$Z \rightarrow ee$ trigger studies of EM25I/e25i

ATLAS UK Standard Model meeting

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Contents

Datasets and analysis method

Sample type	Sample Code	Reco version	Simul version	#events used	LAr range cut
$Z \to ee$	5144	12.0.6.1	12.0.31	430k	30μm
Filtered Dijets	5802	12.0.6.1	12.0.31	3.36M	30μm
J1 ($17 - 35$ GeV)	5010	12.0.6.1	12.0.31	387k	30μm
J2 ($35 - 70$ GeV)	5011	12.0.6.1	12.0.31	360k	fixed 1mm
J3 ($70 - 140$ GeV)	5012	12.0.6.1	12.0.31	365k	30μm
J4 ($140 - 280$ GeV)	5013	12.0.6.1	12.0.31	369k	30μm

Analysis method

- Flat NTuple, originally developed in Liverpool, with additions from Oxford
- Essentially a dump of (nearly) all the AOD information - egamma trigger information added specifically for this work
- This is likely to change for release 13 - many people are looking into a more easily maintainable alternative
- Knowing *which* electron triggers is essential $\Rightarrow$ trigger hypothesis algorithms are emulated in private code, with cuts applied “by hand”
- Code goes to the data - mostly on OSG using pathena (LCG/Ganga can also be used)

Truth/offline normalisation

For the purposes of this talk, an “efficiency” is one arrow in the sequence
(truth →) offline → L1 → L2 → EF

Example: Level 1
The “reconstructed” efficiency uses offline electrons which may (or may not) trigger at L1
The “true” efficiency uses true electrons, which are reconstructed offline, and may trigger at L1
Offline coordinate plotted in both cases

A **true** electron is:

- Stable $e^{\pm}$, from the generator
- $p_{\mathrm{T}} > 25$ GeV (10 GeV for turn-on curves)
- $|\eta| < 1.37 \;\; OR \;\; 1.52 < |\eta| < 2.4$

An **offline** electron is:

- An AOD electron ⇒ loose track match and E/p cut
- Found using the egamma algorithm
- $E_{\mathrm{T}} > 25$ GeV
- $|\eta| < 1.37 \;\; OR \;\; 1.52 < |\eta| < 2.4$
- IsEM loose, medium or tight

Event-level cuts
For truth:

2 fiducial electrons

Tag and Probe:

$e^{+}e^{-}$ pair
$70 \leq M_{ee} < 100$ GeV

For the trigger selection, see https://twiki.cern.ch/twiki/bin/view/Atlas/TriggerHypo

The tag and probe method

Tag and probe: a double-object method used to extract efficiencies from data, minimising reliance on MC

- All events have a preselection applied
  - Z reconstructed using offline variables
- The tag electron must additionally trigger the event, and be reconstructed with a **tight** offline selection
- This (and fiduciality, eg requiring the probe to be in a particular bin of E_{T}, say) may mean there is only one potential probe in a given class of events
- The pre-/post-conditions on the probe then define which efficiency is measured.

Notation: $N_{i\checkmark/\times}$ is the number of *events*, of a particular class, with i tags, and successful($\checkmark$) or failing($\times$) probe(s).

Neglecting background:

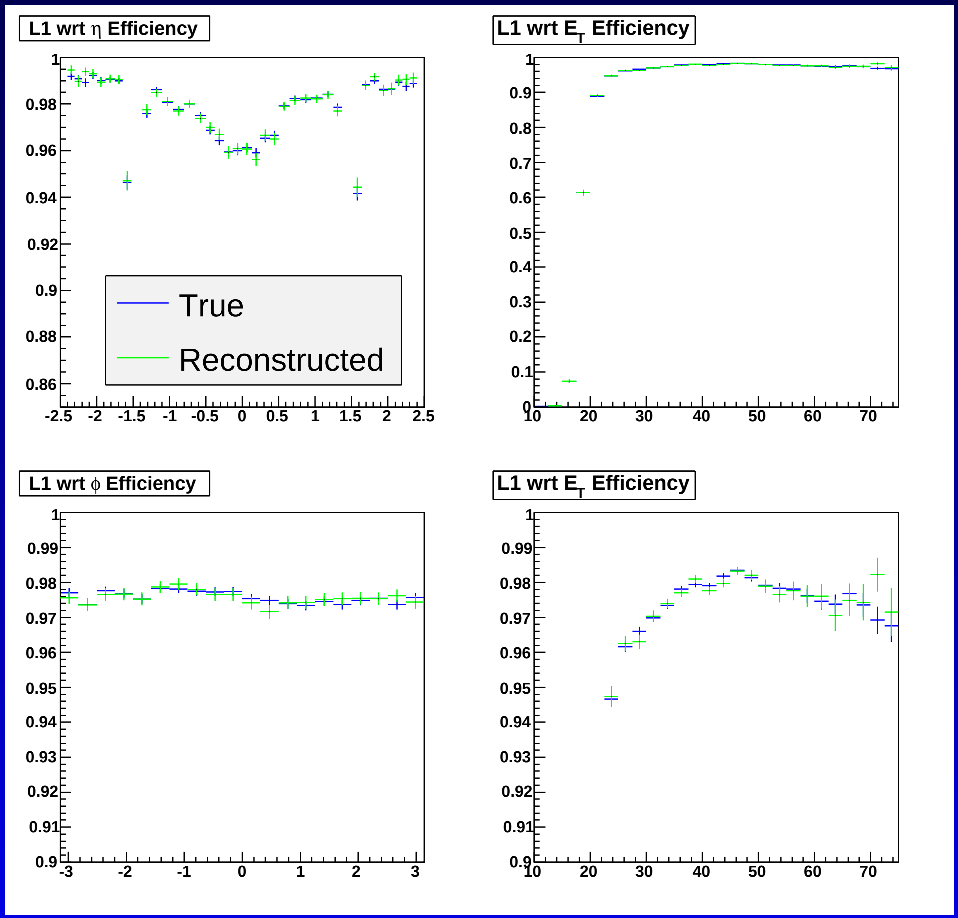
$$\epsilon = \frac{N_{1\checkmark} + 2N_{2\checkmark\checkmark}}{N_{1\times} + N_{1\checkmark} + 2N_{2\checkmark\checkmark}}$$

$$\sigma_\epsilon = \sqrt{\frac{(1-\epsilon)}{N_T}\left[\epsilon + \frac{2N_{2\checkmark\checkmark}}{N_T}(1-\epsilon)\right]}$$

where $N_T = N_{1\times} + N_{1\checkmark} + 2N_{2\checkmark\checkmark}$.

