TTBAR SPIN CORRELATION

Lepton + Jets channel with pTmax

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OVERVIEW

- Introduction to Spin Correlation and existing results
- Lepton+Jets channel
- Reconstructing the top quarks
- Summary and Conclusions

SPIN CORRELATION

- Top quark decays before hadronisation
  - Spins are unaffected by strong interactions
- Spin information influences angular distributions of decay products
  - Can use this to determine the degree of correlation of the ttbar spins
  - Analysis published in dilepton channel: arXiv:1203.4081v1 [hep-ex]

SPIN ANALYSING BASIS

- An analysing basis can be defined for the top quarks
- **Helicity basis**
  - Vector defined along direction of top quark in ttbar rest frame
- **LHC Optimal basis**
  - A basis optimised for ttbar from gg fusion (the dominant production mechanism at the LHC)
- Degree of spin correlation can be then defined, where ↑ and ↓ denote spins measured with respect to the basis

$$A = \frac{N_{like} - N_{unlike}}{N_{like} + N_{unlike}} = \frac{N(\uparrow\uparrow) + N(\downarrow\downarrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)}$$

$A_{helicity} = 0.31$
$A_{maximal} = 0.44$

SPIN CORRELATION

- Angular distribution, θ, from a given spin analysing basis of decay product *i* fixed by,

$$\frac{1}{N}\frac{dN}{d\cos(\theta_i)} = \frac{1}{2}\left[1 + S\,\alpha_i \cos(\theta_i)\right]$$

- α_i is the 'Spin Analysing Power', S is the top polarisation

	b-quark	W^+	l^+	$\bar{d}$-quark or $\bar{s}$-quark	u-quark or c-quark
α_i (LO)	-0.41	0.41	1	1	-0.31
α_i (NLO)	-0.39	0.39	0.998	0.97	-0.32

- In the lepton+jets channel, charged lepton and d-type quark are most effective analysers

