New Fast Beam Conditions Monitoring (BCM1F) system for CMS.

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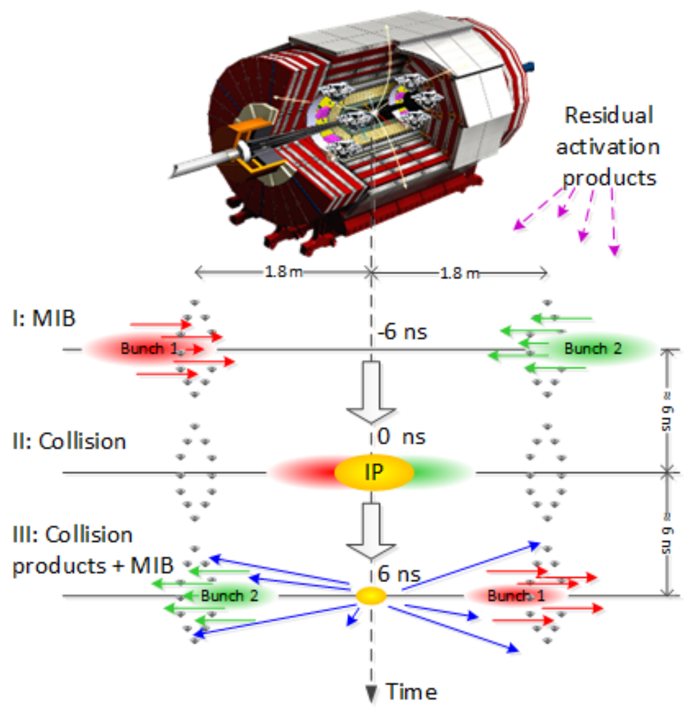
The CMS Beam Radiation Instrumentation and Luminosity (BRIL) project is composed of several systems providing the experiment with protection from adverse beam conditions while also measuring the online luminosity and beam background. Although the readout bandwidth of the Fast Beam Conditions Monitoring system (BCM1F - one of the faster monitoring systems of the CMS BRIL), was sufficient for the initial LHC conditions, the foreseen enhancement of the beams parameters after the LHC Long Shutdown-1 (LS1) imposed the upgrade of the system. This paper presents the new BCM1F, which is designed to provide real-time fast diagnosis of beam conditions and instantaneous luminosity with readout able to resolve the 25 ns bunch structure.

Front-end electronics



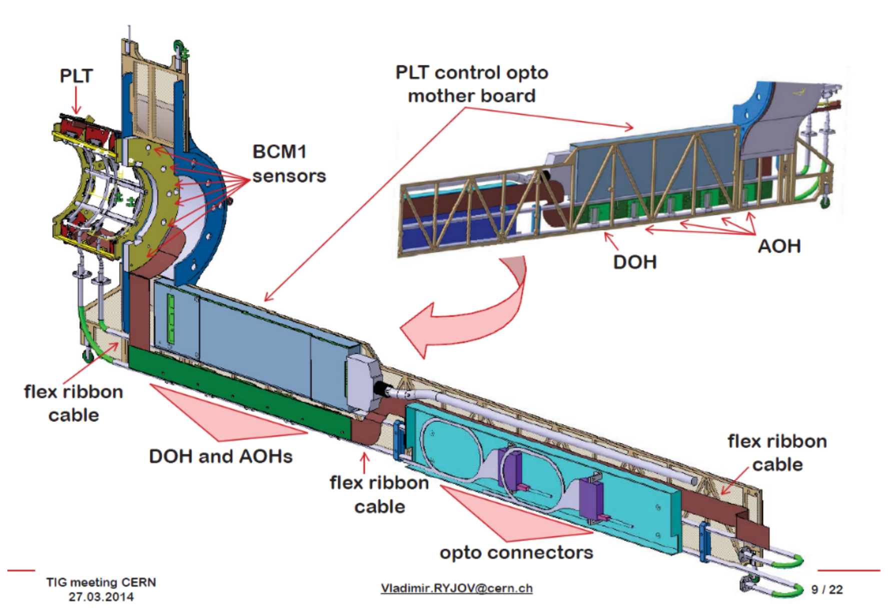
48 detector channels

Diamonds: *A new front-end consist of 24 single crystalline CVD diamond sensors with two pad metallisation: 5 mm x 5 mm with 25um split*

