CMS

Workshop on Experiment Conditions and Beam Induced Detector Backgrounds

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Jeff Spalding for CMS

Contributions from CMS MIG (Machine Interface Group), BRM (Beam Radiation Monitoring), TSG (Trigger Simulation Group), Luminosity Group, Muons, Simulation. Special thanks to Alan Bell, Pushpa Bhat, Maria Chamizo Llatas, Monika Grothe, Richard Hall-Wilton, Valeri Halyo, Mika Huhtinen, Steffen Mueller, Wesley Smith, Francisco Yumiceva + others

1. Approach to monitoring, and reacting to beam conditions
2. Background effects/concerns (see also Huhtinen talk)
3. Detectors for measuring backgrounds/Information for LHC
4. Remarks and Conclusion

1. Approach to monitoring, and beam conditions

Introduction

- Concerns
  1. Tracker safety: both electrical (fast accidents), and radiation
  2. Detector health and efficiency: short term (current trips) and long term (radiation or electrical aging)
  3. Trigger and physics backgrounds
- Goal for early running will be to commission sub-detectors and triggers, and to understand performance of the detector
- Primary concern for 2008 running will be to commission the safety systems and procedures, and to learn about machine backgrounds
- Background issues may become a major concern in 2009 when luminosity is low(ish), initial triggers will be "open" and more susceptible to backgrounds, and backgrounds will be high relative to luminosity
- In general, steady state backgrounds are not expected to be a problem, anomalous sources or spiky losses may well be

Approach at CMS

A. Beam accident (see Macina talk)
  - Major concern from day-one, will be our primary beam issue in 2008
  - Rely on
    - Beam flags, software interlocks and injection inhibit to reduce risk during injection and injection studies
    - Monitoring to limit exposure to high risk beam conditions
    - BCM → abort to protect when circulating beam
    - Collimators to limit exposure to kicker pre-fire (need TCDQ, TCT aligned early)

B. Detector health (current trips, single-event, radiation & elec aging)
  - Currents not expected to be an issue for nominal steady state
  - Rely on
    - PS current limits/trips to avoid damage
    - monitoring and LHC intervention to limit operational disruption and long-term concerns
  - "Single Events" not expected to be an issue under normal conditions, would require anomalous losses

Approach at CMS

C. Trigger, luminosity measurement and data quality
   - Limit the effects via monitoring, measurement and corrective action (beam and triggers)
     - Develop parameters and algorithms to report and tune on critical losses
     - Learn to separate backgrounds from luminosity in triggers & offline

Emphasis on beam monitoring

- LHC will be a component of CMS DSS interlocks and DCS state machine
- Will monitor LHC state, specific devices and conditions (similar to a CMS sub-detector)

Goals

1. Avoid having bias voltages ON when potentially unsafe beam conditions
2. When ON
   - Unsafe beam conditions → abort LHC
   - High backgrounds (trips, trigger problems, long-term aging) → CMS may go to STANDBY (or OFF) until situation resolved
3. Provide background rates for beam tuning & data corrections

2. Background effects/concerns (see also Huhtinen this workshop)

Potential Problems

1. Dose rates for the Tracker
   - Monitor with BCM and take corrective action (STANDBY/Abort)
   - Fast accidents are a serious concern – injection mis-set and asynch abort kicker → fluence ~ 10^9 MIPS cm^{-2} in ~ 100 nsec (prelim)
   - (Compare collisions @10^{34} → 10^8 MIPS $cm^{-2}s^{-1}$ @ radius ~ 4cm)

1. Muon chamber currents (CSC, DT, RPC – in various orientations)
   - An initial estimate: chambers will trip with loss peaks of ~ 2 KHz $cm^{-2}s^{-1}$ (~1000x expected steady state at 10^{34} ?)
   - Not expected to an issue unless spikes are excessive
   - Chambers will be in STANDBY (gain down 1/1000) for injection and ramp

1. Single-events (SEU, SEL, SEB…)
   - All electronics in CMS has been designed to be radiation tolerant
   - Low rate of SEU/SEB OK (reset chips (in general interrupts data-taking)/replace-repair in access)
   - Any problems will be due to truly anomalous conditions

Potential Problems

4. Contamination in HF Luminosity Calculation and in Forward Physics with Rapidity Gap Triggers
   - Halo, local beam-gas and satellite bunches may all be problems - could be quite sensitive to satellite crossings (11.25m) when no crossing angle
   - Use dedicated special runs and MC to estimate
   - Learn to correct using relative measure of backgrounds from BSC

5. Contamination in calorimeter triggers
   - Muon halo >10^2–10^3 $cm^{-2}s^{-1}$ may be an issue for calorimeters (eg. HF PMT)
   - A nuisance rather than a major issue – and not expected to be significant unless there are anomalous sources of halo - see for example the Missing-ET trigger in CDF
   - CMS trigger has more flexibility to adapt to such problems should they arise

