Design, Fabrication & Characterization of Optical Splitters for CMS HCAL Back-End Electronics Upgrade

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Outline

- *Introduction*
  --*CMS Detector*
  --*Hadron Calorimeter*
  --*Electronics*

- *Motivation*

- *Major Milestones*
  --*Installation & Validation of μTCA crate*

- *Prototype Optical Splitter & Test Results @ India and CERN*

- *Summary & Conclusion*

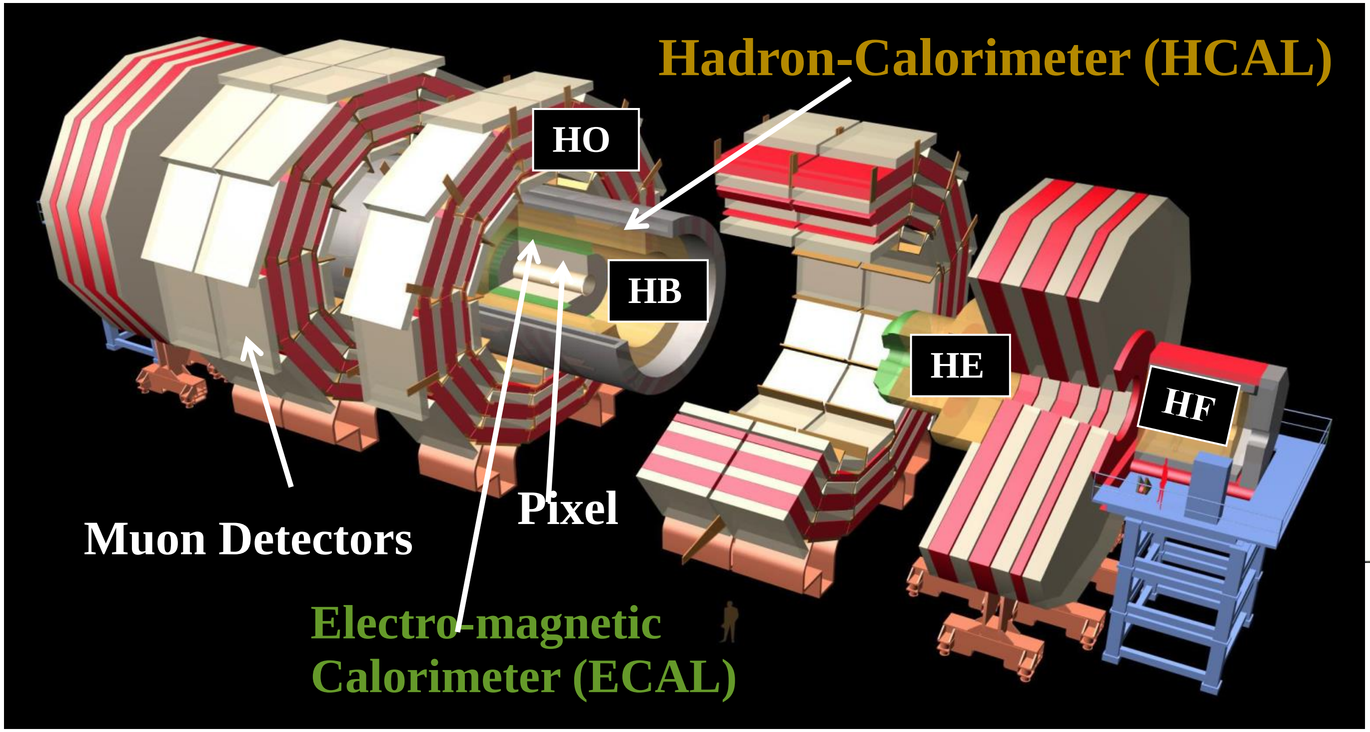
- *Future plan*

Introduction

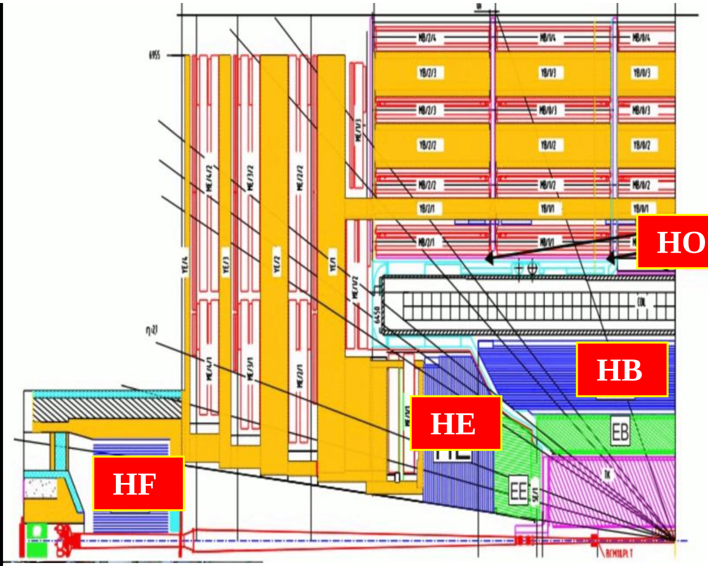
- The CERN Hadron Collider (LHC) is the world's highest energy particle collider.
- Designed to reach a luminosity of $10^{34}cm^{-2}s^{-1}$ at the center of mass energy of 14TeV.
- The Compact Muon Solenoid (CMS) detector has been working extremely well since the start of data taking at LHC

