Leptonic trigger efficiency determination from data in a top/SUSY environment

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Introduction

- This talk will mostly deal with **electron trigger efficiency** measurement in a **top/SUSY** context with the idea of using the Tag and Probe method to extract efficiencies from the Z→ee resonance peak.

- Z→ee Monte Carlo is used and assumed to be equivalent to results that can be obtained using the data driven methods described.

- Trigger Efficiency is an important factor for any analysis and needs to be well understood.

- Want to minimize reliance on Monte Carlo. Need methods of determining efficiency from from data.
  - Tag and Probe – Widely used in CSC notes.
  - Not the only method, orthogonal triggers, bootstrap etc.

- Focus on determining EF_e25i_tight efficiency from Z→ee. (RHUL)
  - Uses Lvl 1 isolation.

- Further discussion of EF_e20_loose (10^{31}).

- **Orthogonal** triggers for **muon** trigger efficiency determination in **top** events. (NIKHEF)

Definitions and Samples (Electron section)

Efficiency = N_1 / N_2

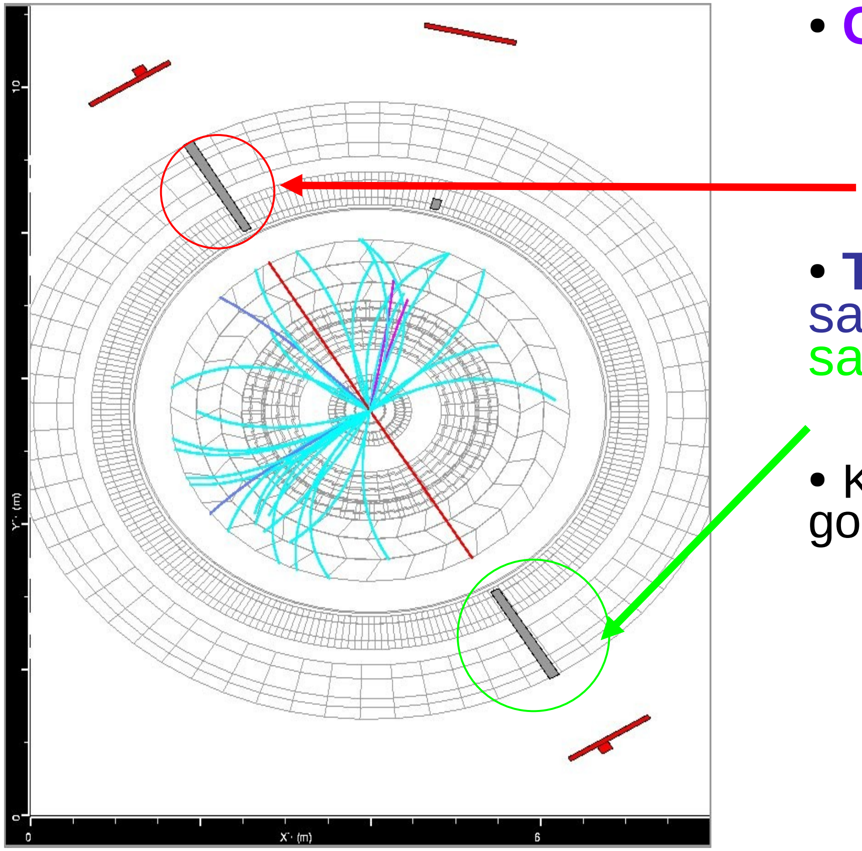
N_1 = Number of good offline reconstructed electrons associated to objects passing trigger, (using ΔR matching).
N_2 = Number of good offline reconstructed electrons.

ΔEfficiency - binomial errors relative to offline. No account of errors in offline definition.

- **SUSY CSC note electron definition**, (tighter than for typical trigger studies).
  - egamma electrons
  - IsEM medium
  - $P_t > 10$ GeV
  - $\eta < 2.5$
  - No crack (exclude $1.37 < |\eta| < 1.52$)
  - Isolation; require etcone20 < 10 GeV (< 6 GeV used in top CSC)
  - Jet Veto in cone 0.4; electron is discarded if within a jet

- **Samples, all rel 13 14TeV samples**
  - 494k **Z→ee**, σ = 1.68nb, $\int\mathscr{L}$ 294pb^{-1}
    trig1_misal1_mc12.005144.PythiaZee.recon.ESD.v13003004
  - 450k **semi-leptonic ttbar**, σ = 234pb, $\int\mathscr{L}$ 1.9fb^{-1}
    trig1_misal1_mc12.005205.AcerMCttbar.recon.ESD.v13003004
  - 98k **SU3**, σ = 18.59pb, $\int\mathscr{L}$ 5.2fb^{-1}
    trig1_misal1_csc11.005403.SU3_jimmy_susy.recon.ESD.v13003003
  - 198k **SU4**, σ = 262pb, $\int\mathscr{L}$ 755pb^{-1}
    trig1_misal1_mc12.006400.SU4_jimmy_susy.recon.AOD.v13004005

Efficiency from Data; Tag and Probe



- **Control sample** defined by:
  “Good” $Z \rightarrow ee$ reconstructed (from 2 offline e^+e^-)+ 1 e trigger signature satisfied

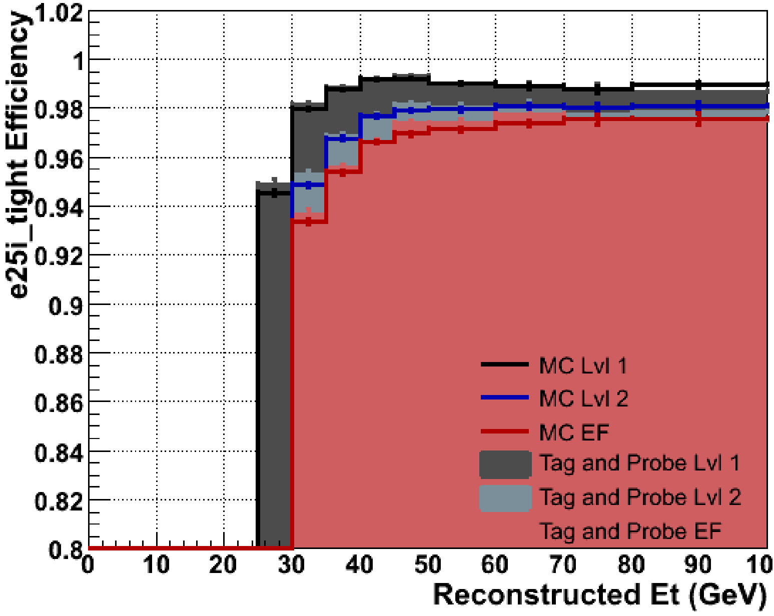
- **Trigger efficiency determined from** control sample counting in how many cases the second $e^\pm$ satisfies the trigger requirements

- Key of the T&P method is that it provides a “clean good sample of electrons”

- To determine “electron trigger efficiency” you need to identify first “a good electron” and with this you can measure the efficiency of your trigger.

