Future Upgrades of the BCM1F Detector at CMS

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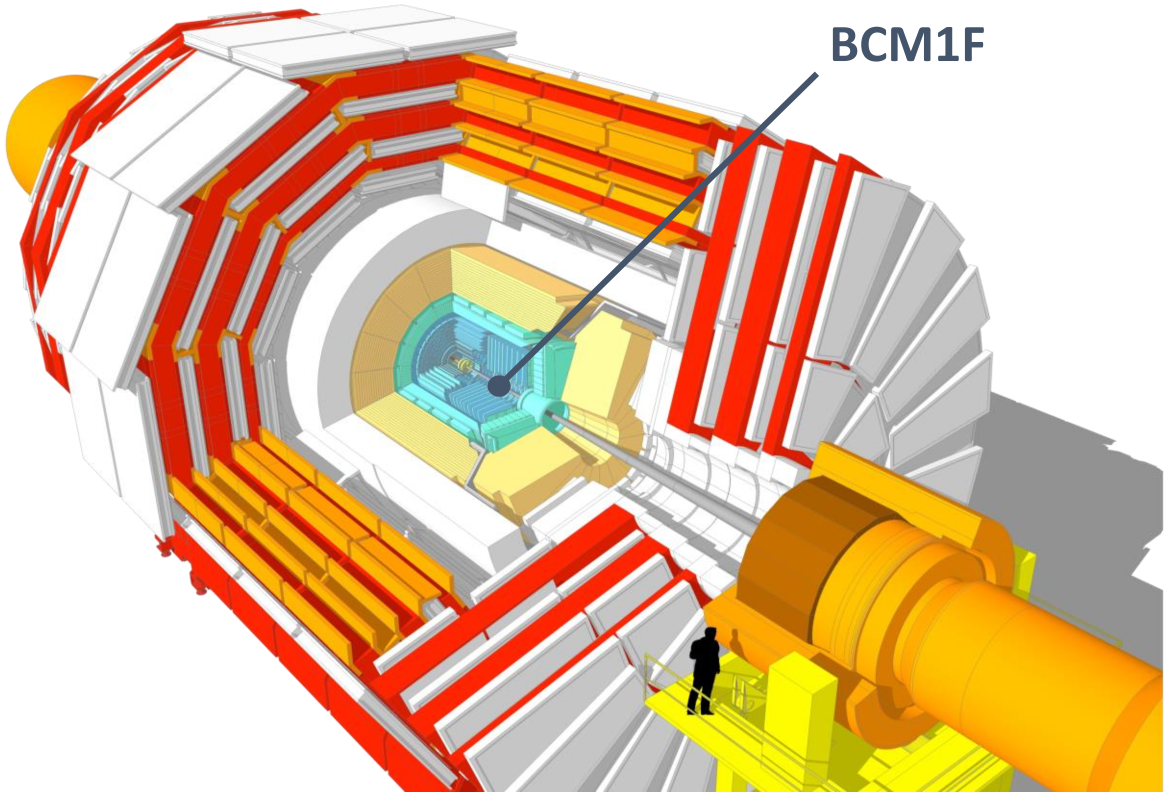
The BRIL Project

- Beam Radiation Instrumentation and Luminosity Project (BRIL) @ CMS
- Online monitoring + real time feedback to LHC on machine induced-background (MIB) in CMS
- Online + passive monitoring and simulation of radiation environment in CMS the detector and cavern
- Beam Timing Monitoring using BPTX
- Online (bunch-by-bunch) luminosity measurement
  - Pixel Luminosity Telescope (PLT)
  - Fast Beam Conditions Monitor (BCM1F)
  - Hadron Forward Calorimeter (HF)
- Offline (precision) luminosity measurement
  - Pixel Cluster Counting (PCC)