Discovery of Higgs boson in 2012 @ center of mass energy of 8TeV

CMS-Detector



CMS-Hadron Calorimeter



HB/HE/HO: Tile Calorimeters
HF: Cherenkov Calorimeter

Overview of Current HCAL Electronics

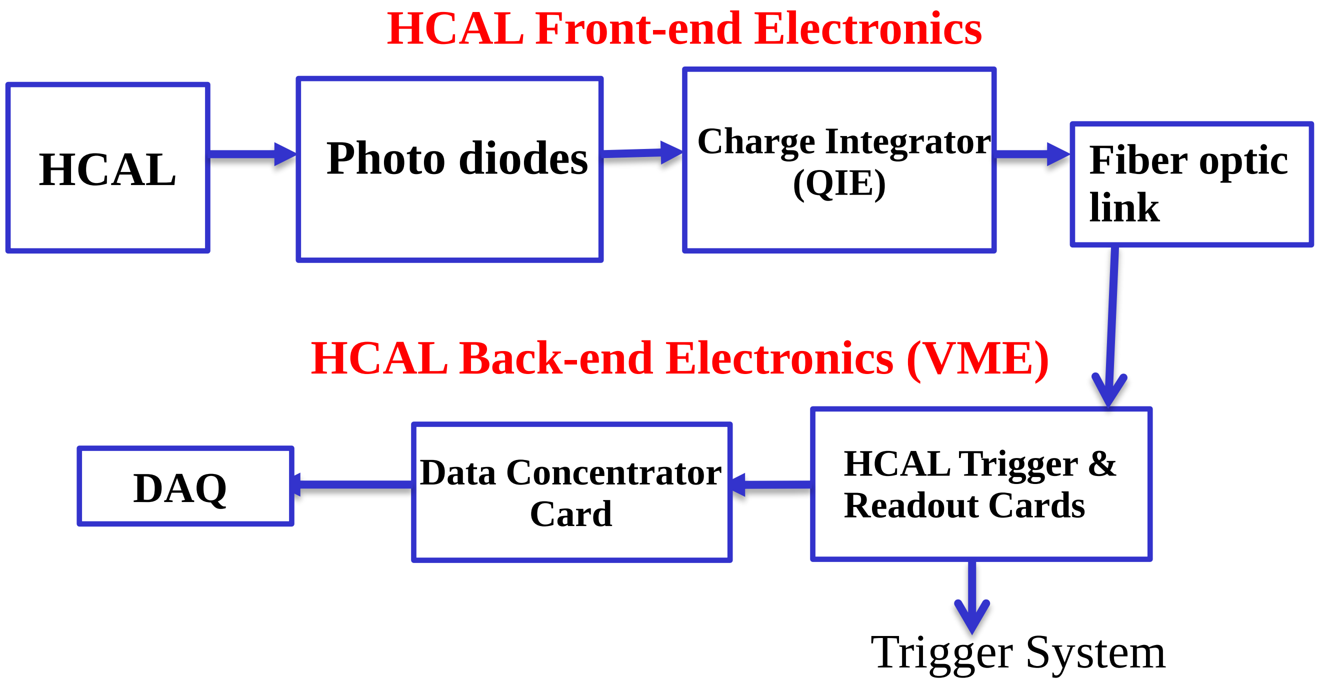
Front-end (FE) Electronics

- Measure the charge of electrical signal
- Digitization of charge by charge integrator QIE

Back-end (BE) Electronics

- Receive and buffer the incoming data from FE though Trigger & Readout (HTR) cards and transfer it to the Data Concentrator Card (DCC)
- The DCC is responsible for collating the data from all HTR cards and send this information to the DAQ

How data flow from HCAL-front-end to back-end electronics



Motivation

- To meet the expected performance of high luminosity of upgrade of LHC, the present CMS-HCAL will require upgrade of detector system and its electronics.

HF: PMT--Single anode → Multi-anode system

HB/HE/HO: HPDs→ SiPM

→ **-Reduce noise and improve performance of detector**

-Increase Segmentation depth

- To store information of more depth in the detector, very high speed DAQ is required

- **Problem:** Current HCAL back-end (VME based system) does not support high bandwidth for global DAQ

  --Upgraded data transfer rate of front-end is high (4.8Gbps) as compare to current data transfer rate (1.6Gbps)

- **Solution:** μTCA (Micro Telecommunication and Computing Architecture) based system will provide more accessible environment and high bandwidth for global DAQ in the CMS experiment.

