Understanding electron trigger performance using Z→ee

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with:
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UNIVERSITY OF LIVERPOOL

Triggering electrons in ATLAS

Level 1
- Calo only
- Loose E_T cut
- (Isolation)

Level 2
- EM E_T
- Shower shape
- Track/cluster match

Event Filter
- EM E_T
- Adaptable selection (like IsEM)
  - Loose
  - Medium
  - (Tight)

Level 1
- EM E_T
- (Lateral isolation)
- (Hadronic leakage)
- (Hadronic lateral isolation)

Level 2 – Cluster
- EM E_T
- Hadronic leakage
- $R_{shape} = E_{37}/E_{77}$
- $E_{Ratio} = (E_1 - E_2)/(E_1 + E_2)$

Level 2 – Cluster + Track
- Track p_T
- $\Delta\eta$ & $\Delta\phi$
- (E_T/p_T)

Event Filter
- EM E_T
- **Loose** selection:
  - Hadronic leakage
  - $R_{\eta 33} = E_{33}/E_{77}$
  - $R_{\eta 37} = E_{37}/E_{77}$
  - Cluster width & energy
- **Medium** selection adds:
  - Shower shape in strips
  - N_{hits} (pixel & SCT)
  - Transverse impact parameter
- (**Tight** selection adds:)
  - (TRT high-threshold hits)
  - ($\Delta\eta$ & $\Delta\phi$)
  - (E/p)

For more details (and cuts) see TrigHLTelectronHypo in the TWiki

Triggers and rates for early running

NpXXi
Number of elements
Type (e=electron)
ET cut at EF
isolation/other info

Low thresholds/loose selections for 10^{31} cm^{-2}s^{-1}

- ~40 Hz EF bandwidth

Main T&P triggers

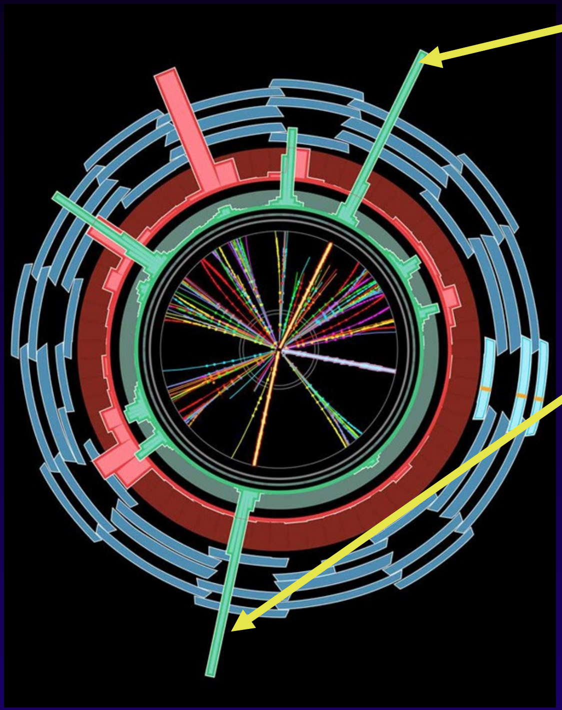
Signature	LVL1 item	EF selection	LVL1 Rate	Pre-scale	EF Rate	Motivation
2e5	2EM3	medium	6.5 kHz	1	6 Hz	$J/\Psi \rightarrow ee$, $Y \rightarrow ee$, Drell-Yan production
2g10	2EM7	loose	0.5 kHz	1	0.1 Hz	di-photon cross-section
e10	EM7	medium	5.0 kHz	1	21 Hz	$e^{\pm}$ from b,c decays, E/p studies
2e10	2EM7	loose	0.5 kHz	1	0.4 ± 0.2 Hz	$Z \rightarrow e^+e^-$
g20	EM18	loose	0.3 kHz	1	5.4 ± 0.2 Hz	direct photon production, jet calibration using γ-jet events, high-p_T physics
e20	EM18	loose	0.3 kHz	1	4.3 ± 0.2 Hz	high-p_T physics, $Z \rightarrow ee, W \rightarrow e\nu$
e20_passL2	EM18	loose	0.3 kHz	1	10 Hz	commissioning trigger for problems at LVL2
e20_passEF	EM18	loose	0.3 kHz	1	12 Hz	commissioning trigger for problems at EF
em105_passHLT	EM100		1.0 Hz	1	1.0 ± 0.1 Hz	New physics, check for possible problems

Table adapted from EG11 note draft (overall eγ trigger strategy)

Not shown:

- Prescaled triggers bypassing HLT
- Built-in redundancy (eg e25)

Measuring trigger efficiencies using Z→ee



Tag selection:
- Tight offline cuts + E_T
- Triggers event

Probe preselection:
- Offline cuts + E_T

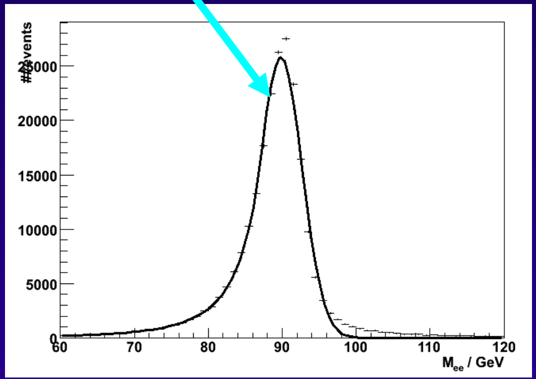
Event selection:
- e^+e^- pair
- $70 < M_{ee} < 100$ GeV
- "True" efficiency also needs 2 electrons

$$\varepsilon = \frac{N_{\text{successful probes}}}{N_{\text{preselected pairs}}} = \frac{N_{\text{p}}}{N_{\text{T}}} = \frac{N_{1p} + 2N_{2p}}{N_{1f} + N_{1p} + 2N_{2p}}$$

