First look at real efficiency with Rel21 samples in SUSY SS/3Lep analysis

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Overview

- Real efficiency: probability for a real/isolated lepton to satisfy the signal lept requirements

→ Input parameter for the matrix method used to measure the fake lepton (e, μ) background

- In the past the efficiencies were measured in data, in a $Z \to \ell\ell$ enriched sample with the Tag&Probe method
  - → Had to subtract the background in the $p_T < 20$ GeV region
  - → Had to estimate correctly the uncertainties associated to the bkg subtraction
  - → Etc. etc. etc
    - All of this already done (and in a more accurately!) in the Egamma and Muon CP gr
    - For this round of the analysis propose to follow the CP groups recommendations (Egamma and Muon twikis)

- Results obtained using AB21p2p35 ntuples (see SS/3Lep twiki for more details)

→ Not using the framework proposed in the IFF group as guidance to PA groups as it's not ready yet to obtain the truth real efficiency and all the needed SFs (nom + uncertainties)

→ However, the CP groups recommendations for the measurement are considered!

Real efficiency (ε_R) measurement

$\varepsilon_R = \frac{N(\text{Pass})}{N(\text{Trial})}$

→ N(Pass) → number of leptons passing the signal definition (tight level)

→ N(Trial) → number of leptons passing + failing the signal definition (loose level)

	Pre-selected Electron	**Pre-selected Muon**
Acceptance	$p_T > 10$ GeV, $\lvert\eta^{\text{clust}}\rvert < 2.47$ except $1.37 < \lvert\eta^{\text{clust}}\rvert < 1.52$	$p_T > 10$ GeV, $\lvert\eta\rvert < 2.5$
Quality	`LooseAndBLayerLLH`	`xAOD::Muon::Medium`
ℓ-jet Isolation	Applied, see SS/3Lep twiki	
Impact parameter	$\lvert d_0/\sigma(d_0)\rvert < 5.0$ $\lvert z_0 \cdot \sin(\theta)\rvert$ <0.5 mm	- $\lvert z_0 \cdot \sin(\theta)\rvert$ <0.5 mm
	Signal Electron	**Signal Muon**
Quality	`MediumLLH` $\lvert\eta\rvert < 2.0$ ElectronChargeIDSelector tool, Rel20.7, 97% OP	- - -
Isolation	"FixedCutTight "	"FixedCutTightTrackOnly"
Impact parameter	-	$\lvert d_0/\sigma(d_0)\rvert < 3.0$

Real efficiency (ε_R) measurement

$\varepsilon_R = \frac{N(\text{Tight})}{N(\text{Loose})}$; $\text{SF} = \frac{\varepsilon_R^{\text{Data}}}{\varepsilon_R^{\text{MC}}}$

- $\varepsilon_R^{\text{Data}} = \varepsilon_R^{\text{MC,Truth}} \times \frac{SF(\text{Tight})}{SF(\text{Loose})}$, using the truth ℓ classification as discussed in IFF gr (twiki)
- To compute the systematic uncertainty, we just take the UP variation:
  - ε_R, syst = fabs($\varepsilon_R^{\text{Data}}$ - $\varepsilon_R^{\text{Data,UP}}$), where $\varepsilon_R^{\text{Data,UP}} = \varepsilon_R^{\text{MC,Truth}} \times \frac{SF^{\text{UP}}(\text{Tight})}{SF^{\text{UP}}(\text{Loose})}$
- SF(Tight): Reco, ID and ISO SFs

→ UP uncertainty for tight electrons:

- EL_EFF_Reco_TOTAL_1NPCOR_PLUS_UNCOR__1up, EL_EFF_ID_TOTAL_1NPCOR_PLUS_UNCOR__1up, EL_EFF_Iso_TOTAL_1NPCOR_PLUS_UNCOR__1up

→ UP uncertainty for tight muons (link):

- MUON_EFF_RECO_STAT/SYST__1up, MUON_EFF_RECO_STAT/SYST_LOWPT__1up
- MUON_EFF_ISO_STAT/SYST__1up

- SF(Loose): Reco and ID SFs

→ UP uncertainty for loose electrons:

- EL_EFF_Reco_TOTAL_1NPCOR_PLUS_UNCOR__1up, EL_EFF_ID_TOTAL_1NPCOR_PLUS_UNCOR__1up (not yet included)

→ UP uncertainty for loose muons (link):

