Pre-results for the CERN PS tests of the eDHCAL

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U. of Manchester
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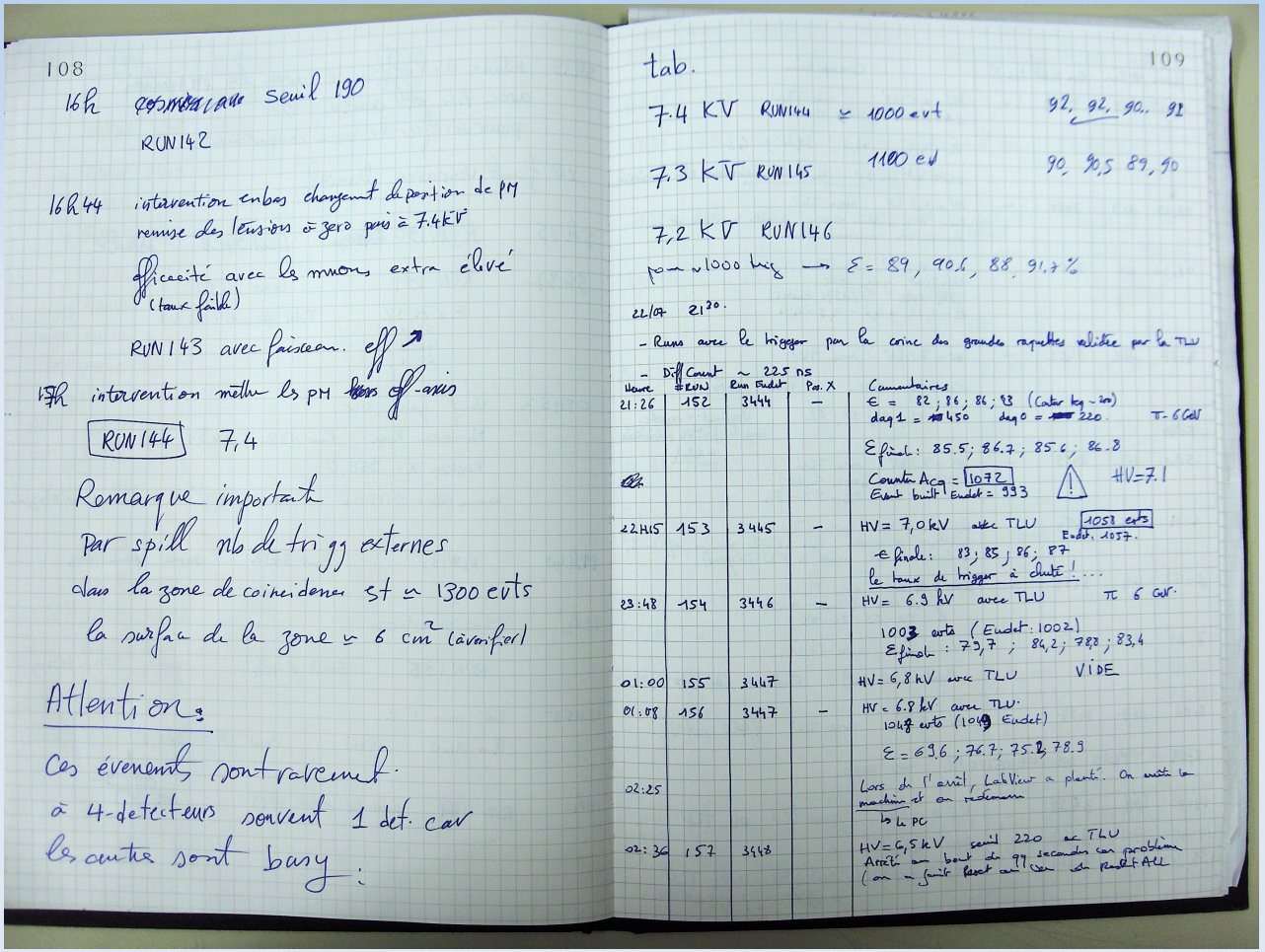
Warning!!

- “Old Style” Adventurous Test period
  - Analogic Logbook
  - “Do-It-Yourself” style
- Very few shiftees
  - Imad Laktineh
  - Emmanuel Latour
  - Robert Kieffer
  - Marc Bedijian
  - Vincent Boudry

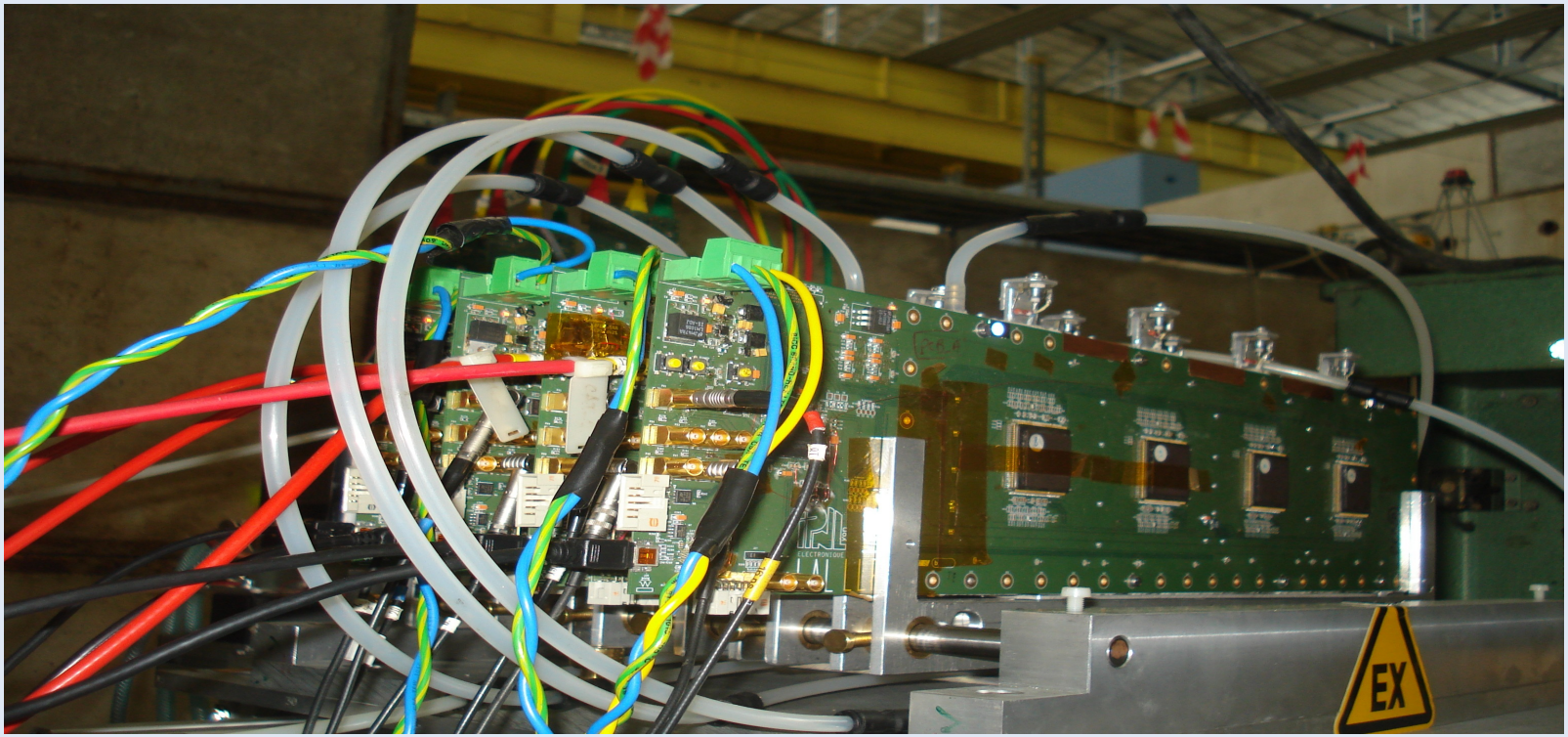


EVERYTHING should be labelled ”VERY PRELIMINARY”

Detectors

- 4 (5) 8×32 cm² GRPC
  - 4 Protvino (Graphite)
  - 1 Lyon (Licron)
- Semi-Digital HCAL (GRPC)
  - High granularity (1 cm²),
  - 2 thresholds

- ILC-like electronics
  - embedded ReadOut Chips with memory
  - low consumption (power pulsing)



Beam periods

PS T10 initially 10—17 july
⇒ 17—24 july with the EUDET telescope

- + 3 additional days in agreement with DEPFET
- With EUDET Pixel Telescope: 7×7 mm² active sensors
  trigger = 9x9 mm² (back) & 4×4 mm² (front) scintillators
- Other data: trigger large scintillators (10×40 cm²)

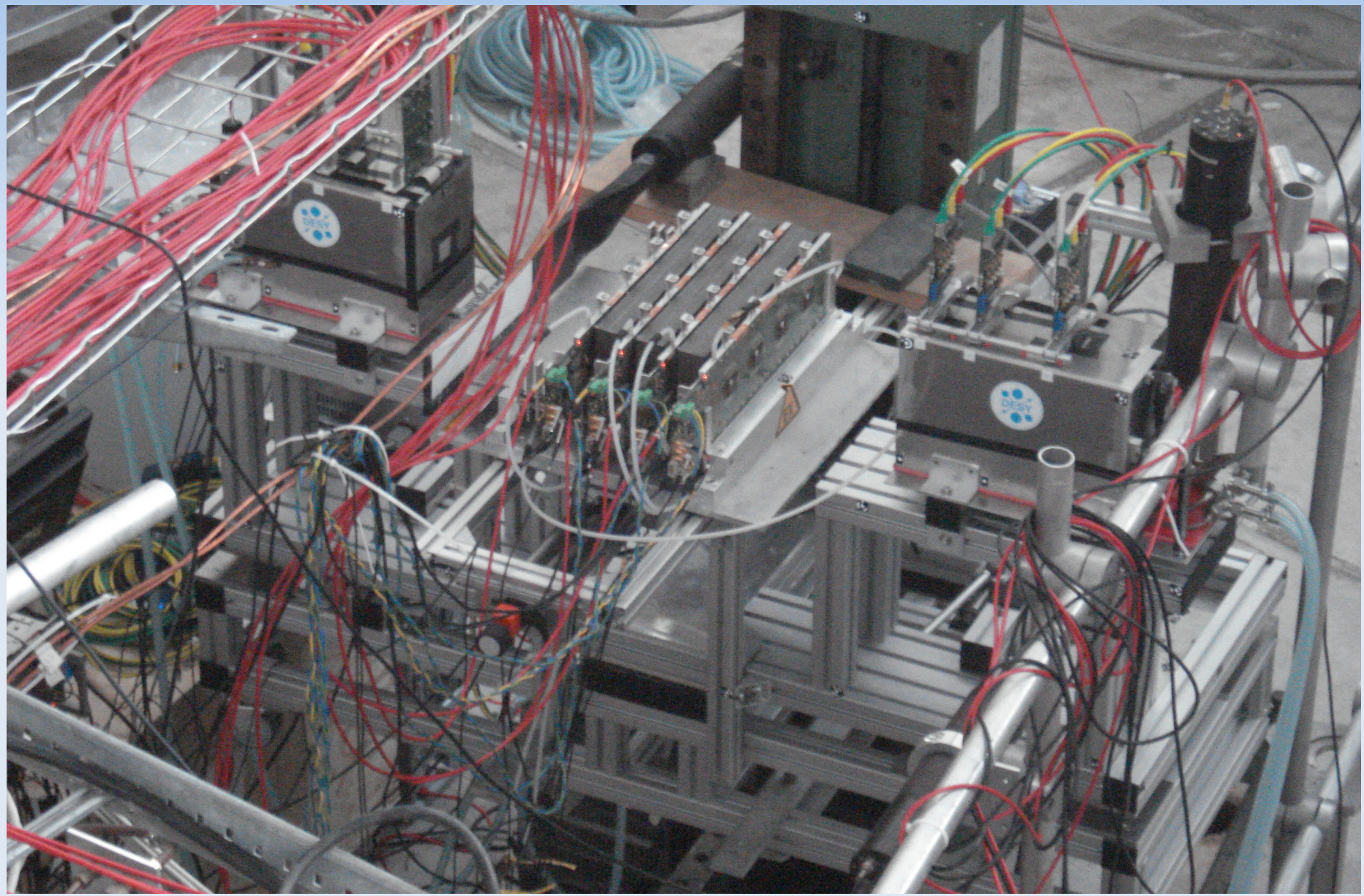
PS T9: 28/07 — 04/08

- Complement Pion data with 2 λ of W
- Analogue readout of 1 chamber
- Test of a wide RPC: 100×35cm²
  - readout with 4 PCB ⇒ ~32×32cm² of readout (1cm² pads)

Mostly π (3-12 GeV) + few μ, very few e-

SPS H2: 4 — 13/08: used solely for MicroMegas⇒ see Catherine's talk

T10 & T9 Set-ups



Data taking (DAQ)

- CERN PS: **400 ms** spills every 48 or 33s (day/night cycles).
  - low multiplicity: low part. density, mostly punch through π's
- 4 HardRocs managed by 1 FPGA × 3-5

- Running mode: **single event with auto trig**
  + BUSY logic & automatic RAMFULL recovery (⊃ BUSY signal)
  - Using the TLU for synchronization with telescope

- USB readout: LabView (R. Della Negra) + libDhcal (C. Jauffret)
  - asynchroneously RO of all cards (”LabView thread”)
  - 2 commands: polling cards (every ms) ; readout
- Data re-formated on PC for a fixed length (~ for ”memory allocation”)
  - Storage as such in binary files
  - dominated by 0's ⇒95% of reduction by std bzip2

DAQ Performances:

Bad start

- “electronic test set-up modified for cosmics, modified for TB”
- last minute changes (command reduction, RAMFULL clearing)

BUT working!!!

