Searches for direct slepton production in the compressed-mass corridor

Moriond Electroweak - 26/3/25

Based on the paper submitted to JHEP: arXiv:2503.17186

Alessandro Ruggiero (alessandro.ruggiero@cern.ch)

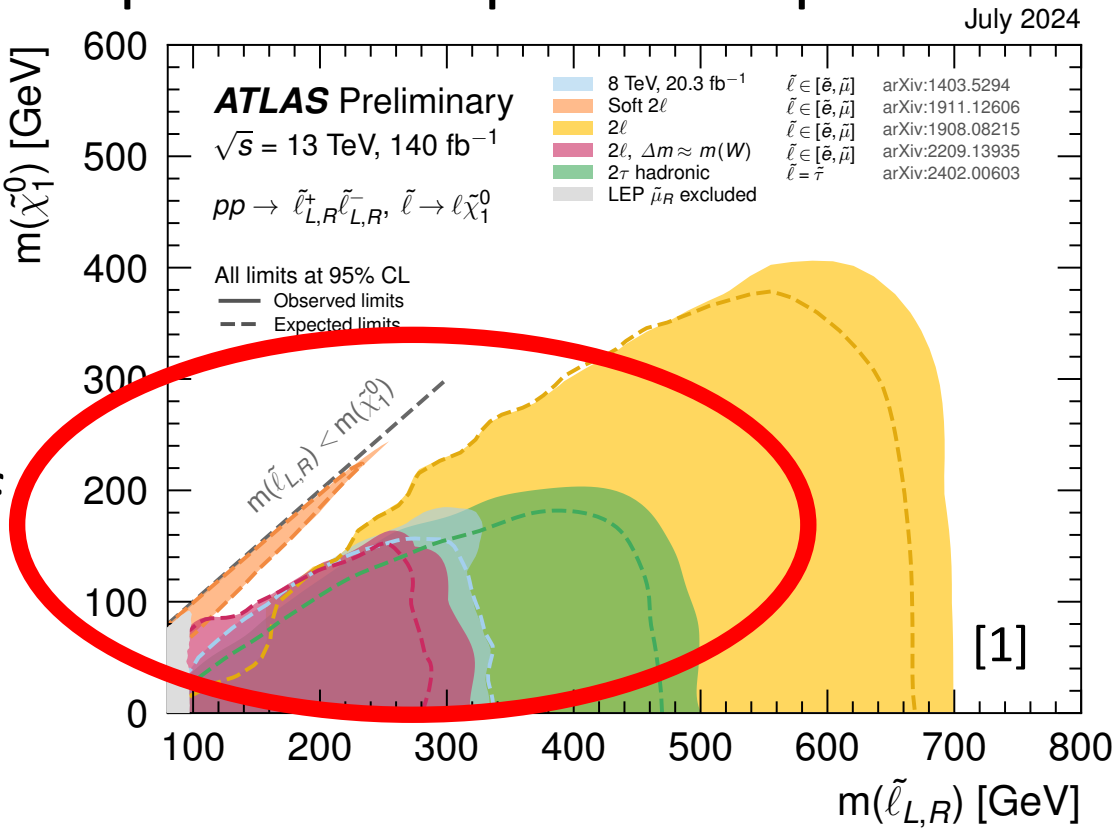
On behalf of the ATLAS collaboration

[1] SUSY July 2024 Summary Plot Update. Tech. rep. Geneva: CERN, 2024. url: https://cds.cern.ch/record/2904978

Motivation

- Still interesting regions of SUSY parameter space to explore!
- A large gap in slepton exclusion at small mass splitting: $\Delta m(\tilde{l}, \chi_1^0) < m_w$

Why here?

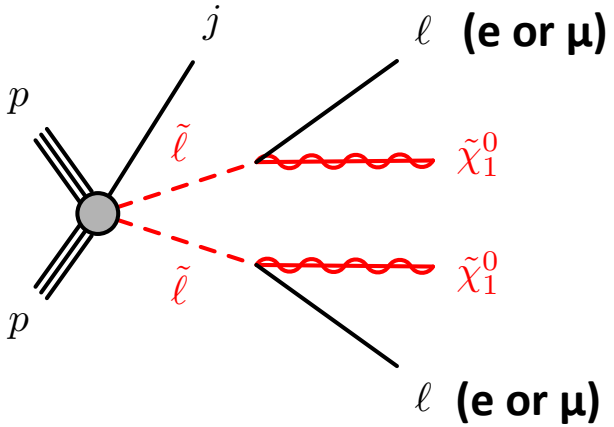


- No sensitivity for a range of models since LEP
- Light smuons explain g-2
- The lightest neutralino (χ_1^0) is a Dark Matter candidate

Aim: use the ATLAS Run 2 dataset and ML techniques to cover this region

Analysis strategy

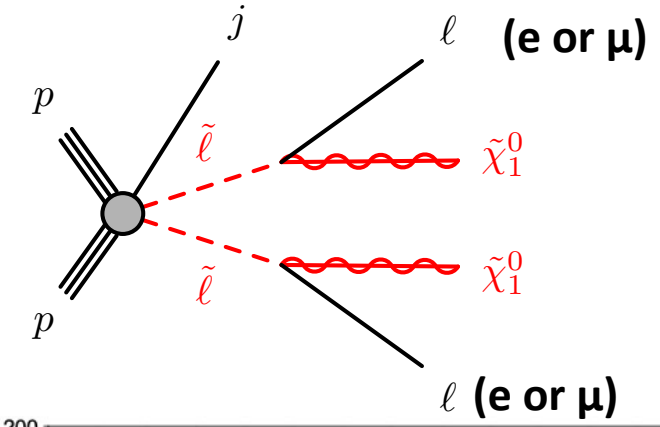
Target process

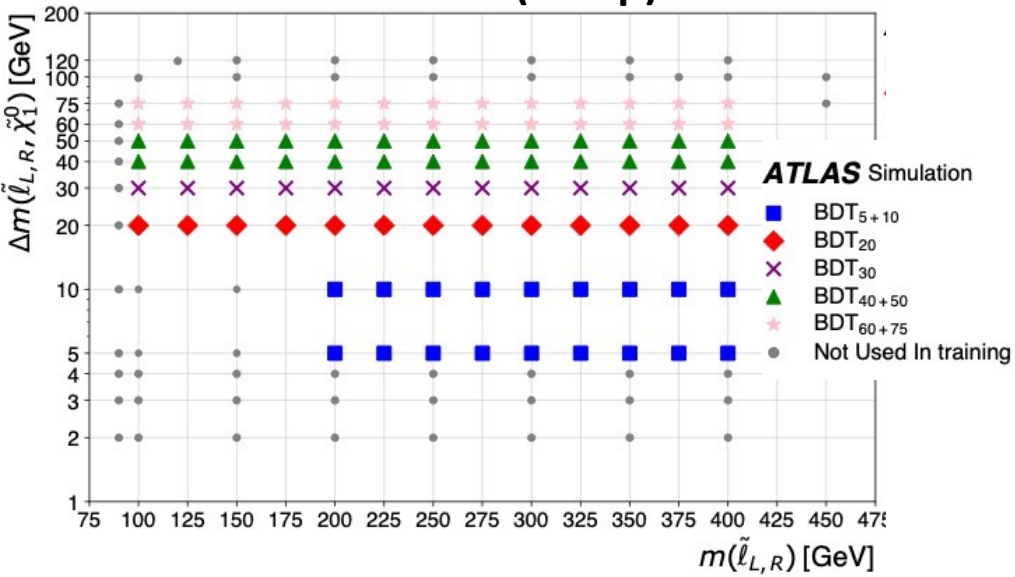


- 2 same flavour opposite sign leptons **(e or μ)**
  - Jet from initial state radiation
  - Large missing transverse energy

Analysis strategy

Target process





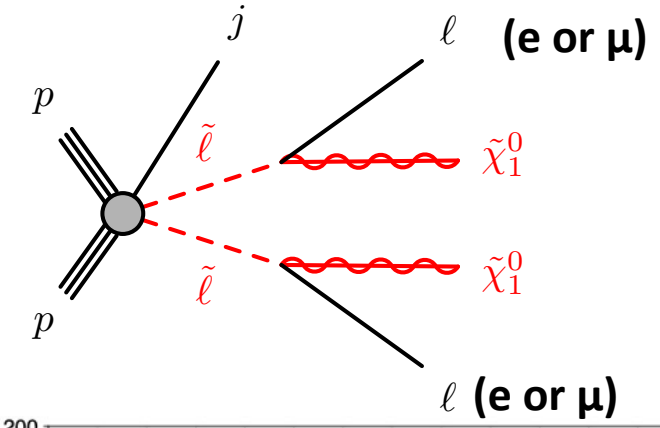
BDT Approach

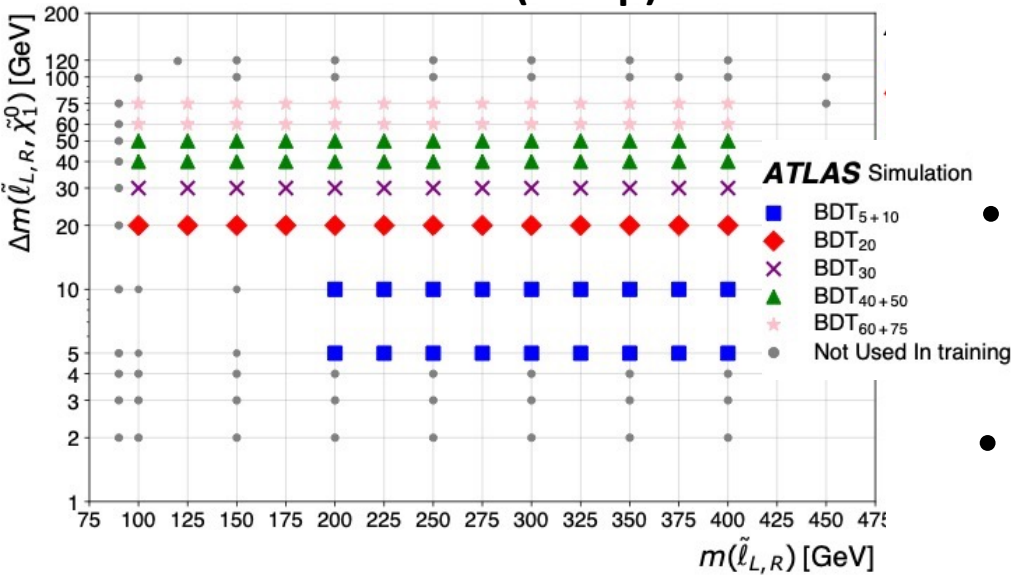
- Train 5 BDTs on different signal models, grouped based on $\Delta m(\tilde{l}, \chi_1^0)$
- Maximise sensitivity to the simplified models