- MUON_EFF_RECO_STAT/SYST__1up, MUON_EFF_RECO_STAT/SYST_LOWPT__1up

→ Total norm factor: x-section, MC generator and pile-up weights, and lepton SFs

→ No e.g TTVA unc for muons as it will enter both at nume and deno and cancel out

Methodology

To validate the new implementation, compare different measurements

LHS New, using MC truth efficiency & Egamma/Muon CP groups SFs

$\longrightarrow$ No triggers are applied

Mid MC efficiency measured in $Z \to \ell\ell$ MC simulations with Tag&Probe method

RHS Data efficiency measured with 2015→2017 data using the Tag&Probe method

→ Lowest unprescaled single lepton triggers (twiki): data-taking period and trigger list

- 2015: HLT_e24_lhmedium_L1EM20VH, HLT_mu20_iloose_L1MU15
- 2016: HLT_e24_lhtight_nod0_ivarloose, HLT_e24_lhmedium_nod0_L1EM20VH, HLT_e26_lhtight_nod0_ivarloose, HLT_mu24_ivarloose, HLT_mu24_ivarmedium and HLT_mu26_ivarmedium
- 2017: HLT_mu26_ivarmedium || HLT_e26_lhtight_nod0_ivarloose

→ Only SFOS tag and probe pairs in the [80,100] GeV mass window for the nominal measurement and [60,80] and [100,120] GeV for the background subtraction

→ Tag lepton should satisfy the signal requirements, have $p_T > 27$ GeV and satisfy the `tight` ID requirement

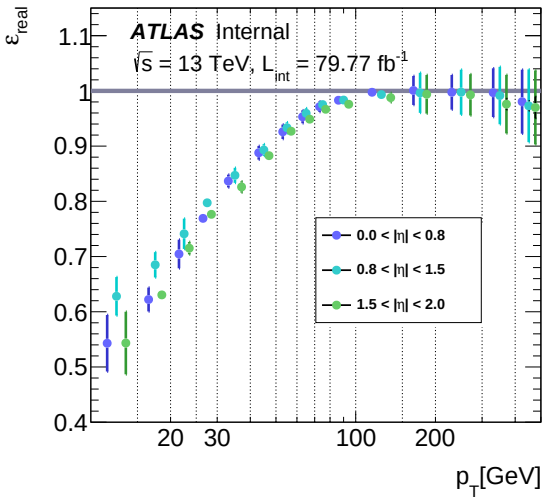
→ Probe lepton: check if passes or not the signal requirements

→ Background subtraction applied, using the "side-band" method (and not the template-based one used in e.g the Egamma group)

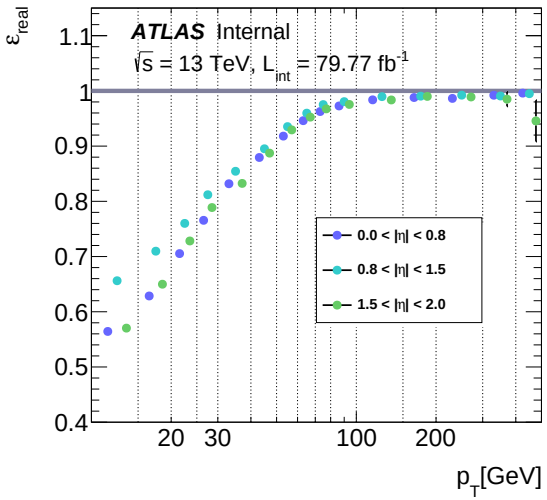
Validation, electrons

Real electron efficiency measured in a sample enriched in $Z \to ee$ events

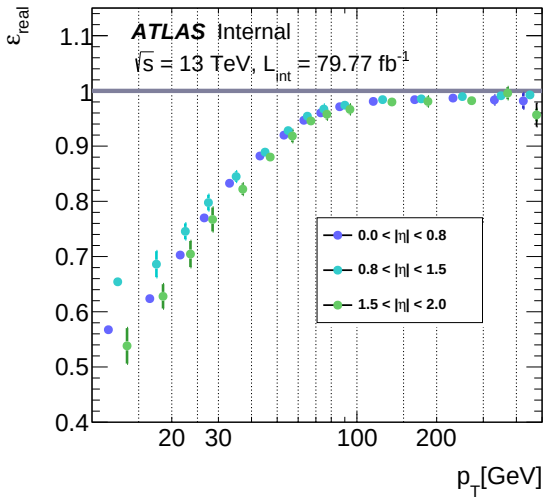
- Stat uncertainties: black line; Syst uncertainties: colored line



