With low <mu> data

Lepton (non)-universality in W decays in ATLAS

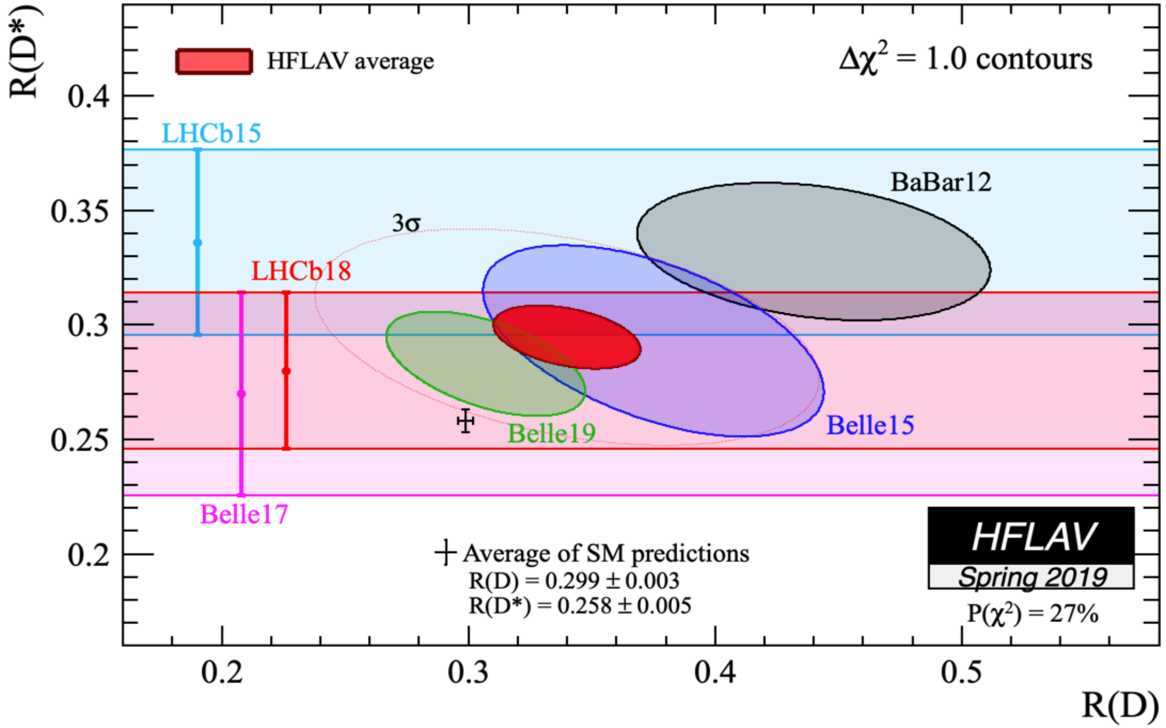
Daniil Ponomarenko

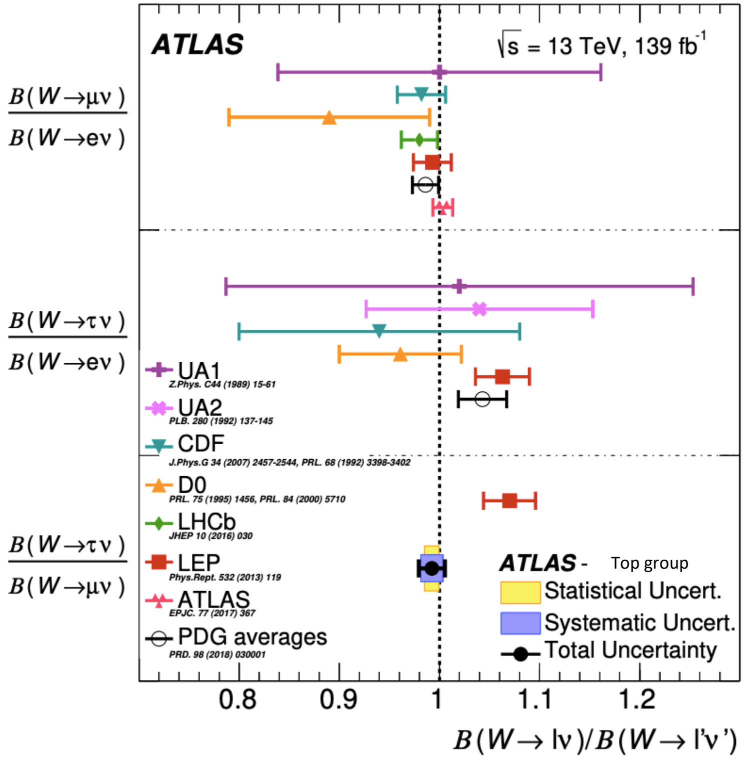
MEPhI@ATLAS group meeting, 06-November-2020

ATLAS EXPERIMENT
Nikhef
Radboud Universiteit Nijmegen
IN·DEI·NOMINE·FELICITER
NRNU MEPhI NATIONAL RESEARCH NUCLEAR UNIVERSITY MEPhI
Carleton UNIVERSITY

Motivation

[ATLAS-only talk]

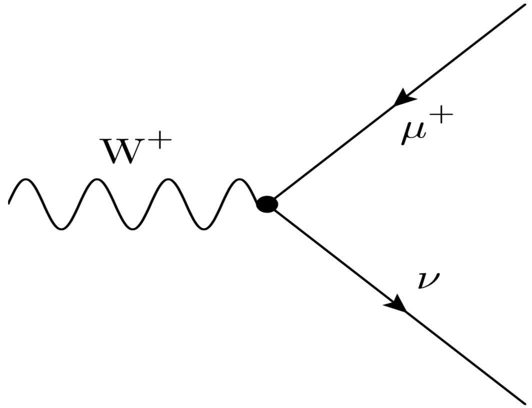




- We have most precise measurement to date from the Top group
  - R(**τ**/μ)= 0.992 ± 0.013 [± 0.007(stat) ± 0.011(syst)]
- The goal is to measure the W branching ratio in pp and search for lepton non-universality in ATLAS in direct W decays
  - We have very large statistics for W decay at ATLAS
  - Excellent possibility to test SM and lepton universality
  - The aim of this measurement is to achieve $\mathcal{O}(1.5\%)$ error

Ongoing ATLAS analysis

- Run1: Standard Model group analysis
  - Luminosity 4.6 fb^{-1}
  - Final states analysed: $W \rightarrow \tau_{lep}\nu \rightarrow \ell\nu\nu$ and $W \rightarrow \ell\nu$
  - Major analysis features:
    - Displacement of the τ decay helps to distinguish leptons from τ decays from prompt leptons
    - Analysis based on previous W mass measurement analysis
  - Status: *Work in progress*
- Run2: Standard Model group low mu analysis - this talk
  - Luminosity 340 pb^{-1}
  - Final states analysed: $W \rightarrow \tau_{lep}\nu \rightarrow \ell\nu\nu$ and $W \rightarrow \ell\nu$
  - Major analysis features:
    - Displacement of the τ decay helps to distinguish leptons from τ decays from prompt leptons
    - 2D fit on d_0 and (BDT output or m_T) leading lepton distributions
    - Analysis statistical power around 1%
  - Status: *Work in progress*
- Run2: Top group effort - PUBLISHED
  - Luminosity 147 fb^{-1}
  - Final states analysed: di-leptonic $t\bar{t}$ decays
  - Major analysis features:
    - Displacement of the τ decay helps to distinguish leptons from τ decays from prompt leptons
    - Tag lepton to trigger on and probe lepton to go for a lower p_T range
  - Result: 0.9923 +/- **0.0131** [+/-0.0072 (stat) +/- 0.0110 (syst)]



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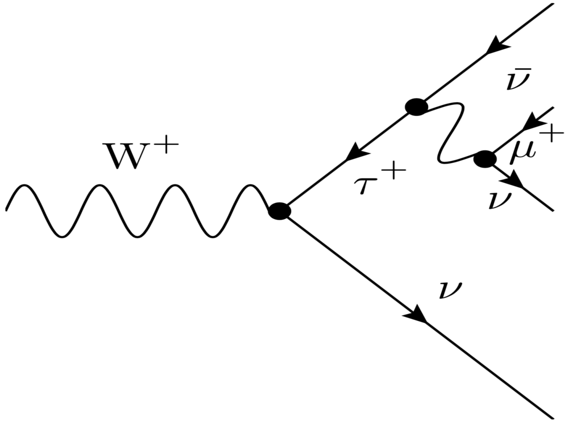

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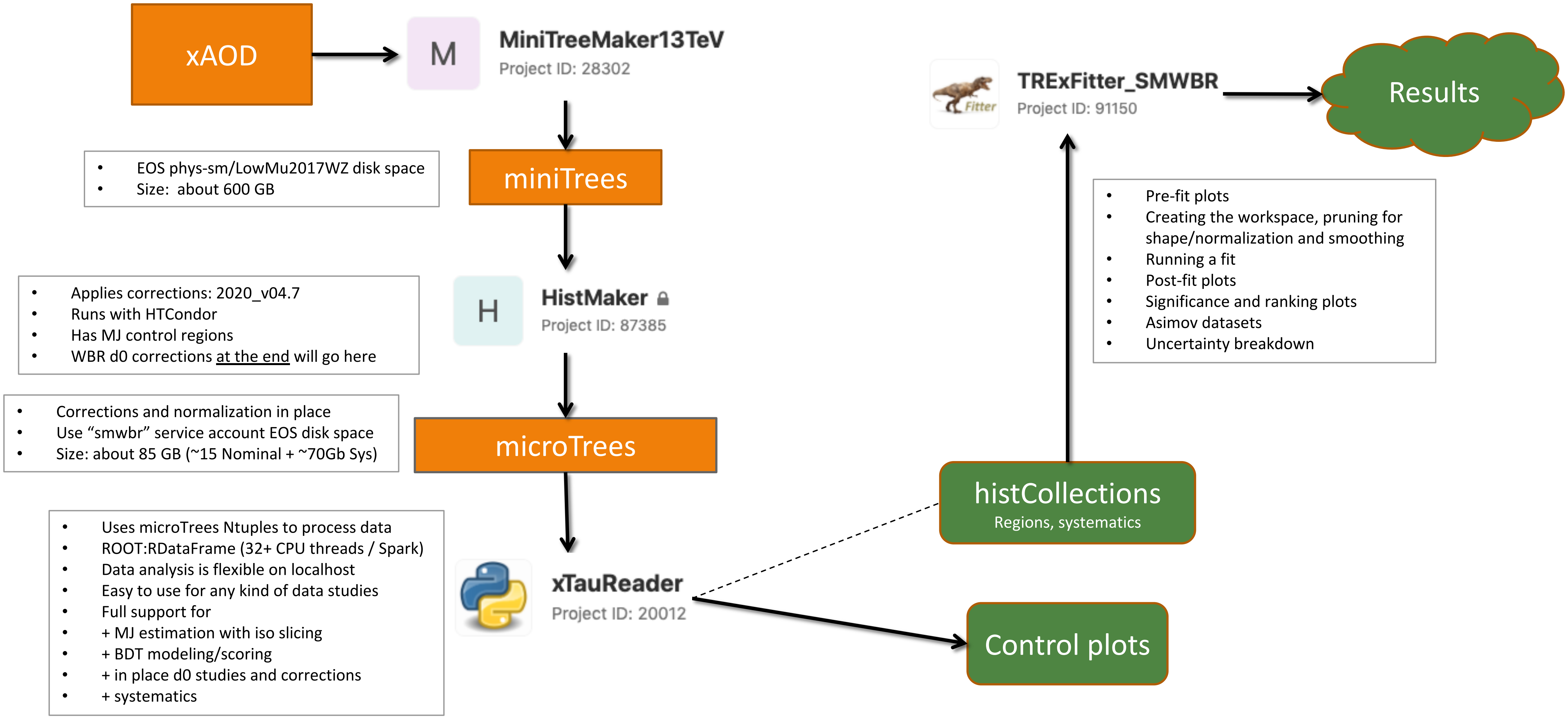
Analysis organization

- Previous status report: 06.05.2020
- E-group: atlas-phys-stdm-wbr-lowmu-analysis-team@cern.ch
- Jira: https://its.cern.ch/jira/browse/ATLASSMWBRLOWMU-1
  - Main page to hold all documentation and workflow
- Git: https://gitlab.cern.ch/atlas-wbr-lowmu
- Storage: /eos/user/s/smwbr/LowMu/
- Main efforts:
  - General analysis supervision: Nicolo
  - Common SW: Daniil
  - Mini/Micro tuples production: Daniil
  - SR selection optimization: Daniil
  - d0 corrections and studies: JJ
  - MJ estimation: Daniil
  - TMVA studies: Grigorii
  - Systematics: Daniil

Software organization

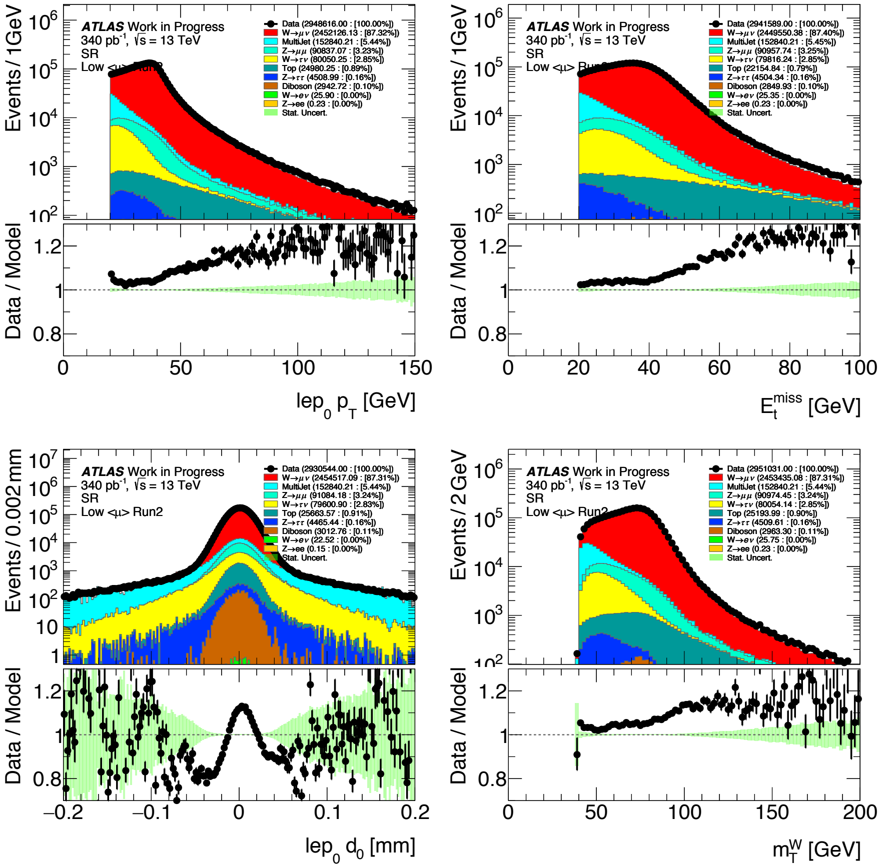


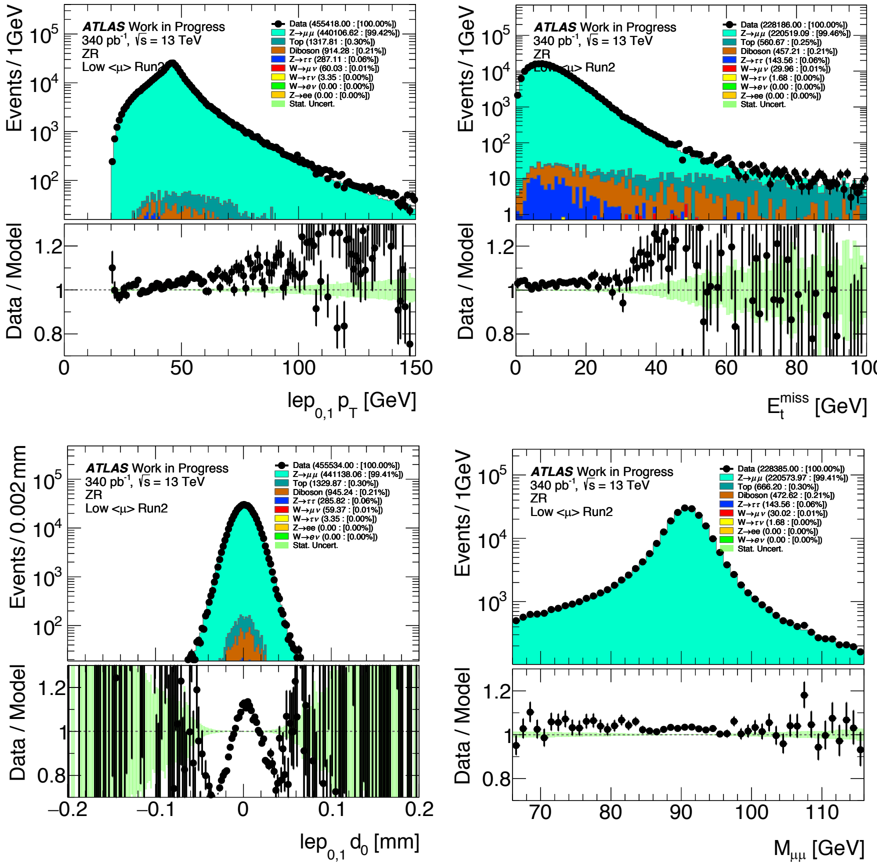
WBR SR configuration

- For WBR analysis we are focused on soft part of mT spectra
- We are using d0 distribution as control variable
  - vertexing cuts suppress our signal region
  - we dropped vertexing cuts and TTVA SF
- Relax kinematics variables:
  - pT > 20 GeV
    - limited by available trigger SF and MJ contribution
  - mT > 40 GeV
    - Suppress MJ background
  - MET > 20 GeV
    - to keep consistency with other low mu analysis groups
- MJ, CR1, CR2 are used for MJ background estimation:
  - Same algorithm as in ATL-COM-PHYS-2019-076
- ZR and ZttR for d_0 studies and corrections

