ZH, H $\rightarrow \gamma\gamma_D$ analysis

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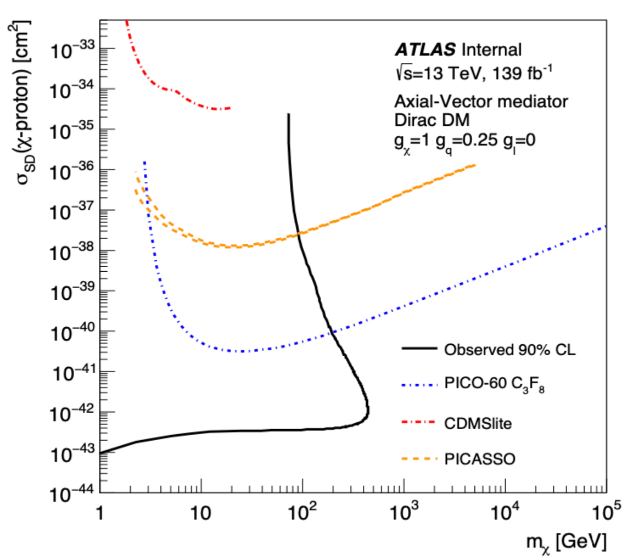
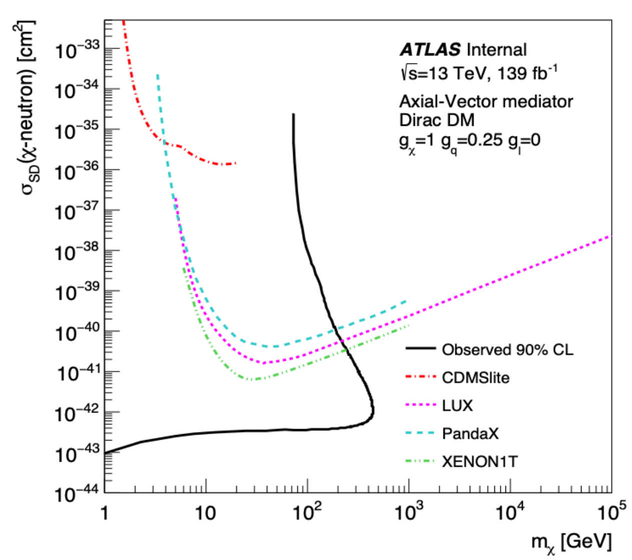
ATLAS EXPERIMENT

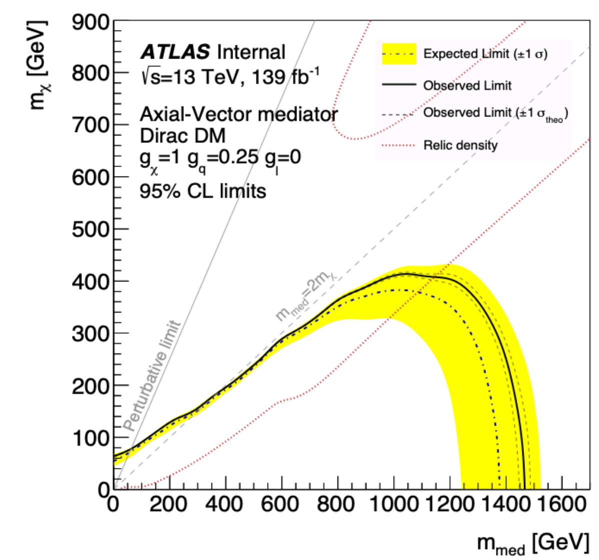
My PhD activities
Physics Analysis

- Focus on Dark-Matter related analyses:

  - **Mono-photon** analysis in the context of Exotics, JDM subgroup (master thesis + 1st PhD year)
    - y+MET final state
    - ▶ Paper accepted by JHEP (arxiv)





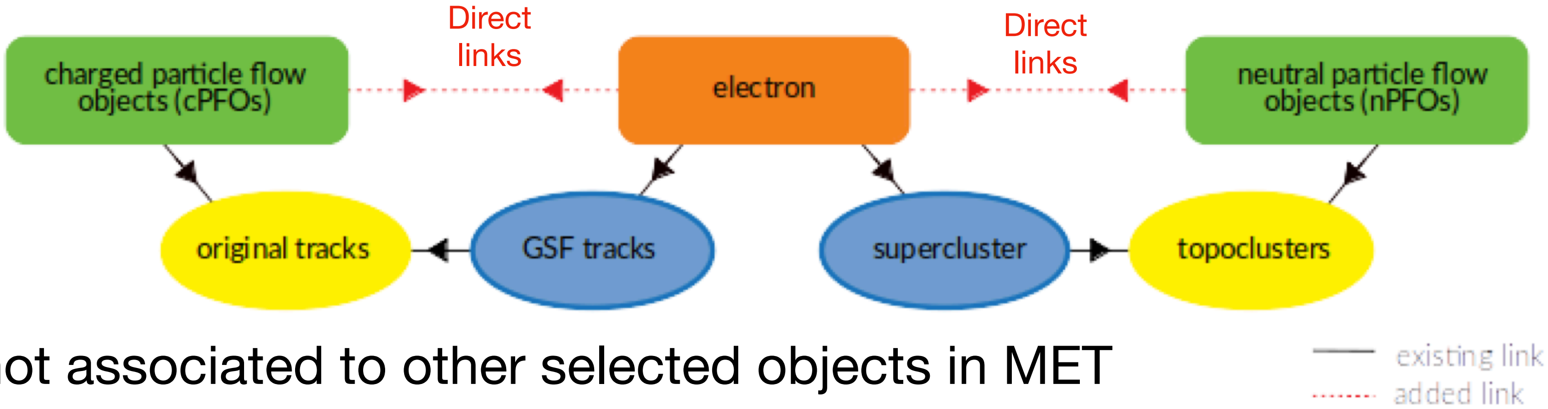


  - **Dark-photon analysis** in the context of HDBS, HLRS subgroup (joined the analysis team in july 2020)
    - Z(ll)H-> yyD
    - ▶ New analysis in ATLAS (CMS results already published)

My PhD activities
Performance

- Performance studies in the context of JetETmiss, MET+PU subgroup: implementation and preliminary validation and performance studies for a MET reconstruction based on Global Particle Flow objects (QT project. End date: 16/12/20)

- Two main tasks:
    1. Association Map based on direct links between PFOs and leptons/photons



    2. Building Jet Term from PFOs not associated to other selected objects in MET

Current PFlow MET
- **PFO association** to $e/\mu/\gamma$through <u>ΔR or clusters/tracks matching</u>
- **JetTerm** from standard jet collection + overlap removal with other objects

GPF MET
- **PFO association** to $e/\mu/\gamma$ using direct links
- **JetTerm** from new “Overlap Removed (OR)” jet collection. No need for overlap removal

- Future plans:
    - Finalize integration of links between FlowElement and egamma/tau/muons in Association Maps
    - Finalize OR MET reconstruction (handling jet-muon overlap)
    - Large scale validation

Dark-photon analysis

- **Glance entry**: ANA-HDBS-2019-13
- **Twiki page**: link
- **Analysis team**
  - BNL: Ketevi Assamagan
  - **Milano**: Leonardo Carminati, Marcello Fanti, Davide Mungo, Federica Piazza, Silvia Resconi + 3 bachelor students (Dario Pullia, Denise Tantucci, Andrea Mitta)
  - Nikhef: Stefano Manzoni
  - Osaka: Hajime Nanjo
  - Rabat: Hassnae El Jarrari, Yahya Tayalati
  - Standford: Stanislava Sevova, Lauren Tompkins, Rocky Garg + 2 Summer Students: Blanca Nino, Elyssa Hofgard
  - Taipei AS: Rachid Mazini

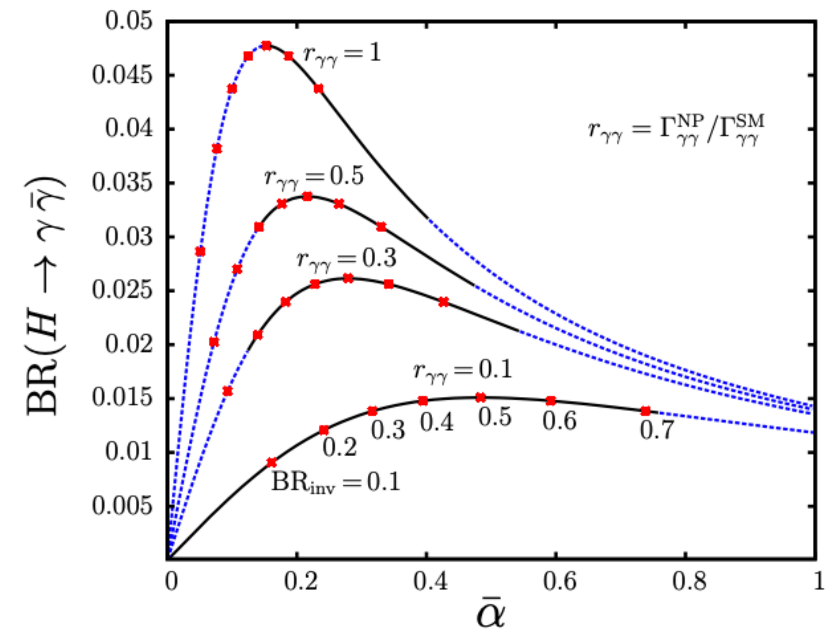
Motivation

- Dark-photon is predicted as a massless (or light) gauge boson of a new unbroken U(1) group
    - Mediator of long range forces in the dark-sector, but also possible DM candidate
    - Can help explaining
        - small-scale structure formation
        - light-DM annihilation in asymmetric DM scenarios
        - Flavor hierarchy problem

- Why massless or light?
    - Given the unbroken U(1) symmetry, massive dark-photon leads to tree-level mixing with SM photons => strong constraints
    - Massless dark-photon => on-shell dark photons fully decoupled from the SM sector at tree level. Coupling with SM sector through higher-dimensional interactions via messenger exchange

Phenomenology

Biswas, Gabrielli, Heikinheimo, Mele (2014)

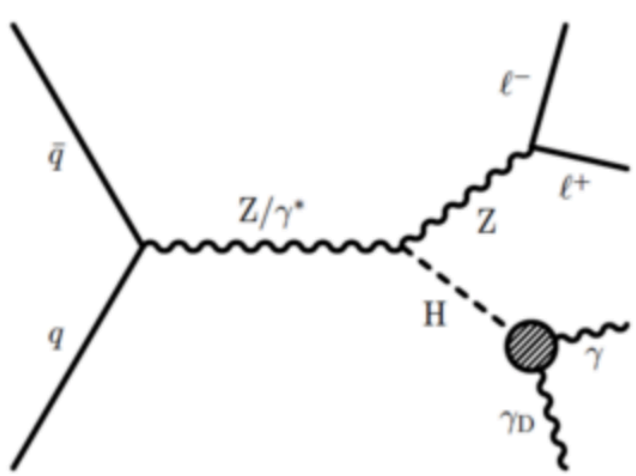


- Dark-photon from Higgs decay:
  - One loop decay
  - BSM BR up to 5% allowed by present constraints (Biswas, Gabrielli, Heikinheimo, Mele (2016))
- Different production modes can be explored:
  - VBF (analysis ongoing in ATLAS) link
  - ggH: potentially high sensitivity, but missing viable triggers for Run-2 (mT distribution spoilt)
  - ZH (this analysis)

ZH, H->yyD

- Lower production cross-section
- But clean final state:

  two leptons from Z decay + one photon + E_T^{miss}
  - VV+y only irreducible bkg (subdominant)
  - Dominant background contributions from Zy+jets and Zjets processes (fake E_T^{miss})



MC samples and Ntuple production

- **MC samples** (HIGG2D1 derivations)
  - Mainly Sherpa NLO
  - Powheg+Pythia8 for single top, Vt, Vtll, ttbar, Higgs related processes, signal
  - MadGraph+Pythia8 for ttV
  - Using $H \to \gamma Gr$ for the signal
    - Graviton behaves like dark-photon
    - m_{Gr} = 0, 1, 10, 20, 30, 40 GeV

- **Framework**:
  - "mini-Ntuple" production using STAnalysisCode framework (based on SUSYTools)
  - "Micro-Ntuple" production and post processing (plots, cutflows, …) using STPostProcessing framework
  - Release 21.2.151

Event selection

Preselections

- GRL, Detector event cleaning, PV selection, Loose Jet Cleaning (MiniNtuple skim)
- At least one baseline electron or muon (MiniNtuple skim)
- Overlap removal between Vy and Vjets MC
- Trigger (single/double lepton)

SR selections (optimization studies by E. Hofgard presented during last update)

- 2 opposite sign muons/electrons with p_T^{lep1}> 26 GeV and p_T^{lep2}> 10 GeV
- 1 photon with p_T^{γ}> 25 GeV
- Njet<=2 and Nbjet=0
- 76 < m_{ll} < 116 GeV
- m_{lly} > 100 GeV
- MET > 60 GeV

Background composition in SR

Background processes

- **Zgam**: Zy+jets => fake MET (fakeMET ABCD method)
- **Zqcd**: Z+jets => fake MET + jet faking photon (j->y ABCD method)
- **Top**: single Top + ttbar + Vtll + ttV + ttbarVV => non resonant background
- **VV**: ggVV, VV ewk => jet faking photons (j->y ABCD) and electron faking photon (e->y fake rate from Zee)
- **VVV** (VVy) => irreducible background (subdominant)
- **HZy**: ttHZy + VHZy + VBFZy + ggHZy (low contribution)

mc16a	HyGr	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	bkgs
ee channel	5.19 +/- 0.12	89 +/- 13	56 +/- 19	36.1 +/- 1.6	9.77 +/- 0.53	6.29 +/- 0.37	1.91 +/- 0.96	0.0689 +/- 0.0019	198 +/- 23
$\mu\mu$ channel	6.49 +/- 0.14	176 +/- 21	153 +/- 35	38.4 +/- 1.7	9.51 +/- 0.60	7.07 +/- 0.43	0.40 +/- 0.29	0.0885 +/- 0.0022	385 +/- 41

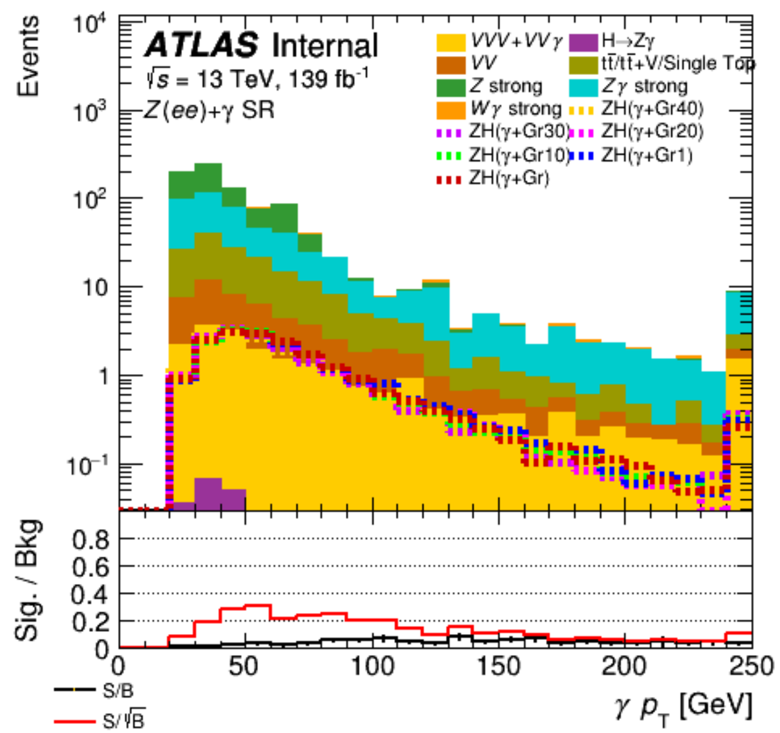
mc16d	HyGr	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	bkgs
ee channel	5.86 +/- 0.13	95 +/- 12	56 +/- 29	35.6 +/- 1.6	10.32 +/- 0.44	6.49 +/- 0.41	4.5 +/- 2.4	0.0762 +/- 0.0020	209 +/- 31
$\mu\mu$ channel	7.25 +/- 0.14	256 +/- 21	216 +/- 47	37.3 +/- 1.6	11.46 +/- 0.47	6.88 +/- 0.39	0.70 +/- 0.41	0.1007 +/- 0.0024	528 +/- 51

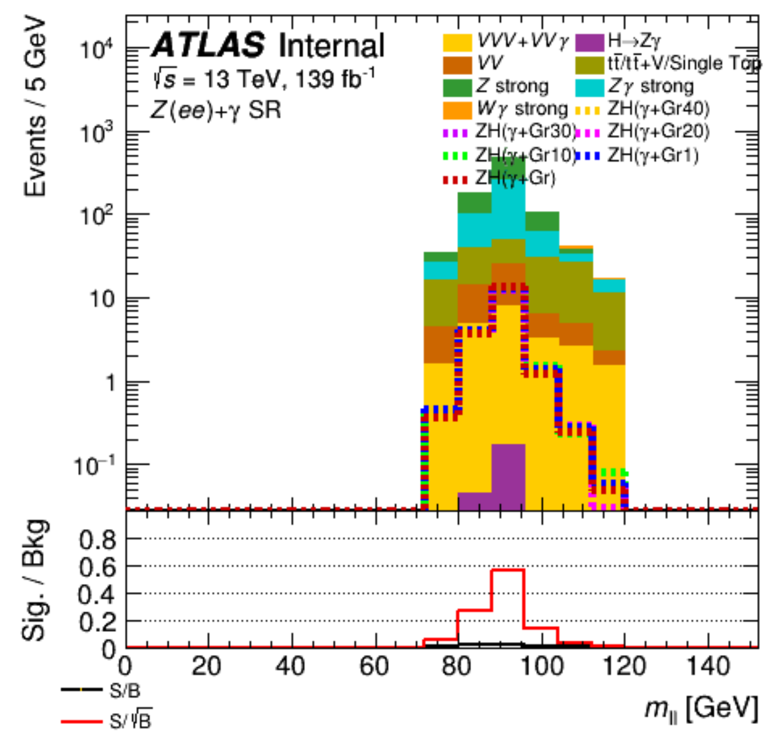
mc16e	HyGr	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	bkgs
ee channel	8.12 +/- 0.15	134 +/- 13	260 +/- 53	47.9 +/- 1.8	15.62 +/- 0.68	9.04 +/- 0.48	4.4 +/- 1.5	0.0943 +/- 0.0023	471 +/- 55
$\mu\mu$ channel	9.47 +/- 0.17	318 +/- 20	200 +/- 55	55.1 +/- 2.0	14.42 +/- 0.65	9.76 +/- 0.46	-1.7 +/- 1.8	0.1275 +/- 0.0027	596 +/- 58

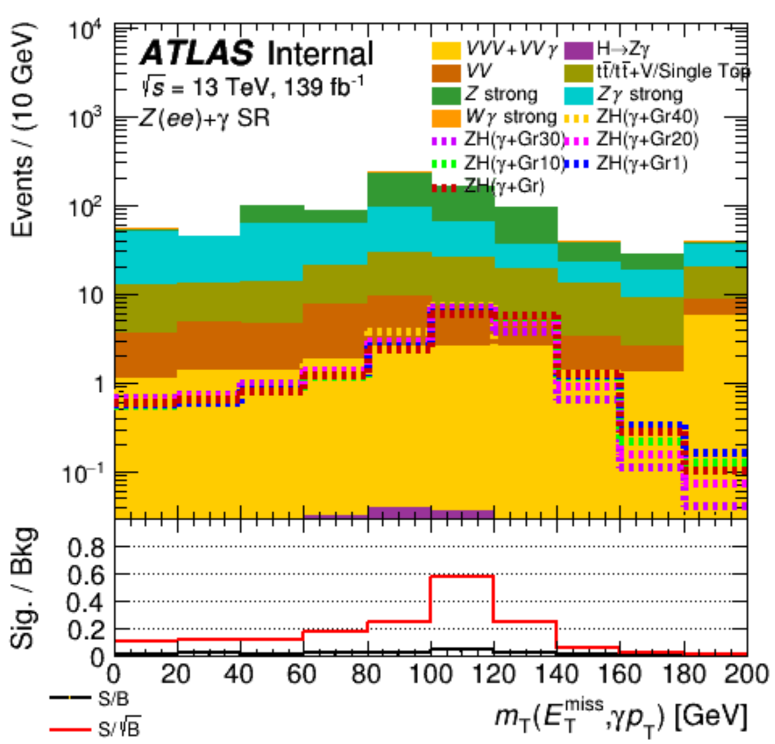
(Plots by H. El Jarrari)

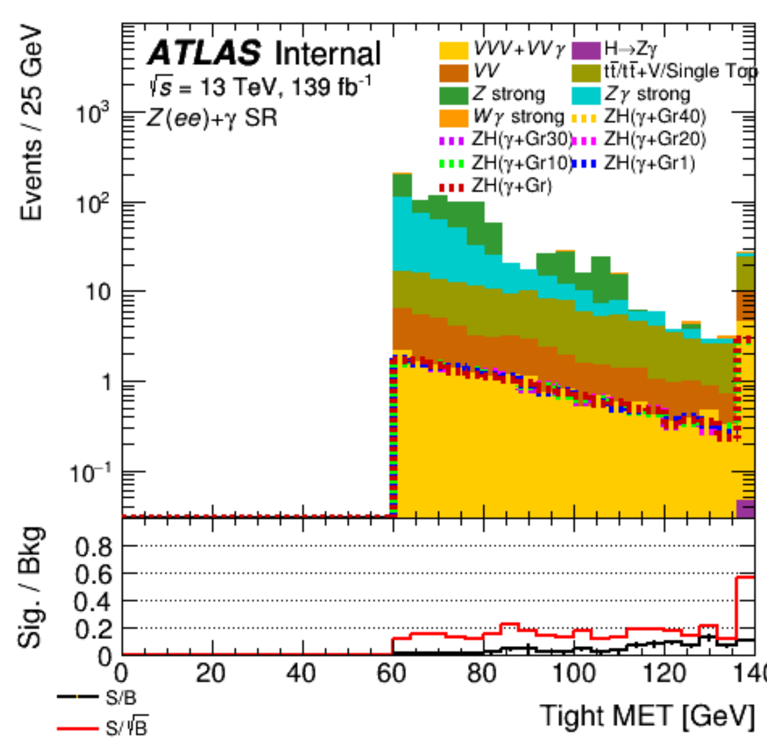
Distributions in SR:

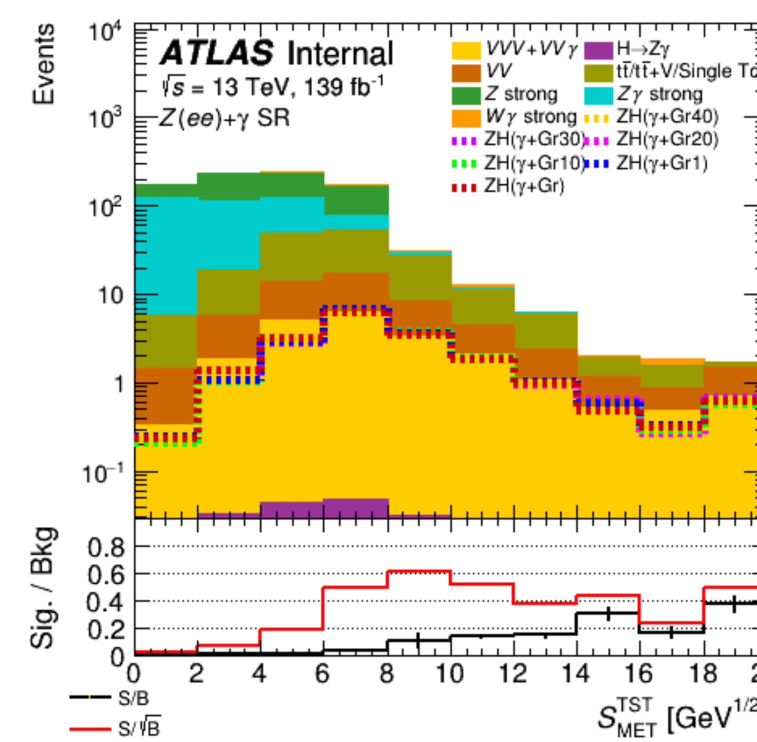
ee-channel







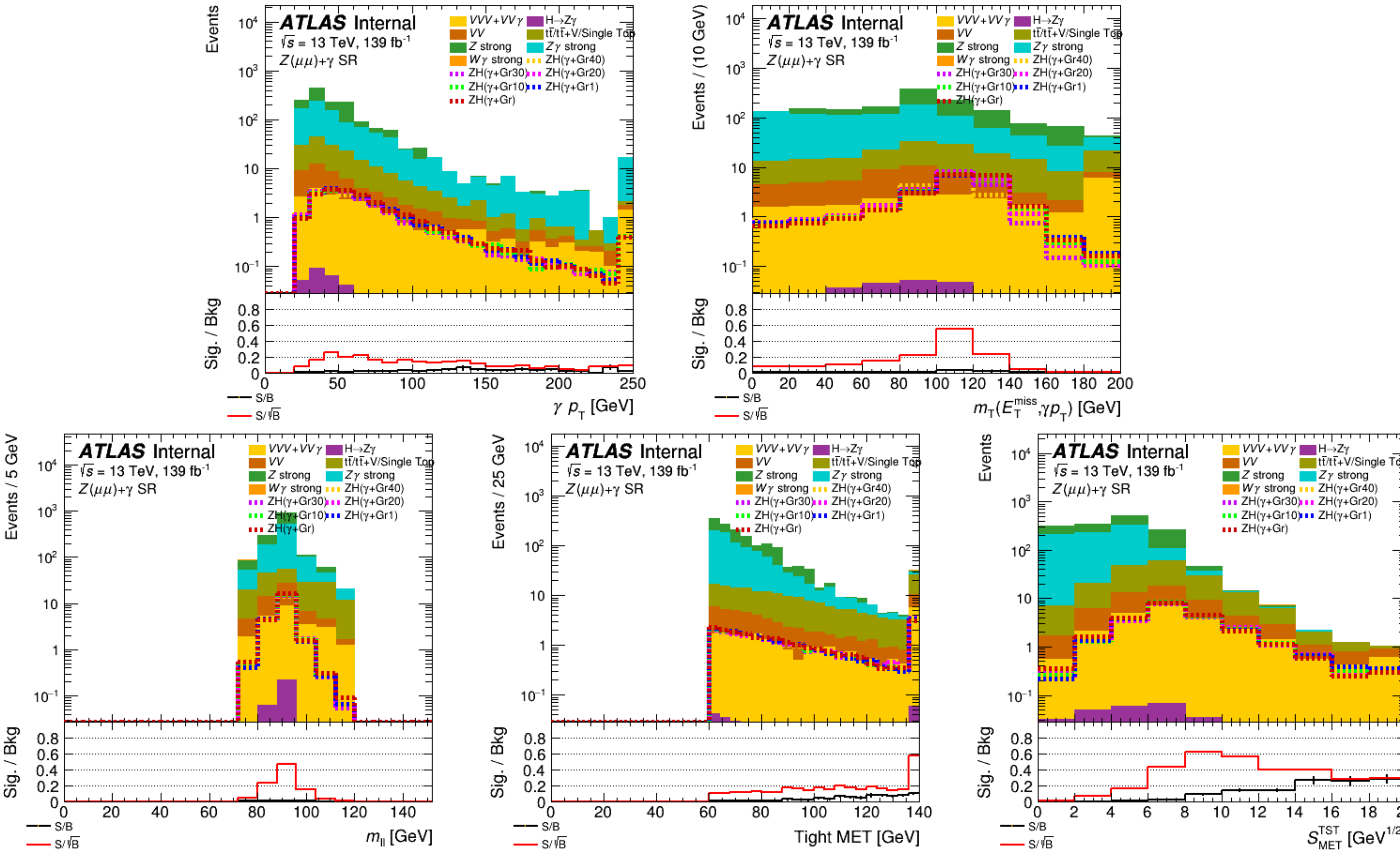




(Plots by H. El Jarrari)

Distributions in SR:

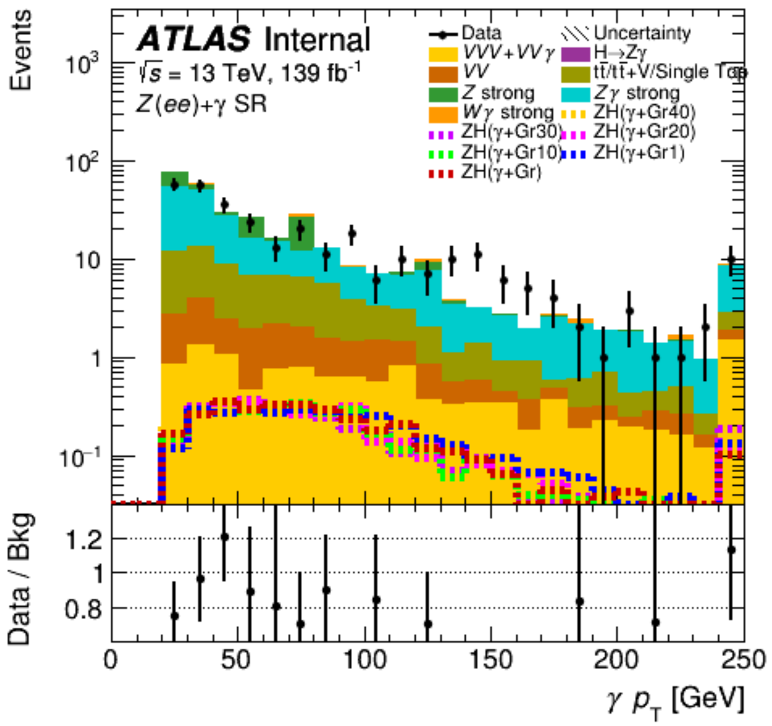
uu-channel

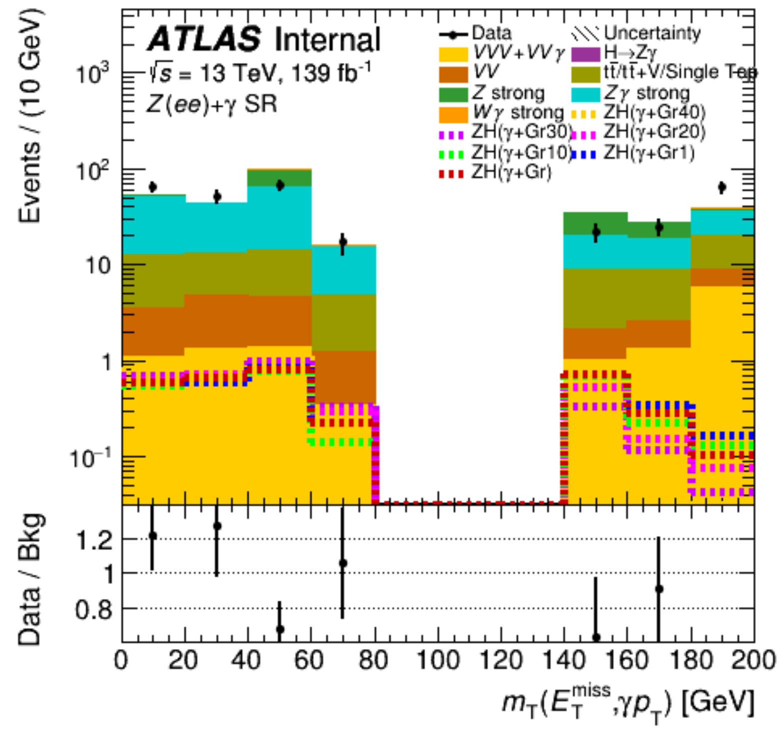


(Plots by H. El Jarrari)

