FEC-CCS:
A common Front-End Controller card for the CMS detector electronics.

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CERN PH/MIC-DG

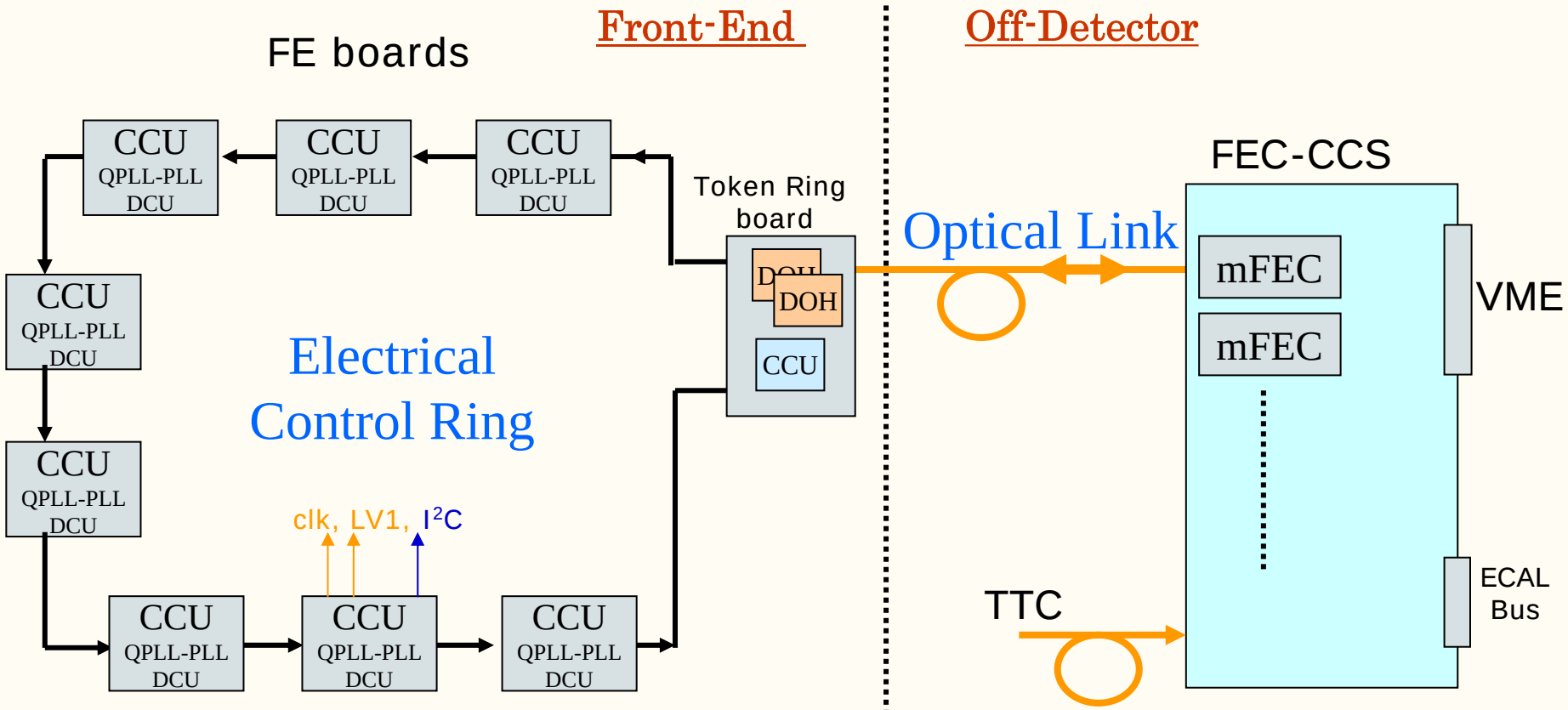
Outline

- FEC-CCS Design Architecture
- Sub-system integration phase
- Production Testing
- Summary

Front-End Control System Overview

- Main Functionalities:
  - Establish control bi-directional links with the Front-End chips.
    - Setup/configure FE chips.
    - Read back status information from FE chips and monitor detector environmental parameters.
  - Distribute Fast Timing signals to the Front-End chips
    - 40MHz LHC clock
    - Trigger commands

Front-End Control System Overview



A common CMS Front-End Control System

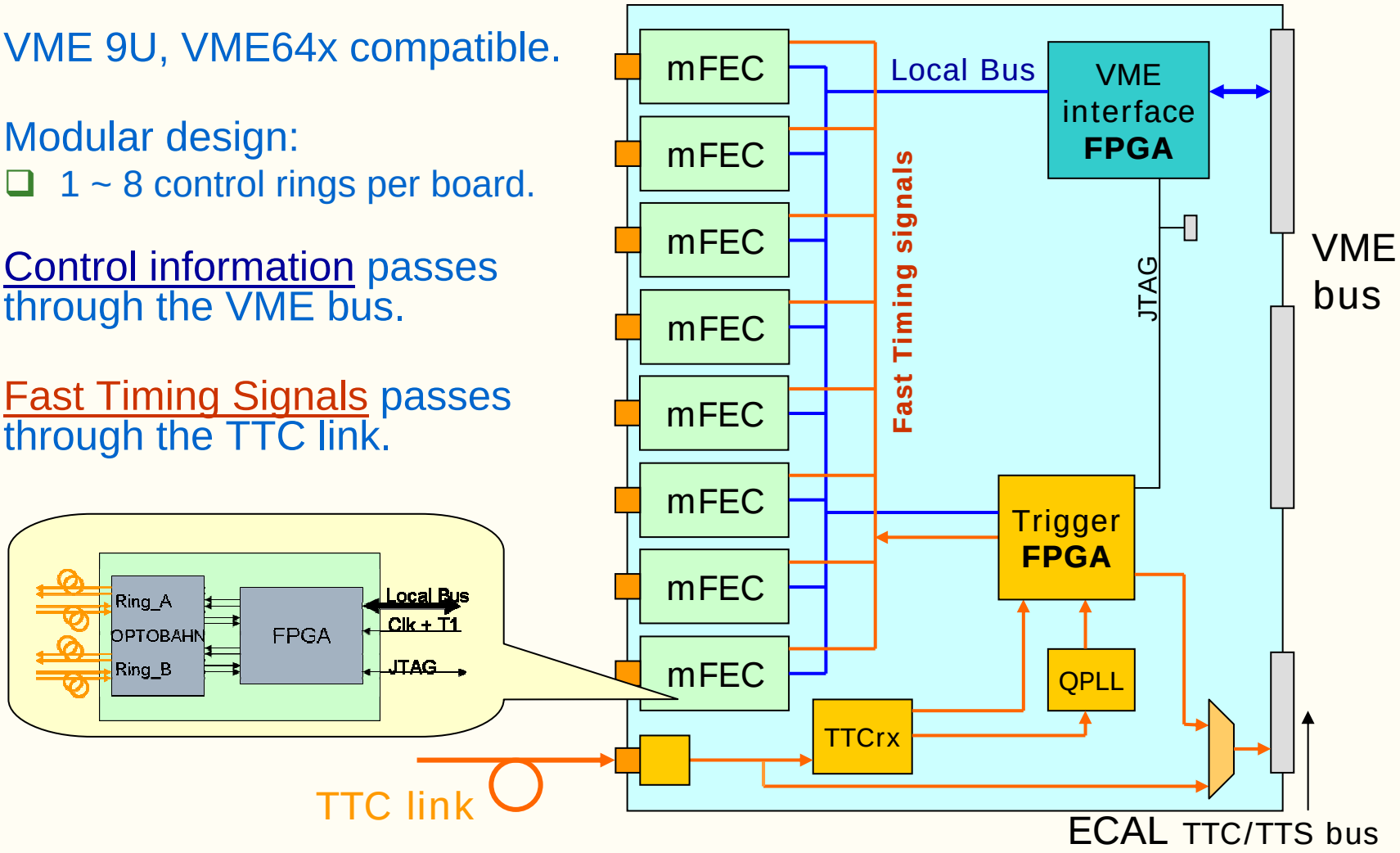
- TRACKER
- ECAL
- Preshower
- PIXELS
- RPCs
- TOTEM

CMS FEC-CCS System

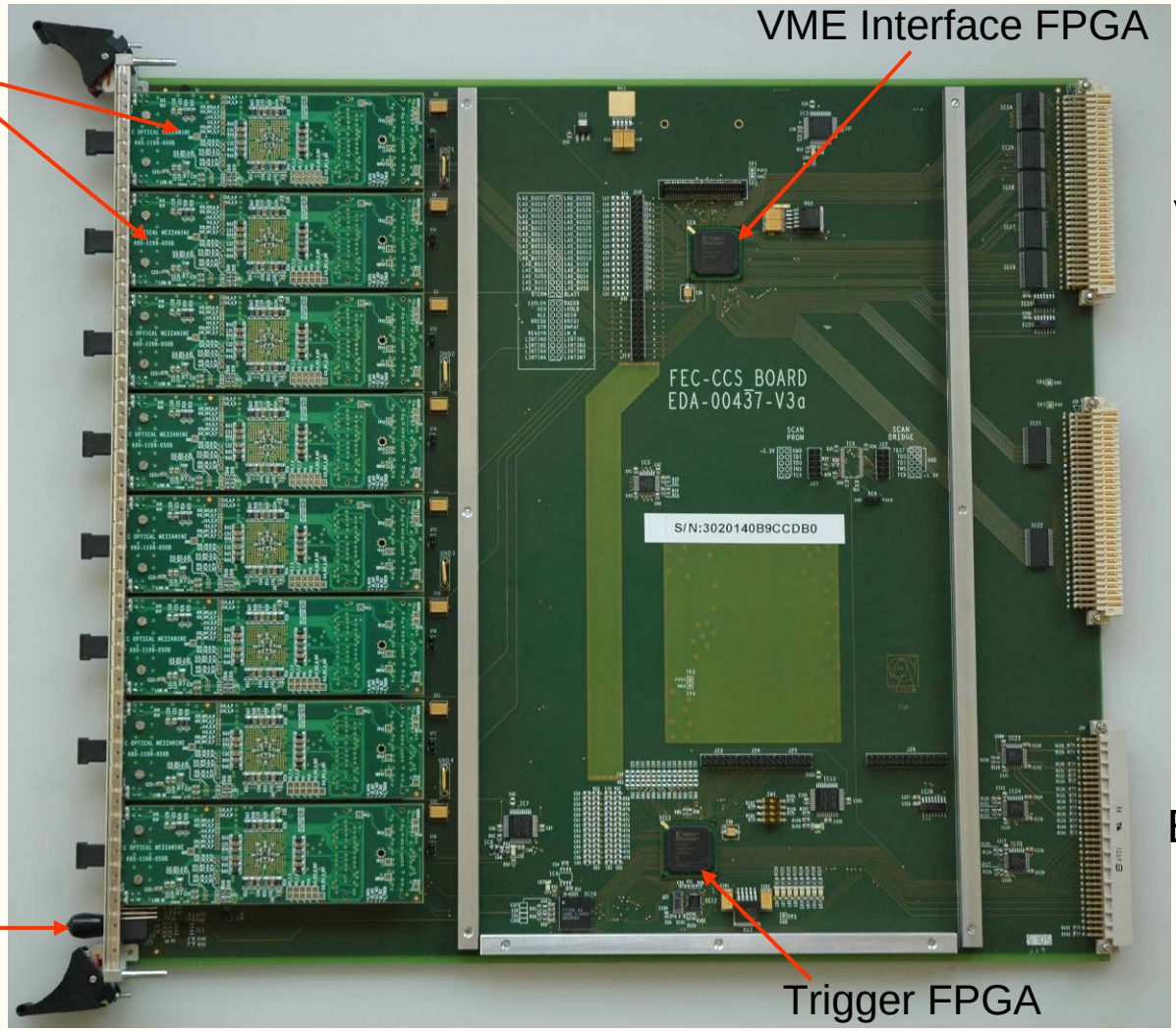
- A common Front-End controller card for the CMS sub-systems.
  - Advantages:
    - Minimize design effort and production cost.
    - Maximize system maintenance and support services.
  - Requirements:
    - Accommodate the differences of the CMS sub-systems architectures.
    - Modular design.
    - Flexibility.
    - Conform to the CMS VME electronics specifications.
  - The VME FEC-CCS card primary users
    - TRACKER : FEC (Front End Controller)
    - ECAL : CCS (Clock & Control System)

