



12th Workshop on Electronics for LHC Experiments

València, September 26th, 2006

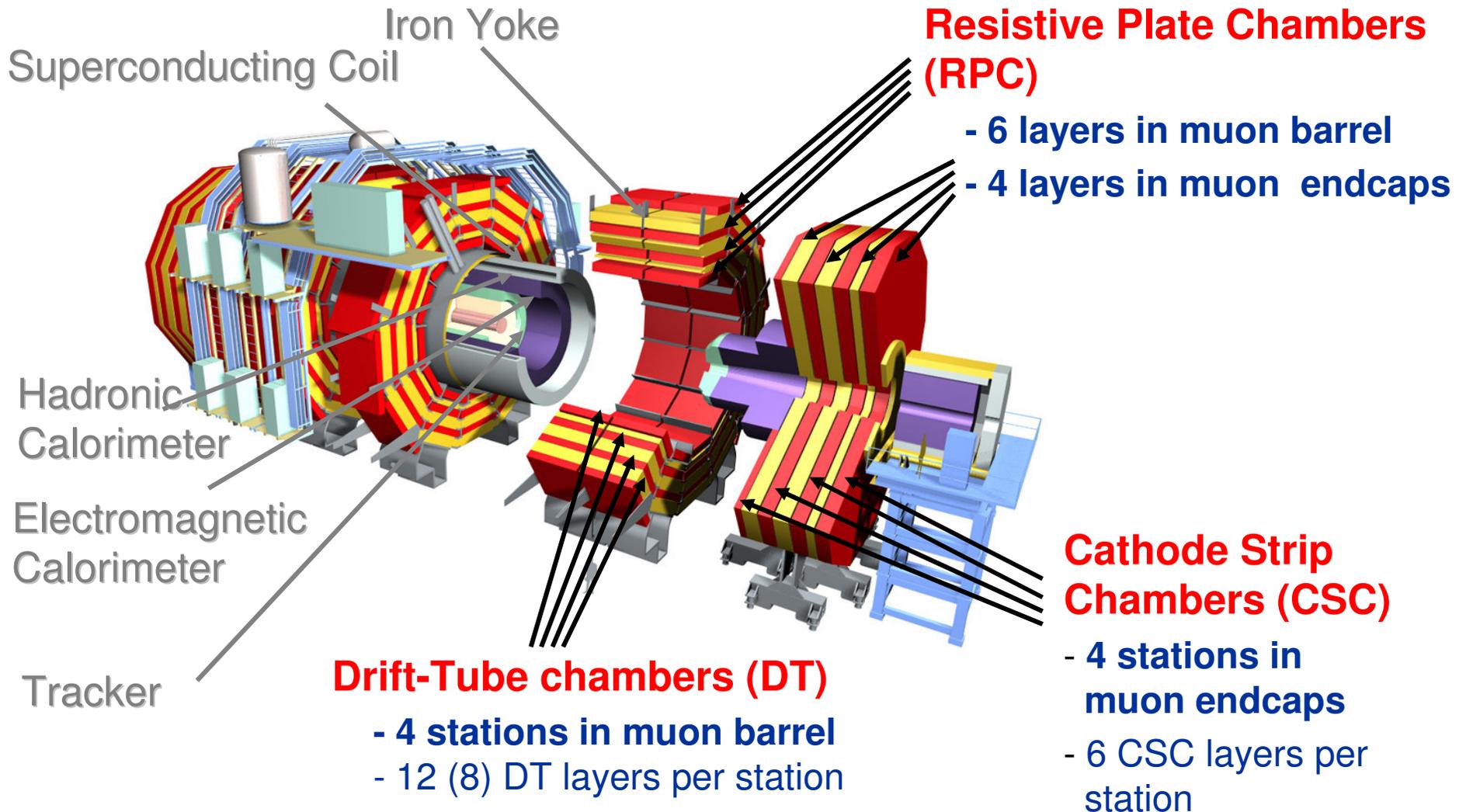


The Drift-Tube Track-Finder Trigger at the CMS Experiment

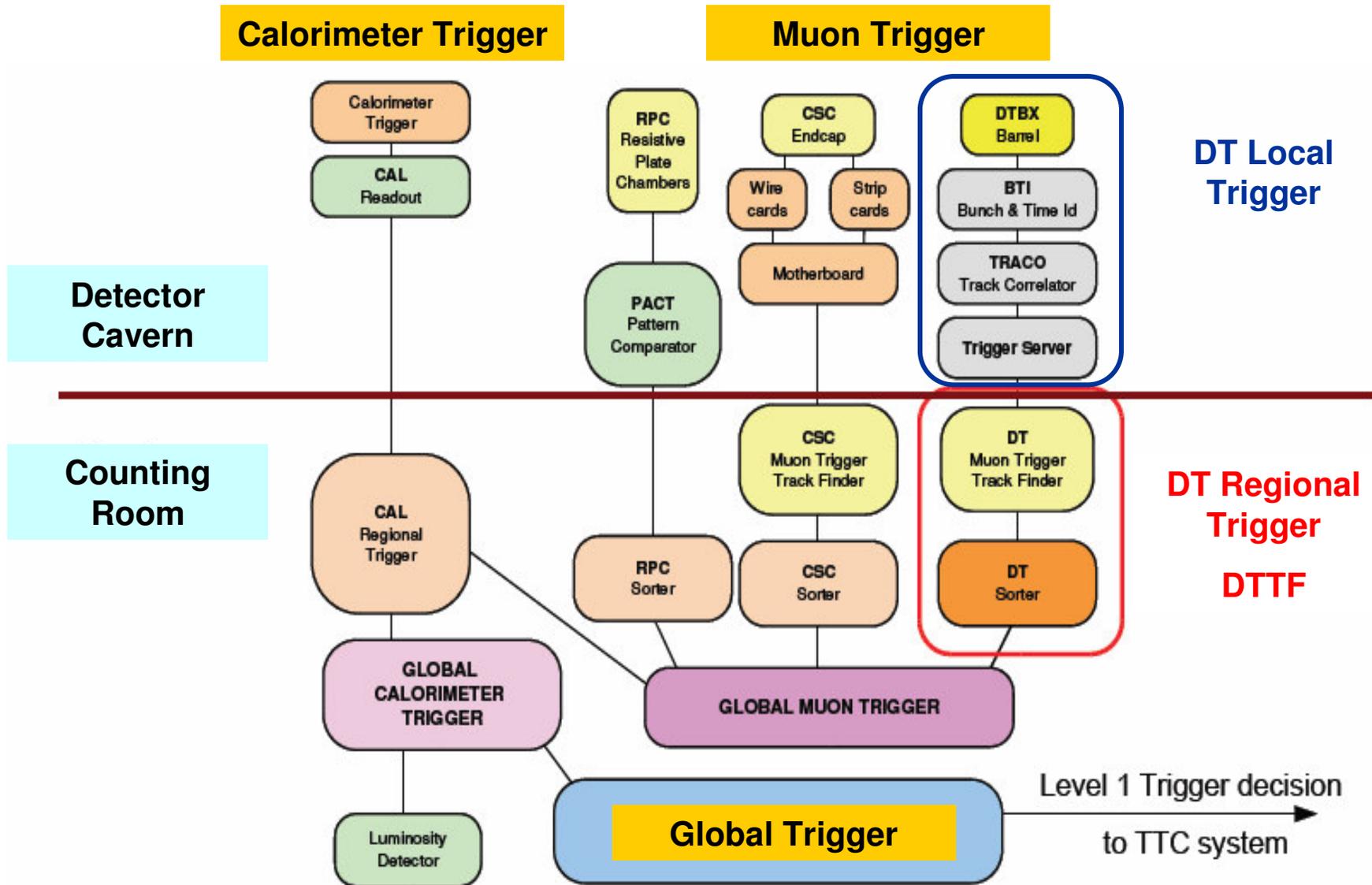
Jorge F. de Trocóniz

Universidad Autónoma de Madrid - CMS

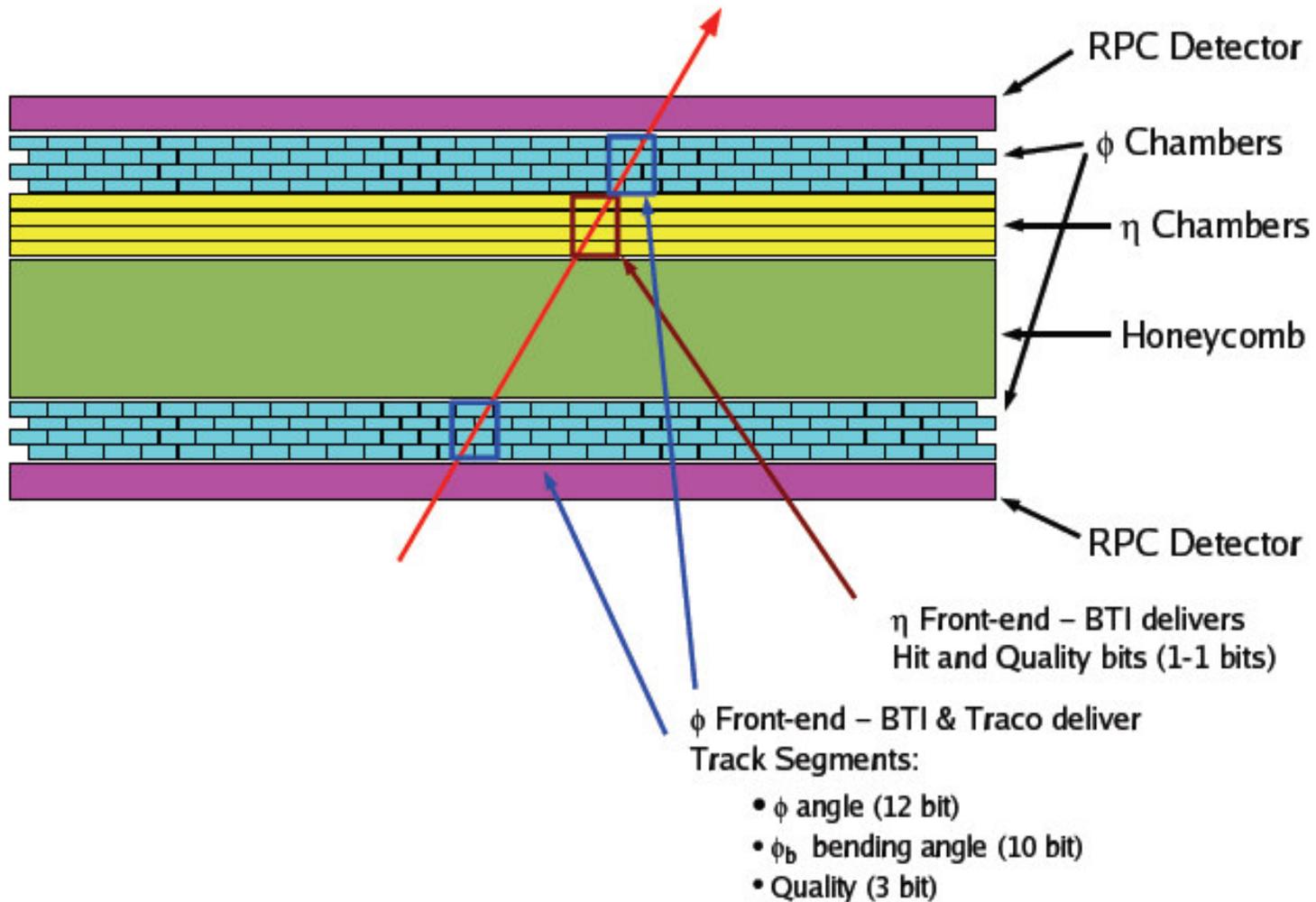
CMS and Muon Detection System



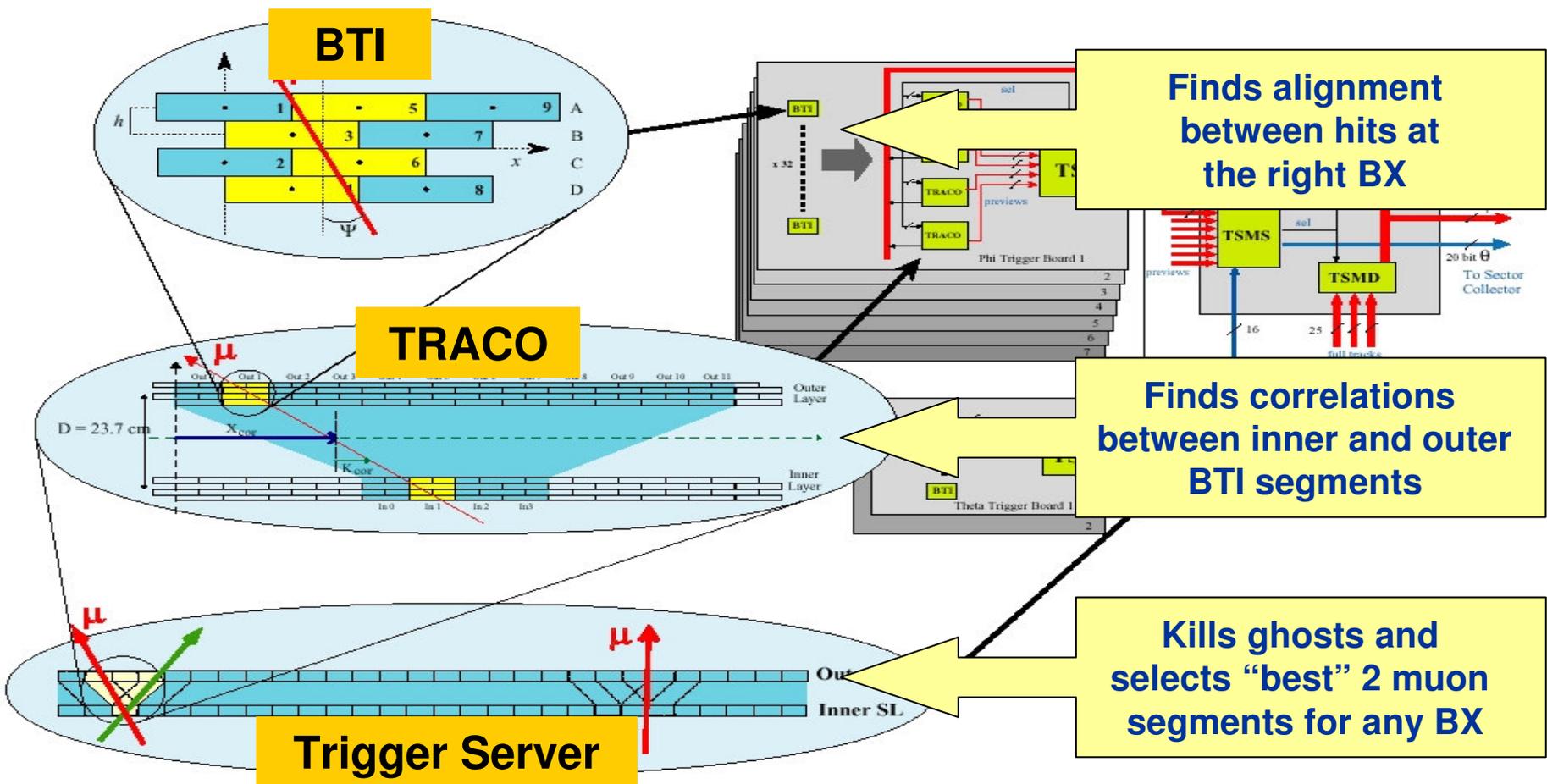
The CMS L1 Trigger



Muon Chambers and Trigger Data



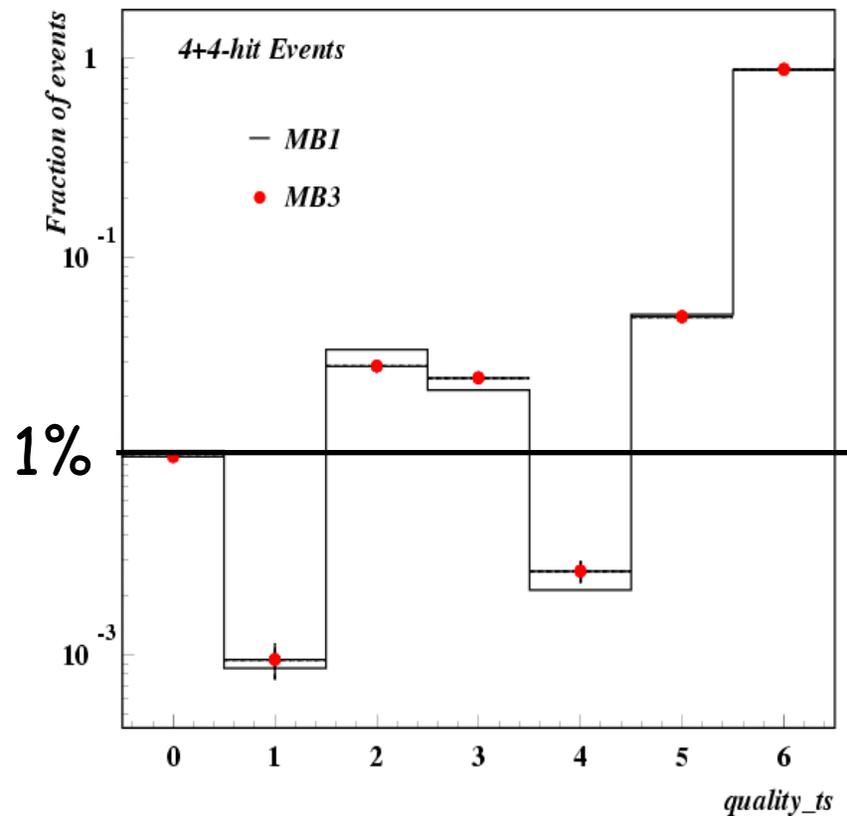
DT Local Trigger



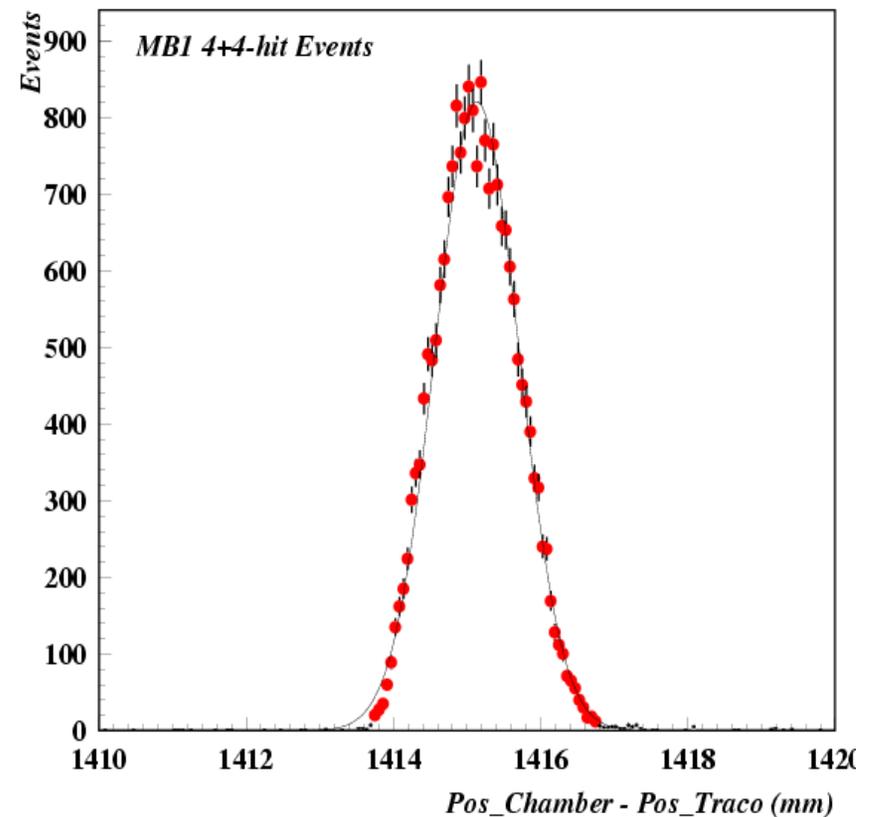
In addition, the **Sector Collector** collects segments from 4 DT stations, synchronizes them, and sends them via optical links to DTF