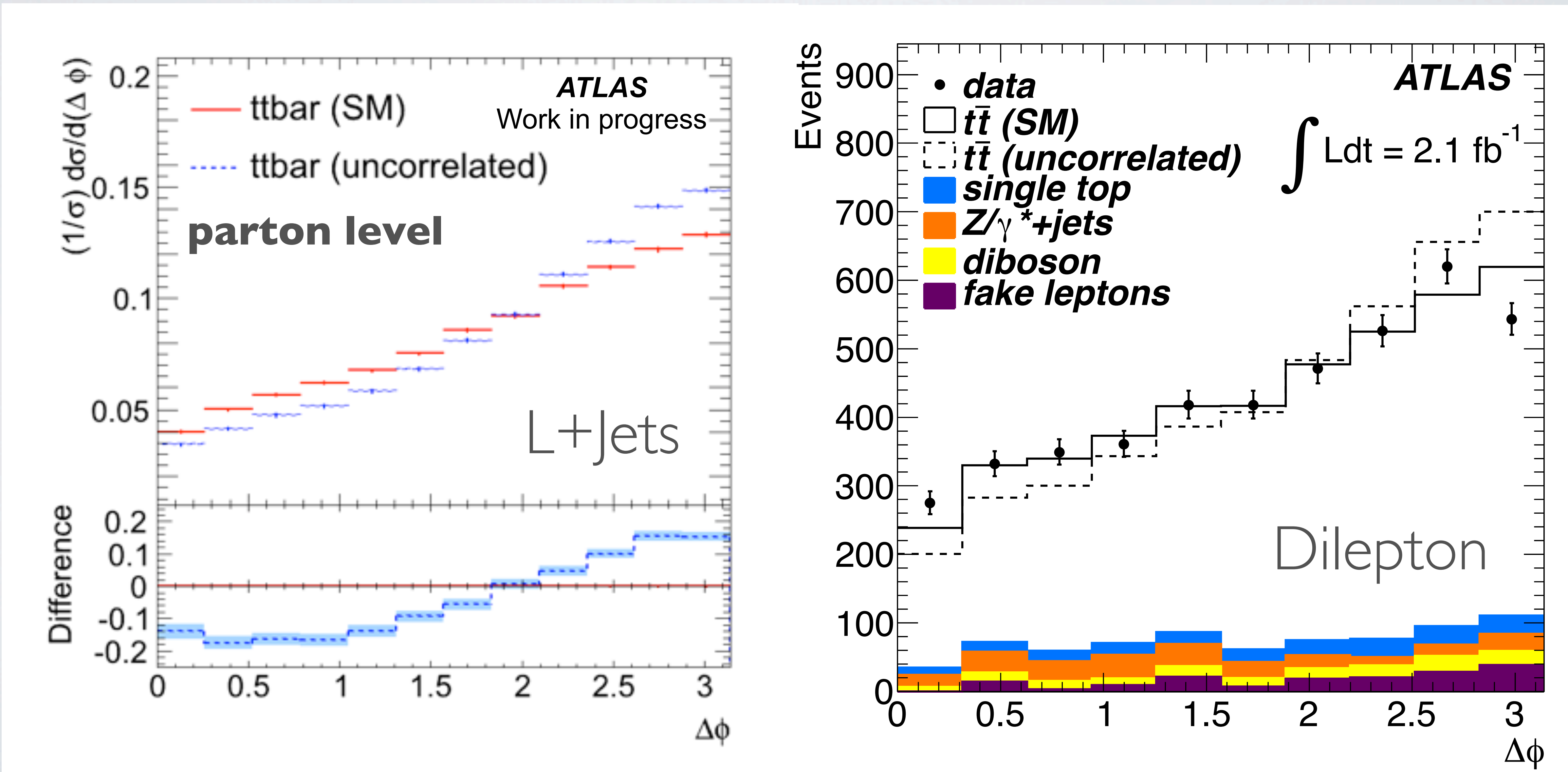
A NOTE ABOUT MONTE CARLO

- We use two Monte Carlo simulations to model our ttbar signal
- Standard Model includes Spin Correlations where $A_{helicity} = 0.31$
- Uncorrelated sample sets $A = 0$
  - ie, as many tops are produced with spins parallel as anti-parallel

OBSERVABLE - DELTA PHI

- The azimuthal angular difference ($\Delta\phi$), in the lab frame, between the charged lepton and down-type quark (other lepton) is sensitive to spin correlations

- Benefit from not having to perform full ttbar reconstruction (no boosting needed)



[1] G. Mahlon and S. Parke, Phys. Rev. D81, 074024 (2010)

