SUSY Stop 4b - The road so far

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University of Salento & INFN Unit of Lecce

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Introduction

Search for pair produced top squarks decaying in 4-bodies in final states with two leptons in pp collisions at $\sqrt{s}$ = 13 TeV and $\sqrt{s}$ = 13.6 TeV

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A search for direct pair production of top squarks in final states with two opposite-charge leptons (electrons or muons), jets and missing transverse momentum is reported, using 139 fb^{-1} of integrated luminosity from proton–proton collisions at $\sqrt{s}$ = 13 TeV, collected by the ATLAS detector at the Large Hadron Collider during Run 2 (2015-2018) and 53 fb^{-1} collected during Run 3 (2022-2023) at $\sqrt{s}$ = 13.6 TeV. The considered stop decay mode is the one in 4-bodies $\tilde{t} \to b\ell\nu\tilde{\chi}_1^0$, i.e. a bottom quark, an off-shell W -boson which finally decays leptonically in $\ell\nu$, and the lightest neutralino $\tilde{\chi}_1^0$.

Internal Note available on gitlab, *ANA-HMBS-2024-10-INT5*, fully updated with current results.

DNN and HF codes stored on gitlab, *fgravili/ttmet2l*: will perform of cleanup of the repository soon!

Technical Setup

- AnalysisBase 25.2.56, with DAOD_PHYS
- Full list of background and signal samples in the note: mc20(a/d/e) + mc23(a/d)[1] campaigns. *2024 to be added!*
- Data from GRL, up to 2023:
  - data15_13TeV/20170619/physics_25ns_21.0.19.xml
  - data16_13TeV/20180129/physics_25ns_21.0.19.xml
  - data17_13TeV/20180619/physics_25ns_Triggerno17e33prim.xml
  - data18_13TeV/20190318/physics_25ns_Triggerno17e33prim.xml
  - data22_13p6TeV/20230207/physics_25ns.xml
  - data23_13p6TeV/20230828/physics_25ns_data23_ignoreTRIG_JETCTPIN.xml
- MET triggers

Data period	Trigger items
2015-2016	HLT_xe70_mht HLT_xe90_mht_L1XE50 HLT_xe100_mht_L1XE50 HLT_xe110_mht_L1XE50
2017	HLT_xe90_pufit_L1XE50 HLT_xe100_pufit_L1XE55 HLT_xe100_pufit_L1XE50 HLT_xe110_pufit_L1XE50 HLT_xe110_pufit_L1XE55
2018	HLT_xe110_pufit_xe70_L1XE50 HLT_xe120_pufit_L1XE50 HLT_xe110_pufit_xe65_L1XE50
2022	HLT_xe65_cell_xe90_pfopufit_L1XE50 HLT_xe80_cell_xe115_tcpufit_L1XE50
2023	HLT_xe55_cell_xe70_tcpufit_xe90_pfsum_vssk_L1XE50 HLT_xe55_cell_xe70_tcpufit_xe95_pfsum_cssk_L1XE50 HLT_xe60_cell_xe95_pfsum_cssk_L1XE50 HLT_xe65_cell_xe100_mhtpufit_pf_L1XE50 HLT_xe65_cell_xe105_mhtpufit_em_L1XE50 HLT_xe75_cell_xe65_tcpufit_xe90_trkmht_L1XE50 HLT_xe65_cell_xe90_pfopufit_L1XE50 HLT_xe80_cell_xe115_tcpufit_L1XE50

[1] Identified bug in 4b LSF: x10 larger hardcoded cross section for ttZ. Preparing fix MR

Object Definition

SUSYTools ConfigFiles: *Run2*, *Run3*

Electrons

Cut	Value/description
Baseline Electron	
Acceptance	$p_T > 4.5$ GeV, $\|\eta\| < 2.47$
PID Quality	LooseAndBLayerLLH
Impact parameter	$\|z_0 \sin\theta\| < 0.5$ mm
Signal Electron	
Acceptance	$p_T > 4.5$ GeV, $\|\eta\| < 2.47$
PID Quality	MediumLLH
Isolation	Loose_VarRad
Impact parameter	$\|d_0/\sigma_{d_0}\| < 5$

Muons

Cut	Value/description
Baseline Muon	
Acceptance	$p_T > 4$ GeV, $\|\eta\| < 2.7$
PID Quality	Medium - 1
Impact parameter	$\|z_0 \sin\theta\| < 0.5$ mm
Signal Muon	
Acceptance	$p_T > 4$ GeV, $\|\eta\| < 2.7$
PIDQuality	Medium - 1
Isolation	PflowLoose_VarRad
Impact parameter	$\|d_0/\sigma_{d_0}\| < 3$

Jets

Cut	Value/description
Baseline jet	
Collection	PFlow
Acceptance	$p_T > 20$ GeV , $\|\eta\| < 2.8$
JVT	FixedEffPt (Default WP)
fJVT	Loose (Default WP) for jets with $p_T < 60$ GeV and $\|\eta\| > 2.5$
b-tagging	GN2v01 - Continuous WP
b-tagging Acceptance	$p_T > 20$ GeV
MET Jet	Tight WP

No FNP estimate in place, so the same criteria are used to evaluate MCFakes, with Origin request reverted

Preselection

ML strategy implemented: define a NN model to be fed with variables after a preselection skim

Variable	Preselection cut value	Motivation
Cleaning Cuts and Overlap Removal	Default	
Number of signal leptons	$= 2$	Final state
MET [GeV]	> 250	Trigger Plateau
Lepton charge	Opposite Sign	Final state
Leading lepton p_T [GeV]	$p_T < 100$	Soft lepton
SubLeading lepton p_T [GeV]	$p_T < 100$	Soft lepton
Dilepton Invariant Mass [GeV]	> 10	Low-mass resonances
Leading jet p_T [GeV]	$p_T > 150$	ISR

NN Model

DNN Model built with `Keras` and `TensorFlow` backend:

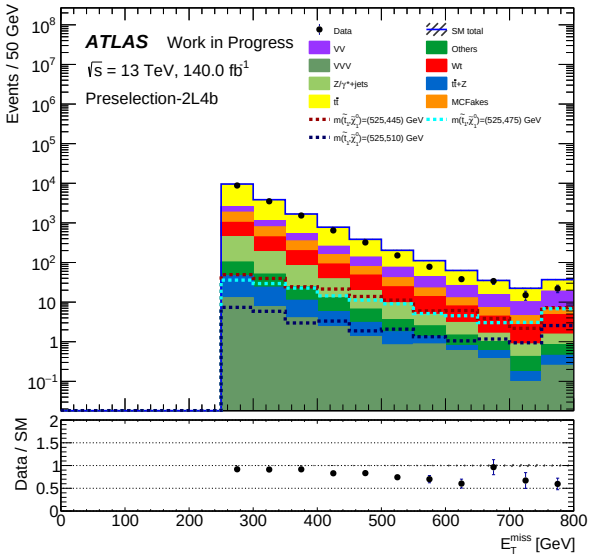
- 21 input variables:
  - the leading and subleading lepton p_T, η and ϕ
  - the leading and subleading jet p_T, η and ϕ
  - MET, METsig, $R_{2\ell} = MET/(p_T^{\ell_1} + p_T^{\ell_2})$, $R_{lj} = MET/(p_T^{\ell_1} + p_T^{\ell_2} + p_T^{j_1 \cdots 4})$
  - the number of jets and b-tagged jets in the event
  - $m_{\ell\ell}$, $\min\Delta R_{\ell_1, j_i}$, $\min\Delta R_{\ell_2, j_i}$
- 4-fold output with unitary probability sum: Signal (class 0), $t\bar{t}$ (class 1), VV (class 2), Others (class 3)
- Signal samples split according to $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0)$:
  - Small Δm [GeV]: 8, 10, 15, 20
  - Medium Δm [GeV]: 30, 40, 50
  - Large Δm [GeV]: 60, 70, 80
- Even/Odd training split and application to the other half $\rightarrow$ 6 trainings in total
- Input variables normalized by scaling $x_i \rightarrow x_i' = (x_i - \min_i)/(\max_i - \min_i)$, with $\min_i$ and $\max_i$ values in the full signal plus background joint sample, rescaling in a $[0, 1]$ range

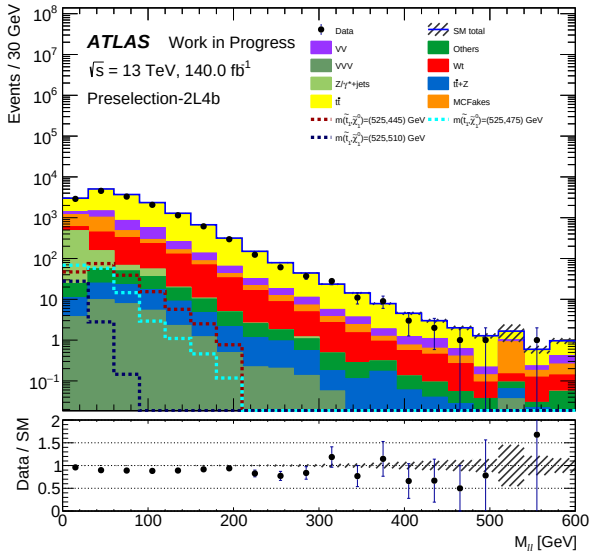
NN Model: architecture

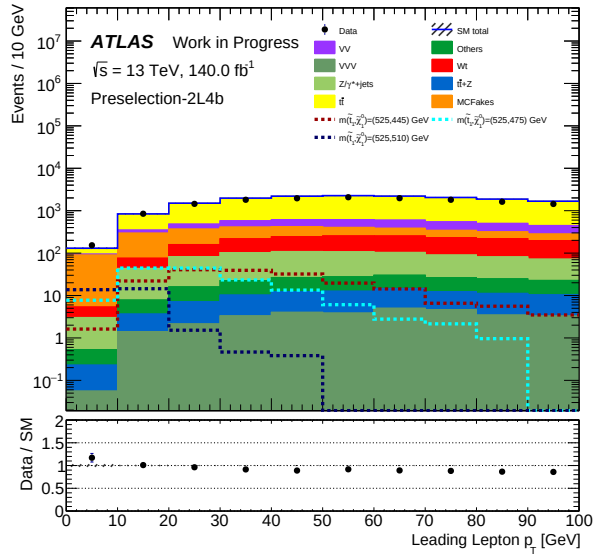
Features of the DNN architecture, optimised for each signal selection:

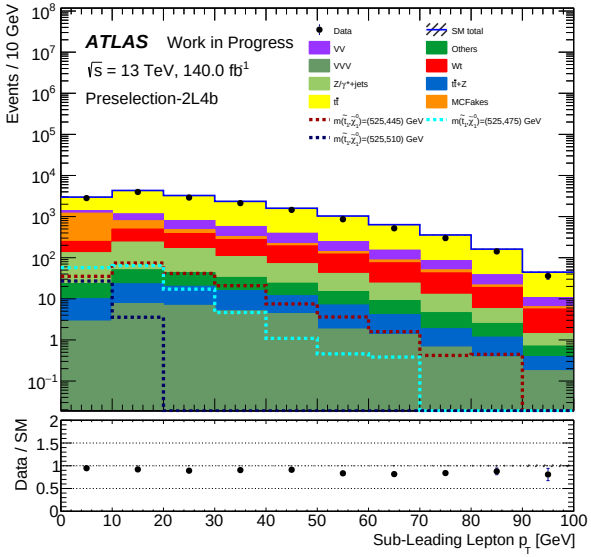
Parameter	Setting
Number of layers	3
Number of hidden nodes	(256,512,128) for small Δm (256,256,64) for medium Δm (128,512,128) for large Δm
Activation function	ReLU
Output activation function	Softmax
Optimized	Adam
Learning rate	10^{-3}
Dropout rate	30%
Batch size	128
Loss function	Categorical Cross-Entropy