Data/MC in blinded SR:

ee-channel

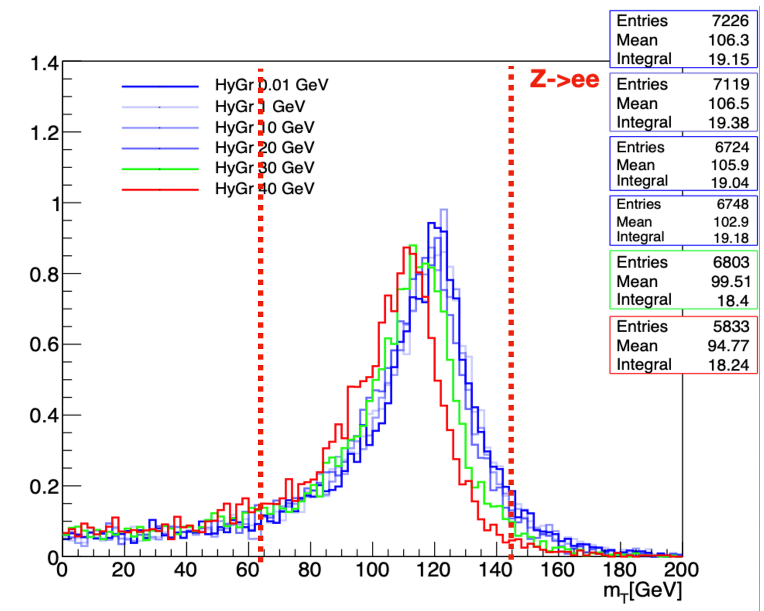


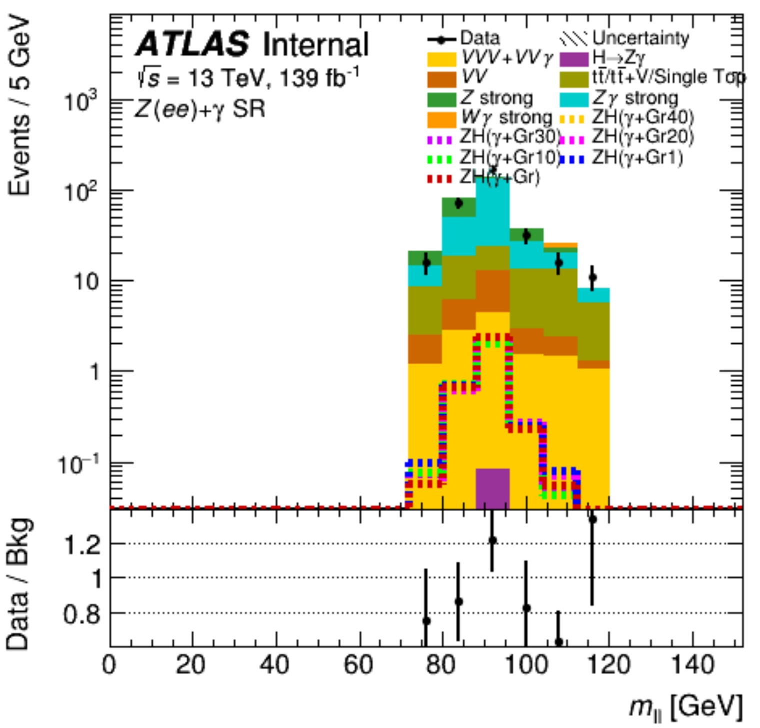


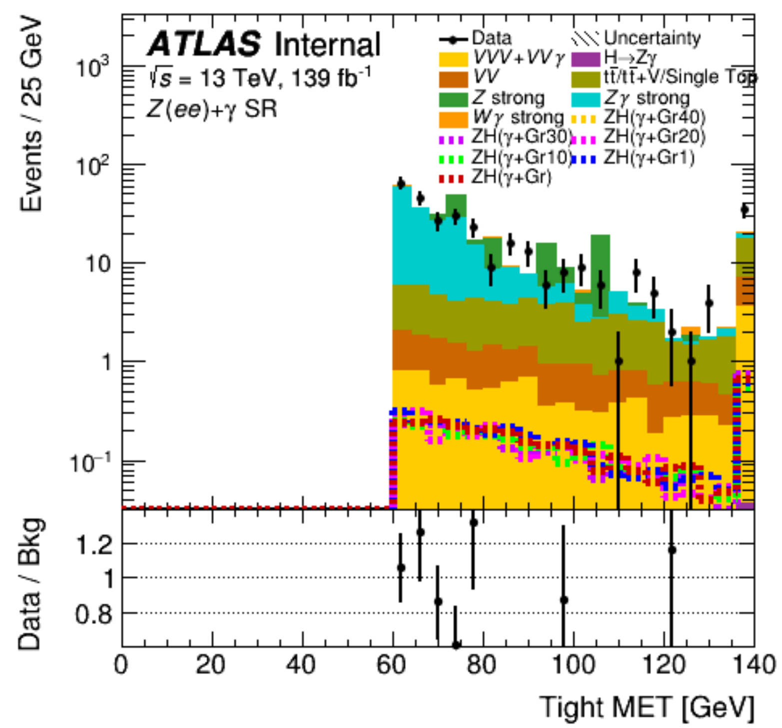
Blinding

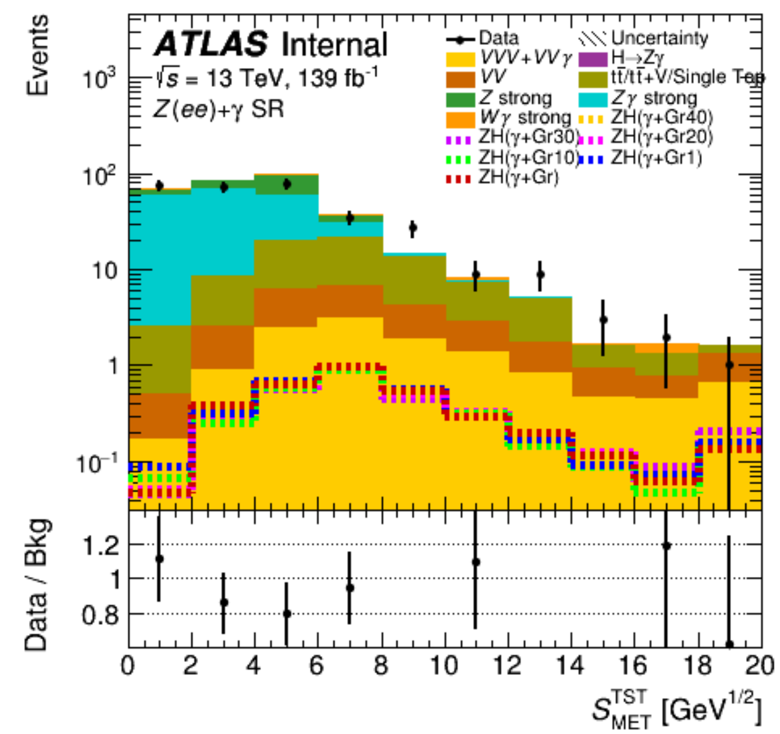
m_T < 65 GeV || m_T > 145 GeV

=> about 82% signal rejected



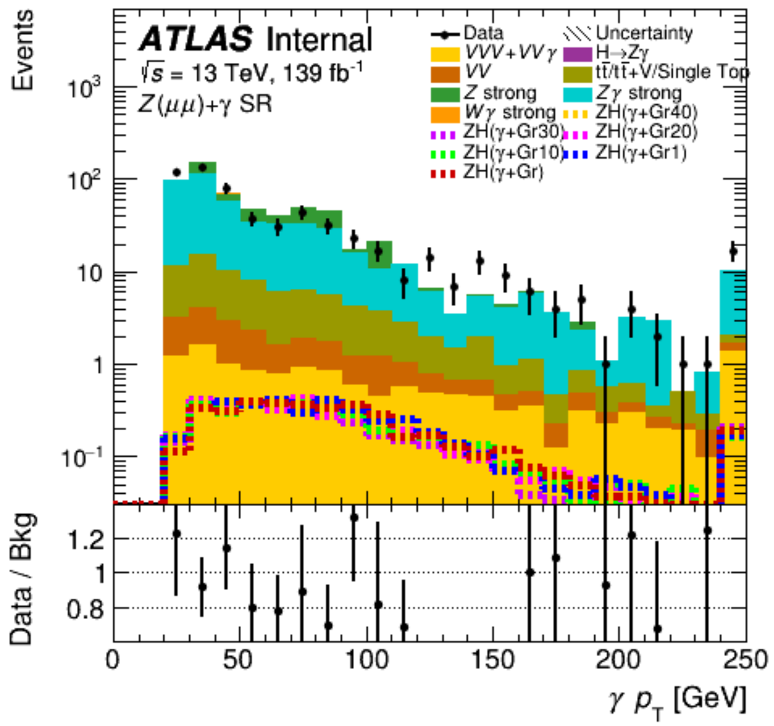


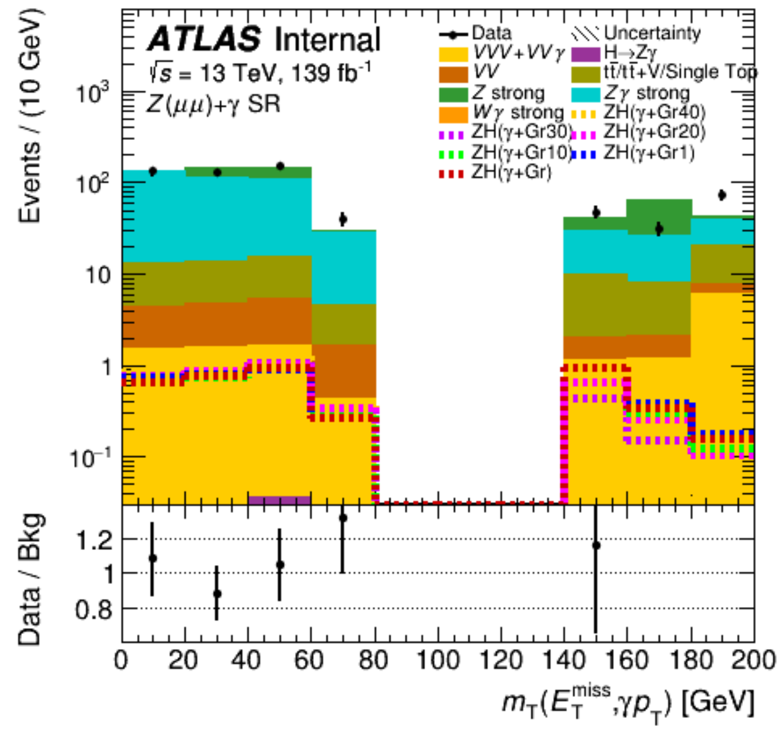




Data/MC in blinded SR:

uu-channel





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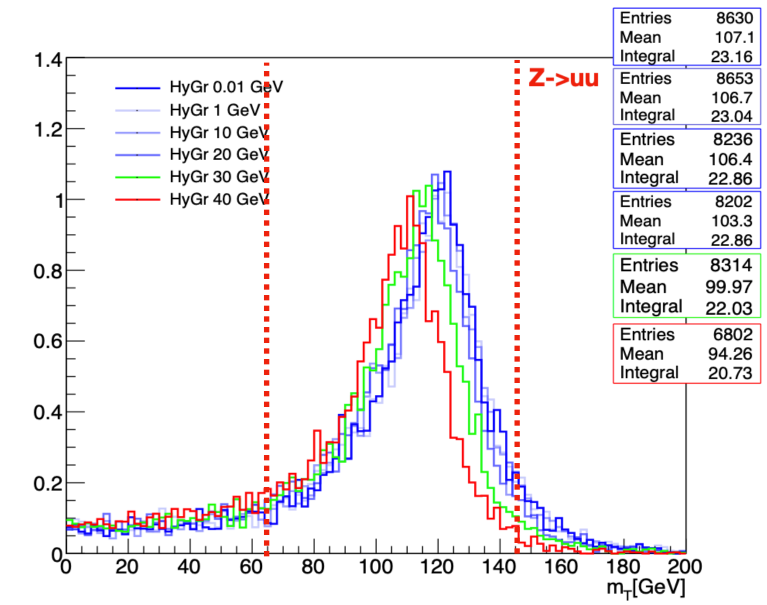
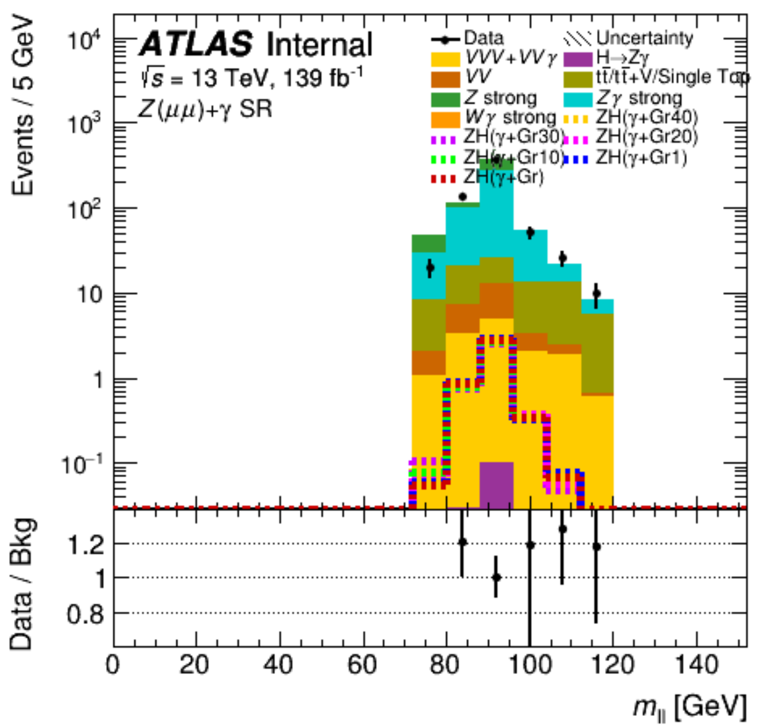
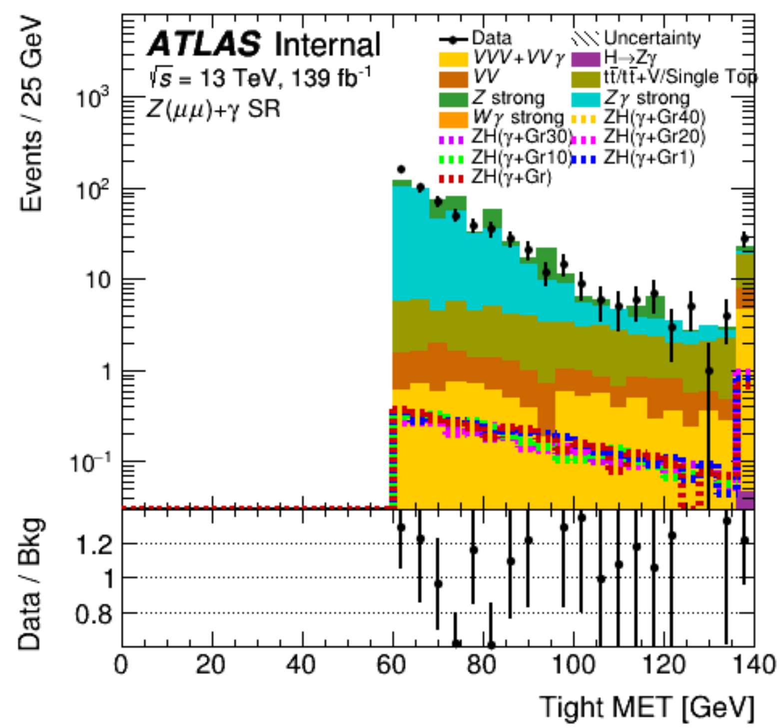
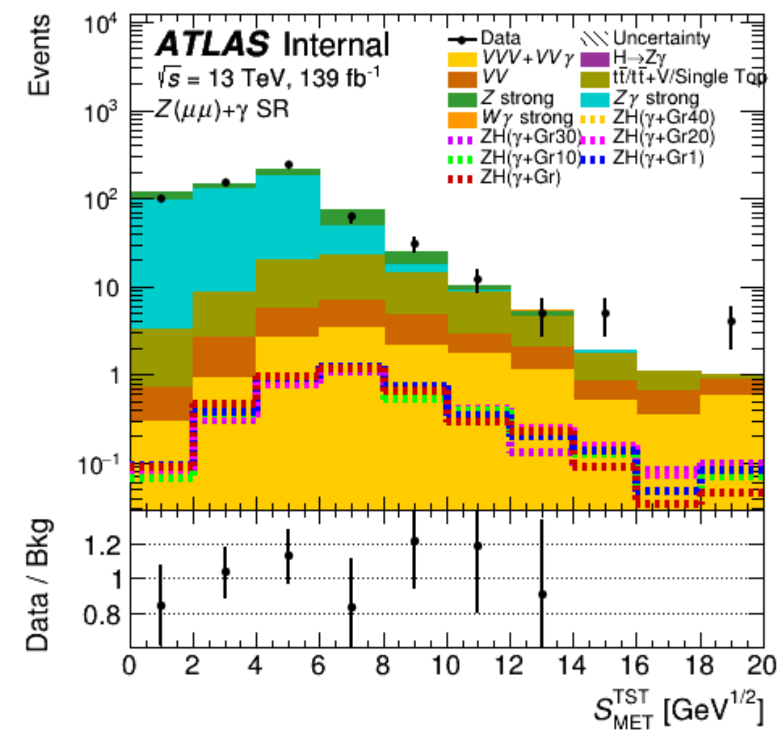








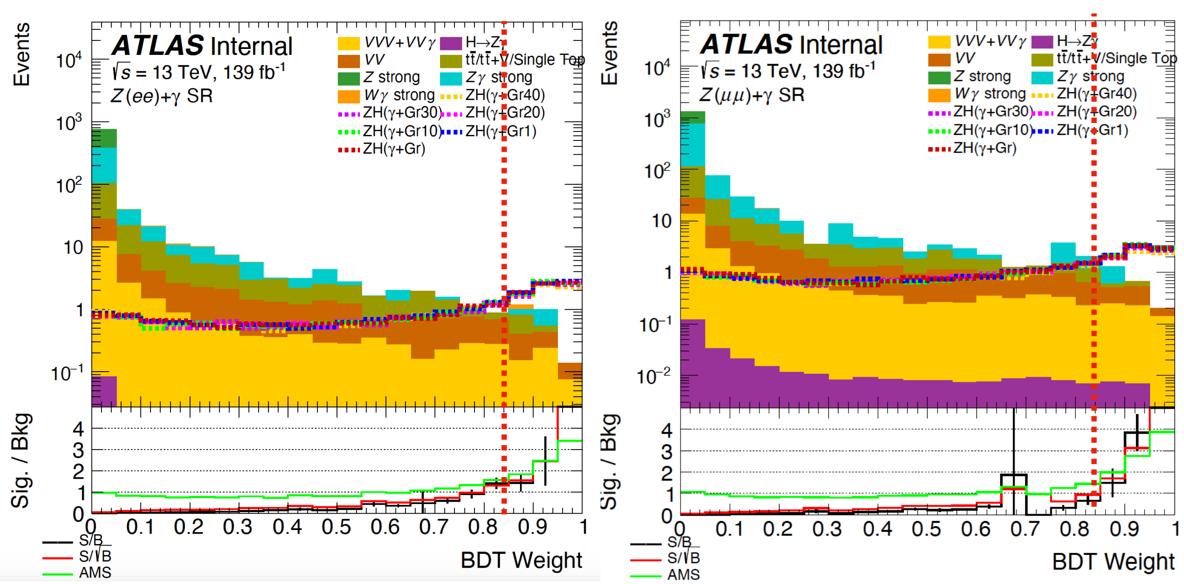
(E. Hofgard)

SR optimization with Machine Learning

Impact of BDT cut in SR

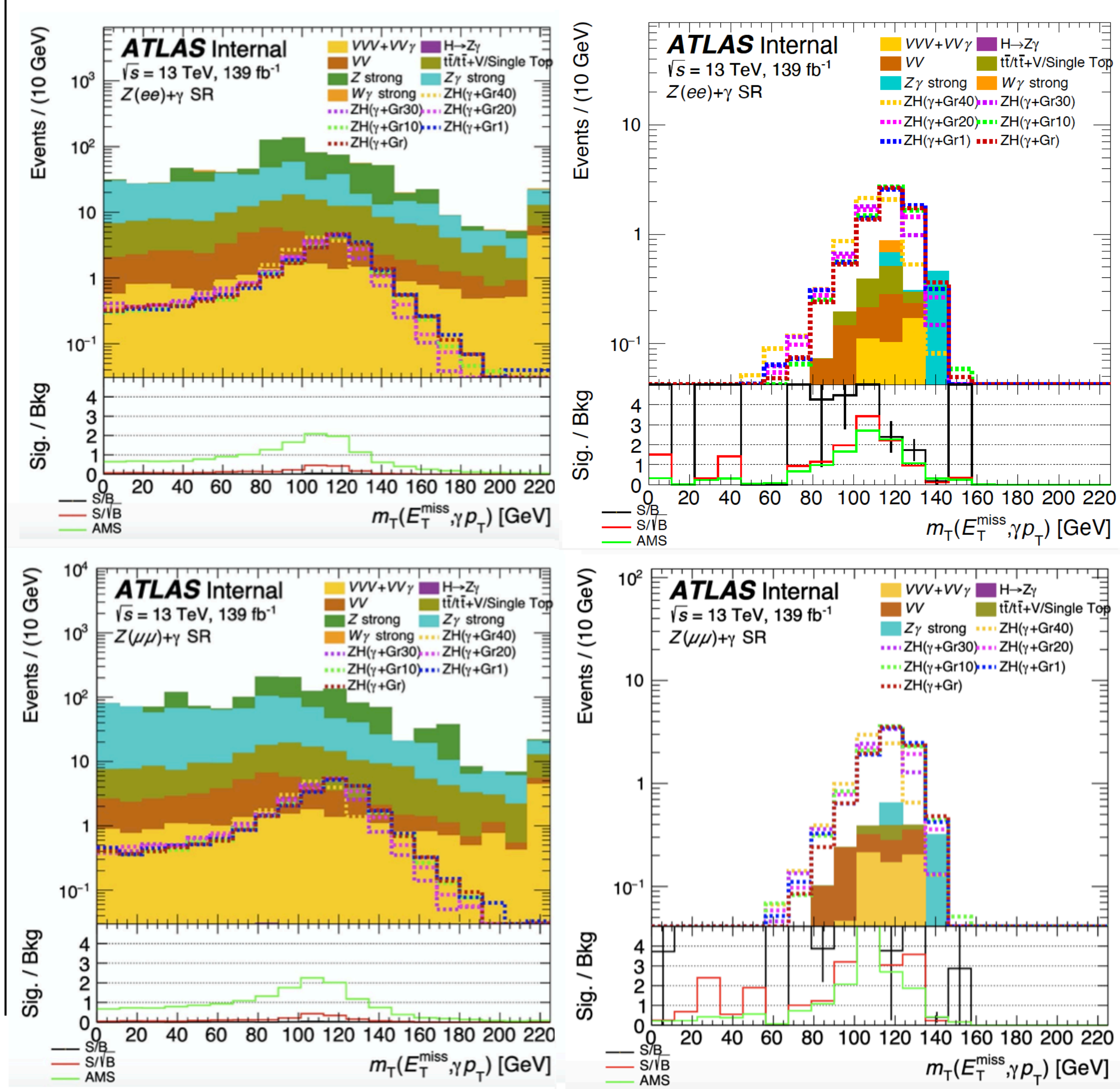
- Input variables: met_tight_tst_et , met_tight_tst_phi , mT , ph_pt , dphi_mety_ll , AbsPt , Ptll , mllg , lep1pt , lep2pt , mll , metsig_tst , Ptllg ,dphi_met_ph
- Hyperparameter tuning performed with hpogrid

Optimisation of cut on BDT weight based on AMS metric: $\sqrt{2[(s+b)\ln(1+s/b)-s]}$



Work in progress

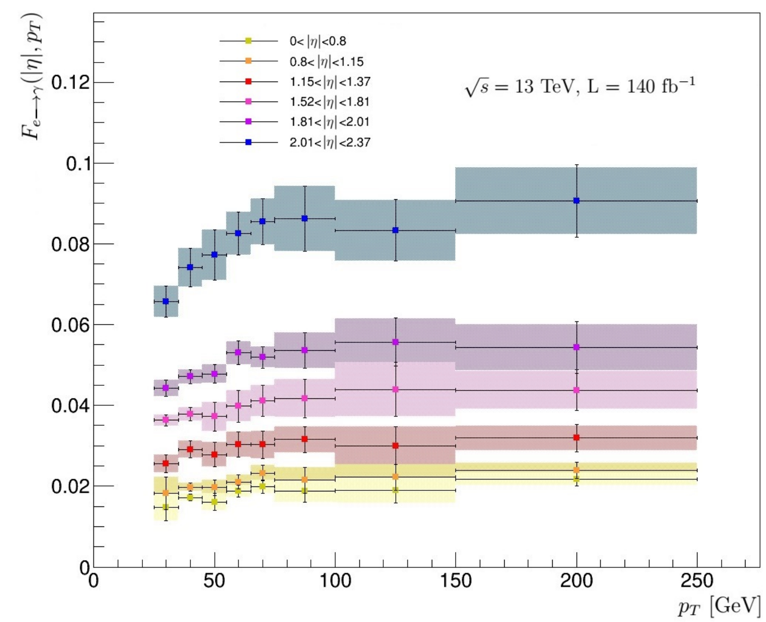
SR optimization **BDT > 0.85**



Electrons-faking-photons

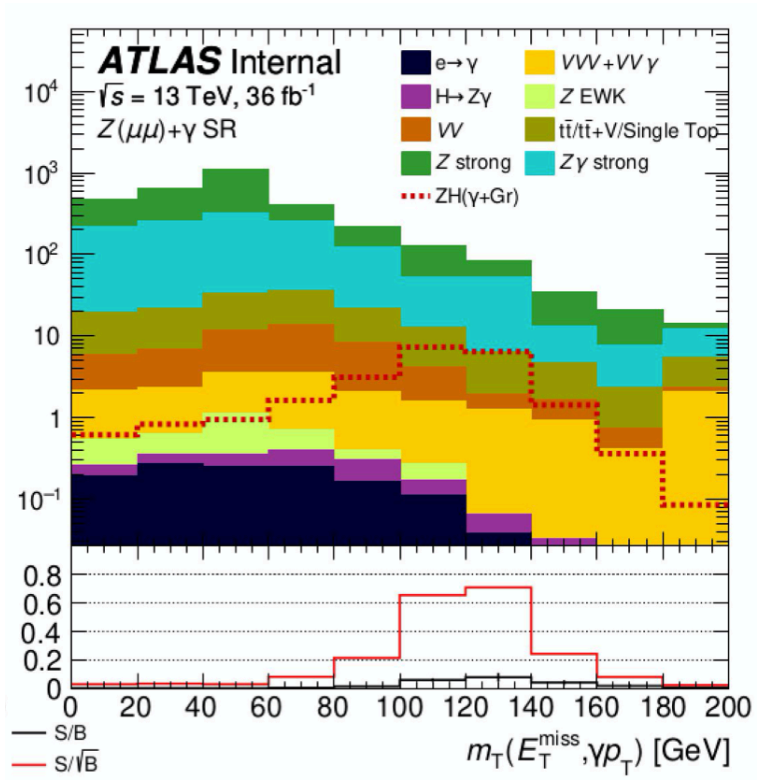
- Mainly W(ev)Z(ll) events with the electron from W decay misidentified as a photon
- Using e-to-γ fake rate from mono-photon analysis
- Data yields in the WZ CR (defined as the SR, but requiring an electron in place of the signal photon) rescaled by fake-rate
- Similar procedure will be applied to all the analysis CRs
- Will be bachelor thesis project of Andrea Mitta

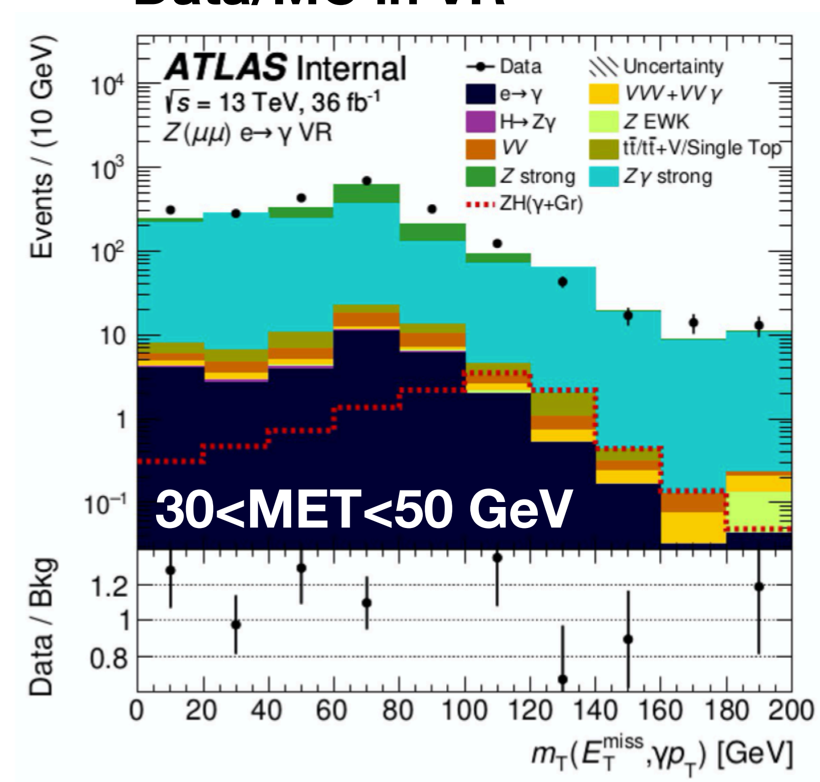
Mono-photon analysis



Data/MC in VR

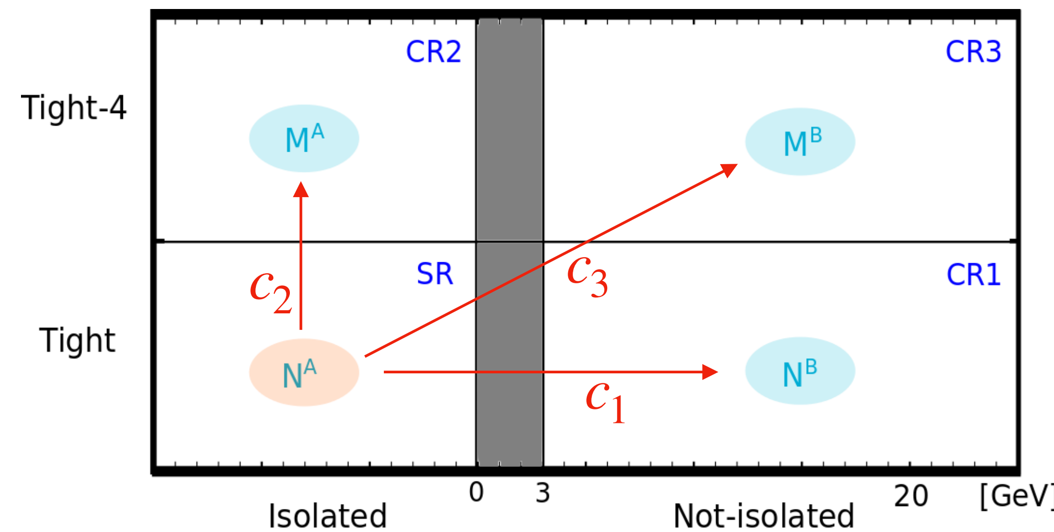
Preliminary results (B. Nino, S.Sevova), using previous version of the ntuples (AthAnalysis 21.2.123)





(L. Carminati, S. Manzoni, D. Mungo, D. Tantucci)

Jets-faking-photons



- Mainly from Z+jets events, with one jet misidentified as a photon
- ABDC method, based on photon isolation and identification
- Number of jets-faking-photons: $N_{j\to\gamma} = (1 - P)N_A$ with $P = N_A^{sig}/N_A$

$$N_A^{sig} = N_A - R_{MC}\frac{(N_B - c_1N_A^{sig})(M_A - c_2N_A^{sig})}{M_B - c_3N_A^{sig}}$$

- The c_i and R_{MC} coefficients are evaluated from MC, and allow to take into account deviations from the basic assumptions of the method (uncorrelated variables and negligible signal leakage in the B,C and D regions)
  - $c_i = N_i/N_A$: signal (real-photon) leakage in the i-th CR, estimated from Zy+jets MC
  - $R_{MC} = (N_AM_B)/(N_BM_A)$: correlation factor between tight and isolated regions, estimated from Z+jets MC
- Study ongoing

(M. Fanti, D. Pullia, F. Piazza, S. Resconi)

Fake MET background
A new ABCD method

(Due to mismeasured jets in Zy+jets process)

- Defining an ABCD method
  - Different pair of variables and cut values tested
  - MET significance or MET as a first variable (MET significance variable allows good discrimination between fake MET and real MET)
  - Several second variables considered. Most promising from preliminary studies:

    $\Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}, \mathbf{p}_{\mathrm{T}}^{ll\gamma})$

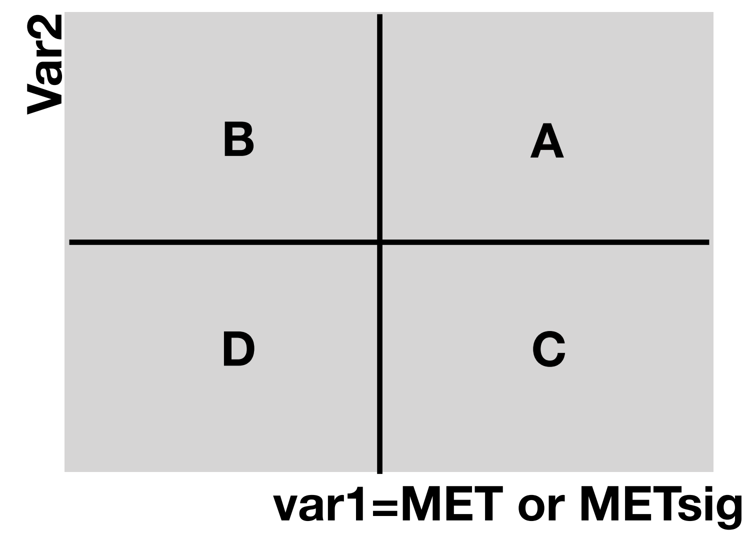
    $\Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}} + \mathbf{p}_{\mathrm{T}}^{\gamma}, \mathbf{p}_{\mathrm{T}}^{ll})$

    $\Delta\phi(|\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}+\mathbf{p}_{\mathrm{T}}^{ll\gamma}|, \mathrm{nearest}(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}},\mathbf{p}_{\mathrm{T}}^{ll\gamma}))$

    $\Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}, \mathrm{nearest\ obj.})$

    $|\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}/\mathbf{p}_{\mathrm{T}}^{ll\gamma}|$

