Upgrades of the CMS Detector

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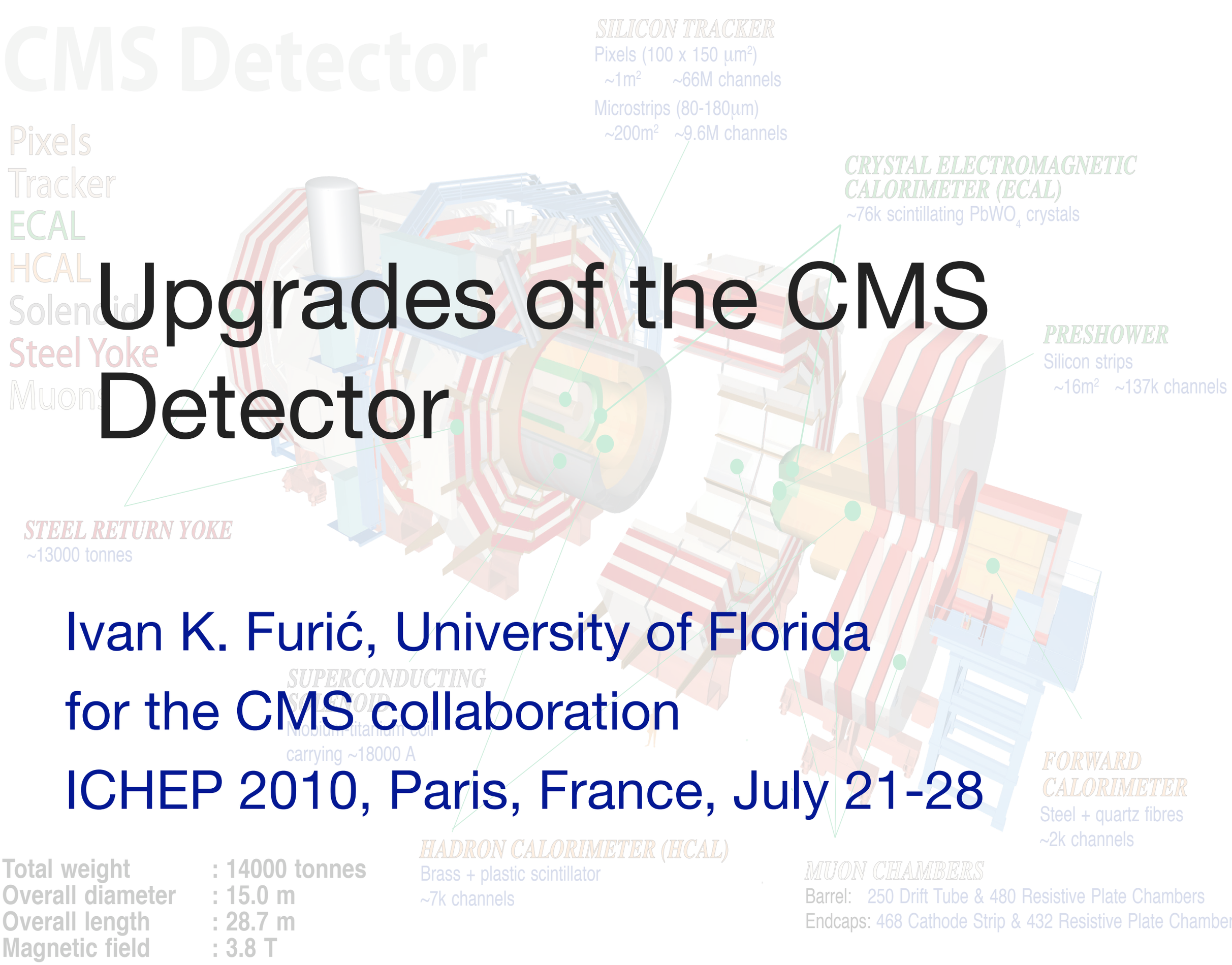


LHC Timeline

LHC Phase 1

LHC revisions necessary to run at 14 TeV

install collimation for $\mathcal{L}$ beyond design (10^{34} cm^{-2}s^{-1})

7 TeV collisions gather 1 fb^{-1}

14 TeV, peak $\mathcal{L}$ ~10^{33} cm^{-2}s^{-1}

$\mathcal{L}$ ~ 1-2×10^{34}cm^{-2}s^{-1} BX spacing 25 or 50 ns

Now — 2012 — 2015-16 — 2020(+)

LHC Phase 2

CMS Phase 1 Upgrades

- Pixel Tracking System

replace: radiation damage
data loss at full trigger rate

- Muon System

add redundancy in forward
region, improve trig. primitives

- Hadron Calorimeter

depth segmentation, 1 ns timing
new, high gain photodetectors

- Trigger

cal. trigger - finer clustering & isolation
μ trigger - more coverage, meas. inputs

