(Re)Interpreting LHC results

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16th MCnet Meeting
Karlsruhe

Reinterpretation of ATLAS/CMS results

- Results - ATLAS/CMS searches/measurements
  - What different results do we produce
  - What are the implications for interpreting these results for arbitrary new physics models
- The MCnet point of view
  - What do we need from our physics predictions to reinterpret results
  - Rivet/Contur - MCnet projects aiming to tackle these problems

Results

Roughly speaking need to know how to convert a particle level simulation (MC Generator output) **σ** to an observed count in a detector volume $\mathbf{N_{obs}}$

$$N_{\text{obs}} = L \cdot \sigma_{\text{Total}} \cdot A \cdot \epsilon$$

- L - Luminosity, known
- A - Acceptance, effectively the analysis definition
  - Can be simple, what about complicated analyses, BDTs for S/B discrimination etc.
- ϵ - Efficiency, Detector simulation
  - Approximate detector sims, e.g. Delphes used

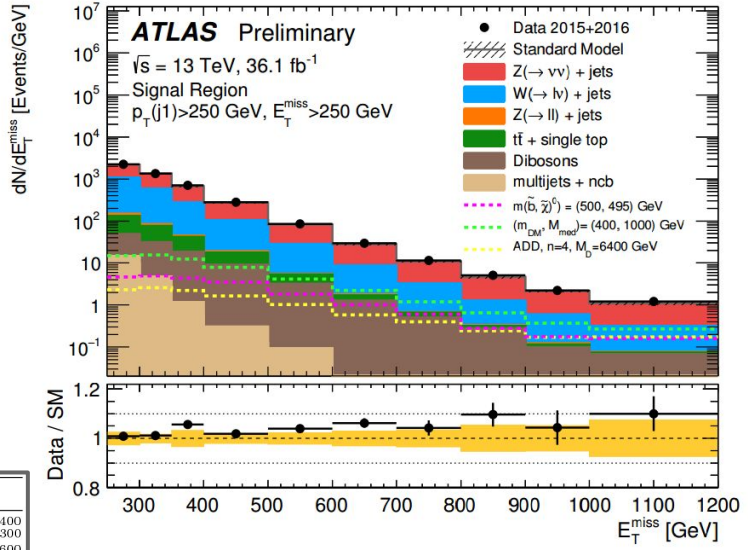
Current hot topic inside/outside experiment, how do we deliver A and ϵ better?

Example: Detector level results

Detector Level Result - e.g. monojet

Need Detector Simulation and Signal Acceptance

Something like CheckMATE (Delphes + analysis def)
To reinterpret these results in terms of a new model



Signal channel	$\langle\sigma\rangle^{95}_{\text{obs}}$ [fb]	S^{95}_{obs}	S^{95}_{exp}
IM1	531	19135	11700^{+4400}_{-3300}
IM2	330	11903	7000^{+2600}_{-2600}
IM3	188	6771	4000^{+1400}_{-1100}
IM4	93	3344	2100^{+770}
IM5	43	1546	
IM6	19	696	
IM7	7.7	276	
IM8	4.9	178	
IM9	2.2	79	76^{+29}_{-21}
IM10	1.6	59	56^{+21}_{-16}

$$r \equiv \frac{S - 1.96 \cdot \Delta S}{S^{95}_{\text{Exp.}}} = \frac{95\%\text{ lower limit on the number of signal events, determined by CheckMATE}}{\text{Experimentally measured 95\% confidence limit on signal events}}. \quad (1)$$