    $|\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}+\mathbf{p}_{\mathrm{T}}^{ll\gamma}|/E_{\mathrm{T}}^{\mathrm{miss}}$



- Further investigation based on the following criteria:
  - R stability: non dependence of R coefficient on the choice of cut values → Low $\chi^2_{V1V2} = \sum_{ij=cut_1cut_2} \left(\frac{R_{ij} - <R>}{\sigma(R_{ij})}\right)^2$
  - R close to 1 (uncorrelated variables)
  - High signal efficiency in SR and low leakage of dark-photon and real MET events in the CRs
  - Good statistics in CRs

  } High $(RV_{ij})_{V1V2} = \left(\frac{\epsilon_{ij}}{\sigma_{R_{ij}} \times (R_{ij} + 1/R_{ij})}\right)_{V1V2}$

Fake MET background

Choice of variables

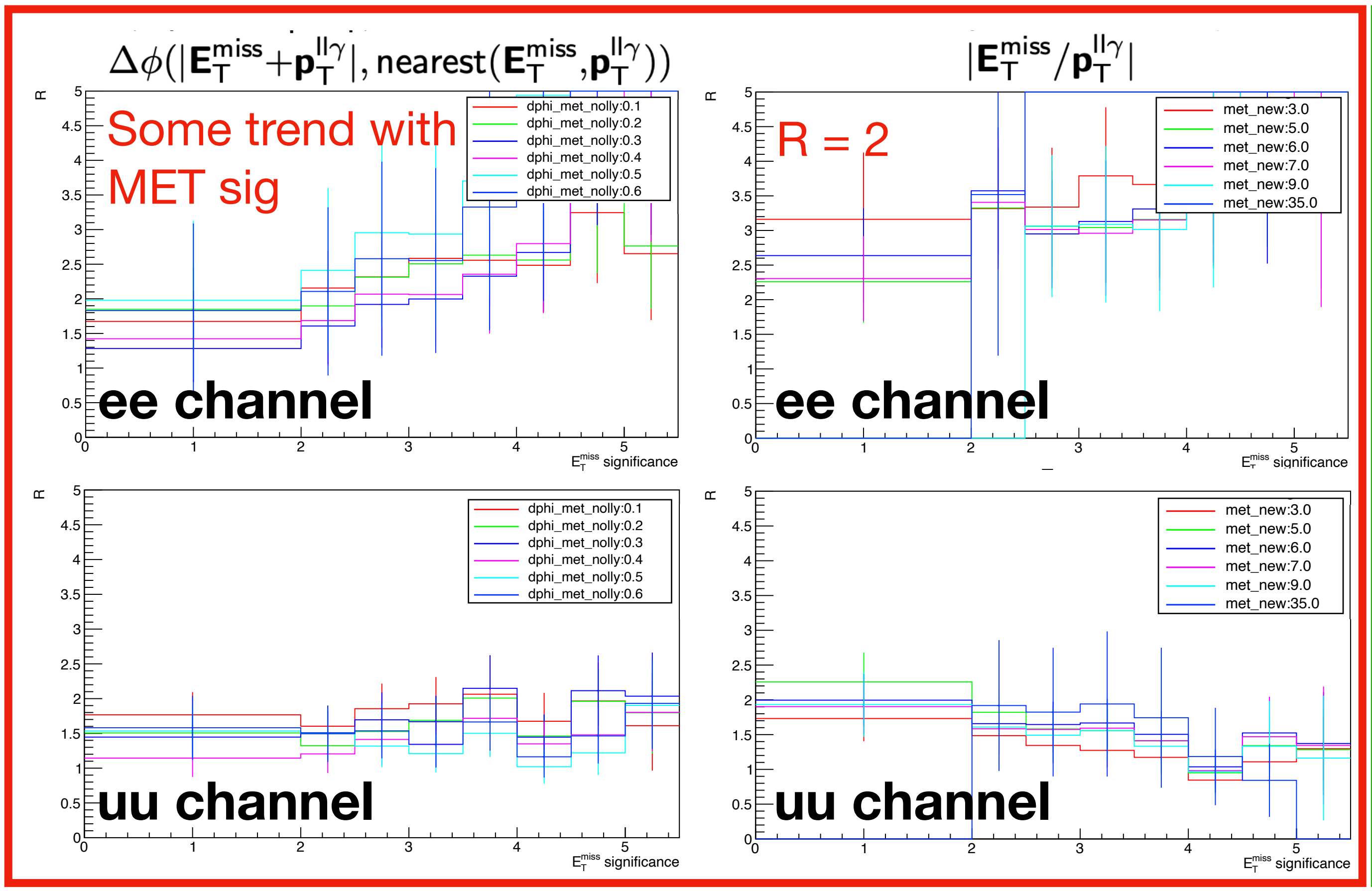
Stability tested scanning different cut values on var1 and var2, with both MET and MET significance as var1

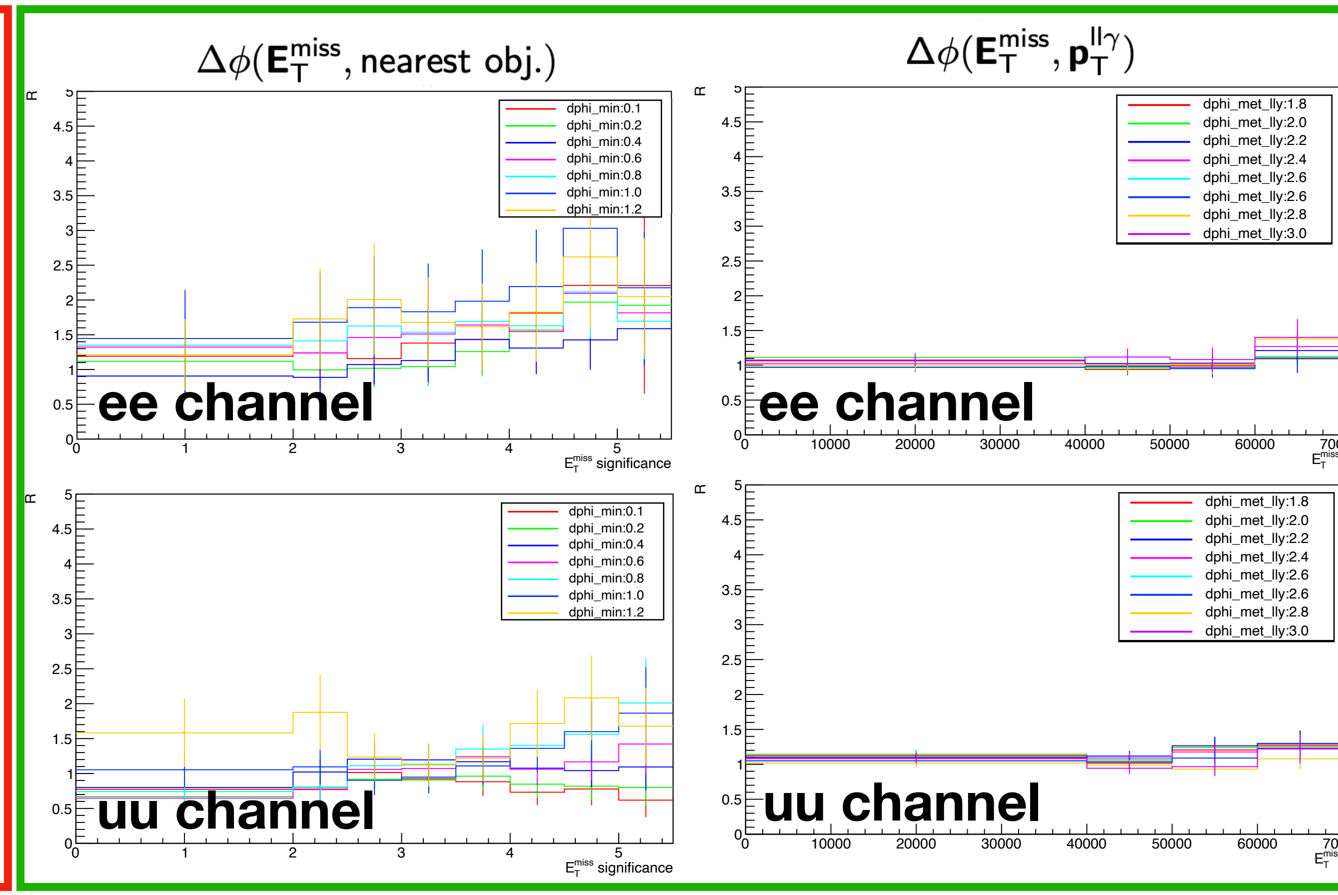
var1	var2	mean	ee	uu
met_tight_tst_et	dphi_met_lly	0.62	0.49	0.76
metsig_tst	dphi_met_nolly	0.66	0.76	0.56
metsig_tst	met_over_ptlly	0.71	0.50	0.93
metsig_tst	dphi_min	0.83	0.61	1.06
metsig_tst	mlly	0.88	0.73	1.04
metsig_tst	dphi_met_lly	0.94	1.12	0.76
metsig_tst	dphi_mety_ll	1.07	1.02	1.12
met_tight_tst_et	dphi_min	1.14	1.36	0.92
met_tight_tst_et	dphi_mety_ll	1.25	0.49	2.01
met_tight_tst_et	dphi_met_nolly	2.36	3.30	1.43
met_tight_tst_et	met_over_ptlly	2.44	3.25	1.64

chi2 in ee-channel, uu-channel and the mean of the two reported in columns ee, uu, and mean respectively

dphi_met_lly	$\Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}, \mathbf{p}_{\mathrm{T}}^{ll\gamma})$
dphi_mety_ll	$\Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}} + \mathbf{p}_{\mathrm{T}}^{\gamma}, \mathbf{p}_{\mathrm{T}}^{ll})$
dphi_met_nolly	$\Delta\phi(\lvert\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}+\mathbf{p}_{\mathrm{T}}^{ll\gamma}\rvert, \text{nearest}(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}, \mathbf{p}_{\mathrm{T}}^{ll\gamma}))$
dphi_min	$\Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}, \text{nearest obj.})$
met_over_ptlly	$\lvert\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}/\mathbf{p}_{\mathrm{T}}^{ll\gamma}\rvert$
met_nolly	$\lvert\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}+\mathbf{p}_{\mathrm{T}}^{ll\gamma}\rvert/E_{\mathrm{T}}^{\mathrm{miss}}$

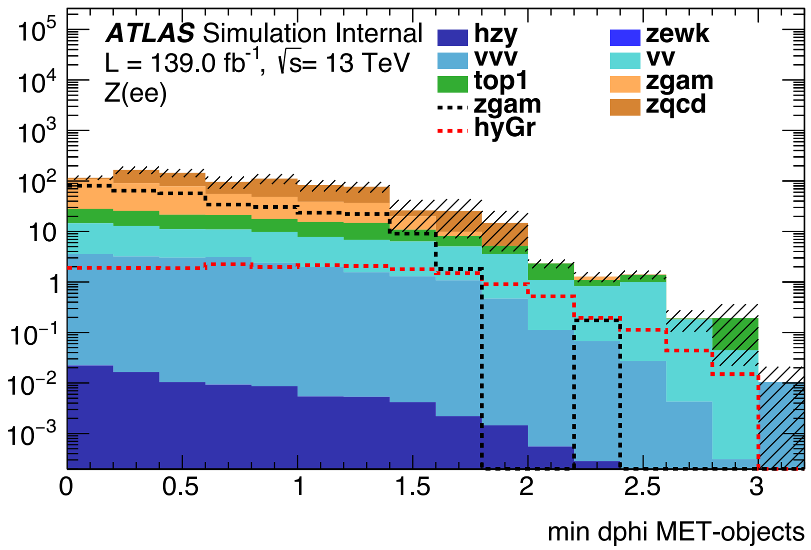
Best choices based on R stability

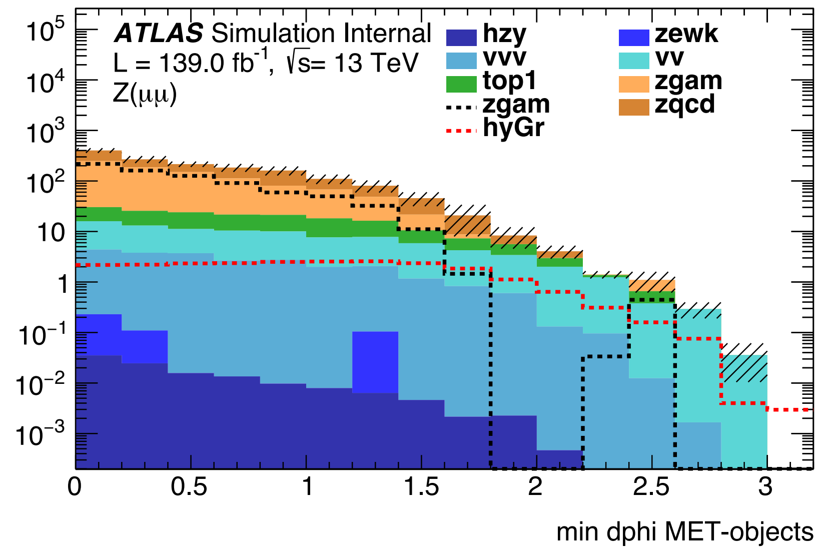


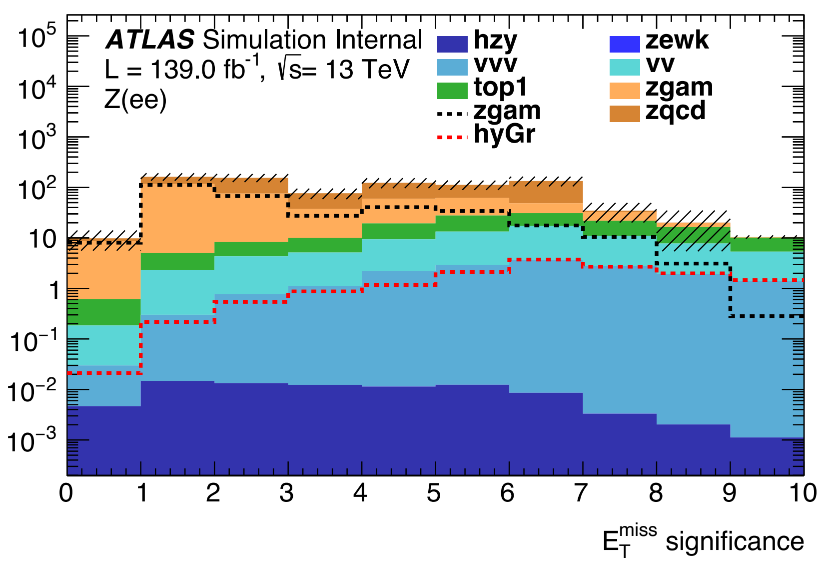


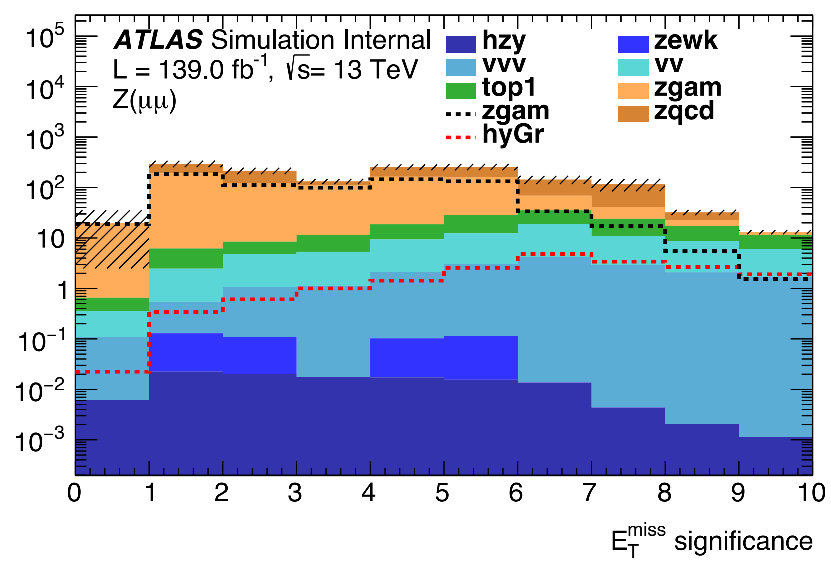
Fake MET background

Variable distributions for METsig-based ABCD



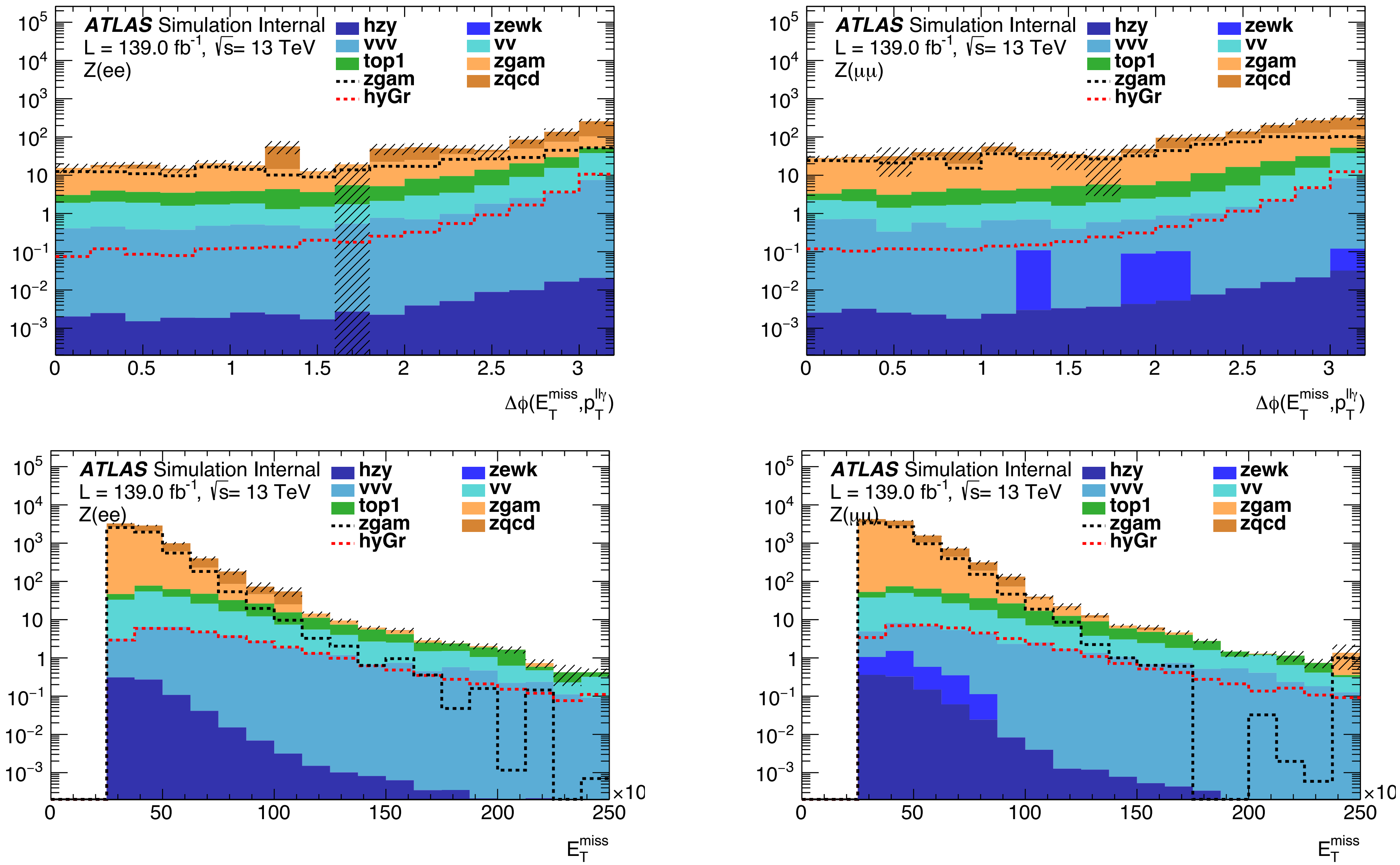






Fake MET background

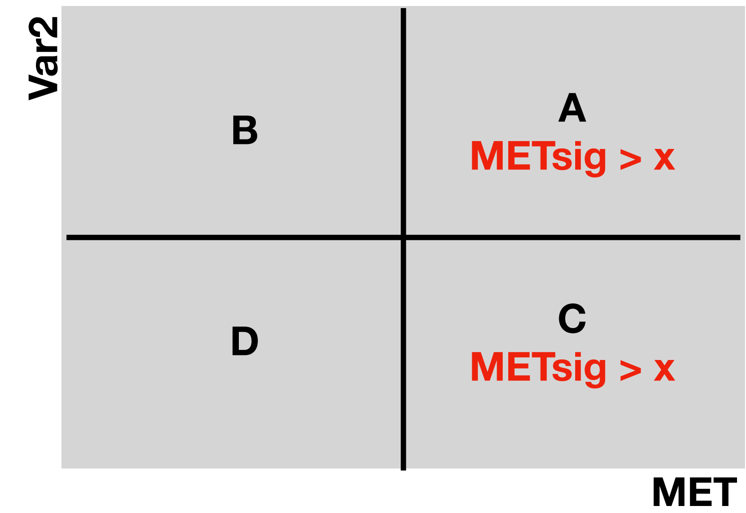
Variable distributions for MET-based ABCD



Fake MET background

Including METsig cut in MET-based ABCD

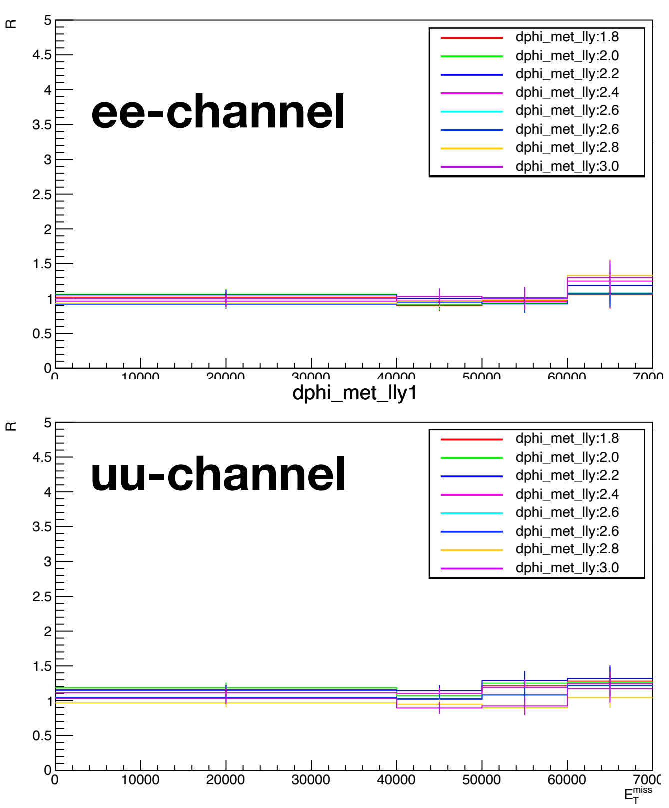
- MET significance cut improves sensititity thanks to high discrimination between real MET and fake MET
- Trying to include a MET significance cut in high MET regions, in the MET-based ABCD



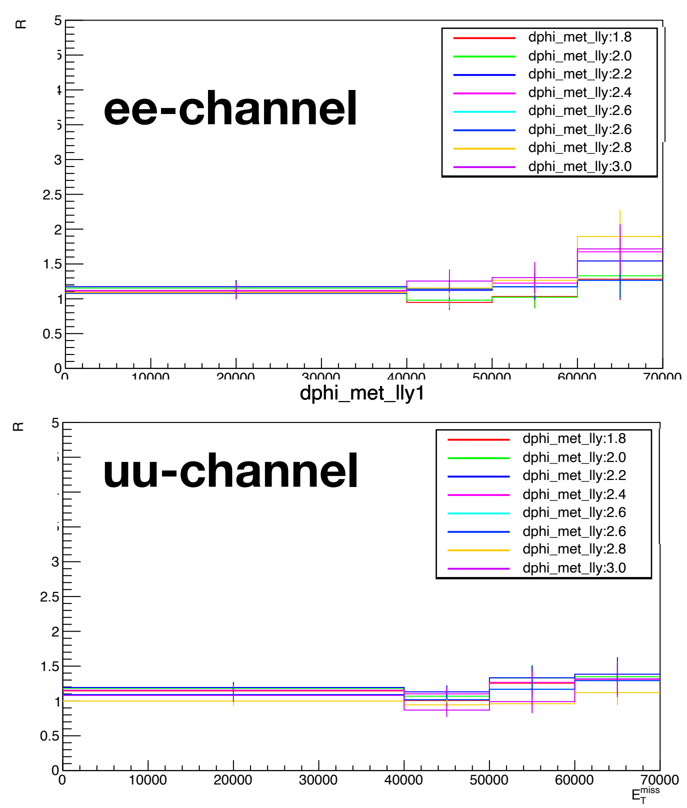
var1	var2	metsig	mean	ee	uu
met_tight_tst_et	dphi_met_lly	0.0	0.62	0.49	0.76
met_tight_tst_et	dphi_met_lly	3.0	0.92	0.70	1.13
met_tight_tst_et	dphi_met_lly	4.0	1.78	1.22	2.33

$$\text{dphi\_met\_lly} = \Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}, \mathbf{p}_{\mathrm{T}}^{ll\gamma})$$

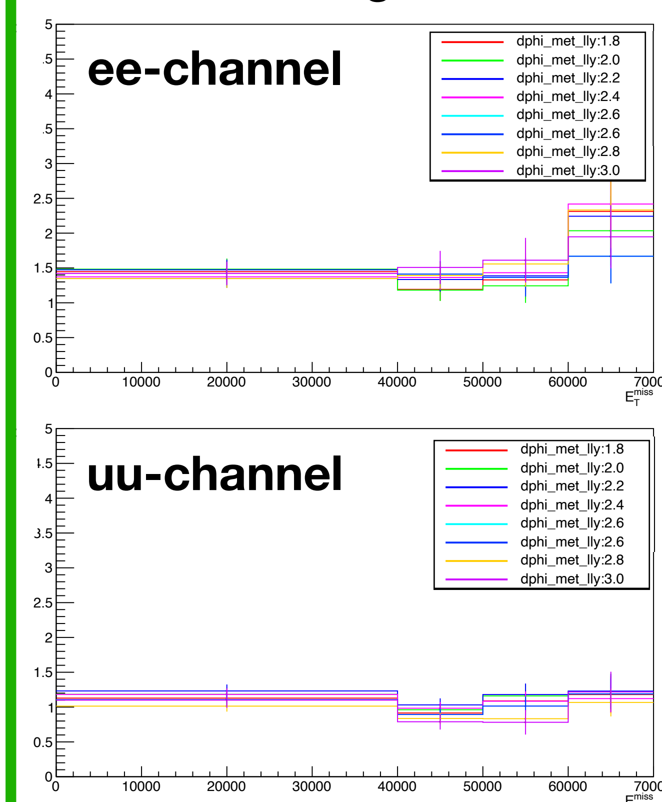
No MET sig cut



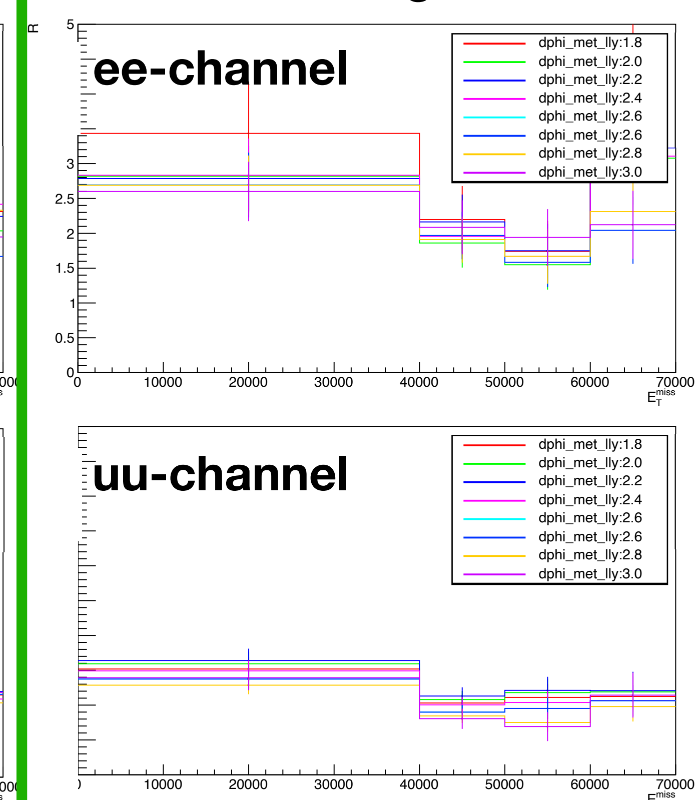
MET sig > 2



MET sig > 3



MET sig > 4



Fake MET background

Best cut values

Considering best MET-based and best METsig-based ABCD

ee-channel

var1	var2	metsig	cut1	cut2	R
met_tight_tst_et	dphi_met_lly	3.0	40000.0	2.0	1.28 +\- 0.25
metsig_tst	dphi_min	3.0	3.0	0.2	1.02 +\- 0.27
metsig_tst	dphi_min	4.0	4.0	0.2	1.26 +\- 0.35

uu-channel

var1	var2	metsig	cut1	cut2	R
met_tight_tst_et	dphi_met_lly	3.0	40000.0	2.0	1.23 +\- 0.17
metsig_tst	dphi_min	3.0	3.0	0.2	0.92 +\- 0.19
metsig_tst	dphi_min	4.0	4.0	0.2	0.96 +\- 0.20

METsig-dphi_min

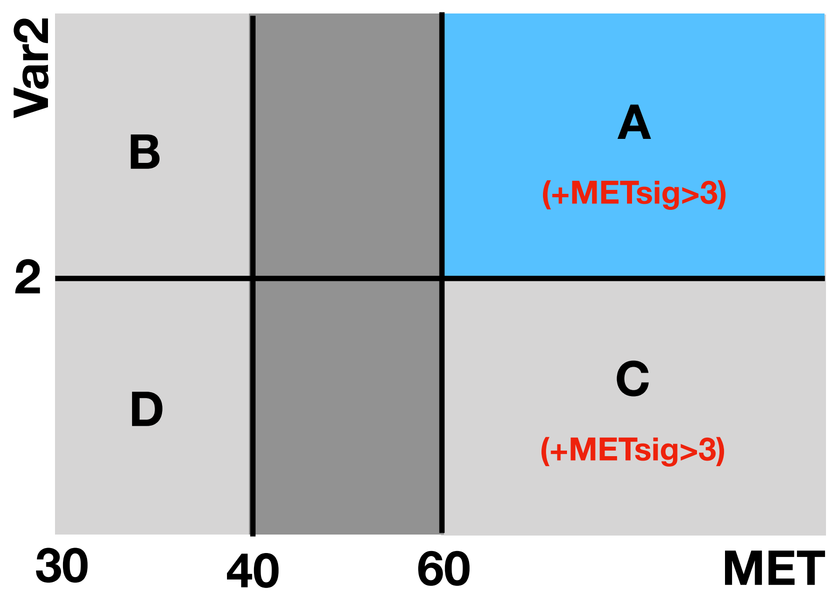
			ee-channel				uu-channel			
sample	V1	V2	nA	nB	nC	nD	nA	nB	nC	nD
hyGr	4	0.2	318.4+/-4.3	26.9+/-1.2	32.0+/-1.4	6.2+/-0.6	389.5+/-4.8	31.2+/-1.3	35.2+/-1.4	8.3+/-0.7
zgam	4	0.2	83.8+/-11.3	158.3+/-15.8	23.9+/-4.2	56.8+/-7.9	237.7+/-21.2	295.0+/-21.6	99.3+/-14.4	118.6+/-12.4
zqcd	4	0.2	202.3+/-49.1	161.7+/-39.5	2.1+/-5.4	5.4+/-5.6	269.5+/-53.0	145.1+/-46.9	76.5+/-27.6	77.9+/-25.8
realMET	4	0.2	127.7+/-2.7	18.0+/-1.0	22.2+/-1.1	6.0+/-0.6	136.7+/-2.8	19.3+/-1.0	22.9+/-1.1	7.4+/-0.7

