The CMS BRM System

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On behalf of the
CMS Beam Conditions and Radiation Monitoring Group

Institutes Involved:
Auckland, Canterbury, CERN, DESY, Karlsruhe, Princeton, Rutgers, Tennessee, UCLA

BRM Group Remit

Provide monitoring of the beam-induced radiation field within the UXC55 cavern and the adjacent straight sections.

Provide real-time fast diagnosis of beam conditions and initiate protection procedures in the advent of dangerous conditions for the CMS detector

- System features must include:
  - Active whenever there is beam in LHC
  - Ability to initiate beam aborts
  - Provision of warning & abort signals to CMS subdetectors
  - Postmortem reporting
  - Provision of online and offline beam diagnostic information to CMS and LHC
  - Bench-marking of integrated dose and activation level calculations
  - Integration of all online beam diagnostic information (including subdetectors).
    - Updating at ≥1 Hz

BRM Subsystems: The Prioritized List

PHASE 1: Installed for Startup

- RADMON
  - Extension of LHC wide radiation monitoring system
- BCM2: Diamond leakage current monitor at rear of HF
  - Readout as extension of the LHC Beam Loss Monitor (BLM) system
    - Commissioned against BLM ionization chambers in Long Straight Section
    - Output to CCC and CMSCR
  - Input into beam abort (after commissioning against LHC BLM)
- BCM1L: Diamond leakage current monitor in tracker vol. (close to beampipe)
  - No FE electronics
    - Commissioned in conjunction with BCM2
    - Output to CCC and CMSCR
  - Input into beam abort after commissioning (against BCM2)
- BSC: Beam Scintillator Counters
  - Large area scintillator tiles on the front of HF
  - Output to CMSCR
  - Initially only a monitoring system

PHASE 2

- BCM1F: Diamond + fast amplifier for bunch by bunch monitoring
  - Installed prior to First physics run (or earlier)
  - Output to CMSCR
  - Initially only a monitoring system

CCC=CERN Central Control RM
CMSCR=CMS Control Rm

PHASE 3

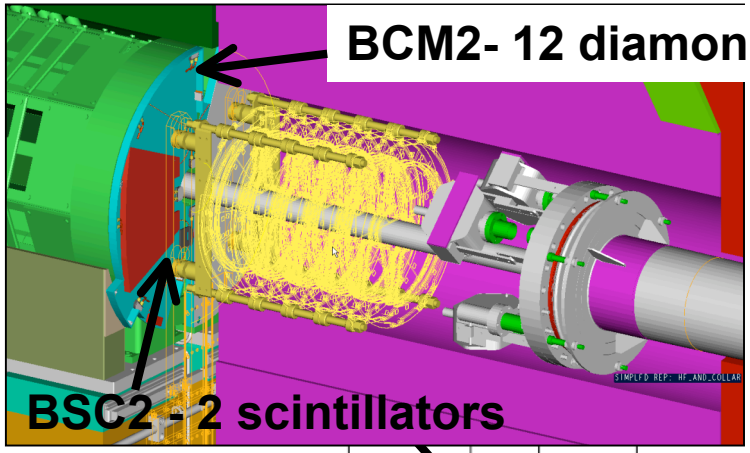
Upgrade systems under consideration for 2008/9

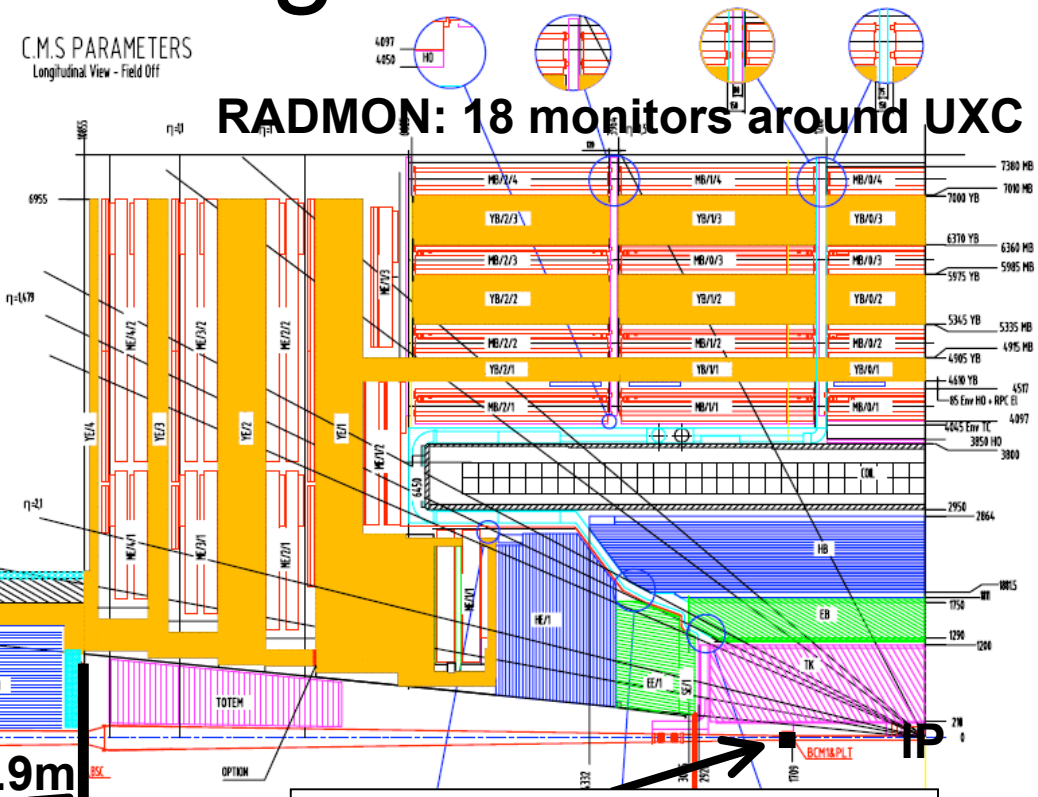
- Upgraded BSC (position, robustness, technical trigger)
- PLT: Pixel Luminosity Telescope (not yet endorsed).
  - Would also be a beam diagnostic device