FEC-CCS Block Diagram

- VME 9U, VME64x compatible.
- Modular design:
  - 1 ~ 8 control rings per board.
- Control information passes through the VME bus.
- Fast Timing Signals passes through the TTC link.



The FEC-CCS Card

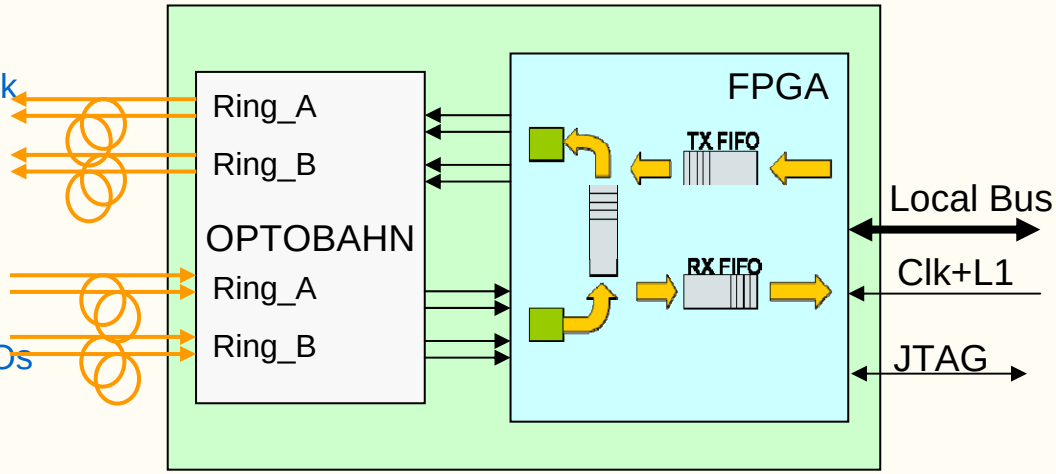


Power consumption:
(8 mFECs installed)

- 7A @ 3.3V,
- 1A @ 5.0V
- Total power: ~30W

The mezzanine FEC (mFEC)

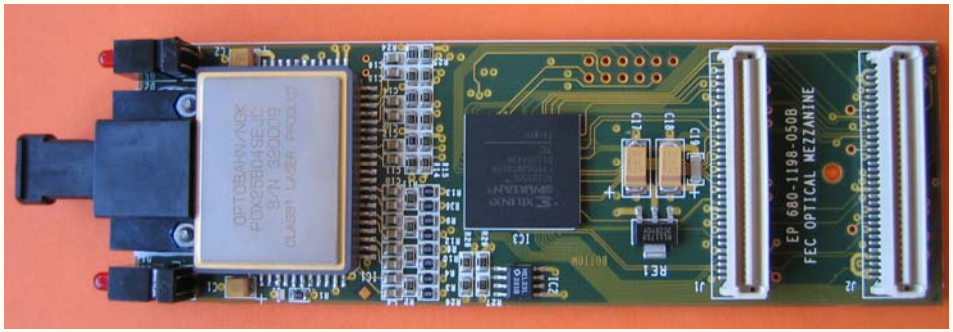
- mFEC Functionality
  - Token Ring Controller
  - Data Link synchronized to the LHC clock
  - Data Link raw throughput: 40Mbps.
  - Trigger Commands encoded on the clock line.
    - 100 (LV1A)
    - 110, 101, 111
  - Dual Rings for redundancy
  - Local Bus interface through TX/RX FIFOs



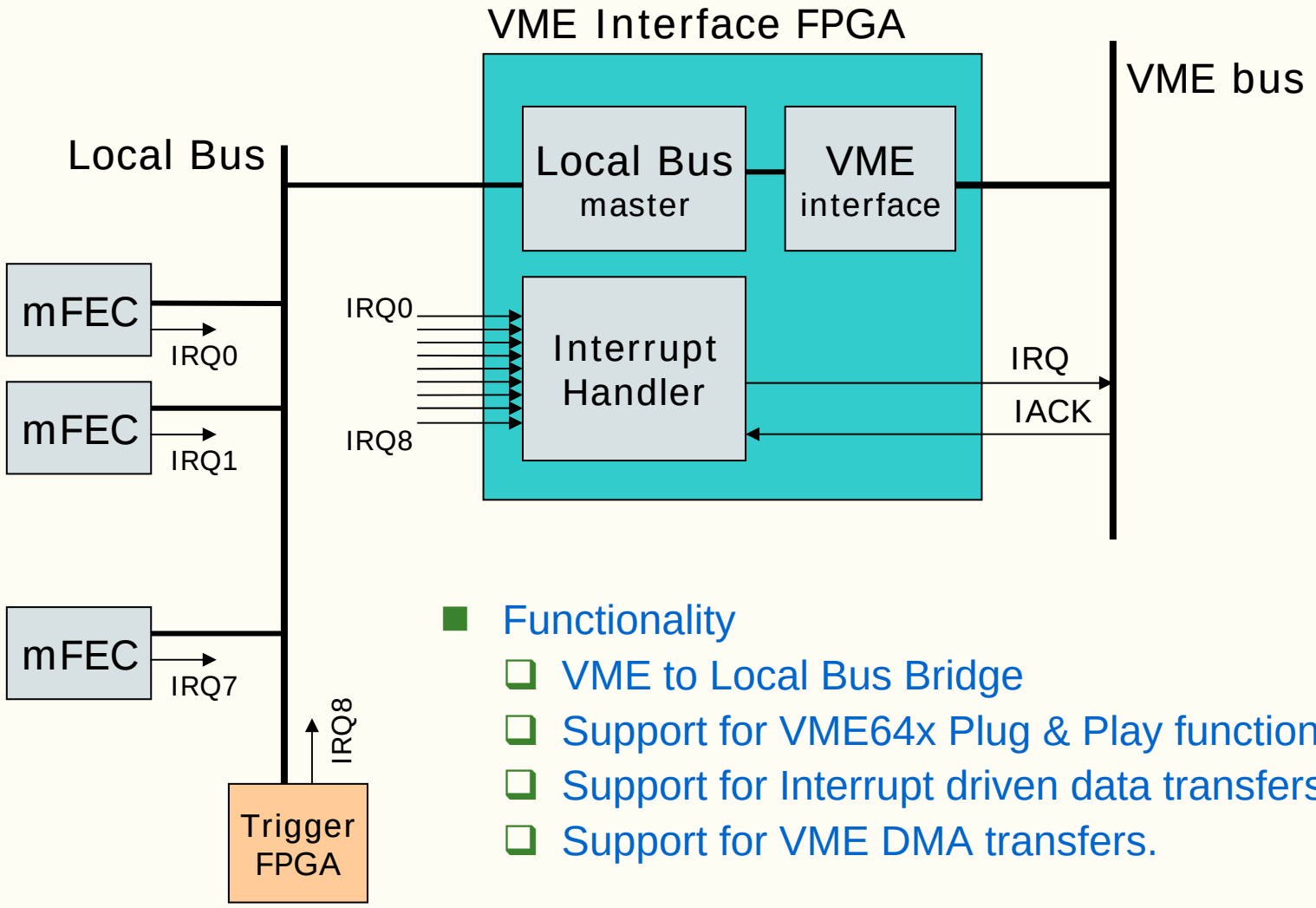
- Local Bus
  - 40 MHz, 32 bit multiplexed.
  - 4 bit geographical address.
  - 16 words address space .

- JTAG port for Firmware upload
  - Firmware resides on the carrier board.
  - No configuration Jumpers.