Also have a cut-based approach but no time to talk about it here

Analysis strategy

Target process





BDT Approach

- Train 5 BDTs on different signal models, grouped based on $\Delta m(\tilde{l}, \chi_1^0)$
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Background estimate

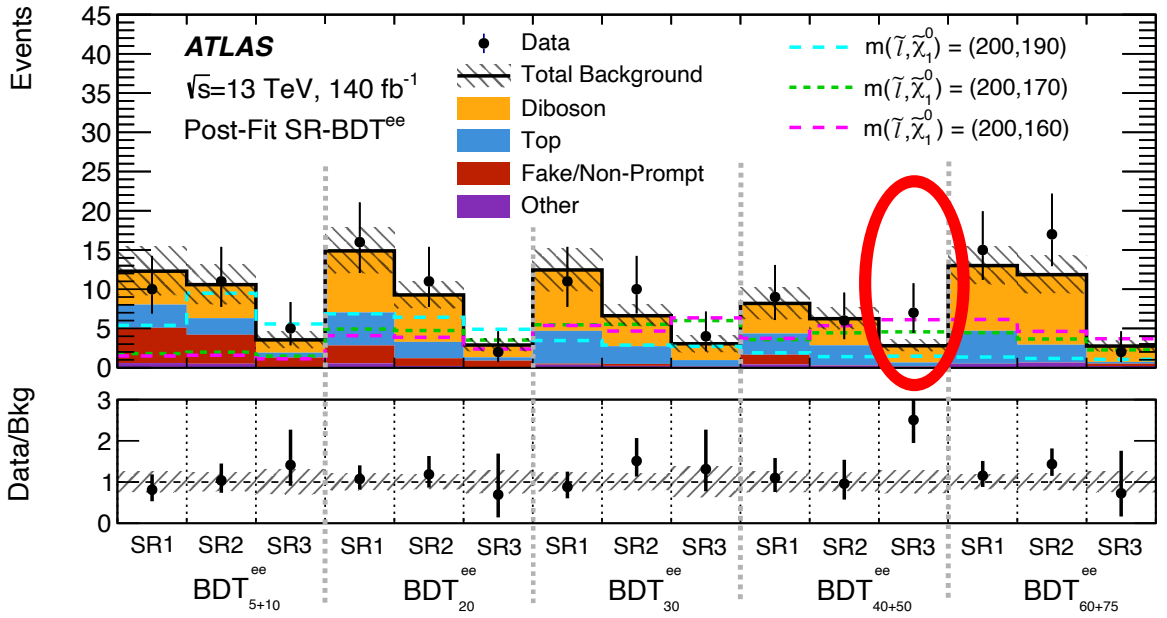
- Use BDT score to define: 3 e^+e^- and 3 $\mu^+\mu^-$ SRs per BDT
- Individual CRs defined for each BDT, to target major bkgs (top, diboson) and extract normalisation factors.
- Dedicated VRs for each BDT to validate bkg estimate

Largest deviation in:
$\mathrm{BDT} - \mathrm{SR3}^{\mathrm{ee}}_{40+50}$

Single SR significance: 2.0σ

BDT SRs

Post-fit, CR only results



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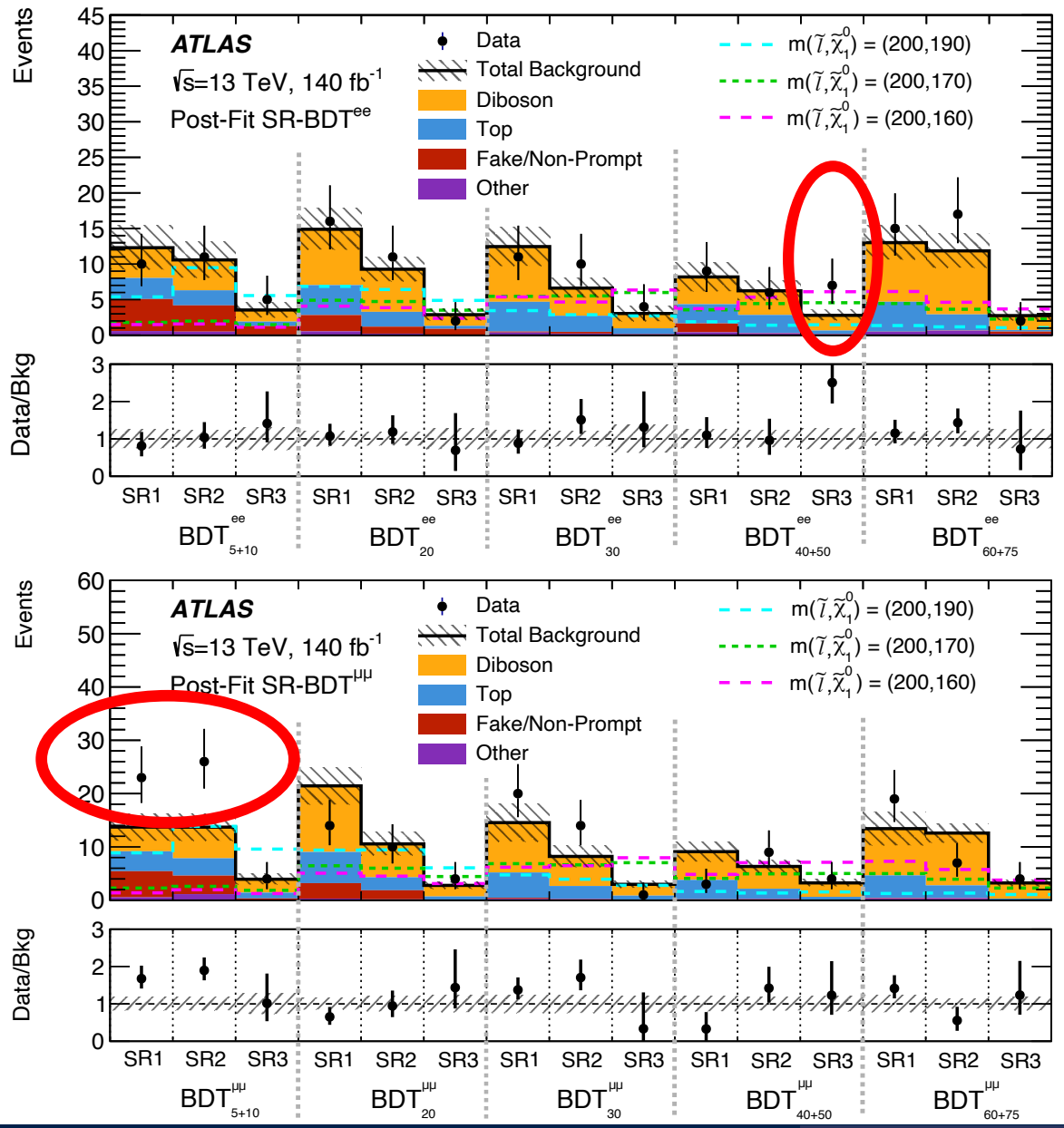
BDT SRs

Post-fit, CR only results

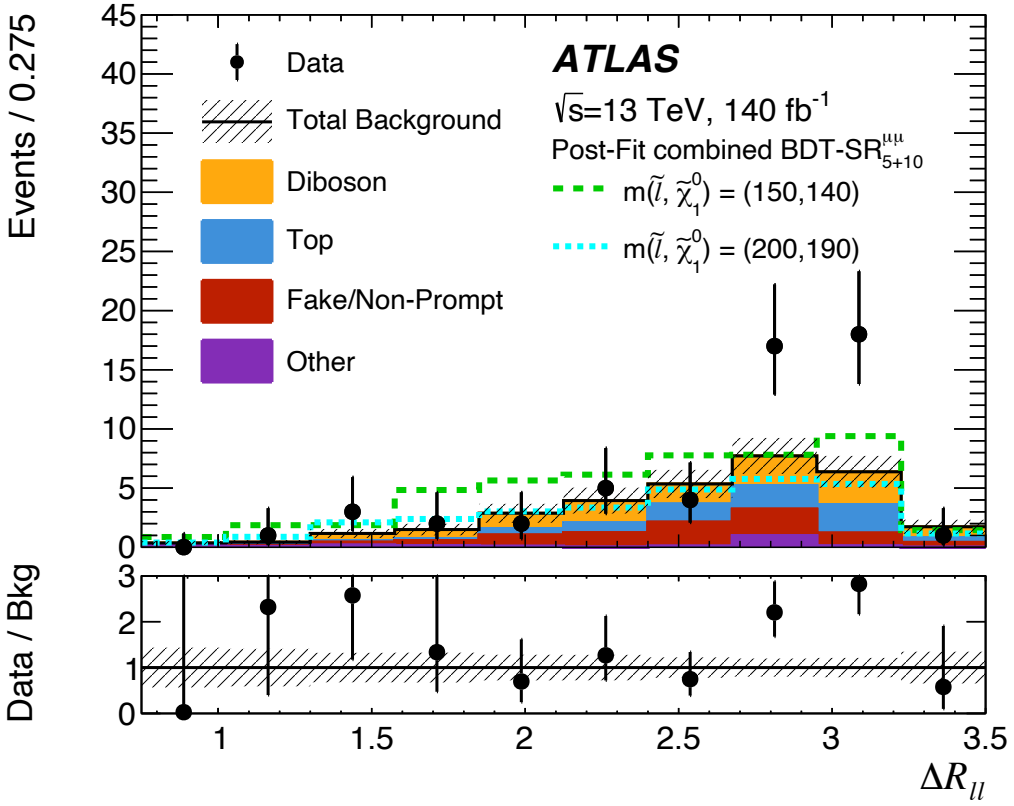
Largest deviation in:
$\mathrm{BDT} - \mathrm{SR}^{\mu\mu}_{5+10}$

