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New DAQ for TAPI and some thoughts on EUDET evolution

Wojciech Dulinski

Outline

- Short presentation of TAPI in few particular set-ups
- DAQ for analog pixel sensors based on TNT-2 board
- DAQ requirements for the EUDET binary chip (M22+)
- Some option for future evolution of EUDET telescope

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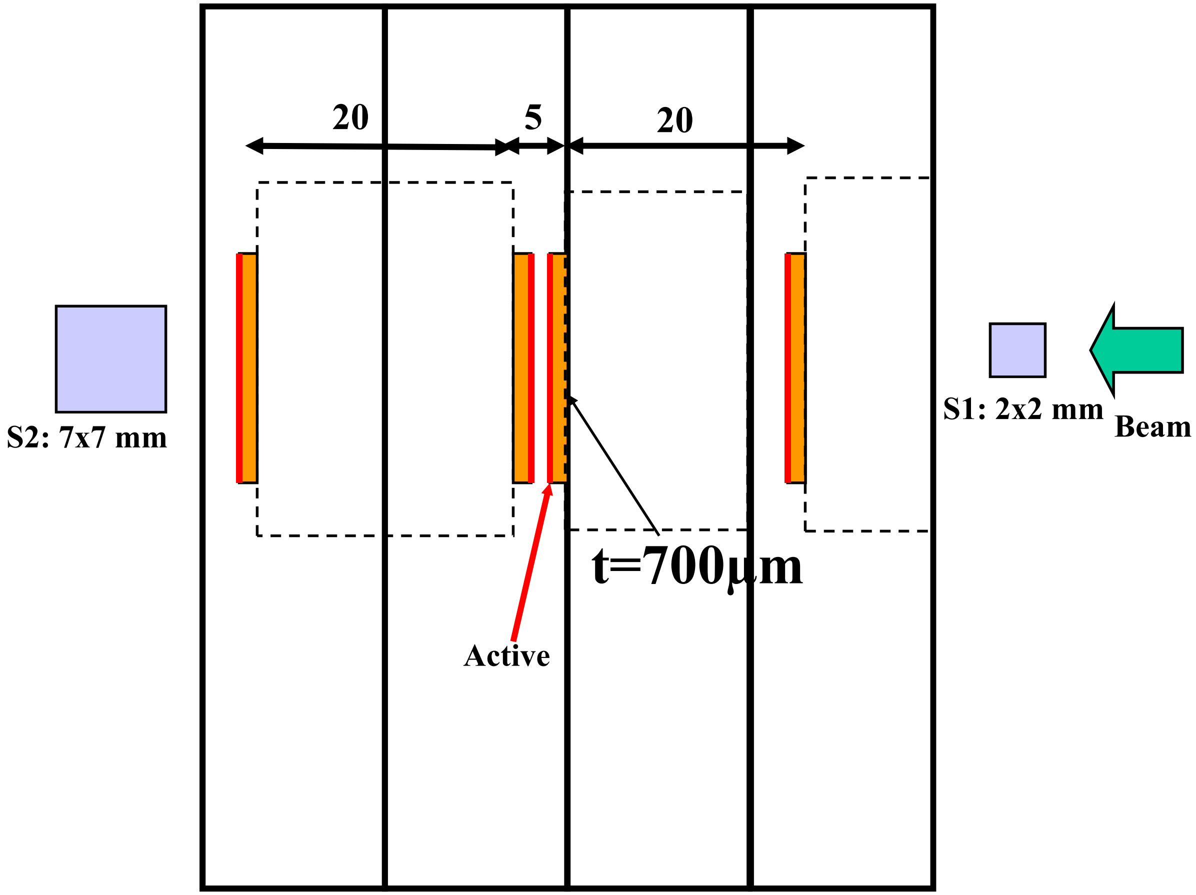
TAPI: very compact, Mimosa18 based beam telescope assembled at IPHC, Strasbourg



First beam tests at DESY in June 2007,(1 – 6 GeV electrons, 2 ref + DUT) and at CERN in September 2007 (120 GeV pions, 3 ref +DUT)

DAQ based on single "Strasbourg" USB board: readout of only 1 sub-array/plane

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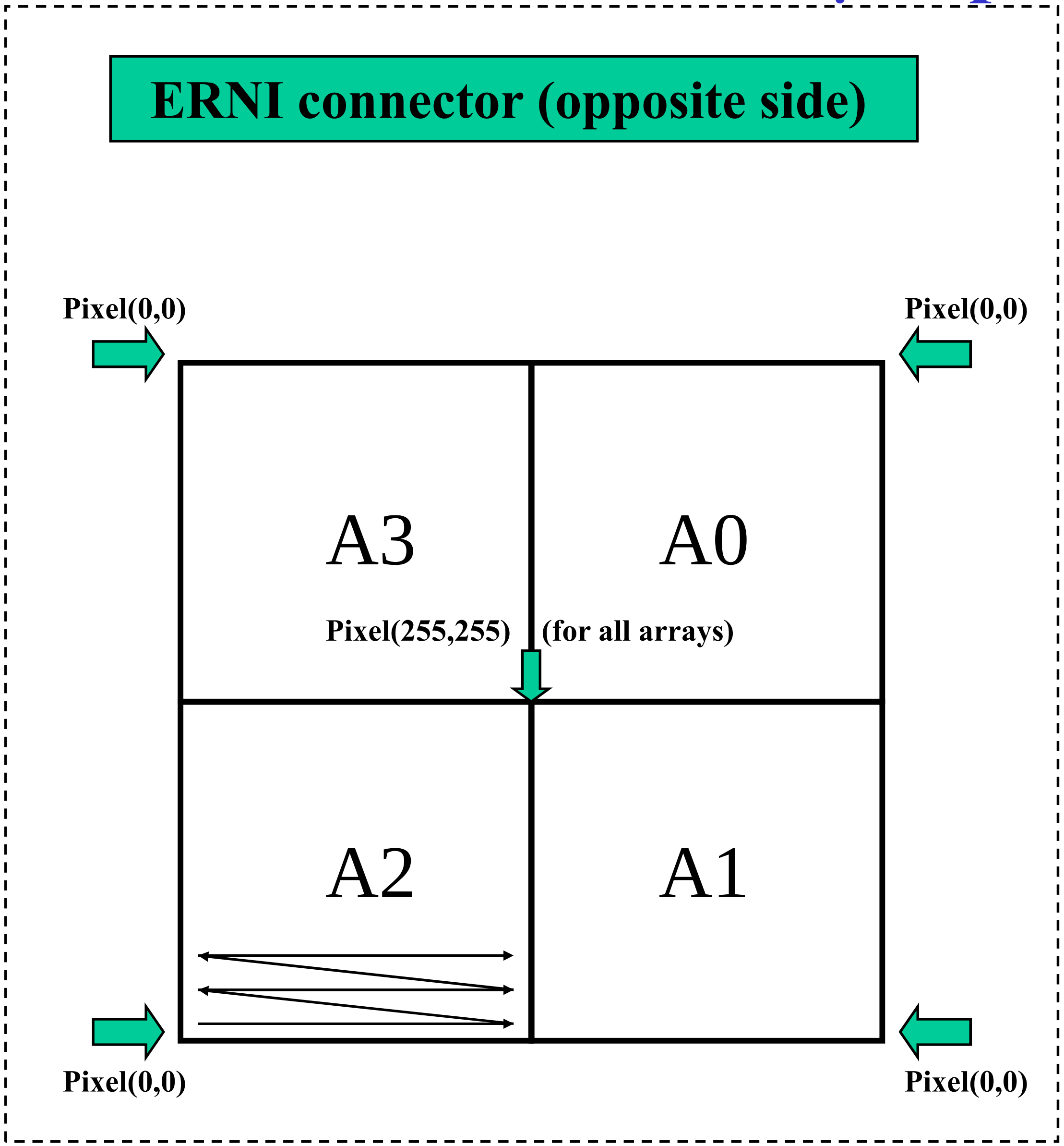
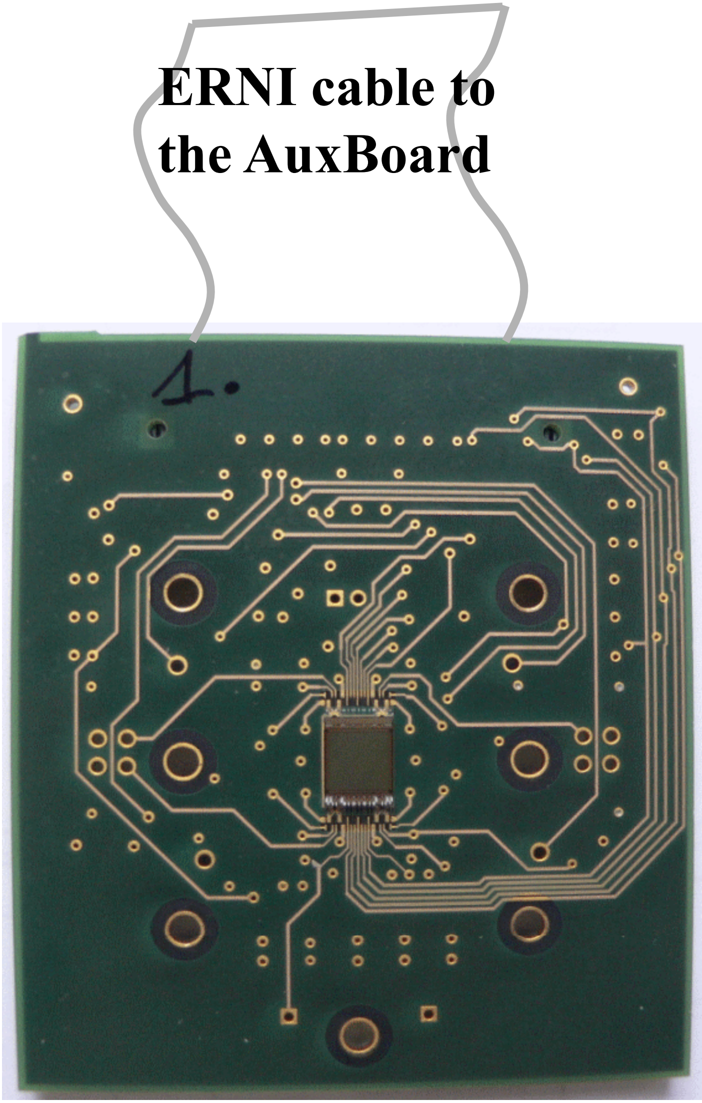
Mimosa18: 512x512 pixel array (in 4 sub-arrays), 10 µm pitch.