- Can be plugged onto different types of carrier boards
  - VME FEC-CCS cards
  - PCI carrier cards



VME Interface FPGA

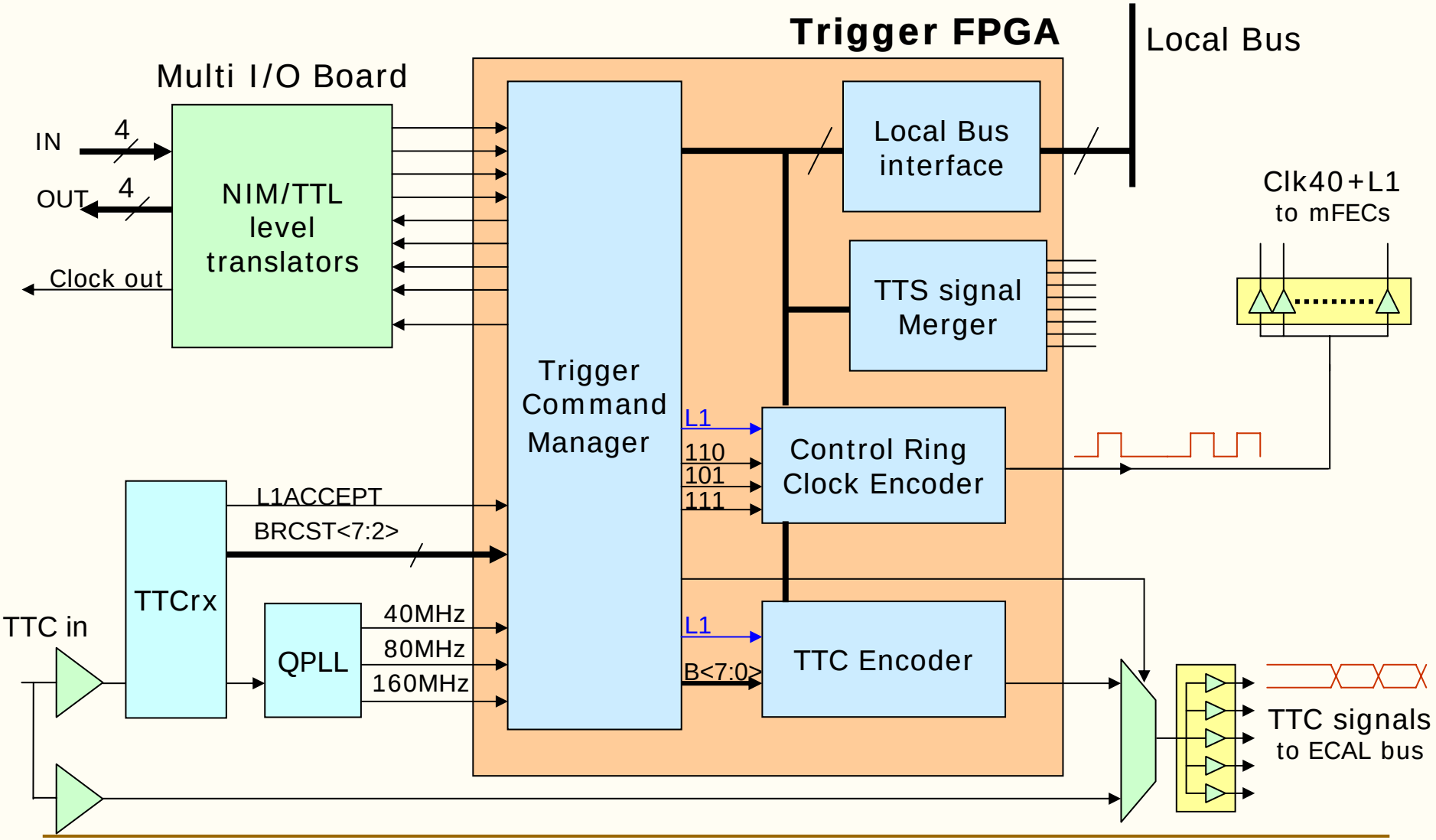


- Functionality
  - VME to Local Bus Bridge
  - Support for VME64x Plug & Play functionality.
  - Support for Interrupt driven data transfers.
  - Support for VME DMA transfers.

Fast Timing Functionalities

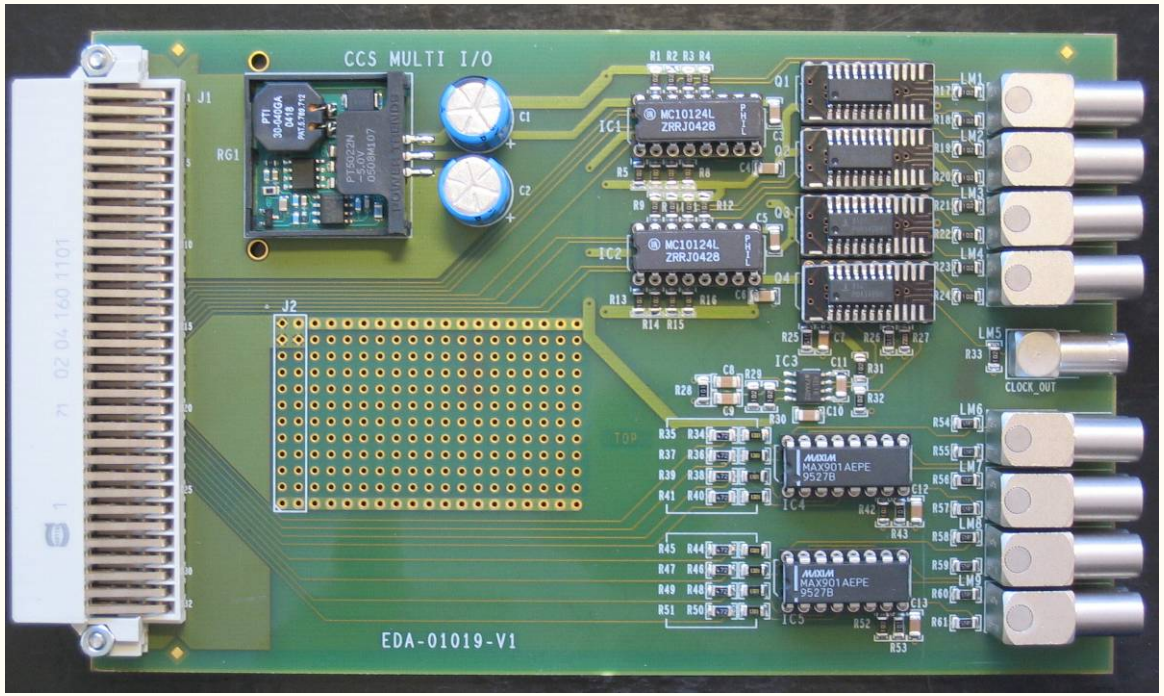
- Distribute Clock & Trigger Commands to the FE electronics.
  - Mapping of TTC B-channel commands to Control Ring Trigger Commands.
  - Monitoring of incoming TTC B-channel commands.
  - Masking of individual TTC B-channel commands.
- Generate a local 40MHz clock in the absence of the TTC signal.
  - Automatic selection of *Remote/Local* Modes.
  - User programmable *Forced Local* Mode.
- Generate Local Trigger Commands
  - To support debugging during system integration & commissioning.
  - To support the operation of stand alone setups (without TTC system).
- Provide support for the ECAL special TTC/TTS bus and functionalities
  - TTC signal fan-out to the DCC & TCC VME modules.
  - TTS signal fan-in from the DCC & TCC VME modules.
- Interface with external equipment via NIM I/O signals.

The Trigger FPGA



FEC-CCS Multi I/O board

VME RJ2 connector



NIM I/O
4 Inputs

1 clock out

4 Outpus

- Provides synchronization with external equipment.
- 3U Rear VME Backplane Transition Board
- Connects on VME RJ2 connector.

Trigger Command Manager

Mapping of TTC B-channel commands to Control Ring Trigger Commands

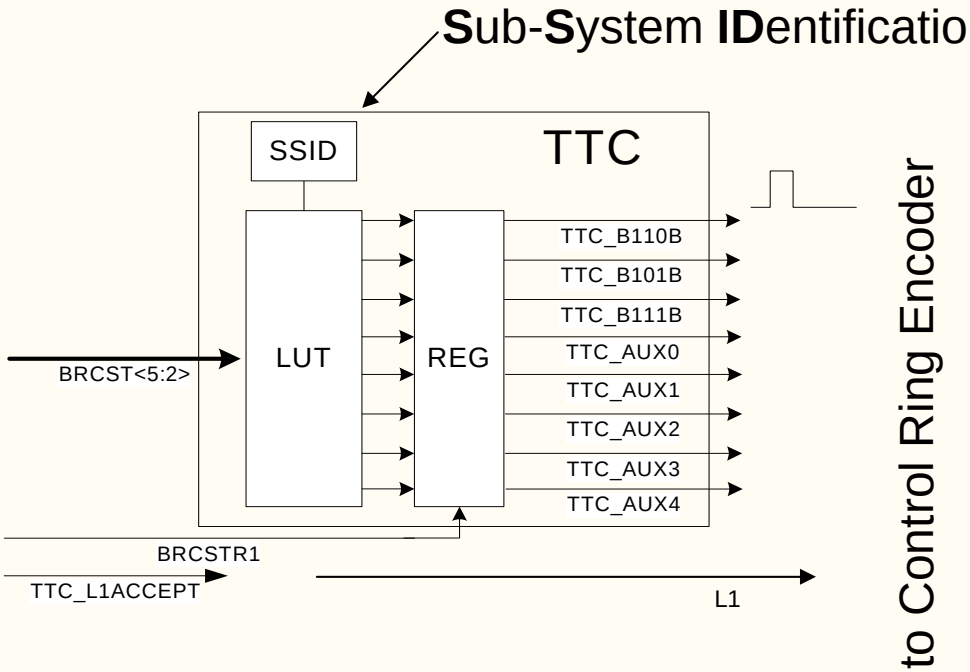
TTC B-Go channels for the FEC-CCS VME board

			TRACKER		ECAL		Preshower		PIXEL		RPCs	
B-Go ch.	TTC Brcst<5:2>	Command	T Ring	Function	T Ring	Function	T Ring	Function	T Ring	Function	T Ring	Function
	0000	Not Used										
1	0001	BC0			101	BC0	101	BC0				
2	0010	Test Enable	110	APV_CALIBRATE	111	Monitoring	111	CalPulse				
3	0011	Private Gap										
4	0100	Private Orbit										
5	0101	ReSync	101	RESYNC	110	ReSync	110	ReSync	101	ResetTBM		
6	0110	HardReset	101	APV_RESET								
7	0111	Reset Event Counter							111	ResetROC		
8	1000	Reset Orbit Counter								Send	NOT IN USE	
9	1001	Start										
10	1010	Stop										
11	1011	Free1							110	CalSync		
12	1100	Free2										
13	1101	Free3										
14	1110	Free4										
15	1111	Free5										
TTCrx signal												
L1ACCEPT			100	L1	100	L1	100	L1	100	L1	NOT IN USE	

- Control Ring Trigger Command Assignments are not common for all the subsystems.
- The decoding of these commands by the Frond-End ASICs is hardwired.

Trigger Command Manager

- **Solution:**
  - Mapping of TTC B channel commands to Control Ring Trigger Commands can be done using a LUT in the Trigger FPGA.