Beam Test 2003: Local Trigger

First tests of DT Local Trigger with real data

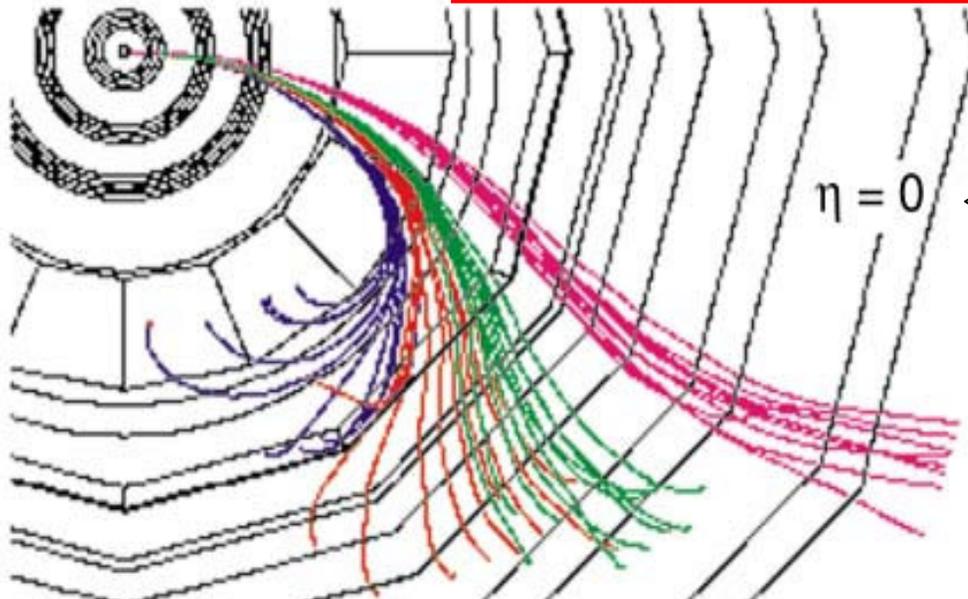


Muon efficiency at right BX: 99%



Position resolution: 0.5 mm

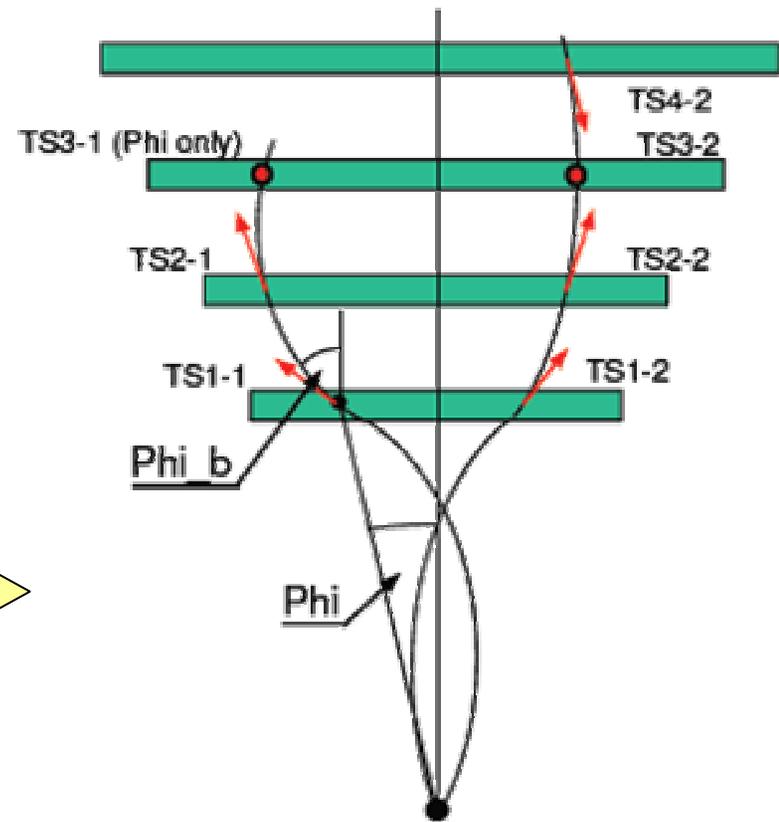
DT Regional Trigger



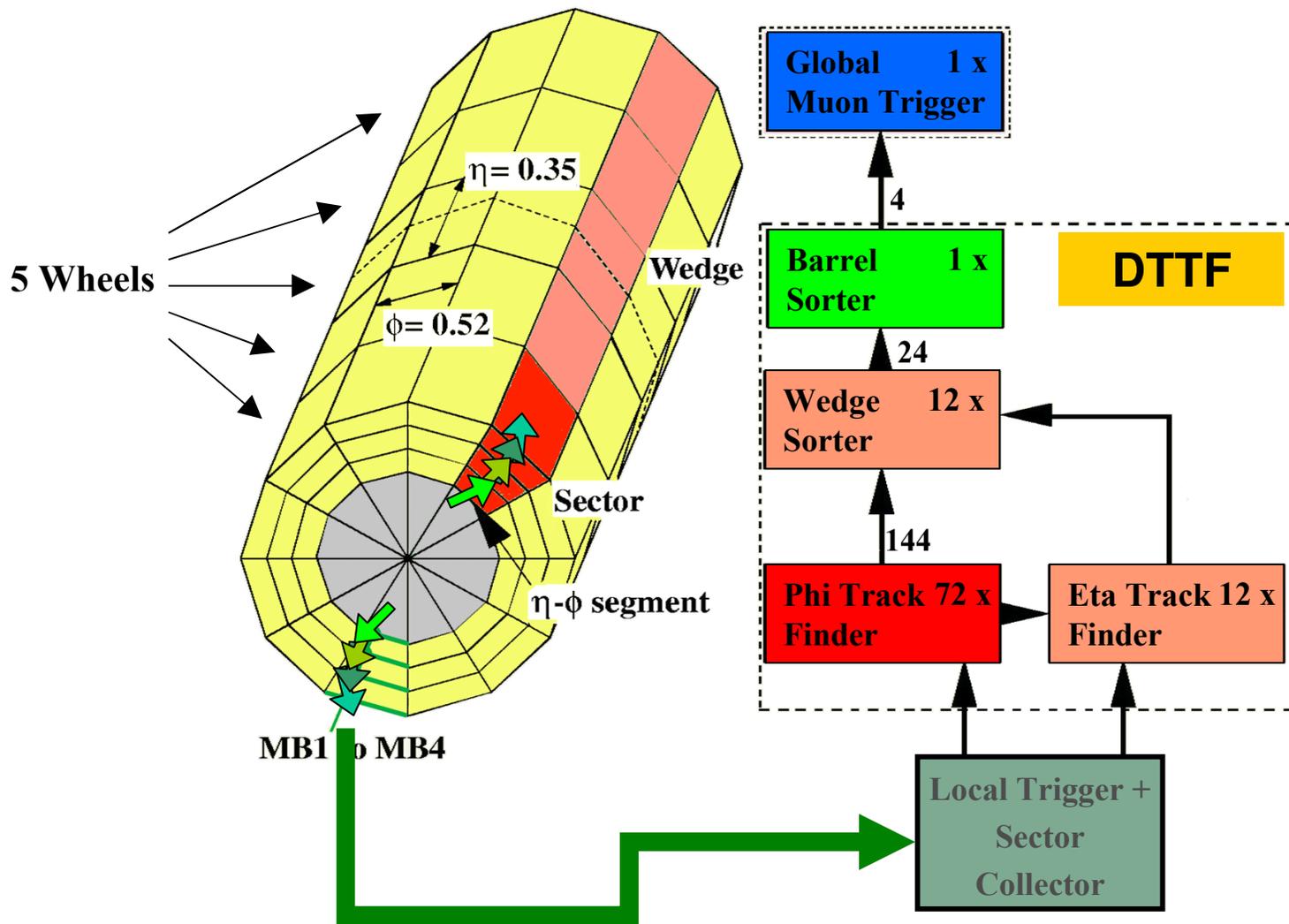
**Muon Tracks with
3.5, 4.0, 4.5, 6.0 GeV/c**

**Strong magnetic field in
iron return yoke ($\sim 2\text{T}$)
efficiently discriminates
muons as a function of p_T**

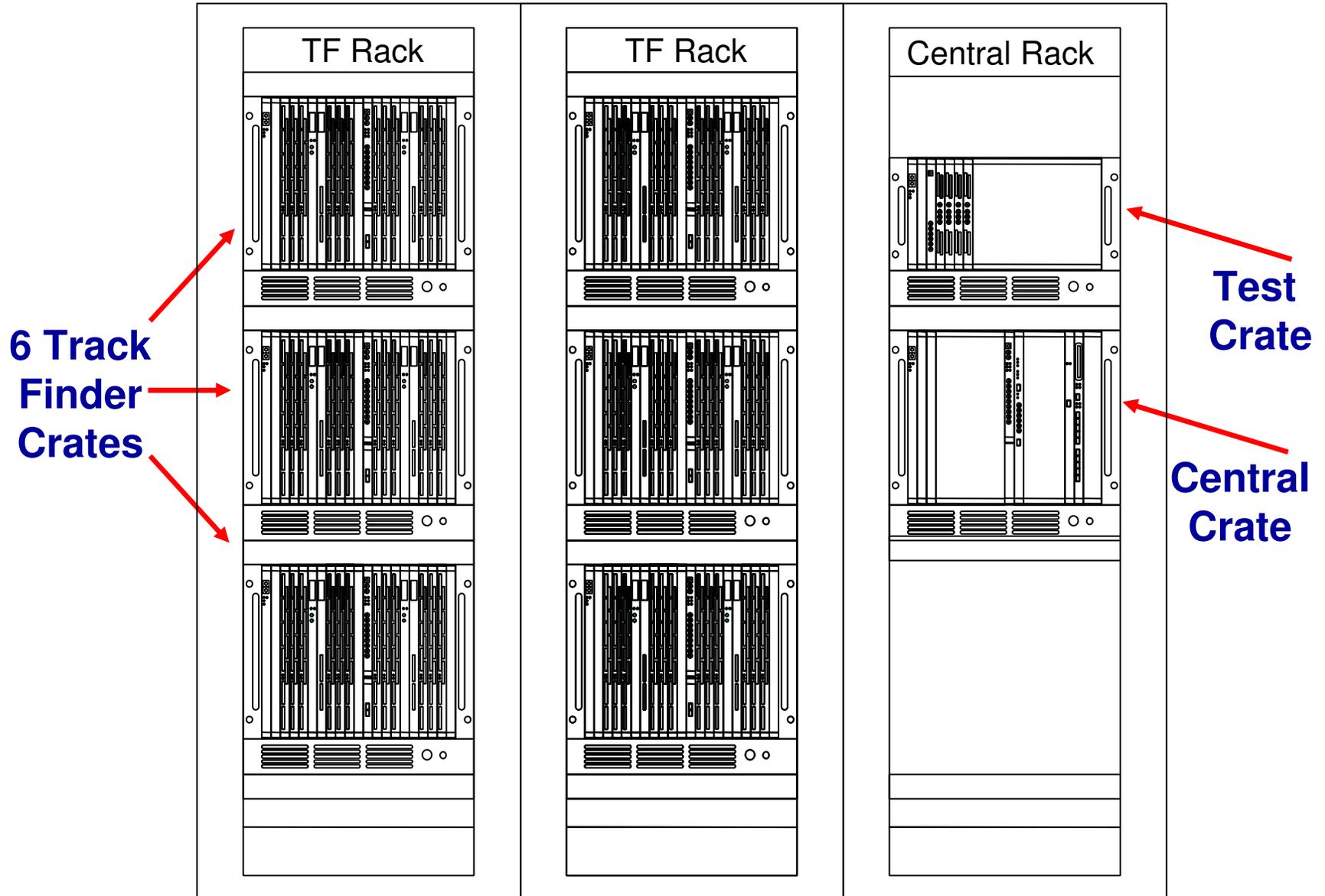
**Perform tracking
analysis in real time
for L1 Muon Trigger:
DT Track-Finder**



