# New dark matter searches with $E_{miss}^{T}$ + $bb$ final states at ATLAS

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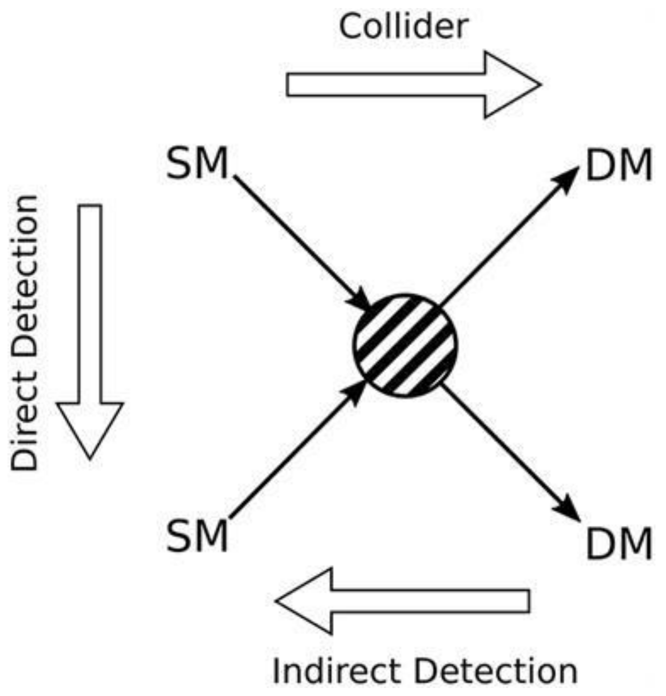
# Introduction

- Dark matter (DM) may be composed of weakly interacting massive particles (WIMPs)
- WIMPs could be produced in pairs at the LHC via the decay of a new mediator particle that couples to SM quarks
- The lightest supersymmetric particle (LSP) is a DM WIMP candidate

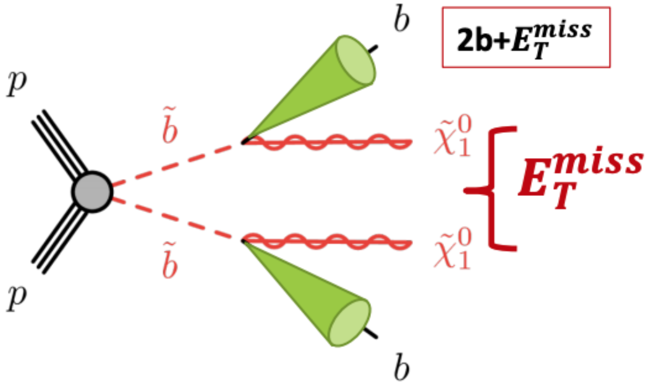


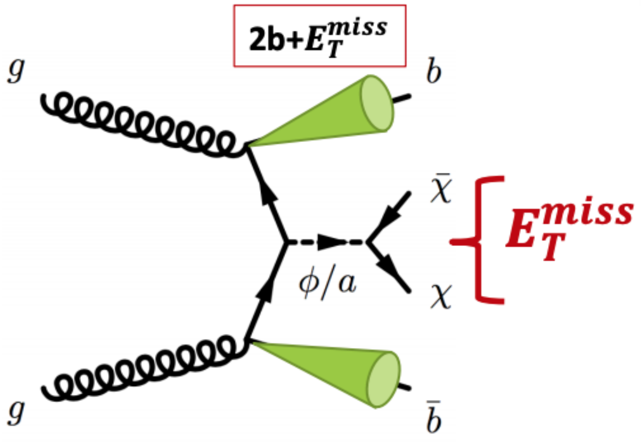
# Introduction

- Analysis searching for new physics in final states with 0 lepton, 2 b-jets and missing transverse energy (MET)

- Analysis using full run-2 139fb$^{-1}$ dataset
  - this iteration builds on two of the 36.1fb$^{-1}$ sbottom[1] and DM+bb[2] analyses due to a shared final state
  - Improvements in analysis strategy, such as the employment of machine-learning techniques and soft b-tagging

- Public as of 1st Feb 2021 [arXiv:2101.12527]





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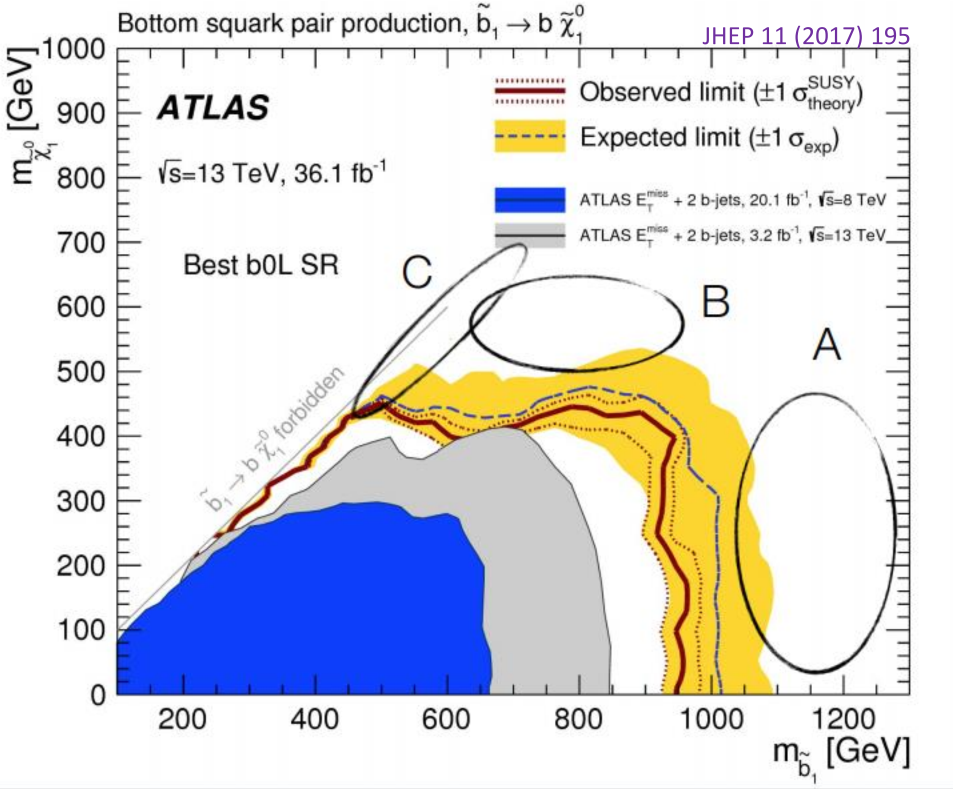
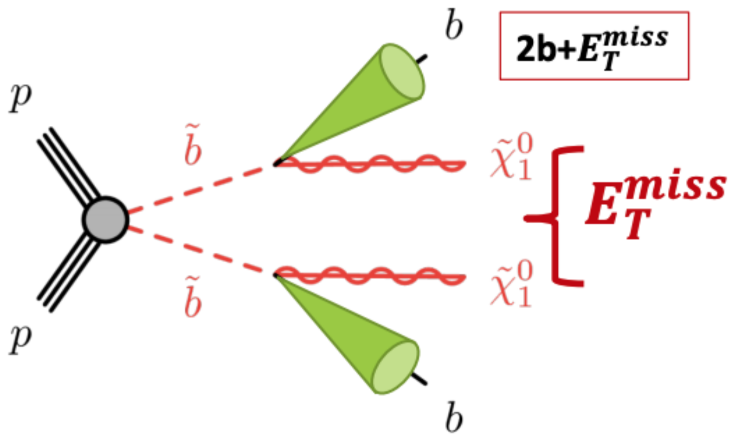
[1] arXiv:1708.09266
[2] arXiv:1710.11412

# Sbottom model

- Sbottom pair production, each decaying to a b-jet and a neutralino (LSP) with BR = 100%



JHEP 11 (2017) 195

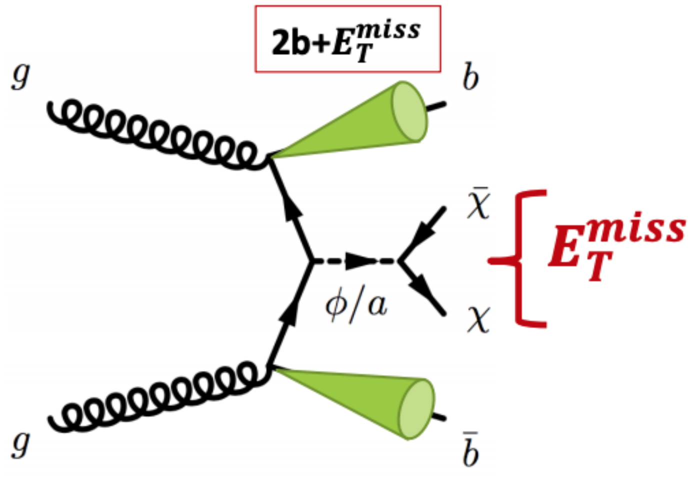


- The sbottom/ neutralino mass plane  mass plane is targeted with 3 fiducial regions
  - bulk region – **A**
  - Intermediate region – **B**
  - Compressed region - **C**

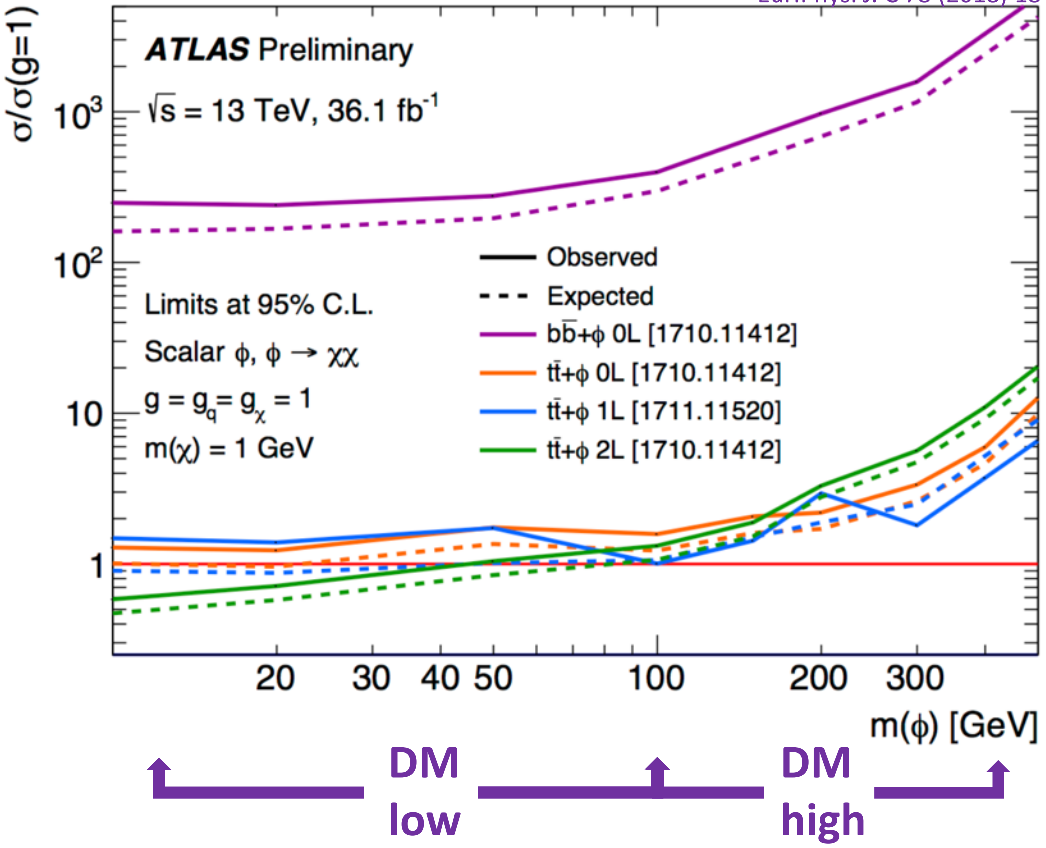
Now combined into AB to increase coverage

# Simplified DM Model

- DM production in association with b-jets, with either a scalar (ϕ) or pseudo-scalar (a) mediator to the dark sector