- Data Acquisition System

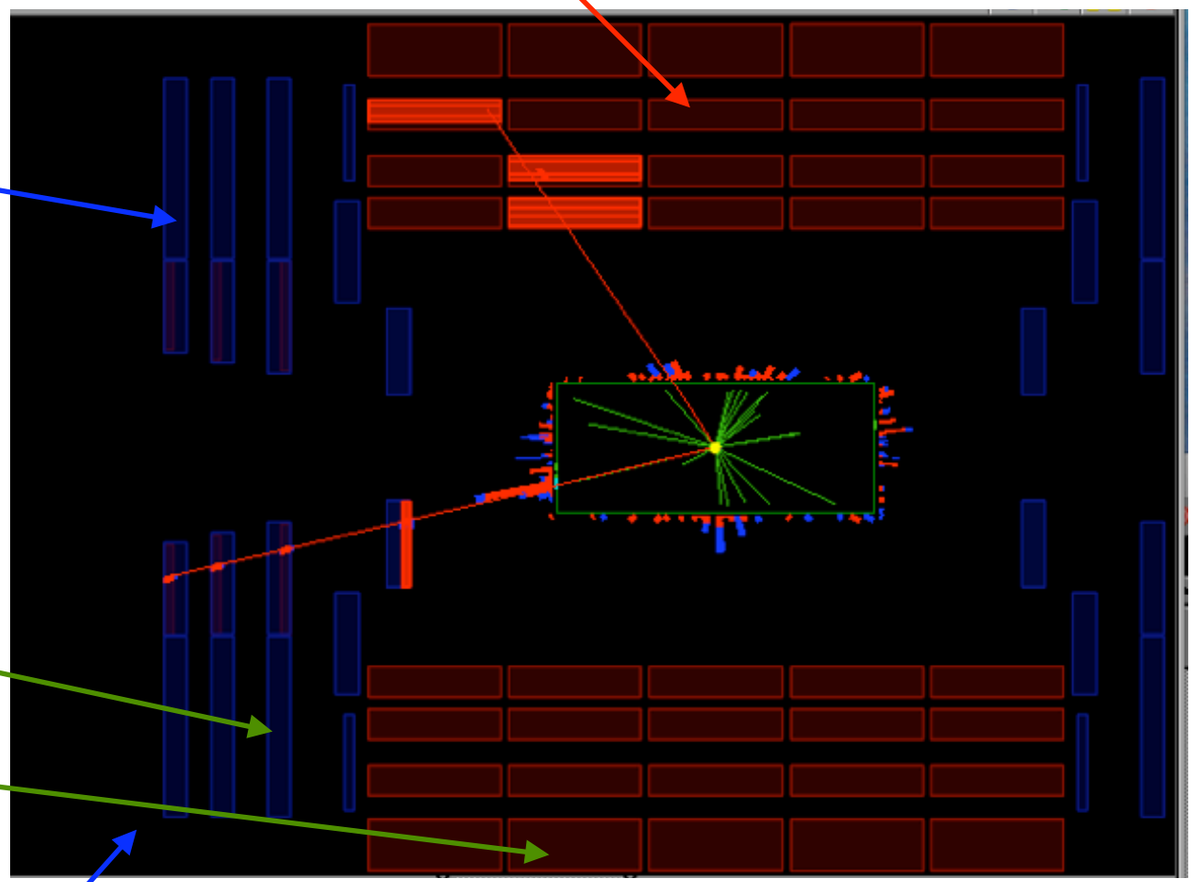
increase bandwidth ×2-5

CMS Muon System

Drift Tube (DT) chambers in central (barrel) region

Cathode Strip (CSC) chambers in forward region

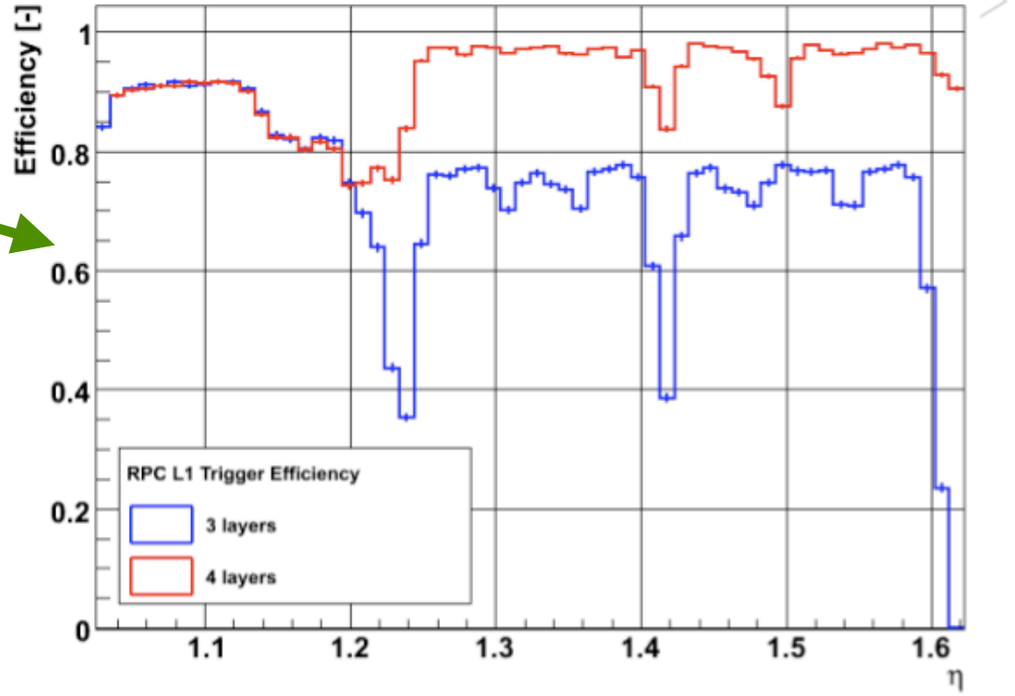
Resistive Plate (RPC) chambers in both regions

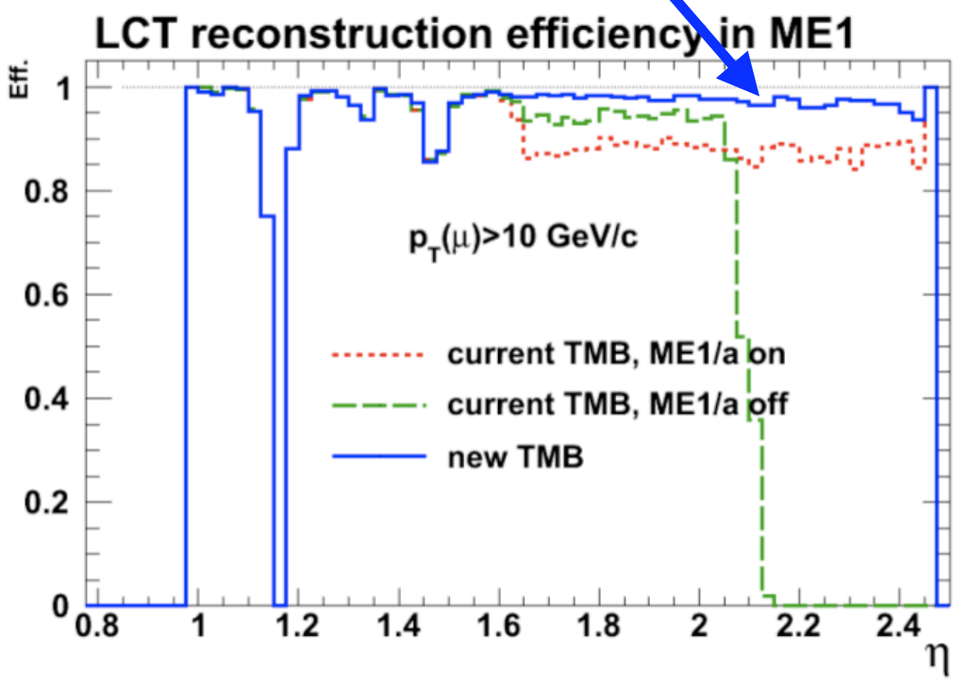


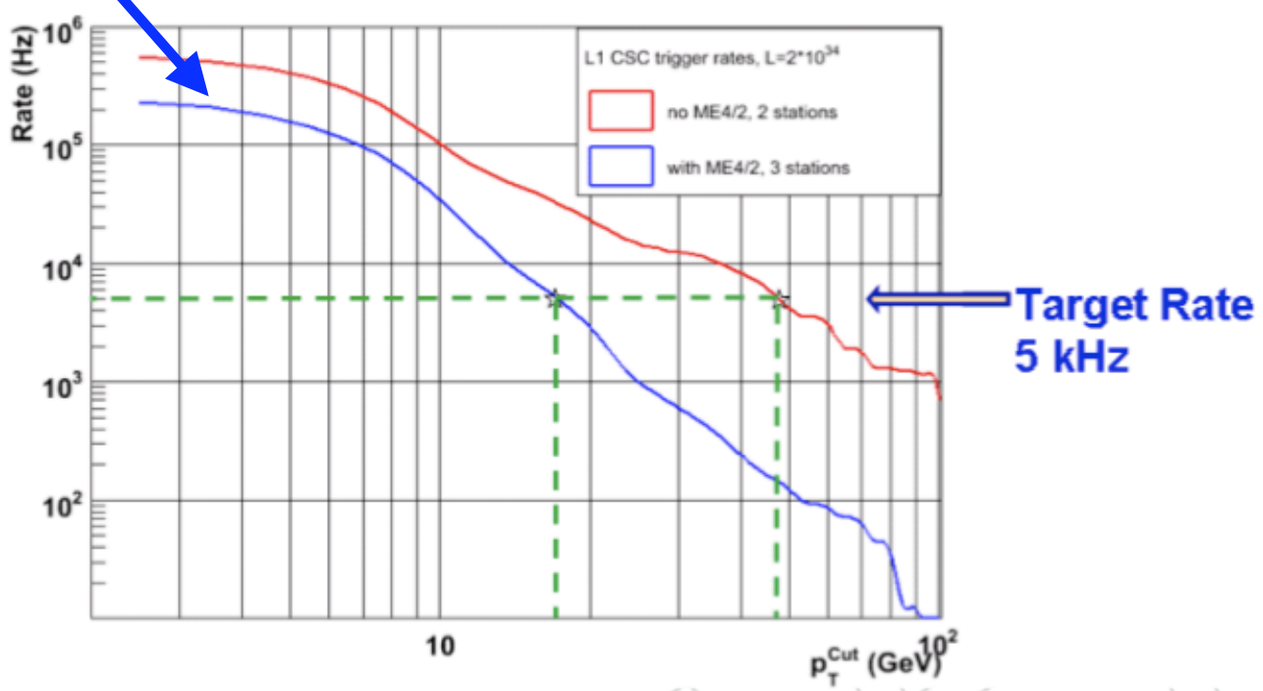
outer ring, endcap station 4 currently not instrumented

Muon System Upgrades

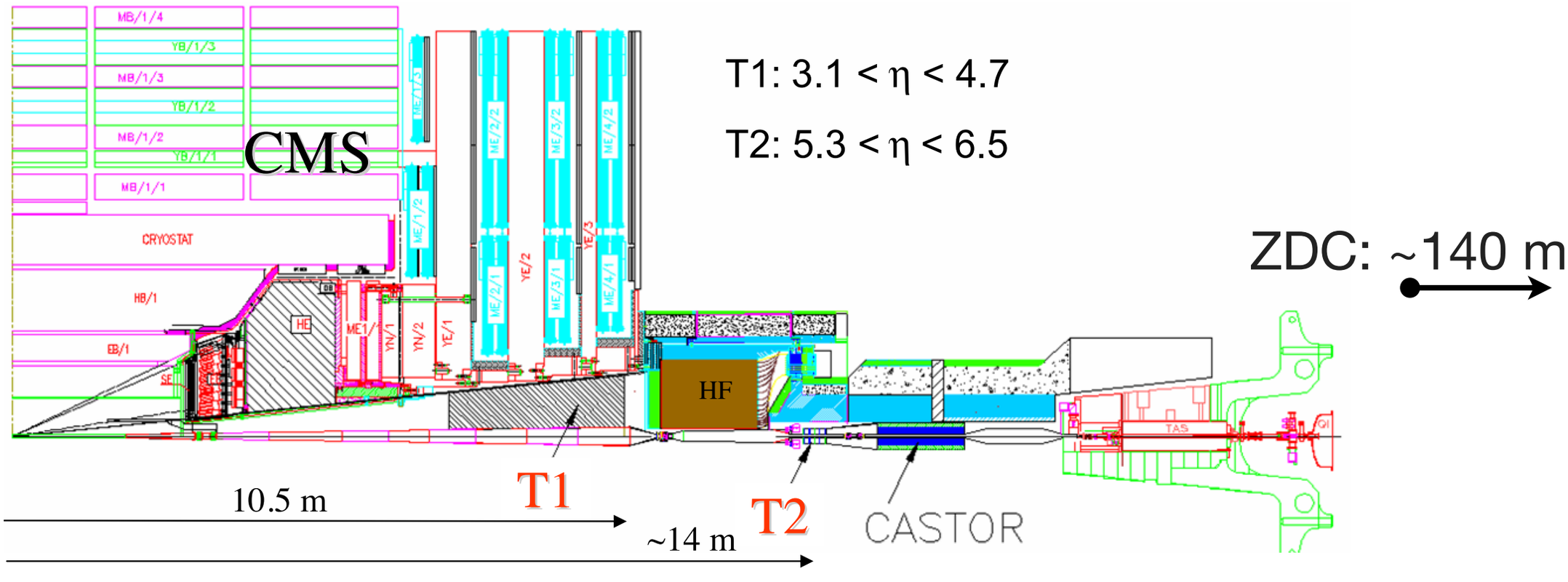
- RPC: complete coverage
- DT: improve electronics, move trig. prim. syst. out of cavern
- CSC: complete coverage, improve trigger primitives







