Multijet strategy for W-Ai analysis

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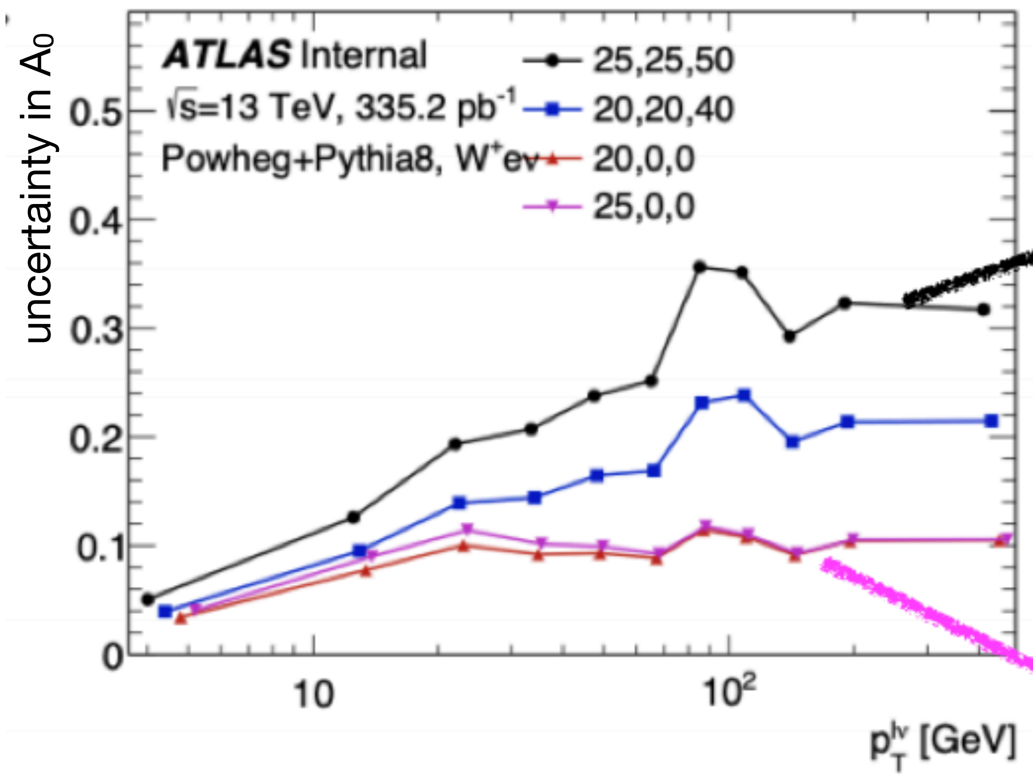
Ai meeting, 09.11.20

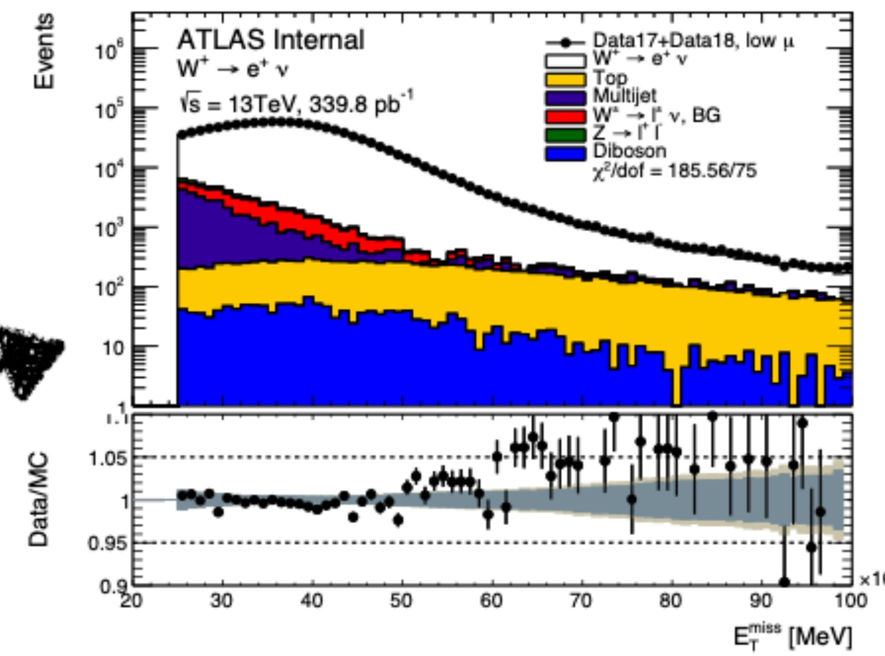
Many slides from M. Boonekamps talk here (work also by T. Xu)

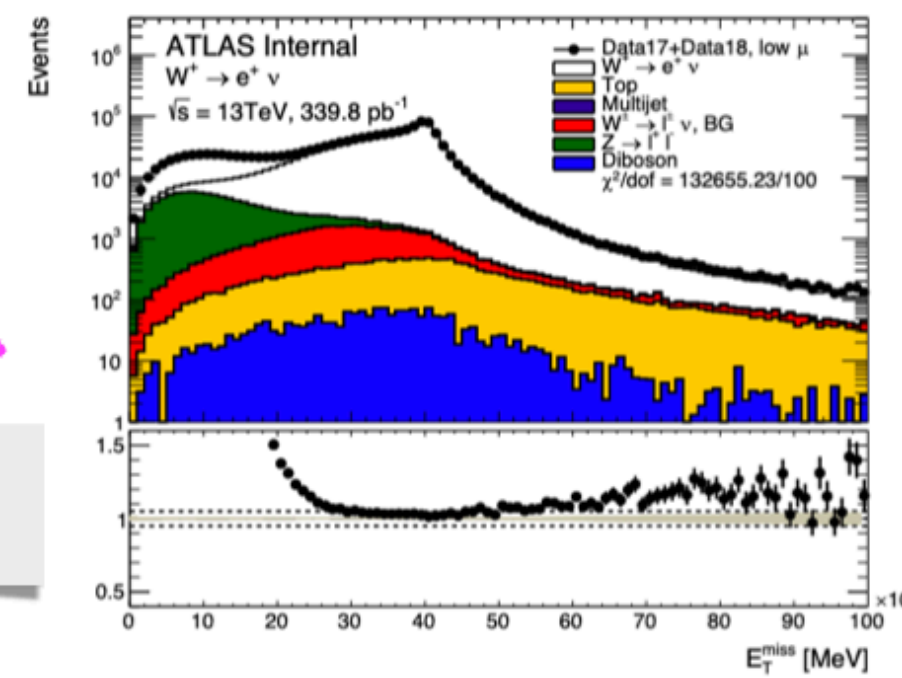
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Reminder: Optimized WAi selection







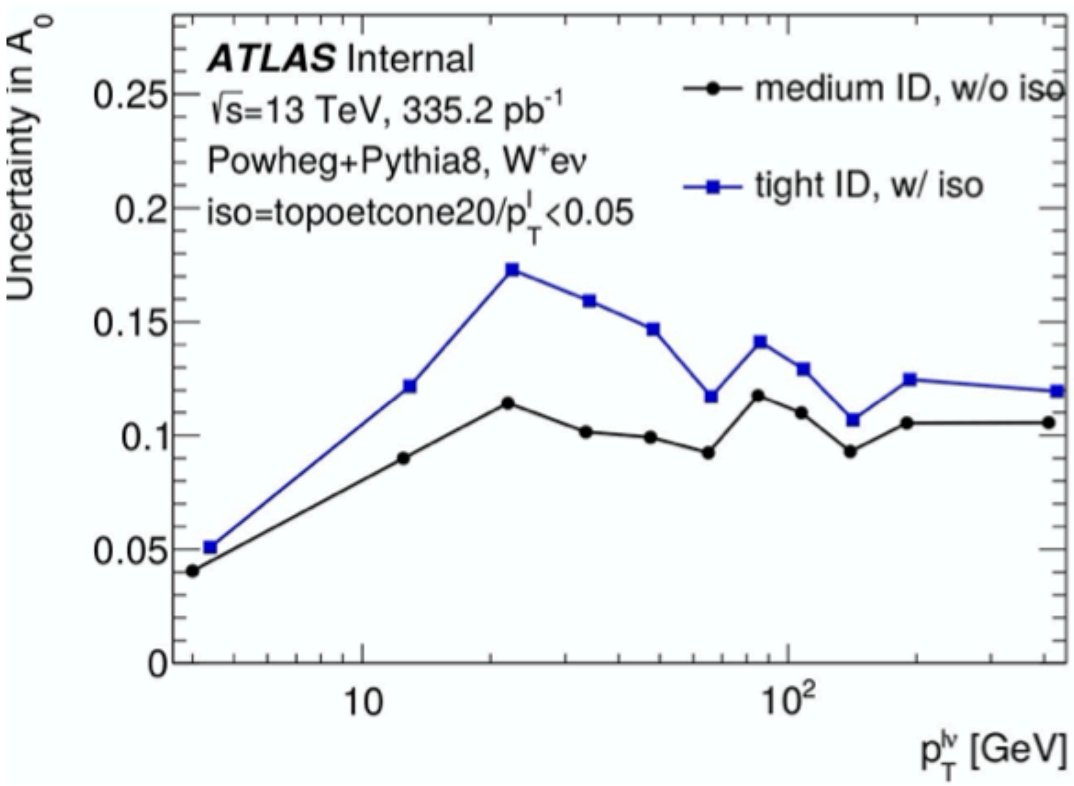
+ new optimise tight requirement on the leptons