EVENT SELECTION

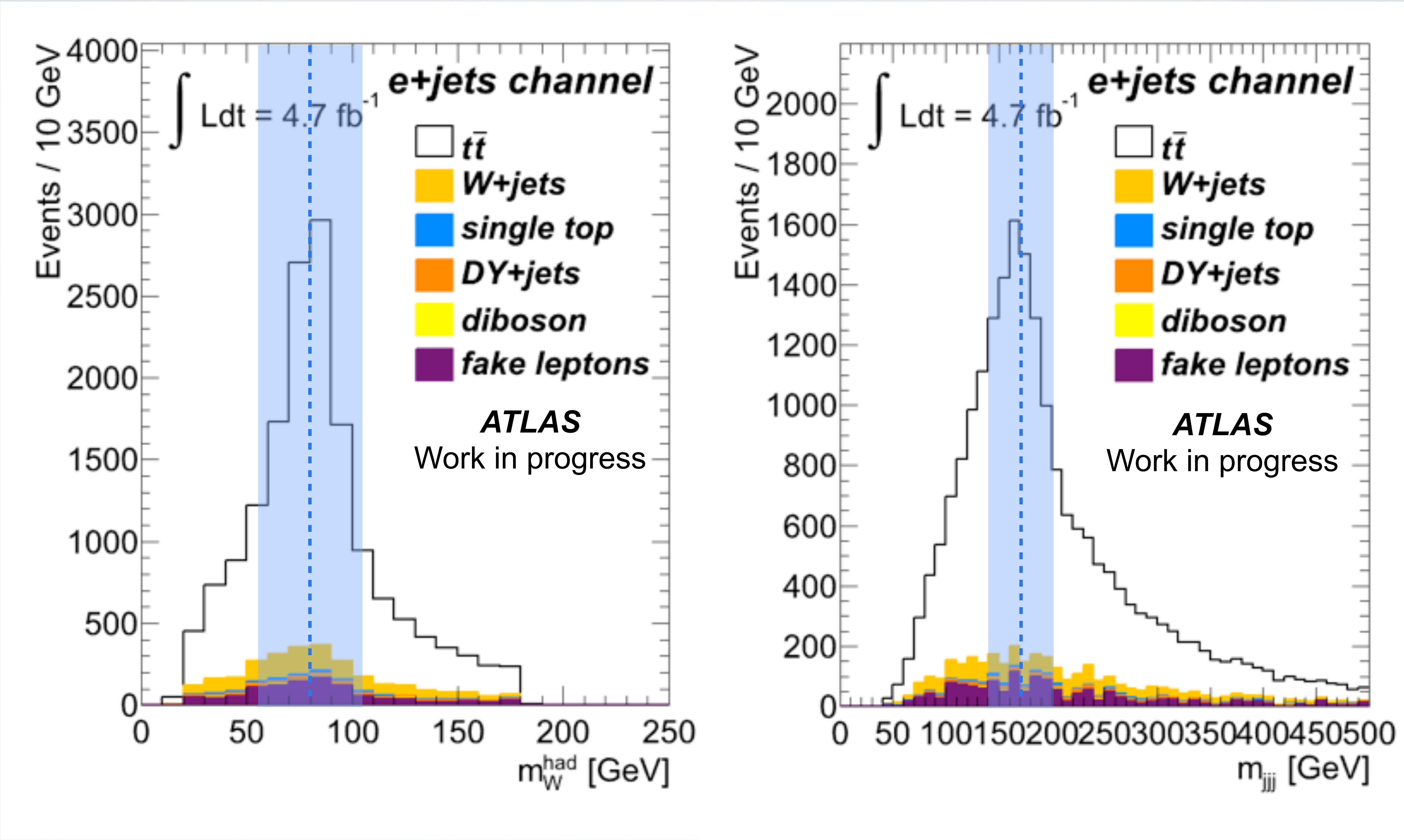
- Event must pass trigger with a 'good' primary vertex
- Exactly 1 electron (muon) and 0 muons (electrons)
- Selected lepton must have fired the trigger
- At least 4 jets
- Missing ET > 30 (20) GeV
- Transverse W mass > 30 GeV (MWT+MET > 60 GeV)
- At least 1 b-tagged jet

