Electron and photon performance in CMS in Run2

Anshul Kapoor
Institute of high energy physics
CAS, Beijing

The 6th China LHC Physics Workshop
7th November 2020

Basic idea

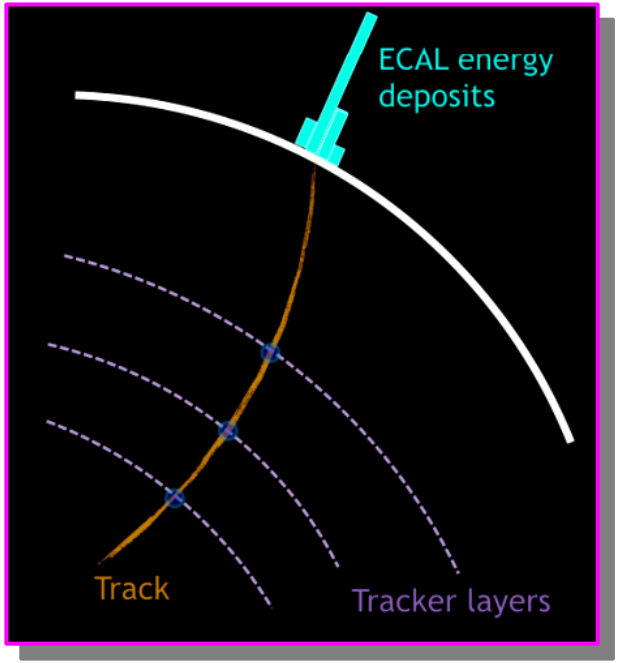
Performed Online (Trigger) and Offline

Today we will focus on online reconstruction
(Offline reconstruction is similar but optimized for speed)

Basic properties used for identification are similar in offline and online algorithms

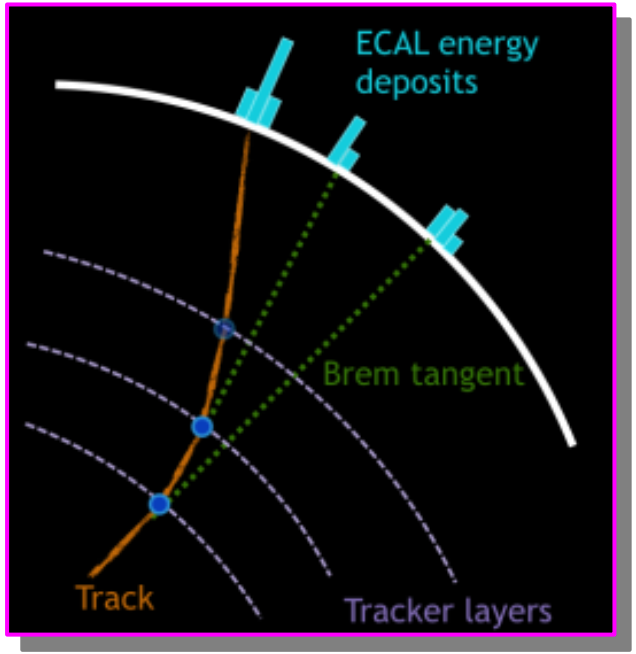
Energy correction is primarily done at online reconstruction

Signature of electrons



Track + Energy Deposit = Electron Candidate

Signature of electrons



Track + Energy Deposit = Electron Candidate

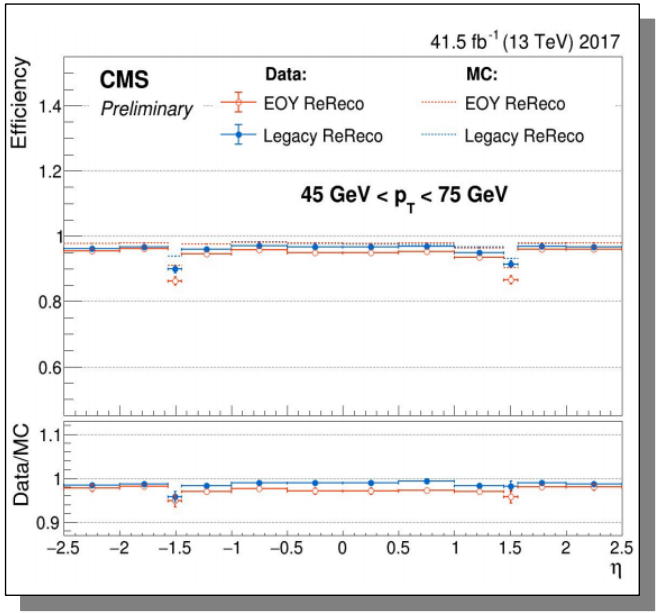
Well, there are other complications:
Bremsstrahlung: Electron can brem in tracker

This leads to multiple energy deposits in ECAL
Corresponding brem tangents need to be drawn
The deposits are attributed and added to total energy

Tracking needs to take into account brems:
Special Gaussian Sum Filter (GSF) tracking

<u>This makes the final electron!</u>

Tracking Efficiency



Electron track reconstruction algorithm is close to 95% efficient!