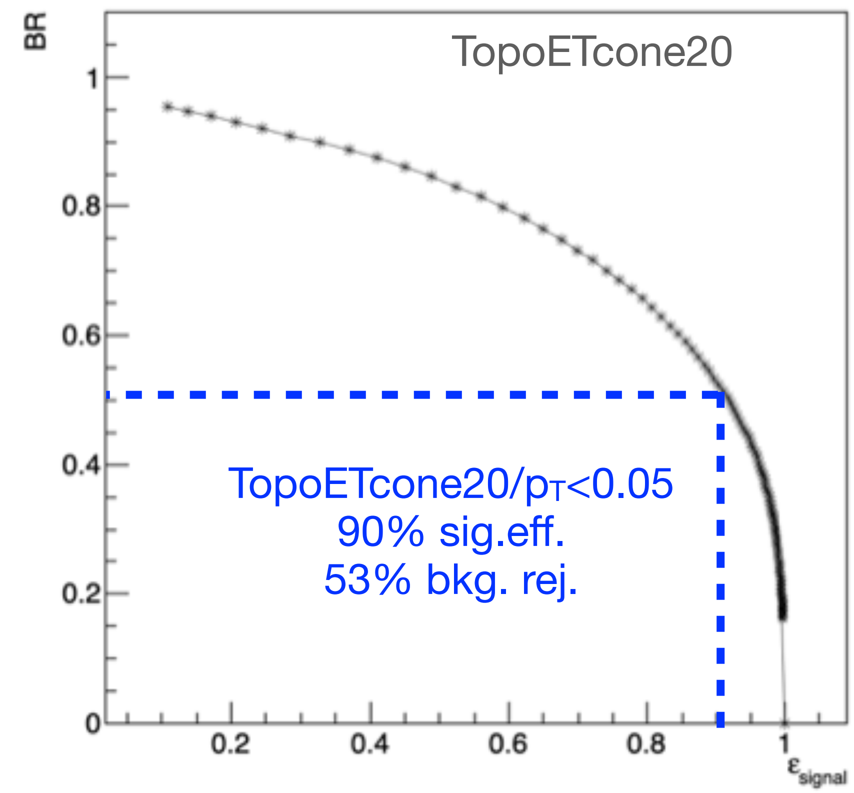
- gained a lot of A_i sensitivity by relaxing cuts on MET or $m_{T,W}$ in our signal region
- but also a lot of background…

DESY.