SR Vars: d_0 and p_T (m_T) Exactly 1 lepton with: p_T>20, tightID, isoMedium E_T^{miss}>20 m_T>40 ptvarcone20/pt < 0.1	**MJ** Vars: p_T , m_T, E_T^{miss}, $d\varphi$ Exactly 1 lepton with: p_T>20,, tightID&!isoMedium E_T^{miss}>20 m_T>40 ptvarcone20/pt > 0.1 && sliced
CR1 Vars: p_T , m_T, E_T^{miss}, $d\varphi$ Exactly 1 lepton with: p_T>20, tightID, isoMedium E_T^{miss}>0 m_T>0 ptvarcone20/pt < 0.1	**CR2** Vars: p_T , m_T, E_T^{miss}, $d\varphi$ Exactly 1 lepton with: p_T>20, tightID&! isoMedium E_T^{miss}>0 m_T>0 ptvarcone20/pt > 0.1 && sliced
ZR Vars: M_{ll}, d_0 tightID, isoMedium 2 leptons p_T>20, OS, SF, 66<M_{ll}<116	**ZttR** Vars: d_0 tightID, isoMedium 2 leptons p_T>20, OS, OF, M_{ll}<85

Control plots: SR and ZR





- Have some discrepancies for pT and MET variables: critical for TMVA classification
- The d0 shows same bias / resolution structure for SR and ZR
- PowhegPythia8EvtGen_AZNLOCTEQ6L1

Cross check with pTWanalysis

MJ Introduction

- Algorithm is same as in ATL-COM-PHYS-2019-076
- MJ Background Estimation
  - The shape of MJ background
  - The total number of MJ background
- A data-driven method
  - Reverse two independent cuts and 3 control region (CR)

$$\frac{N_{CR3}}{N_{CR1}} = \frac{N_{SR}^{BKG}}{N_{CR2}}$$

  - Here we can do the calculation bin-by-bin and get both the shape and the total number of MJ background
  - We can take other BKG into the consideration, so we have

$$T = \frac{N_{CR3}^{Data} - N_{CR3}^{EW\ BKG}}{N_{CR1}^{Data} - N_{CR1}^{EW\ BKG}} = \frac{N_{SR}^{MJ\ BKG}}{N_{CR2}^{Data} - N_{CR2}^{EW\ BKG}}$$

MJ Introduction

$$T = \frac{N_{CR3}^{Data} - N_{CR3}^{EW\ BKG}}{N_{CR1}^{Data} - N_{CR1}^{EW\ BKG}} = \frac{N_{SR}^{MJ\ BKG}}{N_{CR2}^{Data} - N_{CR2}^{EW\ BKG}}$$

- Strategy
  - For FR and CR1, both M_T and E_T^{miss} cuts are removed
  - Additional u_T cut for CR1 and FR to suppress jet activity
    - u_T < [15,20,30,10000]
  - Choose 6 different slices of CR, with different isolation region
    - [0.1,0.15,0.2,0.25, 0.3,0.35,0.4]
  - A parameter fitting is used instead of the direct calculation to get the parameter T
    - $N_{FR}^{Data} = \alpha N_{FR}^{EW\ BKG}$ + T (N_{CR1}^{Data} - $N_{CR1}^{EW\ BKG}$)
  - α is also a parameter in the fitting, but it should be close to 1 within the uncertainty
  - Extrapolate $N_{SR}^{MJ\ BKG}$ = T (N_{CR1}^{Data} – $N_{CR1}^{EW\ BKG}$) by a linear relationship to 0

Isolation Correction on the Recoil Measurement

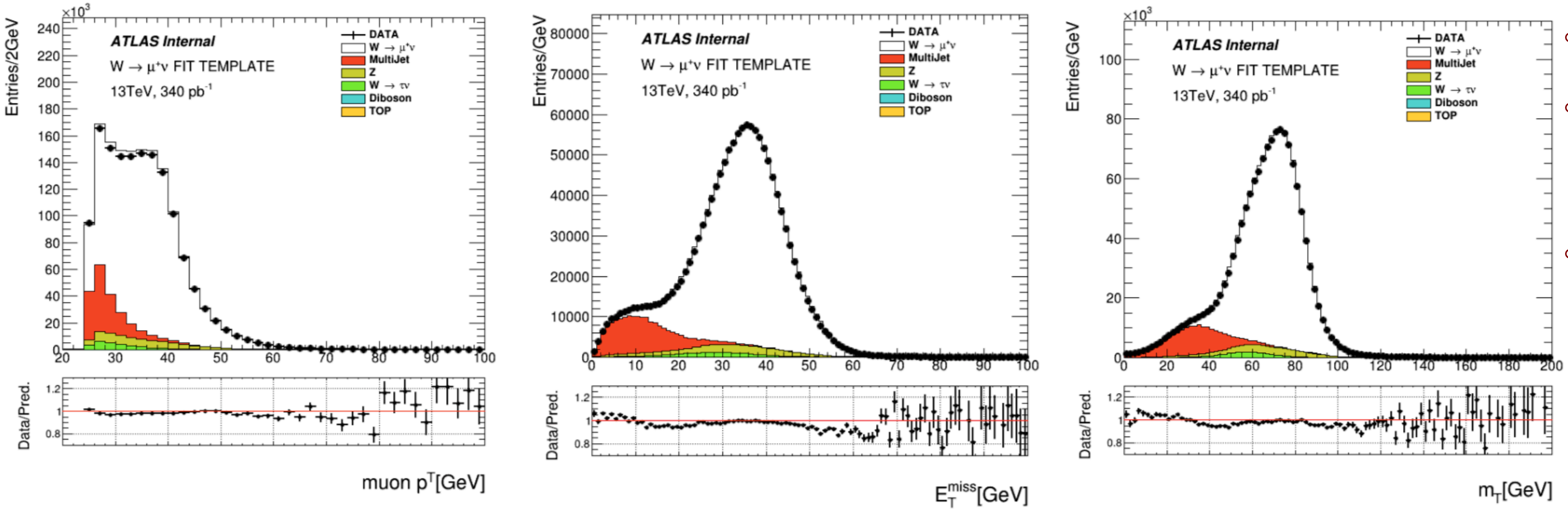
- Lepton removal in the recoil measurement
  - Excluding a cone of ΔR = 0.2 around the selected leptons
  - Replaced by a same size cone in the same η but away from lepton or the hard activity
- For leptons which is anti-isolated, it is close to the hard activity
  - This replacement approach fails
- The difference is fixed by a isolation correction

$$u_T = u_{base} + u_{iso}$$
$$u_{iso} = ptcone20 * n_l$$

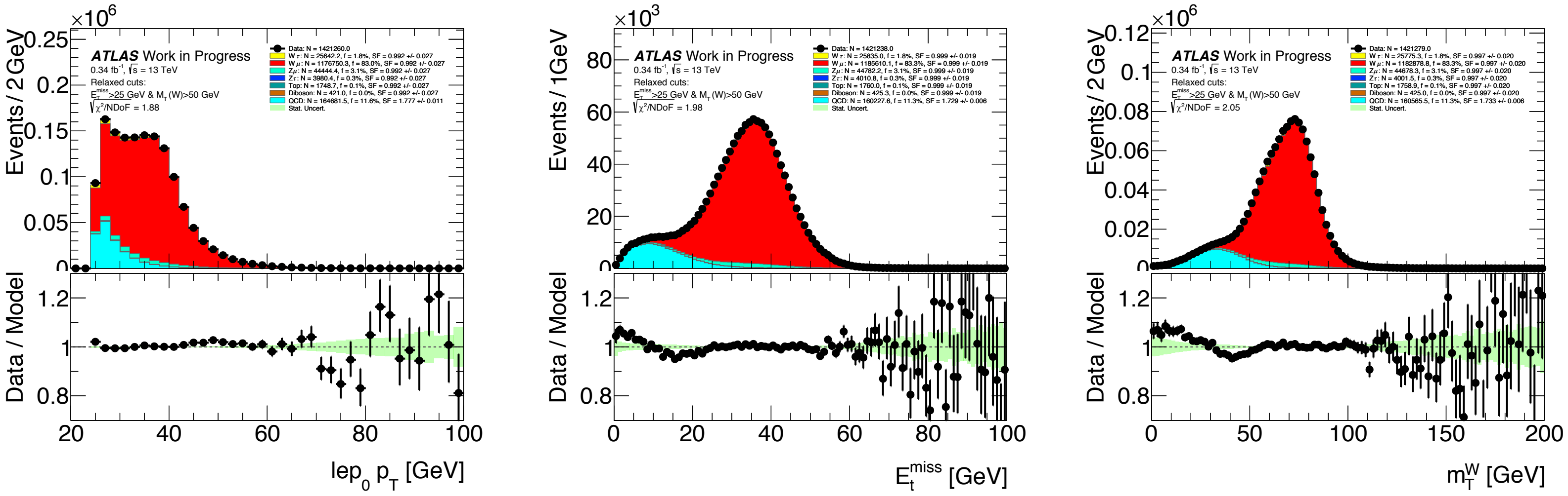
  - $ptcone20$ is used to correct the hard activity in the cone which is originally removed.
  - $ptvarcone20$ is the isolation WP we are using now
- This correction is now applied to all the anti-isolated leptons

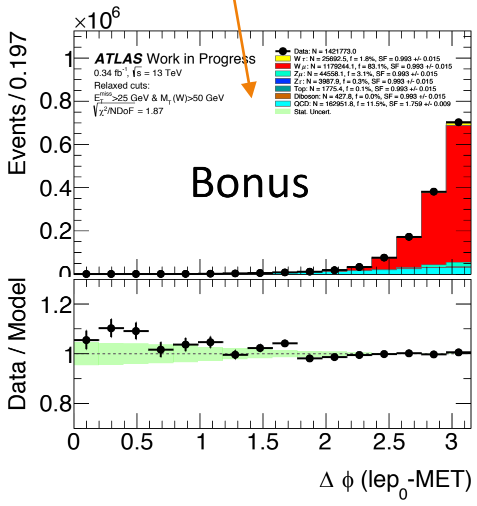
(Validation pTWanalysis) FR first slice for W->numu+

Figure 7.17: Multi-jet background template fits performed in distributions of p_T^e (top), MET (middle) and m_T (bottom) with the MJ template obtained from isolation slice 0.10<ptvarcone20/pt<0.20. The fits are presented



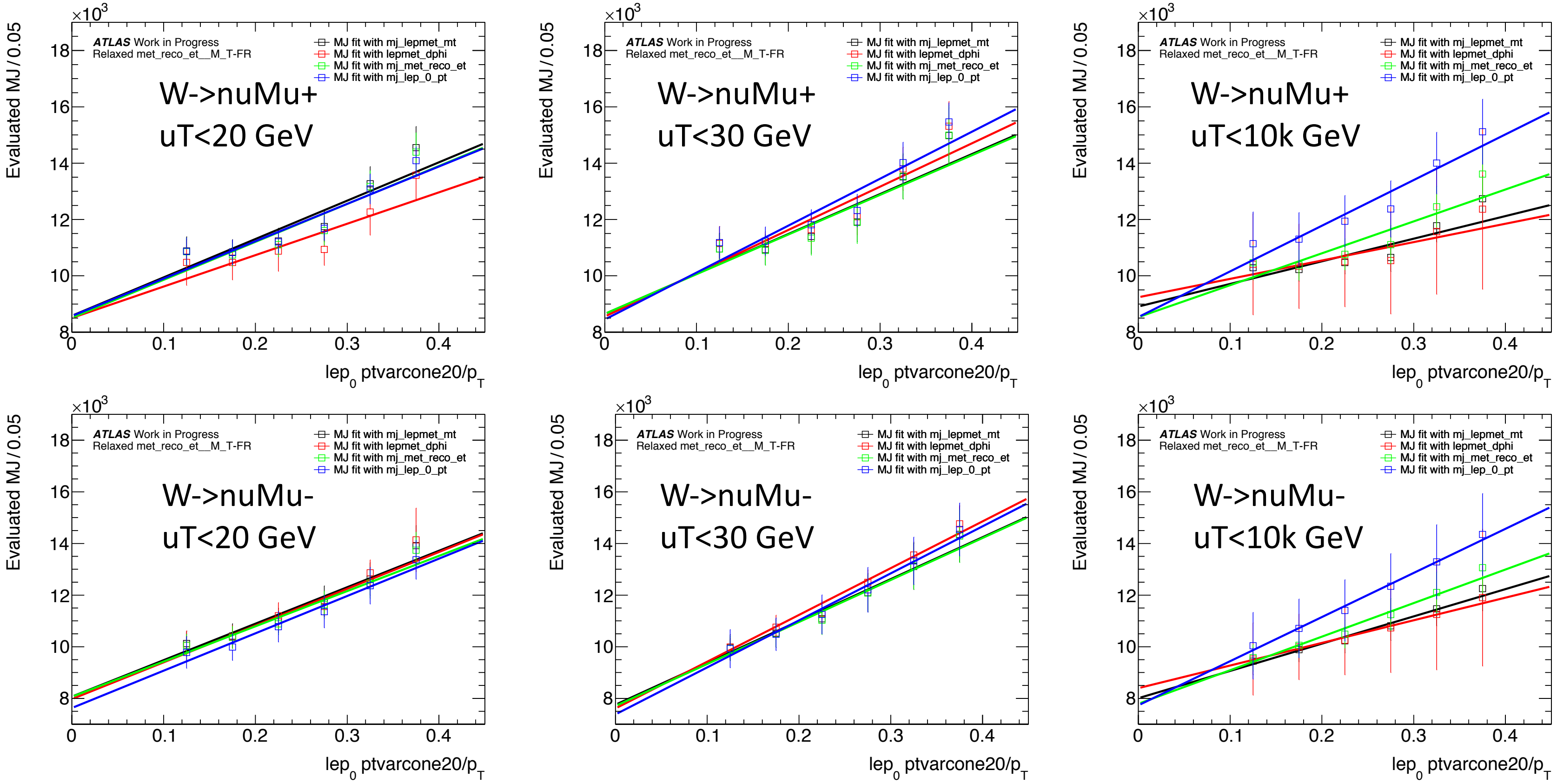
- **We reproduce plots from the note!**
- Small difference comes from miniTrees production versions
  - April2019 -> March2020
- Have additional variable for extrapolation





(Validation pTWanalysis) Fine scans

- The error bars are multiplied by $\sqrt{x^2/ndf}$
- We calculate yield and yield's error as weighted average:
  - same approach as been used in early Run2 paper

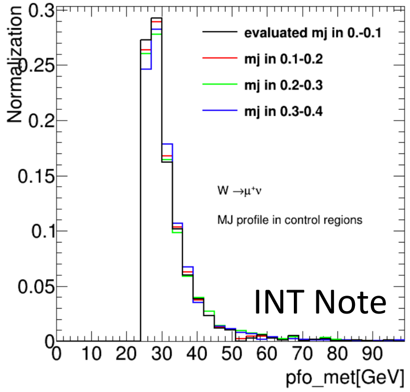


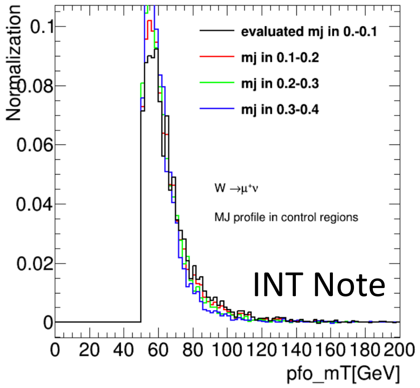
Extrapolation point	at 0 %	at 5 %
Wplusmunu	8605 +/- 224 (+/-2.6%)	9258 +/- 270 (+/-2.92%)
Wminusmunu	7820 +/- 218 (+/-2.8%)	8566 +/- 265 (+/-3.09%)

INT Note at 0%

$$n_{\mathrm{MJ}}^{\mu+} = 9044 \pm 796,$$
$$n_{\mathrm{MJ}}^{\mu-} = 9053 \pm 617$$

(Validation pTWanalysis) Multi-jet shape extraction



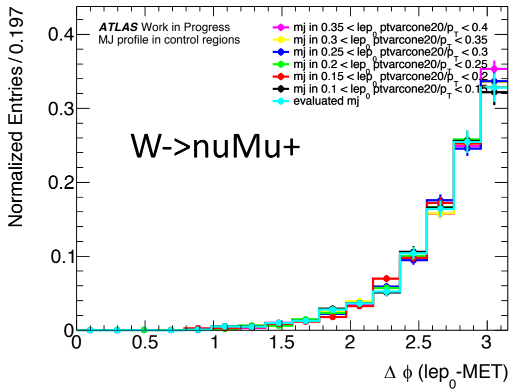


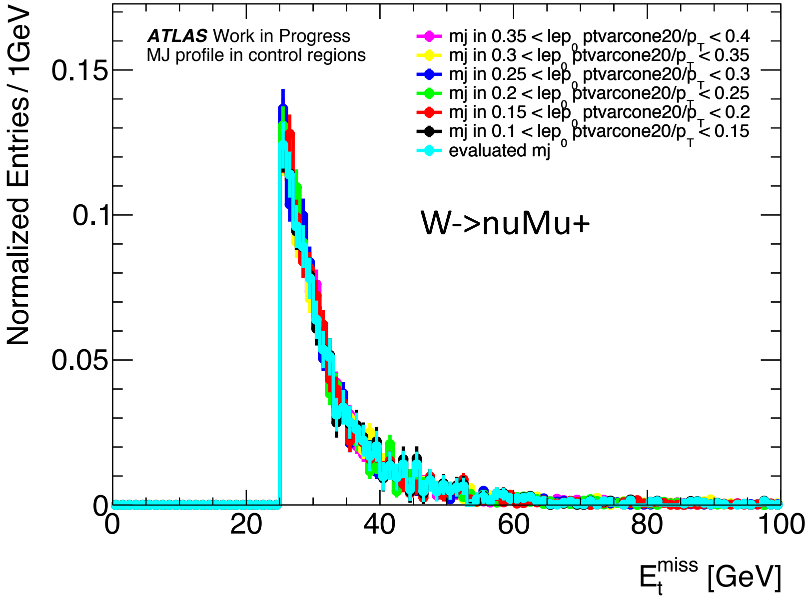
$$H_{MJ}^{[0.1,0.2]}[X] = H_{data}^{[0.1,0.2]}[X] - H_{MC}^{[0.1,0.2]}[X];$$