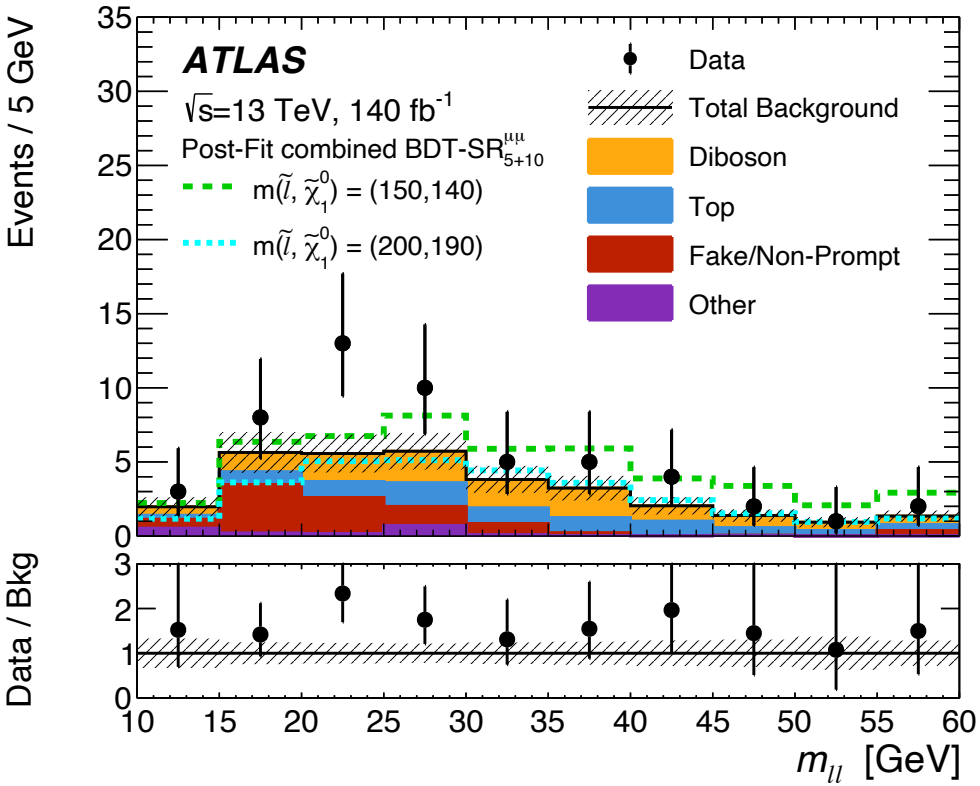
Largest **single** SR significance: 2.4σ



BDT – $SR^{\mu\mu}_{5+10}$: A closer look

- Kinematic distributions of $SR^{\mu\mu}_{5+10}$ 1,2,3 combined, with example signal models
- Events characterised as: back-to-back in ϕ, di-muon invariant mass ≈ 20-30 GeV



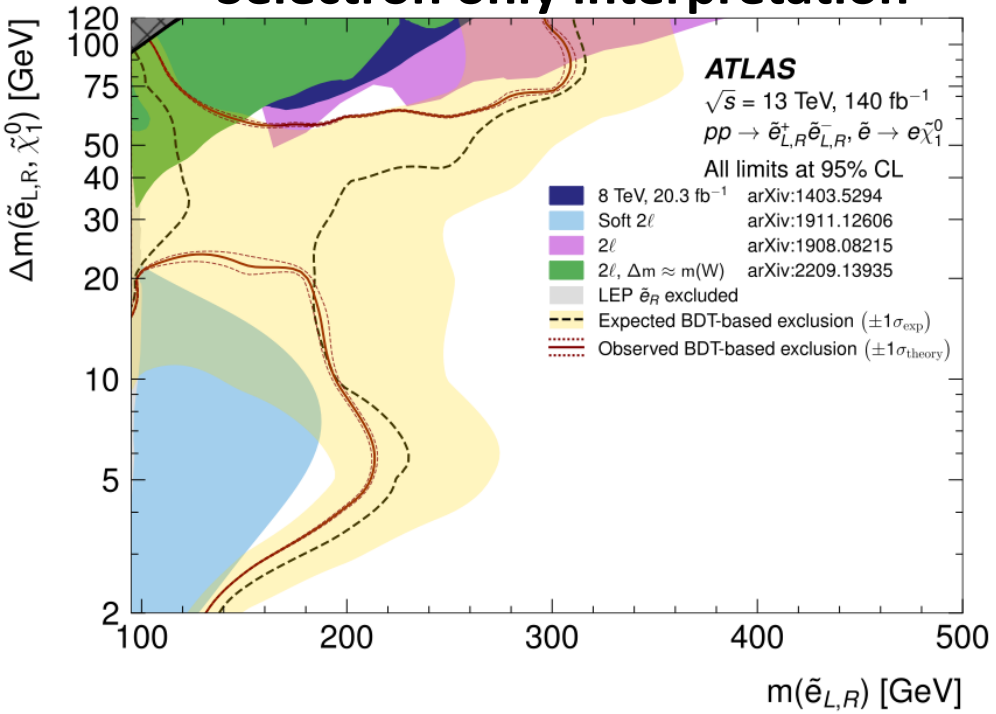


Not seen in $\mathrm{BDT} - SR^{ee}_{5+10}$ or the dedicated VRs, and orthogonal to cut and count.

Interpretations

- In each interpretation, simultaneous CR+SR fits to extract a CLs for each signal model
  - Contours interpolated using the BDT SRs with the best expected CLs.
    - A “discovery” significance is also calculated for each signal model.

Selectron only interpretation



Maximal discovery significance: 1.9σ

For model: $m(\tilde{e}, \chi_1^0) = (375{,}335)$ GeV

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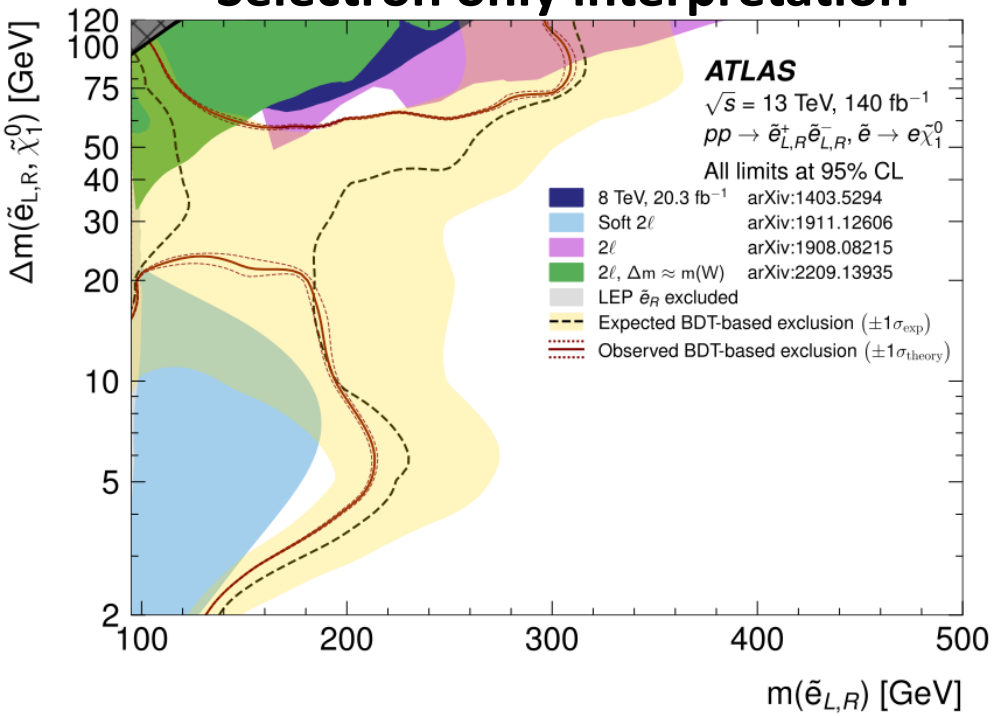