CDF Missing-ET

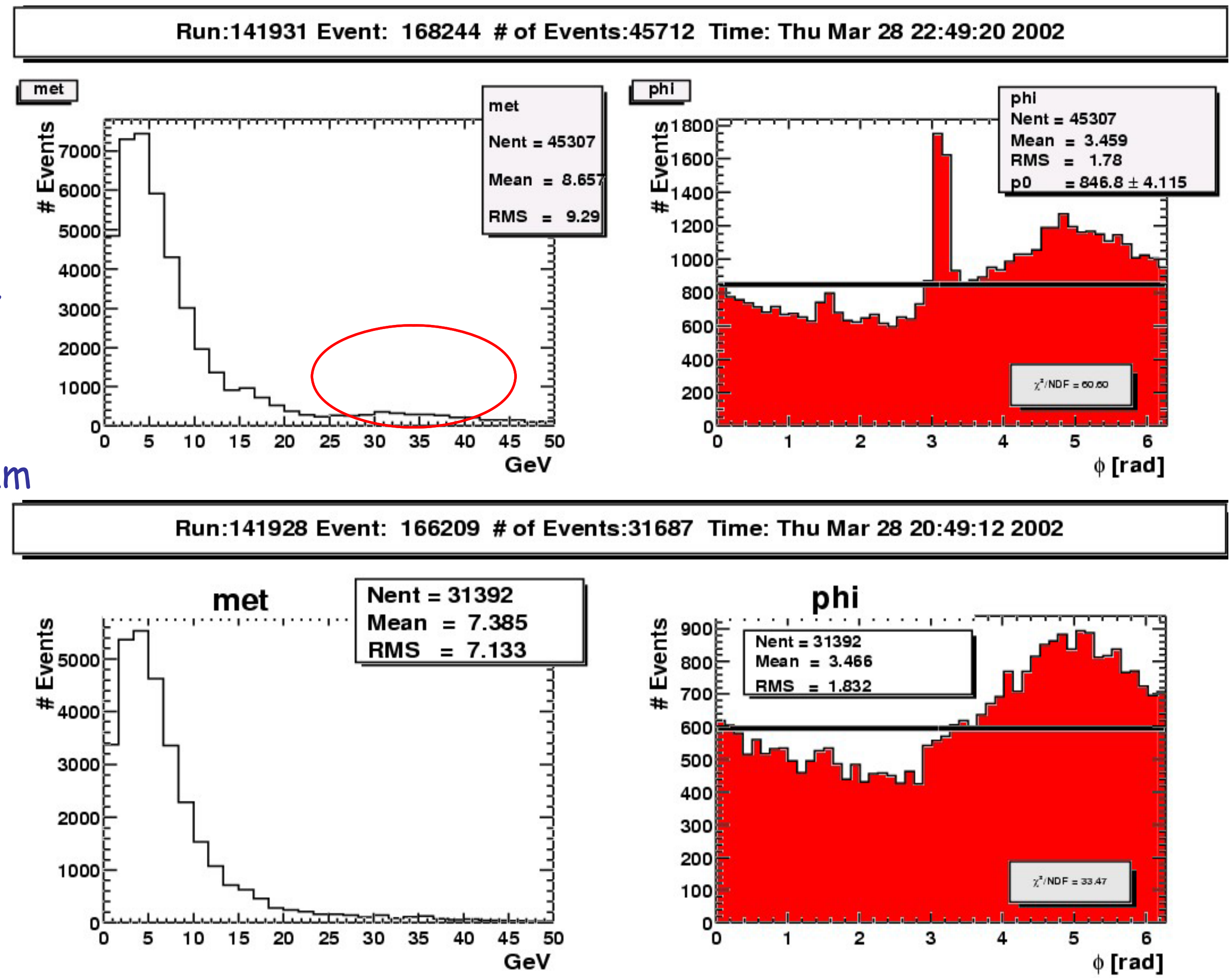
CDF observed a large peak in the MET-Φ distribution at beginning of Run 2

Easy to identify and remove off-line.

Studies determined that the source was muons generated by beam halo hitting the Roman Pots.

→ Expt data as a beam diagnostic

Raw Plots – Early Running



3. Detectors for measuring backgrounds/Information for LHC

The CMS detector will provide precision beam instrumentation at the IR for the accelerator, including bunch-by-bunch loss and halo measurements, and precision beam spot information

