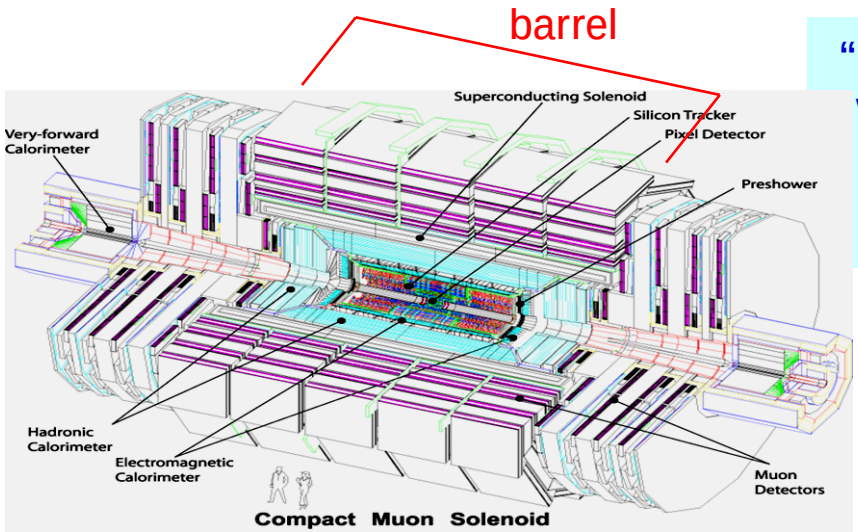
The Sector Collector of the CMS DT Trigger System: Installation and Performance

R.Travaglini
Physics Dept. & INFN Bologna

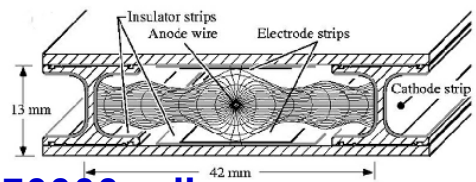
Topical **W**orkshop on **E**lectronics for **P**article **P**hysics 20**08**

Parallel Session A6 – Trigger 2
19 Sept 08

Muon detection in the barrel region of the CMS experiment at LHC

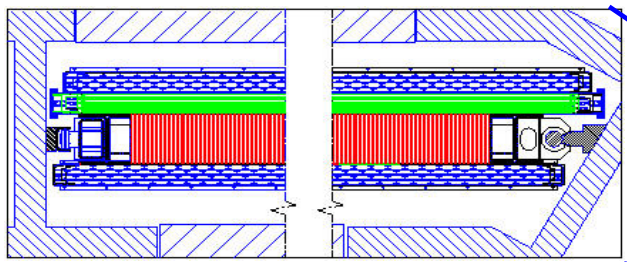


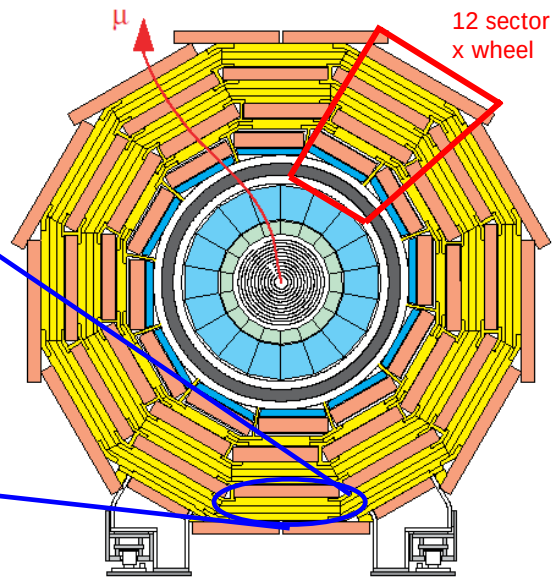
"barrel" iron yoke segmented in **5 wheels**
Wheels arranged in 30° azimuthal sectors
4 muon stations x sector
Each station equipped with DT and RPC



~ 170000 cells

250 stations





•DT chambers perform muon detection and triggering

250 chambers (staggered layers of drift tubes)

DT Level-1 Trigger System and the Sector Collector

- CMS Muon Trigger
  - Muon identification
  - Transverse momentum (P_t) measurement
  - Assignment to the correct Bunch Crossing

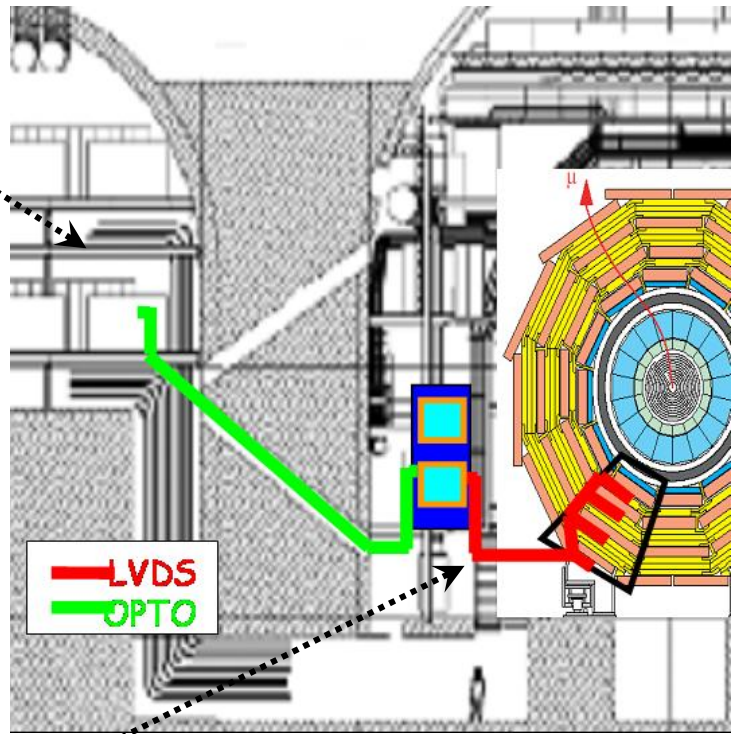
- Drift Tubes Level 1 Trigger (custom electronics)
  - On-detector : local (= any chamber) muon identification and selection of 2 track segments with higher P_t
    - Reliability
    - Radiation tolerance (ASICs, pASICs)
  - Off-detector : correlates chamber information (track finding)

- The Sector Collector boards have to:
  - Collect local output from 4 chamber electronics each one
  - Synchronize them
  - Transmit data (properly remapped) to the counting room electronics

Sector Collector system: location and data transmission

Regional trigger electronics
(underground counting room)

SC Output links :
6 optical @ 1.6 Gbit/s per link
1 GOL chip per link



SC Input links :
Cat-5 FTP cables
(480 Mb/s LVDS) :
2 copper cables/chamber
4 twisted pairs/cable

Located on detector towers,
60 SC boards (1/DT 30° sector),
2 VME 9U crates / wheel

