Commissioning of the LHCb Preshower

With Cosmic Rays and First LHC Collisions

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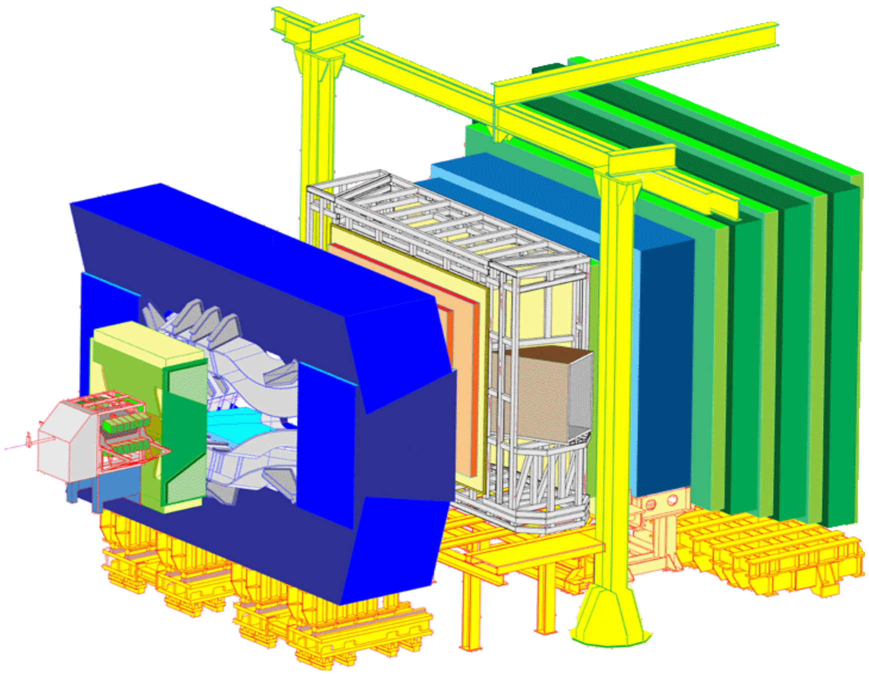
Outlines

- **Overwiew 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

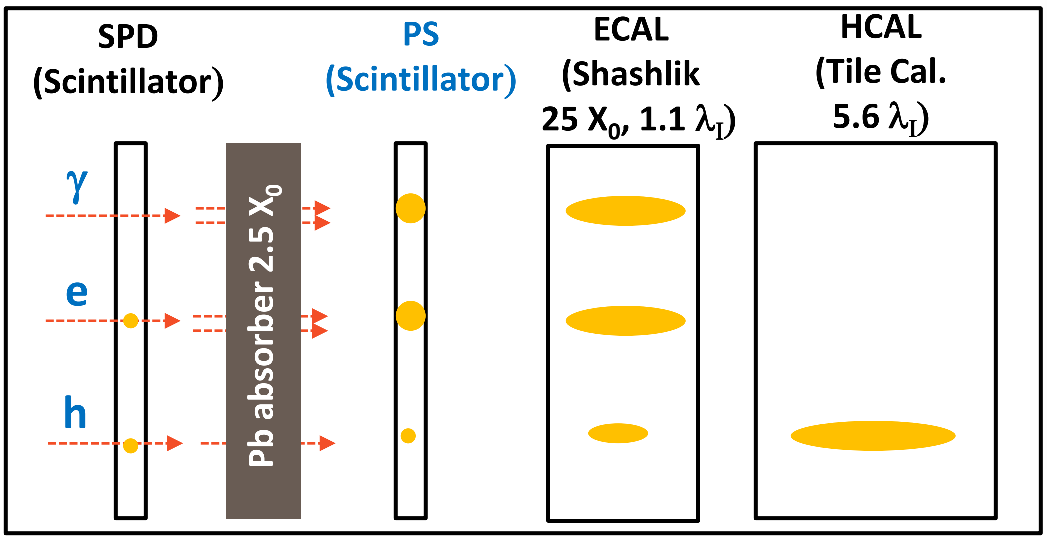
- **Interplay of 4 sub-detectors in a row:**

  Scintillator Pad Detector (SPD), **Preshower (PS)**, Electromagnetic (ECAL) and Hadronic (HCAL) calorimeters divided in projective cells with their **dedicated electronics**.

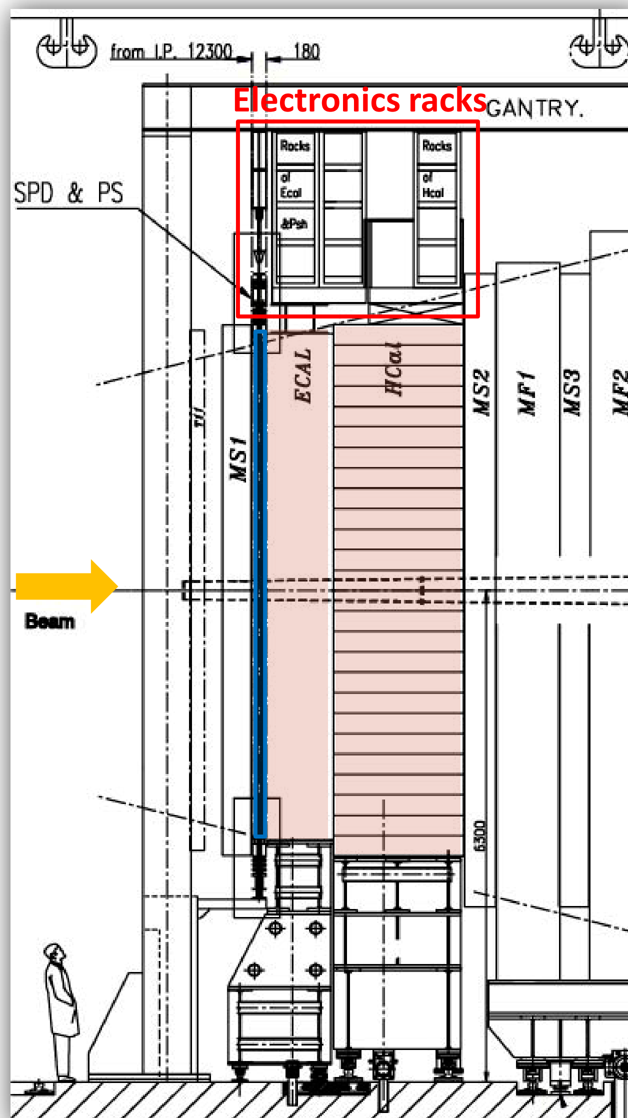
- **Role is double:**
  - Key Part of the **L0 trigger** @ 40 MHz:

  identify **high P_T h**, **e**, **γ** 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



