Commissioning the LHCb calorimeters with cosmic rays

Xavier Vilasis-Cardona
On behalf of the
LHCb calorimeter group

1st international conference on Technology and
Instrumentation in Particle Physics
TIPP09-Tsukuba, Japan, March 2009

LHCb Calorimeters

- Preshower (PS)/Scintillator Pad Detector (SPD)
 - Electromagnetic Calorimeter (ECAL)
 - Hadronic Calorimeter (HCAL)
- See Andreas Schopper Talk

- Noise measurements
- Inject known patterns into system memories
- LED system
 - ECAL, HCAL, PS, SPD
- Cs source for HCAL
- Time Alignment events -TAE events
 - Store trigger + previous and next Bunch Crossing ID (Clock cycle identifier - BXID)
 - Up to 15 samples
 - usually 5,
 - Prev2, Prev1, T0, Next1, Next2
- **COSMIC RAYS**
- Injection Test Events

Full System Test (May 2007)

- Vertical flow in cavern:
 - 0.9 Hz/m² (under HCAL), $\langle E \rangle = 50$ GeV.
- PMT high voltages set initially to obtain an uniform gain on PMT of $2 \cdot 10^5$
- Trigger strategies

- First cosmics seen in December 2007
- Overall more than 3M cosmic triggers

Example of Cosmic Event in the Calorimeter

Another cosmic event

Cosmic Ray crossing the SPD

- Check channel map identification along the DAQ and trigger path.
- Relative Time Alignment
 - Bunch Crossing ID (Clock cycle identifier)
 - Integration time
- Track reconstruction in the Calorimeter
 - PreShower and SPD Efficiency
- Provide Trigger for other subdetectors

Correct channel mapping with comics

Trigger path validation with cosmics

Wrong Trigger
Cabling should deliver
this

Electron Ecal map

Electron Ecal map

Actually we had this

Detector time alignment (muon vs calo)

- Calo-triggered event

- Muon-triggered event: Muon signal seen 2 clock cycles earlier

Time Alignment Strategy

- Equalise an a-priori delay from theoretical values
- Adjust BXID so that an event is mainly seen on Current
- Adjust integration time t_0
 - Select the pair of BX with maximum signal
 - Prev1/Current vs. Current/Next1
 - Compute the asymetry R

$$R = -0.149dT_0 + 2.06$$

ECAL / HCAL time alignment

Within each detector the RMS of R is coherent with time aligned cells within 3 ns

PS time alignment

ECAL-PRS alignment with cosmos data (Prev)

ECAL-PRS alignment with cosmos data (Prev)

ECAL-PRS alignment with cosmos data (Next)

ECAL-PRS alignment with cosmos data (Next)

Outer

Middle

- Integration time is the same for 1 PMT(64 channels)

PS aligned within 4ns

ECAL-PRS alignment with cosmos data (Prev)

ECAL-PRS alignment with cosmos data (Next)

Inner

SPD time alignment

- SPD has binary output
- Integration time is the same for groups of 64 channels
- Asymetry is computed over the shape of the average ratio of detected particles

Full SPD aligned within 5 ns

- A tool has been developed to reconstruct tracks in the calorimeter
- Determine azimuthal angle (ϕ) in HCAL & ECAL and combine them
- Select events with $\chi^2 < 15$
- Selected tracks are extrapolated for position & timing
 - PS/SPD
 - Other subdetectors

- **PS**
 - Efficiency 87 %

- **SPD** efficiency as a function of threshold

- Threshold at 9σ above noise:	~500k	94%
- Threshold at 0.5 MIP :	~1M	82 %
- Threshold at 1.5 MIP :	~500k	19.6%

PS calibration with cosmons

From Cosmons events :

-Each PS region calibrated - using the time model of signals

Injection tests events

- SPD multiplicity was used as trigger for LHC synchronization tests
 - 1 injection test shot $\approx$ 3 h Cosmics
 - Coherent with cosmics results

Connectics
problems

Flow $\approx 0.1\text{-}1 \text{ MIP}/\text{cm}^2$

- Calorimeter system has provided cosmic triggers to the LHCb detector
- Cosmics have allowed a first approximation to
 - Time alignment
 - Efficiency
- This procedures will be repeated with the first data
- And we are now of course

Eagerly waiting for collisions !

Commissioning the LHCb calorimeters with cosmic rays

Xavier Vilasis-Cardona
On behalf of the
LHCb calorimeter group

1st international conference on Technology and
Instrumentation in Particle Physics
TIPP09-Tsukuba, Japan, March 2009

Backup Slides

Photon - electron trigger path

- ECAL $\rightarrow$ PS/SPD $\rightarrow$ TVB tested on cosmics

Photon Ecal map all

Validation by PRS and veto of SPD
First campaign of tests: debug of
 $\frac{1}{2}$ boards mapping, cabling, ...

Photon Ecal map

Low rate fine timing problems

Hardware problem, located either in the PRS
crate's backplane, or in one PRS Front-End
board

Data Quality Survey

- Check of connections with cosmoics
 - With 900 events, if all cables were not plugged or if backplane connections were wrong, we would see (ie we checked that all cables are plugged at the correct place):

Time alignment PS/SPD & ECAL/HCAL

HCAL & ECAL: Time Alignment

Aout: 87k Event

Improvement in the internal time alignment of the ECAL with the HV corrections

$$R = \frac{N(\text{Current}) - N(\text{Next})}{N(\text{Current}) + N(\text{Next})}$$

Forward tracks - PP:
Slope = 2.38
Offset = -2.20 ns

Calorimeter Trigger System

LHCb DAQ System

Cosmics in the calorimeter

Hcal

Ecal

Prs

Spd

- Vertical flow in cavern:
 - 0.9 Hz/m^2 (under HCAL), $\langle E \rangle = 50 \text{ GeV}$.
- Horizontal muons:
 - $\langle E \rangle = 100 \text{ GeV}$
 - $\langle 30^\circ$; 0.0046 Hz/m^2 (outer HCAL $\times 40 \text{ m}^2 = 0.18 \text{ Hz}$)
 - $\langle 11^\circ$; 0.0009 Hz/m^2 (inner HCAL $\times 15 \text{ m}^2 = 0.013 \text{ Hz}$)

Time Alignment Strategy - SPD

- SPD has binary output
- Integration time is the same for groups of 64 channels
- Asymmetry has to be computed performing statistics over many events
- Threshold value is capital
 - Too low : noise
 - Too high : no signal
 - Fixed at 9σ from the pedestal

100 GeV PGun muons (SPD inner cell), 1k events, B off Threshold ~ 0.5 MIP Threshold ~ 0.25 MIP

- Using Cosmics sample study the efficiency as a function of threshold.
 - 9 sigma recipe: ~500k - 94%
 - 0.5 MIP recipe: ~1M - 82 %
 - 1.5 MIP recipe: ~500k - 19.6%

Correspondance of 9 sigma recipe
to computed MIP

- Correction needed for cosmics
- Select cosmics in middle BX