Architecture of the upgraded BCM1F Backend Electronics for Beam Conditions and Luminosity measurement

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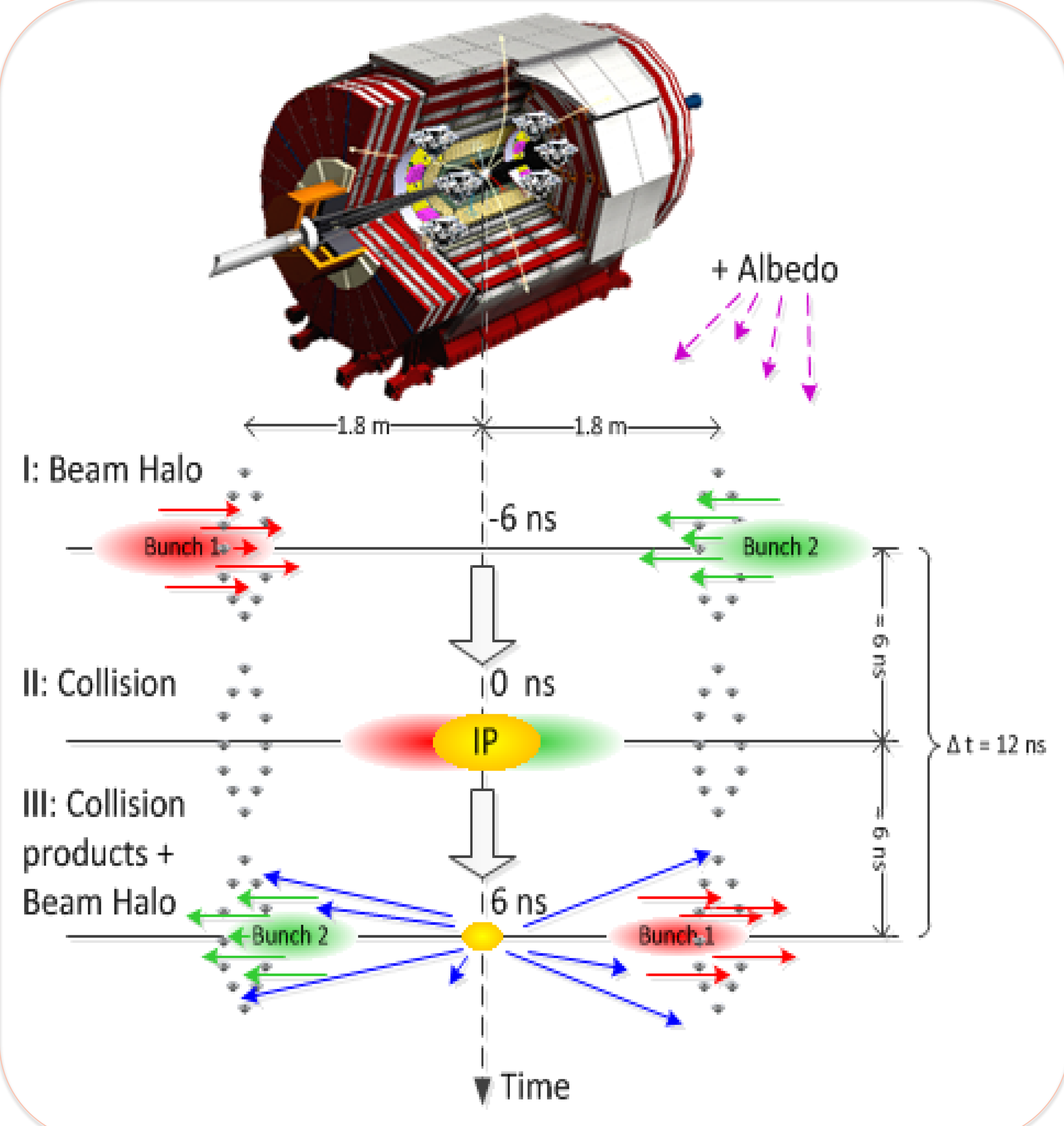
Abstract

The Beam Radiation Instrumentation and Luminosity Project of the CMS experiment, consists of several beam monitoring systems and luminometers. The upgraded Fast Beams Condition Monitor, is based on 24 single crystal diamond sensors with a two-pad metallization and a custom designed readout. Signals for real time monitoring are transmitted to the counting room, where they are received and processed by new back-end electronics designed to extract count rates on LHC collision, beam induced background and activation products to be used to determine the luminosity and the Machine Induced Background. The system architecture and the signal processing algorithms will be presented.

