# Impact of improved detector calibration on high energy electron reconstruction and identification in CMS

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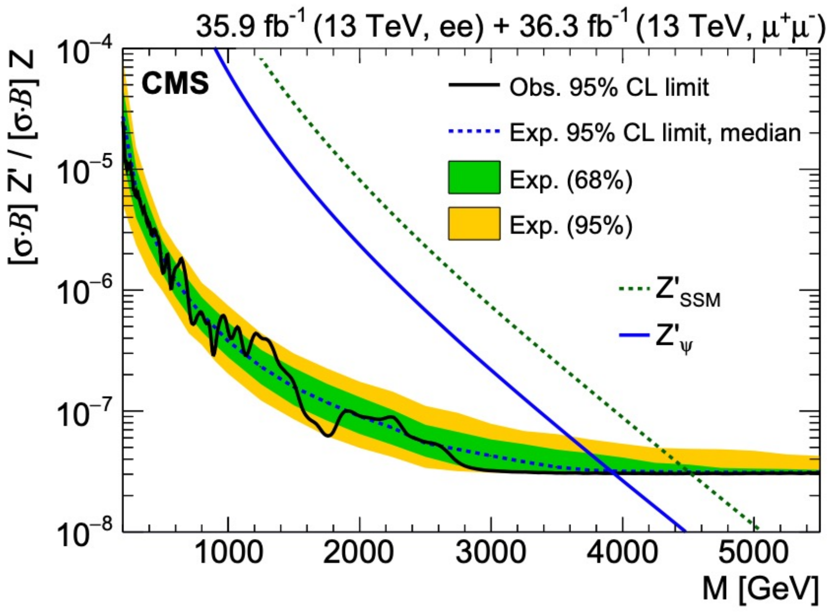
# Motivation

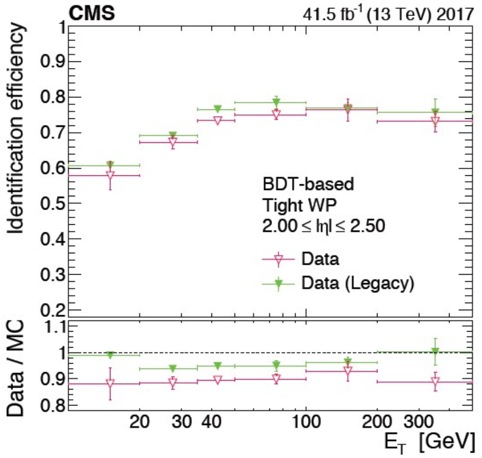
- Z' search – looking for new high mass resonances decaying to two leptons
  - CMS requires electron candidates to pass a set of dedicated high energy electron criteria (HEEP ID)
- In Run 2, CMS was able to place a mass limit on spin-1 $Z'_{SSM}$ of 4.50 TeV (95% CL) using both the dielectron and dimuon channels.
- Will collect more data in Run 3, also expecting an increase in energy from 13.0 to 13.6 TeV
  - Run 2 increased the $Z'_{SSM}$ mass limit by 1.1 TeV, so expect to be able to explore Z' higher mass ranges in Run 3



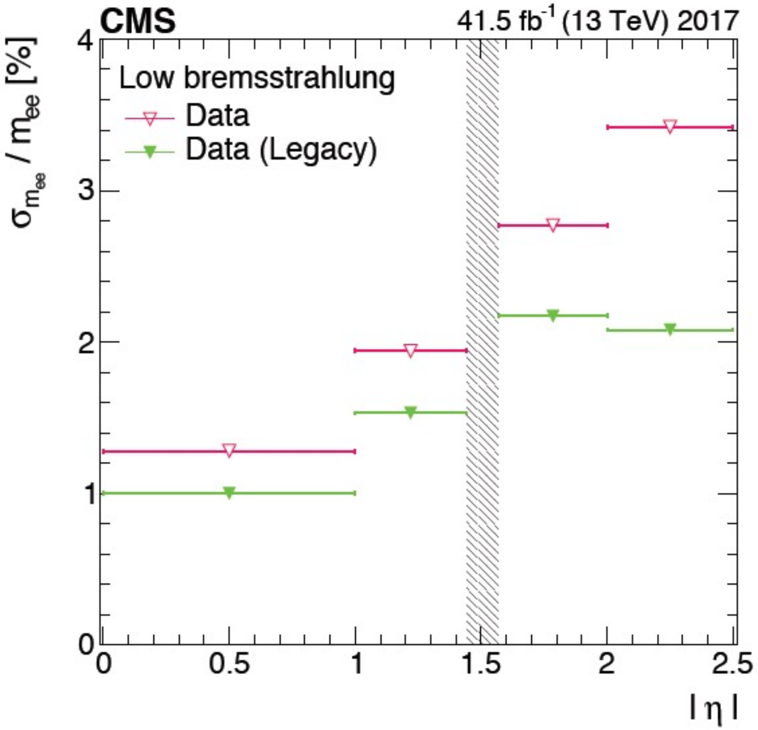

The upper limits (95% CL) on the product of production cross section and branching fraction for a spin-1 resonance with a width equal to 0.6% of the resonance mass. From arXiv:1803.06292

# Ultra Legacy Data

- Recalibrated ECAL using Run 2 data
- Well known resonances of $\pi_0$ and Z were used calibrate crystals on a per year basis
- Evaluating impact of UL calibration on Z' analysis:
  - UL provides better electron energy resolution, especially in forward region
  - UL may also improve HEEP ID efficiency and data/MC agreement




Tight BDT-based electron identification efficiency (upper panel) and data-to simulation correction factors (lower panel)
From arXiv:2012.06888