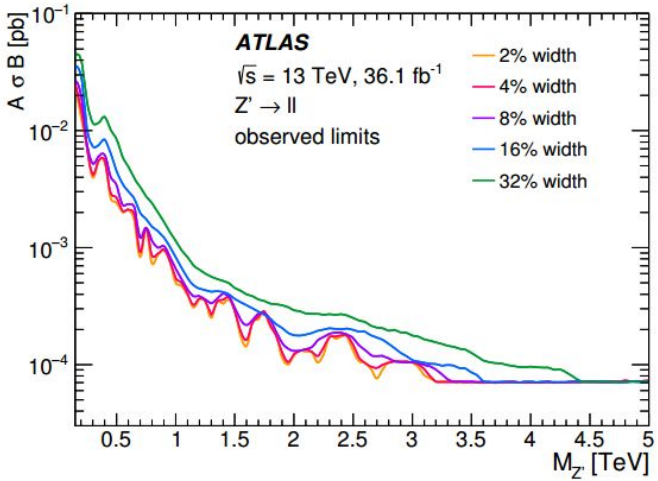
In that case, a model can be considered as excluded to the 95% confidence level, if $r \geq 1$.

Example: Particle level results

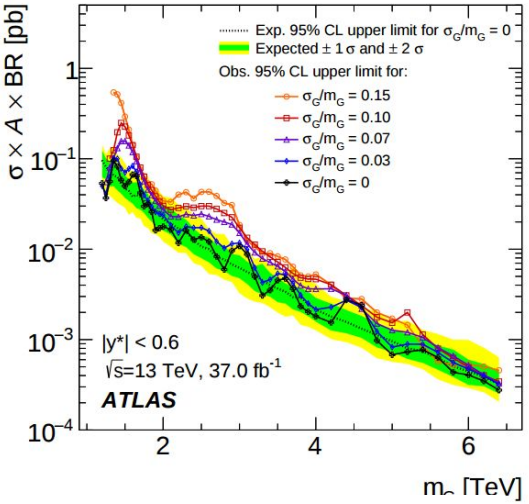
Particle Level Result

Lots of different ways to try and do more for reinterpretability from the experiments, no clear solution fo all

All come with different caveats on usability



Generic resonance limits Z'->ll



Range in E_T^{miss} [GeV]	$\sigma^{obs}_{vis,h(b\bar{b})+DM}$ [fb]	$\sigma^{exp}_{vis,h(b\bar{b})+DM}$ [fb]	$\mathcal{A} \times \varepsilon$ [%]
[150, 200)	19.1	$18.3^{+7.2}_{-5.1}$	15
[200, 350)	13.1	$10.5^{+4.1}_{-2.9}$	35
[350, 500)	2.4	$1.7^{+0.7}_{-0.5}$	40
[500, ∞)	1.7	$1.8^{+0.7}_{-0.5}$	55

Conservative limits with A.ϵ given

Example: Unfolding

Segues nicely to a particular ATLAS analysis that is of interest (and that I work on!)

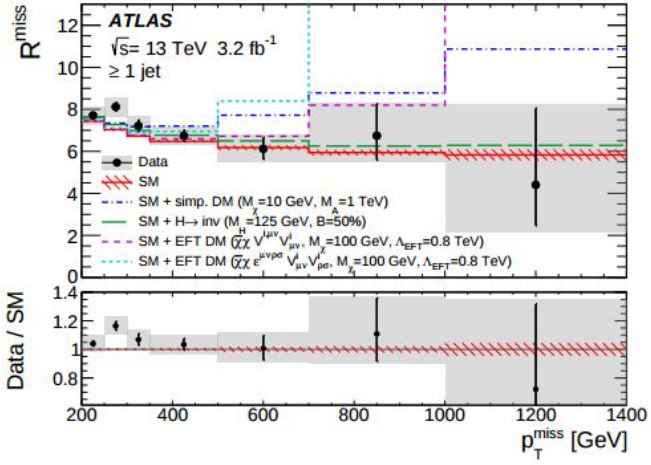
Experiment takes care of ϵ, use full detector simulation

