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QUALIFICATION OF THE BCM1F DETECTOR FOR LUMINOSITY MEASUREMENT IN THE CMS EXPERIMENT

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PSA Master Project Presentation
20/06/2019

Outline

I. BRIL Project, Luminosity measurement at CMS

II. Description of the BCM1F Detector

III. DESY test beam setup

IV. Test beam DAQ SW framework

V. Test beam data analysis

VI. Conclusion

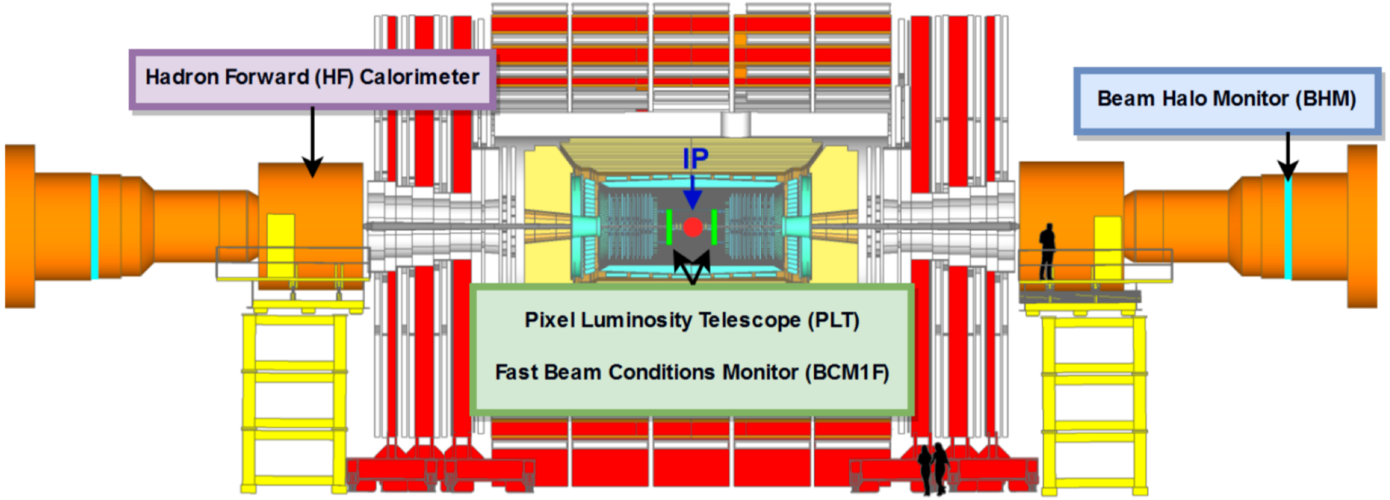
BRIL Project, Luminosity

Luminosity $dR/_{dt} = L \cdot \sigma_p$

- Key parameter of collider performance
- Ability to produce a certain number of specific particle interactions
- Used as normalisation in cross-section measurements

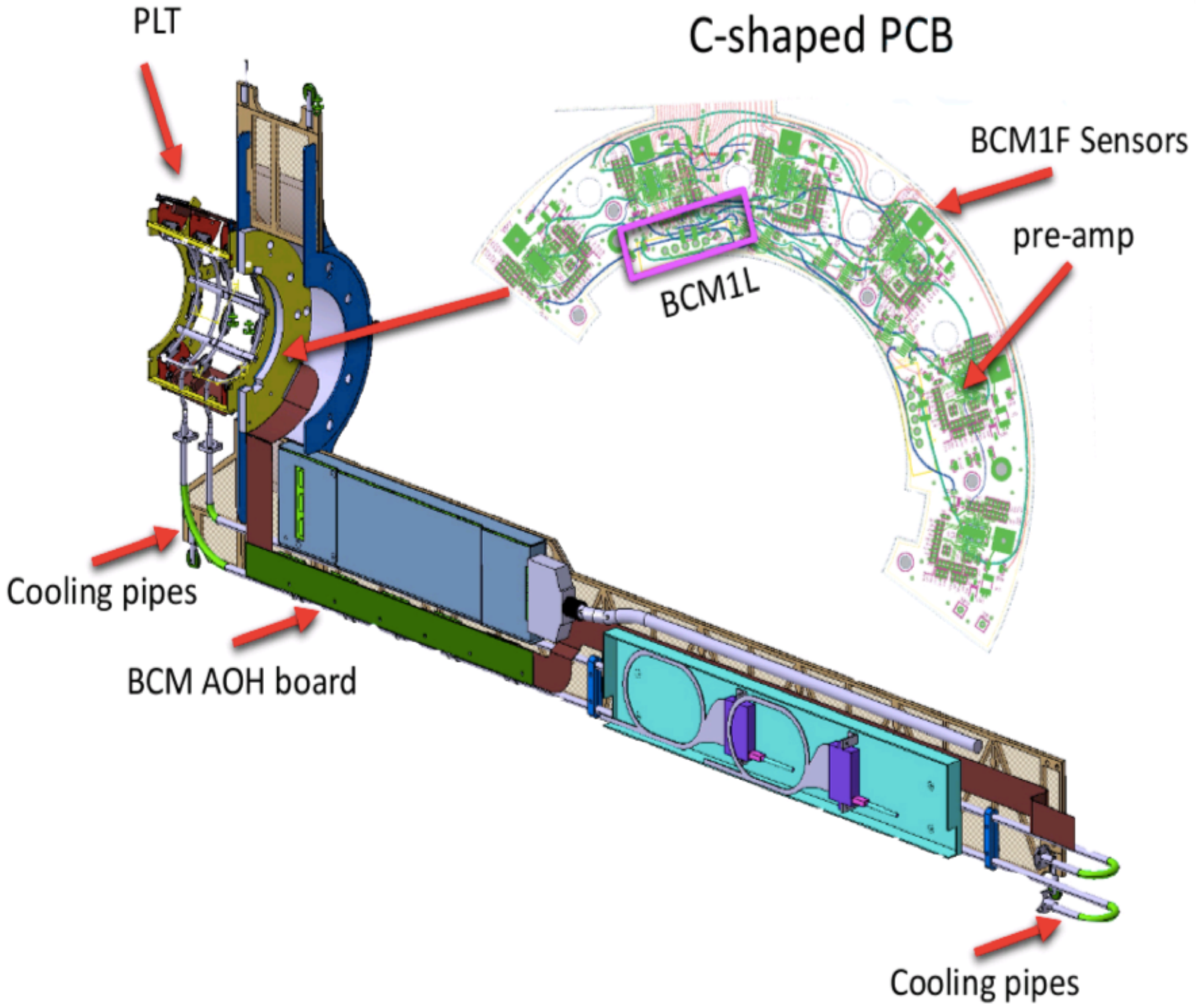
BRIL project

- Beam Radiation Instrumentation and Luminosity
- Online and Offline measurements of Luminosity and Machine Induced Background (MIB)
- Bunch by bunch Lumi measurements
- Various sub-detectors, different designs, operated independently



BCM1F Detector

- Online luminometer that provides Luminosity and MIB measurements
- C-shaped module at 1.83m from the Interaction Point
- pCVD and Si sensors, FE ASIC, Optoelectronic transmission chain
- Fast timing, Non-clocked readout chain, Fully analog signal path untill the back-end system



BCM1F upgrade motivation

- **BCM1F old version =** Combination of pCVD and Si sensors.
- Si sensors showed larger signal and less noise than pCVD before it dies from radiation damage
- **BCM1F new version =** AC-coupled Si-pad detectors in radiation hard silicon substrate with active cooling.
- Need for sensor qualification in a test beam campaign for the upgrade

Front End electronics

Sensors

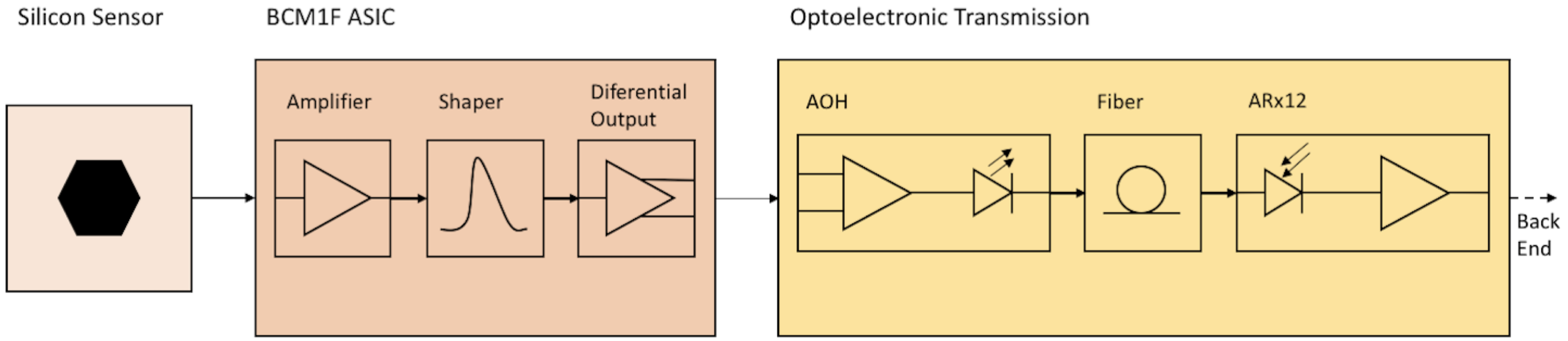
- AC-coupled double diode Silicon sensors

BCM1F ASIC

- Preamplifier with active feedback
- Shaper
- High performance differential output