Hadron Calorimeter System



T1: $3.1 < \eta < 4.7$

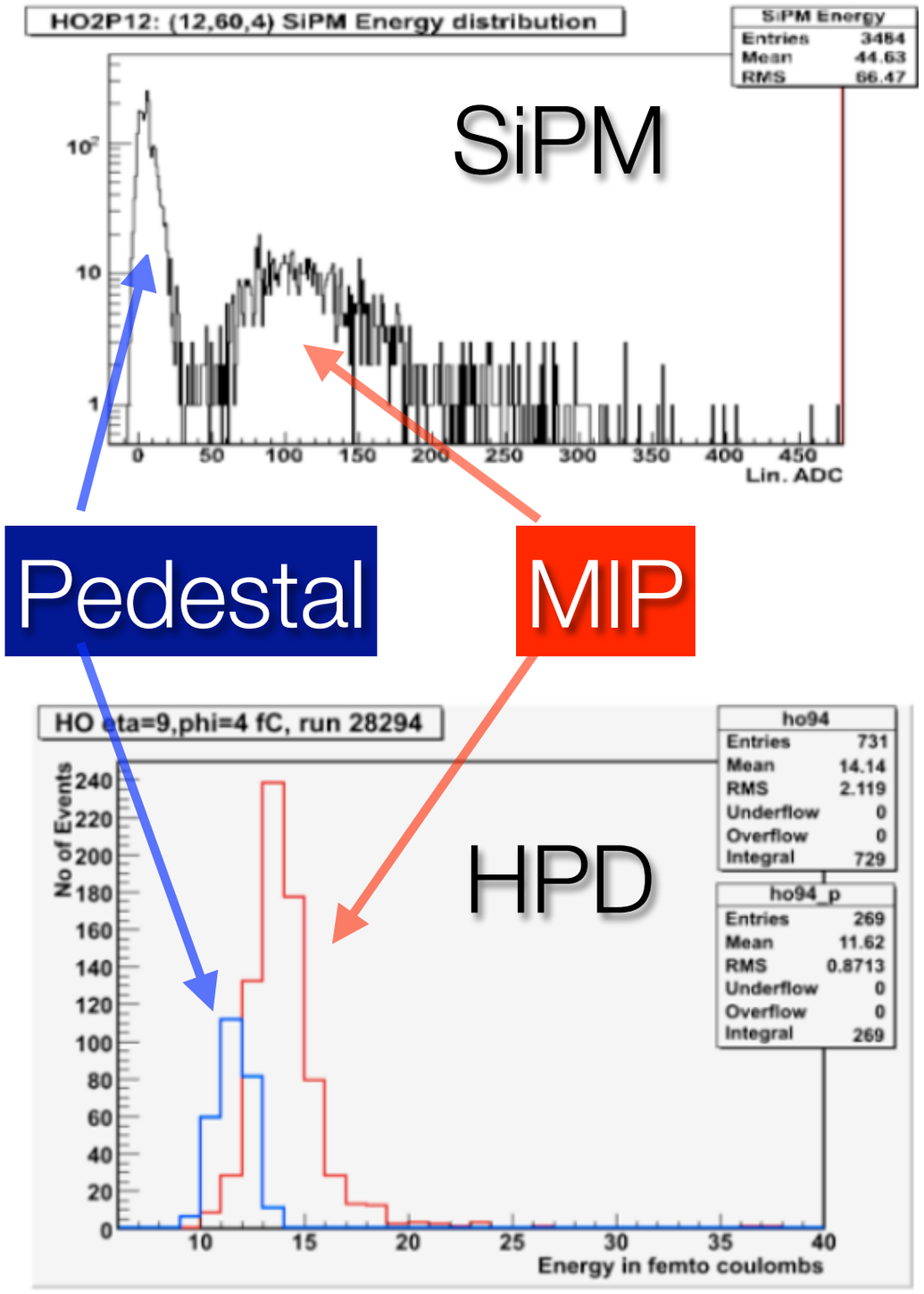
T2: $5.3 < \eta < 6.5$

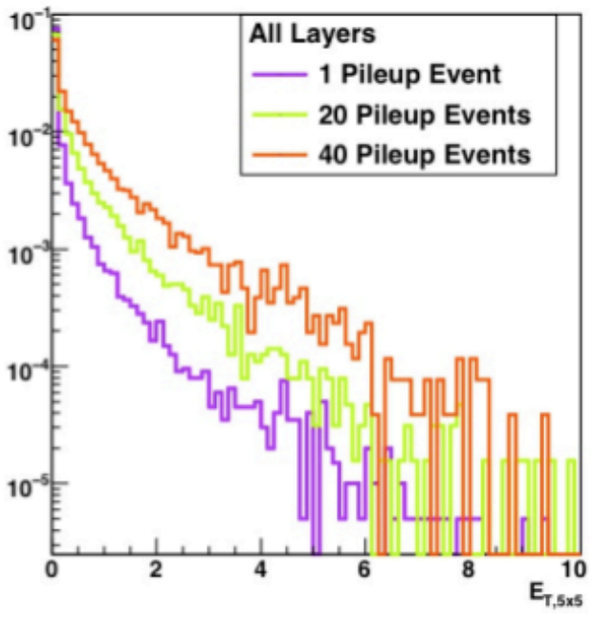
ZDC: ~140 m

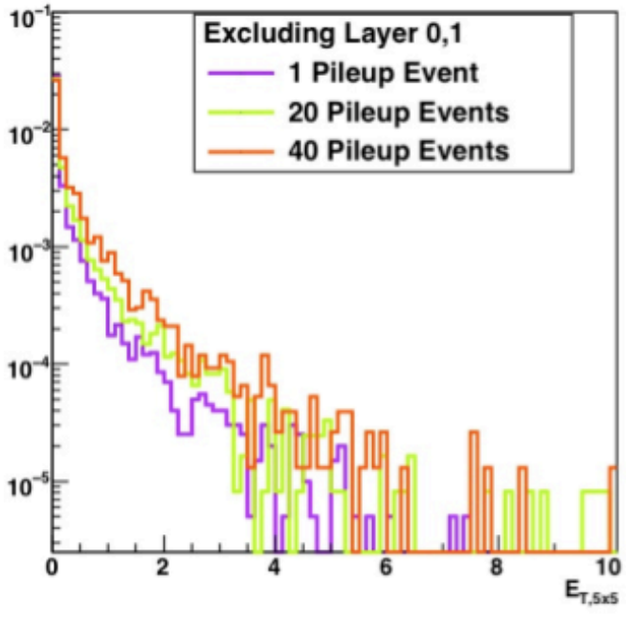
Device	$\lvert\eta\rvert$ range	absorber	active material	photo-detector
Barrel Hadron Calorimeter (HB)	0.0 - 1.5	brass	scintillator	HPD
Endcap Hadron Calorimeter (HE)	1.5 - 3.0	brass	scintillator	HPD
Outer Hadron Calorimeter (HO)	0.0 - 1.5	brass + cryostat	scintillator	HPD
Forward Hadron Calorimeter (HF)	3.0 - 5.0	steel	quartz fiber	PMT
CASTOR	5.2-6.6	tungsten	quartz plate	PMT
Zero Degree Calorimeter	$\lvert\eta\rvert > 8.3$	tungsten	quartz fiber	PMT

