CMS Trigger Upgrades

- Trigger upgrades at CMS aim to:
  - Reduce the background rate by at least a factor of two ($L = 2\ 10^{34}$)
  - Improve CMS' capability in terms of efficiency and object resolution
  - Provide sufficient contingency to meet future physics challenges
- Muon Triggers Upgrades:
  - CSC, DT, RPC
- Calorimeter Trigger Upgrades:
  - Electron Triggers
  - Tau Triggers
  - Jets, MET, MHT….

Guidelines of the Trigger Upgrade

- They must be robust both at the hardware as well as at the firmware and software level.
  - Obviously we cannot end-up with the trigger that is worse than the current.
- They must be simple both at the hardware and firmware level
  - Simplicity of firmware must be included in the hardware considerations.
  - Online software should be equally simple.
  - The combination of Hardware + Firmware must be self-testable.
- The number of electronic components should be kept to a minimum.
  - Ideally all triggers should use the same hardware platform
  - Should minimize maintenance effort and number of experts
- The should provide for enhanced physics capability.
  - It is not enough that the hardware is adequate for the current algorithms.
  - The architecture should not impose constrains on algorithms.
  - Enough contingency should be allowed for future algorithms.

Key Principles of the Upgrade

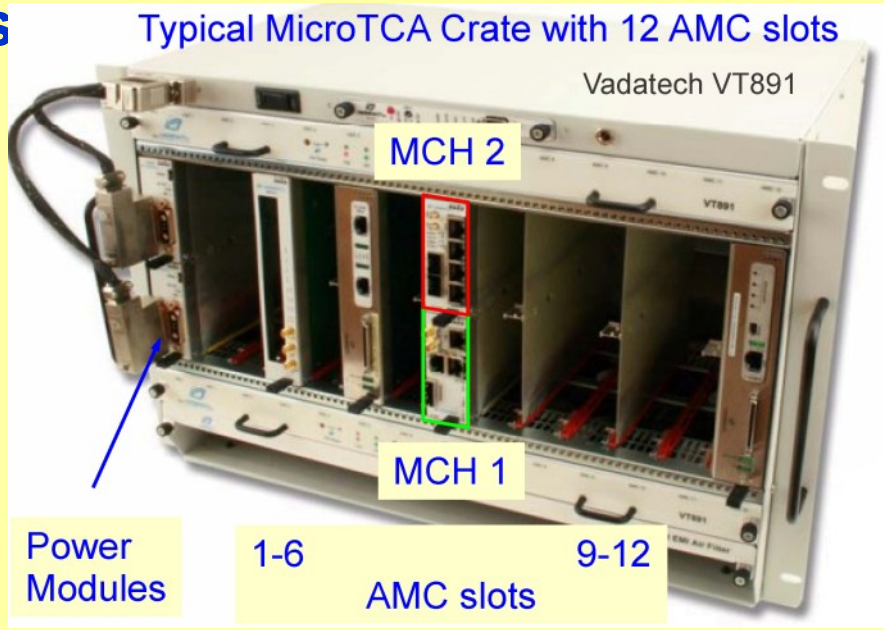
- Hold the Level 1 Accept Rate at 100kHz
  - (plus side) Avoids as much as possible rebuilding front end and readout electronics
  - (minus side) Puts more pressure on the DAQ to deal with increased data size
- Employ full granularity of detectors in trigger
  - (0.087 x 0.087 in $\eta-\phi$)
- Rely on powerful modern FPGAs with huge processing and I/O capability to implement more sophisticated algorithms
- Use state of the art telecom technology to support increased bandwidth requirements
  - Hardware standardization is inevitable (schedule, manpower)

CMS Upgrade Architecture: μTCA

- **Advanced Telecommunications Computing Architecture ATCA**
- **μTCA derived from AMC std.**
  - Advanced Mezzanine Card
  - Up to 12 AMC slots
    - *10-11 Processing modules*
    - 1-2 Controller Modules
    - 10 GB/s point-to-point links
- **Dramatic increase in computing power and I/O.**
- **Possible to built a trigger based on a μTCA card ? →**