Prototype µTCA *Crate for HB/HE Upgrade*

- To validate the µTCA, it is required to run µTCA in parallel with current VME.
- Split the optical signal coming from front-end electronics into two equal parts to feed the present VME and µTCA simultaneously for complete HB/HE.

HCAL Front-end Electronics

Current Optical Splitters (OSB)

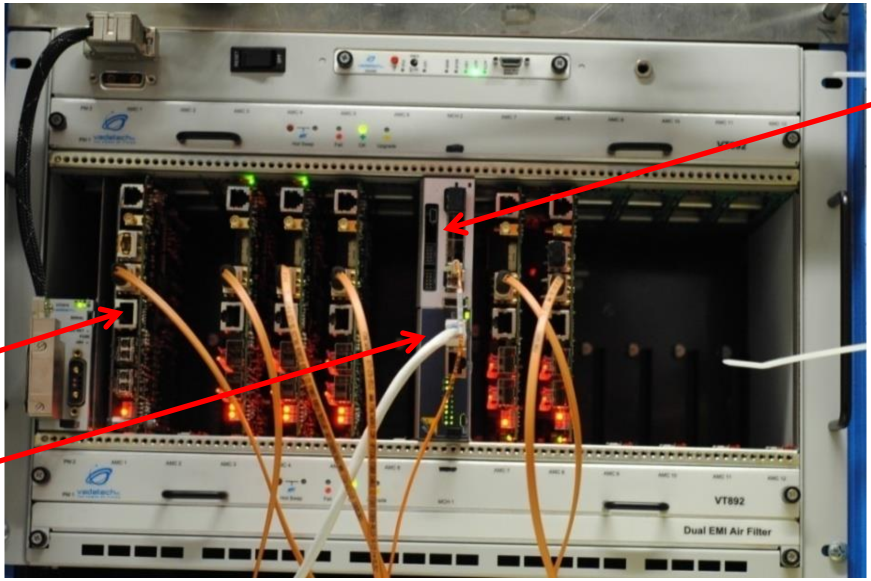
Current back-end (VME)

Future back-end (µTCA)

Validation of μTCA Crate for HB/HE Upgrade

Major Milestones

- μTCA crate has been installed successfully at CMS.

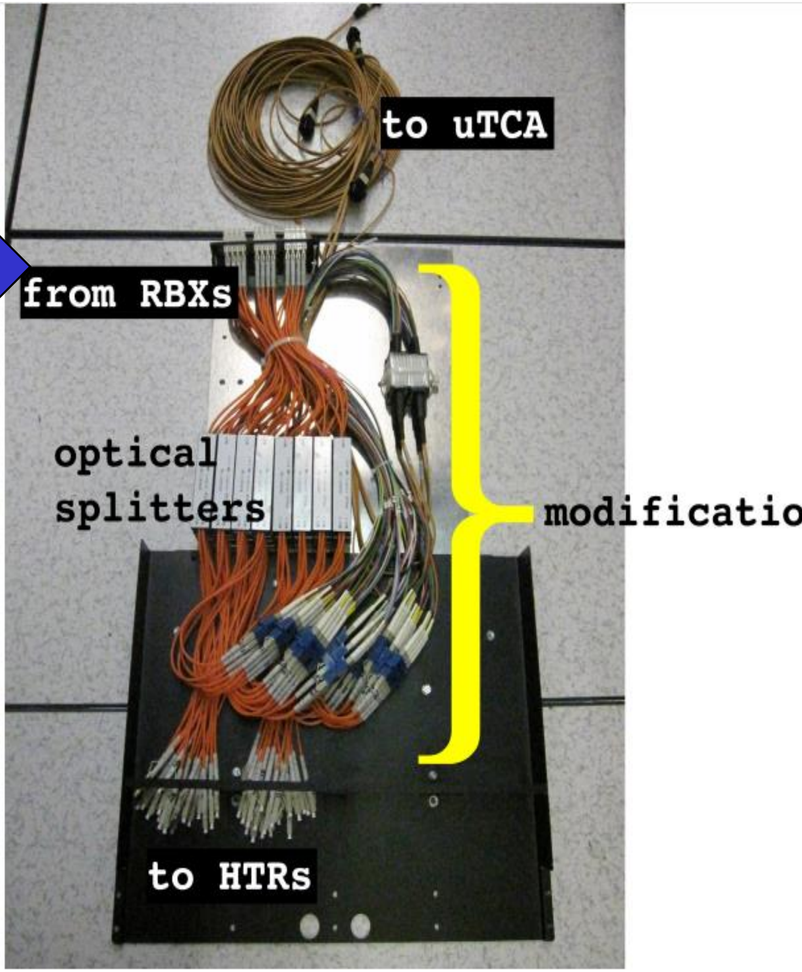


- For one HCAL slice, different tests have been performed. All cards are successfully found to receive the data, and error bit rate is found to be zero.

