BSM in Generators: ATLAS Perspective

MC4BSM, Durham 2018

David Yallup

THE CHALLENGES

Brief of this talk:

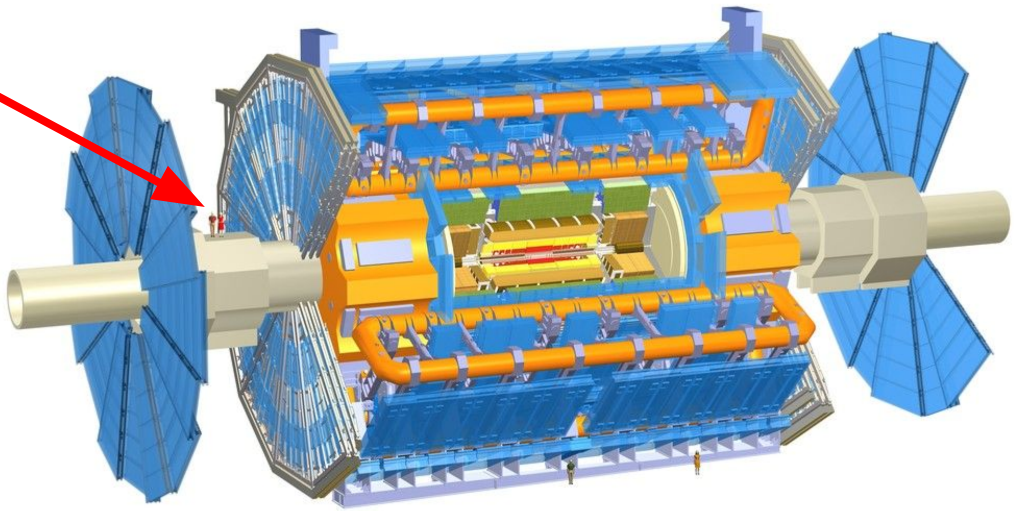
- Don't talk too much about the physics - Want to think about the MC tools
- Don't talk about SM (background) MC too much
- Cover as much ATLAS as possible (A very birdseye view)

