

# The CMS electron and photon trigger for the LHC Run 2

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on behalf of the CMS collaboration

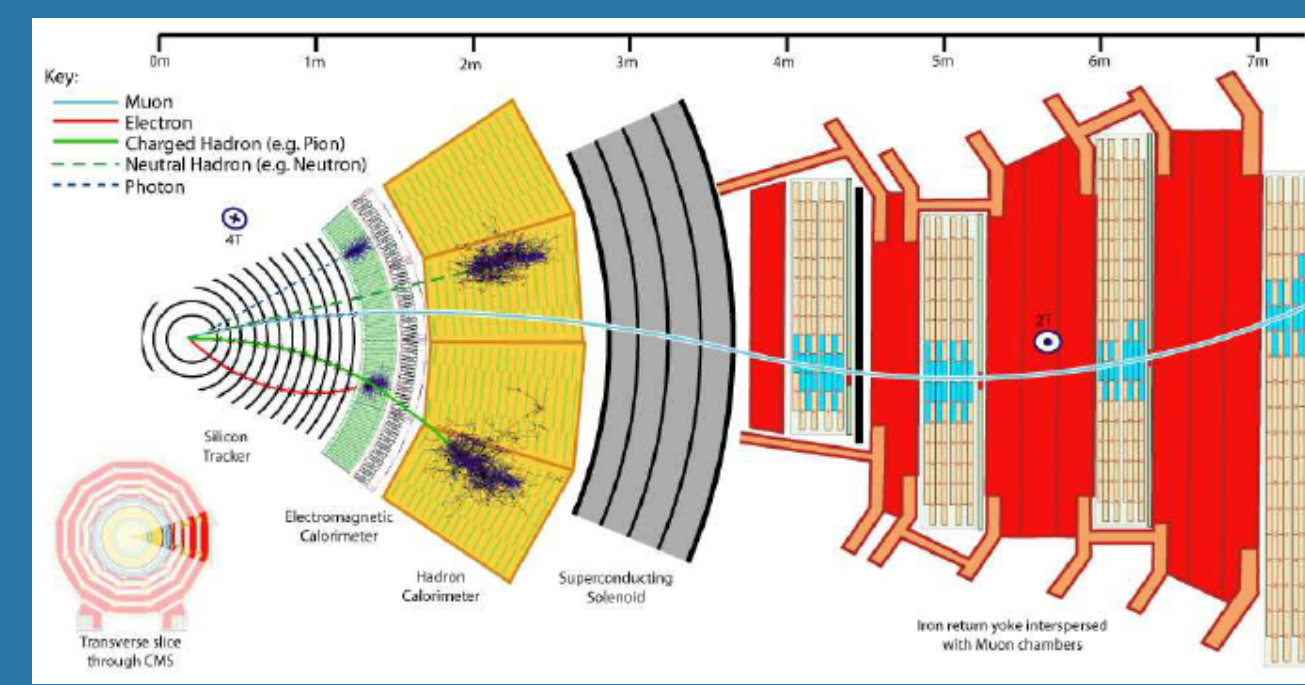
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## Introduction

- ▶ During 2017 the LHC will deliver collisions with an instantaneous luminosity up to  $2 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ 
  - Up to 60 collisions per bunch crossing (pileup, PU)
- ▶ The Level-1 (L1) trigger of CMS was upgraded in 2016:
  - Architecture based on MicroTCA technology
  - Efficient electron and photon ( $e/\gamma$ ) identification
- ▶ L1  $e/\gamma$  algorithm retuned in 2017 to fully exploit the potential of the system