SSID	Sub-System
x000	Reserved
x001	TRACKER
x010	ECAL
x011	PRESHOWER
x100	PIXELS
x101	RPC
x110	Reserved
x111	Reserved

FEC-CCS card Trigger Latency

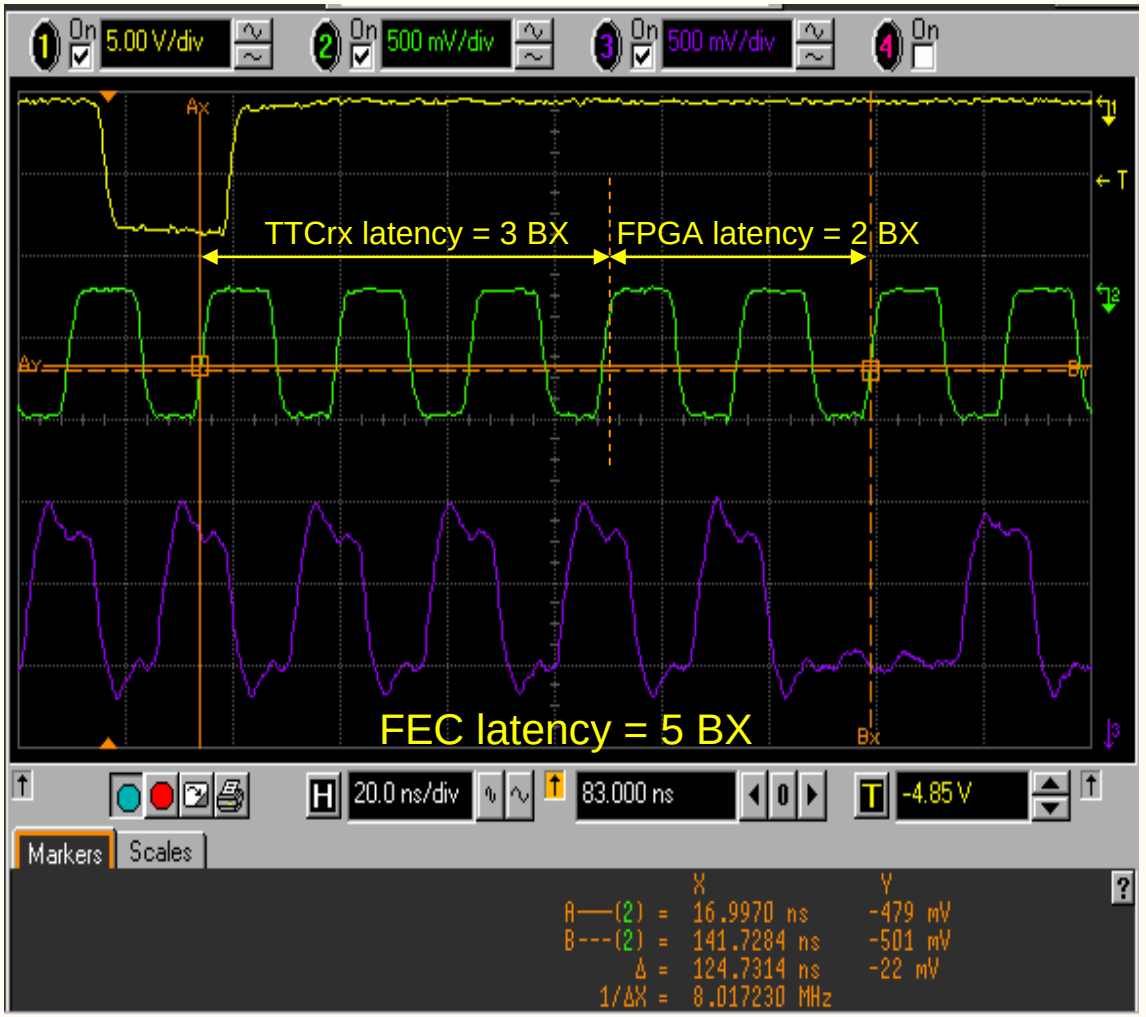
Trigger Latency = 5 BX

from TTC input to mFEC output

TTCci L1A out

TTCci CLK out

VME FEC
mFEC CLK_OUT_P

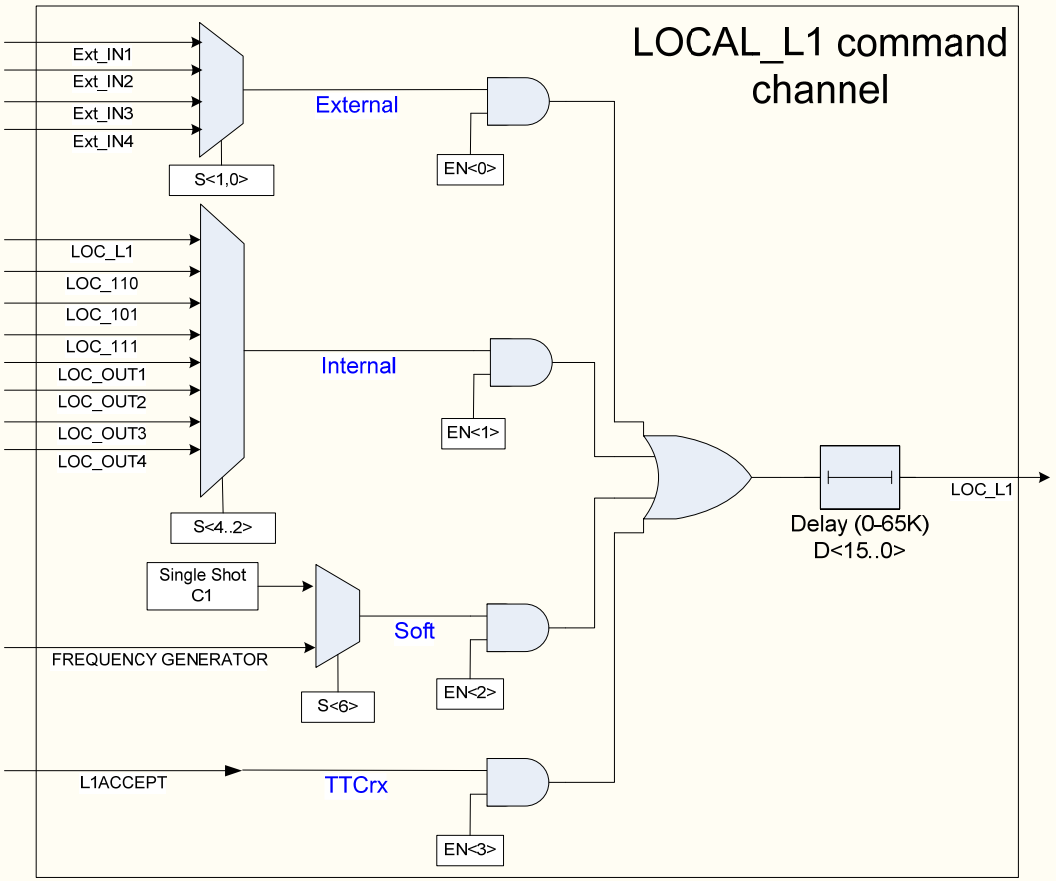


Local Trigger Generation Logic

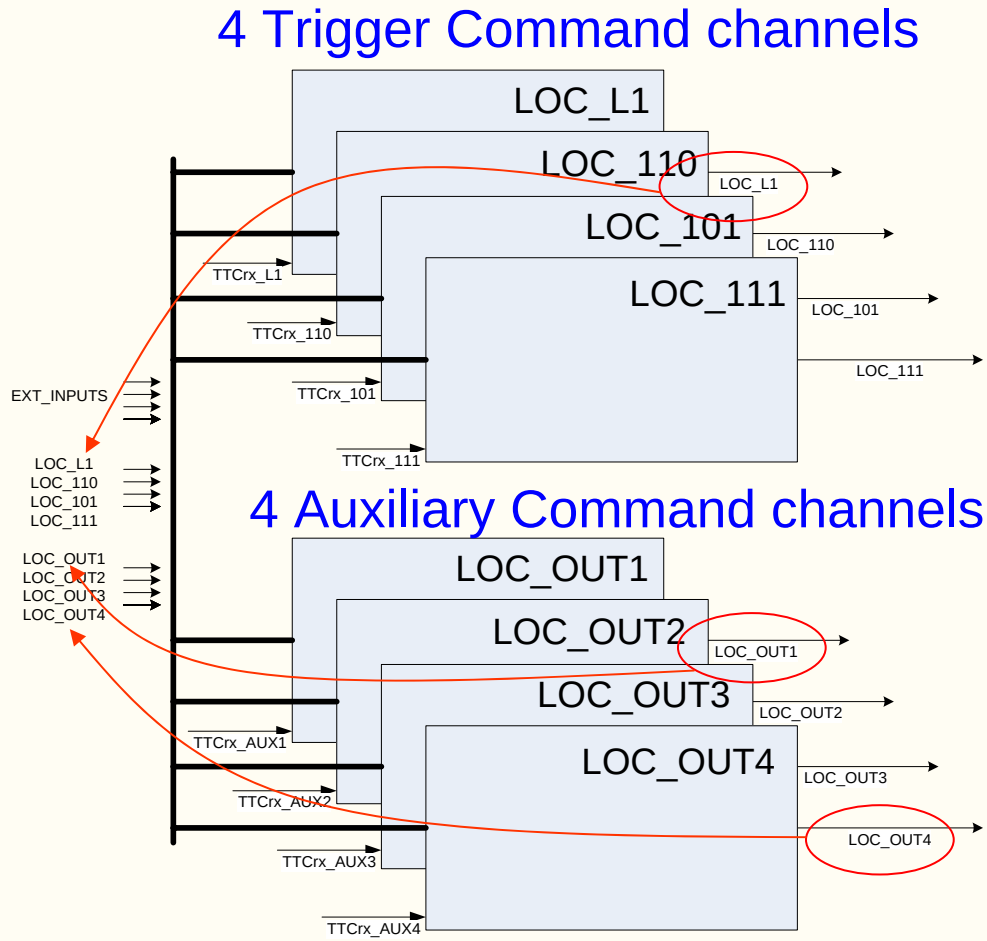
- Functionality needed in stand alone DAQ system setups, without a TTC system support.
- Generic Logic architecture
  - Instead of a hardwired trigger logic customized for a specific test setup, a flexible, user configurable trigger logic, is implemented.
  - The Physicists and Engineers can configure the Trigger Generation logic as required for each test system setup.
- Flexible and configurable logic
  - Generation of
    - Single trigger commands.
    - Bursts of trigger commands.
    - Single shot sequences of trigger commands.
    - Periodic sequences of trigger commands.
  - Programmable delays for the timing of the trigger commands.
  - Synchronization with external signals.

