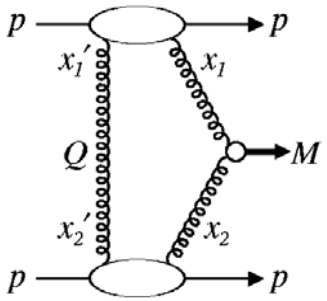
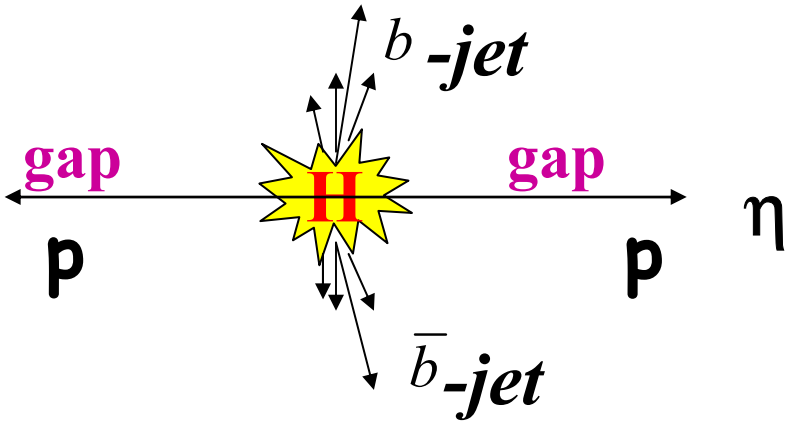
# Triggering on Diffraction with the CMS Level-1 Trigger

Monika Grothe, U Wisconsin
HERA-LHC workshop March 2004

**The fish we want to catch ! (in case it exists)**

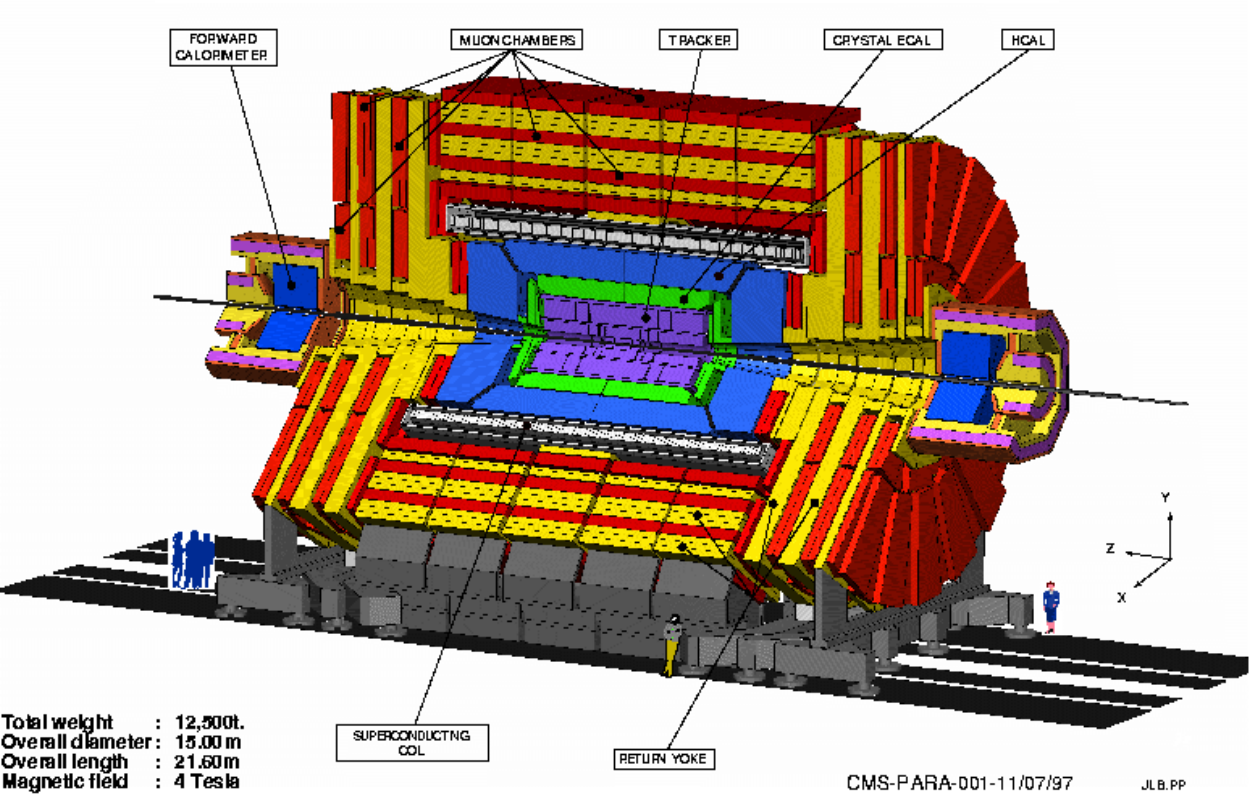



Need highest achievable LHC Lumi, $\mathcal{L}_{LHC}$ = $10^{33}$ to $10^{34}$ cm$^{-2}$ s$^{-1}$
Diffractive program with TOTEM at $\mathcal{L}$ = $10^{28}$ to $10^{31}$cm$^{-2}$ s$^{-1}$ + special high-β* optics
TOTEM acceptance at $\mathcal{L}_{LHC}$ and nominal beam optics: 0.02 <ξ <0.2

