
Reinterpretation of LLP searches with SModelS 2.0

in collaboration with

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Jan Heisig



Chargé de
recherches



Searching for long-lived particles at the LHC and beyond: Ninth workshop of the LLP Community



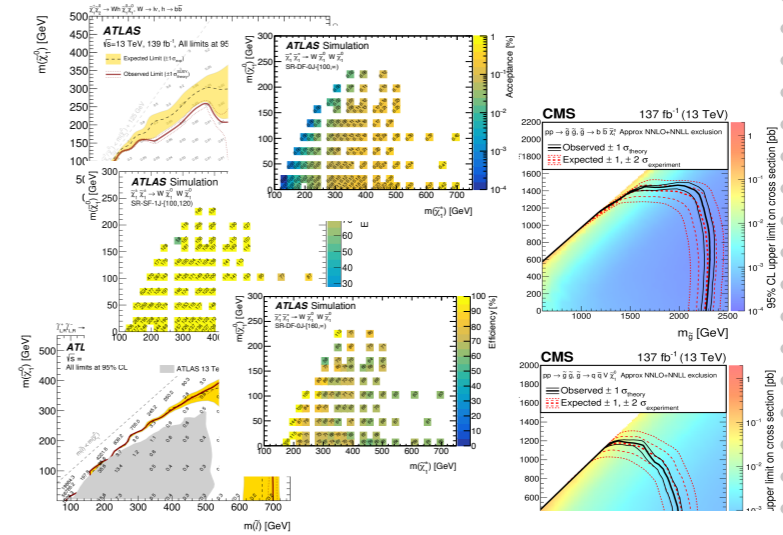
Reinterpretation of new physics searches

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

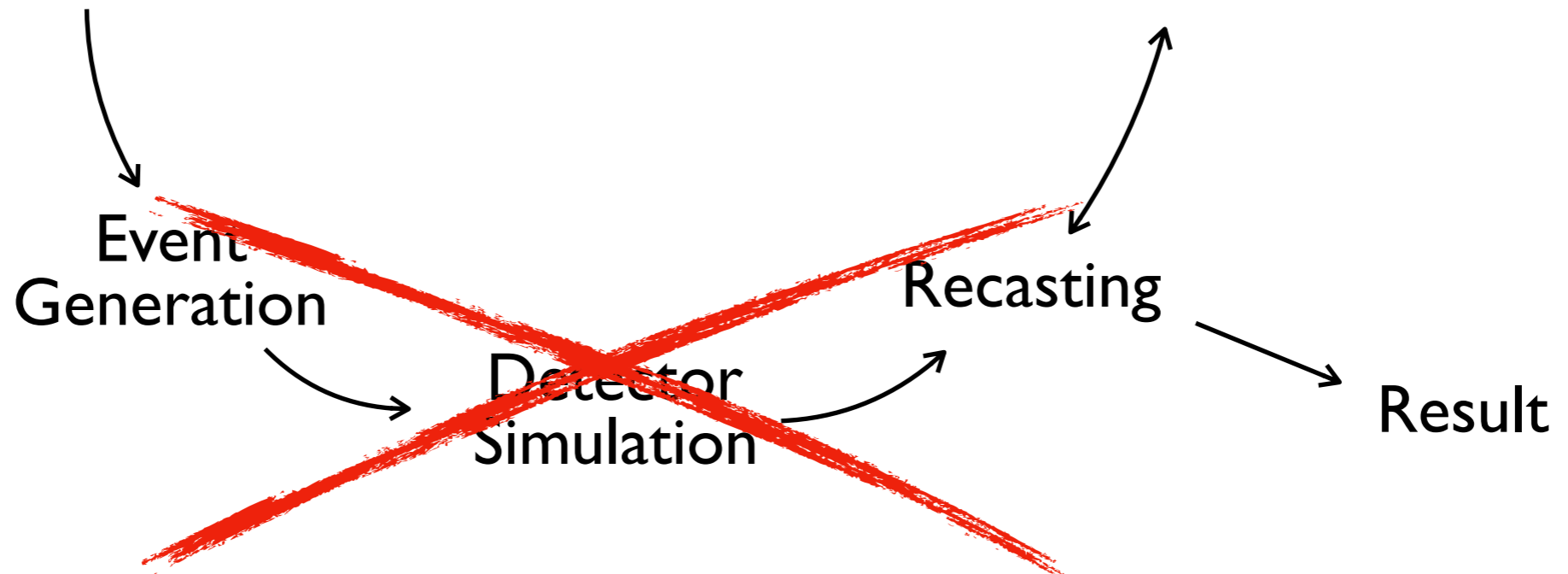
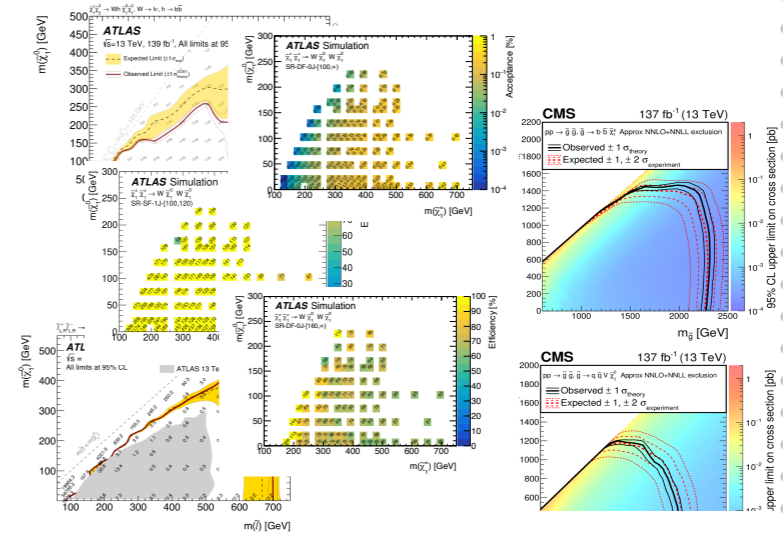
Reinterpretation of new physics searches

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



Experiment



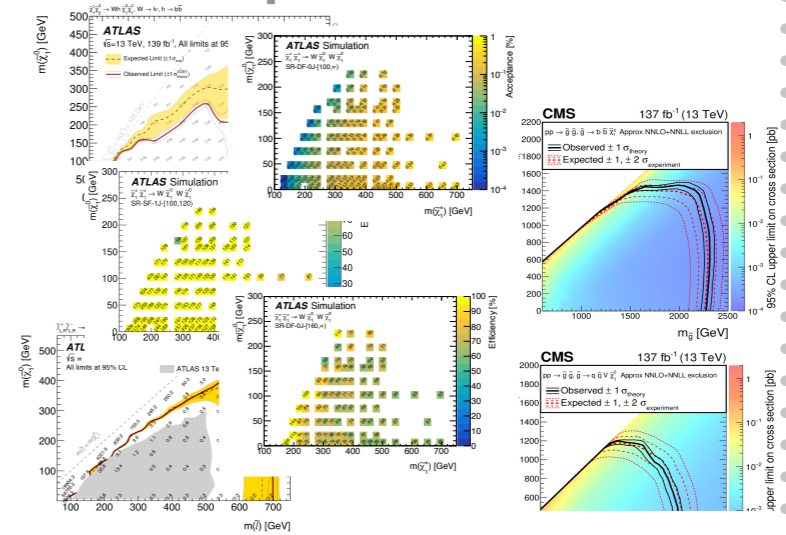
Reinterpretation of new physics searches

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

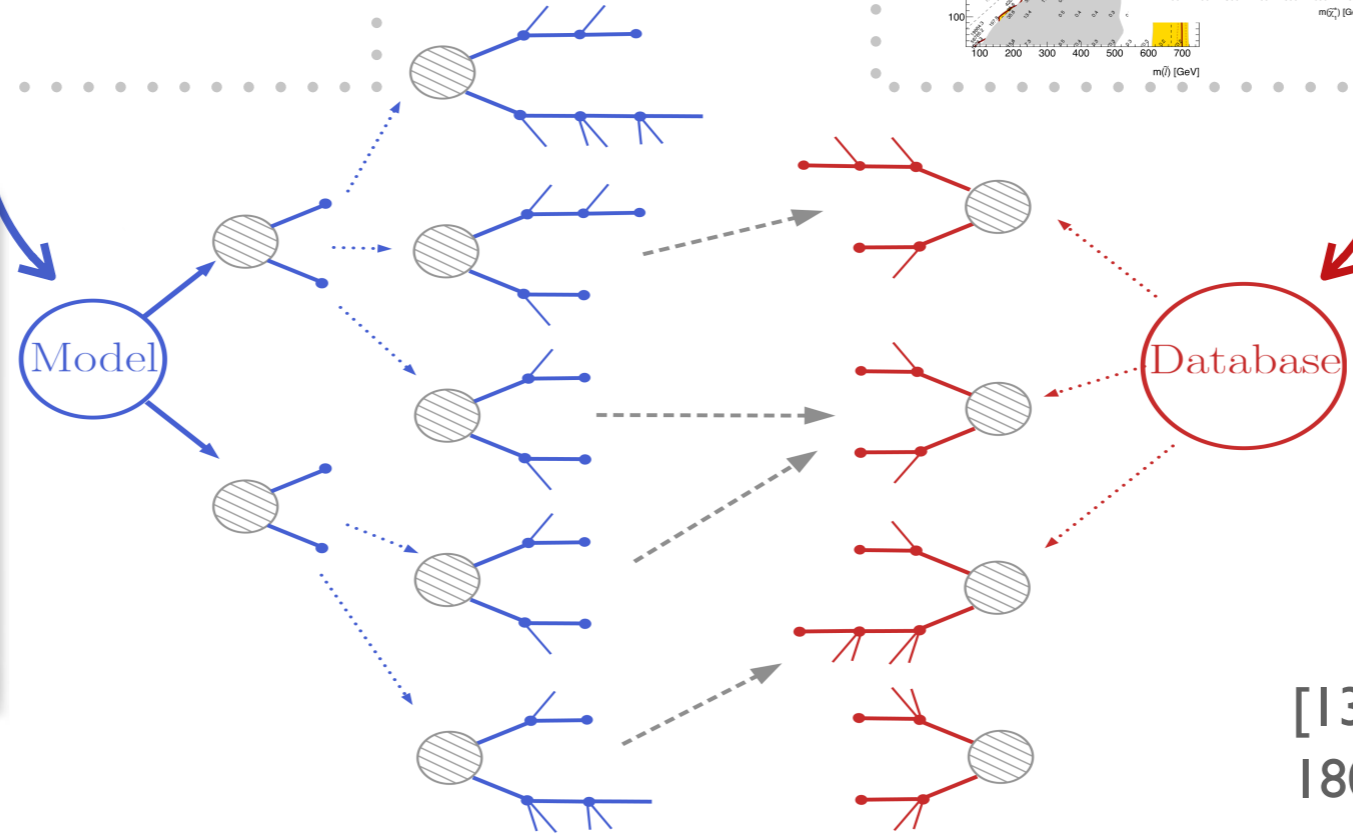


```
spectrum.slha
BLOCK MASS # Mass Spectrum
# PDG code mass particle
[ ]
1000006 6.48255292E+02 # -t_1
1000022 3.00681405E+02 # -chi_10
1000023 3.06894404E+02 # -chi_20

# PDG Width
DECAY 1000006 1.03408965E+01 # stop1 decays
# BR NDA ID1 ID2
# 2.39885744E-01 2 1000022 6
# 2.11305478E-01 2 1000023 6
# 5.57808779E-01 2 1000024 5

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

XSECTION 1.30E+04 2212 2212 2 -1000006 1000006
0 2 0 0 0 1.06248924E-01 SModelSV1.1.tnc3
XSECTION 1.30E+04 2212 2212 2 1000022 1000022
0 0 0 0 0 3.48210655E-02 SModelSV1.1.tnc3
[ ]
```



Simplified-models (SMS) results

[13|2.4|75,|701.06586,
1808.05229, 2009.0|809]

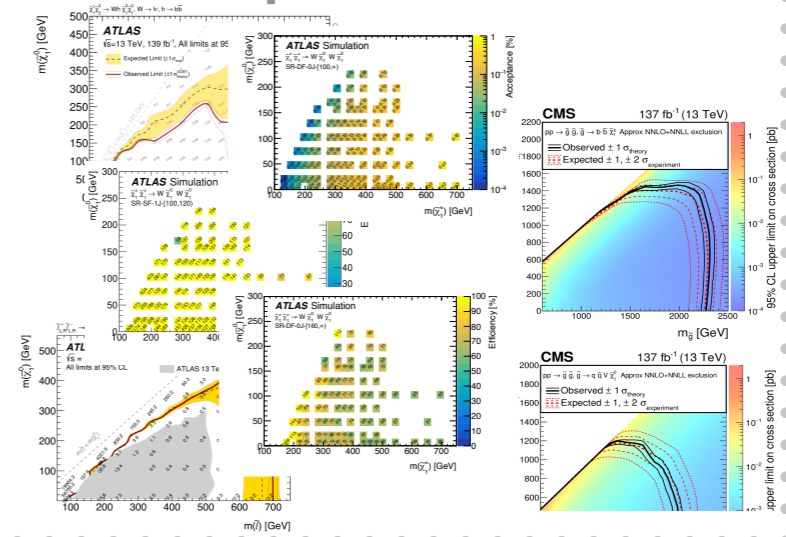
Reinterpretation of new physics searches