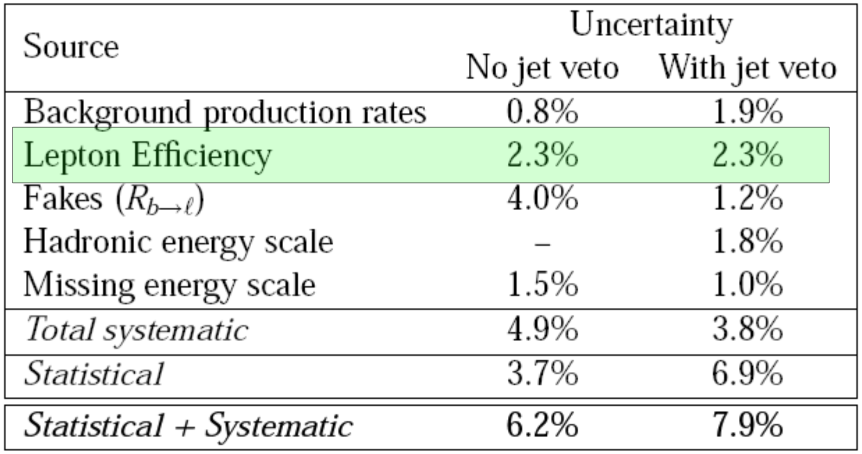
- Infrastructure set up to record Tag and Probe efficiency in N-Dimensions.
  - Matthias Schott et al.

- Alternative orthogonal trigger method discussed later.

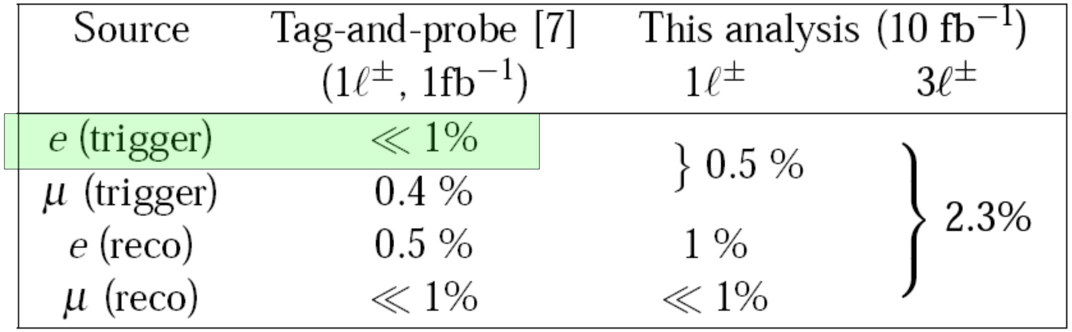


Electron trigger systematic uncertainties in CSC notes

- **SUSY** multilepton search systematics from CSC note 10fb^{-1} at 14TeV



Source	Uncertainty	
	No jet veto	With jet veto
Background production rates	0.8%	1.9%
Lepton Efficiency	2.3%	2.3%
Fakes ($R_{b\to\ell}$)	4.0%	1.2%
Hadronic energy scale	–	1.8%
Missing energy scale	1.5%	1.0%
Total systematic	4.9%	3.8%
Statistical	3.7%	6.9%
Statistical + Systematic	6.2%	7.9%

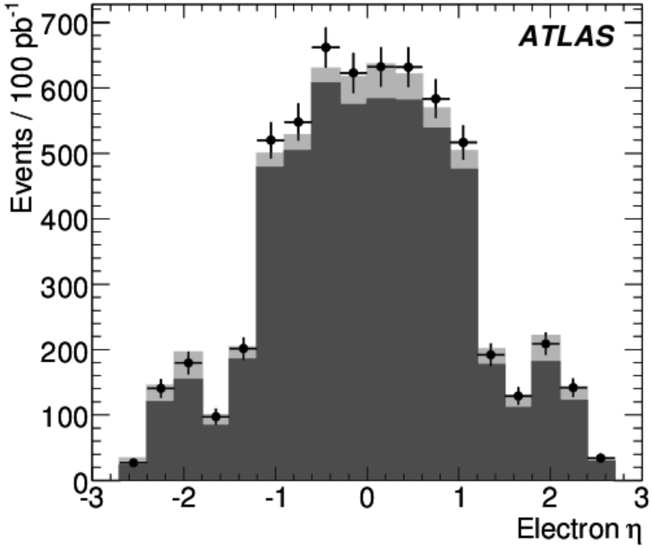


Source	Tag-and-probe [7] ($1\ell^\pm$, 1fb^{-1})	This analysis (10 fb^{-1}) $1\ell^\pm$	$3\ell^\pm$
e (trigger)	$\ll 1\%$	} 0.5 %	2.3%
μ (trigger)	0.4 %		
e (reco)	0.5 %	1 %	
μ (reco)	$\ll 1\%$	$\ll 1\%$	

- Uncertainties scaled from EW boson cross section measurement CSC note.
  - Uses tag and probe to determine the **Global trigger efficiency** (0D) ie not differential in P_t and η.

- **Top** uses more sophisticated differential efficiency correction in P_t and η (2D).

- Systematics O(1%) from 100pb^{-1} Tag and Probe data.



Gray histogram: η with no trigger
Black histogram: η after trigger.
Points: η after trigger with 2D T&P corrections

Trigger efficiency

- Main factors that can effect trigger efficiency;
  1. Electron kinematics.
  2. Fakes.
  3. Event topologies, i.e nearby Jets etc.

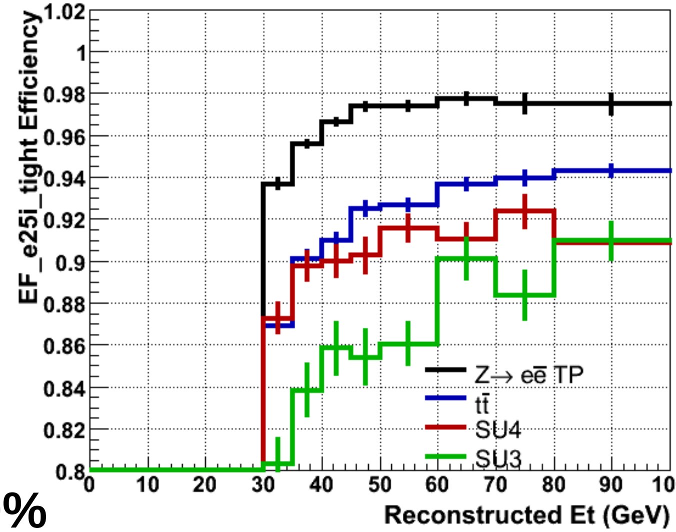
1. Trigger efficiency differs over the η spectrum. If different samples have different η distributions then the trigger efficiency integrated over this will show differences.

2. Fakes are not electrons so should not be passing trigger cuts.

3. If an event has more jets, these will interfere with the isolation and identification of electrons.

- Trigger efficiency for all 'good' offline electrons

Sample	Efficiency	error
Z→ee TP	97.07	0.07
ttbar	92.87	0.10
SU3	87.69	0.36
SU4	90.60	0.25



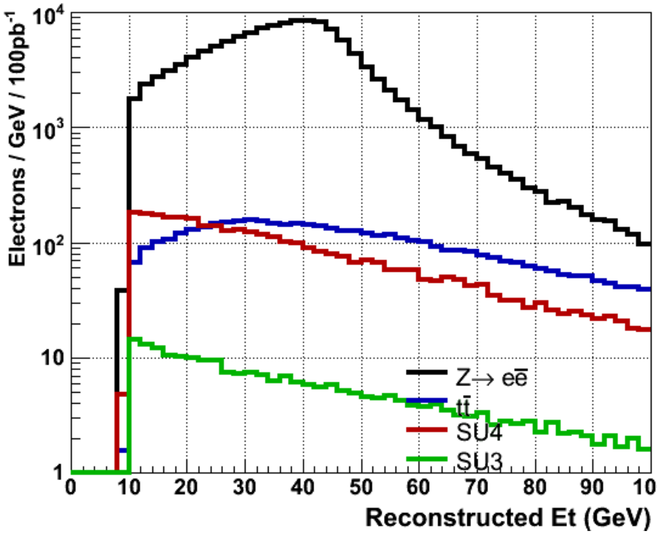
- **Systematic differences between samples of up to 10%**
  - If this efficiency is determined as in SUSY note it will be not be representative of the efficiency in SUSY events.

