Commissioning of the LHCb Preshower

With Cosmic Rays and First LHC Collisions

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Outlines

- **Overview of the Preshower:**
  - Goals and principles
  - The Preshower detector
  - Its electronics

- **Commissioning:**
  - Goals and strategy
  - Time alignment
  - MIP scale calibration
  - Trigger path tuning

- **Conclusion and outlooks**
The Calorimeter Systems and the Preshower

- **Interplay of 4 sub-detectors in a row:**
  - Scintillator Pad Detector (SPD), **Preshower (PS),** Electromagnetic (ECAL) and Hadronic (HCAL) calorimeters divided in projective cells with their **dedicated electronics.**

- **Role is double:**
  - **Key Part of the L0 trigger @ 40 MHz:**
    - Identify **high** $P_T$ h, e, $\gamma$ candidates from heavy B’s. E.i: count **MIP’s in the Preshower** to identify showering/EM primaries.
  - **Offline energy reconstruction of showering Events:**
    $$E_{EM} = \alpha \cdot Q_{ECAL} + \beta \cdot Q_{PS}$$

**Schematic view of the Calorimeter**

**Side view**
The Preshower: Detector and VFE Electronics

6016 Cells of 15 mm thick Polystyrene Scintillator Pads
3 Granularities: Inner 4×4 cm², Middle 6×6 cm², Outer 12×12 cm²
WLS fibres are used to collect the light

Bundles of clear fibres carry the light to MAPMT’s located in shielded boxes at the top & bottom
+ Embedded LED’s for monitoring

100 Multi Anode PMT:
Handling clusters of 8×8 = 64 PS channels mounted on VFE electronic boards:
2 chips integrating light signal alternatively @ 40 MHz (no dead time)
The Preshower: Front End Electronics

- 100 FE boards operating @ 40 MHz and mapped 1 to 1 to VFE (located in racks on top of the calorimeters)
  - Tuneable corrections for each 64 channels: pedestals, spillover (see next slide) and gains to uniformise response. Calibration to set gains such that ‘10 ADCs = 1 MIP’ ⇒ 100 MIP’s full dynamic.
  - Centralising PS & SPD trigger information.

Need to dial @ 40 MHz with other CALO electronics: PS VFE, PS neighbouring FE, SPD Control Boards, ECAL FE, Trigger Validation Boards.
⇒ Connectics: {23 RJ45 cables + backplane links} to 6 different FE/VFE boards. Delay Chips to synchronise the various I/O’s.

View of a PS FE Crate

View of a cable chain (RJ45 connection between FE and VFE)

Schematic of the connections between PS cells, VFE and FE

- Scintillator
- MAPMT
- Integrated PMT charge (16×27 m RJ45)
- ADC
- FE
- VFE
- Clock (27 m RJ45)
- ×16
- ×1
- Light signal (optical Fibres)
- ×64

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Phasers and Signal Shape

- **The scintillation signal** collected in Preshower cells extends to more than one cycle (25 ns). In nominal operating conditions the VFE integration start time, \( \Phi_{VFE} \), has to be tuned to get a maximal efficiency in the triggering cycle (T0). ADC sampling phase, \( \Phi_{ADC} \), and PGA latching phase, \( \Phi_{FE} \), should then be adjusted consequently.
- There are 2 quantities of interest:
  - The charge asymmetry, \( A[dT_0] = (Q_{T0} - Q_{Next1})/(Q_{T0} + Q_{Next1}) \), which is a measurement of the time difference, \( dT_0 \), between the scintillation signal start and the VFE integration start.
  - The spillover ratio, \( \alpha = Q_{Next1}/Q_{T0} \), once the detector alignment has been tuned.

*Schematic of the DAQ chain*
**Commissioning Goals and Strategy**

- **Goals:**
  - **Time align** the 100 PS VFE boards. Tune $\Phi_{VFE}$ for the best signal efficiency. Then measure spillover ratio.
  - Tune the **charge response for the** 6016 PS channels ($1 \text{ MIP} = 10 \text{ ADC at output of PS FE}$). This can be done by:
    1. Modifying the MAPMT HV which controls a group of 64 channels.
    2. Adjusting the PS FE gain for each 64 channels of a board. But these gain values can be set in the range $[1;2]$ only.
  - **Synchronise the trigger** data by tuning phasers (interplay of various electronics).

- **Strategy:**
  - Precalibration with **cosmics data**. 1.5 M events with a CALO only trigger (coincidences on ECAL+HCAL at a rate of $\sim 10 \text{ Hz}$) + track reconstruction from CALO clusters.
  - **Fine calibration with Collisions:**
    1. Dedicated timing runs with global time shifts of the CALO. Allows to measure the integrated charge shape as time for the PS.
    2. Use of LHCb tracking system for a clean selection and reconstruction of MIP events.
Time Inter alignment: Crosscheck with Cosmics

- **1st synchronise VFE channels** by delaying the integration start time from the time the light takes to travel from the scintillator cell to the MAPMT, **according to measurements of optical fibres lengths**.

  ⇒ **cross check results with cosmics data**. Compare the signal start time given by PS charge asymmetries to the one given by ECAL asymmetries and extrapolated to the PS plan.

