Scintillator HCAL technological prototype: analysis software and results

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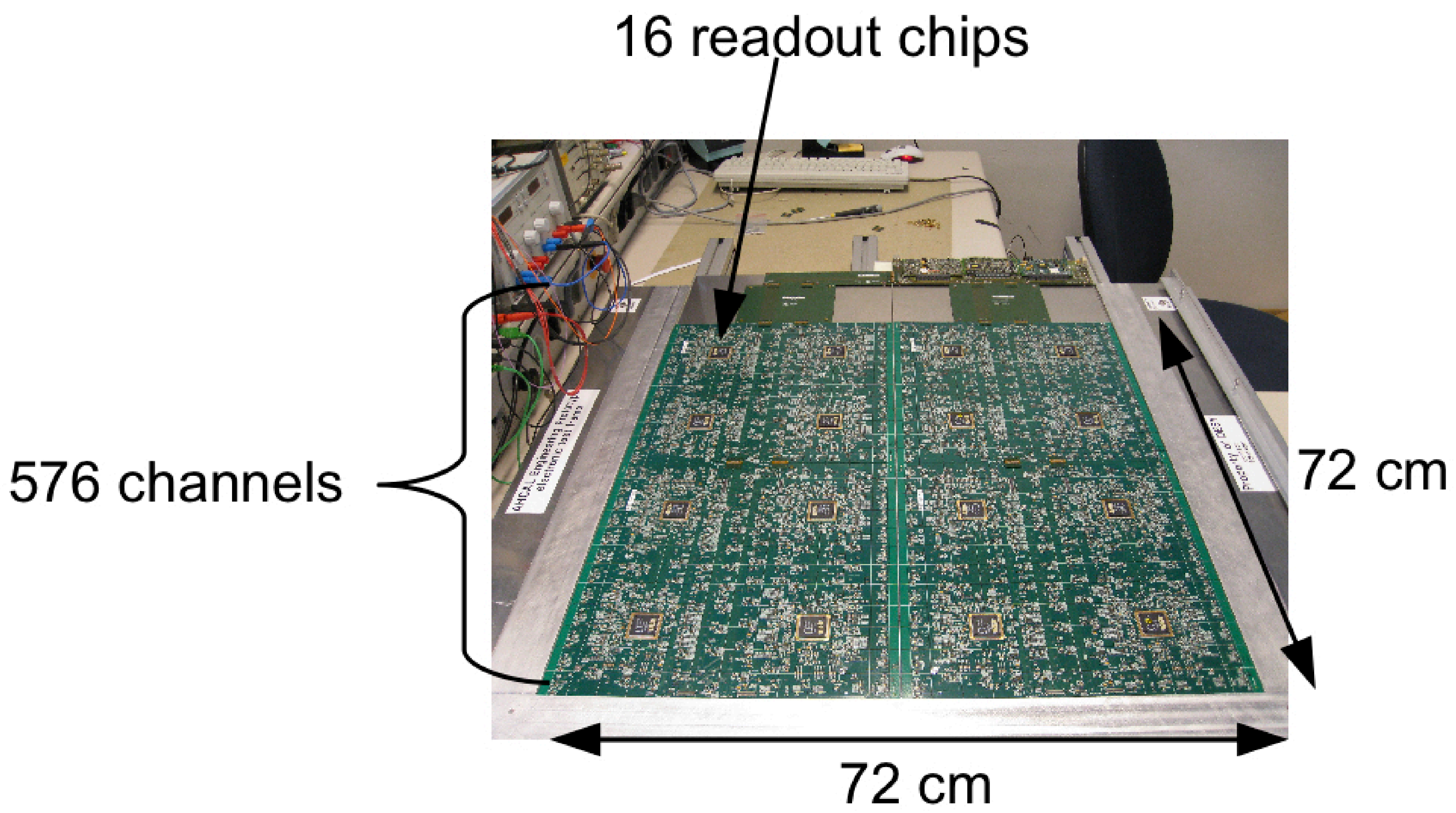
on behalf of the CALICE Collaboration
ECFA-LC2013, 29th May 2013

Outline

- The scintillator HCAL technological prototype
- CERN test beam setup
- DAQ and event building
- Test beam data offline analysis software
- Preliminary results from MC and TB
- Summary

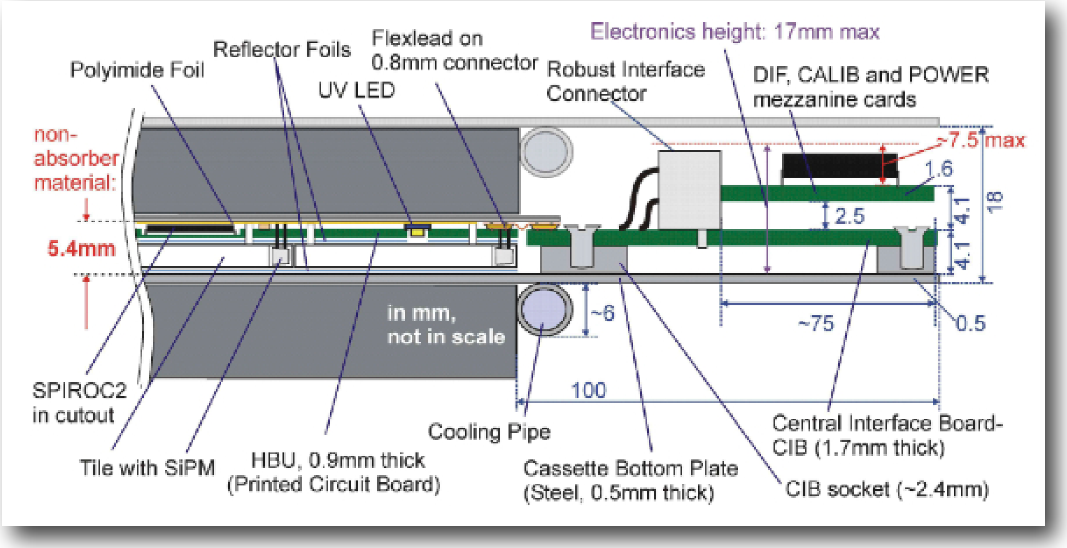
The scintillator HCAL technological prototype

- CERN test beam hardware: one layer with 4 HBU



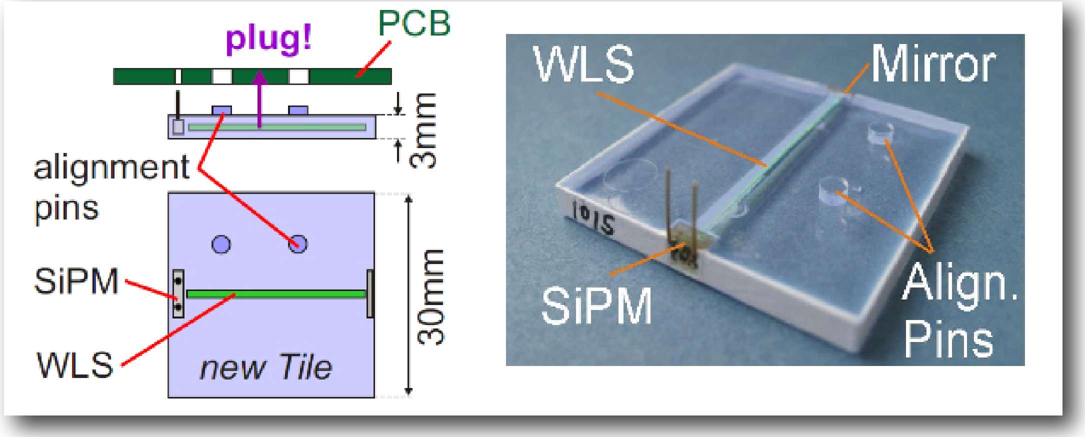
- HCAL Base Unit: 36*36 cm^2, 144 tiles, 4 readout ASICs
- All 36 channels on one chip can be operated with a single trigger threshold
- SiPMs from different batches (different gains, different bias voltages) can be operated within one layer

The scintillator HCAL technological prototype



Compact detector:

- front-end electronics integrated in active layers
- thin layers → ASICs embedded in PCB, only 5.4 mm thickness including 3 mm tiles
- power pulsing → no active cooling needed



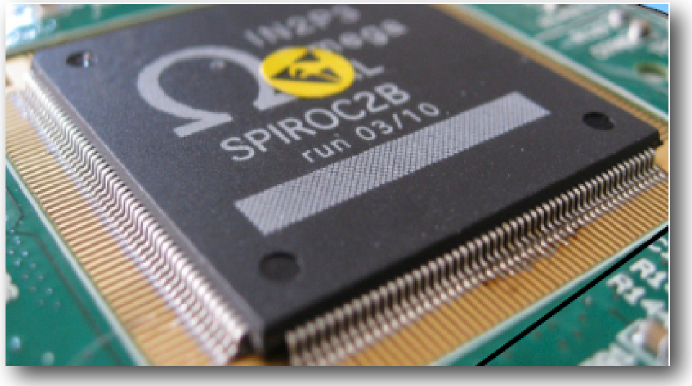
Active material:

- 3*3*0.3 cm^3 scintillator tiles with WLS fibers

Detector: SiPM

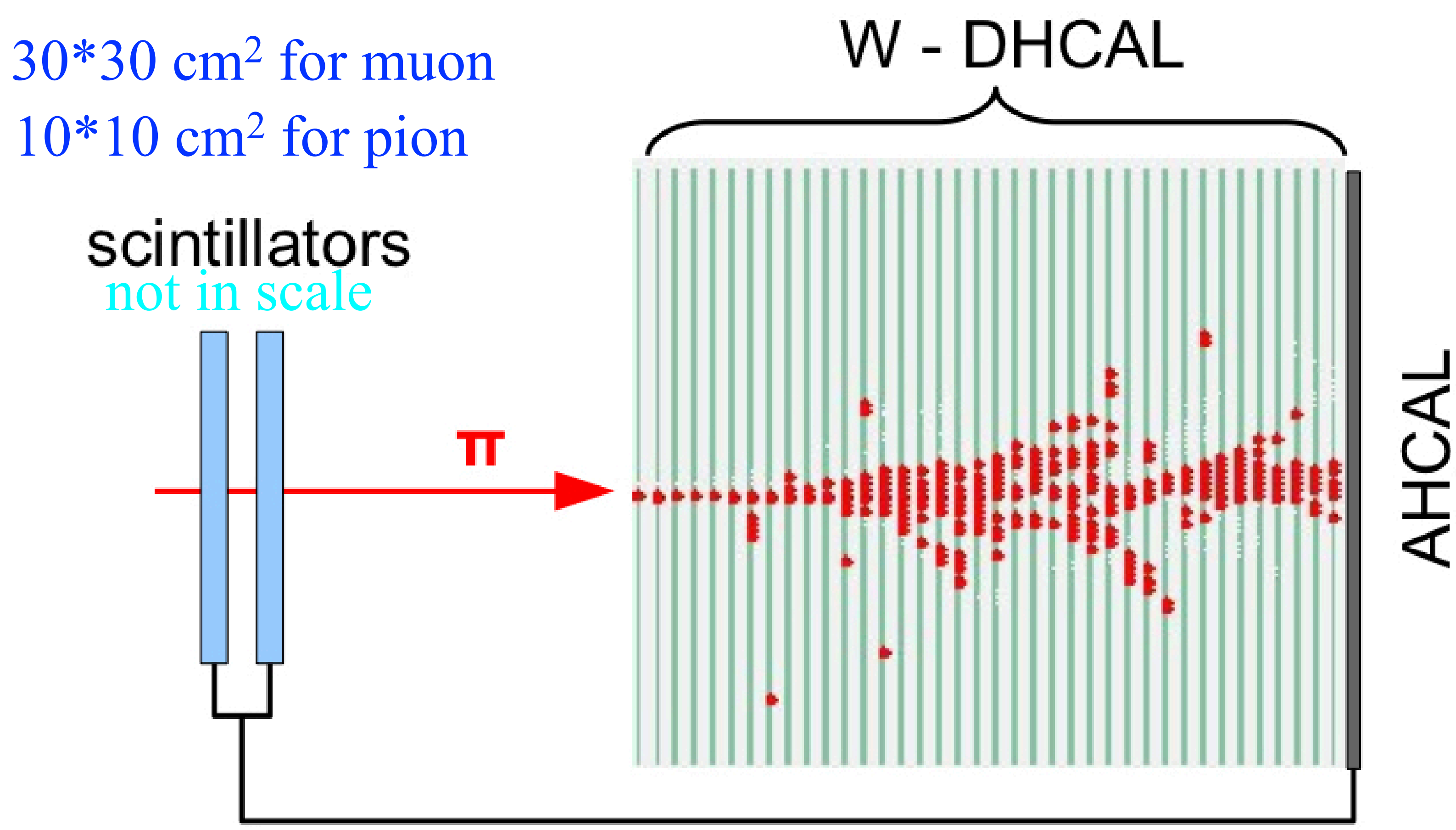
- pixelated Geiger-mode avalanche photodiodes
- insensitive to magnetic fields
- high gain, low operating voltage, very low power consumption

SPIROC: highly integrated specific chip for SiPM readout (system on chip)



- channel-wise bias adjustment
- channel-wise adjustable gain
- dual gain setup per channel, high gain/low gain ~10
- designed for ILC operation:
  - power pulsing → 25 µW/ch
  - auto-trigger mode, channel-wise fine adjustment of threshold
- has also special testbeam mode

CERN test beam



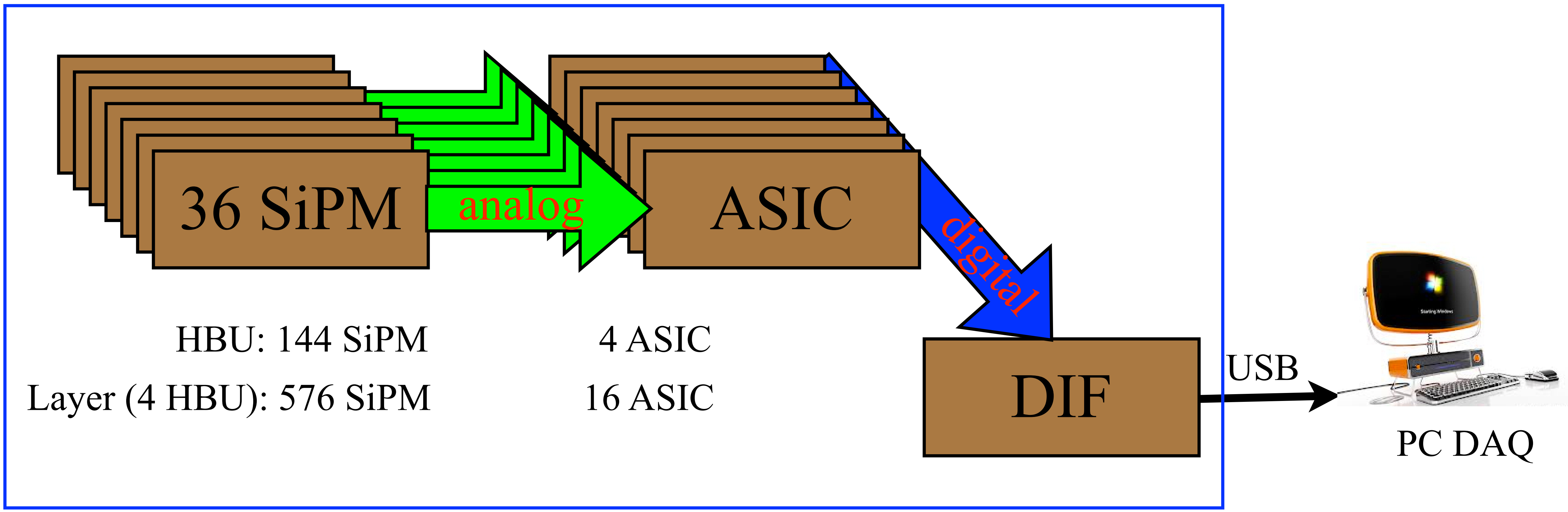
- Detectors set in conditioned tent:
  - stable temperature conditions
- Trigger scintillators in coincidence
  - online validation signal
  - into two AHCAL channels for absolute time reference

- Muon runs
  - for further MIP calibration

- Pion runs
  - at 50GeV and 180GeV

DAQ Hardware

- readout by Labview DAQ



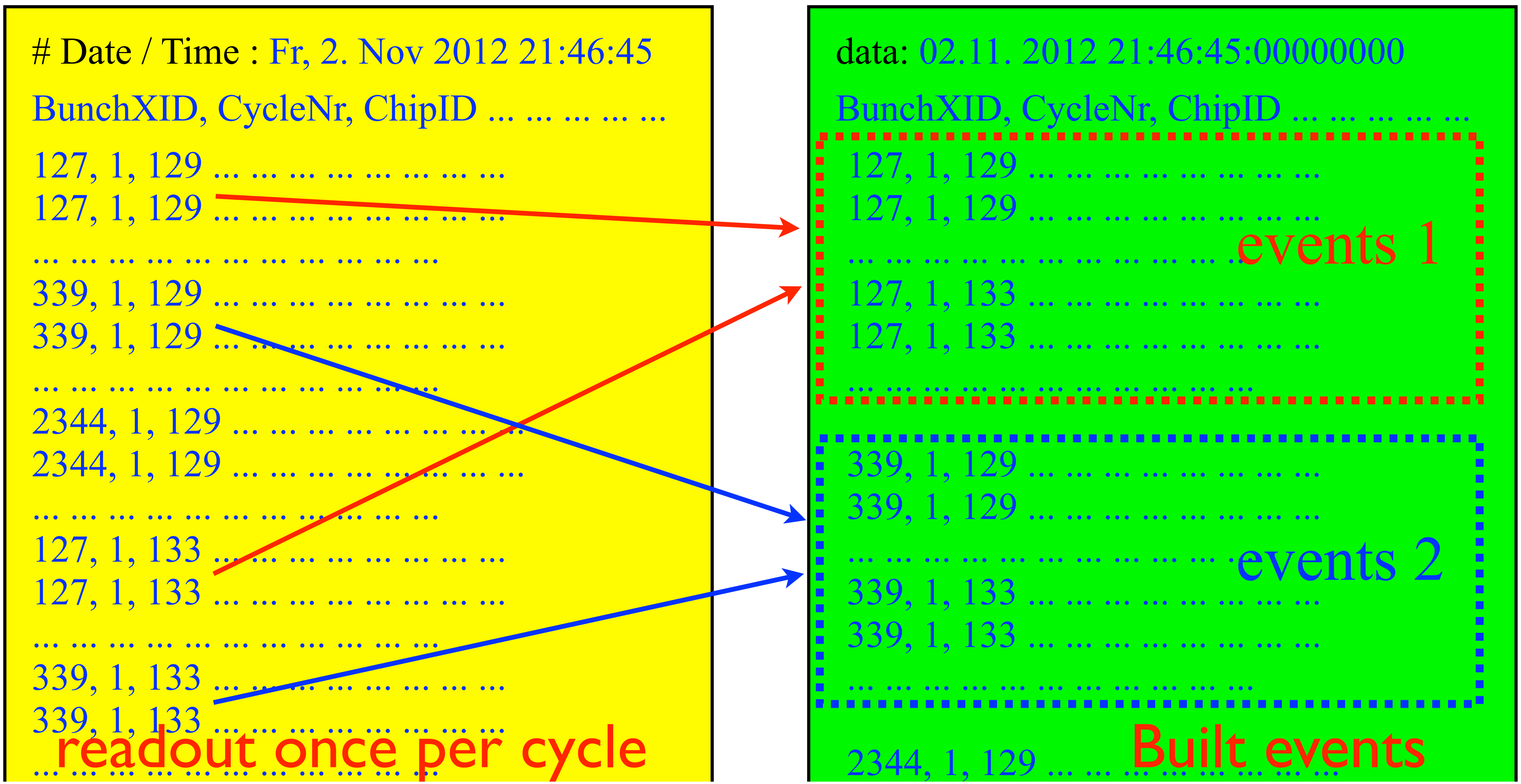
CERN test beam:

- beam cycle: 10s on, 35s off
- during 10s beam:
  - 12-16 readout cycles with up to 16 events per cycle

Event building

Labview DAQ data structure (CERN test beam): Ascii file

- 12 integers: BunchXID, CycleNr, ChipID, ..., Channel, TDC, ADC, ... HitBit, GainBit
- event building: BunchXID + CycleNr == Event
- Database timestamp: # Date / Time : Fr, 2. Nov 2012 21:46:45