Truth-Reconstruction comparison: L1

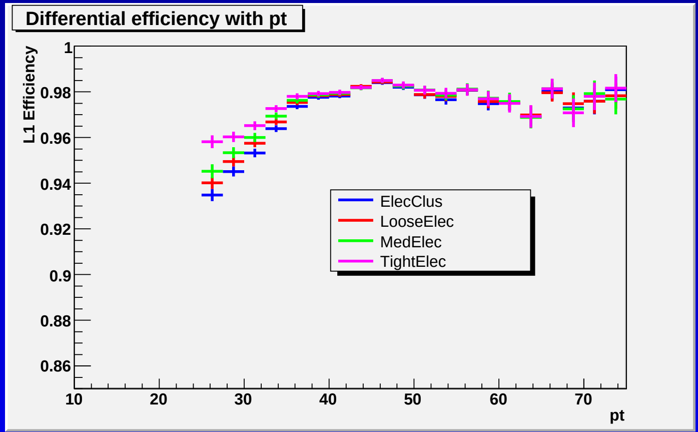
Trigger efficiencies are obtained with respect to coordinates η, ϕ and E_T (shown twice, for full turn-on and plateau detail)
More efficient wrt tight selection, up to 5% at 20 GeV



wrt LooseElectron

Comparison of different offline conditions:

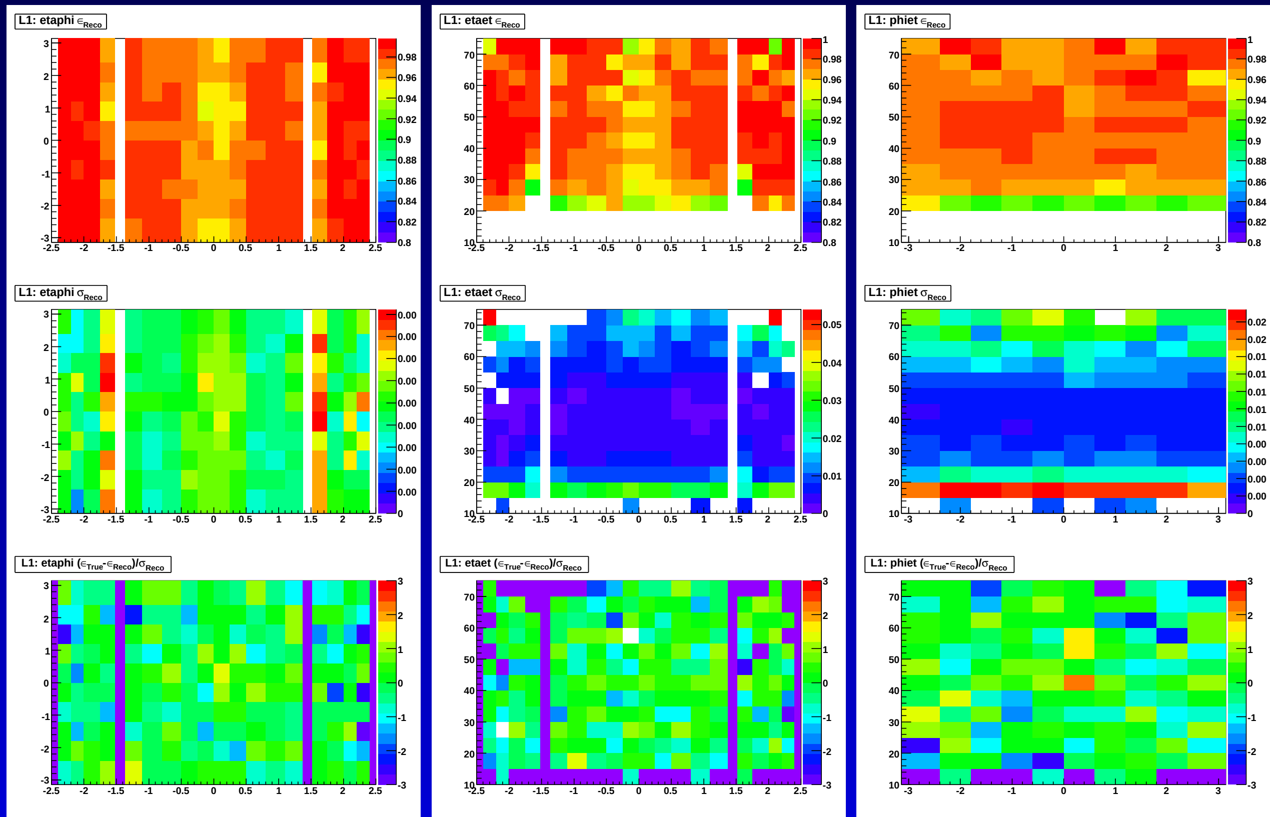
- Bare cluster (no IsEM cut)
- Loose electron (IsEM&0x7==0)
- Medium electron (IsEM&0x30F==0)
- Tight electron (IsEM==0)



Truth-Reconstruction comparison: L1

Trigger efficiencies are obtained with respect to coordinates η, ϕ and E_{T} with respect to LooseElectron

At $300pb^{-1}$ and with this binning, errors are $< 1\%$ and systematics well under control over almost all of the kinematical range.



