



# *An RPC-Based Technical Trigger for the CMS Experiment*



## ■ **Outline:**

- **Requirements**
- **Implementation**
- **Performance during CMS MTCC**

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*On behalf of the CMS RPC/Trigger Collaboration*



# *Motivations and requirements*

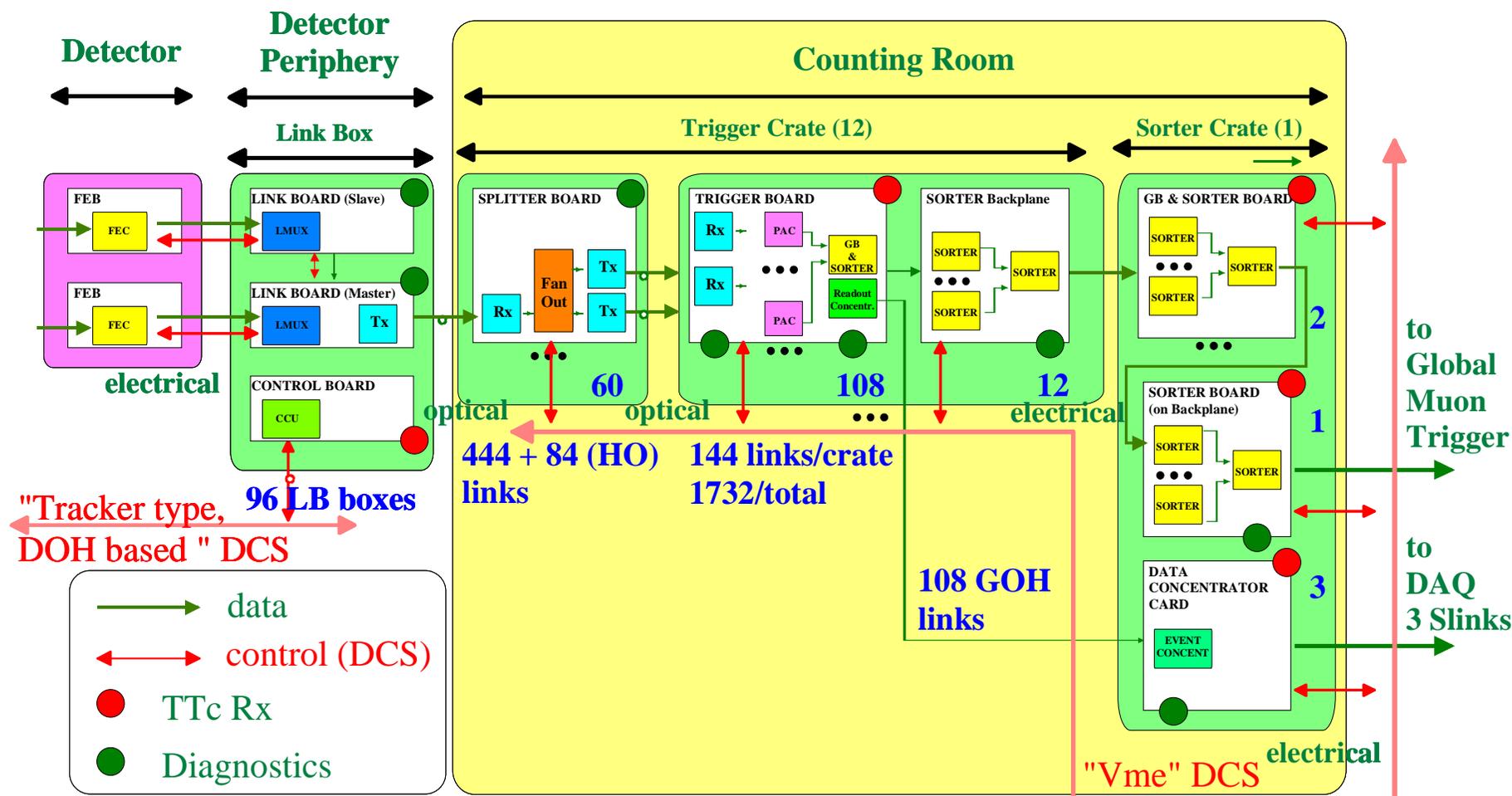


- **Goal of this project is to produce an RPC-based Cosmic Ray Trigger for:**
  - ❑ the Commissioning of RPCs, to test the detector efficiency
  - ❑ the Magnet Test-Cosmic Challenge
  - ❑ later running of CMS as ***Technical Trigger***, to calibrate the detectors in the off-beam periods
  
- **The main requirements are:**
  - ❑ Compact
  - ❑ Inexpensive

→

**Use existing infrastructures and services (electronics and cables in the experimental hall)**

## The Resistive Plate Chambers are part of the CMS Muon Trigger System





## *Cosmic Trigger with RPC Trigger electronics?*



- In CMS the RPC Trigger Boards are connected in vertex geometry, which is not adequate to cosmic trigger
- It could be possible with additional optical splitters and TBs, but the new proposed architecture provides redundancy and an independent tool for calibration and debugging
- Overall costs are similar to the solution with additional splitters and TBs