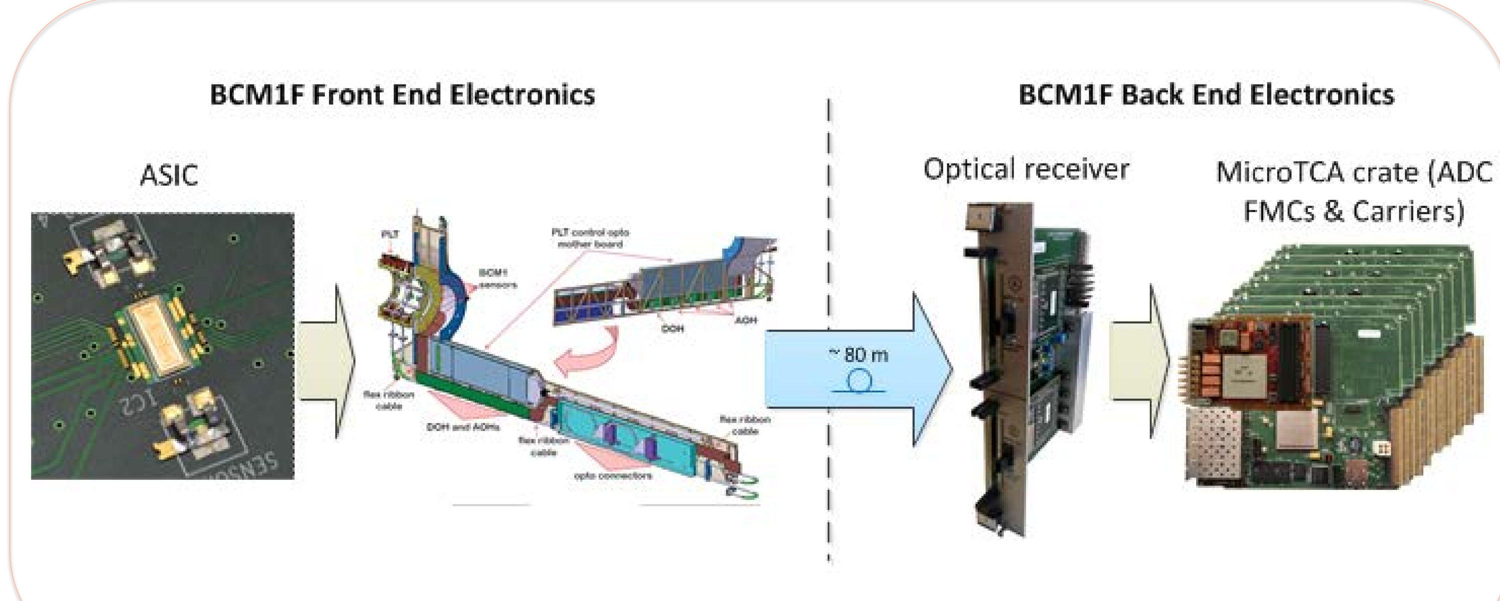
Overview of the CMS BCM1F System (1)



Diamond sensors:

- **Type**: single crystal CVD diamonds;
- **Number**: 12 two-pad per end (48 channels);
- **Position**: z = ±1.8 m from the interaction point (IP), r = 7.2 cm
- **Two pad metallization**: 5 mm x 5 mm with 25 µm split