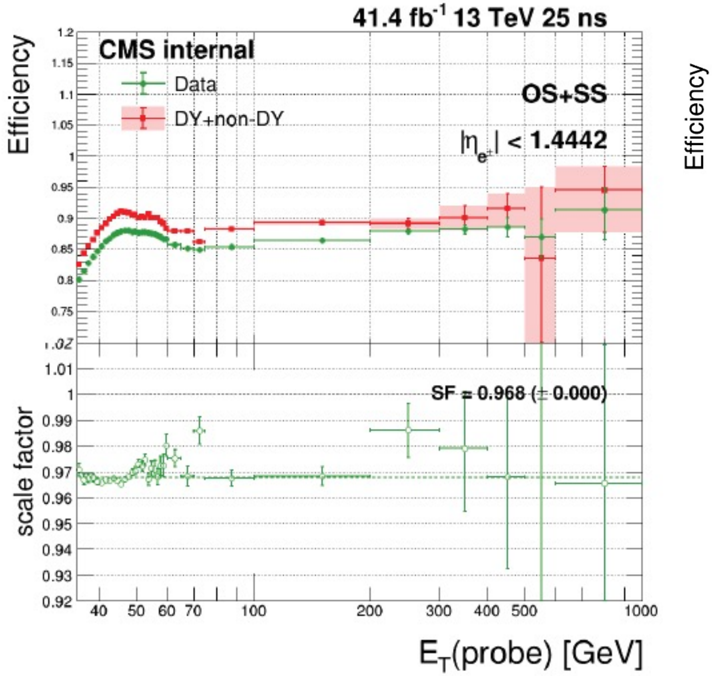

Dielectron mass resolution from Z -> ee events
From arXiv:2012.06888

# HEEP ID

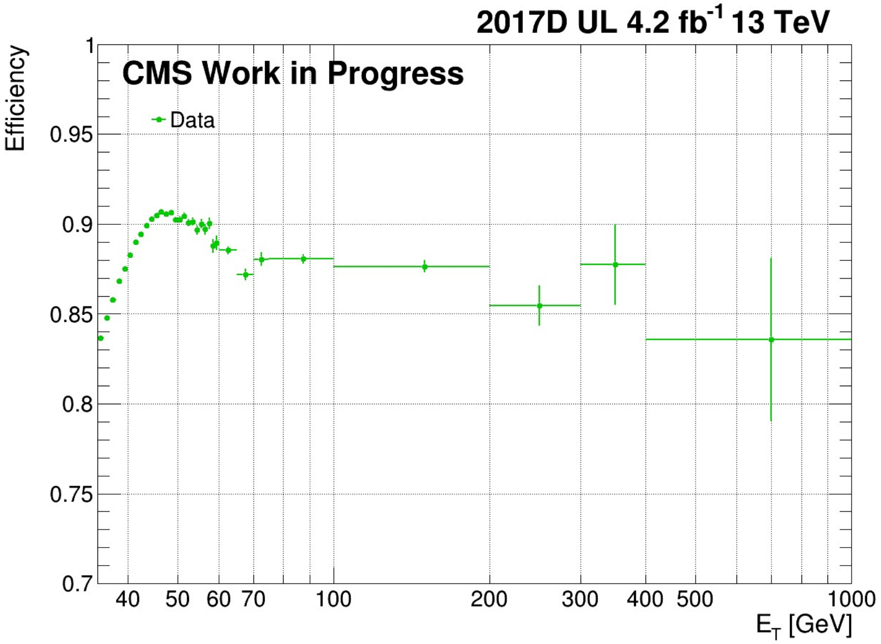
| Variable | Barrel | Endcap |
|---|---|---|
| $E_T$ | > 35 GeV | > 35 GeV |
| η range | $\|\eta_{sc}\|< 1.4442$ | $1.566<\|\eta_{sc}\|< 2.5$ |
| isEcalDriven | =1 | =1 |
| $\|\Delta\eta_{in}^{seed}\|$ | < 0.004 | < 0.006 |
| $\|\Delta\phi_{in}\|$ | < 0.06 | < 0.06 |
| H/E | < 1/E + 0.05 | < 5/E + 0.05 |
| full 5x5 $\sigma_{i\eta i\eta}$ | n/a | <0.03 |
| full 5x5 $E^{2x5}/E^{5x5}$ | > 0.94 OR $E^{1x5}/E^{5x5}$ > 0.83 | n/a |
| EM + Had Depth 1 Isolation | <2+0.03*Et +0.28*rho | < 2.5 +0.28*rho for Et<50 else < 2.5+0.03*(Et-50) +0.28*rho |
| Track Isol: Trk Pt | <5 | <5 |
| Inner Layer Lost Hits | <=1 | <=1 |
| \|dxy\| | <0.02 | <0.05 |

- Subdetector based isolation rather than PF isolation
  - Uses information from ECAL, HCAL and tracker
- Simple, robust ID
- Requires that the lateral spread of energy deposits in the ECAL is consistent with that of a single electron and that the track is matched to the ECAL deposit

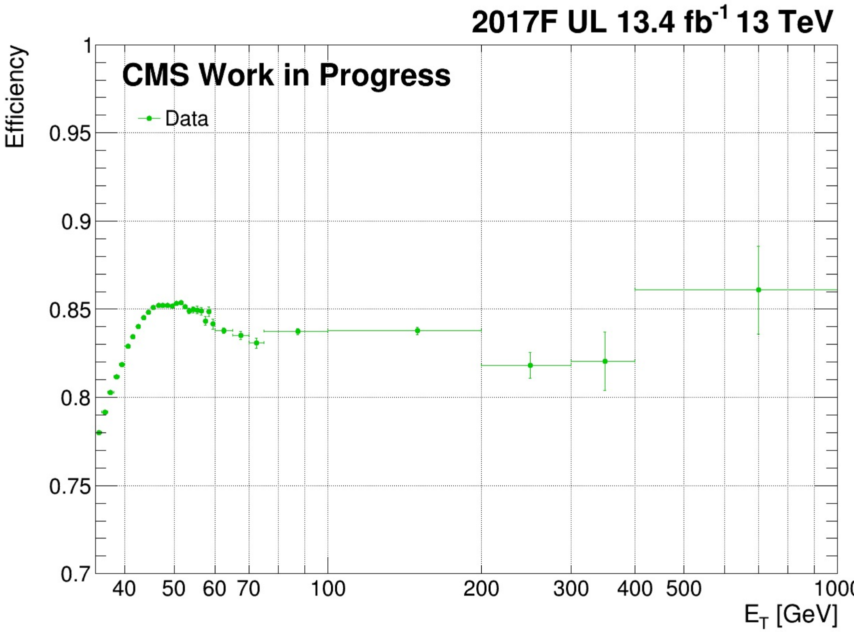
# HEEP ID using Ultra Legacy Data (Barrel)




