Investigation of Drell-Yan process with e^+e^- yield in 13 TeV pp-collisions using 2016 year data

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CMS Compact Muon Solenoid

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ANLS-EPD, 30.06.2021

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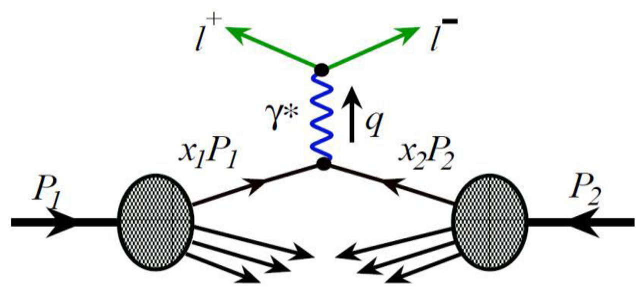
Introduction

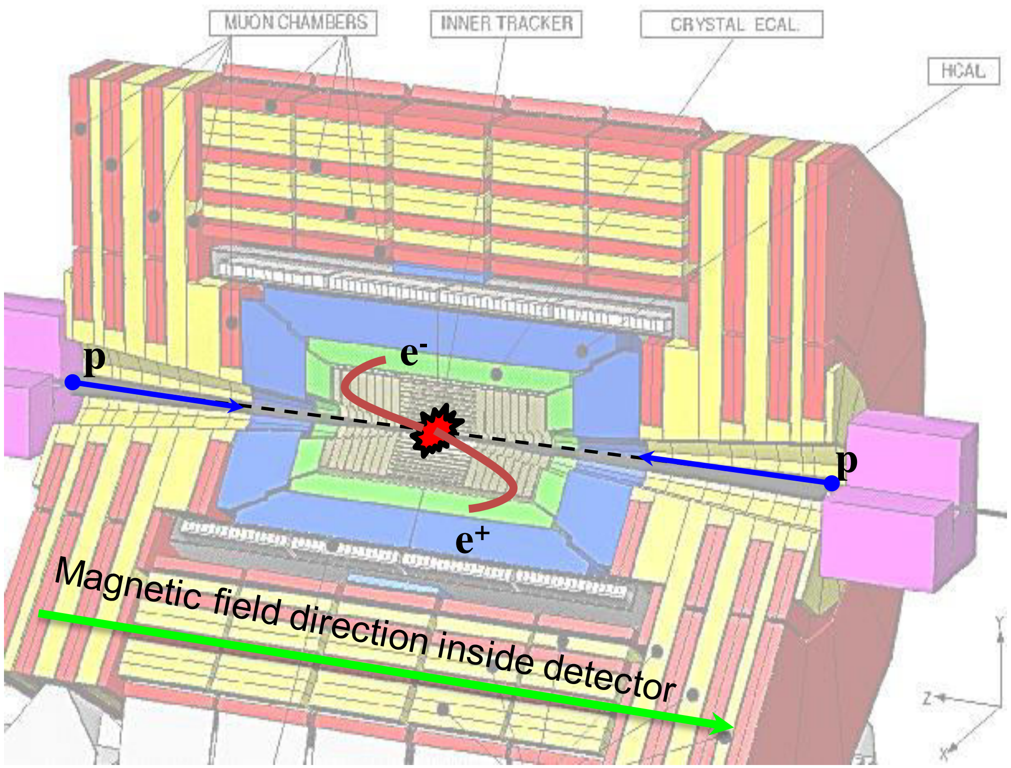
- Drell–Yan (DY) process is described as a quark and antiquark annihilation producing a virtual photon or a Z boson, with a subsequent decay into two oppositely charged leptons (in this investigation e^+e^-). In pp-interaction at 13 TeV



$$\sigma * BR = 1980 \text{ pb}, BR(Z \rightarrow e^+e^-) \sim 3.36\%$$

Features

- Very attractive for investigation
- Has a high detection accuracy
- Can be used for detector calibration
- Can be used for validations of other analyses approaches (as Standard candle)
- Is a background process for other fundamental and exotic processes with e^+e^- yield, so the quality of the new measurements directly depend on the accuracy of those investigations.



General information

Used data:

- CMS 2016-18 simulations of DY-process. Contribution of other processes with e^+e^- yield passing selection criteria estimated to be negligible (<1% in signal region).
- CMS 2016-18 experimental data of pp-collisions at 13 TeV **(~137 fb^{-1})**

Electron reconstruction:

- Particle flow (PF)

Event selection:

- Online triggers (SingleElectron HLT)
- Offline selections

Trigger efficiency calculation:

- “Tag & Probe”

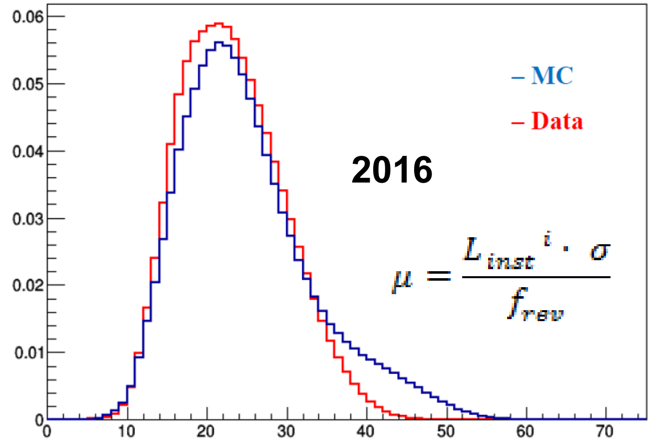
Applied corrections on MC:

- Xsec, GenWeights normalization:

$$\frac{L_{int} * \sigma}{N_{MC}}$$

- Pileup (PU) reweighting

Pileup distribution for Data and MC



Pile Up (data)

μ - number of events in bunch – bunch collision (pileup)

L_{inst}^{i} – instant value of luminosity

σ – p-p interaction cross section

f_{rev} – the orbital frequency of proton bunches in LHC

Electron reconstruction

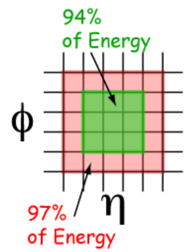
Particle-Flow (PF) global reconstruction using information from all subsystems: e, μ, γ, charged and neutral hadrons, missing-E_T etc.

Algorithm consists of several steps:

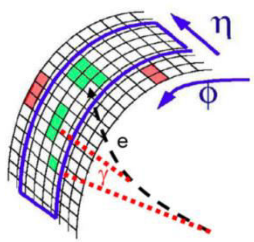
- Particle track extrapolation to ECAL.
- Selection of ECAL cluster where an electron was detected.