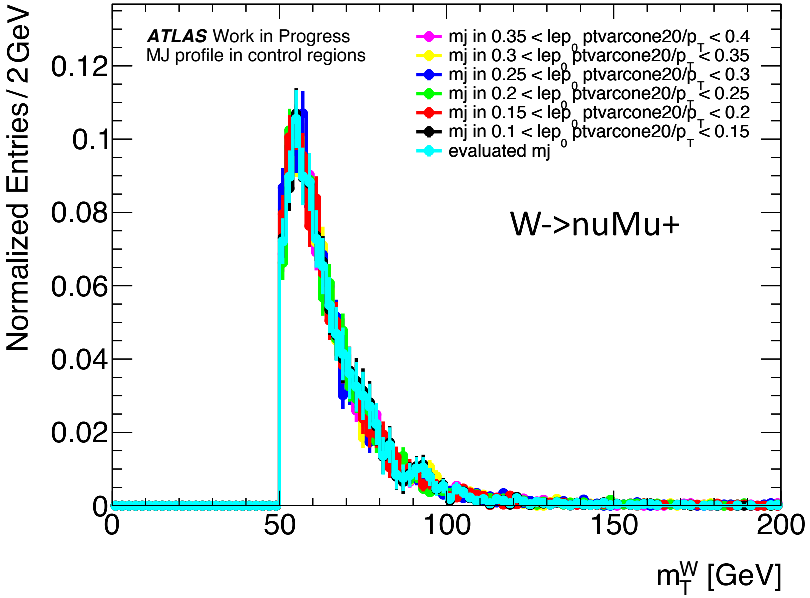
$$\Delta[X] = 1/2\left[(H_{MJ}^{[0.1,0.2]}[X] - H_{MJ}^{[0.2,0.3]}[X]) + (H_{MJ}^{[0.2,0.3]}[X] - H_{MJ}^{[0.3,0.4]}[X])\right]$$

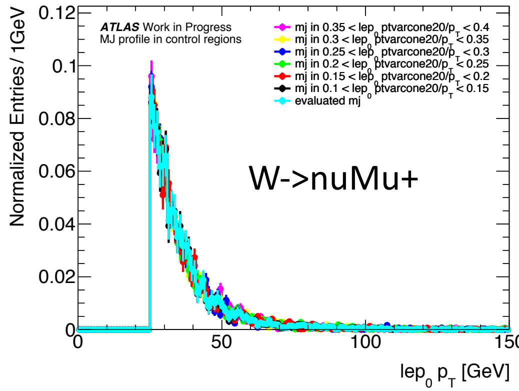
$$H_X^{sig} = H_X^{[0.1,0.2]} - \Delta[X]$$

- Given the large statistical uncertainty and the linear approximation used, the shift Δ[X] applied is assigned a 100% relative uncertainty

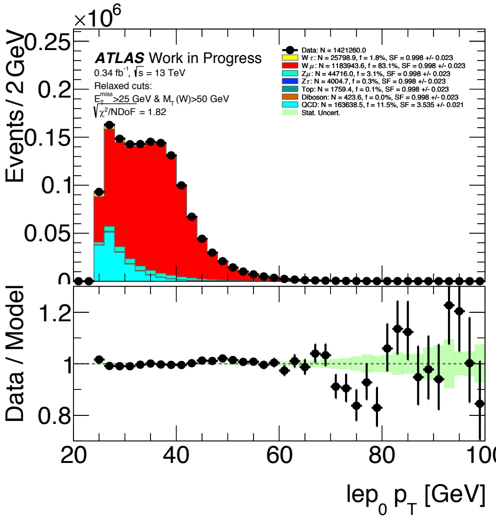


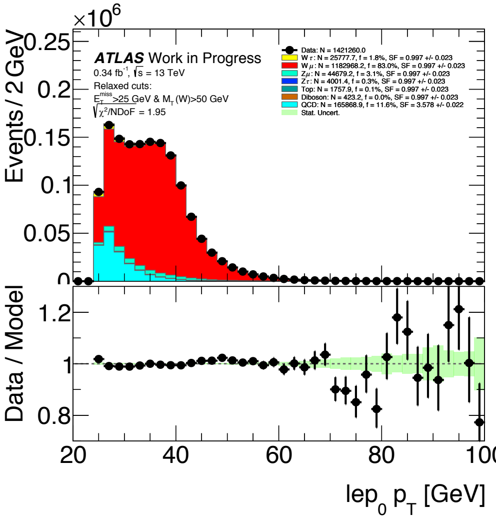


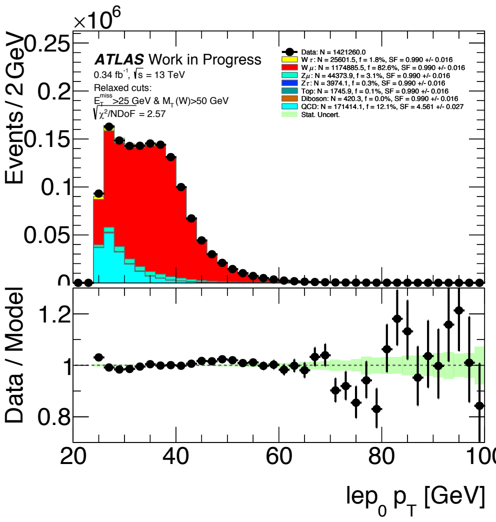


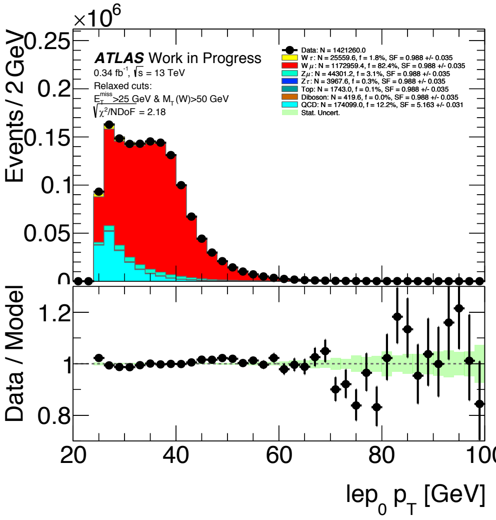


(Validation) FR degradation over isolation slices scan (1)







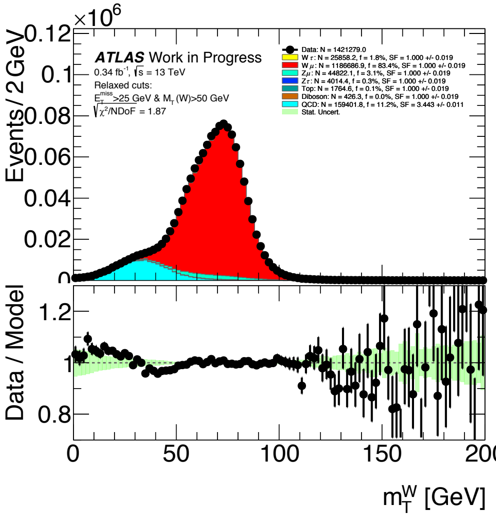


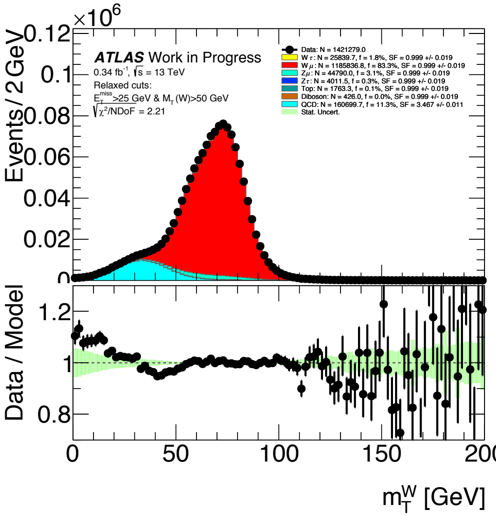
0.1 < 0.15

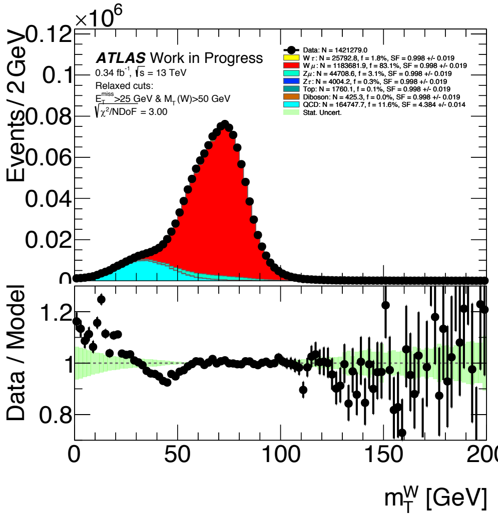
0.15 < 0.2

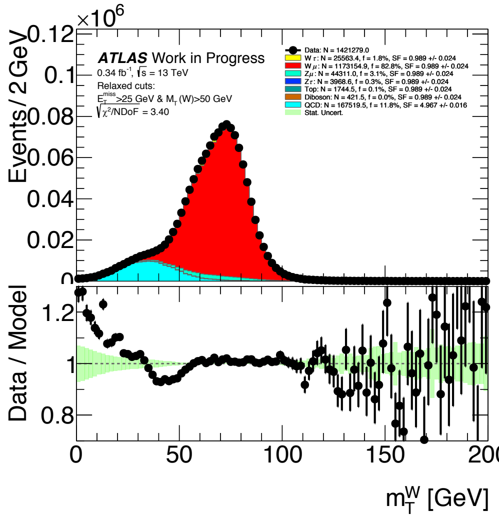
0.3 < 0.35

0.35 < 0.4

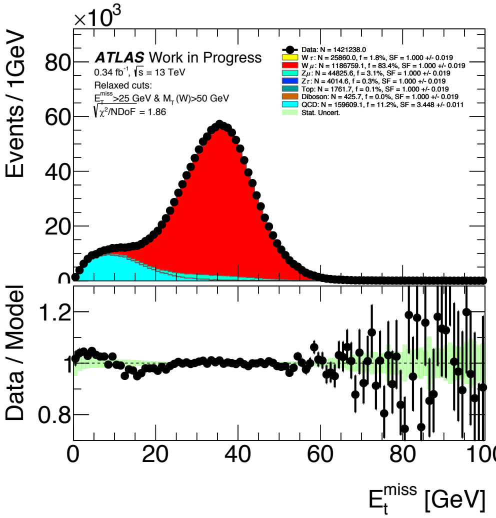


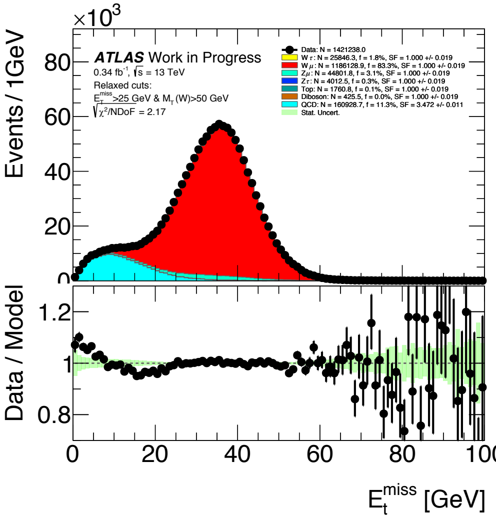


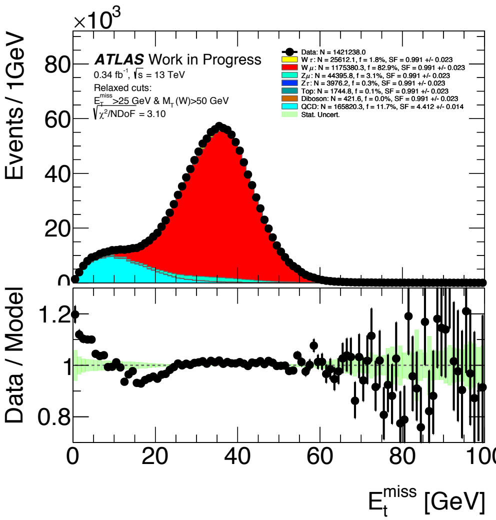


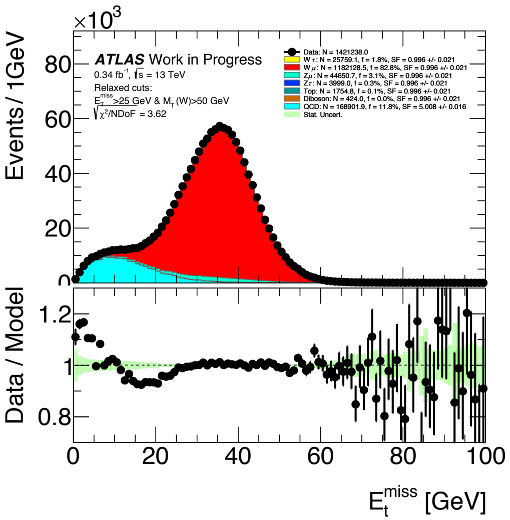


(Validation) FR degradation over isolation slices scan (2)







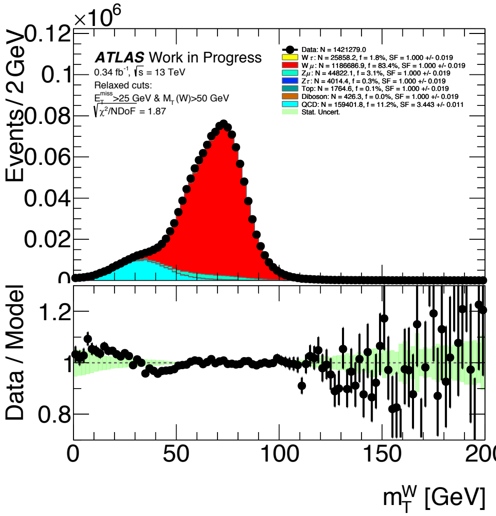


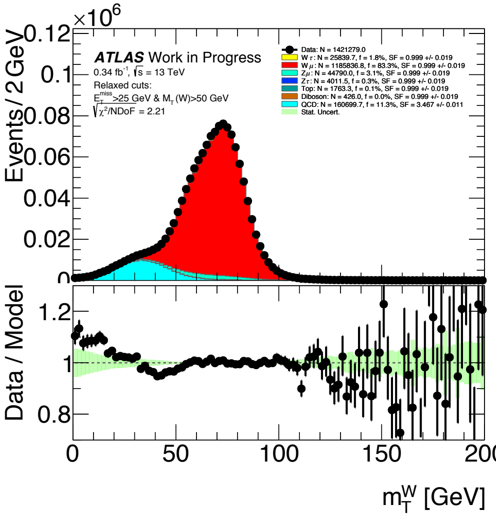
0.1 < 0.15

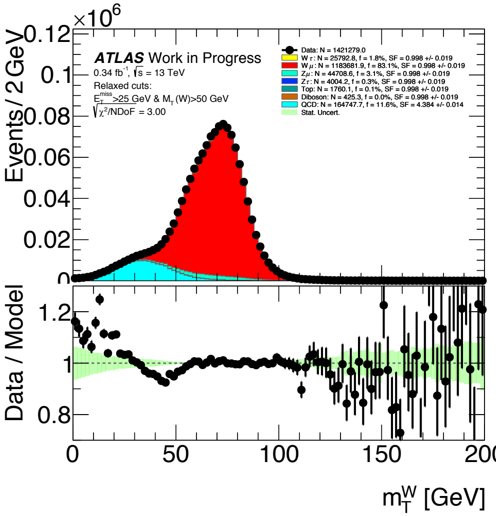
0.15 < 0.2

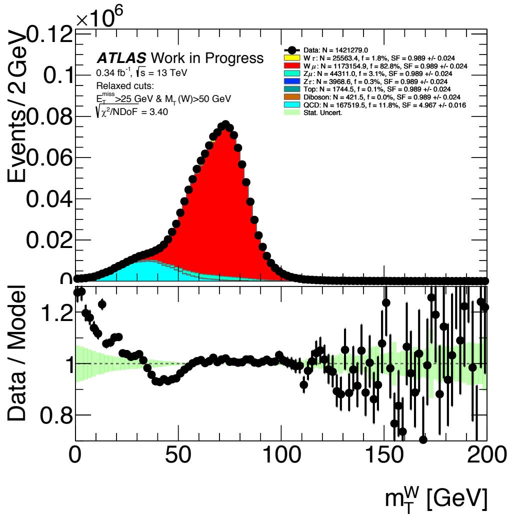
0.3 < 0.35

0.35 < 0.4

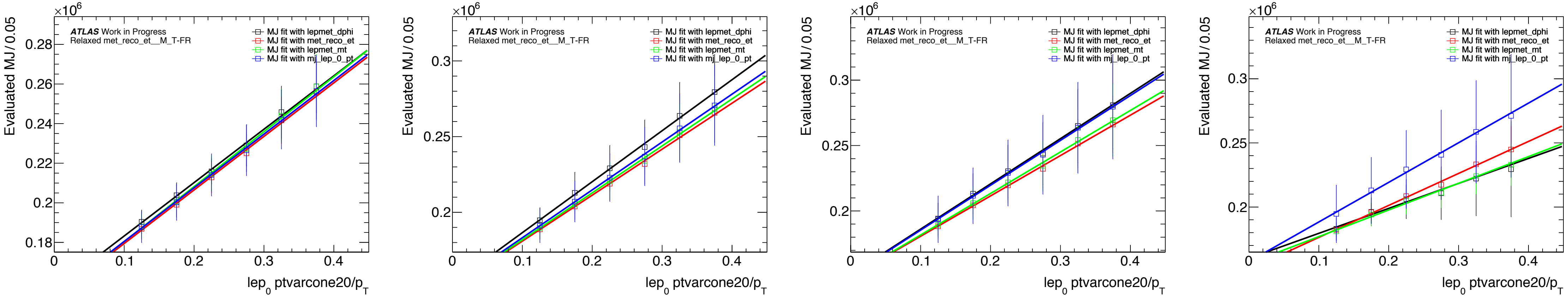






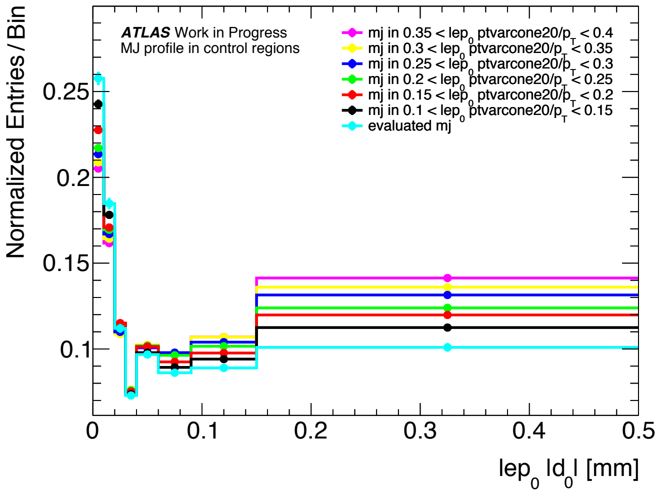


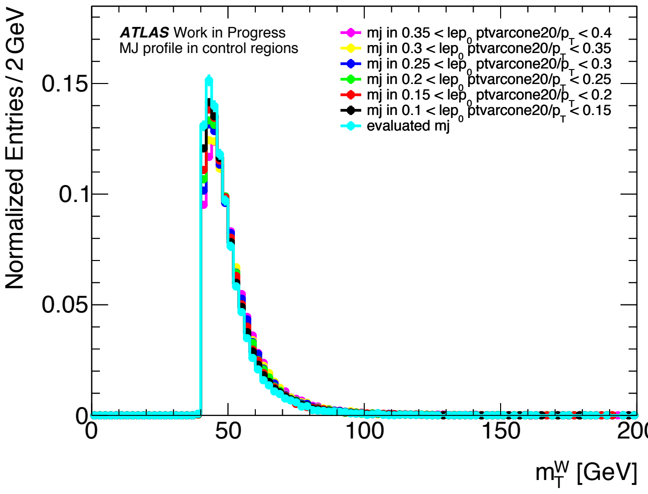
MJ estimation in WBR analysis



Extrapolation point at 5 %

152840 +/- 3234 (+/-2.11%)