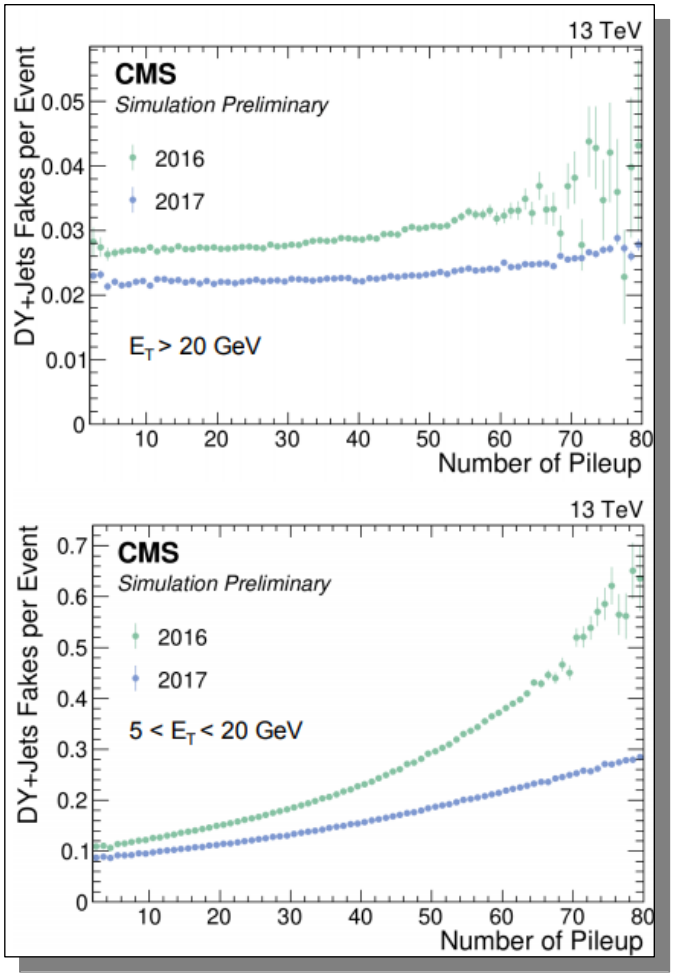
After Legacy reprocessing: Improved calibration, better description of data conditions in Monte Carlo Simulation

The efficiency is measured with the tag-and-probe method and shown as a function of supercluster η

Shown for only a specific pT range for representation purposes

Uncertainty is a combination of statistical and systematic uncertainty!

Lower fake rate



Less fakes in 2017 compared to 2016

This happens because of improvement in tracking due to the new pixel detector in the tracker

The new pixel detector has one additional barrel layer and two additional endcaps.

Fake rate is low even at high pileup

This is true to both high and low E_T

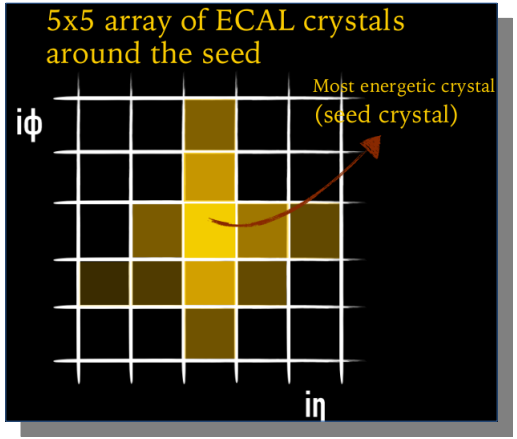
Basic properties used for identification

Shower shape

Isolation

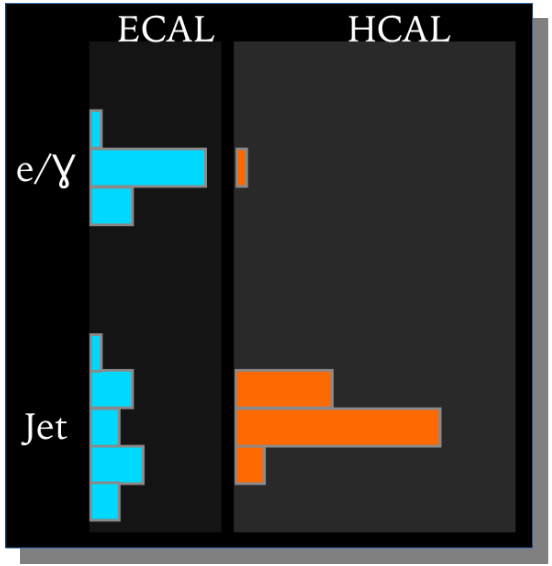
Track-Deposit Compatibility

Looking at two of the shower shape variables!



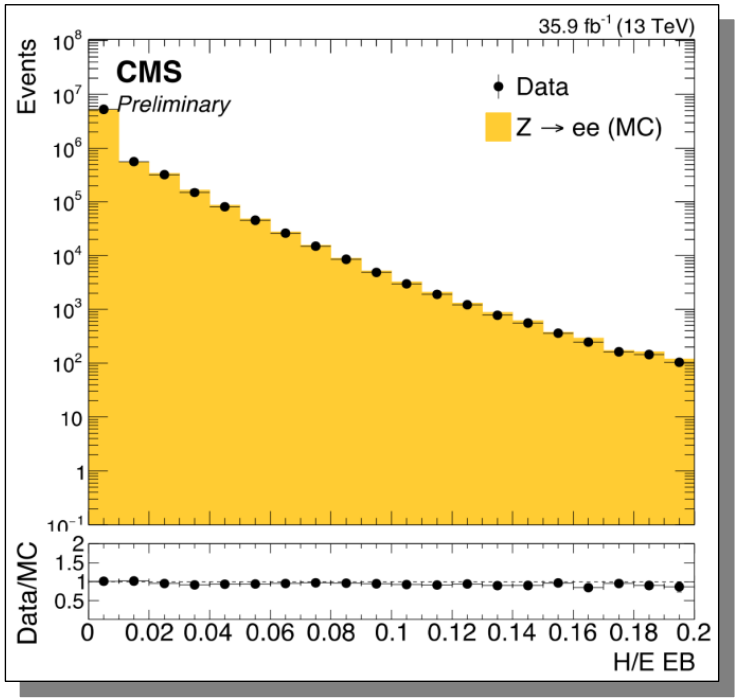
$\sigma_{i\eta i\eta}$ measures spread of a EM shower along η direction