Validatation of micro TCA with 2012 data, CMS-Detector Note.
CMS DN-2013/003

Need of Prototype Optical Splitter for HB/HE Upgrade

The present splitting System at CERN



- **Constraint:** Size of current optical splitter (OSB) at CERN, which can not be fitted into the available space.
- Tested at P5 (CERN) - found 12 weak fibers out of 1728

- We have searched for different industries MICROTEK, AUTORAMAA and PDR-Mumbai in INDIA
- PDR-Mumbai provide required specification of optical splitter

Prototype Optical Splitter for HB/HE Upgrade

Prototype optical splitters manufactured by PDR-Mumbai fulfils specification requirements.

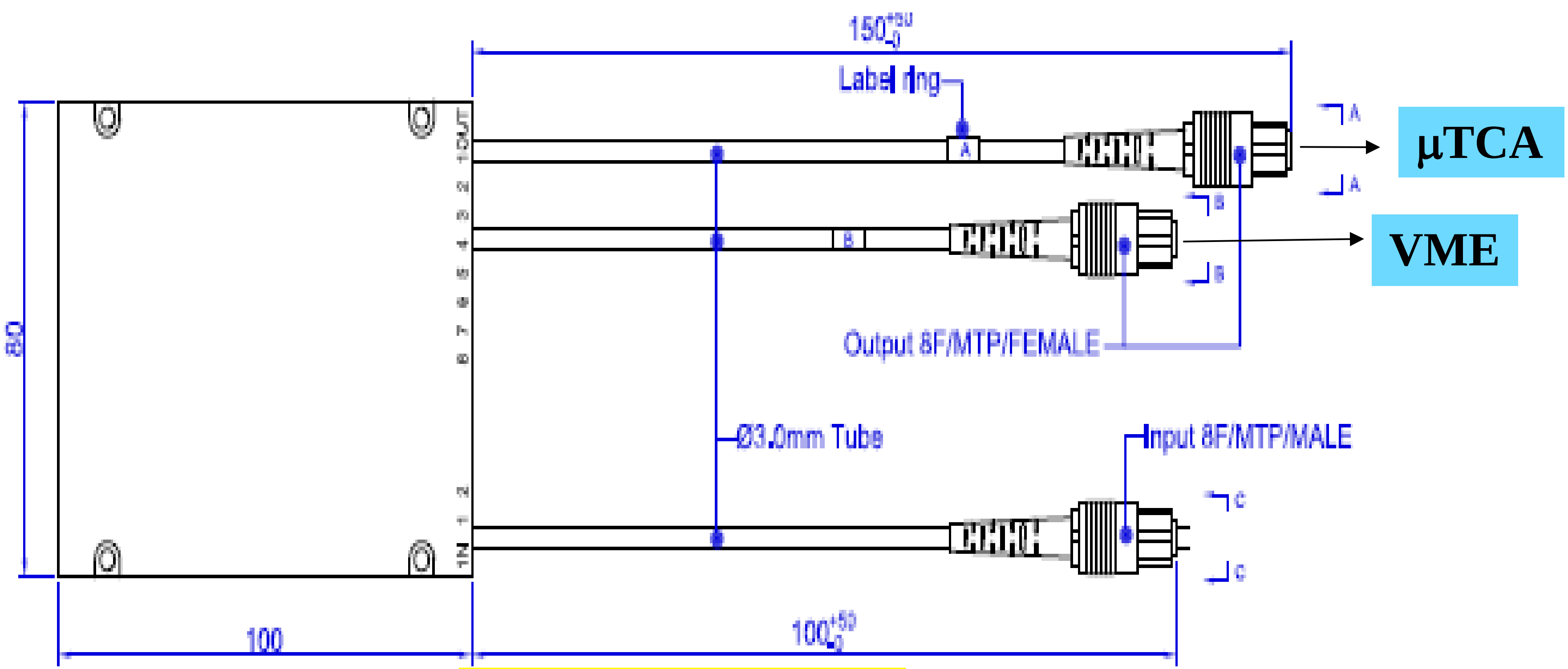
Specifications:

Operating wavelength: 850nm

Size: $(80\times100\times10)mm^3$

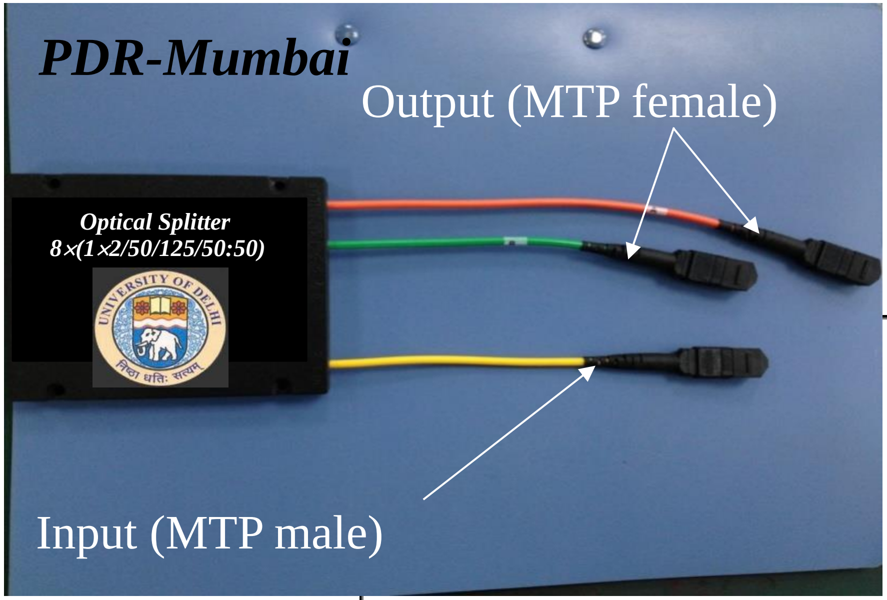
50:50 splitting ratio

Diameter of input & output channel: 3.0mm PVC jacket



Prototype Design

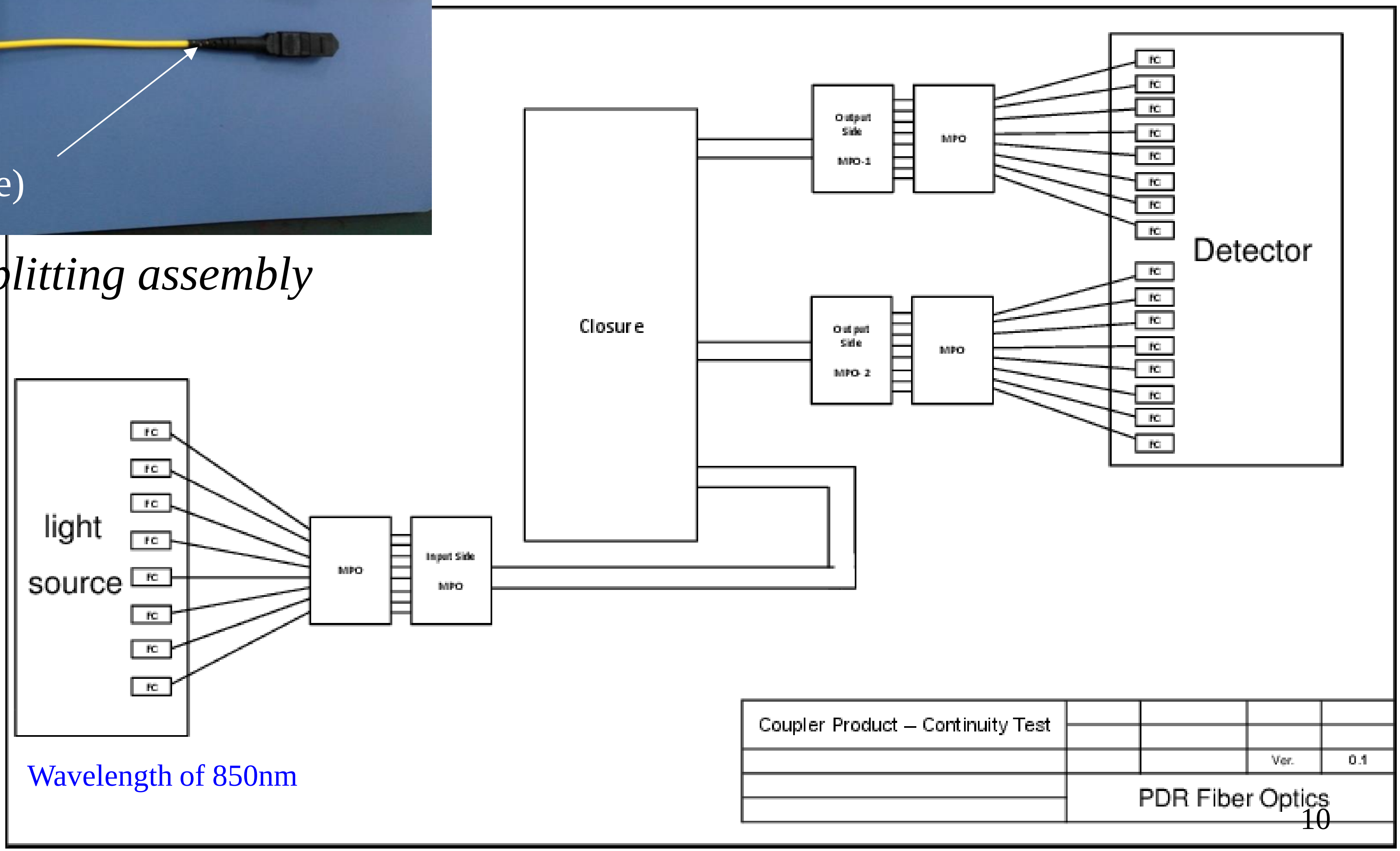
Prototype Optical Splitter for HB/HE Upgrade



