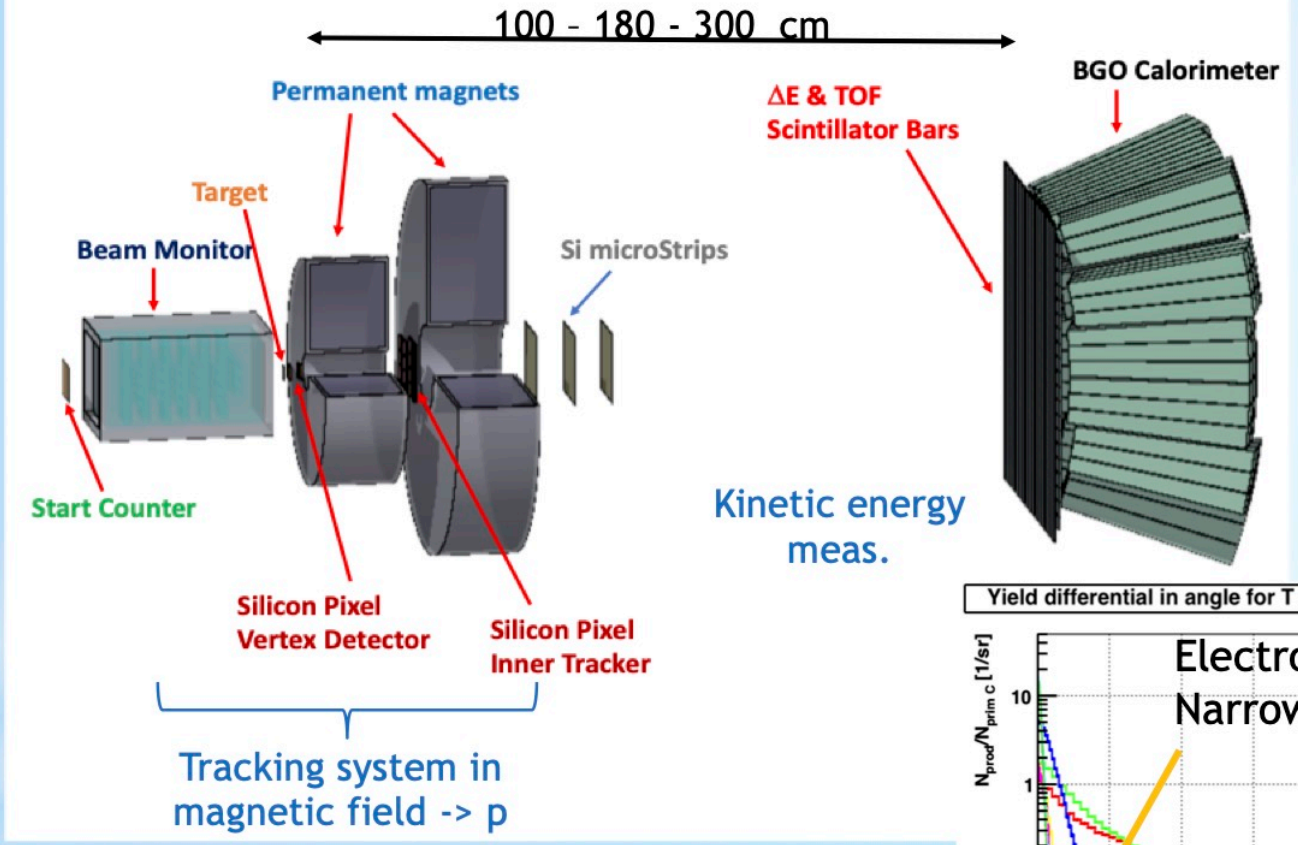
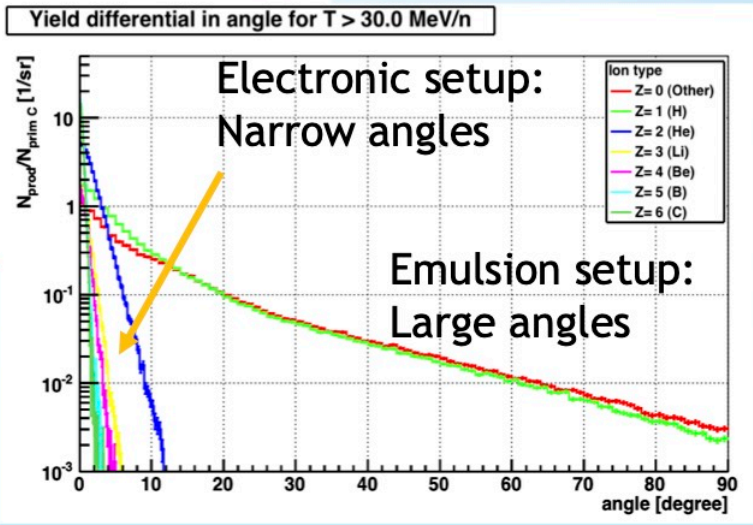
FOOT (FragmentatiOn Of Target) pixel tracker status

1. FOOT electronic setup
2. The magnet system
3. The FOOT Vertex detector
4. Inner Tracker (IT) status
5. IT ladders assembly (today: end november, 2021)
6. Conclusions

The FOOT electronic setup



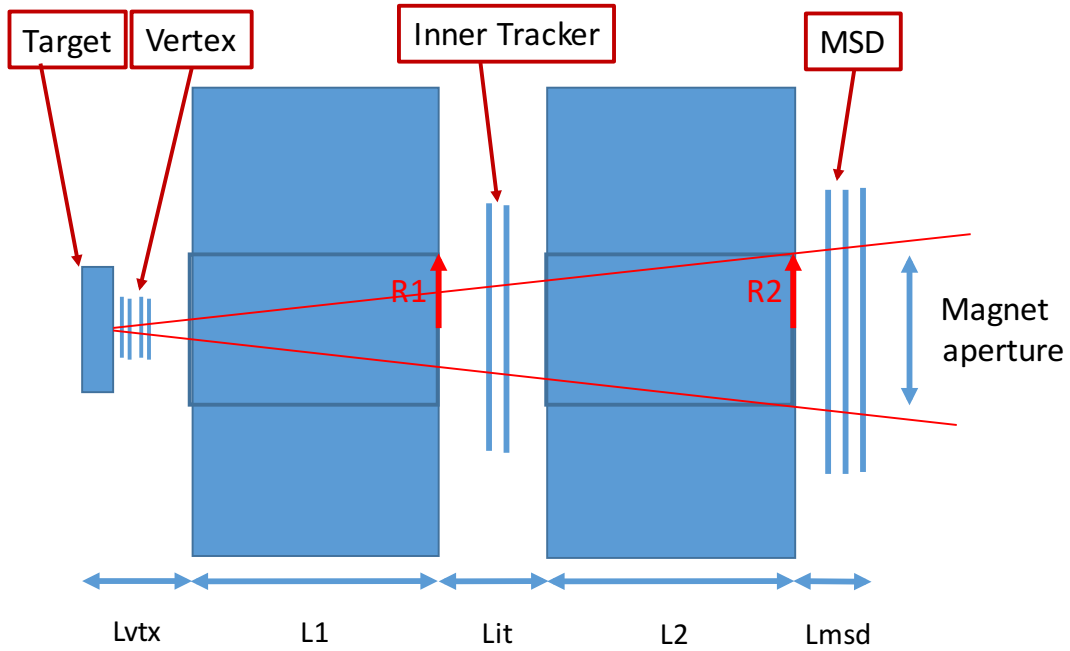
Z and A id by means of redundant combination of ΔE, ToF, p and E

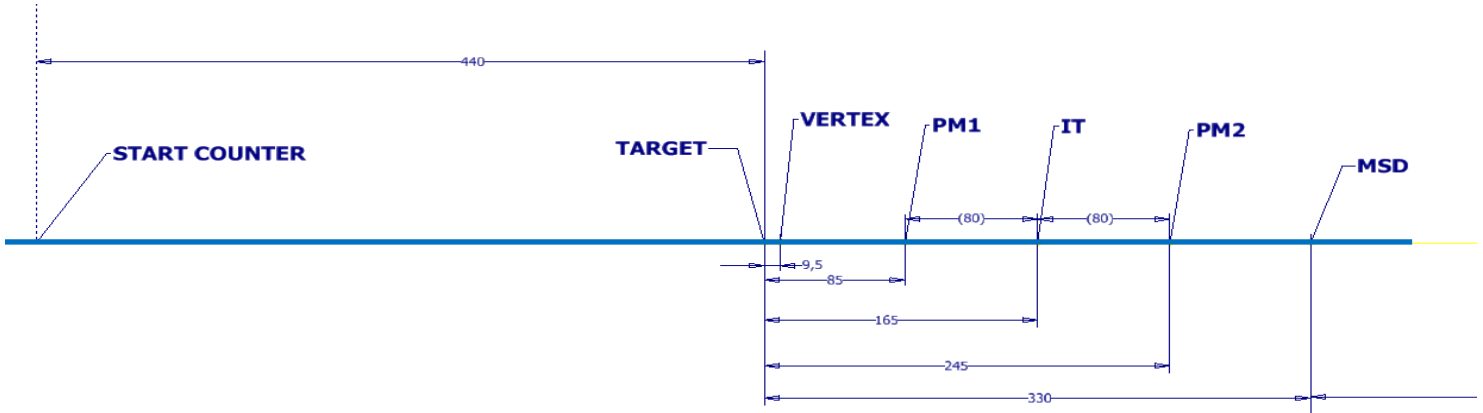


Electronic setup:
heavy fragments at narrow angle < 10 deg
Emulsion setup:
light fragments at large angle > 10 deg