➡ Need CMS & need CMS Level-1 trigger to retain this possible discovery channel

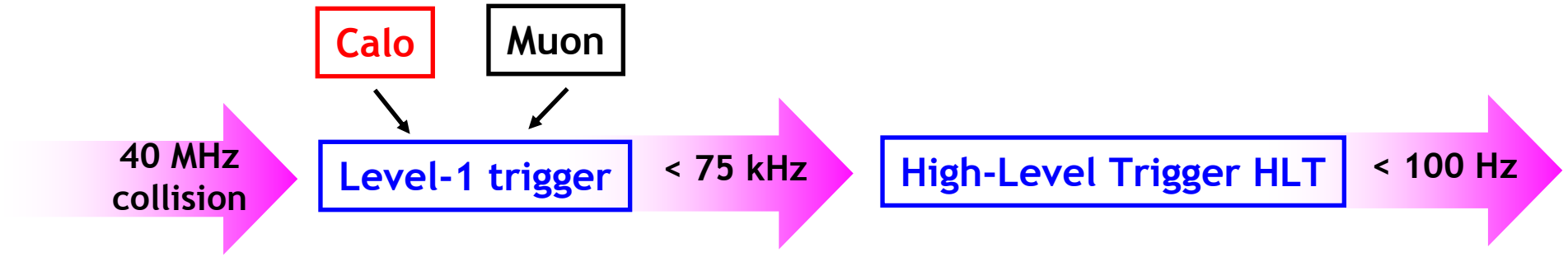
# CMS and its Level-1 trigger



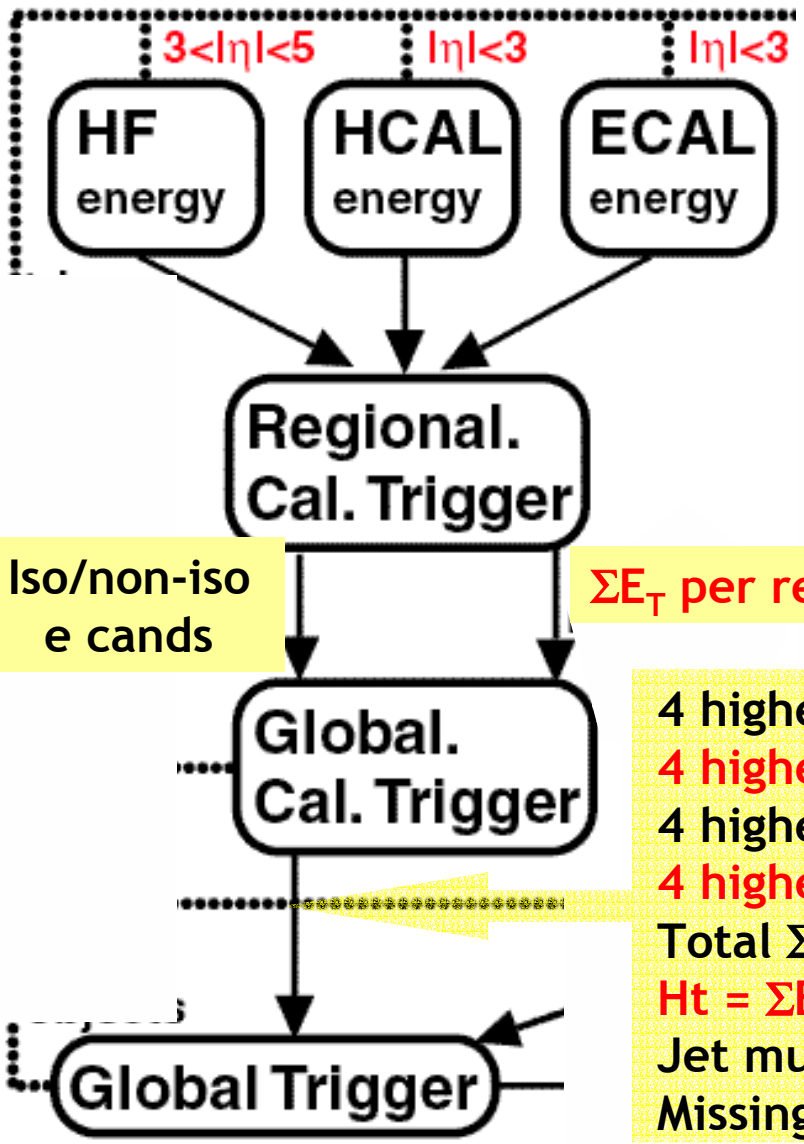

Tracking: Si pixels + Si strips
Calorimetry:
- ECAL PbWO4 crystals
- HCAL Scintillator/copper
- HF Quartz/copper