# *RPC Technical Trigger: Implementation*



**Phase I: Sector-based Trigger** for testing RPC  
(and DT) during Commissioning and MTCC

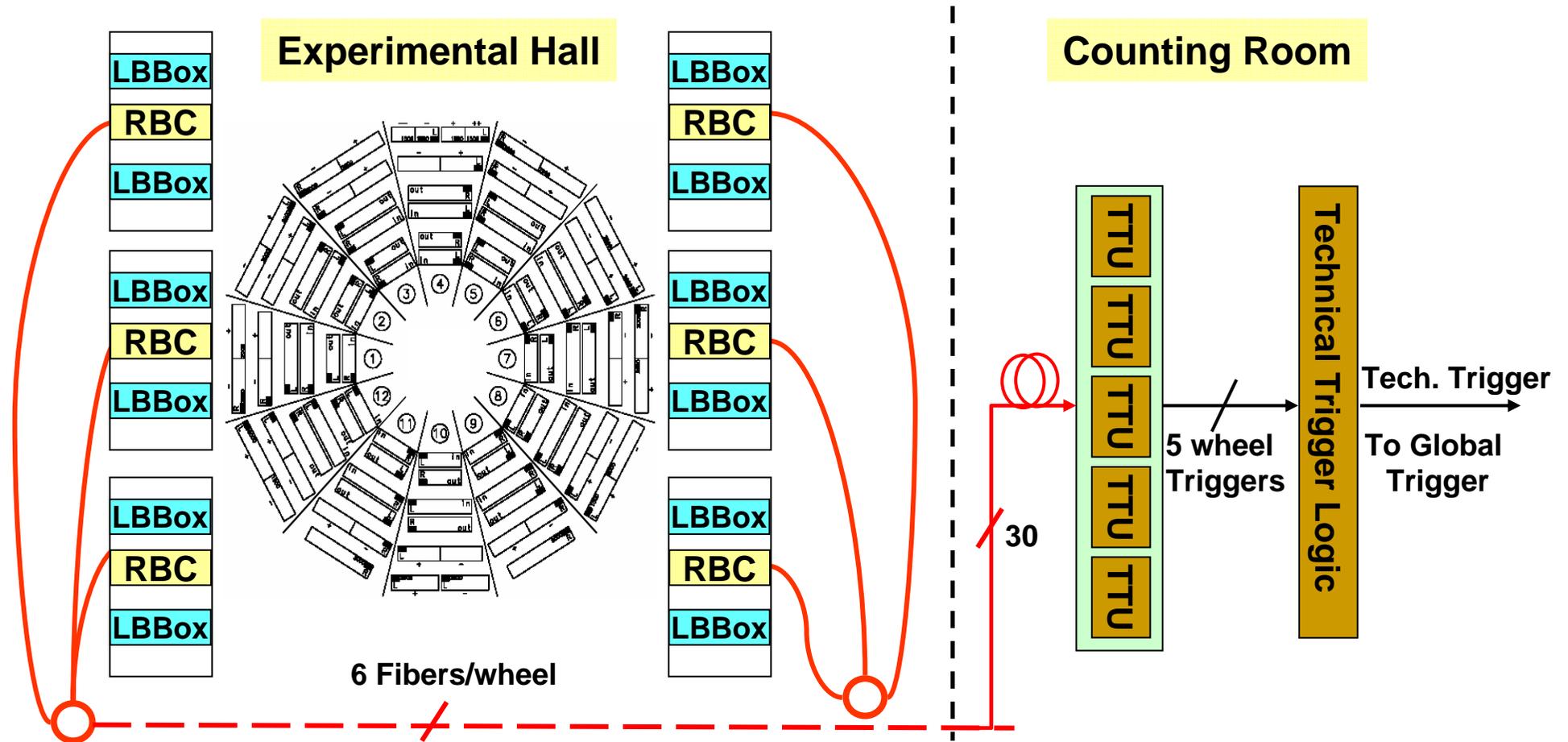


RBC (RPC Balcony Collector), on the detector

**Phase II: Wheel-based trigger (Technical trigger)**  
to be used during CMS



RBC + TTU (Technical Trigger Unit), in the Counting Room





## *RBC Implementation*



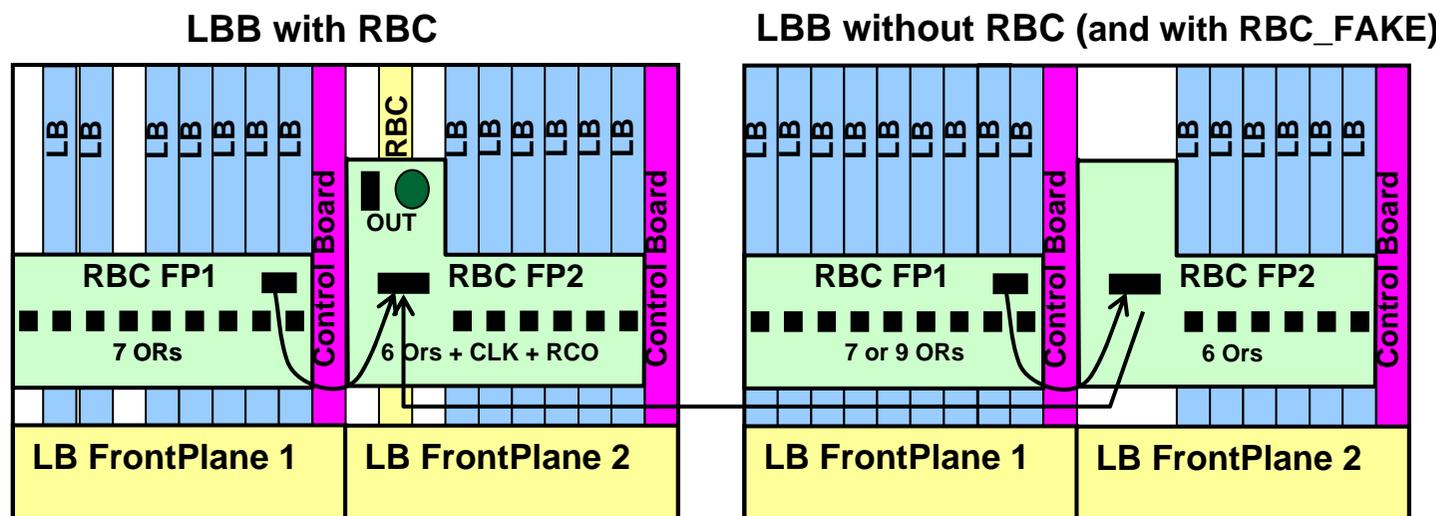
- The RPC signal cables (LVDS) are connected to the *Link Boards* (LB) for synchronization, data compression and optical conversion
- Each LB reads 96 strips of one  $\eta$  partition (1 roll = half/chamber) and can produce 1 OR to be used for our goal
- On LB front-panel, the CSC connector is used only in the Forward region, to send synchronization signals from RPC to CSC. It can be used in the Barrel to send signals from LB to RBC
- In the endcap, the cosmic muon rate is very low and not adequate for fast monitoring run with cosmics



