

# BSM Searches Using SM Measurements

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HEPP Workshop, Venda, 30th January, 2020





# Disclaimer(s)

- There is no such thing as SM measurement.
- My main interest is analysing ATLAS data, focussing on jet substructure (DW) and unusual topologies (LCD, MMEF, SS).
- However, this talk will focus on some of the other fun things I have been





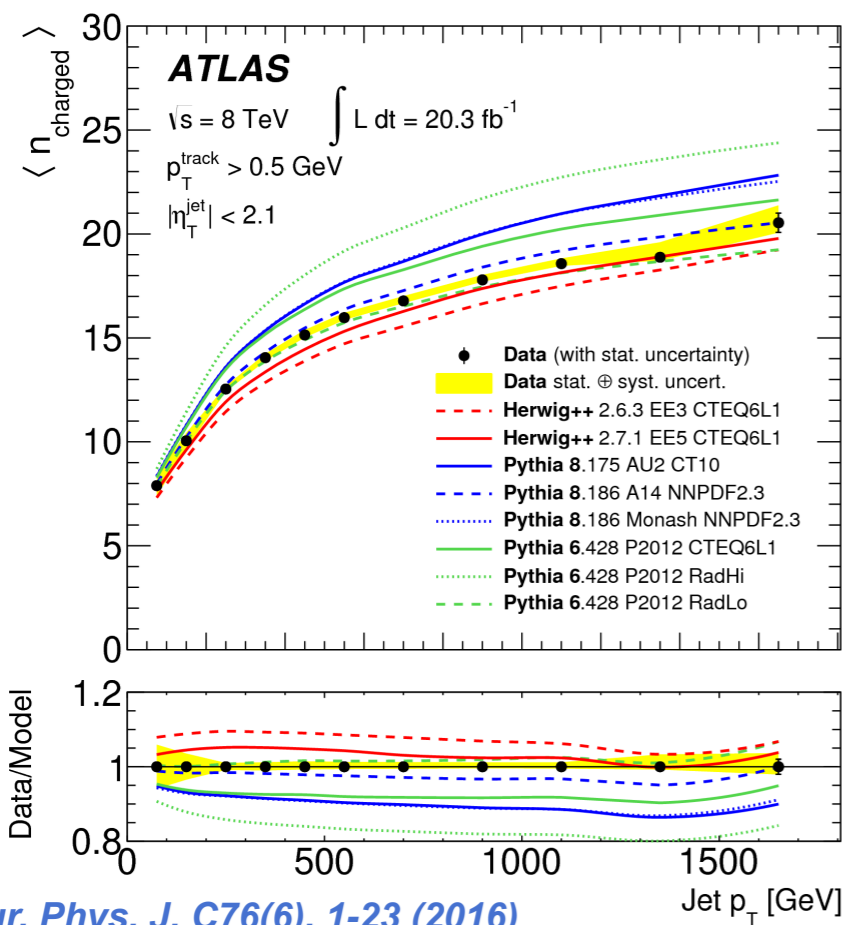


# Why Measurement?

Jet (sub)structure is mostly dependent on Parton Shower models

Non negligible differences from data are observed in MC predictions

(Unfortunately) Grooming to get rid of uncorrelated radiation also throws away the soft part we wish to tune to!



[Eur. Phys. J. C76\(6\), 1-23 \(2016\)](#)

“Your garbage is my treasure”

Attributed to Stefan Prestel



# Why Measurement?

Sensitive to both perturbative and non-perturbative QCD (“precision substructure”)

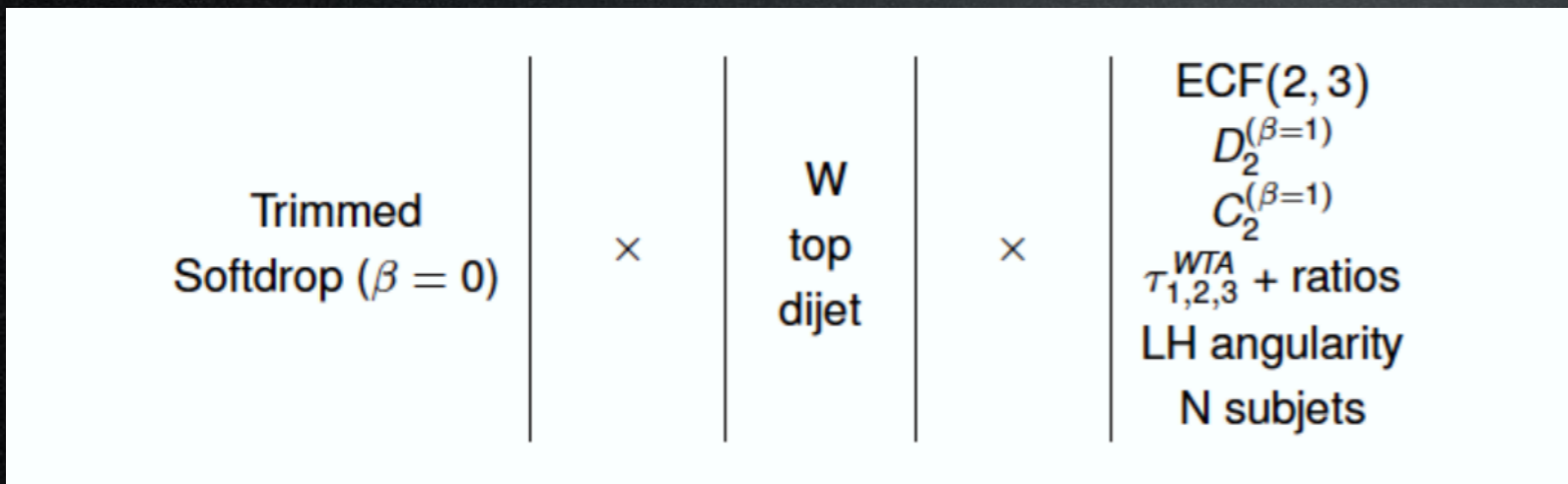
Input to tune/improvement models and analytic calculations

Helps in tagging algorithm development.