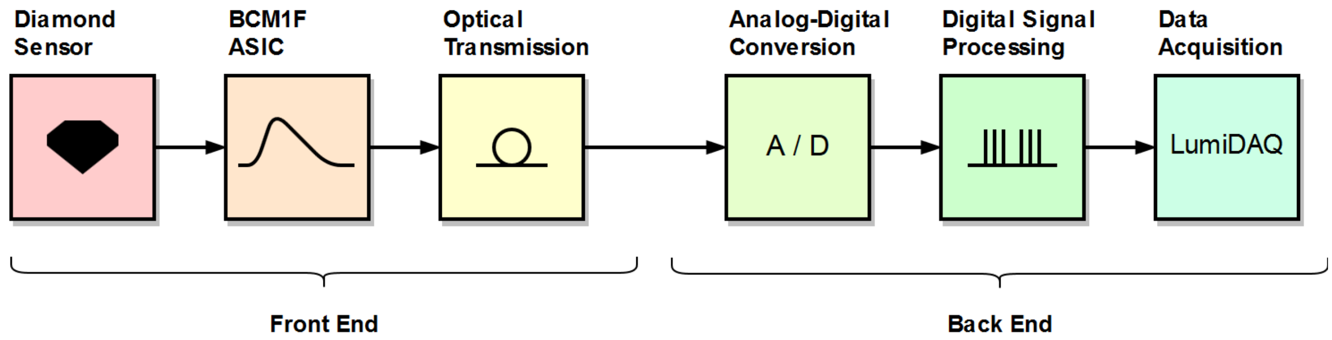
The BCM1F Detector



Location of the BCM1F detector inside CMS

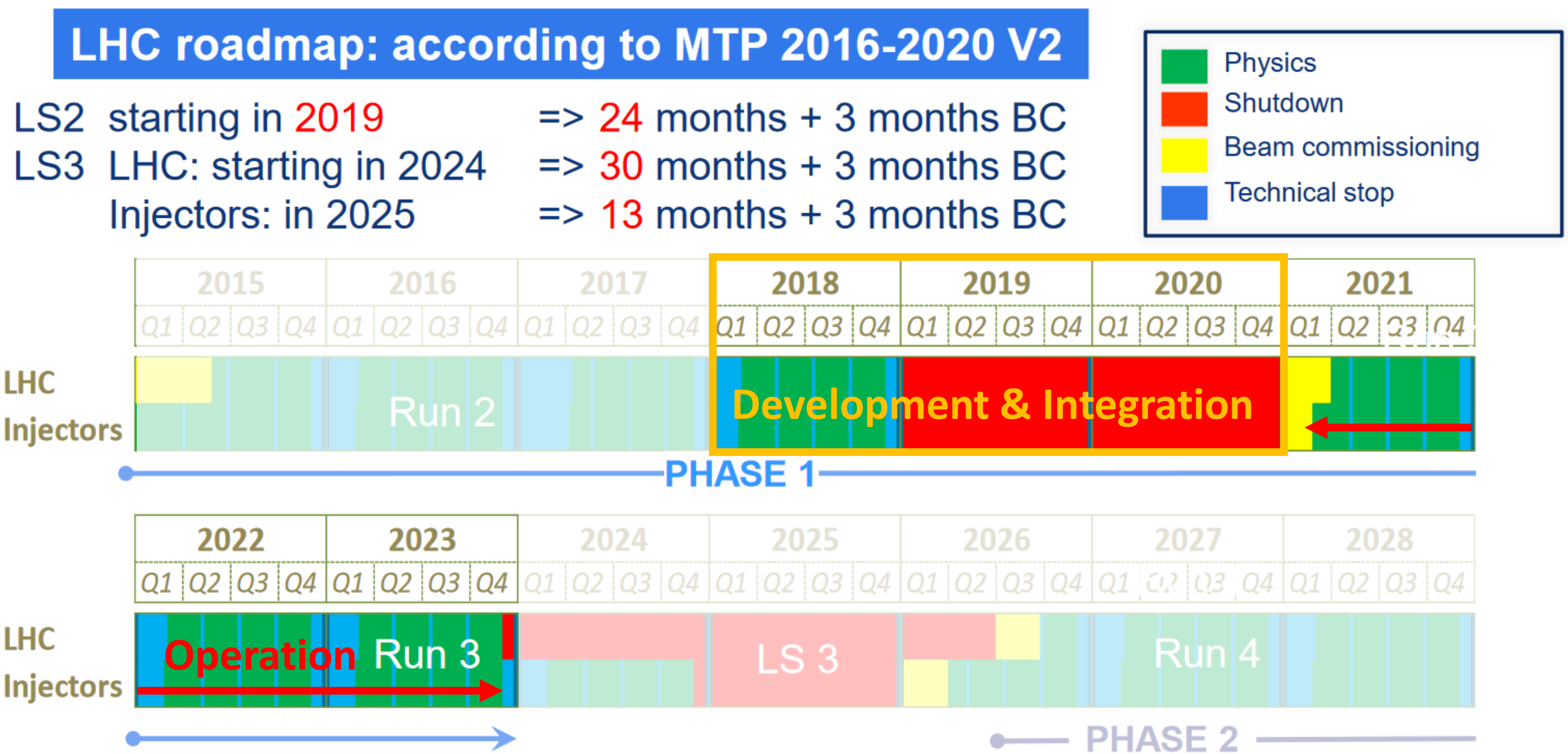
Illustration: doi:10.1088/1742-6596/513/2/022032

The BCM1F Detector



- Fast Beam Conditions Monitor
- Online (bunch-by-bunch) Luminosity + MIB measurement
- 48 sensor positions at z = 1.82 m away from IP
- Fast front end ASIC (< 10 ns FWHM)
- Optical transmission to back end
- legacy VME back end & new MicroTCA back end system
- Dead time free Luminosity DAQ system

LHC Schedule



https://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC%20schedule%20beyond%20LS1%20MTP%202015_Freddy_June2015.pdf

Run 2:

13…14 TeV c.m. energy

~1.7 x $10^{34} cm^{-2} s^{-1}$ peak luminosity

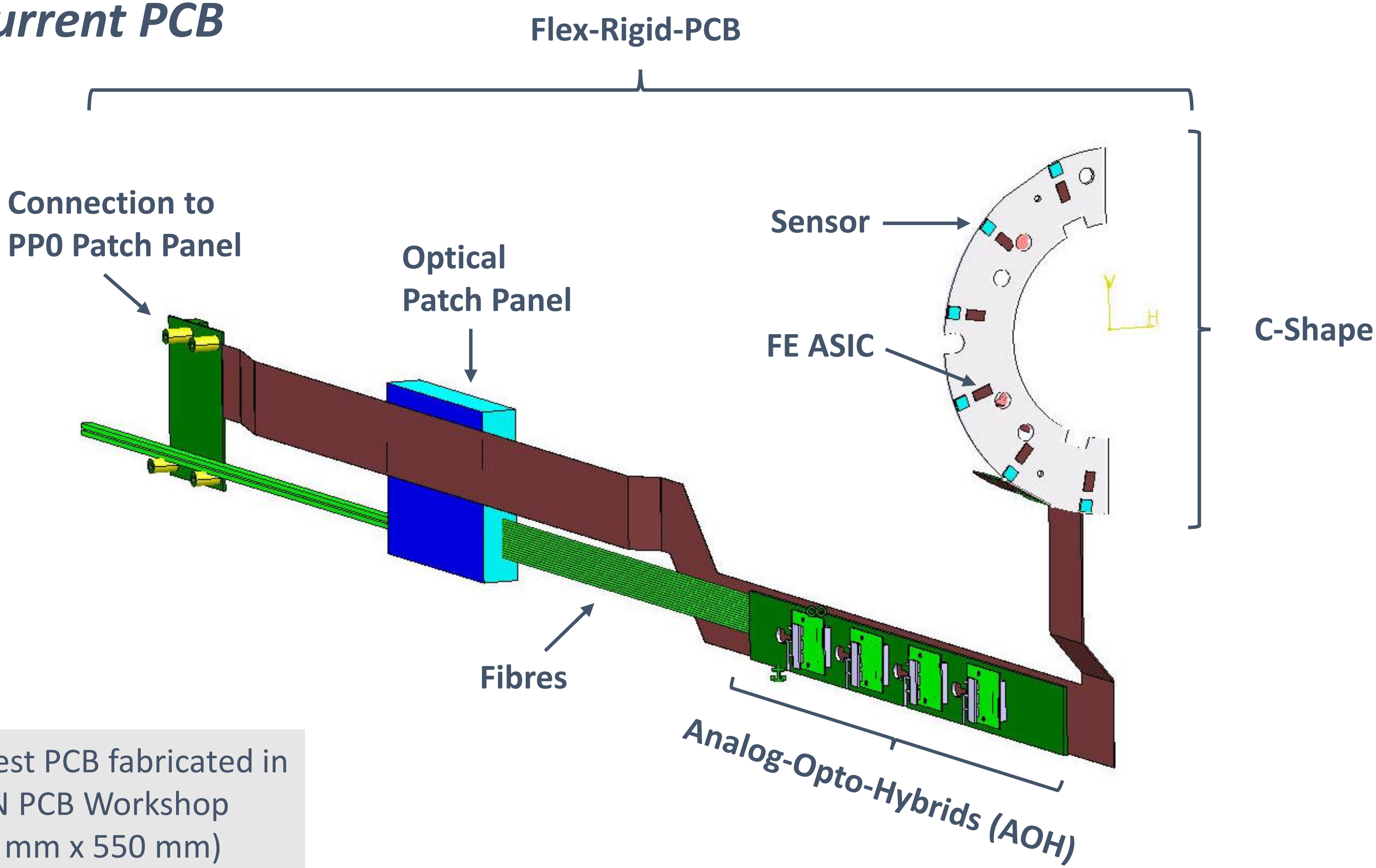
Run 3:

14 TeV c.m. energy

~2.0 x $10^{34} cm^{-2} s^{-1}$ peak luminosity

The BCM1F PCB

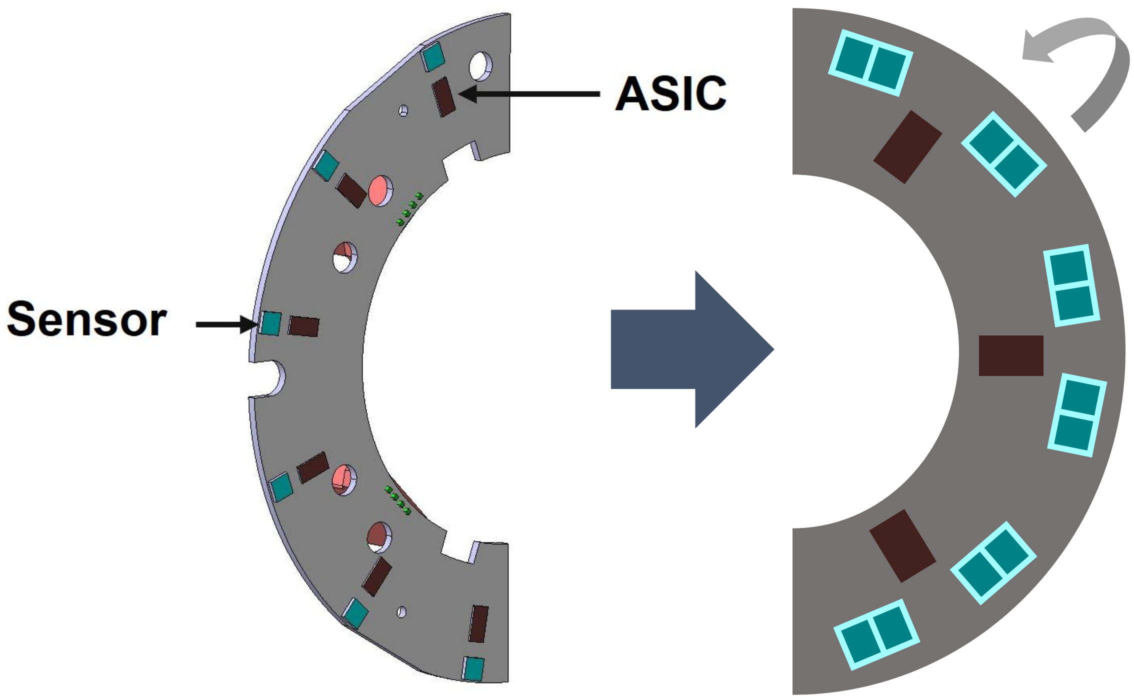
Current PCB



Biggest PCB fabricated in CERN PCB Workshop (550 mm x 550 mm)

C-Shape Upgrades

Current C-shape ***Upgraded C-shape***



Active cooling (-20°C) from back side of PCB

Support for new Si sensors (external bias resistor)

3 ASICs, 4 channels each

Improved tooling for (double) vias

Sensor Upgrades

Run 1: sCVD Diamond sensors (DC-coupled), 8 channels

- Significant efficiency loss due to radiation in sCVD sensors

(late) Run2: sCVD +pCVD +Si Sensors (DC-coupled), 38 channels (48 positions)

- pCVD is more radiation hard than sCVD, but has small signal
- Silicon provides large signal but has significant leakage current
- Silicon leakage current biases optoelectronic transmitter (AOH)
  - Baseline shift
  - Signal degradation

Run3: AC-coupled Silicon-only, 48 possible positions

- Silicon provides large signal
- AC-coupling prevents undesired biasing due to leakage current

Sensor Upgrades

HGCal production:

1.7 x 1.7 mm double-diodes

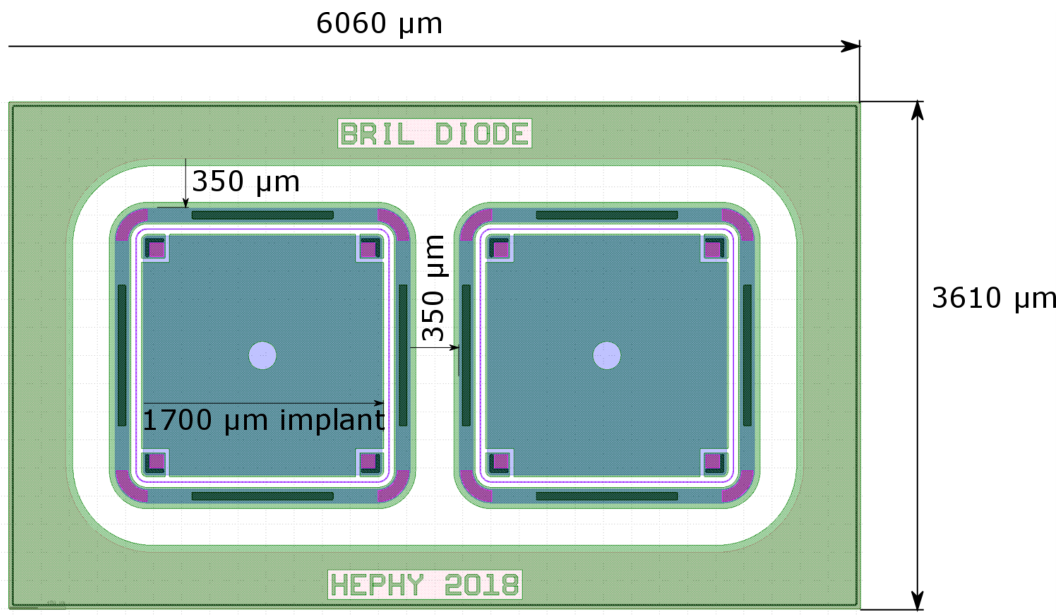
~ 140 pF coupling capacity

External bias resistor (~ 10 MOhm)

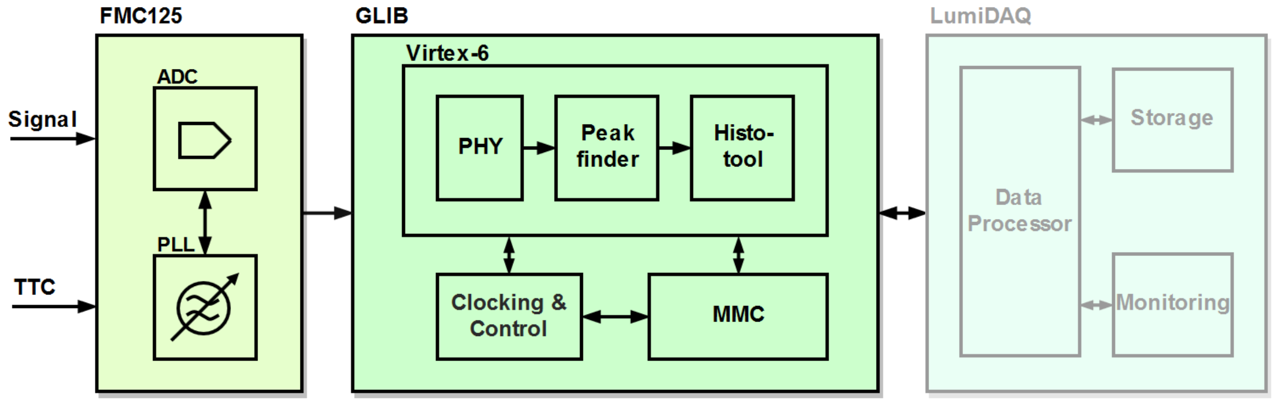
Tracker production (TBC):

