EGAMMA HLT

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Introduction

- For low luminosity 2×10^{33} $cm^{-2}s^{-1}$:
  - We assume a Level1 trigger rate of 50 kHz
  - We apply a safety factor of 3 and set the L1 rate at 17 kHz
  - HLT output is fixed at 150 Hz (was 100 Hz in DAQ TDR)

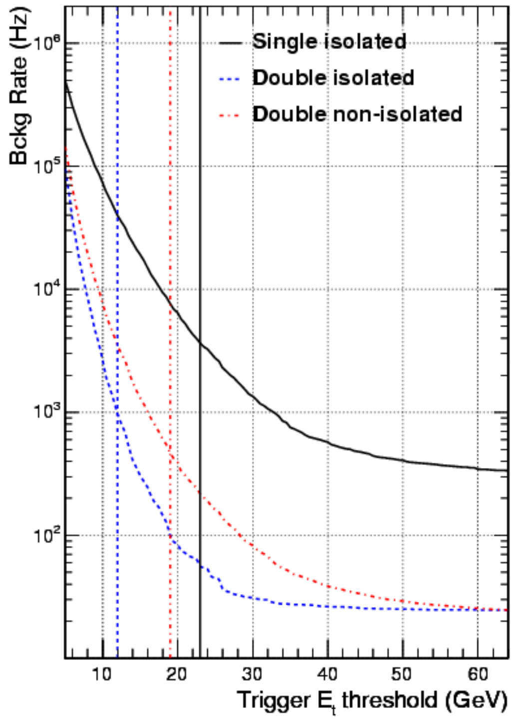
- The allowed CPU time is computed with the nominal 50 KHz and is estimated to be 40 msec per event (based on the old idea of having 2000 Dual CPU PCs)
- HLT for electrons and photons was studied for the Physics TDR for the low luminosity of 2×10^{33} $cm^{-2}s^{-1}$
- Main improvement compared to the DAQ TDR: possible set of isolation requirements was indicated for electrons and photons
- Now HLT selection is included in CMSSW and algorithms are more realistic than in ORCA

Level 1 EM Trigger

- The L1 EM trigger candidates can be isolated or non-isolated
- Isolated candidates are required to satisfy electromagneticity cuts also on the 8 neighbouring trigger towers
- Four trigger types are currently envisaged:
  - Single Isolated
  - Single Non-Isolated (or Relaxed)
  - Double Isolated
  - Double Non-Isolated (or Relaxed)
- The Et range of the L1 EM trigger towers is from 0 to 63 GeV
- For L1 candidates exceeding a given threshold all cuts can be removed (including e/h) (was 63 GeV for the PTDR and it should be now 50 GeV)

L1 Rate and Efficiency (PTDR) $2x10^{33}$ $cm^{-2}s^{-1}$

Jet events



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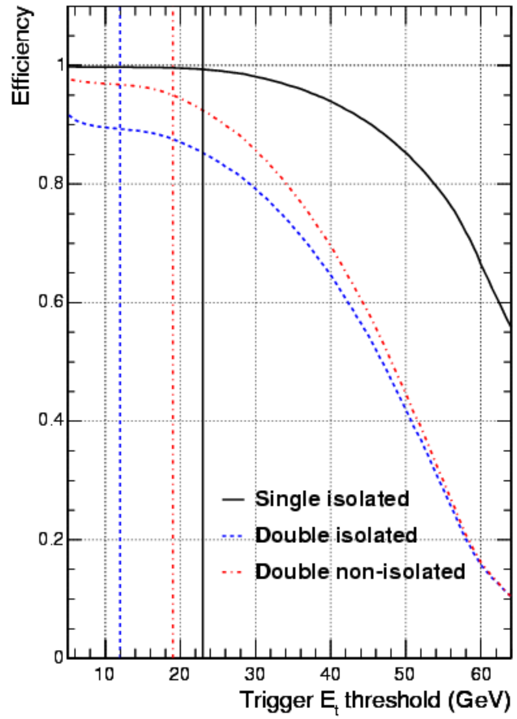