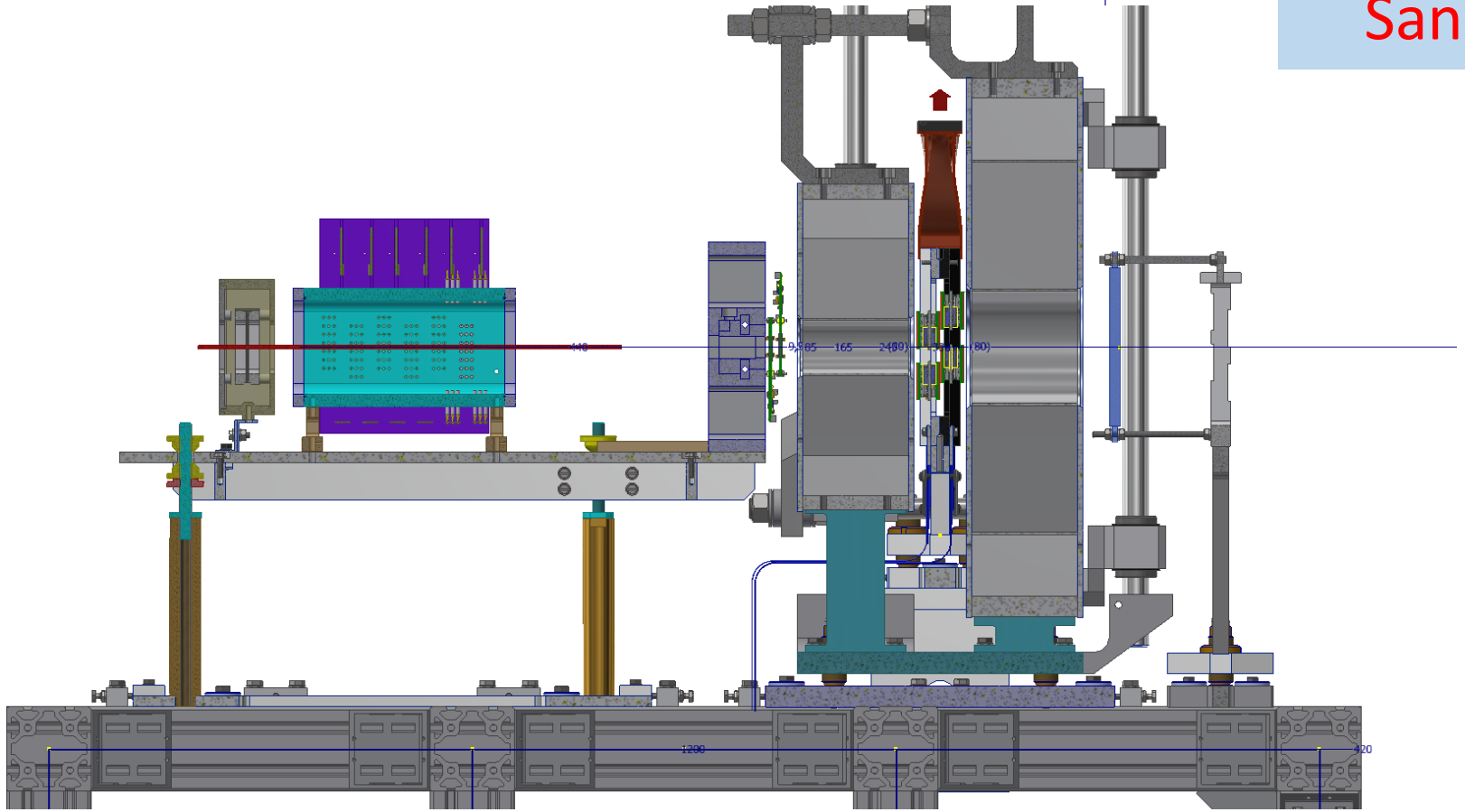
Magnetic system

					Radianti	Gradi
Lvtx	3,00		0,179	Accettanza M1 (gradi)	0,177	10,12
L1	11,00		0,177	Accettanza M2 (gradi)	0,175	10,02
Lit	5,00		0,171	Accettanza MSD (gradi)	0,169	9,70
L2	11,00		0,171	Accettanza IT1 (gradi)		
Lmsd	1,00			Accettanza IT2 (gradi)		
Rin1	2,50					
Rin2	5,30					
Dmsd	9,00					
ITdist	1,00					

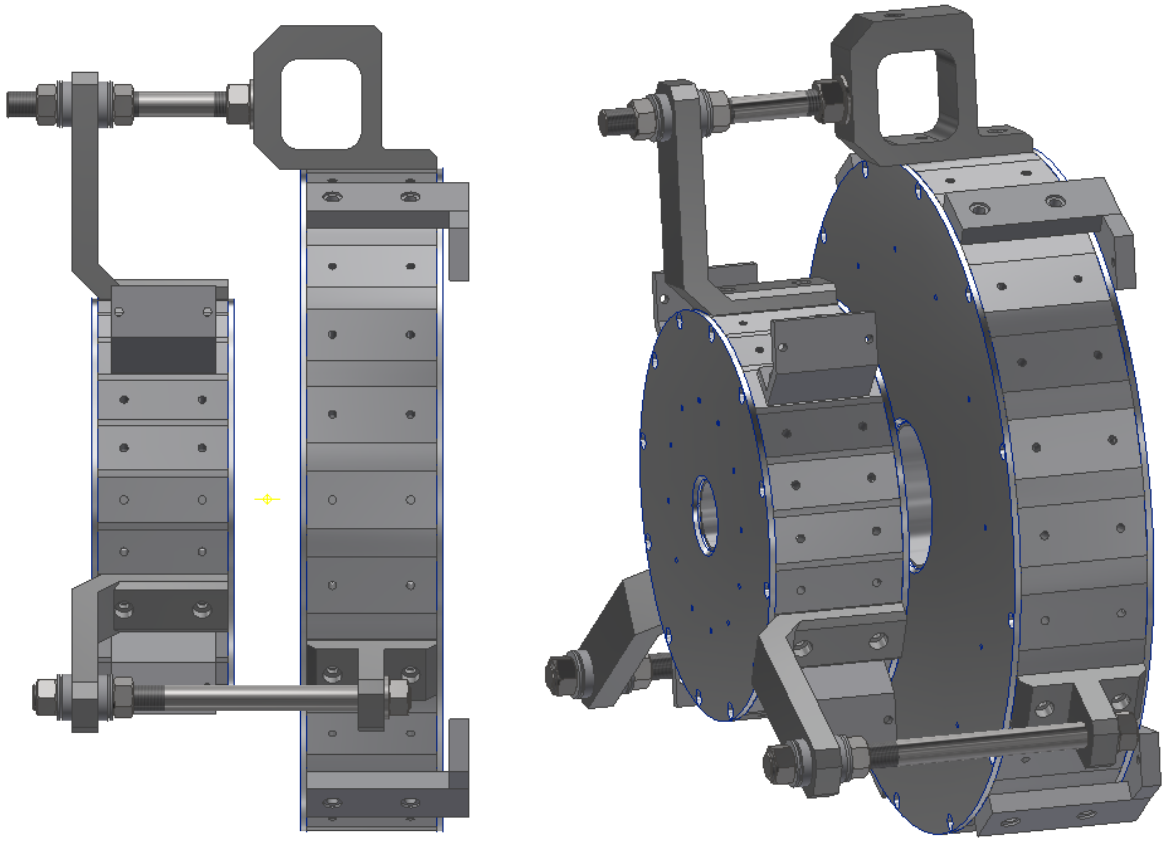




FOOT Tracking region Mechanical Layout: designer Sandro Tomassini



	Z [mm]
TARGET	0
VERTEX	9.5
PM1	85
IT	165
PM2	245
MSD	330
S. COUNTER	- 440



S. Tomassini, INFN-LNF- Research Division

Two Permanent Magnet Dipoles in one assembly to avoid handling issues (special toolings required for safe handling)