  reduce: complexity + maintenance

  + manpower costs

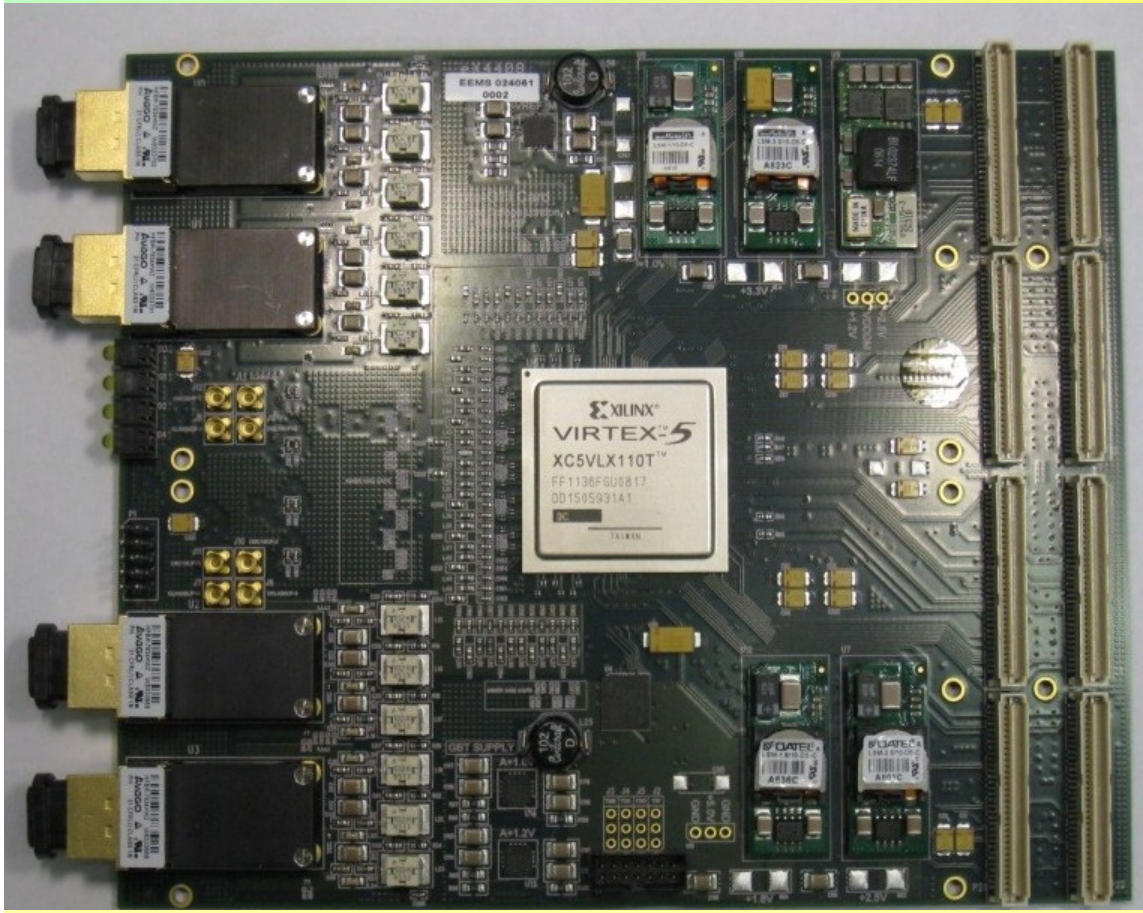


Single Module μTCA card 75x180

CMS GCT Matrix Card 75x180 mm (2009)

Global Trigger Input Links Upgrade

End of 2011



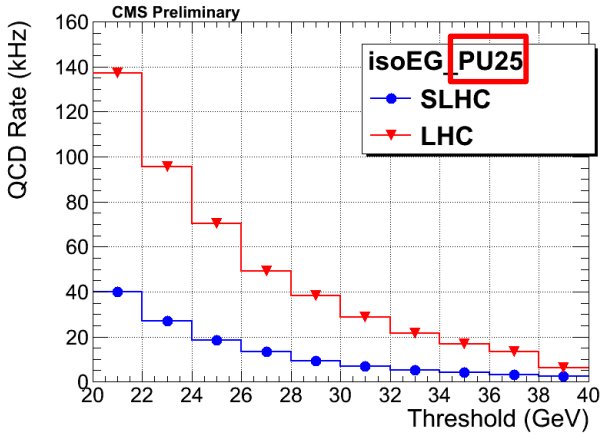
Future GT in μTCA

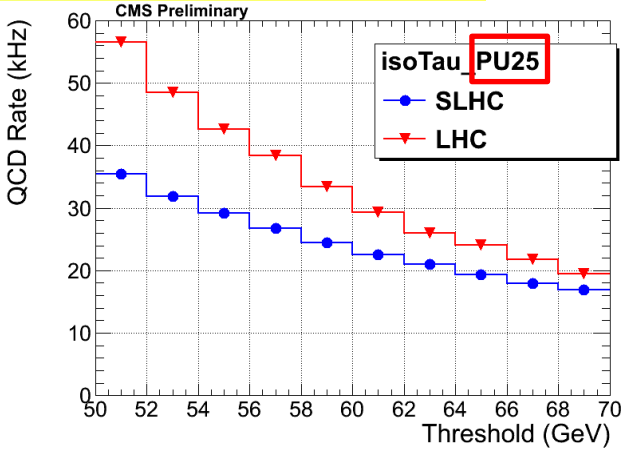
- Replace old copper links with 3 GBps optical links.
- Based on Virtex 5 FPGAs.
- Will increase robustness of the Global Trigger Links.
- Will make GT compatible with future Calorimeter Trigger and HCAL upgrades.
- Ready to be installed in the next LHC shutdown.

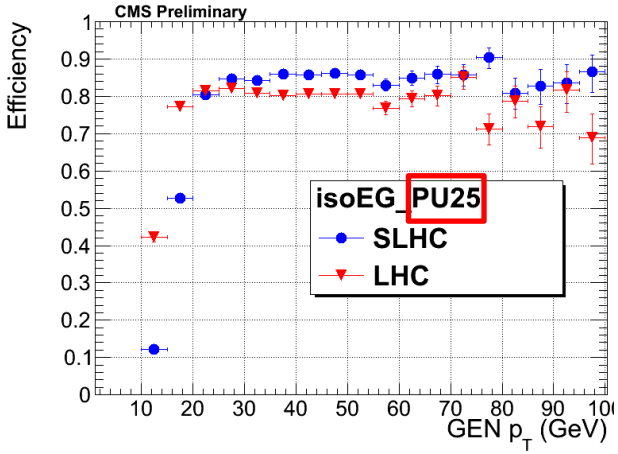
Efficiencies + Rates for Electron + Tau Triggers

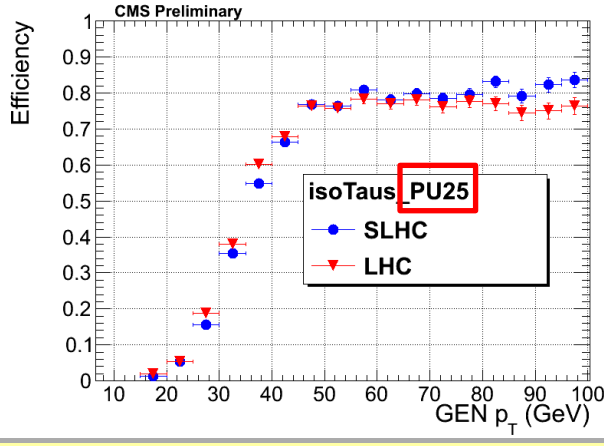
- **Current FPGA technologies allow sophisticated cluster algorithms at Lvl-1 which permit fine tuning of electron energy and isolation cuts.**
- **Current (LHC) algorithm in red for comparison.**