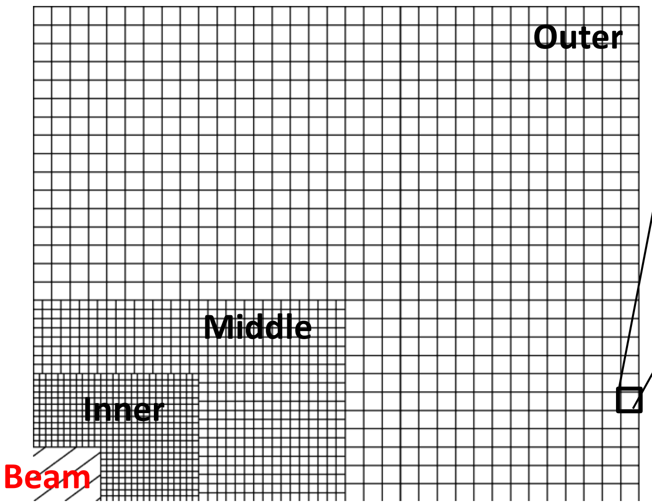
Side view

The Preshower: Detector and VFE Electronics

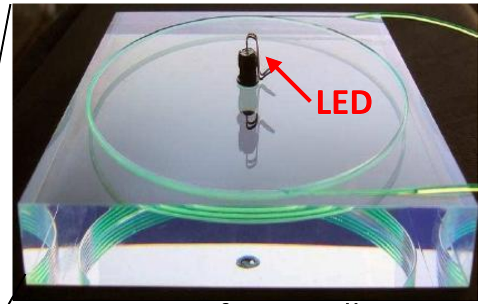
6016 Cells of 15 mm thick Polystyrene Scintillator Pads

3 Granularities: Inner 4×4 cm^2, Middle 6×6 cm^2, Outer 12×12 cm^2

WLS fibres are used to collect the light



¼ view of a of full scintillator plan



View of a scintillator Pad

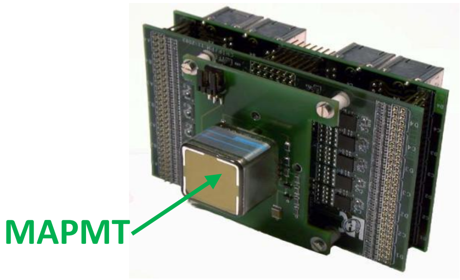
Bundles of clear fibres carry the light to **MAPMT**'s located in shielded boxes at the top & bottom

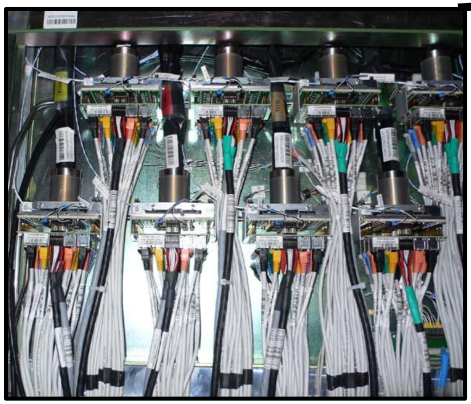
\+ **Embedded LED**'s for monitoring

100 Multi Anode PMT:

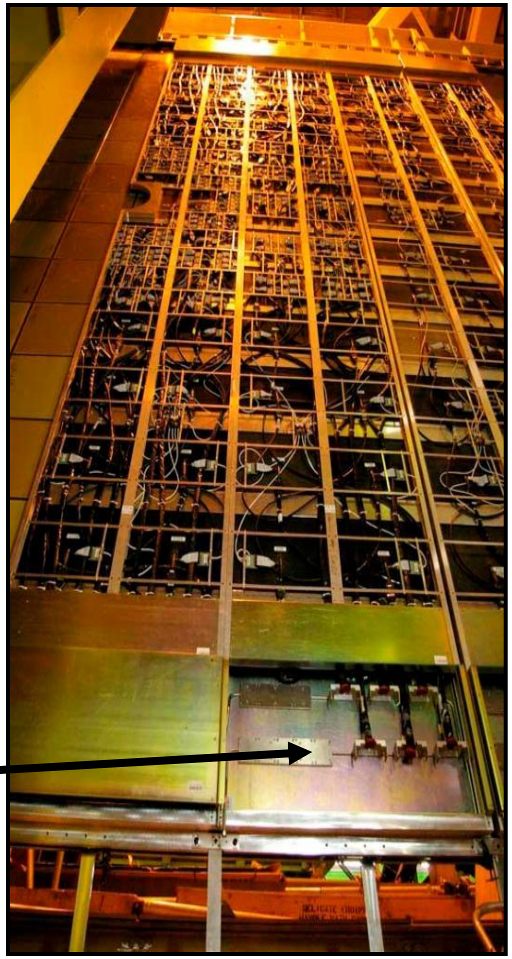
Handling clusters of 8×8 = 64 PS channels mounted on **VFE electronic boards:**

2 chips integrating light signal alternatively **@ 40 MHz** (no dead time)





