Commissioning of the Scintillator Pad Detector of LHCb with cosmic rays and first LHC collisions

Ricardo Vázquez Gómez (UB/ICC)

on behalf of the LHCb collaboration

CALOR2010 MAY10-14, IHEP, BEIJING
XIV International Conference on Calorimetry in High Energy Physics

Outline

- Introduction: the LHCb calorimeter
- SPD commissioning
  - **Time alignment**
  - **Calibration**
- Conclusions

Introduction: the LHCb experiment

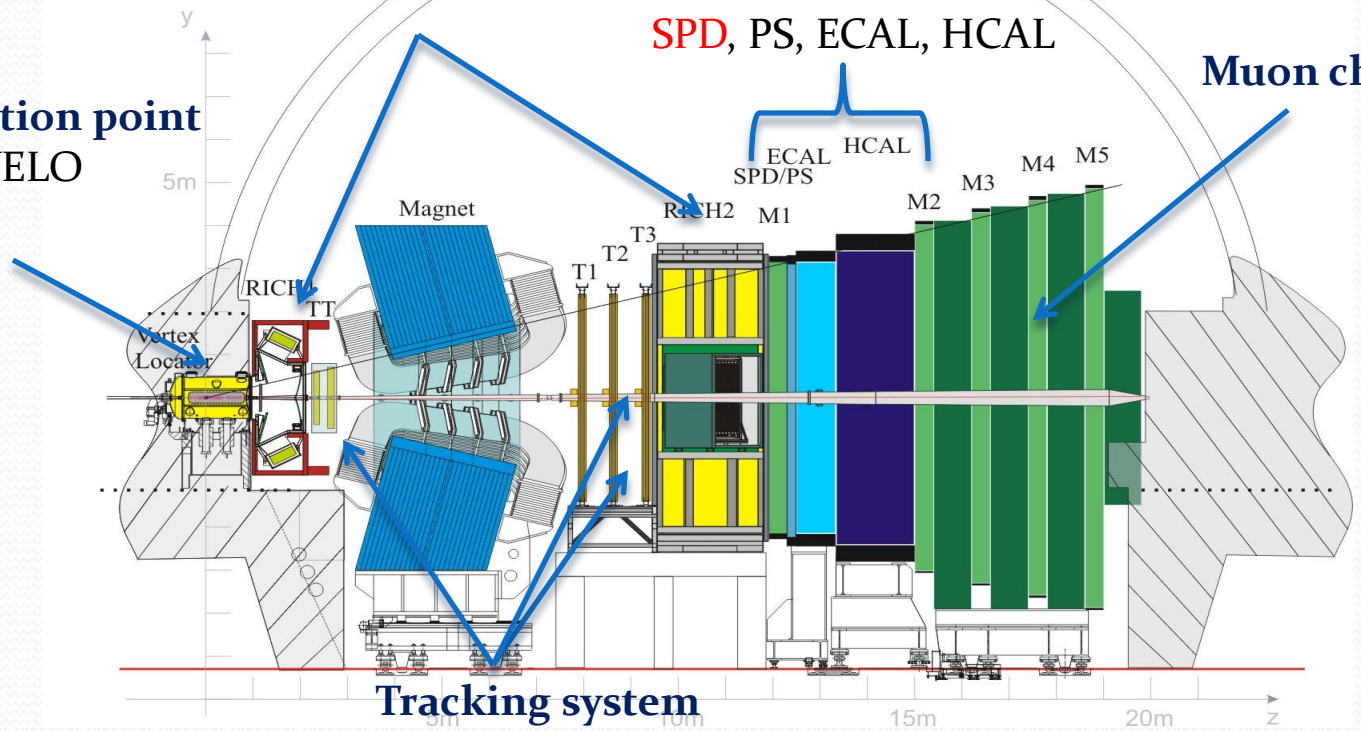
- Single-arm forward spectrometer
  - Acceptance 10-250 mrad (V)/ 10-300 mrad (H) ⟶ $1.6 < \eta < 4.9$