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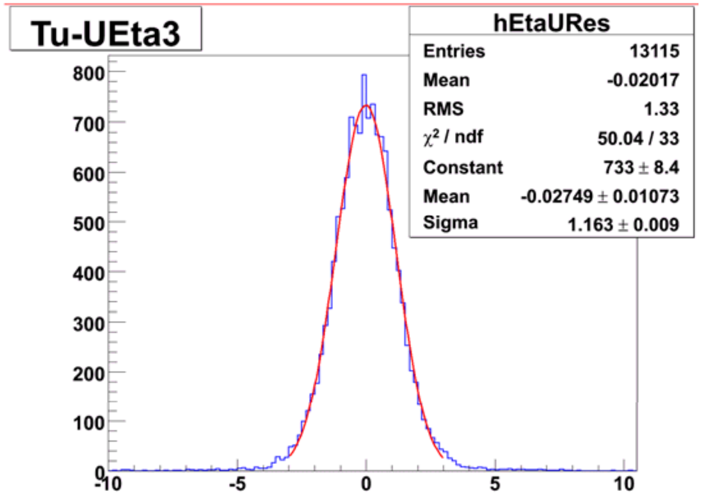
Typical tracking performance of Mimosa18

ENC ~10 e- (room temperature)
S/N ~28 (Landau MP for seed pixel)



Residuals using 3x3 center-of-gravity on reference and η (eta) correction on DUT

σ_{COG} = 1.2 μm

σ_{ETA} = 0.95 ± 0.1 μm

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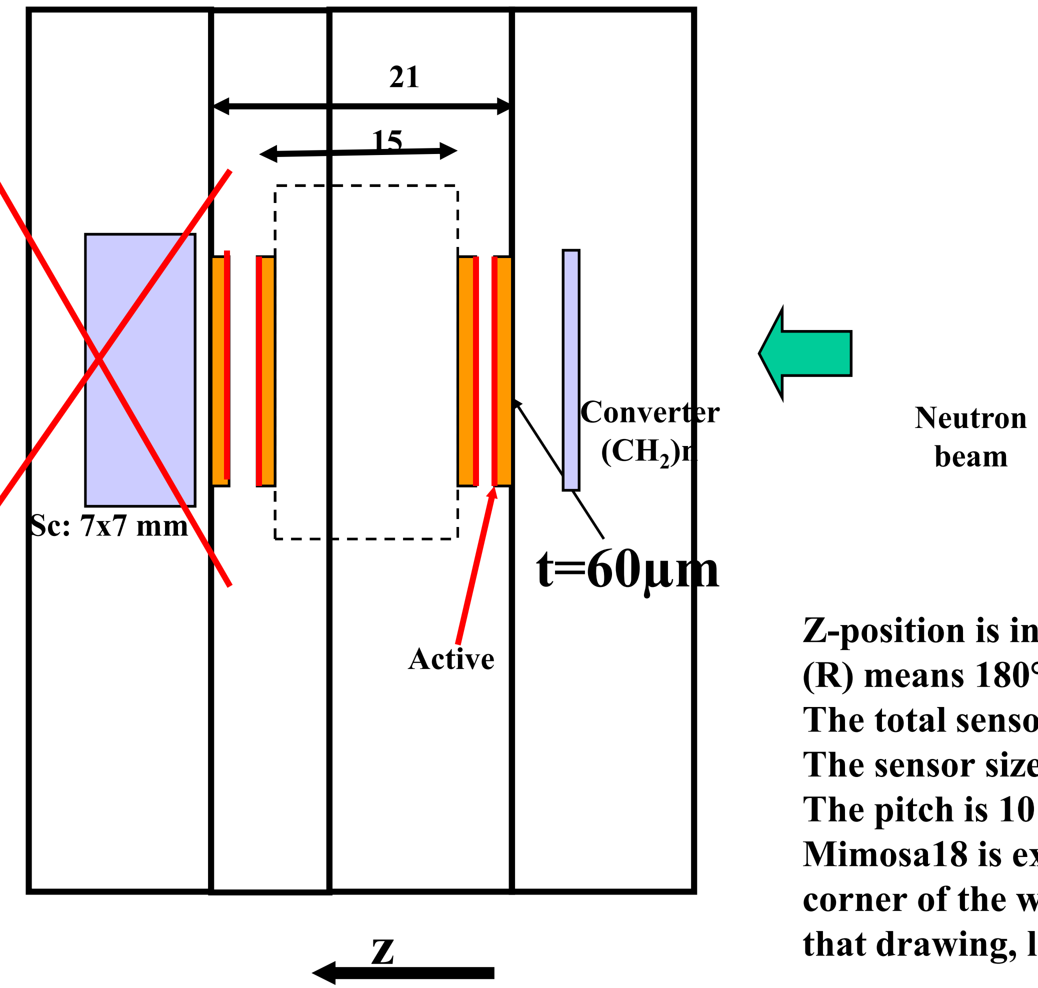
TAPI-1: 4-planes, 50 µm thick sensors, very compact set-up for Cadarache. EUDET DAQ: sparsification mode @16 MHz, 100 Hz event rate → active during 30% of time



Readout Ch.#	z [mm]	rotation	Thickness [µm]	Epi [µm]
0	0	R	60	20
1	3	N	60	20
2	18	R	60	20
3	21	N	60	20

Information for alignment

Z-position is in mm, along the beam direction. Estimated precision: ± 200 µm. Rotation (R) means 180° rotation along vertical axis (N is no rotation).
The total sensor thickness is in microns, same for the epi layer thickness.
The sensor size is 512x512 pixels (four square sub-arrays of 256x256 pixels).
The pitch is 10 microns, so the dimension of 5.12x5.12 mm. The readout direction of Mimosa18 is explained in the next page (first pixel of each sub-array starts in the corner of the whole array). No rotation (N) means that the sensor has the position as on that drawing, looking FROM the beam upstream.

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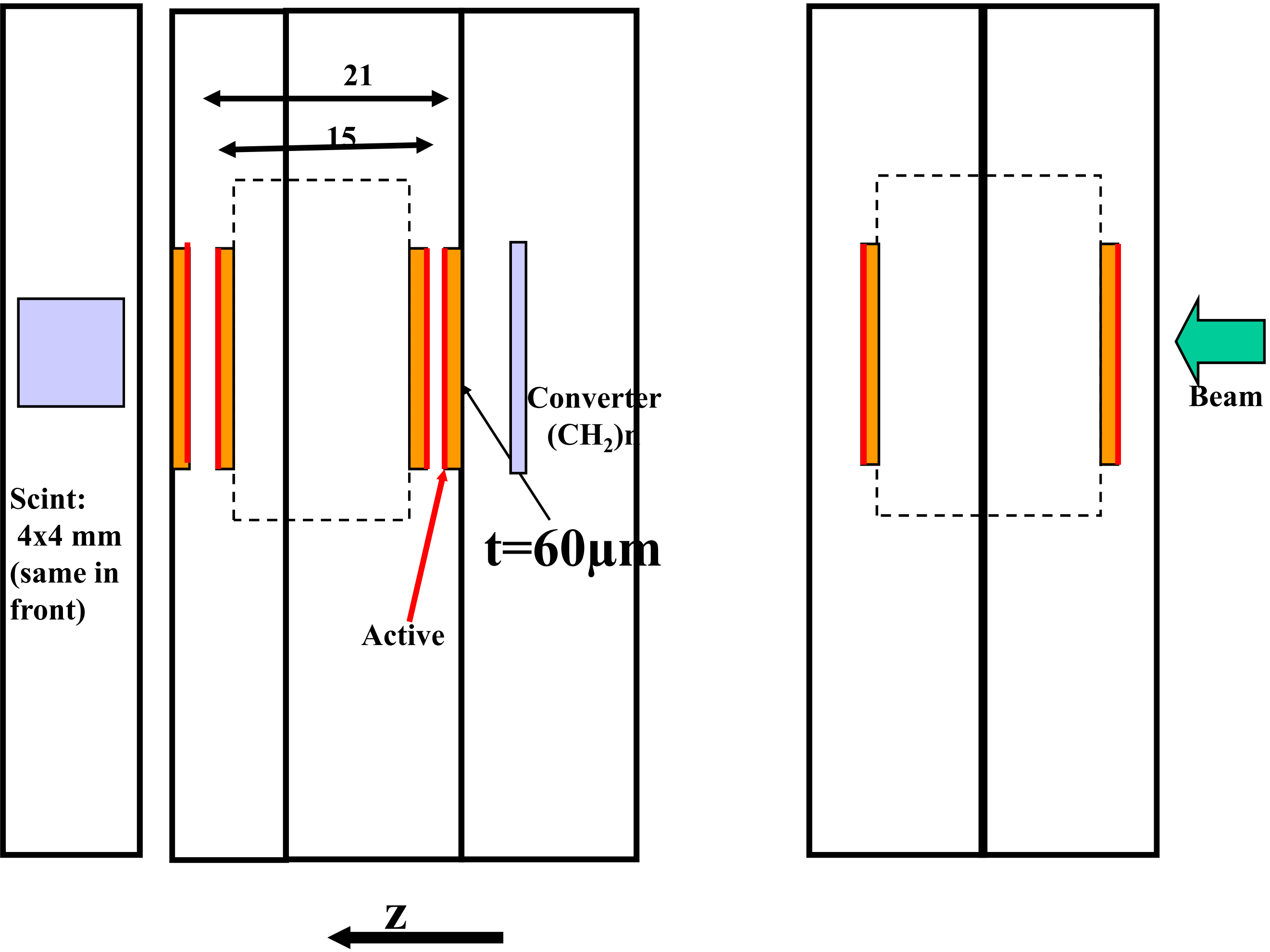
TAPI-1: alignment of Cadarache set-up at CERN (July/August 08, EUDET DAQ)



