Test beam experience with partially instrumented AHCAL prototypes

LCWS16 at Morioka
6.12.2016

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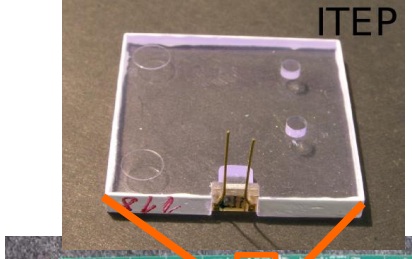
for the CALICE collaboration

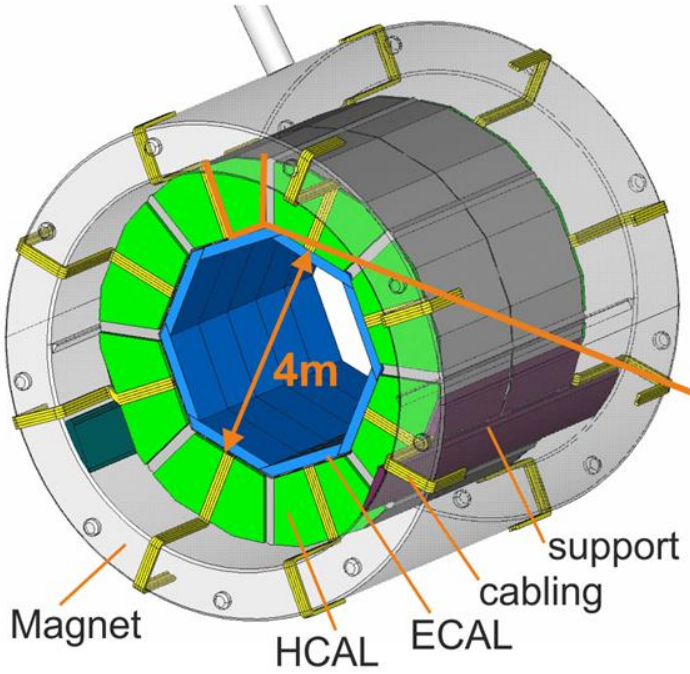
AIDA 2020

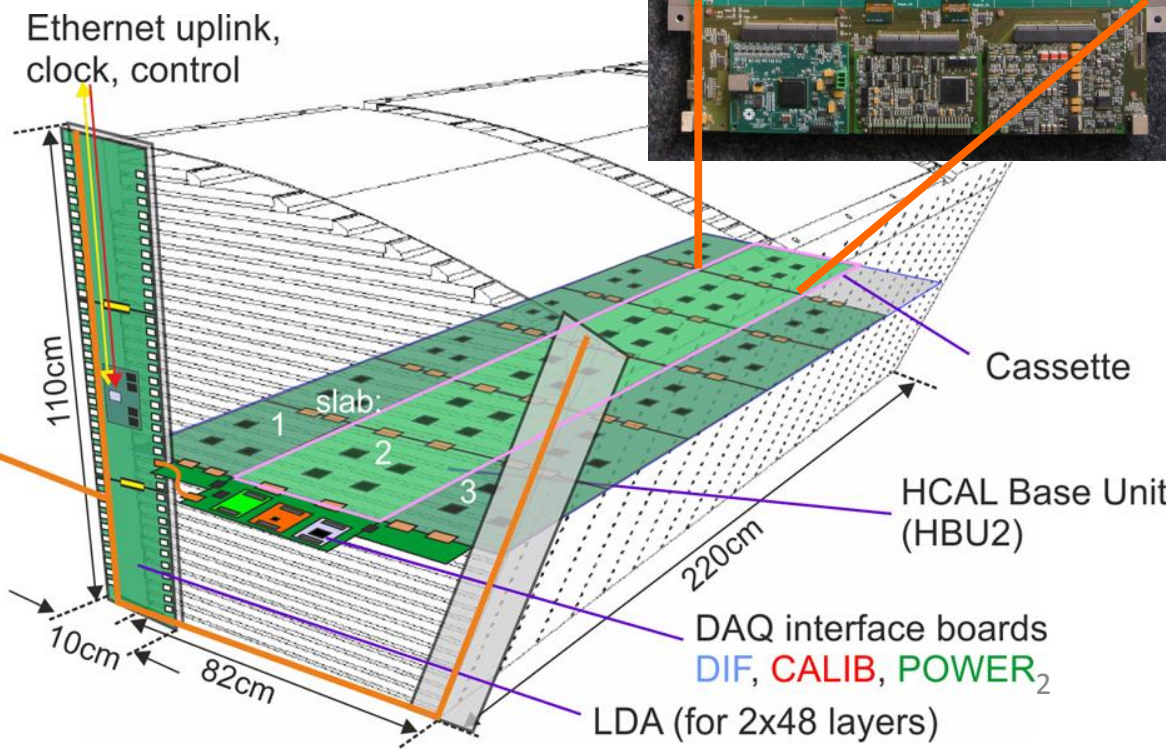
CALICE AHCAL

- **A highly granular hadron calorimeter for ILD**
  - Iron (or Tungsten) absorbers
  - 3x3cm^2 plastic scintillator tiles
  - Readout by individual SiPMs
  - 8 million channels (with endcaps), 50k PCBs

  →**Readout fully integrated into the layer**

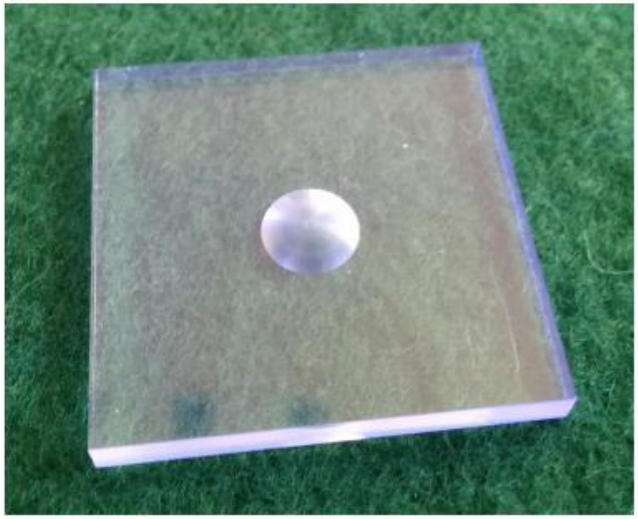


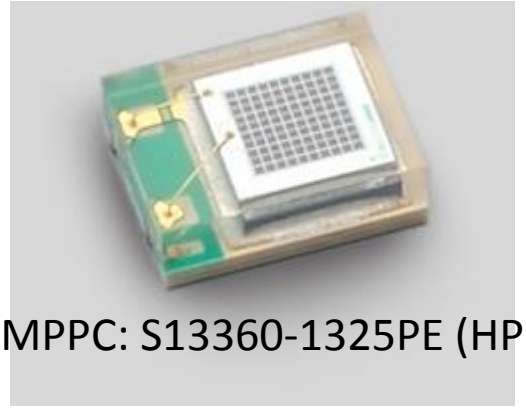




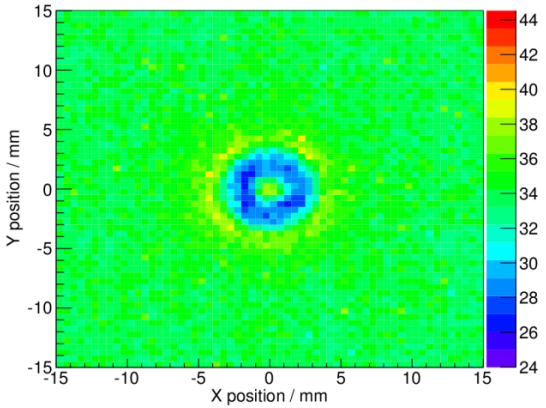
CALICE AHCAL

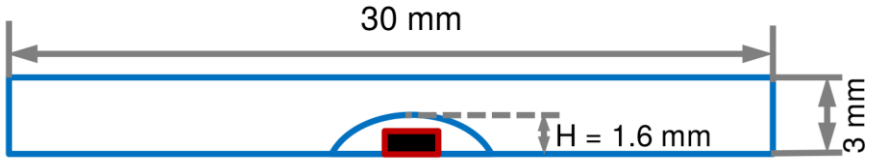
- **A highly granular hadron calorimeter for ILD**
  - Iron (or Tungsten) absorbers
  - 3x3cm^2 plastic scintillator tiles
  - Readout by individual SiPMs
  - 8 million channels (with endcaps), 50k PCBs
    → **Readout fully integrated into the layer**
- **New design**
  - Surface mount design SiPMs
    → **easy assembly, uniform response**
  - Positive experience at CERN SPS 2015
  - **Used in DESY test beam campaign 2016**





