# Trigger Subsystem Summary

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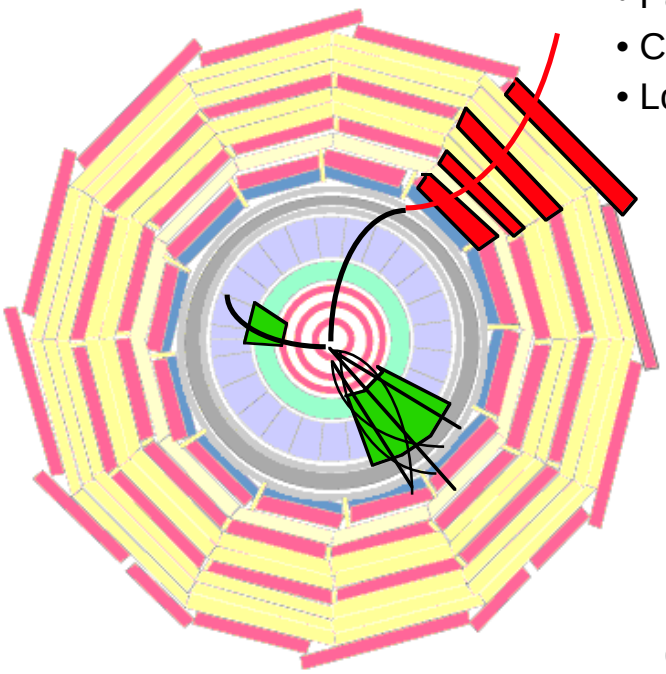
## Outline:

- System Overview
- Organization
- Milestones
- Status and Progress
- WBS Summary
- Schedule (MS Project) summary
- Manpower Profile
- Obligation Profile
- Concerns and actions taken

# CMS Trigger Levels

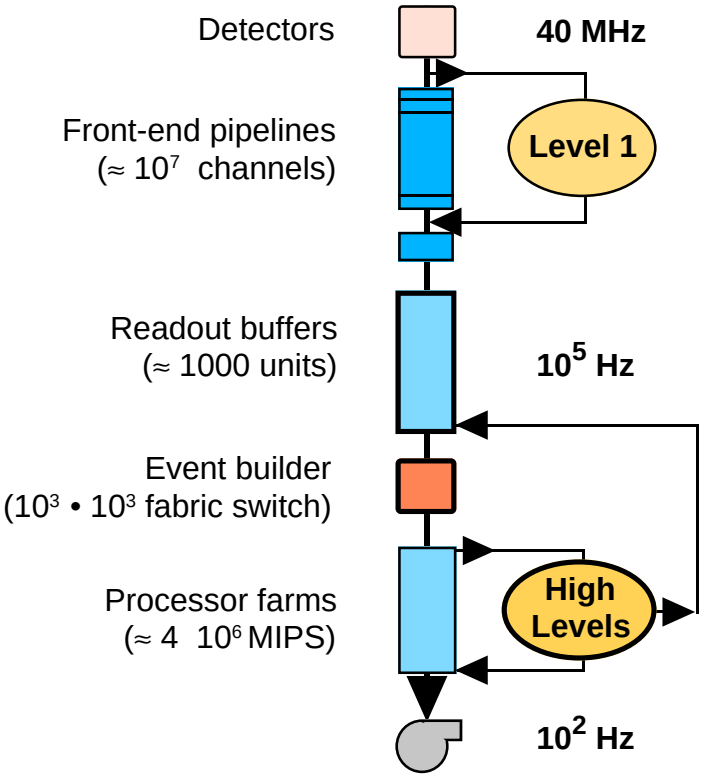
**40 MHz**

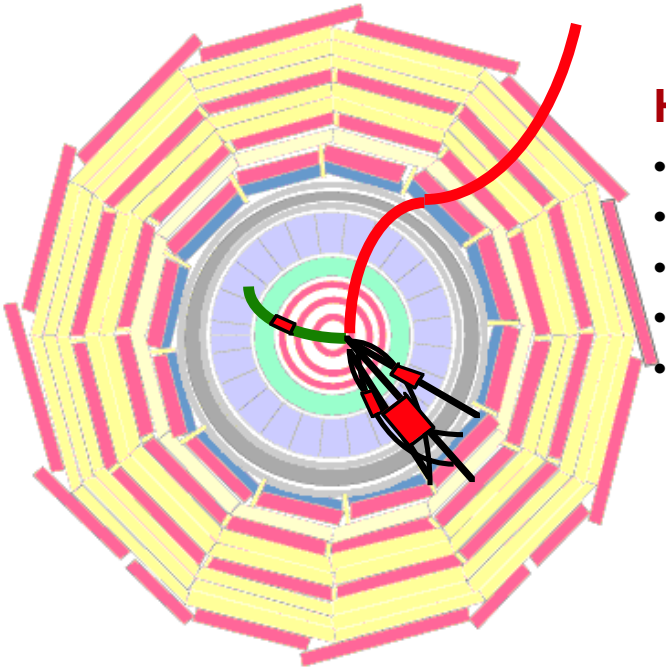


**up to 100 kHz**

## Level-1. Specialized processors

- Particle ID: electron/γ, muon, jets, missing $E_T$
- Coarse granularity to reduce data volume
- Local pattern recognition and energy sums

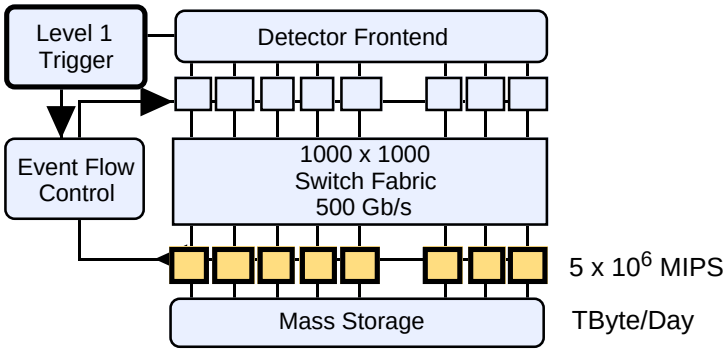


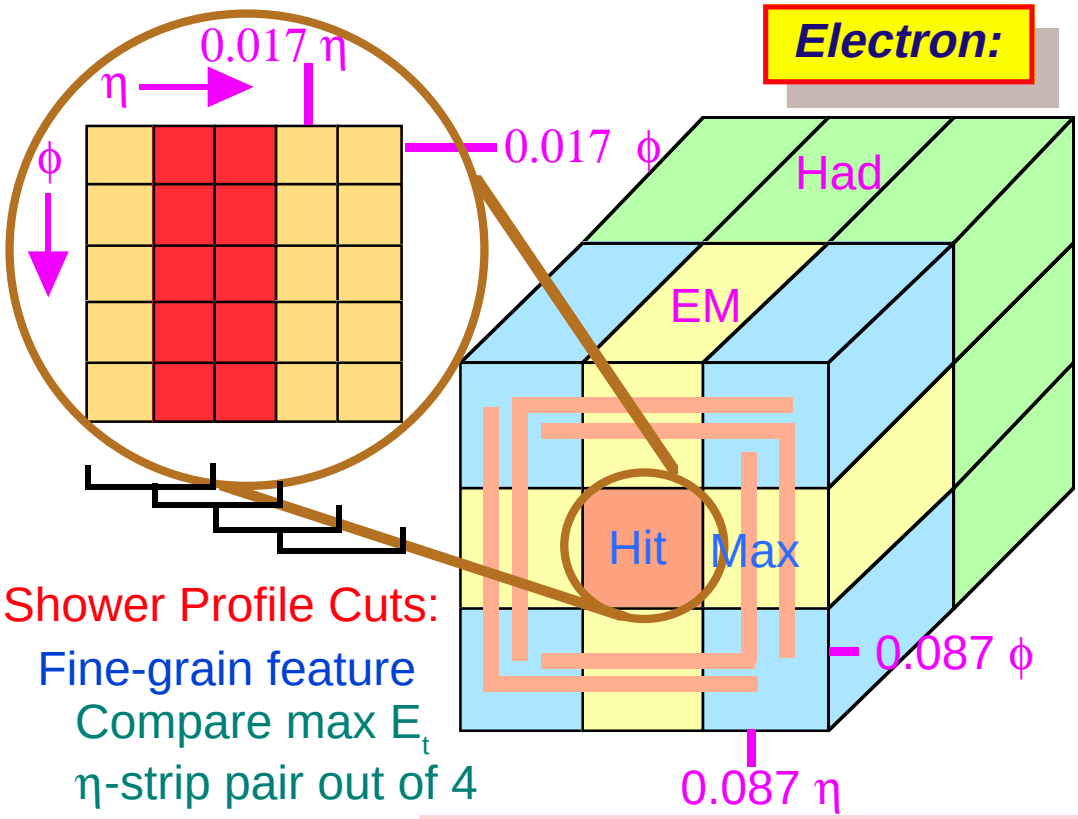
**≈ 100 Hz**

## High trigger levels. CPU farms

- Clean particle signature (Z, W, quarks..)
- Finer granularity precise measurement
- Kinematics. Effective mass cuts and topology
- Track reconstruction and detector matching
- Event reconstruction and analysis



