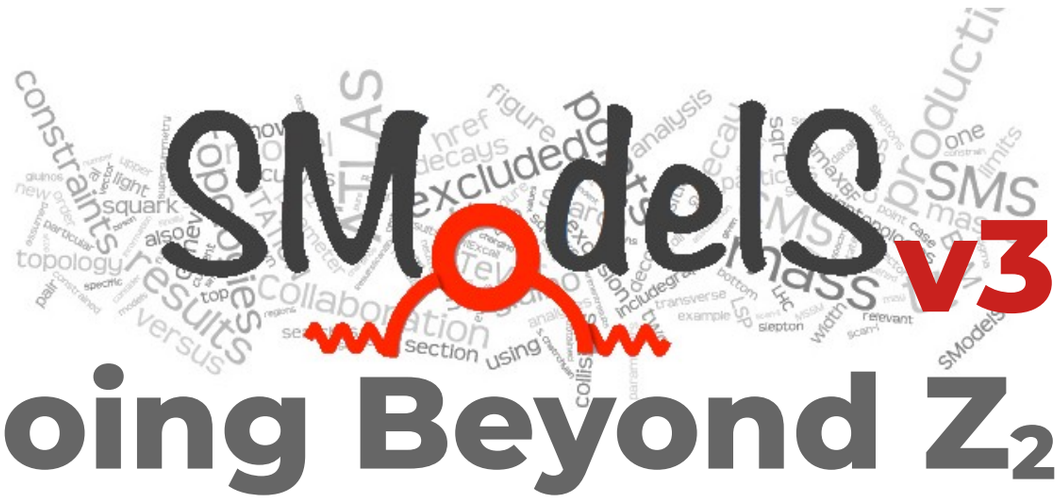


André Lessa
(UFABC – São Paulo)

REI Workshop

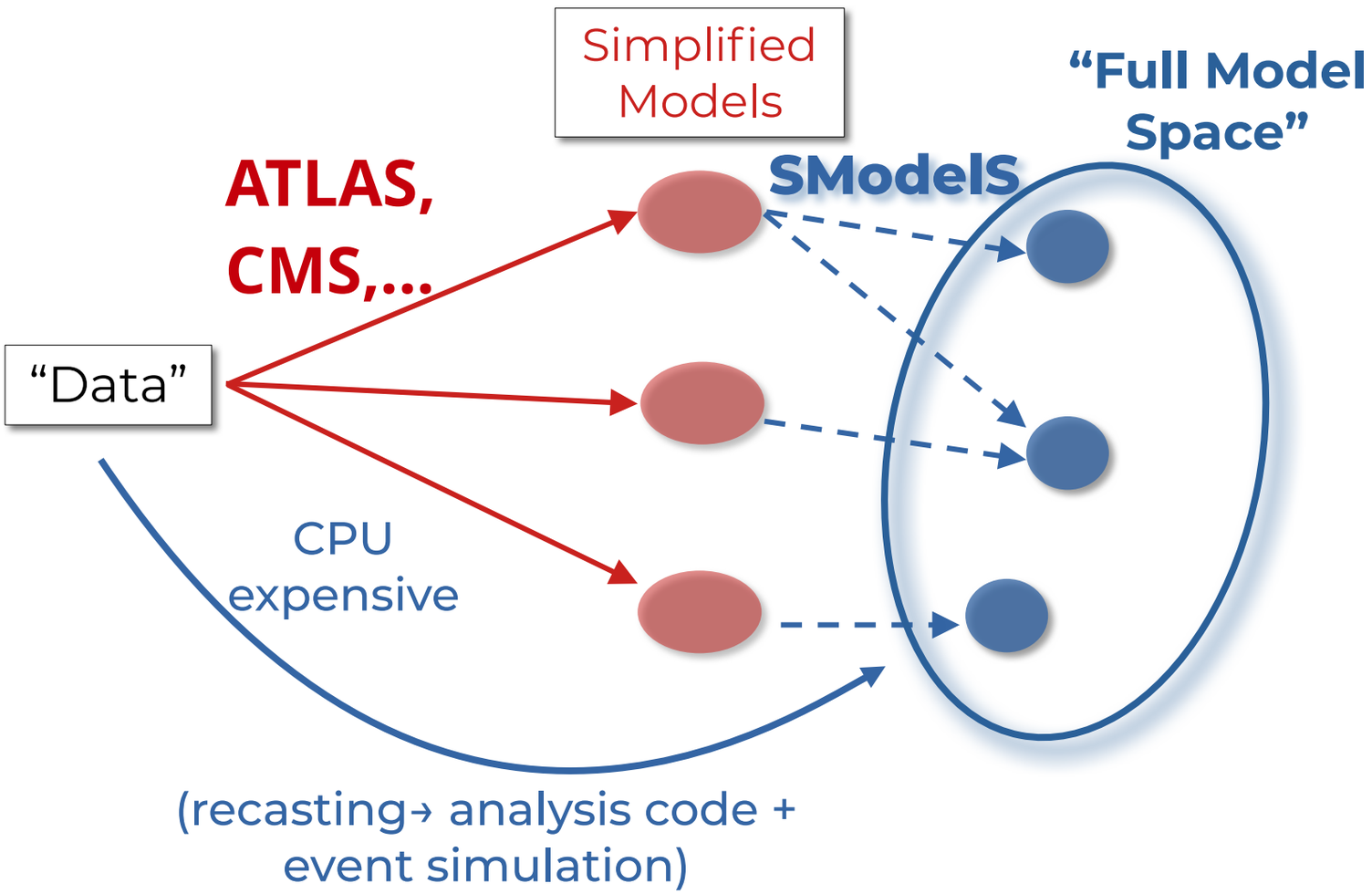
February 27th, 2025

In collaboration with M. Altakach, S. Kraml, S. Narasimha, T. Pascal, C. Ramos, Y. Villamizar and W. Waltenberger

arXiv: 2409.12942

SModelS: Basics

- Tool for reintrepretation of LHC results based on rescaling of simplified model (SMS) results:

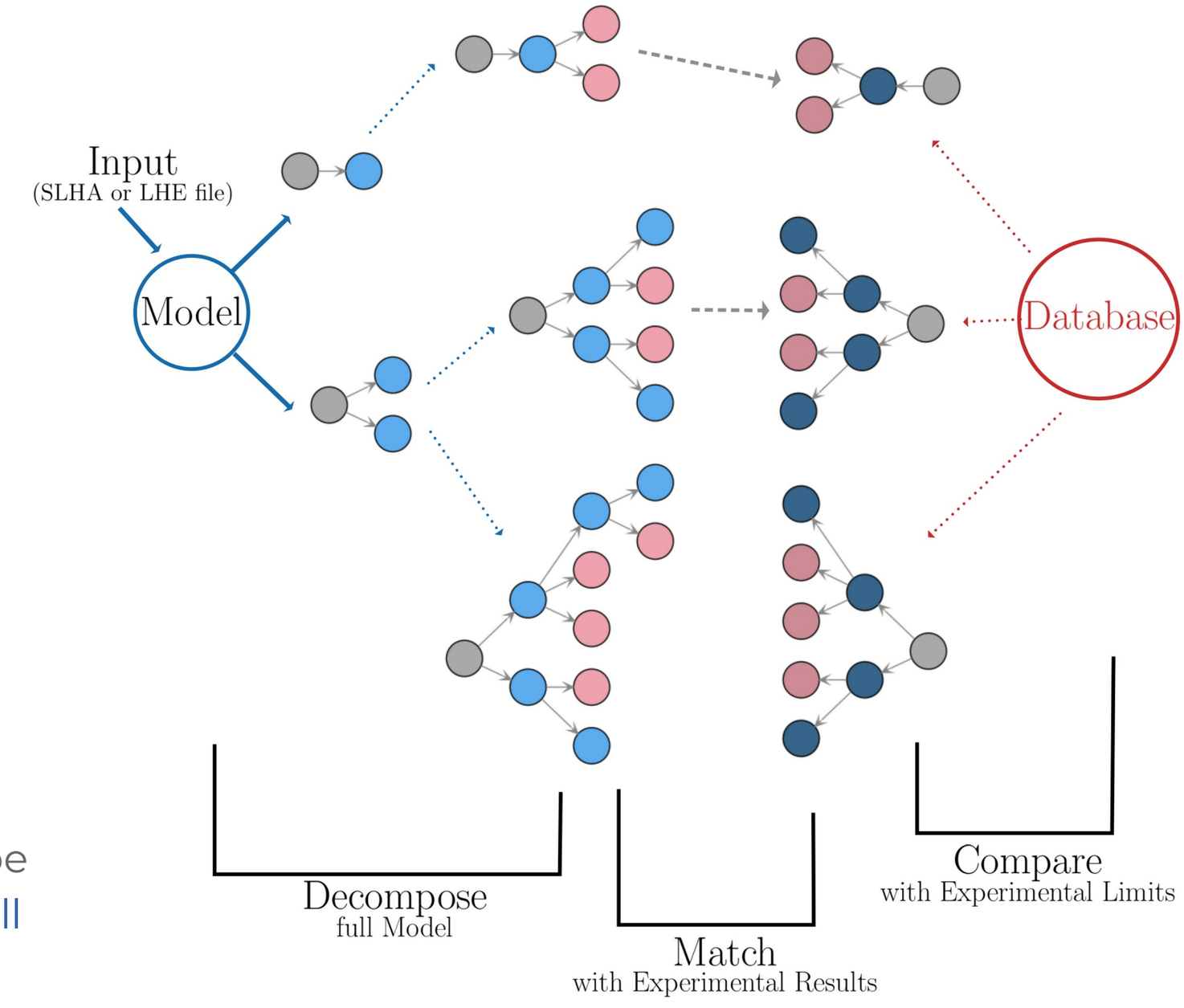


- Pros:
  - Many SMS results have been produced by the experimental collaborations
  - No need for recasting or event simulation
  - Sometimes the only alternative for complex searches
  - Very fast!
- Cons:
  - The rescaling extrapolates/interpolates signal efficiencies
  - Results are limited by the available simplified models
  - Results tend to be conservative and underestimate the experimental sensitivity

SModelS: Basics

- SModelS performs 3 main tasks:

1. UV model → sum of SMS
2. Find the matching results in the database
3. Compute constraints (limit setting)

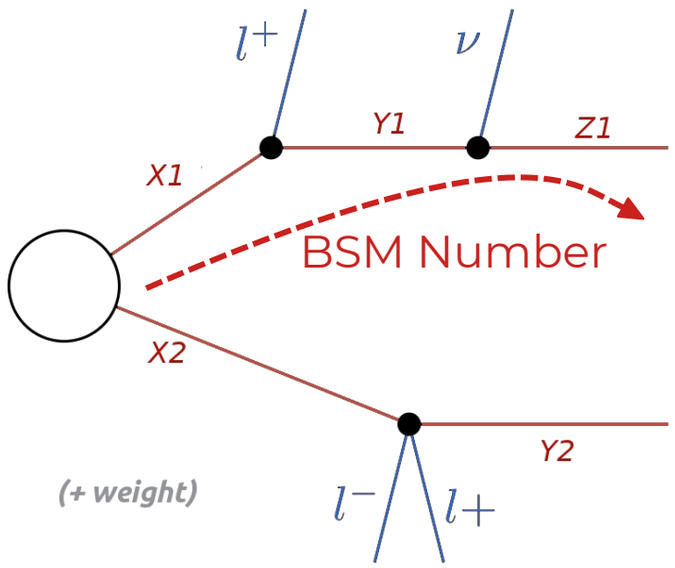


- Main approximation:

  SMS efficiencies are assumed to be driven by the properties of on-shell particles → masses, widths and quantum numbers

SModelS v2

- Versions 1 and 2 assumed SMS with “BSM number conservation”:



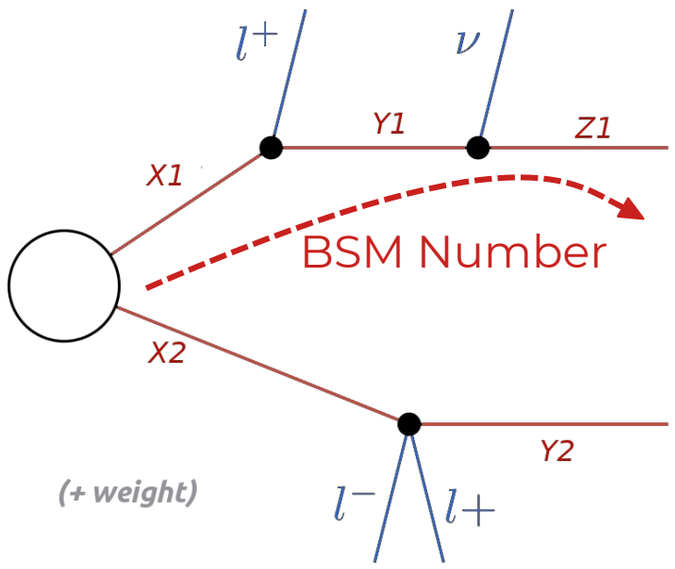
SModelS “Element”

$$[\ [X_1, Y_1, Z_1]\,,\ [X_2, Y_2, Z_2]\ ]$$

- A Z_2 type symmetry was assumed
- Limited to models with a “two branch” structure.

SModelS v3

- Versions 1 and 2 assumed SMS with “BSM number conservation”:



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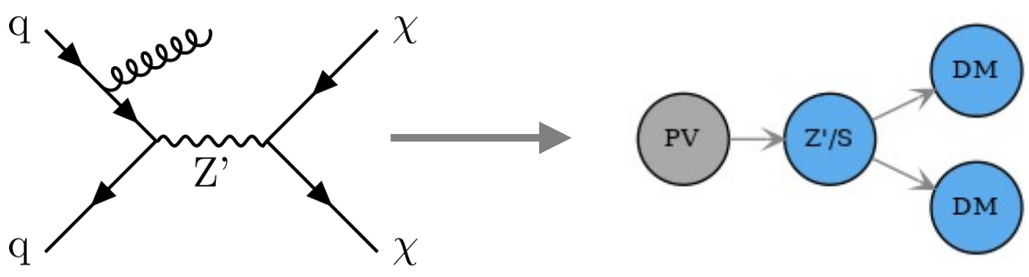
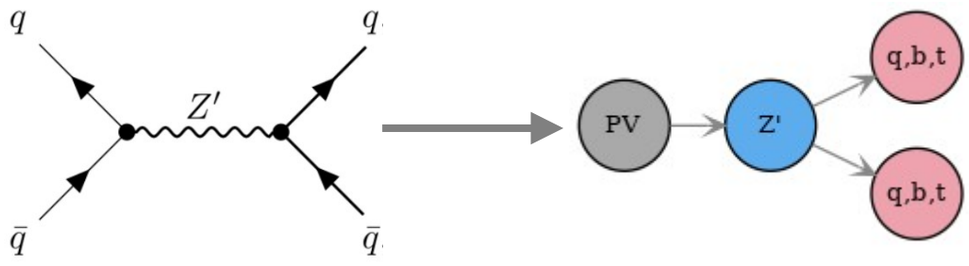
$$[\ [X_1, Y_1, Z_1]\,,\ [X_2, Y_2, Z_2]\ ]$$

- A Z_2 type symmetry was assumed
- Limited to models with a “two branch” structure.