ϵ_{Reco}

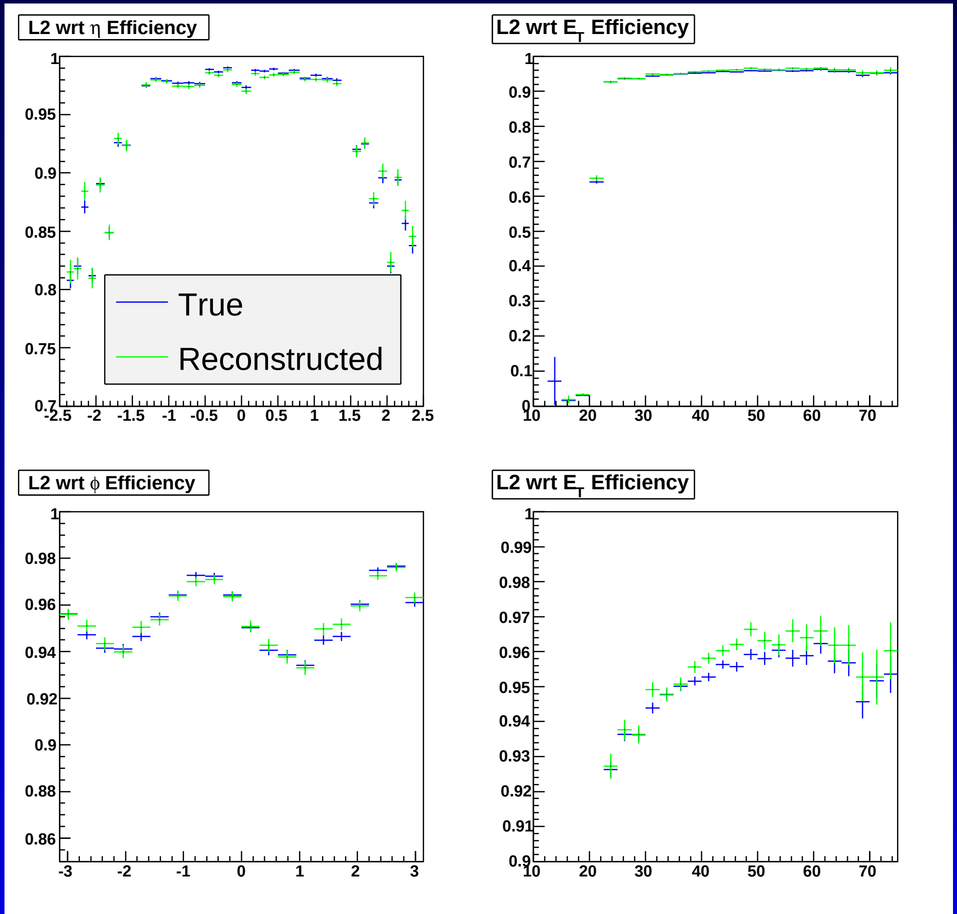
σ_{Reco}

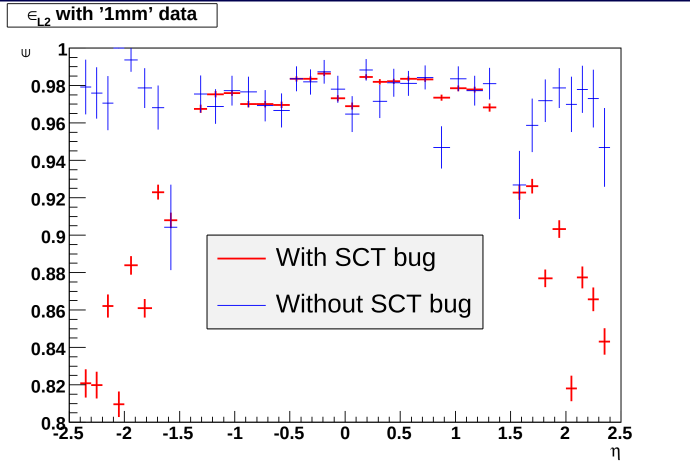
$\frac{\epsilon_{True}-\epsilon_{Reco}}{\sigma_{Reco}}$

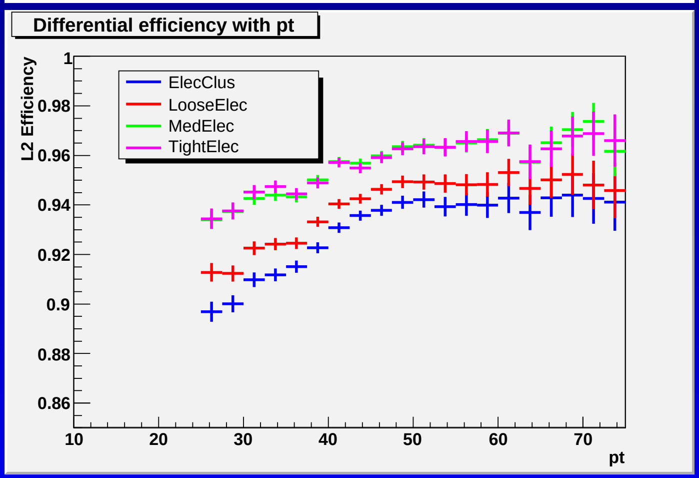
η-ϕ η-E_{T} ϕ-E_{T}

Truth-Reconstruction comparison: L2

LVL2 plateau is more sensitive than LVL1 to offline selection, shift from $\sim 98\%$ to ~ 1 in barrel
End cap efficiency limited by SCT space-point bug present in release 12
Greater dependence on offline preselection than L1