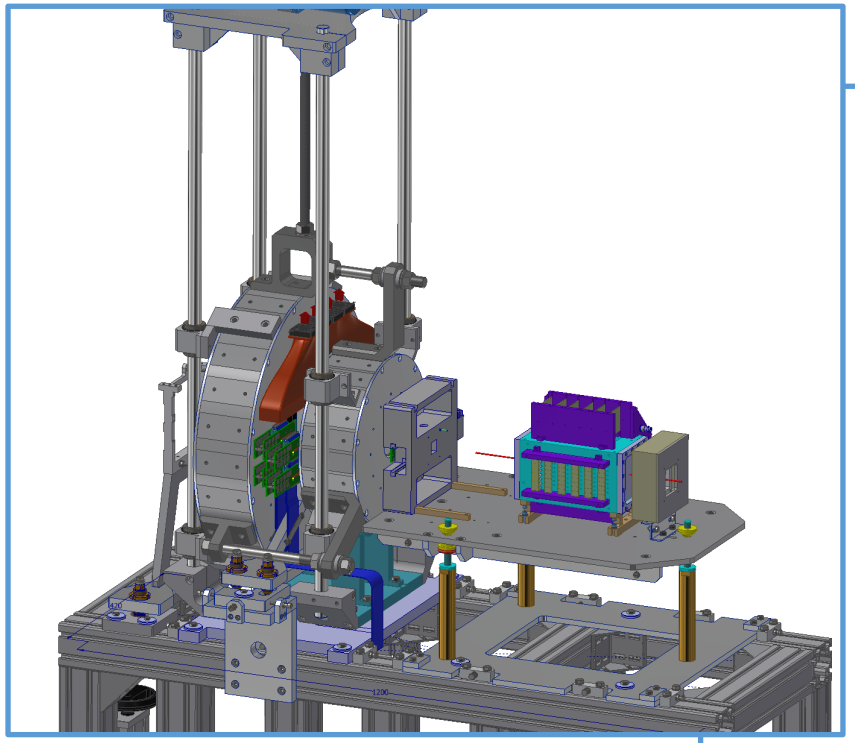
Repulsion force: 2000 N @ 50 mm gap

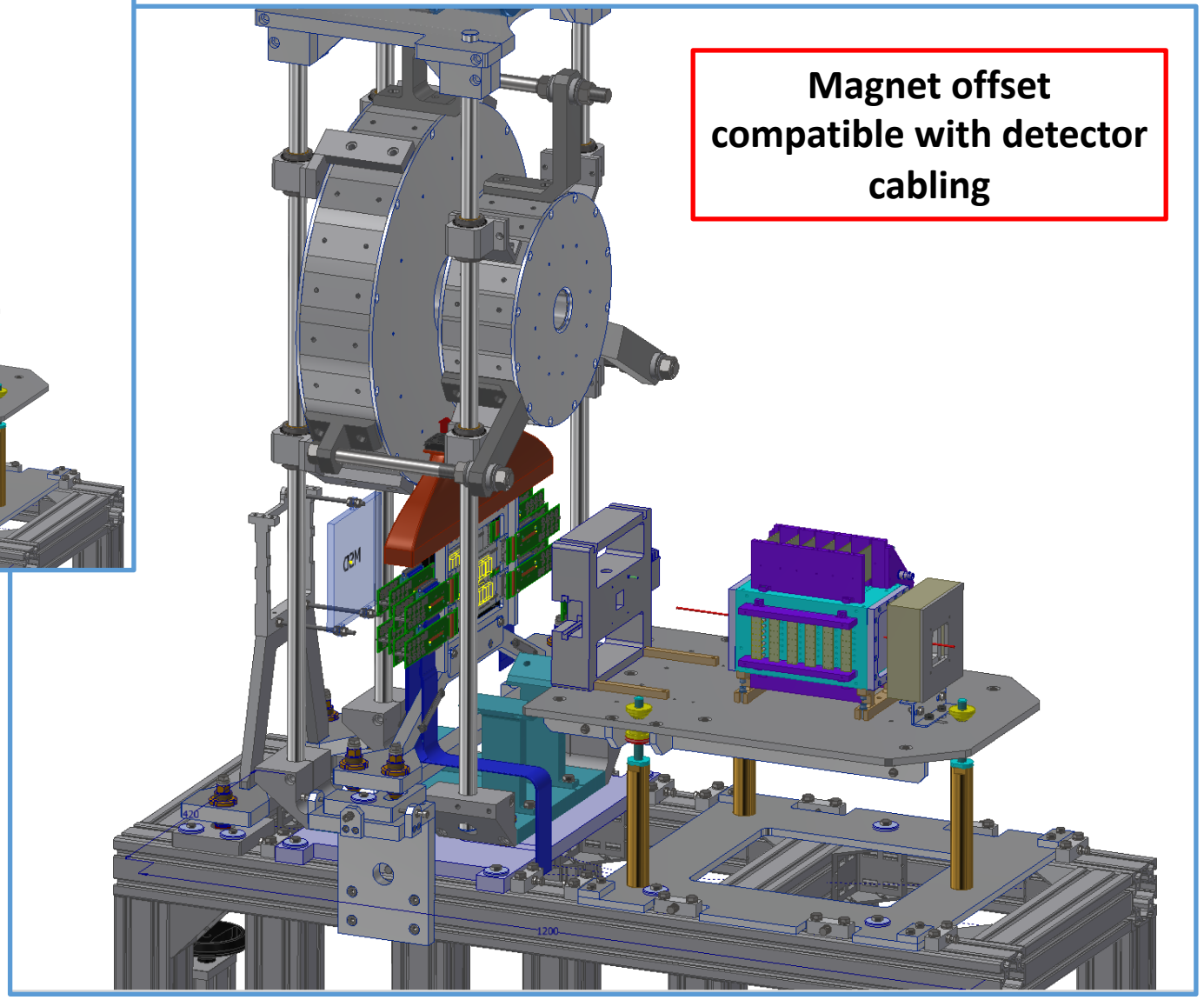
Weight: 250 kg

Magnetic field aligned at the vendor

Magnetic map to be checked at LNF after delivery

Calibration with straight tracks

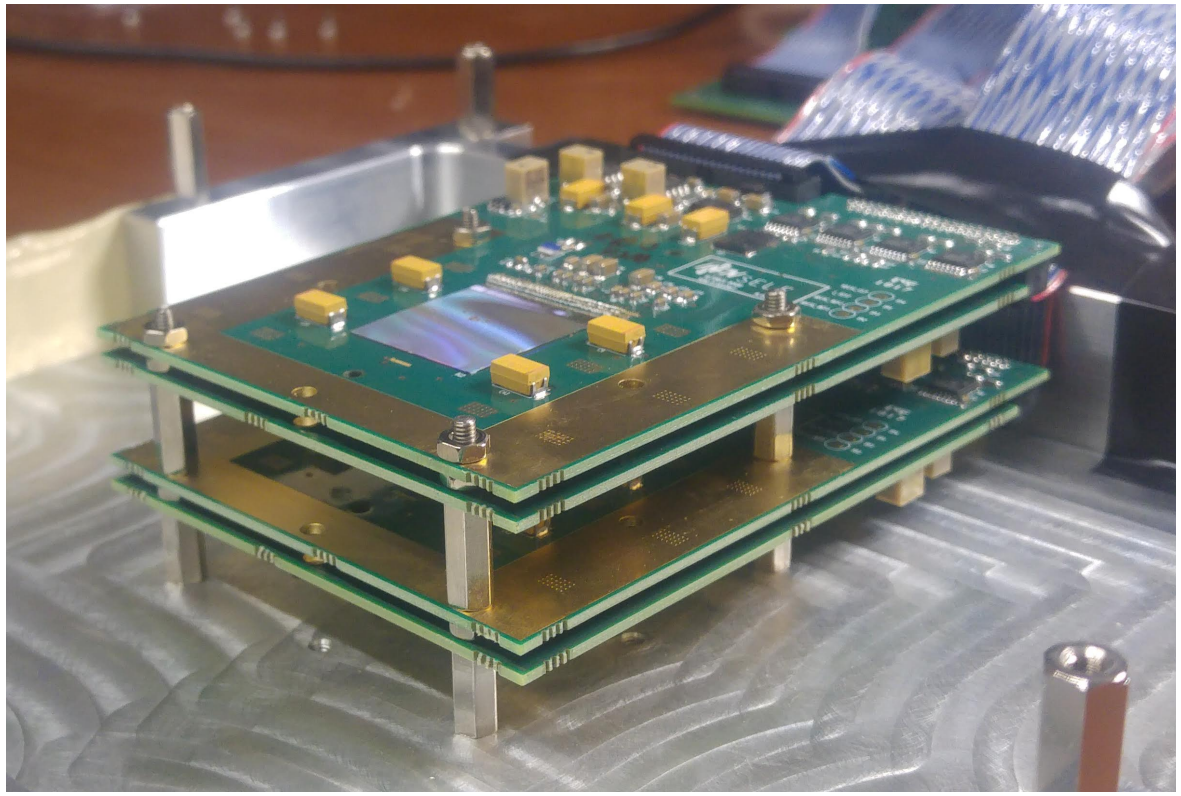


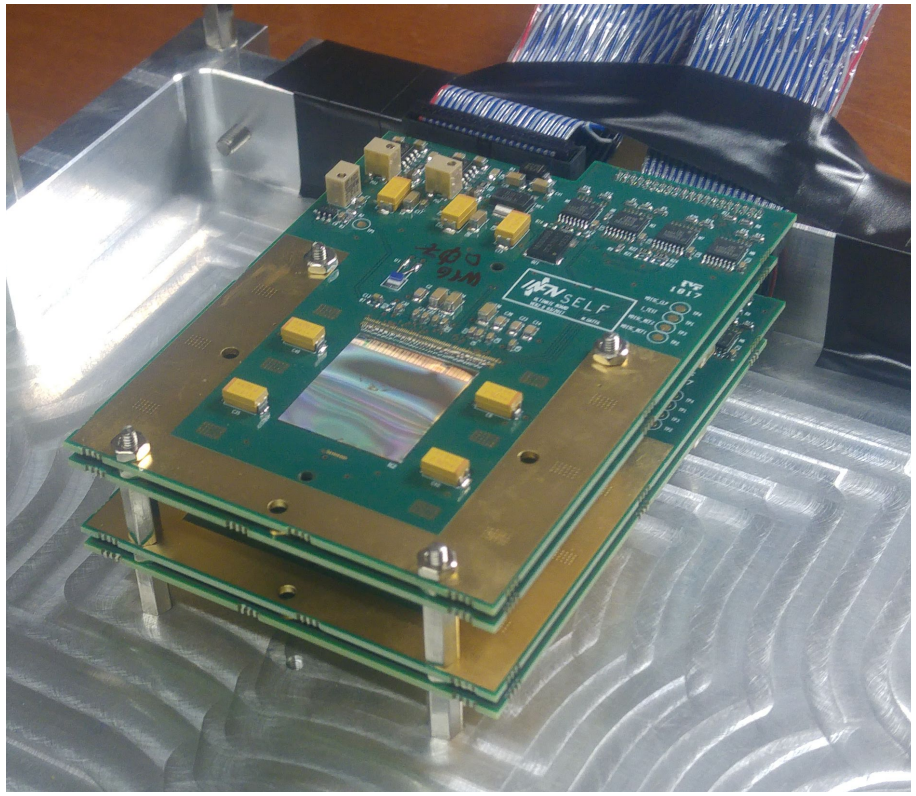


Magnet offset compatible with detector cabling

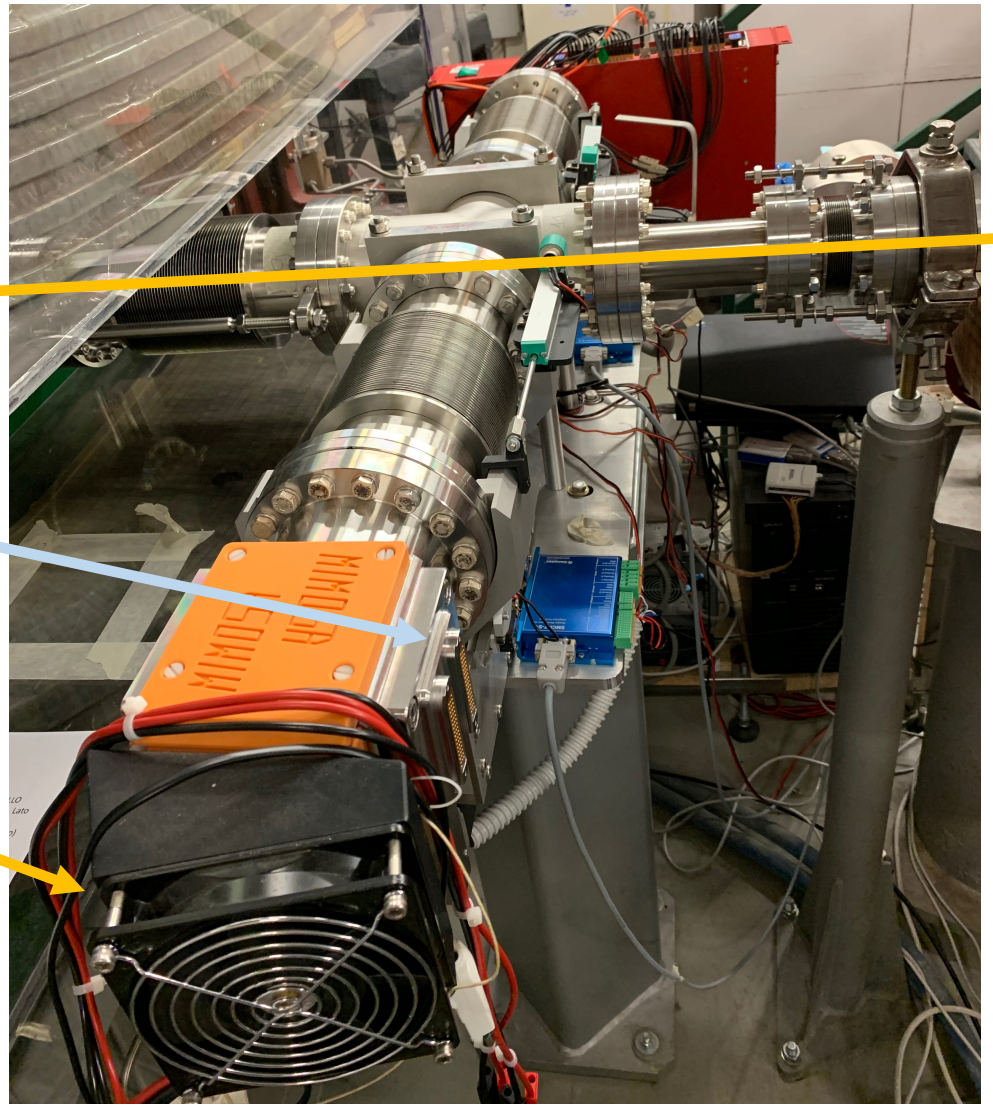
FOOT Vertex Tracker

- Four Ultimate boards, designed in Frascati (SEA), sensors glued and bonded in Strasbourg (IPHC - In2p3)
- Already used for data taking at GSI (Darmstadt)
- Already used for data taking at PADME (see next slide) **IN VACUUM**