- Version 3: generalization to graphs



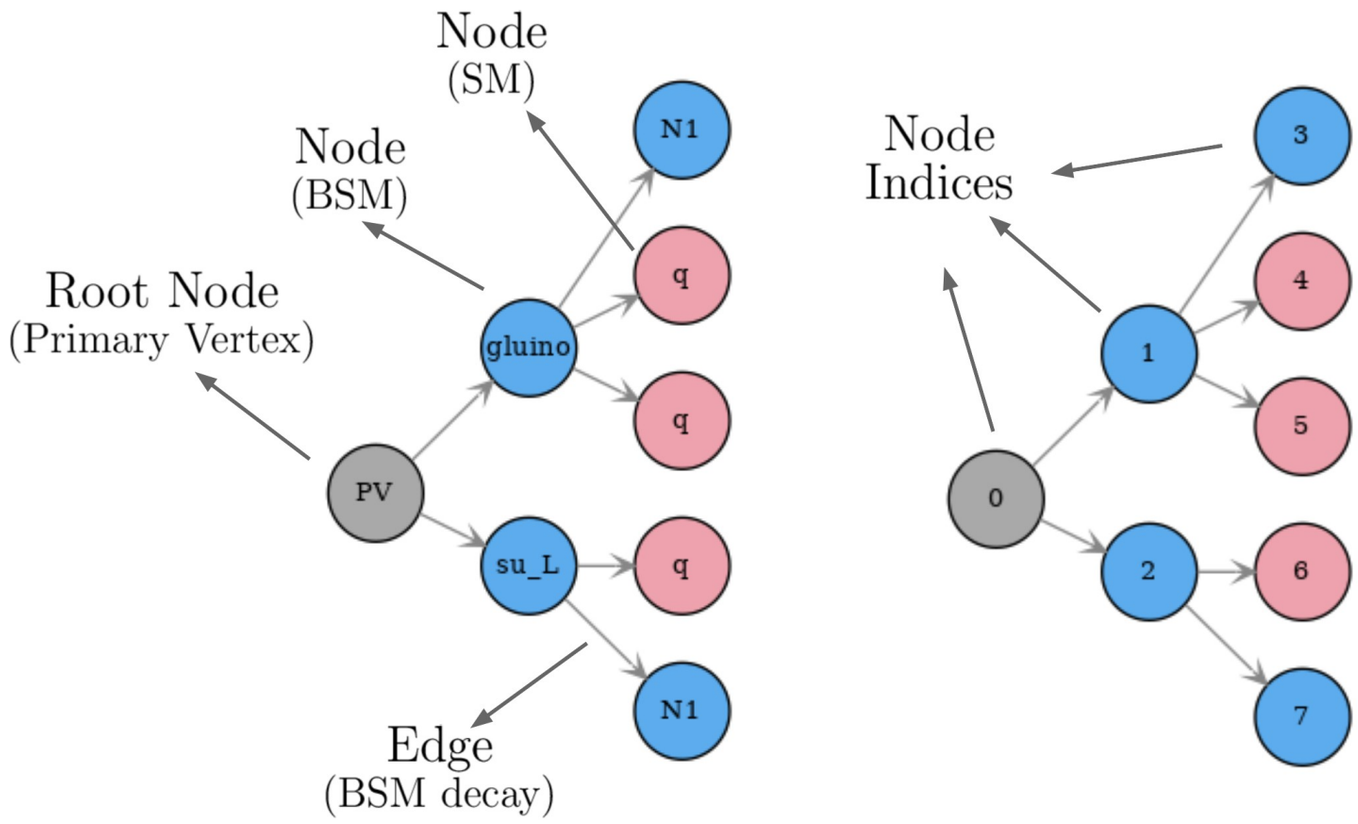


- Allows to describe most simplified model topologies

  → more UV models can be explored!

SModelS Graphs

- Graph Representation:



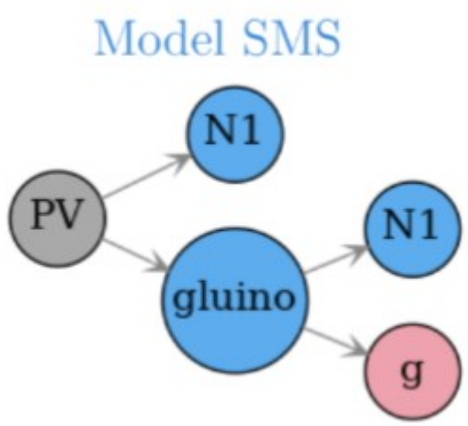
- Text Representation:

```
(PV > gluino(1),su_L(2)), (gluino(1) > N1(3),q(4),q(5)), (su_L(2) > q(6),N1(7))
```

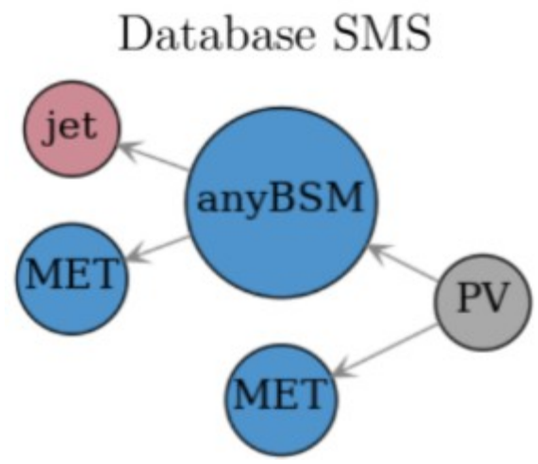
node number

SModelS Graphs

- Graphs generated by the input model:
  - Used to describe the model signatures
  - Contain well defined particles, masses, widths,...



- Graphs stored in the database:
  - Used to describe experimental results
  - Contain signature-based (generic) particles



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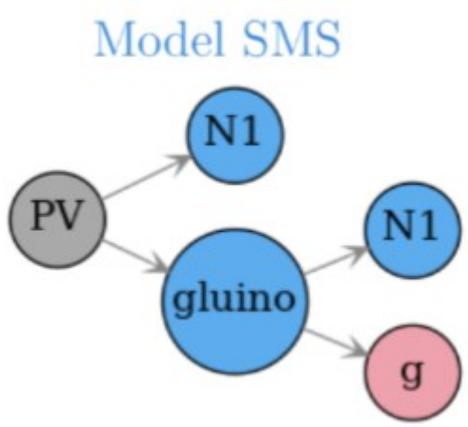

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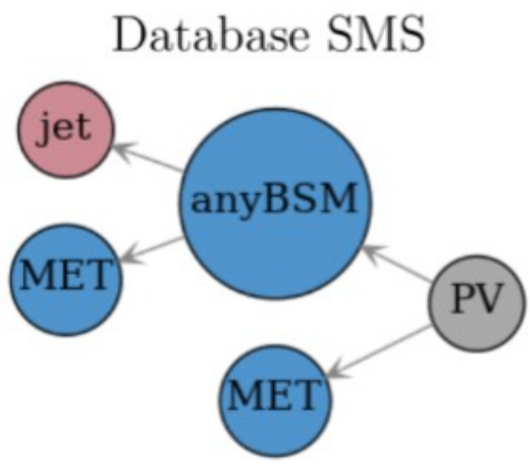
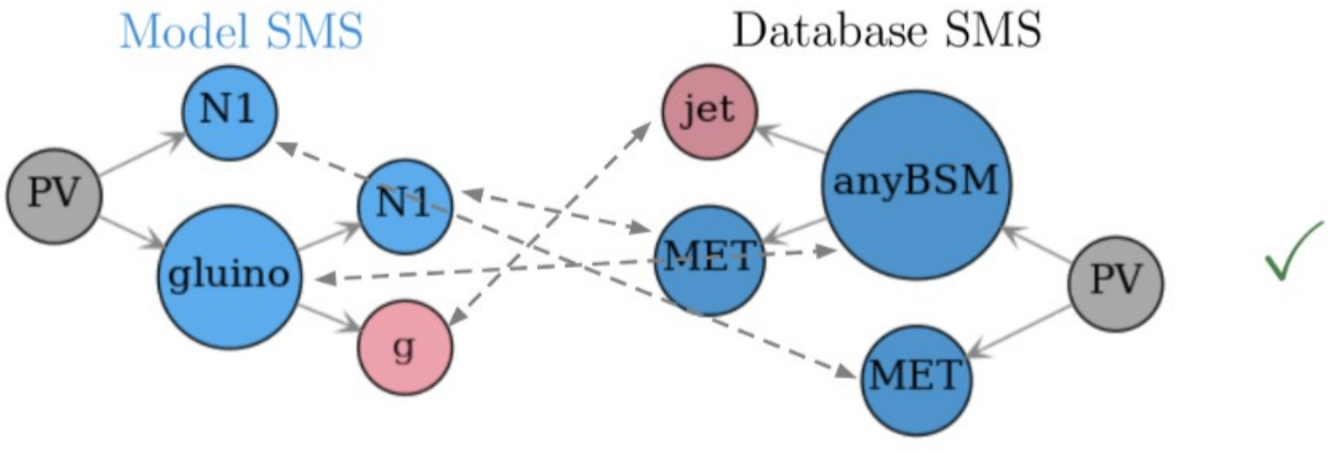