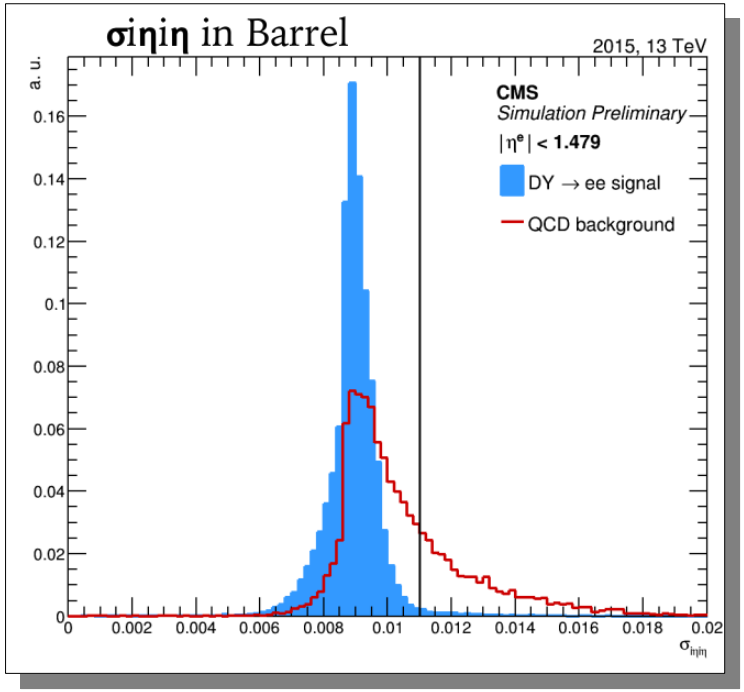
$$\sigma_{i\eta i\eta} = \sqrt{\left(\frac{\Sigma_i^{5\times5} w_i (\eta_i - \bar{\eta}_{5\times5})^2}{\Sigma_i^{5\times5} w_i}\right)}$$



