Hit Time Calibration using Beam Interface Information

Summer Project Report

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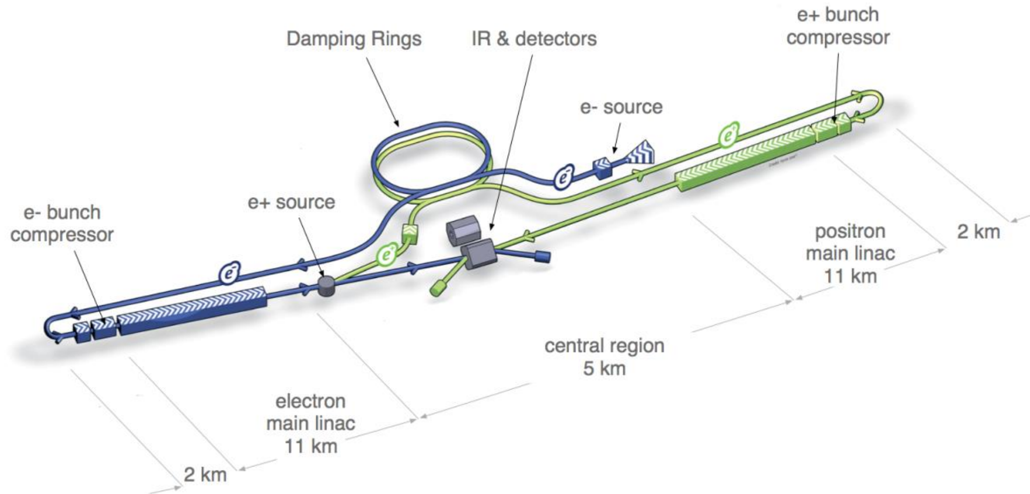
FLC Group Meeting, 5.9.2016

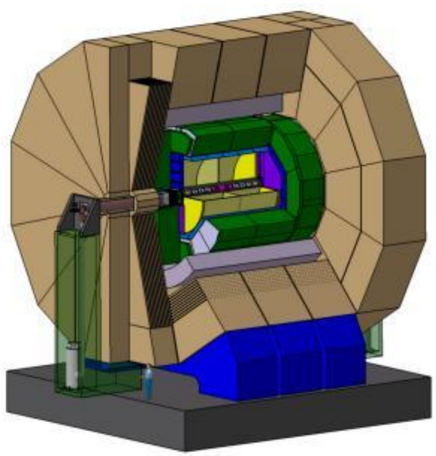
Project aims

- Conversion of hit time measurements in TDC to real time values (ns)
- Channel wise calibration
- Implement this functionality in the online monitor for the AHCAL

ILC & ILD

- International Linear Collider (ILC) – project for future lepton collider
- Electron-positron collider
- Collision energy of 500 GeV, upgradable to 1 TeV





- International Large Detector (ILD) – one of two detector concepts for ILC
- Detector for particle flow reconstruction: tracker providing very good momentum resolution with low material budget, highly granular calorimeters
- Analog Hadronic Calorimeter (AHCAL) is one of the hadronic calorimeter options for ILD

DESY

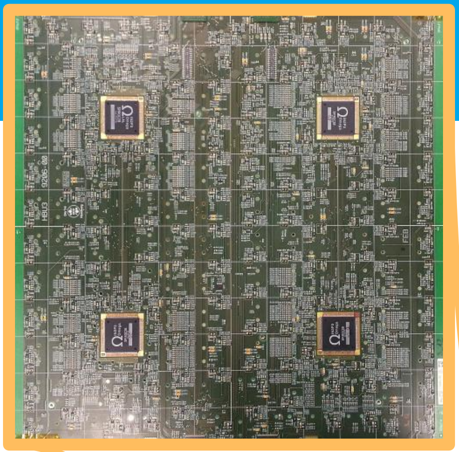
Analog Hadronic Calorimeter

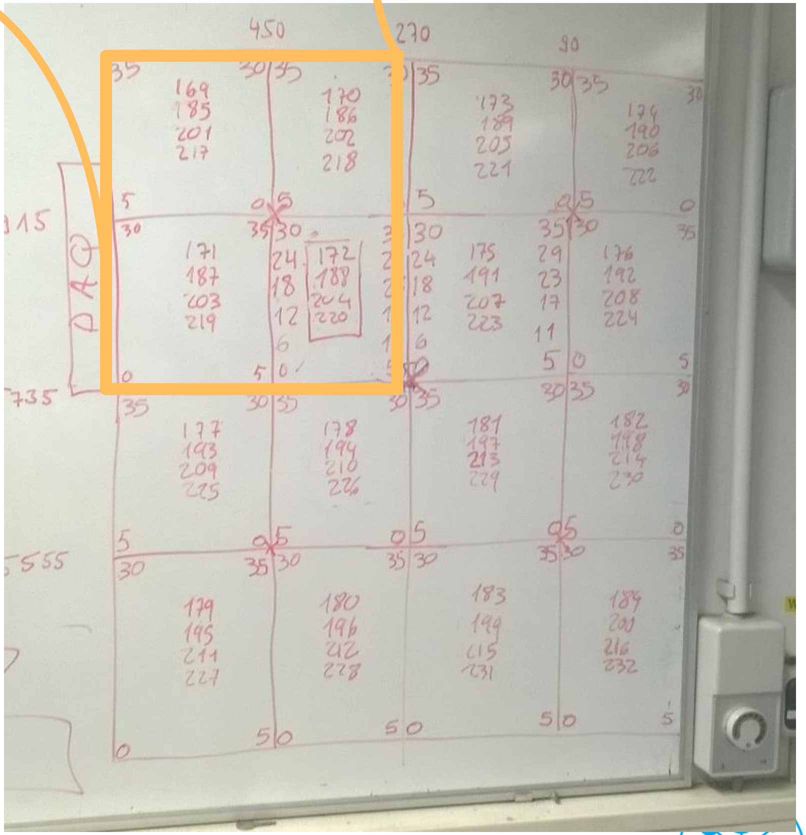
- Highly granular calorimeter developed by the CALICE collaboration

- Physics principles demonstrated by physics prototype

- Technological prototype stage, exploring:
  - Scalability of AHCAL
  - Capability to be mass produced
  - Integration of electronics into layers of the calorimeter