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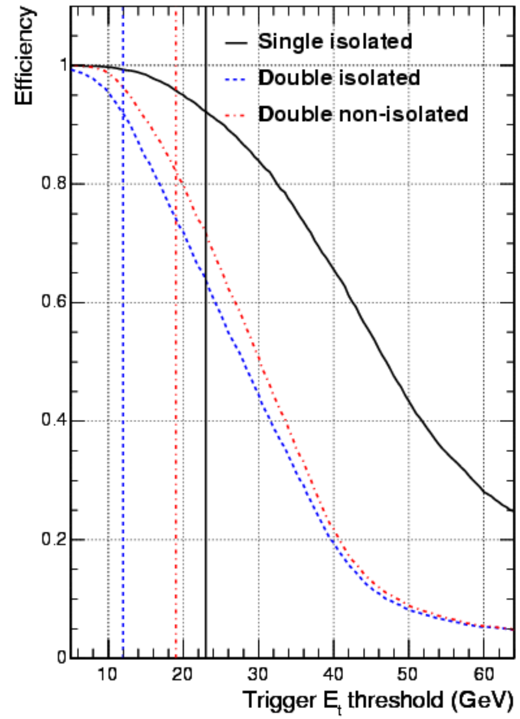
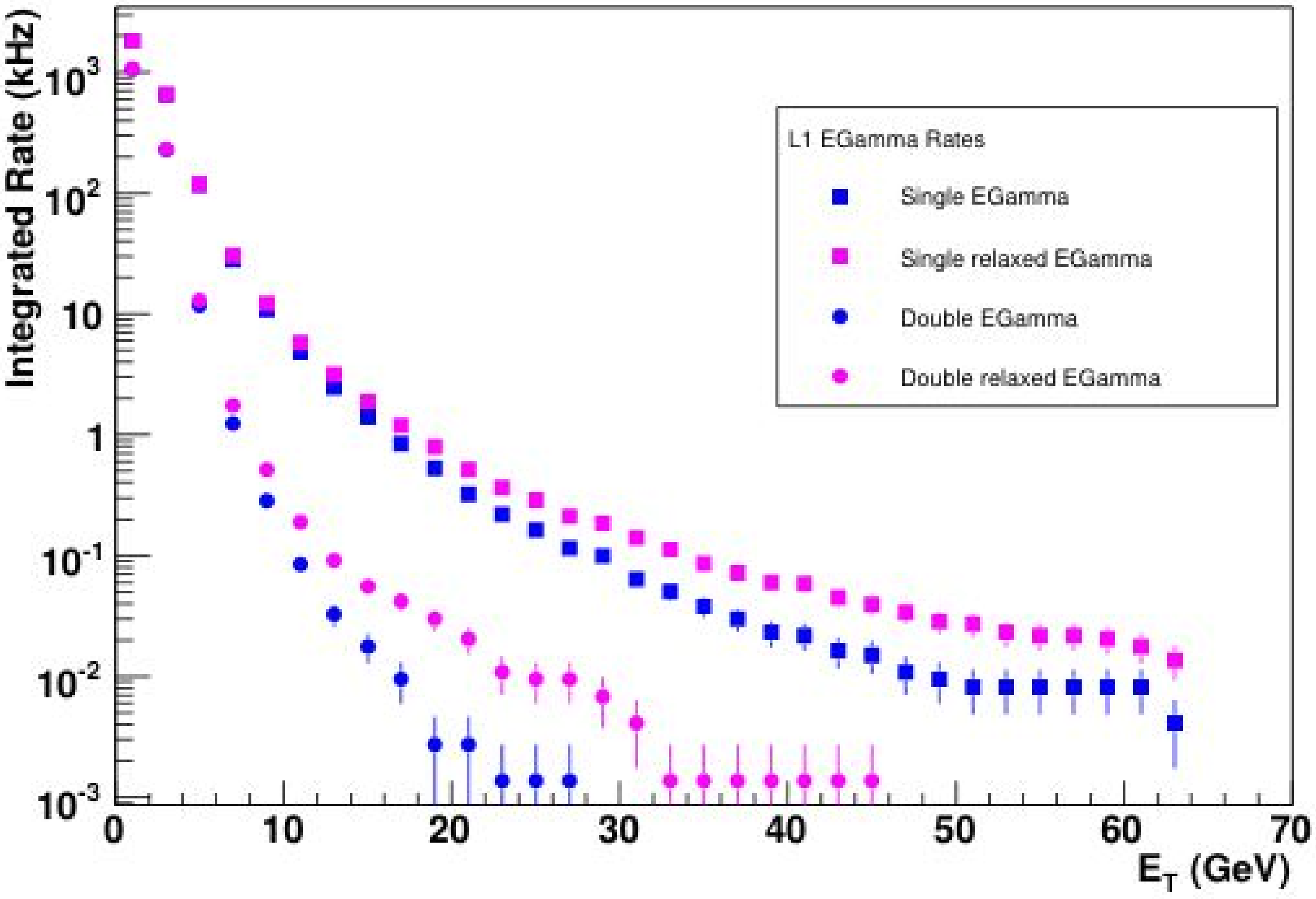