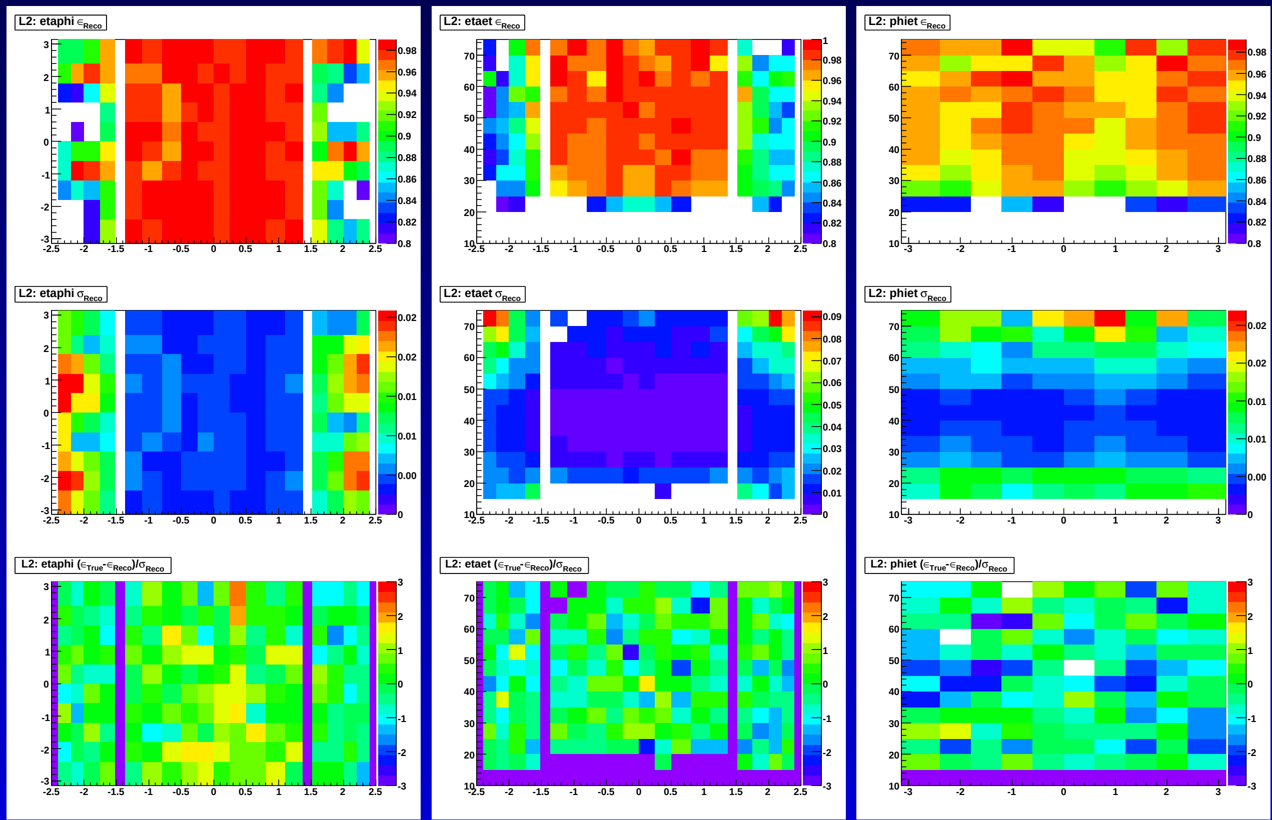
wrt LooseElectron

Truth-Reconstruction comparison: L2

Trigger efficiencies are obtained with respect to coordinates η, ϕ and E_{T} with respect to LooseElectron

