

Rencontres QGP-France-14

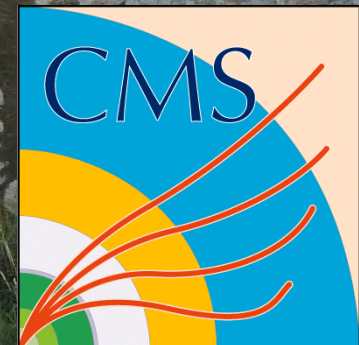
Etretat 15-18 septembre 2014

CMS L1 CALORIMETER TRIGGER UPGRADE



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15/09/2014



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Outline

- What do we have currently?
- Why do we need an upgrade?
- What do we want to do?
- What is it ongoing?

WHAT DO WE HAVE CURRENTLY?

→ **The Legacy system**

CMS detector and its trigger system

CMS DETECTOR

Total weight : 14,000 tonnes
 Overall diameter : 15.0 m
 Overall length : 28.7 m
 Magnetic field : 3.8 T

STEEL RETURN YOKE
 12,500 tonnes

SILICON TRACKERS
 Pixel ($100 \times 150 \mu\text{m}$) $\sim 16\text{m}^2 \sim 66\text{M}$ channels
 Microstrips ($80 \times 180 \mu\text{m}$) $\sim 200\text{m}^2 \sim 9.6\text{M}$ channels

SUPERCONDUCTING SOLENOID
 Niobium titanium coil carrying $\sim 18,000\text{A}$

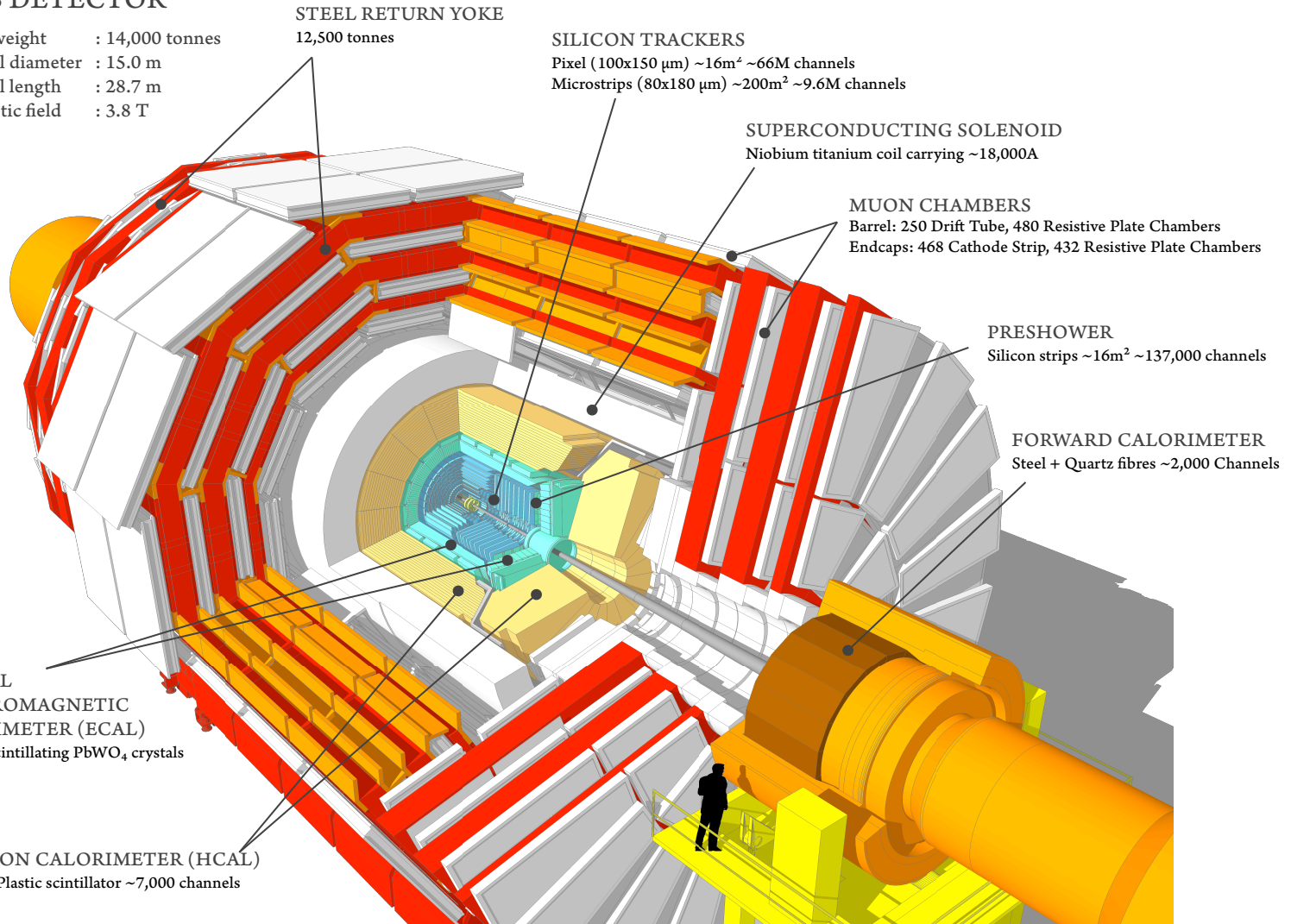
MUON CHAMBERS
 Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
 Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

PRESHOWER
 Silicon strips $\sim 16\text{m}^2 \sim 137,000$ channels

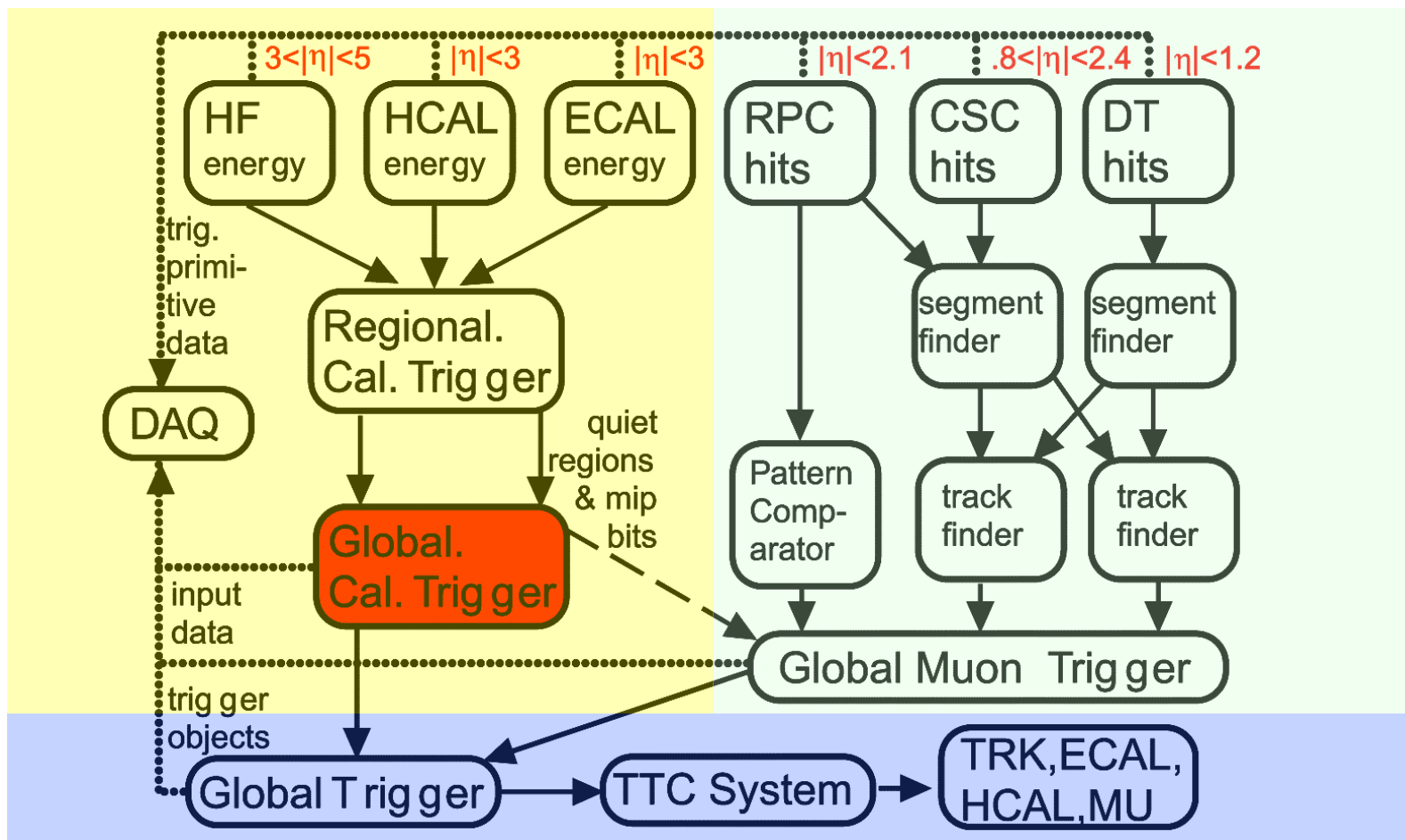
FORWARD CALORIMETER
 Steel + Quartz fibres $\sim 2,000$ Channels

CRYSTAL
 ELECTROMAGNETIC
 CALORIMETER (ECAL)
 $\sim 76,000$ scintillating PbWO_4 crystals