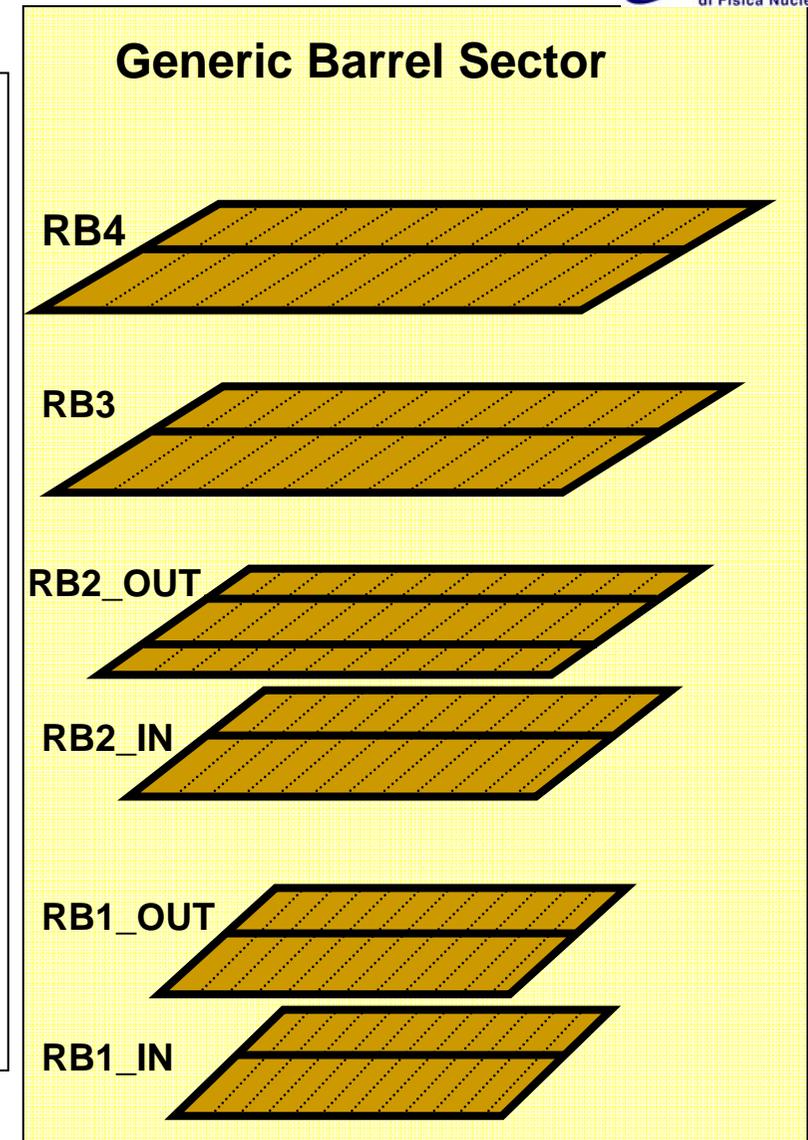
Technical Trigger involves only the Barrel RPCs

- Each *LBox* (LBB) houses 13 or 15 LBs of 1 Barrel Sector
- The LBBs are distributed in the 30 periphery racks in groups of 2
- We can house 1 RBC/rack  $\Rightarrow$  1RBC/2 sect  $\Rightarrow$  30 RBCs in total

- RBCs will be housed in slot #12 of LBBox of odd sectors. The ORs and LHC\_Clock are collected by 2 FrontPlanes
- RBC\_Fake (just a connector collecting the ORs to be sent to RBC) will be housed in slot #12 of LBB of even sectors
- I<sup>2</sup>C (from Control Board) and Power Supplies will be accessible on the backplane



- **Receive 2x13 (or 15) ORs from LB (LVDS)**  
(OR of 96 strips (1 bi-gap = half RPC))
- **Mask noisy/dead Ors**
- **Produce Sector Trigger (LVDS) according to pre-loaded patterns, with selectable Majority level (1÷6)**
- **Force selected ORs to be in the coincidence, to increase trigger selectivity**
- **Introduce latency (step = 25 ns) for synchronization with other triggers**
- **I<sup>2</sup>C Interface**
- **Transmit input OR to Counting Room using the GOL optical transmitter for Wheel-based trigger**



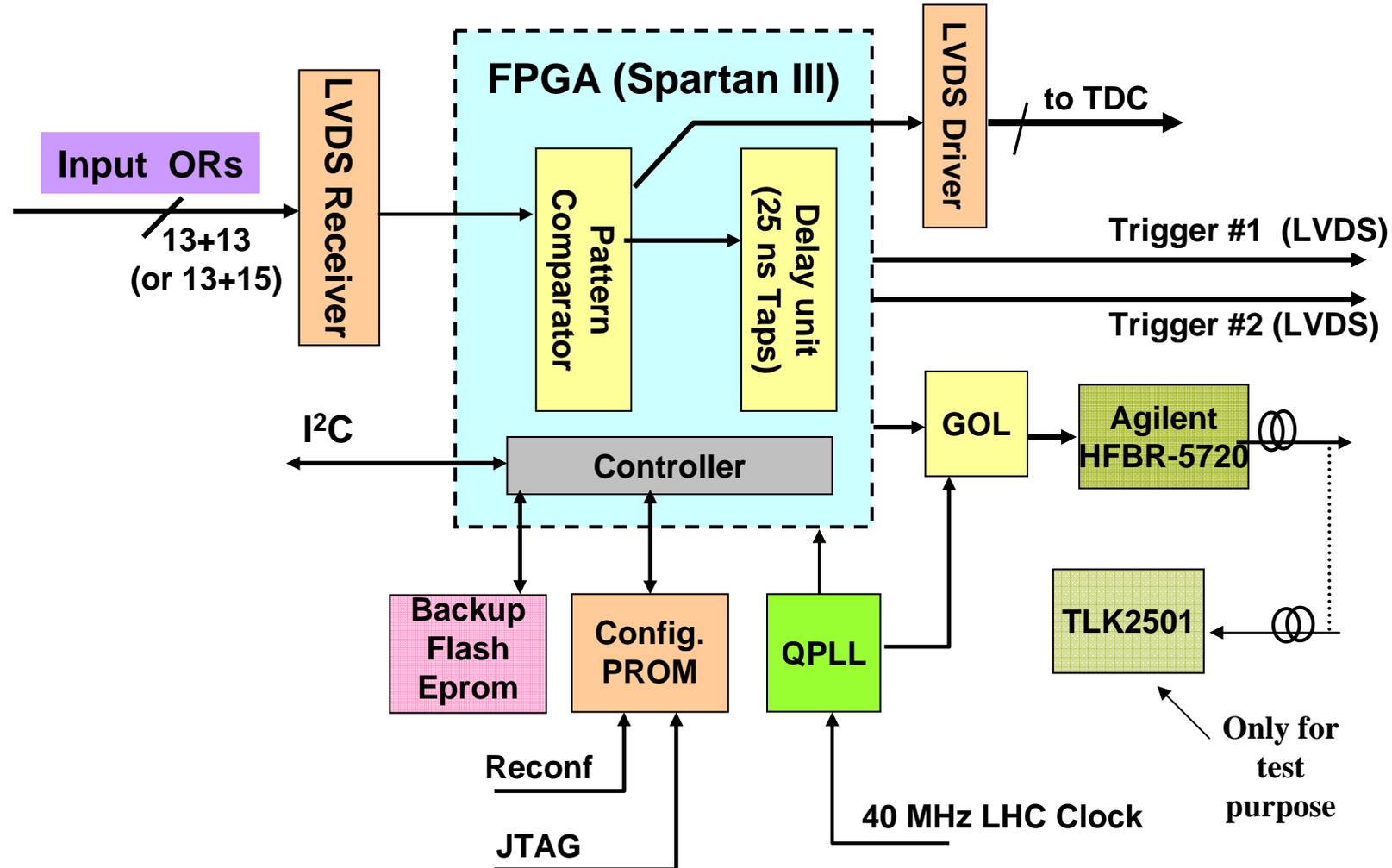


## *RBC Main Features*



- Based on Xilinx Spartan-3
- Configure with JTAG through Flash Prom
- Not inserted in the CCU chain controlling LBs
  - ⇒ firmware upgrade only *in situ*
  - This is not a major limitation, since all internal parameters and muon patterns are configurable via I<sup>2</sup>C
  - The ORs will be available also in the Counting Room, where the TTU Boards might be upgraded “on line” through Slow Control