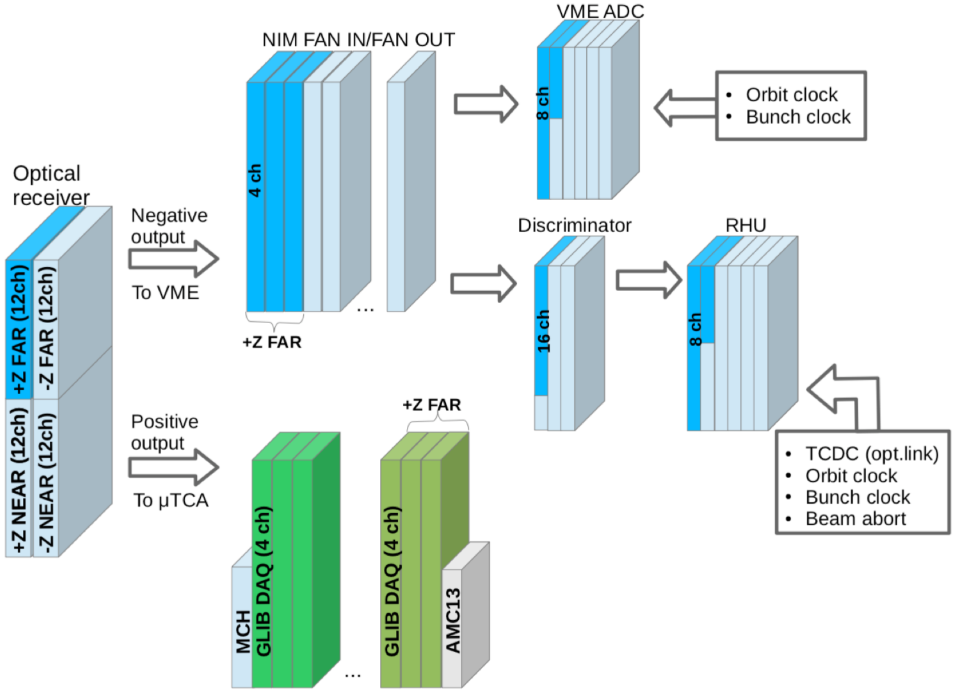
Optoelectronic Transmission

- Analog-OptoHybrid (AOH)
- Linear Laser Driver (LLD)
- ARx12 Optical Transeiver



Back End electronics

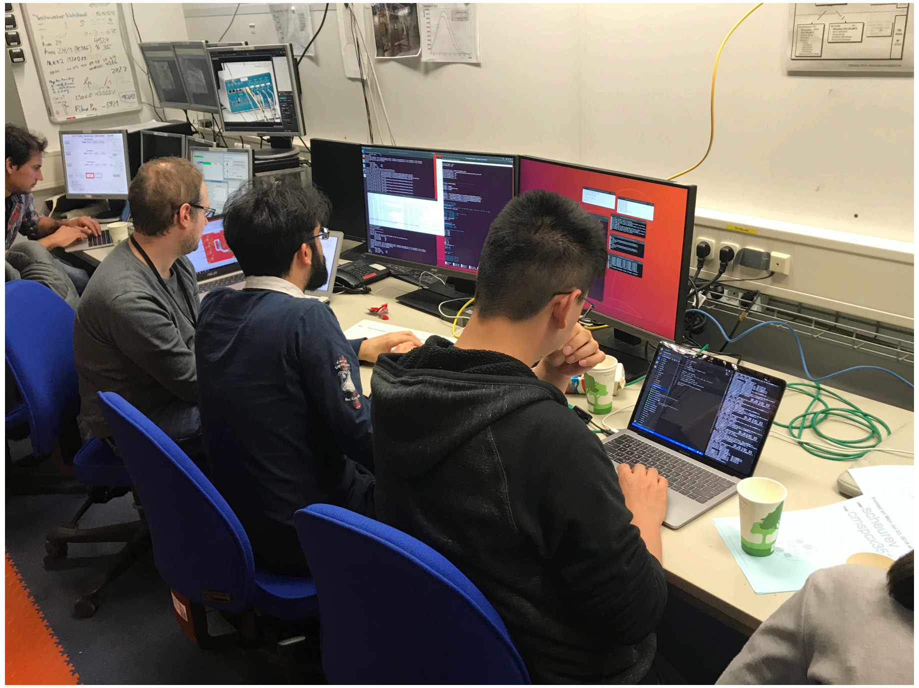
- VME back-end (legacy system, Run1,2) :
  - NIM Fan-In/Fan-Out
  - 8 bits VME ADCs, 500Ms/s for amplitude histograms
  - VME RHU (Real-time histogramming unit) for occupancy histograms for luminosity
- MicroTCA back-end (full commissioning for Run3) :
  - Gigabit Link Interface Board (GLIB)
  - 8 bits ADC FMC (FPGA Mezzanine Card), 1.25Gs/s
  - NAT MicroTCA Hub Module as crate controler
  - AMC13 interface to CMS clock & synchronous signals
- MicroTCA advantages :
  - Custom Firmware
  - Combines features of VME ADC & RHU
  - Advanced Peak detection
  - Higher resolution timing histogram



Test beam campaing

- Took place at the Deutsches Elektronen Synchrotron (DESY) in Hamburg

- From 20/05/2019 to 26/05/2019

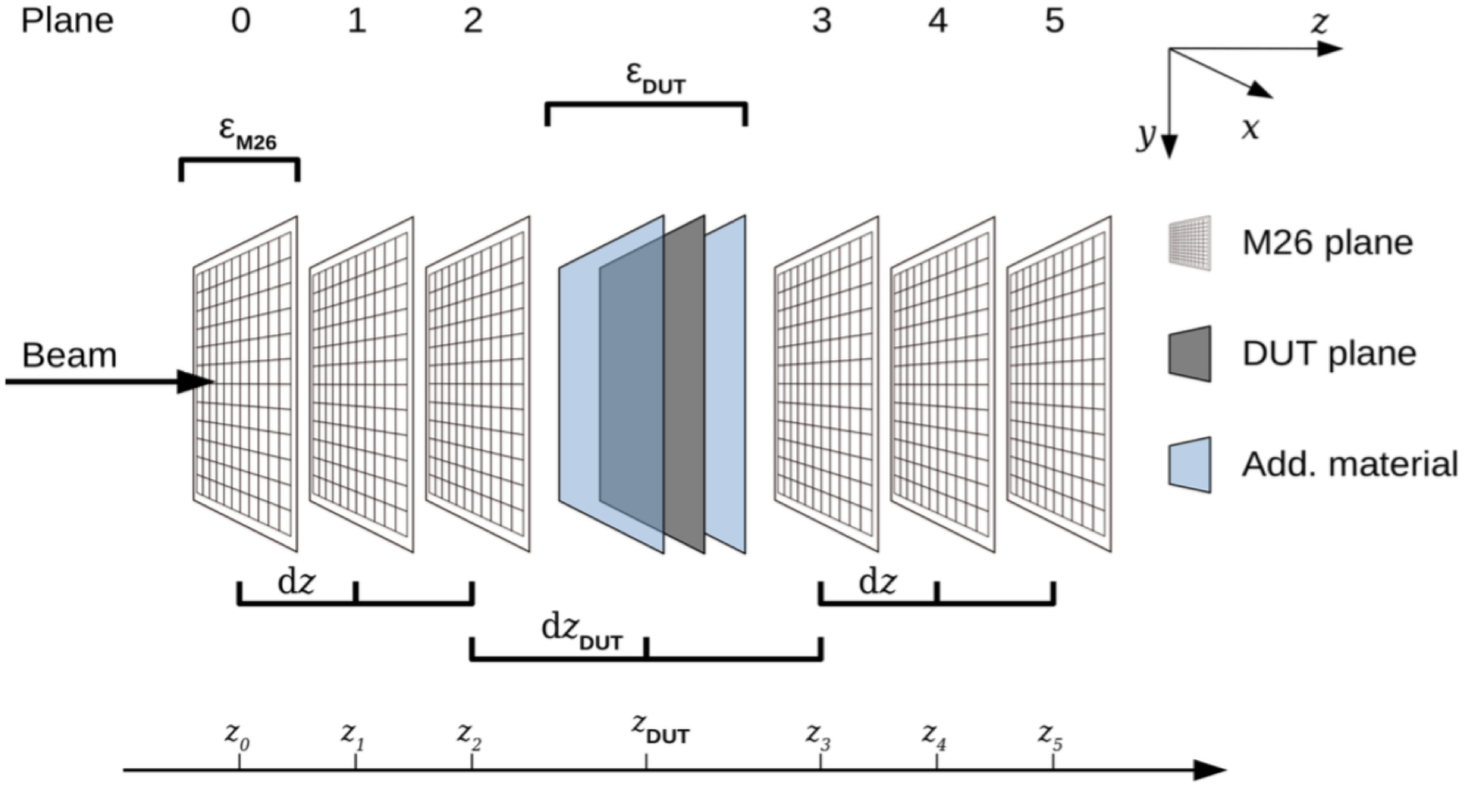


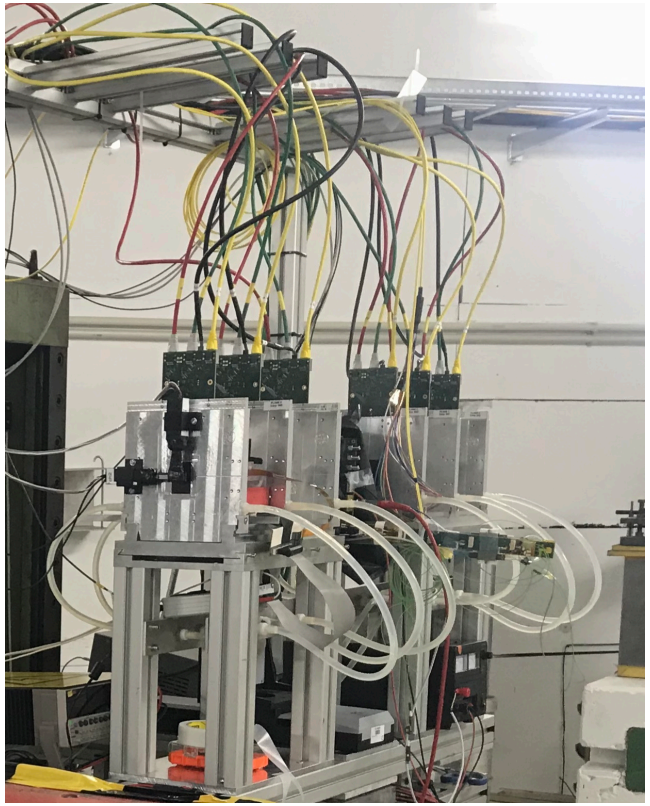
- DESY II test beam facility, beam area n°24