Readout Ch.#	z [mm]	rotation	Thickness [µm]	Epi [µm]
0	4	N	700	14
1	26	R	700	14
2	62	R	60	20
3	65	N	60	20
4	80	R	60	20
5	83	N	60	20

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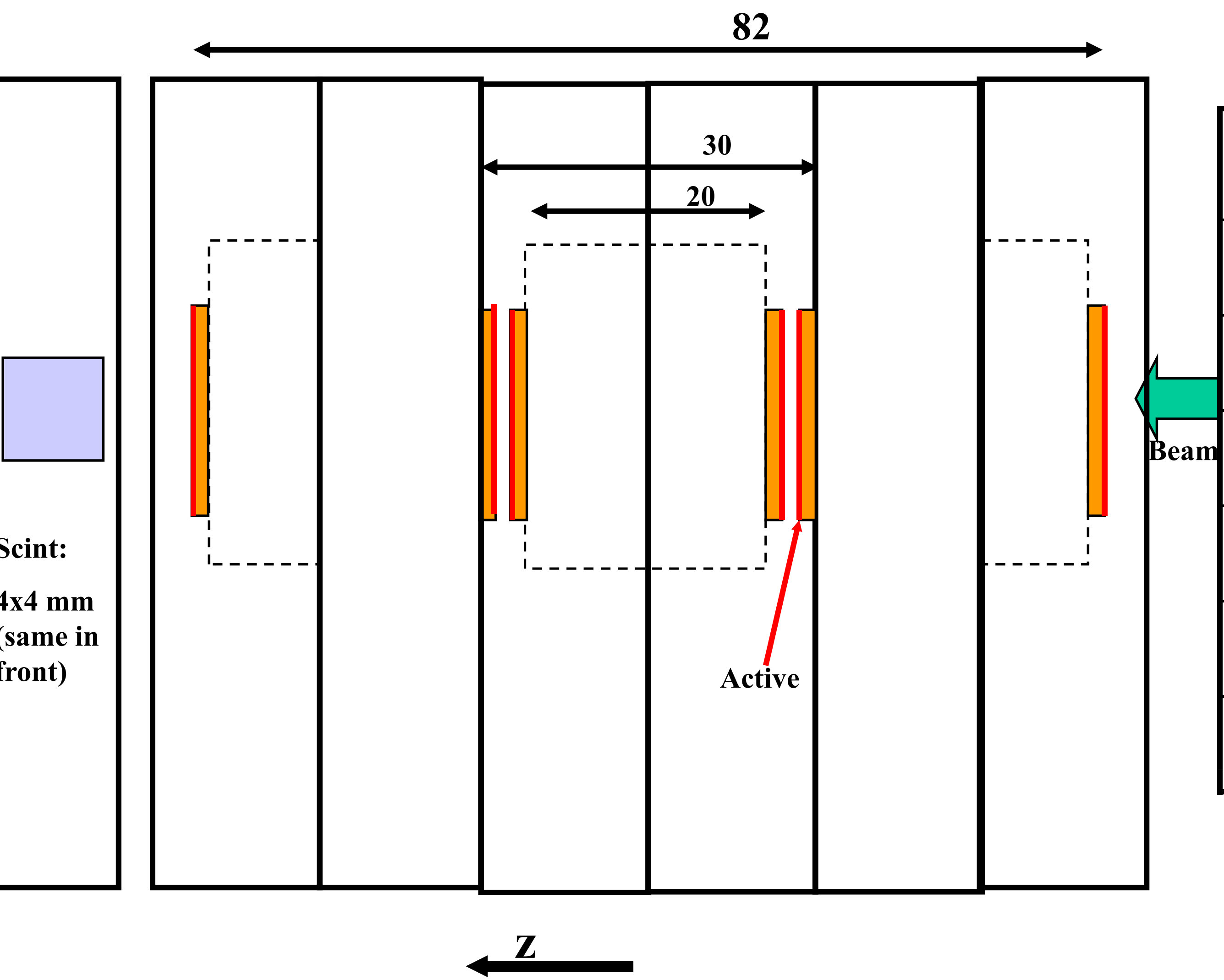
TAPI-2: set-up to measure M18 tracking precision, CERN, August 08 (EUDET DAQ).



Readout Ch.#	z [mm]	rotation	Thickness [µm]	Epi [µm]
0	4	N	700	20
1	31	R	700	20
2	34	N	700	20
3	56	R	700	14
4	59	N	700	14
5	86	R	60	20

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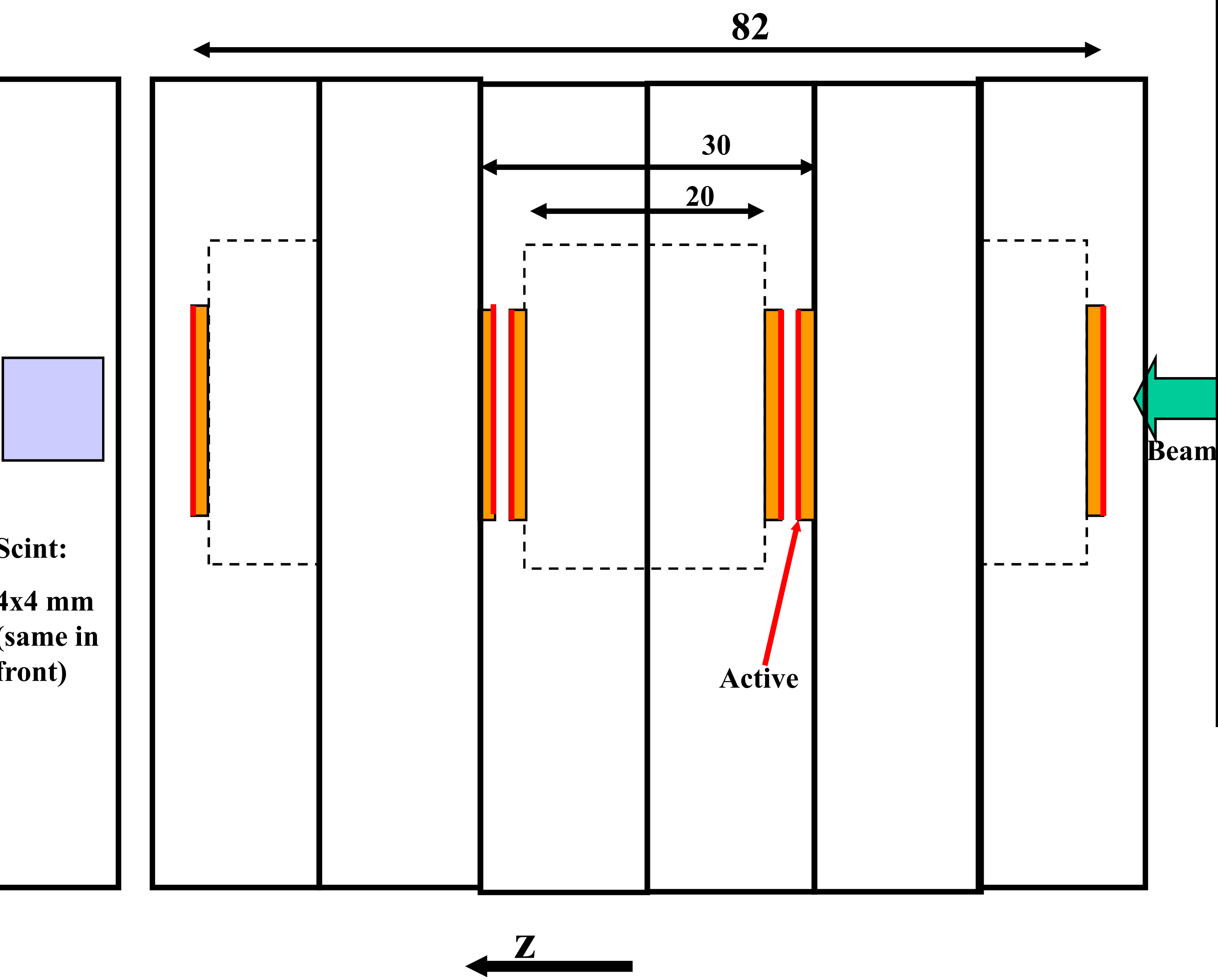
TAPI-2: set-up to measure M18 tracking precision, CERN, September 08 (TNT2 based DAQ). For each plane, only sub-array 0 and 3 were readout. S0→ch1 or ch3, S4 → ch2 or ch4



Readout TNT# / Ch.#	z [mm]	Rotation, sensor	Thickness [µm]	Epi [µm]
17/1,2	4	N, S4	700	20
17/3,4	31	R, S1	700	20
12/1,2	34	N, S2	700	20
12/3,4	56	R, D004	700	14
15/1.2	59	N, D0??	700	14
15/3,4	86	R, D003	60	20

Run# : 1,2,3,4,5,6,7,8

Comments/suggestions:

7: low intensity beam, reference run (thr. 15)

8: low + high intensity, high statistics (thr.20)