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

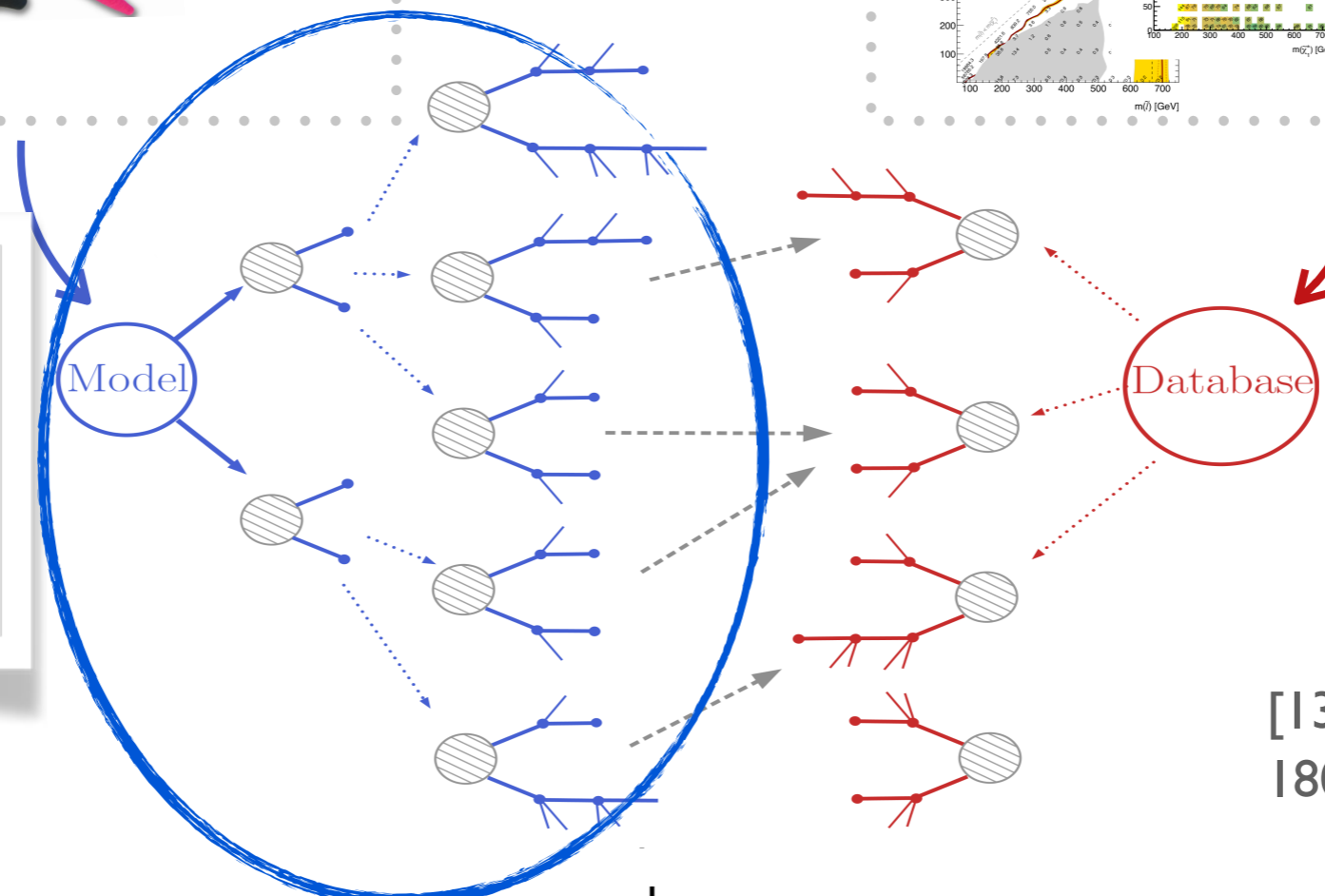


```
spectrum.slha
BLOCK MASS # Mass Spectrum
# PDG code mass particle
[...]
1000006 6.48255292E+02 # -t_1
1000022 3.00681405E+02 # -chi_10
1000023 3.06894404E+02 # -chi_20

# PDG Width
DECAY 1000006 1.03408995E+01 # stop1 decays
# BR NDA ID1 ID2
2.39885744E-01 2 1000022 6
2.11305478E-01 2 1000023 6
5.57808779E-01 2 1000024 5

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

XSECTION 1.30E+04 2212 2212 2 -1000006 1000006
0 2 0 0 0 1.06248924E-01 SModel1SV1.1.tnc3
XSECTION 1.30E+04 2212 2212 2 1000022 1000022
0 0 0 0 0 3.48219655E-02 SModel1SV1.1.tnc3
[...]
```



Simplified-models (SMS) results

[1312.4175, 1701.06586, 1808.05229, 2009.01809]

Working principle

[13|2.4|75]

spectrum.slha

```

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
[...]

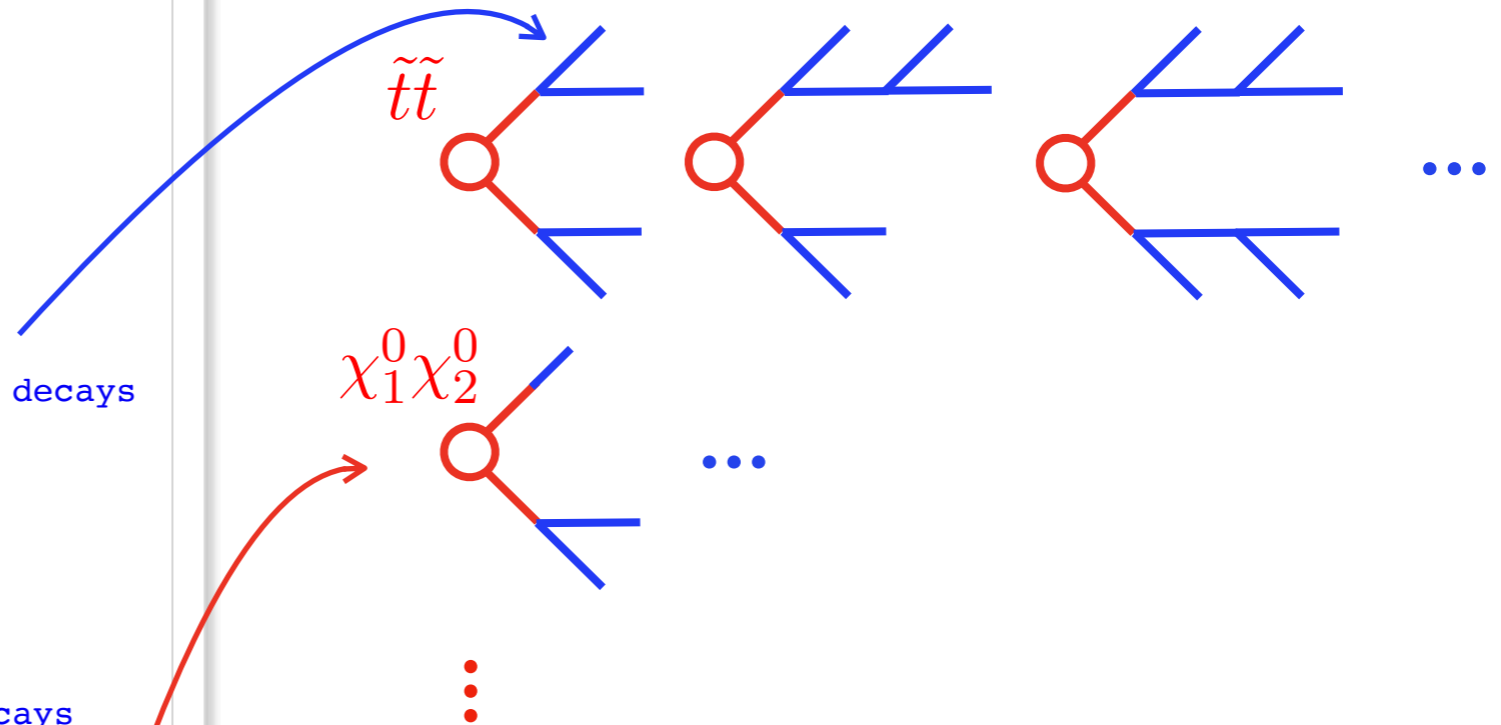
#           PDG           Width
DECAY  1000006      1.03408969E+01  # stop1 decays
#           BR           NDA           ID1           ID2
 2.30885744E-01      2           1000022           6
 2.11305478E-01      2           1000023           6
 5.57808778E-01      2           1000024           5
[...]

#           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
[...]

```



- Construct all topologies
- Assign corresponding weight:

$$\sigma_{\text{prod}} \times \prod_i \text{BR}_i \times \prod_j \text{BR}_j$$

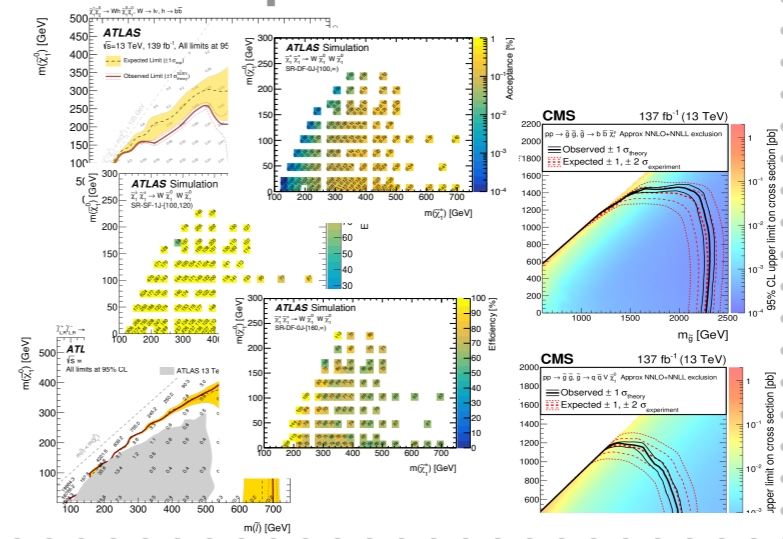
Reinterpretation of new physics searches

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



Experiment



spectrum.slhe

```

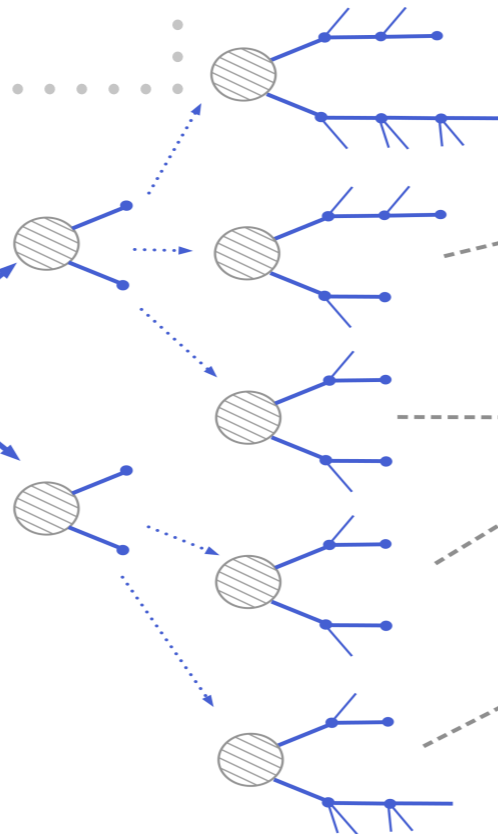
BLOCK MASS # Mass Spectrum
# PDG code mass particle
[ ]
1000006 6.48255292E+02 # -t_1
1000022 3.00681405E+02 # -chi_10
1000023 3.06894404E+02 # -chi_20

# PDG Width
DECAY 1000006 1.03408995E+01 # stop1 decays
# BR NDA ID1 ID2
2.39885744E-01 2 1000022 6
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5.57808779E-01 2 1000024 5

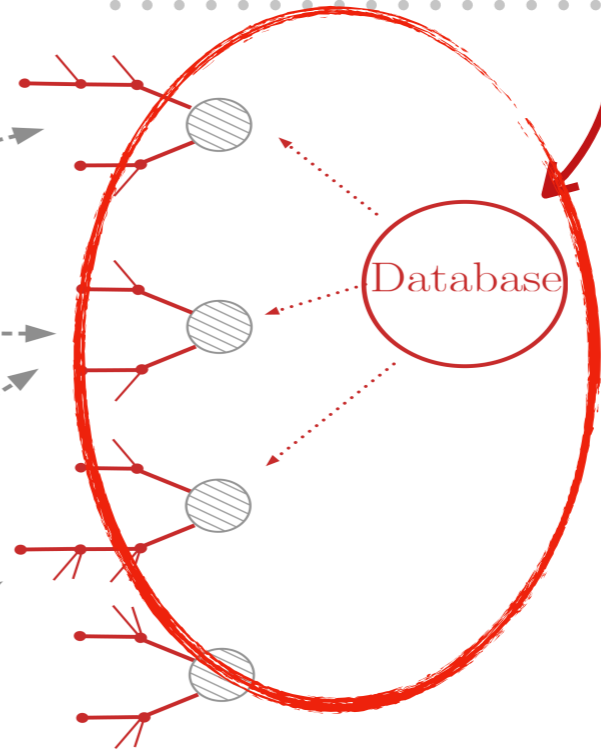
# PDG Width
DECAY 1000022 0.00000000E+00 # n1 decays
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7.99513486E-09 # n2 decays
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0 2 0 0 0 1.06248924E-01 SModel1SV1.1.tnc3
XSECTION 1.30E+04 2212 2212 2 1000022 1000023
0 0 0 0 0 3.48219655E-02 SModel1SV1.1.tnc3
[ ]
    
```