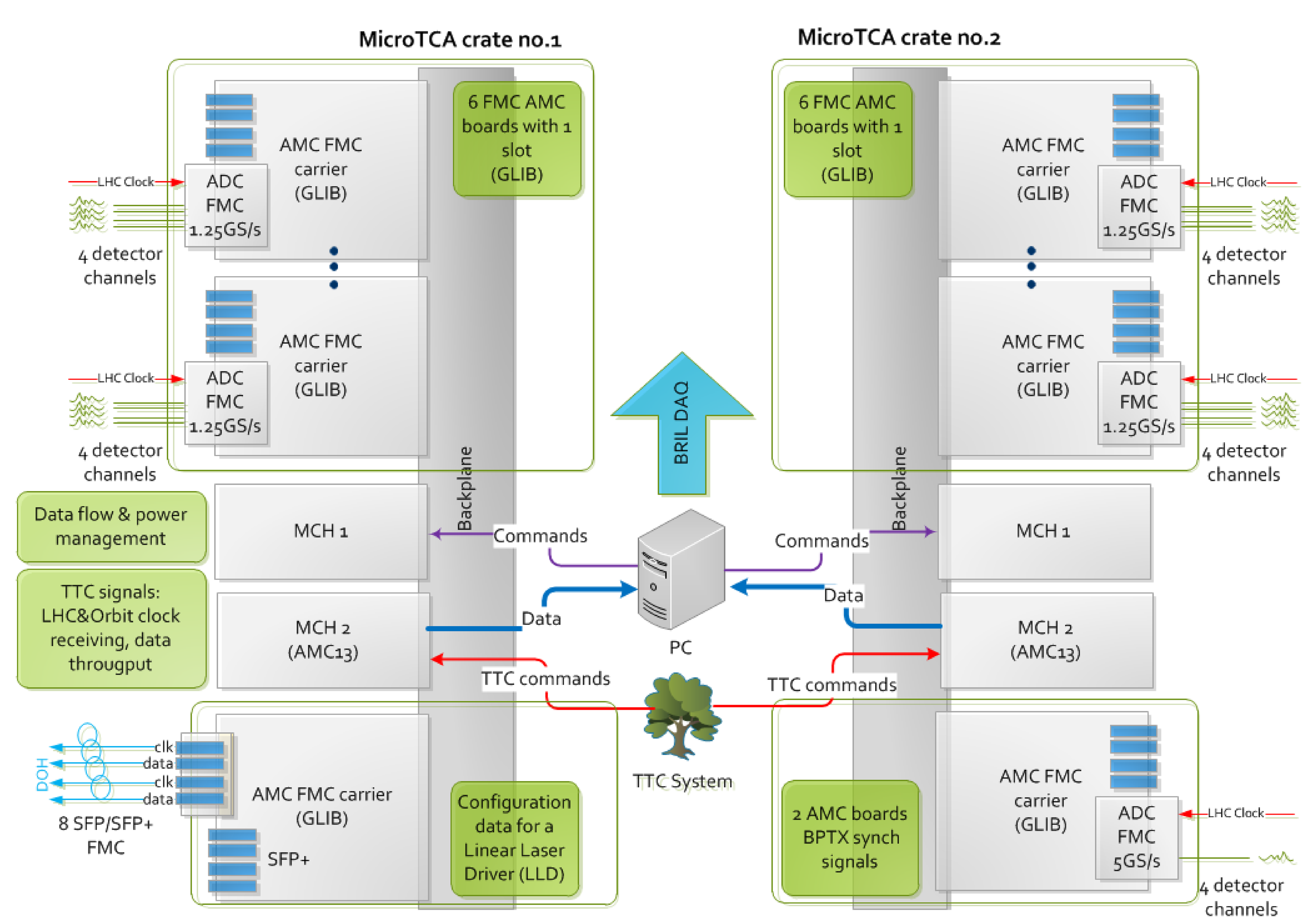
3 sources of the hits: Using the arrival time of the signal they are assigned to originate from **collisions, M**achine **I**nduced **B**ackground (**MIB** / **beam halo**) and activation (**albedo**). The corresponding count rates are used to measure in real time luminosity, background and activation products rates(2).