- L1 Et thresolds:
  - Single isolated: 23 GeV
  - Double relaxed: 12 GeV
  - Double relaxed: 19 GeV

L1 Rates (CMSSW) $1x10^{32}$ $cm^{-2}s^{-1}$



Level1 Rate and Efficiency (PTDR)

Single isolated	Double isolated	Double non-isolated	Total
3400 Hz	1010 Hz	420 Hz	4440 Hz

- L1 Rate dominated by jet events

Signal Process	Single isolated	Double isolated	Double non-isolated	Total
$H \to \gamma\gamma$ ($M_H = 120$ GeV)	99.3%	89.2%	94.7%	99.7%
$H \to ZZ \to e^+e^-e^+e^-$ ($M_H = 120$ GeV)	90.8%	89.5%	79.5%	96.5%
$Z \to e^+e^-$	93.5%	81.0%	85.1%	97.1%
$W \to e\nu$	89.8%	2.7%	2.0%	90.0%

- Efficiencies are computed requiring two generator level candidates to satisfy preselection cuts and to be in the ECAL fiducial region ($|\eta|<1.4442$ or $1.566<|\eta|<2.5$):

EGAMMA HLT Paths (PTDR)

The Egamma HLT paths used in PTDR analysis and DAQ TDR are the following:

Level 1	HLT electron	HLT photon
L1 single Isolated	•SingleElectron	•SinglePhoton
L1 double Isolated	•DoubleElectron	•DoublePhoton
L1 double Relaxed	•DoubleElectronRelaxed	•DoublePhotonRelaxed

Isolated and Relaxed paths at HLT only differ for Et thresholds that are matched with the Level 1 Et thresholds

HLT Selection Requirements (PTDR and CMSSW)

- Electrons:
  - Supercluster matched with L1 triggers with energy satisfying the L1 trigger threshold
  - HCAL Et within ΔR<0.15 from the candidate less than a threshold
  - Pixel match (or inner SiStrip matching)
  - E/P for single electron trigger
  - P_t Tracks with 0.02< ΔR<0.2 divided by P_t electron less than a threshold
- Photons:
  - Supercluster matched with L1 triggers with energy satisfying the L1 trigger threshold
  - ECAL Et within 0.3 from the candidate less than a threshold
  - HCAL Et within 0.3 from the candidate less than a threshold
  - Number of tracks with ΔR<0.3 from the photon candidate less than a threshold

- The HLT selection for the PTDR ($L=2x10^{33}$ cm^{-2} s^{-1}) and CMSSW is the same.
- For $L=1x10^{32}$ cm^{-2} s^{-1} we only lowered Et thresholds.

HLT Selection Cut Values (PTDR) $L=2x10^{33}$ cm^{-2} s^{-1}

	Single Electron	Double Electron	Single Photon	Double Photon
$\|\eta\|$	< 2.5	< 2.5	< 2.5	< 2.5
E_t	> 26 GeV	> 12(19) GeV	> 80 GeV	> 30, 20 GeV
TK isol	< 0.06	< 0.4	< 1	< 3
HCAL isol barrel	< 3 GeV	< 9 GeV	< 6 GeV	< 8 GeV
HCAL isol endcaps	< 3 GeV	< 9 GeV	< 4 GeV	< 6 GeV
ECAL isol	-	-	< 1.5 GeV	< 2.5 GeV
E/P Barrel	< 1.5	-	-	-
E/P Endcaps	< 2.45	-	-	-

HLT Efficiency for Electrons and Photons (PTDR)