$N_{ip/f}$ = # events with i probes, passing/failing trigger

$$\sigma_\varepsilon = \sqrt{\frac{1}{N_{\text{T}}^2}\left[(1-2\varepsilon)N_{\text{p}} + \varepsilon^2 N_{\text{T}} + (1-\varepsilon)^2 \cdot 2N_{2p}\right]}$$

Signal extraction:
- Simple counting (this study)
- Signal+background fit, background subtraction, ... (real life)



Results are v13 unless otherwise stated

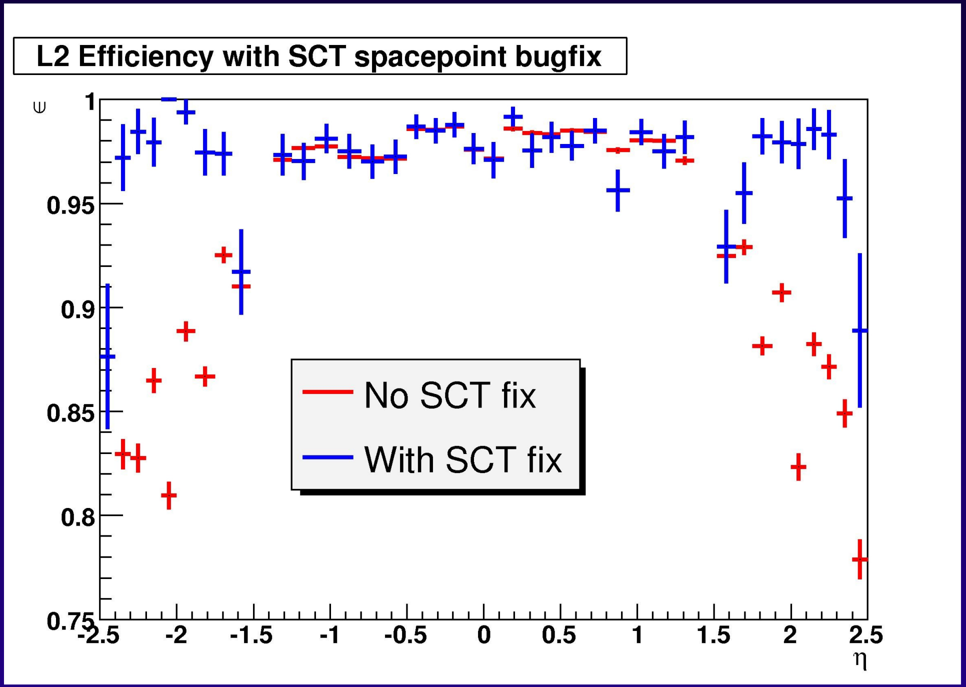
Sample type	Number	Reco	Simul	σ (Filtered)	# events
Z → ee	5144	12.0.6.1	12.0.31	1432 pb	430k
Z → ee	5144	13.0.30.1/2	12.0.31	1432 pb	260k
J1	5010	12.0.6.1	12.0.31	1.4×10^9 pb	387k
J2	5011	12.0.6.1	12.0.31	9.3×10^7 pb	360k
J3	5012	12.0.6.1	12.0.31	5.9×10^6 pb	365k
J4	5013	12.0.6.1	12.0.31	3.1×10^5 pb	369k

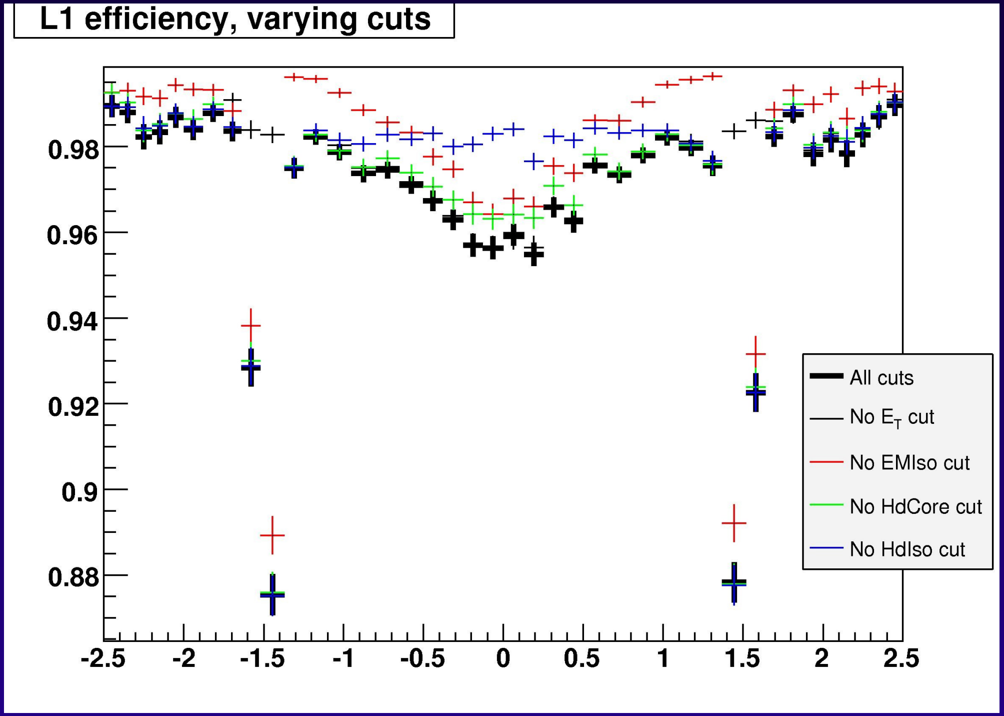
Problems in release 12

Problems can be found even before data-taking

Software bug in IDSCAN and confirmation of fix

Problem with Level 1 lateral hadronic isolation:
- Characterised using tag & probe
- Requirement now loosened