Electronics: *The front-end electronics consists of the fast trans-impedance preamplifier with an active feedback, a shaper stage and fully differential output buffer; 4 analog-opto-hybrids (AOH) and 1 digital-opto-hybrid (DOH)*

Location: *The detectors are mounted on two parallel planes positioned at the distance of z = ±1.83 m away from the interaction point (IP), mounted radially at r = 7.2 cm from the beam line.*

Purpose: *The system is designed for distinguishing of collision and machine induced background, both synchronous to the LHC clock, from the residual activation products based on measurements of the signal characteristics.*

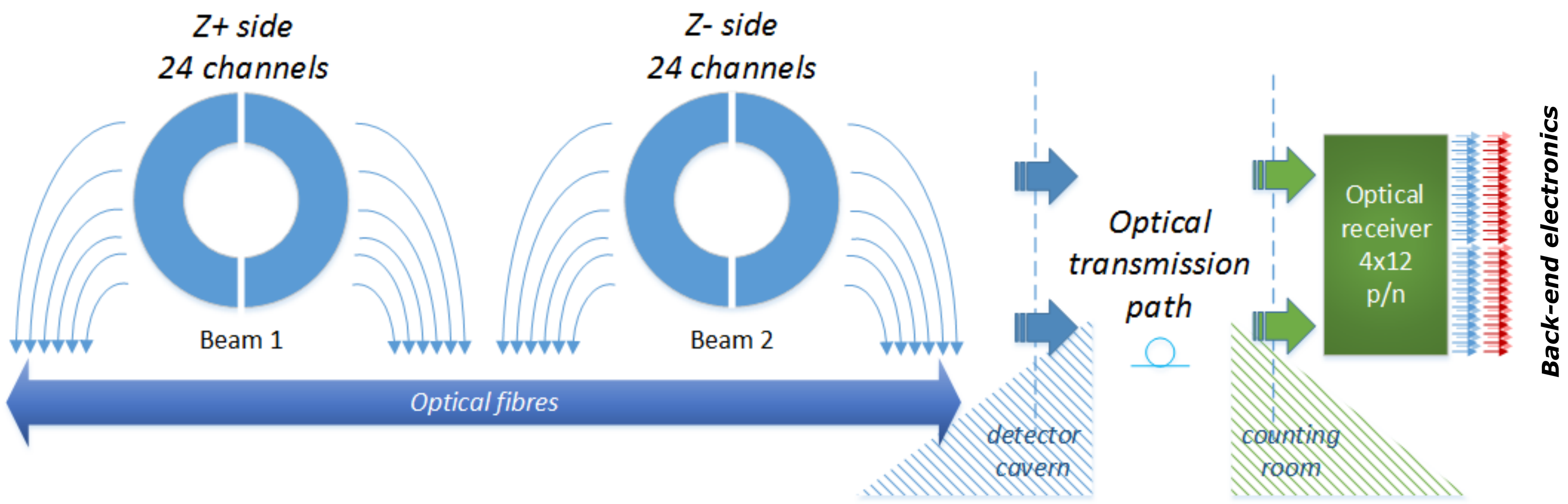


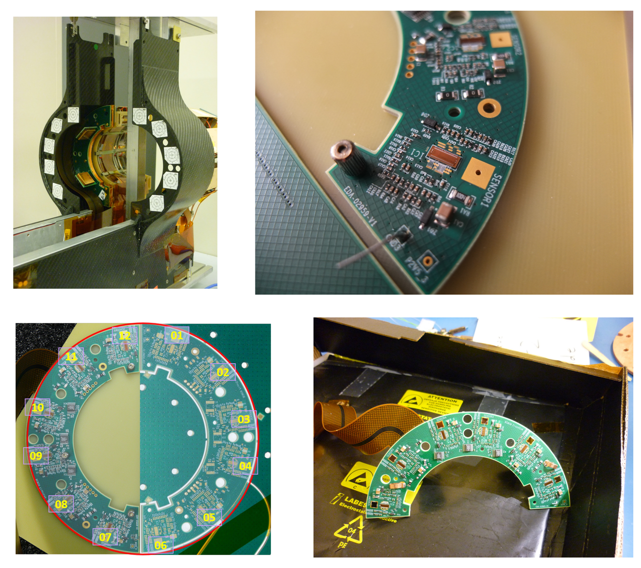
Front-end readout electronics:

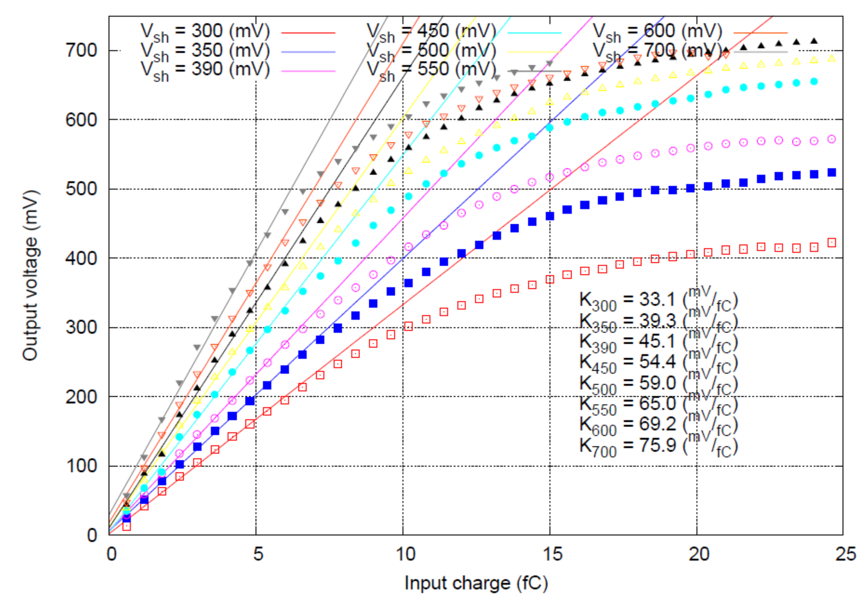
- 130 nm technology
- Detector capacitance Cdet = 2 – 5 pF
- Charge gain Kq ~50 mV/fC
- Input linear range up to 9 fC input charges
- Peaking time Tp = 6.6 to 9.6 ns
- Pulse full-width-half-maximum (FWHM) = 8 to 10.4 ns
- Equivallent Noise Charge ENC (e−) < 1000
- Fast baseline recovery after overdrive detector signal
- Differential output buffer able to drive 100 load
- Noise level around 500e- for 3 pF input capacitance

The FEE return to baseline could be less than 25 ns for proper bias settings

The linearity and gain measurement for various shaper bias and 2pF input capacitance are presented below. A good linearity is obtained for the input charges below 6 to 9 fC depending on a charge gain. Above those values circuit starts to saturate until charges values around 15 – 20 fC.[1]







Back-end electronics

Back-end electronics: VME

- Important luminometer and background monitor operating continously
- Reliable system upgraded on the basis of the previous experiences
- Compatible with the new front-end electronics
- Relatively low resolution in time (4 bins/BX), 7 ns double pulse resolution

Fan out

CAEN ADCs
- CAEN **V1721**
- **8 channel** digitizer
- 8 bit, 500 MS/s (4 ns) analog-to-digital conv.
- Current efficiency and signal characteristics monitoring
- internal or external triger
- **45 beam orbits**
- ring buffer with timestamps
- readout via an on-board optical link and processed in a PC

Discriminators
- **CAEN V895** Discriminators
- 3 boards, **48 input** channels
- Mask register for individual **channel enable/disable**
- **Thresholds** individually programmed

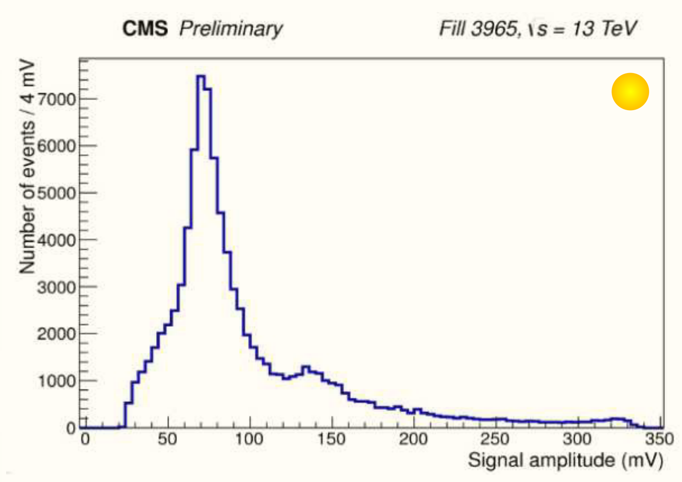
RHU
- RHU: **Realtime Histogramming Unit** (DESY)[2]
- Arrival time histogram
- Deadtimeless **full-orbit histograms, 65535 orbits**
- 4 ms post mortem buffer
- 4 bins (6.25 ns) / BX