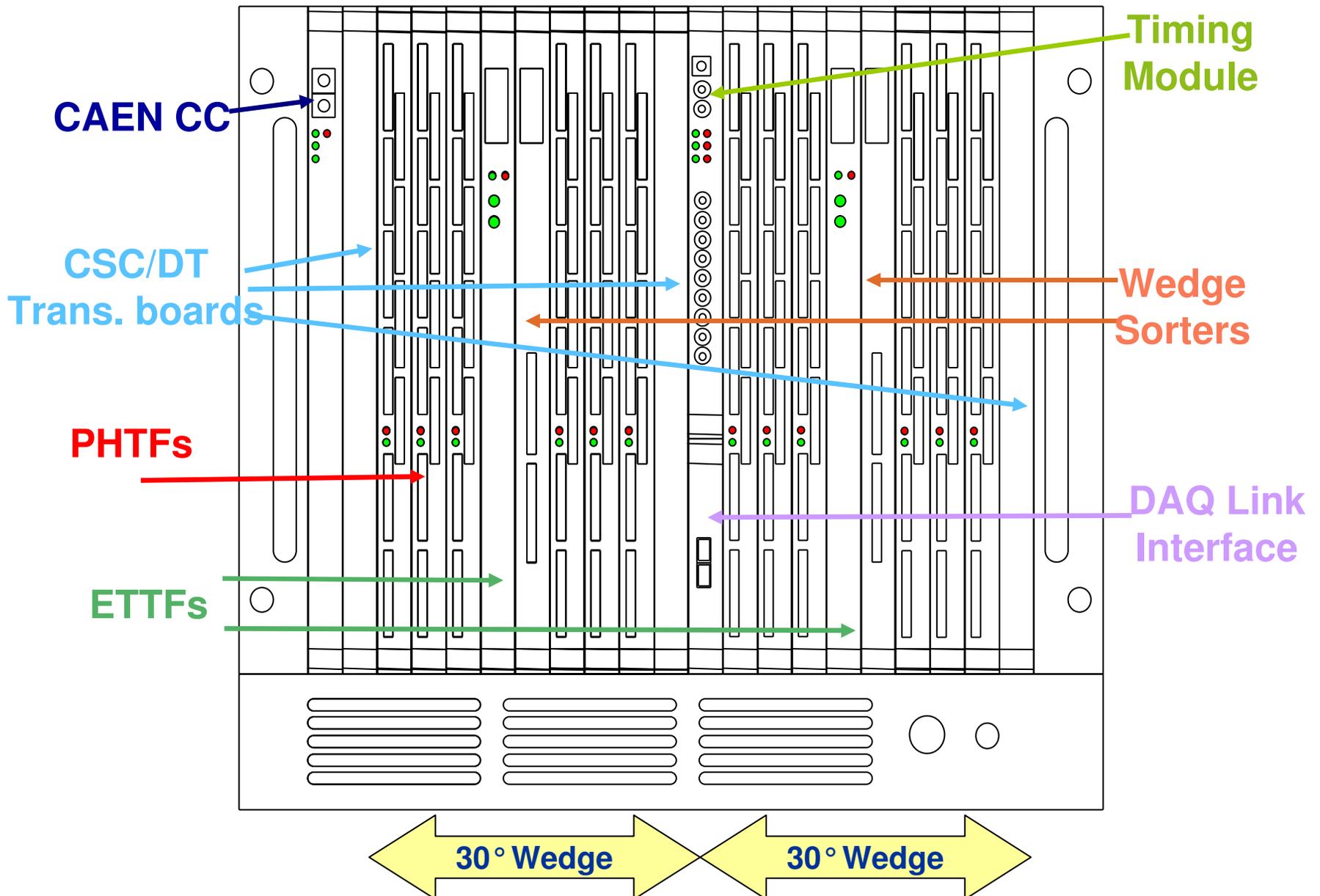
CMS Barrel Geometry



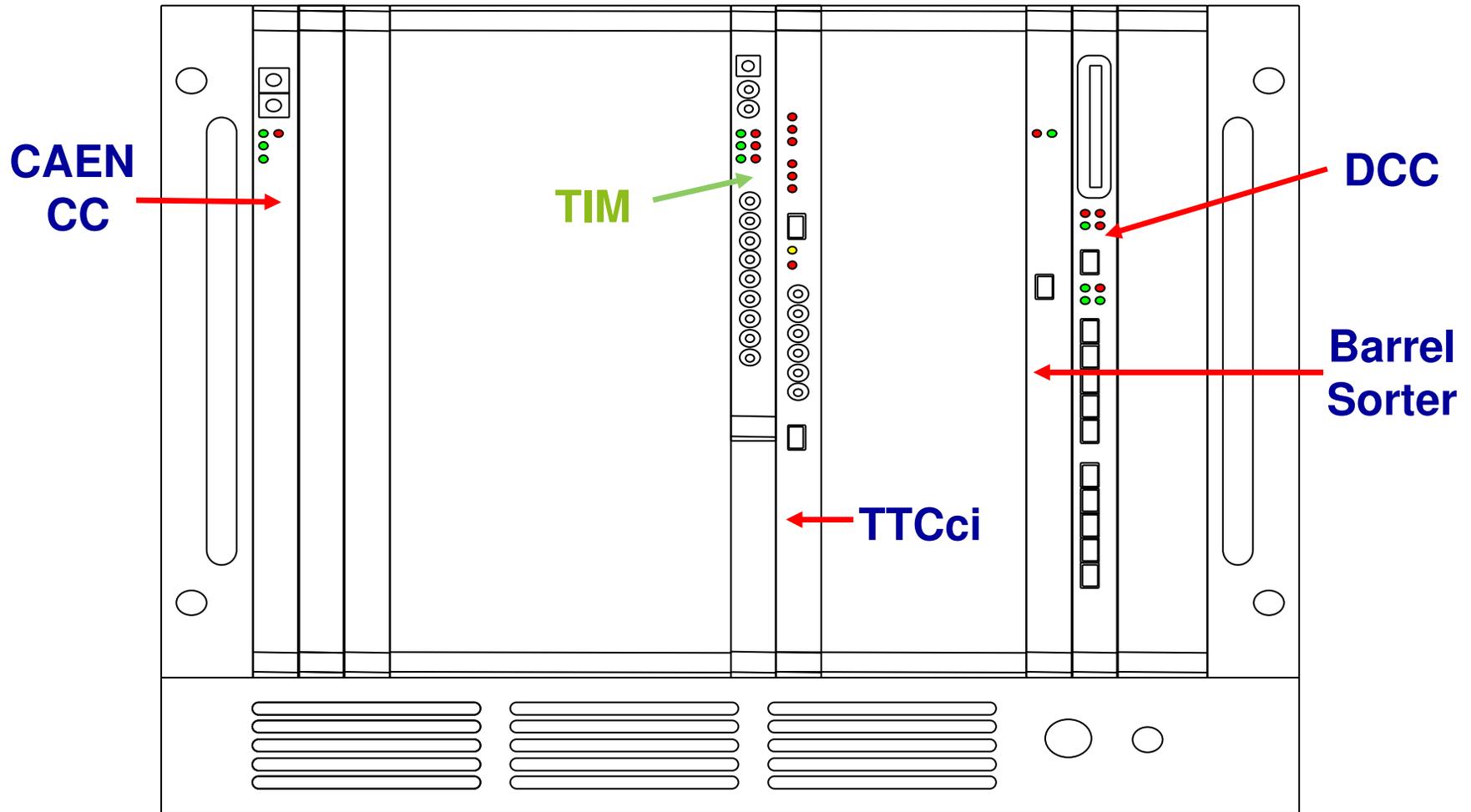
DTTF Racks



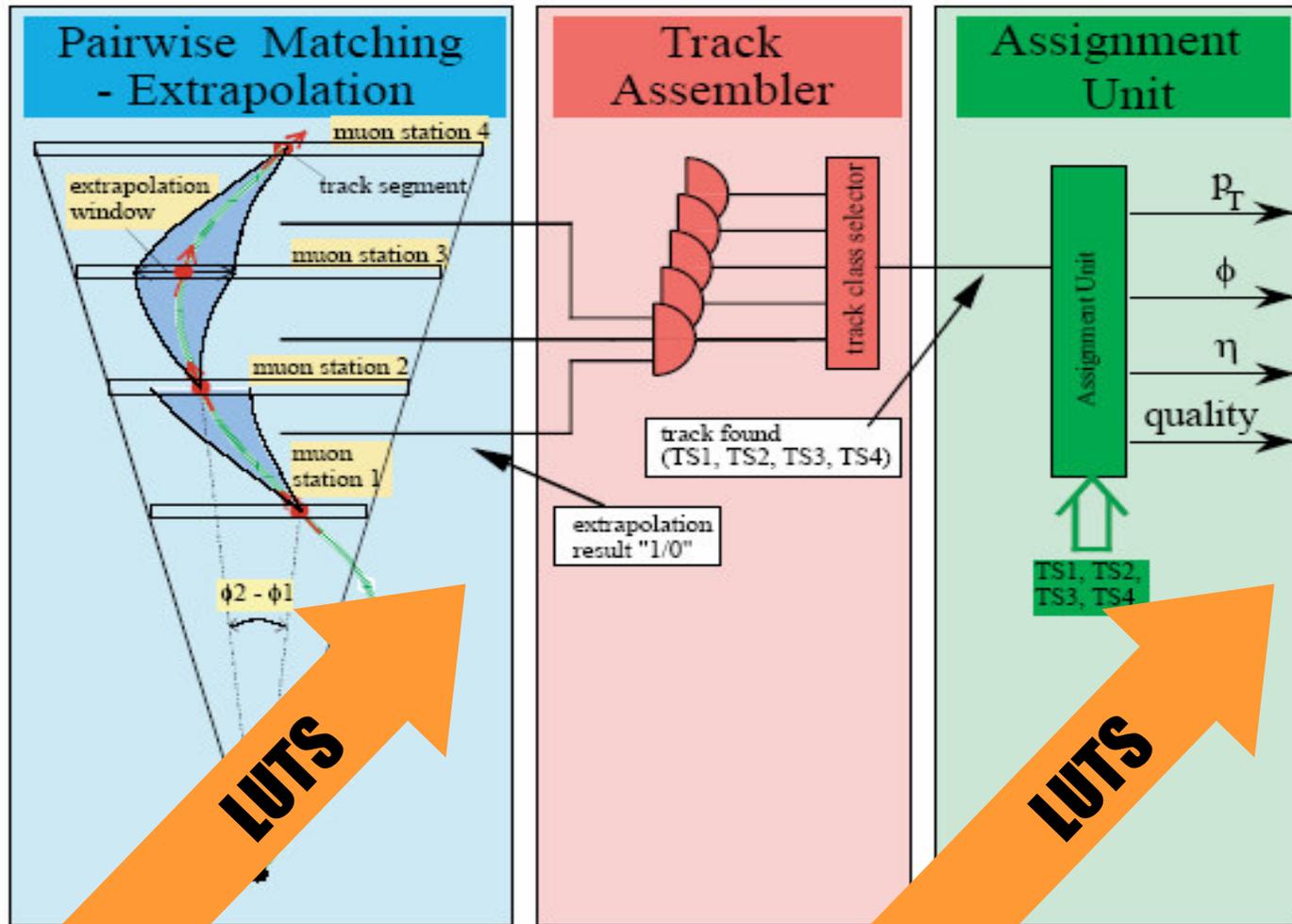
DT-TF Track-Finder Crate



DT-TF Central Crate



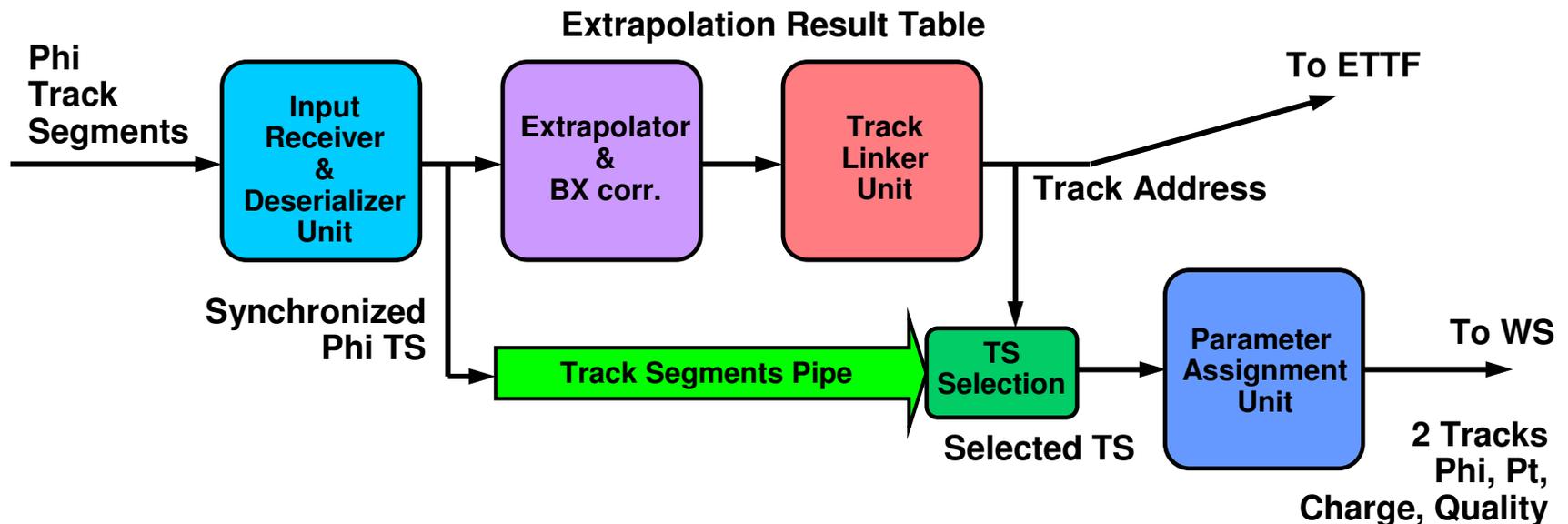
Phi Track-Finder Algorithm



PHYSICS

Phi Track-Finder Implementation

- 72 9U VME PHTF boards.
- Inputs: 506 bits @ 40 MHz; 110 bits optical inputs from Local Trigger, rest parallel ϕ - (η -) interconnections. Outer wheel PHTFs interchange info with CSC TF.