- Beam provided by the DESY II storage ring, up to 6GeV

EUDET-type telescope

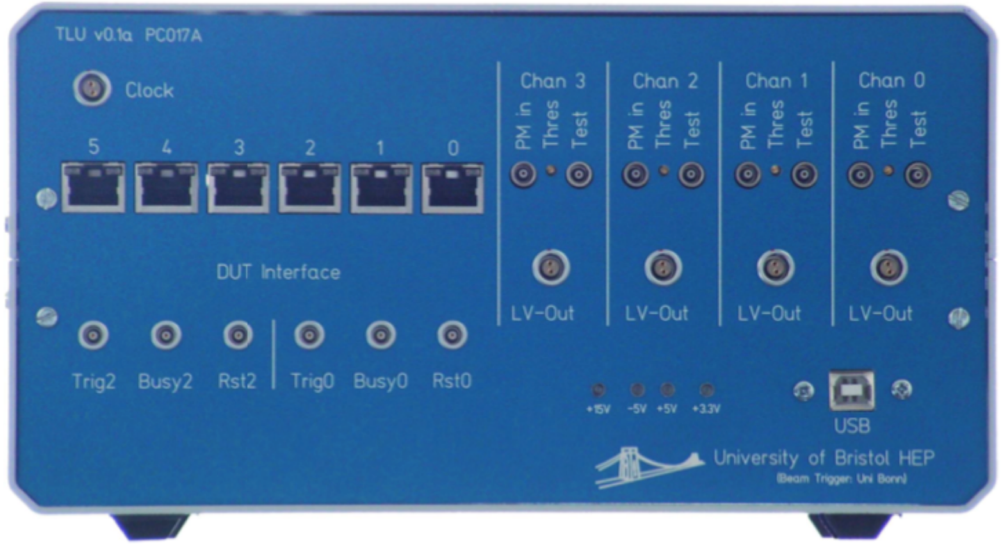
- MIMOSA-26 Monolithic active pixel sensors
- 18.4um x 18.4um pitch size
- 1152 col x 576 row
- 50um Si sensors, 24um Kapton foil shield
- 21.2mm x 10.6mm active area
- Low material budget, high track resolution

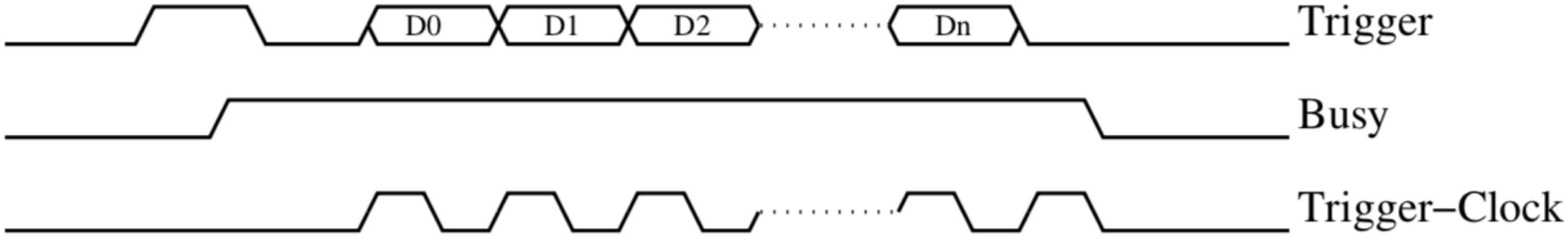




Trigger Logic Unit (TLU)

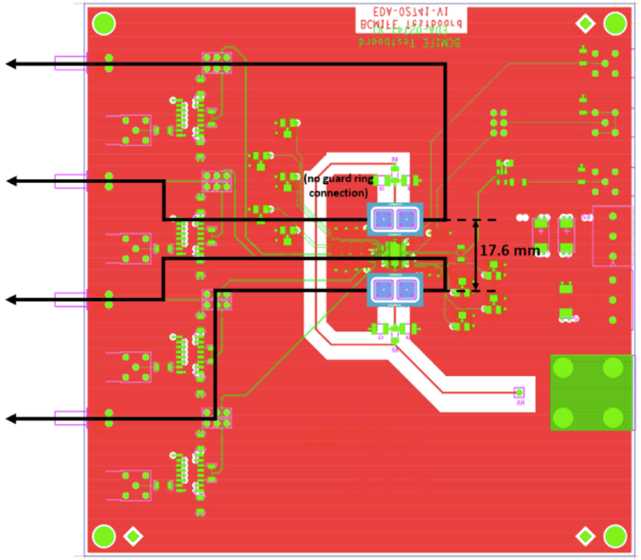
- Central part of the trigger system
- Provides 4 scintillator trigger inputs (AND, OR)
- Outputs a digital trigger fed to other devices
- Handshake mode to synchronise data acquisition

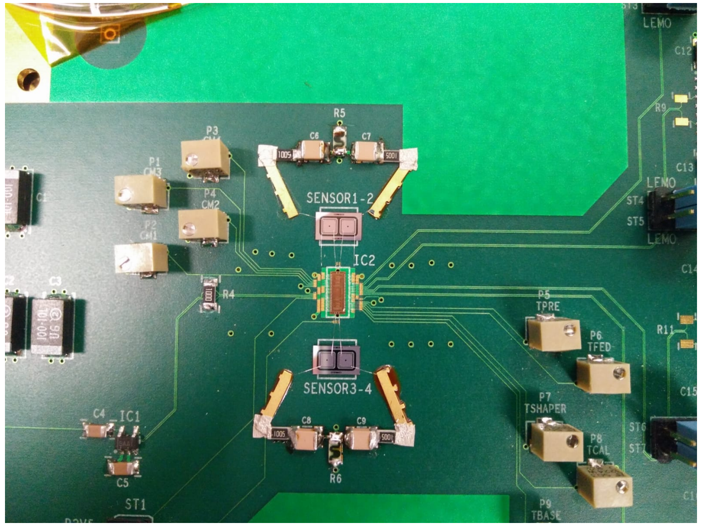


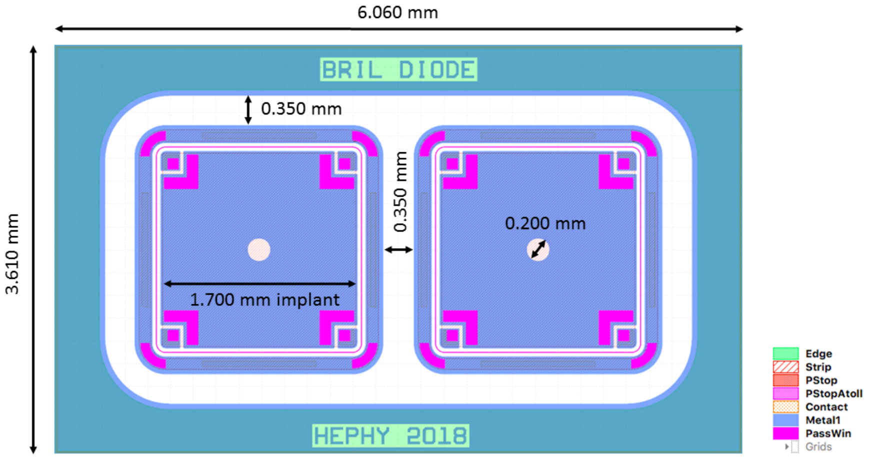


Device Under Test (DUT)

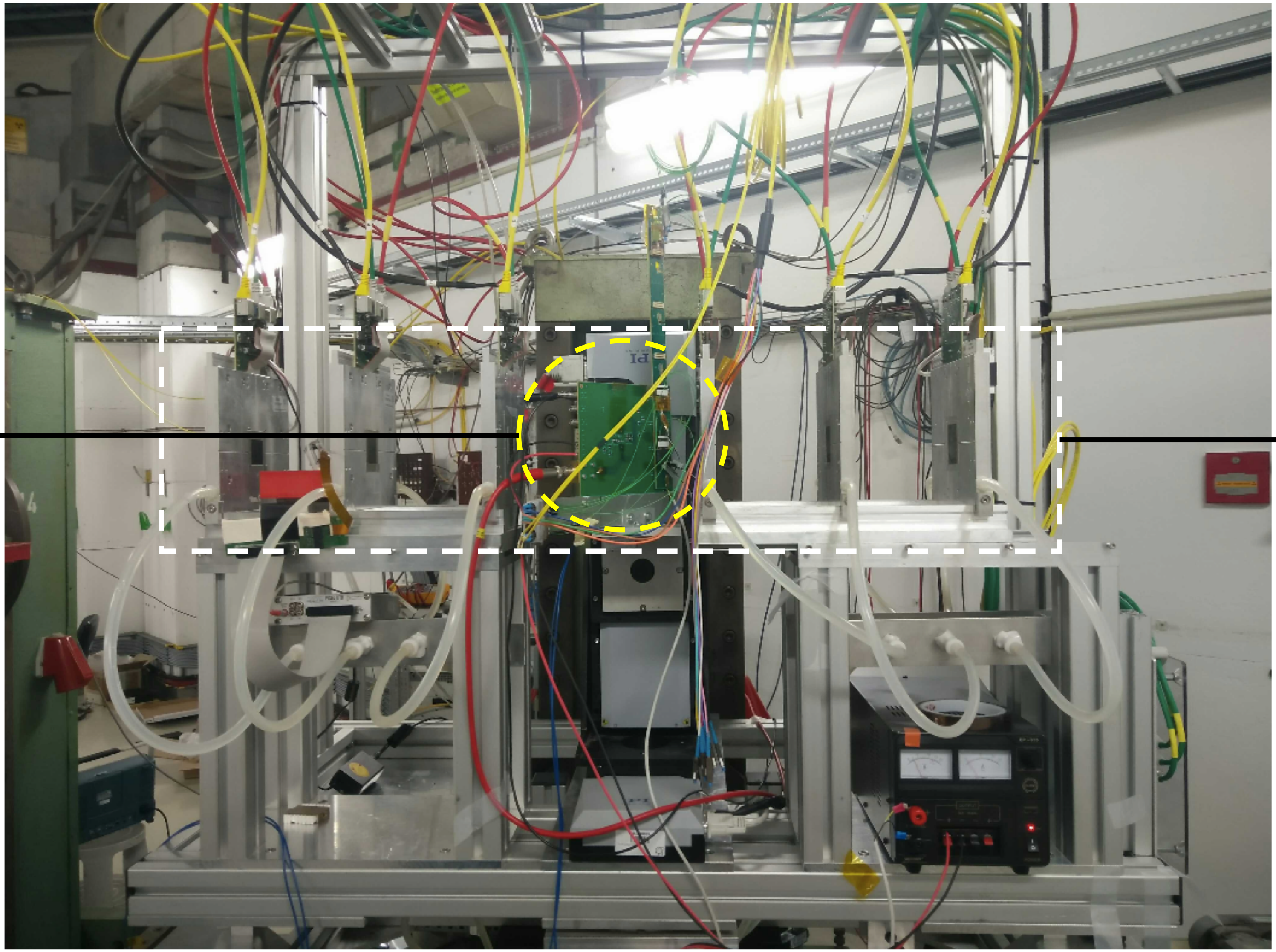
- 14cm x 14cm PCB with dedicated Optoboard
- 1.7mm x 1.7mm AC-coupled double diode Si sensors :
  - 200um, 300um
- Sensors equipped with guard ring :
  - Grounded on 200um sensor
  - Floating on 300um sensor