Sector Collector system overview

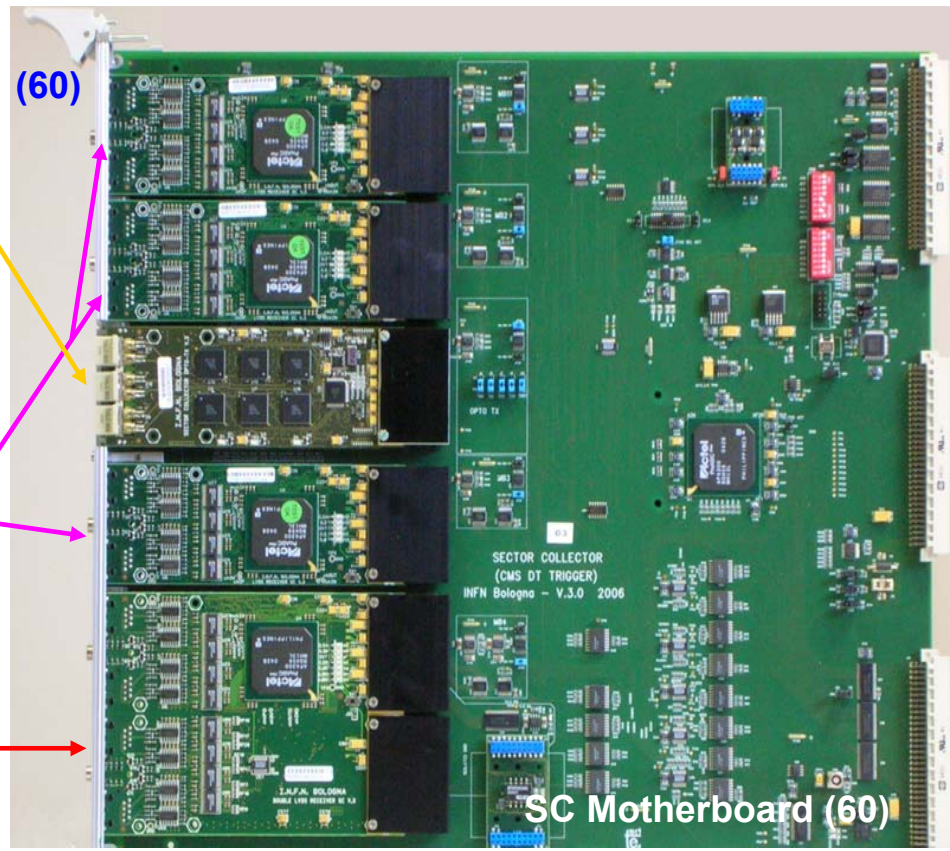
Underground Counting room

Tower crates

Opto TX (60)

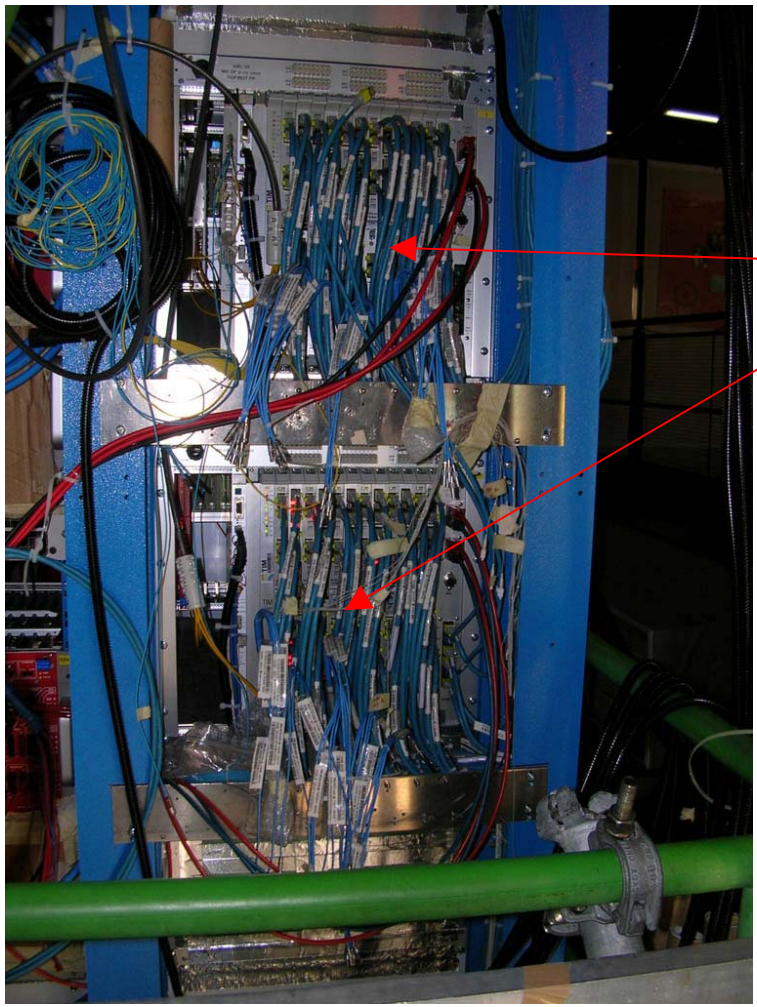
Opto RX (60φ+24η)

LVDS RX [240 2ch + 10 4ch)]



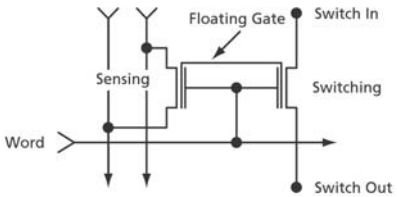
SC Motherboard (60)

Sector Collector crate



LVDS
copper cables

Sector Collector implementation main hardware features



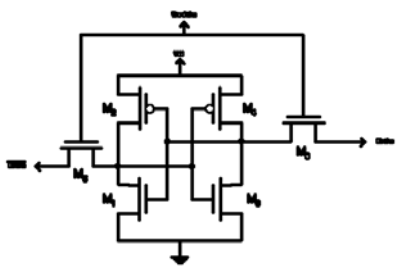
Processing devices used on Near-detector electronics:
ProAsicPlus 300, FPGA from Actel(456 balls)

- configuration memory is **FLASH-based (rad-hard)**
- on board programming via custom VME-Altera Jtag interface

Independent Mezzanine powering: each mezzanine (LVDS-Rx and Opto-Tx) can be Powered off in case of failure with I/O lines isolation

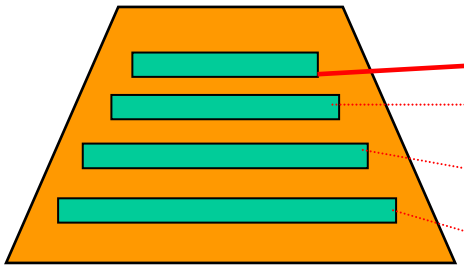
Spying: a partial copy of the trigger data (quality bits, ...)
from any chamber is injected in the DAQ-boards located in the same VME crate

Control: I2C bus accessing temperature and current sensors;
JTAG chain for meazzinines FPGA access (boundary scan, configuration, ...)