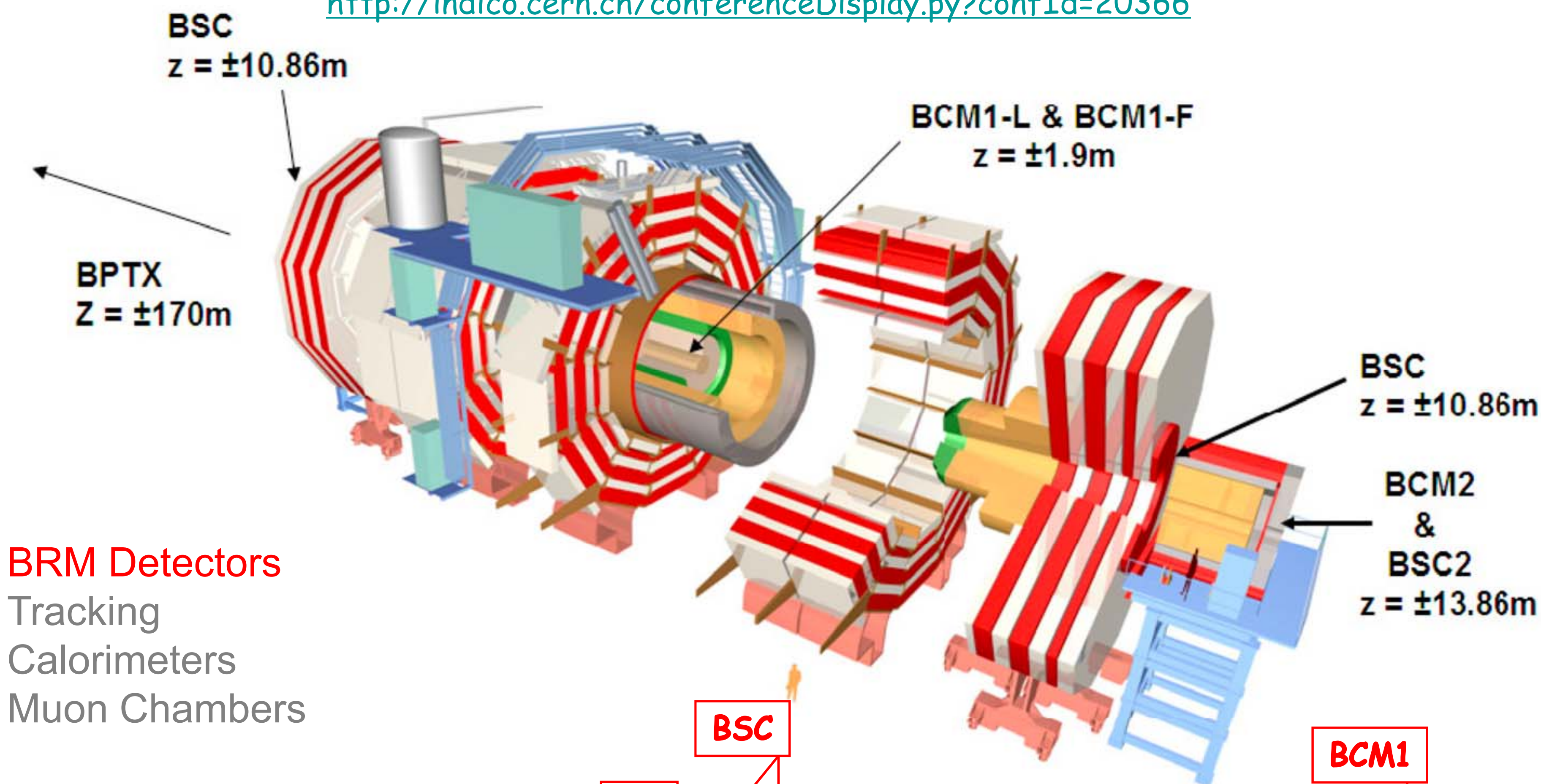
Detectors/Measurements

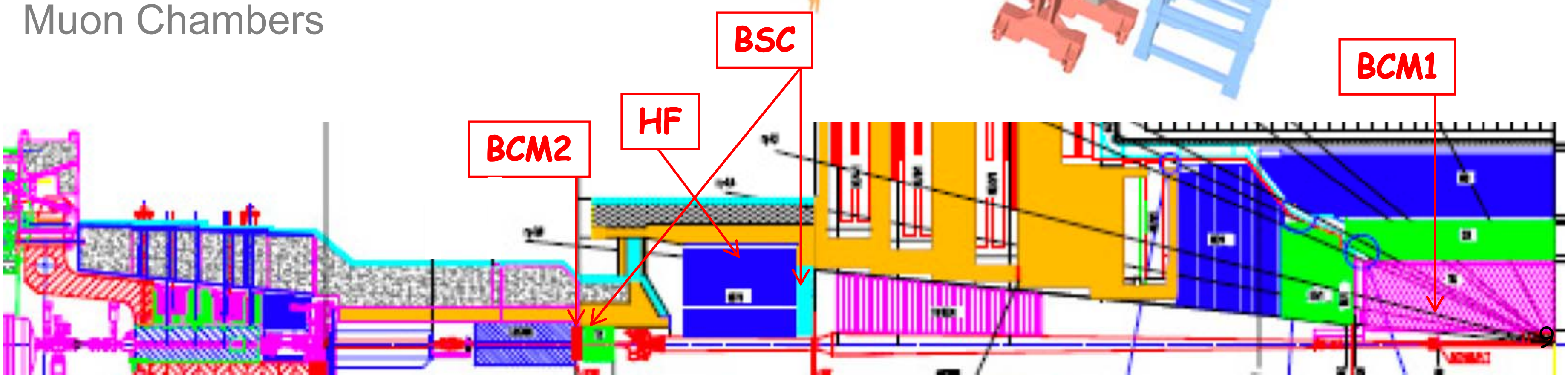
- Dedicated beam conditions monitors – ALWAYS ON
  - BCM diamond detectors (radiation rate)
  - BSC scintillators (halo)
  - BPTX position monitors (bunch structure and timing)
  - HF-Luminosity (crossing-by-crossing luminosity)
- Additional information when CMS is ON and taking data
  - Currents and Occupancies
  - Tracking (precision measurement of beam spot)
- Data will be provided to CCC via DIP, including summary parameters: "pseudo-devices"

Detectors for Measuring Backgrounds

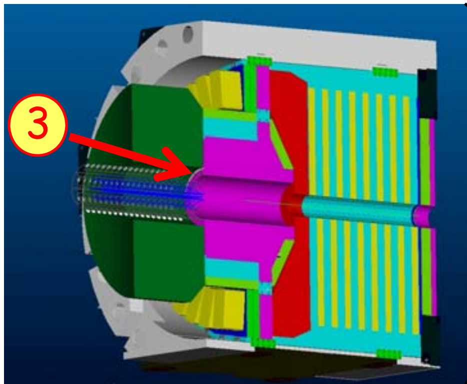
See Richard Hall-Wilton's talk at the the Nov07 Radiation Workshop