~2 x 2 mm double-diodes

AC coupling with integrated bias resistor

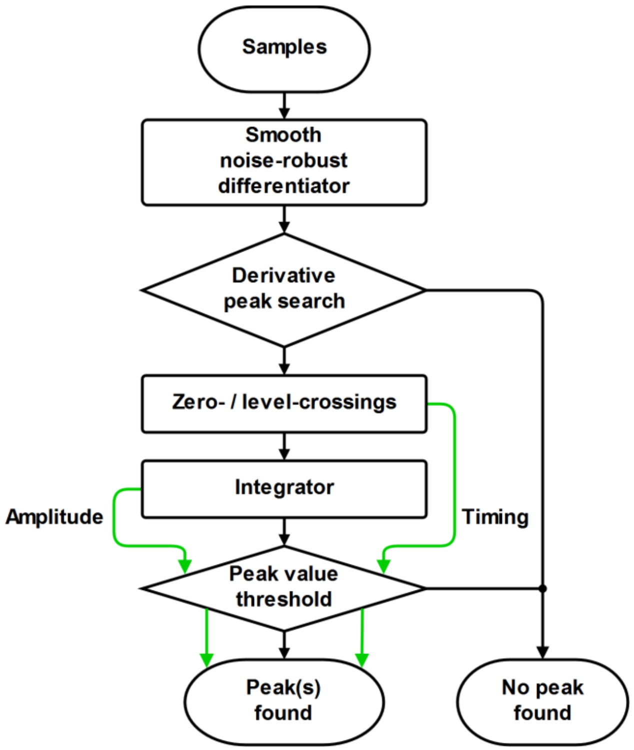


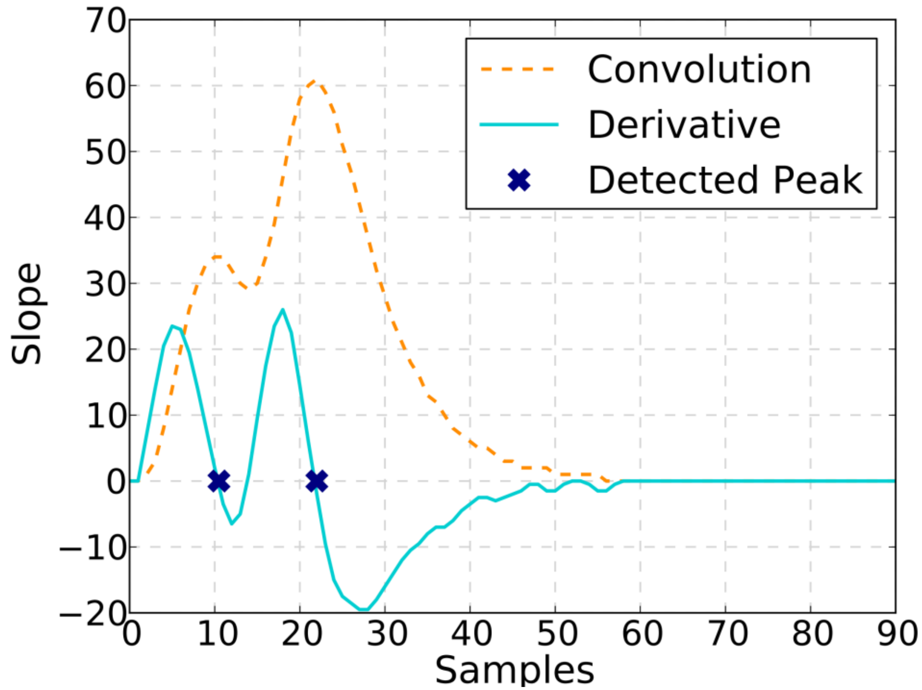
Back End Electronics



- MicroTCA Backend (2 crates), test run 2018
- 1.25 GHz quad-ADC (FMC125 from Abaco systems, formerly 4DSP)
- GLIB AMC card (CERN PH-ESE-BE)
  - Virtex 6 FPGA
  - Communication via IPBus
- New peak finder and histograming modules
- Planned: Frozen firmware and software for Run 3