LCIO conversion

Marlin Processor: LabviewConverter

- events building
- data format conversion
- database run timestamp creation

- LCIO conversion is still needed
- to be done online in the future

```
============================================================================
        Event  : 1 - run:  10005 - timestamp 1351889236000000000 - weight 1
============================================================================
 date:      02.11.2012  20:47:16.000000000
 detector : unknown
 event parameters:

 collection name : LabviewData
 parameters:

--------------- print out of LCGenericObject collection ---------------

  flag:  0x80000000
 parameter DataDescription [string]: i:BunchXID; i:CycleNr; i:ChipID; i:ASICNr; i:EvtNr; i:Channel; i:TDC; i:ADC; i:XPos; i:YPos; i:HitBit; i:GainBit,
 parameter TypeName [string]: LabviewBlock,

 [   id   ] i:BunchXID; i:CycleNr; i:ChipID; i:ASICNr; i:EvtNr; i:Channel; i:TDC; i:ADC; i:XPos; i:YPos; i:HitBit; i:GainBit - isFixedSize: true
 ------------------------------------------------------------
 [00000004] i:19; i:1; i:129; i:0; i:0; i:0; i:989; i:227; i:6; i:7; i:0; i:1;  --------------------------------------------------------
 [00000005] i:19; i:1; i:129; i:0; i:0; i:1; i:982; i:240; i:5; i:7; i:0; i:1;  --------------------------------------------------------
 [00000006] i:19; i:1; i:129; i:0; i:0; i:2; i:997; i:232; i:4; i:7; i:0; i:1;  --------------------------------------------------------
 [00000007] i:19; i:1; i:129; i:0; i:0; i:3; i:988; i:223; i:3; i:7; i:0; i:1;  --------------------------------------------------------
 [00000008] i:19; i:1; i:129; i:0; i:0; i:4; i:984; i:251; i:2; i:7; i:0; i:1;  --------------------------------------------------------
 [00000009] i:19; i:1; i:129; i:0; i:0; i:5; i:991; i:254; i:1; i:7; i:0; i:1;  --------------------------------------------------------
 [0000000a] i:19; i:1; i:129; i:0; i:0; i:6; i:1001; i:233; i:6; i:8; i:0; i:1;  --------------------------------------------------------
 [0000000b] i:19; i:1; i:129; i:0; i:0; i:7; i:984; i:256; i:5; i:8; i:0; i:1;  --------------------------------------------------------
 [0000000c] i:19; i:1; i:129; i:0; i:0; i:8; i:993; i:245; i:4; i:8; i:0; i:1;  --------------------------------------------------------
 [0000000d] i:19; i:1; i:129; i:0; i:0; i:9; i:997; i:238; i:3; i:8; i:0; i:1;  --------------------------------------------------------
 [0000000e] i:19; i:1; i:129; i:0; i:0; i:10; i:993; i:230; i:2; i:8; i:0; i:1;  --------------------------------------------------------
 [0000000f] i:19; i:1; i:129; i:0; i:0; i:11; i:992; i:226; i:1; i:8; i:0; i:1;  --------------------------------------------------------
 [00000010] i:19; i:1; i:129; i:0; i:0; i:12; i:974; i:230; i:6; i:9; i:0; i:1;  --------------------------------------------------------
 [00000011] i:19; i:1; i:129; i:0; i:0; i:13; i:990; i:241; i:5; i:9; i:0; i:1;  --------------------------------------------------------
 [00000012] i:19; i:1; i:129; i:0; i:0; i:14; i:982; i:236; i:4; i:9; i:0; i:1;  --------------------------------------------------------
 [00000013] i:19; i:1; i:129; i:0; i:0; i:15; i:986; i:244; i:3; i:9; i:0; i:1;  --------------------------------------------------------
 [00000014] i:19; i:1; i:129; i:0; i:0; i:16; i:985; i:230; i:2; i:9; i:0; i:1;  --------------------------------------------------------
 [00000015] i:19; i:1; i:129; i:0; i:0; i:17; i:980; i:237; i:1; i:9; i:0; i:1;  --------------------------------------------------------
```

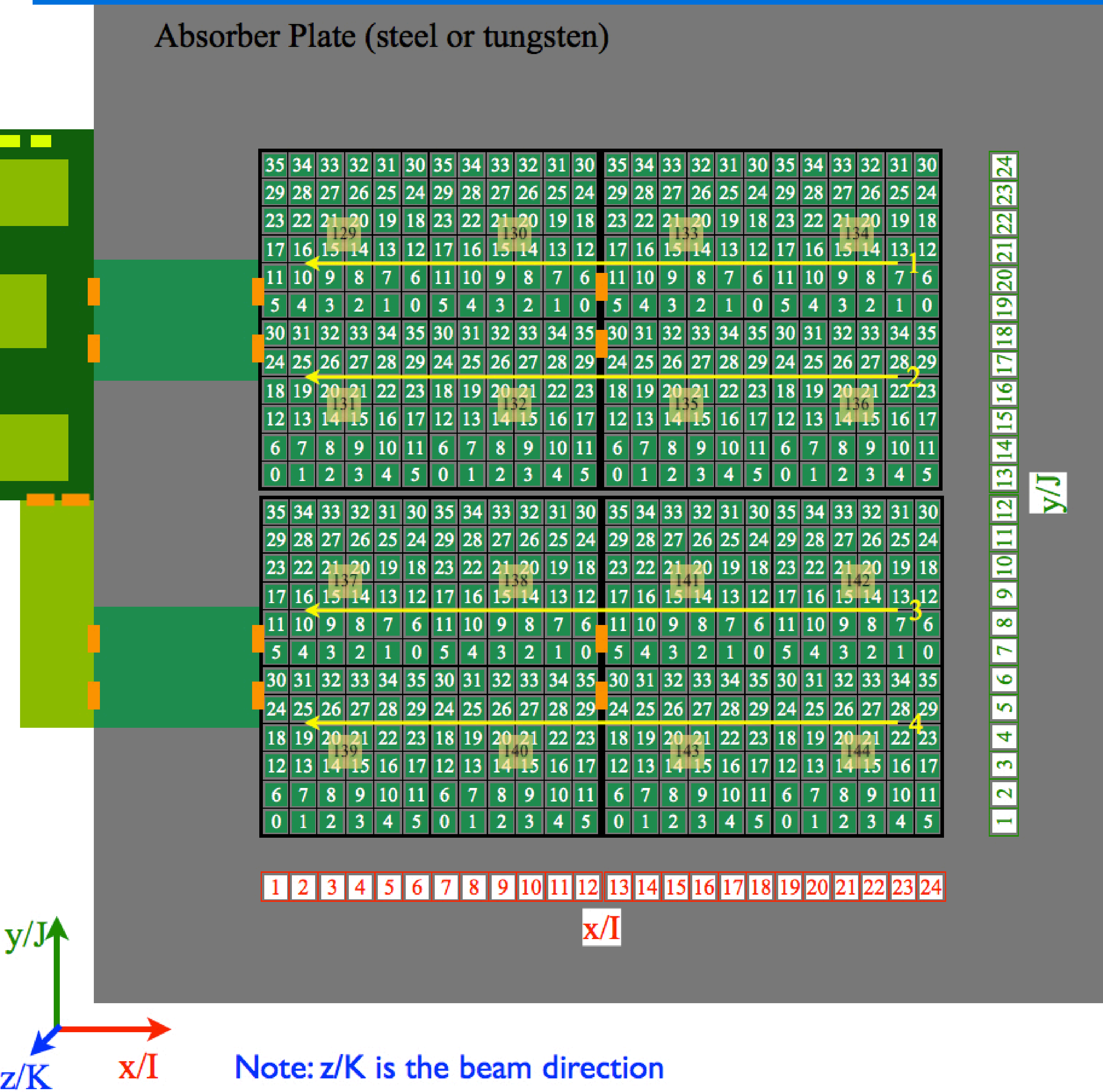
LCIO format

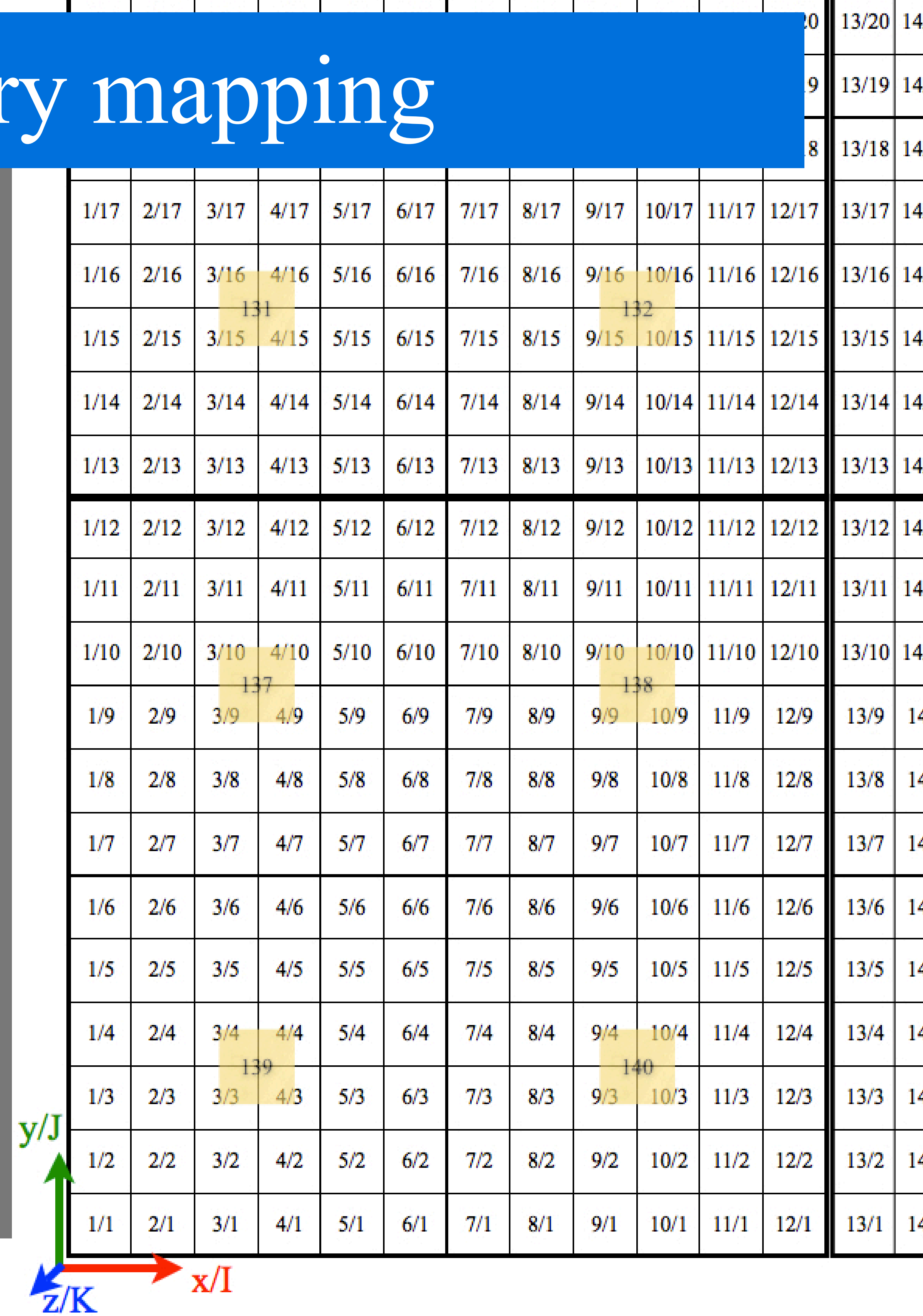
Test beam data offline analysis software