Ratio of energy in ECAL and HCAL can help discriminate from Jets

Shower shape variables

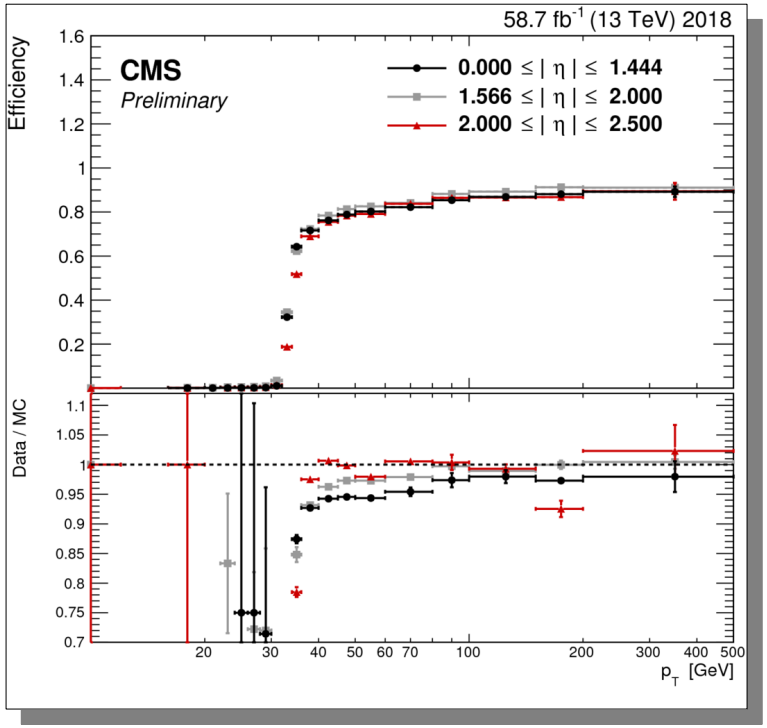


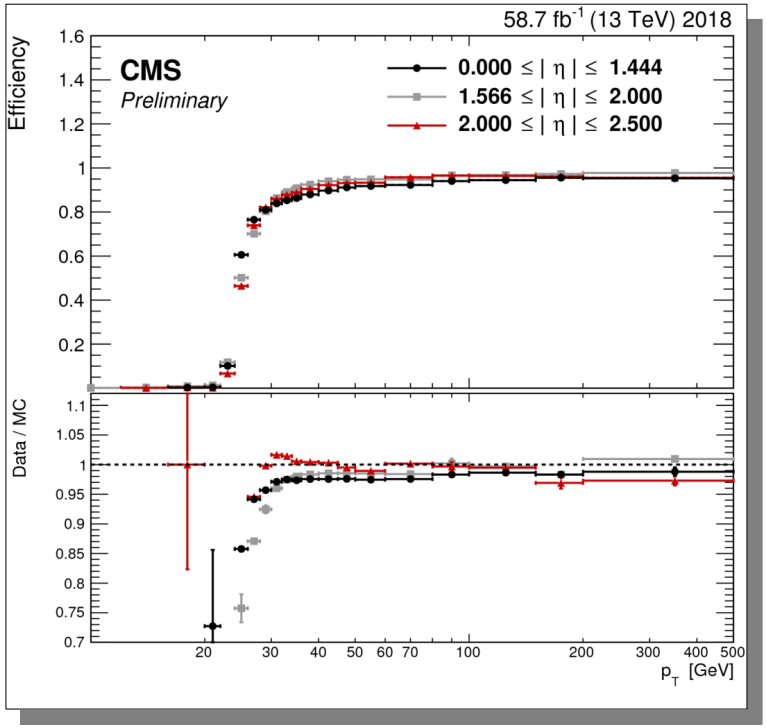


H/E is a very important and useful variable used in both electron and photon identification

Both H/E and $\sigma_{i\eta i\eta}$ are great in signal-background discrimination

Trigger Efficiency





L1+HLT efficiency of single electron trigger (left) and double electron trigger (right) as a function of p_T of offline electron for the year 2018.

<u>80-90% efficient depending on pT</u>

Offline Identification

Various schemes of identification: Different IDs used!

MVA ID

Cut based ID

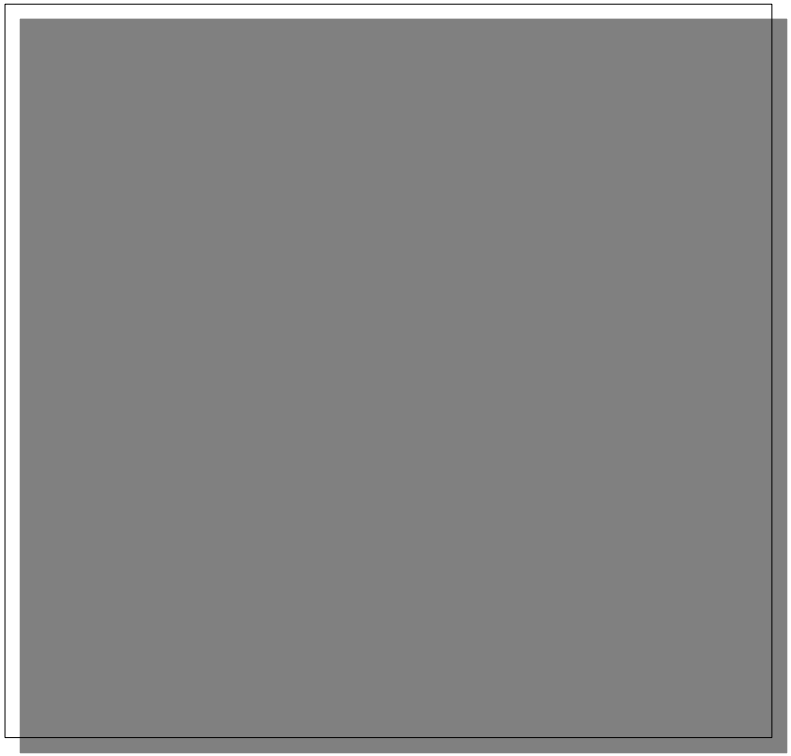
Dedicated high pT Cut based ID (Only for electrons)

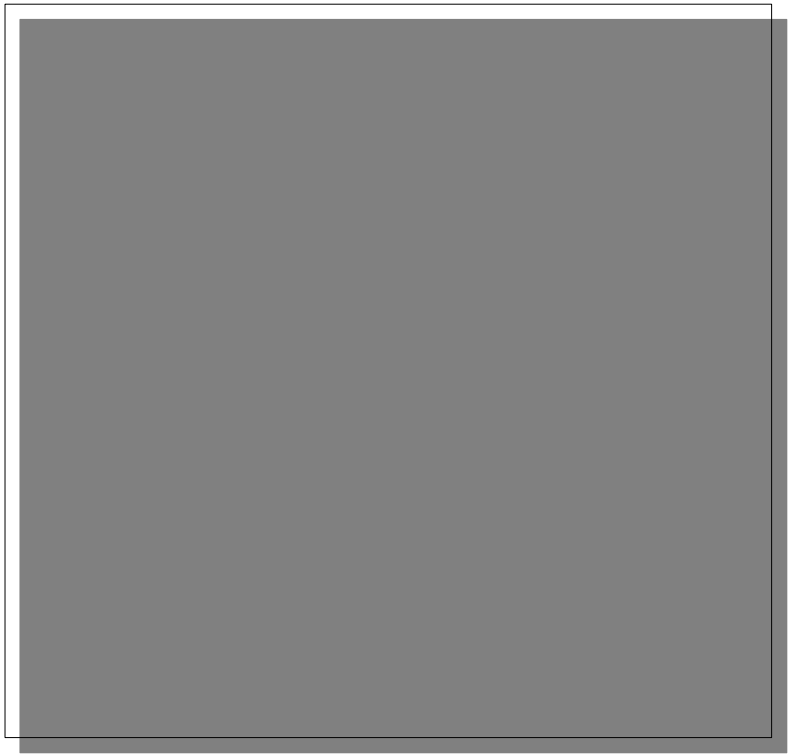
MVA ID maybe trained with and without isolation variables
2 working points: 80% and 90% efficiency respectively!