PTMAX RECONSTRUCTION

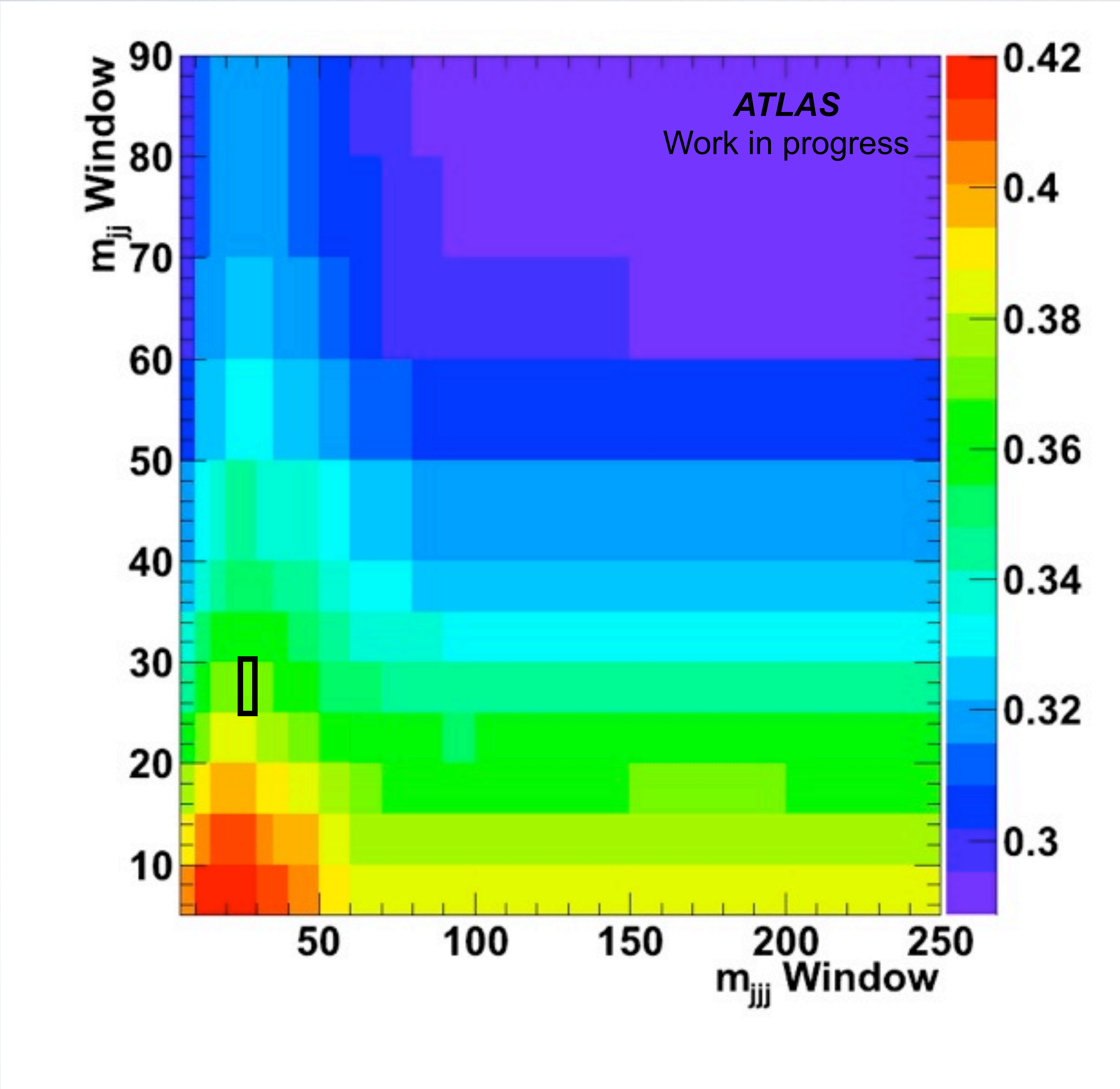
- To find the correct jet originating from the down-type quark, a small amount of reconstruction is needed
- Take each combination of 3 jets *(satisfying $|m_{jjj} - m_{top}| < XX$ GeV)* in the event and reconstruct as a hadronic top 'candidate'
- Take the candidate with highest pT as our final hadronic top
- Within our final hadronic top, consider each of the 3 (un-b-tagged) jet pairs and reconstruct as a W 'candidate'
- Take the W candidate *(satisfying $|m_{jj} - m_W| < YY$ GeV)* closest to the true W mass (80.4 GeV)
- Finally, from the jets in the W, take the least energetic jet, in the top rest frame, and take it as the jet originating from the down quark
  - On truth, the down quark is the least energetic jet around 54% of the time