- Maximum rate 5 ↗ ~20 Hz for a low volume of data (≤100Hz: single board with no data)
  - event for muons / punch through pions ⇒ dominated by noise
  - maximum volume/card:
    - 20 kbit × 4: 80 kBits @ 1 MHz ⇒ ~ 8 ms
  - Speed limited by the USB connection establishement ~16ms,
  - due partly to the the preparation of data (no pipelining)
    - USB link: ↗ 1 MB/s with one card
    - not fully understood...

”Much better than expected”

Data volume

Very successful data taking

- Mostly π (3-12 GeV) + few μ, very few e-

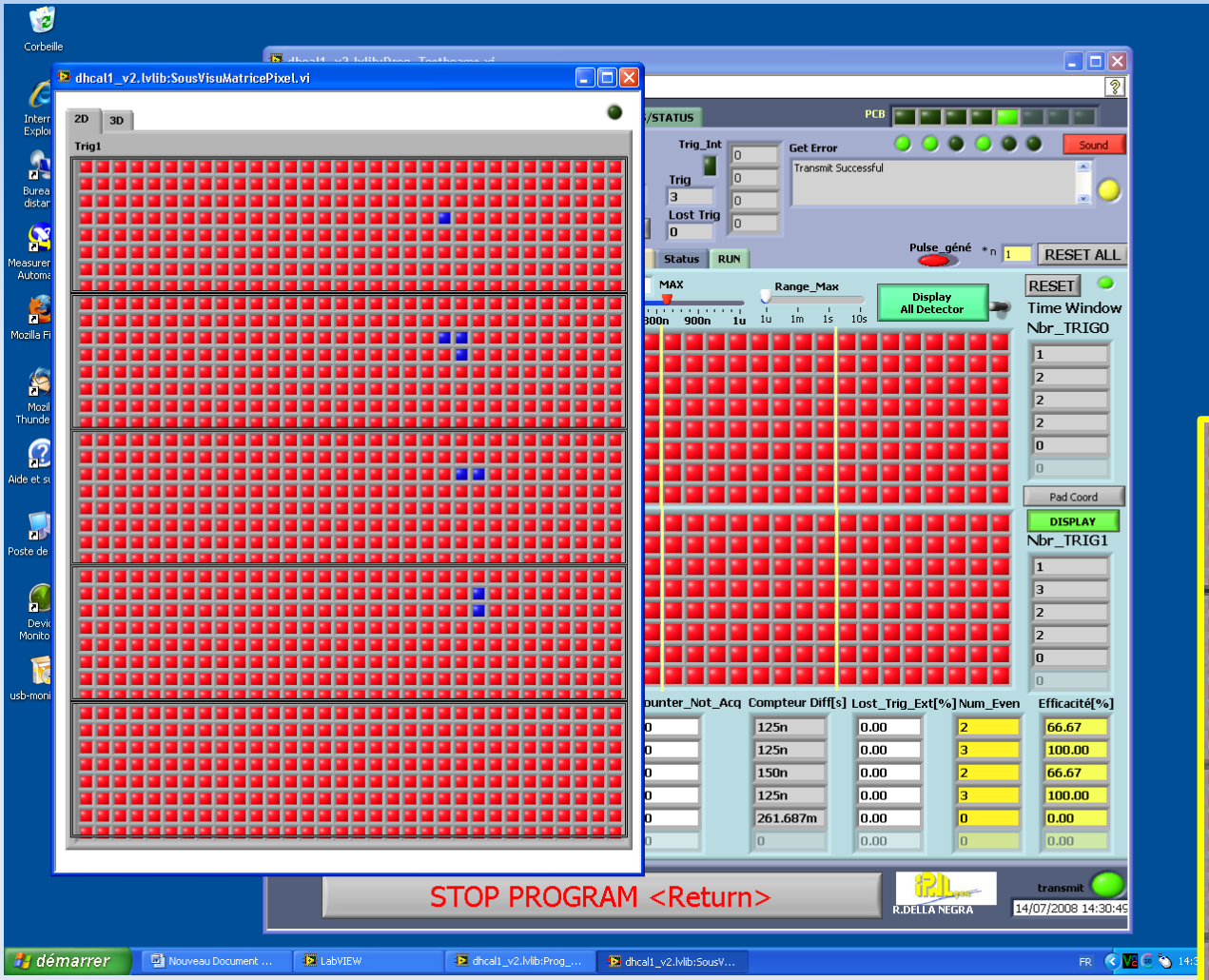
On line **T10**: **~260k** triggered evts taken in 10 days

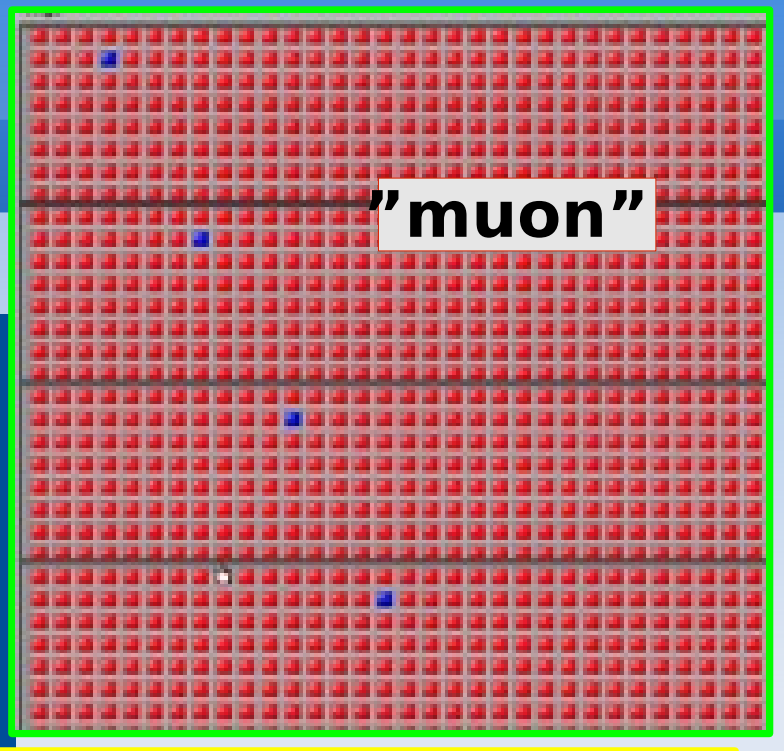
- (+ 500k of noise events)
- Mostly without absorbers
- Most data with EUDET Pixel Telescope:
  trigger = 7×7 mm² scintillators
- Other data: large scintillators (10×40 cm²)
- Scans in **position** (with telescope), **angle**, **HV**, **thresholds**

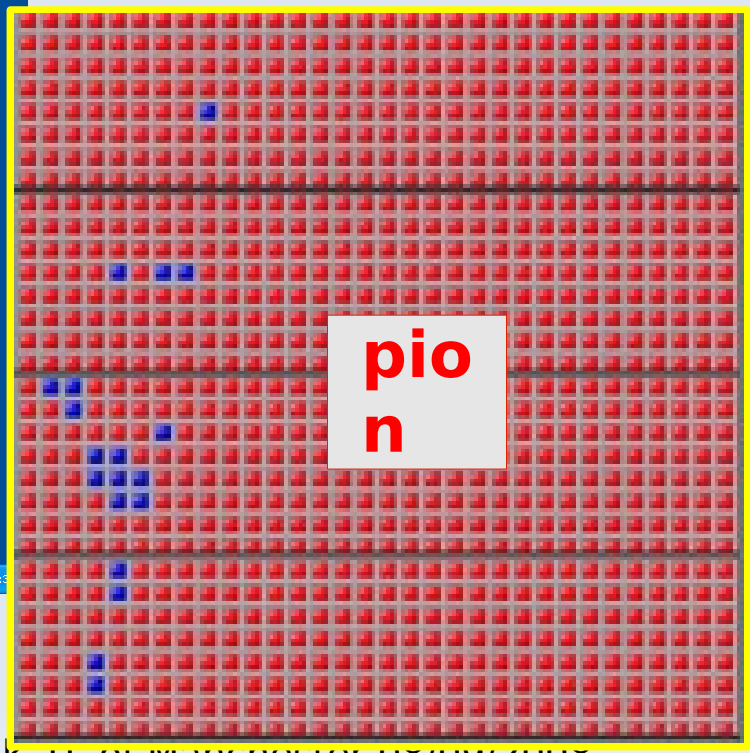
On line **T9**: **~80k** triggered events

- Pion shower response
  - **Energy** & Angle scan 3-12 GeV
    with absorbers (2cm SS (~0.12λ) + opt^{ly} 2 λ of W)
- Large chamber (35×100cm²): mechanical constraints ⇒ 1 SLAB RO
- Analog readout of 1 of the boards

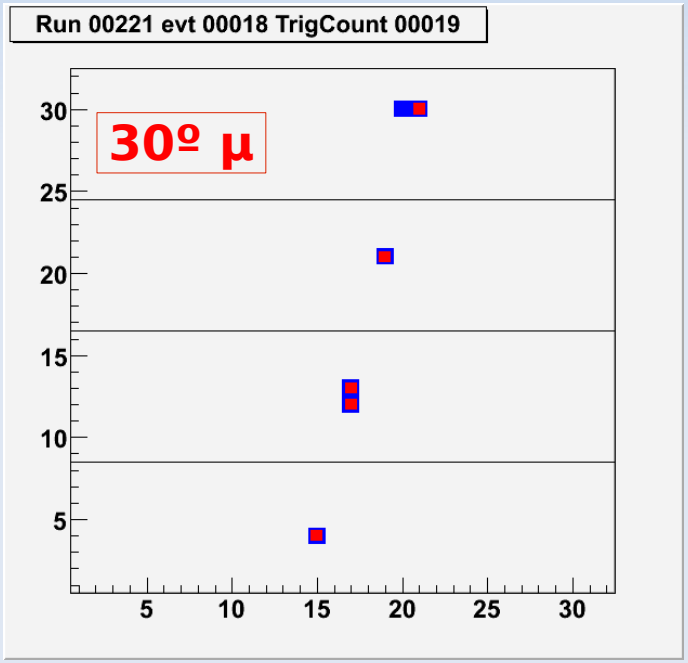
Some events

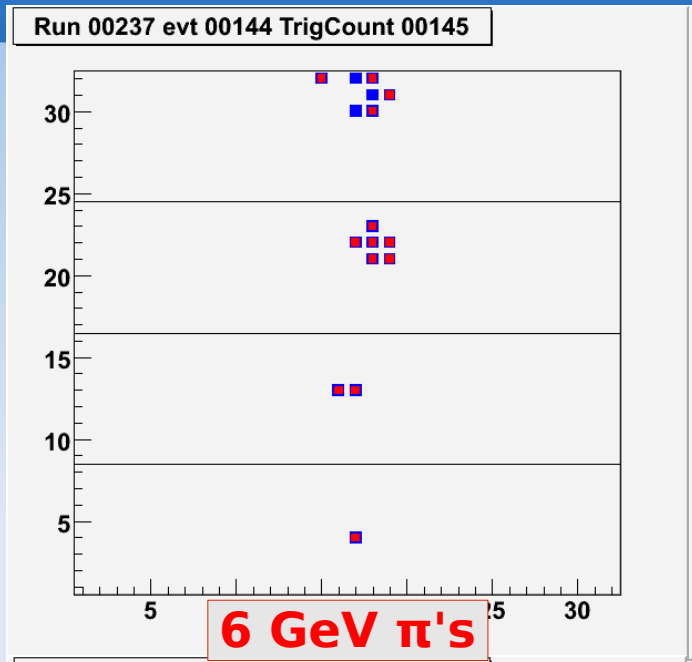

dhcal1_v2.lvlib:SousVisuMatricePixel.vi
2D
3D
Trig1
STOP PROGRAM <Return>

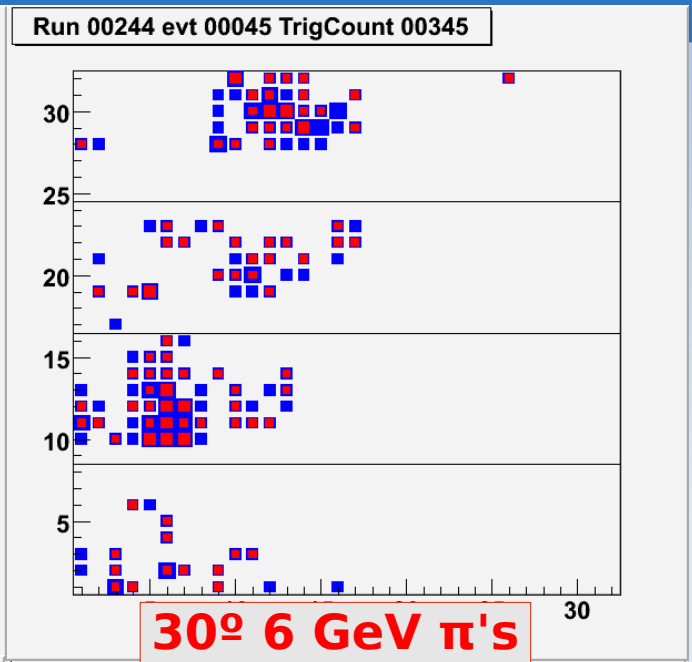

”muon”