The scintillator HCAL technological prototype:

- Analysis software for CERN test beam
  - test beam data have been converted to slcio format
  - the analysis process continue to stick to the ILCsoft LCIO/MARLIN framework
  - mapping from electronics to geometry
  - the understanding from the physics prototype will be transferred
  - and expand to the understand of the 4th dimension - time
  - analysis the data and write into root for final plots

Electronics geometry mapping



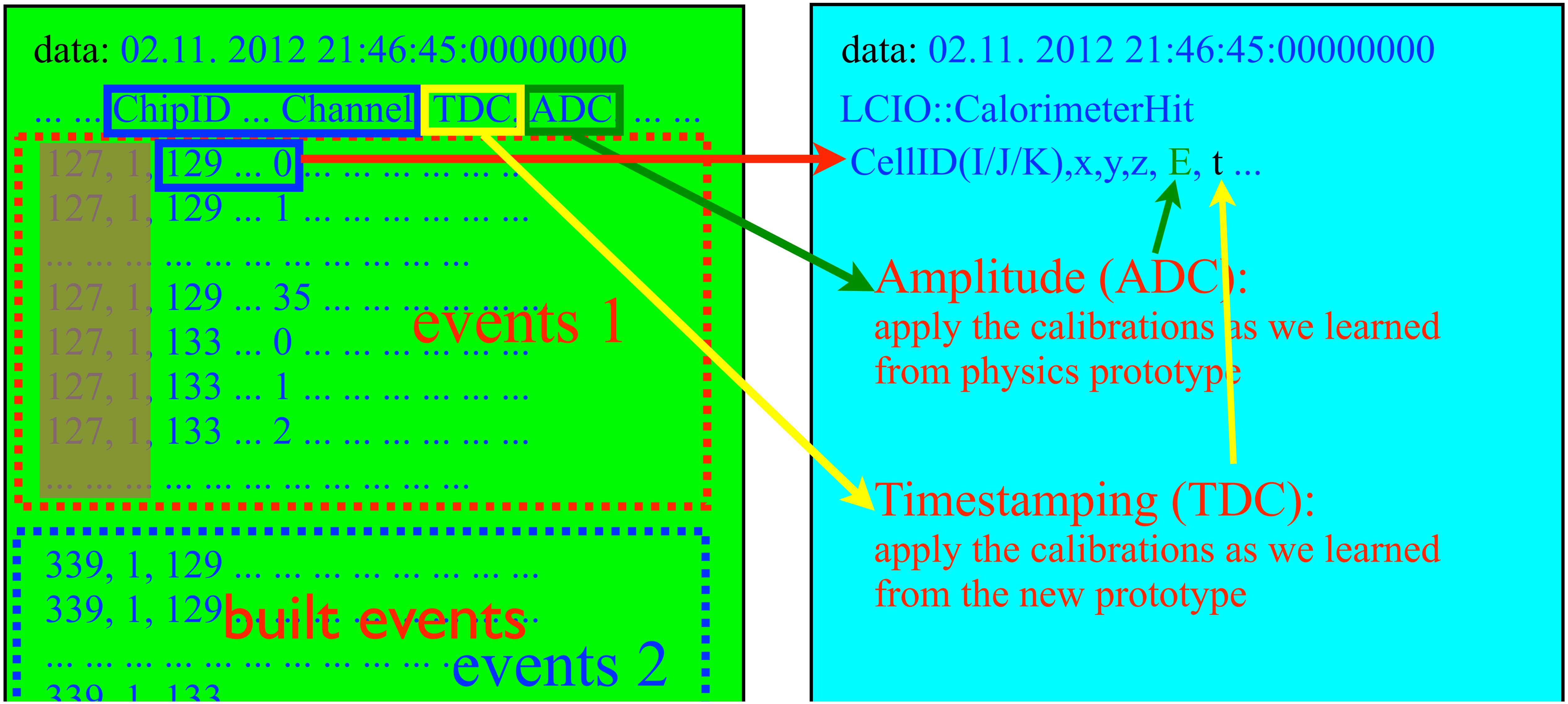


- Mapping of CERN test beam hardware setup
  - right hand coordinate
  - coordinate definition: z/K is the beam direction, y/J direction is up.
  - Mapping between model/chip/channel(HW), I/J/K and x/y/z (SW Reconstruction).

Reconstruction overview

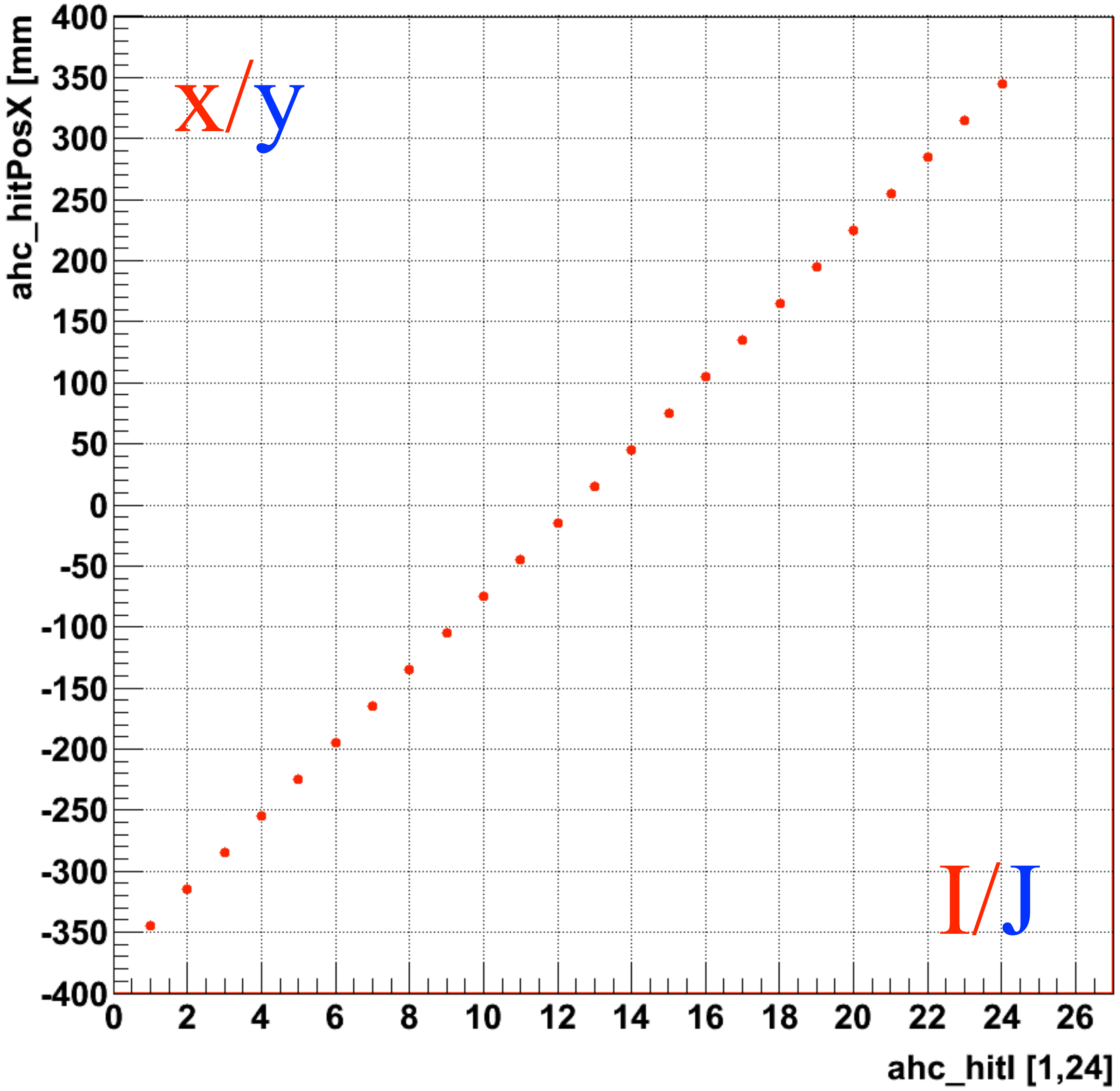
USE ILCsoftware framework:

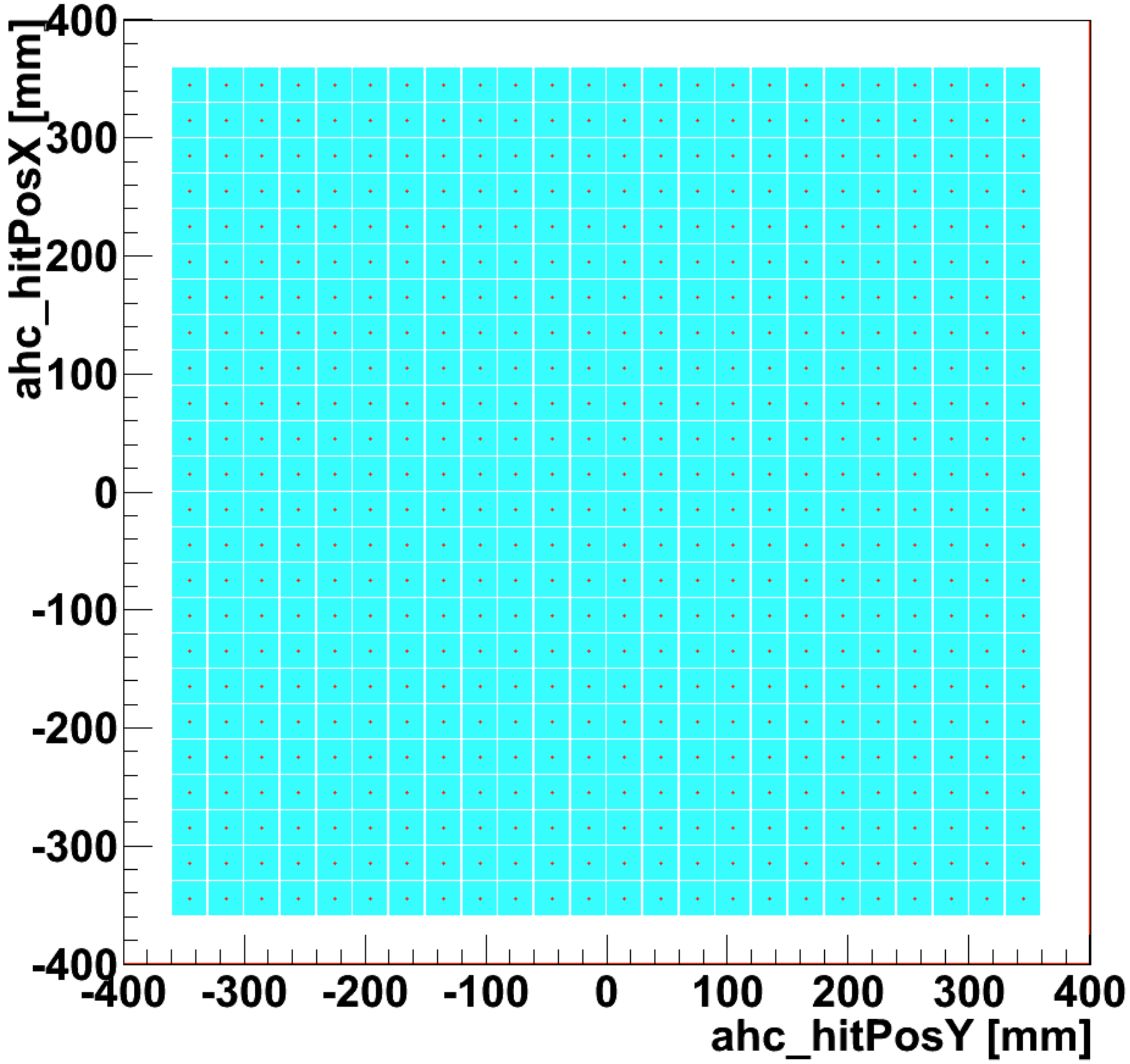
- using MySQL database to handle the geometry mapping and condition/calibration constants
- using Marlin Processors for algorithm: Amplitude calibration, time stamping calibration ...
- write out as CalorimeterHit in LCIO format
  - reconstructed CellID,x,y,z,E,t ...



Reconstructed geometry

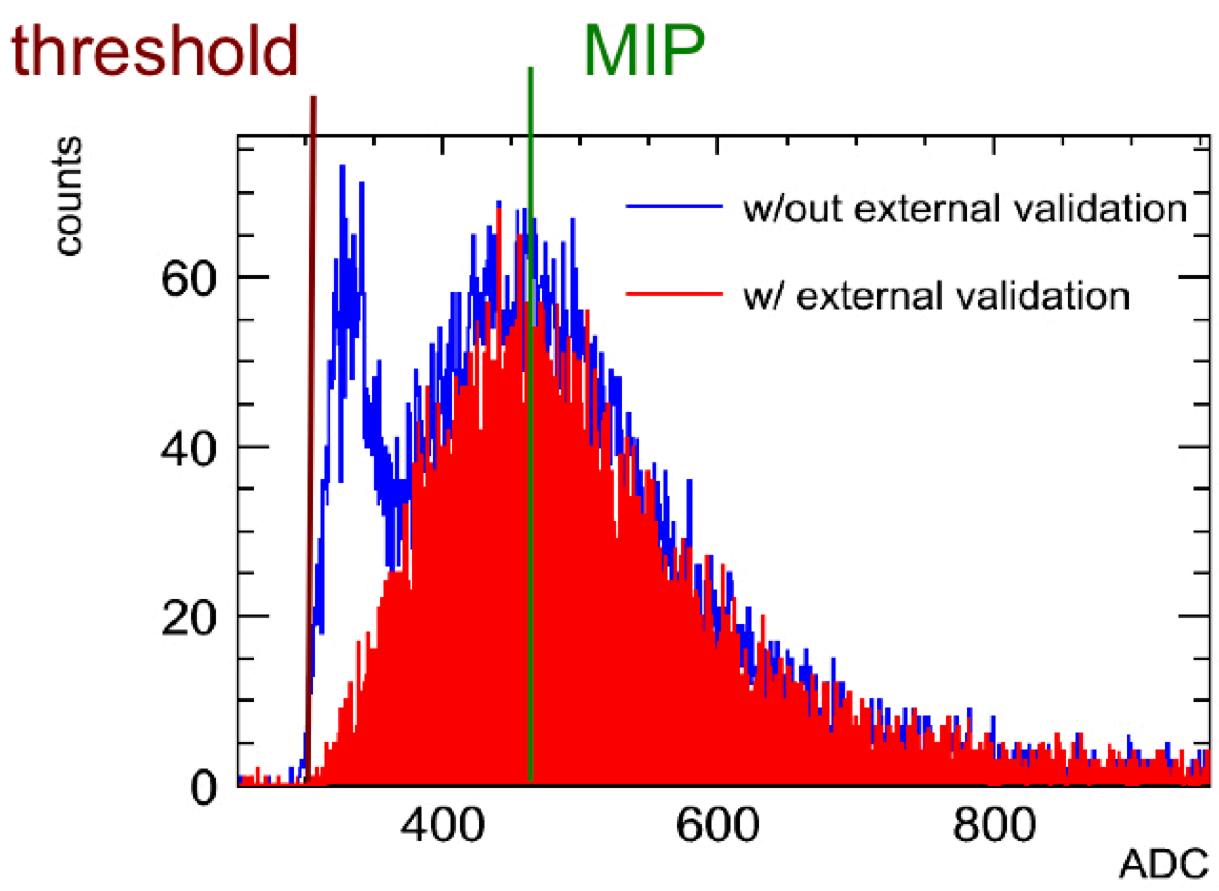
- Geometry reconstructed for 180GeV Muon





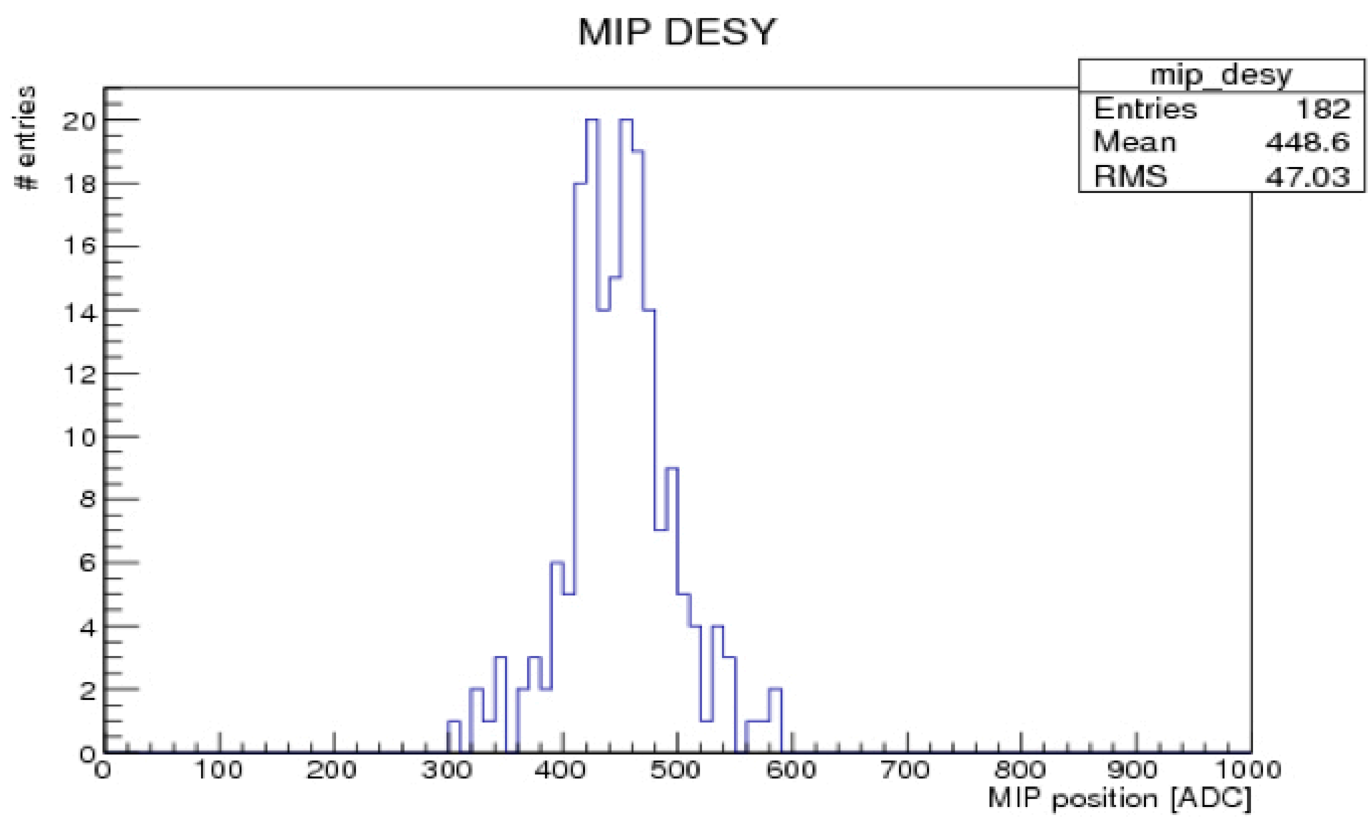
- Blue square shows the tiles and the dot in the centre shows the position
- After reconstruction, the correlation of the coordination for the hits