Eur.Phys. J. C 78 (2018) 18

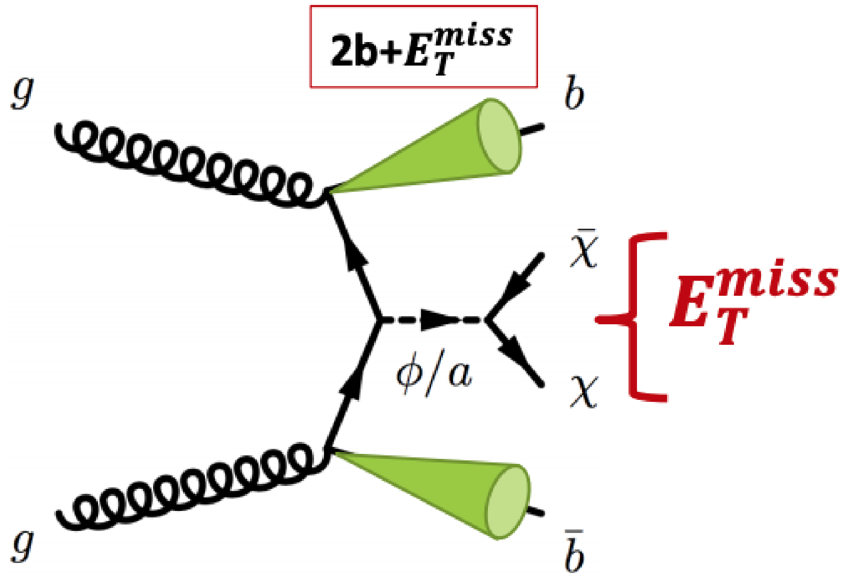


DM low

DM high

- bb+ϕ 0L behind tt+ϕ exclusions due to less sensitivity
  - **lots of room to work with!**
- Split into two regions
  - low mass mediators – **DM_low**
  - high mass mediators – **DM_high**

# Topology



Optimized to target DM by making use of a BDT
cos(ϑ)* main discriminating variable

$$\cos(b_1, b_2)^* = |\tanh\left(\frac{\Delta\eta_{bb}}{2}\right)|$$

## Low mediator mass:

10-100 GeV

- invariant bb mass peak
- lower MET
- higher angular separation of b-jets

## High mediator mass:

100-500 GeV

- peak broadens in invariant b mass
- higher MET
- less angular separation of b-jets

# Discovery Variable

## Why is cos(ϑ)* a useful variable for DM discovery?

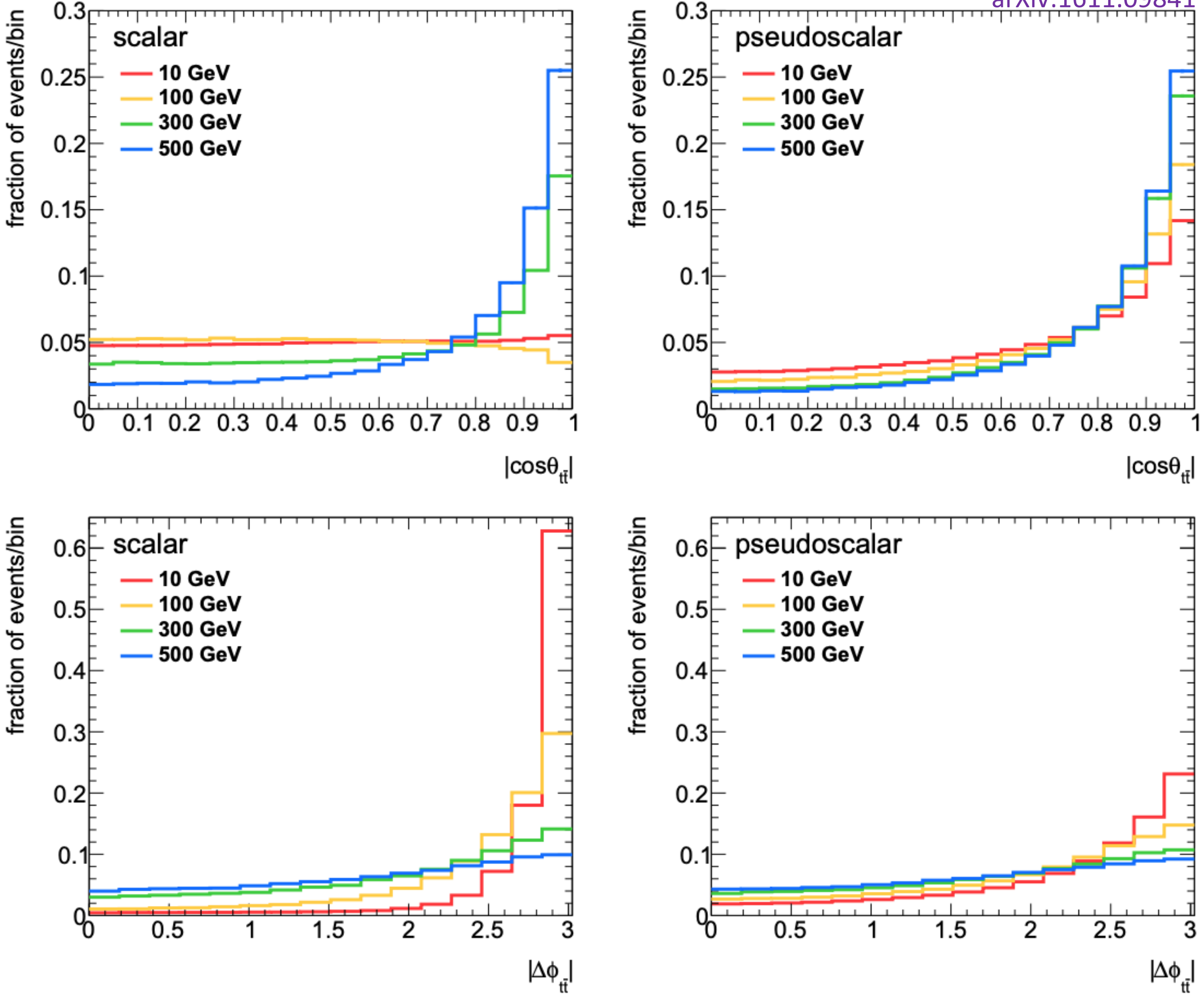
- this variable is expected to be mostly flat for SM but in general shows enhancement in high cos(ϑ)* for high mass scalar mediators and in all pseudo-scalars mediators
  - This is discussed more in detail in a paper [arXiv:1611.09841]

- These plots also show why the delta variables are useful in the BDT

$$\delta^{+} \qquad |\Delta\Phi(E_T^{\mathrm{miss}}, j^{1-3}) + \Delta\phi_{bb} - \pi|$$

$$\delta^{-} \qquad \Delta\Phi(E_T^{\mathrm{miss}}, j^{1-3}) - \Delta\phi_{bb}$$

N.B $\Delta\emptyset_{bb}$ is small for the Z(*vv*)+*bb* background from the gluon splitting process



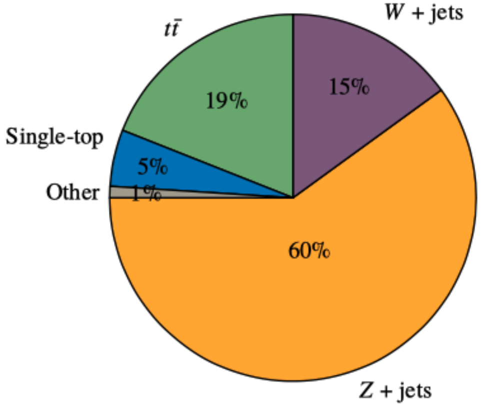
arXiv:1611.09841

# Signal Region Selections

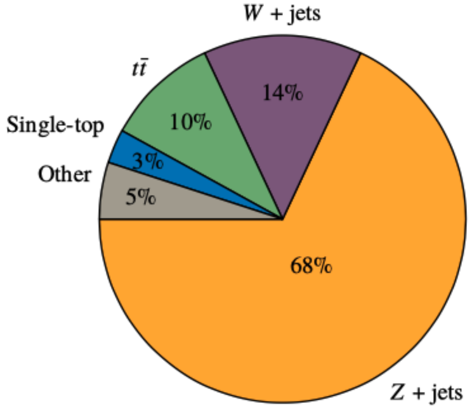
- Two BDTs trained on either low or high mediator masses
  - input variables include leading jets' $p_T$, MET and angular variables related to the jets

- Z+jets are the dominant background in both of our signal regions followed by W+jets and ttbar

SR_low



SR_high

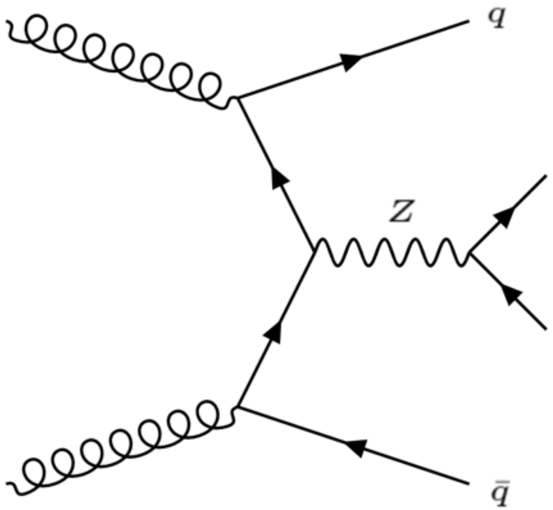


- Despite the large increase in data and the region being designed to enhance signal, the fraction of signal events is still small
  - e.g. last bin in cos(bb)* for SR_low we expect about 145 SM events but only about 2 DM events (where the scalar mediator has a mass of 20 GeV)

- A signal free CR is needed to check modelling of SM backgrounds
  - Incorrect modelling can lead to an under or overestimate of the SM backgrounds which can enhance or mask signal events

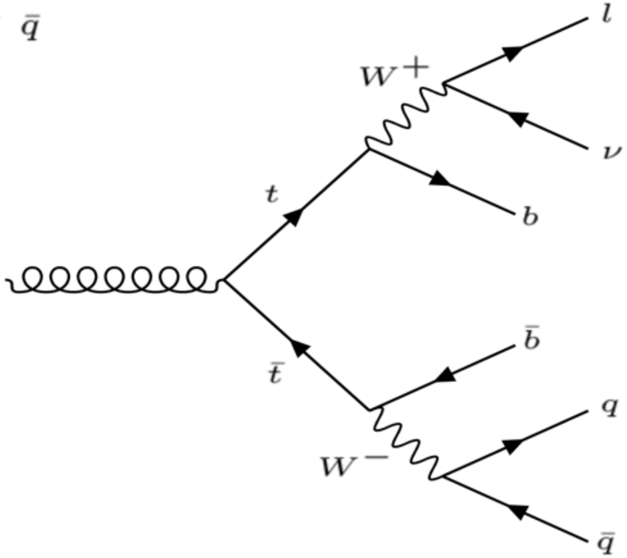
# Topology - Backgrounds

Z backgrounds



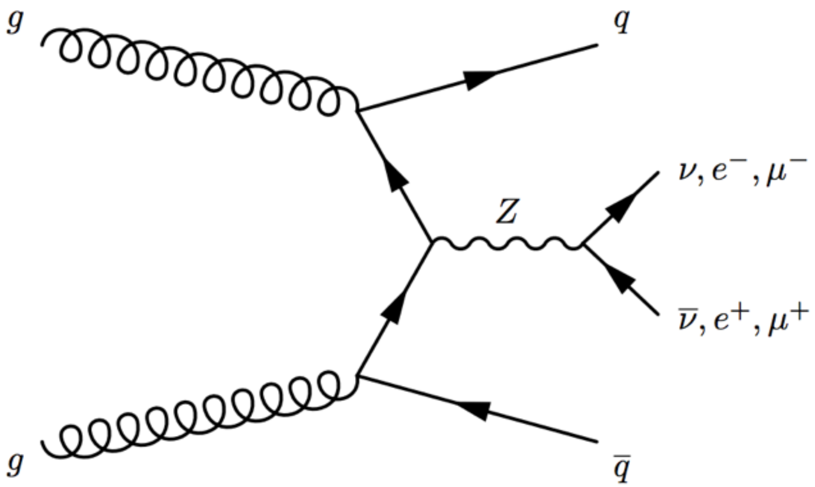
neutrinos will appear as a MET signature similar to our expected DM signal

top and W backgrounds



a neutrino and missed lepton from W can contaminate our MET distribution much like Z($vv$)