May 2016 Testbeam

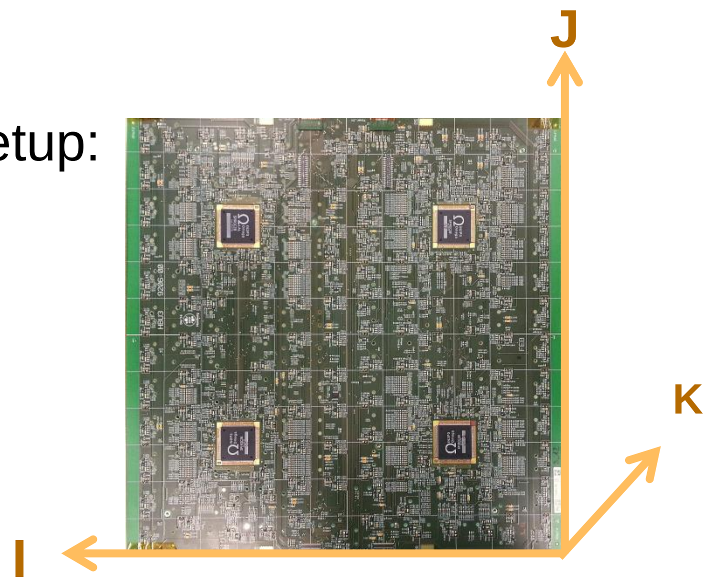




- 4^{th} – 9^{th} May testbeam with ‘big’ modules
  - 2 x 2 HBU layers
  - 4 layers
- Focus on MIP calibration & TDC calibration
- Beam Interface (BIF) included in setup
  - External, independent clock
  - Provides absolute time reference for hits
  - Data from BIF forms basis of hit time calibration

Data used for this project

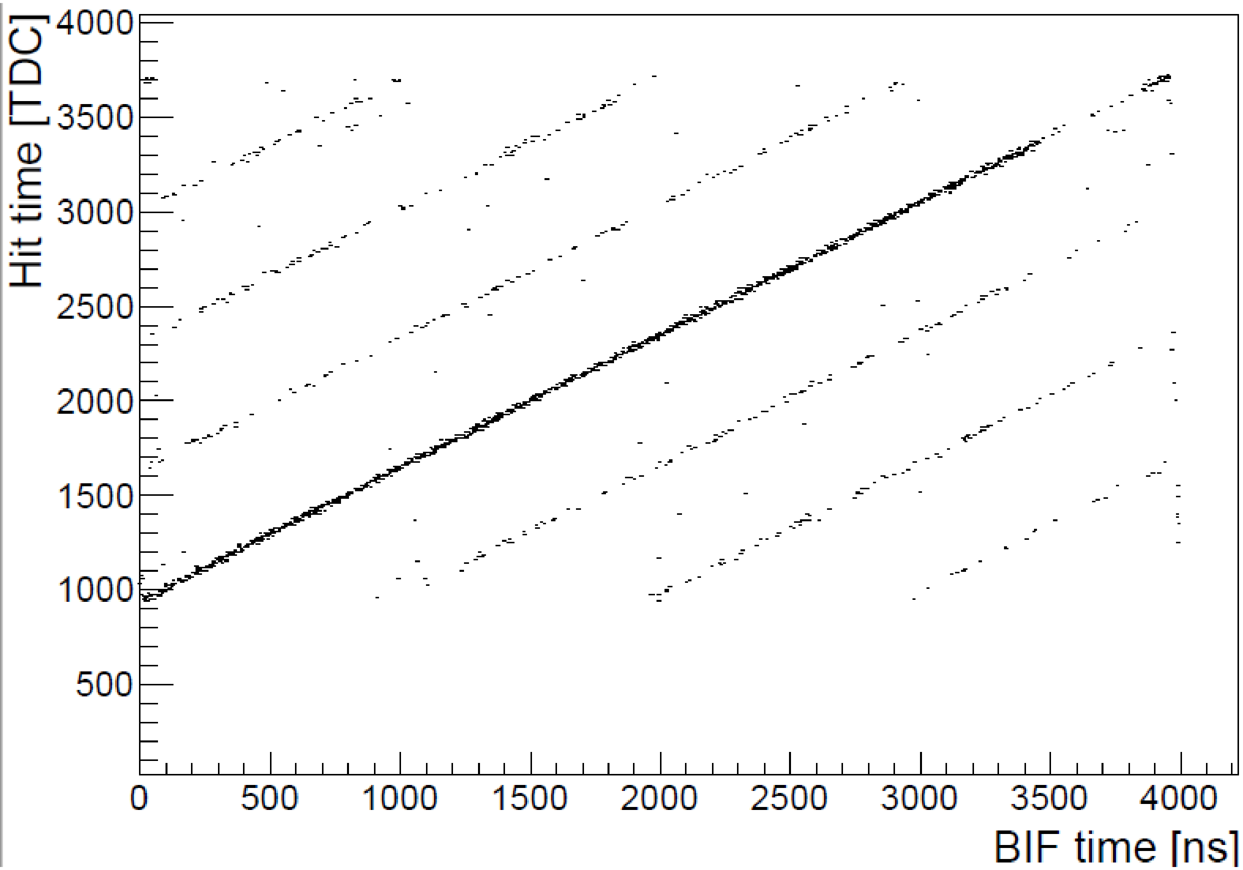
- Data used from Runs 41145, 41146 & 41175 from May testbeam
  - Combined runs 41145 & 41175 for this study
- Electron data
- Tile coordinates I, J & K identify position of hit in AHCAL
- For May 2016 setup:
  - I, J ∈ [1, 24]
  - K ∈ [1, 4]



TDC Calibration

- Time digital conversion (TDC) used to measure time of hit in AHCAL
- Time resolution important for AHCAL
  - Separation of events
  - Identification of jets
- One method is to correlate hit time data from AHCAL with information from BIF
- C++ programs written to perform analysis of hit time data from AHCAL and BIF
  - Make correlation plots of hit time in AHCAL & BIF data
  - Perform linear fit to data, record fit parameters
  - Convert hit time in AHCAL from TDC $\longrightarrow$ ns
  - Plot spectrum of (Hit time (ns) – BIF time)