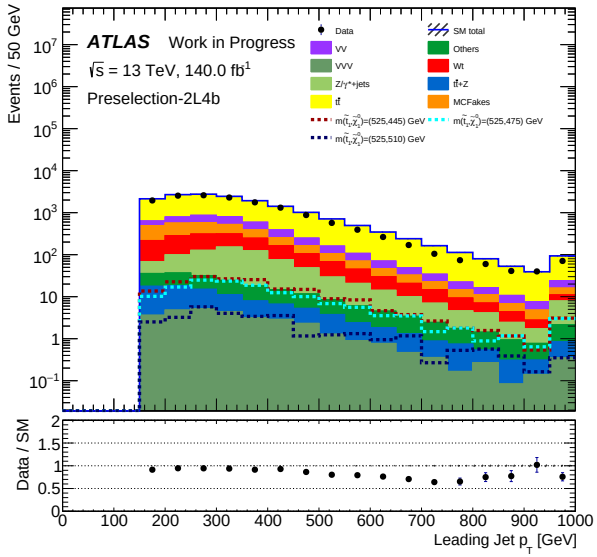
DNN input variables at preselection level - Run2 - Stat-only uncertainties

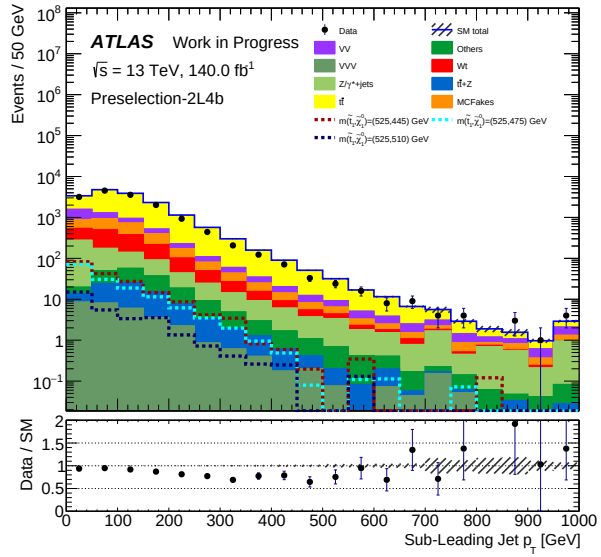












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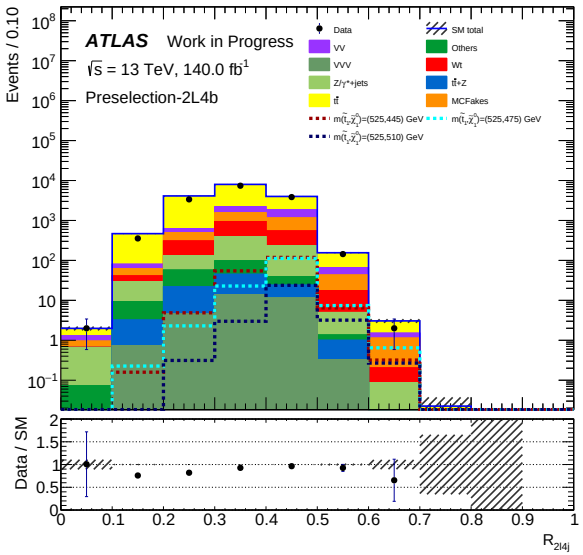