Model



Database



Simplified-models (SMS) results

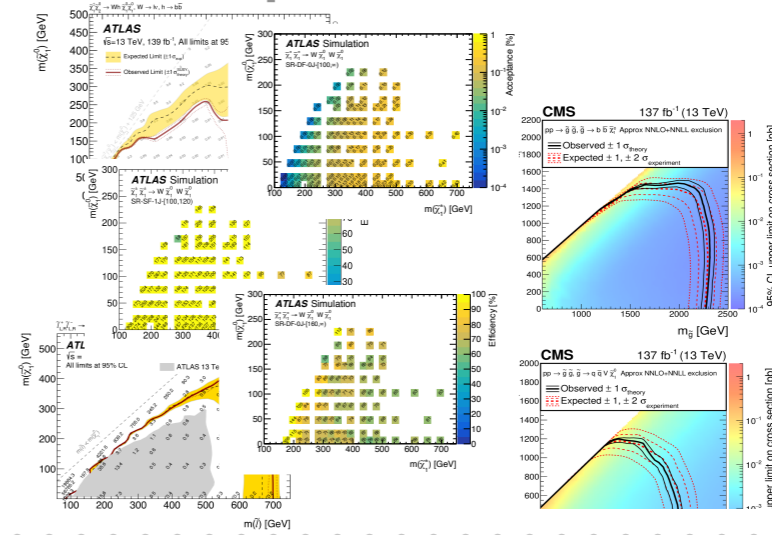
Reinterpretation of new physics searches

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



spectrum.slhe

BLOCK	MASS	# Mass Spectrum	particle
# PDG code	mass		
[...]			
1000006	6.48255292E+02	# -t_1	
1000022	3.00681405E+02	# -chi_10	
1000023	3.06894404E+02	# -chi_20	
#	PDG	Width	# stop1 decays
BRCAV	1000006	1.03408995E+01	
#	BR	BRD	ID1 ID2
	2.39885744E-01	2	1000022 6
	2.11305478E-01	2	1000023 6
	5.57908779E-01	2	1000024 5
#	PDG	Width	# n1 decays
BRCAV	1000022	0.00000000E+00	

Model

Database

Simplified-models (SMS) results

Result depends on type of data provided:

- Upper limits (UL): Excluded/allowed
- Efficiency maps (EM): Combining topologies, Likelihood

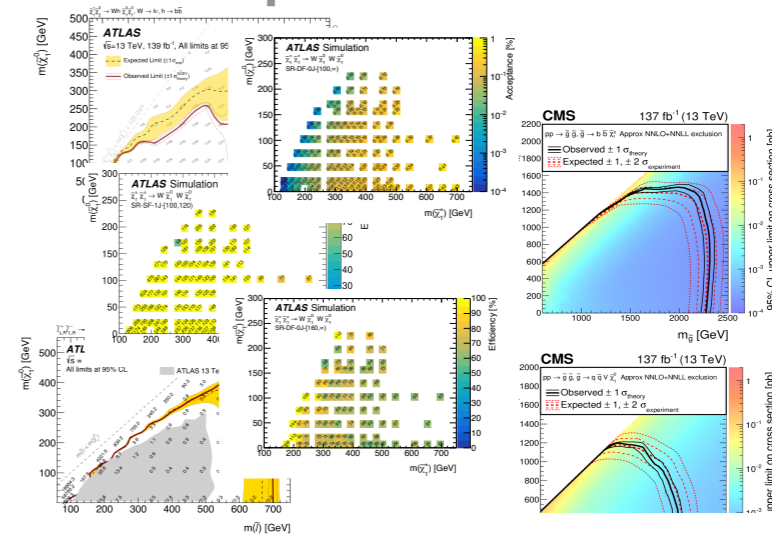
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Model

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



Experiment



Pros:

- No MC simulation \Rightarrow fast
- No approximations from recasting
- Works beyond cut-and-count (e.g. ML)
- Prompt and long-lived on same footing

Cons:

- Approximations (SMS, interpolation)
- Currently, only models with Z_2 -symmetry
- Only test existing SMS results \Rightarrow often conservative ('missing topologies')

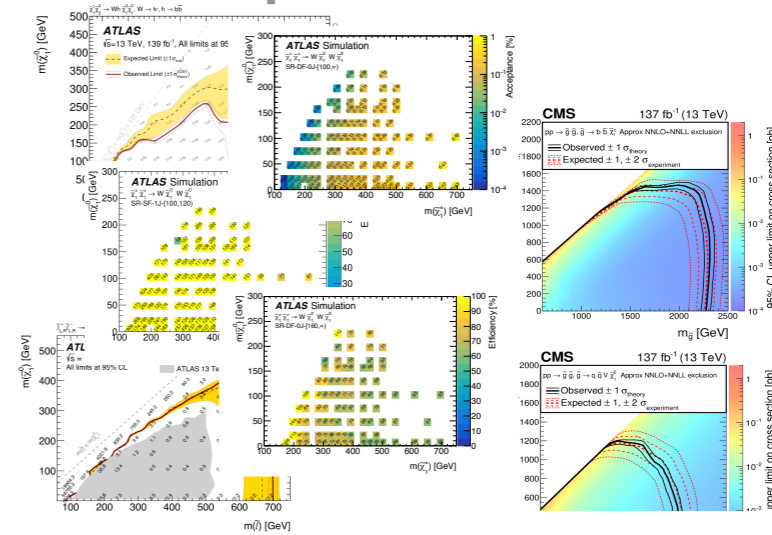
Reinterpretation of new physics searches

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



Pros:

- No MC simulation \Rightarrow fast
- No approximations from recasting
- Works beyond cut-and-count (e.g. ML)
- Prompt and long-lived on same footing
- Useful to detect experimental gaps

Cons:

- Approximations (SMS, interpolation)
- Currently, only models with Z_2 -symmetry
- Only test existing SMS results \Rightarrow often conservative ('missing topologies')

SModels Database

Run 2 - 13 TeV

In total, we have results from 26 ATLAS and 31 CMS 13 TeV searches.

- **ATLAS upper limits:** 24 analyses, 55 (of which 4 LLP) results
- **ATLAS efficiency maps:** 11 analyses, 37 (of which 9 LLP) results, 340 individual maps
- **CMS upper limits:** 29 analyses, 120 (of which 3 LLP) results
- **CMS efficiency maps:** 3 analyses, 14 results, 166 individual maps

Run 1 - 8 TeV

In total, we have results from 25 ATLAS and 18 CMS 8 TeV searches.

- **ATLAS upper limits:** 15 analyses, 37 results
- **ATLAS efficiency maps:** 18 (of which 9 FastLim) analyses, 191 (of which 163 FastLim) results, 1557 individual maps
- **CMS upper limits:** 16 analyses, 56 (of which 3 LLP) results
- **CMS efficiency maps:** 8 analyses, 45 (of which 9 LLP) results, 972 individual maps

CMS, upper limits, 13 TeV (29 analyses)

ID	short description	L [1/fb]	Tx names	exp. ULs (4)
PAS				
CMS-PAS-EXO-16-036	hscp search	12.9	THSCPM1b, TRHadGM1, TRHadGM1	
CMS-PAS-SUS-16-062	soft lepton, <= 2 jets	35.9	T2bbWWoff, T6bbWWoff	
Publications				
CMS-SUS-16-009	multijets + Emiss, top tagging	2.3	T1tttt, T1ttttoff, T2t, T2ttt, T5tctc	✓
CMS-SUS-16-032	Sbottom and compressed stop (jets + Emiss)	35.9	T2bb, T2cc	
CMS-SUS-16-033	0L + jets + Emiss (using MHT)	35.9	T1, T1bbbb, T1ttt, T1ttt, T1ttt, T2, T2bb, T2cc, T2t, T2ttt	✓
CMS-SUS-16-034	2 OSF leptons	35.9	TSZZ, TCHWZ	
CMS-SUS-16-035	2 SS leptons	35.9	T1ttt, T1ttt, T5WW, T5WWoff, T5cc, T5bbWWoff, T5ttt, T6ttWW, T6ttWWoff, T6ttWW	
CMS-SUS-16-036	0L + jets + Emiss (using M _{2j})	35.9	T1, T1bbbb, T1ttt, T1ttt, T2, T2bb, T2cc, T2t, T2ttt, T6bbWW	✓
CMS-SUS-16-037	1L + jets + Emiss with MJ (sum of masses of large radius jets)	35.9	T1ttt, T1ttt, T5t, T5t	
CMS-SUS-16-039	Multi-lepton EWK searches	35.9	TCHChimSlep, TCHChimSlepStau, TCHChimSlepStau, TCHWH, TCHWZ, TCHWZoff, TCHWZoff	
Publications				
CMS-SUS-16-062	soft lepton, <= 2 jets	35.9	T2bbWWoff, T6bbWWoff	
CMS-SUS-16-009	multijets + Emiss, top tagging	2.3	T1ttt, T1ttt, T2t, T2ttt, T5tctc	✓
CMS-SUS-16-032	Sbottom and compressed stop (jets + Emiss)	35.9	T2bb, T2cc	
CMS-SUS-16-033	0L + jets + Emiss (using MHT)	35.9	T1, T1bbbb, T1ttt, T1ttt, T2, T2bb, T2cc, T2t, T2ttt, T6bbWW	✓
CMS-SUS-16-034	2 OSF leptons	35.9	TSZZ, TCHWZ	
CMS-SUS-16-035	2 SS leptons	35.9	T1ttt, T1ttt, T5WW, T5WWoff, T5cc, T5bbWWoff, T5ttt, T6ttWW, T6ttWWoff, T6ttWW	
CMS-SUS-16-036	0L + jets + Emiss (using M _{2j})	35.9	T1, T1bbbb, T1ttt, T1ttt, T2, T2bb, T2cc, T2t, T2ttt, T6bbWW	✓
CMS-SUS-16-037	1L + jets + Emiss with MJ (sum of masses of large radius jets)	35.9	T1ttt, T1ttt, T5t, T5t	
CMS-SUS-16-039	Multi-lepton EWK searches	35.9	TCHChimSlep, TCHChimSlepStau, TCHChimSlepStau, TCHWH, TCHWZ, TCHWZoff	

ID	short description	L [1/fb]	Tx names	exp. ULs (4)
CMS-SUS-17-006	jets + boosted H(bb) + Emiss	35.9	TS4H, TS4Z	✓
CMS-SUS-17-009	SFOS leptons + Emiss	35.9	TSelSel, TSlepSlep, TSnuSnu	✓
CMS-SUS-17-010	2L stop	35.9	T2t, T2st, T6bbWW, TCHChimSlepStau	✓
CMS-SUS-19-002	photon, jets, b-jets + Emiss, top tagging	35.9	TS4g, TS6bbZg, TS4ttZg, T6ttZg	✓
CMS-SUS-19-006	0L + jets, MHT	137.0	T1, T1bbbb, T1ttt, T1ttt, T2, T2bb, T2t, T2ttt	✓
CMS-SUS-19-009	1L + jets, MHT	137.0	T2tL, T2ttt, T6bbWW	

CMS, efficiency maps, 13 TeV (3 analyses)

ID	short description	L [1/fb]	Tx names	SR comb. (5)
Publications				
CMS-EXO-19-001	displaced vertices	137.0	T2Dsp	
PAS				
CMS-PAS-SUS-16-062-agg	soft lepton, <= 2 jets	35.9	T2bbWWoff (3), T6bbWWoff (3)	cov.
Publications				
CMS-SUS-16-033	0L + jets + Emiss (using MHT)	35.9	T1, T1bbbb, T1ttt, T1ttt, T2, T2bb, T2cc, T2t, T2ttt	

ATLAS, upper limits

ID	short description	L [1/fb]	Tx names	exp. ULs (4)
Publications				
ATLAS-SUSY-2015-01	2 b-jets + Emiss	36.1	TSZZ, TEZZ	
ATLAS-SUSY-2015-02	single lepton stop	3.2	T2t	
ATLAS-SUSY-2016-07	0L + jets + Emiss	36.1	T1, T2, T5WW, T5WWoff, T5WZ, T5Z, T6WW, T6WWoff, T6WZ	
ATLAS-SUSY-2016-08	displaced vertices	32.8	T5Dsp	
ATLAS-SUSY-2016-14	2 same-sign or 3 leptons + jets + Emiss	36.1	T1ttt, T1ttt, T1ttt, T2ttt, T6ttWW	
ATLAS-SUSY-2016-15	0L stop	36.1	T2bb, T2t, T2ttt	✓
ATLAS-SUSY-2016-16	1L stop	36.1	T2bb, T2t, T2ttt, T6bbWW	
ATLAS-SUSY-2016-18	1L stop	36.1	T2bb, T2t, T2ttt, T6bbWW	
ATLAS-SUSY-2016-19	2 opposite sign	36.1	T2bbWWoff, T2t, T2ttt	

ATLAS, upper limits, 13 TeV (24 analyses)

ID	short description	L [1/fb]	Tx names	exp. ULs (4)
Publications				
ATLAS-SUSY-2015-01	2 b-jets + Emiss	3.2	T2bb	
ATLAS-SUSY-2015-02	single lepton stop	3.2	T2t	
ATLAS-SUSY-2015-09	jets + 2 SS leptons or >= 3 leptons	3.2	T1ttt	
ATLAS-SUSY-2016-07	0L + jets + Emiss	36.1	T1, T2, T5WW, T5WWoff, T5WZ, T5Z, T6WW, T6WWoff, T6WZ	
ATLAS-SUSY-2016-08	displaced vertices	32.8	T5Dsp	
ATLAS-SUSY-2016-14	2 same-sign or 3 leptons + jets + Emiss	36.1	T1ttt, T1ttt, T1ttt, T2ttt, T6ttWW	
ATLAS-SUSY-2016-15	0L stop	36.1	T2bb, T2t, T2ttt	✓
ATLAS-SUSY-2016-16	1L stop	36.1	T2bb, T2t, T2ttt, T6bbWW	
ATLAS-SUSY-2016-18	1L stop	36.1	T2bb, T2t, T2ttt, T6bbWW	
ATLAS-SUSY-2016-19	2 opposite sign	36.1	T2bbWWoff, T2t, T2ttt	

