Electron reconstruction and selection in CMS Higher Level Trigger

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Outline:

- Why electrons?
- Level 1 selection
- Higher Level Trigger selection
- Complete online selection for low luminosity

Where do we get electrons in 14 TeV pp collisions?

- **Electrons from the primary vertex:**

  $Z \longrightarrow e^+e^-$

  $W^\pm \longrightarrow e^\pm\nu_e$

  $\pi^0 \longrightarrow (e^+e^-)\gamma$ **(Dalitz decay)**

- **Electrons from a displaced vertex:**

  $b \longrightarrow e^\pm$

  $b \longrightarrow c \longrightarrow e^\pm$

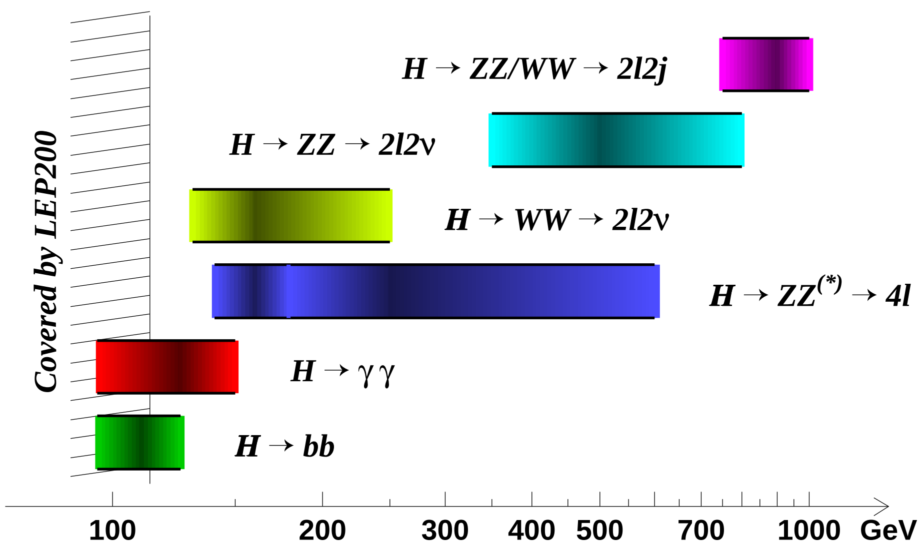
  $\tau^\pm \longrightarrow e^\pm\nu_e\nu_\tau$

  $\gamma \longrightarrow e^+e^-$

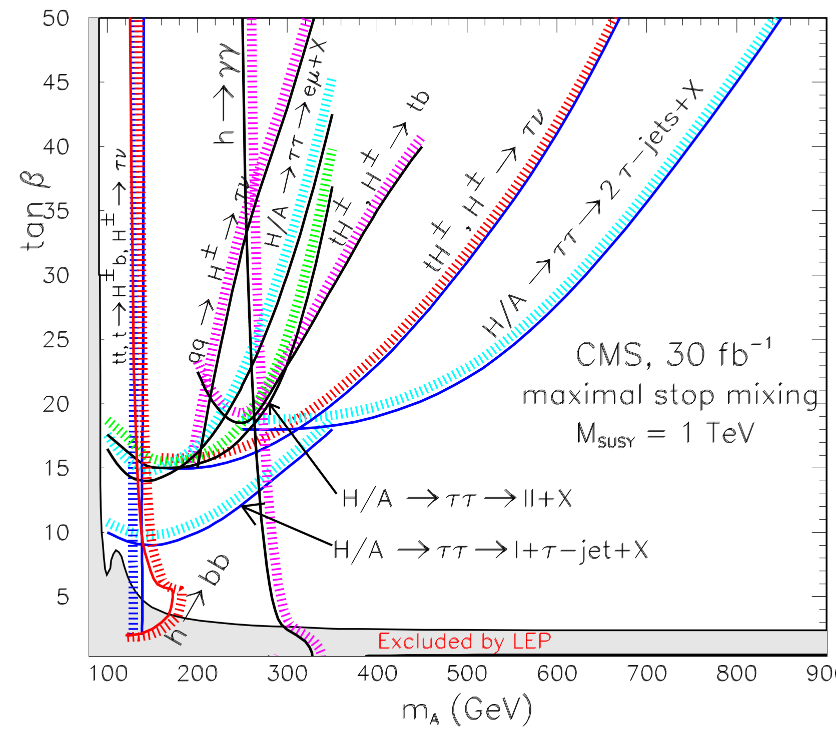
Why do we want to see the electrons?

- leptonic decays of the Higgs boson and supersymmetric particles
- leptonic tagging of hadronic decay modes
- calibration.