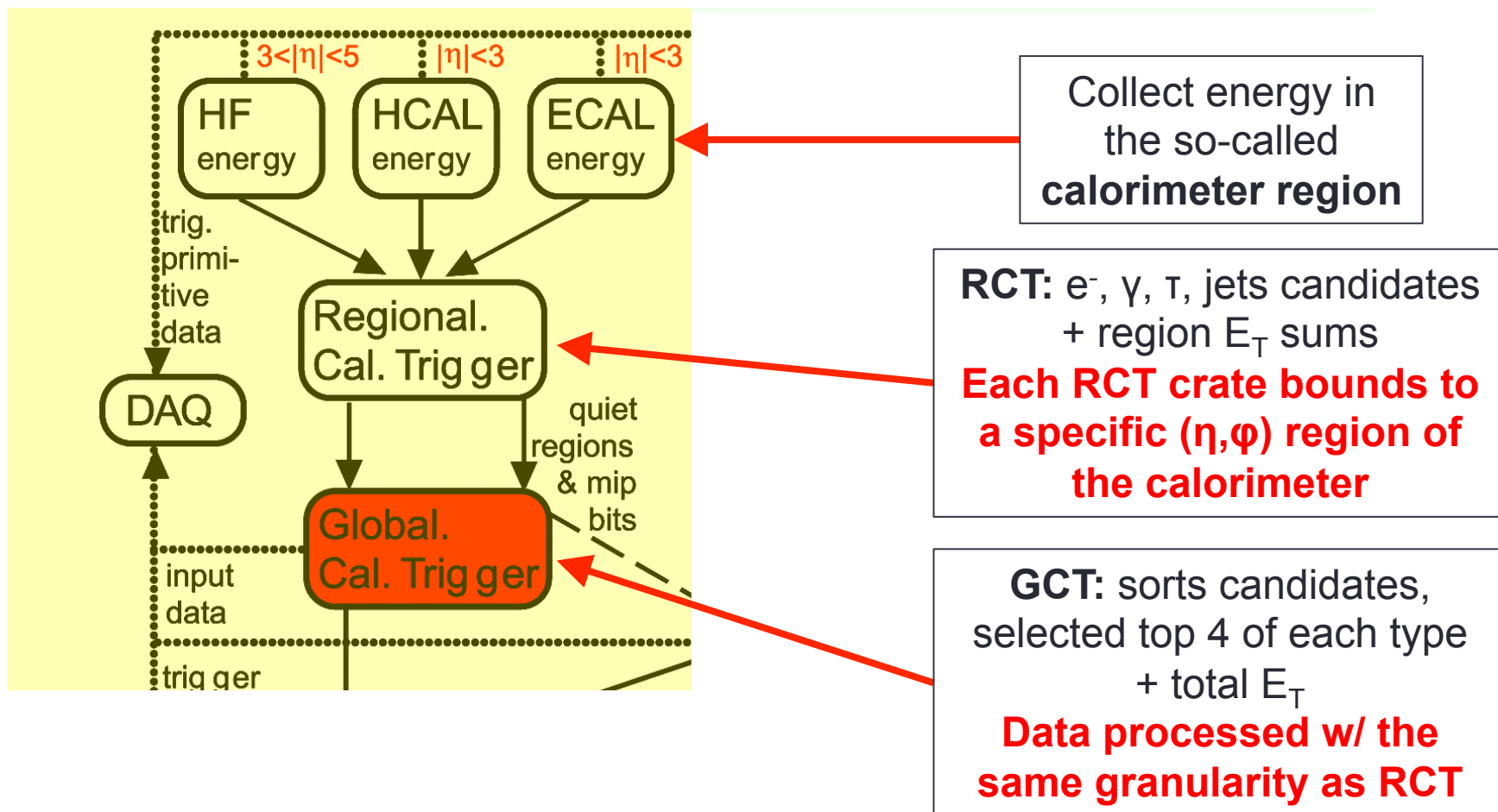
HADRON CALORIMETER (HCAL)
 Brass + Plastic scintillator $\sim 7,000$ channels



Current trigger system (Legacy)



Current trigger system (Legacy)



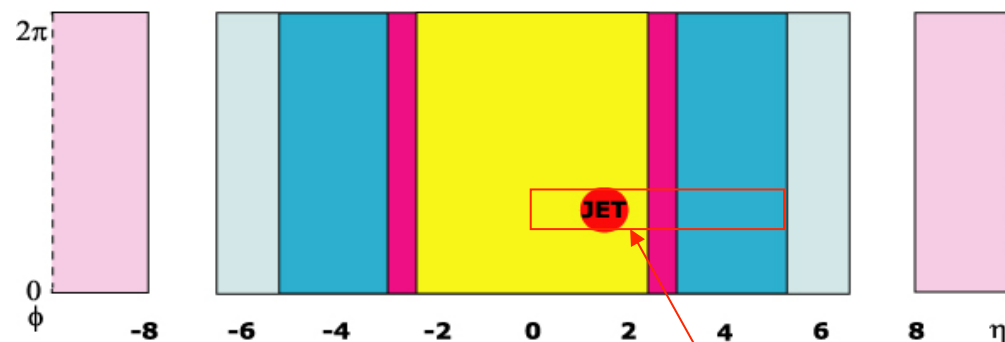
- Calorimeter region = 4x4 calorimeter towers in ECAL/HCAL
- Calorimeter tower = 3x3 crystals in ECAL + equivalent coverage in HCAL

WHY DO WE NEED AN UPGRADE?

→ Motivations

Motivations for HI (1)

Stage-1 HI L1 algorithm: phi ring background subtraction in region level



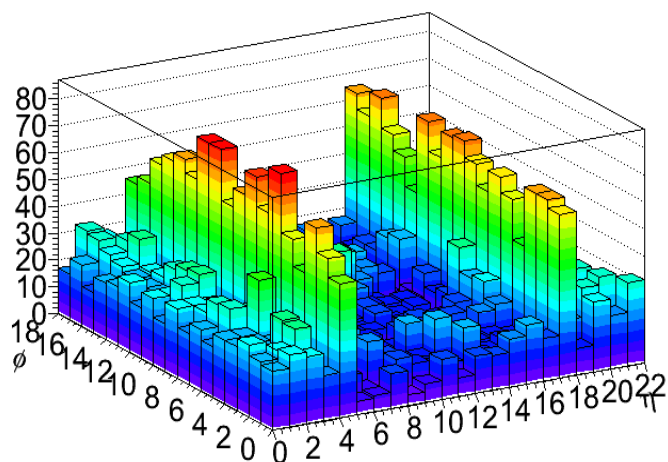
Current L1 Jet Finder:
- Processes eta strips at const. phi
- Sliding window jet finder

- Current strategy: Jet Finder at L1 and Jet Background subtraction at HLT

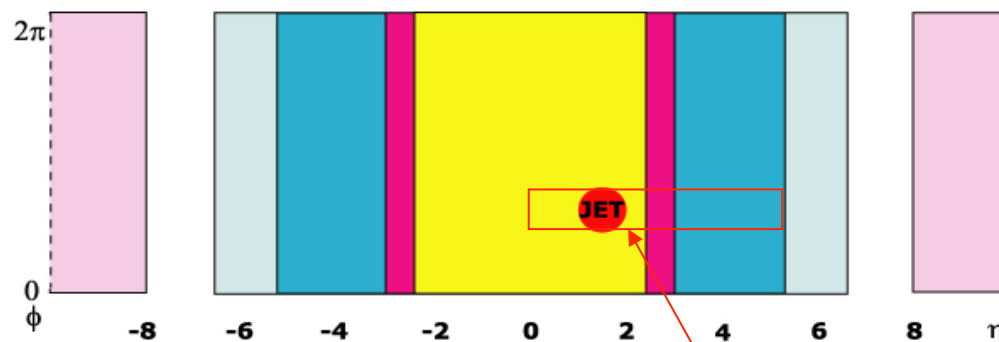
Motivations for HI (1)

Region Energy Distributions
One Central Event

Detector Map before subtraction, event #9670448



Stage-1 HI L1 algorithm: phi ring background subtraction in region level



Current L1 Jet Finder:
 - Processes eta strips at const. phi
 - Sliding window jet finder

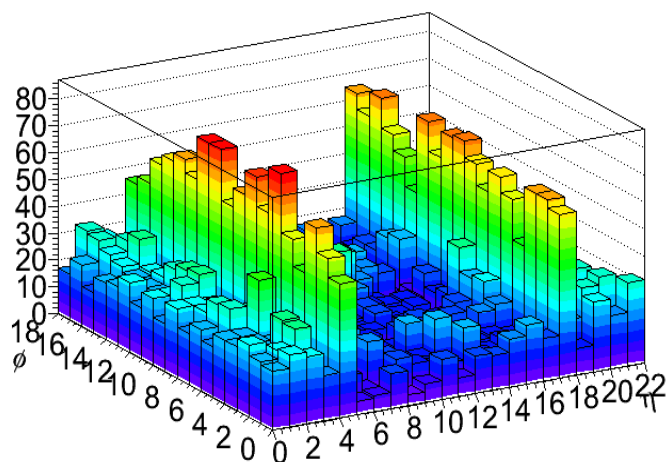
➤ Current strategy: Jet Finder at L1 and Jet Background subtraction at HLT

- high non-uniformity in η of HI events does not permit a useful BG subtraction within a single 2×11 sector