PID
RICH-1, RICH-2

Calorimeter
SPD, PS, ECAL, HCAL

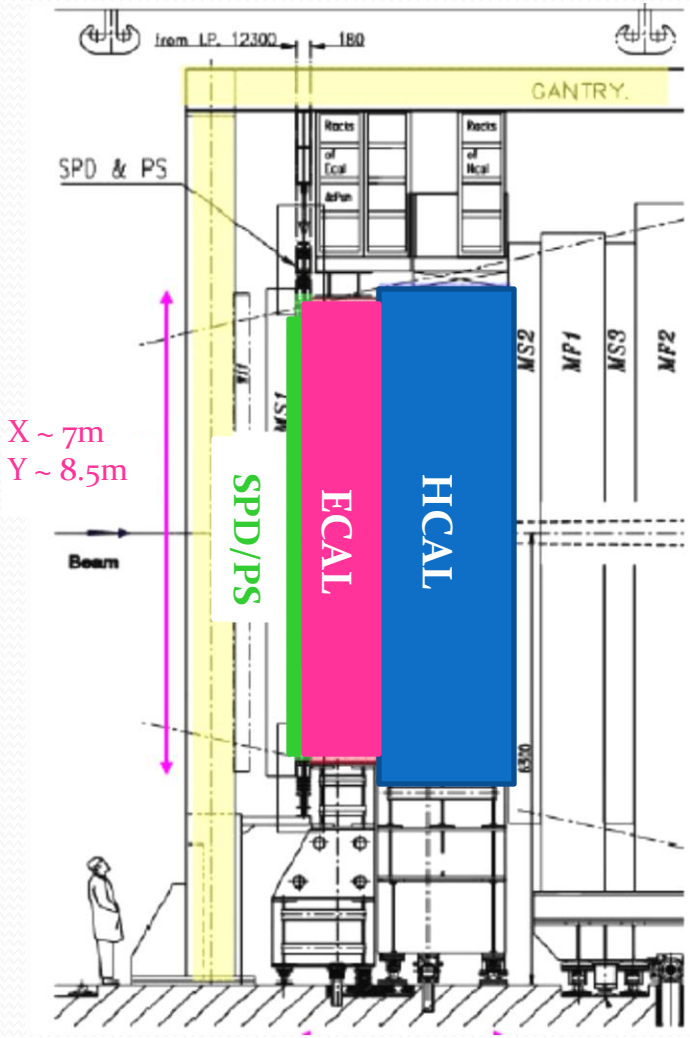
Muon chambers

Interaction point
VELO

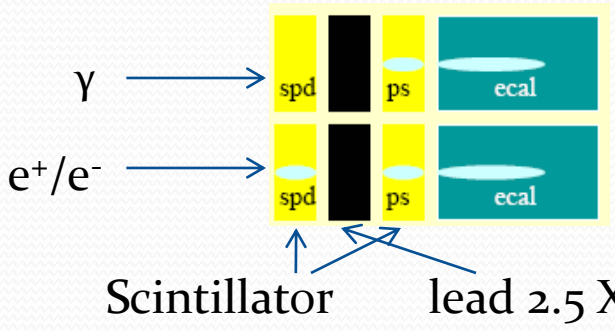


Tracking system
TT+IT+OT

The LHCb calorimeter

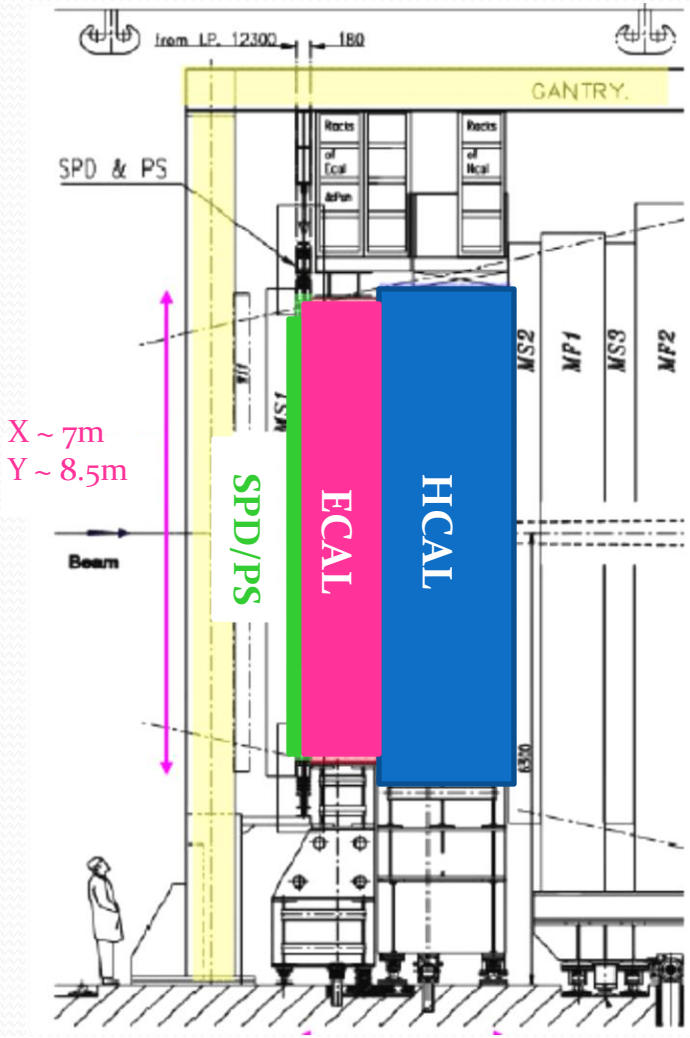


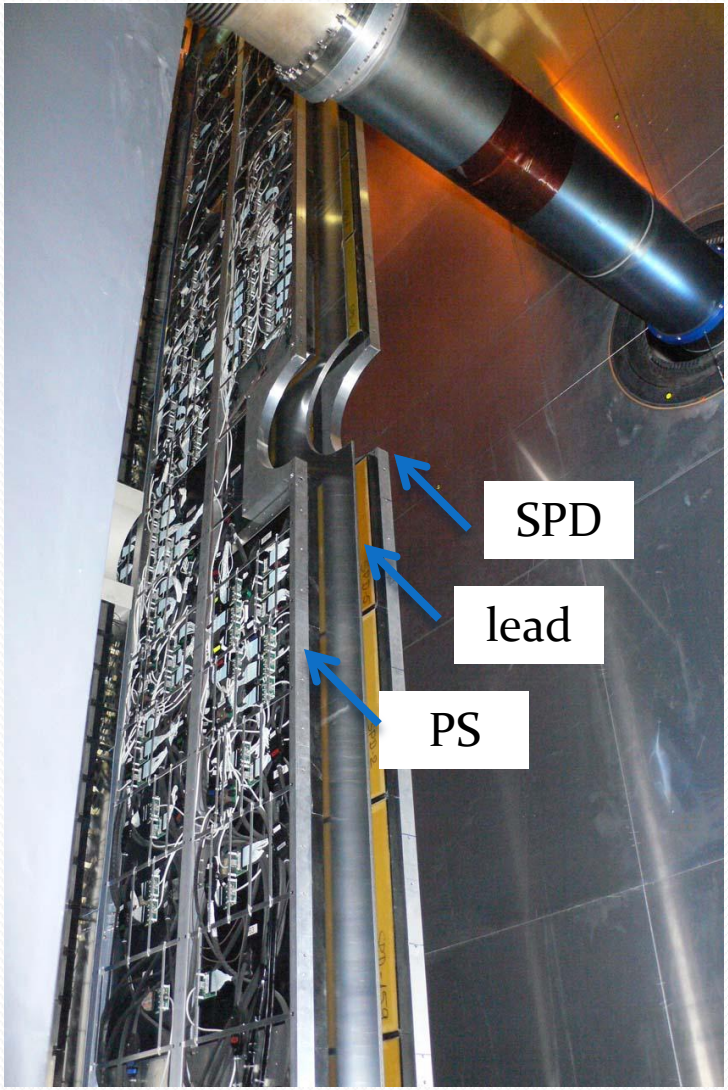
- **Scintillator Pad Detector (SPD):**
  - Contributes to the first level of trigger (L0 at 40 MHz) by:
    - Photon/Electron separation
    - Multiplicity veto
  - Multiplicity used in 2009 & 2010 collisions as minimum bias trigger.
- **PreShower Detector (PS):**
  - Separation of electrons, photons and π^0 from hadrons at the L0 trigger
  - Offline PID for electron and photon