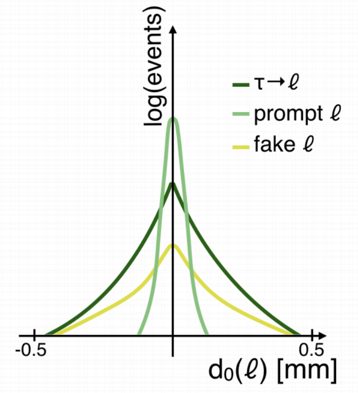


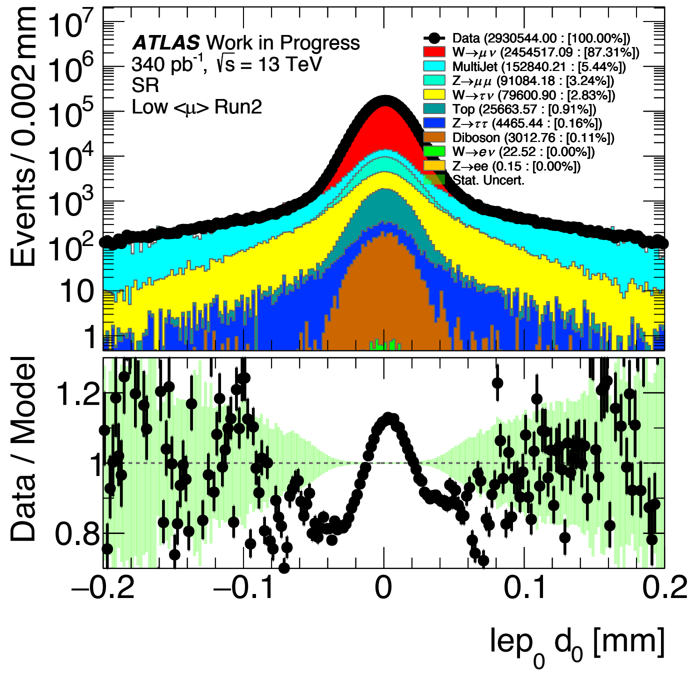


- MJ is one of the biggest sources of uncertainty for the final measurement
- Looking for variables to suppress MJ in the SR :
  - ptcone40 – isolation variable
  - MMBS (Muon Momentum balance significance) – the difference in momentum between the ID and MS standalone measurements with respect to the uncertainty sigma on energy lost in the calorimeter system.

The d0: introduction

- We define 3 types of tau decays
  - **prompt** (W) leptons are leptons produced in $W \rightarrow l\nu$ decays
  - **tau** are leptons produced in the leptonic decay chain $W \rightarrow \tau\nu \rightarrow l\nu$
  - **prompt** (non W) are leptons from Z^0 or other EWK process where these leptons do not originate from W decays: for example di-boson, single top or $t\bar{t}$ process.
  - **fake** are reconstructed leptons from all other sources, including wrongly identified leptons.
- IBL alignment problem:
  - bias and mismatching data/MC d0 resolution
  - Needs to be fixed, and validated (next slides)
- No d0 and/or z_0 cuts
  - Lot of bad reconstructed vertexes and cosmic background
- We derive and apply d0 corrections for prompt and tau decays separately
  - Needs to take life-time into account
- Performed as a function of pT and eta bins:
  - 27 kinematic bins in total for prompt → use ZR as control region
  - 8 kinematic bins in total for tau → use ZttR as control region
- Assume that d0 distribution is a Gaussian
  - The d0 tails has not-Gaussian nature!





The d0: corrections

- Strategy
  - Take clean ZR region for prompt leptons
    - Slice to 27 kinematic bins in total
    - Derive bias corrections →
      - apply directly to the Data SR
    - Derive Data/MC resolution corrections →
      - apply to the SR *prompt* MC samples
  - To take tau lifetime into account use ZttR for leptons originated from tau decays
    - Slice to 8 kinematic bins in total
    - Derive Data/MC resolution corrections →
      - apply to the SR *tau* MC samples
  - Resolution corrections on per event basis:

$n_k = n_{p_T} + 9 * n_\eta$

- 9 p_T^μ bins
  - [20-25), [25-30), [30-35), [35-40), [40,45), [45, 50), [50,65), [65-80), [80- 250)
- 3 η^μ bins
  - [0, 0.8), [0.8, 1.5), [1.5, 2.5)

$n_k = n_{p_T} + 4 * n_\eta$

- 4 p_T^μ bins
  - [20, 25), [25, 35), [35,45), [45, 250)
- 2 η^μ bins
  - [0, 1.0), [1.0, 2.5)
- Correction from Ztt derived from lep_0 (muon) only, and apply to lep_0 only. (lep_1 is electron)

$$F^\ell(d_0) = \sum_{i=0}^{9} \sum_{j=0}^{2} \left(\bar{d}_{0ij}(MC) + (d_0 - \bar{d}_{0ij}(MC)) * \frac{\sigma_{ij}(RD)}{\sigma_{ij}(MC)} \right)$$

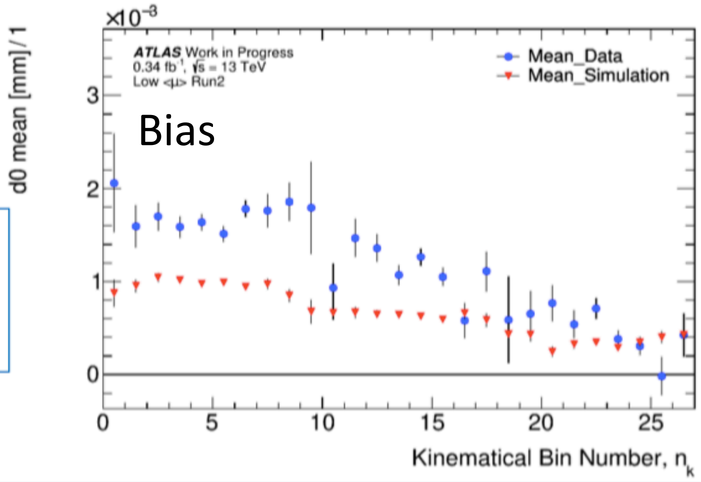
where $\bar{d}_{0ij}(MC)$ stands for mean value of d_0 distribution in Monte Carlo

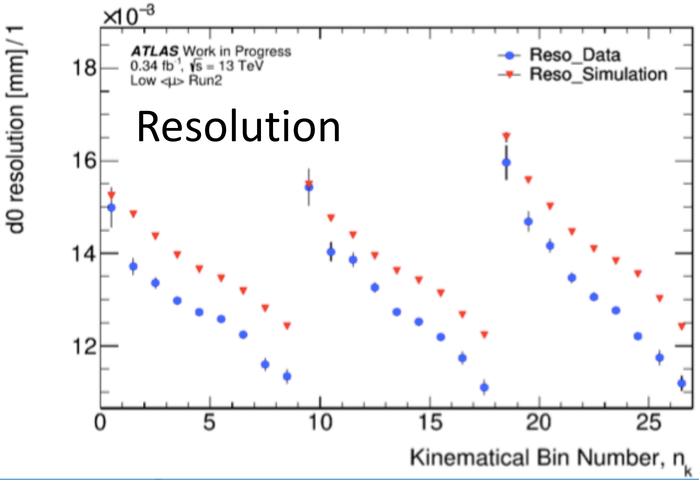
The d0 studies in ZR

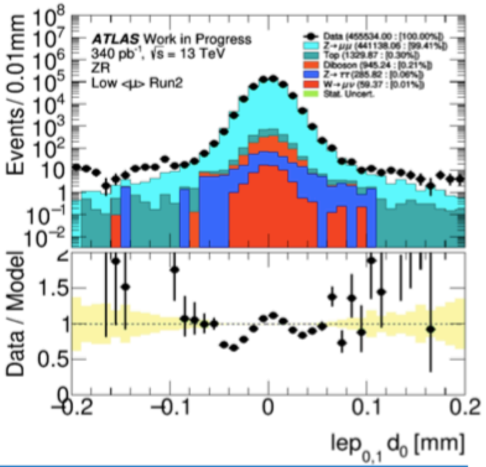
$$n_k = n_{p_T} + 9 * n_\eta$$

- 9 p_T^μ bins
  - [20-25), [25-30), [30-35), [35-40), [40,45), [45, 50), [50,65), [65-80), [80- 250)
- 3 η^μ bins
  - [0, 0.8), [0.8, 1.5), [1.5, 2.5)

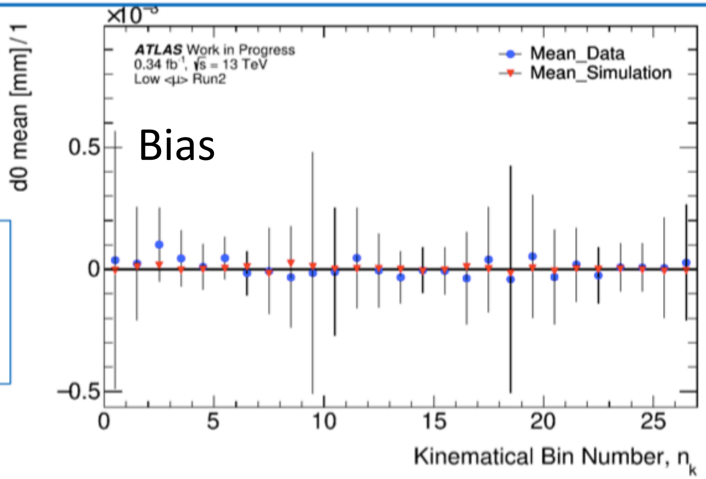
before

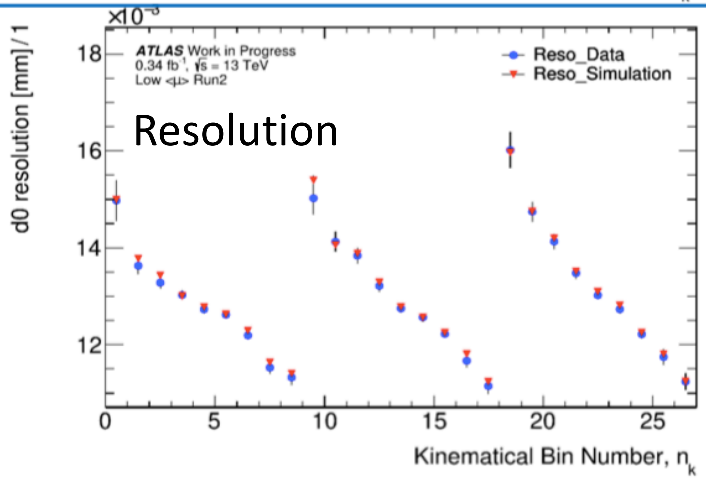


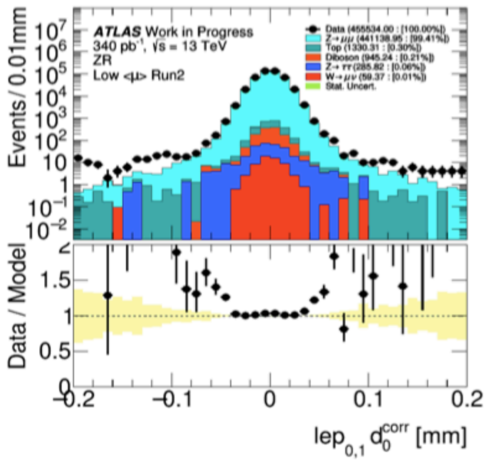




after







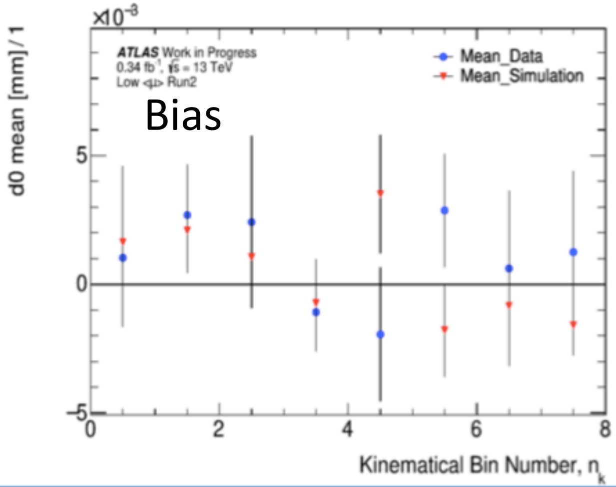
- No d0 and/or z_0 cuts
  - Lot of bad reconstructed vertexes and cosmic background on the tails

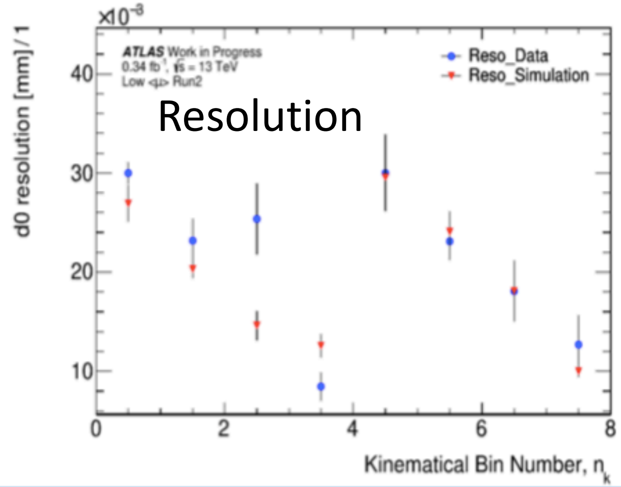
The d0 studies in ZttR

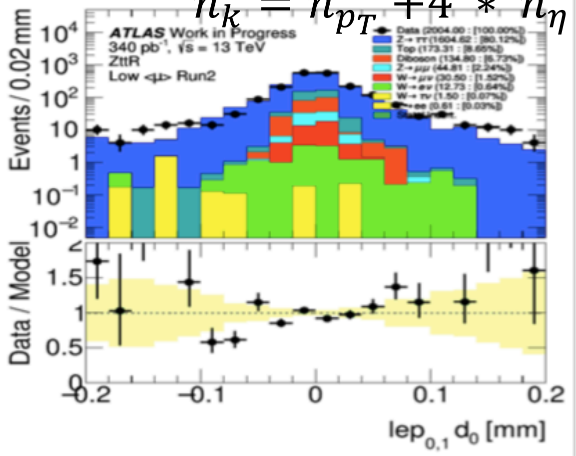
- 4 p_T^{μ} bins
  - [20, 25), [25, 35), [35,45), [45, 250)
- 2 η^{μ} bins
  - [0, 1.0), [1.0, 2.5)
- Correction from Ztt derived from lep_0 (muon) only, and apply to lep_0 only. (lep_1 is electron)

$n_k = n_{p_T} + 4 * n_\eta$

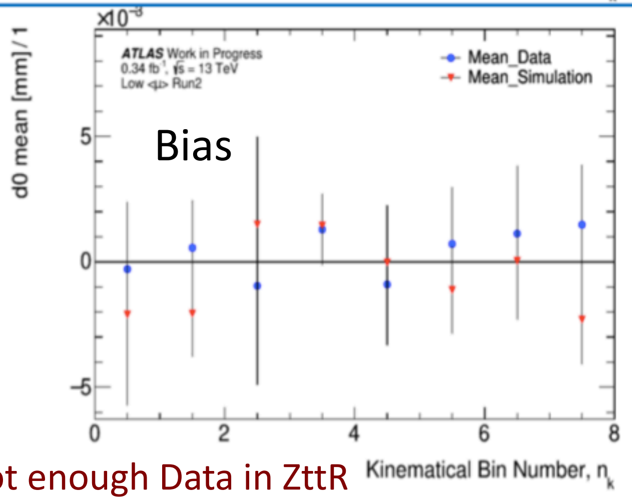
before

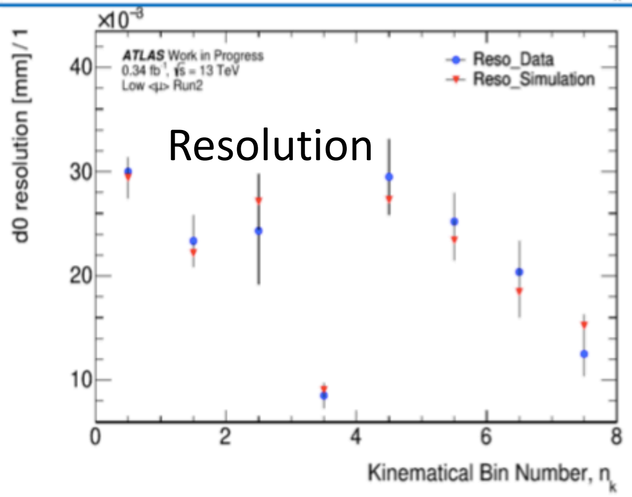


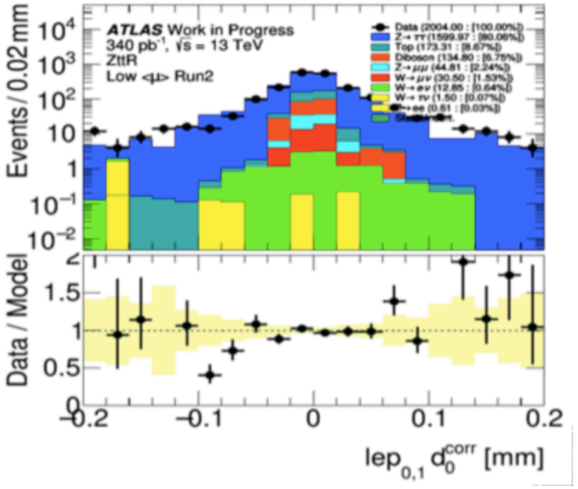




After (Ztt to Ztt)