Main SM Higgs discovery channels

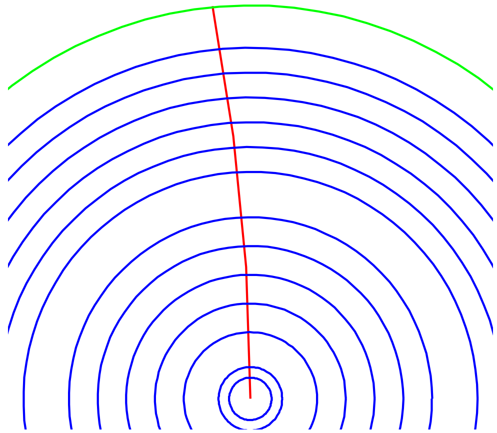


Parameter space coverage in MSSM



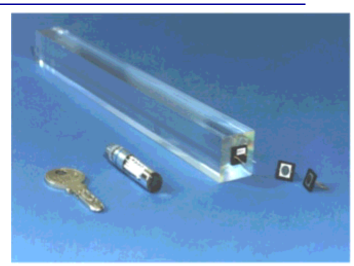
What does an electron look like in CMS?

B-field

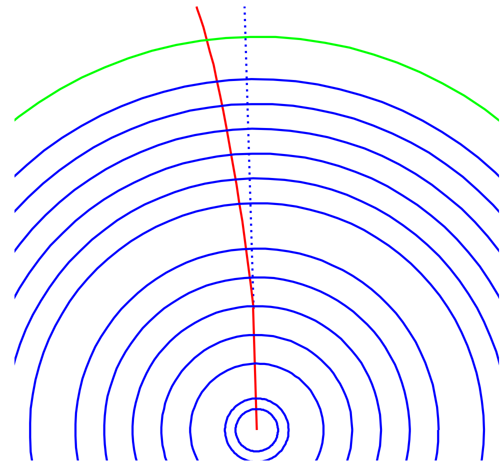


- $r_{calorimeter} = 130$ cm
- B-field = 4 T
- electrons of interest $p_T \gtrsim 5$ GeV

p_T	Deviation at ECAL	Crystal size 22×22 mm
10 GeV	10 cm	
15 GeV	6.7 cm	
25 GeV	4.0 cm	
50 GeV	2.0 cm	



Material



- **Tracker: 0.4 – 1.2 X_0 of material**
- **X_0: Bremsstrahlung E loss on the average $1 - 1/e = 63.2\%$**

  $\Rightarrow$ **we must recover the radiated photon E in ECAL**

  $\Rightarrow$ **we can have a dedicated $e^{\pm}$ track reconstructor.**

Level 1 triggers

- Low luminosity ($2{\cdot}10^{33}$ cm^{-2}s^{-1} first years of the LHC running) maximum 50 kHz

  → safety factor 3: $50/3 \approx$ 16 kHz

  → four trigger groups 4 kHz each:

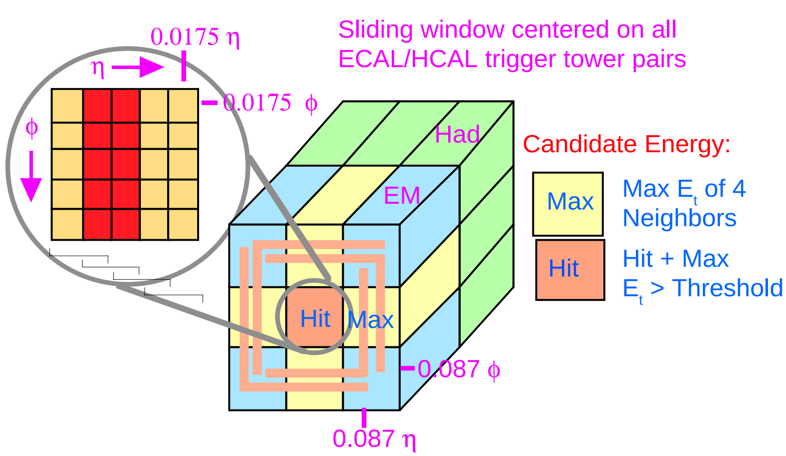
  · electromagnetic (single and double electron/photon)