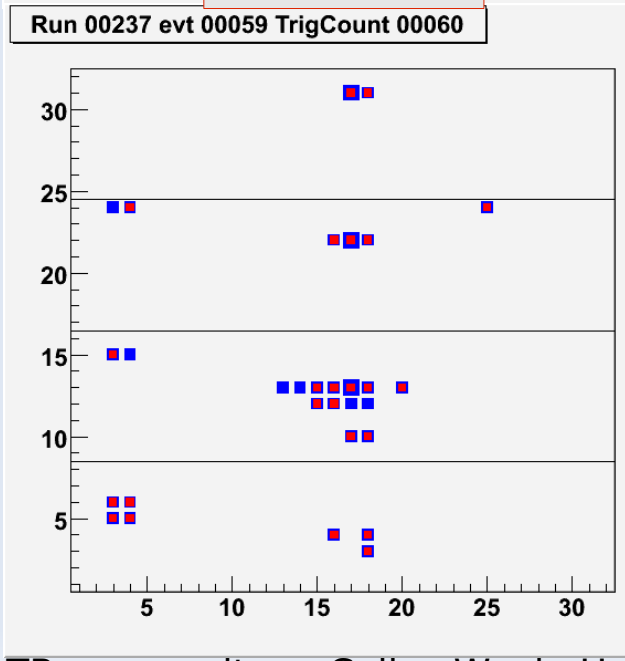

pio
n

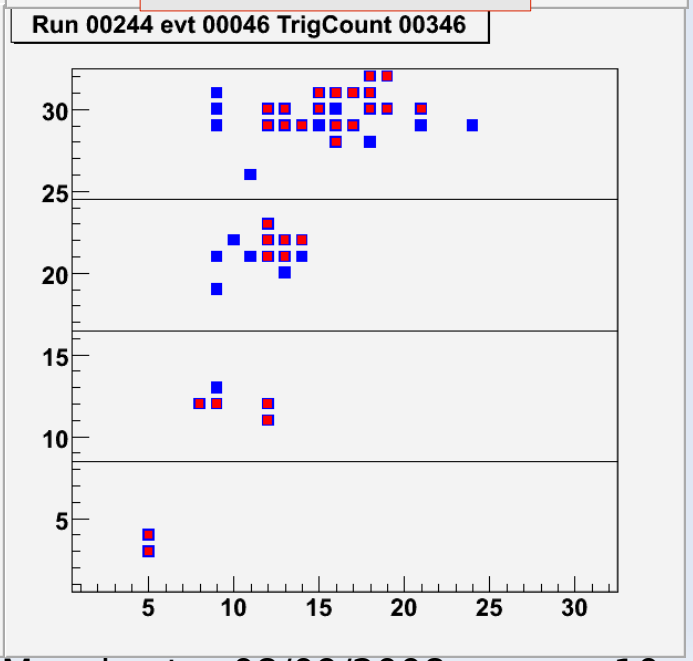
Some events


Run 00221 evt 00018 TrigCount 00019
30º μ


Run 00237 evt 00144 TrigCount 00145
6 GeV π's


Run 00244 evt 00045 TrigCount 00345
30º 6 GeV π's


Run 00237 evt 00059 TrigCount 00060


Run 00244 evt 00046 TrigCount 00346

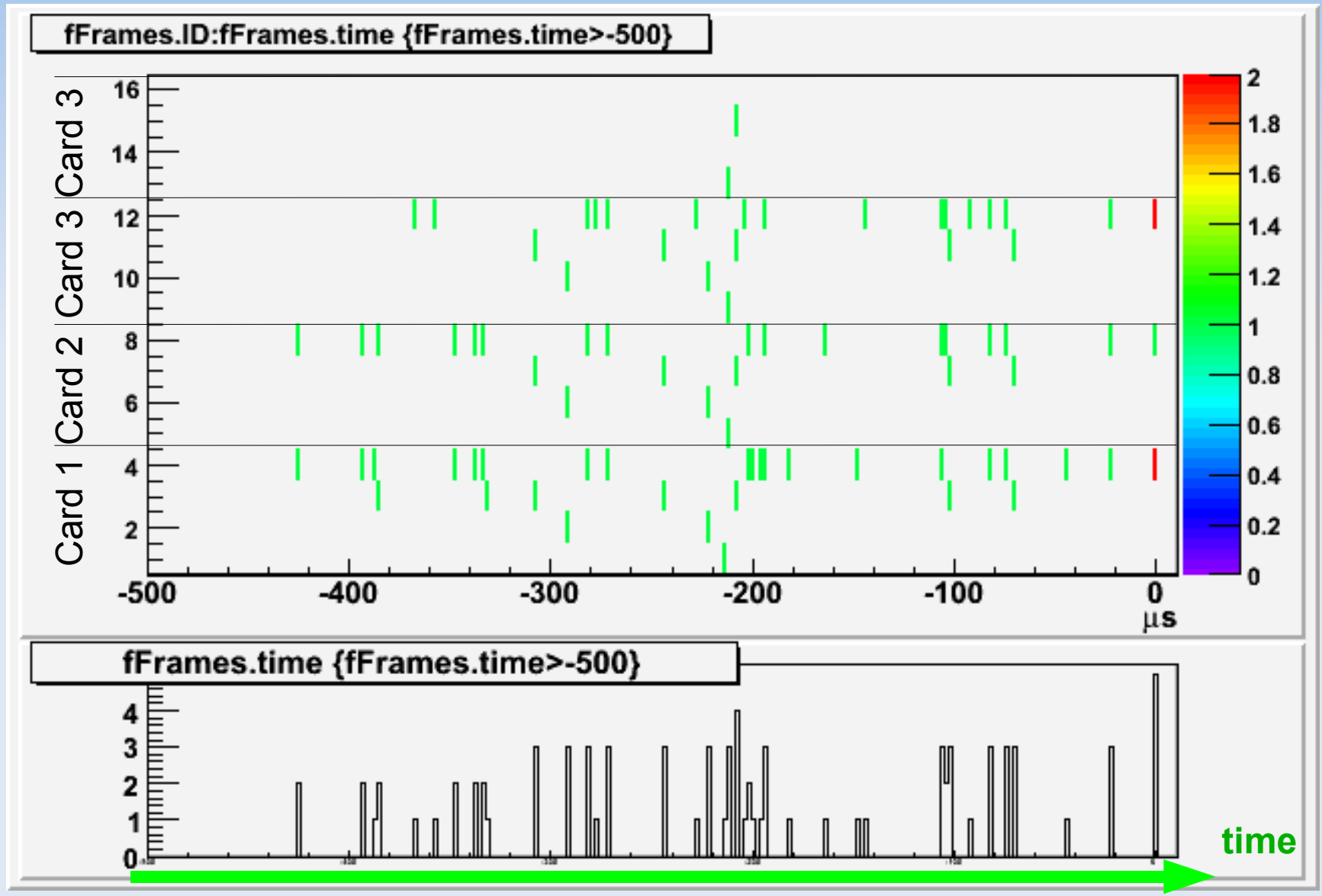
DHCAL single event + auto-trig

- All the hits (thr0 OR thr1) are recorded with a timestamp
  - on RAM full (128 evts) of one of the ROC the memory is cleared
- The timestamp (== BC ID @ 5 MHz) is local to each card
  - Reset on Card Reset OR RAMFull
- A counter @ 40 MHz in the FPGA measures the time difference between the last internal trigger (of any of the ROC) and the external trigger
- The ext. trigger stops the acquisition and the data is transferred from the ROC to the PC
- Synchronizatgion of cards done on the trigger

$$\text{time} = (BC - LastBC) \times \tau_{BC} - DiffCounter \times \tau_{DiffCounter}$$

Timing: single event + auto-trig

ASIC #
(4 / Card)



Raw Event Data format

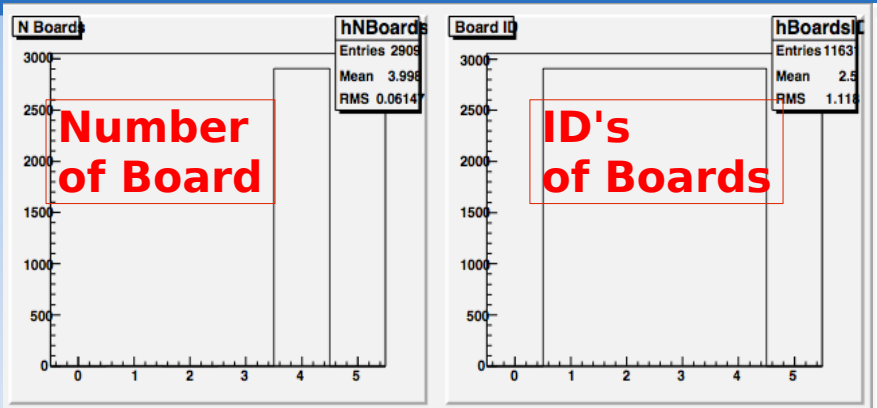
```
class RawEvent4Tree {
public:
    ulong TrigCount;     // should be the same
                         //on all boards
    uint fNBoards;       // Number of Boards
    TClonesArray *fBoards; // Array with all boards
    uint  fNAsics;       // Number of Asics
    TClonesArray *fAsics;  // Array with all Asics
    uint fNFrames;       // Number of Frames
    TClonesArray *fFrames; // Array with all frames
}
```

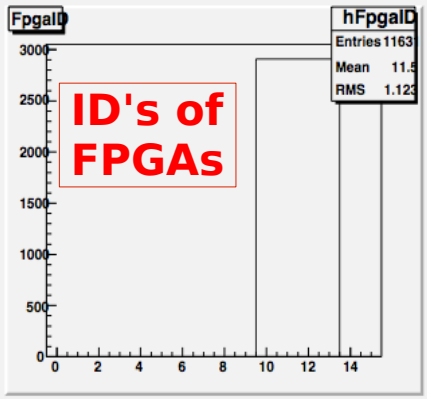
```
class Board : public TObject {
    uchar BoardID;  // Board ID from the DAQ
    ulong FpgaID;   // Board ID from the FPGA
    ulong TrigCount;  // DIF internal event counter
    ulong ExtTrigInAcq;  // DIF inter counter of
                         // trigger in Acq mode
    ulong ExtTrigOutAcq; // DIF inter counter of
                         // trigger outside Acq mode
    ushort Flags;     // DIF internal flags
    ulong DiffCount;  // 40MHz (25ns) counter between
                      // last ROC intTrig & ExtTrig
    ulong LastBC;     // BC ID

    int fNAsics_in_Board;     // Number of Asics
    static const unsigned int vers;  // version
}
```

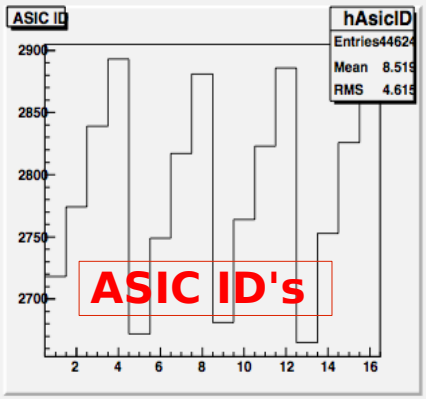
```
class Frame {
    unsigned char ID;  // ASIC ID
    unsigned long BC;  // BC ID
    double time;       // time of frame
                       // in µs wrt trigger (neg)
    bool t0[NChan];    // Thresholds 0
    bool t1[NChan];    //                 1
}
```

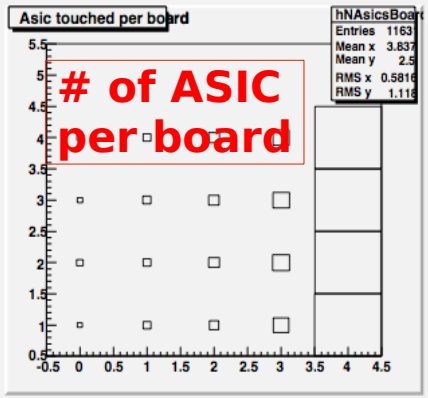
```
class Asic {
    int ID;   // should be the same on all frames
    unsigned long LastBC;       // BC ID
    unsigned int fNFrames_in_Asic;  // Number of
                                    // Frames
}
```