Reminder: Optimized WAi selection

Craigs studies



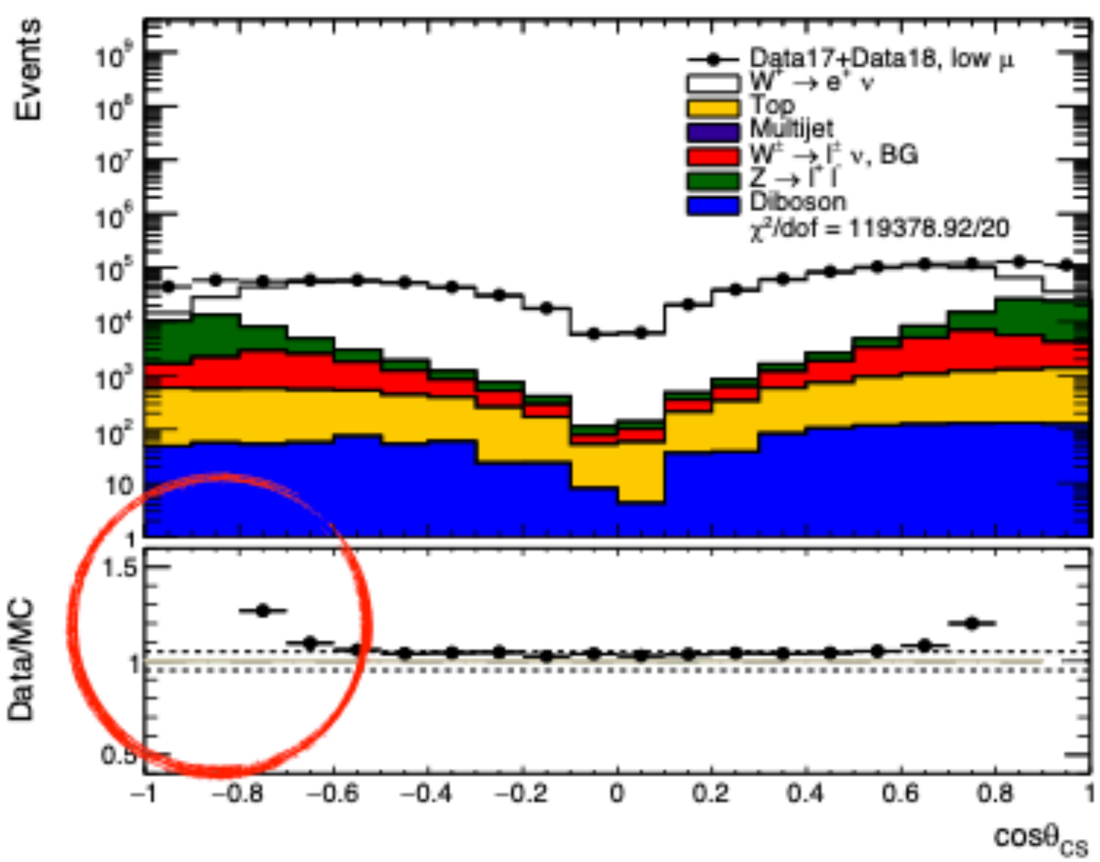


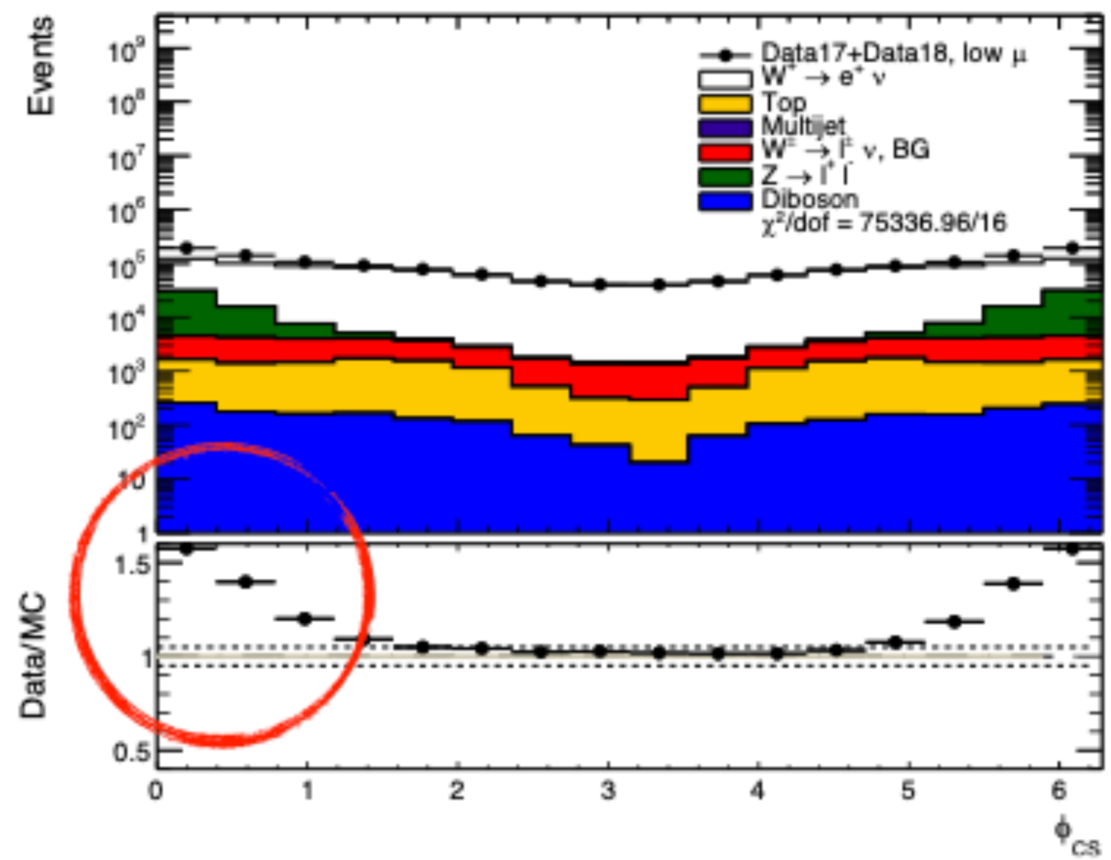
Cut	Electron channel	Muon Channel
ID	Tight	Medium
lepton p_T	p_T>25 GeV	p_T>25 GeV
lepton eta	$\|\eta\| < 2.4$ (excluding gap $\eta \in [1.37, 1.52]$)	$\|\eta\| < 2.4$
Isolation	ptvarcone20/p_T < 0.1 TopoETcone20/p_T < 0.05	ptvarcone20/p_T < 0.1 TopoETcone20/p_T < 0.05
Track IP	$\|d_0$ significance$\| < 5$ $\|z_0 \sin\theta\| < 0.5$	$\|d_0$ significance$\| < 3$ $\|z_0 \sin\theta\| < 0.5$

We now cut on two isolation variables (track- & calo-based), SF from Alex in place!

What do we actually need?

- our analysis goal: Measure A_i in template fit of angular variables $\cos\theta_{CS}$ and ϕ_{CS}
  → need a 2D MJ template in [$\cos\theta_{CS}$,ϕ_{CS}] (in bins of p_{TW} and y)





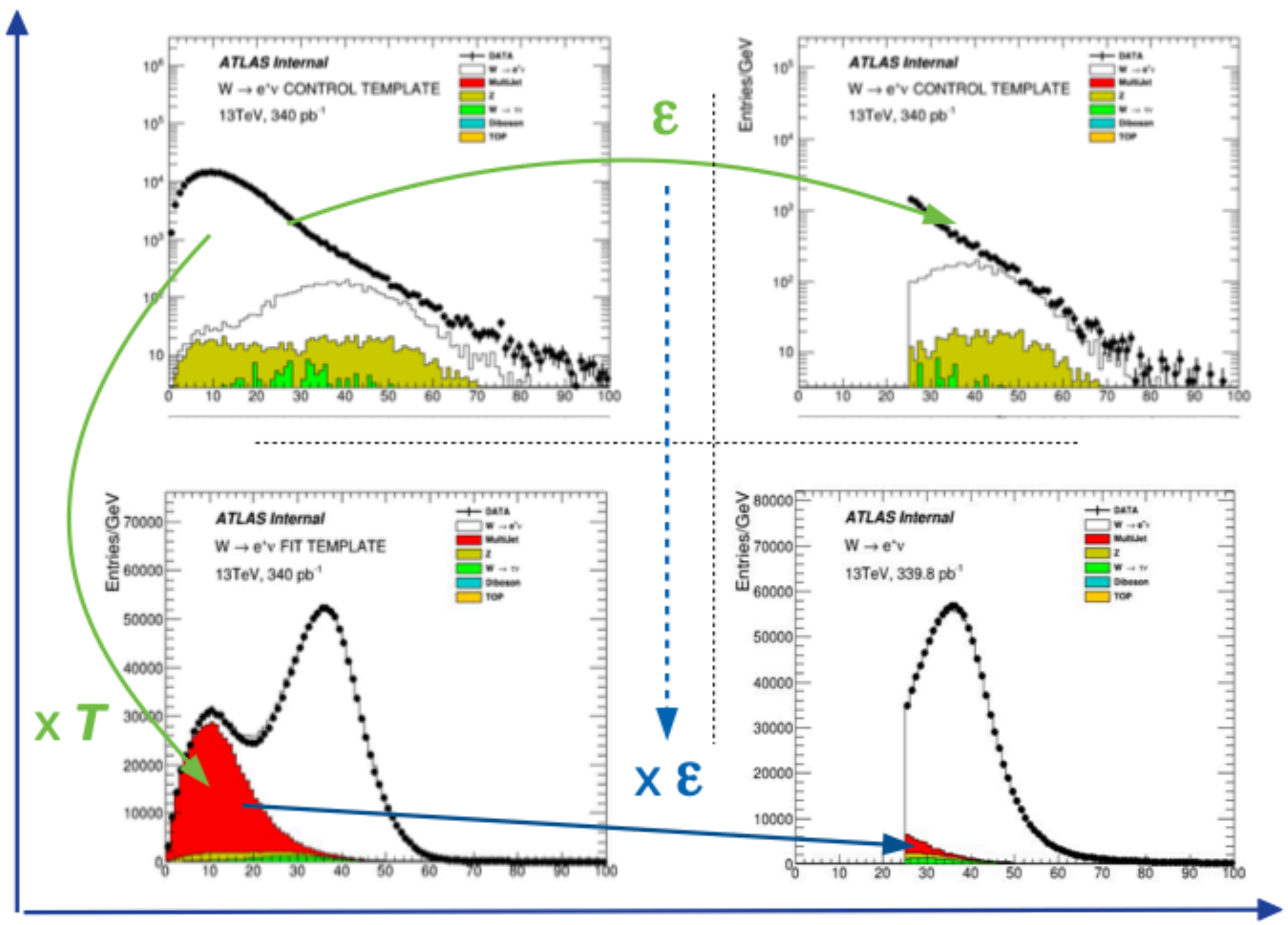
mj very localised in costCS and phiCS

- technically, need MJ **shape** only (A_i template fit could do the rest), but need norm for validation anyway → excellent cross-check!