# RBC Block diagram





## *RBC SEU Strategy*



On the detector periphery the environment is not critical:

- **Total DOSE < 1 krad**
- **Neutron flux ( $E > 20 \text{ MeV}$ ) <  $100 \text{ cm}^{-2}\text{s}^{-1}$   $\Rightarrow$  Fluence <  $10^{10} \text{ cm}^{-2}$**

**Optical transceiver: Agilent HFBR-5720L**

**Tested by E. Denes, T. Kiss et al. (ALICE)**

- **Fluence:  $10^{11} \text{ n/cm}^2$  at different energies: 10 MeV, 150 MeV, 180 MeV**

**Serializer**

**Rad-tolerant GOL chip developed at CERN**

**The most sensitive device is the SRAM – FPGA!**



## *RBC SEU Strategy*



### Test on Spartan-3

- Performed by Fabula et al. (Xilinx) and presented at MAPLD 2004
- Test facility: Los Alamos Neutron Science Center

$$\sigma_{\text{bit}} \sim 3.0 \times 10^{-14} \text{ cm}^2/\text{bit} \rightarrow \sigma \sim 2.9 \times 10^{-8} \text{ cm}^2 \quad (E > 10 \text{ MeV})$$

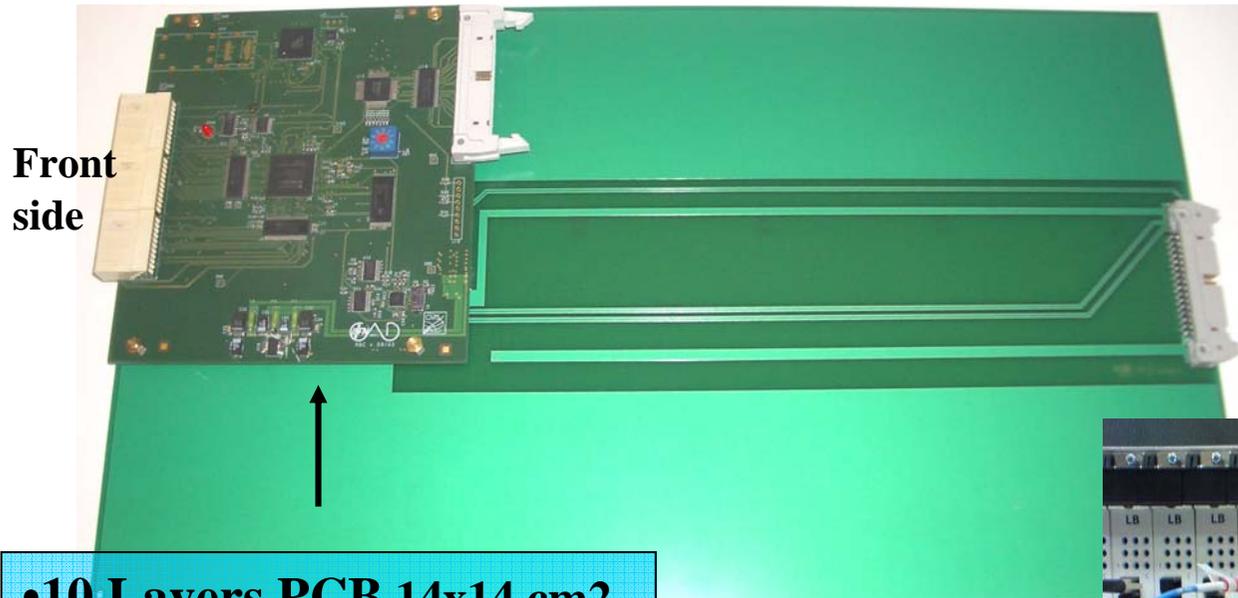
$$\text{Time to Configuration upset} = 1/(\sigma * \text{Flux}) \sim 95 \text{ Hours/device}$$

Since also LBs are based on Spartan-3 devices, the same strategy is adopted to mitigate the SEU effects on FPGA:

- periodical re-load configuration SRAM from Flash EPROM (extremely robust against our level of irradiation)
- upon the receipt of the *Reconf* signal from LB, the time to load the bitstream is ~ 200 ms
- backup Flash Memory to store internal registers for fast reload



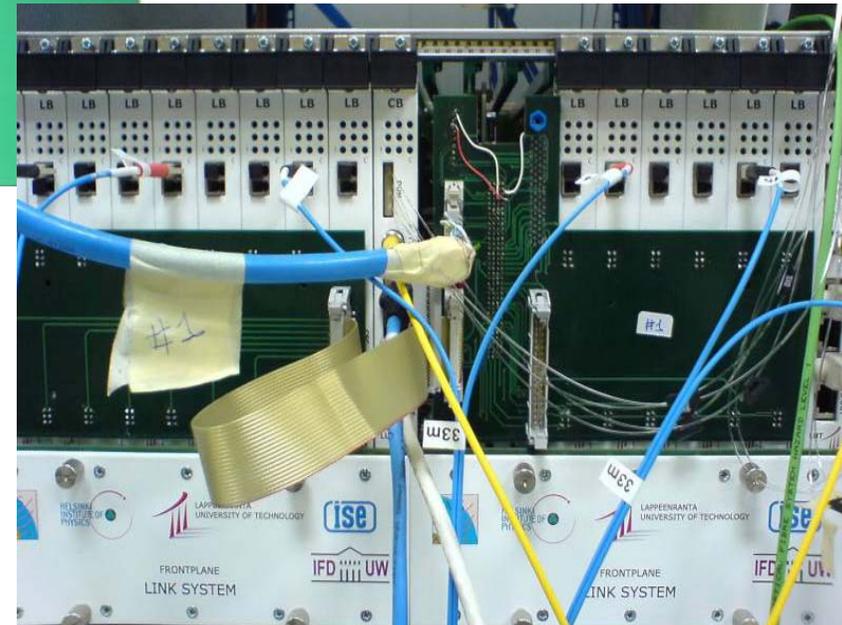
# RBC prototype



## Backplane connector:

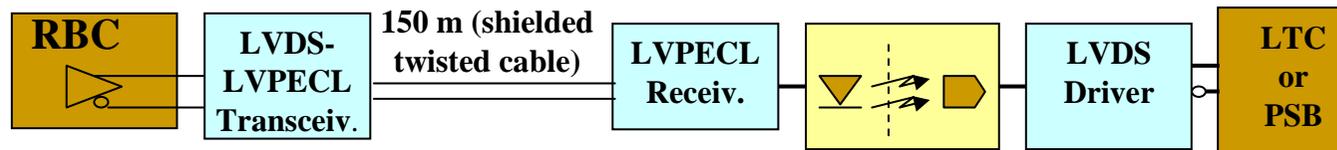
- 3.3 V
- 2.5 V
- GND
- I<sup>2</sup>C

•10 Layers PCB 14x14 cm<sup>2</sup>  
to be housed on Mother  
Board, fitting LBox  
dimensions