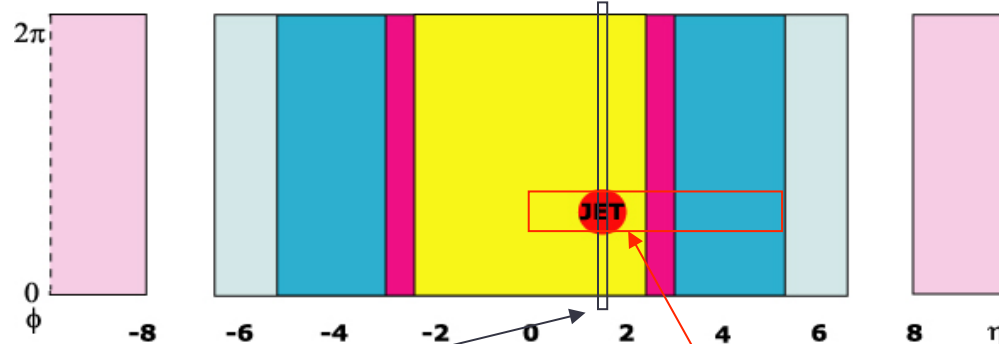
Motivations for HI (1)

Region Energy Distributions
One Central Event

Detector Map before subtraction, event #9670448



Stage-1 HI L1 algorithm: phi ring background subtraction in region level



HLT/Offline background subtraction:

- Process phi rings at const. eta
- Calculate average and subtract
- Jet finder runs after BG subtraction

Current L1 Jet Finder:

- Processes eta strips at const. phi
- Sliding window jet finder

➤ Current strategy: Jet Finder at L1 and Jet Background subtraction at HLT

- high non-uniformity in η of HI events does not permit a useful BG subtraction within a single 2×11 sector
- Access to the **full eta phi map** at L1: **efficient underlying event subtraction** (phi-rings)

Motivations for HI (2)

- CMS L1 accept rate limited to **3 kHz** for HI collisions
- In 2011 the collision rate was of 4.5 kHz hence using event rejection/background subtraction mostly at HLT
- Expectation for Run II: collision rate of 20-30 kHz
 - A rejection factor of 10 is needed
 - Legacy L1 trigger **cannot** deliver required performance
 - **Upgrade is needed**

WHAT DO WE PLAN TO DO AND WHAT IS IT ONGOING?

- L1 Calorimeter upgrade
- L1 Trigger performance studies

Summary

- Upgrade architecture and plans

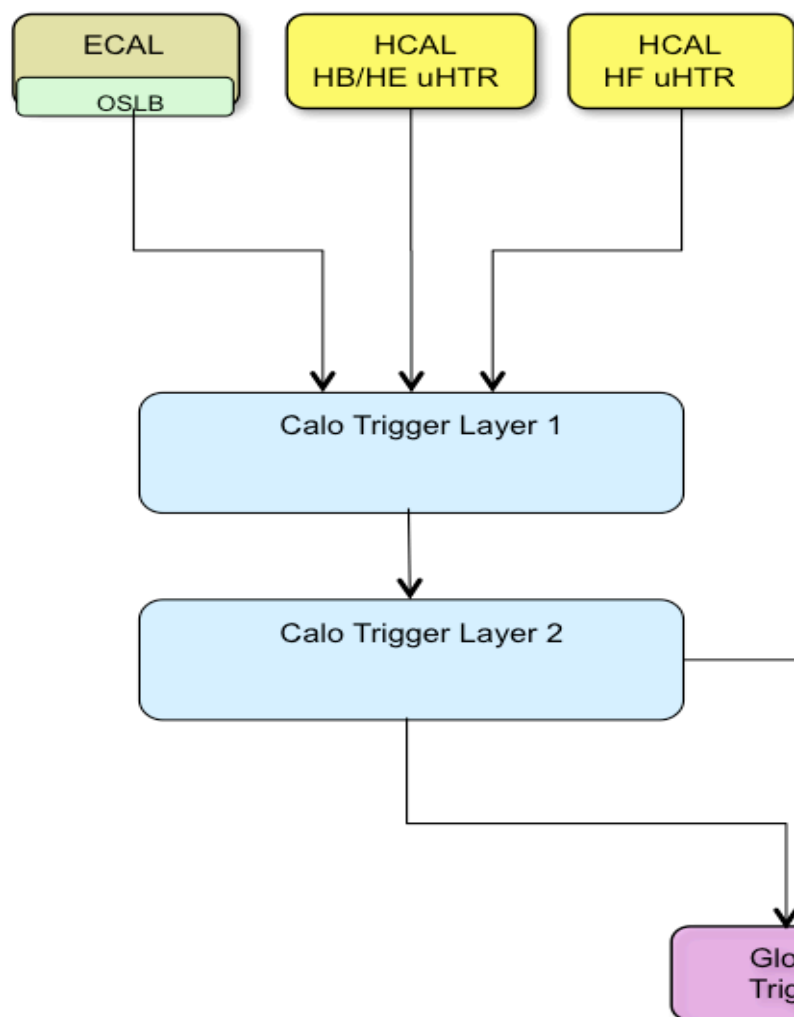
- Stage-1 calorimeter upgrade
 - Overview
 - Technical description

- Stage-2 calorimeter upgrade

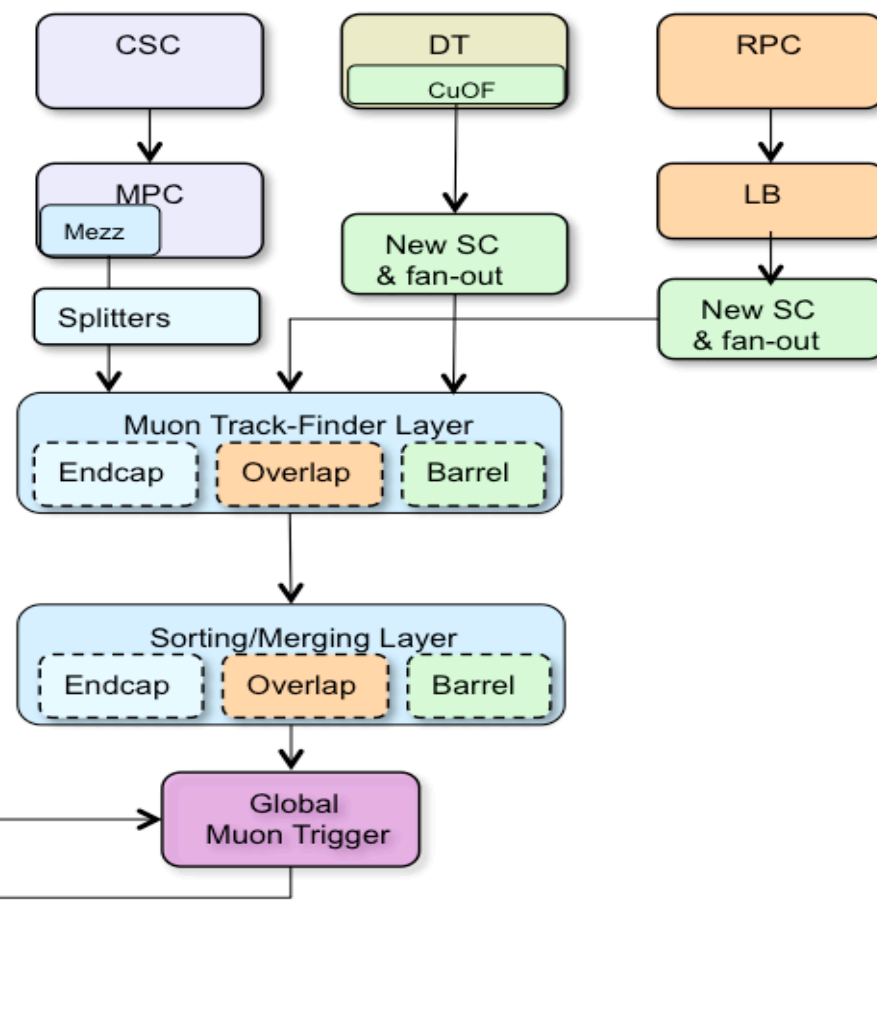
- First trigger performances
 - L1 HI Jet trigger
 - L1 HI Single High- p_T Track trigger
 - Centrality trigger results