ECAL & **HCAL**: talk by Irina Machikhiliyan
PS: talk by Valentin Niess

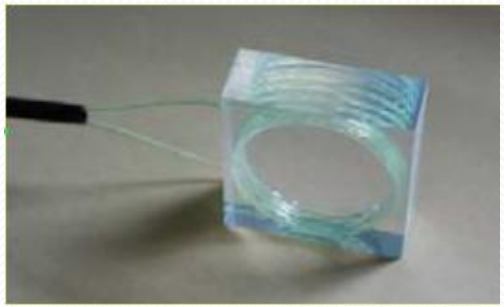
The LHCb calorimeter

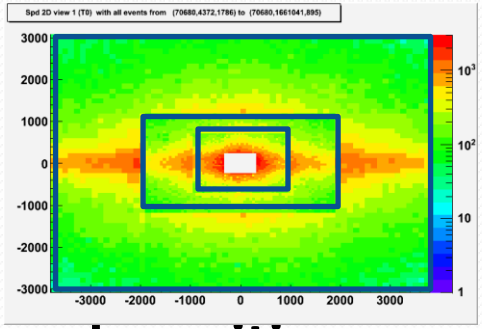




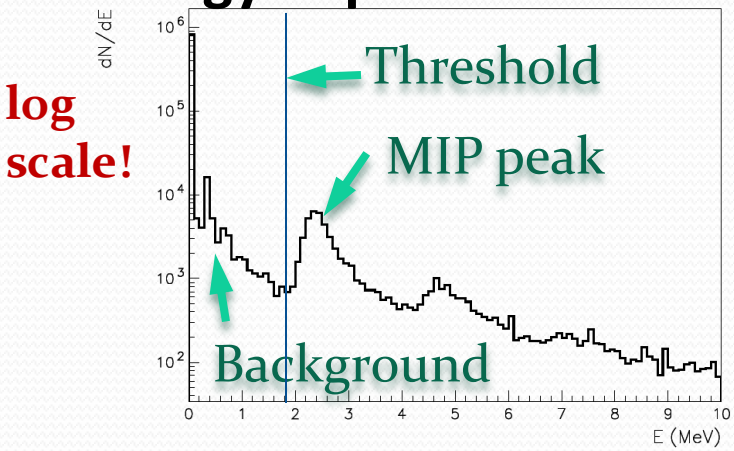
The SPD detector

- Layer of 6016 scintillating plastic cells.
  - 1.5 cm thickness.
  - 3 regions with different granularity at different distances to beam line (4x4 cm^2 inner, 6x6 cm^2 middle and 12x12 cm^2 outer).
- Read-out by 100 64-channel MAPMT coupled to a single Very Front End (VFE).
- Electronics apply a **binary discrimination** ⟹ dedicated calibration and time alignment.
  - Pre-calibration of threshold based on cosmic rays and test bench (offset, nphe, electronics gain, HV gain).





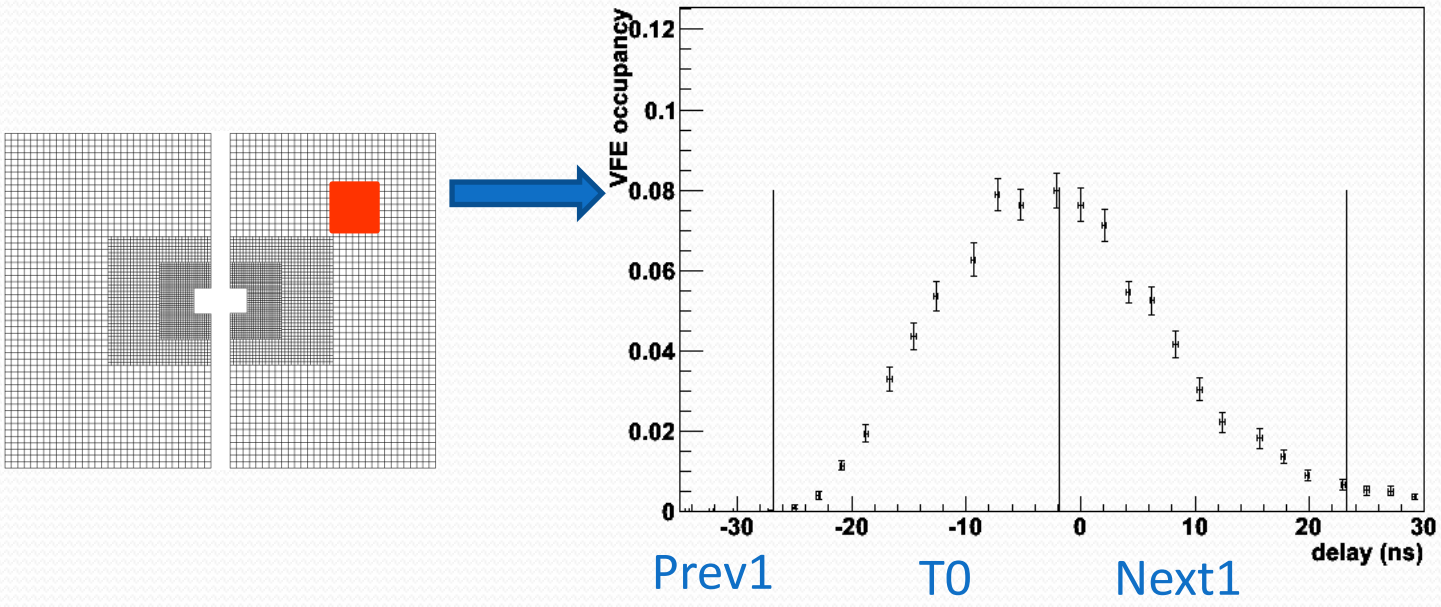
Energy deposition:



Time alignment

Objective and method

- Find the delay that maximizes the number of hits in the collision bunch crossing (T0) and has nothing before (Prev1).
  - Delays only applied by groups of 64 channels (VFE).
- LHCb trigger allows to readout consecutive bunch crossings.

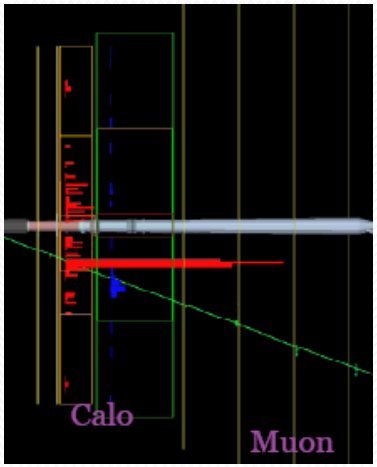


Cosmic rays

- Although LHCb has **NOT** the optimal shape to take cosmic data more than 1.5M events were recorded.

Cosmic direction	Rate (Hz/m^2)
Vertical	0.9
Horizontal < 30º	0.0046

- Using the energy deposited, we can define a track only with the calorimeter.