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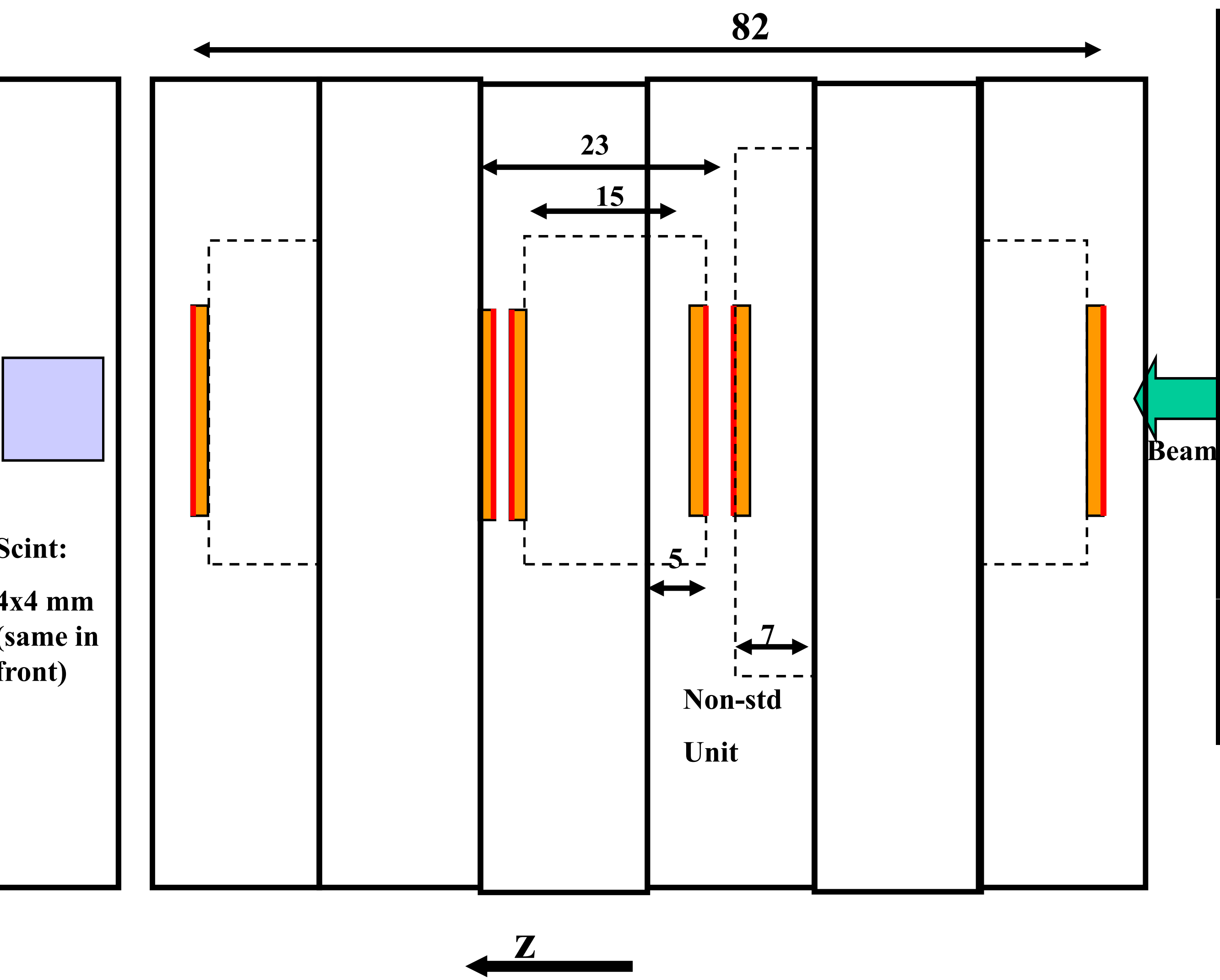
TAPI-2a: set-up to measure M18 tracking precision, CERN, September 08 (TNT2 based DAQ). For each plane, only sub-array 0 and 3 were readout. S0→ch1 or ch3, S4 → ch2 or ch4



Readout TNT# / Ch.#	z [mm]	Rotation, sensor	Thickness [µm]	Epi [µm]
17/1,2	4	N, S1	700	20
17/3,4	37	R, ??	60	20
12/1,2	40	N, ??	60	20
12/3,4	56	R, D036	700	14
15/1.2	59	N, D0??	700	14
15/3,4	86	R, S5	700	20

Run# : 9, 10, 11, 12

Comments/suggestions:

10: low intensity beam, 100k, (thr. 20)

11. Low intensity beam, 120k, (thr. 15)

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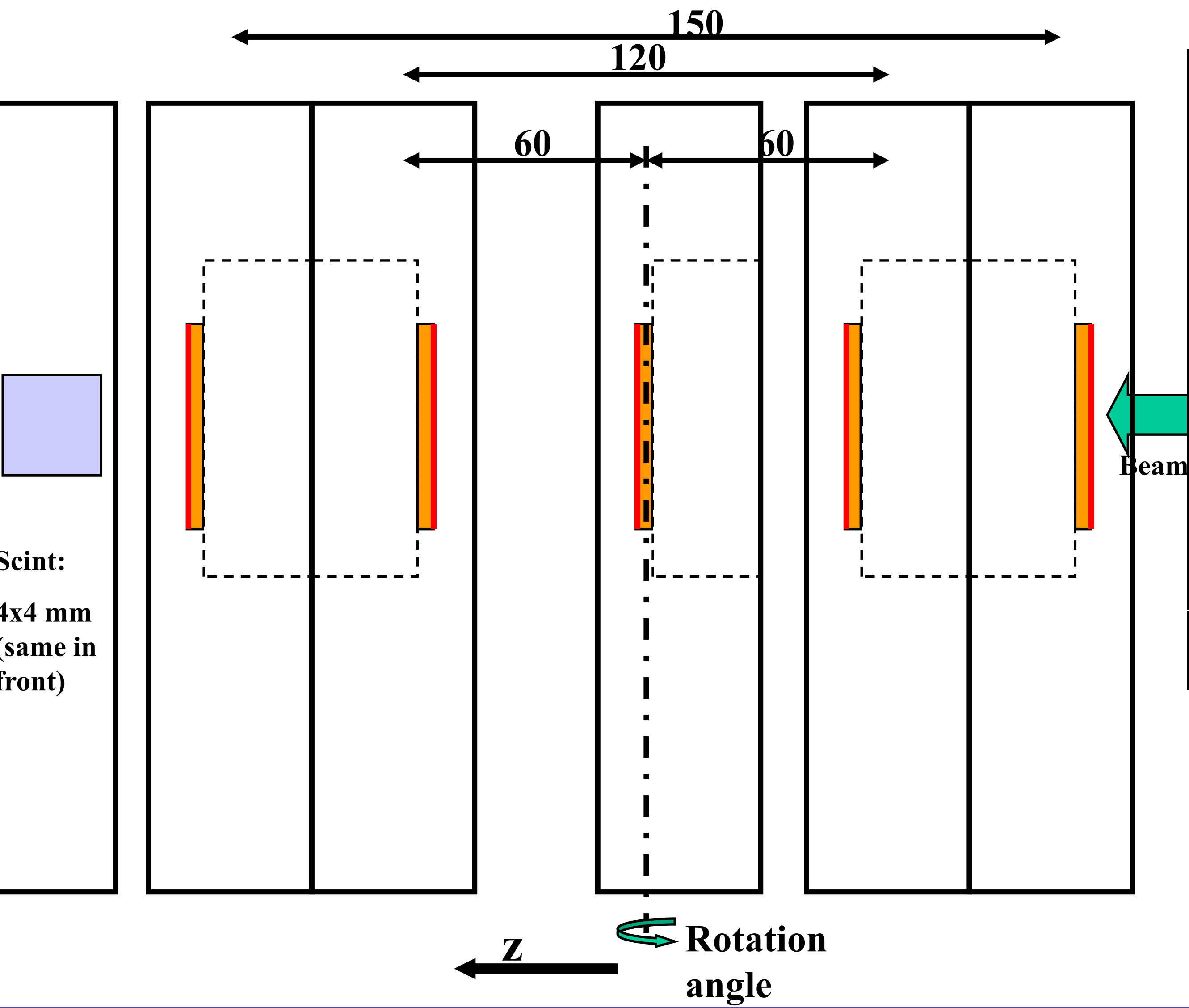
TAPI-3: a "standard" configuration with a DUT in the middle, CERN, September 08 (TNT2 based DAQ). Incident angle study.



Readout TNT# / Ch.#	z [mm]	Rotation, sensor	Thicknes s [µm]	Epi [µm]
17/1,2	4	N	700	20
17/3,4	26	R	700	20
12/1,2	139	N	700	20
12/3,4	161	R	700	20
15/1,2, 3,4	82.5	N	60	20

Run# : 13, 14, 15, 16, 17

Comments/suggestions:

16: rotation 0°

17: rotation 90°

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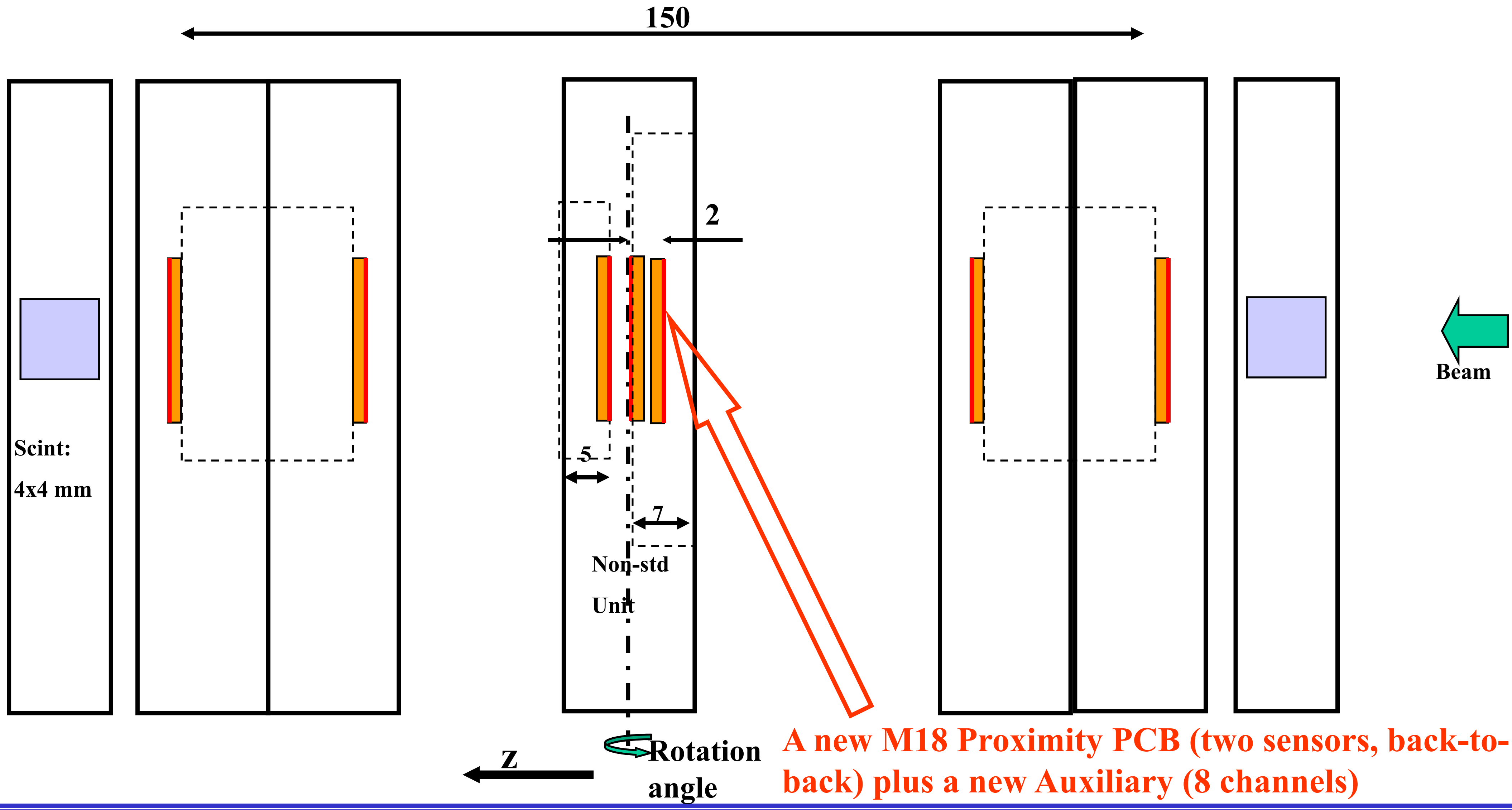
TAPI: future "final" configuration with a DUT and two high precision planes in the middle, fast (binary) planes in arms



A new M18 Proximity PCB (two sensors, back-to-back) plus a new Auxiliary (8 channels)

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Basic requirement for data acquisition in such system: fully exploit sensors capability in term of position and time resolution. Logically, EUDET should follow similar scenario…

- No dead-time

- No trigger rate limitation

- (Sparsified) data flow capability adapted for the highest practical particle rate

- If possible, hardware (and software) building blocs based on commercial products

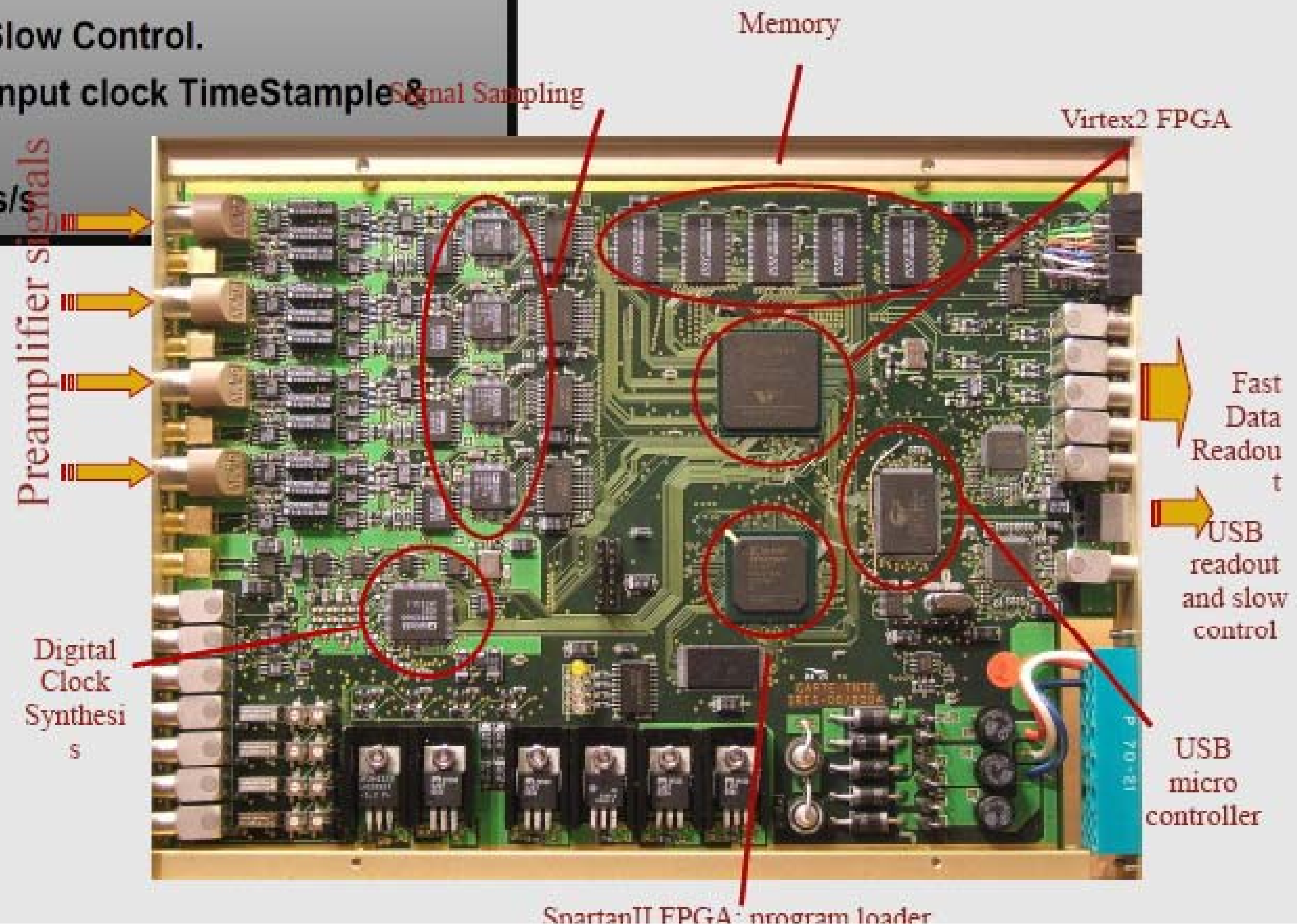
In practice, taking into account M22+ (Mimosa26) and Mimosa18 characteristics, this translates into:

- For the binary chip: few clusters per frame (100µs) PLUS unknown amount of hot pixels (up to 600/frame/sensor). In the worst case, this means 100 MBy/s for the system. But, if hot pixels on-fly filtered out (FPGA), this may go down to reasonably low 1 MBy/s… <u>Strong motivation for keeping some intelligence in the DAQ digital boards</u>.

- For the analog sensor: order of magnitude higher multiplicity/frame, but similar absolute data rate in sparsified mode (1Mby/s)

DAQ for analog sensor based on TNT2 commercial board (CAEN)

- 4 channels, 100 MHz, 14 bits.
- 512K 32bits-words Memory Depth.
- VII FPGA 3M Gates.
- SpartanII FPGA for config loader through USB port.
- USB Readout & Slow Control.
- 1 input clock / 1 input clock TimeStample & Trigger
- 1 output 2.5 Gbits/s