Upgrade architecture

Calorimeter Trigger

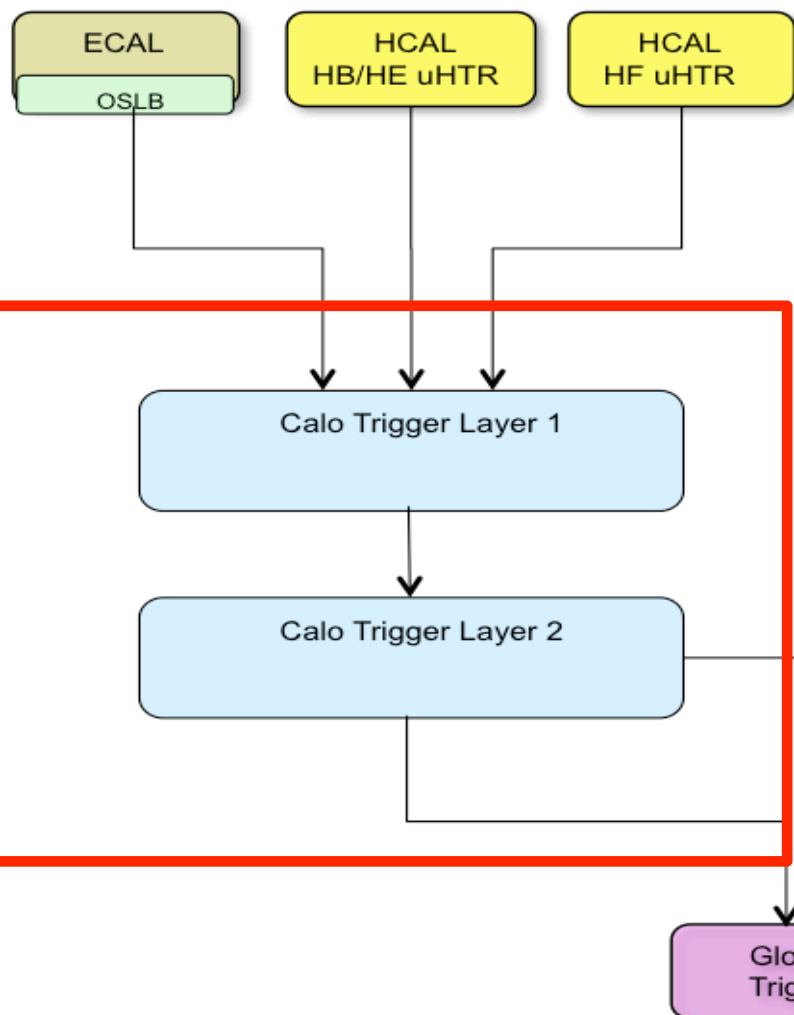


Muon Trigger

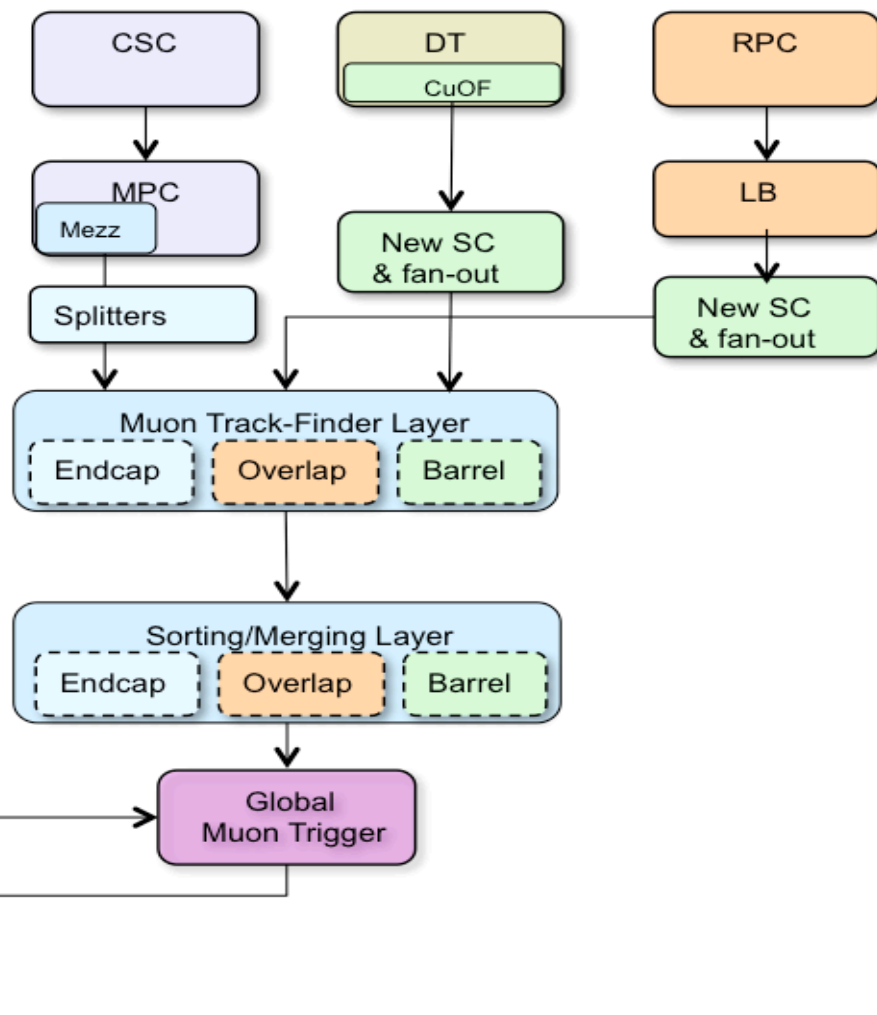


Upgrade architecture

Calorimeter Trigger



Muon Trigger



Upgrade plans (1)

➤ **Current concept:**

- Each RCT crate bounds to a region of the calorimeter and receives only a regional information
- The regional information sent from RCT are processed with the same granularity in GCT
- All the GCT outputs are sent to Global Trigger

➤ **Upgrade requirements:**

- Allow to access the full event information at L1
- Develop a new concept for the L1 CMS trigger

Considering the amount of time needed for the whole project, it was split in two steps

Upgrade plans (2)

➤ **Stage-1 concept: 2015 (ongoing now)**

- RCT layer is maintained
- The GCT is replaced with a Layer-2 concentrating all the RCT information in only one FPGA
- Allow to be prepare for Stage-2 to and fulfill the requirements for the restart in 2015
- Both systems (Legacy and Stage-1) will run in parallel for commissioning purposes

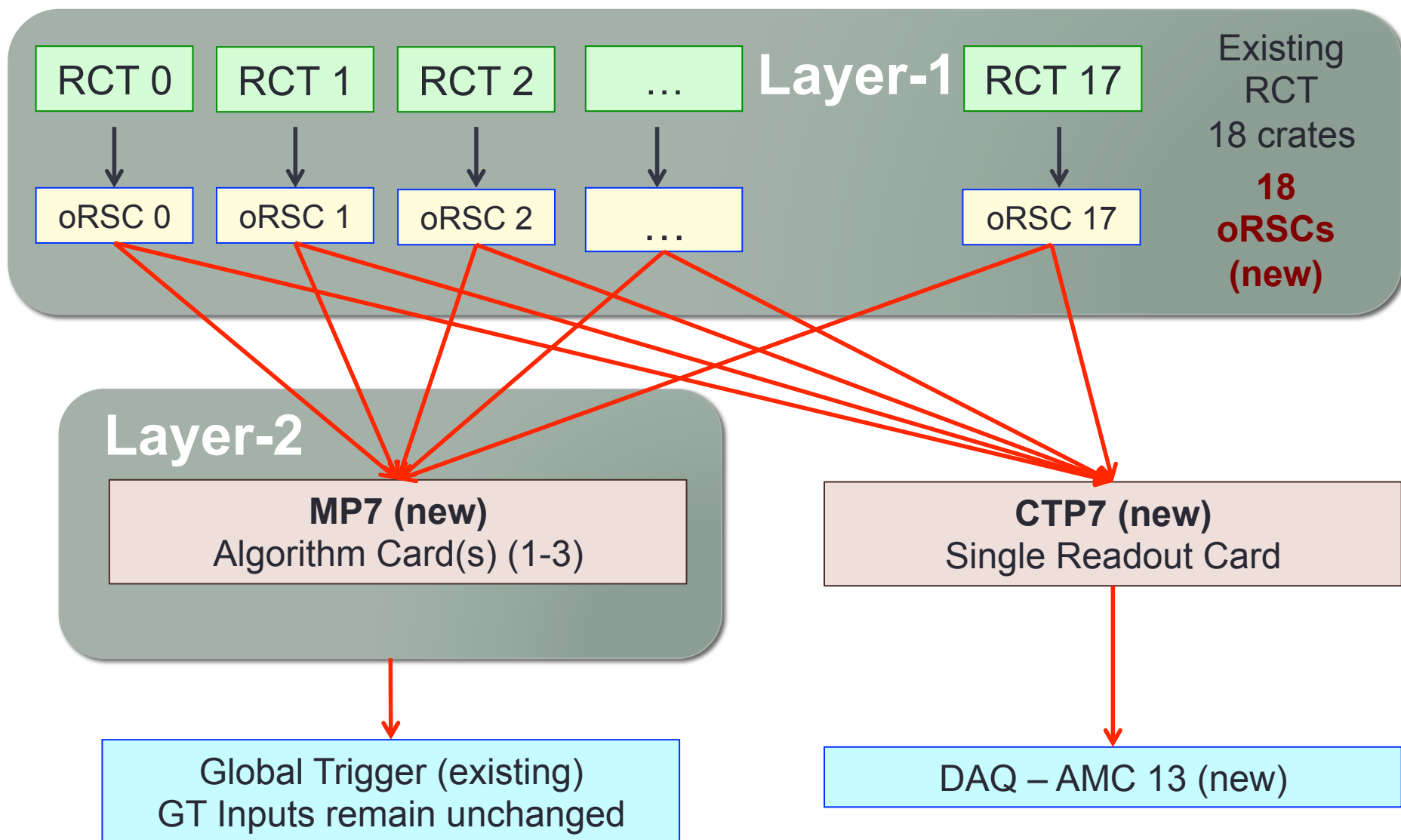
At present is foreseen to collect the 1st fb-1 (pp) with the legacy calorimeter trigger

Upgrade plans (3)

- **Stage-2 concept:** TMT (Time Multiplexer Trigger) 2016-2017
 - All the informations are sent to one crate in the Layer-1
 - Each bunch crossing the Layer-1 crate send informations to one processor on the Layer-2
 - Full upgrade of the trigger system included
 - ✓ Upgrade of HF/HCAL FEE
 - ✓ Upgrade with the Layer-1 instead of RCT

- **Allow to access the full η - ϕ map** of events and perform the background subtraction at L1