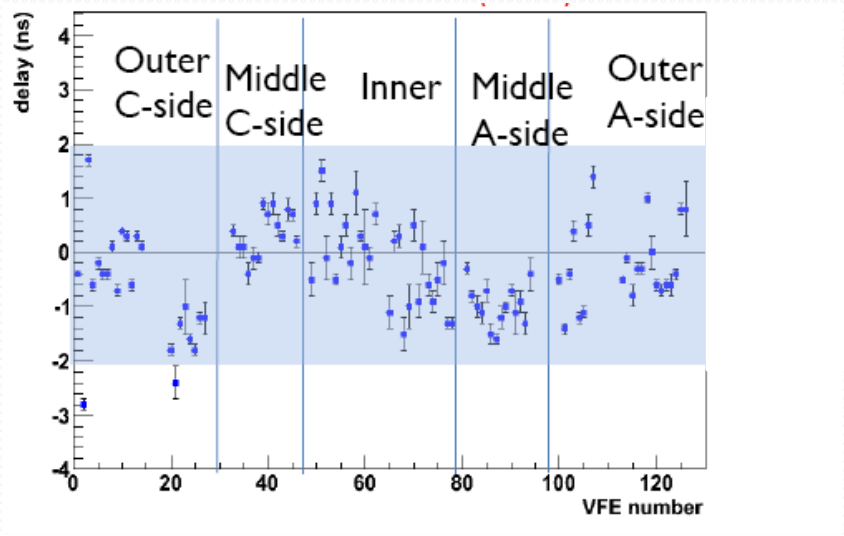


Cosmic track

Results

With cosmics

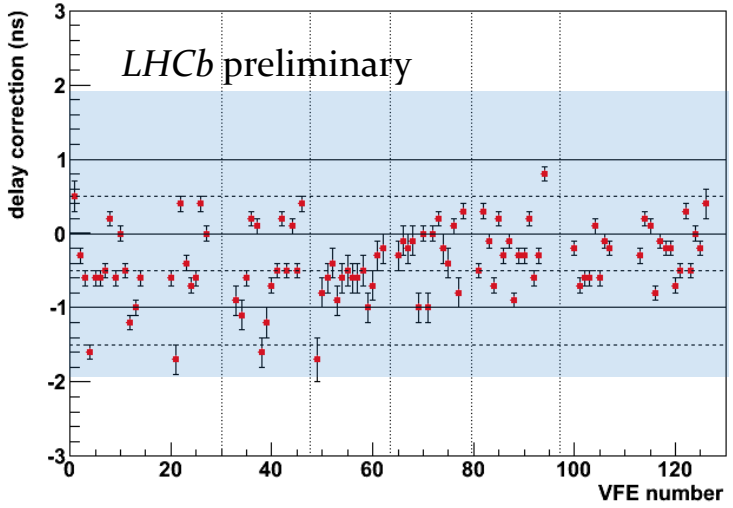
- Triggering on ECAL & HCAL coincidence.
- Arrival time wrt integration provided by ECAL & HCAL.



Statistical precision of ~0.5 ns with 1M cosmic events.
Delays implemented in October 2009.

With 7 TeV collisions

- Cosmic results provided an excellent starting point. SPD used as Minimum bias trigger.
- Minimum bias trigger.
- Timing is wrt LHC beam.
- Half of SPD kept as trigger while scanning with different delays the other half.



Statistical precision of ~0.3 ns with 600k collision events.
Delays implemented in April 2010.

Calibration

Calibration strategy

- SPD efficiency to detect charged particles is a function of the threshold.
- Can be measured as:

  ε = # tracks with a hit in a cell / # total tracks in the cell

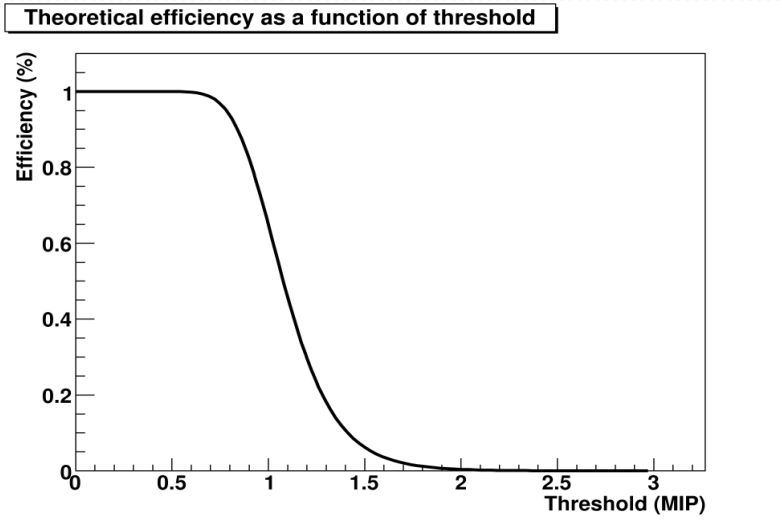
- Study the efficiency as a function of the threshold value for all cells. Compare with the theoretical expectation.
- Electronic resolution for setting the value of the threshold value is 5% of E_{MIP}. This sets our objective resolution.