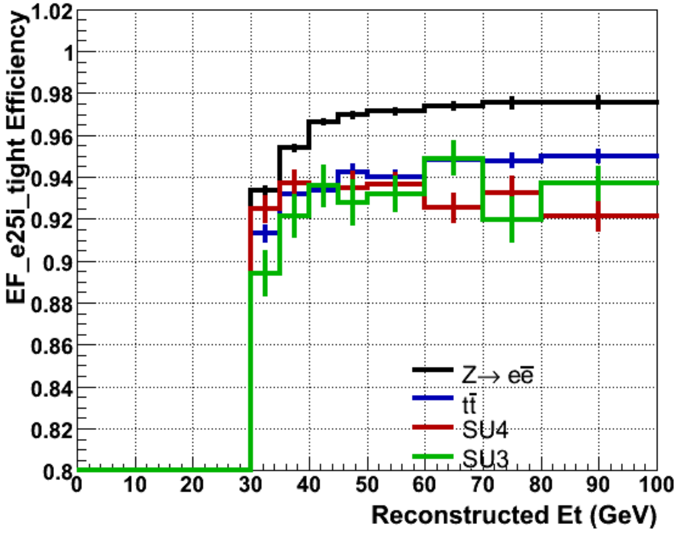
Truth matched EF_e25i_tight Efficiencies

- **Truth Matched** electrons
  - Used from now on.
  - Fakes not considered.

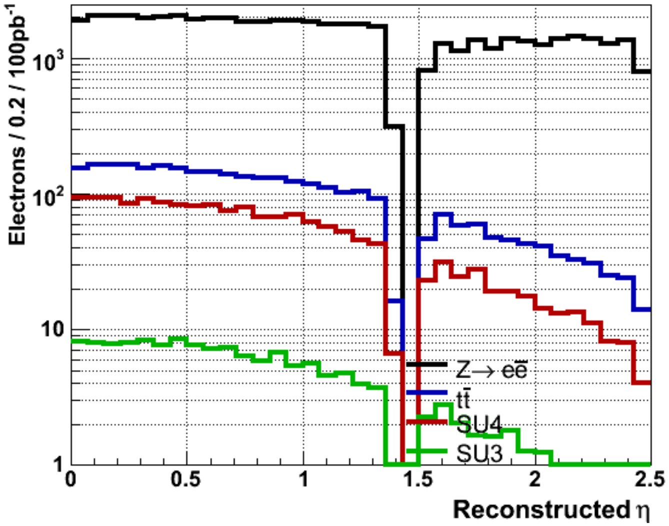
- Plateau Efficiencies
  - $E_t > 40$ GeV

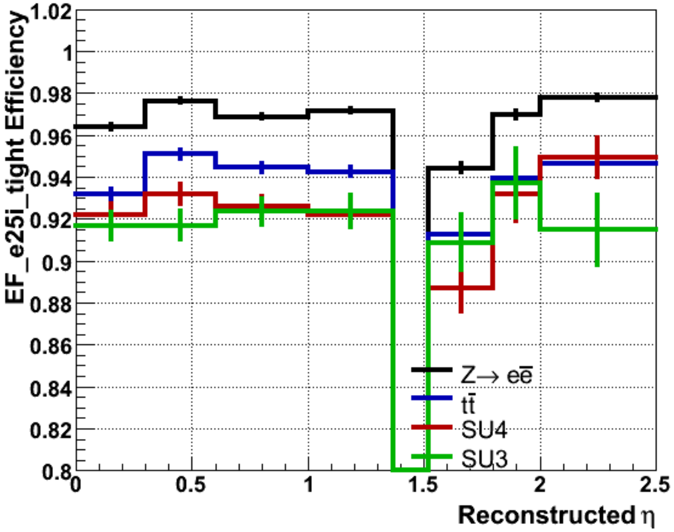
Sample	Efficiency	error
Z→ee	96.91	0.04
ttbar	94.02	0.09
SU3	92.43	0.23
SU4	91.95	0.31





- Errors from Full MC stats





1D and Global efficiencies in Z→ee samples are not the same as SUSY or ttbar samples

Differences up to 5%

2D Efficiencies E_t vs η

- Take Z→ee MC, work out 2D (E_t vs η) efficiency then apply to sample and compare to MC.
  - Parameterisation made from all Z→ee MC data. Done from T&P with real data.
  - Plateau Efficiencies ($40 < E_t < 100$ GeV) -upper cut introduced.

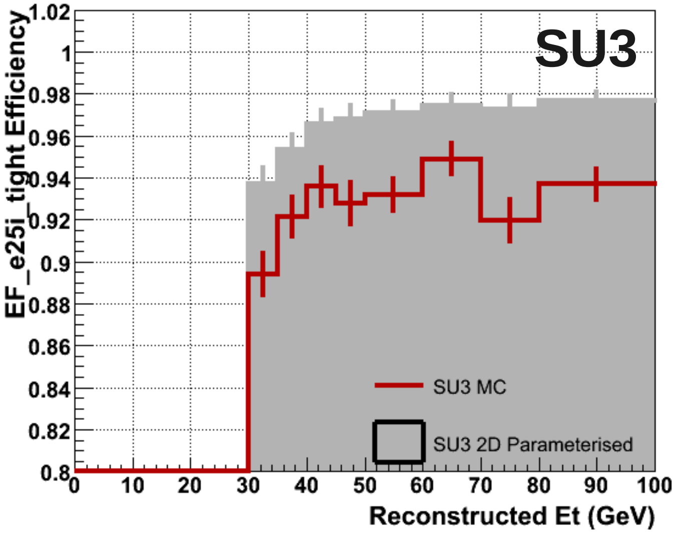
Sample	Monte Carlo	error	2D parameterised	error
Z→ee	96.94	0.04		
ttbar	94.39	0.10	97.19	0.07
SU3	93.40	0.34	97.18	0.23
SU4	93.11	0.25	97.15	0.16

