LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

[Search for vector-like quarks]

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IDPASC Workshop - June 26, 2020

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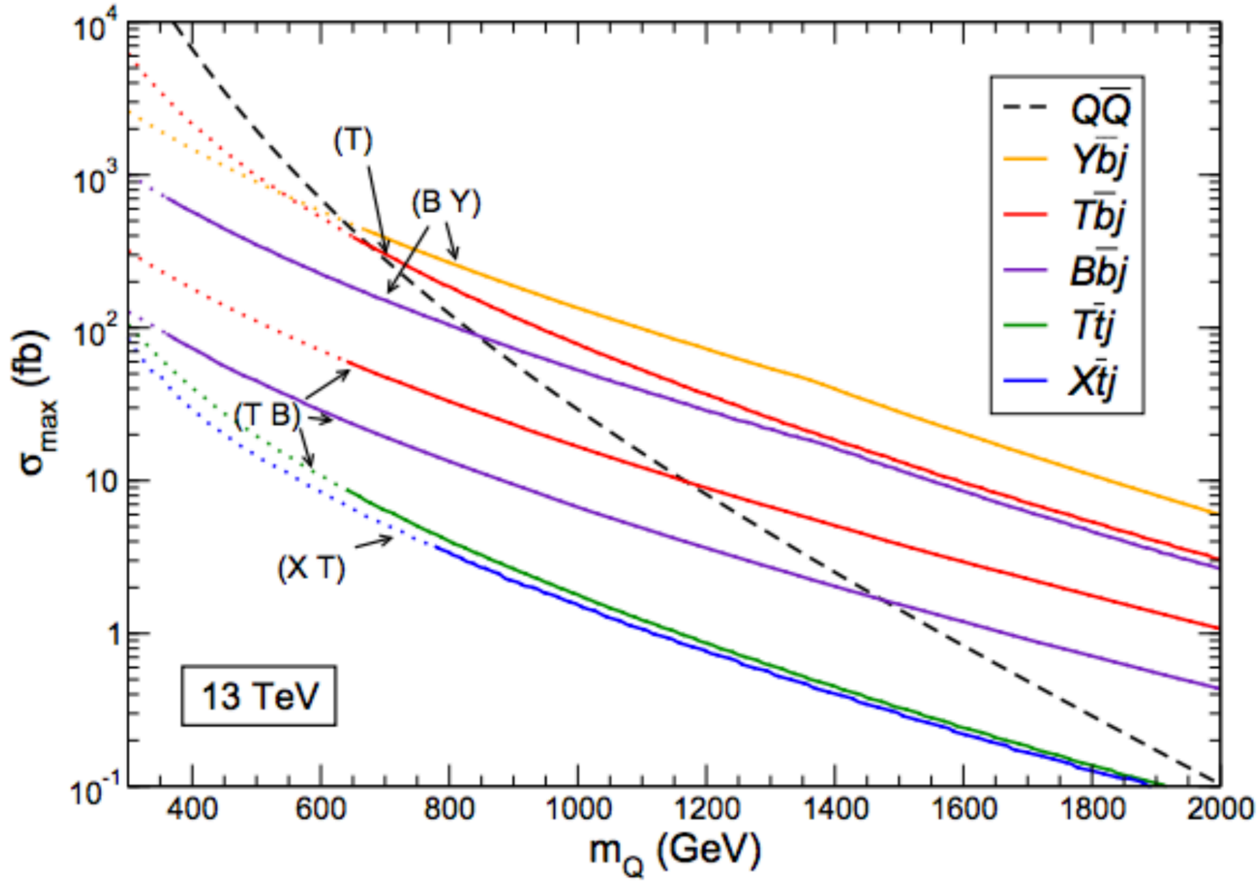
VLQ
Introduction

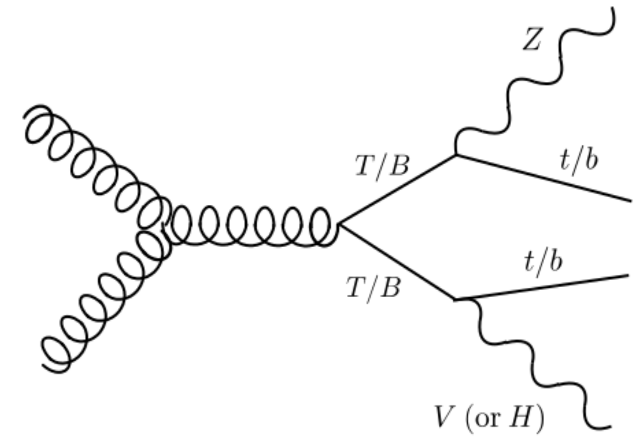


- Same SU(2) representation for left and right-handed chiralities
  - Allows for a Dirac mass term
  - Motivated by many BSM theories that tackle the naturalness problem (eg. Composite Higgs models, Extra Dimensions)

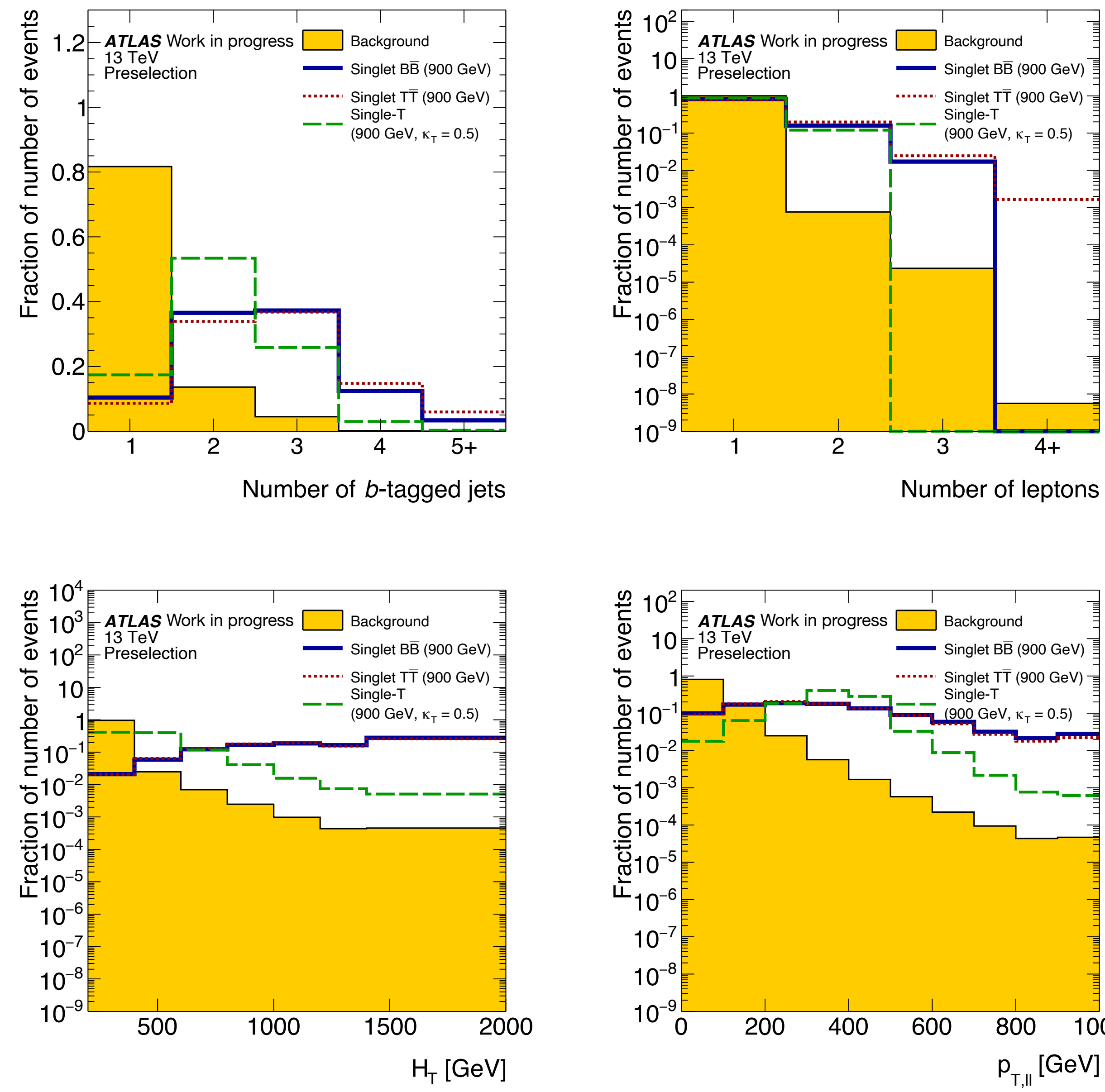
- Can be singlets, doublets or triplets

- Can be pair and single produced
  - Pair production via QCD → fairly model independent
  - Single production via EW → bigger model dependency
    - Dominant mechanism for higher VLQ masses

Analysis
Goal



- Search for pair production of VLQ
- Looking for VLT and VLB
- Targeting a leptonic decay of a Z boson and a third generation quark
- Channels split into dilepton (TU Dortmund) and trilepton (LIP)
- Optimised individually
- DNN tagger used to categorize signal regions:
  V, H, top and background jets
- Statistical combination afterwards