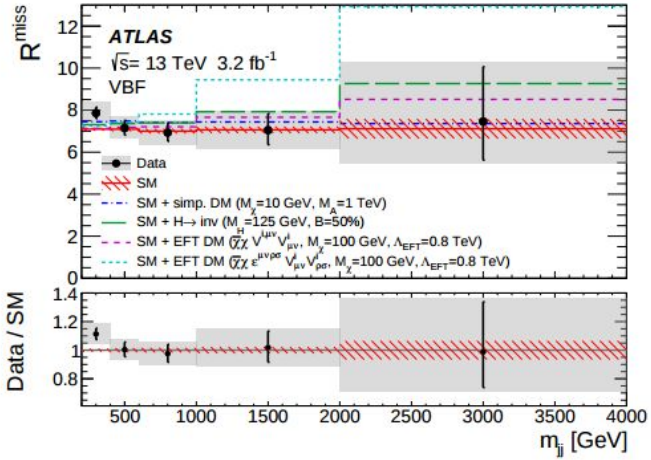
Validated rivet analysis gives A (as for all SM rivet routines that are already in Rivet

arxiv.org/abs/1707.03263

Unfold a measurement of **σ(**Z->$\nu\nu$/Z->ll**)** = R^{Miss}

Provides detector corrected measurements of distribution sensitive to production of invisible particles at the LHC,
first unfolded measurement to do this
Can apply to DM models, SUSY….





Activity

Complex spectrum of Analyses, models, information that need bringing together.

Very much a hot button topic right now, many MCnet members involved in various projects that touch upon these areas

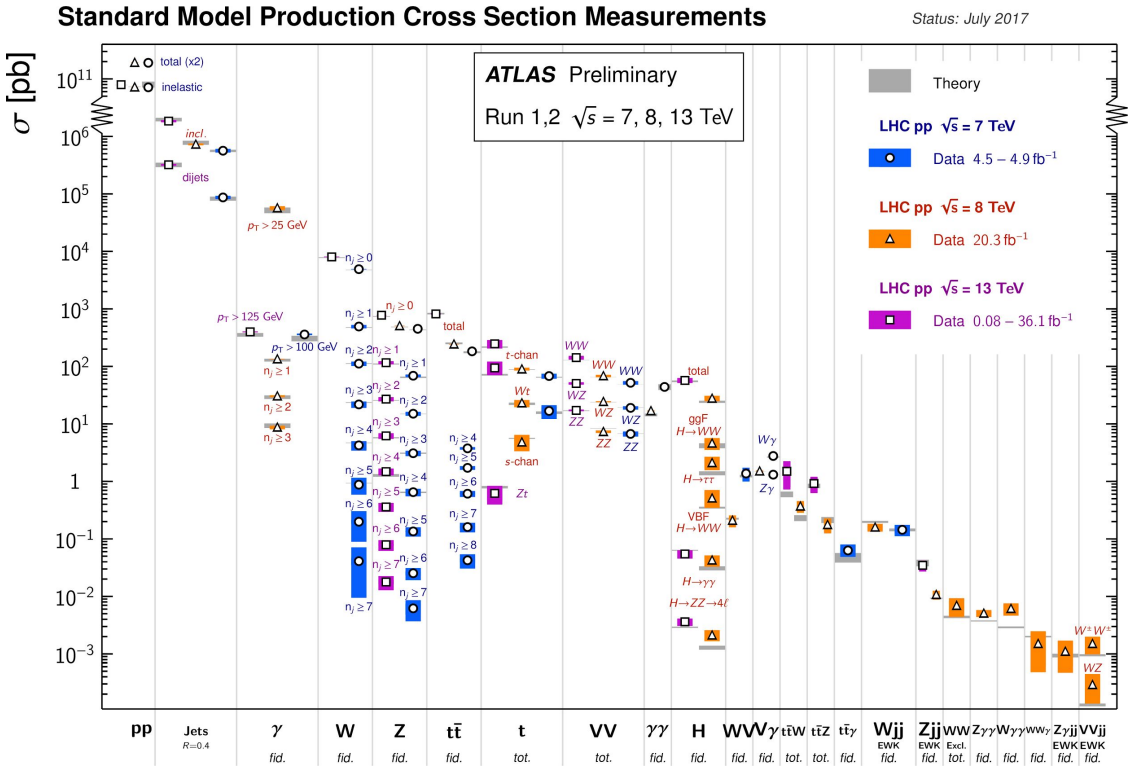
Loads of Activity/Initiatives from both sides:

Rivet, Contur, CheckMATE, MadAnalysis, Delphes, Simplified Likelihoods, SModelS, Gambit…. Many more

Contur

- MCnet project for ITN3, under the CEDAR banner
  - MCnet ITN3 long term associated PhD student @ UCL/Glasgow nodes
  - Strong ties to Rivet - involvement with Glasgow node
  - Jon Butterworth, David Grellscheid, DY. Currently involved MCnet members.

