Trigger & DAQ

US CMS "JTerm" III

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Outline:

Introduction to LHC Triggering

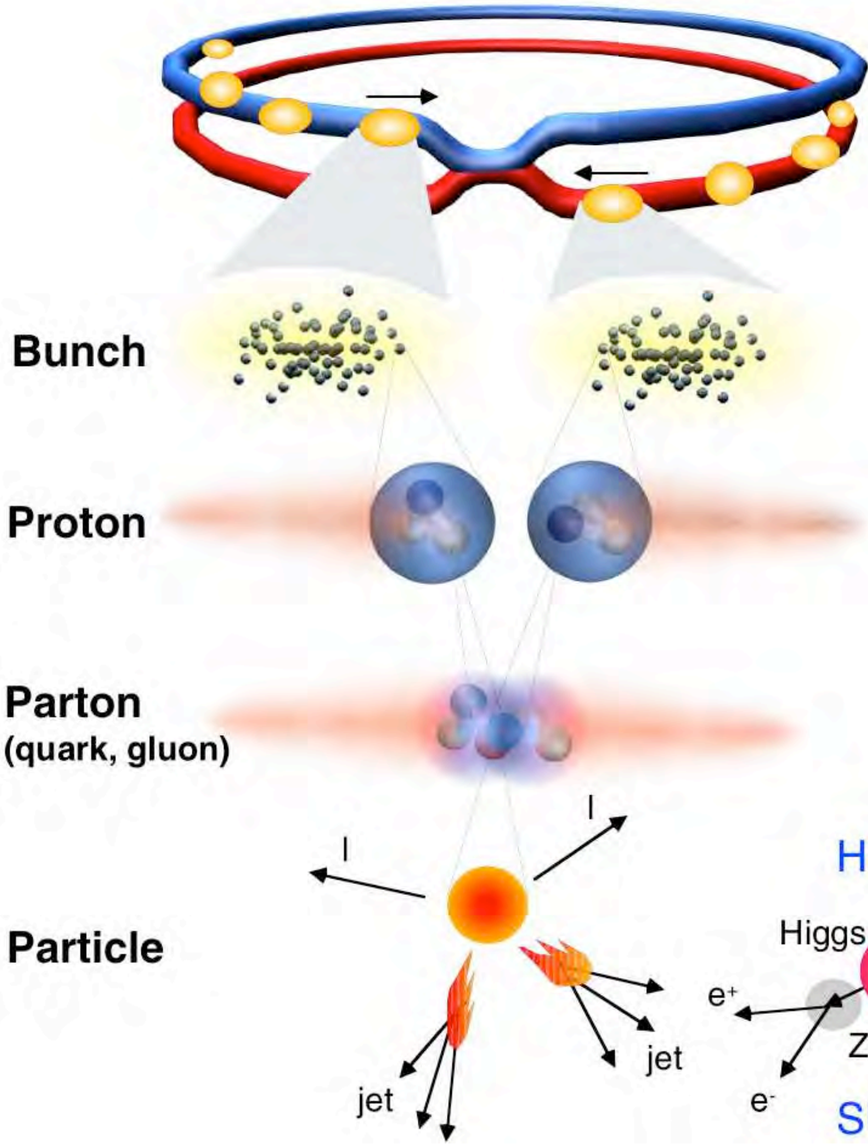
Challenges, Architecture & Timing

Level-1 Calorimeter & Muon Triggers

Higher Level Triggers

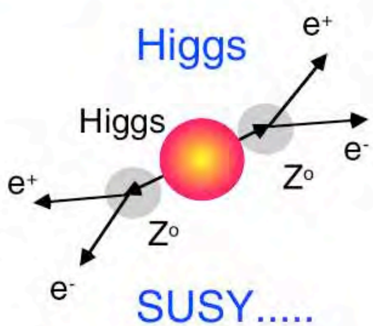
The Future: SLHC Trigger

LHC Collisions



Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV ($7x10^{12}$ eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz

with every bunch crossing
23 Minimum Bias events
with ~1725 particles produced

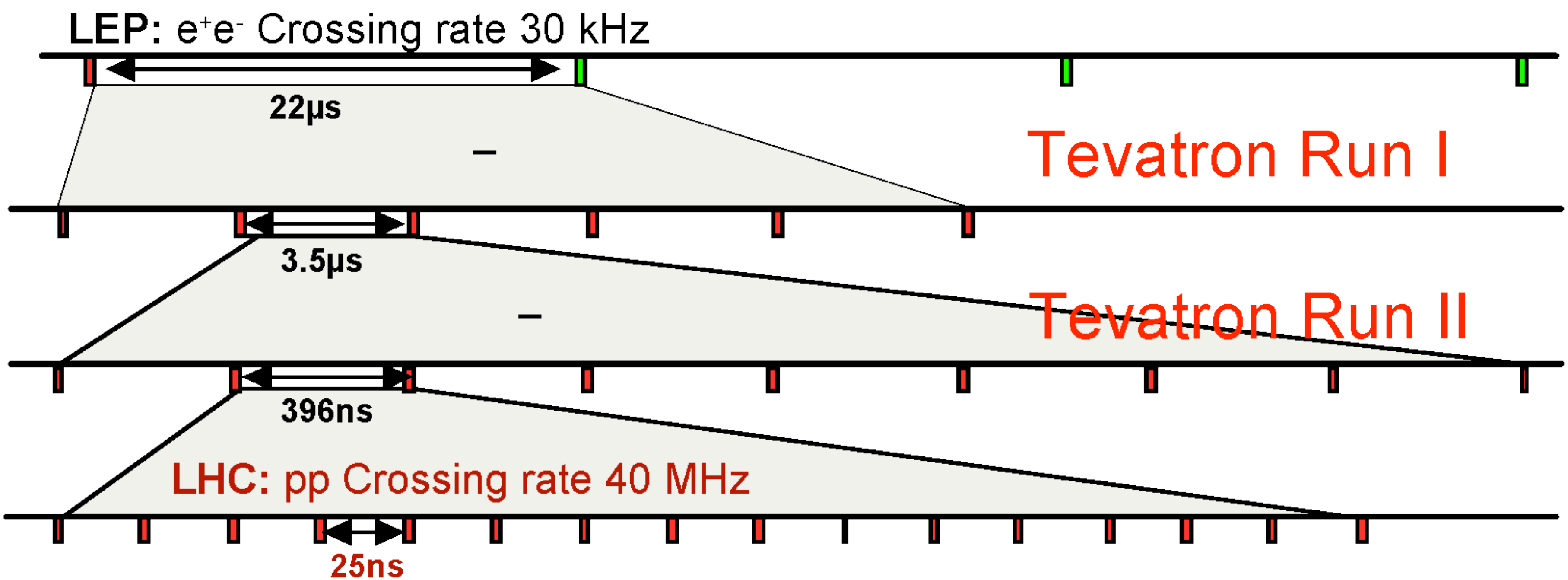


Selection of 1 in 10,000,000,000,000

Beam Xings: LEP. TeV, LHC

LHC has ~3600 bunches

- And same length as LEP (27 km)
- Distance between bunches: 27km/3600=7.5m
- Distance between bunches in time: 7.5m/c=25ns



LHC Physics & Event Rates

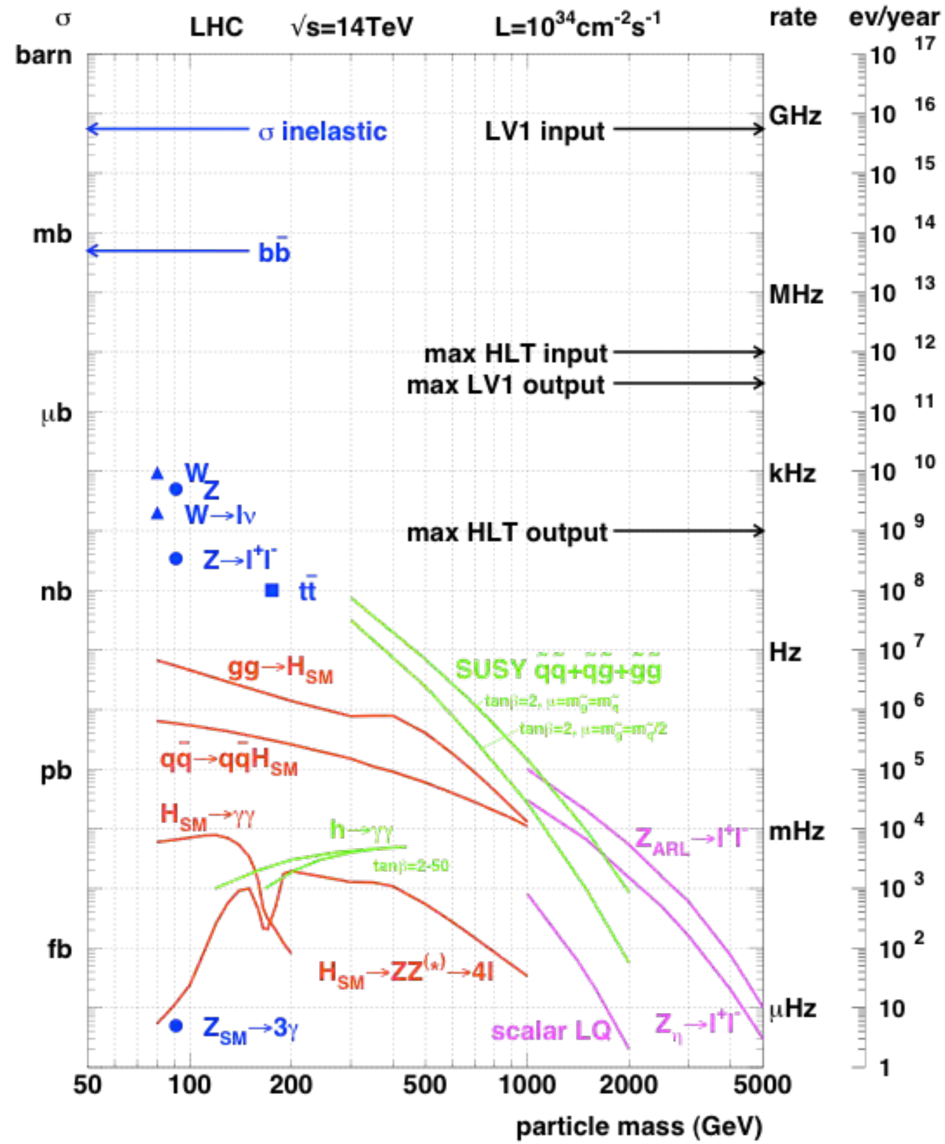
At design *L* = 10^{34}cm^{-2}s^{-1}

- **23 pp events/25 ns xing**
  - ~ 1 GHz input rate
  - "Good" events contain ~ 20 bkg. events
- **1 kHz W events**
- **10 Hz top events**
- **< 10^4 detectable Higgs decays/year**

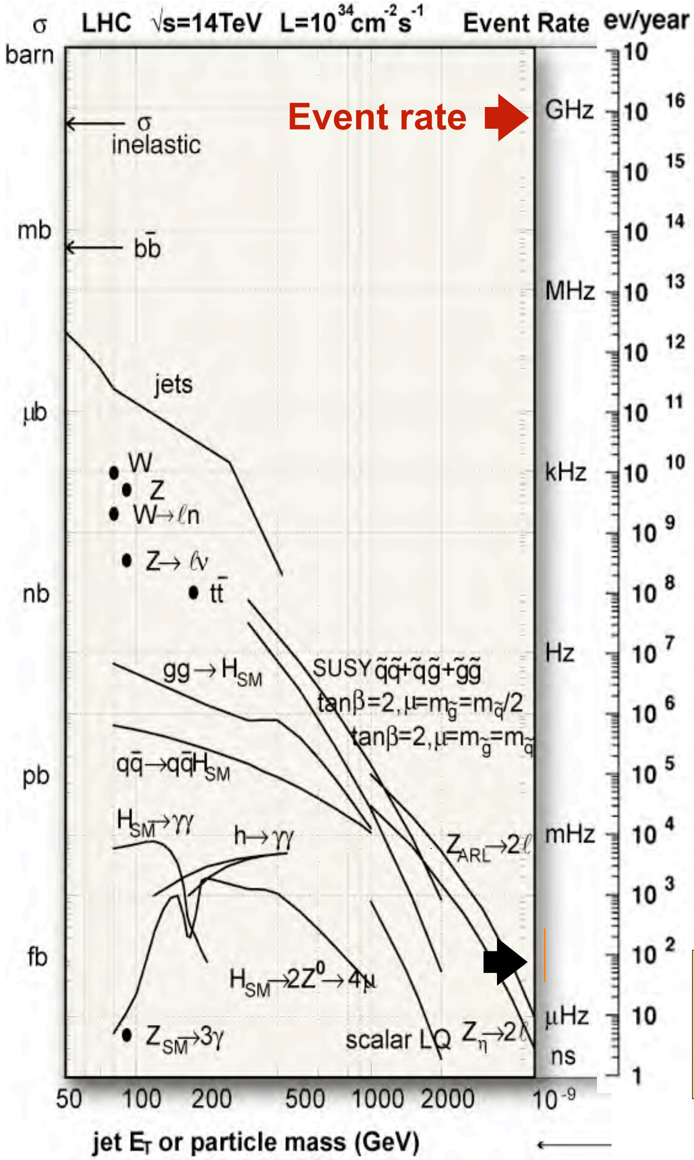
Can store ~ 300 Hz events

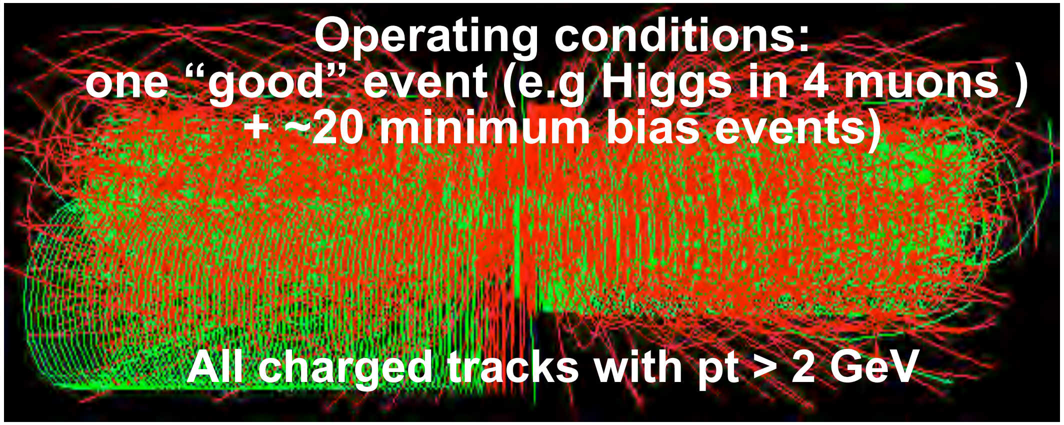
Select in stages

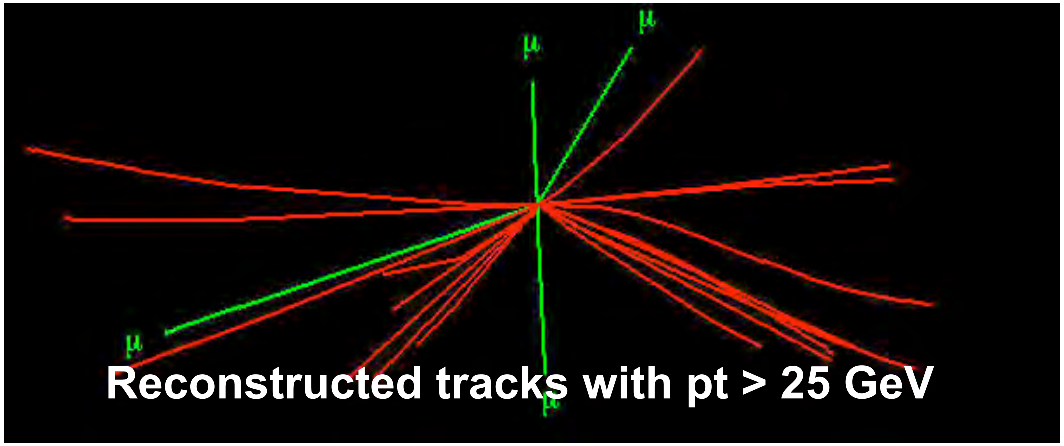
- **Level-1 Triggers**
  - 1 GHz to 100 kHz
- **High Level Triggers**
  - 100 kHz to 300 Hz



Collisions (p-p) at LHC

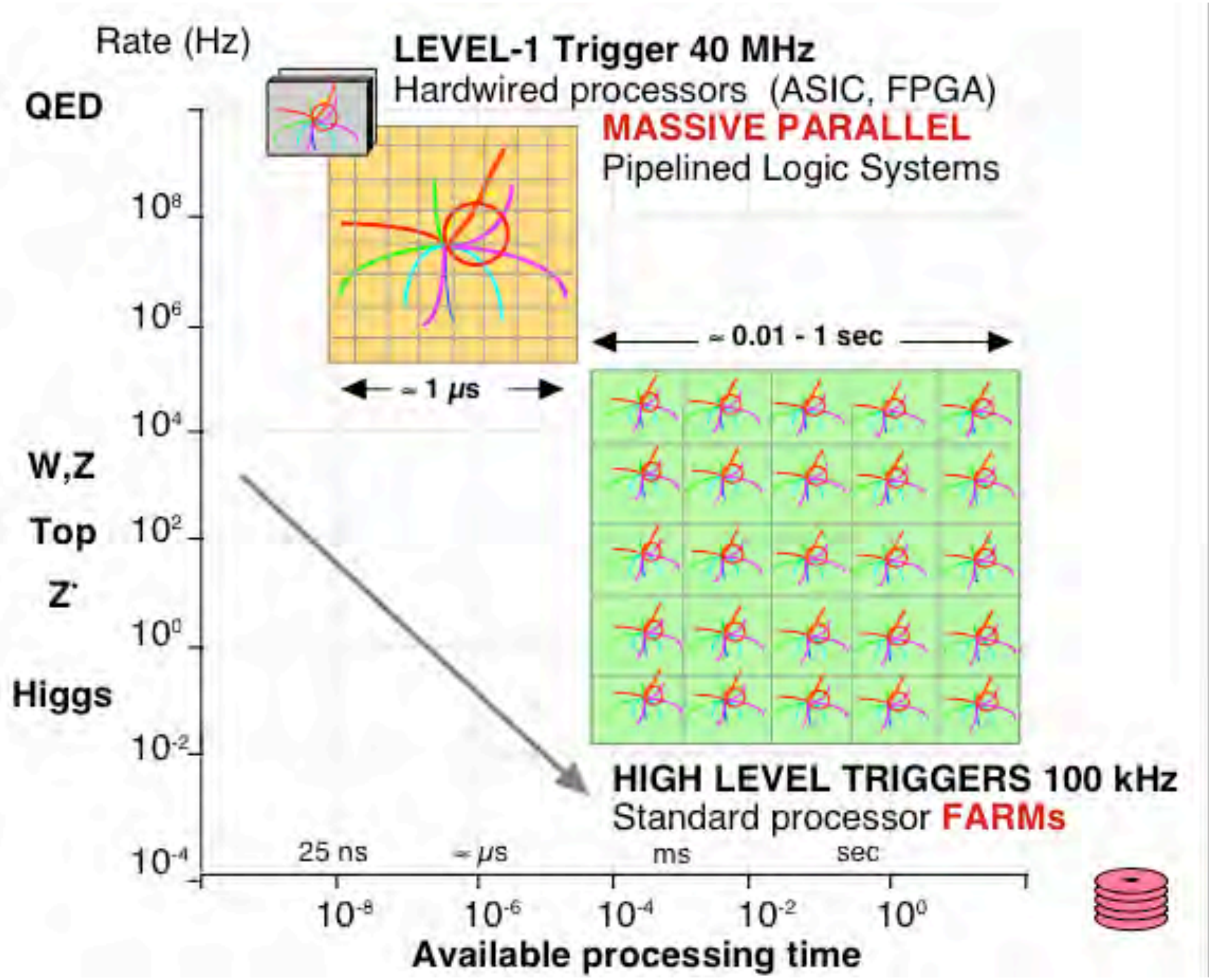




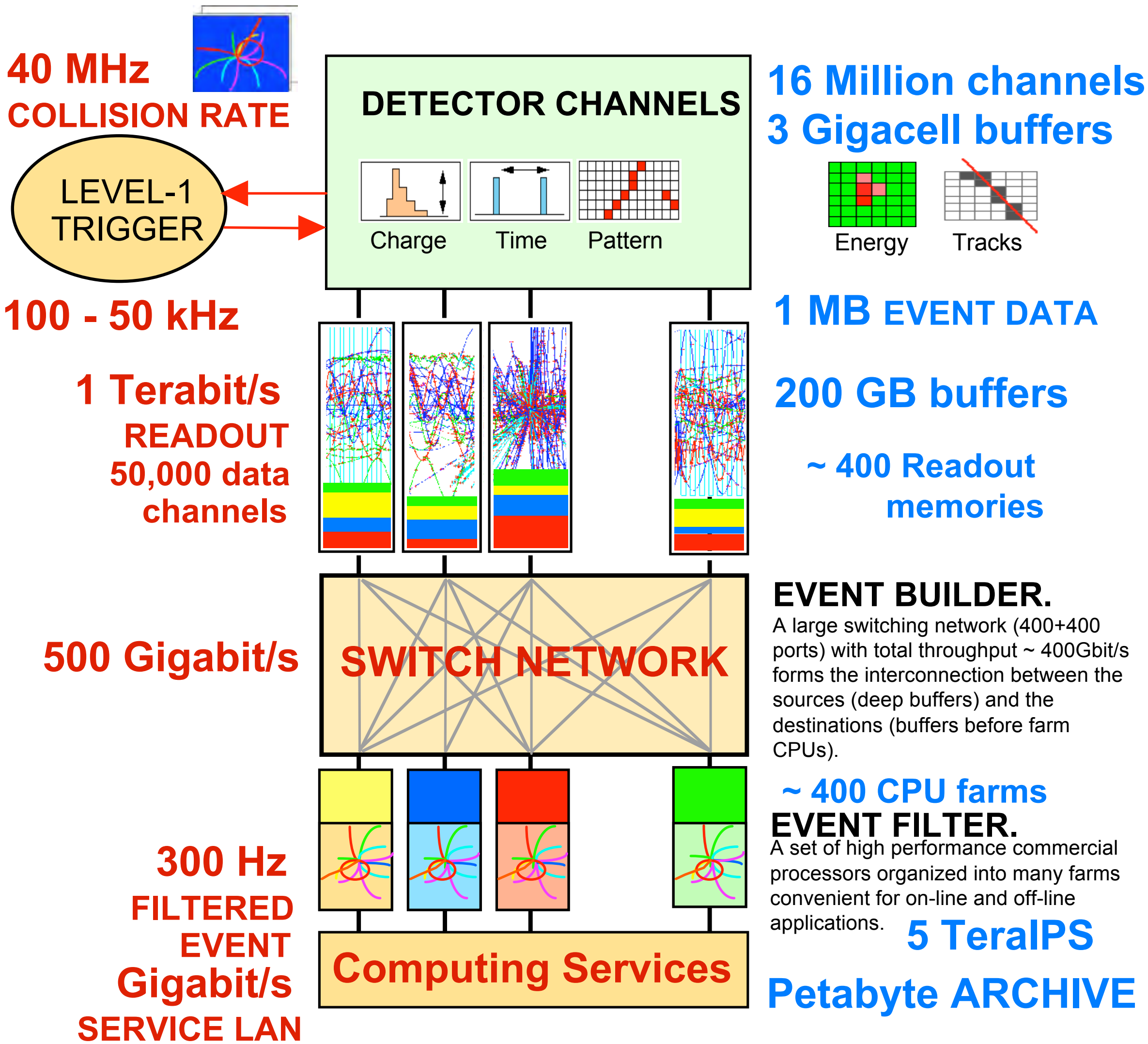


Event size:	**~1 MByte**
Processing Power:	**~X TFlop**

Processing LHC Data



LHC Trigger & DAQ Challenges



Challenges:

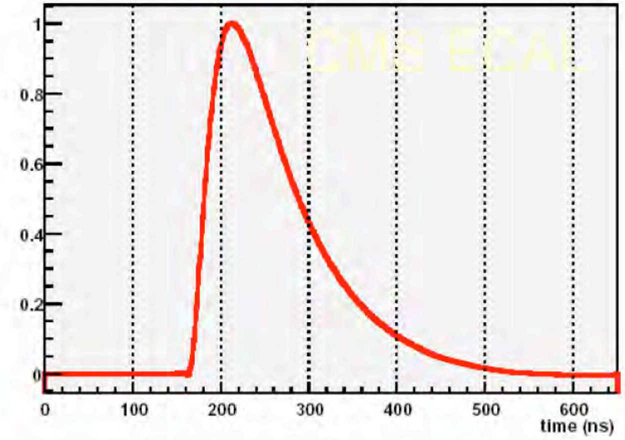
1 GHz of Input Interactions

Beam-crossing every 25 ns with ~ 23 interactions produces over 1 MB of data

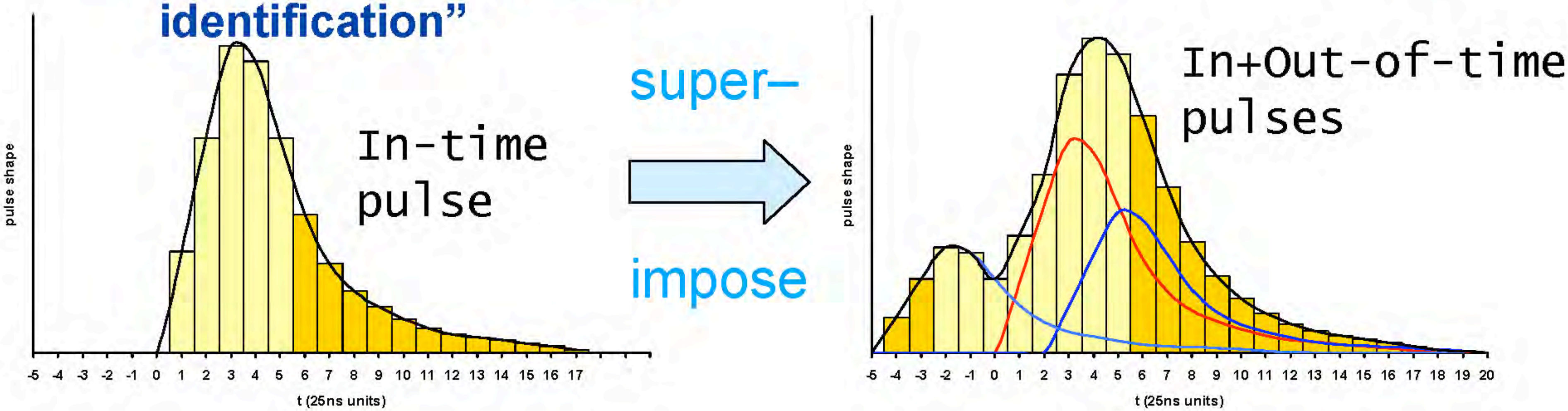
Archival Storage at about 300 Hz of 1 MB events