## The CMS Electromagnetic Calorimeter (ECAL)

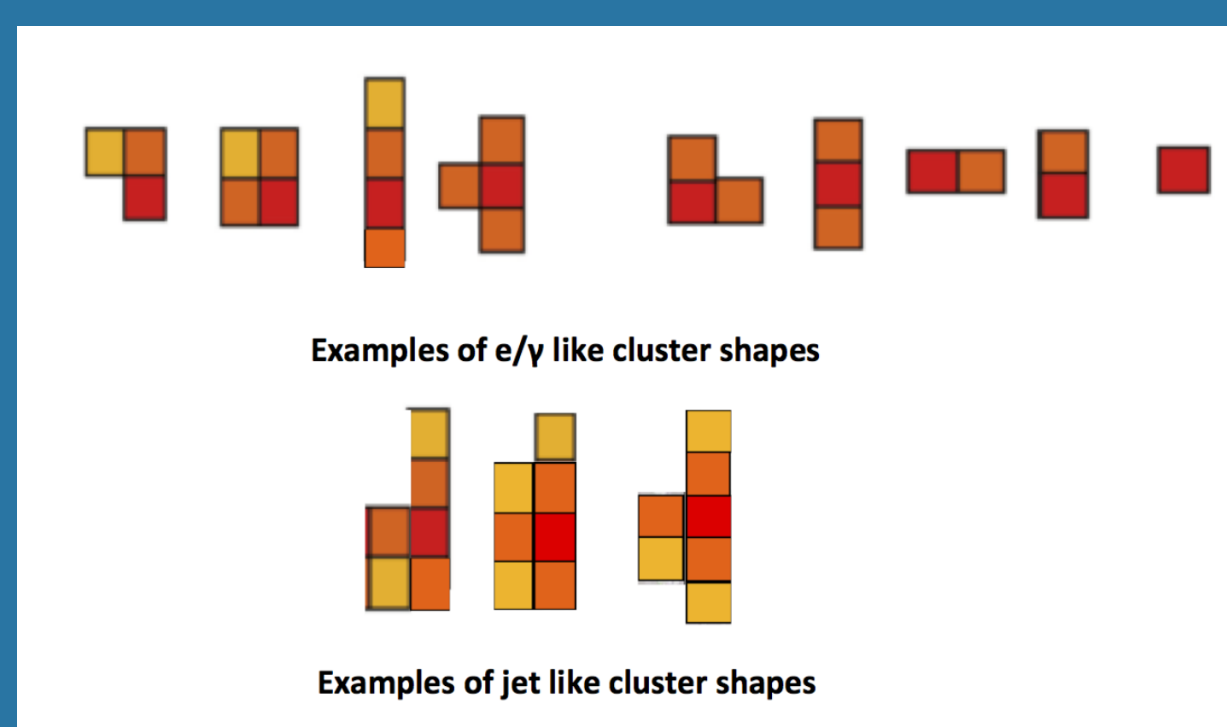
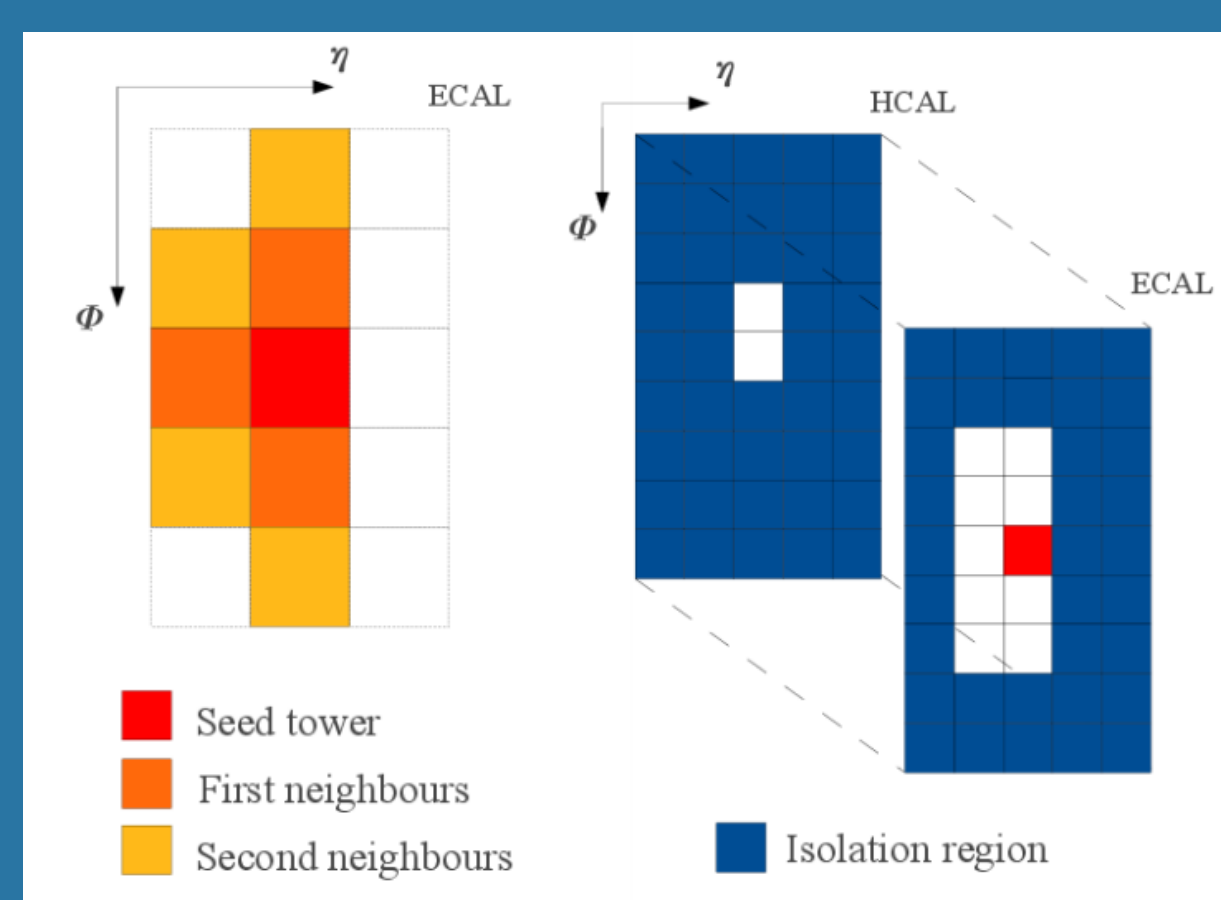