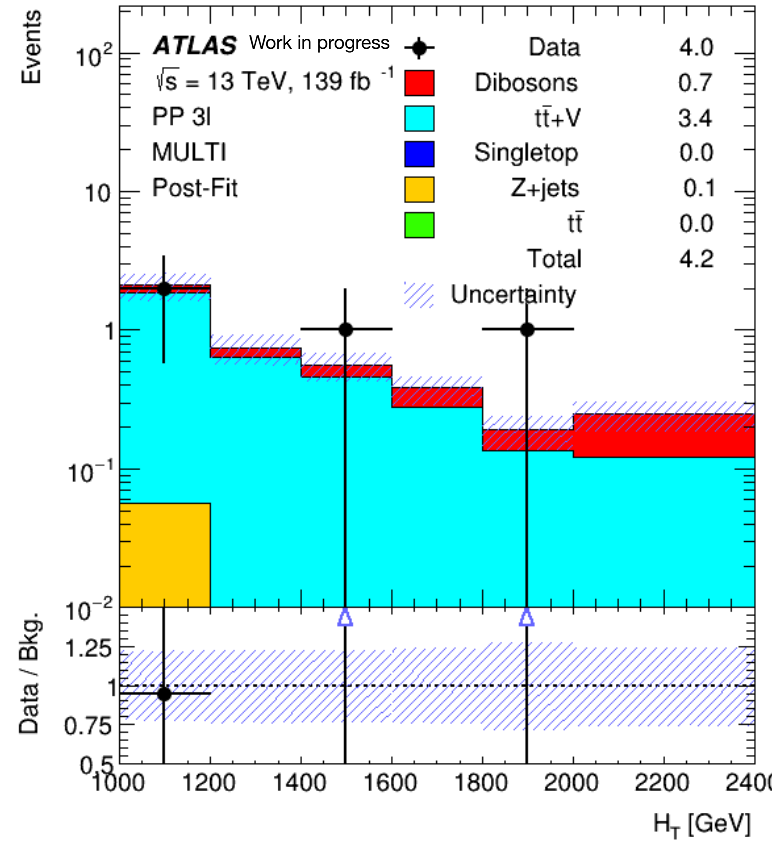


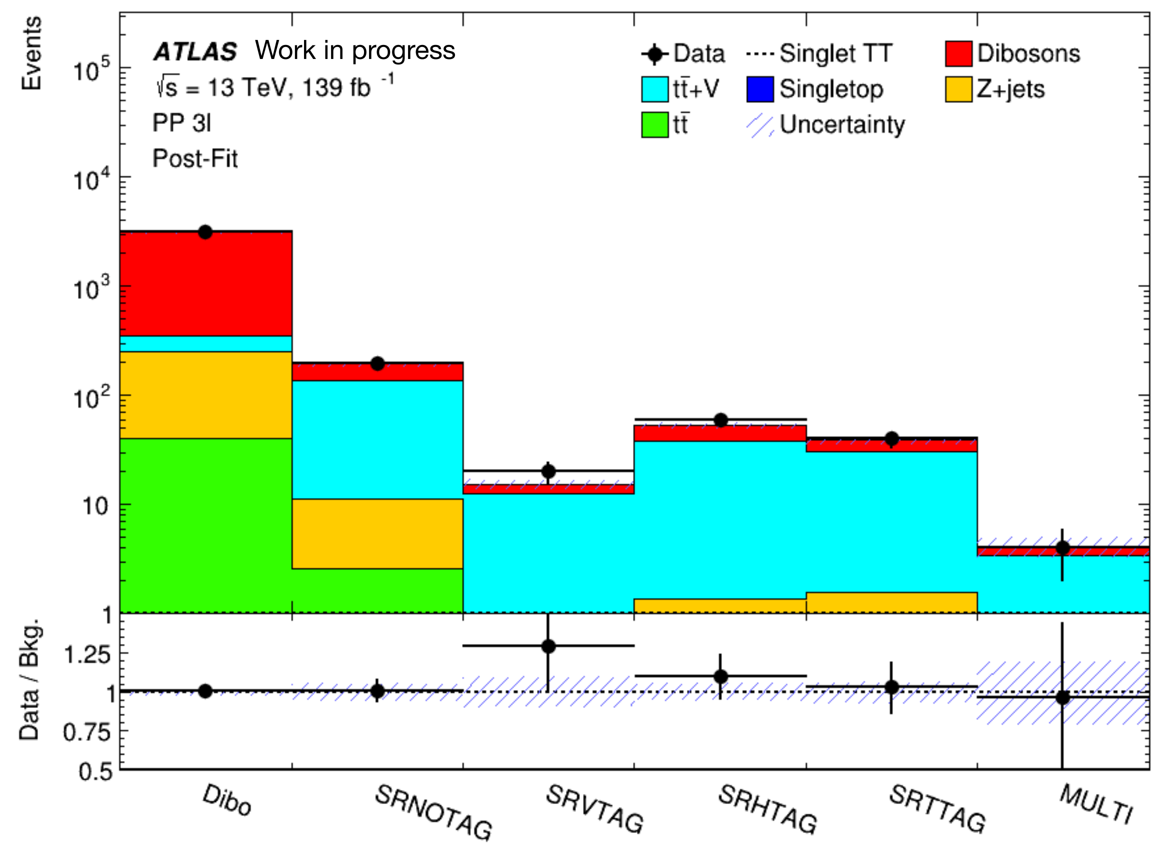
Trilepton Channel

VV unblinded region	Signal enriched regions
2 central jets with $p_{\mathrm{T}} > 25\,\mathrm{GeV}$	
≥ 3 leptons with $p_{\mathrm{T}} > 28\,\mathrm{GeV}$	
pair of OS-SF leptons with $\lvert m_{\ell\ell} - m_{Z} \rvert < 10\,\mathrm{GeV}$	
$H_{\mathrm{T}}(\text{jets + lep.}) > 300\,\mathrm{GeV}$	
$= 0$ b-tagged jets	≥ 1 b-tagged jet
	$p_{\mathrm{T}}(Z) \geq 200\,\mathrm{GeV}$

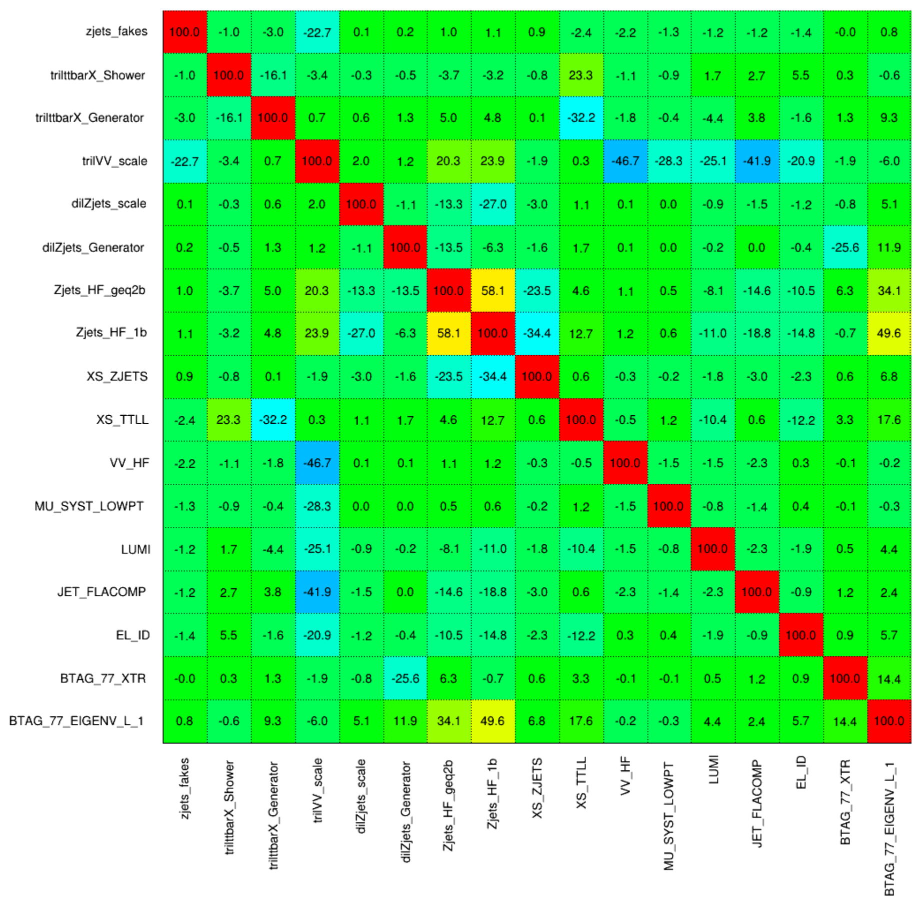
Name	# V tags	# H tags	# top tags
NOTAG	0	0	0
VTAG	≥ 1	0	0
HTAG	0	≥ 1	0
TTAG	0	0	≥ 1
MULTI	0	≥ 1	≥ 1
	≥ 1	0	≥ 1
	≥ 1	≥ 1	0
	≥ 1	≥ 1	≥ 1

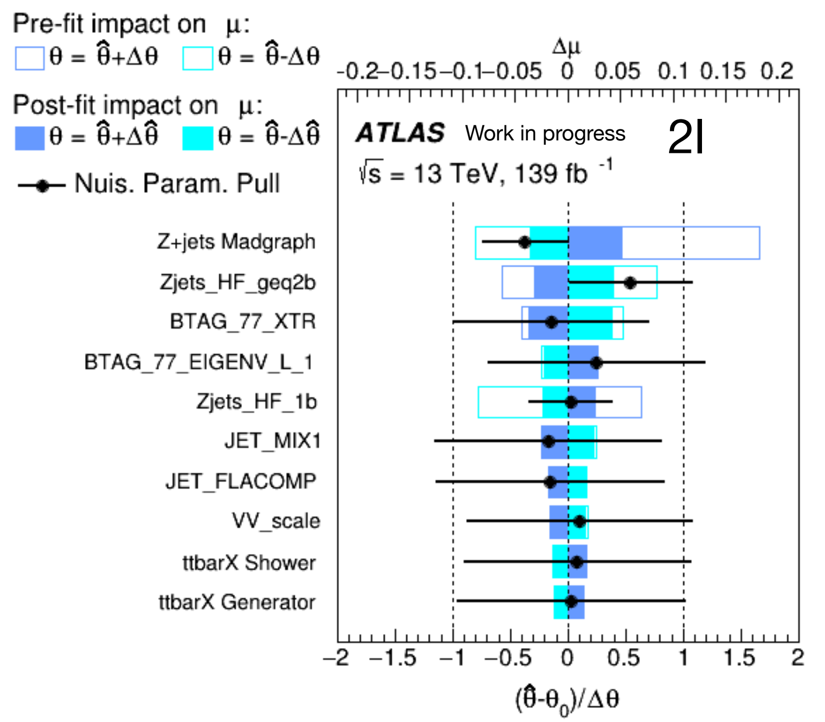
- 0 b-tags region for dibosons
- High pT(Z) signal regions
- HT(jets + leptons) as the discriminant variable

