W-Ai measurements

Towards 2D MJ background

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Brief summary on previous studies

Report from Ruth: Measurements of Drell-Yan angular coefficients 26.03.2021

- Relaxed kinematic cuts on E_T^{miss} and m_T^W in our signal region
- For SR cut on track-based isolation ($ptvarcone20/pt < 0.1$) & calo-based isolation ($topoetcone20/pT < 0.05$)
- Defined strategy to work with $ptvarcone20/pt$ isolation variable scan in MJ region:
  - Relax and scan track isolation & keep calo isolation
- Recoil track isolation correction is applied

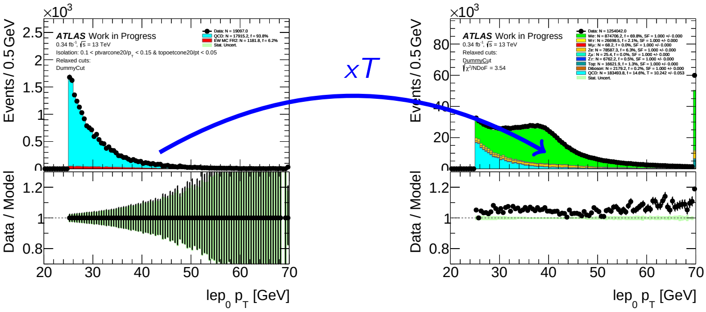
Outline for today

- Overview of the 1D MJ background estimation procedure in W-Ai
- 1D control plots
- 2D MJ background estimation approach
- Problem with MJ template derived from signal region
- Summary table for MJ uncertainties

- In this presentation would mainly focus on electrons channel
- Results for muons channel are in the backup slides

MJ background in W-Ai analysis

anti-isolated slice   Fit region



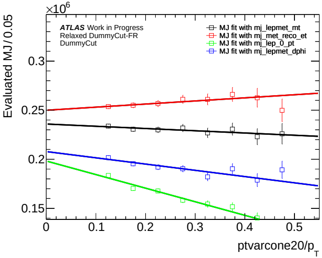
Note for $W^- \to e^- \nu$

- The EWK comtamination in the 1^{st} isolation slice is 6.2%
- 5.2% comes from the signal
- for muons we have almost the same

- Two steps to get MJ background:
  - Calculate MJ normalization:
    - repeat MJ estimation for different anti-isolation slices
    - fit linear function
    - extrapolate back to SR
  - Calculate MJ template shape:
    - MJ distributions in $\bar{iso}$-slices don't match SR shape
    - apply bin-by-bin linear shape extrapolation
    - assign 100% uncertainty
- Use 4 discriminative variables:
  - p_T, m_T, E_T^{miss} and $|\Delta\phi(\ell - MET)|$
- Use 8 slicing bins in $ptvarcone20/pt$:
  - Binning(8, 0.1, 0.5)
- In the fit use fixed EWK background normalization.
- Isolation $ptvarcone20/pt$ slices for $W^- \to e^- \nu$ for all 4 variables are on Slides 21, 22, 23 and 24.

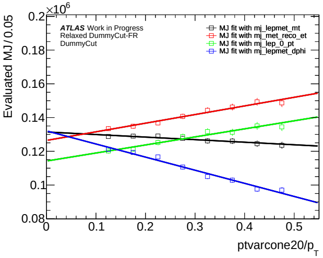
Calculate MJ normalization in the signal region

$W^- \to e^- \nu$



ToDo: old numbers

$W^- \to \mu^- \nu$



ToDo: old numbers

$W^- \to e^- \nu$	Signal region
Total Number of MJ bkg	**213593**
Luminosity and cross section	774 (0.36%)
Intersection point	37474 (17.54%)
Extrapolation target	1109 (0.52%)
Choice of hists	12492 (5.82%)
Isolation correction	*NaN*
Correlated Uncertainty	**39542 (18.5%)**

$W^- \to \mu^- \nu$	Signal region
Total Number of MJ bkg	**118754**
Luminosity and cross section	405 (0.34%)
Intersection point	11269 (9.49%)
Extrapolation target	15 (0.01%)
Choice of hists	3756 (3.16%)
Isolation correction	*NaN*
Correlated Uncertainty	**11275 (9.49%)**

- The error bars are **not** multiplied by $\sqrt{\chi^2/NDoF}$
- Take final MJ yield as mean at $ptvarcone20/pt = 0.025$
- Less MJ background contribution for muon channel (as expected)
- Dominant MJ yield uncertainty comes from intersection point
- For now we don't use u_T slicing as pTW analysis does:
    - To improve yields precision might also consider to use set of u_T cuts to take control over jets activity: *[15, 20, 25, 30, 35, 40,* **None***]*

Calculate MJ template shape

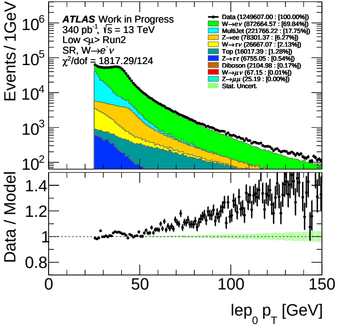
- Calculate shape correction using isolation slices for final MJ templates
- Given the large statistical uncertainty and the linear approximation used, the shift $\Delta H[X]$ applied is assigned a 100% relative uncertainty

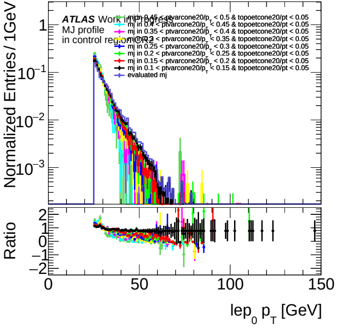
In assumption, extrapolation is linear:

$$H_{MJ}^{[0.A,0.B]}[X] = H_{Data}^{[0.A,0.B]}[X] - H_{MC}^{[0.A,0.B]}[X]$$

$$\Delta H[X] = \frac{1}{4}\{(H_{MJ}^{0.1,0.15} - H_{MJ}^{0.15,0.2}) + (H_{MJ}^{0.2,0.25} - H_{MJ}^{0.25,0.3}) + (H_{MJ}^{0.3,0.35} - H_{MJ}^{0.35,0.4}) + (H_{MJ}^{0.4,0.45} - H_{MJ}^{0.45,0.5})\}$$

$$H_{MJ}^{sig}[X] = H_{MJ}^{0.1,0.15}[X] + 2 \cdot \Delta H[X]$$



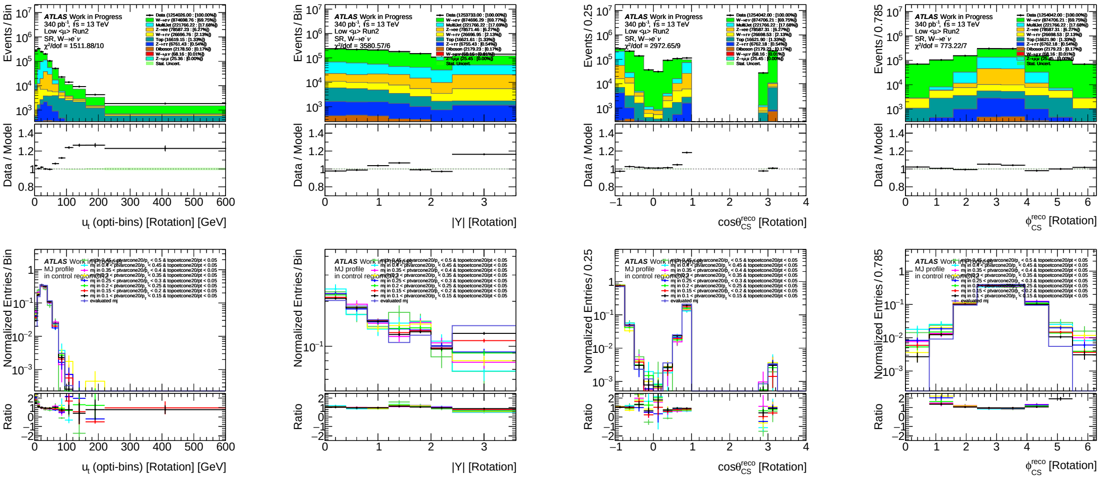


ToDo: old numbers

$W^- \to e^- \nu$	Signal region
Total Number of MJ bkg	**213593**
Data Stat.	1546 (0.72%)
MC Stat.	2120 (1%)
Shape Correction	3236 (1.52%)
Uncorrelated Uncertainty	**4166 (1.95%)**