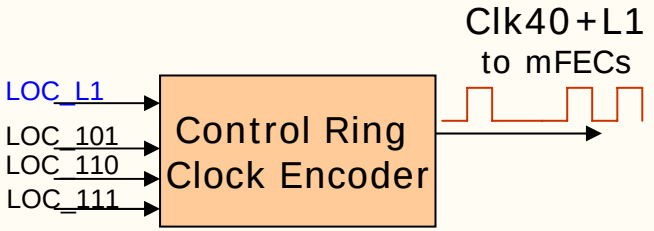
Local Trigger Generator

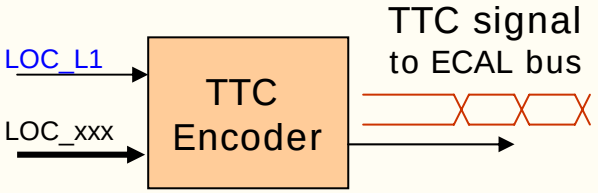
- Modular design
  - 8 identical “command channels”.
    - 4 Control Ring command channels.
    - 4 Auxiliary command channels.
- Trigger Command sources
  - User selectable
    - External signals
    - Internal signals
    - Software (VME)
- Trigger Command outputs
  - Control Rings
  - ECAL bus
  - NIM Outputs

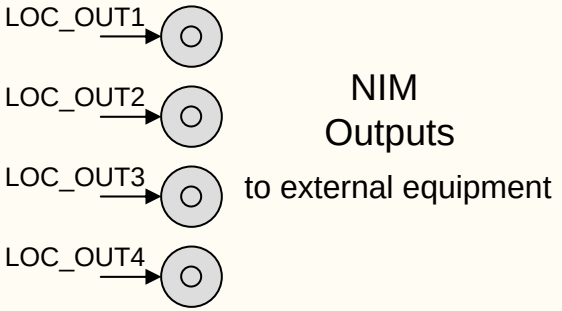


Local Trigger Generator

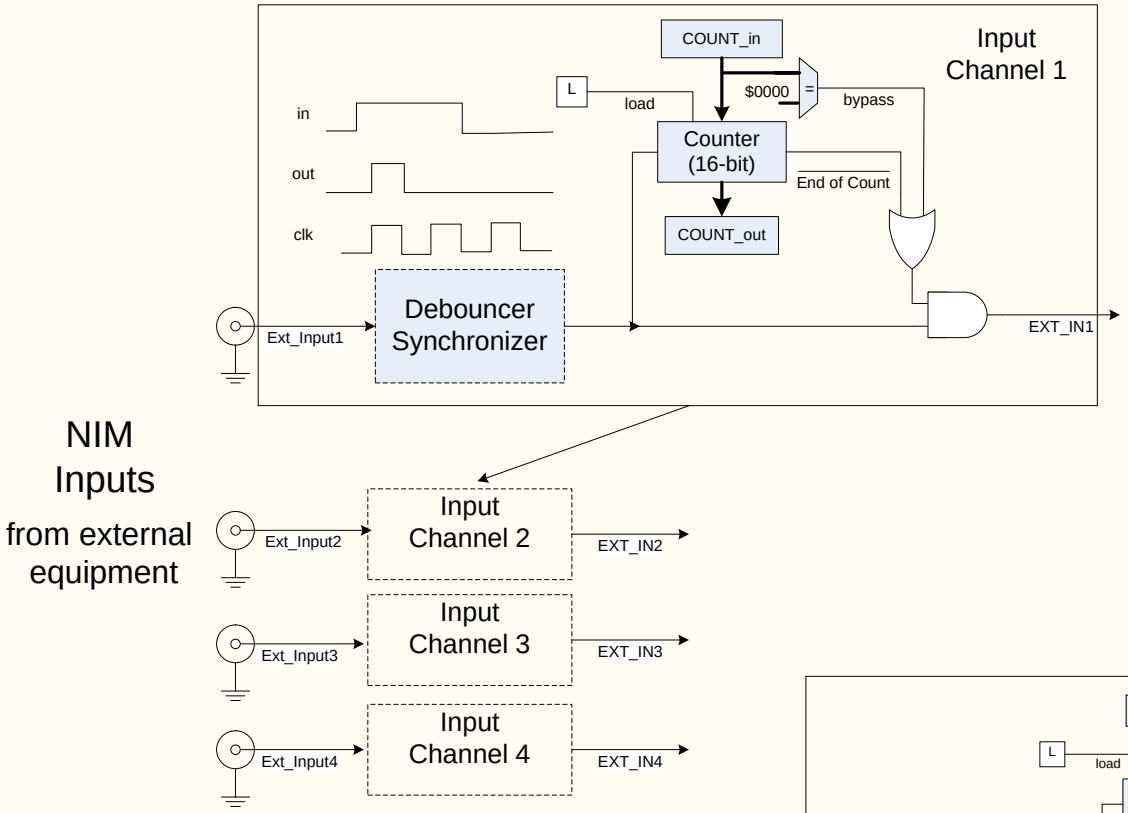


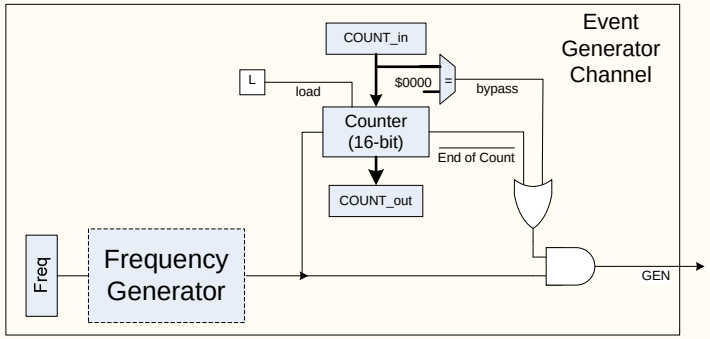






Local Trigger Generator





- 4 External Input Channels
  - Event rate prescaling.
- 1 Generator for Periodic Events
  - Emulate LHC Orbit signal.

Results from Field operations

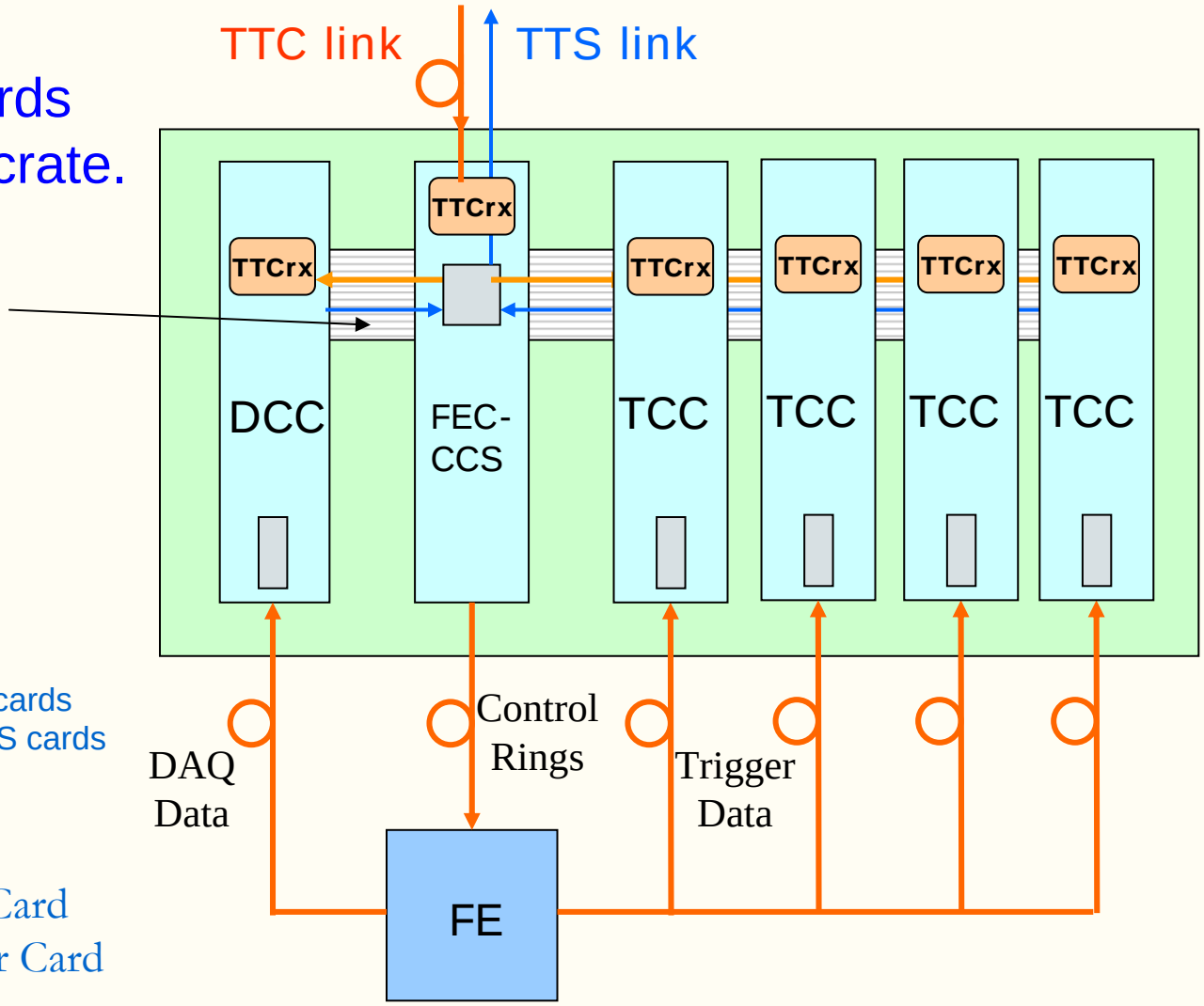
- Local Trigger Generation Logic use in ECAL system setups:
  - ECAL Test Beam run 2004.
  - Supermodule Integration Hall (Bldg. 867).
  - H4 Cosmic calibration stand.
  - H4 ECAL Test Beam stand.
  - H2 ECAL+HCAL Test Beam stand.
  - MTCC (Magnet Test Cosmic Challenge) run 2006.
    - Local mode used for debugging. Remote mode used with TTCci.

- Typical Operations
  - Pedestal Run
    - Software programmed periodic L1 triggers.
  - Electronics Calibration Run
    - Sequence of FE charge injection commands followed by delayed L1 trigger.
  - Laser Calibration Run
    - Command the firing of Laser pulser. Receive trigger from Laser apparatus.
  - Test Beam Run
    - Receive external trigger from counters and NIM logic.