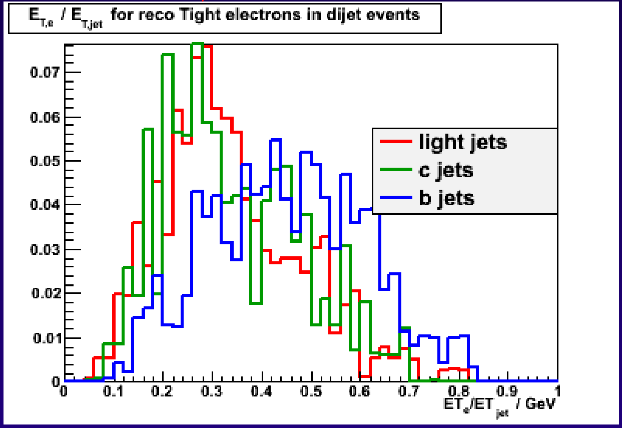




Treatment of backgrounds (v12)

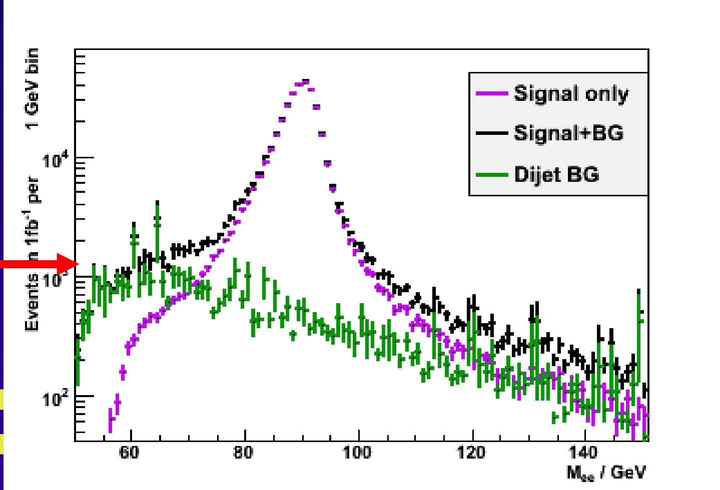
Main background is from QCD dijets faking two electrons

- MC statistics for this will be small compared to data
- Possible solution: Parameterise P(jet→electron) and use this to boost MC statistics
  - Parameters: jet E_T and flavour
- Produce "Fake rate" and correction for jet/EM scale difference



$$
\begin{aligned}
EventWeight \;=\; & P(jet1 \rightarrow tag) * P(jet2 \rightarrow probe) \\
& + P(jet1 \rightarrow probe) * P(jet2 \rightarrow tag) \\
& - P(jet1 \rightarrow tag) * P(jet2 \rightarrow tag)
\end{aligned}
$$

"Worst case" selection for tag & probe



Treatment of backgrounds (v12)

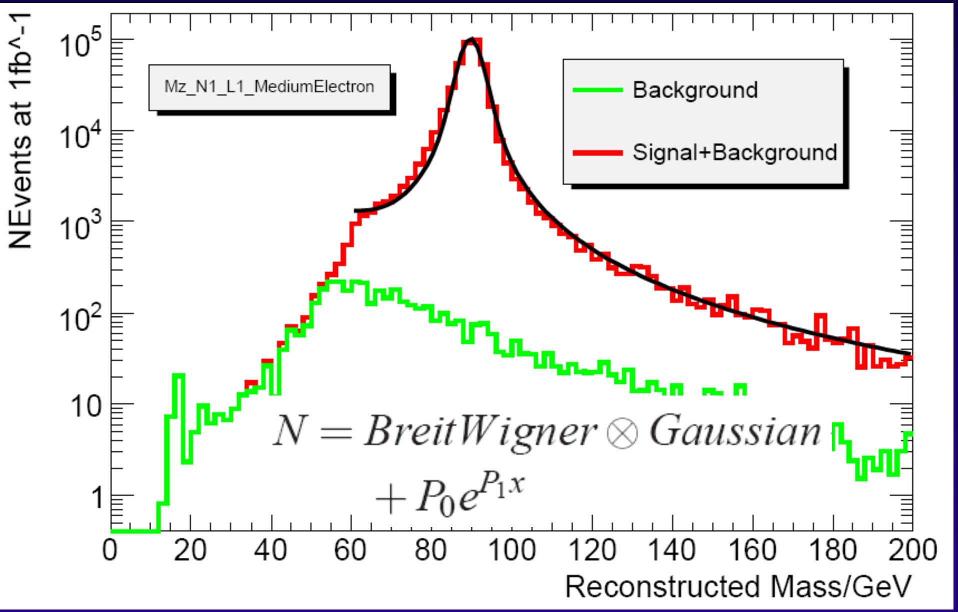
E. Dobson

Background levels can be estimated and subtracted using fits to the data

- Sideband subtraction assumes Drell-Yan is "background"
  - Alternatives exist in data that are difficult to implement in MC
- Change in measured efficiency is only significant at Level 1
  - Needs further study

ε (Signal) – ε (with BG subtraction) [%]

