Jet trigger performance and background studies for a dark matter search in ATLAS

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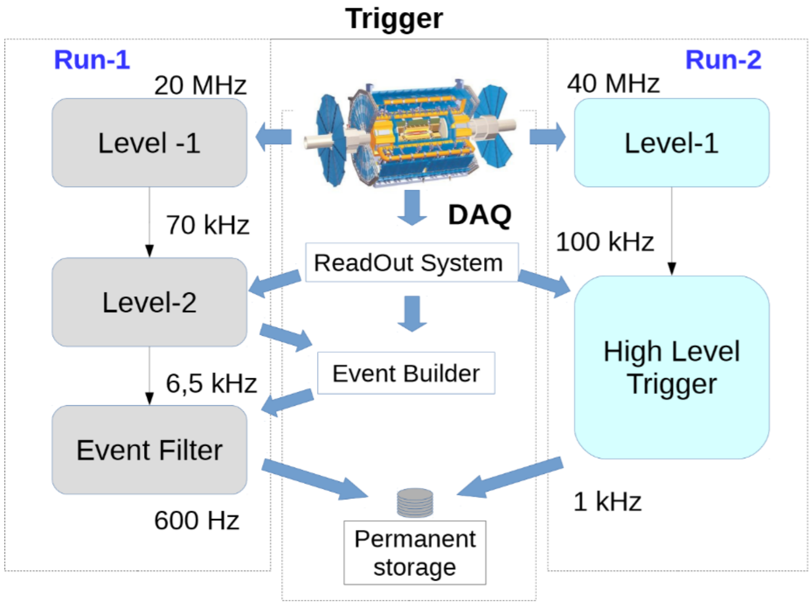
Jet trigger performance

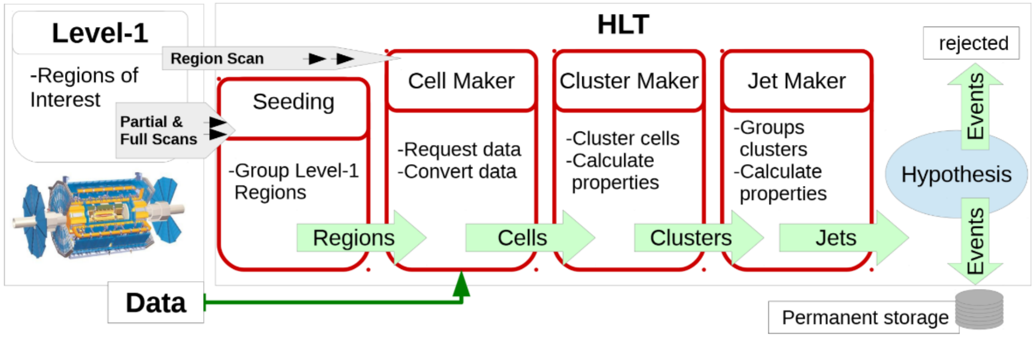
ATLAS triggers

- ATLAS uses a two-level trigger system:
  - Level 1 (L1) trigger: hardware trigger that creates Regions of Interest (RoIs) and reduces the rate to 100 kHz
  - High Level Trigger (HLT): software trigger seeded by L1 RoIs, reducing rate to 1 kHz