- Design based on Synthesizable Behavioral VHDL code.
- Outputs: 48 bits @ 40 MHz to WS; 2 muon transverse tracks found after 475 ns.
- In addition, output track categories sent to ETTF: 10 bits @ 40 MHz.

PHTF Board

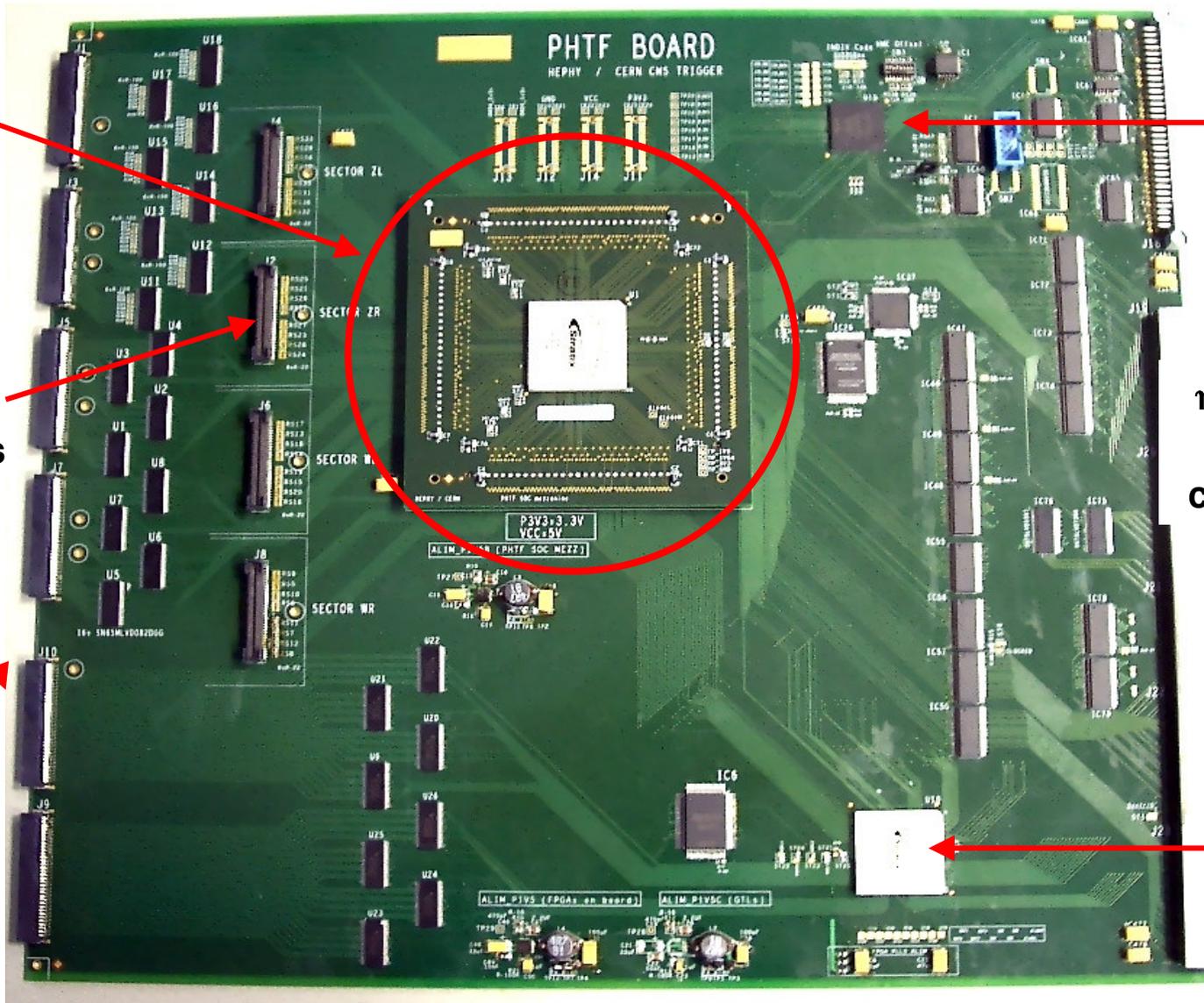
System-on-Chip (SOC) on mezzanine

ϕ -neighbor connections

VME Interface, Control & Readout

η -neighbor, ETTF, WS connections

Input Receiver



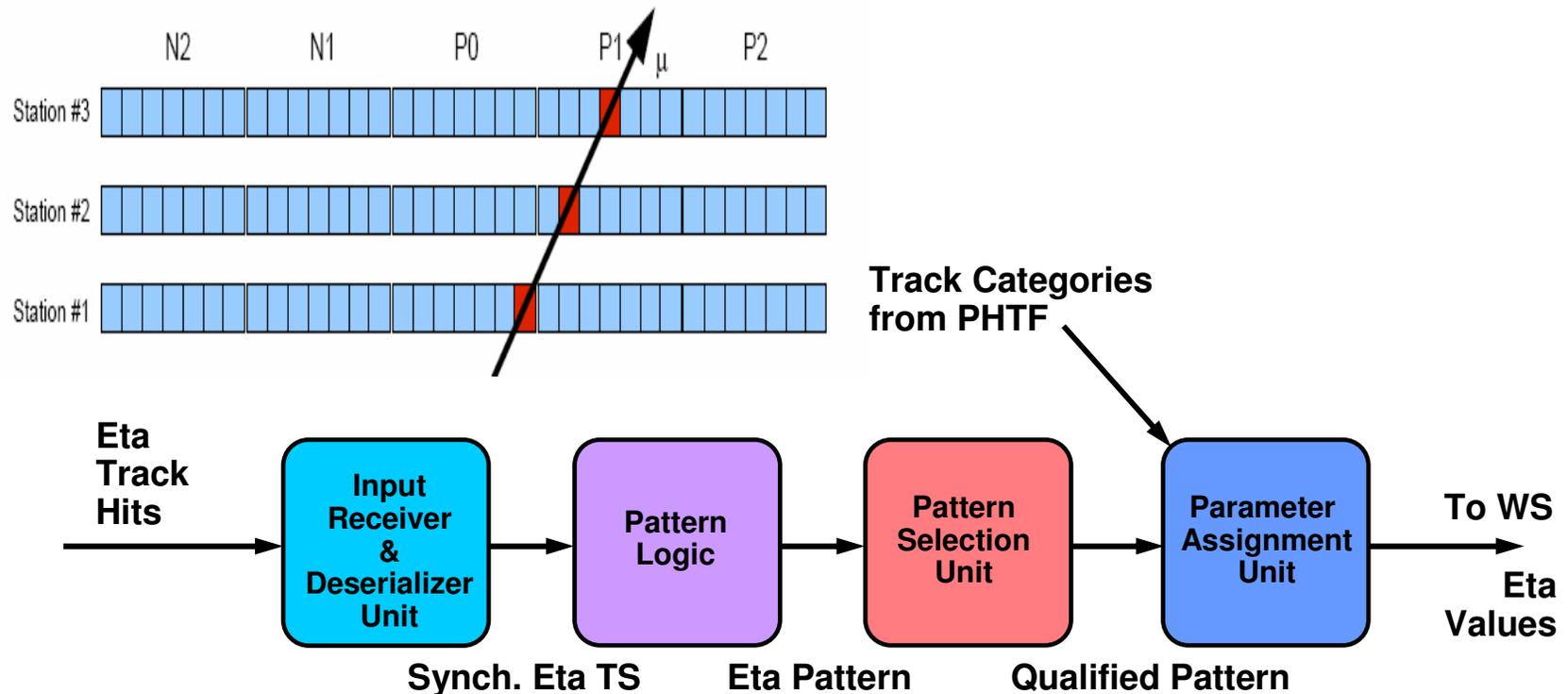
SOC Mezzanine Board

- For **Altera Stratix EP1S40** FPGA (1020 pins).
- Accommodates all Track-Finding Logic and Look-Up Tables (LUTs).
- Programmed **Spy system** (synchronous triggerable 2nd JTAG chain) to follow up internal data flow and check trigger decision.
- Used also for ETTF (Stratix EP1S25) and DCC boards.



Eta Track-Finder Implementation

- Calculates η -coordinate to PHTF tracks, based on predefined set of patterns.



- 12 9U VME ETTF boards.
- Inputs: 235 bits @ 40 MHz from Local Trigger; 60 bits @ 40 MHz from PHTFs.
- Outputs: 84 bits @ 40 MHz to Wedge Sorter; "Rough" or "Fine" η -values.