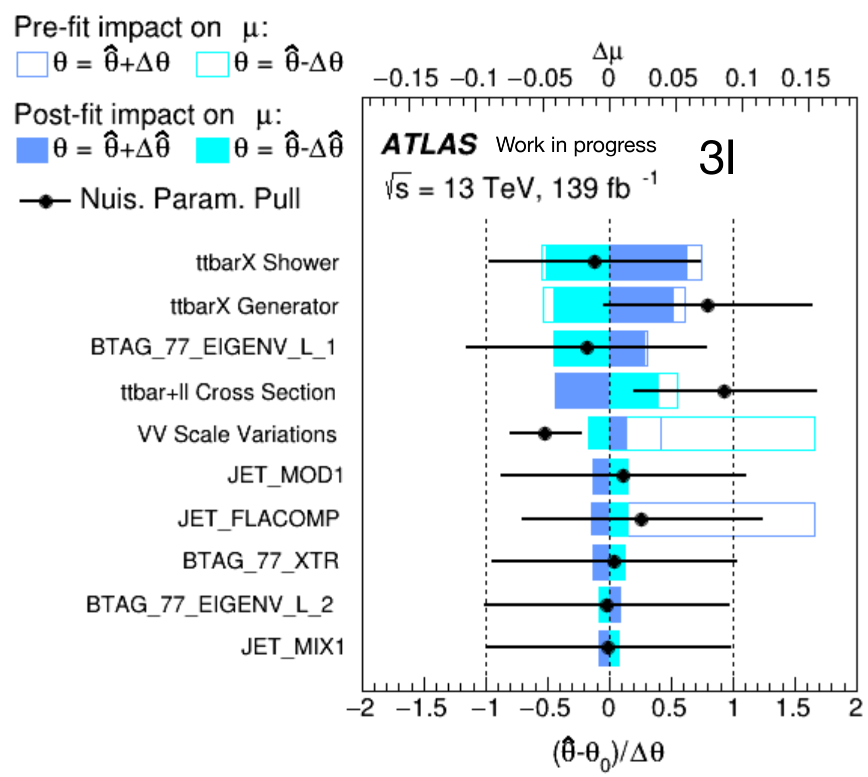


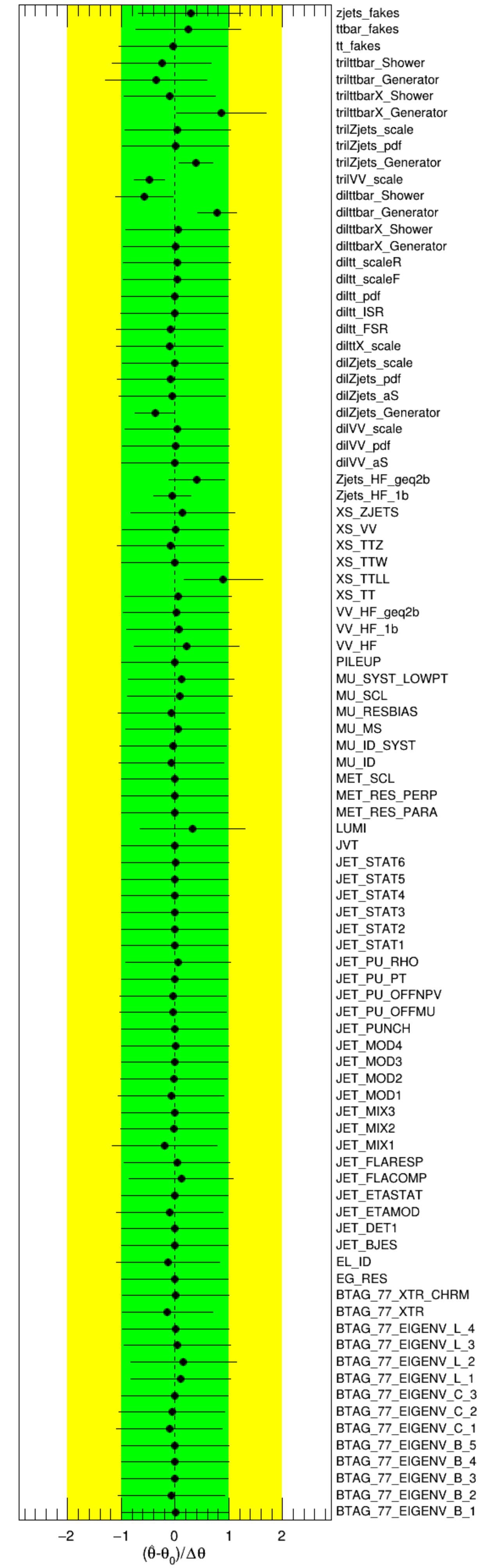


B-only Fit





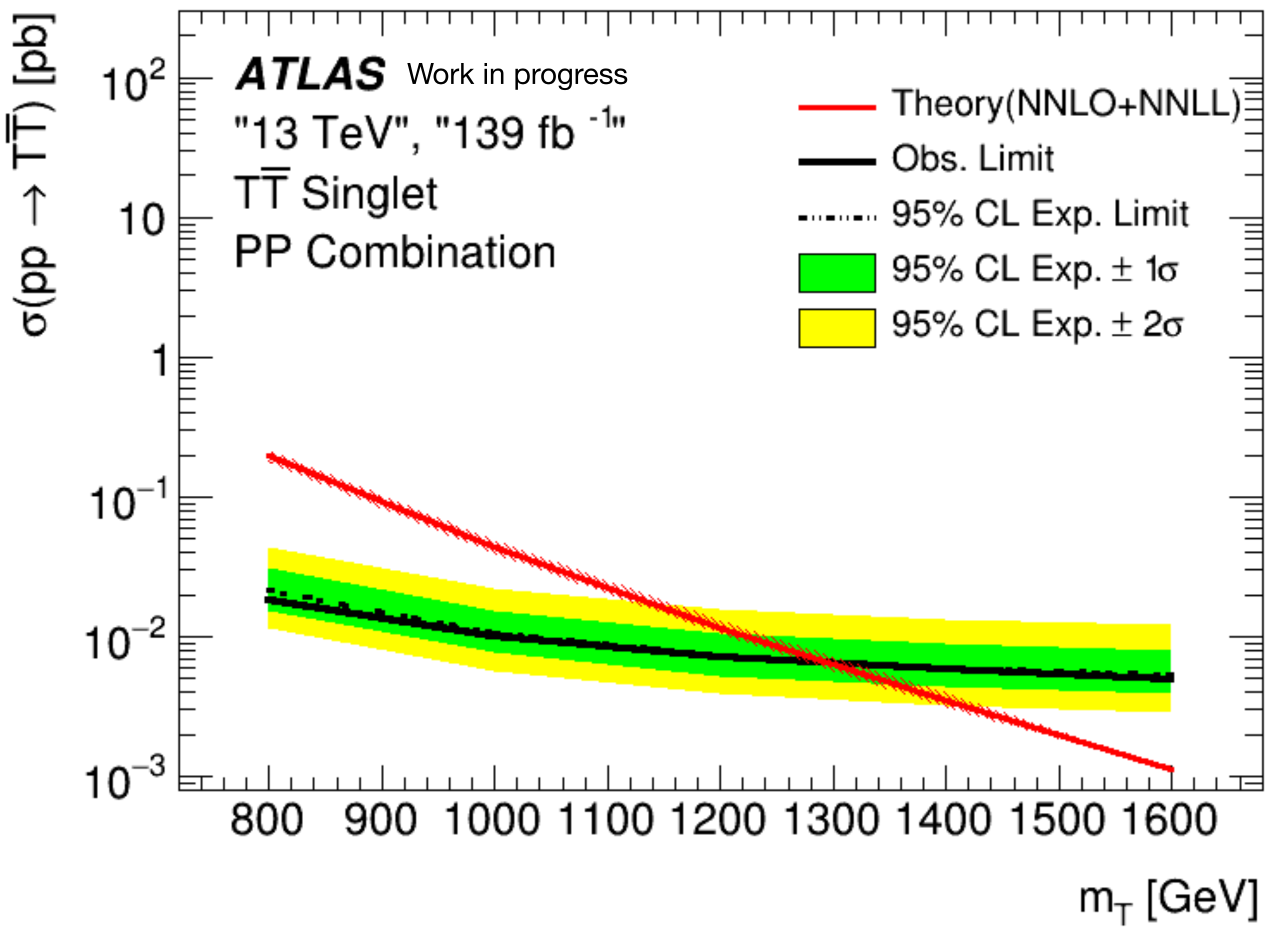


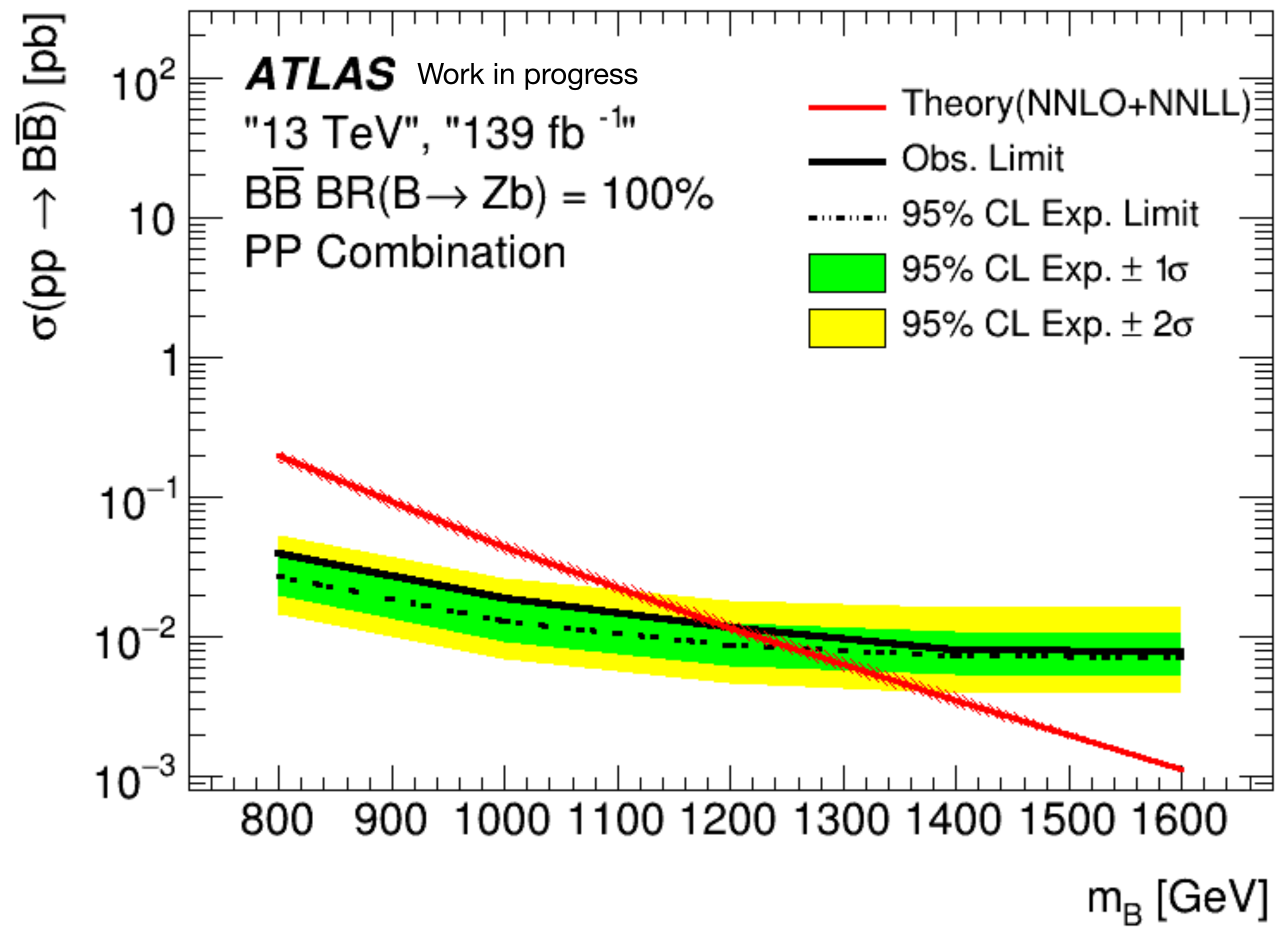


Uncorrelated modelling systematics
Fit seems to be stable
No visible changes in the pulls from the individual channels

Combined mass

Limits





	VLT [GeV] obs (exp)	VLB [GeV] obs (exp)
singlet	1275 (1270)	1200 (1240)
doublet	1455 (1430)	1300 (1375)
100% BR	1600 (1560)	1425 (1470)