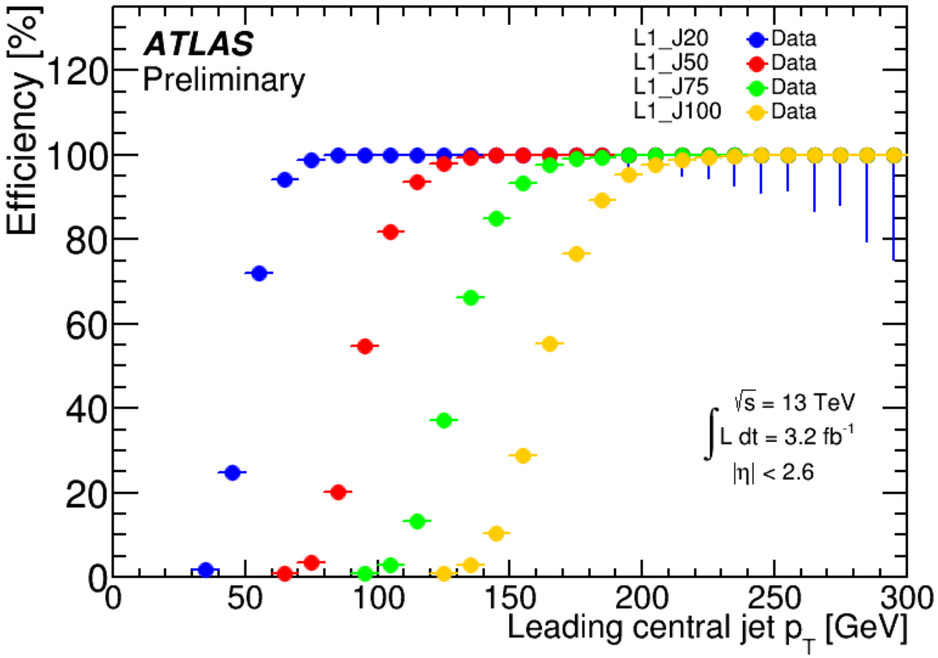


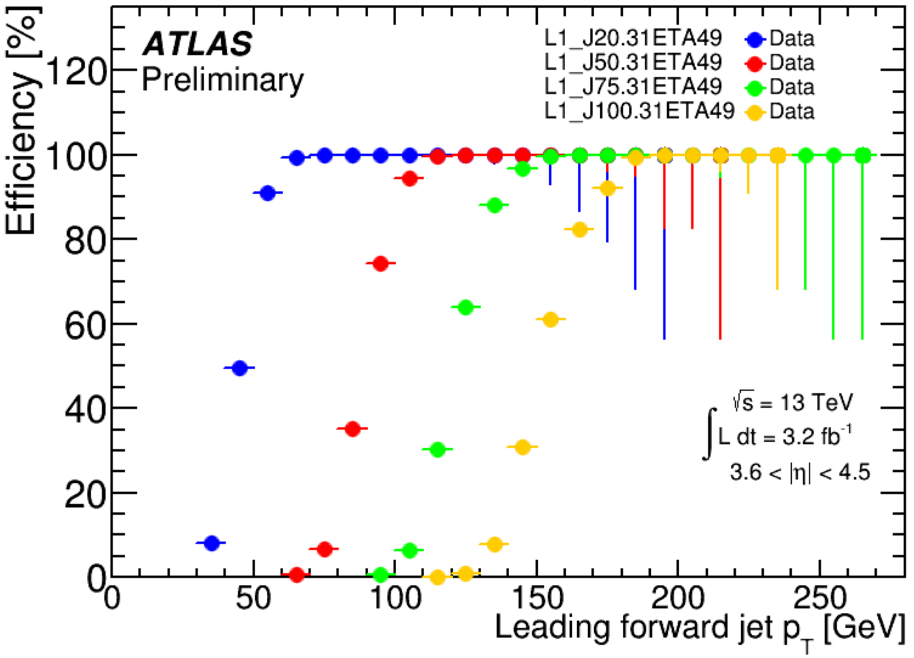
Jet triggers:

- Primarily select events with high transverse momentum (p_T)
- L1 trigger jets are formed from RoIs, of size 0.8 x 0.8 in η x φ, at the electromagnetic energy scale
- HLT jets are formed from calorimeter clusters at the electromagnetic energy scale using the anti-k_T algorithm with distance parameter R = 0.4