$W^- \to \mu^- \nu$	Signal region
Total Number of MJ bkg	**118754**
Data Stat.	775 (0.63%)
MC Stat.	924 (0.78%)
Shape Correction	1014 (0.85%)
Uncorrelated Uncertainty	**1561 (1.31%)**

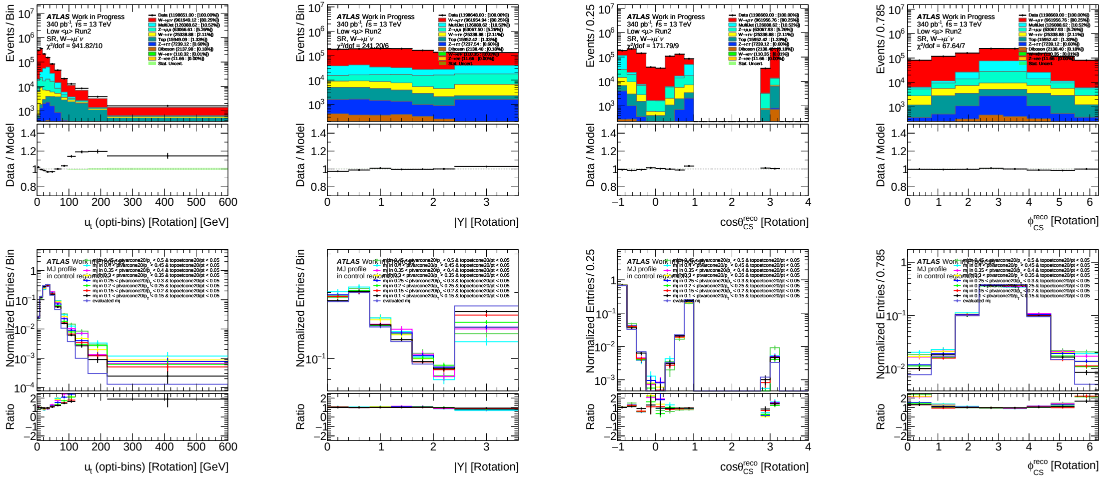
MJ background: control plots in the Signal Region for $W^- \to e^- \nu$



Not good Data/Bkg agreement for u_T and $|Y|$ distributions. Problems with $\cos\theta_{CS}$ in SR.

- u_T region [50, 100] GeV seems has wrong correction? This also observed for muons (see slide 8).
- high $|Y|$ region: non linear $\bar{iso}$-extrapolation effects in MJ?

MJ background: control plots in the Signal Region for $W^- \to \mu^- \nu$



Bearable Data/Bkg agreement except u_T distribution:

- u_T shows same issue for [50, 100] GeV region.
- Comparing to electrons: high rapidity region works better. No huge discrepancies for $\cos\theta_{CS}$ and ϕ_{CS}.

Towards MJ in 2D

2D MJ estimation: general idea

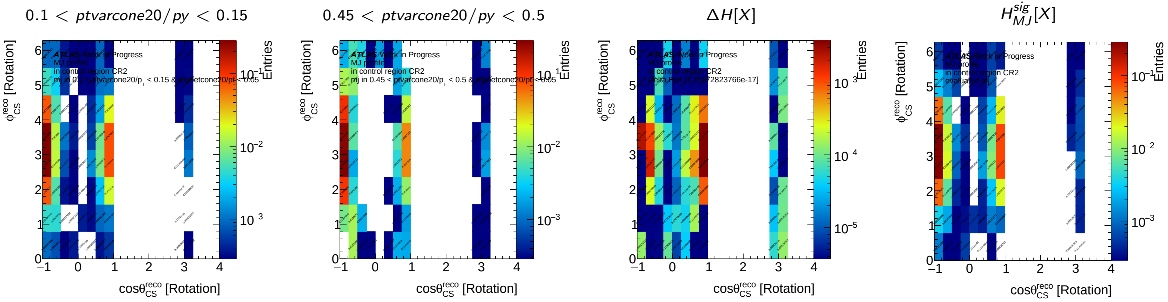
- Same approach as for 1D (bin-by-bin extrapolation), but working with 2D histograms:
  1. Calculate 2D shape via isolation extrapolation method in SR
  2. Scale derived MJ template by MJ yield from SR (see Slide 5)
- If possible, use one MJ template from SR along all $|Y|$ and u_T bins.

Note

Some bins for derived 2D templates are negative.

- Set them to 0.
- More on Slide 25

Example of 2D MJ shape calculations for $\cos\theta_{CS}^{reco}$ vs. ϕ_{CS}^{reco}:

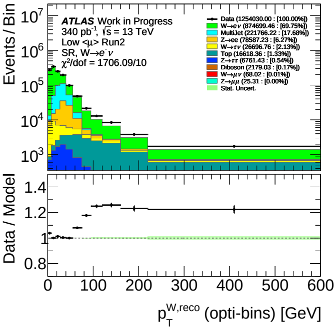


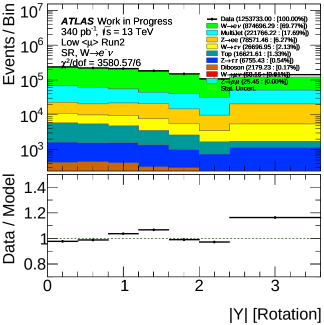
W-Ai analysis binning and MJ shape

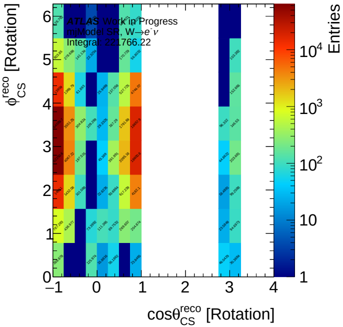
Signal region binning

- u_T: [0., 8., 17., 27., 40., 55., 75., 95., 120., 160., 220., 600]
- $|Y|$: [0, 0.4, 0.8, 1.2, 1.6, 2.0, 2.4, 3.6]
- Have to provide MJ estimation for **18 bins in total**

- Use MJ yield normalization from given bin in 1D distribution
- Use 2D MJ template ($\cos\theta_{CS}^{reco}$ vs. ϕ_{CS}^{reco}) derived from SR for all u_T and $|Y|$ bins:
  - as a temporary solution to see if MJ shape from SR would work for all bins.
  - in short - it doesn't work for electrons (slides 12 and 15).

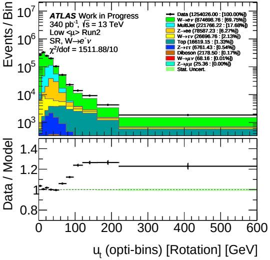


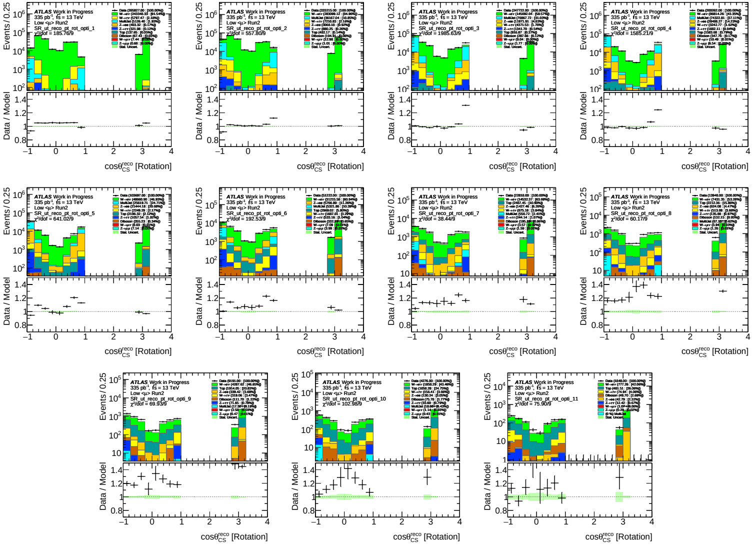




MJ agreement: $\cos\theta_{CS}^{reco}$ as function of u_T bins

Binning variable:

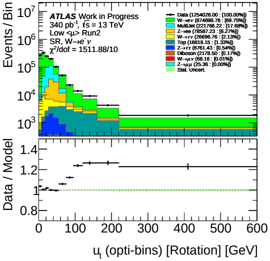


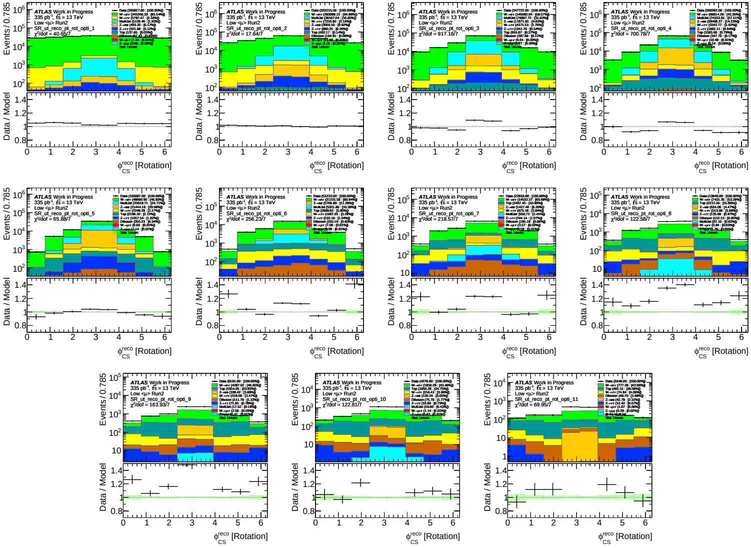


- Use $\cos\theta_{CS}^{reco}$ MJ template from SR for all u_T bins
- MJ yield normalization is provided by MJ yield in given u_T bin
- In the MJ populated u_T bins (2,3 and 4) Data/Bkg prediction discrepancy $\sim 20\%$ at the $\cos\theta_{CS}^{reco}$ tails

MJ agreement: ϕ_{CS}^{reco} as function of u_T bins

Binning variable:

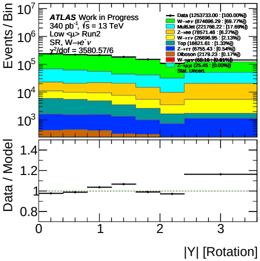




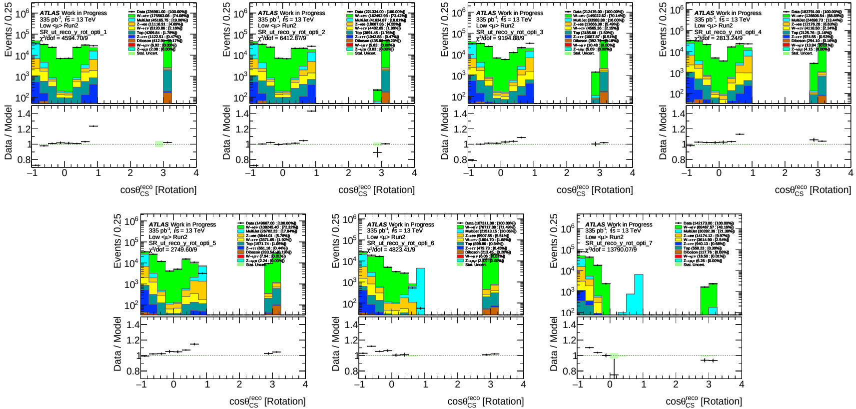
- Use ϕ_{CS}^{reco} MJ template from SR for all u_T bins
- MJ yield normalization is provided by MJ yield in given u_T bin
- In the MJ populated u_T bins (3 and 4) Data/Bkg prediction discrepancy $\sim 15\%$

MJ agreement: ϕ_{CS}^{reco} as function of $|Y|$ bins

Binning variable:



- Use ϕ_{CS}^{reco} MJ template from SR for all $|Y|$ bins
- MJ yield normalization is provided by MJ yield in given $|Y|$ bin

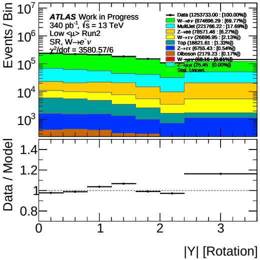


Note

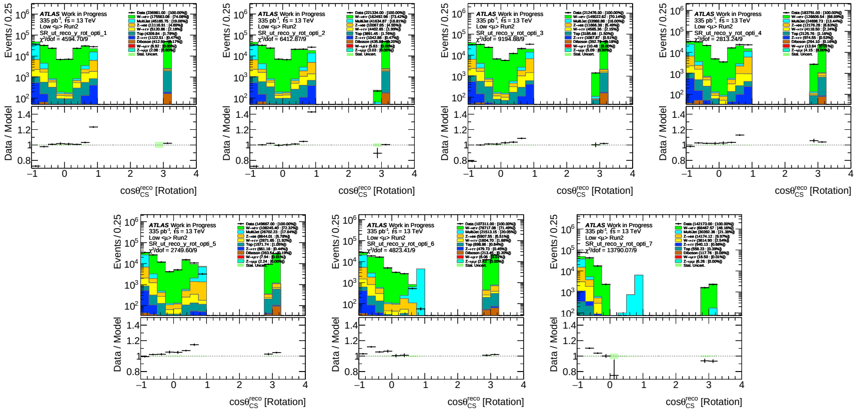
- ϕ_{CS}^{reco} shows some MJ normalization problems

MJ agreement: $\cos\theta^{reco}_{CS}$ as function of $|Y|$ bins

Binning variable:



- Use $\cos\theta^{reco}_{CS}$ MJ template from SR for all $|Y|$ bins
- MJ yield normalization is provided by MJ yield in given $|Y|$ bin



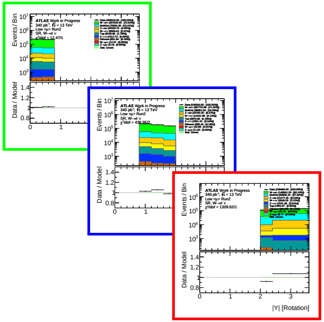
Note

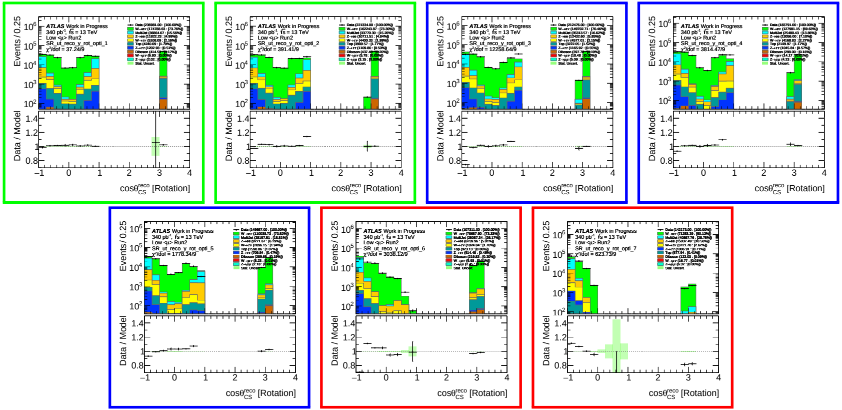
- $\cos\theta^{reco}_{CS}$ MJ shape should be treated as function of $|Y|$
- We have enough statistics to split $|Y|$ in 3 regions and derive MJ templates for each region individually

MJ from 3 independent $|Y|$ bins: $\cos\theta_{CS}^{reco}$ as function of $|Y|$ bins

Split SR in 3 regions:

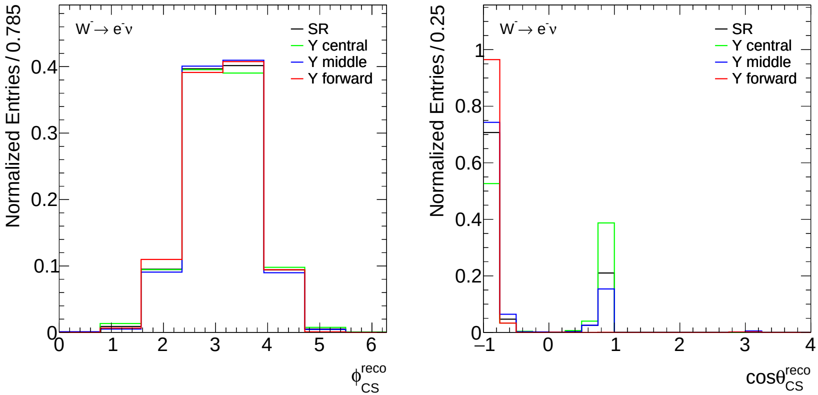
- $|Y| < 0.8$
- $0.8 < |Y| < 2.0$
- $|Y| > 2.0$





- Calculate MJ yield and shape individually for each $|Y|$ region
- Splitting in 3 $|Y|$ bins shows positive effect, but not able to cope with $\cos\theta_{CS}^{reco}$ vs $|Y|$ dependency effectively

MJ from 3 independent $|Y|$ bins: $\cos\theta_{CS}^{reco}$ and ϕ_{CS}^{reco} as function of $|Y|$ bins



Note

- $\cos\theta_{CS}^{reco}$ MJ template shape depends on $|Y|$
- Same behaviour in the muon channel

Impact of $|Y|$ binning on sys. uncertainty for $W^- \to e^-\nu$

ToDo: old numbers

$W^- \to e^-\nu$	Signal region	Central $\|Y\| < 0.8$	Middle $0.8 < \|Y\| < 2.0$	Forward $\|Y\| > 2.0$
Total Number of MJ bkg	**213593**	66379	85483	68633
Luminosity and cross section	774 (0.36%)	234 (0.35%)	332 (0.39%)	172 (0.25%)
Intersection point	37474 (17.54%)	13077 (19.7%)	19137 (22.39%)	14634 (21.32%)
Extrapolation target	1109 (0.52%)	457 (0.69%)	798 (0.93%)	1260 (1.84%)
Choice of hists	12492 (5.85%)	4359 (6.57%)	6379 (7.46%)	4878 (7.11%)
Isolation correction	N/A	N/A	N/A	N/A
Correlated Uncertainty	39542 **(18.5%)**	13079 (19.7%)	20191 (23.6%)	15478 (22.5%)
Data Stat.	1546 (0.72%)	770 (1.16%)	984 (1.15%)	1071 (1.56%)
MC Stat.	2120 (1%)	1039 (1.57%)	1257 (1.47%)	1779 (2.59%)
Shape Correction	3236 (1.52%)	1017 (1.53%)	1785 (2.09%)	1031 (1.5%)
Uncorrelated Uncertainty	4166 **(1.95%)**	1645 (2.48%)	2394 (2.8%)	2318 (3.38%)

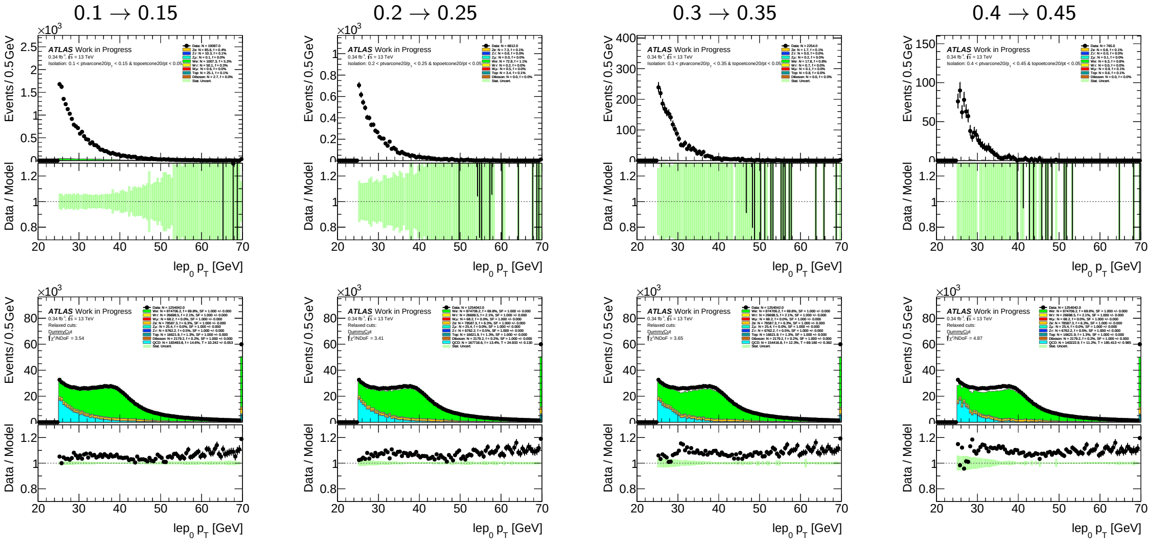
- Preliminary MJ uncertainty estimation
  - have to sync MJ unc. calculation with W precision analyses
  - *TODO:* no sys. unc. for isolation correction included.

Conclusions

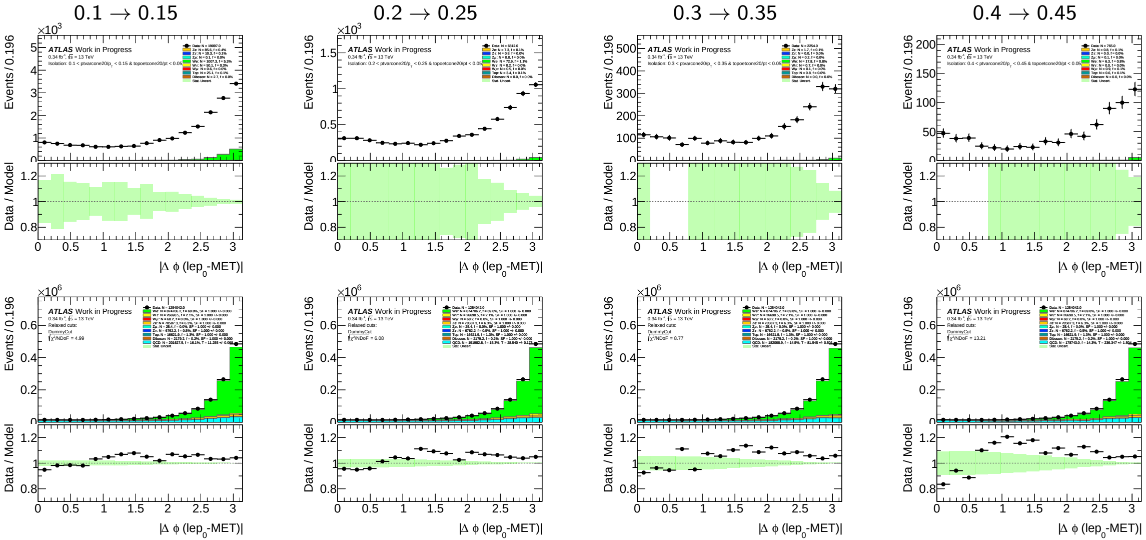
- Control 1D plots (u_T and $|Y|$) shows Data/Bkg disagreement:
  - For high u_T due to problems with u_T reweighing in electrons and muons
  - For high $|Y|$ bins underestimate MJ background yield in electrons channel only
- For 2D MJ template some bins are negative. This happens for regions where MJ close to 0.
  - set all negative bins to 0
- MJ templates for $\cos\theta_{CS}^{reco}$ depends on Y and u_T:
  - Same behaviour for electron and muon channels
  - Calculating MJ $\cos\theta_{CS}^{reco}$ individually for 3 $|Y|$ bins doesn't solve an issue for electrons, but might be an option for muons
    - ★ Could be this is effect of Data/MC disagreement for electrons for ϕ_{CS} and $\cos\theta_{CS}$ in SR
  - Might consider building acceptance functions to calculate MJ templates for each u_T and $|Y|$ bin using MJ 2D template from signal regions
- Preliminary 2D templates are available on */eos* for electron and muons channels (3 Y bins):
  - Electrons */eos/home-d/dponomar/Storage/Science/Wai/results/v20210713ptrw_ruth/WS*
  - Muons */eos/home-d/dponomar/Storage/Science/Wai/results/v20210906ptrw_ruth/WS*
  - Summary for muon channel is in the backup slides
- (Old numbers)$W^- \rightarrow e^-\nu$ in the SR: 213593 $\pm$ 18.5% (corr) $\pm$ 1.95% (uncorr)
- (Old numbers)$W^- \rightarrow \mu^-\nu$ in the SR: 118754 $\pm$ 9.49% (corr) $\pm$ 1.31% (uncorr)