Counting room: Altera StratixGX FPGA (672 balls)
with 8 embedded **gigabit transceivers**

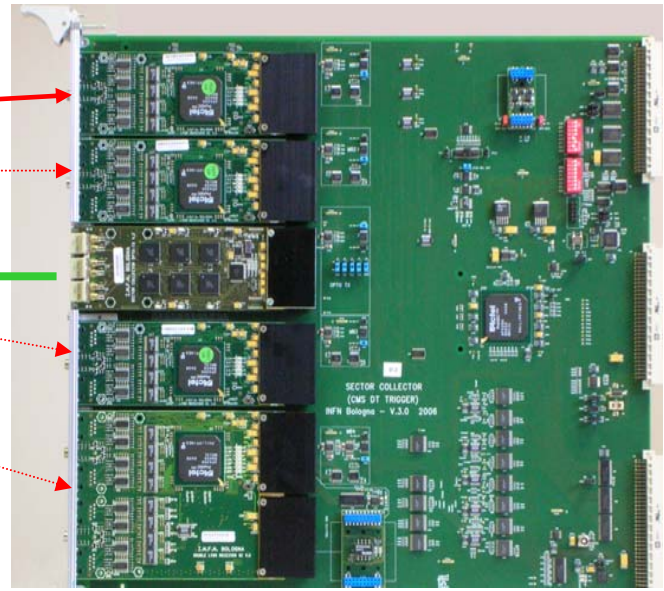
DT trigger synchronization with the Sector Collector (1): desynchronization sources



30° sector of the DT detector

2 lvds copper cables per chamber

10 m < L < 40 m



Every chamber electronics act as a synchronous system, only its overall clock phase vary, depending on its relative tuning w.r.t. LHC beam phase

=> Different chambers have different phases

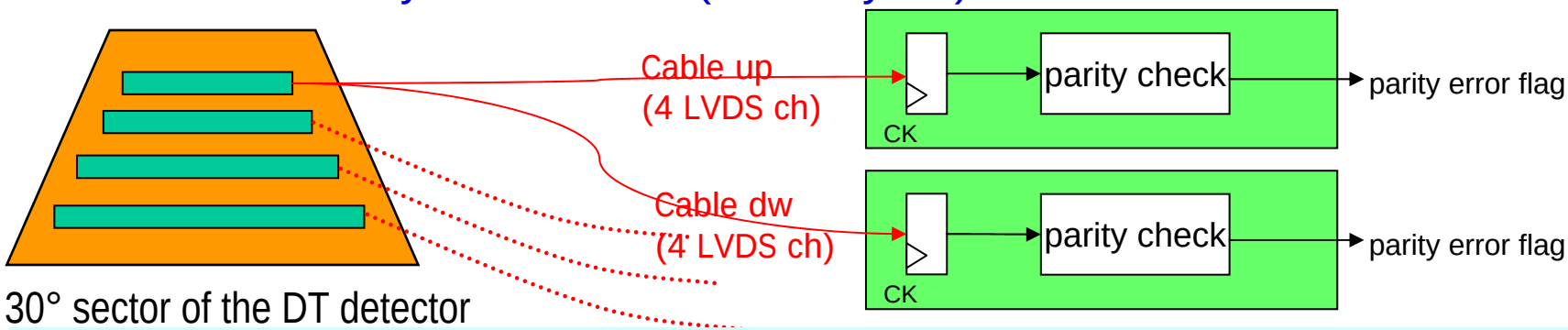
6 optical links per sector

Skew between Max $_{lenght}$ link and Min $_{lenght}$ link < ~20 ns

Looking at fibers for all wheels

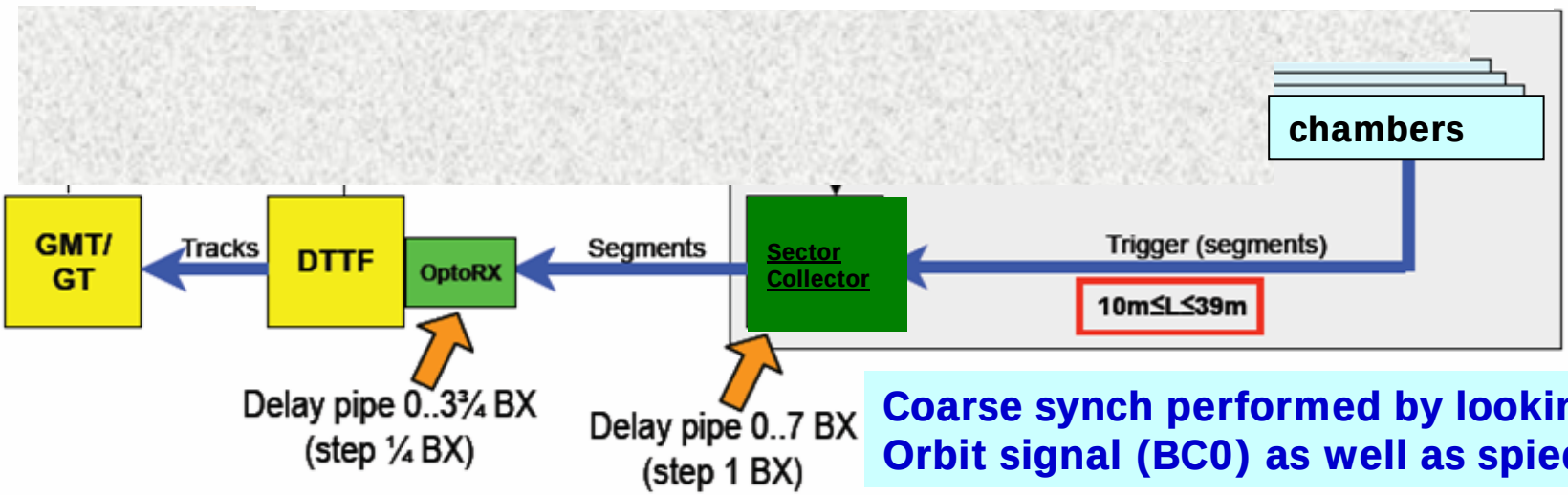
DT trigger synchronization with the Sector Collector (2): synchronization tools

Fine Synchronization (sector synch)



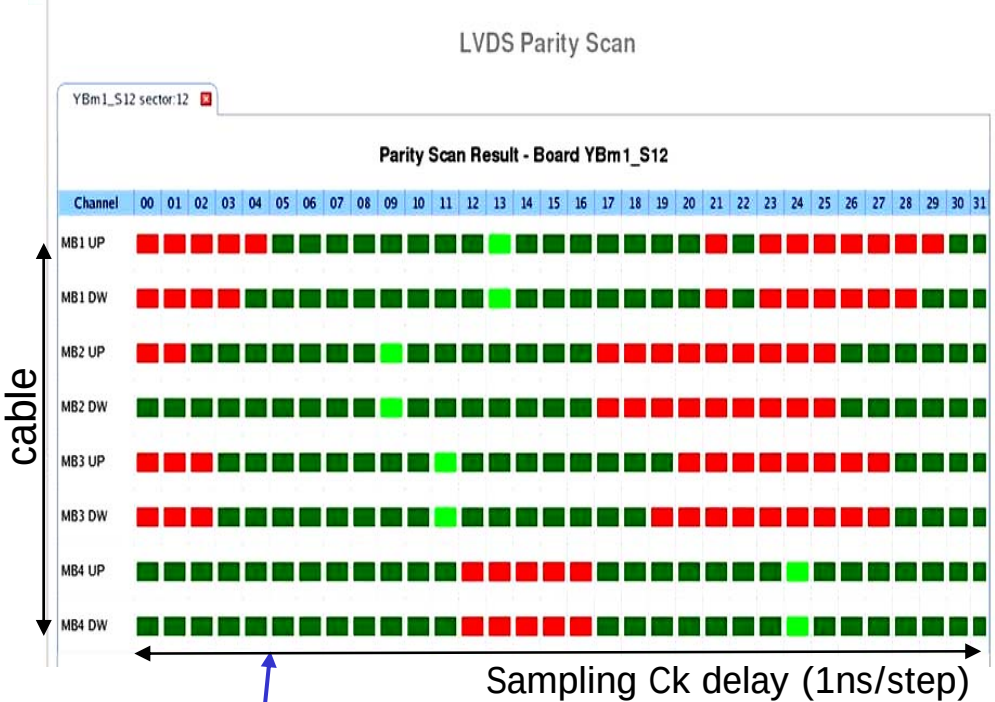
Each mezzanine has independent delayble sampling clock (32 step – 1ns/step)