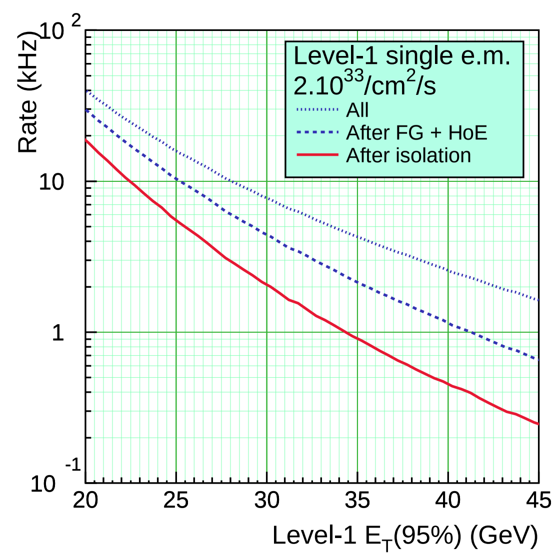
  · μ (single and double)

  · jets (1, 2, 3 or 4 jets, missing E_T)

  · mixed (τ + e, jet + e, e + μ, etc)

- Electromagnetic trigger (only calorimeter, no tracker)



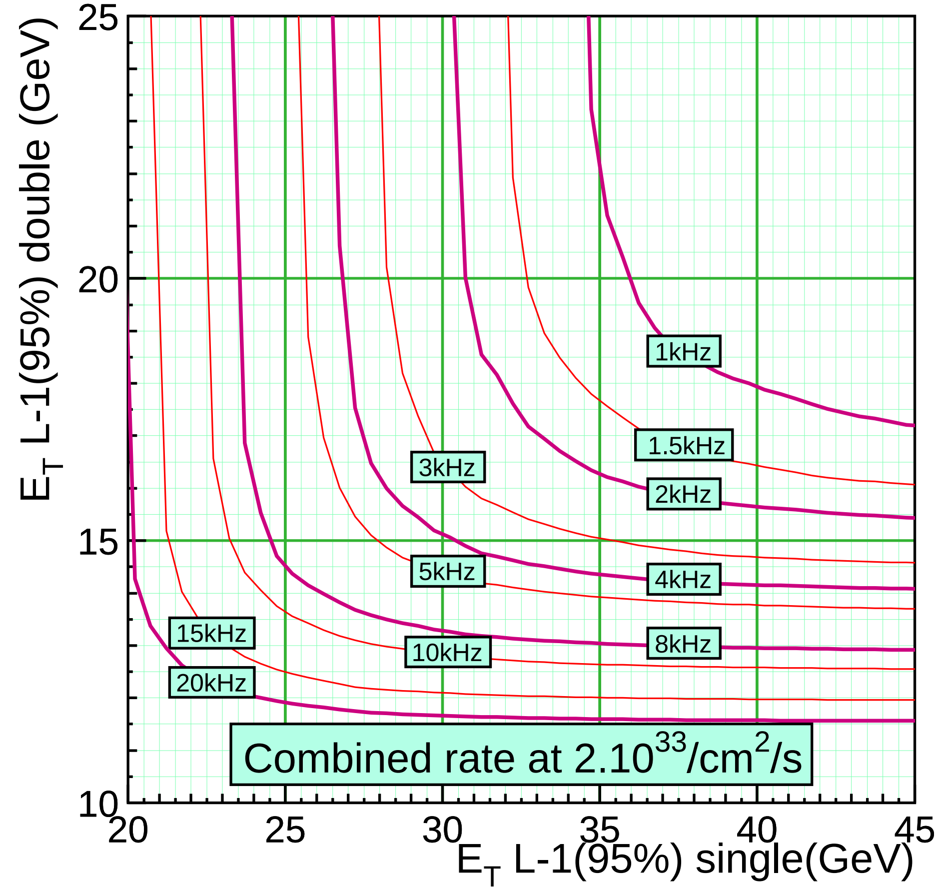


At level 1, the rate is completely dominated by fake electrons, e.g. jets with a leading, energetic π^0.