- Challenging task: Graph “matching”



SModelS v3: Database

- Database of SMS results:

Run 2 - 13 TeV

In total, we have results from 45 ATLAS and 44 CMS 13 TeV searches.

- ATLAS efficiency maps: 28 analyses, 94 (of which 14 LLP) results, 1197 individual maps
- ATLAS upper limits: 40 analyses, 97 (of which 4 LLP) results
- CMS efficiency maps: 11 analyses, 62 results, 3555 individual maps
- CMS upper limits: 40 analyses, 153 (of which 3 LLP) results

Run 1 - 8 TeV

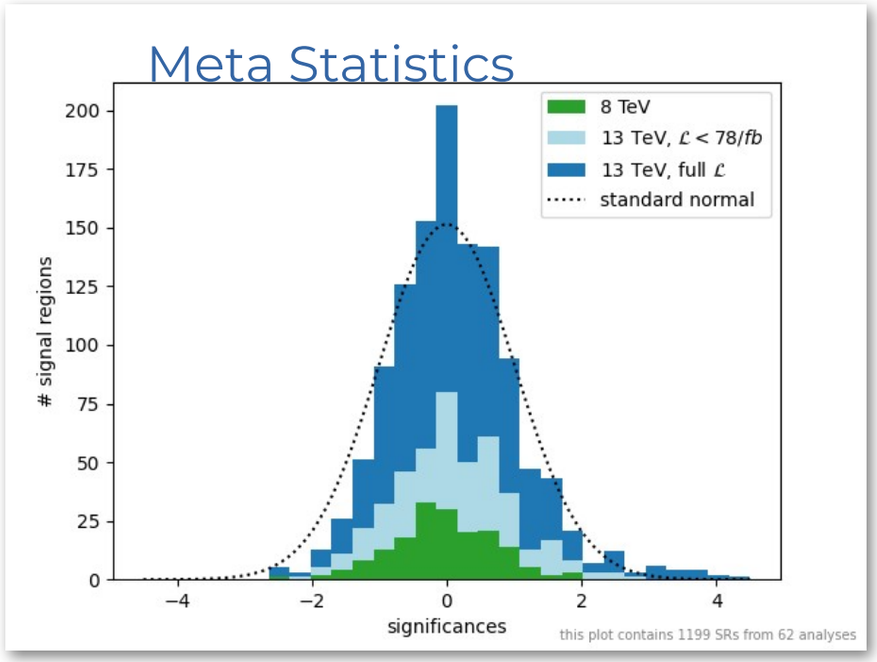
In total, we have results from 16 ATLAS and 20 CMS 8 TeV searches.

- ATLAS efficiency maps: 11 analyses, 36 results, 274 individual maps
- ATLAS upper limits: 14 analyses, 35 results
- CMS efficiency maps: 9 analyses, 47 (of which 9 LLP) results, 980 individual maps
- CMS upper limits: 18 analyses, 58 (of which 3 LLP) results

