Student Lecture

MET + Jet(s) Dark Matter Search
and Other Things You Always Wanted to Know

Manuel Geisler

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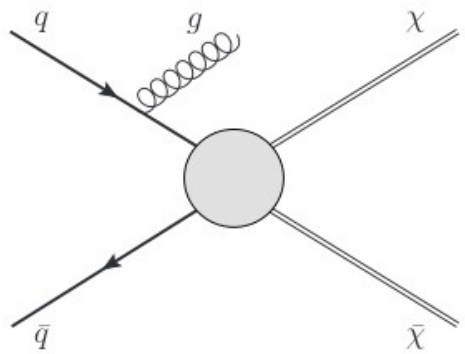
Heidelberg

KIRCHHOFF-
INSTITUT
FÜR PHYSIK

Motivation

- My PhD topic: search for Dark Matter with the ATLAS detector at the LHC



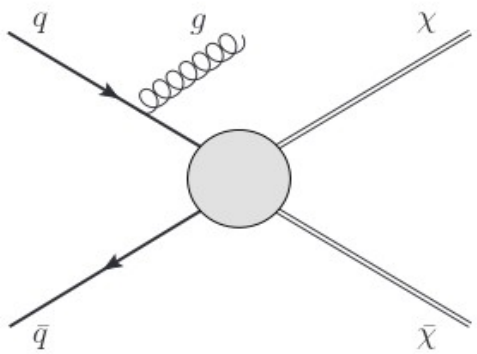
- General signature: MET, some jets, maybe other stuff

Things To Cover

- Motivation and introduction to MET + jets Dark Matter searches
- Selection & backgrounds
- Multijet background estimate
- Theoretical models we consider

Motivation

Dark Matter searches



The most common approach:
Monojet search

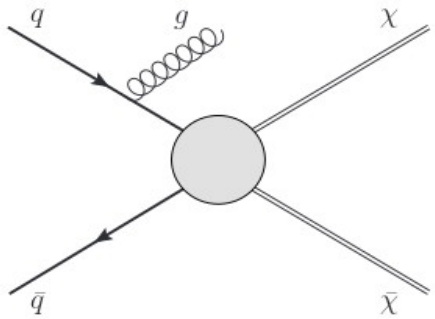
- Final state
  - Missing transverse Energy
  - At least 1 jet

- Inclusive search
- Quick analyses (→ discovery/limits)

- Large background from Standard Model processes
- (Usually) no unfolded* distributions

*unfolding = cleaning results from detector effects

The Signatures

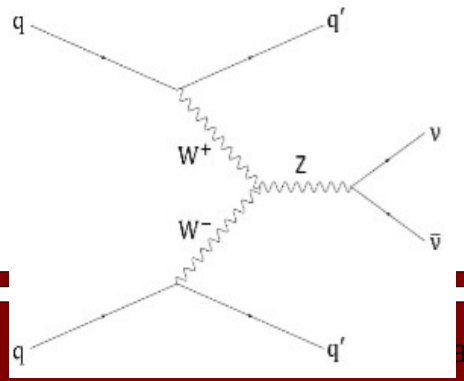


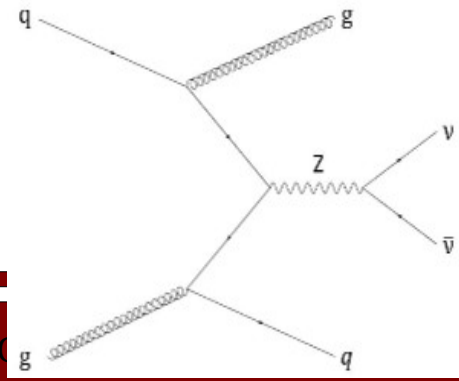
Monojet phase space
Lepton veto
MET > 200 GeV
At least 1 high-p_T jet
1st jet pt > 120 GeV

Two-jet phase space
Lepton veto
MET > 200 GeV
At least 2 high-p_T jets
1st jet pt > 80 GeV
2nd jet pt > 50 GeV
M_{jj} requirement
No 3rd jet in y-gap

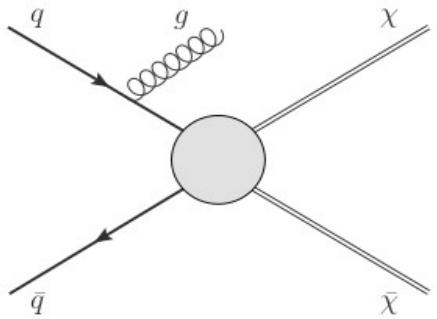
$\sigma(\text{MET+jet(s)})/\sigma(Z \rightarrow ll + \text{jets(s)})$

- Numerator includes $Z \rightarrow \nu\nu$ plus potential new physics
- For denominator: define pseudo-MET (“treat leptons like neutrinos”)

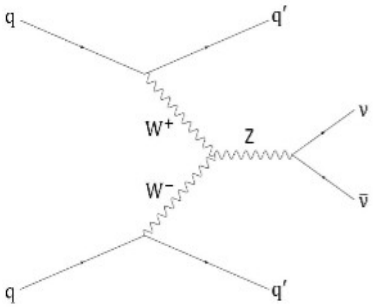




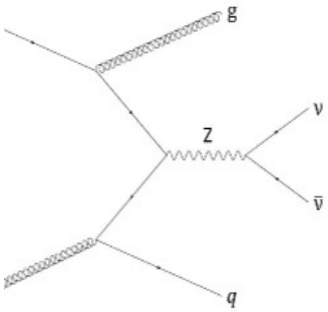
Important Processes



→ MET + ≥ 2 Jets → Signal

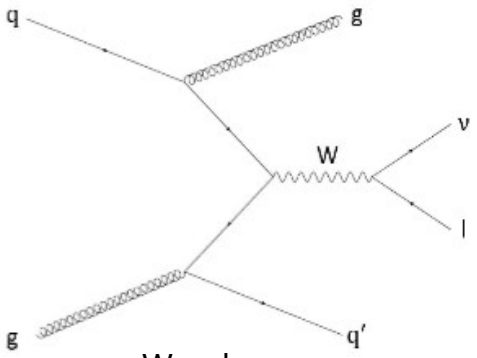


Z → ν ν [EWK]



Z → ν ν [QCD]

→ MET + ≥ 2 Jets → Signal



W → l ν

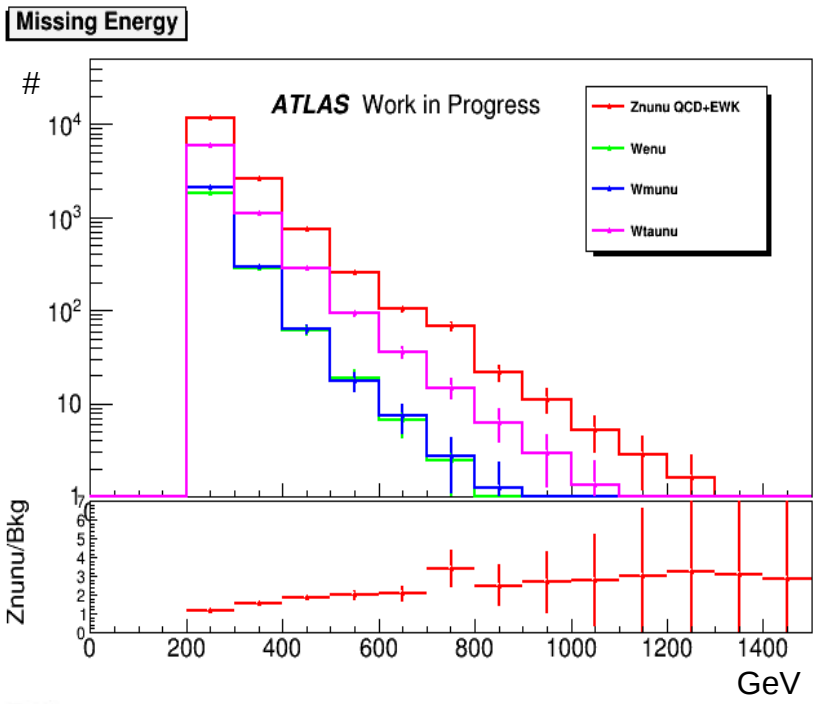
→ Different final states → Fake signal, Background

→ subtract background estimates from measurement

Selection & W Backgrounds

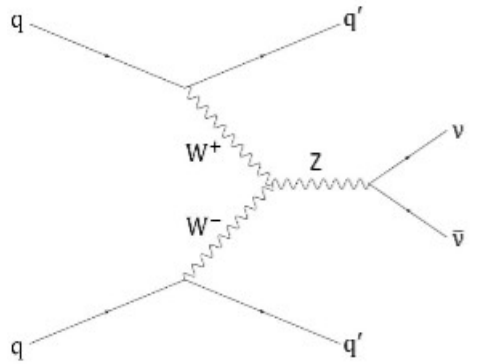
Applying basic selection:

- MET > 200 GeV
- Lepton veto
- At least 2 jets > [80,50] GeV
- M_{jj} > 250 GeV

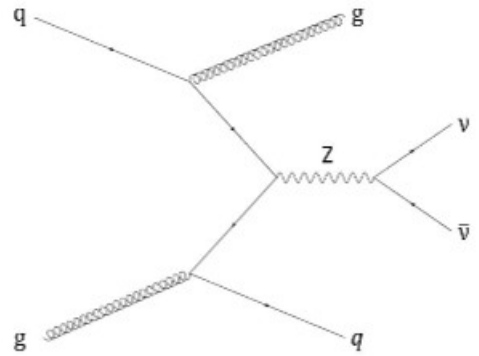


ATLAS Work in Progress

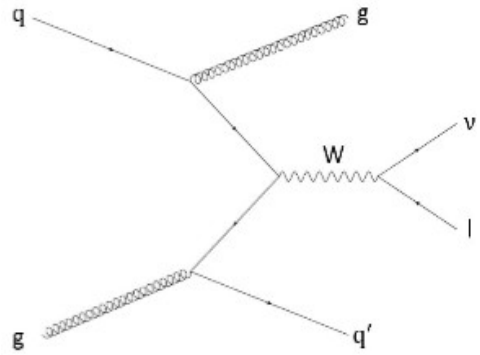
Sample	Expected no of events (3.2 fb^{-1})
Z → ν ν [QCD]	14872
Z → ν ν [EWK]	712
W → τ ν	7538
W → μ ν	2456
W → e ν	2114



EW production via VBF



QCD



W background

Representative leading order Feynman diagrams

→ data-driven background estimate for W backgrounds

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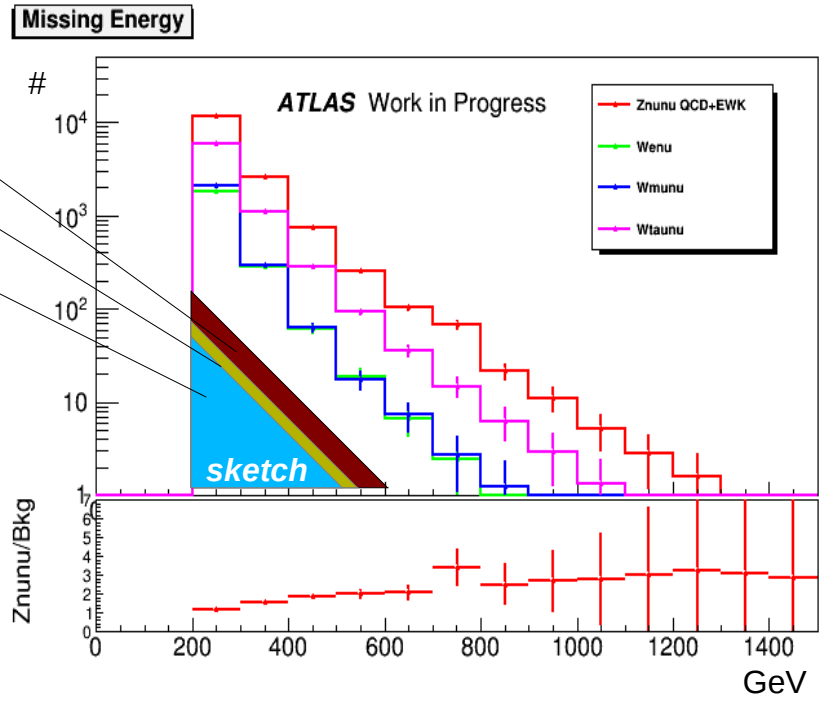
Selection & Backgrounds

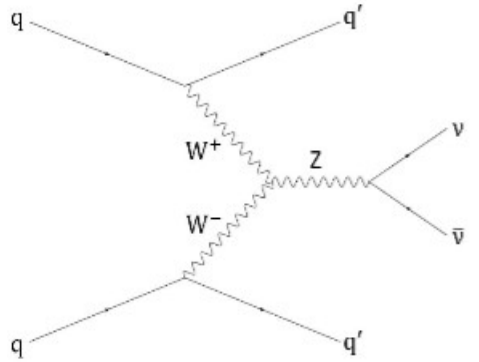
Applying basic selection:

- MET > 200 GeV
- Lepton veto
- At least 2 jets > [80,50] GeV
- M_{jj} > 250 GeV

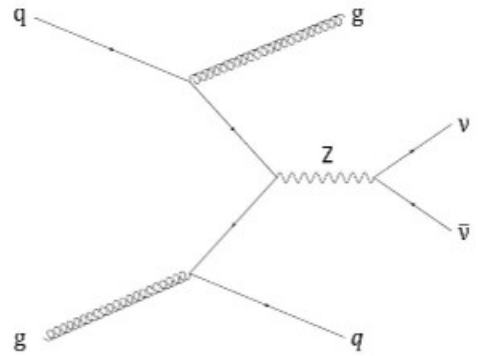
$Z \rightarrow \tau\,\tau$
$Z \rightarrow \mu\,\mu$
$Z \rightarrow e\,e$

→ Z backgrounds from MC

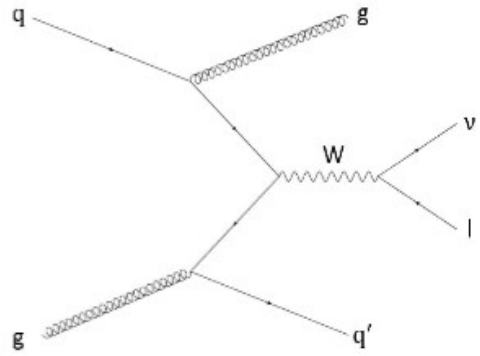




EW production via VBF



QCD



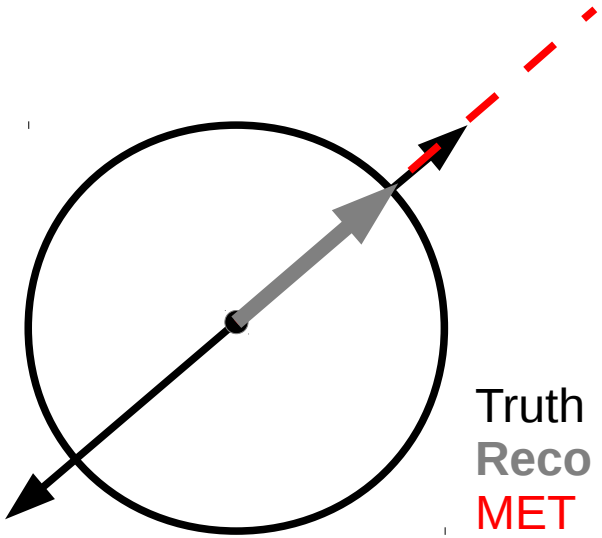
W background

Representative leading order Feynman diagrams

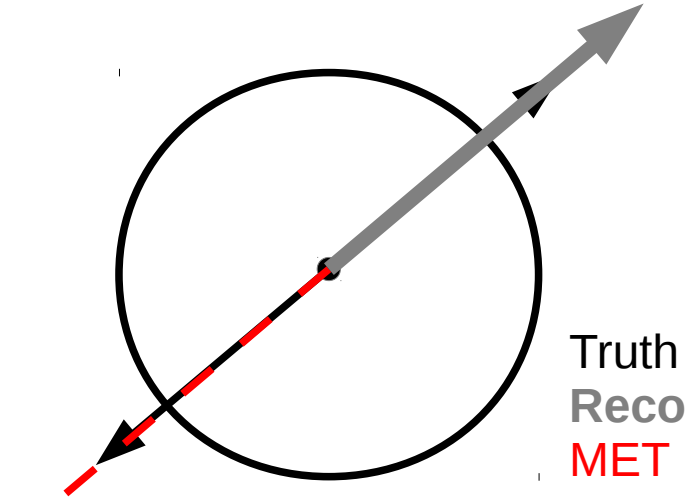
→ backgrounds from acceptance and efficiency losses

Multijet Background

- Energy **mismeasurement** of jets causes **fake MET**
- If jet energy is underestimated
  - MET points along jet [φ]
- If jet energy is overestimated
  - MET points away from jet [φ]
- Possible sources
  - Dead modules
  - Finite acceptance
  - JER (finite resolution)
- Easy handle on multijet background by cutting
- Caveat: dijet MC sample satistics sparse in high-MET region and modelling known to be mediocre

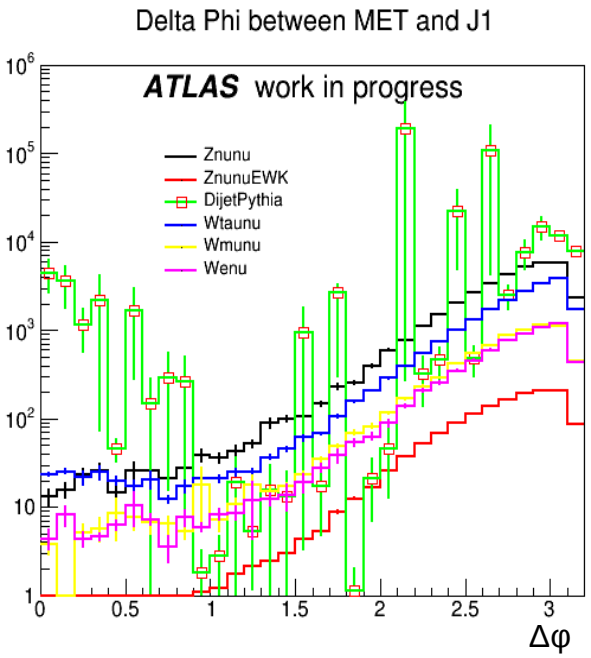


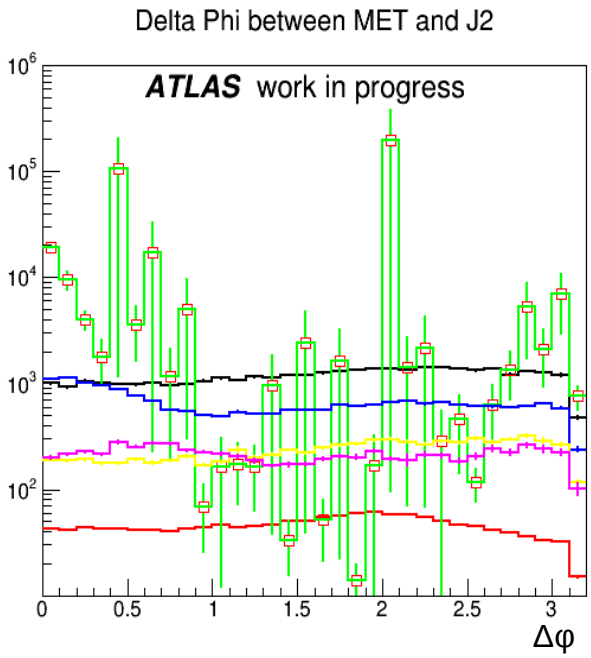
φ-projection of ATLAS



φ-projection of ATLAS

Δφ Cuts

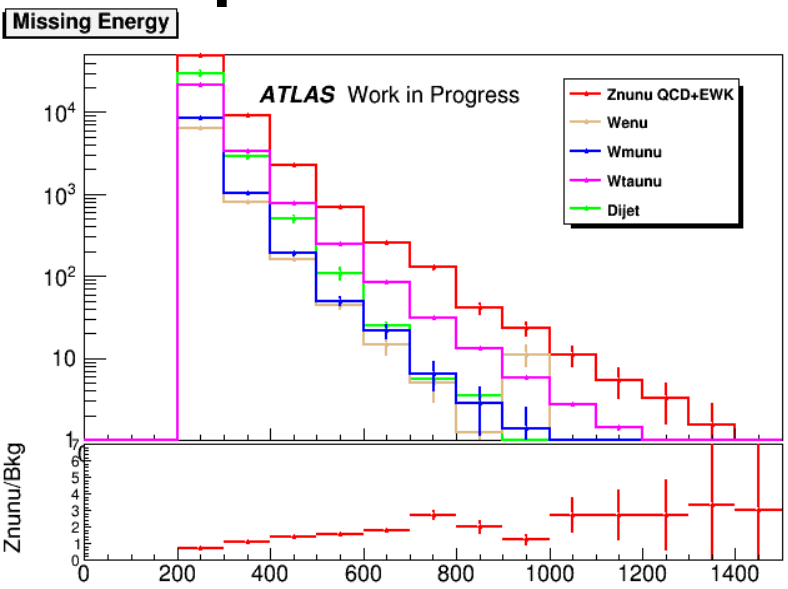




Expand signal region definition with Δφ cuts:

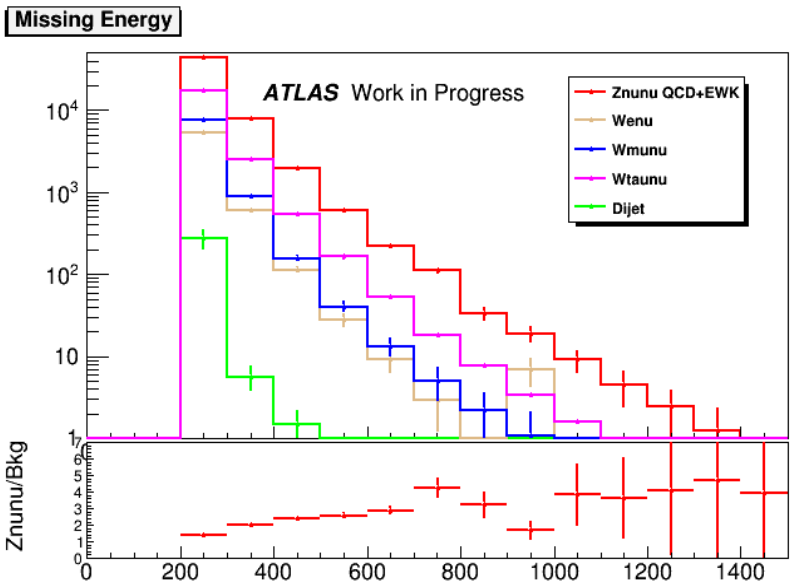
- $\Delta\varphi(\text{MET}, J^i) > 0.4$, i = 1, 2, 3, 4

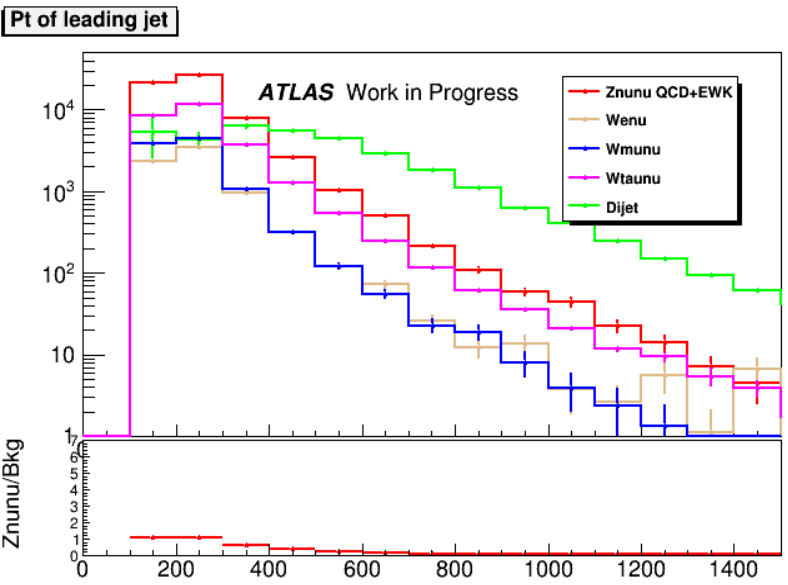
Δφ Cut Effectiveness

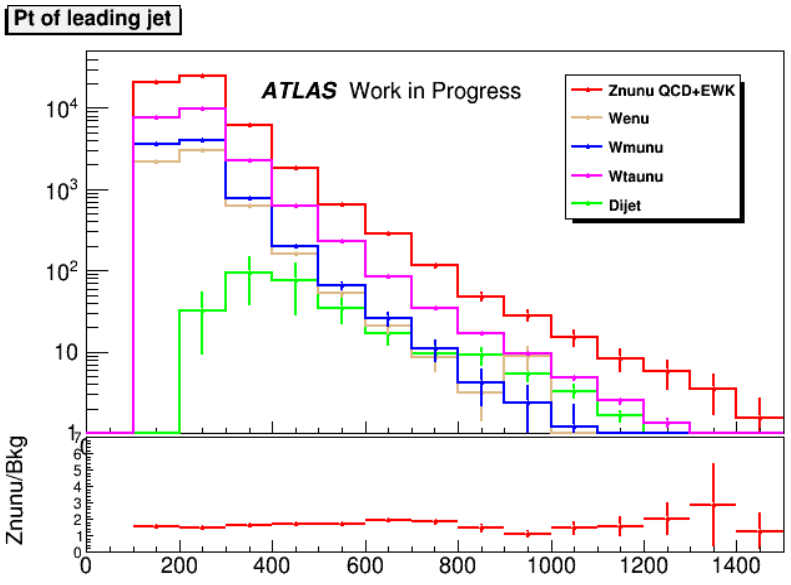


Monojet Topology:

- MET > 200 GeV
- Lepton veto
- At least 1 jet > 120 GeV
- Δφ(MET, J^i) > 0.4







Multijet Background Estimate

- Do **data-driven** background estimate:

$$N_{bkg}^{SR} = R \times N_{bkg}^{CR}$$

Transfer function from CR to SR

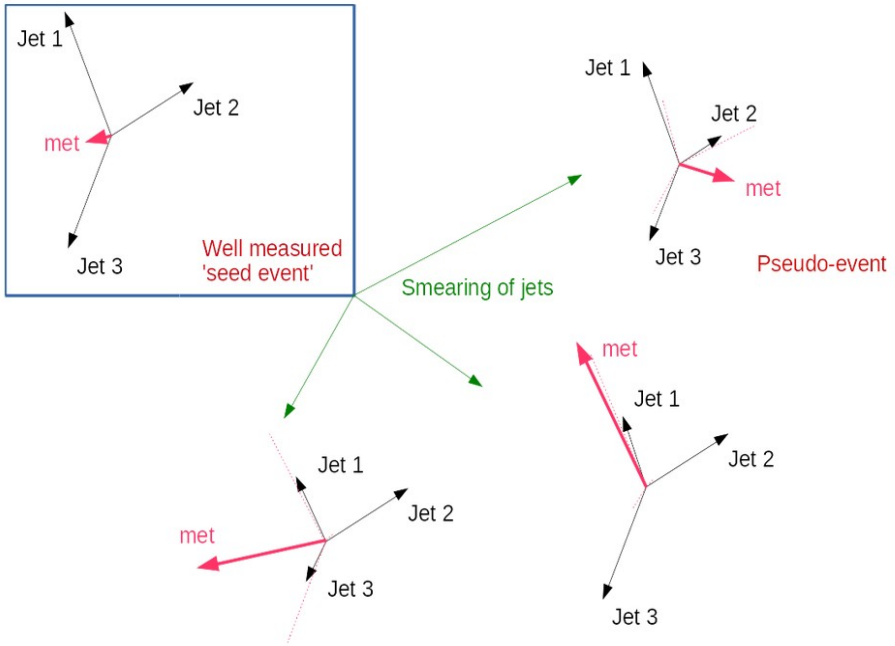
Control region definition:
Logical OR of:

- 1) $\Delta\varphi(\text{MET}, j1) < 0.1$
- 2) $\Delta\varphi(\text{MET}, j2) < 0.1$
- 3) $\Delta\varphi(\text{MET}, j3) < 0.1$
- 4) $\Delta\varphi(\text{MET}, j4) < 0.1$

- Get R either from
  - Smeared data events: $R = N^{SR}_{SMR} / N^{CR}_{SMR}$ (default)
  - MC: $R = N^{SR}_{MC} / N^{CR}_{MC}$ (consistency checks)

Smearing

- Run on 2015 data set
  - Smear good seed events 2000 times
- Good seed event: hadronic, well measured* event. Get weight according to trigger prescale
  - $R = N^{SR}_{SMR} / N^{CR}_{SMR}$



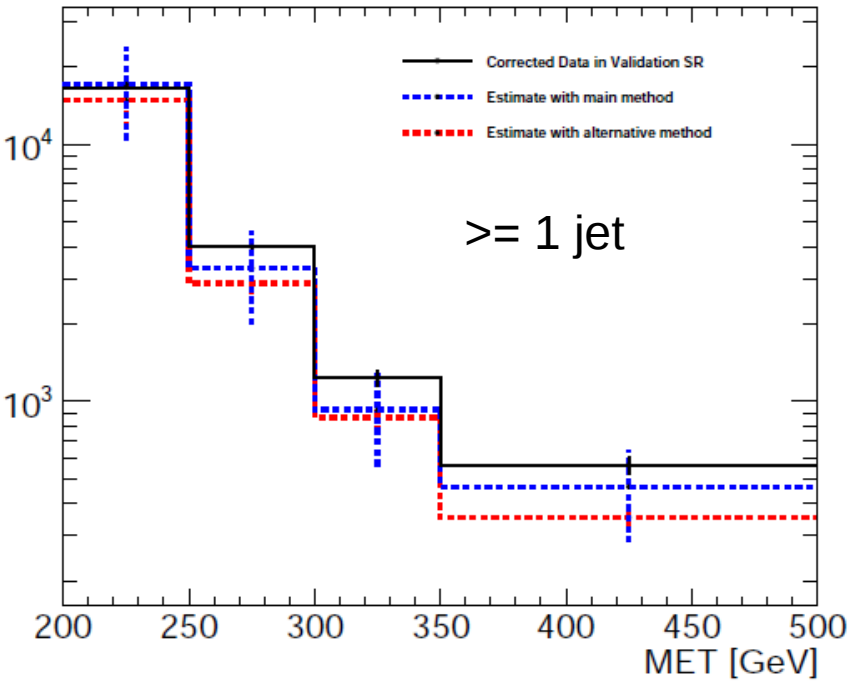
* small MET significance, small MET/avg jet pt

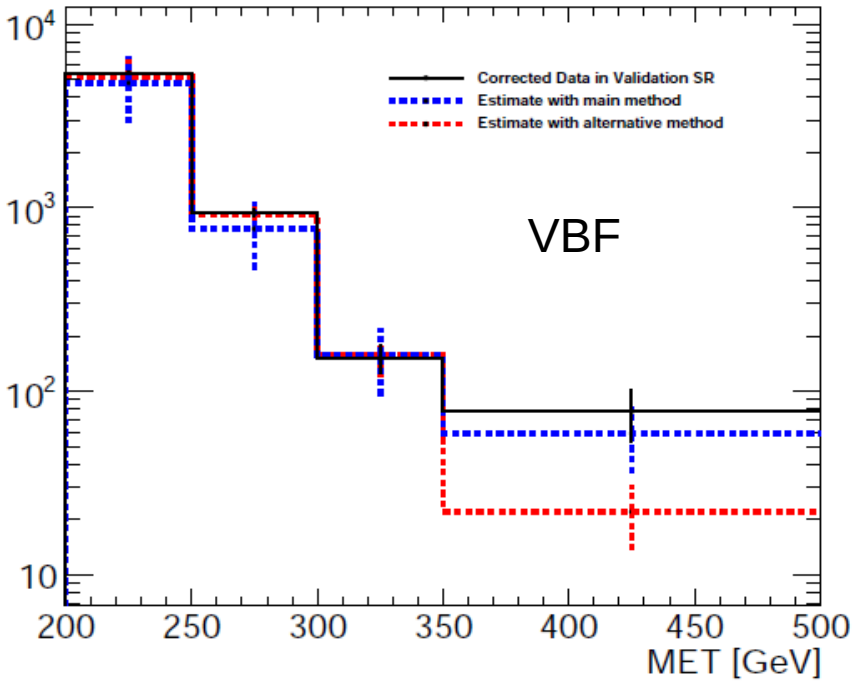
$$E_{\mathrm{T}}^{\mathrm{miss}}\ \mathrm{Significance} = \frac{E_{\mathrm{T}}^{\mathrm{miss}} - M}{\sqrt{\sum E_{\mathrm{T}}}}$$

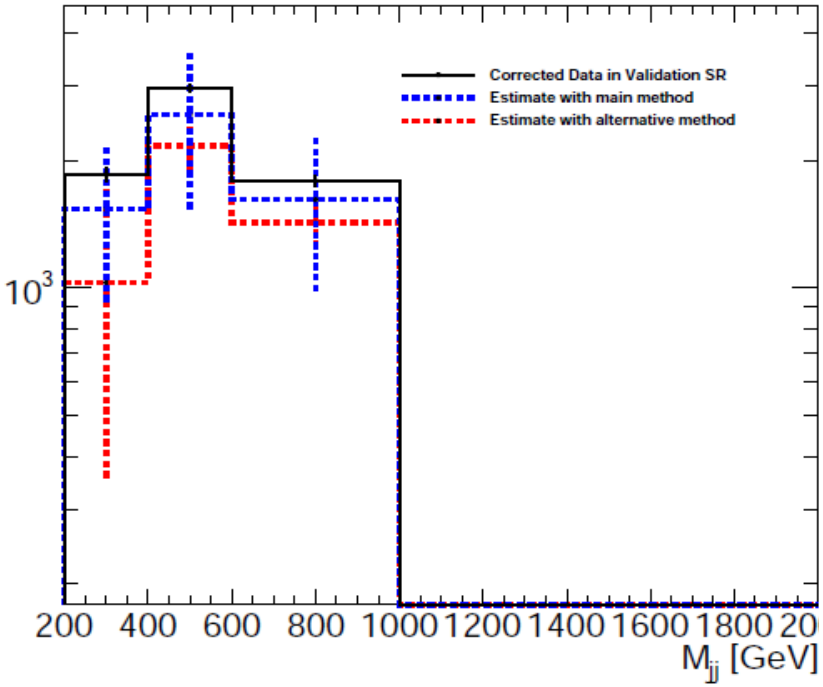
Validation Study

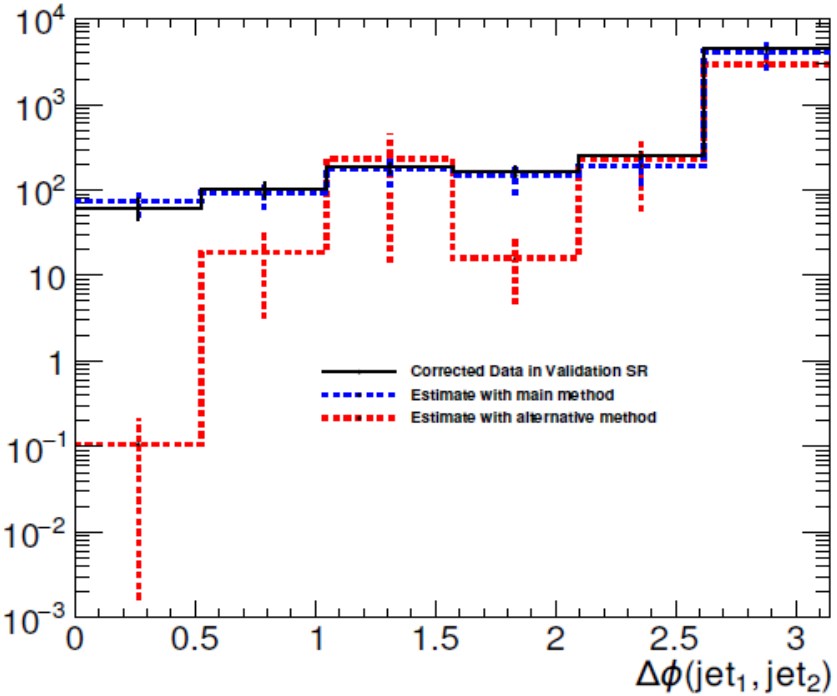
- Validation SR just as blinded analysis SR except for
  - $0.1 < \Delta\varphi(\text{MET},J_i) < 0.5$ for any of first 4 jets
- Very close to analysis cuts (trigger, CRs)
- Since high in MET: correct for other processes using MC

Results


Corrected Data in Validation SR
Estimate with main method
Estimate with alternative method
>= 1 jet
MET [GeV]


Corrected Data in Validation SR
Estimate with main method
Estimate with alternative method
VBF
MET [GeV]


Corrected Data in Validation SR
Estimate with main method
Estimate with alternative method
M_{jj} [GeV]


Corrected Data in Validation SR
Estimate with main method
Estimate with alternative method
$\Delta\phi(\mathrm{jet}_1, \mathrm{jet}_2)$

Conclusion and Next Steps

- We are on the way of being approved by ATLAS so stay tuned!
- Introduced and motivated MET+Jets Dark Matter searches
- Discussed multijet background
- Very quick introduction to our unfolding
- Introduced model sensitivity

Thanks for your attention!