The CMS ECAL case

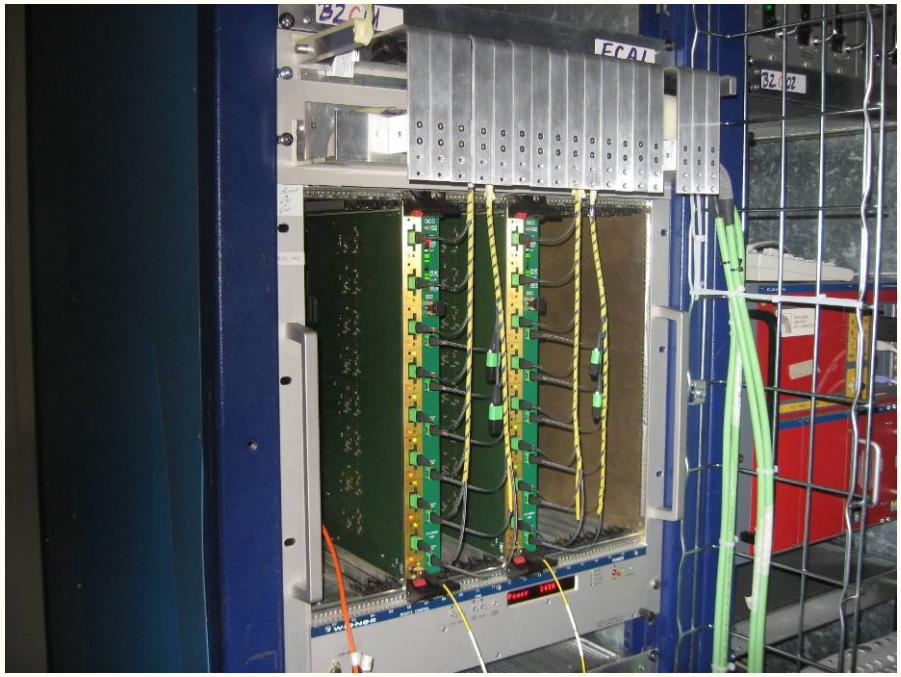
DAQ and Control cards coexist in the same crate.

- ECAL TTC/TTS bus:
  - Distribute TTC signal
    - PECL
  - Merge TTS signals
    - LVDS
  - Bus Length:
    - Endcap: 3 VME slots
    - Barel: 6 VME slots
- ECAL system
  - EB (Barel) 36 FEC-CCS cards
  - EE (Endcap) 18 FEC-CCS cards



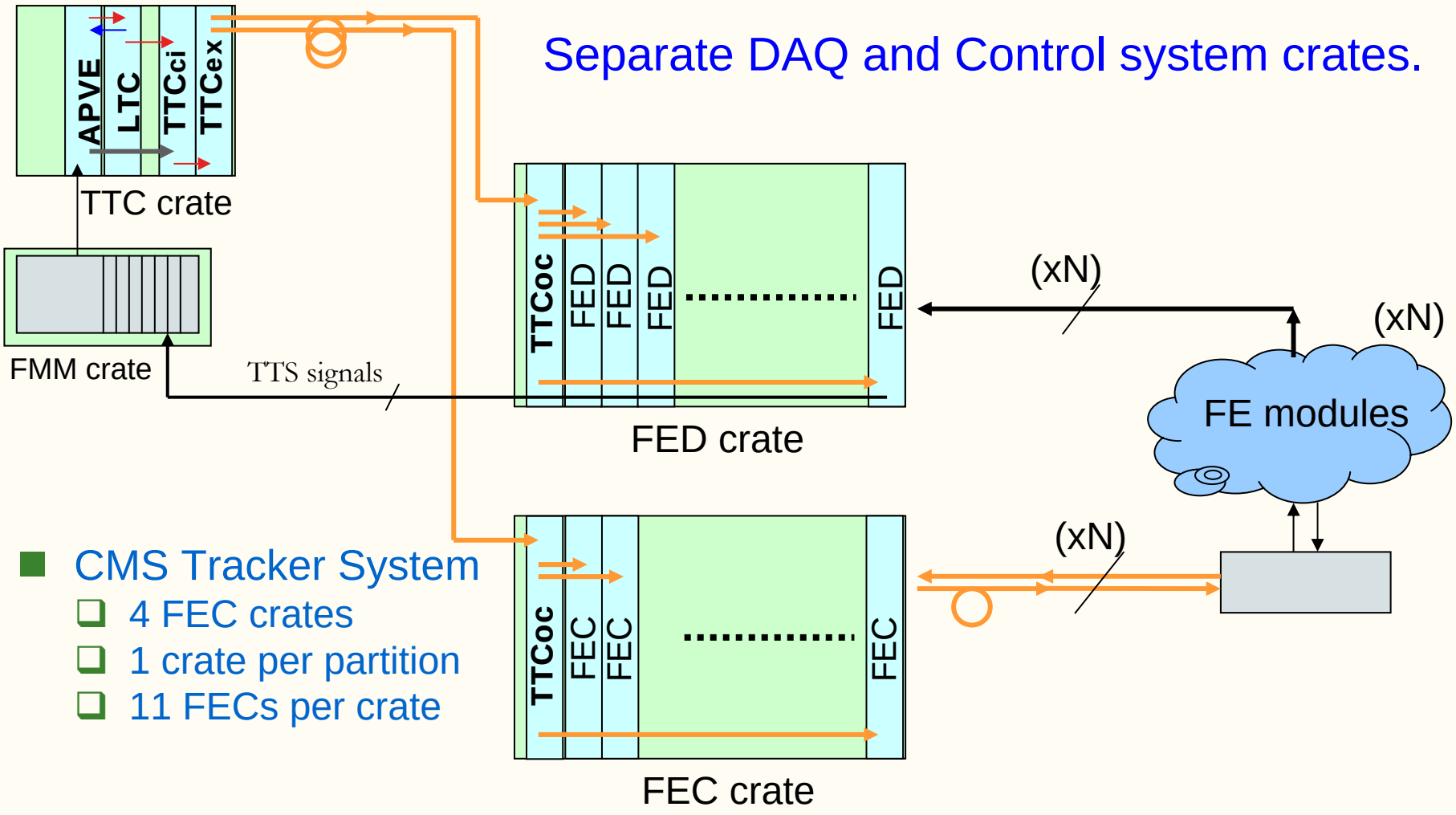
DCC: Data Concentrator Card
TCC: Trigger Concentrator Card

The CMS ECAL case



- 5 different setups in operation:
  - Supermodule Integration Hall (Bldg 867)
  - H4 Cosmic calibration stand
  - H4 ECAL Test Beam stand
  - H2 ECAL+HCAL Test Beam stand
  - MTCC (Magnet Test Cosmic Challenge)

The CMS Tracker case

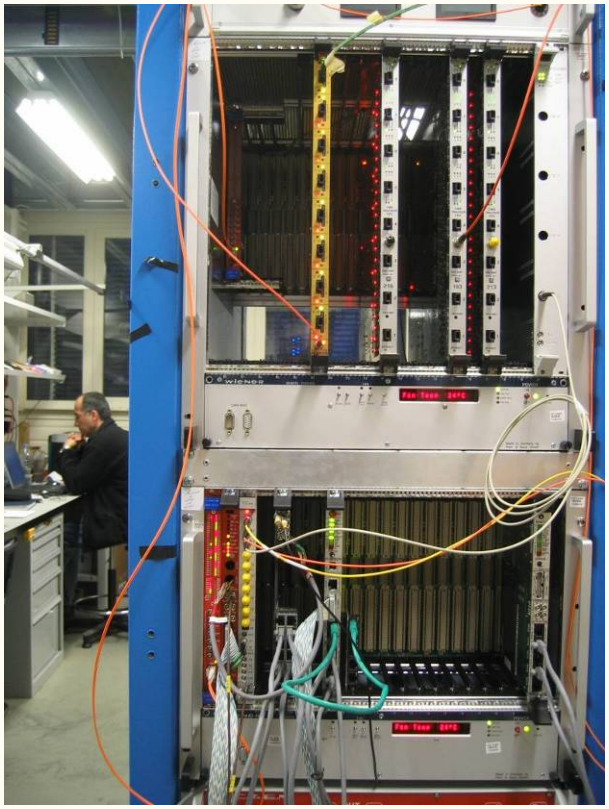


Separate DAQ and Control system crates.

- CMS Tracker System
  - 4 FEC crates
  - 1 crate per partition
  - 11 FECs per crate

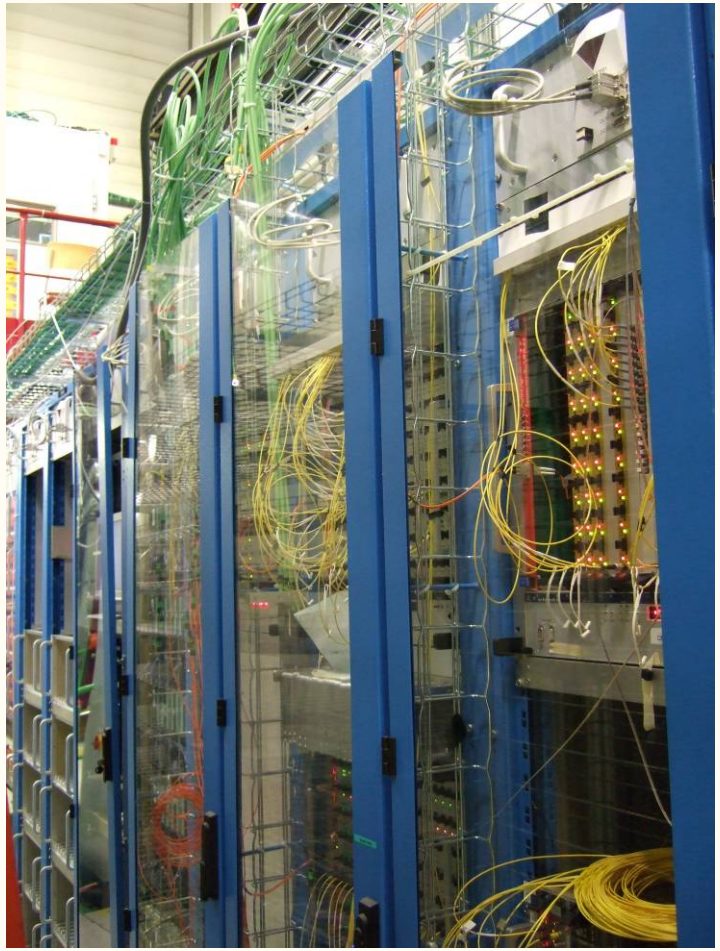
The CMS Tracker case

- Tracker electronics system setups:
  - Electronics System integration center, bldg. 904
  - Tracker Integration Facility (TIF), bldg. 186
    - TOB (Tracker Outer Barrel)
    - TIB (Tracker Inner Barrel)
    - TEC+ (Tracker End Cap +)
  - Aachen
    - TEC- (Tracker End Cap -)
  - Firenze/Pisa
    - TID (Tracker Inner Disk)



