whenever we can **compute likelihoods** (efficiency-maps available): easy to combine independent analyses into a global llhd.

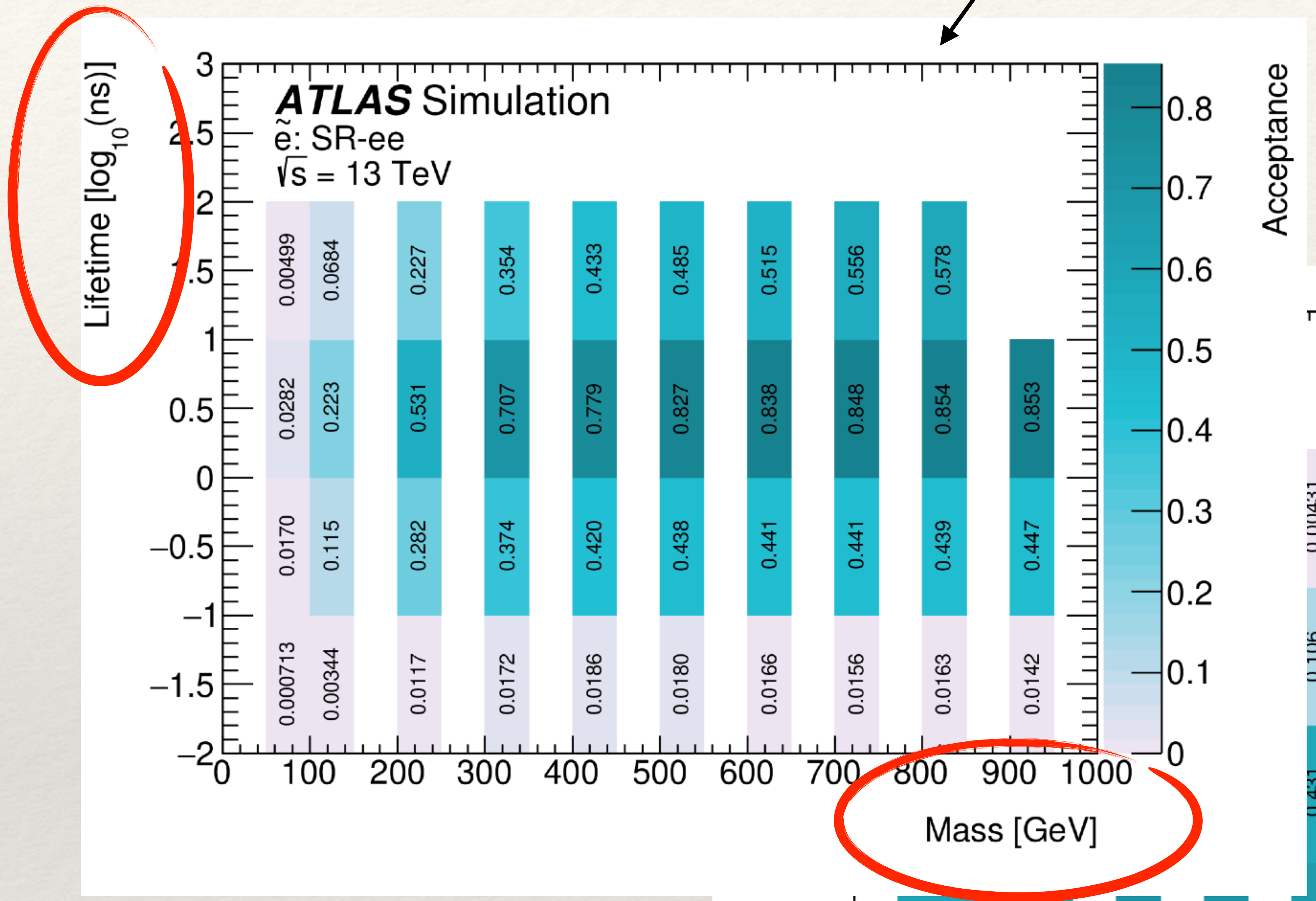


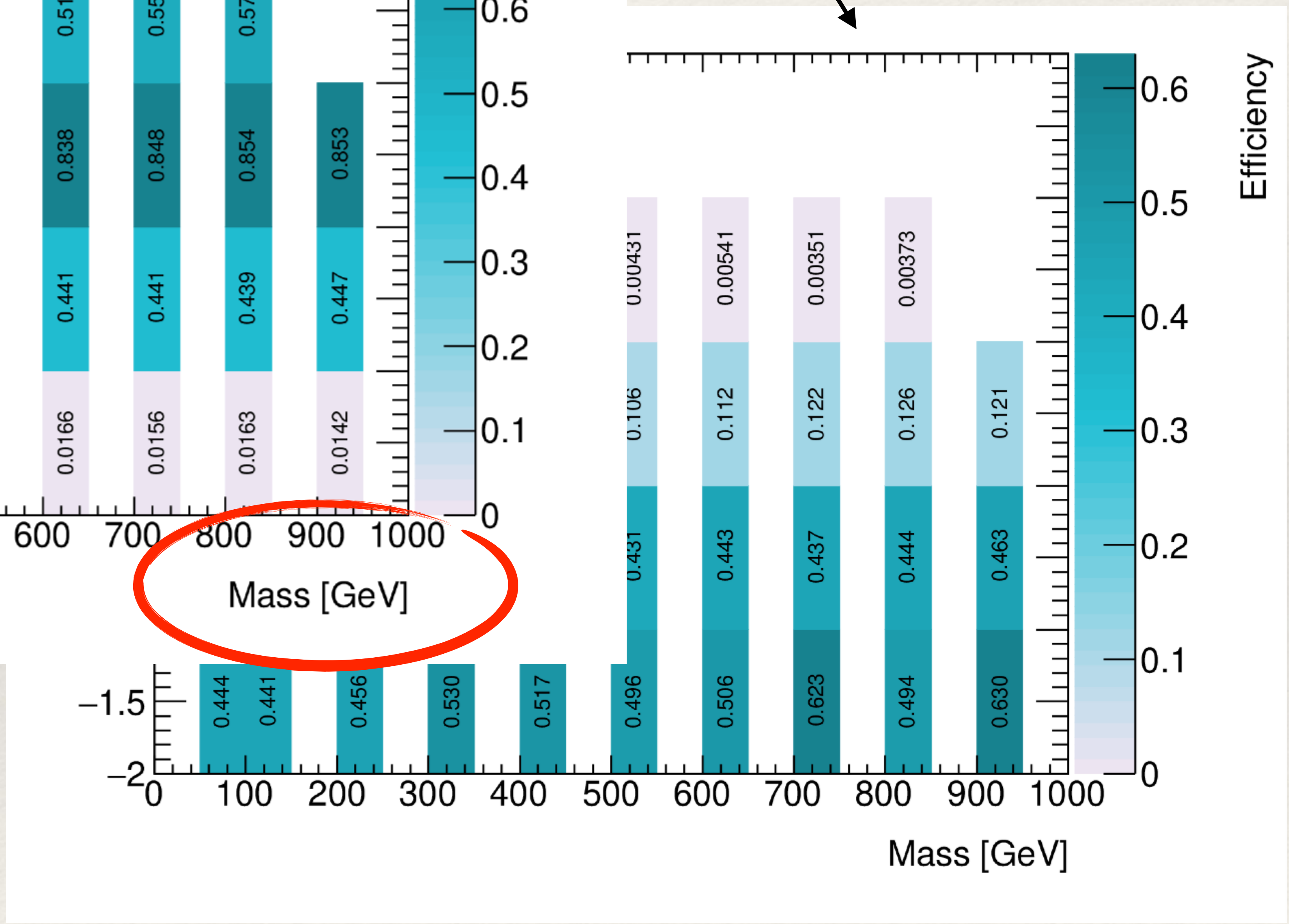
schematic view of the working principle

Experimental results used in SModelS

Simplified-models' **upper limit (UL) maps** and **A×ε 'efficiency' maps (EM)**







LLP results are 'maps' in terms of mass(es) and lifetime

→ in principle **higher dimensionality** than prompt results

EMs allow us to compute likelihoods

arXiv:2112.00769

111 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	1ℓ stop	3.2	✓		✓	
ATLAS-SUSY-2015-06	0ℓ + 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	0ℓ + 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	0ℓ stop	36.1	✓			
ATLAS-SUSY-2016-16	1ℓ 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	$\geq 2\,c$-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	0ℓ + 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	2ℓ + jets, EWK	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-05	2ℓ + jets, strong	139.0			✓	
ATLAS-SUSY-2018-06	3ℓ, EWK	139.0	✓	✓	✓	
ATLAS-SUSY-2018-08	2 OS ℓ	139.0	✓		✓	
ATLAS-SUSY-2018-10	1ℓ + jets	139.0	✓		✓	
ATLAS-SUSY-2018-12	0ℓ + 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	$2b + 2h(bb)$	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-32	2 OS ℓ	139.0	✓		✓	PYHF
ATLAS-SUSY-2018-40	$2b + 2h(\tau\tau)$	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	$1\ell + h(bb)$, EWK	139.0	✓		✓	PYHF
ATLAS-SUSY-2019-09	3ℓ, 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	0ℓ + jets, top tag	2.3	✓	✓		
CMS-SUS-16-032	2 b- or 2 c-jets	35.9	✓			
CMS-SUS-16-033	0ℓ + 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	0ℓ + jets	35.9	✓	✓		
CMS-SUS-16-037	1ℓ + 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	1ℓ + 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	0ℓ + top tag	35.9	✓	✓	✓	SLv1
CMS-SUS-16-051	1ℓ stop	35.9	✓	✓		
CMS-SUS-17-003	2 taus	35.9	✓			
CMS-SUS-17-004	EWK combination	35.9	✓			
CMS-SUS-17-005	1ℓ + 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	2ℓ 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	0ℓ + jets, MHT	137.0	✓	✓	✓	SLv1
CMS-SUS-19-008	2–3ℓ + jets	137.0	✓	✓		
CMS-SUS-19-009	1ℓ + jets, MHT	137.0	✓	✓		
CMS-SUS-19-010	jets + top and W-tag	137.0	✓	✓		
CMS-SUS-19-011	2ℓ 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

Made possible by **extended topology description in v2.0**:

- introduced **flexible number of attributes** for the BSM particles, such as **spin**, charge, **decay width**, etc.

full Run-2 luminosity:
17 ATLAS,
13 CMS

v2.3: 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

arXiv:2306.17676

v2.3: combination of analyses

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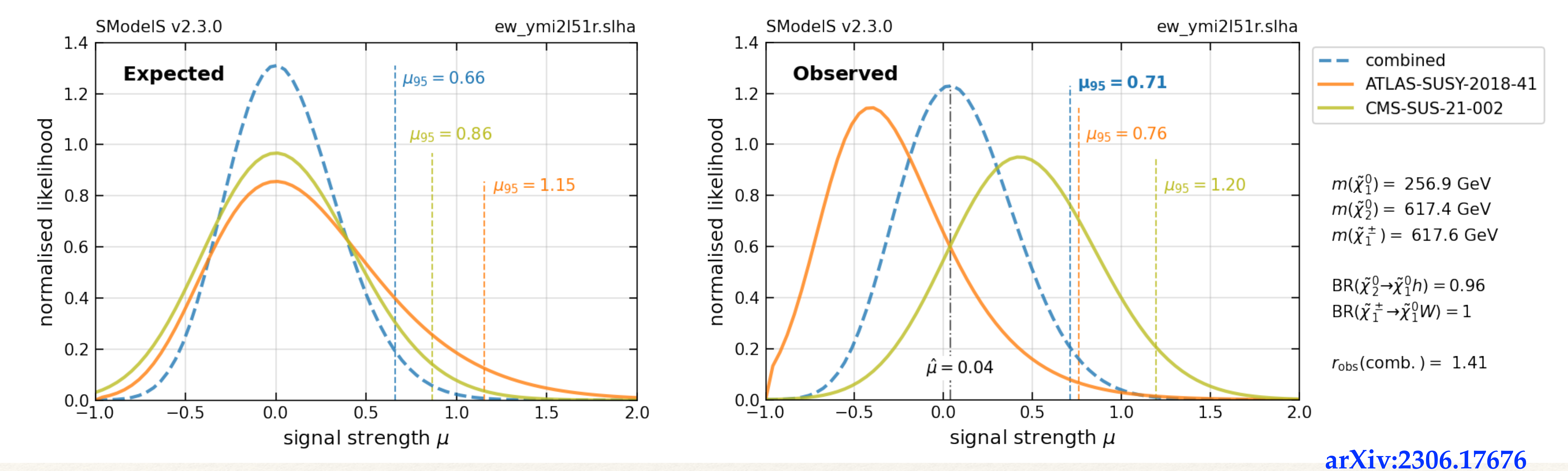
- Combined likelihood is computed as $\mathcal{L}_C(\mu) = \prod_{i=1} \mathcal{L}_i(\mu\, s^i)\,.$



arXiv:2306.17676

v2.3: combination of analyses

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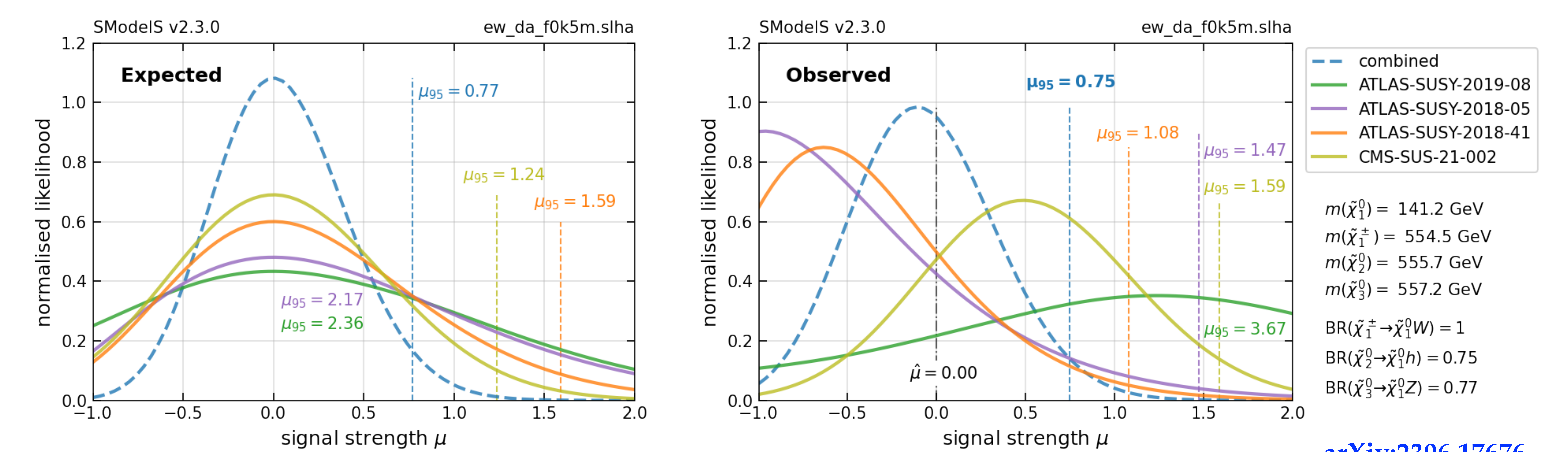
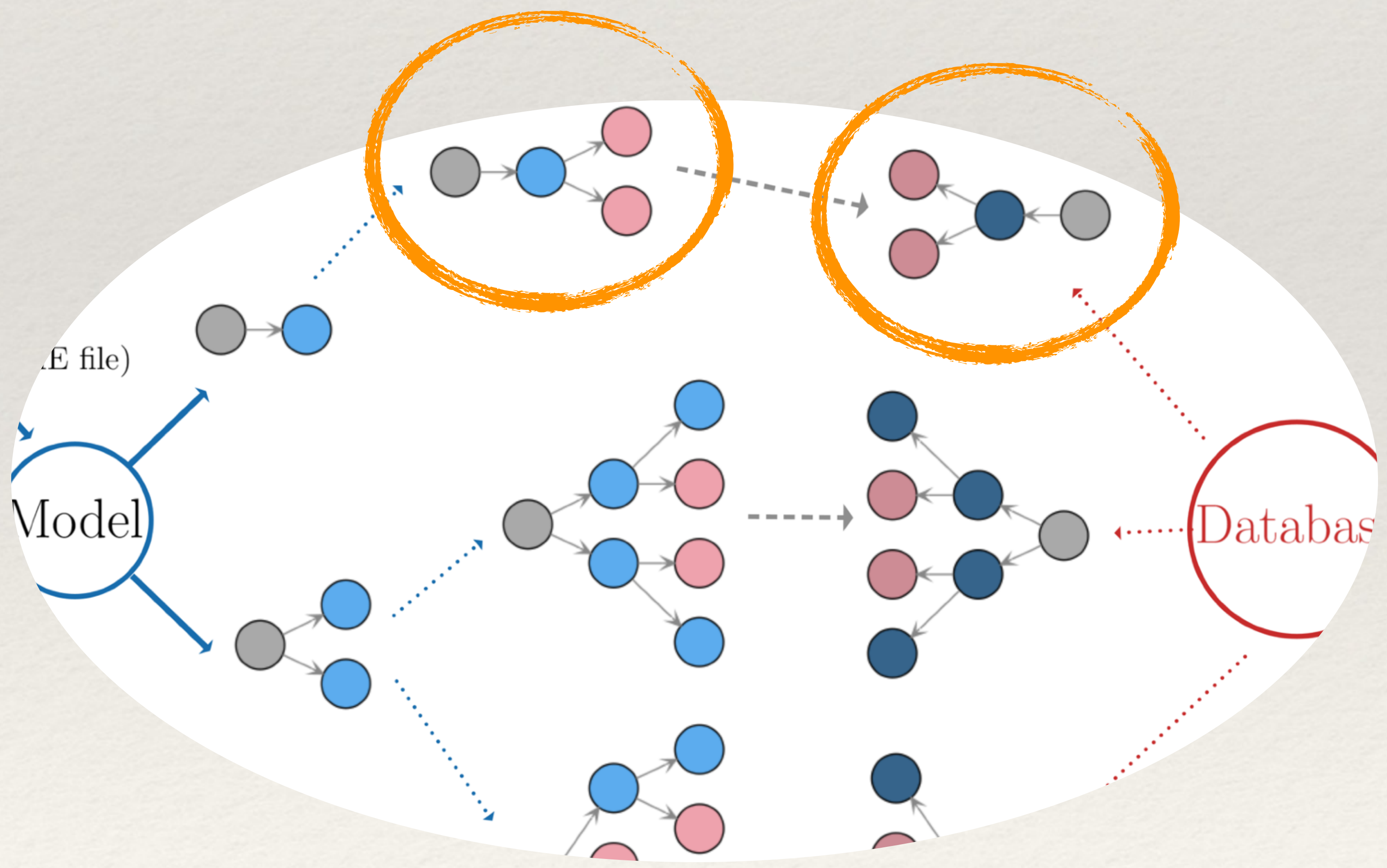


arXiv:2306.17676

So far, SModelS could only treat signatures from 2 → 2 production of BSM particles followed by linear cascade decays (SUSY-like)