Cut based ID is a generic ID with different working points available!
Corresponding to the interplay of signal acceptance and background rejection!
Side band studies can be easily performed using only n-1 cuts.

High pT ID is is tuned to perform better at high pT since the generic Cut based ID does not recover all of the electrons.

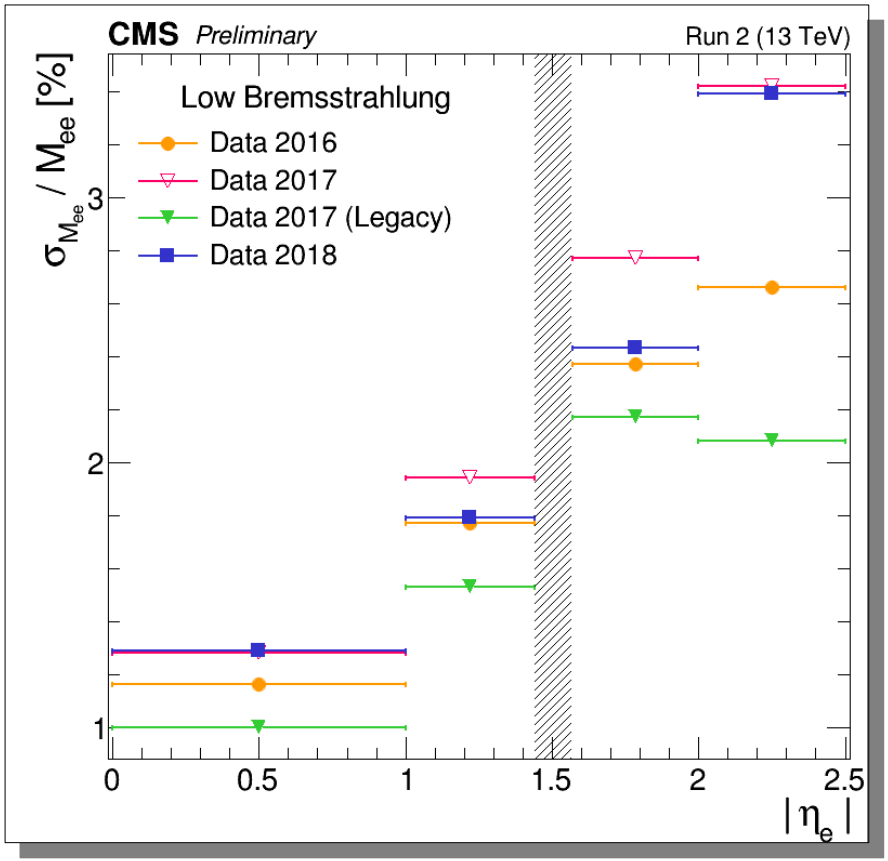
Cut based Medium ID performance





Greater than 80% efficiency for pT>20 GeV for generic IDs
After Legacy reprocessing MC models data really well!

Energy scale and resolution



Multi-step BDT-based energy regression. Energy correction factors obtained from MC, applied on data and simulation

The relative resolution of the reconstructed invariant mass of the Z-boson as a function of the pseudo-rapidity (η) of the electron.

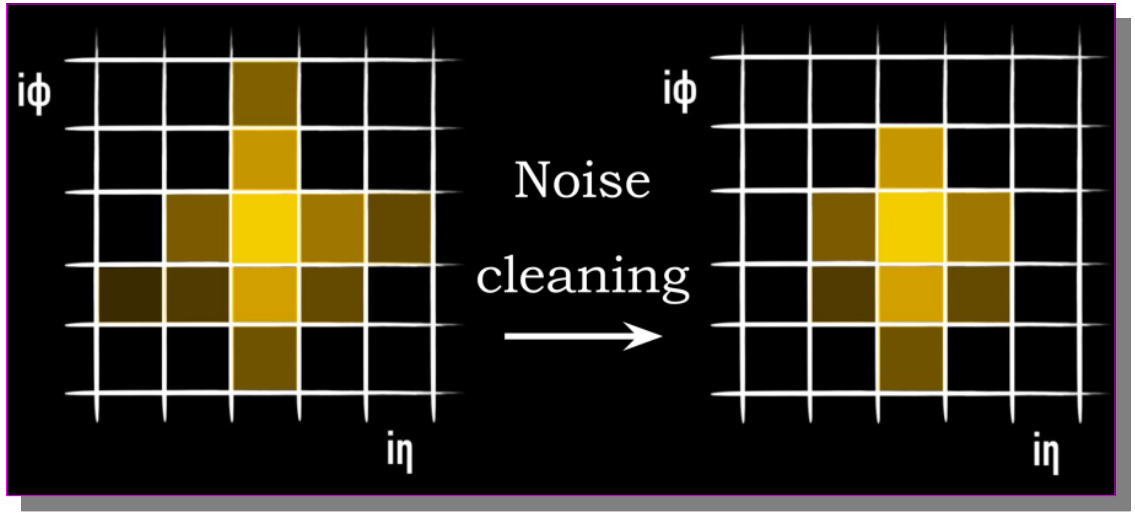
Energy resolution is between 1-3.4% depending on η

~40% improvement in highest η bin in legacy-2017 w.r.t EOY-2017

Run-3 challenges

- Run-3 brings harsher environment for electromagnetic object reconstruction and identification
  Pileup interactions increase
  Noise in the ECAL increases especially in the endcaps by a factor 1.8, 3 and 4 at |η|=1.5, 2.5 and 3 respectively