Calibration: MIP



Performed at DESY test beam

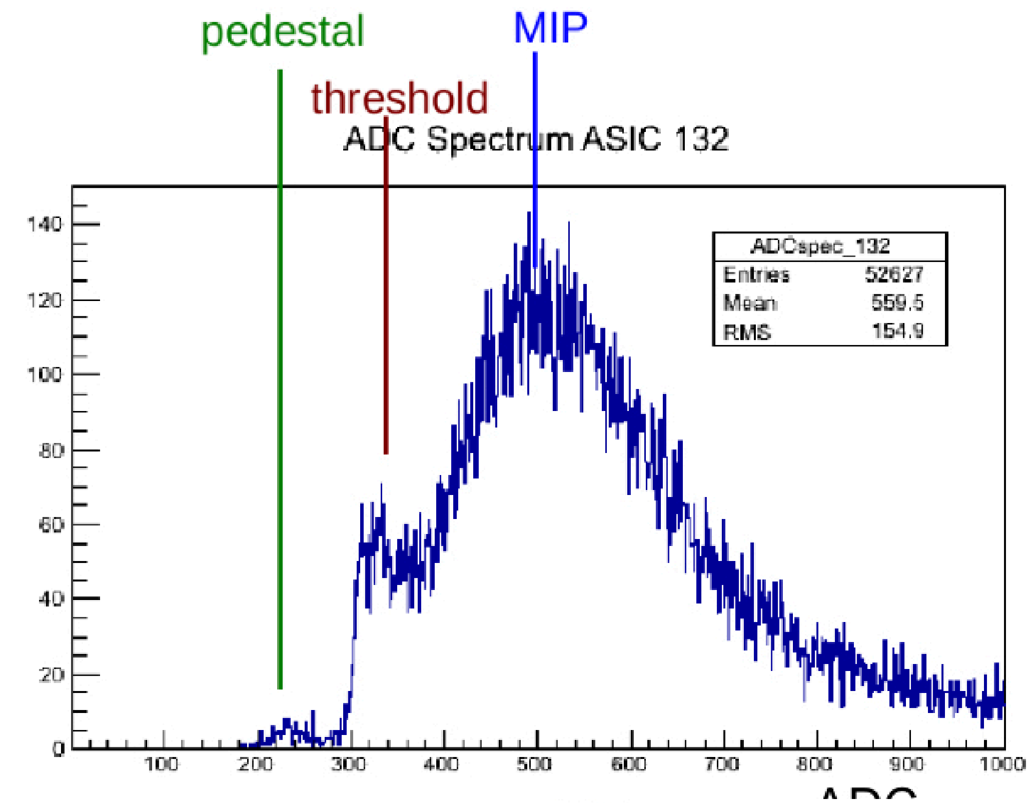
- 3 GeV electron
- on individual tiles
- individual threshold adjustment
- test for the event validation

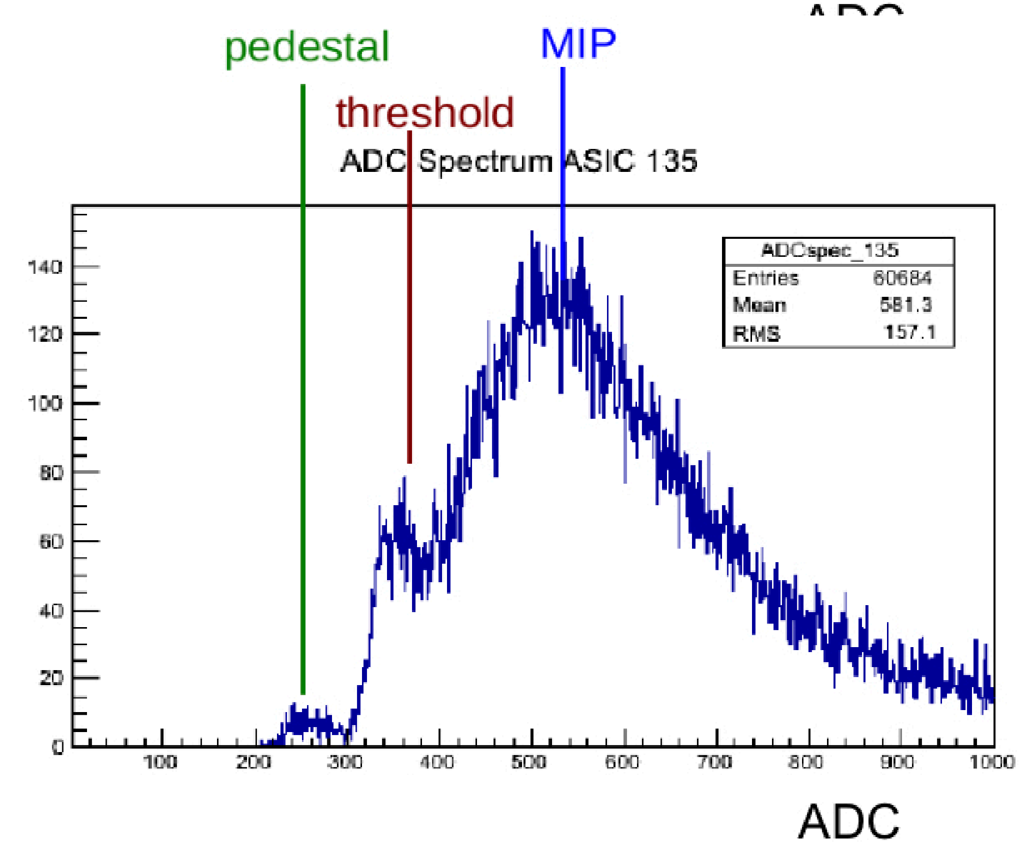


- Spread of the MIP most probable value ~ 10%
- This value includes:
  - individual SiPM bias adjustment
  - SiPM gain equalization via preamplifiers

CERN test beam: Muons

- Cross-check of threshold calibration
  - flexible electronics allows equalization of detector response
  - homogeneity of MIP positions
- Successful test for external validation:
  - Threshold < 0.5 MIP
  - Noise < 50 Hz/HBU (up to 700 Hz/HBU w/ out validation)
  - Beam rate 1 – 50 Hz



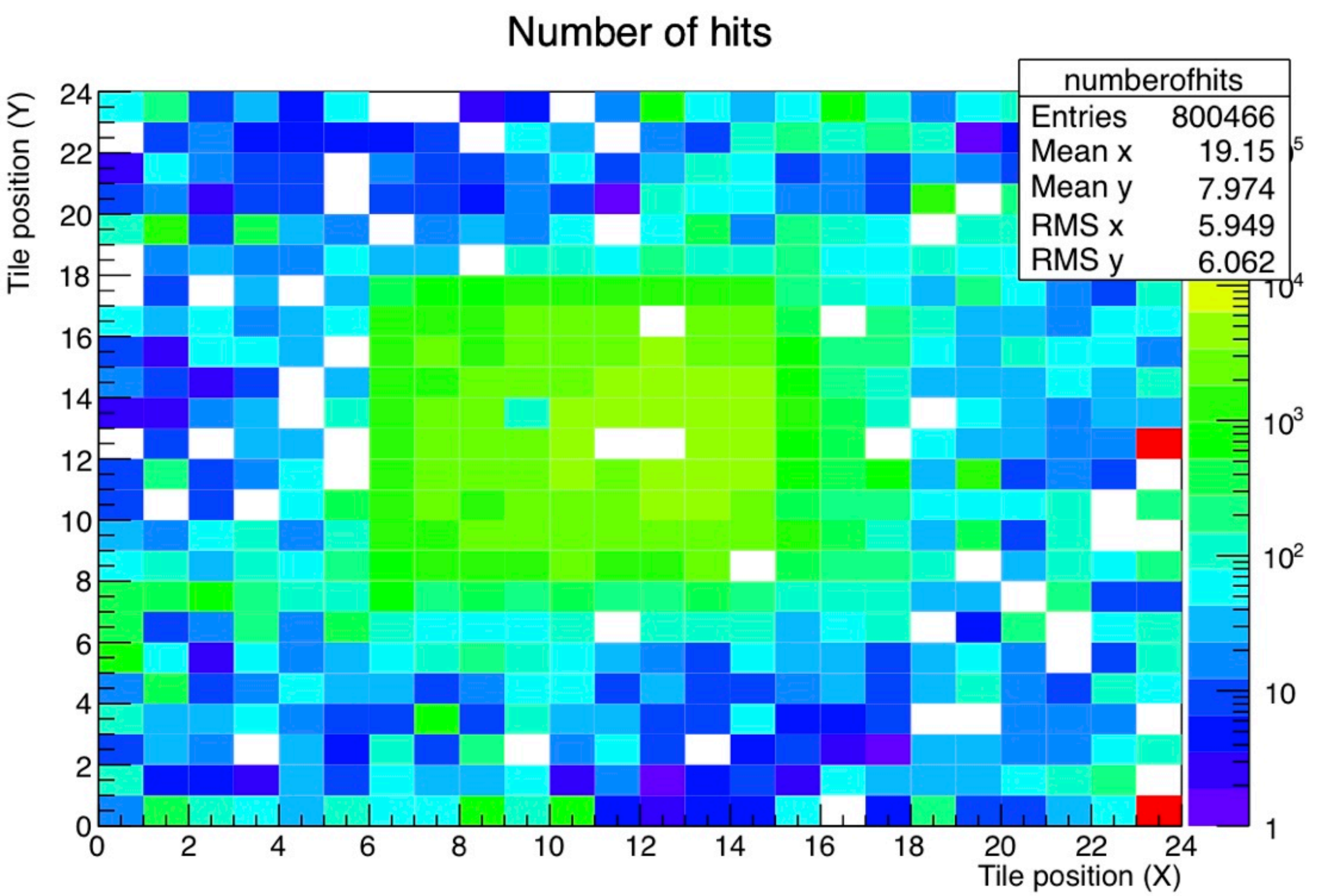


- 36 channels superimposed
- Noise peak due to known small inefficiency of external validation