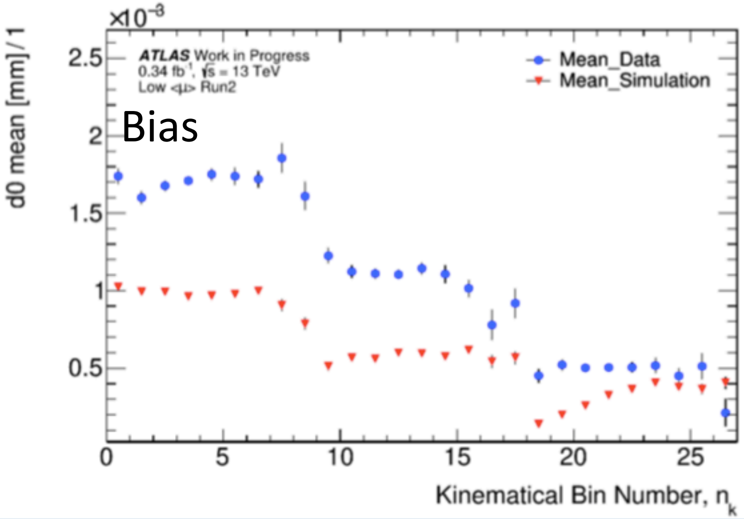
- Not enough Data in ZttR
  - 2k events vs. ~270k in Top analysis for Run2 data
- No d0 and/or z_0 cuts
  - Lot of bad reconstructed vertexes and cosmic background on the tails

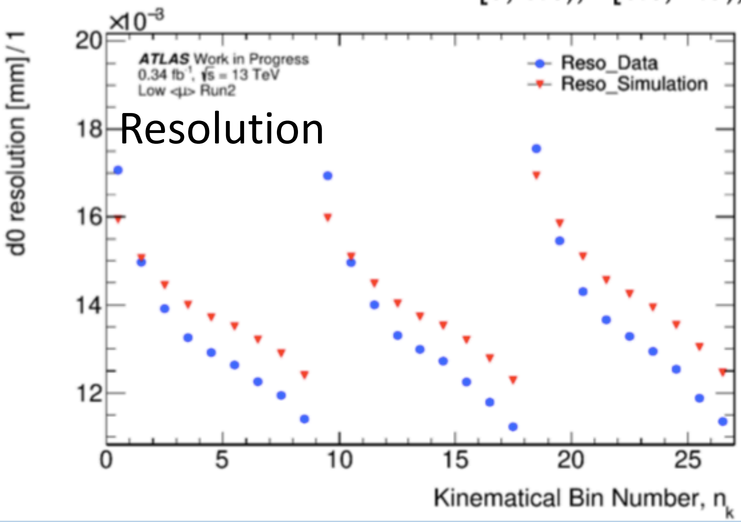
Appling d0 corrections to SR

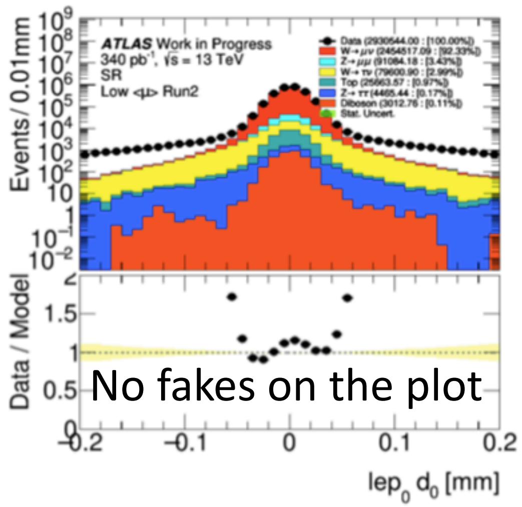
- 9 p_T^{μ} bins
  - [20-25), [25-30), [30-35), [35-40), [40,45), [45, 50), [50,65), [65-80), [80- 250)

- 3 η^{μ} bins
  - [0, 0.8), [0.8, 1.5), [1.5, 2.5)

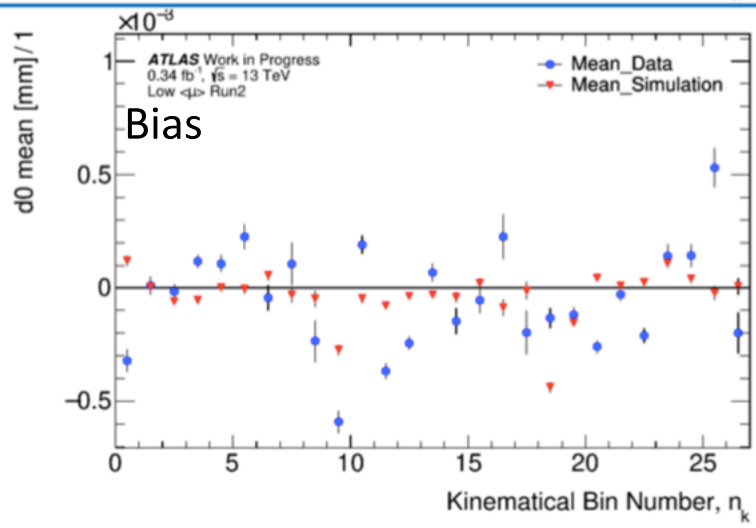
before

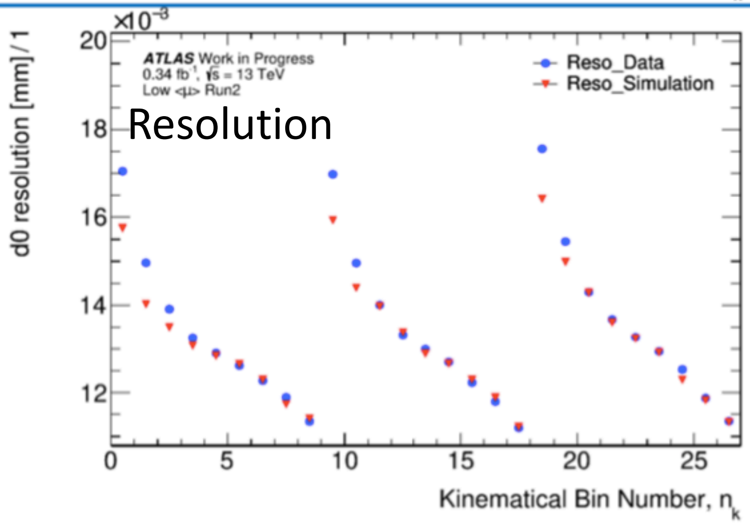


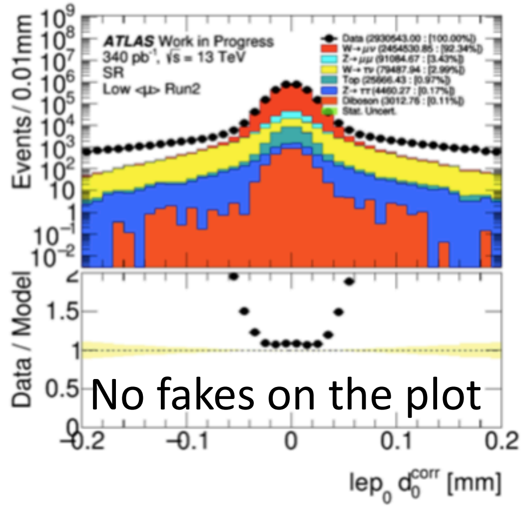




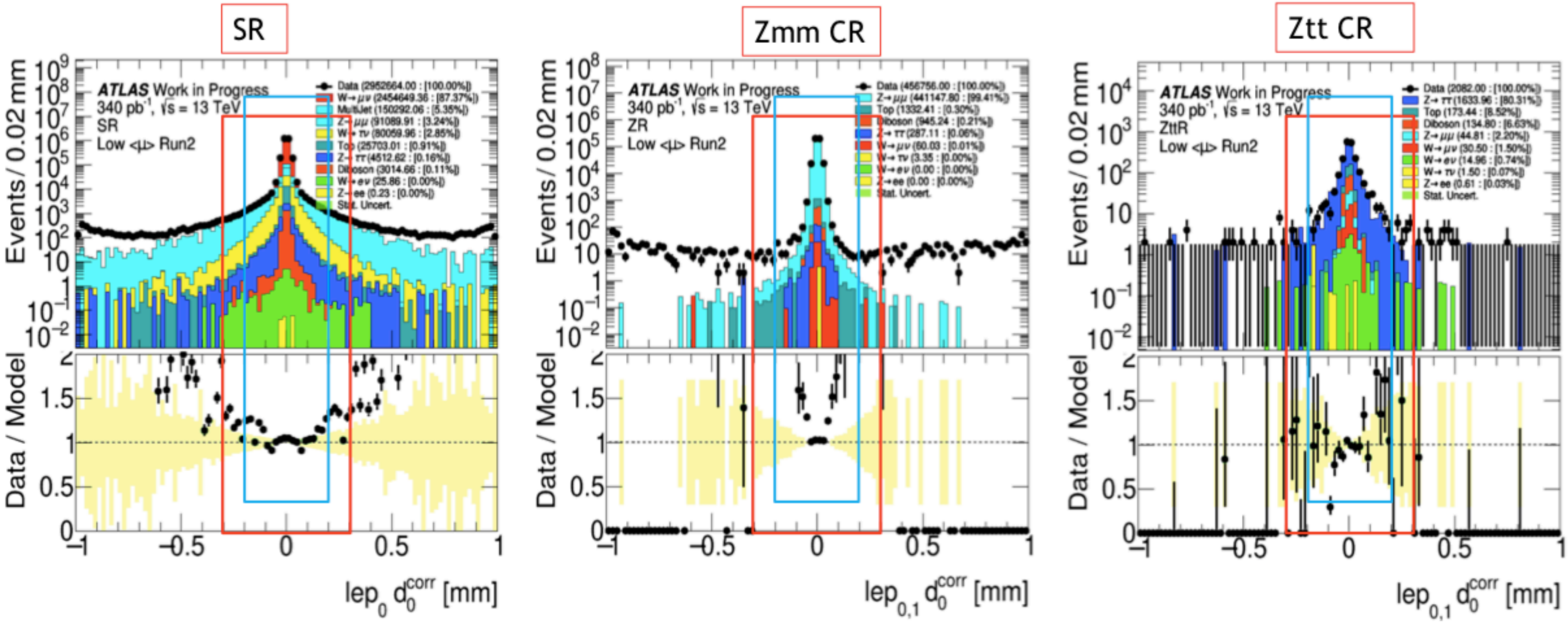
From both Zmm and Ztt







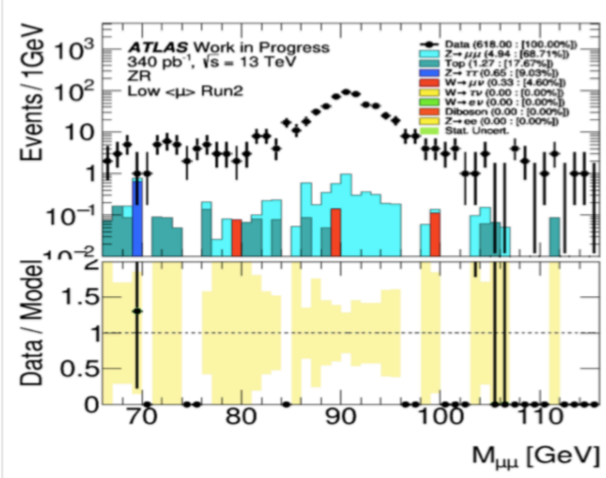
The d0 studies: extended range



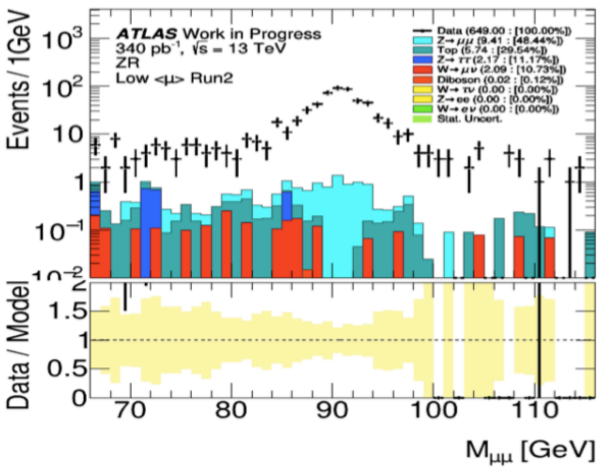
- Correction derived from an approximation of a Gaussian. Only the core where most of the events are, were corrected.
- Not enough MC in region beyond the red box in both Zmm CR and Ztt CR.

The d0 tails in extended range

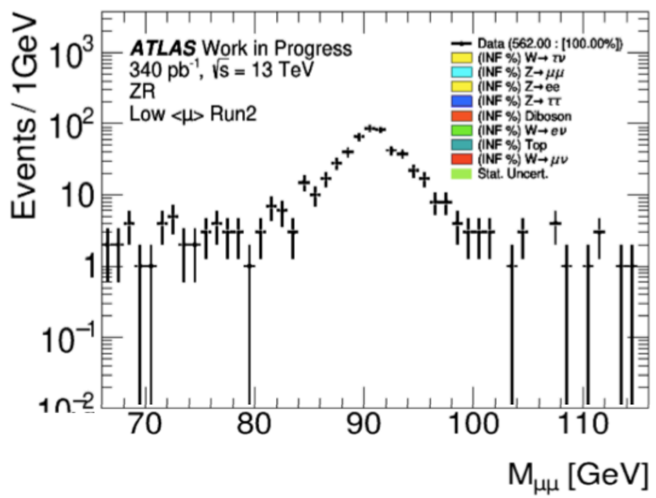
|d0_lep0|>0.2 [mm]



|d0_lep1|>0.2 [mm]

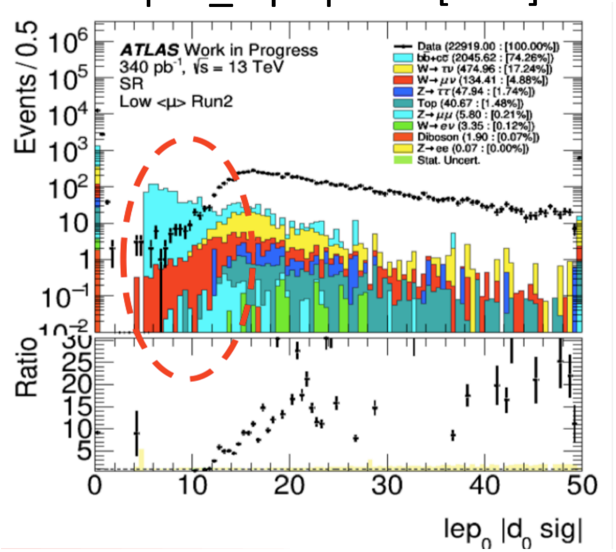


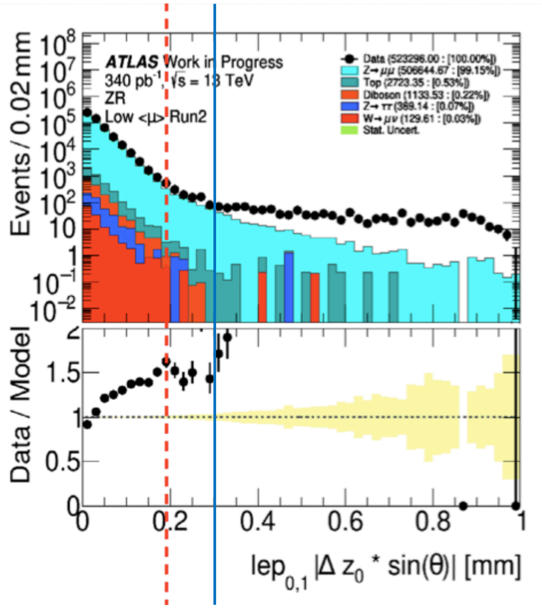
|d0_lep0|>0.2 [mm] && |d0_lep1|>0.2 [mm]



QCD_MC
(DSID's 361250, 361251)

|d0_lep0|>0.2 [mm]





- We see perfect Z peak in the d0 tails in ZR
- For SR we verified that difference comes not from MJ background
- Next steps:
  - investigate cuts |z0sin(theta)| < 0.3 and $|d_0|$<0.5
  - look at the track/vertex fit related variables to see if there is any handle we can use

Another approach?