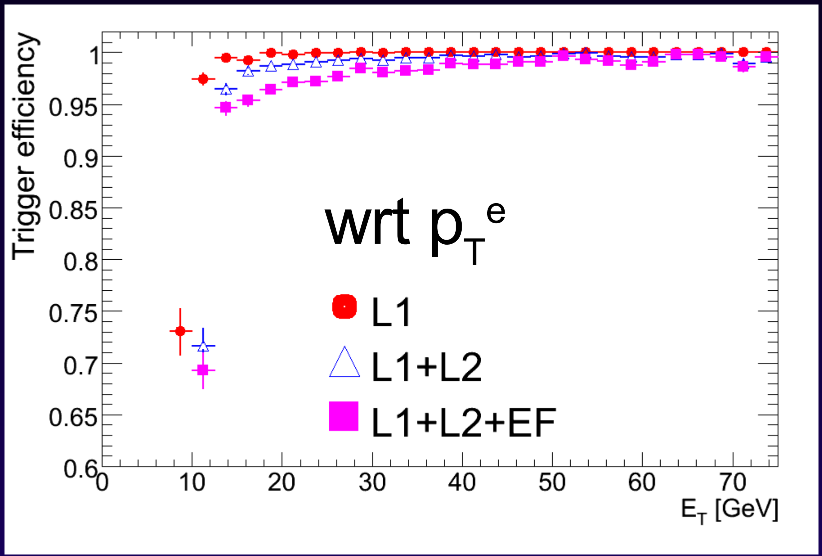
Trigger Level	wrt loose	wrt medium	wrt tight
LVL1	-0.85	-0.70	0.53
LVL2	0.08	0.01	0.03
EF	∼0	∼0	∼0
Whole trigger	-0.69	-0.60	0.53

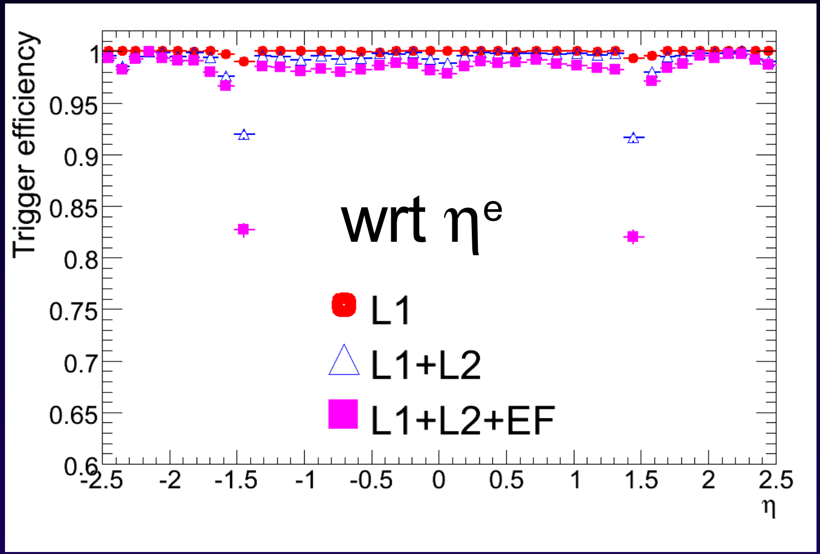


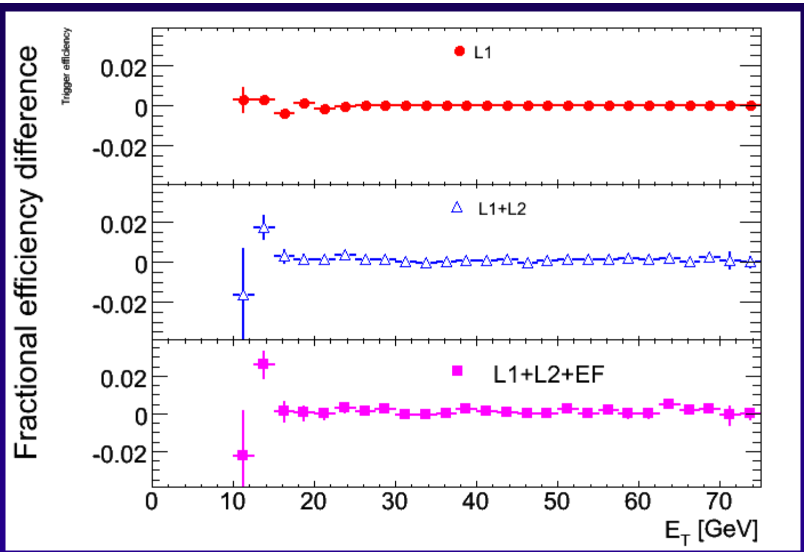
Results that follow are "signal only", and just count the events in range

Efficiency results

Trigger element: e10
For trigger signature: 2e10
EF selection: loose
Luminosity: 10^{31} cm^{-2}s^{-1}
Offline normalisation: ElectronMedium