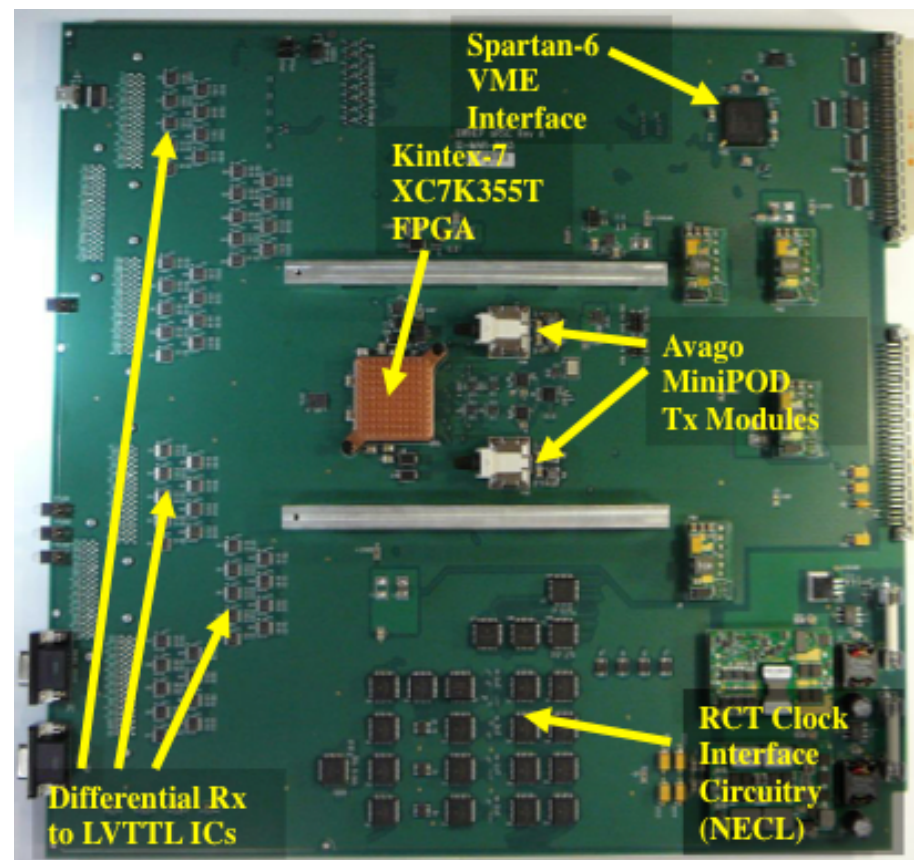
Stage-1 calorimeter upgrade



Technical description: RCT w/ oRSC

Layer 1

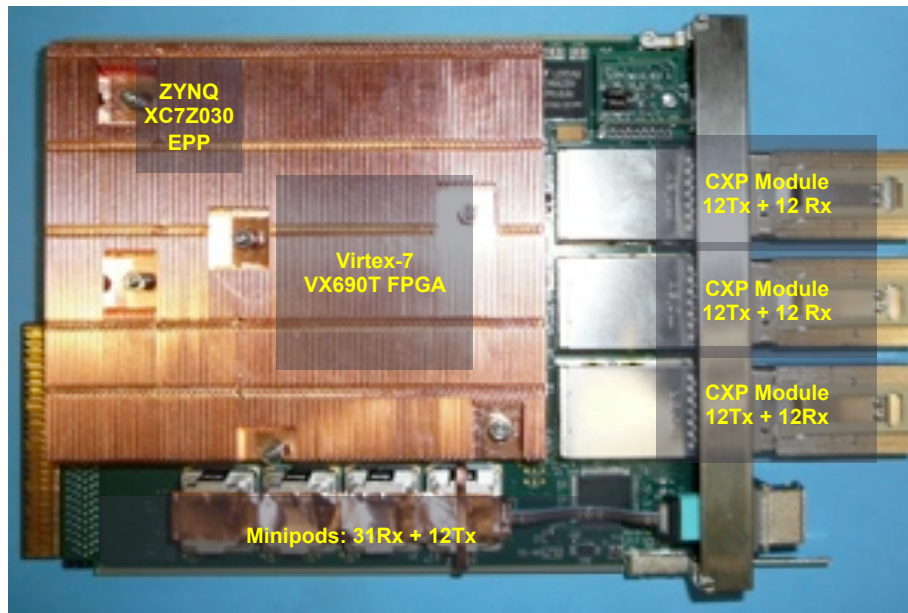
- VME crate (CTP6*) w/ optical output provide by oRSC (optical Regional Summary Card)
- oRSC provide conversion from electrical input to optical output
- Multiple optical output provide
 - Possibility to run Legacy and upgrade system in parallel



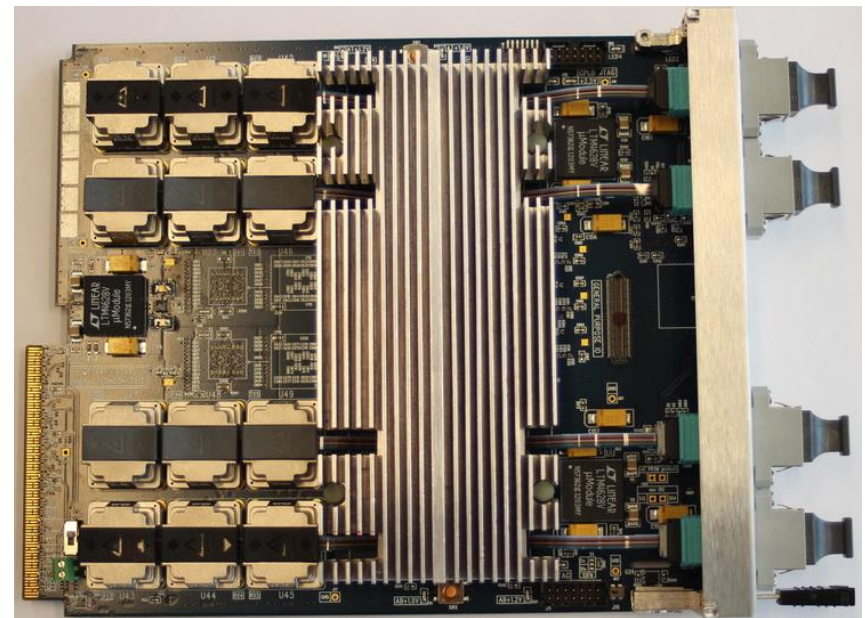
*: *Compact Trigger Processor*

Technical description: MP7* and CTP7 Layer 2

- FPGA technology with the latest generation Xilinx Virtex-7



- Receives data from 18 oRSCs
- Formats & provides data for triggered events

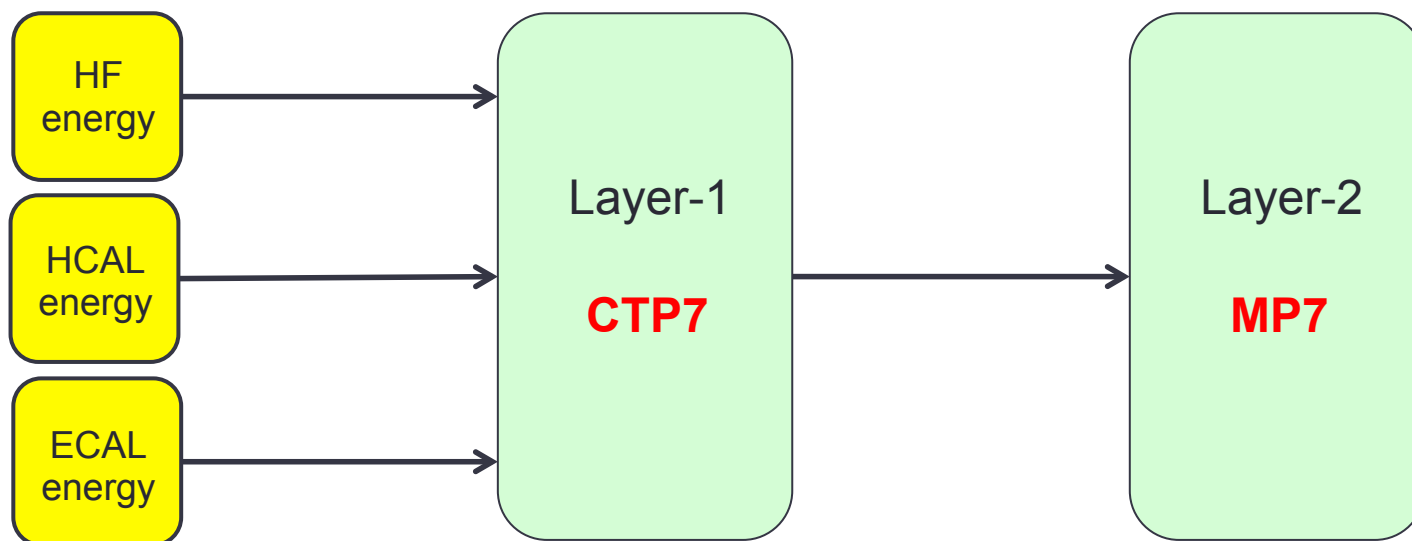


- ~1.5Tb/s signal processor
- Algorithms for L1 triggering implemented on these boards

*: *Multipurpose Processor*

Stage-2 calorimeter upgrade

- Calorimeter trigger upgrade final stage (TMT)
 - RCT will be replaced by Layer-1 (CTP7s)
 - At this stage the full granularity of the calorimeter should be accessible
- Upgrade on the muon trigger will also take place for Stage-2 and performances for HI has to be studied in a near future



L1 HI Jet Background subtraction trigger

- L1 HI Jet Background subtraction trigger
- L1 HI high- p_T Track trigger
- L1 Centrality trigger
- L1 Isolated Photon trigger