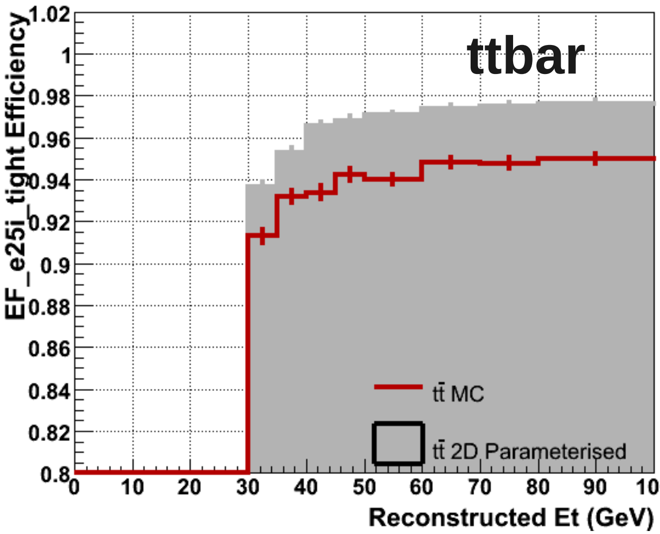
Parameterised Red

MC Gray

Differences up to 4%

2D efficiencies in Z → ee samples are not the same as SUSY or ttbar samples





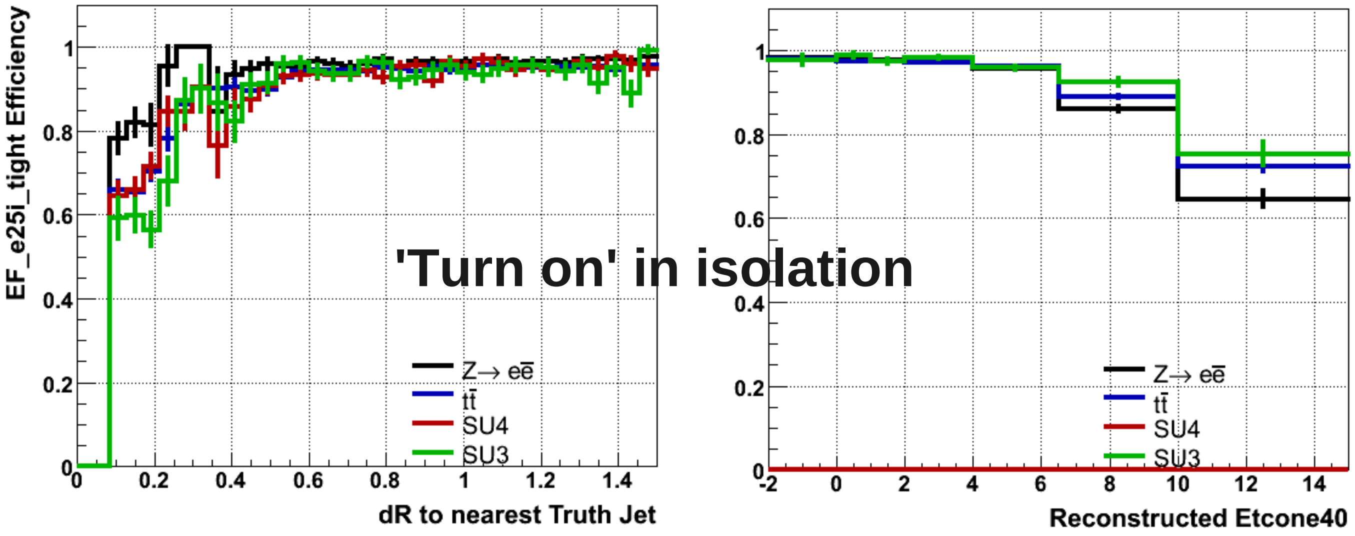
- Errors on parameterised curves should be larger to account for errors on parameterisations.

Efficiency as a function of other variables

- E_t and η are not the only variables that effect trigger efficiency.

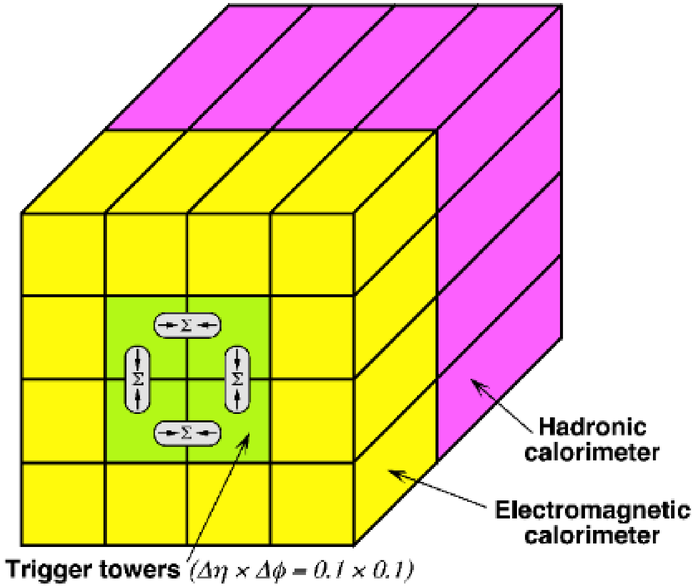
- Can get better agreement by requiring tighter isolation.

- Efficiency vs Isolation;
  - Etcone40
  - ΔR to Truth Jets



'Turn on' in isolation

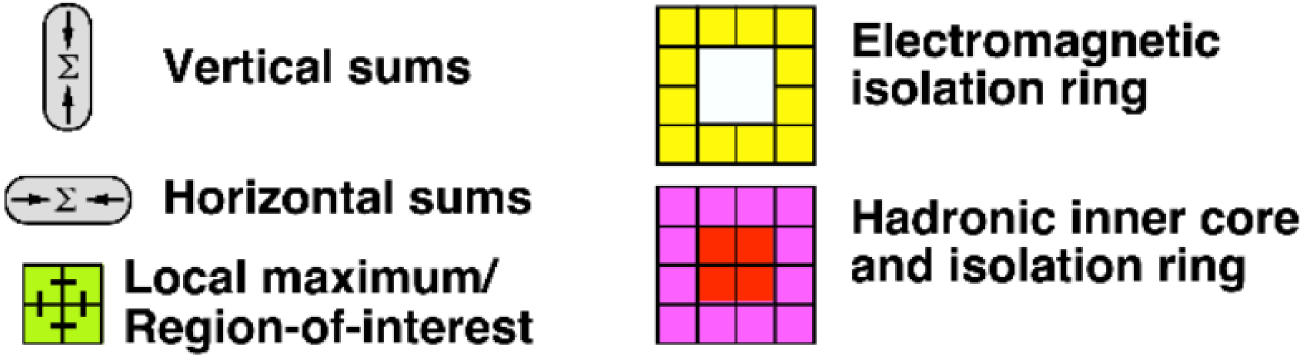
- etcone40; energy in a cone (hollow in EM cal) of ΔR 0.4



Isolation as applied at Lvl 1

EM ring $\leq$ 4 GeV
Had core $\leq$ 2 GeV
Had ring $\leq$ 3 GeV

etcone40 is similar to these.



3D Parameterised Efficiencies E_t vs η vs Etcone40

- Take Z→ee MC, work out 3D (E_t vs η vs Etcone40) efficiency then compare to Monte Carlo.
  - Parameterisation made from all Z→ee MC data
  - Plateau Efficiencies ($40 < E_t < 100$ GeV)

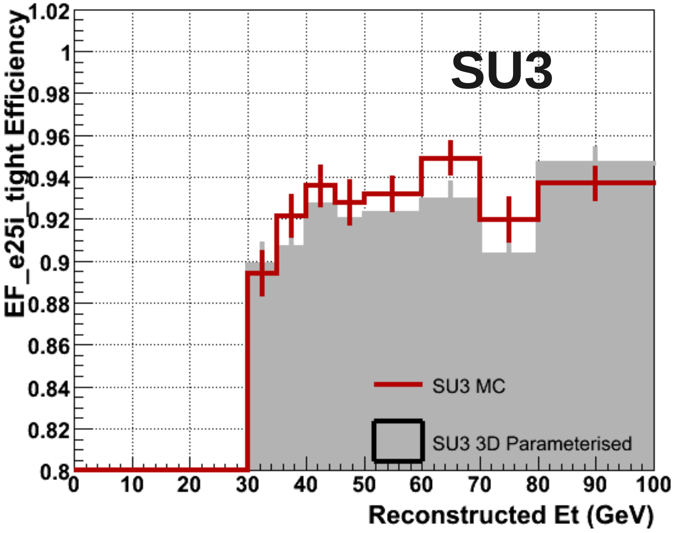
Sample	Monte Carlo	error	3D parameterised	error
Z→ee	96.94	0.04		
ttbar	94.39	0.10	94.64	0.10
SU3	93.40	0.34	92.59	0.36