m_{top} = 172.5 GeV
m_W = 80.4 GeV

RECONSTRUCTION

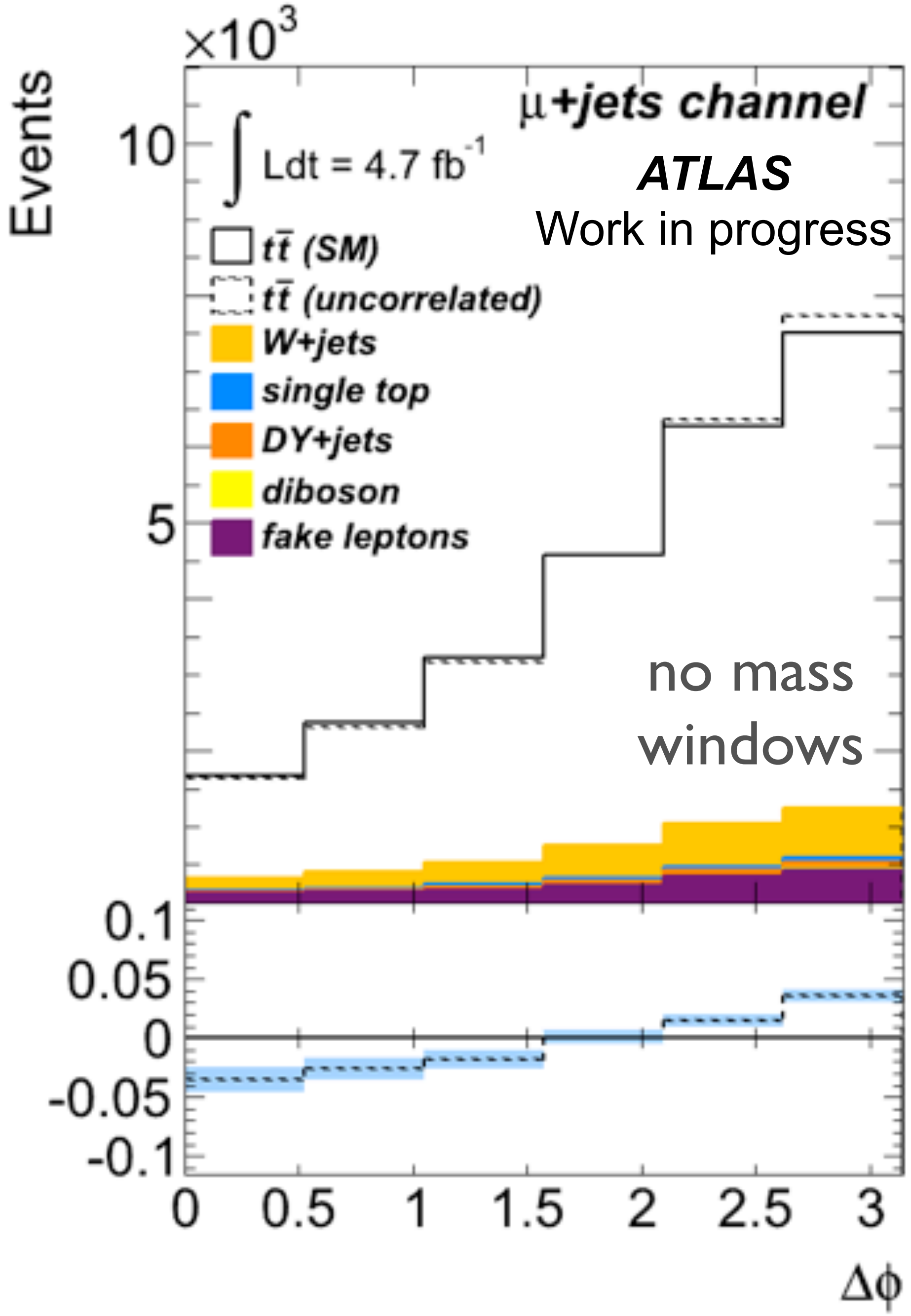


DOWN QUARK PURITY

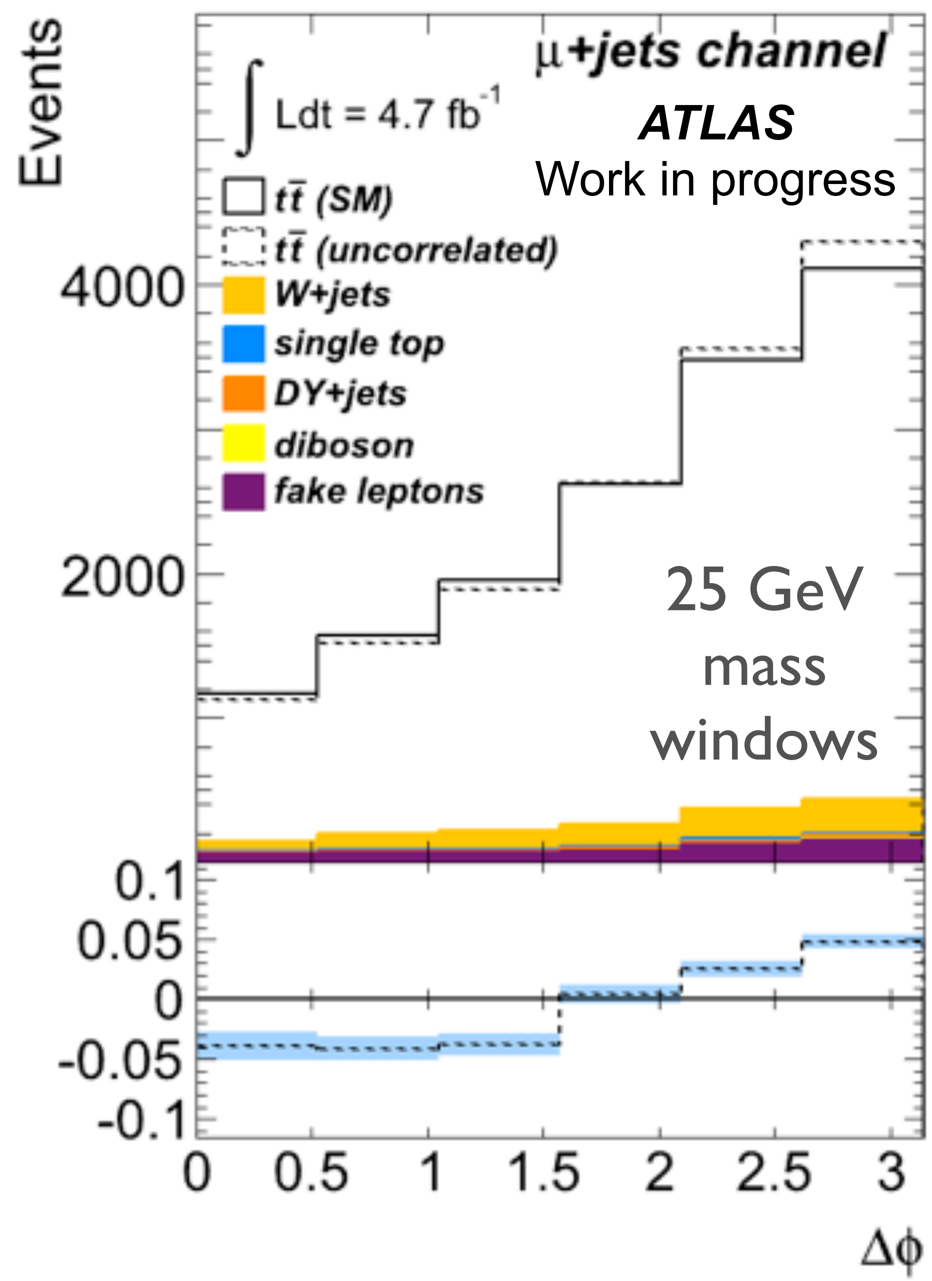


- Without any window requirement, purity = 28.4%
- With 25 GeV for both windows, purity = 36.9%
- Compared to 14.9% picking leading jet, 16.2% picking 2nd

DELTA PHI



×10^3
Events
μ+jets channel
∫ Ldt = 4.7 fb^-1
ATLAS
Work in progress
tt̄ (SM)
tt̄ (uncorrelated)
W+jets
single top
DY+jets
diboson
fake leptons
no mass windows
Δφ