4T solenoid
Muon detection with instrumented iron

Coverage
Tracking $0 < |\eta| < 3$
Calorimeters $0 < |\eta| < 5$

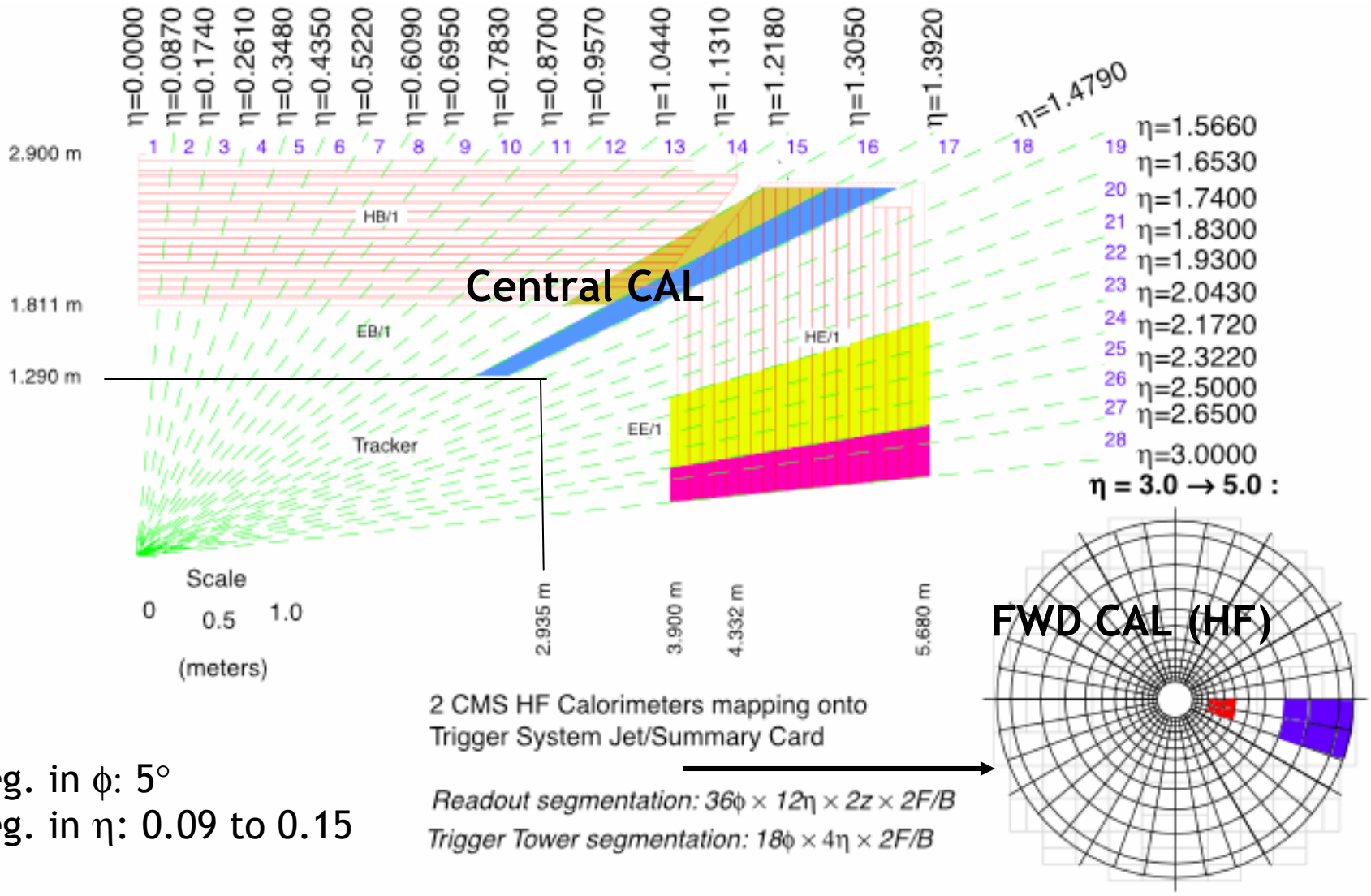


# CMS Level-1 Calorimeter Trigger



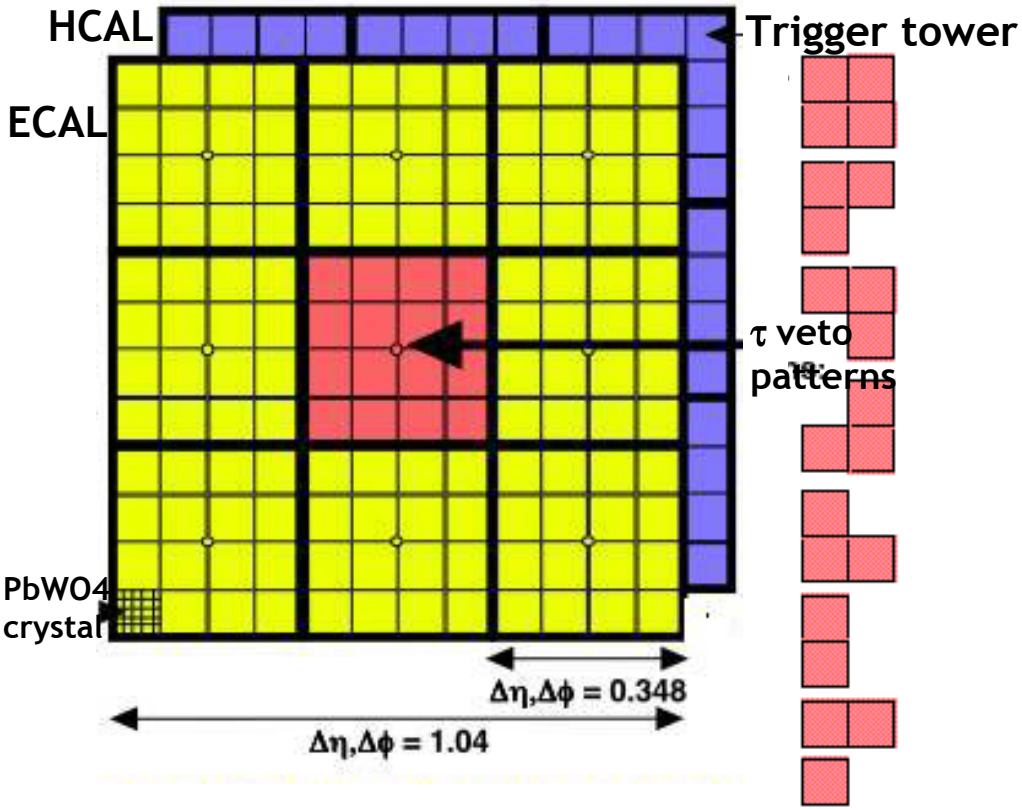

4 highest $E_T$ iso e + non-iso e
4 highest $E_T$ central jets
4 highest $E_T$ central tau jets
4 highest $E_T$ fw jets
Total $\Sigma E_T$
Ht = $\Sigma E_T$ in jets
Jet multiplicities
Missing $E_T$

# Cal trigger tower segmentation




Seg. in $\phi$: 5°
Seg. in $\eta$: 0.09 to 0.15

# Level-1 Jets and $H_T$




$H_T$ = sum of scalar $E_T$ of all jets with $E_T$(jet)>threshold

Advantage over total scalar $E_T$:
- Sums only over $E_T$ around local energy maxima
- More robust against noise and minimum bias events
- At L1 tower-by-tower $E_T$ calibration not possible, but jet $E_T$ calibration possible, $f(E_T, \eta, \phi)$

- 4x4 trigger towers = **region**
- Search for jets with **sliding 3x3 regions window**
- **Jet** = 3x3 region with $E_T$ in central region above some threshold and with $E_T$> $E_T$ in any of 8 outer regions
- Jet = τ if τ veto off in all 9 regions

# Cal-based CMS L1 diffractive trigger

- Exclusive diffractive Higgs production pp$\rightarrow$ p H p of a light Higgs (120GeV) might occur at LHC with 3-10 fb according to theory
- Current foreseen $E_T$ threshold in 2-jet events at L1 is ~120 GeV per jet
