Determining the ATLAS electron trigger efficiency in BSM channels from Data

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Overview

The LHC and ATLAS

The ATLAS trigger system
- Overview
- Electron trigger

Trigger Efficiency
- Measurement from data

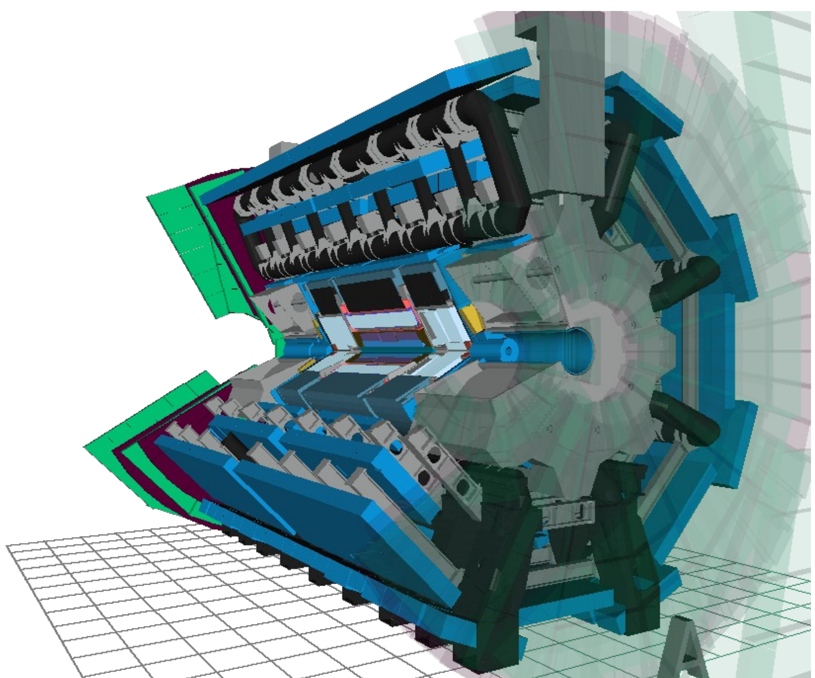
Monte Carlo studies of efficiency

Application of data driven methods
- SUSY
- Dielectron resonances at high mass

Conclusions

ATLAS and the Large Hadron Collider

LHC	Design Values
CoM energy	14 TeV
Luminosity ($cm^{-2}s^{-1}$)	Low: $2x10^{33}$ High: 10^{34}
Bunch crossing	25 ns
Overlaid events	23 @ $10^{34}cm^{-2}s^{-1}$
Stored energy	362 MJ/beam



	ATLAS
Magnetic field	2T solenoid + toroid (0.5 T barrel 1 T endcap)
Tracker	Si pixels, strips + TRT $\sigma_{pt}/p_T \approx 5x10^{-4}p_t + 0.01$
EM calorimeter	Pb +Lar $\sigma_E/E \approx 10\%/\sqrt{E} + 0.007$
Hadronic calorimeter	Fe+scint, Cu +Lar (10λ) $\sigma_E/E \approx 50\%/\sqrt{E} + 0.03$ GeV
Muon System	$\sigma_{pT}/p_T \approx 2\%$ @ 50GeV to 10 % @ 1 TeV (ID+MS)
Trigger	Hardware Level 1 + Region of Interest-based HLT

ATLAS trigger

Maximum raw **event rate** seen in ATLAS at design luminosity ~ **40 MHz** (from the 25 ns bunch crossing).

Trigger system needs to reduce this to the **100-200Hz rate able to be written to tape**.