More in next talk by Greg Iles



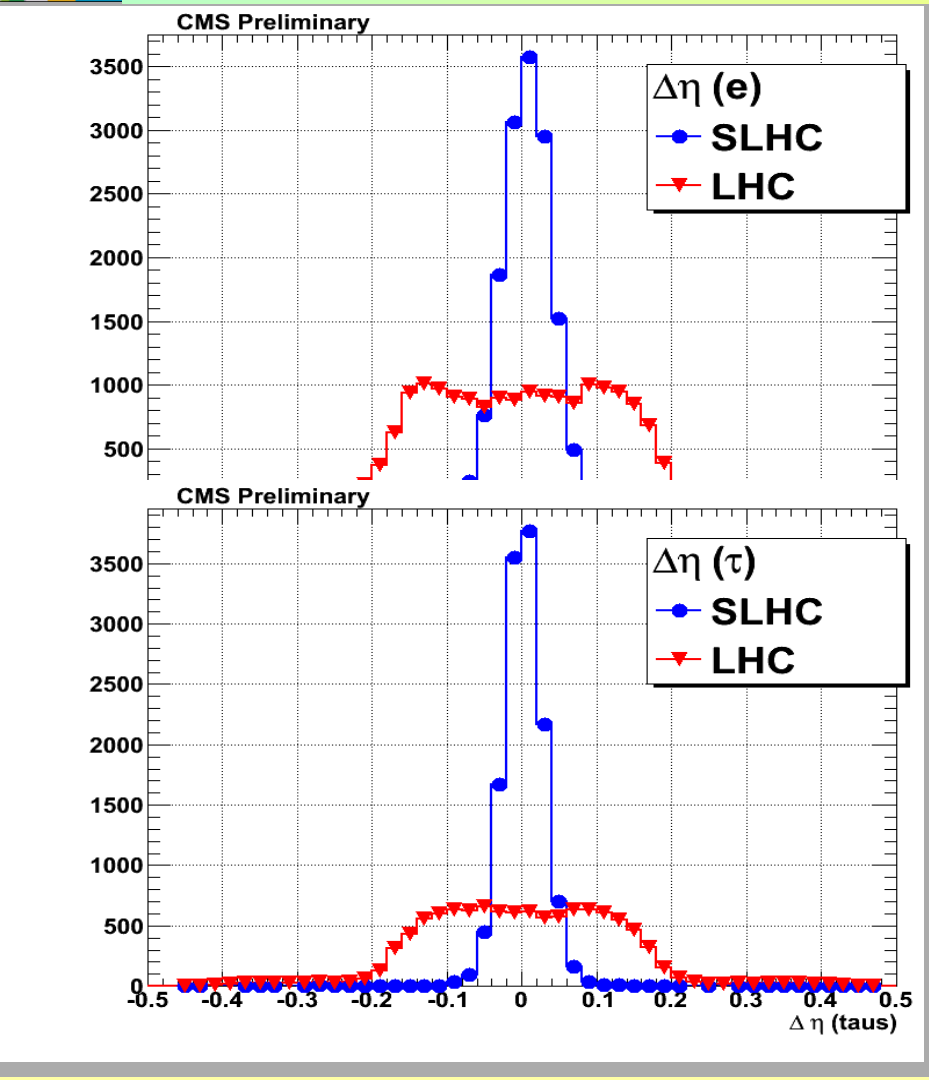


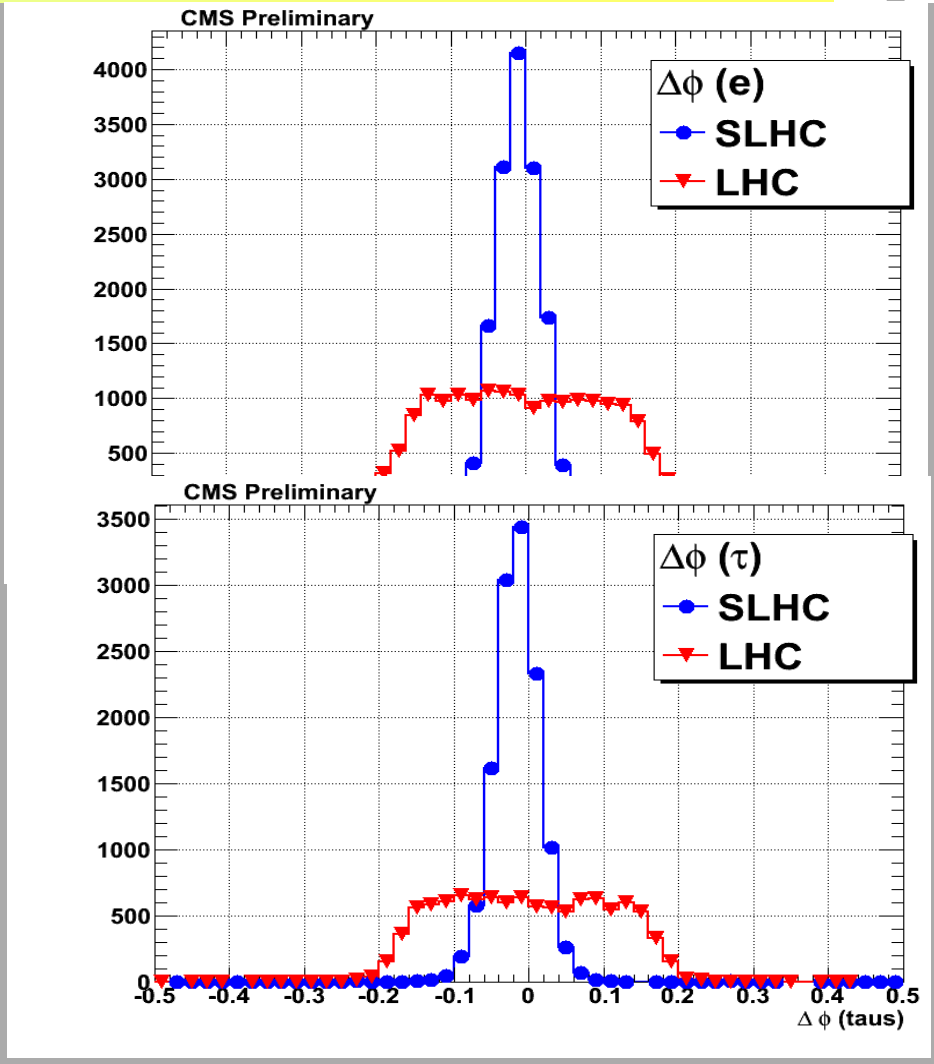




- **New electron algorithms achieve large rate reduction in the 25 PU environment for the same electron finding efficiency.**
- **New tau triggers benefit from Lvl-1 clustering and improved algorithms:**
  - **New algorithms reduce significantly the rate at 25 PU.**
  - **At the same time they maintain the LHC efficiency.**