ATLAS BSM Modelling challenge - Scope

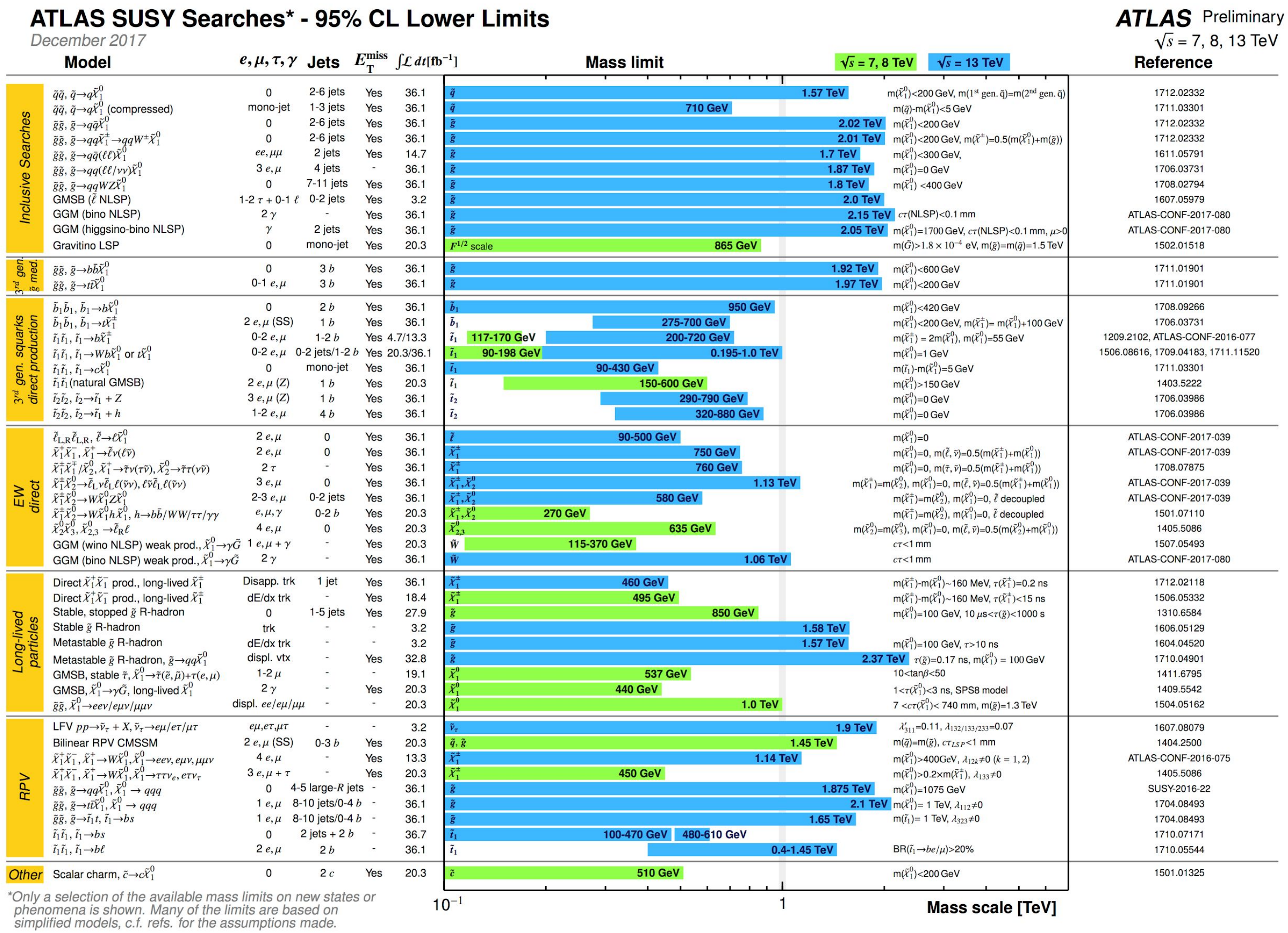
ATLAS is **BIG**

ATLAS Collaboration (Morad Aaboud (Oujda U.) *et al.*) Show all 2851 authors

Apr 10, 2018 - 39 pages

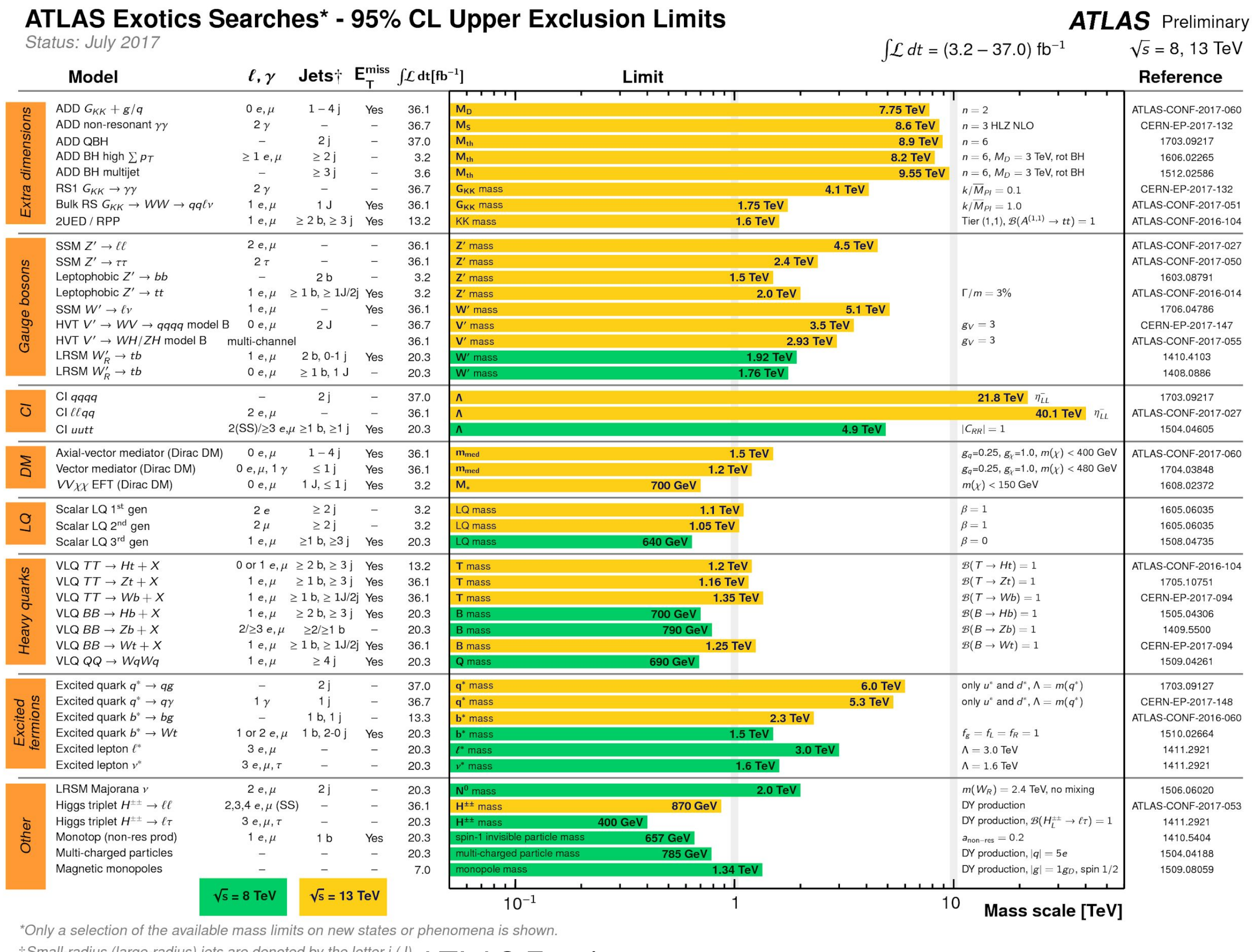


ATLAS BSM Modelling challenge – Scope



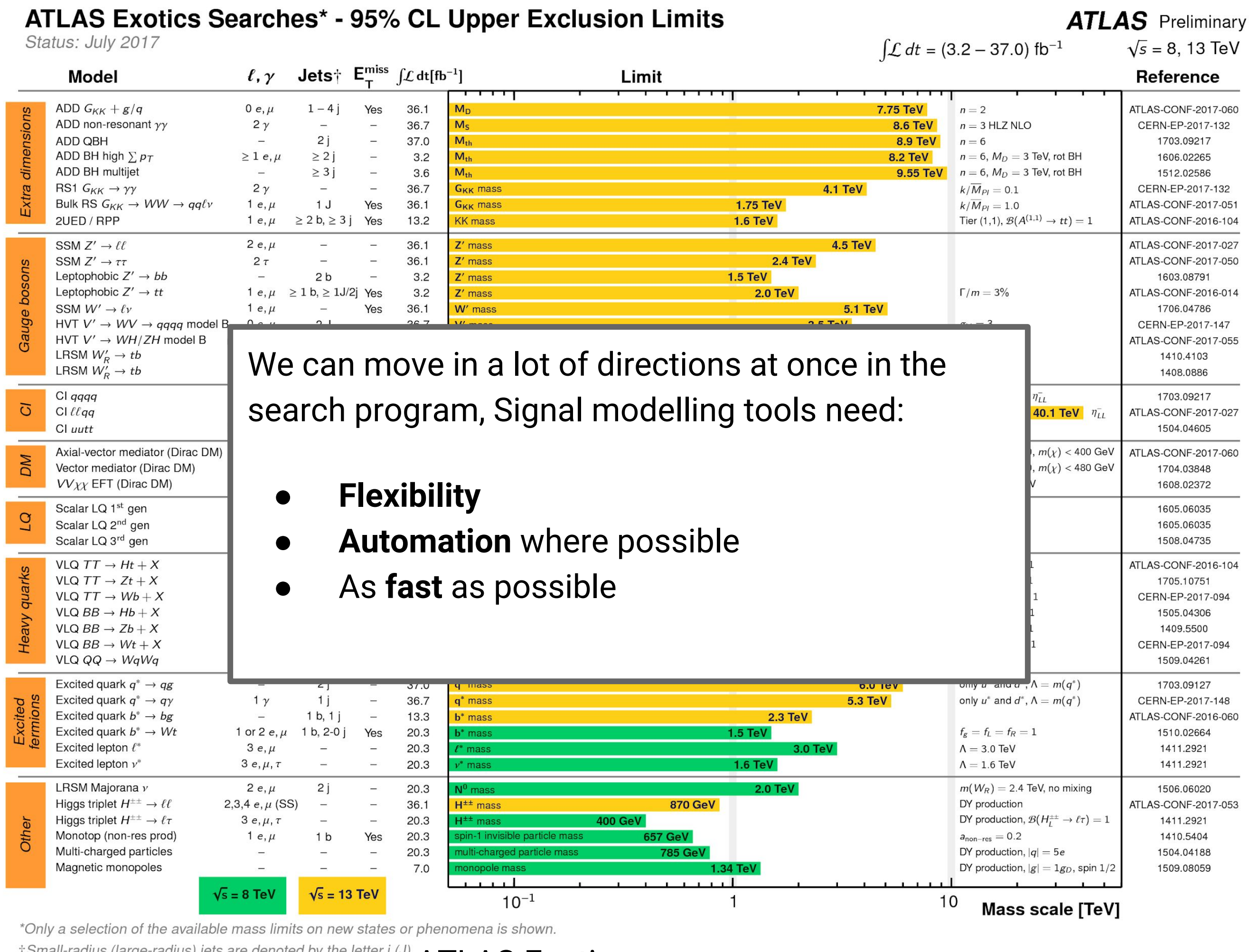
ATLAS SUSY summary

ATLAS BSM Modelling challenge – Scope



ATLAS Exotics summary

ATLAS BSM Modelling challenge – Scope



We can move in a lot of directions at once in the search program, Signal modelling tools need:

- **Flexibility**
- **Automation** where possible
- As **fast** as possible

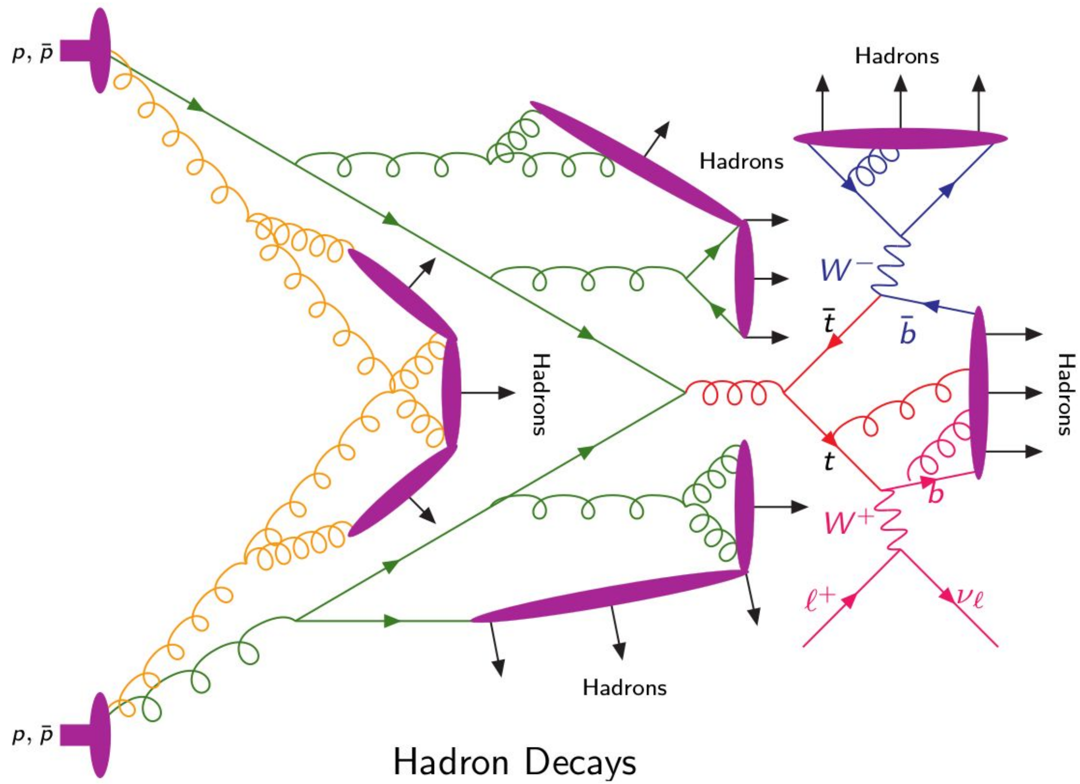
ATLAS Exotics summary

ATLAS BSM Modelling challenge - Accuracy

LHC theoretical predictions (BSM and SM)

- Tools need to lead to predictions of particle level final states in a hadron collider
- **Complicated!**

Continually demand higher precision in SM backgrounds, when do we worry about Signal modelling?



Stolen from P. Richardson

Aside – Precision

SM processes missing comparable to signal size? e.g. EW corrections

Background (SM) modelling ties into a lot of this discussion (again not the focus of this conference!)

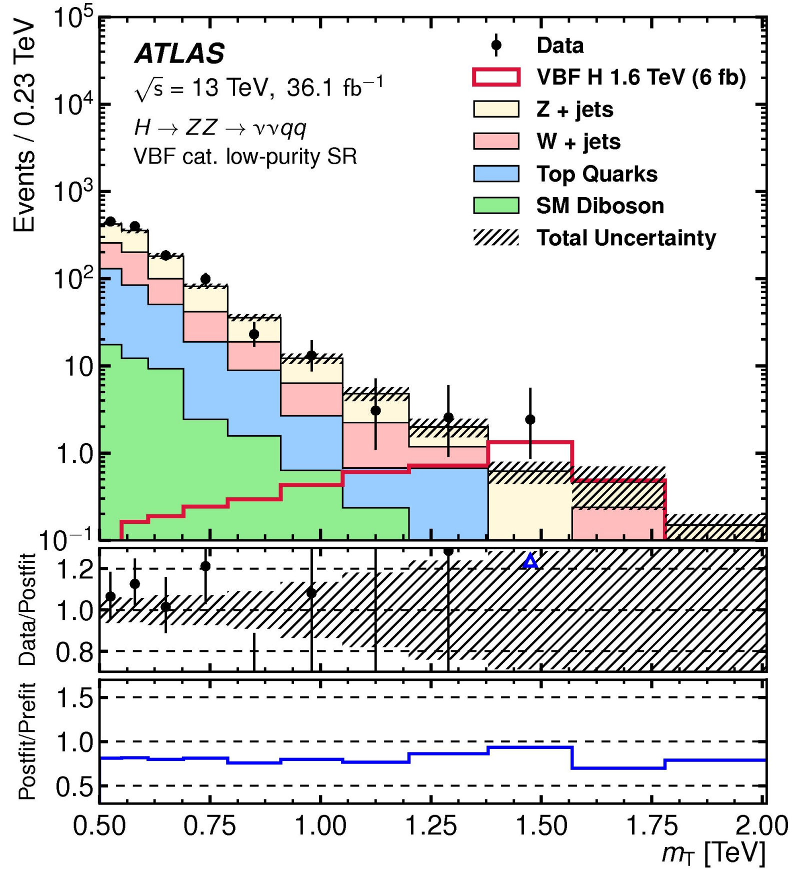
Searches generally seen to be:

- Stat limited
- Systematically limited

Limitation often driven from SM modelling e.g.:

- Top/V pT
- Higher jet multiplicities
- Exotic phase space (e.g. VBF)
- etc.

Does precision QCD necessitate precision signal - claim sensitivity down to O(signal size)



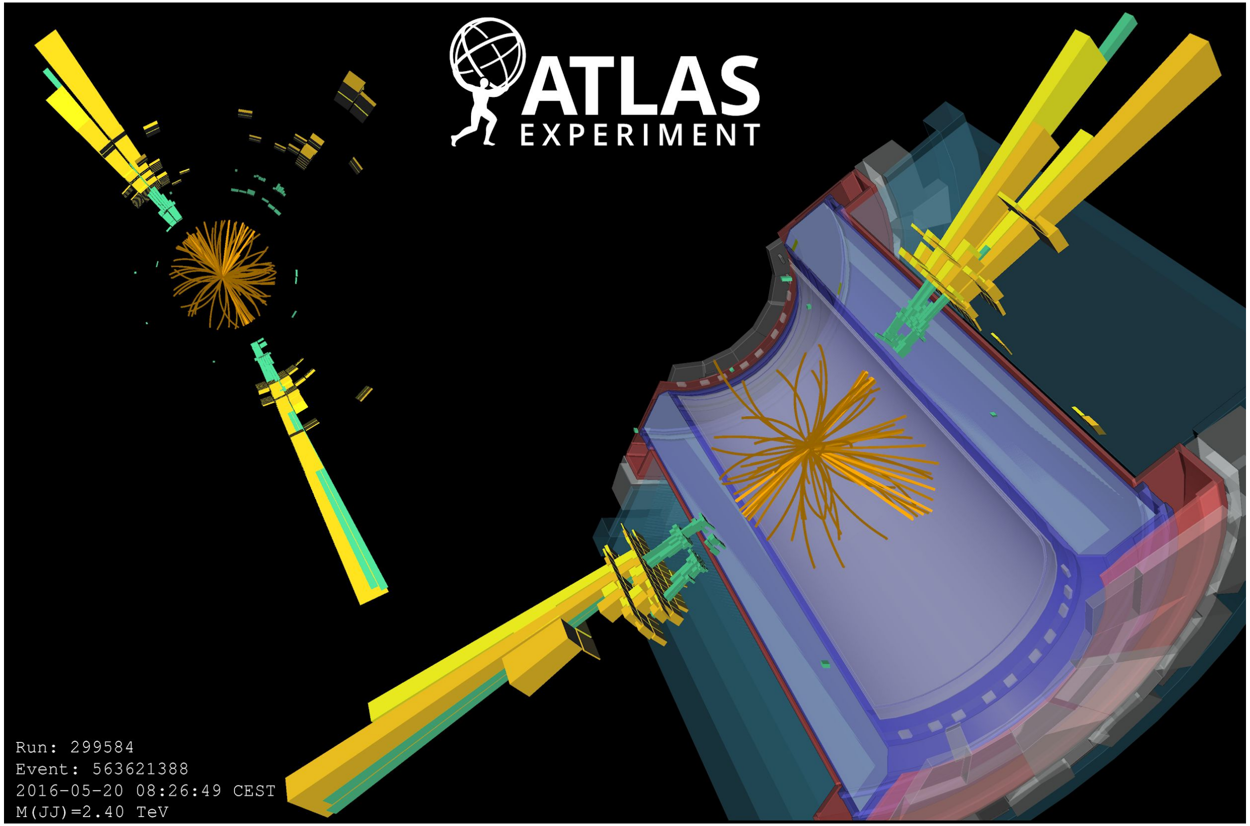
ATLAS ZZ/ZW (VBF) 1708.09638

ATLAS BSM Modelling challenge - The detector

The detector itself presents a big challenge to BSM modelling

- Some BSM is very dependent on our detector response (e.g. Long Lived Particles)
- It can be a big barrier to getting information out of the collaboration