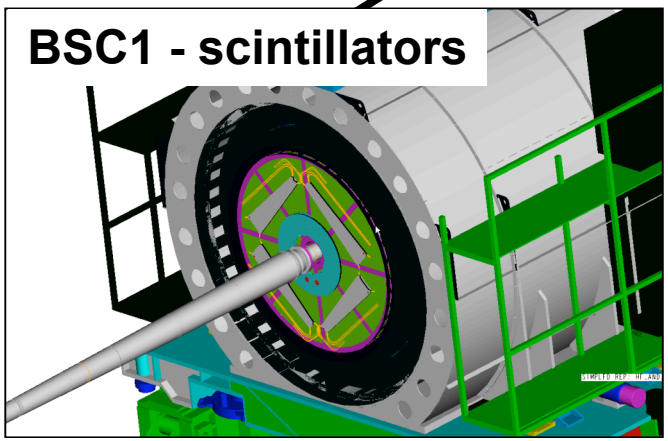
Increased complexity/deviation from standard LHC interfaces

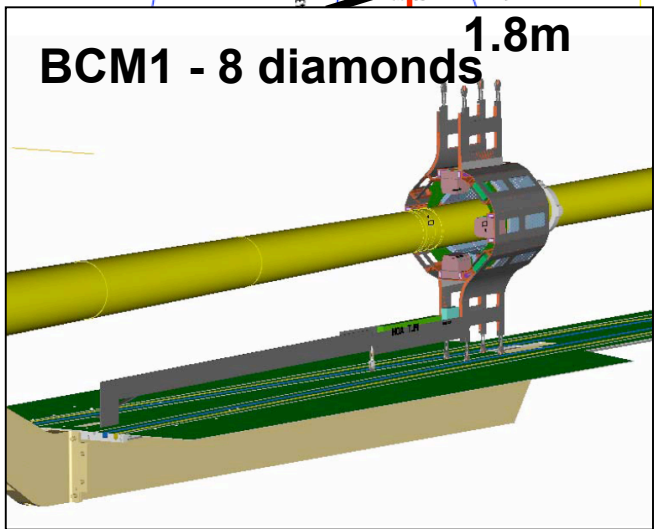
CMS Beam Monitoring

Symmetric +ve, -ve Z



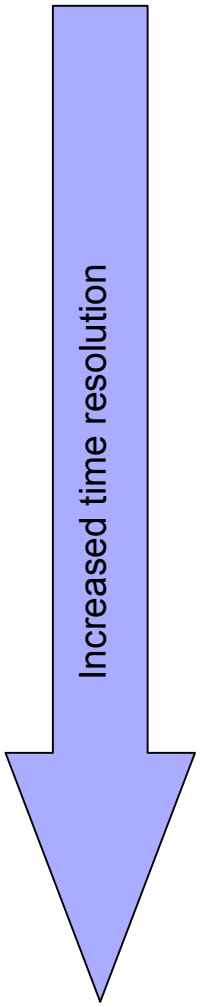






BRM Subsystem Summary

Subsystem	Location	Sampling time	Function	Readout + Interface
Passives	In CMS and UXC	Long term	Monitoring	---
RADMON	Around CMS	1s	Monitoring	CMS + Standard LHC
BCM2	At rear of HF	40 us	Protection	CMS + Standard LHC
BCM1L	Pixel Volume	Sub orbit ~ 5us	Protection	CMS + almost std LHC
BSC	Front of HF	Bunch by bunch	Monitoring	CMS Standalone
BCM1F	Pixel volume	Bunch by bunch	Monitoring + protection	CMS Standalone



All online systems read on when machine operational and possibility of beam in LHC
Systems are independent of CMS DAQ

BCM Functionality

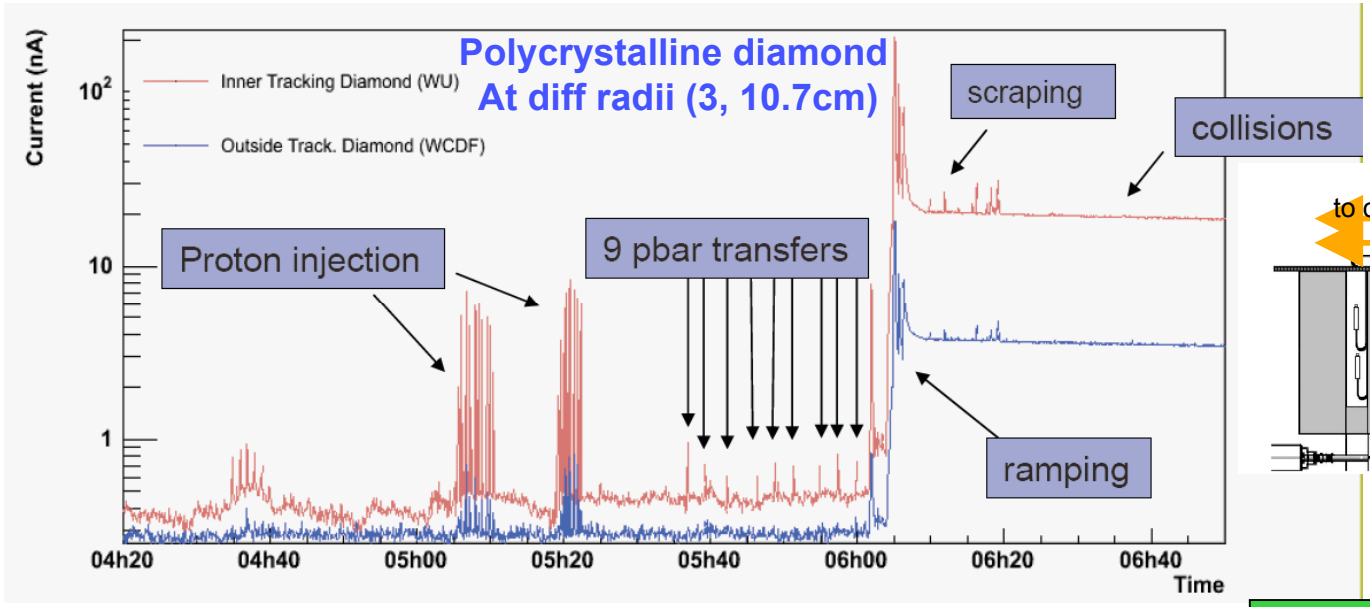
- Use synthetic diamond sensors as simple Flux/rate monitors
  - 2003-2006: Prototypes tested in CDF, CERN East Hall, KAZ (Karlsruhe), PSI