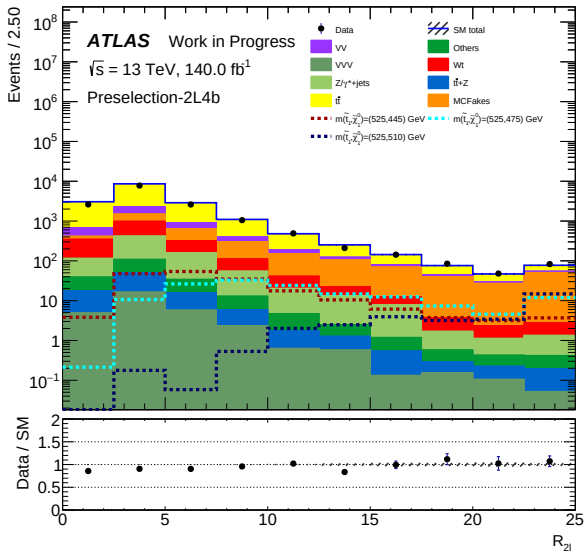

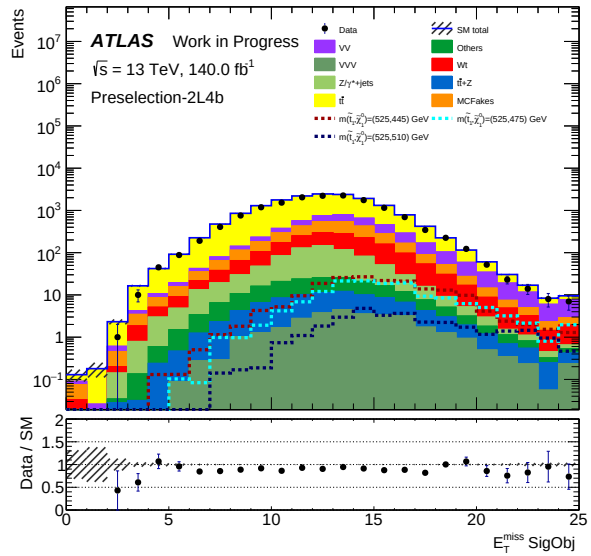

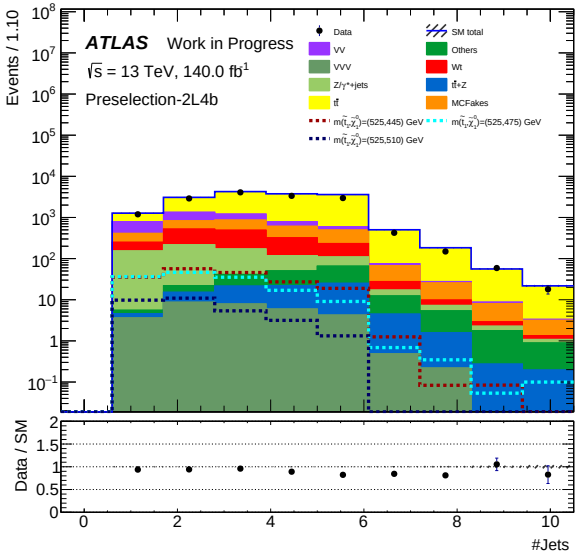

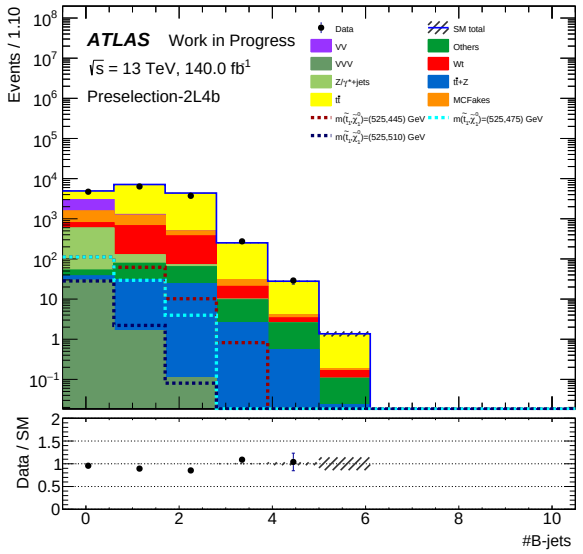

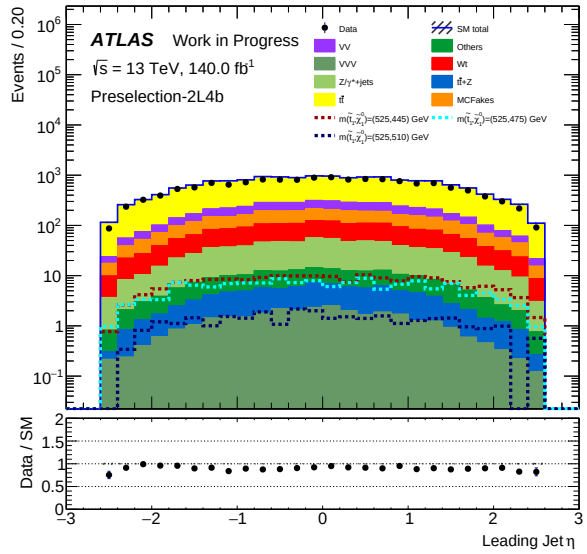

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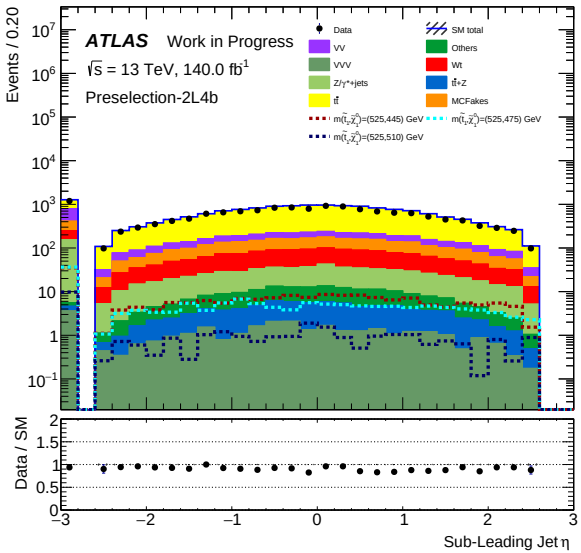
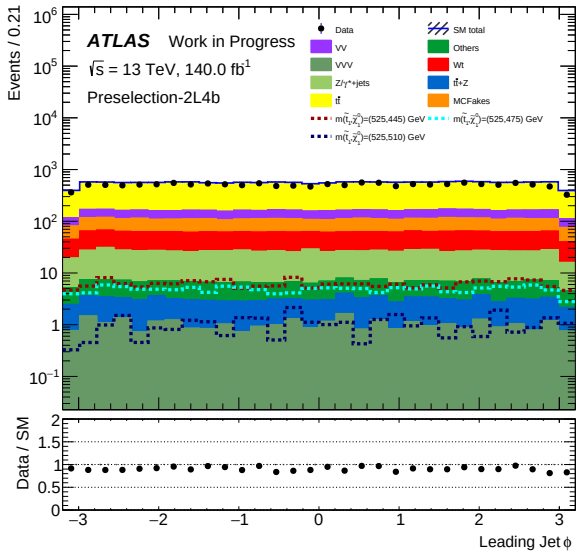
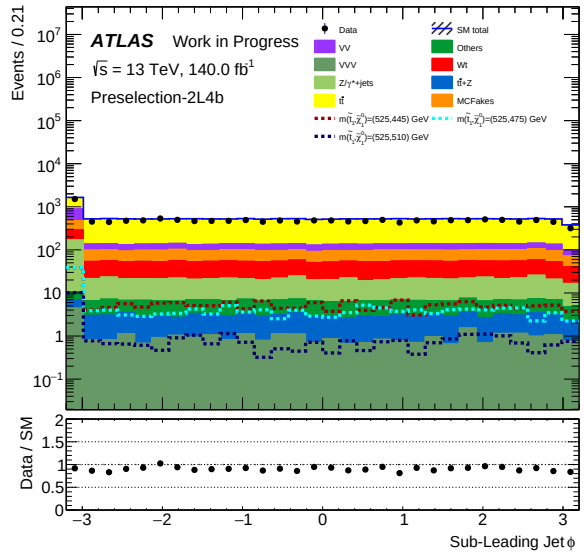
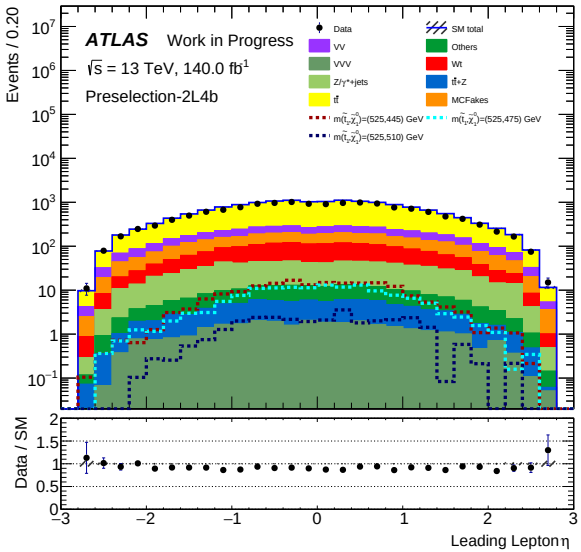
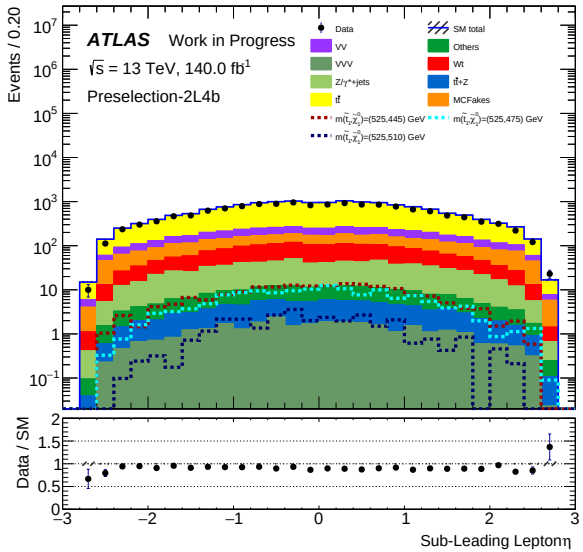
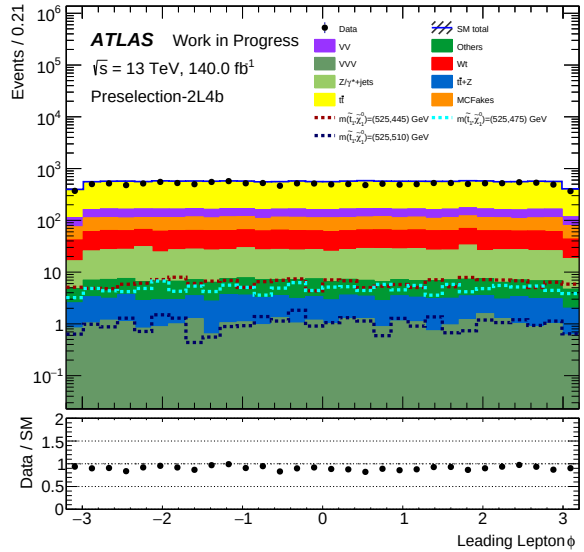




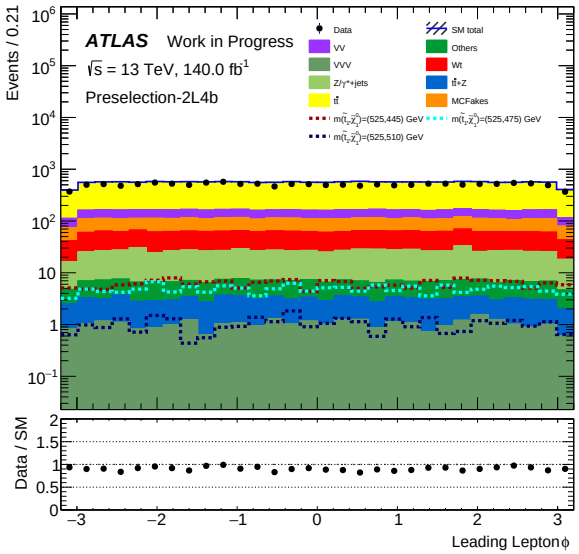


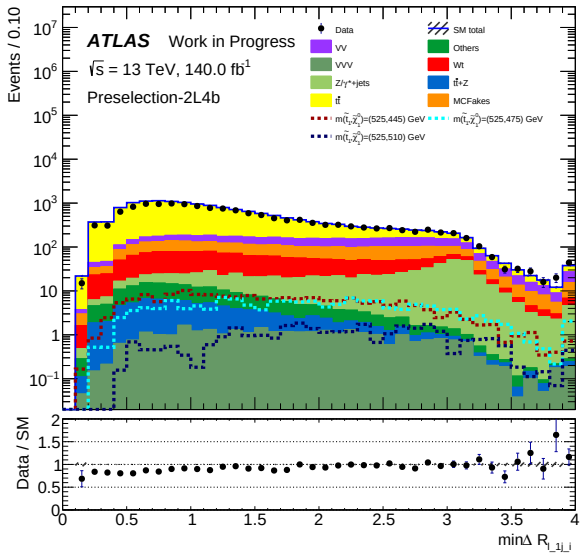


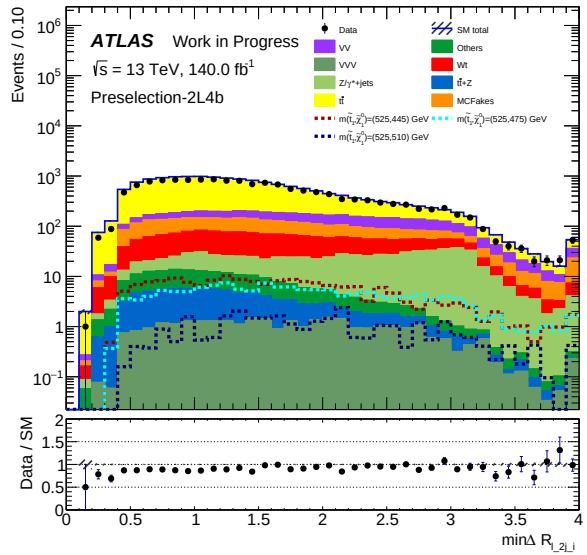




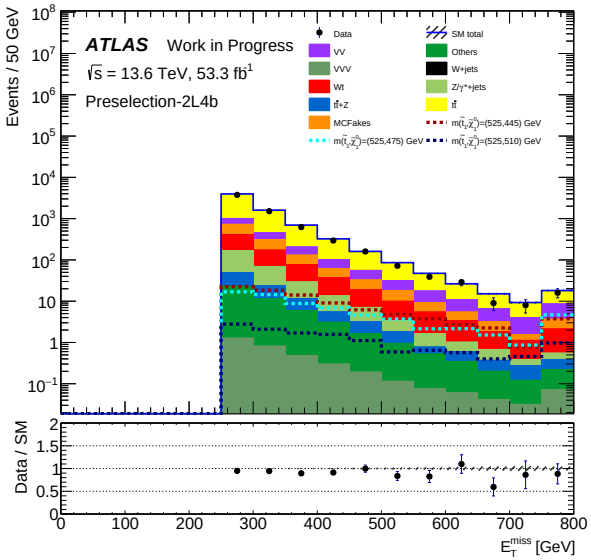
Input variable at preselection level - Run2 - Stat-only uncertainties

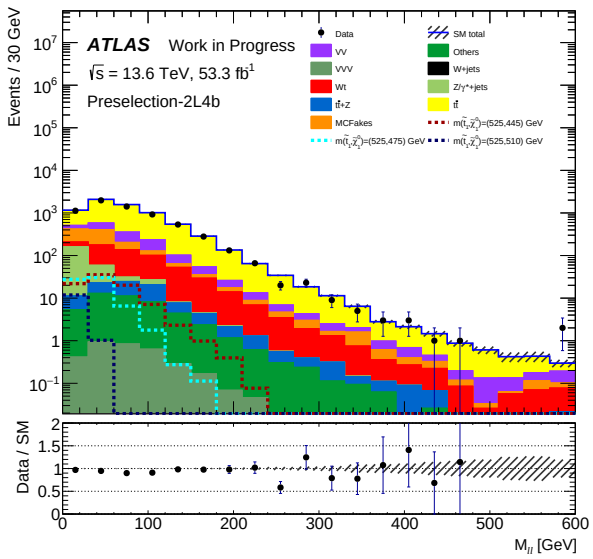


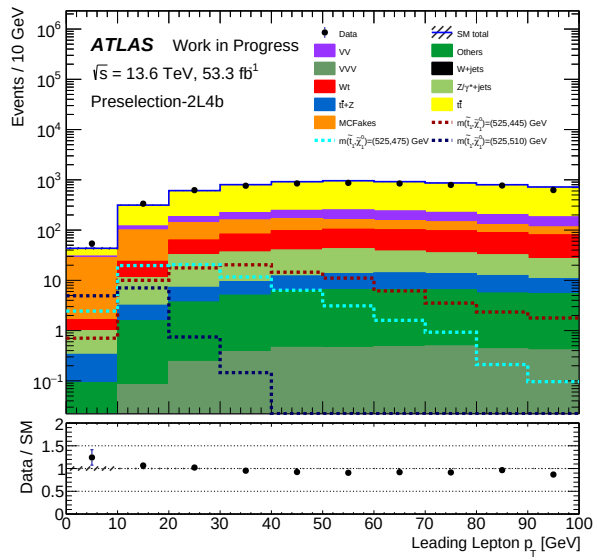


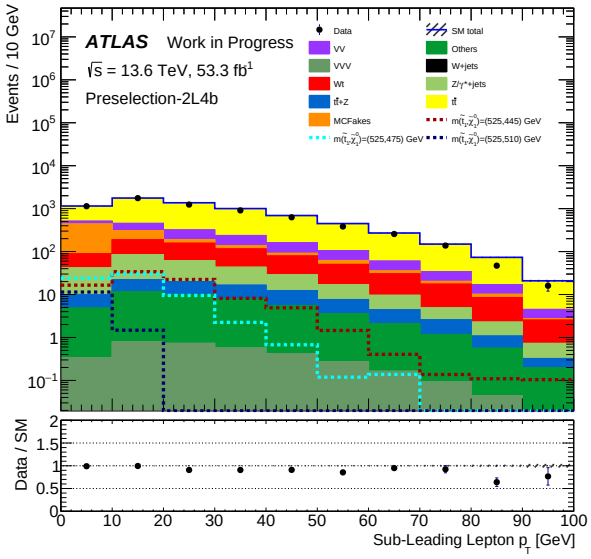


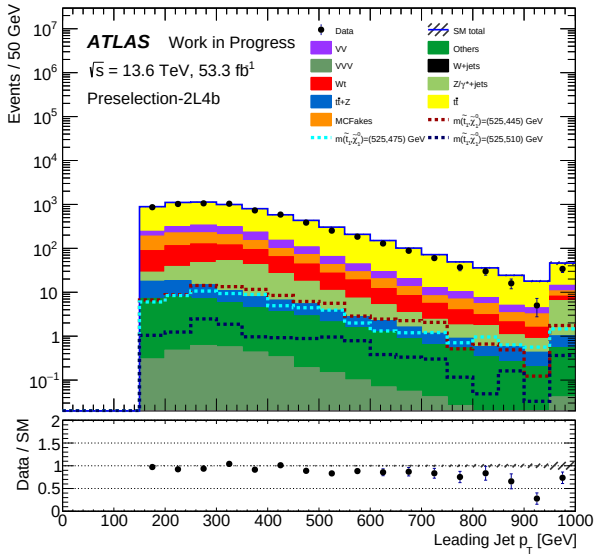
DNN input variables at preselection level - Run3 - Stat-only uncertainties