# Electron & Jet Triggers




**Electron:**

***3 x 3 sliding window centered on ECAL/HCAL trigger tower pairs***
***Tower count = 72ϕ x 54η x 2 = 7776***

**Shower Profile Cuts:**

Fine-grain feature
Compare max $E_t$ η-strip pair out of 4 pairs vs. total $E_t$

HAC Veto
Compare HCAL versus ECAL $E_t$

**Candidate Energy:**

Max — Max $E_t$ of 4 Neighbors

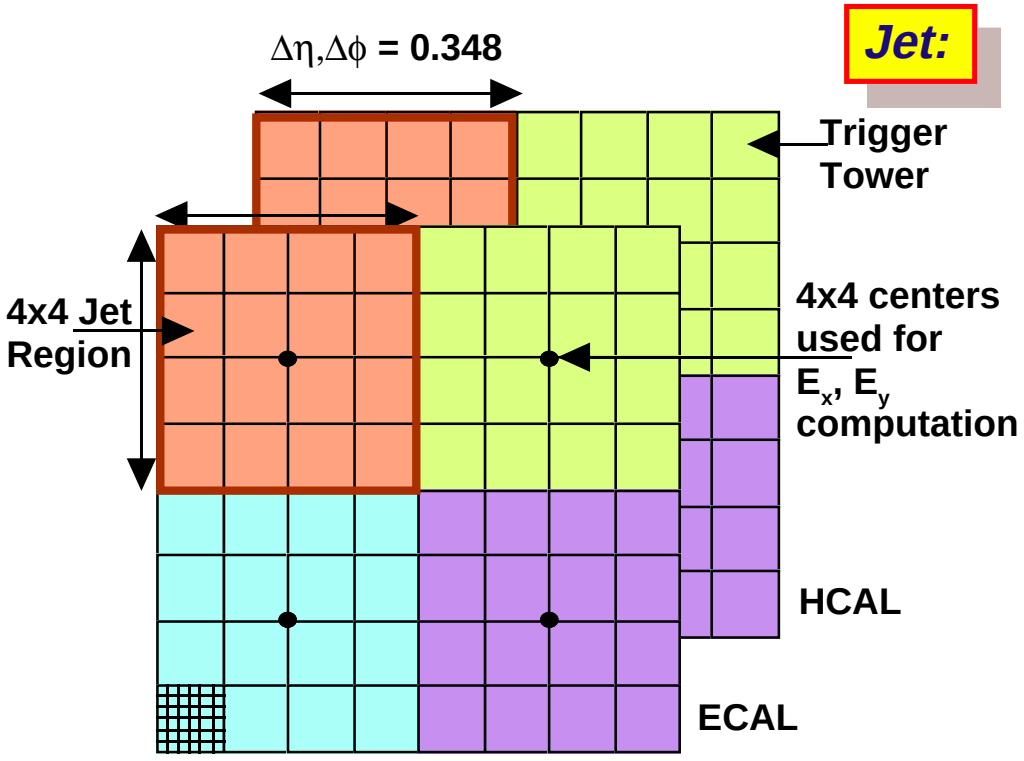
Hit — Hit + Max $E_t$ > Thrsh

**Isolation Cuts:**

Neighbor HAC Veto
HAC Veto passes on all 8 neighbors.

Neighbor $E_t$ Veto
$\Sigma_5$ Neighbors $E_t$
At least one of four corners has $\Sigma_5 E_t$ < 1.0 GeV