Barrel, Endcap HCAL Upgrades

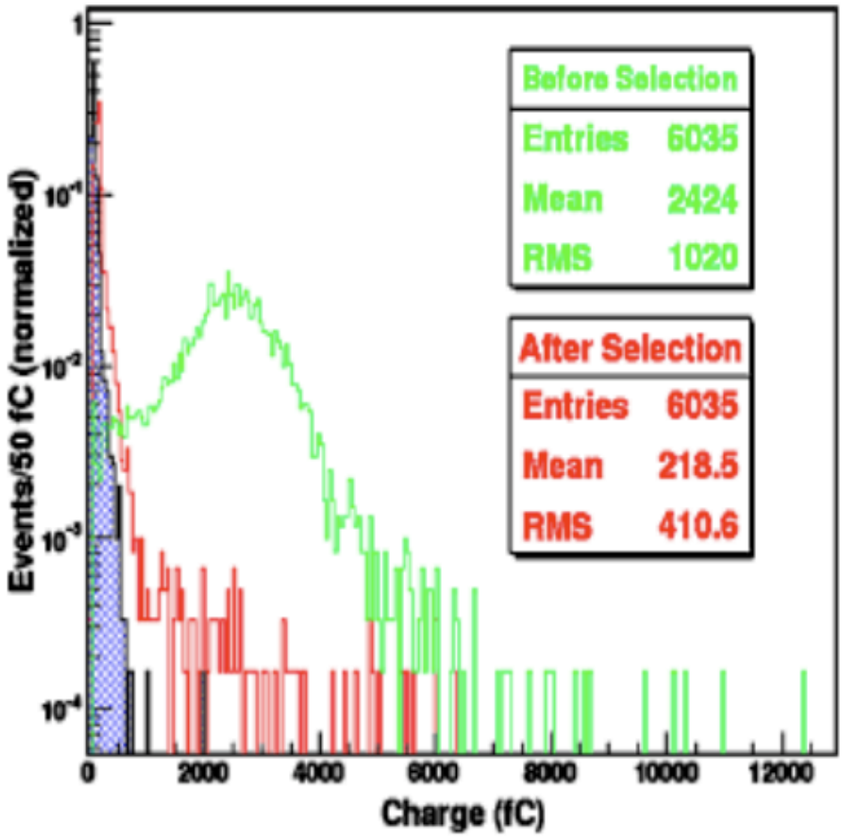
- replace photodetector - eliminate anomalous signals
- scintillator TDC - nanosecond timing to reject non-collision bg
- longitud. segmentation - reduce performance loss due to pile-up







Forward HCAL Upgrades



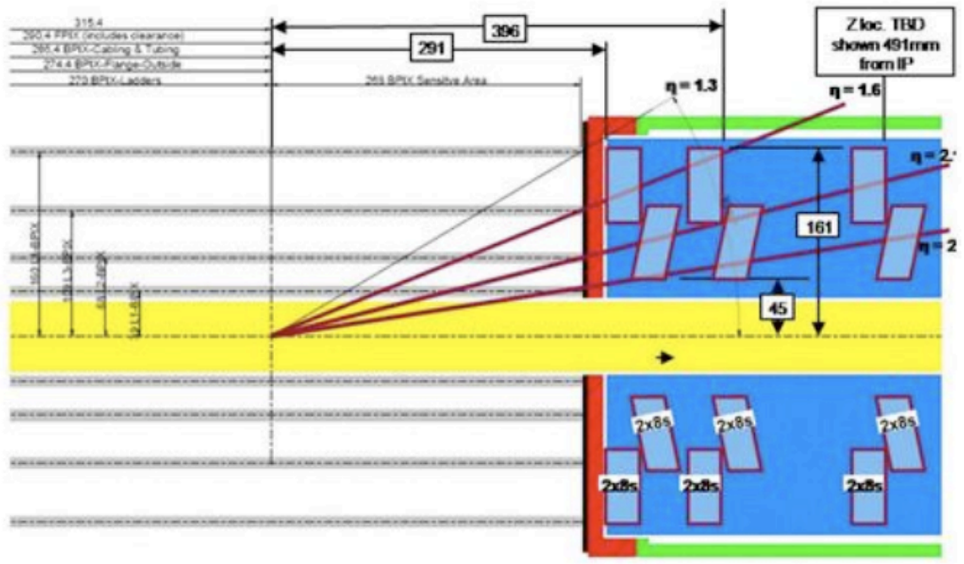
HF calorimeter - μ hitting PMT window fake high energy deposits

replace PMT - thinner window, better shielding (metal envelope), four-way segmented anodes to reject muons hitting the PMT window

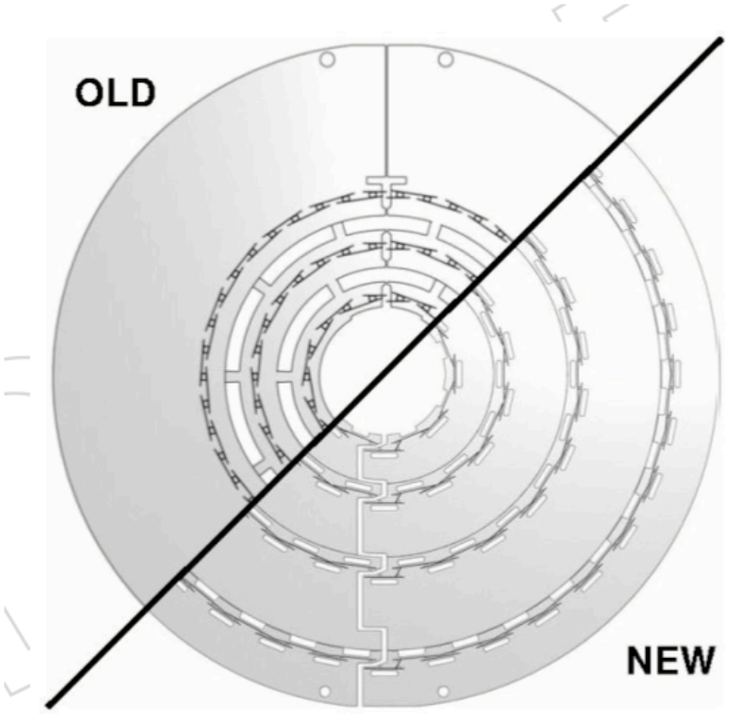
- CASTOR - replace PMTs with more radiation hard devices, replace light guides

Pixel Tracker Upgrade

- current pixel tracker designed to withstand ~200-300 fb^{-1} of L
- not meant for $L > 10^{34}\ cm^{-2}s^{-1}$:
  1st layer - 16% inefficient @ $2x10^{34}$

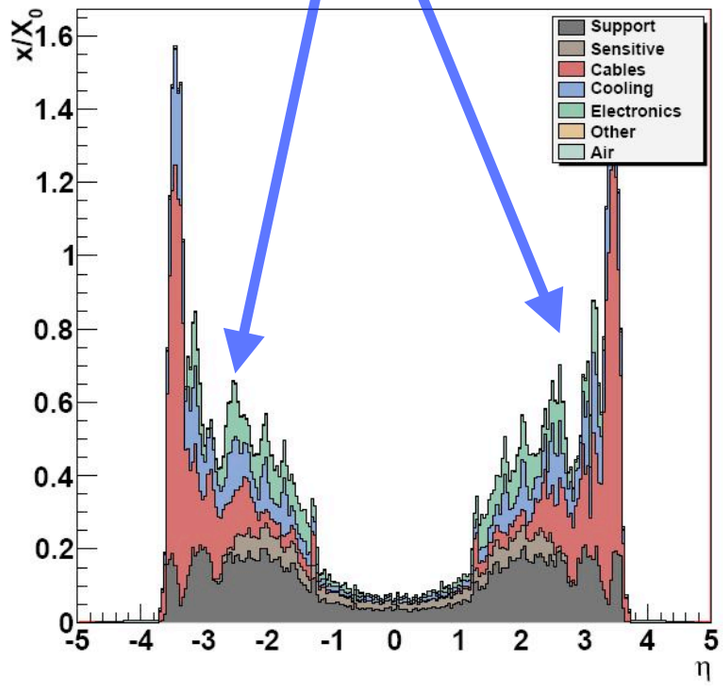


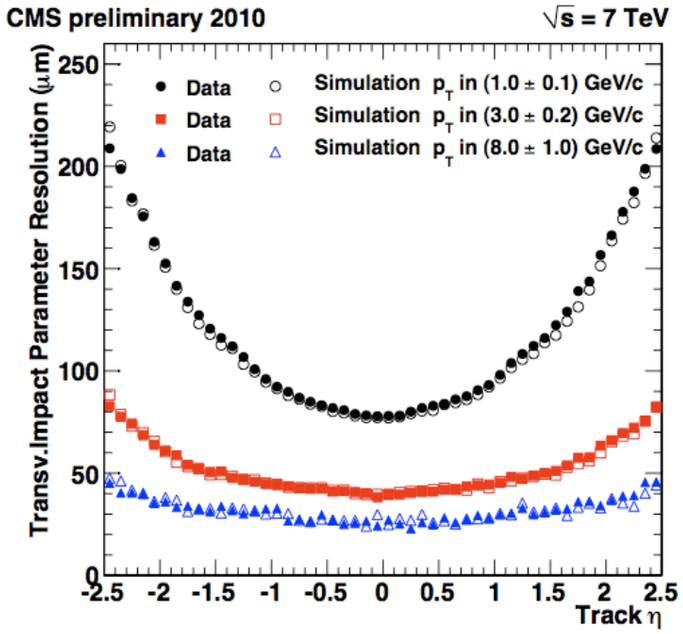
- current system: 3 barrel layers, 2 disks
- upgrade: 4 barrel layers, 3 forward disks
- will provide 4 hit coverage up to $|\eta| < 2.5$
- less material than current system - ultra-light mechanics, CO_2 cooling