MPPC: S13360-1325PE (HPK)





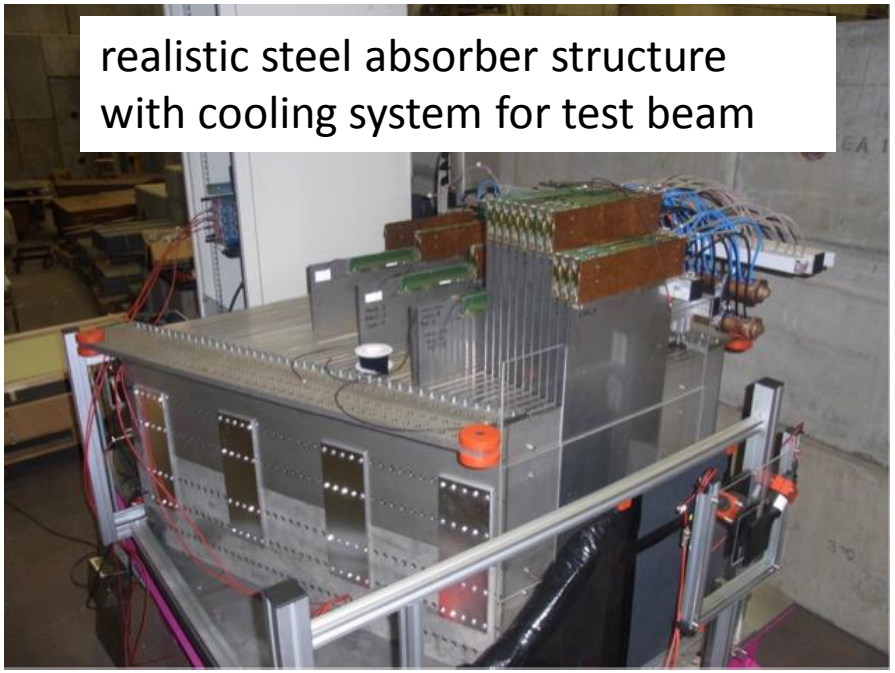
D = 8.0 mm Round hole in foil: D=4mm for SMD-SiPM

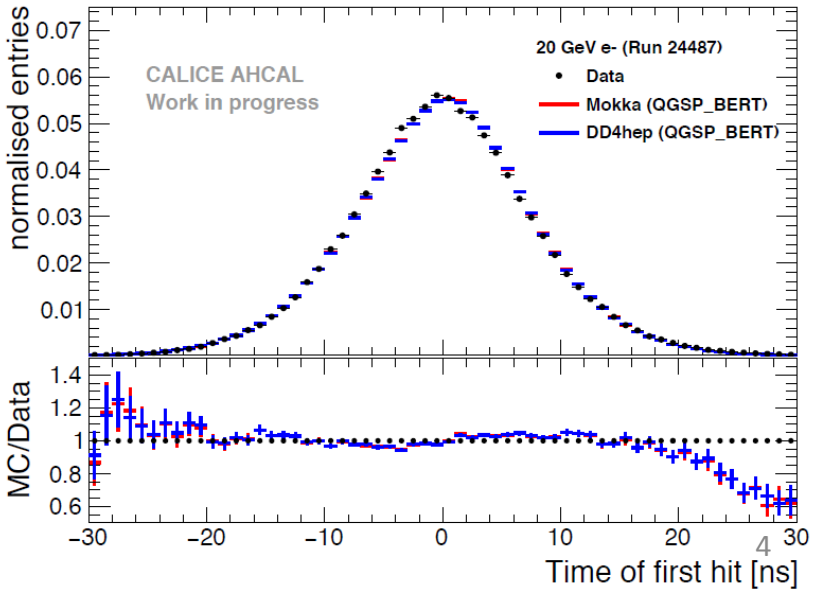
Test beam data analysis for CERN SPS 2015

- test beam campaigns in 2015 at CERN SPS
  * muon runs for MIP calibration
  * electron runs for EM shower
  * pion runs for hadronic shower
- Ongoing works

✓ detailed study on amplitude and timing to electron and pion beam comparing with data and MC in Mokka and DD4HEP

✓ simulations for time of hit are in good agreement with data





CALICE AHCAL technological prototype Test beam campaigns in 2016 at DESY

- Toward full-scale ILD AHCAL, important tests are performed
- Integration of new electronics and DAQ, monitoring
- Testing new AHCAL modules with surface mount tiles

- using EUDAQ1.6 for run control and data taking
- **BIF** (Beam InterFace) module to record beam timestamp
- AHCAL **online monitoring within DQM4HEP** framework
- latest **surface mount type SiPMs and tiles on HBU4**
- data taking with **power-pulsing** operation
- common running with pixel telescope

May : first test of BIF with beam, power-pulsing
July-August : 15 layer small stack, power-pulsing
October : common running with telescope
December : collect more beam data with telescope

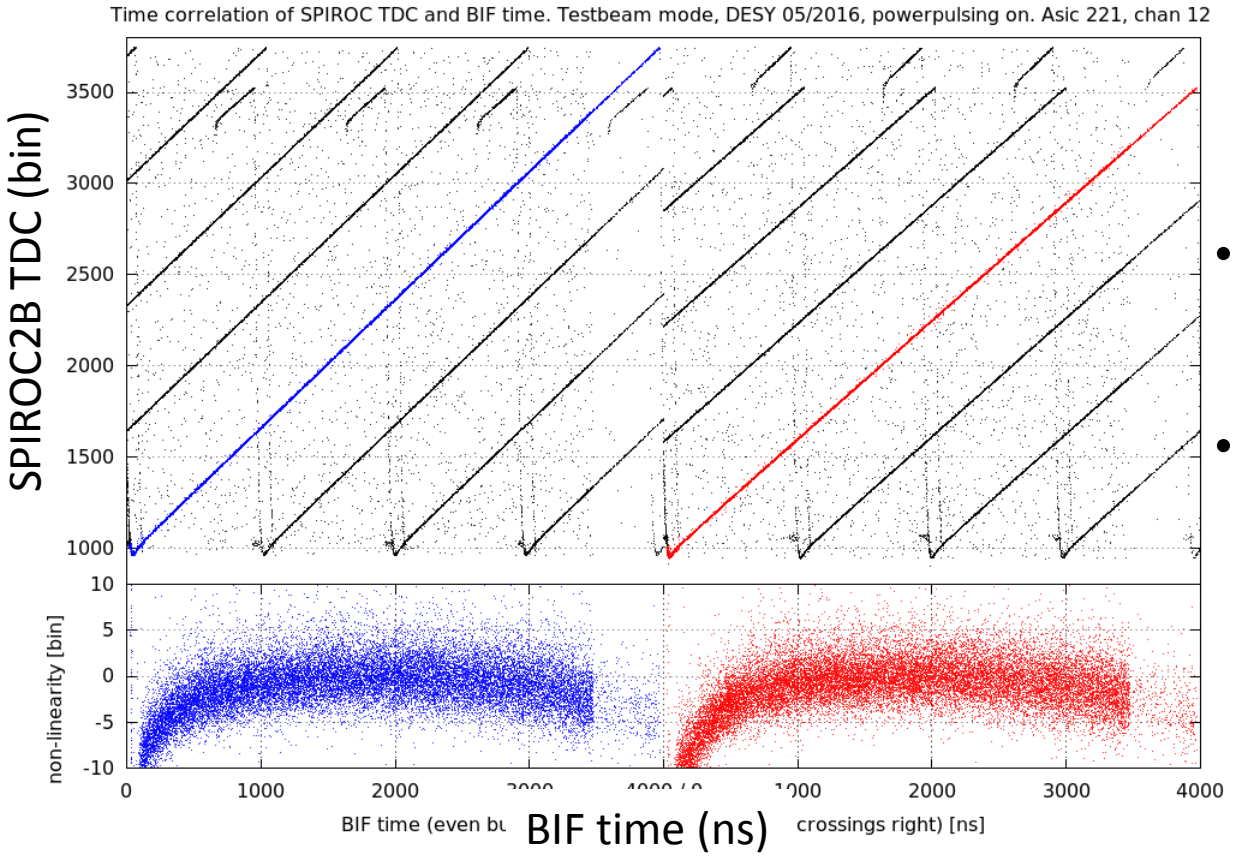
AHCAL test beam in May 2016 at DESY

- We had 2 weeks of beam time at DESY.