☞ limited to models with a Z_2-like symmetry

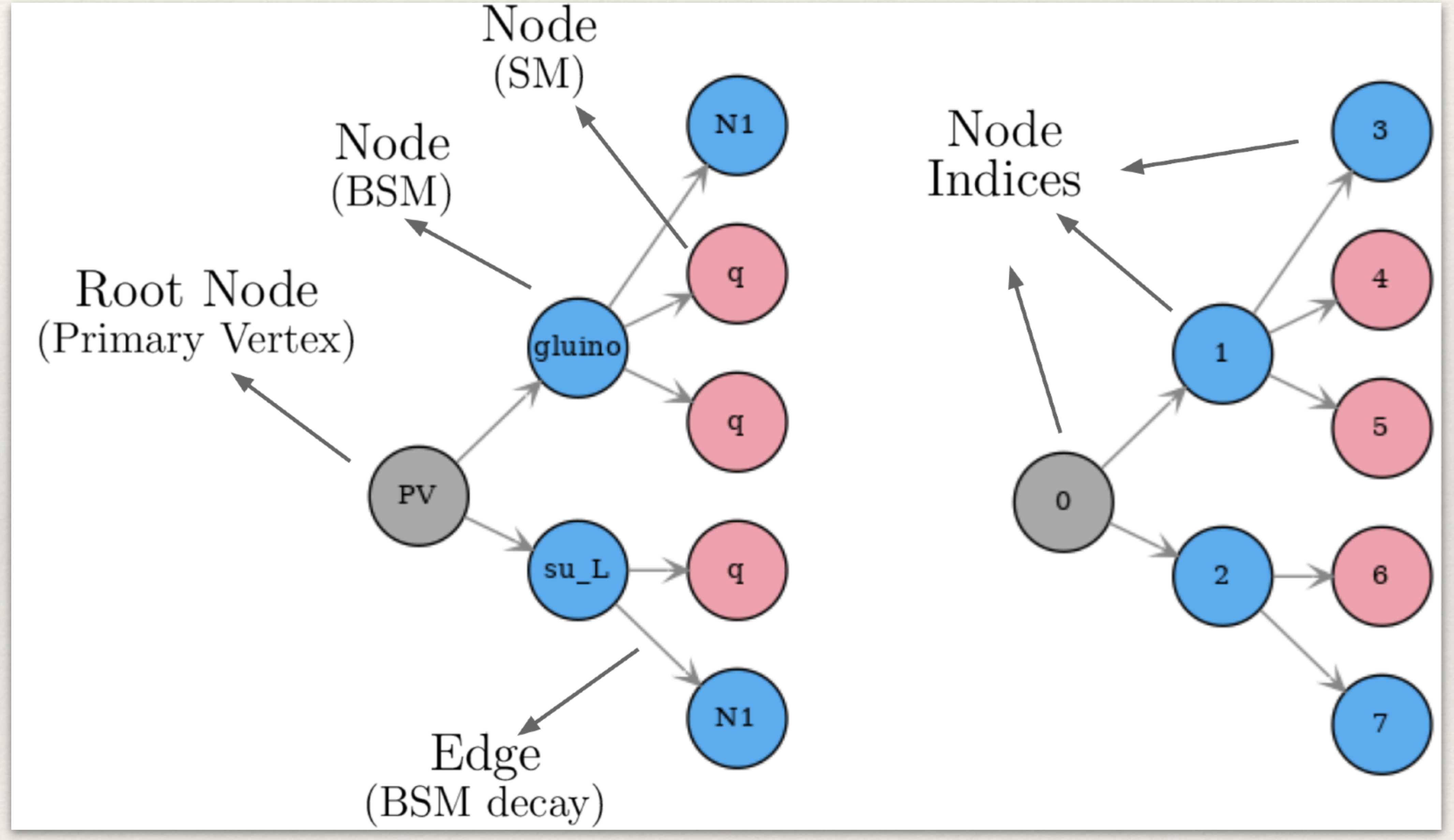
☞ alleviated in v3



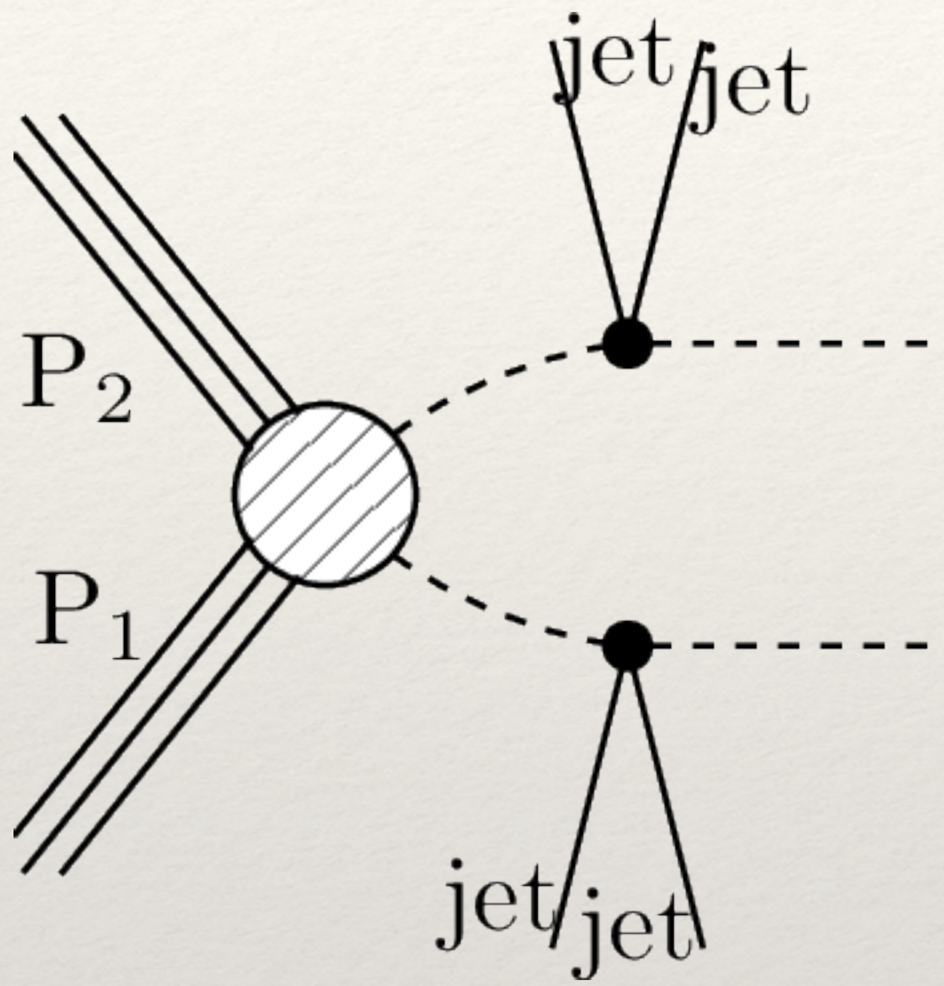
SModelS version 3

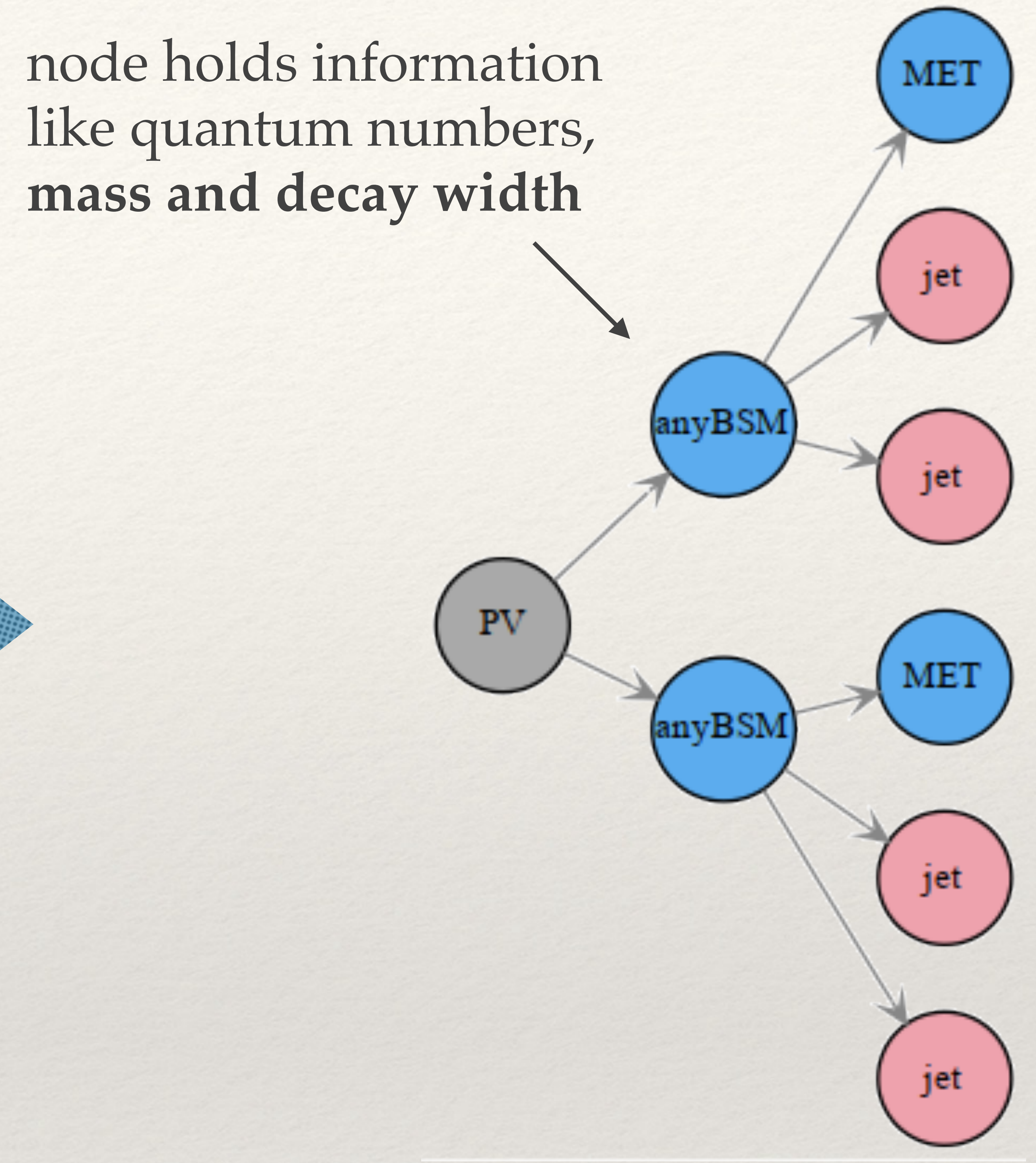
In v3 of SModelS, we are moving from the text-based bracket notation to a much more general and flexible **graph-based topology description** through **directed rooted trees**

- **Root node (PV)** represents the hard scattering collision
- All **particles** appearing in the SMS topology correspond to **graph nodes**
- BSM **decays** are represented by **edges** connecting the parent particles to their daughters.
- The **nodes hold all required information**, i.e. quantum numbers, mass and total width, of the respective particle



v2 vs v3 : jets+MET (prompt or DV)

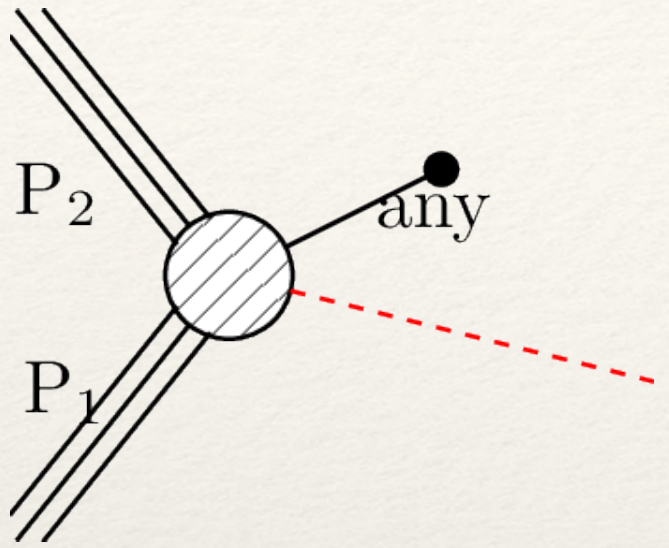




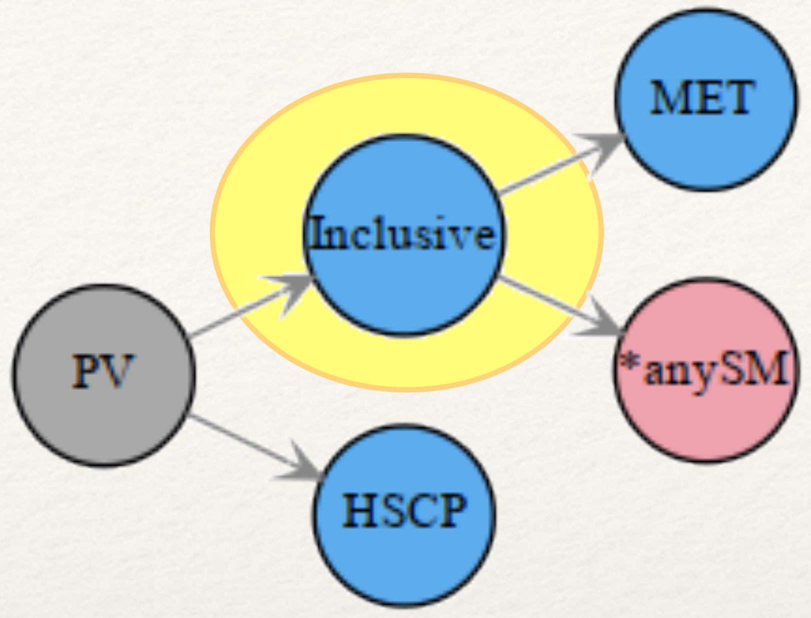

```
[[[jet,jet]],[[jet,jet]]] (MET, MET)
```

```
(PV > anyBSM(1),anyBSM(2)),
 (anyBSM(1) > MET,jet,jet),
  (anyBSM(2) > MET,jet,jet)
```

v2 vs v3 : HSCPs (analogous for R-hadrons of different charges)

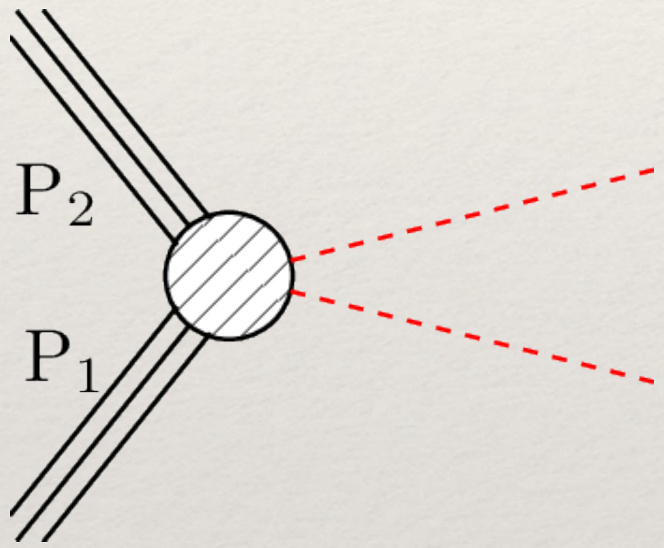


`[[*],[]] (MET,HSCP)`

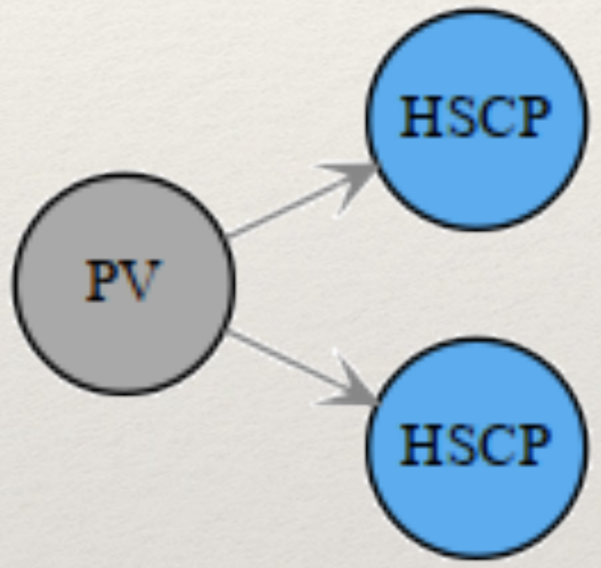



```
(PV > Inclusive(1),HSCP),
(Inclusive(1) > MET,*anySM)
```