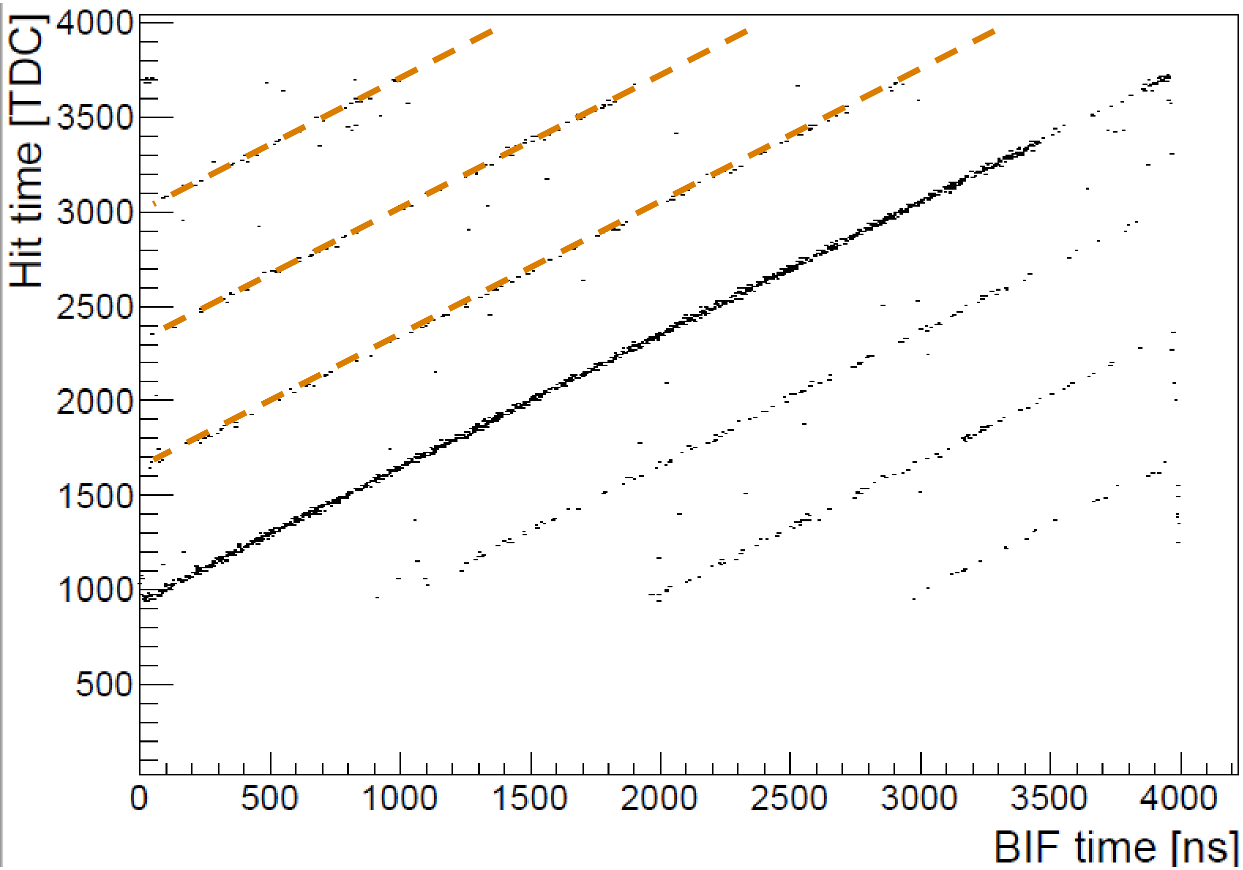
Correlation of AHCAL & BIF hit time



Example: Hit time vs BIF time for
[I=12; J=19; K=4; BXID=0]

- Channel by channel separation; labelled by
  - Tile coordinates (I, J, K)
  - Bunch crossing ID (BXID)
- Channels with >1000 entries used for further analysis
  - Combining runs for more statistics

Correlation of AHCAL & BIF hit time



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- 1 MHz DESY beam structure
- Miscorrelations due to ASIC missing trigger but SiPM recorded later events

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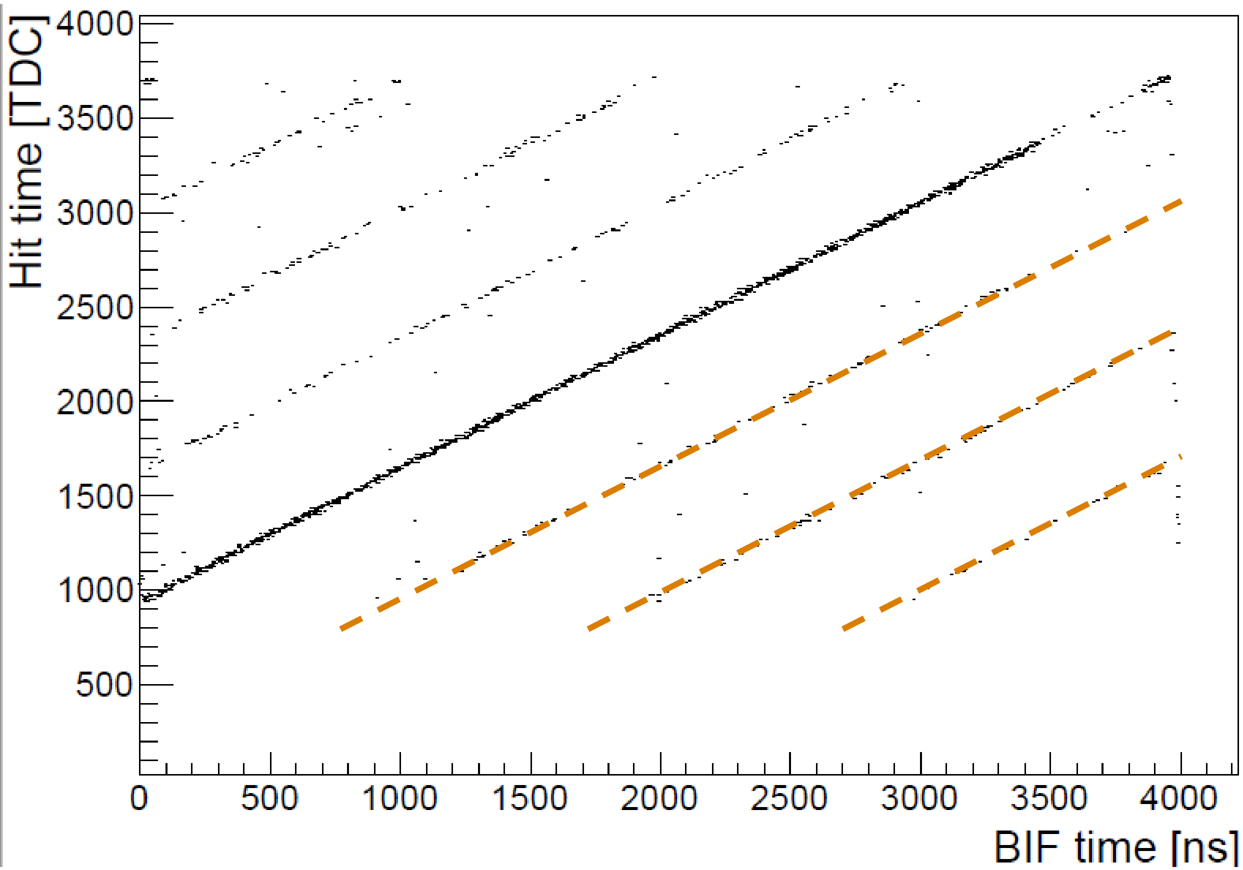