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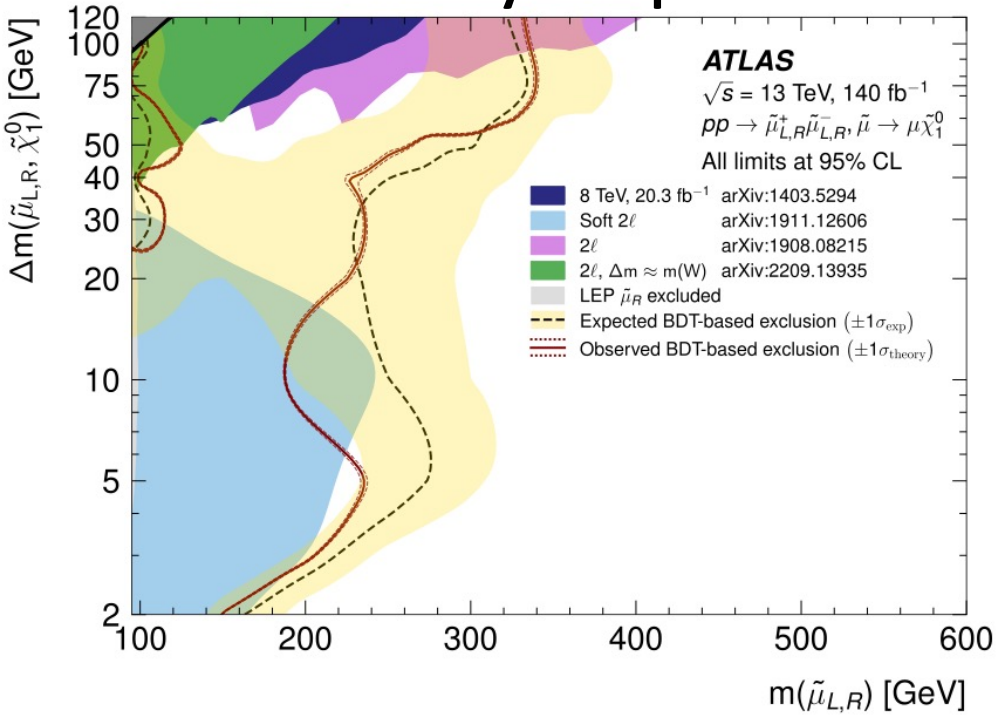
Smuon only interpretation



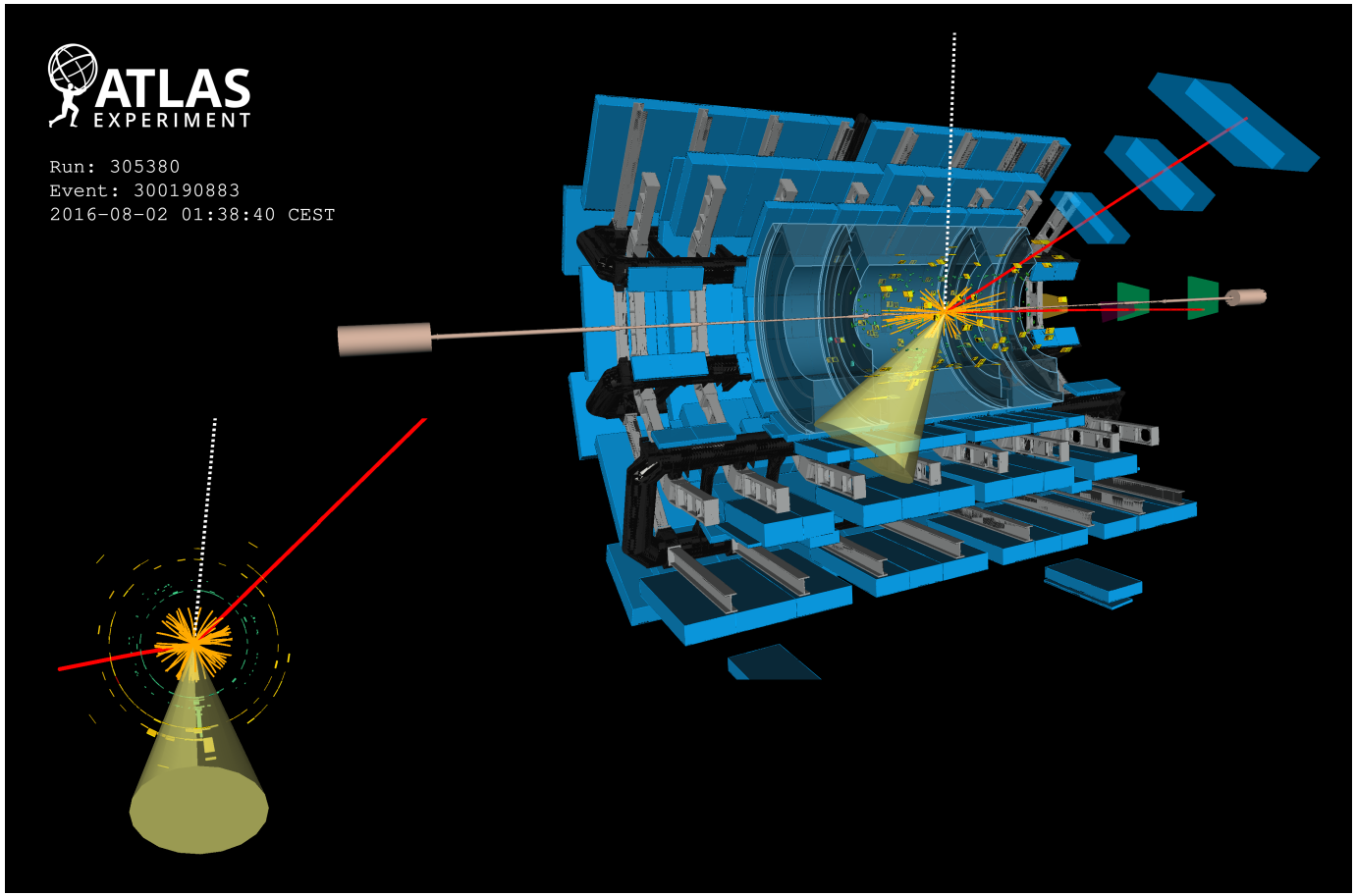
Maximal discovery significance: 2.1σ

For model: $m(\tilde{\mu}, \chi_1^0) = (150,140)$ GeV

Conclusion

Presented results from ATLAS search for sleptons in the compressed mass corridor: arXiv:2503.17186

Improved sensitivity across a large range of compressed slepton models, in some places for the first time since LEP



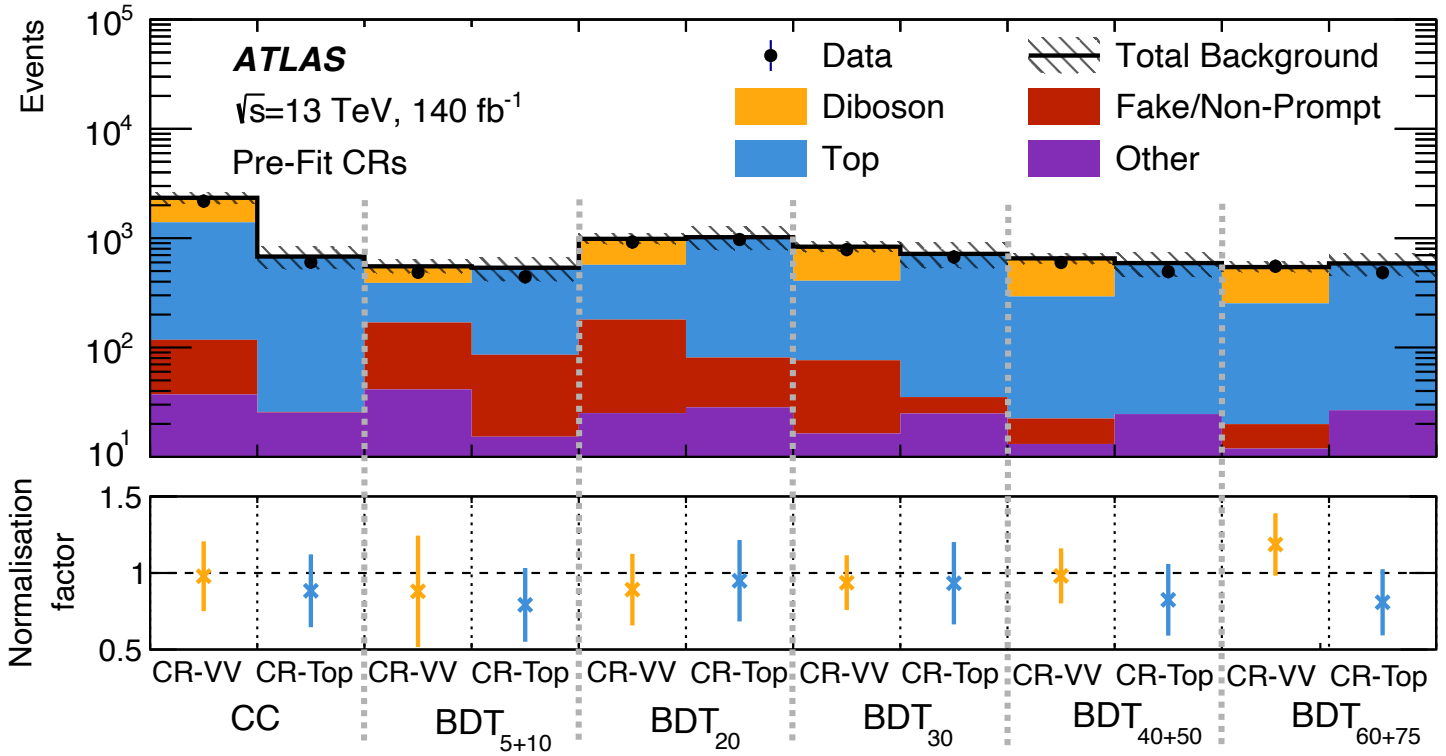
With a couple of interesting excesses, favouring:

$\Delta m(\tilde{e}, \chi_1^0)$ = 40 GeV

$\Delta m(\tilde{\mu}, \chi_1^0)$ = 10 GeV

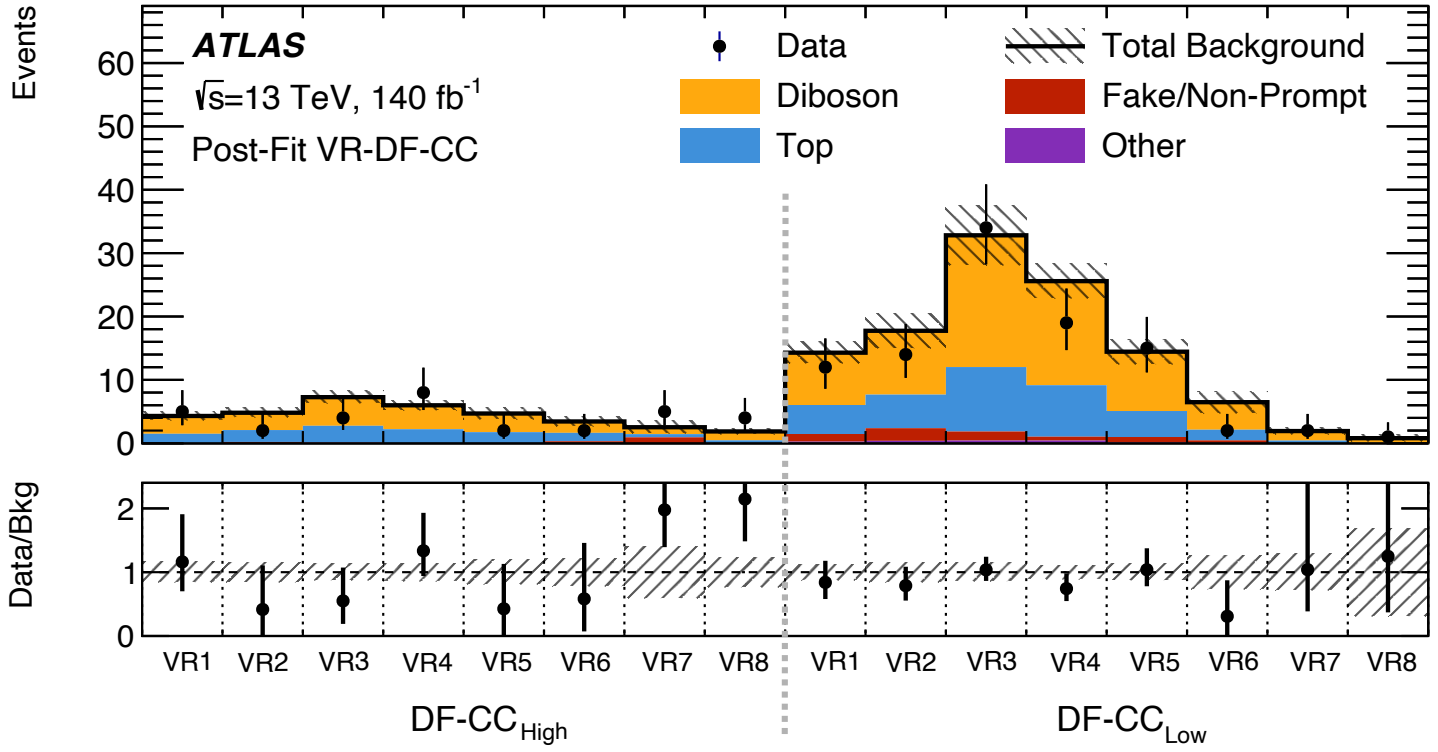
Backup

CR summary plot

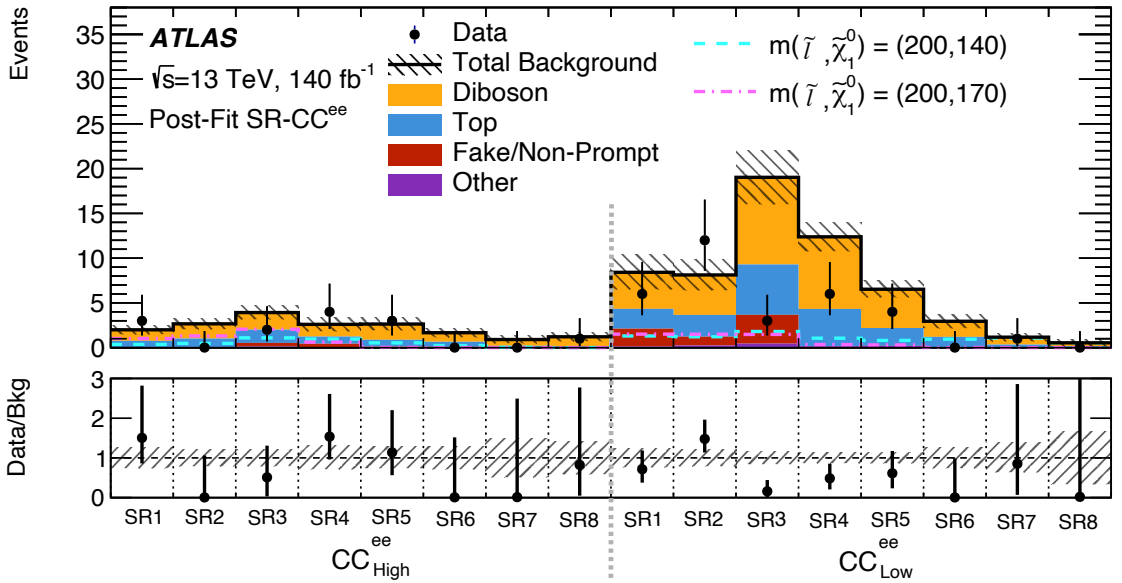


Cut and count approach

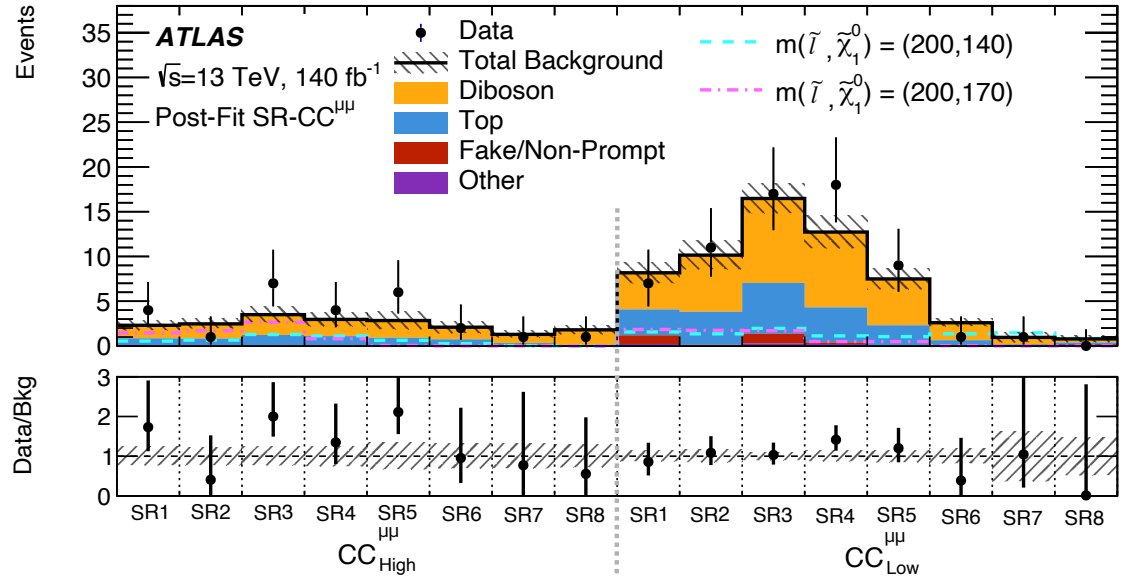
Cut and count VRs



$CC - SR^{ee}$



$CC - SR^{\mu\mu}$



Additional BDT material

Excess SR tables

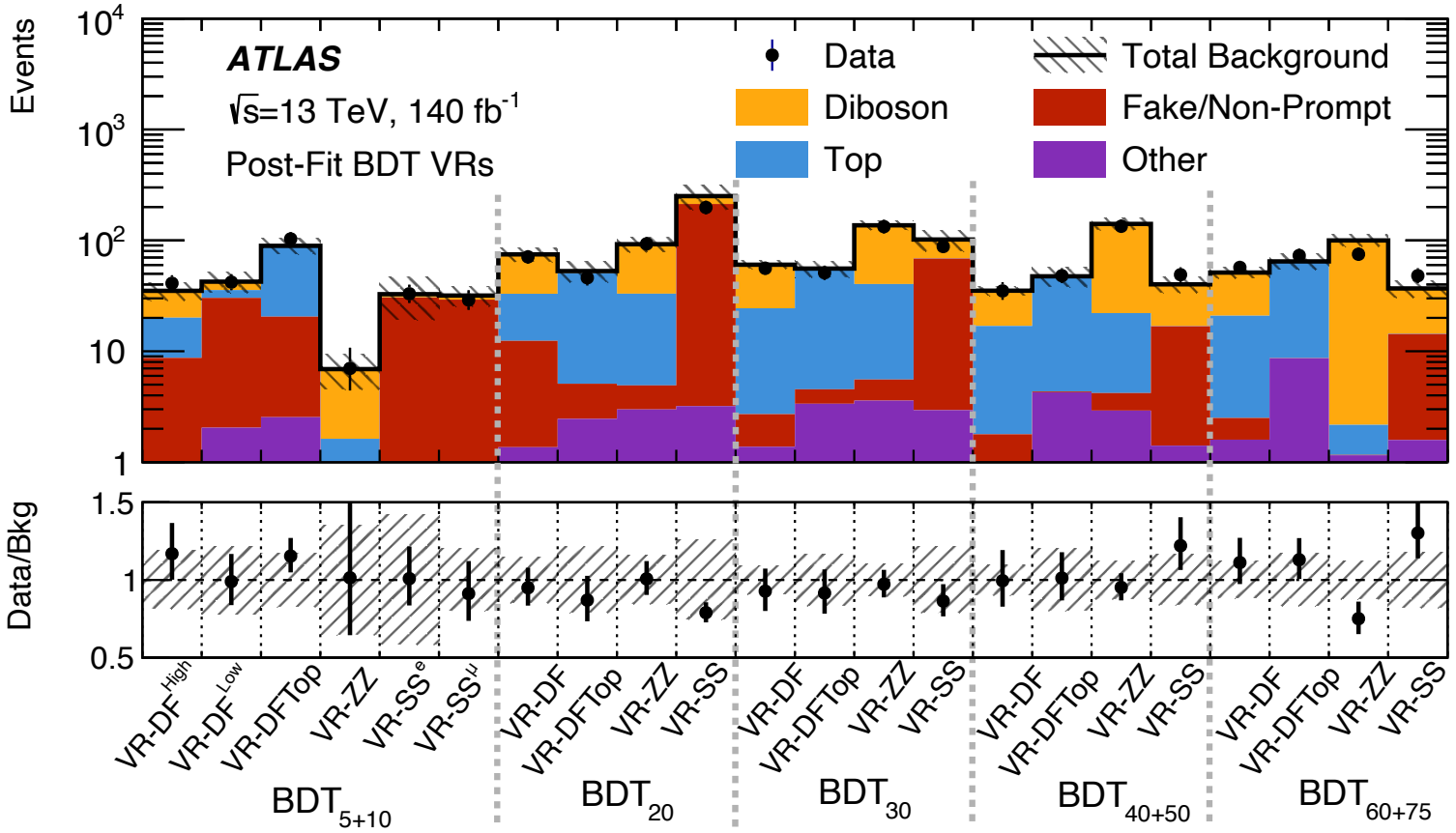
Table 17: Summary of observed and predicted yields in SR-BDT$_{5+10}$ using the CR-only fit. The category 'Other' contains rare backgrounds from processes such as $t\bar{t}V$, multi-top and triboson production. Uncertainties in the fitted background estimates combine statistical and systematic uncertainties.