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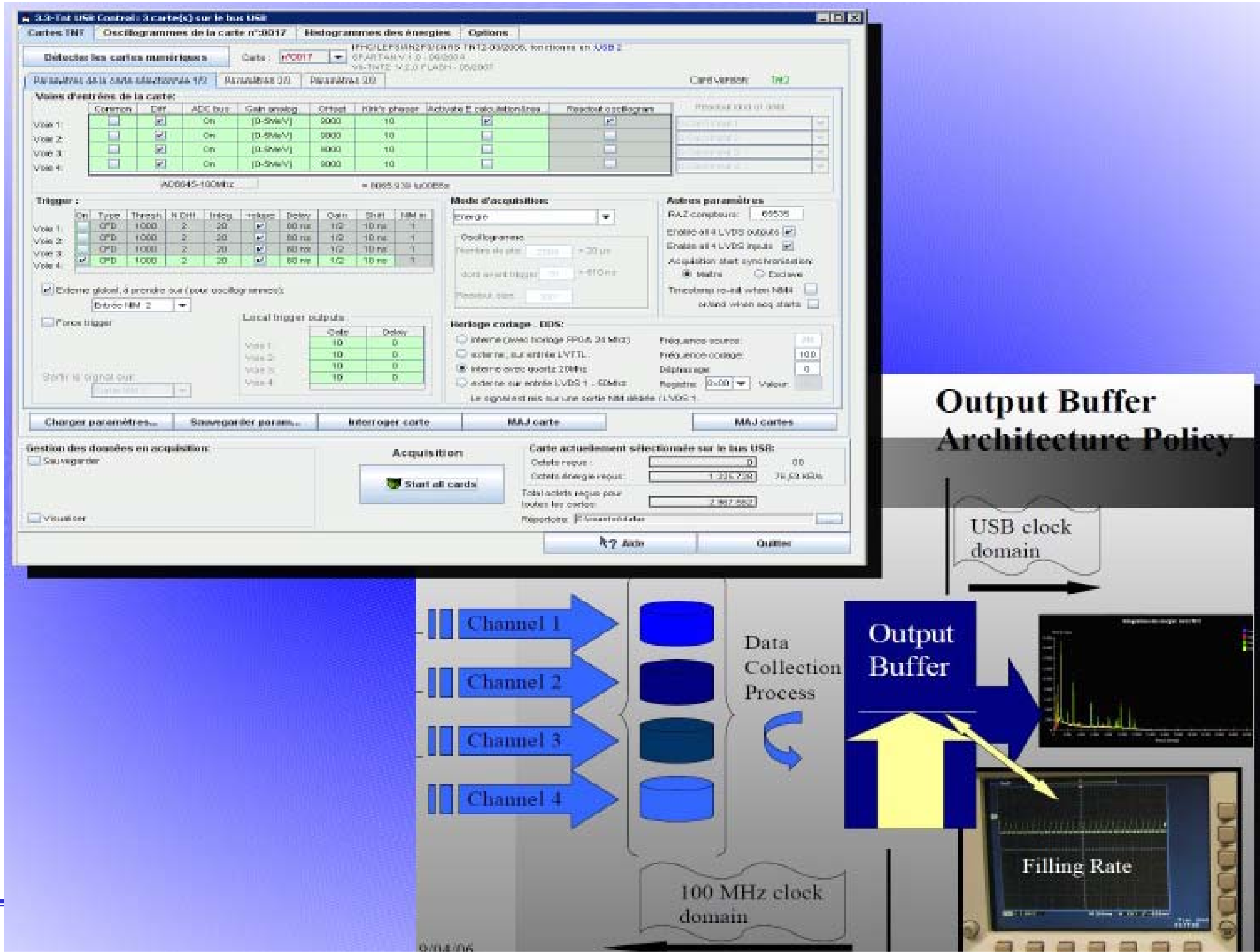
TNT2: single unit NIM format. Developed at IPHC for nuclear spectroscopy (digital filtering method)



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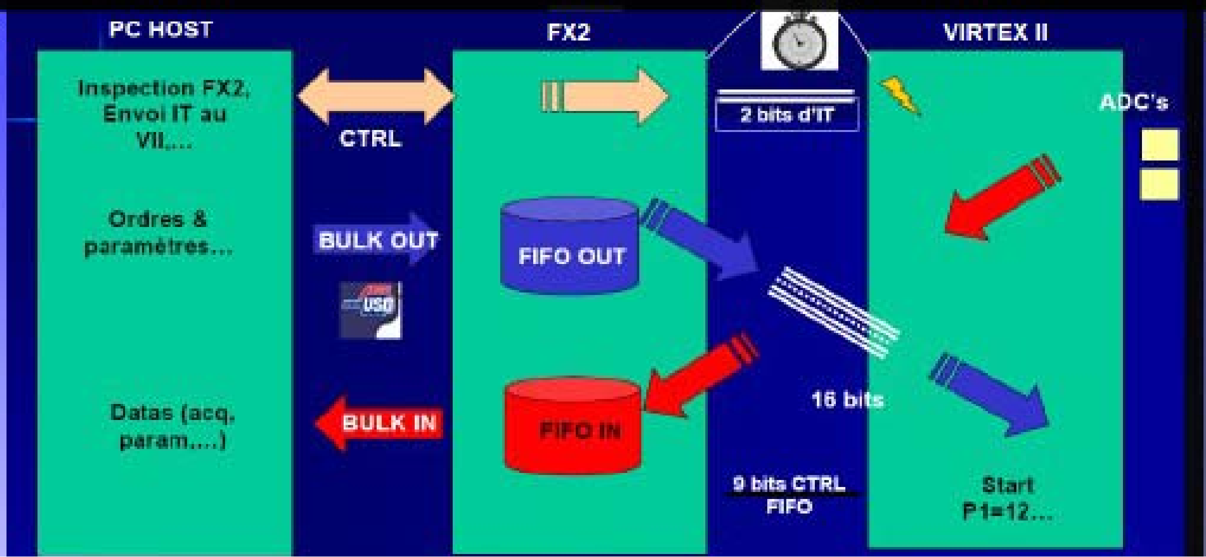
TNT2: USB2 port specification

- Up to 480 Mbps data transfer
- Currently delivered with every PC motherboard
- Windows and Linux RedHat 7.2
- Easy installation : hot plug, automatic detection, light installation (ex : 2 files for W2K)
- Up to 127 TNT devices on the bus
- Host development : Visual C++, Tcl/Tk or Java
  - easy to program with Cypress driver
- Embedded development (8051 C)→ lot of software facilities delivered with Chip Cypress FX2.
  - USB low level hardwired, handled by the chip
  - Many examples ready and easy to use and configure



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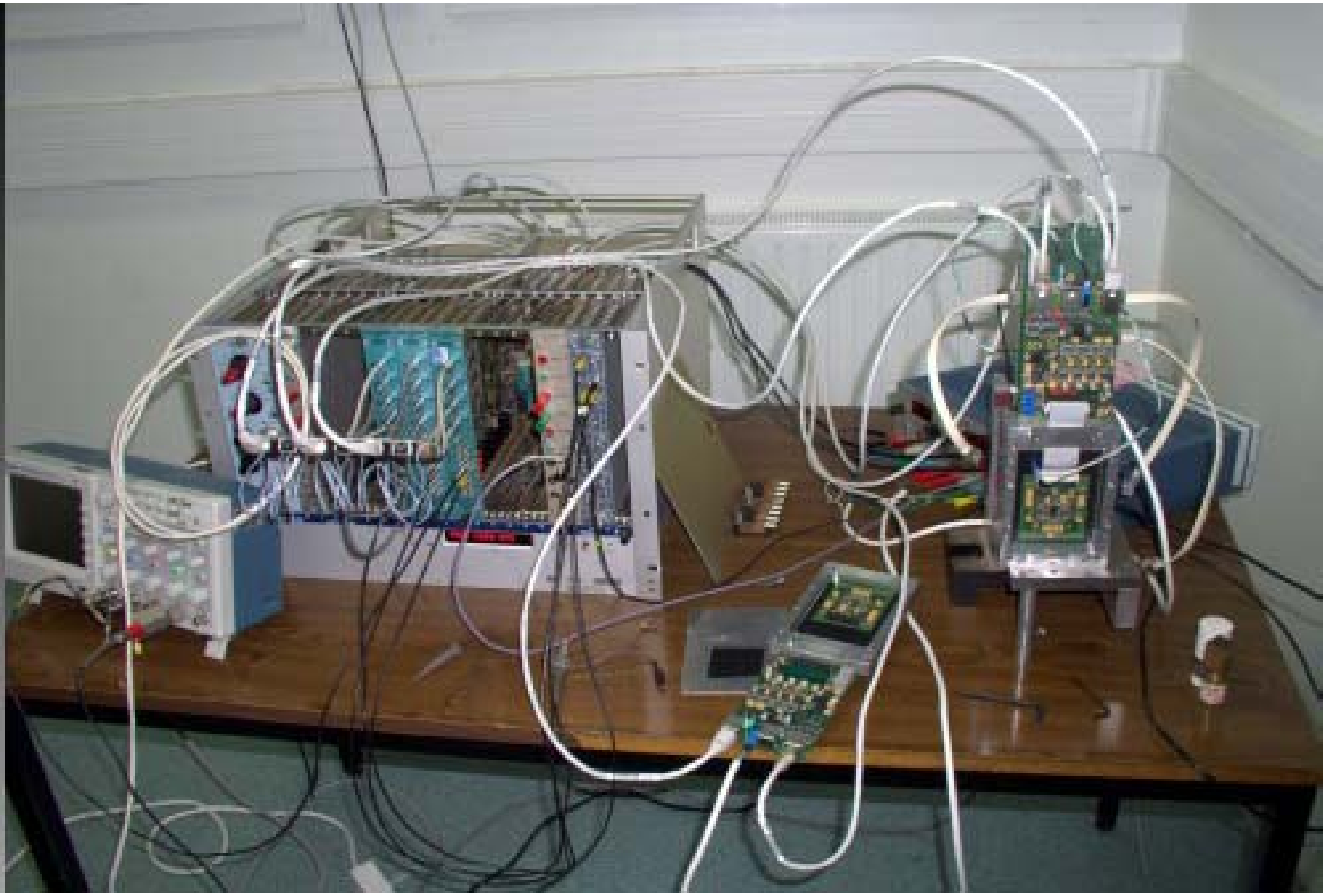
TNT2 based DAQ for TAPI: new firmware developed by Cayetano Santos, originally for medical (positron) imaging, provides data sparsification with no dead time. Real time image display (MATLAB)