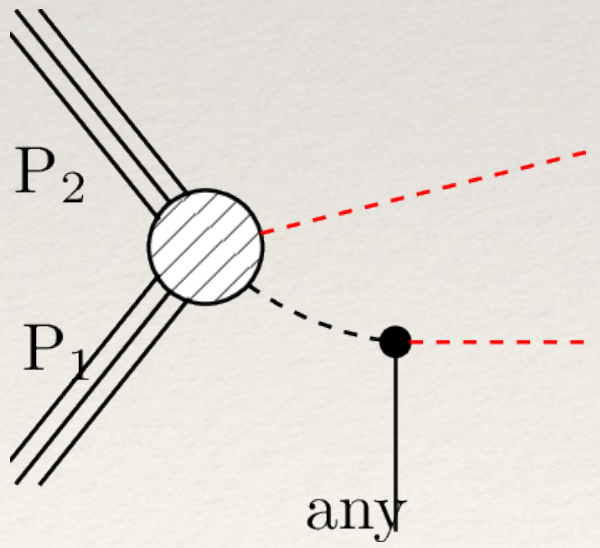
‘inclusive’ node holds a list of particles



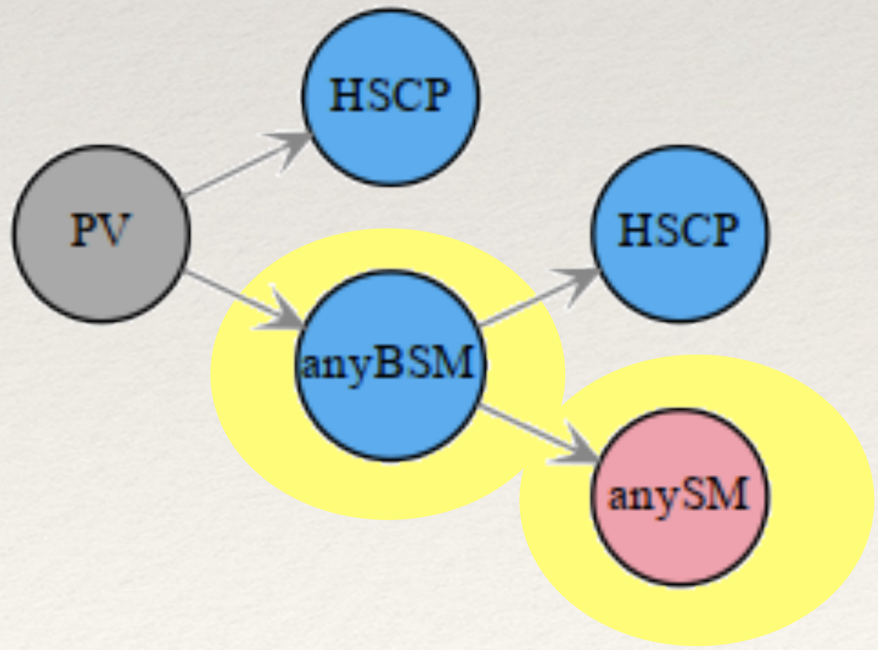
`[[],[]] (HSCP,HSCP)`



`(PV > HSCP,HSCP)`



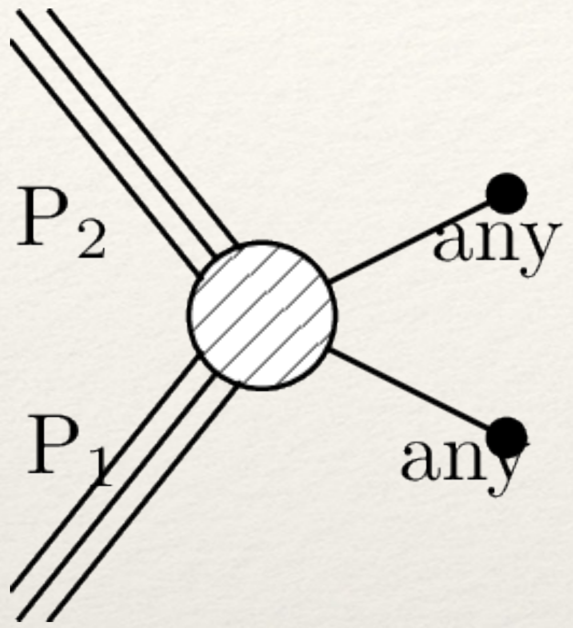
`[[],[*]] (HSCP,HSCP)`



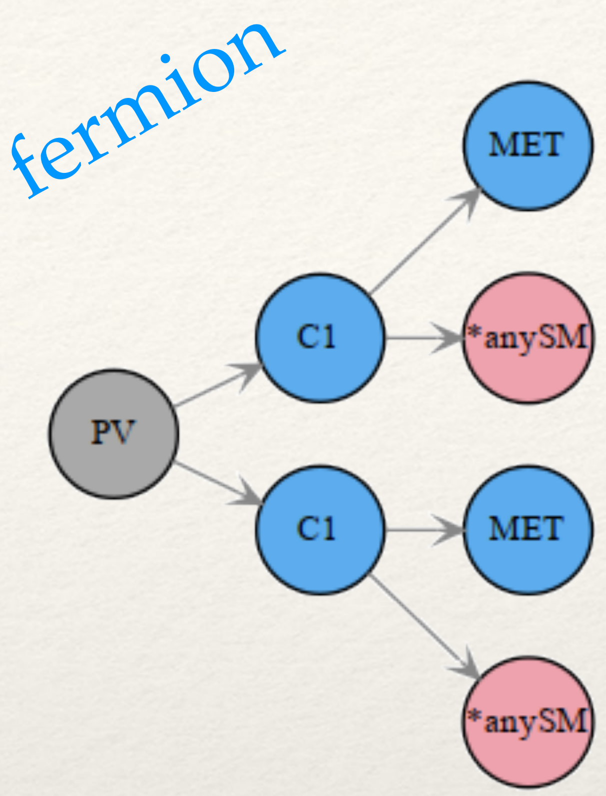

```
(PV > HSCP,anyBSM(2)),
(anyBSM(2) > HSCP,anySM)
```

‘anyBSM’: represents any BSM state
‘anySM’: represents any SM state

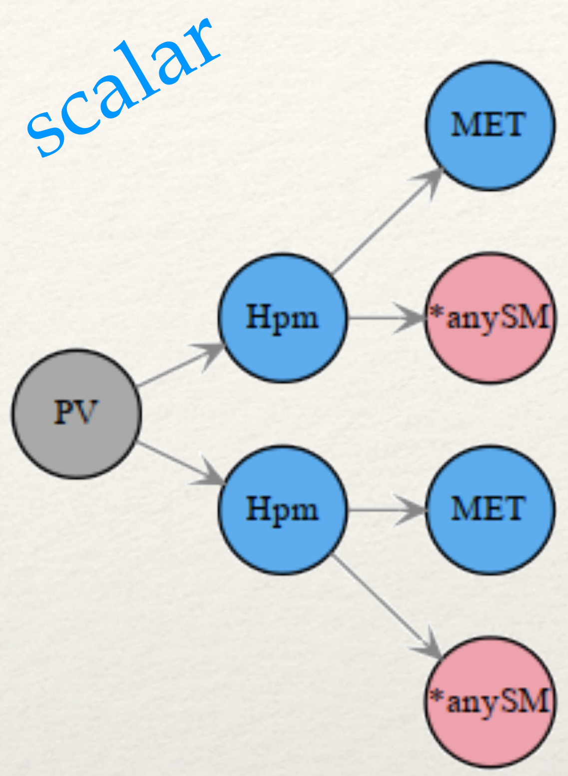
v2 vs v3 : disappearing tracks



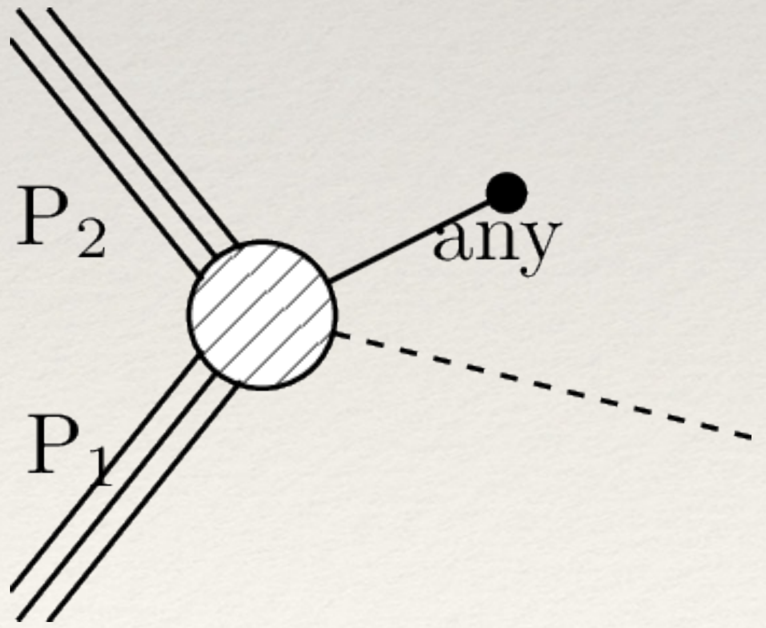

```
TDTM1F, TDTM1S :
[[*],[*]] (MET,MET)
```



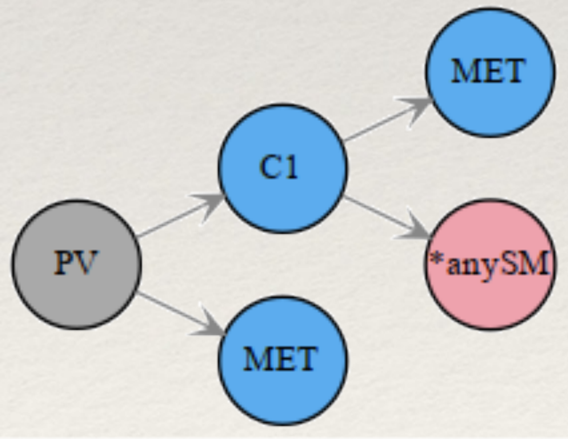

```
(PV > C1(1),C1(2)),
(C1(1) > MET,*anySM),
(C1(2) > MET,*anySM)
```



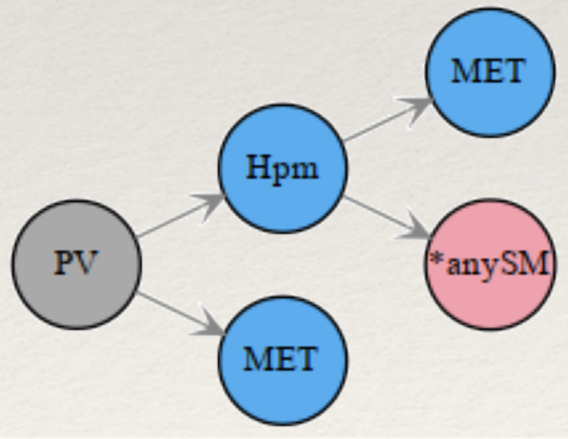

```
(PV > Hpm(1),Hpm(2)),
(Hpm(1) > MET,*anySM),
(Hpm(2) > MET,*anySM)
```




```
TDTM2F, TDTM2S :
[[*],[]] (MET,MET)
```




```
(PV > C1(1),MET),
(C1(1) > MET,*anySM)
```

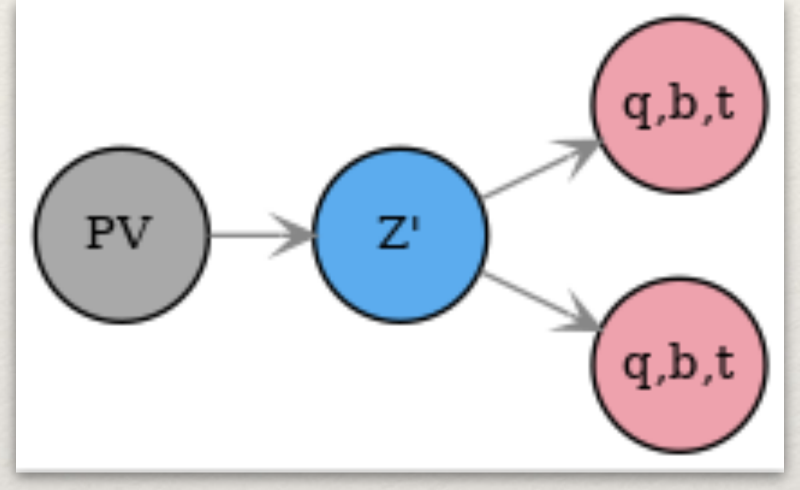


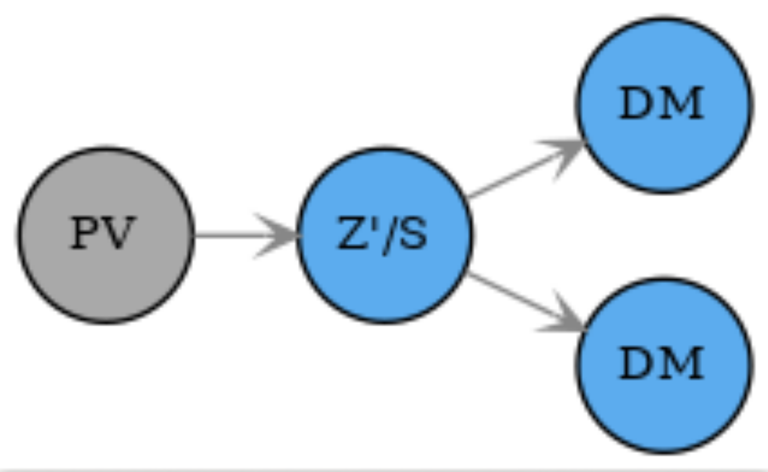

```
(PV > Hpm(1),MET),
(Hpm(1) > MET,*anySM)
```

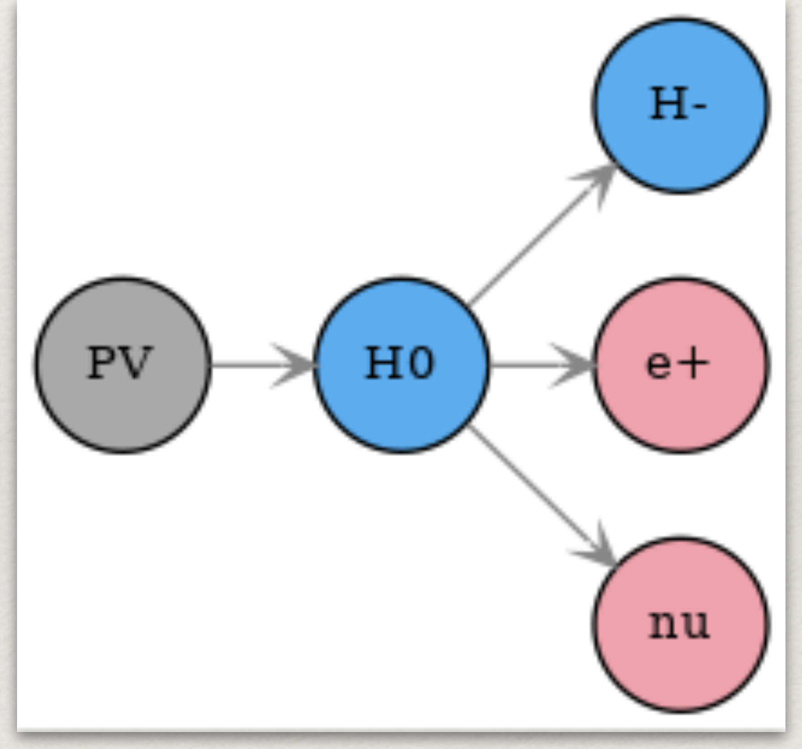
Beyond Z_2 topologies

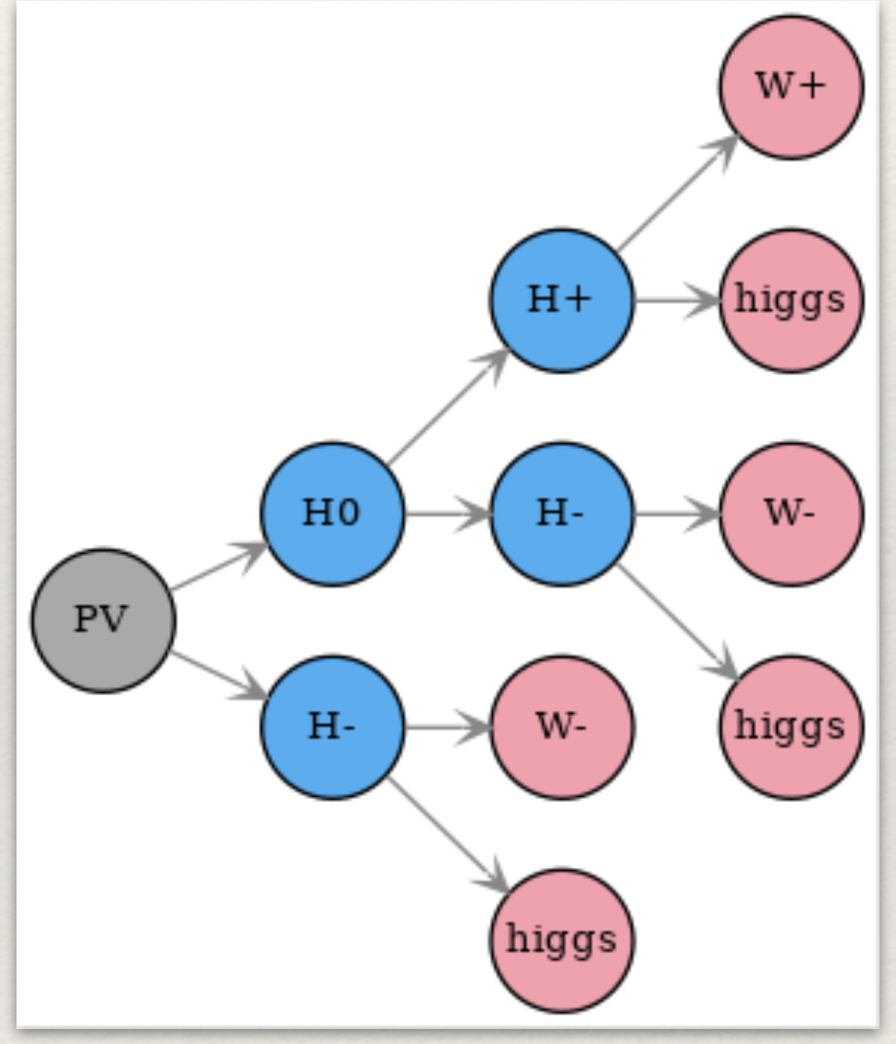
Graph-based description allows us to go beyond the 2-branch structure of SUSY-like signatures with conserved R-parity → resonant production, associated prod. w/SM, sub-branches, RPV, etc.