ETTF Board

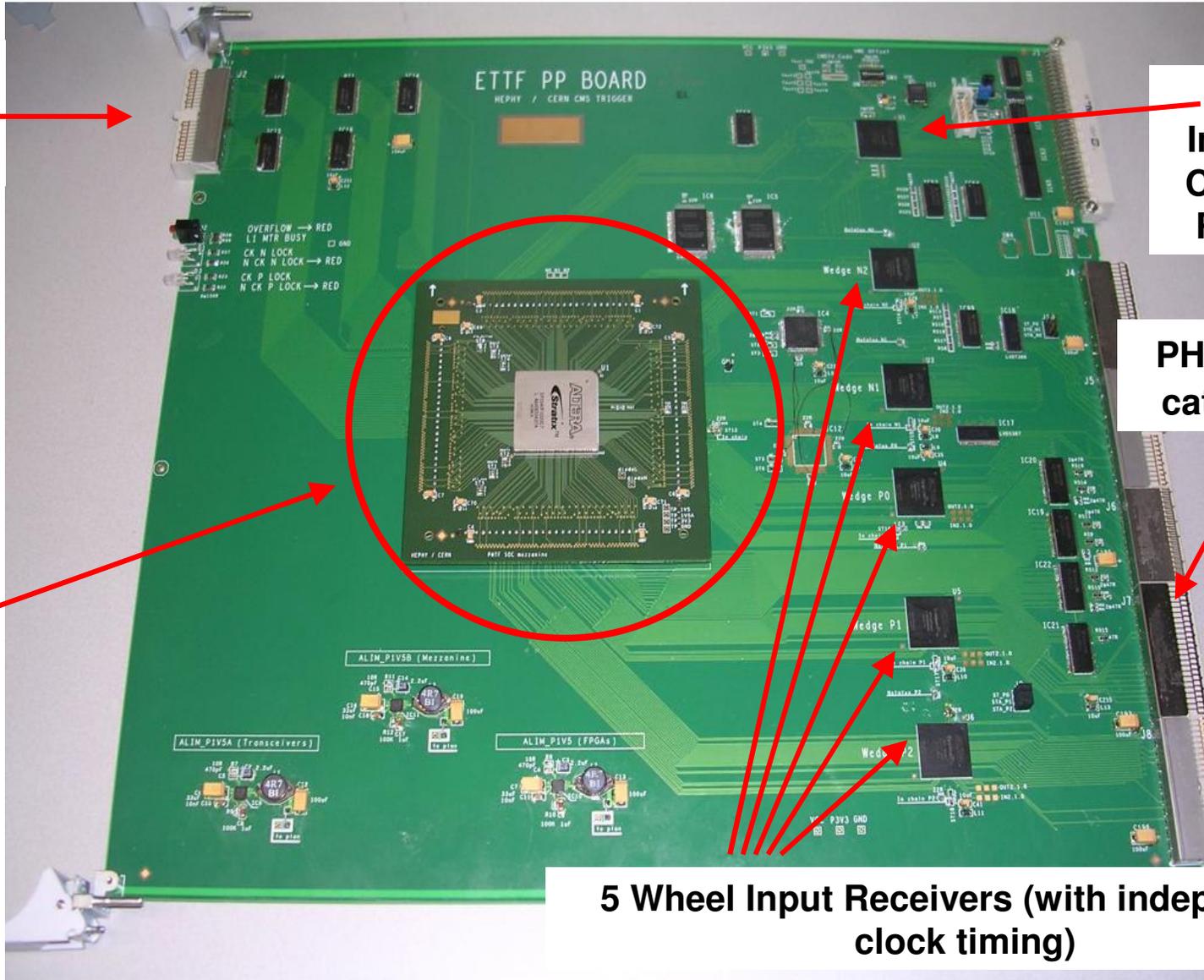
Output to Wedge Sorter

VME Interface, Control & Readout

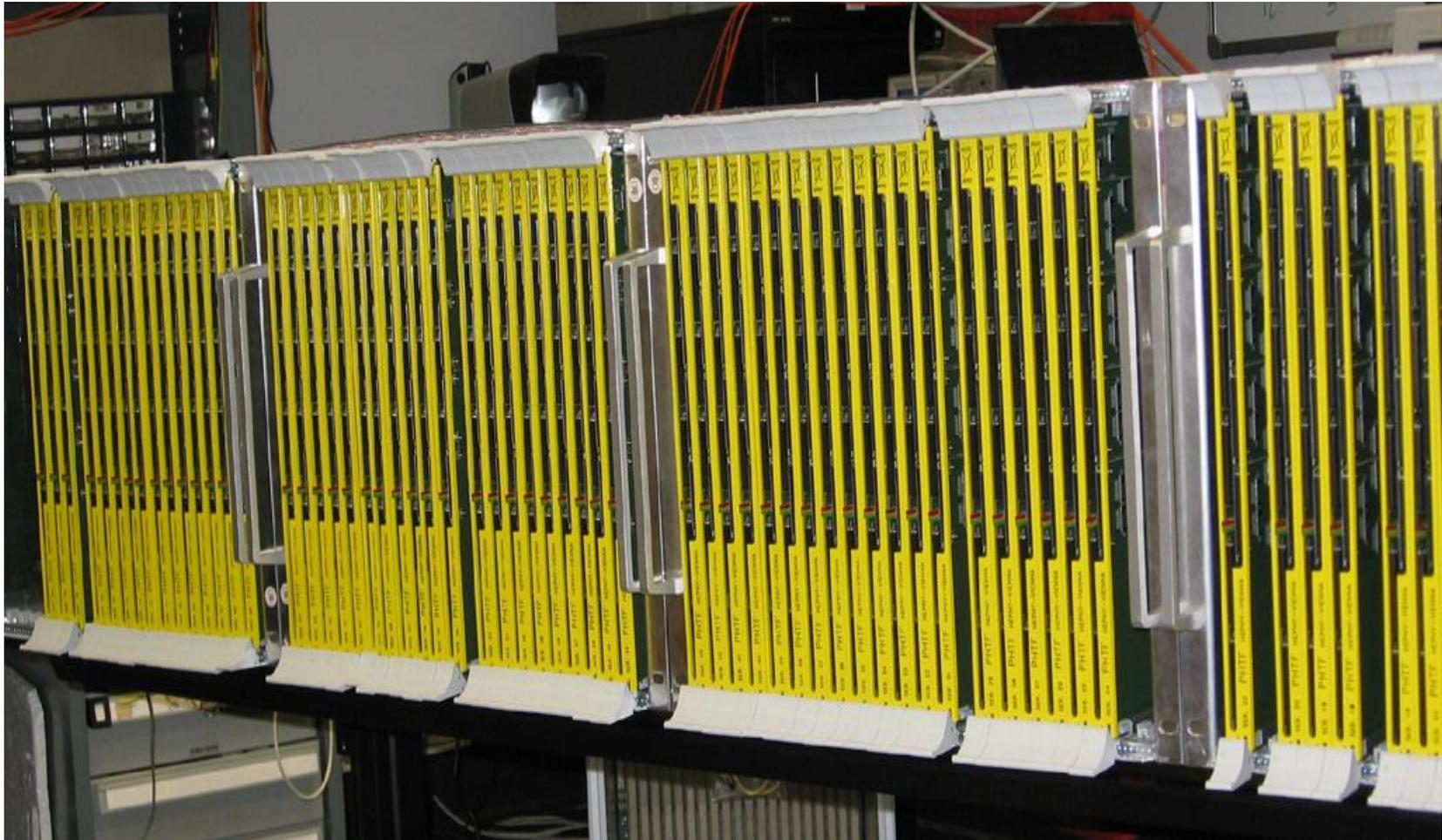
PHTF input categories

System-on-Chip (SOC) on mezzanine

5 Wheel Input Receivers (with independent clock timing)

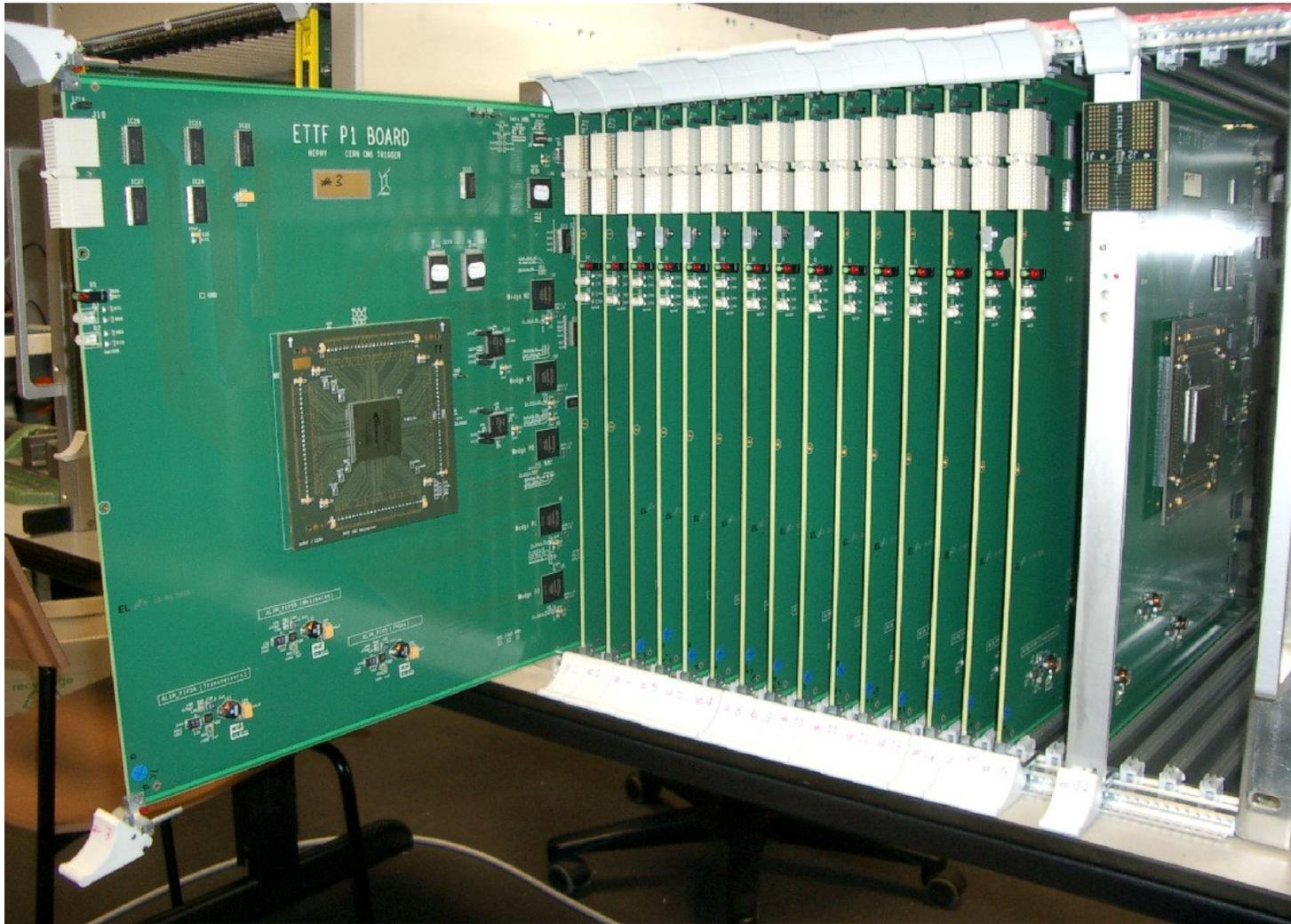


PHTF Production Boards



PHTF boards(72)+spares(8) produced and tested

ETTF Production Boards



ETTF boards(12)+spares(5) produced and tested

Wedge Sorters

- Selects “best” 2 muon candidates in a wedge.

- Ghost suppression in η -direction.

- Assigns ETTF output η -values to PHTF output tracks.

ETTF η -values

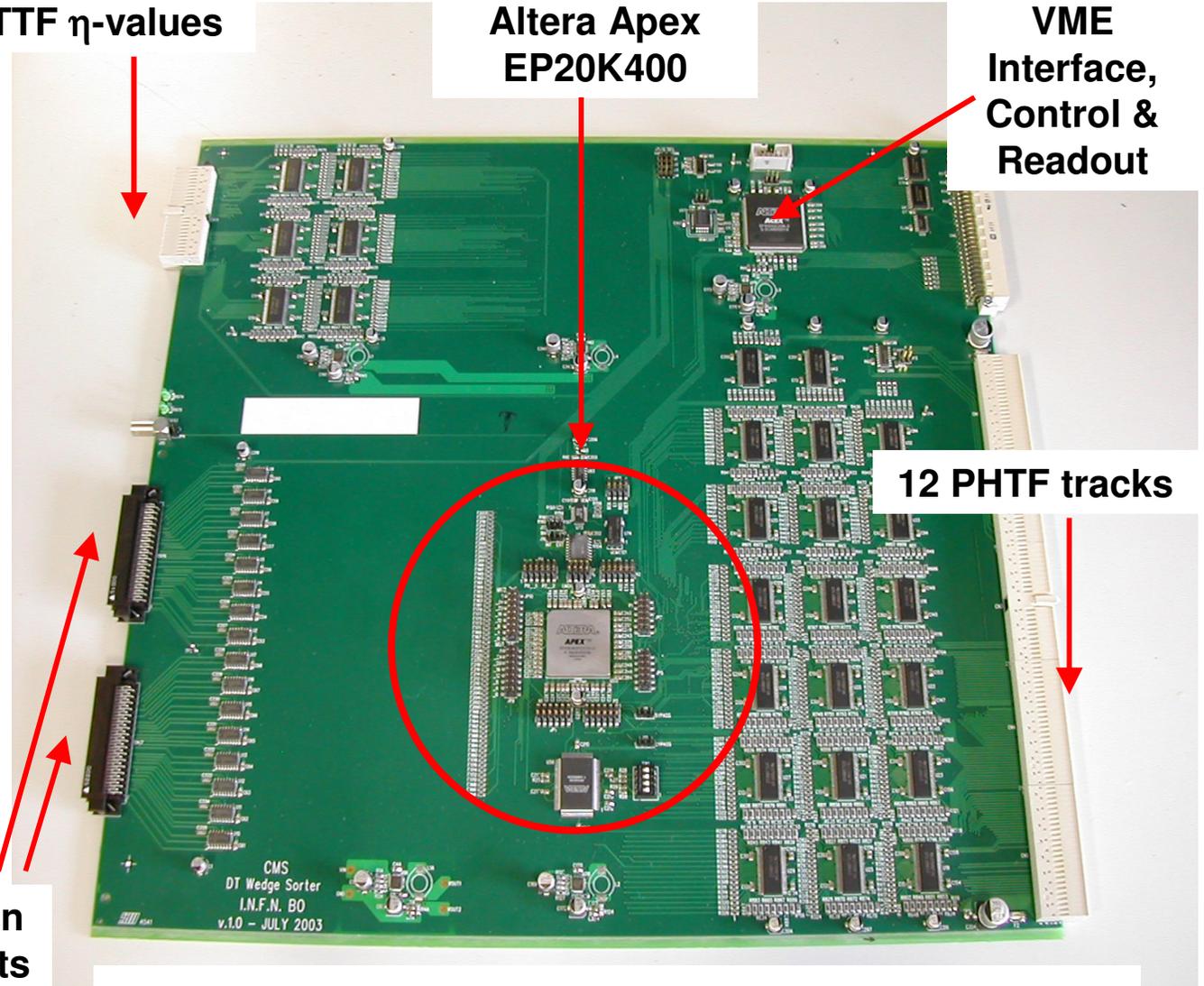
Altera Apex EP20K400

VME Interface, Control & Readout

12 PHTF tracks

2 Muon Outputs to BS

WS boards(12)+spares(6) produced and tested



Barrel Sorter

- Selects “best” 4 DT muons in barrel.
- Ghost suppression in ϕ -direction.
- Local trigger generation under programmable conditions.
- Checks synchronization of 12 Wedge Sorters.
- Checks trigger data through spy registers.

Trig OUT (NIM/TTL/ECL)