Statistical uncertainties reach 2% in endcaps, where efficiency is low

Evidence of some systematic bias here, ϵ is overestimated



ϵ_{Reco}

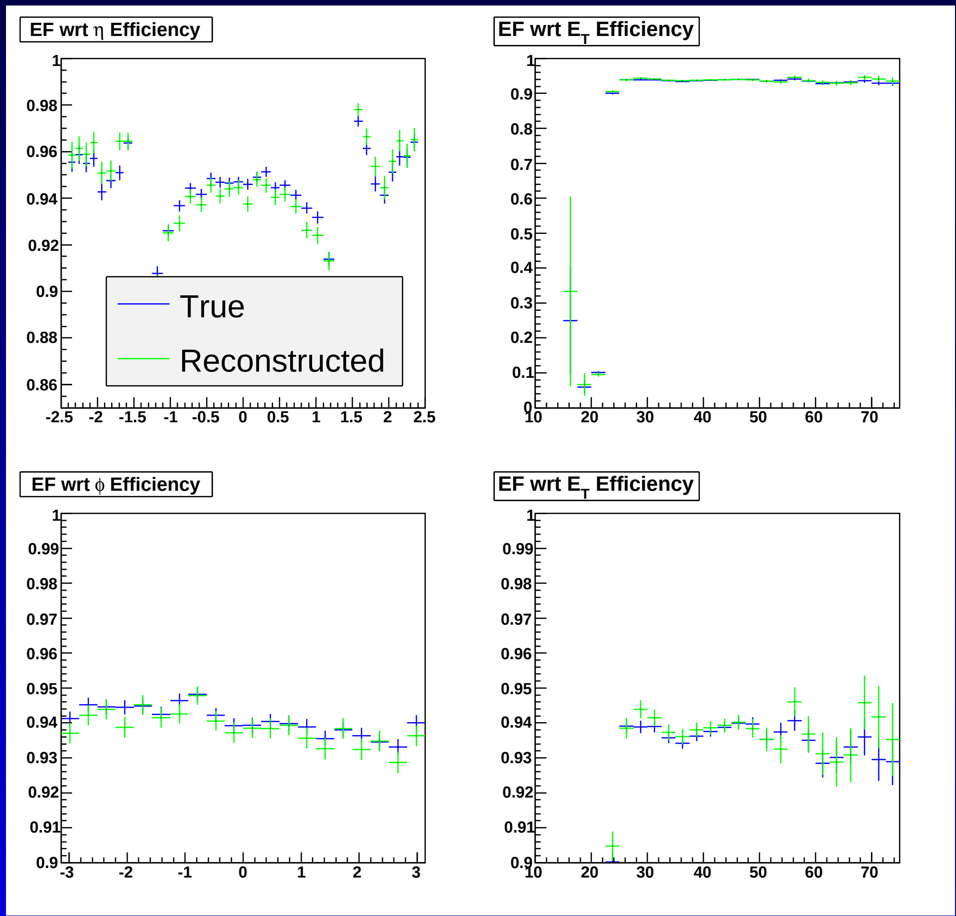
σ_{Reco}

$\frac{\epsilon_{True}-\epsilon_{Reco}}{\sigma_{Reco}}$

η-ϕ η-E_{T} ϕ-E_{T}

Truth-Reconstruction comparison: EF

EF efficiency varies by $\sim 4\%$ depending on the offline selection
Low statistics below 20 GeV - remember this plot is *relative* to L1+L2



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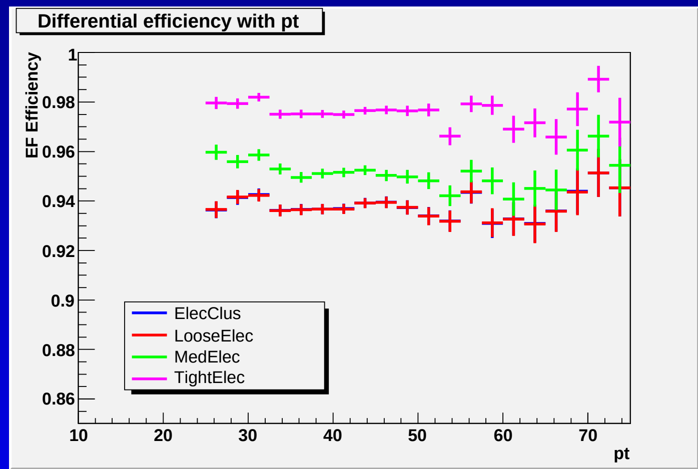
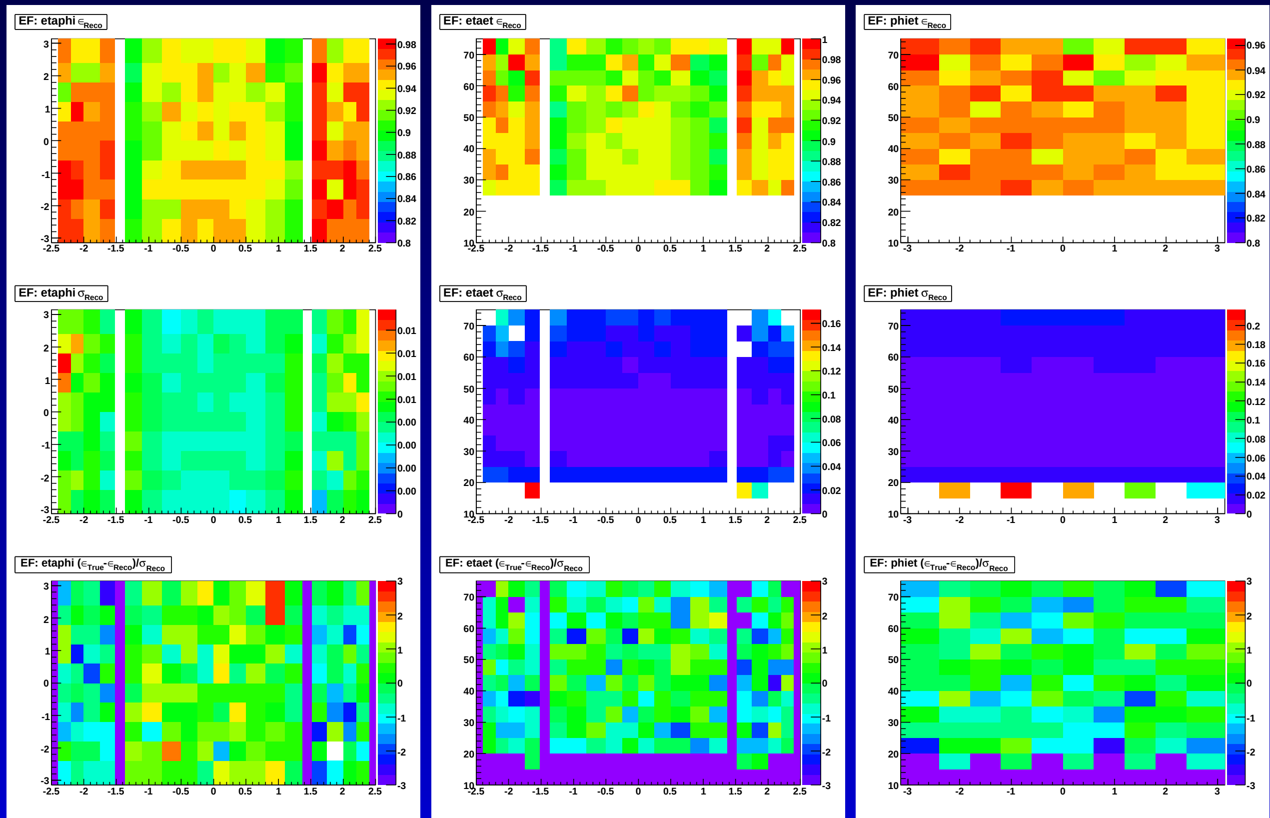


Truth-Reconstruction comparison: EF

Trigger efficiencies are obtained with respect to coordinates η, ϕ and E_{T} with respect to LooseElectron