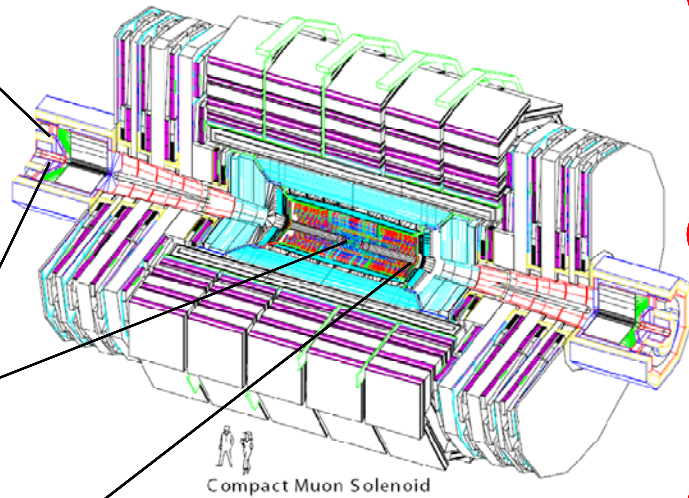
http://indico.cern.ch/conferenceDisplay.py?confId=20366





BCM: Beam Conditions Monitors

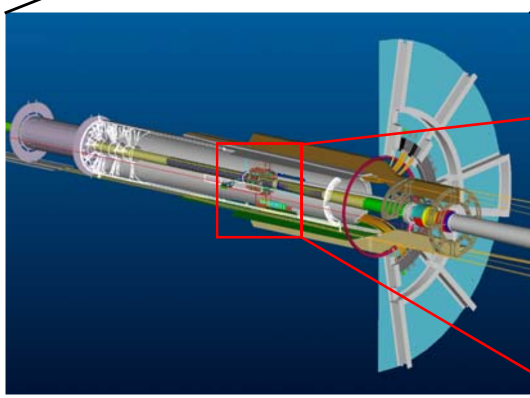


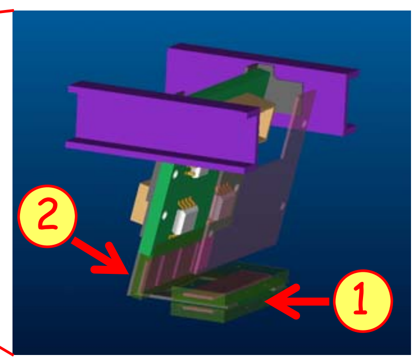


1 BCM1L: Leakage current monitor
Location: z=±1.9m, r=4.5cm
4 stations in φ
Sensor: 1cm^2 PCVD Diamond
Readout: 100kHz

2 BCM1F: Fast BCM unit
Location: z=±1.9m, r=4.3cm
4 stations in φ
Sensor: Single Crystal Diamond
Electronics: Analog+ optical
Readout: bunch by bunch

3 BCM2: Leakage current monitor
Loc'n: z=± 14.4m, r=29cm, 5cm
8 stations in φ
Sensor: 1cm^2 PCVD Diamond
Readout: ~20kHz
Sensors shielded from IP





- Primarily safety devices
- ALWAYS ON
- Measure dose rate
- Use BLM DAB64 readout
- Calibrated relative to BLM

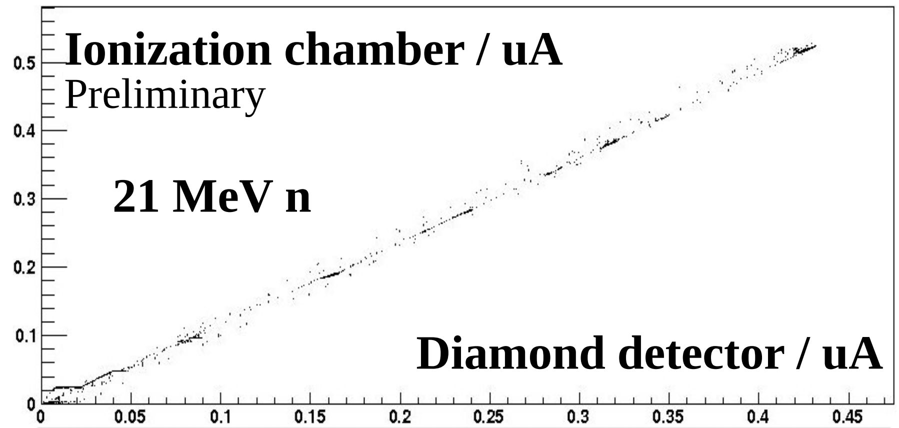
2 Sensor Locations, 3 Monitoring Timescales