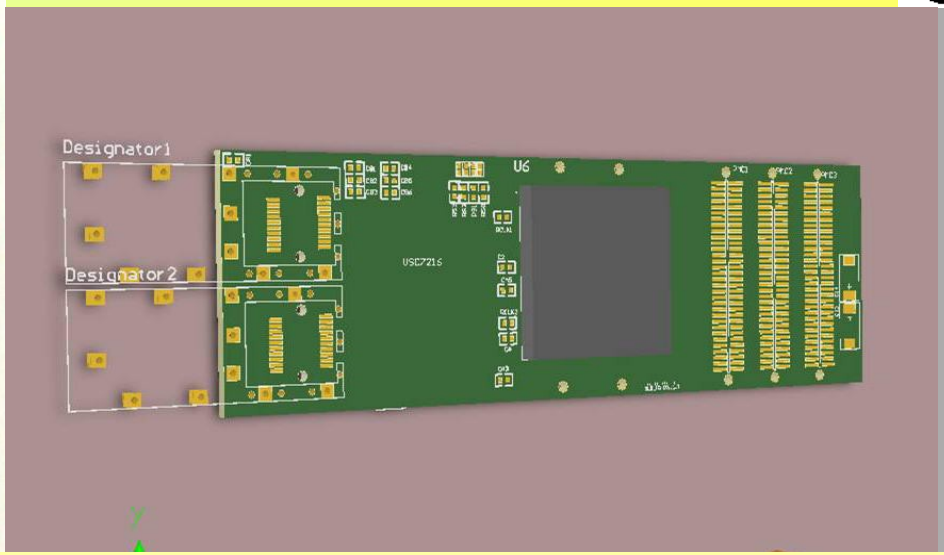
Lvl-1 Resolutions for topological Triggers





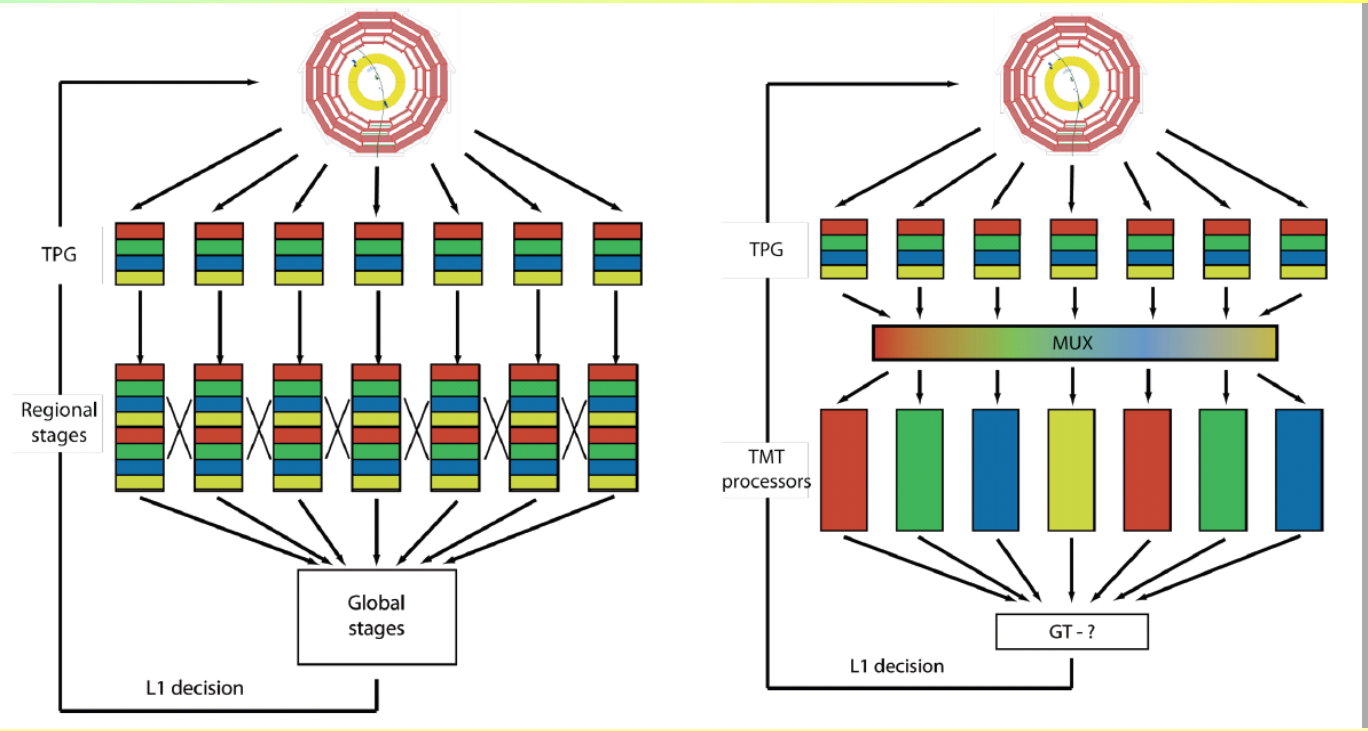
- LvL-1 Resolutions for Pseudorapidity η, and ϕ improve markedly.
- Provides an excellent handle for reducing rate using topological triggers.