Backup

Isolation $ptvarcone20/pt$ slices for $W^- \to e^-\nu$: leading lepton p_T

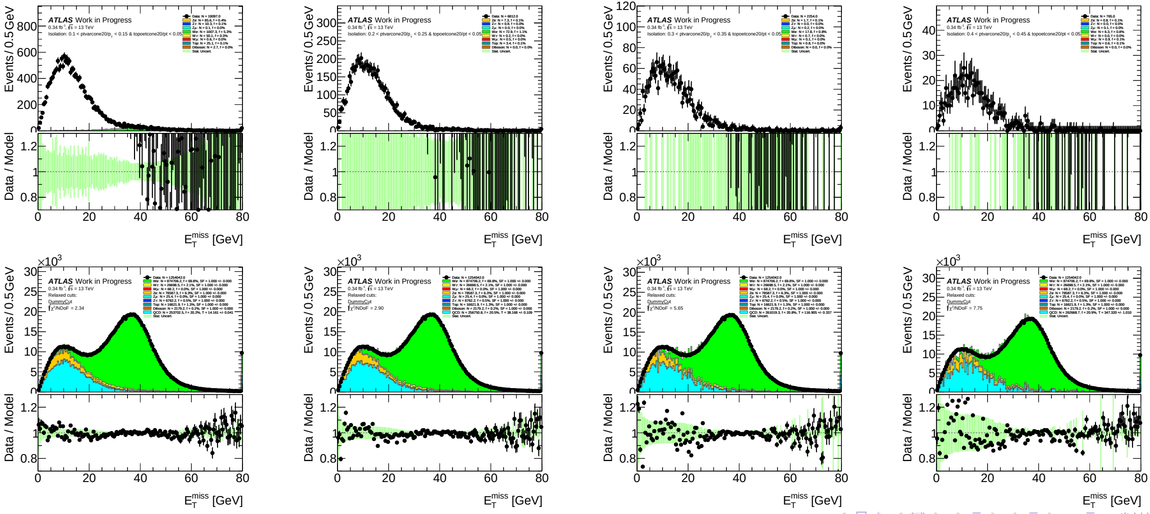


Isolation $ptvarcone20/pt$ slices for $W^- \to e^- \nu$: $|\Delta\phi(\ell - MET)|$



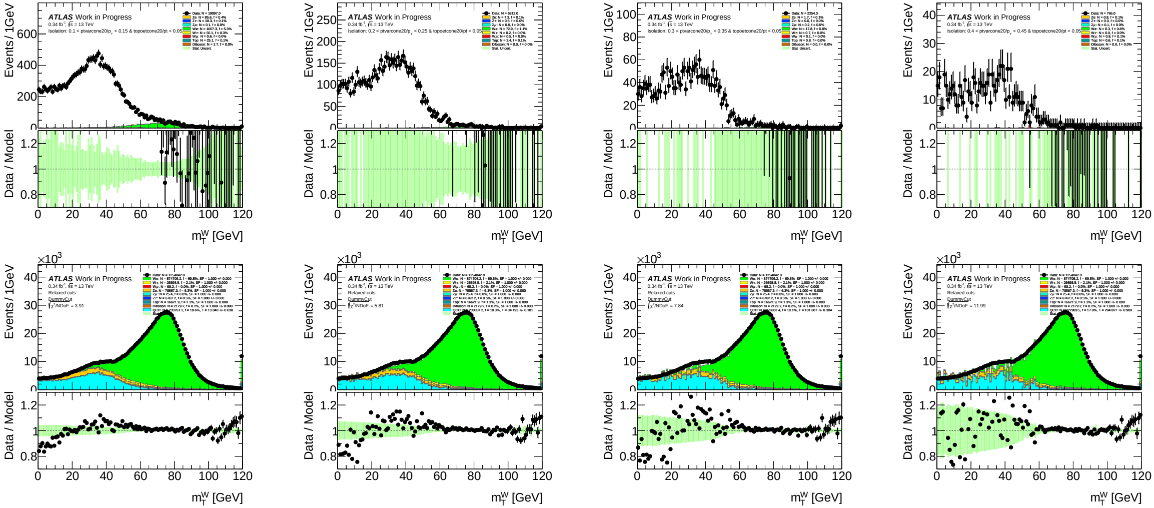
Isolation $ptvarcone20/pt$ slices for $W^- \to e^- \nu$: E_T^{miss}

$0.1 \to 0.15$ | $0.2 \to 0.25$ | $0.3 \to 0.35$ | $0.4 \to 0.45$

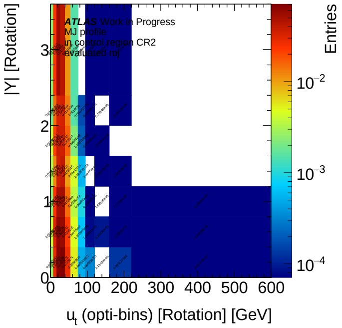


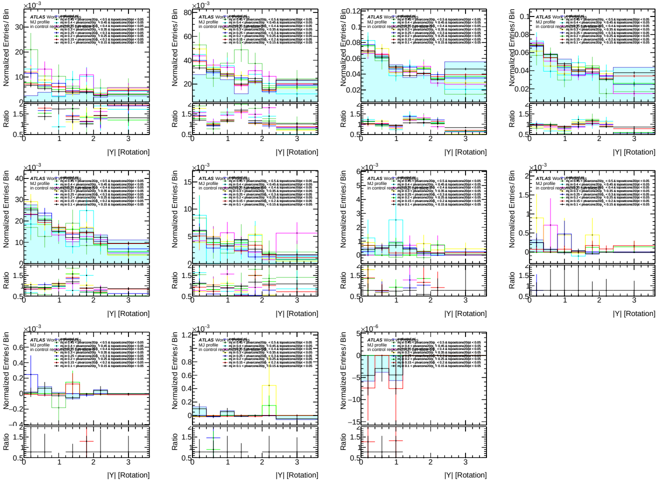
Isolation $ptvarcone20/pt$ slices for $W^- \to e^-\nu$: m_T^W

0.1 → 0.15 | 0.2 → 0.25 | 0.3 → 0.35 | 0.4 → 0.45



2D MJ estimation: extrapolation and projections on Y axis





- Some of the bins are negative.
- Set them to 0 with assumption it should not affect overall normalization too much.