Test beam setup



DUT

Telescope

EUDAQ SW Framework

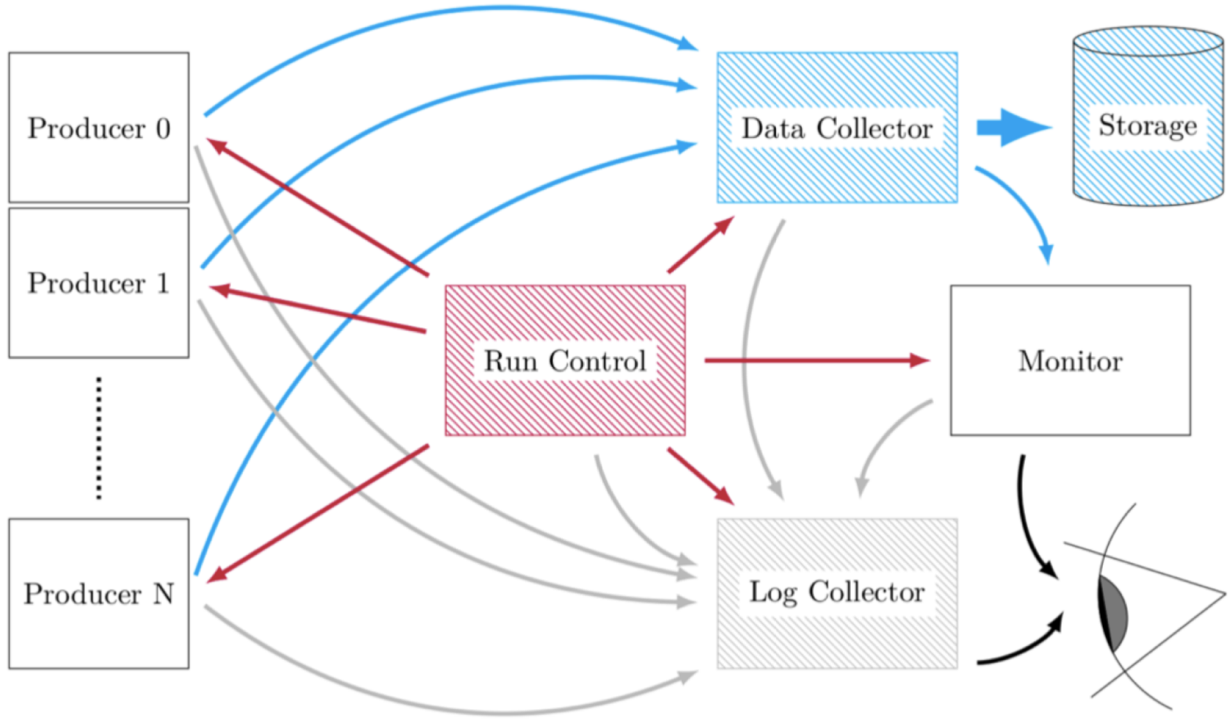
RunControl
- Initialize (*.init file)
- Configure (*.conf file)
- Start, Stop, Terminate

LogCollector
- Collects log and error messages
- Saves them in a file

Producers
- Configure DAQ devices
- Read data and stream them to DataCollector

DataCollector
- Collects data streamed by Producers
- Save data in a file (raw, root, LCIO, …)

OnlineMonitor
- Reads a file and shows useful plots for online monitoring



BCM1F DAQ SW integration

VME Producer

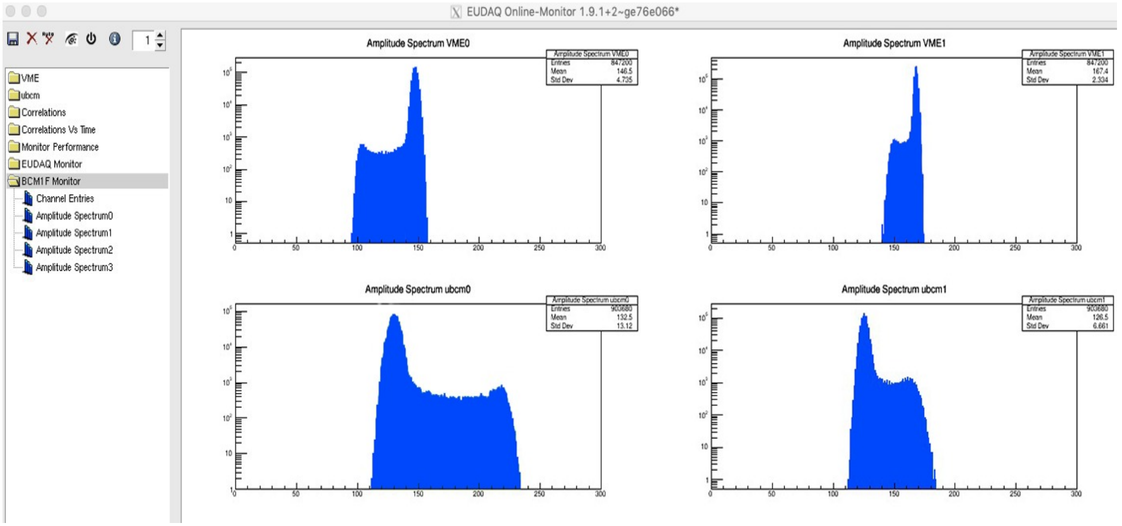
- ➢ Linked to the VME library
- ➢ Acknoledgment of the VME ADC
- ➢ Parameter configuration :
  - Channel mask
  - Acquisition window
  - Buffer size, Pre-trigger samples
  - External/Internal trigger

uTCA Producer

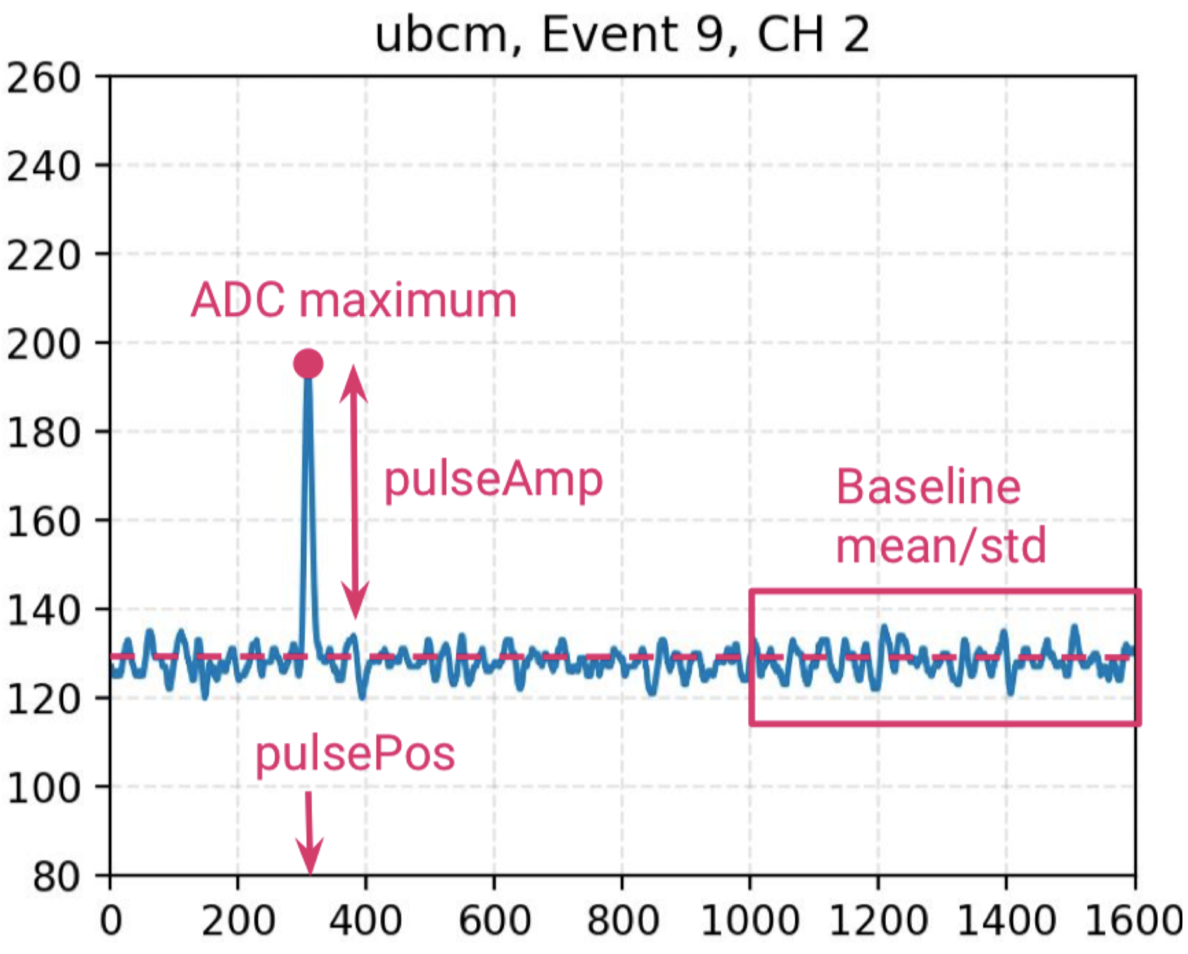
- ➢ Linked to uTCA library
- ➢ IP address assignement to GLIB card
- ➢ Sets the trafic to AMC GLIB
- ➢ Parameter configuration:
  - Thresholds for Pulse peak detection
  - Acquisiton window
  - Buffer size
- ➢ Functionnal checks on AMC GLIB