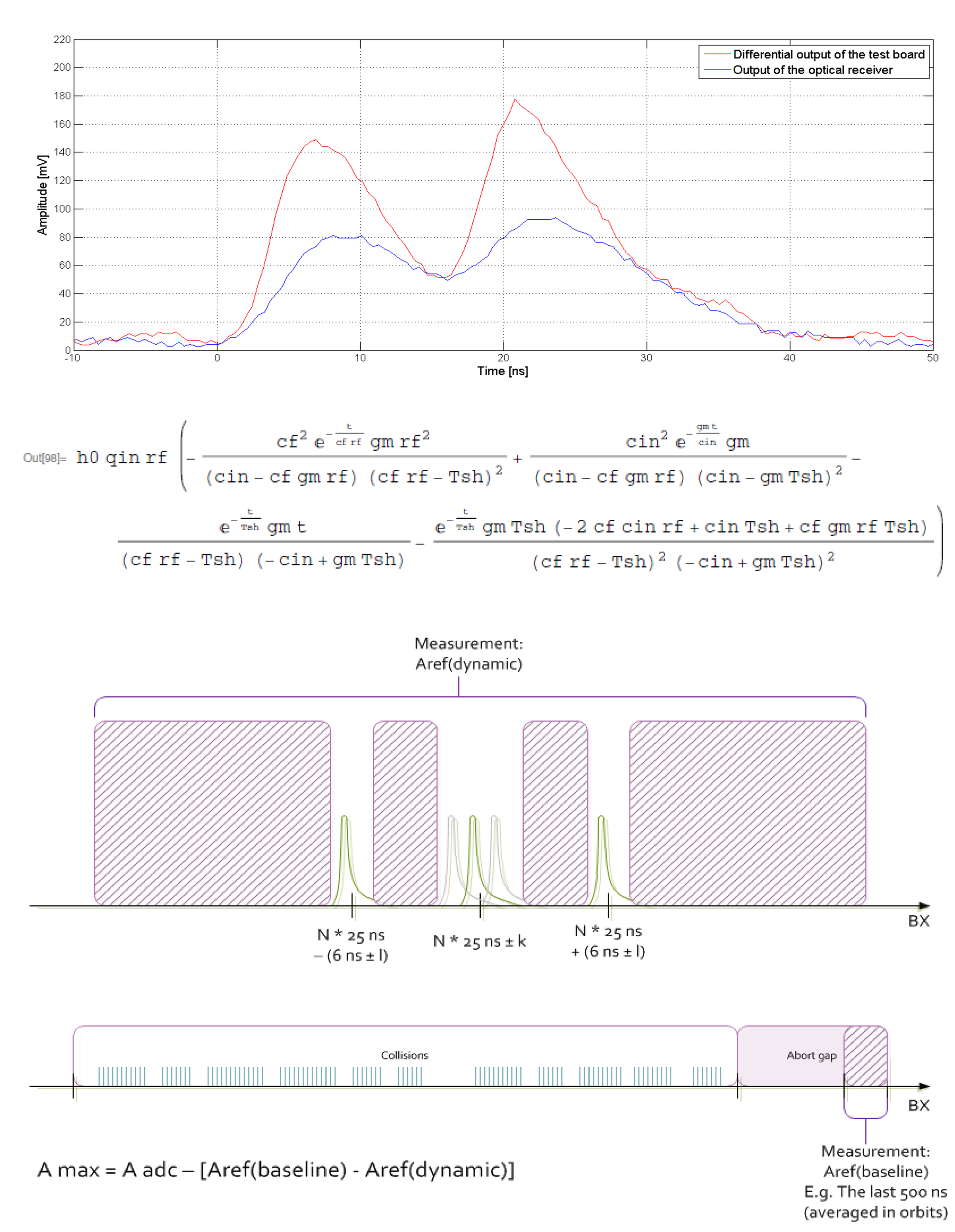
Signal transmission path (3)