OptoSLB Development (Lisbon)



- **Interim solution for HCAL and long term solution of ECAL which enables old and new trigger to operate in parallel**
- **They convert the copper links (left) to optical (right) between the CAL TPG and the Calorimeter Trigger.**
- **2400 cards**
- **A number of links will be replaced to optical in the next long LHC shutdown to provide the capability of running a μTCA trigger in parallel to the existing one**

Different Trigger Architectures

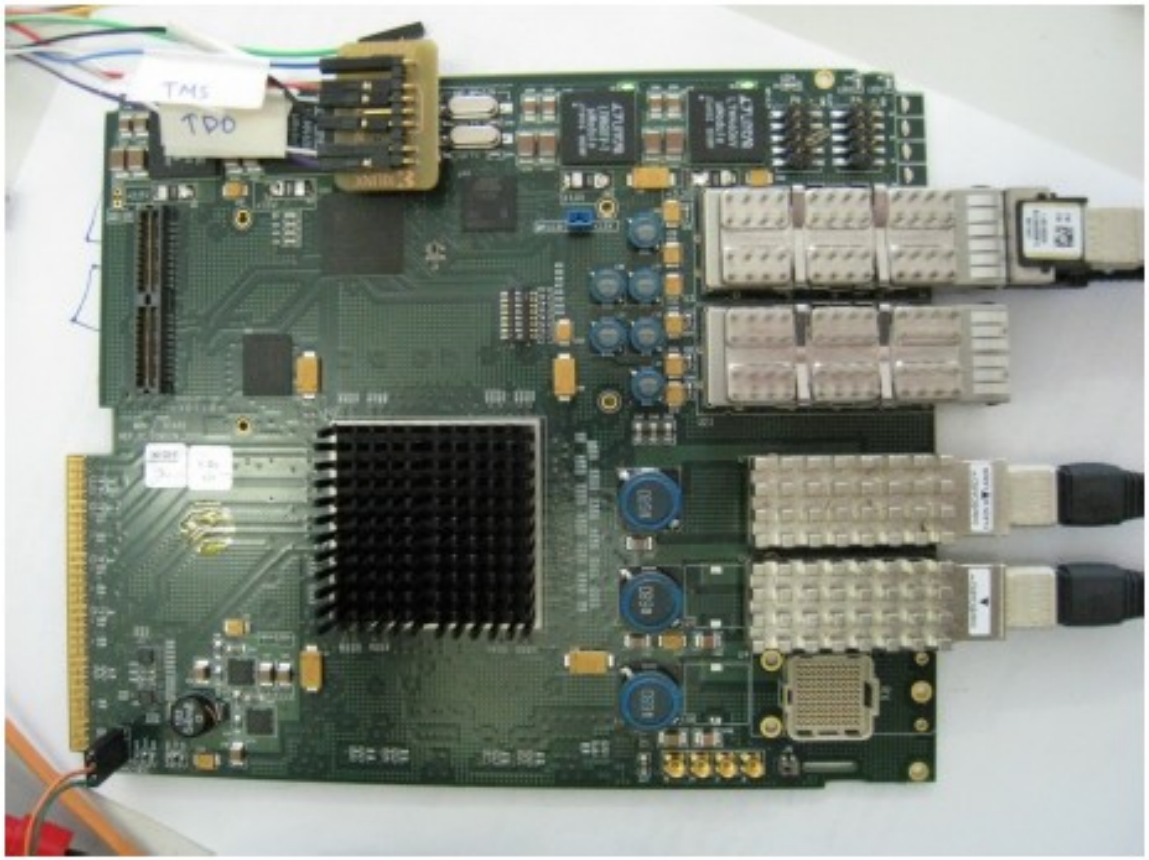


- Two approaches for Calorimeter Trigger
  - Compact Trigger: **CT**—early formation of 2x2 clusters (with fractional tower resolution) leading to reduction in hardware footprint
  - Time Multiplexed Trigger: **TMT** – similar to HLT, enables entire calorimeter to be processed in a single FPGA
- Currently evaluating different designs and how to integrate them into the LHC schedule

Trigger Demonstrators: Mini-T

Based around MINI-T5

- Double Width AMC Card
- Virtex 5 TX150T or TX240T
- Optics
  - IN = 160 Gb/s (32x 5Gb/s)
  - OUT = 100 Gb/s (20x 5b/s)
- Parallel LVDS
  - BiDir 64Gb/s
  - 2x40Pairs at 800Mb/s
- AMC
  - 2x Ethernet, 1x SATA
  - 4x FatPipe, 1x Ext FatPipe

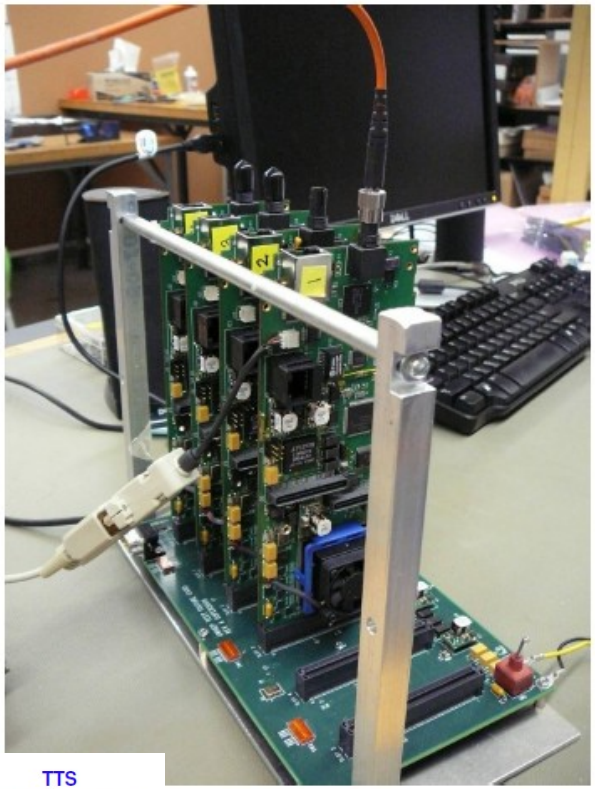


- **Two Mini-T Cards have been produced and are in working order.**
- **The two card are used for testing new architectures and gaining experience with the technologies of the future trigger system.**