Coarse Synchronization (cross-sectors synch -> wheels synch)



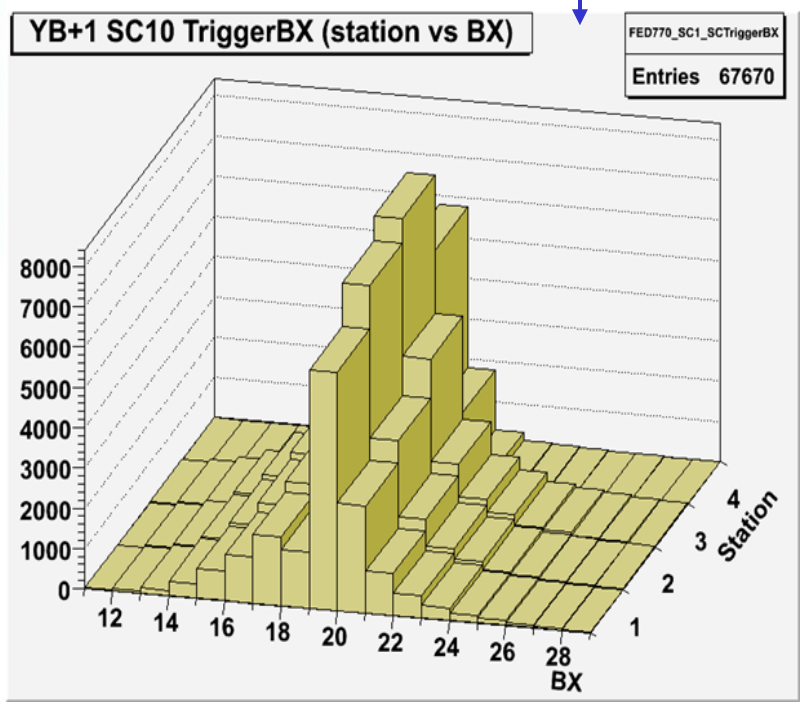
Coarse synch performed by looking at: Orbit signal (BC0) as well as spied data

Sector Synchronization



Fine synchronization of Input links
(parity bit check)

Coarse synchronization
of stations
(one station triggers spy regs;
look for trigger coincidences in others)



Installation, commissioning and integration tests

• **Devices production** (Jan 07 to Mar 07) , **tests** and **installation** on situ (ended in Jul 07) have been relatively **fast**

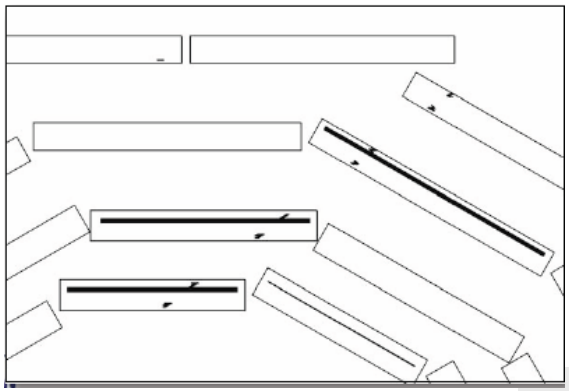
• **Commissioning step 1**:
Electronics commissioning performed together with commissioning of DT detector and electronics in **whole sectors** (4 chambers ,local electronics, read-out and control chains, …)
• **Commissioning step 2**:
Wheel by wheel commissioning

• A **dedicated technical trigger for cosmics** muon based on DT trigger electronics have been implemented for commissioning

Since June 07 DT system is partecipating to CMS integration tests (**Global Runs**) aimed to integrate subdetectors in common data-taking

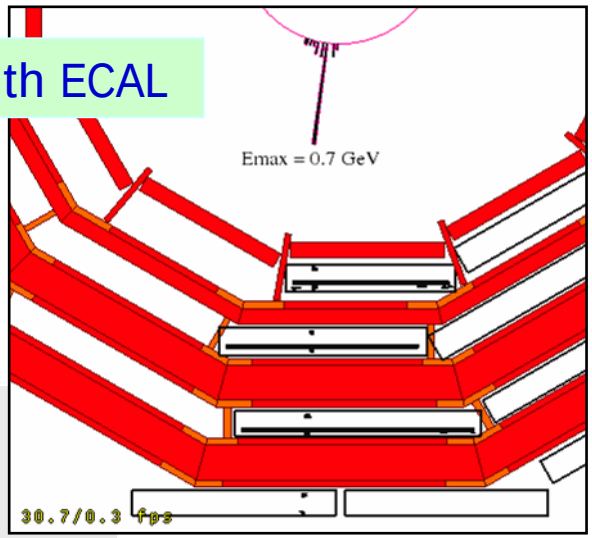
• Starting from few sectors partecipating in Jun 07 in the **last Global Run (August 08) the whole DT subsystem was included**
• **DT trigger has been included** from the beginning, providing a **reliable trigger on cosmics** muons, suitable for data-taking, syncronization issues and performance studies

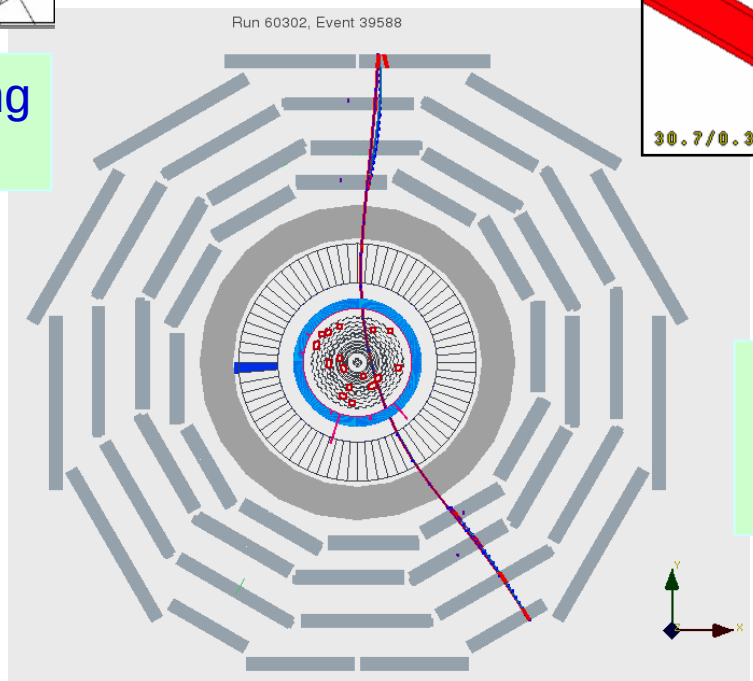
DT Trigger at Global Runs event display examples