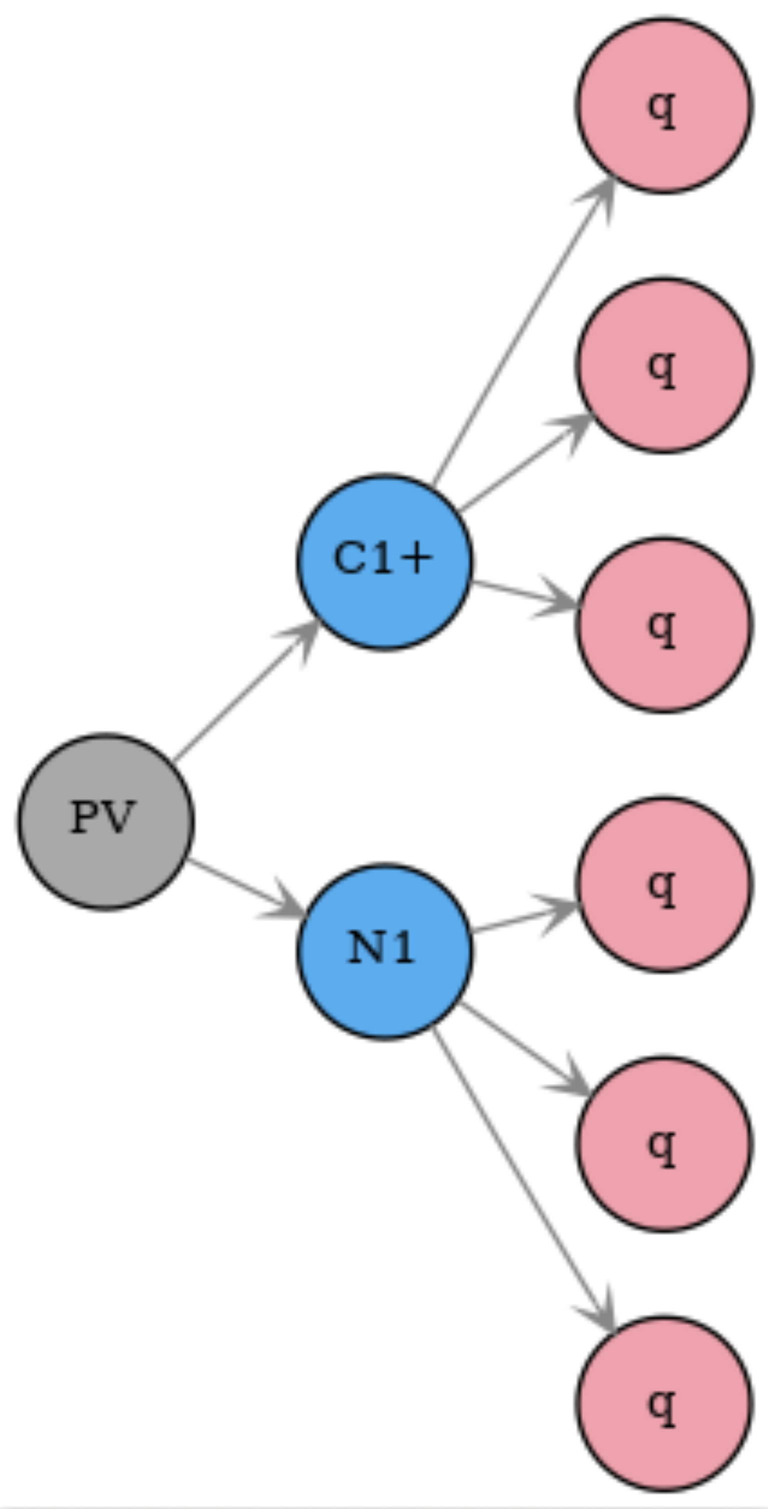
Examples:











NB: can include width dependence ∀ BSM states, from LLPs to broad resonances

On the user side

https://smodels.readthedocs.io/en/develop/

parameters.ini

```
[options]
checkInput = True ; set True to check the input file.
doInvisible = True ; set True if invisible compression should be performed.
doCompress = True ; set True if mass compression should be performed.
testCoverage = False ; set True if topologies not covered by experiments
                       (missing topologies) should be identified
computeStatistics = True ; set True to compute likelihoods for EM-type results.
combineSRs = True ; set True to combine signal regions when stat. model available.
combineAnas = ATLAS-SUSY-2016-06,CMS-EXO-19-010 ; list of statistically independent
                                                  analyses to combine.
[…]

[particles]
model=share.models.mssm ; path to the BSM model definition (default: MSSM).
promptWidth = 1e-11 ; particles with widths (in GeV) above this value are considered prompt
stableWidth = 1e-25 ; particles with widths (in GeV) below this value are considered stable
ignorePromptQNumbers = spin, eCharge, colordim ; Quantum numbers to be erased for promptly
                                                 decaying particles (more inclusive results)
[…]

[printer]
outputType = summary, python ;Define the output formats
outputFormat = current ; Define output format: ‘current’ (v3) or ‘version2’
```

New results in the database

(v3.0 release & paper in preparation)

Full list of analyses: https://smodels.github.io/docs/ListOfAnalyses300-beta

ID	Signature	Luminosity	SMS Topology	Type
Run II - 13 TeV				
ATLAS-EXOT-2019-03 [5]	Dijet resonance	139 fb^{-1}	$pp \to Z' \to jj$	UL
ATLAS-EXOT-2018-48 [6]	$t\bar{t}$ resonance	139 fb^{-1}	$pp \to Z' \to t\bar{t}$	UL
CMS-EXO-19-012 [3]	Dijet resonance	138 fb^{-1}	$pp \to Z' \to j\bar{j}$	UL
CMS-EXO-20-008 [7]	b-jet resonance	138 fb^{-1}	$pp \to Z' \to b\bar{b}$	UL
CMS-EXO-20-004 [8]	Jets plus E_T^{miss}	138 fb^{-1}	$pp \to Z', \phi \to \chi\bar{\chi}$	EM
ATLAS-SUSY-2018-22 [9]	Multi-jet plus	139 fb^{-1}	$pp \to Z' \to \chi\bar{\chi}$	EM
ATLAS-SUSY-2018-13 [4]	Displaced jets	139 fb^{-1}	$pp \to \tilde{\chi}\tilde{\chi} \to jjj, jjj, \ldots$	EM
Run I - 8 TeV				
CMS-EXO-16-057 [10]	b-jet resonance	19.7 fb^{-1}	$pp \to Z' \to b\bar{b}$	UL
CMS-EXO-12-059 [11]	Dijet resonance	19.7 fb^{-1}	$pp \to Z' \to jj$	UL
ATLAS-EXOT-2013-11 [12]	Dijet resonance	20 fb^{-1}	$pp \to Z' \to q\bar{q}$	UL

+ extension of ATLAS-SUSY-2018-42 (charged LLPs, dE/dx) EMs

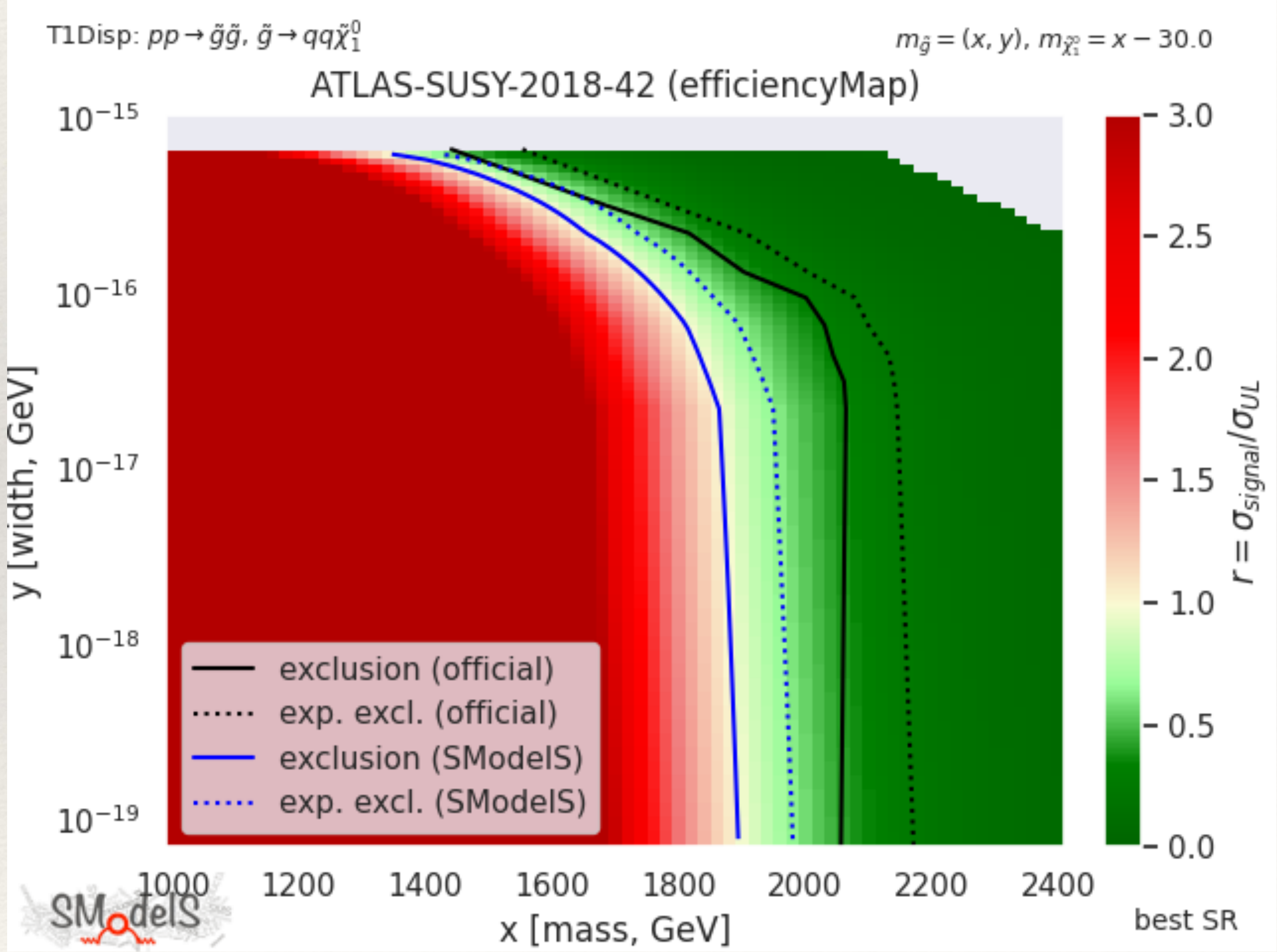
ATLAS-SUSY-2018-42 (*dE/dx*) : exclusive SRs

cf. Andre's talk at LLP 2023

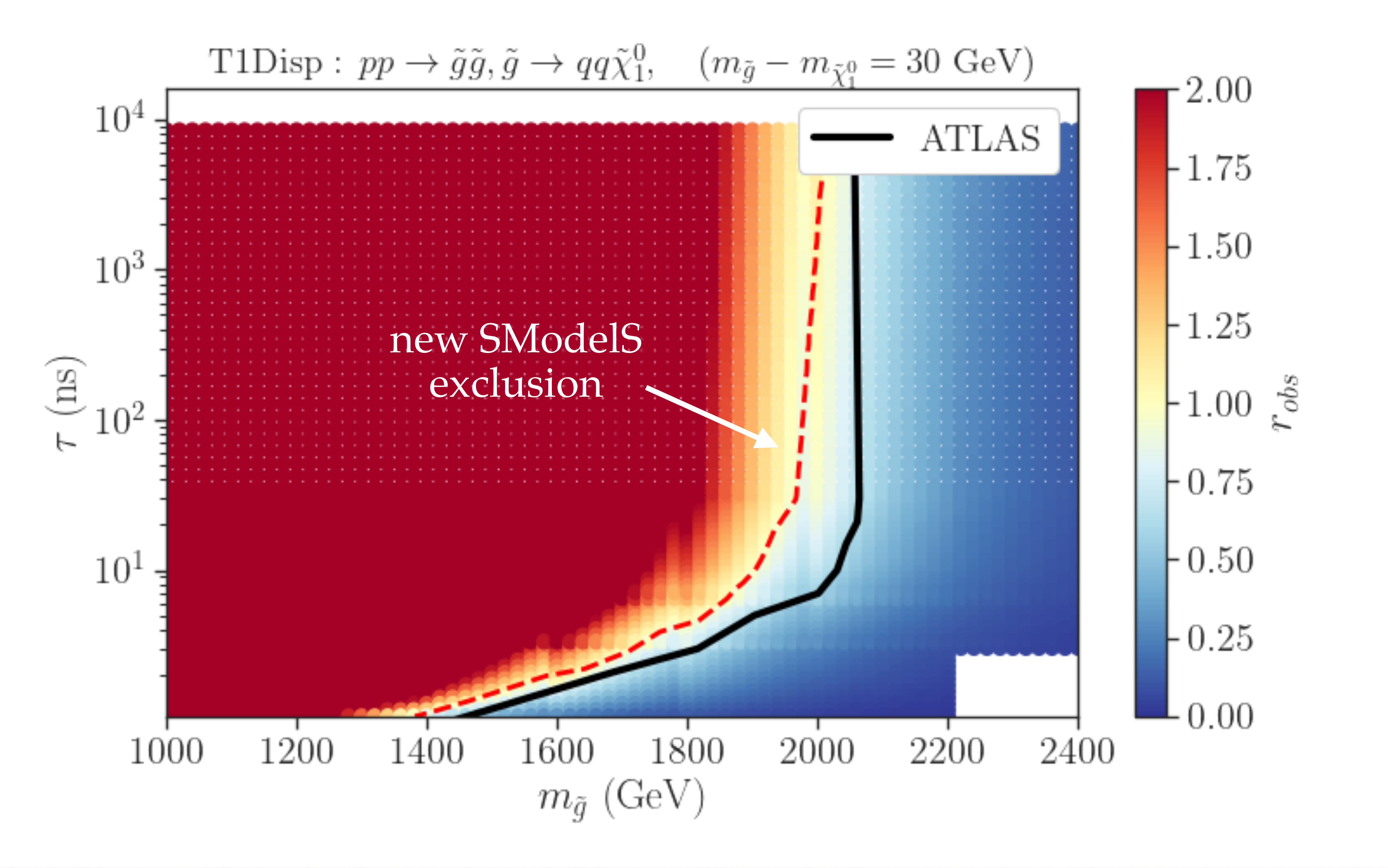
Heavy, charged LLPs with large ionisation energy loss; interpreted in terms of R-hadrons, charginos and staus.