MJ estimate in low-mu

ATL-COM-PHYS-2019-076

Isolation



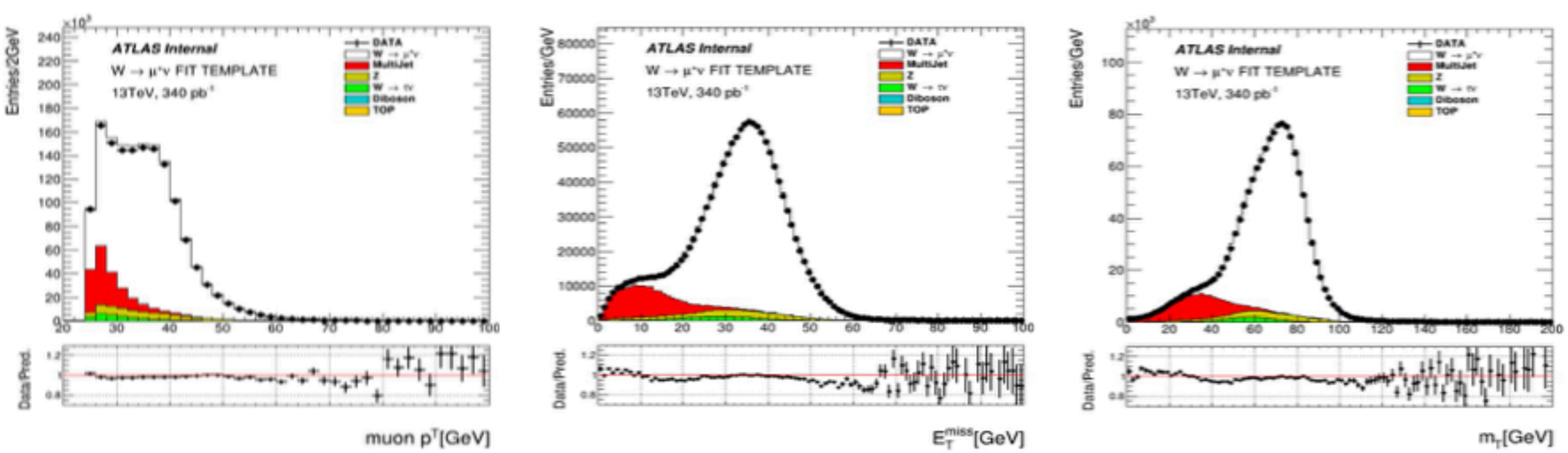
Kinematic cuts

Isolation

Control region 1 $p_t^l > 25$ GeV $E_T^{miss} > 0$ GeV $m_T > 0$ GeV anti-isolated	**Control region 2** $p_t^l > 25$ GeV $E_T^{miss} > 25$ GeV $m_T > 50$ GeV anti-isolated
Fit region $p_t^l > 25$ GeV $E_T^{miss} > 0$ GeV $m_T > 0$ GeV Isolated	**Signal region** $p_t^l > 25$ GeV $E_T^{miss} > 25$ GeV $m_T > 50$ GeV Isolated

Kinematic cuts

– p_t^l, E_t^{miss}, m_T all carry discriminating power



DESY.

MJ estimate in low-mu

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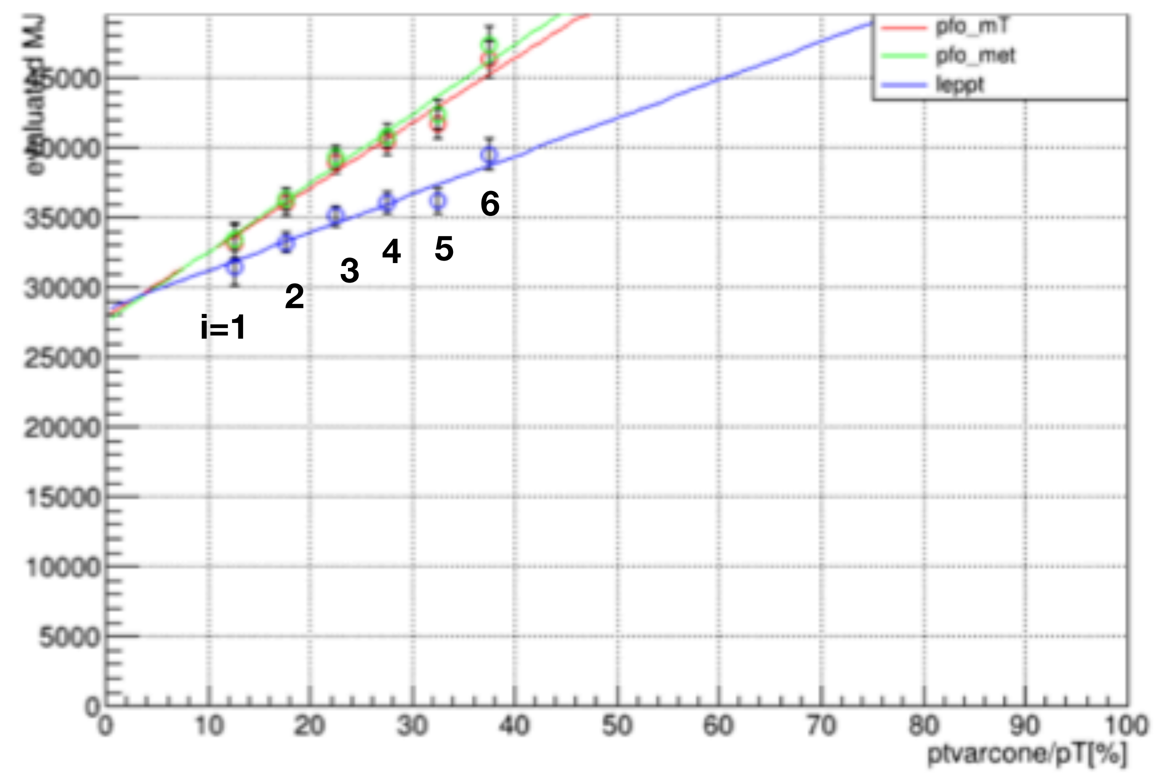
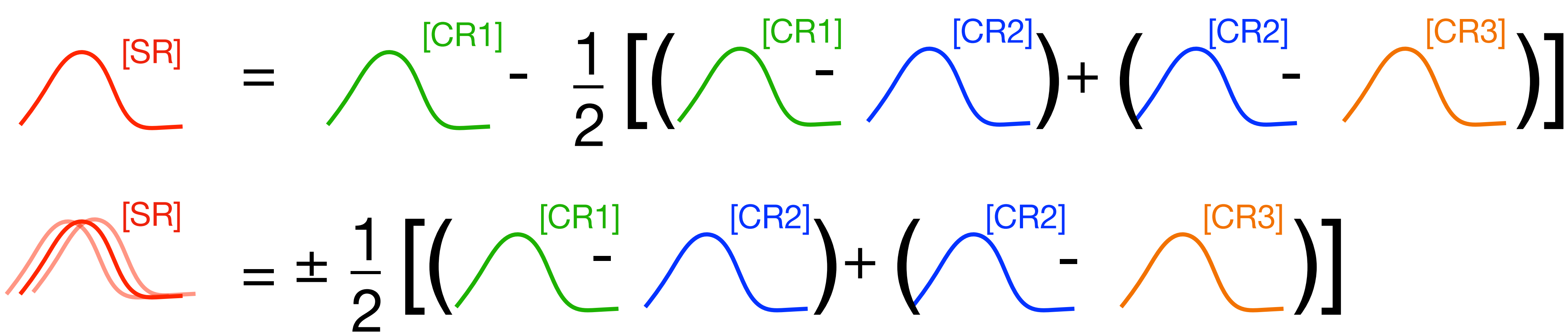
MJ Normalization:

- repeat MJ estimation for different anti-isolation slices (CR_i)
- fit linear function
- extrapolate back to the SR



MJ Template Shape:

- MJ distributions in CR_i don't match their SR counterparts
- bin-by bin linear shape extrapolation
- assign 100% uncertainty



Recoil isolation correction

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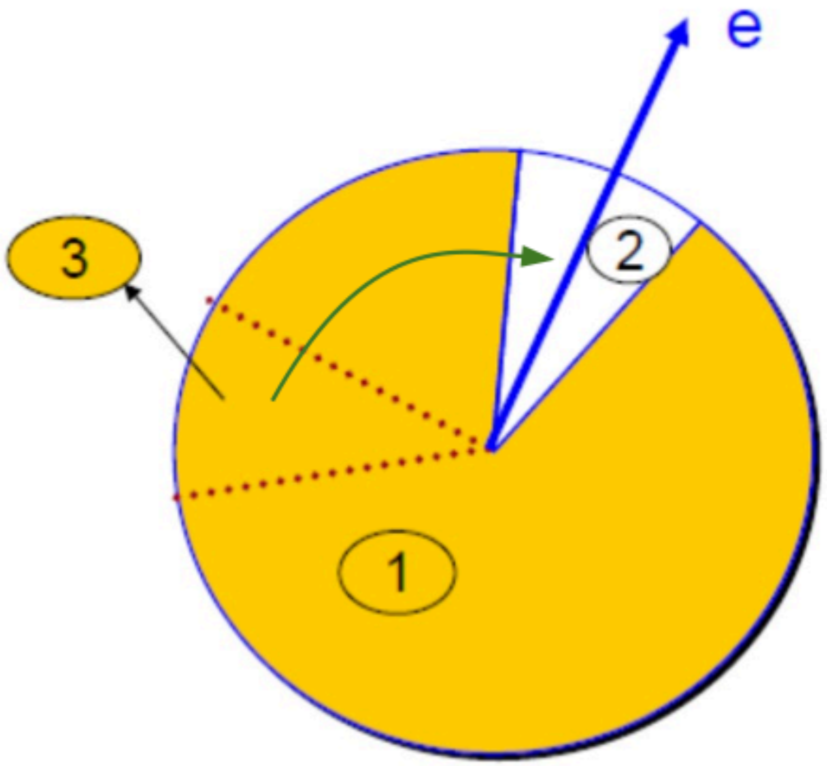