8-fiber splitting assembly

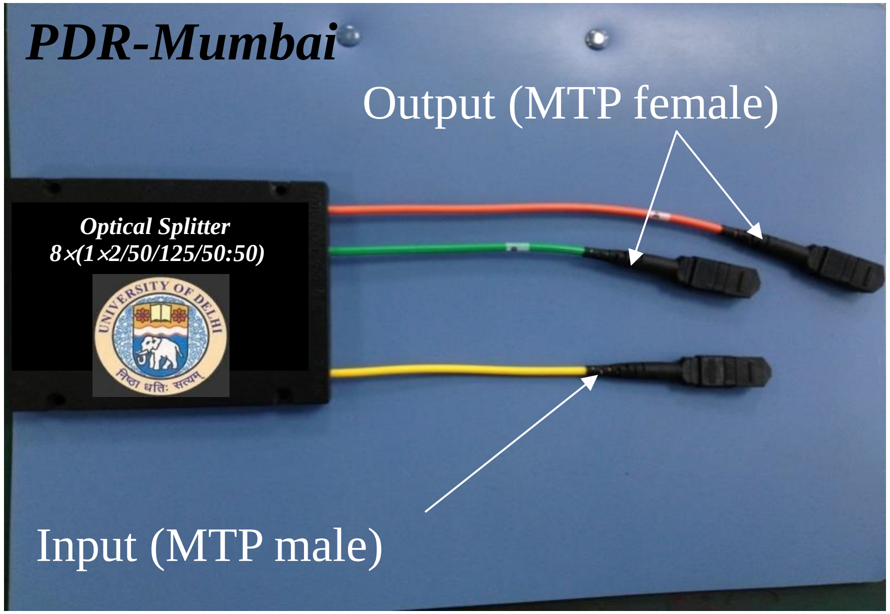
Testing Procedure

Light Loss = Input power (P_{Source}) – output power ($P_{power\ meter}$))



Wavelength of 850nm

Test Results in India



8-fiber splitting assembly

- Laser source of wavelength 850 nm was used for testing.

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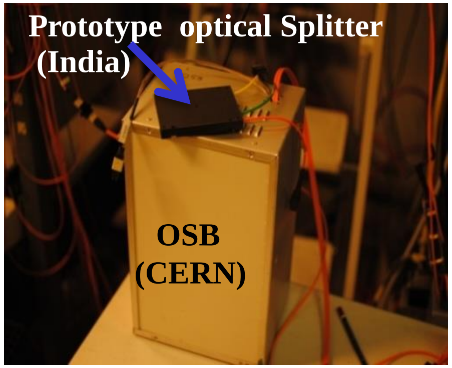
Spec:	MMC-MTP/Male/8F-MTP/Female/8F	
Input/ output	A(Orange)	B(Green)
	Light Loss (dB)	Light Loss (dB)
1	3.79	3.66
2	3.6	3.87
3	3.4	3.66
4	3.48	3.48
5	3.55	3.8
6	3.47	3.43
7	3.52	3.77
8	3.46	3.41

losses were measured including the connector

Test Results @ CERN

Measured optical losses in the splitters with HO signal



Prototype Optical splitter (India) vs current OSB (CERN)

Power Meter	OVPM				B1365A			
Input/ output	Prototype Optical Splitter (From India)		current OSB		Prototype Optical Splitter (From India)		current OSB	
	Orange	Green	P1	P2	Orange	Green	P1	P2
2	3.3	4.19	5.17	5.01	3.53	4.18	5.67	5.38
3	3.52	4.31	6.67	8.2	3.47	4.32	6.89	8.75
4	3.13	3.51	3.89	3.61	3.04	3.52	4.32	4.16
5	3.96	3.32	6.86	4.89	4.02	3.82	7.1	5.37
6	3.59	3.62	7.95	4.83	3.07	3.53	8.12	4.98
7	3.84	4.45	4.76	6.05	3.53	4.37	4.84	6.2

Good Result: Losses with prototype optical splitter (India) 3dB - 4.45dB
Losses with OSB (CERN) > 5dB

Test Results with HB/HE signal @ CERN

Total Fibers = 1728

Prototype Optical Splitter (by Indian group)

1 channel was weak

OSB Splitters (CERN)

12 channels were weak

➡ Good results with prototype optical splitter

Four more optical splitter ordered (PDR-Mumbai) for optical margin tests @ P5 (CMS) and delivered at CERN.