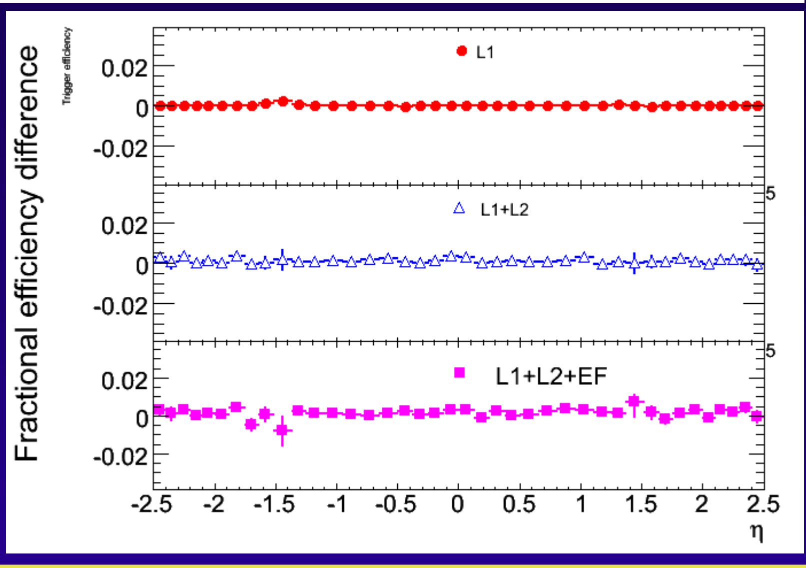




L1

L2

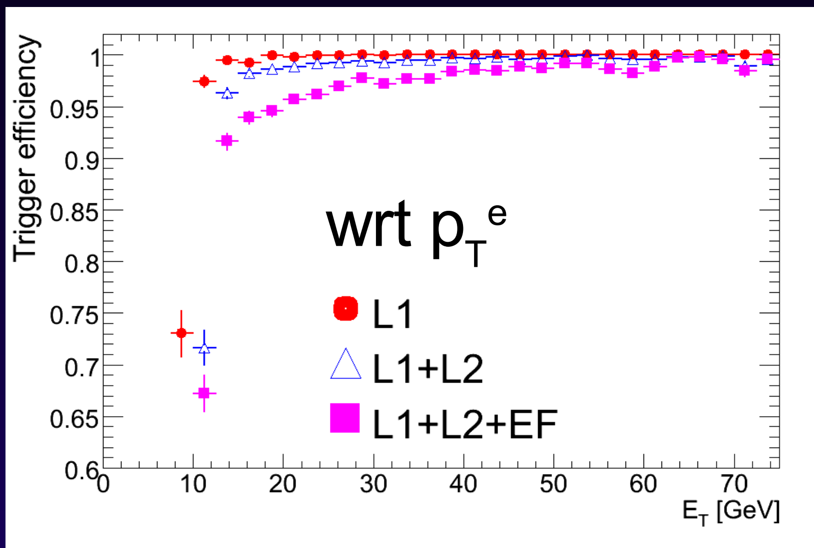
EF

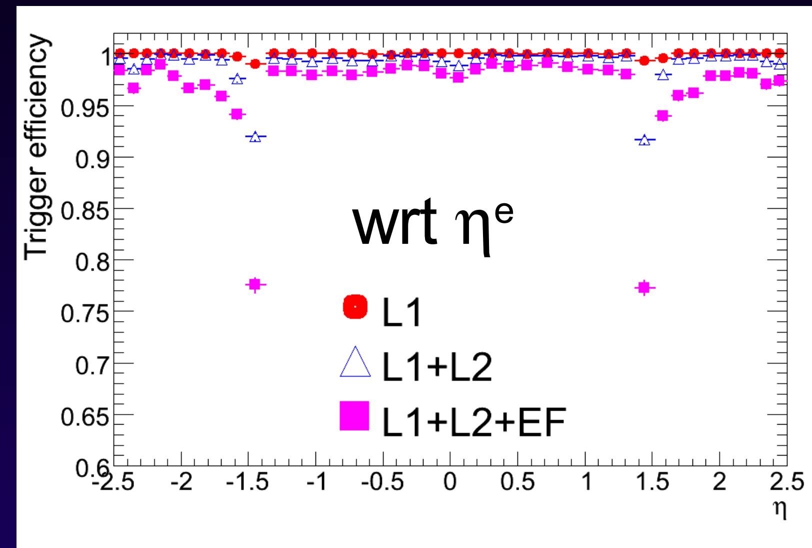


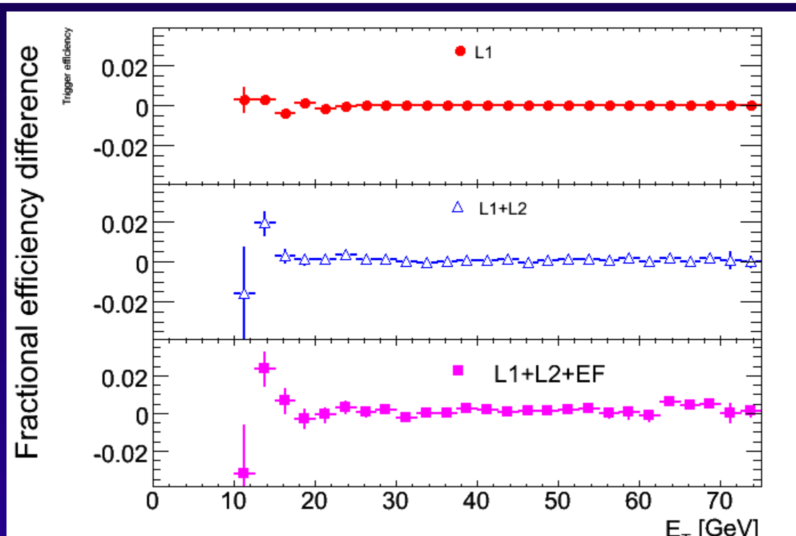
$$\text{Fractional Efficiency Difference} = \frac{\varepsilon_{\text{Reco}} - \varepsilon_{\text{True}}}{\varepsilon_{\text{True}}}$$

Efficiency results

Trigger element:	e10_tight
For trigger signature:	e10
EF selection:	medium
Luminosity:	10^{31} cm^{-2}s^{-1}
Offline normalisation:	ElectronMedium