- many tests for BIF, DAQ, monitoring and new SMD module

➢ **BIF successfully integrated and tested with beam**

➢ stable response under power-pulsing operation



- Correct correlations are blue and red lines in the main diagonals.
- black lines come from additional particles in the same BX interval.
  - beam structure (1MHz) of DESY TB

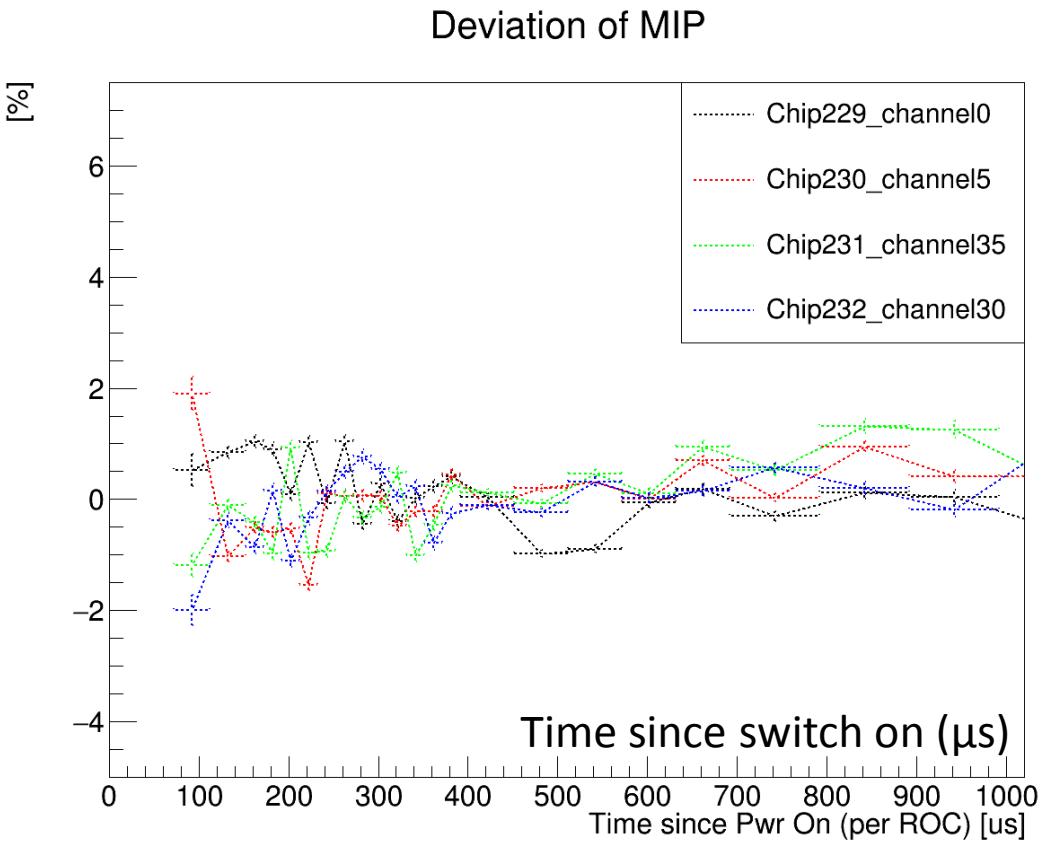
AHCAL test beam in May 2016 at DESY

- We had 2 weeks of beam time at DESY TB22, 2nd-14th of May.

- many tests for BIF, DAQ, monitoring and new SMD module

➢ BIF successfully works with beam

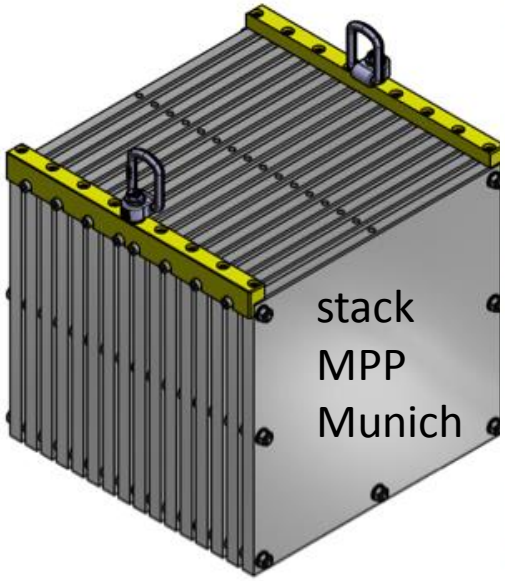
➢ **stable response under power-pulsing operation**

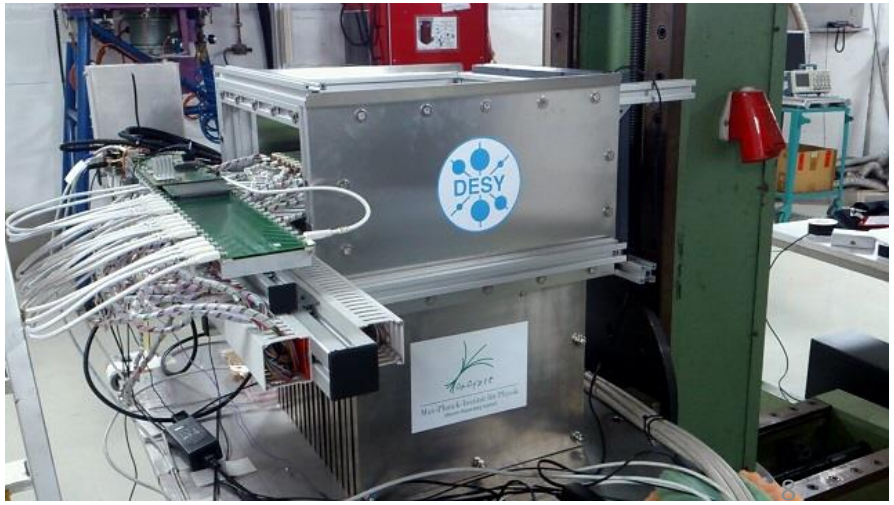


- running stably
- stable MIP response after 150 µs (consistent with lab results)