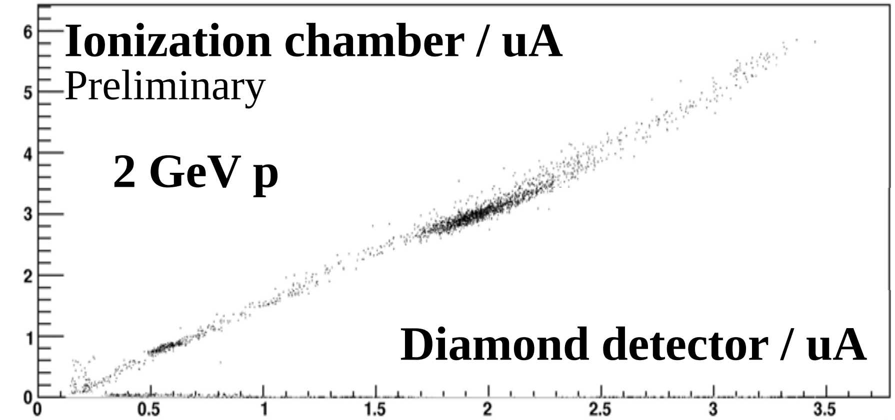
BCM/BLM Calibration

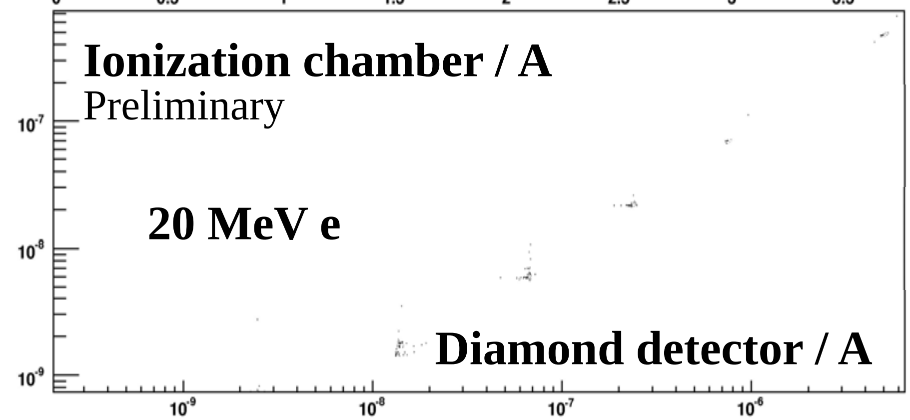
- Goal: BCM → equivalent to BLMs within the experiment cavern
- BCM and BLM cross calibration
  - 21 MeV neutrons (Louvain)
  - 2 and 150 Gev p/π (PS and SPS)
  - 20 MeV e (Dresden)
- Will provide BCM data in BLM units

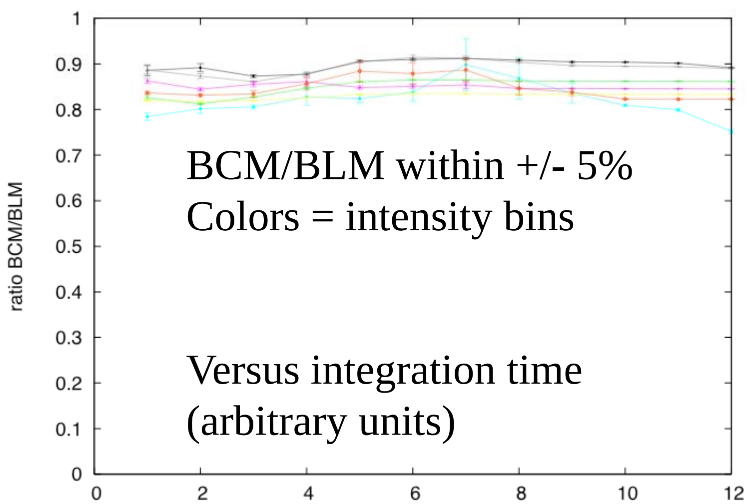
Diamonds:

- Linear over 6 orders of magnitude
- Sensitivity ~ 10^4 MIPs $cm^{-2}s^{-1}$
- (≡ luminosity of 10^{30} $cm^{-2}s^{-1}$)