Fundamental design choice, see what precision Standard Model measurements can tell us about new physics



We measure a lot (and differentially), a lot of information covering a lot of final states!

Contur – A quick example

Simplified DM model

Introduce BSM model with 4 degrees of freedom

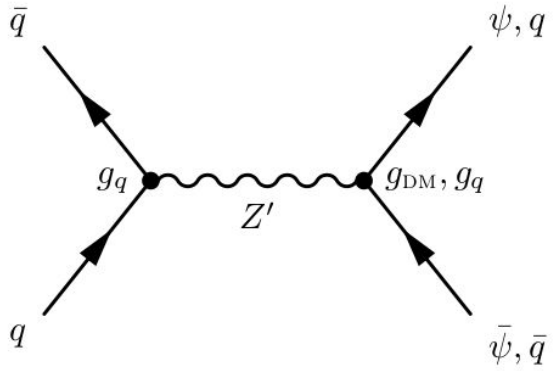
$$\mathcal{L} \supset g_{\mathrm{DM}}\,\overline{\psi}\gamma_\mu\gamma_5\psi\,Z'^{\mu} + g_q \sum_q \bar{q}\gamma_\mu q\,Z'^{\mu}\,,$$

Vector Mediator mass M_z

DM Mass M_{DM}

DM-Mediator Coupling g_{DM}

Quark Mediator coupling g_q



Commonly discussed at LHC DM WG

Contur – A quick example

Simplified DM model

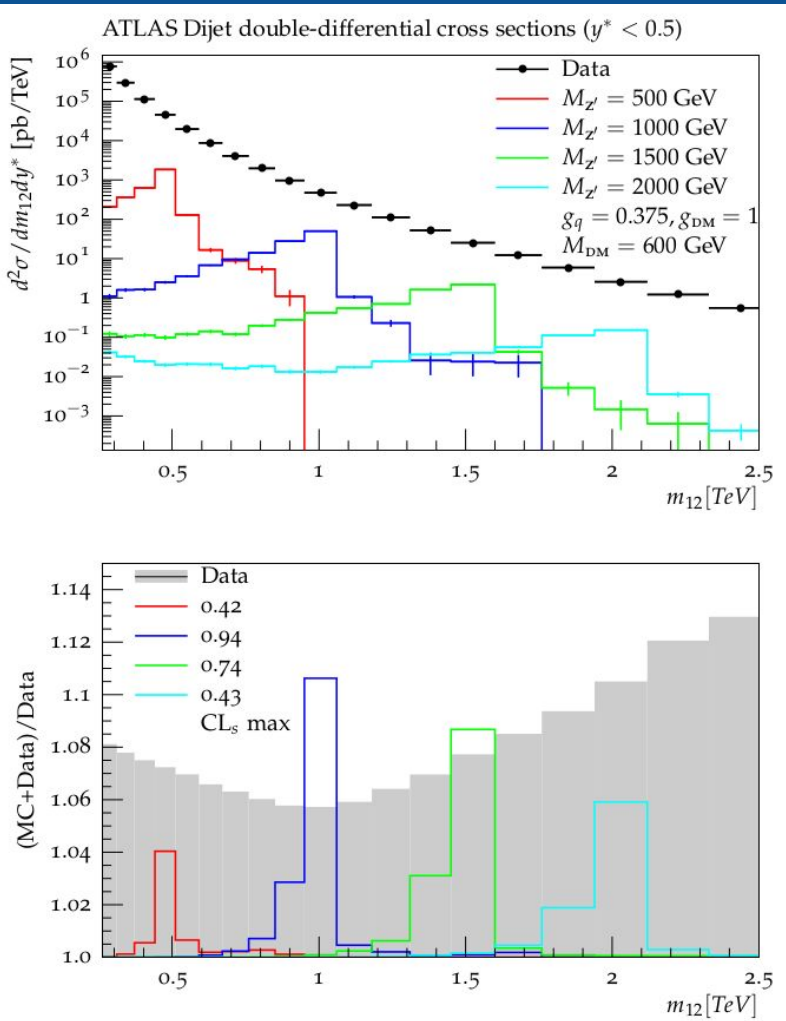
Throw events (from Herwig) through SM Rivet routines