View of an equipped VFE box



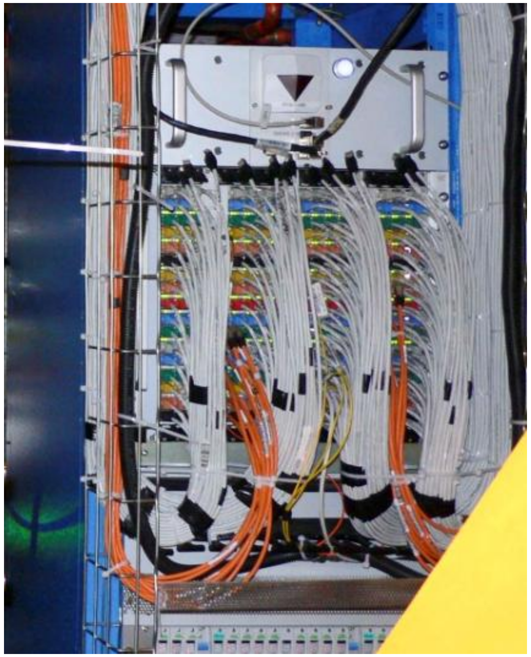
Back view of pads plan

THE PRESHOWER: DETECTOR AND VFE ELECTRONICS

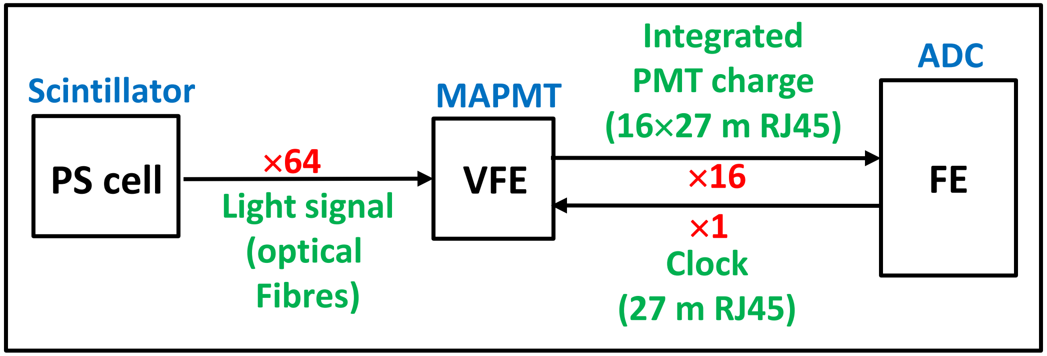
The Preshower: Front End Electronics

- **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

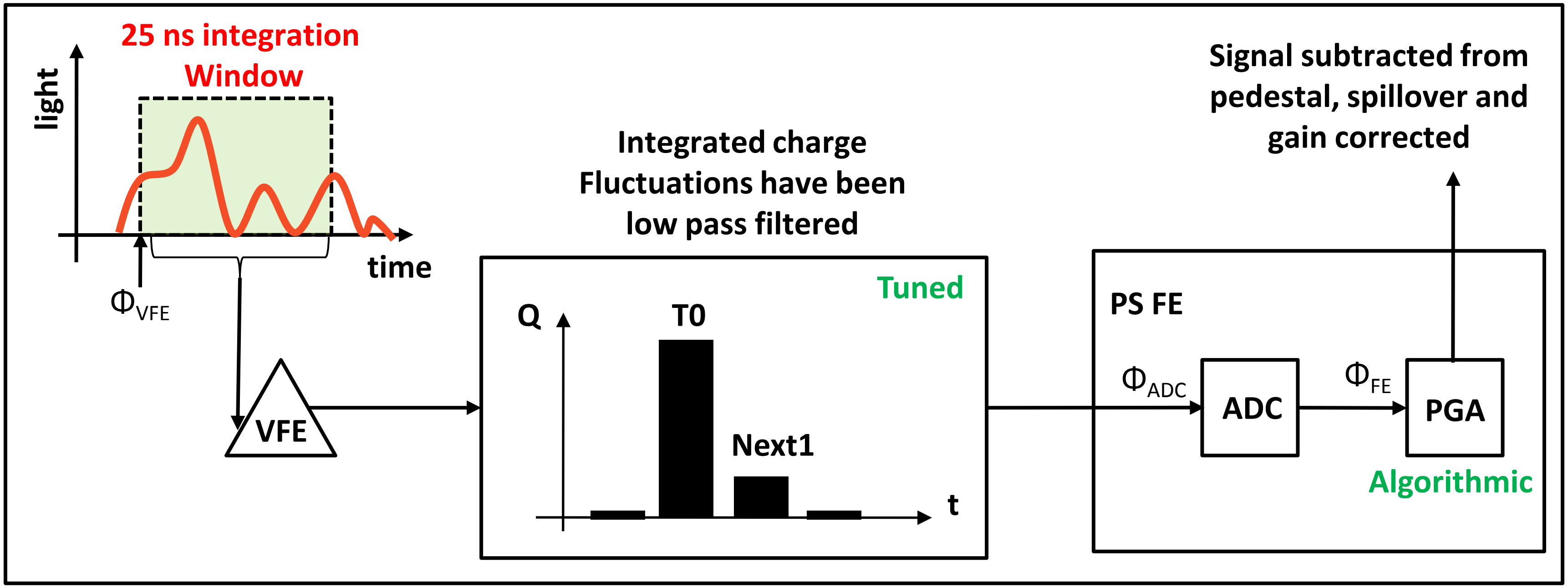


Schematic of the connections between PS cells, VFE and FE

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

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, Φ_{VFE}, has to be tuned to get a **maximal efficiency in the triggering cycle (T0).** ADC sampling phase, Φ_{ADC}, and PGA latching phase, Φ_{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 Φ_{VFE} for the best signal efficiency. Then measure spillover ratio.
  - Tune the **charge response for the** 6016 PS channels (1 MIP = 10 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).

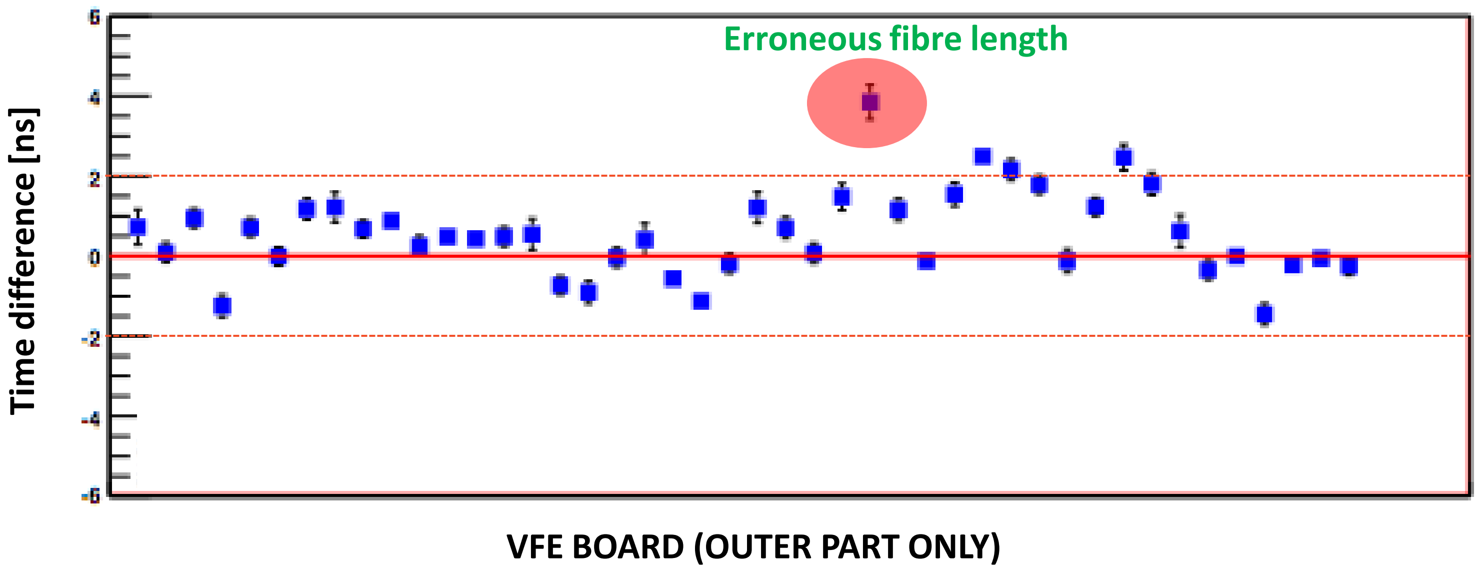
- **Strategy**:
  - Precalibration with **cosmics data**. 1.5 M events with a CALO only trigger (coincidences on ECAL+HCAL at a rate of ~10 Hz) + track reconstruction from CALO clusters.
  - **Fine calibration with Collisions**:
    1) Dedicated timing runs with global time shifts of the CALO. Allows 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**.