2017 end of year calibration (EOY)
From CMS AN-2018/143




2017 UL Run D, 4.2 $fb^{-1}$




2017 UL Run F, 13.4 $fb^{-1}$

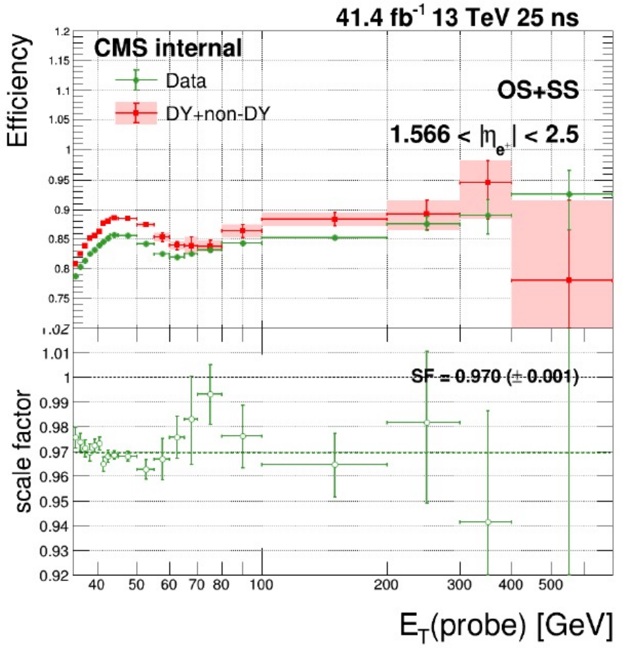
- All three plots are for the barrel region, |eta| < 1.4442
- Run D was a well-behaved run and shows similar improved efficiency compared to full 2017 EOY plots
- Run F suffered from some detector issues which caused the decreased HEEP ID efficiency

# Plans for Run 3

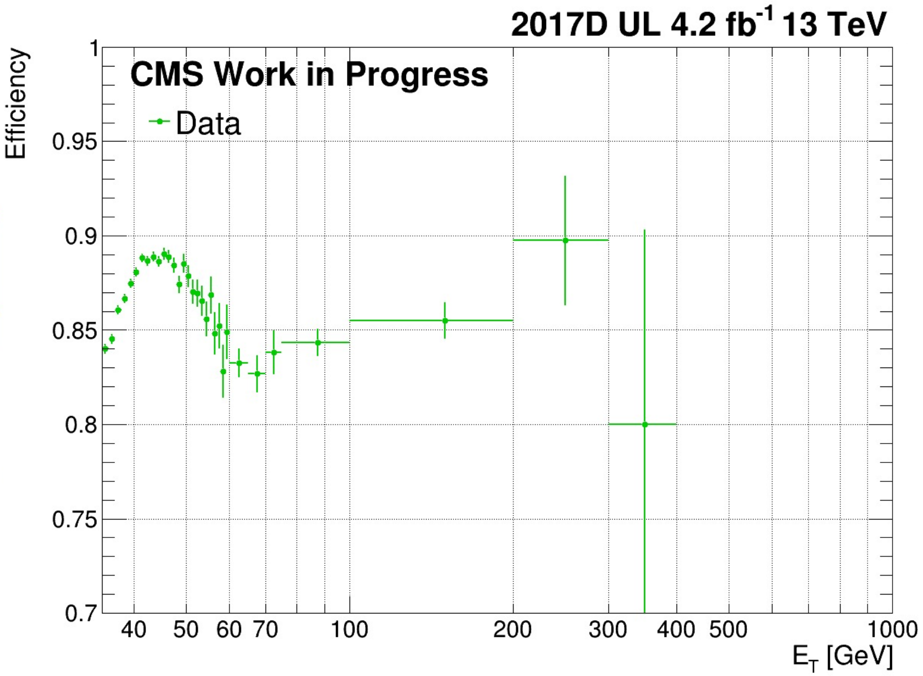
- Expected to start around May 2022 and last for at least three years
- First task will be to qualify HEEP ID and single electron trigger
  - Will be running with upgraded Pixel and HCAL detectors
- Expect Run 3 to have similar calibration quality to ultra legacy due to calibration improvements, including a move from twice weekly laser calibration to once a spill
- Also expect these improvements to be pushed to HLT
  - Better resolution, more stable rates and energy scales
  - Therefore, performance closer to offline reconstruction

# Backup

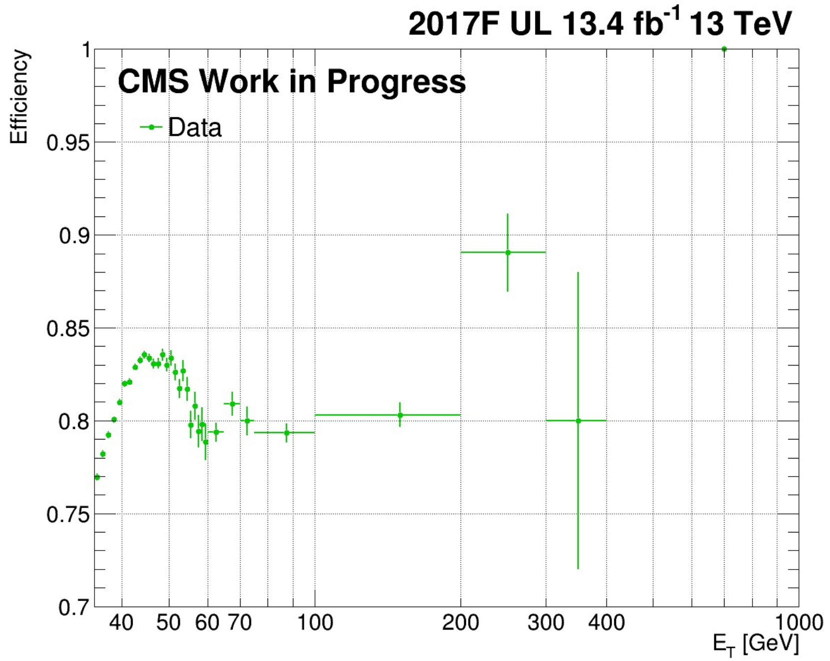
# HEEP ID using Ultra Legacy Data (Endcap)