Right, ATLAS 7TeV Dijet

The Caveat:

Assume SM expected background is equal to data
(Conclusion, roughly, from the paper, mirrors how we already understand these data)

Compute significance of resulting BSM deviations (Profile Likelihood formalism)



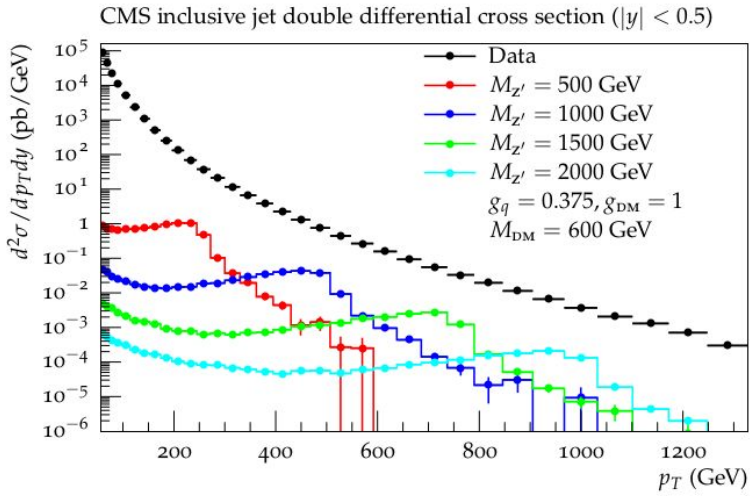
Contur – A quick example

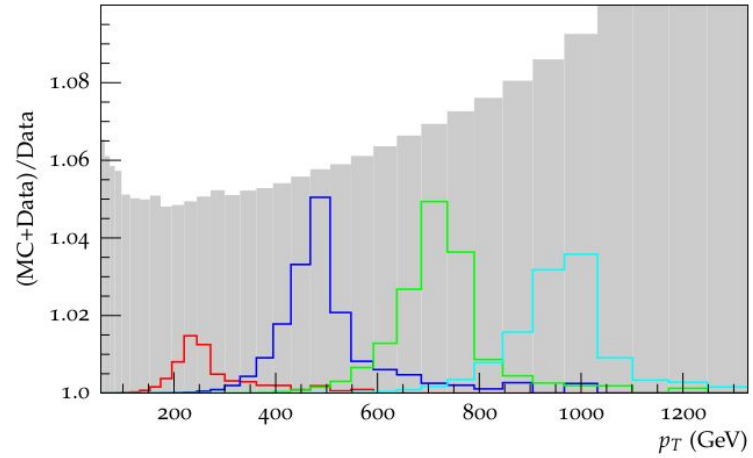
Simplified DM model

Throw events (from Herwig) through SM Rivet routines

Simultaneous fit to orthogonal datasets:

CMS jet measurement (right)