# Design of Data-Driven Control Regions



## Z+jets CR:

- Use $Z \rightarrow ll$ which is kinematically similar to $Z \rightarrow \upsilon\upsilon$
- Mark leptons as invisible to replicate MET in signal
  - Introduces a Z $p_T$ cut
- Cut on 'real' MET to remove ttbar and W backgrounds as $Z \rightarrow ll$ should not have a MET signature
- However this introduces additional selections
  - lepton selections
  - invariant mass of di-lepton system to select Z mass peak

# Analysis Strategy

## Signal Region (SR):

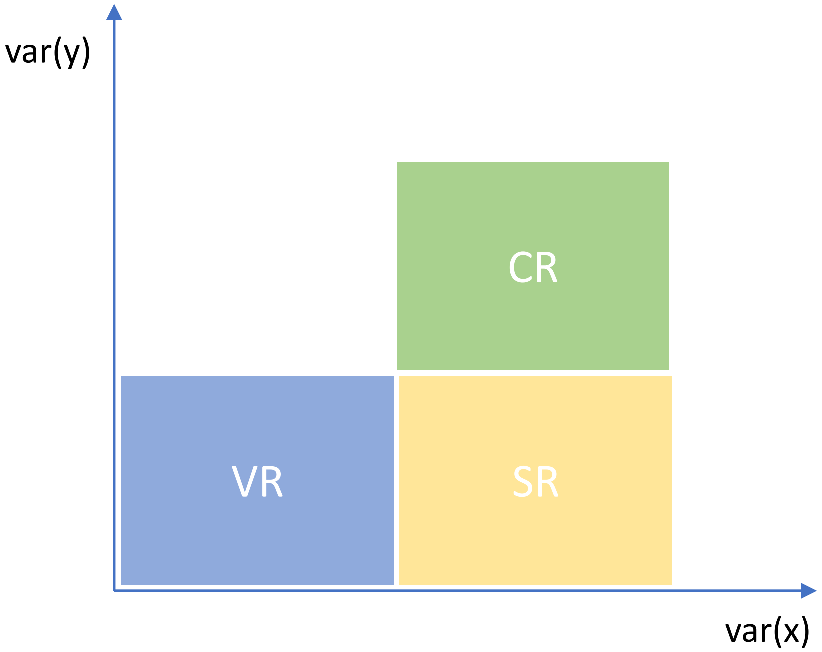
- A region designed to be high in signal and low in backgrounds

## Control Region (CR):

- A region designed to select a specific SM background
- Kinematically similar to the SR
- Used to check background modeling and derive a normalization factor through a background only fit
- No signal should be present

## Validation Region (VR):

- Designed to validate the normalization factor derived from the CR
- Also kinematically similar to the SR



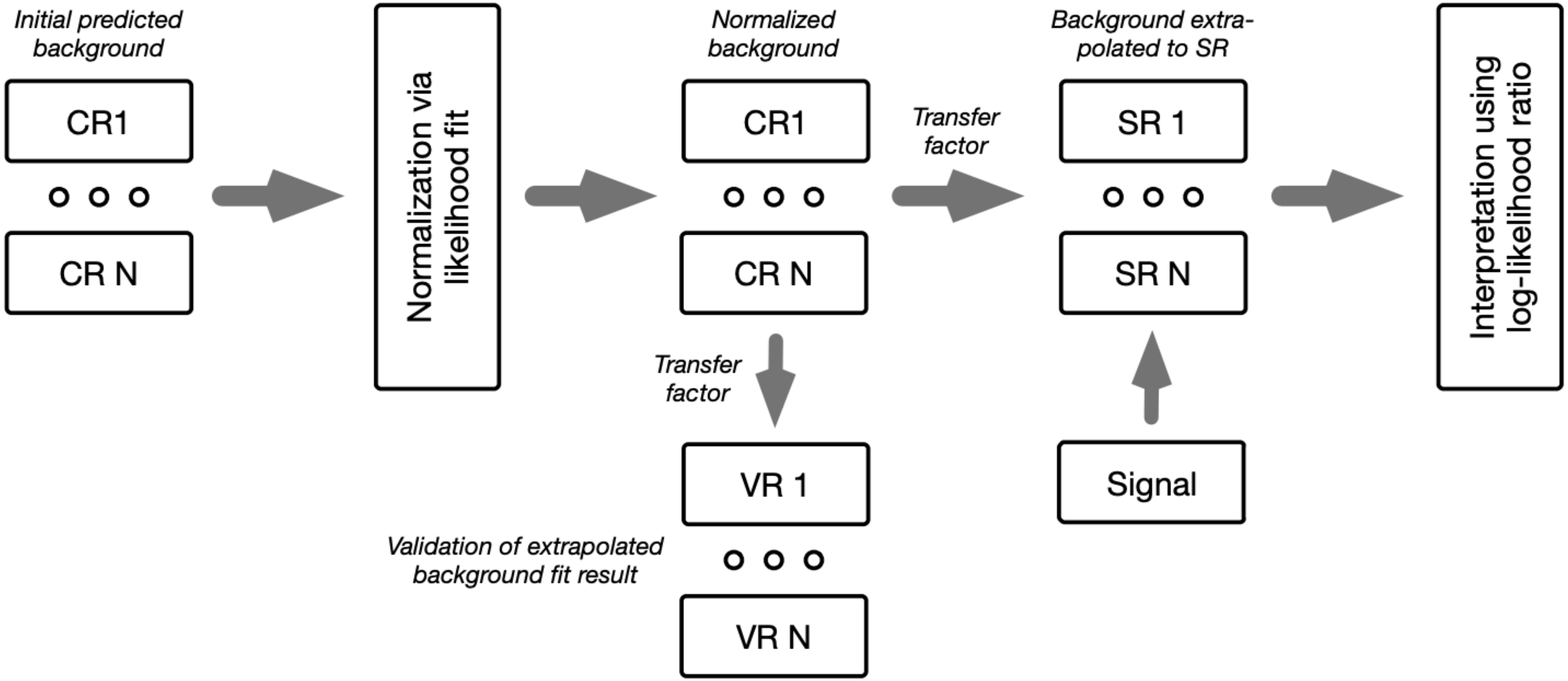
# Background Fit

- A fitting framework (HistFitter) is used to perform a profile likelihood fit that uses:
  - the expected number of Monte Carlo (MC) events
  - the number of data events
  - the statistical and systematic uncertainties on the expected number of MC events

- A background only fit makes use of the Z CR to extract a normalization factor by fitting the Z Monte Carlo to data

- Other backgrounds are normalized using theoretical calculations

# Background Fit

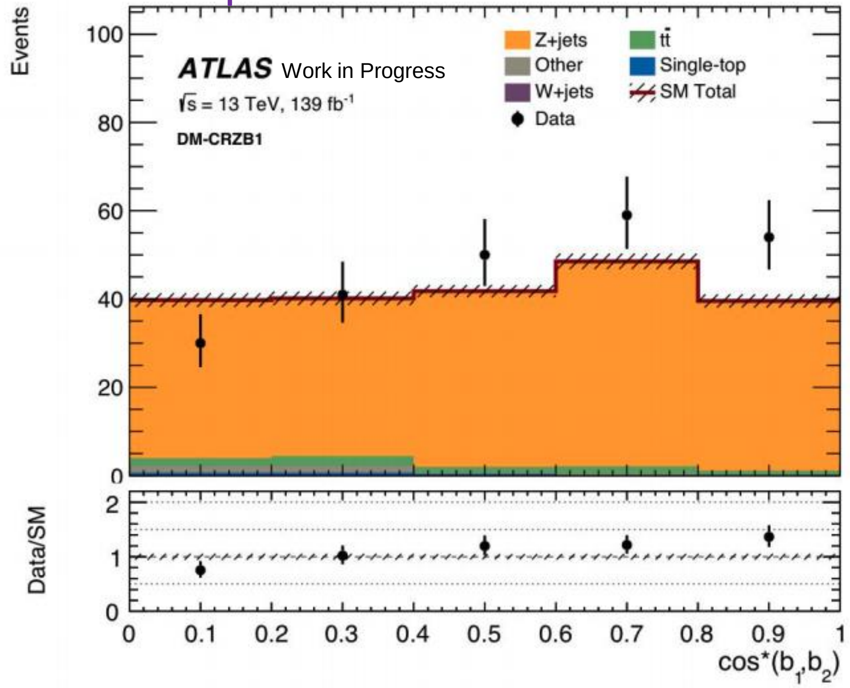


arXiv:1410.1280

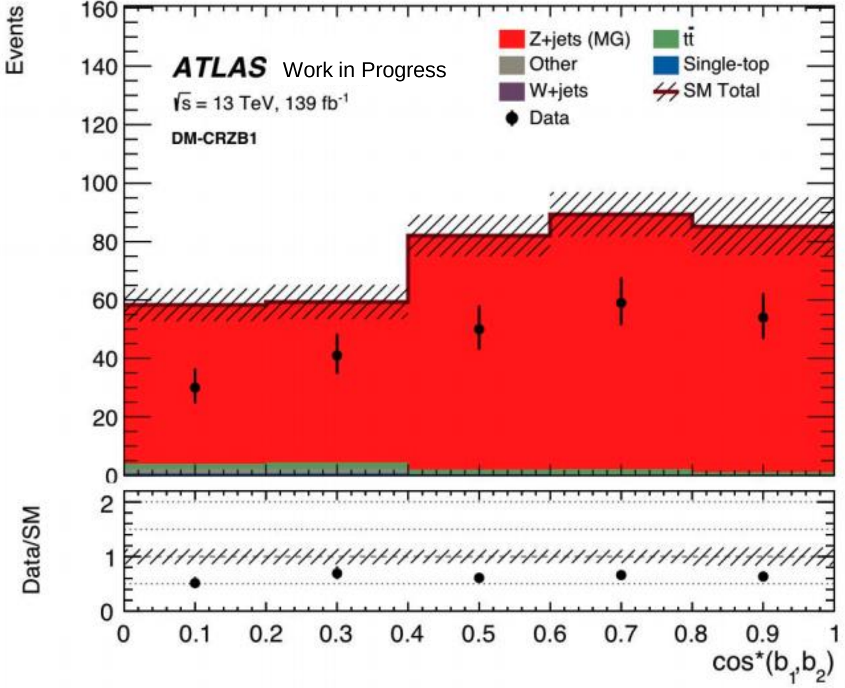
# Modelling of Z+bb in CR

- A good CR is crucial, as significant differences in shape and normalization predicted between generators as shown below (pre-fit)
  - The same data and selections are used in both plots
  - Indications of problem in modelling and normalization that isn't 'solved' by either generator
  - Theory uncertainties within an MC prediction are not the only (or even main) source of uncertainty

Sherpa



MadGraph

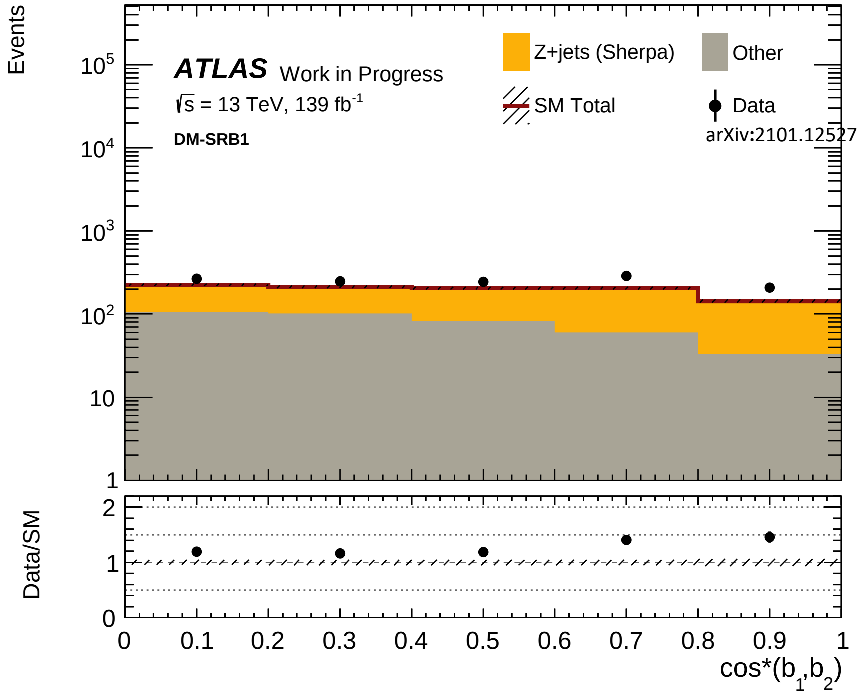


N.B: Overall experiment and theory systematic uncertainties of ~7% not shown in plots above