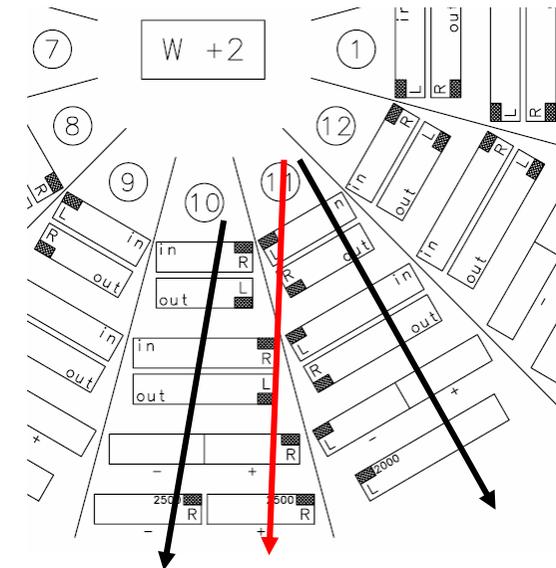


# RBC Trigger in MTCC

Since last June, **2 RBC prototypes + 1 RBC\_fake** are providing two Cosmic Triggers to the detectors involved in the CMS Magnet Test Cosmic Challenge



- **W+1:** Sect. 10 → **RBC1**
- **W+2:** Sect. 10  
Sect. 11 → **RBC2**  
Sect.10-11 patterns  
(but only Sect.10 equipped with LBs during MTCC phase I)
- **RPC-TB** pointing to the tracker



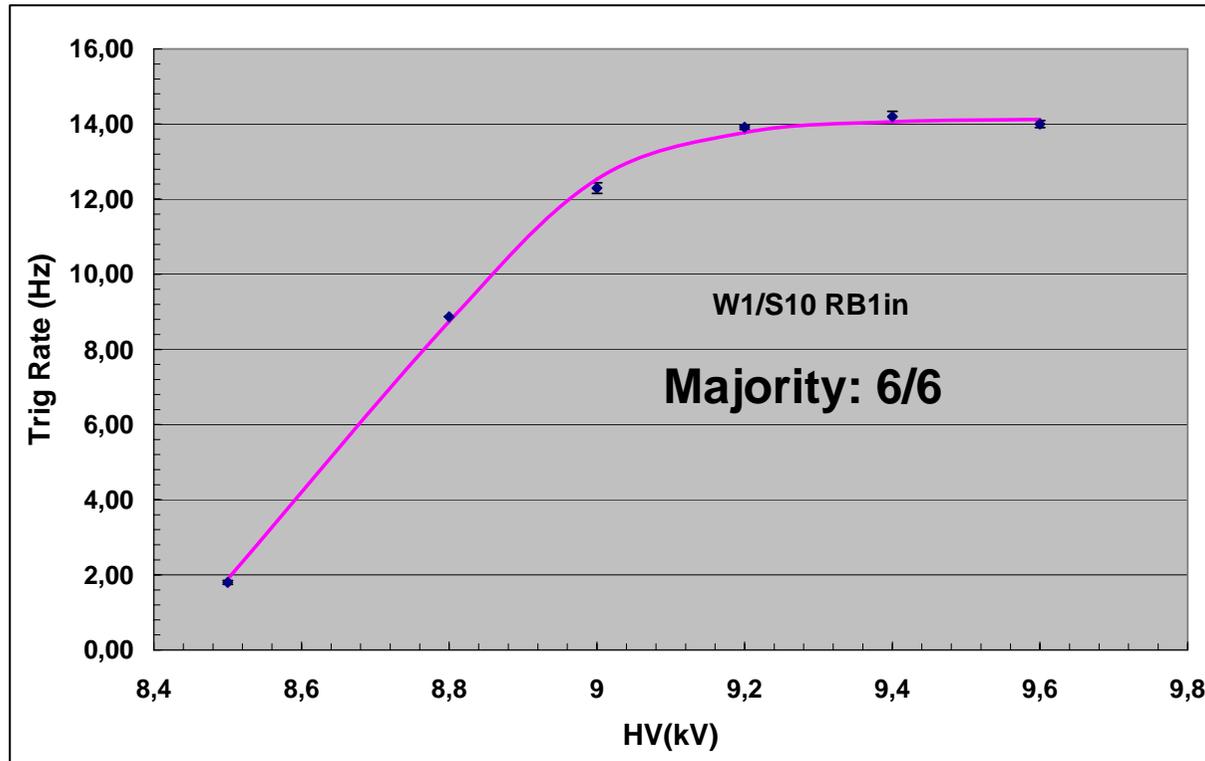
The RBC triggers were well synchronized with RPC-TB trigger and with other muon triggers (DT and CSC)