Simulation not in the scope of this conference (GEANT4 etc.) but worth remembering



Resonance search with boson tagged jets

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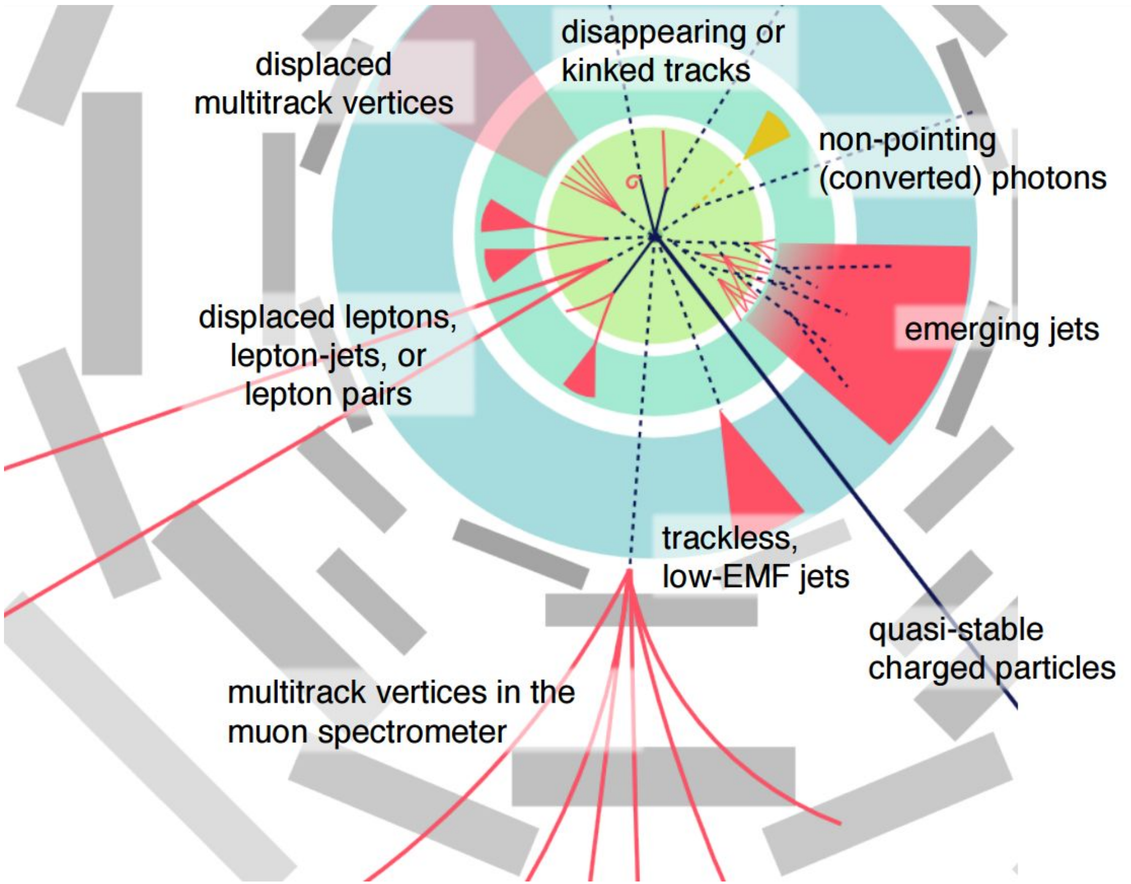


LLP cartoon (credit Heather Russell)

WHERE WE ARE AT

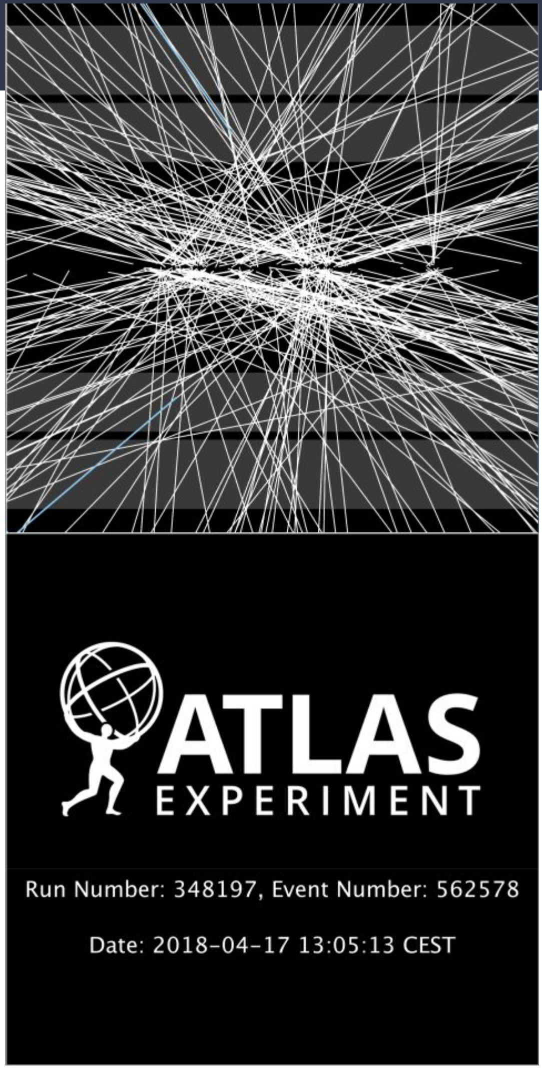
Where we are at

Personal perspective:

- Largely appear to be happy with the tools we have from an experimental PoV
- Not uncommon to hear people grabbing a model from theory friends to test - standardized formats to get these into ATLAS simulation exist
    - This is a big positive