- ▶ The CMS ECAL is a hermetic, homogeneous calorimeter made of scintillating lead tungstate crystals
- ▶ L1  $e/\gamma$  trigger based on elements (trigger towers, TT) of the ECAL and the hadronic calorimeter (HCAL)

## Algorithm & Performance

### Identification of $e/\gamma$ candidates

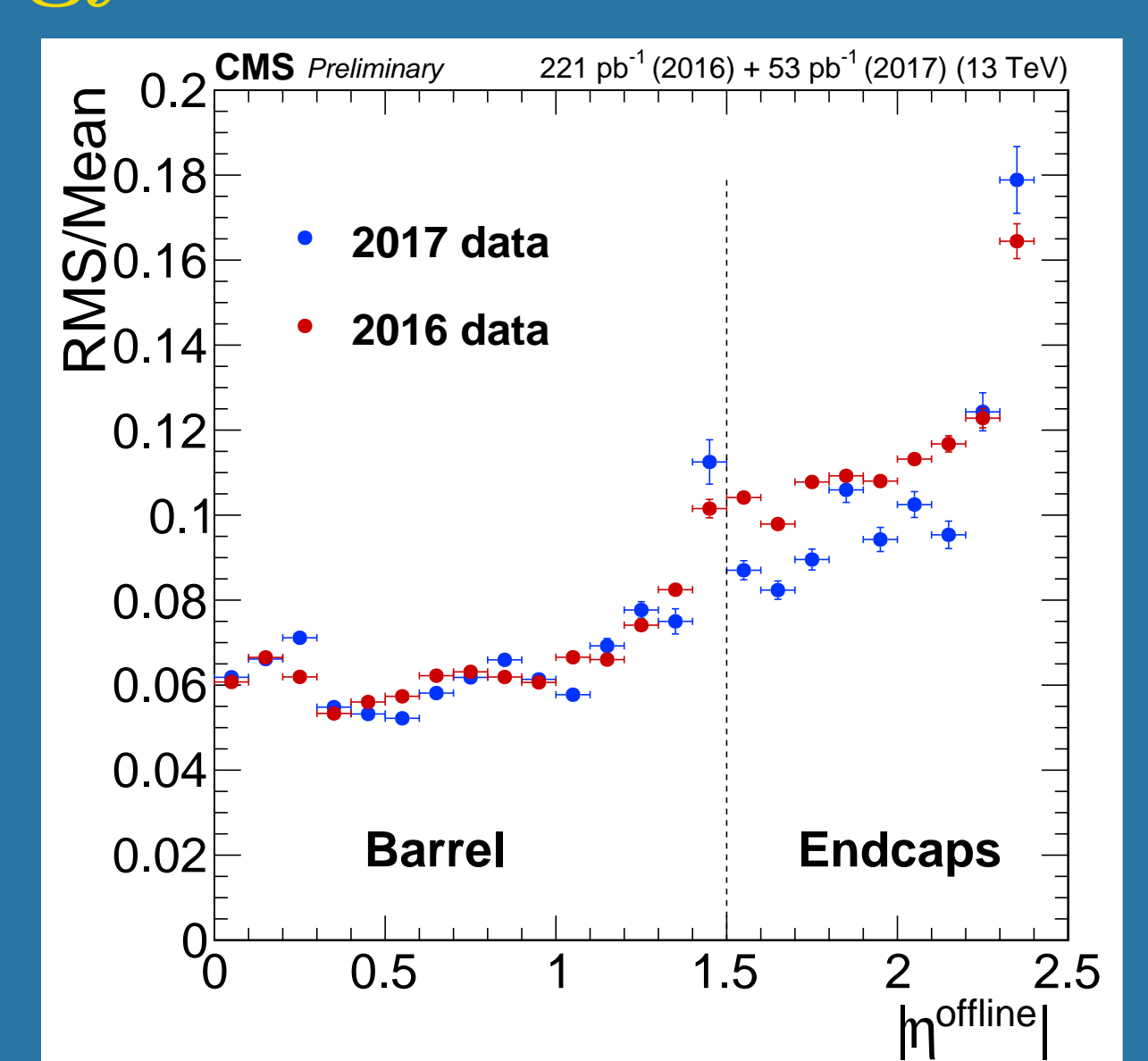
- ▶ Dynamic Clustering of ECAL and HCAL TTs
  - Recovery energy loss due to bremsstrahlung, improved energy resolution
- ▶ Energy of  $e/\gamma$  from sum of energy of TTs
  - Calibration to further improve energy resolution