Challenges: Pile-up

- "In-time" pile-up: particles from the same crossing but from a different pp interaction

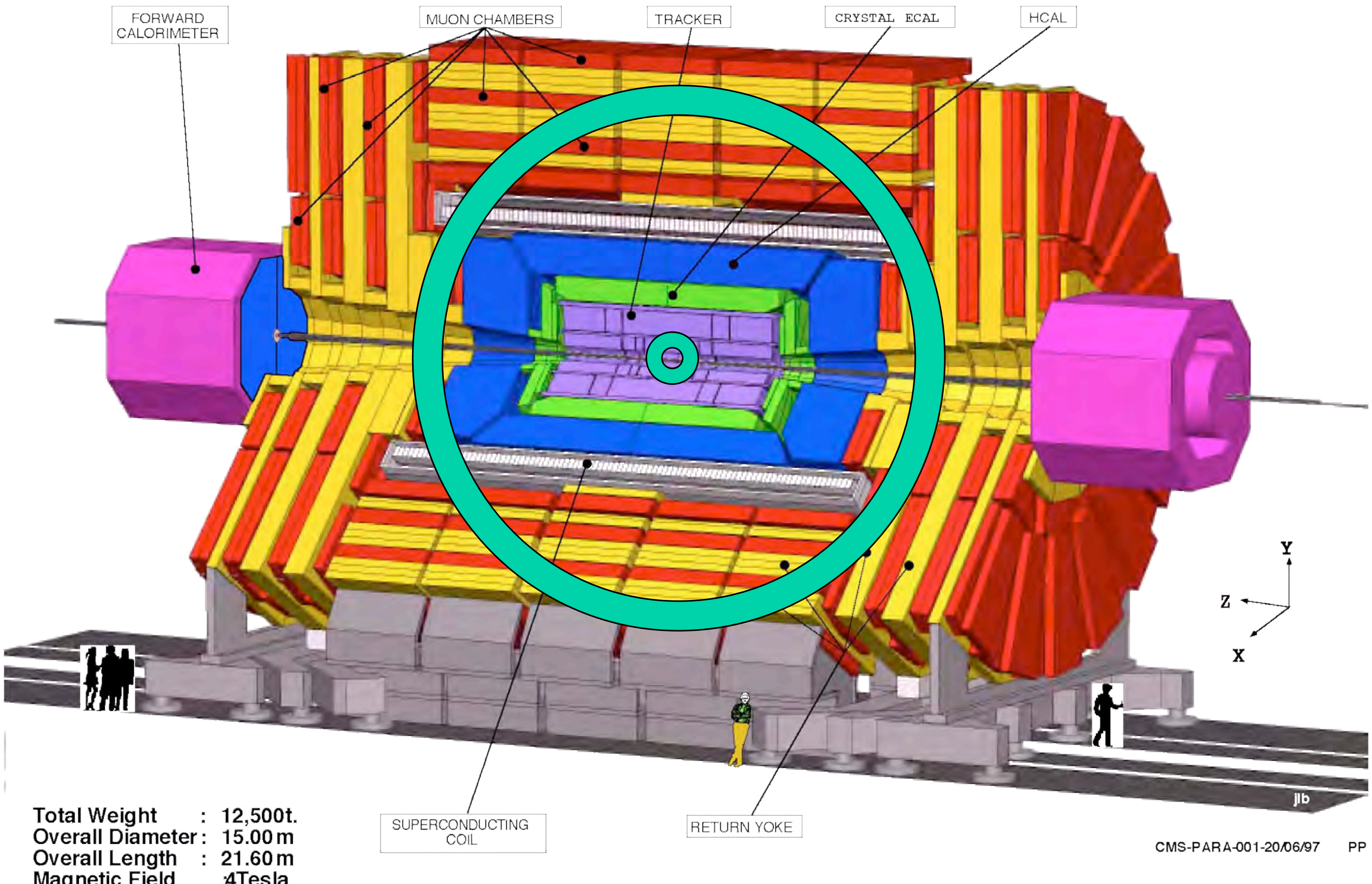


- Long detector response/pulse shapes:
  - "Out-of-time" pile-up: left-over signals from interactions in previous crossings
  - Need "bunch-crossing identification"

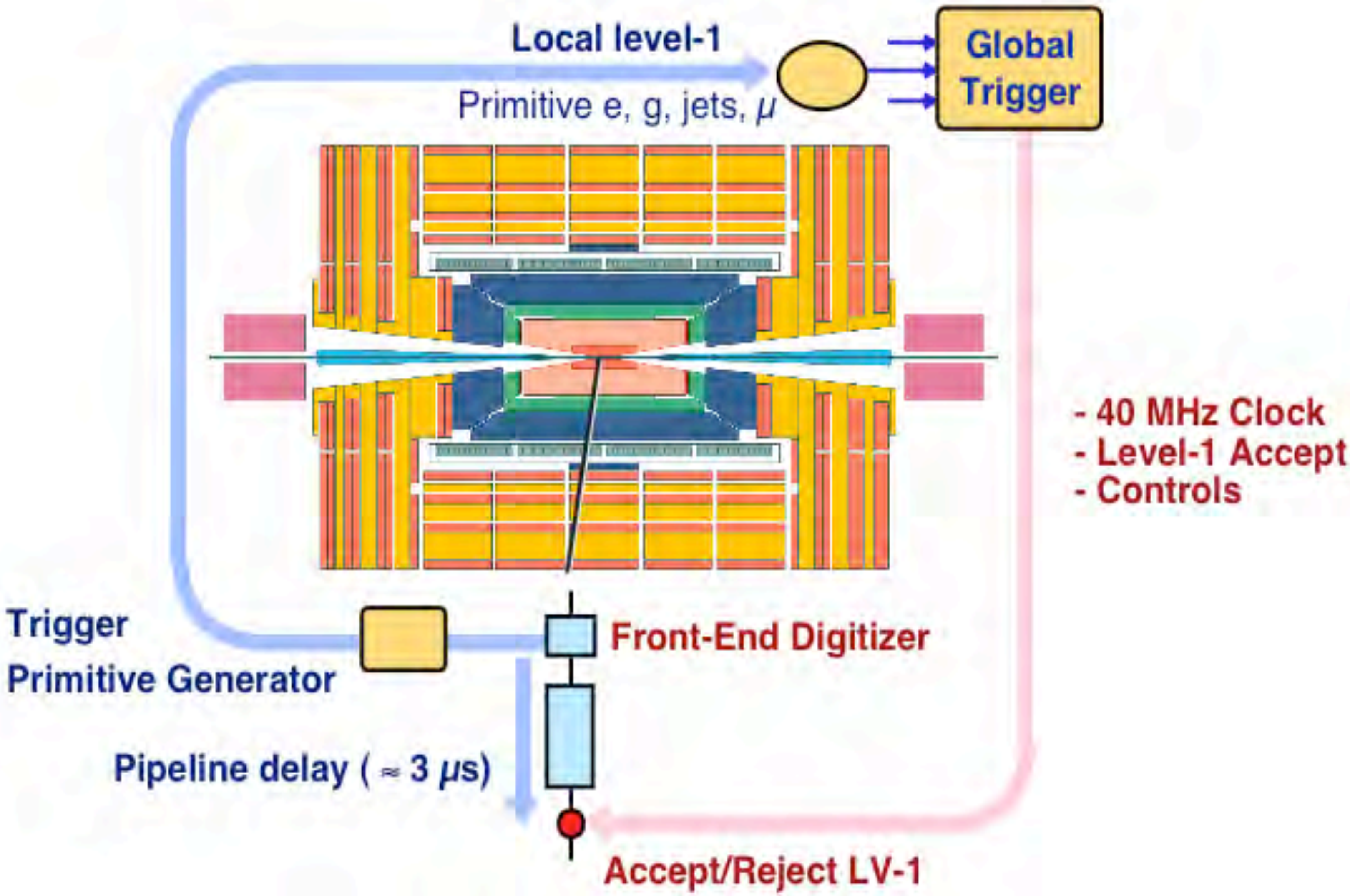


Challenges: Time of Flight

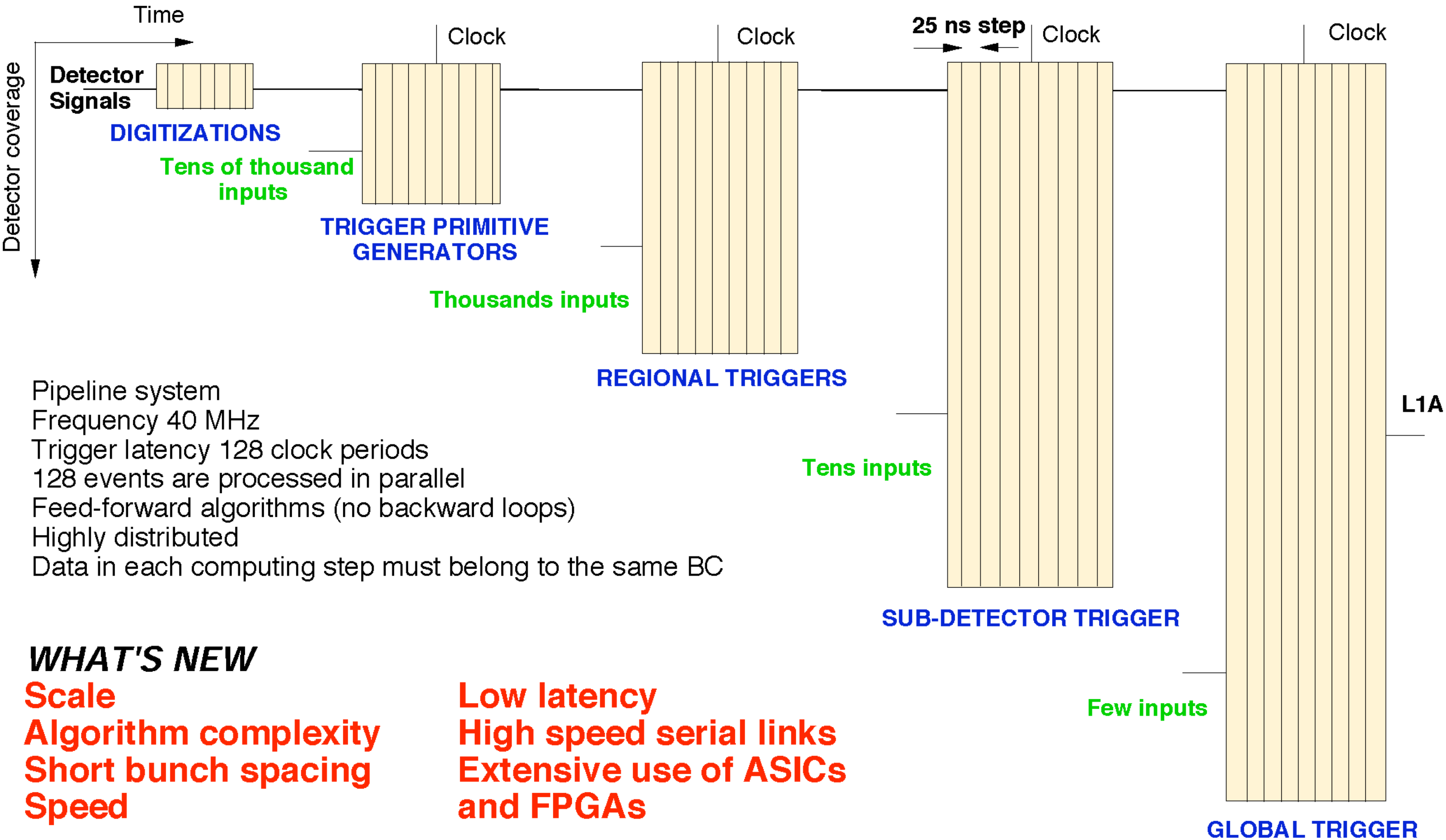
c = 30 cm/ns → in 25 ns, s = 7.5 m



Level 1 Trigger Operation



Level 1 Trigger Organization



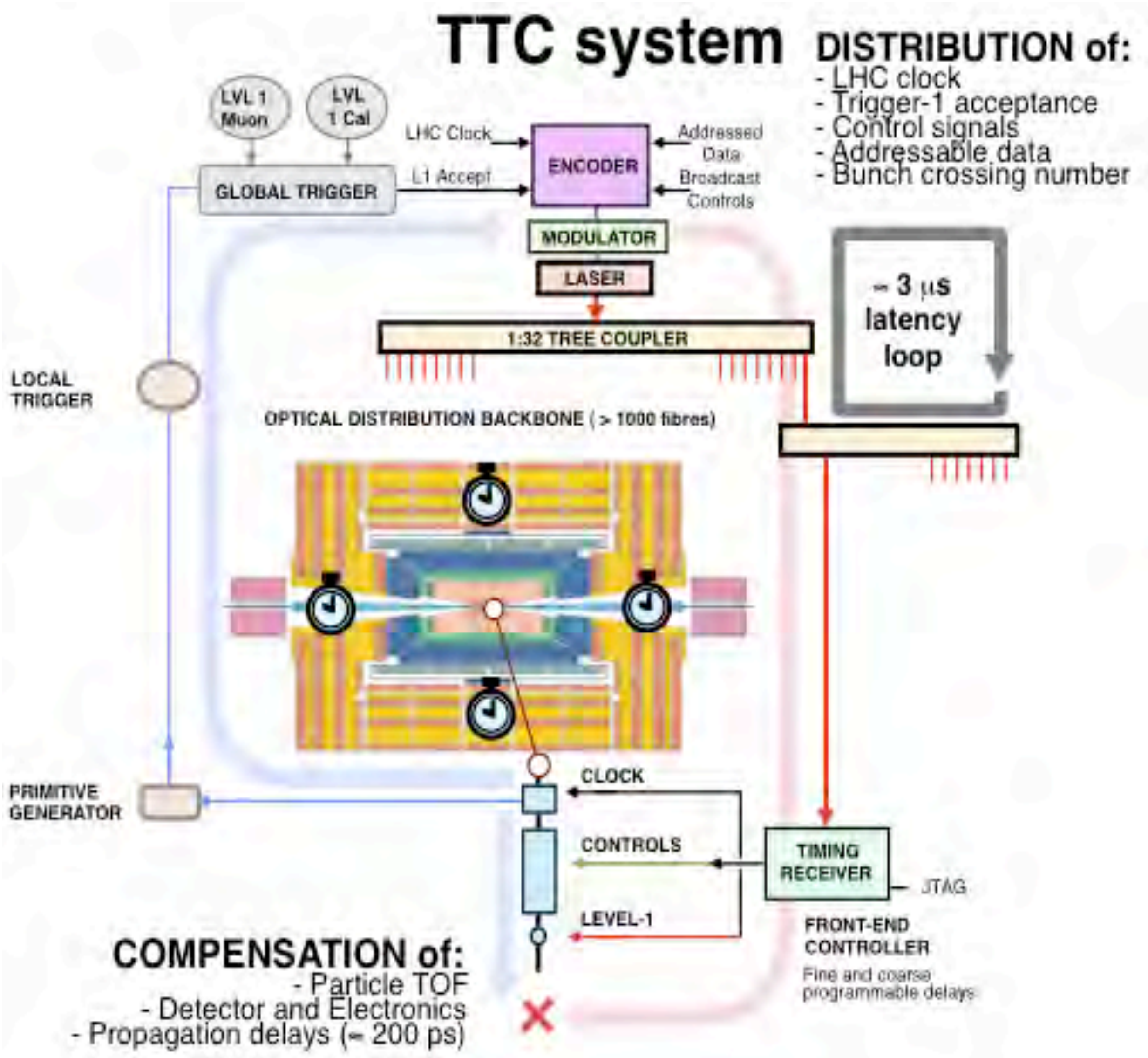
Pipeline system
Frequency 40 MHz
Trigger latency 128 clock periods
128 events are processed in parallel
Feed-forward algorithms (no backward loops)
Highly distributed
Data in each computing step must belong to the same BC

WHAT'S NEW

Scale
Algorithm complexity
Short bunch spacing
Speed

Low latency
High speed serial links
Extensive use of ASICs and FPGAs

Trigger Timing & Control



Optical System:

gle High-Power

er per zone

- **Reliability, transmitter upgrades**
- **Passive optical coupler fanout**

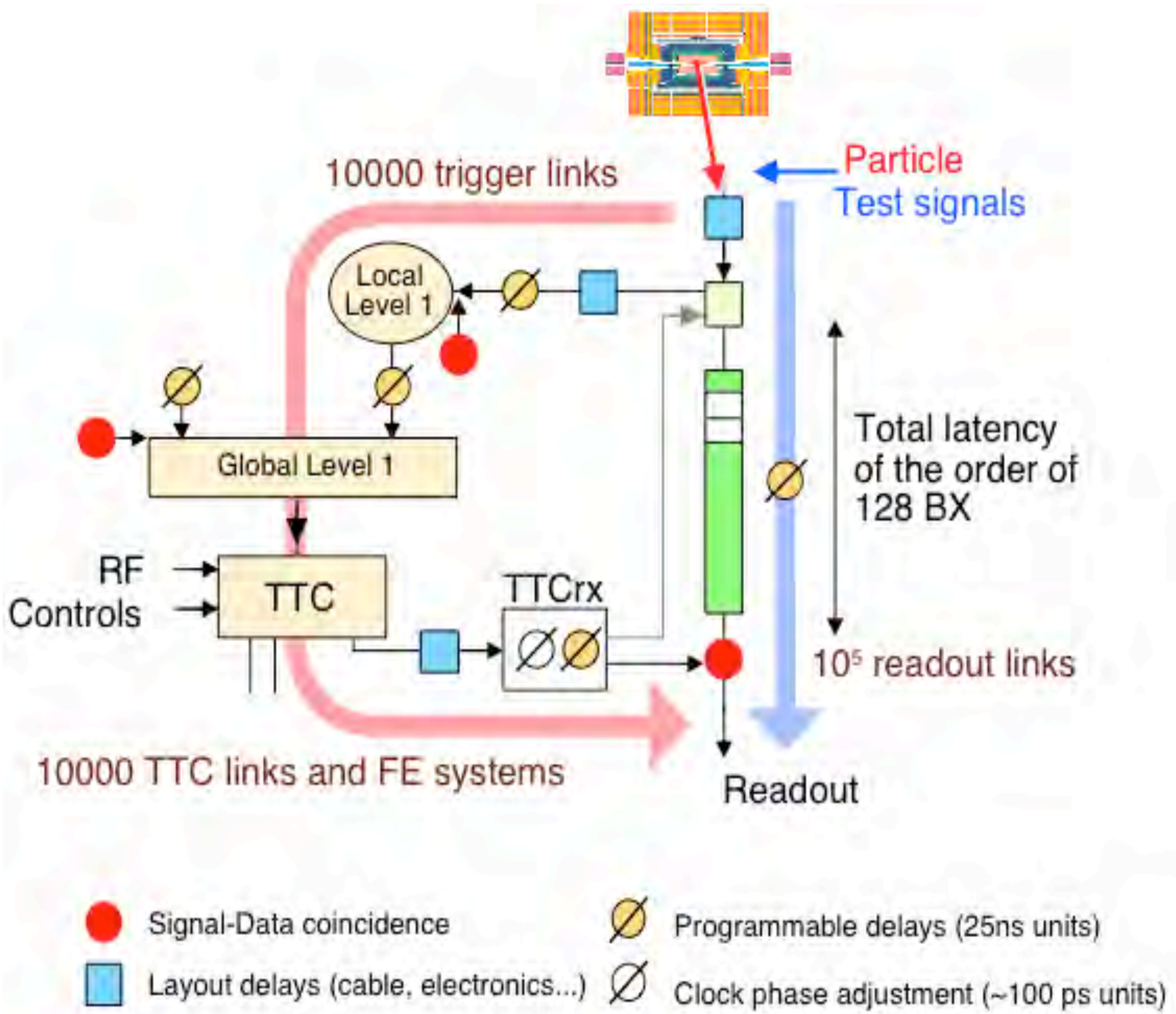
0 nm Operation

- **Negligible chromatic dispersion**

aAs photodiodes

- **Radiation resistance, low bias**

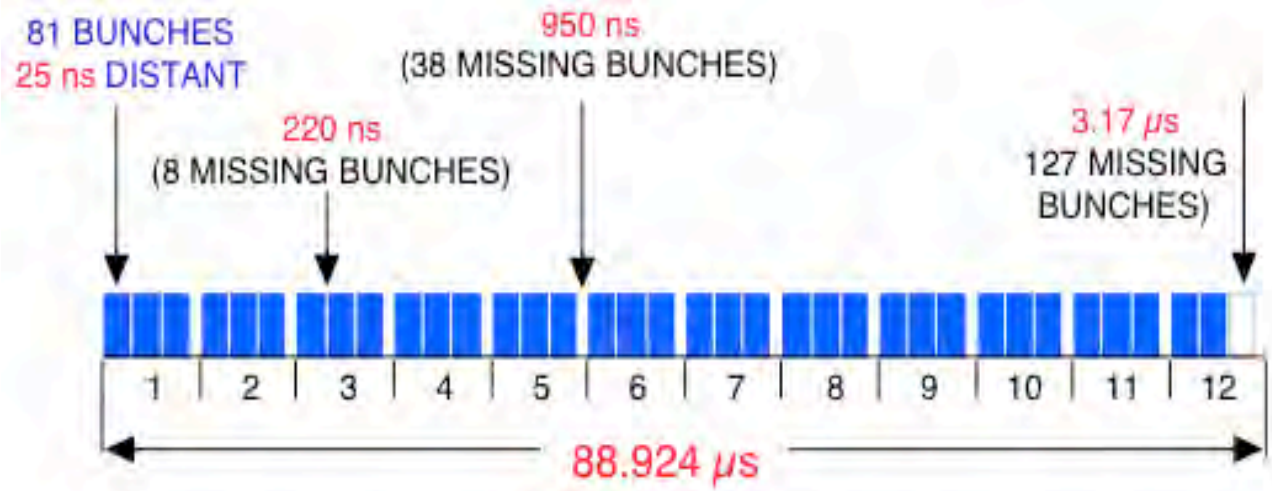
Detector Timing Adjustments



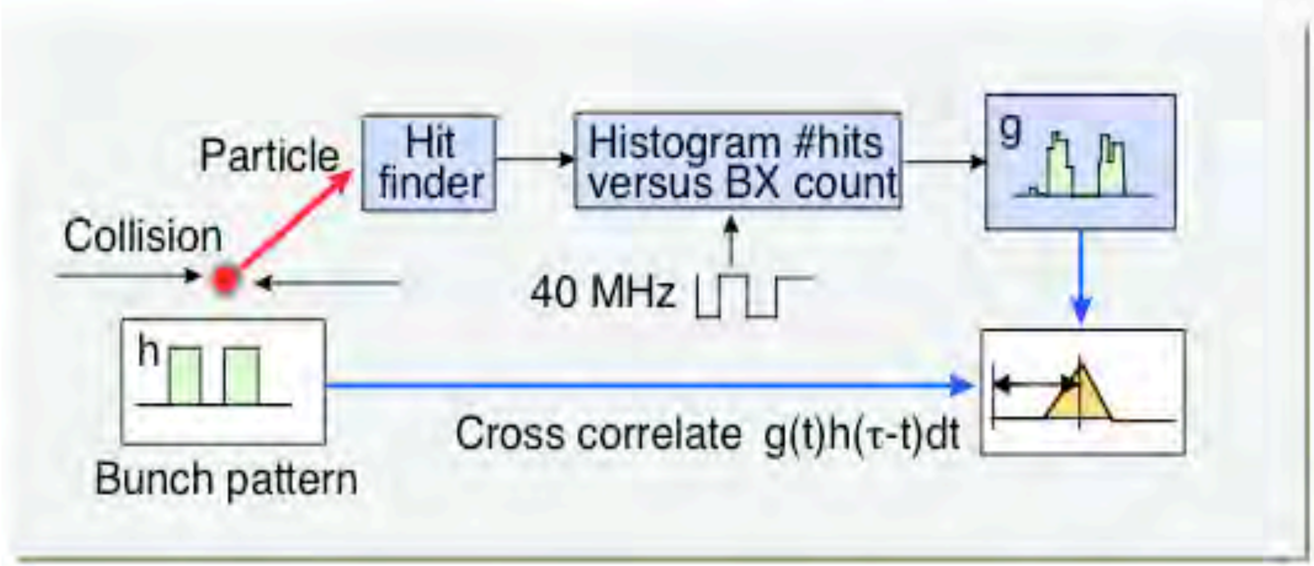
to Align:

- etector pulse /collision at IP
- rigger data w/ eadout data
- ifferent etector trigger ata /each other
- unch Crossing umber
- evel 1 Accept umber

Synchronization Techniques

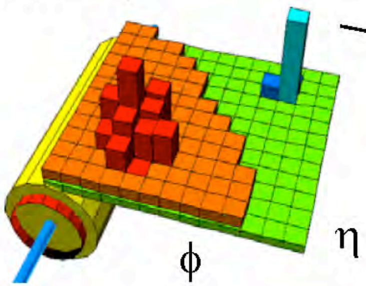


2835 out of 3564 p bunches are full, use this pattern:



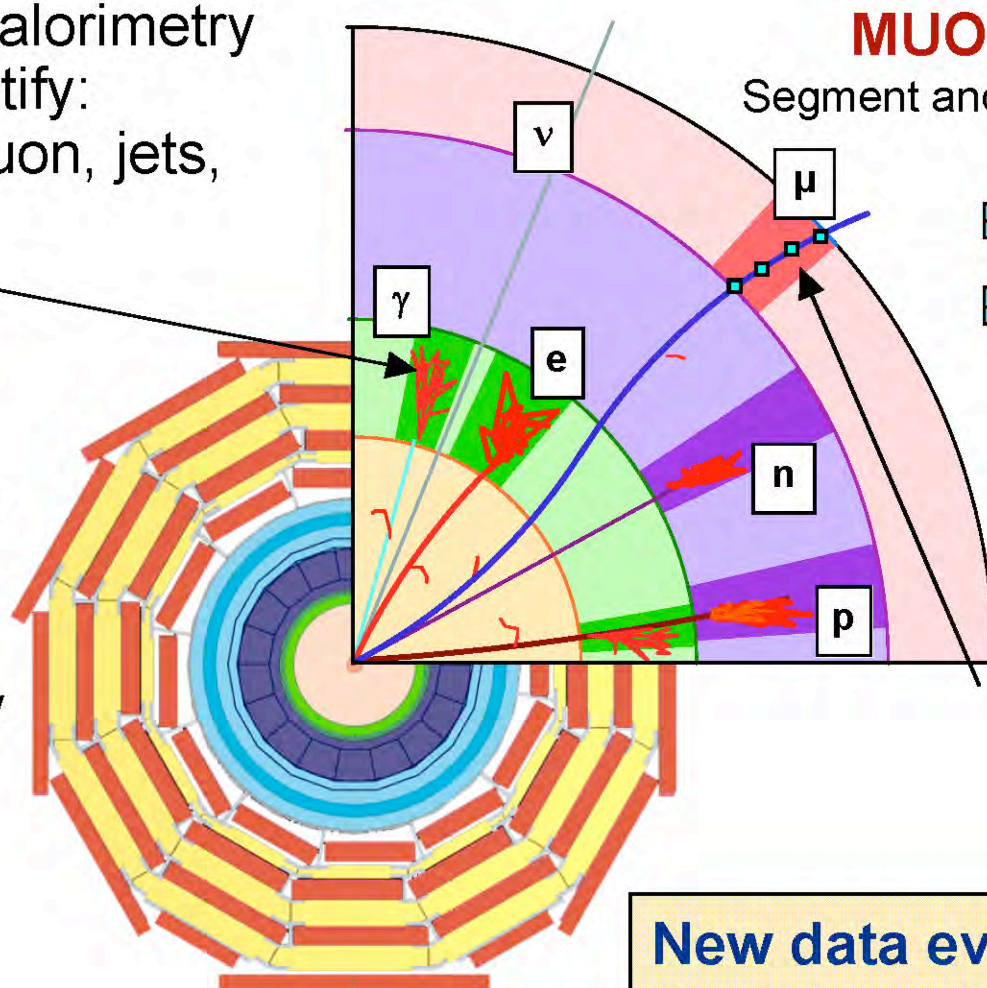
CMS Trigger Data

Use prompt data (calorimetry and muons) to identify:
High p_t electron, muon, jets, missing E_T



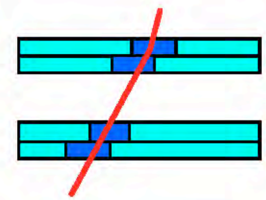
CALORIMETERs

Cluster finding and energy deposition evaluation



MUON System

Segment and track finding

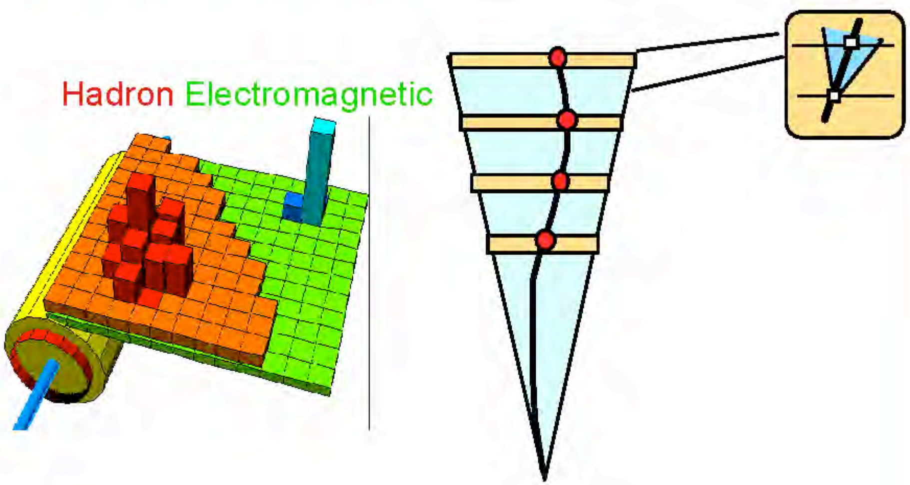


New data every 25 ns
Decision latency ~ μs

Level 1: Only Calorimeter & Muon

High Occupancy in high granularity tracking detectors

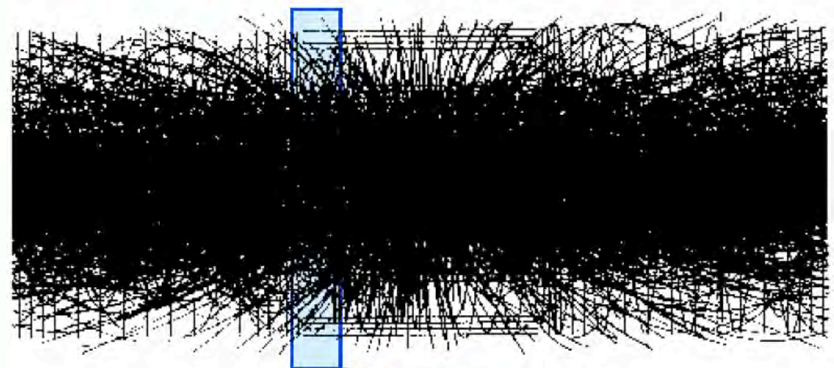
- **Pattern recognition much faster/easier**



Simple Algorithms

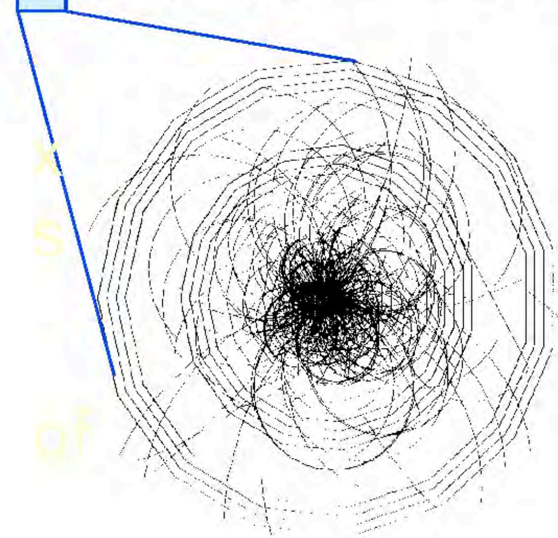
Small amounts of data

- **Compare to tracker info**



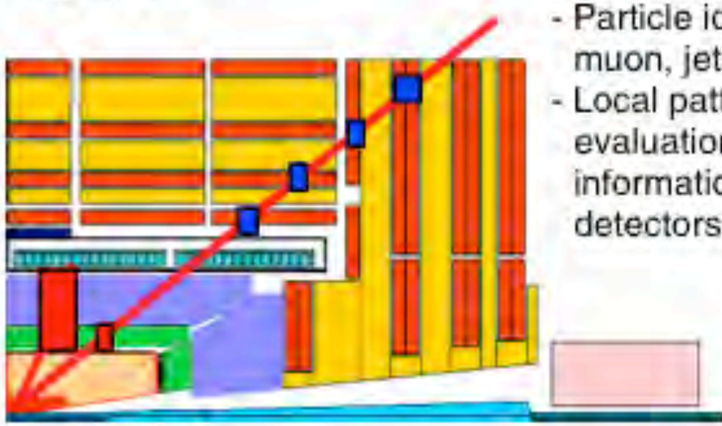
Complex Algorithms

Huge amounts of data



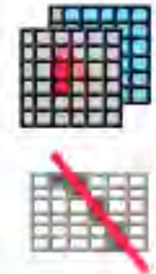
CMS Trigger Levels

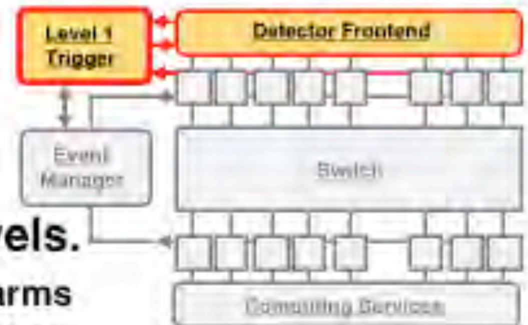
40 MHz



Level-1. Specialized processors

- Particle identification: high p_T electron, muon, jets, missing E_T
- Local pattern recognition and energy evaluation on prompt macro-granular information from calorimeter and muon detectors



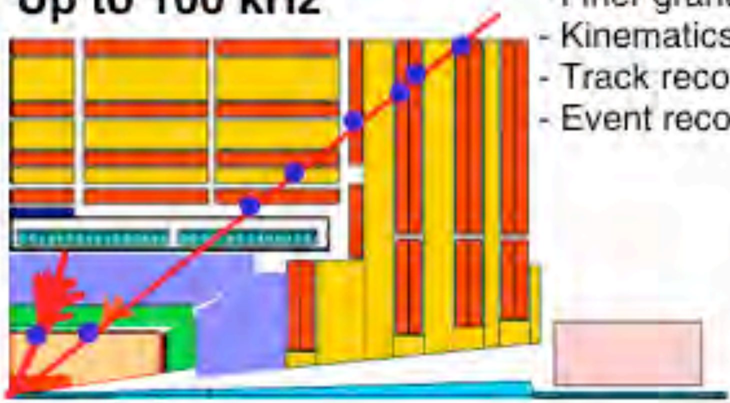


High trigger levels.

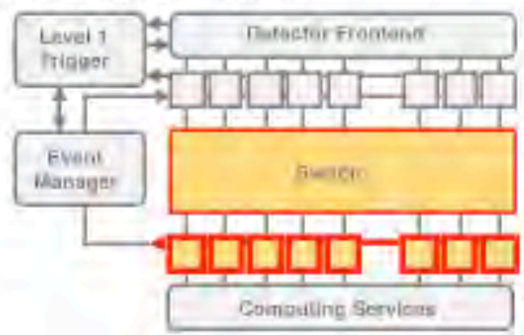
Network and CPU farms

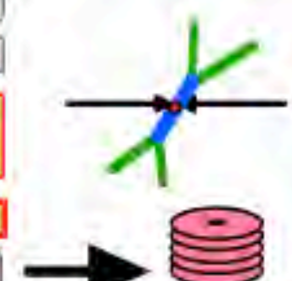
- Clean particle signature
- Finer granularity precise measurement
- Kinematics. effective mass cuts & event topology
- Track reconstruction and detector matching
- Event reconstruction and analysis

Up to 100 kHz



≃ 100 Hz



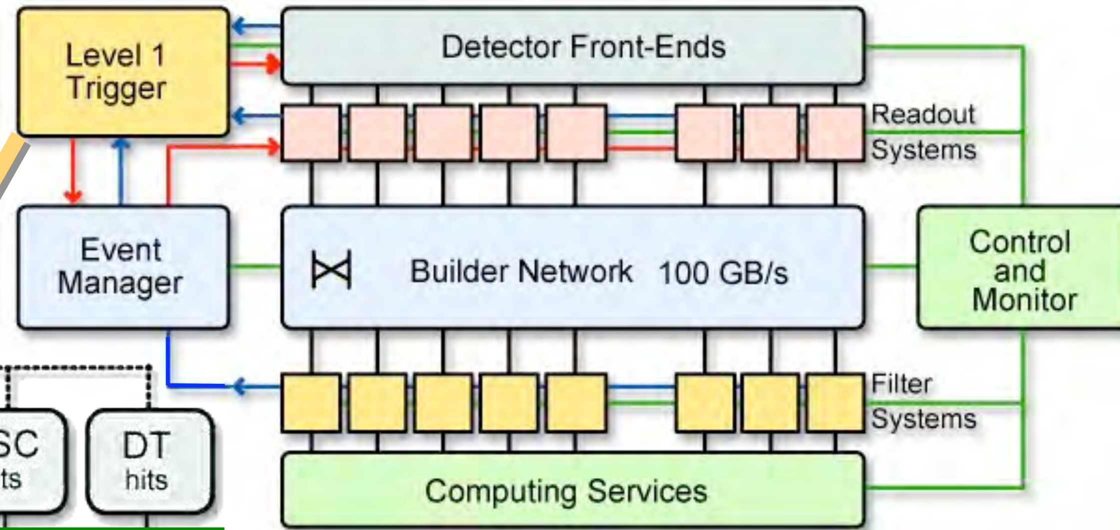


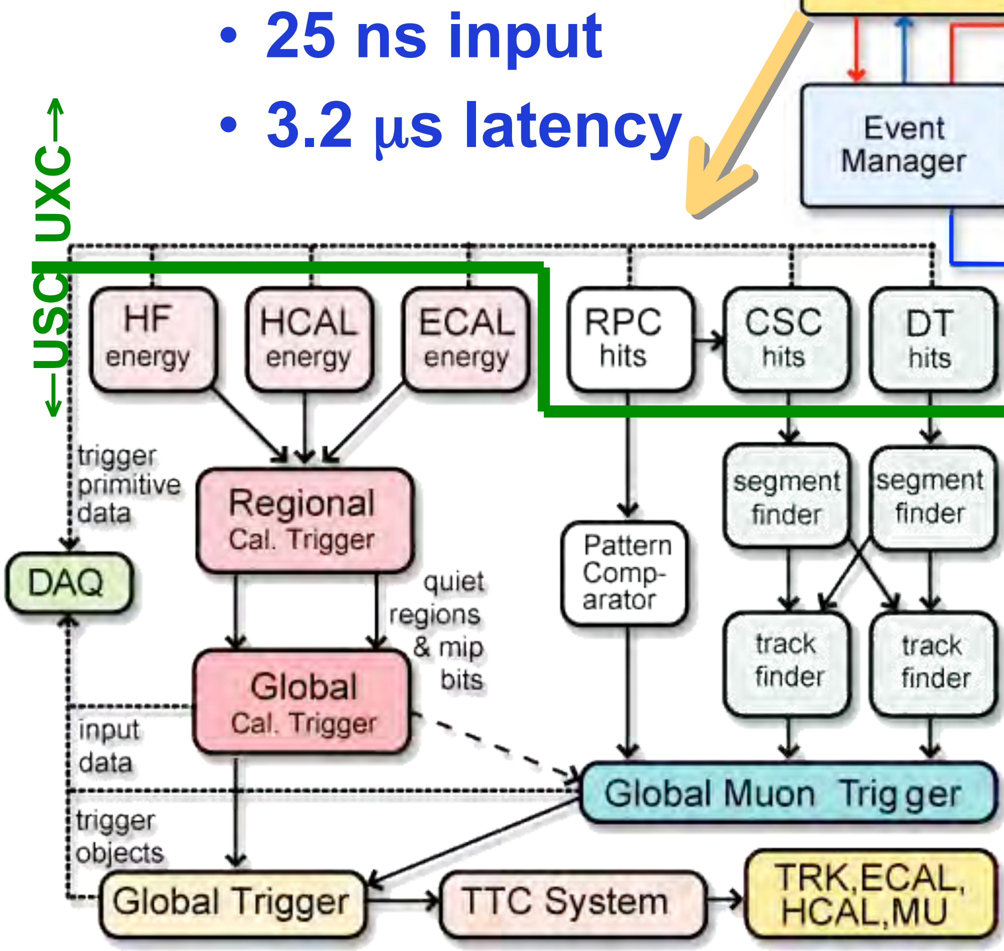
CMS Level-1 Trigger & DAQ

Overall Trigger & DAQ Architecture: 2 Levels:

Level-1 Trigger:

- 25 ns input
- 3.2 μs latency





Interaction rate: 1 GHz

Bunch Crossing rate: 40 MHz

Level 1 Output: 100 kHz (50 initial)

Output to Storage: 100 Hz

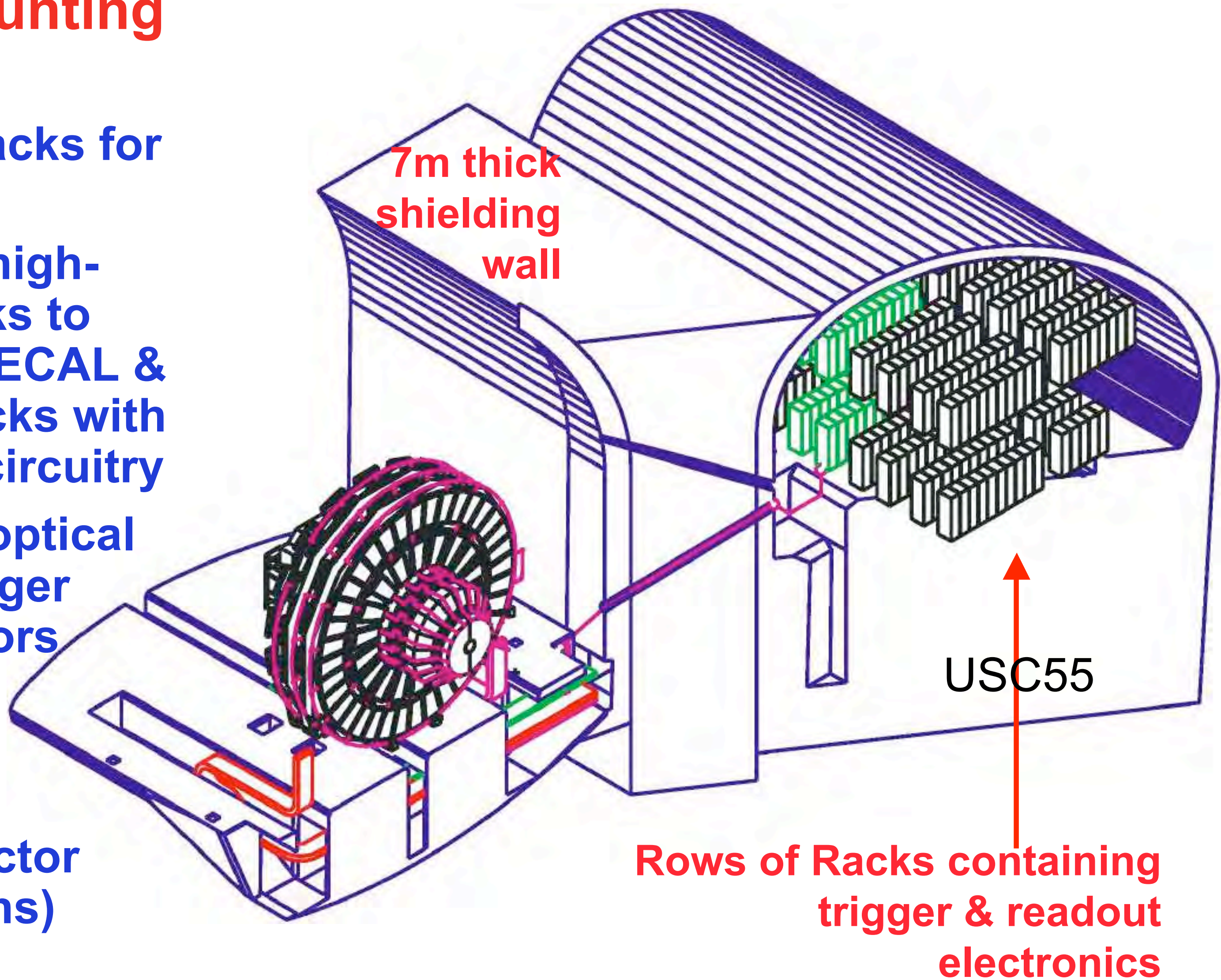
Average Event Size: 1 MB

Data production 1 TB/day

L1 Trigger Locations

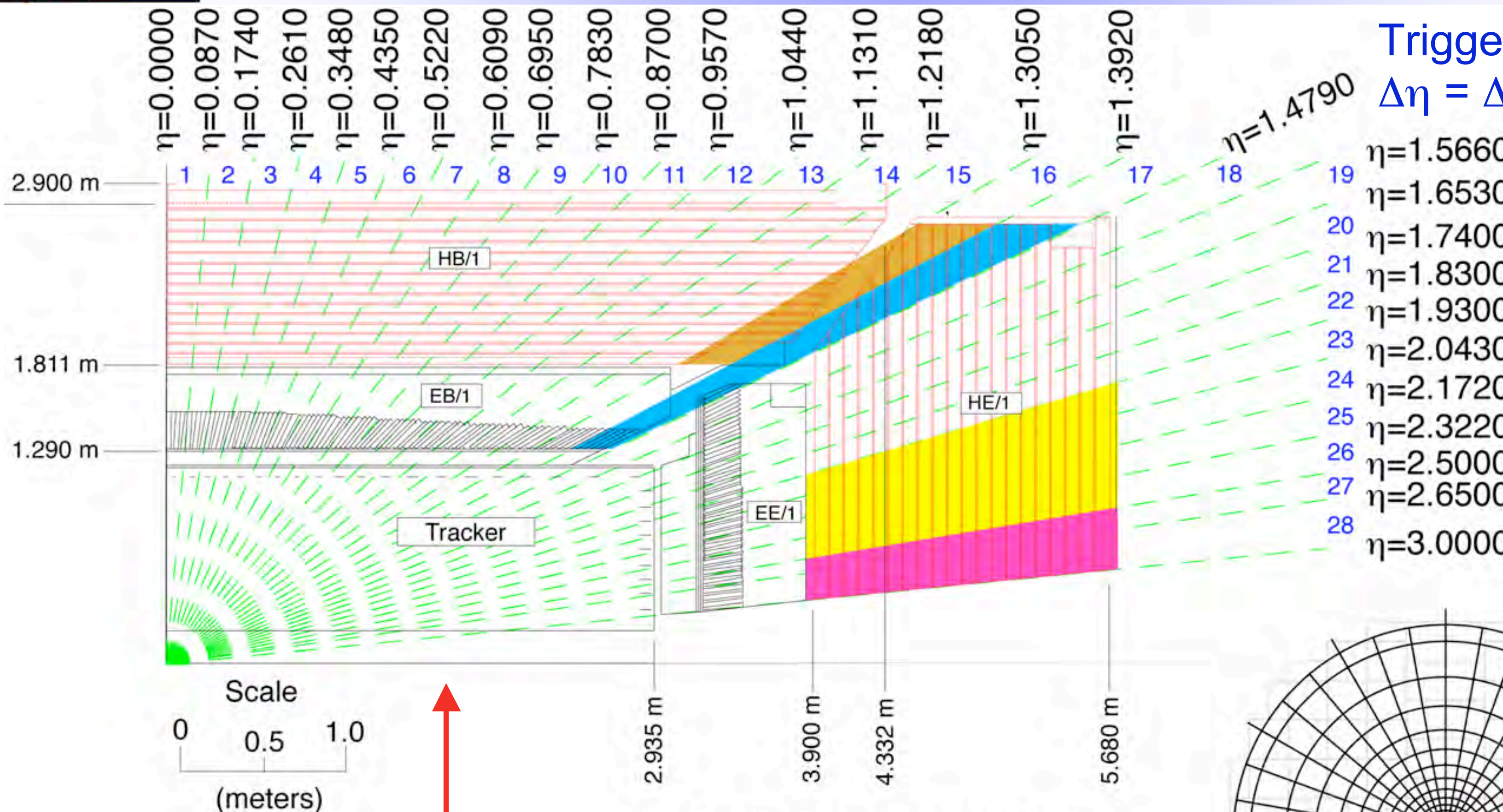
Underground Counting Room

- Central rows of racks for trigger
- Connections via high-speed copper links to adjacent rows of ECAL & HCAL readout racks with trigger primitive circuitry
- Connections via optical fiber to muon trigger primitive generators on the detector
- Optical fibers connected via “tunnels” to detector (~90m fiber lengths)



CMS Calorimeter Geometry

Trigger towers:
$\Delta\eta = \Delta\phi = 0.087$



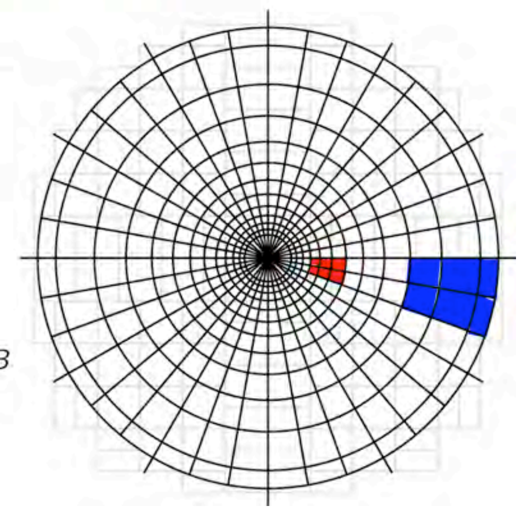
EB, EE, HB, HE map to 18 RCT crates

Provide e/γ and jet, τ, E_T triggers

2 HF calorimeters map on to 18 RCT crates

Readout segmentation: 36ϕ × 12η × 2z × 2F/B

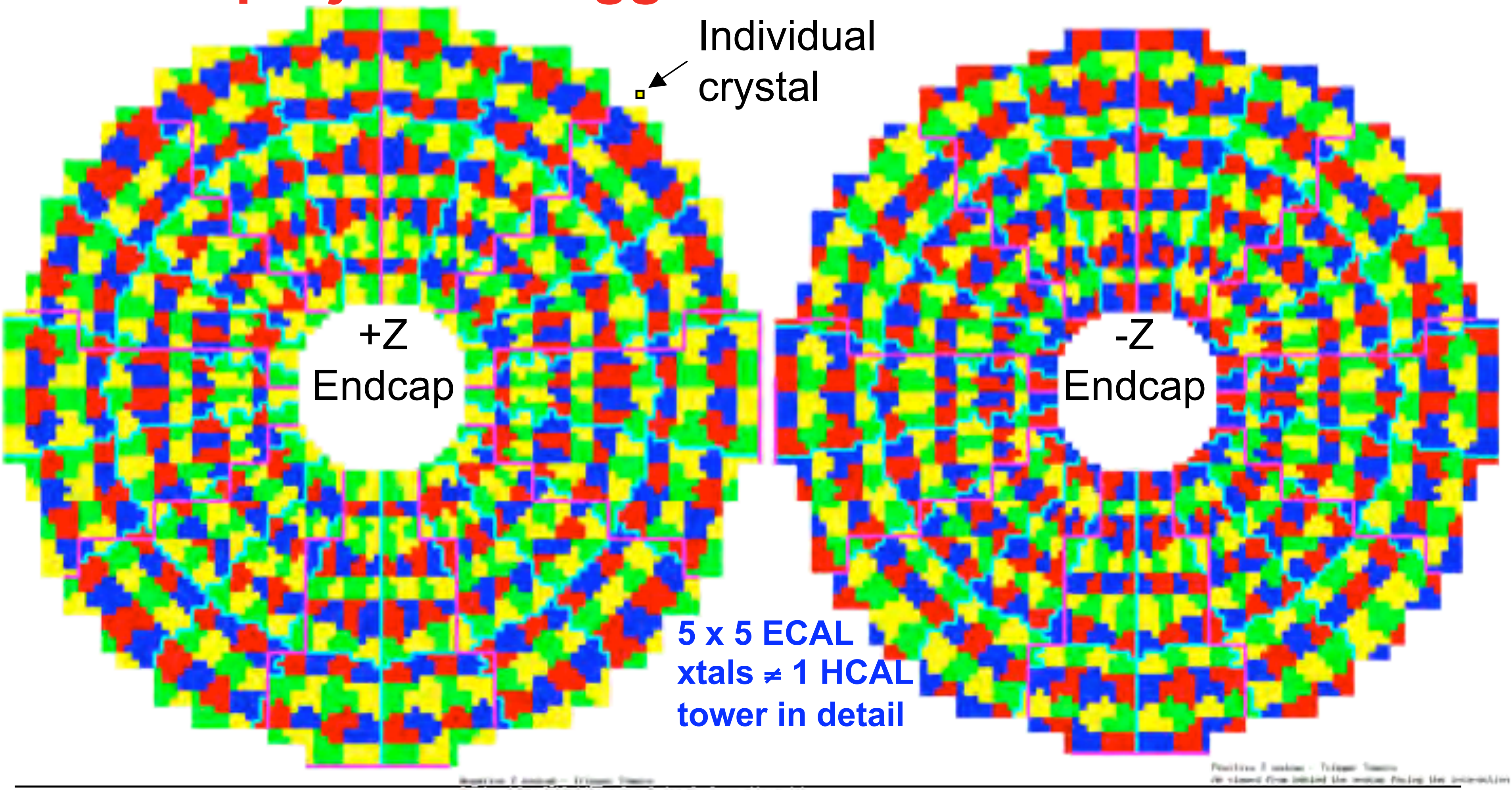
Trigger Tower segmentation: 18ϕ × 4η × 2F/B