Signal Process	Single electron	Double electron	Total
$W \to e\nu$	68.0%	–	68.0%
$Z \to e^+e^-$	81.2%	76.7%	89.5%
$H \to ZZ \to e^+e^-e^+e^-$ ($M_H = 120$ GeV)	76.9%	83.2%	90.2%

Signal Process	Single photon	Double photon	Total
$H \to \gamma\gamma$ ($M_H = 120$ GeV)	14.0%	85.8%	87.4%
$H \to \gamma\gamma$ ($M_H = 120$ GeV) After analysis cuts	16.9%	96.9%	97.2%
$Z \to e^+e^-$	–	68.9%	68.9%
$H \to ZZ \to e^+e^-e^+e^-$ ($M_H = 120$ GeV)	–	57.8%	57.8%

Efficient also for double electron processes

HLT Output Rates

	Signal		Background		Total
Single electron (E_t >26 GeV)	$W \to e\nu$ $Z \to e^+e^-$	9.8 Hz (11.6 Hz) 1.3 Hz (1.5 Hz)	Jets	9.4 Hz	21 Hz
Double electron (E_t^1, E_t^2 >12 GeV)	$Z \to e^+e^-$	1.1 Hz (1.3 Hz)	Jets	0.8 Hz	1.9 Hz
Single photon (E_t >80 GeV)	$\gamma + \text{jet}$	2.1 Hz	Jets	1.4 Hz	3.5 Hz
Double photon (E_t^1 >30, E_t^2 >20 GeV)		~0 Hz	Jets $\gamma + \text{jet}$	1.9 Hz 0.4 Hz	2.3 Hz
Total:		13.3 Hz		13.9Hz	27.2 Hz

HLT Exercise (Egamma part)

- Aimed at a LHCC report beginning of July 2007
- The main emphasis has finally been to optimize the algorithms and evaluate the CPU time needed for the HLT
- The selection was modified for luminosity $1x10^{32}$ $cm^{-2}s^{-1}$
- We only reduced Et thresholds and included single paths from non-isolated L1 triggers
- Two new paths were added for very high EM objects:
  - No distinciton between electrons and photons
  - Looser (or no) isolation cuts

- Mainly due to the delays in the L1 Emulator that was only usable a couple of months ago, the selection was not optimized
- Other paths use the same producers (e+mu and e+jet for example)

Current Implementation

- For the first time the HLT was coded thinking about the speed of the algorithms

- CMSSW/HLT Framework requirements:
  - Data and collections in the event, once put in, cannot be modified
  - Execution paths must be predetermined
  - Trigger paths are independent one from the other and are made by a succession of producers and filters. Once a filter rejects the event the path execution is stopped
  - If the same producer is needed in one of the paths that are run later it does not rerun

- We took some time to understand how to cope with these requirements but we finally got to an acceptable prototype

Regional Reconstruction

- We (Egamma) insisted since the beginning for having regional reconstruction at all levels
  - Finally it was accepted that this is needed by everybody
- We are ready to perform Regional Reconstruction in the most important areas:
  - ECAL FED unpacking:
  - ECAL RecHit production
  - ECAL Clustering
  - Track finding
- Still missing:
  - Pixel unpacking and recHit
  - SiStrip unpacking and recHit (will come with 1_5_0)
  - HCAL unpacking (not very important)
- Regional reconstruction is carried out producing different collections (currently we only produce one collection for all seeds for ECAL unpacked data)

- We have split all producers between Isolated and Non-isolated:
  - Isolated use regions around Isolated em L1 candidates
  - Non Isolated use regions around non isolated em L1 candidates

- The idea of the paths is that producers produce everything around the original L1 seed while filters select on objects that passed previous filters
- Additional producers are needed when we want to have pre-scaled HLT paths with much lower L1 thresholds

- The main problem of the current implementation is the fact that the input parameters of the producers are also coupled to those in the filters (>200 cfg files or cloned and replaced modules just for the Egamma triggers)
- A large part of the HLT exercise was actually a fight with config file (.cfi and .cff)

Current Egamma Et Thresholds

Luminosity: 1×10^{32} $cm^{-2}s^{-1}$

L1 Trigger	Trigger Name	HLT Threshold (GeV)
A_SingleIsoEG12	Single Electron	15
A_SingleEG15	Relaxed Single Electron	17
A_DoubleIsoEG8	Double Electron	10
A_DoubleEG10	Relaxed Double Electron	12
A_SingleIsoEG12	Single Photon	30
A_SingleEG15	Relaxed Single Photon	40
A_DoubleIsoEG8	Double Photon	20, 20
A_DoubleEG10	Relaxed Double Photon	20, 20
A_SingleEG15	High EM Objects	80
A_SingleEG15	Very High EM Objects	200