Vertex: results from PADME



PADME beam line

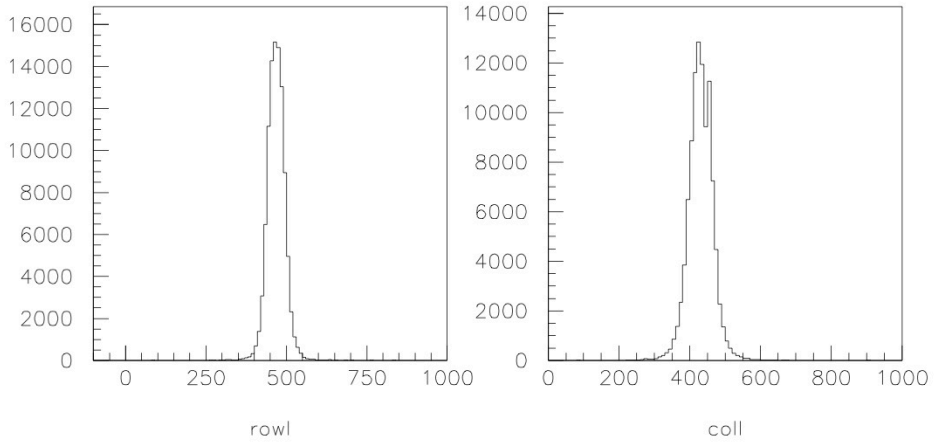
M28 signal connector

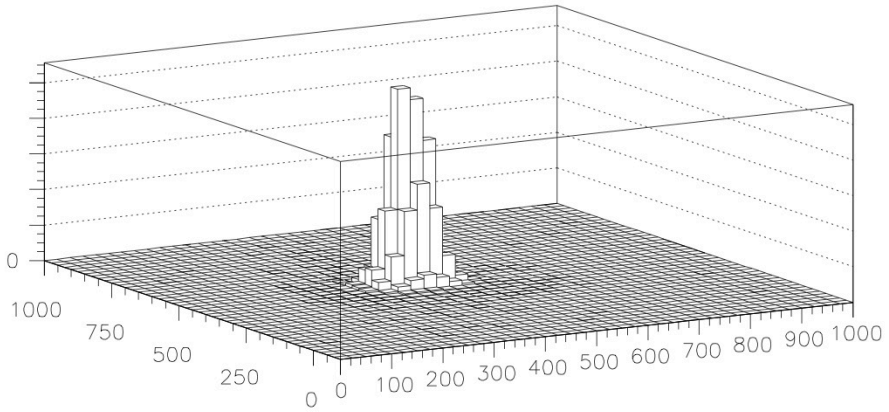
Cooling fan

Vertex: results from PADME

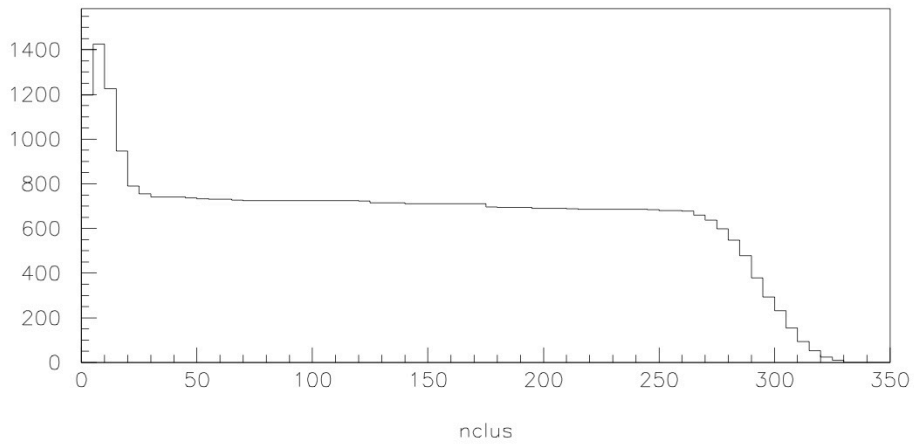
Main goal of the measure: check maximum multiplicity allowed by Ultimate/M28
Collected about 1.5 Milion event without DAQ problems

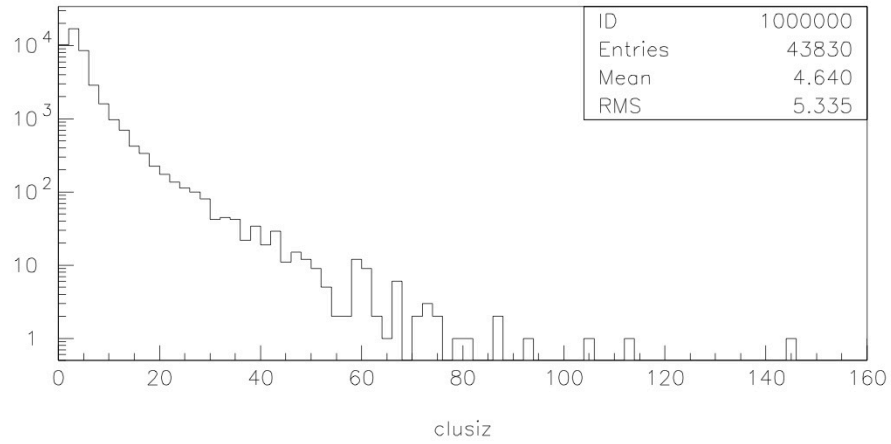
Beam profile (positrons @ about 500 MeV)





Cluster multiplicity and size





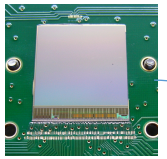
FOOT Vertex Readout Architecture

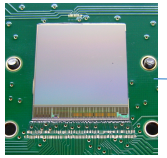
40 wires cable

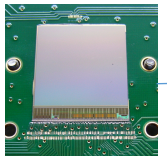
11*4=44 signals
- 22 LVDS pairs
- 11 single ended

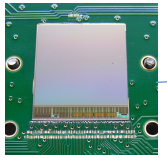
Terasic DE10 SoC
Local pixel DAQ:
FPGA firmware +
Read Out program

Global FOOT DAQ

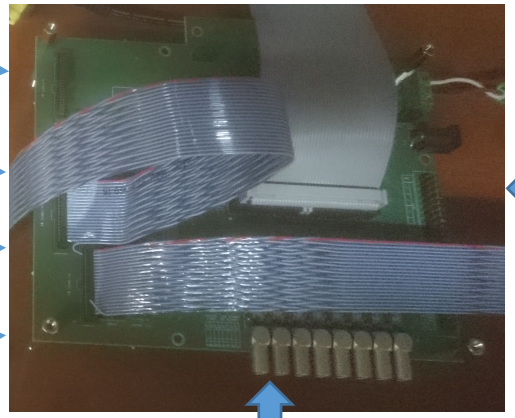


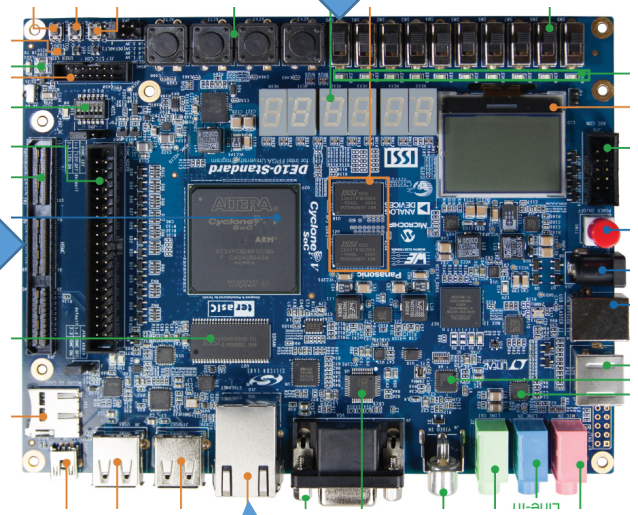






Vertex adapter board

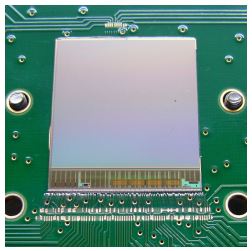




Trigger

Gigabit ethernet connection
(UDP protocol)

Readout Architecture logic (for both Vertex and IT)



Two serial out DO0, DO1 (160MHz)

JTAG

SoC FPGA firmware

DP RAM DO0

DP RAM DO1

SoC Arm A9 CPU Local pixel DAQ program

Send UDP packets on Gigabit ethernet

Intermediate PC

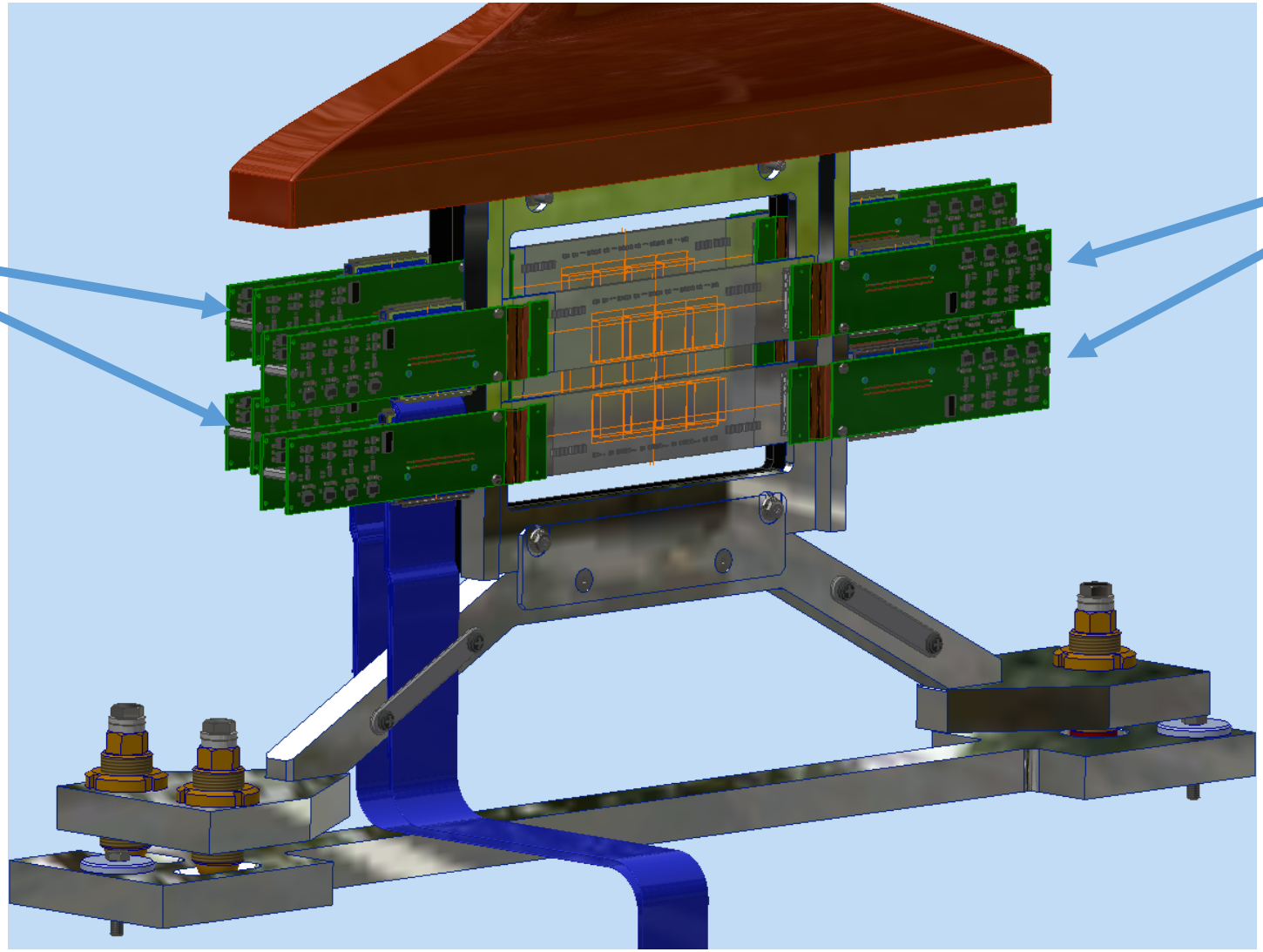
Trigger

Architecture running also on PADME.
PADME trigger rate requirement at **50 Hz!!!!!!!!**

Data logger listening on sockets, one for each readout board and writing data on files.