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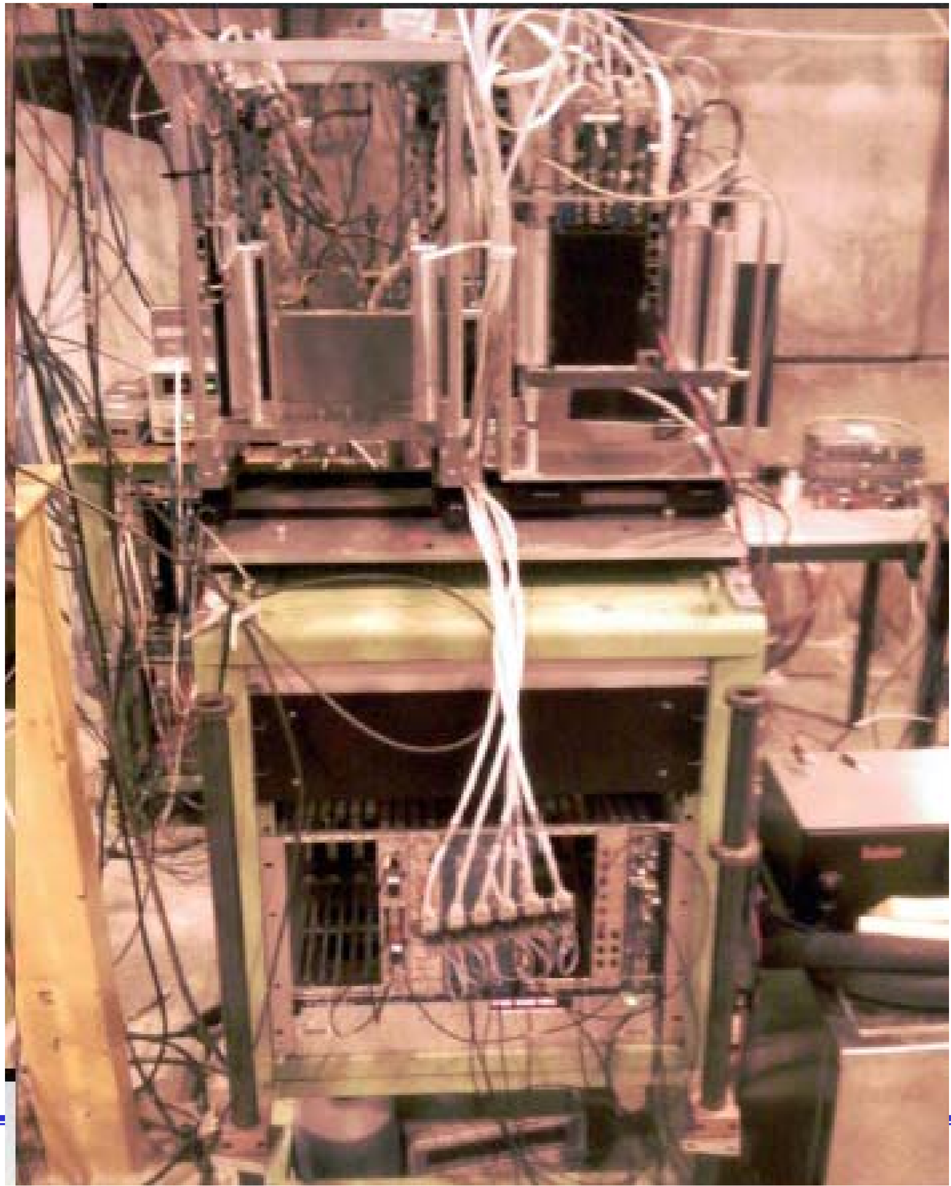
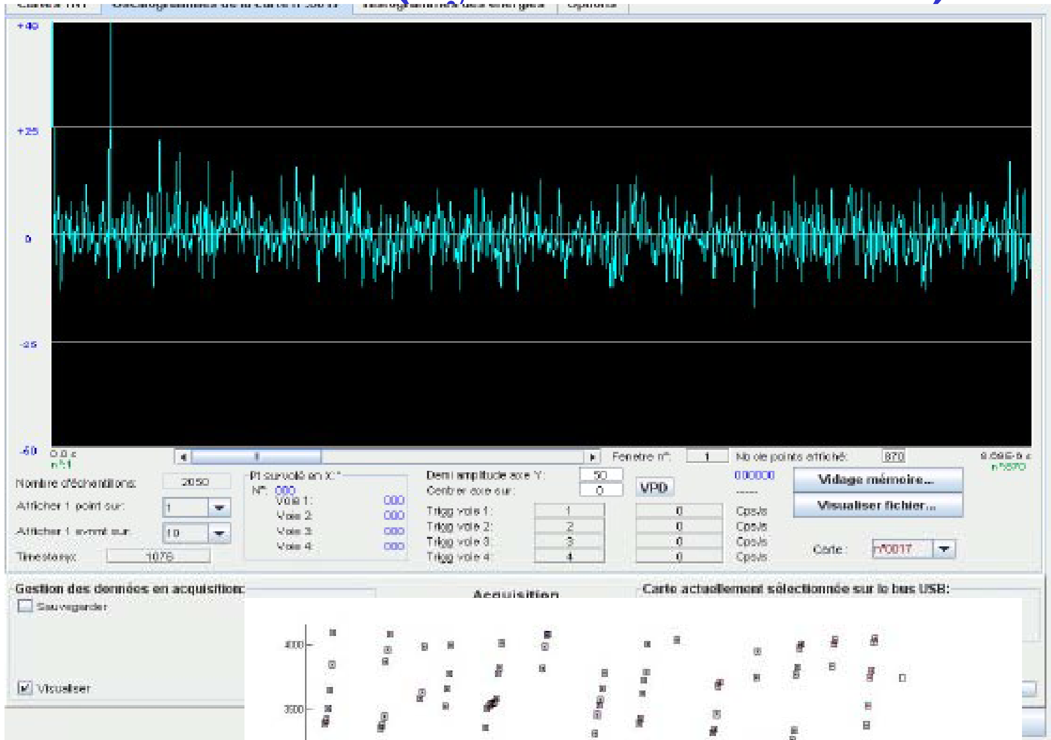
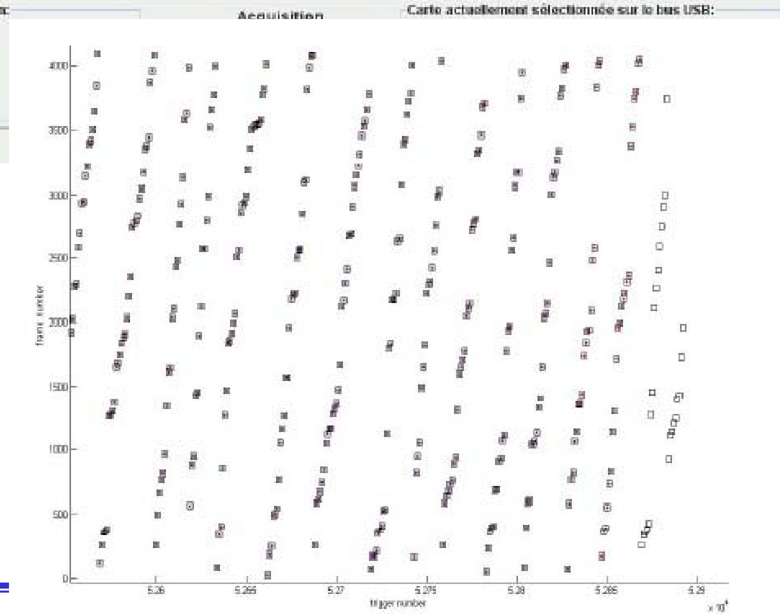
TNT2 based DAQ for TAPI: set-up at CERN, oscilloscope mode, trigger number versus frame number (synchronization)







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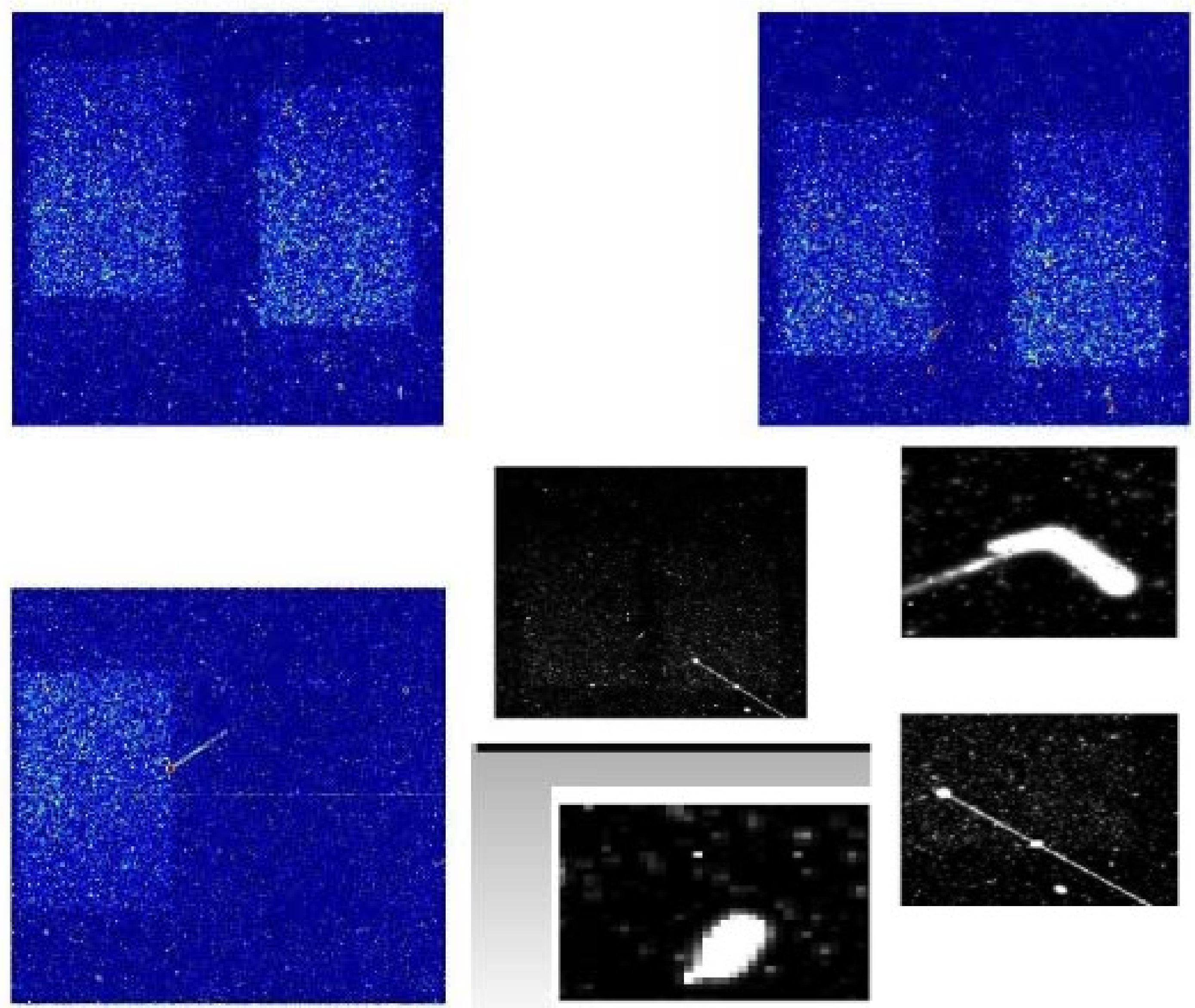
On-line beam profile display: 4 reference plus DUT