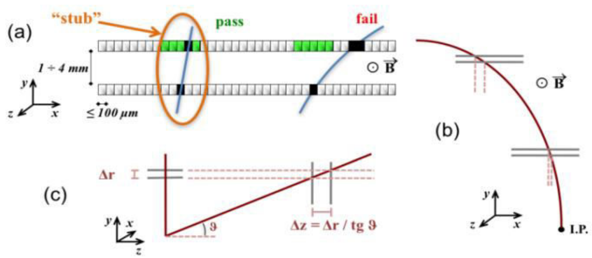
$$|\Delta\eta| = |\eta^{SC} - \eta^{extrap}{}_{in}| < 0.02$$

$$|\Delta\varphi| = |\varphi^{SC} - \varphi^{extrap}{}_{in}| < 0.15$$



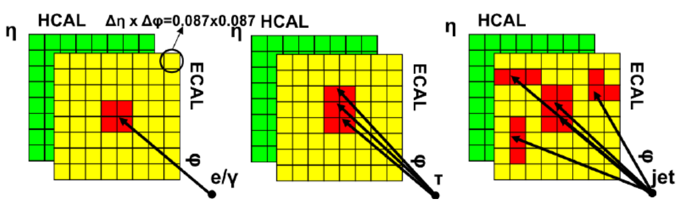
- In case of being detected in a defined range:



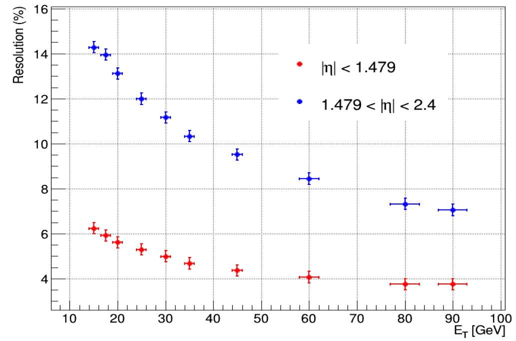


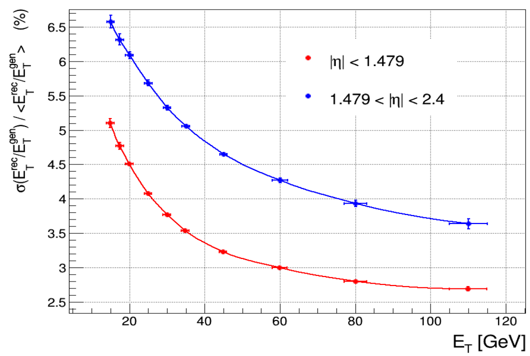
it is said that those particles are the same.

- "WPTight": the tightest restriction on identification probability (~0.1%) has been used.



[1]





Electron energy resolution in different domains of η

Trigger efficiency calculation

Problem: Difference of online triggers efficiencies in experimental and simulated data sets due to various missmodeling effects.

Goal: Calculation of trigger efficiencies and introduction of corresponding SFs to treat Data/MC disagreement.

Targets:

2016	HLT_Ele27_WPTight_Gsf	(~ 35.80 fb^{-1})
2017 B-C	HLT_Ele27_WPTight_Gsf	(~ 14.13 fb^{-1})
2017 D-F	HLT_Ele32_WPTight_Gsf	(~ 27.10 fb^{-1})
2018	HLT_Ele32_WPTight_Gsf	(~ 59.69 fb^{-1})

Events: data and MC selected with control trigger and offline selection:

Control trigger: HLT_Ele27_WPTight_Gsf

Offline selections:

- An existence of only two oppositely charged tight electrons with P_T > 35, 20 GeV within $|\eta| \in (0, 1.44)$ and $(1.57, 2.4)$
- Accordance to the interaction point condition`
  in $|\eta| \leq 1.479$: $|dz| < 0.1$ and $|dxy| < 0.05$,
  In $1.479 < |\eta| < 2.4$: $|dz| < 0.2$ and $|dxy| < 0.1$
- Narrow interval of electrons invariant mass around Z-mass (91.2±10 GeV) to select $Z \to e^+e^-$ decays

Tag&Probe method

Tag and probe method is used for any object efficiency measurement, where

Tag particle - well identified, triggered particle (tight selection criteria).

Probe particle - unbiased set of candidates (very loose selection criteria), either passing or failing the criteria for which the efficiency is to be measured.

Event Interpretation:

Tag electron: P_T-leading offline electron with P_T>35 GeV, |η|< 2.4, matched (dR<0.1) to high P_T L3 electron with P_T>27 GeV

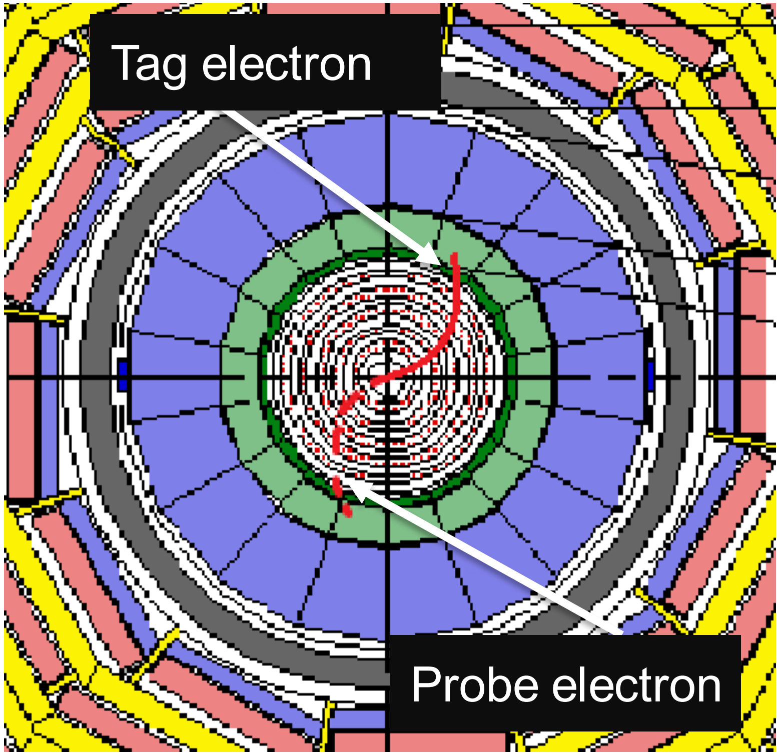
Probe electron: The other electron with P_T>20 GeV, |η|<2.4 without any trigger object matching requirement

Probe matched electron: is the probe electron, which matches to trigger (online) electron with P_T greater than corresponding P_T - threshold (in our case 27 GeV for 2016/17 and 32 for 2017/18)

