The CMS Beam and Radiation Monitoring

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Functions

- monitoring of the beam induced radiation (UXC55 and adjacent straight sections)
- monitoring of the machine status, define conditions to safely operate sub-detectors
- real time fast diagnostics of beam conditions, initiate protection procedures in case of dangerous conditions for the CMS detector

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LHC und CMS

Proton-Proton Wechselwirkungen, 7 TeV x 7 TeV
Physik auf der "Tera Skala",
Hoffnung auf Entdeckung des Higgs Bosons
(Ursache der Ruhemasse), neue Teilchen, neue Symmetrien

Energie: 10 x Tevatron
Luminosität: 100 x Tevatron
Neue Anforderungen an die Kontrolle der Strahlen und des Strahlhintergrundes

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The BRM group is run as a sub-project within CMS technical coordination.


About 40 people, 8-10 at CERN.
**CMS-BRM**

**Be aware**

- Before LHC starts filling the BRM must be operational to ensure safely running of the detector.
- During data taking BRM is needed to ensure high ‘usable’ luminosity.

**En Detail**

- Must be active whenever there might be beam in LHC
- Ability to initiate beam aborts
- Warning and abort signals to CMS subdetectors, i.e. ramp down HV, LV
- Integration of online beam information into CMS, LHC control and data taking
- Post-mortem analysis, e.g. after beam loss
- Benchmarking of integrated dose and activation level calculations

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**The components**

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- Systems are independent of the CMS DAQ and LHC UPS power
Passive Monitors: TLD (Thermo Luminescent Dosimeter) and Alanine (PAD)

TLD uses LiF, photon sensitivity over a wide energy range. Accumulated energy is stored as transition to metastable states. Heat releases the energy via light emission. $^6\text{Li}$ captures neutrons with large cross section, the recoil products contribute to the excitation.

Alanine is an amino acid, ionising radiation creates free radicals. Dose measurement using EPR (electron paramagnetic resonance) analysis.
RADMON
- 18 Monitors deployed around CMS, close to equipment and shielding, to measure:

• Dose and doserate using RadFETs trapped charge in gate oxide

• Hadrons (E > 20MeV) flux, SEU rate via SRAM radiation induced voltage spikes in a reversed bias p-n junction

• 1 MeV equiv. neutron fluence using pin diodes, fluence of a with E>100 keV Conductivity variation

- Data reported to the RADMON database
- Used as online benchmark points for the verification of simulations

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CVD Diamond Sensors
CVD polycrystalline diamonds are produced as disks with radii up to 10 cm
Single crystal up to a few mm²

Sensors are made as cm² pieces, 150-900 μm thick, metallized at both sides (Ti-Pt-Au) and then operated as a "solid state ionisation chamber"

Interesting features:
- high thermal conductivity
- high electron/hole mobility
- low ε (5.7)
- radiation hard

Problems:
- small released charges, for pCVD limited charge collection efficiency
- small size, expensive

Typical spectrum of a Mip
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**CVD Diamond Sensors, our experience with ZEUS**

Operation of a single crystal diamond near the HERA beampipe and comparison of the count rate with ZEUS beam monitor (Sasha Ignatnko)

Sensor with preamplifier

Count rate vs. time from the diamond sensor

ZEUS beam monitor

Stable operation over half a year (monitored with a mip signal)

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**BCM2, Diamonds**

Fully assembled sensor, 1x1cm², 500μm thick

Mounted on Castor installation table

z=14.4 m, R=5 and 29 cm

4 inner sensors sensitive to IP products
8 outer sensors sensitive to incoming background (shielded against the IP)

Readout: 25 kHz, 40μs, standard LHC beam loss monitor electronics,
Active from day 0, included in abort decision

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BCM2, Diamonds

Comparison of diamond response with a LHC beam loss monitor (BLM)

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BCM1L, Diamonds

Same sensor type, current measurement,
\( z = 1.8 \text{m}, R = 4.5 \text{ cm} \)

Readout: 200 kHz (5\(\mu\)s) no FE electronics

Synchronised sampling over the LHC bunch train structure and abort gap
Enable beam permit

CVD diamond sensors are metallized at Rutgers
Characteristica are measured at DESY
Assembled in Karlsruhe

CERN
Four single crystal CVD diamond sensors, size 0.25 cm² @ z=±1.8 m, r=4.3 cm

BCM1F, Diamonds

Test mounting of the boards

Instrumentation of the forward region
BCM1F, Diamonds

Test bench at CERN,

A complete copy of the spectroscopic readout chain in the Zeuthen lab.

First full chain test using a $^{90}$Sr source in the lab at CERN.
**Beam Orbit Diagnostics**

- **Start DAQ**
- **Stop DAQ**
- **Digitizing with 500 MS/s**
- **AOC Buffer full after about 4 ms (~45 Orbits)**
- **Readout digitized data “offline”**
- **Histogramming over 45 Orbits averaged beam current distribution**

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**Detector Warning and Shut down Mode**

- **Schwelle – selbstauslösend (Koinzidenz)**
- **Detector Warning**
- **Detector HV off**

**ADC v1721: via LVDS**

**Reset Trigger Time Tag (every 8 sec)**

**ADC v1721: Set external Trigger Out**

**Beam Control**

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BCM1F, Diamonds

The next topics to complete the commissioning including montage:

- Complete and test FE the 8 readout chains
- Replacing the C.I. ADC by Flash ADCs (500 MHz)
- Configure the controler and PC software to extract the important information to display in the counting room, to set limits for subdetector background level and ensure post-mortem beam diagnostics
- Complete hard and software test in the lab.
- Montage in April
- Debugging

For software development/debugging an identical system will be set up at DESY

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Here the mechanical frame will sit

**BCM1F, Diamonds**

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Beam scintillation counter (BSC)

BSC1 --- 11 000 cm²
Inner radius - 15 cm

BSC are forseen as a commissioning tool, first 1-2 years
Replacement (e.g. diamond sensors) depending on experience in the first operational phase
No FE electronics, mip sensitive, same back end as BCM1F
Single hit time resolution 1-2 ns

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**Beam pick up (BPTX)**

- Analog signal, 200 ps sampling
- Measures the phase between bunch and 40 MHz (bunch) clock,
- IP position
- Checks filling scheme, bunches in the correct RF buckets
- Check that abort gap is empty
- Check for satellite bunches
- Measure charge of each bunch

**BRM DATA Display**

Developed with AB/CO, combined Display with Lumi Group

Display will be part of the DESY remote Control Centre at DESY, plus a display for details of the BCM1F data
**Dose and rate estimate from Monte Carlo**

**Expected diamond currents at Nominal Luminosity**

**BCM1, 1 cm²**
- estimated rate: $1-3.2 \times 10^8$ cm$^{-2}$s$^{-1}$
- expected signal current: 200 nA
  - about 200 times higher than noise

**BCM2, 1 cm²**
- estimated rate: $10^8$ cm$^{-2}$s$^{-1}$ inner
- $10^6$ cm$^{-2}$s$^{-1}$ outer
- expected signal current:
  - 100 nA inner
  - 1 nA outer

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**CMS-BCM**

There are Milestones:

- Completion of the Tests at DESY: beginning of March
- Completion of BCM1L Commissioning: mid April
- Installation: Mid April
- Debugging before first beam

**In case the system will work- nobody will complain:**
Otherwise, we are in big trouble ……..

We use “Synergy” between FCAL (ILC detector R&D) and CMS
- Application of diamond sensors in a harsh environment
- fast readout and luminosity optimisation