- The Top group analysis used template method
- For prompt leptons:
  - Determine shape of |d0| in 27 kinematical bins from data using $Z \rightarrow \mu\mu$ selection
    - subtract remaining backgrounds estimated in MC
    - use shapes as prompt muon templates in signal region
    - residual resolution correction from data
  - Systematic uncertainty due to application of |d0| shape from Z boson decays to $t\bar{t}$ signal region
    - estimated by ratio of |d0| between $t\bar{t}$ and $Z \rightarrow \mu\mu$
- For leptons produced in tau-lepton decays
  - Use templates from the "tau" MC sources in the SR
  - Apply resolution correction only
  - Check of Impact parameter of τ-decays leptons with $Z \rightarrow \tau\tau$ region
- We have small ZttR statistics:
  - 2k events vs. ~270k in Top analysis for Run2 data
  - It would be hard to make same validation with ZttR

p_T bin number (n_{p_T})	p_T range (GeV)	p_T bin number (n_{p_T})	p_T range (GeV)
0	5 – 10	6	40 – 50
1	10 – 15	7	50 – 65
2	15 – 20	8	65 – 100
3	20 – 25	9	100 – 250
4	25 – 30	10	> 250
5	30 – 40		

$\|\eta\|$ bin number (n_η)	$\|\eta\|$ range
0	0 – 0.8
1	0.8 – 1.5
2	1.5 – 2.5

$$F^{pr}(d_0) = \sum_{i=0}^{11}\sum_{j=0}^{2} r_{ij}^{pr} F_{ij}^{pr}(d_0)$$

$$\sigma_{ij}^{sm} = \sqrt{|\sigma_{ij}^2(RD) - \sigma_{ij}^2(MC)|}$$

After random smearing:

$$\delta_{ij}(d_0) = f_{ij}^{sm}(d_0) - f_{ij}^{ns}(d_0).$$

$$\text{If } \sigma_i(RD) > \sigma_i(MC), \quad F_{ij}^{\tau}(d_0) = f_{ij}^{ns}(d_0) + \delta_{ij}(d_0) = f_{ij}^{sm}(d_0).$$

$$\text{If } \sigma_{ij}(RD) < \sigma_{ij}(MC), \quad F_{ij}^{\tau}(d_0) = f_{ij}^{ns}(d_0) - \delta_{ij}(d_0)$$

$$F^{\tau}(d_0) = \sum_{i=0}^{11}\sum_{j=0}^{2} r_{ij}^{\tau} F_{ij}^{\tau}(d_0).$$

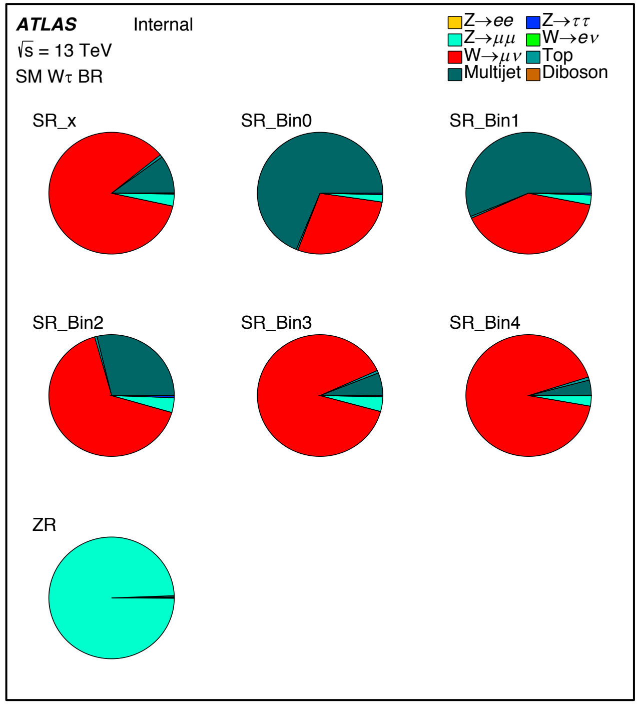
Asimov data: 2D hist [mT x |d0|] and fit construction

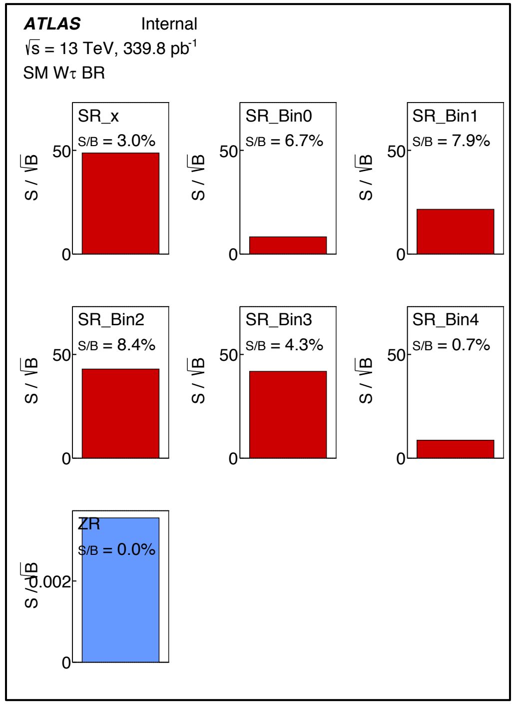
v20200821_dponomar

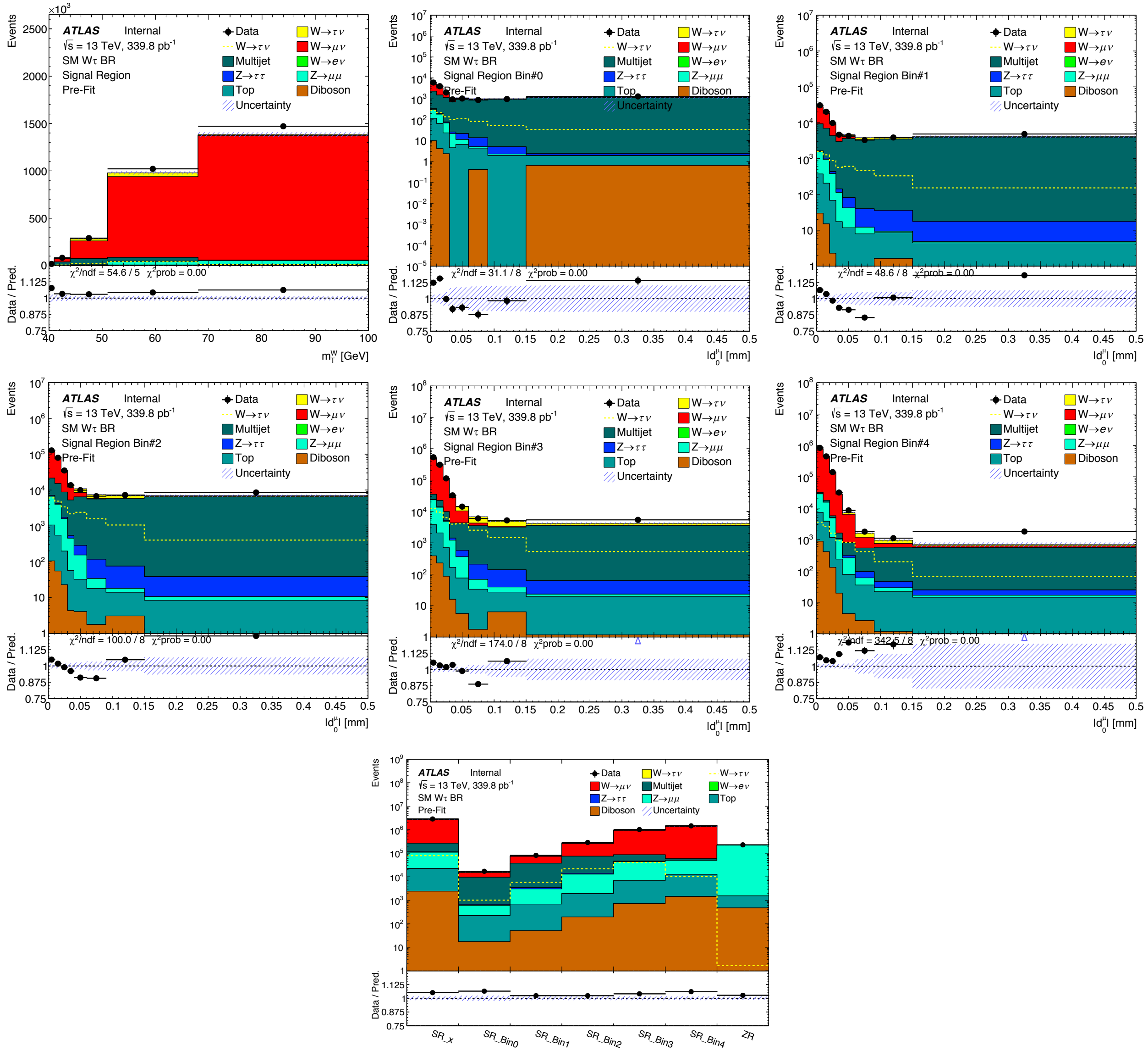
The overall rate of the W events is allowed to float along with the property of interest — the ratio of $W \rightarrow \tau\nu$ and $W \rightarrow l\nu$ events.

SR	μ_{SIG}, μ_W	$[\mu_{SIG} W_t + W_\ell] \cdot \mu_W + MC \cdot \mu_Z + QCD \cdot \mu_{QCD}$
ZR	μ_Z	$MC \cdot \mu_Z$

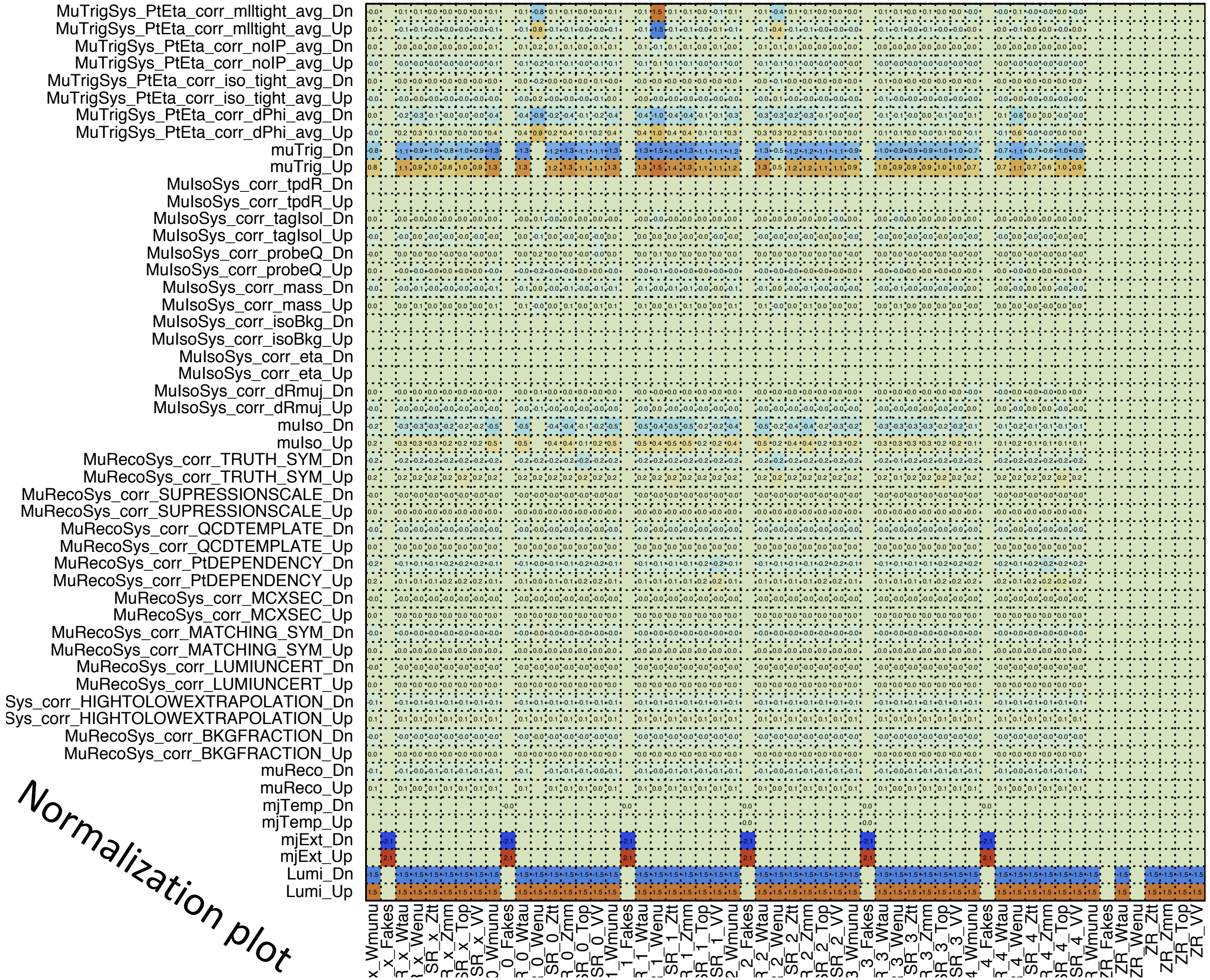
$$\mu_{SIG} = \mathcal{R}_{W_\ell} = \frac{\mathcal{B}(W \rightarrow \tau\bar{\nu}_\tau)}{\mathcal{B}(W \rightarrow \ell\bar{\nu}_\ell)}$$

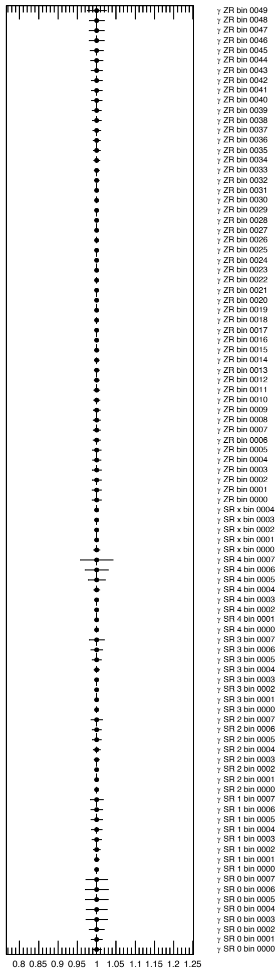


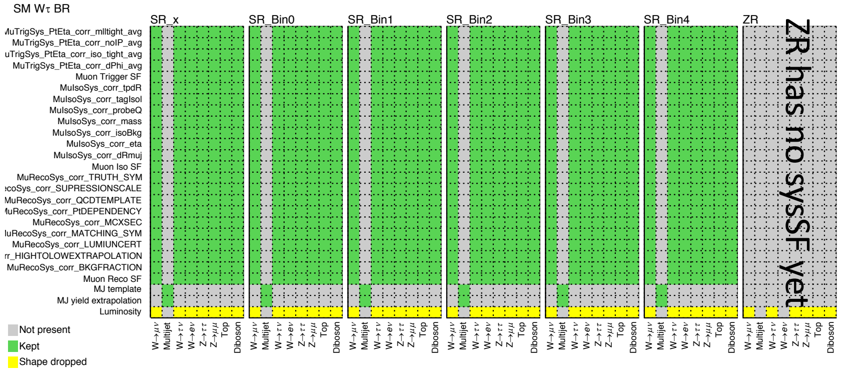


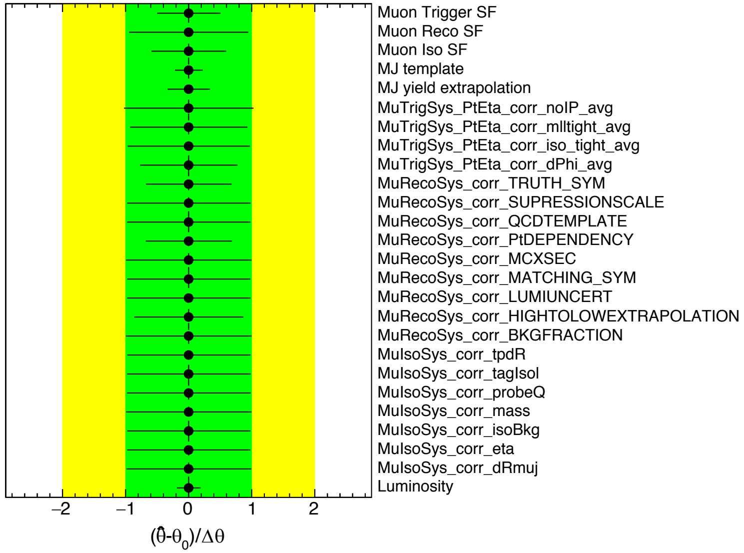


Asimov data: Fit quality







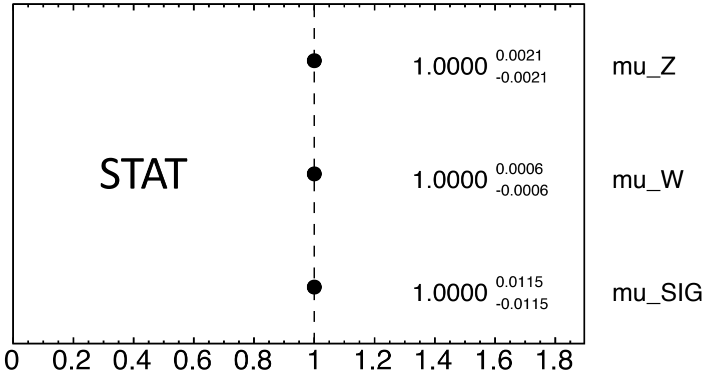


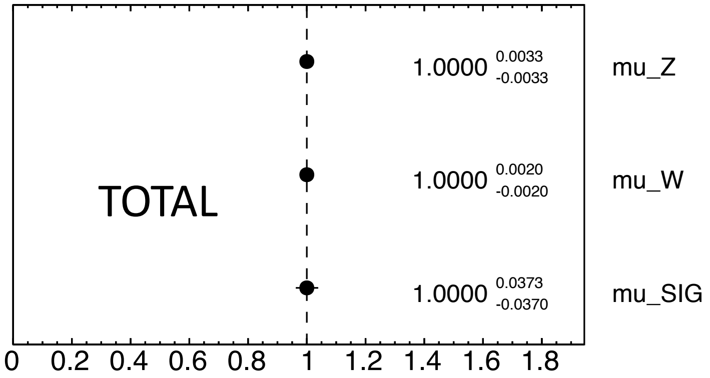
- No tree systematics: MUON_SCALE, MUON_ID, MUON_MS
- No sysSF systematics in ZR
- Main impact is from muTrig sysSF: ~ 1-1.5% variation for all samples
- We also see some impact from muIso sysSF: ~ 0.5% variation overall samples

Asimov data: Fit breakdown

$$\mu_{SIG} = 1.0000 \pm^{0.0115}_{0.0115} (stat) \pm^{0.0355}_{0.0352} (syst) \pm^{0.0373}_{0.0370} (total)$$