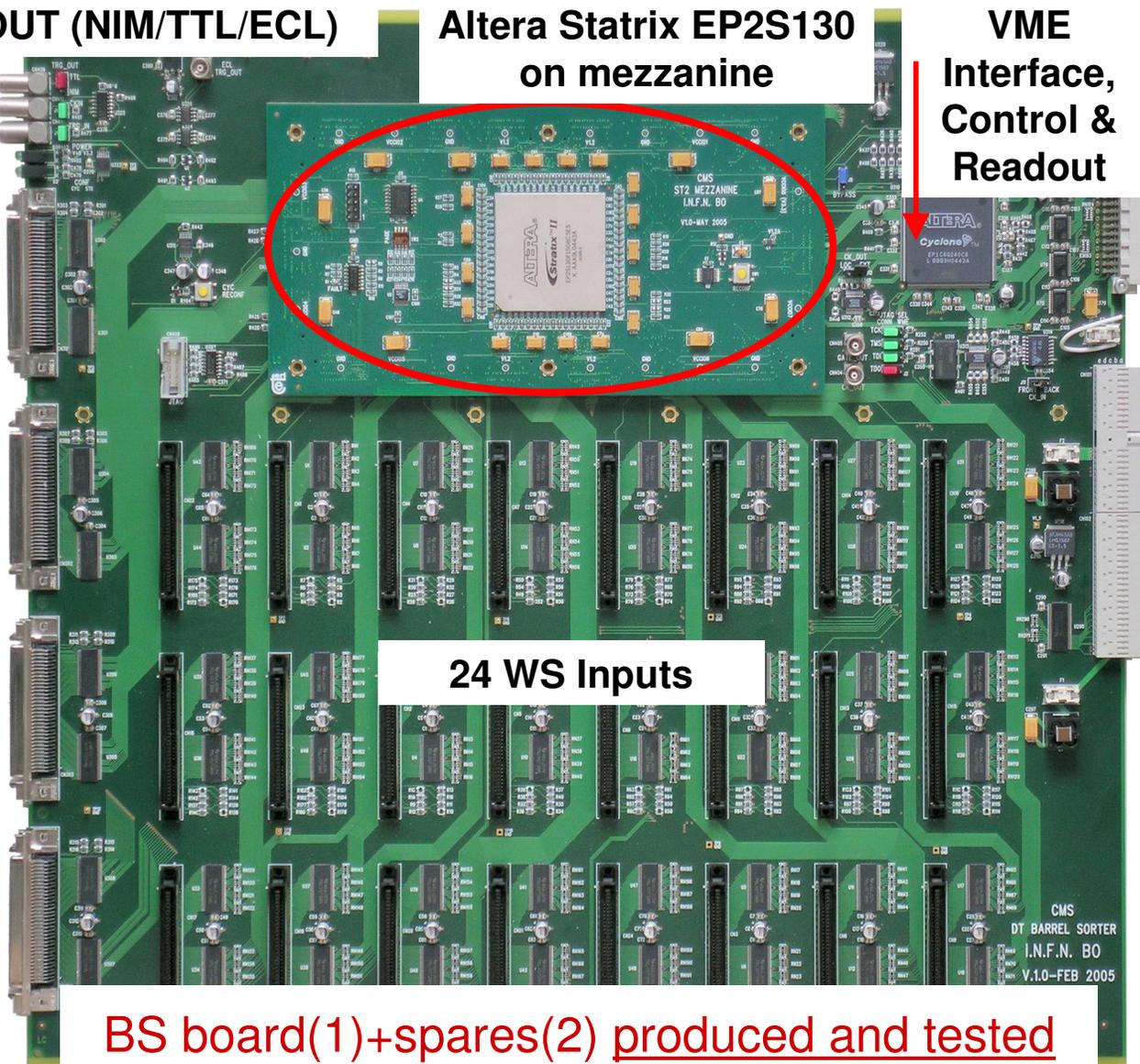
Altera Statrrix EP2S130 on mezzanine

VME Interface, Control & Readout

4 Muon Outputs to GMT

24 WS Inputs

BS board(1)+spares(2) produced and tested



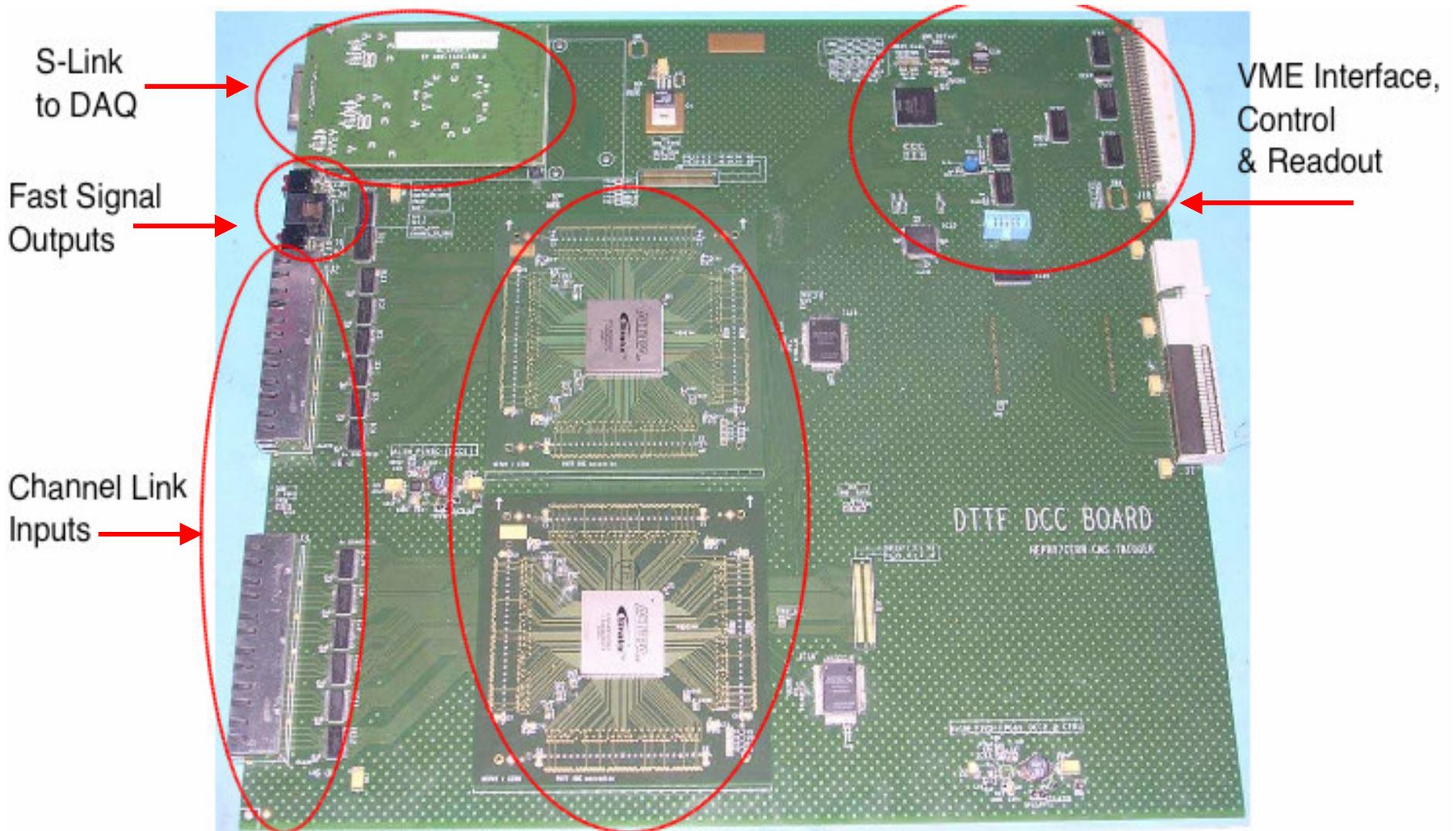
Local DAQ

- Based in PHTF/ETTF/BS Spy systems: **Spy_DAQ**.
- Access to **full DTTF data flow in 512 BX (128 BX for BS)**.
- Organized in **maintenance, setup, operation, monitoring, and emulation modules in XDAQ** (CMS online software standard platform).
- Intensively used at **prototyping, test** (beam test, electronics integration center, MT/CC), **production and commissioning phases**.

Central DAQ

- **DTTF Readout** sends input and output data to CMS DAQ at every L1-Accept (3 BX).
- At **100 kHz L1A** rate, total DTTF info is **635 MB/s**; allowed bandwidth is **200 MB/s**: **zero-suppression scheme** worked out.
- Hardware implementation: **PHTF/ETTF DAQ Block (SOC) → Data-Link (DTTF Crates) → DCC Board (Central Crate) → to CMS DAQ (via Slink-64 protocol)**.
- DCC prevents buffer overflows using **Fast Signals to Trigger Throttling System**.
- DTTF info in event stream checked **online** by C++ **DTTF Emulator** and **Data Quality Monitor**; and in **offline** analysis.