**Jet:**

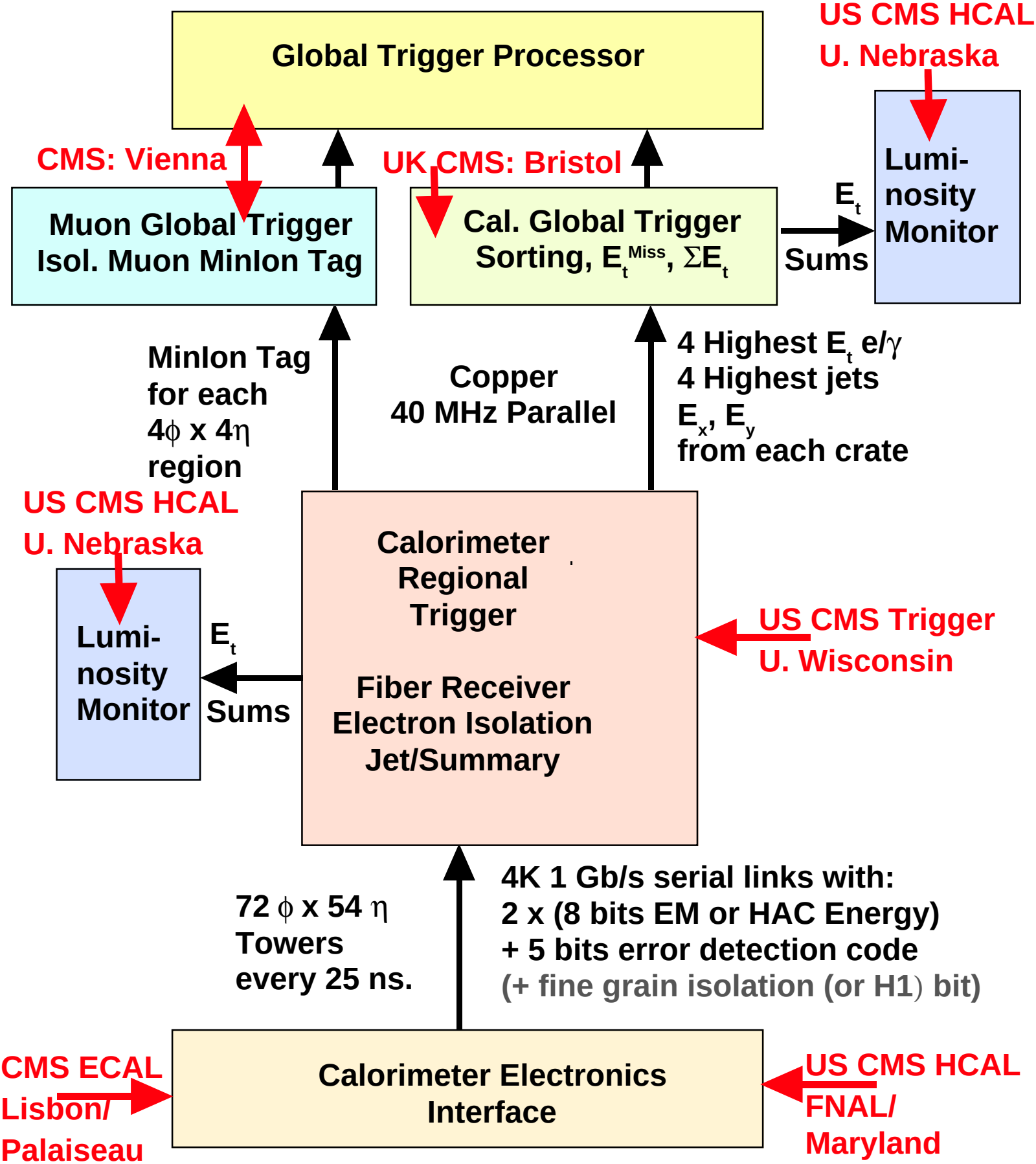



***Jet $E_t$ from sum of ECAL& HCAL trigger tower $E_t$ in non-overlapping 4x4 regions***

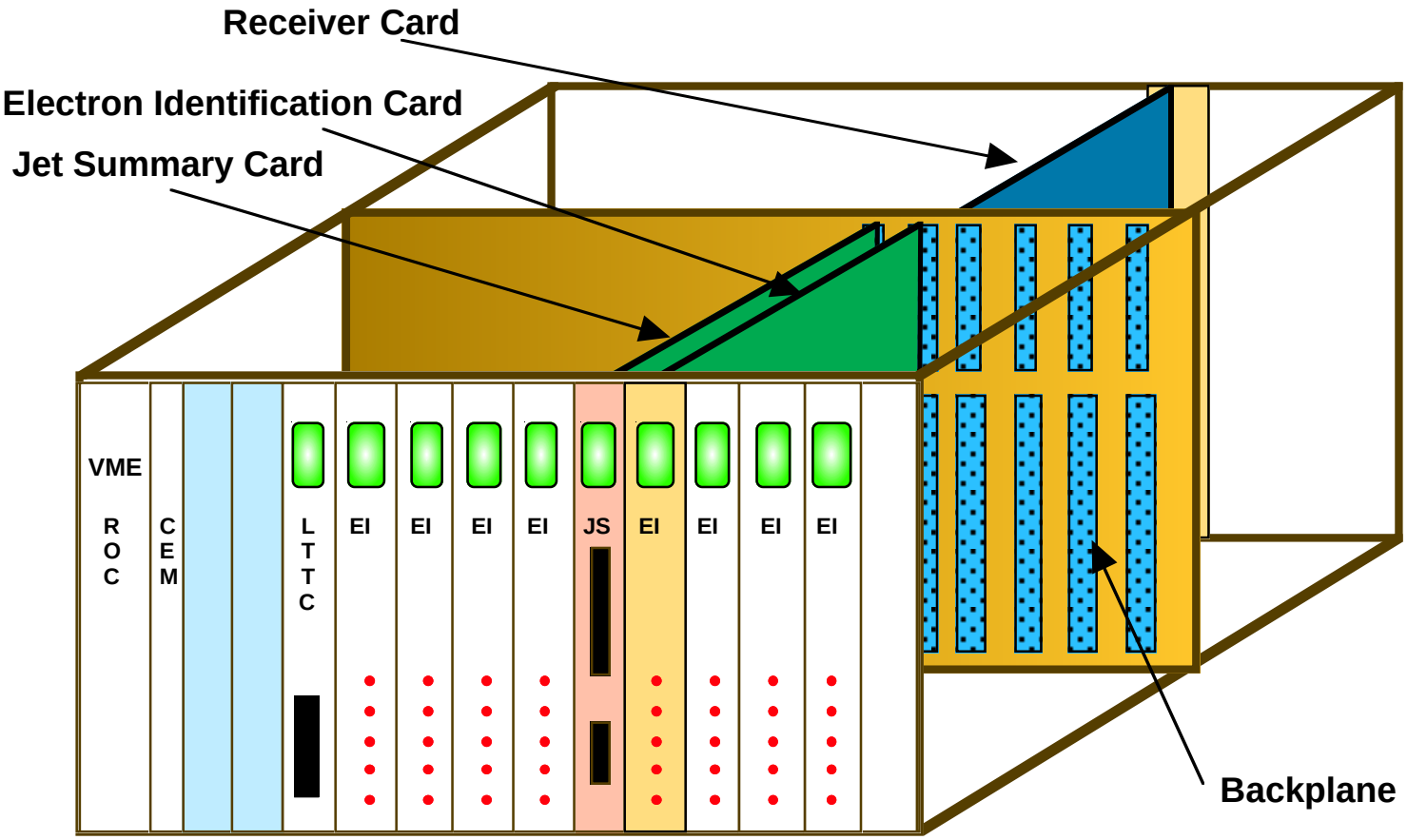
***Use multijet triggers***

***Jet candidates are sorted to find highest energy jets***

# Calorimeter Trigger Overview



# Regional Calorimeter Crate




**Data from calorimeter FE on Cu links @ 1.2 Gbaud**

- Into rear-mounted Receiver Cards **(proto. being built)**

**160 MHz point to point backplane (built!)**

- Clock&Control **(built!)** , Electron Identification, Jet/Summary, Receiver Cards operate @ 160 MHz

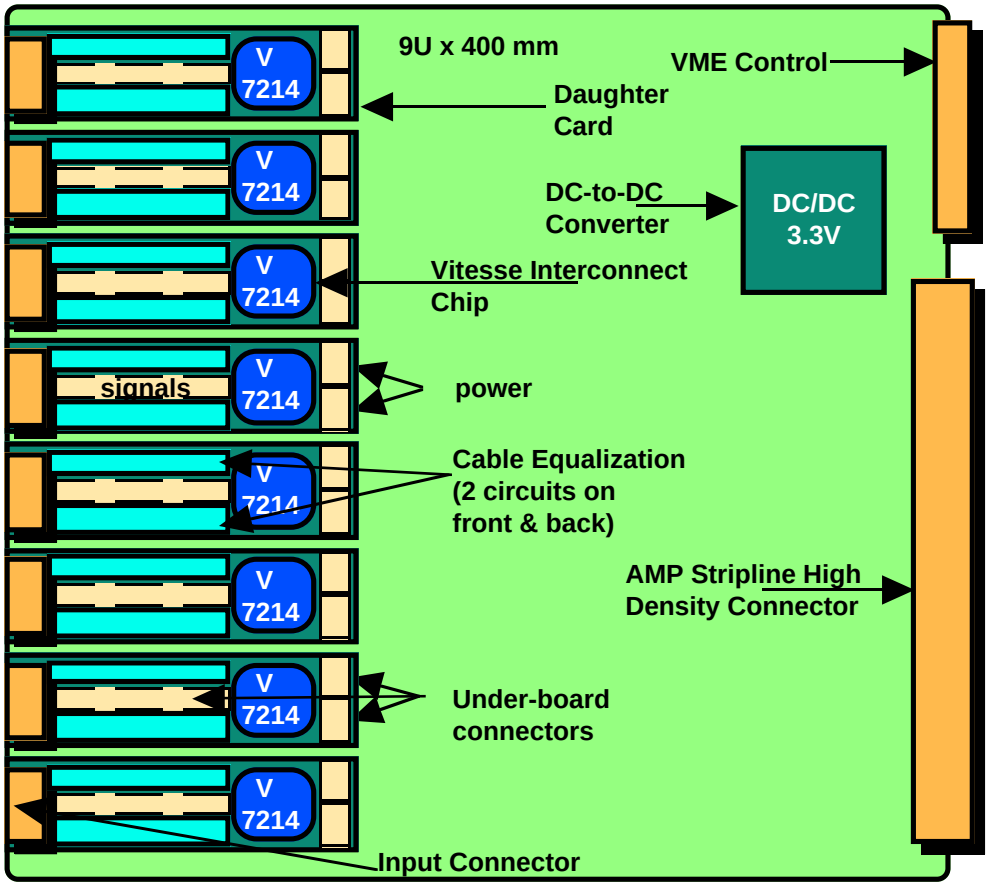
**Output to calorimeter global trigger**