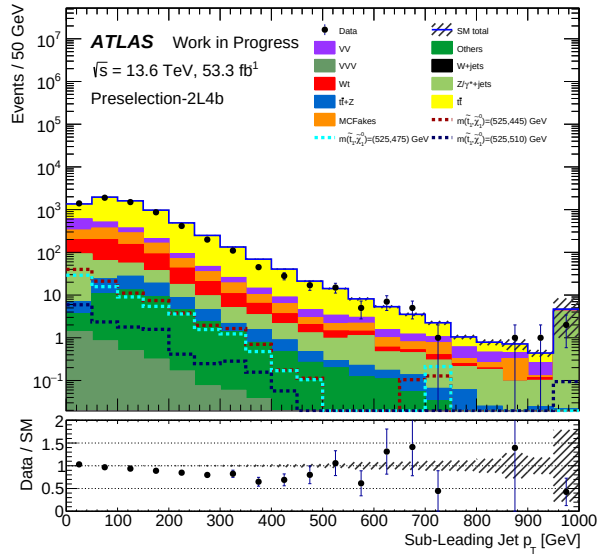




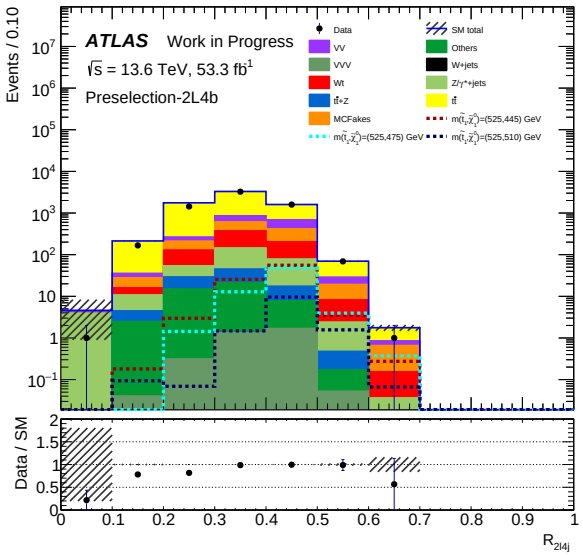


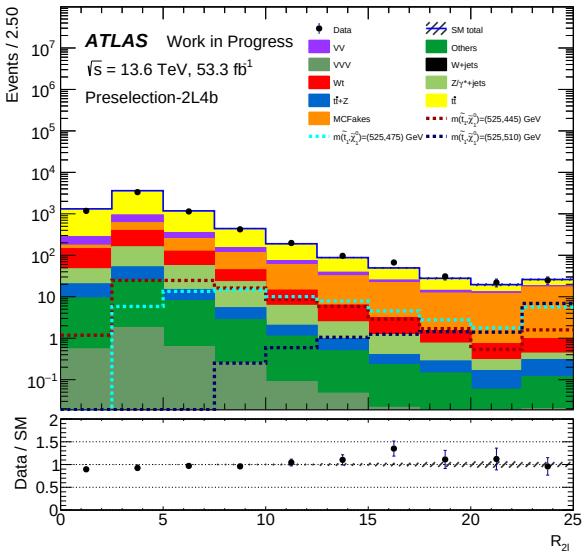


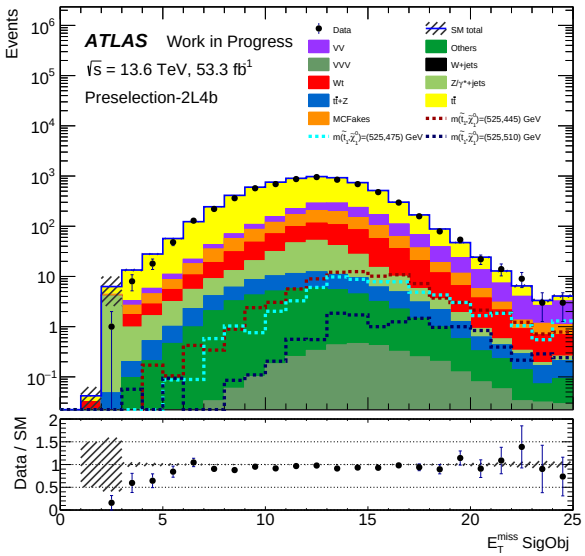


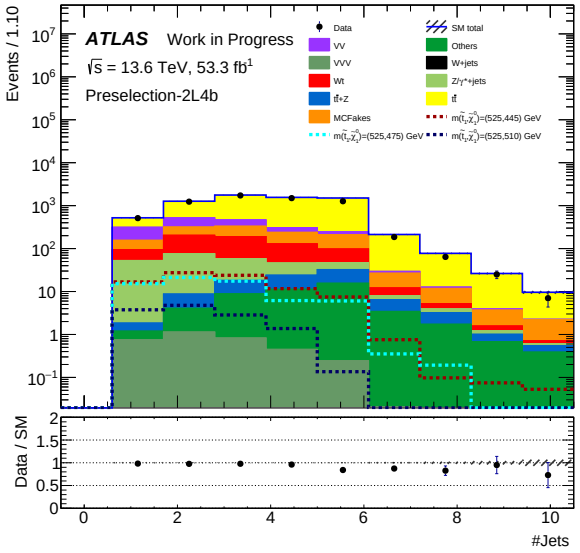


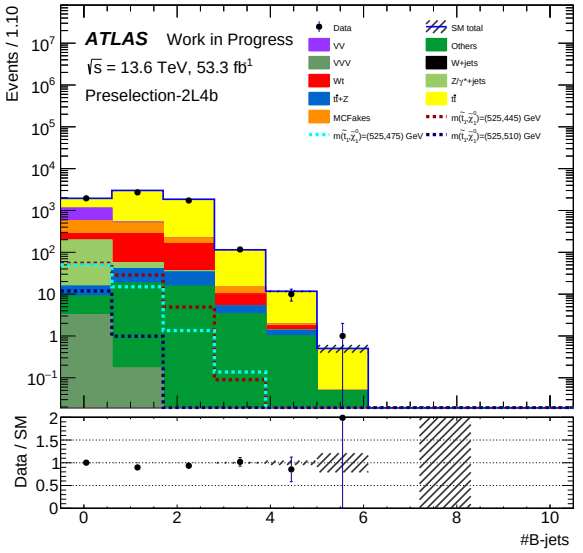
DNN input variables at preselection level - Run3 - Stat-only uncertainties