Similar patterns/levels of bias to L2



ϵ_{Reco}

σ_{Reco}

$\frac{\epsilon_{True}-\epsilon_{Reco}}{\sigma_{Reco}}$

η-ϕ $\quad$ η-E_{T} $\quad$ ϕ-E_{T}

Global efficiency summary

Correlations between the electrons in $Z \rightarrow ee$, combined with non-uniform efficiencies can lead to bias in any global result

Trigger Level	wrt loose (truth)	wrt medium (truth)	wrt tight (truth)
LVL1	97.57 (4) (97.57 (3))	97.75 (4) (97.76 (3))	97.82 (5) (97.83 (3))
LVL2	95.51 (6) (95.45 (4))	97.51 (5) (97.32 (4))	97.31 (5) (97.09 (4))
EF	93.86 (7) (94.08 (5))	95.31 (6) (95.67 (4))	97.73 (5) (97.86 (4))
Whole trigger	87.46 (9) (87.62 (6))	90.83 (9) (91.02 (6))	93.02 (8) (92.94 (6))

Errors are for $300pb^{-1}$, multiply by 2.4 for $50pb^{-1}$, or by 0.55 for $1fb^{-1}$

Trigger efficiencies in hadronically active events

The behaviour of trigger efficiencies as a function of hadronic activity is interesting for several reasons:

- W/Z + jet(s) events are interesting in their own right, eg measuring α_s
- Z+jets events provide a useful handle on detector performance, eg the missing E_{T} resolution and jet energy scale
- The same events form important backgrounds to some search channels, eg Higgs or SUSY
- Searches and measurements (eg $t\bar{t}$ cross-section) require lepton identification to be understood in events with a high jet multiplicity

Specialised Alpgen+Jimmy Z+jets samples have been used, and compared with the Pythia inclusive sample

- Alpgen+Jimmy events include matrix elements for hard parton emission
- Pythia includes only soft/colinear processes

Sample	Code	Reco	#events
0 jets	8130	12.0.6.4	147k
1 jet	8131	12.0.6.4	150k
2 jets	8132	12.0.6.4	134k
3 jets	8133	12.0.6.4	101k
4 jets	8134	12.0.6.4	46k
5 jets	8135	12.0.6.4	17k

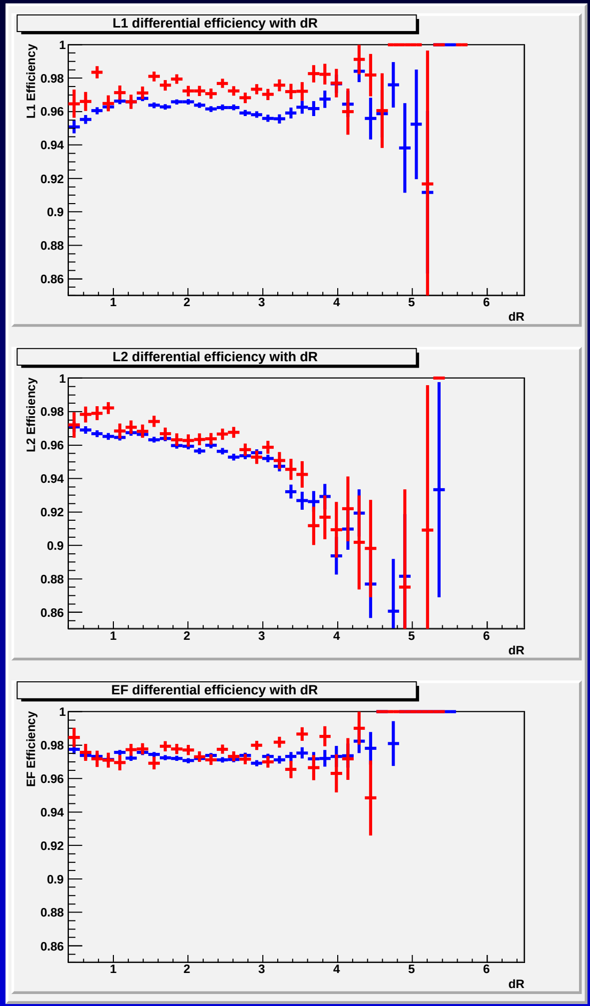
Comparison of Alpgen and Pythia $Z \to ee$

On average, trigger efficiencies in Z+jets events are $0.4 - 1\%$ lower than for the inclusive channel

- Requiring hadronic activity does have some effect on trigger identification

Efficiencies shown as a function of separation (ΔR) between electron and the nearest jet

- Pythia, inclusive $Z \to ee$
- Alpgen Z+jets
- L1: Efficiency drops by almost 2% when a jet is “close” to the electron, due to strict isolation requirements
- L2: Severe drop at high ΔR is a by-product of known SCT bug
- EF: No further dependence on ΔR at this level