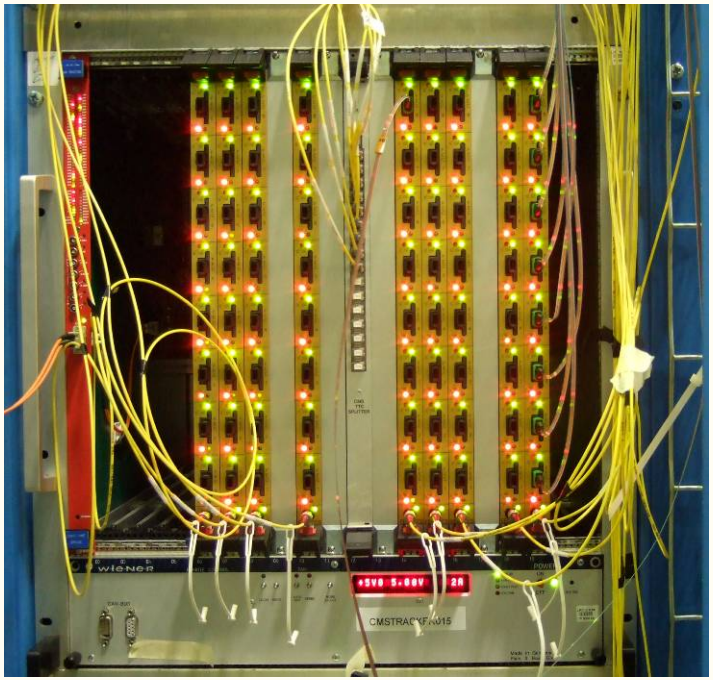
- MTCC test results
  - Validation of Front-End configuration procedures.
  - Validation of the Control Ring Redundancy.
  - Successful integration with the global TTC system.
  - Validation of the Tracker Trigger Throttling control loops.
    - APVE loop (APV emulator module)
    - FMM loop (TTS signals)

The CMS Tracker case



Tracker Integration Facility

CERN building 186



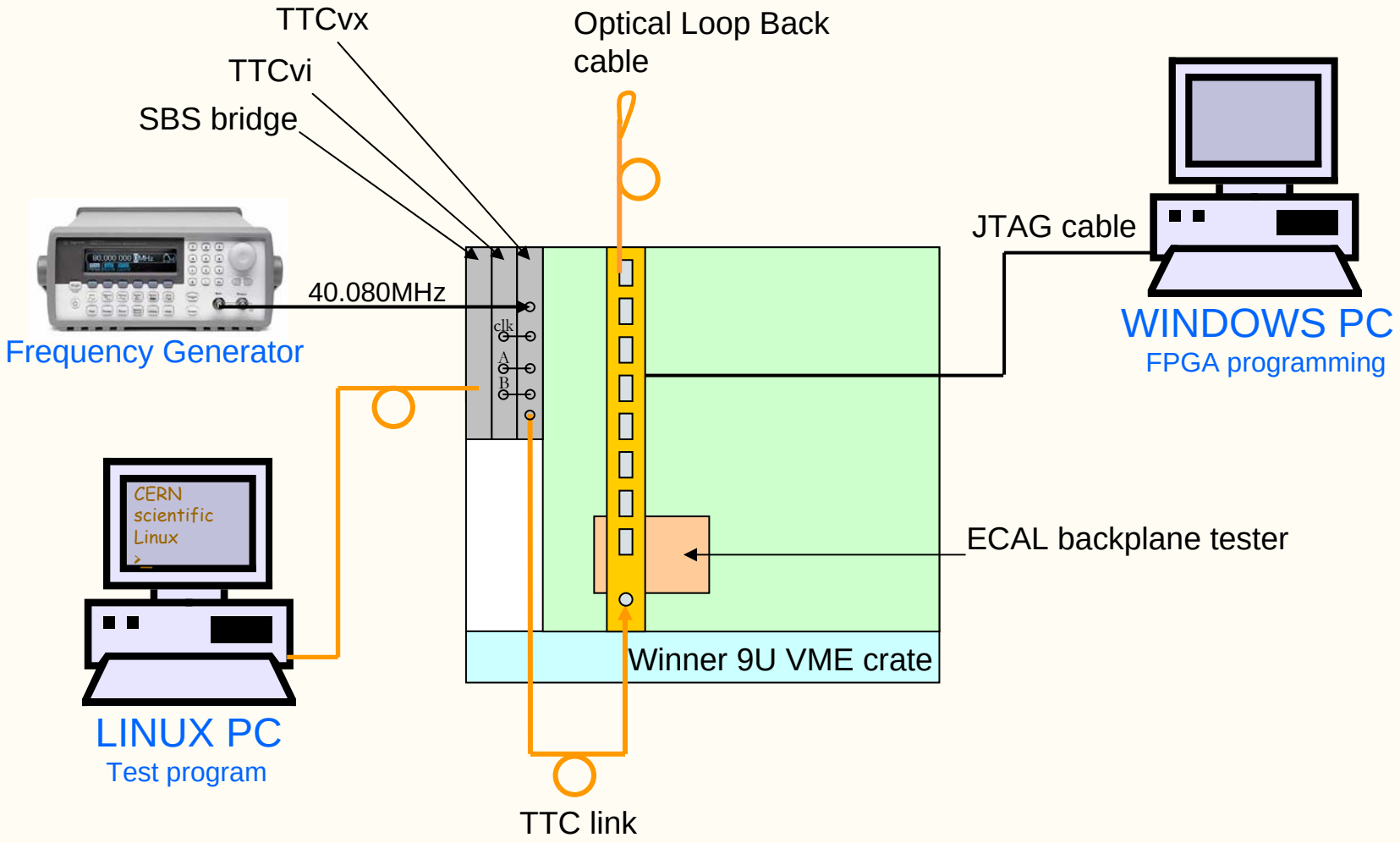
Other CMS subsystems

- Preshower
  - 20 FEC-CCS cards, 54 mFECs
  - Use of ECAL bus and special functions.
- PIXELs
  - 16 FEC-CCS cards, 80 mFECs
  - Special mFEC firmware for PIXEL specific Control Rings.
  - Special functions implemented on Trigger FPGA firmware.
- RPCs
  - 4 FEC-CCS cards, 25 mFECs
  - System used only for FE electronics control.
    - Timing distribution is done with on-detector TTCrx chips.
- TOTEM
  - 4 FEC-CCS cards, 16mFECs
  - Use of ECAL bus and special functions