A lot more info in backup

Deep Learning
Transferability

https://journals.aps.org/prd/abstract/10.1103/PhysRevD.101.035042

PHYSICAL REVIEW D **101,** 035042 (2020)

Transferability of deep learning models in searches for new physics at colliders

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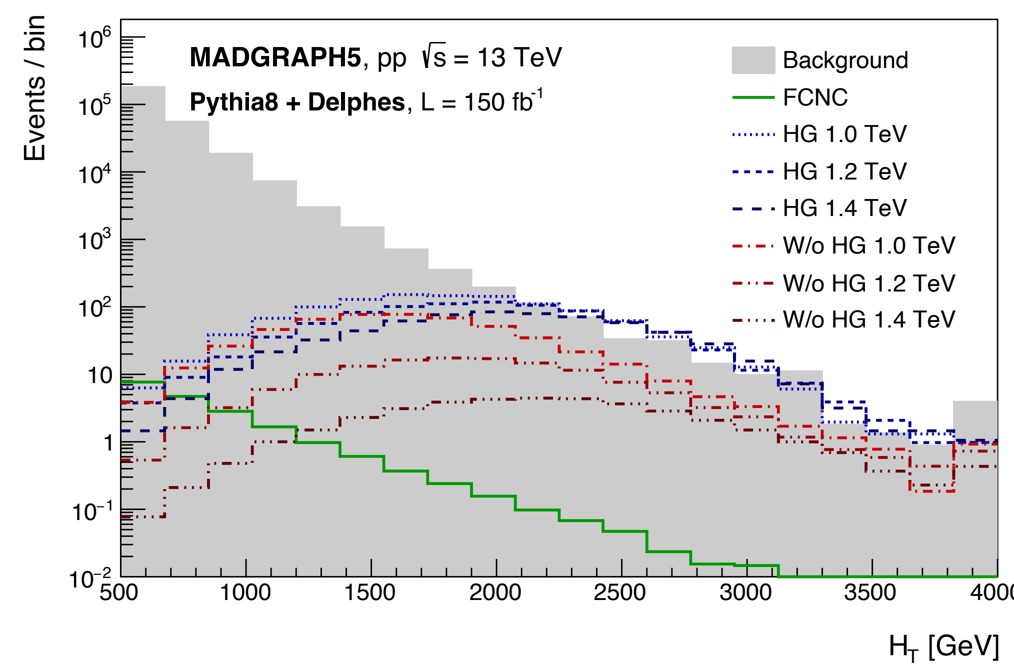
In this work we assess the transferability of deep learning models to detect beyond the standard model signals. For this we trained deep neural networks on three different signal models: tZ production via a flavor changing neutral current, pair production of vectorlike T-quarks via standard model gluon fusion and via a heavy gluon decay in a grid of three mass points: 1, 1.2 and 1.4 TeV. These networks were trained with $t\bar{t}$, $Z+$jets and dibosons as the main backgrounds. Limits were derived for each signal benchmark using the inference of networks trained on each signal independently, so that we can quantify the degradation of their discriminative power across different signal processes. We determine that the limits are compatible within uncertainties for all networks trained on signals with vectorlike T-quarks, whether they are produced via heavy gluon decay or standard model gluon fusion. The network trained on flavor changing neutral current signal, while struggling the most on the other signals, still produces reasonable limits. These results indicate that deep learning models are capable of providing sensitivity in the search for new physics even if it manifests itself in models not assumed during training.

DOI: 10.1103/PhysRevD.101.035042

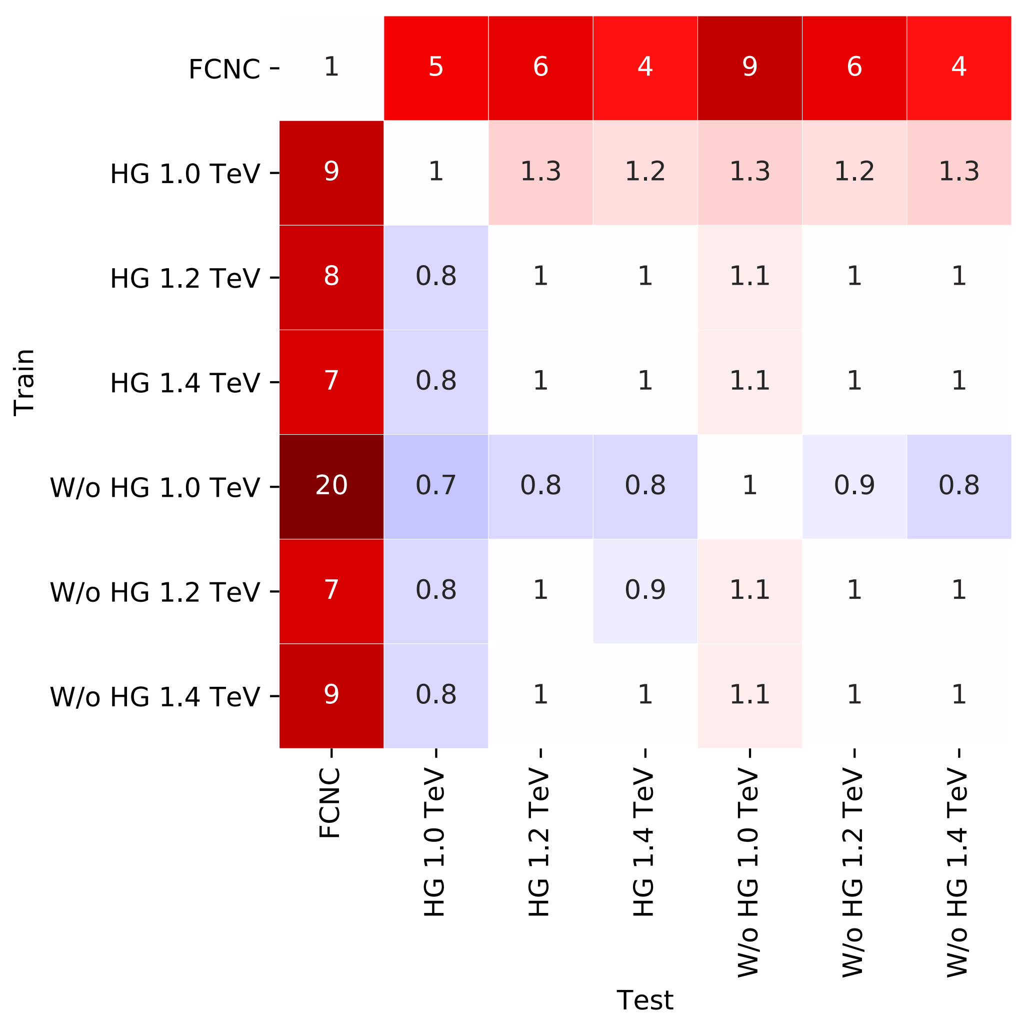
- Assess the transferability of deep learning models
- Would a new physics signal be missed in our searches if a DNN was trained on another BSM signal?
- Train a DNN on a signal sample and test on different models
- BSM models used:
  - Pair produced VLQ via QCD with 1, 1.2 and 1.4 TeV
  - VLQ via a 3 TeV heavy gluon decay (same mass grid)
  - tZ production via FCNC

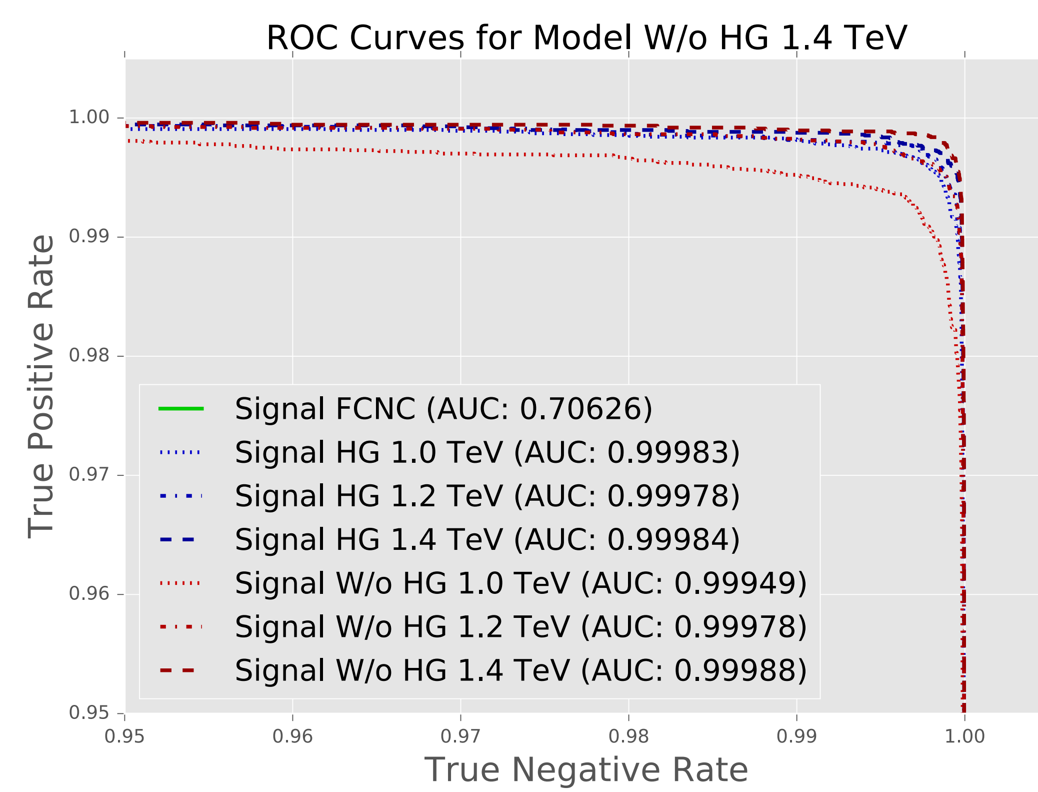


https://journals.aps.org/prd/abstract/10.1103/PhysRevD.101.035042

Deep Learning
Transferability

- Most limits are compatible within uncertainties
- This indicates that deep learning models provide sensitivity to models not included in training
- Very relevant as machine learning becomes more frequently used in searches





Final Remarks

- VLQ search ongoing
  - Highly restrictive mass exclusion limits
  - Currently going through the last steps of ATLAS approval

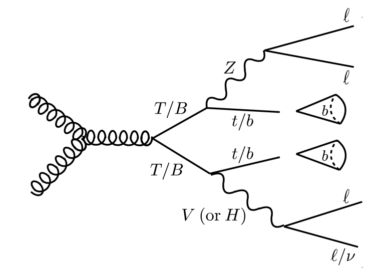
- Phenomenology studies with Machine Learning show promising results
  - Tested models show that DNN can be sensitive to different BSM signals not present during training
  - Very relevant for Exotics searches that are increasingly more reliant on machine learning

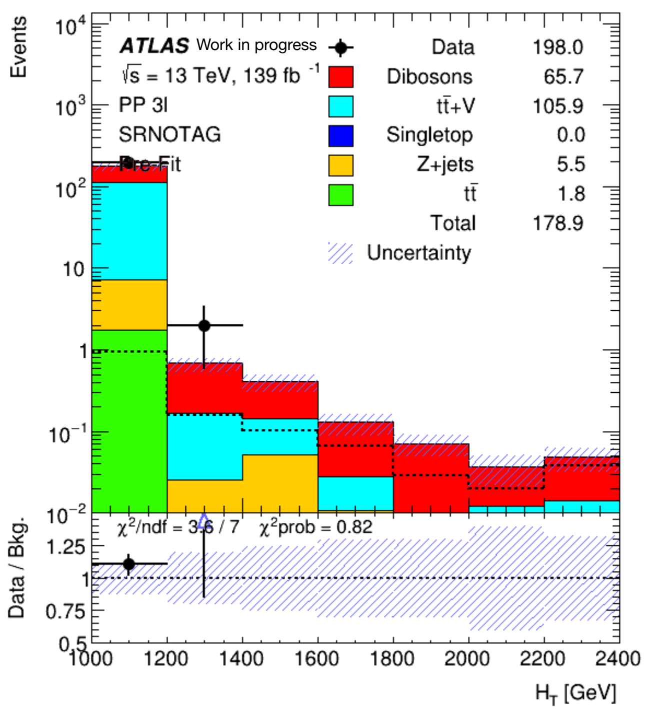
- Once the critical stage of the analysis approval is surpassed the fun of writing begins :)

Thank you!