- In order to retain H $\rightarrow$ bbar signal on Level-1 need to lower $E_T$ threshold to 40 to 50 GeV
- Need additional constraint to keep QCD background rate in check
- Possible solution: Select 2-jet events in the central Cal and require $\Sigma(E_T$ 2 jets$)/H_T$ cut on Level-1
- At L =$10^{33}$, where pile-up is not a big problem, this cut effectively excludes events with jets in the HF ($3 < |\eta| < 5$) , i.e. corresponds to requiring a minimum rap gap of bigger 2
- At L =$10^{34}$ , with ~20 overlapping events, this should still be true because $H_T$ excludes the typically low $E_T$ deposits of minimum bias events
- Additional possibility at L1: correlating $\eta$ and $\phi$ position of jets

Work on-going by Helsinki (TOTEM) and Nebraska, Wisconsin(CMS) groups

# CMS Level-1 Trigger & TOTEM (I)

- TOTEM physics program: total pp, elastic & diffractive cross sections
- Apparatus:) $\beta^*$ Inelastic Detectors (T1 $3<\eta<5$, T2 $5<\eta<6.5$) & Roman Pot stations at 150 m and 220 m, with $\eta$ coverage up to 10 (13) at low (high) $\beta^*$
- Dedicated runs planned with high $\beta^*$ optics at L =$10^{28}$-$10^{30}$cm$^{-2}$s$^{-1}$ : >90% of all diffractive protons will be seen in the RPs
- At nominal low $\beta^*$ LHC running with L=$10^{33}$-$10^{34}$cm$^{-2}$s$^{-1}$ diffractive acceptance low At 220 m: $0.02 < \xi < 0.2$, could be extended with RPs at 300/400 m: $0.002 < \xi < 0.2$