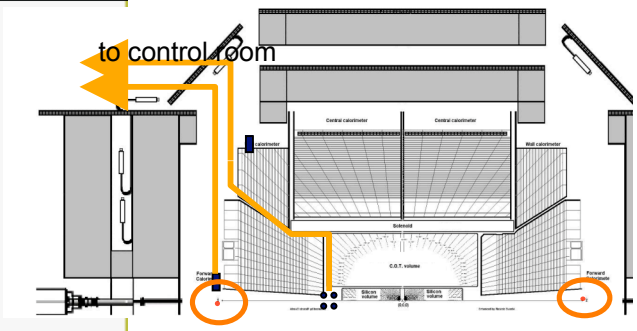
- Generate warnings/alarms/beam aborts based on sustained above-threshold readings or very rapid rate of increase towards threshold
  - Deadtime free monitoring
  - CMS configurable thresholds
  - Rolling history of conditions available online,
  - Initiate CMS beam abort if conditions above abort threshold

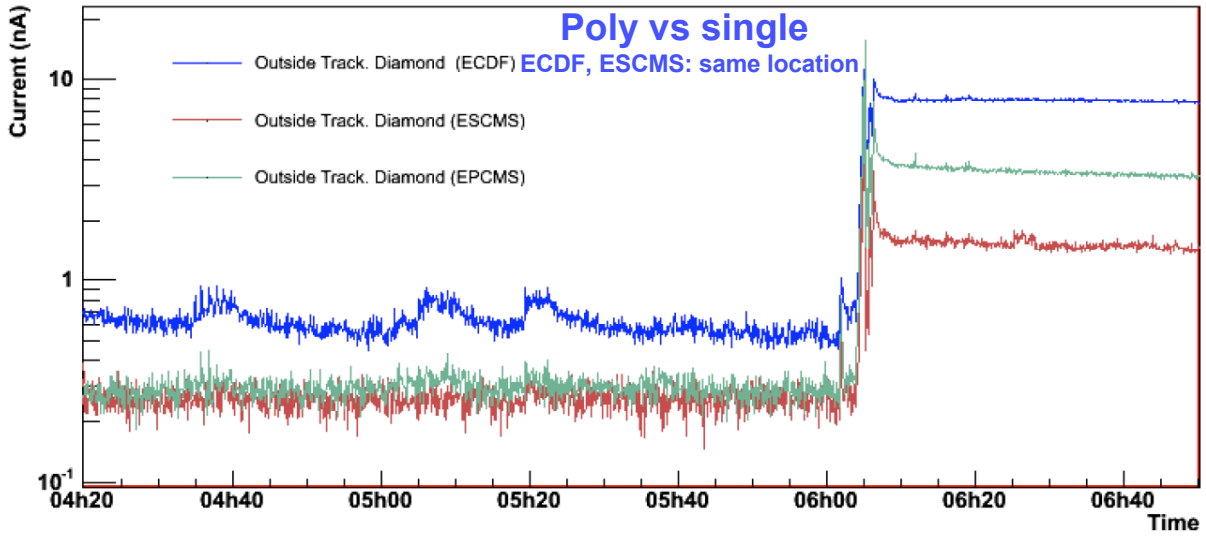
  - CMS:
    - Direct warning/alarm, monitoring, diagnostic and postmortem information
    - User selectable time scales over which above-threshold conditions assessed

  - LHC:
    - Provide full monitoring + beam dump post-mortem reporting to CCC
    - Close interaction with LHC operations and LHC machine protection group

Example: CMS BCM Sensors in CDF- Online Monitoring Plots







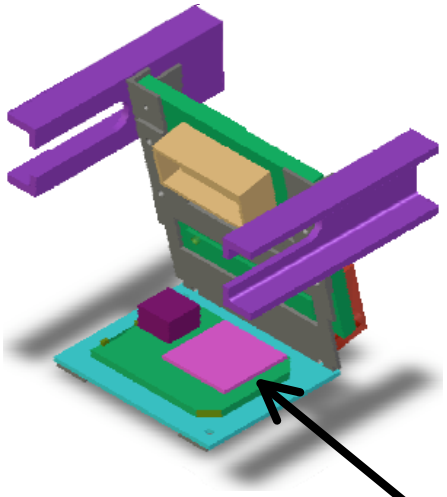
CMS BCM Sensors in CDF:
- Sensors + electronics in realistic hadron collider environ
- Cross calibrate with existing CDF beam monitoring (BLM and diamond based)
- **Uses 20us Sampling**