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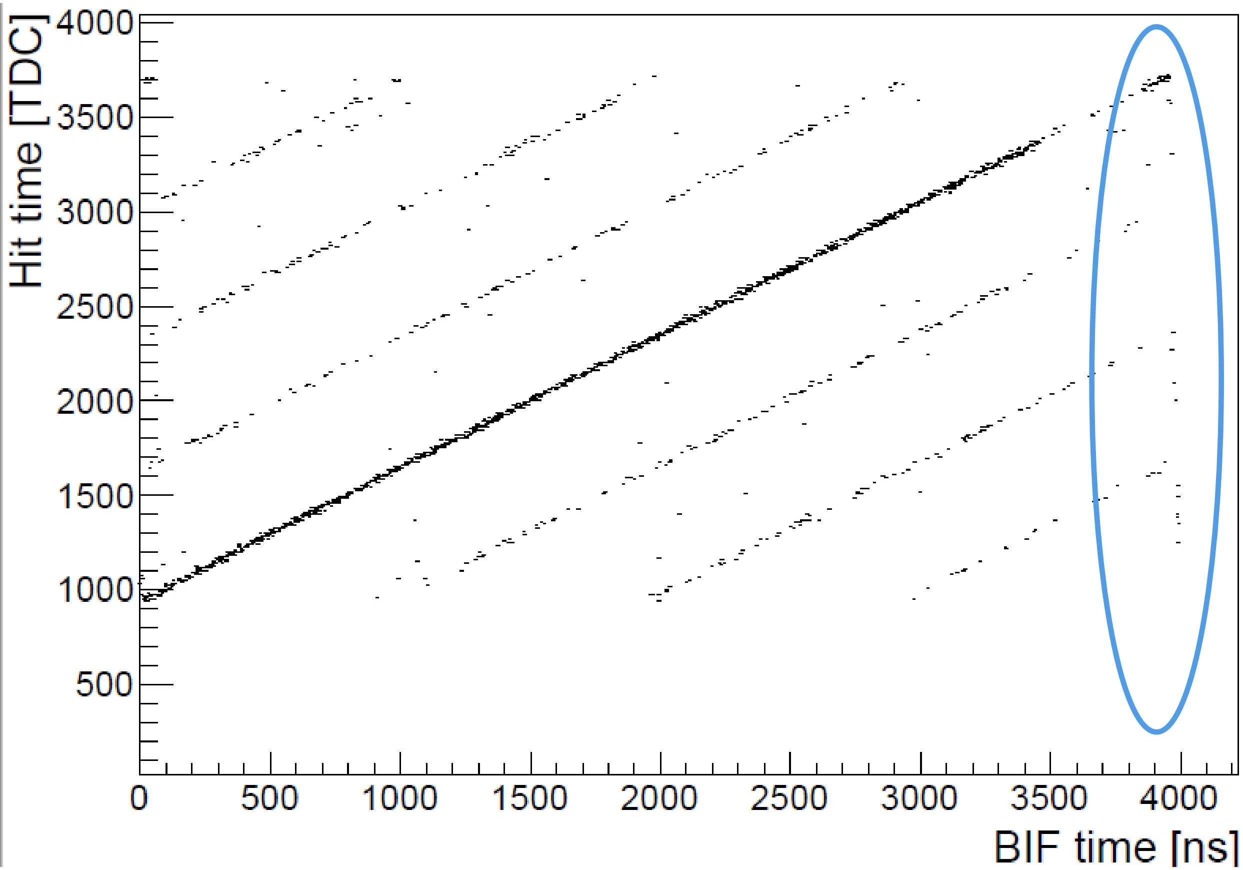