o TOTEM wants to implement its DAQ and trigger systems in CMS-compatible fashion

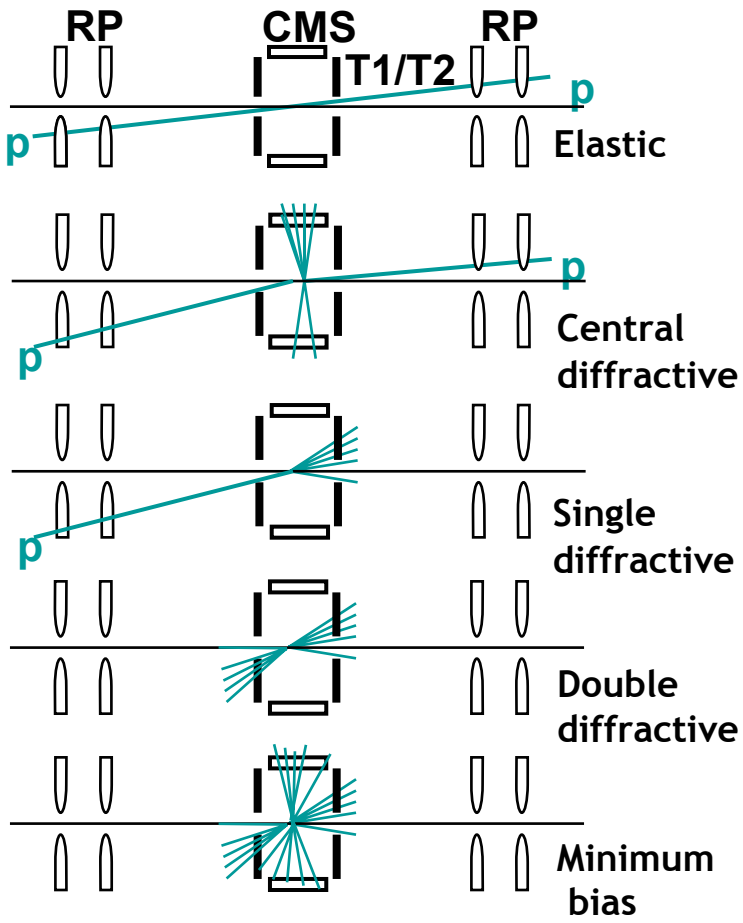
o Possible triggering scheme, preferred by TOTEM:
The CMS Level-1 trigger receives TOTEM trigger decision and sends a Level-1 Accept to both TOTEM and CMS front-end electronics

→ Opens up possibility of cross-correlating CMS and TOTEM diffractive triggers

For more details on TOTEM and its diffractive program see talk by F.Ferro this morning

# CMS Level-1 Trigger & TOTEM (II)

TOTEM plans for Level-1 Triggers
at $\mathcal{L} = 1.6\ 10^{28}\ cm^{-2}\ s^{-1}$




Courtesy K. Eggert

**Want CMS operational in low-luminosity start-up phase of LHC when TOTEM runs will take place**
**Goal:**
**Study and validate CMS-Calo based diffractive L1- trigger ($E_T$/$H_T$) with the help of TOTEM's Roman pot-based diffractive triggers**

# Conclusions

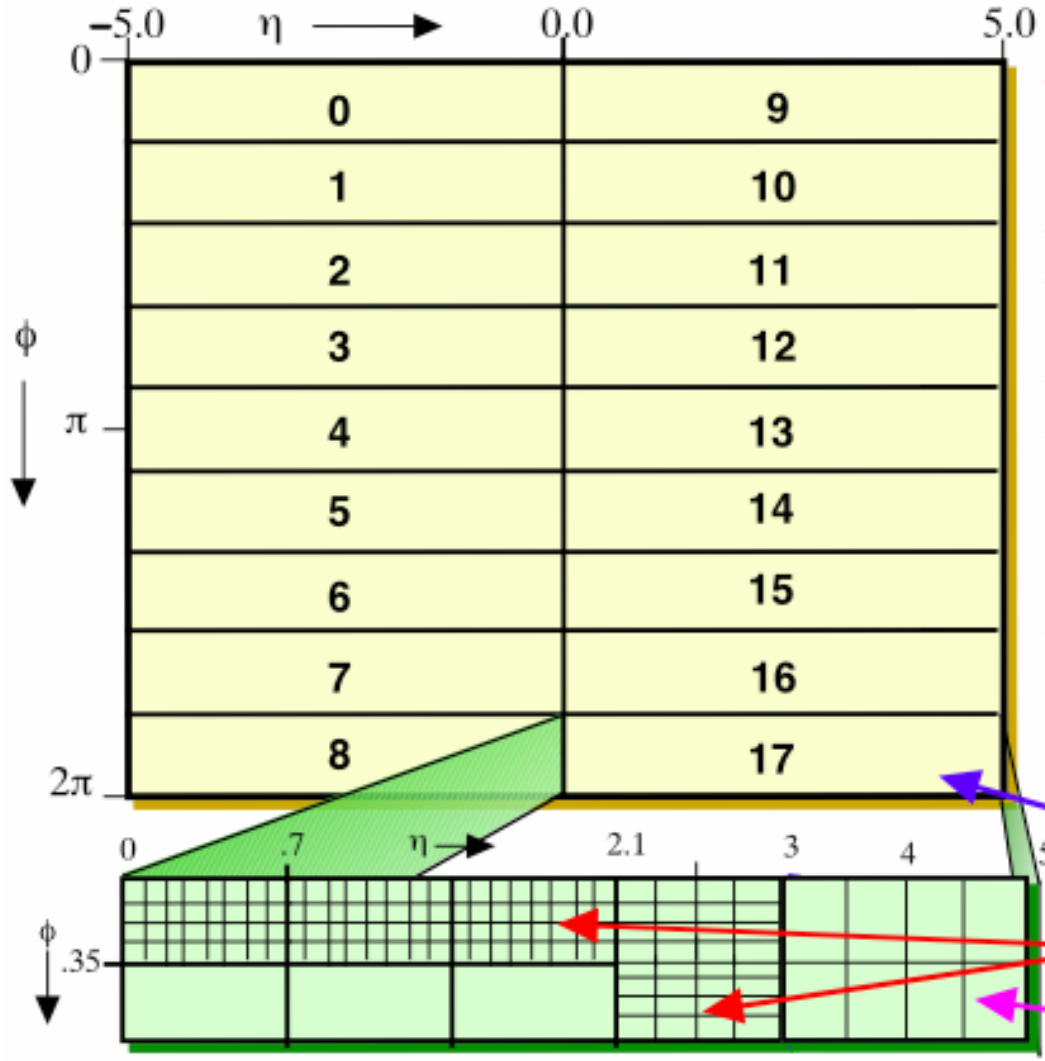
**TOTEM Roman-pot based triggers** will trigger diffractive events at low-luminosity ($\mathcal{L}$ = **$10^{28}$ - $10^{31}$ cm$^{-2}$ s$^{-1}$**) in runs with special high-$\beta^*$ optics
The TOTEM trigger signal is planned to be sent to the CMS Level-1 trigger within its latency requirements.
TOTEM will operate as a CMS trigger/DAQ partition