2017 EOY
From CMS AN-2018/143



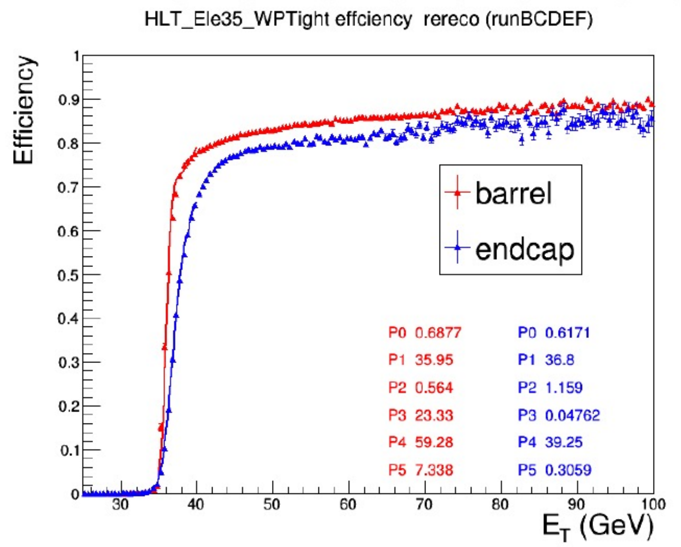

2017 UL Run D, 4.2 $fb^{-1}$



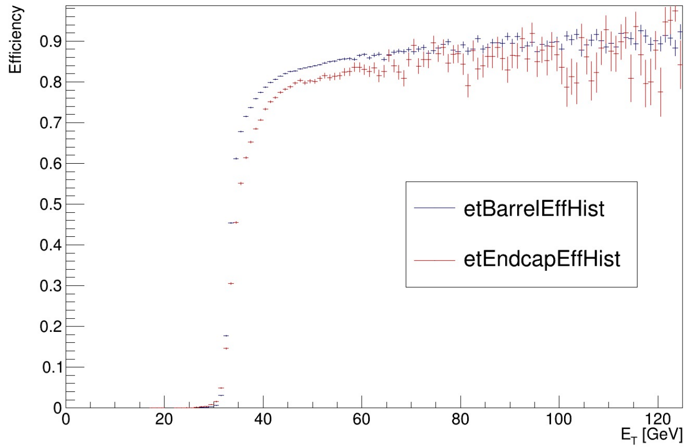

2017 UL Run F, 13.4 $fb^{-1}$

# High Level Trigger

- High level trigger (HLT) is a software implemented trigger that reduces the rate in CMS by O(1000)
- HEEP ID efficiency is measured using tag and probe
- Require the tag to be in the barrel, pass the HEEP ID and a 32 GeV electron trigger
- As electron ET has changed during ultra legacy the HLT turn on curve has changed from EOY




Trigger turn on curve for HLTEle35 using 2017 EOY data



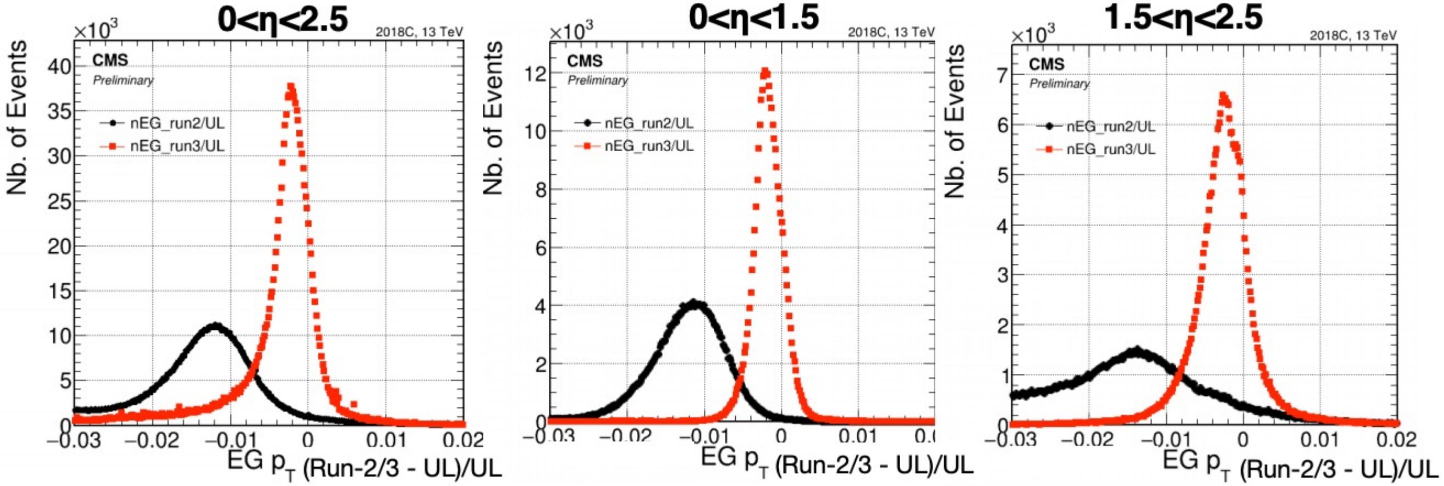

EOY trigger turn on curve for HLTEle32 using 2017 Run D ultra legacy data

# Resolution for more Frequent Transparency Corrections

**Breakdown of the HLT resolution for EG in EB and EE:**

$$\text{Resolution} = \frac{p_T(\text{Run2(3)}) - p_T(\text{UL})}{p_T(\text{UL})}$$