- From Jet Summary Card

**Min Ion and Quiet bits to muon trigger**

# Receiver Card

## (prototype being built by U. Wisconsin)



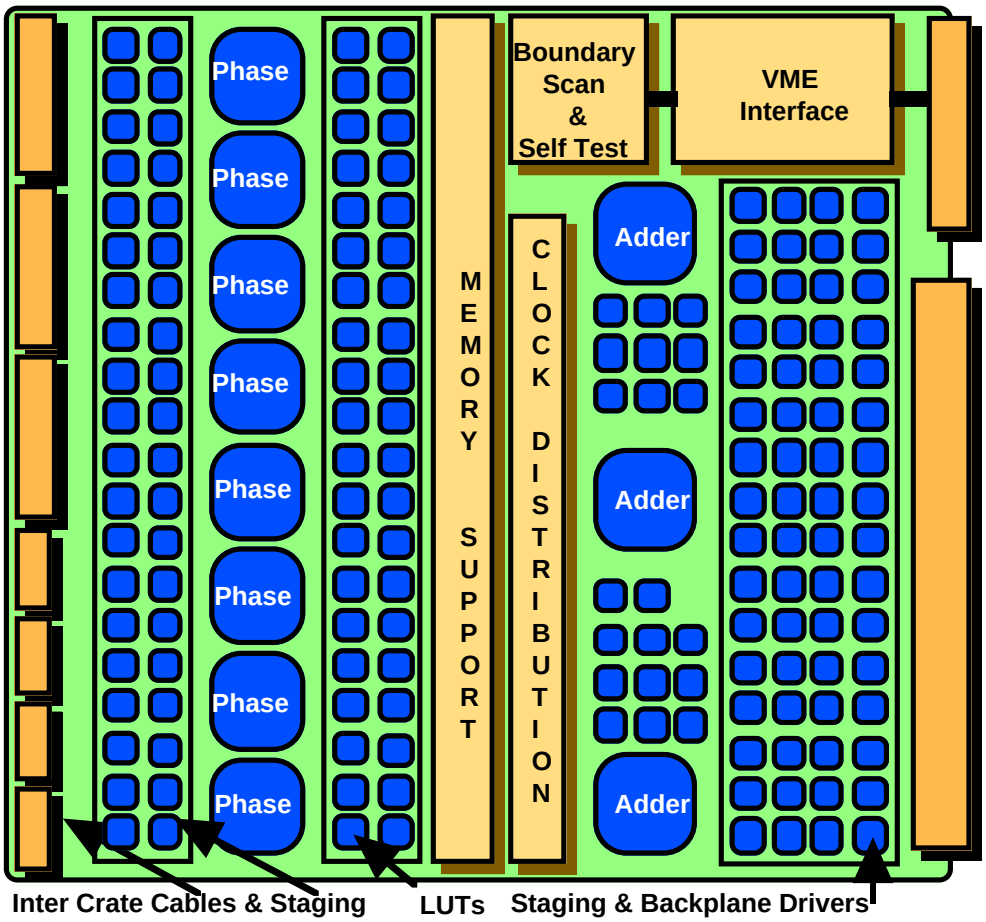

## Rear:

32 Channels = 4 Ch. x 8 daughter cards

1.2 GBaud copper rcvrs

18 bit (2x9) data + 5 bit error det. codes

Vitesse Chip Converts Serial to Parallel




## Front:

Data from Rear @ 120 MHz TTL

Phase ASIC: Deskew, EDC, Mux @ 160MHz ECL, Test vectors

Error bit for each 4x4

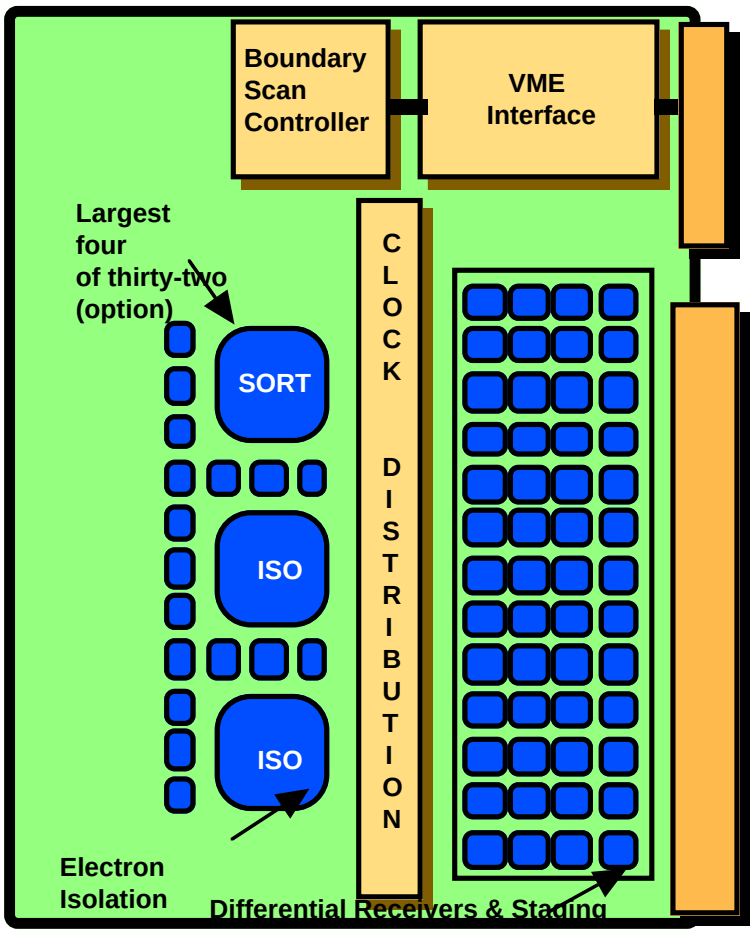
Memory LUT @ 160 MHz

Adder ASIC: 8 inputs @ 160 MHz in 25 ns. (built!)

Differential Out@160 MHz

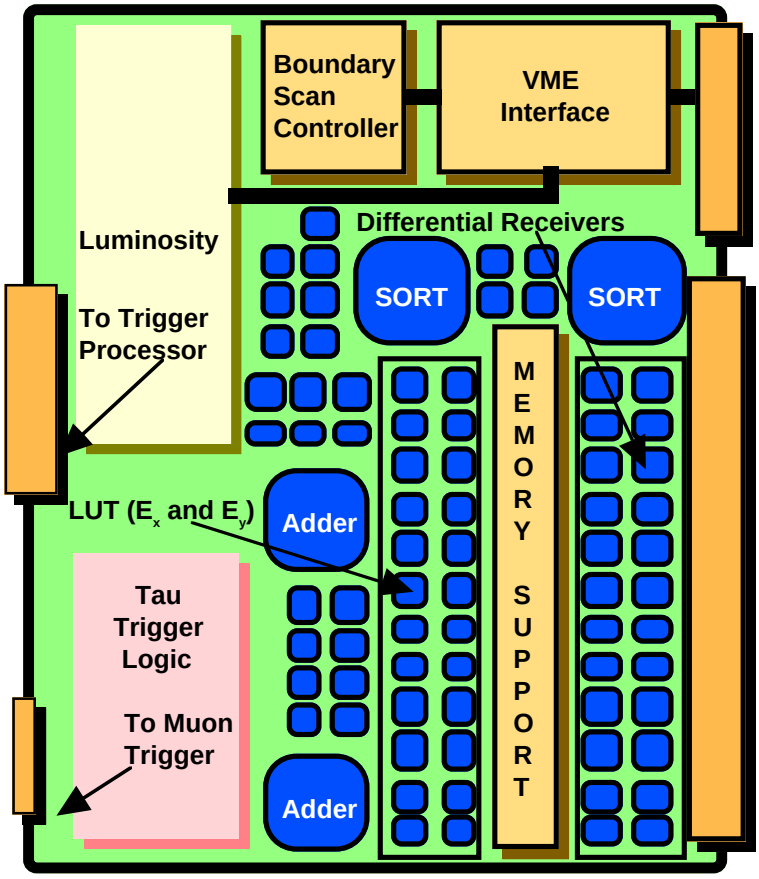
# Electron ID & Jet/Summary Cards

(U. Wisconsin)




## Electron Identification:

- Processes 4x8 region @ 160 MHz
- Electron isolation on ASIC
- Lookup tables for ranking
- Sort highest 4 rank candidates (option to take max)




## Jet/Summary:

- Summarizes full crate:
- Sorts 32 electrons for top 4
- Sorts 32 4x4 $E_t$ sums for top 4 jets
- LUTs generate $E_x$ & $E_y$ from $E_t$ for 4x4 region
- Adder tree for crate $E_t$, $E_x$ and $E_y$ sums
- Quiet/MinI bits for each 4x4 region
- Reserved space for Tau & Lumi
- 40 MHz output to global and muon systems

# Physics at high luminosity

| Trigger Type | Trigger Et Cutoff (GeV) | Rate (kHz) | | | |
|---|---|---|---|---|---|
| | | CMSIM | | FASTSIM | |
| | | Individual | Incremental | Individual | Incremental |
| Sum Et | 400 | 0.3 | 0.3 | 0.4 | 0.4 |
| Missing Et | 80 | 1.2 | 0.9 | 1.7 | 1.3 |
| Electron | 25 | 11.4 | 9.3 | 4.5 | 3.9 |
| DiElectron | 12 | 2.1 | 1.8 | 1.0 | 1.0 |
| Single jet | 100 | 1.5 | 1.0 | 2.0 | 1.3 |
| Dijet | 60 | 1.2 | 0.7 | 1.9 | 1.1 |
| Trijet | 30 | 2.3 | 1.3 | 3.1 | 1.8 |
| Quadjet | 20 | 2.6 | 1.1 | 3.3 | 1.4 |
| Jet+Elctrn | 50 & 12 | 1.3 | 0.3 | 0.7 | 0.2 |
| Cumulative Rate | | 16.7 | | 12.4 | |

**Luminosity = $10^{34}$ $cm^{-2}$ $s^{-1}$**

**QCD Background**

The sum & missing $E_t$ cutoffs chosen to yield 2 kHz rate.