- Discrimination power of $\sigma_{i\eta i\eta}$ affected by high noise
  Mitigate the effect by noise cleaning using a new **DNN based algorithm**



Summary

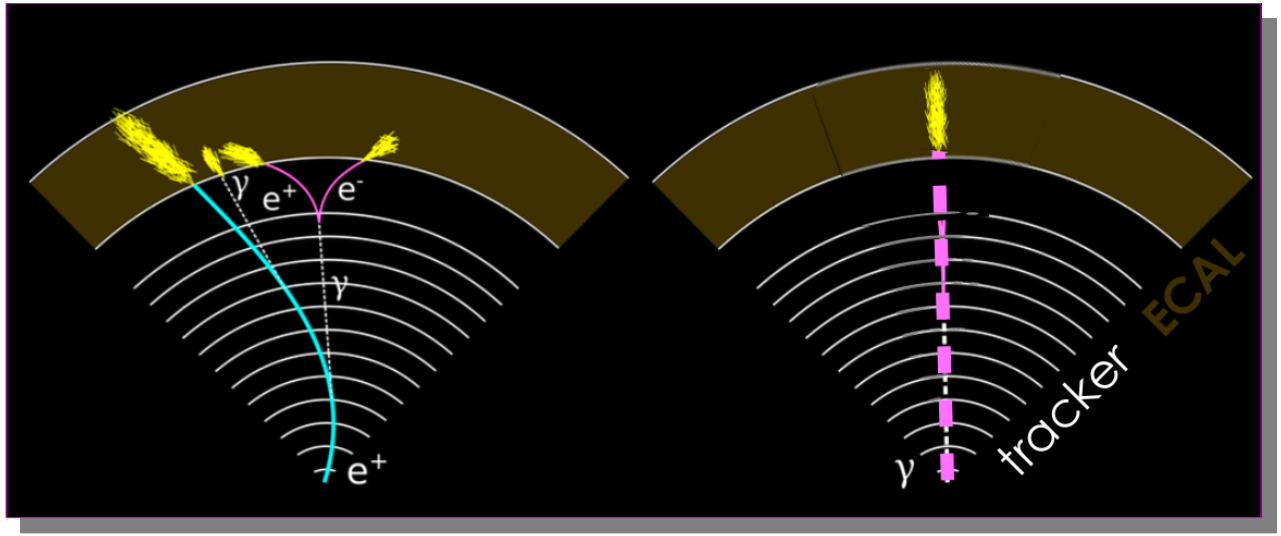
- Highly efficient reconstruction algorithms & identification criteria of electrons/photons play an important role in the physics program of CMS
- For Run-2 the performance was excellent for all different components of reconstruction & identification
- Run-3 challenges are being tackled as we speak. Some already tackled and some are work in progress.

Backup

References

- https://cds.cern.ch/record/2718815/files/DP2020_024.pdf
- https://cds.cern.ch/record/2320638/files/DP2018_017.pdf
- https://cds.cern.ch/record/2714882/files/DP2020_015.pdf
- https://twiki.cern.ch/twiki/bin/view/CMSPublic/CMSEgammaFullRun2PerformancePlotsICHEP2020
- https://cds.cern.ch/record/2718815/files/DP2020_024.pdf
- https://twiki.cern.ch/twiki/bin/view/CMSPublic/CMSEgammaFullRun2PerformancePlotsICHEP2020
- https://twiki.cern.ch/twiki/bin/view/CMSPublic/CMSEgammaFullRun2PerformancePlotsICHEP2020

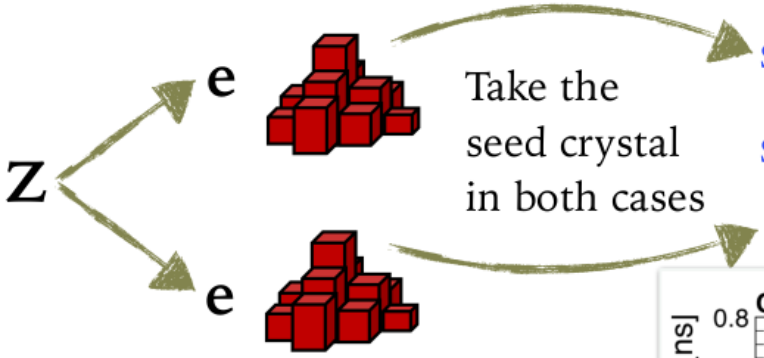
Photons and Electrons



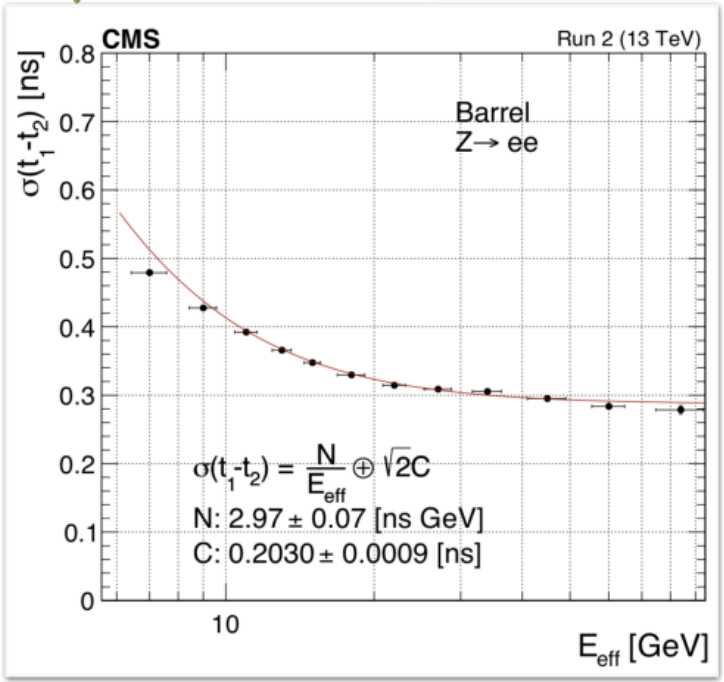
Photons are thus characteristically different from electron because of no track