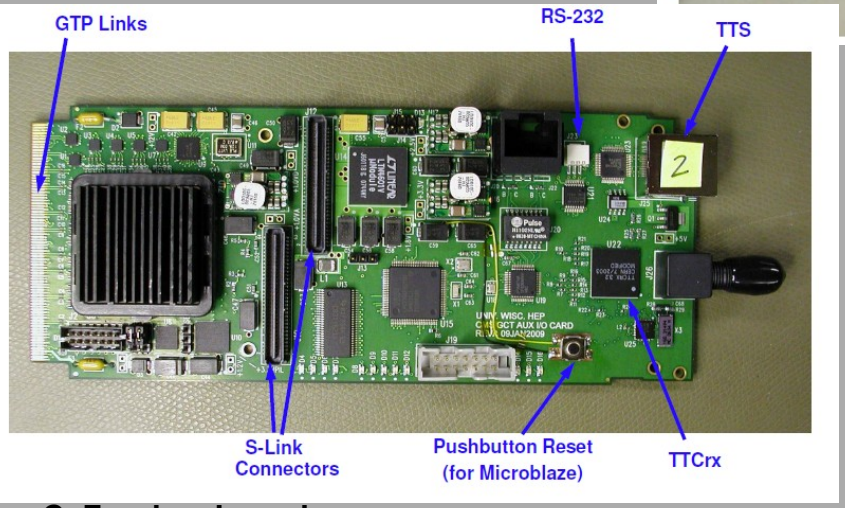
Trigger Demonstrators

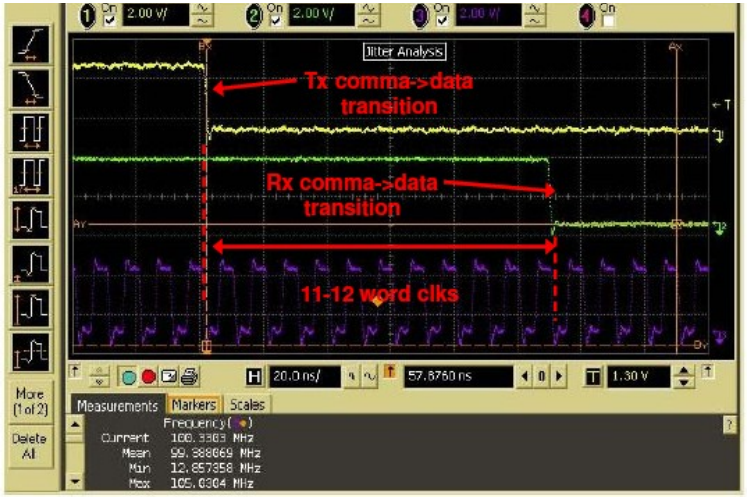
Test Setup for testing Triggering Architecture:

- **Uses the AUX Card**
- **Link Latency Tests**
- **Backplane Tests**



- **4 Aux Cards in a 2x2 test fabric**
- **TTC-based timing and link synchronization test bed**
- **Simulates 2 separate crates of 2 cards each**
- **Demonstrate alignment of 56 separate channels all operating on the same timebase**

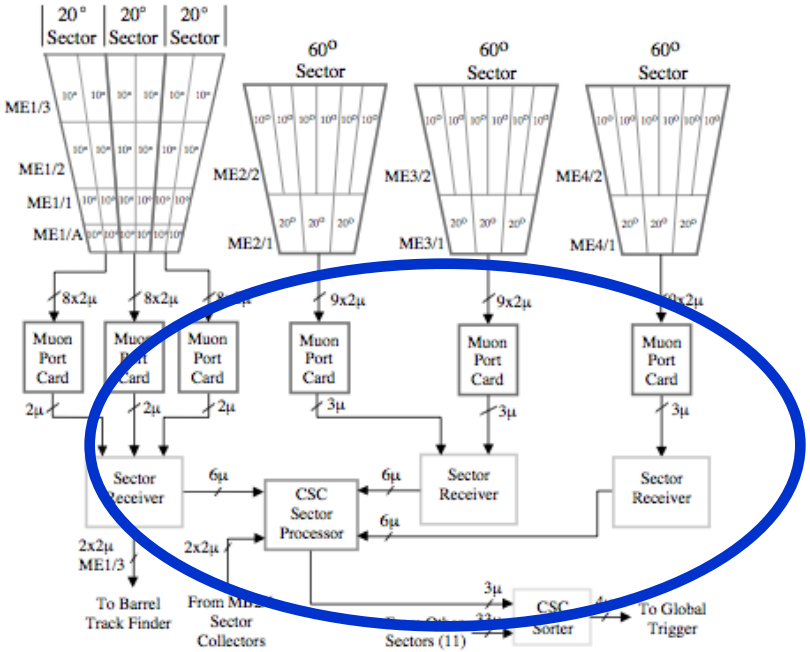




CSC Trigger Upgrades

Phase 1 CSCTF upgrade goals:

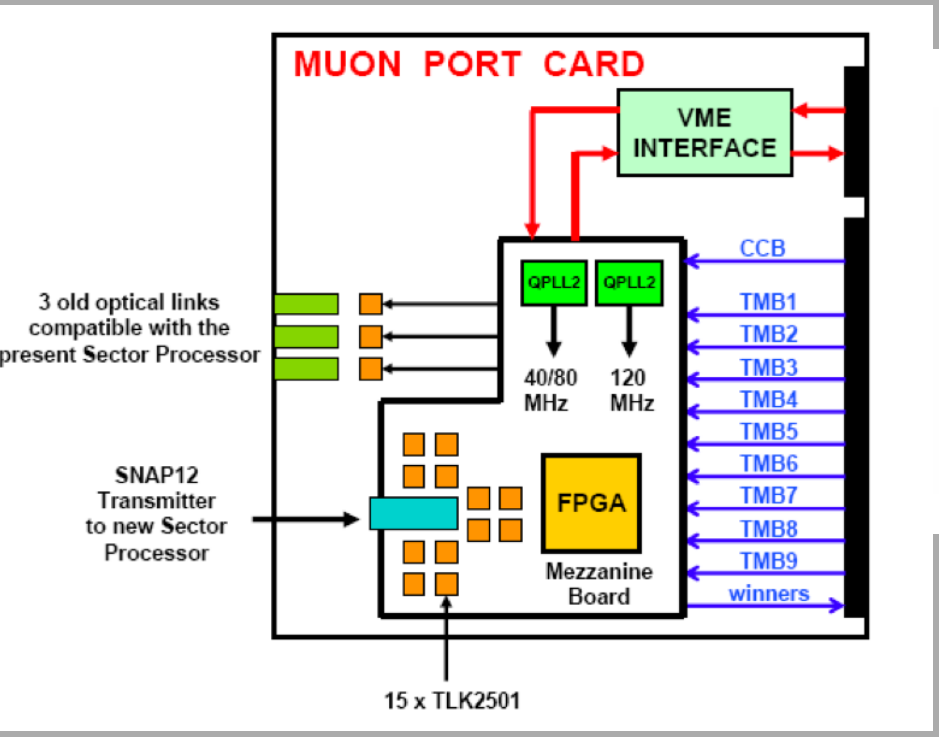
- make the trigger maximally robust for the high multiplicity environment of Phase 1 and Phase 2
- improve track p_T assignment algorithms
- Provide fine granularity of muon candidate data (p_T, η, φ); (key to clean matching with tracker in Phase 2)
- remove any unwanted features of the current design (small inefficiencies at sector borders)

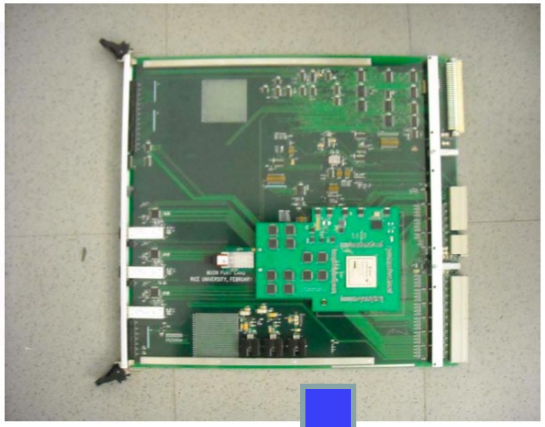


Upgrade Muon Port Cards and Sector Processor to increase available bandwidth and processing power.