SR	SR1-BDT$^{ee}_{5+10}$	SR2-BDT$^{ee}_{5+10}$	SR3-BDT$^{ee}_{5+10}$	SR1-BDT$^{\mu\mu}_{5+10}$	SR2-BDT$^{\mu\mu}_{5+10}$	SR3-BDT$^{\mu\mu}_{5+10}$
Observed	10	11	5	23	26	4
Fitted SM events	12.3 ± 3.1	10.6 ± 2.5	3.5 ± 1.0	13.7 ± 2.6	13.7 ± 2.6	3.9 ± 1.1
Top	3.0 ± 0.9	2.1 ± 0.5	0.62 ± 0.19	3.7 ± 0.8	3.3 ± 0.7	1.10 ± 0.27
Diboson	4.3 ± 1.9	4.3 ± 1.7	1.6 ± 0.7	4.5 ± 1.9	5.8 ± 2.3	2.5 ± 1.0
Fake/Non-Prompt	4.5 ± 2.3	3.7 ± 1.9	1.2 ± 0.8	4.9 ± 1.6	3.5 ± 1.3	$0.3^{+0.4}_{-0.3}$
Other	0.6 ± 0.4	0.50 ± 0.35	0.09 ± 0.05	0.6 ± 0.5	1.1 ± 0.6	0.05 ± 0.04

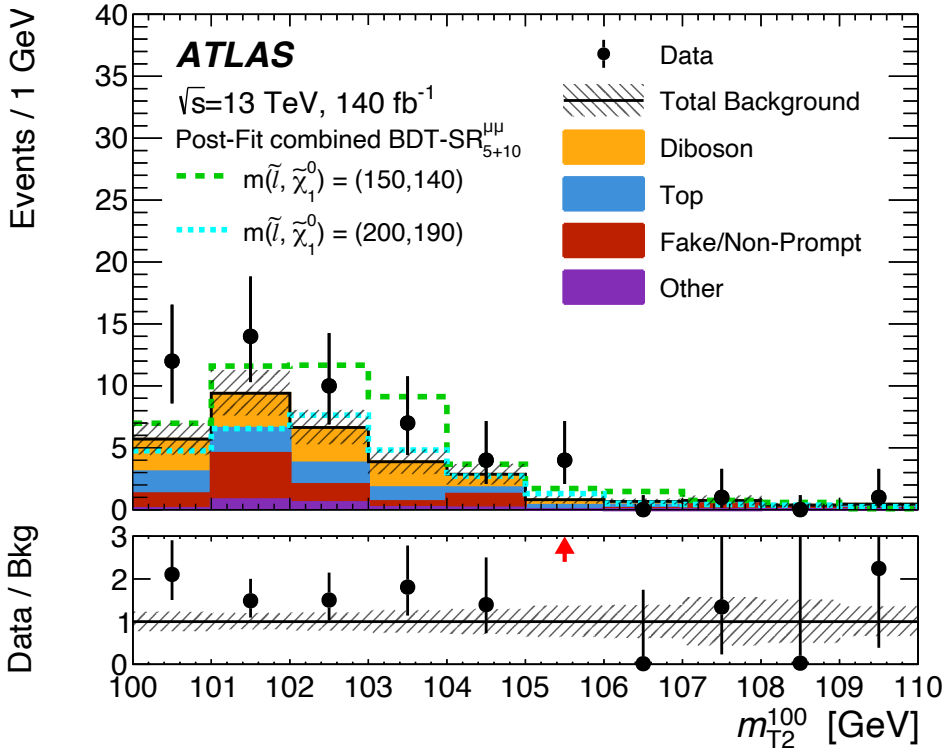
Table 20: Summary of observed and predicted yields in SR-BDT$_{40+50}$ using the CR-only fit. The category 'Other' contains rare backgrounds from processes such as $t\bar{t}V$, multi-top and triboson production. Uncertainties in the fitted background estimates combine statistical and systematic uncertainties.

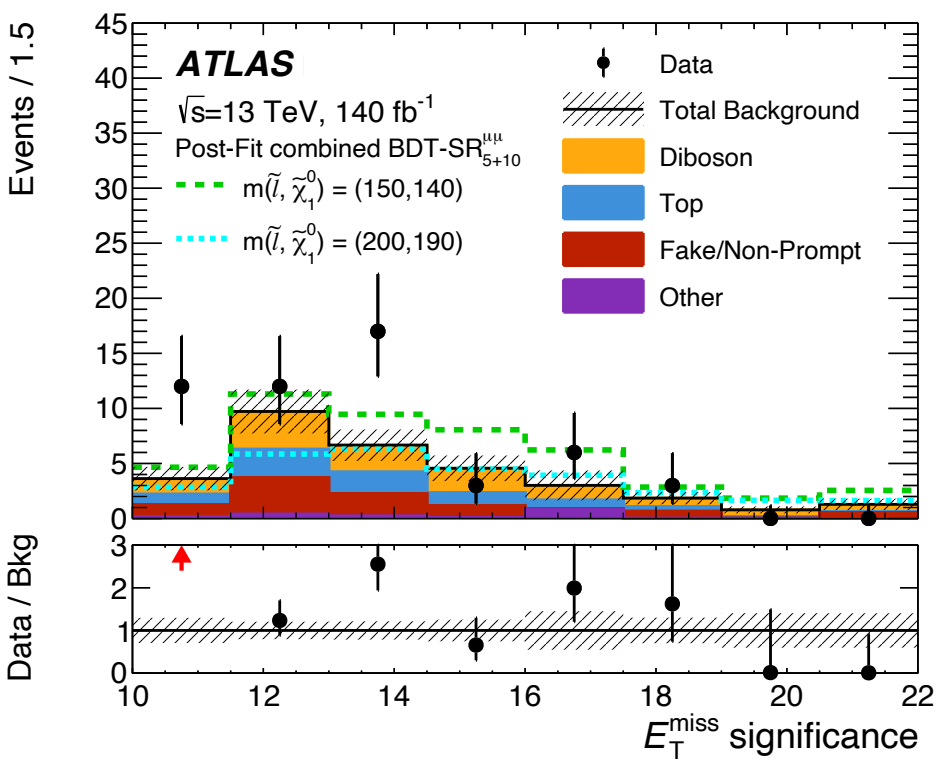
SR	SR1-BDT$^{ee}_{40+50}$	SR2-BDT$^{ee}_{40+50}$	SR3-BDT$^{ee}_{40+50}$	SR1-BDT$^{\mu\mu}_{40+50}$	SR2-BDT$^{\mu\mu}_{40+50}$	SR3-BDT$^{\mu\mu}_{40+50}$
Observed	9	6	7	3	9	4
Fitted SM events	8.2 ± 2.0	6.2 ± 1.4	2.8 ± 0.8	9.1 ± 1.9	6.3 ± 1.2	3.2 ± 0.7
Top	2.7 ± 1.2	2.6 ± 1.2	0.5 ± 0.4	3.7 ± 1.6	1.9 ± 1.0	0.53 ± 0.28
Diboson	3.8 ± 1.2	3.4 ± 0.8	2.1 ± 0.5	5.3 ± 1.1	4.2 ± 0.8	2.6 ± 0.5
Fake/Non-Prompt	$1.2^{+1.3}_{-1.2}$	$0.01^{+0.31}_{-0.01}$	$0.01^{+0.31}_{-0.01}$	$0.00^{+0.15}_{-0.00}$	$0.01^{+0.18}_{-0.01}$	$0.04^{+0.09}_{-0.04}$
Other	0.41 ± 0.25	0.28 ± 0.24	0.15 ± 0.08	$0.16^{+0.22}_{-0.16}$	$0.22^{+0.23}_{-0.22}$	0.07 ± 0.05