New small AHCAL prototype July 2016

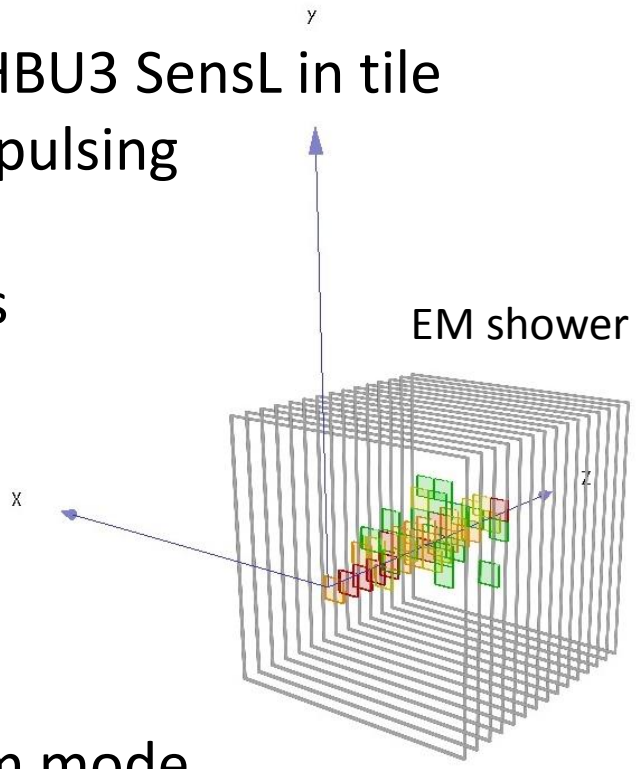
- 15 good, low-noise layers for electromagnetic shower
  - * 6 brand new HBU4 with new generation MPPCs (HPK)
  - * 9 older but still good HBU3
- demonstrate response to 1-5 GeV electron
  power-pulsing performance for a calorimeter system





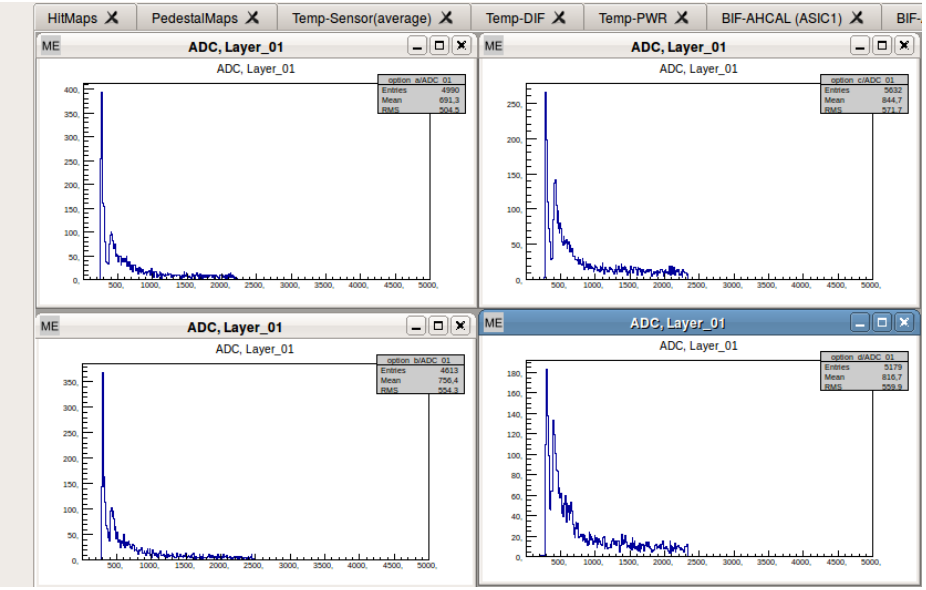
AHCAL test beam in July-August 2016

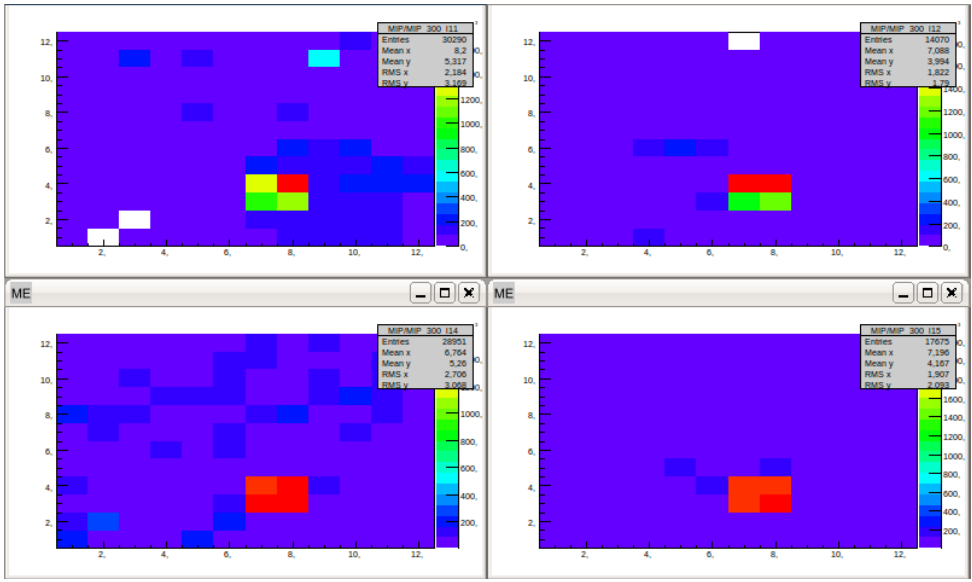
- We had 2 weeks of beam time at DESY
- before the beam time, commissioning was done for all HBUs
- setup: 15 layers of 1 HBU
  * 6new HBU4_SMD + 1 HBU3_SMD + 8 HBU3 SensL in tile
  * new interfaces for all layers for power-pulsing
- 1st week: Calibration run
  * integration of new HBUs and interfaces
  * MIPs
- 2nd week: EM showers run
  * small steel absorber stack
  * energy scans 1 -5 GeV
  * 3.5 days for no power-pulsing
  * 1 day for power-pulsing with test beam mode
  * 2.5 days for power-pulsing with nearly ILC time structure



Online data quality monitoring

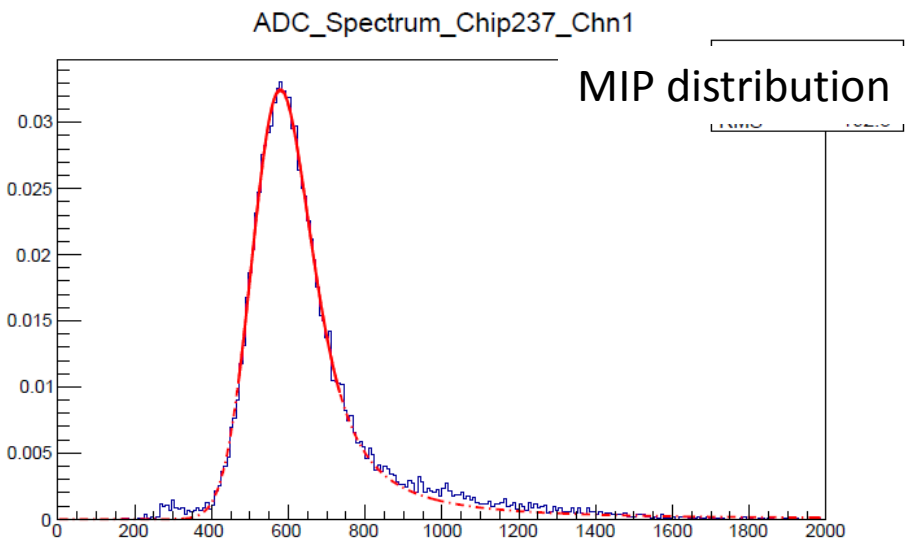
- New online monitoring (DQM4HEP)
  - Developed by Remi Ete et al (Lyon, Gent)
  - Framework for general use by any detector
  - Adopted by Tom Coates (Sussex, UK)
  - lcio format raw data