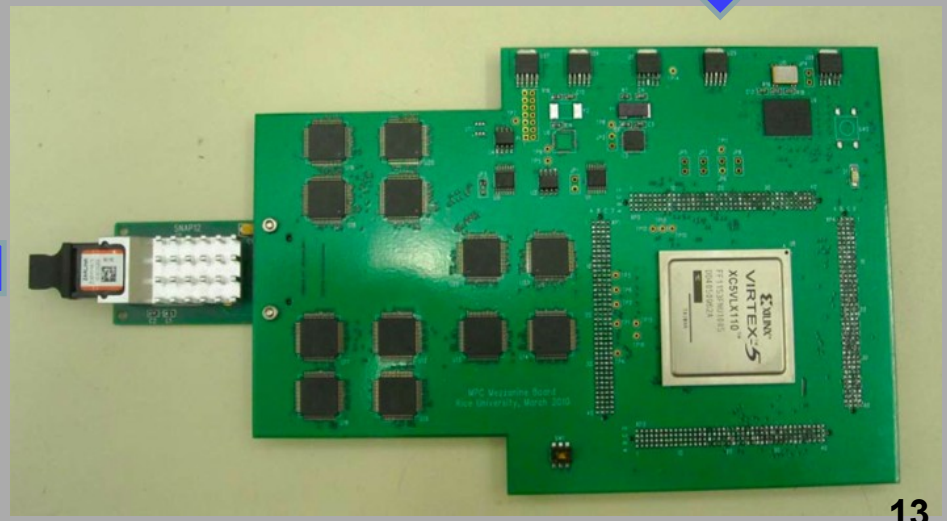
More in next talk by Ivan Furic

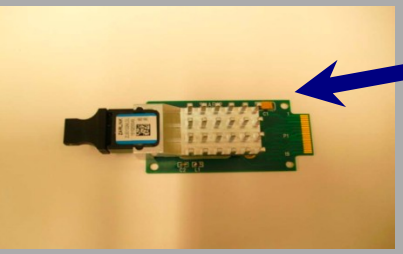
Upgrade R&D for new Muon Port Cards





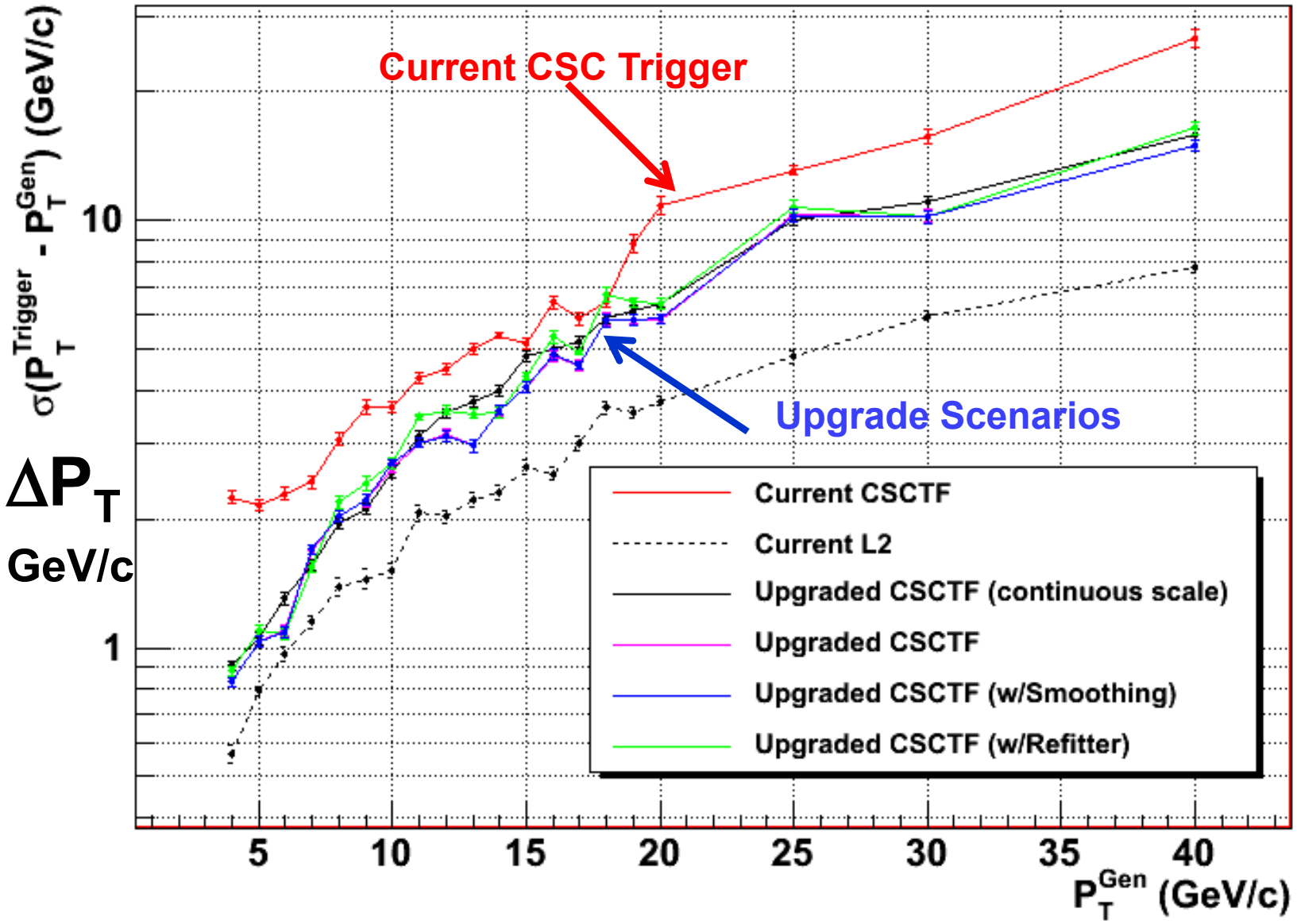
Redesign of the Muon Port Card Mezzanine at Rice





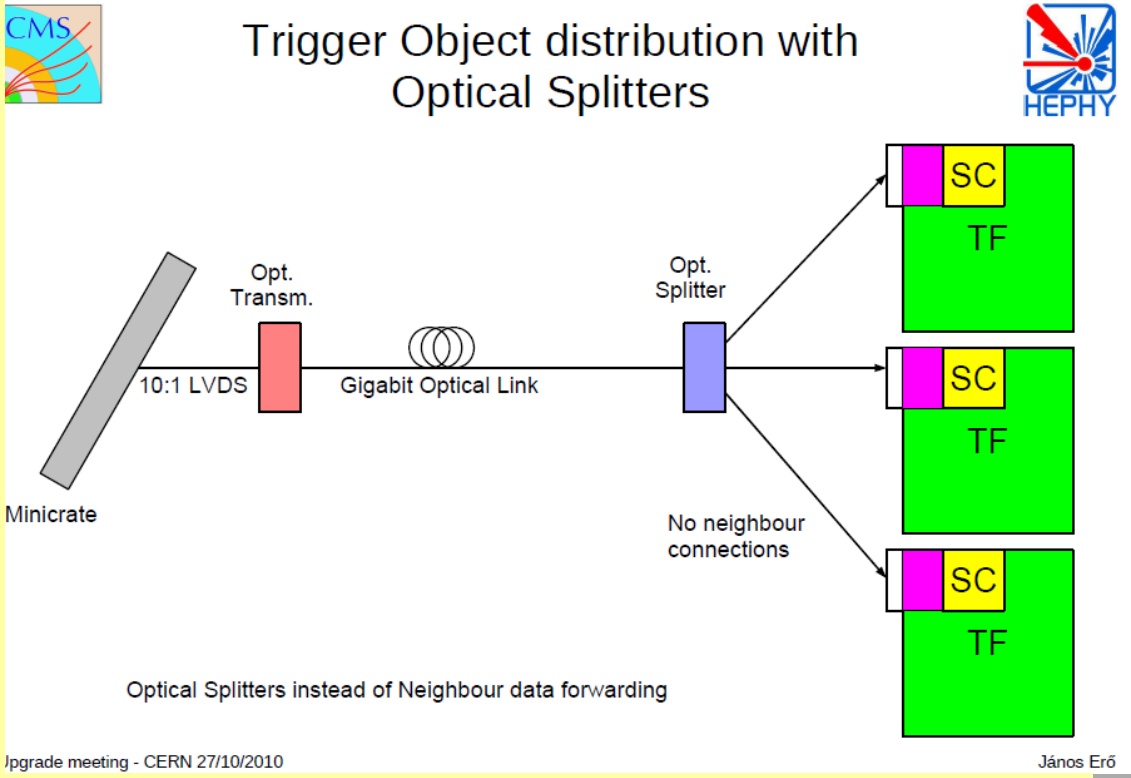
SNAP12 Plug-in Transmitter Board

Expected Improvement in P_T Resolution



DT+RPC Triggers

- **DT:**
  - **The group is investigating different technologies and architectures for the upgraded DT trigger.**
  - **In this it benefits from μTCA, FPGA and Multi-Gigabit-Link developments of other CMS trigger groups.**
  - **Aim to use existing devices to shorten the R&D phase and move rapidly to construction**



- **RPC:**
  - **Increase η coverage from 1.6 → 2.1**
  - **Working on better pattern recognition algorithms**

Summary: CMS Trigger Upgrades

- Upgrade is based on a clear set of principles
- Substantial experience has been gained in the R&D work carried out by several groups
  - Moving to consolidate progress and go to construction mode.
  - Review Panels will be setup to monitor progress.
- When a Track Trigger based on central tracking is implemented for Phase 2, this systems provides the basis for using the tracking information with the information from the calorimeters and muon detectors

More in next talk on Phase-II by Marcello Mannelli