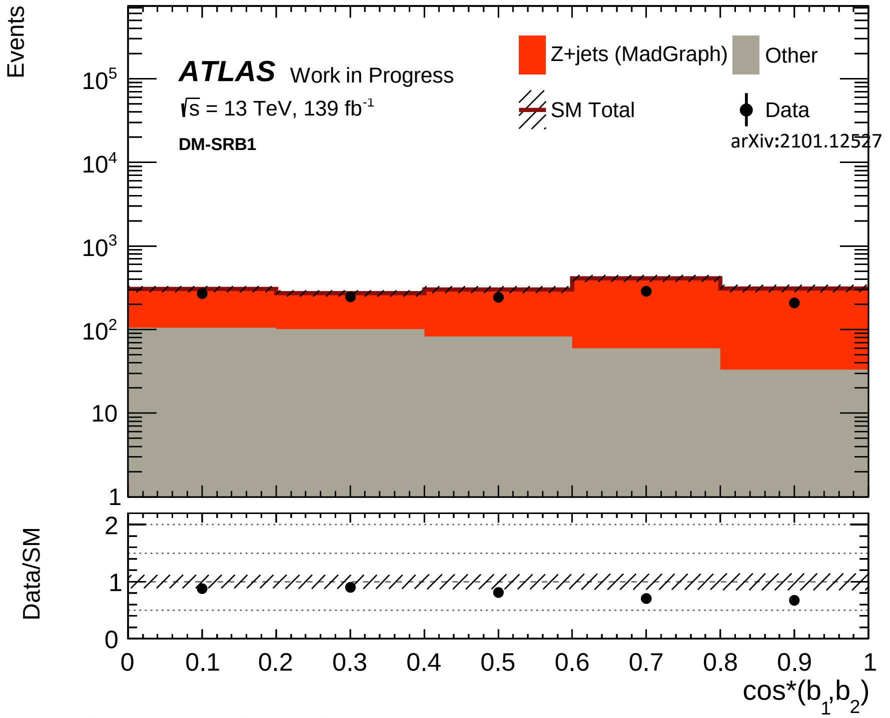
# Modelling of Z+bb in SR

- Below plots show the cos(bb)* distributions pre-fit for low mass mediators in the SR
- The difference in prediction from the different generators is seen to have an affect here as well
  - MadGraph overpredicts and Sherpa underpredicts

Sherpa



MadGraph

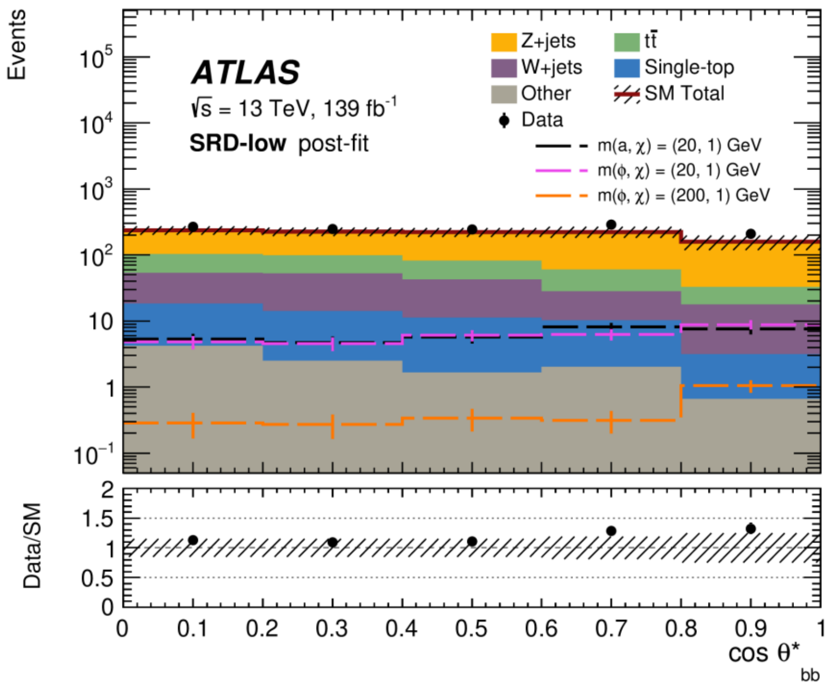


N.B: Overall experiment and theory systematic uncertainties of ~13% not shown in plots above

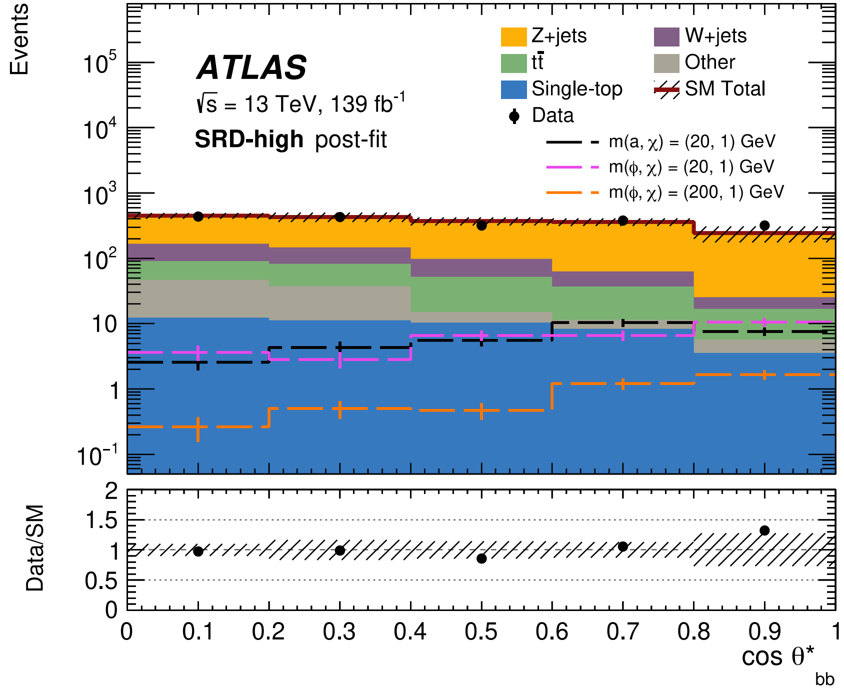
Data and SR from arXiv:2101.12527 shown here in comparison to SM theory predictions

# Modelling of Z+bb in SR

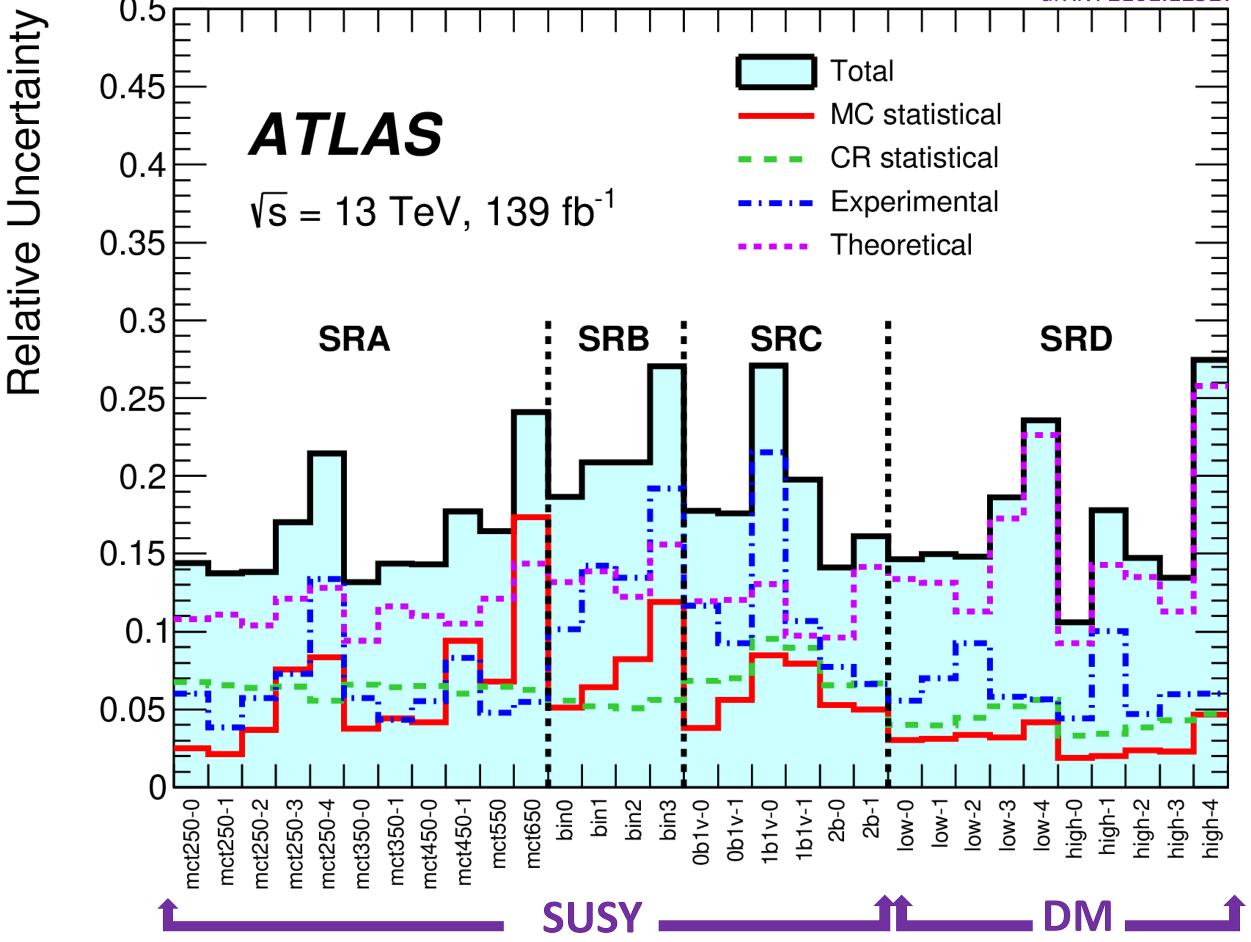
- The below plots show the cos(bb)* distributions with Z+jets fitted from CR constraints for high and low mass mediators extrapolated to the SR
- The central value for Z+jets is taken from Sherpa but a generator systematic has been included (in the shaded region) to account for the difference in prediction from MadGraph
- The last two bins in both distributions were blinded as this is where we have the most discriminating power but is also where we saw the most disagreement between Sherpa and MadGraph