Design of Rack

- To house optical splitters of a crate, it is require to have a good designed rack

Rack containing 96 connector

Two design of racks (PDR-Mumbai):
(A) 19 in. 2U containing 48 connectors (B) 19 in. 4U containing 96 connectors

Can customize it to 3U for housing 72 connectors for μTCA

Good for cabling

Summary and Conclusion

- CMS-HCAL(HB/HE) upgrade require running VME and μTCA simultaneously.

- μTCA is installed successfully at CMS.

- First prototype optical splitter made in India- successfully tested and being used @ CERN

- Optical losses have been measured with HO signal at CERN.
  with prototype optical splitter (India), losses: 3dB – 4dB
  with OSB (CERN), losses are ≥ 5dB

- Tested prototype optical splitter with HB/HE signal,
  only one channel was weak out of 1728 fibers as compared to
  OSB where 12 channels were weak.

- Four more optical Splitter ordered for optical margin tests @ CMS
  and delivered at CERN.

Future Plans

- Testing and validation of Four optical splitters @ CERN.
- Final requirement will be of 250 optical splitters for complete HB/HE upgrade.
- Fabricate a prototype of rack for housing a crate.
- Plan to make a setup for in-house testing of optical splitters.
- Participation in the fabrication and testing of μHTR card at SINP, INDIA.

Thank You…

Back up slides

Why 72 connectors ?
one crate has 12 uHTR cards
Each card has two part (bottom and top)
Each splitter has one input and two output = 3 connectors)

Total connectors for one crate = 12*2*3 = 72

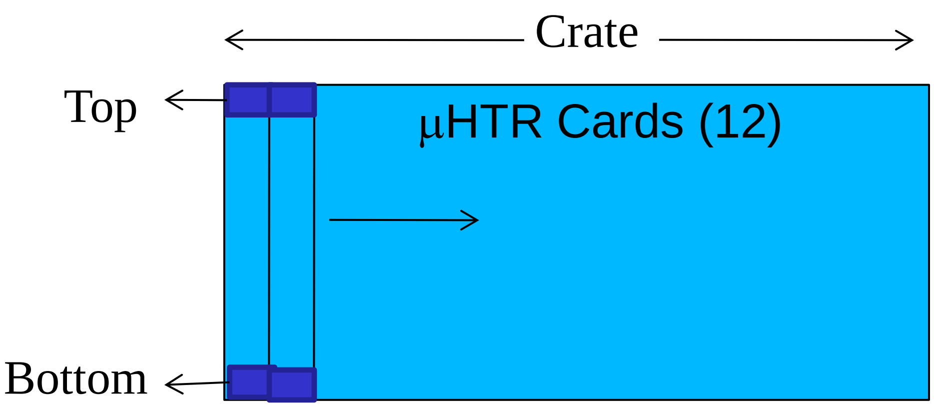
Each crate need two splitters

The other reason we are replacing uTCA with VME is because electonics will be now almost 20 years old and it is difficult to get replacements and spares.
The CMS -HCAL is the first sub system to adopt this change. Later on other systems like Tracker, Pixel are expected to go for this change

Total fibers:1728

For HB/HE, we need 9 crates of μTCA
Each crate has 12 μHTR cards
Each μHTR has top and bottom part and each part need 8 fiber input
So we need 2 splitters per μHTR card
So total splitters required: 9*12*2= 216

Each output fiber has 8 fibers in bundle so 216 * 8 = 1728 fibers in total



($\Delta\phi = 360^0/40^0 = 9$ crates)

Upgraded Back-end Electronics

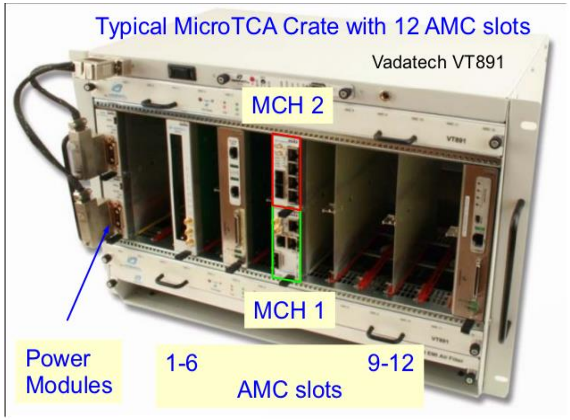
HCAL Back-end Electronics will use modern FPGA (Field Programmable Gate Array) and μTCA (Micro TeleCommunications Computing Architecture)

μTCA Electronics (High speed, small size computing system):