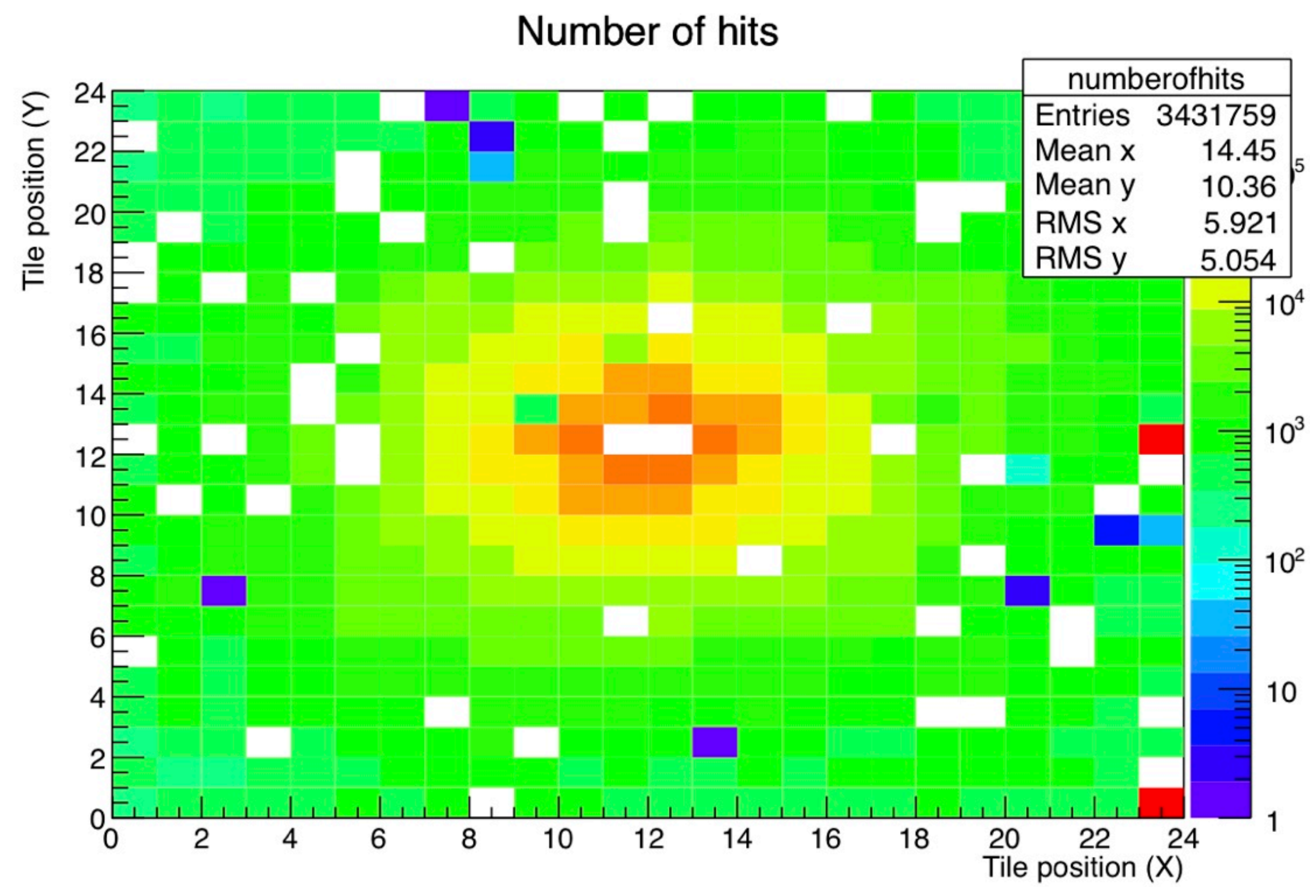
CERN test beam: Muons and Pions

The events collected at CERN:

- more than 400k muons events reconstructed
- ~ 420k pion events reconstructed at 180 GeV
- ~ 86k pion events reconstructed at 50 GeV



180 GeV muons



180 GeV pions

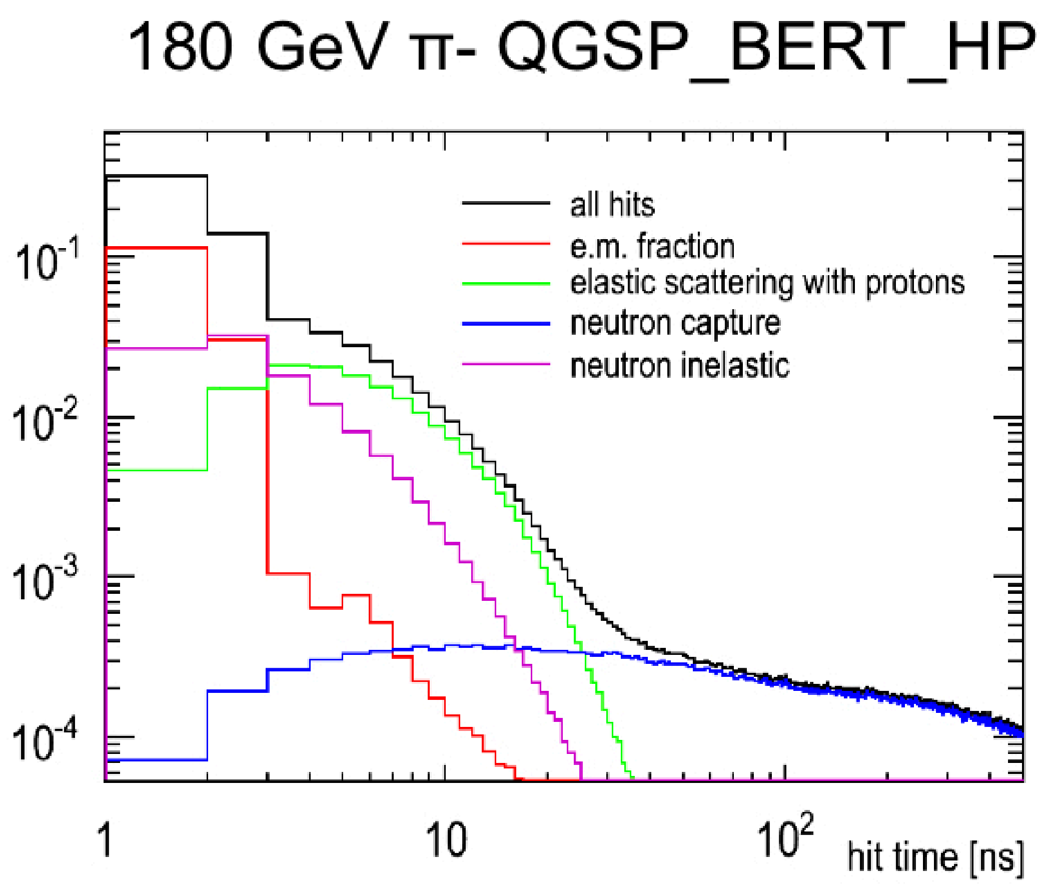
The two white color channels in the center are dead channels

dead channels due to SiPM, ASIC, connection

The two red color channels are the "T0" reference channels

- input from the coincidence triggers

Hadronic shower timing



see Frank Simon's talk

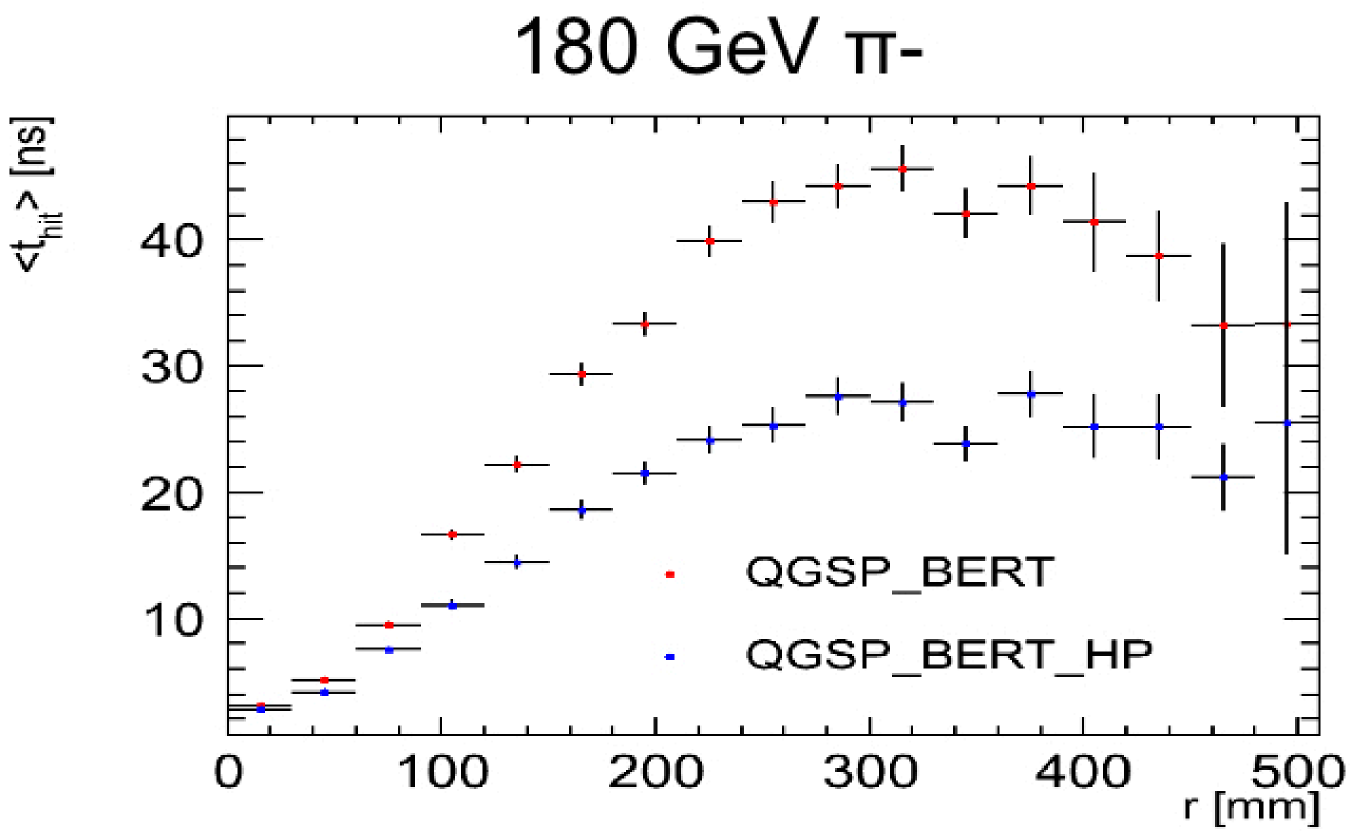
First timing experiment in CALICE (T3B)

- One dimensional: row of 15 channels
- Picosecond resolution (not scalable)

- Late neutron component in hadronic showers: Impact on Particle Flow Algorithm
  - Improve shower reconstruction with time cuts
- Estimate effect of pile-up (CLIC)

Hadronic shower timing

Do we have the sensitivity?