arXiv: 2101.12527



# Systematic Uncertainties on Final Results



arXiv: 2101.12527

Post-fit relative systematic uncertainties

- ➢ CR constraints already taken into account

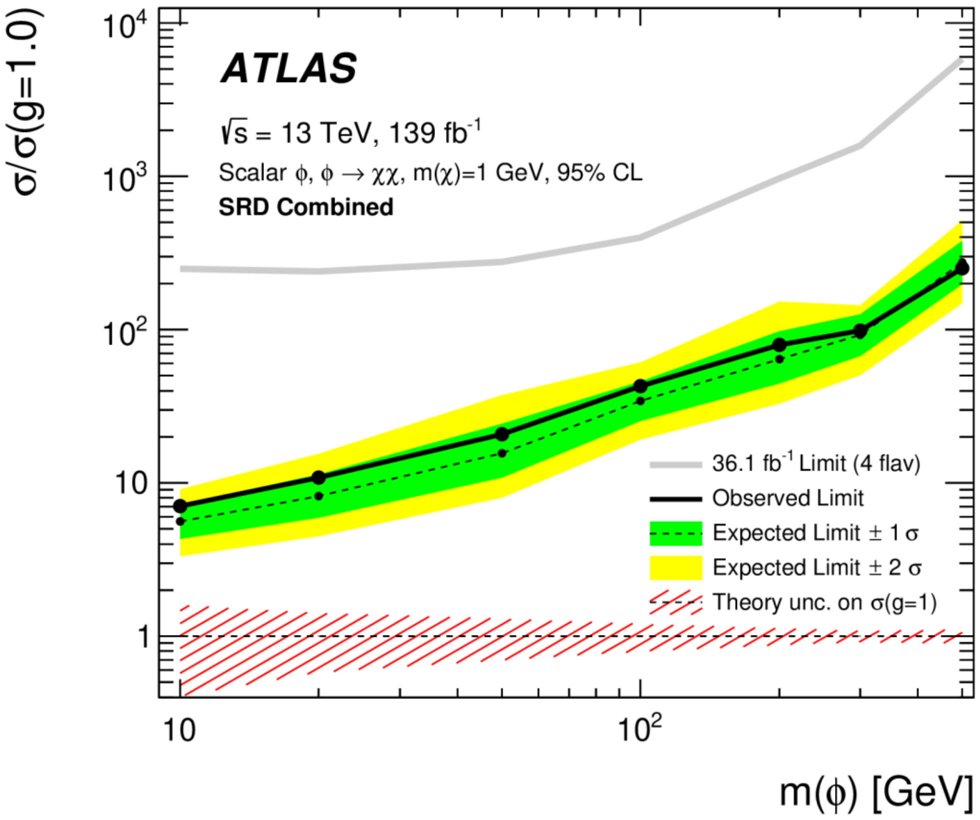
Majority of regions dominated by theoretical uncertainties

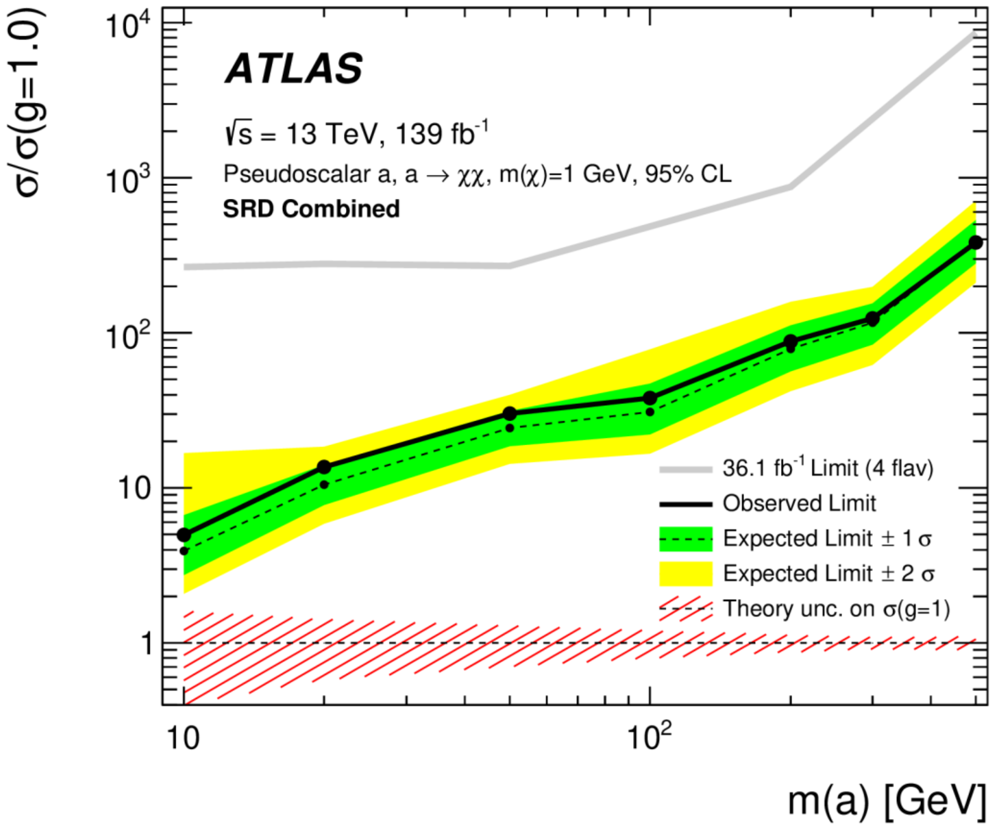
- ➢ Especially DM

# Results

- New search results around 10x more sensitive than previous 36.1*fb*$^{-1}$ results but no evidence of DM
- small excess (<1 sigma) in high cos(bb)* weakens limits compared to expected
  - generator selection has a large affect on conclusion – understanding of Z and theory uncertainties could be the difference between a discovery and not