EMs for 2 inclusive SRs provided by ATLAS already implemented in v2.3 database, lead to under-exclusion

v3.0 has 'home-grown' **EMs for all 38 mass window bins** from recast by Andre Lessa; much better performance



v2.3, 2 inclusive SRs



v3.0, 38 exclusive SRs (mass window bins)

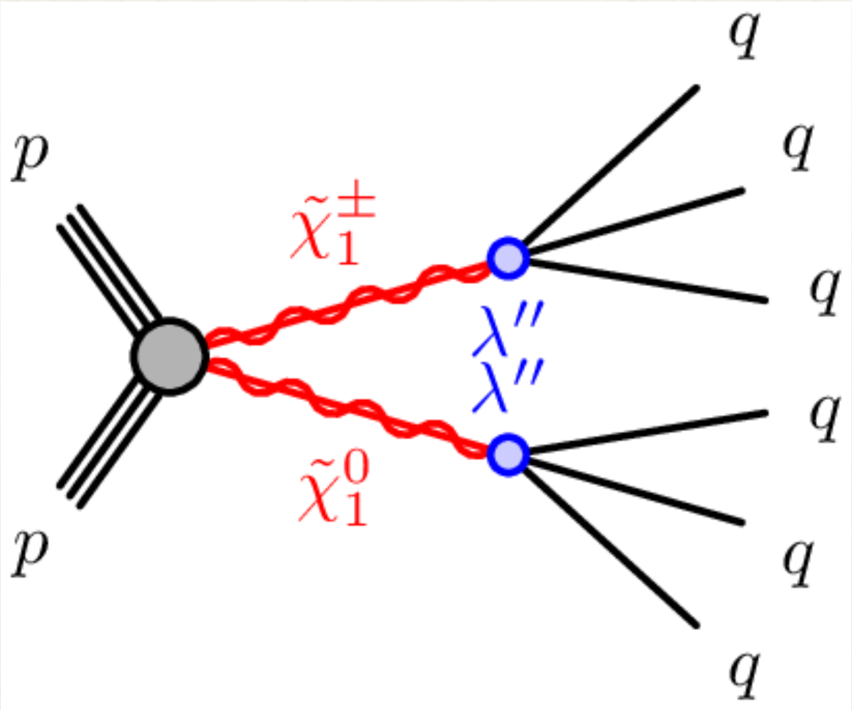
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2018-13
https://www.hepdata.net/record/137762

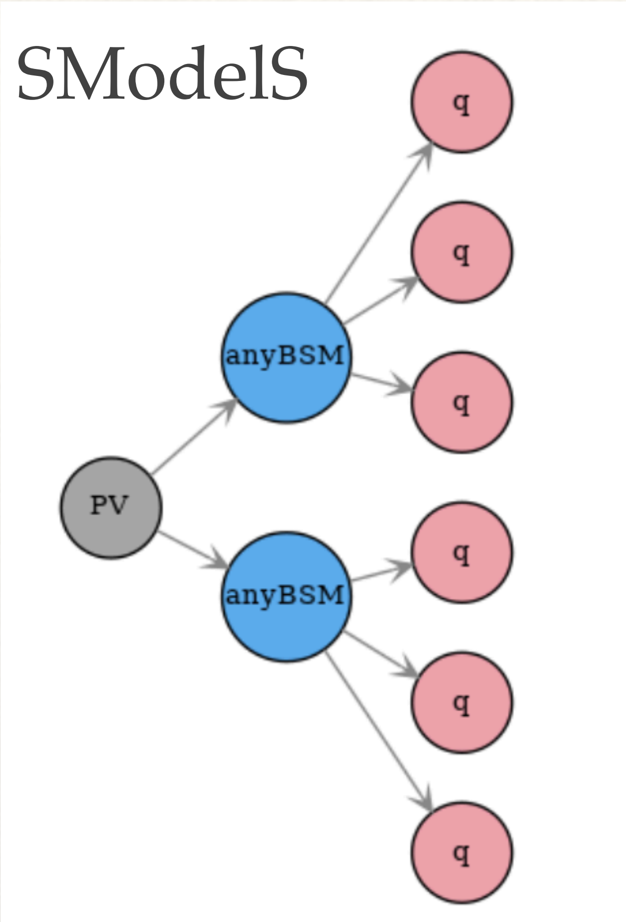
ATLAS-SUSY-2018-13 (displaced jets) validation

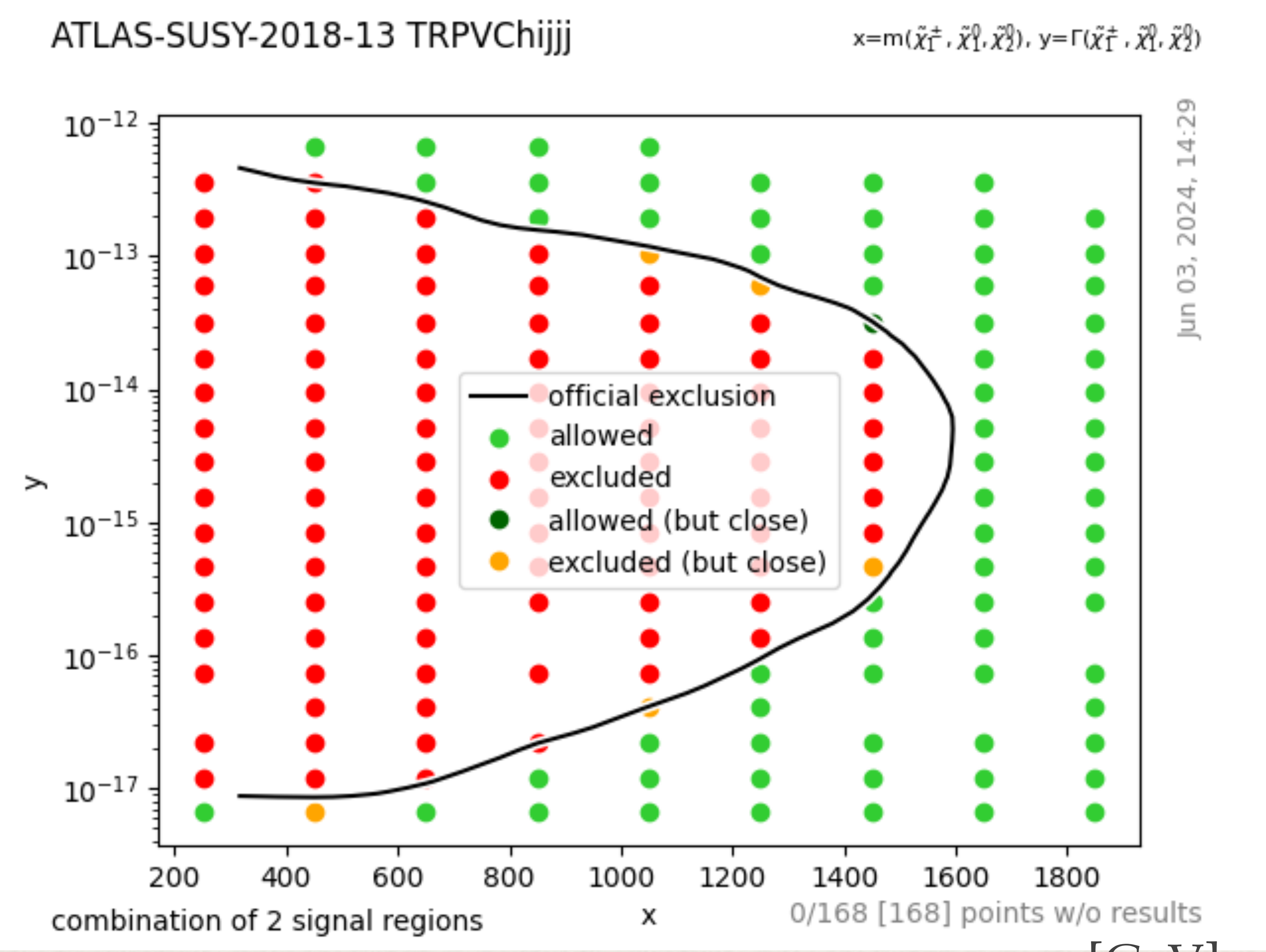
c.f. talk by Hideyuki Oide on Mon.

LLP search in events that contain multiple energetic jets and a displaced vertex; employs dedicated reconstruction techniques that increase the sensitivity to LLPs decaying in the ATLAS inner detector. **Extensive auxiliary material** on HEPData.

ATLAS







width [GeV]

mass [GeV]

Signal Region	Observed	Expected	S^{95}_{obs}	S^{95}_{exp}	$\langle\sigma_{\text{vis}}\rangle^{95}_{\text{obs}}$ [fb]
High-p_T jet SR	1	$0.46^{+0.27}_{-0.30}$	3.8	$3.1^{+1.0}_{-0.1}$	0.027
Trackless jet SR	0	$0.83^{+0.51}_{-0.53}$	3.0	$3.4^{+1.3}_{-0.3}$	0.022

covariance: [[9e-02,0], [0,2.809e-01]]

Analysis recast by Andre Lessa → 2-dim EMs for SModelS

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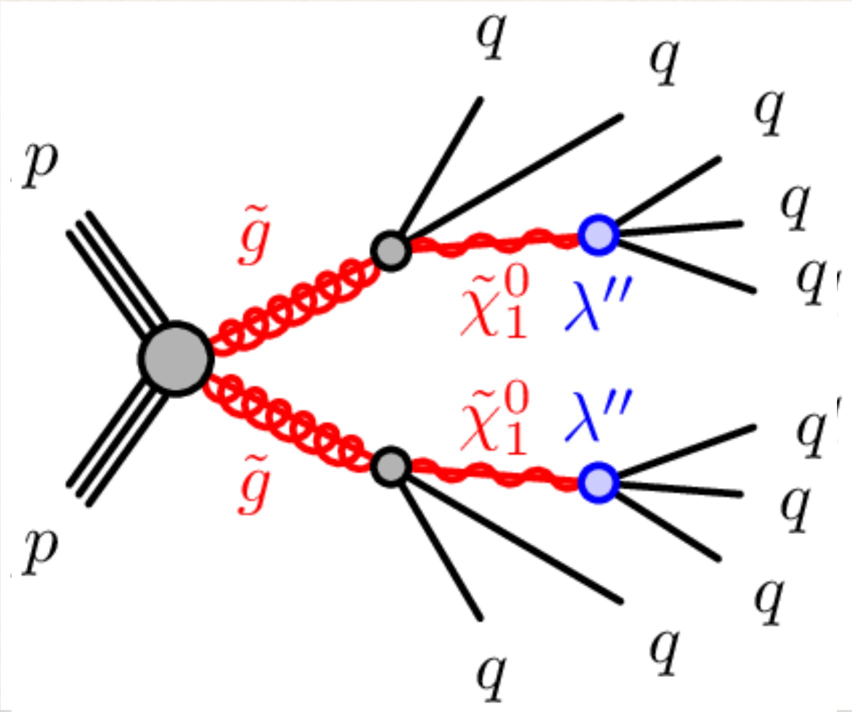
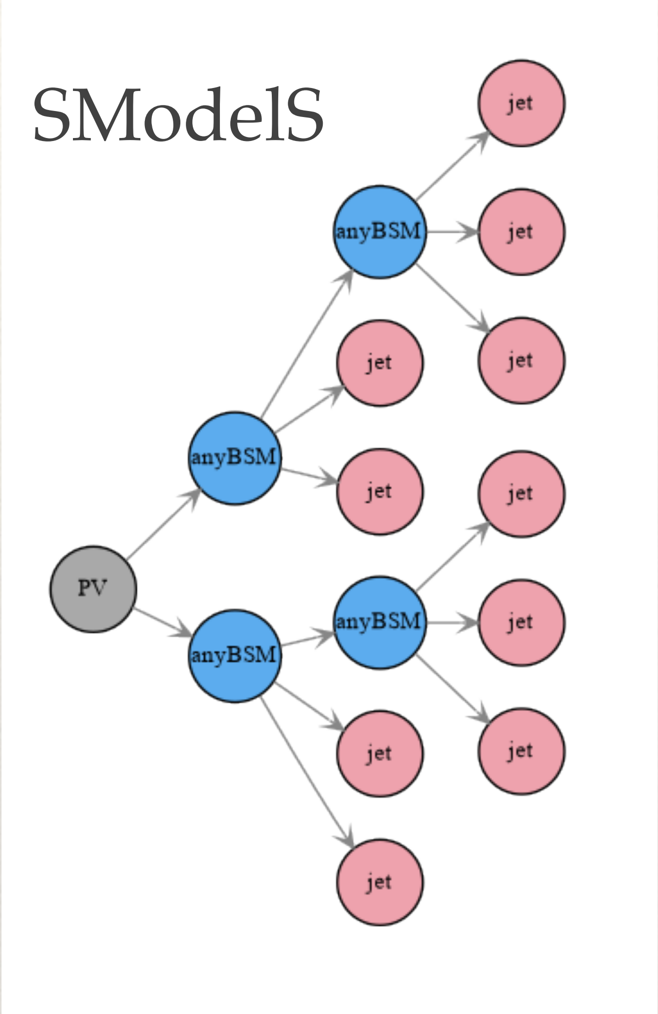
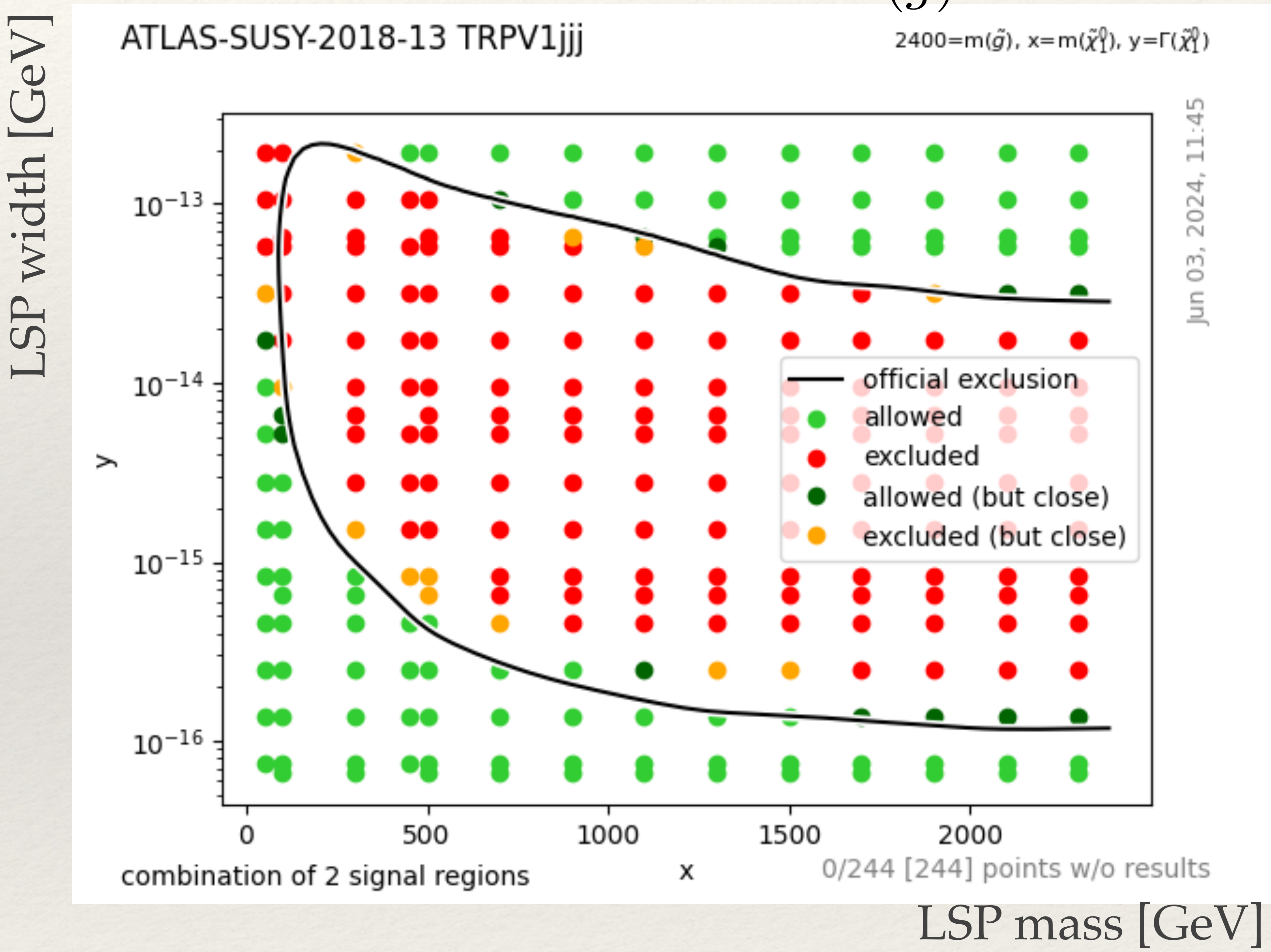




$m(\tilde{g}) = 2.4$ TeV



Signal Region	Observed	Expected	$S^{95}_{\rm obs}$	$S^{95}_{\rm exp}$	$\langle\sigma_{\rm vis}\rangle^{95}_{\rm obs}$ [fb]
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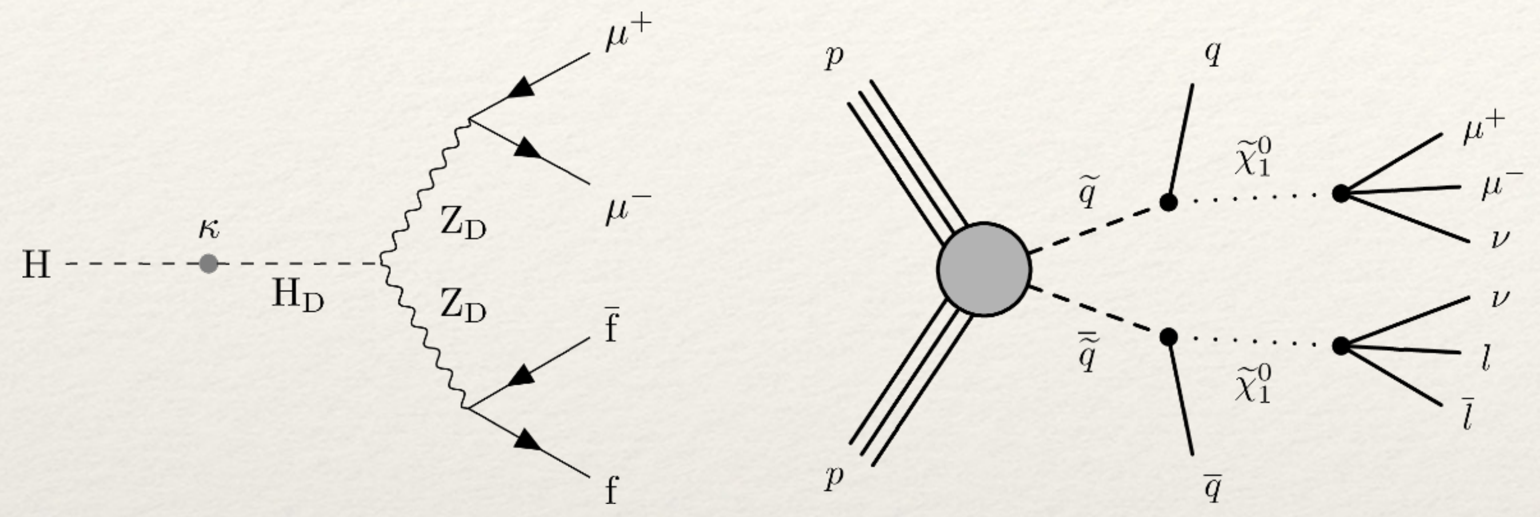
`covariance: [[9e-02,0], [0,2.809e-01]]`