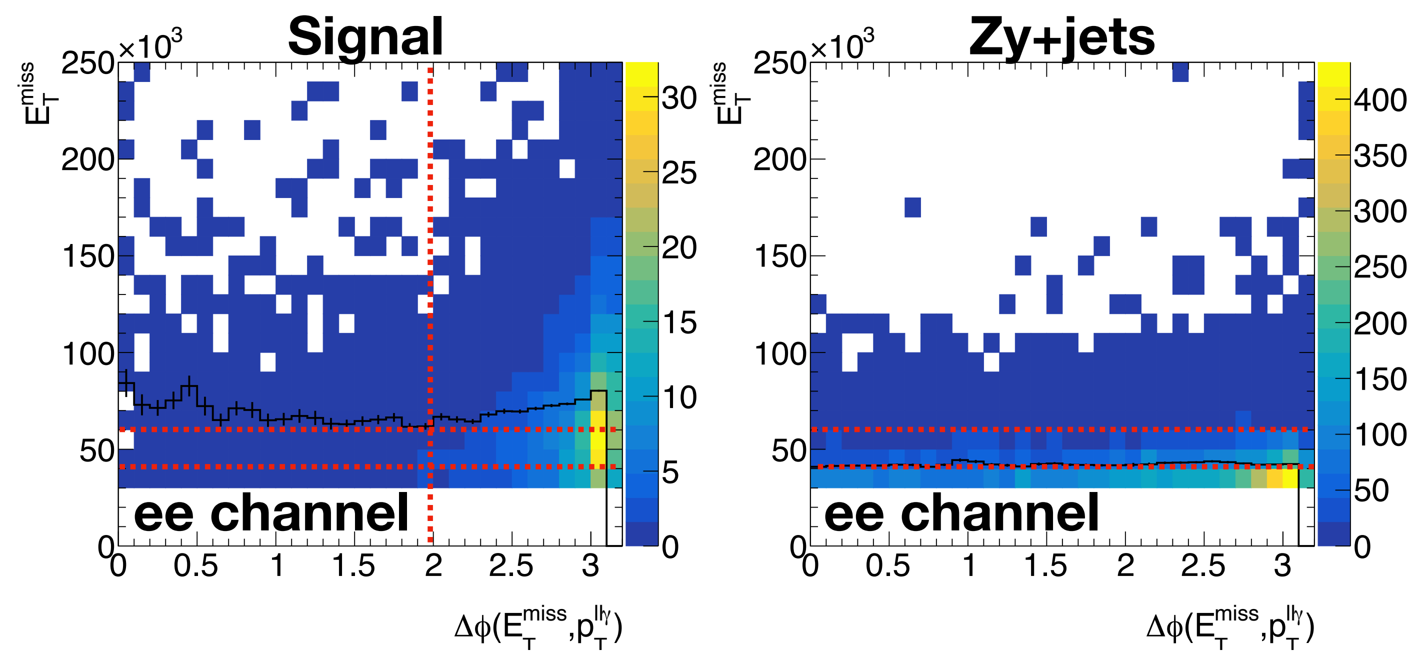
MET-dphi_met_lly

			ee-channel				uu-channel			
sample	V1	V2	nA	nB	nC	nD	nA	nB	nC	nD
hyGr	40	2	342.2+/-4.4	69.9+/-2.0	25.6+/-1.2	10.5+/-0.8	415.1+/-4.9	80.6+/-2.2	29.6+/-1.3	13.7+/-0.9
zgam	40	2	91.1+/-11.8	1955.2+/-56.0	44.1+/-6.4	1212.1+/-45.2	274.7+/-20.5	2407.9+/-64.5	161.7+/-18.5	1741.0+/-49.9
zqcd	40	2	216.5+/-50.1	739.3+/-97.0	27.0+/-14.7	199.3+/-41.8	335.1+/-59.0	1079.1+/-113.2	32.7+/-15.1	156.4+/-50.3
realMET	40	2	123.9+/-2.6	44.5+/-1.3	36.1+/-1.5	19.2+/-1.0	131.7+/-2.8	49.6+/-1.4	39.3+/-1.5	19.3+/-1.0

Fake MET background

ABCD regions definition





- Add a gap region for 40 < MET < 60 GeV (reduce signal leakage in B and D regions, leaves room for VR)
- MET cut: 40 GeV
- dphi(MET, lly) cut: 2
- MET significance > 3 in high MET regions

R= 1.28 +\- 0.25 in ee channel
R= 1.23 +\- 0.17 in uu channel

ee channel

Sample	nA	nB	nC	nD
hyGr	17.11+/-0.22	3.49+/-0.10	1.28+/-0.06	0.52+/-0.04
zgam	91.1+/-11.8	1955.2+/-56.1	44.1+/-6.4	1212.1+/-45.2
zqcd	216.5+/-50.1	739.3+/-97.0	27.0+/-14.7	199.3+/-41.8
realMET	123.9+/-2.6	44.5+/-1.3	36.1+/-1.5	19.2+/-1.0

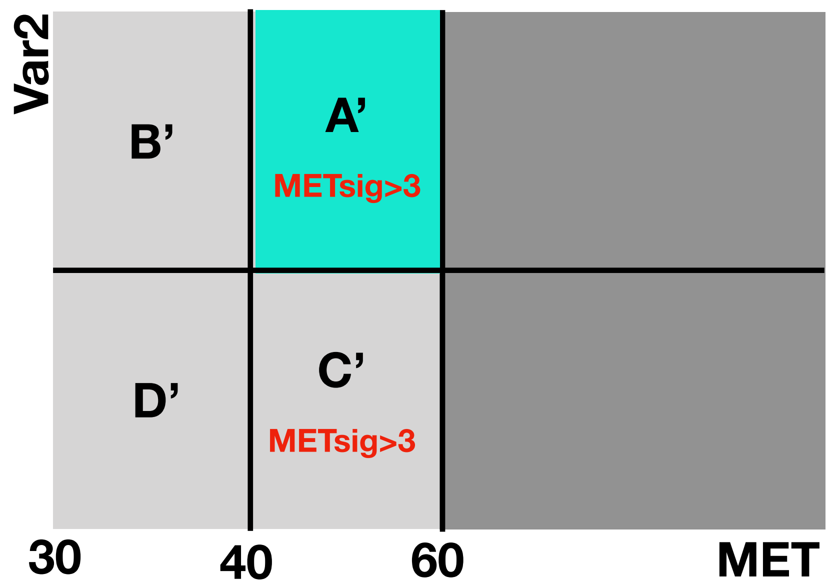
$\mu\mu$ channel

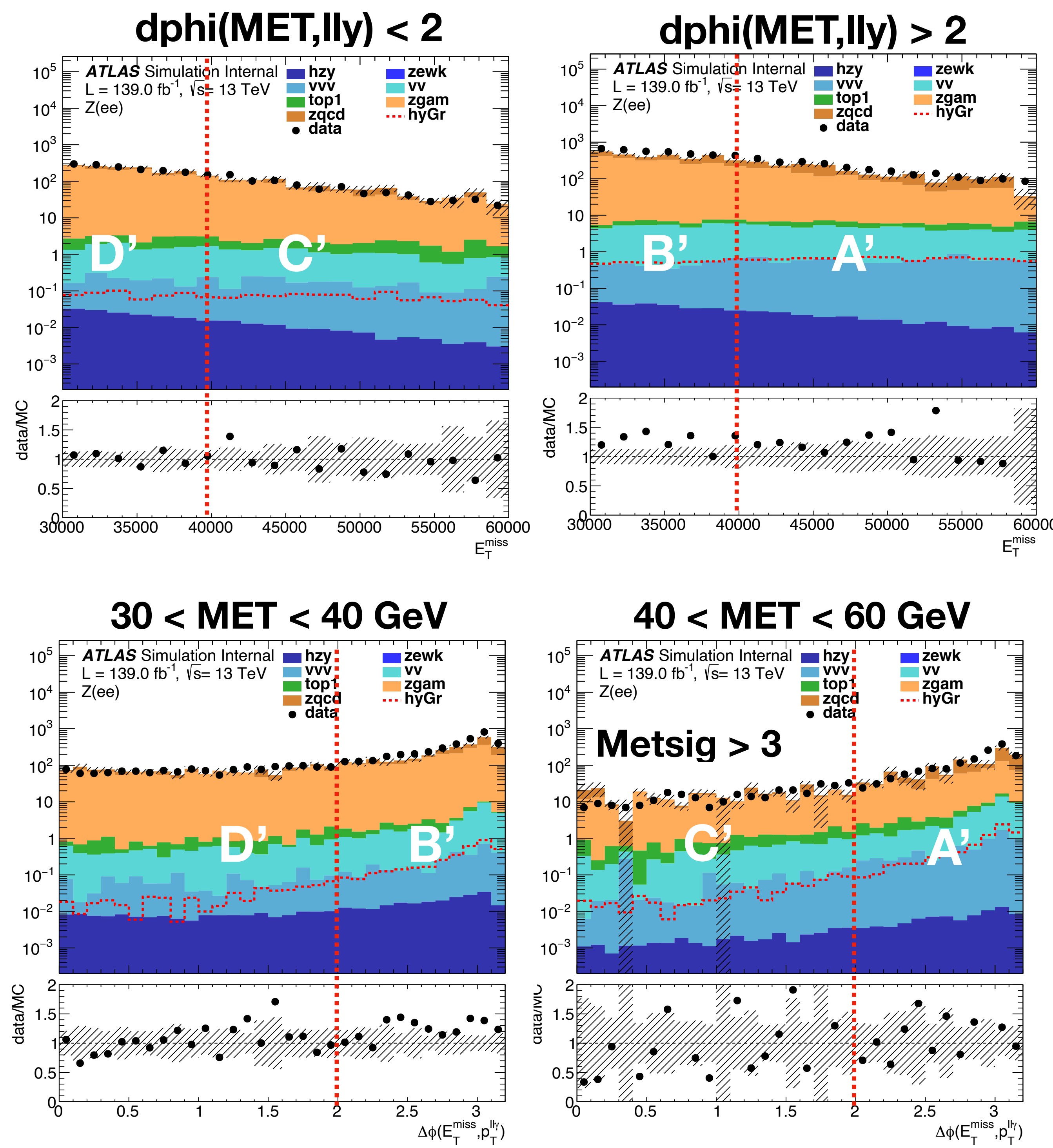
Sample	nA	nB	nC	nD
hyGr	20.76+/-0.25	4.03+/-0.11	1.48+/-0.07	0.68+/-0.04
zgam	274.7+/-20.5	2407.9+/-64.5	161.7+/-18.6	1741.0+/-49.9
zqcd	335.1+/-59.0	1079.1+/-113.2	32.7+/-15.1	156.4+/-50.3
realMET	131.7+/-2.8	49.6+/-1.5	39.3+/-1.5	19.3+/-1.0

Fake MET background

Preliminary validation: data/MC in low MET region

(Signal contamination < 0.5%)





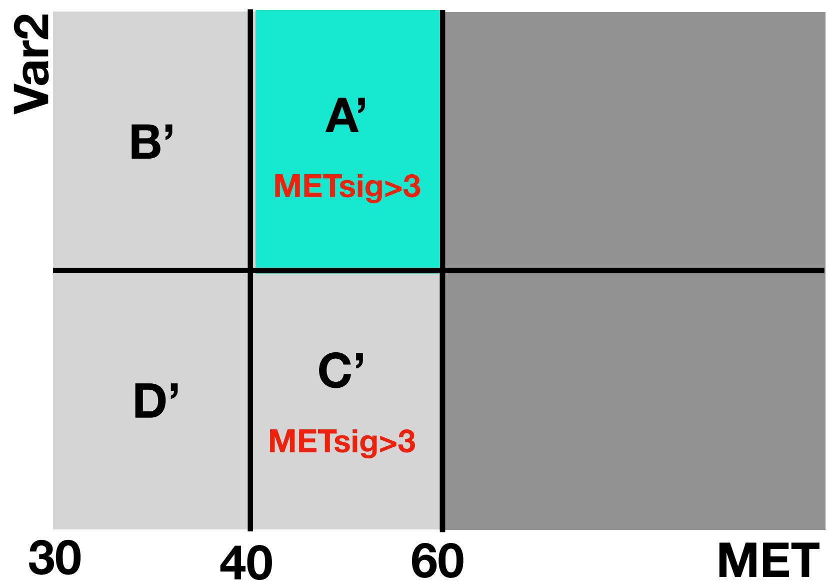
Sample	nA	nB	nC	nD
hyGr	7.6+/-0.1	3.5+/-0.1	0.7+/-0.0	0.5+/-0.0
zgam	555.3+/-33.0	1954.8+/-56.0	226.1+/-18.8	1211.7+/-45.2
zqcd	564.2+/-85.5	739.3+/-97.0	46.3+/-25.0	199.3+/-41.8
totalMC	1191.6+/-91.7	2739.1+/-112.1	292.6+/-31.4	1430.6+/-61.5
totalDat	1474.0+/-38.4	3620.0+/-60.2	308.0+/-17.5	1513.0+/-38.9

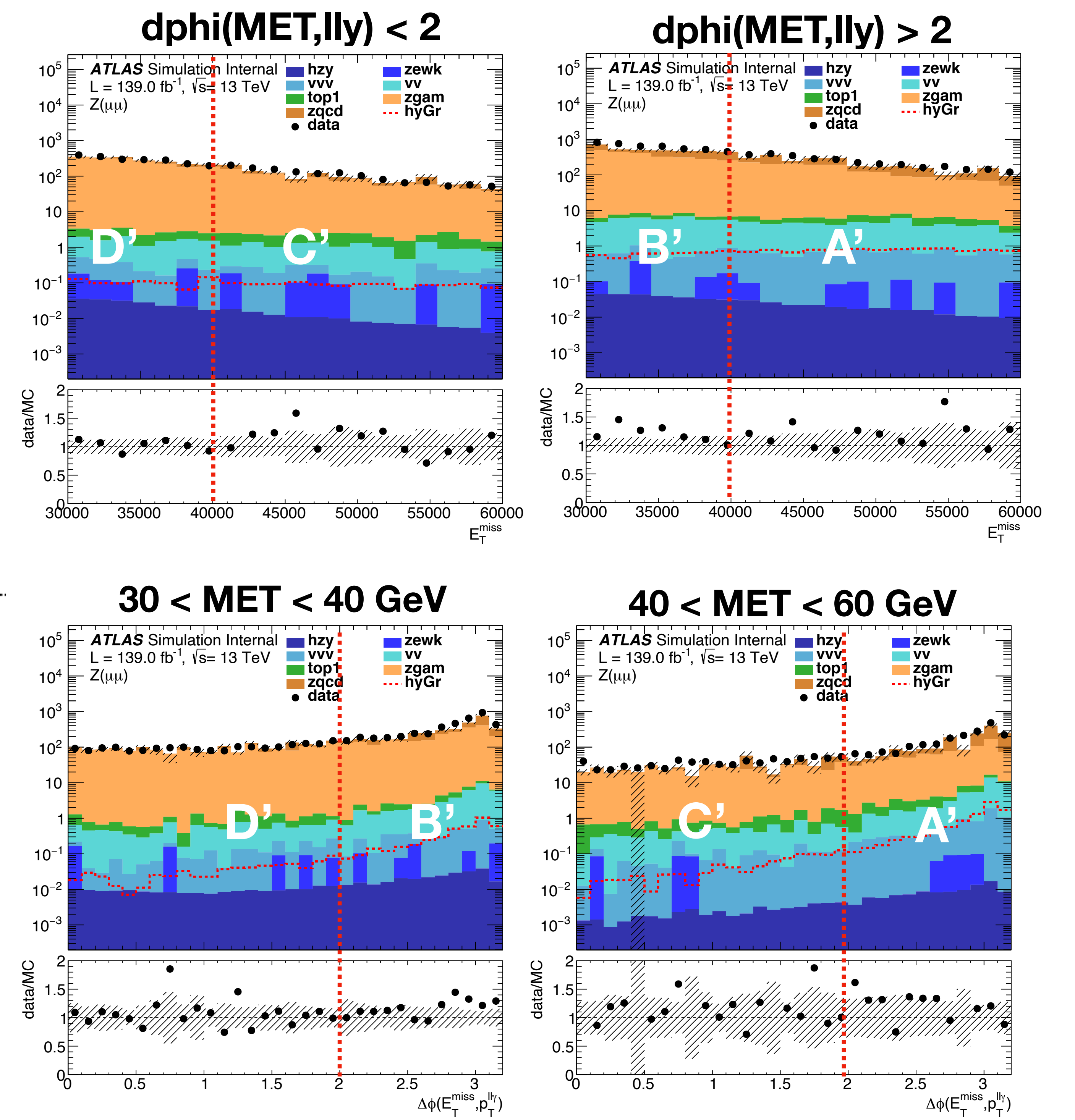
- Good data/MC agreement in low MET regions (MET < 60)

Fake MET background

Preliminary validation: data/MC in low MET region

(Signal contamination < 0.5%)





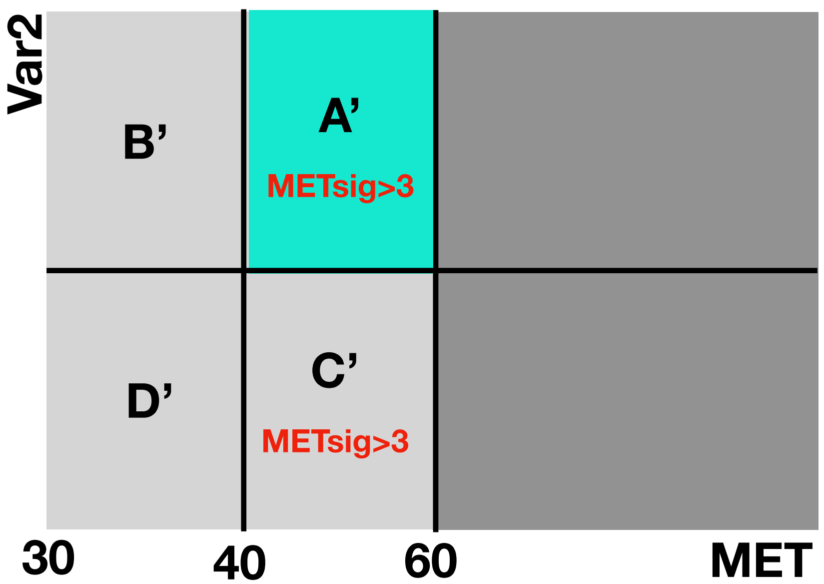
Sample	nA	nB	nC	nD
hyGr	9.1+/-0.2	4.0+/-0.1	0.9+/-0.1	0.7+/-0.0
zgam	783.8+/-34.7	2407.6+/-64.5	484.6+/-29.9	1740.8+/-49.9
zqcd	798.7+/-105.2	1079.1+/-113.2	101.8+/-32.4	156.4+/-50.3
totalMC	1650.5+/-110.8	3536.7+/-130.3	605.3+/-44.1	1916.7+/-70.9
totalDat:	1986.0+/-44.6	4236.0+/-65.1	749.0+/-27.4	1979.0+/-44.5

- Good data/MC agreement in low MET regions (MET < 60)

Fake MET background

Preliminary validation: results in VR

(Signal contamination < 0.5%)



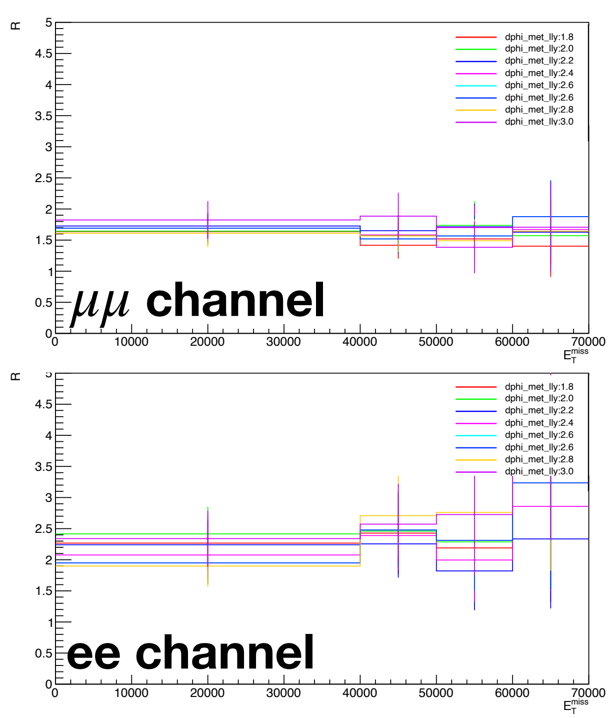
- All regions dominated by Zy+jets and Z+jets background
- In situ estimates for other backgrounds still not available. Preliminary tests with temporary solutions

  => Rzyzjet: evaluating R from Zy+jets AND Z+jets (both are characterized by sizeable fake MET)

  => Rzy : R from Zy only

  For background not used in R estimation, MC yields in each region subtracted from data

R stability from Zy+Zjets MC



$\mu\mu$ channel

	Rmc	Rdata	MC	Data	ABCD
Rzyzjet	1.468 +-0.170	1.230 +-0.113	1582 +- 111	1918 +- 66	2291 +- 329
Rzy	1.169 +-0.100	1.034 +-0.170	784 +- 35	1120 +- 124	1266 +- 188

ee channel

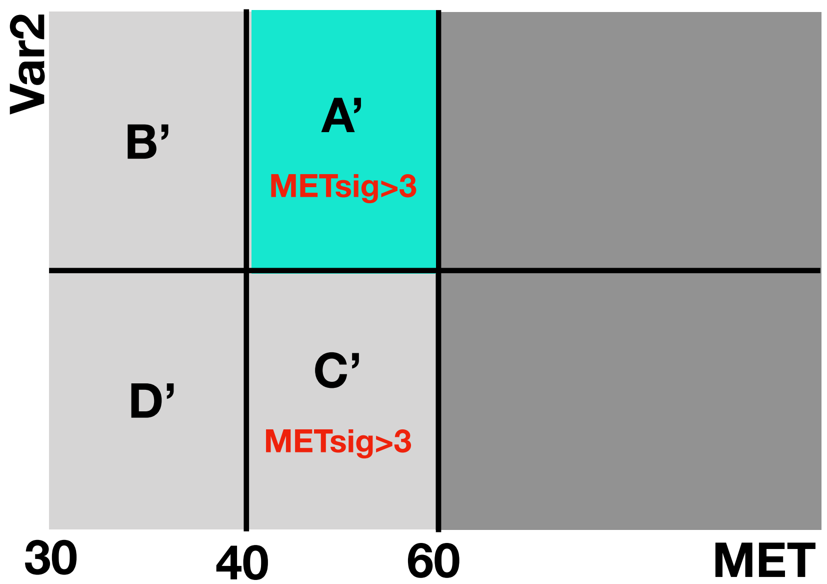
	Rmc	Rdata	MC	Data	ABCD
Rzyzjet	2.153 +-0.330	2.035 +-0.269	1120 +- 92	1402 +- 60	1483 +- 293
Rzy	1.523 +-0.172	1.583 +-0.356	555 +- 33	838 +- 105	806 +- 176

=> R from data is consistent with R from MC

=> ABCD estimates consistent with observed data

Fake MET background

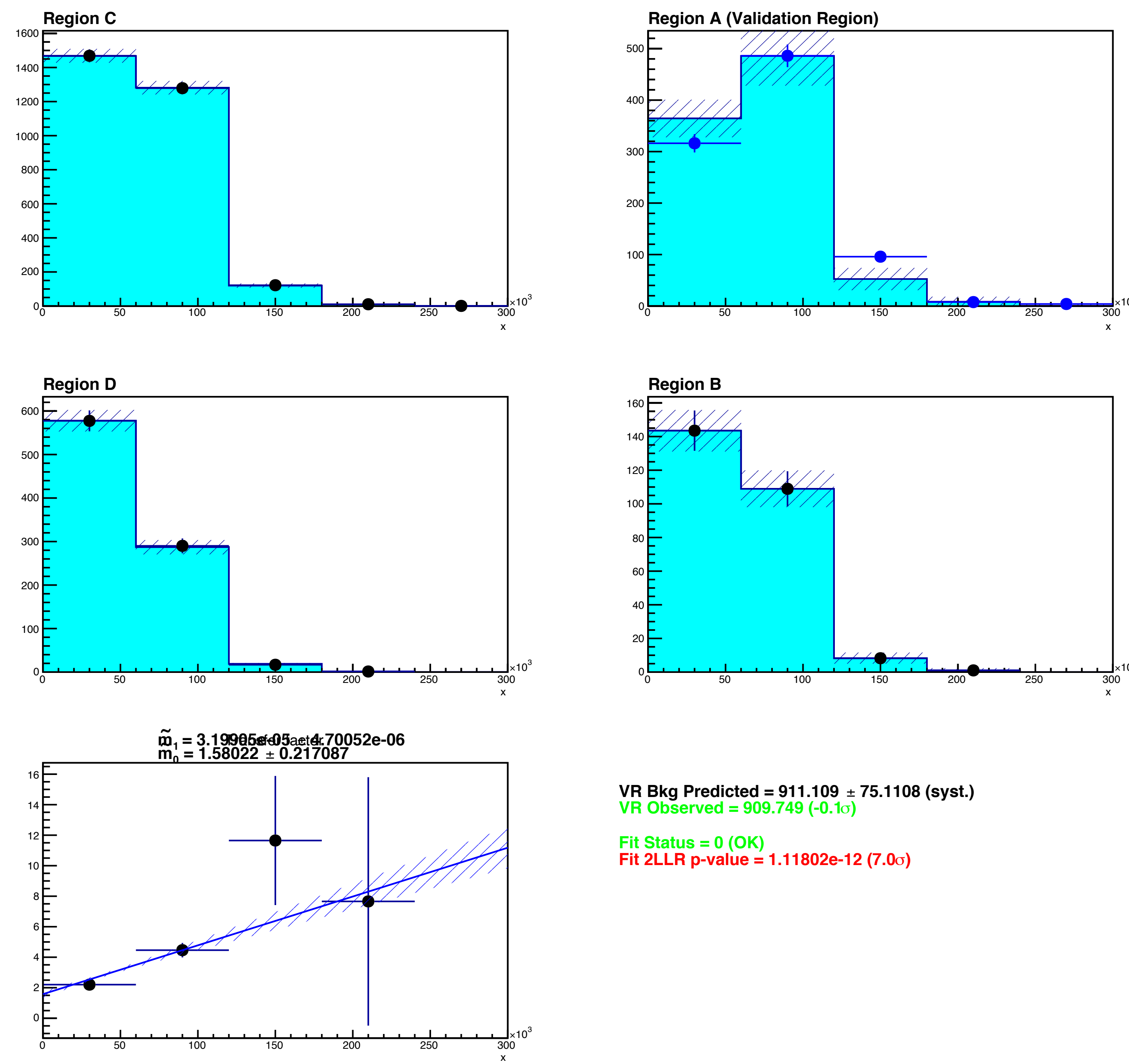
TRooABCD, ee channel



mT distribution in region A’ from simultaneous fit on the B,C,D regions with TRooABCD

- mT histograms in each B,C,D region as input
- Using data in VR, and **subtracting Zjets from MC** (first approximation)
- Correct for R=(nA nD)/(nC nB) by scaling the histogram in region D by 1/R (with R estimated from Zy+jet MC)

Rzy, subtracted Zjet



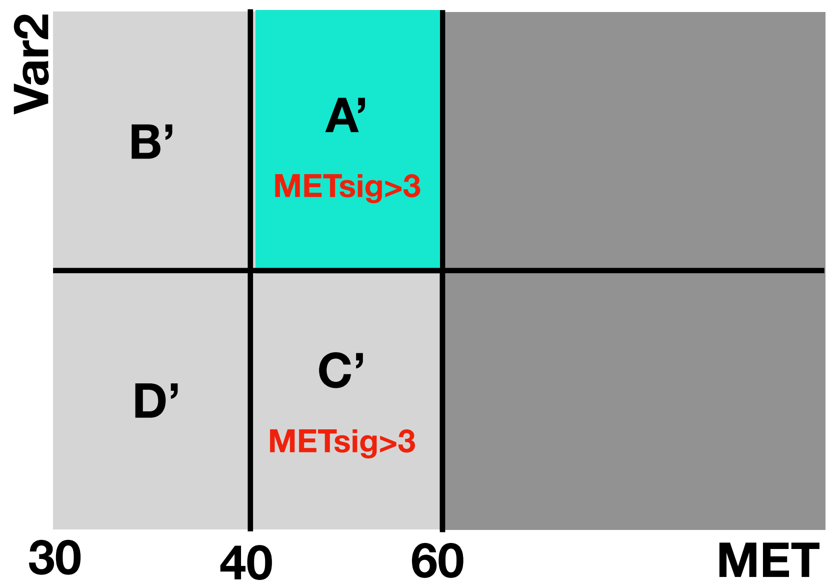
Only statistical uncertainties

nA(x) = (m_0+m_1(x)) x nB(x)
nC(x) = (m_0+m_1(x)) x nD(x)

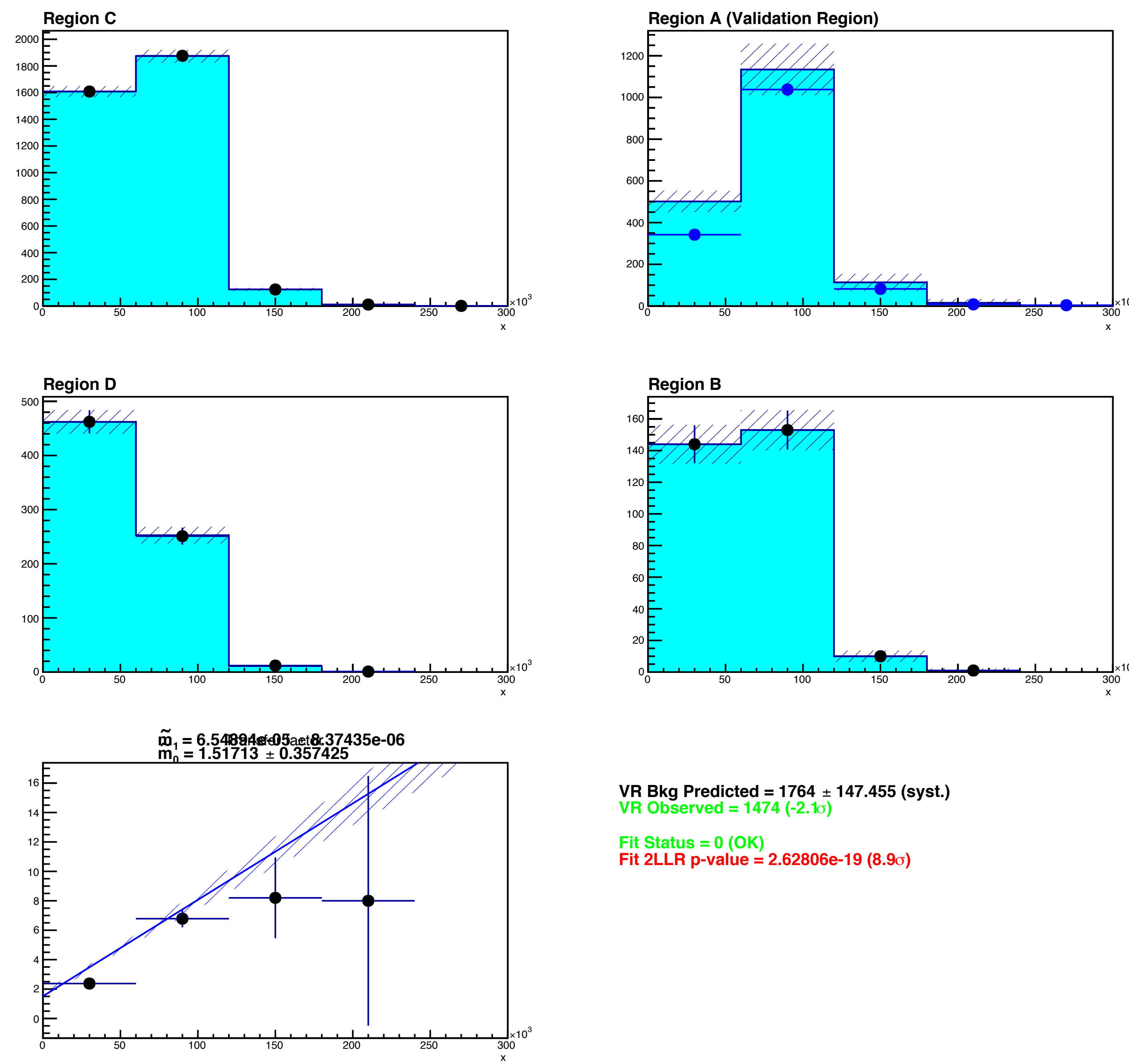
(x labels the bin)

Fake MET background

TRooABCD, ee channel



Rzy+zjet



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- mT histograms in each B,C,D region as input
- Using data in VR
- Correct for R=(nA nD)/(nC nB) by scaling the histogram in region D by 1/R (with **R estimated from Zy+jet and Zjet MC**)