New Peak Finder

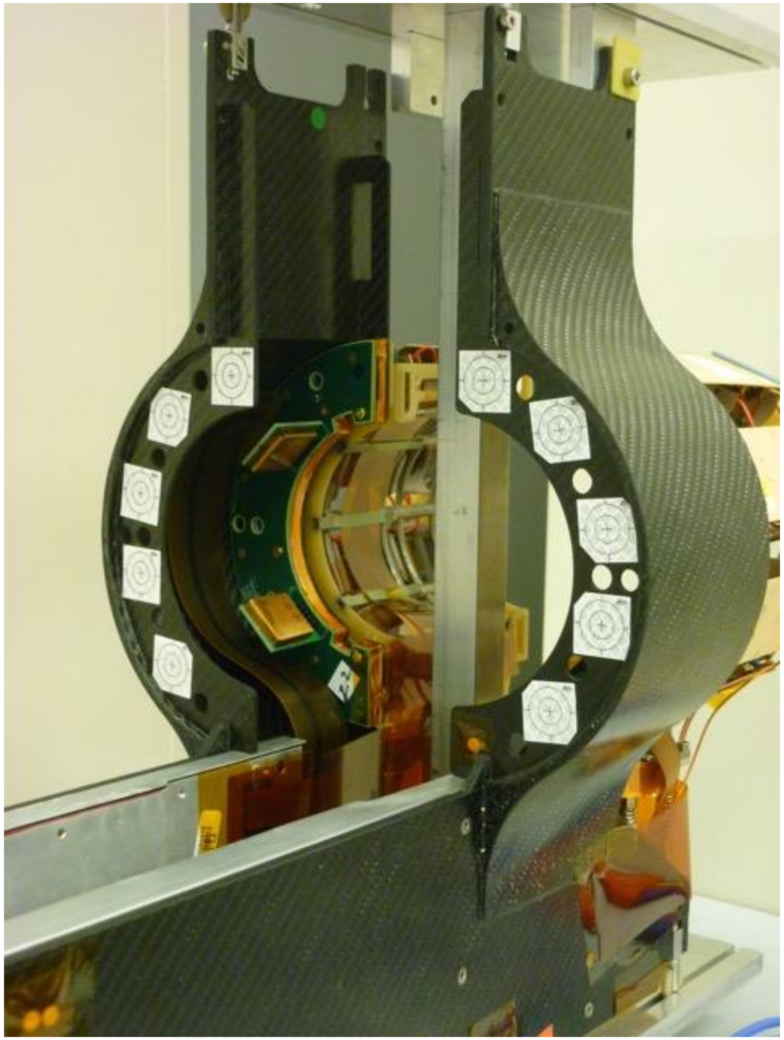


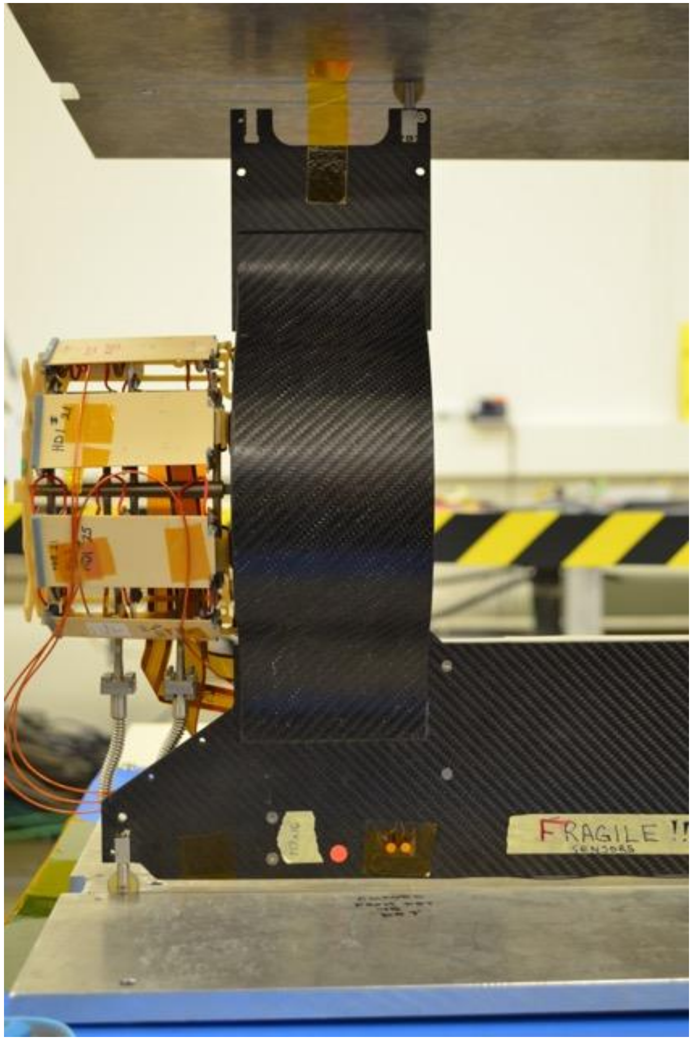


- Improved double-pulse resolution using derivative-based algorithm
- Parameterized VHDL-implementation for individual channel configuration
- Simulation promises improved peak detection