MC truth $\times$SFs, Z



MC T&P, Z



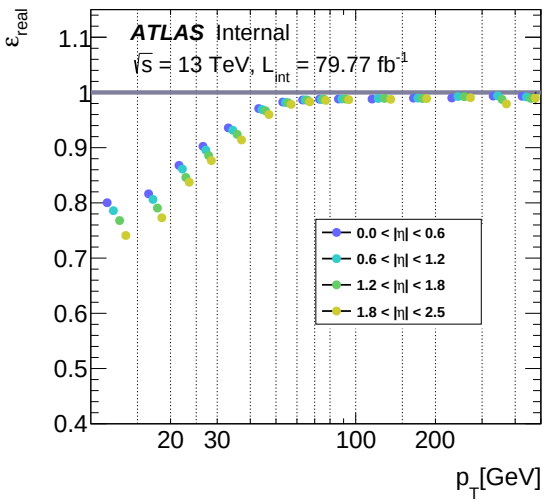
Data T&P, Z

- Data vs. MC truth $\times$SFs, Z: 4% difference if p_T <15 GeV otherwise below 1% (in some bins 2%)
- MC truth $\times$SFs vs. MC T&P, Z: most of the time diff around 1% (in few bins also $\sim$2%)
- MC truth $\times$SFs: higher uncertainties in the low p_T region (expected, as the unc on the electron ID SFs are quite high below 20-30 GeV given the differences between Z-mass and Z-iso methods)

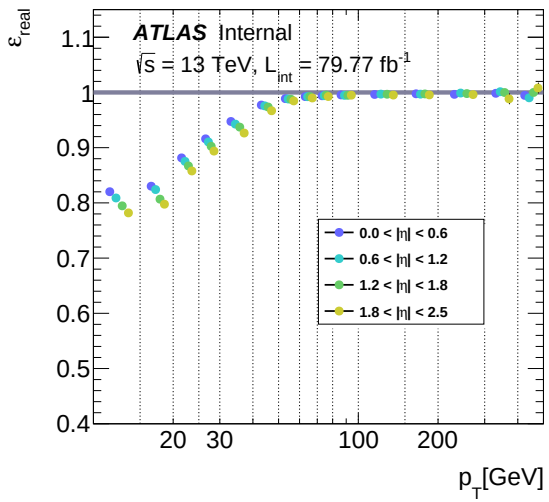
Validation, muons

Real muon efficiency measured in a sample enriched in $Z \to \mu\mu$ events

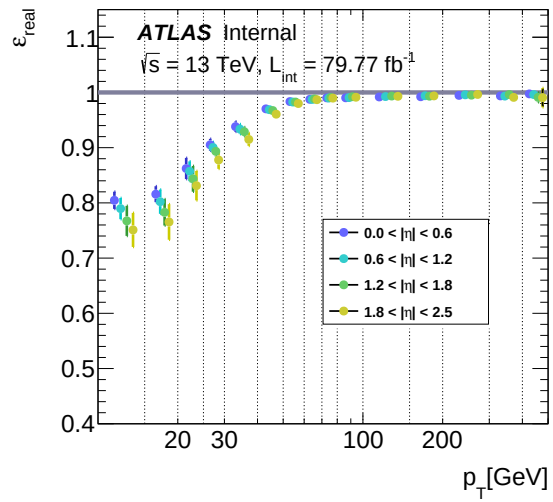
- Stat uncertainties: black line; Syst uncertainties: colored line