Only statistical uncertainties

$nA(x) = (m_0+m_1(x)) \times nB(x)$

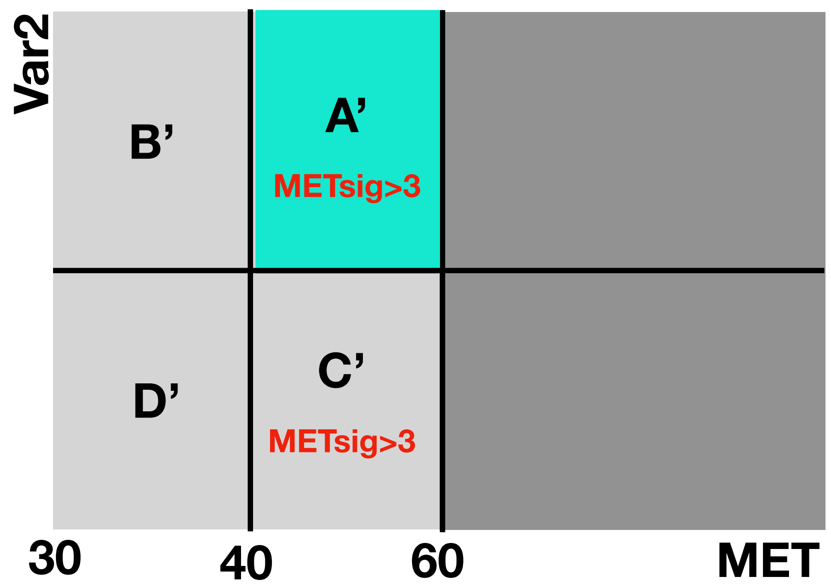
$nC(x) = (m_0+m_1(x)) \times nD(x)$

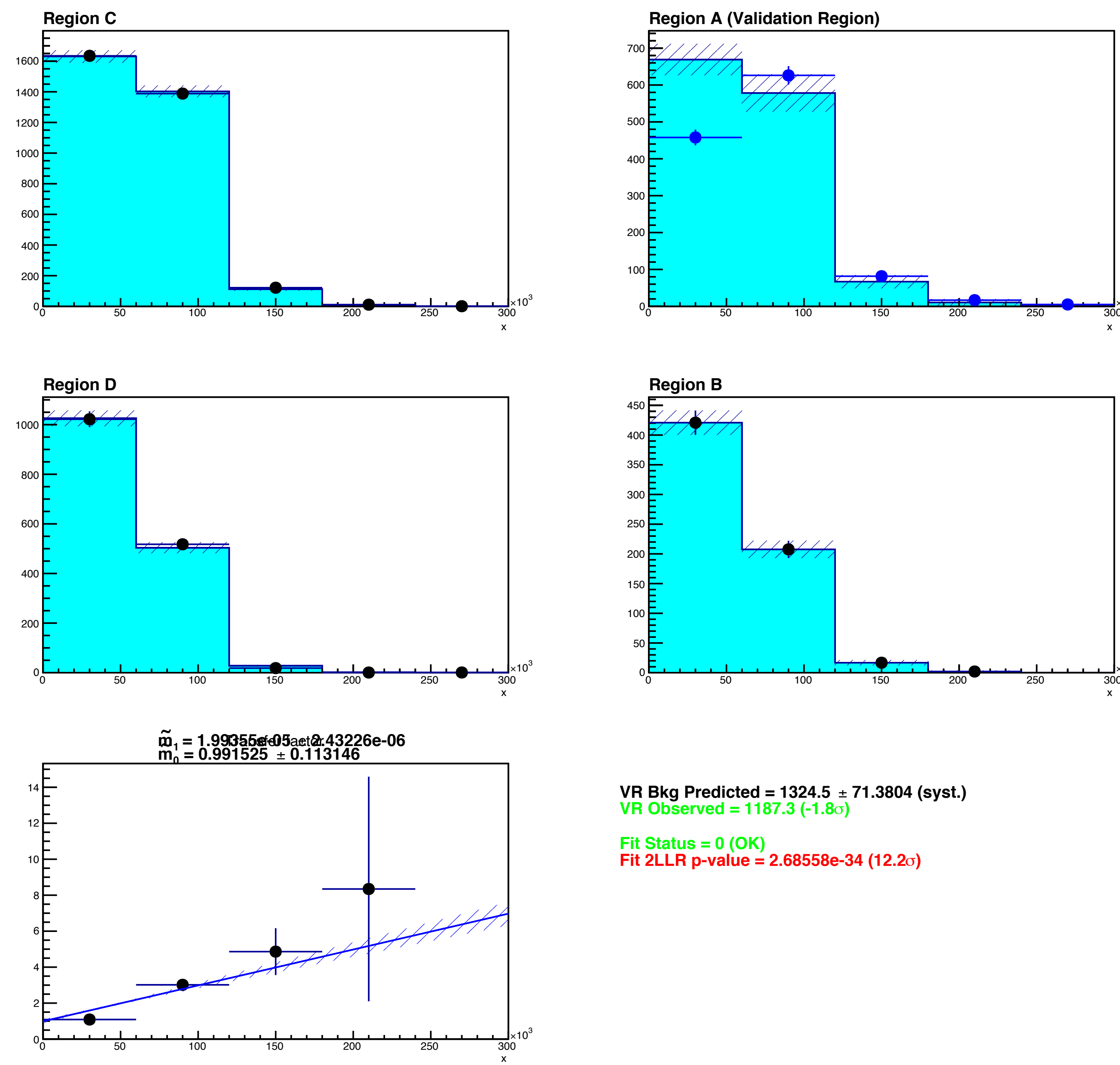
(x labels the bin)

Fake MET background

TRooABCD, uu channel

Rzy, subtracted Zjet





mT distribution in region A' from simultaneous fit on the B,C,D regions with TRooABCD

- mT histograms in each B,C,D region as input
- Using data in VR, and **subtracting Zjets from MC** (first approximation)
- Correct for R=(nA nD)/(nC nB) by scaling the histogram in region D by 1/R (with R estimated from Zy+jet MC)

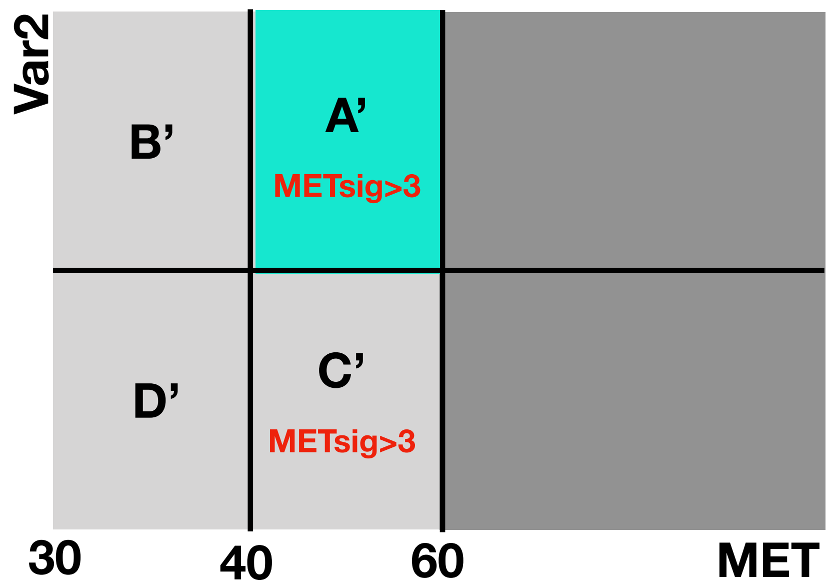
Only statistical uncertainties

$nA(x) = (m_0+m_1(x)) \times nB(x)$
$nC(x) = (m_0+m_1(x)) \times nD(x)$

(x labels the bin)

Fake MET background

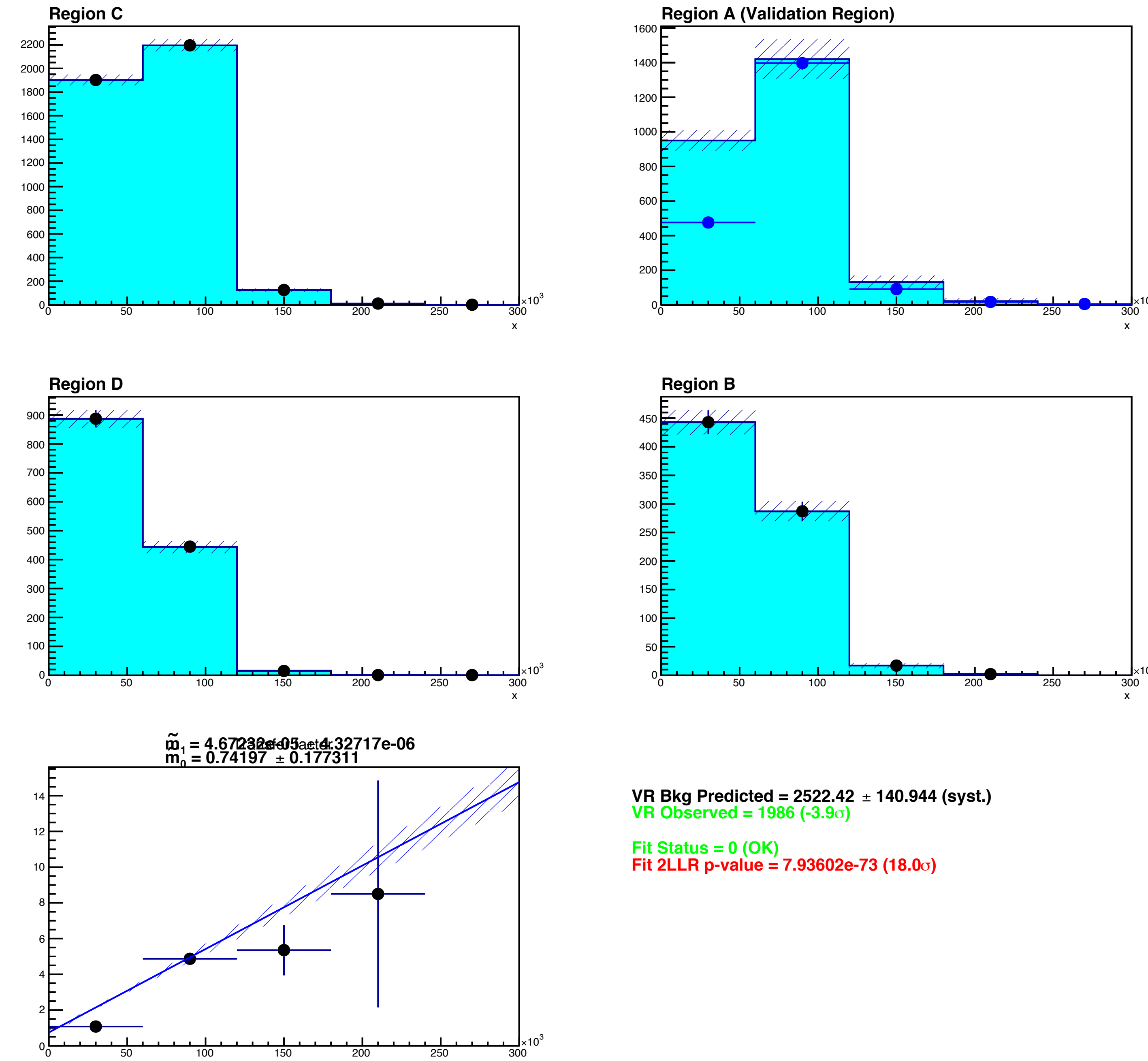
TRooABCD, uu channel



mT distribution in region A' from simultaneous fit on the B,C,D regions with TRooABCD

- mT histograms in each B,C,D region as input
- Using data in VR
- Correct for R=(nA nD)/(nC nB) by scaling the histogram in region D by 1/R (with **R estimated from Zy+jet and Zjet MC**)

Rzy+zjet



Only statistical uncertainties

$nA(x) = (m_0+m_1(x)) \times nB(x)$

$nC(x) = (m_0+m_1(x)) \times nD(x)$

(x labels the bin)

Summary

- ZH, H->yyD analysis ongoing for the first time in ATLAS
- Challenging analysis, due to background estimation strongly relying on data-driven techniques
  - Dominant background from fake MET and jets-faking-photons, while low irreducible background
  - Defined background estimation strategies (taking advantage of experience gained in monophoton analysis for in-situ background):
    - Electron-faking-photon: scaling data in WZ CR by electron fake-rate (from mono-photon analysis)
    - Jet-faking-photon: ABCD based on photon iso and ID
    - Fake MET: ABCD based on MET and dphi(MET,yll)
      - New method has been defined => choice of variables, regions definition, VR
      - Preliminary validation show promising results
      - Room for further optimization
  - Still need to study ttbar, VV, VVV, Higgs related backgrounds
- Fitting strategy still to be defined (mT or BDT as discriminating variable)
- Internal note in preparation

Backup slides

Objects selection

Electrons

$p_T > 10$ GeV, $|\eta| < 2.47$

$|\Delta z_0 \sin\theta| < 0.5$ mm

- Baseline

  LooseAndBLayerLLH ID
- Selected

  $|d_0(\sigma)| < 5$

  MediumLLH ID and FCLoose isolation

Photons

$p_T > 10$ GeV, $|\eta| < 2.37$

- Baseline

  Loose ID
- Selected

  $p_T > 25$ GeV

  Tight ID and FixedCutTight isolation

Muons

$p_T > 10$ GeV, $|\eta| < 2.7$

$|\Delta z_0 \sin\theta| < 0.5$ mm

- Baseline

  Loose ID
- Selected

  $|d_0(\sigma)| < 3$

  Medium ID and FLoose_VarRad isolation

Jets

PFlow jets

$p_T > 25$ GeV, $|\eta| < 4.5$

Medium JVT WP

$\mathbf{E_T^{miss}}$: Tight WP

Cutflow in preliminar SR mc16a

AHOI optimized SR selections:

- 2 tight opposite sign muons/electrons with $p_T^{lep1} > 26$ GeV and $p_T^{lep2} > 10$ GeV
- 1 tight photon with $p_T^{\gamma} > 25$ GeV
- Njet<=2 and Nbjet=0$p_T^{lep1} > 26$ GeV
- $76 < m_{ll} < 116$ GeV
- $m_{ll\gamma} > 100$ GeV

pass_sr_all_ee_Nominal::DoSave - print cutflow table: Assuming Br(H->y+Gr) = 5%

	HyGr	HyGr1	HyGr10	HyGr20	HyGr30	HyGr40	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	EltoPhFakes	bkgs
Input	16.95 +/- 0.22	17.24 +/- 0.23	17.23 +/- 0.23	16.81 +/- 0.22	16.35 +/- 0.22	16.08 +/- 0.24	4070 +/- 77	3570 +/- 210	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	105.0 +/- 9.7	0.3612 +/- 0.0046	+/-	9130 +/- 230
CutMergeExt	16.95 +/- 0.22	17.24 +/- 0.23	17.23 +/- 0.23	16.81 +/- 0.22	16.35 +/- 0.22	16.08 +/- 0.24	3680 +/- 75	3570 +/- 210	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	105.0 +/- 9.7	0.3612 +/- 0.0046	+/-	8740 +/- 230
CutMCOverlap	16.95 +/- 0.22	17.24 +/- 0.23	17.23 +/- 0.23	16.81 +/- 0.22	16.35 +/- 0.22	16.08 +/- 0.24	3597 +/- 74	980 +/- 110	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	104.1 +/- 9.7	0.3612 +/- 0.0046	+/-	6070 +/- 130
CutTrig	16.69 +/- 0.22	16.99 +/- 0.22	16.95 +/- 0.22	16.58 +/- 0.22	16.08 +/- 0.22	15.83 +/- 0.24	3401 +/- 72	970 +/- 110	1083.7 +/- 8.9	134.0 +/- 2.8	120.9 +/- 1.9	99.6 +/- 9.5	0.3557 +/- 0.0046	+/-	5810 +/- 130
CutJetClean	16.69 +/- 0.22	16.99 +/- 0.22	16.95 +/- 0.22	16.58 +/- 0.22	16.08 +/- 0.22	15.83 +/- 0.24	3401 +/- 72	970 +/- 110	1083.7 +/- 8.9	134.0 +/- 2.8	120.9 +/- 1.9	99.6 +/- 9.5	0.3557 +/- 0.0046	+/-	5810 +/- 130
CutChannel	7.37 +/- 0.14	7.68 +/- 0.15	7.42 +/- 0.15	7.36 +/- 0.15	7.24 +/- 0.15	7.33 +/- 0.16	1162 +/- 41	373 +/- 68	302.9 +/- 4.7	49.4 +/- 1.4	34.6 +/- 1.0	36.1 +/- 5.5	0.1503 +/- 0.0029	+/-	1958 +/- 80
CutNjet	7.37 +/- 0.14	7.68 +/- 0.15	7.42 +/- 0.15	7.36 +/- 0.15	7.24 +/- 0.15	7.33 +/- 0.16	1162 +/- 41	373 +/- 68	302.9 +/- 4.7	49.4 +/- 1.4	34.6 +/- 1.0	36.1 +/- 5.5	0.1503 +/- 0.0029	+/-	1958 +/- 80
CutMet	7.37 +/- 0.14	7.68 +/- 0.15	7.42 +/- 0.15	7.36 +/- 0.15	7.24 +/- 0.15	7.33 +/- 0.16	1162 +/- 41	373 +/- 68	302.9 +/- 4.7	49.4 +/- 1.4	34.6 +/- 1.0	36.1 +/- 5.5	0.1503 +/- 0.0029	+/-	1958 +/- 80
CutNumPho	7.20 +/- 0.14	7.46 +/- 0.15	7.17 +/- 0.15	7.20 +/- 0.15	7.03 +/- 0.14	7.14 +/- 0.16	1110 +/- 40	375 +/- 67	276.6 +/- 4.5	47.8 +/- 1.3	33.3 +/- 1.0	35.5 +/- 5.5	0.1446 +/- 0.0029	+/-	1879 +/- 79
CutNumEle	7.20 +/- 0.14	7.46 +/- 0.15	7.17 +/- 0.15	7.20 +/- 0.15	7.03 +/- 0.14	7.14 +/- 0.16	1110 +/- 40	375 +/- 67	276.6 +/- 4.5	47.8 +/- 1.3	33.3 +/- 1.0	35.5 +/- 5.5	0.1446 +/- 0.0029	+/-	1879 +/- 79
CutVetoExtraLep	7.19 +/- 0.14	7.45 +/- 0.15	7.16 +/- 0.15	7.20 +/- 0.15	7.02 +/- 0.14	7.13 +/- 0.16	1103 +/- 40	374 +/- 67	263.1 +/- 4.4	47.6 +/- 1.3	33.1 +/- 1.0	35.5 +/- 5.5	0.1437 +/- 0.0029	+/-	1856 +/- 79
CutL0Pt	7.15 +/- 0.14	7.43 +/- 0.15	7.14 +/- 0.15	7.16 +/- 0.14	7.00 +/- 0.14	7.12 +/- 0.16	1059 +/- 39	375 +/- 67	257.6 +/- 4.3	45.7 +/- 1.3	32.7 +/- 1.0	33.7 +/- 5.4	0.1433 +/- 0.0029	+/-	1804 +/- 78
CutL1Pt	7.15 +/- 0.14	7.43 +/- 0.15	7.14 +/- 0.15	7.16 +/- 0.14	7.00 +/- 0.14	7.12 +/- 0.16	1059 +/- 39	375 +/- 67	257.6 +/- 4.3	45.7 +/- 1.3	32.7 +/- 1.0	33.7 +/- 5.4	0.1433 +/- 0.0029	+/-	1804 +/- 78
CutVetoBjets	7.15 +/- 0.14	7.43 +/- 0.15	7.14 +/- 0.15	7.16 +/- 0.14	7.00 +/- 0.14	7.12 +/- 0.16	1059 +/- 39	375 +/- 67	257.6 +/- 4.3	45.7 +/- 1.3	32.7 +/- 1.0	33.7 +/- 5.4	0.1433 +/- 0.0029	+/-	1804 +/- 78
CutHighMet	5.72 +/- 0.13	5.96 +/- 0.13	5.70 +/- 0.13	5.78 +/- 0.13	5.67 +/- 0.13	5.75 +/- 0.14	434 +/- 25	111 +/- 40	215.6 +/- 4.0	33.3 +/- 1.1	25.80 +/- 0.88	22.9 +/- 4.2	0.0940 +/- 0.0023	+/-	842 +/- 48
CutMass	5.44 +/- 0.12	5.68 +/- 0.13	5.38 +/- 0.13	5.52 +/- 0.13	5.42 +/- 0.13	5.46 +/- 0.14	157 +/- 15	110 +/- 40	55.6 +/- 2.0	14.98 +/- 0.69	8.22 +/- 0.45	3.3 +/- 1.6	0.0899 +/- 0.0022	+/-	349 +/- 43
CutPhPt	5.20 +/- 0.12	5.44 +/- 0.13	5.07 +/- 0.12	5.21 +/- 0.12	5.13 +/- 0.12	5.12 +/- 0.13	90 +/- 13	56 +/- 19	36.5 +/- 1.6	10.12 +/- 0.54	6.37 +/- 0.38	1.91 +/- 0.96	0.0689 +/- 0.0019	+/-	201 +/- 23
CutMllg	5.19 +/- 0.12	5.43 +/- 0.13	5.06 +/- 0.12	5.20 +/- 0.12	5.11 +/- 0.12	5.10 +/- 0.13	89 +/- 13	56 +/- 19	36.1 +/- 1.6	9.77 +/- 0.53	6.29 +/- 0.37	1.91 +/- 0.96	0.0689 +/- 0.0019	+/-	198 +/- 23

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pass_sr_all_uu_Nominal::DoSave - print cutflow table: Assuming Br(H->y+Gr) = 5%

	HyGr	HyGr1	HyGr10	HyGr20	HyGr30	HyGr40	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	EltoPhFakes	bkgs
Input	16.95 +/- 0.22	17.24 +/- 0.23	17.23 +/- 0.23	16.81 +/- 0.22	16.35 +/- 0.22	16.08 +/- 0.24	4070 +/- 77	3570 +/- 210	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	105.0 +/- 9.7	0.3612 +/- 0.0046	+/-	9130 +/- 230
CutMergeExt	16.95 +/- 0.22	17.24 +/- 0.23	17.23 +/- 0.23	16.81 +/- 0.22	16.35 +/- 0.22	16.08 +/- 0.24	3680 +/- 75	3570 +/- 210	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	105.0 +/- 9.7	0.3612 +/- 0.0046	+/-	8740 +/- 230
CutMCOverlap	16.95 +/- 0.22	17.24 +/- 0.23	17.23 +/- 0.23	16.81 +/- 0.22	16.35 +/- 0.22	16.08 +/- 0.24	3597 +/- 74	980 +/- 110	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	104.1 +/- 9.7	0.3612 +/- 0.0046	+/-	6070 +/- 130
CutTrig	16.69 +/- 0.22	16.99 +/- 0.22	16.95 +/- 0.22	16.58 +/- 0.22	16.08 +/- 0.22	15.83 +/- 0.24	3401 +/- 72	970 +/- 110	1083.7 +/- 8.9	134.0 +/- 2.8	120.9 +/- 1.9	99.6 +/- 9.5	0.3557 +/- 0.0046	+/-	5810 +/- 130
CutJetClean	16.69 +/- 0.22	16.99 +/- 0.22	16.95 +/- 0.22	16.58 +/- 0.22	16.08 +/- 0.22	15.83 +/- 0.24	3401 +/- 72	970 +/- 110	1083.7 +/- 8.9	134.0 +/- 2.8	120.9 +/- 1.9	99.6 +/- 9.5	0.3557 +/- 0.0046	+/-	5810 +/- 130
CutChannel	9.24 +/- 0.17	9.22 +/- 0.17	9.48 +/- 0.17	9.16 +/- 0.16	8.79 +/- 0.16	8.45 +/- 0.17	2204 +/- 58	596 +/- 82	326.4 +/- 4.9	47.3 +/- 1.5	38.3 +/- 1.1	5.9 +/- 2.2	0.2025 +/- 0.0035	+/-	3220 +/- 100
CutNjet	9.24 +/- 0.17	9.22 +/- 0.17	9.48 +/- 0.17	9.16 +/- 0.16	8.79 +/- 0.16	8.45 +/- 0.17	2204 +/- 58	596 +/- 82	326.4 +/- 4.9	47.3 +/- 1.5	38.3 +/- 1.1	5.9 +/- 2.2	0.2025 +/- 0.0035	+/-	3220 +/- 100
CutMet	9.24 +/- 0.17	9.22 +/- 0.17	9.48 +/- 0.17	9.16 +/- 0.16	8.79 +/- 0.16	8.45 +/- 0.17	2204 +/- 58	596 +/- 82	326.4 +/- 4.9	47.3 +/- 1.5	38.3 +/- 1.1	5.9 +/- 2.2	0.2025 +/- 0.0035	+/-	3220 +/- 100
CutNumPho	8.98 +/- 0.16	8.86 +/- 0.16	9.19 +/- 0.17	8.92 +/- 0.16	8.57 +/- 0.16	8.24 +/- 0.17	2137 +/- 58	592 +/- 82	298.0 +/- 4.7	46.1 +/- 1.5	36.9 +/- 1.1	5.8 +/- 2.2	0.1944 +/- 0.0034	+/-	3120 +/- 100
CutNumMu	8.98 +/- 0.16	8.86 +/- 0.16	9.19 +/- 0.17	8.92 +/- 0.16	8.57 +/- 0.16	8.24 +/- 0.17	2137 +/- 58	592 +/- 82	298.0 +/- 4.7	46.1 +/- 1.5	36.9 +/- 1.1	5.8 +/- 2.2	0.1944 +/- 0.0034	+/-	3120 +/- 100
CutVetoExtraLep	8.98 +/- 0.16	8.85 +/- 0.16	9.18 +/- 0.17	8.91 +/- 0.16	8.57 +/- 0.16	8.24 +/- 0.17	2134 +/- 58	594 +/- 82	282.4 +/- 4.6	45.5 +/- 1.5	36.6 +/- 1.1	5.8 +/- 2.2	0.1928 +/- 0.0034	+/-	3099 +/- 100
CutL0Pt	8.98 +/- 0.16	8.83 +/- 0.16	9.17 +/- 0.17	8.90 +/- 0.16	8.56 +/- 0.16	8.23 +/- 0.17	2127 +/- 57	594 +/- 82	281.4 +/- 4.5	45.3 +/- 1.5	36.6 +/- 1.1	5.8 +/- 2.2	0.1925 +/- 0.0034	+/-	3090 +/- 100
CutL1Pt	8.98 +/- 0.16	8.83 +/- 0.16	9.17 +/- 0.17	8.90 +/- 0.16	8.56 +/- 0.16	8.23 +/- 0.17	2127 +/- 57	594 +/- 82	281.4 +/- 4.5	45.3 +/- 1.5	36.6 +/- 1.1	5.8 +/- 2.2	0.1925 +/- 0.0034	+/-	3090 +/- 100
CutVetoBjets	8.98 +/- 0.16	8.83 +/- 0.16	9.17 +/- 0.17	8.90 +/- 0.16	8.56 +/- 0.16	8.23 +/- 0.17	2127 +/- 57	594 +/- 82	281.4 +/- 4.5	45.3 +/- 1.5	36.6 +/- 1.1	5.8 +/- 2.2	0.1925 +/- 0.0034	+/-	3090 +/- 100
CutHighMet	7.18 +/- 0.15	7.15 +/- 0.15	7.37 +/- 0.15	7.24 +/- 0.15	6.97 +/- 0.14	6.65 +/- 0.15	929 +/- 37	261 +/- 55	232.1 +/- 4.1	32.6 +/- 1.3	29.55 +/- 0.96	3.1 +/- 1.1	0.1250 +/- 0.0027	+/-	1487 +/- 67
CutMass	6.83 +/- 0.14	6.81 +/- 0.14	6.94 +/- 0.14	6.86 +/- 0.14	6.61 +/- 0.14	6.30 +/- 0.15	331 +/- 26	224 +/- 53	58.0 +/- 2.0	15.23 +/- 0.88	8.98 +/- 0.49	0.03 +/- 0.47	0.1182 +/- 0.0026	+/-	637 +/- 59
CutPhPt	6.49 +/- 0.14	6.52 +/- 0.14	6.57 +/- 0.14	6.49 +/- 0.14	6.18 +/- 0.13	5.72 +/- 0.14	181 +/- 21	153 +/- 35	38.6 +/- 1.7	9.17 +/- 0.74	7.07 +/- 0.43	0.40 +/- 0.29	0.0885 +/- 0.0022	+/-	389 +/- 41
CutMllg	6.49 +/- 0.14	6.52 +/- 0.14	6.54 +/- 0.14	6.47 +/- 0.14	6.17 +/- 0.13	5.72 +/- 0.14	176 +/- 21	153 +/- 35	38.4 +/- 1.7	9.51 +/- 0.60	7.07 +/- 0.43	0.40 +/- 0.29	0.0885 +/- 0.0022	+/-	385 +/- 41

Cutflow in preliminar SR mc16d

AHOI optimized SR selections:

- 2 tight opposite sign muons/electrons with $p_T^{lep1} > 26$ GeV and $p_T^{lep2} > 10$ GeV
- 1 tight photon with $p_T^{\gamma} > 25$ GeV
- Njet<=2 and Nbjet=0$p_T^{lep1} > 26$ GeV
- $76 < m_{ll} < 116$ GeV
- $m_{ll\gamma} > 100$ GeV

pass_sr_all_ee_Nominal::DoSave - print cutflow table: Assuming Br(H->y+Gr) = 5%

	HyGr	HyGr1	HyGr10	HyGr20	HyGr30	HyGr40	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	EltoPhFakes	bkgs
Input	18.83 +/- 0.23	18.68 +/- 0.23	18.78 +/- 0.23	18.80 +/- 0.23	18.47 +/- 0.23	17.56 +/- 0.24	5691 +/- 92	5600 +/- 270	1098.9 +/- 9.0	148.9 +/- 1.9	133.0 +/- 2.0	93 +/- 10	0.3932 +/- 0.0048	+/-	12770 +/- 280
CutMergeExt	18.83 +/- 0.23	18.68 +/- 0.23	18.78 +/- 0.23	18.80 +/- 0.23	18.47 +/- 0.23	17.56 +/- 0.24	5215 +/- 90	5600 +/- 270	1098.9 +/- 9.0	148.9 +/- 1.9	133.0 +/- 2.0	93 +/- 10	0.3932 +/- 0.0048	+/-	12290 +/- 280
CutMCOverlap	18.83 +/- 0.23	18.68 +/- 0.23	18.78 +/- 0.23	18.80 +/- 0.23	18.47 +/- 0.23	17.56 +/- 0.24	5041 +/- 89	1850 +/- 150	1098.9 +/- 9.0	148.9 +/- 1.9	133.0 +/- 2.0	93 +/- 10	0.3932 +/- 0.0048	+/-	8370 +/- 170
CutTrig	18.69 +/- 0.23	18.46 +/- 0.23	18.57 +/- 0.23	18.59 +/- 0.23	18.24 +/- 0.23	17.33 +/- 0.24	4845 +/- 88	1840 +/- 150	1077.3 +/- 8.9	144.8 +/- 1.9	131.3 +/- 2.0	92 +/- 10	0.3879 +/- 0.0048	+/-	8130 +/- 170
CutJetClean	18.69 +/- 0.23	18.46 +/- 0.23	18.57 +/- 0.23	18.59 +/- 0.23	18.24 +/- 0.23	17.33 +/- 0.24	4845 +/- 88	1840 +/- 150	1077.3 +/- 8.9	144.8 +/- 1.9	131.3 +/- 2.0	92 +/- 10	0.3879 +/- 0.0048	+/-	8130 +/- 170
CutChannel	8.21 +/- 0.15	8.15 +/- 0.15	8.26 +/- 0.15	8.34 +/- 0.15	8.11 +/- 0.15	7.94 +/- 0.16	1665 +/- 52	660 +/- 100	301.9 +/- 4.8	52.5 +/- 1.1	36.4 +/- 1.0	33.8 +/- 6.4	0.1651 +/- 0.0031	+/-	2750 +/- 110
CutNjet	8.21 +/- 0.15	8.15 +/- 0.15	8.26 +/- 0.15	8.34 +/- 0.15	8.11 +/- 0.15	7.94 +/- 0.16	1665 +/- 52	660 +/- 100	301.9 +/- 4.8	52.5 +/- 1.1	36.4 +/- 1.0	33.8 +/- 6.4	0.1651 +/- 0.0031	+/-	2750 +/- 110
CutMet	8.21 +/- 0.15	8.15 +/- 0.15	8.26 +/- 0.15	8.34 +/- 0.15	8.11 +/- 0.15	7.94 +/- 0.16	1665 +/- 52	660 +/- 100	301.9 +/- 4.8	52.5 +/- 1.1	36.4 +/- 1.0	33.8 +/- 6.4	0.1651 +/- 0.0031	+/-	2750 +/- 110
CutNumPho	7.94 +/- 0.15	7.85 +/- 0.15	7.99 +/- 0.15	8.11 +/- 0.15	7.82 +/- 0.15	7.70 +/- 0.16	1568 +/- 50	655 +/- 98	275.6 +/- 4.6	50.4 +/- 1.1	34.63 +/- 1.00	32.4 +/- 6.2	0.1574 +/- 0.0030	+/-	2620 +/- 110
CutNumEle	7.94 +/- 0.15	7.85 +/- 0.15	7.99 +/- 0.15	8.11 +/- 0.15	7.82 +/- 0.15	7.70 +/- 0.16	1568 +/- 50	655 +/- 98	275.6 +/- 4.6	50.4 +/- 1.1	34.63 +/- 1.00	32.4 +/- 6.2	0.1574 +/- 0.0030	+/-	2620 +/- 110
CutVetoExtraLep	7.93 +/- 0.15	7.84 +/- 0.15	7.98 +/- 0.15	8.11 +/- 0.15	7.81 +/- 0.15	7.69 +/- 0.16	1564 +/- 50	653 +/- 98	260.1 +/- 4.4	50.0 +/- 1.1	34.45 +/- 1.00	32.4 +/- 6.2	0.1568 +/- 0.0030	+/-	2590 +/- 110
CutL0Pt	7.93 +/- 0.15	7.83 +/- 0.15	7.97 +/- 0.15	8.11 +/- 0.15	7.81 +/- 0.15	7.69 +/- 0.16	1559 +/- 50	653 +/- 98	259.6 +/- 4.4	49.9 +/- 1.1	34.40 +/- 1.00	32.3 +/- 6.2	0.1566 +/- 0.0030	+/-	2590 +/- 110
CutL1Pt	7.93 +/- 0.15	7.83 +/- 0.15	7.97 +/- 0.15	8.11 +/- 0.15	7.81 +/- 0.15	7.69 +/- 0.16	1559 +/- 50	653 +/- 98	259.6 +/- 4.4	49.9 +/- 1.1	34.40 +/- 1.00	32.3 +/- 6.2	0.1566 +/- 0.0030	+/-	2590 +/- 110
CutVetoBjets	7.93 +/- 0.15	7.83 +/- 0.15	7.97 +/- 0.15	8.11 +/- 0.15	7.81 +/- 0.15	7.69 +/- 0.16	1559 +/- 50	653 +/- 98	259.6 +/- 4.4	49.9 +/- 1.1	34.40 +/- 1.00	32.3 +/- 6.2	0.1566 +/- 0.0030	+/-	2590 +/- 110
CutHighMet	6.42 +/- 0.13	6.38 +/- 0.14	6.46 +/- 0.14	6.65 +/- 0.14	6.39 +/- 0.14	6.20 +/- 0.14	611 +/- 32	266 +/- 71	213.7 +/- 4.0	37.55 +/- 0.92	27.37 +/- 0.89	28.4 +/- 4.8	0.1044 +/- 0.0024	+/-	1185 +/- 78
CutMass	6.14 +/- 0.13	6.08 +/- 0.13	6.18 +/- 0.13	6.34 +/- 0.13	6.10 +/- 0.13	5.94 +/- 0.14	183 +/- 16	234 +/- 67	53.8 +/- 2.0	16.40 +/- 0.58	8.24 +/- 0.45	5.9 +/- 2.6	0.0984 +/- 0.0023	+/-	502 +/- 69
CutPhPt	5.87 +/- 0.13	5.80 +/- 0.13	5.91 +/- 0.13	5.98 +/- 0.13	5.73 +/- 0.13	5.49 +/- 0.13	99 +/- 12	56 +/- 29	36.0 +/- 1.6	10.71 +/- 0.45	6.49 +/- 0.41	4.5 +/- 2.4	0.0762 +/- 0.0020	+/-	213 +/- 31
CutMllg	5.86 +/- 0.13	5.80 +/- 0.13	5.90 +/- 0.13	5.98 +/- 0.13	5.72 +/- 0.13	5.48 +/- 0.13	95 +/- 12	56 +/- 29	35.6 +/- 1.6	10.32 +/- 0.44	6.49 +/- 0.41	4.5 +/- 2.4	0.0762 +/- 0.0020	+/-	209 +/- 31