Theoretical efficiency

ε = Landau ⊗ Poisson

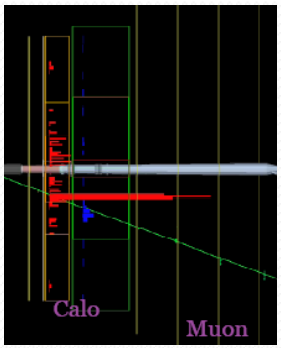
Energy loss

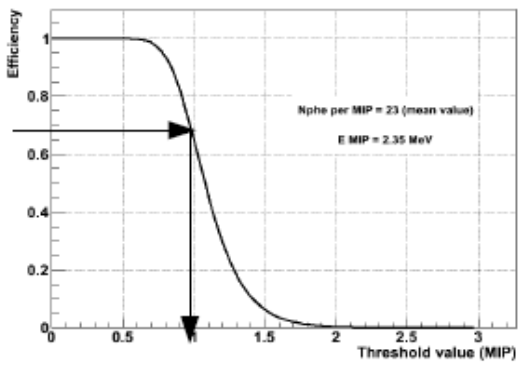
Fluctuations of nphe at photocathode.

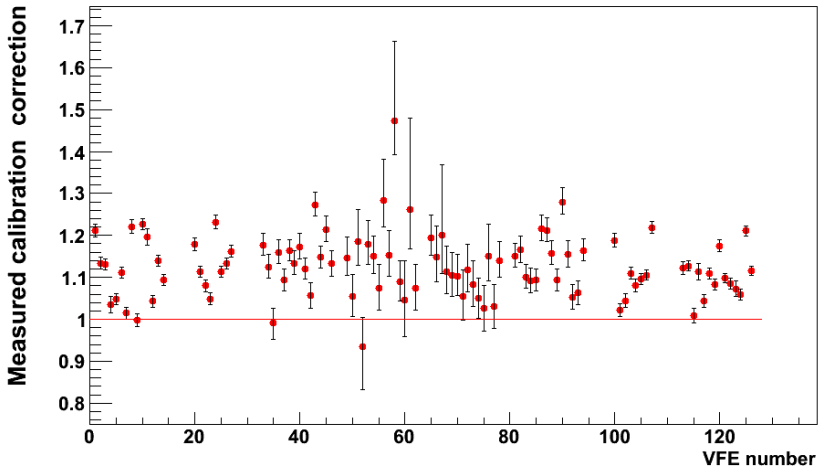


Cosmic rays

- Cosmic selection criteria based on ECAL and HCAL signal:
  - Cosmic arrival time centered in the integration time window.
  - Select only low angle tracks wrt to perpendicular to avoid excessive ionization.
- Take data at threshold value of 1 E_{MIP} .
- Due to limited statistics, only an efficiency per VFE was extracted.
- Cells in the same VFE share HV value ➡ same global correction.
- Average deviation showed that pre-calibration was correct up to 15%.



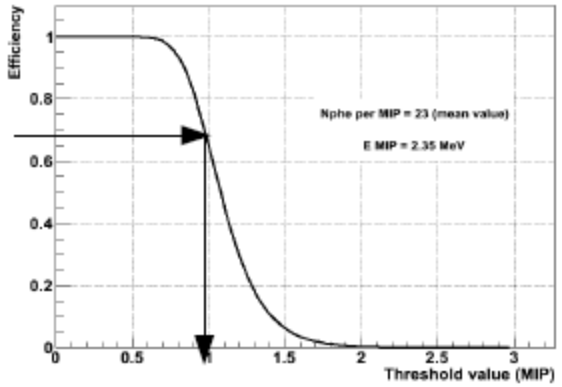


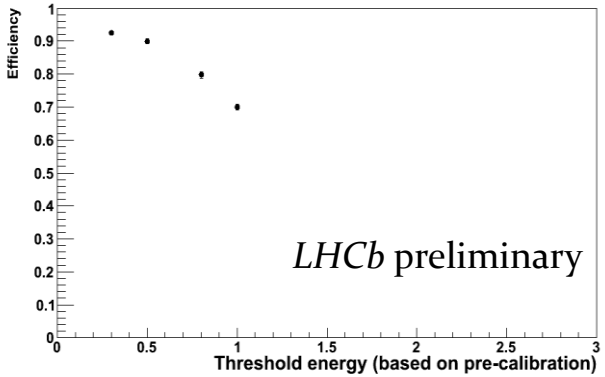


LHC collisions

- Cell by cell calibration can be achieved.
- Take data at different threshold values (from pre-calibration) values and compare with the theoretical curve.