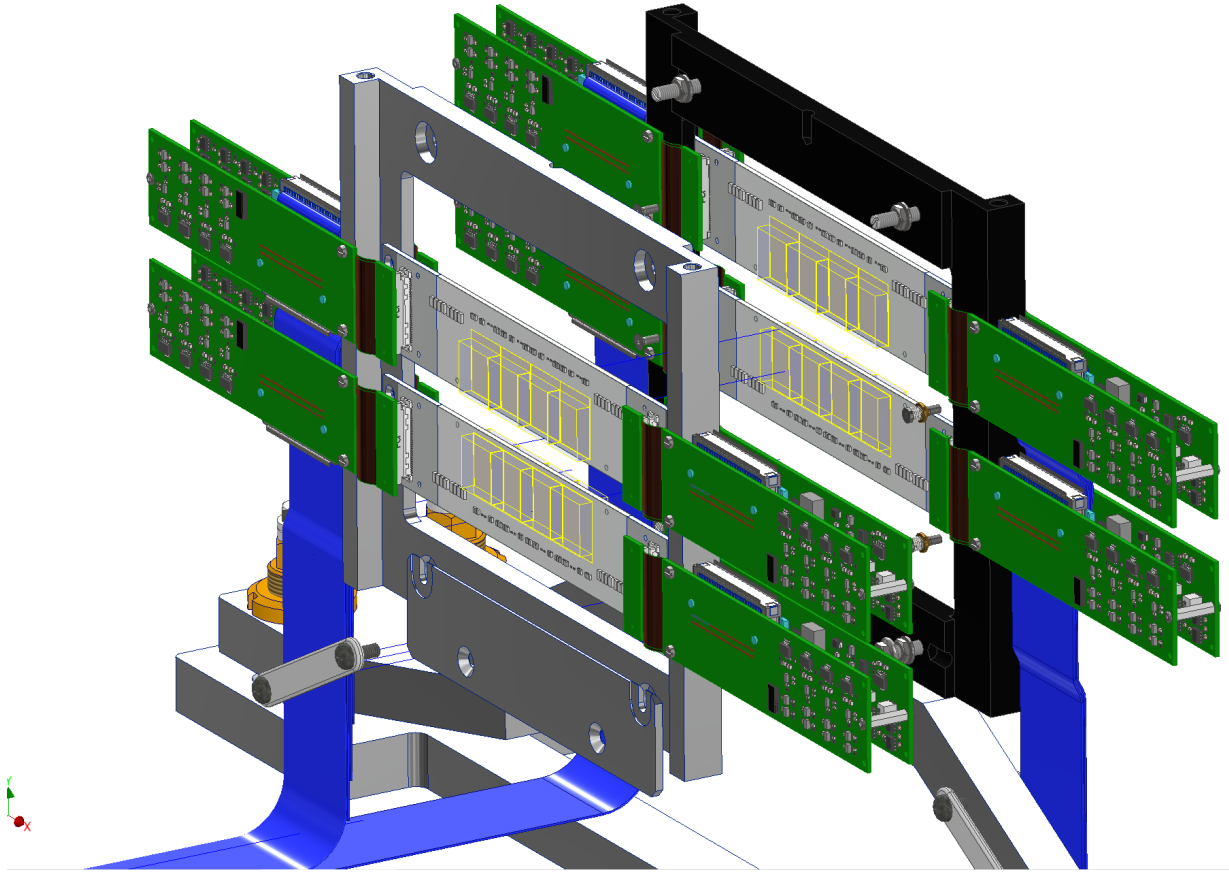
Inner Tracker (IT)

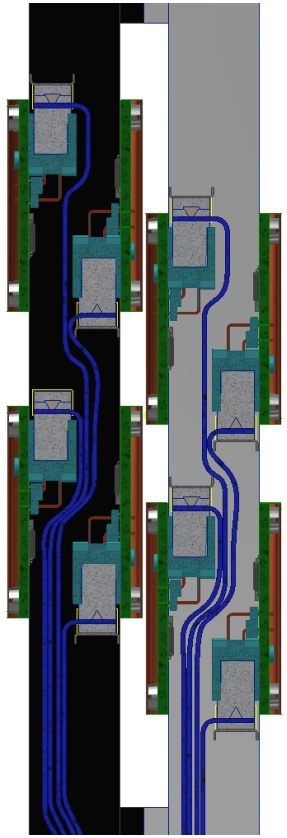
Two back ladders: one PlumeM28 + four Adapter_PlumeM28 each

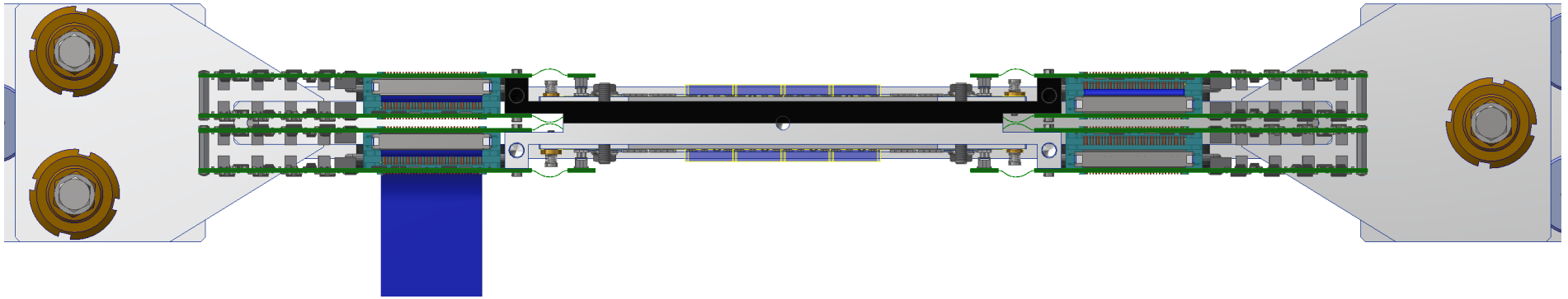


Two front ladders: one PlumeM28 + four Adapter_PlumeM28 each

Inner Tracker INTEGRATION SEQUENCE







Inner Tracker (IT) status

Memorandum of Understanding between the Laboratori Nazionali di Frascati of the Istituto Nazionale di Fisica Nucleare (INFN-LNF) and the Institut Pluridisciplinaire Hubert Curien (IPHC) regarding the assembly of the FOOT inner tracker

1. Purpose

The purpose of this Memorandum is to document the understanding between the Laboratori Nazionali di Frascati (LNF) of the INFN, hereby represented by its Director, Dr. Fabio BOSSI, and the Institut Pluridisciplinaire Hubert Curien of Strasbourg (IPHC), hereby represented by its Director, Dr. Rémi BARILLON regarding the assembly work for the internal tracker of the FOOT experiment over the 2020-2021 timeframe.

2. Scientific and technical context

The FOOT experiment of INFN is run by a collaboration of different INFN sites and other institutes, including IPHC. The scientific goals of the experiment concern the measurement of nuclear fragmentation cross sections to be used in applied physics contexts such as medical physics and space radioprotection.

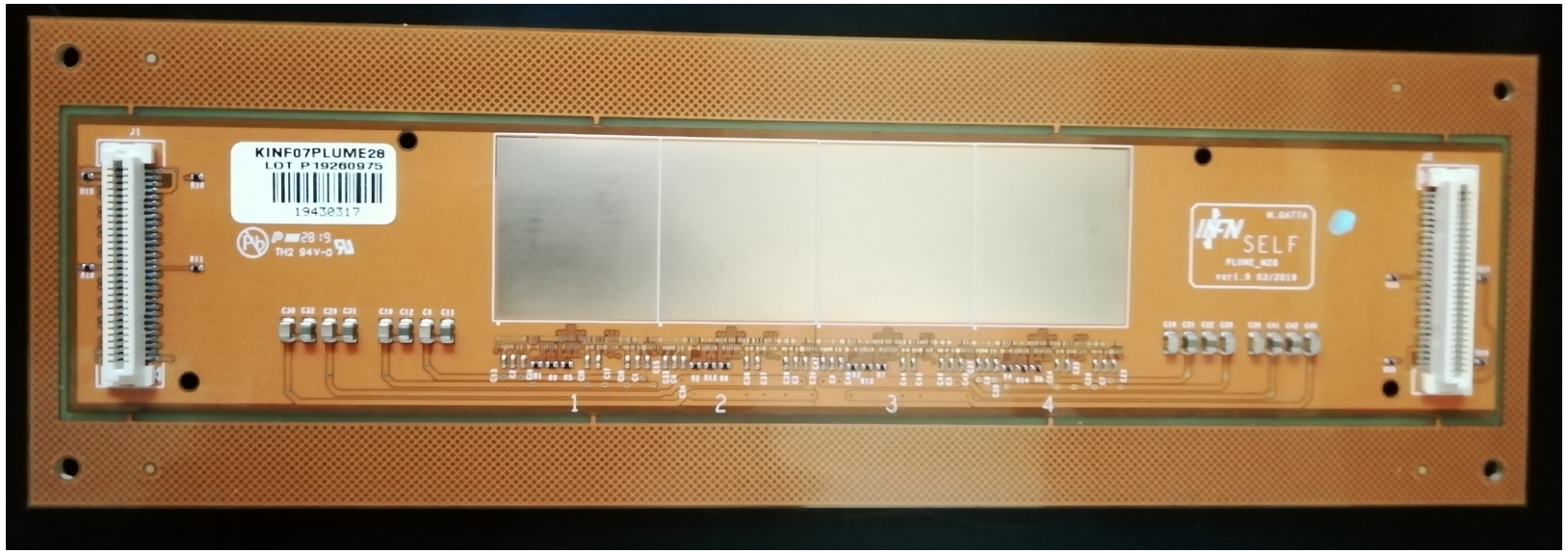
The apparatus currently under construction by the FOOT collaboration is a multi-detector, which includes a high precision inner tracker (ITR) made of 4 so-called detection *ladders*. Such ladders are built from the assembly of three main parts: CMOS pixel sensors, flex print cables and a spacer made of carbon-based foam.