**Fill#6956-6961**




- Resolution is significantly better (narrower width) and energy scale closer to UL (mean closer to 0)
  - Significant improvements seen in both EB and EE

Preliminary results of this study were presented at the *TSG/STEAM meeting* by Yash

**Plot courtesy: Amina Zghiche**

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ECAL DPG Meeting, 13/10/2021

From: ECAL DPG meeting

# More Details on UL

## Step 1

**Refined baseline conditions**

- ☑ Pedestals
- ☑ PulseShapes
- ☑ LaserAPDPNRatios

+ Re-alignment, ES calibration, timing calibration

**Time-dependent corrections to make response flat in time**

- Laser PN drift corrections (EB)
- α studies (EE)

**New for Run 2**

## Step 2

**Derivation of intercalibration (IC) constants**

- ☑ ϕ-symmetry
- ☑ $\pi^0$ ($\eta^0$)
- ☑ E/p
- ☑ Zee

**IC combination:** crystal-by-crystal relative calibration

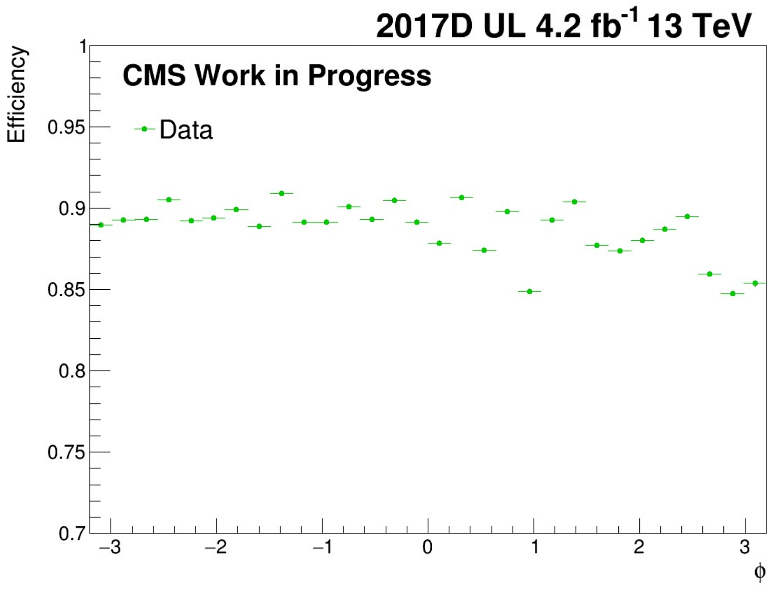
Zee never used in Run 1 to make IC (only for η-scale)

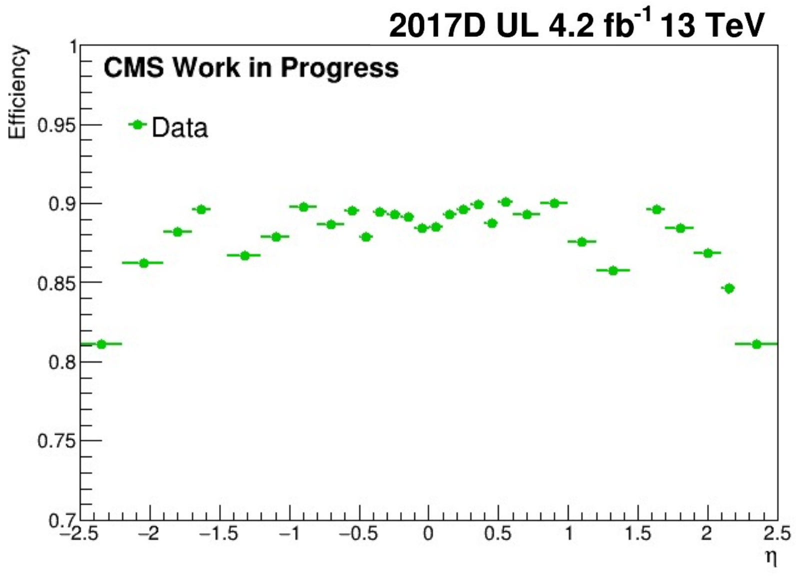
## Step 3

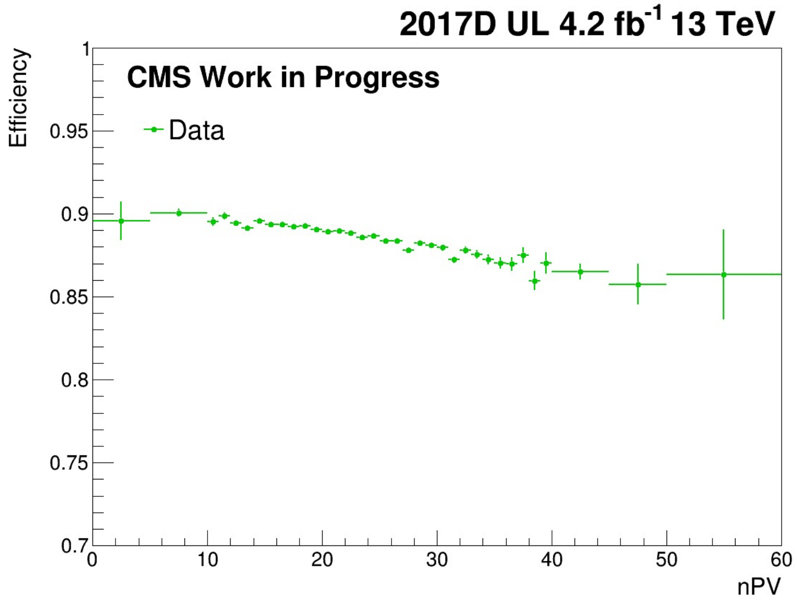
**Absolute η-scale derivation** (equalization wrt MC using $Z \rightarrow ee$ events)