**NEW**

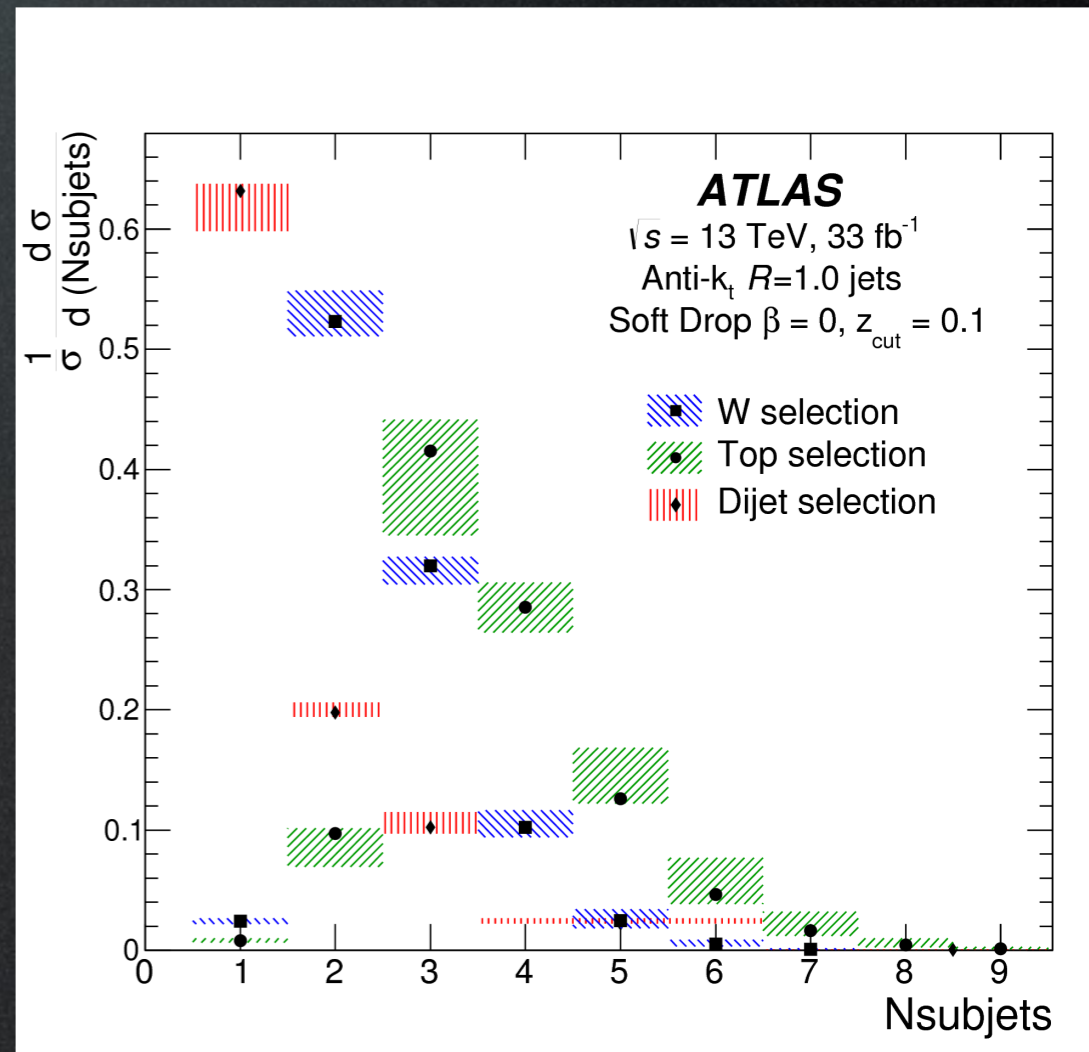
# Most comprehensive jet substructure measurement at the LHC



Comparison between topologies

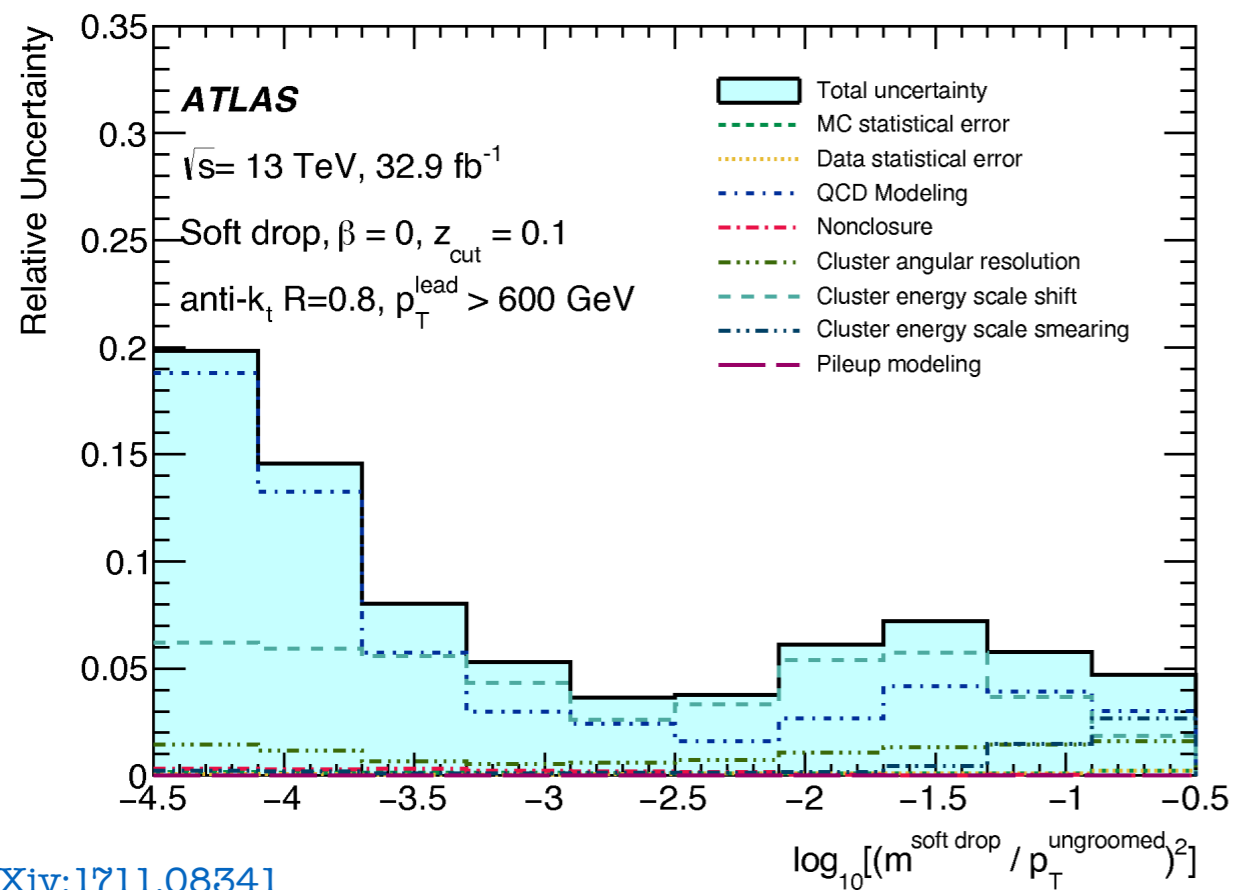
+

Test of MC modelling





# Uncertainty for JSS measurements



[arXiv:1711.08341](https://arxiv.org/abs/1711.08341)