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pass_sr_all_uu_Nominal::DoSave - print cutflow table: Assuming Br(H->y+Gr) = 5%

	HyGr	HyGr1	HyGr10	HyGr20	HyGr30	HyGr40	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	EltoPhFakes	bkgs
Input	18.83 +/- 0.23	18.68 +/- 0.23	18.78 +/- 0.23	18.80 +/- 0.23	18.47 +/- 0.23	17.56 +/- 0.24	5691 +/- 92	5600 +/- 270	1098.9 +/- 9.0	148.9 +/- 1.9	133.0 +/- 2.0	93 +/- 10	0.3932 +/- 0.0048	+/-	12770 +/- 280
CutMergeExt	18.83 +/- 0.23	18.68 +/- 0.23	18.78 +/- 0.23	18.80 +/- 0.23	18.47 +/- 0.23	17.56 +/- 0.24	5215 +/- 90	5600 +/- 270	1098.9 +/- 9.0	148.9 +/- 1.9	133.0 +/- 2.0	93 +/- 10	0.3932 +/- 0.0048	+/-	12290 +/- 280
CutMCOverlap	18.83 +/- 0.23	18.68 +/- 0.23	18.78 +/- 0.23	18.80 +/- 0.23	18.47 +/- 0.23	17.56 +/- 0.24	5041 +/- 89	1850 +/- 150	1098.9 +/- 9.0	148.9 +/- 1.9	133.0 +/- 2.0	93 +/- 10	0.3932 +/- 0.0048	+/-	8370 +/- 170
CutTrig	18.69 +/- 0.23	18.46 +/- 0.23	18.57 +/- 0.23	18.59 +/- 0.23	18.24 +/- 0.23	17.33 +/- 0.24	4845 +/- 88	1840 +/- 150	1077.3 +/- 8.9	144.8 +/- 1.9	131.3 +/- 2.0	92 +/- 10	0.3879 +/- 0.0048	+/-	8130 +/- 170
CutJetClean	18.69 +/- 0.23	18.46 +/- 0.23	18.57 +/- 0.23	18.59 +/- 0.23	18.24 +/- 0.23	17.33 +/- 0.24	4845 +/- 88	1840 +/- 150	1077.3 +/- 8.9	144.8 +/- 1.9	131.3 +/- 2.0	92 +/- 10	0.3879 +/- 0.0048	+/-	8130 +/- 170
CutChannel	10.41 +/- 0.17	10.25 +/- 0.17	10.26 +/- 0.17	10.18 +/- 0.17	10.06 +/- 0.17	9.33 +/- 0.17	3152 +/- 70	1180 +/- 110	319.0 +/- 4.9	51.3 +/- 1.2	41.0 +/- 1.1	8.4 +/- 4.0	0.2195 +/- 0.0036	+/-	4750 +/- 130
CutNjet	10.41 +/- 0.17	10.25 +/- 0.17	10.26 +/- 0.17	10.18 +/- 0.17	10.06 +/- 0.17	9.33 +/- 0.17	3152 +/- 70	1180 +/- 110	319.0 +/- 4.9	51.3 +/- 1.2	41.0 +/- 1.1	8.4 +/- 4.0	0.2195 +/- 0.0036	+/-	4750 +/- 130
CutMet	10.41 +/- 0.17	10.25 +/- 0.17	10.26 +/- 0.17	10.18 +/- 0.17	10.06 +/- 0.17	9.33 +/- 0.17	3152 +/- 70	1180 +/- 110	319.0 +/- 4.9	51.3 +/- 1.2	41.0 +/- 1.1	8.4 +/- 4.0	0.2195 +/- 0.0036	+/-	4750 +/- 130
CutNumPho	10.05 +/- 0.17	9.92 +/- 0.17	9.90 +/- 0.17	9.85 +/- 0.17	9.80 +/- 0.16	9.00 +/- 0.17	3020 +/- 69	1110 +/- 110	291.1 +/- 4.7	49.3 +/- 1.2	39.4 +/- 1.1	8.4 +/- 4.0	0.2091 +/- 0.0035	+/-	4520 +/- 130
CutNumMu	10.05 +/- 0.17	9.92 +/- 0.17	9.90 +/- 0.17	9.85 +/- 0.17	9.80 +/- 0.16	9.00 +/- 0.17	3020 +/- 69	1110 +/- 110	291.1 +/- 4.7	49.3 +/- 1.2	39.4 +/- 1.1	8.4 +/- 4.0	0.2091 +/- 0.0035	+/-	4520 +/- 130
CutVetoExtraLep	10.04 +/- 0.17	9.91 +/- 0.17	9.90 +/- 0.17	9.84 +/- 0.17	9.79 +/- 0.16	9.00 +/- 0.17	3015 +/- 69	1110 +/- 110	273.3 +/- 4.5	48.7 +/- 1.2	39.0 +/- 1.1	8.4 +/- 4.0	0.2081 +/- 0.0035	+/-	4500 +/- 130
CutL0Pt	10.04 +/- 0.17	9.91 +/- 0.17	9.90 +/- 0.17	9.84 +/- 0.17	9.79 +/- 0.16	9.00 +/- 0.17	3015 +/- 69	1110 +/- 110	273.3 +/- 4.5	48.7 +/- 1.2	39.0 +/- 1.1	8.4 +/- 4.0	0.2081 +/- 0.0035	+/-	4500 +/- 130
CutL1Pt	10.04 +/- 0.17	9.91 +/- 0.17	9.90 +/- 0.17	9.84 +/- 0.17	9.79 +/- 0.16	9.00 +/- 0.17	3015 +/- 69	1110 +/- 110	273.3 +/- 4.5	48.7 +/- 1.2	39.0 +/- 1.1	8.4 +/- 4.0	0.2081 +/- 0.0035	+/-	4500 +/- 130
CutVetoBjets	10.04 +/- 0.17	9.91 +/- 0.17	9.90 +/- 0.17	9.84 +/- 0.17	9.79 +/- 0.16	9.00 +/- 0.17	3015 +/- 69	1110 +/- 110	273.3 +/- 4.5	48.7 +/- 1.2	39.0 +/- 1.1	8.4 +/- 4.0	0.2081 +/- 0.0035	+/-	4500 +/- 130
CutHighMet	8.06 +/- 0.15	8.18 +/- 0.15	8.05 +/- 0.15	7.97 +/- 0.15	7.75 +/- 0.15	7.37 +/- 0.15	1335 +/- 47	605 +/- 80	225.4 +/- 4.1	36.1 +/- 1.0	31.62 +/- 0.96	7.9 +/- 4.0	0.1374 +/- 0.0028	+/-	2241 +/- 93
CutMass	7.60 +/- 0.15	7.77 +/- 0.15	7.56 +/- 0.15	7.50 +/- 0.14	7.29 +/- 0.14	7.00 +/- 0.15	440 +/- 28	509 +/- 74	57.2 +/- 2.0	18.91 +/- 0.63	9.12 +/- 0.44	0.70 +/- 0.41	0.1298 +/- 0.0027	+/-	1036 +/- 79
CutPhPt	7.25 +/- 0.14	7.35 +/- 0.14	7.20 +/- 0.14	7.06 +/- 0.14	6.95 +/- 0.14	6.57 +/- 0.14	260 +/- 21	216 +/- 47	37.6 +/- 1.6	11.95 +/- 0.49	6.88 +/- 0.39	0.70 +/- 0.41	0.1007 +/- 0.0024	+/-	533 +/- 51
CutMllg	7.25 +/- 0.14	7.35 +/- 0.14	7.18 +/- 0.14	7.04 +/- 0.14	6.93 +/- 0.14	6.56 +/- 0.14	256 +/- 21	216 +/- 47	37.3 +/- 1.6	11.46 +/- 0.47	6.88 +/- 0.39	0.70 +/- 0.41	0.1007 +/- 0.0024	+/-	528 +/- 51

Cutflow in preliminar SR mc16e

AHOI optimized SR selections:

- 2 tight opposite sign muons/electrons with p_T^{lep1}> 26 GeV and p_T^{lep2}> 10 GeV
- 1 tight photon with p_T^{γ}> 25 GeV
- Njet<=2 and Nbjet=0p_T^{lep1}> 26 GeV
- 76 < m_{ll} < 116 GeV
- $m_{ll\gamma}$ > 100 GeV

pass_sr_all_ee_Nominal::DoSave - print cutflow table: Assuming Br(H->y+Gr) = 5%

	HyGr	HyGr1	HyGr10	HyGr20	HyGr30	HyGr40	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	EltoPhFakes	bkgs
Input	25.19 +/- 0.27	24.81 +/- 0.27	24.94 +/- 0.29	25.04 +/- 0.29	23.96 +/- 0.27	23.46 +/- 0.28	7320 +/- 100	7550 +/- 310	1488 +/- 10	201.6 +/- 3.1	173.6 +/- 2.3	129 +/- 12	0.5097 +/- 0.0056	+/-	16860 +/- 330
CutMergeExt	25.19 +/- 0.27	24.81 +/- 0.27	24.94 +/- 0.29	25.04 +/- 0.29	23.96 +/- 0.27	23.46 +/- 0.28	6709 +/- 98	7550 +/- 310	1488 +/- 10	201.6 +/- 3.1	173.6 +/- 2.3	129 +/- 12	0.5097 +/- 0.0056	+/-	16260 +/- 330
CutMCOverlap	25.19 +/- 0.27	24.81 +/- 0.27	24.94 +/- 0.29	25.04 +/- 0.29	23.96 +/- 0.27	23.46 +/- 0.28	6519 +/- 96	2410 +/- 170	1488 +/- 10	201.6 +/- 3.1	173.6 +/- 2.3	125 +/- 12	0.5097 +/- 0.0056	+/-	10910 +/- 190
CutTrig	25.01 +/- 0.27	24.66 +/- 0.27	24.73 +/- 0.29	24.79 +/- 0.29	23.78 +/- 0.27	23.30 +/- 0.28	6357 +/- 95	2370 +/- 170	1471 +/- 10	199.0 +/- 3.1	172.6 +/- 2.3	124 +/- 12	0.5056 +/- 0.0055	+/-	10700 +/- 190
CutJetClean	25.01 +/- 0.27	24.66 +/- 0.27	24.73 +/- 0.29	24.79 +/- 0.29	23.78 +/- 0.27	23.30 +/- 0.28	6357 +/- 95	2370 +/- 170	1471 +/- 10	199.0 +/- 3.1	172.6 +/- 2.3	124 +/- 12	0.5056 +/- 0.0055	+/-	10700 +/- 190
CutChannel	11.48 +/- 0.18	11.51 +/- 0.19	11.47 +/- 0.20	11.52 +/- 0.20	11.00 +/- 0.18	10.91 +/- 0.19	2206 +/- 57	990 +/- 110	420.2 +/- 5.6	72.8 +/- 1.9	49.5 +/- 1.2	47.6 +/- 7.6	0.2115 +/- 0.0036	+/-	3790 +/- 120
CutNjet	11.48 +/- 0.18	11.51 +/- 0.19	11.47 +/- 0.20	11.52 +/- 0.20	11.00 +/- 0.18	10.91 +/- 0.19	2206 +/- 57	990 +/- 110	420.2 +/- 5.6	72.8 +/- 1.9	49.5 +/- 1.2	47.6 +/- 7.6	0.2115 +/- 0.0036	+/-	3790 +/- 120
CutMet	11.48 +/- 0.18	11.51 +/- 0.19	11.47 +/- 0.20	11.52 +/- 0.20	11.00 +/- 0.18	10.91 +/- 0.19	2206 +/- 57	990 +/- 110	420.2 +/- 5.6	72.8 +/- 1.9	49.5 +/- 1.2	47.6 +/- 7.6	0.2115 +/- 0.0036	+/-	3790 +/- 120
CutNumPho	11.10 +/- 0.18	11.10 +/- 0.18	11.14 +/- 0.19	11.08 +/- 0.19	10.59 +/- 0.18	10.55 +/- 0.19	2124 +/- 56	960 +/- 110	385.3 +/- 5.4	69.8 +/- 1.8	47.5 +/- 1.2	46.4 +/- 7.5	0.2009 +/- 0.0035	+/-	3630 +/- 120
CutNumEle	11.10 +/- 0.18	11.10 +/- 0.18	11.14 +/- 0.19	11.08 +/- 0.19	10.59 +/- 0.18	10.55 +/- 0.19	2124 +/- 56	960 +/- 110	385.3 +/- 5.4	69.8 +/- 1.8	47.5 +/- 1.2	46.4 +/- 7.5	0.2009 +/- 0.0035	+/-	3630 +/- 120
CutVetoExtraLep	11.09 +/- 0.18	11.09 +/- 0.18	11.13 +/- 0.19	11.06 +/- 0.19	10.58 +/- 0.18	10.55 +/- 0.19	2121 +/- 56	950 +/- 110	368.3 +/- 5.2	69.2 +/- 1.8	47.2 +/- 1.2	46.4 +/- 7.5	0.1996 +/- 0.0035	+/-	3600 +/- 120
CutL0Pt	11.06 +/- 0.18	11.05 +/- 0.18	11.10 +/- 0.19	11.03 +/- 0.19	10.55 +/- 0.18	10.53 +/- 0.19	2053 +/- 55	920 +/- 110	362.3 +/- 5.2	67.6 +/- 1.8	46.6 +/- 1.2	45.0 +/- 7.5	0.1988 +/- 0.0035	+/-	3500 +/- 120
CutL1Pt	11.06 +/- 0.18	11.05 +/- 0.18	11.10 +/- 0.19	11.03 +/- 0.19	10.55 +/- 0.18	10.53 +/- 0.19	2053 +/- 55	920 +/- 110	362.3 +/- 5.2	67.6 +/- 1.8	46.6 +/- 1.2	45.0 +/- 7.5	0.1988 +/- 0.0035	+/-	3500 +/- 120
CutVetoBjets	11.06 +/- 0.18	11.05 +/- 0.18	11.10 +/- 0.19	11.03 +/- 0.19	10.55 +/- 0.18	10.53 +/- 0.19	2053 +/- 55	920 +/- 110	362.3 +/- 5.2	67.6 +/- 1.8	46.6 +/- 1.2	45.0 +/- 7.5	0.1988 +/- 0.0035	+/-	3500 +/- 120
CutHighMet	8.93 +/- 0.16	9.09 +/- 0.17	9.04 +/- 0.17	8.95 +/- 0.17	8.51 +/- 0.16	8.65 +/- 0.17	794 +/- 35	503 +/- 70	298.3 +/- 4.7	50.7 +/- 1.6	37.6 +/- 1.0	27.9 +/- 6.2	0.1292 +/- 0.0027	+/-	1712 +/- 79
CutMass	8.57 +/- 0.16	8.62 +/- 0.16	8.59 +/- 0.17	8.50 +/- 0.17	8.08 +/- 0.16	8.25 +/- 0.17	274 +/- 20	431 +/- 66	74.8 +/- 2.3	23.61 +/- 0.87	11.60 +/- 0.53	4.8 +/- 1.5	0.1231 +/- 0.0026	+/-	820 +/- 69
CutPhPt	8.13 +/- 0.15	8.24 +/- 0.16	8.15 +/- 0.17	8.04 +/- 0.16	7.58 +/- 0.15	7.67 +/- 0.16	139 +/- 13	260 +/- 53	48.3 +/- 1.8	16.09 +/- 0.71	9.10 +/- 0.48	4.4 +/- 1.5	0.0943 +/- 0.0023	+/-	477 +/- 55
CutMllg	8.12 +/- 0.15	8.24 +/- 0.16	8.13 +/- 0.17	8.03 +/- 0.16	7.58 +/- 0.15	7.67 +/- 0.16	134 +/- 13	260 +/- 53	47.9 +/- 1.8	15.62 +/- 0.68	9.04 +/- 0.48	4.4 +/- 1.5	0.0943 +/- 0.0023	+/-	471 +/- 55

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pass_sr_all_uu_Nominal::DoSave - print cutflow table: Assuming Br(H->y+Gr) = 5%

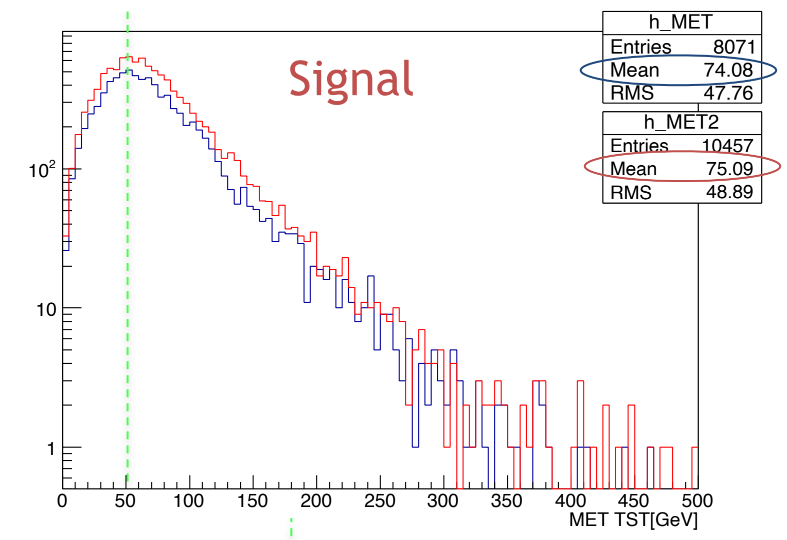
	HyGr	HyGr1	HyGr10	HyGr20	HyGr30	HyGr40	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	EltoPhFakes	bkgs
Input	25.19 +/- 0.27	24.81 +/- 0.27	24.94 +/- 0.29	25.04 +/- 0.29	23.96 +/- 0.27	23.46 +/- 0.28	7320 +/- 100	7550 +/- 310	1488 +/- 10	201.6 +/- 3.1	173.6 +/- 2.3	129 +/- 12	0.5097 +/- 0.0056	+/-	16860 +/- 330
CutMergeExt	25.19 +/- 0.27	24.81 +/- 0.27	24.94 +/- 0.29	25.04 +/- 0.29	23.96 +/- 0.27	23.46 +/- 0.28	6709 +/- 98	7550 +/- 310	1488 +/- 10	201.6 +/- 3.1	173.6 +/- 2.3	129 +/- 12	0.5097 +/- 0.0056	+/-	16260 +/- 330
CutMCOverlap	25.19 +/- 0.27	24.81 +/- 0.27	24.94 +/- 0.29	25.04 +/- 0.29	23.96 +/- 0.27	23.46 +/- 0.28	6519 +/- 96	2410 +/- 170	1488 +/- 10	201.6 +/- 3.1	173.6 +/- 2.3	125 +/- 12	0.5097 +/- 0.0056	+/-	10910 +/- 190
CutTrig	25.01 +/- 0.27	24.66 +/- 0.27	24.73 +/- 0.29	24.79 +/- 0.29	23.78 +/- 0.27	23.30 +/- 0.28	6357 +/- 95	2370 +/- 170	1471 +/- 10	199.0 +/- 3.1	172.6 +/- 2.3	124 +/- 12	0.5056 +/- 0.0055	+/-	10700 +/- 190
CutJetClean	25.01 +/- 0.27	24.66 +/- 0.27	24.73 +/- 0.29	24.79 +/- 0.29	23.78 +/- 0.27	23.30 +/- 0.28	6357 +/- 95	2370 +/- 170	1471 +/- 10	199.0 +/- 3.1	172.6 +/- 2.3	124 +/- 12	0.5056 +/- 0.0055	+/-	10700 +/- 190
CutChannel	13.45 +/- 0.20	13.05 +/- 0.20	13.15 +/- 0.21	13.18 +/- 0.21	12.71 +/- 0.19	12.32 +/- 0.20	4123 +/- 76	1370 +/- 130	445.1 +/- 5.7	68.2 +/- 1.9	55.1 +/- 1.3	2.7 +/- 2.6	0.2894 +/- 0.0042	+/-	6060 +/- 150
CutNjet	13.45 +/- 0.20	13.05 +/- 0.20	13.15 +/- 0.21	13.18 +/- 0.21	12.71 +/- 0.19	12.32 +/- 0.20	4123 +/- 76	1370 +/- 130	445.1 +/- 5.7	68.2 +/- 1.9	55.1 +/- 1.3	2.7 +/- 2.6	0.2894 +/- 0.0042	+/-	6060 +/- 150
CutMet	13.45 +/- 0.20	13.05 +/- 0.20	13.15 +/- 0.21	13.18 +/- 0.21	12.71 +/- 0.19	12.32 +/- 0.20	4123 +/- 76	1370 +/- 130	445.1 +/- 5.7	68.2 +/- 1.9	55.1 +/- 1.3	2.7 +/- 2.6	0.2894 +/- 0.0042	+/-	6060 +/- 150
CutNumPho	13.00 +/- 0.20	12.64 +/- 0.19	12.68 +/- 0.20	12.74 +/- 0.20	12.30 +/- 0.19	11.91 +/- 0.20	3929 +/- 74	1280 +/- 120	404.0 +/- 5.5	65.7 +/- 1.9	52.2 +/- 1.2	3.1 +/- 2.6	0.2742 +/- 0.0041	+/-	5740 +/- 140
CutNumMu	13.00 +/- 0.20	12.64 +/- 0.19	12.68 +/- 0.20	12.74 +/- 0.20	12.30 +/- 0.19	11.91 +/- 0.20	3929 +/- 74	1280 +/- 120	404.0 +/- 5.5	65.7 +/- 1.9	52.2 +/- 1.2	3.1 +/- 2.6	0.2742 +/- 0.0041	+/-	5740 +/- 140
CutVetoExtraLep	12.99 +/- 0.20	12.62 +/- 0.19	12.67 +/- 0.20	12.73 +/- 0.20	12.30 +/- 0.19	11.90 +/- 0.20	3927 +/- 74	1280 +/- 120	381.8 +/- 5.3	64.8 +/- 1.9	51.7 +/- 1.2	3.1 +/- 2.6	0.2727 +/- 0.0041	+/-	5710 +/- 140
CutL0Pt	12.99 +/- 0.20	12.62 +/- 0.19	12.67 +/- 0.20	12.73 +/- 0.20	12.30 +/- 0.19	11.90 +/- 0.20	3927 +/- 74	1280 +/- 120	381.8 +/- 5.3	64.8 +/- 1.9	51.7 +/- 1.2	3.1 +/- 2.6	0.2727 +/- 0.0041	+/-	5710 +/- 140
CutL1Pt	12.99 +/- 0.20	12.62 +/- 0.19	12.67 +/- 0.20	12.73 +/- 0.20	12.30 +/- 0.19	11.90 +/- 0.20	3927 +/- 74	1280 +/- 120	381.8 +/- 5.3	64.8 +/- 1.9	51.7 +/- 1.2	3.1 +/- 2.6	0.2727 +/- 0.0041	+/-	5710 +/- 140
CutVetoBjets	12.99 +/- 0.20	12.62 +/- 0.19	12.67 +/- 0.20	12.73 +/- 0.20	12.30 +/- 0.19	11.90 +/- 0.20	3927 +/- 74	1280 +/- 120	381.8 +/- 5.3	64.8 +/- 1.9	51.7 +/- 1.2	3.1 +/- 2.6	0.2727 +/- 0.0041	+/-	5710 +/- 140
CutHighMet	10.50 +/- 0.18	10.21 +/- 0.17	10.15 +/- 0.18	10.40 +/- 0.18	10.02 +/- 0.17	9.70 +/- 0.18	1764 +/- 48	695 +/- 91	313.2 +/- 4.8	48.6 +/- 1.5	42.2 +/- 1.1	0.9 +/- 2.4	0.1755 +/- 0.0032	+/-	2860 +/- 100
CutMass	9.92 +/- 0.17	9.67 +/- 0.17	9.62 +/- 0.18	9.84 +/- 0.18	9.51 +/- 0.17	9.09 +/- 0.17	561 +/- 28	634 +/- 88	82.7 +/- 2.5	23.39 +/- 0.87	12.97 +/- 0.55	-1.5 +/- 1.9	0.1654 +/- 0.0031	+/-	1313 +/- 92
CutPhPt	9.48 +/- 0.17	9.24 +/- 0.16	9.17 +/- 0.17	9.38 +/- 0.17	8.98 +/- 0.16	8.48 +/- 0.17	323 +/- 20	200 +/- 55	55.4 +/- 2.0	14.95 +/- 0.66	9.80 +/- 0.46	-1.7 +/- 1.8	0.1275 +/- 0.0027	+/-	601 +/- 59
CutMllg	9.47 +/- 0.17	9.23 +/- 0.16	9.16 +/- 0.17	9.37 +/- 0.17	8.97 +/- 0.16	8.46 +/- 0.17	318 +/- 20	200 +/- 55	55.1 +/- 2.0	14.42 +/- 0.65	9.76 +/- 0.46	-1.7 +/- 1.8	0.1275 +/- 0.0027	+/-	596 +/- 58

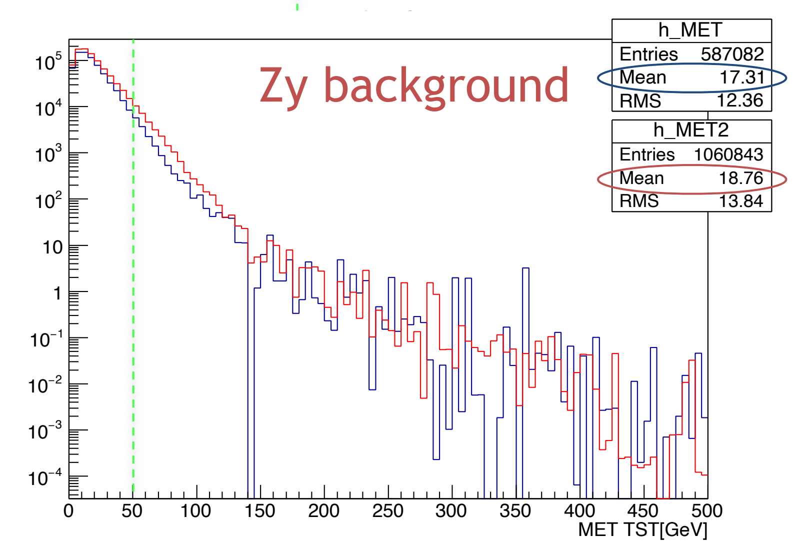
ee VS $\mu\mu$ channel discrepancy

S. Resconi

	HyGr	Zgam	Zqcd
Input	16.95 +/- 0.22	4070 +/- 77	3570 +/- 210
CutMergeExt	16.95 +/- 0.22	3680 +/- 75	3570 +/- 210
CutMCOverlap	16.95 +/- 0.22	3597 +/- 74	980 +/- 110
CutTrig	16.69 +/- 0.22	3401 +/- 72	970 +/- 110
CutJetClean	16.69 +/- 0.22	3401 +/- 72	970 +/- 110
CutChannel	7.37 +/- 0.14	1162 +/- 41	373 +/- 68
CutNjet	7.37 +/- 0.14	1162 +/- 41	373 +/- 68
CutMet	7.37 +/- 0.14	1162 +/- 41	373 +/- 68
CutNumPho	7.20 +/- 0.14	1110 +/- 40	375 +/- 67
CutNumEle	7.20 +/- 0.14	1110 +/- 40	375 +/- 67
CutVetoExtraLep	7.19 +/- 0.14	1103 +/- 40	374 +/- 67
CutL0Pt	7.15 +/- 0.14	1059 +/- 39	375 +/- 67
CutL1Pt	7.15 +/- 0.14	1059 +/- 39	375 +/- 67
CutVetoBjets	7.15 +/- 0.14	1059 +/- 39	375 +/- 67
CutHighMet	5.72 +/- 0.13	434 +/- 25	111 +/- 40
CutMass	5.44 +/- 0.12	157 +/- 15	110 +/- 40
CutPhPt	5.20 +/- 0.12	90 +/- 13	56 +/- 19
CutMllg	5.19 +/- 0.12	89 +/- 13	56 +/- 19

	HyGr	Zgam	Zqcd
Input	16.95 +/- 0.22	4070 +/- 77	3570 +/- 210
CutMergeExt	16.95 +/- 0.22	3680 +/- 75	3570 +/- 210
CutMCOverlap	16.95 +/- 0.22	3597 +/- 74	980 +/- 110
CutTrig	16.69 +/- 0.22	3401 +/- 72	970 +/- 110
CutJetClean	16.69 +/- 0.22	3401 +/- 72	970 +/- 110
CutChannel	9.24 +/- 0.17	2204 +/- 58	596 +/- 82
CutNjet	9.24 +/- 0.17	2204 +/- 58	596 +/- 82
CutMet	9.24 +/- 0.17	2204 +/- 58	596 +/- 82
CutNumPho	8.98 +/- 0.16	2137 +/- 58	592 +/- 82
CutNumMu	8.98 +/- 0.16	2137 +/- 58	592 +/- 82
CutVetoExtraLep	8.98 +/- 0.16	2134 +/- 58	594 +/- 82
CutL0Pt	8.98 +/- 0.16	2127 +/- 57	594 +/- 82
CutL1Pt	8.98 +/- 0.16	2127 +/- 57	594 +/- 82
CutVetoBjets	8.98 +/- 0.16	2127 +/- 57	594 +/- 82
CutHighMet	7.18 +/- 0.15	929 +/- 37	261 +/- 55
CutMass	6.83 +/- 0.14	331 +/- 26	224 +/- 53
CutPhPt	6.49 +/- 0.14	181 +/- 21	153 +/- 35
CutMllg	6.49 +/- 0.14	176 +/- 21	153 +/- 35





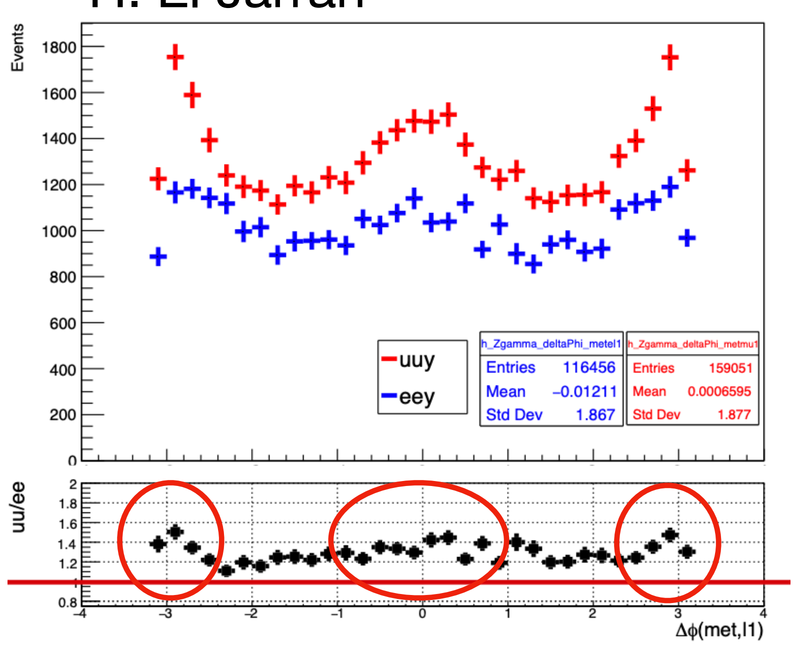
- Higher differences in Zgam and Zqcd wrt signal
- Arising from MET distribution (MET>50 GeV cut included in “Input” yields)
- Discrepancy investigated removing MET > 50 preselections
  - Requiring 2 opposite charge leptons:
    - Signal uu/ee=1.32
    - Zy uu/ee=1.25
  - 2 opposite charge leptons && MET > 50
    - Signal uu/ee = 1.32
    - Zy. uu/ee = 2.04