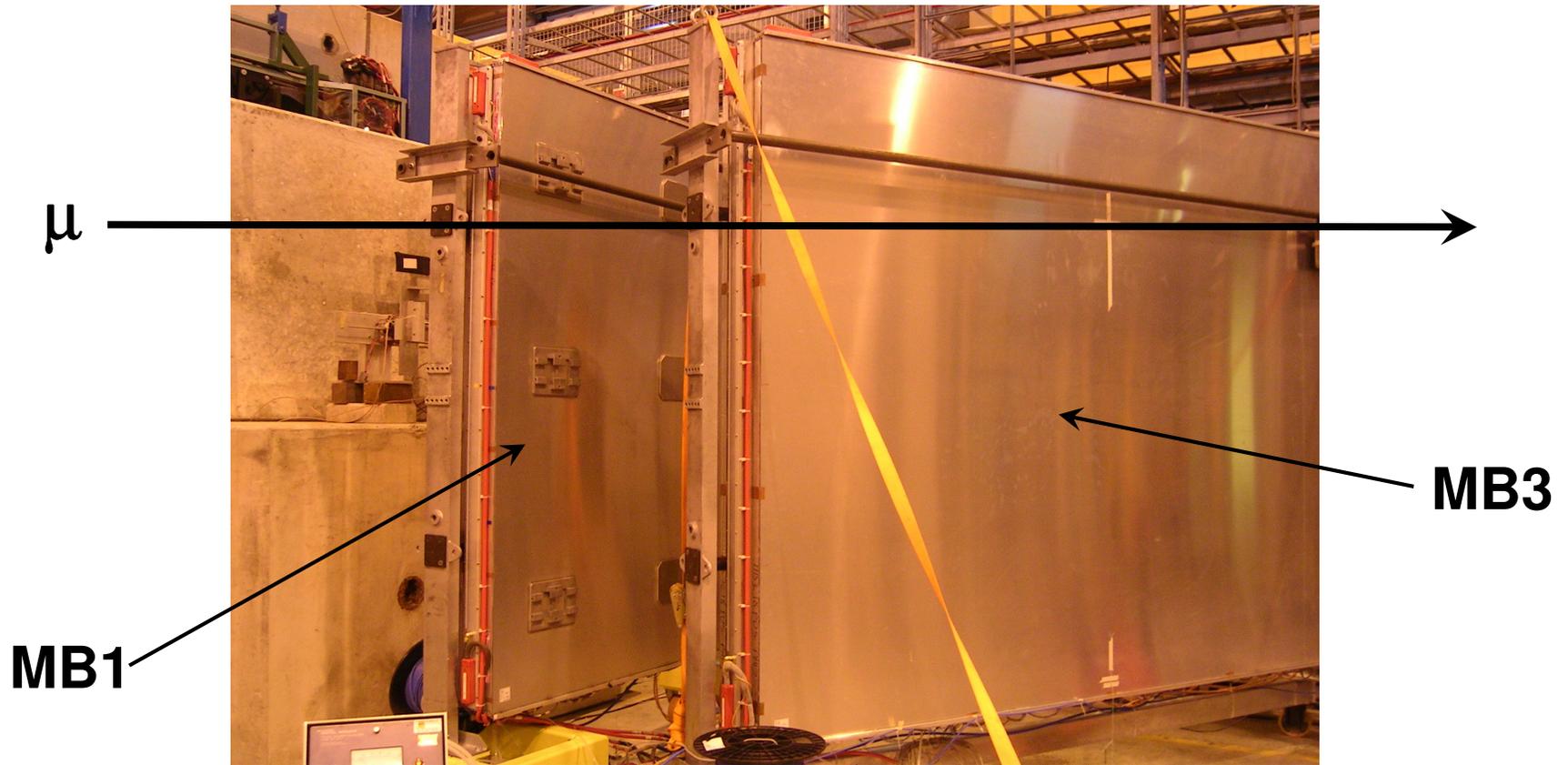
DCC Board



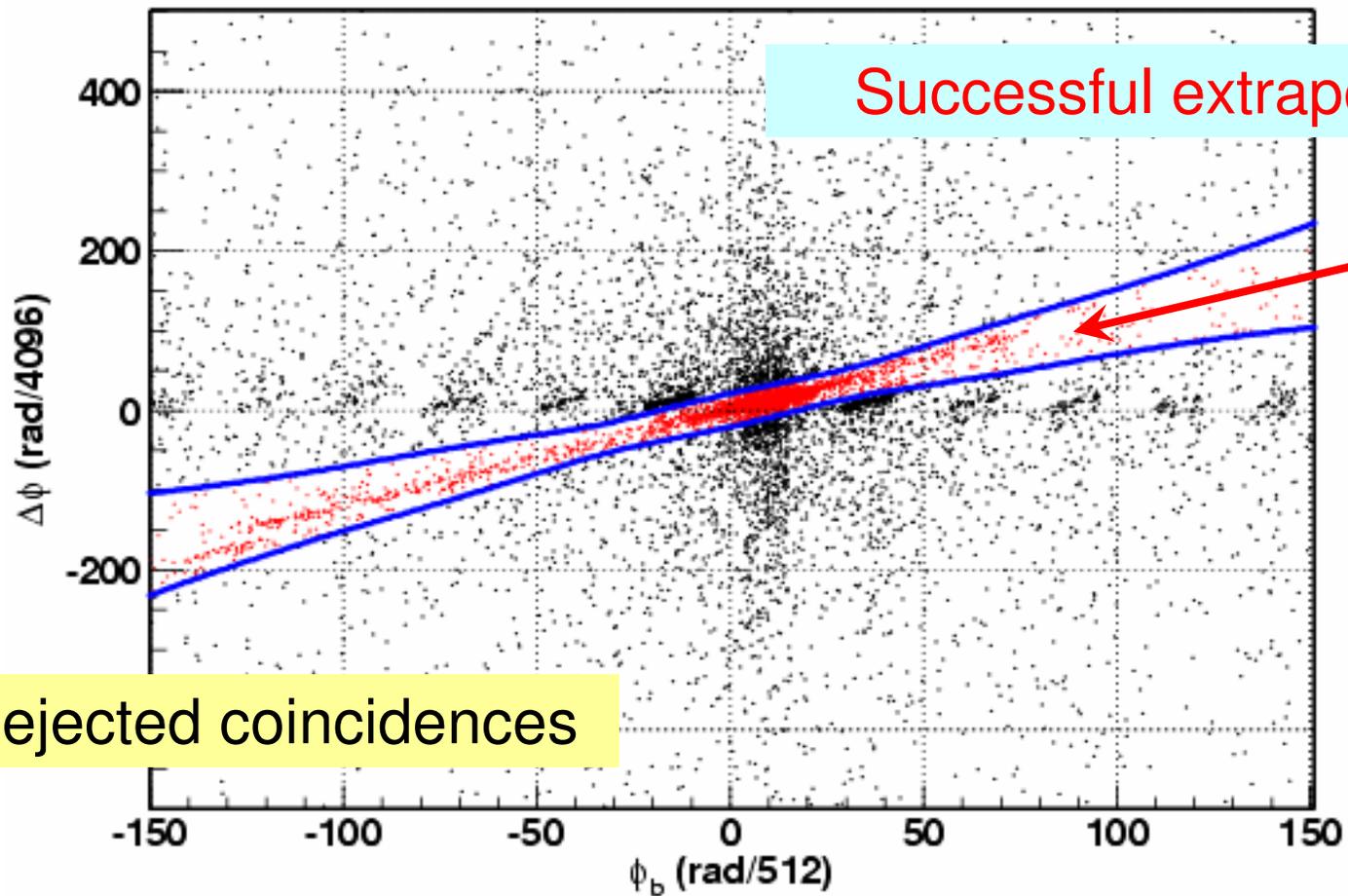
DCC Chips

DCC board(1) produced and tested

Beam Test 2004



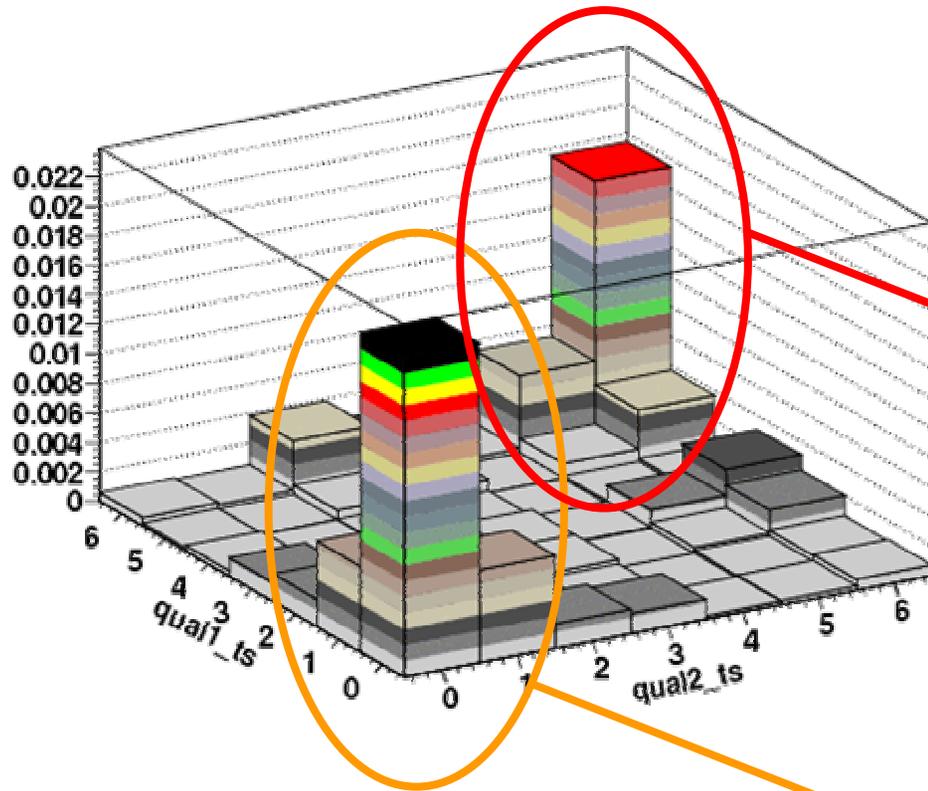
DTTF Beam Test 2004: Extrapolation



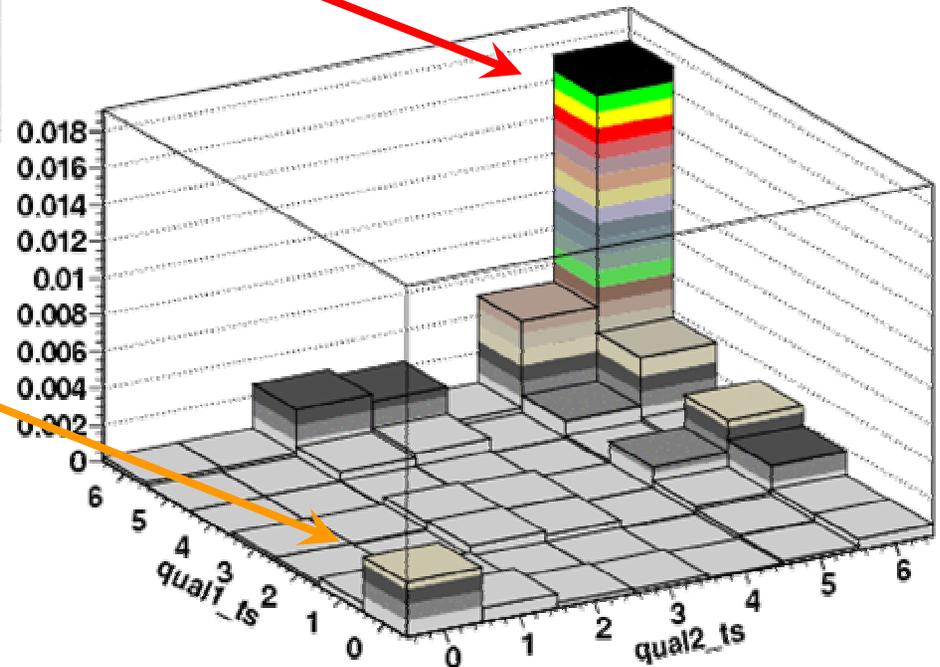
Successful extrapolations

Rejected coincidences

DTTF Beam Test 2004: Efficiency

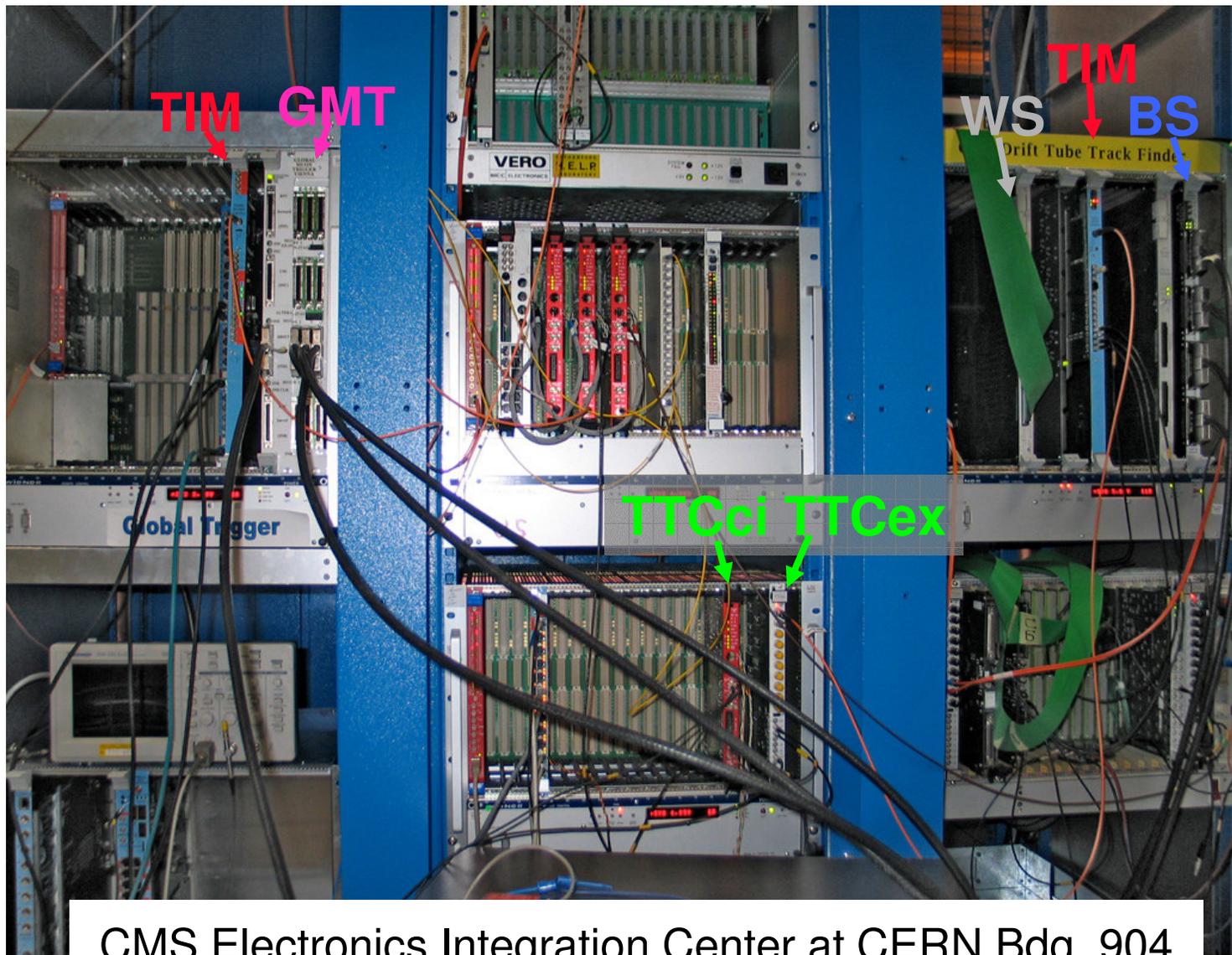


High-quality Muons:
> 99% efficient

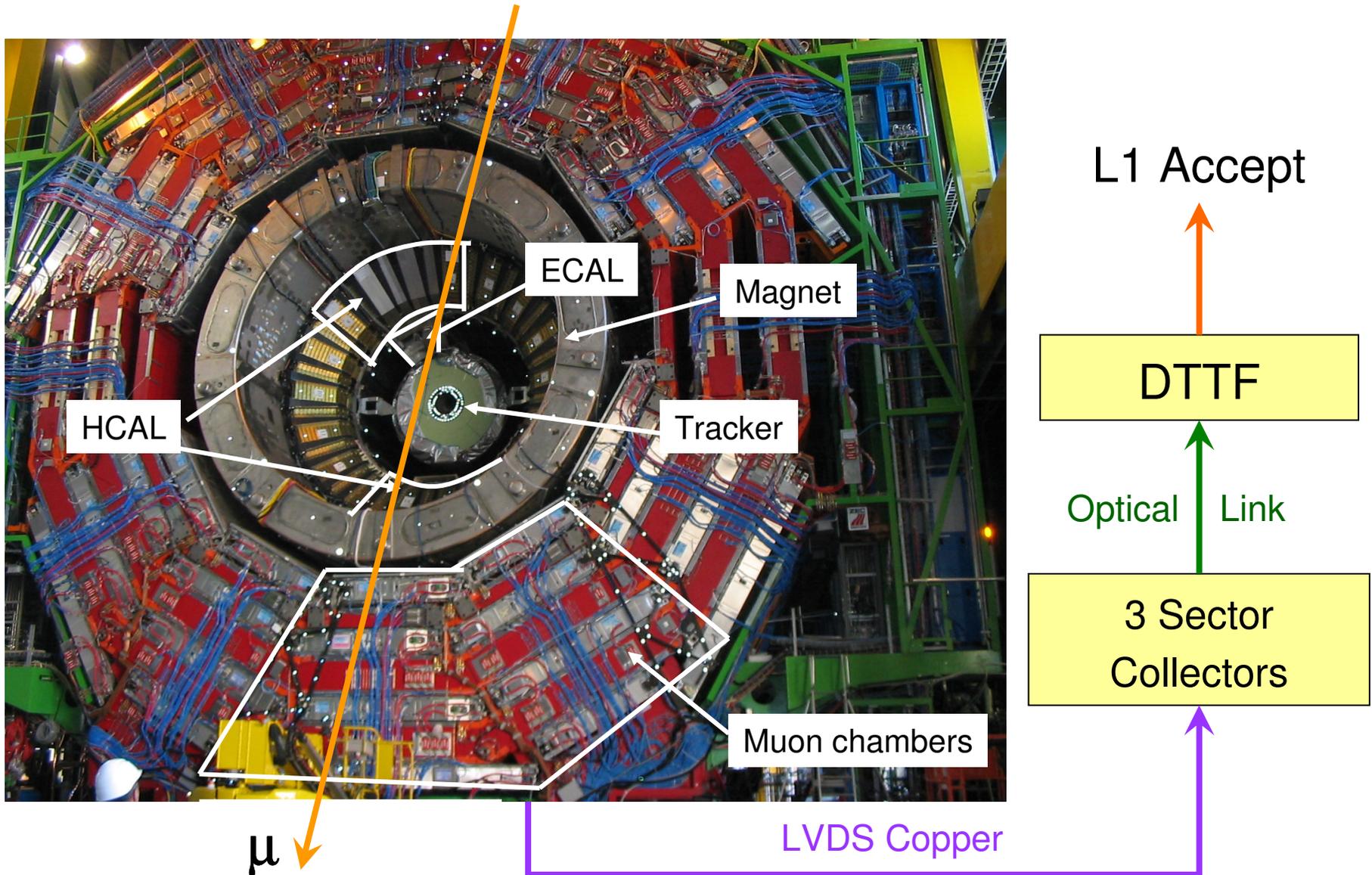


Low-quality Ghosts:
Rejection Power > 10

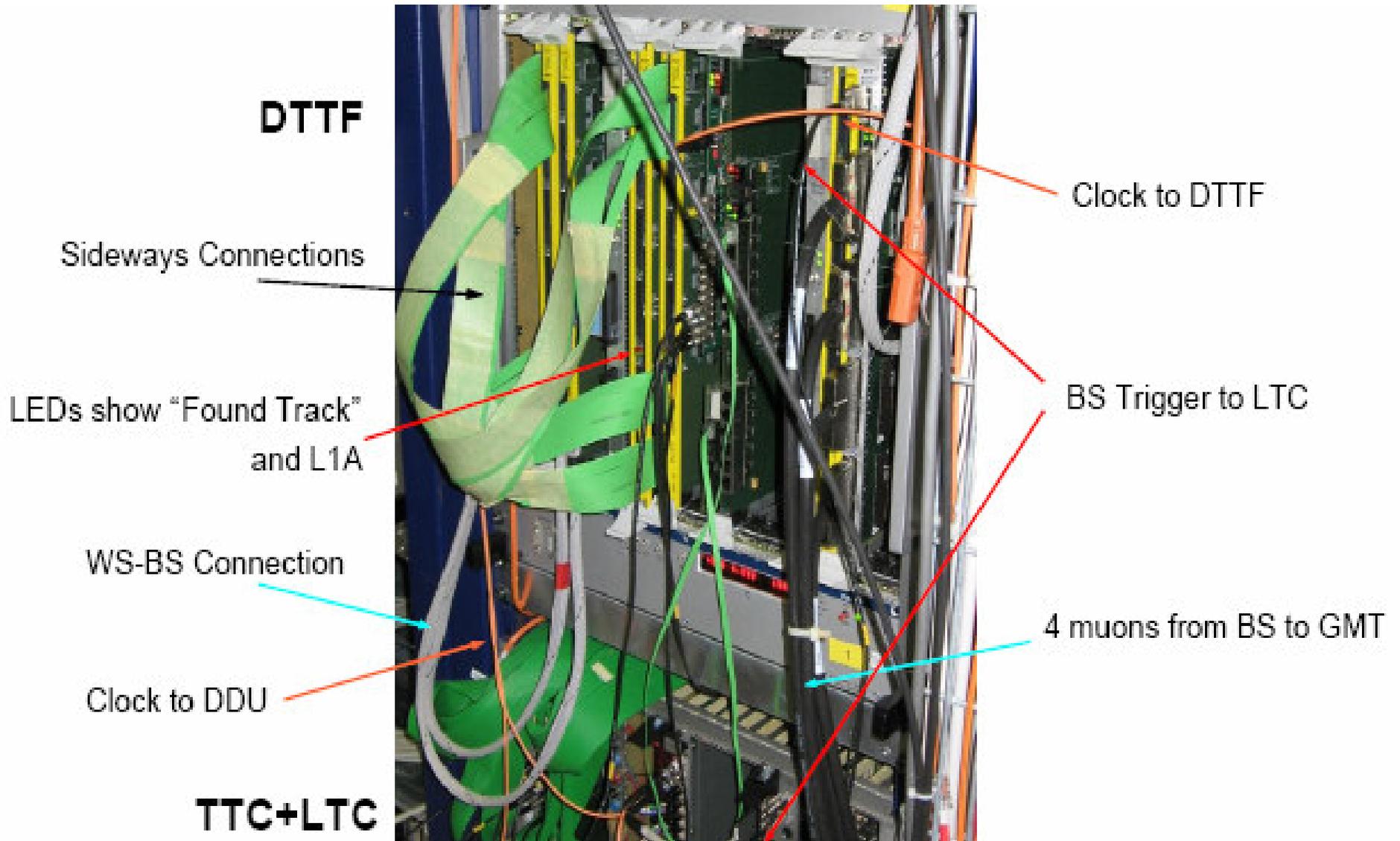
DTTF-CSC-GMT Integration Test 2006



Magnet Test – Cosmic Challenge 2006

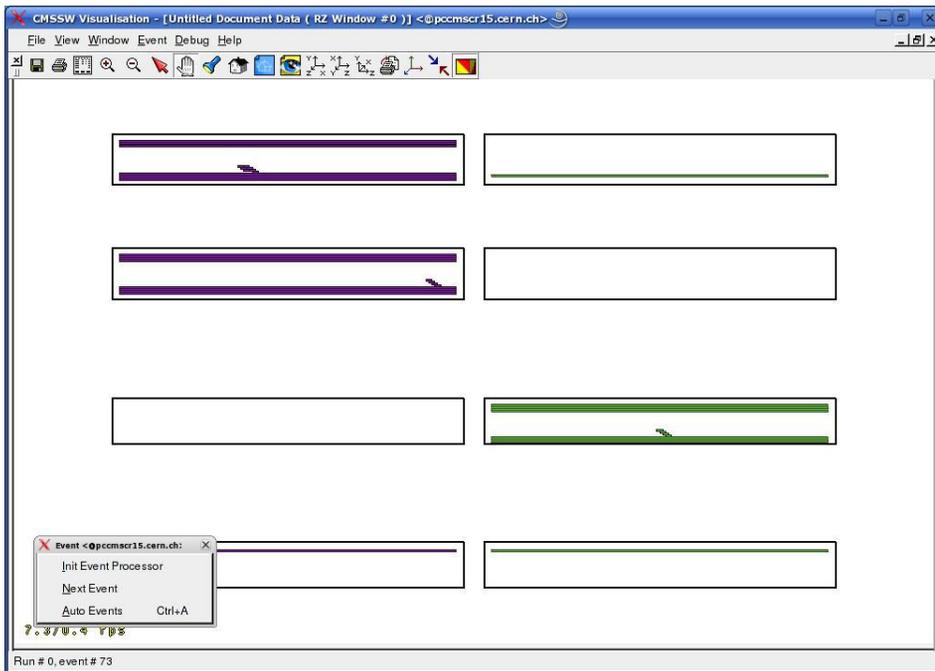
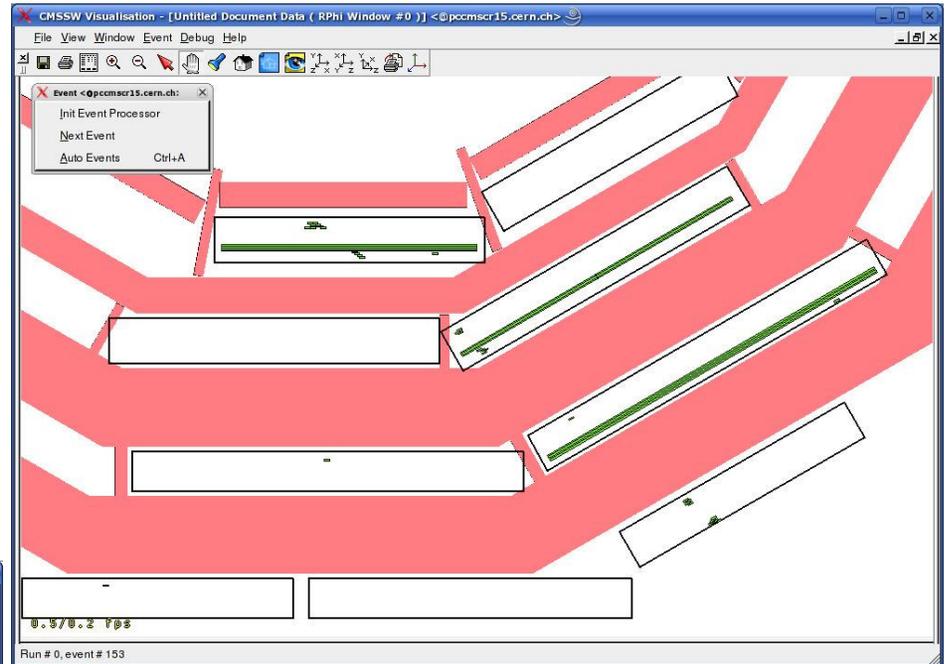