BDT VR summary

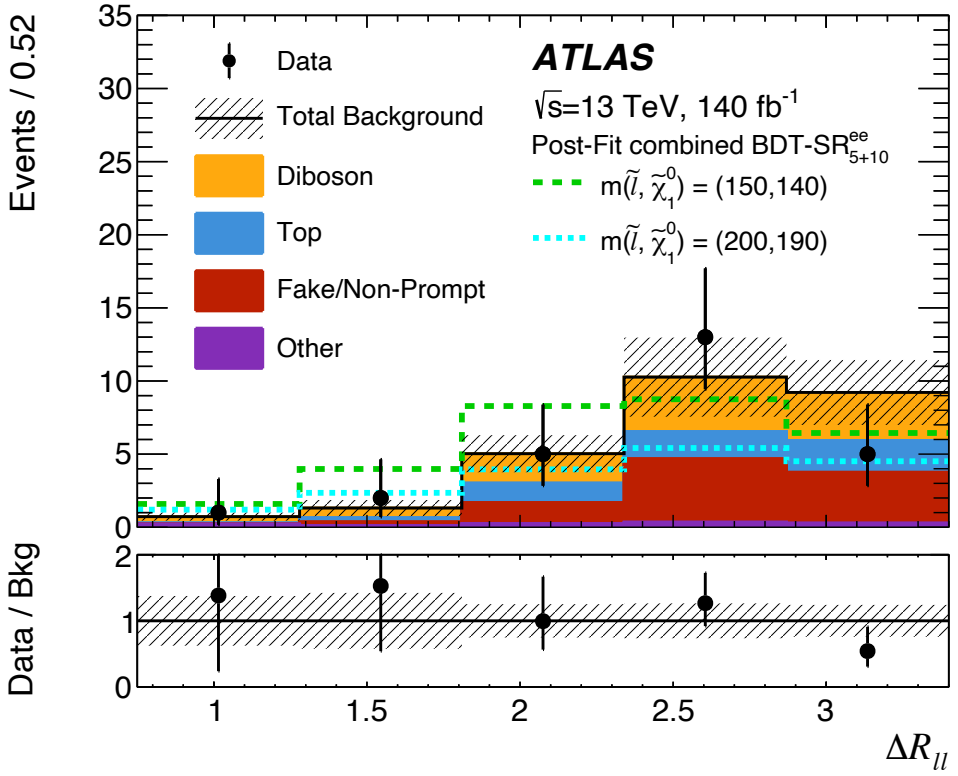


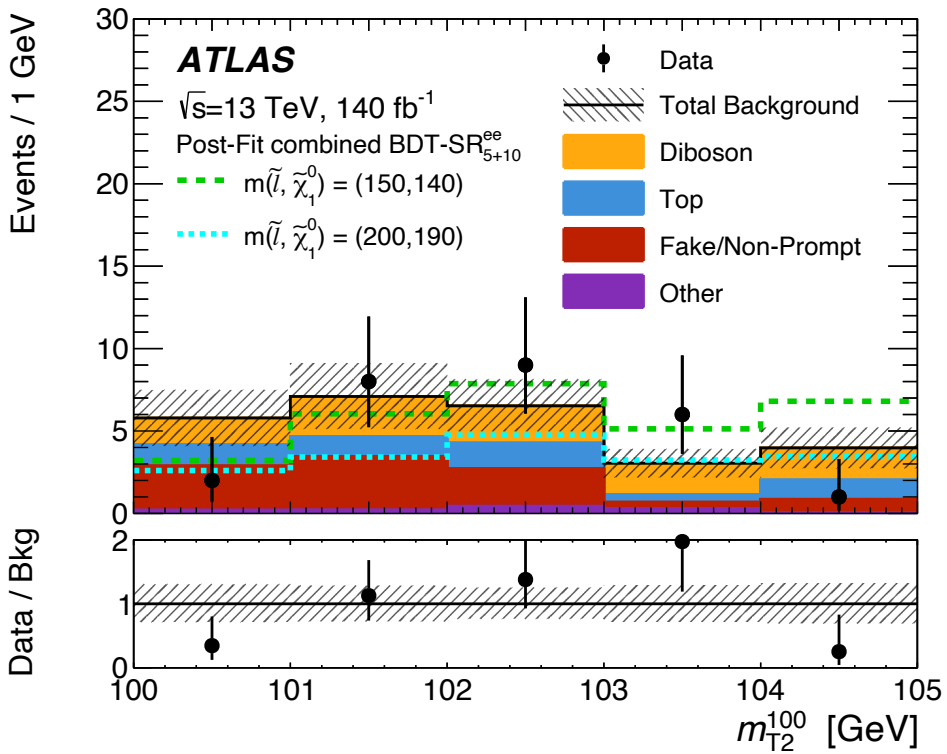
Additional BDT – $SR^{\mu\mu}_{5+10}$ plots