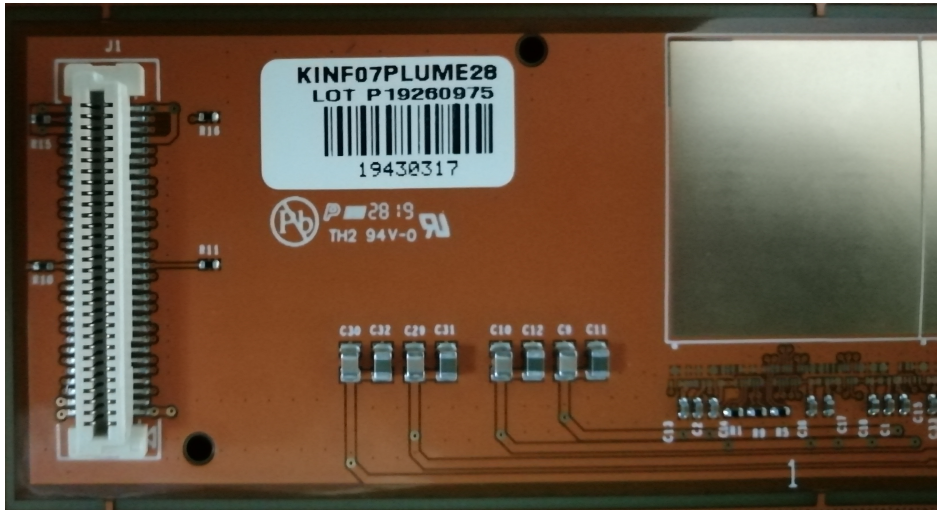
october 30, 2020 Final signature of MoU

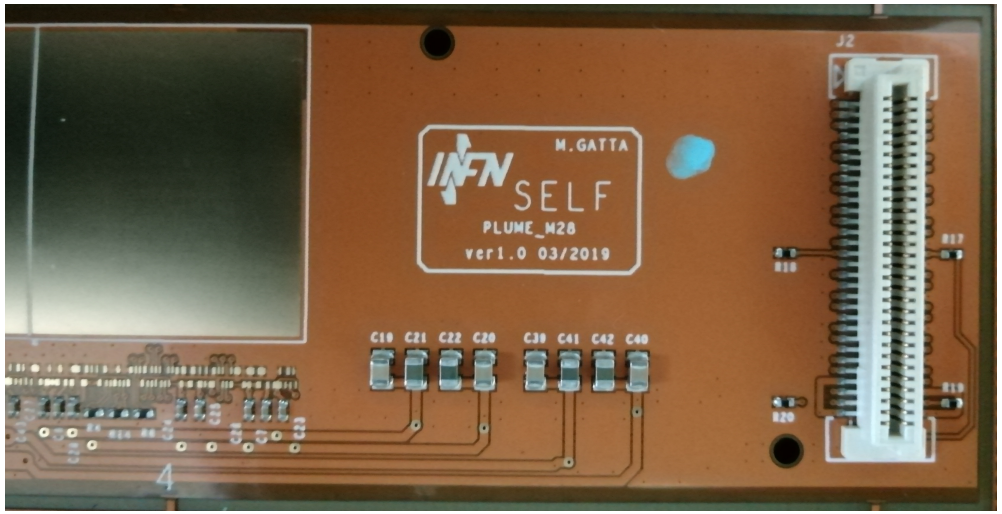
december 4, 2020 Inner Tracker assembly order issued