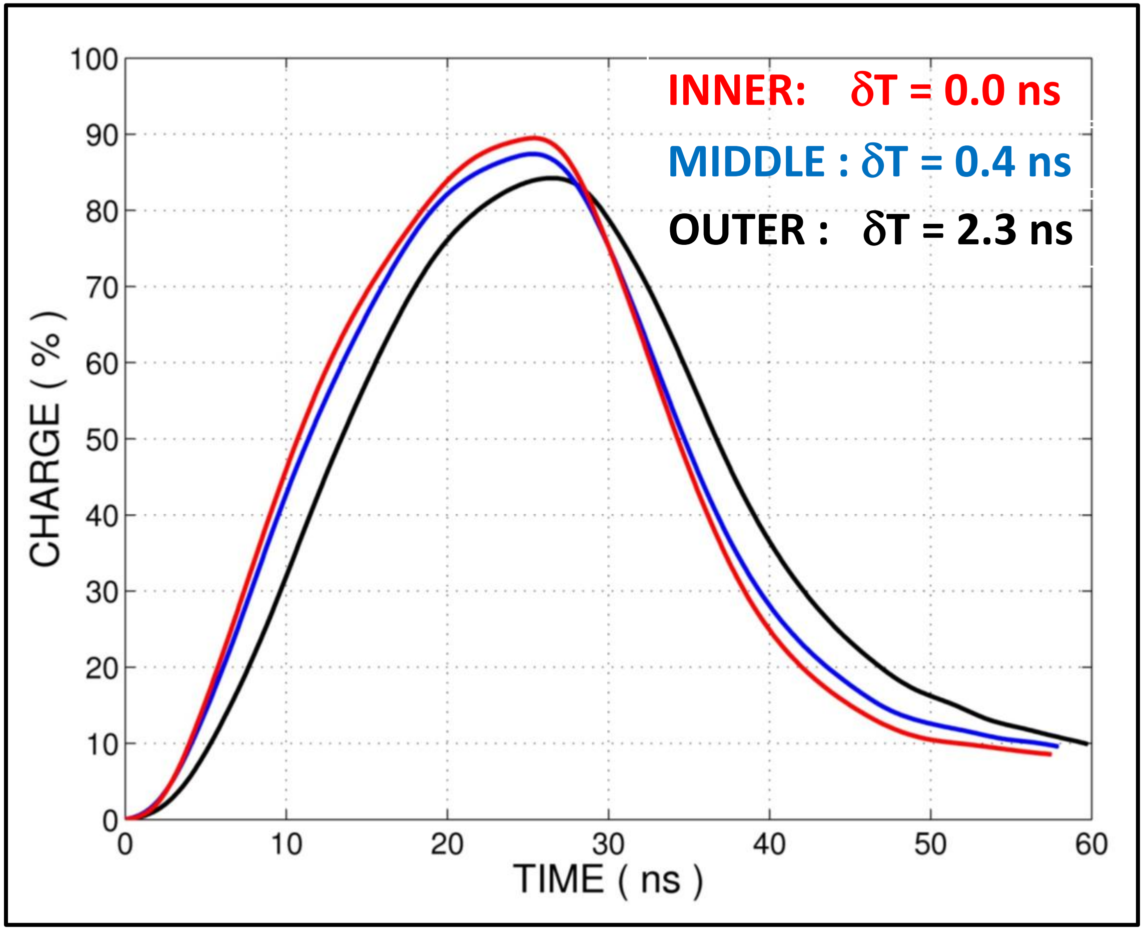
⇒ **cross check results with cosmics data**. Compare the signal start time given by PS charge asymmetries to the one given by ECAL asymmetries and extrapolated to the PS plan.

❑ **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



Time Alignment: the Cell Size Effect

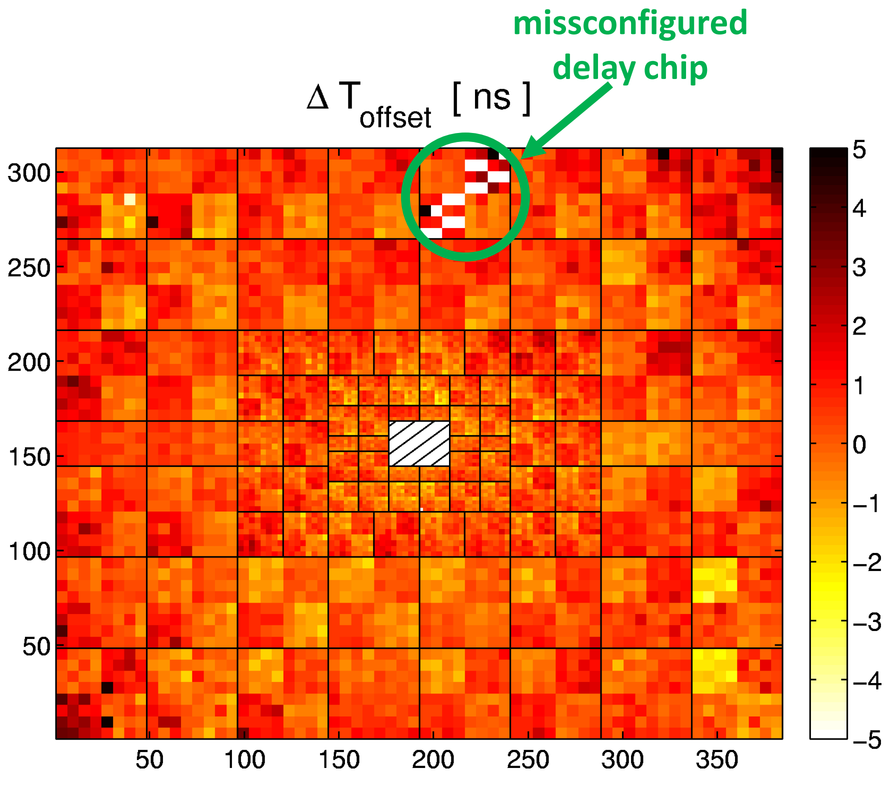
- From dedicated timing runs with collisions it was checked that the **charge signal is slower in Outer** (large) cells **than in Inner** cells (small). It results in a **2 ns systematic** time shift on the signal rise time.



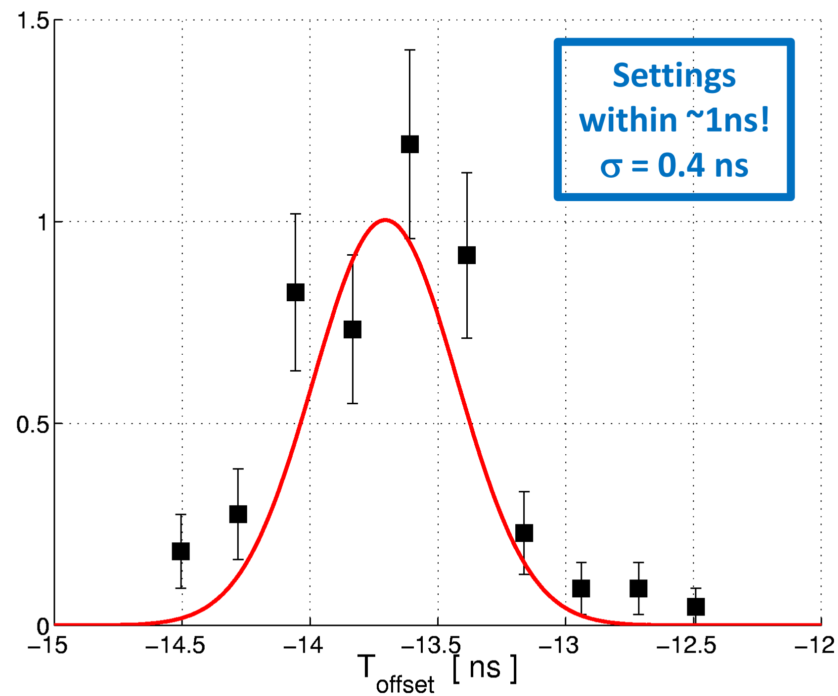
VFE average signal shape in Outer, Middle and Inner cells

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).