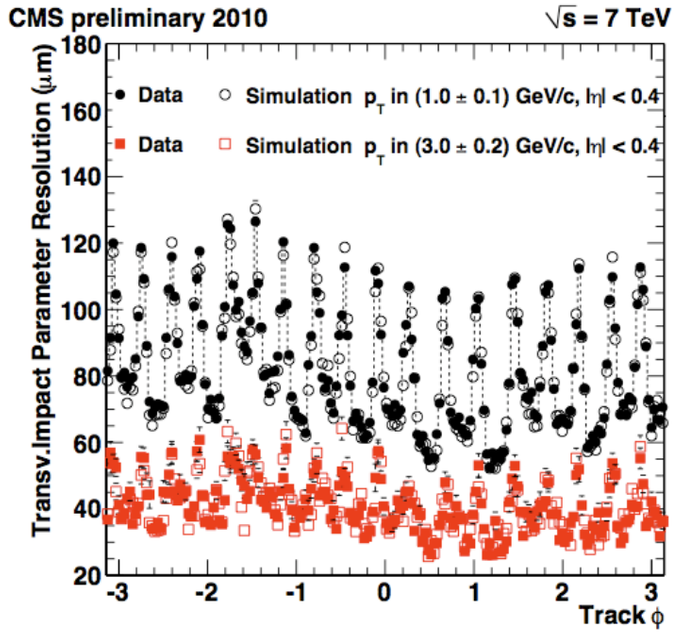


Pixel Tracker, cont'd

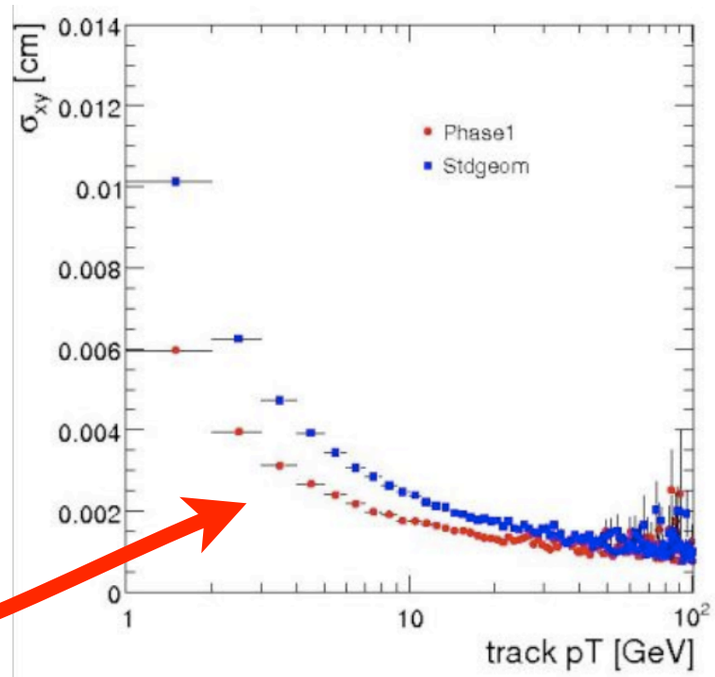
material: cooling, PCB flange, cabling..







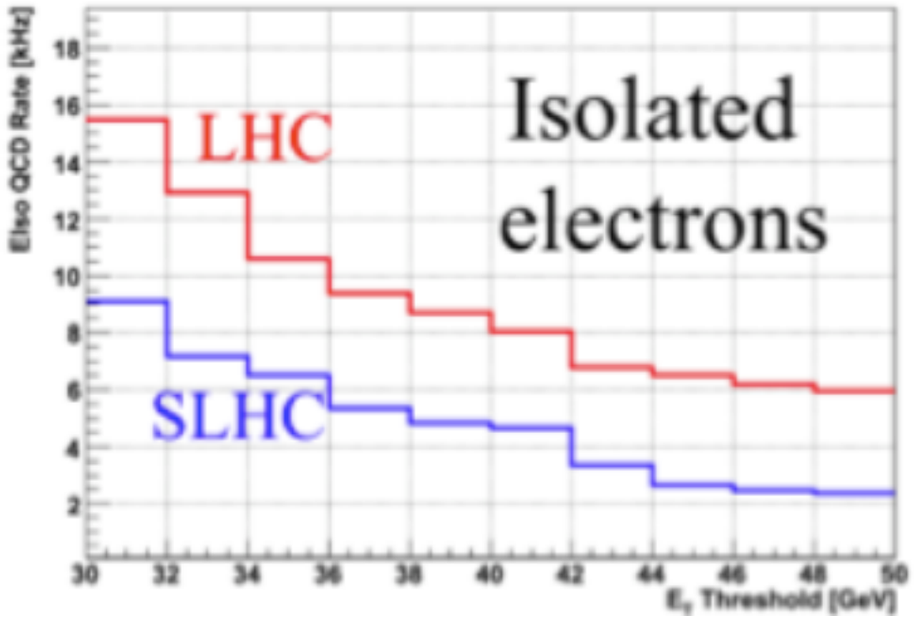
smaller material budget, reduce innermost layer radius to 3.4 cm

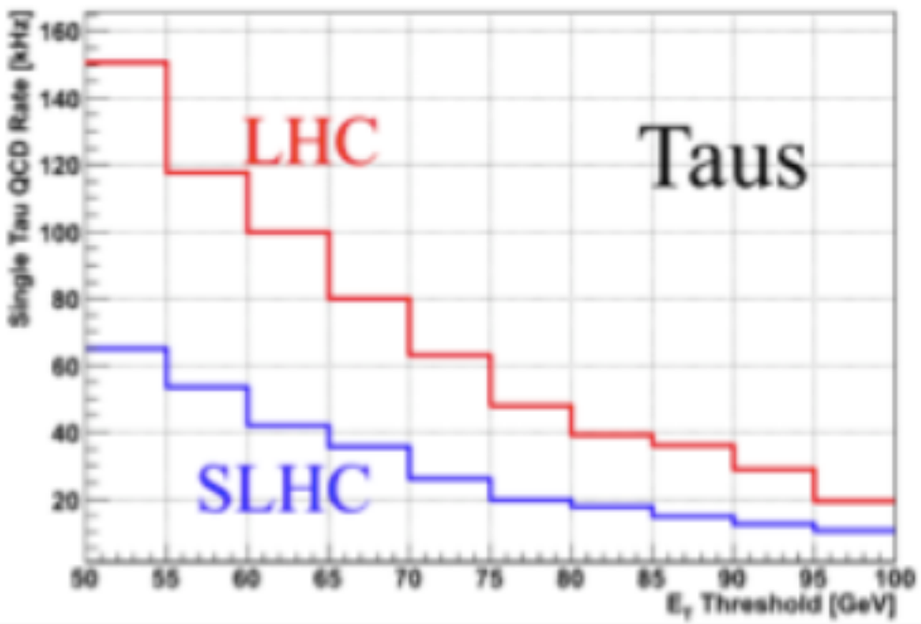


L1 Trigger: Calorimeter

QCD Rate

- increase granularity of calorimeter trigger internal processing
- exploit higher granularity- more sophisticated cluster algorithms & precise isolation
- state of the art Telecom technology to support required bandwidth
- prepare for matching with Level-1 Tracking trigger in Phase 2 LHC