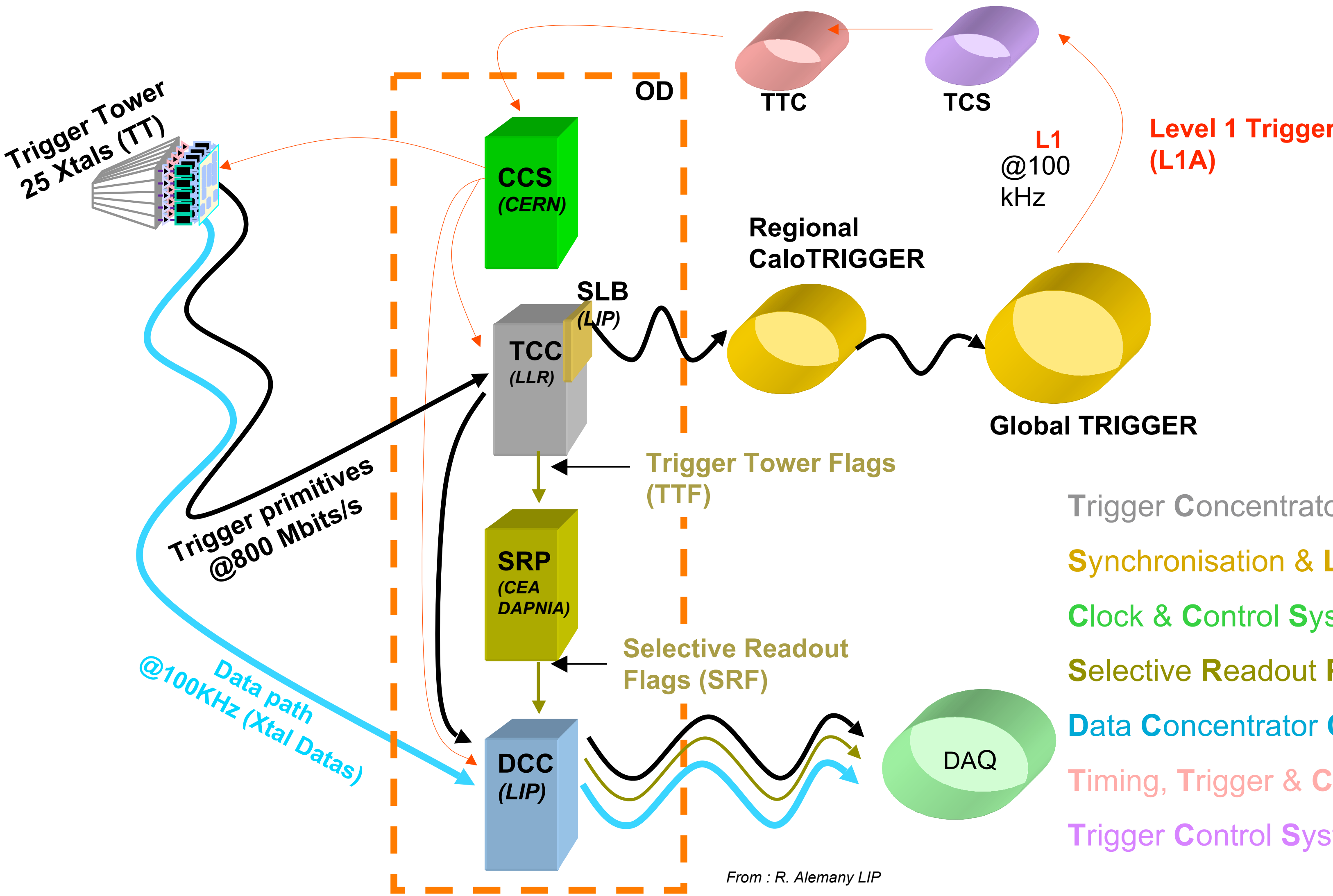
1 trigger tower (.087η x .087ϕ) = 5 x 5 ECAL xtals = 1 HCAL tower

ECAL Endcap Geometry

Map non-projective x-y trigger crystal geometry onto projective trigger towers:



Calorimeter Trigger Processing



Trigger Concentrator Card

Synchronisation & Link Board

Clock & Control System

Selective Readout Processor

Data Concentrator Card

Timing, Trigger & Control

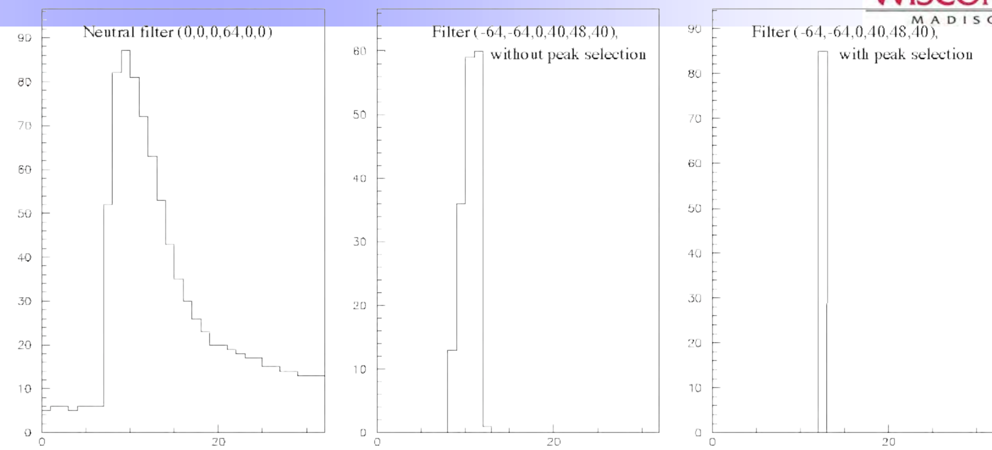
Trigger Control System

ECAL Trigger Primitives

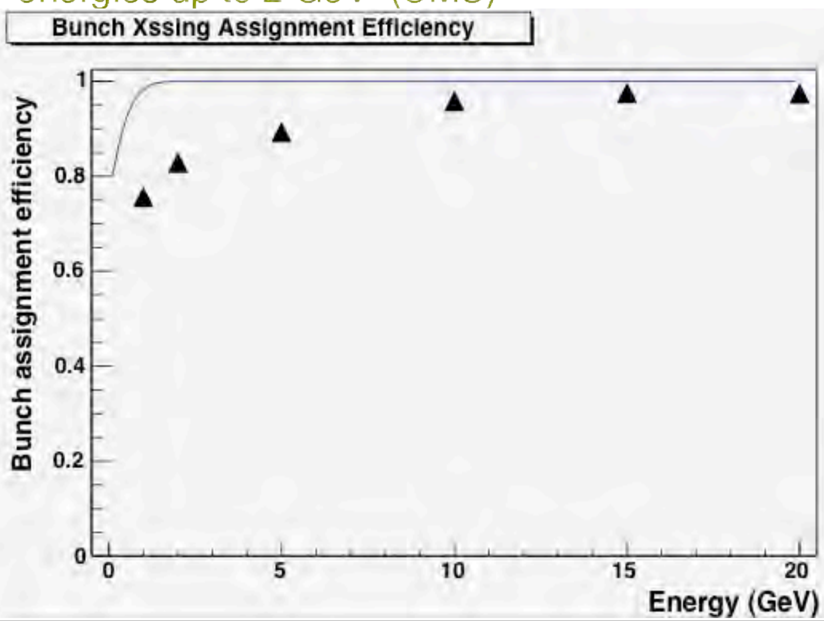
In the trigger path, **digital filtering** followed by a **peak finder** is applied to energy sums **(L1 Filter)**

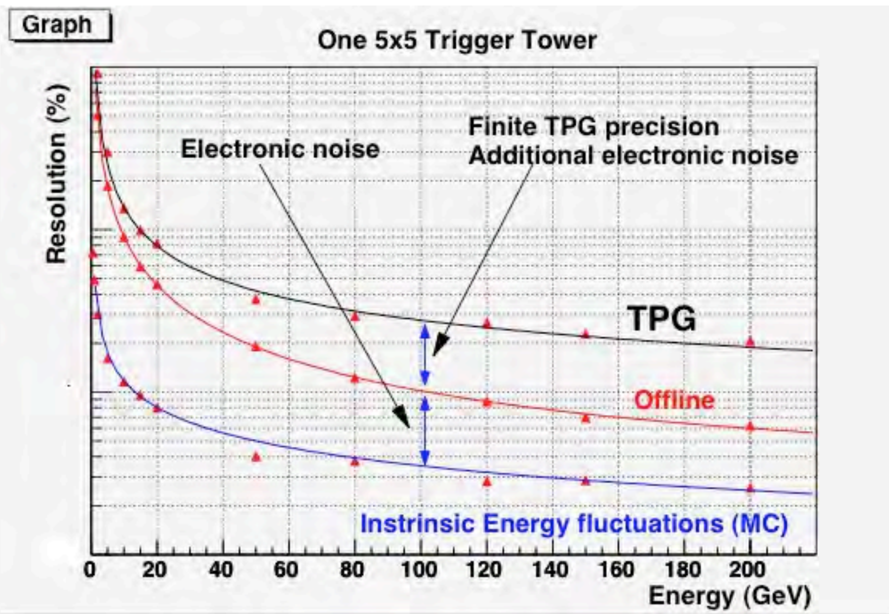
Efficiency for energy sums above 1 GeV should be close to 100% (depends on electronics noise)

Pile-up effect: for a signal of 5 GeV the efficiency is close to 100% for pile-up energies up to 2 GeV (CMS)



Test beam results (45 MeV per xtal):





CMS Electron/Photon Algorithm

Trigger Primitive Generator

Fine grain Flag Max of (, , ,) & Sum ET

Regional Calorimeter Trigger

E_T cut + Max ( ) > Threshold

AND

Longitudinal cut (H/E) / < 0.05

AND

Isolation, Hadronic & EM < 2 GeV

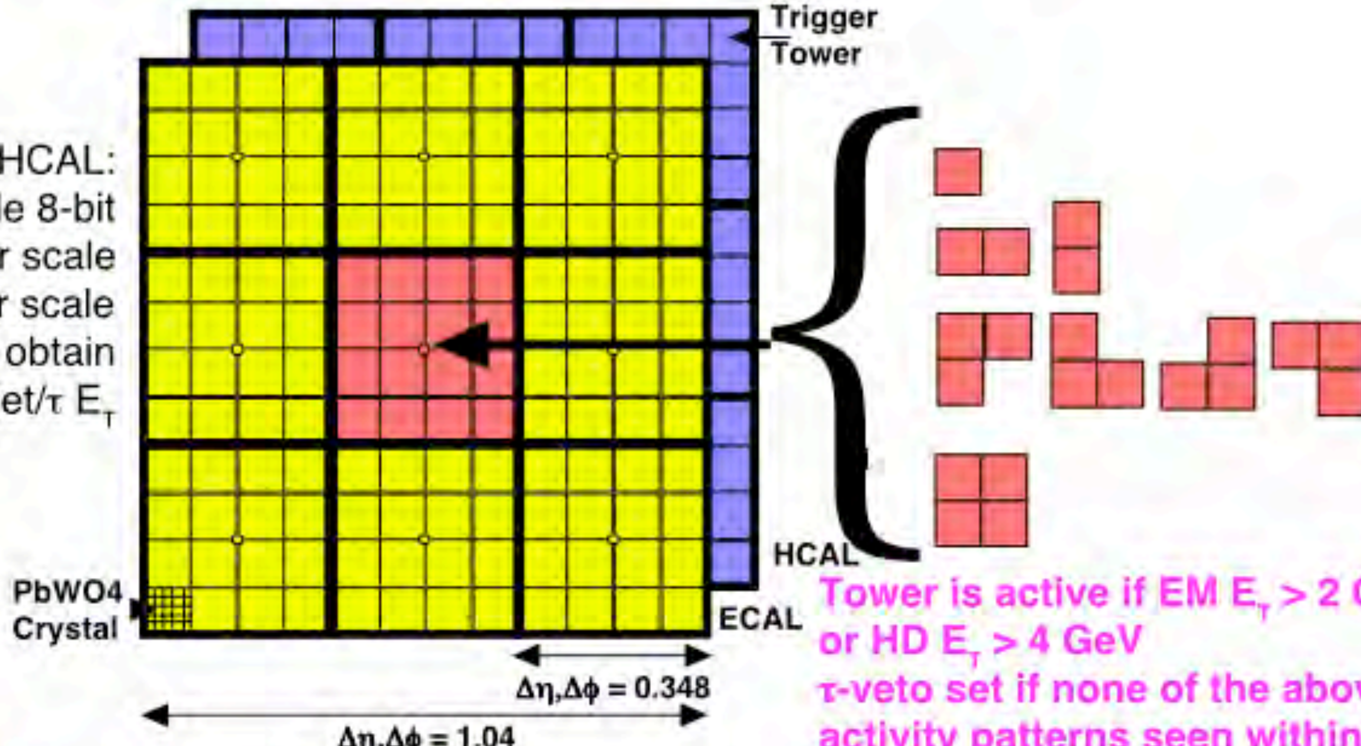
AND

One of (, , ,) < 1 GeV

ELECTRON or PHOTON

CMS τ / Jet Algorithm

Input from E/HCAL:
Programmable 8-bit non-linear scale
Converted to linear scale and summed to obtain 10-bit range jet/τ E_T



Tower is active if EM E_T > 2 GeV or HD E_T > 4 GeV
τ-veto set if none of the above activity patterns seen within 4x4

Jet or τ E_T

- 12x12 trigger tower E_T sums in 4x4 region steps with central region > others
- Larger trigger towers in HF but ~ same jet region size, 1.5 η x 1.0 φ

τ algorithm (isolated narrow energy deposits), within $-2.5 < \eta < 2.5$

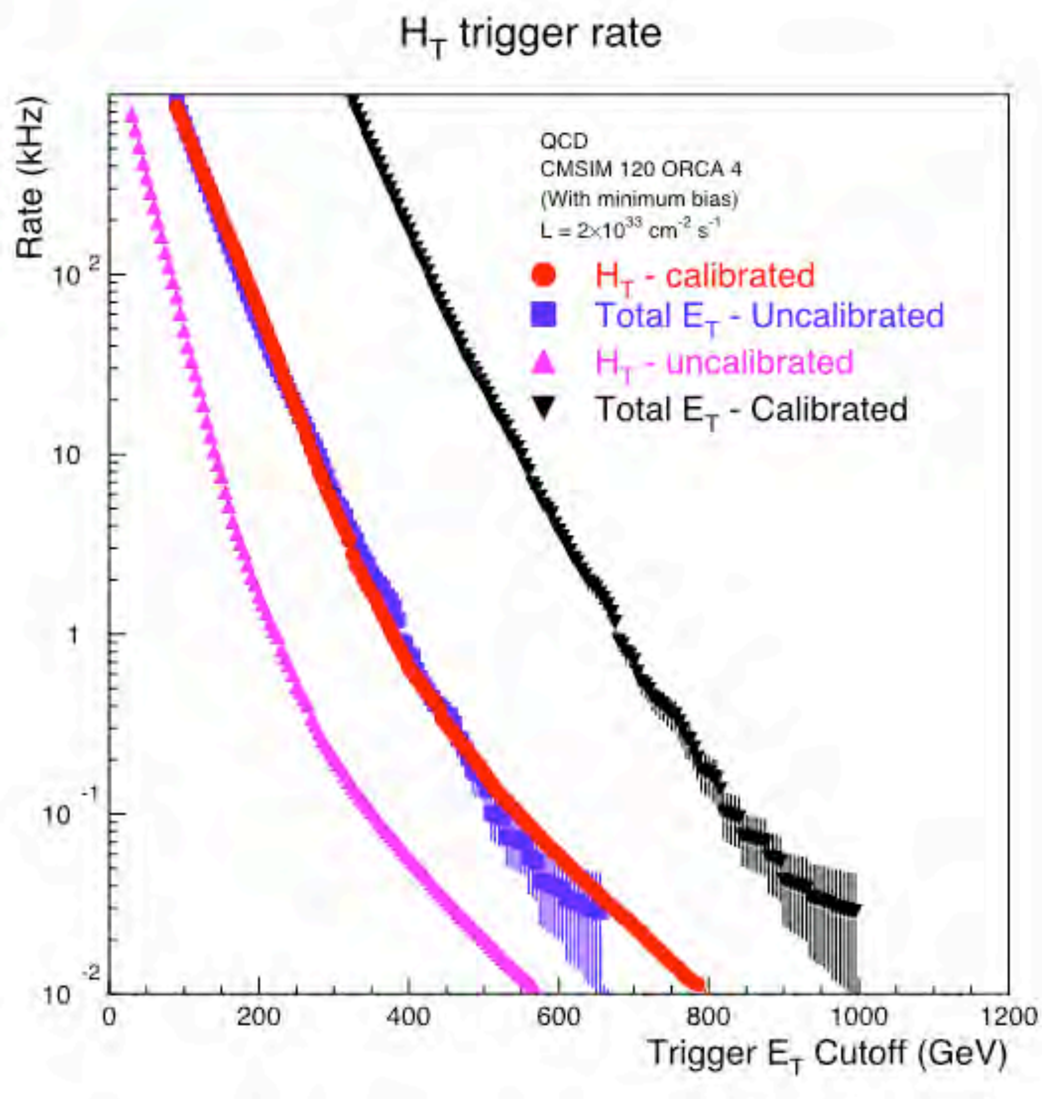
- Redefine jet as τ jet if none of the nine 4x4 region τ-veto bits are on

Output

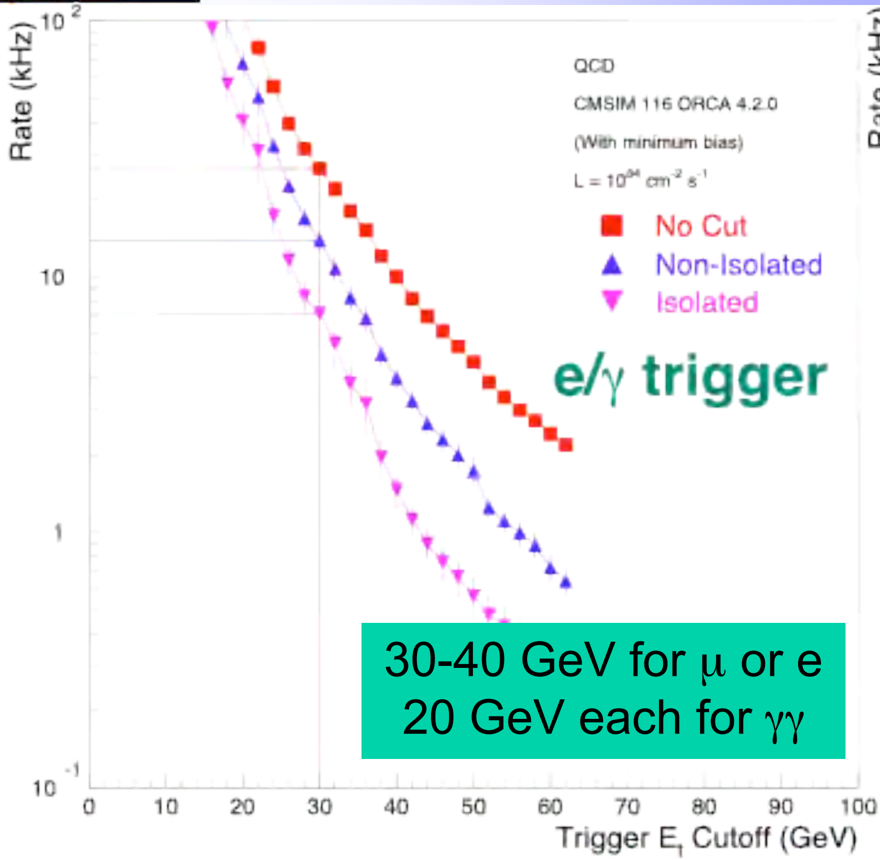
- Top 4 τ-jets and top 4 jets in central rapidity, and top 4 jets in forward rapidity

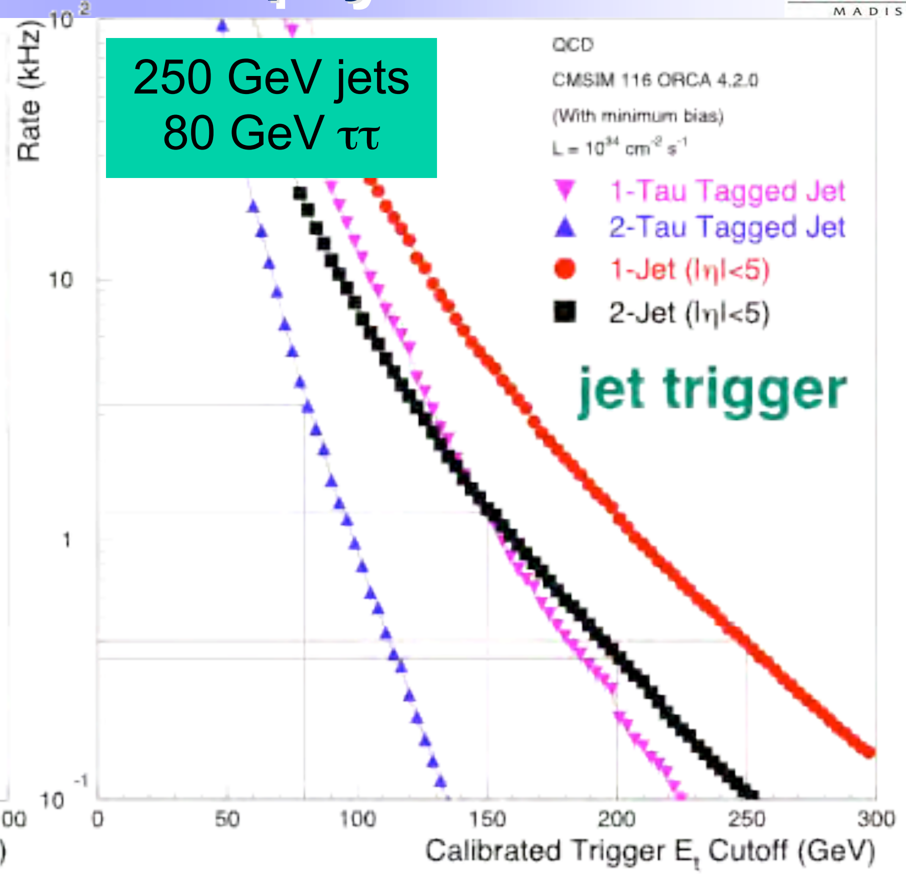
H_T Trigger

- Total scalar E_T integrates too much noise and is not easily calibrated
  - At L1 tower-by-tower E_T calibration is not available
- However, jet calibration is available as function of (E_T, η, ϕ)
- Therefore, H_T which is the sum of scalar E_T of all high E_T objects in the event is more useful for heavy particle discovery/study
  - SUSY sparticles
  - Top