ID	short description	L [1/fb]	Tx names	exp. ULs (4)
ATLAS-SUSY-2016-04	2 hadronic taus (OS)	139.0	TStauStau	
ATLAS-SUSY-2016-06	3 leptons EW-ino	139.0	TCHWZ, TCHWZoff	✓
ATLAS-SUSY-2016-31	2b + 2H(bb) + Emiss	139.0	T6bbHH	
ATLAS-SUSY-2018-32	2 OS leptons + Emiss	139.0	TCHWW, TCHChimSlep, TSlepSlep	
ATLAS-SUSY-2019-08	1L + higgs + Emiss (EWino)	139.0	TCHWH	

ATLAS, efficiency maps, 13 TeV (11 analyses)

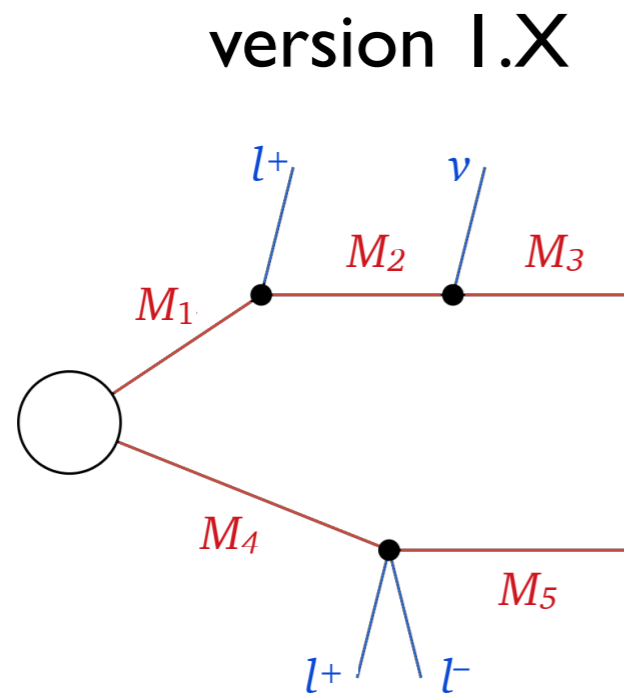
ID	short description	L [1/fb]	Tx names	exp. ULs (4)
Publications				
ATLAS-SUSY-2016-04	2 hadronic taus	139.0	TStauStau	
ATLAS-SUSY-2016-31	Higgs + b-jets + MET	139.0	T6bbHH	
ATLAS-SUSY-2019-08	1L + higgs + Emiss (EWino)	139.0	TCHWH	

CMS, efficiency maps, 8 TeV (8 analyses)

ID	short description	L [1/fb]	Tx names	SR comb. (5)
Publications				
CMS-EXO-12-026	hscp search	18.8	THSCPM1b, TRHadGM1, TRHadLM1	
CMS-PAS-SUS-13-016	2 OS leptons + >= 4 (2 b-jets + Emiss, M _{2j})	19.7	T1ttt, T1ttt	
CMS-PAS-SUS-13-018	1-2 b-jets + Emiss	19.4	T2bb	
CMS-PAS-SUS-13-023	hadronic stop	18.9	T2t, T2ttt, T6bbWW, T6bbWWoff	
Publications				
CMS-SUS-12-024	0 leptons + >= 3 (b-jets + Emiss)	19.4	T1ttt, T1ttt	
CMS-SUS-12-028	jets + Emiss	19.4	T1ttt, T1ttt	

100 searches; ~270 UL results; ~3000 EMs
 Complete list of analyses on:
<https://smodels.github.io/docs/ListOfAnalyses>

New features in SModelS 2.0

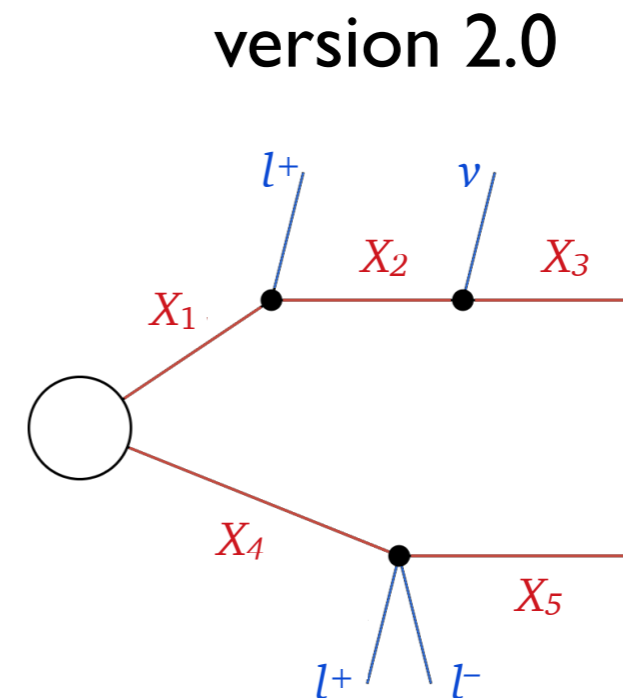


Simplified model topology contains:

- Structure
- Weight
- Final state particles
- Masses M_i

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

[see 1808.05229, 1811.10624]



X_i = Particle object

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

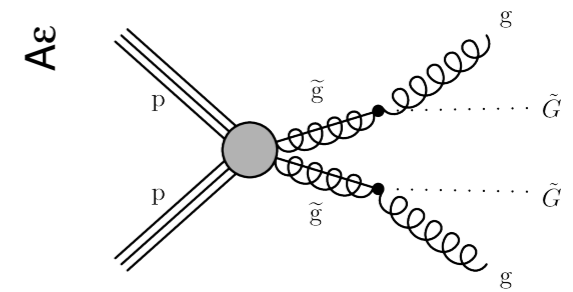
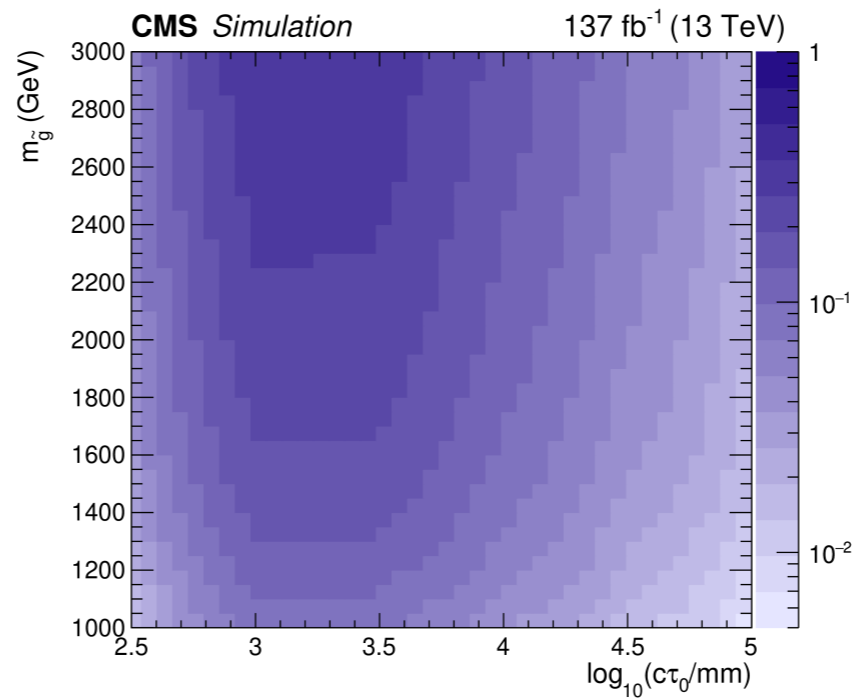
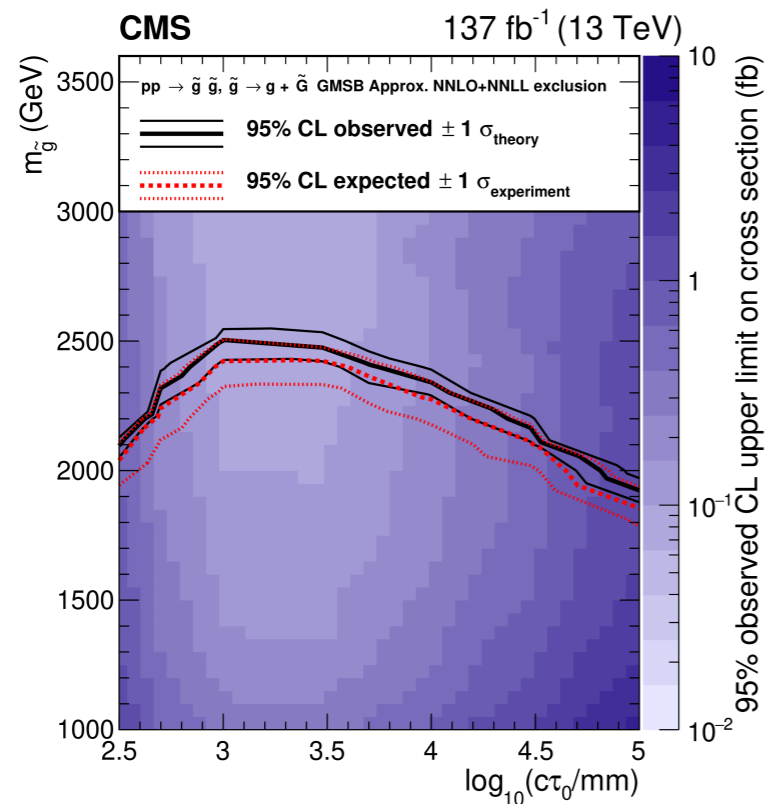
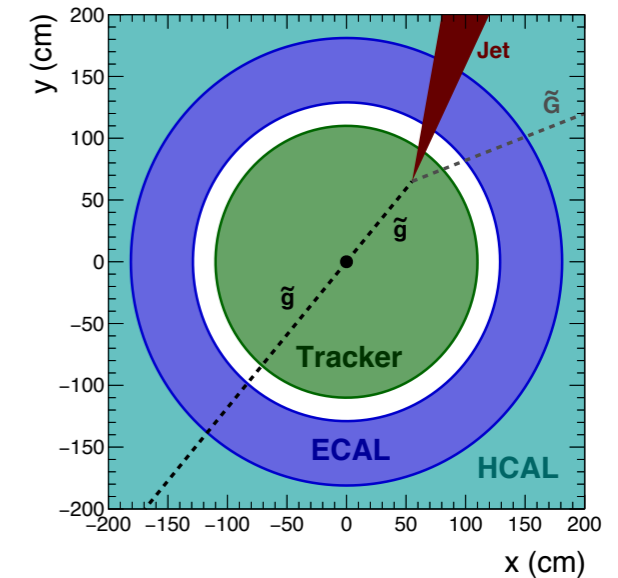
Enables:

- 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:

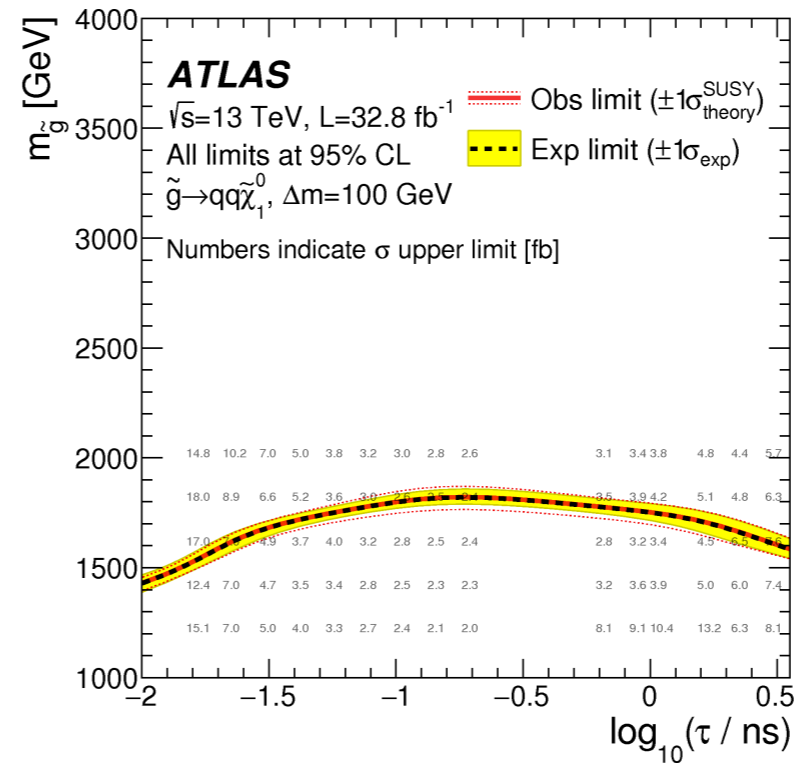
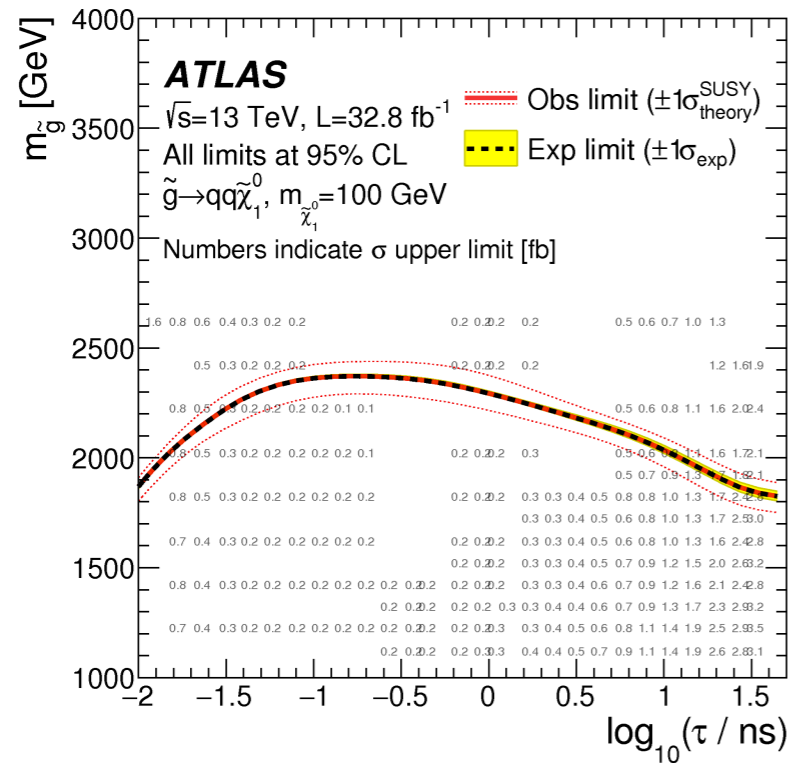
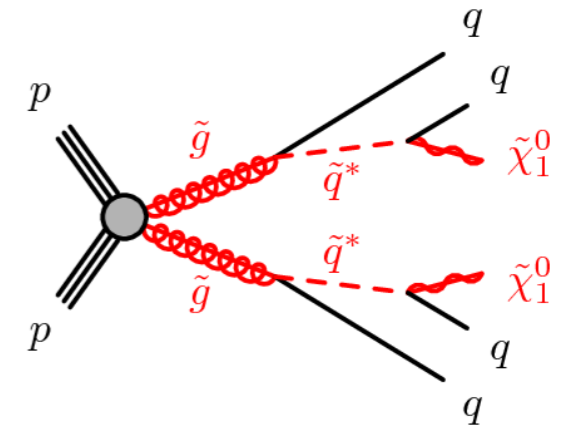
1. CMS-EXO-19-001: delayed jets + MET (EM)