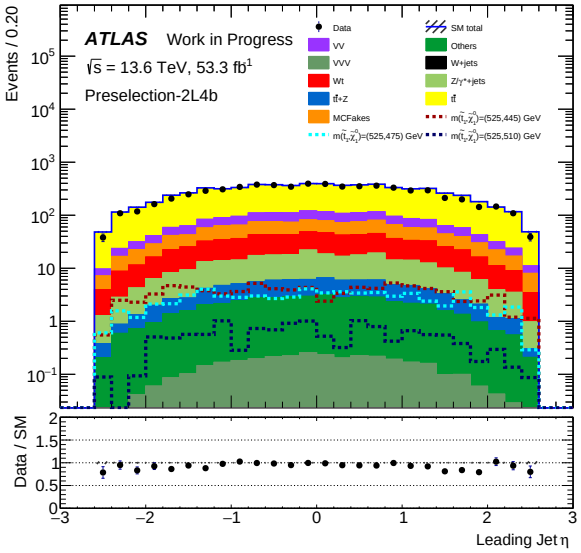




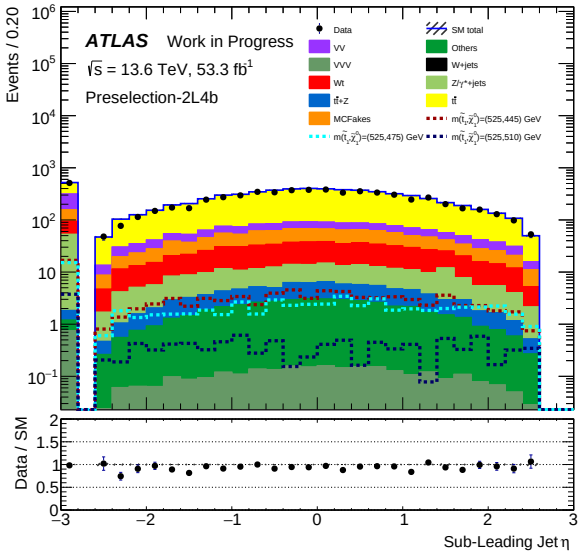


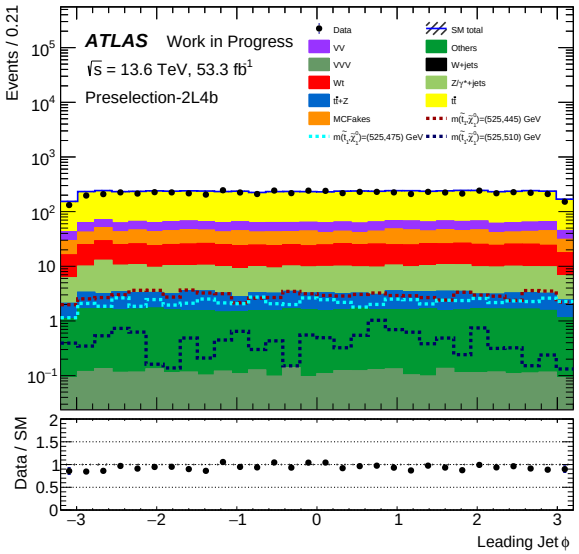


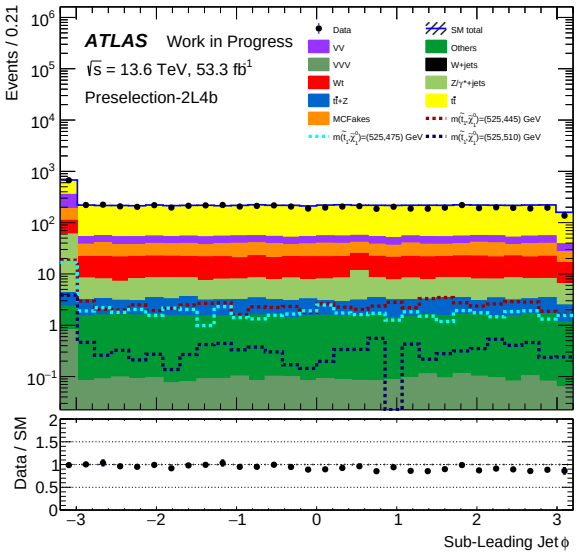


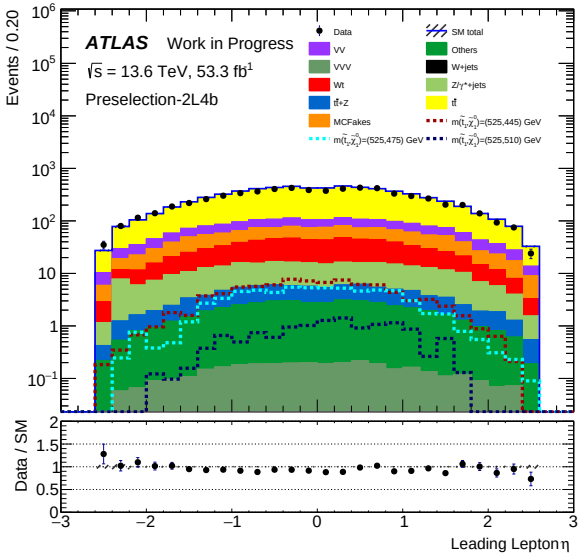


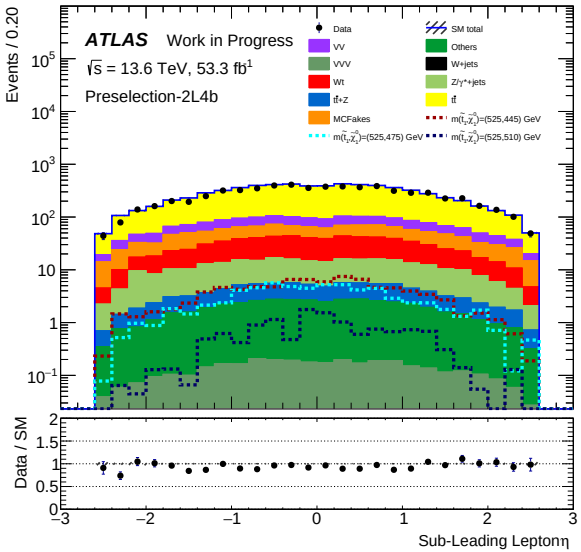
DNN input variables at preselection level - Run3 - Stat-only uncertainties

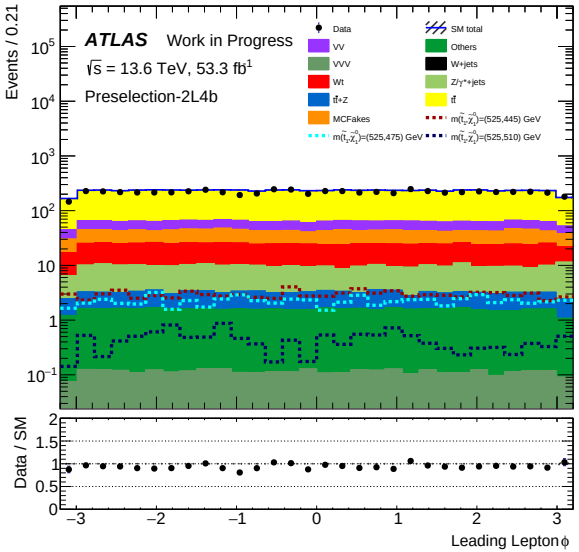




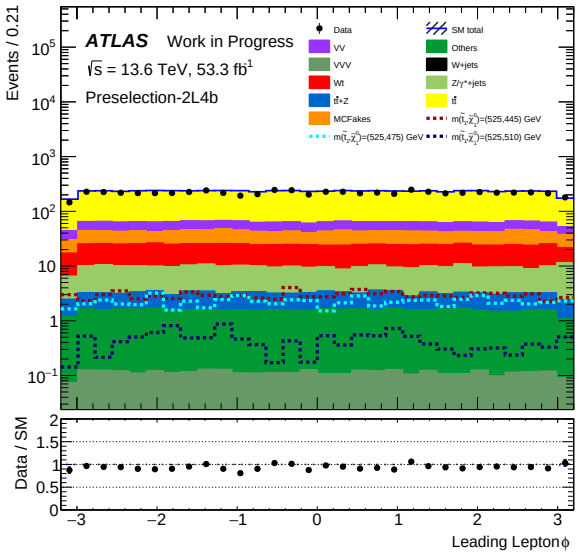


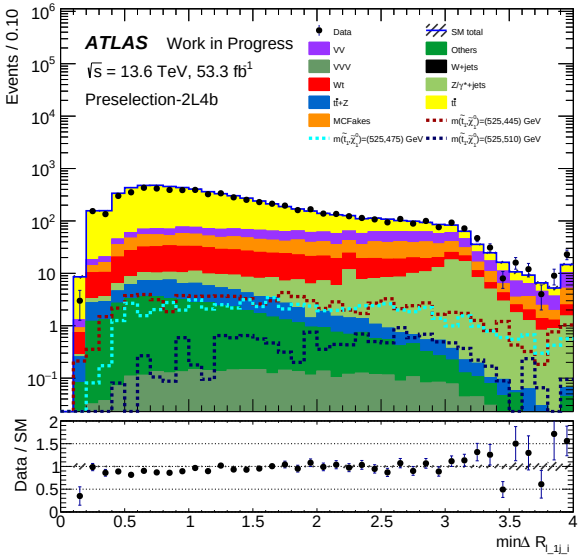


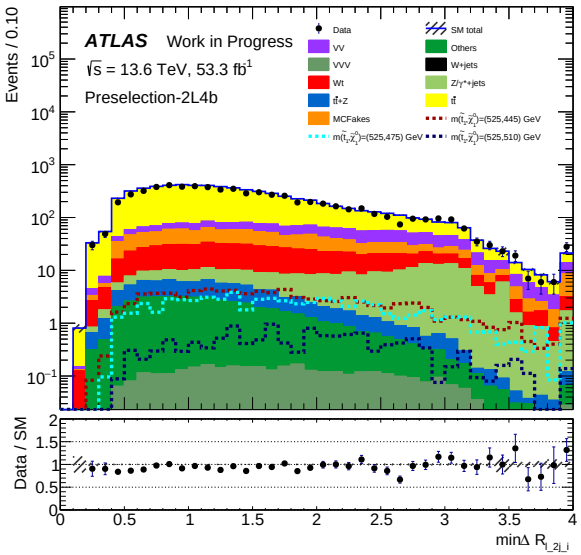




Input variable at preselection level - Run3 - Stat-only uncertainties



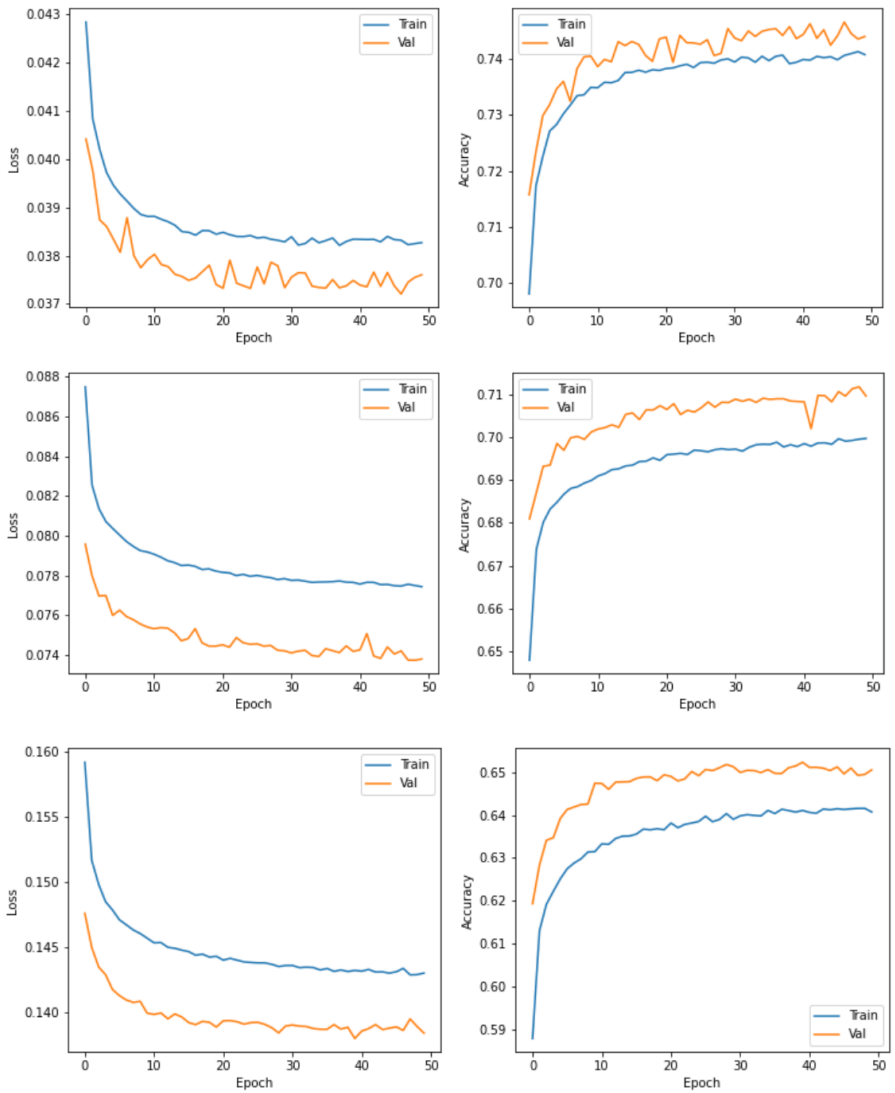




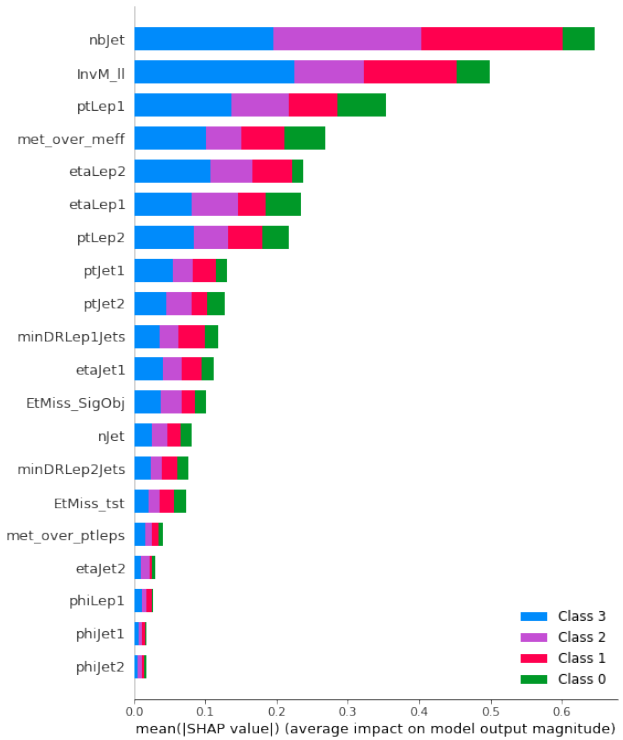
DNN Validation

Validation through *Loss* and *Accuracy*. SHAP values for feature importance

(Small/Medium/Large) Δm Even trainings



- Similar for Odd trainings
- *To be checked if curves can reach a better convergence*
- *Retrain for mc23e inclusion*