MC truth $\times$SFs, Z



MC T&P, Z



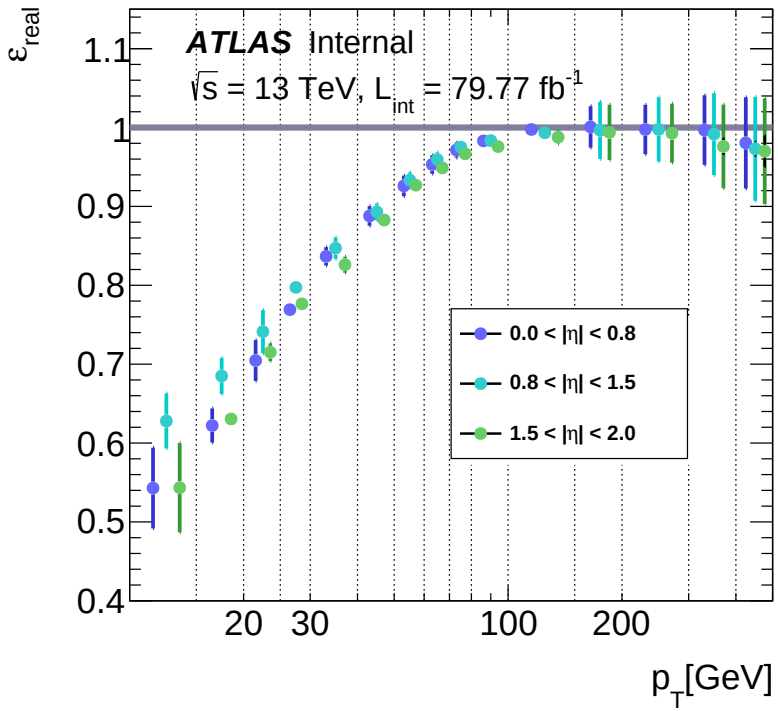
Data T&P, Z

- Data vs. MC truth $\times$SFs, Z: 0.5-1% diff if muon p_T <35 GeV otherwise below 0.5-0.6%
- MC truth $\times$SFs vs. MC T&P, Z: 1.5-3% diff when muon $p_T < 40$ GeV otherwise 0.6-1%

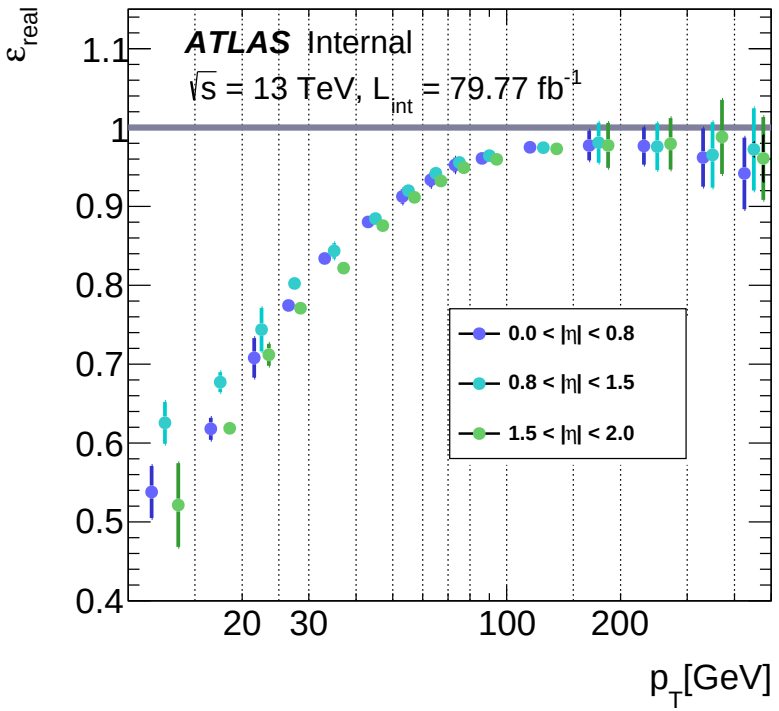
Results, electrons

Real electron efficiency measured in a sample enriched in $Z \to ee$ (left) and $t\bar{t}$ (right) events