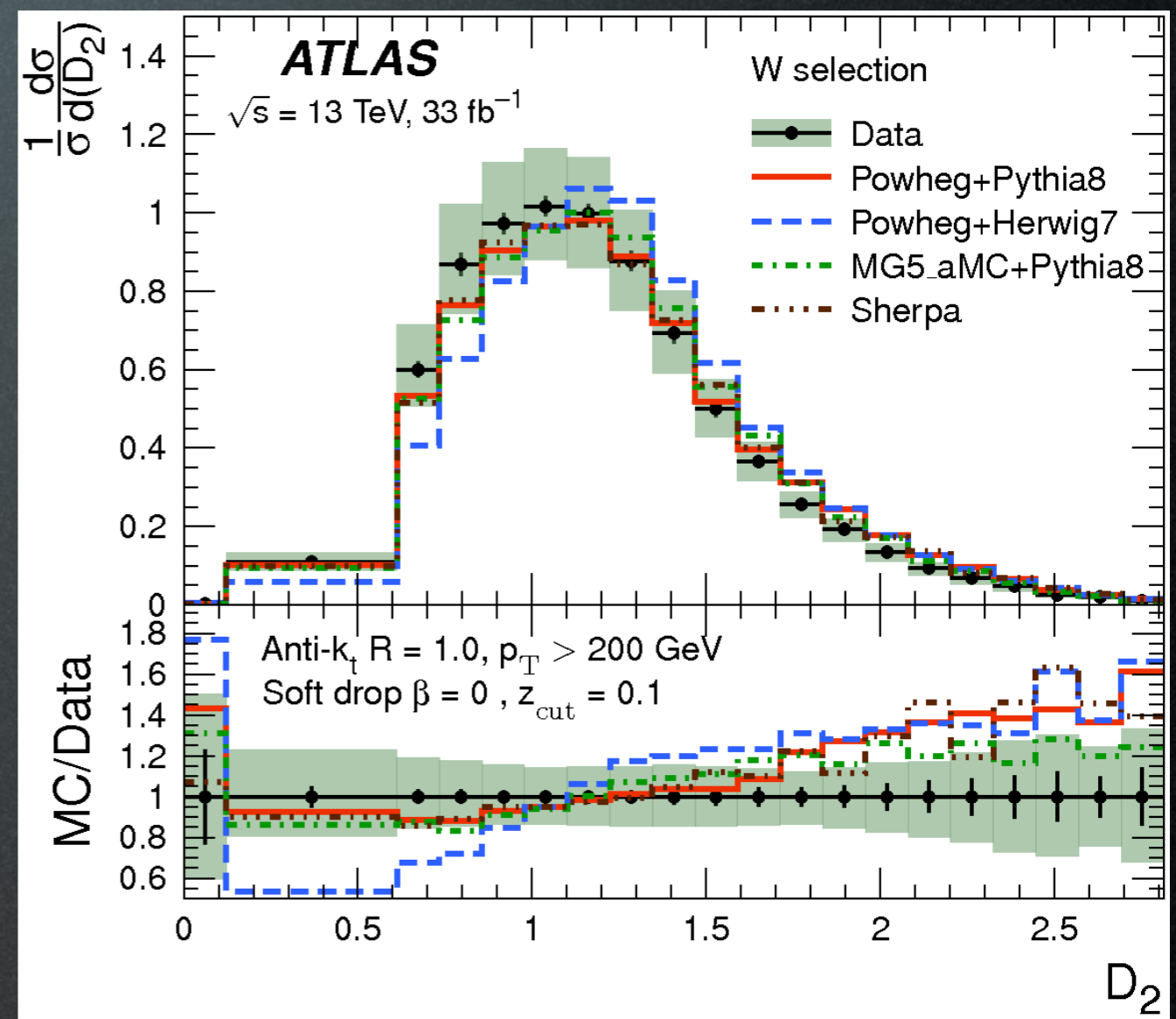
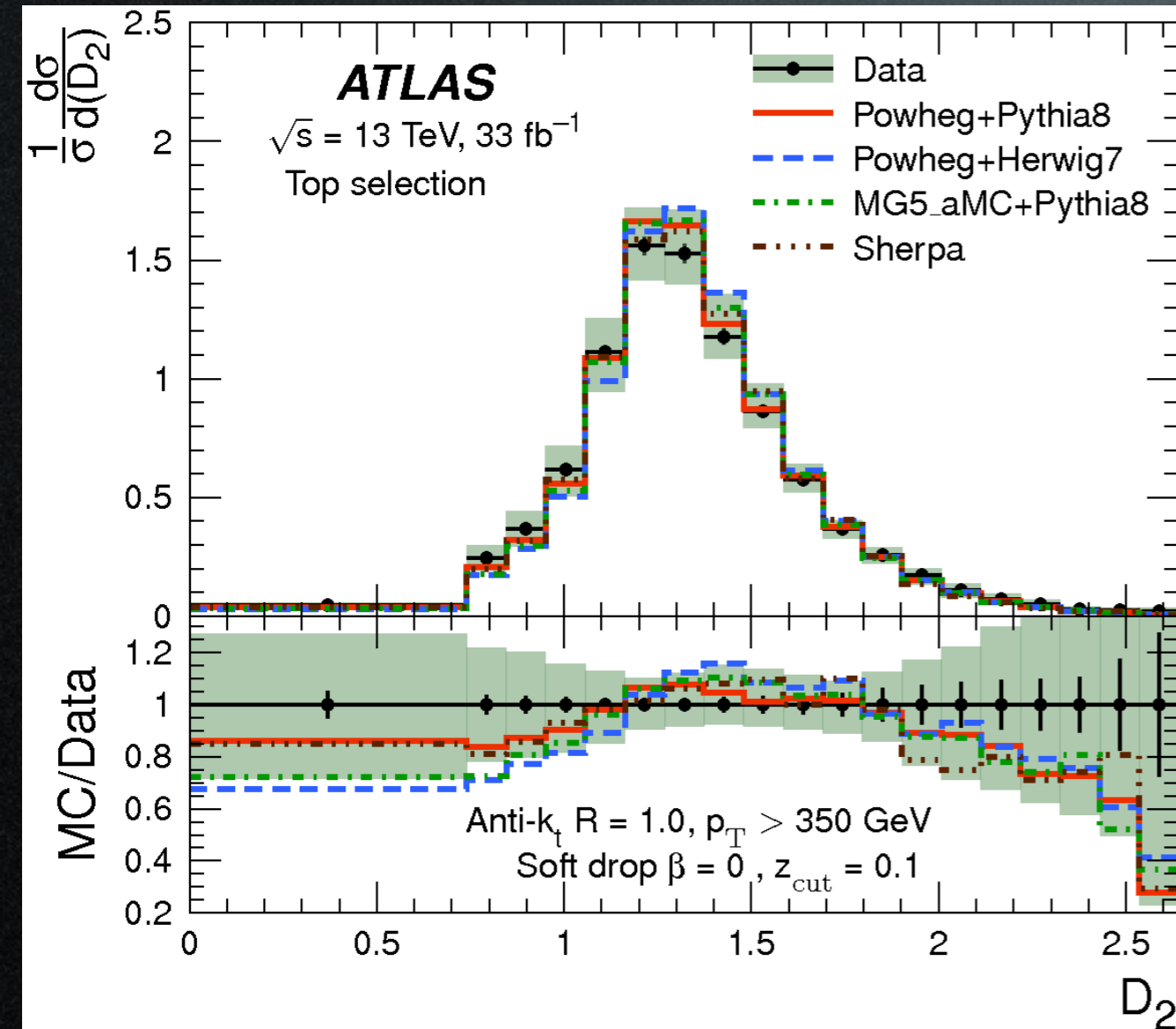
Leading experimental uncertainty from calorimeter cell-cluster energy, resolution, efficiency etc.

Cluster energy scale and resolution uncertainties estimated by track to cluster  $E/p$  ratio, angular resolution uncertainty by relative position shift