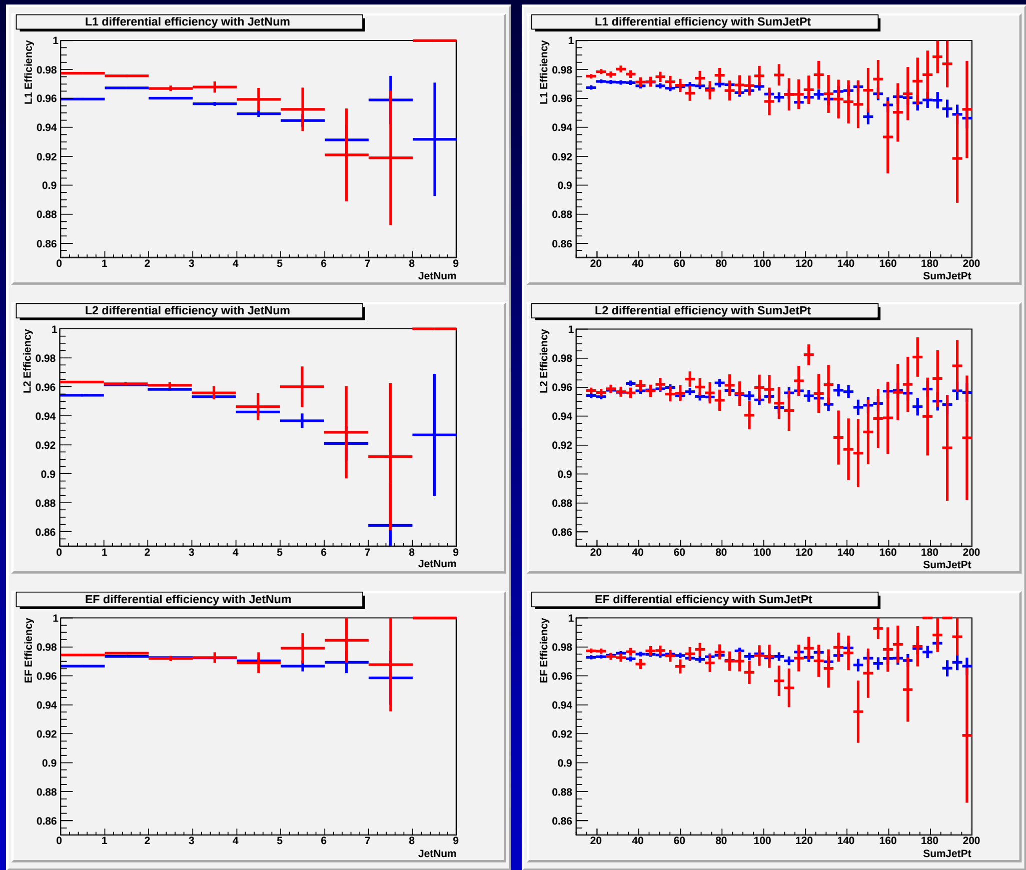


Parameterising hadronic activity

Inclusive Z
Z+jets

Left: Efficiency with number of jets
Discrepancy was not understood at first, now believed to be model-dependence of this variable

Right: Efficiency with $\sum_{jets} p_{\mathrm{T}}^{jet}$
Seems more model-independent, although efficiency dependence is now weaker



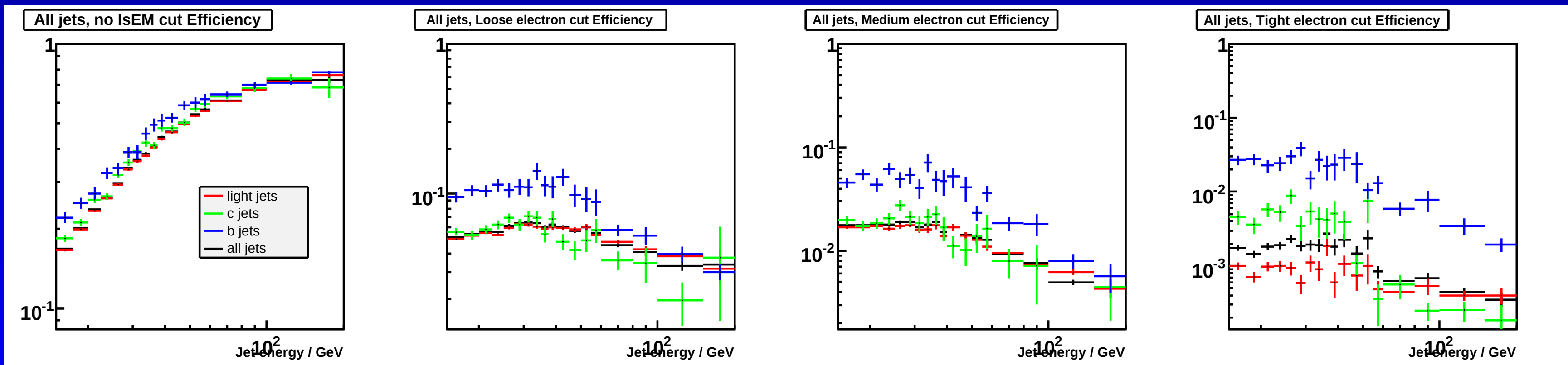
Background considerations

At first, a small background in this analysis cannot be assumed. But several factors help reduce background to manageable levels:

- The tag electron must trigger the event at all levels
- The probe electron must pass loose offline cuts
- The tag can have much harder offline cuts

Methodology Two passes of each dijet sample are made:

1. Obtain *single* jet fake rates for various combinations of offline+trigger criteria
   - Parameters: jet E_{T} and true flavour (offline weights shown below)
   - Probability to fake an electron of any energy
2. Apply weights to *di*jet events, and plot resulting mass spectrum
   - Correction to electron energy scale on a jet-by-jet basis
   - E_{T} cut at $25\ \mathrm{GeV}$ performed after scale correction