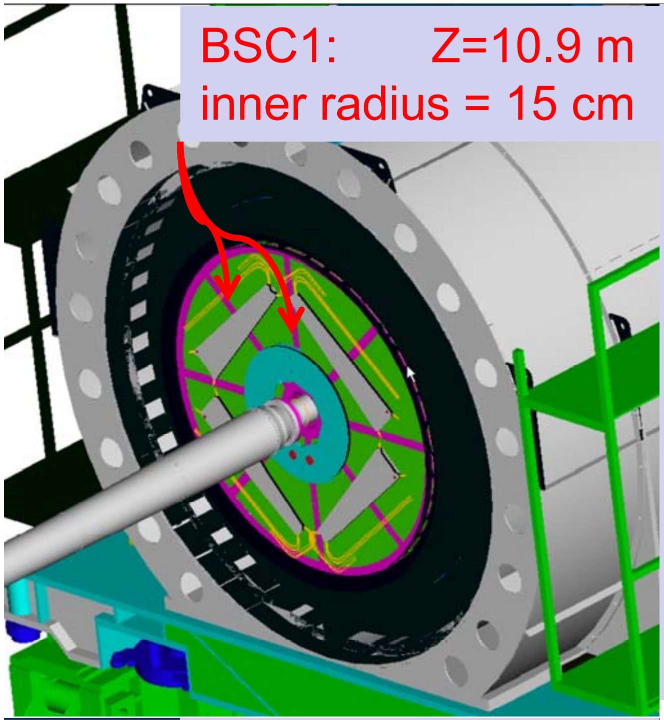




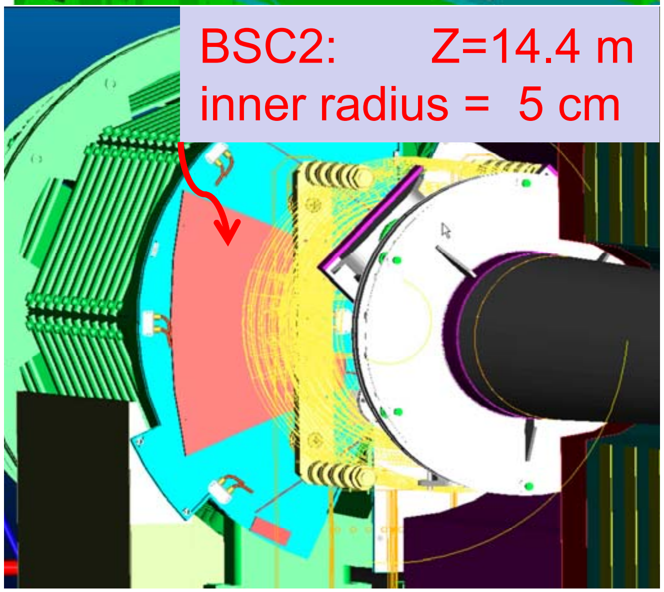


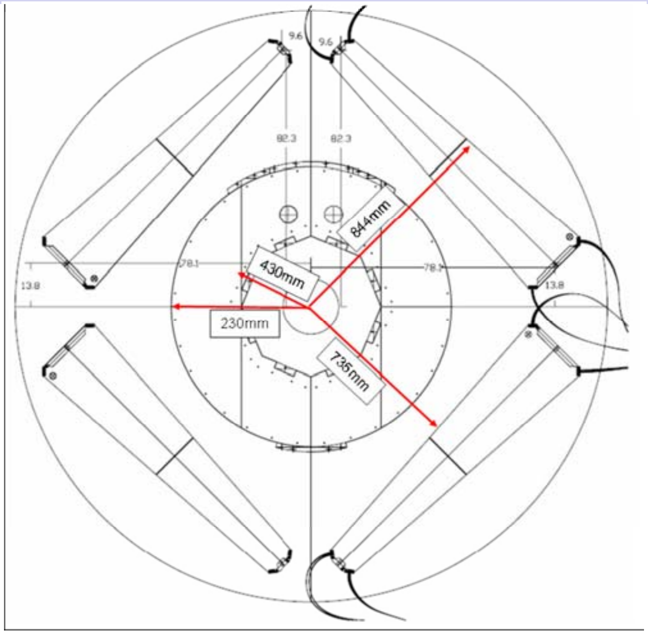


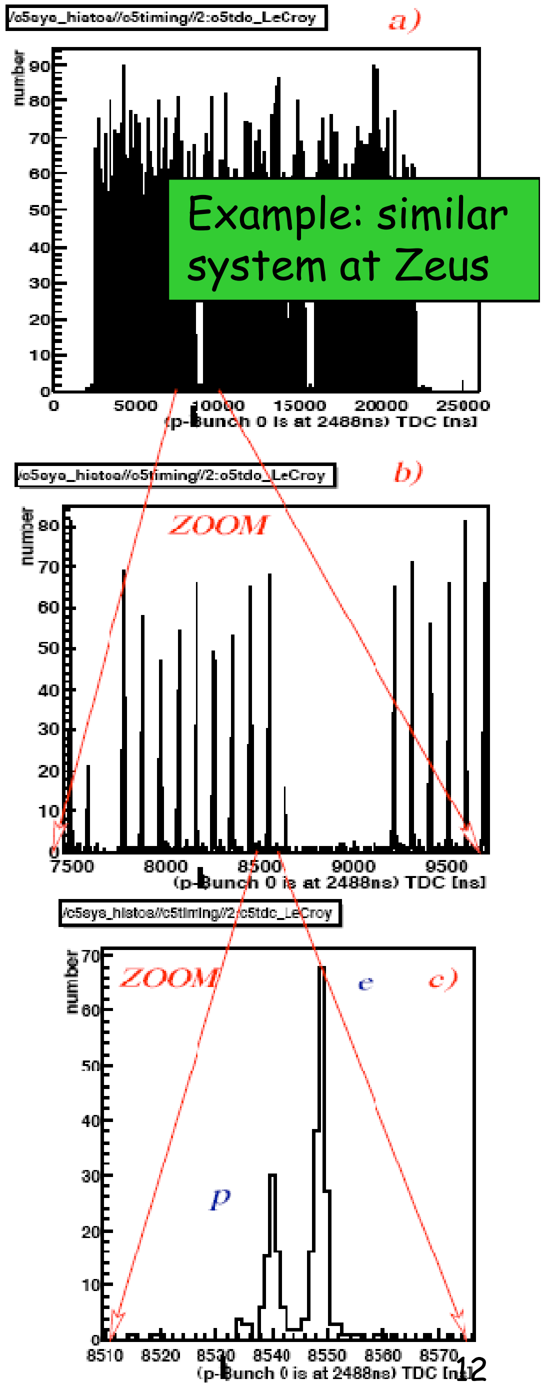
BSC: Beam Scintillation Counters



- ALWAYS ON
- Relative halo measure, tagged Beam 1, 2, abort gap via timing (σ~ 3nsec)
- Sensitive to incoming halo, halo+interactions, including satellites
- Position on HF will provide monitoring for luminosity
- Provides min-bias and halo triggers