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- 1 MHz DESY beam structure
- Miscorrelations due to ASIC missing trigger but SiPM recorded later events
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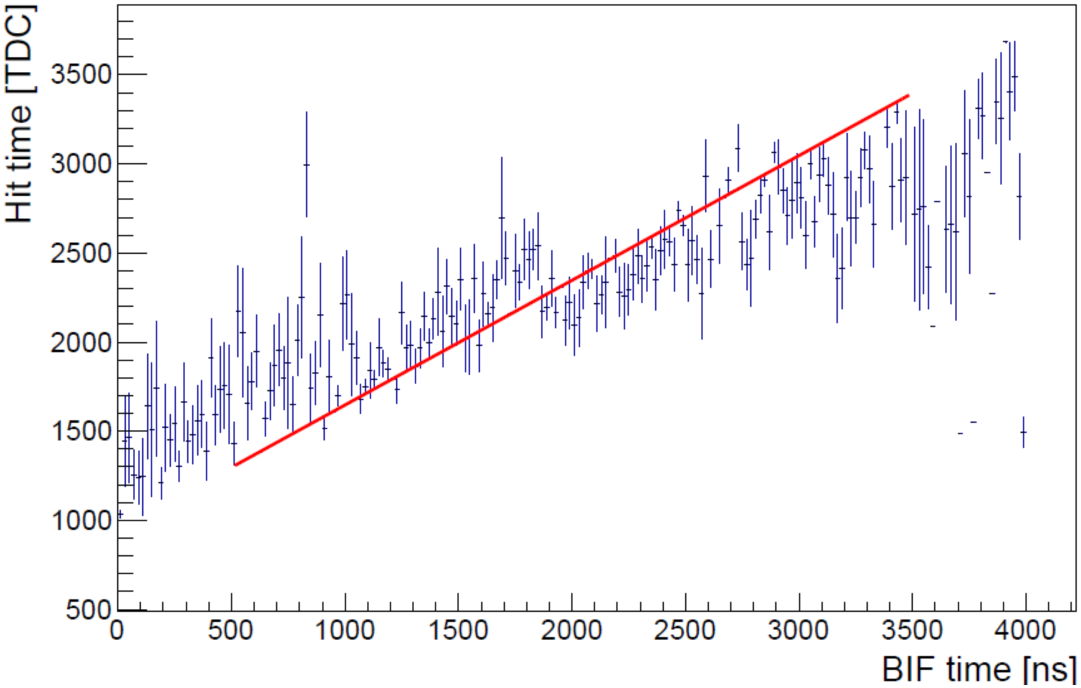
- Saturation & validation gap effect
  - Data ignored in further analysis

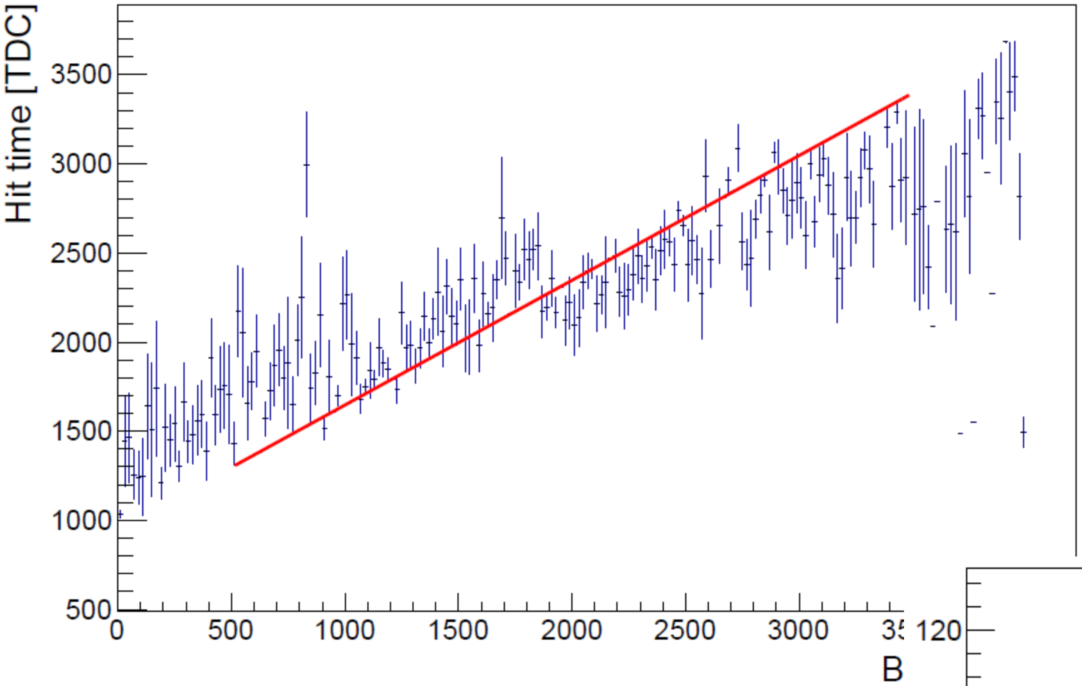
Fitting the Data



Profile histogram & fit for
[I=12; J=19; K=4; BXID=0]

- Straight line fitted to data for each channel, fit parameters recorded
- For this channel:
  - **χ^2 / ndf = 2.652**
  - **Offset = 947.541(±2.675) ns**
  - **Slope = 0.700(±0.001) TDC/ns**
- Line fitted in range [500, 3500] ns
- Outliers caused by miscorrelations