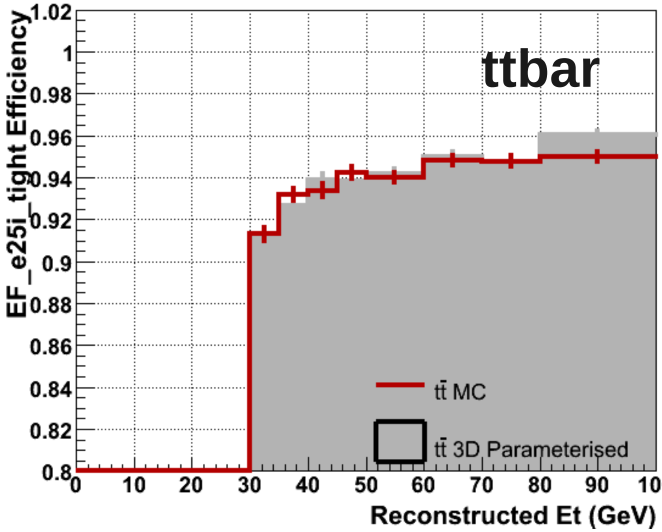
Parameterised Red

MC Gray

Differences < 1%

To determine electron trigger efficiency to <1% then we need to parameterise in 3D.



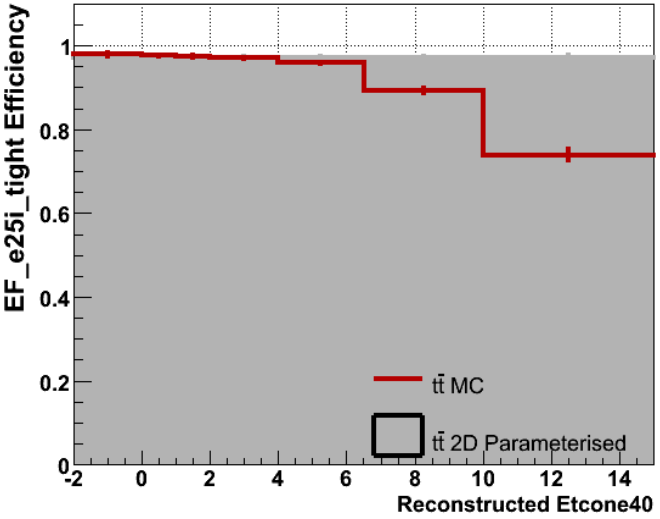


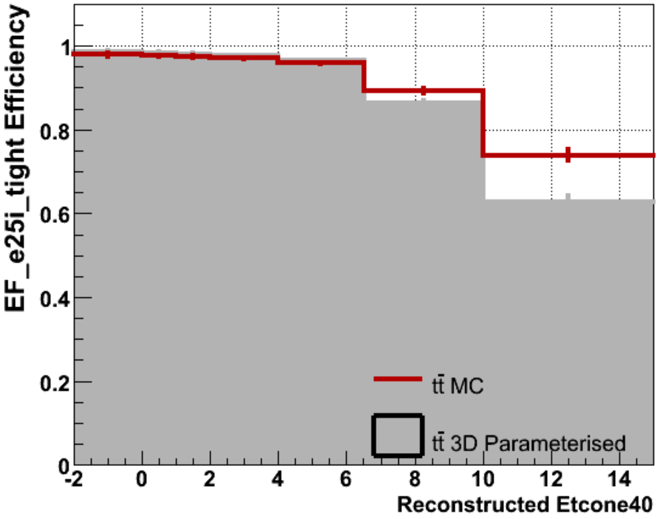
- Errors on parameterised curves should be larger to account for errors on parameterisations.

Other variables after parameterisation

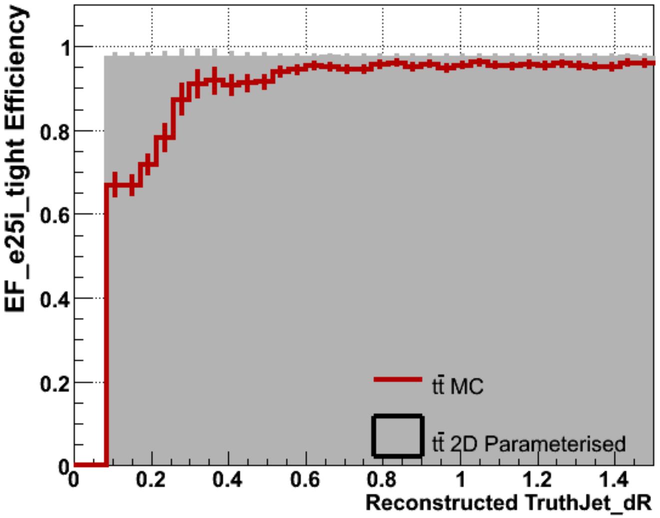
2D ttbar

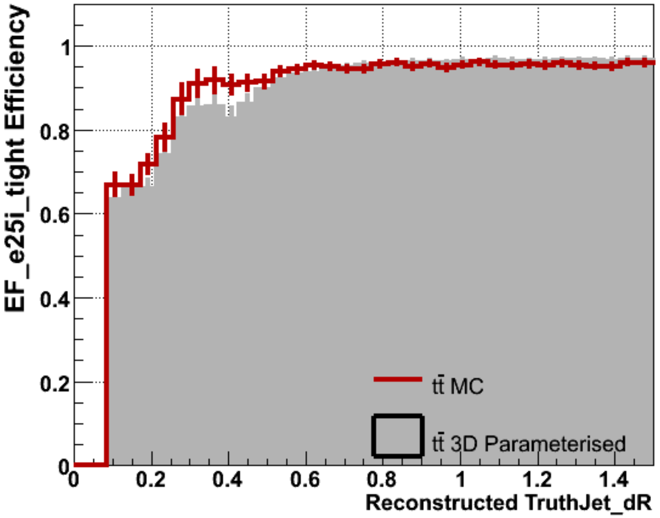
3D ttbar





Etcone40

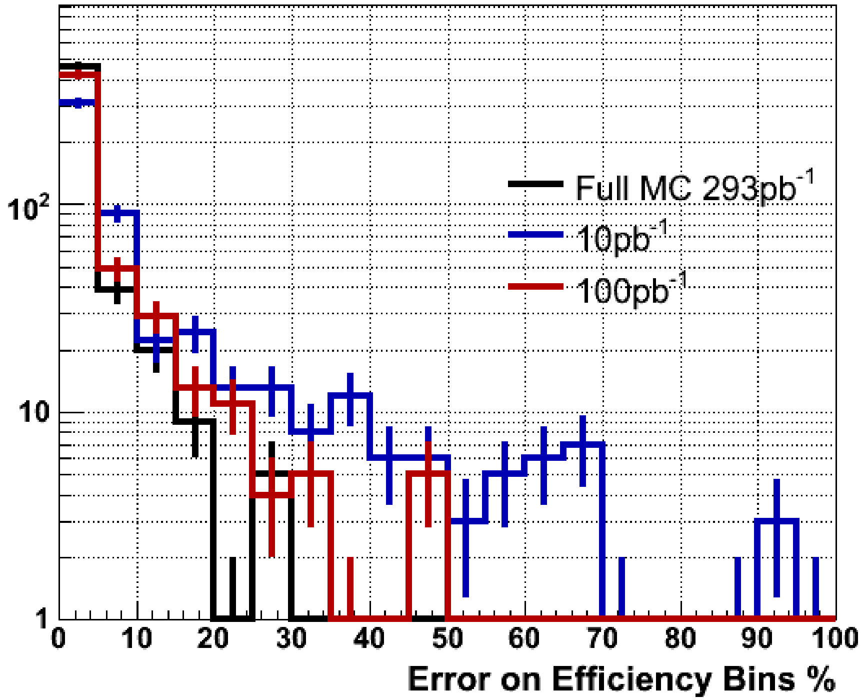




ΔR to nearest Truth Jet

3D efficiency Matrix errors

p_t (GeV) = [0, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 100]
$|\eta|$ = [0, 0.3, 0.6, 1.0, 1.37, 1.52, 1.8, 2.0, 2.5]
etcone40 (GeV) = [-2, 0, 1, 2, 4, 6.5, 10, 15] **616 bins**



- In 3D **Errors can be very high**, especially at high values of Etcone.
  - Requires high statistics.