From: monitoring and calibration report

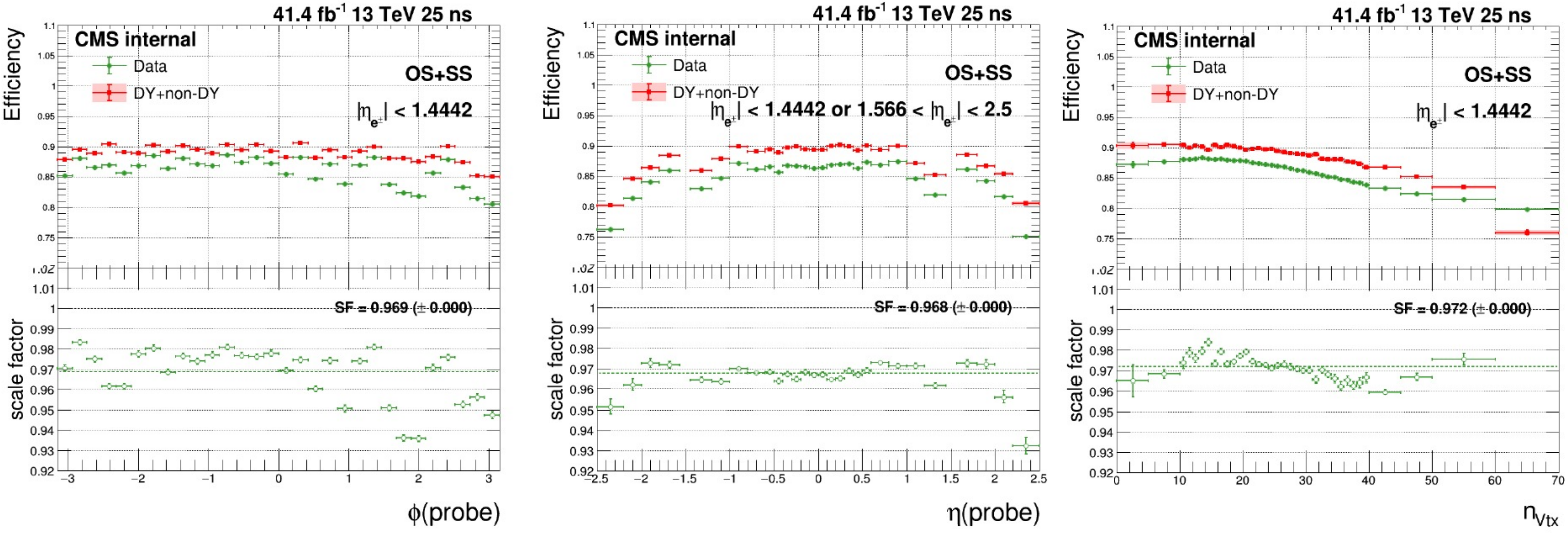
# HEEP ID 2017D Ultra Legacy (Barrel)



