The CMS Beam Conditions and Radiation Monitoring System
(Principles, Hardware & Software)

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for the FCAL group

Technisches Seminar DESY Zeuthen
Introduction
CMS Detector

Proton bunch → Collisions

Collision → Detector signals → Filter → Interesting Event

Detector = sensitive and expensive device
Background & Perils

- Proton bunch
- Beam Halo
- Collision Remnants
- Beam control
- Detector has to be protected! → Monitor Beam Conditions

- mis-steering
- focusing
Analogy

Detector = Retina
  = level 1 trigger
  = radiation monitor

Brain = CE & SE

Analogy

Optic nerve
  = signal data line

Thalamus
  = level 2 trigger

Visual cortex
  = high level trigger

Protection by Monitoring and Emergency Shutdown

Eylid & Pupil
  = detector protection

Lens
  = final quadrupole
### BRM

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1 Orbit ~ 90 µs, Bunch Spacing ~ 25 ns
BCM1F (& BCM1L)

Optical Fiber

Voltage supply

Assembled by W. Lange

Beam pipe
BCM1F details + Readout Electronics

Incident particle (energy $E$)

- E-field
  - $Q_{\text{induced}}(E)$: eh-pairs by ionization
  - $Q_{\text{collected}} \rightarrow I_{\text{signal}}$
- Signal amplification & shaping
- Laser Diode

Signal Area $\propto Q_{\text{collected}}$

Signal $I_{\text{signal}}$ & shaping

$100 \text{ ns}$ (Bunch Spacing $25 \text{ ns}$)

optical receiver

optical

hv
Monitoring Issues

1. Monitoring Mode:

- **low signal rate**
  - “long time”
  - nothing
  → put threshold (discriminator) → **Count Rate Monitor**

- **(very) high signal rate**
  → **Level Monitor** (~ Leakage Current Monitor)
  (Threshold for Warning or Emergency Shutdown)
2. Detector Performance:

\[ Q_{\text{induced}}(E) \geq Q_{\text{collected}}(\text{dose}) \]

\[ CCE = \frac{Q_{\text{collected}}}{Q_{\text{induced}}} \]

→ Calibration/Adjustment

2. Environment:

Thresholds depend on baseline
→ Baseline Monitor

Baseline Shift due to temperature, electronic noise, etc
Digitization Electronics

- Optical receiver

- Discriminator
  - set thresholds
  - output logical on/off

- TDC
  - output start trigger & hit time

- ADC (Sampling)
  - 500 MB/s sampling
  - 8 channels
  - Ext./Int. Trigger
  - Interval adjust.
  - 16 MB (45 orbits)

- Control & Readout
- PC
Modes of Operation: Learning Mode

- ADC only
- Store on Orbit Clock (= ext. Trigger) 45 orbits (buffer full)
- Readout & Store/Treat Data online (½ sec dead time)
- Analyze Data offline / online (slow, Software)
- Useful ONLY at high Luminosity
  (11. Sept. low Luminosity → GBytes of baseline)
- Optimized – but not flexible
- Check for Bunch Filling and Bunch Timing

No Monitor !!
Modes of Operation: Maintenance Mode

- ADC only

- Use Self-Trigger / Ext. Trigger (flexible)

- Adjust Trigger and Acquisition Interval (e.g. few 100 ns)

- Readout & Store/Treat Data online (dead time much smaller)

- Analyze Data offline/SW (No precise Time Assignment)

- 11. Sept. OP Mode
  Useful for any signal rate
  - For Sensor Performance / Baseline / Calibration

- Flexible – but not optimized

No Monitor !!  Ext. Trigger → BPTX
Data From 1\textsuperscript{st} LHC Testrun

Offline Analysis:
Beam from one side, BPTX Trigger

One channel had bad cable

12 ns ≡ 3.6 m
Modes of Operation: Warning Mode

- ADC only
- Use Self-Trigger
- Store few orbits
- Readout & Store Data offline
- Analyze Data offline/SW (post-mortem analysis)
- Permanent Monitoring, but \textbf{NO online output for control}!!
- For Level Monitor, internal Trigger $\rightarrow$ ext. Trigger out (to Control)
- fast, only hardware
- needs Baseline Monitoring for Trigger Thresholds
Modes of Operation: Count Rate Monitor

- ADC = Baseline Monitor & TDC Count Rate Monitor
- Discriminator Threshold adjusted w.r.t. Baseline
- TDC start trigger = Orbit clock (Time Reference)
- Readout & Store Data online (no dead time at low rates)
- Analyze Data online: Counting hits per Orbit, Timing Info
- Permanent Monitoring
- Permanent Online Info for Control
- fast (no Software-based Under-Threshold discrimination)
- Works only, if no pile-up!
What is still to do ...

• DAQ Software for Monitoring Mode (TDC) → Elena Castro

• Data Analysis Software / User Interface Performance → Ringo Schmidt

• Publishing Routines (DIP) → both

• Test of the Software (This cannot be done often enough!) → volunteers
FCAL Group (on Testbeam Darmstadt)
Thanks to all DESY People!

Special Thanks to UCO ;)

Goodbye!

Also thanks to GIMP!