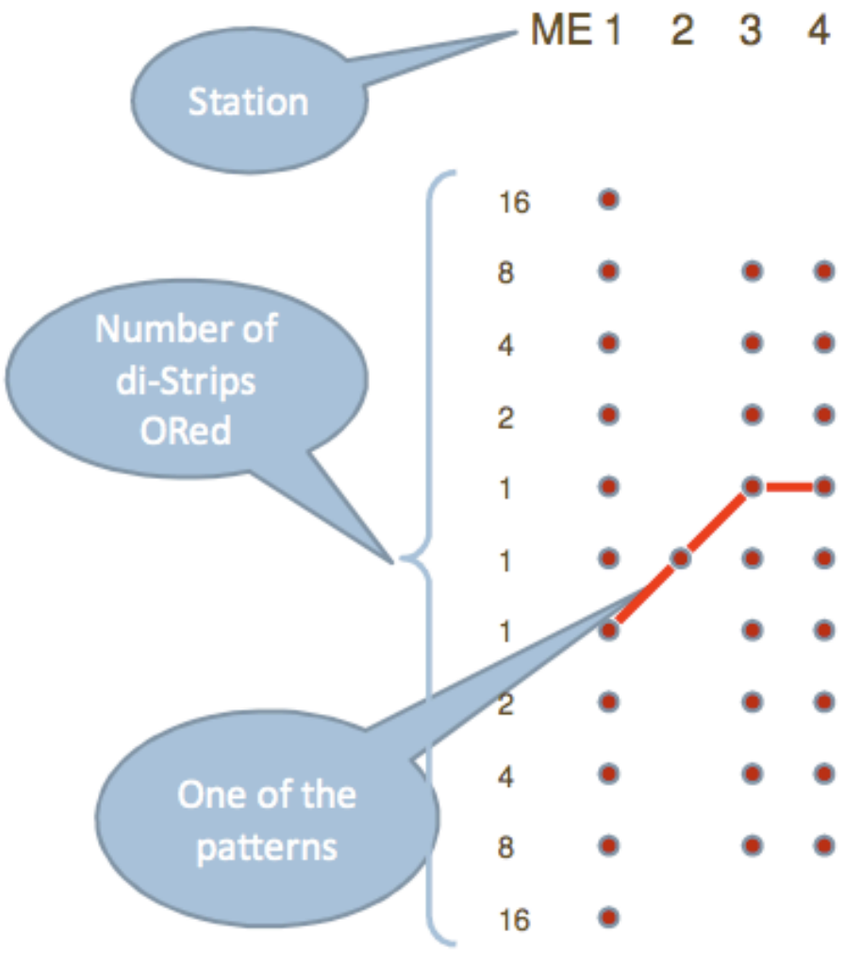


L1 Trigger: Muon Trigger

- CSC muon finder - increased occupancy at high luminosities - redesign muon finding logic (cut based → pattern based)

- DT muon finder has complex internal connections - take advantage of new FPGAs, simplify system, maintenance

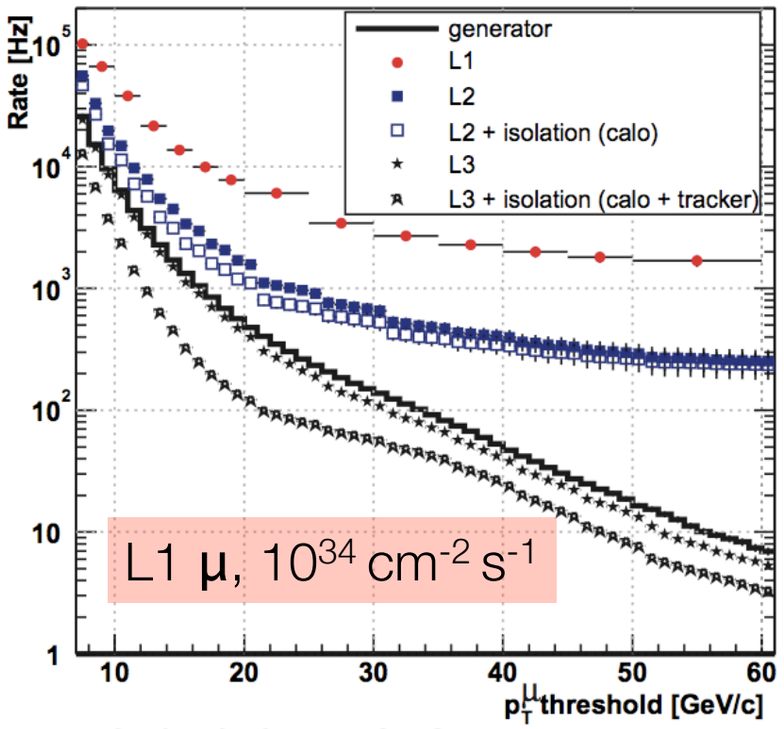
- RPC trigger - handle new RPC η coverage, new high η muon chambers



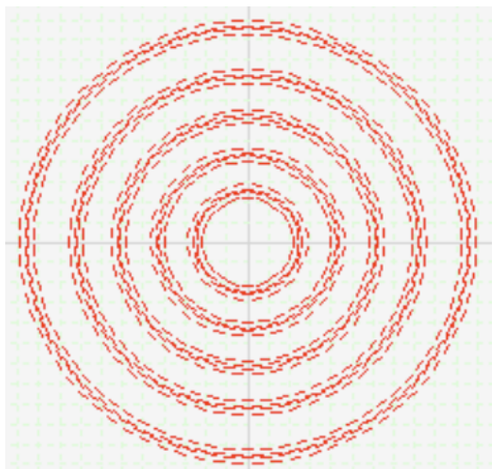
Possible φ pattern envelope structure

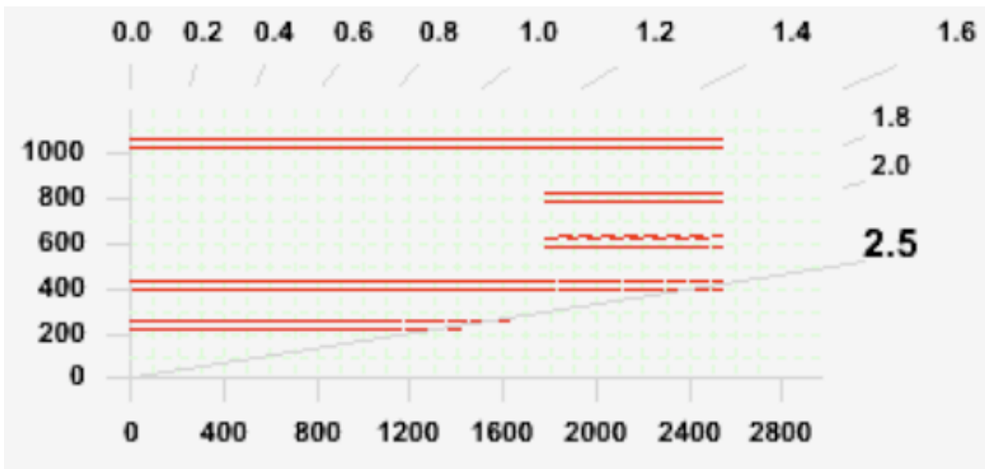
Phase 2: Tracker @ L1

- at ~10^{35} $cm^{-2}s^{-1}$, tracker information necessary to control trigger rate
- tracking in L1 trigger difficult - lots of combinations, little time (<4 μs)



- a proposed solution: stacked Si layers proximity of stacks - reduced combinations





- deduce track p_T from tracklet direction, cut away soft tracks (do not point back to I.P.)

Conclusions

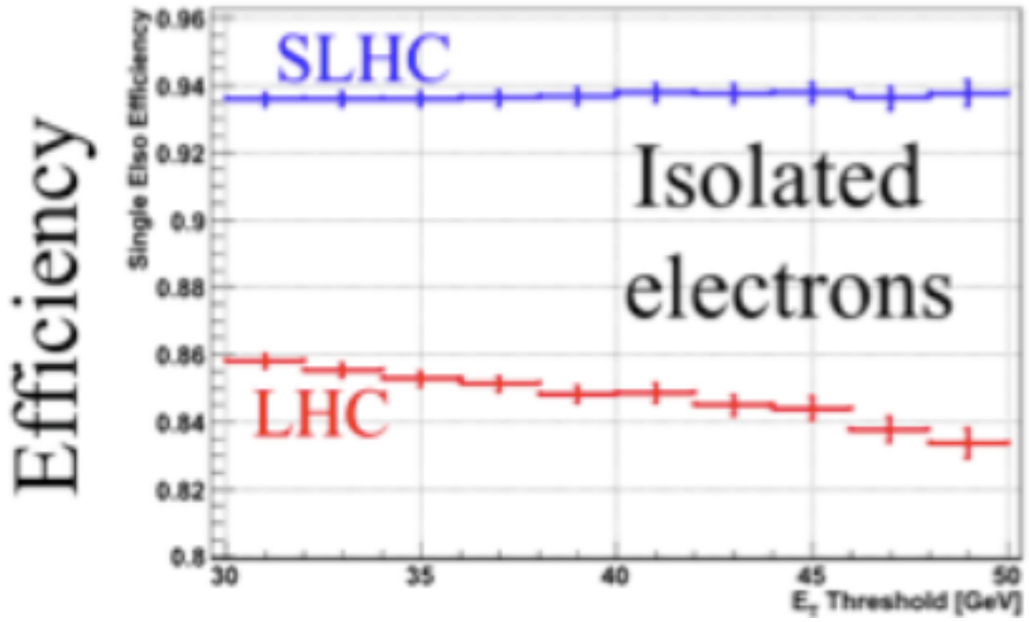
- LHC has started colliding; luminosity will keep increasing - detector upgrades maximize physics output
- CMS upgrade program staggered, track luminosity increase
  - current focus: LHC Phase 1 upgrades
  - fraction of upgrades shown target 2012 technical stop
  - pixel upgrade target: 2015/16 technical stop
  - all upgrades aligned to also prepare for Phase 2 (major new element - tracking at first level of the trigger)