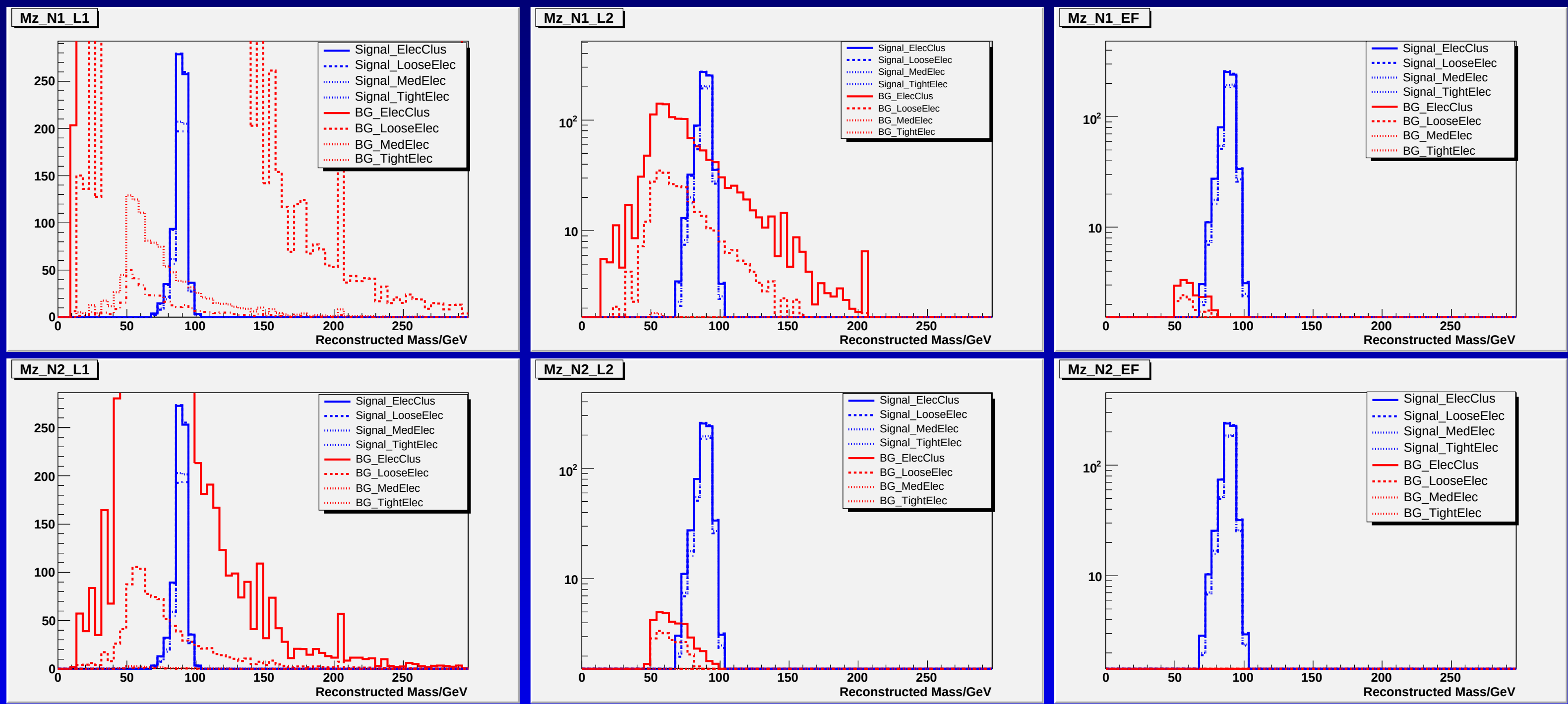


First background estimates

Scale: $1pb^{-1}$
Jet algorithm: Cone, radius 0.4
Background is hugely overestimated:

- The tag is not required to trigger the event
- The offline requirement on the tag electron is the same as for the probe (ie not tighter)

Study into the effect of these conditions has started - the first point alone seems to increase rejection by a factor O(10)



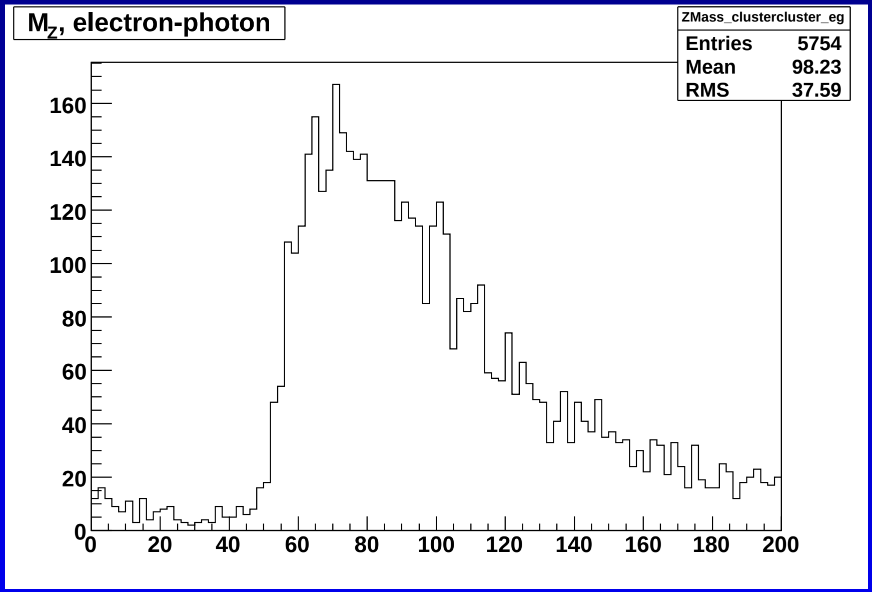
Estimating backgrounds from data

Several potential methods exist for estimating background levels from data:

- Sideband method - Convenient, but due to high E_{T} cut, lower sideband may not be large enough
- "CDF" method - Use fake rates (measured from data) to weight 1 electron + jet(s) events - size and shape obtainable
- Swap one electron cut on one leg of Z analysis - shape obtained with careful choice of selection, fit to high-mass tail to normalise

Example of third method: electron-photon spectrum obtained directly from filtered dijets sample (5802). Shows superficially the same structure as other MC background estimates

For tighter selections (including trigger), another MC fake-rate method will have to be applied



Conclusions and future work

- Work is contributing directly to three CSC notes - EG11 (trigger strategy), W/Z inclusive cross-section measurement, and the W/Z+jets note
- Good agreement between “true” efficiencies and tag and probe in differential efficiencies, where good agreement is expected
- Global efficiencies sensitive to precise kinematical distributions
- Measurement sensitive to offline electron definition (especially in the HLT) - complementary offline efficiency study is ongoing
- Studies into the effect of hadronic activity are ongoing
- First background estimates show that:
  1. For some measurements, backgrounds may be significant
  2. (near-)Lack of low mass background could make sideband fitting infeasible. Other estimation techniques are under investigation
- Work started on early running and the 10^{31} menu - awaiting full menu definition