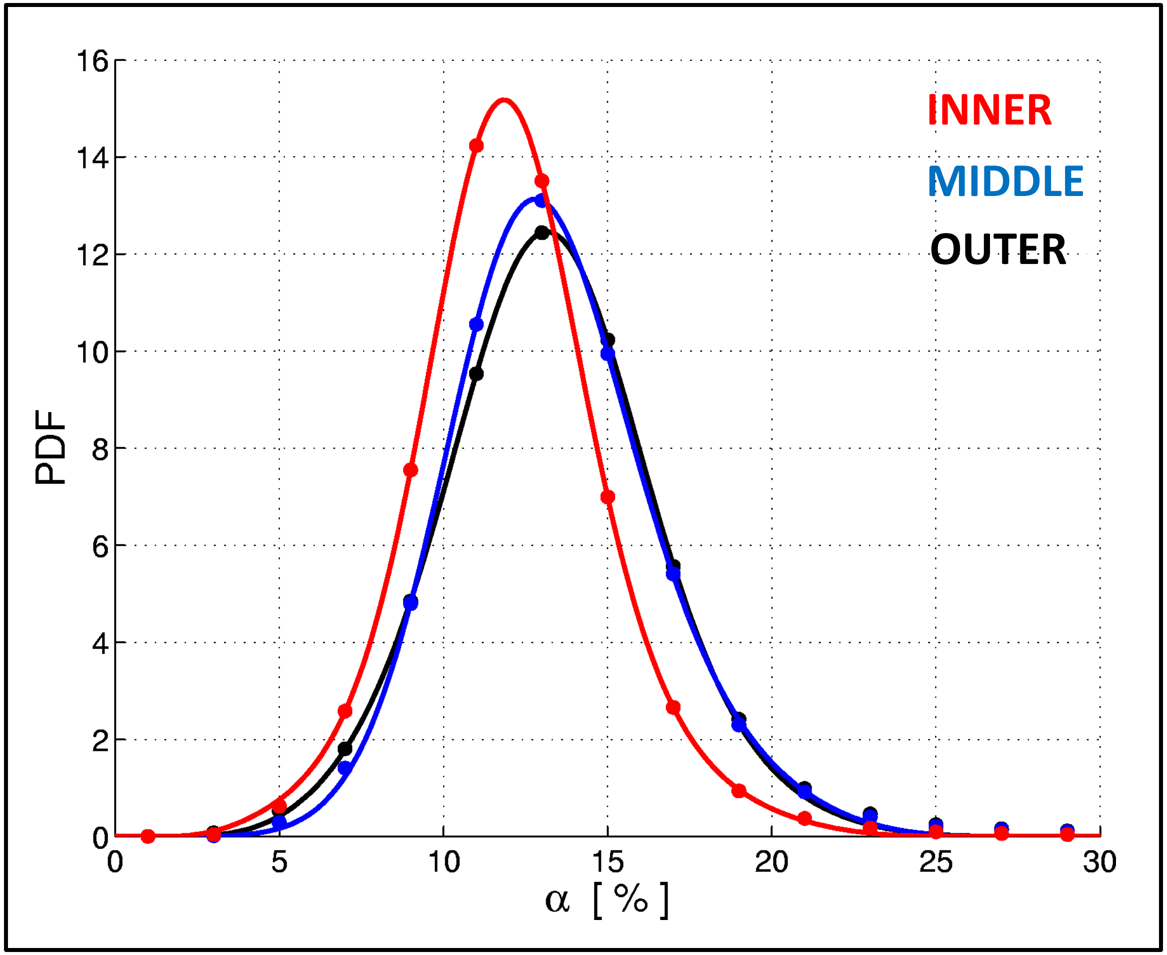
Map of PS channels relative timings



Distribution of PS VFE relative timings

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).



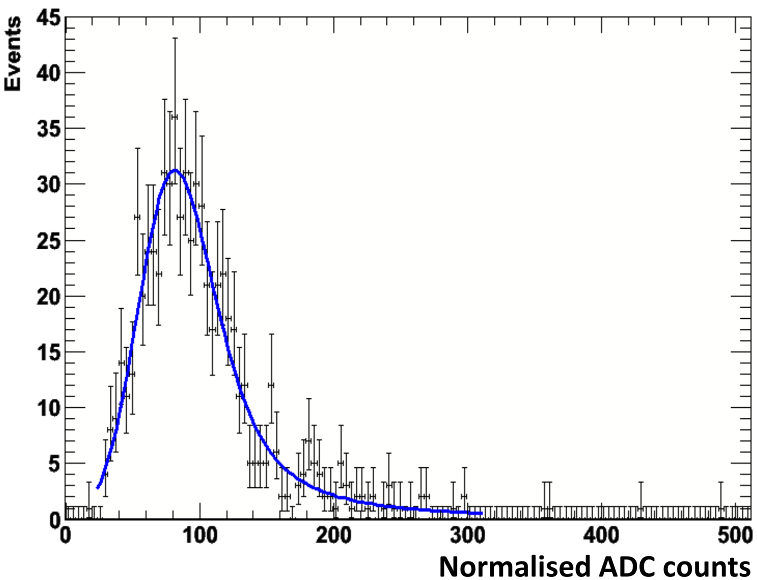
PDF of average spillover ratio per regions. Note that individual channels have a thinner distribution with typically 3% standard deviation.

MIP Scale Precalibration with Cosmics

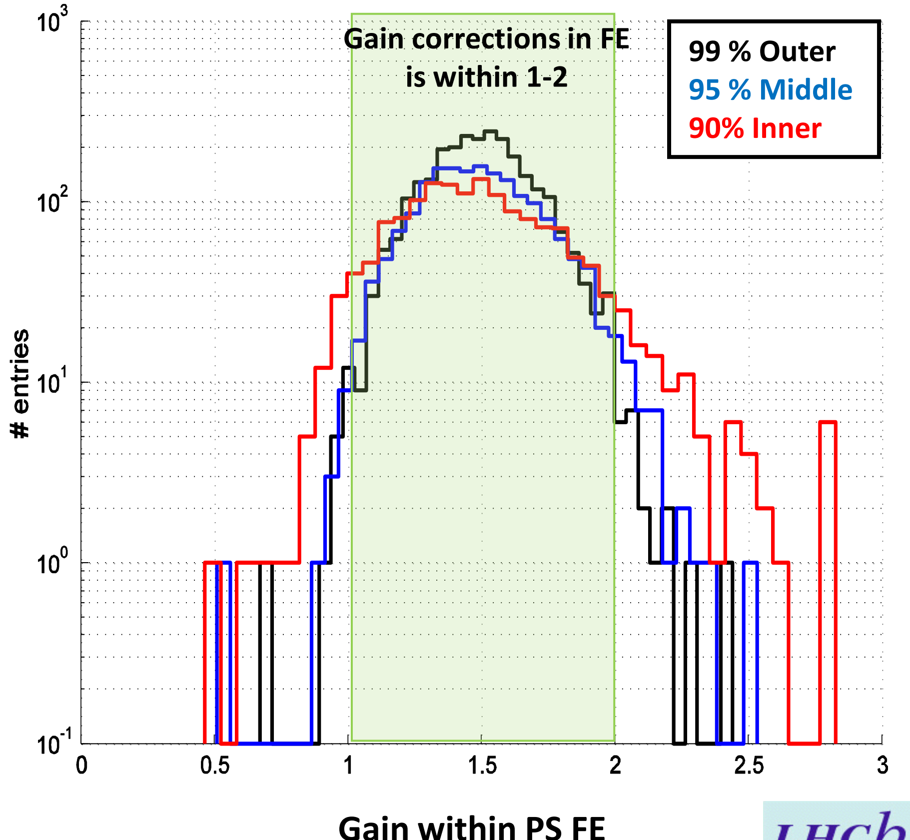
❑ **Scale the cosmics track charge by the track length** to get a dE/dx signal because the typical cosmic track makes a ~45° angle as respect to beam like events. (**5-45% correction**).