Trigger efficiency vs probe electron (P_T, η)

$$Efficiency = \frac{Tag * MatchedProbe}{Tag * Probe}(pt_{probe}, eta_{probe})$$

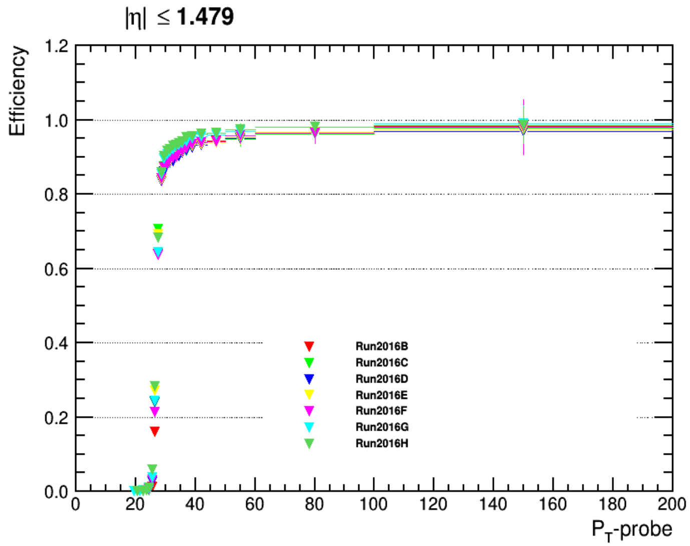
$$SF = \frac{Data_{Efficiency}}{MC_{Efficiency}}(pt, eta)$$