BCM1F Online Monitor

- ➢ Converter Plug-In : Raw → StdEvent (EUDAQ)
- ➢ BCM1F collection class for the GUI
- ➢ BCM1F Histogram class for amplitude spectra



Amplitude Spectra (1)



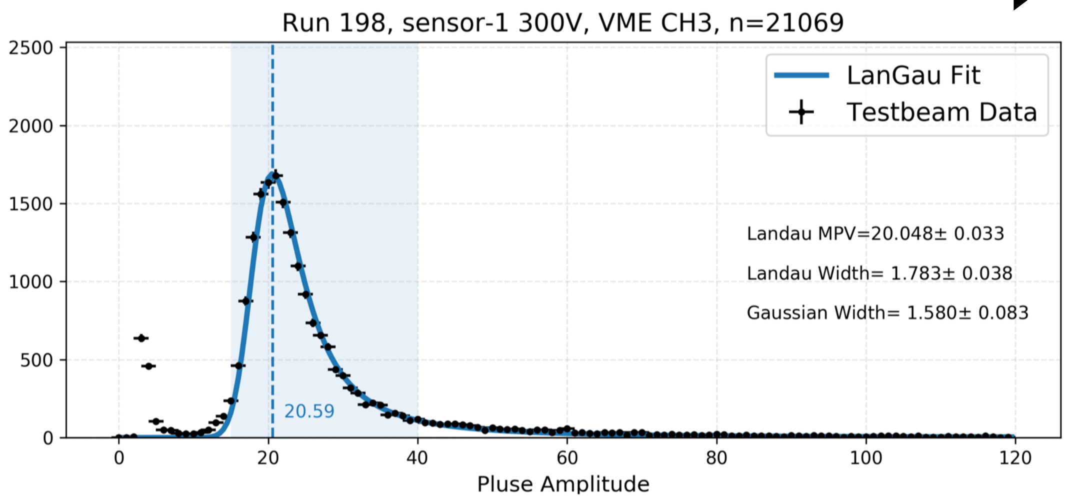
Acquired waveform

Extract pulse features

Fill pulseAmp histograms

Convoluted Landau*Gaussian fit

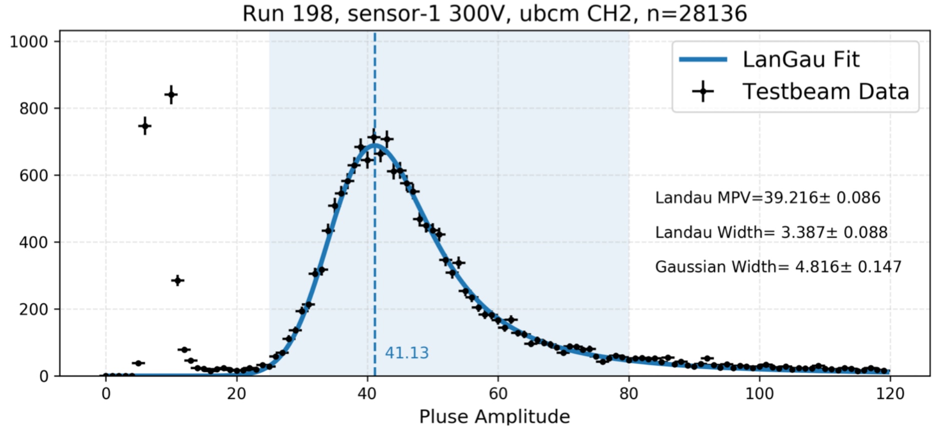
Extract Most Probable Value

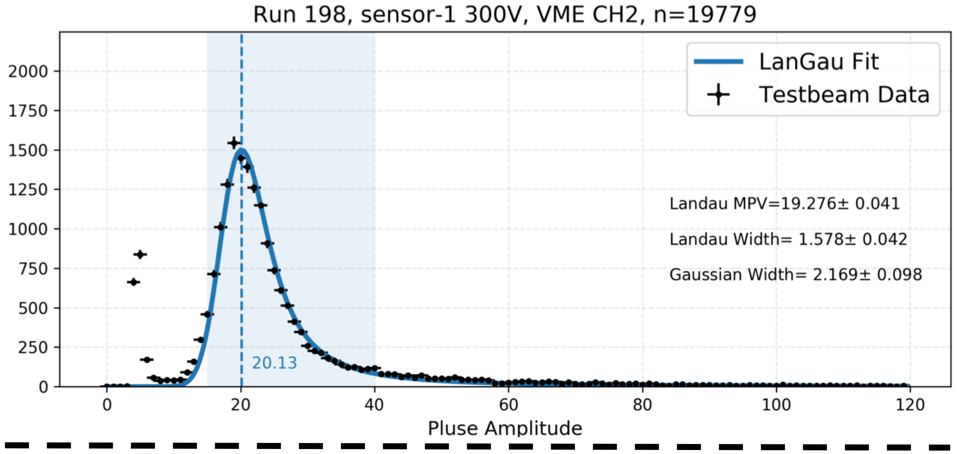


Amplitude Spectra (2)

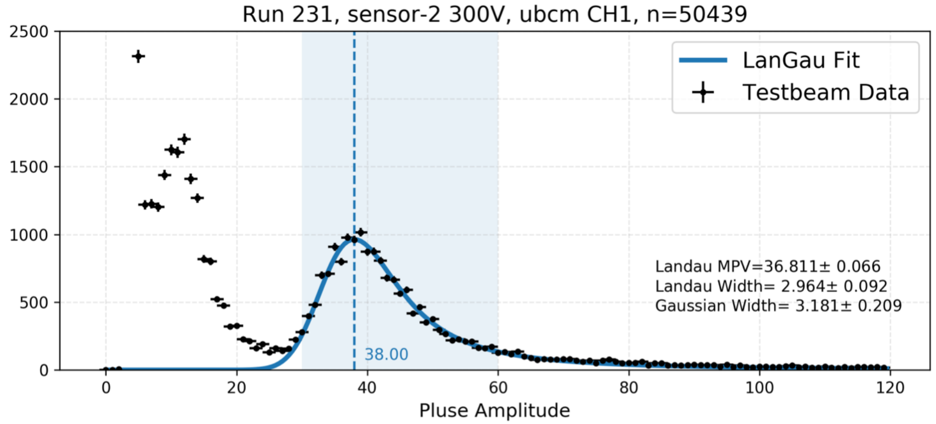
MicroTCA | **VME**

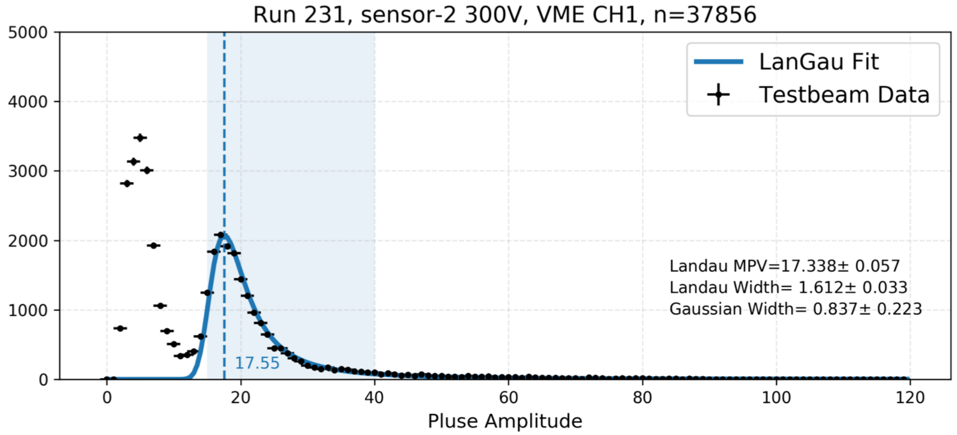
Sens1 200um Grounded GR





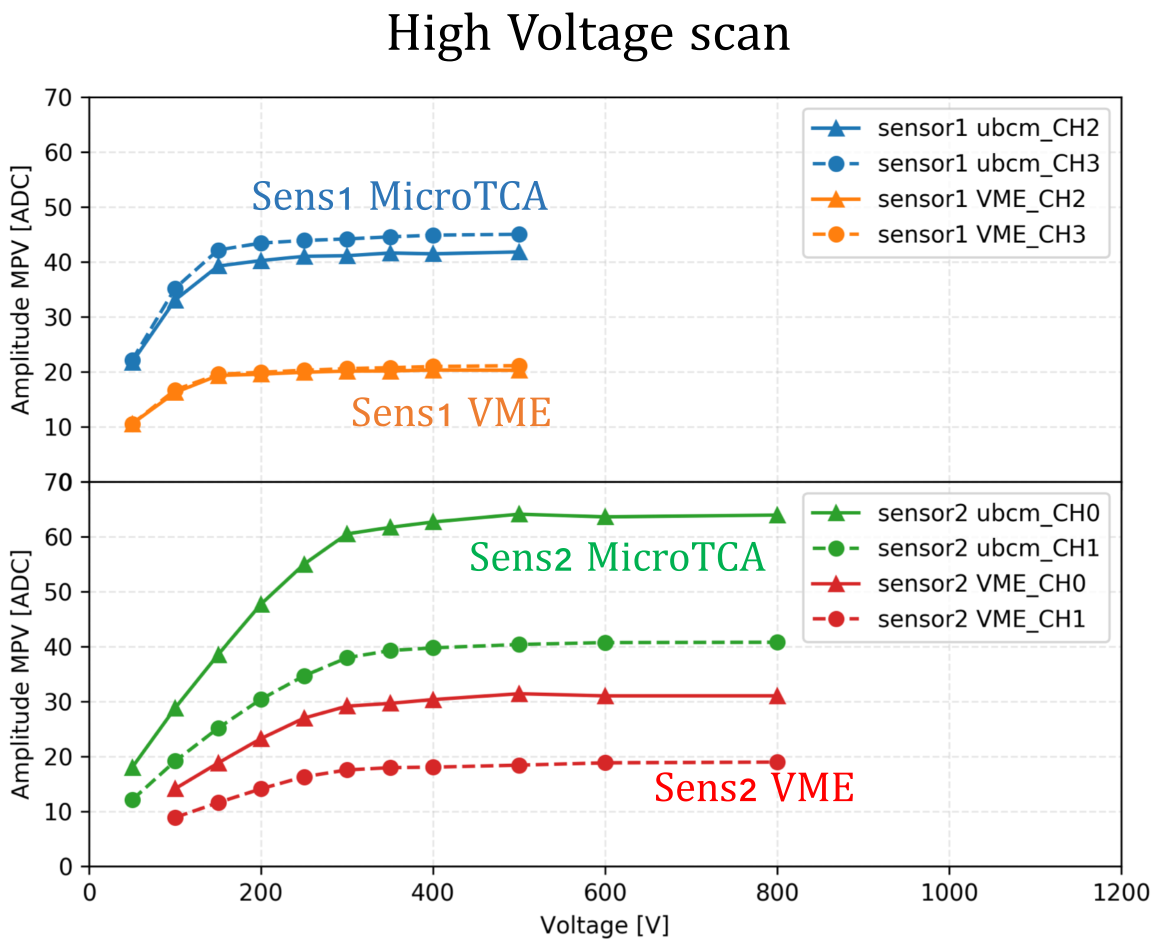
Sens2 300um Floating GR





Better separation between the signal and noise on sensor 1 with guard ring grounded