- 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



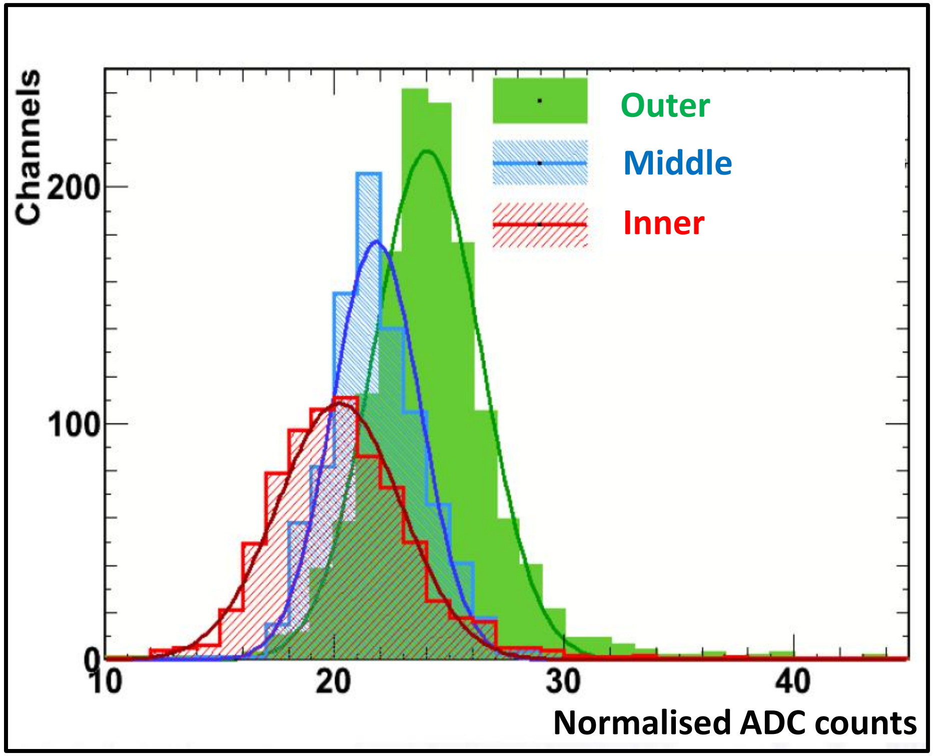
Typical cosmics dE/dx distribution for an Outer cell of the Preshower



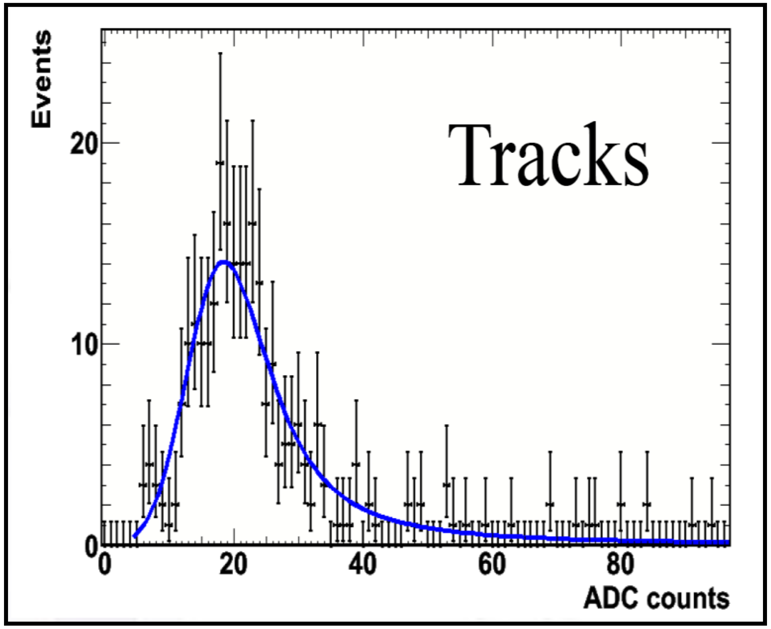
MIP Scale Calibration: Tracking Collisions

- **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** (σ/μ) for channels response to MIP is **10% in Outer** to 16% in Inner. There is a **20% systematic offset with the cell size**.



MIP most probable normalised charge
after precalibration with cosmics (target was 20 ADC = 1 MIP)