61 ATLAS searches

64 CMS searches

~120 Simplified Models



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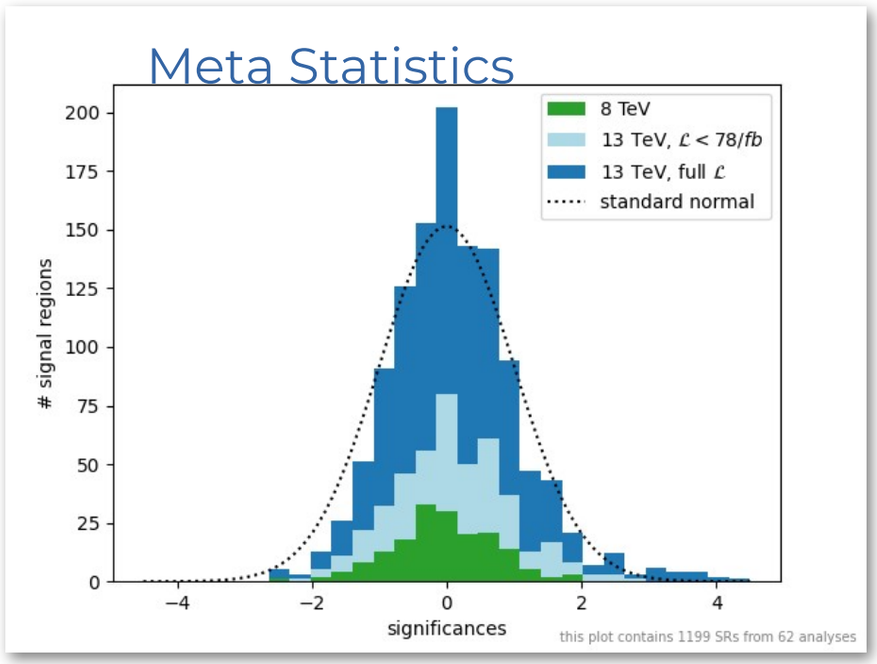
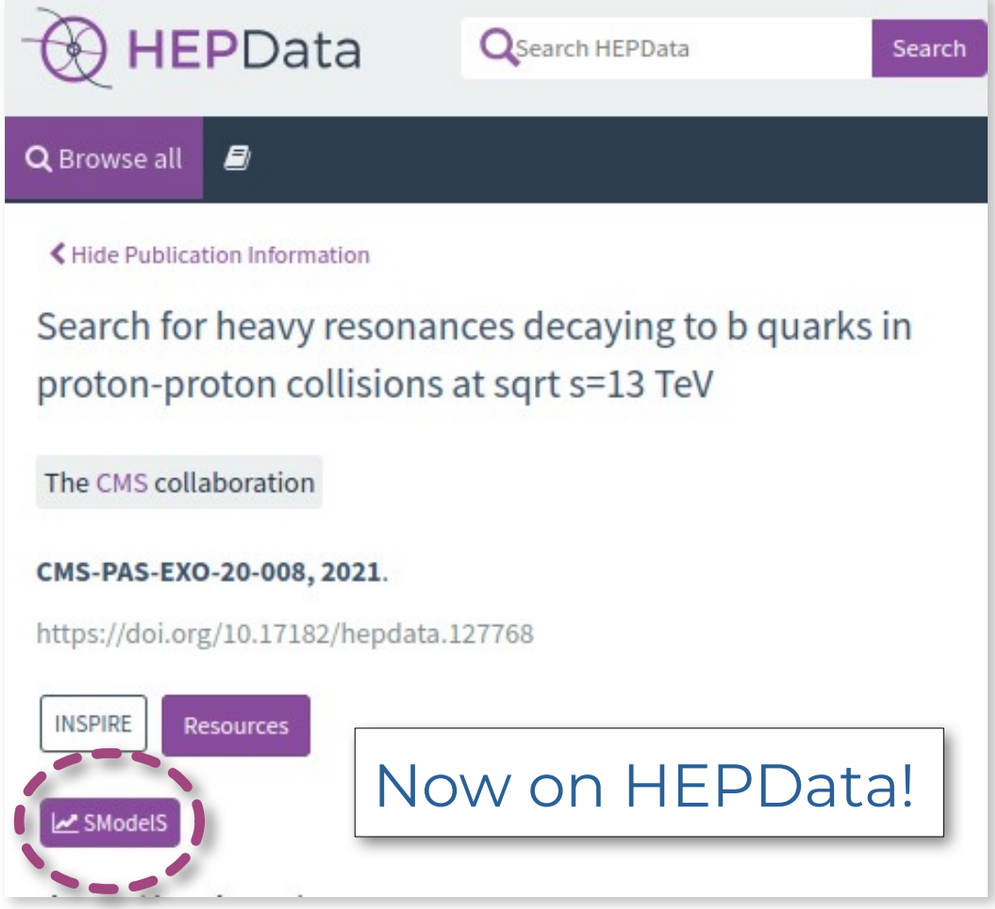


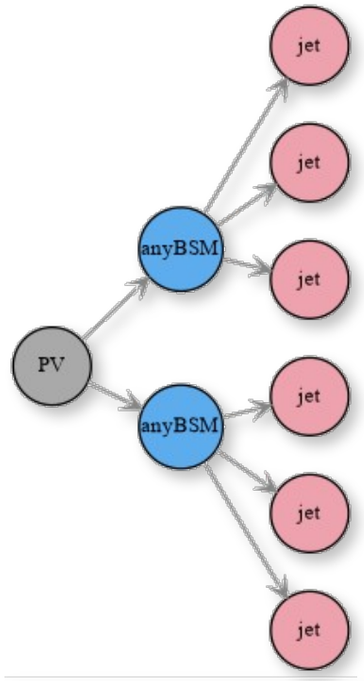


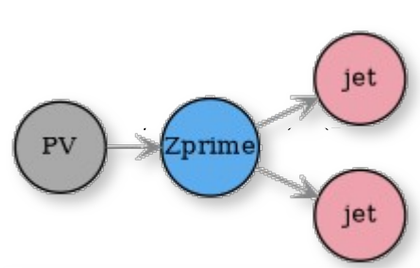
Now on HEPData!

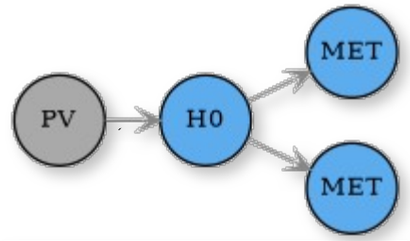
SModelS v3: Database

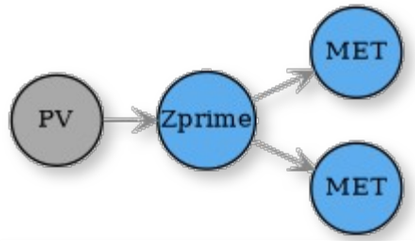
- Non-Z_2 results:

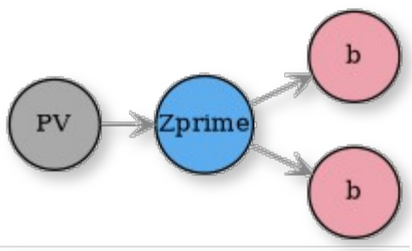
ID	Signature	Luminosity	SMS Topology	Type
		Run 2 - 13 TeV		
ATLAS-EXOT-2019-03	Dijet resonance	139 fb^{-1}	$pp \to Z' \to jj, b\bar{b}$	UL
ATLAS-EXOT-2018-48	$t\bar{t}$ resonance	139 fb^{-1}	$pp \to Z' \to t\bar{t}$	UL
CMS-EXO-19-012	Dijet resonance	137 fb^{-1}	$pp \to Z' \to jj, b\bar{b}$	UL
CMS-EXO-20-008	b-jet resonance	138 fb^{-1}	$pp \to Z' \to b\bar{b}$	UL
CMS-EXO-20-004	Monojet	137 fb^{-1}	$pp \to Z', S \to \chi\chi$	EM
ATLAS-EXOT-2018-06	Monojet	139 fb^{-1}	$pp \to Z' \to \chi\chi$	UL
ATLAS-SUSY-2018-22	Multi-jet plus	139 fb^{-1}	$pp \to Z' \to \chi\chi$	EM
ATLAS-SUSY-2018-13	Displaced jets	139 fb^{-1}	$pp \to \tilde{\chi}\tilde{\chi} \to jjj, jjj; \ldots$	EM
		Run 1 - 8 TeV		
CMS-EXO-16-057	b-jet resonance	19.7 fb^{-1}	$pp \to Z' \to b\bar{b}$	UL
CMS-EXO-12-059	Dijet resonance	19.7 fb^{-1}	$pp \to Z' \to jj$	UL
ATLAS-EXOT-2013-11	Dijet resonance	20.3 fb^{-1}	$pp \to Z' \to jj$	UL