## RBC Trigger rate in MTCC: rate plateau

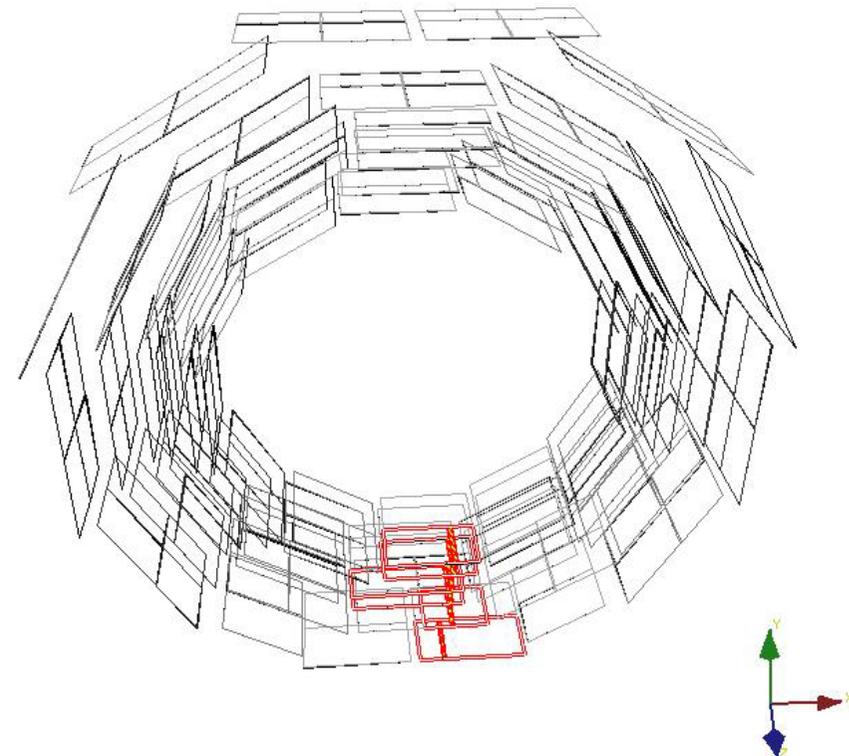
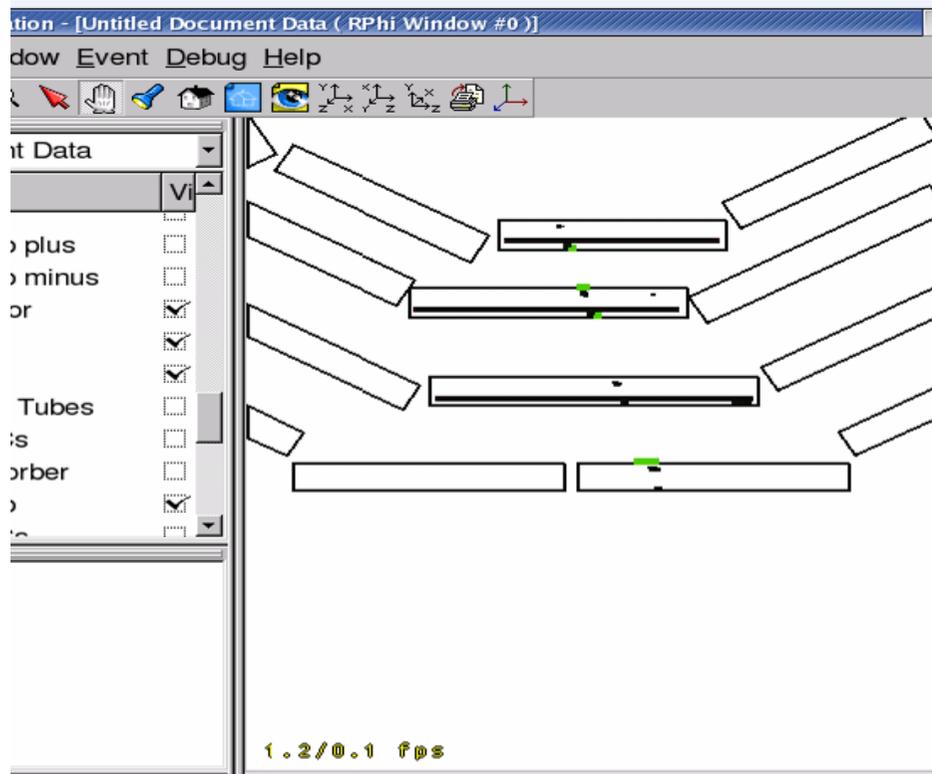


Some measurements to find the working point of the RBC1 and RBC2 triggers vs. variation of the RPCs HV set points



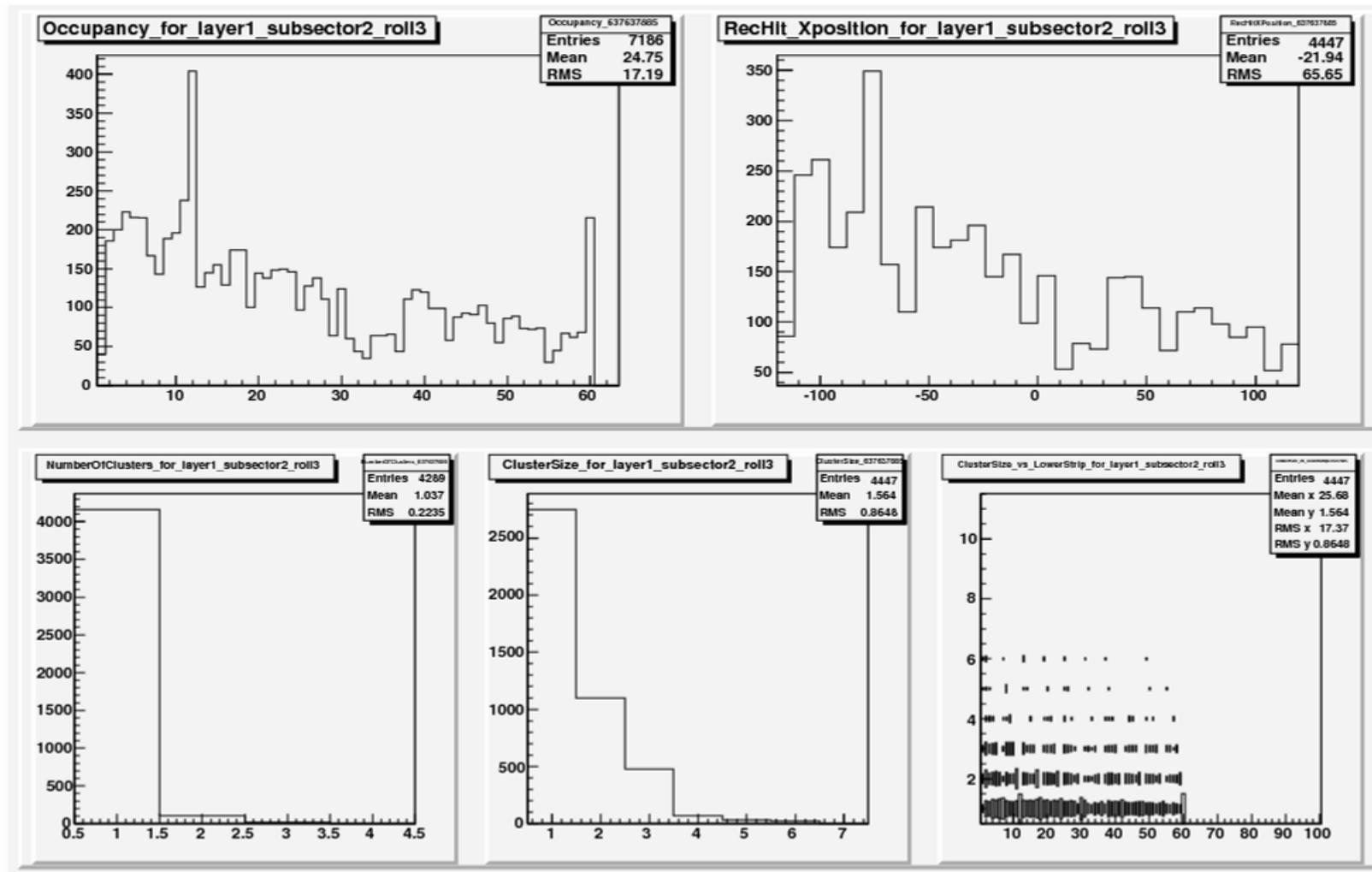
**Majority 5/6** - trigger rate ~30 Hz per wheel  
**Majority 6/6** - trigger rate ~13 Hz per wheel