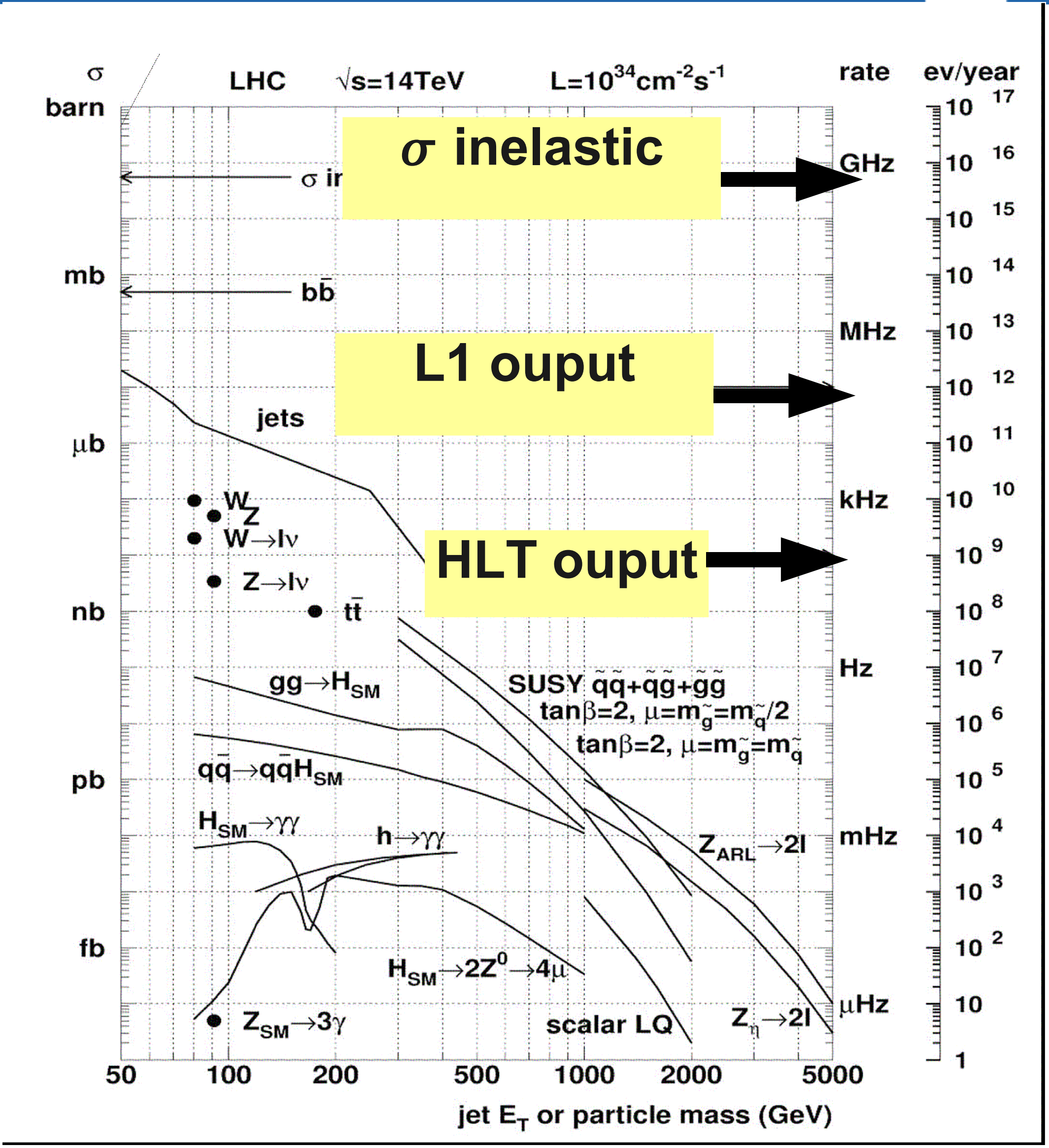
Rejection factor to be achieved at maximum luminosity ~ 10^7.

Interesting cross sections often at least **~10^6 times smaller than total cross section.**

Trigger must remain efficient for rare signal processes.

In one second at design luminosity:

 40,000,000 bunch crossings
 ~1,000 W events
 ~ 500 Z events
 ~ 10 top events
 ~ 9 SUSY events?
 ~ 0.1 Higgs events?
 200 events written out



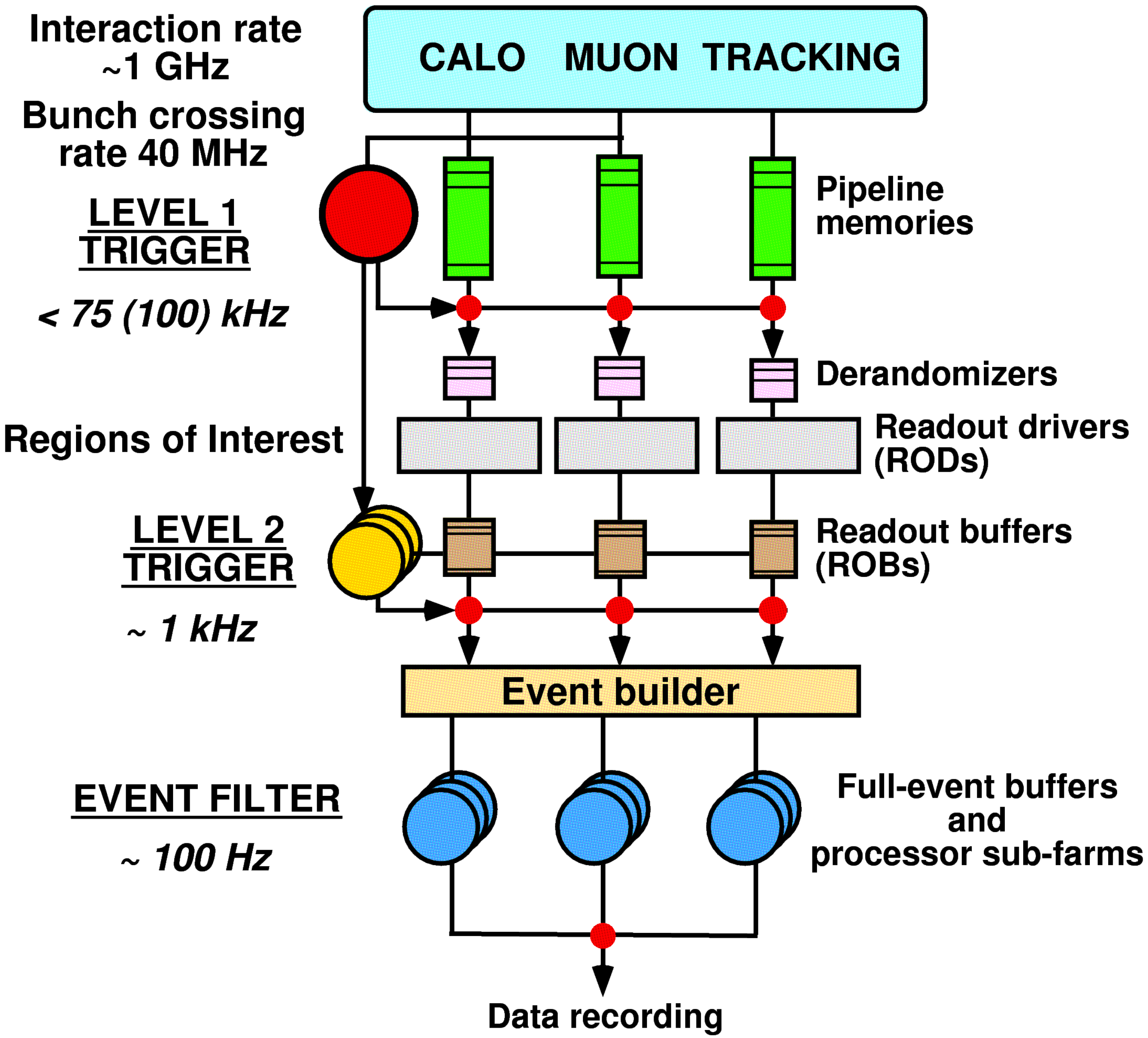
Must ensure the correct 200 events are recorded.