p

The Level 1 trigger thresholds

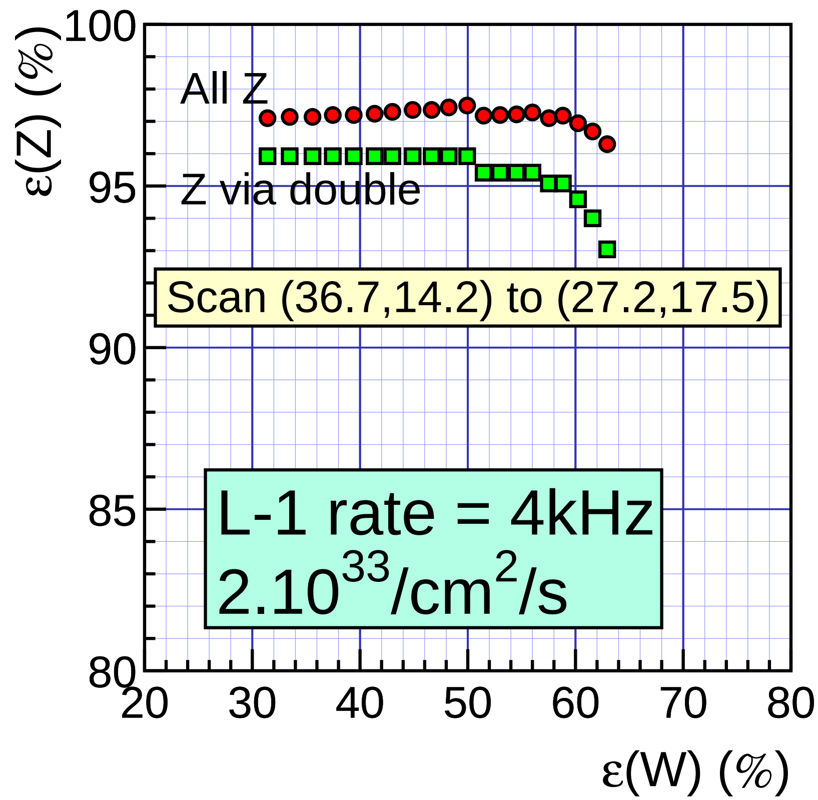
- **We have 4 kHz at our disposal for low luminosity**
  - **how to share this between the single e.m. and the double e.m. triggers?**
- **Choose the thresholds by optimizing the efficiency for signal**
  - $Z \to e^+e^-$
  - $W \to e\nu$.



Optimizing the Level 1 trigger thresholds

- **Take trigger threshold values from the 4 kHz contour**
  - **scan from (high single, low double) to (low single, high double)**

  and see what happens to the signal efficiency.
- **High efficiency for $W \rightarrow e\nu$ is reached at low single threshold values.**
- **The efficiency for $Z \rightarrow e^+e^-$ remains constant down to fairly low single threshold values.**

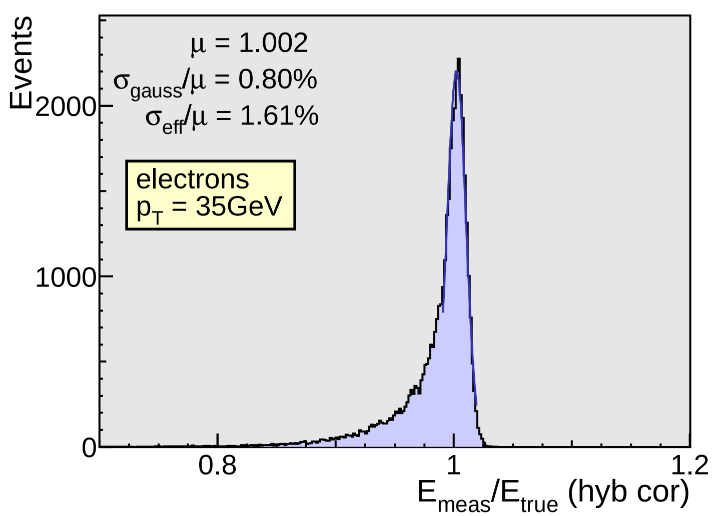


⇒ **Choose the operation point**
  - **27.7 GeV for the single**
  - **16.6 GeV for the double**

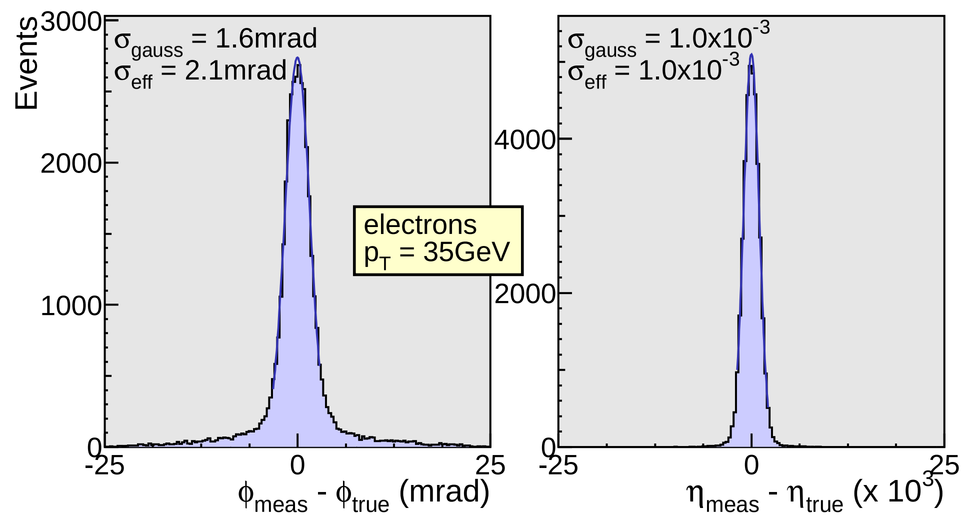
Higher level trigger algorithms, Level 2