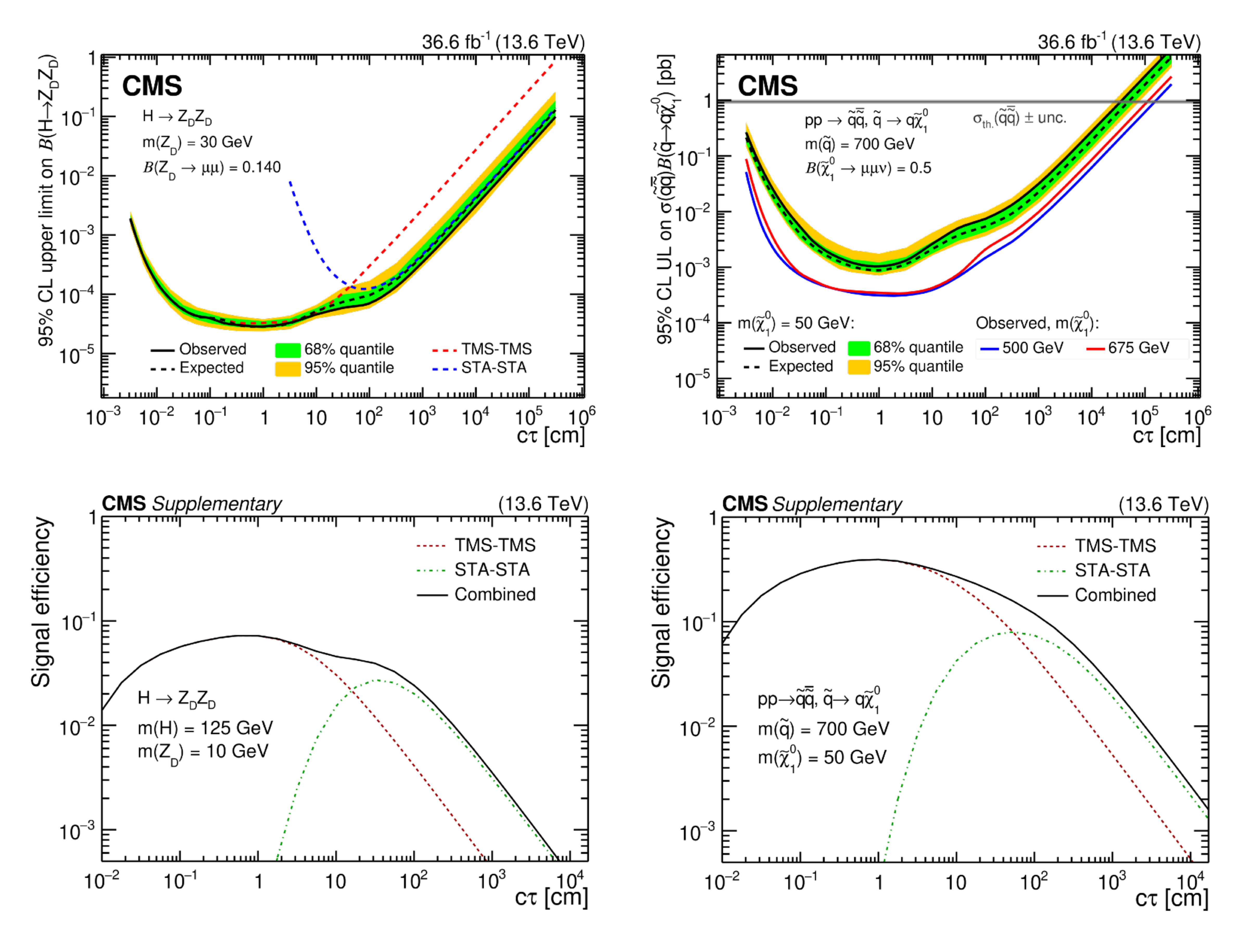
Analysis recast by Andre Lessa → 3-dim EMs for SModelS

CMS-EXO-2023-014 (displ. dimuons)

c.f. talks by A.S. Frankenthal (Mon.) & M. Sonawane (Thu)

LLP search in events with a pair of muons with a DV from several hundred μm to several meters; 36.6/fb of Run 3 data.
Extensive auxiliary material on HEPData.





However:

- Z_D model has $\mathrm{BR}(Z_D \to \mu^+\mu^-) = 10\% - 15\%$
- the RPV SUSY model assumes $\mathrm{BR}(\tilde{\chi}^0 \to \mu^+\mu^-\nu) = \mathrm{BR}(\tilde{\chi}^0 \to e^+e^-\nu)$

→ mix of signal with 1 or 2 muon pairs
not a pure simplified model for us

- Statistical model (correlation information) is not provided

→ cannot combine
STA-STA and TMS-TMS categories

CMS-EXO-2023-014 (displ. dimuons)

c.f. talks by A.S. Frankenthal (Mon.) & M. Sonawane (Thu)

LLP search i … Run 3 data.

Extensive a …

However:

- ZD mod…
- the RPV … BR($\tilde{\chi}^0$ –
- Statistica… is not pr…

HEPData Instructions for Reinterpretation

→ need to recast and produce EMs ourselves

While the search presented specifically addresses two benchmark models described in the paper, its results may be applied to other models predicting long-lived particles that decay to final states with a pair of oppositely charged muons. In Figs. A18-A19, we provide a set of generator-level efficiency maps that approximate the reconstruction-level efficiencies of this analysis and allow for reinterpretation of the results in the framework of other models.

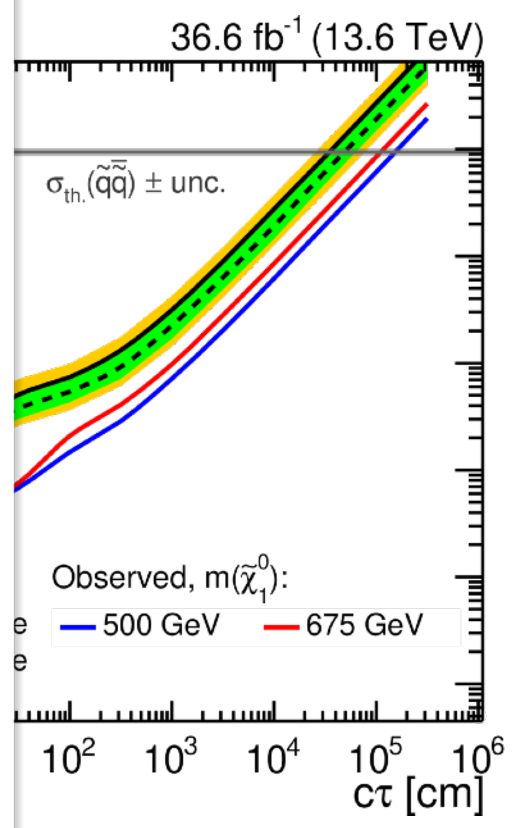
Signal efficiencies are provided as a function of the smaller of the two values of generated muon p_T, $\min(p_T)$, and of generated muon d_0, $\min(d_0)$, in three intervals of the generated transverse decay length L_{xy} of the signal dimuon, $L_{xy} < 20$ cm, $20 < L_{xy} < 70$ cm, and $70 < L_{xy} < 500$ cm. The efficiencies are given separately for the HAHM and RPV SUSY signal models used in the paper. Efficiency maps obtained from HAHM samples are recommended for models featuring $\mu\mu$ decay vertices and collinear signatures, while maps obtained from RPV SUSY samples are recommended for models featuring $\mu\mu\nu$ decay vertices and non-collinear signatures. The 3D efficiency maps $\epsilon\left(\min(p_T); \min(d_0); L_{xy}\right)$ are provided separately for the two dimuon categories, TMS-TMS and STA-STA, and are shown in Fig. A18 for the HAHM signal model and Fig. A19 for the RPV SUSY signal model. They are valid to approximate the efficiencies in the analysis of the 2022 data set.

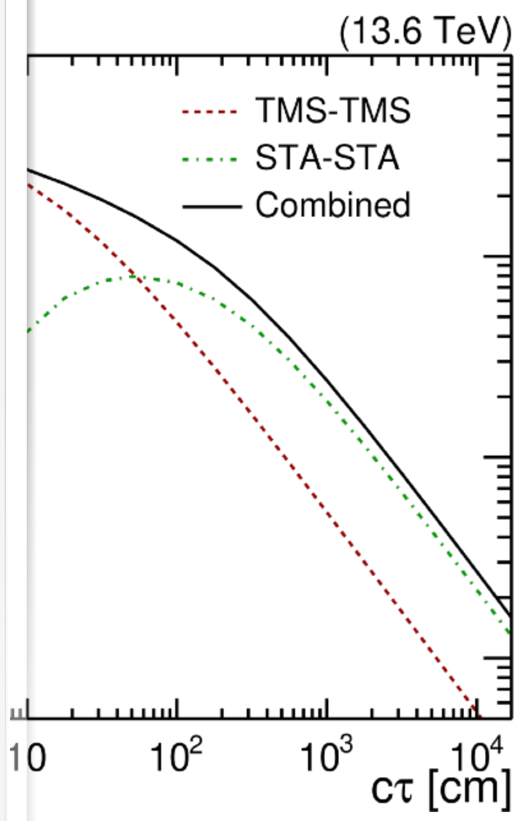
The efficiency in each $(\min(p_T); \min(d_0); L_{xy})$ bin of the 3D efficiency map is computed as the ratio of the number of simulated signal dimuons in that bin that pass the trigger requirements and selection criteria applied for a given dimuon category to the total number of simulated signal dimuons in that bin and within the geometric acceptance. The computation is performed separately using the ensemble of all generated HAHM and RPV SUSY signal samples listed in the paper. The geometric acceptance is defined as $\min(d_0) < 300$ cm, $L_{xy} < 500$ cm, generated longitudinal decay length L_z smaller than 800 cm, and $|\eta|$ of both generated muons forming the dimuon smaller than 2.0. The efficiencies obtained from simulation are further corrected by the data-to-simulation scale factors described in the paper.

When applied to the previously untested models, the signal efficiency in each dimuon category j, ϵ_j, can be obtained from the 3D efficiency maps using the p_T, d_0, and L_{xy} at generator level:

$$\epsilon_j = \frac{1}{N}\sum_{n=1}^{N^{\rm acc}}\left[1 - \left[1 - \epsilon_j^n\left(\min(p_T); \min(d_0); L_{xy}\right)\right]^{k_n}\right],$$

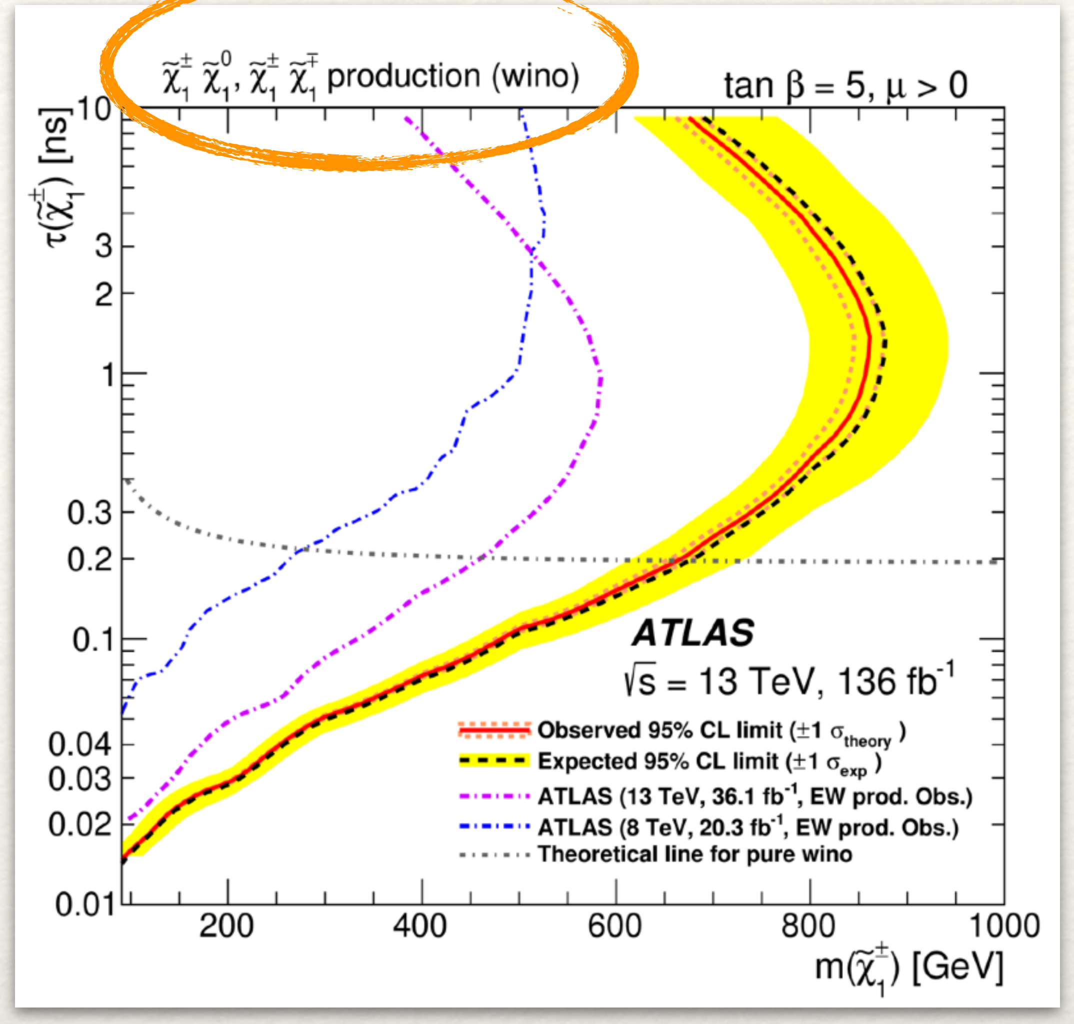
where k_n is the number of dimuons in the n-th event, the sum is over the number of generated signal events $N^{\rm acc}$ in the geometric acceptance defined above and with the true mass larger than 10 GeV, and N is the total number of generated signal events. In cases where more than one dimuon is present in the event, the one with the larger of the two $\min(d_0)$ values should be taken as a reference to apply the efficiency map.



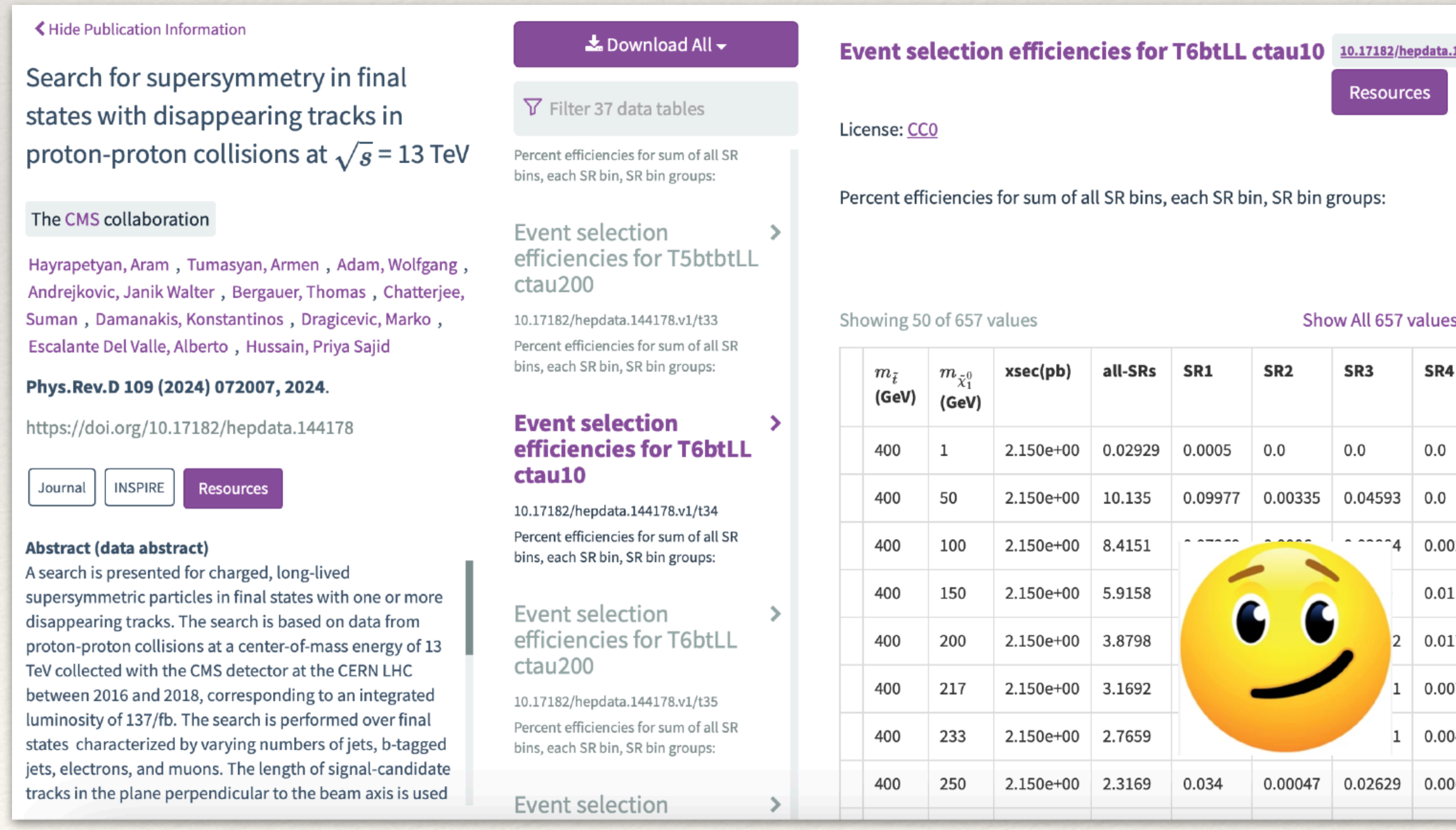


Disappearing track searches

- **[ATLAS-SUSY-2018-19](#)** **(Jan 2022)**
  - Search for long-lived charginos from Run 2, 136/fb.
  - Chargino-chargino and chargino-neutralino production lumped together: mix of two simplified models; not usable in SModelS.
  - No auxiliary materials, no HEPData record !