Long-lived particle results in SModelS 2.0

Validated:

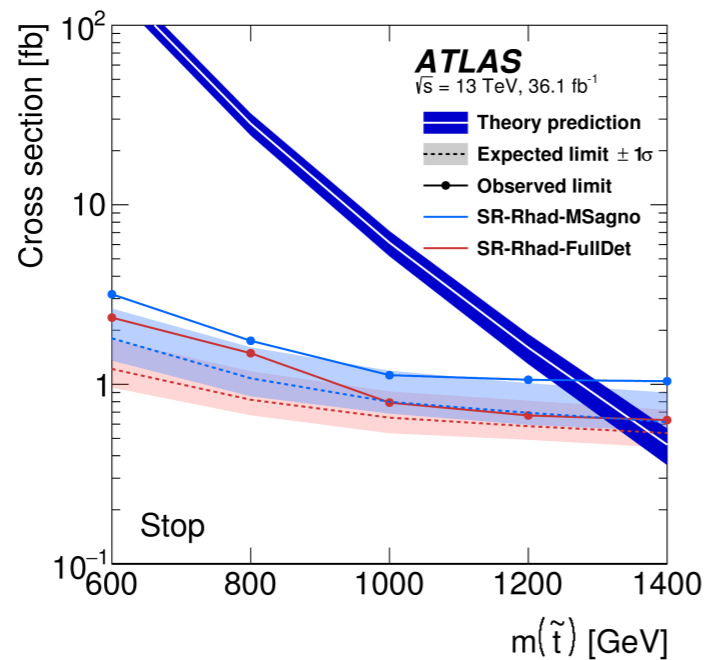
1. CMS-EXO-19-001: delayed jets + MET (EM)
2. ATLAS-SUSY-2016-08: displaced vertices + MET (UL)



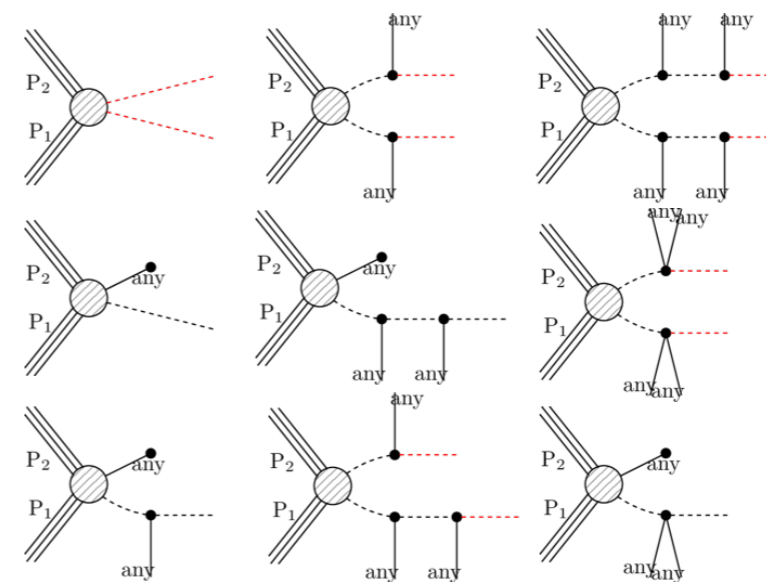
Long-lived particle results in SModelS 2.0

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 (UL, EM)
 4. CMS-EXO-13-006: HSPCs, R -hadrons (UL, EM)
- } recasting prescription



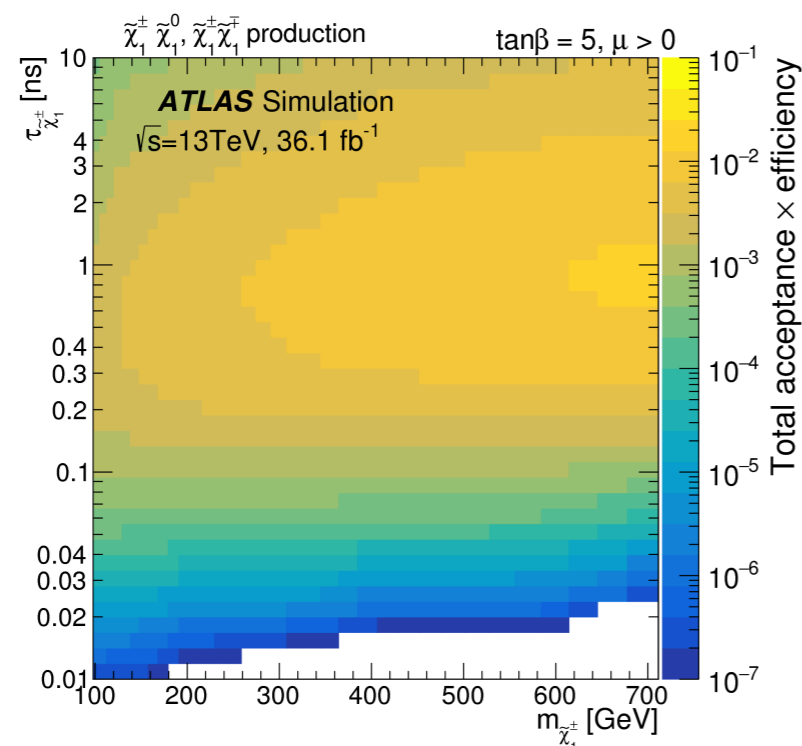
Efficiency maps for:



Long-lived particle results in SModelS 2.0

Validated:

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2. ATLAS-SUSY-2016-08: displaced vertices + MET (UL)
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4. CMS-EXO-13-006: HSPCs, R -hadrons (UL, EM)
5. ATLAS-SUSY-2016-06 disappearing tracks (EM)*



*) Efficiency maps for individual production modes (and for different spins) kindly provided by A. Belyaev, S. Prestel, F. Rojas-Abbate, J. Zurita [2008.08581]

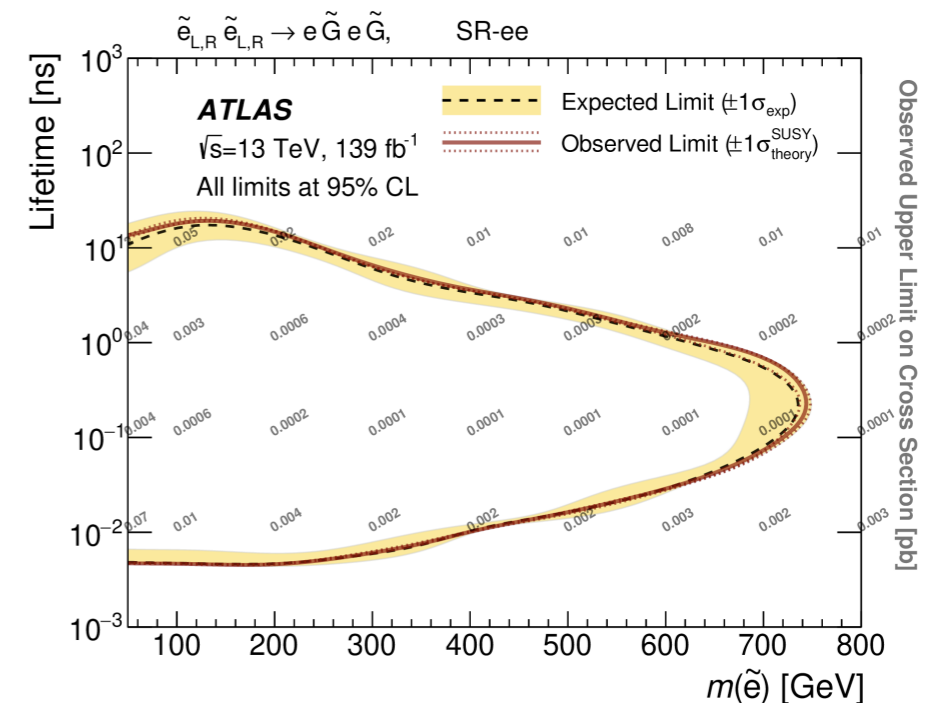
Long-lived particle results in SModelS 2.0

Validated:

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4. CMS-EXO-13-006: HSPCs, R -hadrons (UL, EM)
5. ATLAS-SUSY-2016-06 disappearing tracks (EM)

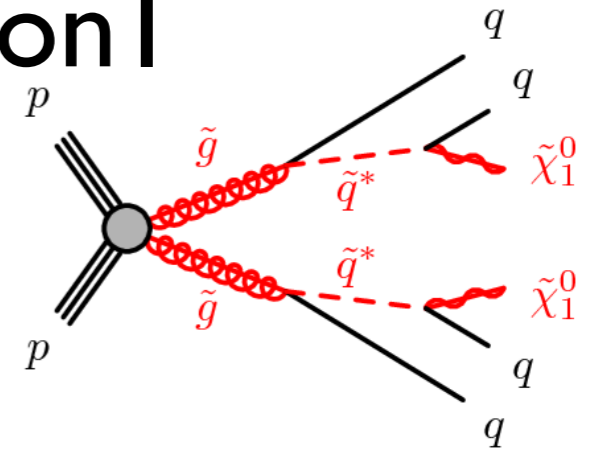
On its way:

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



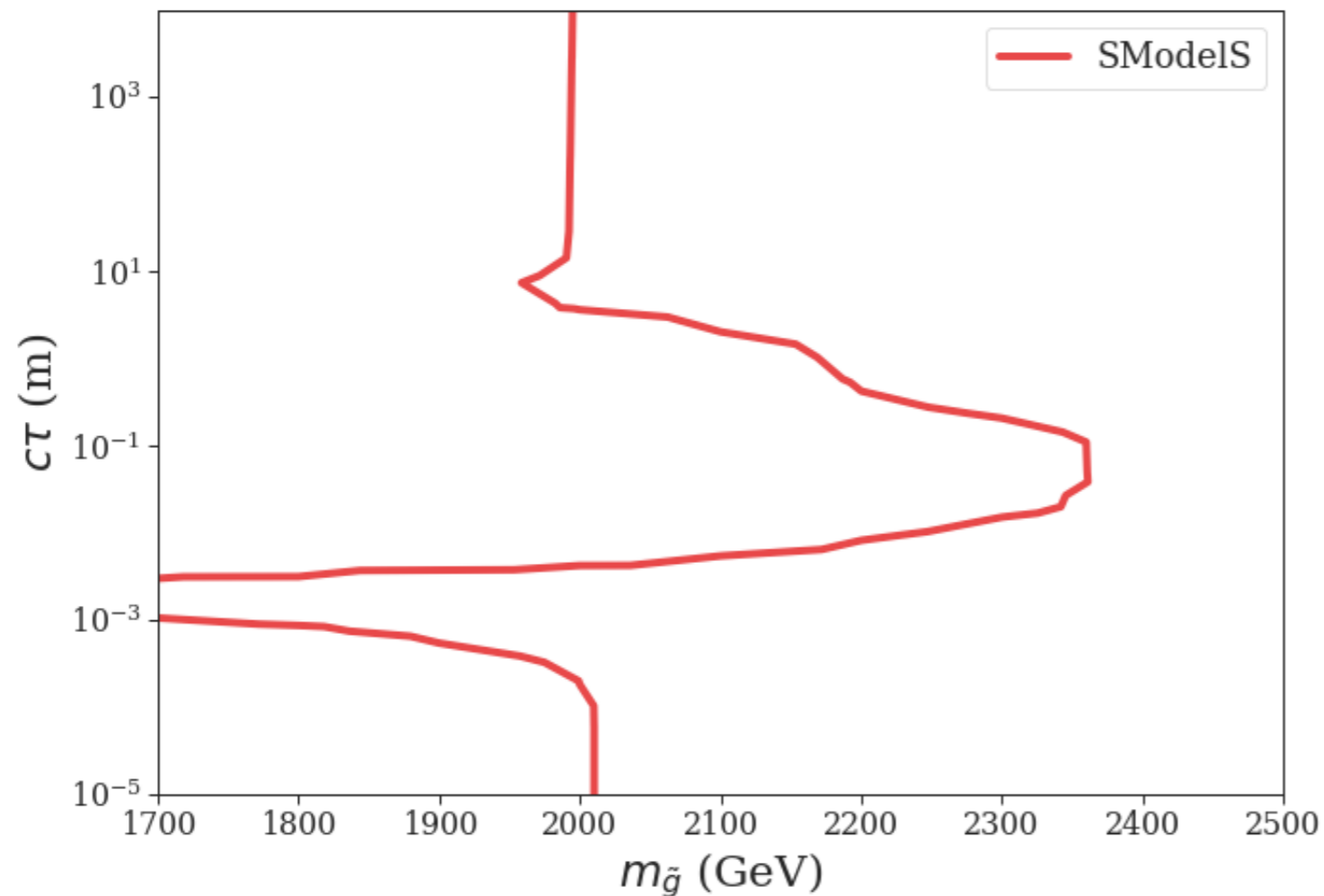
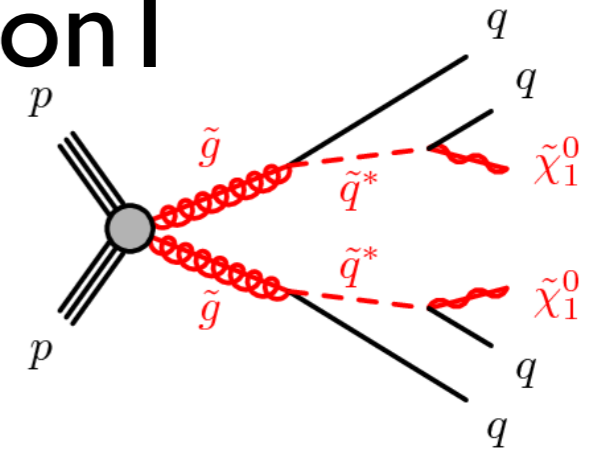
Long-lived particles: Application I

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



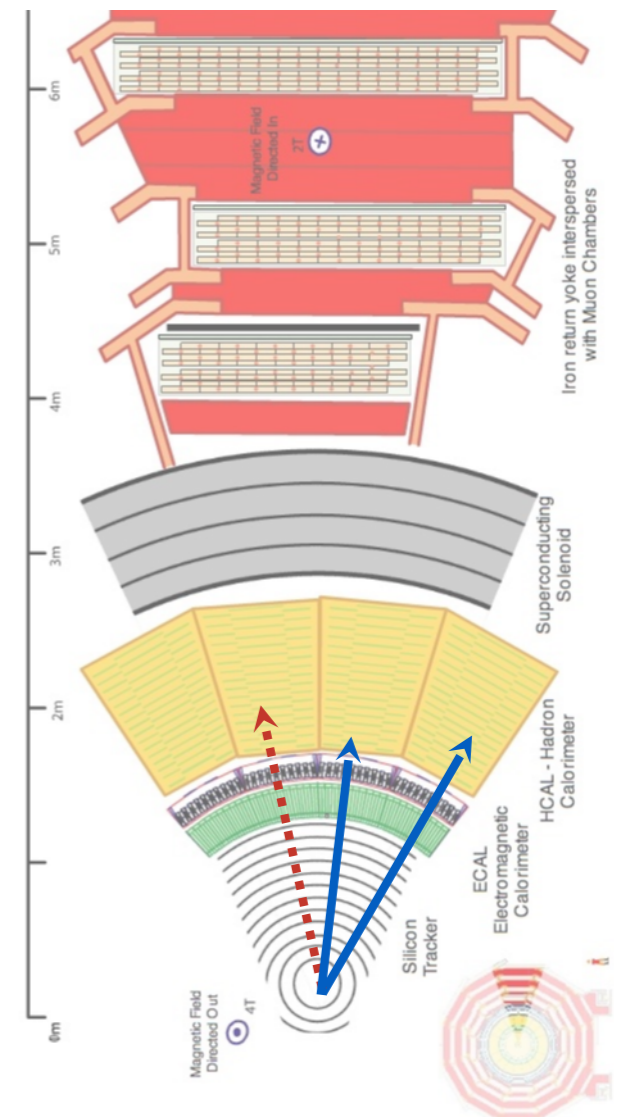
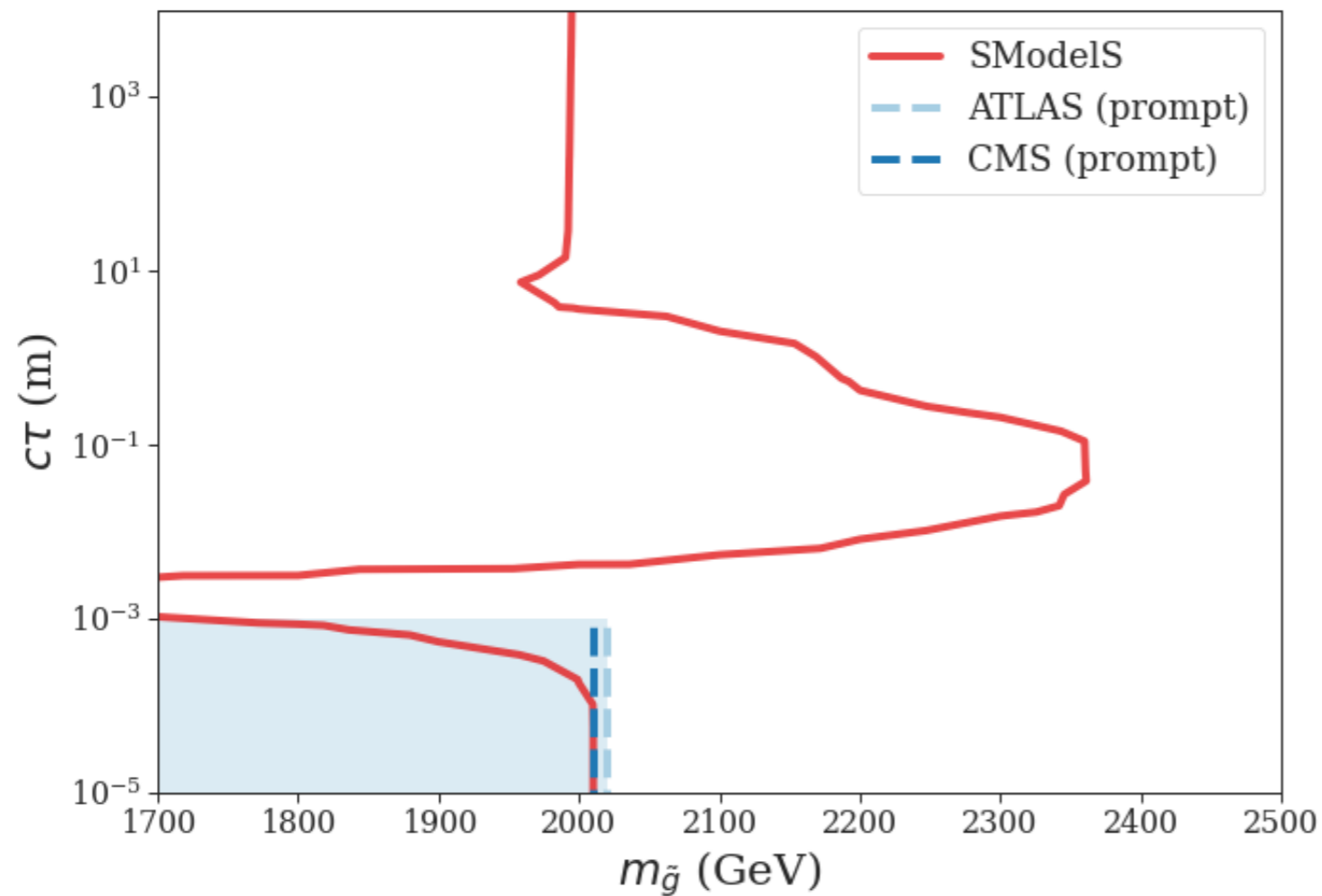
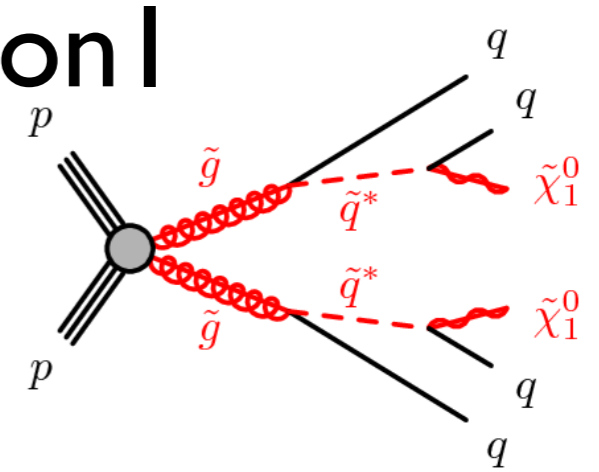
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Long-lived particles: Application I

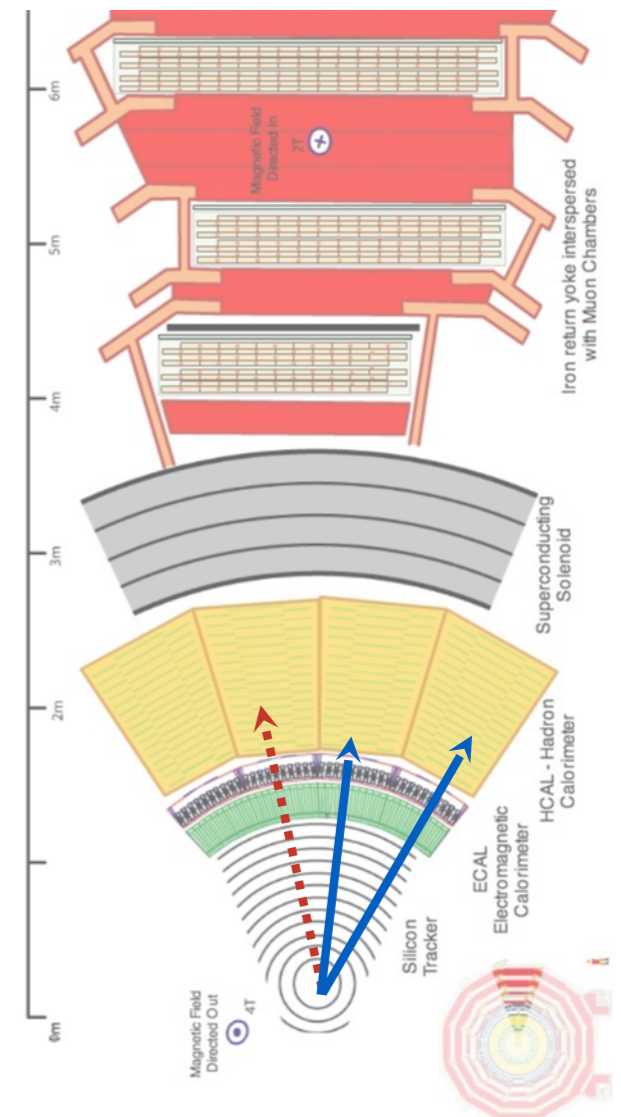
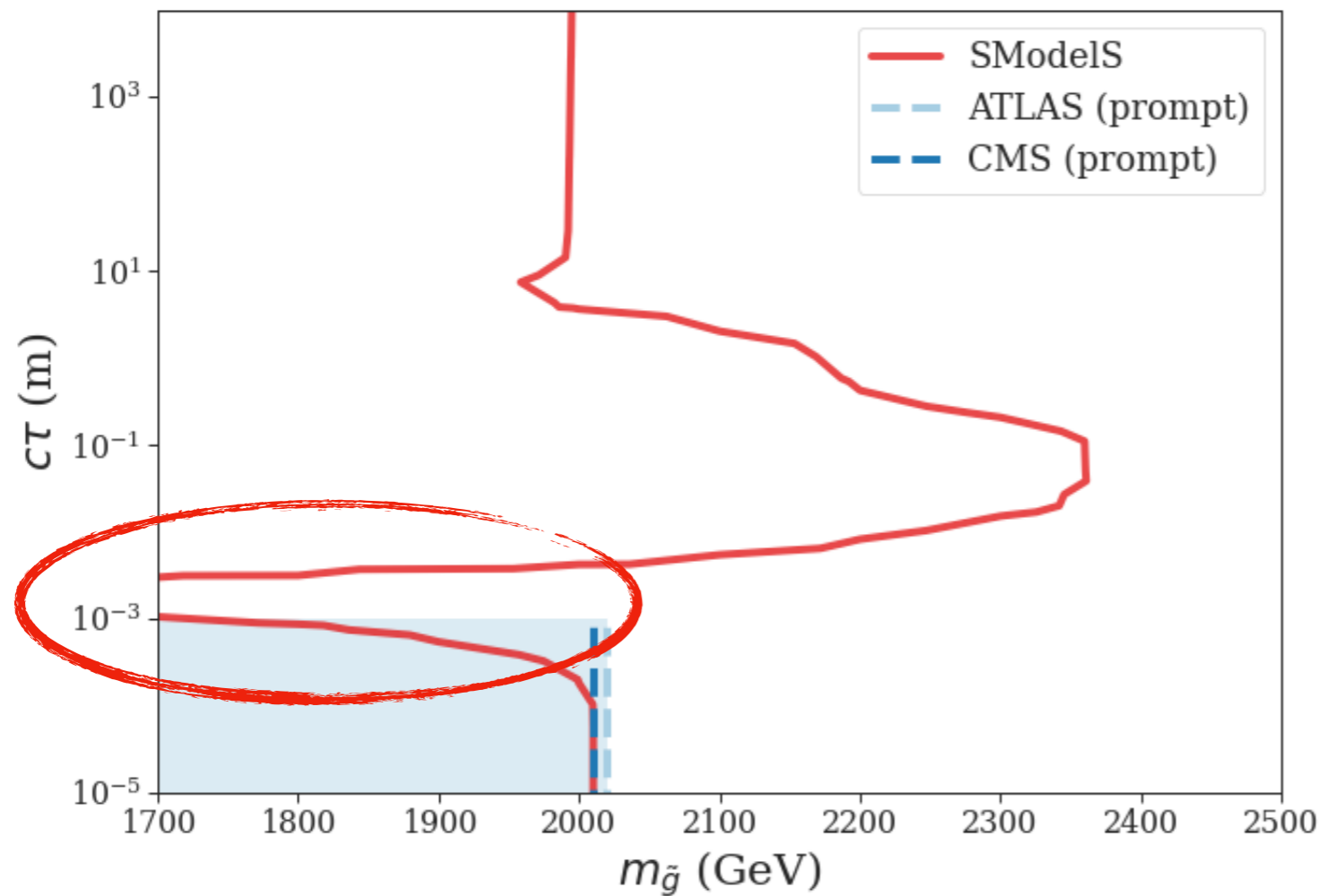
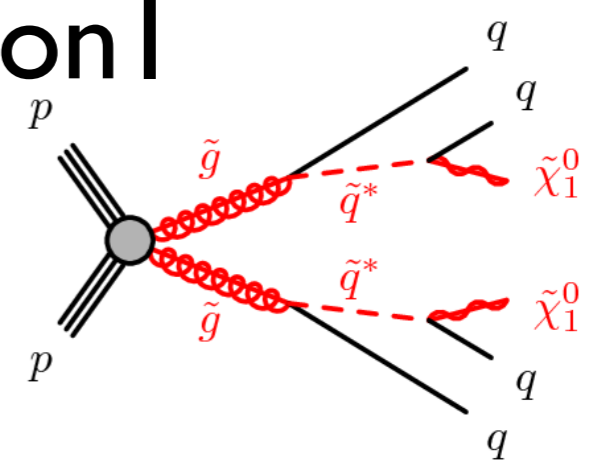
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Thanks to Andre Lessa