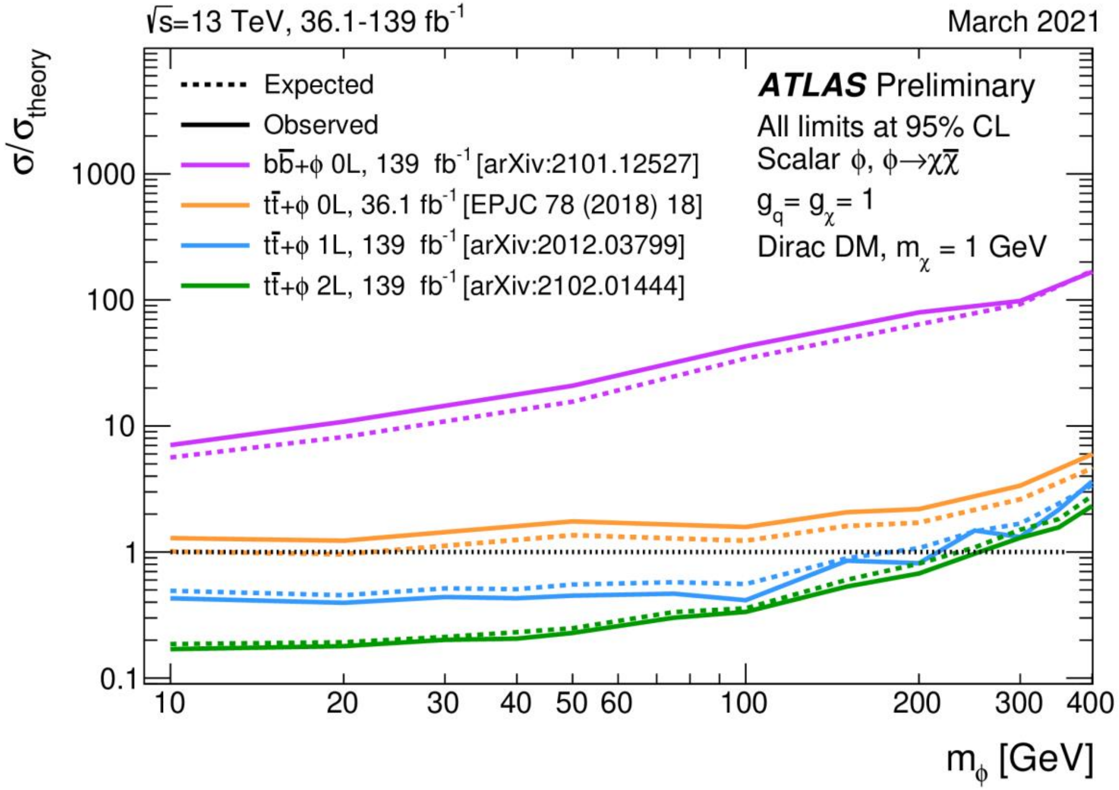
arXiv: 2101.12527

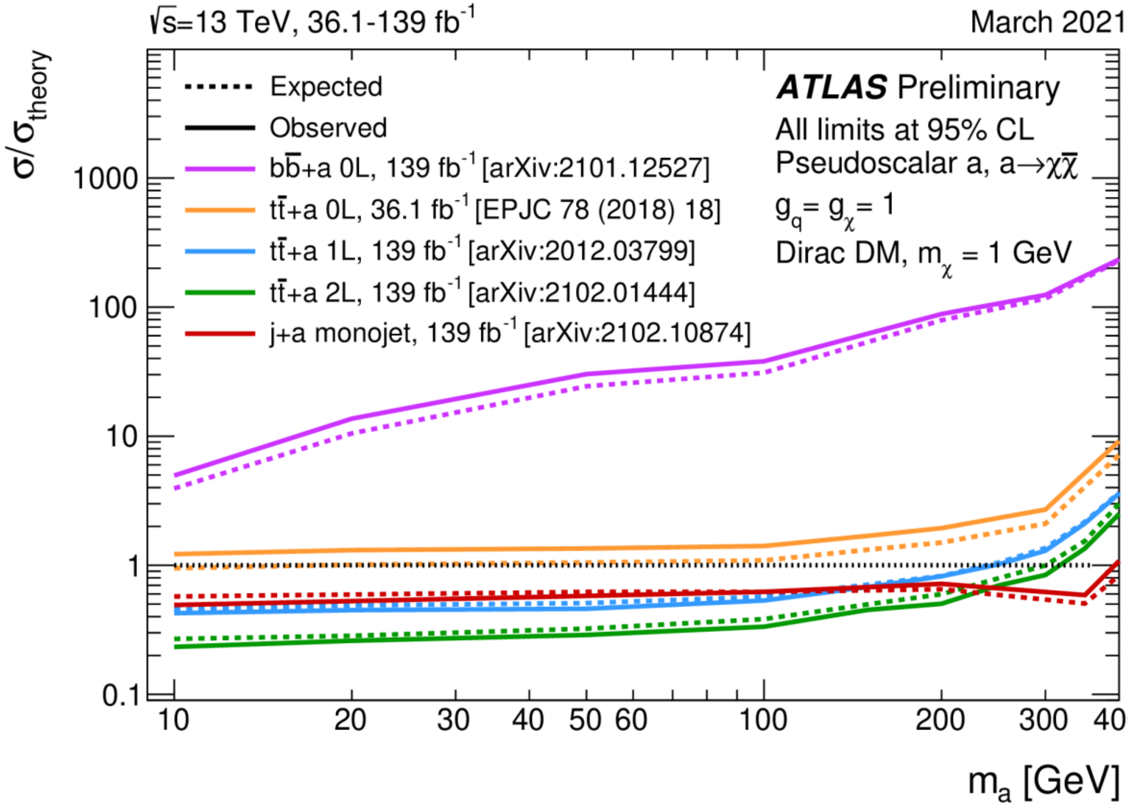




# Results

- New summary plot for 2021 for s-channel mediators





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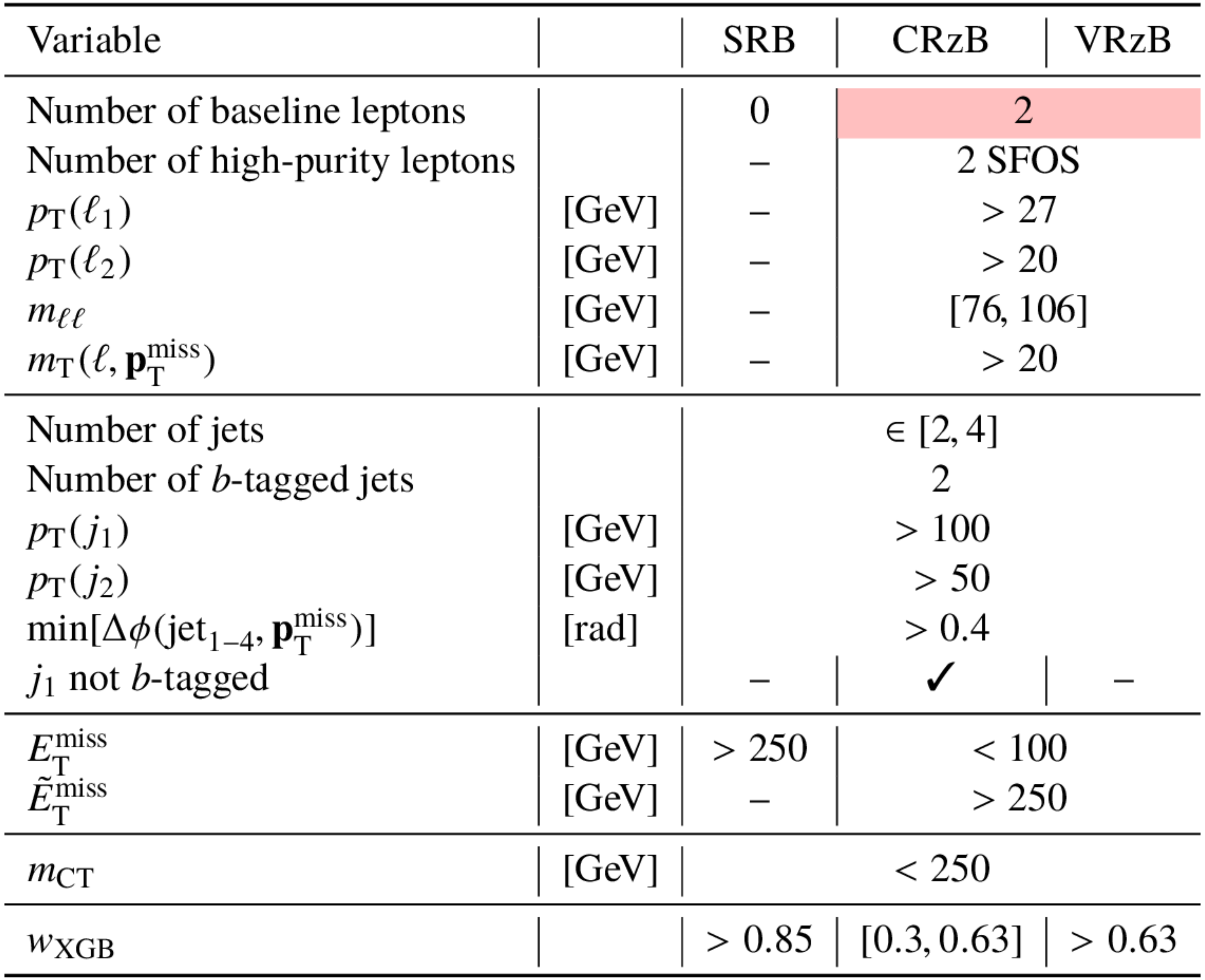
# Conclusion

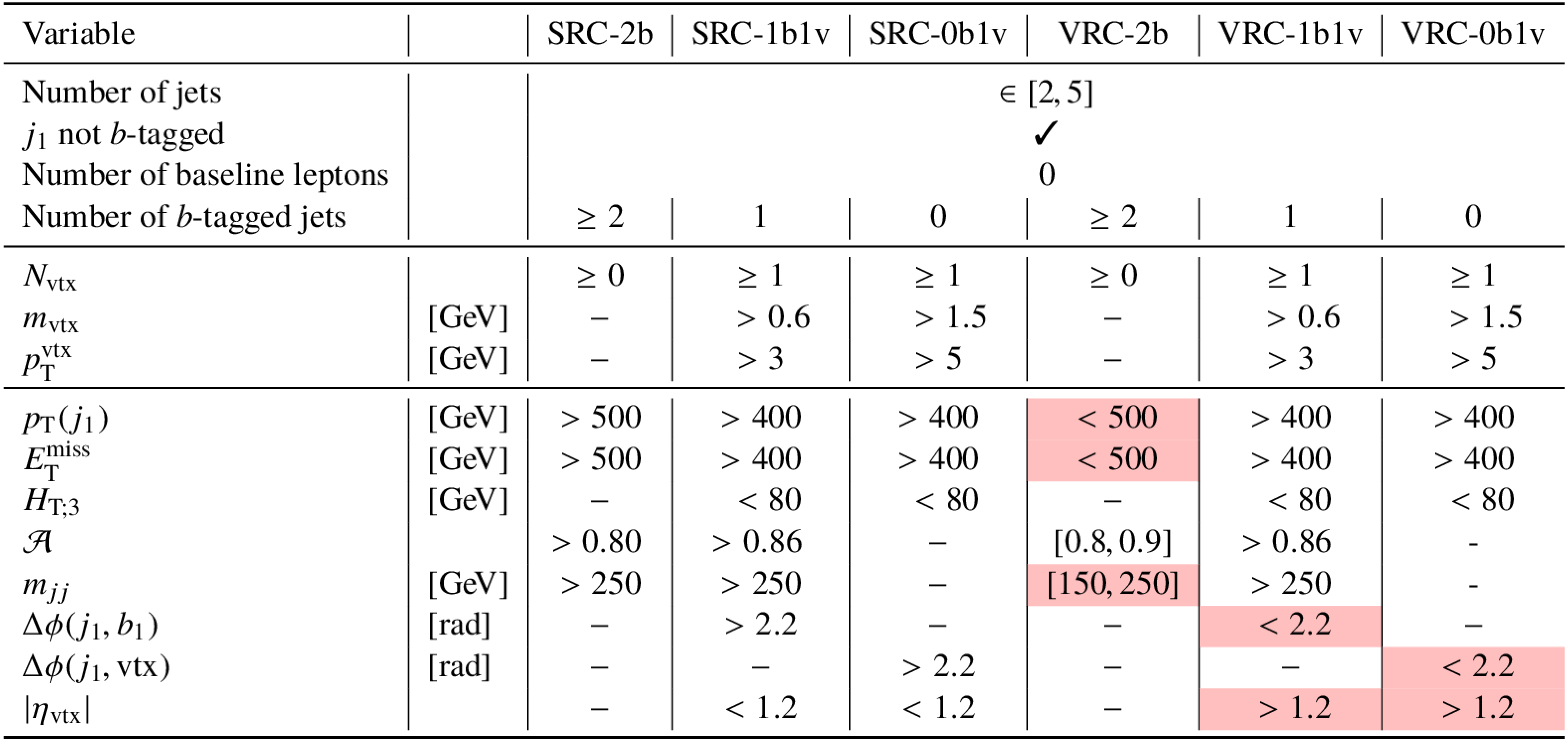
- Search for third generation SUSY and DM with no evidence for either found
- Limits on DM produced in association with b-jets improved by about 10x over previous iteration
- Theory uncertainties on modeling of SM backgrounds was a limiting factor in this analysis
- DM limits or deviation from SM could be stronger with better Monte Carlo prediction of the background in this phase space
- Further measurements of these SM backgrounds to searches in these regions of phase space needed

# Backup

| Variable | | SRA | CRzA | $\mathrm{VR}_{\mathrm{A1}}^{m_{\mathrm{CT}}}$ | $\mathrm{VR}_{\mathrm{A1}}^{m_{bb}}$ | $\mathrm{VR}_{\mathrm{A2}}^{m_{\mathrm{CT}}}$ | $\mathrm{VR}_{\mathrm{A2}}^{m_{bb}}$ |
|---|---|---|---|---|---|---|---|
| Number of baseline leptons | | 0 | 2 | 0 | | | |
| Number of high-purity leptons | | – | 2 SFOS | – | | | |
| $p_{\mathrm{T}}(\ell_1)$ | [GeV] | – | $> 27$ | – | | | |
| $p_{\mathrm{T}}(\ell_2)$ | [GeV] | – | $> 20$ | – | | | |
| $m_{\mathrm{T}}(\ell, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}})$ | [GeV] | – | $> 20$ | – | | | |
| $m_{\ell\ell}$ | [GeV] | – | [81, 101] | – | | | |
| Number of jets | | $\in [2, 4]$ | | | | | |
| Number of *b*-tagged jets | | 2 | | | | | |
| $j_1$ and $j_2$ *b*-tagged | | ✓ | | | | | |
| $p_{\mathrm{T}}(j_1)$ | [GeV] | $> 150$ | | | | | |
| $p_{\mathrm{T}}(j_2)$ | [GeV] | $> 50$ | | | | | |
| $p_{\mathrm{T}}(j_4)$ | [GeV] | $< 50$ | | | | | |
| $\min[\Delta\phi(\mathrm{jet}_{1-4}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}})]$ | [rad] | $> 0.4$ | | | | | |
| $E_{\mathrm{T}}^{\mathrm{miss}}$ | [GeV] | $> 250$ | $< 100$ | $> 250$ | | | |
| $\tilde{E}_{\mathrm{T}}^{\mathrm{miss}}$ | [GeV] | – | $> 250$ | – | | | |
| $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$ | | $> 0.25$ | – | – | | | |
| $\tilde{E}_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$ | | – | $> 0.25$ | – | | | |
| $m_{bb}$ | [GeV] | $> 200$ | | $< 200$ | $> 200$ | $< 200$ | $> 200$ |
| $m_{\mathrm{CT}}$ | [GeV] | $> 250$ | | $> 250$ | [150, 250] | $> 250$ | [150, 250] |
| $m_{\mathrm{eff}}$ | [GeV] | $> 500$ | | [500, 1500] | | $> 1500$ | |



| Variable | | SRB | CRzB | VRzB |
|---|---|---|---|---|
| Number of baseline leptons | | 0 | 2 | |
| Number of high-purity leptons | | – | 2 SFOS | |
| $p_{\mathrm{T}}(\ell_1)$ | [GeV] | – | $> 27$ | |
| $p_{\mathrm{T}}(\ell_2)$ | [GeV] | – | $> 20$ | |
| $m_{\ell\ell}$ | [GeV] | – | [76, 106] | |
| $m_{\mathrm{T}}(\ell, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}})$ | [GeV] | – | $> 20$ | |
| Number of jets | | $\in [2, 4]$ | | |
| Number of $b$-tagged jets | | 2 | | |
| $p_{\mathrm{T}}(j_1)$ | [GeV] | $> 100$ | | |
| $p_{\mathrm{T}}(j_2)$ | [GeV] | $> 50$ | | |
| $\min[\Delta\phi(\mathrm{jet}_{1-4}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}})]$ | [rad] | $> 0.4$ | | |
| $j_1$ not $b$-tagged | | – | ✓ | – |
| $E_{\mathrm{T}}^{\mathrm{miss}}$ | [GeV] | $> 250$ | $< 100$ | |
| $\tilde{E}_{\mathrm{T}}^{\mathrm{miss}}$ | [GeV] | – | $> 250$ | |
| $m_{\mathrm{CT}}$ | [GeV] | $< 250$ | | |
| $w_{\mathrm{XGB}}$ | | $> 0.85$ | $[0.3, 0.63]$ | $> 0.63$ |



| Variable | | SRC-2b | SRC-1b1v | SRC-0b1v | VRC-2b | VRC-1b1v | VRC-0b1v |
|---|---|---|---|---|---|---|---|
| Number of jets | | $\in [2, 5]$ | | | | | |
| $j_1$ not $b$-tagged | | ✓ | | | | | |
| Number of baseline leptons | | 0 | | | | | |
| Number of $b$-tagged jets | | $\geq 2$ | 1 | 0 | $\geq 2$ | 1 | 0 |
| $N_{\mathrm{vtx}}$ | | $\geq 0$ | $\geq 1$ | $\geq 1$ | $\geq 0$ | $\geq 1$ | $\geq 1$ |
| $m_{\mathrm{vtx}}$ | [GeV] | – | $> 0.6$ | $> 1.5$ | – | $> 0.6$ | $> 1.5$ |
| $p_{\mathrm{T}}^{\mathrm{vtx}}$ | [GeV] | – | $> 3$ | $> 5$ | – | $> 3$ | $> 5$ |
| $p_{\mathrm{T}}(j_1)$ | [GeV] | $> 500$ | $> 400$ | $> 400$ | $< 500$ | $> 400$ | $> 400$ |
| $E_{\mathrm{T}}^{\mathrm{miss}}$ | [GeV] | $> 500$ | $> 400$ | $> 400$ | $< 500$ | $> 400$ | $> 400$ |
| $H_{\mathrm{T;3}}$ | [GeV] | – | $< 80$ | $< 80$ | – | $< 80$ | $< 80$ |
| $\mathcal{A}$ | | $> 0.80$ | $> 0.86$ | – | $[0.8, 0.9]$ | $> 0.86$ | - |
| $m_{jj}$ | [GeV] | $> 250$ | $> 250$ | – | $[150, 250]$ | $> 250$ | - |
| $\Delta\phi(j_1, b_1)$ | [rad] | – | $> 2.2$ | – | – | $< 2.2$ | – |
| $\Delta\phi(j_1, \mathrm{vtx})$ | [rad] | – | – | $> 2.2$ | – | – | $< 2.2$ |
| $\lvert\eta_{\mathrm{vtx}}\rvert$ | | – | $< 1.2$ | $< 1.2$ | – | $> 1.2$ | $> 1.2$ |