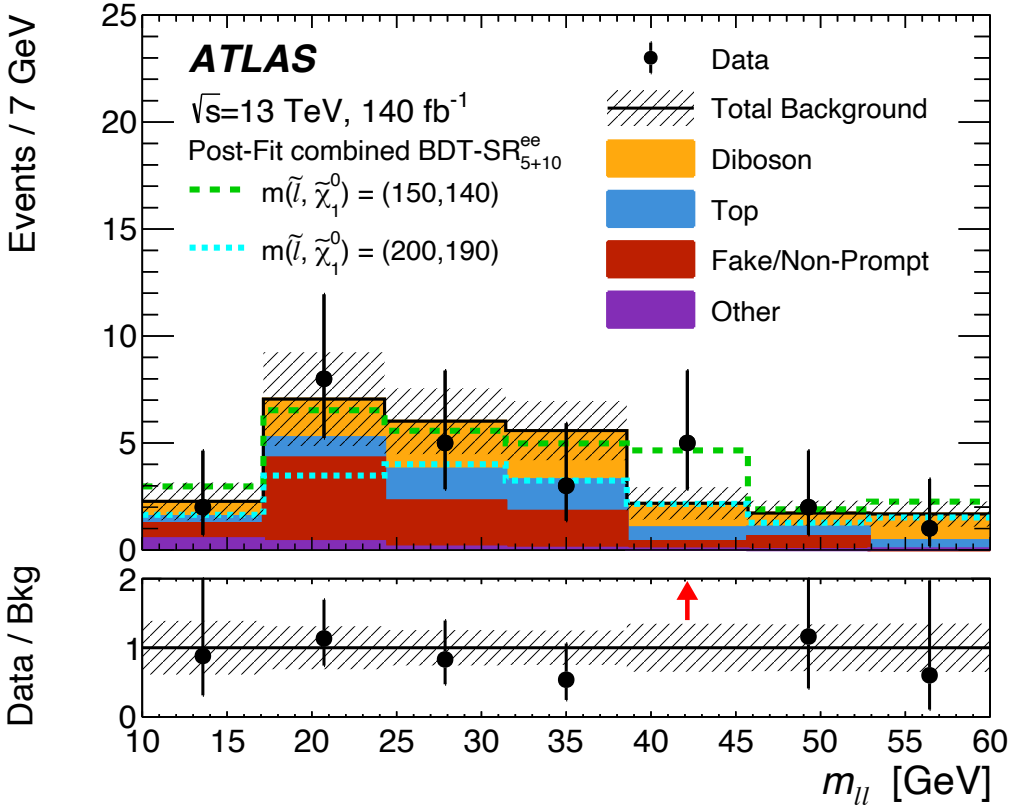


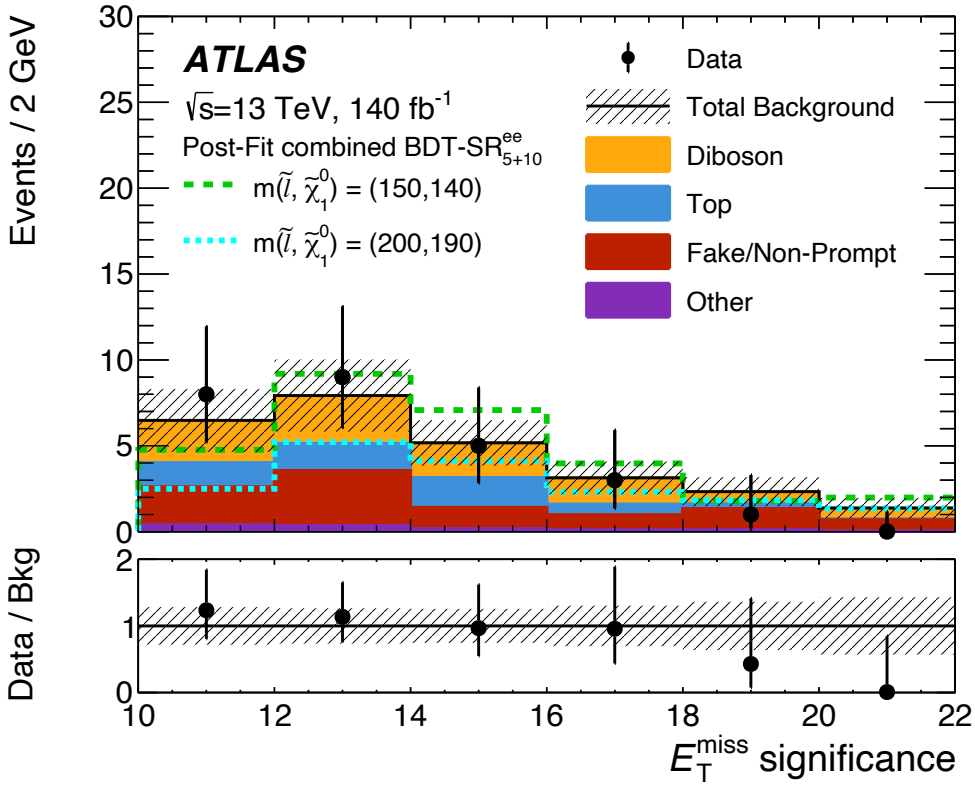
BDT – SR^{ee}_{5+10} plots



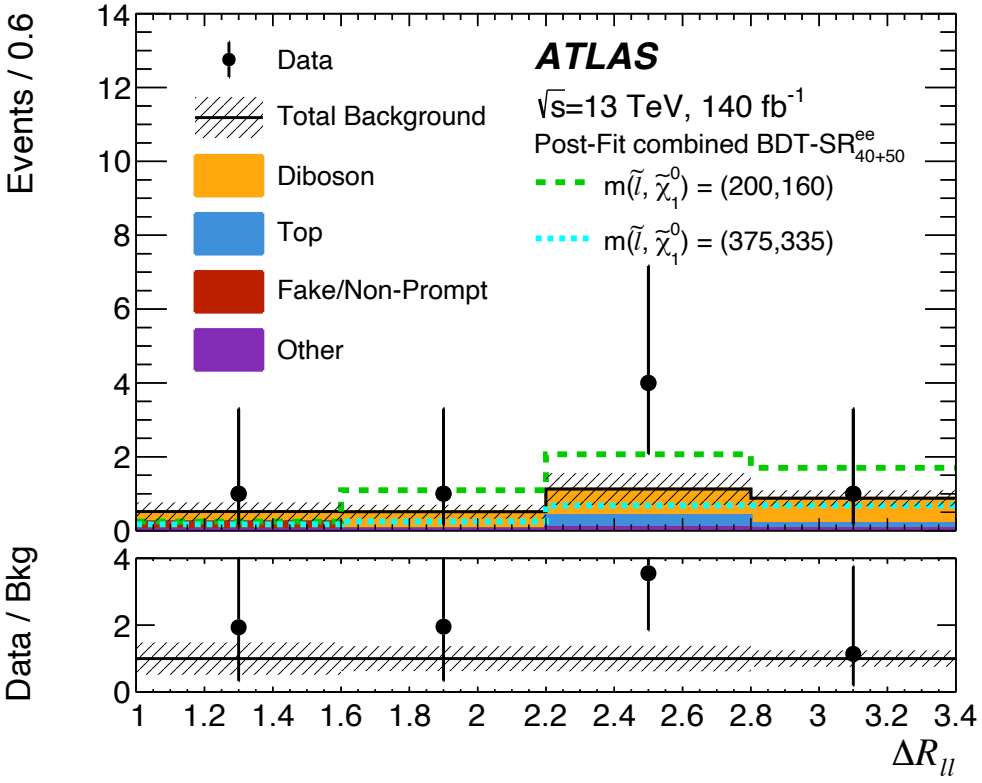


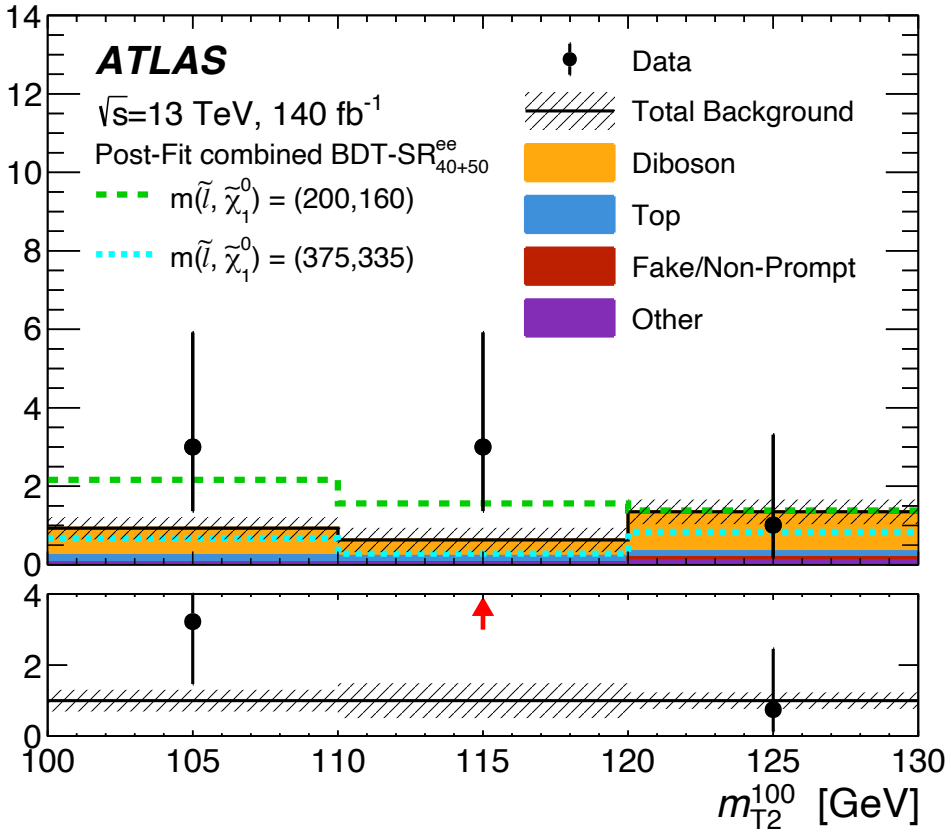
BDT – SR^{ee}_{5+10} plots





Additional BDT – SR^{ee}_{40+50} plots





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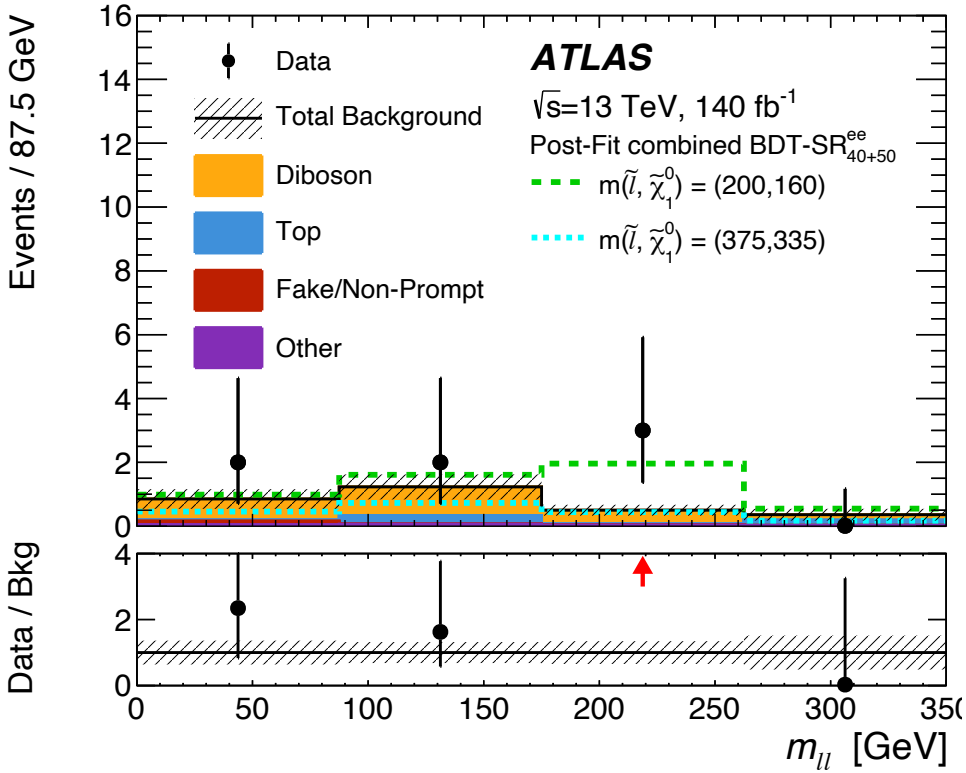

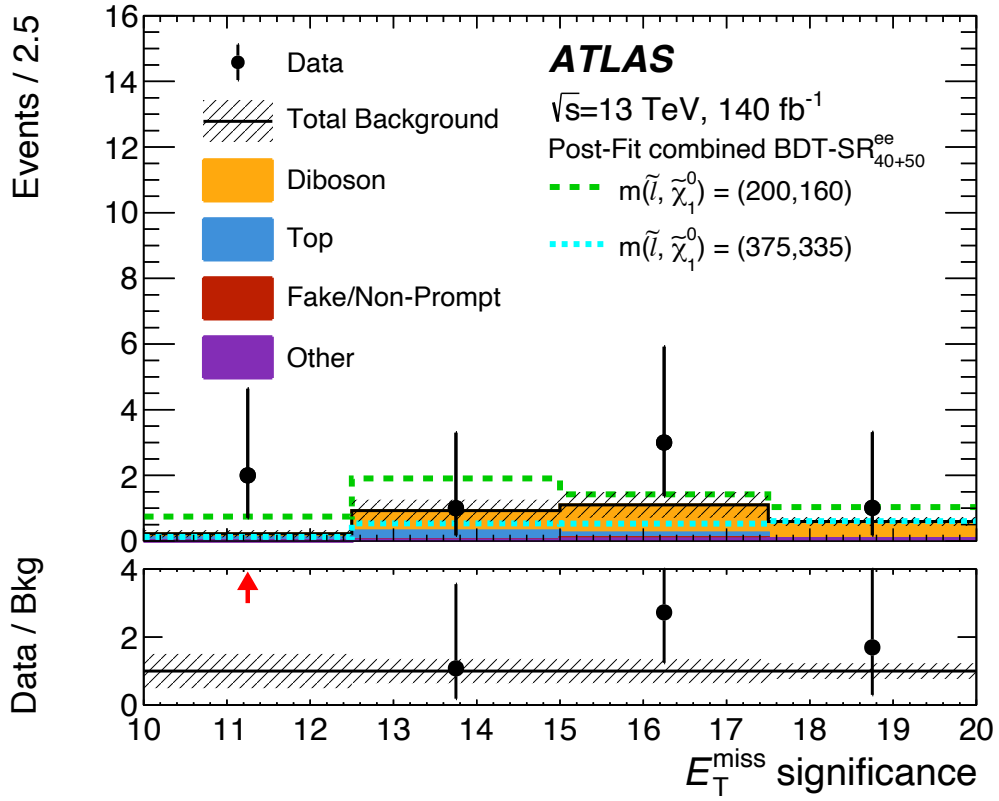

Exclusion comparison