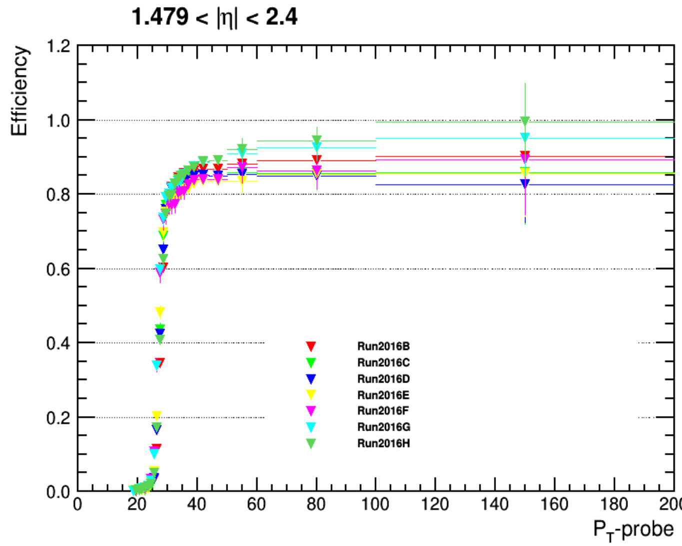
Online triggers efficiencies

HLT_Ele27_WPTight_Gsf

2016

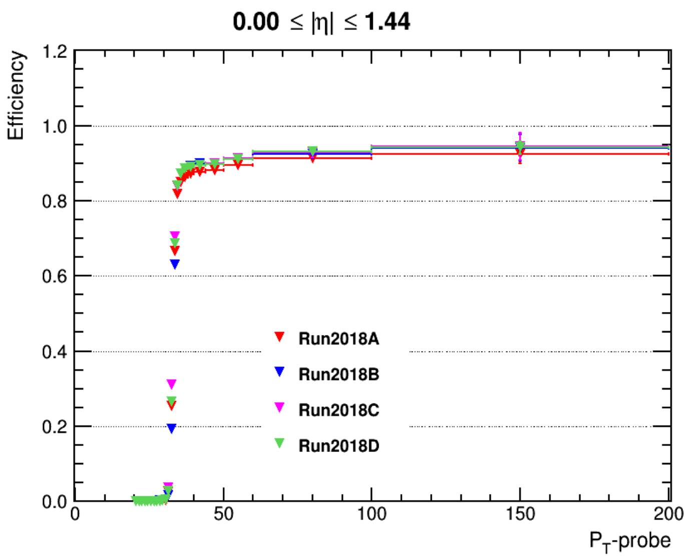


2016

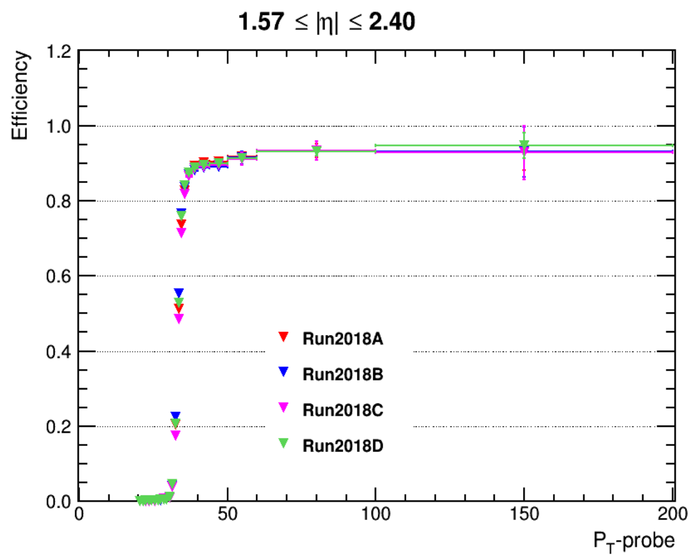


HLT_Ele32_WPTight_Gsf

2018

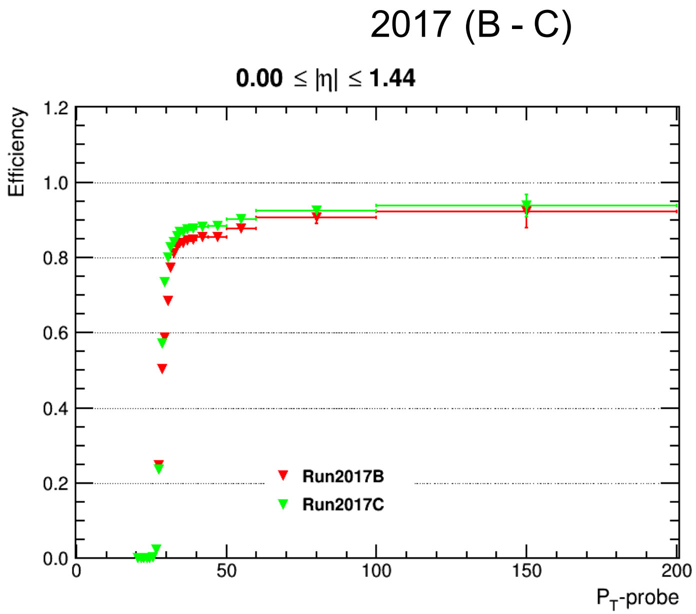


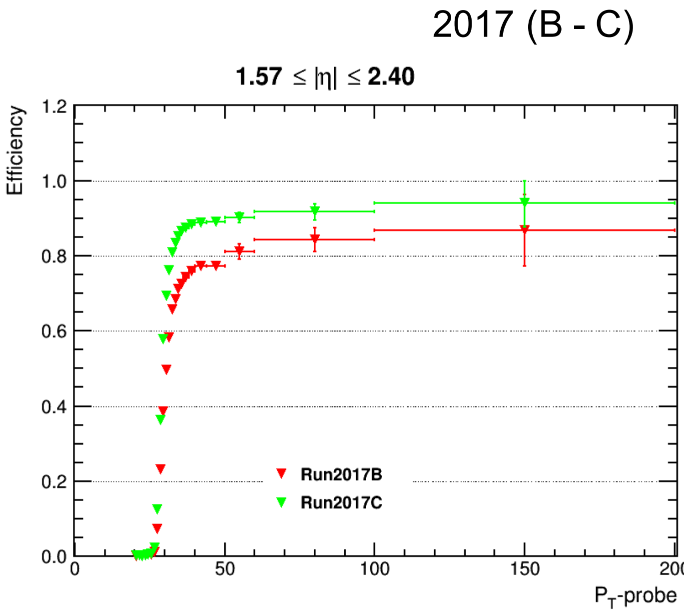
2018



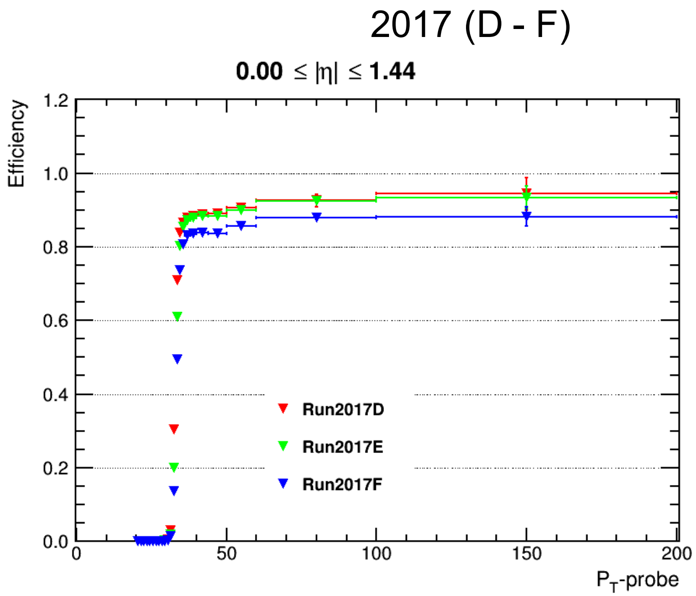
Online triggers efficiencies

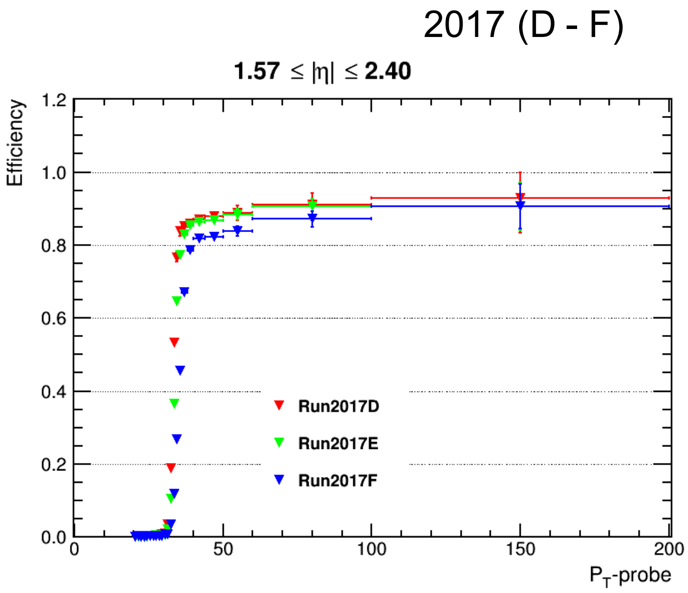
HLT_Ele27_WPTight_Gsf





HLT_Ele32_WPTight_Gsf





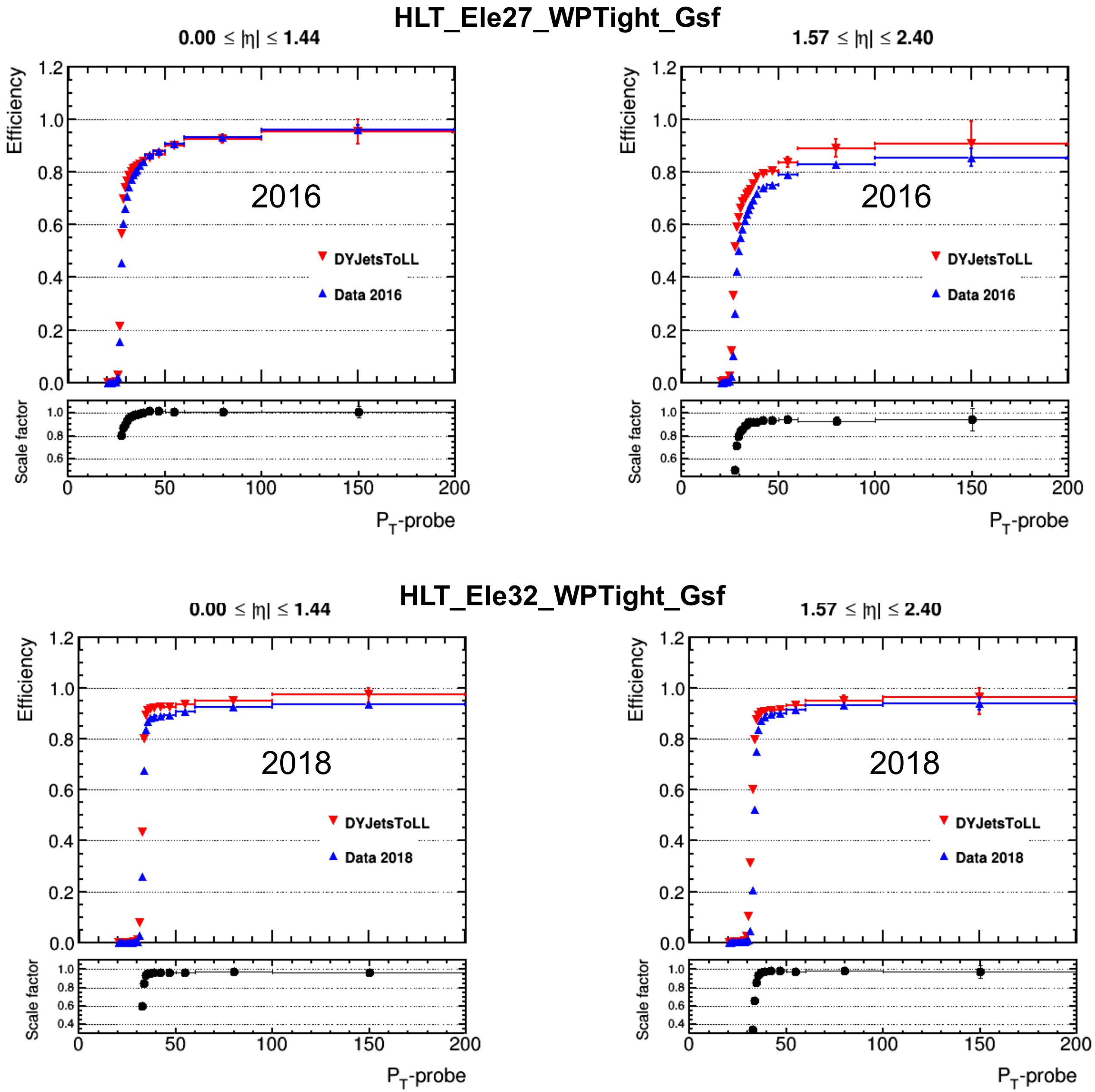
Online triggers scale factors

Interpretation:

Scale factors are introduced as a ratio of calculated efficiencies for data to MC depending on probe electron P_T and η.

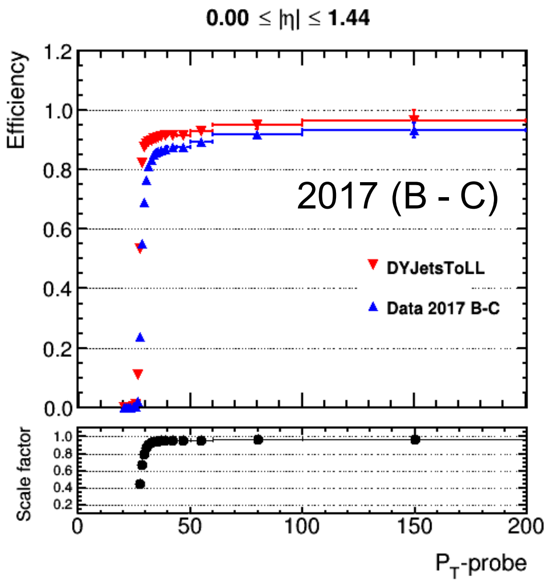
Application:

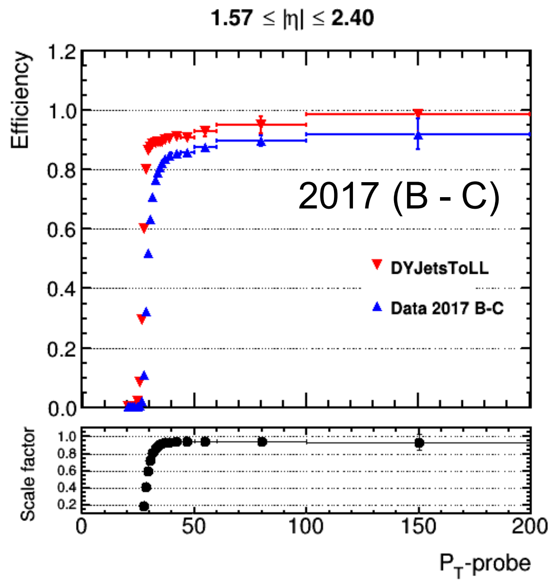
In analysis SF is calculated for electron which fires online trigger (identification is done with dR<0.1 condition between online and offline electron). Then MC event is weighted by corresponding SF.



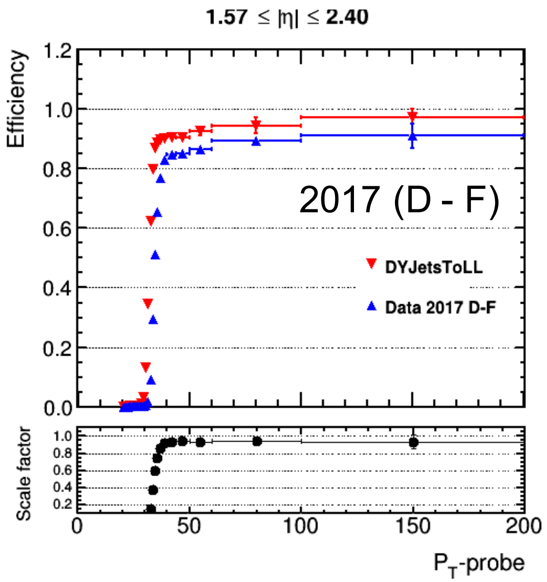
Online triggers scale factors

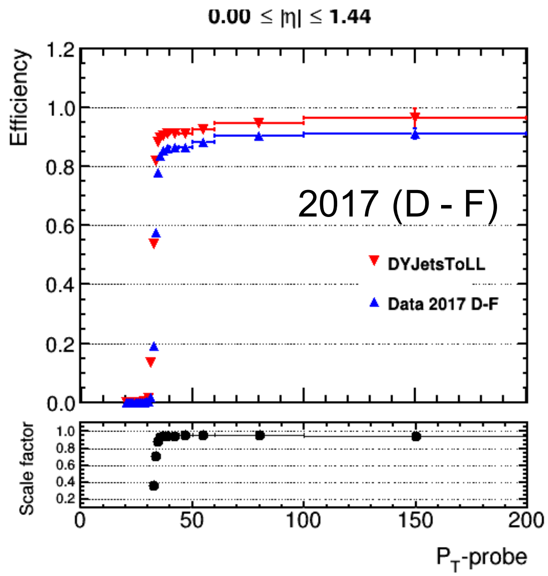
HLT_Ele27_WPTight_Gsf





HLT_Ele32_WPTight_Gsf





How scale factor works

2016 data/MC

Event selection:

Online:

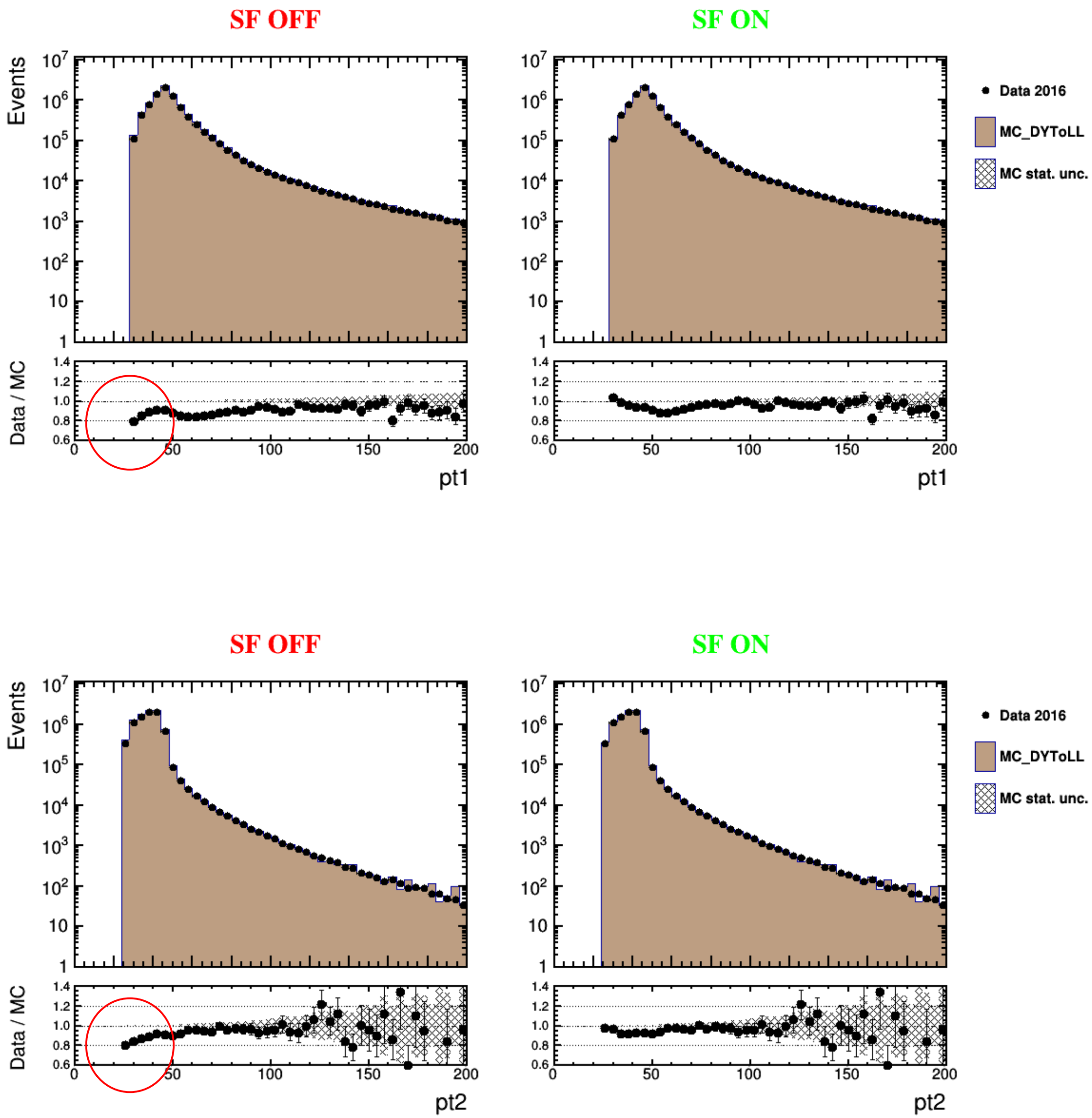
HLT_Ele27_WPTight_Gsf

Offline:

- Two oppositely charged Tight electrons with P_T > 35, 27 GeV within $|\eta|$ < 2.4
- Narrow interval of Z-mass (+/- 10 GeV)
- At least one of offline electrons matched to online electron with P_T > 27 GeV

Weights:

- Xsec, Pu-Reweighting
- Trigger P_T - scale factors

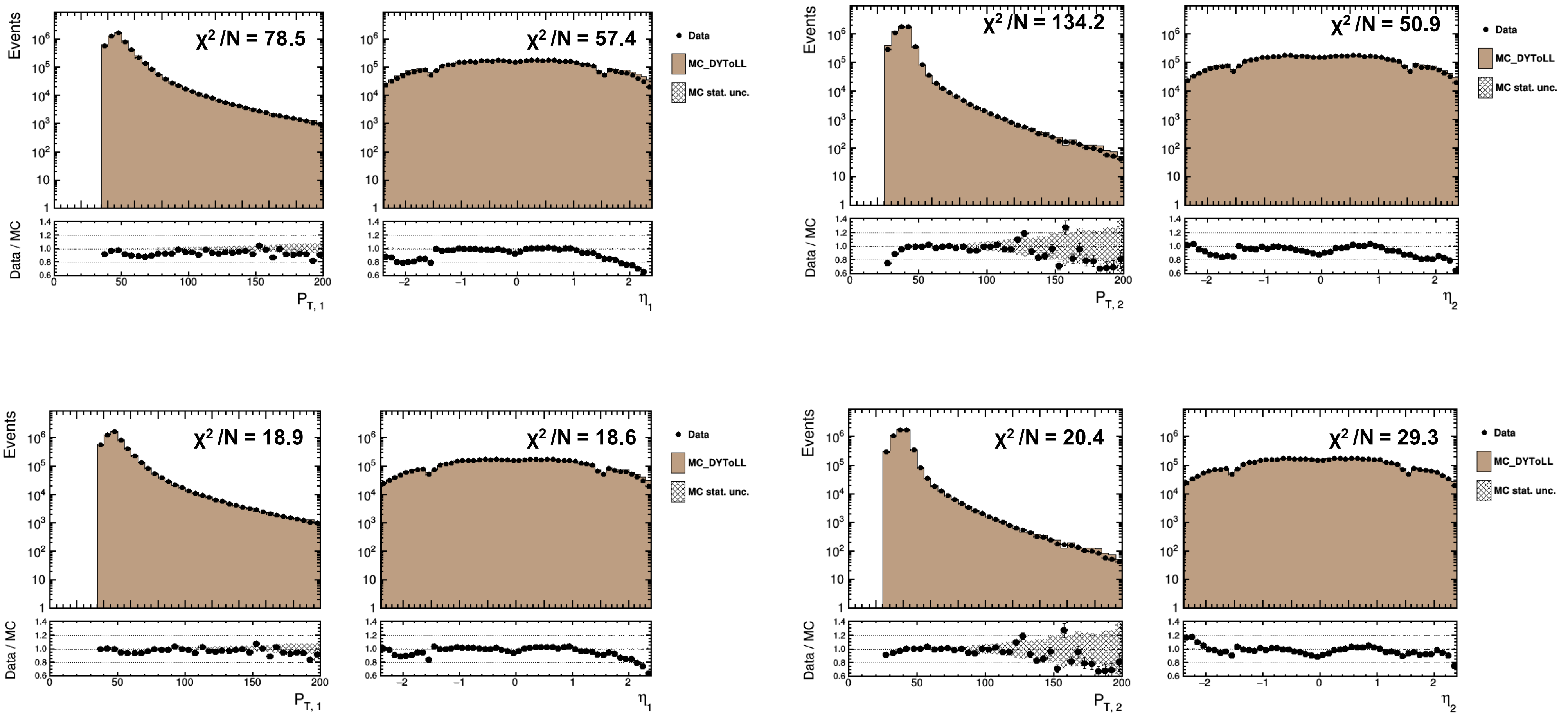


Performance of SFs

Datasets: **2016 data/MC**

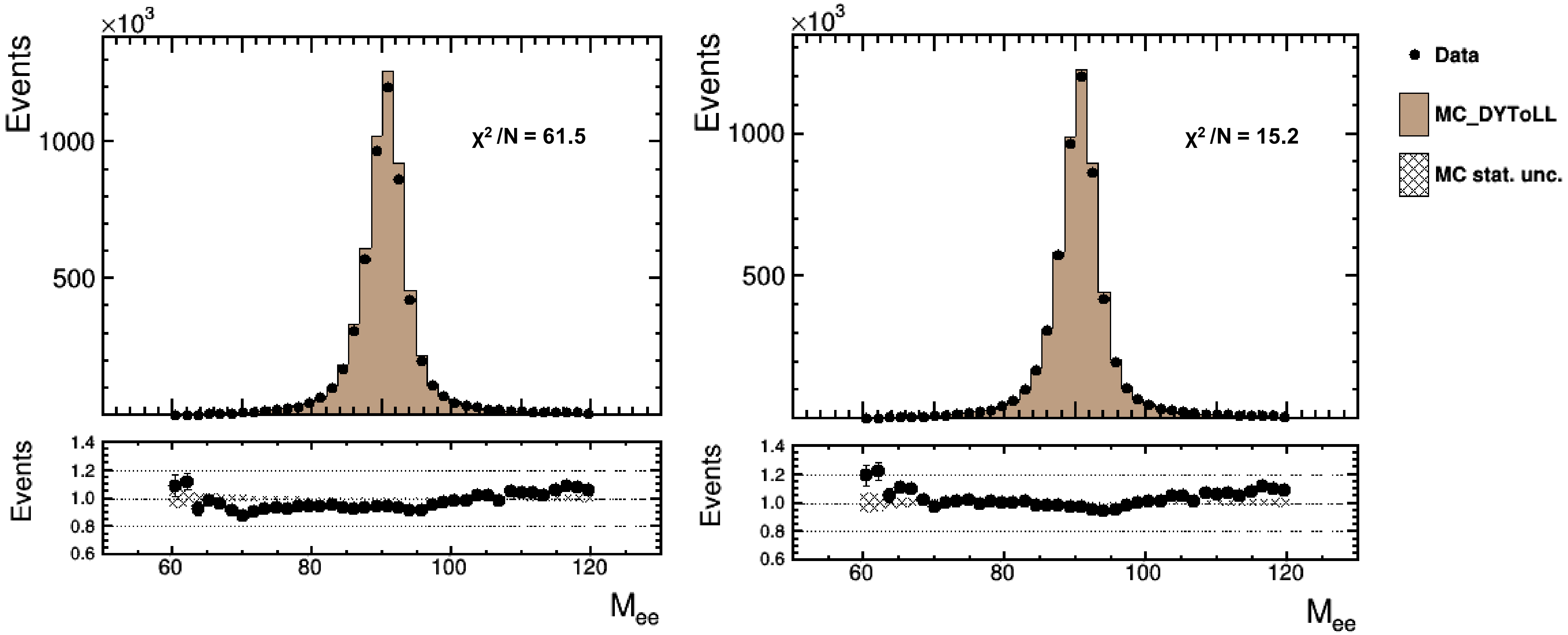
Events selection: HLT_Ele27_WPTight_Gsf,

Two (only) oppositely charged Tight electrons with P_T > 35, 27 GeV within $|\eta|$ < 2.4 matched to online electrons with P_T > 27 GeV (straightforward way to apply SFs and avoid combinatorial issues)



Performance of SFs in analysis region

2016 data/MC



Summary

- Single electron triggers SFs has been calculated using “Tag&Probe” method
- SFs are extracted in P_T, η bins for 2016-18 Triggers
- Validation of SFs was done with Drell-Yan process in e^+e^- mass range 60-120 GeV
- Significant improvement in Data/MC comparison has been observed

Thank You

Links

1. A. Hayrapetyan, THE STUDY OF ELECTRONS ENERGY RESOLUTION, IN CMS (LHC) EXPERIMENT USING SIMULATED DATA, YSU. Proceedings of the Physical and Mathematical Sciences, Yerevan Armenia, 2020, v. 54,

Backup

Ongoing activity

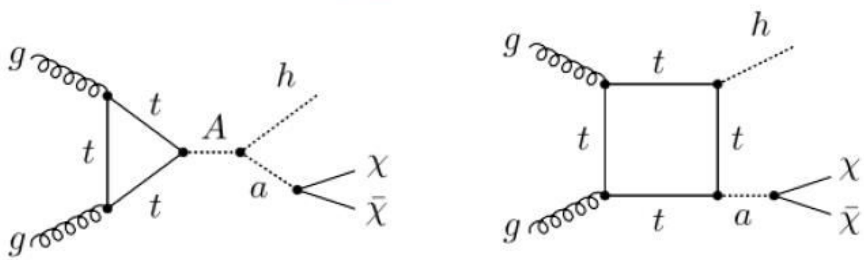
Dark matter (DM) investigation with “2HDM + a” model

Interesting processes within this model:

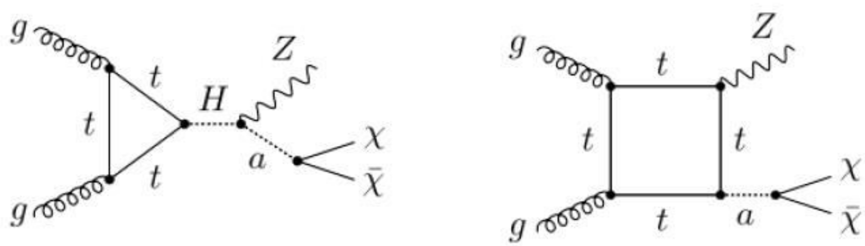
Investigated processes:
for different parameters of the particles.