Beam Conditions Monitor in detail:

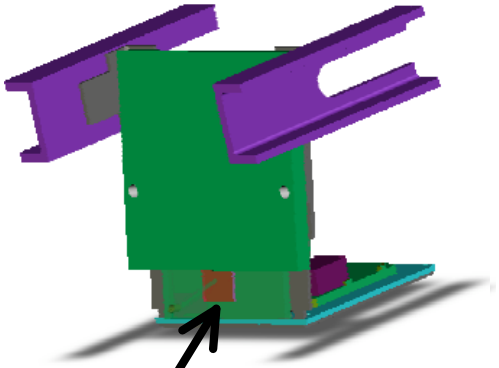
- Three locations
  - **BCM1:** Inside the CMS detector, z=1.8m from the IP, r=4.8cm
    - 8 Diamonds per end (4 poly- and 4 single- crystal diamonds)
  - **BCM2:** Outside the central detector (z= 14.365 m)
    - Two locations (12 diamonds per end)
      - Shielded from IP (r= 29cm)
      - As close as possible to Beampipe (r=5cm)

- All locations:
  - monitor diamond leakage current synthetic polycrystalline diamond sensor
    - Warning/alarm abort thresholds to be CMS configurable
- Readout:
  - BCM2:
    - Standard LHC BLM readout (Tunnel card to DAB board to database)
    - Exactly the same readout and reporting structure
  - BCM1_L:
    - LHC BLM readout from DAB card onwards.
    - Sub orbit monitoring (~10us) synchronized to orbit Clock
    - No tunnel card
    - Custom mezzanine card on DAB board. Uses BLM interface and reporting structure
- BCM1_L, BCM2 have marginal sensitivity for pilot run
- Post-mortem and monitoring data
  - Reporting mechanism unchanged from BLM system ie CMW/FESA

BCM1 Unit



Carbon fibre frame
Modular design
Compact



BCM1_ L

- Leakage current measurement
- Sensor: polycrystalline diamond
  - 10x10x0.4mm
  - 7000e-/MIP
- No front end electronics
- Bias voltage: 500V (nominal)
- Sensor orientation set by need for ExB to avoid anomalous leakage currents
- No direct cooling

BCM1_ F

- Bunch by bunch measurement
- Sensor: Single crystal diamond
  - 5x5x0.5mm
  - 18000e-/MIP
- Dedicated front end electronics
- JK16 amplifier -> optohybrid
- Bias voltage: ~100V (nominal)
- Limited space for front end electronics
- No direct cooling

BCM: Monitoring Timescales

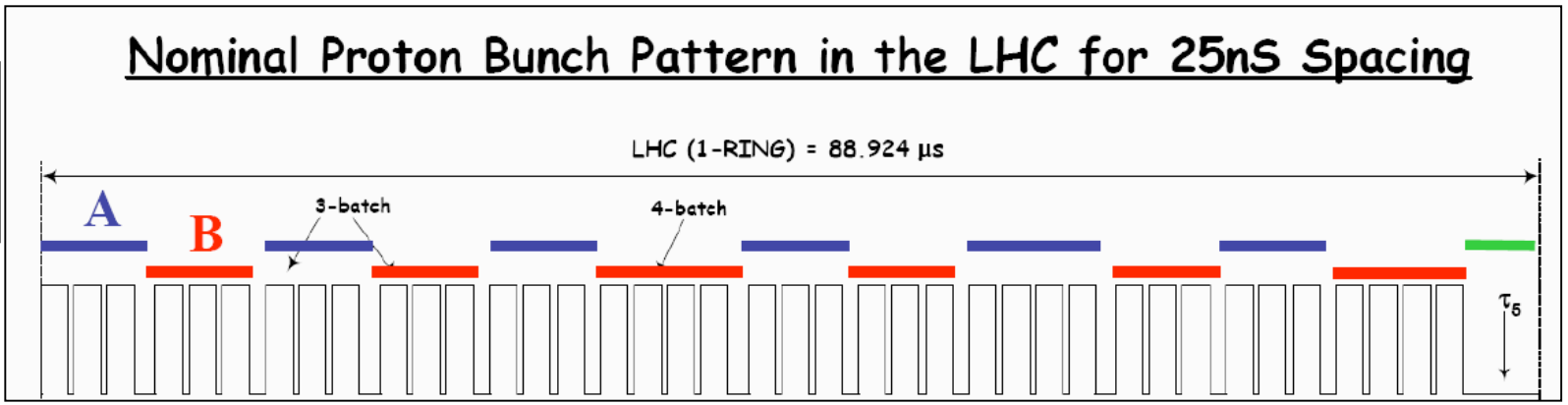
BCM2: monitors leakage current on half-orbit scale

- LHC-standard readout hardware from LHC Beam Loss Monitor (BLM) group
  - Replaced ionization chamber with polycrystalline diamond (10x10x0.4mm)
  - Sampling time: 40 us
    - Monitoring time scales: 12 staggered buffers to cover 40us to 100s history

BCM1L: monitors leakage current on sub-orbit scale

- Synchronizes with orbit marker
- User configurable sub-orbit sampling scheme: (2us minimum)
  - Statistical measurement of conditions at user specified positions in orbit
  - Sub-orbit monitoring averaged and passed to std BCM2 staggered buffer readout
  - Dedicated sampling of beam abort gap