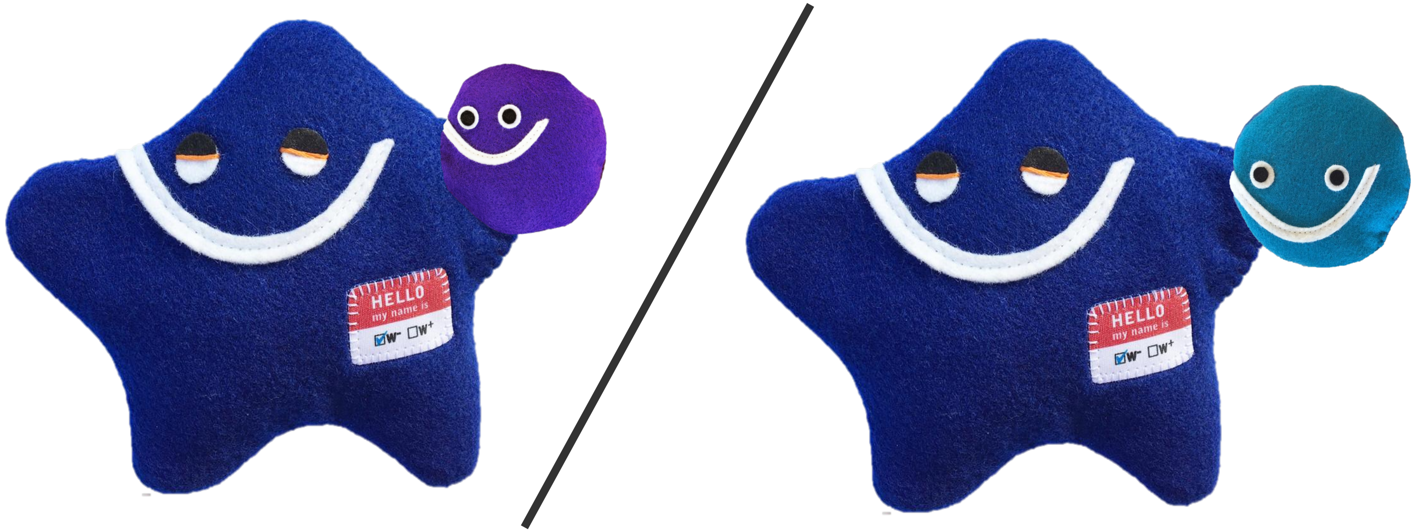
Syst group	Impact
Gammas	0.0373273
MJ	0.0364023
NormFactors	0.0239989
lumi	0.0374435
muIso_STAT	0.0116341
muIso_SYS	-nan
muReco_STAT	0.0206442
muReco_SYS	0.00414479
muTrig_STAT	0.0219416
muTrig_SYS	0.0131252





Conclusions

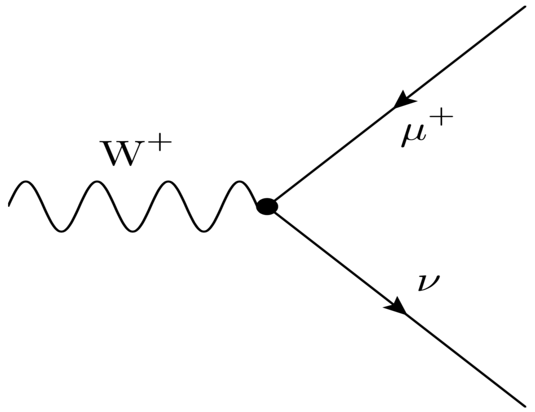
- MJ extraction method is implemented
  - Validated using pTWanalysis supporting note
  - Working in contact with *atlas-phys-sm-W-analyses* MJ team
  - Looking for new variables to suppress MJ in the SR : ptcone40 and MMBS
- d0 correction procedure for low-<mu> data doesn’t work
  - Better d0 resolution in Data rather then in MC
  - Derive corrections from ZR for prompt leptons
  - Could not derive corrections ZttR for “tau”-leptons
    - Will try same approach as for Top analysis
    - Needs to develop proper validation procedure (using ZttR ?)
  - Problem with secondary vertexes could be fixed using vertex cuts
- Stat only error is 1.15%; total 3.7% (preliminary)
  - Wrong lumi setup?
  - Missing tree systematics and systematics for ZR
  - Main sources for systematics errors for now are: MJ method, triggerSF and isoSF
  - TMVA::BDT could potentially improve the fit
    - Need to fix Data/MC mismodelling



Thanks for attention!

Ongoing ATLAS analysis

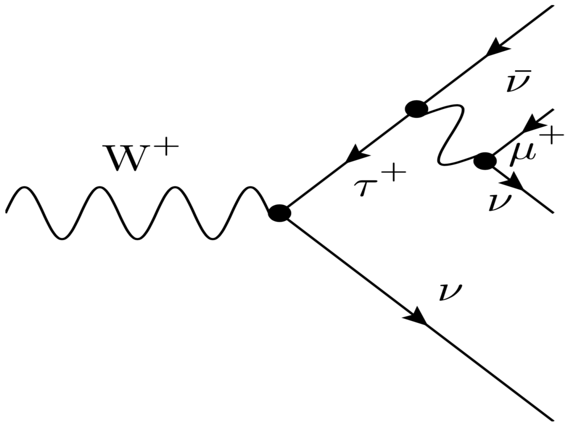
- Run1: Standard Model group analysis
  - Luminosity 4.6 fb^{-1}
  - Final states analysed: $W \rightarrow \tau_{lep}\nu \rightarrow \ell\nu\nu$ and $W \rightarrow \ell\nu$
  - Major analysis features:
    - Displacement of the τ decay helps to distinguish leptons from τ decays from prompt leptons
    - Analysis based on previous W mass measurement analysis
  - Status: Work in progress



∼11%

- Run2: Standard Model group analysis (this talk)
  - Luminosity 147 fb^{-1}
  - Final states analysed: $W \rightarrow \tau_{lep}\nu \rightarrow \ell\nu\nu$ and $W \rightarrow \ell\nu$
  - Major analysis features:
    - Displacement of the τ decay helps to distinguish leptons from τ decays from prompt leptons
    - 2D fit on d_0 and ~~BDT output~~ p_T leading lepton distributions
    - Analysis statistical power less then 1%
  - Status: Work in progress

- Run2: Top group effort
  - Luminosity 147 fb^{-1}
  - Final states analysed: di-leptonic $t\bar{t}$ decays
  - Major analysis features:
    - Displacement of the τ decay helps to distinguish leptons from τ decays from prompt leptons
    - Tag lepton to trigger on and probe lepton to go for a lower p_T range
  - Status: Blind Analysis Approval
  - Total error on blinded fit to data is 1.37%



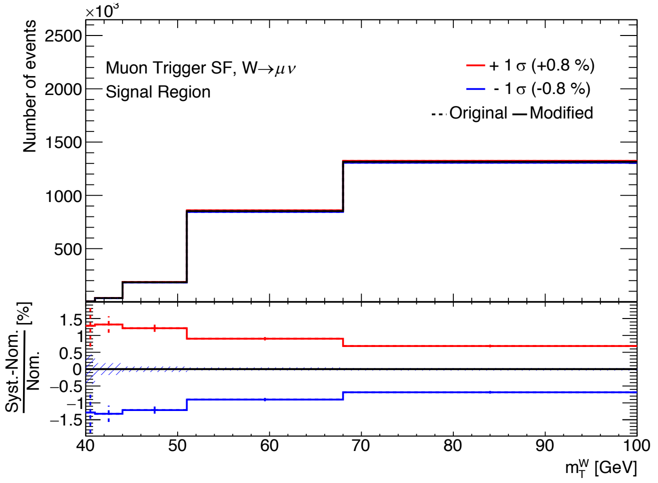
∼11% x 17.4%

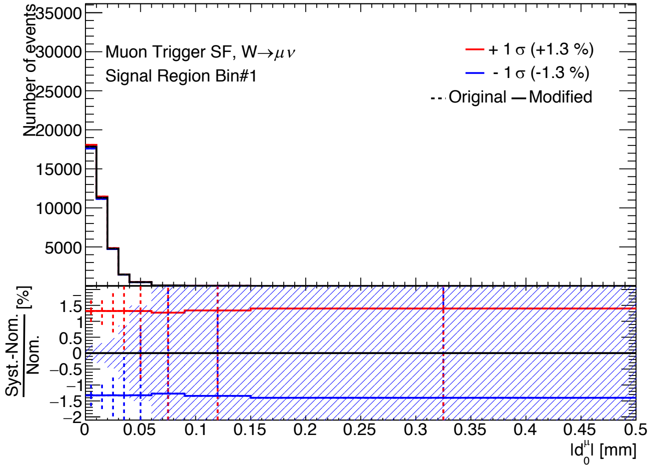
Data and MC samples for low <mu> analysis

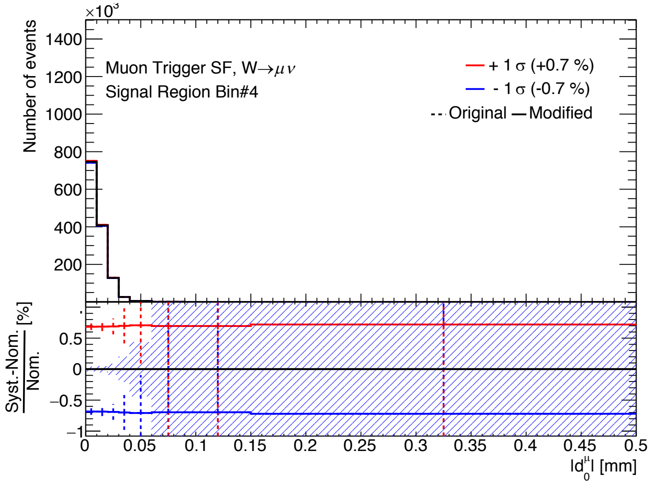
Channel	Samples
Wmu	mc16_13TeV.361101.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Wplusmunu mc16_13TeV.361104.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Wminusmunu
We	mc16_13TeV.361100.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Wplusenu mc16_13TeV.361103.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Wminusenu
Wtau	mc16_13TeV.361102.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Wplustaunu mc16_13TeV.361105.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Wminustaunu
Zee	mc16_13TeV.361106.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Zee
Zmm	mc16_13TeV.361107.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Zmumu
Ztt	mc16_13TeV.361108.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Ztautau
DiBoson	mc16_13TeV.363356.Sherpa_221_NNPDF30NNLO_ZqqZll mc16_13TeV.363358.Sherpa_221_NNPDF30NNLO_WqqZll mc16_13TeV.363359.Sherpa_221_NNPDF30NNLO_WpqqWmlv mc16_13TeV.363489.Sherpa_221_NNPDF30NNLO_WlvZqq mc16_13TeV.364250.Sherpa_222_NNPDF30NNLO_llll mc16_13TeV.364253.Sherpa_222_NNPDF30NNLO_lllv mc16_13TeV.364254.Sherpa_222_NNPDF30NNLO_llvv mc16_13TeV.364255.Sherpa_222_NNPDF30NNLO_lvvv
Top	mc16_13TeV.410013.PowhegPythiaEvtGen_P2012_Wt_inclusive_top mc16_13TeV.410014.PowhegPythiaEvtGen_P2012_Wt_inclusive_antitop mc16_13TeV.410025.PowhegPythiaEvtGen_P2012_SingleTopSchan_noAllHad_top mc16_13TeV.410470.PhPy8EG_A14_ttbar_hdamp258p75_nonallhad

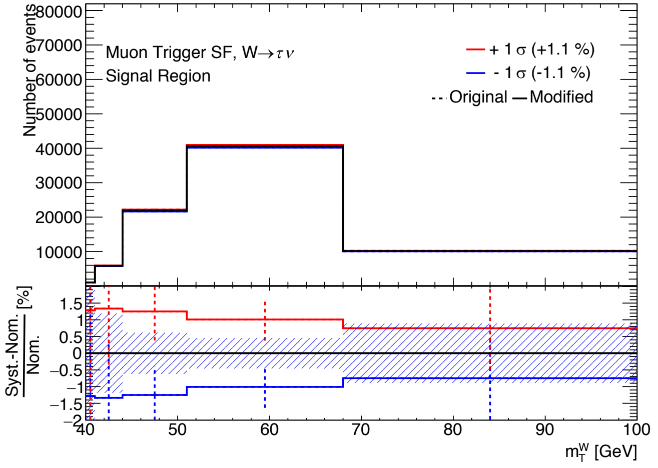
- Data 13 TeV (2017 and 2018)
- March2020 production