- HLT algorithms run on farms of commercial processors
  (if fast enough, the algorithms can be the same as for the final analysis)
- Level 2: better electron energy measurement
  - Recovery of the Bremsstrahlung photons
    (or converted photons, at this point it is not possible to distinguish e/γ)
    * Reminder: solenoidal B-field → clusters widen in the ϕ-direction

Energy resolution

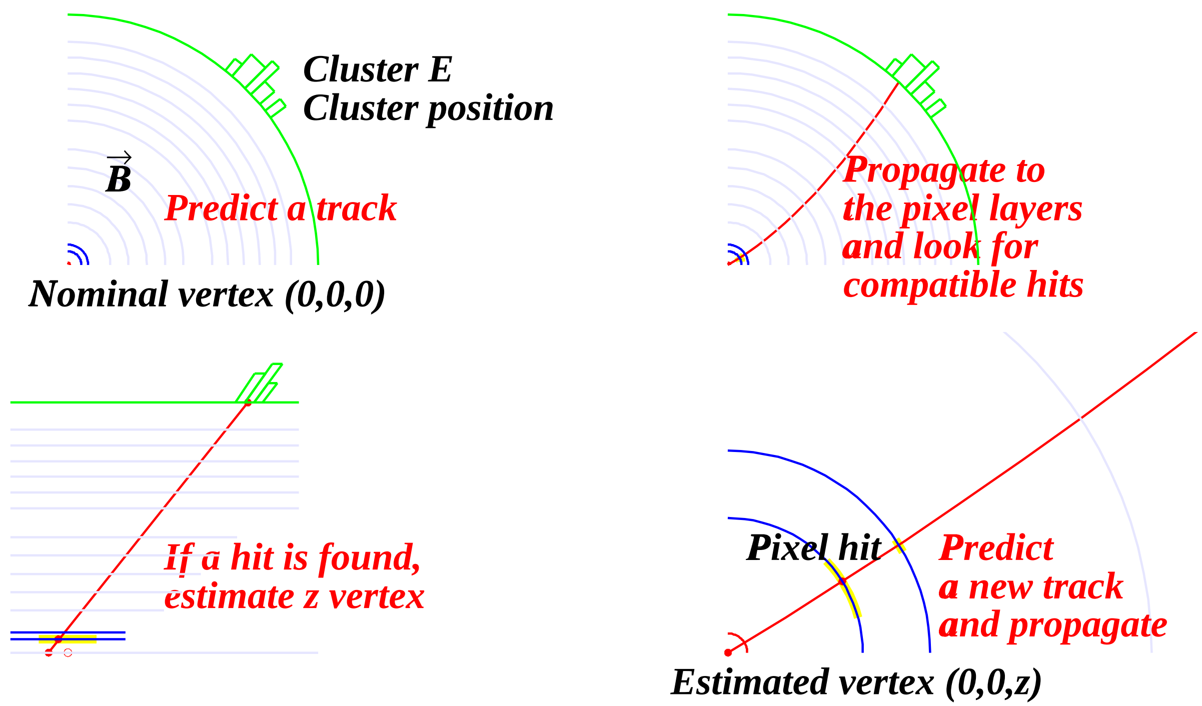


Position resolution



Higher level trigger algorithms, Level >2

- Level "2.5": matching the electron clusters to the innermost pixel hits



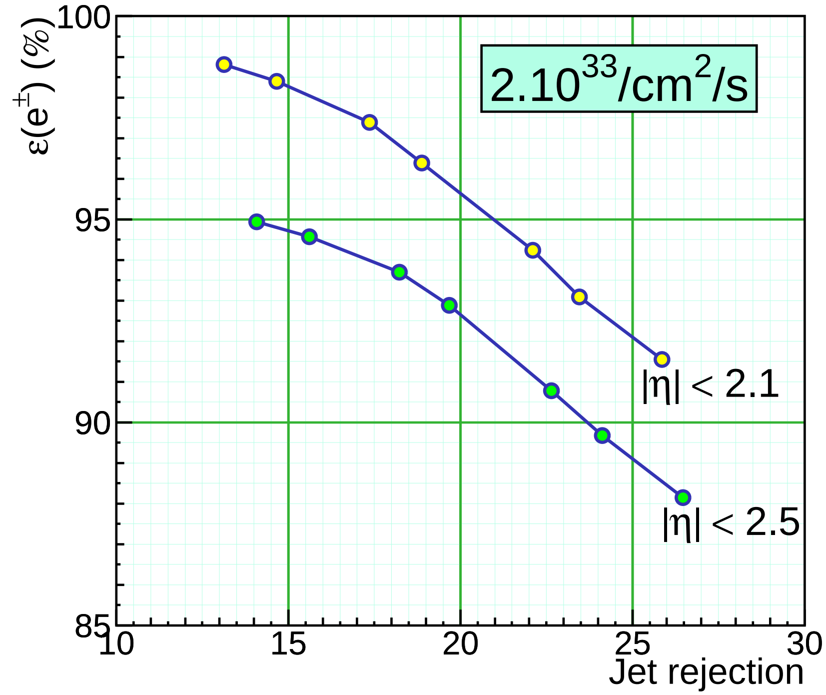
divides the data to the electron and photon streams