BCM1L Sampling Scheme

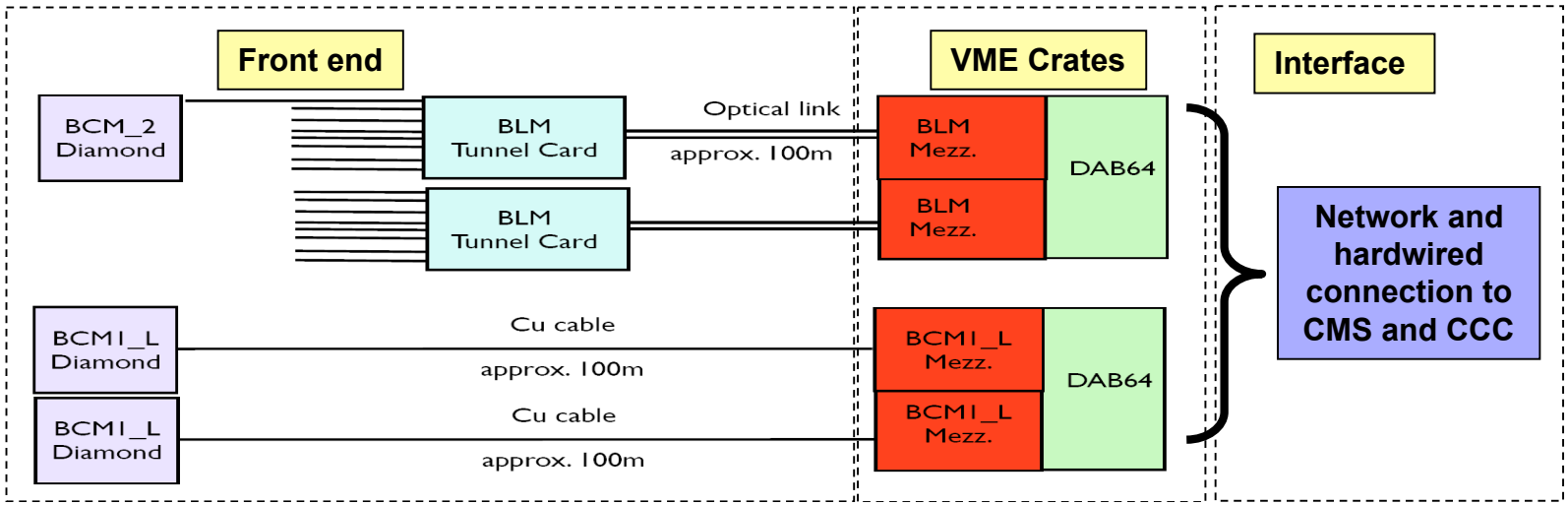


Beam Conditions Monitor - Status

- Diamonds ordered - majority already received
  - BCM2 diamonds metallised. Ready for packages
  - Rest of diamonds ready soon
- Packaging prototype design done -
  - Final packaging soon.
- Support structures design done - manufacture will start soon
- BCM1_F prototype FE electronics complete
- Cables for BCM2 already laid
- Cabling for BCM1 being prepared
- On track for being installed on time

Full BCM Readout Chains

- Baseline systems on track
  - BCM2 readout chain
    - Full chain validated [sensor to backend readout]: Karlsruhe Aug 06
  - BCM1L readout chain
    - Custom Mezzanine card tested: Based on Tevatron design
    - Prototype of chain from sensor to VME backplane expected April 07
- Procurement of final hardware ongoing - no showstoppers expected
- Will complete full slice test by end next Month
  => BCM1, BCM2 readout chain + interface to CMSCR and CCC



CMS Beam Scintillator Counters

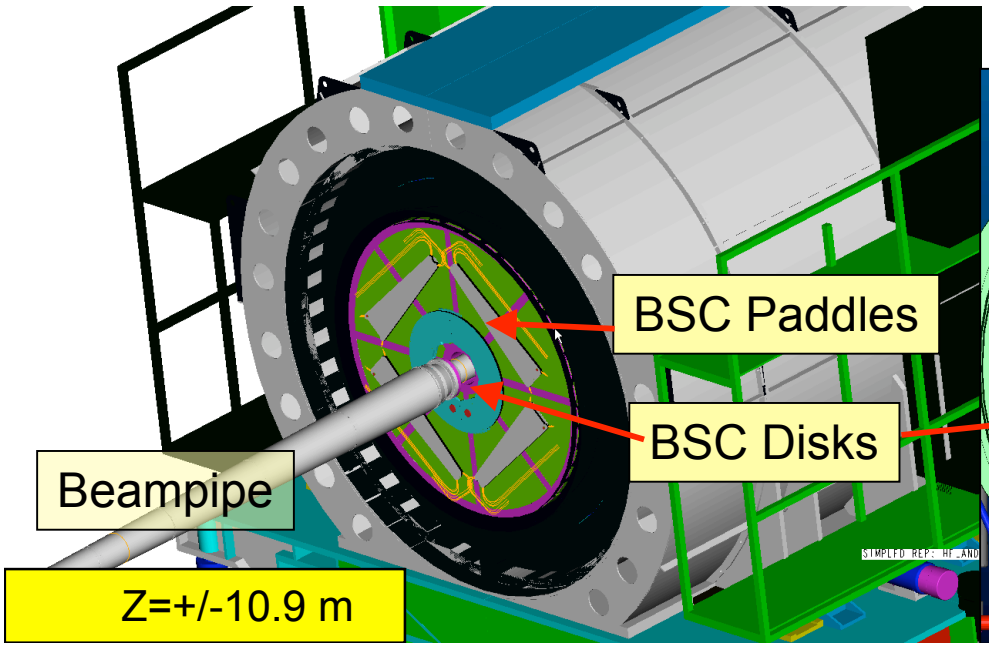
- ✓ Simple standalone system: No front end electronics
- ✓ Simple to commission
- ✓ Monitoring Independent of CMS DAQ status

Readout:

- PMTs mounted on side of HF, readout over long cables (80m) to USC.
- ADC & discriminator + TDC readout
  - Same back end as BCM1F