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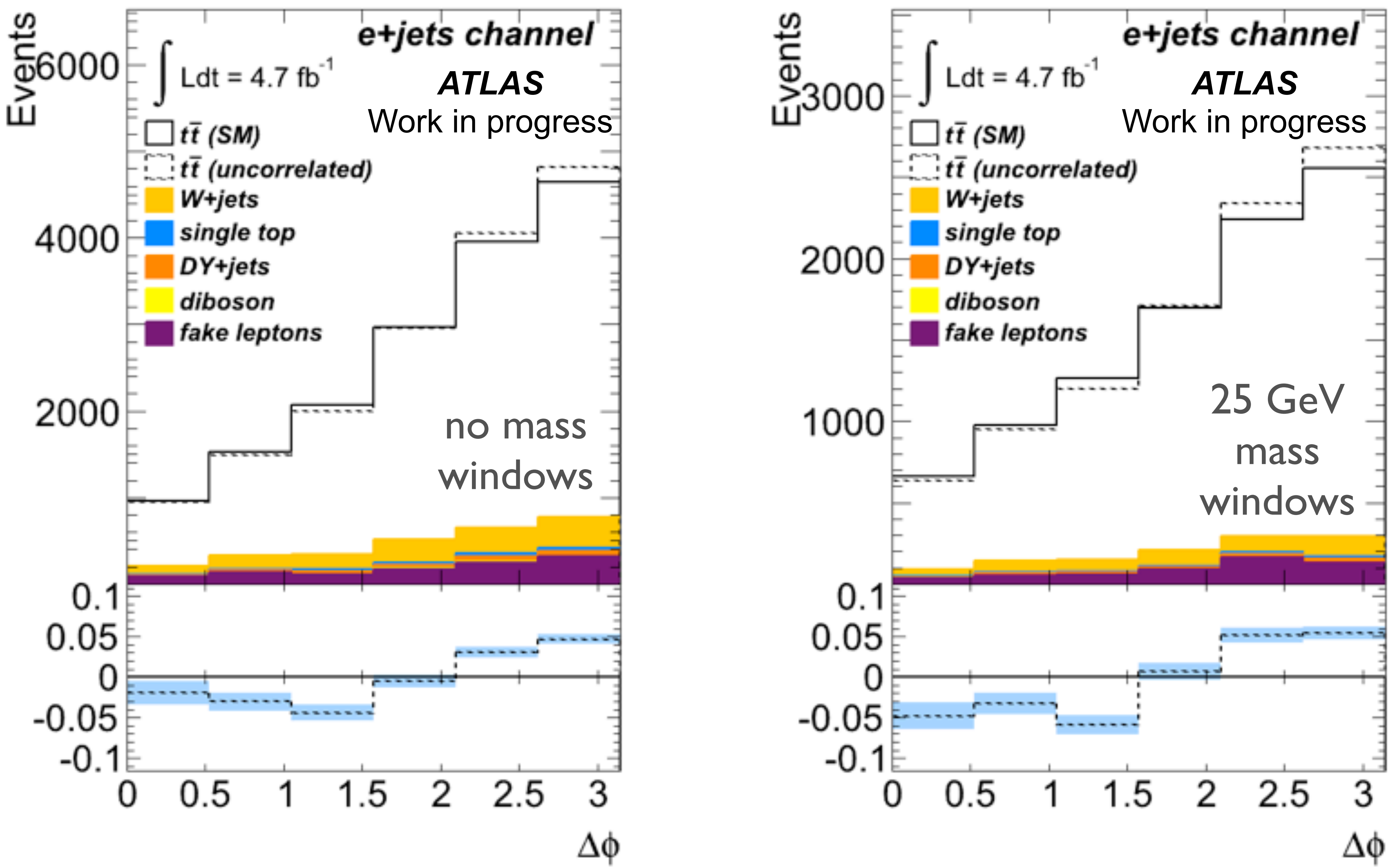
DELTA PHI



Events
$\int$ Ldt = 4.7 fb^{-1}
e+jets channel
ATLAS
Work in progress
$t\bar{t}$ (SM)
$t\bar{t}$ (uncorrelated)
W+jets
single top
DY+jets
diboson
fake leptons
no mass windows
25 GeV mass windows
$\Delta\phi$

EXTRACTING A RESULT

- To measure the degree of spin correlation in data, we perform a binned likelihood fit to the two templates
- Float the ‘fraction of Standard Model’ in the fit, where $f_{SM} + f_{UC} = 1$

ESTIMATING SENSITIVITY

- To measure the degree of spin correlation in data, we perform a binned likelihood fit to the two templates
- Float the 'fraction of Standard Model' in the fit, where $f_{SM} + f_{UC} = 1$
- To estimate the expected statistical uncertainy, we can perform this fit on multiple pseudo experiments created by mixing the templates
  - Result is gaussian around the input value; width gives us an estimate for statistical uncertainty
  - Also works as a linearity check

EXPECTED SENSITIVITY

- Give $f_{SM}=1$ as input, and run 10,000 pseudo experiments
- Perform the fit each time and measure the width of the resulting gaussian
- Mean gives us expected central value, width gives expected statistical
- Applying 25 GeV mass window requirements around the reconstructed W and top gives an improvement in sensitivity of around 6%

CONCLUSIONS

- Applying invariant mass restrictions in the reconstruction improves down quark purity
    - Leads to increased separation between two models
- Improved separation gives us slightly improved expected statistical uncertainties
    - Mass windows could be optimised to maximise sensitivity
- Also investigating the possibility of requiring an additional b-tag in the event selection