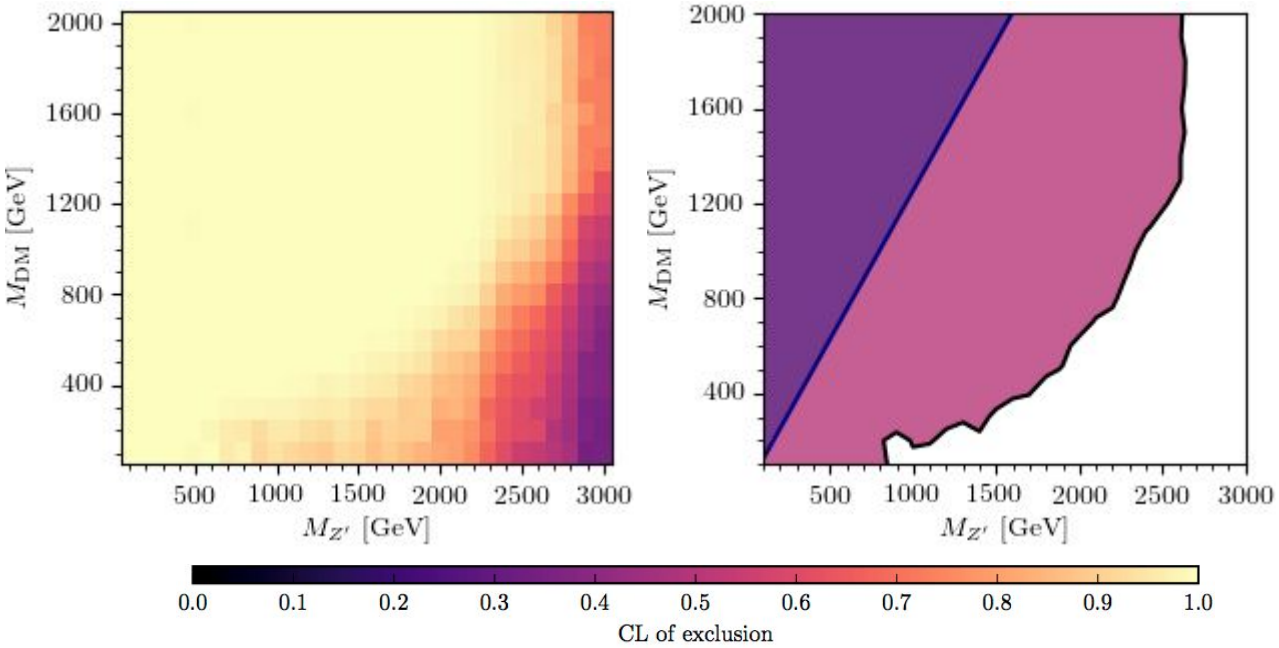


Contur – A quick example

Simplified DM model

Manually scan through mass plane parameter space points

Build exclusion limits from combinations of measurements



Update: Continually updating Rivet routines from original dataset, Thanks to Jon+Masters Students

Define coupling working point, here, g_q=0.5, g_{DM}=1

Combine As many orthogonal analyses as possible 7,8,13TeV

Contur – Developments

Code work

Currently working on a formal release of the Python module containing executables and instructions to compute limits

Hopefully define a framework for generic limit setting on yoda inputs

Extend framework

Extend to cover MC based background predictions, fairly simple change internally but can be driven by MC predictions from experimental papers?

Diversify model studies

Work in progress, nothing public to show but looking at sensitivity to models predicting different final states

Contur – Developments

Correlations

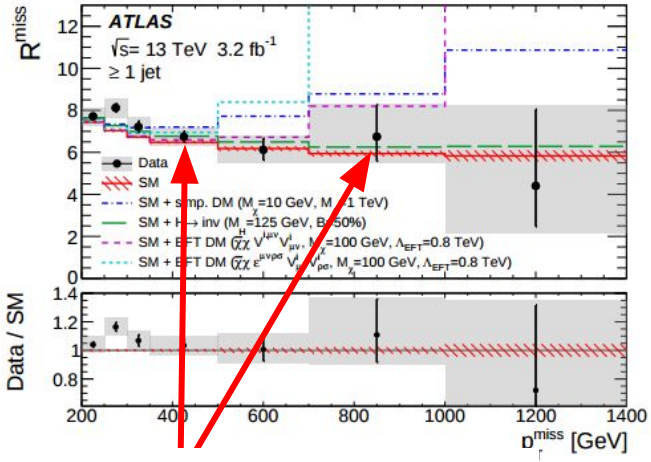
Increasingly experiments looking to give breakdown of systematic correlations, and for non orthogonal kinematic regions, statistical correlations