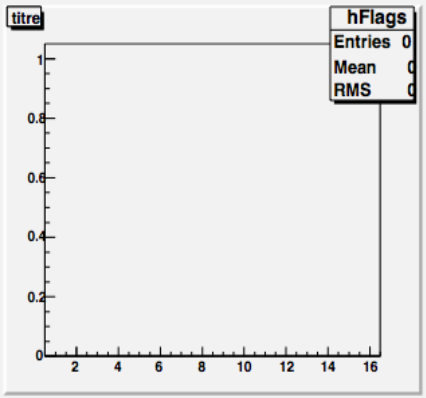
Basic DQ plots: Boards & ASICs

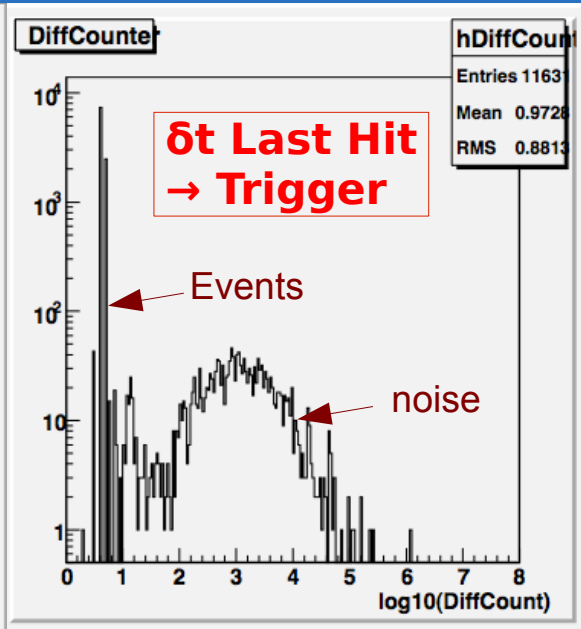


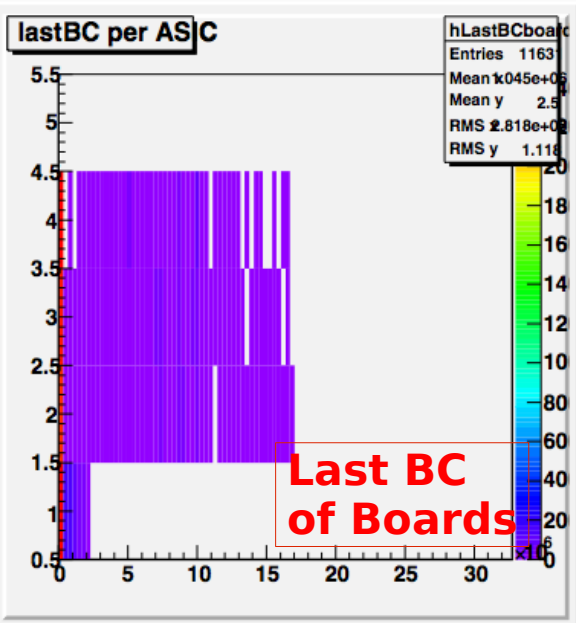


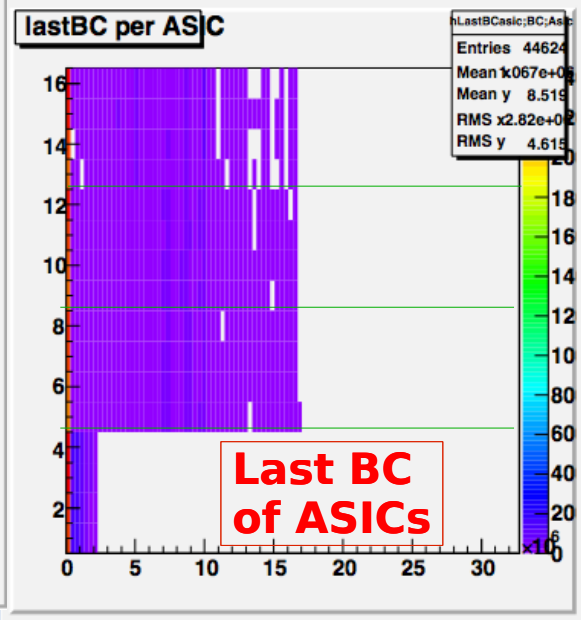


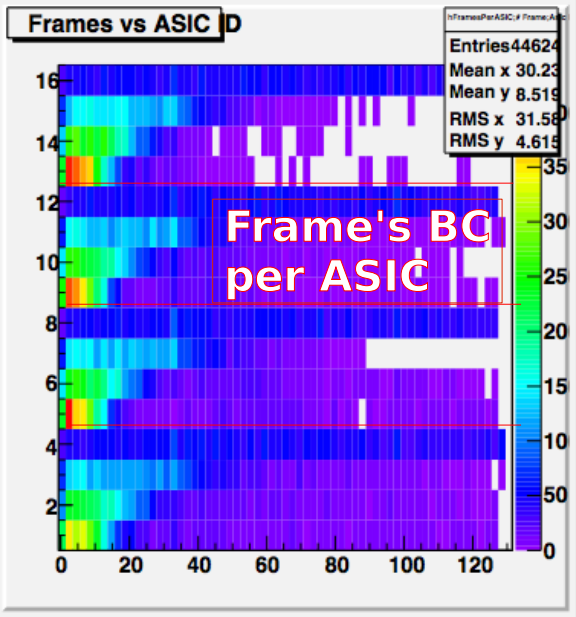






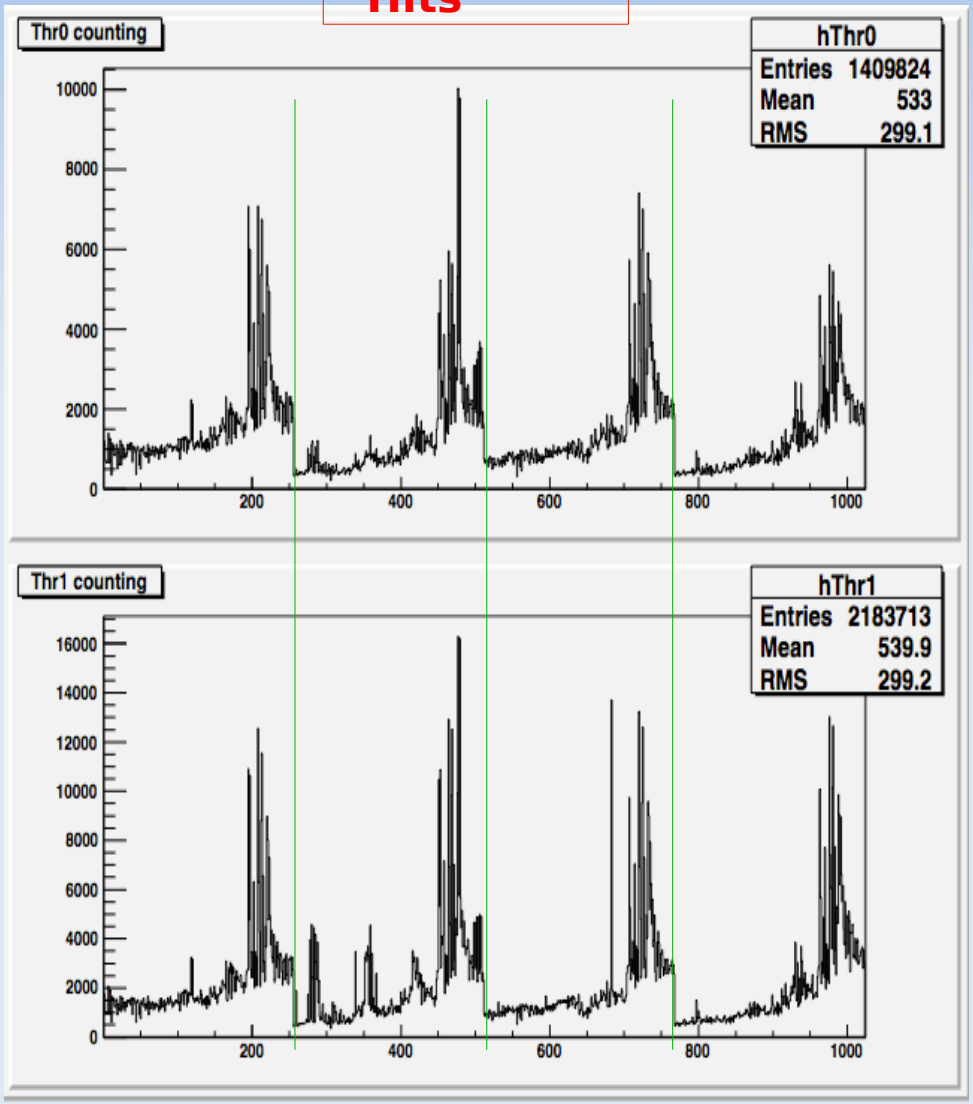






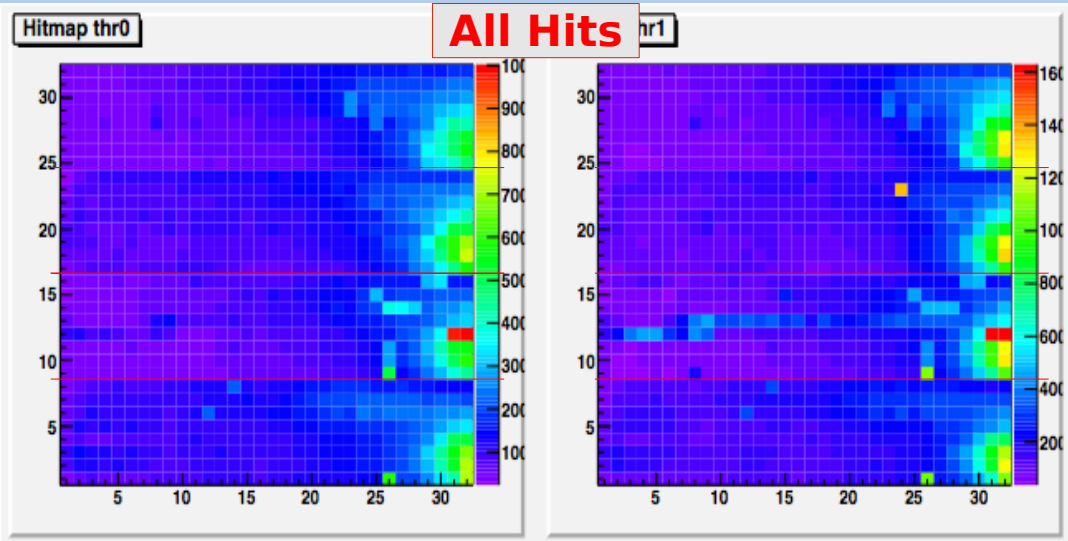
Basic DQ plots: Hits

Cell ID of Hits

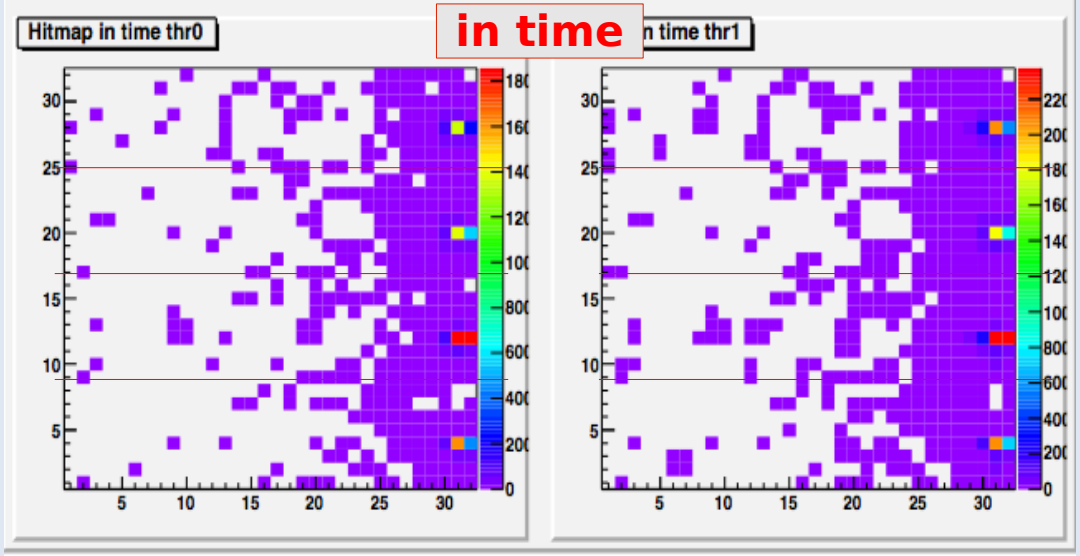


Hit Maps

All Hits

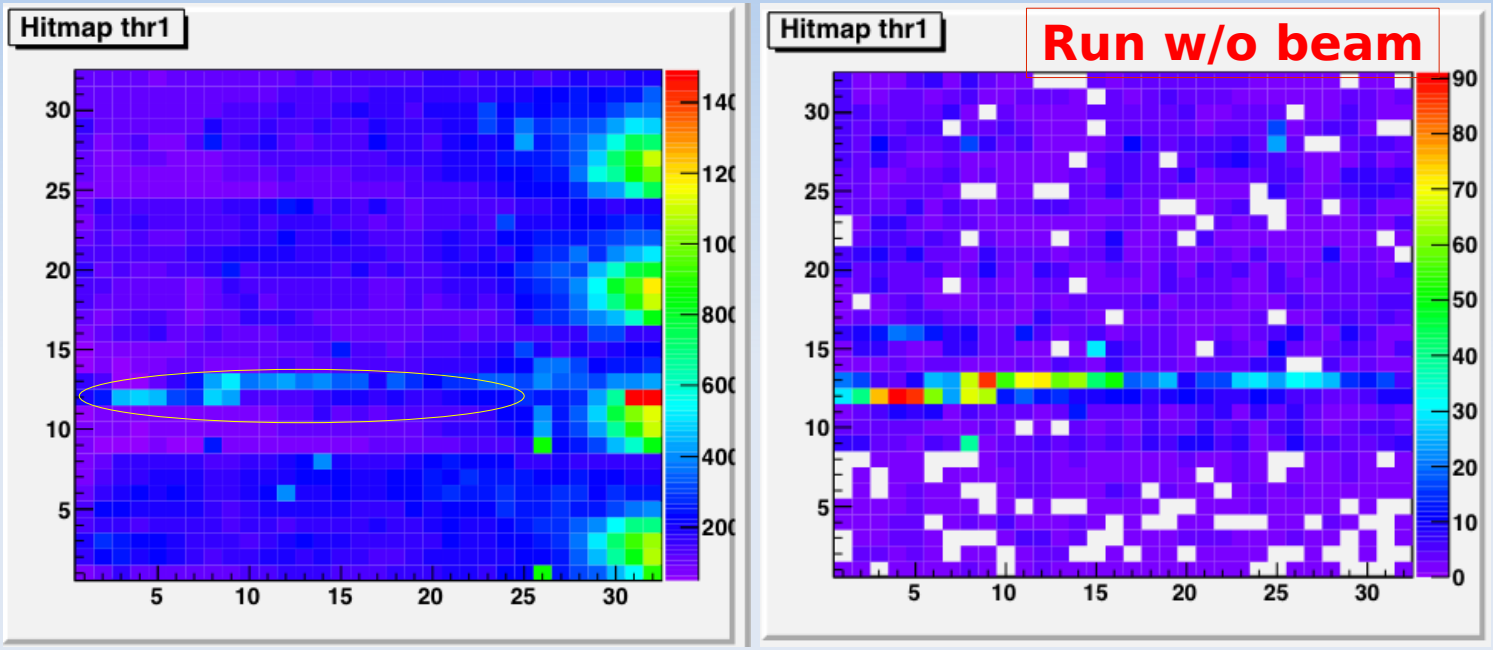


in time

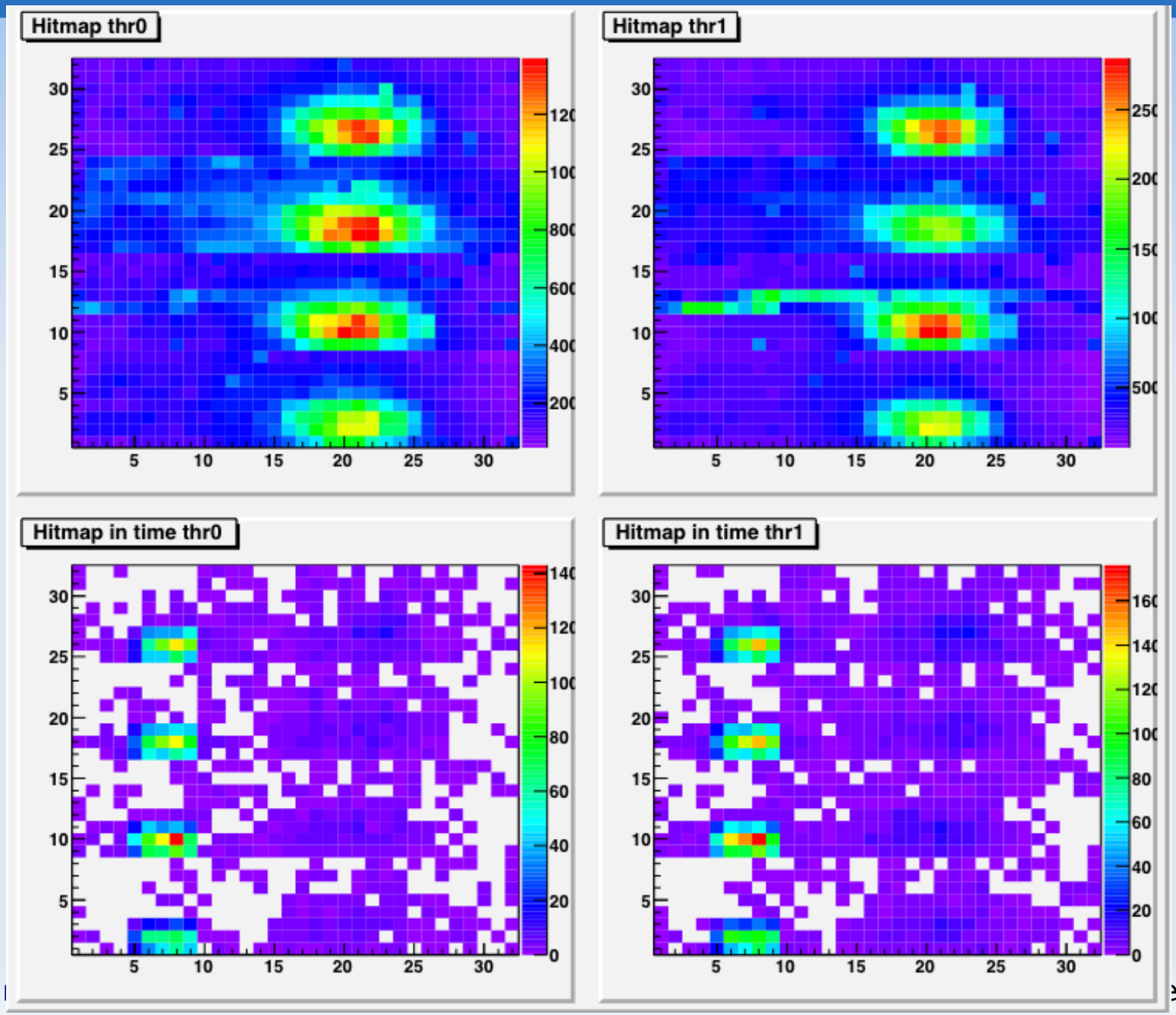


Various pbms

- Loose Fishing line ?