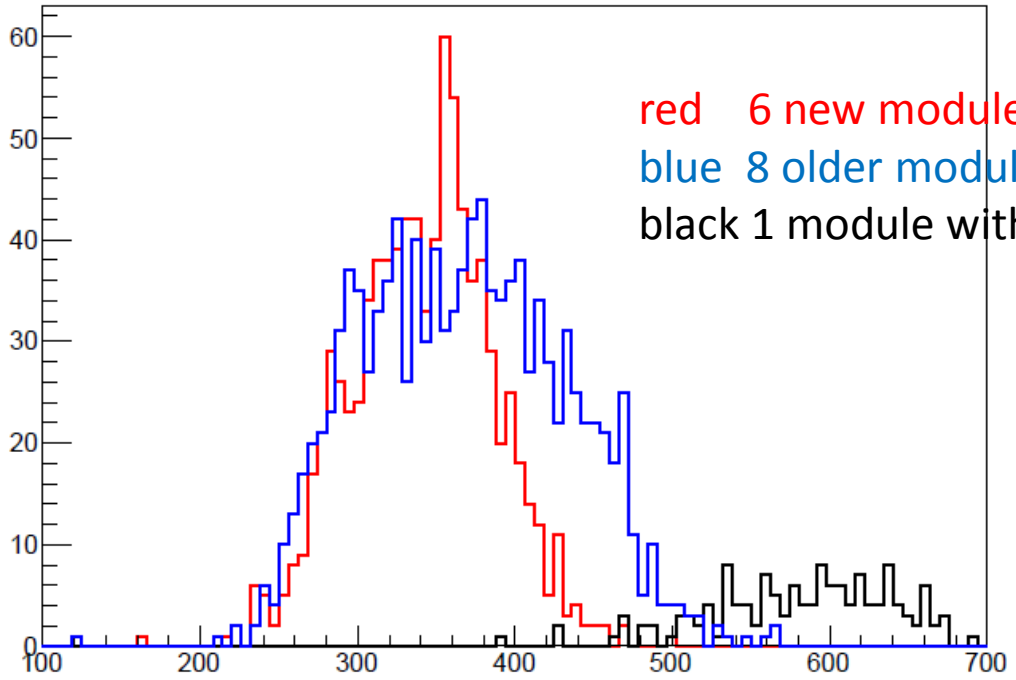


MIP calibration

- Quality of new HBUs very good
- All 864 channels operational.
- 863 show nice MIP spectrum
- only 6 dead cells out of 1152 cells on old HBUs



summary of MIP response in ADC unit



red 6 new modules with latest SMD MPPC
blue 8 older modules with SensL SiPM
black 1 module with older SMD MPPC

AHCAL response to electron beam

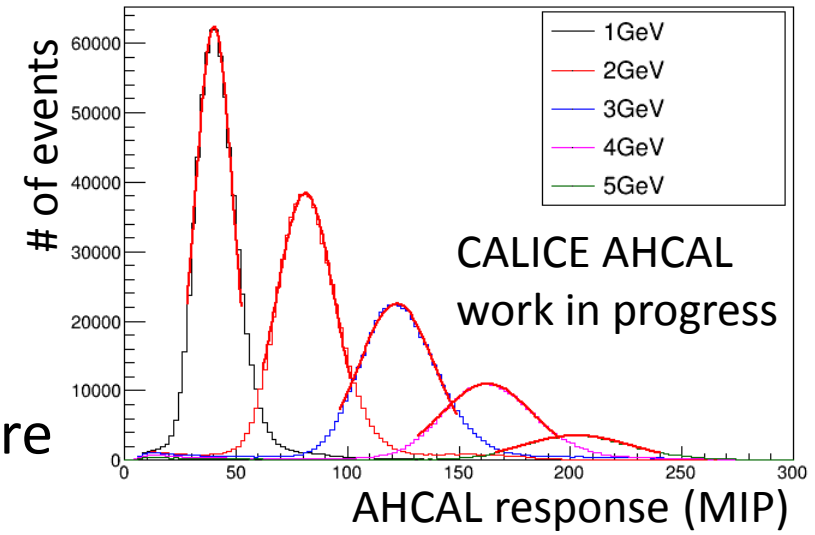
- Beautiful energy spectrums
- Clear EM shower development
- same behavior with