Trigger of track crossing adjacent sectors

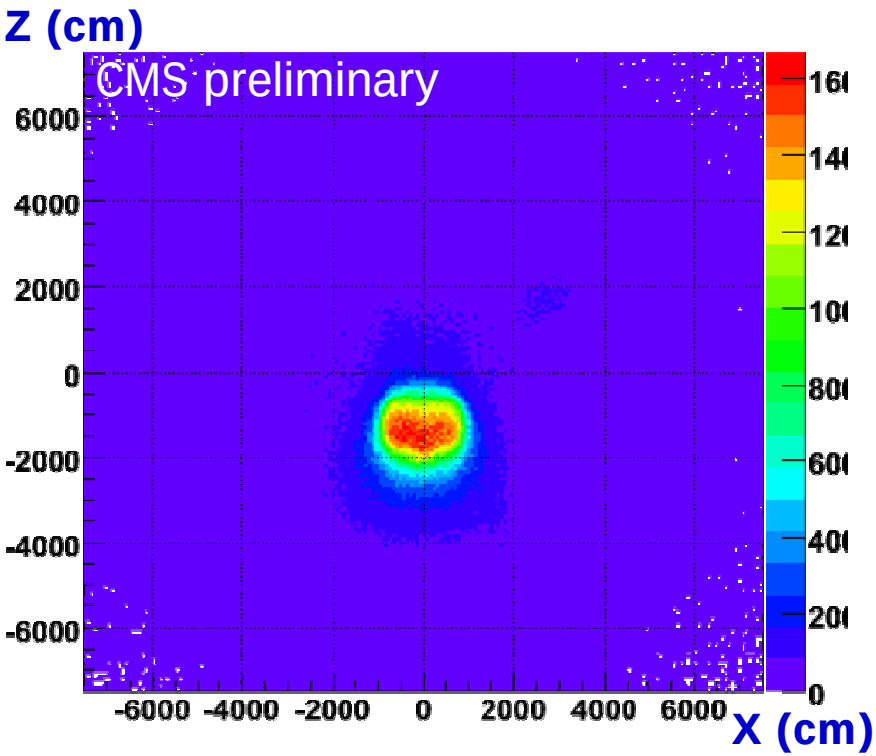
Timing With ECAL



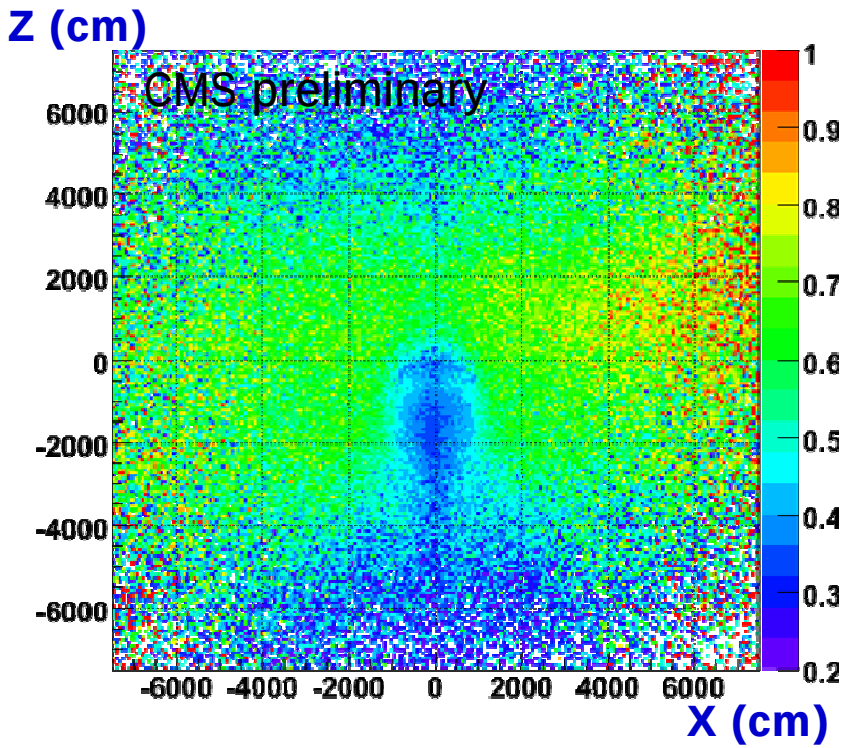


Cosmic trigger on opposite sectors for Tracker

Example of Muon Trigger performances: track reconstruction



Tracks extrapolated to the (earth) surface in CMS coordinates: most of muons from the pit

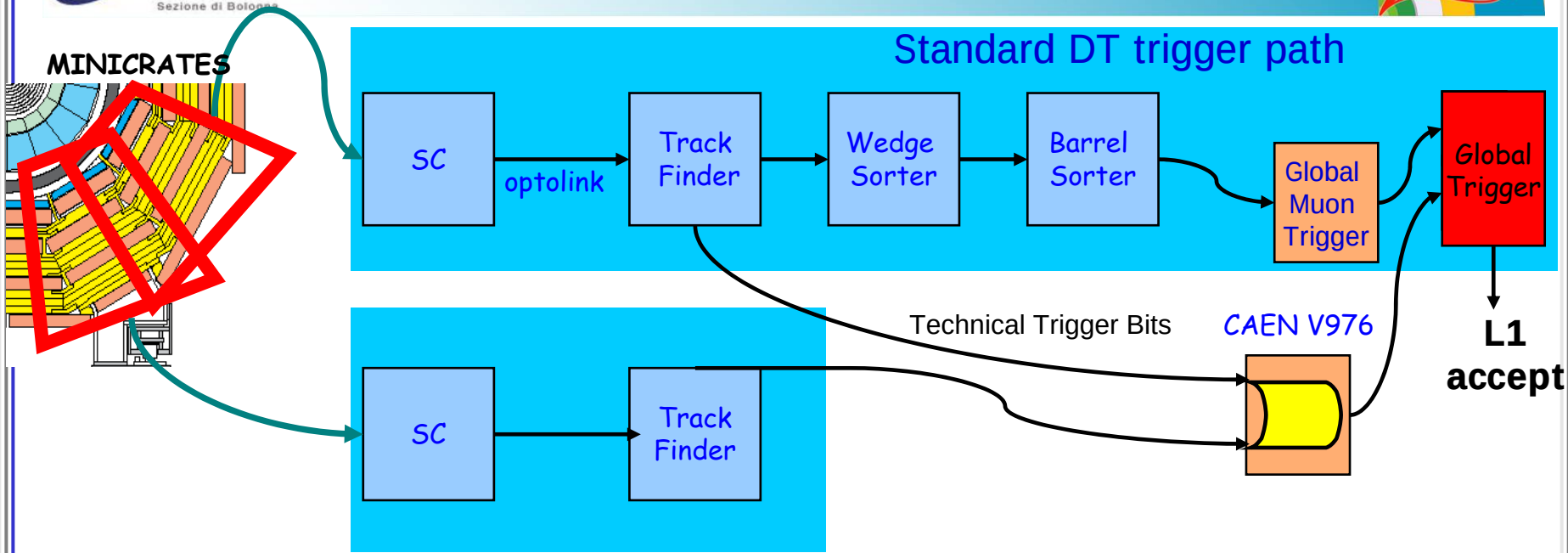


Average probability of a track to pass trough the bottom of CMS if detected at top

projection to the earth surface: shaft muons are softer

Courtesy of I.Mikulec

DT muon technical trigger



- Each Trak-finder device delivers a Technical Trigger Bit if at least one chamber of the correnspondant sector has triggered

- Cabled logic is implemented with CAEN V796 (Quadf 4 Fold AND/OR/MAJ, NIM-TTL TTL-NIM Translator, Fan-In Fan-Out) modules

- Still not integrated with the CMS Global Trigger as a Official Technical Trigger (soon!); used in commissioning and DT-local data-taking

Examples of using the DT muon technical trigger

DT Technical Trigger useful for studies at very low luminosity LHC beam:

For instance, requiring a global OR of all DT chamber:

1. Trigger rate due to cosmics muon:
   Rate < 300 Hz

2. Trigger rate due to collision events:
   Rate ($L = 10^{31}$) < 500 Hz

A useful sample of data needed for DT trigger synchronization can be taken in few hours !