**Discuss in this
talk**

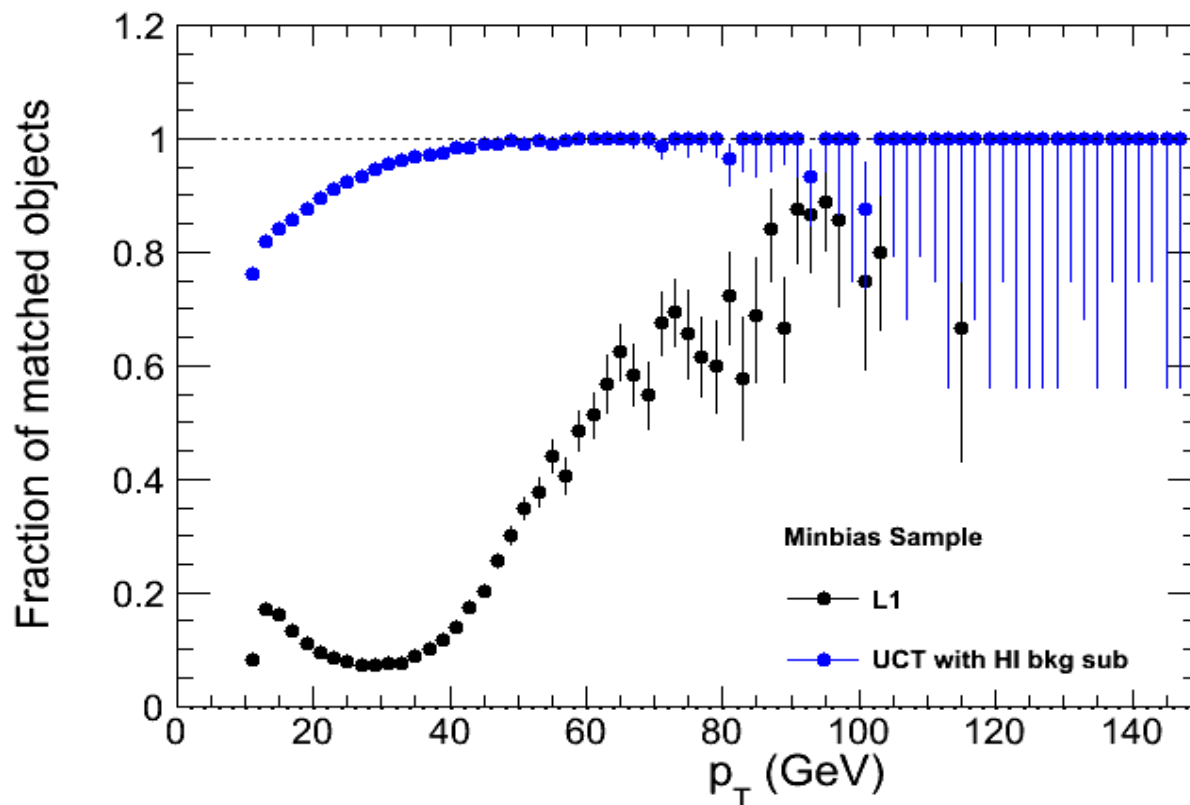
**All the algorithms are going to be
implemented in the MP7 (Layer 2)**

Stage-1 L1 upgrade essential for HI

L1 HI Jet Background subtraction trigger (1)

➤ Algorithm:

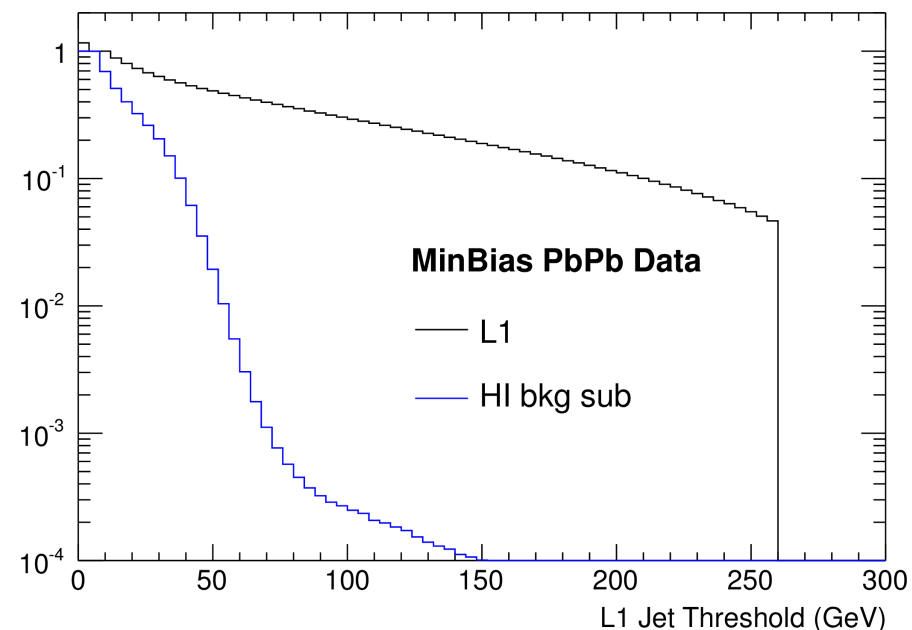
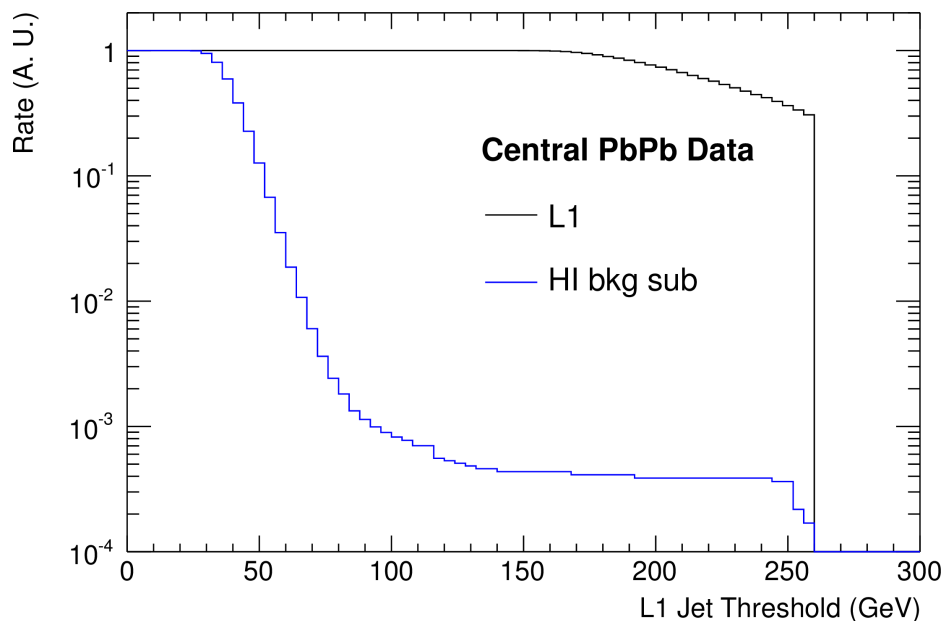
- $\langle E_T \rangle$ is calculated at each constant η in a ϕ -ring
- For each ϕ -ring, corresponding mean is subtracted to the ring
- A standard jet finder method (sliding window) is applied



L1 HI Jet Background subtraction trigger (2)

➤ Comparison between L1 algorithm with and without background subtraction:

- Significant rate decrease with background subtraction
- The algorithm performs well for Central and peripheral PbPb



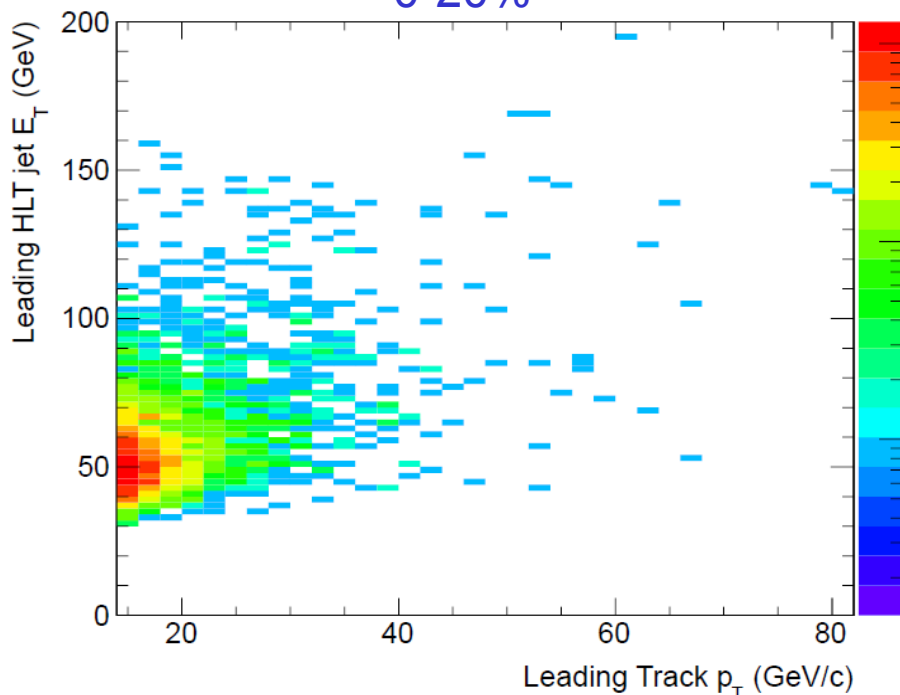
L1 HI High- p_T Single Track trigger (1)

Algorithm:

- Find the highest E_T 4x4-region (2x1 under investigation)
- Background subtraction using phi-ring is used as for the Jet trigger