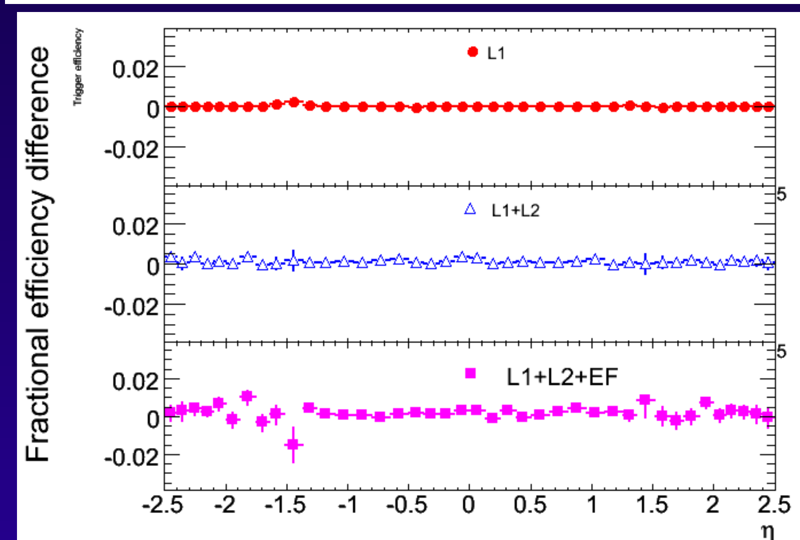




L1

L2

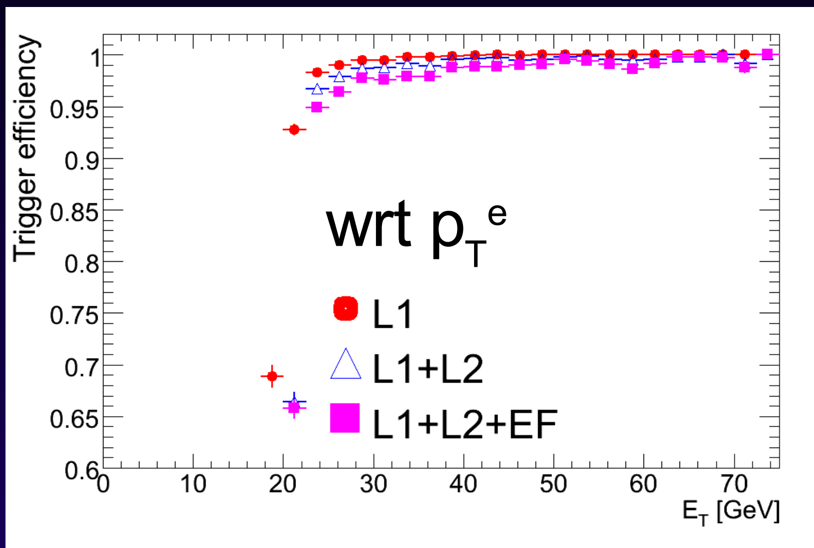
EF

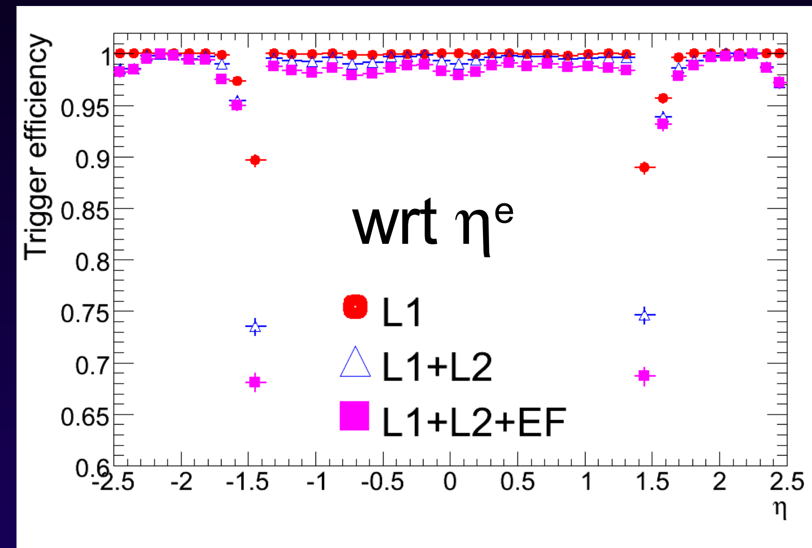


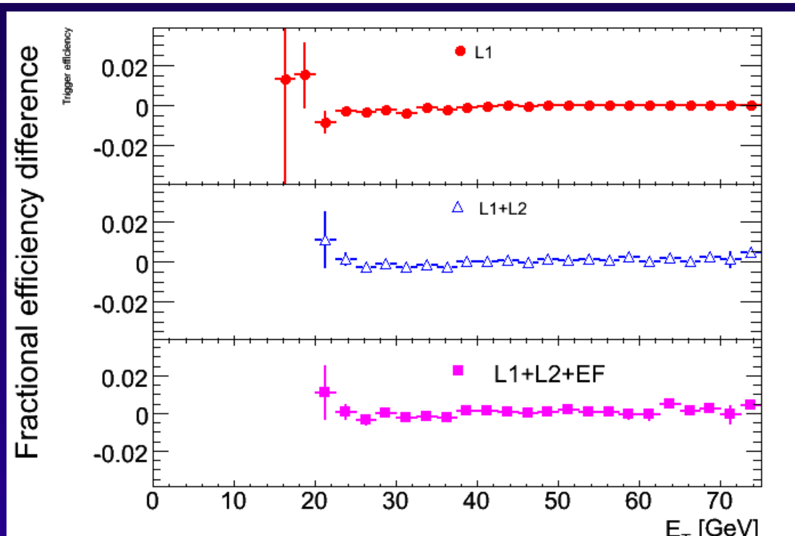
$$\text{Fractional Efficiency Difference} = \frac{\varepsilon_{\text{Reco}} - \varepsilon_{\text{True}}}{\varepsilon_{\text{True}}}$$