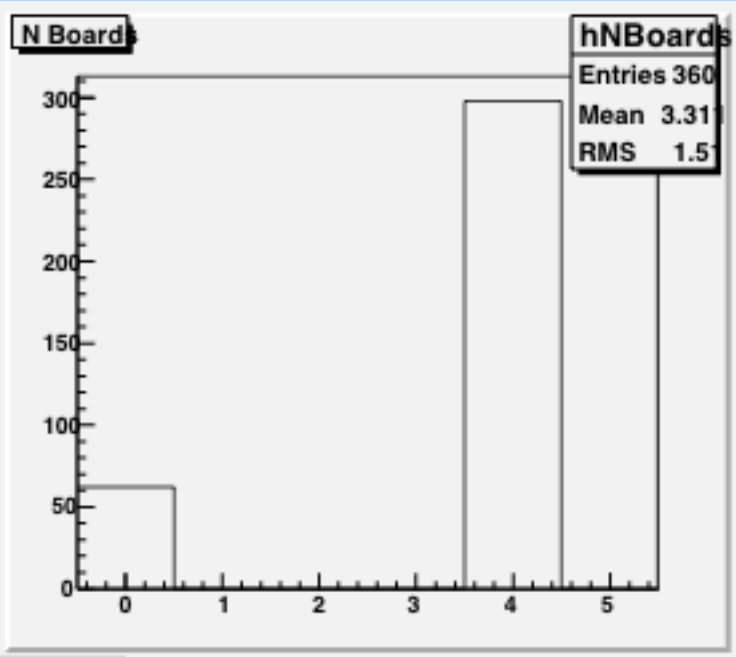


Various pbms: fishing line



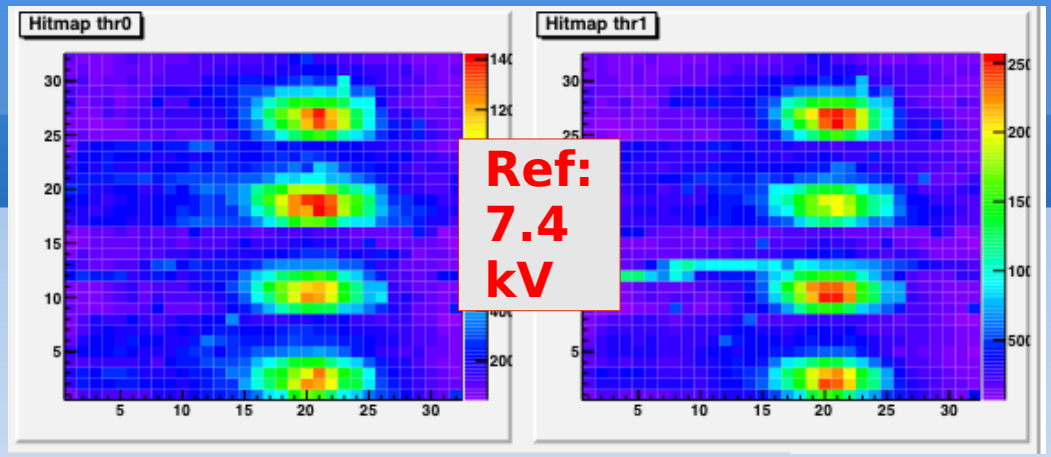
Various small deviations

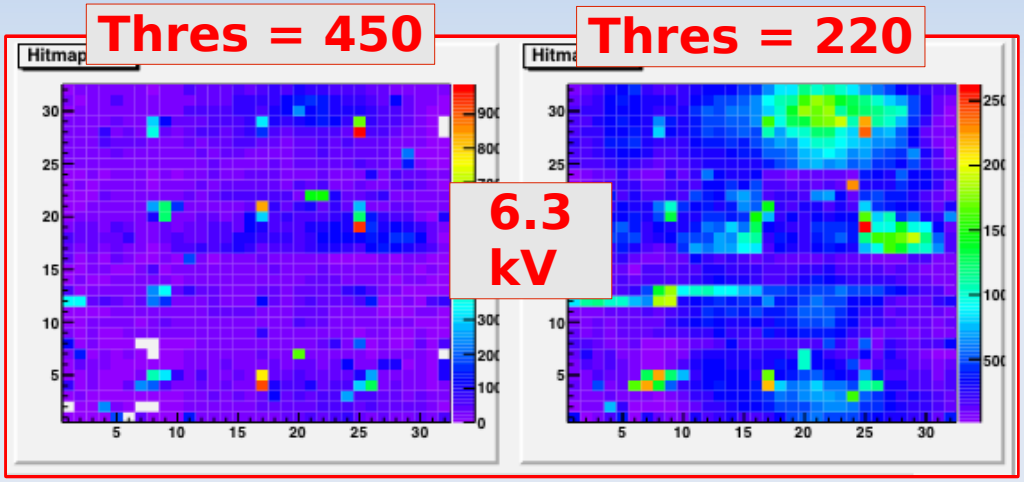
- Events without any touched Board/ASIC

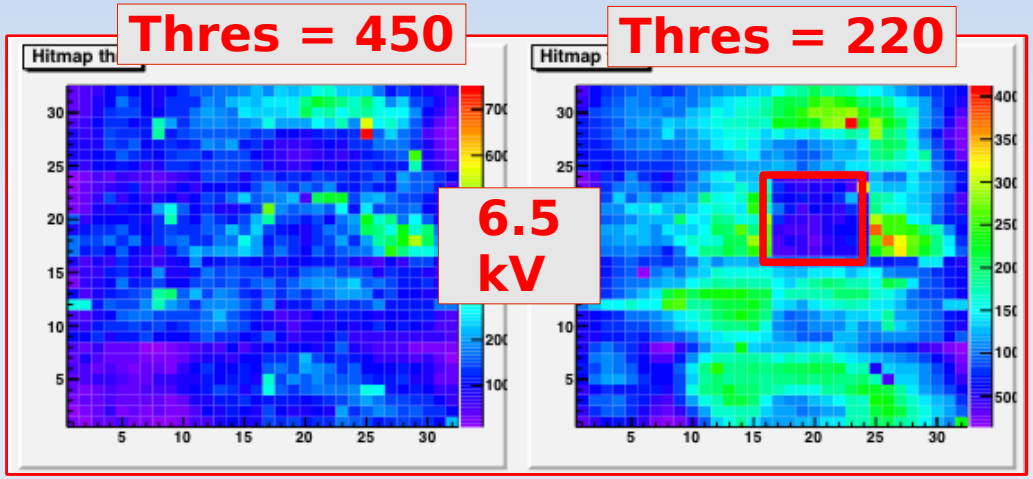


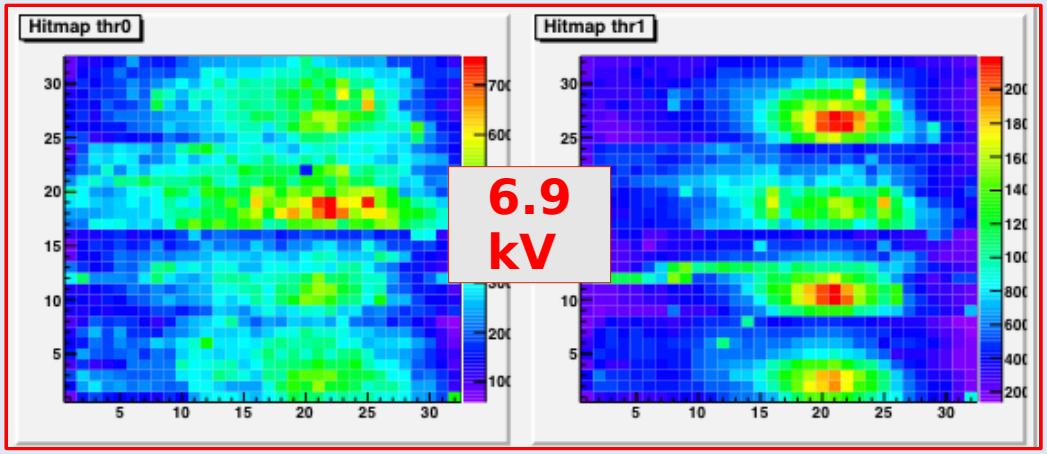
HV scans