3-Sector DTTF Trigger at MT/CC

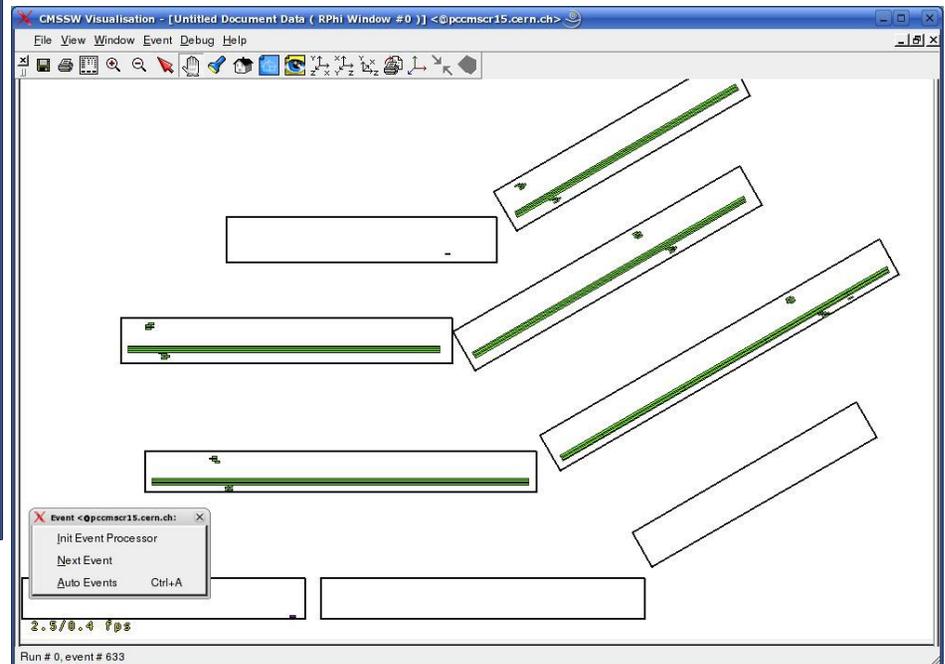


First opportunity to study DTFF performance for:

- PHTF long (3 station) tracks (synchronization)
- Muons changing wheel / sector (synchronization again)
- Dimuons

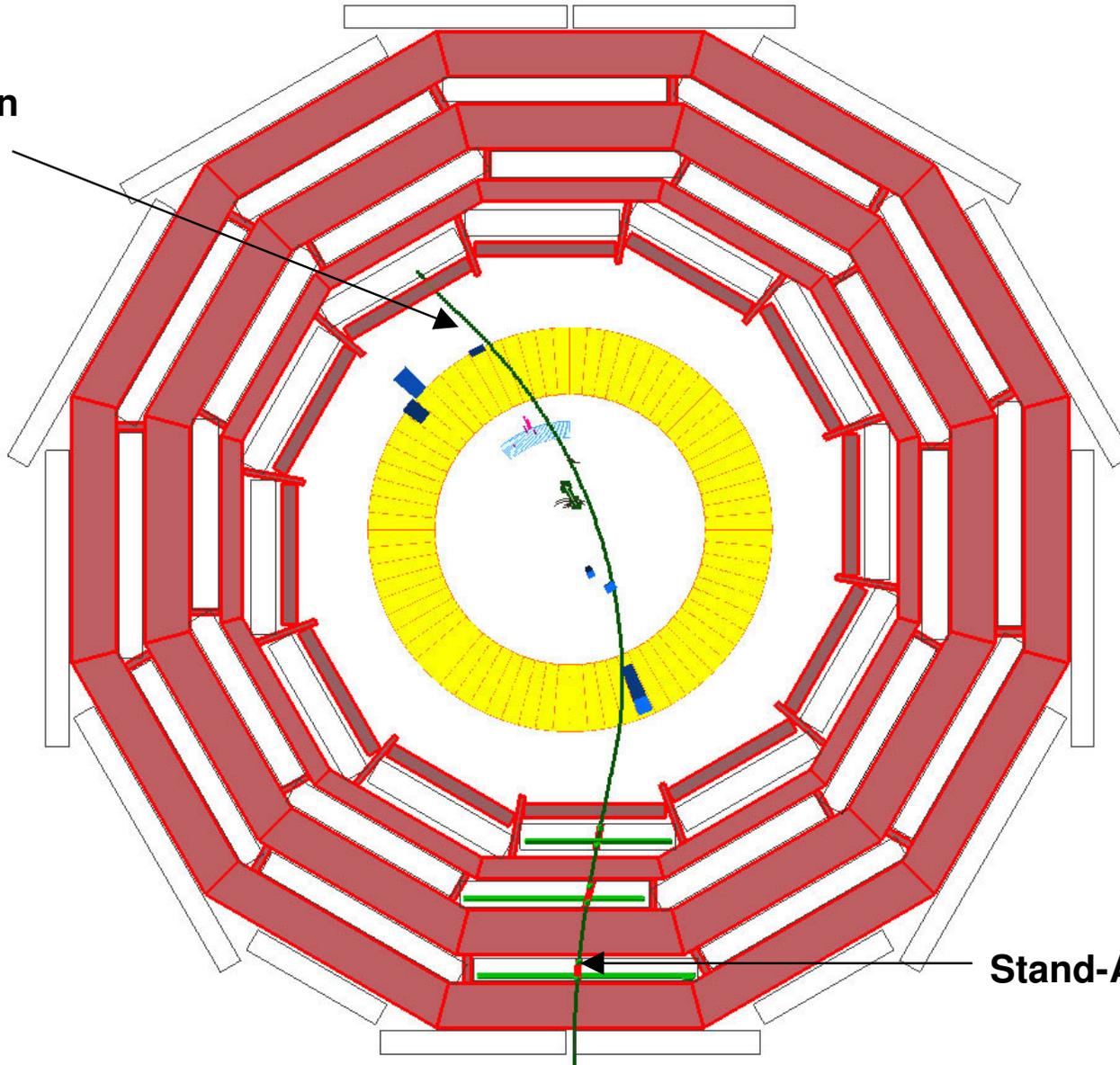


And also...



Triggering CMS at $B = 4\text{ T}$

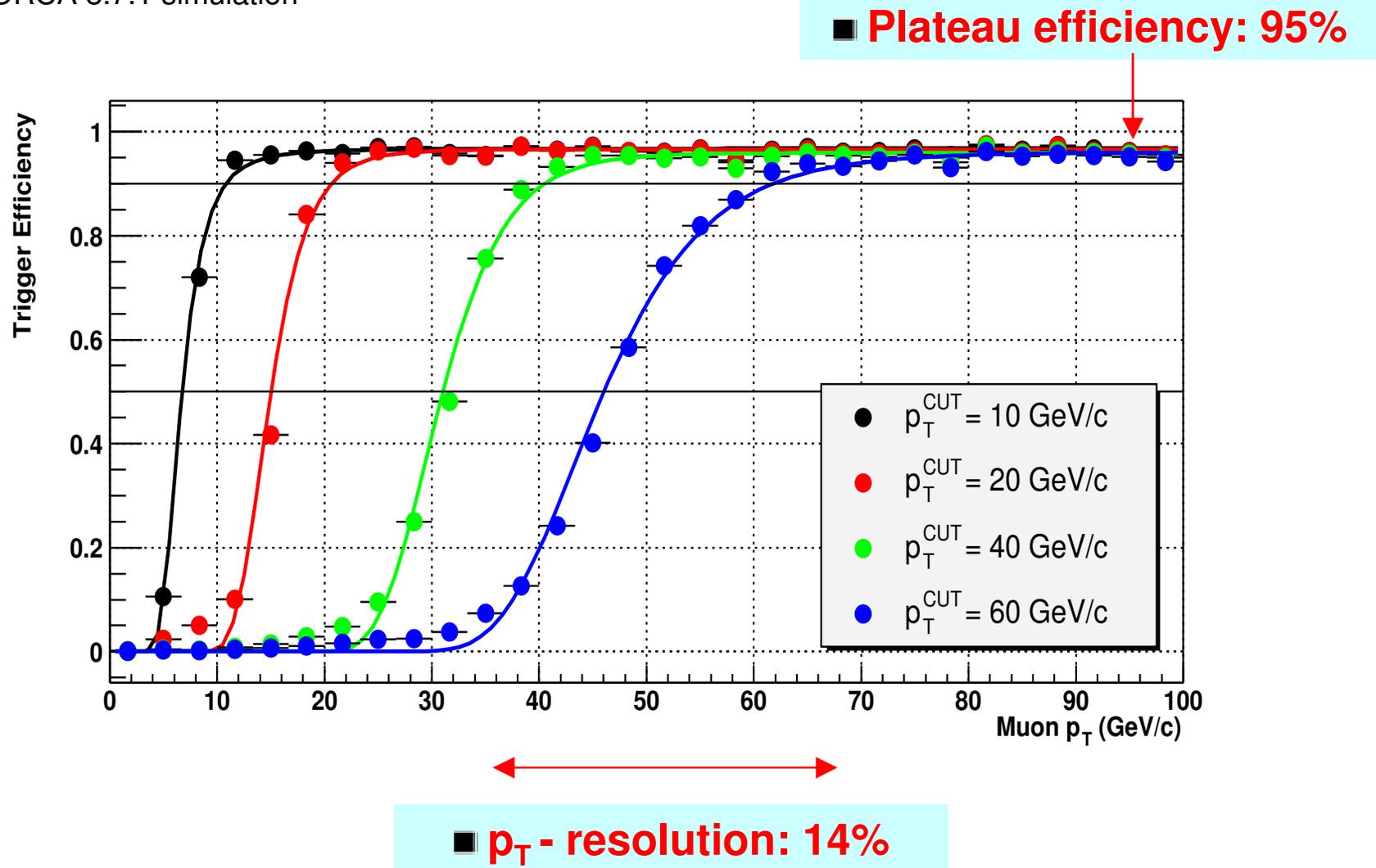
Extrapolation
to Central
Detector



Stand-Alone Muon fit

Expected Performance: Turn-on's

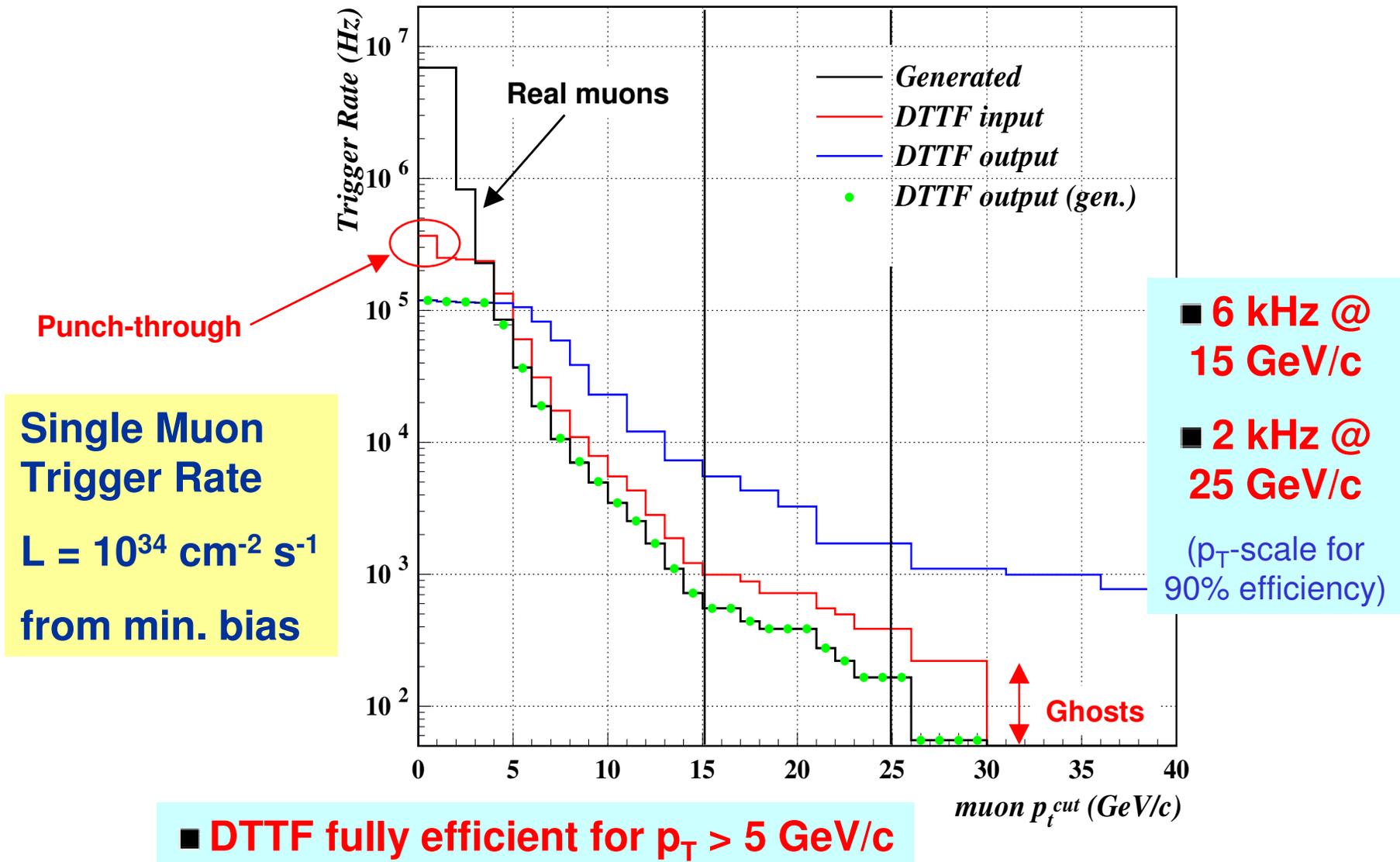
C++ ORCA 8.7.1 simulation



Expected Performance: Rates

C++ ORCA 8.13.1 simulation

barrel: $0 < |\eta| < 1.04$



Summary

- **DT Trigger** provides precise and efficient L1 Muon Trigger in CMS Barrel region.
- **Local DT Trigger** finds muon vectors in transverse and polar planes, including BX identification, at every DT Barrel chamber.
- **Regional DT Trigger** goes beyond the classical coincidence analysis; performs 3D-tracking analysis in real time: **DT Track-Finder**.
- **Hardware implementation** based on highly configurable design: **Track-Finding logic and Look-Up Tables in FPGAs**.
- **Hardware** development is now complete.
- **Hardware and software** thoroughly **tested** at electronics and physics levels.
- **Successfully** used at **Magnet Test / Cosmic Challenge 2006** to provide cosmic trigger to CMS.
- **Commissioning and full integration** with the rest of **CMS L1 Trigger** will follow.
- **Many thanks to the CMS DTTF Collaboration.**