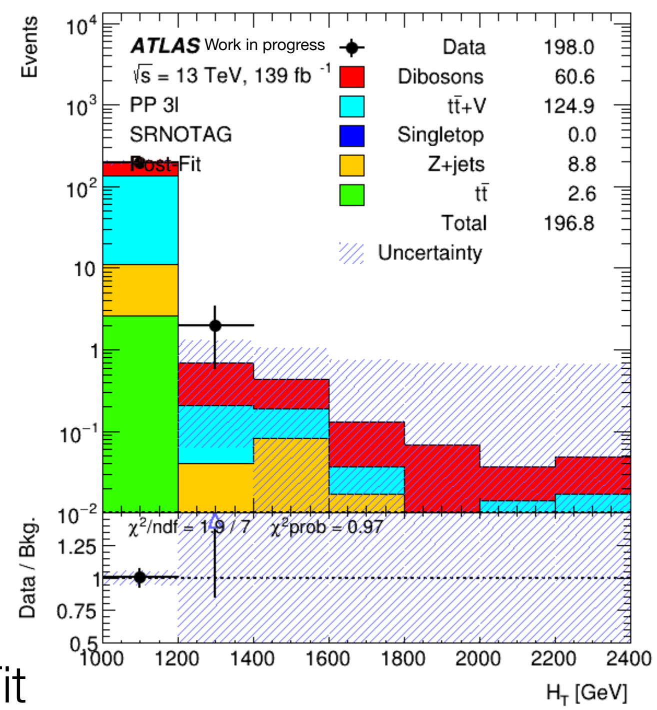
Backup

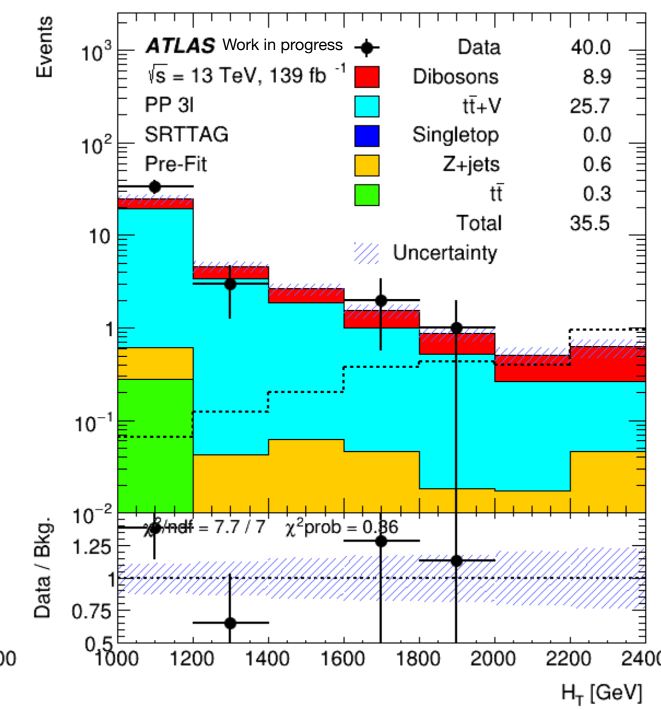
Signal
Regions





Fit





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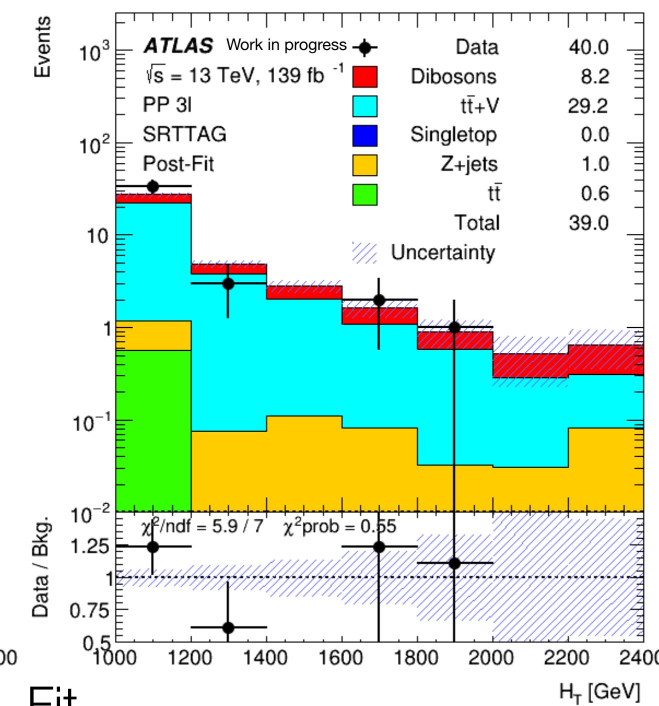
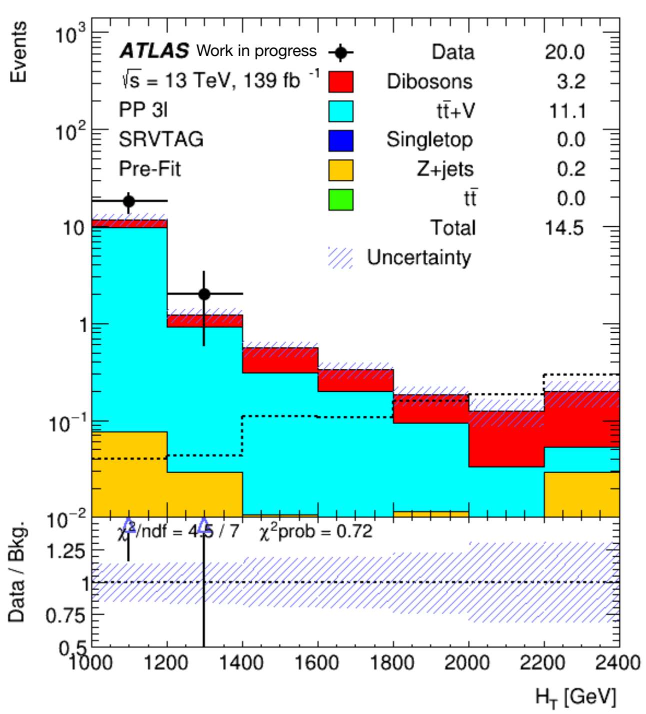
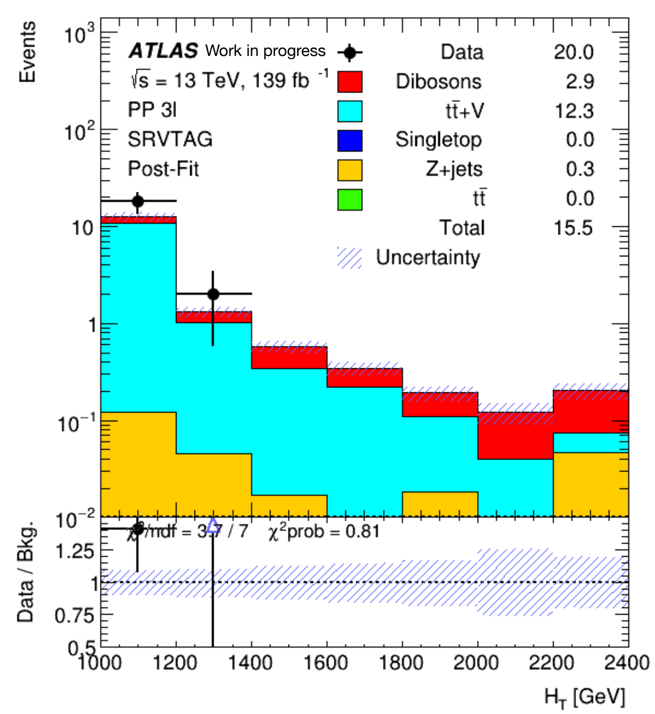
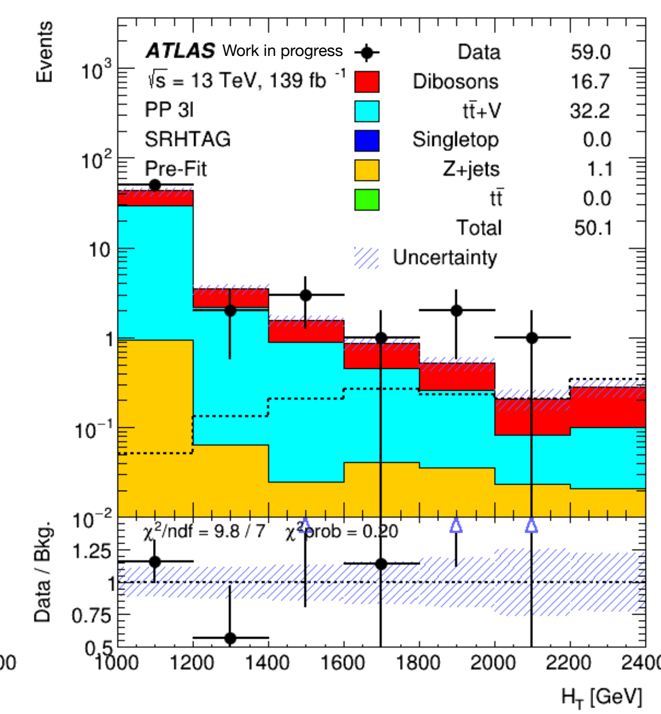
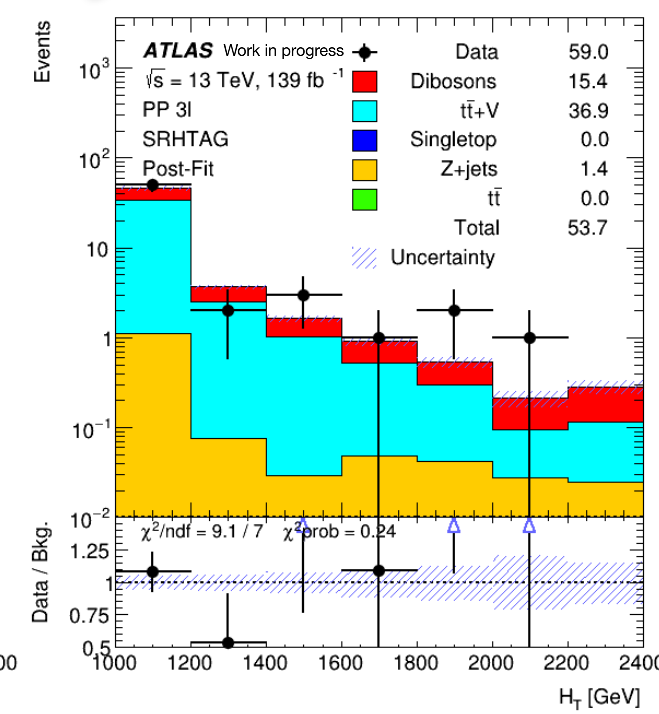