- **Preshower channels are found to be synchronised within ±2 ins** without any additional tunings than the measured optical fibres lengths. Note that a typo in the length measurements was spotted by the way

![Graph showing time difference in ns against VFE board (outer part only)](image)
Time Alignment: the Cell Size Effect

- From dedicated timing runs with collisions it was checked that the charge signal is slower in Outer (large) cells than in Inner cells (small). It results in a 2 ns systematic time shift on the signal rise time.

![VFE average signal shape in Outer, Middle and Inner cells](image)

**INNER:** $\delta T = 0.0$ ns  
**MIDDLE:** $\delta T = 0.4$ ns  
**OUTER:** $\delta T = 2.3$ ns
Fine Time Alignment with Collisions

- Taking the signal shapes differences into account as well as time of flight differences from IP, the various VFE are finally time aligned within ±1 ns.
  - One even sees the skew of the RJ45 cables providing the clocks to the 2 chips of the VFE (damier like structure).

Map of PS channels relative timings

Distribution of PS VFE relative timings

Settings within ~1ns!
σ = 0.4 ns
Spillover Ratio

- Spill over ratio to be extracted channel per channel. Requires to select energetic events (> 10 MIPS) as the spillover ratio can be as low as 5% ⇒ analyse high statistic (ongoing).

PDF of average spillover ratio per regions. Note that individual channels have a thinner distribution with typically 3% standard deviation.
MIP Scale Precalibration with Cosmics

- **Scale the cosmics track charge by the track length** to get a dE/dx signal because the typical cosmic track makes a ~45° angle as respect to beam like events. *(5-45% correction)*.
  - Fit the resulting scaled charge distribution to Landau⊗Gauss for each cell and extract the most probable scaled charge value.
  - Tune MAPMT HV to uniformise the average response per MAPMT
  - Adjust the gains within a FE to uniformise the 64 channels response.

⇒ 99 % of Outer channels could be tuned. The lack of statistics in Inner (smaller cells) increases the measured channels dispersion.

### Typical cosmics dE/dx distribution for an Outer cell of the Preshower

![Typical cosmics dE/dx distribution for an Outer cell of the Preshower](image)

### Gain corrections in FE is within 1-2

- 99 % Outer
- 95 % Middle
- 90 % Inner

### Normalised ADC counts

![Normalised ADC counts](image)

### Gain within PS FE

![Gain within PS FE](image)
MIP Scale Calibration: Tracking Collisions

- **Use any reconstructed track which extrapolation Hits the Preshower**
  - Normalise the charge by the track length as extrapolated from the tracking.
  - ⇒ Compare to the **precalibration with cosmics tracks: non uniformity** ($\sigma/\mu$) for channels response to MIP is **10% in Outer** to 16% in Inner. There is a **20% systematic offset with the cell size**.

![Graphs showing charge distribution for extrapolated tracks](image)

- **MIP most probable normalised charge** after precalibration with cosmics (target was 20 ADC = 1 MIP)
- **Typical charge distribution for Extrapolated tracks**
Commissioning of the Trigger Path

- Electron and Photon candidates using SPD+PS+ECAL
  - Compare the decoding of L0 CALO response to an emulation using the DAQ information.

**Errors Map**

**Candidates Map**
Conclusion and Outlooks

- Cosmic data provided a useful precalibration of the preshower:
  - Timing were checked to be consistent with optical fibres length within 2 ns.
  - Channels response to MIP’s was uniformised to ~10% in Outer (16% in Inner, less statistic) and absolute scale was accurate within 20%.

- 1st collision events allowed us to refine our settings:
  - Dedicated time scan runs allowed to tune timings at ± 0.5 ns accuracy while understanding our last systematics: signal shape differences with the cell size.
  - The more accurate information from LHCb tracking together with the higher statistics should allow us to further reduce our non uniformities on MIP scale to a few percent accuracy.

- Further work focuses on:
  - Accurately measuring spillover corrections channel per channel.
  - Measuring the sampling fractions α and β in ECAL and Preshower (e.i. using π⁰ events).
  - Fine tuning the Preshower for the L0 trigger path (Ongoing).
The LHCb Detector

- **Single Arm Forward Spectrometer:**
  - Peculiar pseudorapidity Coverage: $1.9 < \eta < 4.9$

- **Dedicated to Precision Studies of $b\bar{b}$ Pairs:**
  - Forward/backward production of $b\bar{b}$ @ ~ 100 kHz
  - 1 pp interaction / crossing (beam less focused)
Charge Asymmetry and Integration Time

The curve is from LHCb MC which was tuned according to Test Beam data.
MIP Scale Calibration: Comparison to Energy Flow

- **CALO only precalibration of energy scale using energy flow method.** Assume:
  - A smooth deposit. The deposit in one cell can be approximated by the mean of deposits over its 8 neighbours.
  - A Left/Right symmetric detector.

Average over neighbour/symmetric cells ⇒ **filter out uncorrelated biases.**

- The **correlation** of the gains corrections (2009 data vs 2010 data) extracted from Energy Flow and from the fit to MIP’s varies from 77% in the Inner to 54% in the Outer (small corrections for the latter).

Correlation plot of gain factors determined by energy flow and a fit to MIP’s (x and y axis are in units of standard deviations).