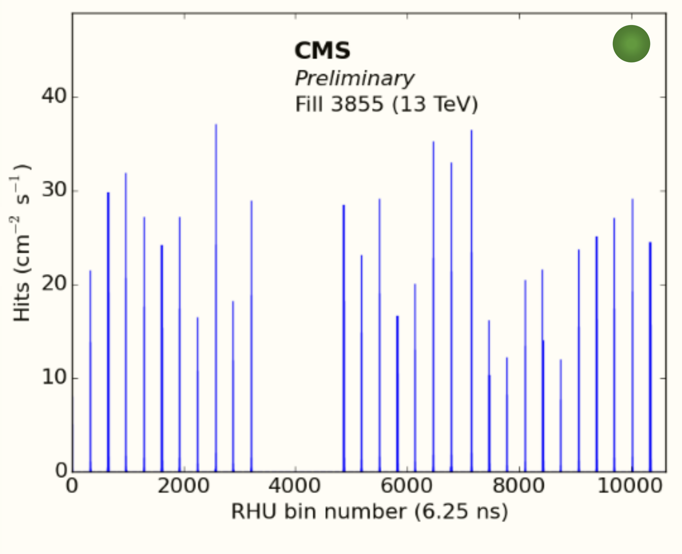
Logic unit
- **V1495** VME module
- 8 luminosity related signals to the RHU:4 logical+4 multiplicity
- **16 BPTX based logic** operations to the central trigger (LVDS) and 7 to the RHU (ECL)

BRILDAQ

TCDS

LHC clock & orbit





Back-end electronics: MicroTCA

- New technology, advanced signal processing possible, high luminosity operation
- Compatible with front-end, resolves the double hit front-end signals
- High resolution in time (31 bins/BX), distinguishing collision from MIB particle hits
- Being developed, foreseen first complete release by the end of the year

Data acqusition path:
front-end (cavern) > optical path > optical receiver (VME) > µTCA (counting room)

48 ADC channels:
- custom modified FMC125 (4DSP) board
- sampling rate 1.25 GS/s,
- 4 channels per processing module

Xilinx Virtex-6 FPGA (CMS GLIB board): processing platform, collecting RAW data and histograms

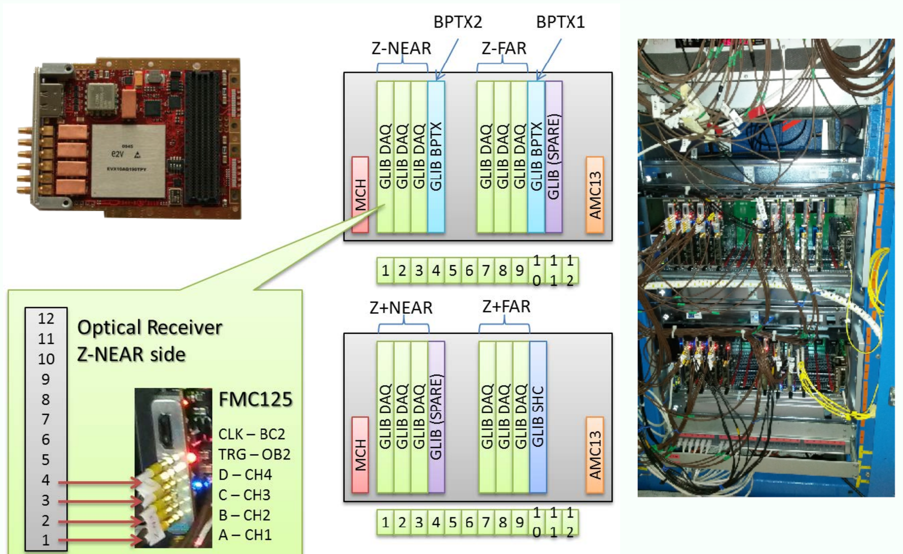
MicroTCA control hubs: NAT MCH and AMC13

RAW Data: 1 LHC orbit stored every 2^{15} orbits;