- **[CMS-SUS-21-006](#)** **(Sep. 2023)**
  - Long-lived charginos either produced directly or from cascade decays, Run 2, 137/fb.
  - Final states characterized by varying numbers of jets, *b*-tagged jets, electrons, and muons.
  - Extensive HEPData, incl. some event selection efficiencies, but not yet what we need (promised for ICHEP)



Conclusions

SModelS v3 soon

Public tool for the **fast reinterpretation** of LHC searches
based on simplified-model exp. results

New graph-based topology description allows us to treat a **much larger variety of signatures** than previously possible.

eager to include more LLP results

☞ **please provide us with appropriate materials (EMs…)** ☜

HEPData

HistFactory

ご清聴ありがとうございました

THANKS FOR YOUR ATTENTION

BACKUP

Pros and Cons w.r.t. simulation-based recasting

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

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

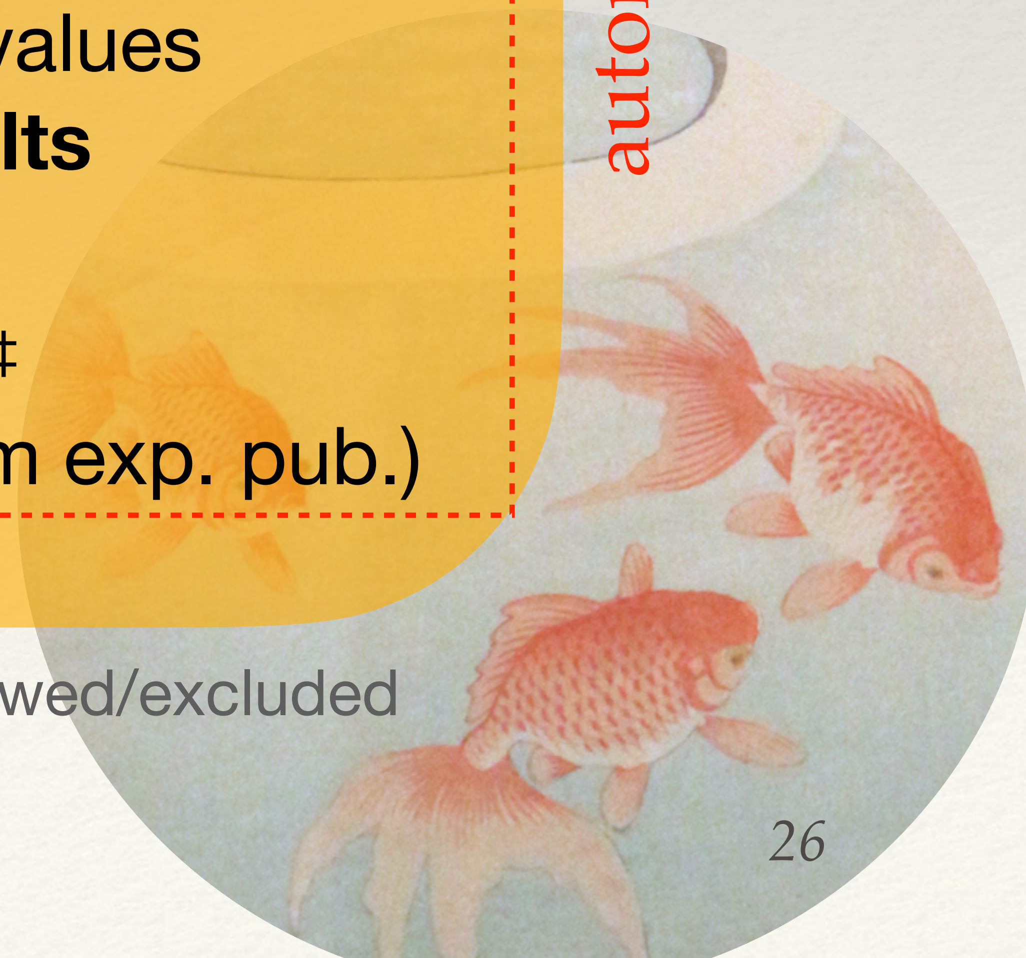
- Applicable also for ML-based analyses
  (difficult to impossible to recast)
- Advantages are simplicity and **speed!**
  → **very fast** b/c no MC simulation needed
  → **well suited for large scans** and model surveys
- **Large database** of >110 experimental results
- ATLAS and CMS, Run1 and Run2, **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)

Create **SLHA file**
with mass spectrum and decay tables
⬇
add **production cross sections**
(SModelS xseccomputer or micrOMEGAs)
⬇
compute all **signal weights** :
σ×BR×BR…
⬇
sum **matching elements**
⬇
find and apply A×ε (or σ_{95}) values
from **experimental results**
⬇
statistical evaluation‡
(background numbers usually from exp. pub.)

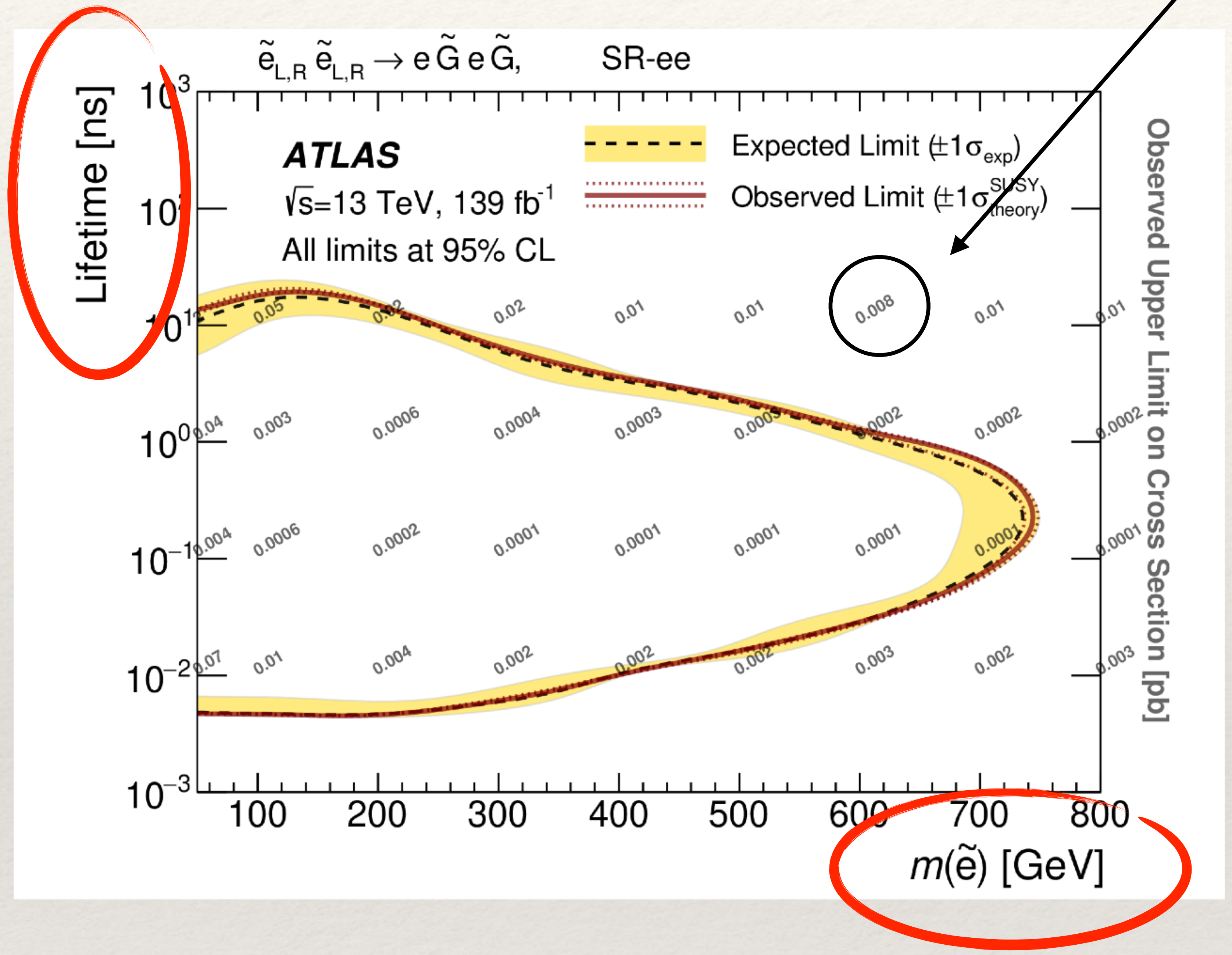
automated

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



Experimental results used in SModelS

upper limit (UL) maps



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

$$r = \frac{[\sigma \times \mathrm{BR} \times \mathrm{BR}]}{\sigma_{95}}$$

← theory prediction for the signal

- Excluded if r ≥ 1
- Binary decision: excluded or not

Experimental results used in SModelS

Maps of A×ε for the signal regions of an analysis allow us

- to **sum different contributions** to the same signal region

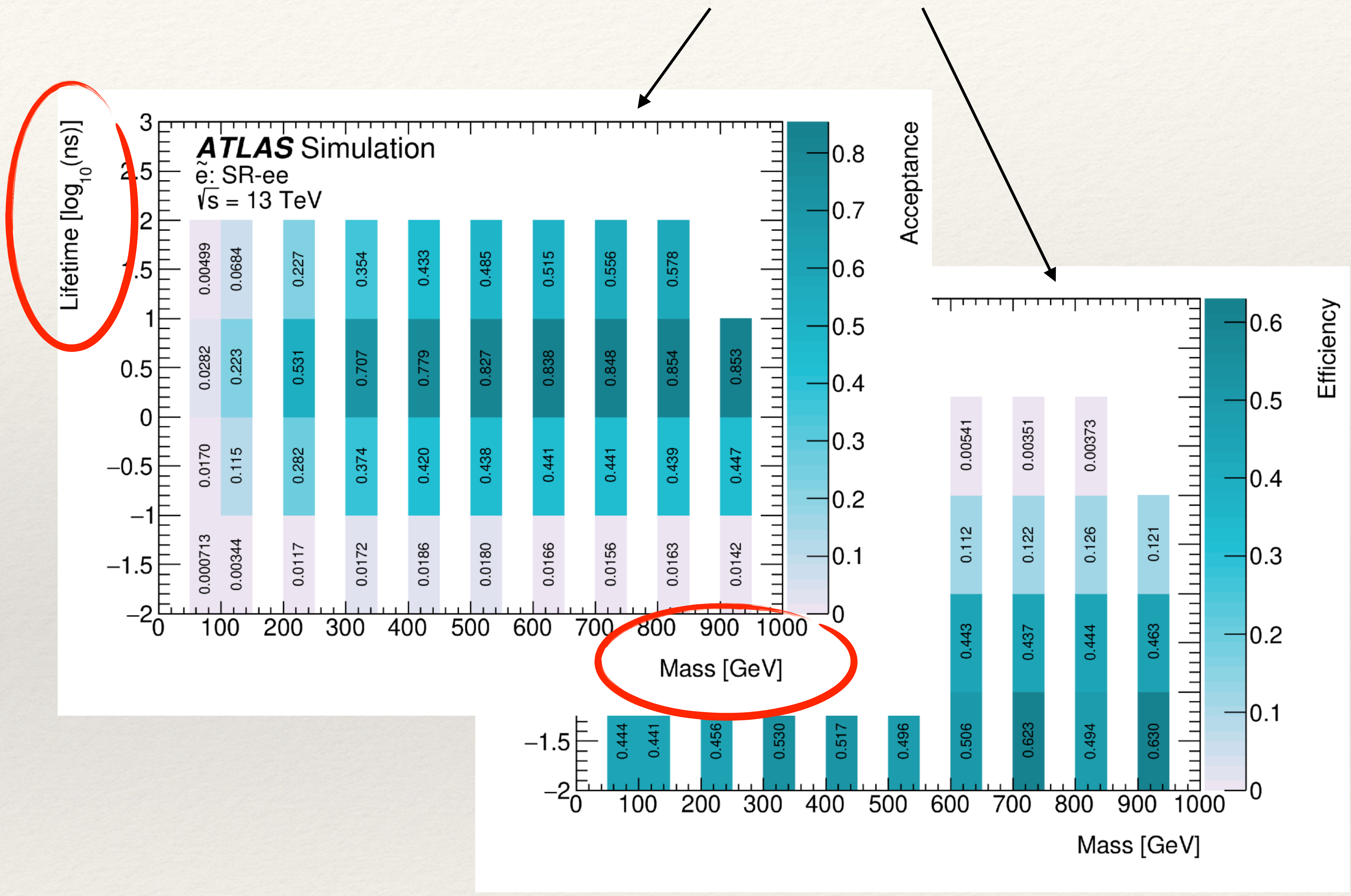
$$n_{\rm sig} = \sum A\epsilon\,[\sigma \times {\rm BR} \times {\rm BR}] \times \mathcal{L}$$

- 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.)

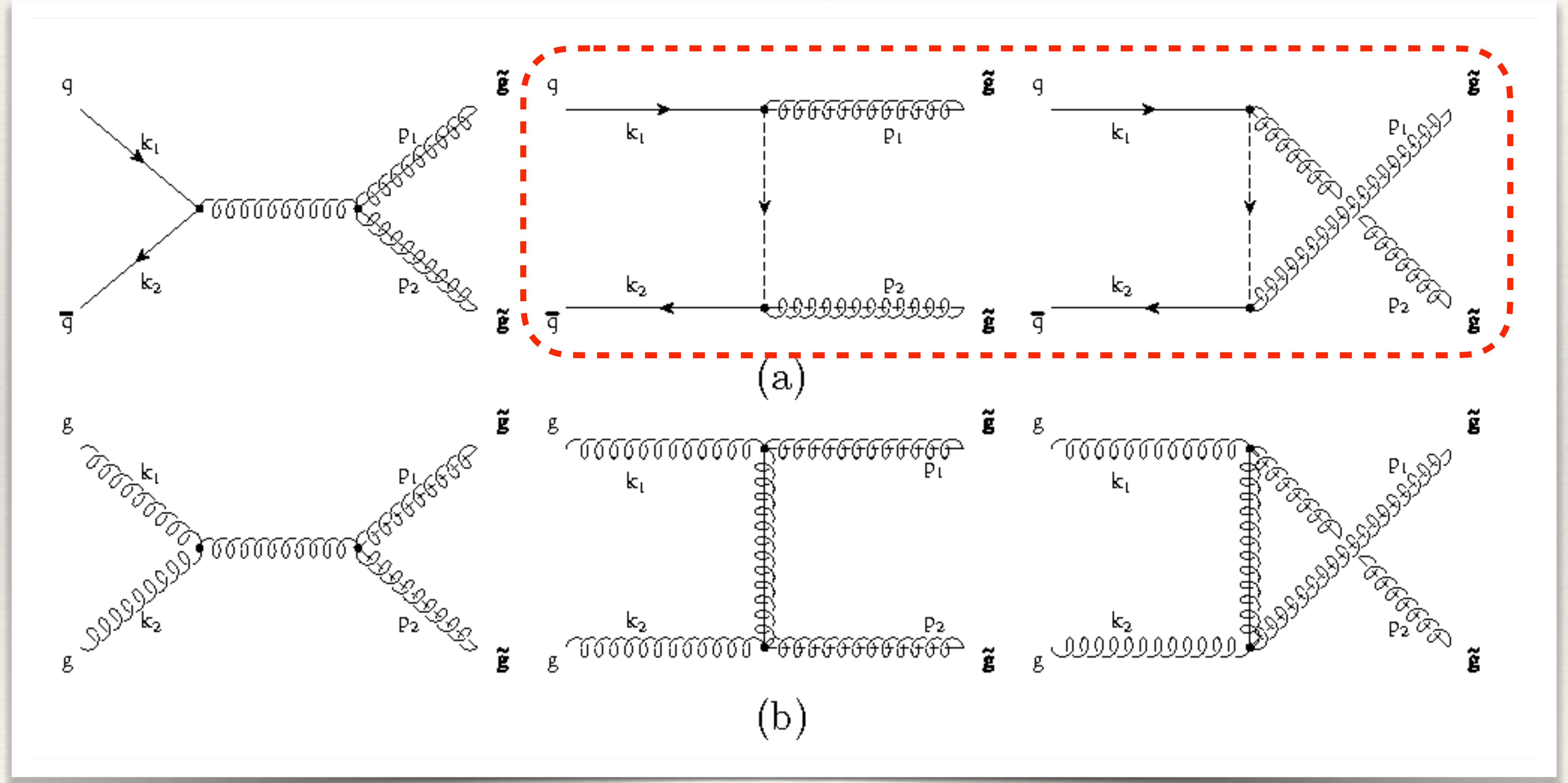
A×ε 'efficiency' maps (EM)



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

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



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

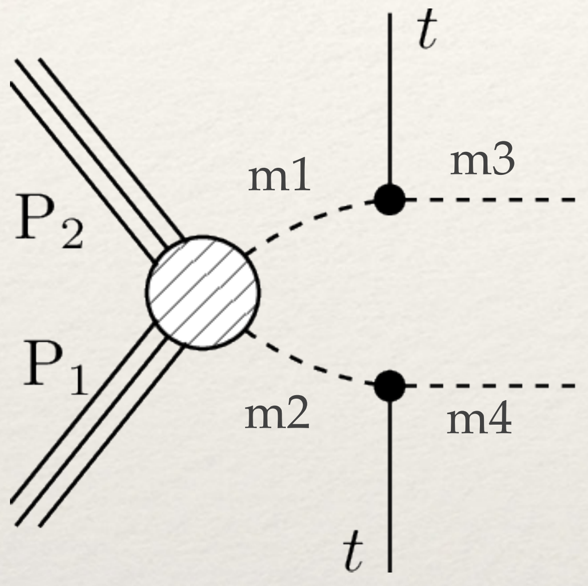
SModelS assumes that presence of squark contribution won't significantly change gluino kinematic distributions

→ signal acceptances and limits on cross sections remain valid

see arXiv:1312.4175

Signal acceptances to good approximation the same ?