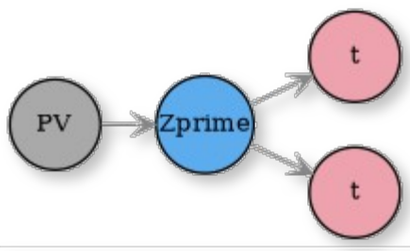


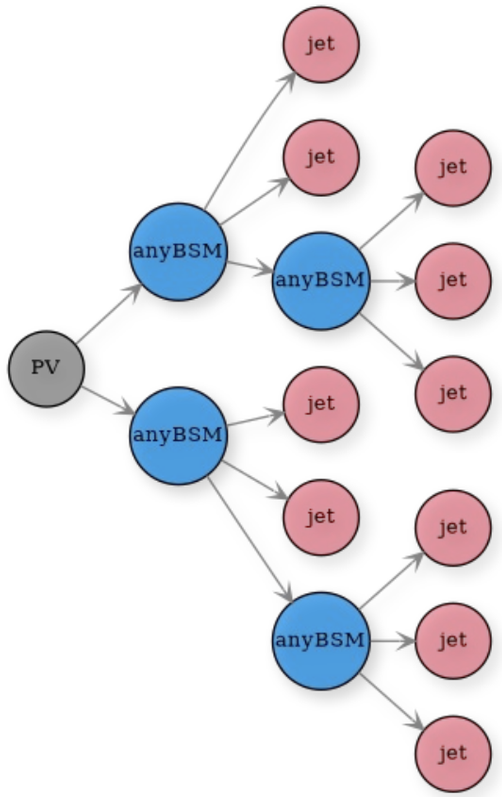












SModelS v3: Output

- Similar to v2 (except for the SMS text representation)

Version 2:

```
Element ID: 1
Particles in element: [[[higgs]], [[W-]]]
Final states in element: [N1, N1~]
```

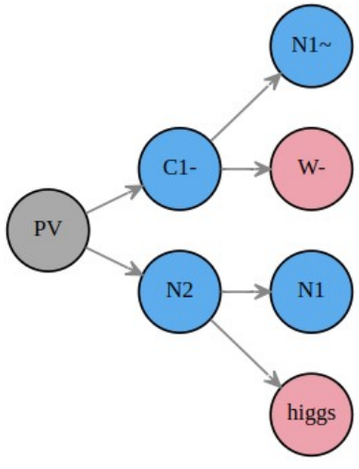
Version 3:

```
SMS ID: 1
SMS: (PV > N2(1),C1-(2)), (N2(1) > N1,higgs),
                          (C1-(2) > N1~,W-)
```

- But running SModelS within a notebook allows for a more user-friendly visualization of the results:

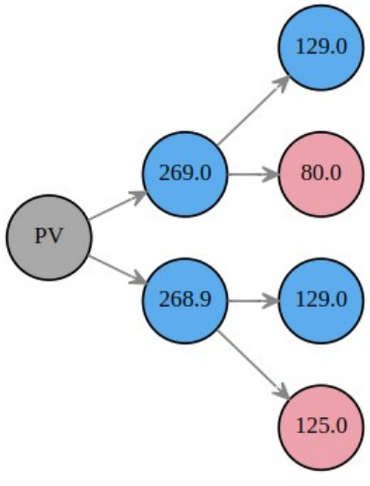
```
# Decompose the model
topDict = decomposer.decompose(model, sigmacut = 10* fb)
# Check the canonical names of all topologies:
# print(topDict.keys())
```

```
# Select a SMS to draw
sms = topDict[11101001101000][0]
# Draw the SMS
sms.draw()
```



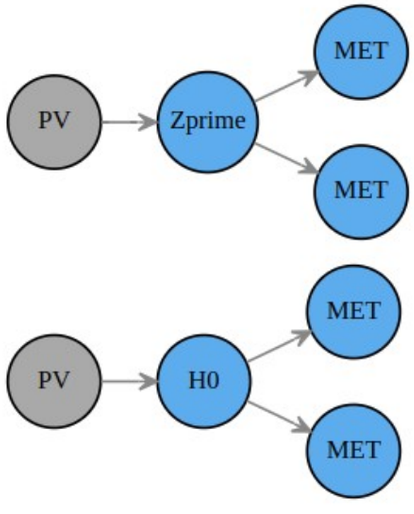

```
# Draw some properties of the SMS
print('Mass:')
sms.draw(labelAttr='mass',attrUnit=GeV)
print('Total width:')
sms.draw(labelAttr='totalwidth',attrUnit=GeV)
print('Electric Charge:')
sms.draw(labelAttr='eCharge')
print('Spin:')
sms.draw(labelAttr='spin')
```

Mass:



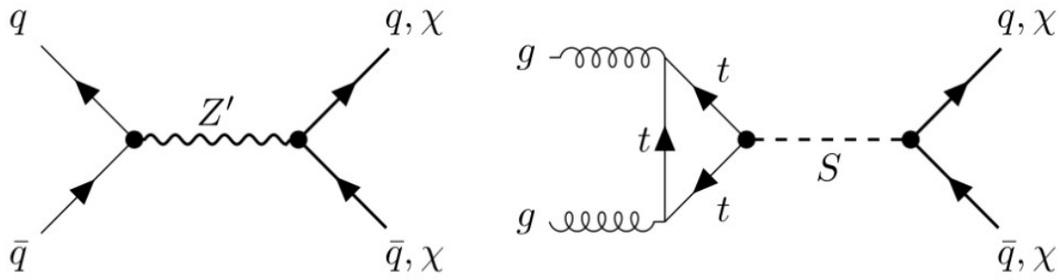

```
# Select an experimental result
database.selectExpResults(analysisIDs=['CMS-EXO-20-004'])
# Get the SMS in the result
smsList = database.getExpSMS()
```