The scintillator HCAL technological prototype:

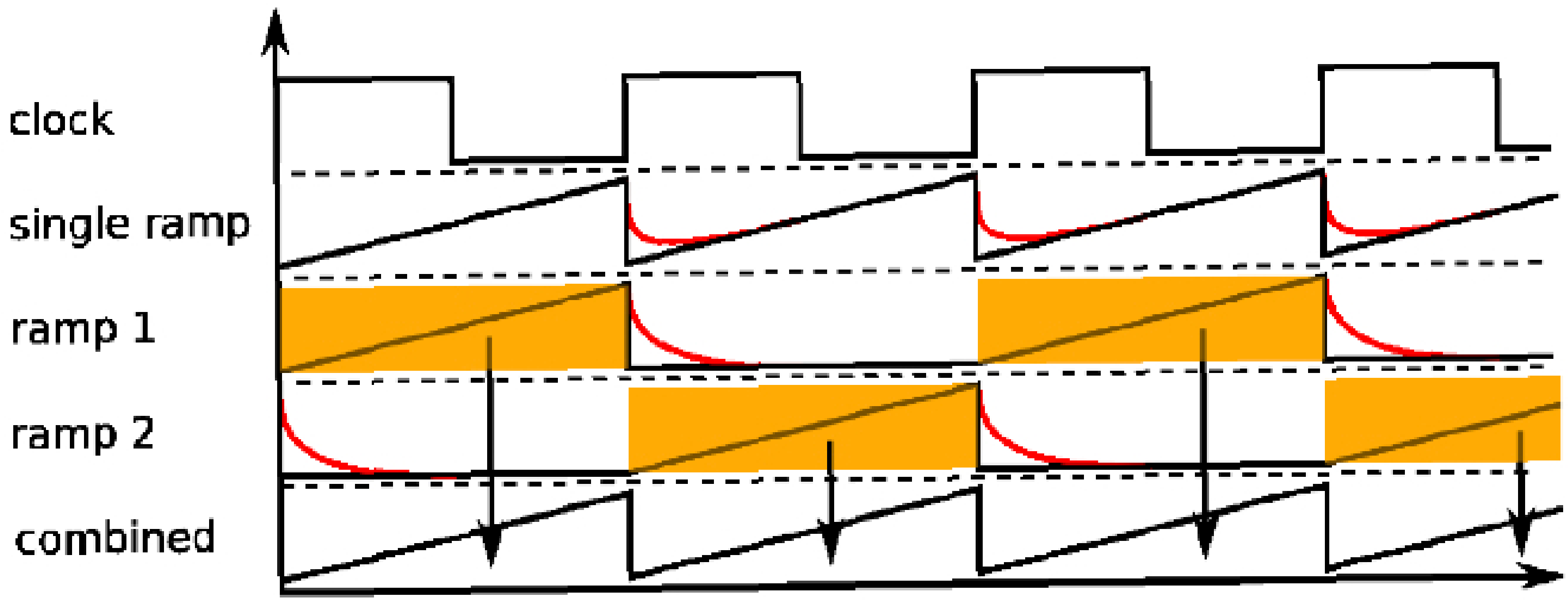
- nanosecond resolution scalable technology
- one layer (4 HBU): tested at CERN

simulation for the CERN AHCAL setup

- 500k MC events

AHCAL time stamping

Time stamping creation:

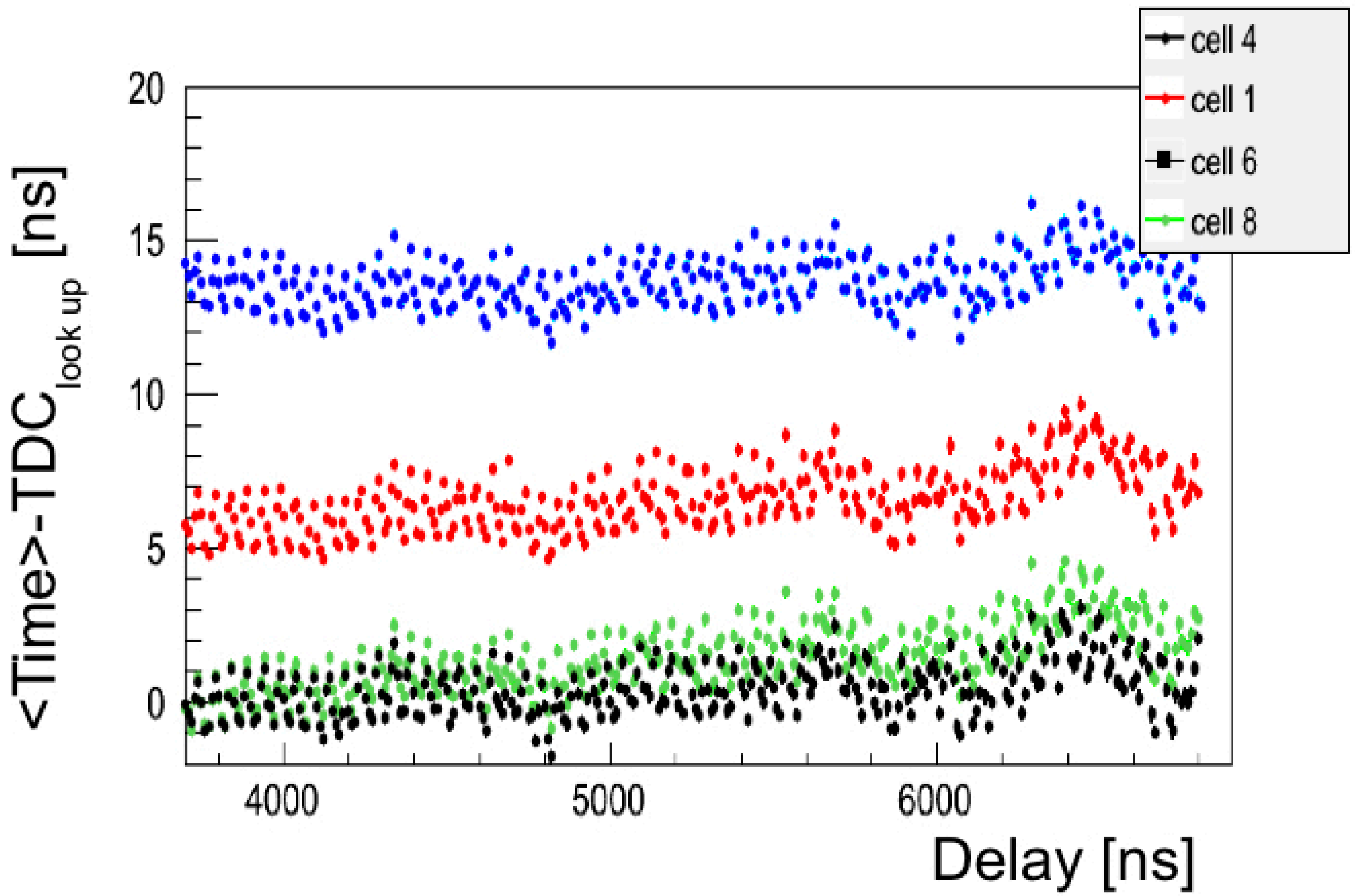


- 2 multiplexed voltage ramps per chip (adj. length):
  - 5 µs long
- voltage value at hit is stored in memory cell:
  - ~ 1.2 ns/bin (5 µs/4096 bins)

Calibration: Time stamping

Ramp calibration performed at DESY

- charge injection with a pulser
- time [ns] = f(TDC) + offset



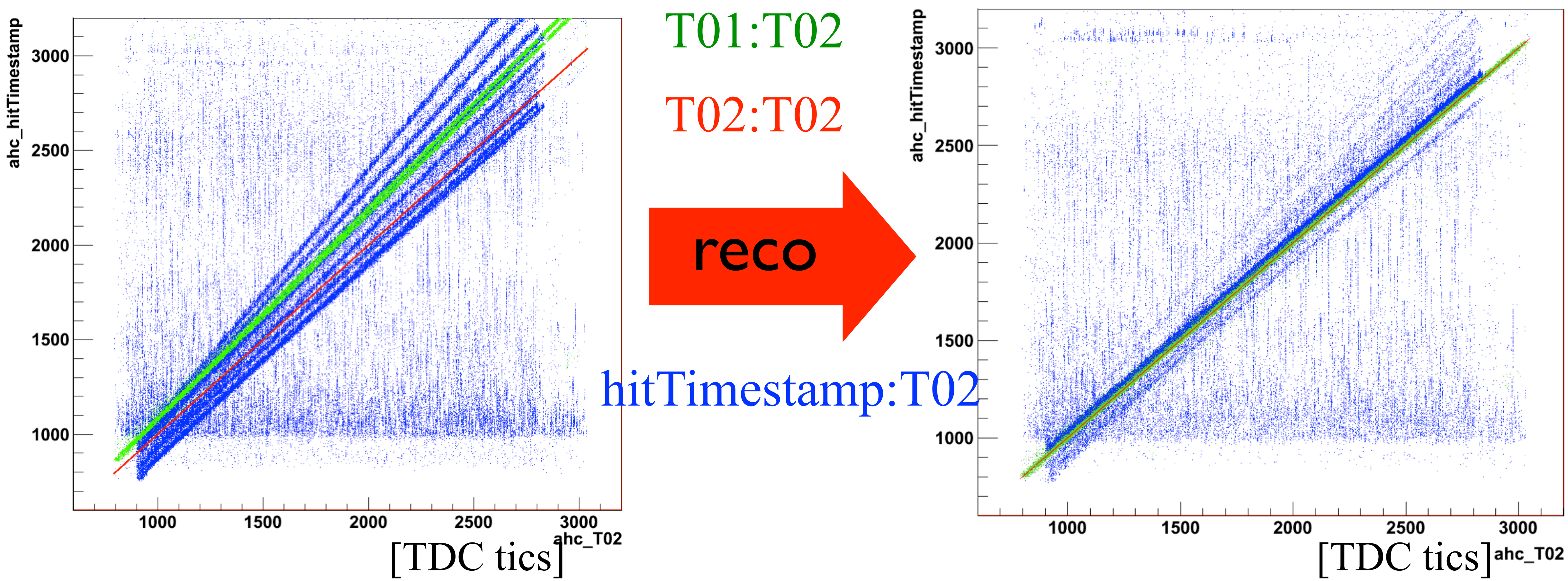
- different time slice / buffer number
- same channel / chip

- each memory cell has different offset
- Single channel spread ~ 3 ns

CERN test beam: Time stamping

- Time stamping: TDC

180GeV Pions



w/o TDC offset calibration

after TDC offset calibration

- Very good calibrations for the central 4 chips
  - high statistic muons selected by the online validation

Calibrations are ongoing

Summary

- For the scintillator HCAL technological prototype, the analysis software framework has been setup.
- The Converter has been done to move "train" back onto the track.
- The reconstruction software development continue to stick to the ILC software framework.
- Reconstruction process has been built.
- To finalize the calibration constants, and continue to improve the calibrations.