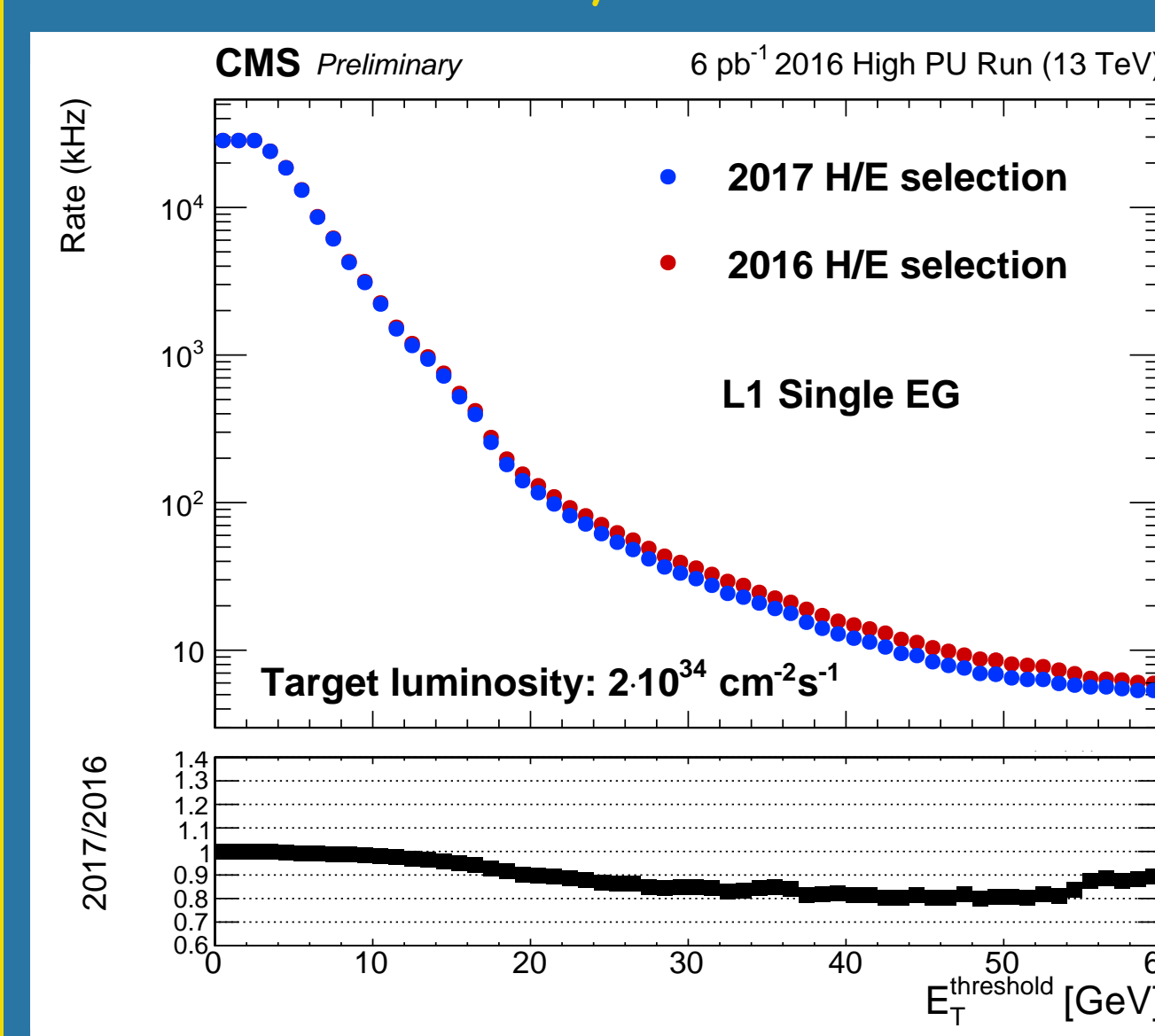
- ▶ Rejection of jets using energy in HCAL (H/E)
- ▶ Shape veto to exclude jet-like candidates, 99.5% efficient on  $e/\gamma$
- ▶ Selection of isolated candidates to reject low  $E_T$  jets

### Level-1 $e/\gamma$ energy resolution

- ▶ Energy of L1  $e/\gamma$ :
 
$$E^{L1} = E_{RAW}^{L1} \times C(E_{RAW}^{L1}, |\eta|, PU)$$
- ▶ Calibrated to match energy of offline reconstruction
- ▶ In 2017 higher PU but similar or better resolution than 2016