- Cross section and DM particle mass dependency
- Entire simulation
- MET comparison

h (→ bbar) + a (→ χχ) = bbar + MET



Z + a (→ χχ) = Z (→ ll) + MET



Changed parameters:

– $M_A > M_a + M_h$

– $M_a > 2M_{xd}$

– M_A = 500 GeV

– M_h = 125 GeV

– $M_{H\pm} = M_H$ = 750 GeV

– $\sin(\beta - \alpha) = 1$

– $\sin(\theta) = 0.35$

– M_a = 100, 300 GeV

– M_χ = 1, 10, 100, 300, 1000 GeV

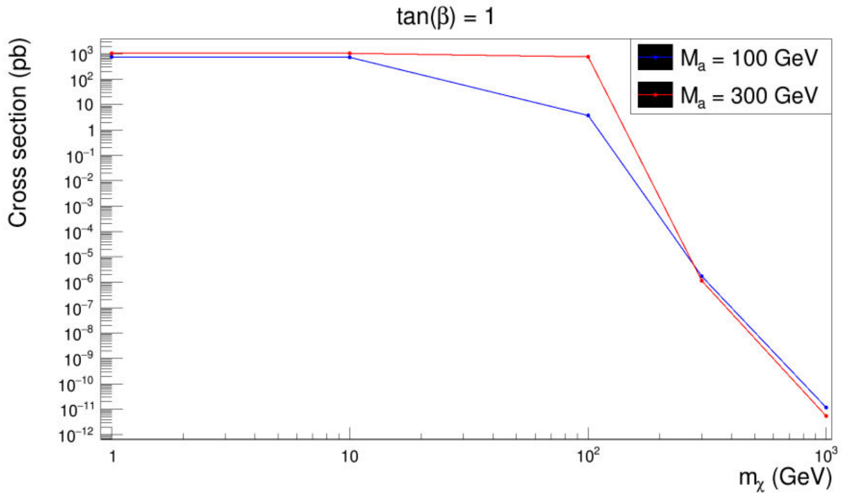
– $\tan(\beta)$ = 1, 10

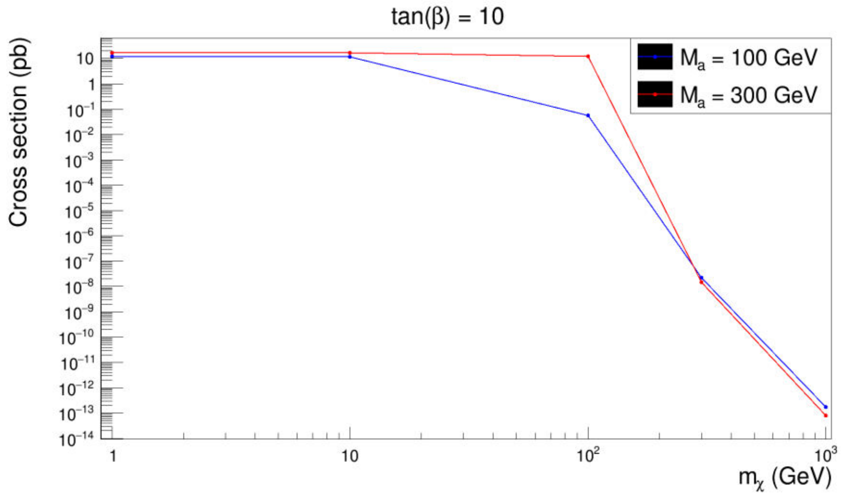
Where:

a is light pseudoscalar (A – heavy pseudoscalar)
H is heavy Higgs boson

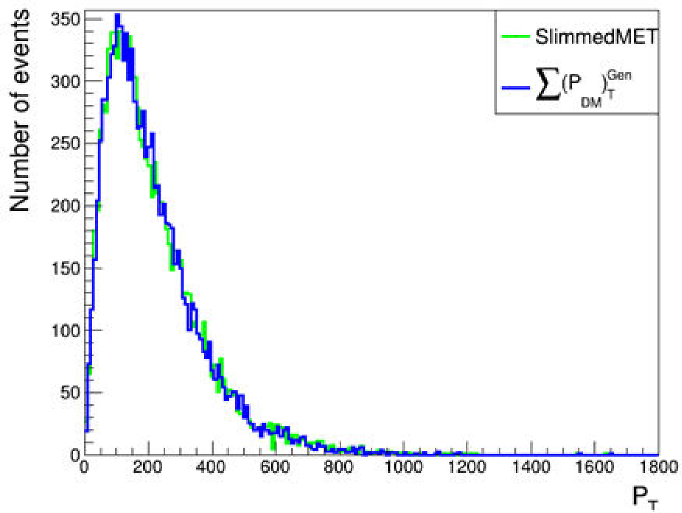
Ongoing activity

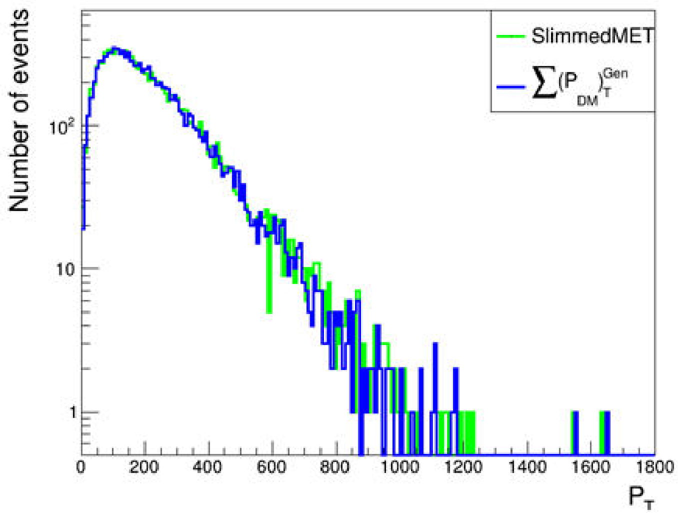
Cross section dependency from DM particle mass





SlimmedMET vs $(\Sigma P_{DM})^{Gen}{}_T$, PU → 2018_Projected





Ongoing activity