Electron/photon triggers are emphasized, with ~8 kHz rate out of total available 15 kHz.

The remaining 5 kHz is available for jet triggers.

| Process | Efficiency (%) | | |
|---|---|---|---|
| | CMS-TN-95/183 | FASTSIM | CMSIM |
| H (80 GeV) $\rightarrow \gamma\gamma$ | 97 | 92 | 94 |
| H (120 GeV) $\rightarrow$ Z Z $\rightarrow$ e e $\mu$ $\mu$ | 76* | 76* | 74* |
| H (200 GeV) $\rightarrow$ Z Z $\rightarrow$ e e j j | 99 | 96 | 95 |
| p p $\rightarrow$ t t $\rightarrow$ e X | 88 | 82 | 82 |
| p p $\rightarrow$ t t $\rightarrow$ $H^+$ X $\rightarrow$ t X | 82 | 76 | 76 |
| SUSY CMS TP Scenario A ($M_{LSP}$ = 45, $M_{spart}$ ~ 300 GeV) | 83# | - | - |

(#old results)

**Signal Efficiency**

High efficiency for all channels with electrons and photons.

The difficult-to-trigger top decay events have high efficiency, enabling studies of associated Higgs production.

*Inclusion of muon trigger provides full efficiency

# Physics at low luminosity

| Trigger Type | Trigger Et Cutoff (GeV) | Rate (kHz) | | | |
|---|---|---|---|---|---|
| | | CMSIM | | FASTSIM | |
| | | Individual | Incremental | Individual | Incremental |
| Sum Et | 150 | 1.0 | 1.0 | 1.2 | 1.2 |
| Missing Et | 40 | 2.7 | 1.7 | 3.1 | 2.0 |
| Electron | 12 | 11.4 | 9.1 | 5.4 | 4.4 |
| DiElectron | 7 | 1.2 | 1.9 | 0.4 | 1.0 |
| Single jet | 50 | 1.5 | 0.3 | 1.8 | 0.6 |
| Dijet | 30 | 1.3 | 0.3 | 1.7 | 0.4 |
| Trijet | 20 | 0.8 | 0.1 | 1.1 | 0.1 |
| Quad jet | 15 | 0.6 | 0.04 | 0.8 | 0.1 |
| Jet+Elctrn | 15 & 9 | 11.2 | 3.4 | 5.6 | 2.0 |
| Cumulative Rate | | 17.8 | | 11.8 | |

**Luminosity = $10^{33}$ $cm^{-2}$ $s^{-1}$**

**QCD Background**

CMSIM and FASTSIM rates are compared for the low luminosity $E_t$ cutoffs selected in CMS-TN-95/183

Electron trigger rate is twice as high in CMSIM results

**Signal efficiency**

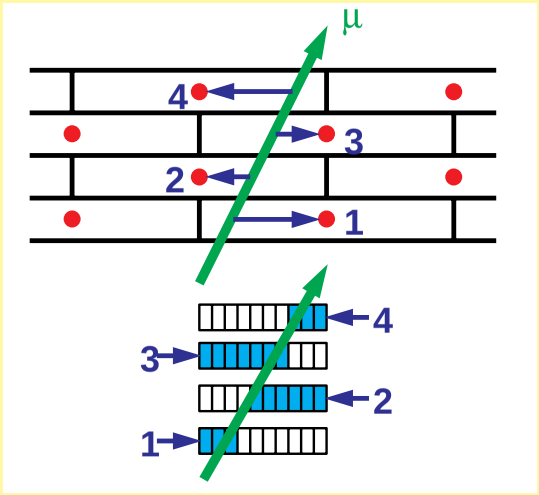
| Process | Efficiency (%) | | |
|---|---|---|---|
| | CMS-TN-95/183 | FASTSIM | CMSIM |
| p p → t t → e X | 99 | 97 | 97 |
| p p → t t → H+ X → t X | 99 | 94 | 94 |
| p p → b b (hadronize), B → e X | 0.2 (But 400Hz) | - | - |
| SUSY CMS TP Scenario A ($M_{LSP}$ = 45, $M_{spart}$ ~ 300 GeV) | 98 | - | - |
| SUSY Neutral Higgs (Range of tan b and $M_H$ values) | 45 - 98 | 30 - 96 | 39 - 96 |

High efficiency is realized for the benchmark processes involving top decays and SUSY sparticles.

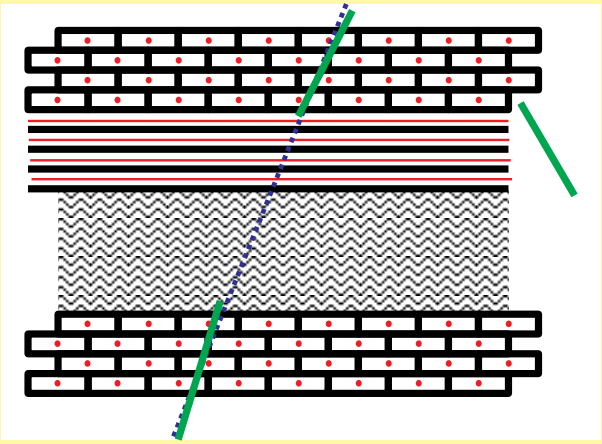
A dedicated tau trigger is under study to improve efficiency for the low mass range of SUSY Higgs.
There is also high rate of B signal in level-1 sample.

# Muon Chamber Trigger Logic

## Drift Tubes

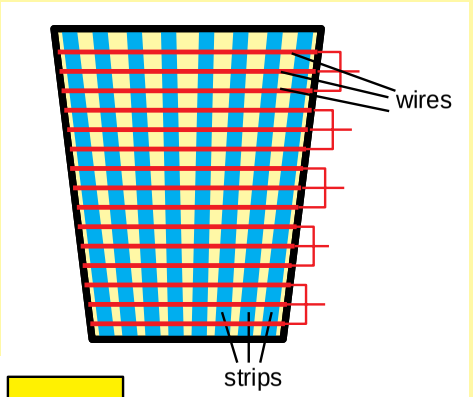


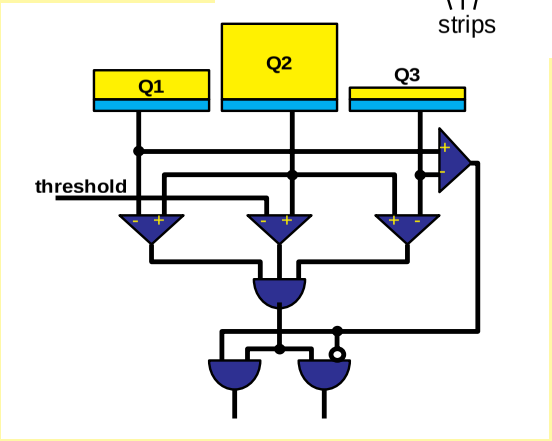

Meantimers recognize tracks and form vector / quartet.



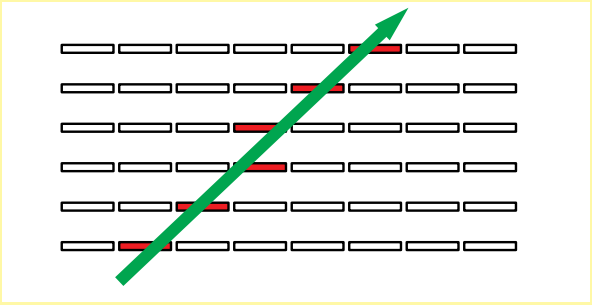
Correlator combines them into one vector / station.

## CSC



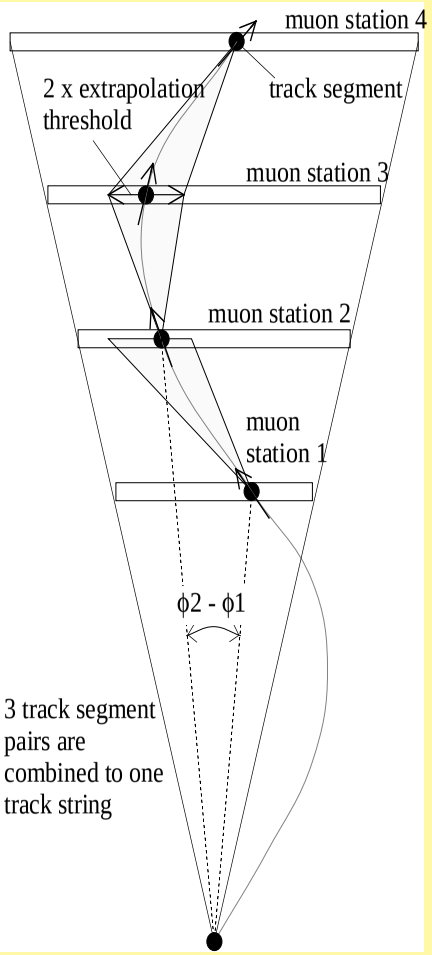




Comparators give 1/2-strip resol.