At nominal LHC luminosity ($\mathcal{L}$ = **$10^{34}$ cm$^{-2}$ s$^{-1}$**) and nominal beam optics, the TOTEM Roman pot acceptance for diffraction is low.
Because of Level-1 latency possible RPs at 300/400 m cannot be used on Level-1.
**CMS** has the possibility to implement a **Calorimeter-based diffractive trigger based on an $E_T/H_T$ threshold.**
In addition, could use the TOTEM inelastic detectors T1, T2 as veto trigger.

Need to study the $E_T/H_T$ trigger with detailed CMS Level-1 simulation to determine rate and signal efficiency as function of the $E_T/H_T$ threshold.

Further possibilities for inclusion in a diffractive trigger: CASTOR
Currently under discussion, see talk by A. Panagiotou this morning

# Trigger Mapping

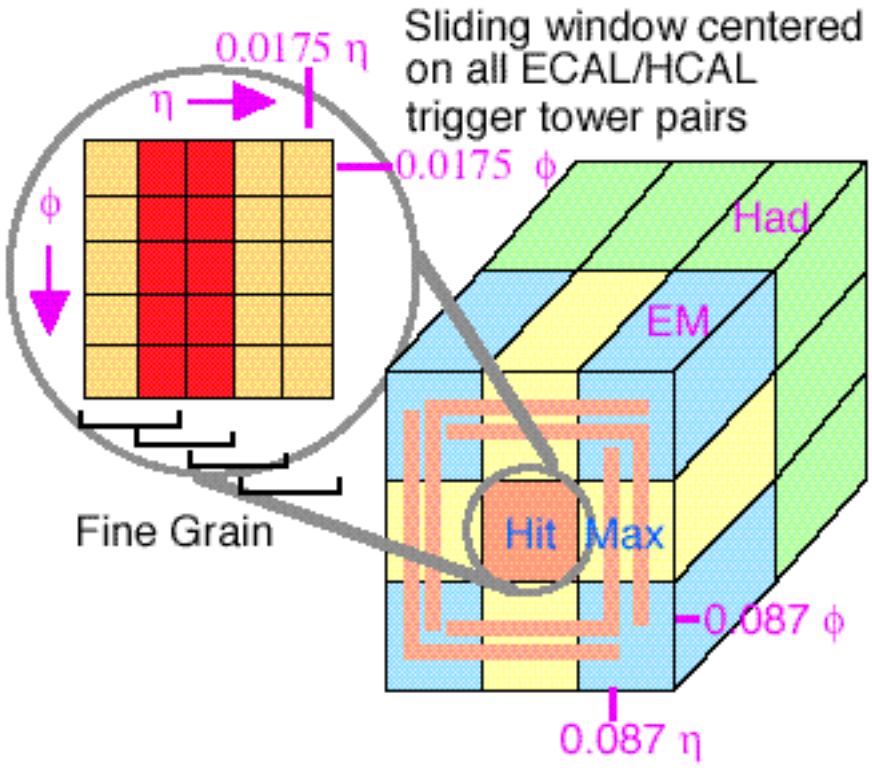


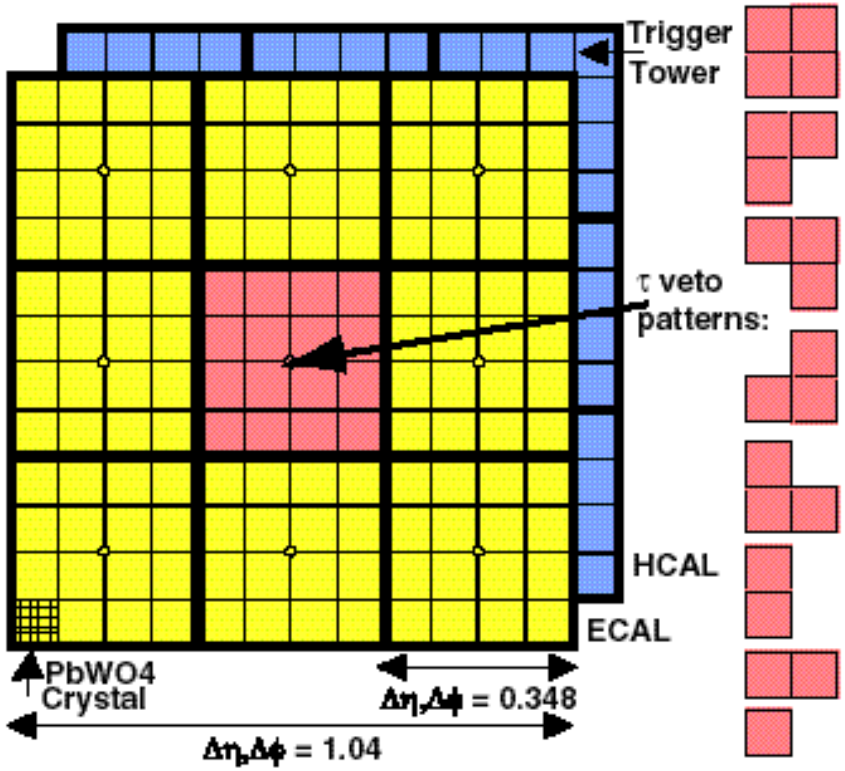

- 18 crates handle all of the CMS calorimeters seamlessly
- Each crate processes a 0.7 ϕ x 5.0 η region.
- Each Receiver/Electron ID card pair typically covers a .35 ϕ x 0.7 η region
- Single Jet/Summary card handles full crate

Calorimeter Regional Trigger Crate (18x)

Receiver Cards (x7/crate)

(New) Jet/Summary Card processes HF data (3<η<5)



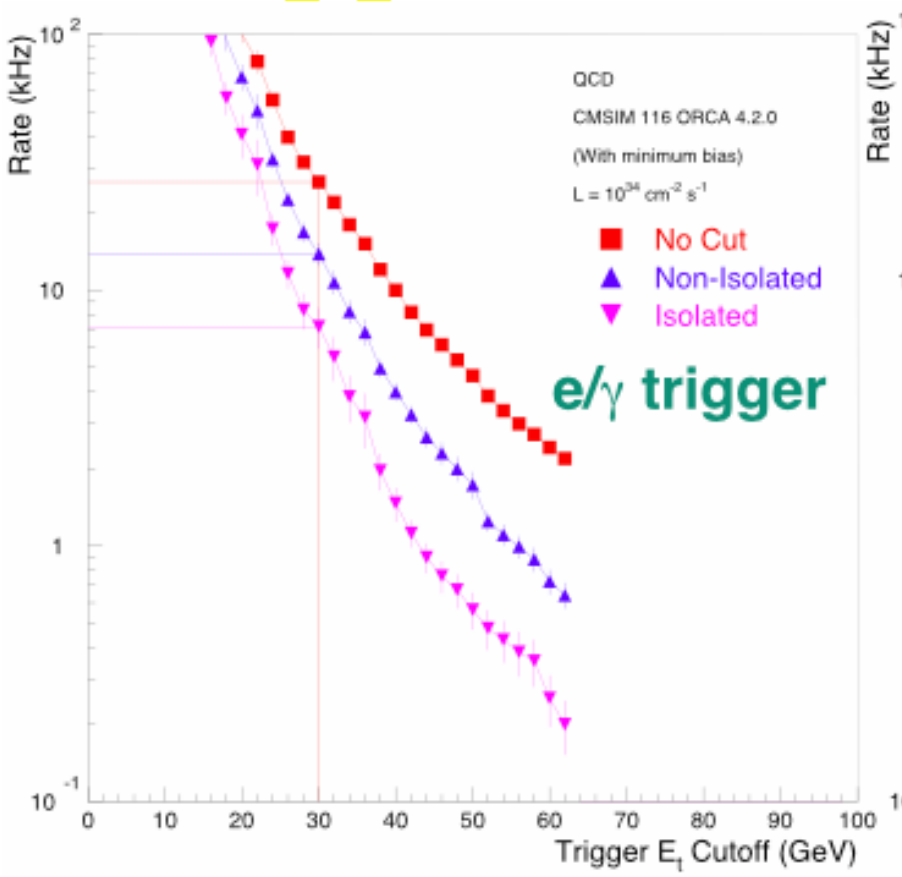

- Electron (Hit Tower + Max)
  - –2-tower $\Sigma E_T$ + Hit tower H/E
  - –Hit tower 2x5-crystal strips >90% $E_T$ in 5x5 (Fine Grain)
- Isolated Electron (3x3 Tower)
  - –Quiet neighbors: all towers pass Fine Grain & H/E
  - –One group of 5 EM $E_T$ < Thr.