Improved recoil calculation:

- recoil calculated from all Pflow objects in event
- cone of ΔR=0.2 around lepton excluded to prevent double-counting
- replace by random ΔR=0.2 cone in the event away from leptons or jets
- this is ok for isolated leptons…

…BUT…

- in MJ events leptons are mostly close to jets
- above method fails

Solution:

- instead of underlying-event-type cone, use isolation:

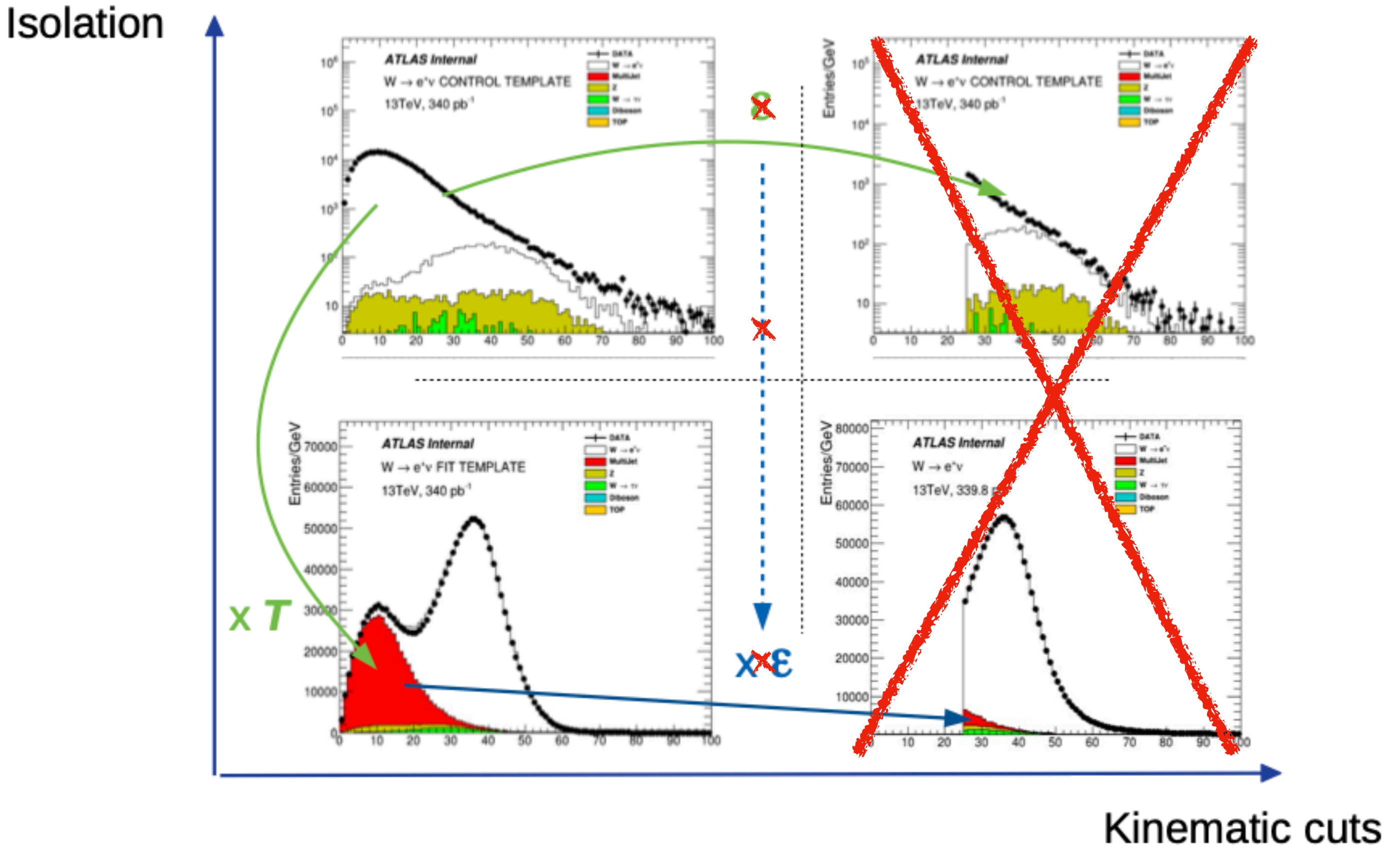
$$\boxed{\begin{aligned} \vec{u}^{\mathrm{corr}} &= \vec{u}^{\mathrm{baseline}} + \vec{u}^{\mathrm{iso}}, \text{ where} \\ \vec{u}^{\mathrm{iso}} &\equiv \mathtt{ptcone20} \cdot \vec{n}_{\ell} \end{aligned}}$$

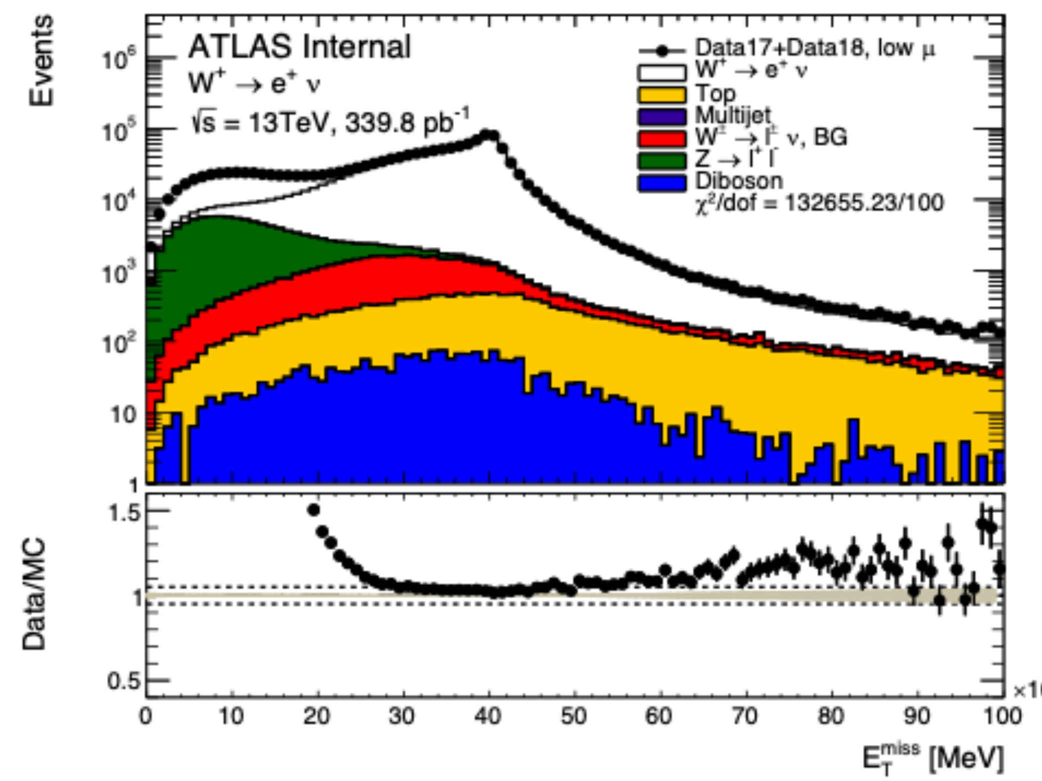
DESY.

What is different for WAi?