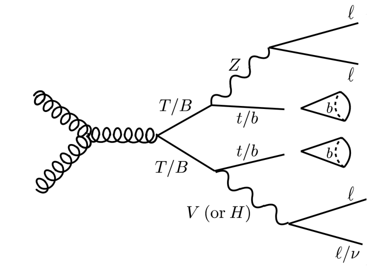


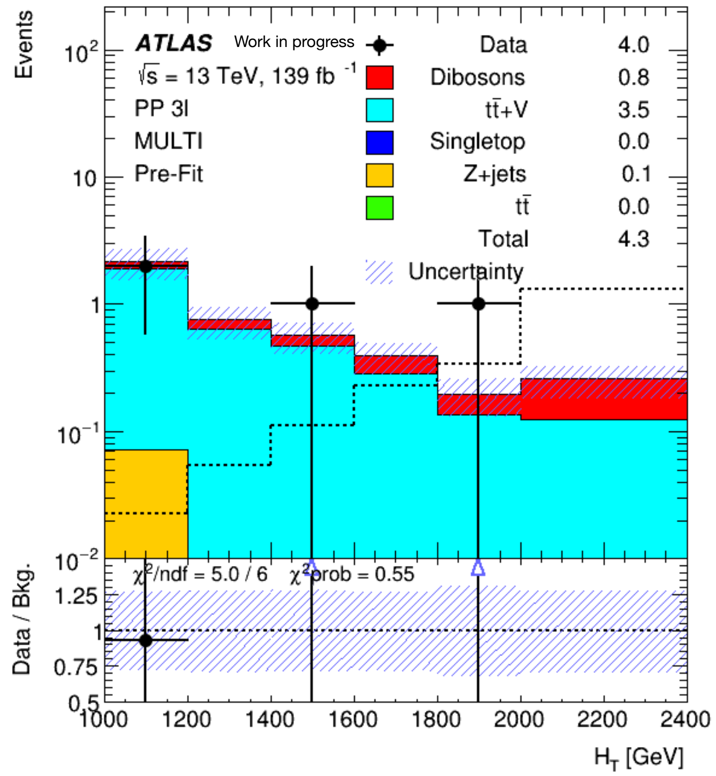






Signal
Regions





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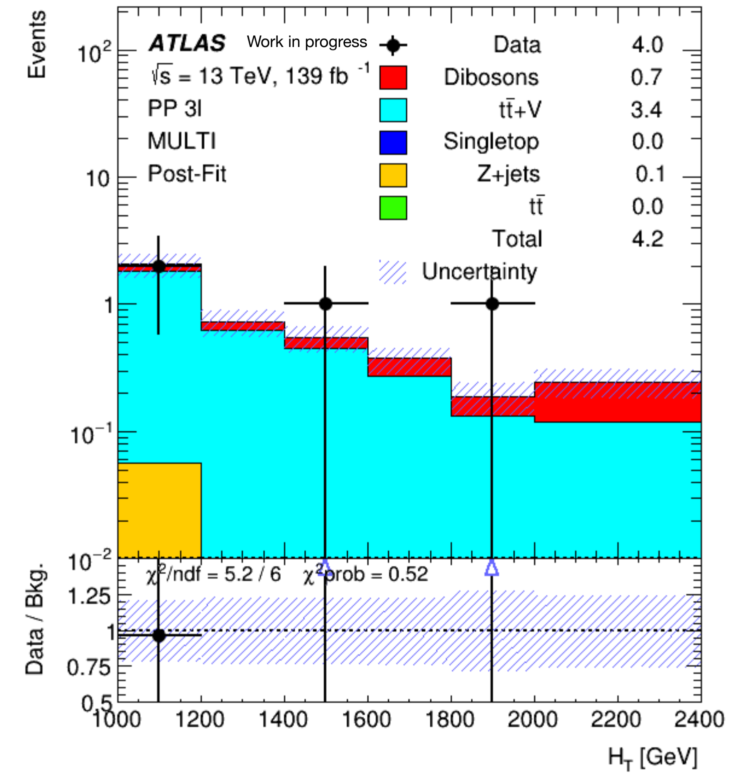
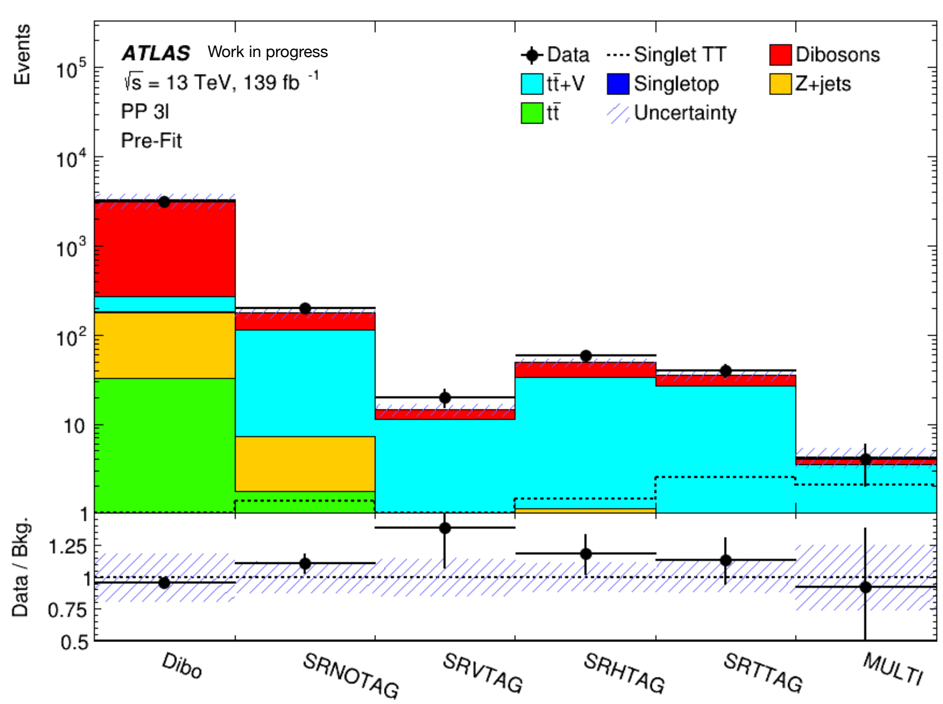
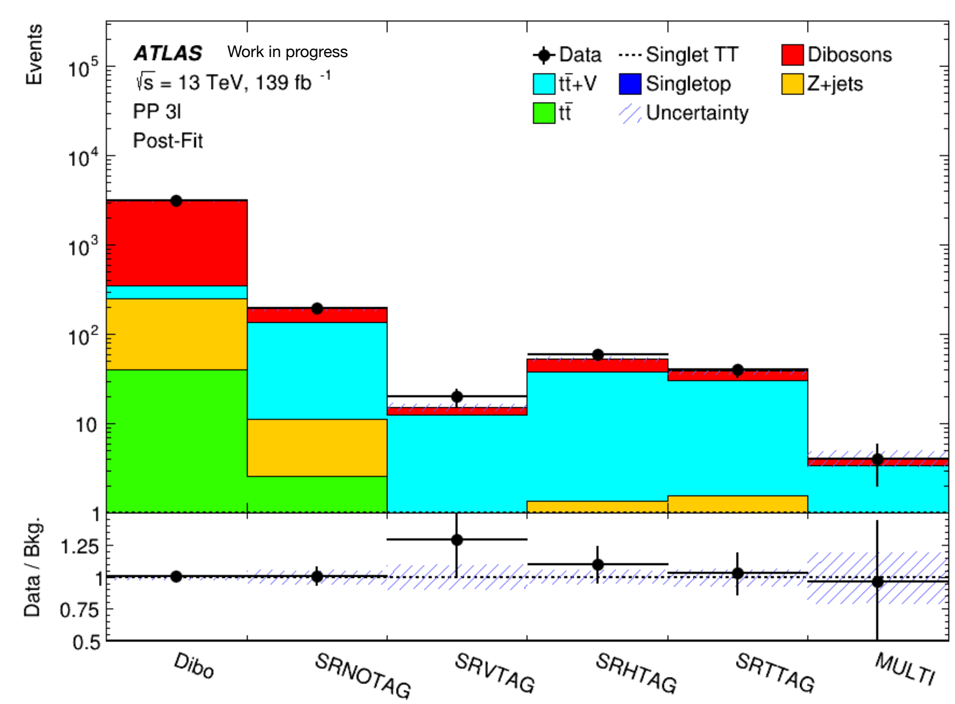
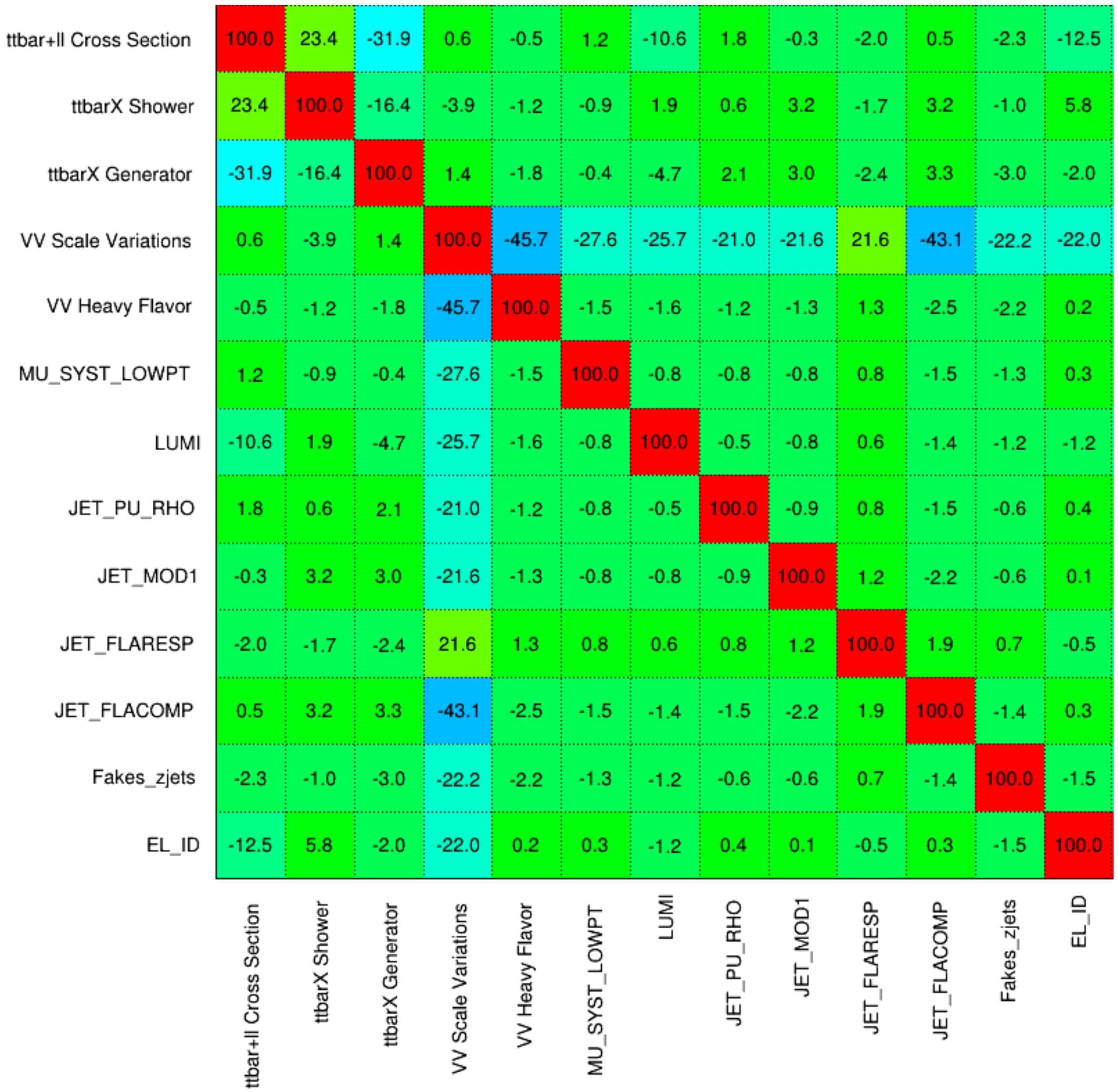