Fitting the Data



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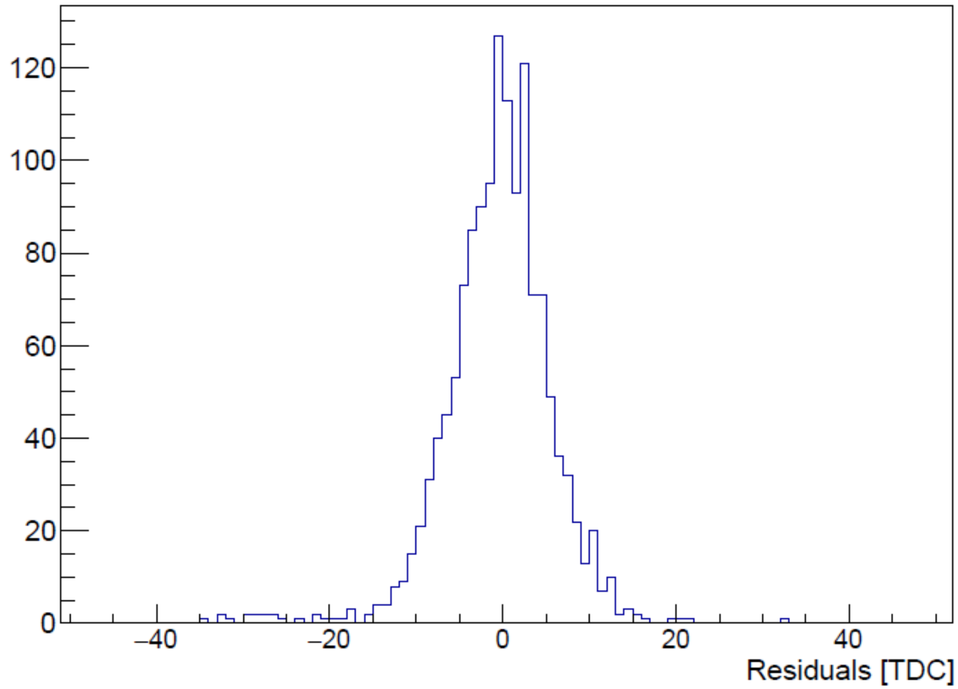
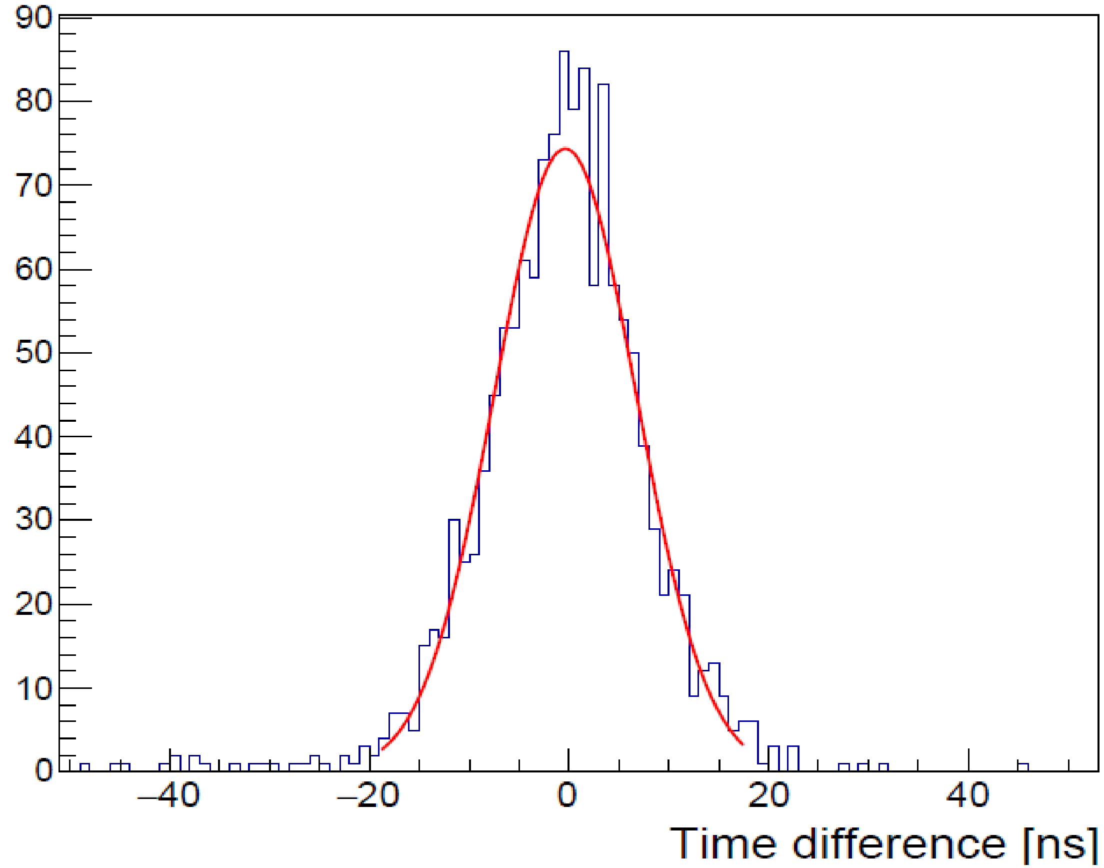


- Residuals show reasonably good fit to data

Conversion from TDC to ns

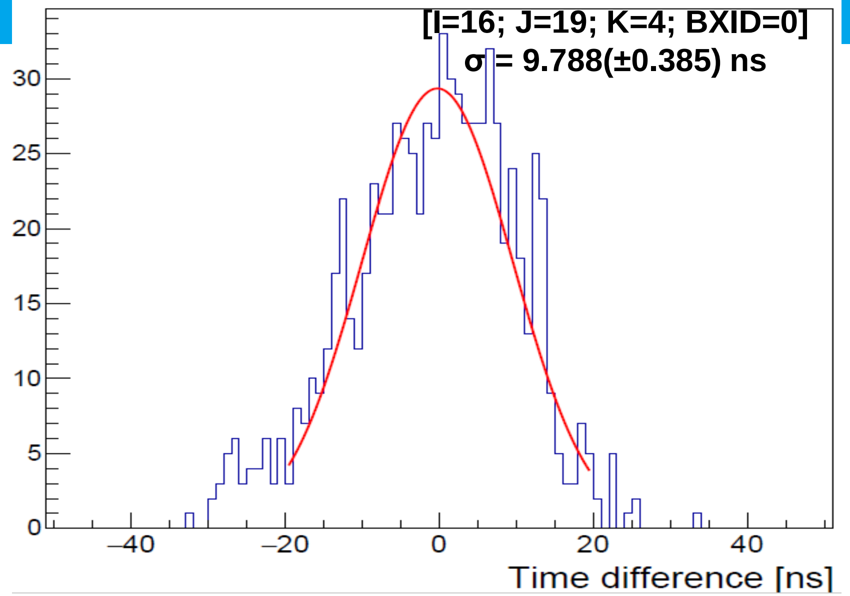
- Each hit in AHCAL converted from TDC to ns according to tile coordinates & BXID
- Plots of Hit time (ns) – BIF time) created for each channel
- Gaussian curve fitted to data, fit parameters recorded
- For this channel:
  - **Mean = - 0.38 ns**
  - **σ = 7.12 ns**