ATLAS trigger

Seeded and stepwise three tier trigger system.

- Custom hardware Level 1 (L1).
  - 40 MHz → 100 kHz.
- Software High Level Trigger (L2+EF).
  - L2: 100 kHz → 1 kHz.
  - EF: 1 kHz → 100-200 Hz.

Region of Interest mechanism means only 1→4% of detector information is needed.



ATLAS electron trigger

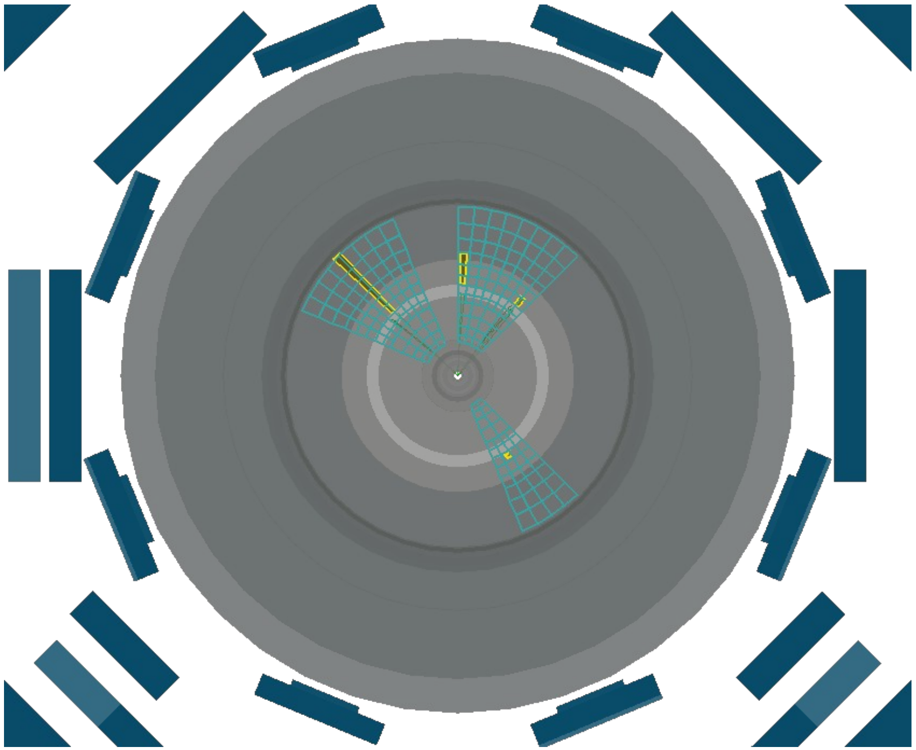
L1 electron trigger applies simple **hardware** cuts in electromagnetic and hadronic calorimeters.

Uses analog sum of **calorimeter** towers with coarse granularity. $\Delta\eta x \Delta\phi = 0.1x0.1$

L2 seeded by L1, fast reconstruction algorithms within **RoIs**. **Full detector granularity including tracking**.

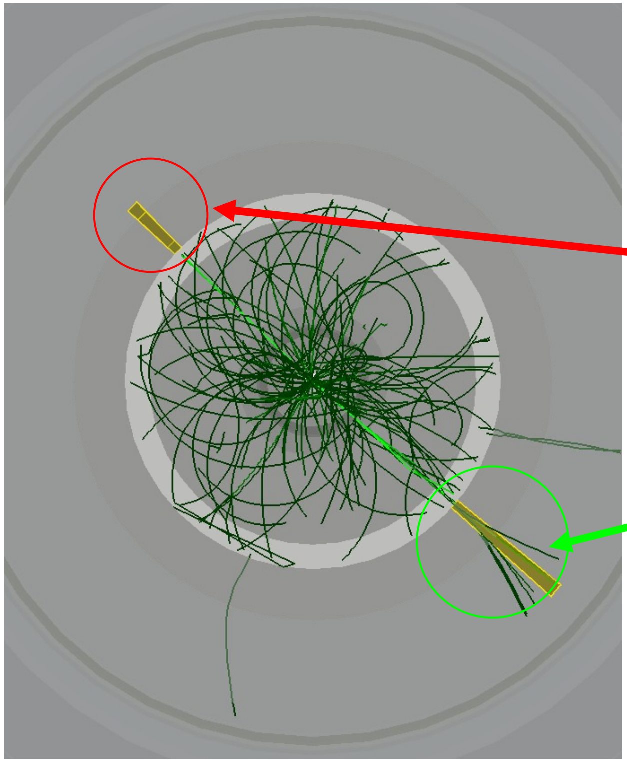
EF seeded by L2. Offline reconstruction algorithms, **refined calibration and alignments**.