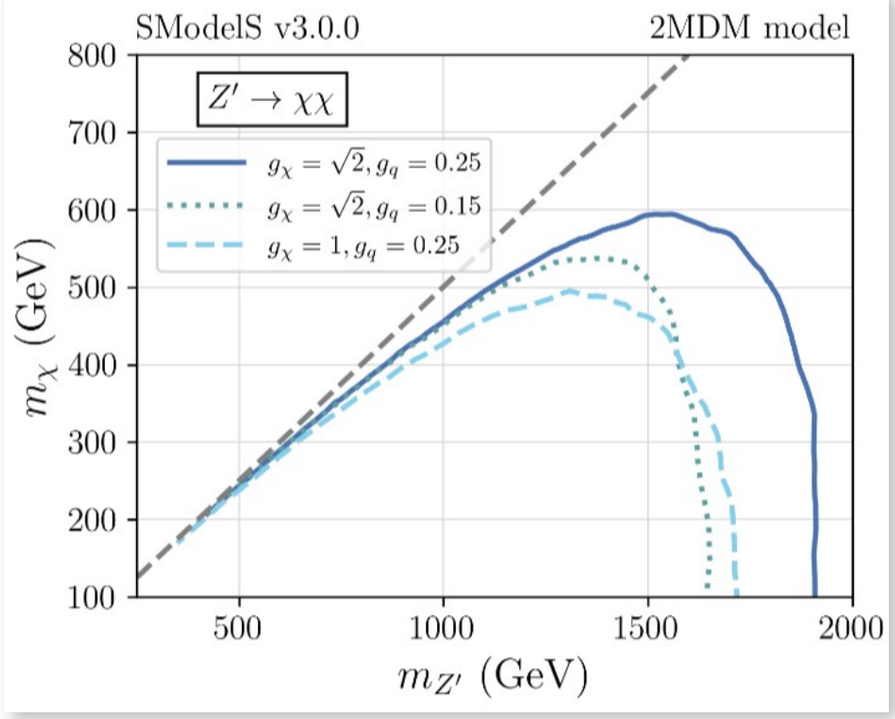
```
# Draw SMS:
for sms in smsList:
    sms.draw()
```



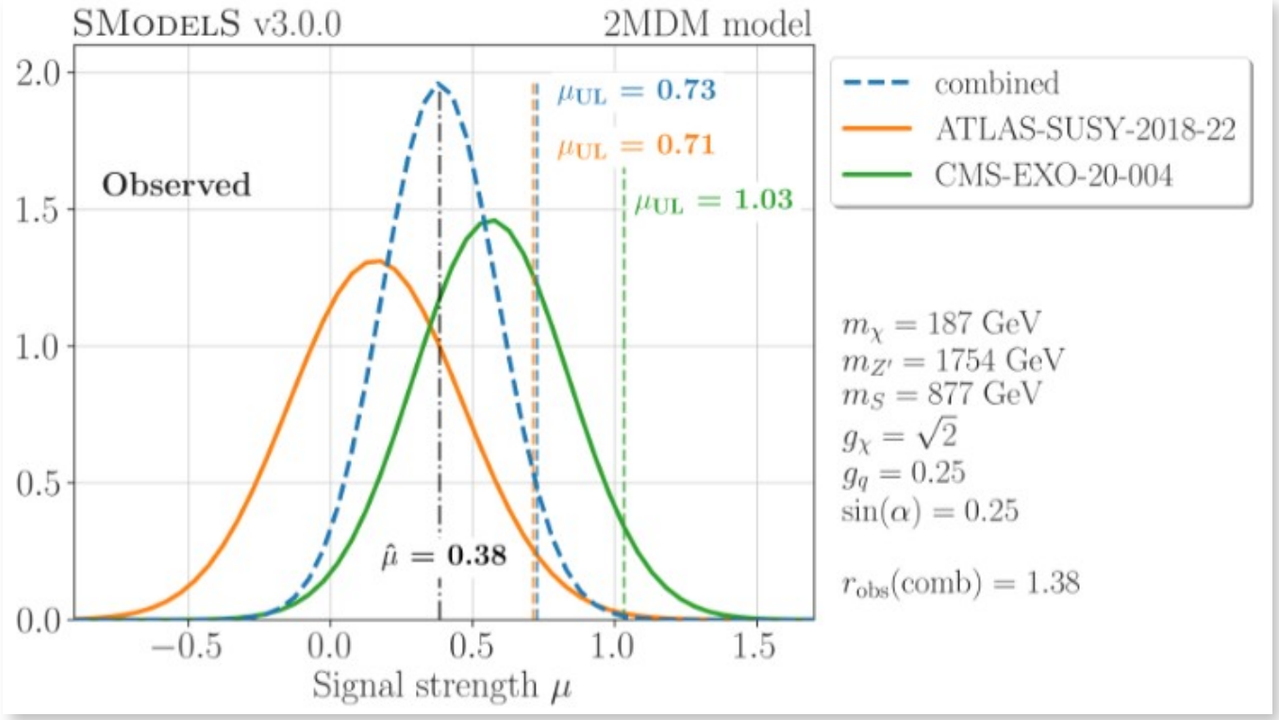
Physics Study: 2MDM

- Two mediator DM





Statistical Combination of ATLAS + CMS



Conclusions

- SModelS v3 opens the way for systematically using all Simplified Model results...

  ...allowing for further explorations of the full BSM model space!

- While the presentation of SMS results within the SUSY groups is well stablished, the same is not always true for other groups.

- Simplified Model results should always be presented as a function of all the SMS parameters and cover the relevant part of the SMS parameter space!

- A lot of work to be done!
  - many results to be included in the database
  - graphical visualization of the output
  - “resolve” the primary vertex
  - ...

For more information: https://smodels.github.io/

Thanks!