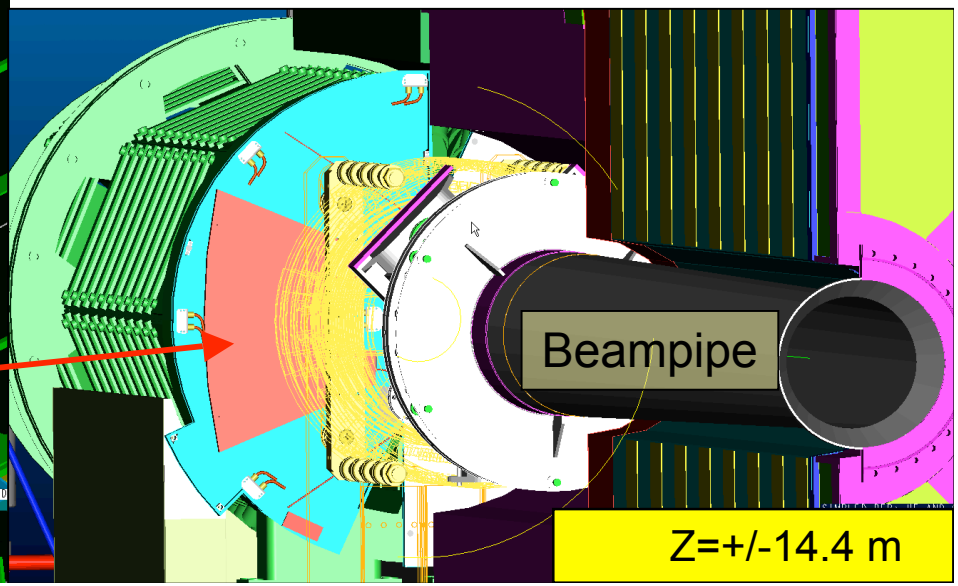
BSC1 --- 11 000 cm^2

Inner radius - 15 cm



BSC2 --- 1 000 cm^2

Inner radius - 5 cm

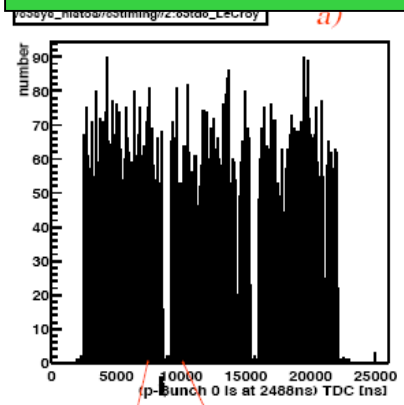


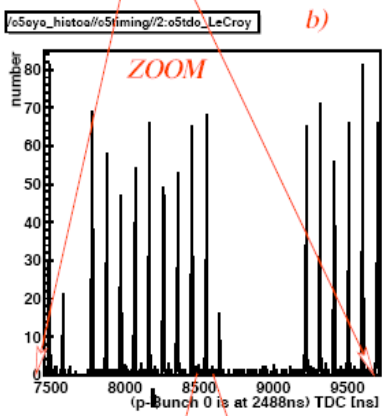
CMS Beam Scintillator Counters

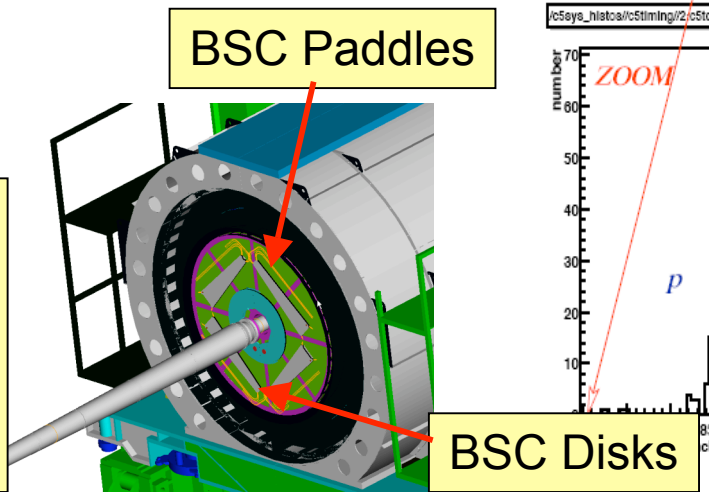
CMS: display similar to ZEUS example

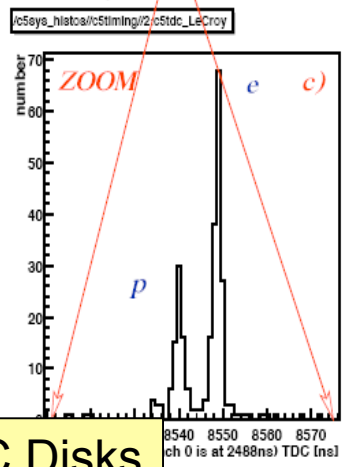
- ✓Output to CMS (+CCC?): statistical measurements
  - Rate monitoring on sub orbit scales + bunch by bunch, inc. Abort gap monitoring
  - Relative time measurements: incoming vs outgoing particles
  - Should be sensitive during 450 GeV run

- Status:
  - Recovered scintillator / PMTs tested
  - PMTs Tested for fringe magnetic field expected
  - Final design of mounting underway
  - Will be mounted in the summer
  - Cables installed
  - Readout design ongoing