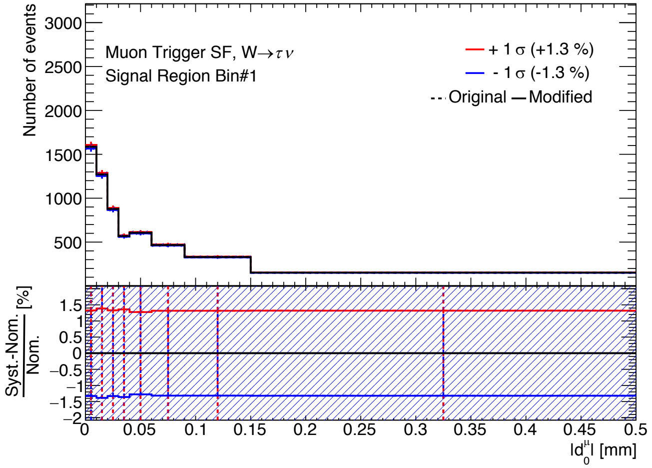
Fit: muTrig sys shape

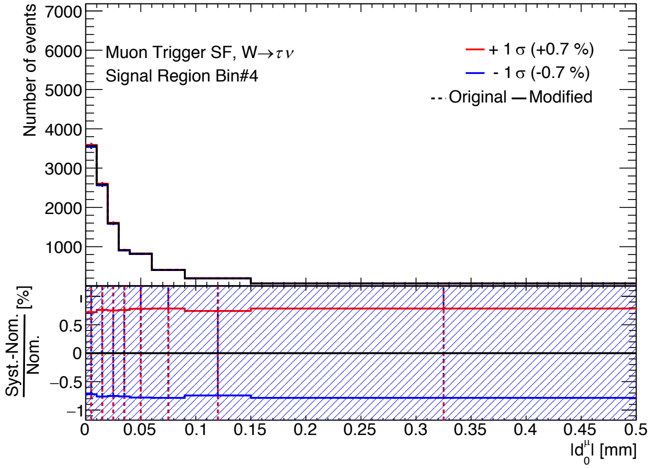




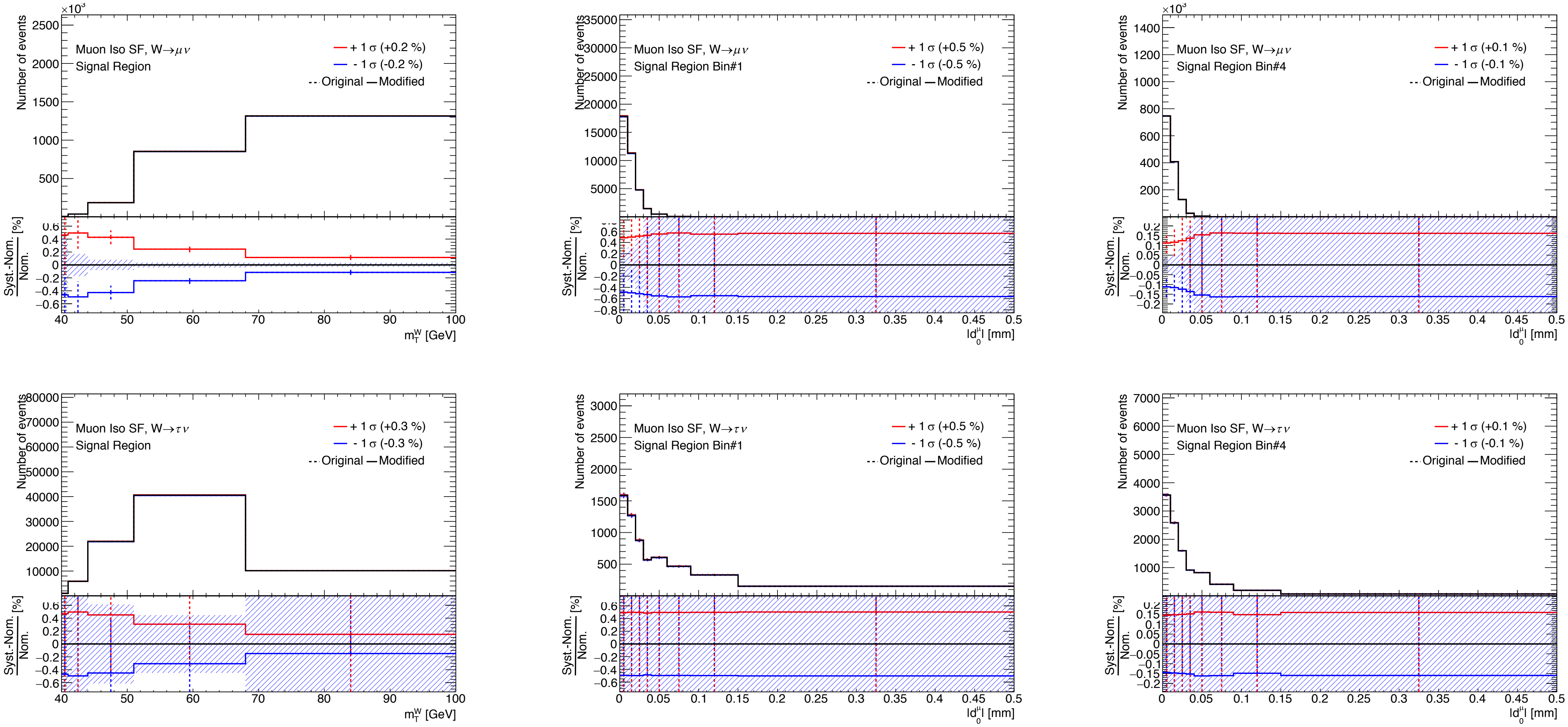




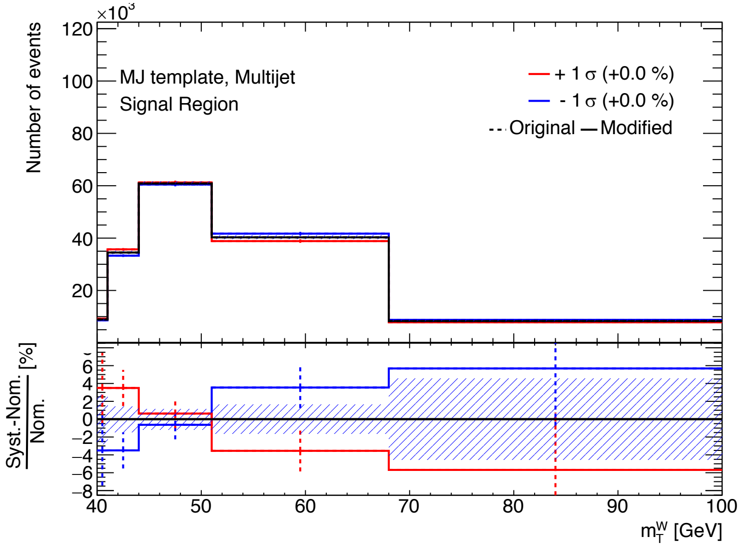


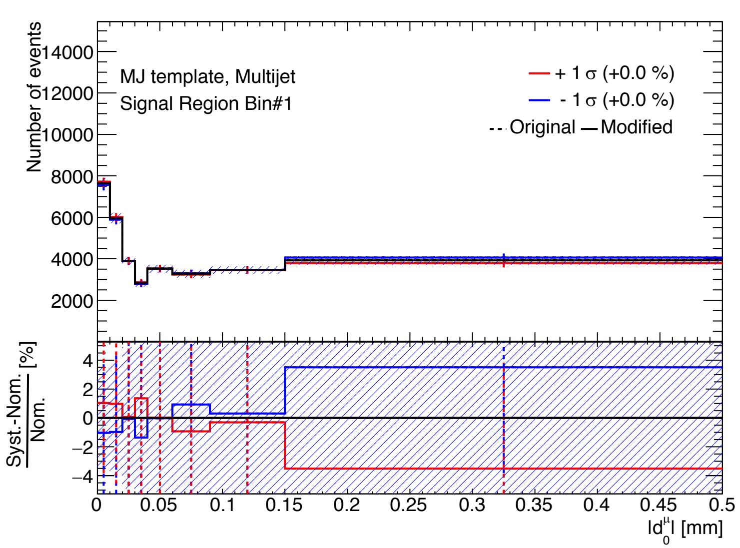


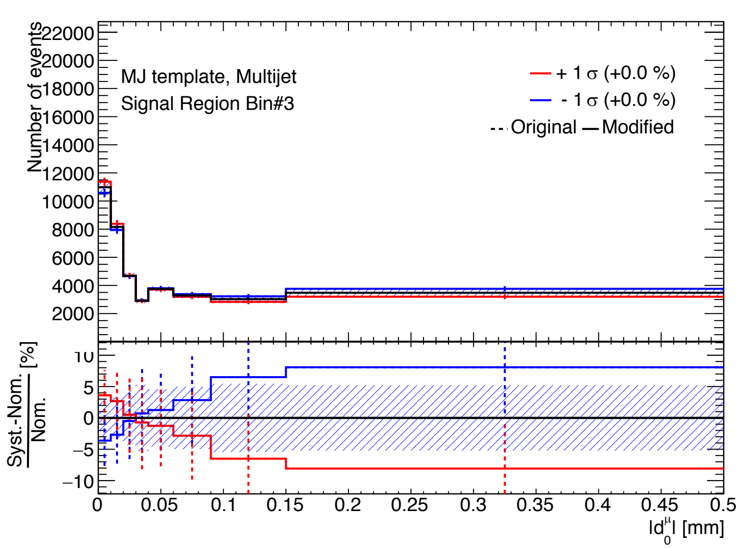
Fit: muIso sys shape

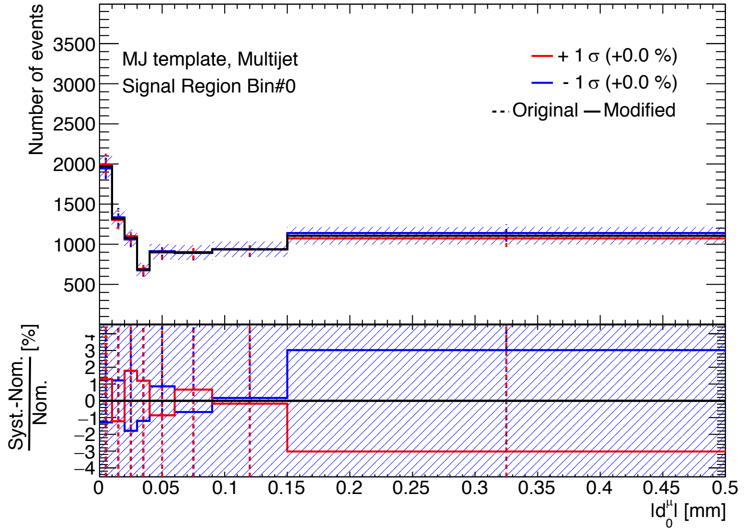


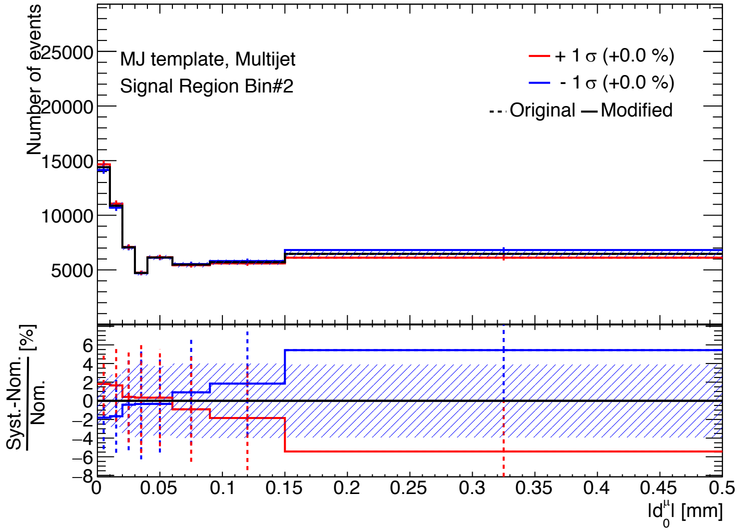
Fit: MJ template shape

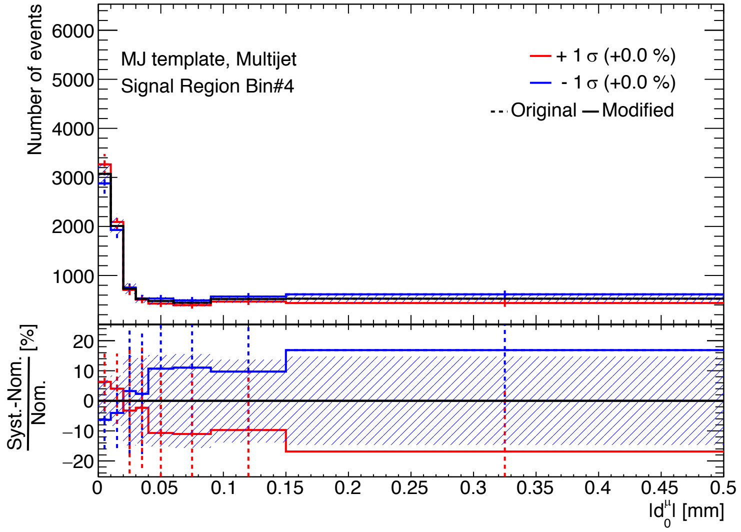




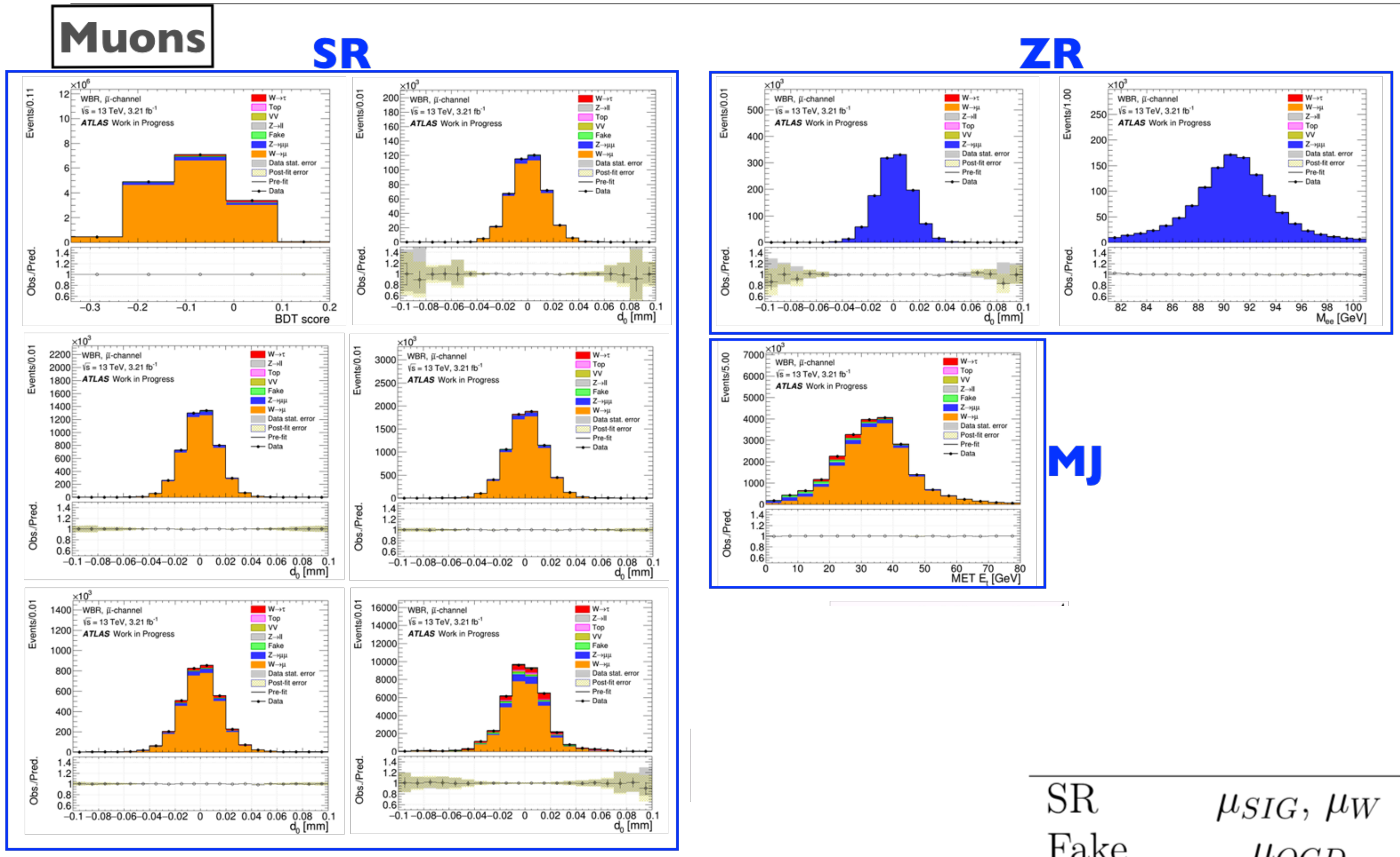








Analysis strategy (full Run2)



- Z control region
  - For Data/MC normalization
- MJ control region if needed
  - For FF MJ estimation
  - With isolation scan will use list of MJ regions

$$\mu_{SIG} = \mathcal{R}_{W_\ell} = \frac{\mathcal{B}(W \to \tau\bar{\nu}_\tau)}{\mathcal{B}(W \to \ell\bar{\nu}_\ell)}$$

SR	$\mu_{SIG},\ \mu_W$	$[\mu_{SIG} W_t + W_\ell] \cdot \mu_W + MC \cdot \mu_Z + QCD \cdot \mu_{QCD}$
Fake	μ_{QCD}	$[W_t + W_\ell] \cdot \mu_W + MC \cdot \mu_Z + QCD \cdot \mu_{QCD}$
ZR	μ_Z	$MC \cdot \mu_Z$

- Use 2D [BDT + d0] fit for SR
- The aim of the measurement is to achieve $\mathcal{O}(1.5\%)$ error

Event selection: full Run2

Year	GRL file	$\int L\, dt\ (fb^{-1})$
2015	data15_13TeV.periodAllYear_DetStatus-v89-pro21-02_Unknown_PHYS_StandardGRL_All_Good_25ns.xml	3.2

Trigger type	Trigger name
Single electron – 2015	HLT_e24_lhmedium_L1EM20VH, HLT_e60_lhmedium, HLT_e120_lhloose
Single muon – 2015	HLT_mu20_iloose_L1MU15, HLT_mu50

Preselection	
GRL	See Table 1
Vertex	> 3 associated tracks
Jets	No b-tagged jets && no bad jets
Lepton Selection - Electrons	
Trigger	Single electron (see Table 2)
pT	> 27 GeV
η	$\lvert\eta\rvert$ < 2.47 && ($\lvert\eta\rvert$ < 1.37 || $\lvert\eta\rvert$ > 1.52)
ID	Tight
Isolation	tight isolation
Lepton Selection - Muons	
Trigger	Single muon (see Table 2)
pT	> 27 GeV
η	$\lvert\eta\rvert$ < 2.4
ID	Tight
Isolation	tight isolation

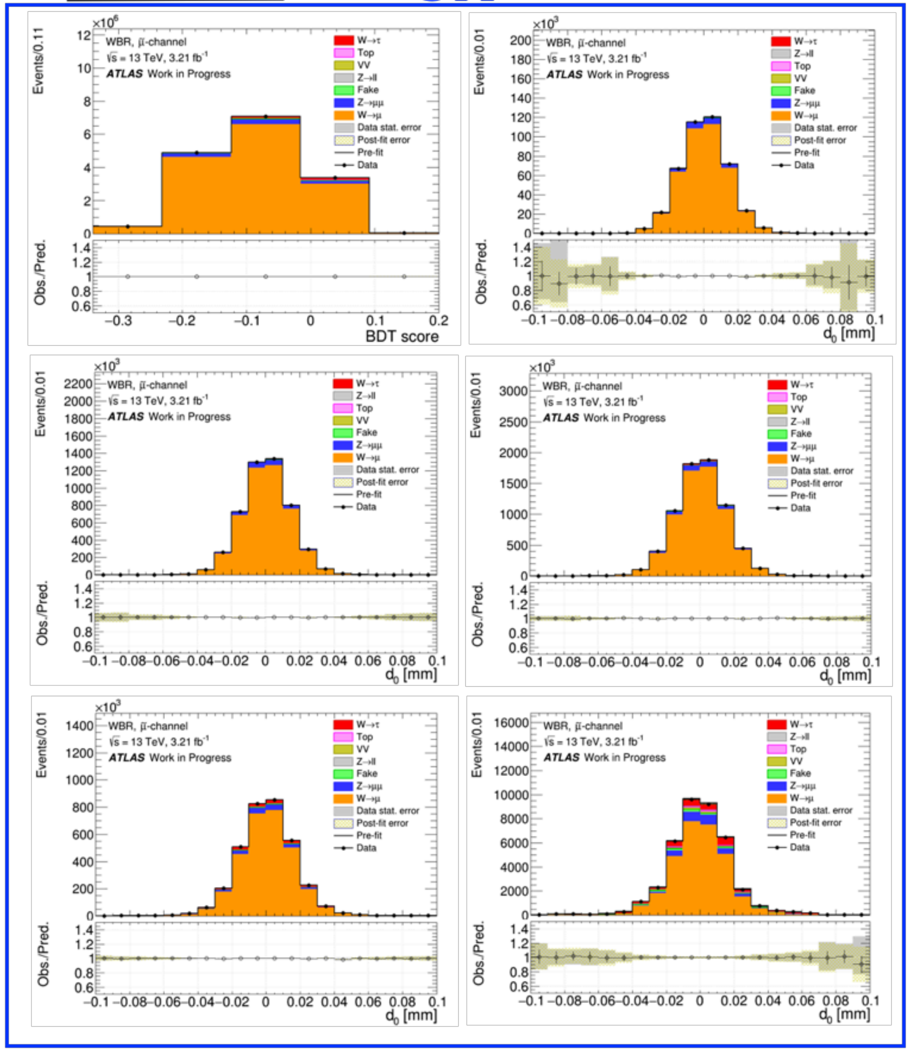
Boson Selection - W	
N leptons	exactly 1
OR	Overlap removal between jets and leptons
E_T^{miss}	> 25 GeV and apply MET cleaning
m_T	> 40 GeV
Boson Selection - $Z \to \ell\ell$, where $\ell = e, \mu$	
N leptons	exactly 2, same flavor && oppositely charged
Mass window	66 GeV < $m_{\ell\ell}$ < 116 GeV

SR Vars: d_0 and p_T (m_T) Exactly 1 lepton with: p_T>27, tightID, isoTight E_T^{miss}>25 m_T>40	**MJ** Vars: p_T , m_T, E_T^{miss}, $d\varphi$ Exactly 1 lepton with: p_T>27, looseID&!tightID, isoLoose&!isoTight E_T^{miss}>25 m_T>40
CR1 Vars: p_T , m_T, E_T^{miss}, $d\varphi$ Exactly 1 lepton with: p_T>27, tightID, isoTight E_T^{miss}>0 m_T>0	**CR2** Vars: p_T , m_T, E_T^{miss}, $d\varphi$ Exactly 1 lepton with: p_T>27, looseID&!tightID, isoLoose&!isoTight E_T^{miss}>0 m_T>0
ZR Vars: M_{ll}, d_0, p_T tightID, tightISO 2 leptons, OS, SF 66<M_{ll}<116	**ZRtt** Vars: d_0 TBD

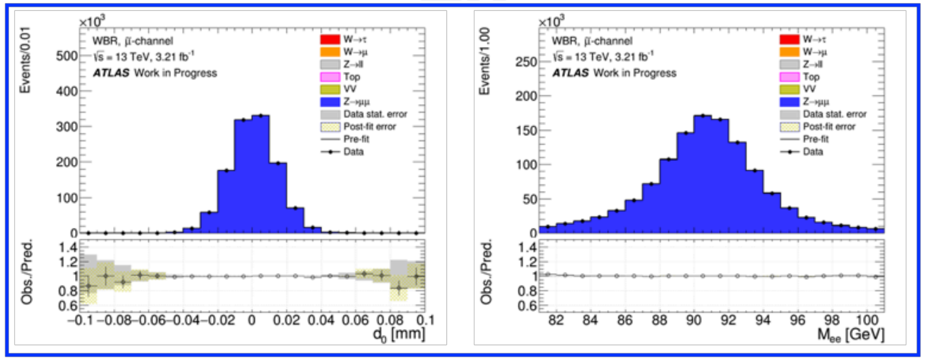
Fit results for Run2, 2015 year: Asimov data

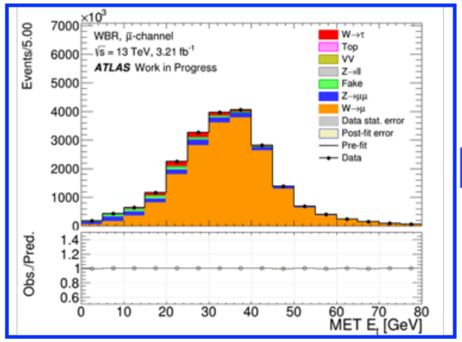
Muons

SR



ZR





MJ

- BDT binning looks OK
- QCD region is under good control

Error

μ_W	2.75×10^{-4}
μ_Z	6.47×10^{-4}
μ_{QCD}	5.33×10^{-3}

$$\mathcal{R}_{W_\mu}^{\text{Asimov}} = 1. \oplus {}^{+0.008724}_{-0.008812}(\text{total}) \oplus {}^{+0.005535}_{-0.005529}(\text{stat.}) \oplus {}^{+0.006744}_{-0.006861}(\text{syst.})$$