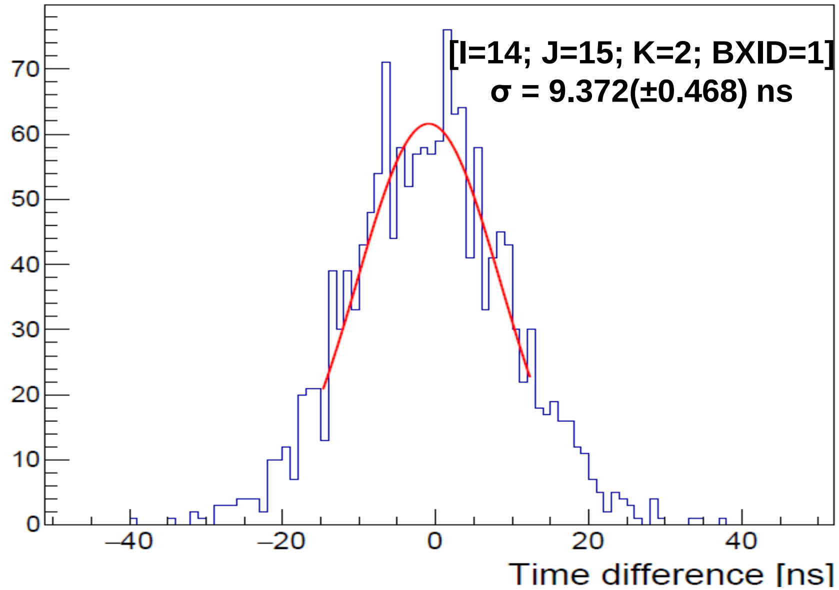


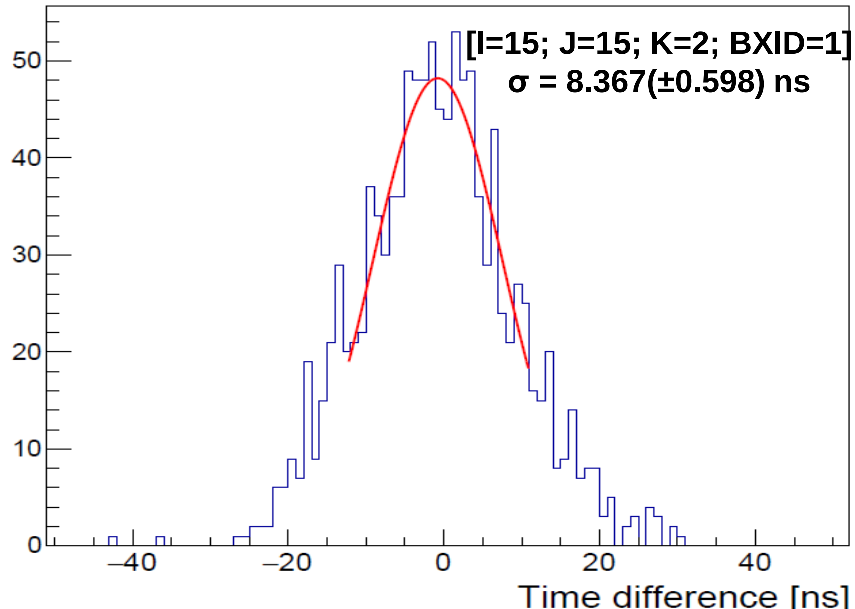
(Hit time (ns) – BIF time) plot for channel [I=12; J=19; K=4; BXID=0]

Conversion from TDC to ns

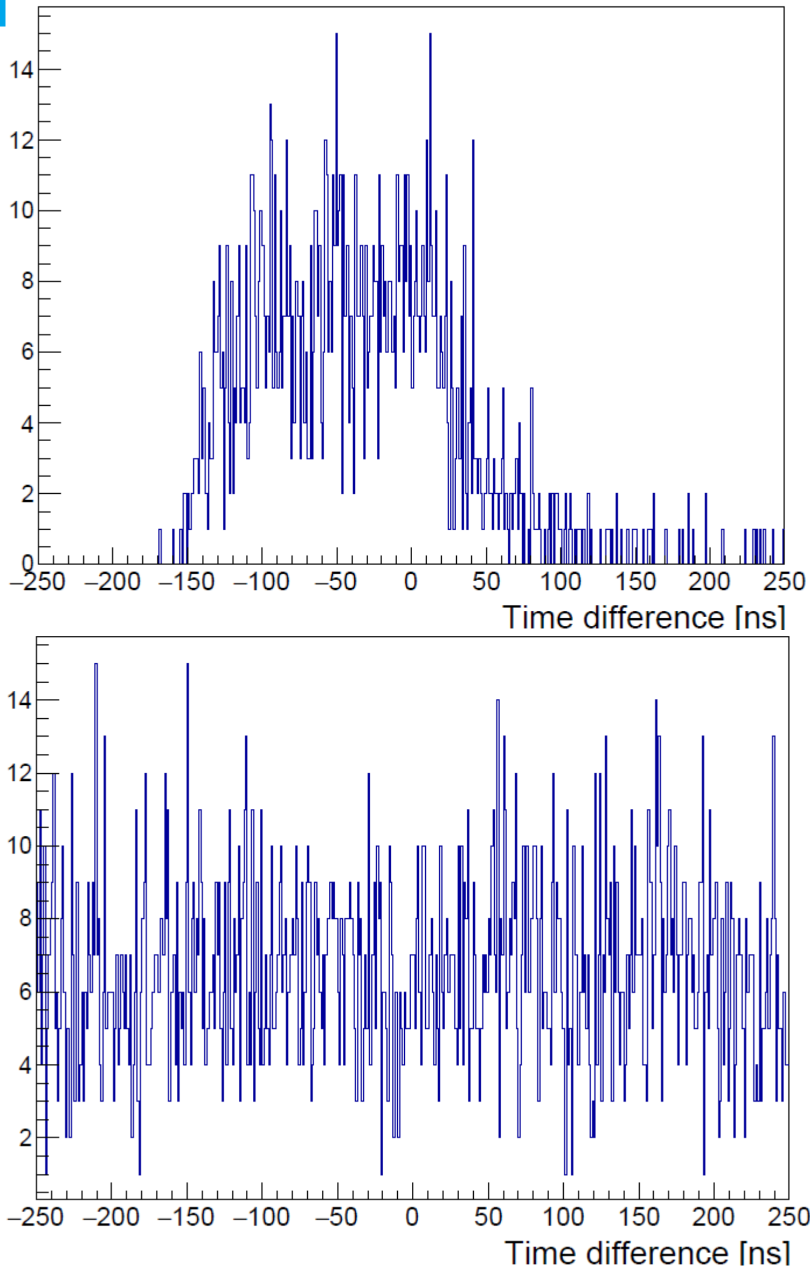
- Gaussian fitted between {mean ± rms} of distributions
- ~200 channels with σ < 20 ns of channels analysed