Long-lived particles: Application I

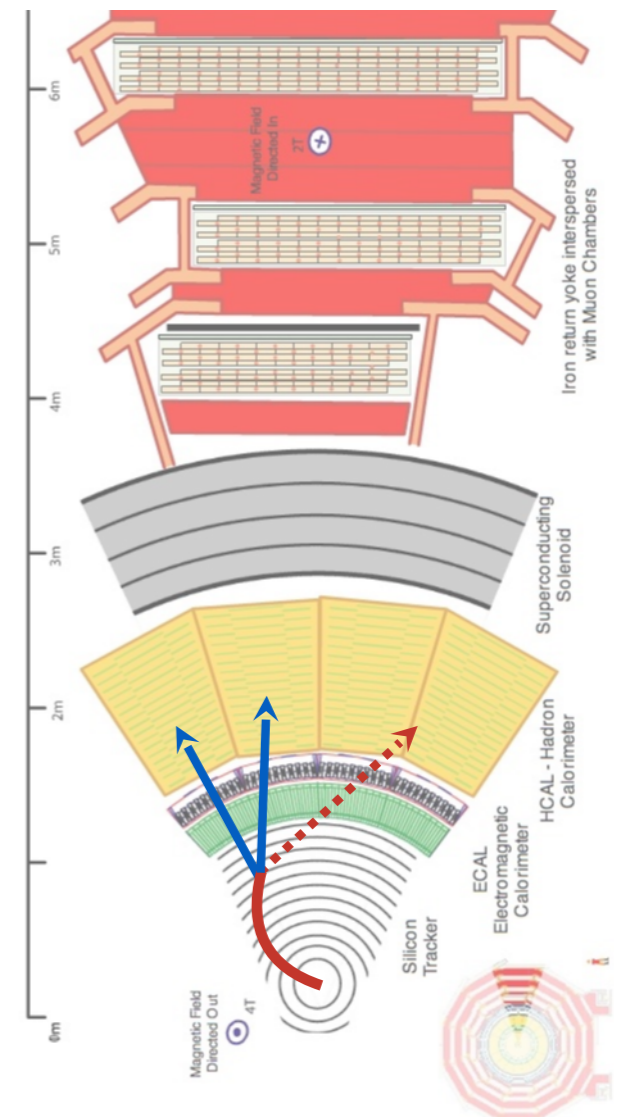
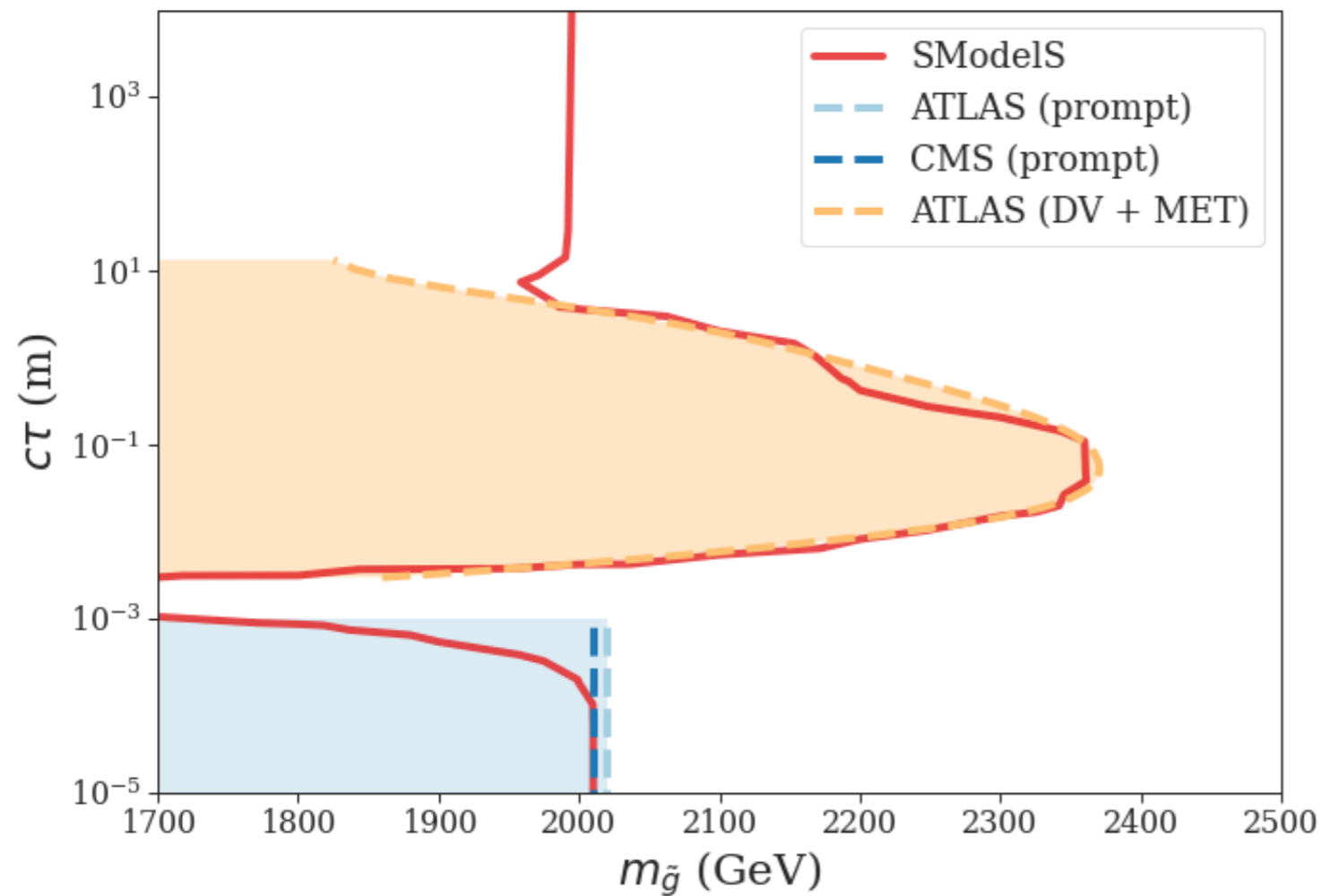
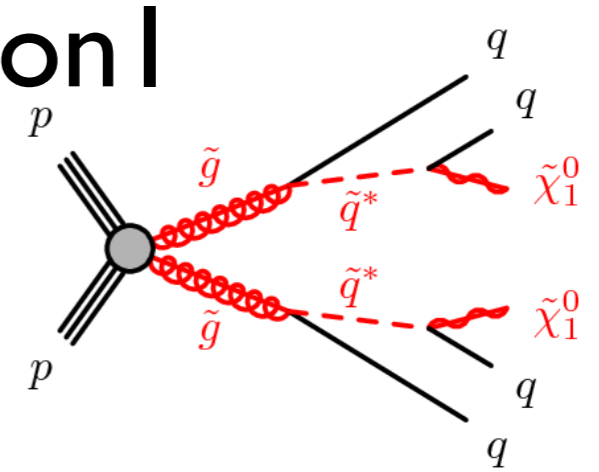
- Illustrative example: Simplified model gluino production:
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Long-lived particles: Application I

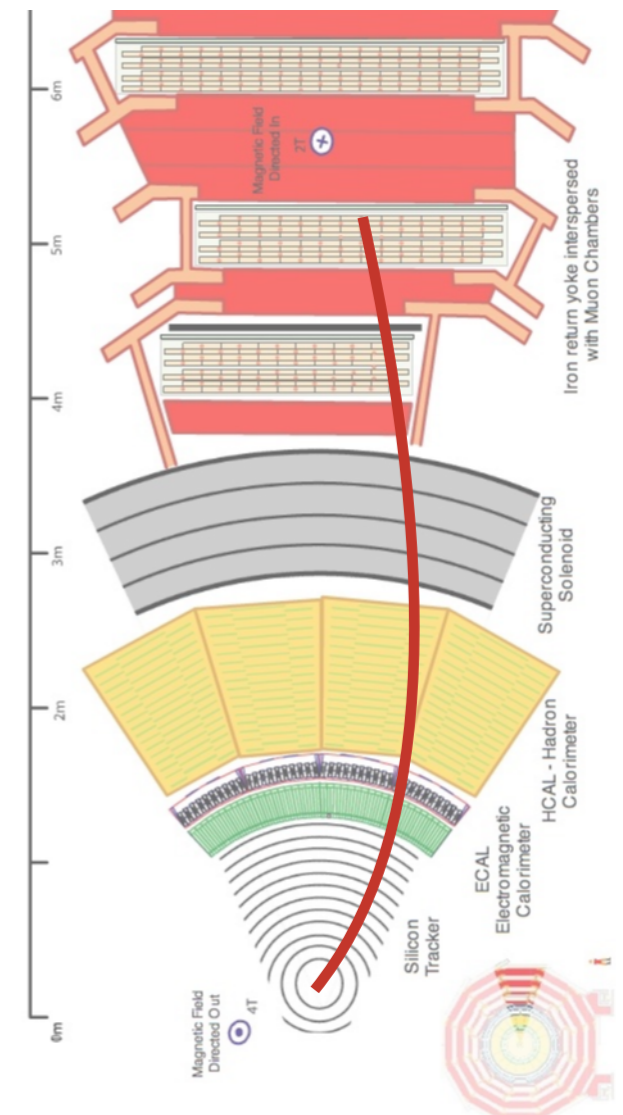
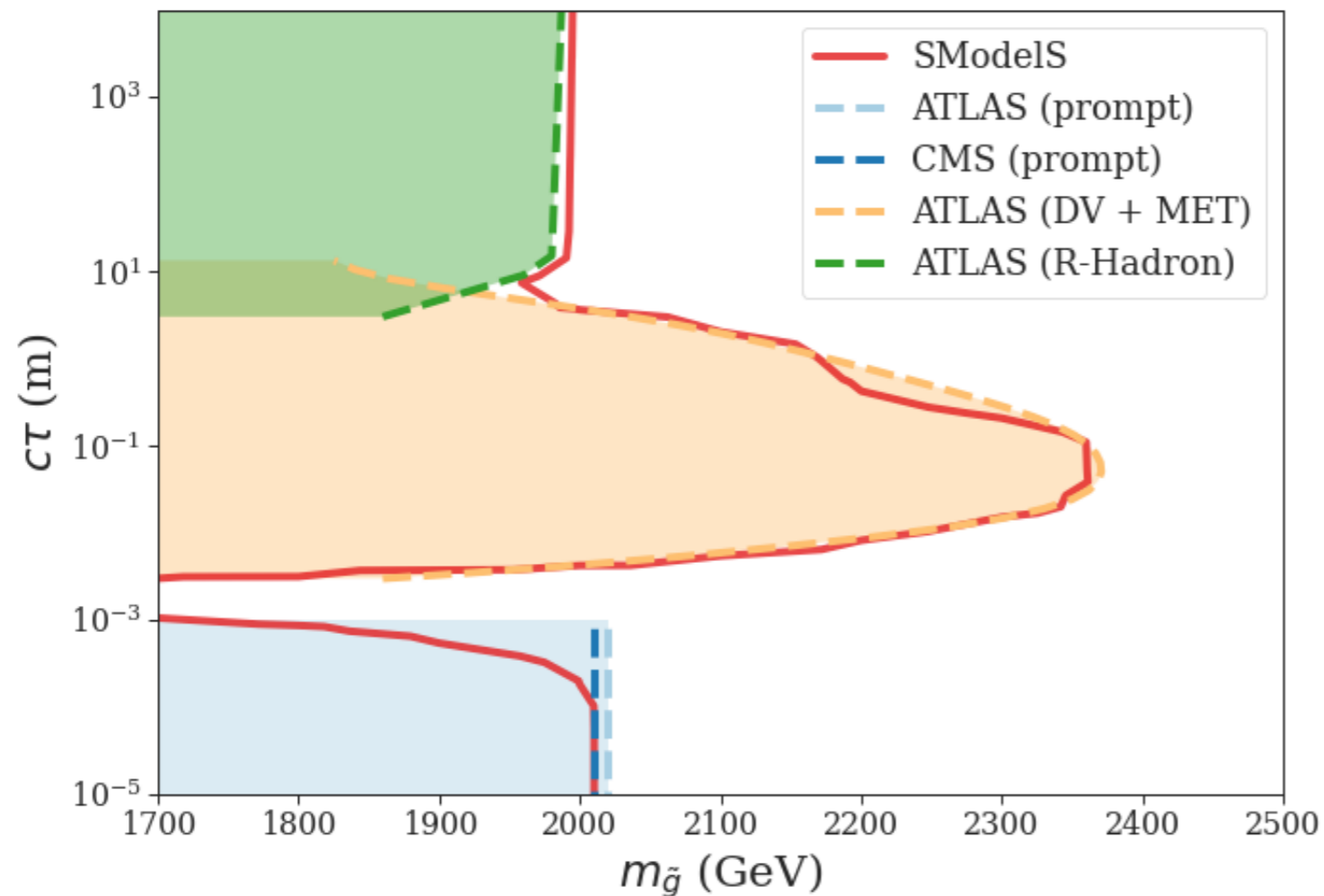
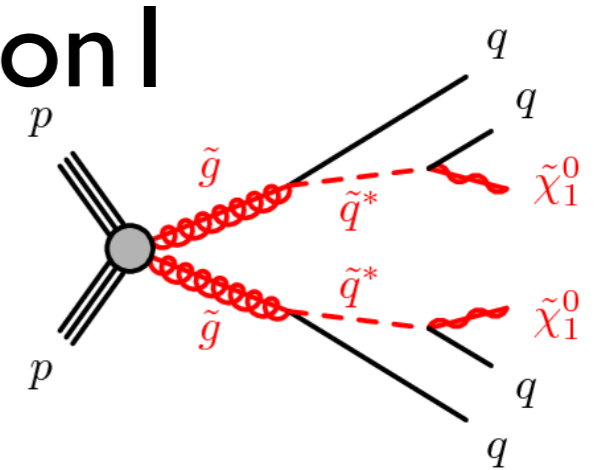
- Illustrative example: Simplified model gluino production:
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Thanks to Andre Lessa