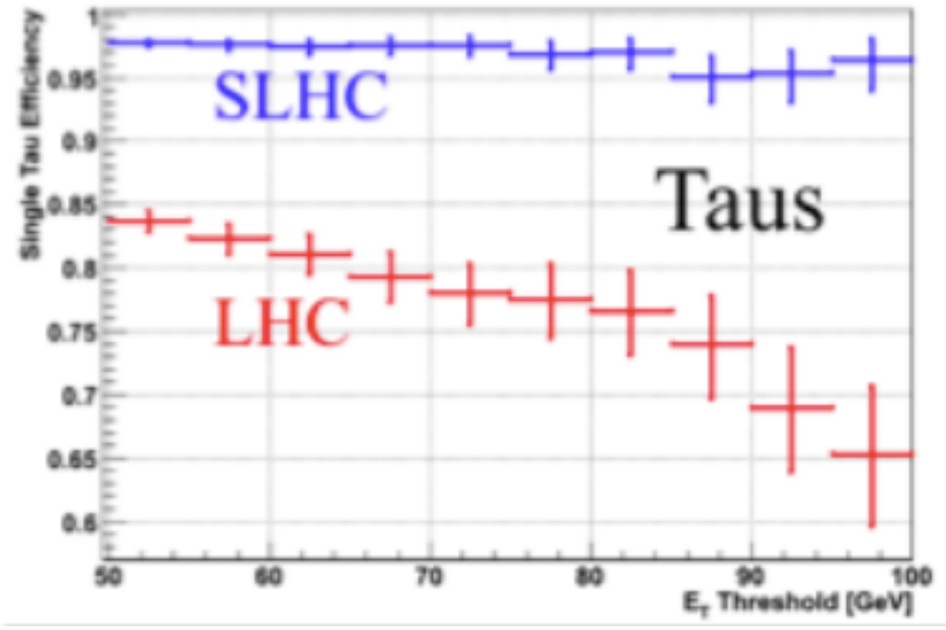
Supporting Material

Why Upgrade?

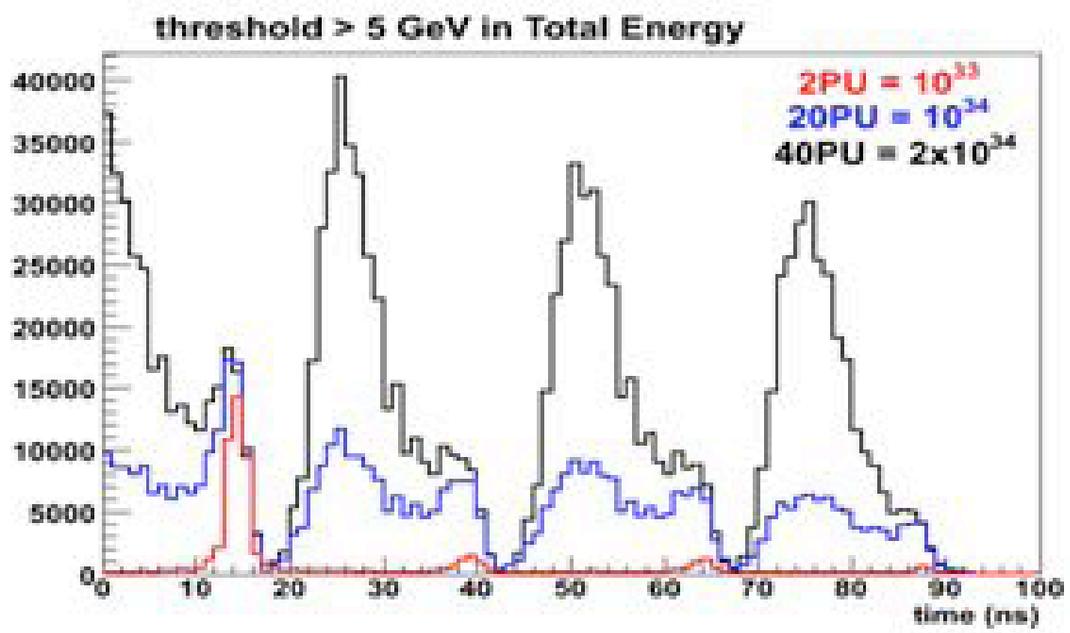
- This decade will see the initial operation of the LHC and the increase of energy and luminosity towards design values
- Goal of extended running in the second half of the decade is to collect ~100s/fb
- This is the first phase of the LHC operation. Any upgrades during this phase are Phase I upgrades
- Their motivation may be based on required performance for higher luminosity, better physics performance, better reliability of operation