Sector Collector control software

Tasks:

1. Retrieving HW configuration from DB
2. Automatic power on of all mezzanines
3. Hw configuration

} All crates in parallel

4. Monitoring of error flags, temperatures, current drawings, ...
5. Exporting of monitored data to DB
6. User-friendly panels showing the sistem health

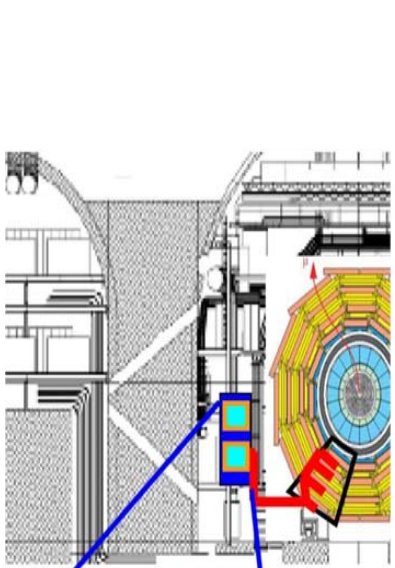
Example of performance when configuring the whole system:
cold start (all mezzanines off) : < 30 s
warm start (only HW config) : ~ 1 s

A CMS common framework for L1 Trigger control: Trigger Supervisor

The Trigger Supervisor is a common framework designed for set up,operate and monitor the CMS L1 trigger devices and the information exchange with the run control and the global CMS monitoring system (http://triggersupervisor.cern.ch)

It provides facilities for customizing single applications (called “cells”), their communications (via SOAP messages), connections with databases (for storage of hardware configurations and run conditions) and graphical user interfaces for managing cells via http client

Overview of the Trigger Supervisor implementation for the Sector Collector



Pci to vme controller

1 Supervisor cell

SOAP messages

Main cell

http

shifter

Wheel -2

1 worker cell

1 worker cell

SOAP messages

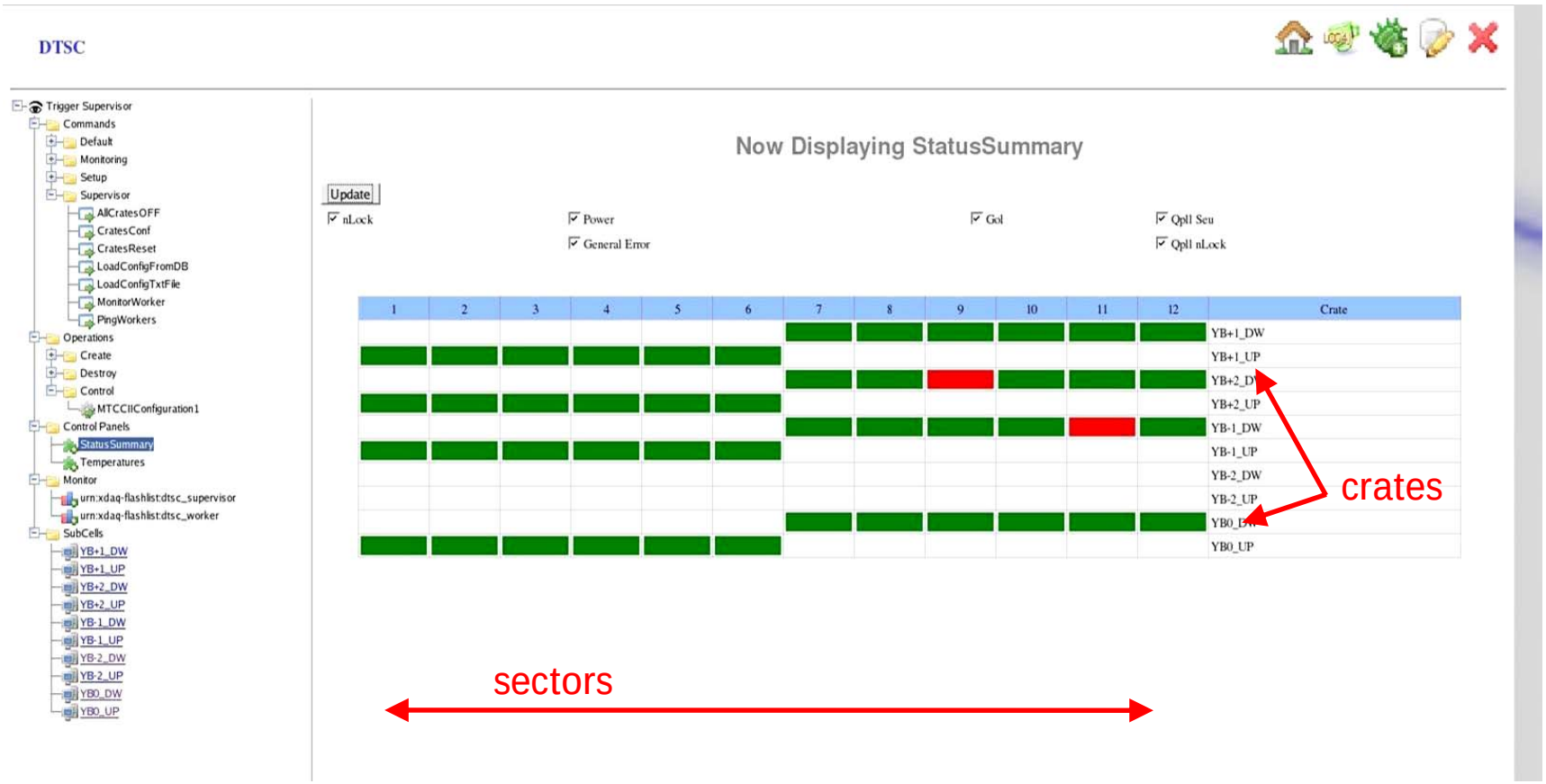
… X 5 wheels

http

expert user

1 supervisor
10 workers
(2 per PC)

Screenshots (1)



Screenshots (2)

One panel per crate

One graph per board (8 sensors per board)

Summary

- The **Sector Collector system**, for the CMS L1 trigger, has been presented
  It consists of:
  60 9U VME boards equipped with **LVDS receiver mezzanines**,
  optical transmitter (@ 1.6 Gbit/s) and
  optical receiver cards (placed in counting room)

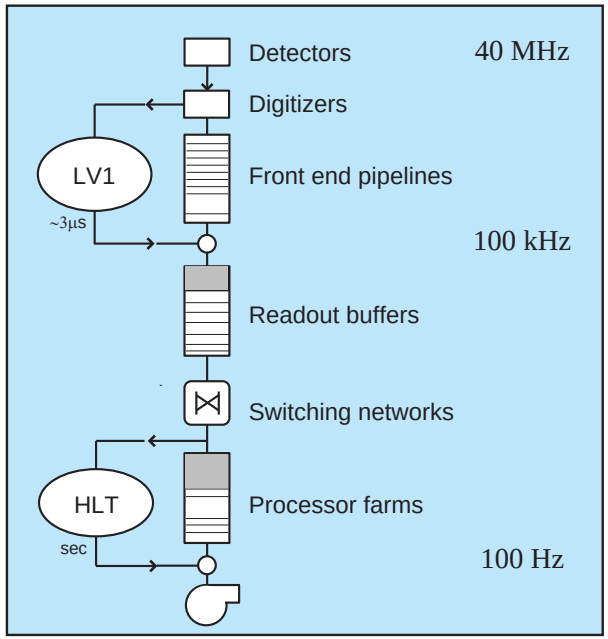
- Several tools have been foreseen on the Sector Collector in order to achieve proper **synchronization** of the DT trigger devices (both sector and wheel level) as well as with the whole detector