<table>
<tr><th>Variable</th><th></th><th>CRtC</th><th>CRwC-1b1v</th><th>CRwC-0b1v</th><th>CRzC-2b</th><th>CRzC-1b1v</th><th>CRzC-0b1v</th></tr>
<tr><td>$j_1$ not $b$-tagged</td><td></td><td colspan="6">✓</td></tr>
<tr><td>Number of high-purity leptons</td><td></td><td colspan="3">1</td><td colspan="3">2 SFOS</td></tr>
<tr><td>$H_{\mathrm{T;3}}$</td><td>[GeV]</td><td colspan="6">$< 80$</td></tr>
<tr><td>$p_{\mathrm{T}}(j_1)$</td><td>[GeV]</td><td colspan="3">$> 400$</td><td>$> 300$</td><td colspan="2">$> 400$</td></tr>
<tr><td>$m_{\mathrm{T}}(\ell, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}})$</td><td>[GeV]</td><td colspan="3">[20, 120]</td><td colspan="3">–</td></tr>
<tr><td>$m_{\ell\ell}$</td><td>[GeV]</td><td colspan="3">–</td><td colspan="3">[81, 101]</td></tr>
<tr><td>$E_{\mathrm{T}}^{\mathrm{miss}}$</td><td>[GeV]</td><td colspan="3">$> 400$</td><td colspan="3">$< 100$</td></tr>
<tr><td>$\tilde{E}_{\mathrm{T}}^{\mathrm{miss}}$</td><td>[GeV]</td><td colspan="3">–</td><td>$> 250$</td><td colspan="2">$> 400$</td></tr>
<tr><td>$\mathcal{A}$</td><td></td><td>$> 0.5$</td><td>$> 0.8$</td><td>–</td><td>$> 0.5$</td><td>$> 0.8$</td><td>–</td></tr>
<tr><td>$m_{jj}$</td><td>[GeV]</td><td>$> 250$</td><td>$> 250$</td><td>–</td><td>–</td><td>$> 250$</td><td>–</td></tr>
<tr><td>$N_{b\text{-jets}}$</td><td></td><td>$\geq 2$</td><td>1</td><td>0</td><td>$\geq 2$</td><td>1</td><td>0</td></tr>
<tr><td>$N_{\mathrm{vtx}}$</td><td></td><td>–</td><td>$\geq 1$</td><td>$\geq 1$</td><td>–</td><td>$\geq 1$</td><td>$\geq 1$</td></tr>
<tr><td>$m_{\mathrm{vtx}}$</td><td>[GeV]</td><td>–</td><td>$> 0.6$</td><td>$> 1.5$</td><td>–</td><td>$> 0.6$</td><td>$> 1.5$</td></tr>
<tr><td>$p_{\mathrm{T}}^{\mathrm{vtx}}$</td><td>[GeV]</td><td>–</td><td>$> 3$</td><td>$> 5$</td><td>–</td><td>$> 3$</td><td>$> 5$</td></tr>
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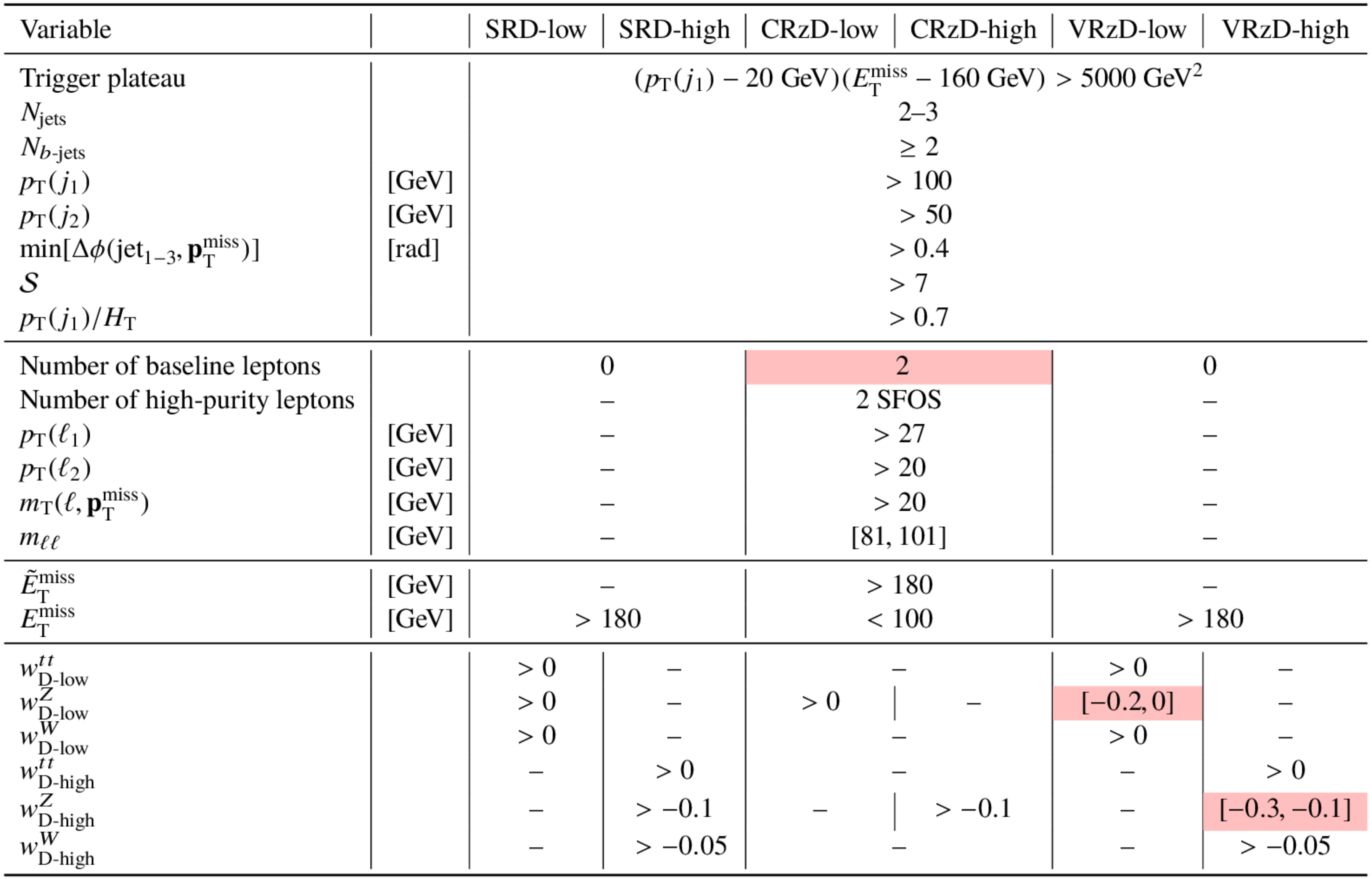
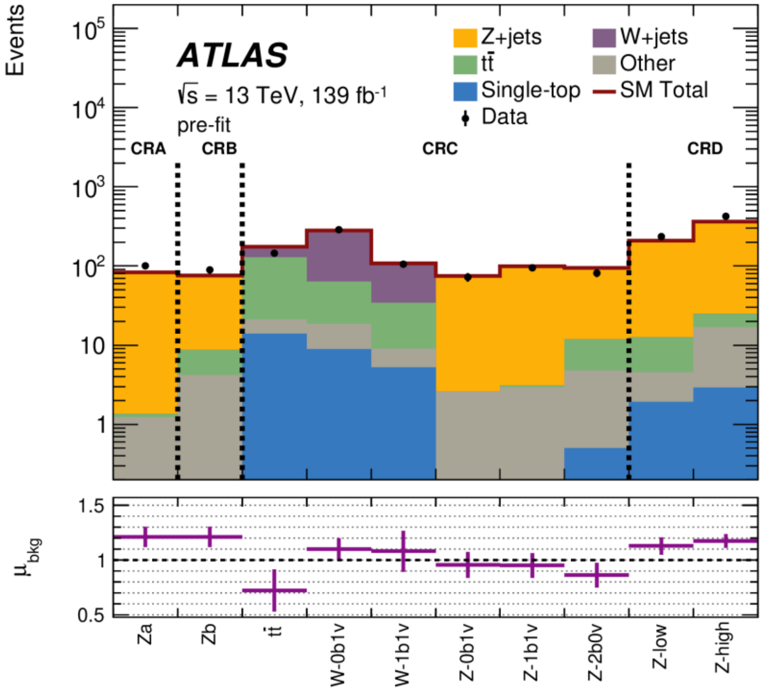
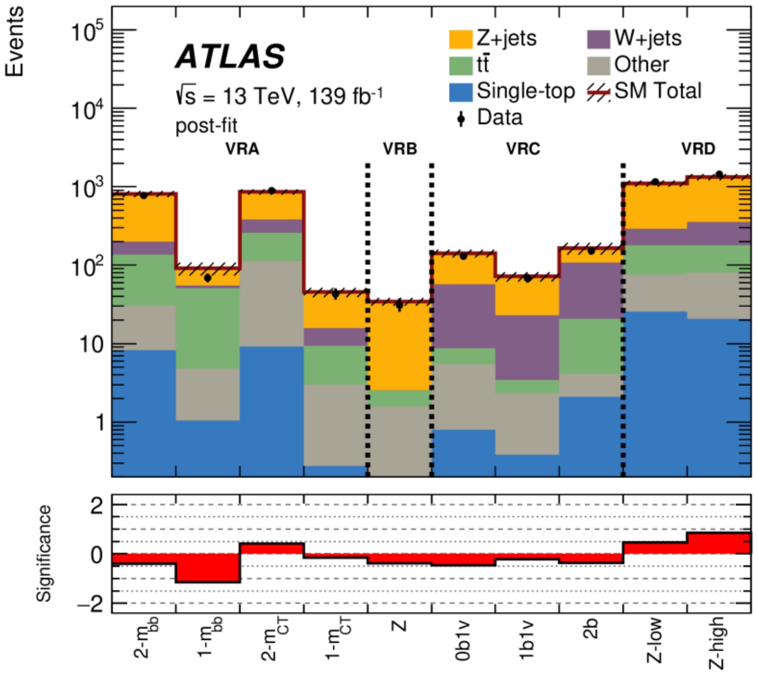
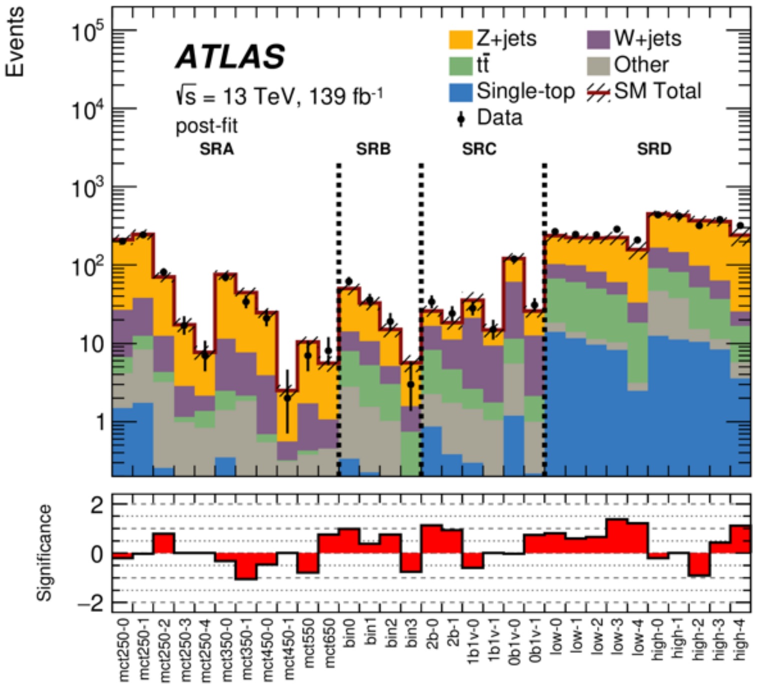
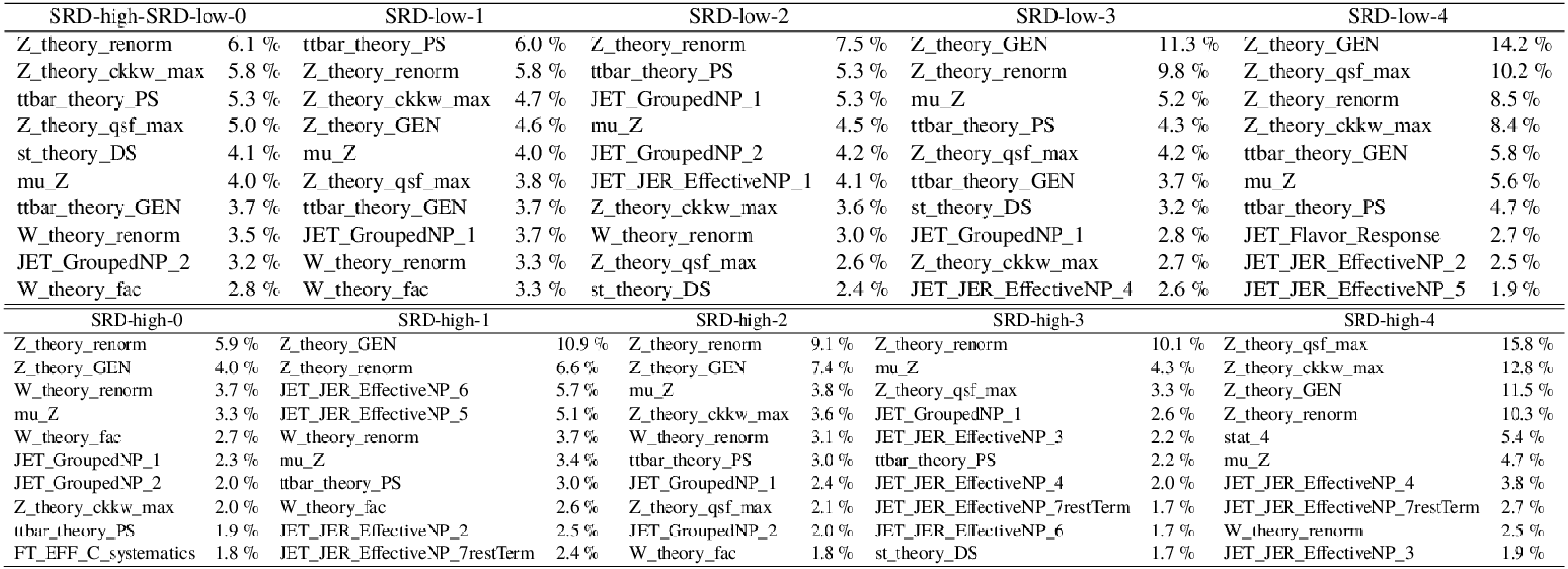