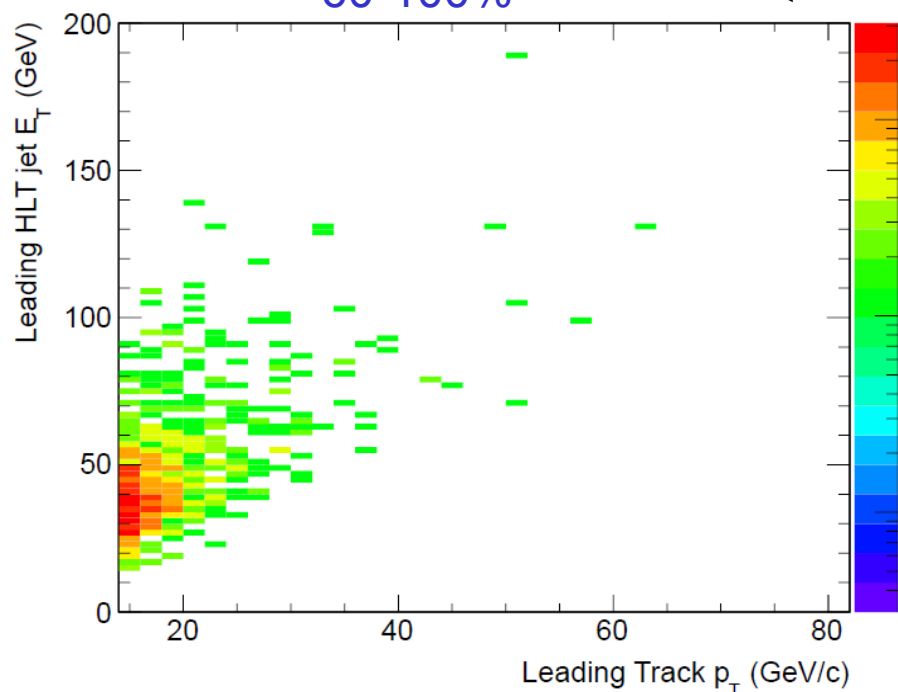
“Central event”

0-20%



“Peripheral event”

60-100%



L1 HI High- p_T Single Track trigger (2)

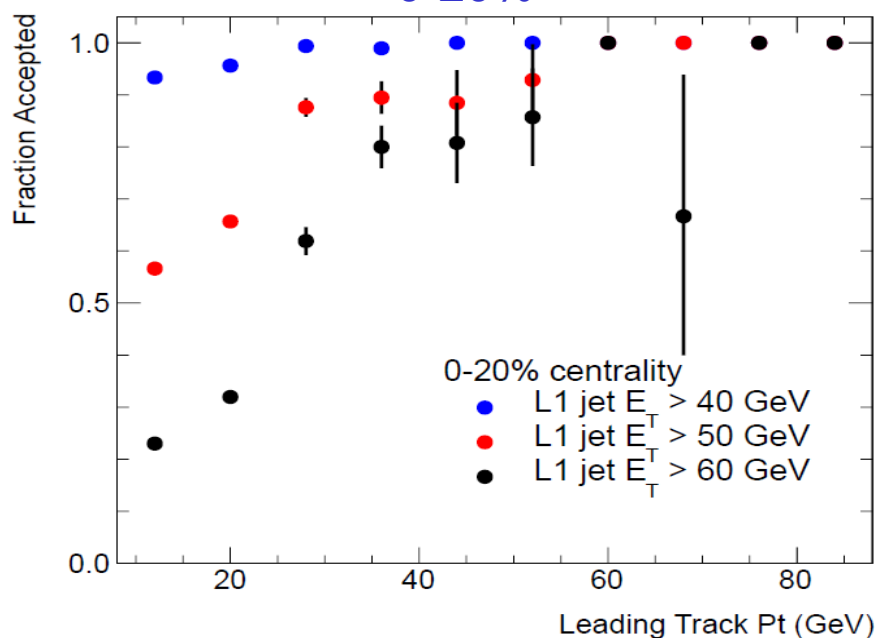
Algorithm:

- Find the highest E_T 4x4-region (2x1 under investigation)
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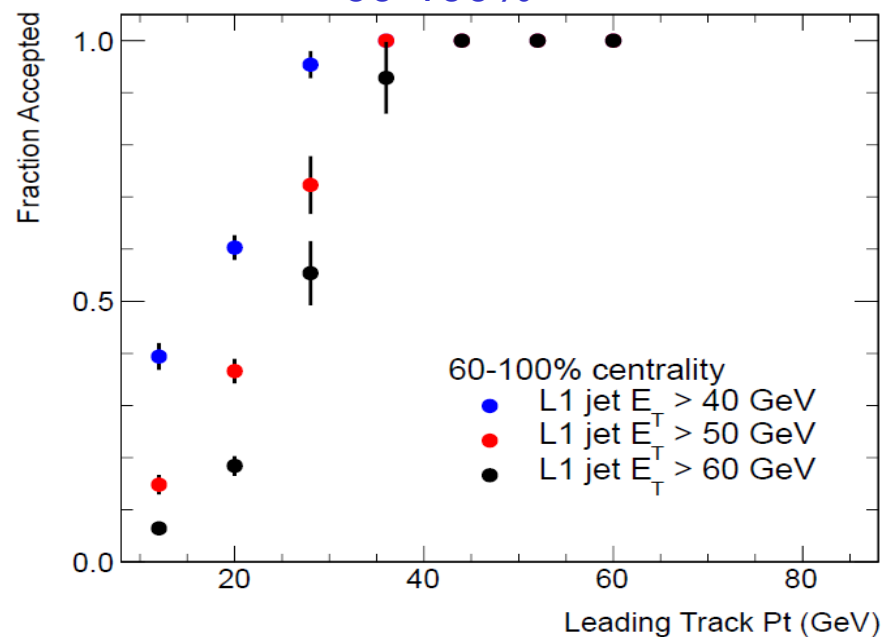
0-20%



“Peripheral event”



60-100%



Centrality trigger

- Algorithm:
 - Calculate only E_T sums by summing all region E_T in HF
 - E_T sums centrality conversion done at the GT level
- Turn on curves shows very efficient centrality trigger in particular for central events
 - plots need are not public yet

Outlook

➤ **Stage-1 status:**

- Hardware production finished and validated. The installation and commissioning of the system is ongoing at CMS
- Online software is being finalized
- The first version of emulation chain is in production

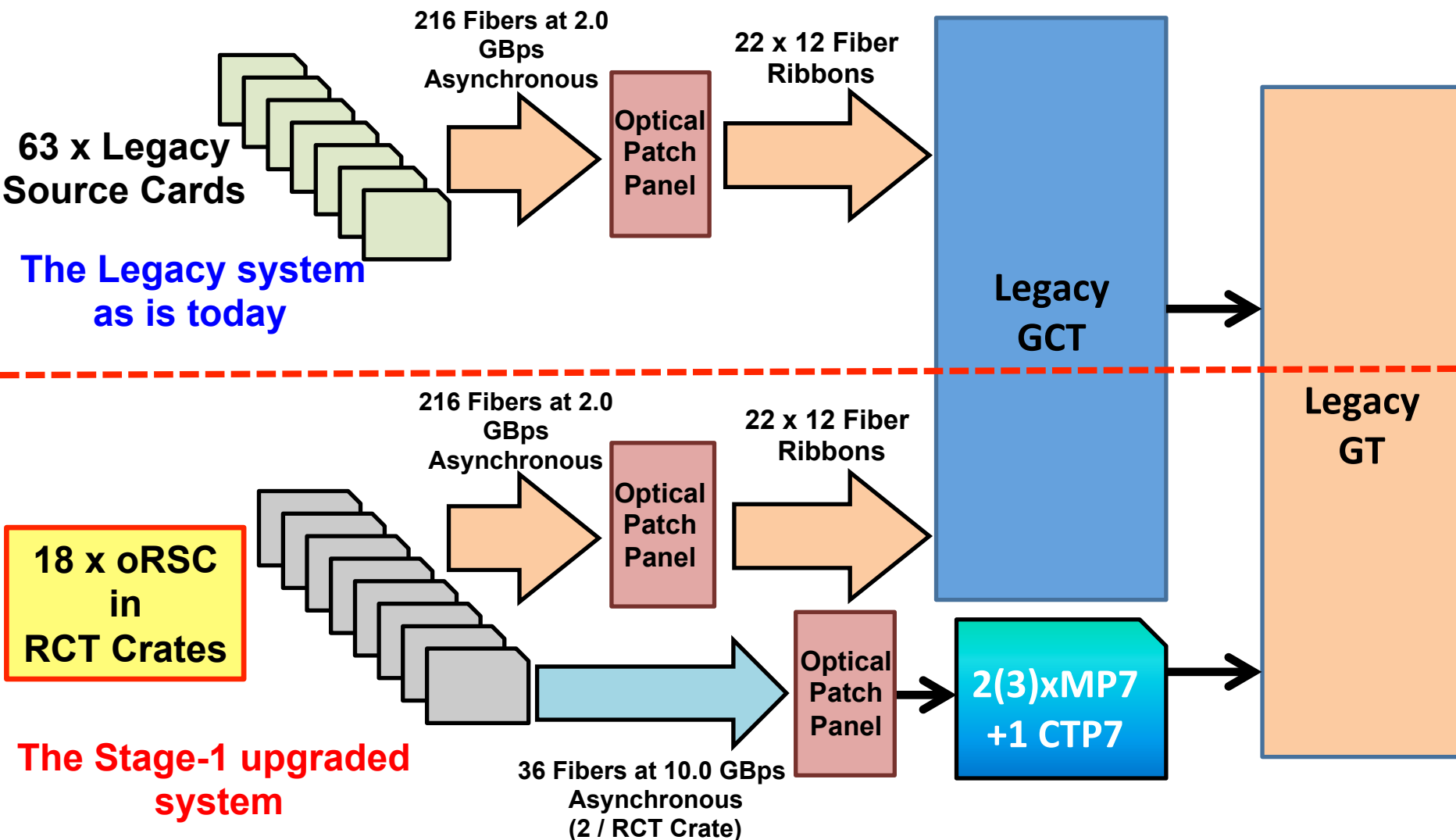
➤ **Stage-2 status:**

- trigger integration test is ongoing
- The installation and commissioning of the system should be finalized in the middle of 2015