Reconstruction efficiency from unmatched tracks to clusters



# D2

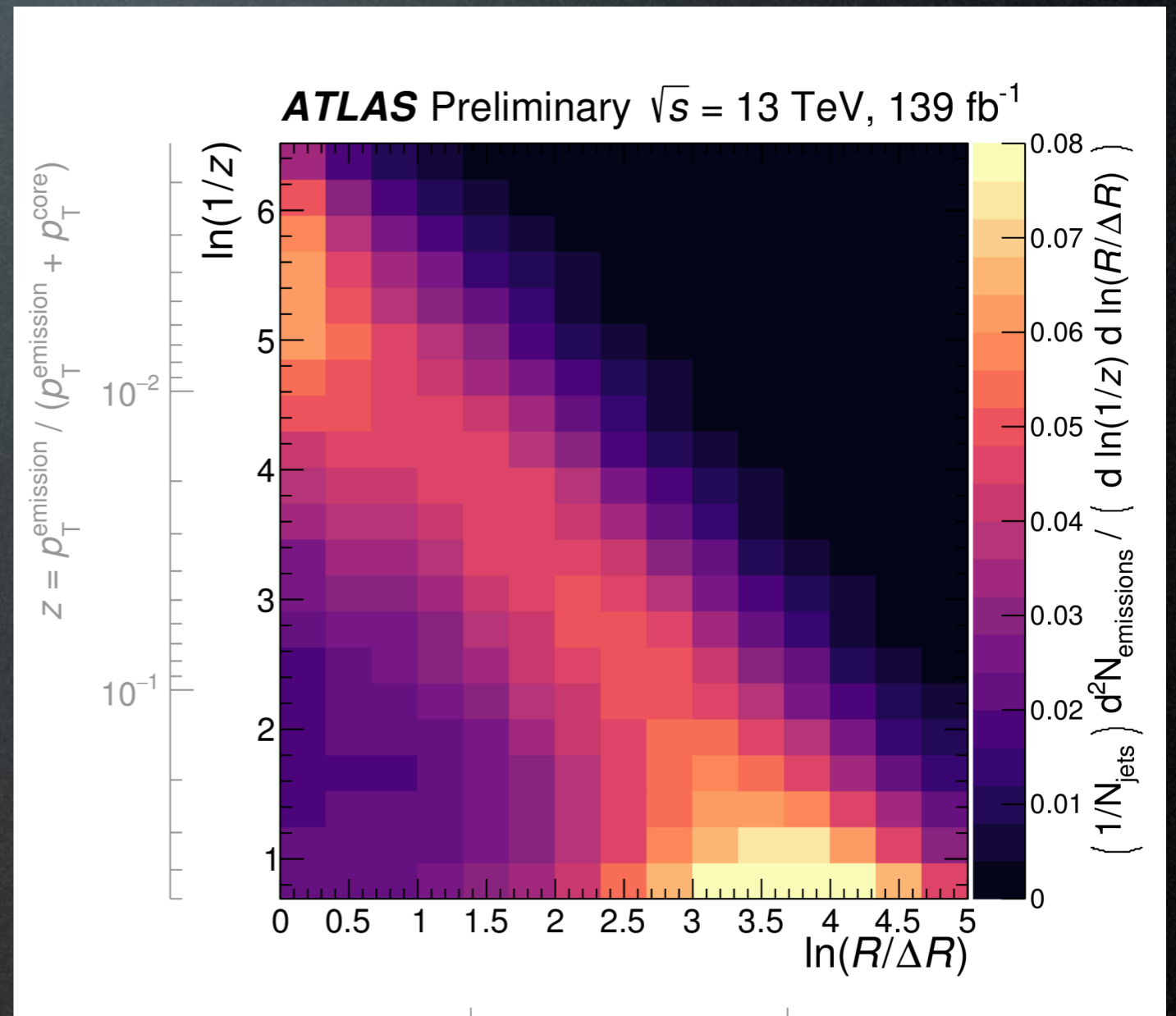
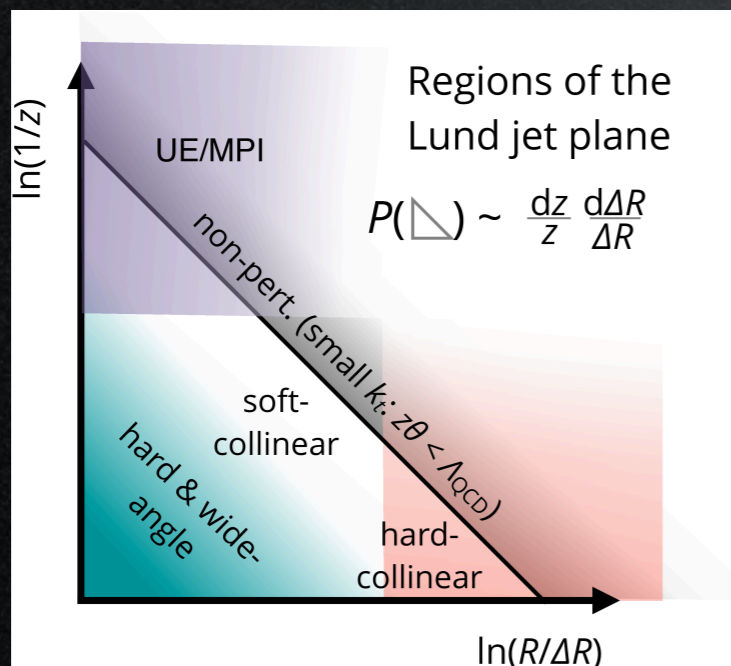
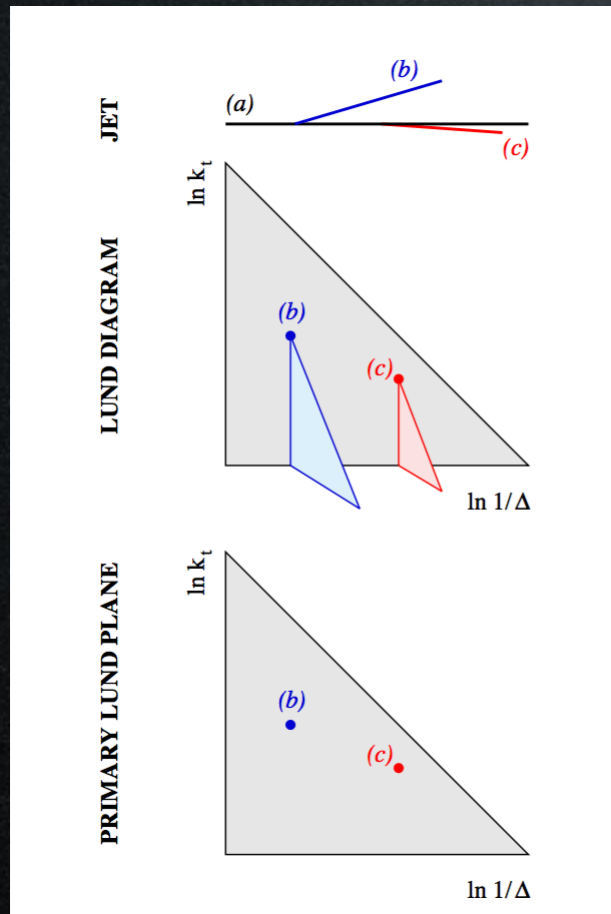