| Variable | | SRD-low | SRD-high | CRzD-low | CRzD-high | VRzD-low | VRzD-high |
|---|---|---|---|---|---|---|---|
| Trigger plateau | | $(p_T(j_1) - 20\text{ GeV})(E_T^{\text{miss}} - 160\text{ GeV}) > 5000\text{ GeV}^2$ | | | | | |
| $N_{\text{jets}}$ | | 2–3 | | | | | |
| $N_{b\text{-jets}}$ | | $\geq 2$ | | | | | |
| $p_T(j_1)$ | [GeV] | $> 100$ | | | | | |
| $p_T(j_2)$ | [GeV] | $> 50$ | | | | | |
| $\min[\Delta\phi(\text{jet}_{1-3}, \mathbf{p}_T^{\text{miss}})]$ | [rad] | $> 0.4$ | | | | | |
| $\mathcal{S}$ | | $> 7$ | | | | | |
| $p_T(j_1)/H_T$ | | $> 0.7$ | | | | | |
| Number of baseline leptons | | 0 | | 2 | | 0 | |
| Number of high-purity leptons | | – | | 2 SFOS | | – | |
| $p_T(\ell_1)$ | [GeV] | – | | $> 27$ | | – | |
| $p_T(\ell_2)$ | [GeV] | – | | $> 20$ | | – | |
| $m_T(\ell, \mathbf{p}_T^{\text{miss}})$ | [GeV] | – | | $> 20$ | | – | |
| $m_{\ell\ell}$ | [GeV] | – | | [81, 101] | | – | |
| $\tilde{E}_T^{\text{miss}}$ | [GeV] | – | | $> 180$ | | – | |
| $E_T^{\text{miss}}$ | [GeV] | $> 180$ | | $< 100$ | | $> 180$ | |
| $w_{\text{D-low}}^{tt}$ | | $> 0$ | – | – | | $> 0$ | – |
| $w_{\text{D-low}}^{Z}$ | | $> 0$ | – | $> 0$ | – | $[-0.2, 0]$ | – |
| $w_{\text{D-low}}^{W}$ | | $> 0$ | – | – | | $> 0$ | – |
| $w_{\text{D-high}}^{tt}$ | | – | $> 0$ | – | | – | $> 0$ |
| $w_{\text{D-high}}^{Z}$ | | – | $> -0.1$ | – | $> -0.1$ | – | $[-0.3, -0.1]$ |
| $w_{\text{D-high}}^{W}$ | | – | $> -0.05$ | – | | – | $> -0.05$ |


Events
ATLAS
√s = 13 TeV, 139 fb-1
pre-fit
Z+jets
W+jets
tt̄
Other
Single-top
SM Total
Data
CRA
CRB
CRC
CRD
$\mu_{\mathrm{bkg}}$
Za
Zb
tt̄
W-0b1v
W-1b1v
Z-0b1v
Z-1b1v
Z-2b0v
Z-low
Z-high


Events
ATLAS
√s = 13 TeV, 139 fb-1
post-fit
Z+jets
W+jets
tt̄
Other
Single-top
SM Total
Data
VRA
VRB
VRC
VRD
Significance
$2\text{-}m_{bb}$
$1\text{-}m_{bb}$
$2\text{-}m_{CT}$
$1\text{-}m_{CT}$
Z
0b1v
1b1v
2b
Z-low
Z-high


Events
ATLAS
√s = 13 TeV, 139 fb-1
post-fit
Z+jets
W+jets
tt̄
Other
Single-top
SM Total
Data
SRA
SRB
SRC
SRD
Significance
mct250-0
mct250-1
mct250-2
mct250-3
mct250-4
mct350-0
mct350-1
mct450-0
mct450-1
mct550
mct650
bin0
bin1
bin2
bin3
2b-0
2b-1
1b1v-0
1b1v-1
0b1v-0
0b1v-1
low-0
low-1
low-2
low-3
low-4
high-0
high-1
high-2
high-3
high-4



| SRD-high-SRD-low-0 | | SRD-low-1 | | SRD-low-2 | | SRD-low-3 | | SRD-low-4 | |
|---|---|---|---|---|---|---|---|---|---|
| Z_theory_renorm | 6.1 % | ttbar_theory_PS | 6.0 % | Z_theory_renorm | 7.5 % | Z_theory_GEN | 11.3 % | Z_theory_GEN | 14.2 % |
| Z_theory_ckkw_max | 5.8 % | Z_theory_renorm | 5.8 % | ttbar_theory_PS | 5.3 % | Z_theory_renorm | 9.8 % | Z_theory_qsf_max | 10.2 % |
| ttbar_theory_PS | 5.3 % | Z_theory_ckkw_max | 4.7 % | JET_GroupedNP_1 | 5.3 % | mu_Z | 5.2 % | Z_theory_renorm | 8.5 % |
| Z_theory_qsf_max | 5.0 % | Z_theory_GEN | 4.6 % | mu_Z | 4.5 % | ttbar_theory_PS | 4.3 % | Z_theory_ckkw_max | 8.4 % |
| st_theory_DS | 4.1 % | mu_Z | 4.0 % | JET_GroupedNP_2 | 4.2 % | Z_theory_qsf_max | 4.2 % | ttbar_theory_GEN | 5.8 % |
| mu_Z | 4.0 % | Z_theory_qsf_max | 3.8 % | JET_JER_EffectiveNP_1 | 4.1 % | ttbar_theory_GEN | 3.7 % | mu_Z | 5.6 % |
| ttbar_theory_GEN | 3.7 % | ttbar_theory_GEN | 3.7 % | Z_theory_ckkw_max | 3.6 % | st_theory_DS | 3.2 % | ttbar_theory_PS | 4.7 % |
| W_theory_renorm | 3.5 % | JET_GroupedNP_1 | 3.7 % | W_theory_renorm | 3.0 % | JET_GroupedNP_1 | 2.8 % | JET_Flavor_Response | 2.7 % |
| JET_GroupedNP_2 | 3.2 % | W_theory_renorm | 3.3 % | Z_theory_qsf_max | 2.6 % | Z_theory_ckkw_max | 2.7 % | JET_JER_EffectiveNP_2 | 2.5 % |
| W_theory_fac | 2.8 % | W_theory_fac | 3.3 % | st_theory_DS | 2.4 % | JET_JER_EffectiveNP_4 | 2.6 % | JET_JER_EffectiveNP_5 | 1.9 % |

| SRD-high-0 | | SRD-high-1 | | SRD-high-2 | | SRD-high-3 | | SRD-high-4 | |
|---|---|---|---|---|---|---|---|---|---|
| Z_theory_renorm | 5.9 % | Z_theory_GEN | 10.9 % | Z_theory_renorm | 9.1 % | Z_theory_renorm | 10.1 % | Z_theory_qsf_max | 15.8 % |
| Z_theory_GEN | 4.0 % | Z_theory_renorm | 6.6 % | Z_theory_GEN | 7.4 % | mu_Z | 4.3 % | Z_theory_ckkw_max | 12.8 % |
| W_theory_renorm | 3.7 % | JET_JER_EffectiveNP_6 | 5.7 % | mu_Z | 3.8 % | Z_theory_qsf_max | 3.3 % | Z_theory_GEN | 11.5 % |
| mu_Z | 3.3 % | JET_JER_EffectiveNP_5 | 5.1 % | Z_theory_ckkw_max | 3.6 % | JET_GroupedNP_1 | 2.6 % | Z_theory_renorm | 10.3 % |
| W_theory_fac | 2.7 % | W_theory_renorm | 3.7 % | W_theory_renorm | 3.1 % | JET_JER_EffectiveNP_3 | 2.2 % | stat_4 | 5.4 % |
| JET_GroupedNP_1 | 2.3 % | mu_Z | 3.4 % | ttbar_theory_PS | 3.0 % | ttbar_theory_PS | 2.2 % | mu_Z | 4.7 % |
| JET_GroupedNP_2 | 2.0 % | ttbar_theory_PS | 3.0 % | JET_GroupedNP_1 | 2.4 % | JET_JER_EffectiveNP_4 | 2.0 % | JET_JER_EffectiveNP_4 | 3.8 % |
| Z_theory_ckkw_max | 2.0 % | W_theory_fac | 2.6 % | Z_theory_qsf_max | 2.1 % | JET_JER_EffectiveNP_7restTerm | 1.7 % | JET_JER_EffectiveNP_7restTerm | 2.7 % |
| ttbar_theory_PS | 1.9 % | JET_JER_EffectiveNP_2 | 2.5 % | JET_GroupedNP_2 | 2.0 % | JET_JER_EffectiveNP_6 | 1.7 % | W_theory_renorm | 2.5 % |
| FT_EFF_C_systematics | 1.8 % | JET_JER_EffectiveNP_7restTerm | 2.4 % | W_theory_fac | 1.8 % | st_theory_DS | 1.7 % | JET_JER_EffectiveNP_3 | 1.9 % |