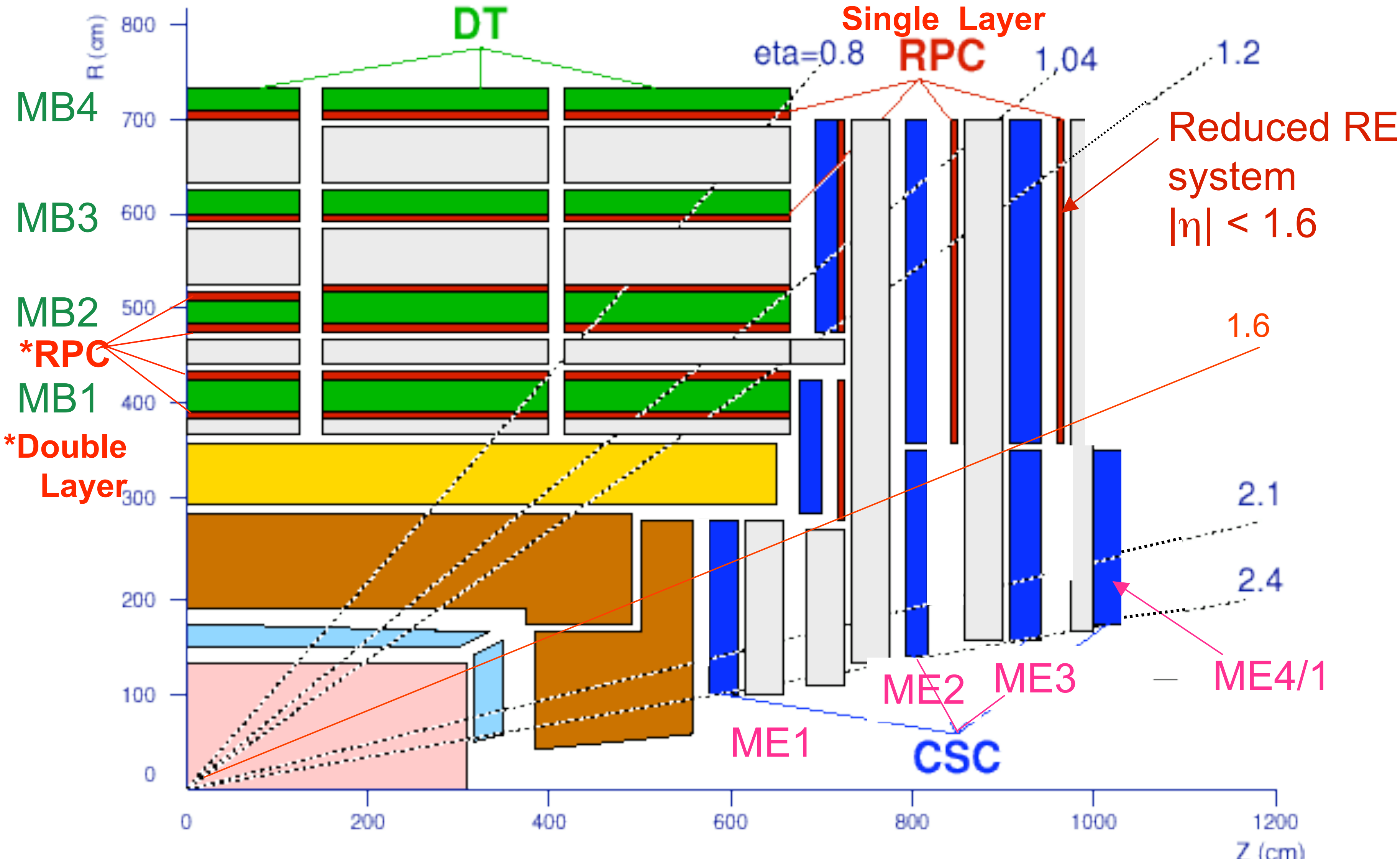
Level-1 Trigger Rates:
Trigger cuts determine the physics reach



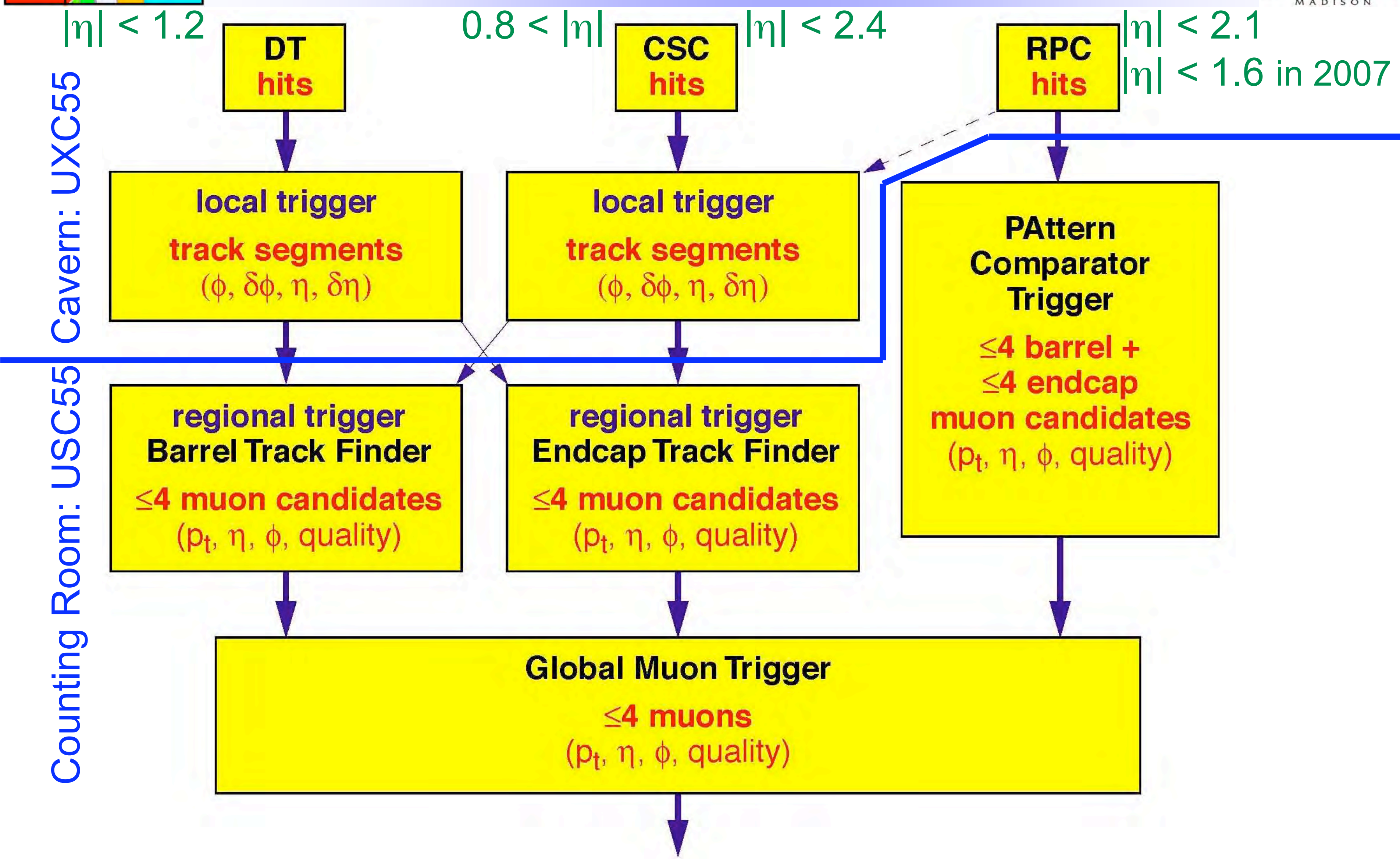


- **Efficiency for H→γγ and H→4 leptons = >90% (in fiducial volume of detector)**
- **Efficiency for WH and ttH production with W→lν = ~85%**
- **Efficiency for qqH with H→ττ (τ→1/3 prong hadronic) = ~75%**
- **Efficiency for qqH with H→invisible or H→bb = ~40-50%**

CMS Muon Chambers

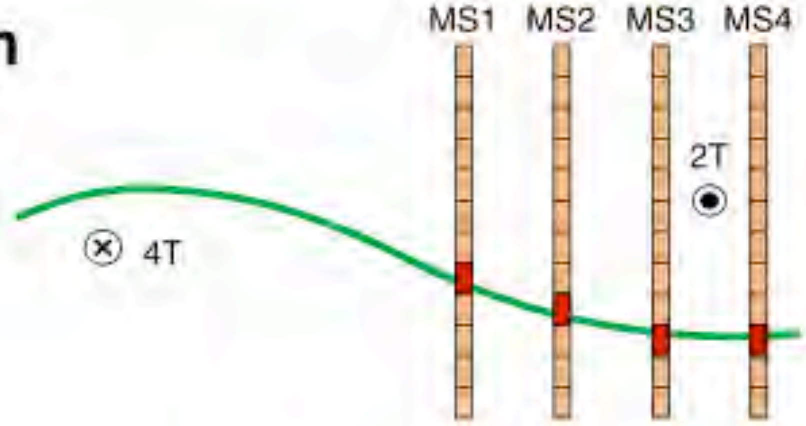


Muon Trigger Overview



CMS Muon Trigger Primitives

RPC pattern recognition
- Pattern catalog
- Fast logic

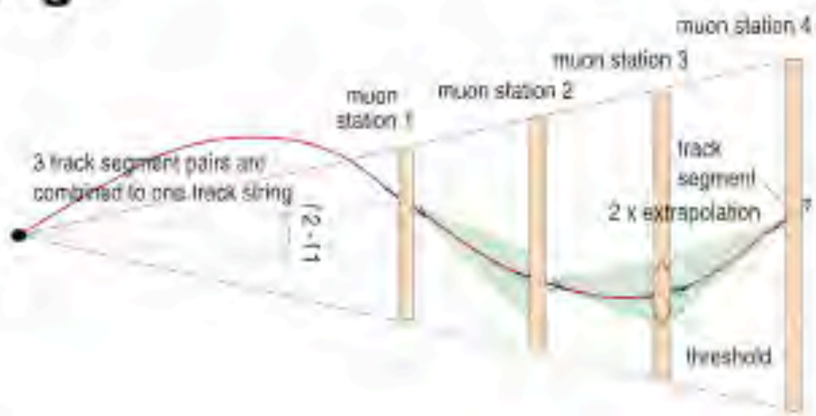


Memory to store patterns

Fast logic for matching

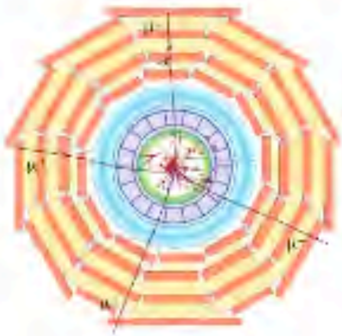
FPGAs are ideal

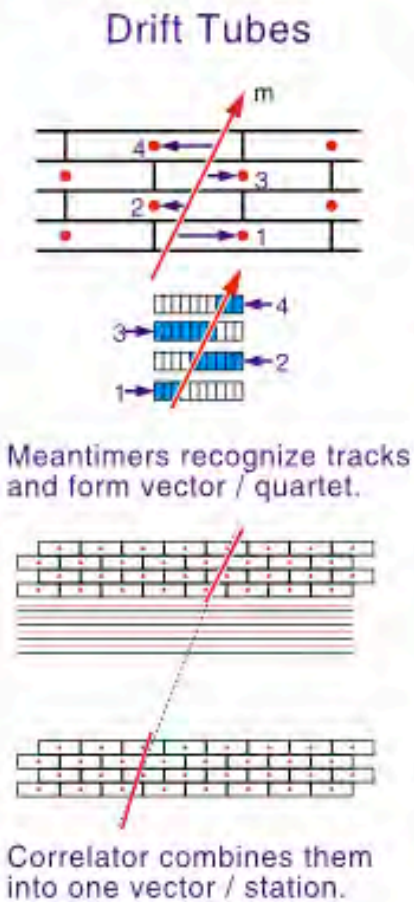
DT and CSC track finding:
- Finds hit/segments
- Combines vectors
- Formats a track
- Assigns p_t value



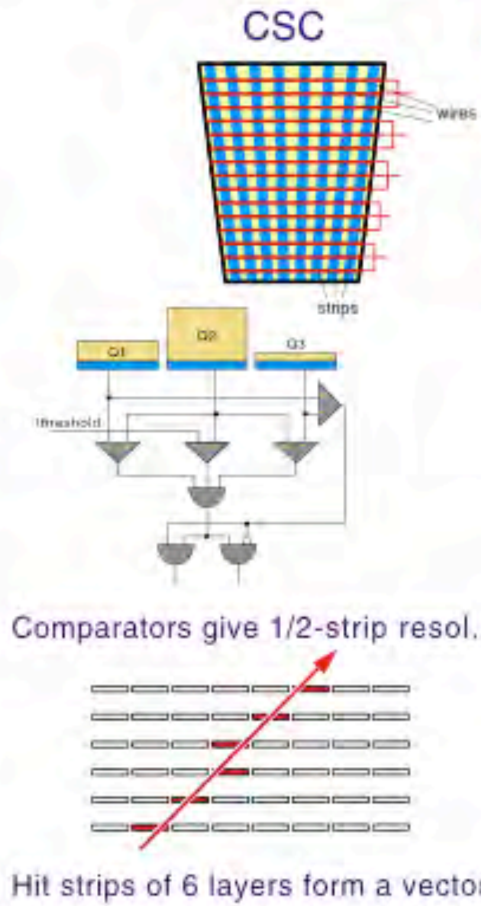
CMS Muon Trigger Track Finders

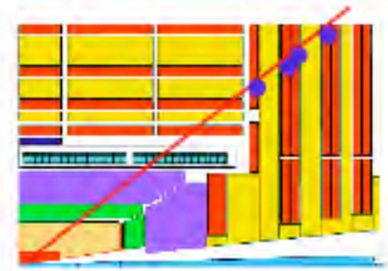
Drift Tubes (DT)





Cathod Strip Chambers (CSC)





Sort based on P_T, Quality - keep loc.

Combine at next level - match

Sort again - Isolate?

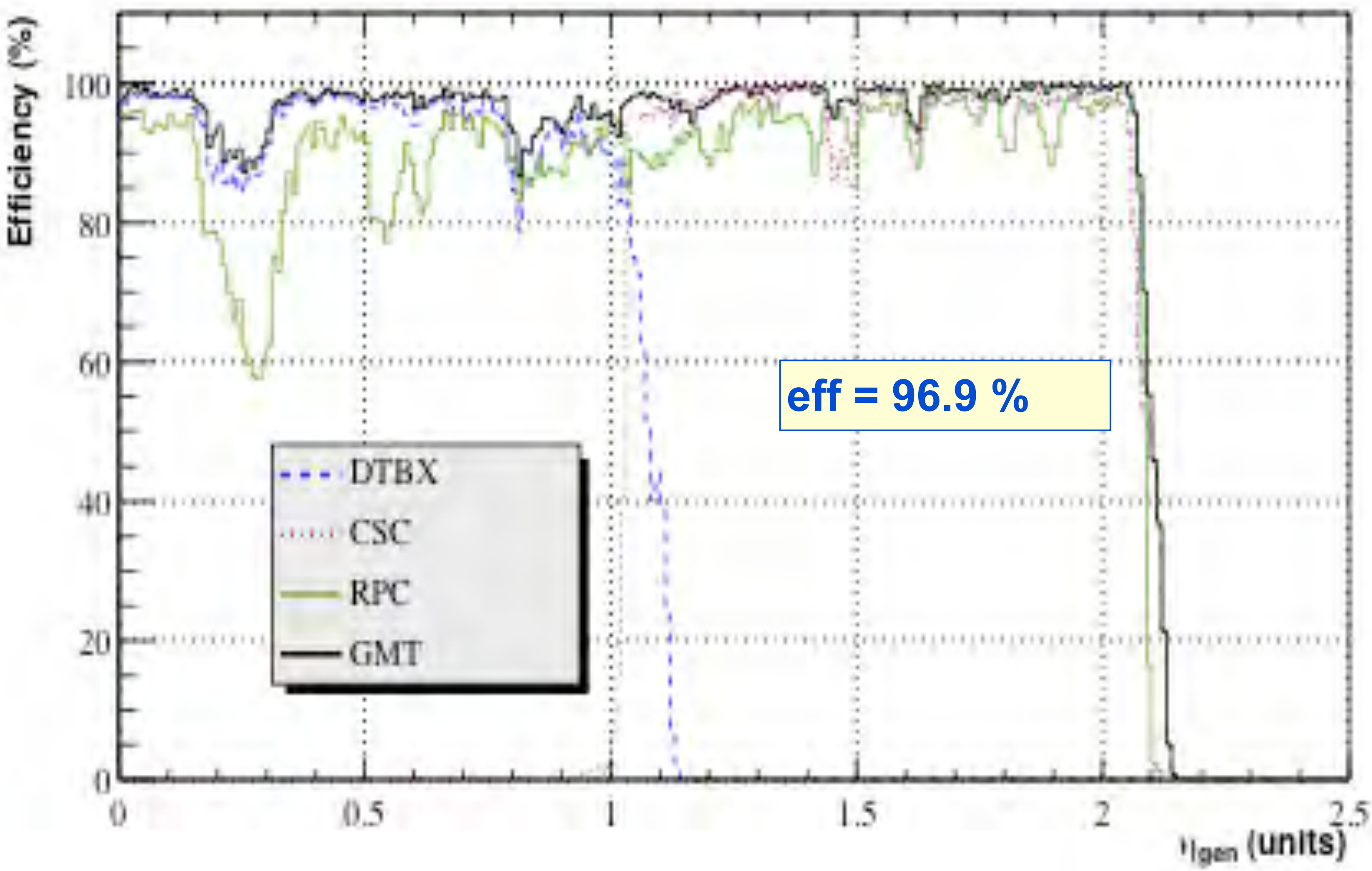
Top 4 highest P_T and quality muons with location coord.

Match with RPC

Improve efficiency and quality

Single muon trigger efficiency vs. η

|η| < 2.1

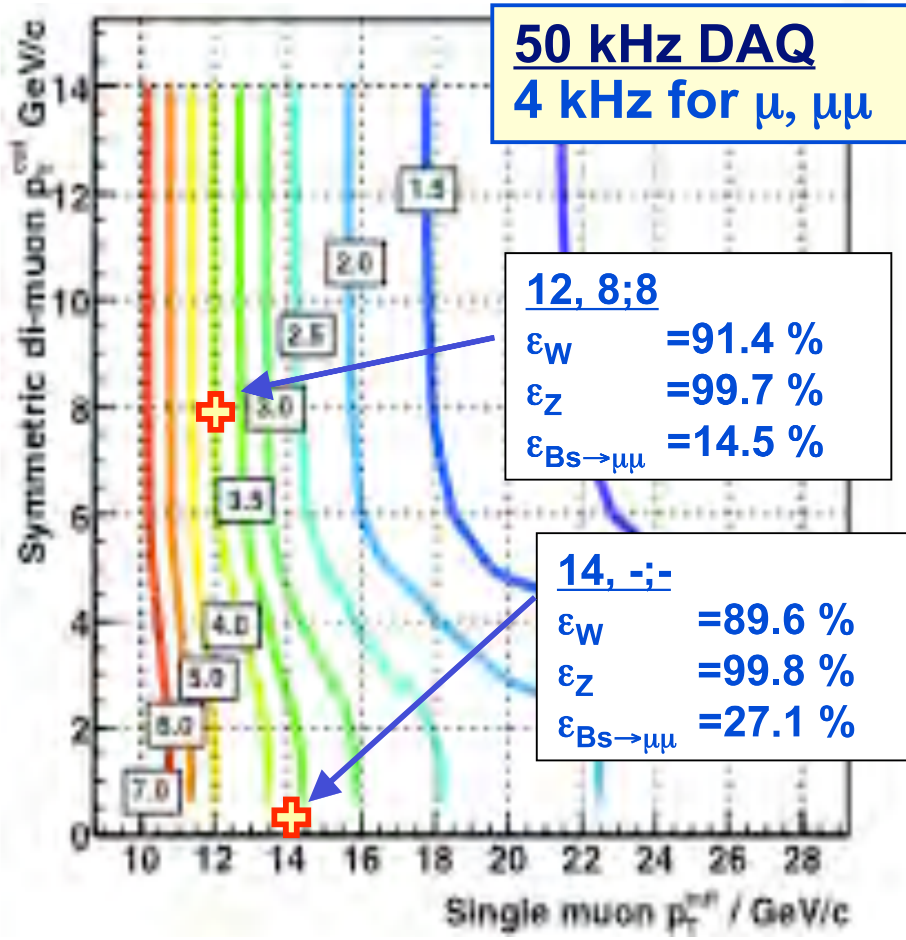


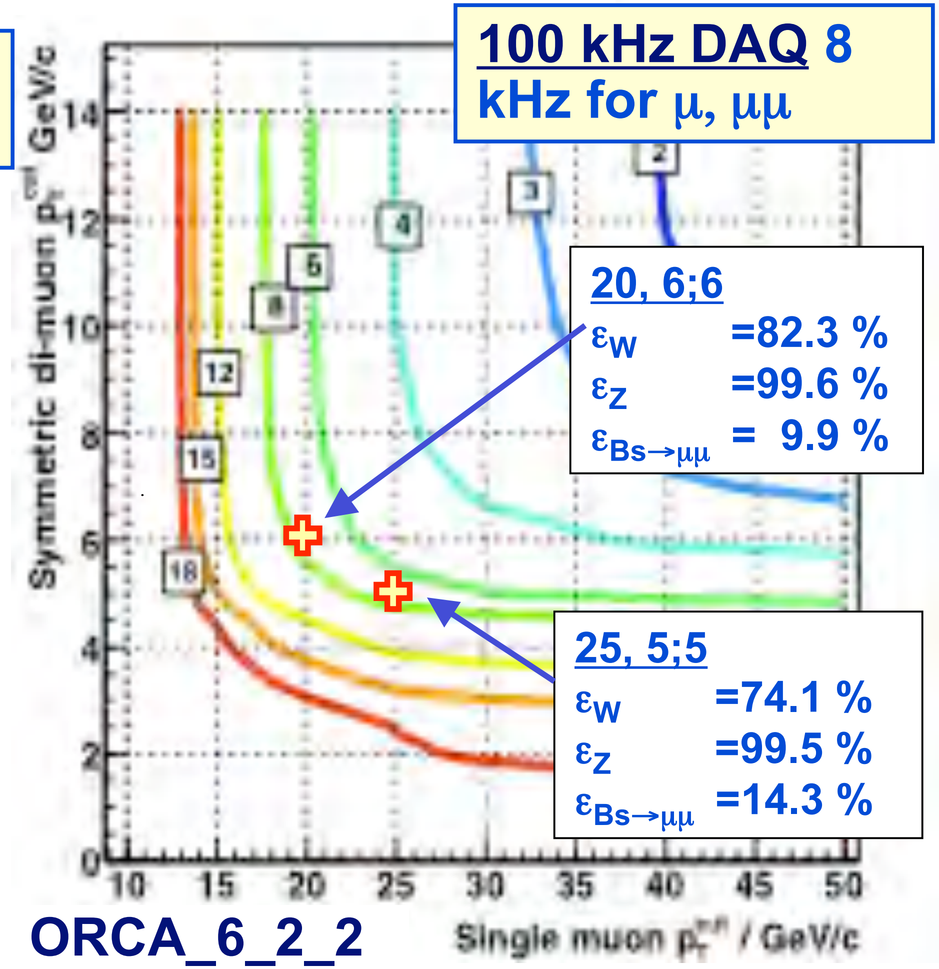
η (*)efficiency to find muon of any p_T in flat p_T =3-100 GeV sample

L1 single & di-muon trigger rates

trigger rates in kHz

$|\eta| < 2.1$





ORCA_6_2_2

✚ working points selected as examples

$L = 2\times10^{33} cm^{-2}s^{-1}$

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

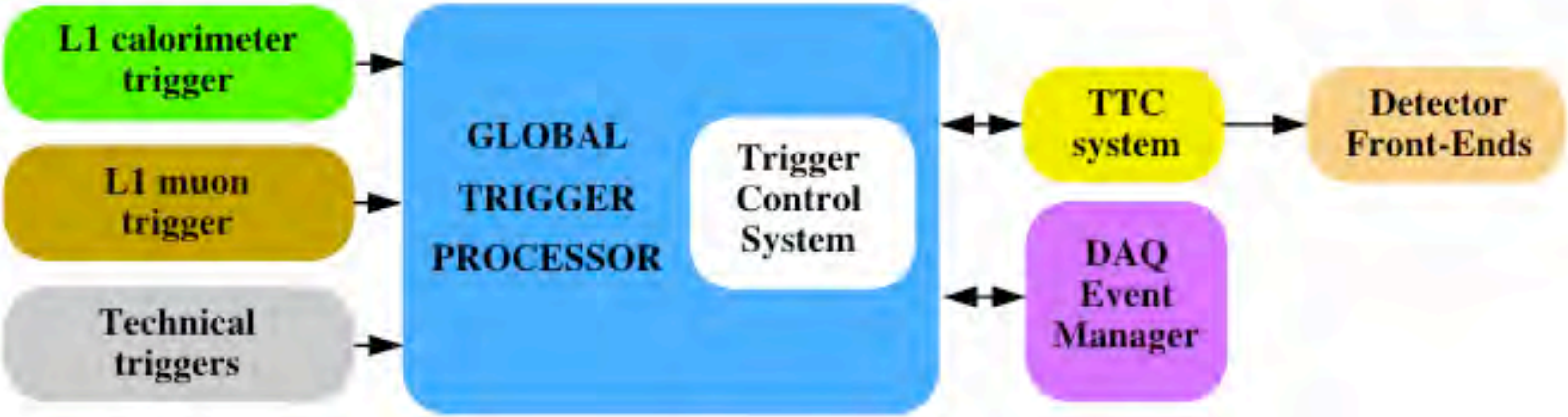
CMS Global Trigger

Input:

- Jets: 4 Central, 4 Forward, 4 Tau-tagged, & Multiplicities
- Electrons: 4 Isolated, 4 Non-isolated
- 4 Muons (from 8 RPC, 4 DT & 4 CSC w/P_t & quality)
  - All above include location in η and ϕ
- Missing E_T & Total E_T

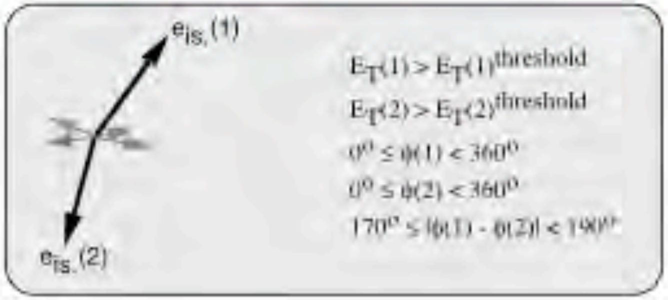
Output

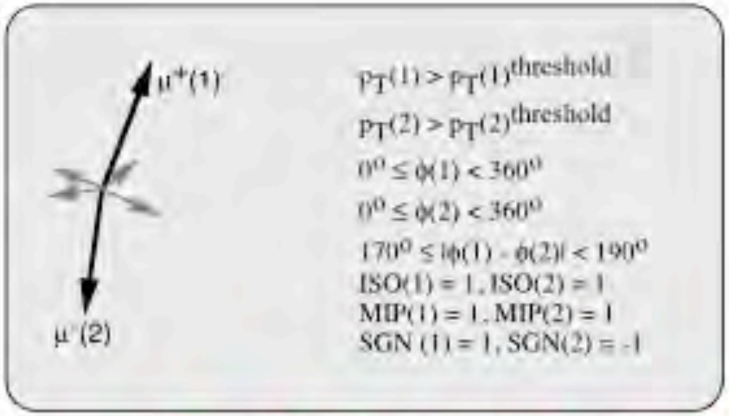
- L1 Accept from combinations & proximity of above