Shifted peak in W, models overestimating gluon radiation



# Lund Plane

Probing emission inside a jet



Measured for the first time:  
highlight of Boost2019

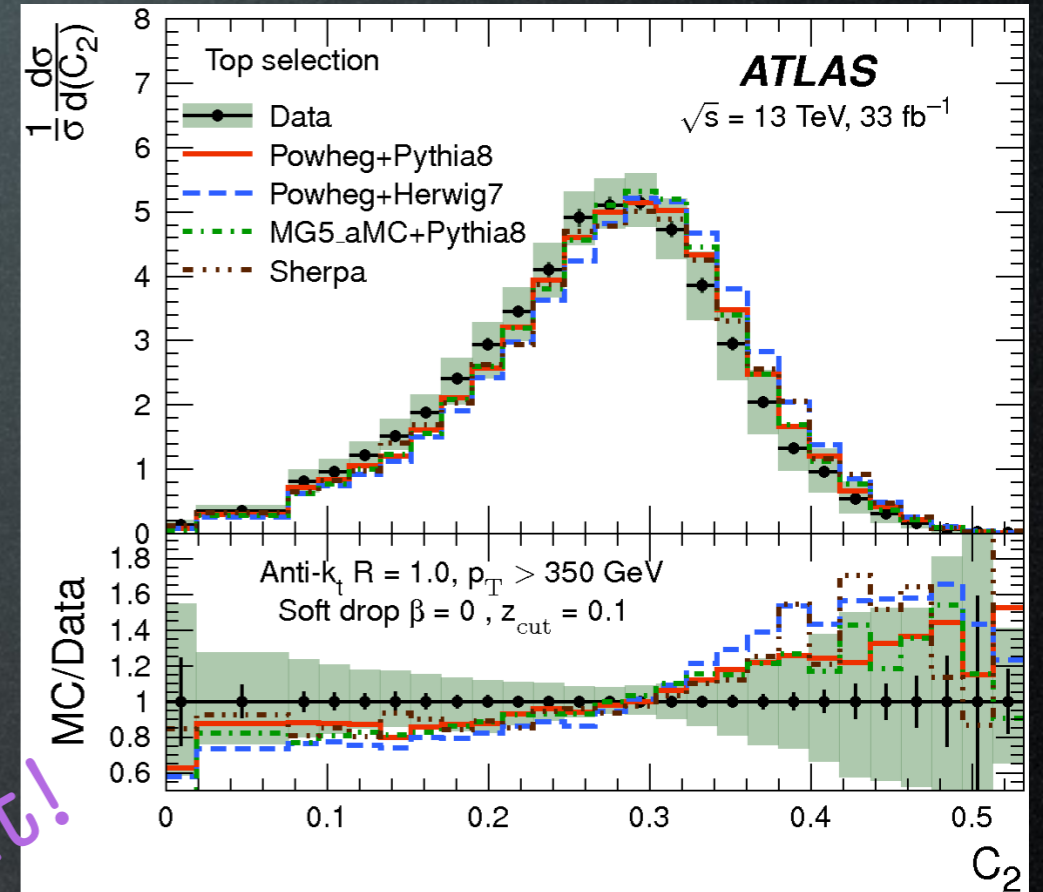
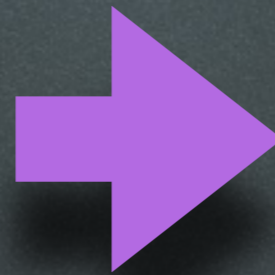
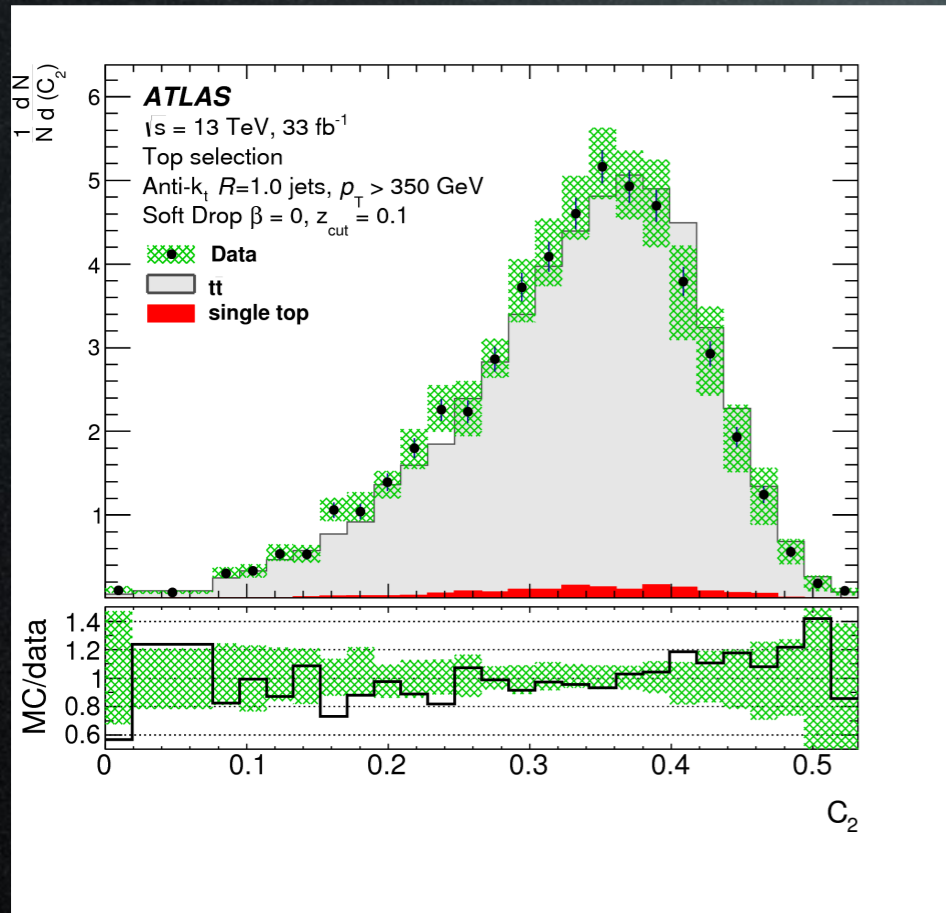


# Smearing

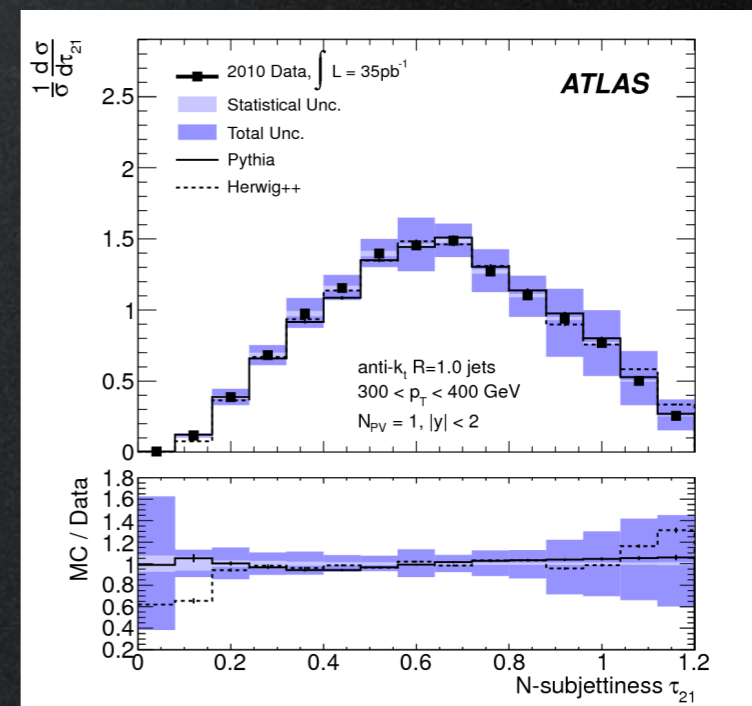
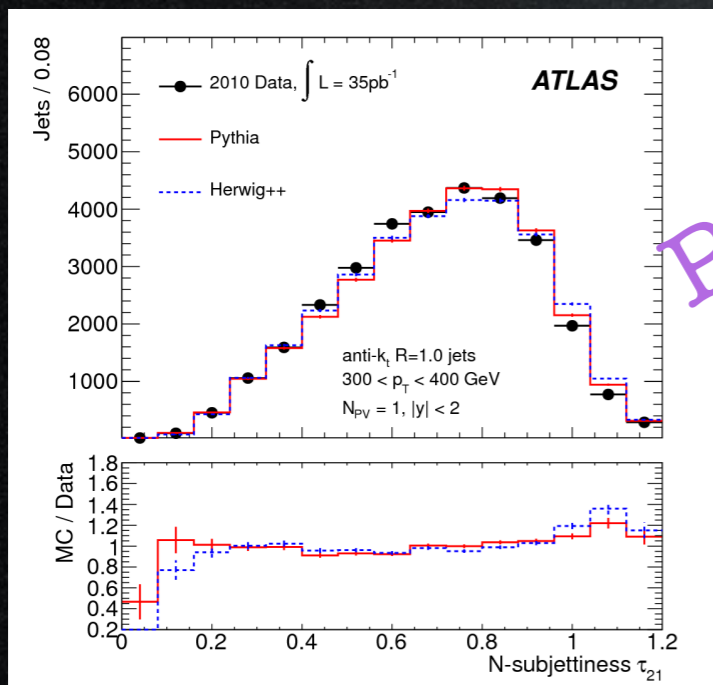
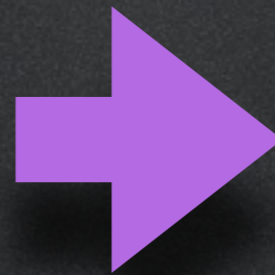
- Delphes only smears JES, so a larger-R jet  $p_T$  and mass smearing(s) are realistic, but not any substructure variables, which show no difference.
- Whereas just as an example, if we construct JSS observables only with charged particles, and apply the typical charged particle  $p_T$  and angular smearing, we see significant effect, which is more inline with experimental results.