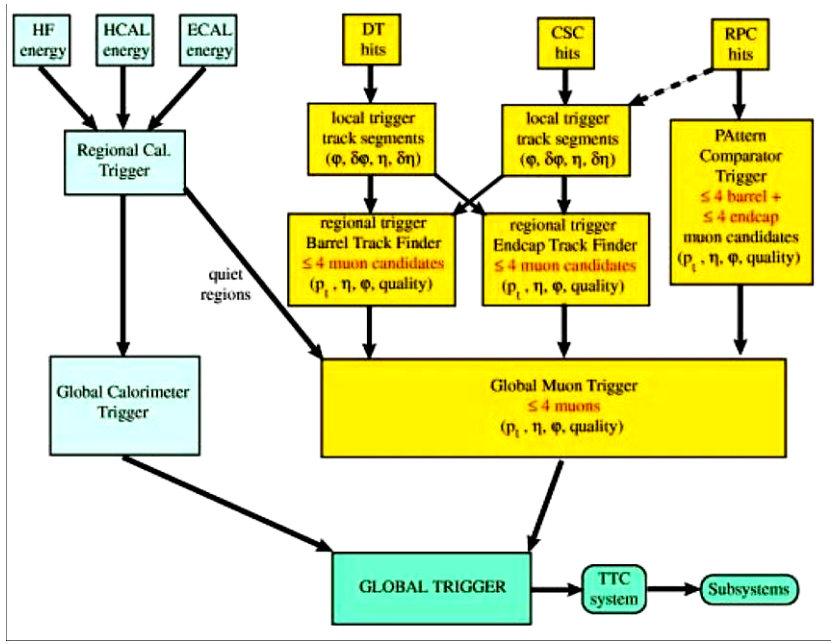
- The Sector Collector **system has been successfully commissioned** and provided **stable and realiable triggering on cosmic muons** during CMS Global Runs

- A **control software application** have been developed and integrated with the CMS Level 1 Trigger framework

Additional slides

CMS Level-1 Trigger System





LV1 trigger:

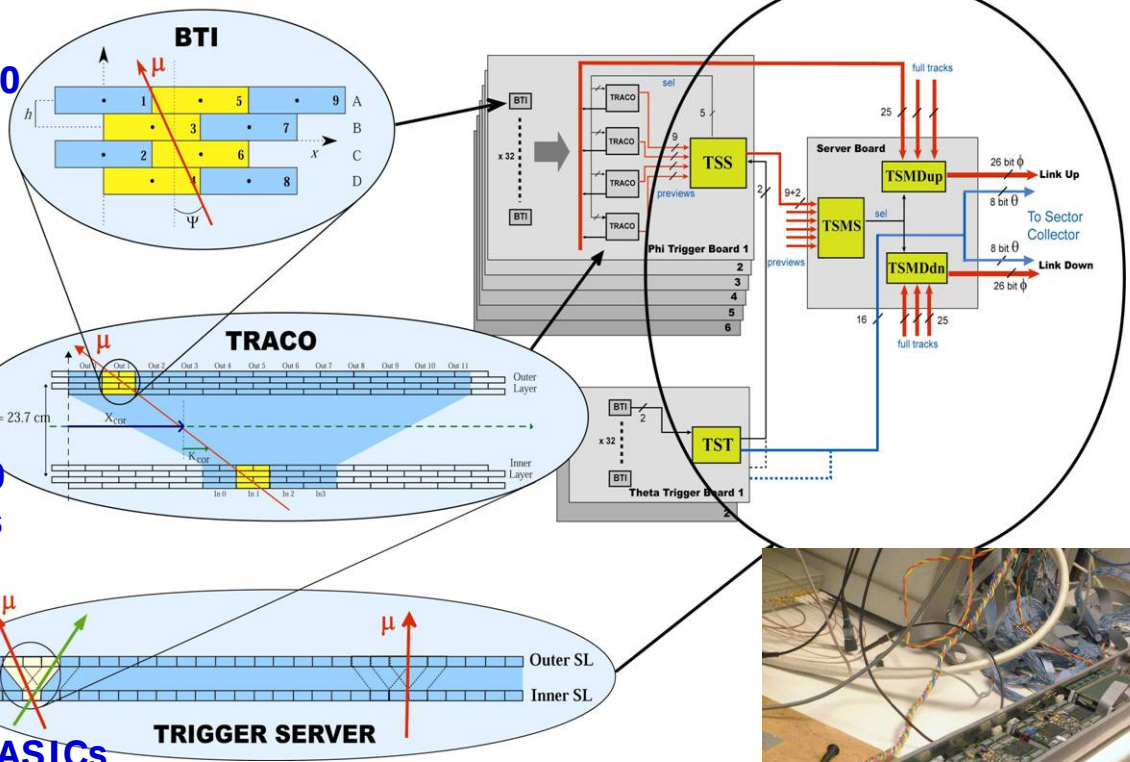
- processes events @ 40 MHz (no dead time)
- based on pipeline processing
- selects events reducing accepted rate up to 100 kHz
- relies on custom electronics
- low latency (3.2 μs) decision

DT Local Trigger

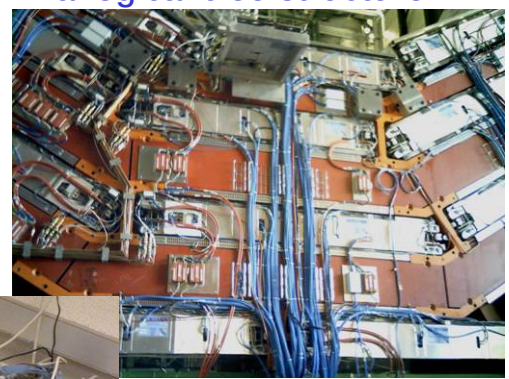
~40000 ASICs

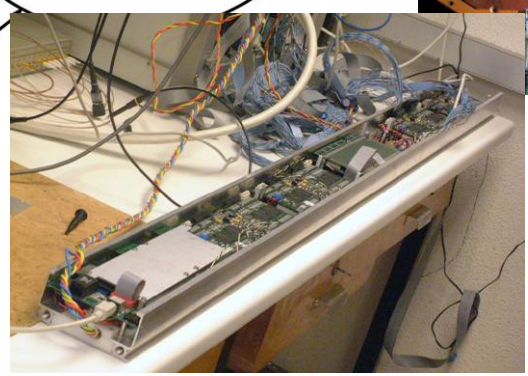
~4400 ASICs

1200 ASICs
+ 250 x3 pASIC

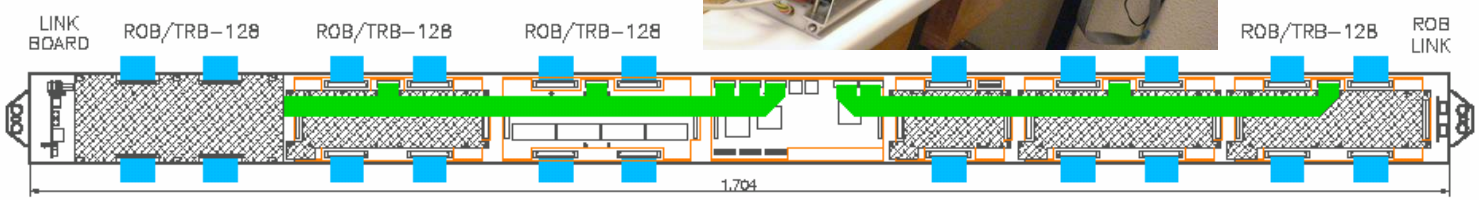


- **Synchronous pipelined system** (40 MHz)
- Processing stages organized in a logical tree structure