Single Electron Path

- l1seedSingle (filter on the L1 bits)
- EcalLocalRecoSequence: Regional ECAL FED unpacking and building of RecHits
- Reconstruction of SuperClusters around the L1 isolated candidates
- L1MatchFilter - ElectronEtFilter : cut on the Et of the super-cluster (14 GeV)
- HcalLocalRecoWithoutHO: global unpacking and building of rechits for HCAL, HO is not reconstructed
- Electron Hcal Isol : calculate the energy deposited in HCAL, summing the rechits (HO is not used) in a cone (R=0.15) around the SC direction for isolated candidates.
- ElectronHcalIsolFilter: cut on the energy in HCAL (Et cut = 3 GeV)
- PixelTrackerlocalreco: global unpacking and reconstruction of the pixels
- Pixel Match: Matching between pixels hits and SC
- Pixel Match Filter: reject candidates not associated with pixels
- StripTrackerlocalreco: global unpacking and reconstruction of the siStrips
- Electrons reconstruction: starting from the pixel seeds reconstruct the electron track, associated to a SC for isolated candidates.
- Electron e/p Filter: filter on E/p (E/p < 1.5 for the barrel and 2.45 for the endcaps).
- Regional RecoTracker: Reconstructs the pixel seeds for the tracks for the isolation. Pixel hits are considered in a region around the isolated candidates, and using the z information from the electron track. Then standard tracks are reconstructed from these seeds.
- Electron Track Isol: sums the pT of the tracks in a region (0.02<R<0.2) around the electron track for isolated candidates.
- TrackIsolFilter: cut on the variable Pt tracks/Pt electron

Single Photon Path

- l1seedSingle (filter on the L1 bits)
- EcalLocalRecoSequence: Regional ECAL FED unpacking and building of RecHits
- Reconstruction of SuperClusters around the L1 isolated candidates
- L1MatchFilter - ElectronEtFilter : cut on the Et of the super-cluster (30 GeV)
- EcalIsol: sums the energy in ECAL, excluding the SC candidate, in a region (R=0.3) around the SC for isolated candidates.
- EcalIsolFilter : cut on the isolation, 1.5 GeV
- HcalLocalRecoWithoutHO: global unpacking and building of rechits for HCAL, HO is not reconstructed
- Photon Hcal Isol : calculate the energy deposited in HCAL, summing the rechit (HO is not used) in a cone (R=0.3) around the SC direction for isolated candidates.
- PhotonHcalIsolFilter : cut on HCAL Et: 4 GeV (endcap), 6 GeV (barrel):
- StripTrackerlocalreco: global unpacking and reconstruction of the siStrips
- Regional RecoTracker: Reconstructs the pixel seeds for the tracks for the isolation. Pixel hits are considered in a region around the isolated candidates. Then standard tracks are reconstructed from these seeds.
- PhotonTrackIsol: count the number of tracks with pT > 1.5 GeV in a cone (R=0.3) around the SC for isolated candidates
- TrackIsolFilter : Reject events with at least one track inside the cone