Single μTCA crate consist of

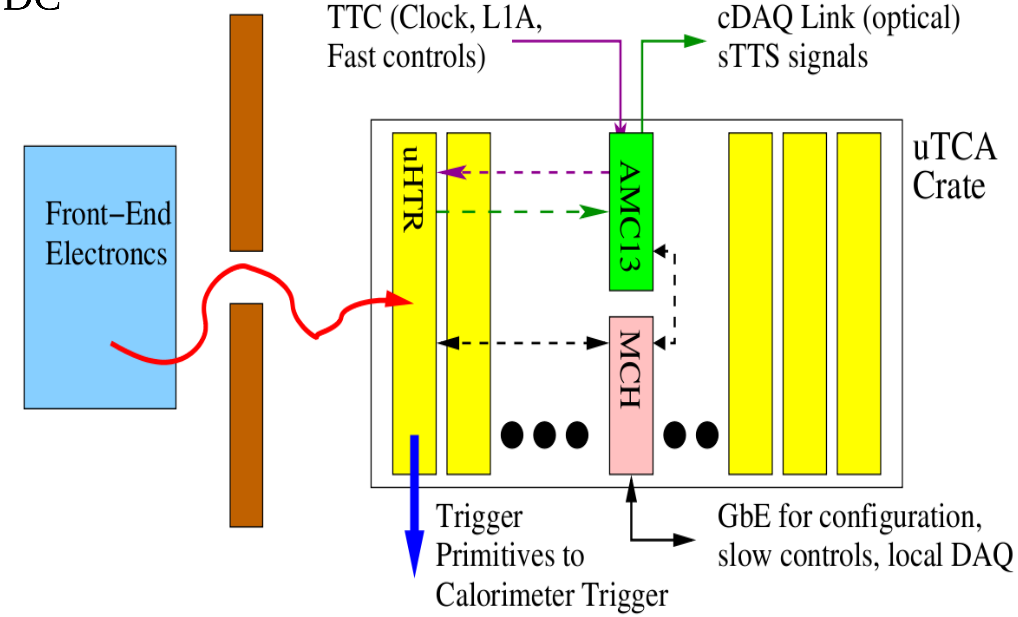
1. **12 μHTR Cards (HCAL Trigger & Readout Card) :**
   a. Receive the continuous stream of ADC and TDC data from Front-end Electronics.
   b. Calculates & transmits Trigger Primitives

2. **AMC-13 (Advanced Mezzanine Card):** responsible for data aquisition as well as distribution of LHC clock and fast control signal



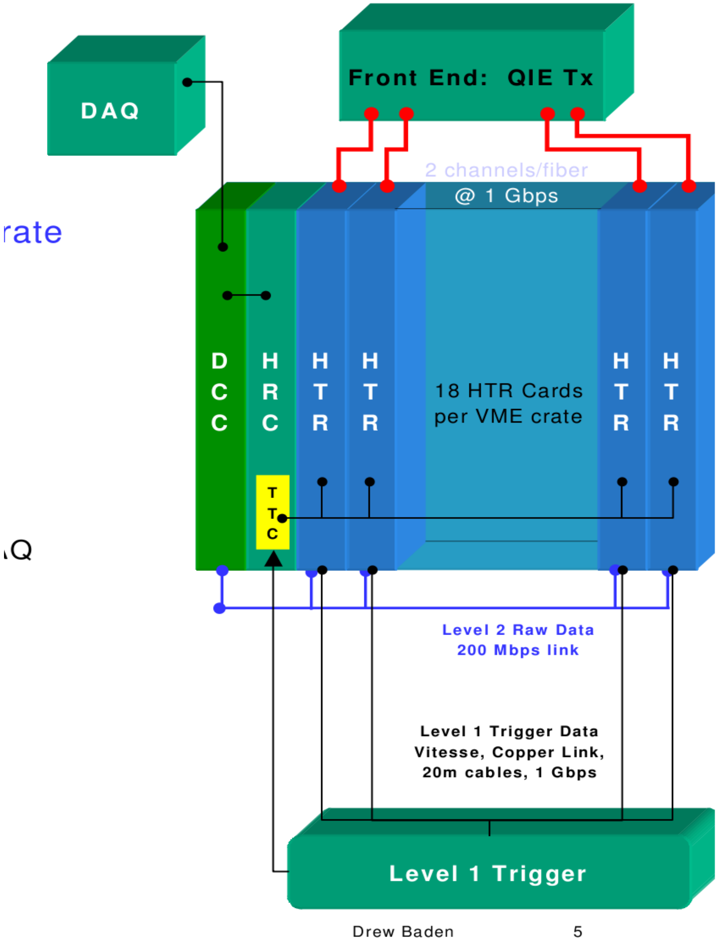
3. **Micro TCA Carrier Hub (MCH): a.** supply voltage, current on AMC card

   b. Responsible for the control of power to each slot and for general house-keeping of the crate



Current Hcal Back-end Electronics (VME):

HTR (HCAL Readout and Trigger cards):
The HTR cards receive and process the incoming digital data and transfers it to the Data Concentrator (DCC) when trigger L1 is accepted



DCC (Data Concentrator Ccard):
The DCC is responsible for collating data from up to eighteen HTRs and transferring it on to the Central DAQ.

HRC (HCAL Readout Control card):
this card is responsible for fast and slow monitoring As well as trigger control distribution .

Splitters will replace existing fiber-ways