HF Luminosity Measurement

- HF Forward-Hadron Calorimeter via parallel readout – ALWAYS ON
  - Cerenkov light - insensitive to neutron background and low energy particles
- Algorithms
  - Primary: count zero occupancy in HF towers, secondary: sum trans. energy
  - Linear with luminosity: 10^{28} – 10^{34} $cm^{-2}s^{-1}$
- Commissioning: debug in 2008, commission in early 2009 running
  - Will cross-calibrate with Van der Meer scans, W and Z offline - estimated accuracy ~ 10% for early running
  - Likely to be sensitive to halo, beam-gas and 11.25m satellite crossings
    - MC studies ongoing – really need event-by-event simulation
    - Use special missing-bunch runs to study contamination & compare MC
    - BSC is well placed to track backgrounds
    - Monitor using min-bias data
- Data to CCC
  - Send via DIP, initially per minute – later per ~ seconds: Total luminosity, relative bunch-by-bunch luminosity
  - Data path already tested (client runs in CCC)

Halo and Background Measurements for CCC

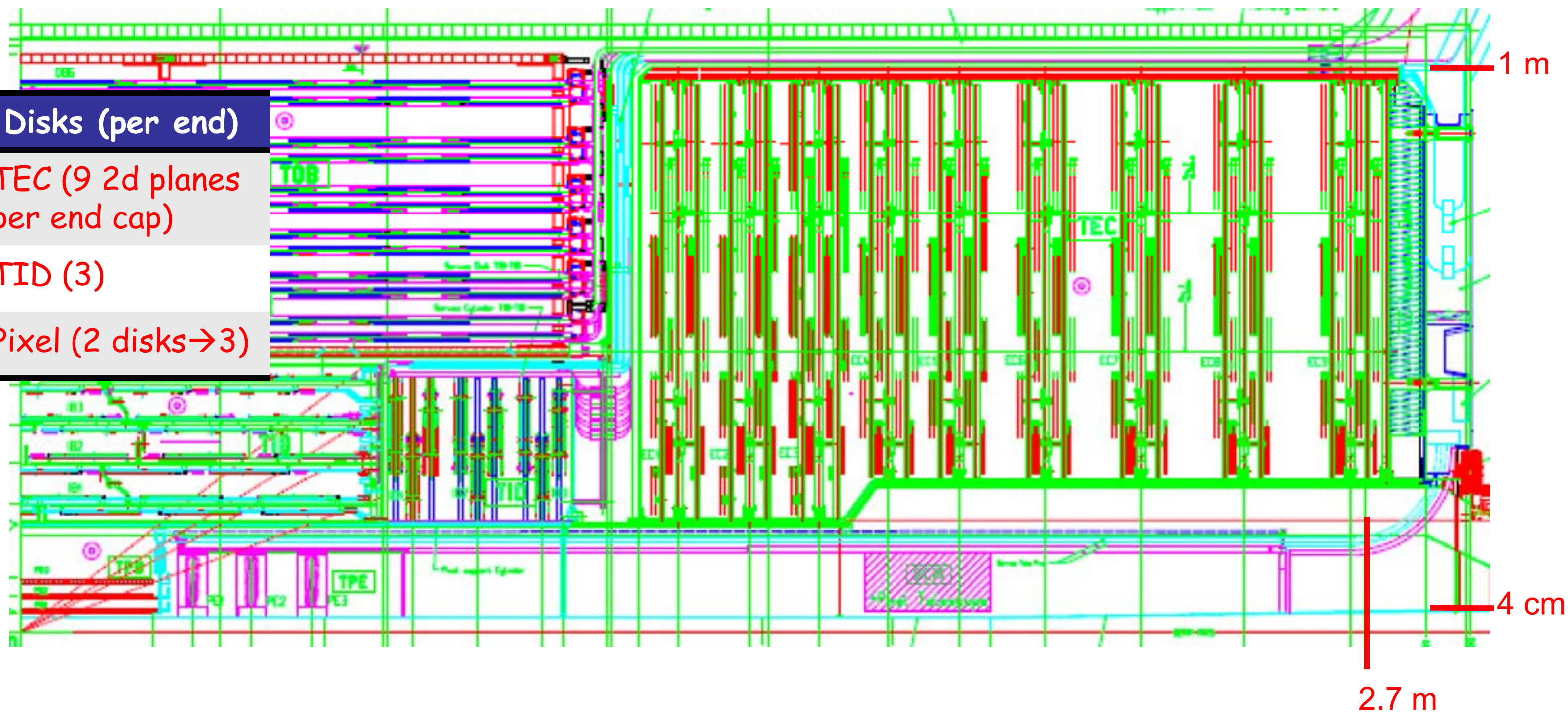
- Several parameters = "pseudo-devices" will be built to provide useful measures of the backgrounds - to be learned and developed.
- They will include "figure-or-merit" parameters for optimizing machine
  1. Obviously the luminosity measurement from HF
  2. and 3. BSC will produce a relative measure of beam halo associated with each beam
  2. BSC and BCM can produce a general measure of losses and radiation at CMS
  - Request is for "2,3,4"-like parameters in the range 1 to >5
- Behind these summary devices there will be more detail with slower accumulation of per-bunch information, radial/phi segmentation in halo rates, and pseudo-devices measuring loss spikiness…
- All devices will be logged at CMS and CCC to allow history analysis

Other Measures: when CMS is ON

- Currents (muon chambers) and Occupancies (calorimters)

- Halo Tracking
  - Only when CMS is fully ON and taking data
  - BSC will provide halo triggers (with specific geometric coverage)
    → track muons parallel to the beam in the Tracker Endcaps
  - Main goal is alignment, but could provide a lot of halo information