BUT

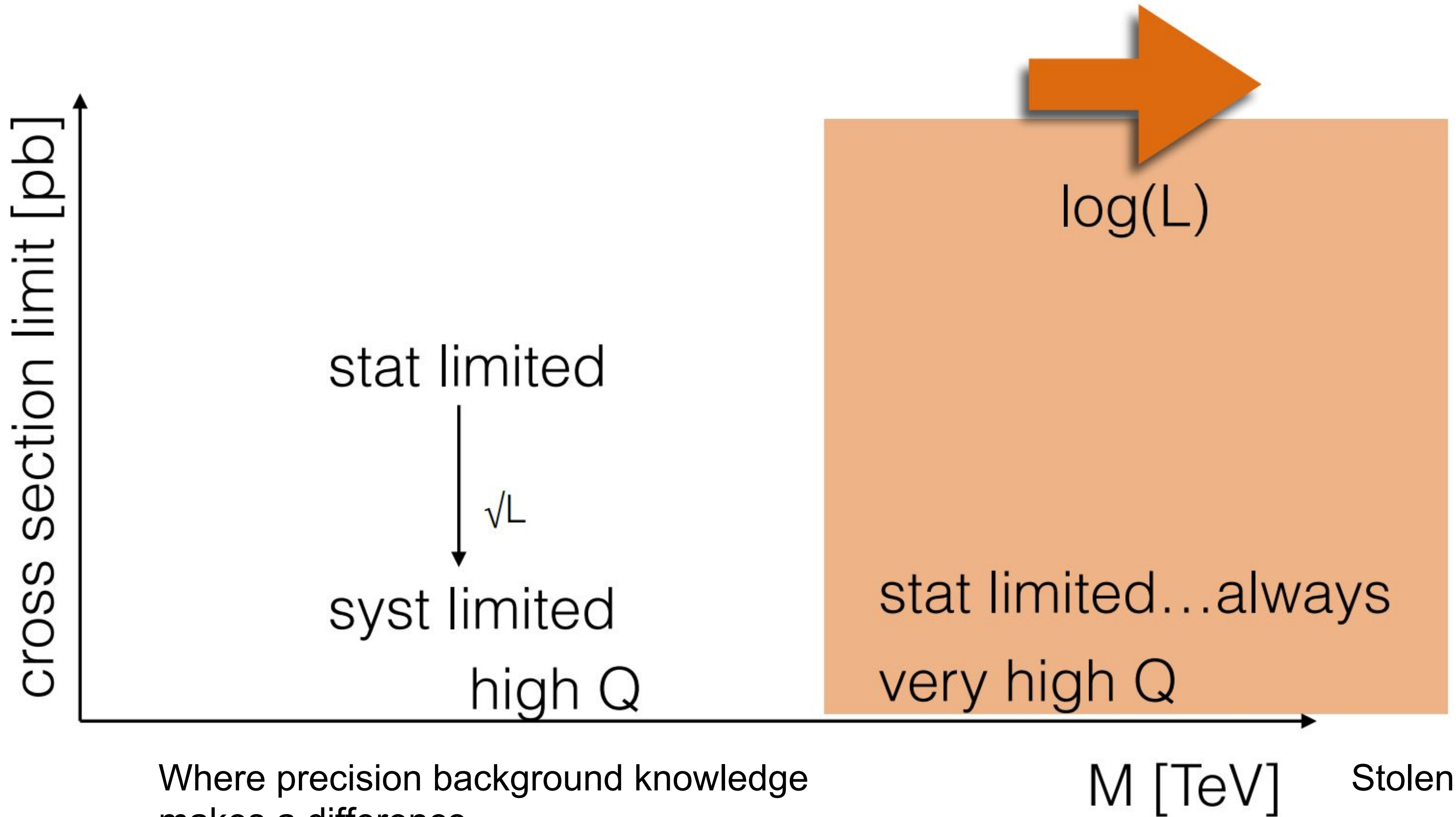
- Can we rest on our laurels on the BSM side?
- Where do we need to push for progress?



2018 first events

Where we are at

We are no longer jumping in Energy, and there's still no new physics, this challenges our search approach



Where precision background knowledge makes a difference

Stolen from G. Facini

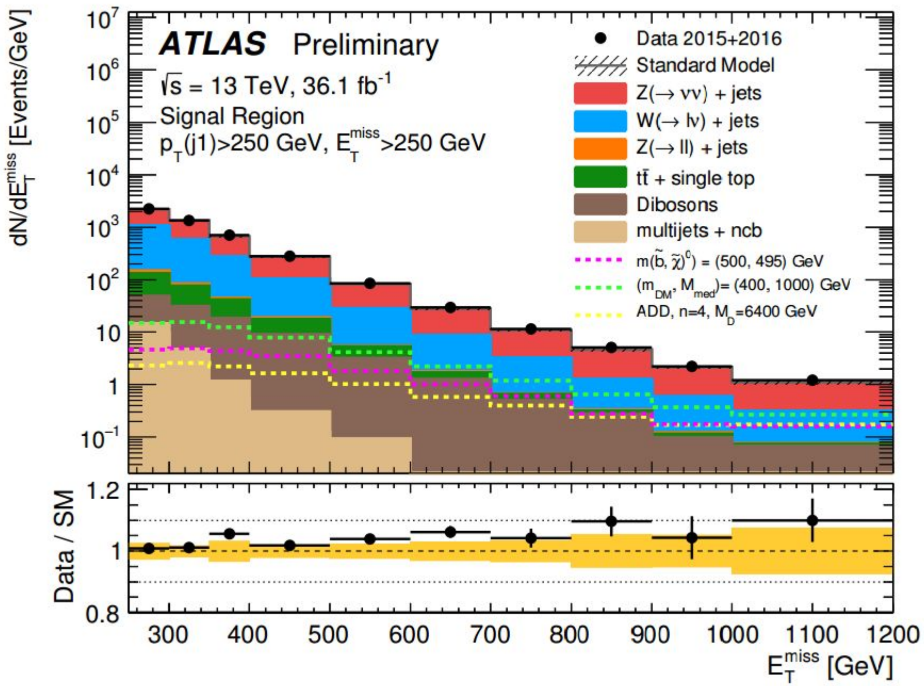
Minor(?) item – NLO QCD in BSM

Obvious benefits from SM modelling in increasing order of perturbative accuracy:

- Can we repeat same recipe for BSM
  - Do we need to?
- At very least we do analysis optimisation to BSM shape
  - Often in a “cut and count” paradigm
  - Do NLO shape differences yield much over k-factors?

⟶ **Pragmatism** is important

Some cases of NLO BSM implemented in generators, initiatives such as LHCDMWG helpful here

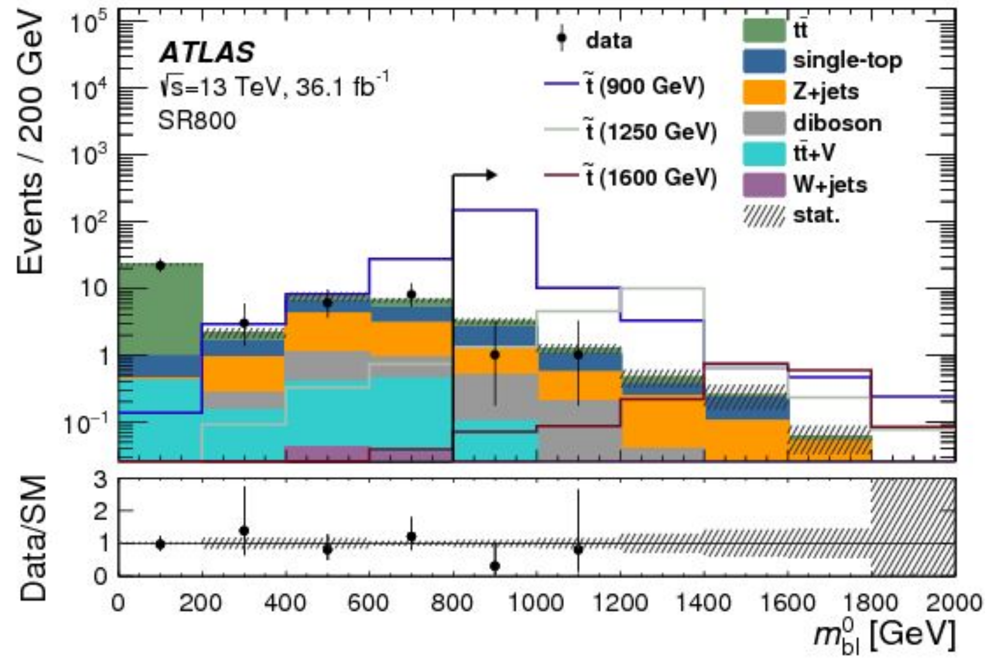


ATLAS Monojet, 1711.03301

SUSY in ATLAS

Procedure fairly Standardised across most SUSY analyses

- Signal ME production MG5_aMC@NLO
  - Up to two additional partons in the ME
- Merged and Matched to Pythia 8 (CKKW-L)
- Use Simplified Models (decouple everything you aren't studying)
- Cross section normalised in nearly all cases to NLO+NLL



ATLAS RPV stop search, [1710.05544]

- Results largely limits on visible cross sections derived from simplified models.
- How do we interpret these (see SModelS, etc.)