– electrons: full track reconstruction,

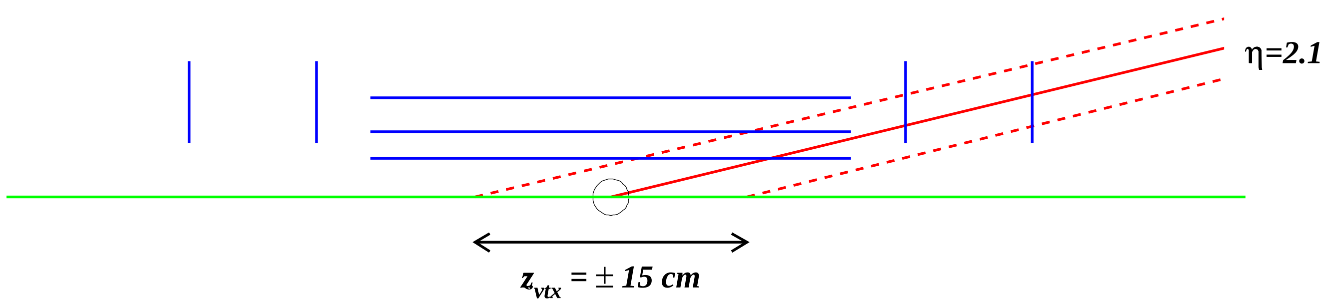
– photons: re-apply higher p_T threshold

Pixel match efficiency

- The efficiency vs jet rejection varying the pixel match search area for the innermost hit
  - Choose
    $\Delta\phi = 0.04$, $\Delta z = \pm\ 30$ cm
    for the innermost hit,
    $\Delta\phi = \pm\ 0.001$, $\Delta z = \pm\ 0.05$ cm
    for the second hit.

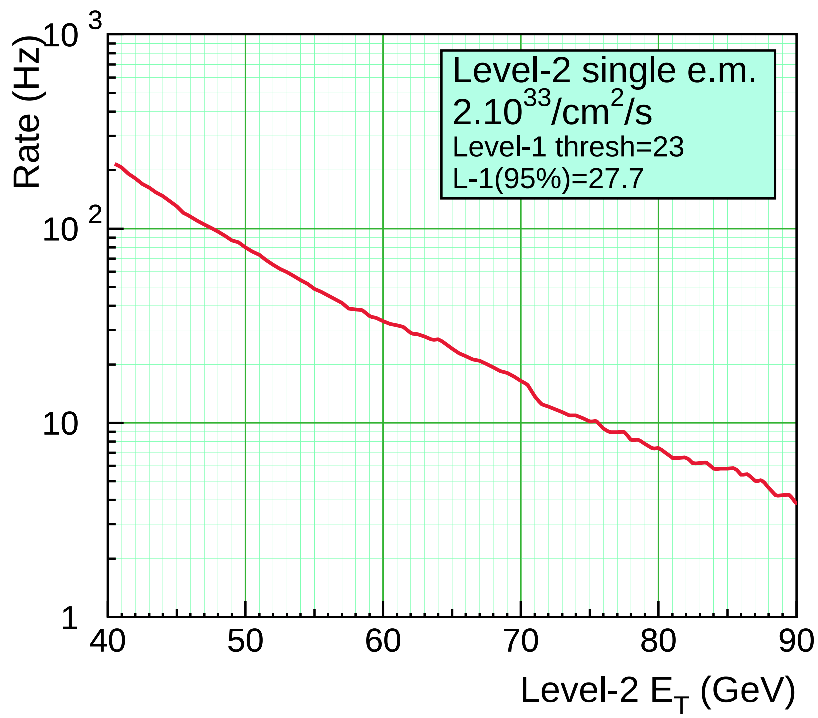


- Inevitable loss of efficiency $|\eta| > 2.1$ due to the actual pixel geometry:



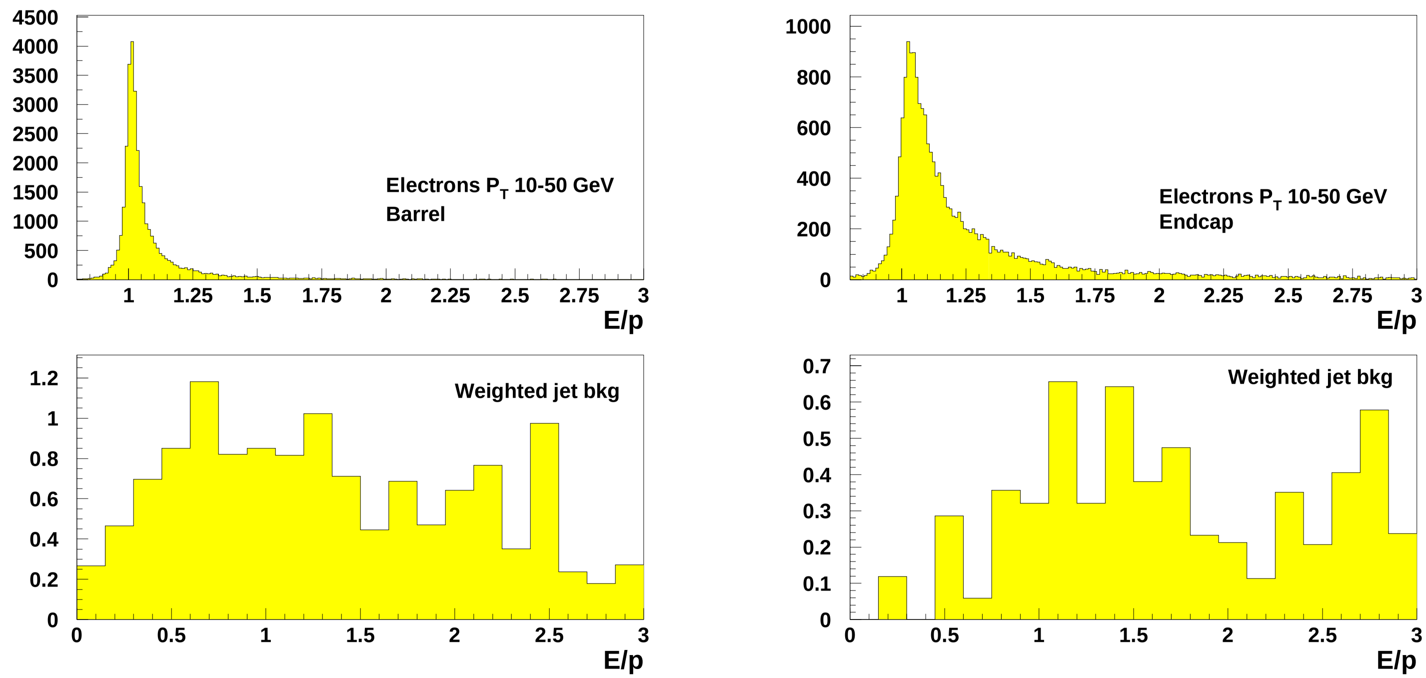
The photon stream

- **Double photon stream (H $\rightarrow \gamma\gamma$)**
  - apply the H $\rightarrow \gamma\gamma$ offline selection cuts of 40, 25 GeV.
- **Single photon stream**
  - To reduce the rate, set the threshold at $E_T > 80$ GeV, further reduction obtained by isolation.