- When using tag and probe expect loss of statistics.

- For **first data may need to check for obvious 1% effects**.
  - Acceptable to factorize our 3D matrix into a lower dimensionality?

- Target efficiency, and hence sophistication of parameterisation needed, is analysis dependent.

- Consider what makes signal sample different from control sample used to determine efficiency.

3 * 1D Parameterised Efficiencies E_t, η and Etcone40

- Apply E_t efficiency, then η, then etcone40.
  - Reduces binning, therefore reduces error per bin.
  - Doesn't account for correlations between variables

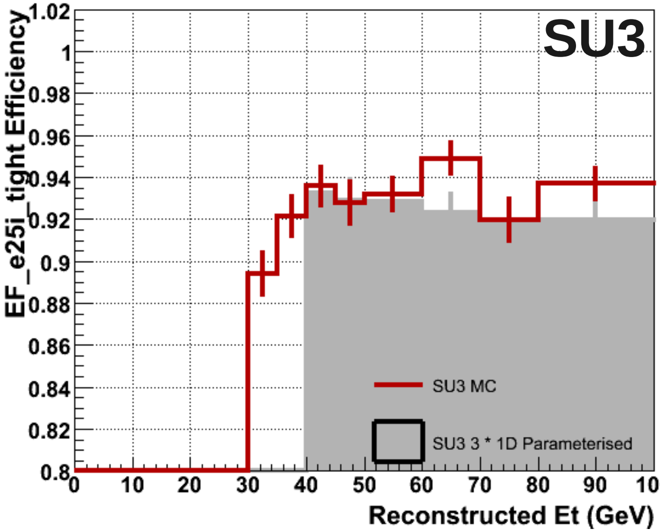
$$\mathbf{Eff(E_t,\eta,etcone40) = (Eff(E_t) * Eff(\eta) * Eff(etcone40)) / ((\int Eff)^2)}$$

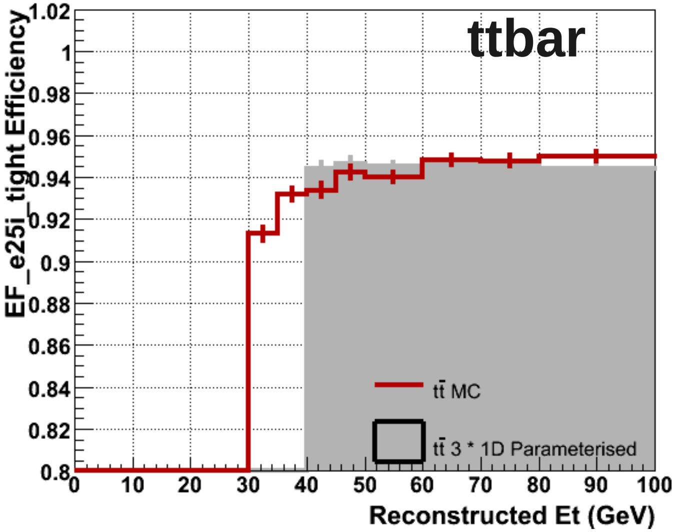
Sample	Monte Carlo	error	3*1D parameterised	error
Z → ee	96.94	0.04		
ttbar	94.39	0.10	94.52	0.10
SU3	93.40	0.34	92.49	0.36

Parameterised Red

MC Gray

- **Differences O(%)**
- Same O() of agreement as 3D.
- **Preliminary**; Systematics need study.





Ttbar Parameterised Efficiencies Summary

- Comparison of efficiency parameterisations (Ratio to Monte Carlo efficiencies).

Black Zee global on All 'good' electrons.

Red Zee global on truth matched 'good' electrons.

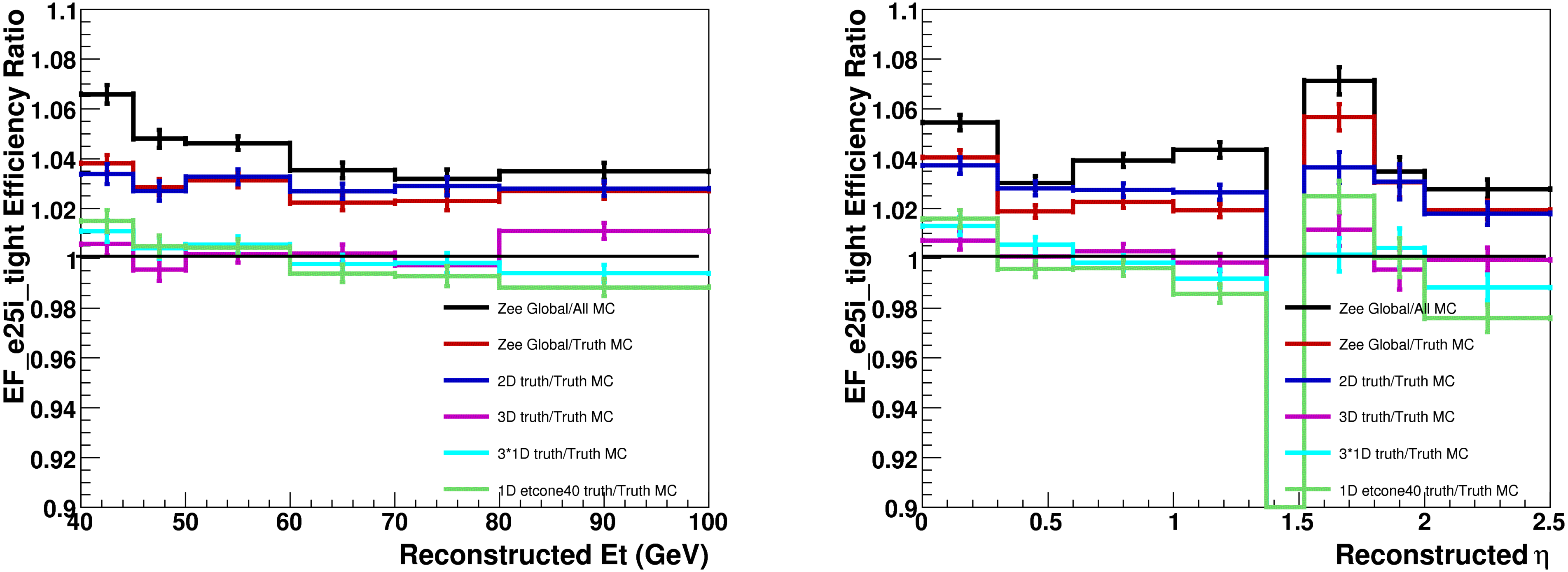
Dark blue 2D Zee on truth.