Double Photon Relaxed Path

- l1seedSingle (filter on the L1 bits)
- EcalLocalRecoSequence: Regional ECAL FED unpacking and building of RecHits
- Reconstruction of SuperClusters around the L1 isolated candidates
- **Reconstruction of SuperClusters around the L1 non isolated candidates**
- L1MatchFilter - ElectronEtFilter : cut on the Et of the super-cluster (20 GeV)
- EcalIsol: sums the energy in ECAL, excluding the SC candidate, in a region (R=0.3) around the SC for isolated candidates.
- **EcalIsol: sums the energy in ECAL, excluding the SC candidate, in a region (R=0.3) around the SC for non isolated candidates.**
- EcalIsolFilter : cut on the isolation, 2.5 GeV
- HcalLocalRecoWithoutHO: global unpacking and building of rechits for HCAL, HO is not reconstructed
- Photon Hcal Isol : calculate the energy deposited in HCAL, summing the rechit (HO is not used) in a cone (R=0.3) around the SC direction for isolated candidates.
- **Photon Hcal Isol : calculate the energy deposited in HCAL, summing the rechit (HO is not used) in a cone (R=0.3) around the SC direction for non isolated candidates.**
- PhotonHcalIsolFilter : cut on HCAL Et: 6 GeV (endcap), 8 GeV (barrel):
- StripTrackerlocalreco: global unpacking and reconstruction of the siStrips
- Regional RecoTracker: Reconstructs the pixel seeds for the tracks for the isolation. Pixel hits are considered in a region around the isolated candidates. Then standard tracks are reconstructed from these seeds.
- **Regional RecoTracker: Reconstructs the pixel seeds for the tracks for the isolation. Pixel hits are considered in a region around the non isolated candidates. Then standard tracks are reconstructed from these seeds.**
- PhotonTrackIsol: count the number of tracks with pT > 1.5 GeV in a cone (R=0.3) around the SC for isolated candidates
- **PhotonTrackIsol: count the number of tracks with pT > 1.5 GeV in a cone (R=0.3) around the SC for non isolated candidates**
- TrackIsolFilter : Reject events with more than 2 tracks inside the cone (keep early conversions)

Efficiencies, Rates and Timing

- Sorry but I did not take the time to copy all the numbers that are now changing twice a day
- Just some ideas, I may give an update in 1-2 weeks from now

- Efficiency:
  - Should be higher than PTDR because thresholds are lower but it is probably a bit smaller:
    - Electrons – pixel match: to be understood
    - Photons – Isolation: to be understood
- Rates:
  - ~15 Hz Single Electron
  - ~10 Hz Single Photon
  - ~1 Hz Double Electron
  - ~1 Hz Double Photon
- Timing:
  - EGAMMA takes ~35-40 msec (per Egamma L1 triggered event)
  - Total of the whole HLT trigger menu ~55 msec (to be confirmed during the next days) on a dual core Xeon 3GHz

Summary and Outlook

- Egamma HLT is already ok for timing
  - 20-50% improvements rather easily achievable in future
  - Selections must be revisited and optimized

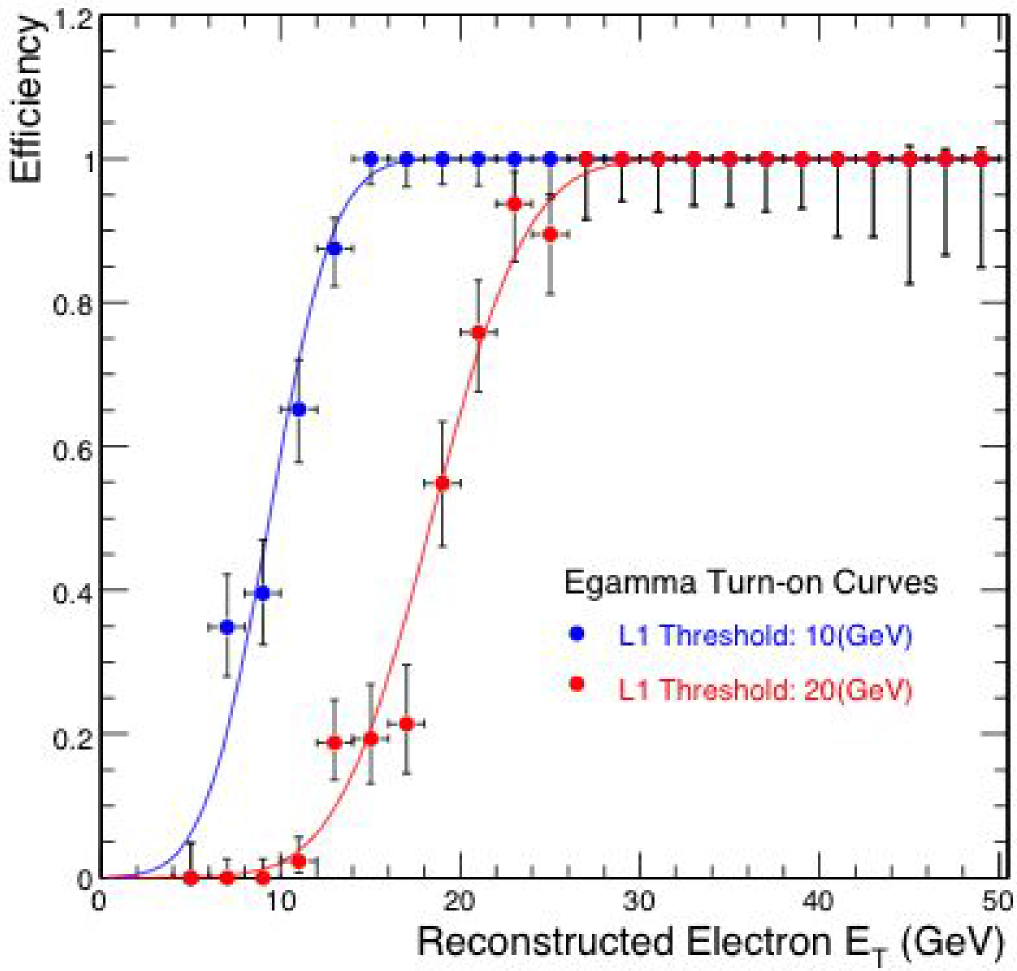
- Further improvements
  - Single triggers with looser isolation requirements aimed at physics measurements
  - Prescaled lower E_t threshold triggers for photon studies (SM γ+jet and $\gamma\gamma$)
  - Multi-electron/photon trigger with looser cuts
  - Prescaled HLT paths without some of the isolation requirements
  - Finally I always wanted to make it and now it seems that it is feasible from the timing point of view:
    - Double (or more) from single: once verified the single candidate, look for superclusters even if they are not matched with any L1 seeds