1) Selection

- relaxed cuts on MET or $m_{T,W}$ in our signal region
- cut on track-based isolation (ptvarcone20/pt<0.1)
  & calo-based isolation (TopoETcone20/p_T<0.05)





- cannot use our signal region directly to derive templates (dominated by signal modelling)
- define CR to extract MJ shape: i) relax both calo and track isolation
  or ii) relax only calo isolation
  or iii) relax both
- define anti-isolation slices based on calo isolation and/or track isolation

Anti-isolation slices for CR

- Options for relaxation/anti-isolation slicing to define CR:

<table>
<tr><td rowspan="2">Relax both track & calo isolation</td><td>Slice calo isolation</td></tr>
<tr><td>Slice track isolation</td></tr>
<tr><td>Relax track isolation</td><td>Slice calo isolation</td></tr>
<tr><td>Relax calo isolation</td><td>Slice track isolation</td></tr>
</table>

- propose anti-isolation slices:

  track-based: ptvarcone20/pt $\in$ [0.1,0.2,0.3,0.4]
  calo-based: TopoETcone20/pt $\in$ [0.05,0.15,0.25,0.35]

→ ToDo: Check the MJ amount for different slices

Fitting the Normalization

Isolation

Control region1

anti-isolated

$$
\begin{aligned}
N_{\mathrm{MJ}}^{CR1} &= N_{\mathrm{data}}^{\mathrm{CR1}} - N_{\mathrm{EW}}^{\mathrm{CR1}} \\
H_{\mathrm{MJ}}^{CR1} &= H_{\mathrm{data}}^{\mathrm{CR1}} - H_{\mathrm{EW}}^{\mathrm{CR1}}
\end{aligned}
$$

Fit Region = Signal Region

isolated

$$
H_{\mathrm{data}}^{\mathrm{FR}} = \alpha \cdot H_{\mathrm{EW}}^{\mathrm{FR}} + \underbrace{T \cdot H_{\mathrm{MJ}}^{\mathrm{CR1}}}_{N_{MJ}^{FR} = N_{MJ}^{SR}}
$$

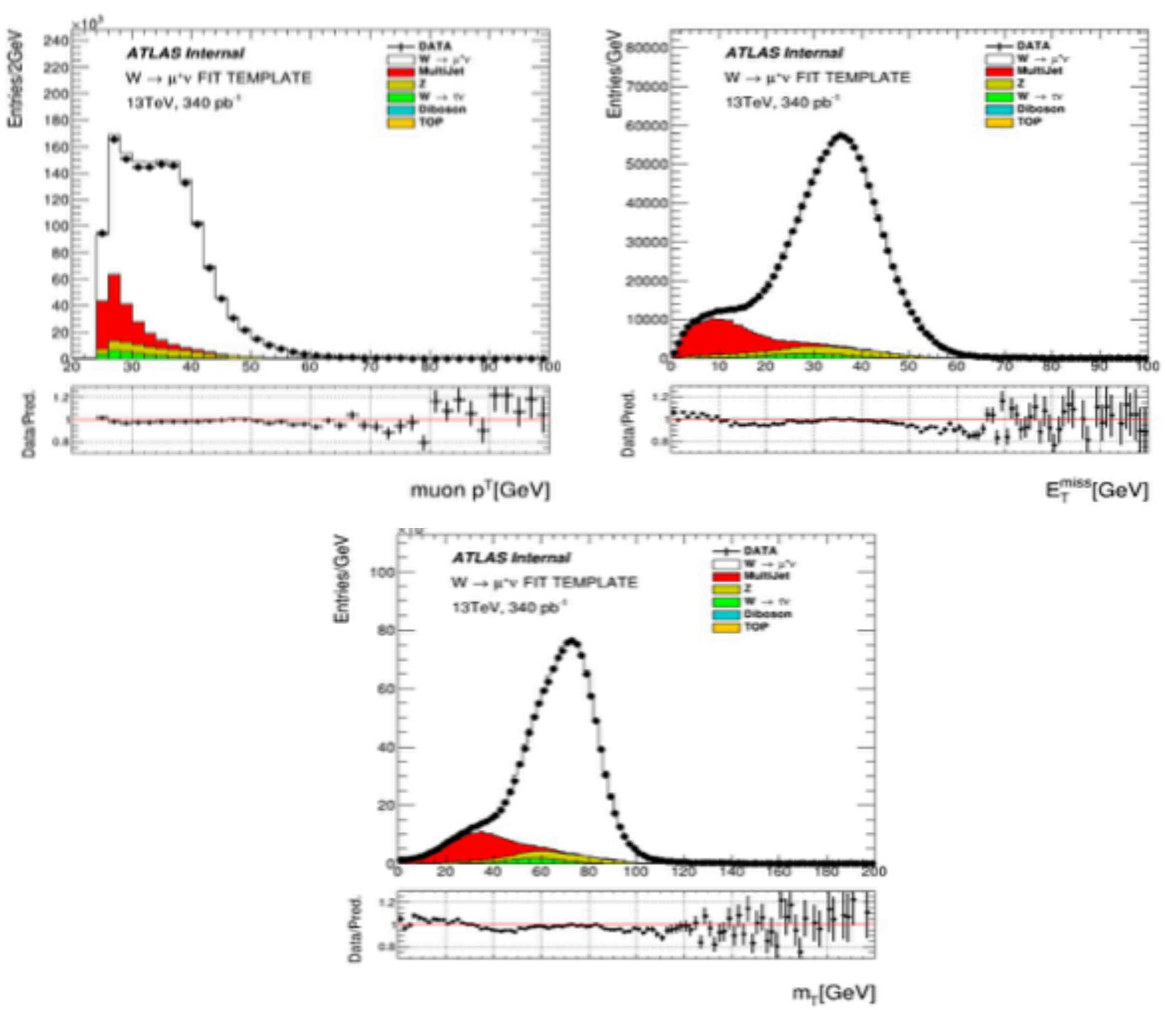
- our fit region is the same as our signal region (we already relaxed kin. cuts)
- need to be careful that signal (& EW background) norm α is not shifted in our fit

What is different for WAi?