Inner Tracker (IT) status

The PlumeM28 first PCB prototypes

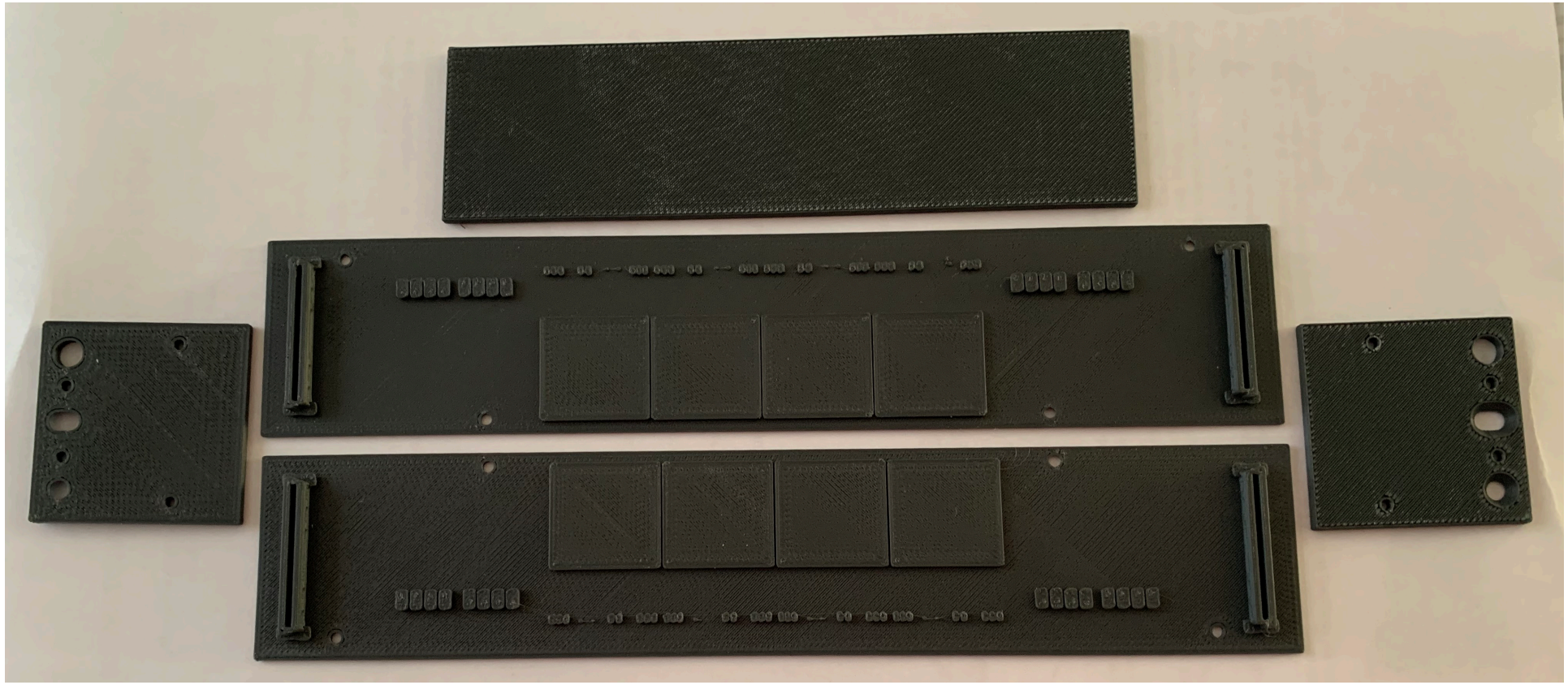






Inner Tracker (IT) status

3D pieces prototype for lab tests of assembly procedure

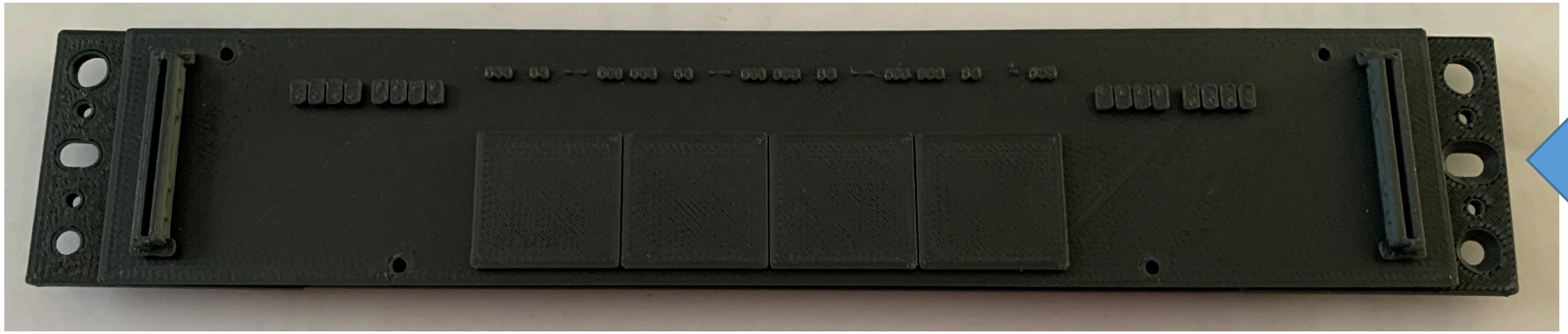


Inner Tracker (IT) status: Strasbourg activity

3D printed pieces

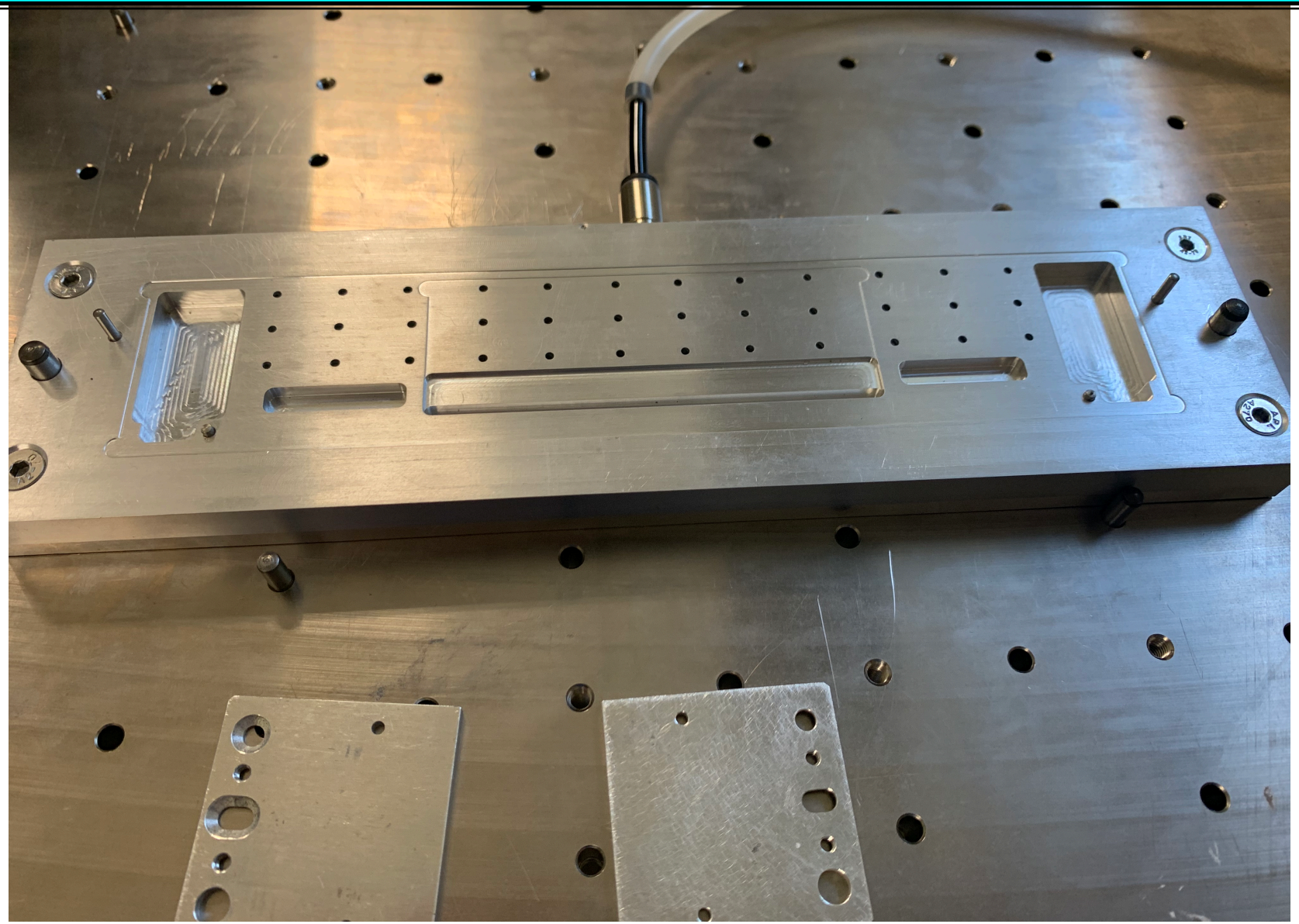
One module + 2 holders

One module + 2 holders + foam

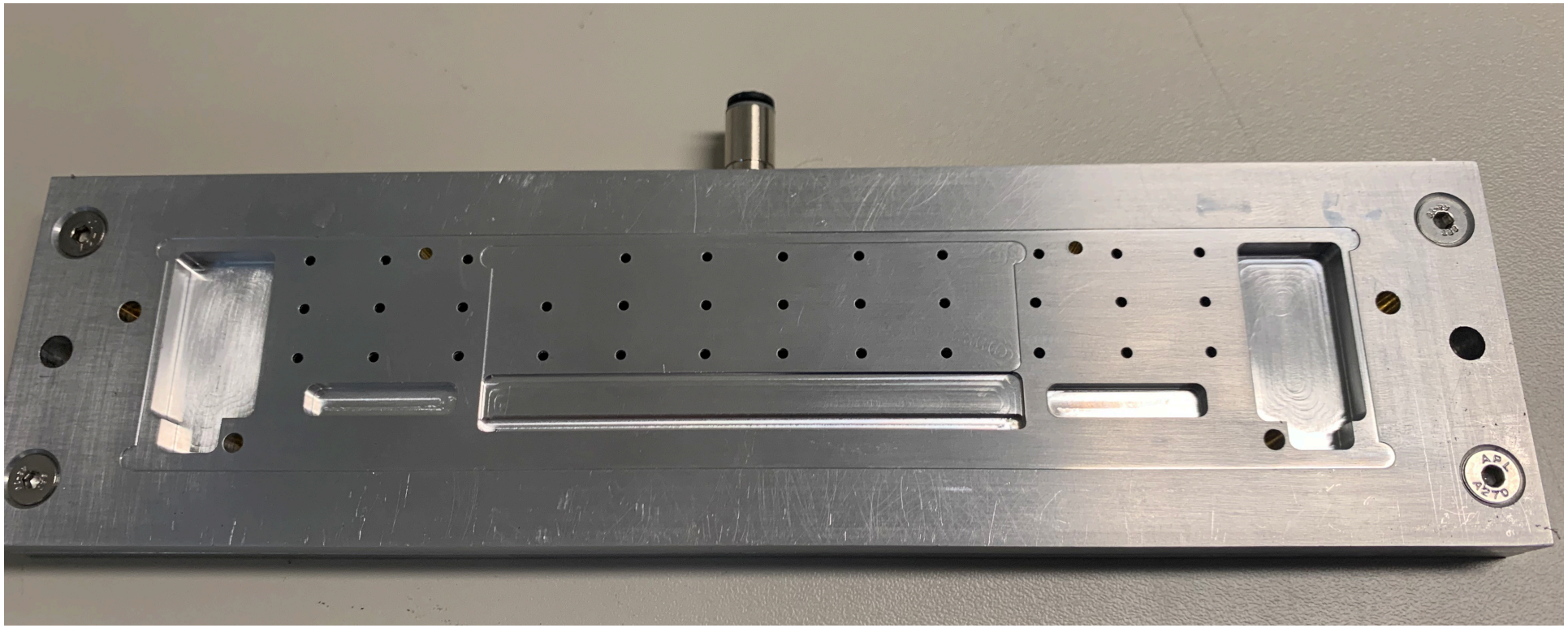


One module + 2 holders + foam + second module = one ladder

Inner Tracker (IT) final assembly jigs in Strasbourg



Inner Tracker (IT) final assembly jigs in Strasbourg



Inner Tracker (IT) list of needed components

Overall for the IT we need 3 different PCBs:

- **PlumeM28** (kapton PCB) to hold the sensors

  1 PlumeM28 holds 4 sensors and is definde a **module**. Two glued modules assembled with a RVC (**R**esistive **V**itreous **C**arbon foam) spacer thick 2mm forms a **Ladder**.
  The Inner Tracker is composed by 4 Ladders covering (acceptance) about 8x8 cm.

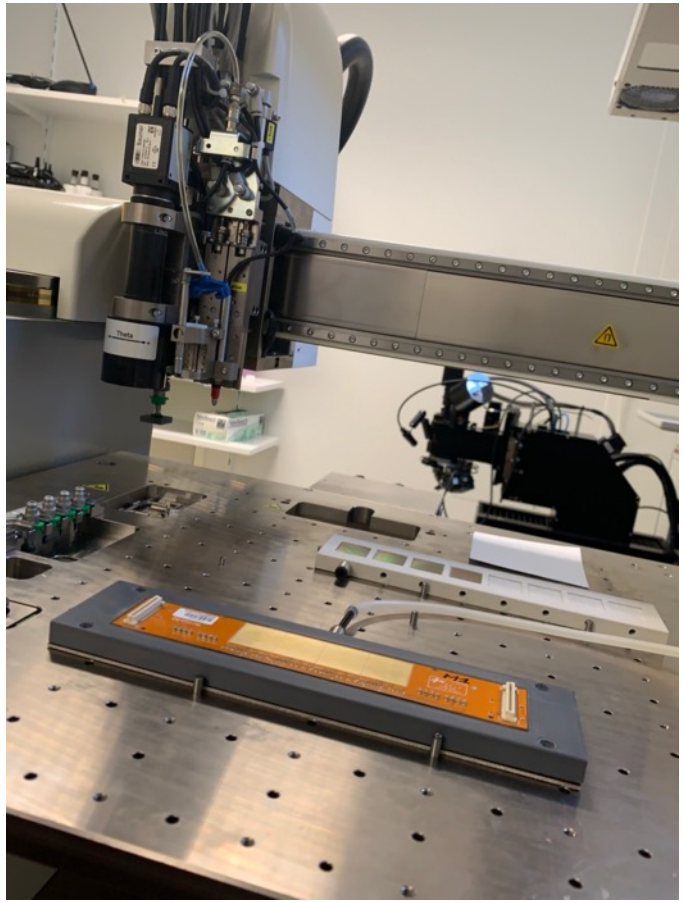
- **Adapter_PlumeM28** (Flex-Rigid PCB) to collect signals from 2 sensors (half of PlumeM28) on each side of a module and houses transcievers, monitors currents and voltages and includes “interlock” circuitry. Each adpapter_PlumeM28 is connected by a 68 wires flat cable to the subsequent CableAdapter_PlumeM28 board.

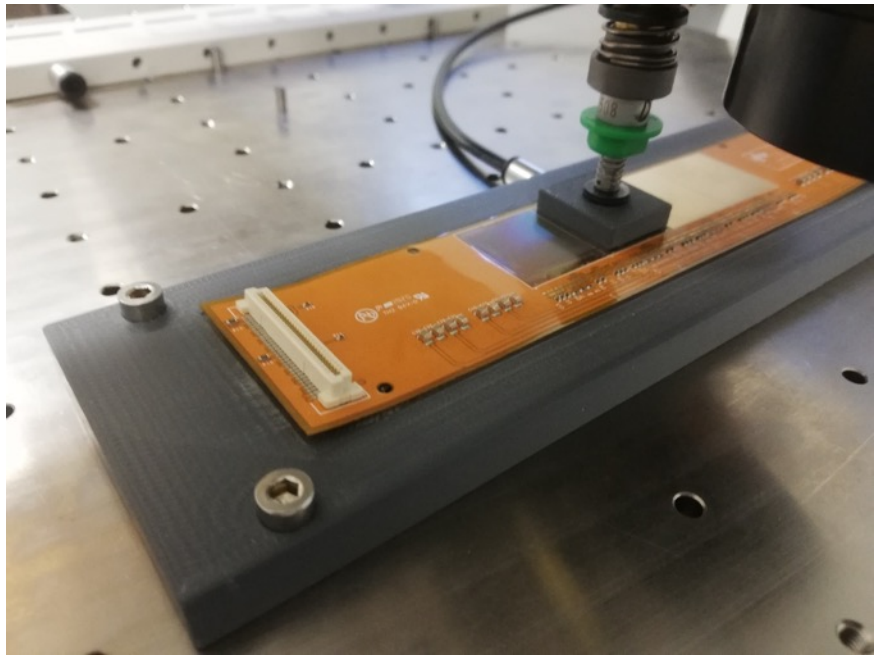
- **CableAdapter_PlumeM28** that translates all differential signals to single ended, provide the power supplies and master the Tigger, Busy, clocsk, etc… control signal.
  Two of this boards (we need 16 of this boards) are connectet to a **DE10_nano_SoC**

- **DE10-Nano-SoC from Terasic** each of the 8 needed reads 4 M28 sensors from 2 different PlumeM28 ladders. Sends data via one Gigabit link to the intermediate PC.