- One comment:
  - I think the current trigger paths are ready to be adapted to pizero calibration needs

BACKUP

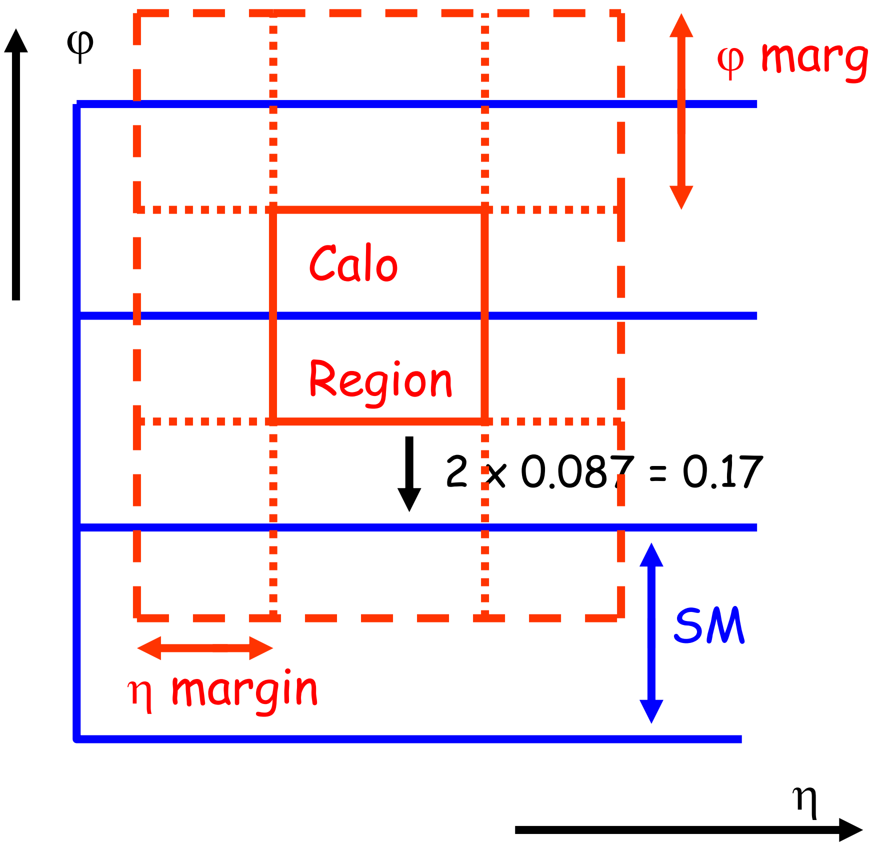
BACKUP

L1 Turn on Curve

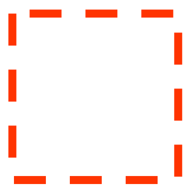


Egamma HLT paths (from E. Perez)