## Combined offline **RPC** (green) and DT digis



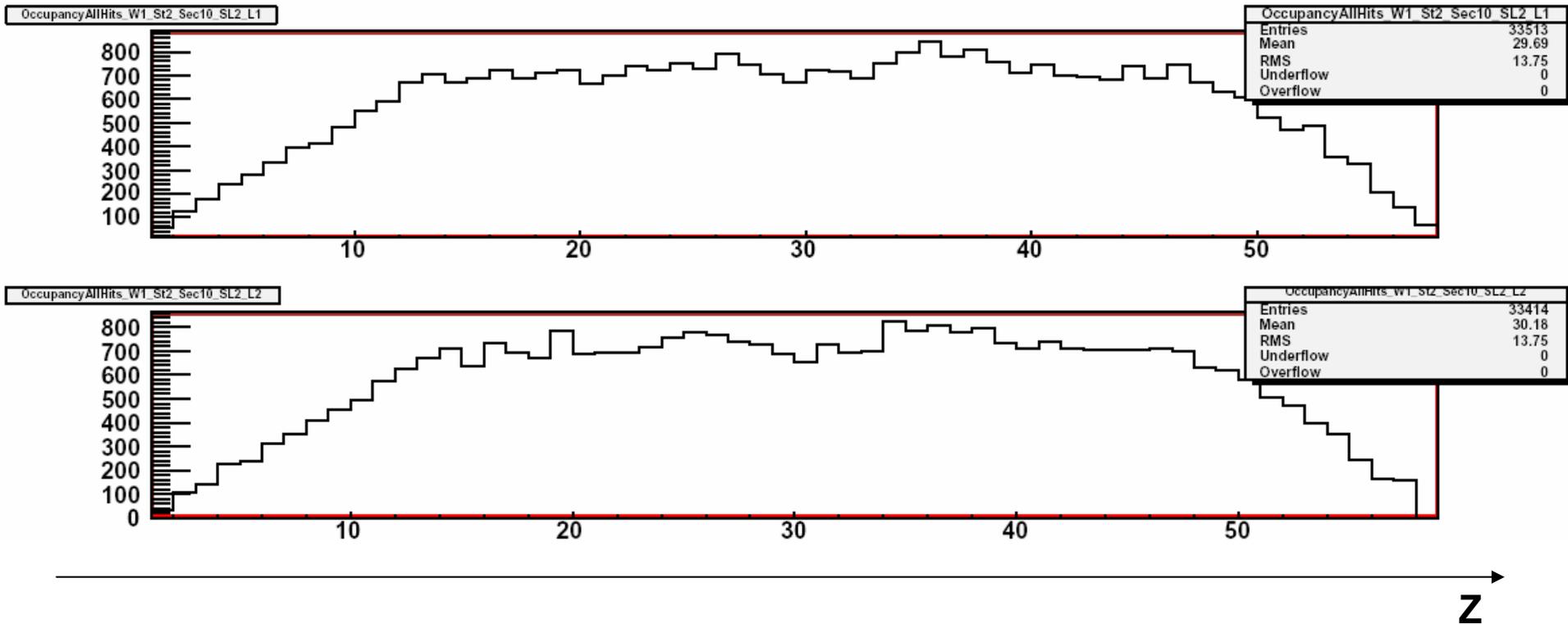


# Examples of DQM plots: RPC Barrel Wheel +2 Sector 10 Station 4

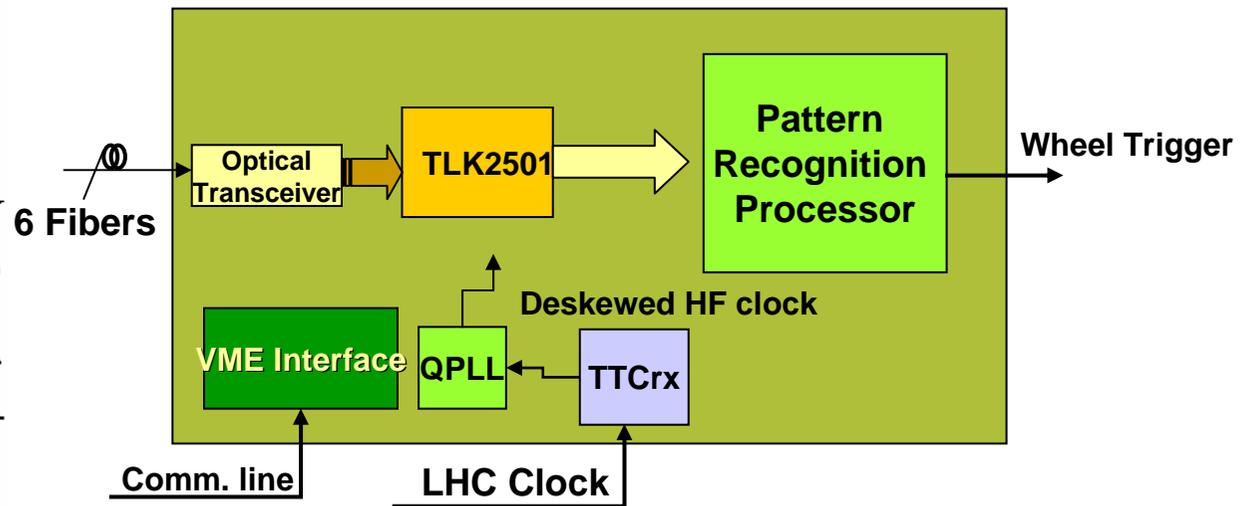
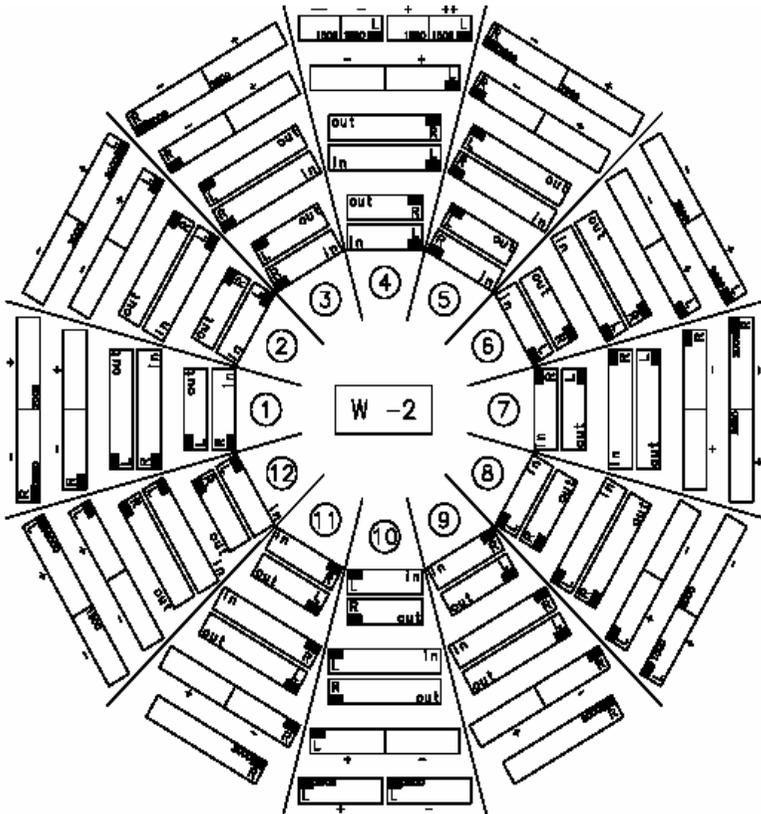