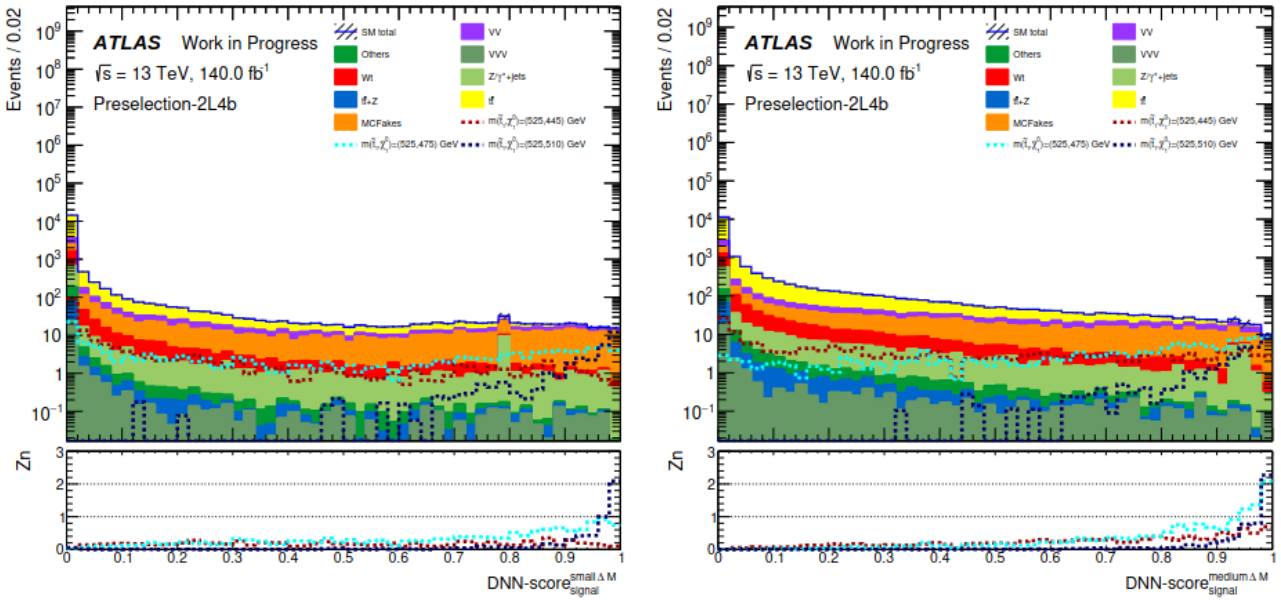
Signal Regions

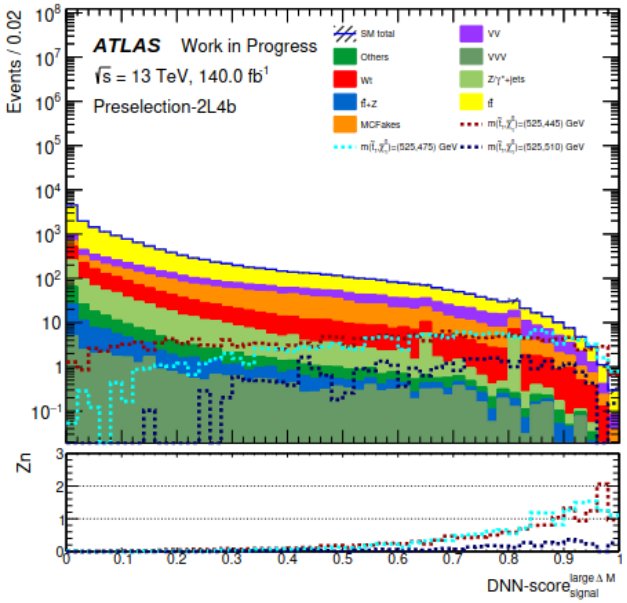
- Iterative procedure to select bins with higher Z_N significance with a minimum of 2 background events
- 3 signal samples as benchmark, at the edge of the contour from *Run2 paper*: (525,445) for large, (525,475) for medium, (525,510) for small Δm
- Define overlapping bins, the one giving the best expected CLs will be chosen
- Include 20% flat systematic

Name	Run2	Run3
DNN-score$^{\textbf{small } \Delta m}_{\textbf{signal}}$	$0.9150 < \text{bin1} < 0.9690$ $0.9690 < \text{bin2} < 0.9920$ $0.9920 < \text{bin3} < 1$	$0.9150 < \text{bin1} < 0.9354$ $0.9354 < \text{bin2} < 0.9840$ $0.9840 < \text{bin3} < 1$
DNN-score$^{\textbf{medium } \Delta m}_{\textbf{signal}}$	$0.6516 < \text{bin1} < 0.7068$ $0.7068 < \text{bin2} < 0.7592$ $0.7592 < \text{bin3} < 0.7980$ $0.7980 < \text{bin4} < 0.8526$ $0.8526 < \text{bin5} < 0.9786$ $0.9786 < \text{bin6} < 1$	$0.6516 < \text{bin1} < 0.7782$ $0.7782 < \text{bin2} < 0.8628$ $0.8628 < \text{bin3} < 0.9102$ $0.9102 < \text{bin4} < 0.9380$ $0.9380 < \text{bin5} < 0.9820$ $0.9820 < \text{bin6} < 1$
DNN-score$^{\textbf{large } \Delta m}_{\textbf{signal}}$	$0.6212 < \text{bin1} < 0.7066$ $0.7066 < \text{bin2} < 0.7880$ $0.7880 < \text{bin3} < 0.8526$ $0.8526 < \text{bin4} < 0.9042$ $0.9042 < \text{bin5} < 0.9406$ $0.9406 < \text{bin6} < 1$	$0.6212 < \text{bin1} < 0.7380$ $0.7380 < \text{bin2} < 0.7770$ $0.7770 < \text{bin3} < 0.8204$ $0.8204 < \text{bin4} < 0.8676$ $0.8676 < \text{bin5} < 0.9094$ $0.9094 < \text{bin6} < 1$

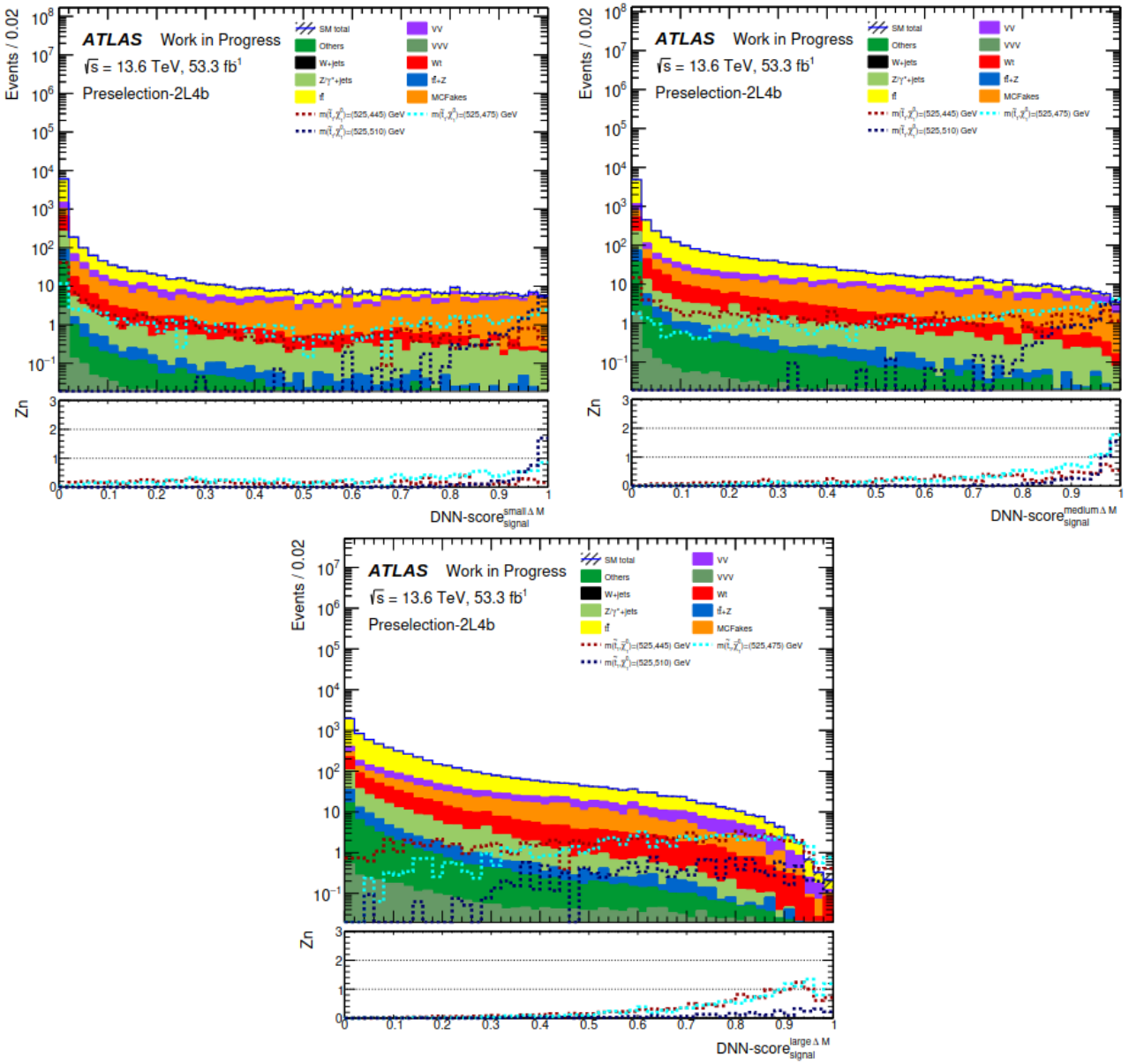
- *Optimize bin ranging and thresholds, e.g. rounding up to 2 digits, better aligning Run2 and Run3*

Signal Regions - Run2





Signal Regions - Run3



Control Regions

Normalised backgrounds: $t\bar{t}$ and VV. Orthogonality through DNN-score$_{\text{signal}}$ cut