Efficiency results

Trigger element: e20
For trigger signature: e20
EF selection: loose
Luminosity: 10^{31} cm^{-2}s^{-1}
Offline normalisation: ElectronMedium



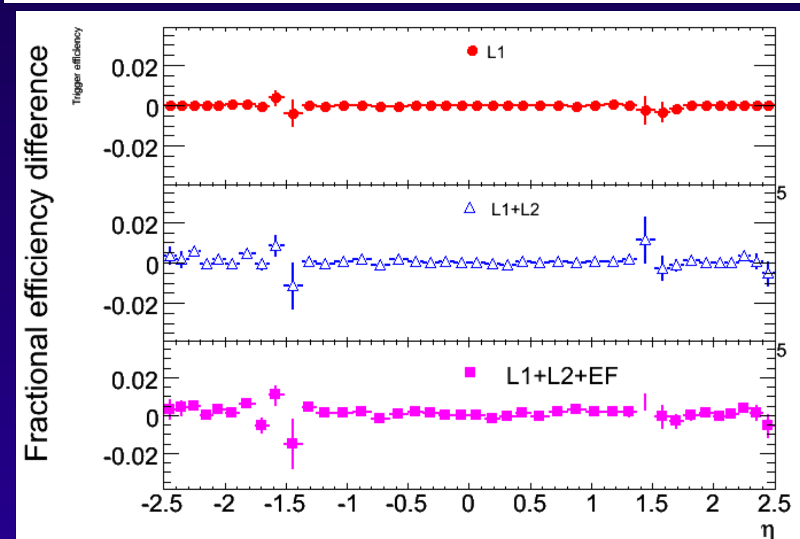




L1

L2

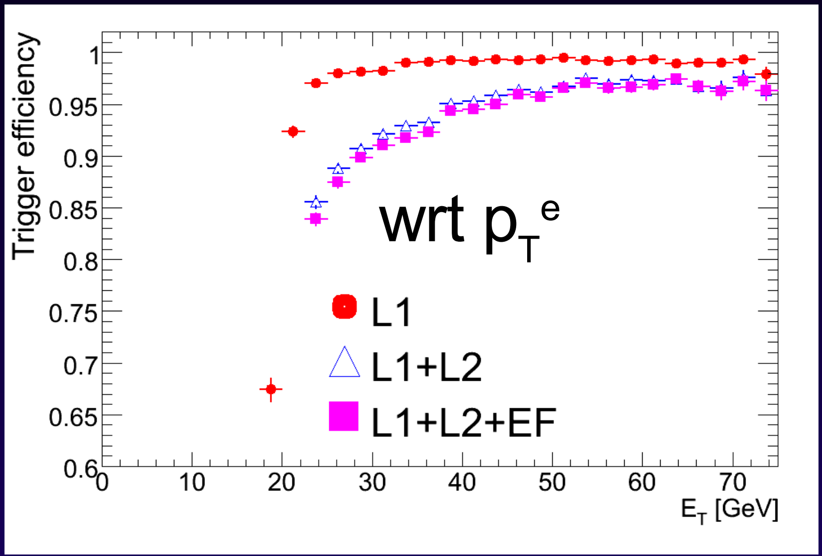
EF

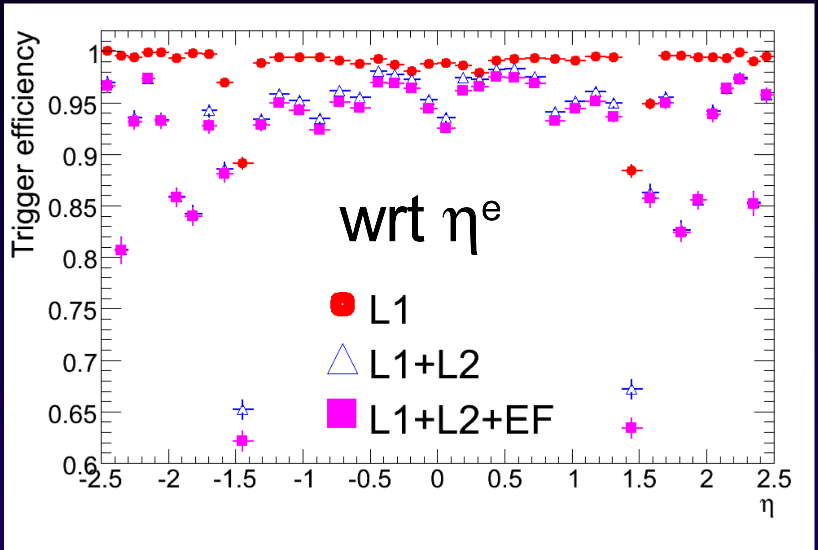


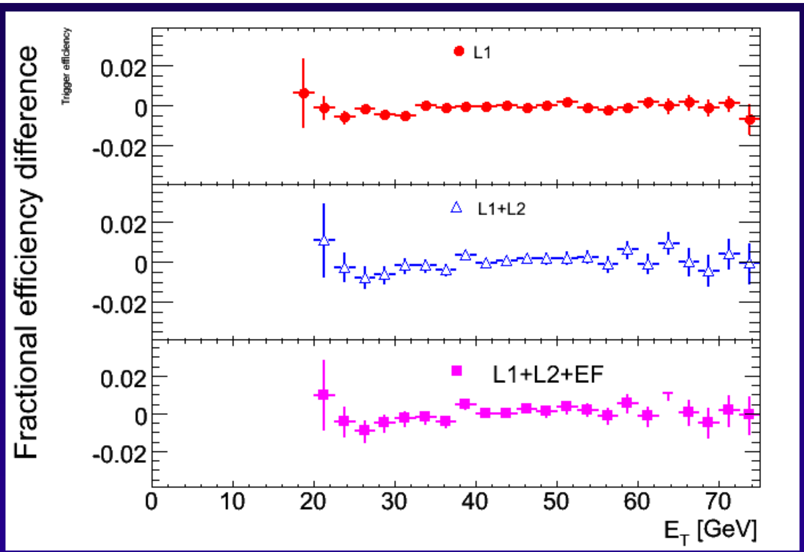
$$\text{Fractional Efficiency Difference} = \frac{\varepsilon_{\text{Reco}} - \varepsilon_{\text{True}}}{\varepsilon_{\text{True}}}$$