Jet backgrounds are rejected by transverse energy thresholds, isolation cuts and electron hypothesis algorithms



Trigger naming conventions:

- **EF_e25i_tight**
- **EF – Event Filter stage**
- **e – electron hypothesis algorithm**
- **25 – transverse energy threshold in GeV**
- **i – isolation required at L1**
- **tight – 'tight ' identification cuts applied at EF**



The Tag and Probe method.

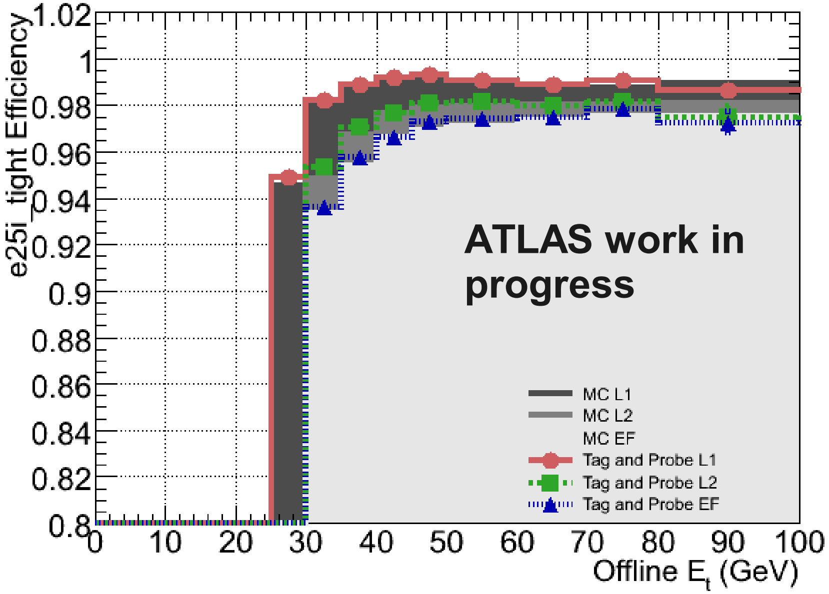
Sample defined by: $Z \rightarrow ee$ reconstructed (from offline e^+e^-) + 1 e trigger signature satisfied (tag).

Trigger efficiency determined by counting in how many cases the second $e^\pm$ satisfies the trigger requirements (probe).

Number of events $= \sigma \cdot \int L dt \cdot \epsilon$

To know the cross section of any process observed at the LHC we must have a good understanding of efficiency.

Efficiency is a convolution of reconstruction efficiency and trigger efficiency.



Supersymmetry

Well motivated **extension to SM** providing answers to divergent loop corrections to Higgs boson mass, cold dark matter and force unification.

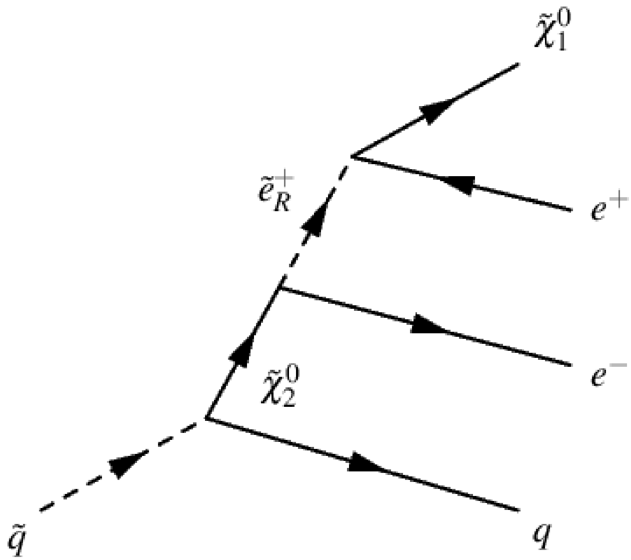
Typical SUSY phenomenology at ATLAS is dominated by pair production of sparticles and cascade decays to the Lightest Supersymmetric Particle (often the $\tilde{\chi}^0_1$).

To evaluate ATLAS performance two **benchmark points** in **mSUGRA** parameter space are studied here that are relavent for **early physics** at ATLAS.

- SU3 – low mass SUSY (in 'bulk region').
- SU4 – low mass SUSY (at the edge of Tevatron limits).

	SU3	SU4
m_0	100	200
$M_{1/2}$	300	160
A_0	0	-400
$\tan\beta$	10	10
sign(μ)	+	+
σ_{total} [pb]	27.68	402.19

mSUGRA parameters of considered points.