Barrel	Disks (per end)
TOB	TEC (9 2d planes per end cap)
TIB	TID (3)
Pixel	Pixel (2 disks→3)

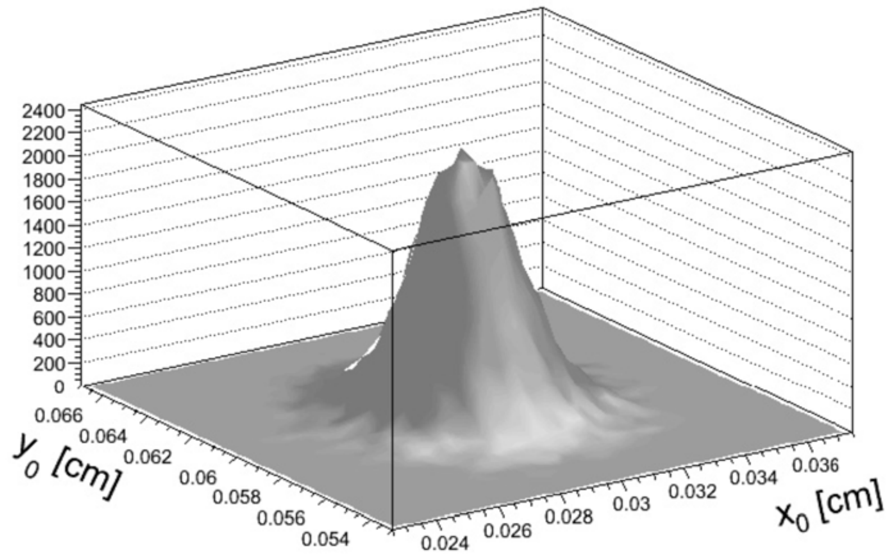


- Beam spot reconstruction…

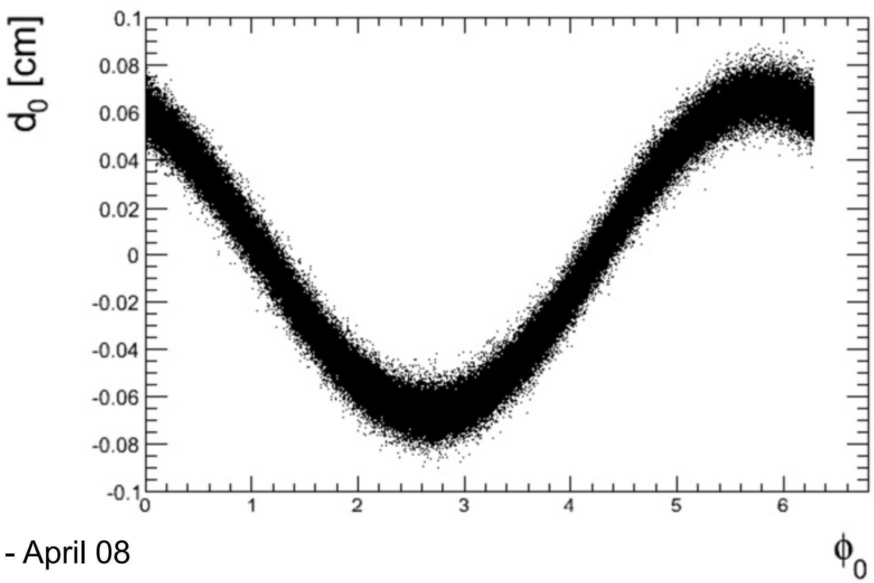
Beam Spot Reconstruction in HLT

Impact parameter: $d_0 = x_0 \cdot \sin\phi_0 + dx\,dz \cdot \sin\phi_0 \cdot z_{tr} - y_0 \cdot \cos\phi_0 - dy\,dz \cdot \cos\phi_0 \cdot z_{tr}$

- Fit the impact parameter for tracks > 2 GeV, online in High Level Trigger
- 1-2 minutes: several K tracks → transverse position to ~ few μm, and z-position ~few 10's μm
- Few hours: several M tracks can yield precision measurement of β* and emmittance
- Information will be sent to CCC via DIP
- Requires fully commissioned tracking and final alignment (so, later in 2009)



simulation with 300 μm offset in x and 600 μm in y



4. Remarks and Conclusion

Will need to understand the commissioning sequence

- When abort and collimator shadowing (TCDQ, TCT) established
- When will the abort gap monitoring be commissioned
- What commissioning sequence: bunch structures and crossing angles
- For the later commissioning: What special bunch patterns to provide single-beam crossing, but with realistic losses, beam-beam effects etc

Communication

- What will procedure be if DIP is interrupted for some period of time (experiment will probably go to STANDBY)
- For safety parameters/flags will use GMT SMP – exception at the start is the SPS Probe Beam Flag

Conclusions

Safety

- Detector (pixel) safety in fast accidents is our most stark concern

Expect anomalous backgrounds

- We do not expect serious background problems for nominal running conditions
- But MANY unforeseen effects can produce high losses, so expect to see abnormal conditions
  - Develop monitoring, with corrective actions (CMS and LHC)
  - Integrate LHC monitoring into CMS state machine, alarms etc
  - Make CMS a precision instrumentation at the IR for ourselves and the accelerator
  - and … studies: compare simulation, measurements and special runs
- All of this will be learned

Good collaboration between the machine and experiments

- Communication and collaboration between the experiments and LHC is essential – thank you for organizing the workshop!