Cross-sectional Areas

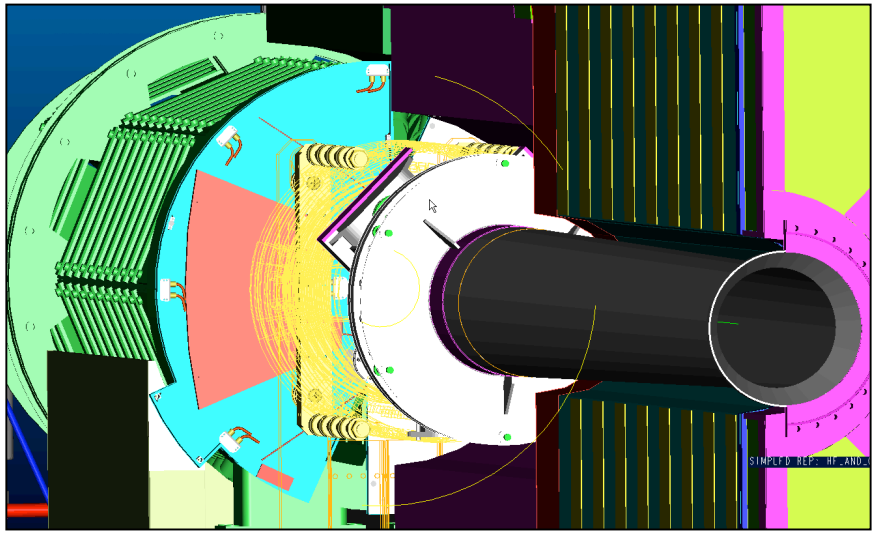
HF = 5.6m^2 TK = 3.8m^2

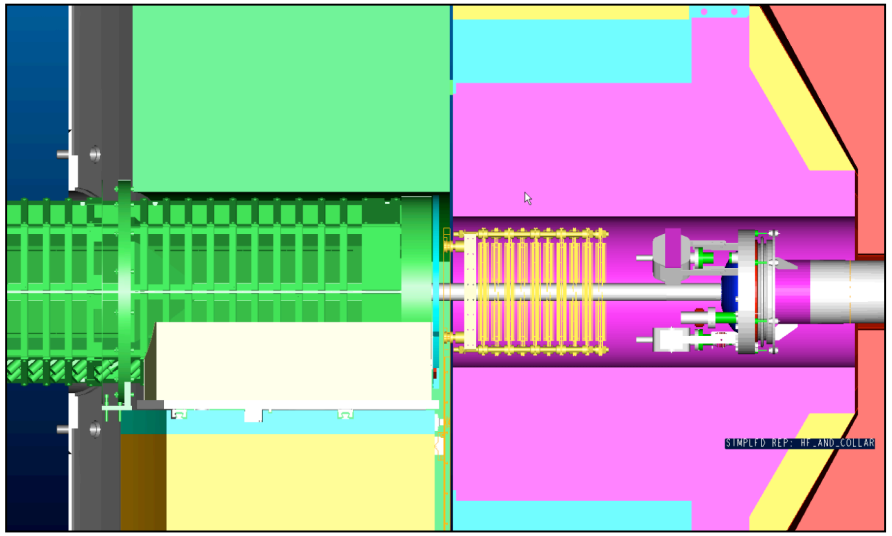
BSC paddles =0.6m^2 BSC =1.1m^2

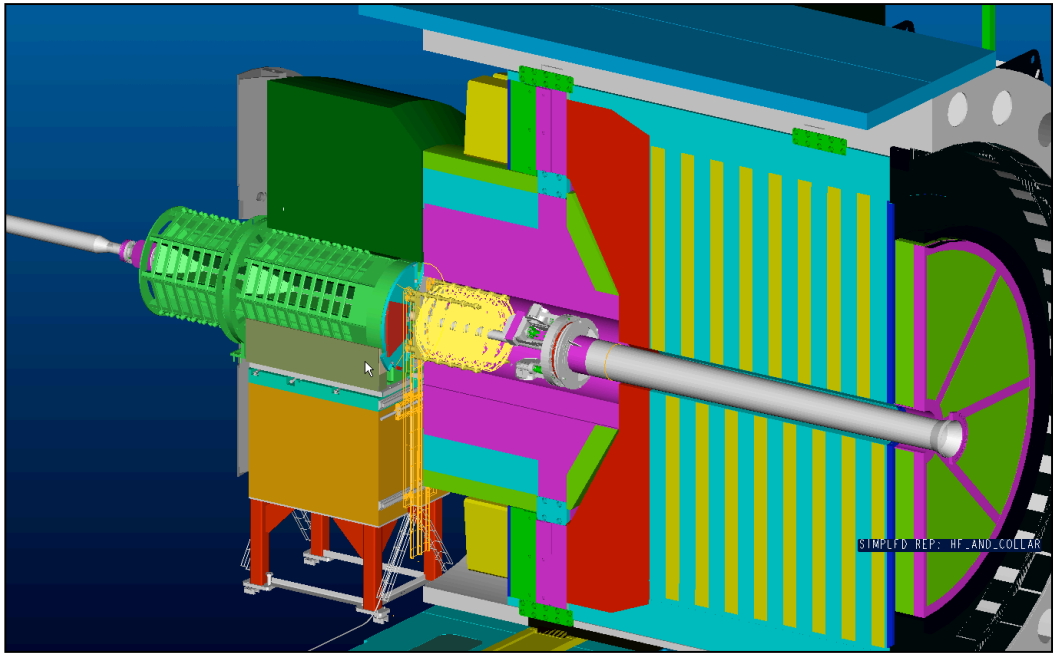
Ratios

BSC_Paddles/TK =17%; BSC/HF =20%

BCM2 + BSC2

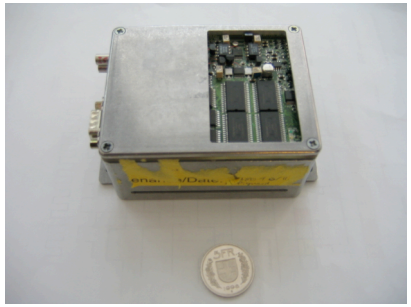






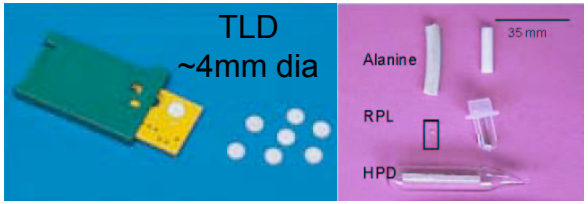
RADMON and Passive Monitors

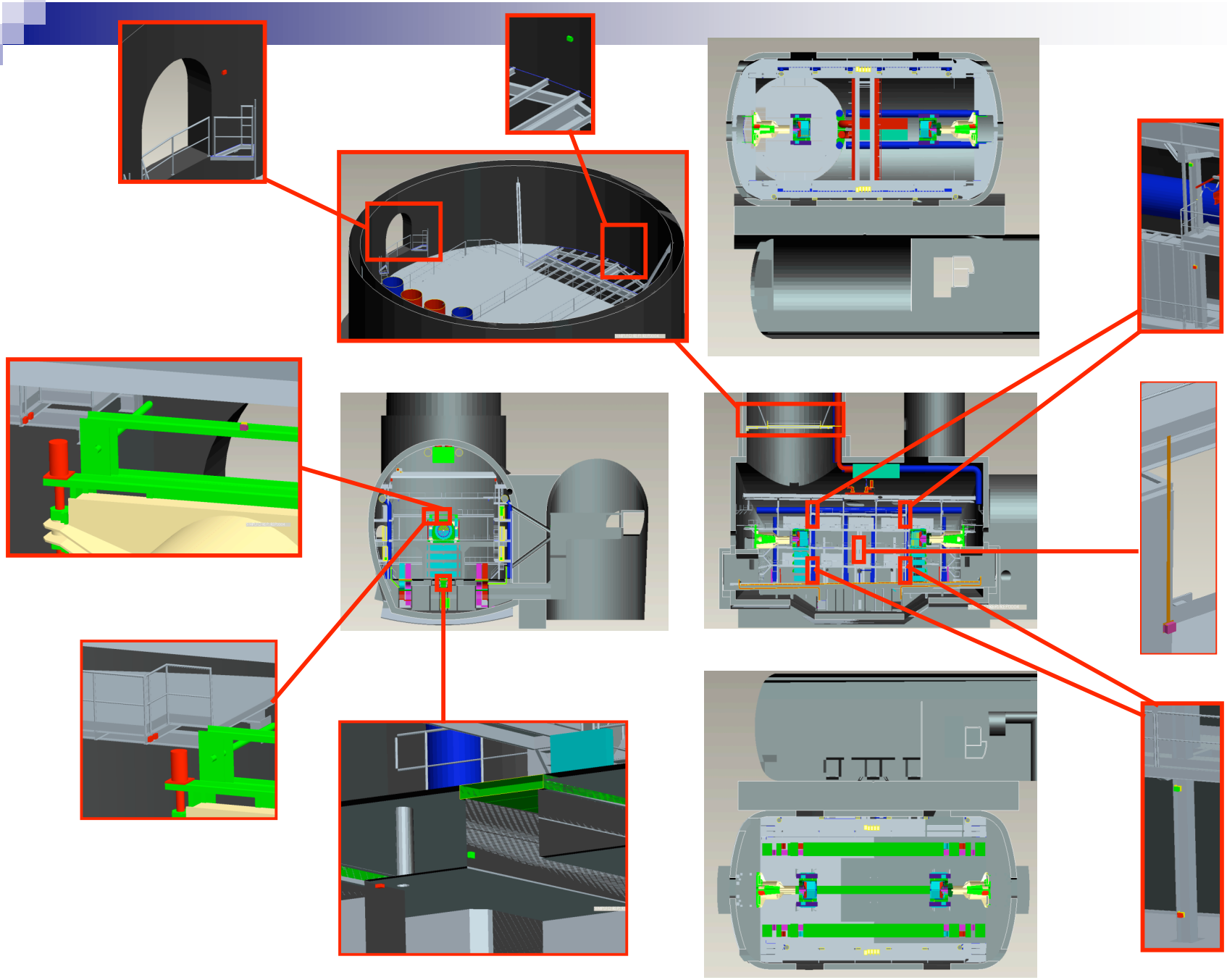
- **RADMON Units (In conjunction with TS-LEA)**
  - Measures
    - Dose, dose rate using RadFETs
    - Hadron (E>20 MeV) flux and fluence, SEU rate via SRAM
    - 1 MeV equiv neutron fluence via pin diodes (α >100keV fluence)



  - 18 Monitors deployed around CMS (UXC +USC)
    - Data reported back to the RADMON database
    - Installation of RADMON infrastructure started
  - **Used for Online benchmark points for verification of simulations**

- **Passive Dosimeters (In conjunction with TS-LEA, DESY)**
  - CERN standard dosimeters
    - Pin diodes, TLDs, RPLs, Alannine
  - Provide detailed radiation mapping after Pilot run





Summary

- Priorities for startup BRM subsystems defined.
- Mechanical Infrastructure well advanced
- Readout chains progressing/well advanced
  - Exception: BSC/BCM1F back end only starting (off-the-shelf solution is forseen)
- Services and Installation schedule
  - Mapped to CMS master schedule.
  - Fine detail of installation sequence still needs to be choreographed
- Interface work commencing
  - Done in close contact with the accelerator groups
    - Mechanism is defined through the LEADE protocols.
- Full BCM slice test expected March 07
  - RADMON system test already done by TS-LEA