- Fast trans-impedance preamplifier with an active feedback, a shaper stage and fully differential output buffer(4): sensor capacitance of 2 pF; peaking time of 7 ns; FWHM of 9 ns; minimal 2 hit resolution 12.5 ns
- Carbon-fiber carriage for holding a complex flex-rigid PCB (C-shape Boards) with front-end electronics
- Four 3-channel Analog Opto-Hybrids for analog to optical conversion on each PCB
- From the experimental cavern to the counting room via approximately 80 m of optical single mode fibers
- Two 12-channel Optical Receivers on a Mother board per end
- Twelve 4-channel FMC mezzanines with 1.25Gs/s, 8-bit ADC converters (FMC125, 4DSP)
- Twelve AMC carriers with single HPC FMC connector (optionally double LPC FMC; 24 mezzanines)

Backend Electronics architecture



Amplitude & time measurement



Enhanced peak finding

(online measurement):

- Time & amplitude measurement
- Characterisation of the single, overlapping and saturated pulses
- Recognition of the pulses of the minimal 6 ns time interval
- Possible indication of the missing peak in case of the overlap of the pulses of different amplitudes
- Noise sensitive *(filtering)*

Peak occurence:
Peaking time of the pulses the same for different amplitudes

Amplitude correction:
Baseline measurement during the abort gap of LHC and a dynamic reference level correction (measurement of the level between pulses)

Deconvolution(4) *(offline)*:

- Used on the representative size of RAW data collected during each LumiNibble

Data rates

Input data

- Hit rate of about 300 MHz for a beam pile-up 50 in 48 detector channels
- 4 channel 8 bit ADC FMC working with a 1.25 Gs/s sampling rate
- Pairs of samples received at 625 MHz with DDR by a single FPGA

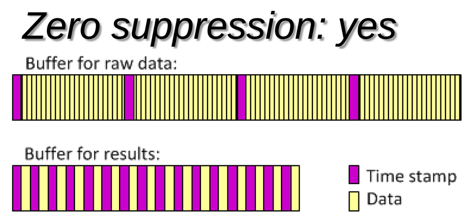
*Data production in Lumi Nibble**

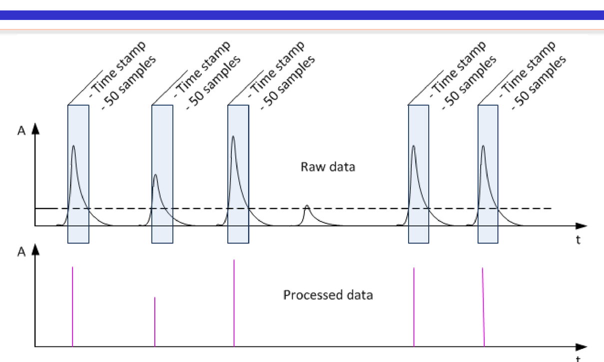
Data format	4 channels	24 channels
Raw data	1.560 Mb (4 Mb/s)	9.3 Mb (24 Mb/s)
Time domain histogram	1.382 Mb	8.294 Mb
Amplitude histogram	22.528 kb	135.168 kb
Histograms in total (single buffer to send, double to store)	**2.8 Mb (3.8Mb/s)**	**16.8 Mb (22.826Mb/s)**
In total	**4.3 Mb (7.8 Mb/s)**	**25.97 Mb (46.826 Mb/s)**

*LN – Lumi Nibble, 2^{12} Orbits, 368.23 ms

Raw data

Minimum: 1 orbit /Lumi Nibble
Zero suppression: yes





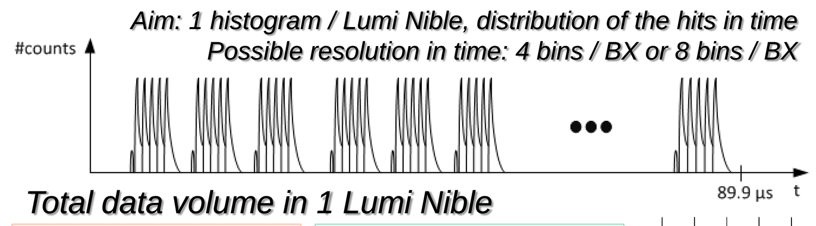
Position in orbit: 17 bits; ***Resolution:*** 8 bits;