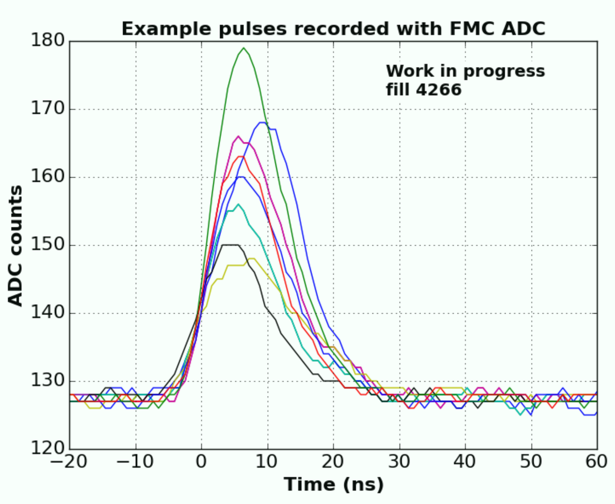
Histogram #1: The amplitude monitor of the gain

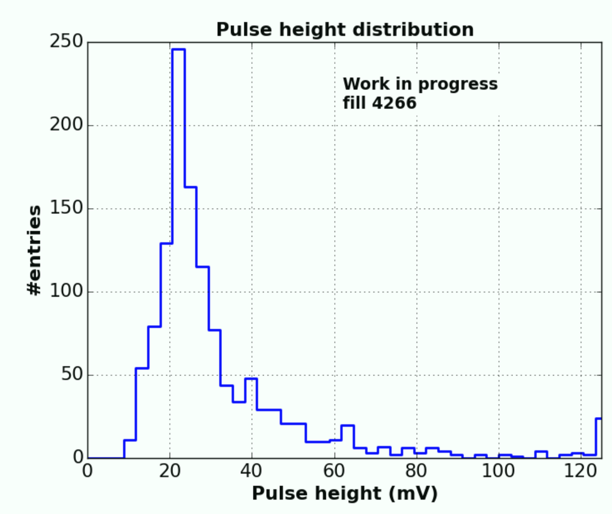
Histogram #2: The time domain histogram

Callibration pulses used as an input to the processor



Data Acquisition is synchronized to the LHC Bunch Clocks BC1 (for Z- side of the CMS) and BC2 (for Z+ side) and triggerd by the LHC Orbit Clocks OC1 and OC2. The CMS timing information is provided by the Trigger, Control and Distribution System (TCDS) and used for presenitng data.



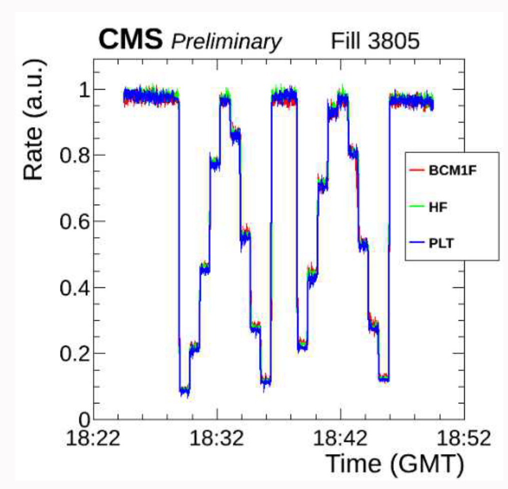


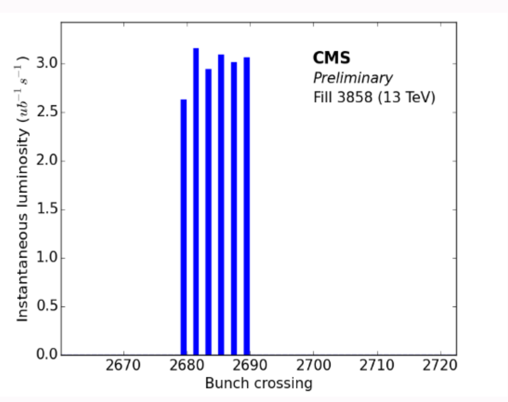
Raw Data (1 Ob/LN)		
Name	Value	Unit
Bits per sample	8	
Samples per BX	31	
BX per Orbit	3564	
Channels	48	
Total	42.43	Mb
LumiNibble	364.95	ms
Bitrate	116.25	Mb/s

Histogram : counts/amplitude (1 per LN)		
Name	Value	Unit
Amplitude values	256	
Count size	32	b
Total per histogram	8192	b
Channels	48	
Total	393.22	kb
LumiNibble	364.95	ms
Bitrate	1.08	Mb/s