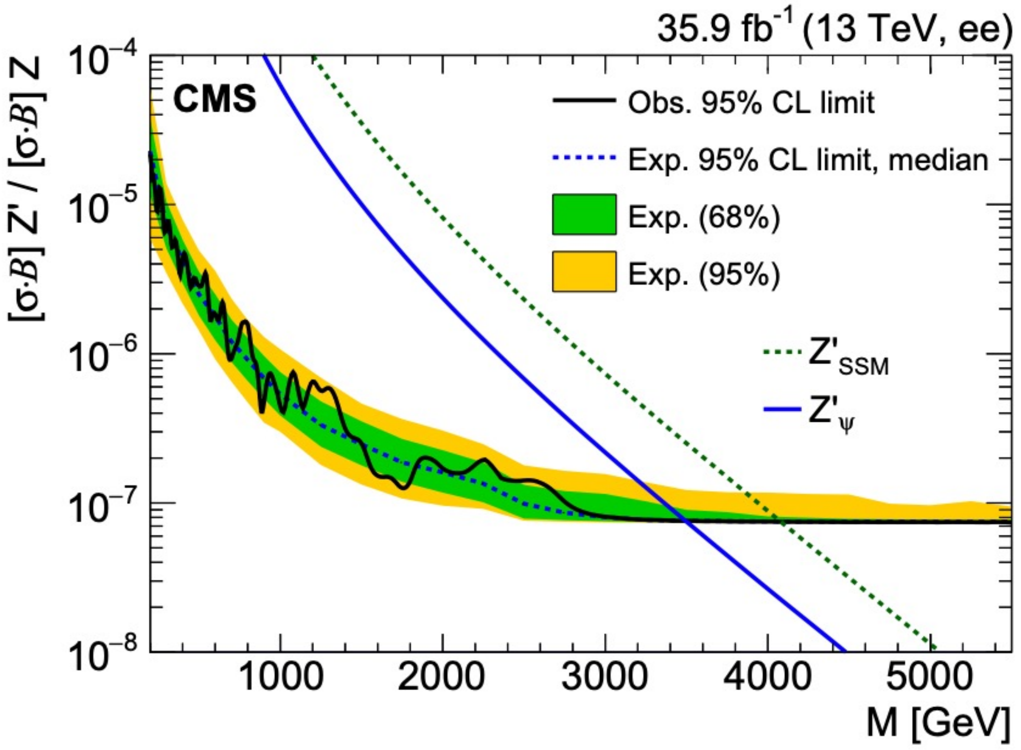



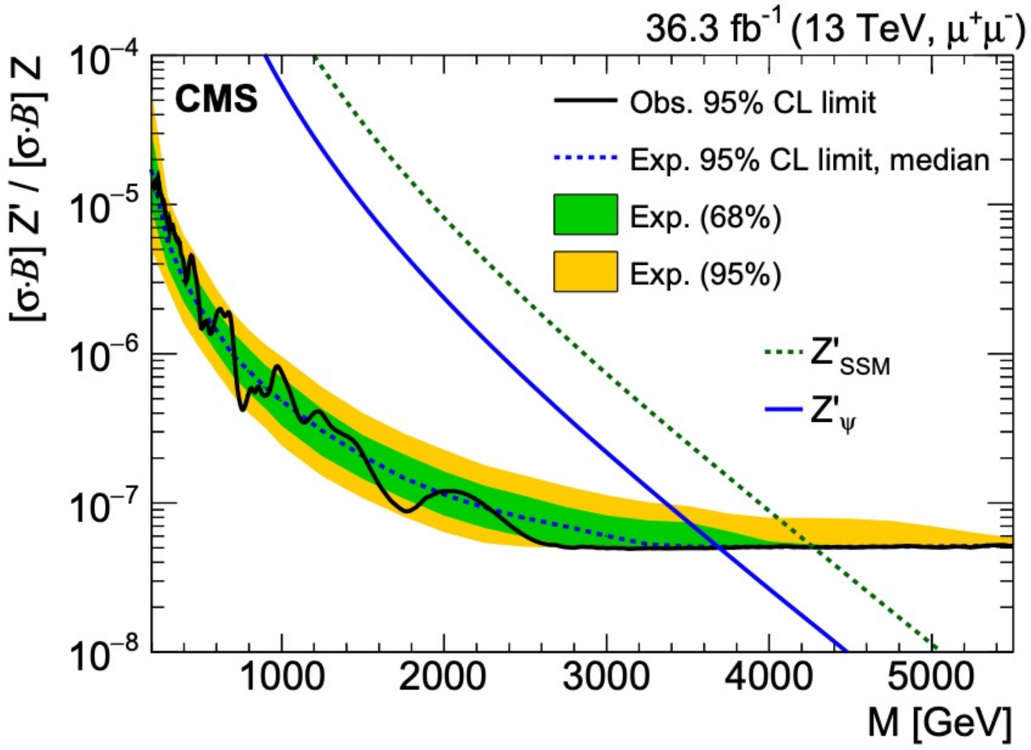
# HEEP ID 2017 EOY (Barrel)




From CMS AN-2018/143

# Run 2 Z’ Search, Separating ee and uu




From arXiv:1803.06292

# 2017 Datasets

EOY:

| Datasets | integrated luminosity ( $fb^{-1}$) |
|---|---|
| /SingleElectron/Run2017B-17Nov2017-v1/MINIAOD | 4.802 |
| /SingleElectron/Run2017C-17Nov2017-v1/MINIAOD | 9.629 |
| /SingleElectron/Run2017D-17Nov2017-v1/MINIAOD | 4.235 |
| /SingleElectron/Run2017E-17Nov2017-v1/MINIAOD | 9.268 |
| /SingleElectron/Run2017F-17Nov2017-v1/MINIAOD | 13.433 |
| Sum | 41.368 |

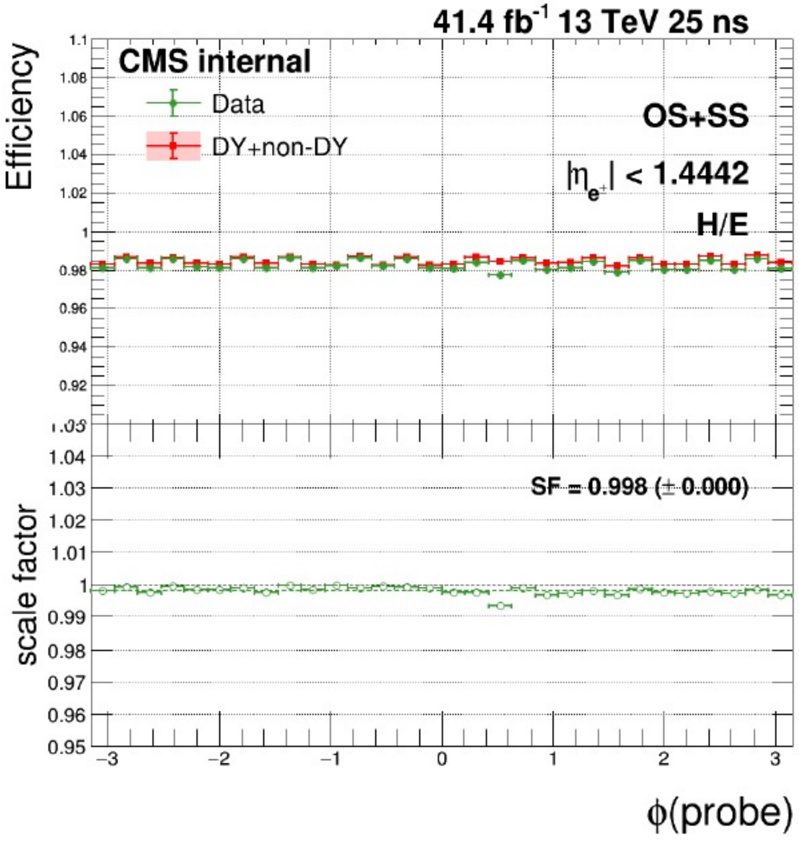
UL:

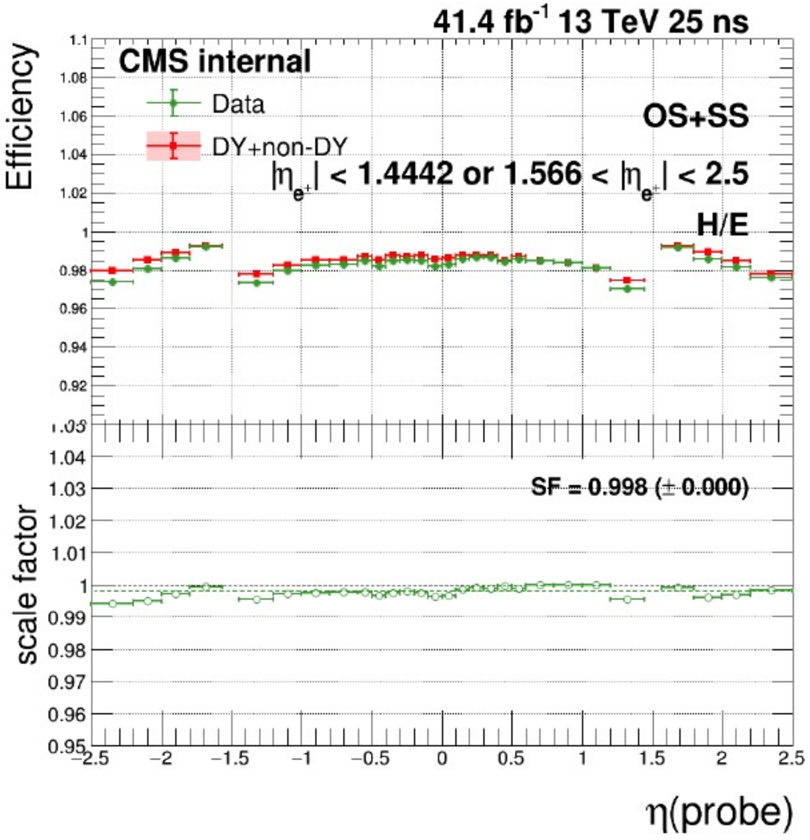
/SingleElectron/Run2017B-09Aug2019_UL2017-v1/MINIAOD
/SingleElectron/Run2017C-09Aug2019_UL2017-v1/MINIAOD
/SingleElectron/Run2017D-09Aug2019_UL2017-v1/MINIAOD
/SingleElectron/Run2017E-09Aug2019_UL2017-v1/MINIAOD
/SingleElectron/Run2017F-09Aug2019_UL2017_rsb-v2/MINIAOD

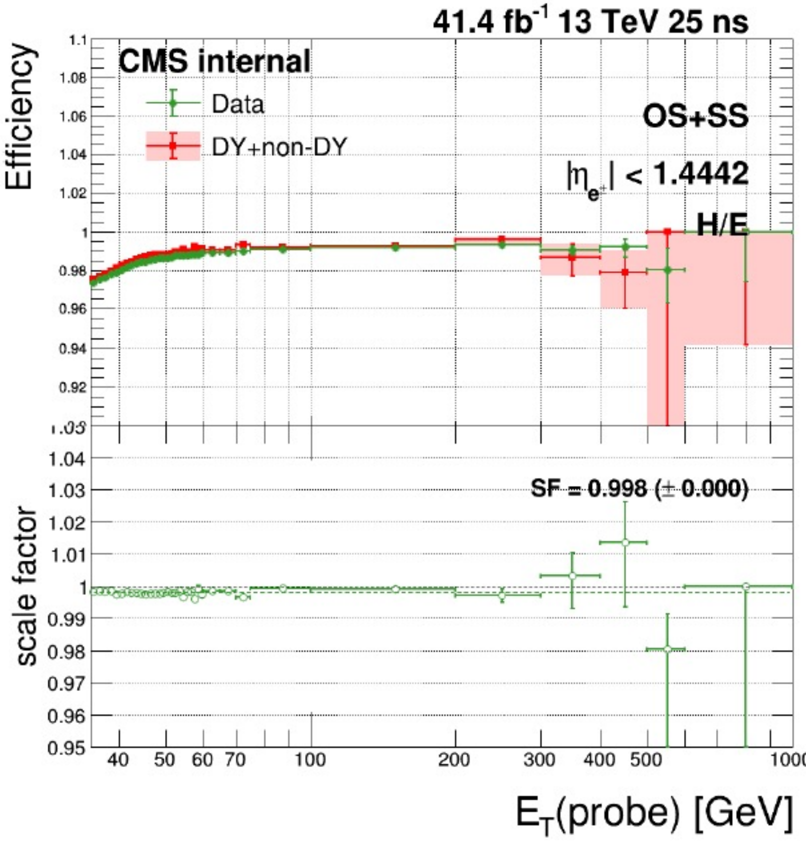
# 2017 UL Monte Carlo Datasets

| Correct Summer20 2017 UL Sample | Cross Section (pb) |
|---|---|
| /DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8/RunIISummer20UL17MiniAODv2-Pilot_106X_mc2017_realistic_v9-v1/MINIAODSIM | 6416 |
| /DYJetsToLL_M-50_HT-70to100_TuneCP5_PSweights_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 139.3 |
| DYJetsToLL_M-50_HT-100to200_TuneCP5_PSweights_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 140.2 |
| /DYJetsToLL_M-50_HT-200to400_TuneCP5_PSweights_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 38.39 |
| /DYJetsToLL_M-50_HT-400to600_TuneCP5_PSweights_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 5.212 |
| DYJetsToLL_M-50_HT-600to800_TuneCP5_PSweights_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 1.269 |
| /DYJetsToLL_M-50_HT-800to1200_TuneCP5_PSweights_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 0.5696 |
| DYJetsToLL_M-50_HT-1200to2500_TuneCP5_PSweights_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 0.1331 |
| /DYJetsToLL_M-50_HT-2500toInf_TuneCP5_PSweights_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 0.002983 |
| /WJetsToLNu_TuneCP5_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 53550 |
| TTTo2L2Nu_TuneCP5_13TeV-powheg-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 687.1 |
| TTToSemiLeptonic_TuneCP5_13TeV-powheg-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 687.1 |
| /ST_tW_top_5f_NoFullyHadronicDecays_TuneCP5_13TeV-powheg-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 32.45 |
| /ST_tW_antitop_5f_NoFullyHadronicDecays_TuneCP5_13TeV-powheg-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 32.51 |
| /GJets_DR-0p4_HT-100To200_TuneCP5_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 5036 |
| /GJets_DR-0p4_HT-200To400_TuneCP5_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 1128 |
| /GJets_DR-0p4_HT-400To600_TuneCP5_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 126.4 |
| /GJets_DR-0p4_HT-600ToInf_TuneCP5_13TeV-madgraphMLM-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 41.24 |
| /WW_TuneCP5_13TeV-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 75.90 |
| /WZ_TuneCP5_13TeV-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 27.56 |
| /ZZ_TuneCP5_13TeV-pythia8/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v1/MINIAODSIM | 12.14 |

# N-1 Tests – H/E Example




From CMS AN-2018/143