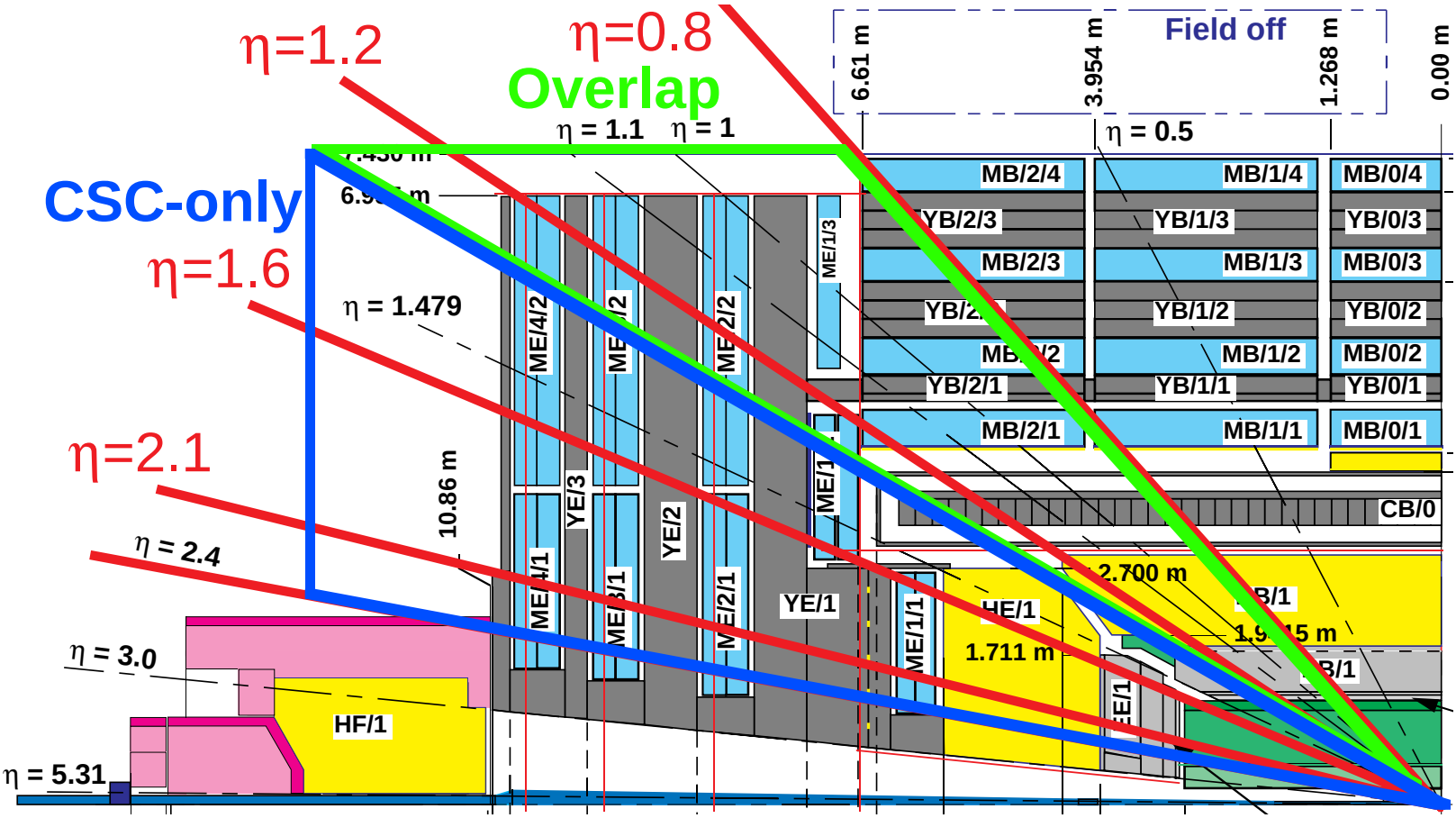
Hit strips of 6 layers form a vector.

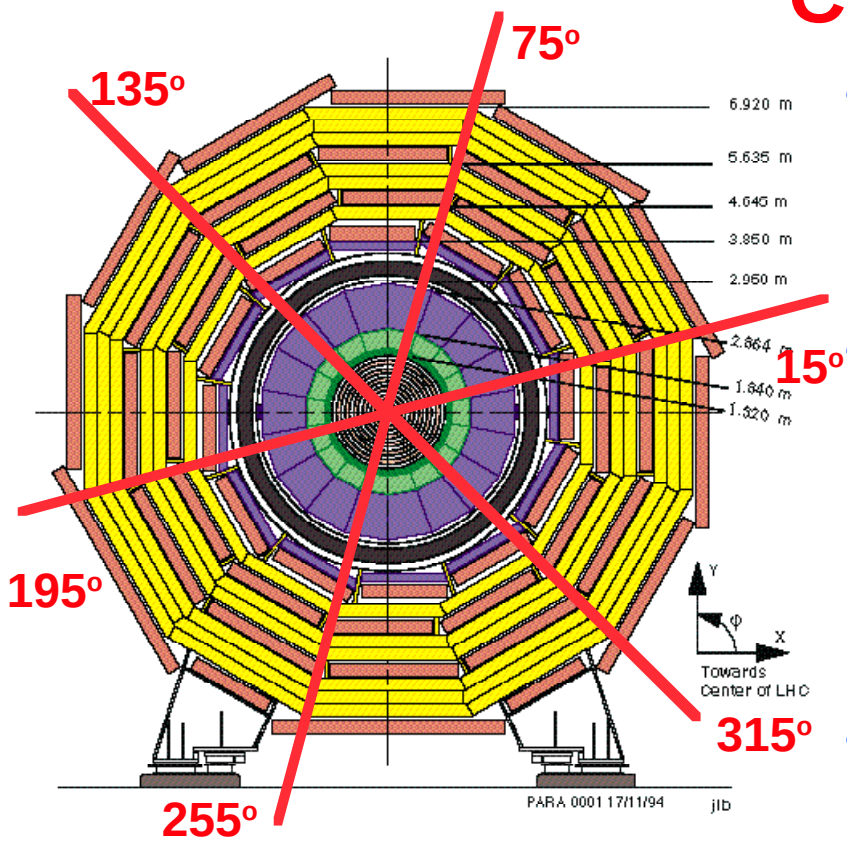
## Track Finder




- combines vectors,
- forms a track,
- assigns $p_t$ value.