Threshold (E_{MIP})	# of collisions
0.3	2.5M
0.5	2.7M
0.8	3.9M
1.0	3.8M



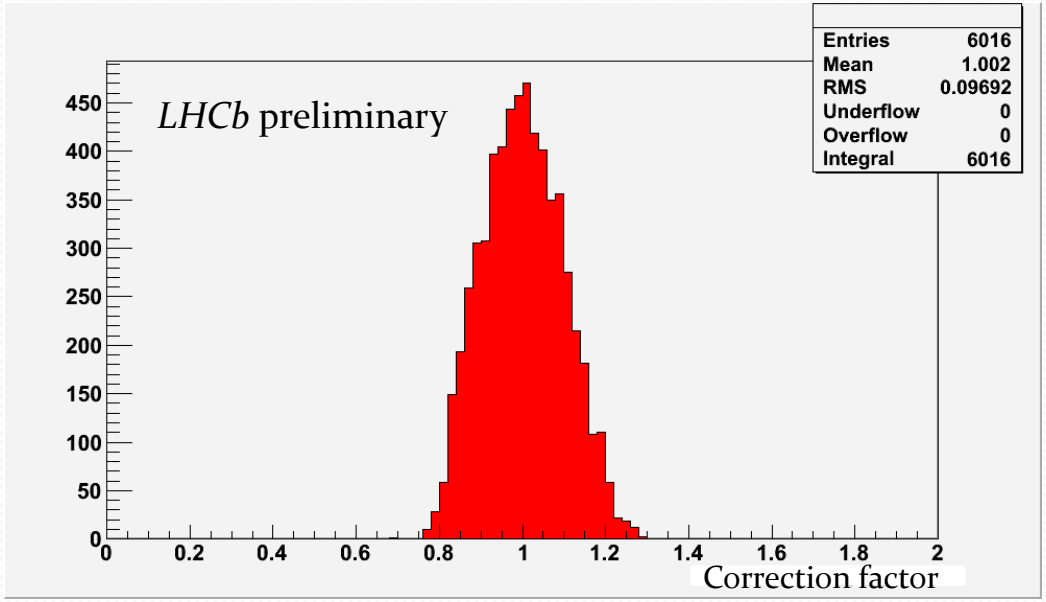


Experimental efficiency for a typical cell

- Corrections extracted from fitting the observed efficiency vs threshold to the theoretical expectation.
- Efficiency at 0.3 E_{MIP} measures plateau efficiency (convolutes effects of misalignment, ghost tracks and dead zones in the detector).

Results

- Using ~12M pp collisions at √s = 7TeV from April 2010.
- Current fitted values show a dispersion of 9.7% and central value shows no significant bias.
- Very preliminary results, as some cells not yet in the efficiency plateau at 0.3 E_{MIP}.



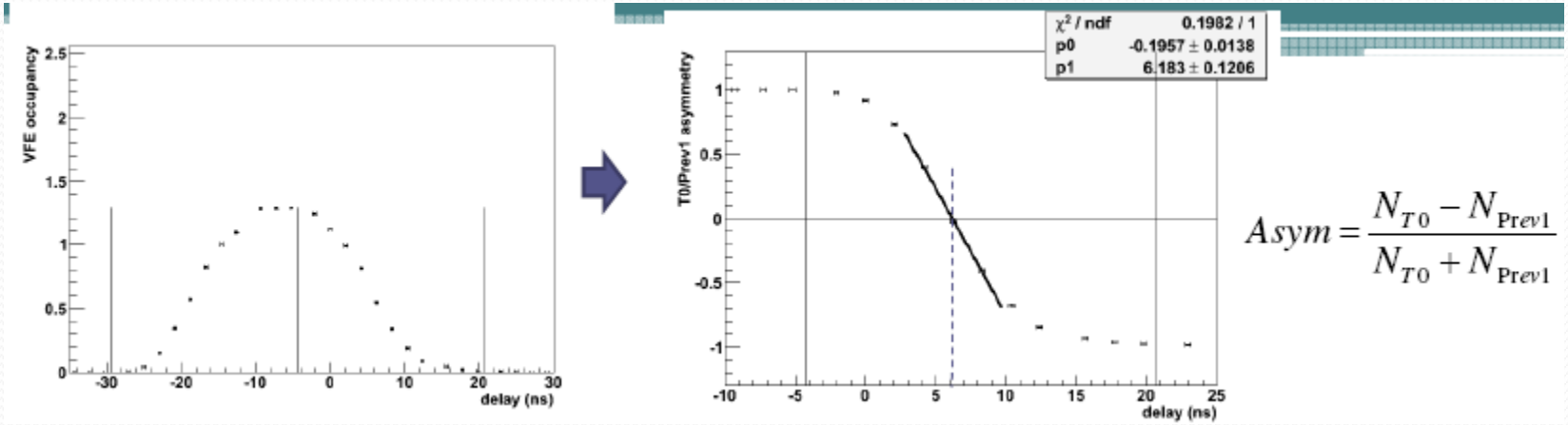
- This corrections will be applied in the hardware for future data taking.