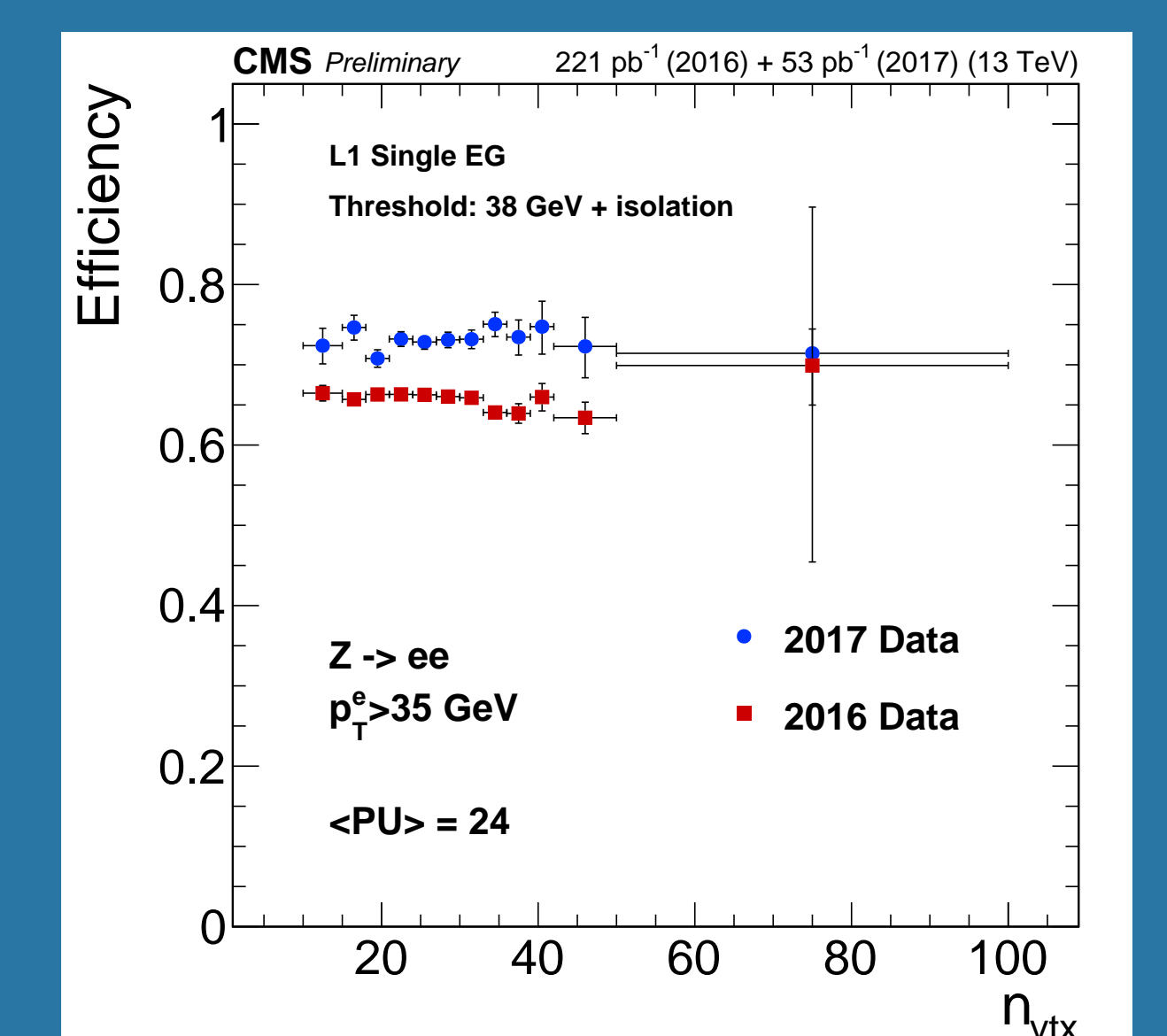
### H/E



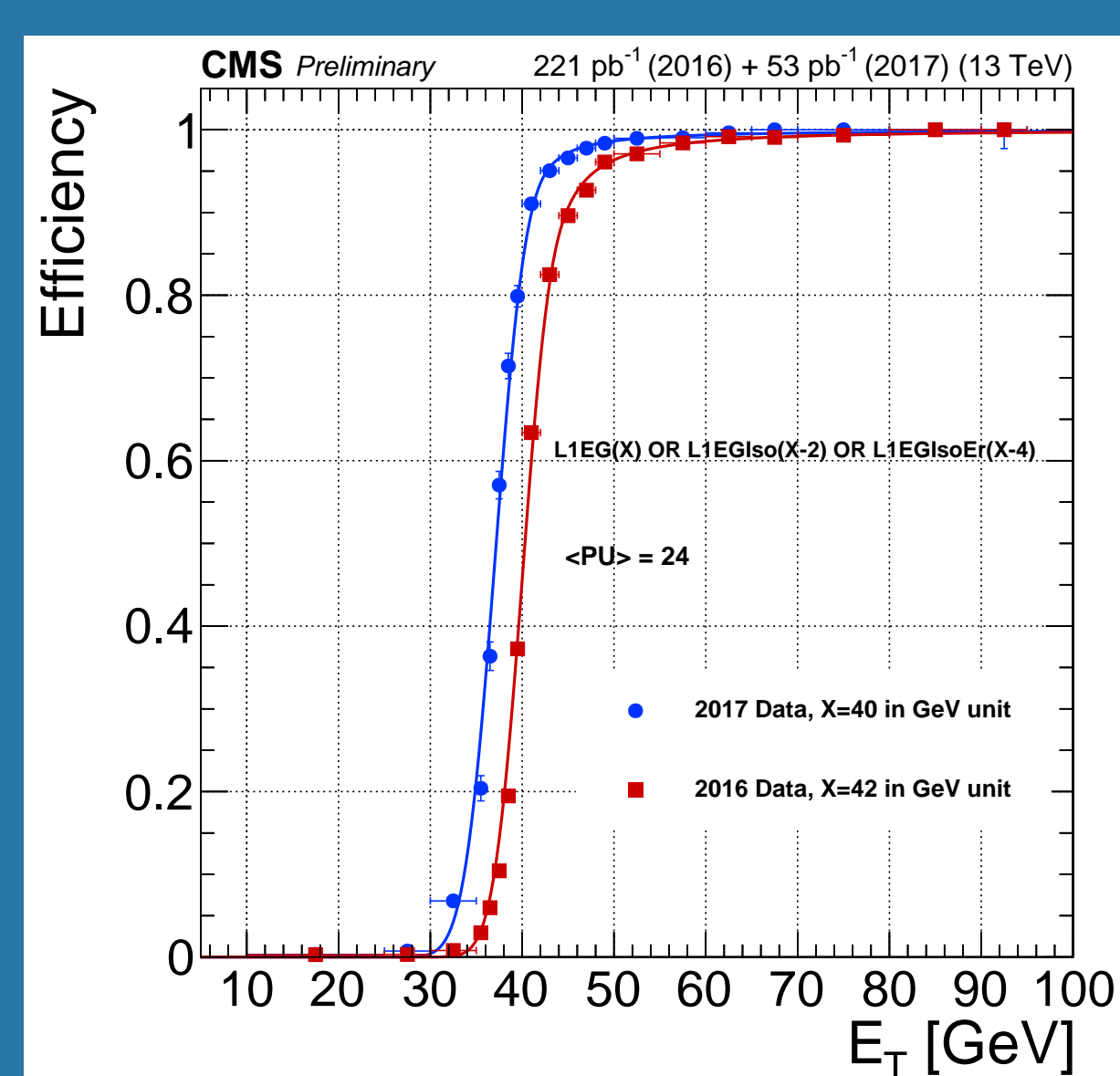
- ▶ HCAL/ECAL TTs energy
- ▶ In 2016 for seed only
- ▶ Since 2017 on a  $3 \times 3$  matrix around the seed:
  - 20% rate reduction
  - No efficiency loss

### Isolation

- ▶ Energy deposit in a  $6 \times 9$  ( $\eta, \phi$ ) TTs window
- ▶ Candidates are isolated if  $E_{6 \times 9} - E_{e/\gamma} < \lambda(\eta, E_{e/\gamma}, PU)$
- ▶ In 2017 new thresholds  $\lambda$ , higher efficiency than 2016