- MET experts have been contacted
  - Agree some differences are expected due to different e/jet and mu/jet OR treatment in MET
  - muon/pfjet bugfix in OR is included in SusyTools but suggestion to check the impact of the flag UseMuonPFlowBugfix in METMaker (default = False) => Need to implement this fix in SUSYTools

ee VS $\mu\mu$ channel discrepancy

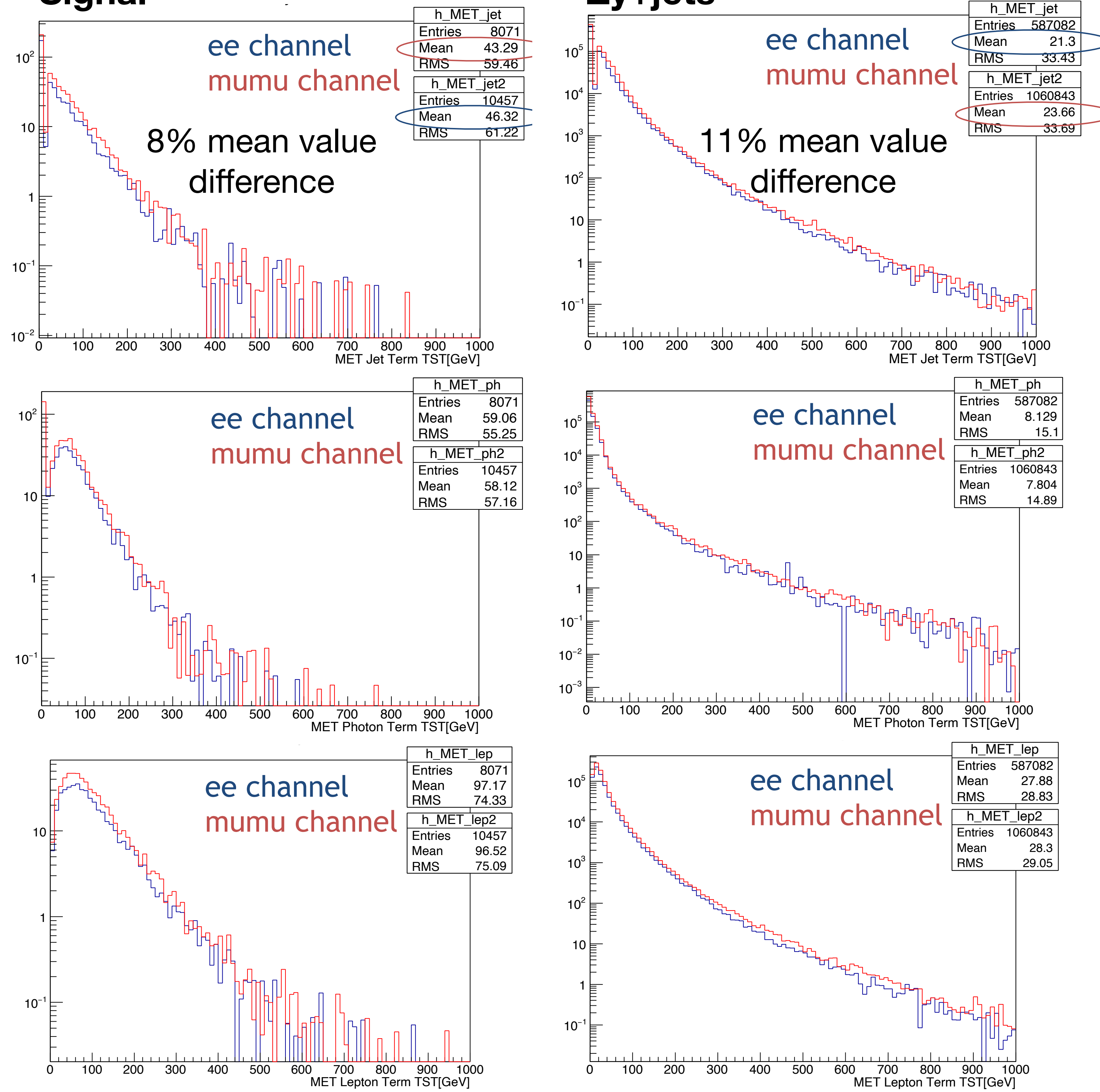
- Main difference in jet term (8% mean value difference in signal, 11% in Zy). Can be related to different treatement of muon-jet and electron-jet overlaps
- Higher impact on global MET in bkg wrt signal, due to higher importance of Jet Term relative to the other MET terms
    - Background: Jet Term value similar to Lepton Term and higher than Photon Term
    - Signal: Jet Term subdominant

H. El Jarrari



S. Resconi

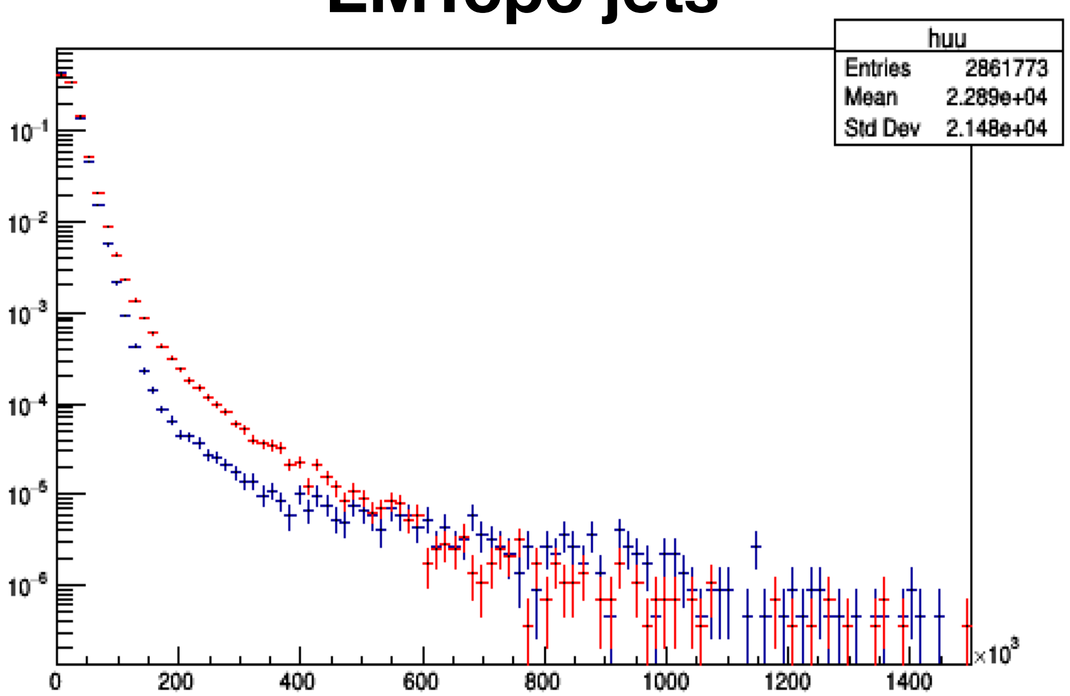
Signal **Zy+jets**



ee VS $\mu\mu$ channel discrepancy

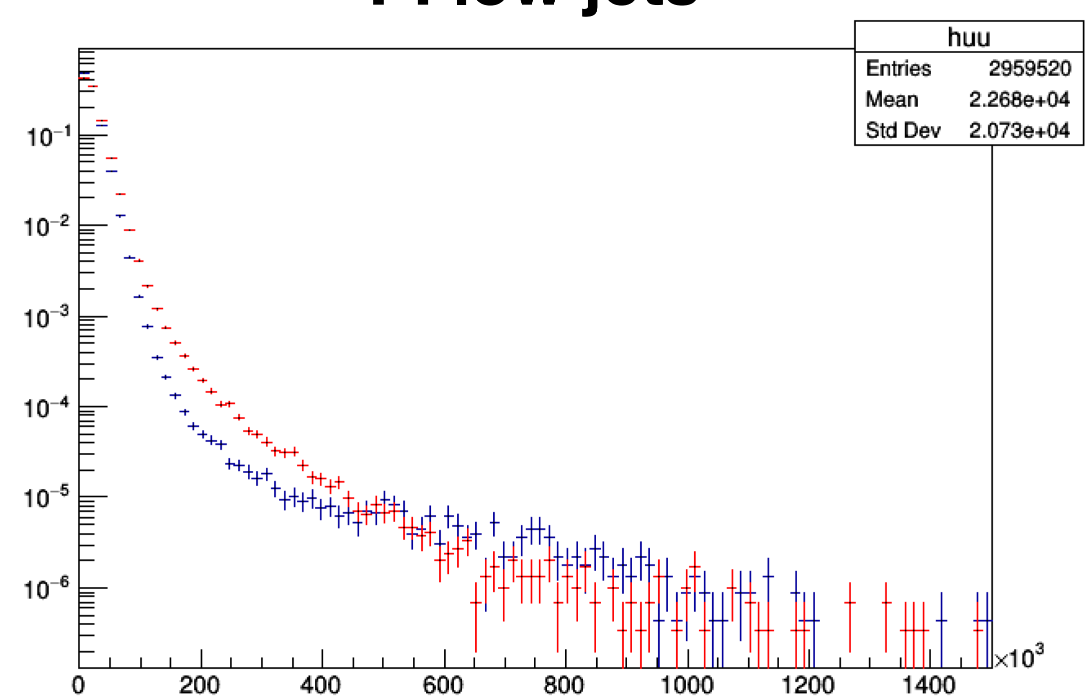
Check behaviour with EMTopo jets (no muon/pfjet bug) to understand if the bug can be the reason for the differences)

EMTopo jets



MET > 50: uu/ee = 1.37

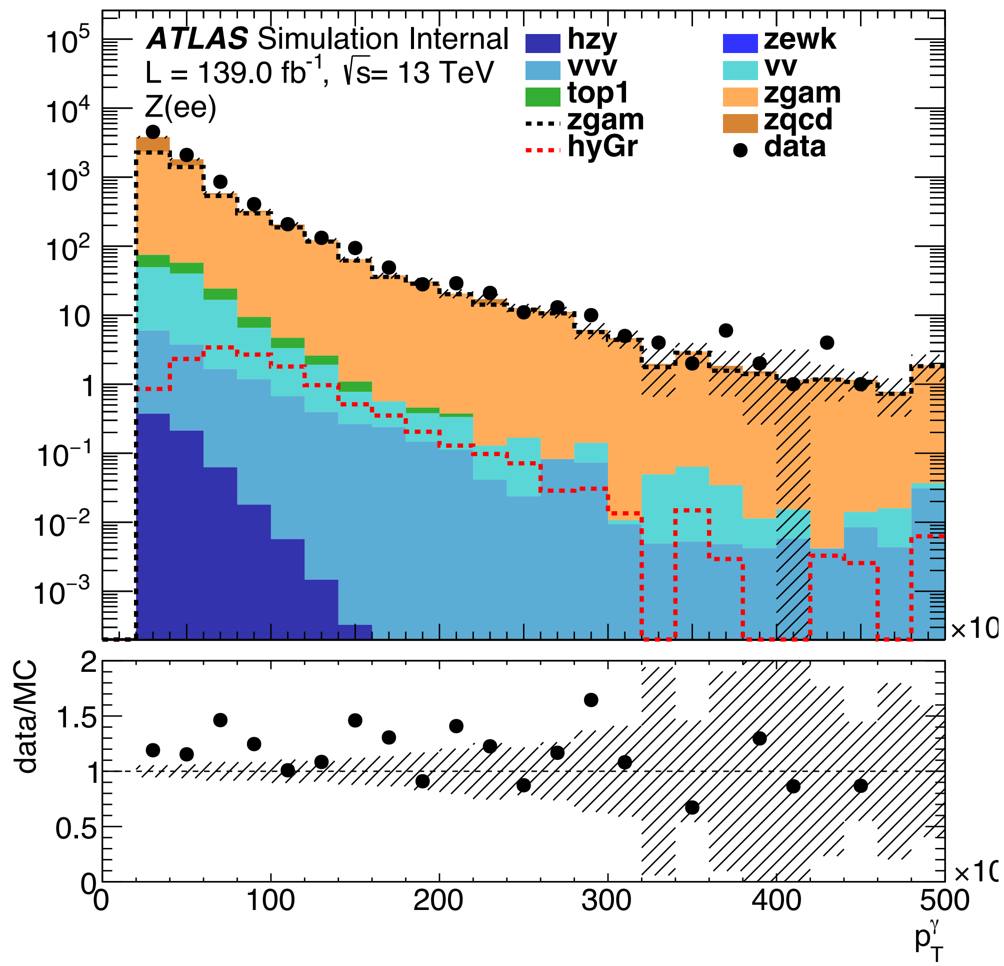
PFlow jets

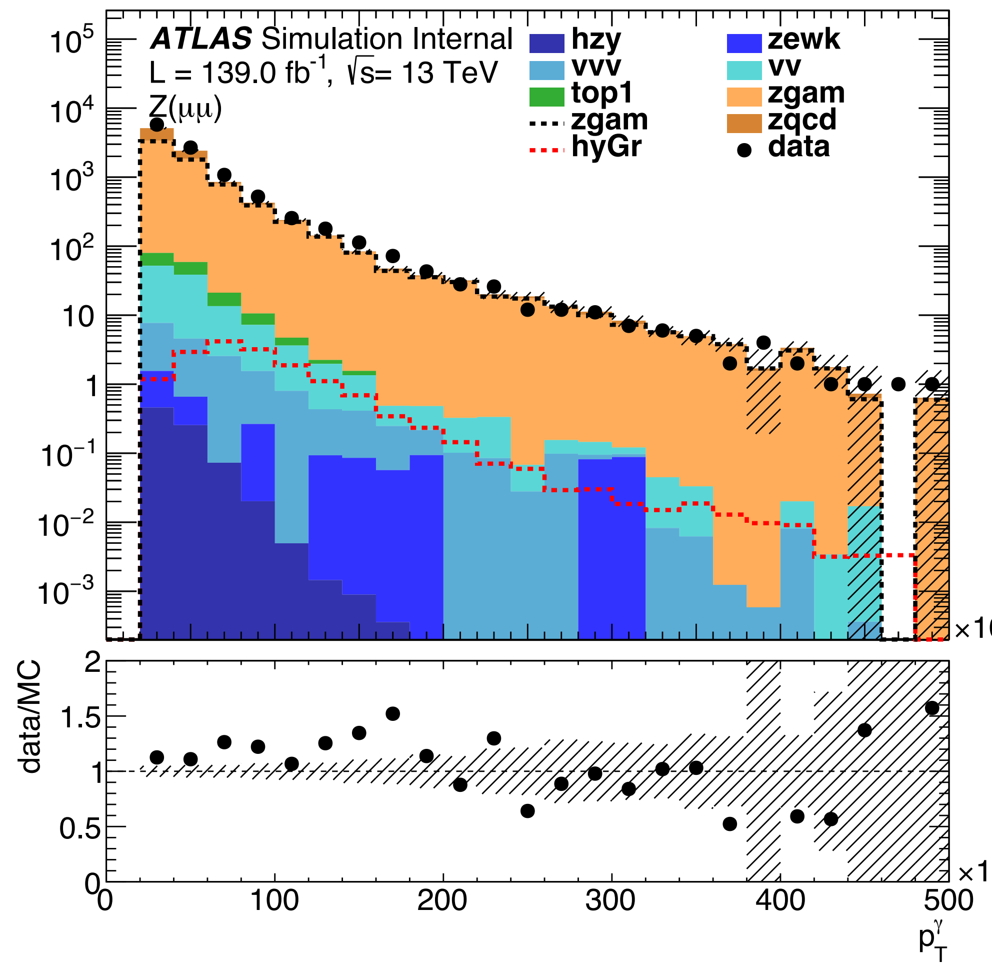


MET > 50: uu/ee = 1.67

Higher difference with PFlow than EMTopo. Might be due to muon/pfjet bug.
Worth testing the bug fix in MET

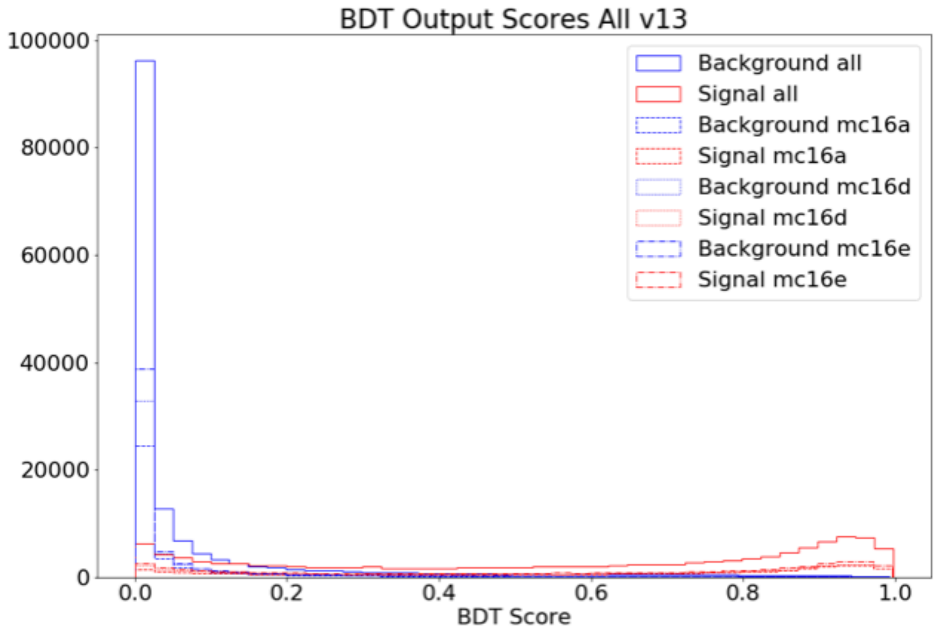
Photon pT in low MET region: data/MC

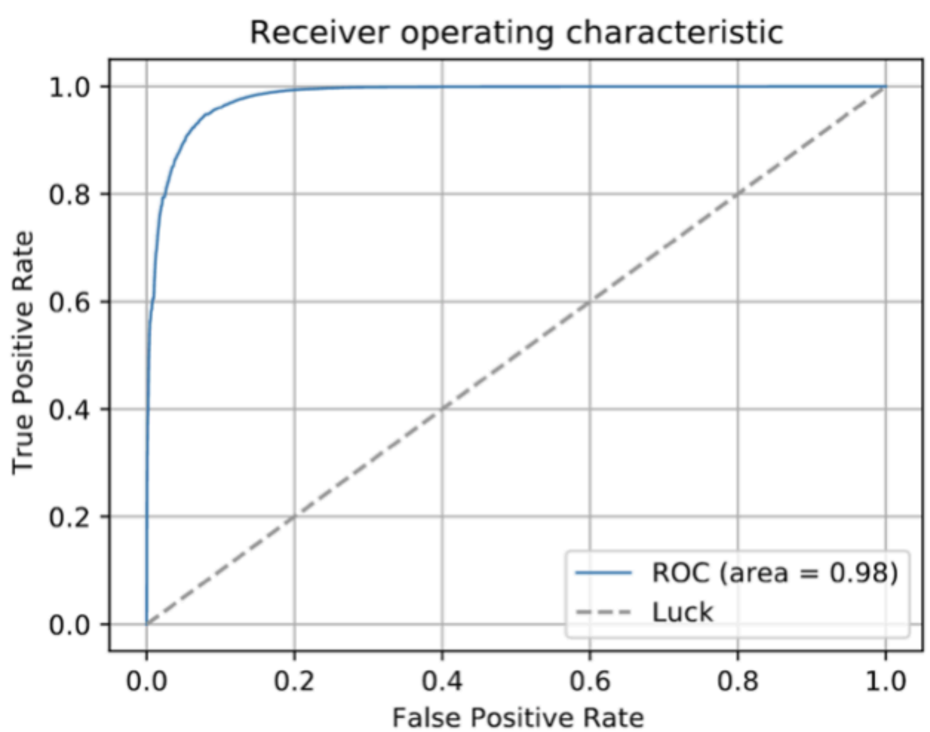


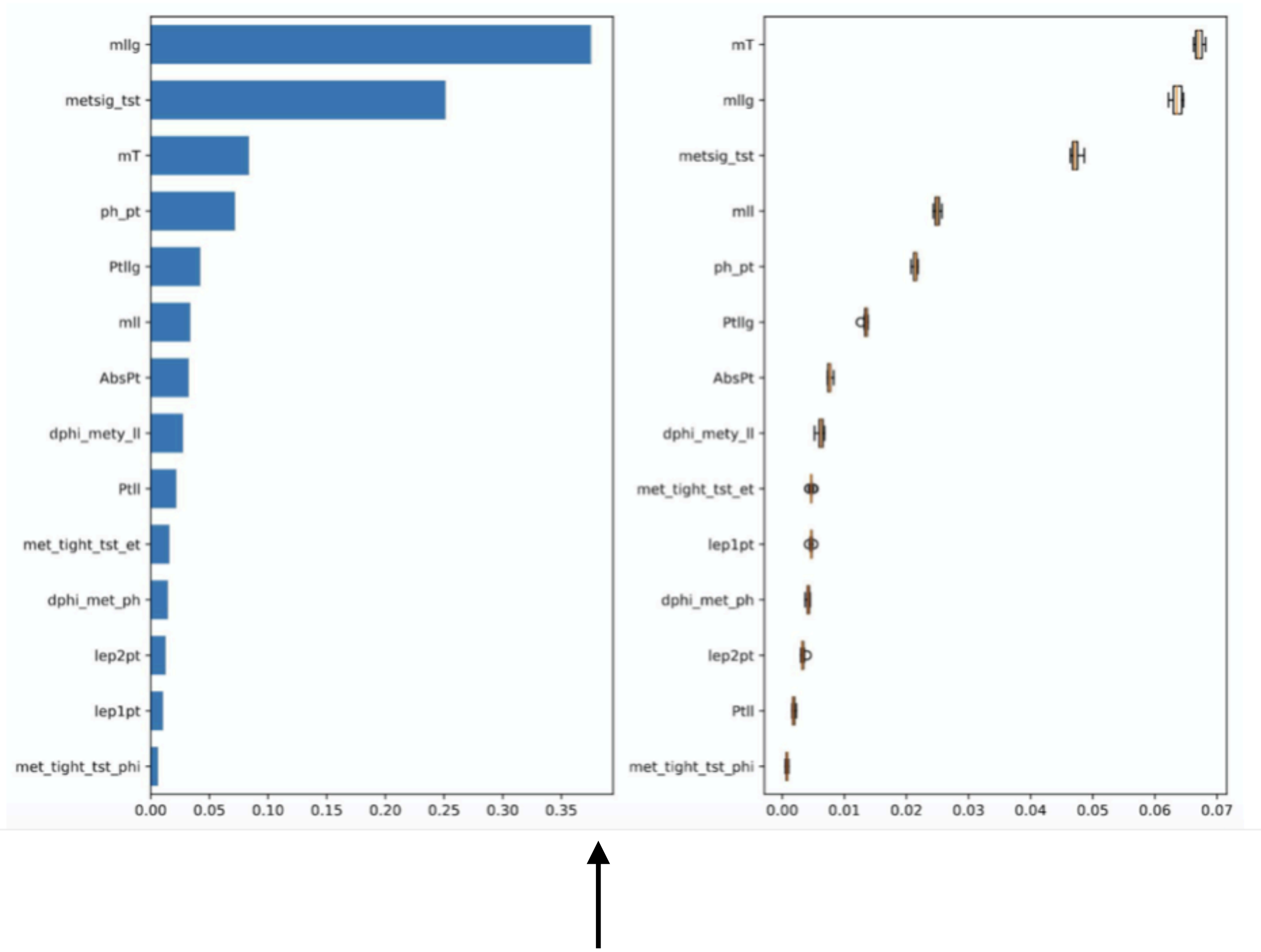


(H. Hofgard)

Machine Learning studies
BDT results







Permutation Feature Importance: Measure the importance of a feature by calculating the increase in the model's prediction error after permuting the feature

(E. Hofgard)

SR optimization with Machine Learning

Impact of BDT cut in SR

SR (AHOI optimization)
BDT > 0.85

ee channel

pass_sr_all_ee_Nominal::DoSave - print cutflow table: Assuming Br(H->y+Gr) = 5%

	HyGr	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	EltoPhFakes	bkgs
Input	16.95 +/- 0.22	4070 +/- 77	3570 +/- 210	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	105.0 +/- 9.7	0.3612 +/- 0.0046	+/-	9130 +/- 230
CutMergeExt	16.95 +/- 0.22	3680 +/- 75	3570 +/- 210	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	105.0 +/- 9.7	0.3612 +/- 0.0046	+/-	8740 +/- 230
CutMCOverlap	16.95 +/- 0.22	3597 +/- 74	980 +/- 110	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	104.1 +/- 9.7	0.3612 +/- 0.0046	+/-	6070 +/- 130
CutTrig	16.69 +/- 0.22	3401 +/- 72	970 +/- 110	1083.7 +/- 8.9	134.0 +/- 2.8	120.9 +/- 1.9	99.6 +/- 9.5	0.3557 +/- 0.0046	+/-	5810 +/- 130
CutJetClean	16.69 +/- 0.22	3401 +/- 72	970 +/- 110	1083.7 +/- 8.9	134.0 +/- 2.8	120.9 +/- 1.9	99.6 +/- 9.5	0.3557 +/- 0.0046	+/-	5810 +/- 130
CutChannel	7.37 +/- 0.14	1162 +/- 41	373 +/- 68	302.9 +/- 4.7	49.4 +/- 1.4	34.6 +/- 1.0	36.1 +/- 5.5	0.1503 +/- 0.0029	+/-	1958 +/- 80
CutNjet	7.37 +/- 0.14	1162 +/- 41	373 +/- 68	302.9 +/- 4.7	49.4 +/- 1.4	34.6 +/- 1.0	36.1 +/- 5.5	0.1503 +/- 0.0029	+/-	1958 +/- 80
CutMet	7.37 +/- 0.14	1162 +/- 41	373 +/- 68	302.9 +/- 4.7	49.4 +/- 1.4	34.6 +/- 1.0	36.1 +/- 5.5	0.1503 +/- 0.0029	+/-	1958 +/- 80
CutNumPho	7.20 +/- 0.14	1110 +/- 40	375 +/- 67	276.6 +/- 4.5	47.8 +/- 1.3	33.3 +/- 1.0	35.5 +/- 5.5	0.1446 +/- 0.0029	+/-	1879 +/- 79
CutNumEle	7.20 +/- 0.14	1110 +/- 40	375 +/- 67	276.6 +/- 4.5	47.8 +/- 1.3	33.3 +/- 1.0	35.5 +/- 5.5	0.1446 +/- 0.0029	+/-	1879 +/- 79
CutVetoExtraLep	7.19 +/- 0.14	1103 +/- 40	374 +/- 67	263.1 +/- 4.4	47.6 +/- 1.3	33.1 +/- 1.0	35.5 +/- 5.5	0.1437 +/- 0.0029	+/-	1856 +/- 79
CutL0Pt	7.15 +/- 0.14	1059 +/- 39	375 +/- 67	257.6 +/- 4.3	45.7 +/- 1.3	32.7 +/- 1.0	33.7 +/- 5.4	0.1433 +/- 0.0029	+/-	1804 +/- 78
CutL1Pt	7.15 +/- 0.14	1059 +/- 39	375 +/- 67	257.6 +/- 4.3	45.7 +/- 1.3	32.7 +/- 1.0	33.7 +/- 5.4	0.1433 +/- 0.0029	+/-	1804 +/- 78
CutVetoBjets	7.15 +/- 0.14	1059 +/- 39	375 +/- 67	257.6 +/- 4.3	45.7 +/- 1.3	32.7 +/- 1.0	33.7 +/- 5.4	0.1433 +/- 0.0029	+/-	1804 +/- 78
CutHighMet	5.72 +/- 0.13	434 +/- 25	111 +/- 40	215.6 +/- 4.0	33.3 +/- 1.1	25.80 +/- 0.88	22.9 +/- 4.2	0.0940 +/- 0.0023	+/-	842 +/- 48
CutMass	5.44 +/- 0.12	157 +/- 15	110 +/- 40	55.6 +/- 2.0	14.98 +/- 0.69	8.22 +/- 0.45	3.3 +/- 1.6	0.0899 +/- 0.0022	+/-	349 +/- 43
CutPhPt	5.20 +/- 0.12	90 +/- 13	56 +/- 19	36.5 +/- 1.6	10.12 +/- 0.54	6.37 +/- 0.38	1.91 +/- 0.96	0.0689 +/- 0.0019	+/-	201 +/- 23
CutMllg	5.19 +/- 0.12	89 +/- 13	56 +/- 19	36.1 +/- 1.6	9.77 +/- 0.53	6.29 +/- 0.37	1.91 +/- 0.96	0.0689 +/- 0.0019	+/-	198 +/- 23
BDT_Cut	2.025 +/- 0.07	0.17 +/- 0.17	+/-	0.120 +/- 0.070	0.105 +/- 0.089	0.169 +/- 0.054	+/-	0.00357 +/- 0.00042	+/-	0.57 +/- 0.21