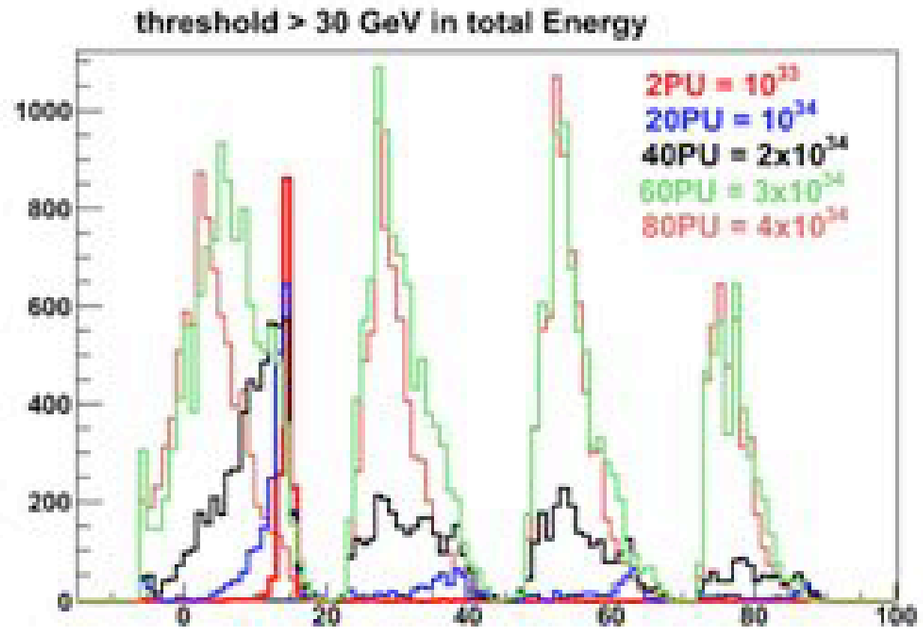
L1 Calorimeter Trigger

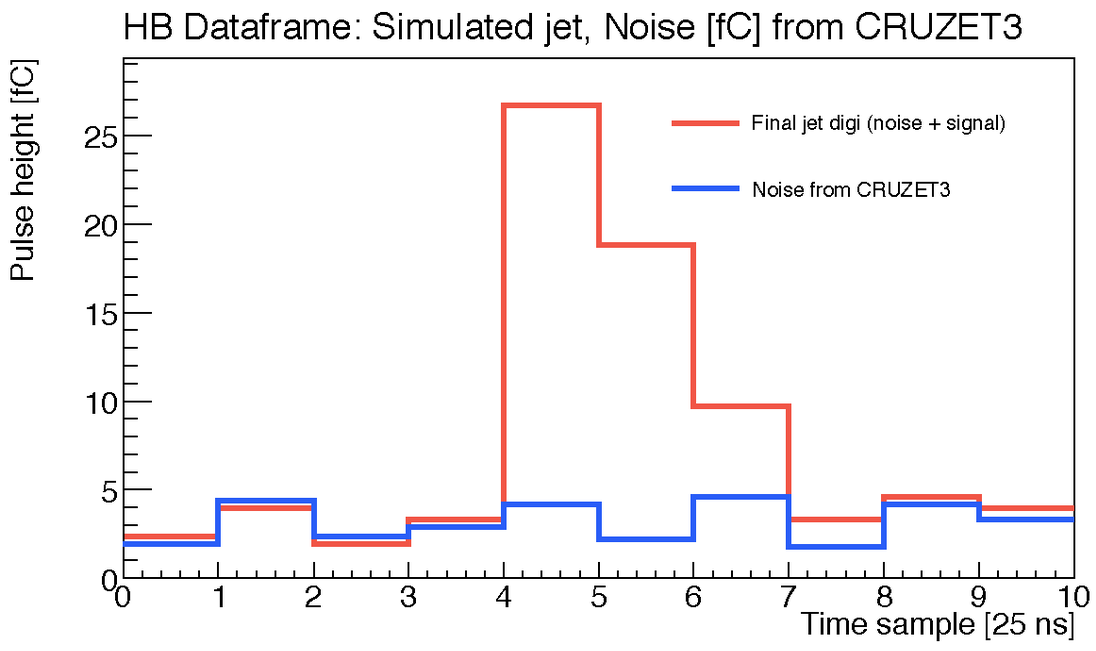


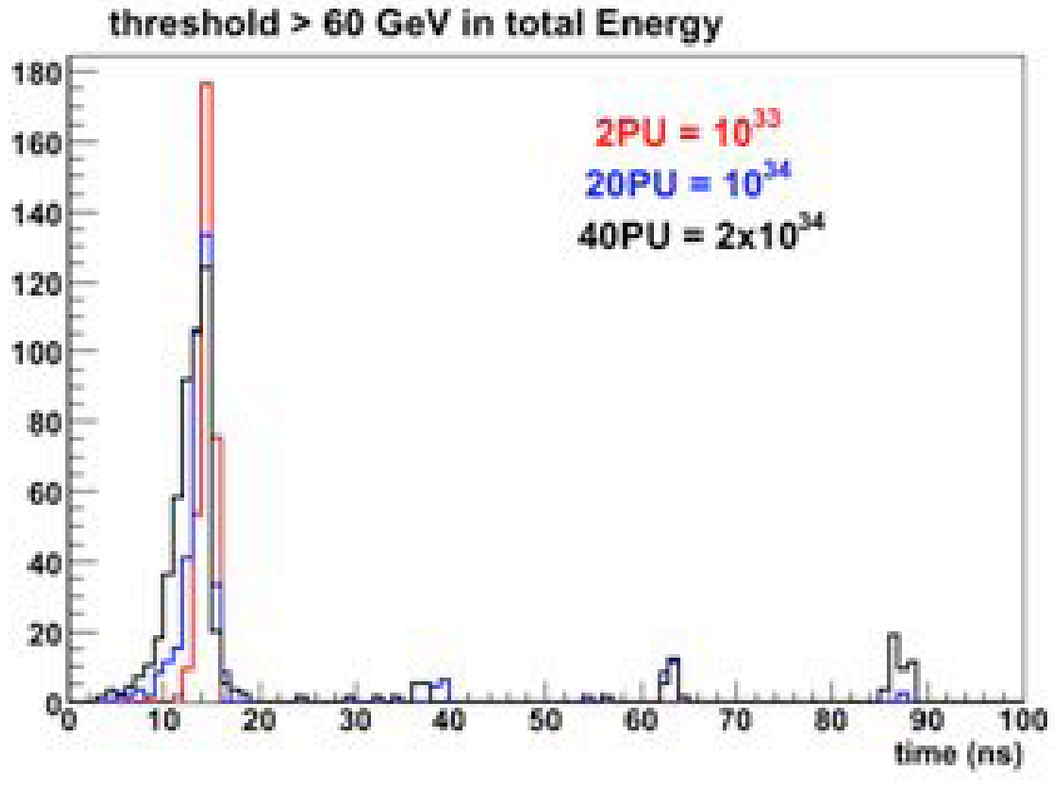


Calorimeter Timing

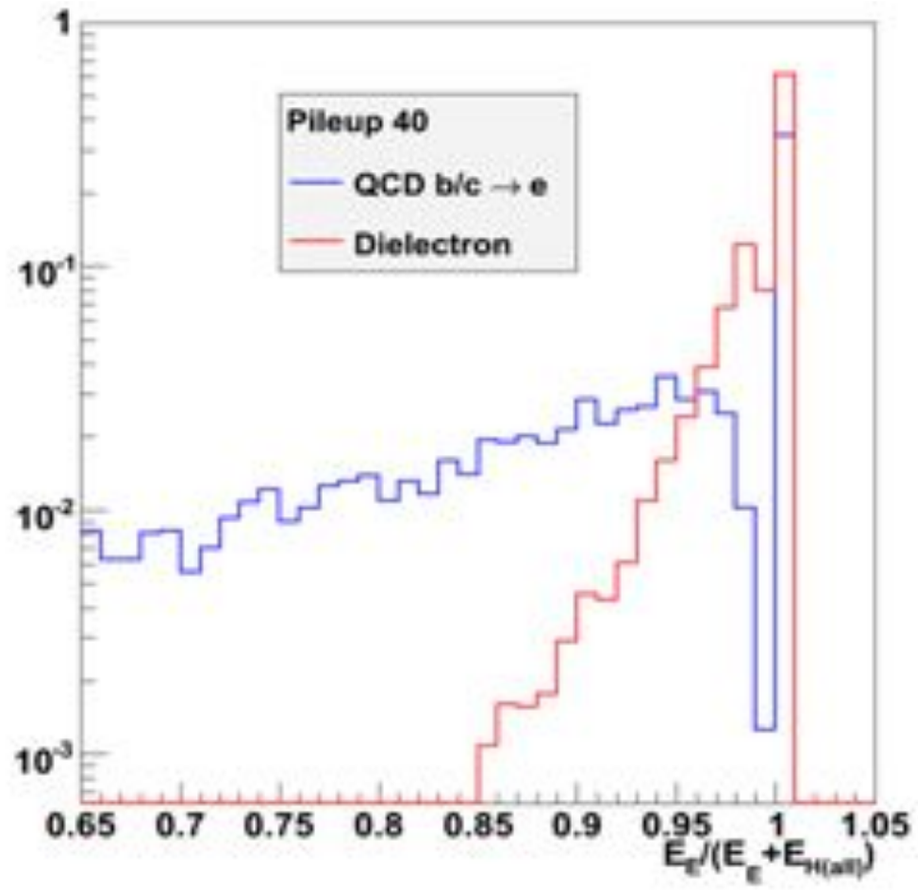


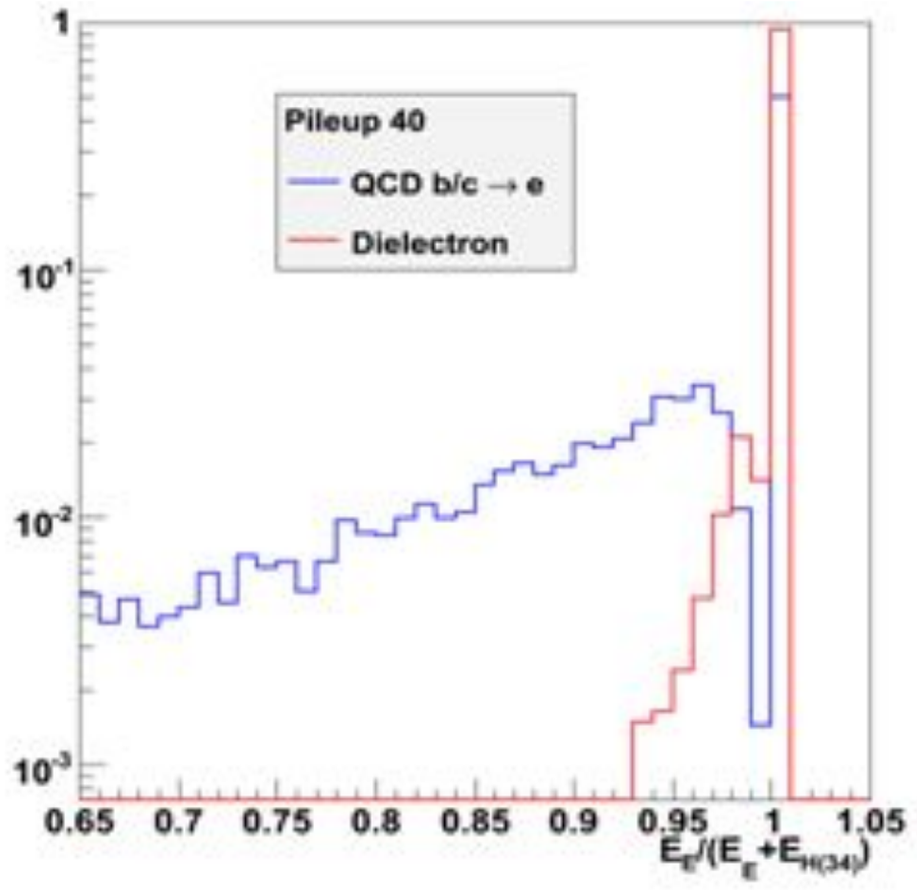






Isolated Electron EM fraction





Muon System Layout