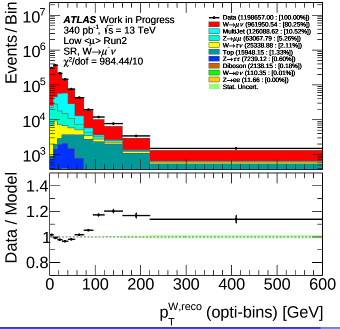
Muons

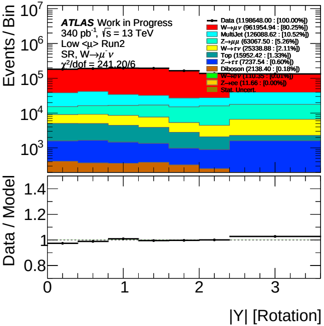
W-Ai analysis binning and MJ shape

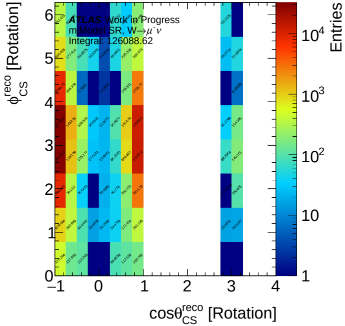
Signal region binning

- u_T: [0., 8., 17., 27., 40., 55., 75., 95., 120., 160., 220., 600]
- $|Y|$: [0, 0.4, 0.8, 1.2, 1.6, 2.0, 2.4, 3.6]
- Have to provide MJ estimation for **18 bins in total**

- Use MJ yield normalization from given bin in 1D distribution
- Use 2D MJ template ($\cos\theta_{CS}^{reco}$ vs. ϕ_{CS}^{reco}) derived from SR for all u_T and $|Y|$ bins:
  - as a temporary solution to see if MJ shape from SR would work for all bins.
  - could work for muons(Slide 28).

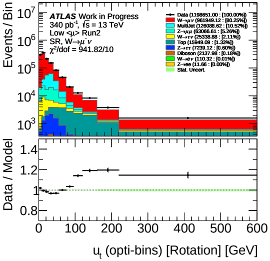




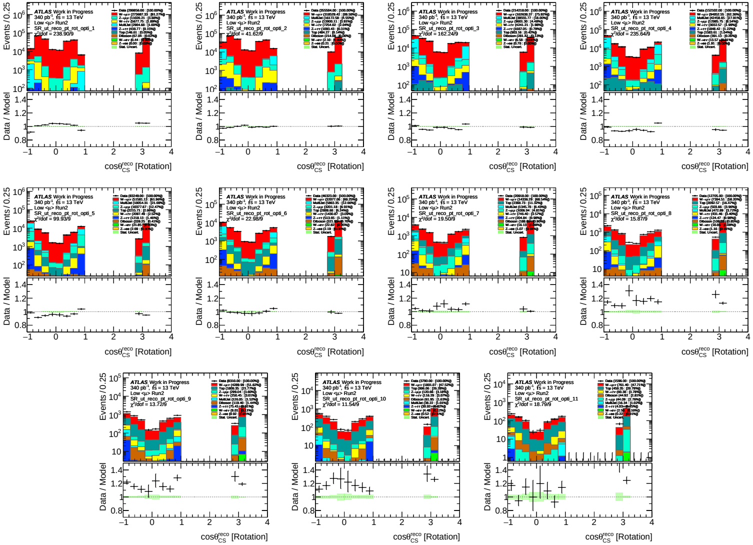


MJ agreement: $\cos\theta_{CS}^{reco}$ as function of u_T bins

Binning variable:

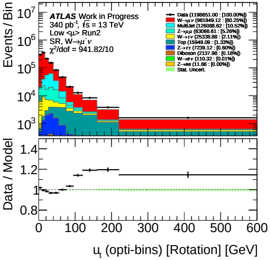


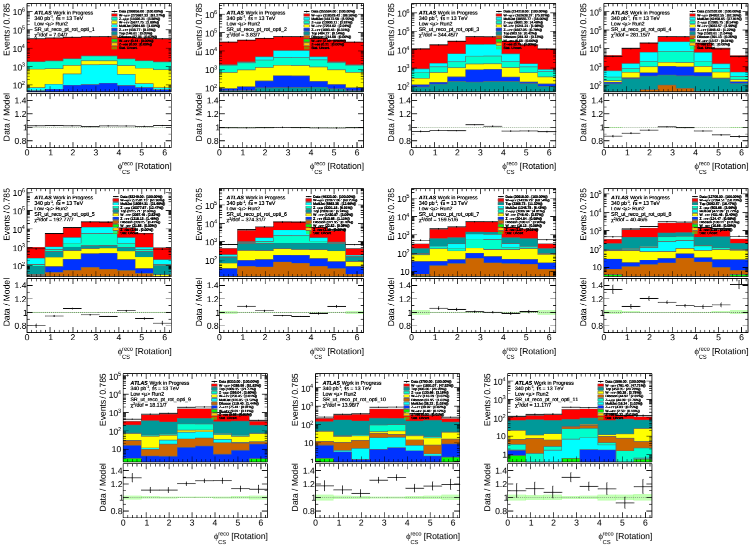
- Use $\cos\theta_{CS}^{reco}$ MJ template from SR for all u_T bins
- MJ yield normalization is provided by MJ yield in given u_T bin
- In the MJ populated u_T bins (3, 4 and 5) Data/Bkg prediction discrepancy $\sim 12\%$.



MJ agreement: ϕ_{CS}^{reco} as function of u_T bins

Binning variable:

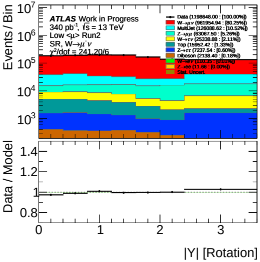




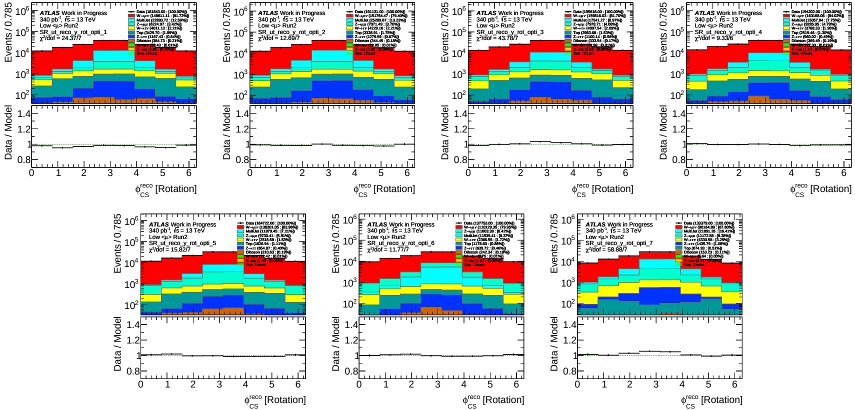
- Use ϕ_{CS}^{reco} MJ template from SR for all u_T bins
- MJ yield normalization is provided by MJ yield in given u_T bin
- In the MJ populated u_T bins (3 and 4) Data/Bkg prediction discrepancy $\sim 15\%$

MJ agreement: ϕ_{CS}^{reco} as function of $|Y|$ bins

Binning variable:



- Use ϕ_{CS}^{reco} MJ template from SR for all $|Y|$ bins
- MJ yield normalization is provided by MJ yield in given $|Y|$ bin

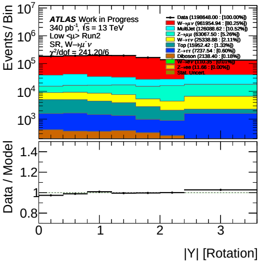


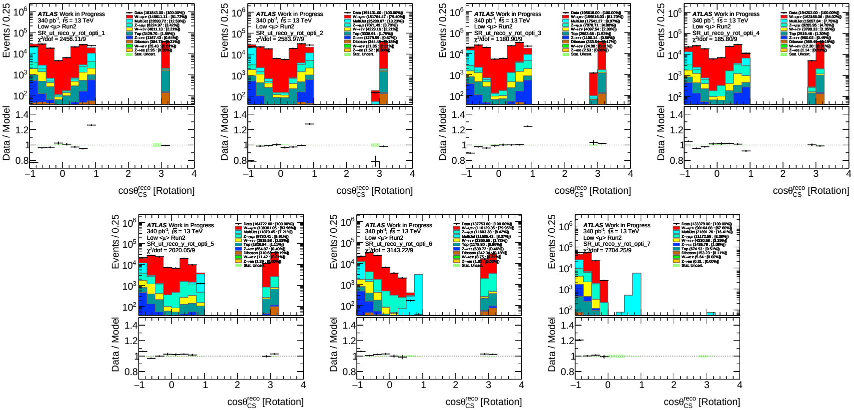
Note

- For muons ϕ_{CS}^{reco} overall good agreement

MJ agreement: $\cos\theta_{CS}^{reco}$ as function of $|Y|$ bins

Binning variable:





- Use $\cos\theta_{CS}^{reco}$ MJ template from SR for all $|Y|$ bins
- MJ yield normalization is provided by MJ yield in given $|Y|$ bin

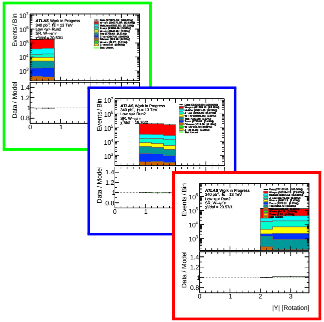
Note

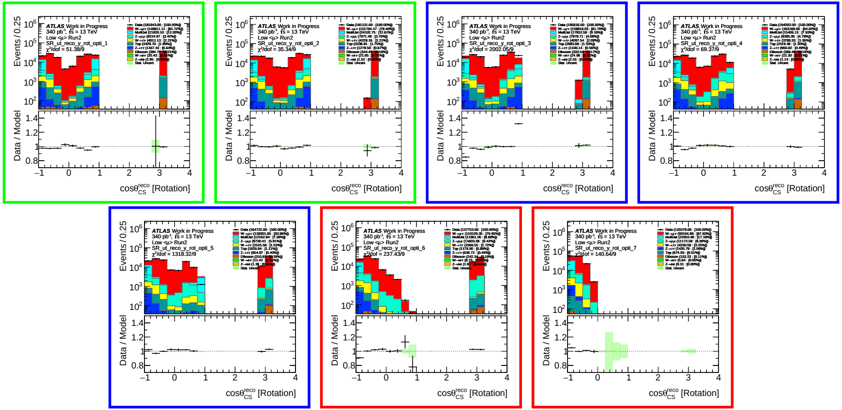
- $\cos\theta_{CS}^{reco}$ MJ shape should be treated as function of $|Y|$
- We can split $|Y|$ in 3 regions and derive MJ templates for each of them individually

MJ from 3 independent $|Y|$ bins: $\cos\theta_{CS}^{reco}$ as function of $|Y|$ bins

Split SR in 3 regions:

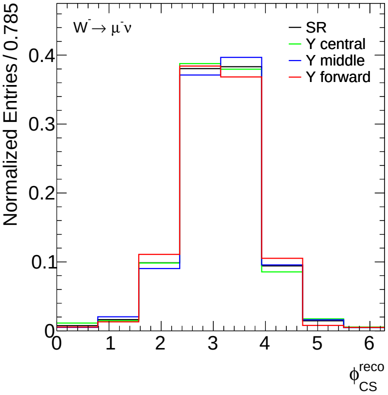
- $|Y| < 0.8$
- $0.8 < |Y| < 2.0$
- $|Y| > 2.0$

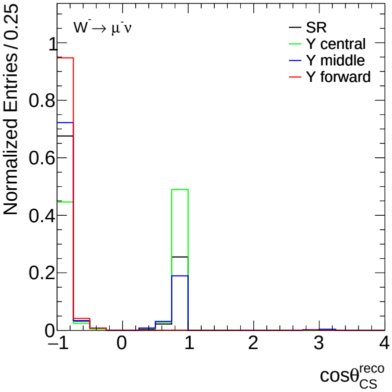




- Calculate MJ normalization and shape individually for aech $|Y|$ region
- Splitting in 3 $|Y|$ bins shows positive effect, but not able to cope with $\cos\theta_{CS}^{reco}$ vs $|Y|$ dependency effectively

MJ from 3 independent $|Y|$ bins: $\cos\theta_{CS}^{reco}$ and ϕ_{CS}^{reco} as function of $|Y|$ bins





Note

- $\cos\theta_{CS}^{reco}$ MJ template shape depands on $|Y|$
- Same observation in the electron channel

Impact of $|Y|$ binning on sys. uncertainty for $W^- \to \mu^-\nu$

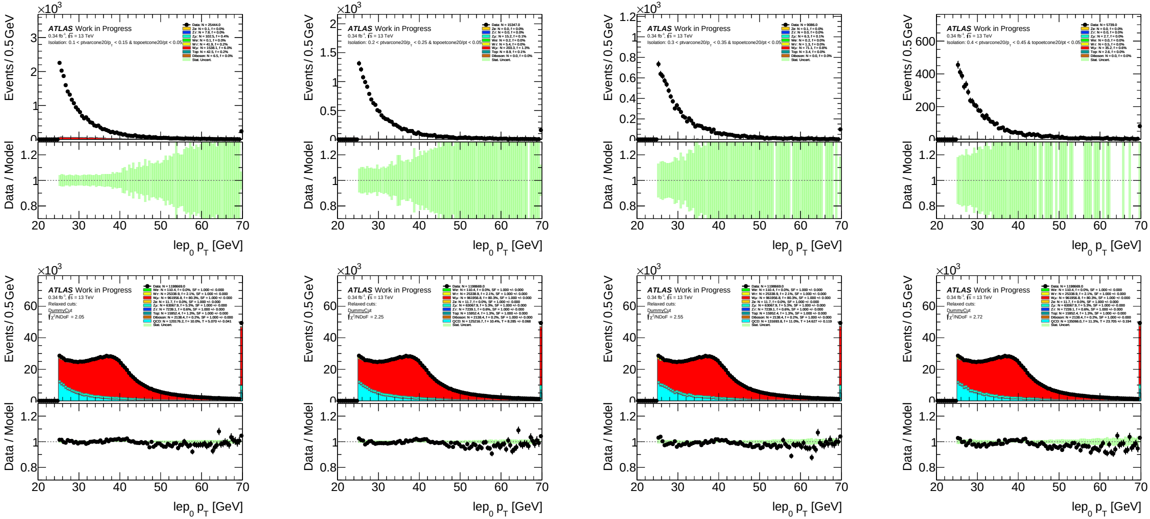
ToDo: old numbers

$W^- \to \mu^-\nu$	Signal region	Central $\|Y\| < 0.8$	Middle $0.8 < \|Y\| < 2.0$	Forward $\|Y\| > 2.0$
Total Number of MJ bkg	**118754**	43200	42069	33938
Luminosity and cross section	406 (0.34%)	126 (0.29%)	175 (0.42%)	103 (0.3%)
Intersection point	11269 (9.49%)	3581 (8.29%)	6078 (14.45%)	1744 (5.14%)
Extrapolation target	15 (0.01%)	66 (0.15%)	82 (0.2%)	42 (0.12%)
Choice of hists	3756 (3.16%)	1194 (2.76%)	2026 (4.82%)	582 (1.71%)
Isolation correction	N/A	N/A	N/A	N/A
Correlated Uncertainty	11275 **(9.49%)**	3777 (8.74%)	6081 (14.46%)	1748 (5.15%)
Data Stat.	775 (0.63%)	438 (1.01%)	436 (1.04%)	424 (1.25%)
MC Stat.	924 (0.78%)	599 (1.39%)	479 (1.14%)	563 (1.66%)
Shape Correction	1014 (0.85%)	759 (1.76%)	419 (1.0%)	67 (0.2%)
Uncorrelated Uncertainty	1561 **(1.31%)**	1061 (2.46%)	771 (1.83%)	708 (2.09%)

- Preliminary MJ uncertainty estimation
  - have to sync MJ unc. calculation with W precision analyses
  - *TODO:* no sys. unc. for isolation correction included.