Typical charge distribution for
Extrapolated tracks

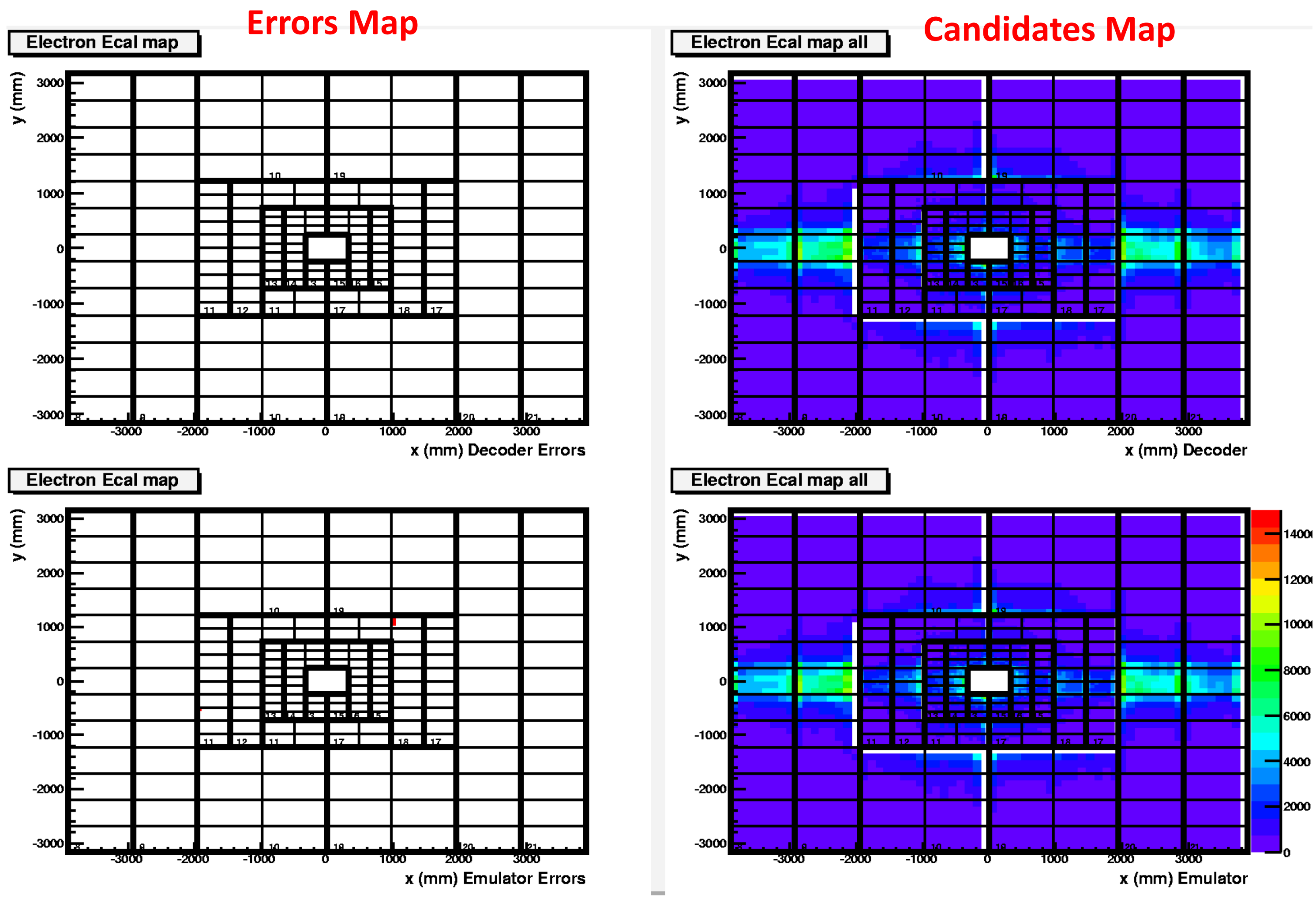
Commissioning of the Trigger Path

❑ Electron and Photon candidates using SPD+PS+ECAL

- Compare the decoding of L0 CALO response to an emulation using the DAQ information.

Trigger Path (Decoding)

DAQ Path (Emulation)



Conclusion and Outlooks

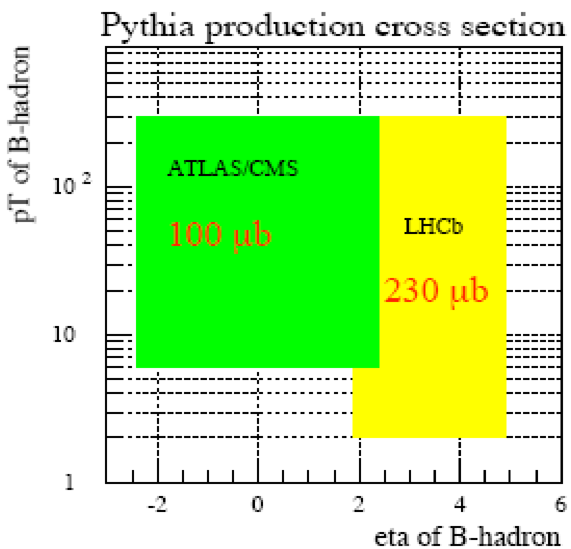
- **Cosmic data provided a useful precalibration of the preshower**:
  - **Timing** were checked to be consistent with optical fibres length within **2 ns**.
  - Channels response to MIP's was **uniformised to ~10%** in Outer (16% in Inner, less statistic) and **absolute scale was accurate within 20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

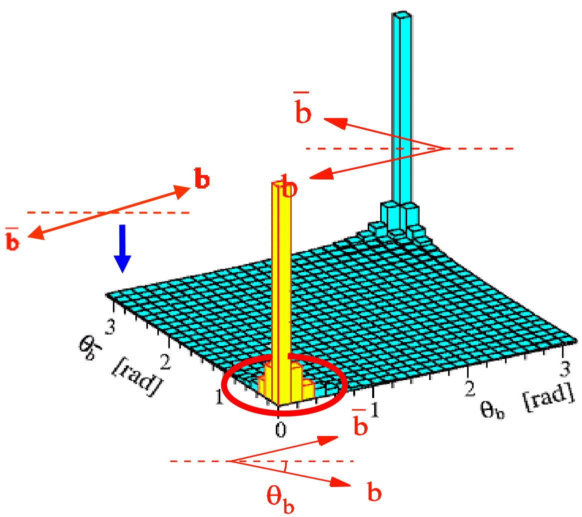
- **1^{st} collision events allowed us to refine our settings**:
  - Dedicated time scan runs allowed to tune **timings at ± 0.5 ns** accuracy while understanding our last systematics: signal shape differences with the cell size.
  - The more accurate information from LHCb tracking together with the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

- **Further work focuses on**:
  - Accuratly measuring spillover corrections channel per channel.
  - Measuring the **sampling fractions** α and β in ECAL and Preshower (e.i. using π^0 events).
  - **Fine tuning** the Preshower for **the L0 trigger path** (Ongoing).