But both require an interplay of calorimetery and tracking

Time resolution



$$E_{\text{eff}} = \frac{E_1 E_2}{\sqrt{E_1^2 + E_2^2}}$$

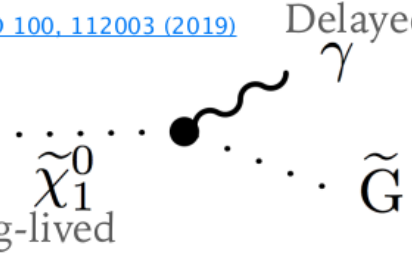


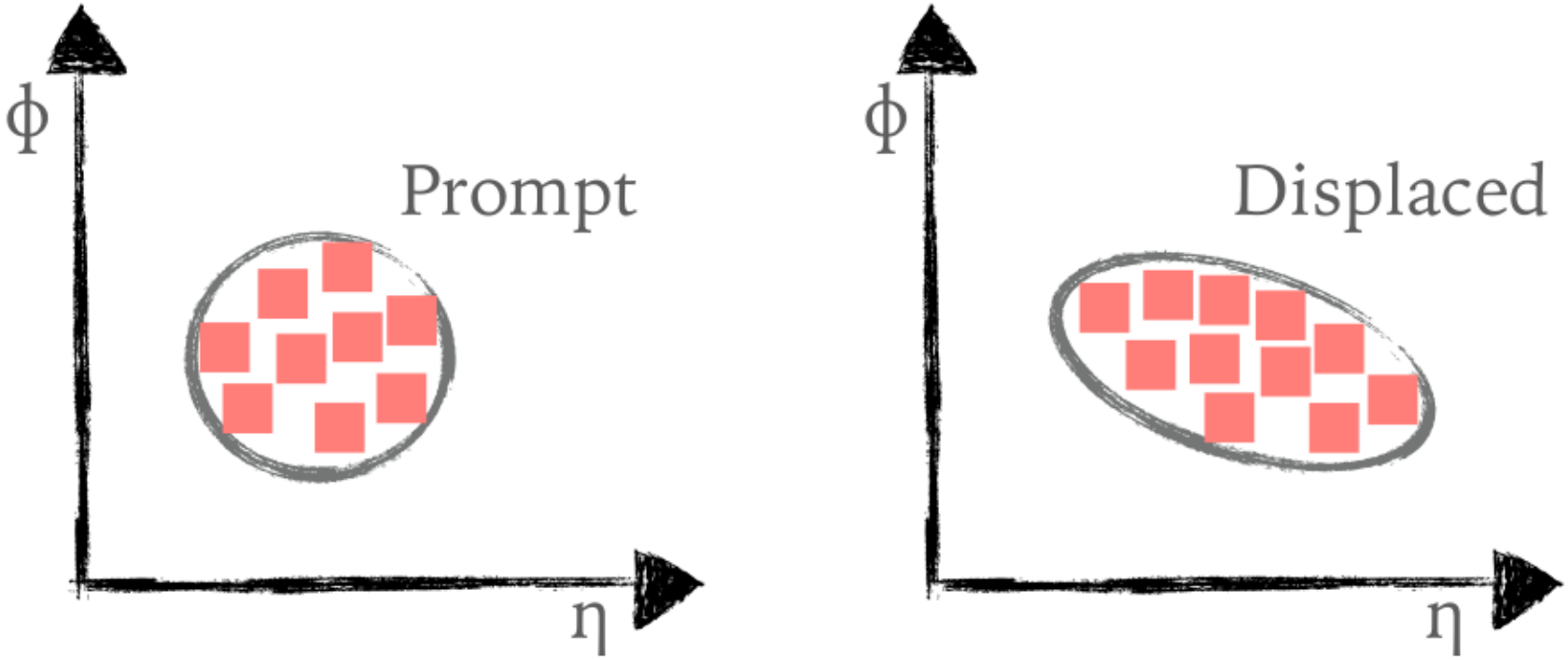
Overall resolution ~300 ps, and constant term ~200 ps.