- Stat uncertainties: black line; Syst uncertainties: colored line



MC truth $\times$SFs, Z



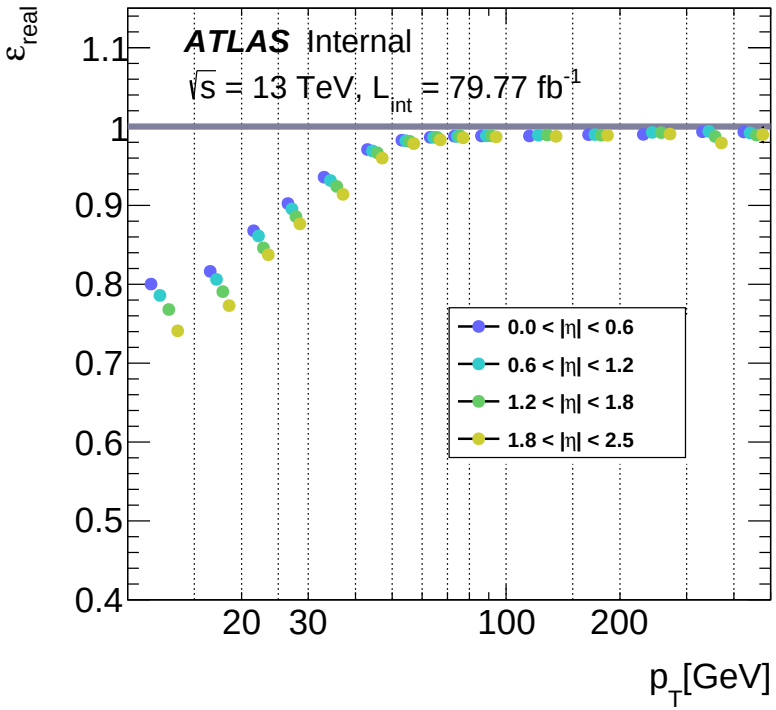
MC truth $\times$SFs, $t\bar{t}$

- Real efficiency in $t\bar{t}$ vs. $Z \to ee$: 1-2% difference (3-4% difference in the >300 GeV region)
- As the signal topologies aimed in this analysis are closer to $t\bar{t}$ processes, propose to use the real efficiency computed with MC truth $t\bar{t}$

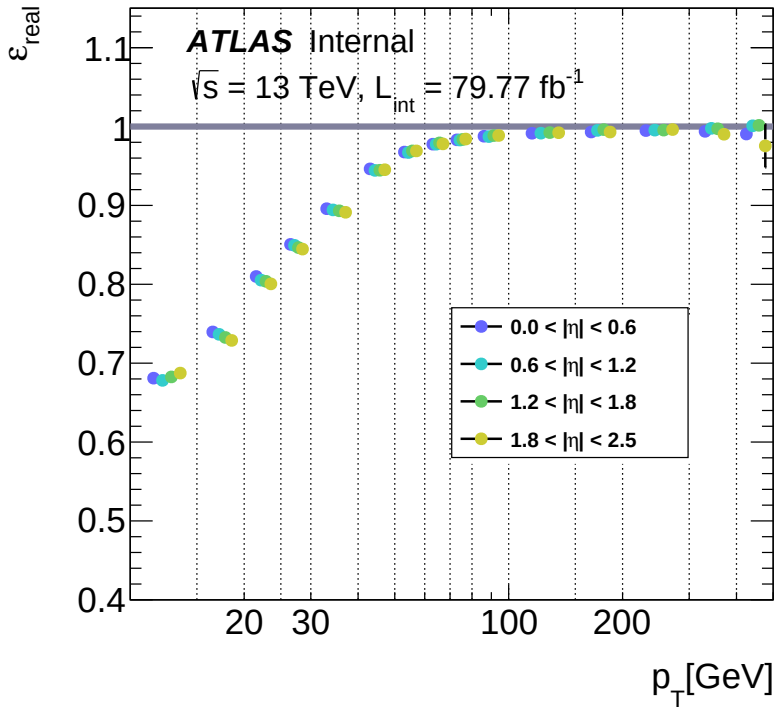
Results, muons

Real muon efficiency measured in a sample enriched in $Z \to \mu\mu$ (left) and $t\bar{t}$ (right) events

- Stat uncertainties: black line; Syst uncertainties: colored line



MC truth ×SFs, Z



MC truth ×SFs, $t\bar{t}$

- Real efficiency in $t\bar{t}$ vs. $Z \to \mu\mu$: 10-20% difference when muon $p_T < 25$ GeV, 3-6% when muon $p_T < 40$ GeV, 1-2% otherwise
- As for electrons, propose to use the real efficiency computed with MC truth $t\bar{t}$

Discussion

- First look at real lepton efficiency needed for the matrix method (use to perform the fake lepton background estimation)

→ While looking at the muon isolation efficiency × SFs in the high p_T region (e.g >500 GeV), saw that the ISO SFs are 1

$\Longrightarrow$ Thus the numerator and the denominator are the same...

→ Twiki describing the ISO recommendations here (but not many details...)

- Still need to look at real lepton efficiency as a function of lepton p_T and $\Delta R(\ell, j)$ in few Gtt boosted SUSY signal points
  - → Extra source of syst unc, to account for the extrapolation to busy environments (where the efficiencies are typically lower due to the proximity of jets and leptons
  - → Boosted Gtt: represents an extreme case of final states with highly boosted top quarks

BACKUP