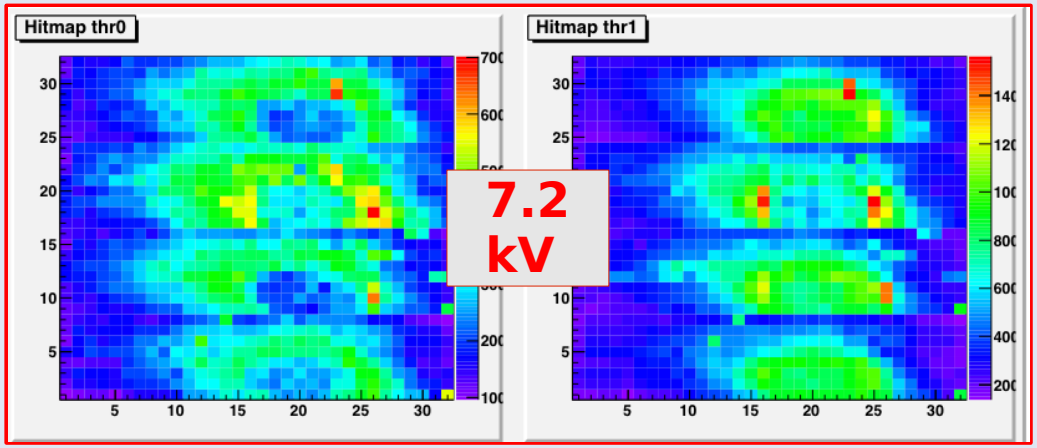
Hit maps of all hits
⇒ Some strange effects
⚠ Not normalized ⚠





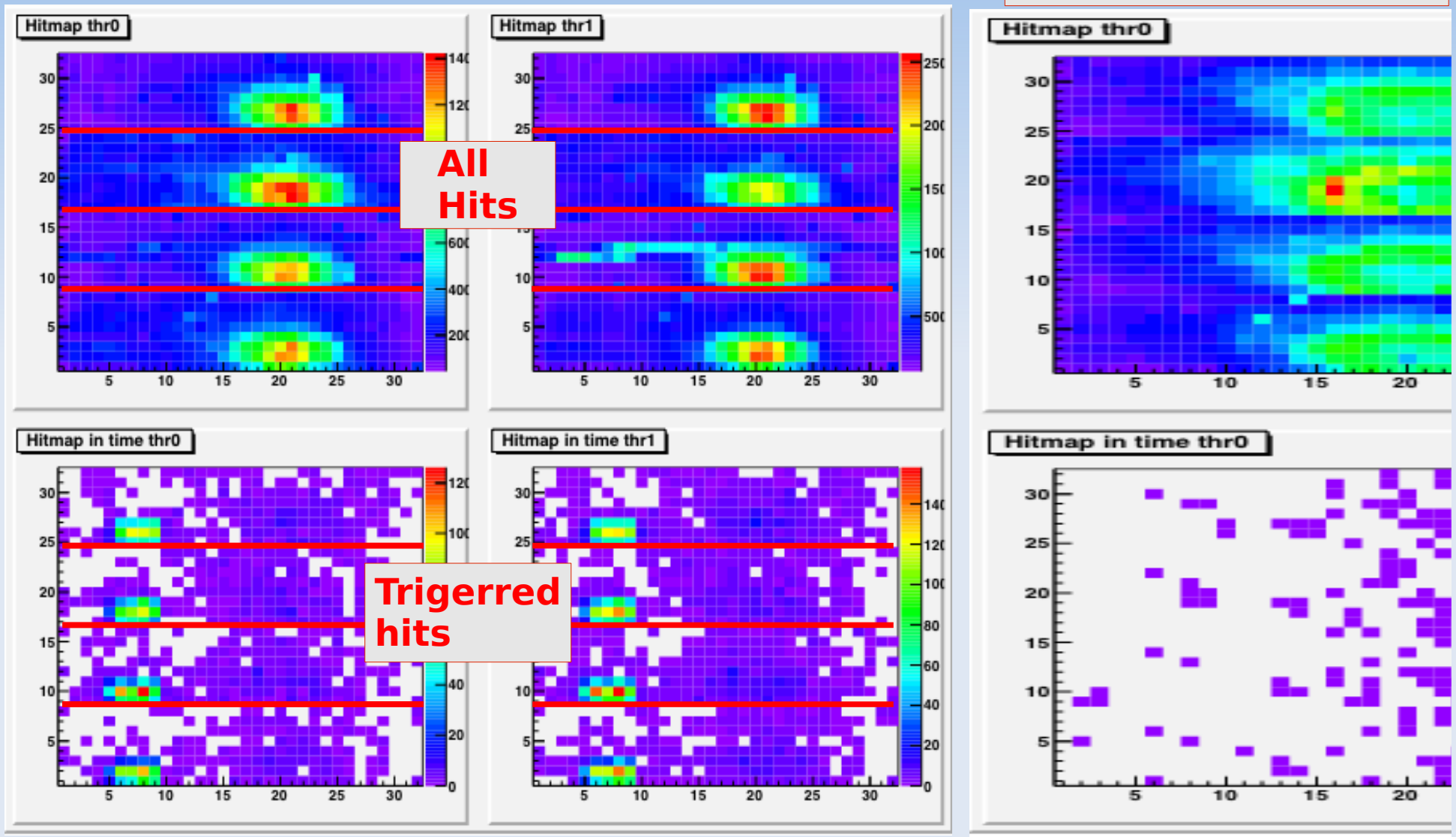




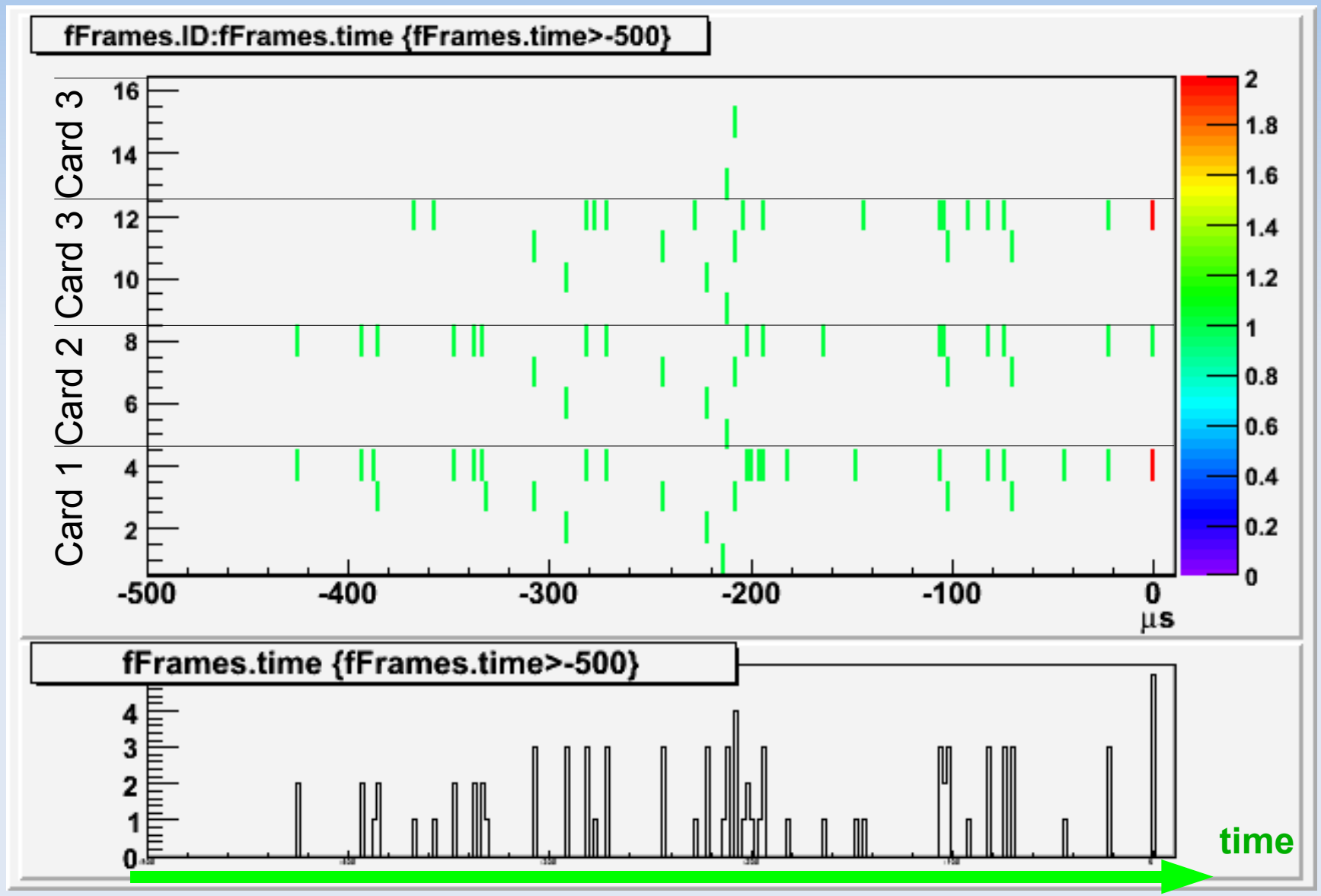


Efficiency determination

8.0 kV 7×7mm² Scint



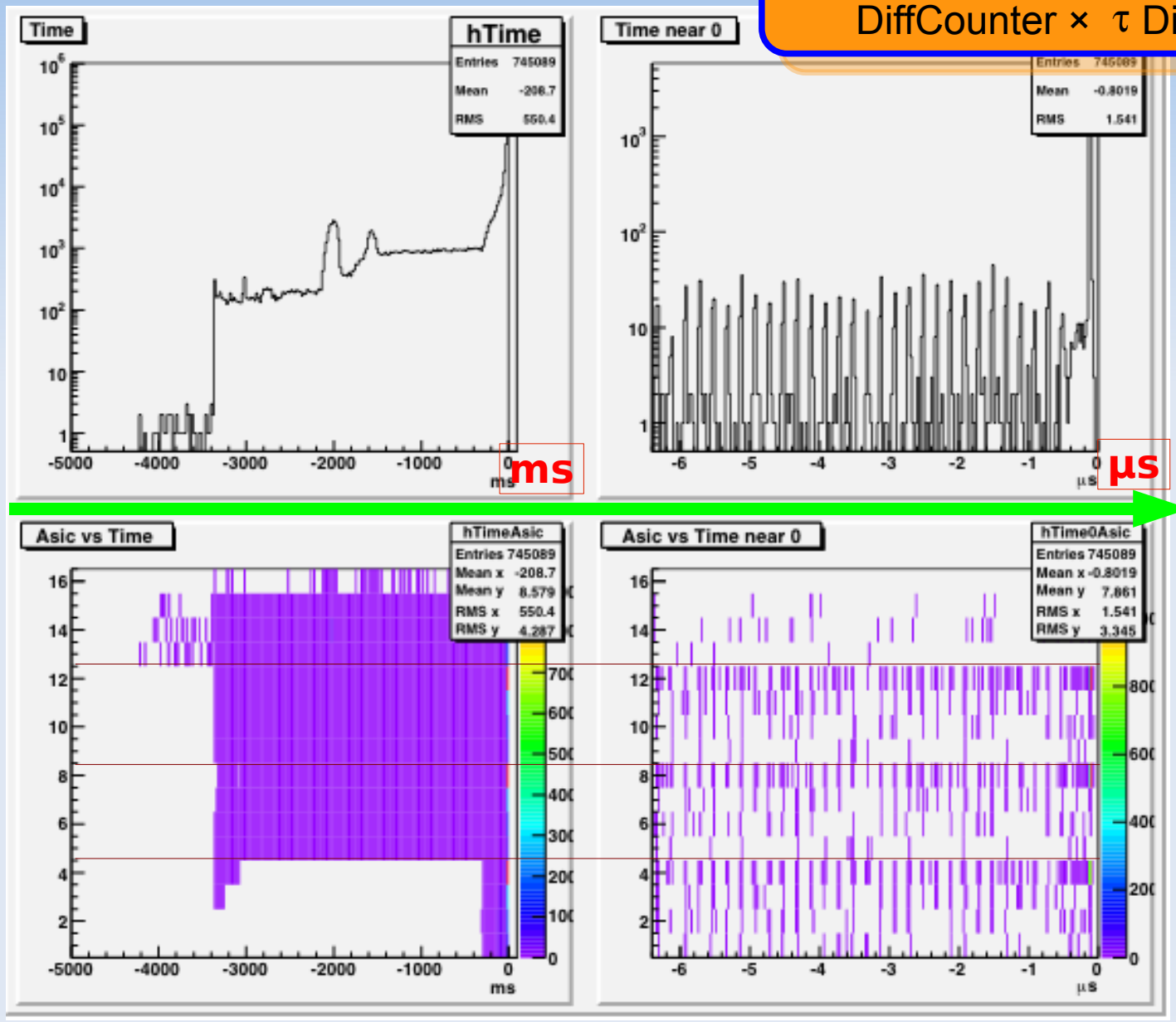
Timing: single event + auto-trig



ASIC #
(4 / Card)