L1 single-jet efficiencies

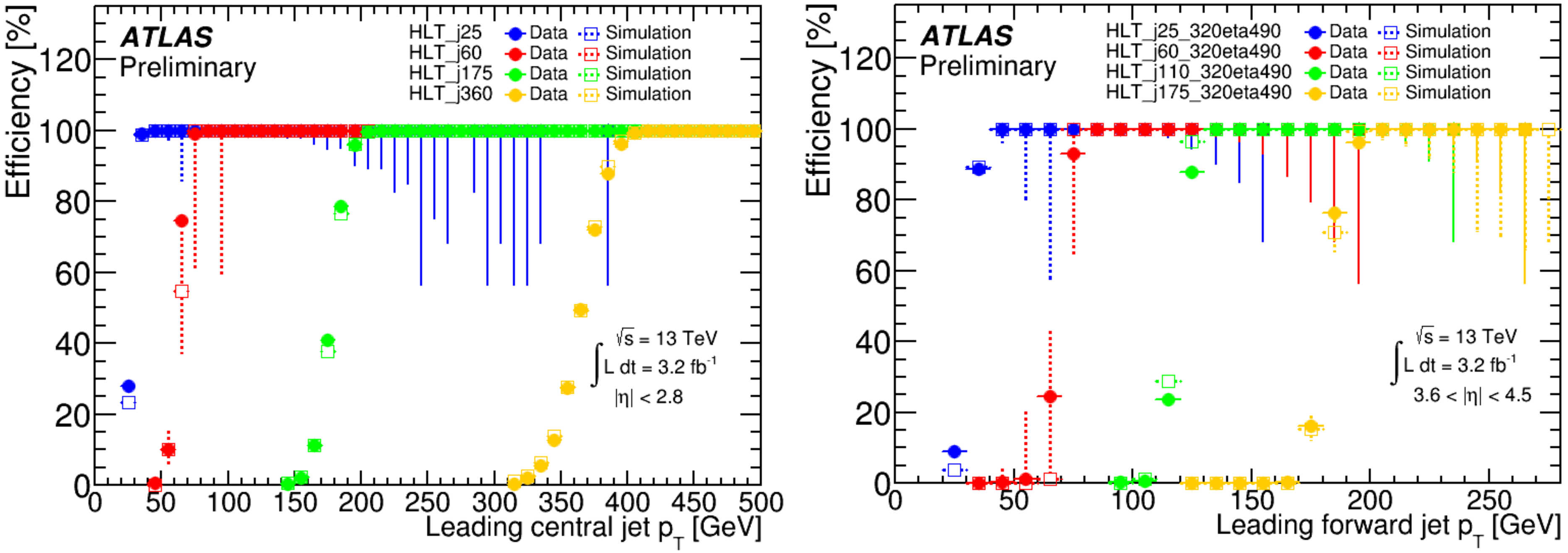




Comparison of (left) L1 central (|η| < 2.6) and (right) forward (3.6 < |η| < 4.5) per-event trigger efficiencies. The geometrical and algorithmic differences between L1 and offline procedures cause broad turn-ons.

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetTriggerPublicResults#Jet_Trigger_Efficiency_Plots_ATL

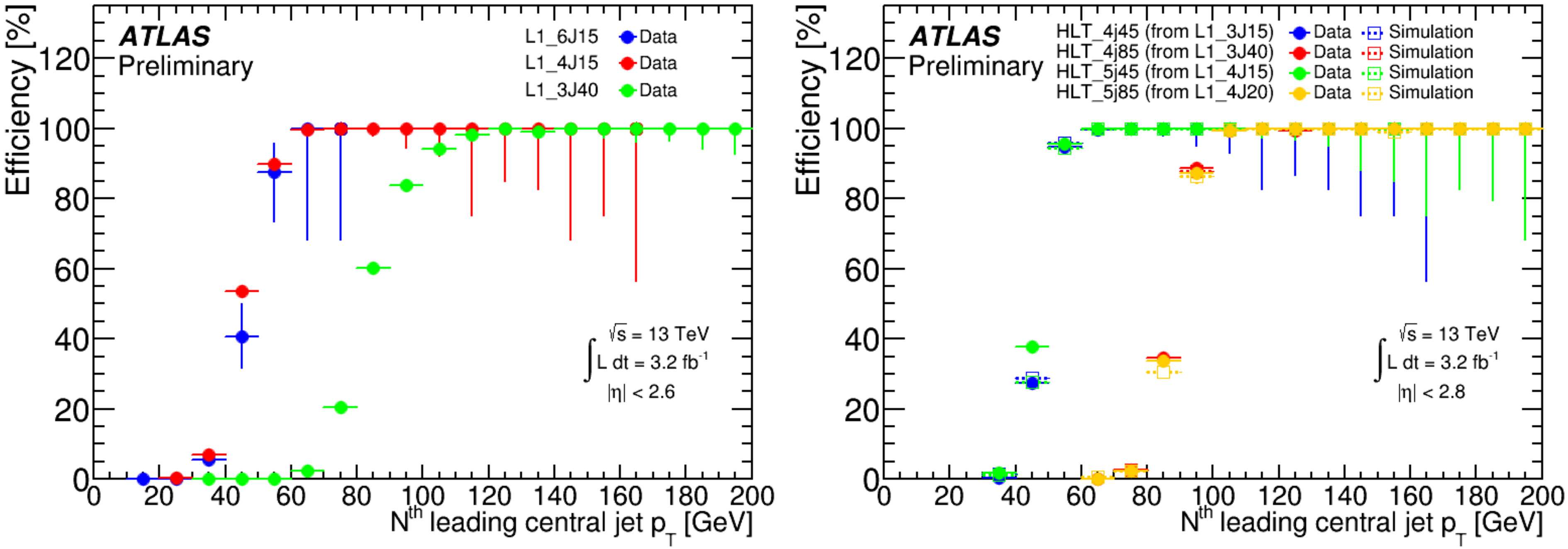
HLT single-jet efficiencies



Comparison of (left) HLT central (|η| < 2.8) and (right) forward (3.6 < |η| < 4.5) per-event trigger efficiency turn-on curves. Steeper turn-on than L1 is observed and good agreement between data and simulation.