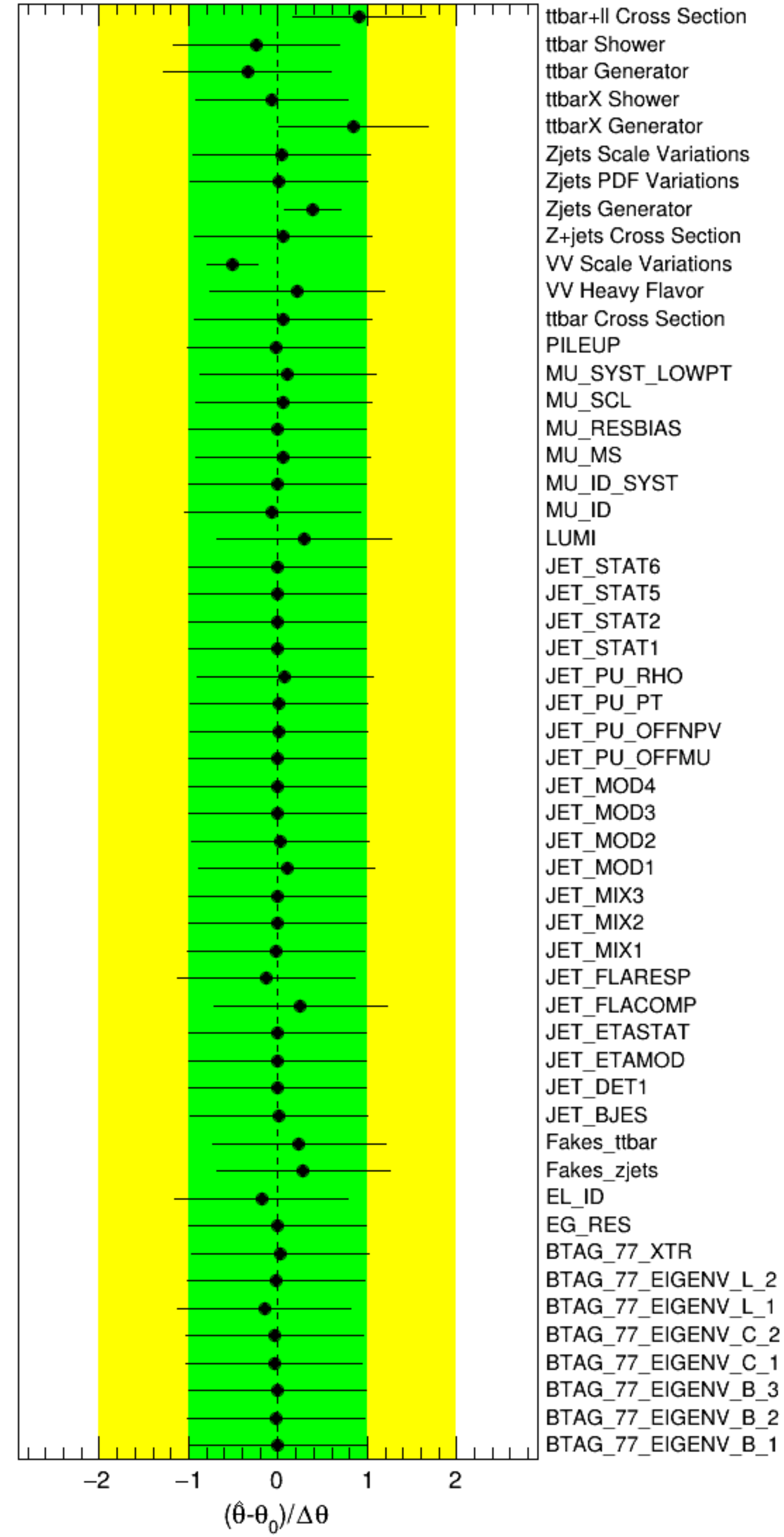




- Fair modelling in all regions

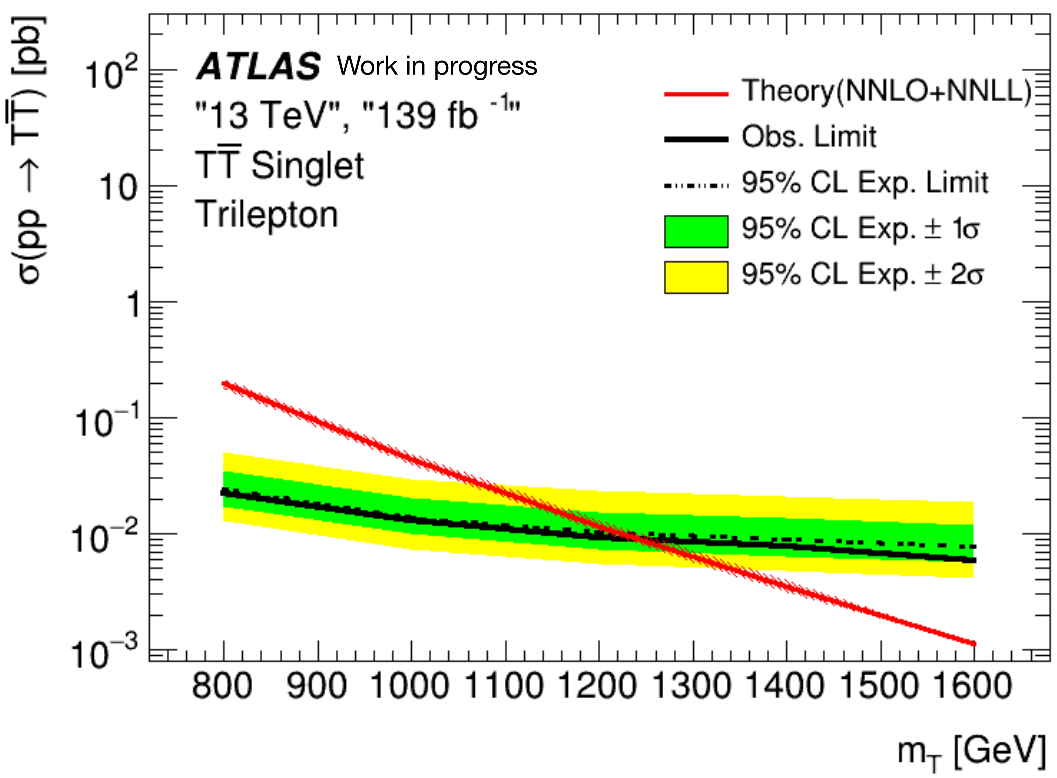
3l B-only
Fit

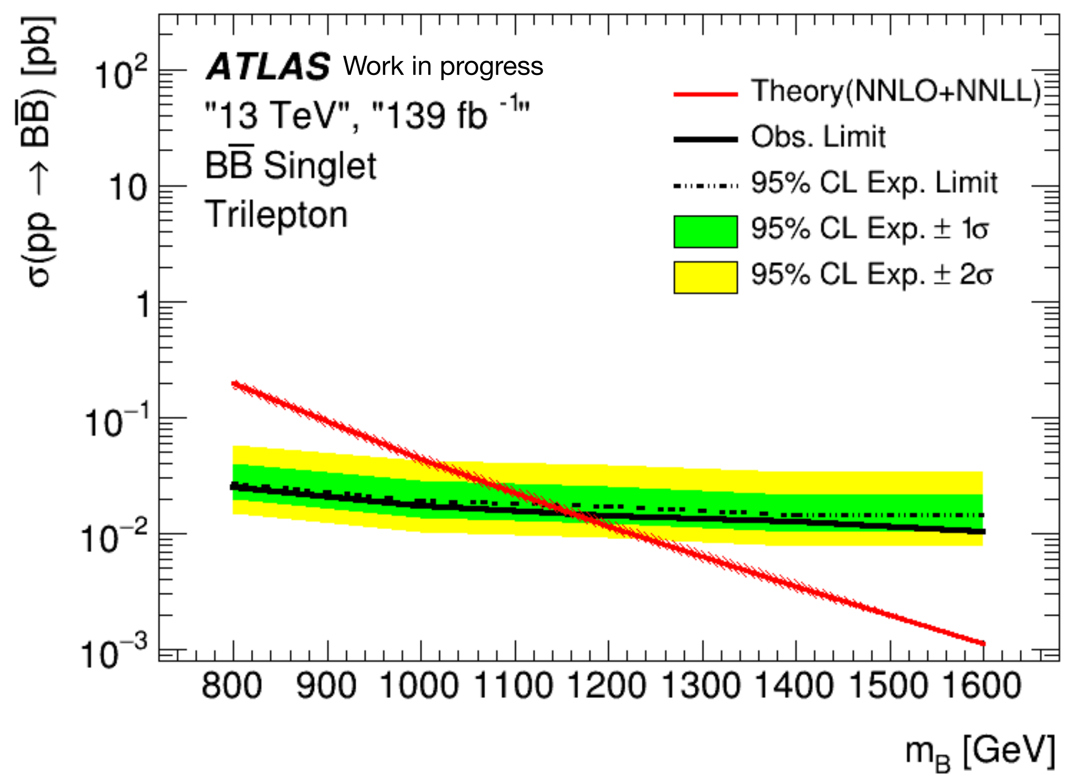




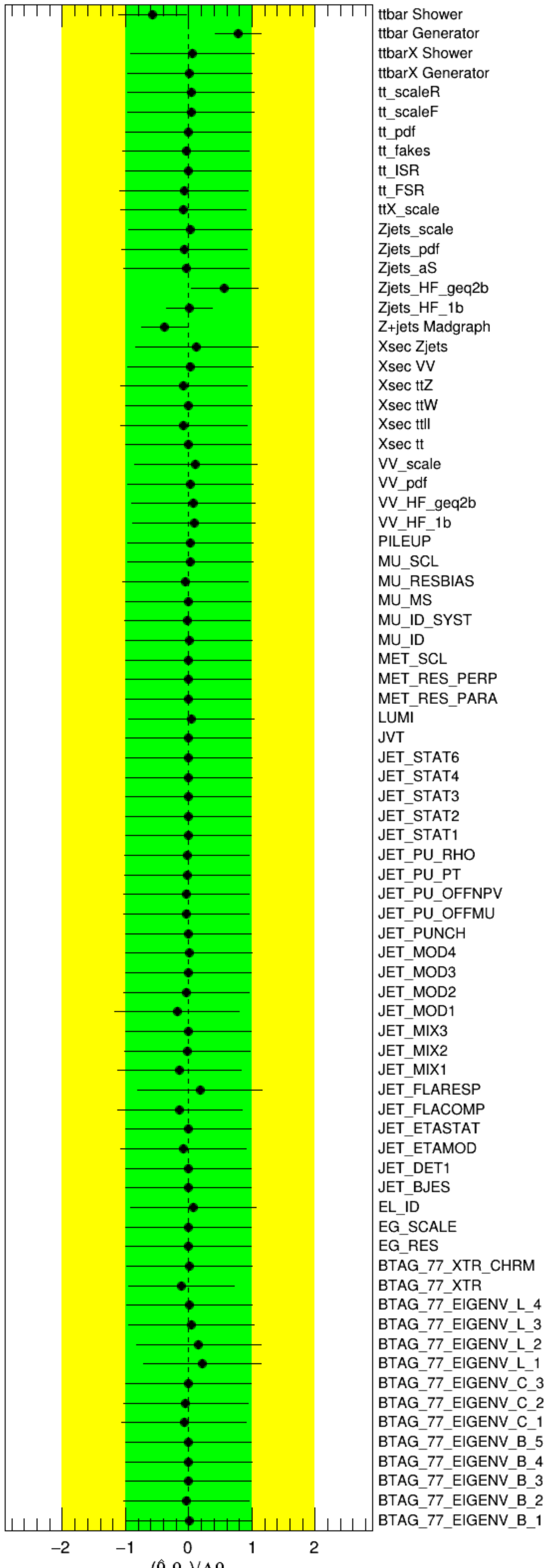
Fit seems stable

3l Mass
Limits





BR scenario	Expected limit (GeV)	Observed limit (GeV)
TTS	1215	1230
TTD	1360	1390
100% Z	1480	1535
BBS	1110	1150
BBD	1060	1070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ttbar Generator
ttbarX Shower
ttbarX Generator
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tt_scaleF
tt_pdf
tt_fakes
tt_ISR
tt_FSR
ttX_scale
Zjets_scale
Zjets_pdf
Zjets_aS
Zjets_HF_geq2b
Zjets_HF_1b
Z+jets Madgraph
Xsec Zjets
Xsec VV
Xsec ttZ
Xsec ttW