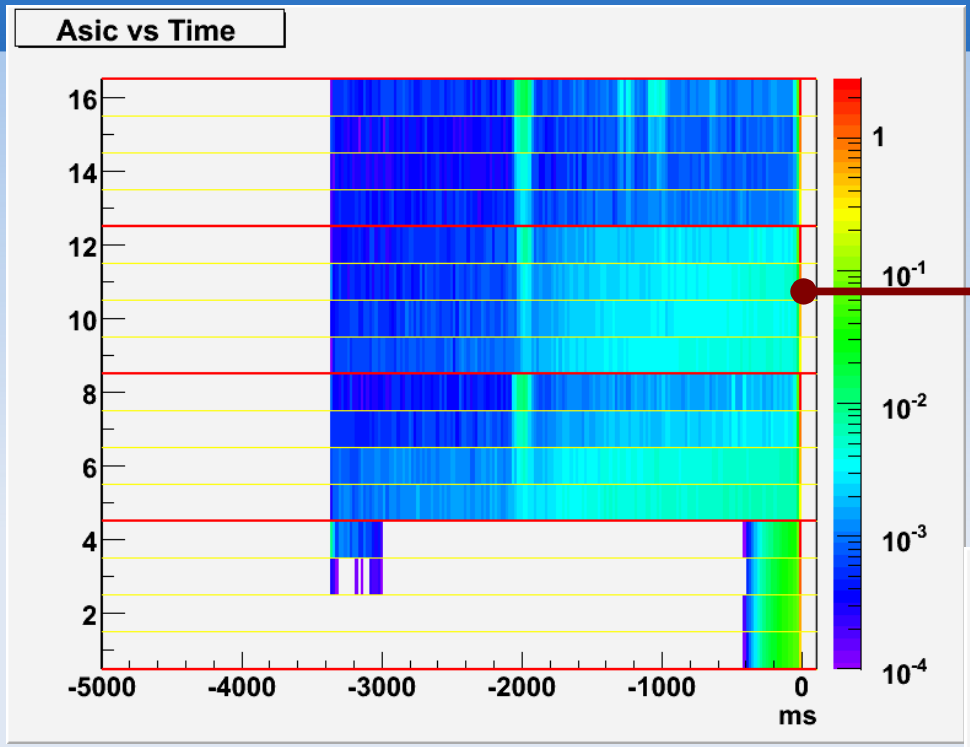
Timing

time = (BC-LastBC) × τ BC – DiffCounter × τ DiffCounter

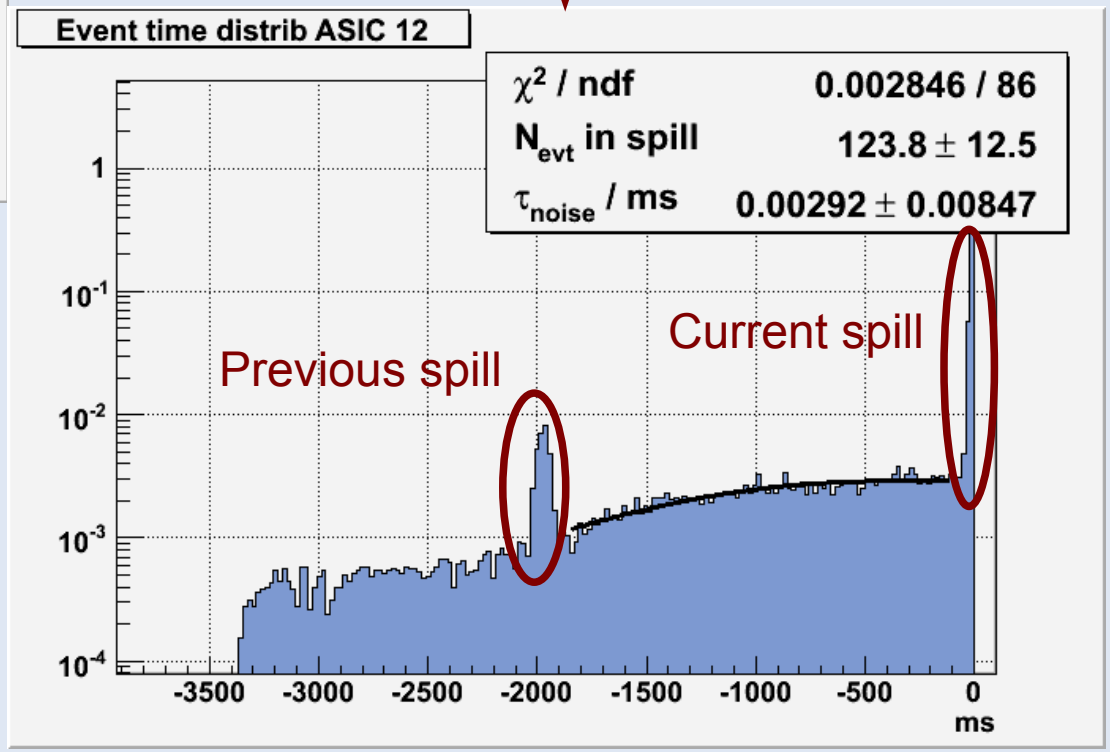


ASIC #
(4 / DIF)

Noise & ROC study



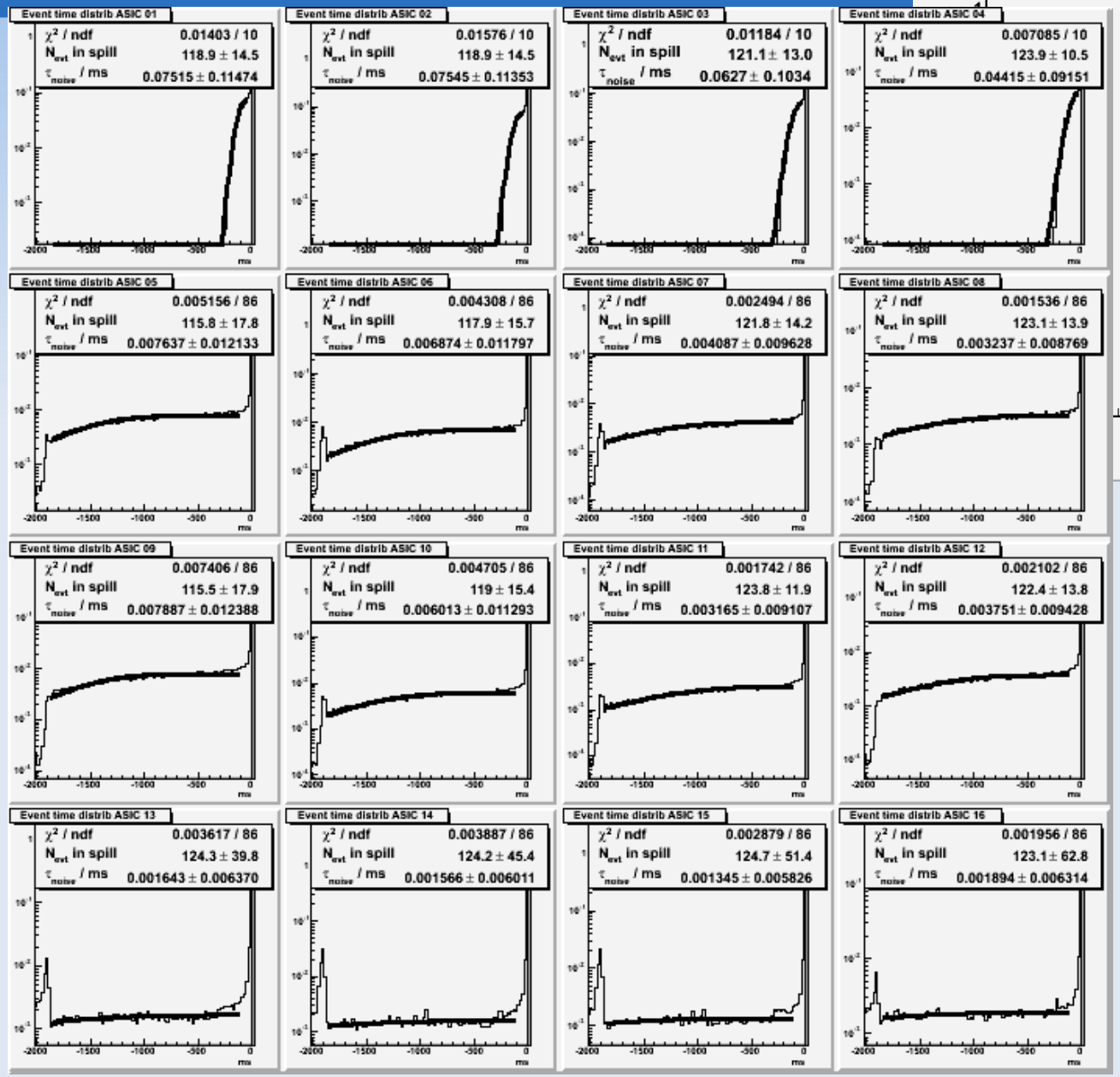
Run00101
Hit rates for each triggered event

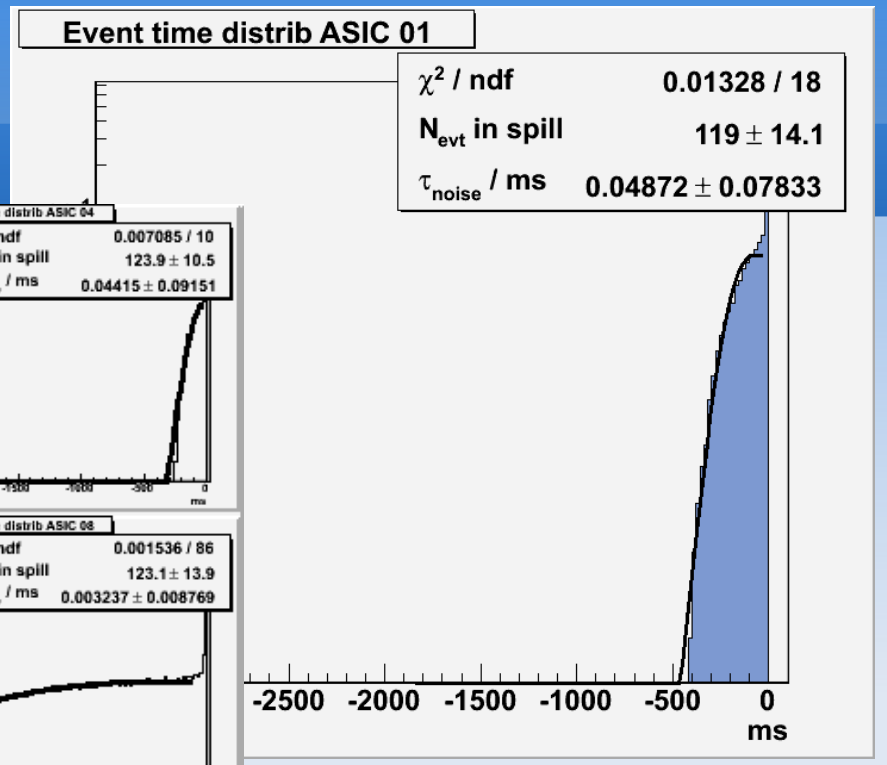


- *Shape:*
- flat noise+event rate τ
- modified by RAMFull (Loss of memory)
- probability at **-t =**
  - (1- P(avail. mem, t × τ))
  - avail. mem = 128 evts – **N_{evt} in spill**