# CSC Muon Trigger Geometry

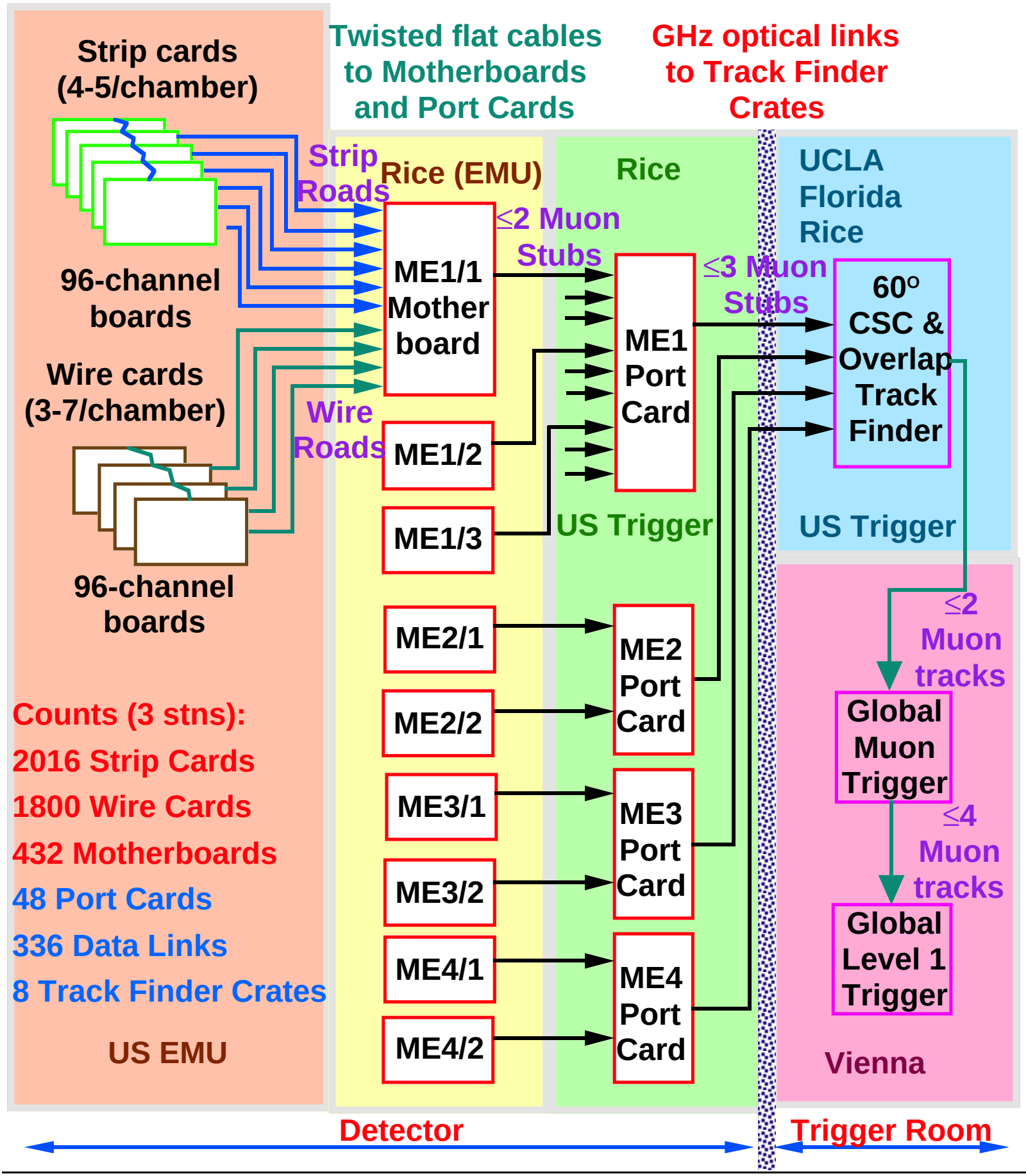



## CSC Track-finding:

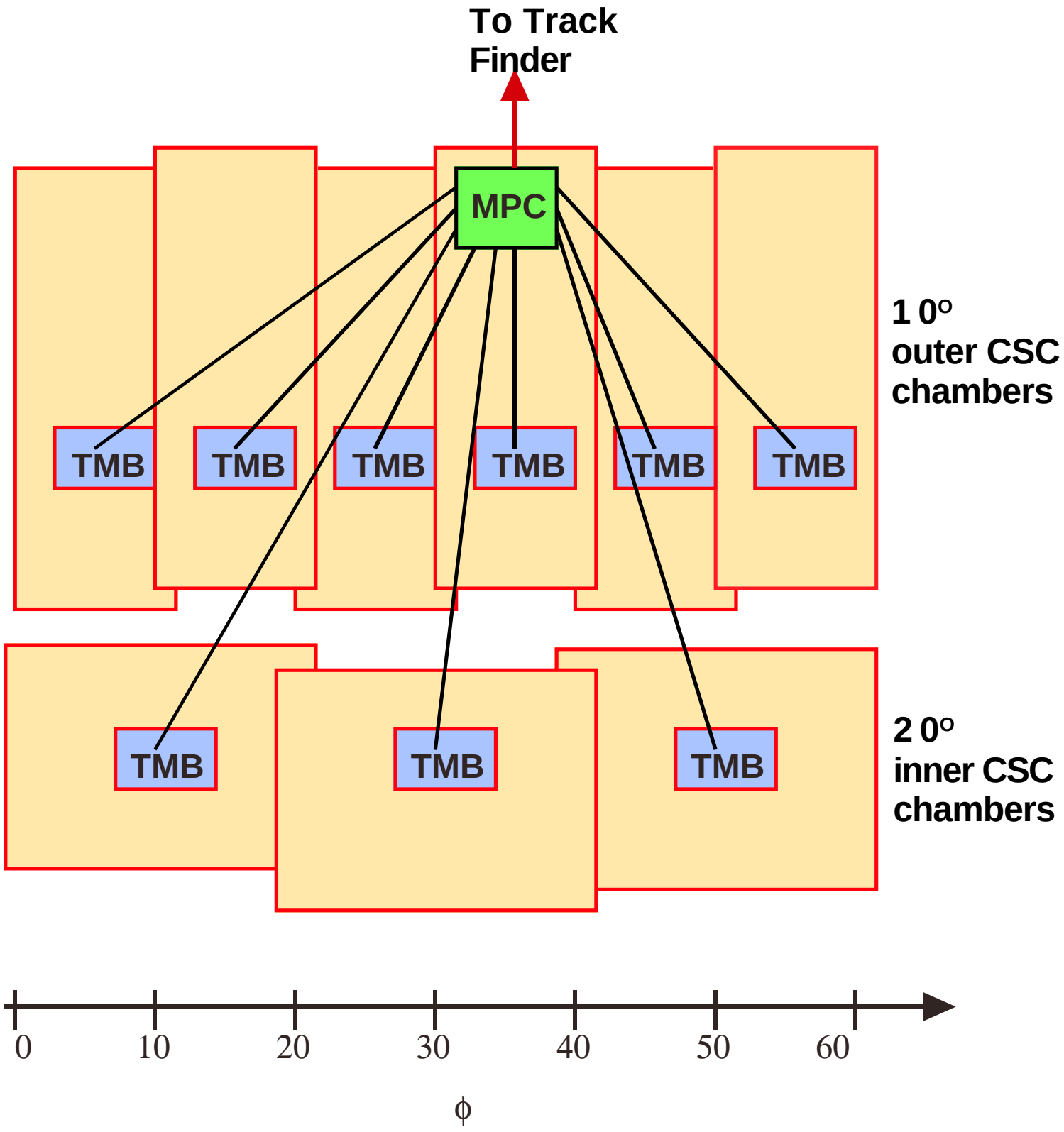
- **Two Types of Crates:**
  - 4 Overlap Crates
  - 4 CSC-only Crates
- **Two Sector Processors**
  - SP-Overlap
    - CSC's & Barrel DT's
  - SP-CSC
    - CSC's only
- **One Receiver Card:**
  - Either DT's or CSC's