Squark cascade decay to SM particles and LSP Neutralino.

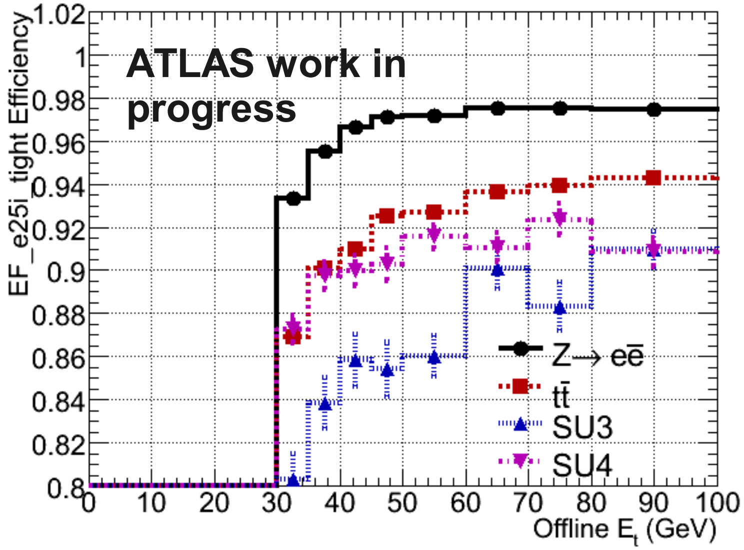
SUSY phenomenology is electron and jet rich.

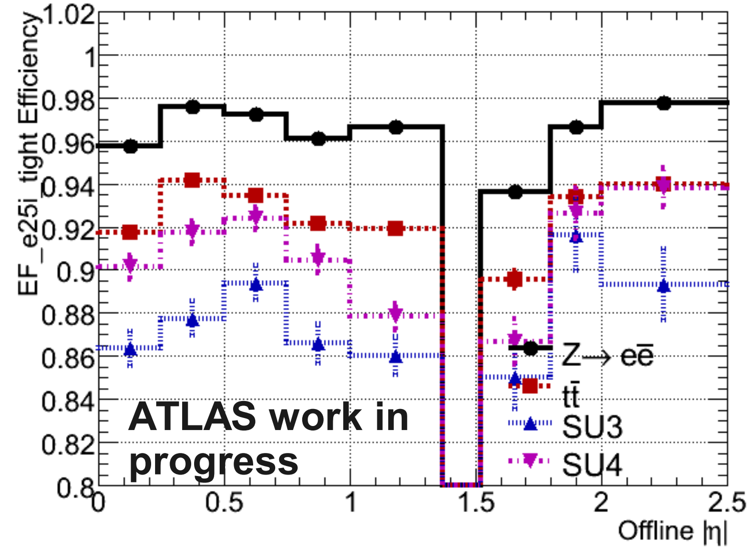
Trigger efficiency in MC simulations of SUSY processes

Efficiency for e25i_tight trigger (L1+L2+EF) vs E_T vs $|\eta|$

Sample	Efficiency (%)
Z→ee	97.1 ± 0.1
ttbar	92.9 ± 0.1
SU3	87.7 ± 0.4
SU4	90.6 ± 0.3

Differences between samples of up to 10%





Main factors that can effect trigger efficiency;

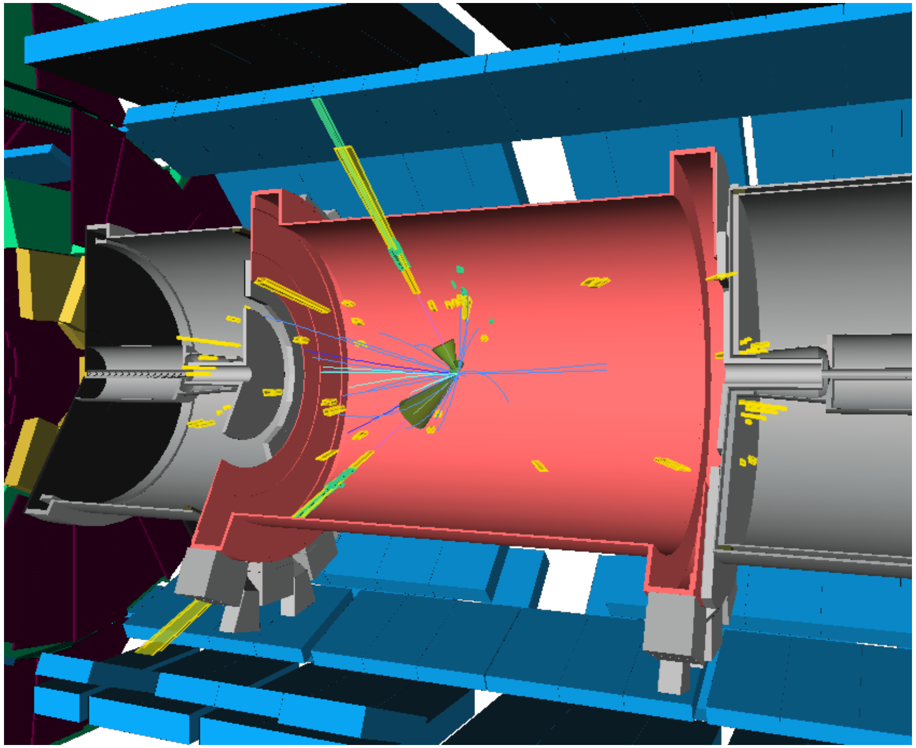
1. Electron kinematics.
   Trigger efficiency differs over the η spectrum (for example). If different samples have different η distributions then trigger efficiency integrated over this will differ.