$$P(a, x) = \frac{1}{\Gamma(a)} \int_0^x t^{a-1} e^{-t}\, dt$$

Noise & ROC study

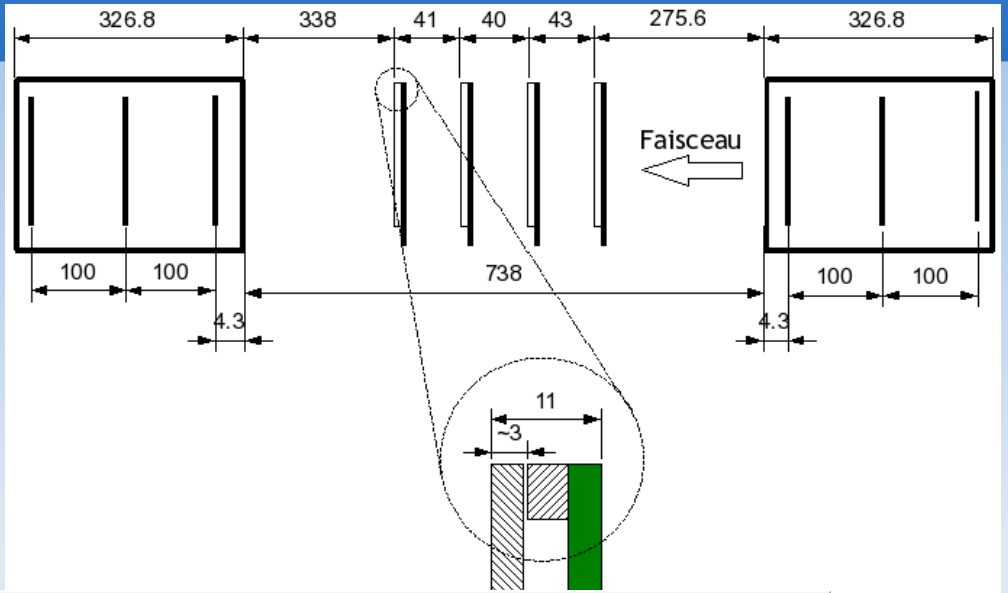


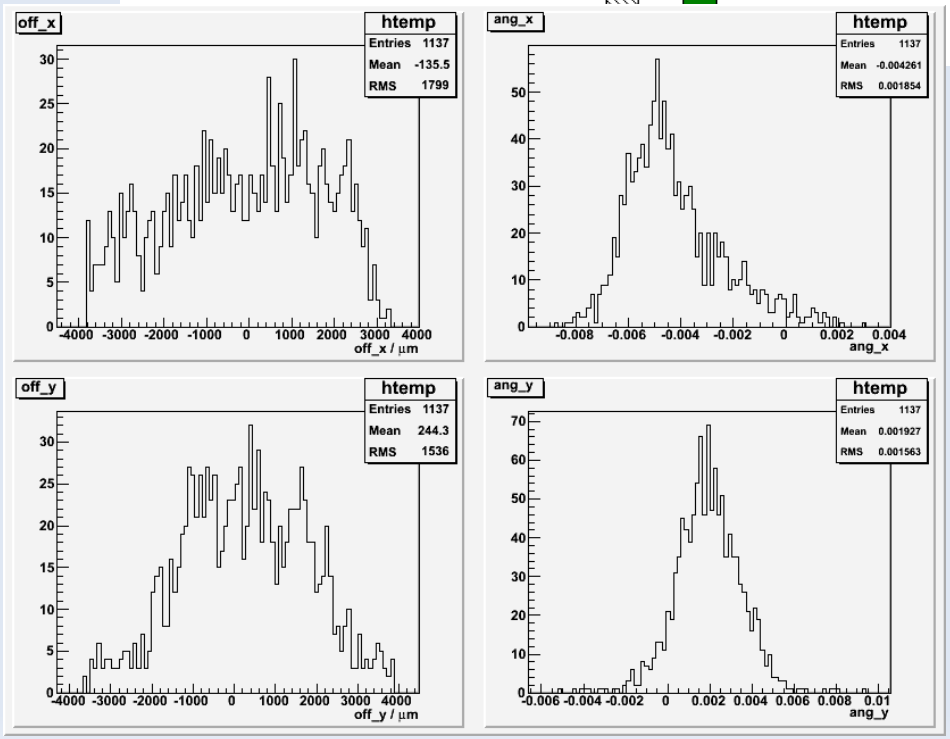


- Fits correctly all the ASICs
- Done for all the runs

Data with EUDET pixel telescope

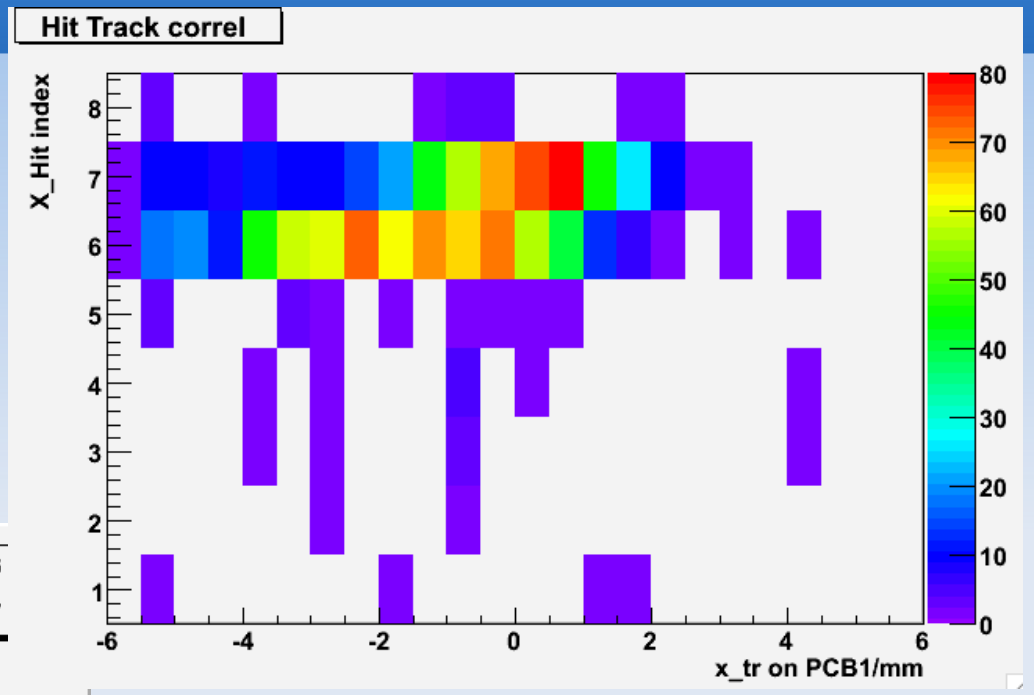
- 2 independent DAQ's
  - → Shift of 1 evt
- small surface: 7×7mm²
- Track precision: ≤5 µm
- Many to thanks to
  - Philipp Roloff (DESY)
  - Daniel Hass (???)
  - Emlyn Corrin

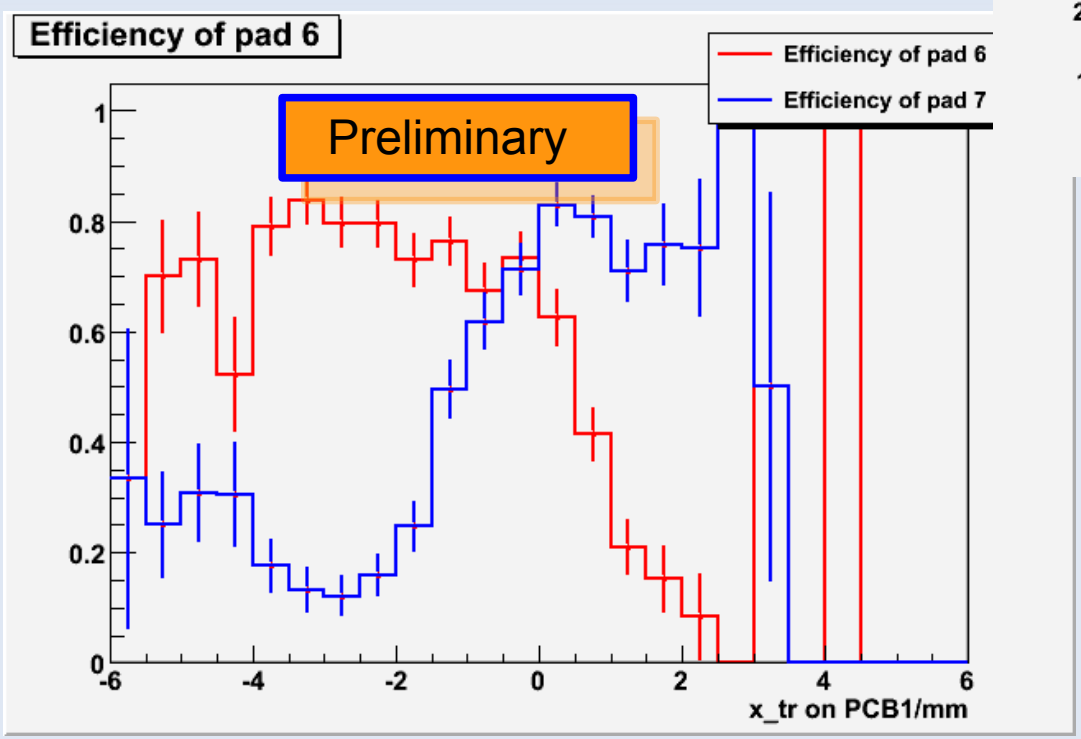




Data with EUDET pixel telescope

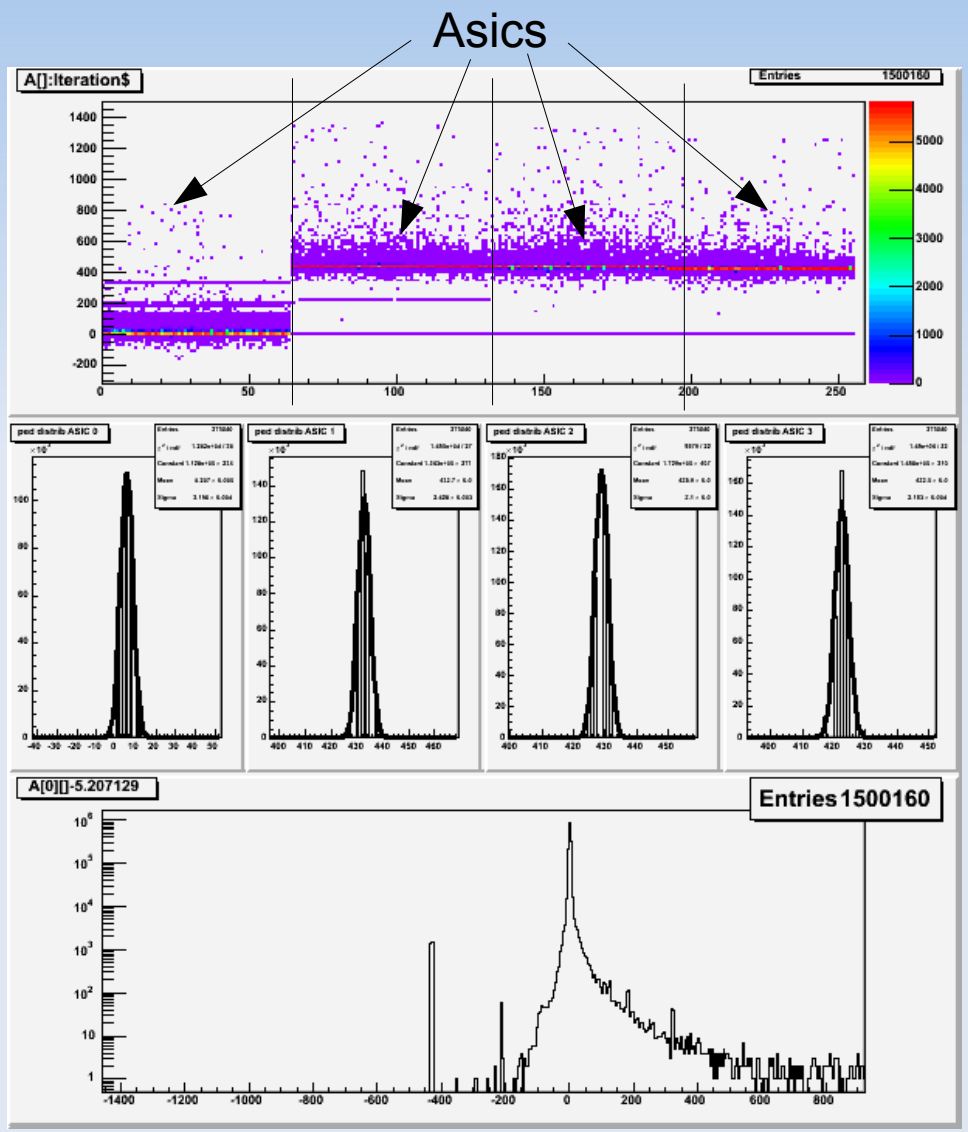
- Correlation seen (once) for 1 run between 2 pixels





- Proof of possibility
- Need some Clean-up
  - multiple tracks
  - multiple hits
  - ...
  - And real analysis

Analogue data



No real work done yet

No combined digital/analog R/O

Pedestals

Ped subtracted

Conclusion & outlook

- First in-beam data with embedded ROC with local memory
- Despite a bad start & “artisanal” DAQ
  - The DAQ behaved & ran well
  - A wealth of good quality triggered & even more non triggered data
- Most runs with 4 slabs
- Many runs with the EUDET telescope
- Some runs with an analog readout
- Test of a large chamber
- Many many studies to be done
  - Efficicency vs HT, angle, position, time (RPC recovery), particle density
  - Shower start & energy reconstruction
  - Event “in train” reconstruction
- Lot of fun in sight!!!

Data format & storage: some lessons

- Binary storage NEEDS some markup & redundancy in case of pbms
  - zero suppression → no fixed length...
- Consistency of Data:
  - number words in header**S** (all headers) & possibly version
    many versions for testing
  - End word ⇒ recovery possible
  - Eventually CRC ? ⇒ local/missing bits
  - Internal counters!!! (trigger numbers)
- Idem for all stage of data (DIF)/event (was missing here)

  ADDITIONAL: possibility to verify FW versions at all stages
  ⇒ ⊃ list of commands
- Exemple mixing of events:
  - asynch. readout of cards ⇒ event mixing (10% of total)
    - evt 1: card 2, 3, 1; evt2; card 2; evt 1: card 4; evt 2: card 4,3,2, ...
    - ⇒ recovery using a “trigger counter” on the cards