Histogram : counts/time (1 per LN)		
Name	Value	Unit
Time values	3564	
Samples per value	31	
Samples size	16	b
Total per histogram	1767.74	kb
Channels	48	
Total	84.85	Mb
LumiNibble	364.95	ms
Bitrate	232.50	Mb/s

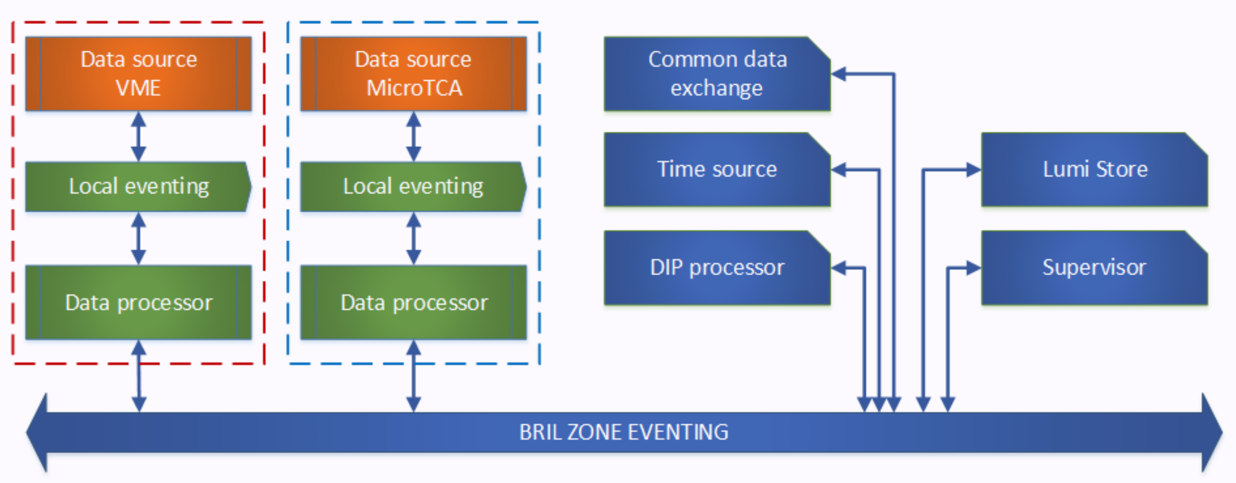
BCM1F performance





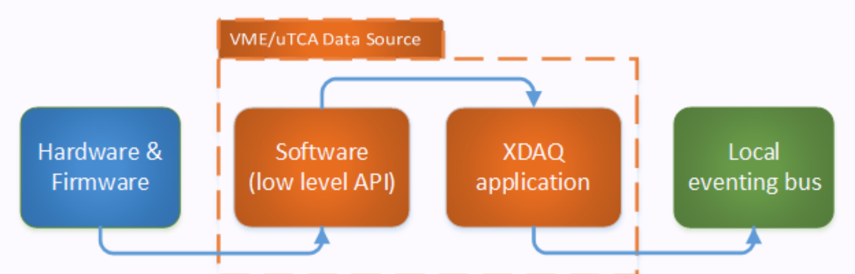
- **Operating continuously**
  - Simple state device
- Reliable measurement of the **delivered & recorded luminosity** and the machine-induced-background rates
- Calibrated using the Van der Meer scans technique
- Background measurement used by tracker/pixels for automatic switch-on semaphore
- Producing **consistent results** with Pixel Luminosity Telescope (PLT)

Data readout - BRIL DAQ & BCM1F uTCA



XDAQ data readout path:
- The data source block communicates with the hardware and performs the data readout
- The data are being sent to the local eventing bus and to the data processor
- The data processor acquires and process the data in order to prepare them for publication
- Results are published to the BRIL Zone Eventing bus.

Each subsystem has a separate data source that communicates with hardware using a low level API that is firmware specific e.g. IPbus and IPMI communication with MicroTCA back-end electronics. An XDAQ application requests the data readout that is performed by software. It stores the data to the local eventing bus. The flow structure is presented on the right side.



1) D.Przyborowski PhD. Thesis, http://winntbg.bg.agh.edu.pl/rozprawy2/10930/full10930.pdf
2) M.Penno et.all, "A Real-time Histogramming Unit for Luminosity Measurement at CMS", TWEPP2013