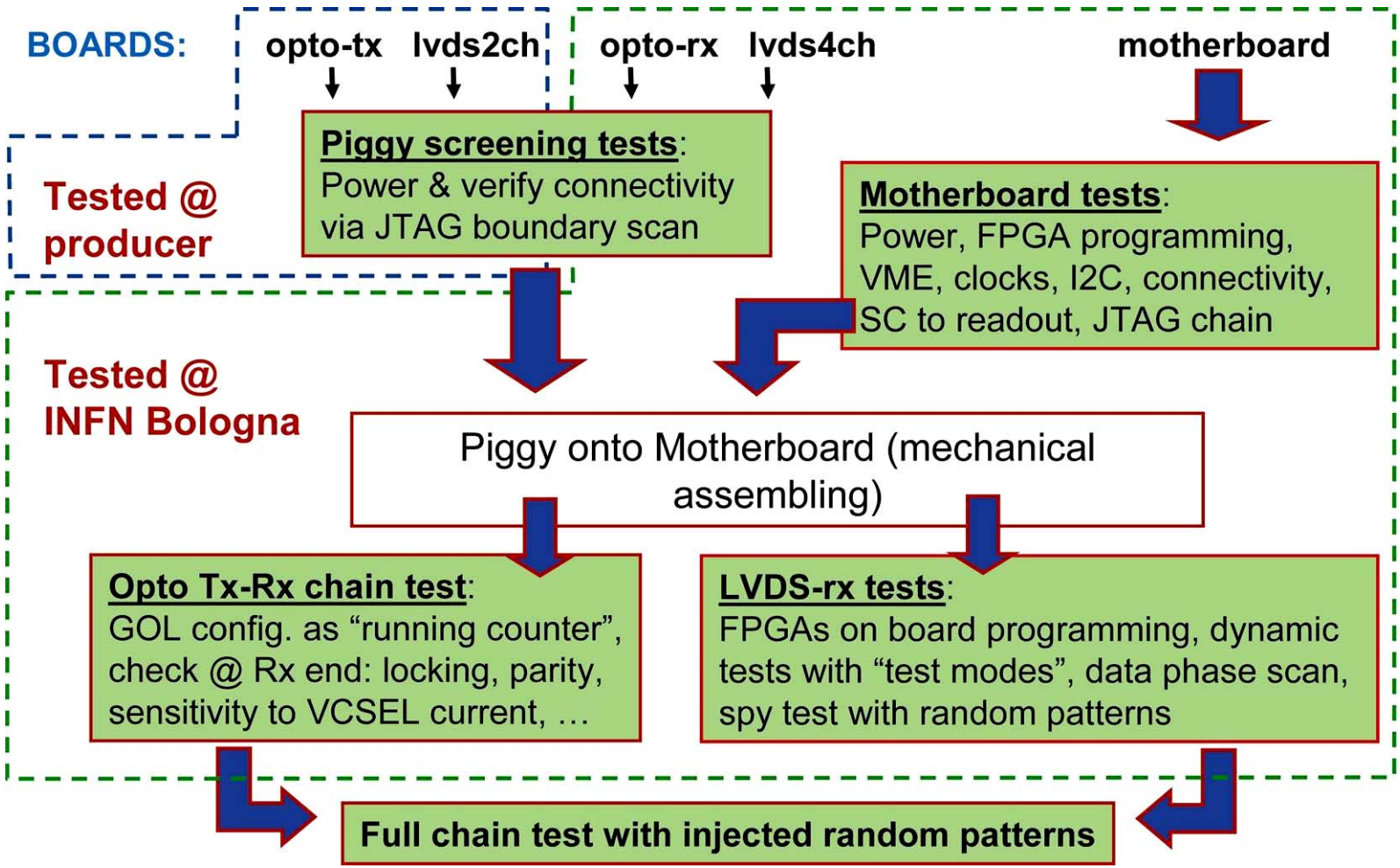




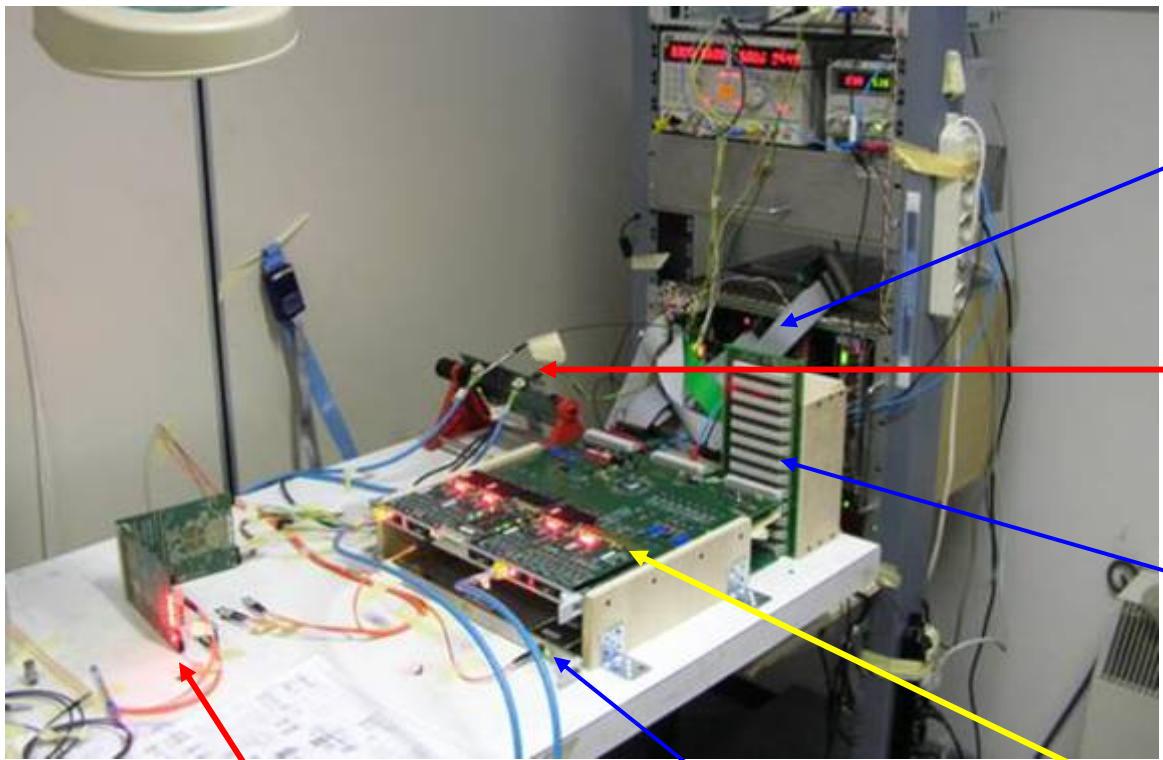
Arranged into a Mini-Crate located on the detector
(w. Read-out elctr.)



Production and test strategy



Test setup



6U VME crate
(VME bridge,
Pattern Units (high speed I/O devices),
clock fanout...)

LVDS-TX connected to a Pattern Unit (data injection, emulates the minicrate)

Custom J3
(TTC signals)

Opto-rx connected to a
Pattern Unit for pattern acquisition
(emulates the DTTF)

TIM
(TTC signals fanout)

SC under test