Purple 3D Zee on truth.

Light blue 3*1D Zee on truth.

Green Zee etcone40 only on truth.

ttbar

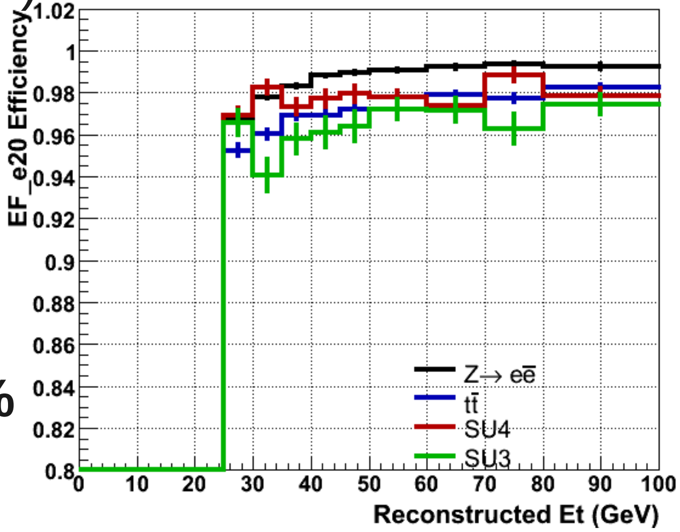


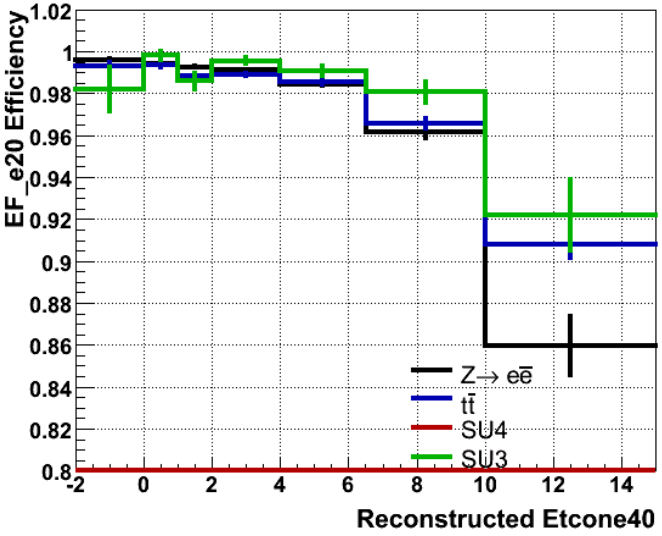
Early running (10^{31}) EF_e20 Efficiencies (EF_e20_loose in 14)

Monte Carlo (< 100 GeV)

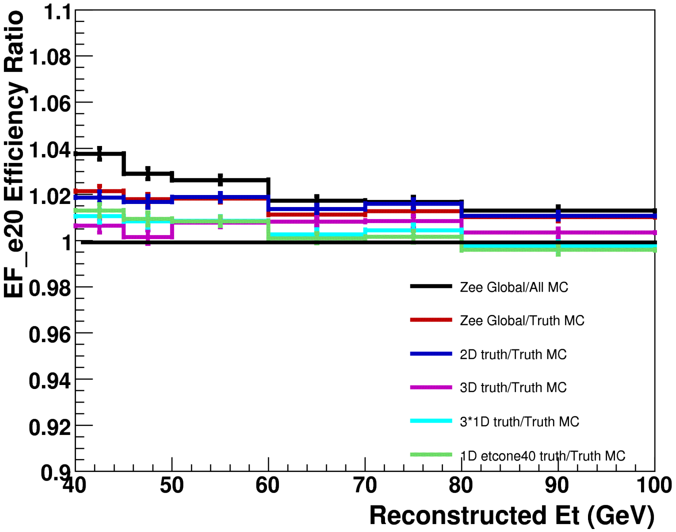
Sample	Efficiency	error
Z → ee	98.97	0.03
ttbar	97.56	0.07
SU3	96.85	0.24
SU4	97.87	0.14

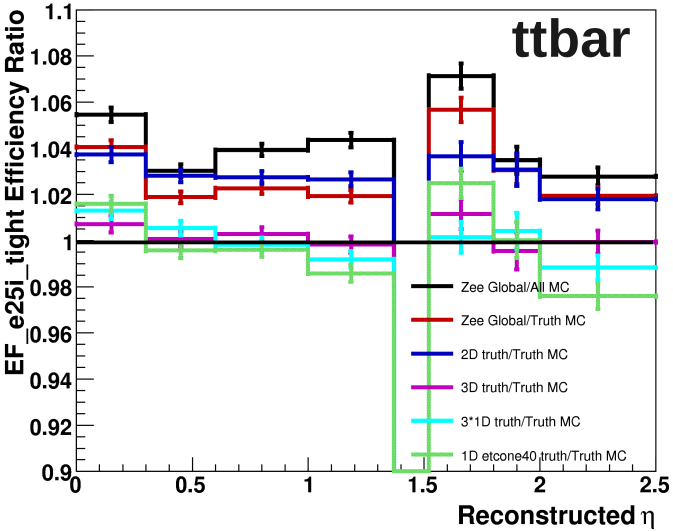
- Global and 1D efficiencies show **1 → 2% differences**





- Much less difference than seen for e25i_tight as e20 doesn't use Lvl1 isolation.





3*1D parameterised

Sample	Efficiency	error
ttbar	98.08	0.06
SU3	97.36	0.22

Differences ~0.5%

Orthogonal triggers in ttbar

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Use trigger X to determine efficiency of orthogonal trigger Y

Select events based on trigger X

$$\mathrm{Eff}_X .(S + B)$$

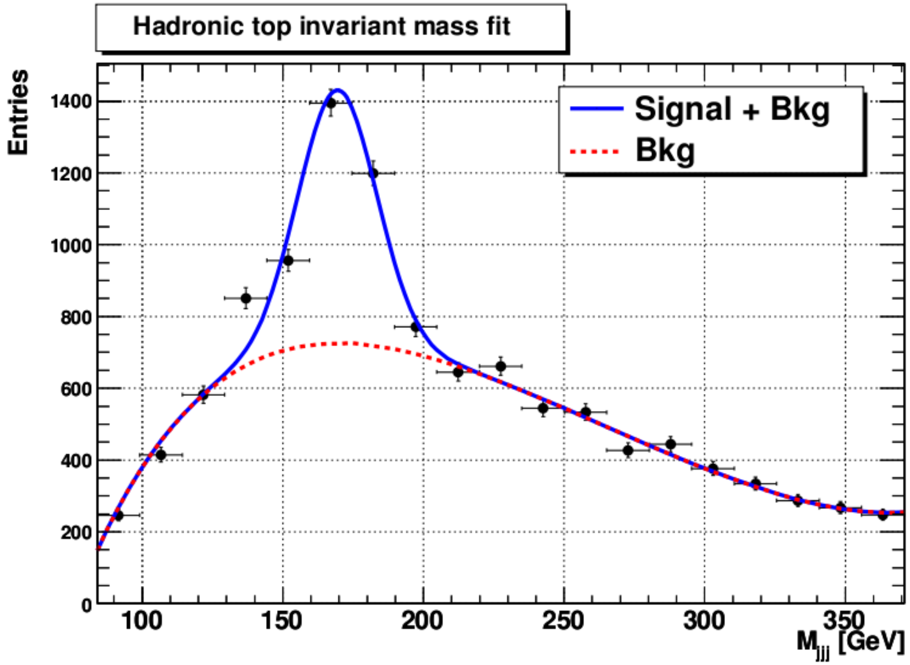
Apply selection cuts for a ttbar final state – Reconstruct top & fit.