Conclusions

- The SPD detector is fully operational.
- Cosmic rays provided a good starting point for time alignment and calibration.
- Fine time alignment has been achieved with collision data with a precision of 0.3 ns.
- The SPD cell intercalibration is better than 10%.
- Final corrections will be soon applied to achieved the optimal performance.

BACK-UP

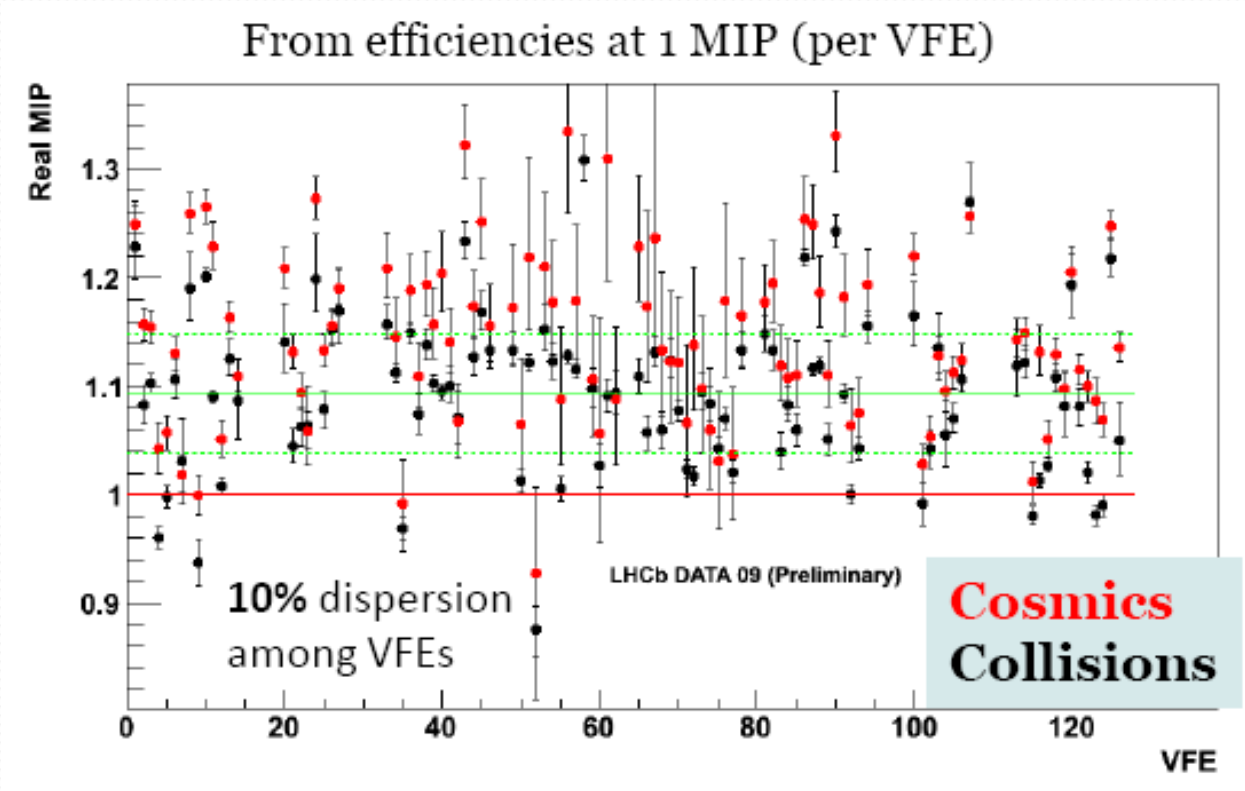
Time alignment asymmetry



$$Asym = \frac{N_{T0} - N_{Prev1}}{N_{T0} + N_{Prev1}}$$

Zero crossing point gives the delay that has to be applied in the electronics

Calibration cosmic vs collisions



Efficiencies at 1MIP are compatible between cosmics and collisions. 10-15% dispersion wrt perfect calibration.

Calibration: track definition

Cosmics

- Use ECAL & HCAL deposits:

❑ Low angle tracks wrt perpendicular.
❑ Time arrival centered in integration window.
❑ Error in the extrapolation to SPD/PS plane.
❑ PS energy deposit
❑ Extrap inside cell at 3sigma level.
❑ Only 1 cell in SPD and 1 in PS.

Collisions

•Use LHCb tracking system
❑ chi2/dof
❑ small error in extrapolation to SPD plane.
❑ low material traversed (avoid mult. scattering)
❑ border cell cut
❑ extrap inside cell with 1 sigma
❑ hit in same cell of SPD and PS
❑ PS energy deposit

Threshold	Min stat.	Max stat.
0.3	25544	3
0.5	24940	8
0.8	32913	12
1.0	39630	13