Long-lived particles: Application I

- Illustrative example: Simplified model gluino production:
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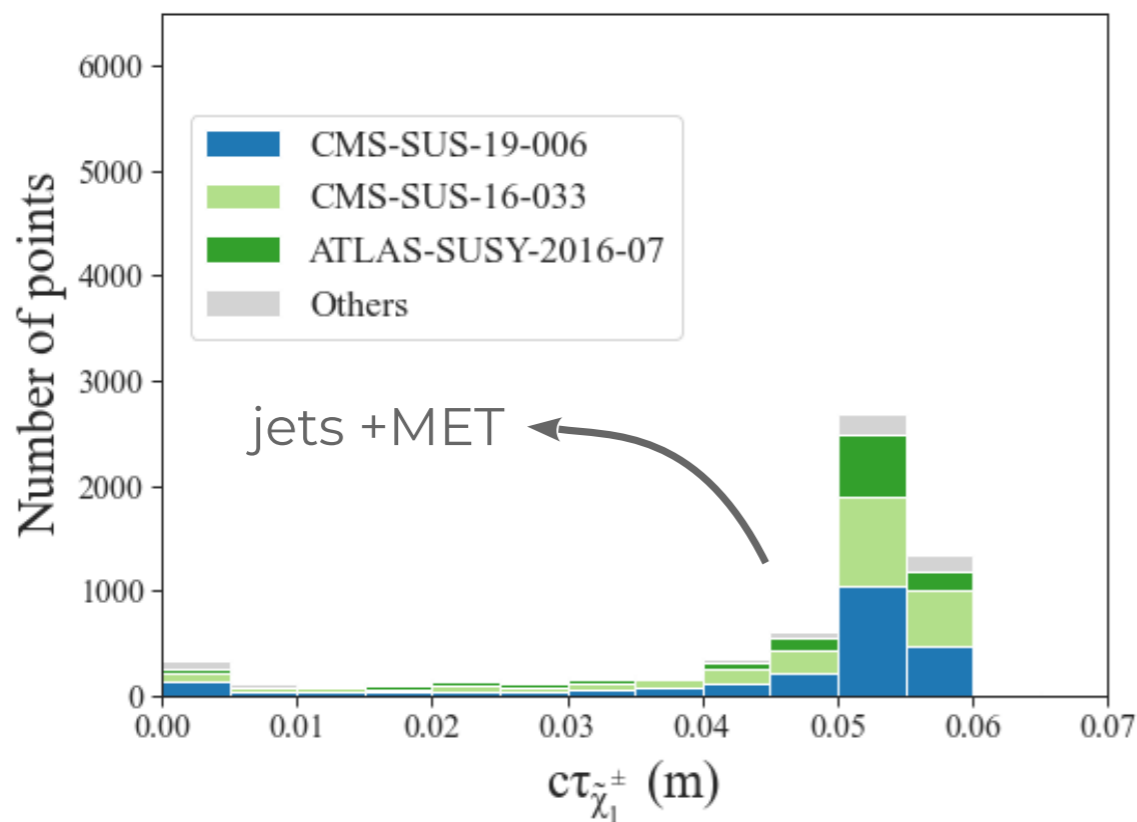


Thanks to Andre Lessa

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

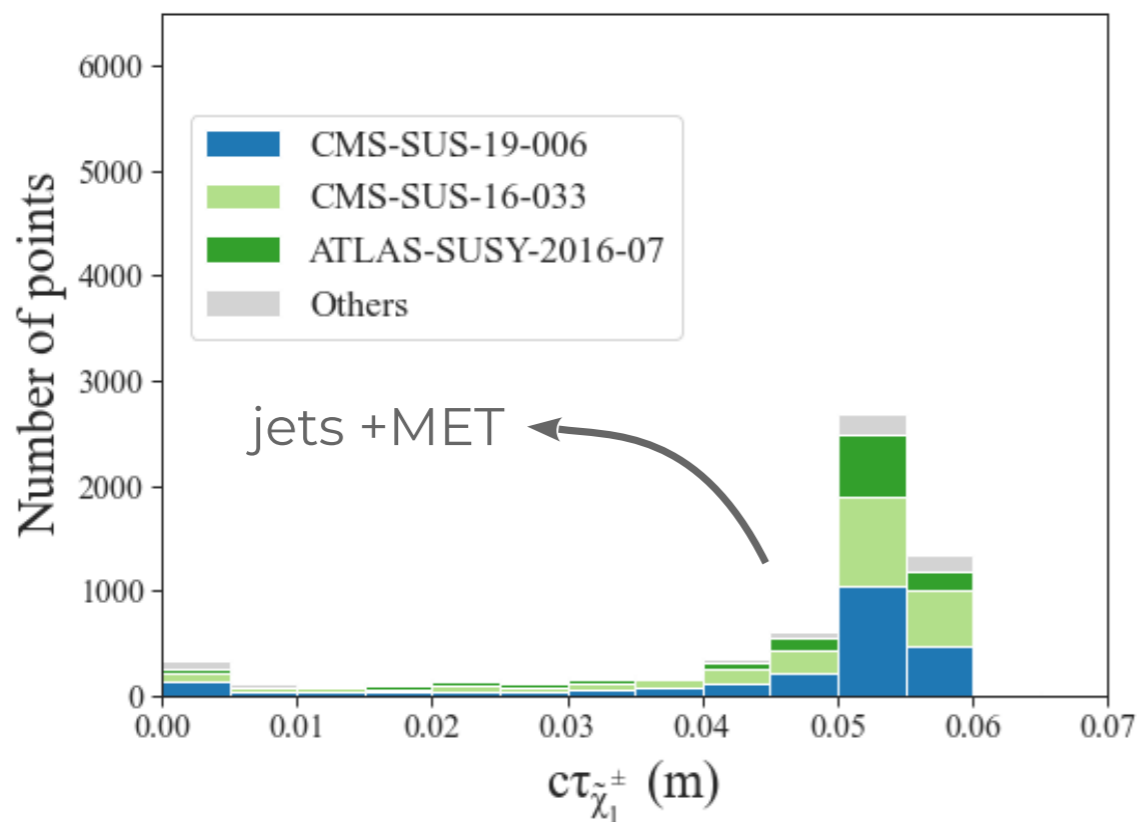
SModelS v1.2.4



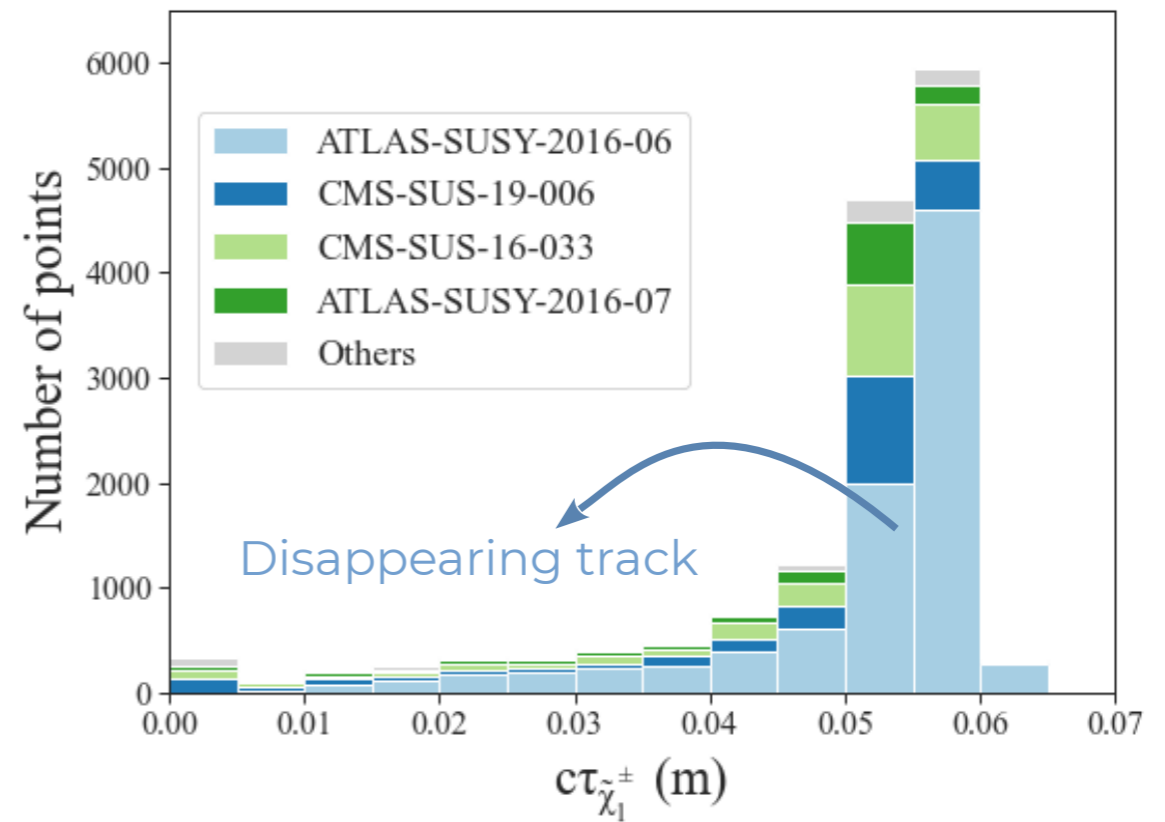
Long-lived particles: Application 2

- Full model: ATLAS pMSSM scan (wino-like LSP) [1508.06608]
 - 43,680 points allowed by 8TeV results
 - 8,832 points excluded by v1.2.4
 - **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
- Works beyond cut-and-count analyses (e.g. using ML)
- Huge database: 100 searches, ~270 UL results, ~3000 EMs
- Prompt and long-lived searches on same footing
- Growing number of long-lived particle searches
- Missing topologies: detect experimental gaps

<https://smodels.github.io>



What's next

- Extend database of long-lived particle searches, wishlist:
 - Disappearing tracks $\Delta m > 1 \text{ GeV}$, kinked tracks [e.g. mot. by CDFO 1705.09292]
 - Close gap between prompt and displaced [e.g. CMS 1909.03460]
 - Stopped particles
- Useful results: (ULs/)EMs, single topologies, reasonable grids
(or well-documented recasting prescription) [see 2003.07868]
- Speed up interpolation by ML techniques
 - Go beyond Z_2 -symmetric models

<https://smodels.github.io>