Exists (right) for R_{Miss} unfolded ratio measurement mentioned earlier

Formalise in HepData

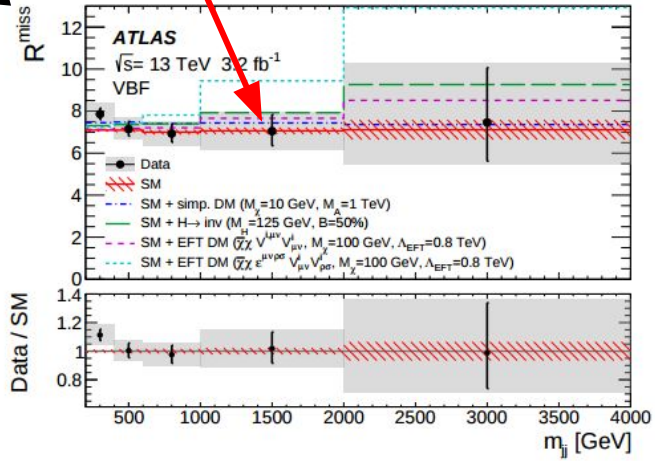
Formalise these objects in Yoda

(hard to work with unless theres a unified way of delivering the data)



Start thinking more about non resonant effects etc.

Start combining bins



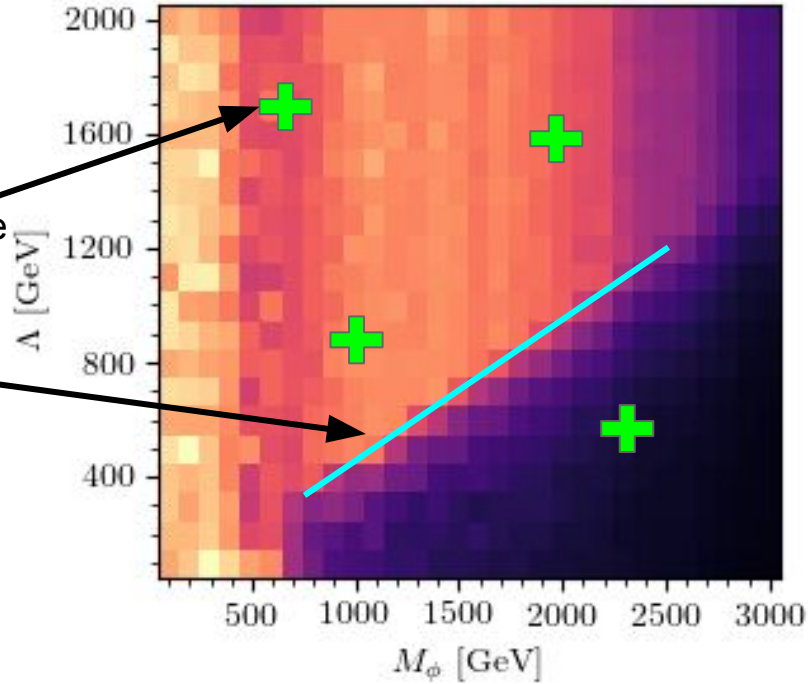
Contur – Developments/Plans

Professor

Idea I wanted to pursue (interested to hear feedback) **WIP**

Use professor to sample parameter space points, parametrize histograms, build exclusions that way

Problem parameterizing steeply falling functions



Won't add much to 2D case but can scale to higher dimension parameter scans faster, scan now in 4D cube, Points off the mass plane

Will work better for EFT (some precedent to use Professor in this context already, see TopFitter)

Conclusion

- Ongoing project with lots of potential extensions
- Interacting with lots of MCnet tools,
  - Currently looking at MadGraph for BSM generation alongside Herwig
  - Rivet, Yoda, Hepdata, Professor etc.
- New Results soon!