Xsec ttll
Xsec tt
VV_scale
VV_pdf
VV_HF_geq2b
VV_HF_1b
PILEUP
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MU_RESBIAS
MU_MS
MU_ID_SYST
MU_ID
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MET_RES_PERP
MET_RES_PARA
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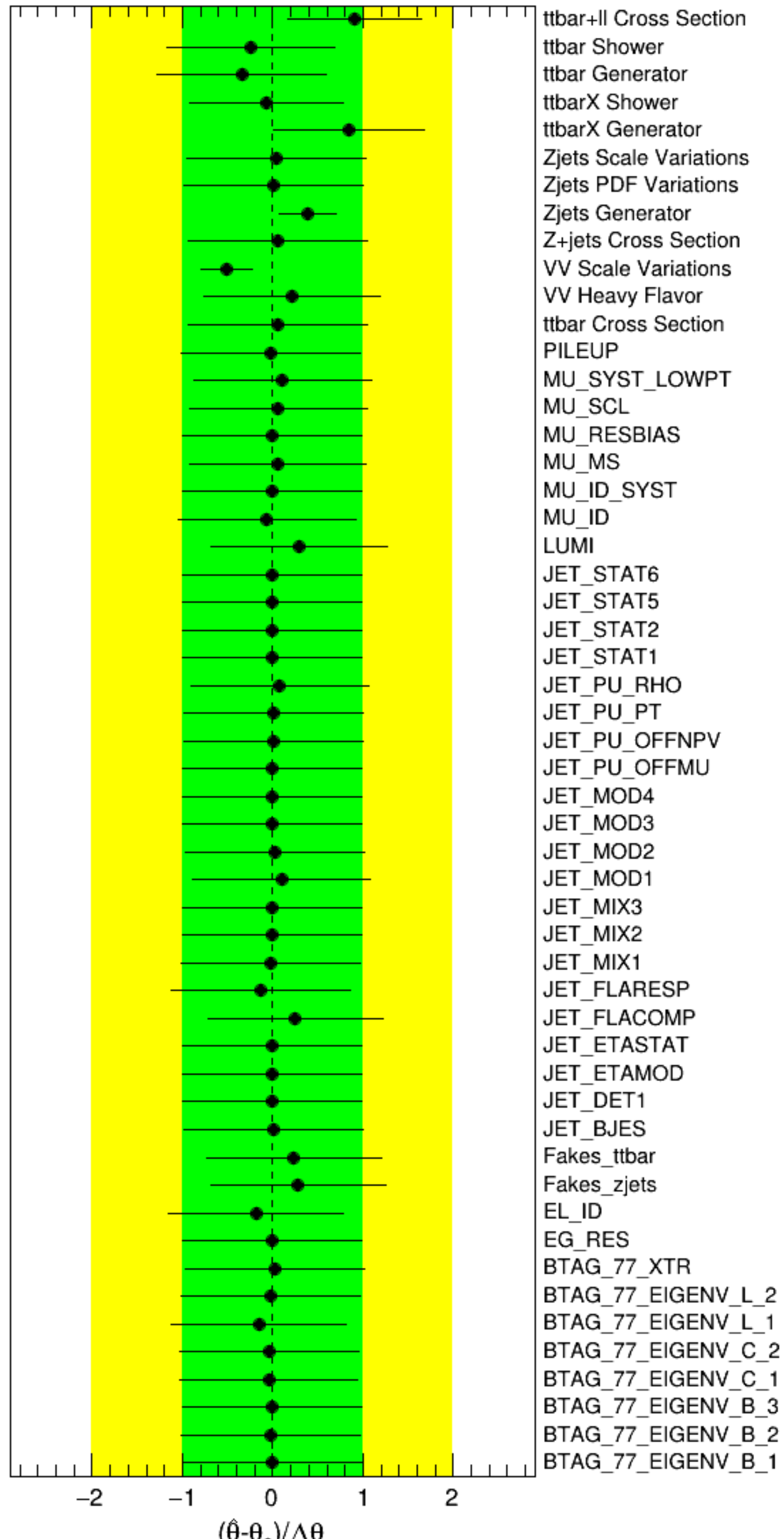
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ttbar Shower
ttbar Generator
ttbarX Shower
ttbarX Generator
Zjets Scale Variations
Zjets PDF Variations
Zjets Generator
Z+jets Cross Section
VV Scale Variations
VV Heavy Flavor
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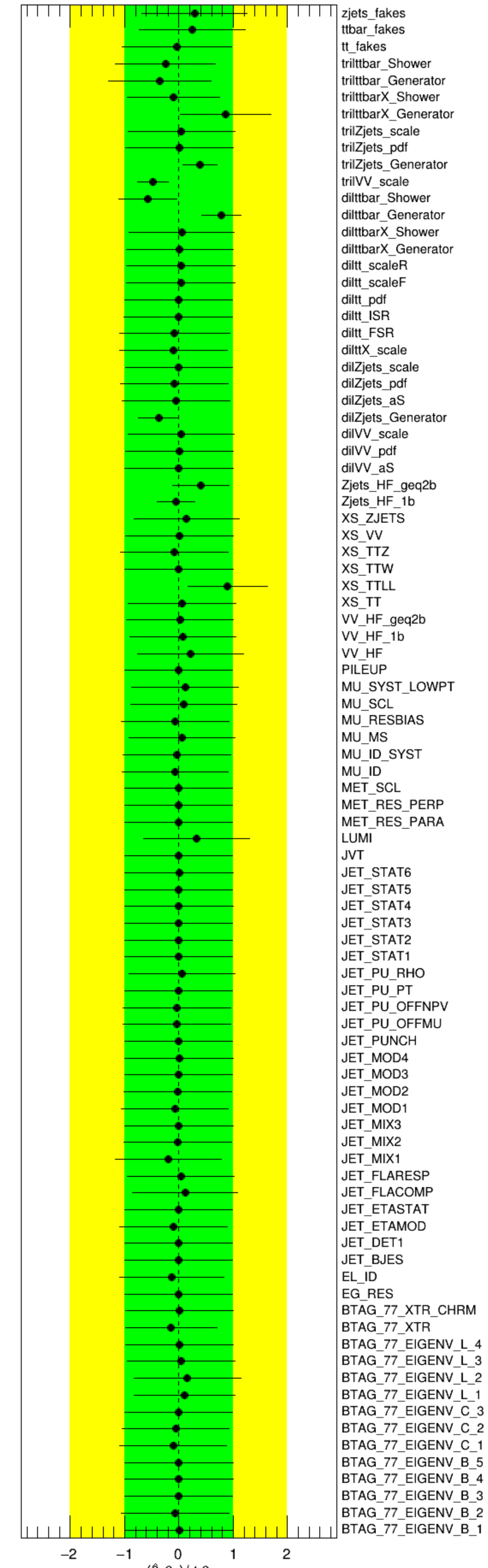
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