Amplitude Spectra (3)



- MPV reaches plateau, as expected from capacitance measurements, at :
  - ~150V for sensor1 (200um)
  - ~280V for senor2 (300um)
- Factor two difference between VME and MicroTCA due to electronic gain

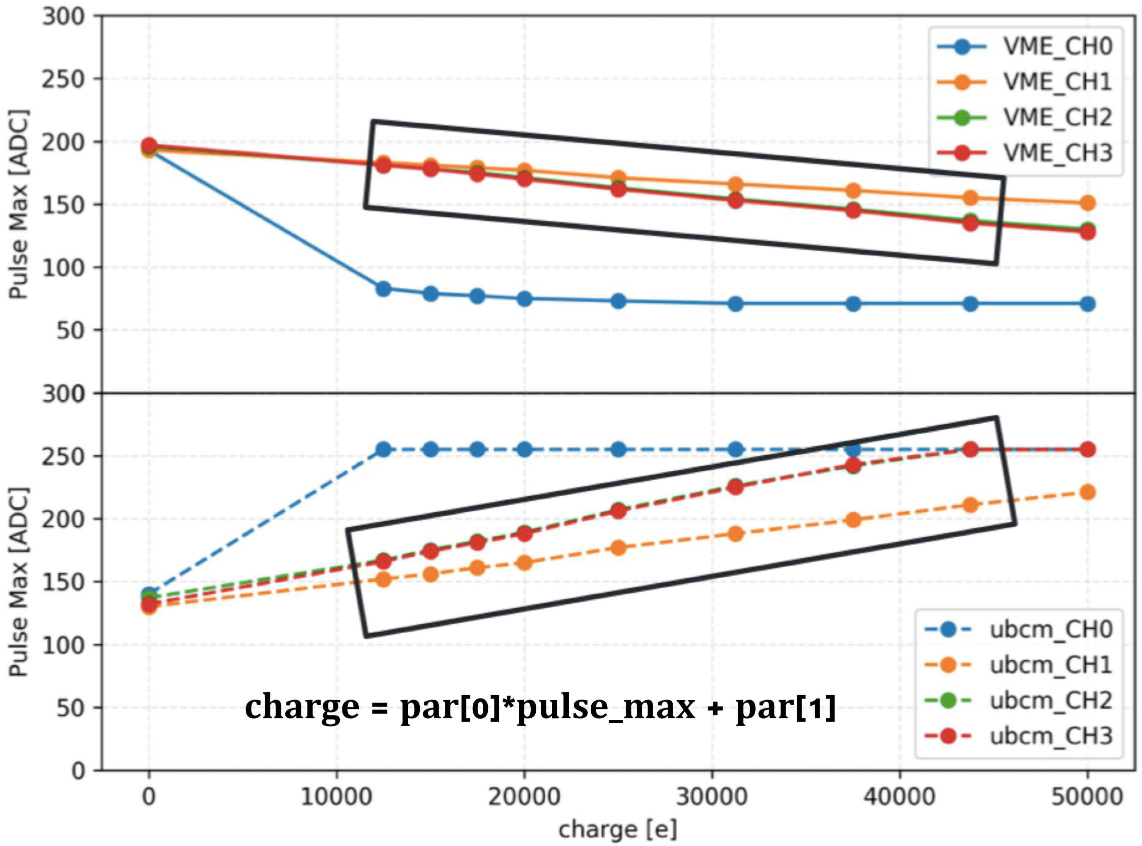
Detector calibration

Charge injection into the ASIC preamp controled by amplitude of injected square signal

ASIC outputs a test pulse

Match pulse amplitude with equivalent injected charge

Linear fit to extract calibration constants



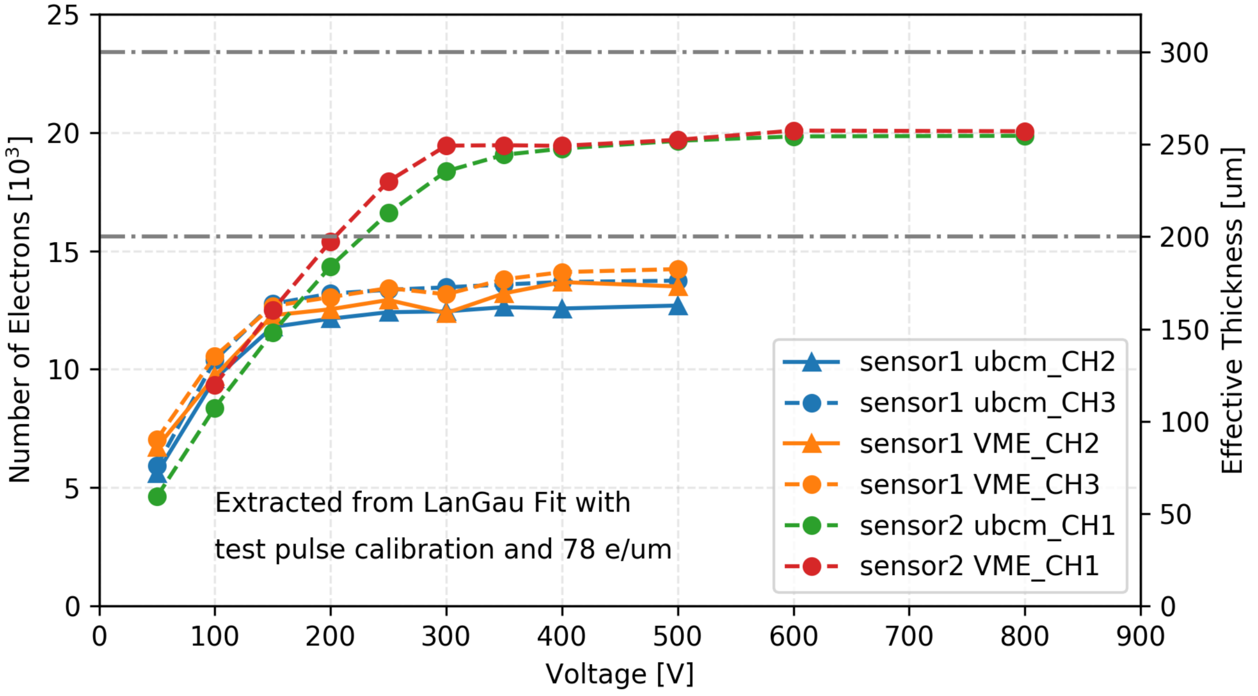
Par	CH	VME CH1	VME CH2	VME CH3	uTCA CH1	uTCA CH2	uTCA CH3
par[0]		-1133.64	-724.15	-695.72	532.81	353.19	341.84
par[1]		219753.98	143273.40	138067.06	-688611.35	-47354.99	-44729.34

Sensor effective thickness

MIPs in Silicon → ~78 e/um

Convert BCM1F MPV values to equivalent number of electrons using calibration constants

$$eff\ thick = \frac{MPV\ number\ of\ eh\ pairs}{1\ MIP\ number\ of\ eh\ pairs\ per\ um}$$



Effective thickness 20% different from actual thickness.
Most likely due to imperfect calibration measurement

Conclusion

Summary

- A test beam at DESY was carried out to verify the performance of AC-coupled Si-pad detectors in radiation-hard Silicon
- Producers were developped and extensively tested in order to integrate the BCM1F DAQ systems into the DESY EUDAQ SW framework
- The native EUDAQ Online Monitor was modified to include BCM1F specific plots
- Preliminary sensor qualification was perfomed based on amplitude spectra and detector calibration
- The analysis showed promising results from AC-coupled design