Higher level trigger algorithms, Level 3 for electrons

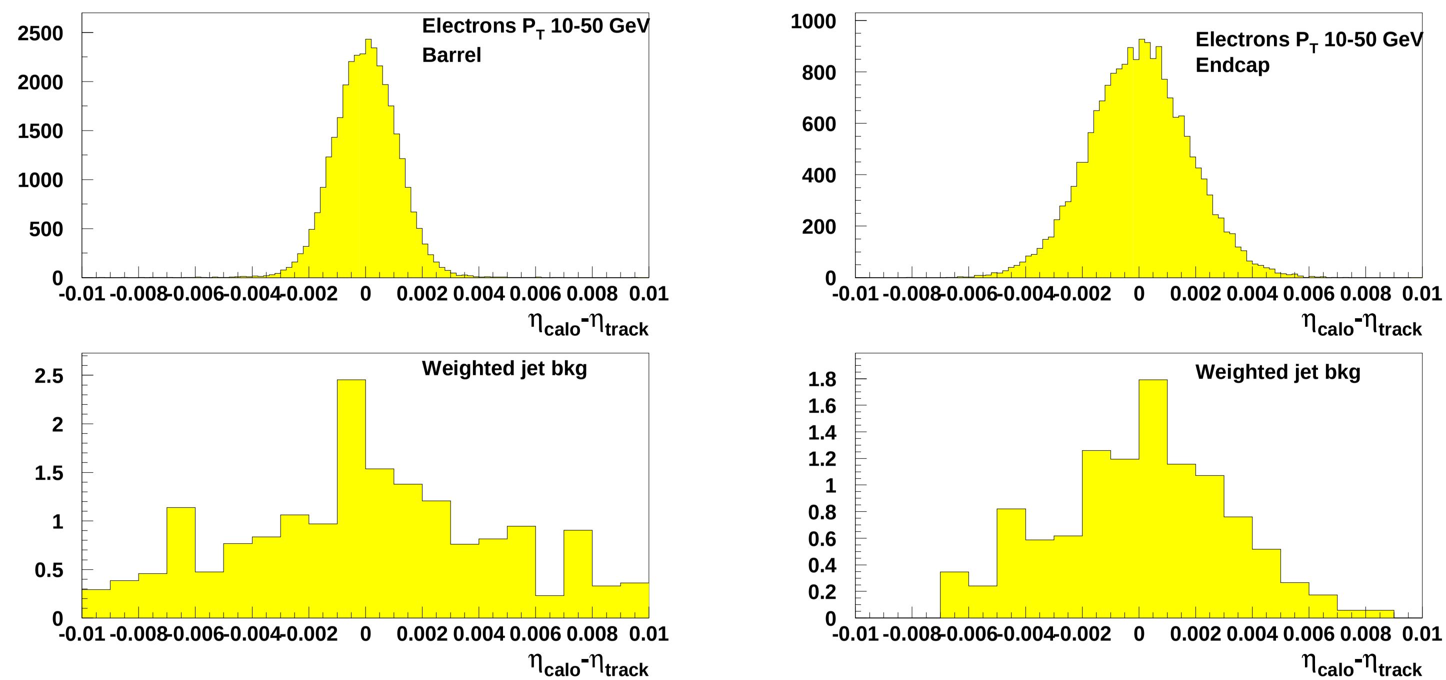
- **Apply E/p** (E from the calorimeter, p from the reconstructed track) **for the remaining electron candidates**



  – **require E/p $<$ 1.2 in the barrel, $<$ 1.7 in the endcaps.**

Higher level trigger algorithms, Level 3 for electrons

- Match the position in η obtained in the calorimeter and in the tracker (the most precise measurement is in η in the calorimeter)



  – require $\Delta\eta < 0.004$ in the barrel.

- Require small energy deposit in the hadronic calorimeter (endcaps).

Electron selection

	Efficiency	Rejection
• **Level 1**		
– Single: $E_T > 27.7$ GeV – Double: $E_T > 16.6$ GeV	95% (loss due to the isolation requirement and gaps) × 95% (at the threshold)	Rate: 3.9kHz
• **Level 2**		
– Reapply the thresholds	95% (at the threshold)	2
• **Level 2.5**		
– Pixel match	97% $\|\eta\| < 2.1$ 94% $\|\eta\| < 2.5$	15
• **Level 3 Barrel**		
– E/p < 1.2, $\Delta\eta < 0.004$	85%	6
• **Level 3 Endcap**		
– E/p < 1.7, H/E < 0.003	82%	6

Online selection for low luminosity

- **Start from 3.9 kHz Level 1 event rate:**

	Signal	Background	Total
Single e	$W \rightarrow e\nu$: 9.7 Hz	$\pi^{\pm}$ π^0 overlap: 4Hz π^0 conversions: 5Hz $b/c \rightarrow e$: 8.5 Hz	27 Hz
Double e	$Z \rightarrow ee$: 1 Hz	≈ 0	1 Hz
Single γ	≈ 0	3 Hz	3 Hz
Double γ	≈ 0	5 Hz	5 Hz
			36 Hz

- **Tools not used for this selection:**
  - track isolation
  - π^0 rejection with the e.m. cluster shape
  - analysis of conversion e^+e^- tracks for π^0's and signal photons.

Summary

- **The full online selection chain for the initial low luminosity has been demonstrated**
  - the electron trigger rate can be reduced to a required level with existing tools
  - the electron efficiency is lower than we would like to (all HLT $\approx$ 70%).
- **We are developing the tools to complete the online selection for high luminosity (event rate 5$\times$ low lumi).**
- **Major milestones:**
  - DAQ Technical Design Report in the end of the year
  - Physics Technical Design Report in 2004.