Total data rate / orbit
8 bits resolution
25 bits every 50 samples
1 channel: 390 kb, 1 Mb/s
4 channels: 1560 kb, 4 Mb/s
24 channels: 9.3 Mb, 24 Mb/s
48 channels: 18.6 Mb, 48 Mb/s

The orbit number can be kept in the IPbus control register

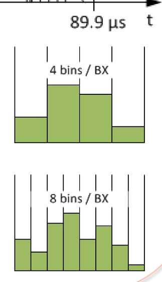
Time domain histogram

Aim: 1 histogram / Lumi Nible, distribution of the hits in time
Possible resolution in time: 4 bins / BX or 8 bins / BX



Total data volume in 1 Lumi Nible

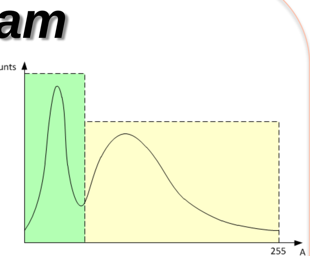
4 bins	8 bins
1 ch.: 1.7 kb *(4 bins)*	1 ch.: 3.5 kb *(8 bins)*
4 ch.: 6.9 kb	4 ch.: 1.4 Mb
24 ch: 4.1 Mb	24 ch. : 8.3 Mb
48 ch.: 8.39 Mb	48 ch.: 16.6 Mb



- *Bins will be sent sequentially – no time stamping for the position in the histogram required*

Amplitude histogram

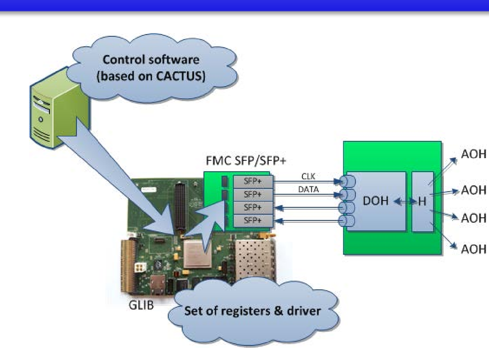
Aim: 1 histogram / Lumi Nible, amplitude distribution of the hits
Amplitude resolution: 8 bits (eventally 10 bi
Maximum bits for counts (forseen): 22 bits
[Integrated 2.5 Mhits / nibble]



Total data volume in 1 Lumi Nibble
1 ch.: 5.6 kb
4 ch.: 22.5 kb
24 ch.: 135.2 kb
48 ch.: 270.3 kb

- *The number of counts for a noise is unknown and difficult to estimate*
- *the histogram can be divided into 2 parts, one for the normal hits count and the second, higher for the noise, that can be continously monitored*
- *Bins will be sent sequentially*

Read-out monitoring



- A custom FMC mezzanine housing 8 optical COTS (Commercial Of The Shelves) SFP transceivers
- Slow control software/firmware driver based on CMS CACTUS repository with a terminal based user interface
- Setting of the Linear Laser Driver (LLD) bias current and gain
- One module for configuration of 16 AOHs and 4 DOHs

(1) Jessica L. Leonard et al.; “Upgraded Fast Beam Conditions Monitor for CMS online luminosity measurement, TIPP Proceedings of Science, CMS CR-2014/108; 2014;
(2) Maria Hempel & Brian Pollack; „Performance Analysis and Future Application of the Upgraded Fast Beam Condition Monitor at CMS”; IBIC 2014
(3) Agnieszka A. Zagozdzinska et al.; „The Fast Beam Condition Monitor BCM1F Backend Electronics upgraded, MicroTCA based architecture”; Proceedings of SPIE , vol. 9290; Wilga2014
(4) Dominik Przyborowski; „Design of a Front–end ASIC for Single Crystal Diamond Sensors”; ACES 2014
(5) Szymon Kulis, Marek Idzik; „Triggerless Readout with Time and Amplitude Reconstruction of Event Based on Deconvolution Algorithm”; Acta Physica Polonica B, Proceedings Suppl., Vol. 4, No. 1 p.49-58, 2011