Efficiency results

Trigger element: e22i
For trigger signature: e22i (ex- e25i)
EF selection: loose
Luminosity: 10^{33} cm^{-2}s^{-1}
Offline normalisation: ElectronMedium



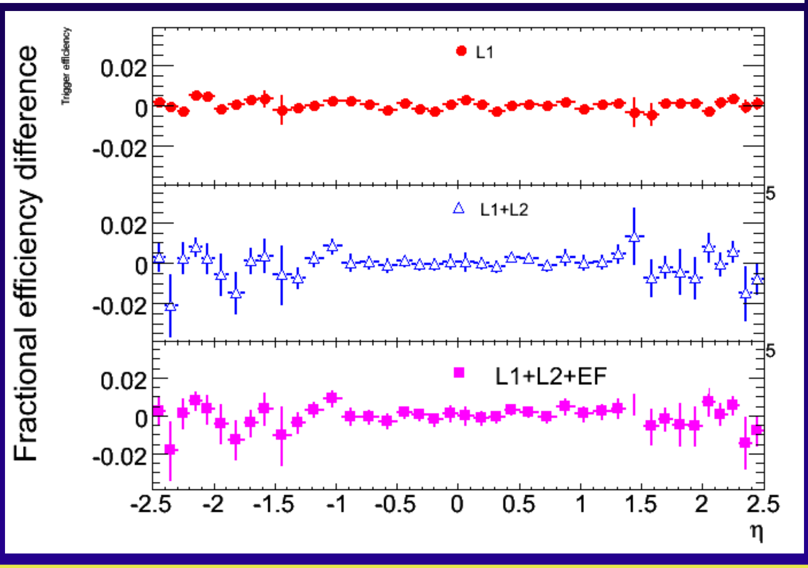




L1

L2

EF



$$\text{Fractional Efficiency Difference} = \frac{\varepsilon_{\text{Reco}} - \varepsilon_{\text{True}}}{\varepsilon_{\text{True}}}$$

Single electron efficiencies

NpXXi
Number of elements
Type (e=electron)
ET cut at EF
isolation/other info

Offline E_T cut = EF threshold + 5 GeV

NB: For multi-electron items (eg e10), tag uses single-electron equivalent (eg e10_tight)

Trigger Item	Efficiency (%) wrt			ε_Reco – ε_True (%) for medium	Lumi cm-2s-1	Trigger type
	loose	medium	tight			
e10	97.07 (5)	98.56 (4)	99.58 (2)	0.09	10^31	multi-e
e10_tight	86.8 (1)	98.06 (4)	99.15 (3)	0.13	10^31	single-e
e15_loose	97.11 (5)	98.58 (4)	99.55 (2)	0.06	10^31	multi-e
e15	87.3 (1)	98.13 (4)	99.15 (3)	0.08	10^31/10^32	single-e
e20	96.98 (5)	98.48 (4)	99.41 (3)	-0.03	10^31	single-e
e20_tight	86.4 (1)	96.63 (6)	97.66 (6)	0.02	10^32	single-e
e22i	90.76 (9)	93.83 (8)	94.91 (8)	-0.06	10^33	single-e
e25	97.10 (6)	98.53 (4)	99.40 (3)	-0.09	10^31	backup
e25_tight	87.1 (1)	96.82 (6)	97.80 (6)	-0.04	10^32	backup

Errors are for 180 pb^{-1} of MC "data"

Reco-Truth discrepancy generally < 0.1%
- Approx. equal to MC statistical error

Efficiencies in Z(ee)+Jets events (v12)

E. Dobson

Events with jets in have ~2% lower trigger efficiencies than the inclusive channel

- Results for e25i in v12
- ALPGEN datasets 8130-5 are used
- parton has $p_T > 20$ GeV
  - Adds to calorimeter activity
  - Events have a different kinematical distribution

See M. Fiascaris talk tomorrow for more

ε (Z+Jets) – ε (inclusive)

Level	Loose	Medium	Tight
LVL 1	-1.46%	-1.22%	-1.21%
LVL 2	-0.88%	-0.35%	-1.39%
EF	-0.61%	-0.52%	-0.41%
Whole trigger	-2.66%	-1.94%	-1.92%

Summary

Trigger efficiencies can be obtained from ATLAS data in the very early stages of running

- ~ 0.2% statistical error with just $50pb^{-1}$ (if $\varepsilon \sim 0.9$)
  - ~ 1% at 55 hours after turn-on??
- Systematic uncertainties will quickly become important

Parts of this study are entering CSC notes:

- v13 results into EG-11 (overall eγ strategy)
- v12 results into Inclusive W/Z cross section note (Talk tomorrow)
- v12 results in W/Z+Jets note (Talk tomorrow)

Tag and Probe is now quite a popular topic

- Many people working on trigger performance
- Offline efficiency measurement (Oxford) (e performace talk)
- Extensions to BSM physics (next talk!)