Name	n_{b-jets}	DNN-score$_{\text{signal}}$	DNN-score$_{t\bar{t}}$	DNN-score$_{VV}$
CR-tt$^{\text{small } \Delta m}_{\text{Run2}}$	≥ 1	$0.01 < \text{DNN}_{\text{sig}} < 0.25$	> 0.7	-
CR-tt$^{\text{small } \Delta m}_{\text{Run3}}$	≥ 1	$0.01 < \text{DNN}_{\text{sig}} < 0.25$	> 0.7	-
CR-tt$^{\text{medium } \Delta m}_{\text{Run2}}$	≥ 1	$0.08 < \text{DNN}_{\text{sig}} < 0.48$	> 0.65	-
CR-tt$^{\text{medium } \Delta m}_{\text{Run3}}$	≥ 1	$0.08 < \text{DNN}_{\text{sig}} < 0.48$	> 0.65	-
CR-tt$^{\text{large } \Delta m}_{\text{Run2}}$	≥ 1	$0.20 < \text{DNN}_{\text{sig}} < 0.52$	> 0.55	-
CR-tt$^{\text{large } \Delta m}_{\text{Run3}}$	≥ 1	$0.20 < \text{DNN}_{\text{sig}} < 0.52$	> 0.55	-
CR-VV$^{\text{small } \Delta m}_{\text{Run2}}$	$= 0$	$0.01 < \text{DNN}_{\text{sig}} < 0.45$	-	> 0.75
CR-VV$^{\text{small } \Delta m}_{\text{Run3}}$	$= 0$	$0.01 < \text{DNN}_{\text{sig}} < 0.45$	-	> 0.73
CR-VV$^{\text{medium } \Delta m}_{\text{Run2}}$	$= 0$	$0.02 < \text{DNN}_{\text{sig}} < 0.45$	-	> 0.7
CR-VV$^{\text{medium } \Delta m}_{\text{Run3}}$	$= 0$	$0.02 < \text{DNN}_{\text{sig}} < 0.45$	-	> 0.7
CR-VV$^{\text{large } \Delta m}_{\text{Run2}}$	$= 0$	$0.20 < \text{DNN}_{\text{sig}} < 0.52$	-	> 0.6
CR-VV$^{\text{large } \Delta m}_{\text{Run3}}$	$= 0$	$0.20 < \text{DNN}_{\text{sig}} < 0.52$	-	> 0.55

- *Signal contamination evaluated on a benchmark point. Perform wide-level check, on the full signal grid*
- *Improve plot aestethics, no changes since last presentation*

Validation Regions

Name	n_{b-jets}	DNN-score$_{\text{signal}}$
VR-tt$^{\text{small } \Delta m}_{\text{Run2}}$	≥ 1	$0.25 < \text{DNN}_{\text{sig}} < 0.9150$
VR-tt$^{\text{small } \Delta m}_{\text{Run3}}$	≥ 1	$0.25 < \text{DNN}_{\text{sig}} < 0.9150$
VR-tt$^{\text{medium } \Delta m}_{\text{Run2}}$	≥ 1	$0.48 < \text{DNN}_{\text{sig}} < 0.6516$
VR-tt$^{\text{medium } \Delta m}_{\text{Run3}}$	≥ 1	$0.48 < \text{DNN}_{\text{sig}} < 0.6516$
VR-tt$^{\text{large } \Delta m}_{\text{Run2}}$	≥ 1	$0.52 < \text{DNN}_{\text{sig}} < 0.6212$
VR-tt$^{\text{large } \Delta m}_{\text{Run3}}$	≥ 1	$0.52 < \text{DNN}_{\text{sig}} < 0.6212$
VR-VV$^{\text{small } \Delta m}_{\text{Run2}}$	$= 0$	$0.45 < \text{DNN}_{\text{sig}} < 0.9150$
VR-VV$^{\text{small } \Delta m}_{\text{Run3}}$	$= 0$	$0.45 < \text{DNN}_{\text{sig}} < 0.9150$
VR-VV$^{\text{medium } \Delta m}_{\text{Run2}}$	$= 0$	$0.45 < \text{DNN}_{\text{sig}} < 0.6516$
VR-VV$^{\text{medium } \Delta m}_{\text{Run3}}$	$= 0$	$0.45 < \text{DNN}_{\text{sig}} < 0.6516$
VR-VV$^{\text{large } \Delta m}_{\text{Run2}}$	$= 0$	$0.52 < \text{DNN}_{\text{sig}} < 0.6212$
VR-VV$^{\text{large } \Delta m}_{\text{Run3}}$	$= 0$	$0.52 < \text{DNN}_{\text{sig}} < 0.6212$

- *Round digits a bit*
- *Check signal contamination, as hint of kinematically close regions*
- *Improve plot aestethics, no changes since last presentation*

Fit Results

3 trainings and 2 normalized backgrounds $\rightarrow$ 6 Scale Factors per each Run:

Background	Training Reference	Run2 SF	Run3 SF
$t\bar{t}$	Small Δm	0.91 ± 0.22	0.99 ± 0.25
	Medium Δm	0.78 ± 0.19	0.99 ± 0.25
	Large Δm	0.92 ± 0.21	0.93 ± 0.23
VV	Small Δm	0.82 ± 0.32	1.08 ± 0.42
	Medium Δm	1.19 ± 0.35	0.99 ± 0.37
	Large Δm	0.95 ± 0.34	1.11 ± 0.42

Some caveats:

- Large SF uncertainties, mainly coming from the application of the 20% flat systematic: larger yield, larger uncertainty
- No Wt included in $t\bar{t}$ normalisation
- Larger discrepancies for dibosons due to lower purities, see next slides...

Fit Results: Run2 small Δm

Run2 small Δm	CRTOP	CRVV	VRTOP	VRVV
Observed events	262	154	213	368
Fitted bkg events	261.91 ± 16.16	154.02 ± 12.35	226.19 ± 18.95	318.58 ± 36.61
Fitted ttbar events	224.71 ± 17.95	50.42 ± 4.14	119.23 ± 9.72	66.76 ± 5.65
Fitted VV events	0.93 ± 0.22	61.45 ± 14.74	1.37 ± 0.34	42.10 ± 10.15
Fitted Zjets events	1.37 ± 0.27	0.59 ± 0.12	0.85 ± 0.17	14.47 ± 2.89
Fitted ttZ events	0.87 ± 0.17	0.21 ± 0.04	0.56 ± 0.11	0.18 ± 0.04
Fitted Wt events	19.15 ± 3.80	9.55 ± 1.90	16.51 ± 3.28	8.04 ± 1.61
Fitted others events	1.22 ± 0.24	1.26 ± 0.25	0.75 ± 0.15	1.33 ± 0.27
Fitted Fakes events	13.71 ± 2.72	31.59 ± 6.28	86.92 ± 17.26	186.65 ± 37.30
Scale Factor	0.91 ± 0.22	0.82 ± 0.32	-	-
MC exp. SM events	285.09 ± 57.09	172.24 ± 34.54	238.78 ± 47.83	334.53 ± 67.44
MC exp. ttbar events	247.64 ± 49.59	55.57 ± 11.15	131.40 ± 26.32	73.58 ± 14.83
MC exp. VV events	1.12 ± 0.22	74.47 ± 14.93	1.66 ± 0.33	50.97 ± 10.28
MC exp. Zjets events	1.37 ± 0.27	0.59 ± 0.12	0.85 ± 0.17	14.49 ± 2.92
MC exp. ttZ events	0.87 ± 0.17	0.21 ± 0.04	0.56 ± 0.11	0.18 ± 0.04
MC exp. Wt events	19.18 ± 3.84	9.56 ± 1.92	16.53 ± 3.31	8.05 ± 1.62
MC exp. others events	1.22 ± 0.24	1.27 ± 0.25	0.75 ± 0.15	1.33 ± 0.27
MC exp. Fakes events	13.73 ± 2.75	31.62 ± 6.34	87.03 ± 17.43	186.87 ± 37.67

Fit Results: Run3 small Δm

Run3 small Δm	CRTOP	CRVV	VRTOP	VRVV
Observed events	114	88	103	138
Fitted bkg events	113.99 ± 10.65	88.00 ± 9.31	91.69 ± 8.74	115.75 ± 12.35
Fitted ttbar events	99.45 ± 11.09	29.85 ± 3.42	50.84 ± 5.91	28.25 ± 3.30
Fitted VV events	0.44 ± 0.12	37.60 ± 10.46	0.84 ± 0.24	20.58 ± 5.80
Fitted Zjets events	0.02 ± 0.00	0.31 ± 0.06	0.15 ± 0.03	1.38 ± 0.28
Fitted ttZ events	0.59 ± 0.12	0.06 ± 0.01	0.52 ± 0.10	0.10 ± 0.02
Fitted Wt events	7.45 ± 1.49	5.55 ± 1.11	7.08 ± 1.42	2.60 ± 0.52
Fitted others events	0.45 ± 0.09	0.20 ± 0.04	0.26 ± 0.05	0.11 ± 0.02
Fitted Fakes events	5.60 ± 1.12	14.45 ± 2.88	32.01 ± 6.41	62.76 ± 12.59
Scale Factor	0.99 ± 0.25	1.08 ± 0.42	-	-
MC exp. SM events	115.11 ± 23.11	85.51 ± 17.16	92.19 ± 18.60	114.49 ± 23.13
MC exp. ttbar events	100.60 ± 20.19	30.20 ± 6.06	51.43 ± 10.38	28.58 ± 5.77
MC exp. VV events	0.41 ± 0.08	34.78 ± 6.98	0.78 ± 0.16	19.03 ± 3.85
MC exp. Zjets events	0.02 ± 0.00	0.31 ± 0.06	0.15 ± 0.03	1.37 ± 0.28
MC exp. ttZ events	0.59 ± 0.12	0.06 ± 0.01	0.52 ± 0.10	0.10 ± 0.02
MC exp. Wt events	7.45 ± 1.50	5.55 ± 1.11	7.08 ± 1.43	2.59 ± 0.52
MC exp. others events	0.45 ± 0.09	0.20 ± 0.04	0.26 ± 0.05	0.11 ± 0.02
MC exp. Fakes events	5.60 ± 1.12	14.44 ± 2.90	31.98 ± 6.45	62.71 ± 12.67

Fit Results: Run2 medium Δm

Run2 medium Δm	CRTOP	CRVV	VRTOP	VRVV
Observed events	206	266	146	252
Fitted bkg events	205.99 ± 14.34	265.98 ± 16.25	146.47 ± 11.33	241.74 ± 19.55
Fitted ttbar events	181.76 ± 15.24	66.97 ± 5.70	87.94 ± 7.52	63.86 ± 5.50
Fitted VV events	0.69 ± 0.09	145.97 ± 19.46	1.46 ± 0.20	60.68 ± 8.18
Fitted Zjets events	0.01 ± 0.00	0.24 ± 0.05	0.27 ± 0.05	5.01 ± 1.00
Fitted ttZ events	0.83 ± 0.16	0.33 ± 0.07	0.32 ± 0.06	0.27 ± 0.05
Fitted Wt events	14.55 ± 2.89	15.11 ± 3.00	12.40 ± 2.47	8.50 ± 1.69
Fitted others events	1.15 ± 0.23	1.60 ± 0.32	0.67 ± 0.13	0.90 ± 0.18
Fitted Fakes events	7.00 ± 1.39	36.91 ± 7.34	43.42 ± 8.64	103.11 ± 20.54
Scale Factor	0.78 ± 0.19	1.19 ± 0.35	-	-
MC exp. SM events	256.05 ± 51.27	261.20 ± 52.31	170.56 ± 34.18	249.82 ± 50.13
MC exp. ttbar events	231.90 ± 46.43	85.45 ± 17.11	112.20 ± 22.48	81.48 ± 16.35
MC exp. VV events	0.58 ± 0.12	122.65 ± 24.56	1.23 ± 0.25	51.01 ± 10.23
MC exp. Zjets events	0.01 ± 0.00	0.24 ± 0.05	0.27 ± 0.05	5.02 ± 1.01
MC exp. ttZ events	0.83 ± 0.17	0.33 ± 0.07	0.32 ± 0.06	0.27 ± 0.05
MC exp. Wt events	14.57 ± 2.92	15.13 ± 3.03	12.42 ± 2.49	8.51 ± 1.71
MC exp. others events	1.15 ± 0.23	1.60 ± 0.32	0.67 ± 0.13	0.90 ± 0.18
MC exp. Fakes events	7.01 ± 1.40	36.95 ± 7.40	43.47 ± 8.71	103.23 ± 20.71