# Smearing



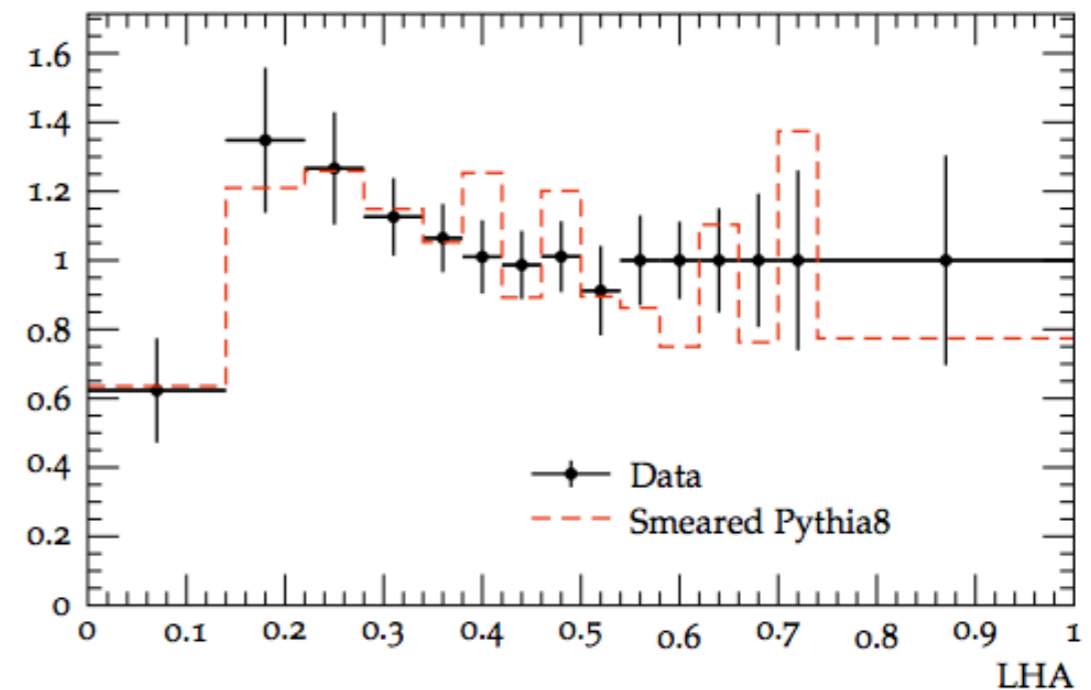
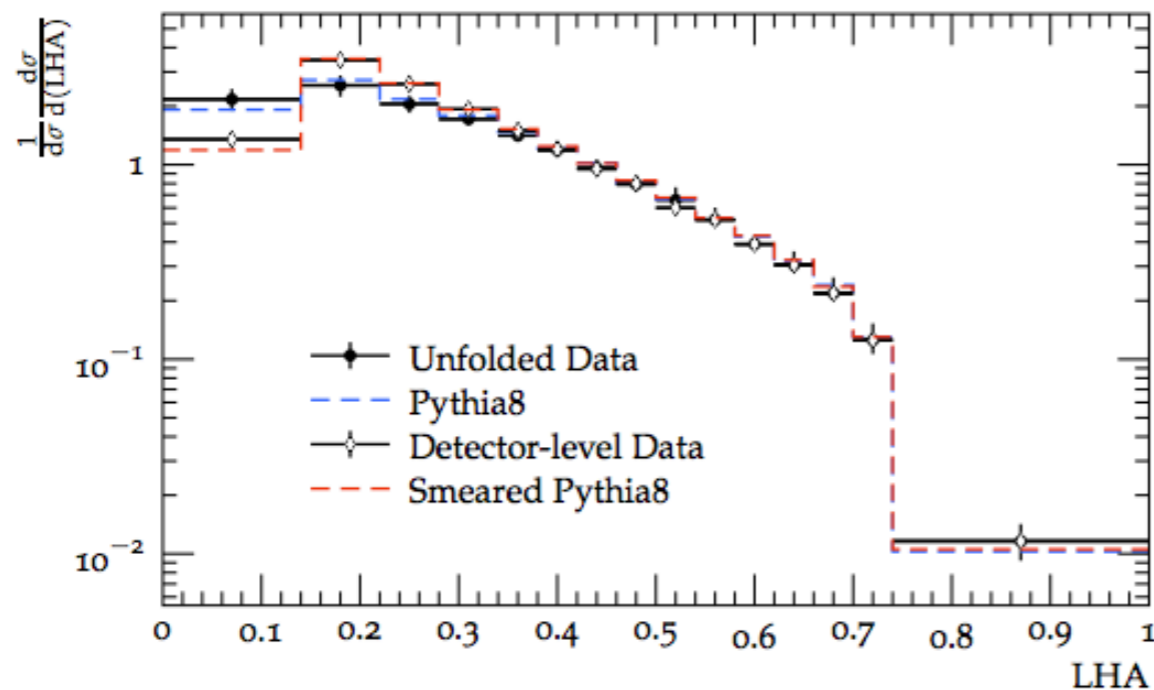
Pronounced shift!



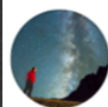


# JSS Smearing in Rivet

(with Andy Buckley and Karl Nordstrom)



- Smearing  $p_T$  and  $\eta$  of the clusters, constructed by adding individual constituents.
- Tuned the smearing to the ATLAS reco/gen ratios as shown.



**James Monk** Why are you smearing Rivet? It's great, I won't have a word said against it! 😊

Haha · Reply · 10w





If you have a measurement, can it do more for you?

More specifically, if we expect a certain measurement to be performed at the LHC, what precision of it can exclude certain parameter space of a specific BSM model