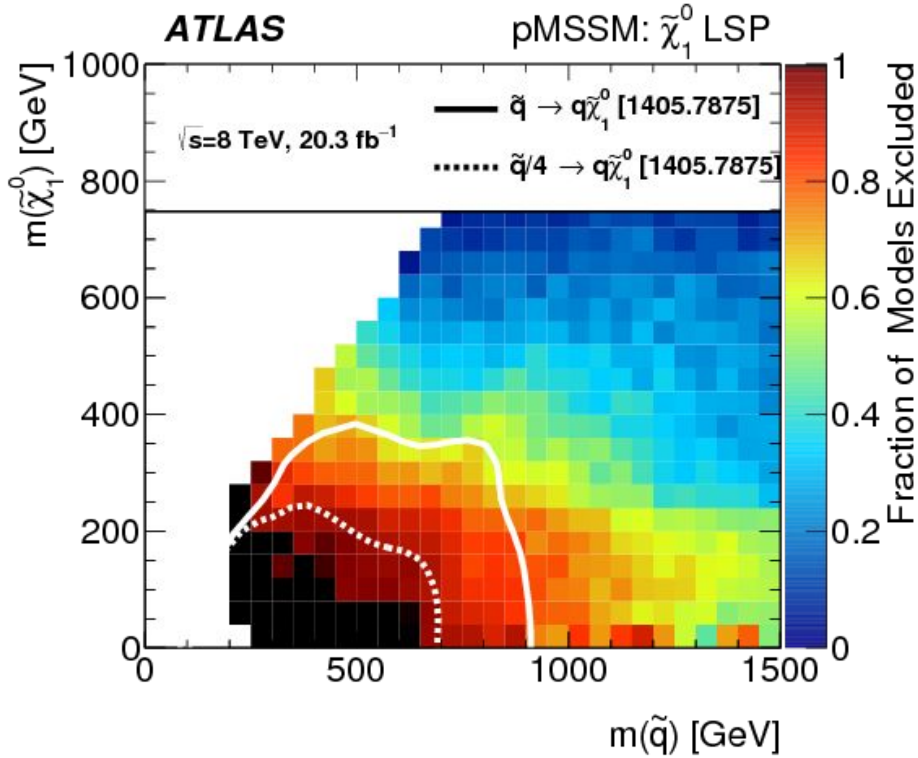
	SR800			
	inclusive	ee	$e\mu$	$\mu\mu$
S^{95}_{exp}	$6.4^{+3.0}_{-1.9}$	$4.1^{+1.8}_{-1.1}$	$4.0^{+2.2}_{-0.9}$	$3.9^{+1.6}_{-0.7}$
S^{95}_{obs}	4.0	3.0	3.0	4.8
σ_{vis}[fb]	0.11	0.08	0.08	0.13

SUSY in ATLAS

Interpretation of the base analyses can be done with more complete models:

- pMSSM
  - Decide on some base constraints to reduce parameter space
- Generate 310,327 model points
- SoftSUSY and MicroOMEGAs used to calculate sparticle spectrum (amongst other tools)
- Where needed use full MC tools as per previous slide, **with ATLAS detector sim**

We can use the full simulation to do this, how do we extend this to the outside world?



ATLAS Run 1 pMSSM scan, [1508.06608](1508.06608)

SUSY in ATLAS

What Works:

- Simplified Model paradigm is very attractive from the experiments PoV
    - What do our results mean once we've decoupled the SUSY from a SUSY paper?
- Tools well established for both event generation and SUSY model study as a whole

What Doesn't:

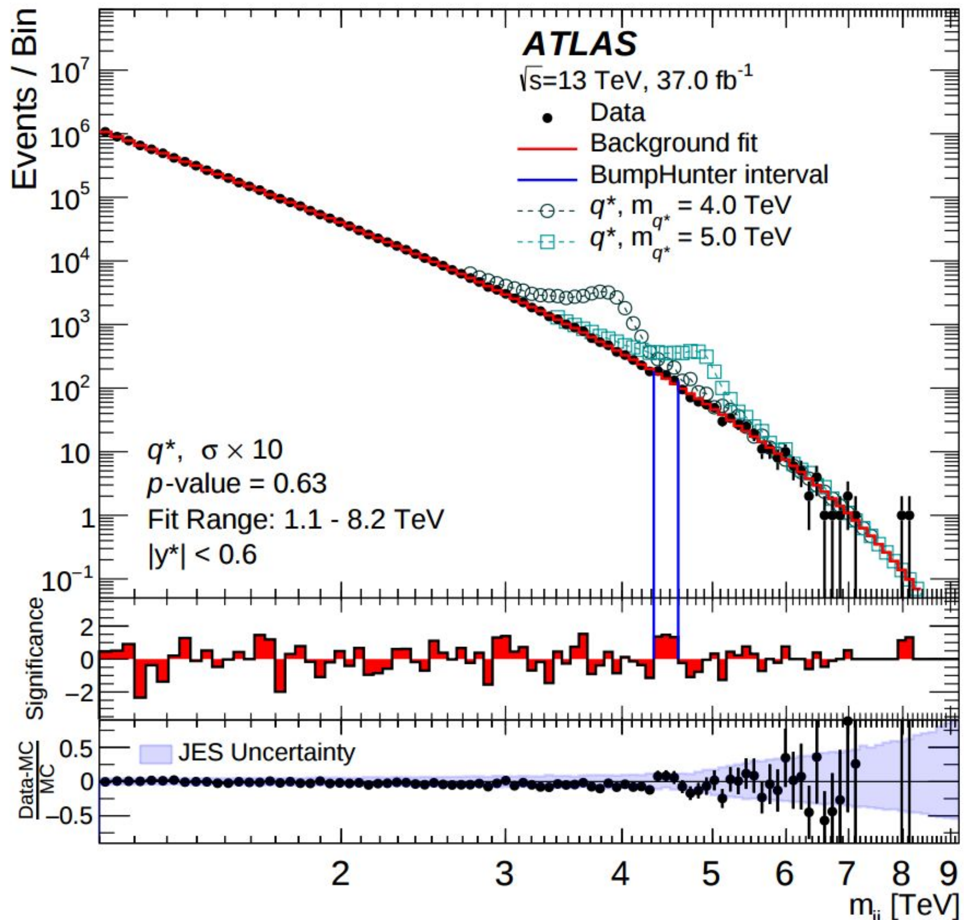
- Are we missing anything with a lack of diversity in generator setup
    - Uncertainties due to, e.g. PS modelling in signal samples should be negligible
- SUSY problem, mixed processes in LHE files (with merging)
    - How do we do merging with multiple signal processes in one file
    - Ongoing work to "guess" process for matching in Pythia

Exotics in ATLAS

Broader catch all for any BSM signal, largely done through a similar toolchain with more variety, here Dijet 2015+2016 (1703.09127) paper considers:

- Excited quarks [R] - Pythia 8
- Black Holes - BlackMax + Pythia
- W'/Z' - MG + Pythia *
- W* - CalcHEP + Pythia

Plus many more across the group, plus options we have but don't use. Simplified models with automated generator interfaces, via e.g. UFO (Feynrules) very successful



ATLAS Dijet search 1703.09127

*Efforts on unity and benchmarking simplified DM models, LHCDMWG

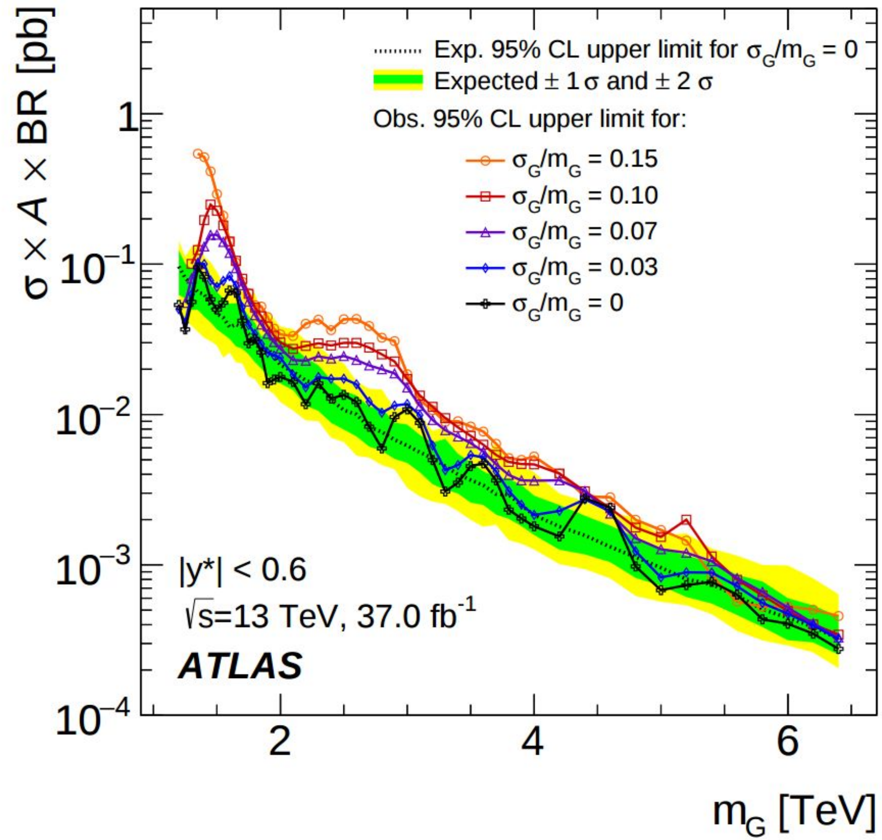
Exotics in ATLAS

Also effort made to do something more "model independent" for re-interpretability:

- In this case present limits on **σ** x **A**cceptance
  - For considered models
  - And hypothetical Gaussian signal

⟶Not perfect, Acceptance still dependent on considered model, e.g. in this example, what can we say about signals beyond narrow width Gaussian?

A lot of work/thought goes on at this interface



ATLAS Dijet search 1703.09127

Exotics in ATLAS

What Works:

- The move to emphasis on Simplified Models rather than “complete” implementations gives the desired flexibility and abstracts most of the more tricky model questions from the experiment
  - This is a good direction
  - Have to keep an eye on this - Lot of work going into a simplified model with no viable UV complete embedding?

What Doesn’t:

- Hopefully all UFO files can be public, Model database efforts welcome
- Flexibility begets instability
  - Use standarized PDG ID codes for common BSM (Z’ etc.)
  - More tests! Things can crash out of the box
- Similar question marks on diversity of tools, maybe not so important?
- When we cover something more unexpected, long lived particles, the tools are less mature

WHAT CAN THE EXPERIMENT DO TO HELP?

How can our results help - Signal regions

Example again from SUSY group

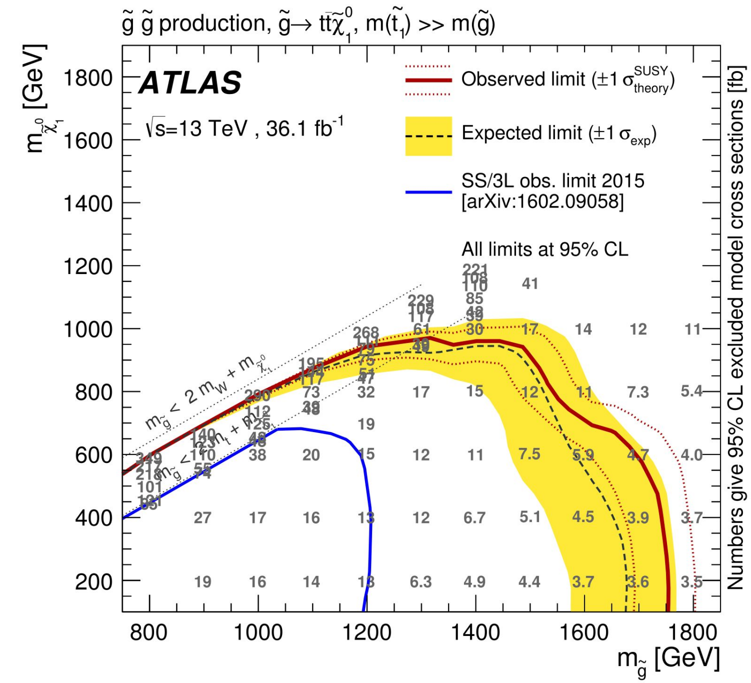
- Provide acceptance and efficiency numbers
- Validated cutflow
    - Can we harmonize with a tool like CheckMATE, Rivet etc.

Go beyond single regions?

- Correlations
- Simplified Likelihoods? (CMS progress here)

SQRT(S)		13000.0 GEV			
Signal region		-	(best)	Rpc2L2bH	
M(GLUINO) [GEV]	**M(NEUTRALINO1) [GEV]**	**Best SR**	**SIG 95%CL [FB]**	**ACC [PCT]**	**EFF [PCT]**
700	355	Rpc2Lsoft2b	125	0.1	51
700	440	Rpc2L2bS	238	0	39
700	490	Rpc2Lsoft1b	449	0	83
800	455	Rpc2Lsoft2b	121	0.1	45

HepData Record



ATLAS Same sign lepton, 1706.03731

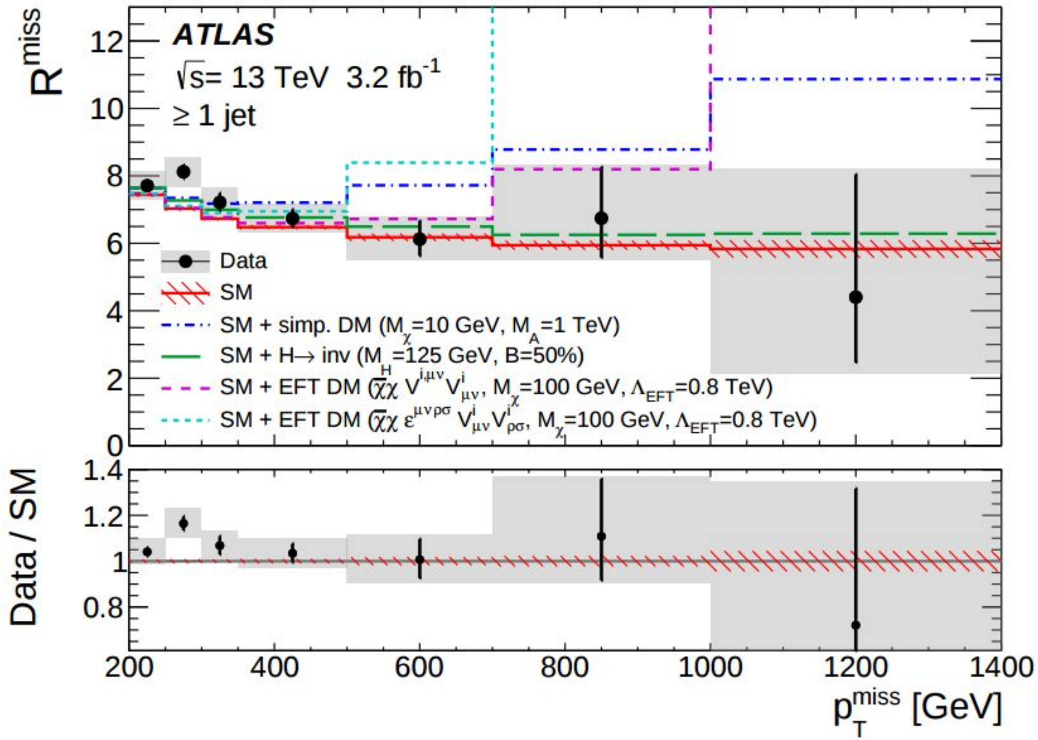
How can our results help - Signal regions

Exotics example, the "nuclear option"

Essentially unfold a search region

(Re)interpretability is now exactly as per the SM measurements, data is presented at the particle level

See e.g. Rivet, Contur



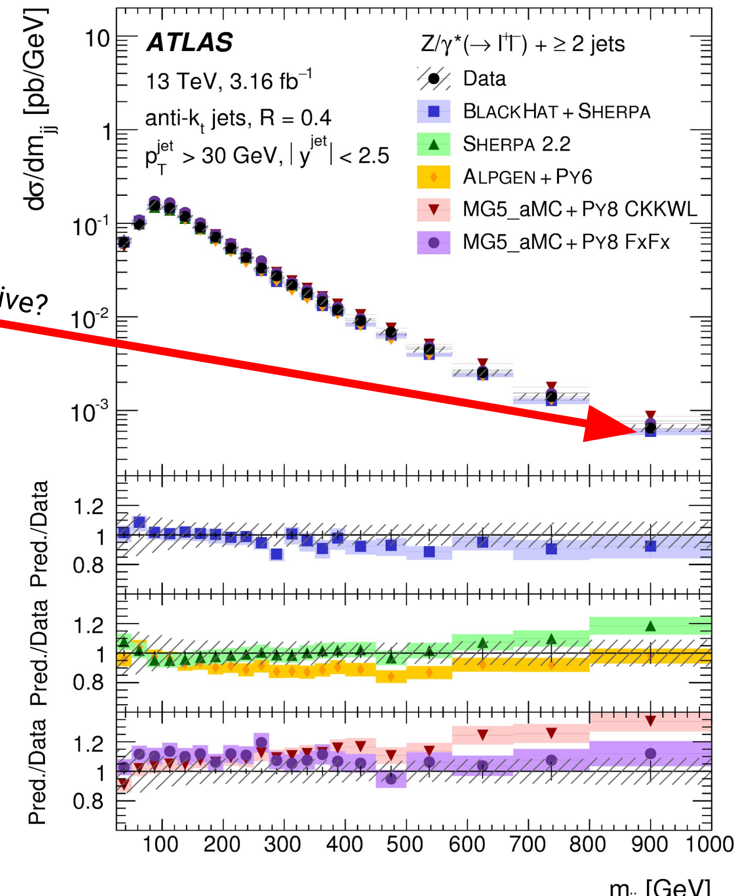
ATLAS Unfolded MET [1707.03263]

How can our results help - Control regions

Our results can be very dependent on background prediction

- Unfolded (Particle level) SM measurements help us inform theory/pheno community how to improve here
  - Tuning, Generator development etc.
- Do we have any consistent idea on how we model the more extreme search regions?
- E.g. Unfolded control regions (Some effort here recently from VLQ analyses), publish information about CR we use in a fit

Where do searches live?



ATLAS Z+Jets 1702.05725

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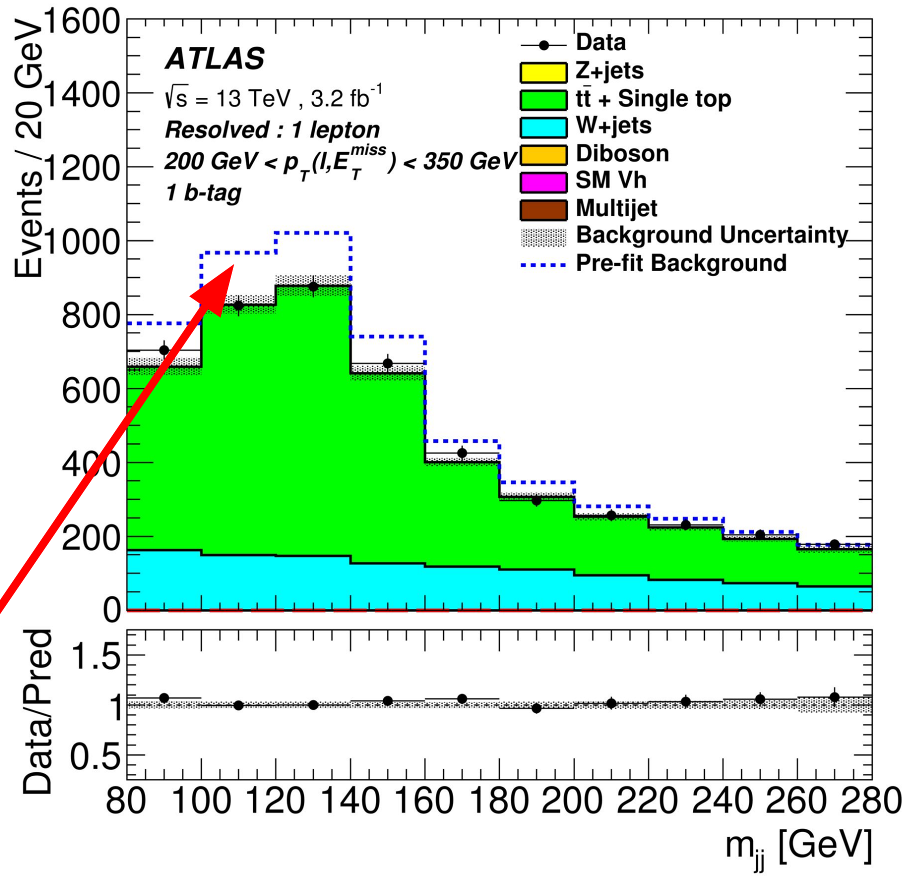

ATLAS DM + Higgs [1609.04572]

More than limits

- How do we compare non unfolded (detector level) results to MC outside of ATLAS
    - Applies to both SR's for recasting and CR's used for improving SM modelling
- Forward folding, prefit background calculations etc. useful?
    - Easy to say yes! But has to be used for the experiment to see it as useful effort
- Where can we make measurements we don't already measure that will help BSM search region calculations
    - Where do we need to unfold and where do we not?

Many recasting workshops and efforts to get involved with

Theory-experiment interactions vital

Conclusion

Hopefully a snapshot of where we are at in ATLAS

- Theres a lot that seems to work well on the BSM front
  - Where do we need to do more

- Main challenges seem to be on feeding back the results to the broader community

Thanks for listening