Fit Results: Run3 medium Δm

Run3 medium Δm	CRTOP	CRVV	VRTOP	VRVV
Observed events	103	104	67	90
Fitted bkg events	103.13 ± 10.14	103.95 ± 10.14	66.75 ± 6.10	92.82 ± 7.94
Fitted ttbar events	92.28 ± 10.45	34.41 ± 4.00	44.34 ± 5.24	32.59 ± 3.87
Fitted VV events	0.24 ± 0.06	46.60 ± 11.60	0.57 ± 0.14	18.63 ± 4.71
Fitted Zjets events	0.02 ± 0.00	0.00 ± 0.00	0.08 ± 0.02	1.19 ± 0.24
Fitted ttZ events	0.47 ± 0.09	0.33 ± 0.07	0.44 ± 0.09	0.26 ± 0.05
Fitted Wt events	5.60 ± 1.12	7.02 ± 1.41	5.00 ± 1.01	3.23 ± 0.65
Fitted others events	0.38 ± 0.08	0.23 ± 0.05	0.21 ± 0.04	0.15 ± 0.03
Fitted Fakes events	4.13 ± 0.83	15.42 ± 3.09	16.12 ± 3.25	36.79 ± 7.44
Scale Factor	0.99 ± 0.25	0.99 ± 0.37	-	-
MC exp. SM events	104.45 ± 20.97	105.42 ± 21.15	67.47 ± 13.62	93.83 ± 18.97
MC exp. ttbar events	93.54 ± 18.78	34.88 ± 7.00	44.93 ± 9.07	33.03 ± 6.68
MC exp. VV events	0.25 ± 0.05	47.47 ± 9.52	0.58 ± 0.12	18.98 ± 3.84
MC exp. Zjets events	0.02 ± 0.00	0.00 ± 0.00	0.08 ± 0.02	1.20 ± 0.24
MC exp. ttZ events	0.47 ± 0.09	0.33 ± 0.07	0.44 ± 0.09	0.26 ± 0.05
MC exp. Wt events	5.63 ± 1.13	7.06 ± 1.42	5.02 ± 1.01	3.25 ± 0.66
MC exp. others events	0.39 ± 0.08	0.23 ± 0.05	0.21 ± 0.04	0.15 ± 0.03
MC exp. Fakes events	4.16 ± 0.83	15.50 ± 3.11	16.20 ± 3.27	36.99 ± 7.48

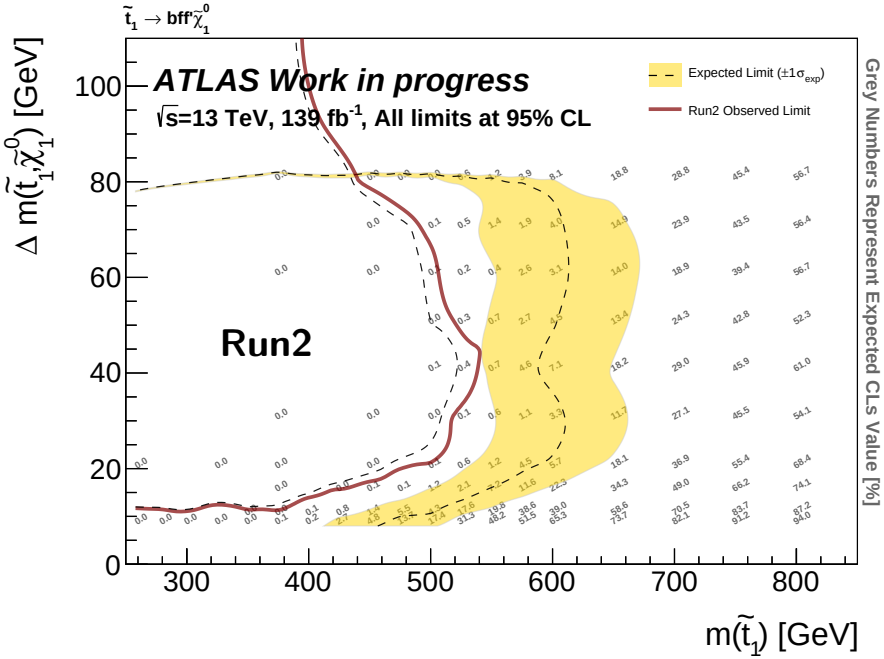
Fit Results: Run2 large Δm

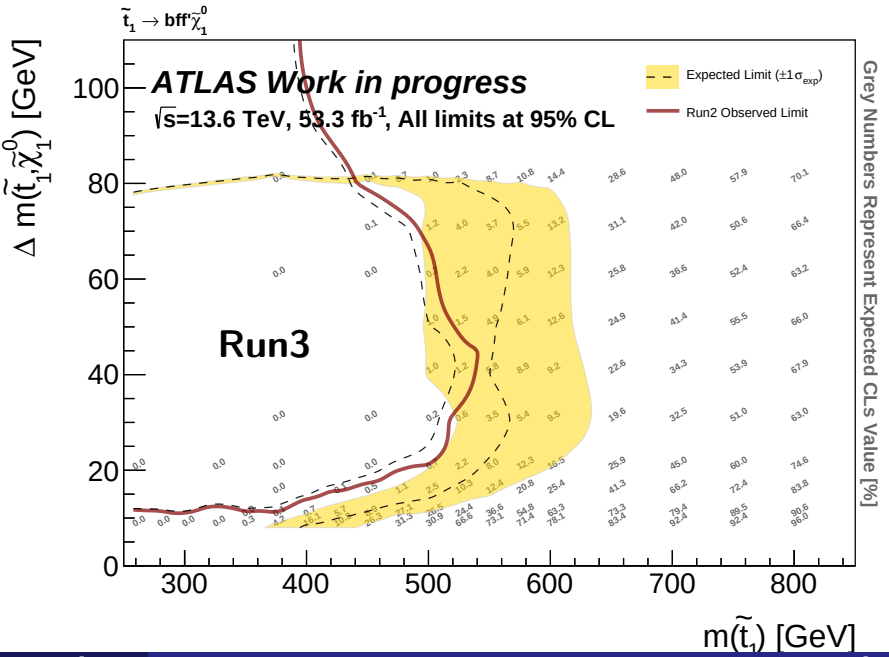
Run2 large Δm	CRTOP	CRVV	VRTOP	VRVV
Observed events	312	84	217	258
Fitted bkg events	311.96 ± 17.64	83.98 ± 9.12	195.65 ± 11.06	237.20 ± 18.06
Fitted ttbar events	279.29 ± 18.97	23.03 ± 1.63	147.93 ± 10.28	85.30 ± 6.00
Fitted VV events	0.66 ± 0.15	42.77 ± 9.80	1.45 ± 0.33	61.73 ± 14.14
Fitted Zjets events	0.06 ± 0.01	0.08 ± 0.02	0.30 ± 0.06	2.35 ± 0.47
Fitted ttZ events	0.99 ± 0.20	0.08 ± 0.02	0.52 ± 0.10	0.21 ± 0.04
Fitted Wt events	19.55 ± 3.88	5.22 ± 1.04	17.73 ± 3.52	11.86 ± 2.36
Fitted others events	1.45 ± 0.29	0.50 ± 0.10	0.84 ± 0.17	1.45 ± 0.29
Fitted Fakes events	9.96 ± 1.98	12.66 ± 2.52	26.93 ± 5.34	75.31 ± 14.97
Scale Factor	0.92 ± 0.21	0.95 ± 0.34	-	-
MC exp. SM events	335.39 ± 67.14	88.02 ± 17.67	208.12 ± 41.69	247.38 ± 49.62
MC exp. ttbar events	302.68 ± 60.59	24.96 ± 5.01	160.32 ± 32.11	92.45 ± 18.55
MC exp. VV events	0.69 ± 0.14	44.88 ± 9.01	1.52 ± 0.31	64.75 ± 12.99
MC exp. Zjets events	0.06 ± 0.01	0.08 ± 0.02	0.30 ± 0.06	2.35 ± 0.47
MC exp. ttZ events	0.99 ± 0.20	0.08 ± 0.02	0.52 ± 0.10	0.21 ± 0.04
MC exp. Wt events	19.55 ± 3.91	5.22 ± 1.05	17.73 ± 3.55	11.87 ± 2.38
MC exp. others events	1.45 ± 0.29	0.50 ± 0.10	0.84 ± 0.17	1.45 ± 0.29
MC exp. Fakes events	9.97 ± 1.99	12.66 ± 2.54	26.93 ± 5.39	75.33 ± 15.11

Fit Results: Run3 large Δm

Run3 large Δm	CRTOP	CRVV	VRTOP	VRVV
Observed events	133	80	93	169
Fitted bkg events	132.97 ± 11.51	79.98 ± 8.88	80.43 ± 6.57	163.35 ± 14.53
Fitted ttbar events	118.89 ± 11.90	24.78 ± 2.58	60.25 ± 6.26	61.42 ± 6.30
Fitted VV events	0.40 ± 0.10	37.35 ± 9.76	0.79 ± 0.21	57.21 ± 15.17
Fitted Zjets events	0.03 ± 0.01	1.15 ± 0.23	0.09 ± 0.02	0.77 ± 0.15
Fitted ttZ events	0.67 ± 0.13	0.25 ± 0.05	0.37 ± 0.07	0.52 ± 0.10
Fitted Wt events	7.98 ± 1.59	4.40 ± 0.88	8.09 ± 1.61	9.09 ± 1.81
Fitted others events	0.56 ± 0.11	0.18 ± 0.04	0.28 ± 0.06	0.35 ± 0.07
Fitted Fakes events	4.45 ± 0.88	11.93 ± 2.38	10.57 ± 2.11	34.07 ± 6.77
Scale Factor	0.93 ± 0.23	1.11 ± 0.42	-	-
MC exp. SM events	141.38 ± 28.36	77.92 ± 15.69	84.64 ± 17.03	161.85 ± 32.46
MC exp. ttbar events	127.34 ± 25.54	26.54 ± 5.34	64.53 ± 12.99	65.79 ± 13.19
MC exp. VV events	0.35 ± 0.07	33.53 ± 6.75	0.71 ± 0.14	51.35 ± 10.30
MC exp. Zjets events	0.03 ± 0.01	1.15 ± 0.23	0.09 ± 0.02	0.77 ± 0.15
MC exp. ttZ events	0.67 ± 0.14	0.25 ± 0.05	0.37 ± 0.07	0.52 ± 0.10
MC exp. Wt events	7.97 ± 1.60	4.40 ± 0.89	8.09 ± 1.63	9.09 ± 1.82
MC exp. others events	0.56 ± 0.11	0.18 ± 0.04	0.28 ± 0.06	0.35 ± 0.07
MC exp. Fakes events	4.45 ± 0.89	11.93 ± 2.40	10.57 ± 2.13	34.06 ± 6.83

Exclusion Contours





- *Combine contours into a global one*
- *Polish plots a bit*

Conclusions

A preliminary skeleton of the analysis ready, aiming to have a PAR next month!

However:

- Some pending items already *highlighted* in the previous slides
- Ntuples with systematics to be processed through LSF and included in HF
- Process and include data/MC samples for 2024
- Start implementing machinery for FNP estimate