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetTriggerPublicResults#Jet_Trigger_Efficiency_Plots_ATL

Multi-jet efficiencies



Comparison of per-event isolated (left) L1 and (right) HLT multi-jet trigger efficiency turn-on curves. Isolation is enforced by requiring each of the N leading jets to be isolated by $\Delta R > 0.6$ from all other reconstructed offline jets with $p_T > 20$ GeV. The efficiency is relatively unaffected by the number of jets.

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetTriggerPublicResults#Jet_Trigger_Efficiency_Plots_ATL

Background studies for a dark matter search in ATLAS

Introduction

- A typical signature of dark matter is missing transverse momentum (MET) produced in association with jets

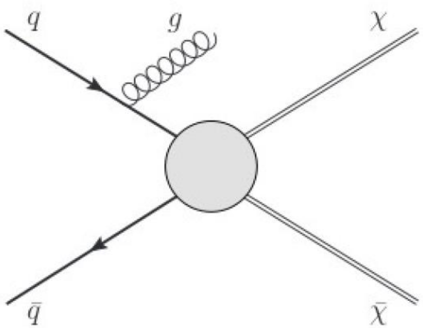
- Studying MET + 1 jet and MET + 2 jet topologies gives sensitivity to different dark matter signatures

- Basic event selection: MET > 150 GeV, lepton veto

MET + 1 jet phase space:

basic selection + 1 jet

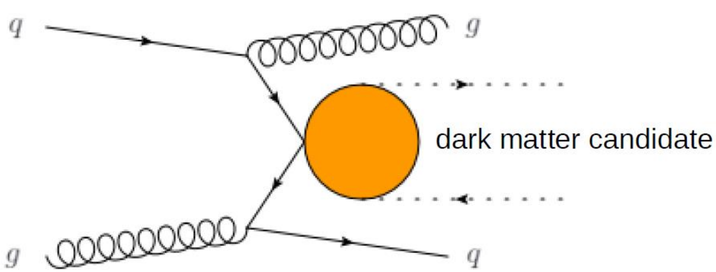
with $p_T > 150$ GeV



MET + 2 jets phase space:

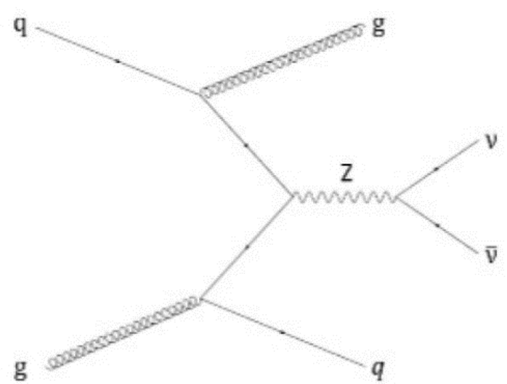
basic selection + 2 jets

with $p_T^1 > 55$ GeV, $p_T^2 > 45$ GeV

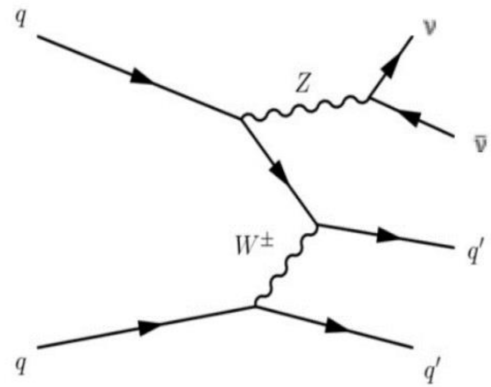


Aim of the analysis

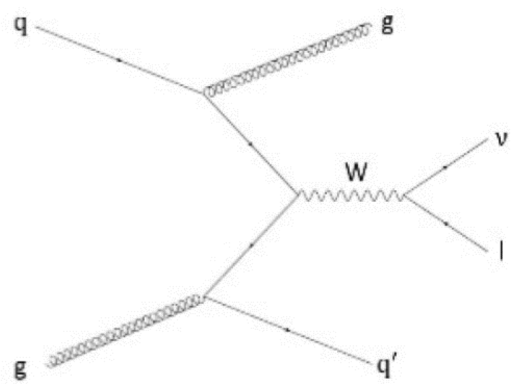
- The analysis plan is to unfold distributions sensitive to dark matter
- In the absence of dark matter, these distributions are dominated by $Z \rightarrow \nu\nu$, making it the target signal
- Search for deviations from the Standard Model prediction of $Z \rightarrow \nu\nu$



QCD production of $Z \rightarrow \nu\nu$



EW production of $Z \rightarrow \nu\nu$



W background

Data-driven estimate of W → μν

- W → μν events contain a lepton and end up in the signal region despite there being a veto on muons:
  - Muons out of acceptance (p_T < 7 GeV or |η| > 2.47)
  - Muon within acceptance but not identified

The plan:

- Measure yield in control region (p_T > 25 GeV, |η| < 2.47)
- Understand the acceptance and efficiency sufficiently well to predict the W background and reduce the uncertainties

- Number of W → μν events in the signal region can be written as:

$$N^{background} = N^{background}_{out\ of\ acceptance} + N^{background}_{in\ acceptance}$$

W events in which muon is out of acceptance (p_T < 7 GeV or |η| > 2.47)

W events in which muon is in acceptance but not identified

Data-driven estimate of W → μν

- The contribution from misidentified muons can be estimated using a control region that selects W → μν events

in acceptance

$$N^{background} = N^{background}_{out\ of\ acceptance} + \frac{a_7}{a_{25}}(1 - \varepsilon)\frac{N_{control}}{\varepsilon}$$

Acceptance correction accounting for muon p_T differences in signal (p_T > 7 GeV) and control regions (p_T > 25 GeV)

W events that make it into the signal region
ε = averaged efficiency of muons
eg. if ε = 95%, 5% make it into signal region

Efficiency corrected yield in control region

Data-driven estimate of W → μν

- The contribution from out of acceptance events can also be extrapolated from the control region using MC corrections

out of acceptance   in acceptance

$$N^{background} = \frac{(1-a_7)}{a_{25}} \frac{N_{control}}{\varepsilon} + \frac{a_7}{a_{25}} (1 - \varepsilon) \frac{N_{control}}{\varepsilon}$$

Acceptance correction that converts measured control yield into out of acceptance predicted yield. Also accounts for muon p_T differences in signal and control regions

Efficiency corrected yield in control region

Data-driven estimate of W → μν

- W → μν events contain a lepton and end up in the signal region despite there being a veto on muon:
  - Muons out of acceptance (p_T < 7 GeV or $|\eta|$ > 2.47)
  - Muon within acceptance but not identified

$$N^{background} = \frac{(1-a_7)}{a_{25}} \frac{N_{control}}{\varepsilon} + \frac{a_7}{a_{25}} (1 - \varepsilon) \frac{N_{control}}{\varepsilon}$$

Measured in MC

Measured in data

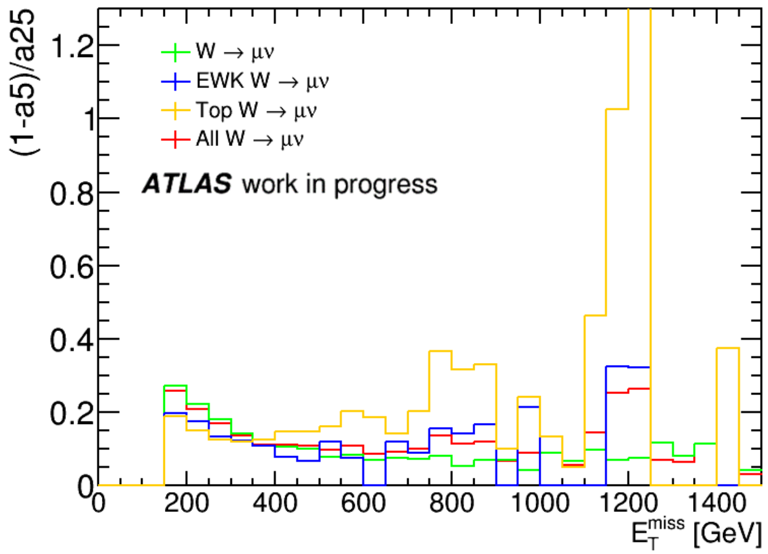
The plan:

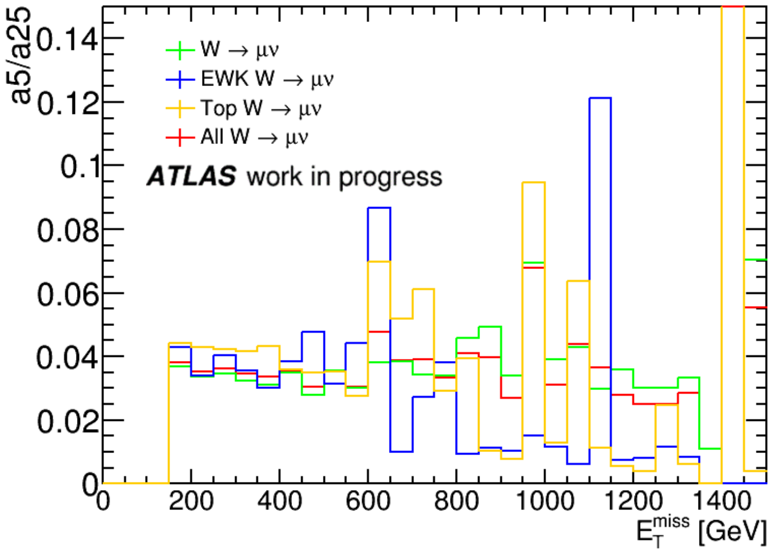
- Measure efficiency corrected event yield in control region
- Use the above equation to estimate background in signal region

Acceptance corrections

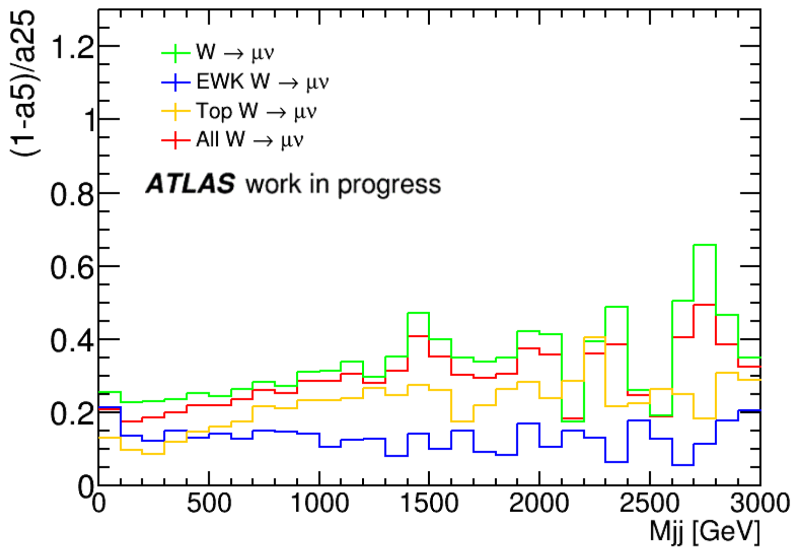
Acceptance corrections from different modes of W production

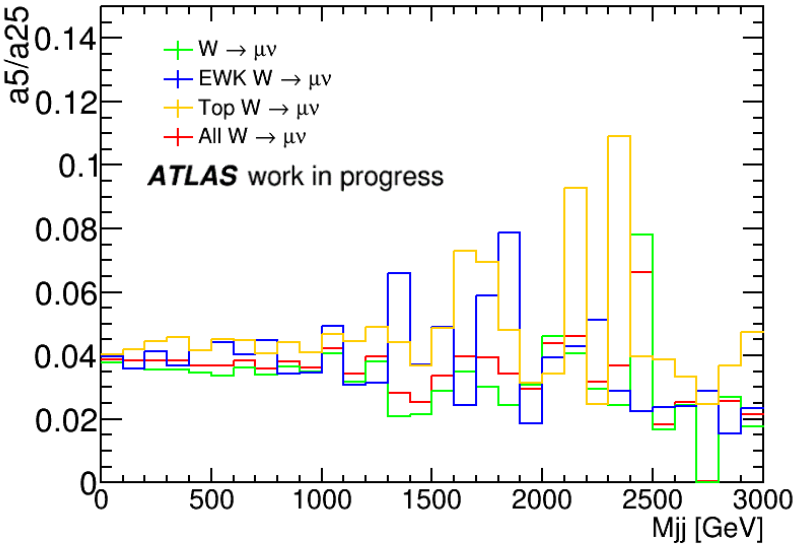
MET in MET + 1 jet region





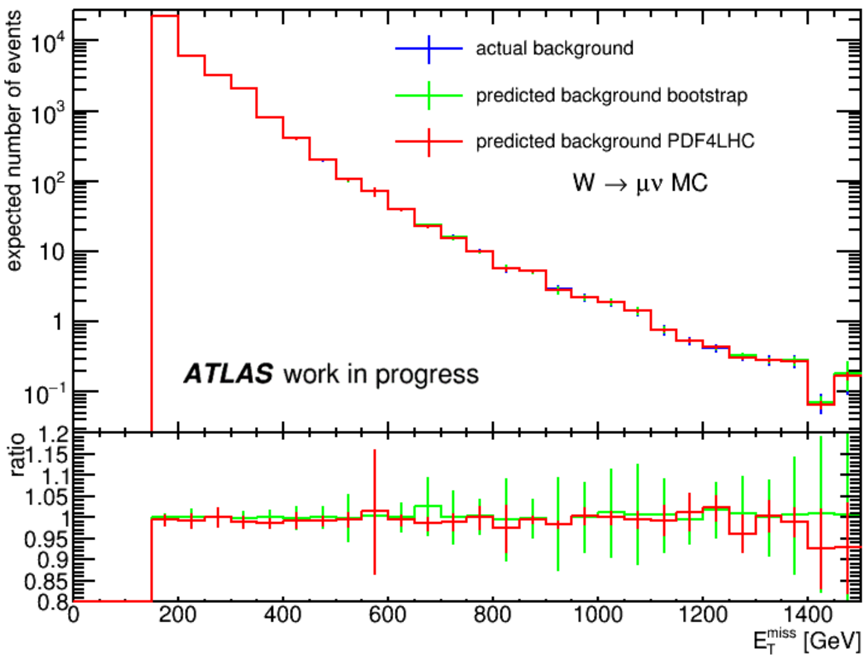
Mjj in MET + 2 jets region



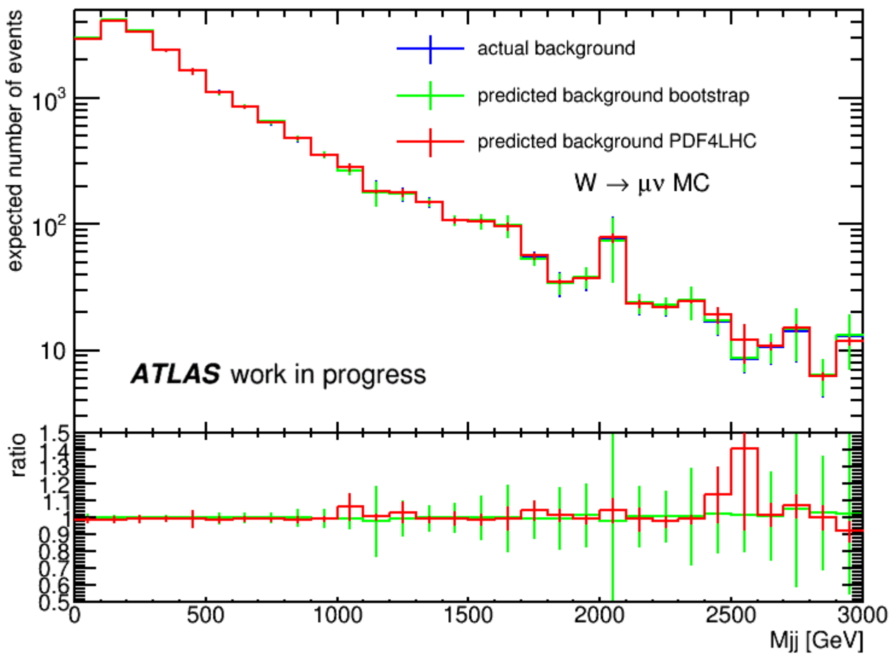


Statistical and PDF errors

MET in MET + 1 jet region



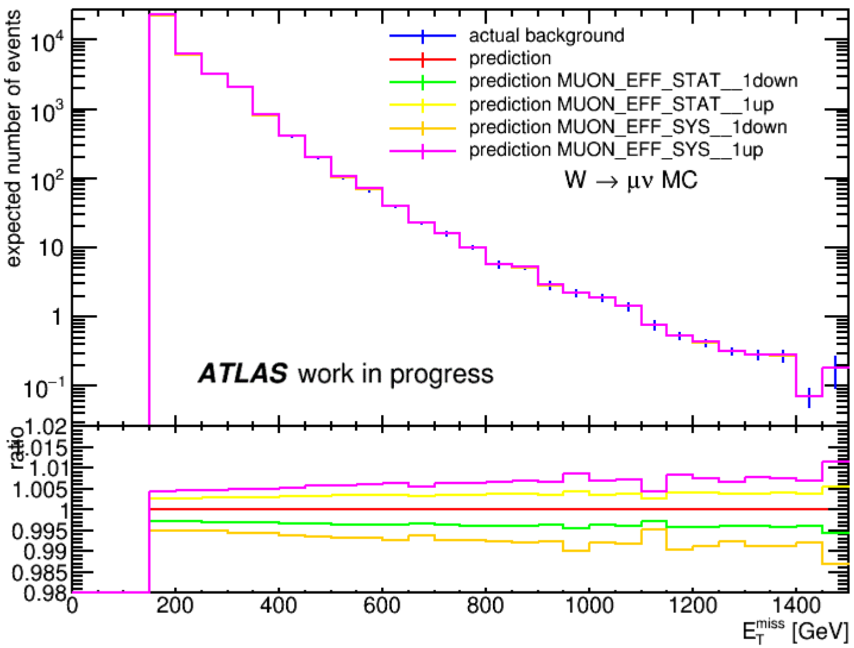
Mjj in MET + 2 jets region



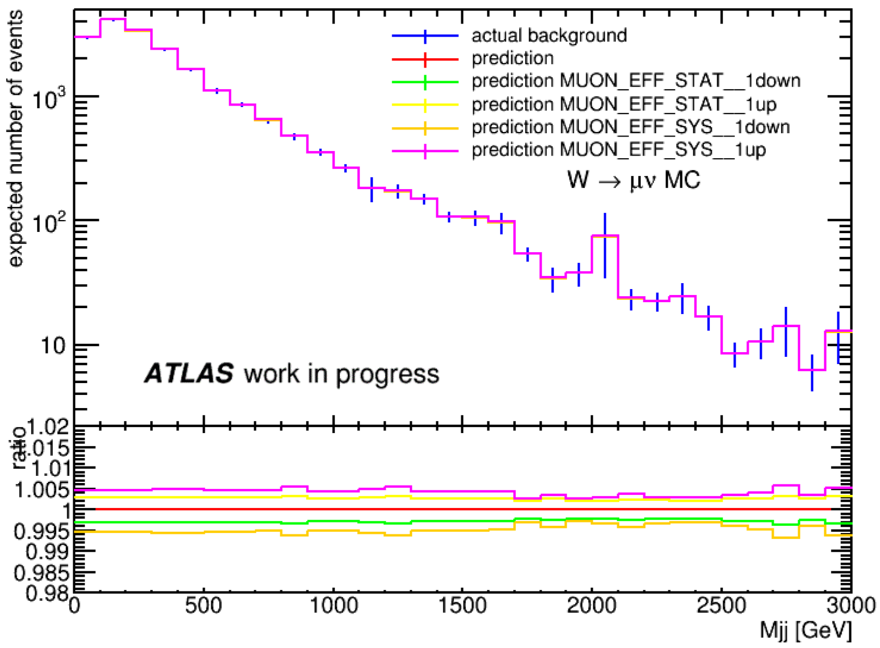
- Blue: actual background
- Green: expected uncertainty in the final result due to finite statistics in the MC
- Red: expected systematic uncertainty due to varying PDF according to PDF4LHC11 recommendations
- Conclusion: PDF error much smaller than MC statistical error

Muon efficiency systematics

MET in MET + 1 jet region



Mjj in MET + 2 jets region



Muon reconstruction efficiency systematics have a small effect on the prediction

Summary and outlook

Summary

- MET + jets is a typical dark matter signature
- Data-drive estimate needed for the large W backgrounds
- MC acceptance corrections are used to correct the prediction
- Statistical errors much larger than PDF errors
- Muon reconstruction efficiency systematics have a small effect on the prediction

Outlook

- Look at data
- Subtract QCD background from data
- Apply prediction to electron and tau channels