no power-pulsing

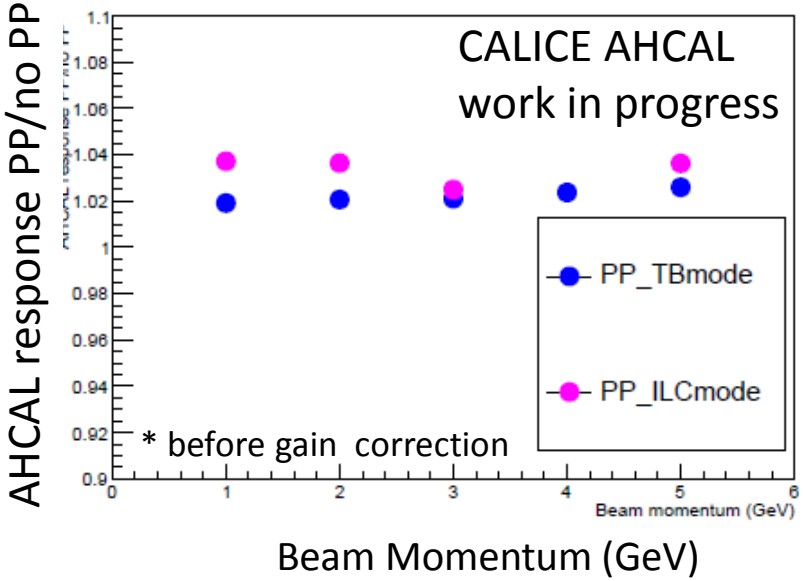
power-pulsing with test beam mode

power-pulsing with ILC timing structure

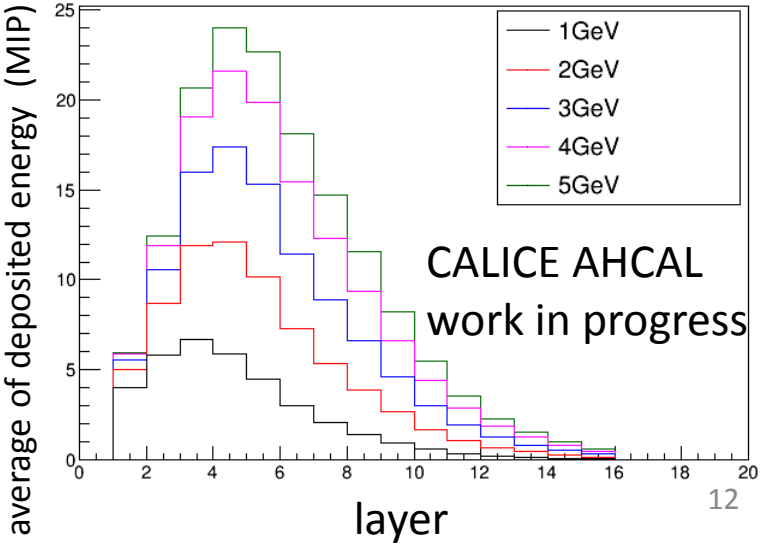
energy spectrum for 1-5 GeV



1-5 GeV electron

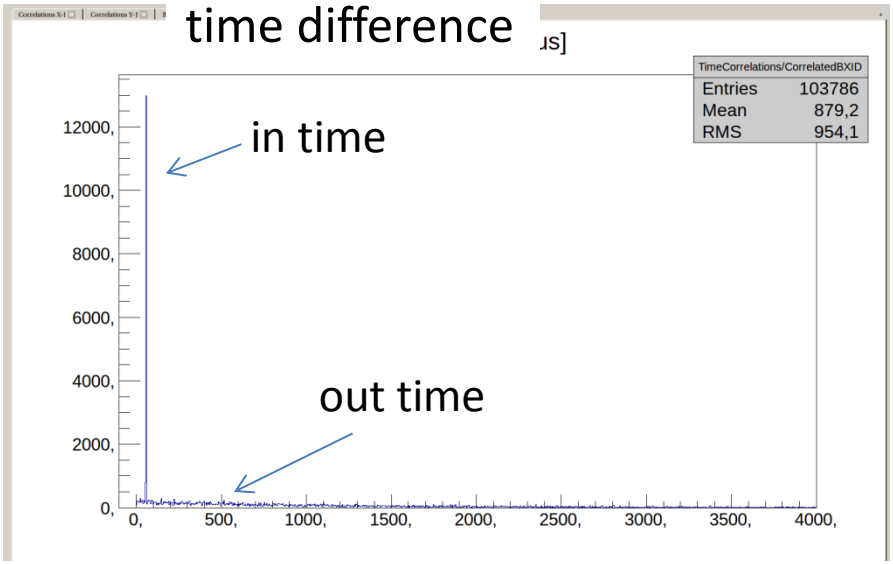


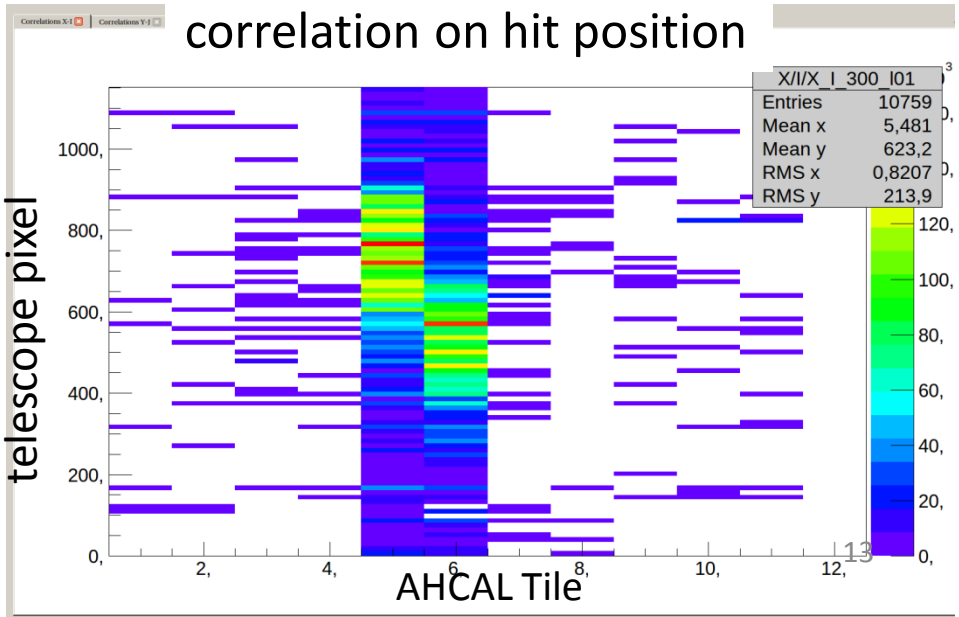
longitudinal shower shapes



AHCAL test beam in October 2016

- Common running with other detector system
- AHCAL runs with EUDET pixel telescope in synchronization
- observed correlations
  - timestamp of telescope trigger – AHCAL hit time (in BXID)
  - telescope hit position vs. AHCAL tile
- next TB is scheduled in 12th-18th of December 2016 (coming soon!)
  - much more statistics

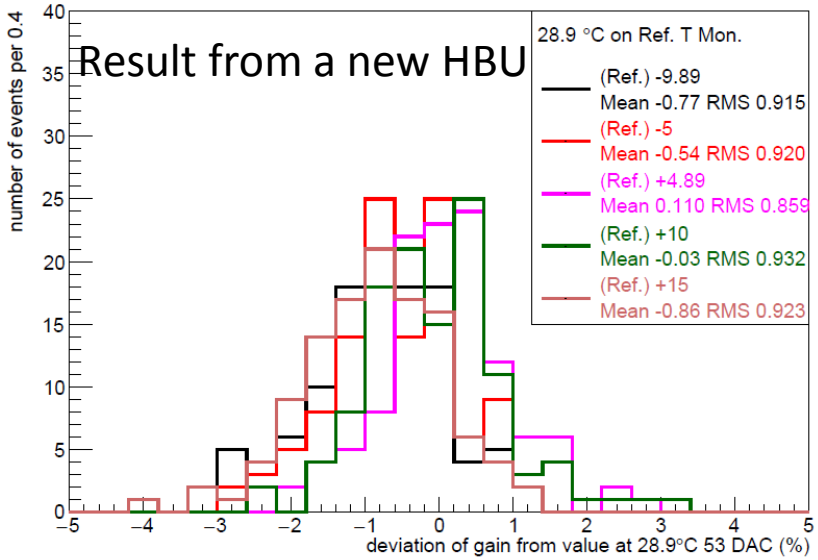


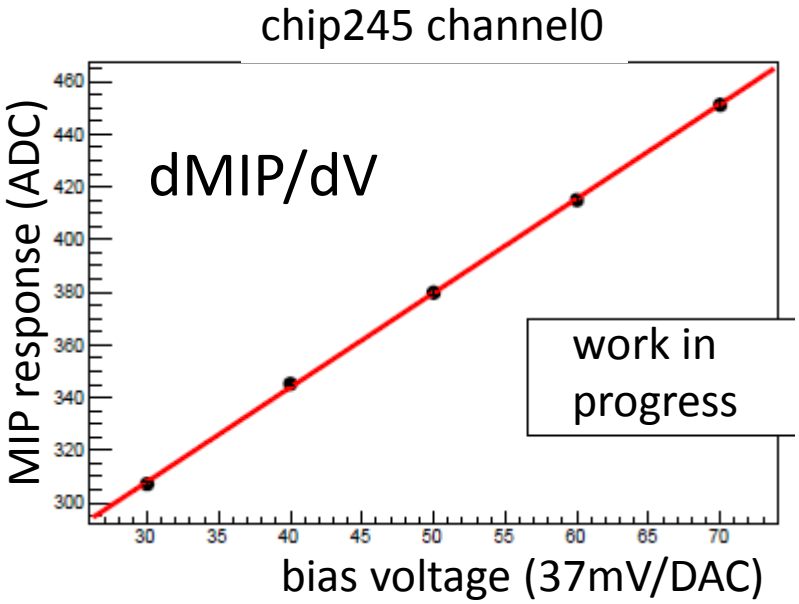


SiPMs gain and response to MIP

- toward the gain compensation on temperature during test beam
  * measure gain dependence on temperature and bias voltage
    - averaging the result from all SiPMs on HBU (single voltage setting on a HBU)
  * Testing temperature compensation on SiPMs gain
    → Gain is kept within 1% RMS for temperature ranging 20 to 45 degrees
  * measure dependence of MIP response on bias voltage at DESY TB in Oct. 2016

a new HBU	dGain/dT	dGain/dV	dV/dT	dMIP/dV
work in progress	-0.7%/˚C	1.7%/100mV	43mV/˚C	1%/40mV





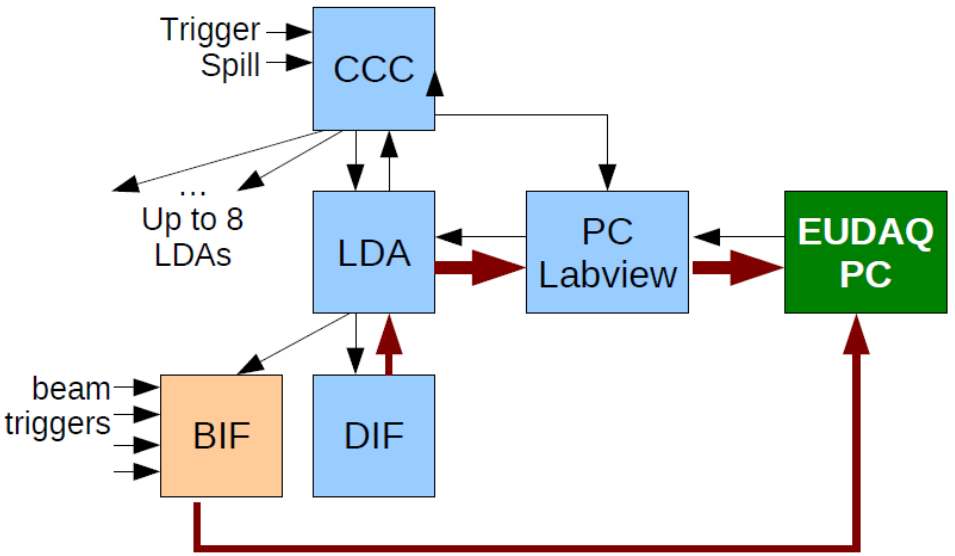
Summary

- Toward full-scale ILD AHCAL, important tests are performed
- Integration of new electronics and DAQ (BIF, power etc.)
- commissioning procedure is simplified by surface mount tiles and new generation SiPMs
- new design 6 HBUs are successfully tested with electron beam
- beautiful response of 15 layer small AHCAL to 1-5 GeV electron beam
- successfully operated in Power-pulsing mode
- common running with pixel telescope