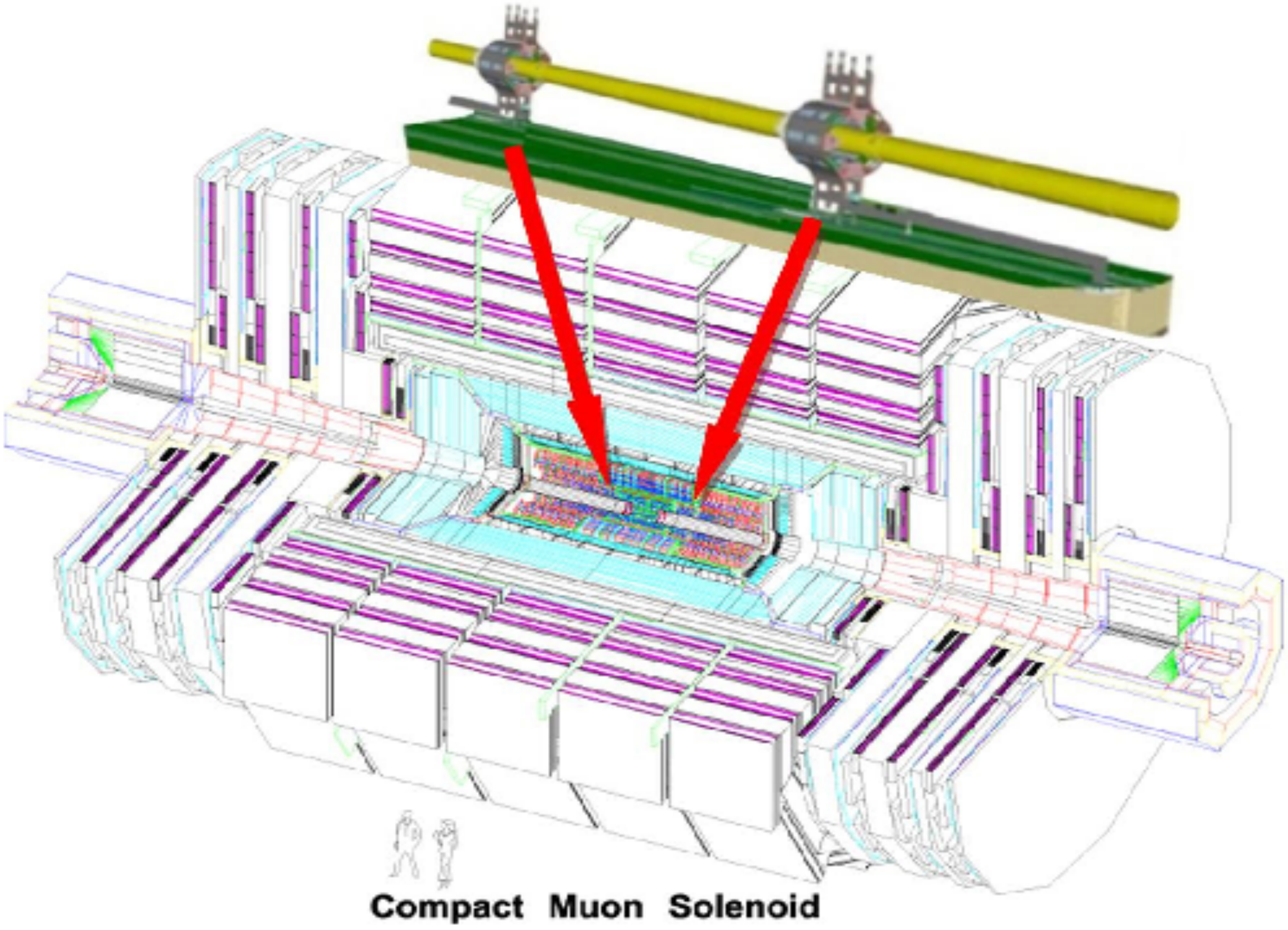
Outlook

- Detailed studies of various detector features (baseline, SNR, efficiency, …)
- Further investigation of the guard ring effects
- Include reconstructed telescope data

Thank you for your attention !

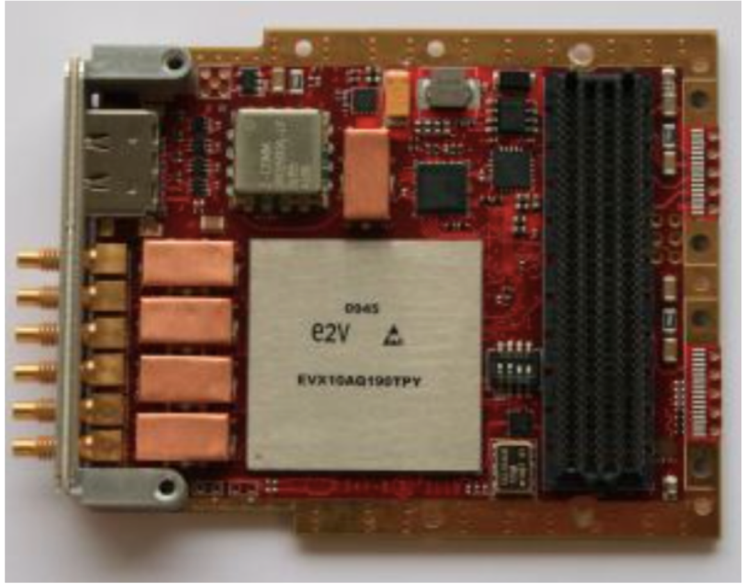
Back up

BCM1F location



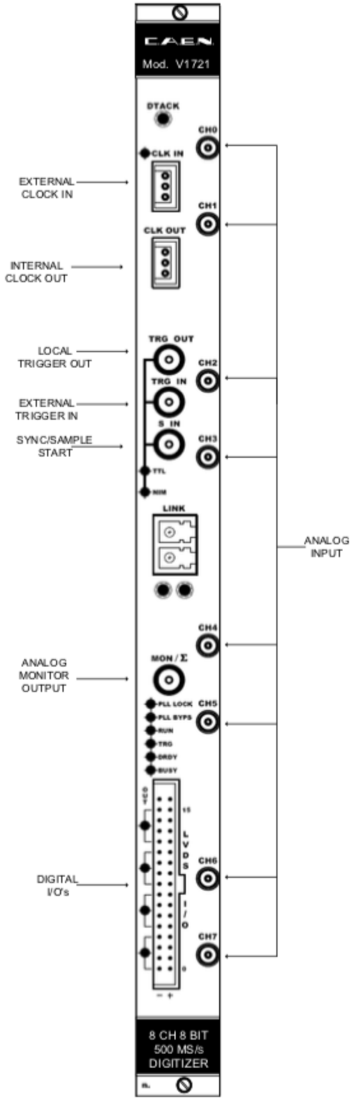
MicroTCA system

Gigabit Link Interface Board (GLIB)



FPGA Mezzanine Card (FMC)

VME system

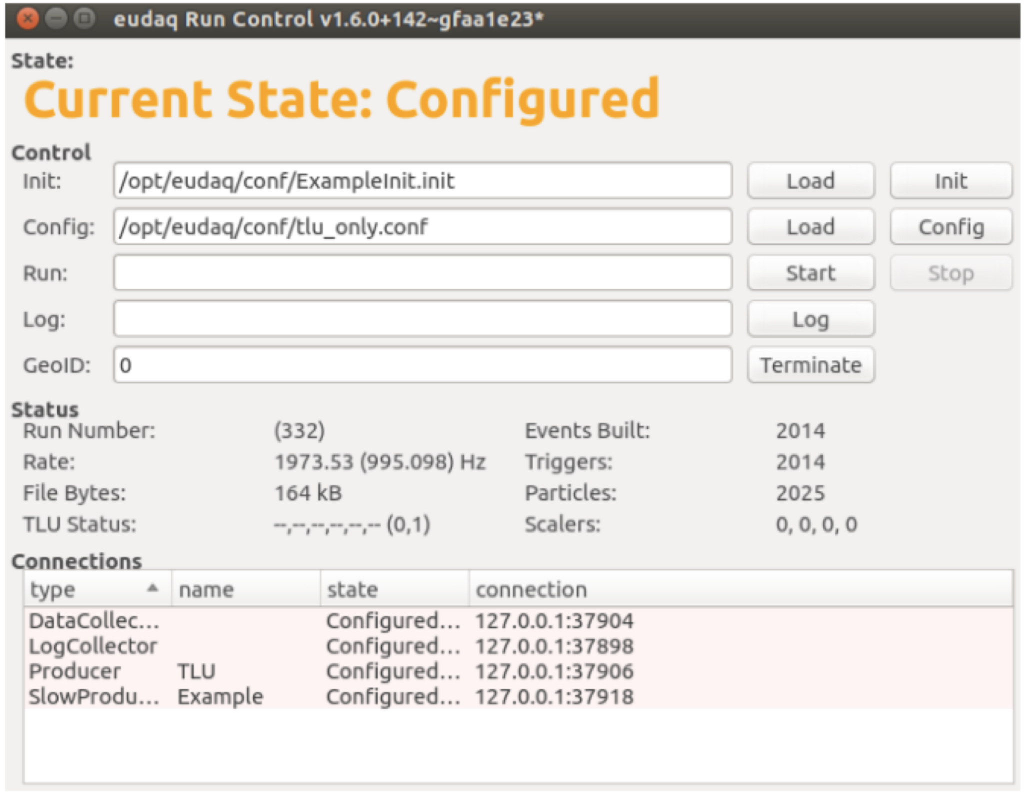


31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

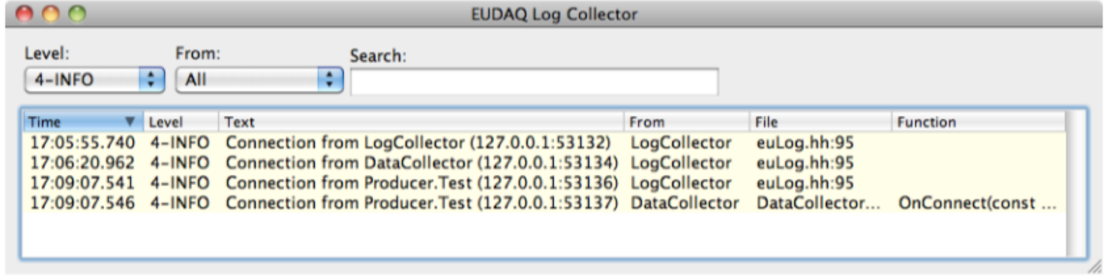
1 0 1 0	EVENT SIZE			HEADER
BOARD-ID, Res., 0	PATTERN		CHANNEL MASK	HEADER
reserved	EVENT COUNTER			HEADER
TRIGGER TIME TAG				HEADER
SAMPLE(3) CH0	SAMPLE(2) CH0	SAMPLE(1) CH0	SAMPLE(0) CH0	DATA CH0
SAMPLE(7) CH0	SAMPLE(6) CH0	SAMPLE(5) CH0	SAMPLE(4) CH0	DATA CH0
• • •				DATA CH0
SAMPLE(N-1) CH0	SAMPLE(N-2) CH0	SAMPLE(N-3) CH0	SAMPLE(N-4) CH0	DATA CH0
SAMPLE(3) CH1	SAMPLE(2) CH1	SAMPLE(1) CH1	SAMPLE(0) CH1	DATA CH1
SAMPLE(7) CH1	SAMPLE(6) CH1	SAMPLE(5) CH1	SAMPLE(4) CH1	DATA CH1
• • •				DATA CH1
SAMPLE(N-1) CH1	SAMPLE(N-2) CH1	SAMPLE(N-3) CH1	SAMPLE(N-4) CH1	DATA CH1
• • •				• • •
SAMPLE(3) CH7	SAMPLE(2) CH7	SAMPLE(1) CH7	SAMPLE(0) CH7	DATA CH7
SAMPLE(7) CH7	SAMPLE(6) CH7	SAMPLE(5) CH7	SAMPLE(4) CH7	DATA CH7
• • •				DATA CH7
SAMPLE(N-1) CH7	SAMPLE(N-2) CH7	SAMPLE(N-3) CH7	SAMPLE(N-4) CH7	DATA CH7