Starts from the collection of L1 isoEM candidates, or L1 nonisoEM candidates.
A L1 EM candidate is a calorimeter region, i.e. 4 x 4 Trigger Towers (~ 0.4 x 0.4) :



Take the corners of the calo Region, add a "margin" in η and φ.



defines an EcalEtaPhiRegion (class defined in RecoEcal/EgammaCoreTools)

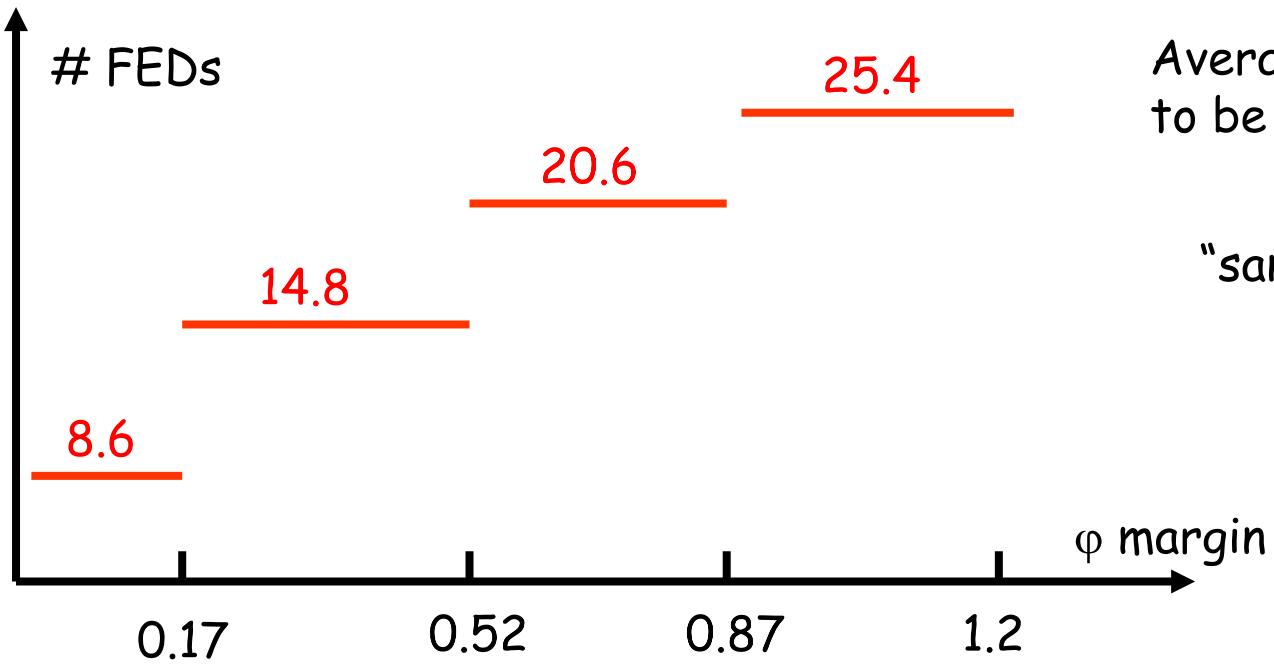
Retrieve the list of FEDs which correspond to the EcalEtaPhiRegion from Geometry/EcalMapping.

For a EcalEtaPhiRegion which is not split over e.g. EB- and EB+, expect, in EB :
- unpack 2 FEDs for φmargin < 0.17
- unpack 4 FEDs for 0.17 < φmargin < 0.52
- etc…

The list of FEDs (vector<int>) to be unpacked is then passed to EcalRawToDigiDev.

#FEDs on QCD events, isoEM seeds (from E. Perez)

Look at QCD events, pt bin 80-120 GeV.
Select those which pass L1 bit A_SingleIsoEG20 , process them through DigiToRaw and then through the unpaking.
Take ηmargin = 0.25   (i.e. the whole $\Delta\eta$ = 0.9)



Average number of FEDs to be unpacked.

"sanity check"

Does not scale exactly because of EE and "recombination effects" : there are 4 L1 isoEM candidates, the corresponding FEDs can overlap esp. when φ margin gets large.