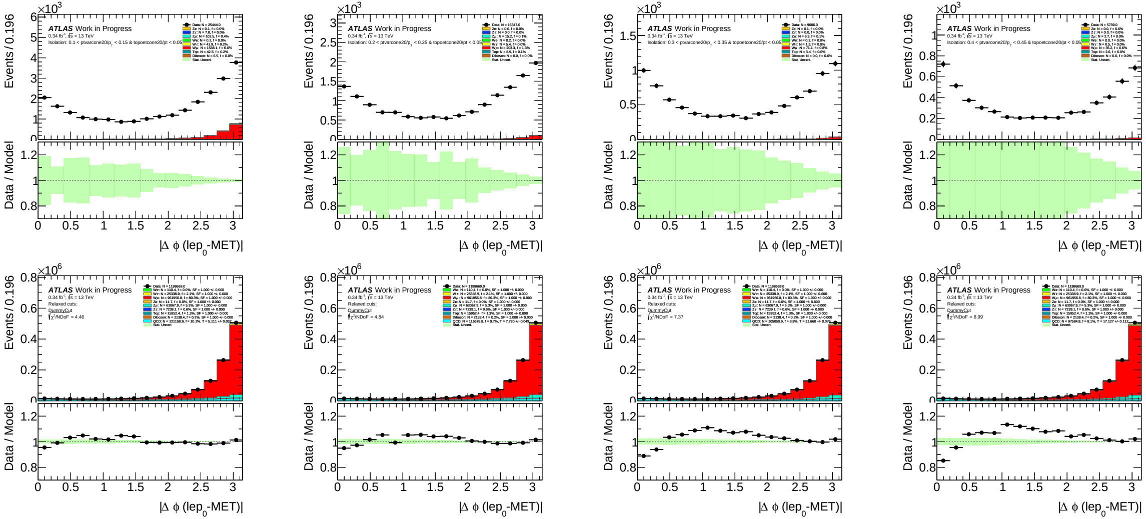
Isolation $ptvarcone20/pt$ slices for $W^- \to \mu^-\nu$: leading lepton p_T

$0.1 \to 0.15$ $\quad$ $0.2 \to 0.25$ $\quad$ $0.3 \to 0.35$ $\quad$ $0.4 \to 0.45$



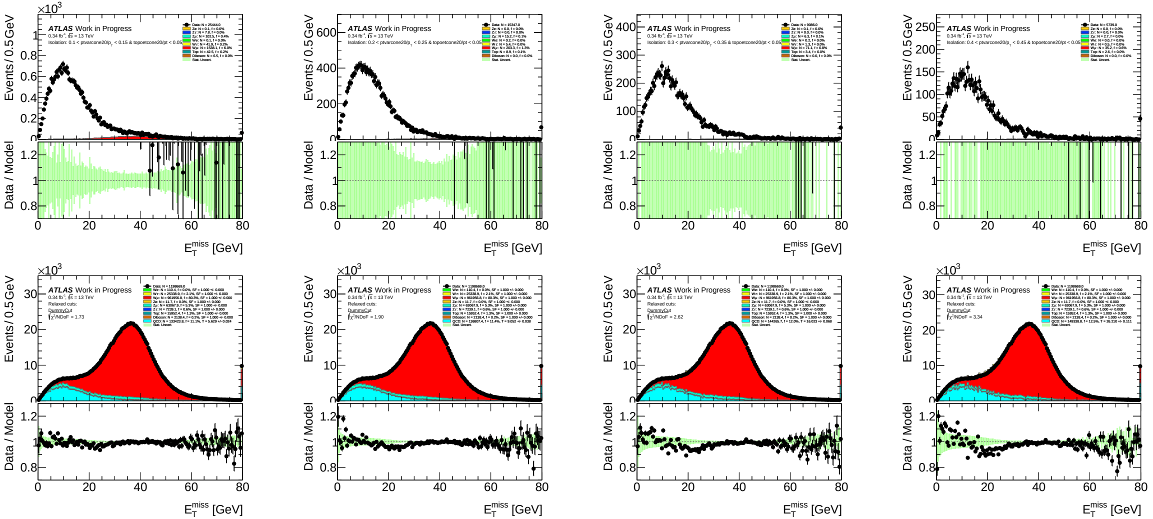
Isolation $ptvarcone20/pt$ slices for $W^- \rightarrow \mu^- \nu$: $|\Delta\phi(\ell - MET)|$

0.1 → 0.15 | 0.2 → 0.25 | 0.3 → 0.35 | 0.4 → 0.45

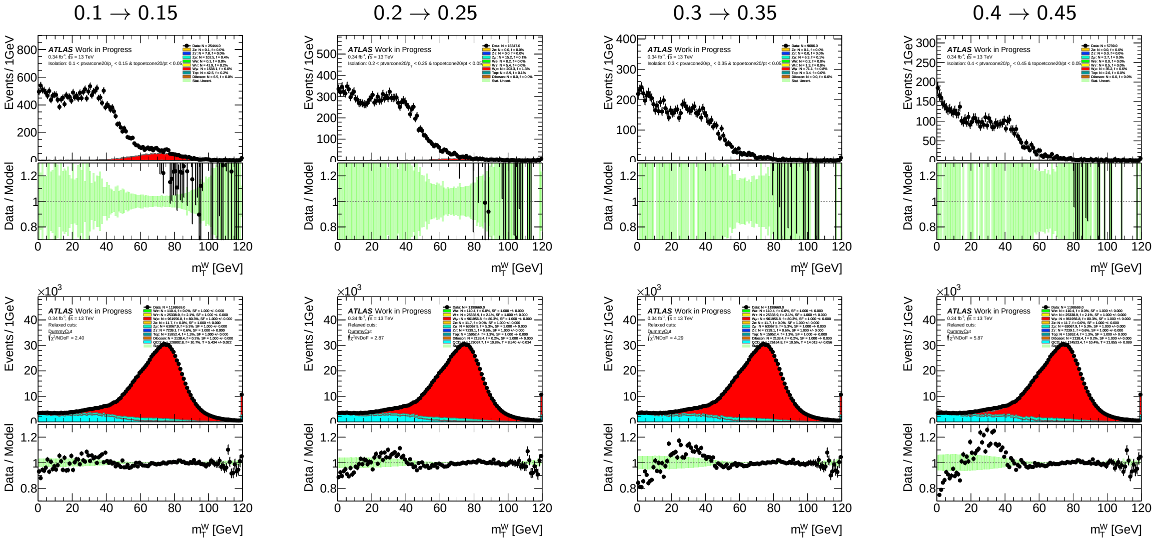


Isolation $ptvarcone20/pt$ slices for $W^- \to \mu^- \nu$: E_T^{miss}

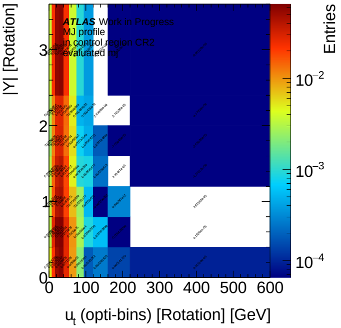
0.1 → 0.15 | 0.2 → 0.25 | 0.3 → 0.35 | 0.4 → 0.45

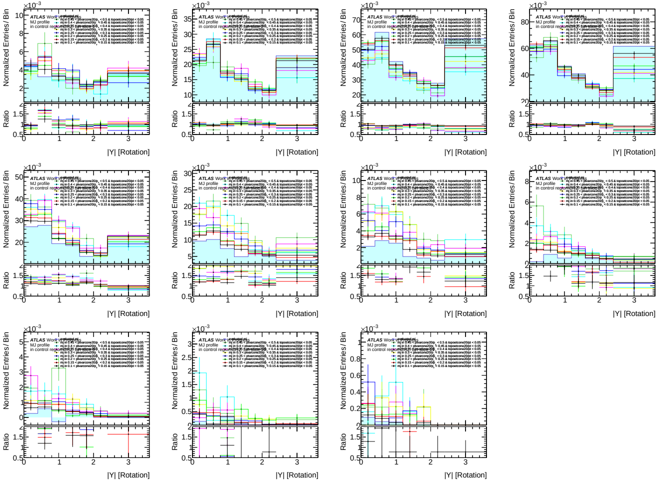


Isolation $ptvarcone20/pt$ slices for $W^- \to \mu^- \nu$: m_T^W



2D MJ estimation: extrapolation and projections on Y axis for $W^- \to \mu^- \nu$





- Some of the bins are negative.
- Set them to 0 with assumption it should not affect overall normalization too much.