# CSC Trigger Layout

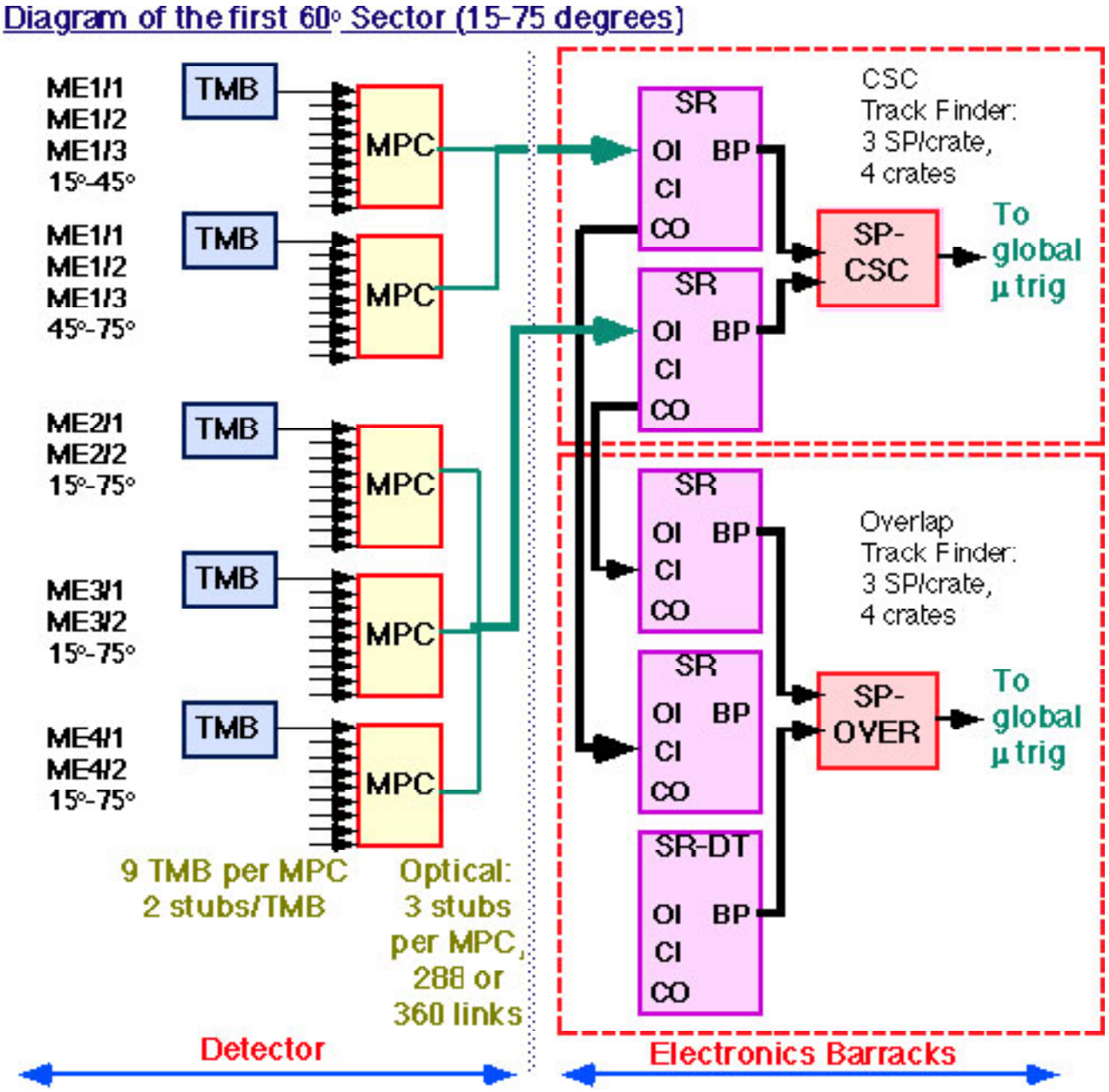


# CSC Trigger Port Cards

**TMB = Trigger MotherBoard**
**MPC = Port Card**



# CSC & Overlap TF Block Diagram




## Glossary and Part Count

**TMB:** Trigger Motherboards (432 or 540)
**MPC:** Muon Port Cards (48 or 60)
**SR:** Sector Receivers for CSC (24)
**SR-DT:** Sector Receivers for DT (12 or 24)
**SP-CSC:** Sector Processors for CSC region (12)
**SP-Over:** Sector Processors for Overlap region (12)
**OI, CI, CO, BP:** Optical in, copper in, copper out, backplane

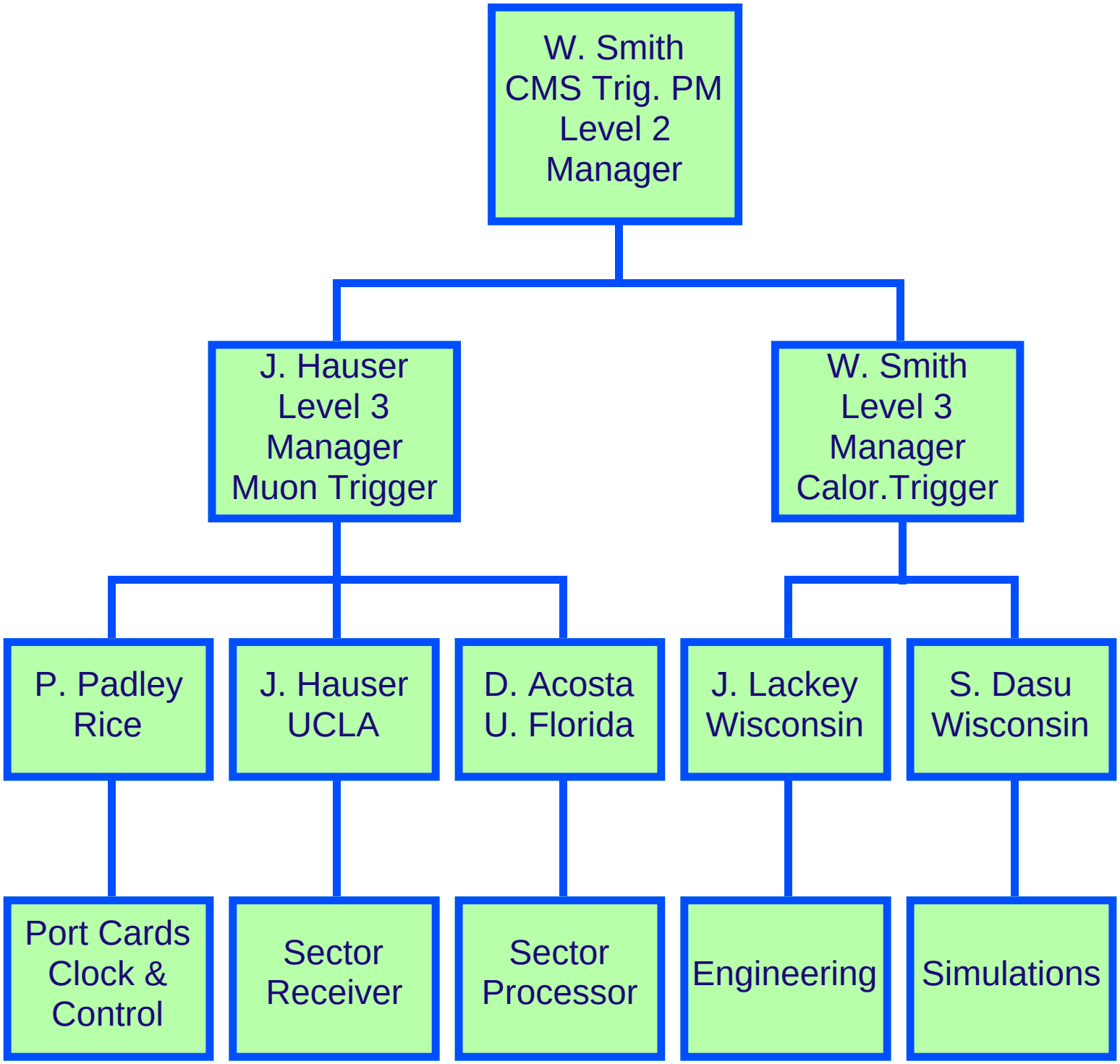
# Muon & Cal. Trigger Rates

## High Luminosity: $L = 10^{34}$ cm$^{-2}$ s$^{-1}$

| trigger type | threshold [GeV] | rate [kHz] | cumulative rate [kHz] |
|---|---|---|---|
| $\mu$ | 20 | 7.8 | 7.8 |
| $\mu\,\mu$ | 4 | 1.6 | 9.2 |
| $\mu$ e | 4, 8 | 5.5 | 14.4 |
| $\mu$ j | 4, 40 | 0.3 | 14.4 |
| $\mu$ $E_t^{miss}$ | 4, 60 | 1.0 | 15.3 |
| $\mu$ $\Sigma E_t$ | 4, 250 | 0.2 | 15.3 |
| $\mu$ | 7 | 9.8 | 9.5 |
| $\mu\,\mu$ | 2-4 | 0.5 | 10.1 |
| $\mu$ e | 2-4, 6 | 2.5 | 12.2 |
| $\mu$ $e_b$ | 2-4, 5 | 3.5 | 13.4 |
| $\mu$ j | 2-4, 12 | 2.2 | 14.5 |
| $\mu$ $E_t^{miss}$ | 2-4, 40 | 0.8 | 14.7 |
| $\mu$ $\Sigma E_t$ | 2-4, 150 | 0.8 | 14.7 |

## Low Luminosity: $L = 10^{33}$ cm$^{-2}$ s$^{-1}$

# U.S.Trigger Organization



# Trigger Responsibilities

## Muon Trigger:

| | |
|---|---|
| RPC Trigger | Warsaw |
| Drift Tube Trigger | Padova |
| CSC Trigger | UCLA, Florida, Rice |
| ME1/1 CSC Trigger | Dubna |
| Muon Sorter | Bari |
| Track Finder | Vienna |
| Global Processor | Vienna |
| DAQ | Turino |

## Calorimeter Trigger:

| | |
|---|---|
| Primitive extraction | Palaiseau, Lisbon |
| Optical Fiber Transmission | Helsinki |
| Regional Calorimeter Trigger | Wisconsin |
| Global Calorimeter Trigger | Bristol |
| DAQ & Control | Lisbon |

## Global Trigger:

| | |
|---|---|
| Trigger Timing & Control | CERN |
| Global Processor | Vienna |