# Detour: Precision vs Accuracy



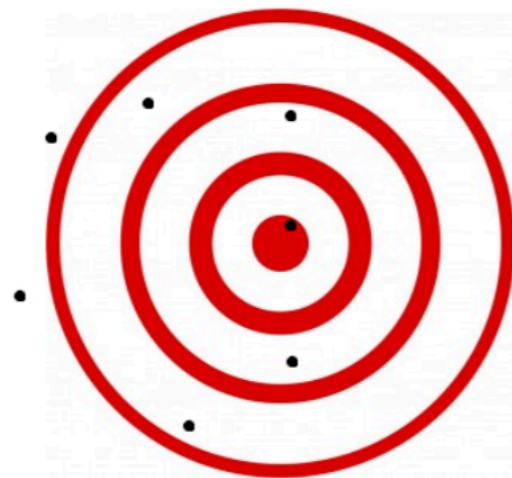
Accurate and Precise



Precise...but not Accurate



Accurate, but not Precise



Neither Accurate nor Precise

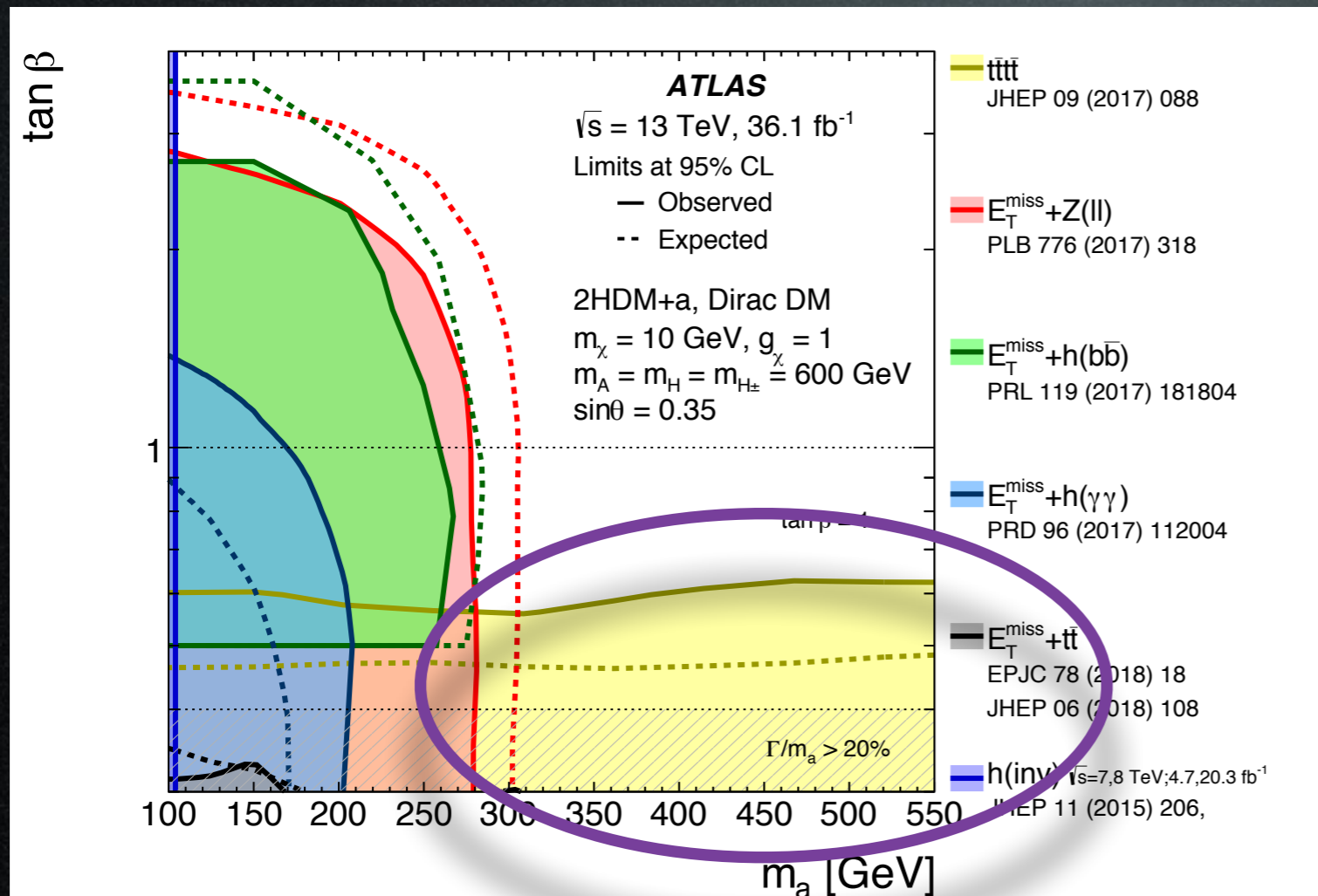
At the LHC,  
almost always  
we are shooting  
for precision ...

Realistic but  
conservative  
systematic  
uncertainties\*



# Les Houches 2020 Project

(with Louie Corpe)

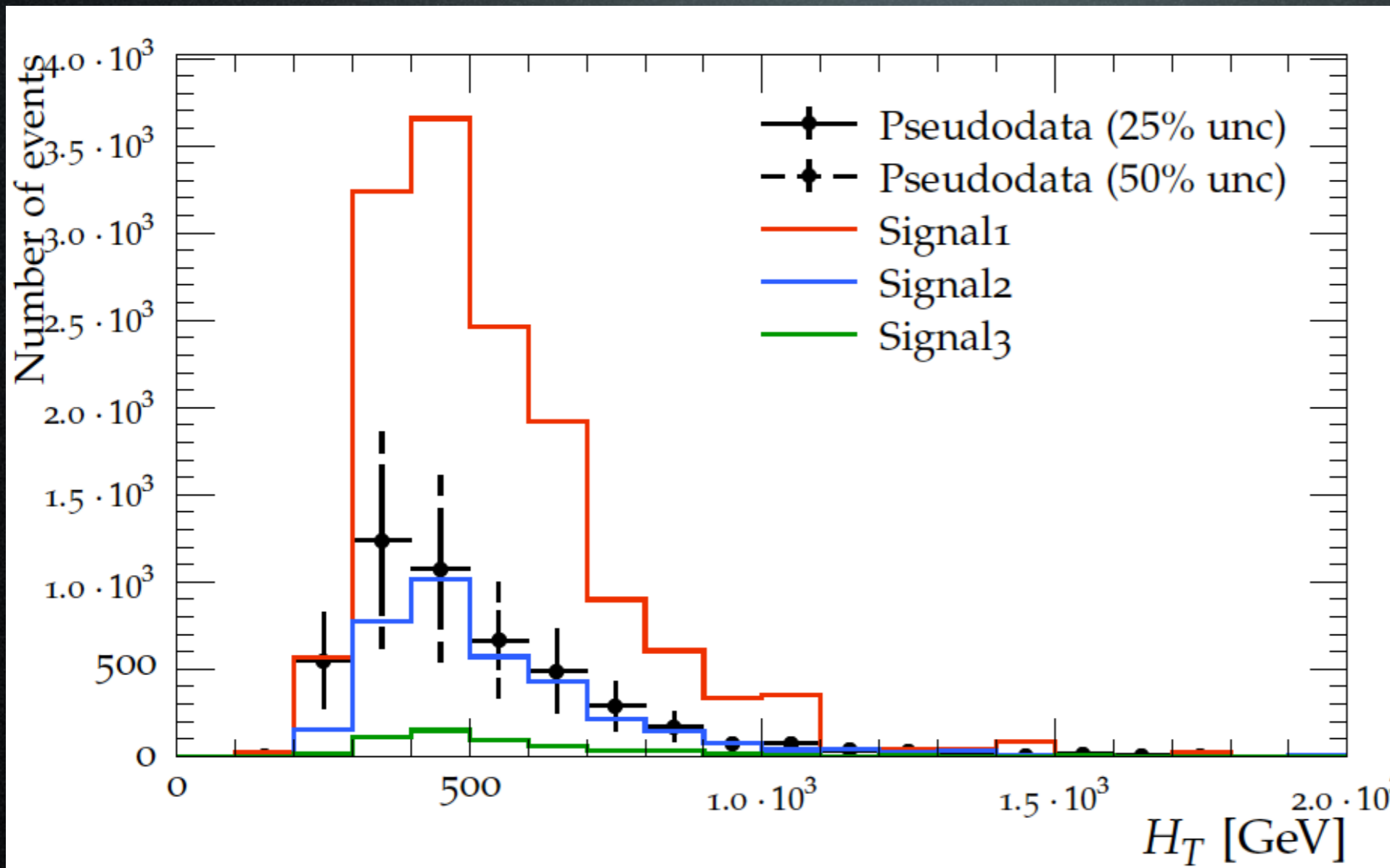


Parameter space  
sensitive to 4 top  
production

ATLAS Collaboration, M. Aaboud et al., *Constraints on mediator-based dark matter and scalar dark energy models using  $\sqrt{s} = 13 \text{ TeV}$   $pp$  collision data collected by the ATLAS detector*, **JHEP 05 (2019) 142**, [arXiv:1903.01400](https://arxiv.org/abs/1903.01400) [hep-ex].



# Our Toy Study



Pseudodata  
(semilep ttbar)  
with 25% and 50%  
uncertainties

Use CONTUR!

Signal1: 100%, 100%  
Signal2: 98%, 84%  
Signal3: 64%, 45%

Proof of principle demonstration ...



# Finally, concluding thoughts on Machine Learning

- Machine Learning is a tool. We need to know where we should be using the tool, how it is being used, and why we need to use it.
- BDT is around for 20 years (if not more!)
- How do you propagate systematic uncertainties



# Finally, concluding thoughts on Machine Learning

- Machine Learning is a tool. We need to know how to use the tool, and why we need it.
- BDT is not more
- How do you propagate systematic uncertainties





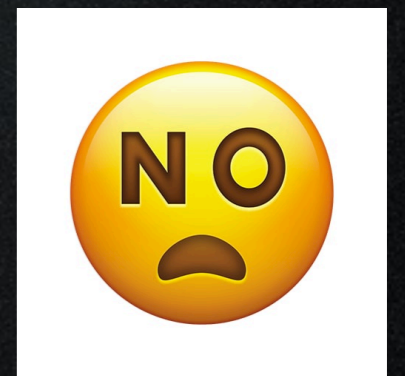
# Test case: Anomaly Detection

- ATLAS and CMS have developed boosted top/W taggers by throwing many (jss) variables into the NNs
- Can simulation describe the data?
- What if the new physics resides at a different place than where we are looking for?