Backup

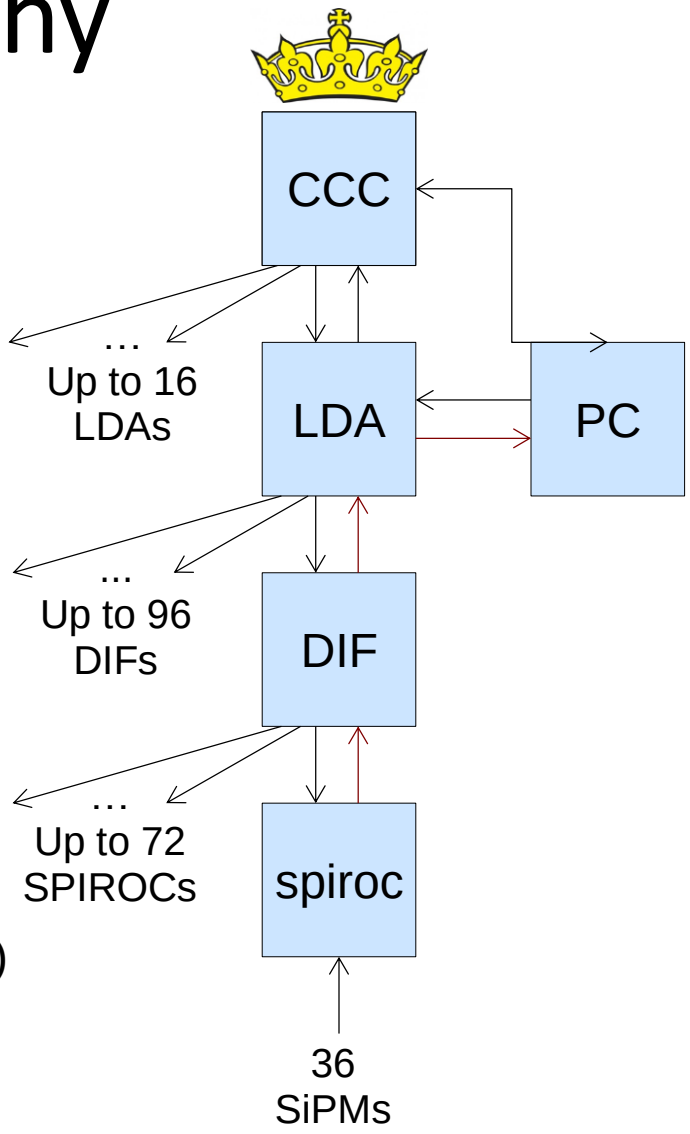
BIF: Beam InterFace

- **Timestamping external signals**
- Modified firmware of the AIDA mini-TLU
  - Receives AHCAL clock
  - Knows AHCAL fast commands from HDMI
- **Records timestamps and start&stop of acquisition**
- acquisition is gated (=records only when AHCAL active)
- Implemented in the “slave mode” – acts like another LDA/DIF



DAQ Hierarchy

- CCC (Clock and Control Card)
  - Provides master clock
  - Synchronizes all DIFS
  - Starts and stops the acquisition according to the spill level and readiness of all DIFs
  - Distributes trigger validation
- LDA (Link Data Aggregator)
  - Merges DIF readout packets
  - Does some decoding, adds headers
  - Send the packets over TCP
- DIF (Detector InterFace)
  - Controls the ASICs
  - Readout the data from all ASICs
  - Sends the data to LDA
- SPIROC 2b (SiliconPM Integrated Read Out Chip)
  - ASIC by Omega, SiGe 0.35 um, 32 mm^2
  - Reads out 36 SiPMs
  - Has 16 memory channels

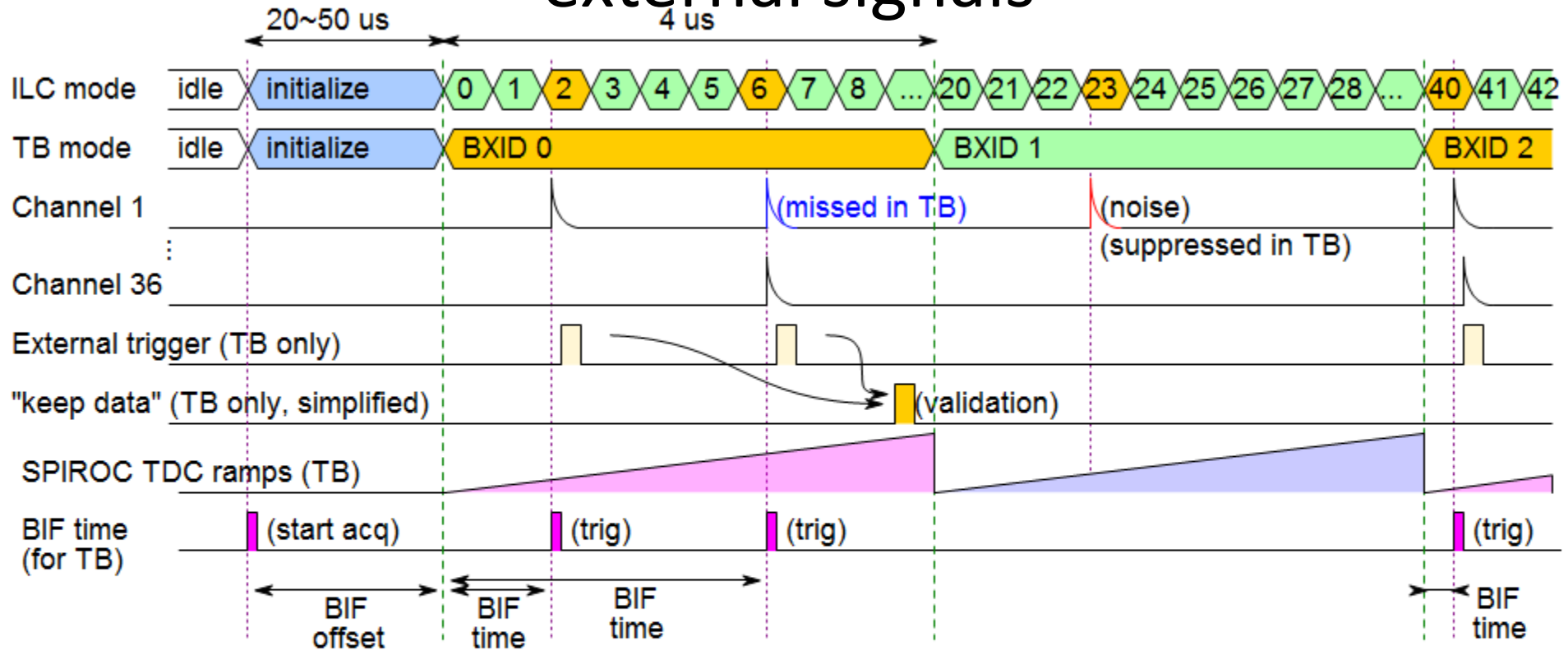


DAQ Challenges

- We want a DAQ, that scales to the ILD calo and will fit the ILC timing
- We need the DAQ for beam tests, now!
  - But with completely different timing requirements...