2. Jet/electron misidentification.
   These fake electrons are not electrons so should not be passing trigger cuts.

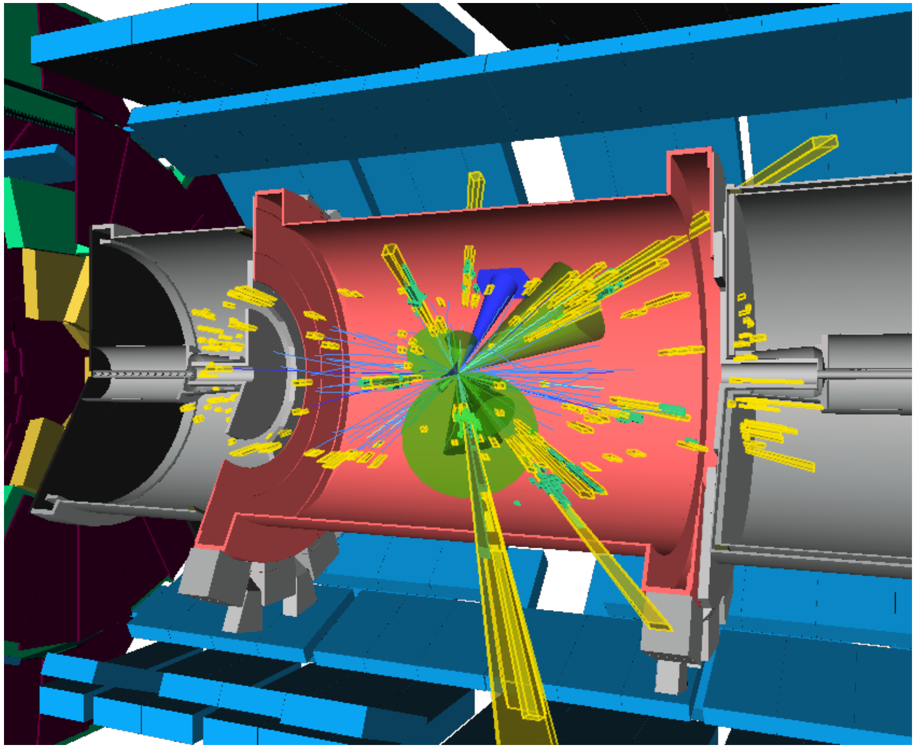
3. Event topologies, i.e nearby Jets etc.
   If an event is more jets rich, these will interfere with the isolation and identification of electrons.

Trigger efficiency in MC simulations of SUSY processes

Z→ee

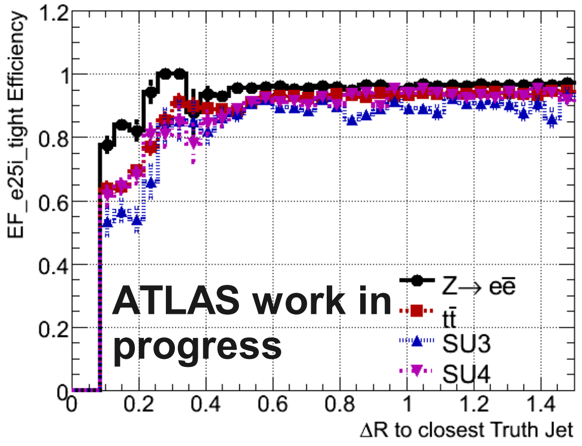


SU4



SUSY and ttbar are much 'busier' environments than Z→ee.

Proximity of energetic objects leads to a decrease in trigger efficiency.



Efficiency as a function of distance to nearest 'truth jet'.

Application of T&P measurements

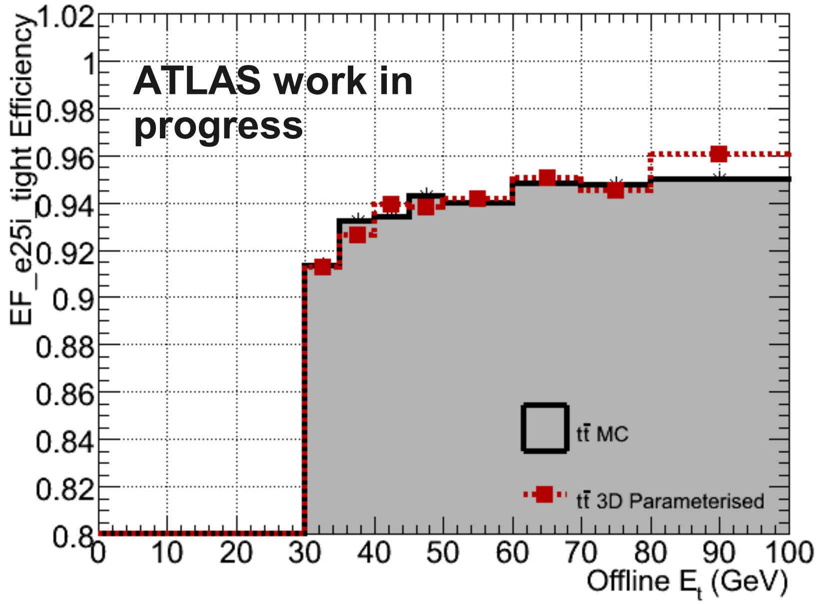
An identical electron should have the same efficiency regardless of its physics origin.