# Test case: Anomaly Detection

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# Way Out?

- Unsupervised learning on data (not easy, how do you define your CR?)
- Mass-decorrelate the tagger, use QCD background for training...

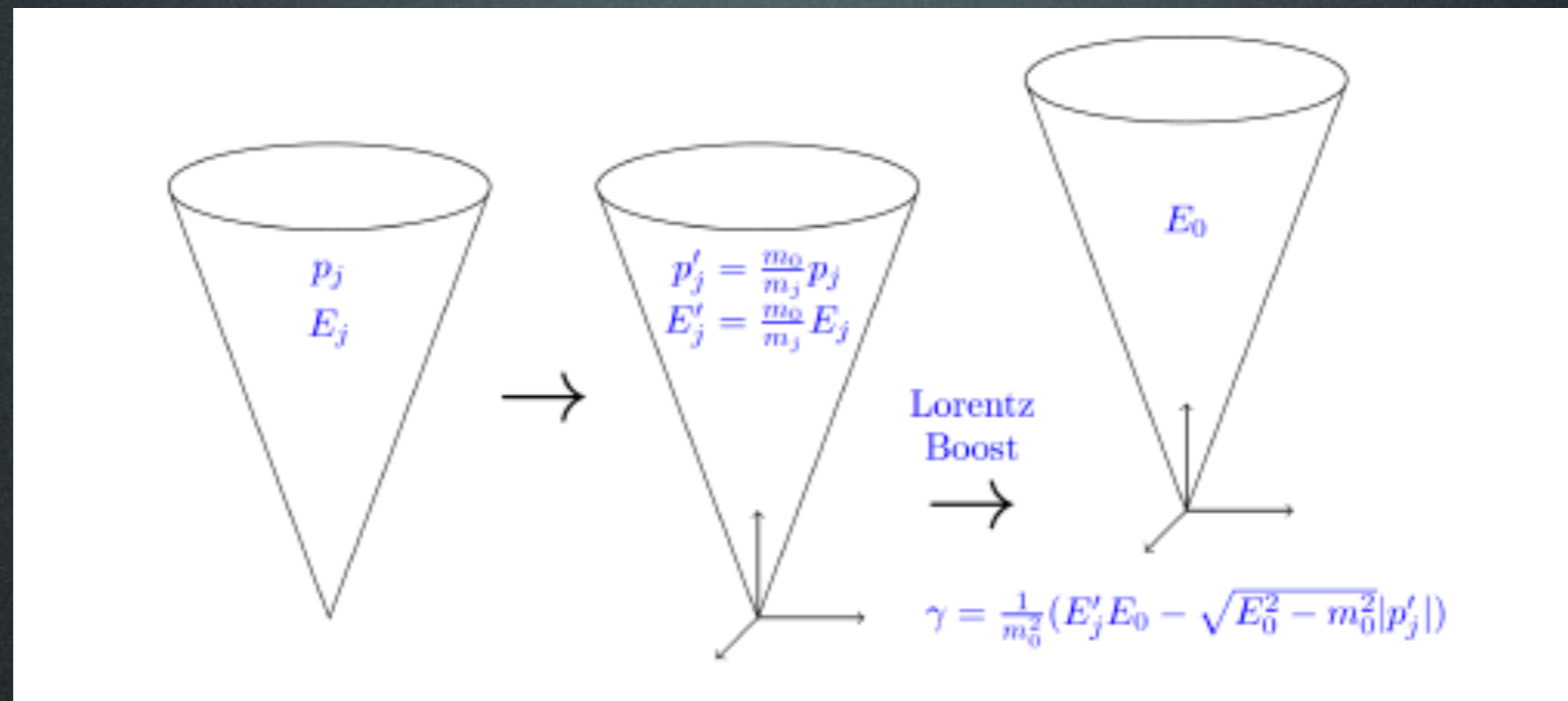
Based on:

Tuhin S Roy and Aravind H Vijay. A robust anomaly finder based on autoencoder.  
*arXiv preprint arXiv:1903.02032*, 2019.

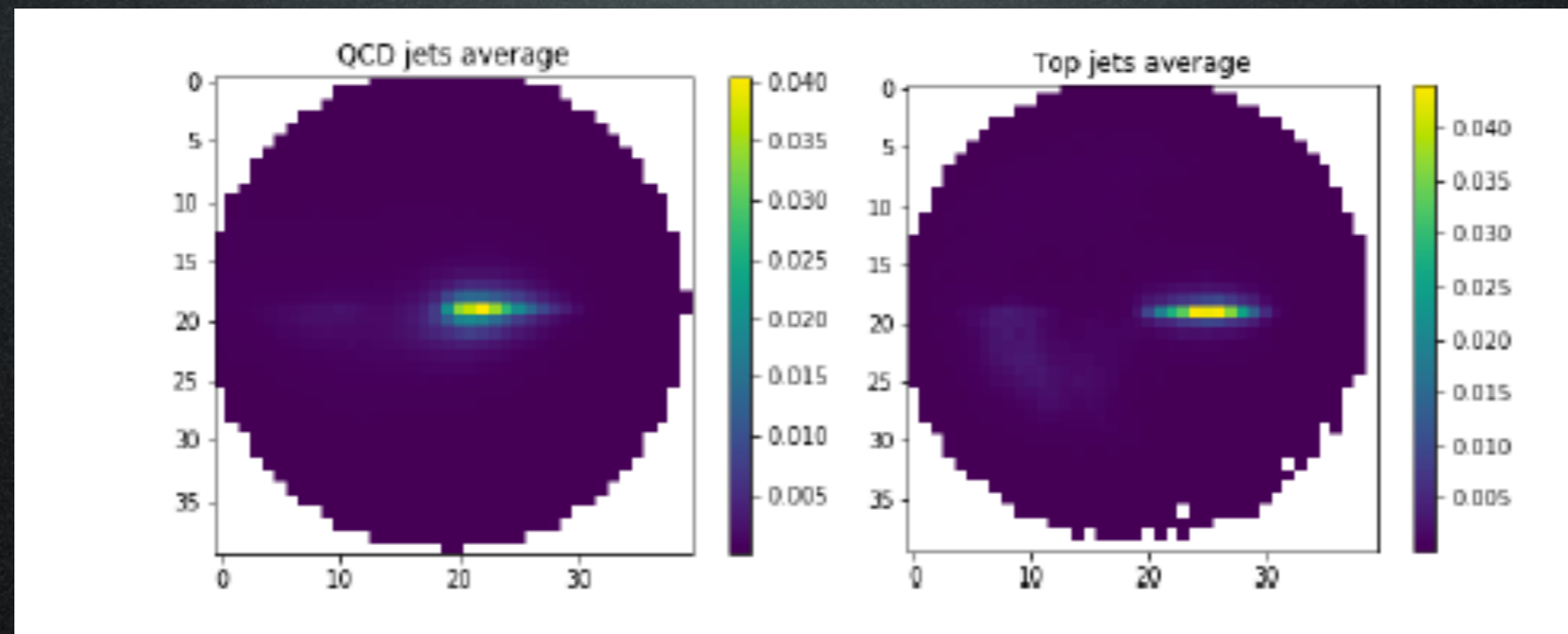


With  
Kokotla  
Rapetsoa

Step 1:



Step 2:



Step 3:

