$Z + b$ jets

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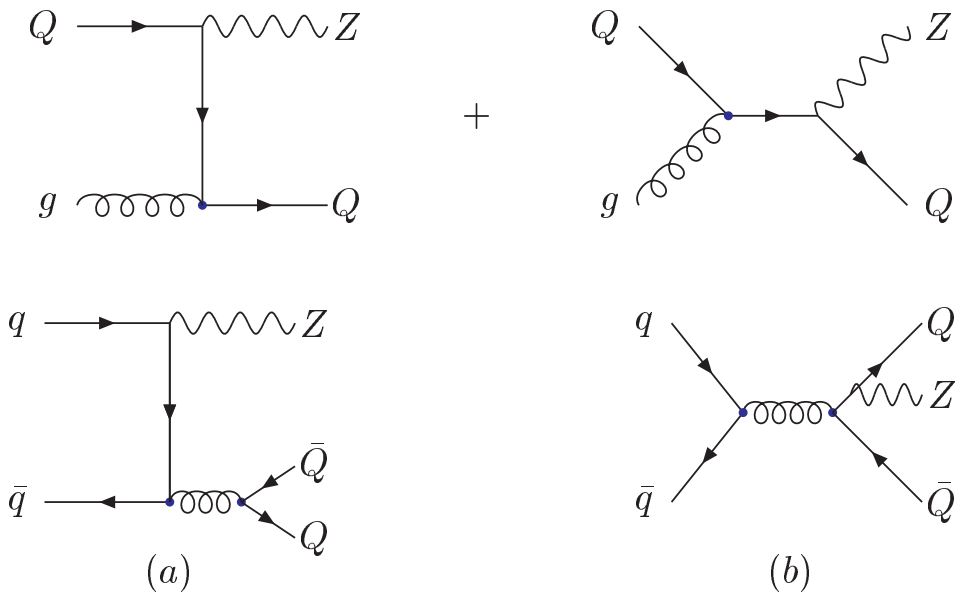
- Motivation
- $Z + b$ jet analyses
- Backgrounds from other processes
- Systematic from energy scale
- Summary and outlook

Why measure $Z + b$ jets?

- QCD
  Constrain b density of the proton. Understand production mechanisms in QCD. Not all measurements agree with NLO QCD. This process has a small scale uncertainty compared with other processes e.g. inclusive b-jets.
- Standard model Higgs
  Important channel is associated production $q\bar{q} \rightarrow Zh_{SM}$, where $h_{SM} \rightarrow b\bar{b}$. QCD $Zb\bar{b}$ is the largest background.
- MSSM Higgs
  At large $\tan\beta$ coupling of A, h, H to $b\bar{b}$ enhanced. $pp \rightarrow b\bar{b}h$. $Z + b$ jets probes b density at similar scale $\mu \sim M_Z$ (c.f. $\gamma + jets$).
- Single top
  b quark density important for 2 of 3 leading diagrams: t-channel $qb \rightarrow q't$ and associated W production $gb \rightarrow Wt$. Study V_{tb} etc.

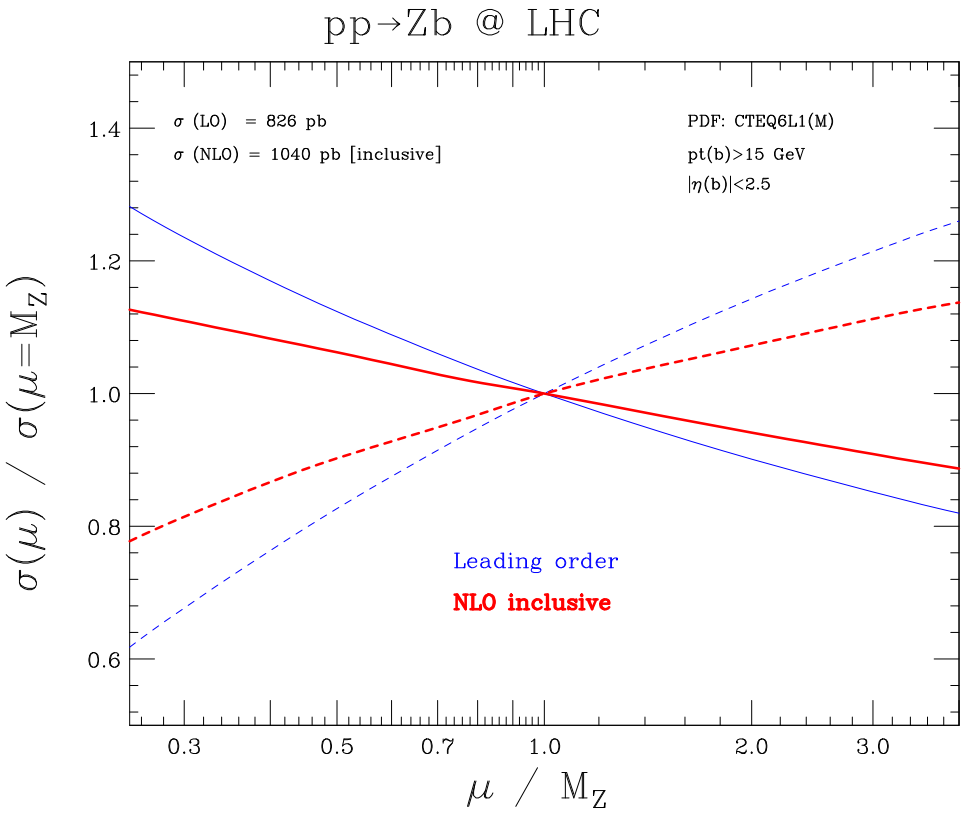
QCD Production Diagrams



Upper diagrams dominates. NLO QCD (MCFM) says $> 95\%$ at LHC (is only 60% at Tevatron)

Lower diagram contributes around 50% of the events with 2 b quarks in 1 jet $Z(Q\bar{Q})$, $< 3\%$ of the cross section.

Scale Dependence



default $\mu_R = \mu_f = M_Z$

vary μ_R - solid lines

vary μ_F - dashed lines

NLO uncertainty $\sim 20\%$

Backgrounds and Systematic Errors

- Light and charm jets
  Fractions of light and charm events will be extracted from fit to the data.
- Other processes
  Use MC simulation to estimate other processes which give real leptons and b jets. $t\bar{t}, t \to Wb, W \to l\nu$ and ZZ most significant. Others WW, WZ, $Z \to \tau\tau$ to be investigated
- Misidentified leptons
  Fraction of misidentified leptons from other particles in final state e.g. $b\bar{b}$ contributing to $Z \to ll$ window is determined from data.
- Systematic Errors
  For heavy flavour tagging analysis tracking uncertainties (e.g. efficiency) likely to dominate. Others include model dependence (e.g. E_T^{jet}, η^{jet}), backgrounds and jet energy scale.

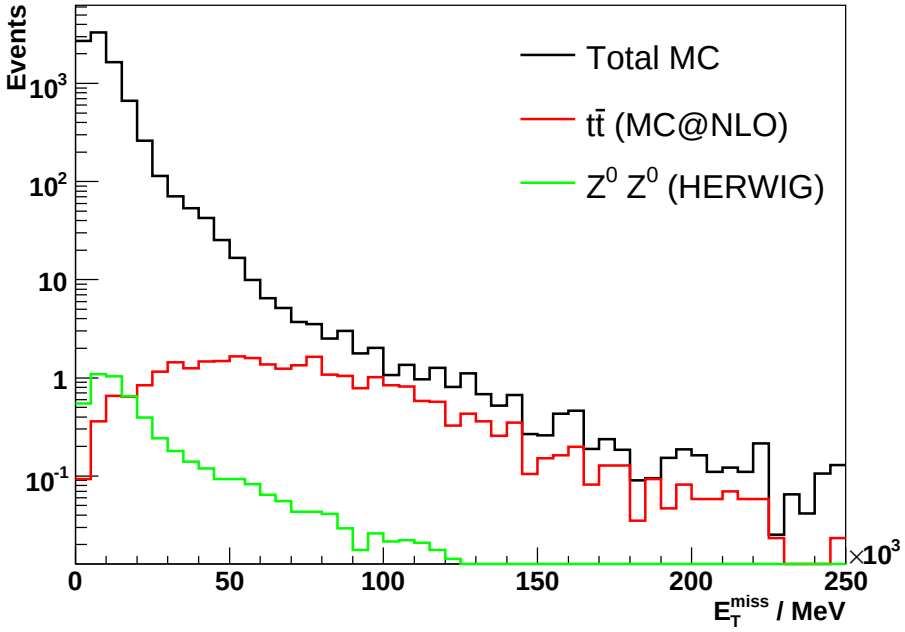
Method Outline

- Reconstruct $Z \rightarrow e^+e^-, \mu^+\mu^-$ using standard cuts.
- Use inclusive Z files (have plenty of b jets in them)
- Look for cone jets in $R < 0.7$.
- Use the standard b tag likelihood output. "weight" - combination of secondary vertex algorithm (SV1) and combined impact parameter probability (IP3D)
- Fit the "weight" distribution in the data with light, c and b templates.
- Correct cross section to the hadron level for events with a Z boson and $E_T^{jet} > 20$ GeV and $\eta^{jet} < 2.5$

Event Selection

- Find electrons. Select on IsEM and isolation. Require 2 'mediums'. $E_t^e > 20$ GeV, $|\eta^e| < 2.5$. Reconstruct $Z \rightarrow e^+e^-$.
- Find Jets("ConeTopoParticleJets"). Cone size 0.7. Exclude electrons from $Z \rightarrow e^+e^-$. $E_t^{jet} > 20$ GeV, $|\eta^{jet}| < 2.5$
- Find muons ("StacoMuonCollection"). Exclude those close to a jet $\Delta R > 0.4$. Gives satisfactory fake rate $\sim 10^{-6}$. $E_t^{\mu} > 15$ GeV, $|\eta^{\mu}| < 2.5$. Find $Z \rightarrow \mu^+\mu^-$.
- Require $71 < M_{ll} < 111$ GeV.
- Cut against $t\bar{t}$ by requiring $MET < 30$ GeV.
- Look at flavour "weight" for all selected jets.

Backgrounds

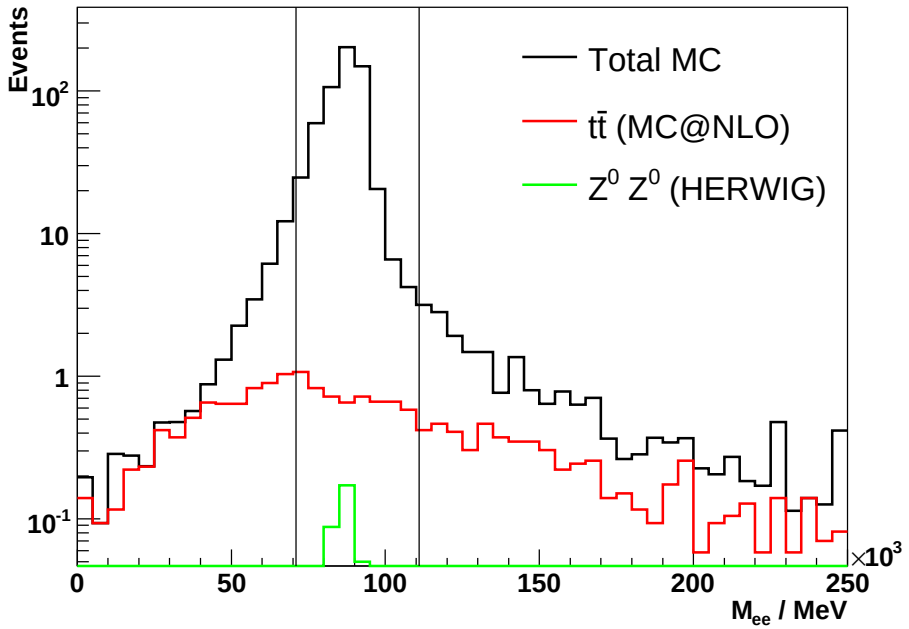


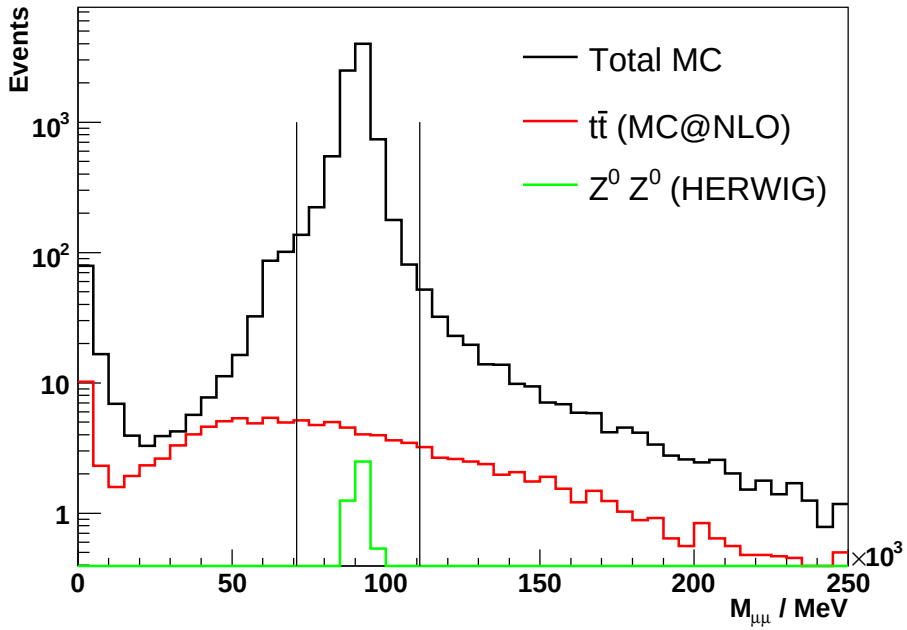
Distribution for missing E_T for total MC and background processes (for all events)

Missing $E_T < 30$ GeV

Efficiency of 97% for signal and rejects 87% $t\bar{t}$, 18% of ZZ (events with ≥ 1 jet)

Z Mass

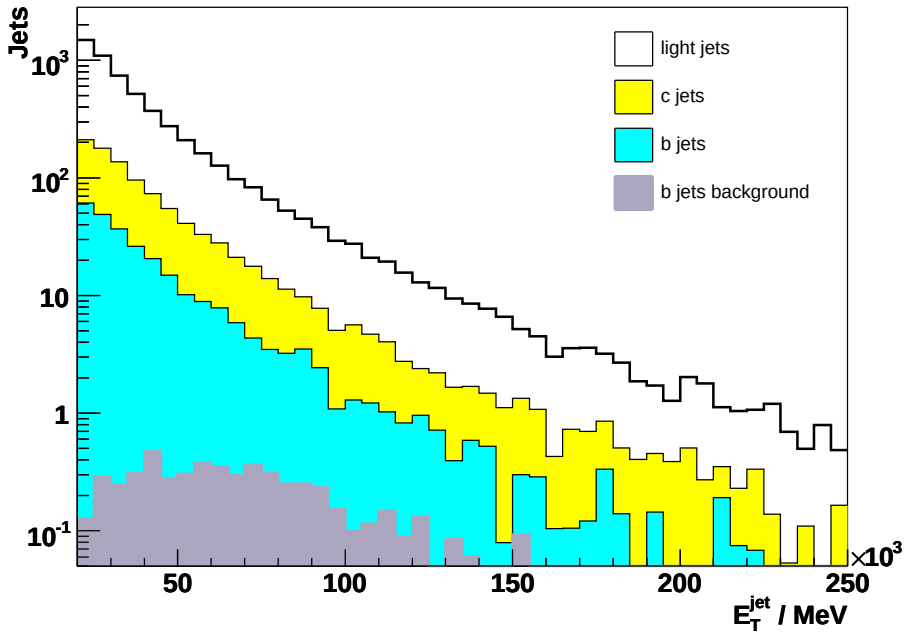


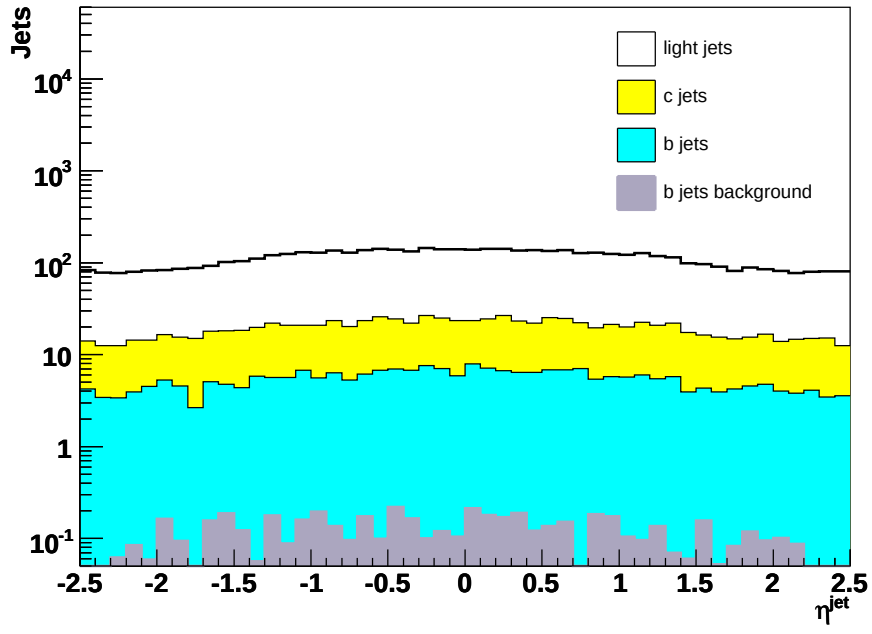


Reconstructed Z mass for ee and $\mu\mu$

Normalized to $15\ \mathrm{pb}^{-1}$ of data.

Jet E_T and η



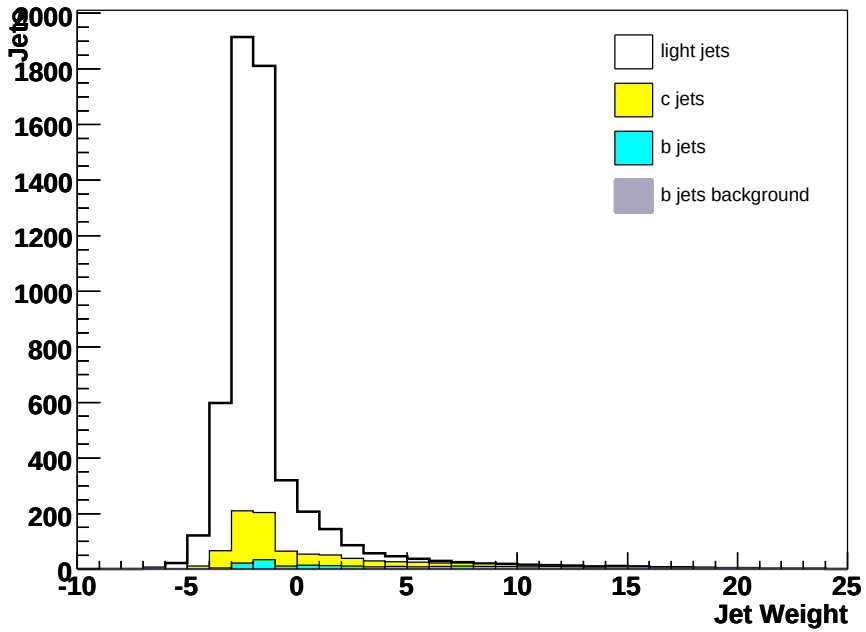


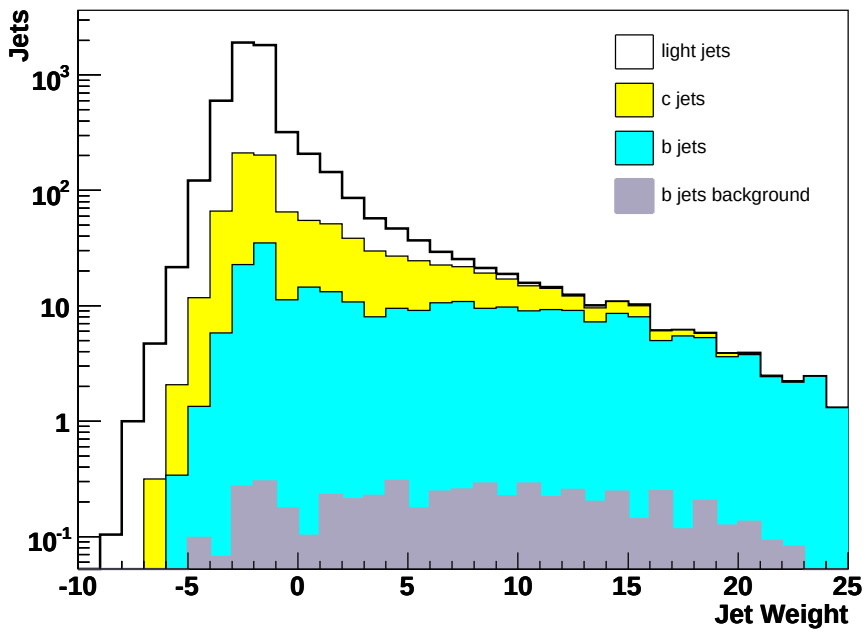
Match to truth flavour of jet.

c, b flavours have similar shapes in this range.

Real b background from $t\bar{t}$ most important, particularly at high E_T.

b Tag Likelihood

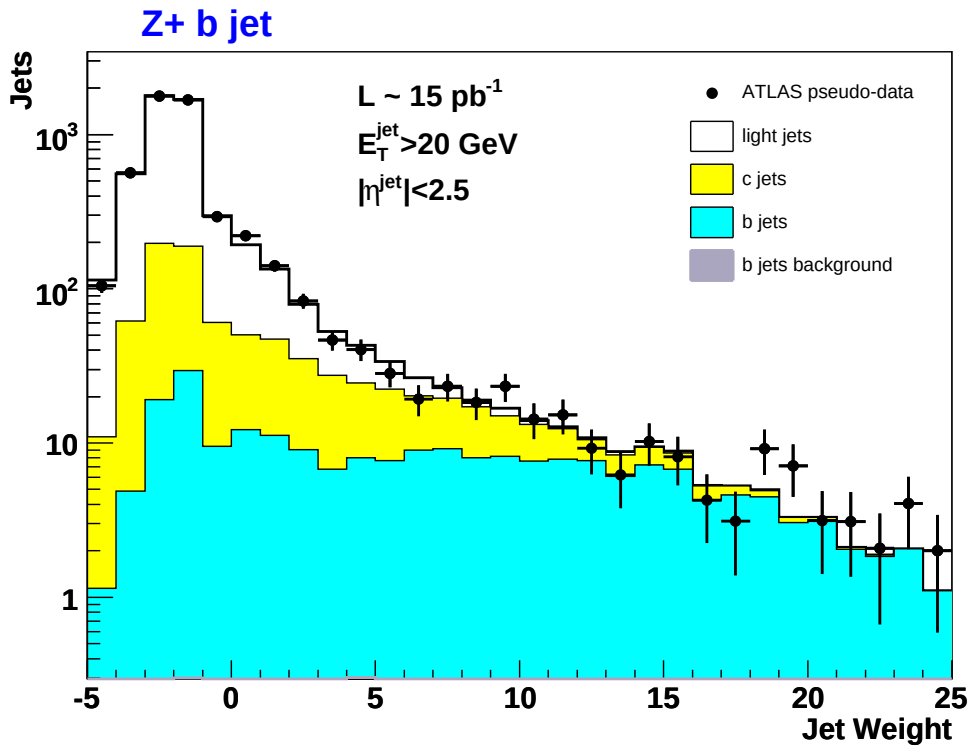




linear scale (left), log scale (right)

light, c, b jets have different shape so may be separated in fit to obtain fraction of events with a b jet.

Fitting the Likelihood Distribution



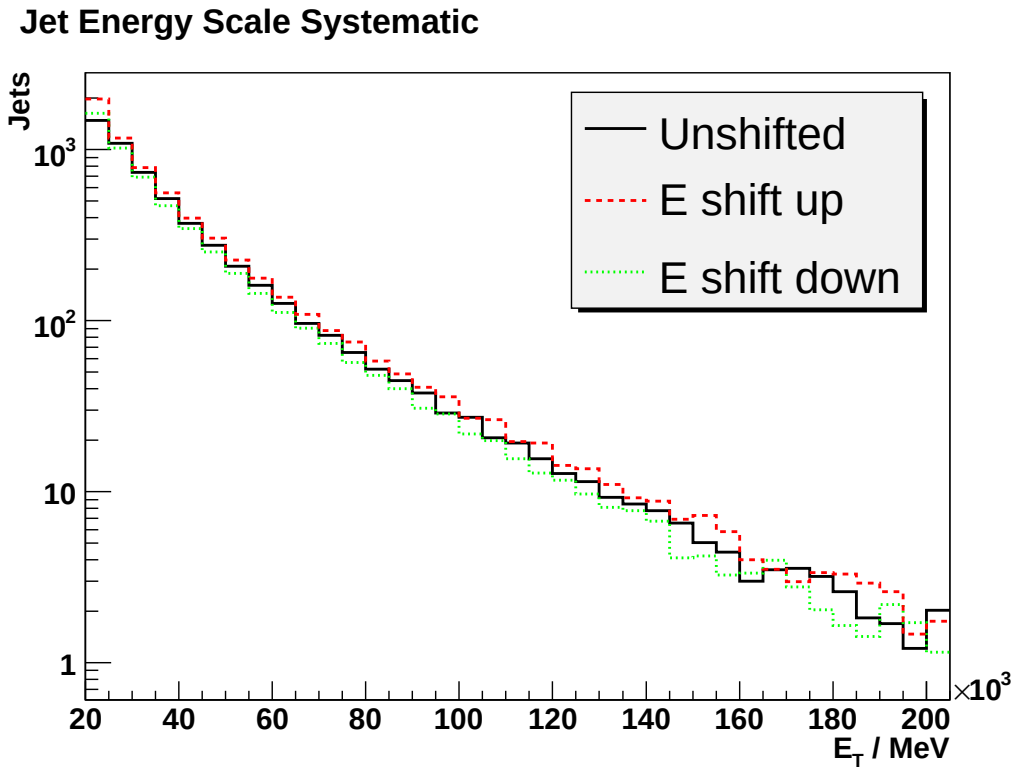
Divided MC randomly into $15\ \mathrm{pb}^{-1}$ 'pseudo-data' samples.

Typical scale factors for c and b jets from fit to pseudo-data

$\rho_b = 1 \pm 0.2$, $\rho_c = 1 \pm 0.2$, $\rho_{light} = 1 \pm 0.02$

i.e. $\sim 20\%$ error on the b fraction

Jet Energy Scale Uncertainty



So far just implemented 4% shift up and down of jet energy scale to get different MC acceptances + templatesfor c, b and light.

Reasonable shift? Effect on cross section determination is 16%.

Summary and Outlook

- $Z + b$ jets important for understanding QCD and needed for background in searches
- Possible for $\sim 20\%$ statistical precision from $15\ \mathrm{pb}^{-1}$ of data
- We should aim to have detector aligned with sufficient precision for b tagging as early as possible
- Looked at most likely dominant backgrounds from other processes
- Estimate of effects of jet energy scale.
- Next steps
- Look at remaining background processes and errors.
- Check have relevant MC samples.