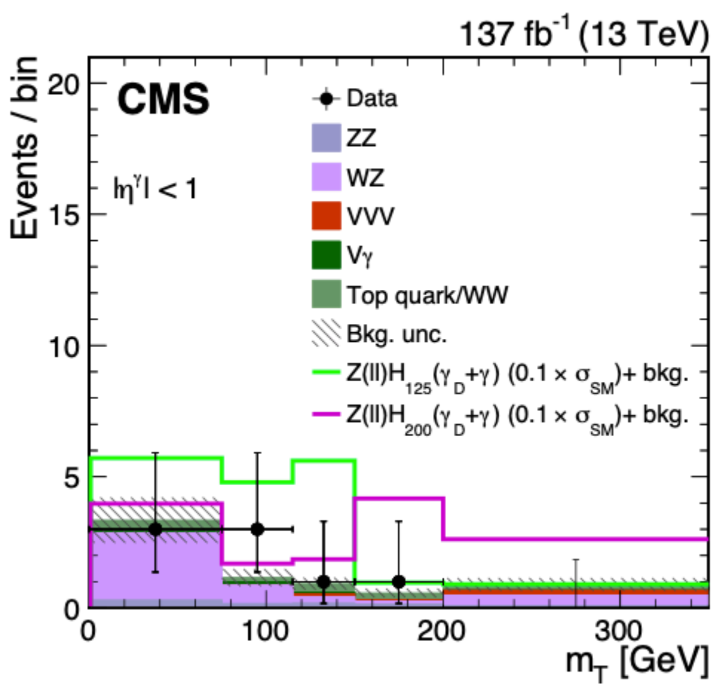
$\mu\mu$ channel

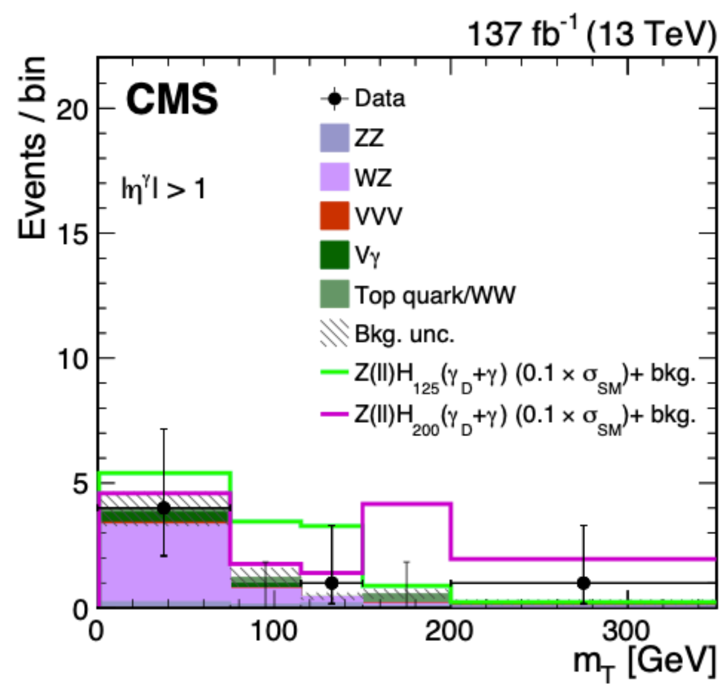
pass_sr_all_uu_Nominal::DoSave -

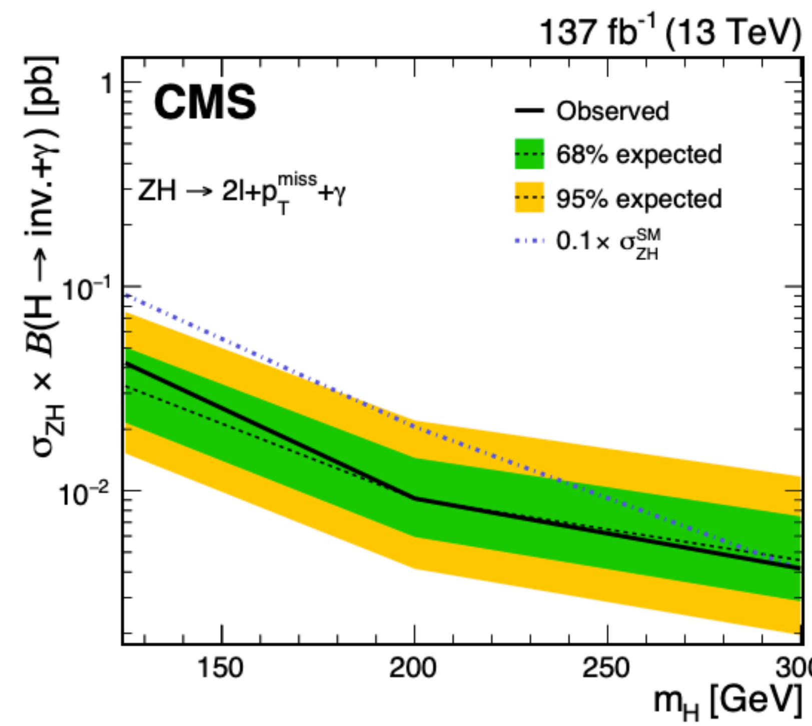
	HyGr	Zgam	Zqcd	Top	VV	VVV	Wgam	HZy	EltoPhFakes	bkgs
Input	16.95 +/- 0.22	4070 +/- 77	3570 +/- 210	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	105.0 +/- 9.7	0.3612 +/- 0.0046	+/-	9130 +/- 230
CutMergeExt	16.95 +/- 0.22	3680 +/- 75	3570 +/- 210	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	105.0 +/- 9.7	0.3612 +/- 0.0046	+/-	8740 +/- 230
CutMCOverlap	16.95 +/- 0.22	3597 +/- 74	980 +/- 110	1122.3 +/- 9.0	138.6 +/- 2.8	123.7 +/- 1.9	104.1 +/- 9.7	0.3612 +/- 0.0046	+/-	6070 +/- 130
CutTrig	16.69 +/- 0.22	3401 +/- 72	970 +/- 110	1083.7 +/- 8.9	134.0 +/- 2.8	120.9 +/- 1.9	99.6 +/- 9.5	0.3557 +/- 0.0046	+/-	5810 +/- 130
CutJetClean	16.69 +/- 0.22	3401 +/- 72	970 +/- 110	1083.7 +/- 8.9	134.0 +/- 2.8	120.9 +/- 1.9	99.6 +/- 9.5	0.3557 +/- 0.0046	+/-	5810 +/- 130
CutChannel	9.24 +/- 0.17	2204 +/- 58	596 +/- 82	326.4 +/- 4.9	47.3 +/- 1.5	38.3 +/- 1.1	5.9 +/- 2.2	0.2025 +/- 0.0035	+/-	3220 +/- 100
CutNjet	9.24 +/- 0.17	2204 +/- 58	596 +/- 82	326.4 +/- 4.9	47.3 +/- 1.5	38.3 +/- 1.1	5.9 +/- 2.2	0.2025 +/- 0.0035	+/-	3220 +/- 100
CutMet	9.24 +/- 0.17	2204 +/- 58	596 +/- 82	326.4 +/- 4.9	47.3 +/- 1.5	38.3 +/- 1.1	5.9 +/- 2.2	0.2025 +/- 0.0035	+/-	3220 +/- 100
CutNumPho	8.98 +/- 0.16	2137 +/- 58	592 +/- 82	298.0 +/- 4.7	46.1 +/- 1.5	36.9 +/- 1.1	5.8 +/- 2.2	0.1944 +/- 0.0034	+/-	3120 +/- 100
CutNumMu	8.98 +/- 0.16	2137 +/- 58	592 +/- 82	298.0 +/- 4.7	46.1 +/- 1.5	36.9 +/- 1.1	5.8 +/- 2.2	0.1944 +/- 0.0034	+/-	3120 +/- 100
CutVetoExtraLep	8.98 +/- 0.16	2134 +/- 58	594 +/- 82	282.4 +/- 4.6	45.5 +/- 1.5	36.6 +/- 1.1	5.8 +/- 2.2	0.1928 +/- 0.0034	+/-	3099 +/- 100
CutL0Pt	8.98 +/- 0.16	2127 +/- 57	594 +/- 82	281.4 +/- 4.5	45.3 +/- 1.5	36.6 +/- 1.1	5.8 +/- 2.2	0.1925 +/- 0.0034	+/-	3090 +/- 100
CutL1Pt	8.98 +/- 0.16	2127 +/- 57	594 +/- 82	281.4 +/- 4.5	45.3 +/- 1.5	36.6 +/- 1.1	5.8 +/- 2.2	0.1925 +/- 0.0034	+/-	3090 +/- 100
CutVetoBjets	8.98 +/- 0.16	2127 +/- 57	594 +/- 82	281.4 +/- 4.5	45.3 +/- 1.5	36.6 +/- 1.1	5.8 +/- 2.2	0.1925 +/- 0.0034	+/-	3090 +/- 100
CutHighMet	7.18 +/- 0.15	929 +/- 37	261 +/- 55	232.1 +/- 4.1	32.6 +/- 1.3	29.55 +/- 0.96	3.1 +/- 1.1	0.1250 +/- 0.0027	+/-	1487 +/- 67
CutMass	6.83 +/- 0.14	331 +/- 26	224 +/- 53	58.0 +/- 2.0	15.23 +/- 0.88	8.98 +/- 0.49	0.03 +/- 0.47	0.1182 +/- 0.0026	+/-	637 +/- 59
CutPhPt	6.49 +/- 0.14	181 +/- 21	153 +/- 35	38.6 +/- 1.7	9.17 +/- 0.74	7.07 +/- 0.43	0.40 +/- 0.29	0.0885 +/- 0.0022	+/-	389 +/- 41
CutMllg	6.49 +/- 0.14	176 +/- 21	153 +/- 35	38.4 +/- 1.7	9.51 +/- 0.60	7.07 +/- 0.43	0.40 +/- 0.29	0.0885 +/- 0.0022	+/-	385 +/- 41
BDT_Cut	2.378 +/- 0.085	+/-	+/-	0.071 +/- 0.049	0.197 +/- 0.069	0.189 +/- 0.066	+/-	0.00485 +/- 0.00051	+/-	0.46 +/- 0.11

CMS results

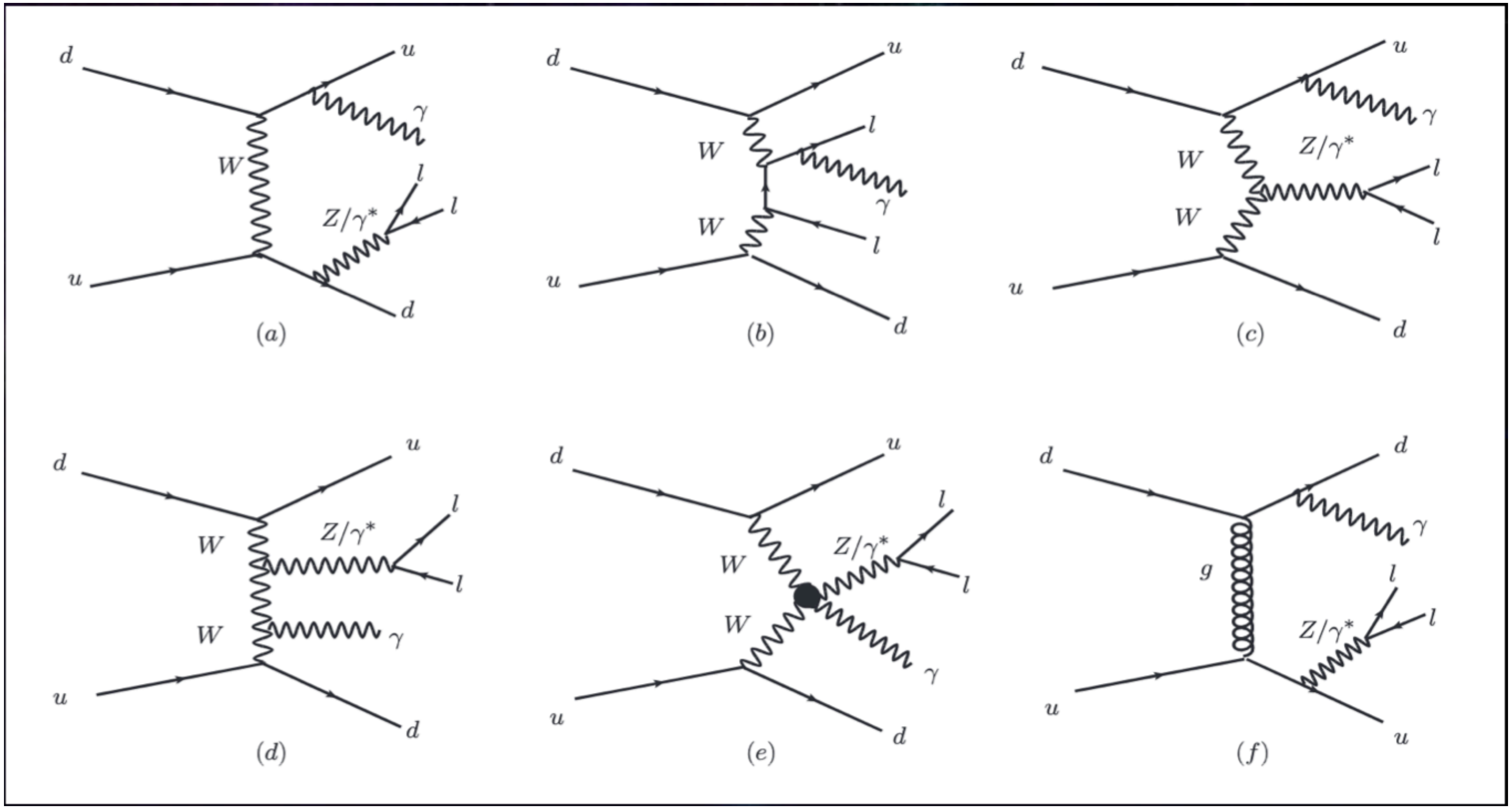
Process	Yield
Data	14
Nonresonant	2.4 ± 1.1
WZ	8.1 ± 2.0
ZZ	1.5 ± 0.3
$Z\gamma$	0.7 ± 0.7
Other	0.6 ± 0.3
Total background	13.3 ± 3.8
ZH_{125} (product of acceptance and efficiency)	17.9 ± 1.2 ($2.13 \pm 0.14\%$)
ZH_{200} (product of acceptance and efficiency)	12.3 ± 0.8 ($6.48 \pm 0.42\%$)
ZH_{300} (product of acceptance and efficiency)	3.9 ± 0.2 ($10.20 \pm 0.51\%$)





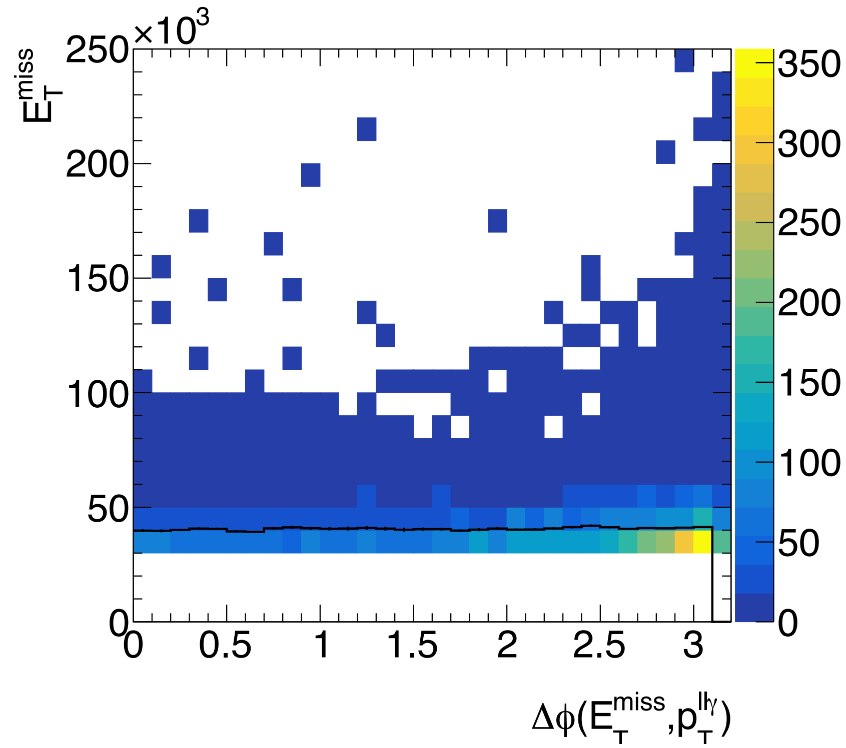


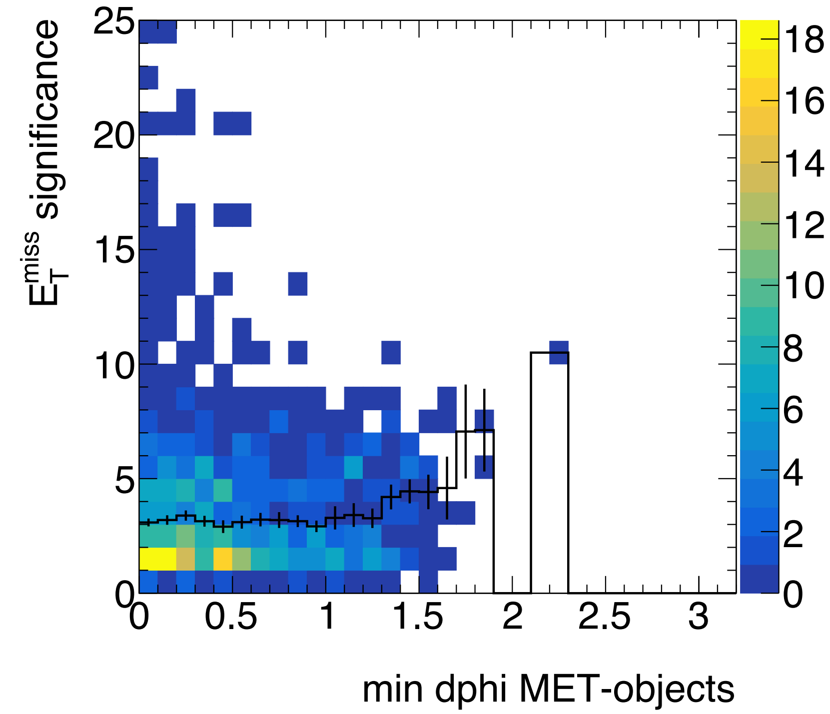
Zy+jets background



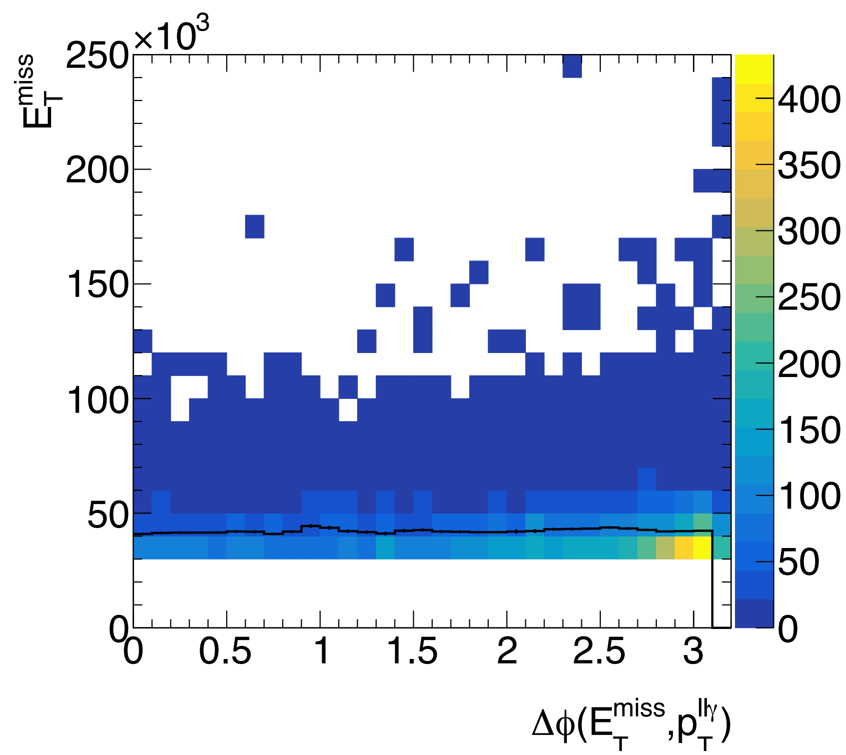
Variable correlation

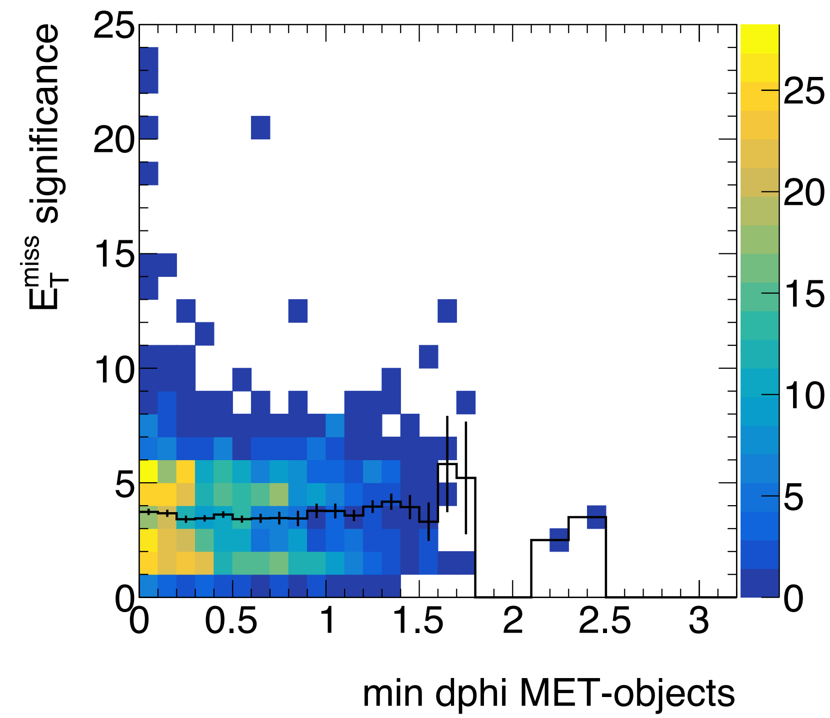
ee-channel





uu-channel

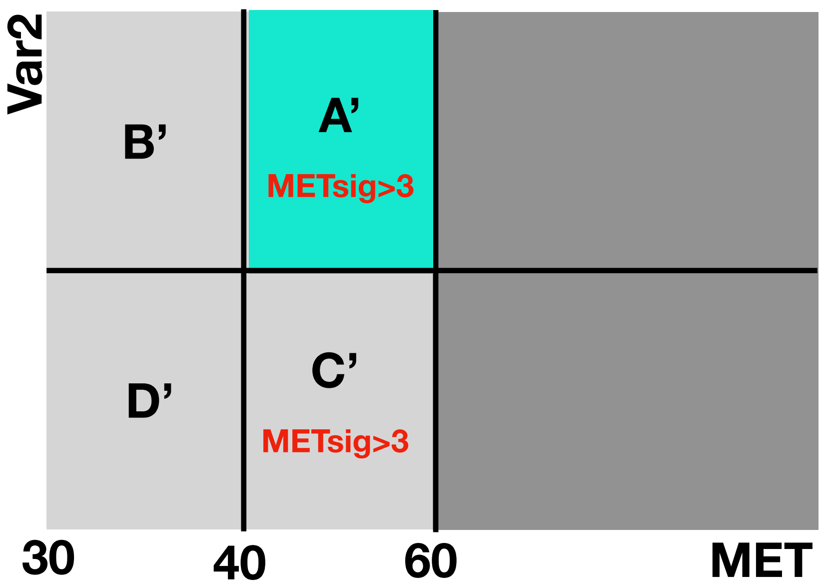




Fake MET background

MET-based ABCD with VS without METsig cut in VR

(Signal contamination < 0.5%)



- All regions dominated by Zy+jets and Z+jets background
- In situ estimates for other backgrounds still not available. Preliminary tests with temporary solutions

  => Rzyzjet: evaluating R from Zy+jets AND Z+jets (both are characterized by sizeable fake MET)

  => Rzy : R from Zy only

  For background not used in R estimation, MC yields in each region subtracted from data

$\mu\mu$ channel

Data in VR	Rmc	Rdata	MC	Data	ABCD
Rzyzjet + metsig	1.468 +-0.170	1.230 +-0.113	1582 +- 111	1918 +- 66	2291 +- 329
Rzyzjet	1.118 +- 0.098	1.019 +- 0.079	2646 +- 133	3088 +- 109	3388 +- 377
Rzy + metsig	1.169 +-0.100	1.034 +-0.170	784 +- 35	1120 +- 124	1266 +- 188
Rzy	1.154 +- 0.077	1.039 +- 0.130	1705 +- 66	2146 +- 159	2384 +- 289

ee channel

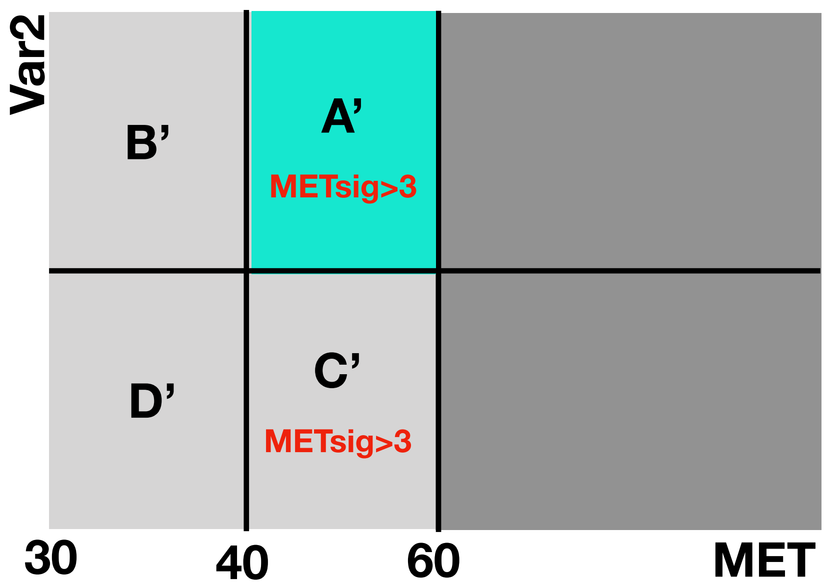
Data in VR	Rmc	Rdata	MC	Data	ABCD
Rzyzjet + metsig	2.153 +-0.330	2.035 +-0.269	1120 +- 92	1402 +- 60	1483 +- 293
Rzyzjet	1.267 +- 0.128	1.202 +- 0.110	1976 +- 106	2418 +- 80	2547 +- 338
Rzy + metsig	1.523 +-0.172	1.583 +-0.356	555 +- 33	838 +- 105	806 +- 176
Rzy	1.080 +- 0.082	1.058 +- 0.156	1175 +- 44	1617 +- 125	1651 +- 242

=> Discrepancy between R with and without METsig cut, but R from data is consistent with R from MC
=> ABCD estimates consistent with observed data

(M. Fanti, D. Pullia, F. Piazza, S. Resconi)

Fake MET background

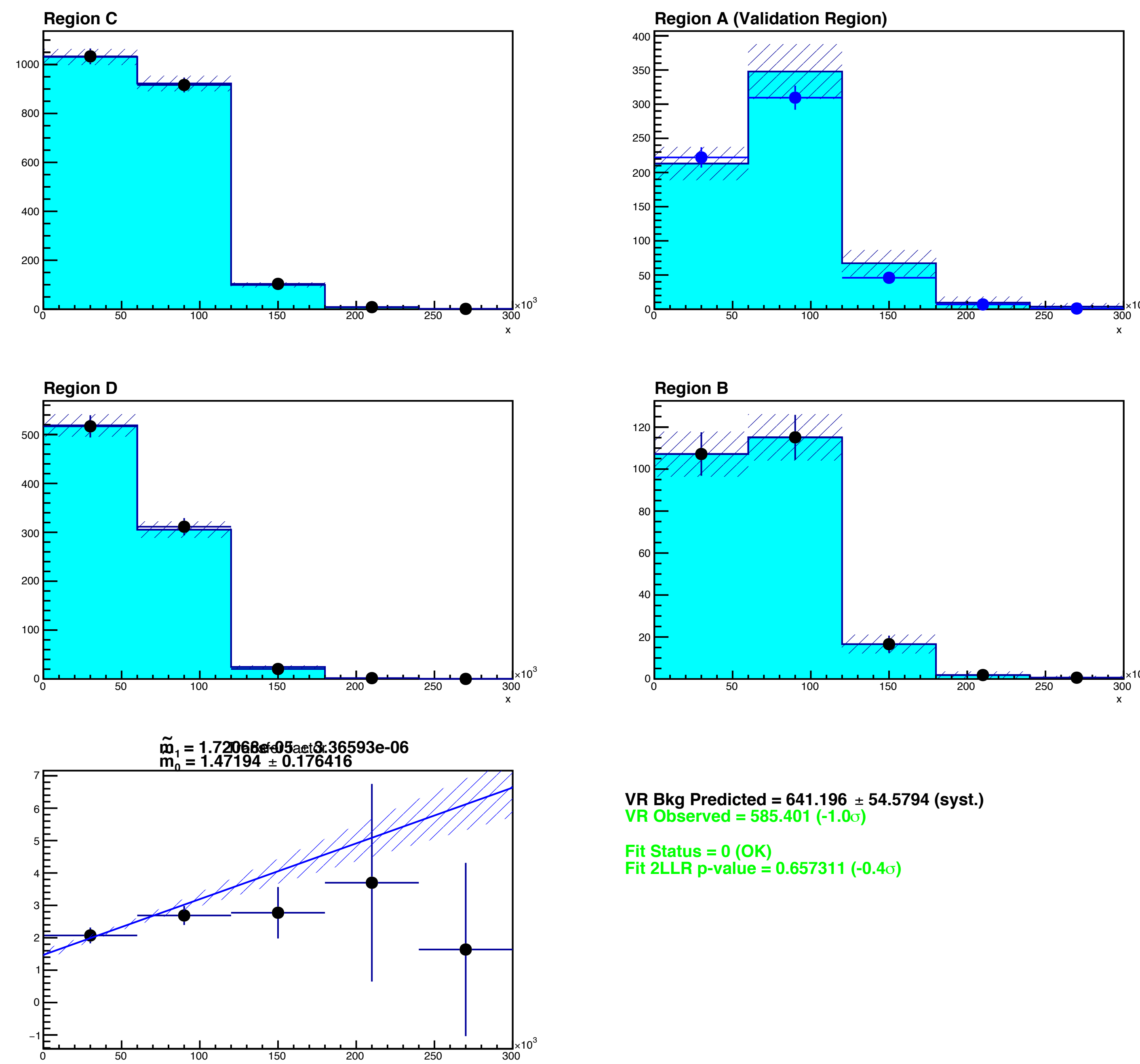
TRooABCD, ee channel



mT distribution in region A' from simultaneous fit on the B,C,D regions with TRooABCD

- mT histograms in each B,C,D region as input
- Using data in VR, and subtracting Zjets from MC (first approximation)
- Correct for R=(nA nD)/(nC nB) by scaling the histogram in region D by 1/R (with R estimated from Zy+jet MC)

Zy MC sample



Only statistical uncertainties

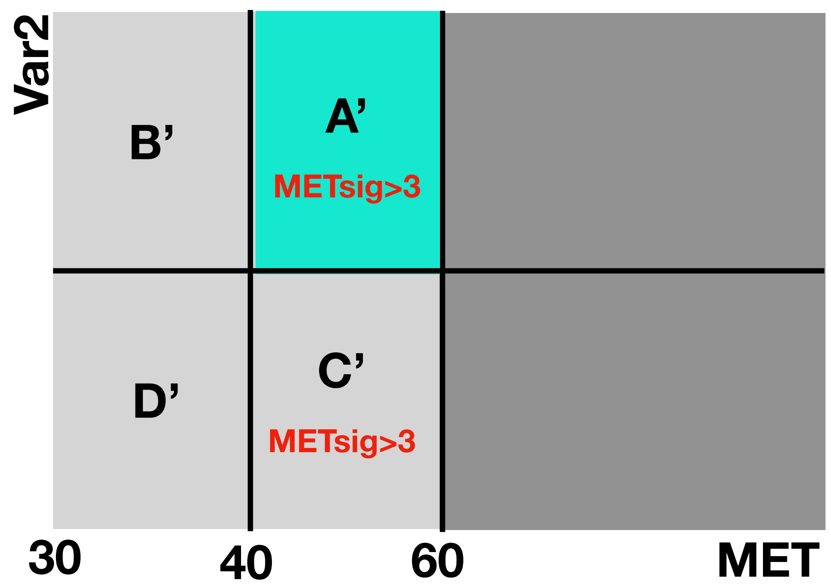
$nA(x) = (m_0+m_1(x)) \times nB(x)$
$nC(x) = (m_0+m_1(x)) \times nD(x)$

(x labels the bin)

(M. Fanti, D. Pullia, F. Piazza, S. Resconi)

Fake MET background

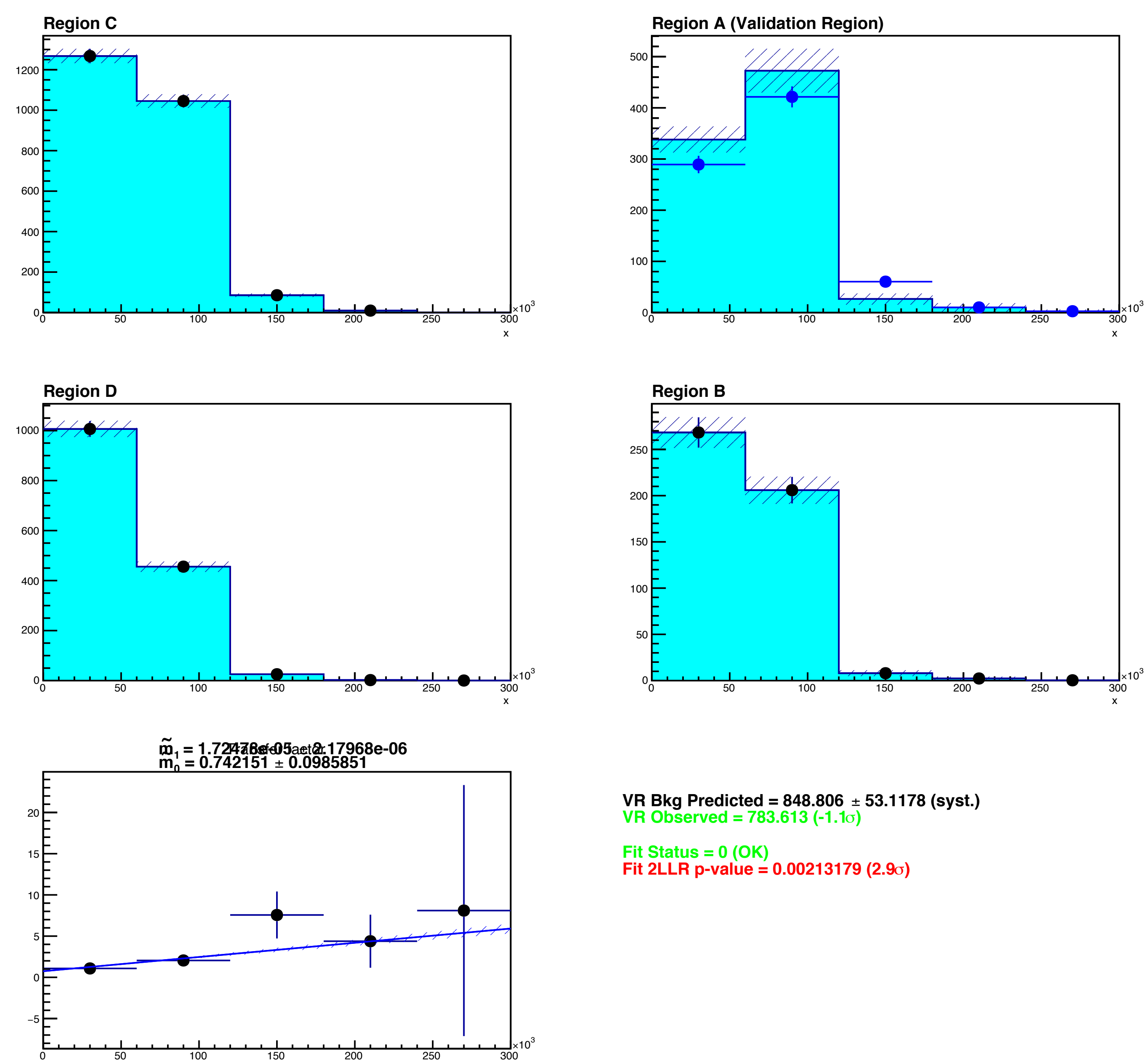
TRooABCD, uu channel



mT distribution in region A' from simultaneous fit on the B,C,D regions with TRooABCD

- mT histograms in each B,C,D region as input
- Using data in VR, and subtracting Zjets from MC (first approximation)
- Correct for R=(nA nD)/(nC nB) by scaling the histogram in region D by 1/R (with R estimated from Zy+jet MC)

Zy MC sample



Only statistical uncertainties

$nA(x) = (m_0+m_1(x)) \times nB(x)$
$nC(x) = (m_0+m_1(x)) \times nD(x)$

(x labels the bin)