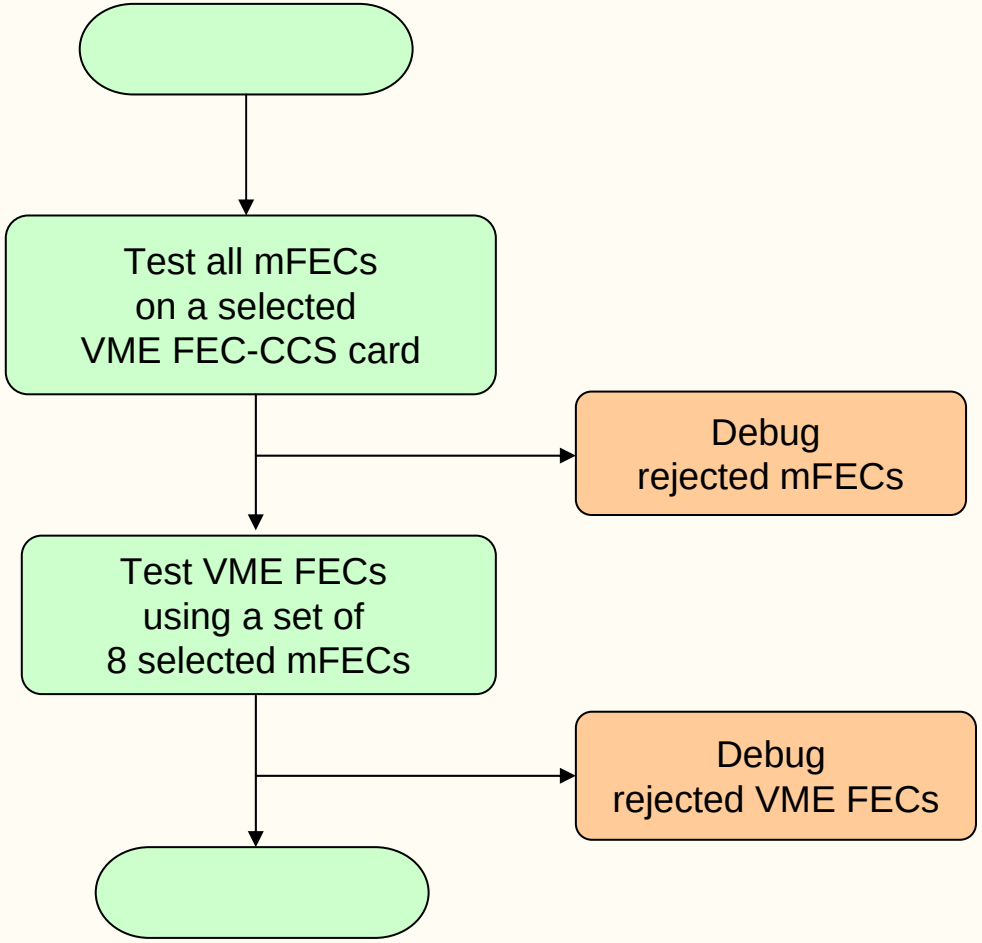
FEC-CCS Production Testing

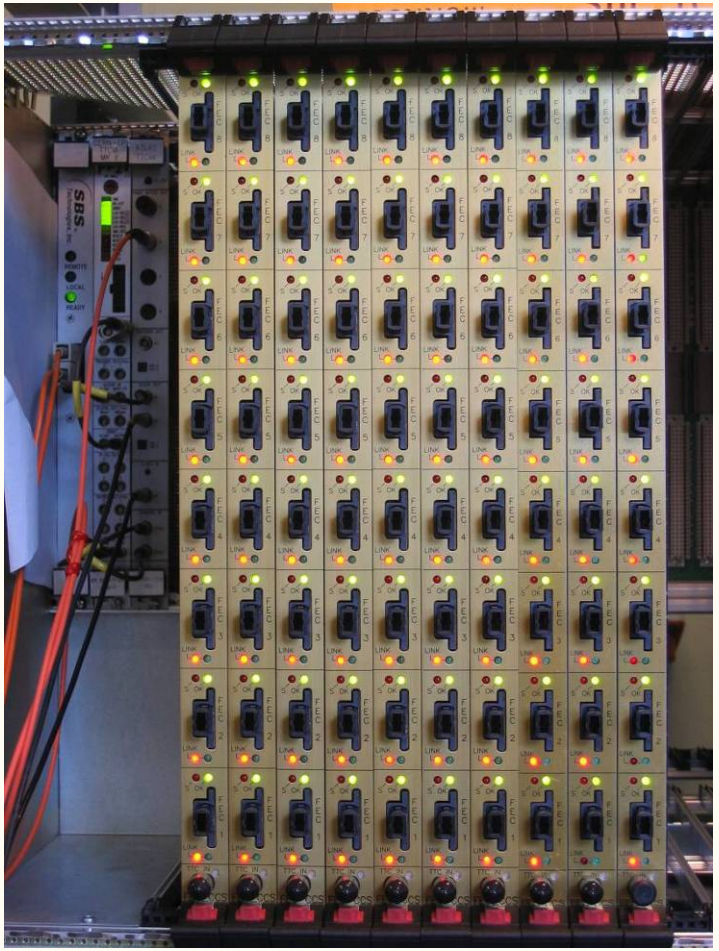
- In-house Production Testing.
  - CERN ECAL Lab. Bldg. 11.
- Custom made production test bench.
  - Test bench hardware based around a VME crate.
  - Test bench software prepared by Evgueni Vlassov.
  - Operated by a technician.
  - Same test bench used for both mFEC modules and VME FEC-CCS cards production testing.

Production Test Bench



Production Testing Procedure





FEC Production Status

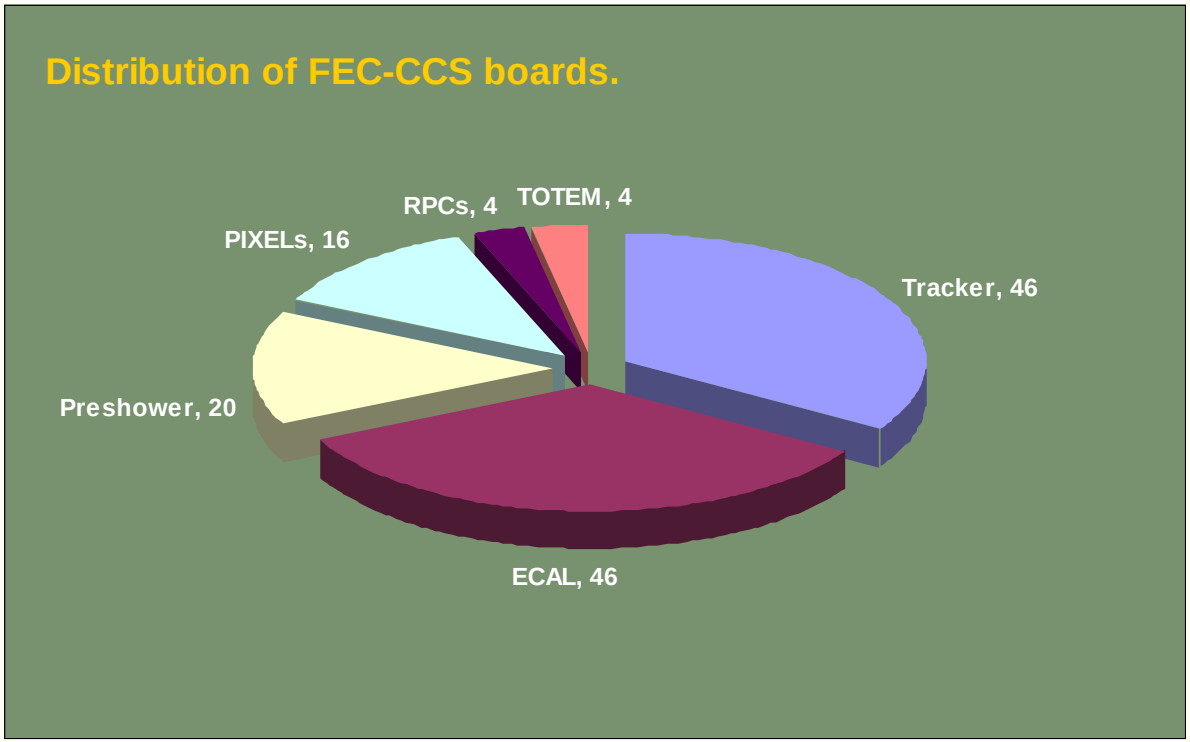
- mFEC Final Production: Completed
  - **900 modules** tested.
    - 35 rejected modules
    - Post-production run of 50 modules to compensate

mFEC

- VME FEC-CCS Production: Testing in Progress
  - Pre-production volume: **40 boards**
    - Distributed to ECAL, Tracker, Pixels, Preshower & RPCs sub-systems to equip their DAQ test setups.
    - These boards will also be used to equip the final systems in CMS.
  - Final production volume: **130 boards**
    - Assembled PCBs delivered at CERN
      - Production testing is in progress.
      - Estimated delivery period ~10/2006.

FEC-CCS

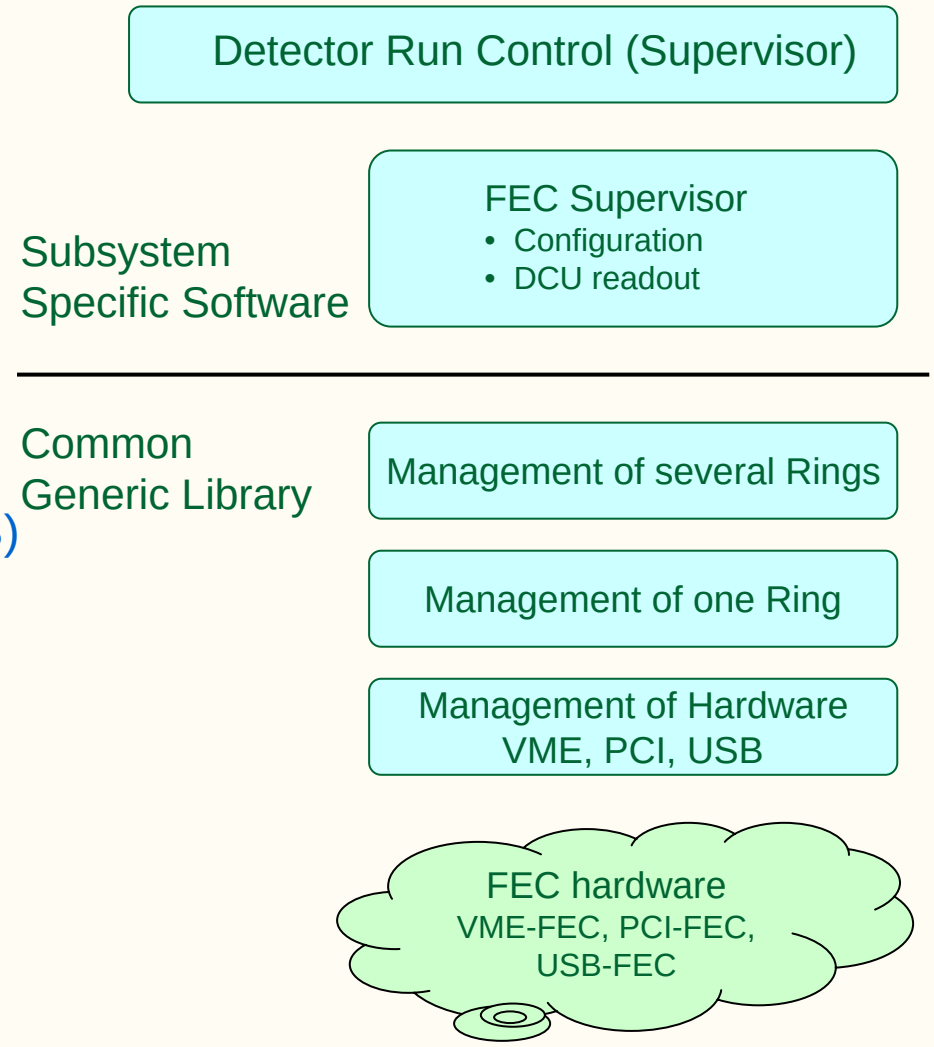
A common module for CMS



- 60 cards already distributed to the CMS sub-system groups.
  - Installed in various test systems at CERN and external institutes.
- PIXEL group received full production cards

FEC Common Software

- FEC Common Software
  - Provide access to the common hardware
  - Facilitate Maintenance and User Support
- Features
  - Multi-Layered software.
  - Support several types of FEC hardware (PCI, VME, USB)
- FEC Common Software development team:
  - Frederic Drouhin (Tracker)
  - Laurent Gross (Tracker)
  - Evgueni Vlasov (ECAL)
  - Wojciech Bialas (Preshower)



FEC-CCS User Support

Hardware

- mFEC, PCI-FEC (optical, electrical), VME FEC-CCS cards.
- Support: CERN MIC group.
- Contact persons: Kostas Kloukinas, Christer Ljuslin and Christian Palliard.

Firmware

- Unique Firmware version for all the sub-systems to ease maintenance.
- New firmware releases fixes various system “glitches” and adds functionality.
- Anticipate to have firmware revisions during the subsystem integration and commissioning periods.
- Visit the FEC-CCS project Web Site for relevant information
  - http://proj-fec-ccs.web.cern.ch/proj-FEC-CCS
  - or GOOGLE it -> (FEC-CCS)

Software

- FEC Common Software support:
- Contact person: Frederic Drouhin
- Provide common software user support for:
  - Tracker, ECAL, Preshower, Pixels, RPCs & TOTEM.
- Web Page:
  - http://x5oracle.cern.ch:8080/JSPWiki/Wiki.jsp?page=FECSoftware

Summary

- A common FE controller card for CMS sub-systems
  - Fulfils the requirements of the CMS sub-systems.
- Modular hardware design and flexible firmware to accommodate the different requirements.
- Successfully tested in numerous sub-system test setups.
- Production testing in final stage.
  - Boards are being delivered to CMS subsystems.
- Provide support during detector commissioning period.