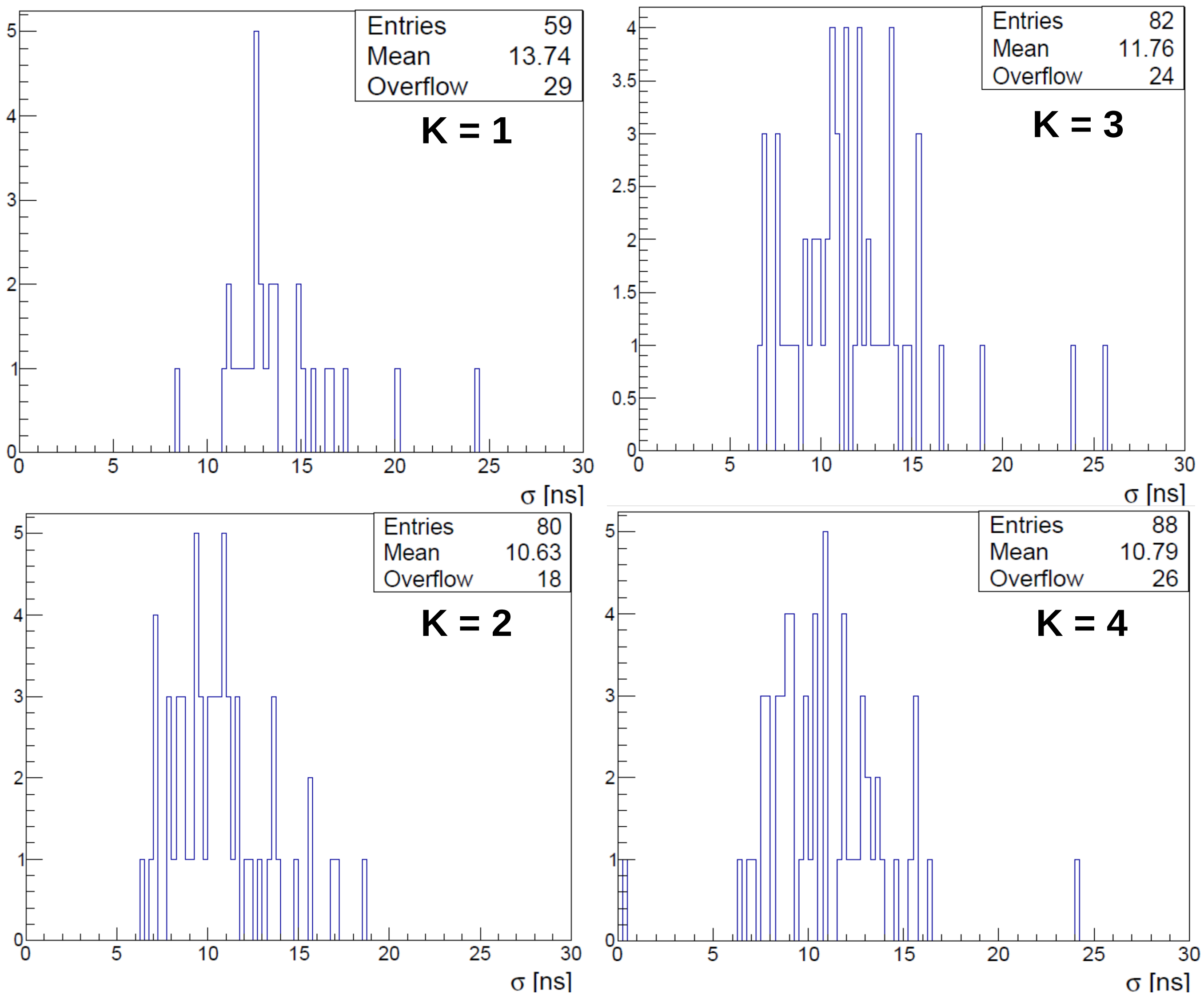
Identification of poor channels



- Some channels produce smeared/chaotic plots
- Indicates possible hardware faults in AHCAL
  - SiPM continuously triggering
- Miscorrelations may be responsible
- Benefit from more statistics

(ahc_hitTime – bif_Time) plot for channels:
[I=12; J=18; K=1; BXID=1] – top;
[I=13; J=16; K=3; BXID=0] – bottom

Distribution of σ between layers



- Distribution of σ values of time difference spectra plotted
- Distribution for each layer monitored during data collection

Summary & Outlook

- Written programs to perform analysis of hit time in AHCAL and external BIF
  - Correlation of AHCAL & BIF hit time plotted
  - Linear fits performed, slope & offset recorded
  - AHCAL hit time converted from TDC $\longrightarrow$ ns, time difference plotted
- Analysis of good and bad channels within AHCAL

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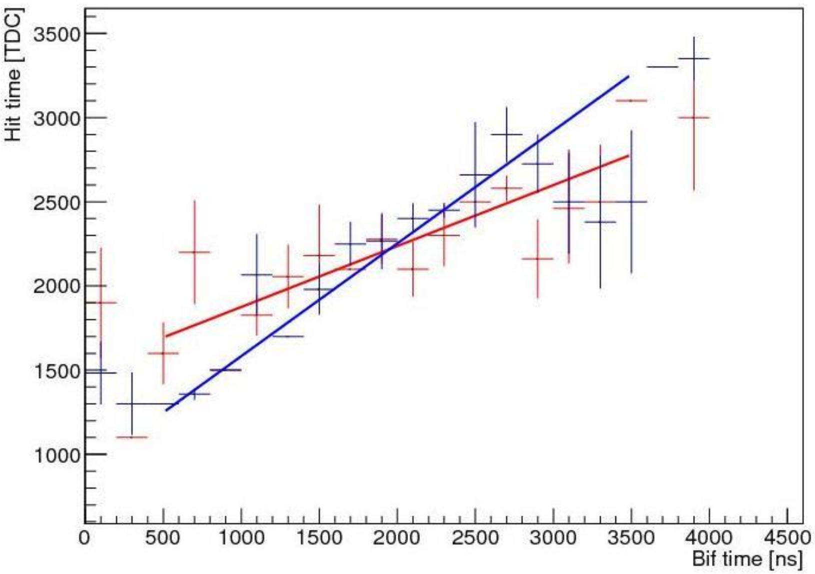

Fitted profile of hit time vs. BIF time for [I=12; J=19; K=4; BXID=1], memory cells 2 & 3 (Run 41145)

- Hit time calibration extended to include memory cell calibration, requires further development
- Implementation in online monitor for AHCAL