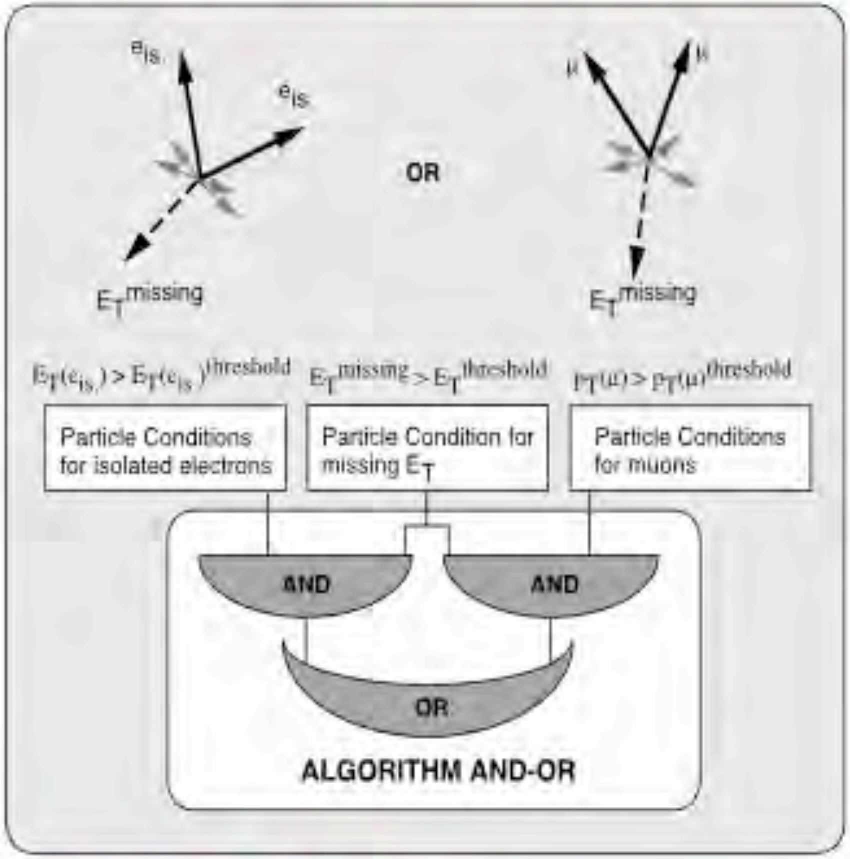
Global L1 Trigger Algorithms

Particle Conditions





Logical Combinations



Flexible algorithms implemented in FPGAs

100s of possible algorithms can be reprogrammed

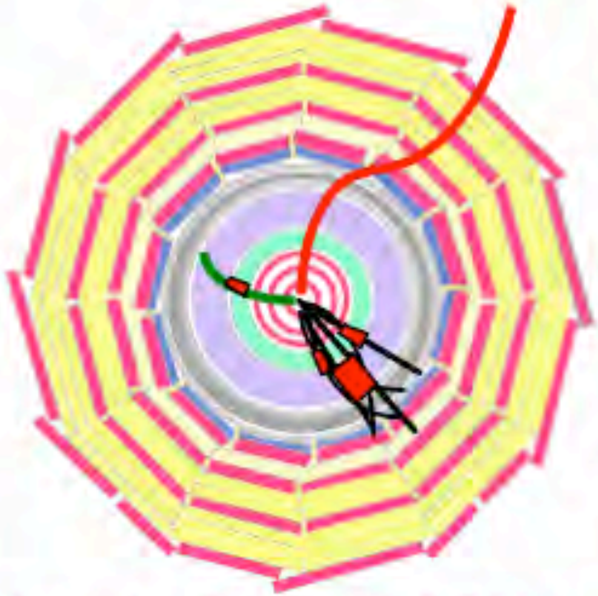
Example Level-1 Trigger Table
(DAQ TDR: L=2 x 10^{33})

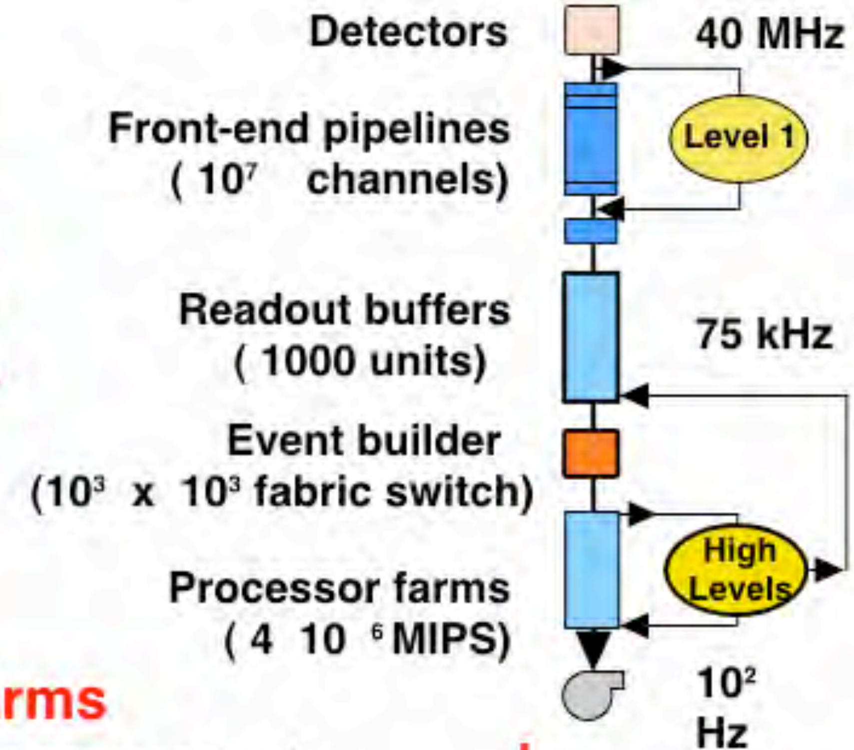
Trigger	*Threshold (GeV or GeV/c)*	*Rate (kHz)*	*Cumulative Rate (kHz)*
Isolated e/γ	29	3.3	3.3
Di-e/γ	17	1.3	4.3
Isolated muon	14	2.7	7.0
Di-muon	3	0.9	7.9
Single tau-jet	86	2.2	10.1
Di-tau-jet	59	1.0	10.9
1-jet, 3-jet, 4-jet	177, 86, 70	3.0	12.5
Jet*E_T^{miss}	88*46	2.3	14.3
Electron*jet	21*45	0.8	15.1
Min-bias		0.9	16.0
TOTAL			**16.0**

× 3 safety factor ⇒ 50 kHz (expected start-up DAQ bandwidth)

Only muon trigger has low enough threshold for B-physics (aka $B_s \rightarrow \mu\mu$)

High Level Trigger Strategy



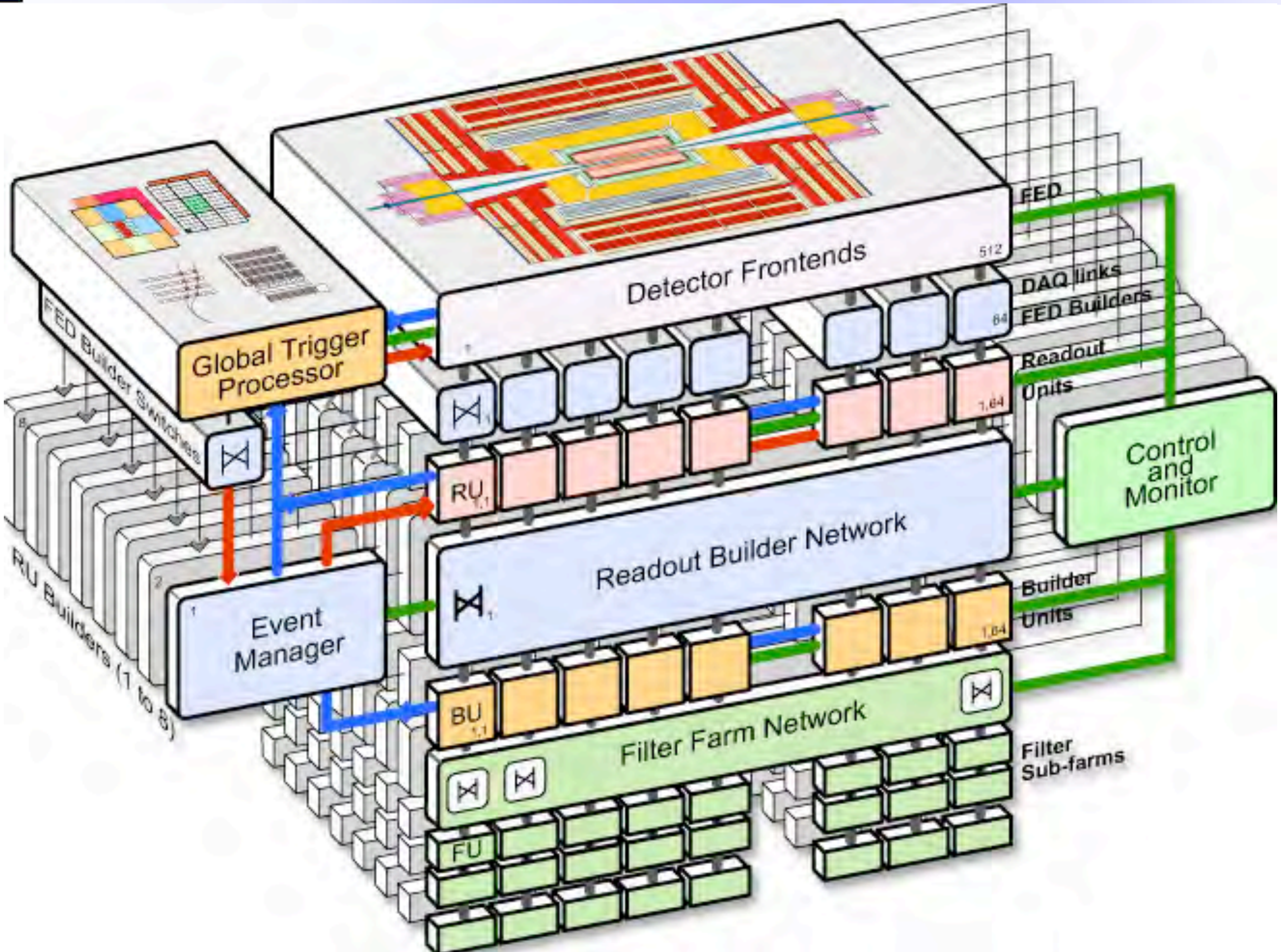


High level triggers. CPU farms

- Finer granularity precise measurement
- Clean particle signature (π^0-γ, isolation, ...)
- Kinematics. Effective mass cuts and topology
- Track reco and matching, b,τ-jet tagging
- Full event reconstruction and analysis

Successive improvements : background event filtering, physics selection

High-Level Trig. Implementation



8 “slices”

All processing beyond Level-1 performed in the Filter Farm

Partial event reconstruction “on demand” using full detector resolution

Start with L1 Trigger Objects

Electrons, Photons, τ-jets, Jets, Missing E_T, Muons

- HLT refines L1 objects (no volunteers)

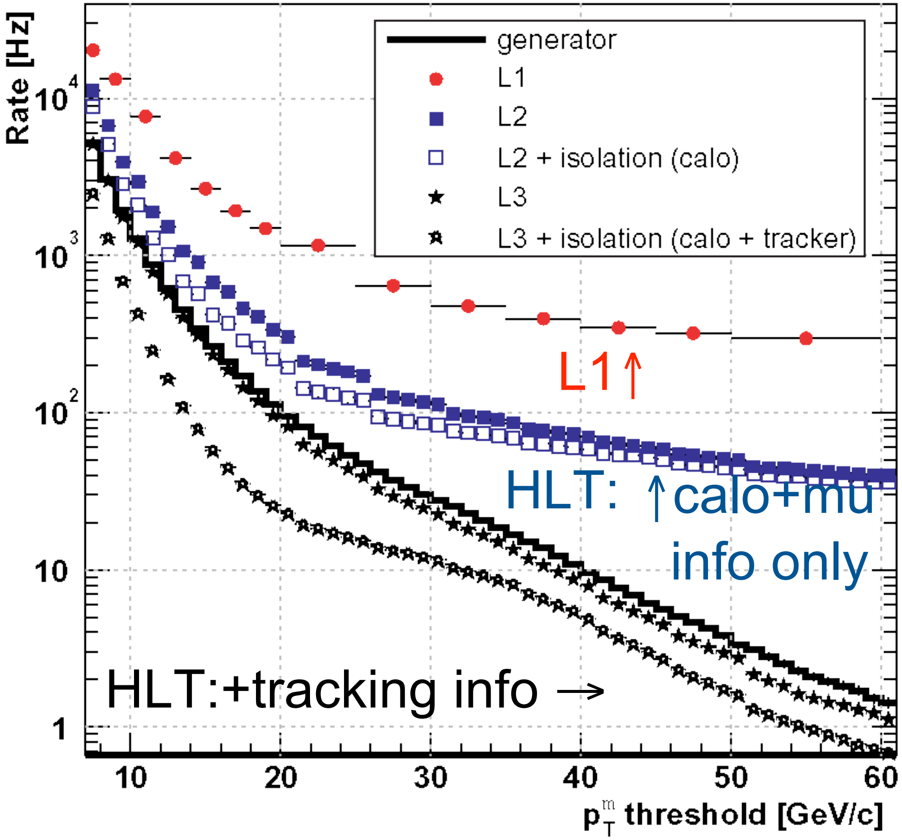
Goal

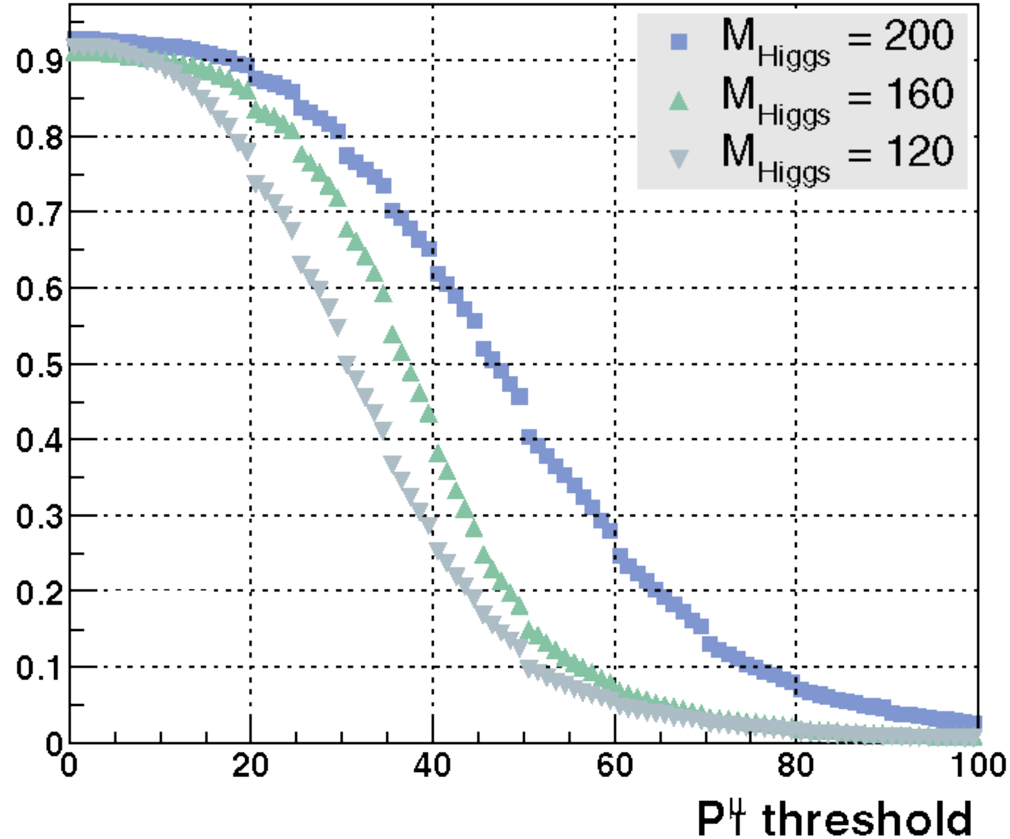
- Keep L1T thresholds for electro-weak symmetry breaking physics
- However, reduce the dominant QCD background
  - From 100 kHz down to 100 Hz nominally

QCD background reduction

- Fake reduction: $e^{\pm}$, γ, τ
- Improved resolution and isolation: μ
- Exploit event topology: Jets
- Association with other objects: Missing E_T
- Sophisticated algorithms necessary
  - Full reconstruction of the objects
  - Due to time constraints we avoid full reconstruction of the event - L1 seeded reconstruction of the objects only
  - Full reconstruction only for the HLT passed events

Muon Higher Level Trigger





Trigger rates vs. muon p_T threshold through levels of HLT processing at $L = 2 \times 10^{33}$

Efficiency for Higgs selection vs. muon p_T threshold for different Higgs masses

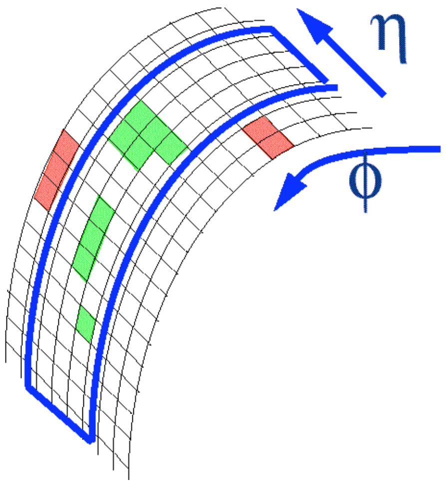
Electron selection: Level-2

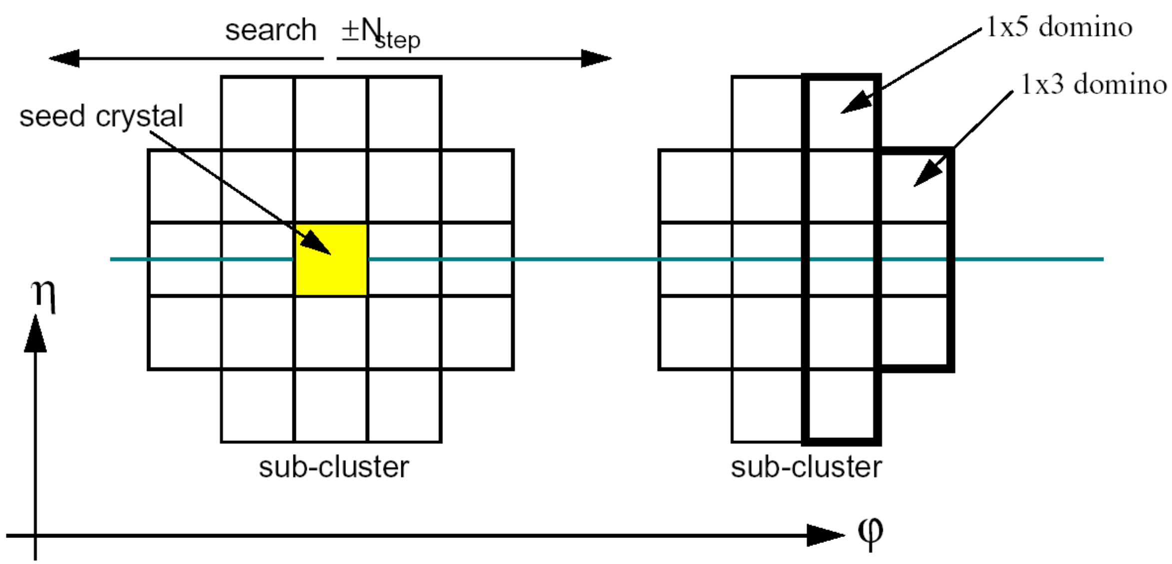
"Level-2" electron:

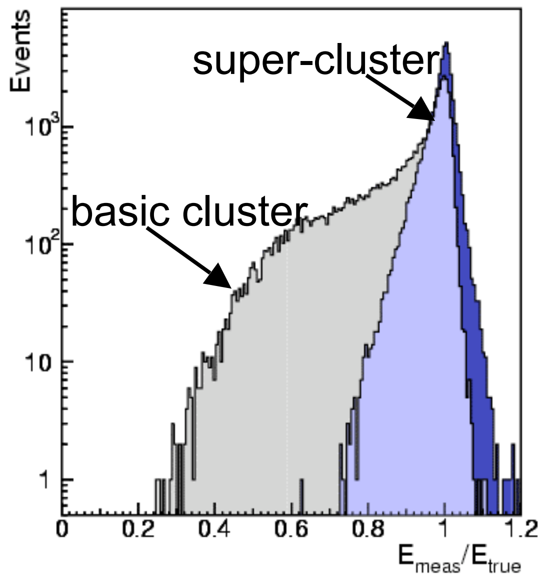
- Search for match to Level-1 trigger
  - Use 1-tower margin around 4x4-tower trigger region
- Bremsstrahlung recovery "super-clustering"
- Select highest E_T cluster

Bremsstrahlung recovery:

- Road along ϕ — in narrow η-window around seed
- Collect all sub-clusters in road → "super-cluster"

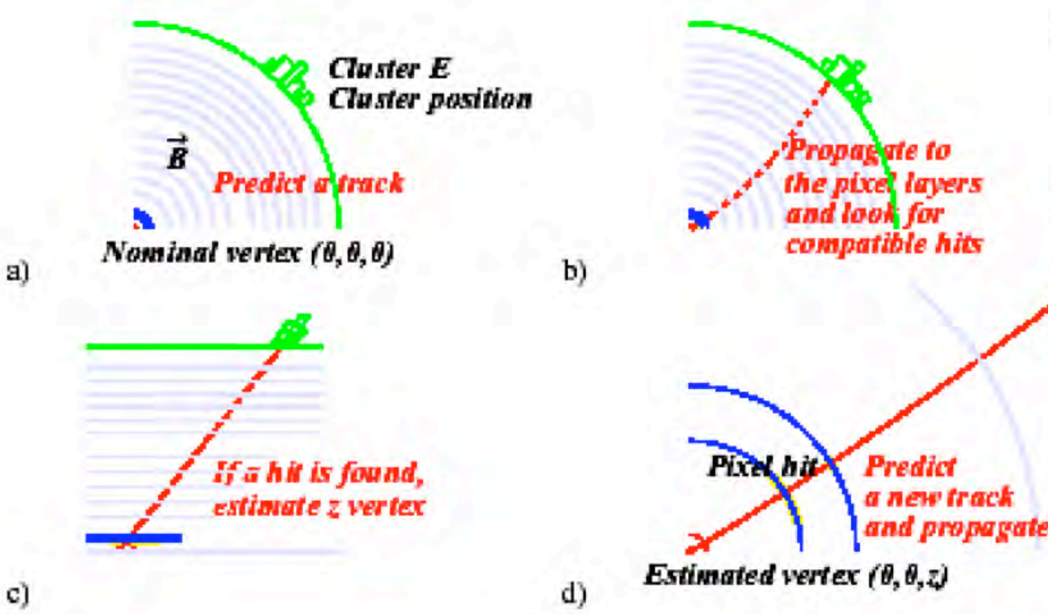


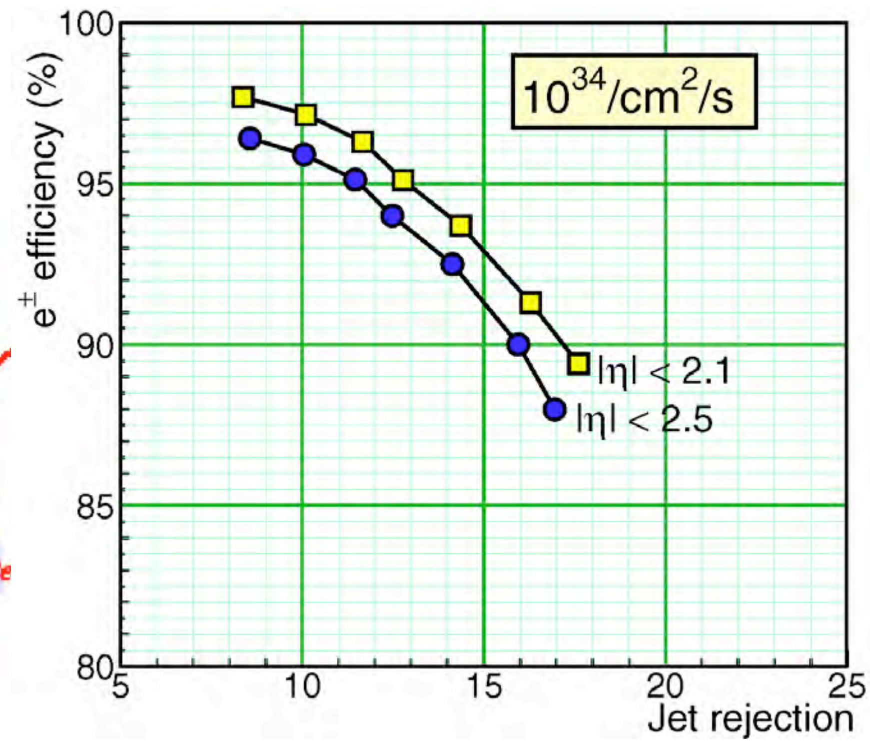




CMS tracking for electron trigger

CMS electron HLT

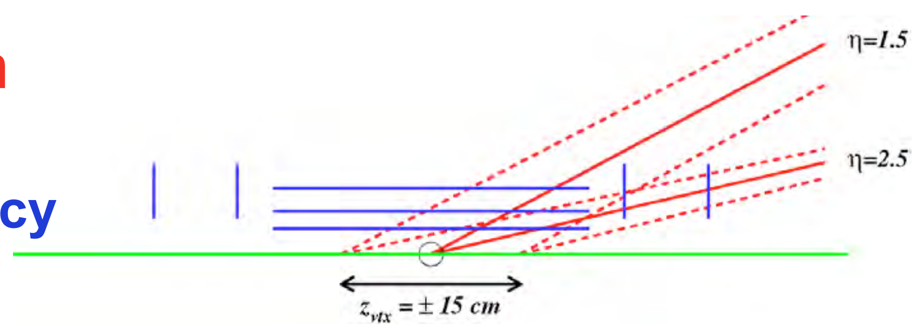




Factor of 10 rate reduction

γ: only tracker handle: isolation

- **Need knowledge of vertex location to avoid loss of efficiency**



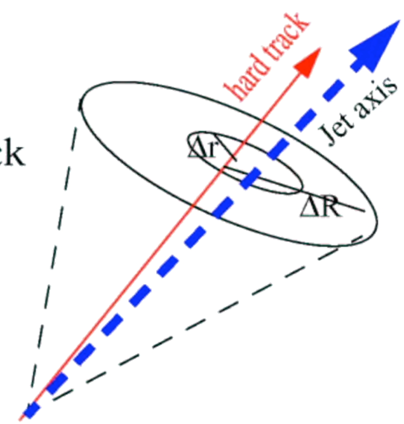
τ-jet tagging at HLT

τ-jet ($E_t^{\tau\text{-jet}} > 60$ GeV) identification (mainly) in the tracker:

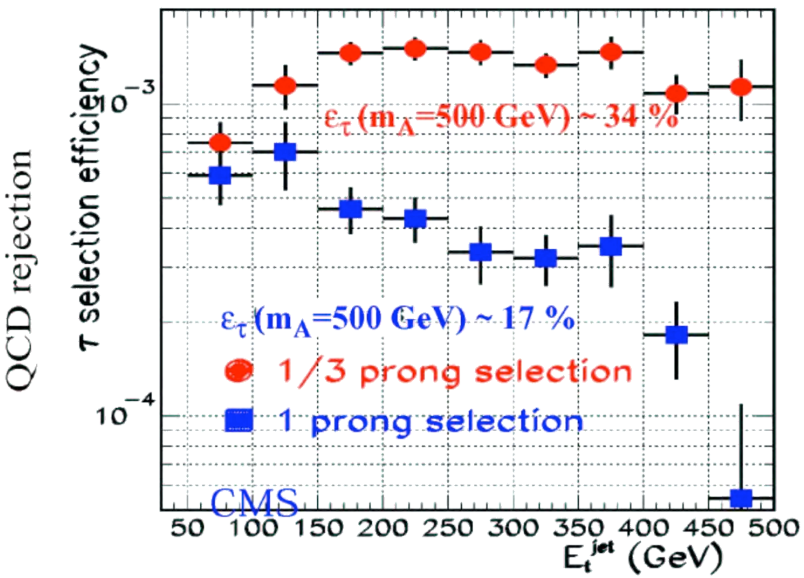
Hard track, $p_t^{max} > 40$ GeV, within $\Delta R < 0.1$ around calorimeter jet axis

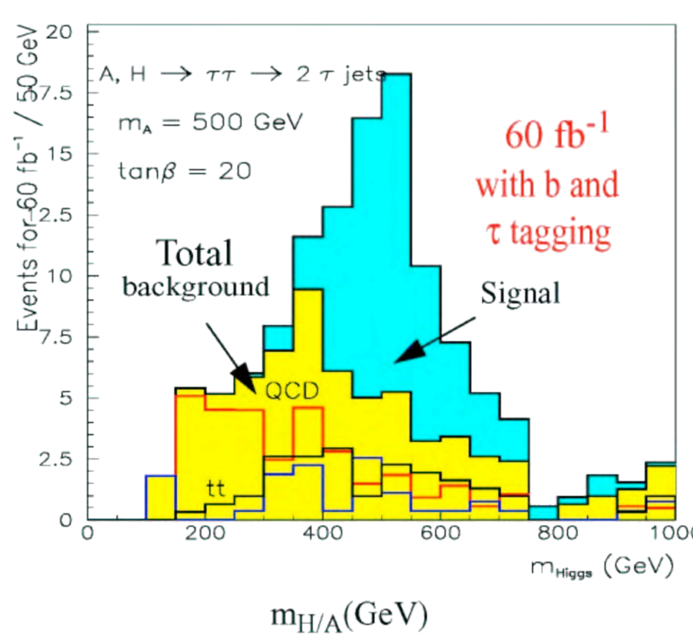
Isolation: no tracks, $p_t > 1$GeV, within $0.03 < \Delta R < 0.4$ around the hard track

For 3-prong selection 2 more tracks in the signal cone $\Delta r < 0.03$



QCD jet rejection from isolation and hard track cuts





Further reduction by ~ 5 expected for 3-prong QCD jets from τ vertex reconstruction (CMS full simulation)

B and τ tagging

Soft b-jets with a wide η-range:

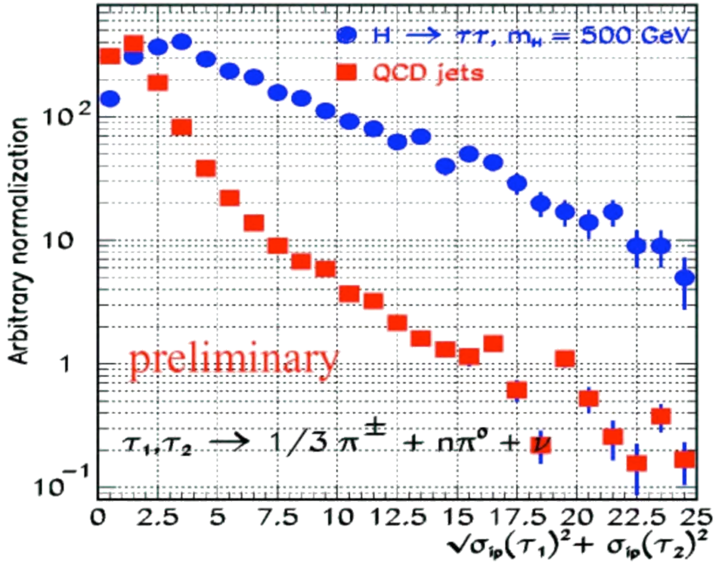
Efficiency to tag one b-jet ~ 35% for ~1% mistagging rate (CMS)

τ - tagging with impact parameter measurement

combining the ip measurements of the hard tracks in the two τ's (τ -> hadron, τ -> lepton) into one variable: $\sqrt{\sigma_{ip}(\tau_1)^2 + \sigma_{ip}(\tau_2)^2}$

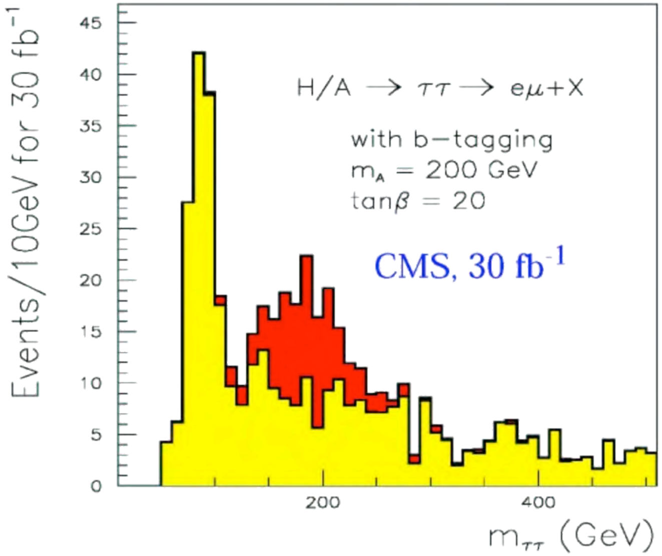
CMS full simulation for

H -> ττ –> 2 τ–jets and QCD events



Expect rejection of 5 - 10 against QCD background and backgrounds with W -> *l*ν, Z -> *ll*

Signal superimposed on the total background for m_A = 200 GeV, tanβ =20



Example HLT Trigger Menu ($L=2\times10^{33}$)

Trigger	Threshold (GeV or GeV/c)	Rate (Hz)	Cumulative Rate (Hz)
Inclusive electron	29	33	33
Di-electrons	17	1	34
Inclusive photons	80	4	38
Di-photons	40, 25	5	43
Inclusive muon	19	25	68
Di-muons	7	4	72
Inclusive τ-jets	86	3	75
Di-τ-jets	59	1	76
1-jet * E_T^{miss}	180 * 123	5	81
1-jet OR 3-jets OR 4-jets	657, 247, 113	9	89
Electron * tau	19 * 45	2	90
Inclusive *b*-jets	237	5	95
Calibration and other events (10%)		10	105
TOTAL			**105**

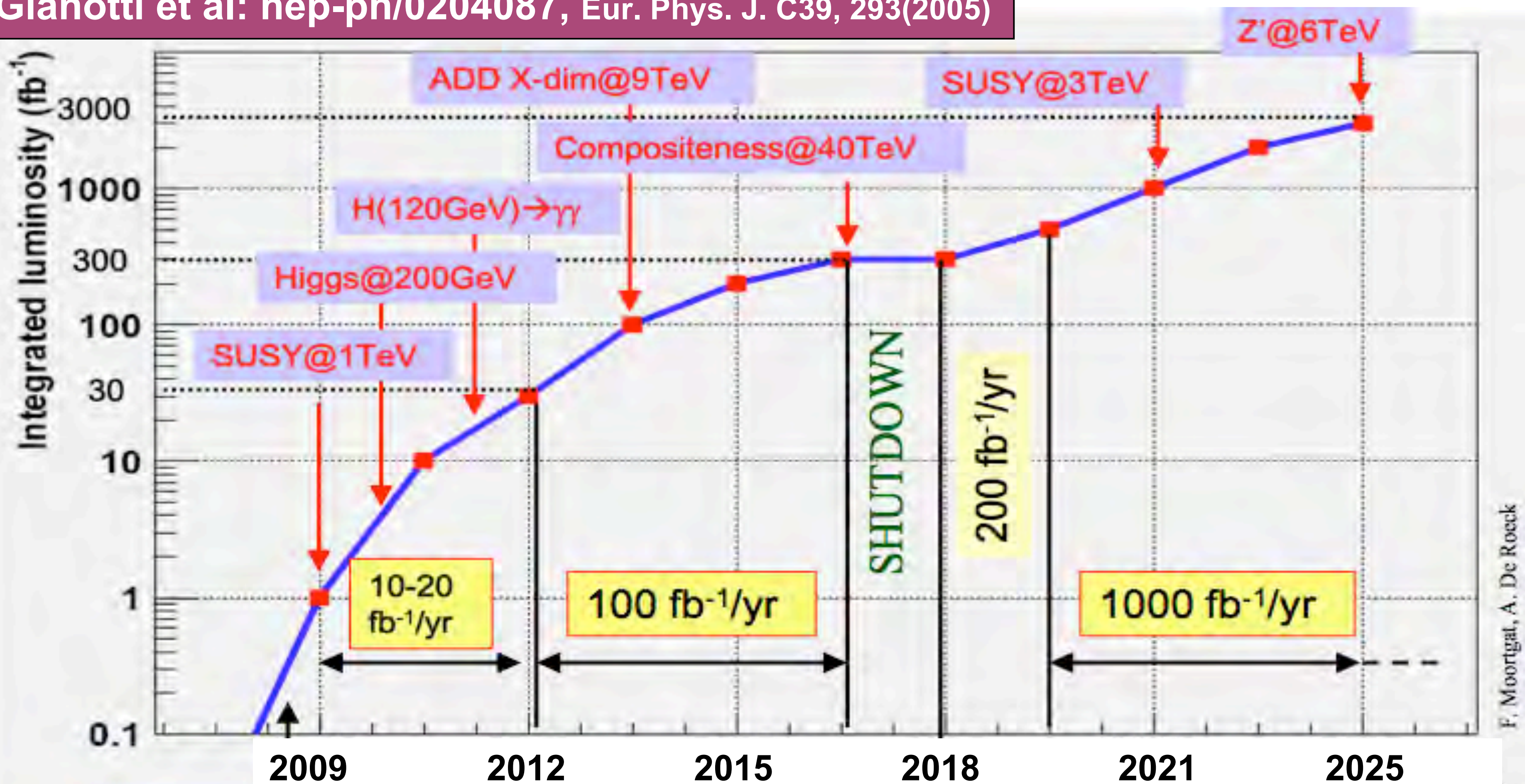
SUSY Efficiencies (MSUGRA benchmark)

SUSY point	Level-1 Trigger: 1 Jet >79 GeV+ E_T^{miss}>46 GeV efficiency (%)	Level-1 Trigger: 3 jets, E_T>86 GeV efficiency (%) (cumulative efficiency)	High-Level Trigger: 1 Jet >180GeV+ E_T^{miss}>123 GeV efficiency (%)	High-Level Trigger: 4 jets, E_T>113 GeV efficiency (%) (cumulative efficiency)
4	88	60 (92)	67	11 (69)
5	87	64 (92)	65	14 (68)
6	71	68 (85)	37	16 (44)
4R	67	89 (94)	27	28 (46)
5R	58	90 (93)	17	30 (41)
6R	47	84 (87)	9	20 (26)
Background	rate (kHz)	rate (kHz) (cumulative rate)	rate (Hz)	rate (Hz) (cumulative rate)
	2.3	0.98 (3.1)	5.1 Hz	6.8 (11.8)

$m(\tilde{g})$ (GeV/c²)	$m(\tilde{u}_L)$ (GeV/c²)	$m(\tilde{\chi}_1^0)$ (GeV/c²)
466	410	70
447	415	66
349	406	45

LHC → SLHC physics evolution

De Roeck, Ellis, Gianotti: hep-ph/0112004
Gianotti et al: hep-ph/0204087, Eur. Phys. J. C39, 293(2005)

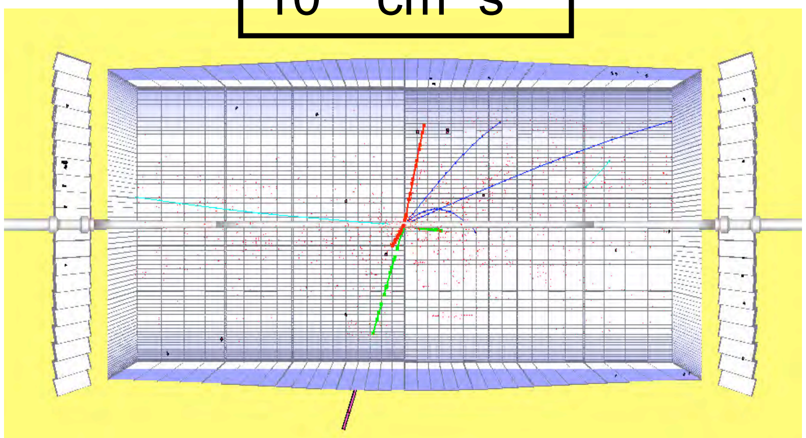


Timescale adjusted

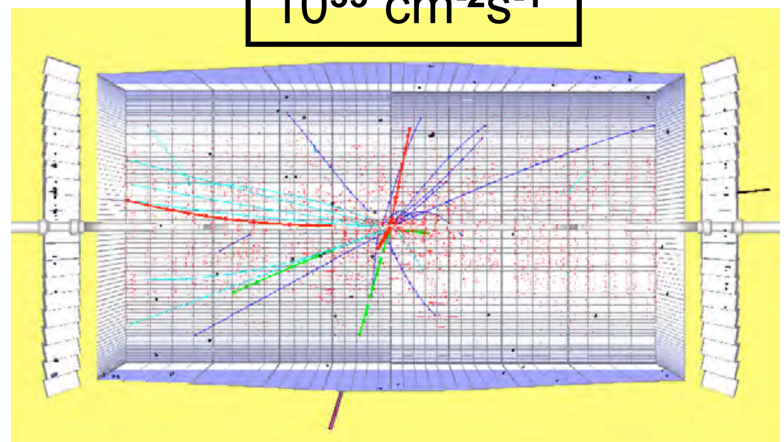
Detector Luminosity Effects

$H \rightarrow ZZ \rightarrow \mu\mu ee$, M_H = 300 GeV for different luminosities in CMS

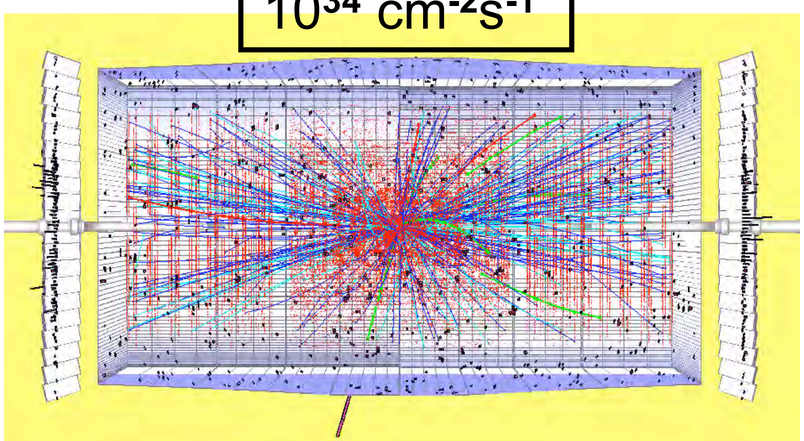
$10^{32}\ cm^{-2}s^{-1}$



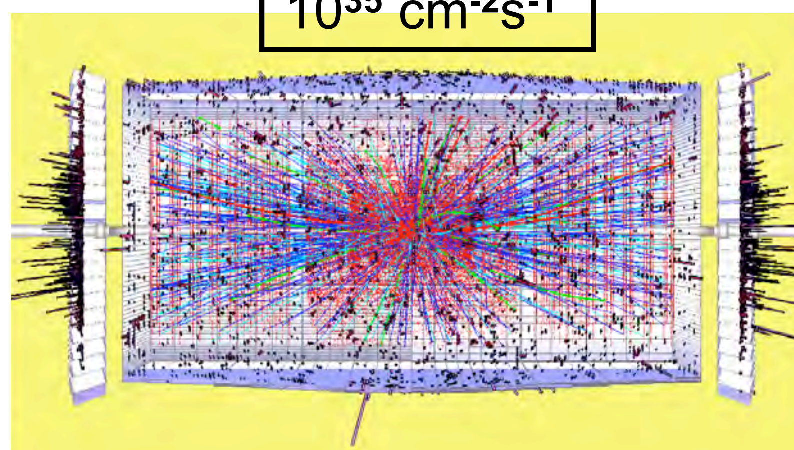
$10^{33}\ cm^{-2}s^{-1}$



$10^{34}\ cm^{-2}s^{-1}$



$10^{35}\ cm^{-2}s^{-1}$



SLHC Level-1 Trigger @ 10^{35}

Occupancy

- **Degraded performance of algorithms**
  - Electrons: reduced rejection at fixed efficiency from isolation
  - Muons: increased background rates from accidental coincidences
- **Larger event size to be read out**
  - New Tracker: higher channel count & occupancy → large factor
  - Reduces the max level-1 rate for fixed bandwidth readout.

Trigger Rates

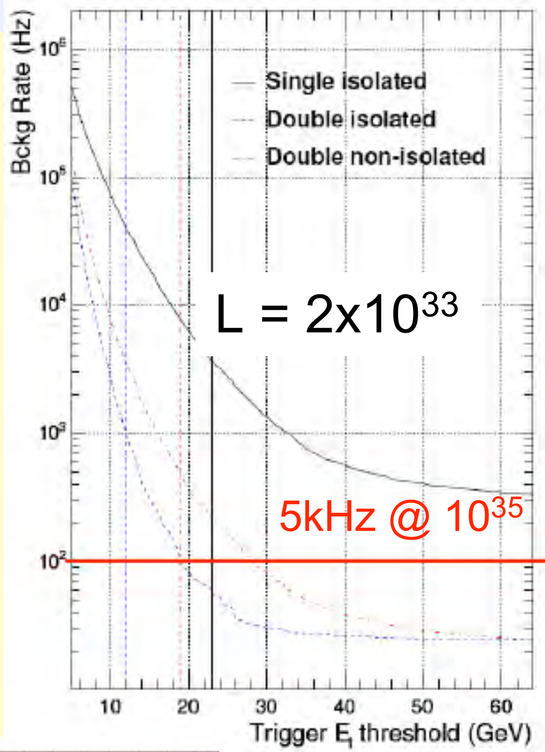
- **Try to hold max L1 rate at 100 kHz by increasing readout bandwidth**
  - Avoid rebuilding front end electronics/readouts where possible
    - **Limits: ⟨readout time⟩ (< 10 μs) and data size (total now 1 MB)**
  - Use buffers for increased latency for processing, not post-L1A
  - May need to increase L1 rate even with all improvements
    - **Greater burden on DAQ**
- **Implies raising E_T thresholds on electrons, photons, muons, jets and use of multi-object triggers, unless we have new information ⇒Tracker at L1**
  - Need to compensate for larger interaction rate & degradation in algorithm performance due to occupancy

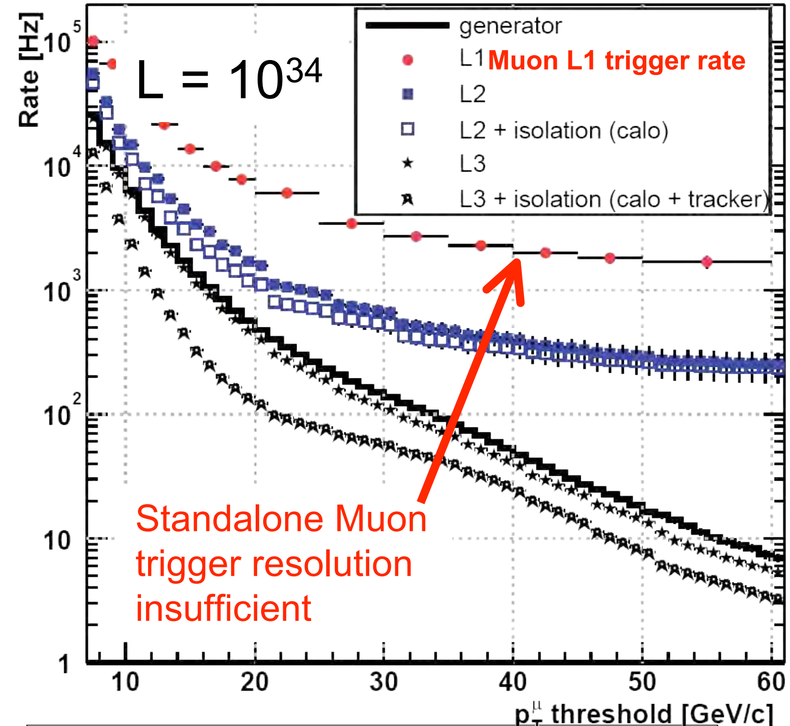
Radiation damage -- Increases for part of level-1 trigger located on detector

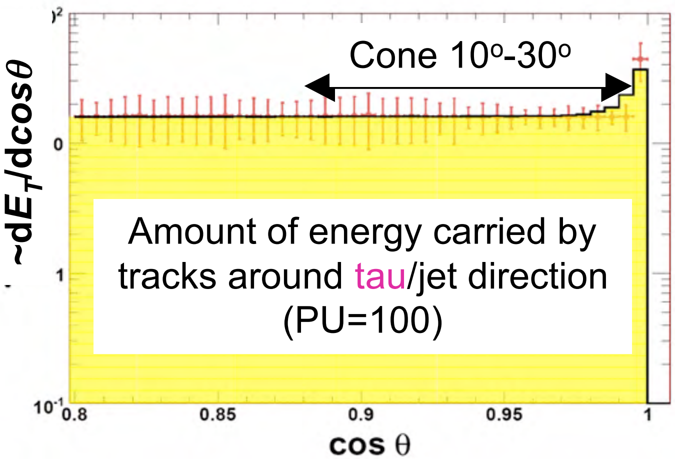
Tracking needed for L1 trigger

Single electron trigger rate

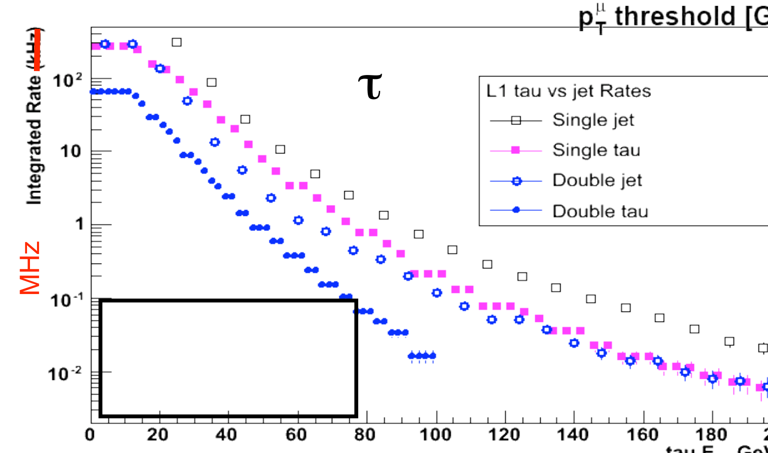
Isolation criteria are insufficient to reduce rate at L = $10^{35}\ cm^{-2}.s^{-1}$







We need to get another x200 (x20) reduction for single (double) tau rate!



Use of CMS L1 Tracking Trigger

Combine with L1 μ trigger as is now done at HLT:

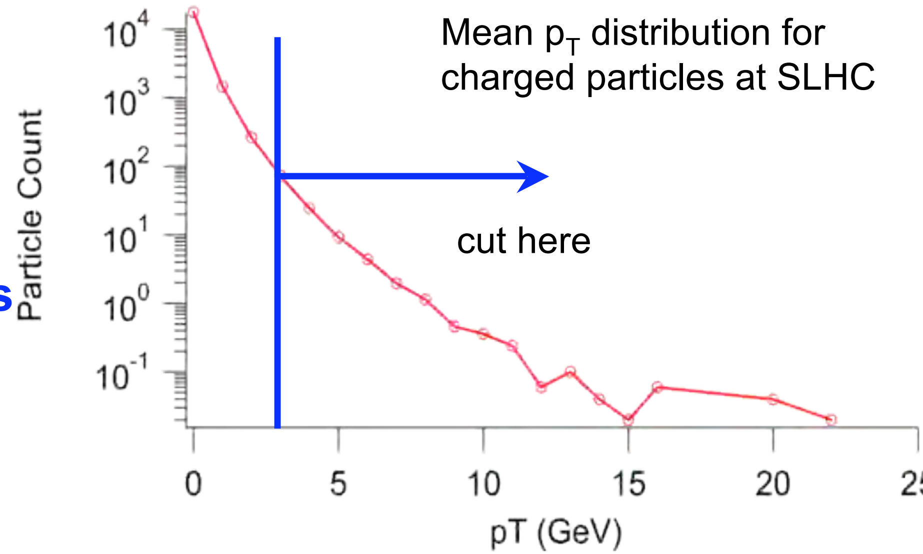
- **Attach tracker hits to improve P_T assignment precision from 15% standalone muon measurement to 1.5% with the tracker**
  - Improves sign determination & provides vertex constraints
- **Find pixel tracks within cone around muon track and compute sum P_T as an isolation criterion**
  - Less sensitive to pile-up than calorimetric information *if* primary vertex of hard-scattering can be determined (~100 vertices total at SLHC!)