➤ HI trigger studies are ongoing and the preliminary results are very encouraging

BACKUP

Stage-1 calorimeter upgrade



Hardware and software status

➤ Hardware

- All Stage-1 hardware component are already in final commissioning phase
- The layer-2 and oRSCs are already installed in CMS (P5)

➤ Software

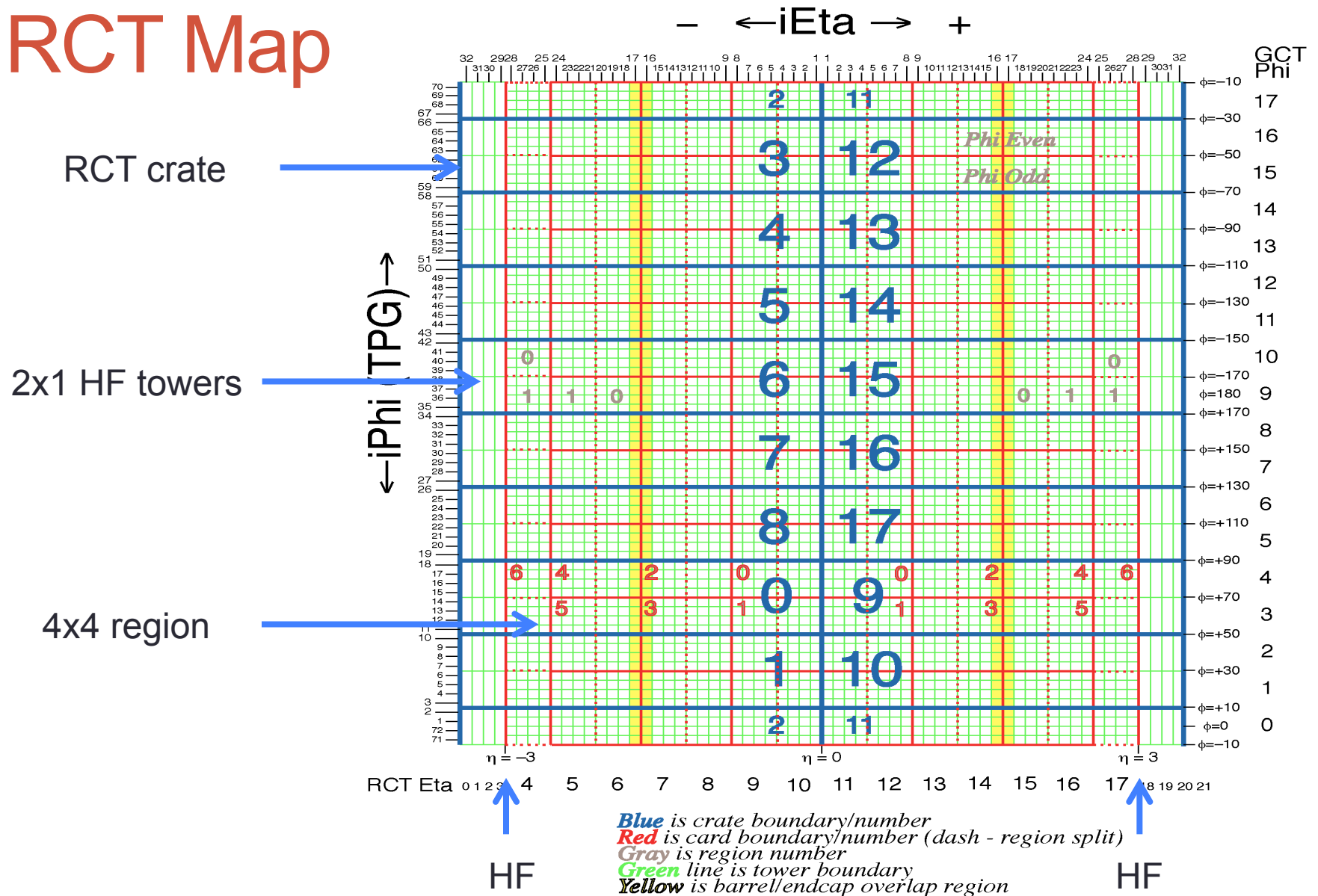
- Development of interconnection test between the various subsystems
- Development of the global online framework SWATCH (**S**oft**W**are for **A**uomating **co**n**T**rol of **C**ommon **H**ardware)

Main pieces of the Stage-1 calorimeter upgrade in place

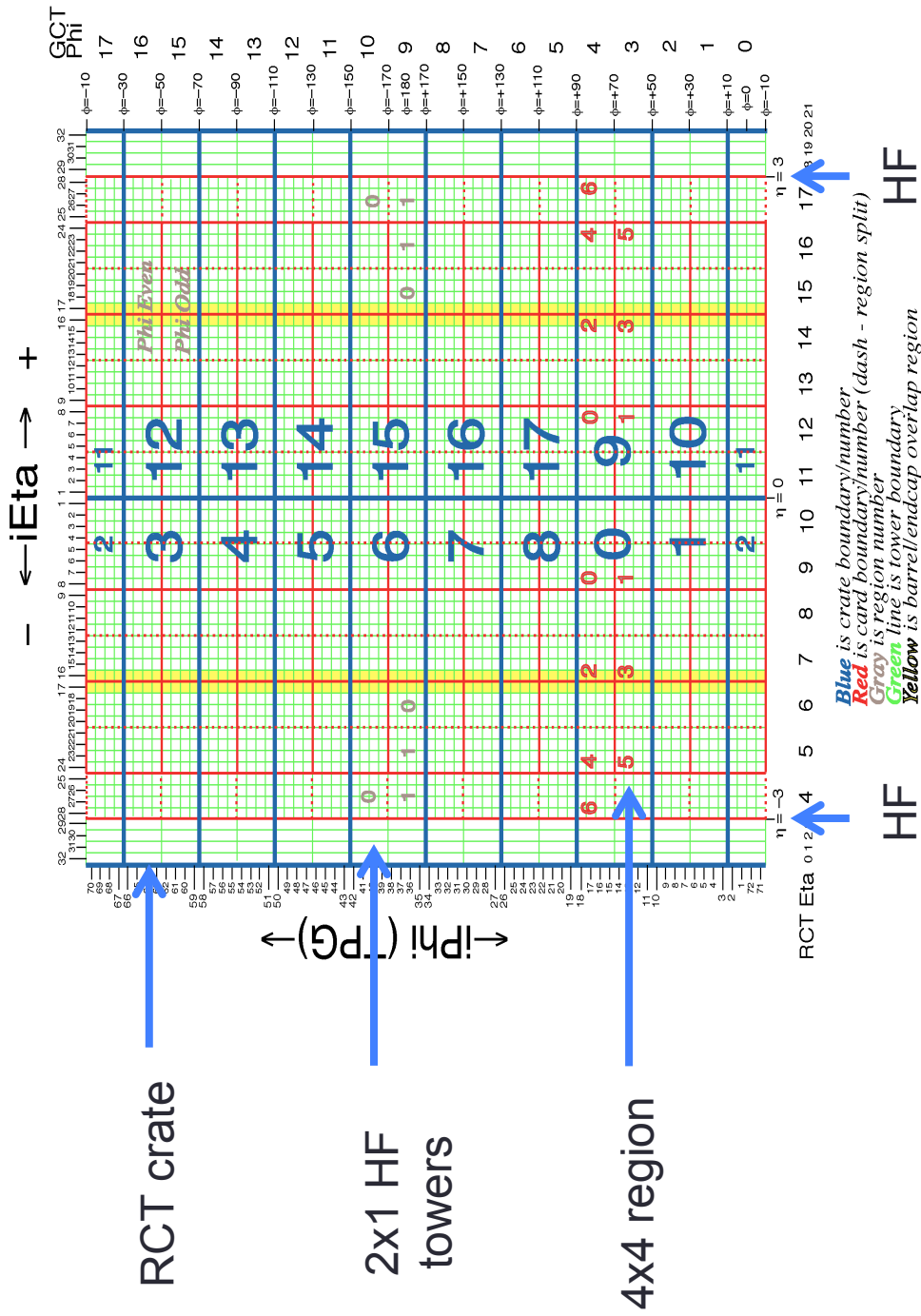
Calorimeter trigger dictionary

Type	Name	Purpose
RCT	Regional Calorimeter Trigger	Existing trigger system
oRSC	Optical Regional Summary Card	Convert & transmit RCT out optically (US DOE NP)
CTP7	Compact Trigger Processor	Large FPGA w/ optical & backplane (US)
MP7	Multipurpose Processor	Large FPGA w/ only optical links (UK)
GT	Global Trigger	Existing global trigger system (Vienna)
AMC13	Readout Module	μ TCA Interface to CMS DAQ (US)

RCT Map



RCT Map



L1 HI Jet Background subtraction trigger (3)

- Accept rate can be controlled by L1 threshold using Stage-1