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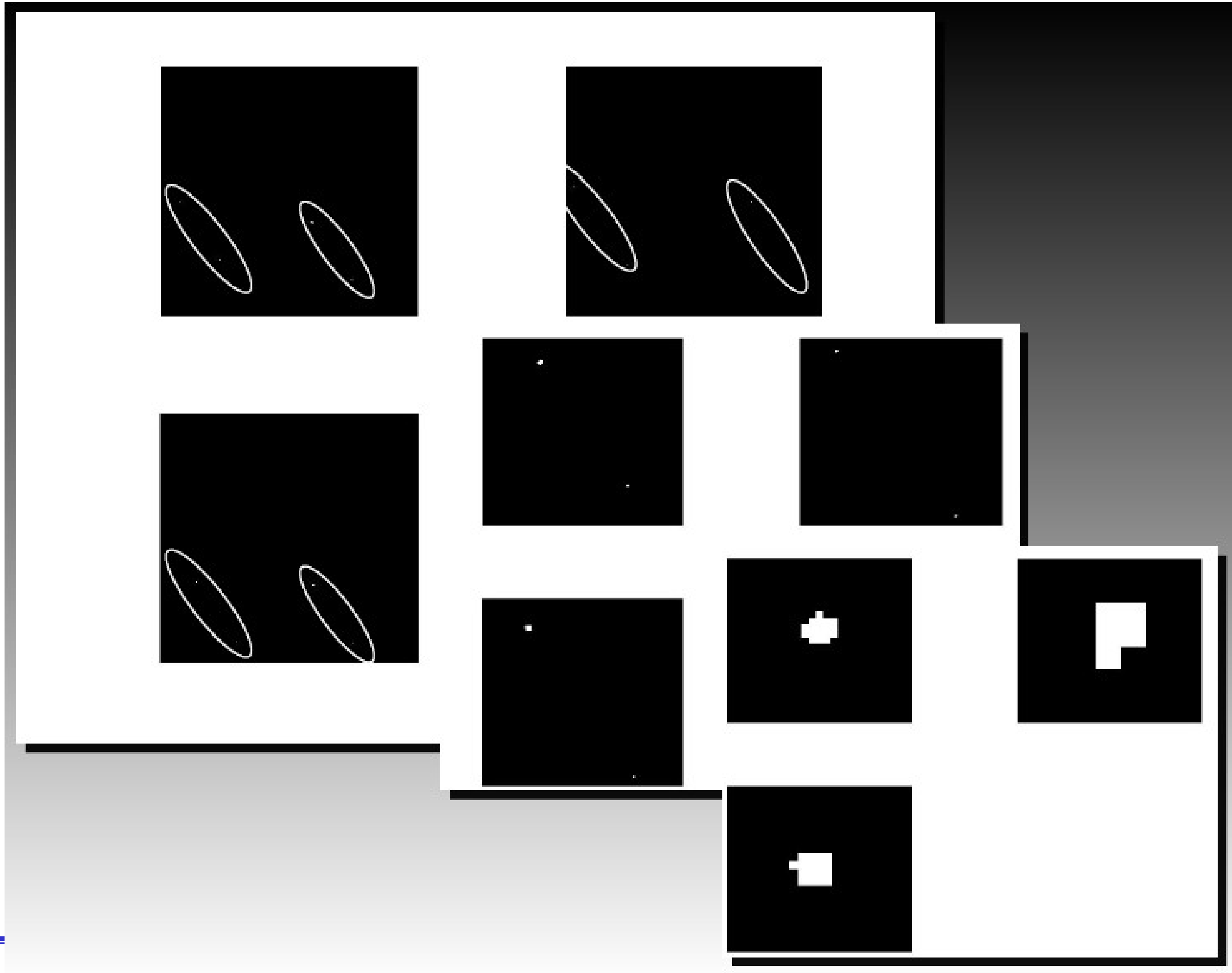
Double-track event: 6 reference planes



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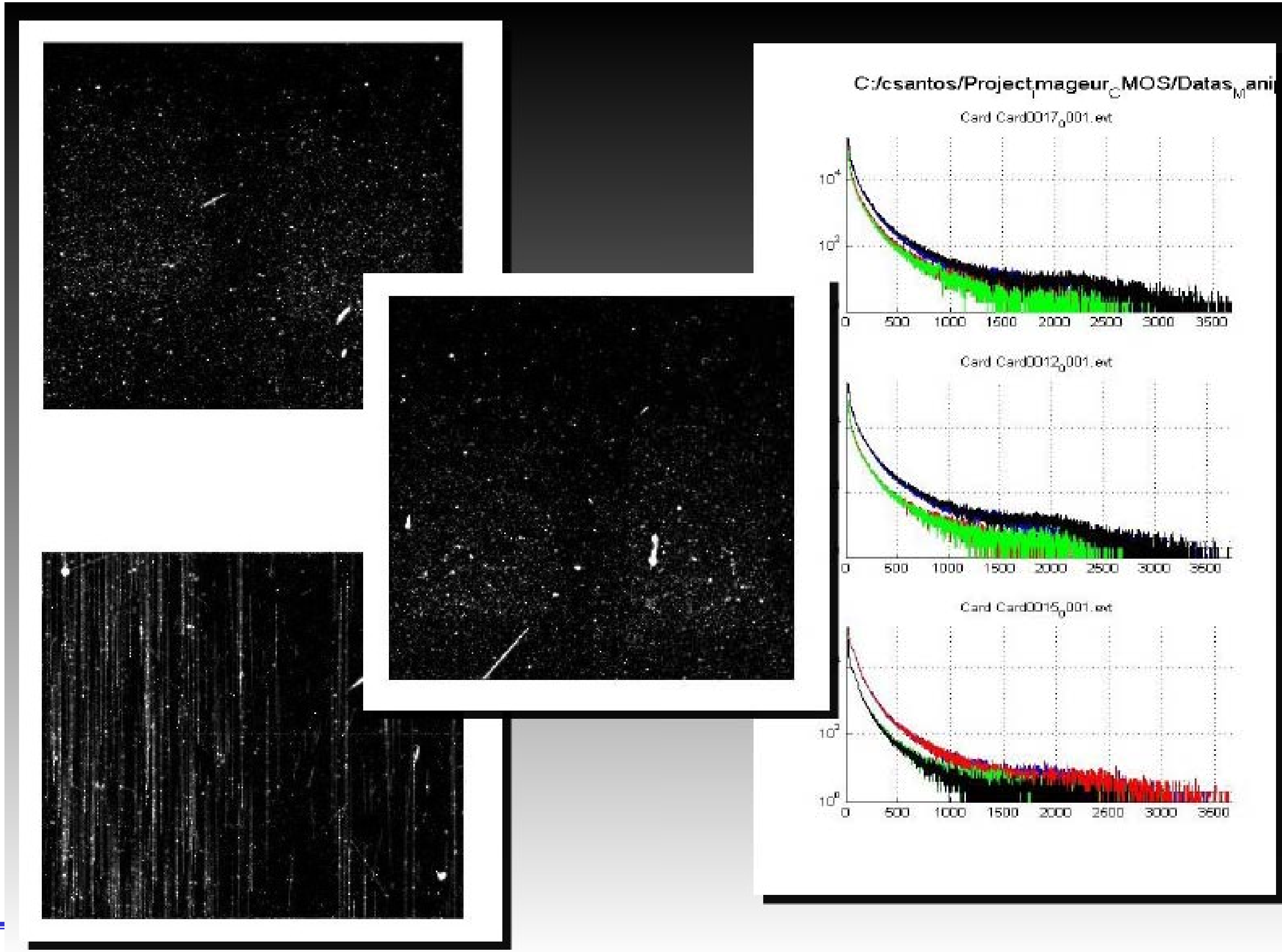
Beam profile and spectrum: 4 reference plus DUT at 90°



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In conclusion:

- The DAQ system for analog sensors based on TNT2 boards seems to work pretty nicely. It is already quite robust, easy to use and may by software-parameterized for array of any size. For smaller (or slower) sensors, forcing discrimination threshold to zero, may provide row data mode within the same procedure.

- Data transfer speed (40 Mby/s for a system using the same USB bus) largely satisfy any predictable application. Example: four sensor planes, four channel each (four TNT2) accept up to 250 000 hits/s (1000 hits/frame in case of Mimosa18@16MHz.

- The board is commercially available through CAEN, the specific firmware supported by IPHC.

- Small software commodities (parameterization and on-line monitoring) may be still welcome, but what exists is already quite complete.

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Future development plans

- The direction towards the final DAQ (including binary chip readout) is not fully defined yet at IPHC. The first version, allowing chip testing but not satisfying zero dead time requirement is based on PXI 6562 digital acquisition board. Basic characteristics: burst readout of 200 frames at full speed (100 MHz, 2 channels/chip), followed by data transfer (2000 frames/s). This results in 80% of dead time… Simple data deserializer may decrease this value to 20%.

- What about next generation sensors? In my opinion, the main problem at present is time resolution, but upgrade is not simple. Starting development in 3D electronics may be the way to gain at least an order of magnitude. Matching the size of the binary chip by high precision device is possible in existing technology. Interesting direction may be super-fine pitch together coupled with fully depleted epitaxy.