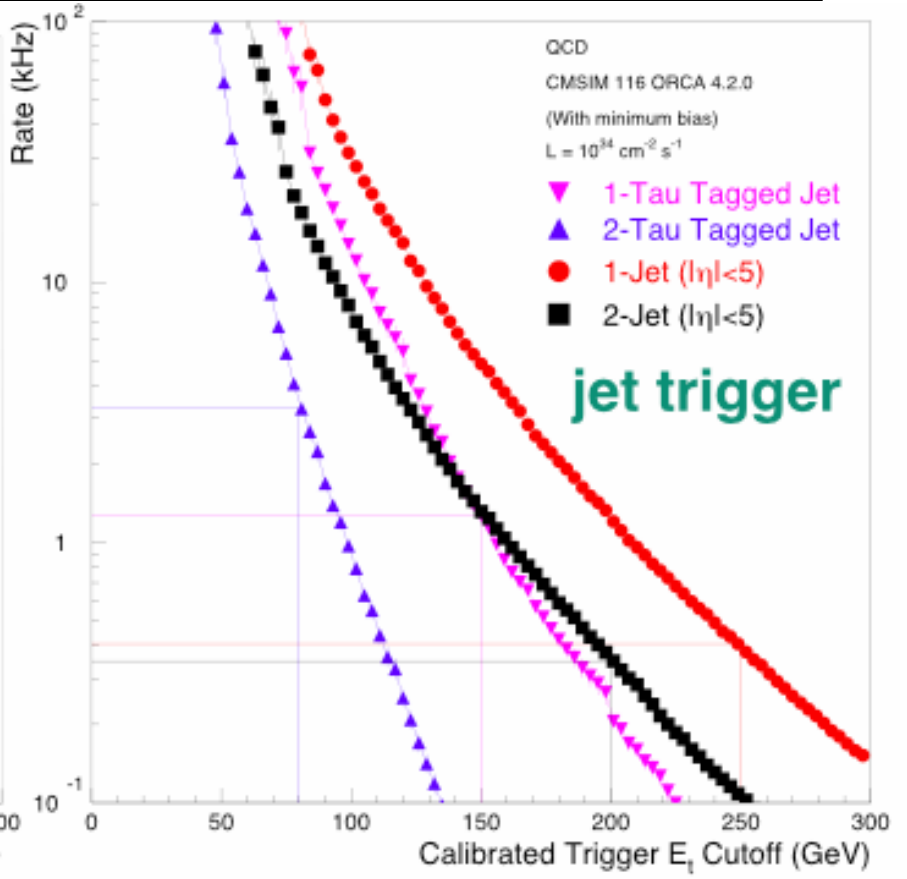
- Jet or τ $E_T$
  - –12x12 trig. tower $\Sigma E_T$ sliding in 4x4 steps w/central 4x4 $E_T$ > others

τ: isolated narrow energy deposits

- –Energy spread outside τ veto pattern sets veto
- –Jet ≡ τ if all 9 4x4 region τ vetoes off

# Trigger Rates vs Threshold




**Rates drop sharply with trigger $E_T$ cutoff**

- Provides ability to tune cuts to sustain rates during operation
- For electron several cuts are available to optimize efficiency versus rate
- For all trigger types there are tunable parameters, e.g., look-up-tables
- QCD background rates are within target (~12 kHz for calorimeter triggers).

# Cal Trigger Rates: 2 x $10^{33}$ $cm^{-2}$ $s^{-1}$

| Trigger | Threshold (GeV) | 95 % Eff. (GeV) | Individual Rate (kHz) | Cumulative Rate (kHz) |
|---|---|---|---|---|
| e | 20 | 27 | 4.9 | 4.9 |
| e e | 15 | 19 | 0.2 | 5.0 |
| τ | 89 | ~114 | 3.8 | 8.6 |
| ττ | 75 | ~100 | 0.7 | 8.8 |
| j | 130 | 152 | 1.5 | 9.5 |
| jj | 115 | 131 | 0.8 | 9.5 |
| jjj | 75 | 77 | 0.3 | 9.6 |
| jjjj | 55 | 62 | 0.2 | 9.6 |
| e·j | 10&100 | 15&125 | 0.4 | 9.8 |
| e·τ | 10&75 | 15&~100 | 0.8 | 10.0 |
| Missing $E_T$ | 140 | 200 | 0.01 | 10.0 |
| e·$ME_T$ | 10&75 | 15&140 | 0.4 | 10.3 |
| j·$ME_T$ | 60&90 | 80&150 | 0.7 | 10.6 |
| Total $E_T$ | 600 | 1200 | 0.04 | 10.6 |
| $H_T$ | 400 | 470 | 0.6 | 10.7 |
| e(NI) | 45 | 51 | 0.2 | 10.8 |
| e e(NI) | 25 | 37 | 0.03 | 10.8 |
| Total Rate | | | | 10.8 |

Selected Scenario: 5 kHz e/g, 5 kHz τ,jets, 1 kHz combined, rest μ