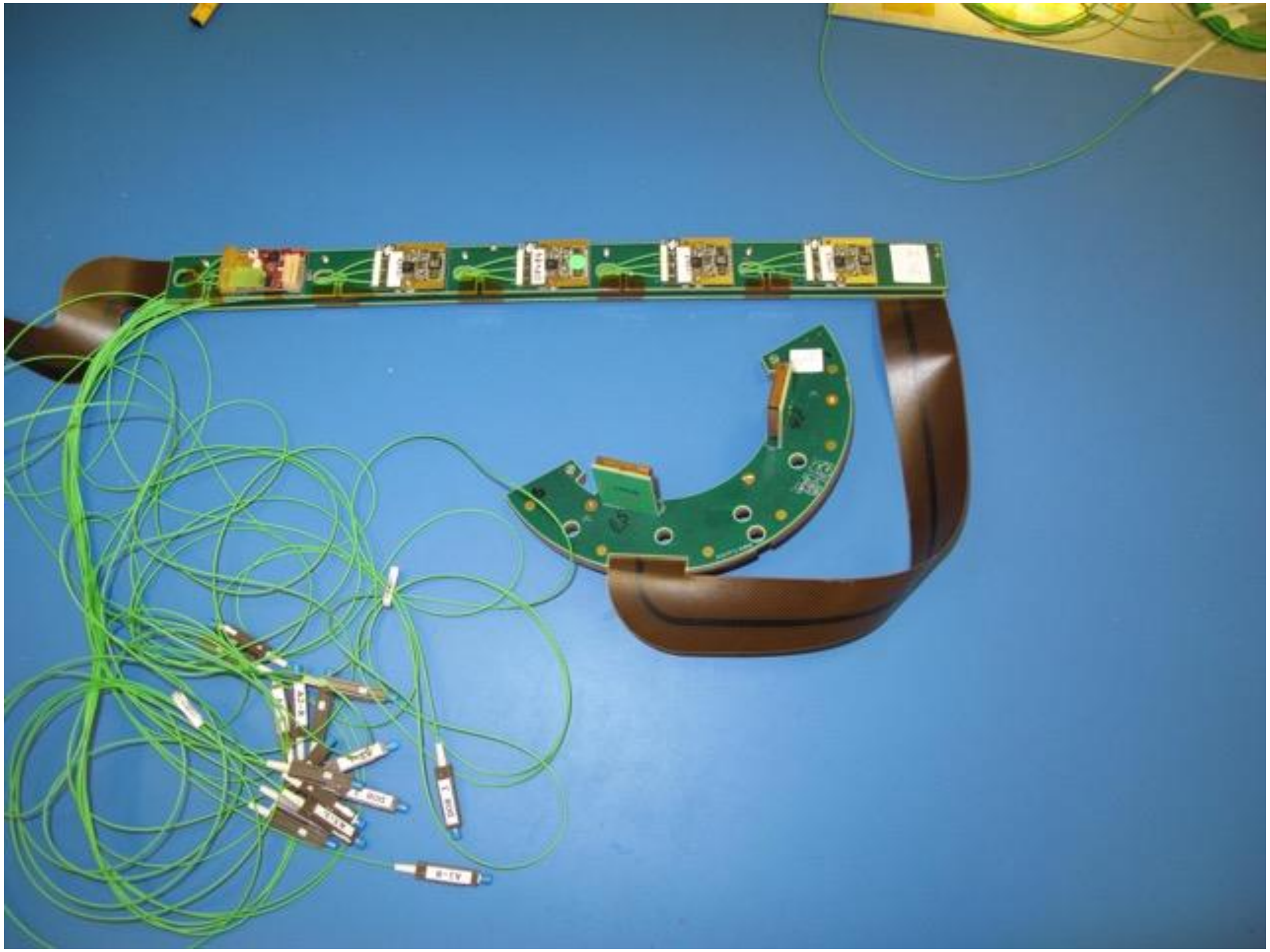
Backup

Carbon-Fibre Carriage

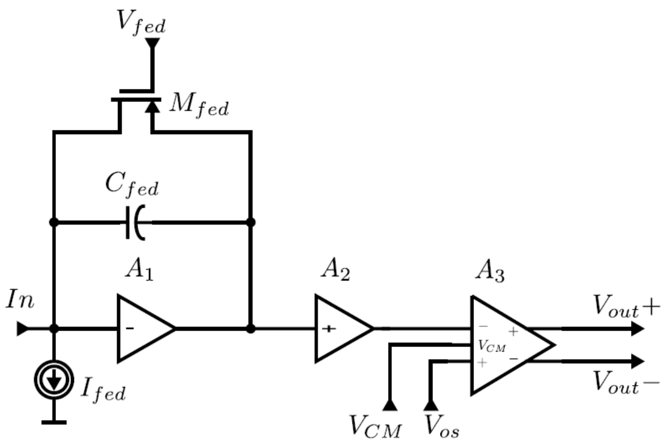


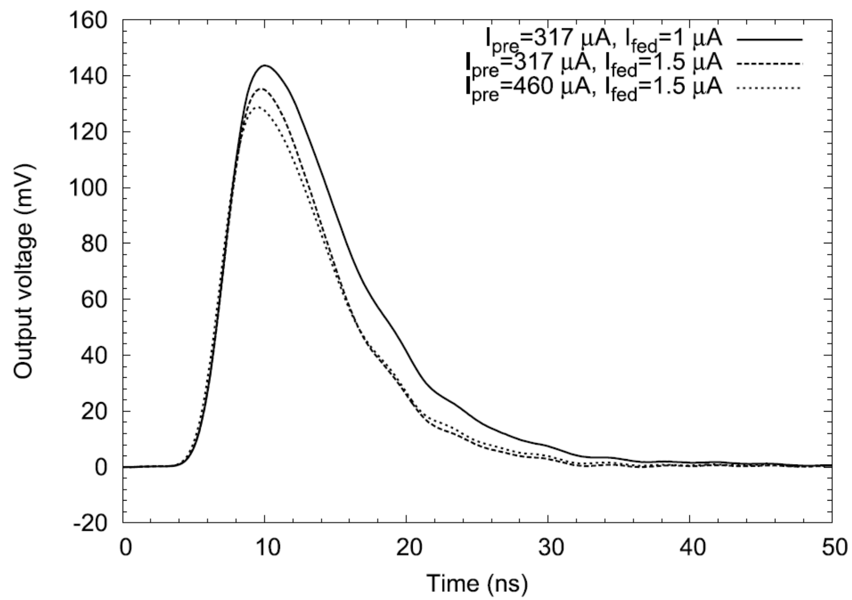


Flex-Rigid-PCB



FE ASIC

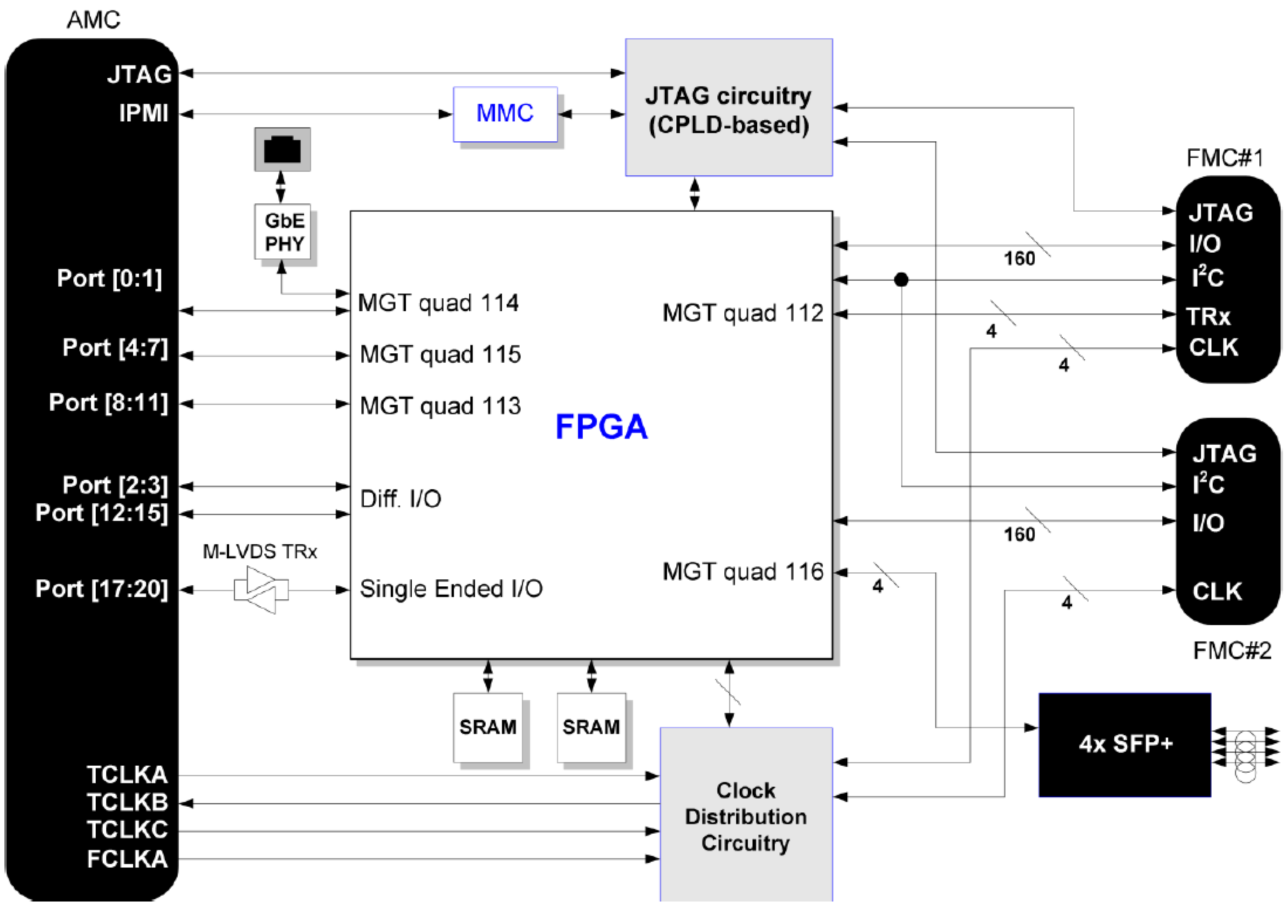




(a) C_{det} = 2 pF

From: *Design and Performance of the BCM1F Front End ASIC for the Beam Condition Monitoring System at the CMS Experiment*, D. Przyborowski, J. Kaplon, P. Rymaszewski, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 63, NO. 4, AUGUST 2016

GLIB



From: GLIB User Manual