Searches for long-lived particles profit from this

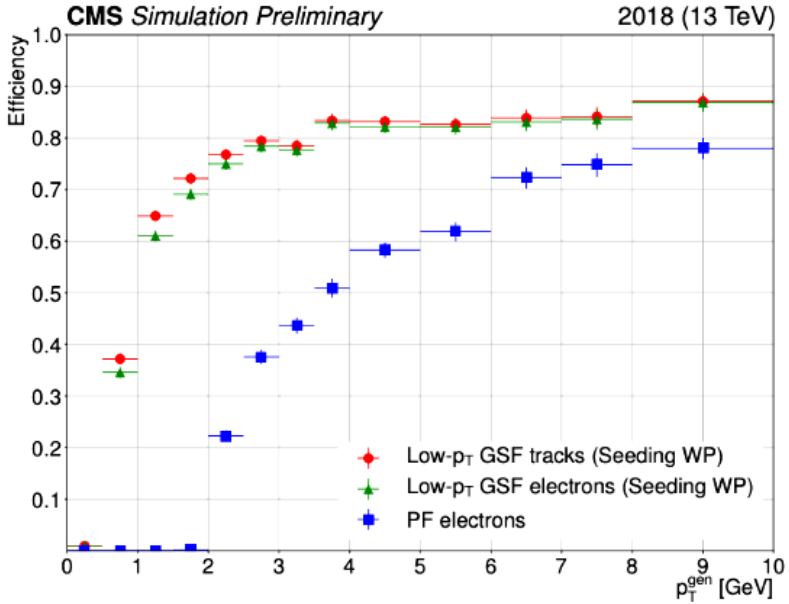
Example:

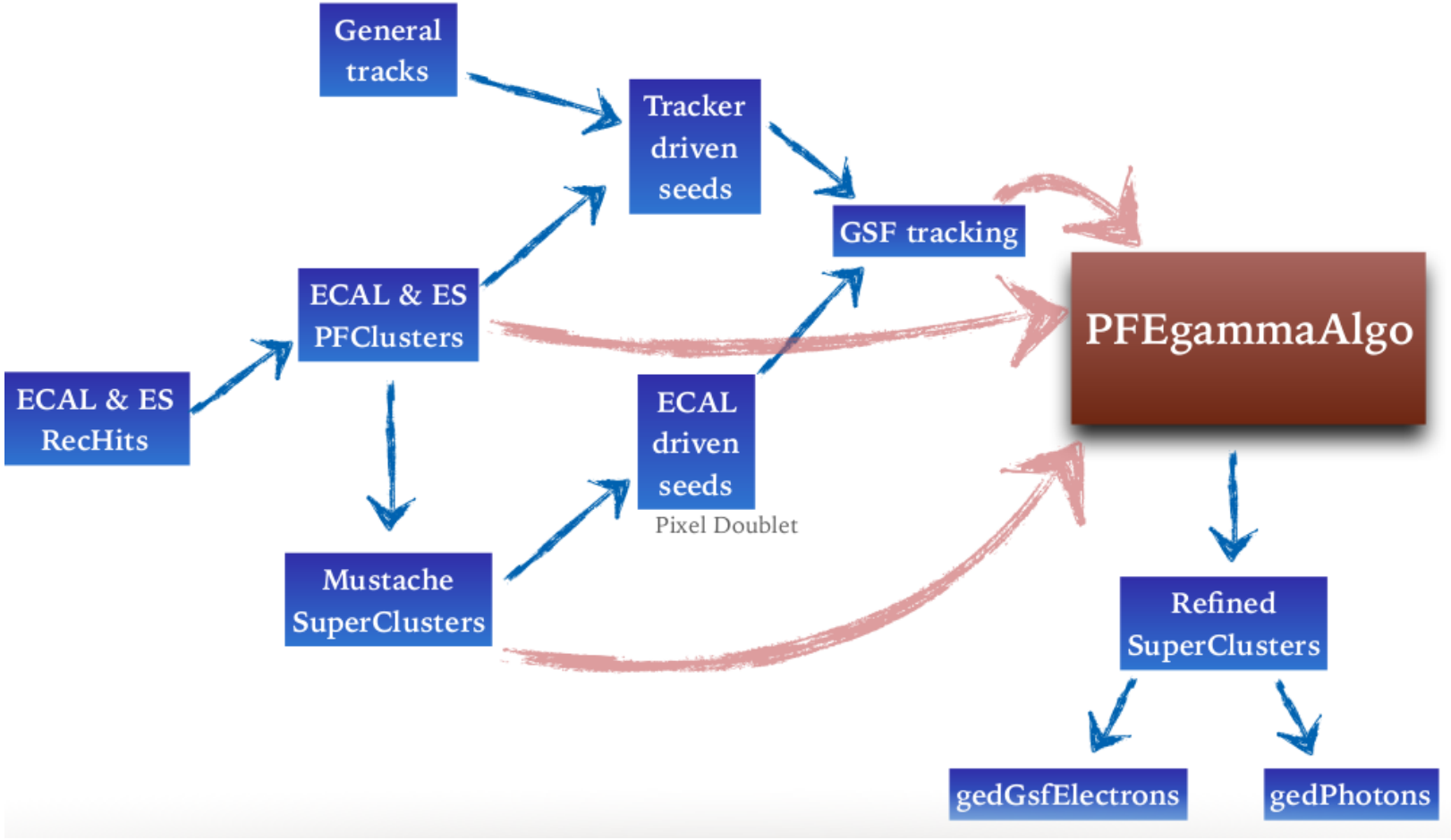
Phys. Rev. D 100, 112003 (2019)




ϕ
Prompt
η
ϕ
Displaced
η

- Custom low-pT electron reconstruction developed for the B Parking data set.
- GSF tracking seeding replaced by a **more computationally efficient logic that identifies low-p_T electron candidates**
- **10% mistag rate** while providing a factor **~2 gain in efficiency**
- However, we require a **sophisticated ID to control purity**




General tracks
Tracker driven seeds
GSF tracking
ECAL & ES PFClusters
ECAL & ES RecHits
PFEgammaAlgo
ECAL driven seeds
Pixel Doublet
Mustache SuperClusters
Refined SuperClusters
gedGsfElectrons
gedPhotons