$$\mathrm{Eff}_{s\&r}.\ \mathrm{Eff}_X.(S+B) == S_A$$

Then request trigger Y to have fired

$$\mathrm{Eff}_Y.\mathrm{Eff}_{s\&r}.\ \mathrm{Eff}_X.(S+B) == S_B$$

$$\mathrm{Eff}_Y = S_B\ /\ S_A$$



Goals

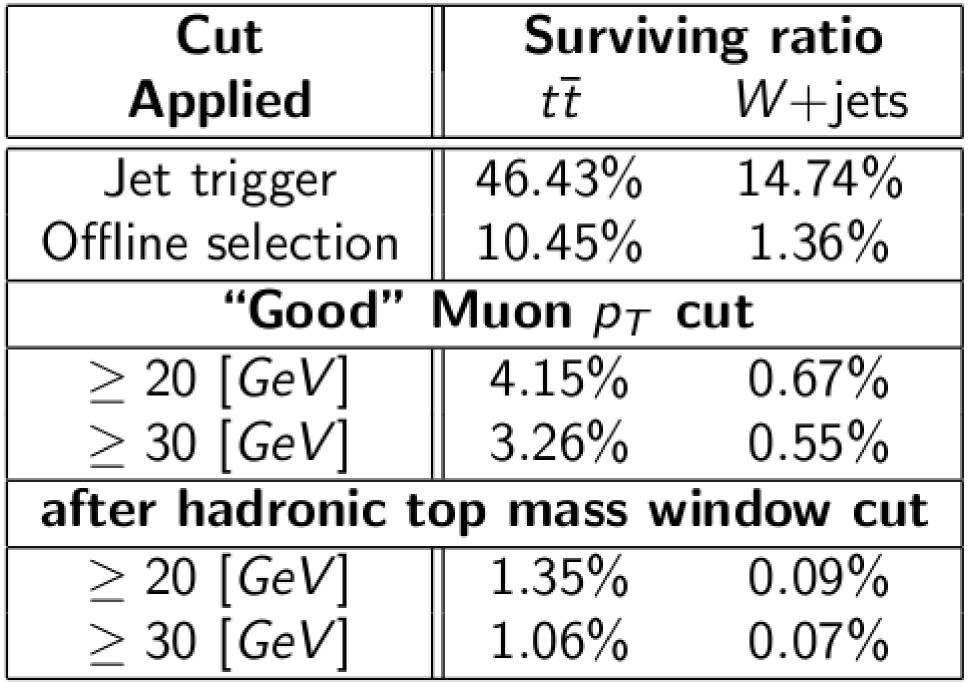
- Study feasibility for different luminosities, biases & correlations.
- Compare to other data-driven methods.

Prelimenary results for Muon triggers ($1fb^{-1}$)

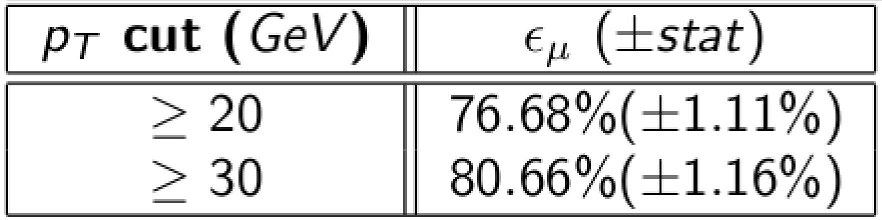
Ttbar signal 225k events.
W+jets background 728k events.

NIKHEF
DESY

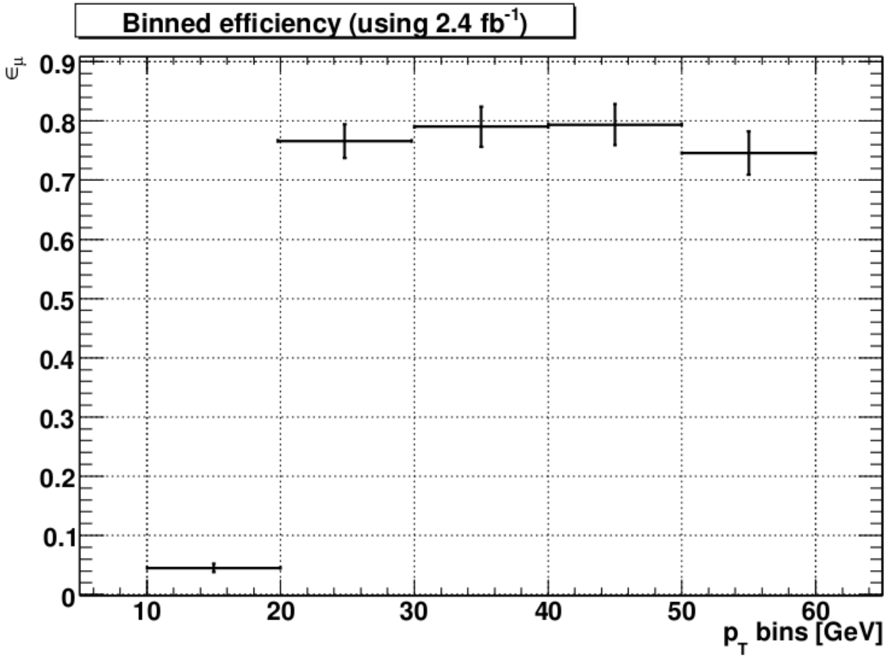
Use **Jet trigger (X) EF_4J95** to determine efficiency of **Muon trigger (Y) EF_mu20.**



Cut Applied	Surviving ratio $t\bar{t}$	Surviving ratio W+jets
Jet trigger	46.43%	14.74%
Offline selection	10.45%	1.36%
"Good" Muon p_T cut		
$\geq$ 20 [GeV]	4.15%	0.67%
$\geq$ 30 [GeV]	3.26%	0.55%
after hadronic top mass window cut		
$\geq$ 20 [GeV]	1.35%	0.09%
$\geq$ 30 [GeV]	1.06%	0.07%



p_T cut (GeV)	ϵ_μ ($\pm stat$)
$\geq$ 20	76.68%($\pm$1.11%)
$\geq$ 30	80.66%($\pm$1.16%)



Binned efficiency for $2.4fb^{-1}$.

Also plans to use lepton to determine Jet efficiency (DESY).

Summary and Conclusions

Tag and Probe with Electrons

- Global and 1D trigger efficiency is not the same in Z→ee and top/SUSY events O(5%).

- Parameterising kinematics and isolation determines trigger efficiency to within 1%.
  - Can be done in 3D or in the case of low statistics 1D or 3*1D (Work ongoing).

- Triggers with no Lvl 1 isolation show smaller deviations in global efficiency between Z→ee and top/SUSY events (O(1→2%)).
  - Efficiency can be determined to within 1→2% by 2D parameterisation or to within 1% using the 3D.

- Binning and complexity of parameterisation used must depend on target accuracy for given luminosities.

Orthogonal triggers with Muons

- Feasibility of orthogonal trigger method demonstrated.
  - Determines trigger efficiency in a top environment.
  - Requires large statistics.
  - Any advantage over Z/Z + jets?