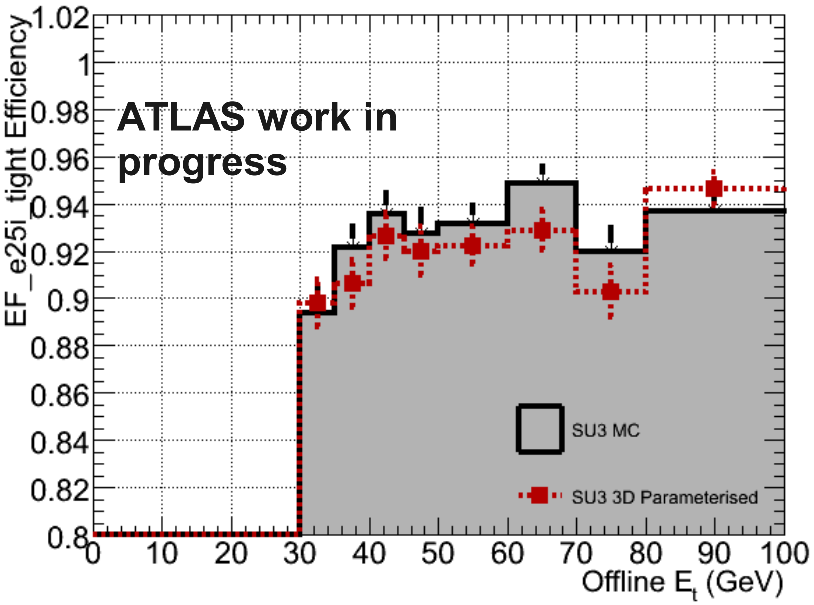
For trigger efficiencies it is sufficient to describe 'identical' electrons as having the same E_T, η, and surrounding energy.

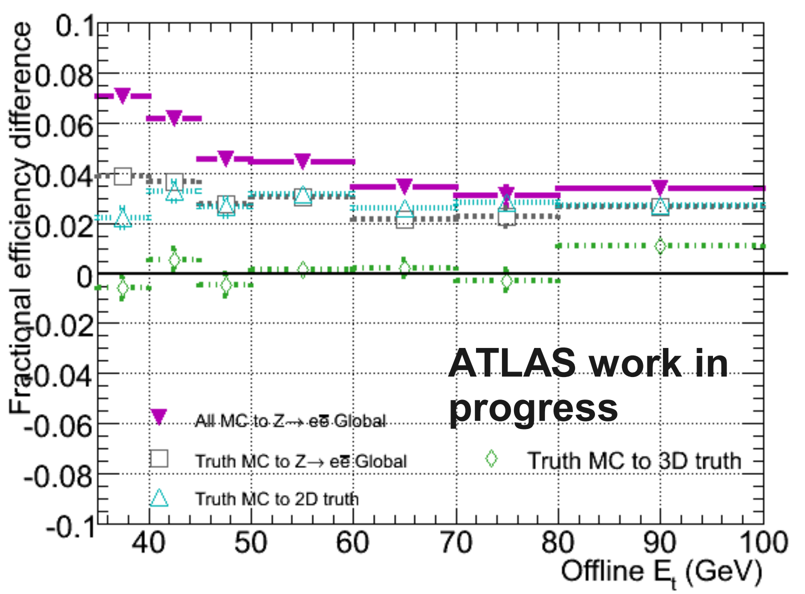
Z→ee efficiency is computed in 3-D (E_T vs η vs etcone40) then applied to other samples and compared to MC.

Agreement to within 1%!

Z→ee efficiencies are **representative of efficiency in a SUSY/top environment** if determined in 3-D.







High Mass Dielectron Resonances

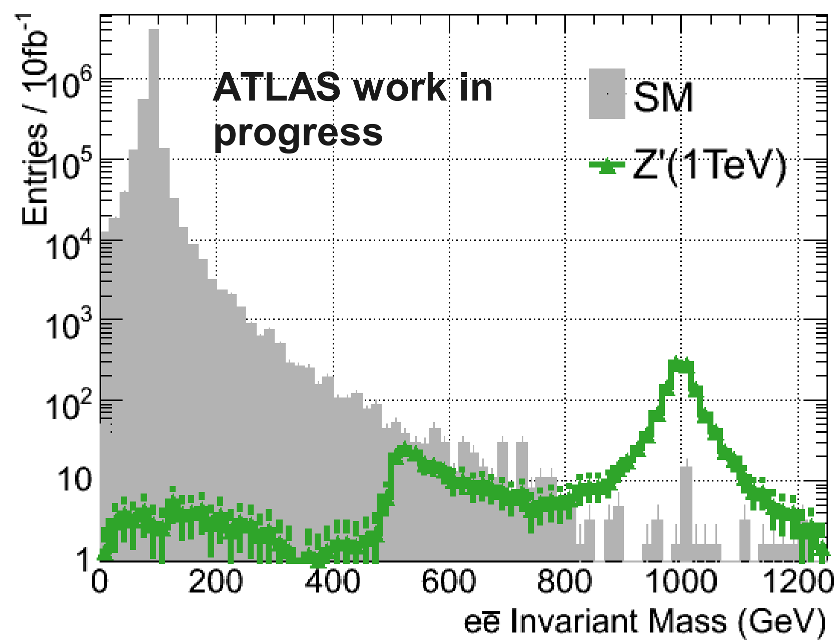
High mass dielectron resonances are predicted by several extensions to the standard model.