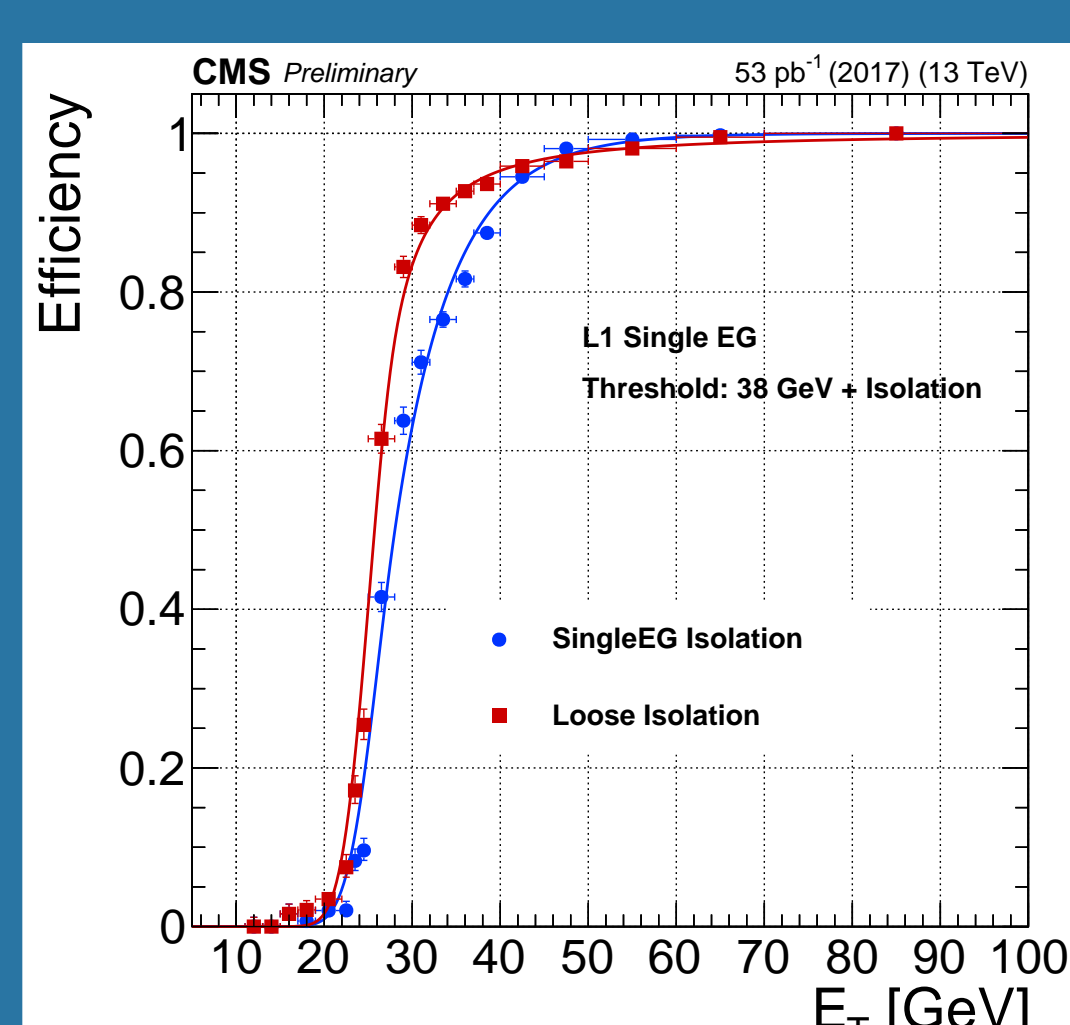
### Performance



- ▶ Isolation and H/E retuned for LHC running conditions expected in 2017:
  - Efficiency plateau at lower  $E_T$  in 2017 data than 2016
  - Same trigger rate
- ▶ Efficiency curve for combination of all single  $e/\gamma$  L1 triggers in 2017

## Cross-triggers

- ▶ Targeting physical processes with  $e/\gamma$  candidates and other objects:
  - Multiple  $e/\gamma$  candidates
  - $e/\gamma + \mu$  or  $\tau$  candidates
  - $e/\gamma + \text{jets}$  or  $E_T$
- ▶ Second isolation thresholds designed to increase acceptance at low  $E_T$  for  $e/\gamma$  in cross seeds



## Transverse mass trigger: $W \rightarrow e\nu$ pilot study

- ▶ Upgraded L1 trigger allows sophisticated algorithms:
  - Isolated  $e/\gamma$  candidate with  $E_T > 33 \text{ GeV}$
  - Transverse mass  $M_T = \sqrt{2E_T E_T^{e/\gamma} (1 - \cos(\Delta\phi))} > 40 \text{ GeV}$
- ▶ Validated on electron calibration stream, used for ultimate precision ECAL intercalibration
  - Acceptance recovery of  $\sim 10\%$ , lower  $e/\gamma$   $E_T$  threshold
- ▶  $W \rightarrow e\nu$  trigger for luminosity higher than  $2 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$

[1] CMS collaboration, A. Zabi, *The CMS Level-1 Calorimeter Trigger Upgrade for the Run II of the LHC*, PoS TIPP2014 (2014) 414. 6 p.

[2] CMS collaboration, S. Chatrchyan et al., *Energy Calibration and Resolution of the CMS Electromagnetic Calorimeter in pp Collisions at  $\sqrt{s} = 7 \text{ TeV}$* , JINST 8 (2013) P09009, [1306.2016].