VME event structure

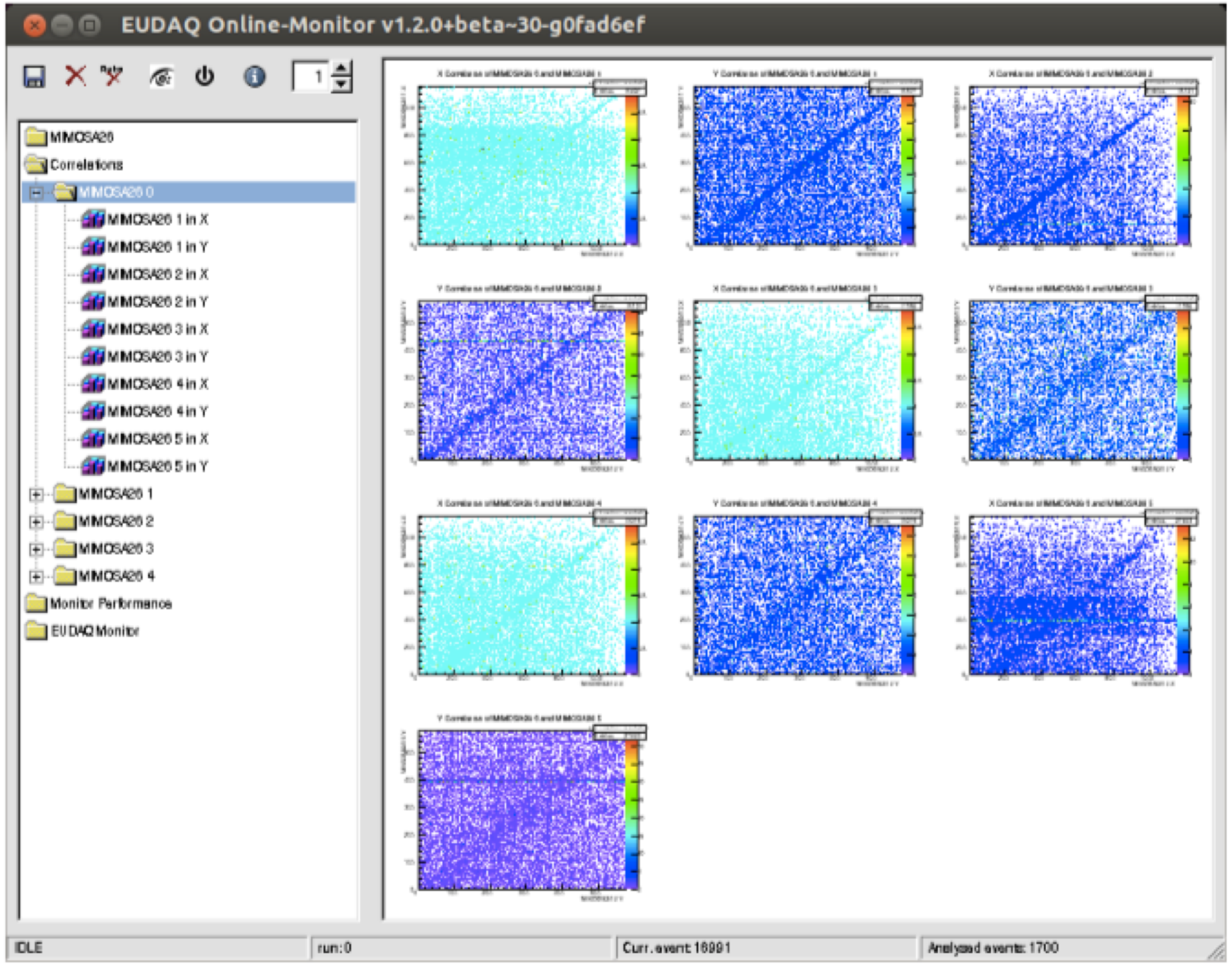
EUDAQ GUI



eudaq Run Control v1.6.0+142~gfaa1e23*
State:
Current State: Configured
Control
Init: /opt/eudaq/conf/ExampleInit.init Load Init
Config: /opt/eudaq/conf/tlu_only.conf Load Config
Run: Start Stop
Log: Log
GeoID: 0 Terminate
Status
Run Number: (332) Events Built: 2014
Rate: 1973.53 (995.098) Hz Triggers: 2014
File Bytes: 164 kB Particles: 2025
TLU Status: --,--,--,--,--,-- (0,1) Scalers: 0, 0, 0, 0
Connections
type name state connection
DataCollec... Configured... 127.0.0.1:37904
LogCollector Configured... 127.0.0.1:37898
Producer TLU Configured... 127.0.0.1:37906
SlowProdu... Example Configured... 127.0.0.1:37918

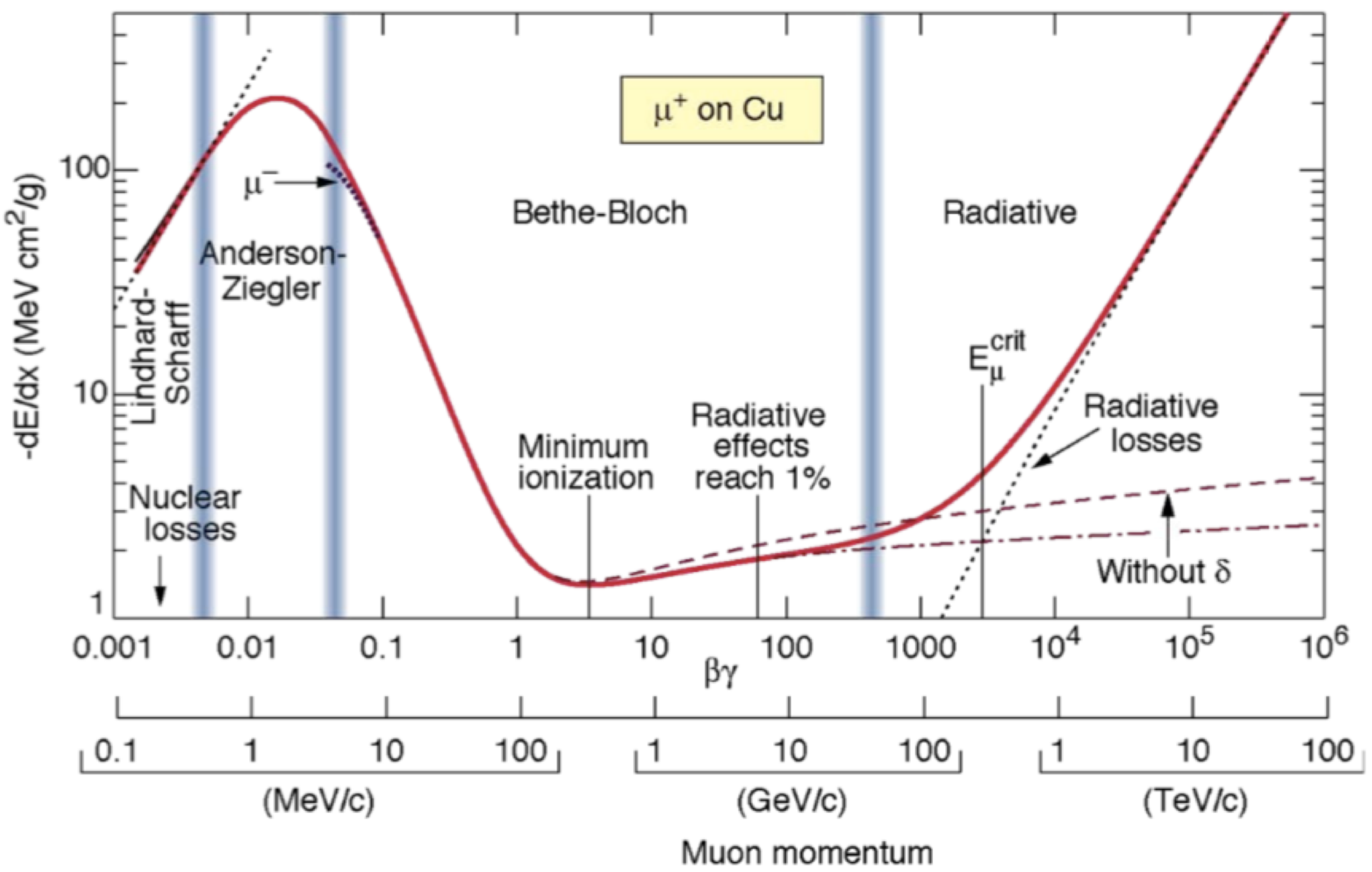


EUDAQ Log Collector
Level: 4-INFO
From: All
Search:
Time Level Text From File Function
17:05:55.740 4-INFO Connection from LogCollector (127.0.0.1:53132) LogCollector euLog.hh:95
17:06:20.962 4-INFO Connection from DataCollector (127.0.0.1:53134) LogCollector euLog.hh:95
17:09:07.541 4-INFO Connection from Producer.Test (127.0.0.1:53136) LogCollector euLog.hh:95
17:09:07.546 4-INFO Connection from Producer.Test (127.0.0.1:53137) DataCollector DataCollector... OnConnect(const ...



EUDAQ Online-Monitor v1.2.0+beta~30-g0fad6ef
MIMOSA26
Correlations
MIMOSA26 0
MIMOSA26 1 in X
MIMOSA26 1 in Y
MIMOSA26 2 in X
MIMOSA26 2 in Y
MIMOSA26 3 in X
MIMOSA26 3 in Y
MIMOSA26 4 in X
MIMOSA26 4 in Y
MIMOSA26 5 in X
MIMOSA26 5 in Y
MIMOSA26 1
MIMOSA26 2
MIMOSA26 3
MIMOSA26 4
Monitor Performance
EUDAQ Monitor
IDLE
run:0
Curr. event: 18091
Analysed events: 1700

Bethe-Bloch



Derive the same for electrons in Silicon, and deduce the equivalent number of charges generated per micron