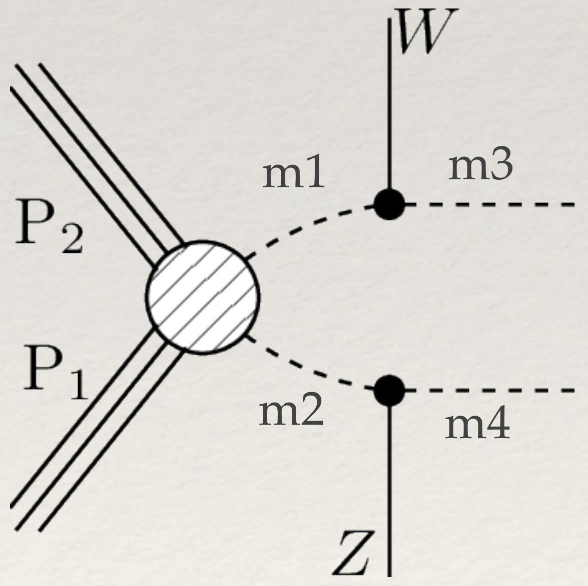
- For "prompt" signatures, SModelS ignores quantum numbers of BSM particles other than their masses



topology: [[[t]], [[t]]] … "T2tt"
masses: (m1,m3), (m2,m4)
final states: (MET, MET)

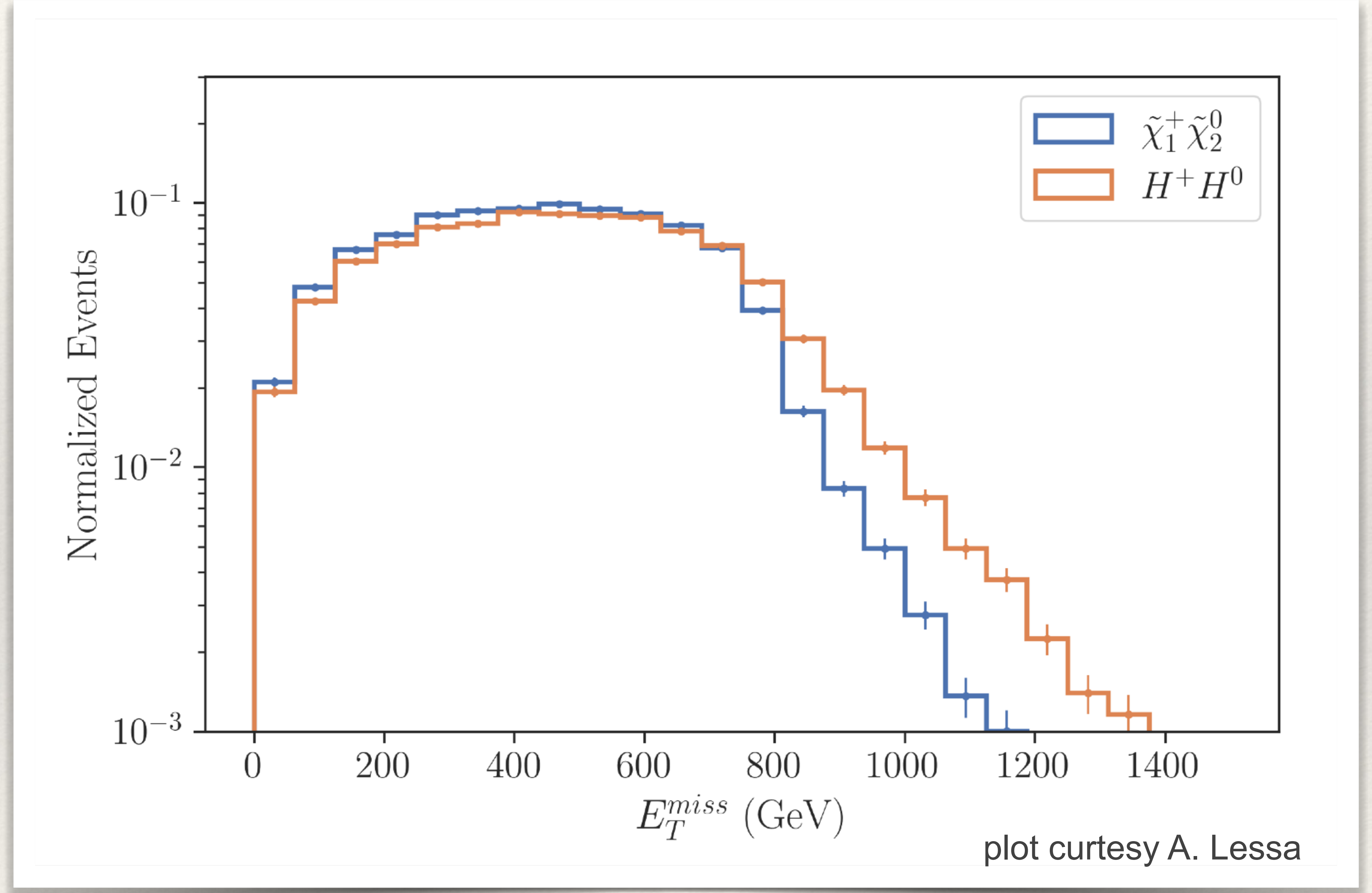
Typically stop → top +LSP, but same signature from fermonic top partner

validity studied in arXiv: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

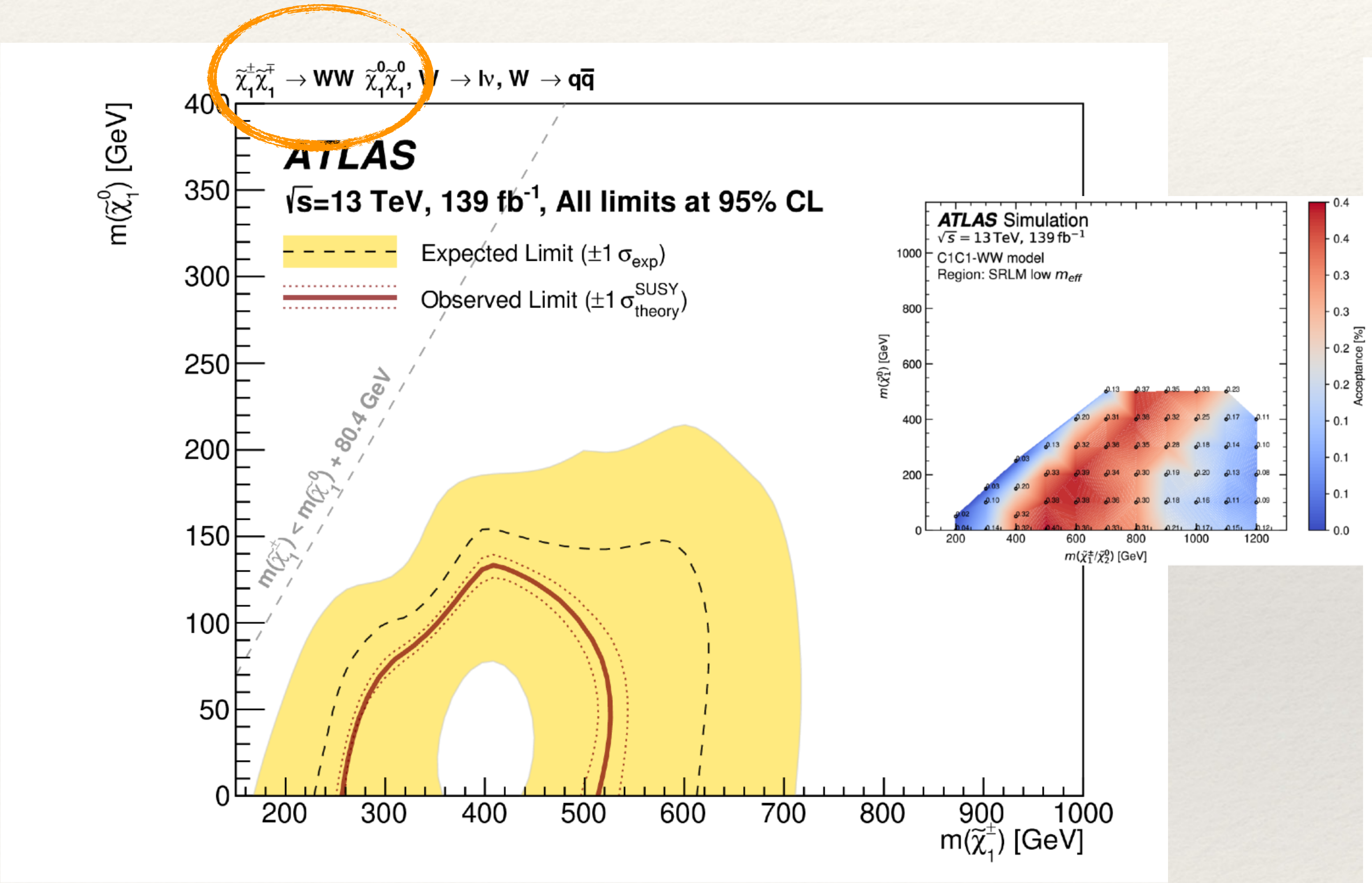


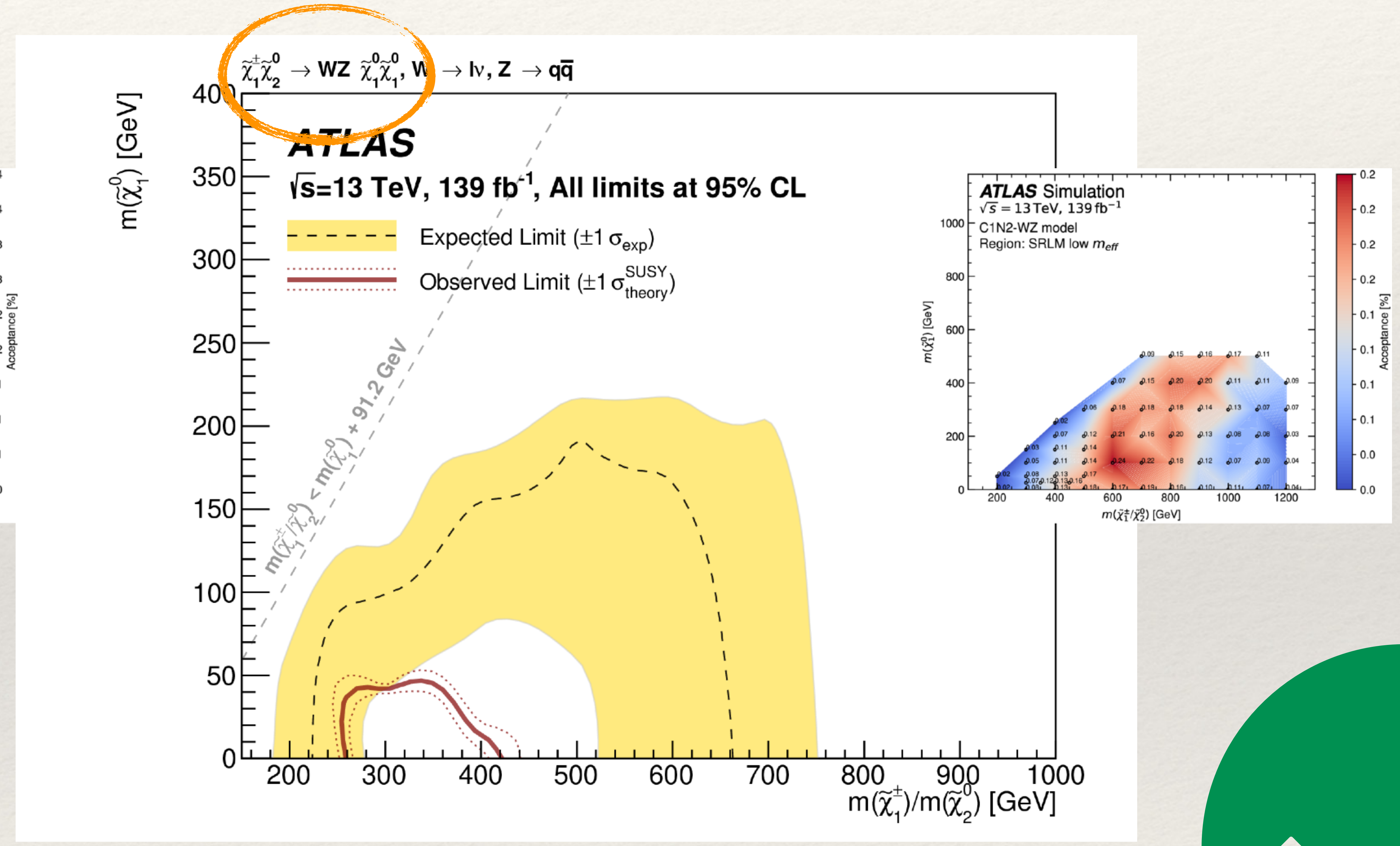
$pp \to \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to W^{\pm}Z\,\tilde{\chi}_1^0\tilde{\chi}_1^0$ versus $pp \to H^{\pm}H^0 \to W^{\pm}Z\,A^0A^0$

$m(\text{mothers}) = 800$ GeV, $m(\text{daughters}) = 100$ GeV

SModelS needs 'pure' simplified-model results

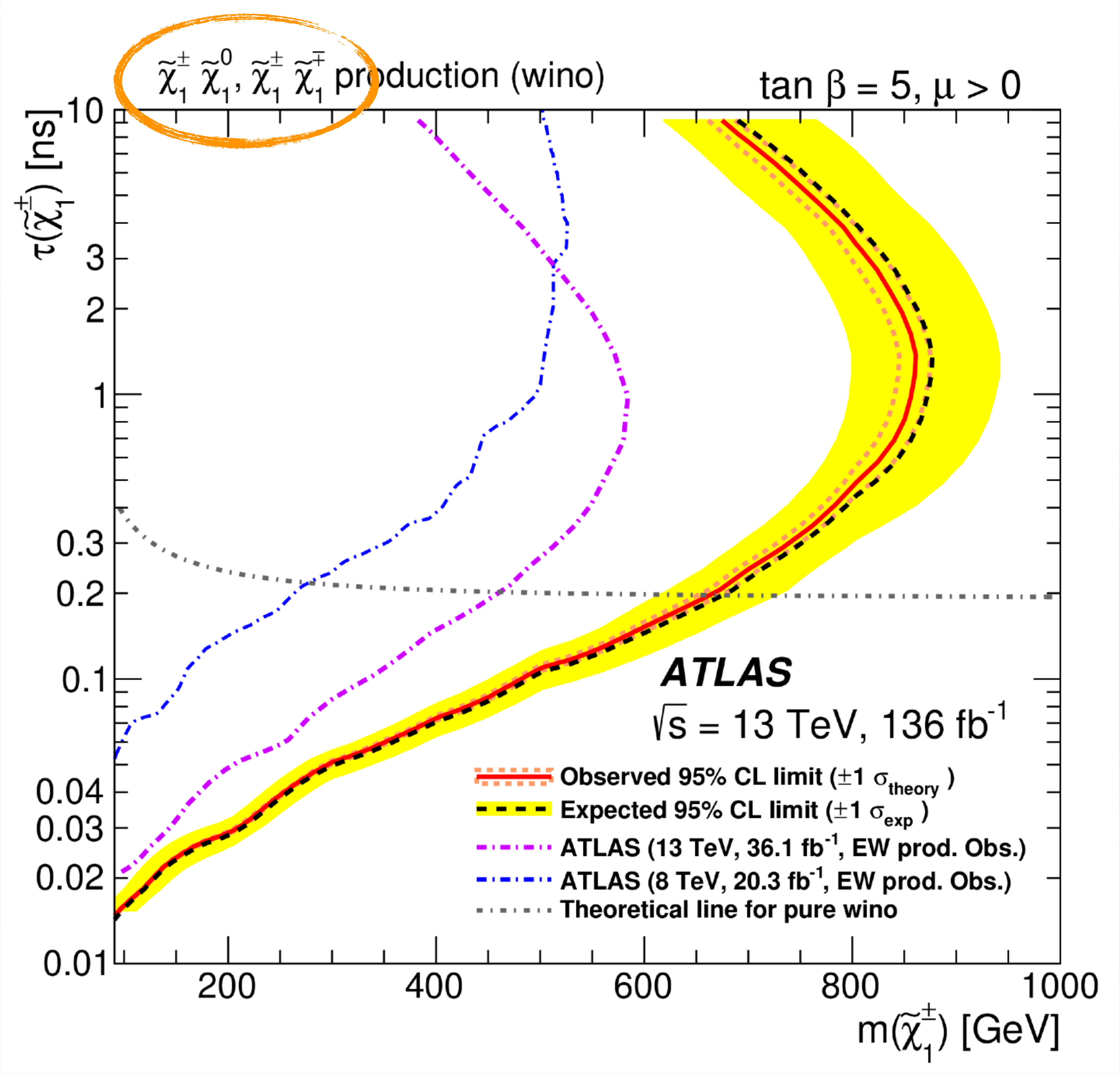
SUSY-2023-01: 1l + jets + MET; separate results for chargino-chargino and chargino-neutralino production





SModelS needs 'pure' simplified-model results

SUSY-2019-19: disappearing tracks; chargino-chargino and chargino-neutralino prod. lumped together



Mix of two simplified models; not reusable !