	ILD	TB CERN SPS	DESY
Spill	1 ms collision 199 ms idle	~2*5 s spill ~40 s idle	Always on
ROC/spill	1	many	
Event rate	~ MHz	10~100 kHz	~10 kHz
Trigger	None (auto)	Auto + validation	
Cooling	Passive	Don't care	
Power pulsing	Obligatory	Not needed	

BIF (Beam Interface): Timestamping external signals

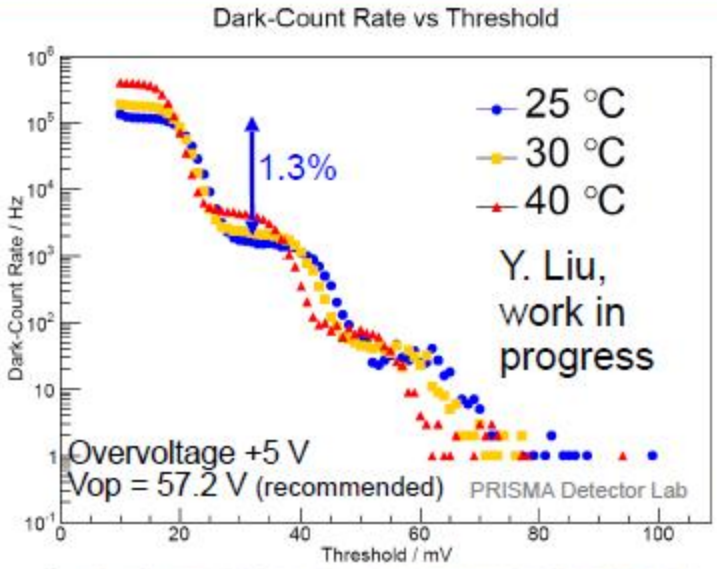


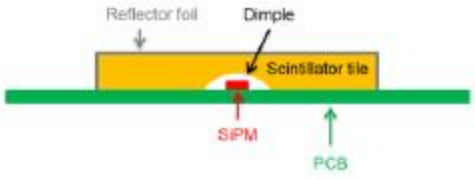
- BIF and AHCAL run the same 40 MHz clock => everything synchronous
- BIF "time": Timestamp difference from the current BX start
- Where the BXID 0 starts? The BIF offset has to be found and calibrated
  - Cable lengths
  - Powerpulsing startup delay
- More triggers in 1 BXID => correlation artifacts
  - Case for the DESY beam: up to 4 triggers in BXID in TB mode

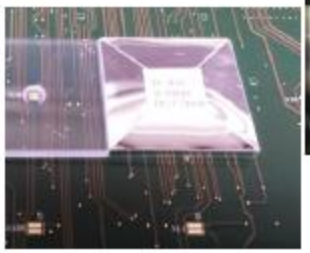
Towards mass production

decided which option to follow:

- recent improvements in SiPM technology:
  - improved sample uniformity
  - dramatically reduced dark rate and pixel-to-pixel cross talk
  - in AHCAL conditions **noise-free**
- new tile design with surface-mount SiPMs
- mass assembly with pick-and-place machine done
- pre-series of 1000 MPPCs ordered
- for the pre-series: use BC408 scintillator, cut and polished

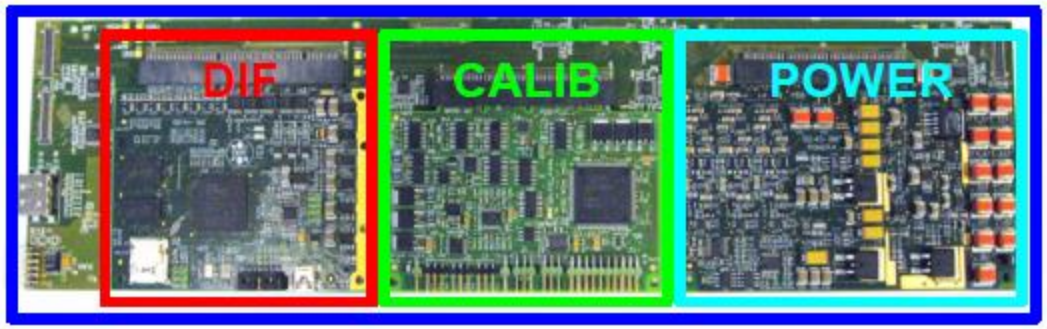






New Electronics 2016: Interface boards & BIF

CIB



new interface boards:

- DIF:
  - more modern FPGA
- POWER:
  - reduced LV (6 → 4 V) for reduced heat
  - capacitor bank for **power pulsing**
  - **software adjustment of SiPM bias voltage**
- CIB:
  - additional capacitors and protection resistors for power pulsing
- new Beam Interface (BIF)
  - time-stamp external signals (trigger, cherenkov...)

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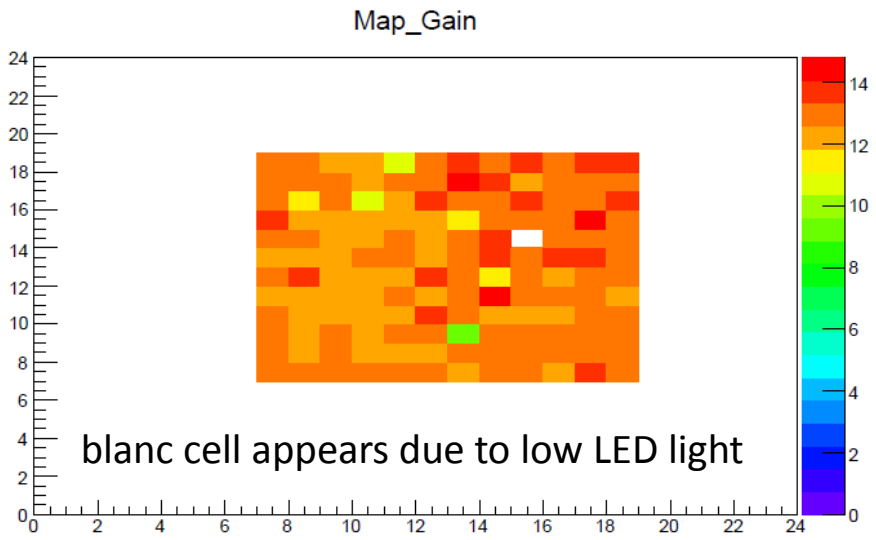
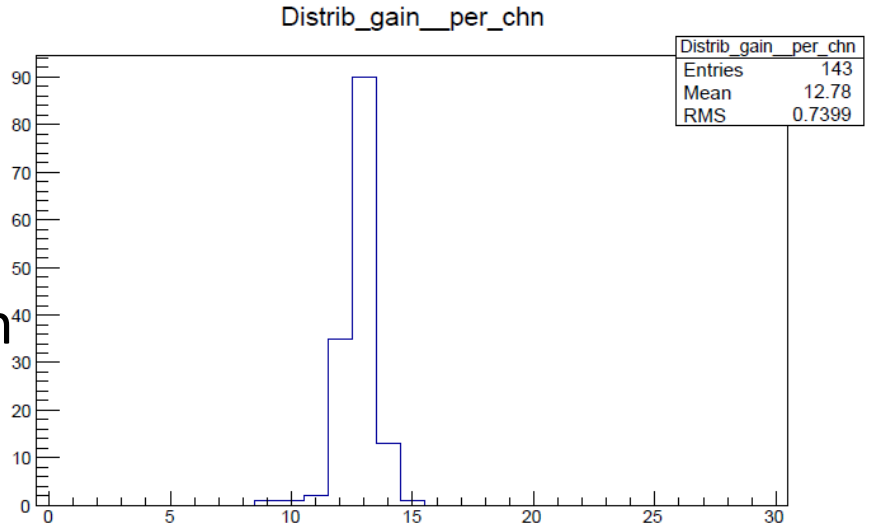
DESY

Commissioning for the TB on July 2016

- All HCAL modules are tested in climate chamber (25˚C) one by one before the test beam.
- hold scan, preamplifier settings gain measurement with LED
- new surface mount MPPCs on modules show quite uniform gain
  - older modules are also good.

→ no cell-by-cell adjustment anymore
We can set single bias voltage for each module.





New small prototype July 2016

- 6 new HBUs with surface-mount tiles
- new generation MPPCs (HPK)
- We have built small prototype for electromagnetic shower together with already existing 9 good HBUs
- demonstrate response to 1-5 GeV electron
  power-pulsing performance for a calorimeter system