To do this requires η–ϕ information on muons finer than the current 0.05–2.5°

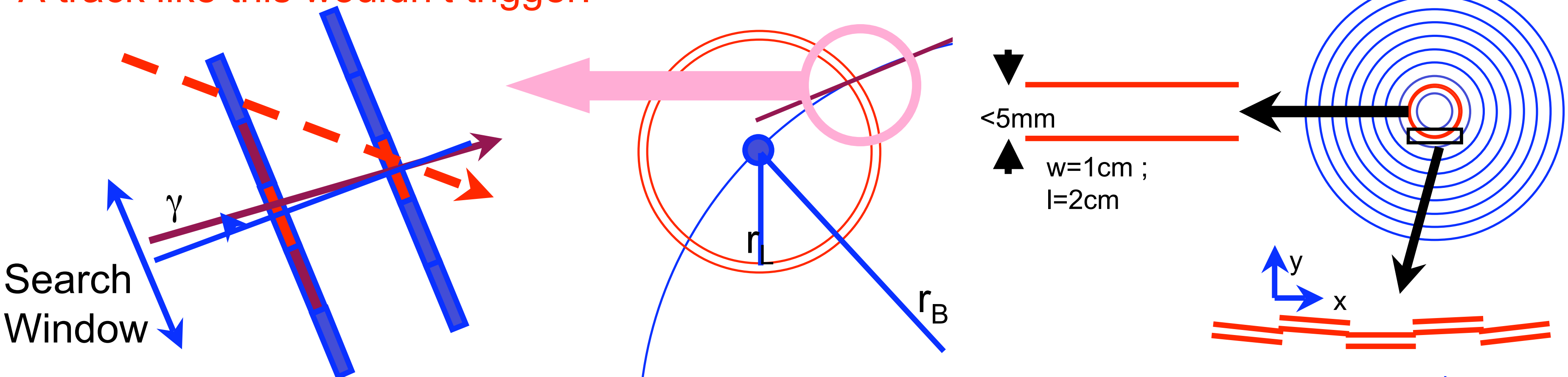
- **No problem, since both are already available at 0.0125 and 0.015°**

CMS ideas for trigger-capable tracker modules -- very preliminary

- Use close spaced stacked pixel layers
- Geometrical p_T cut on data (e.g. ~ GeV):
- Angle (γ) of track bisecting sensor layers defines p_T ($\Rightarrow$ window)
- For a stacked system (sepn. ~1mm), this is ~1 pixel
- Use simple coincidence in stacked sensor pair to find tracklets
- More details & implementation next slides



A track like this wouldn't trigger:



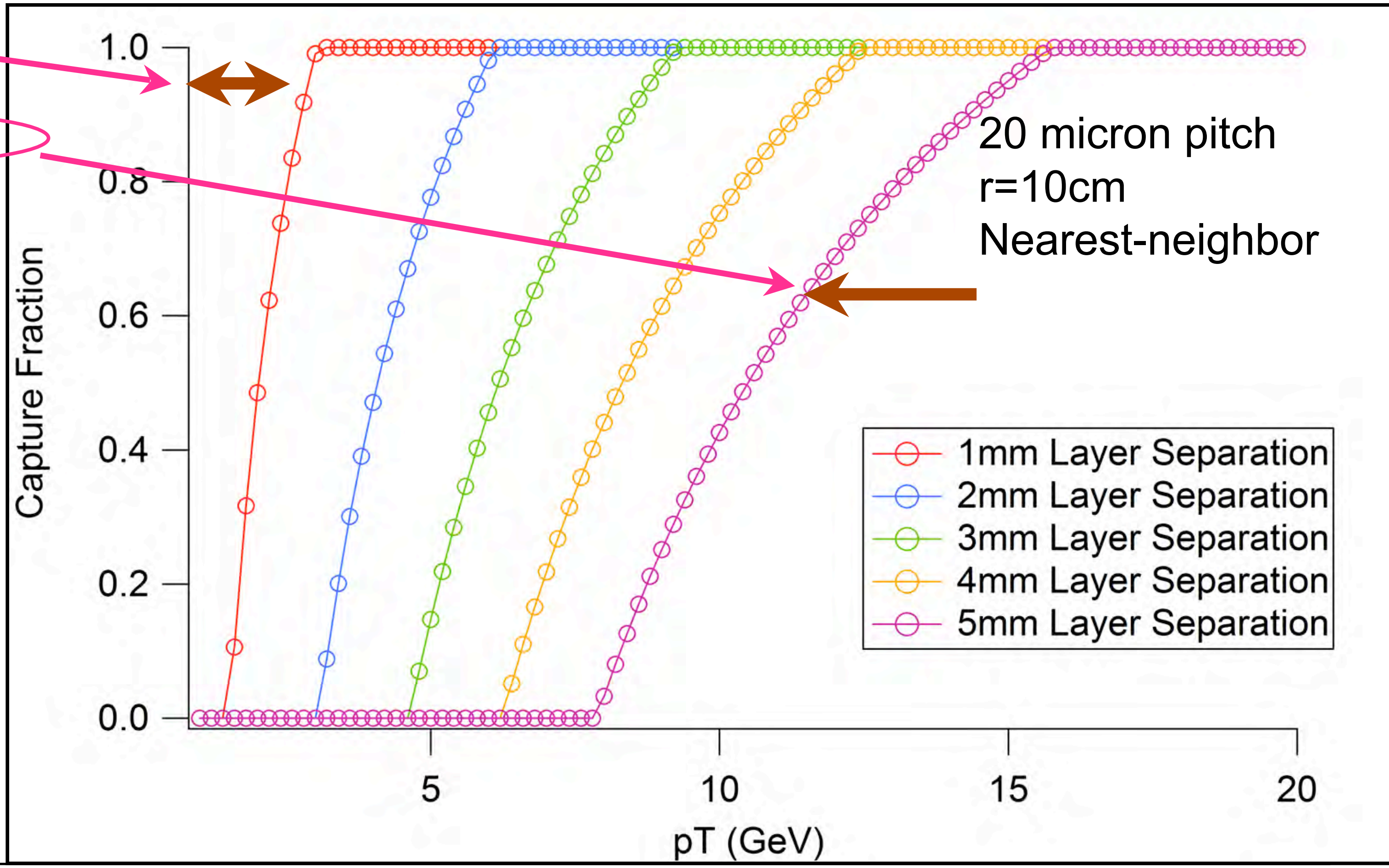
p_T Cuts in a Stacked Tracker – p_T Cut Probabilities

- **Depends on:**

Layer Sepn. & Radius

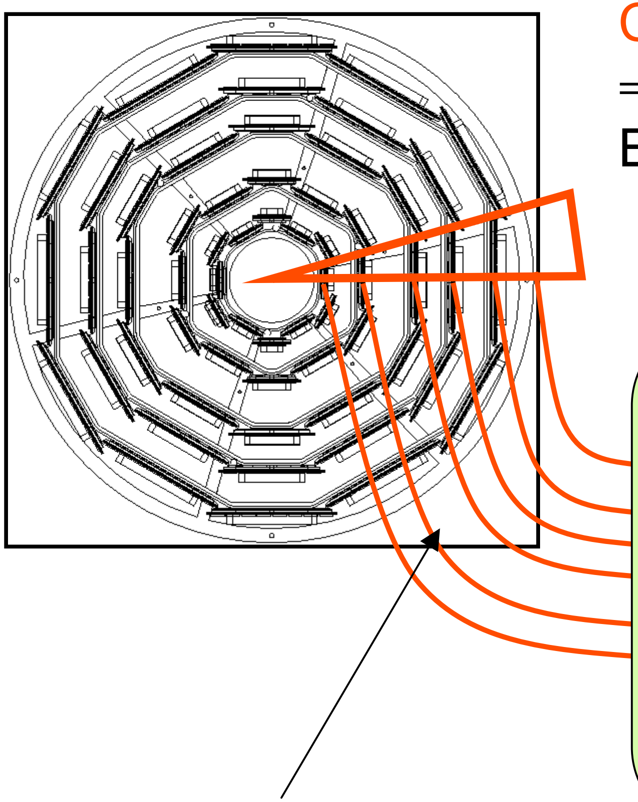
Pixel Size

Search Window



There is an additional 'blurring' caused by charge sharing…

Alternative Tracking Trigger: Associative Memories (from CDF SVX)



Challenge: input Bandwidth
⇒divide the detector in thin ϕ sectors.
Each AM searches in a small $\Delta\phi$

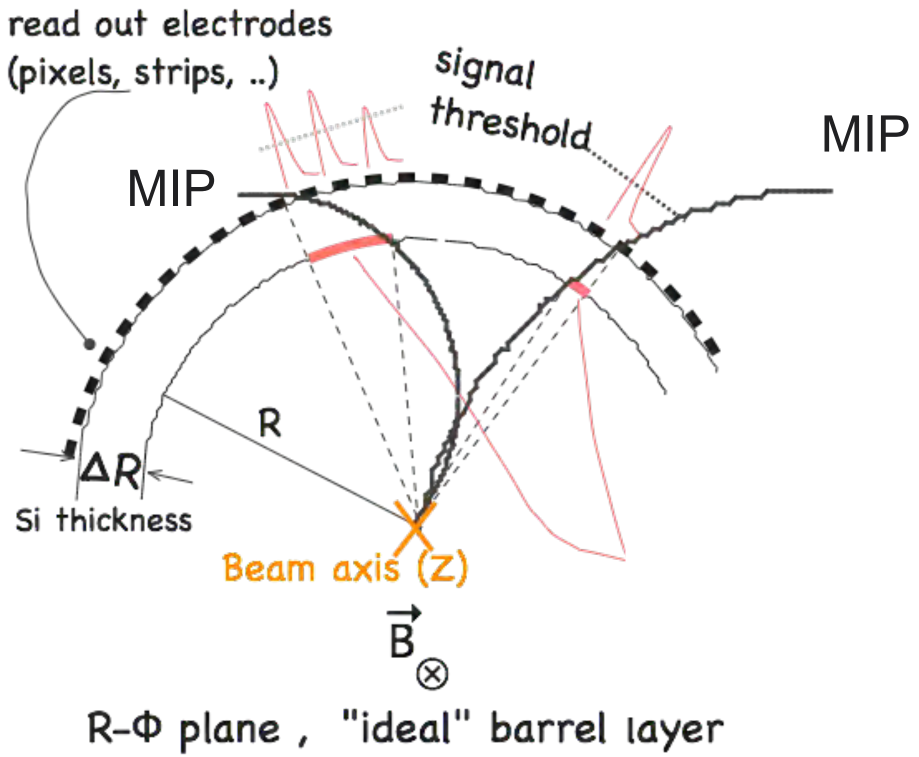
OFF DETECTOR

1 AM for each enough-small $\Delta\phi$
Patterns
Hits: position+time stamp
All patterns inside a single chip
N chips for N overlapping events identified by the time stamp

Event1 AMchip1	Event2 AMchip2	Event3 AMchip3	• • • • •	EventN AMchipN

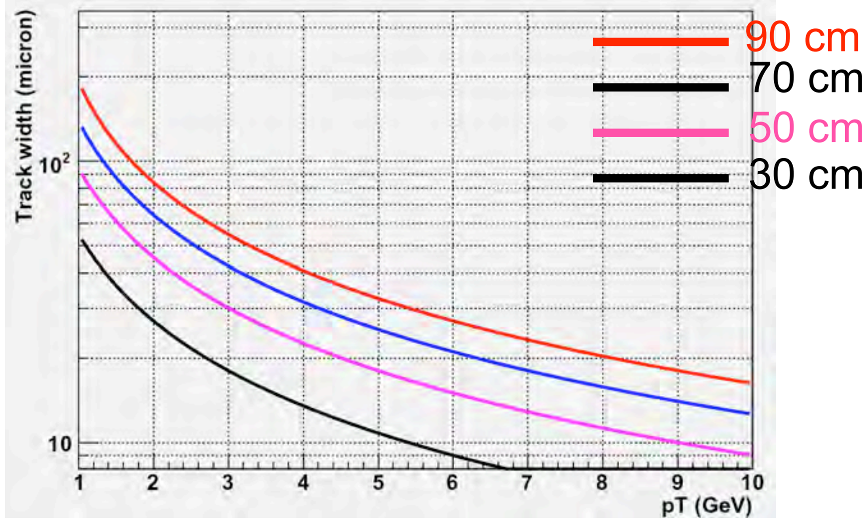
-- F. Palla, A. Annovi, *et al.*

Cluster width discrimination



Discrimination of low p_T tracks made directly on the strip detector by choosing suitable pitch values in the usual range for strip sensors.

(Needed because 25M channels x 4% occupancy would require 6000 2.8 Gbps links at 100 kHz.)



In the region above 50 cm, using 50µm pitch, about 5% of the total particles leave cluster sizes with ≤2 strips

- No. of links (2.5Gbps) ~300 for whole tracker (assuming 95% hit rejection)

Once reduced to ~100 KHz, it would only need few fast readout links to readout the entire Tracker

CMS SLHC Trigger Implementation Goals

Modular

- Develop modules independently
- Share across subsystems

Compact

- Fewer crates → fewer interconnections
- Smaller circuit boards

Flexible

- FPGAs
- Programmably routable backplanes
  - Need flexibility in routing of data and processed results

Higher density inputs

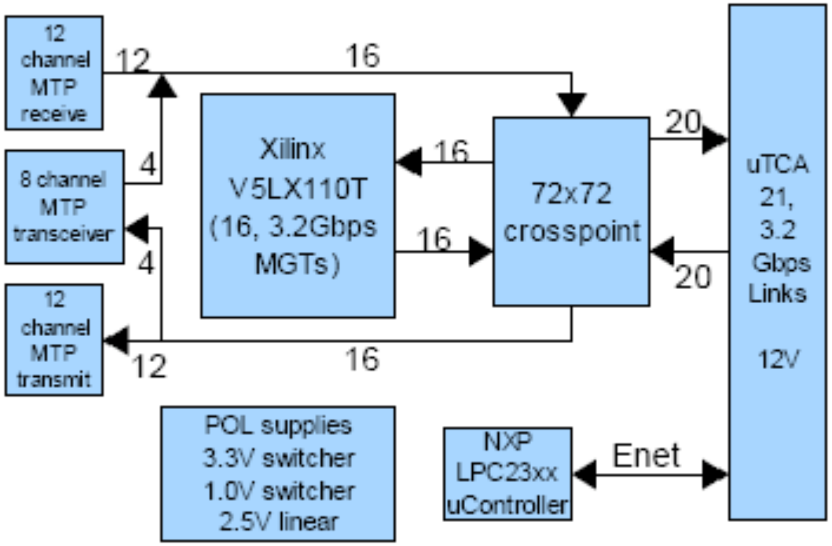
- Bring more in more information on a finer grain scale

More general & modular firmware

- Less device dependence
- Sharing of firmware modules & development

Proto. Generic Trigger System

Concept for Main Processing Card

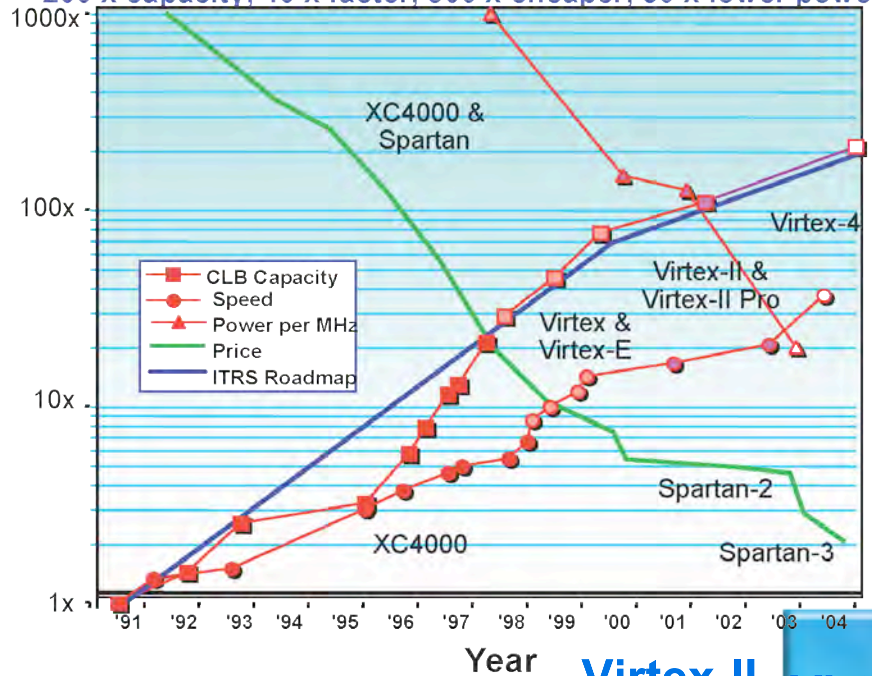


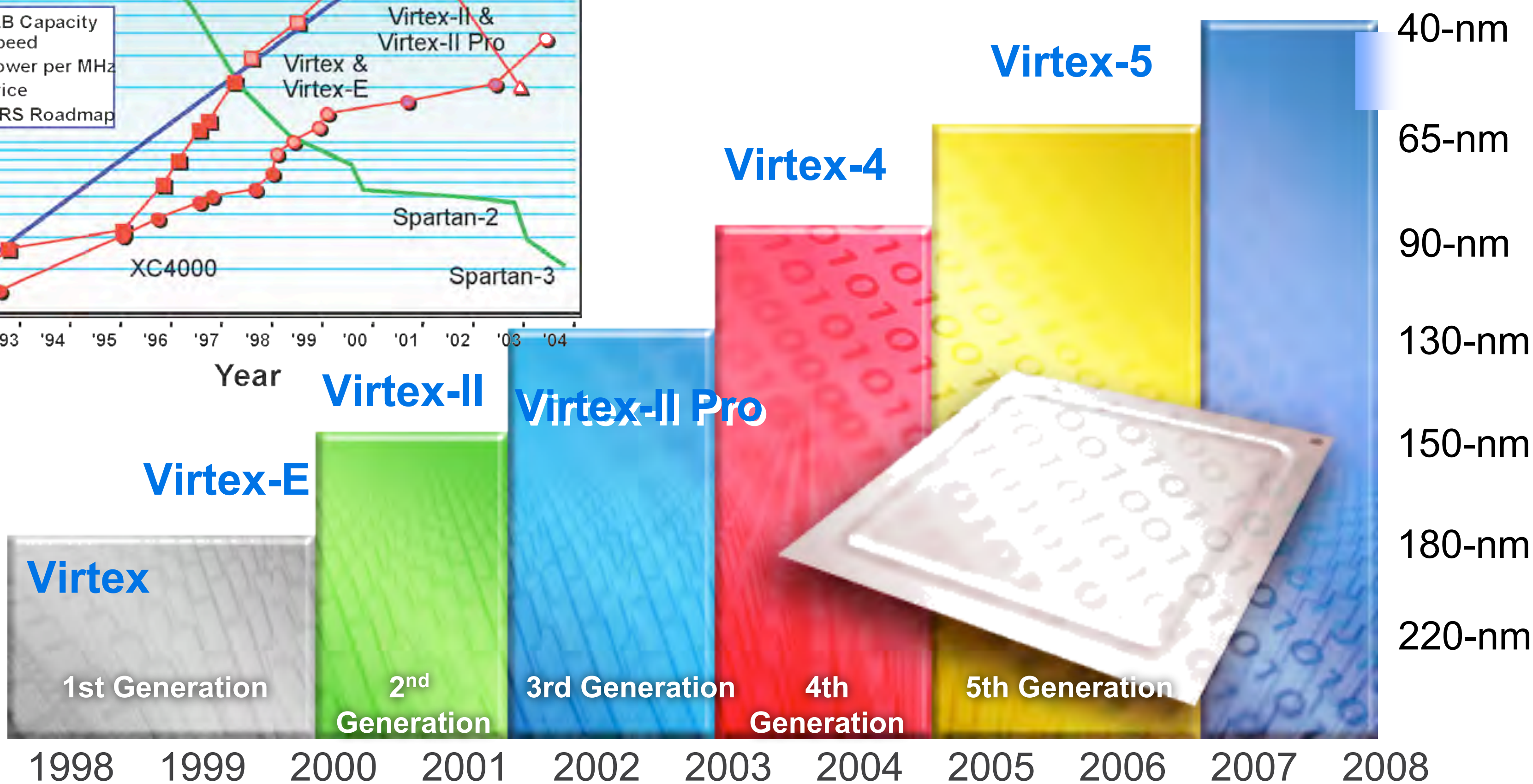
uTCA Crate and Backplane

- **The Main Processing Card (MPC):**
  - **Receives and transmits data via front panel optical links.**
  - **On board 72x72 Cross-Point Switch allows for dynamical routing of the data either to a V5 FPGA or directly to the uTCA backplane.**
  - **The MPC can exchange data with other MPCs either via the backplane or via the front panel optical links.**
- **The Custom uTCA backplane:**
  - **Instrumented with 2 more Cross-Point Switches for extra algorithm flexibility.**
  - **Allows dynamical or static routing of the data to different MPCs.**

FPGA Progress

200 x capacity, 40 x faster, 500 x cheaper, 50 x lower power





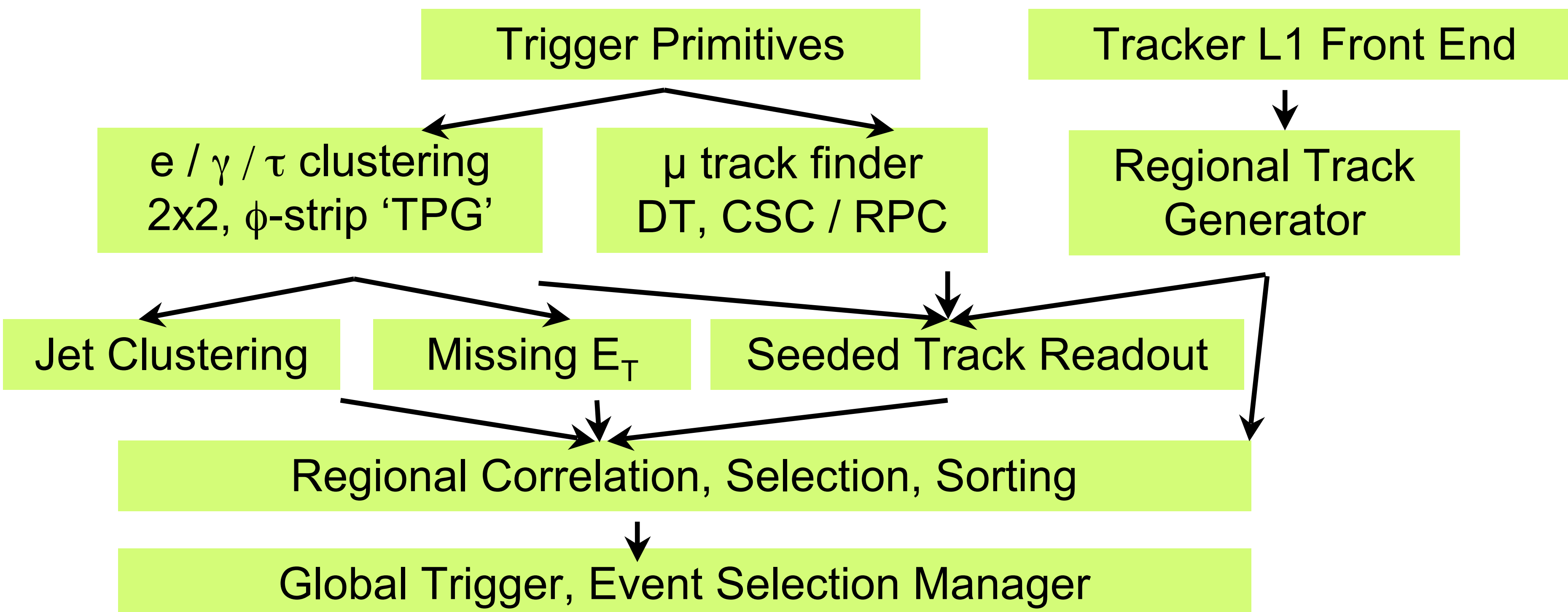
CMS L1 Trigger Stages

Current for LHC:

TPG ⇒ RCT ⇒ GCT ⇒ GT

Proposed for SLHC (with tracking added):

TPG ⇒ Clustering ⇒ Correlator ⇒ Selector



CMS Level-1 Latency

Present CMS Latency of 3.2 μsec = 128 crossings @ 40MHz

- Limitation from post-L1 buffer size of tracker & preshower
- Assume rebuild of tracking & preshower electronics will store more than this number of samples

Do we need more?

- Not all crossings used for trigger processing (70/128)
  - It's the cables!
- Parts of trigger already using higher frequency

How much more? Justification?

- Combination with tracking logic
- Increased algorithm complexity
- Asynchronous links or FPGA-integrated deserialization require more latency
- Finer result granularity may require more processing time
- ECAL digital pipeline memory is 256 40 MHz samples = 6.4 μsec
  - Propose this as CMS SLHC Level-1 Latency baseline

Trigger & DAQ Summary:
LHC Case

Level 1 Trigger

- Select 100 kHz interactions from 1 GHz (10 GHz at SLHC)
- Processing is synchronous & pipelined
- Decision latency is 3 μs (x~2 at SLHC)
- Algorithms run on local, coarse data
  - Cal & Muon at LHC (& tracking at SLHC)
  - Use of ASICs & FPGAs (mostly FPGAs at SLHC)

Higher Level Triggers

- Uses dedicated farm of PCs
- Select regions to unpack & process based on L1 Trigger
- Run software/algorithms as close to offline as possible