# Examples of Drift Tube occupancy plots triggered by RBC



- Receive optical link from RBCs
- Combine ORs from 1 Wheel and produce Wheel Cosmic Trigger → Global Trigger as **Technical Trigger**





# *RPC Trigger Board as TTU*



The required functions are performed by the RPC Trigger Board (**designed by Warsaw RPC Trigger Group**):

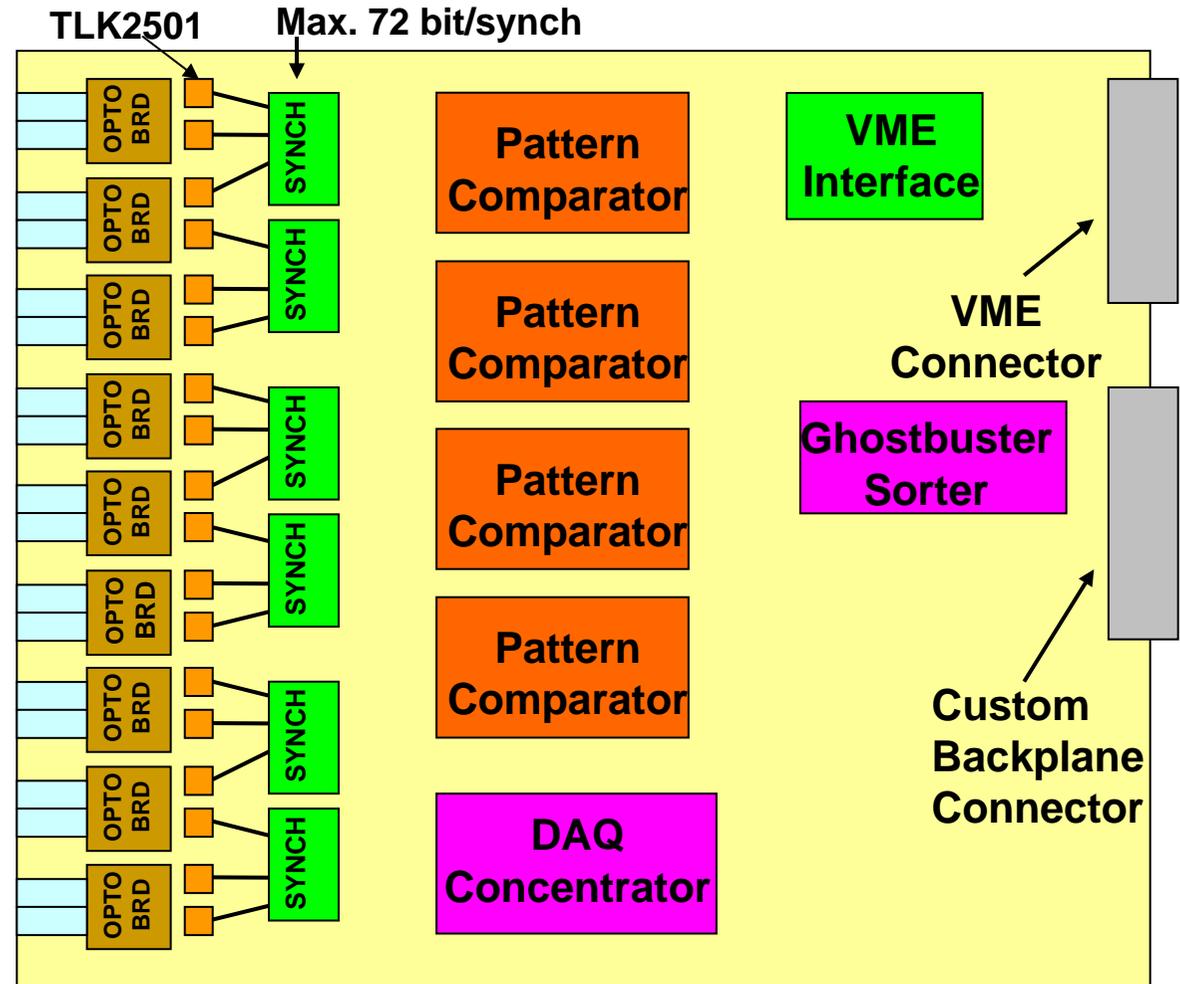
- **TTU needs:**
  1. **30 signals from detector: 1.6 GHz GOL drive multimode fiber;**
  2. **each fiber transfers 26 or 28 bits @ 40 MHz;**
  3. **signals must be synchronized;**
  4. **pattern logic to make cosmic trigger**
- **RPC Trigger Board offers:**
  1. **18 inputs: 1.6 GHz GOL driven multimode fiber;**
  2. **Opto-synch FPGA/3 optical inputs and maximum 72 bits @ 40 MHz;**
  3. **Up to 4 PAC mezzanine boards for pattern recognition algorithm**



# TB as Technical Trigger Unit



- 3 Trigger Boards can be used to cover the whole Barrel, using 12 links per TB
- The Stratix2 PAC mezzanine board have huge amount of logic cells, enough to implement cosmic pattern recognition: 1 or 2 PACs should be enough
- VHDL code for data transmission and Internal Interface (VME driven internal bus) developed by Warsaw Group can be used
- Warsaw software for FPGA upload and diagnostic tools can be used
- TTU custom backplane (for TTCrx and to send out the Trigger) must be designed, but can be derived from the design of TB backplane





## *Conclusions*



- **The RPC Technical Trigger project is under progress:**
  - **2 RPC Balcony Collector (RBC) prototypes are in use for MTCC to provide 2 Sector-based triggers**
  - **The full production is expected to be available before the end of 2006**
  - **The design of the new firmware and the backplane for the Trigger Board-TTU will start in few weeks**