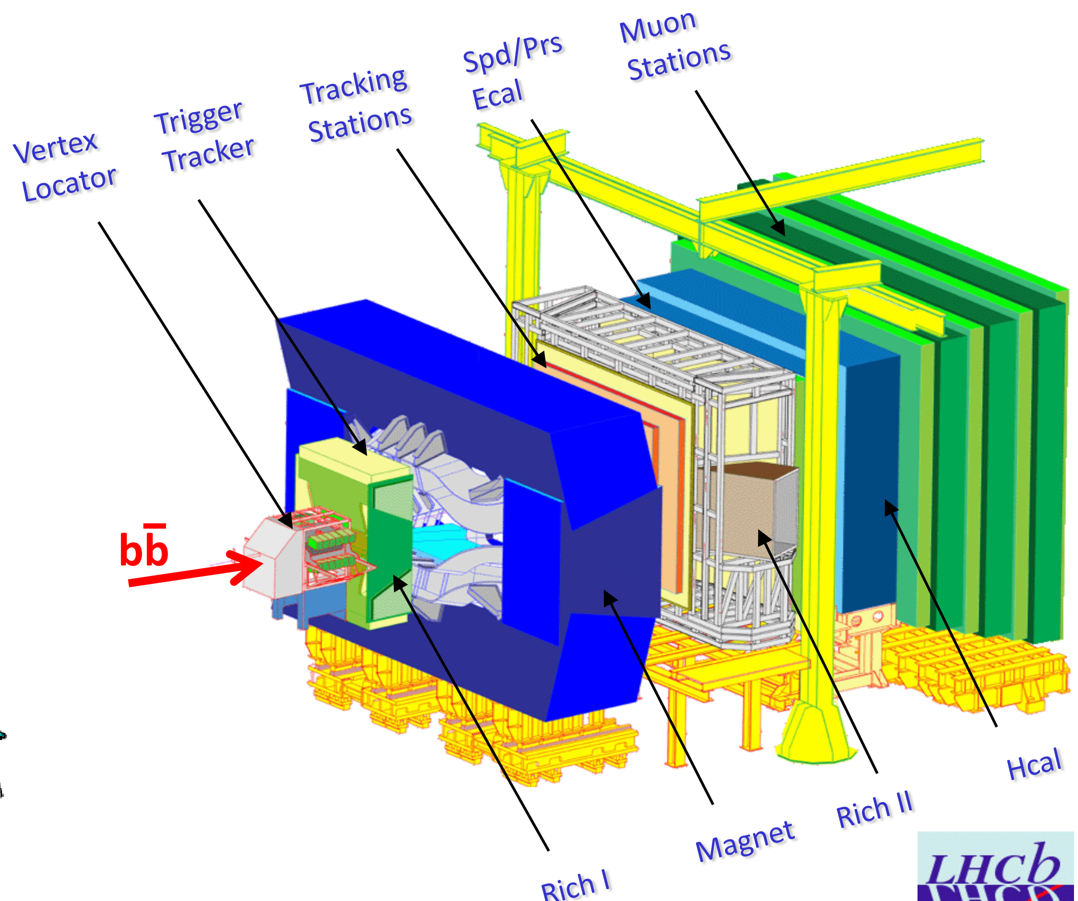
The LHCb Detector

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



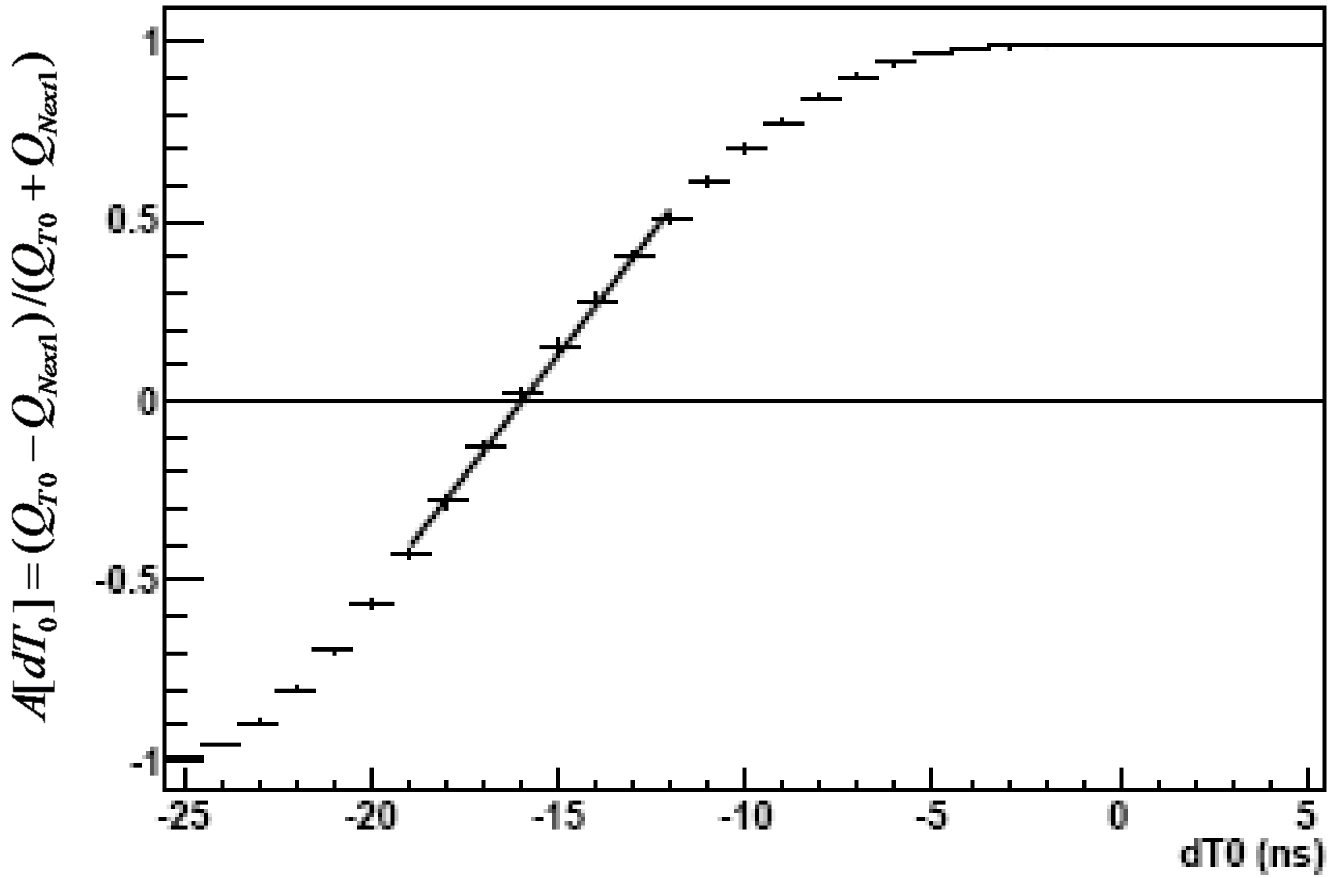


- **Dedicated to Precision Studies of $b\bar{b}$ Pairs:**
  - Forward/backward production of $b\bar{b}$ @ ~ 100 kHz
  - 1 pp interaction / crossing (beam less focused)



Charge Asymmetry and Integration Time

The curve is from LHCb MC which was tuned according to Test Beam data

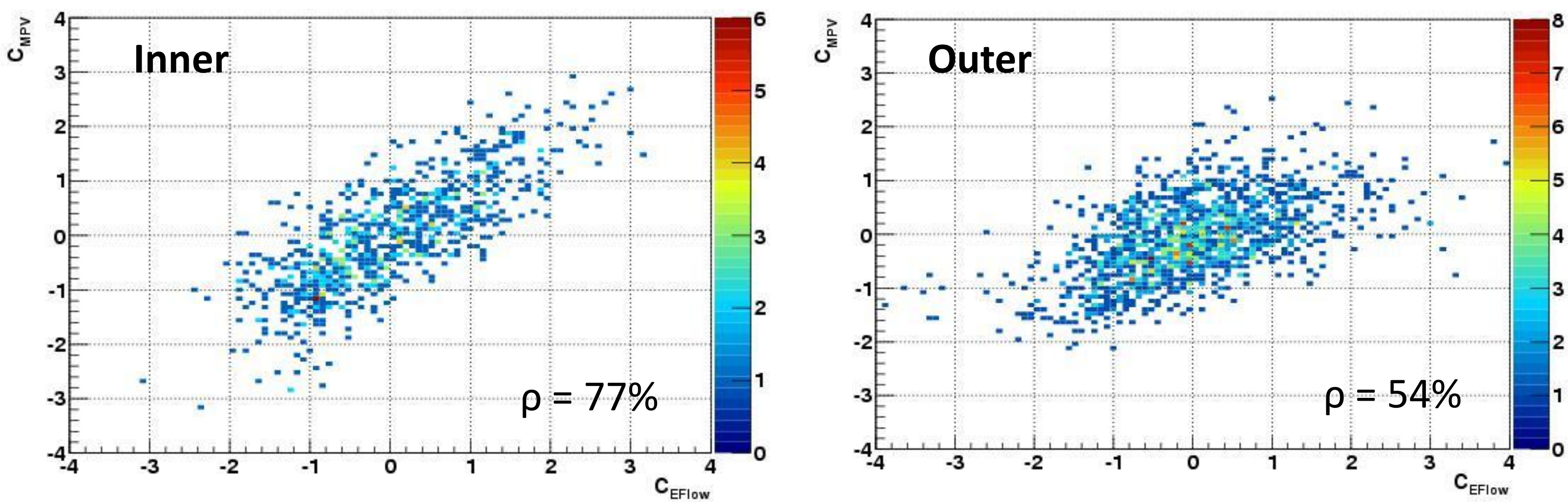


MIP Scale Calibration: Comparison to Energy Flow

- **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).