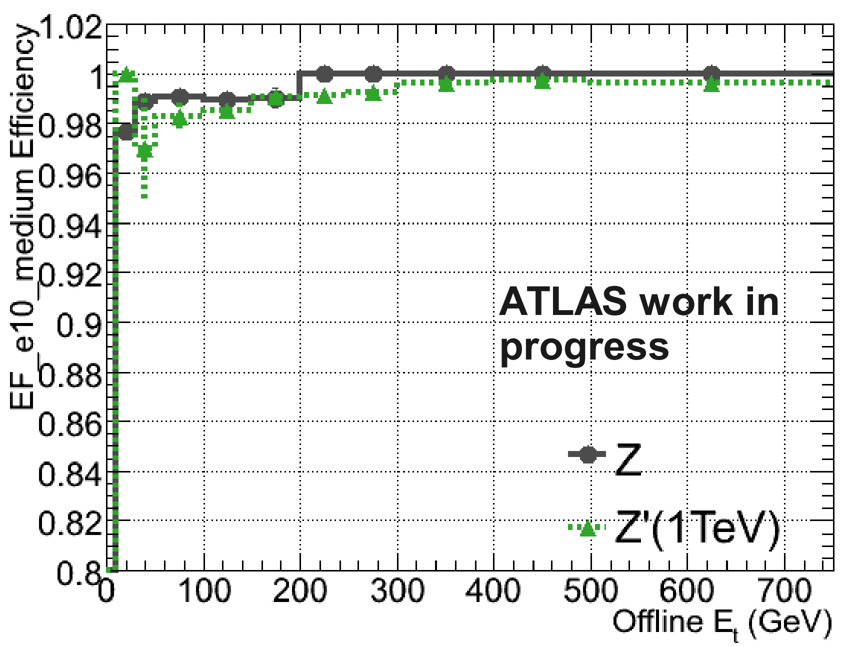
High Mass → very high energetic electrons.

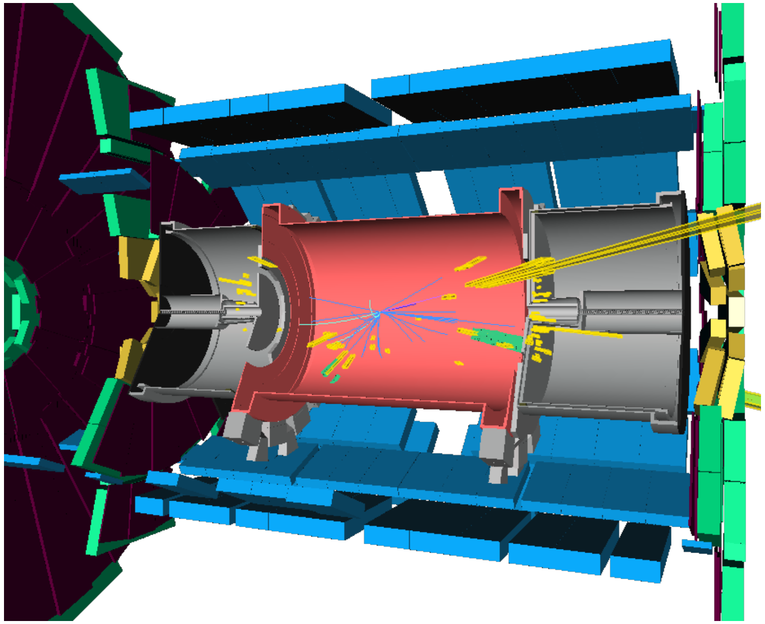
- Unsuited to isolated triggers as energetic electrons have broad showers which cause them to fail isolation cuts.

Z→ee T&P suffers from poor statistics at high energies.

Efficiency shows a flat plateau in E_T => fit plateau efficiency from low mass Z resonance and extrapolate results to high E_T.







Conclusions and Outlook

Conclusions

• Every analysis at ATLAS that utilizes electrons must have an **understanding of the electron trigger efficiency**.

- Studied extensively using MC.

• The Tag and Probe method of **trigger efficiency determination from data** has been validated using MC.

• A **3-D efficiency parameterisation produced using T&P has been shown to well reproduce MC efficiencies in other samples**.

- Therefore **validated as a sample independent method of trigger efficiency determination from data**.

• Efficiency for **highly energetic electrons**, such as those produced from Z' resonances, can be **determined by extrapolation from T&P results** providing energy dependence is flat.

Outlook

• **Other samples** and those including **pile-up** can be studied, and methods extended to **electrons offline and muon trigger/offline efficiencies**..