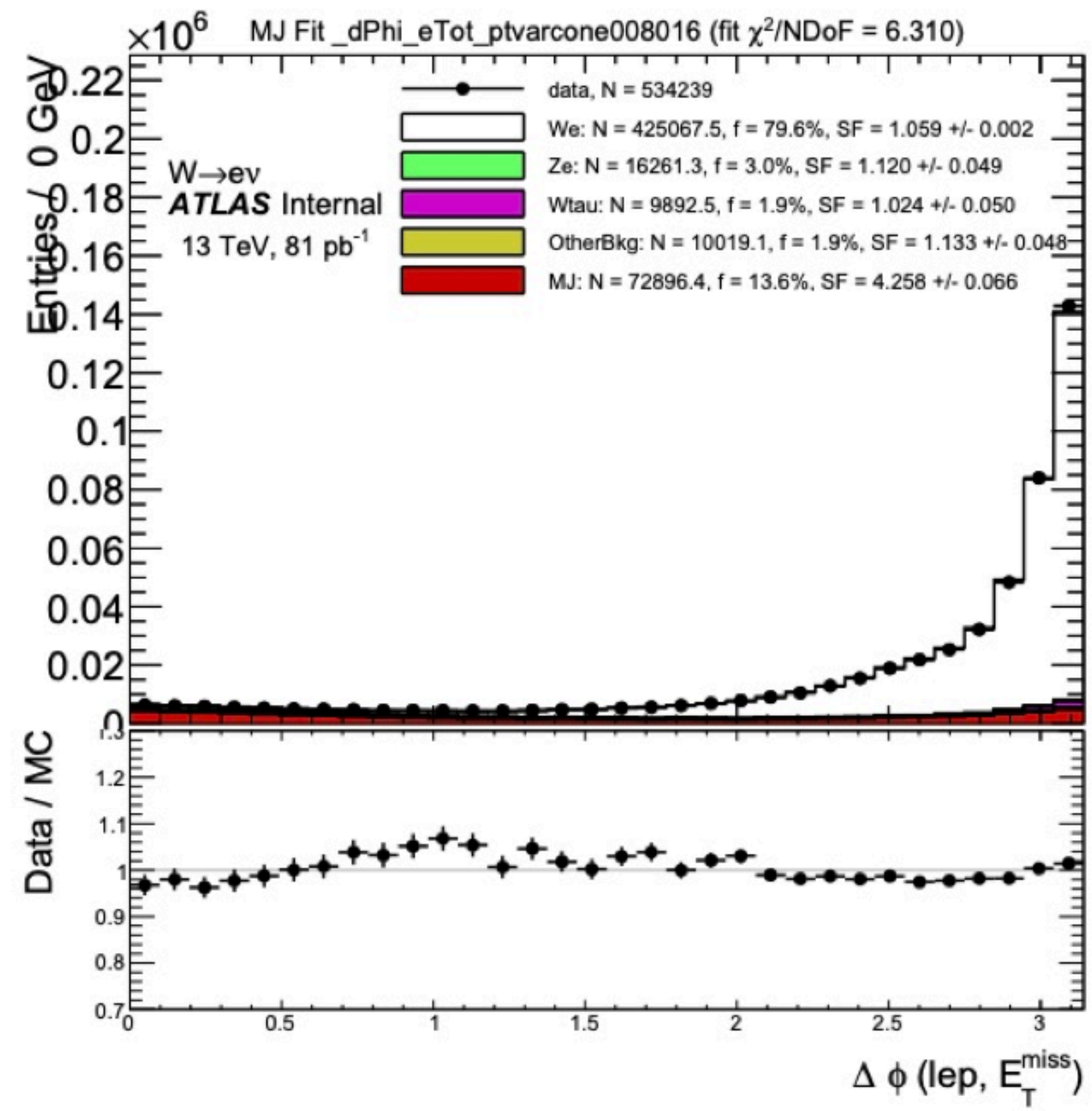
2) Angular Variables

- aim: multijet templates of ϕ_{CS} and $\cos\theta_{CS}$
- angular information in our MJ estimate to constrain angular behaviour
  $\rightarrow$ additional MJ template variable $\Delta\phi(\text{lepton}, E_T^{miss})$

– p_t^l, E_t^{miss}, m_T all carry discriminating power



+



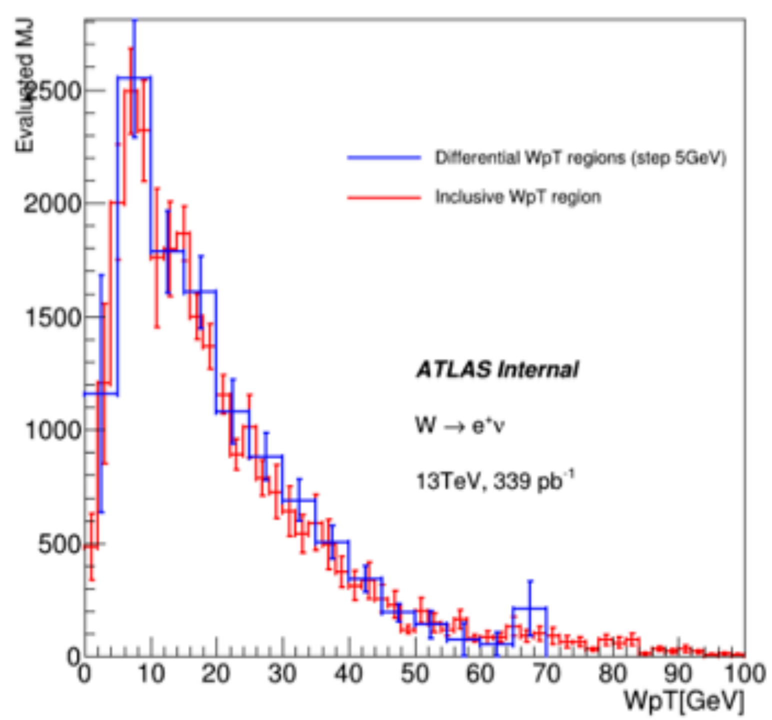
What is different for WAi?

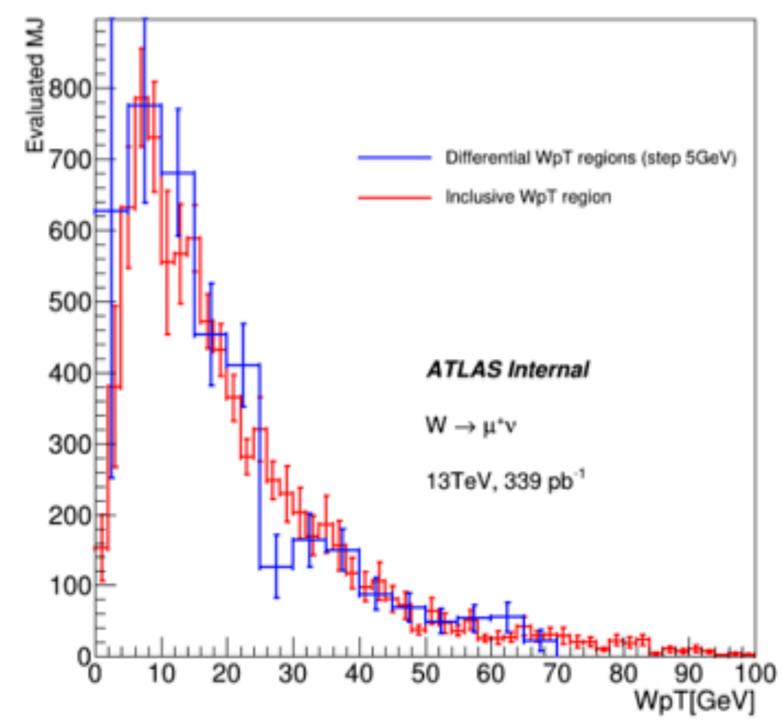
3) Analysis requirements:

- we need templates in bins of $p_{T,W}$ and rapidity
- Ideally: show that MJ template shape for ϕ and $\cos\theta$ is flat in bins of p_T and y

  → would mean we can use template shape derived in inclusive CR

  (the case e.g. for Z-Ai)





Red – uT distribution obtained from the inclusive control region
Blue – repeated MJ estimation procedure in uT bins
→ Good agreement, no additional uncertainty

Summary

MJ in W-Ai analysis:

- relaxation of kinematic cuts and additional isolation requirements impact our multijet estimation strategy
- follow-mu MJ approach: iterative procedure using extrapolation from anti-isolation slices
- aim: ϕ and $\cos\theta$ templates in bins of p_{TW} and y → A_i template fit machinery

Proposed strategy:

- CR: relax one or both isolation criteria, slice the other
- include angular template variable $\Delta\phi$(lepton,MET)
- Fit Region = Signal Region
- analysis bins: ideally use template from inclusive CR in all bins

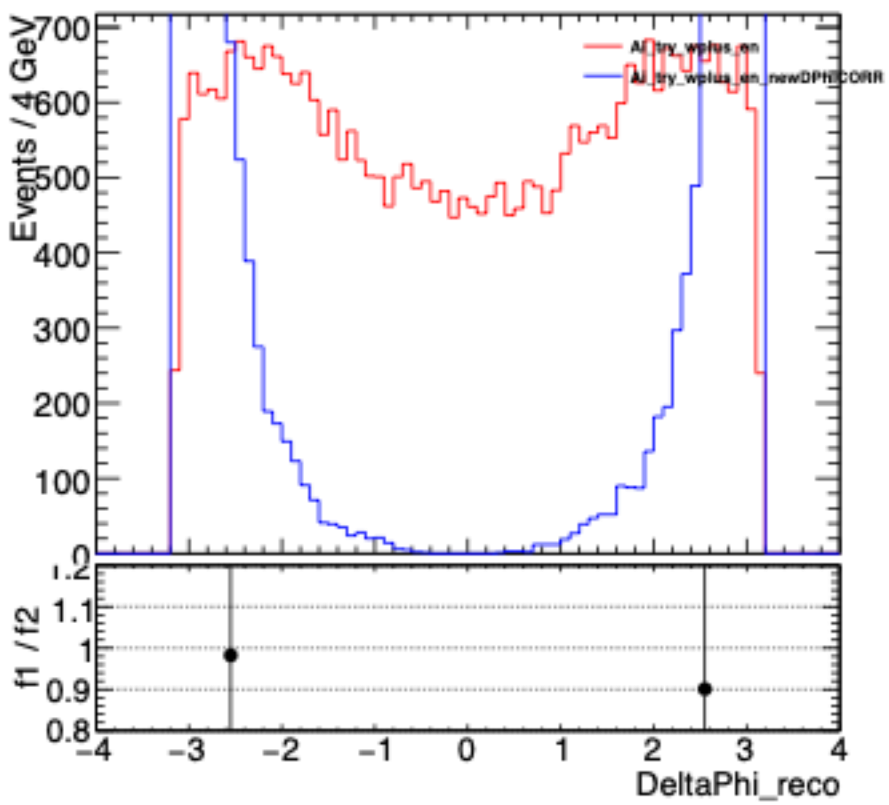
Next steps:

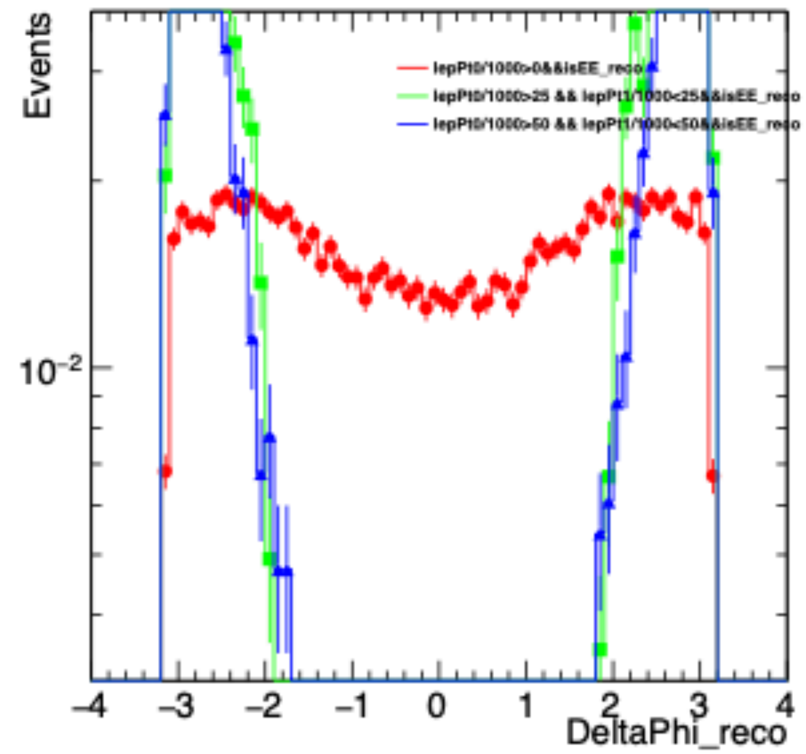
- study whether MJ shape in ϕ and $\cos\theta$ changes as function of p_{TW} or rapidity
- determine which iso slicing to use (check MJ amount in each configuration)
- technicalities (MJ fitting code, HistMaker modifications)

BACKUP

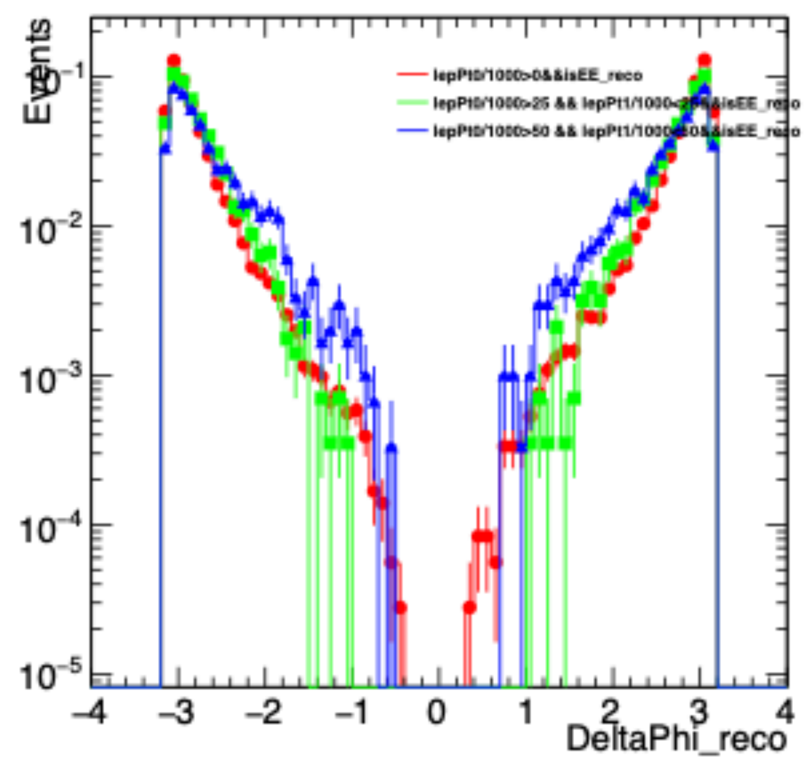
small parenthesis Δφ

wrt what presented here we figured out that the definition of Δφ was misleading: what was shown was Δφ between recoil and lepton, instead of Δφ between lepton and MET





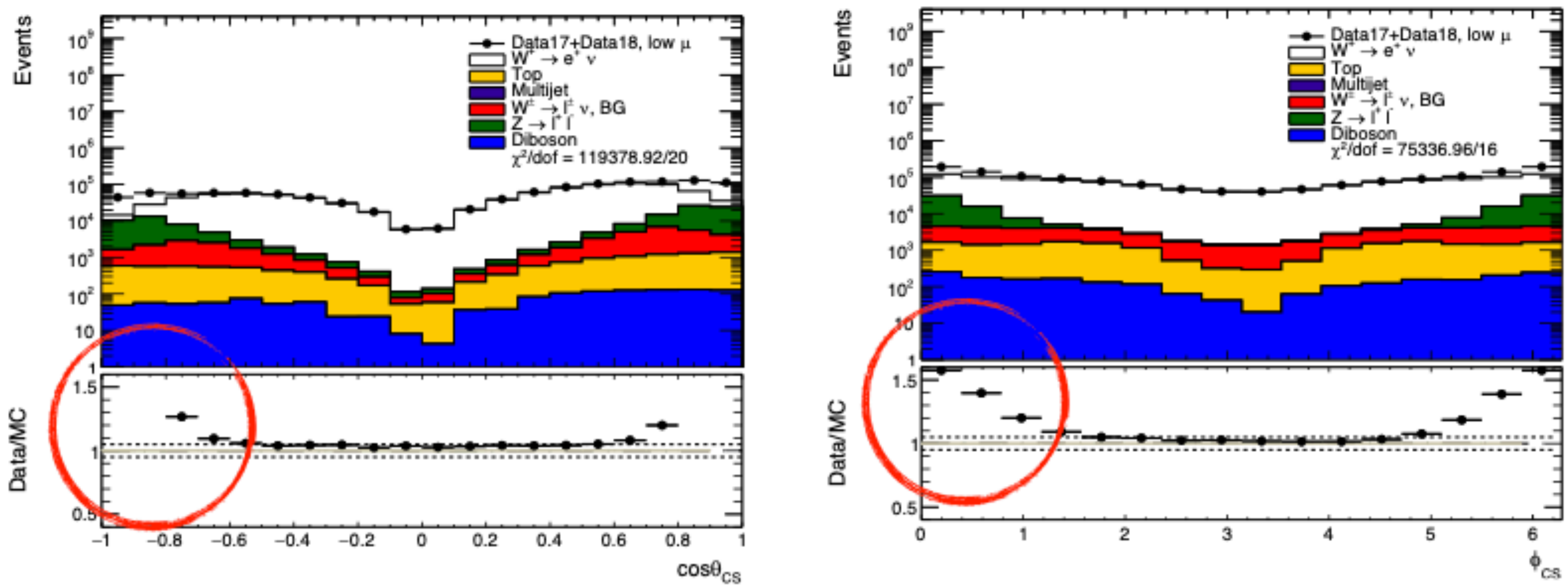
$\Delta\phi(l,u_T)$



$\Delta\phi(l,MET)$

- $\Delta\phi(l,u_T)$
- $\Delta\phi(l,MET\ )$

How much of MJ is entering in our SR ?



mj very localised in costCS and phiCS

Table of Statistics				
Cut	No. of Data Events	No. of Signal Events	No. of EW Bkg Events	No. of MJ Events
lepPt > 25 GeV	2452868	1314812	170669	967387
lepPt > 25 GeV Electron Tight iD	1965857 (-20%)	1214360 (-8%)	155216 (-9%)	596281 (-38%)
lepPt > 25 GeV Electron Tight iD topoetcone20/lepPt < 0.05	1525477 (-38%)	1099013 (-16%)	140191 (-18%)	286273 (-70%)