Inner Tracker ladder assembly in Strasbourg

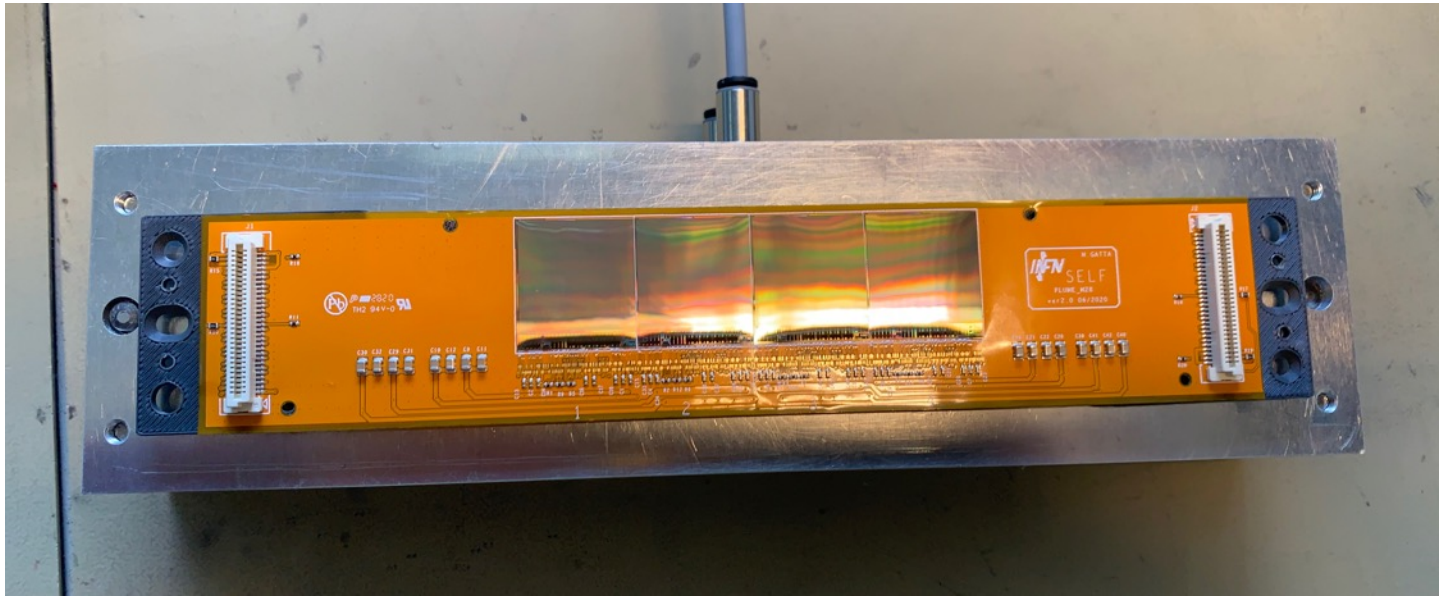
sensors (M28) placement

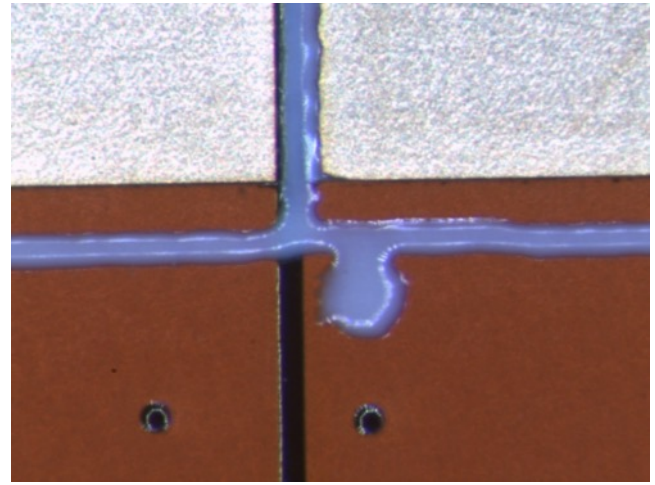




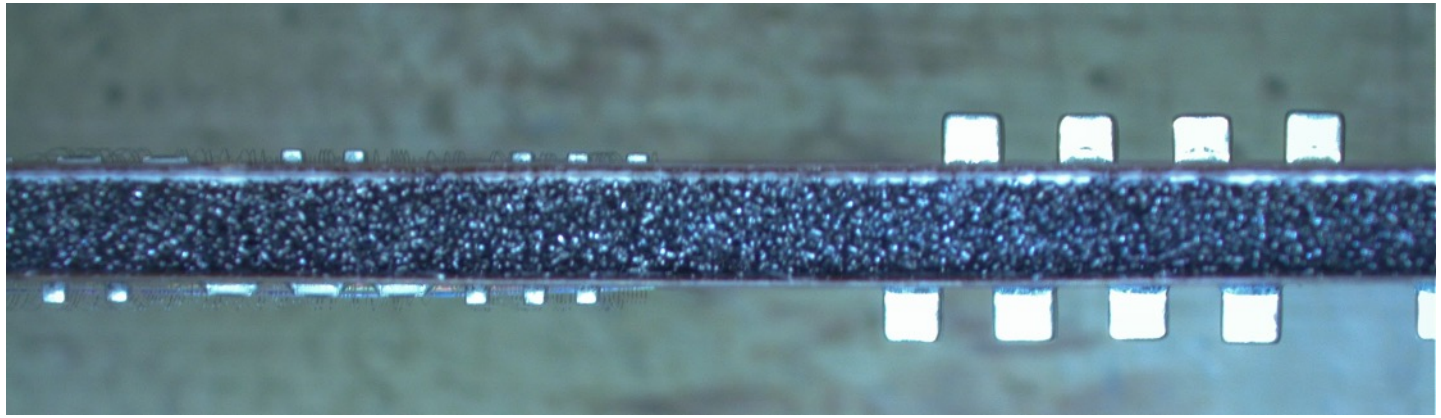
Inner Tracker ladder assembly in Strasbourg

sensors (M28) placement and gluing



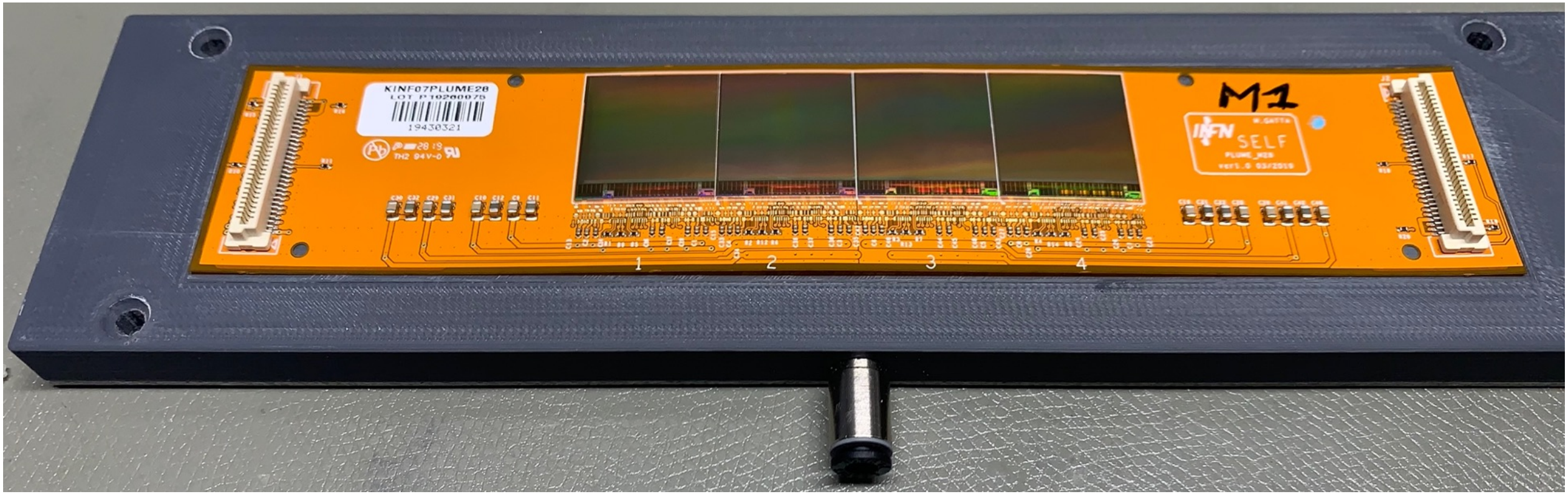


Dummy modules
Dummy stave
March 2021



Inner Tracker ladder assembly in Strasbourg

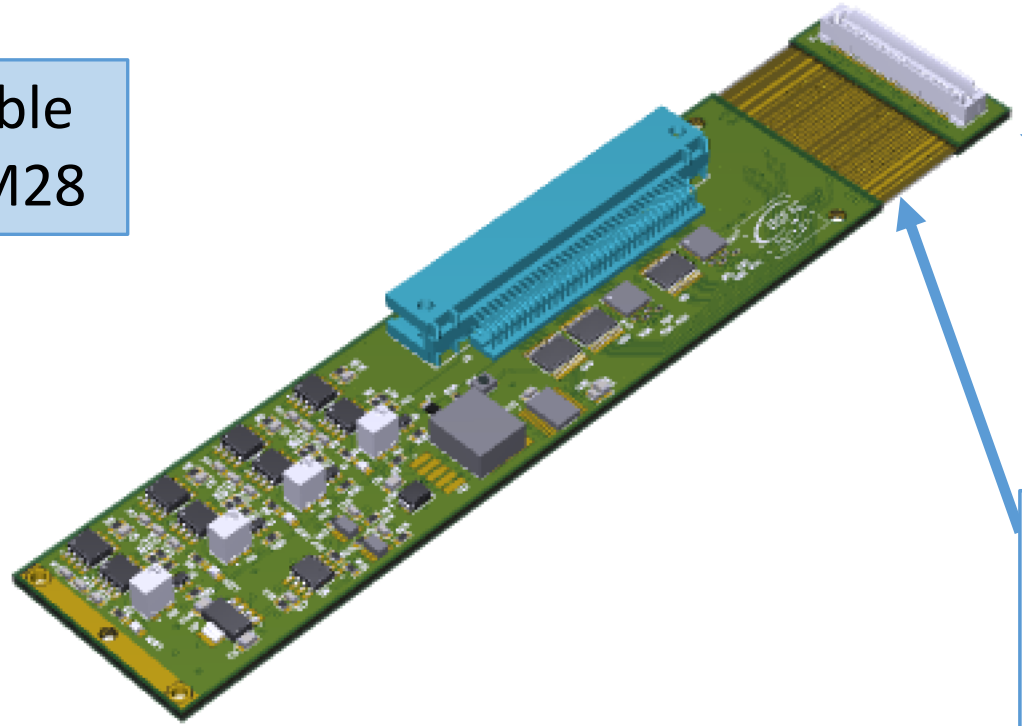
First real module produced



Inner Tracker (IT) status

The Adapter_PlumeM28 (produced only 4 prototypes)

Output 68 pins for flat cable to CableAdapter_PlumeM28

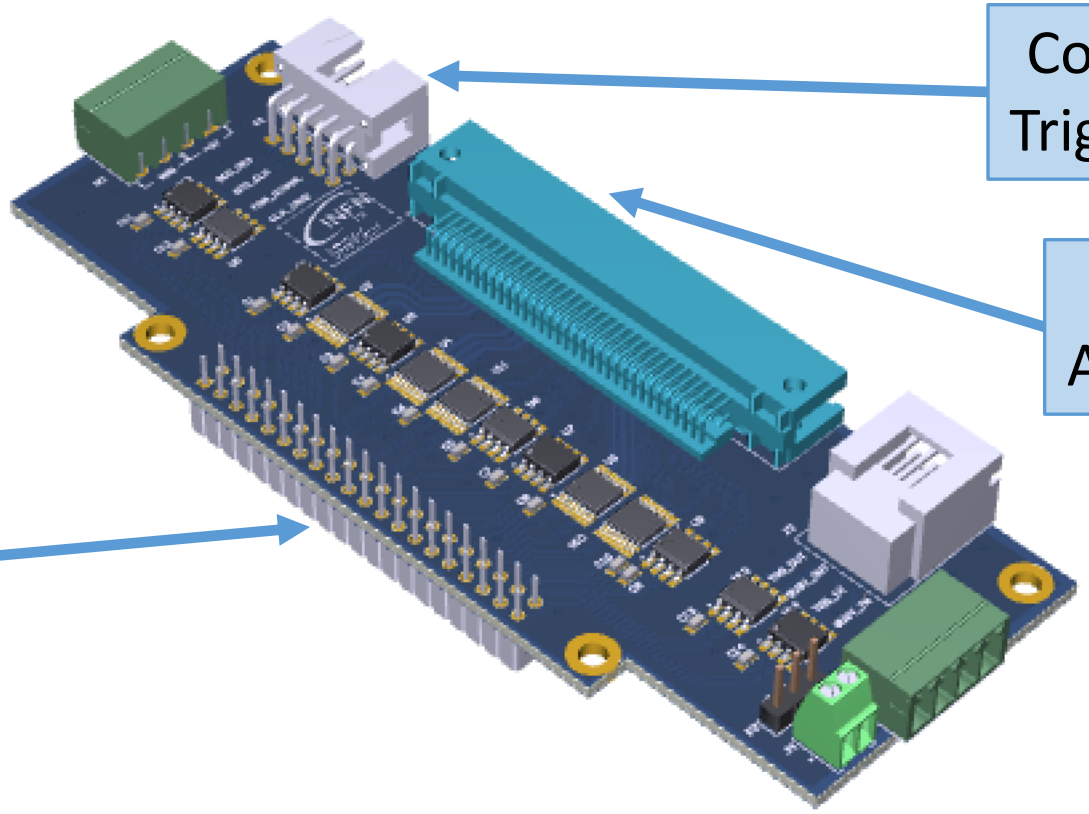


Connector to PlumeM28 side A/B

Kapton cable to mechanical Decouple the PlumeM28 to the Adapter

Inner Tracker (IT) status

The CableAdapter_PlumeM28 (all produced)



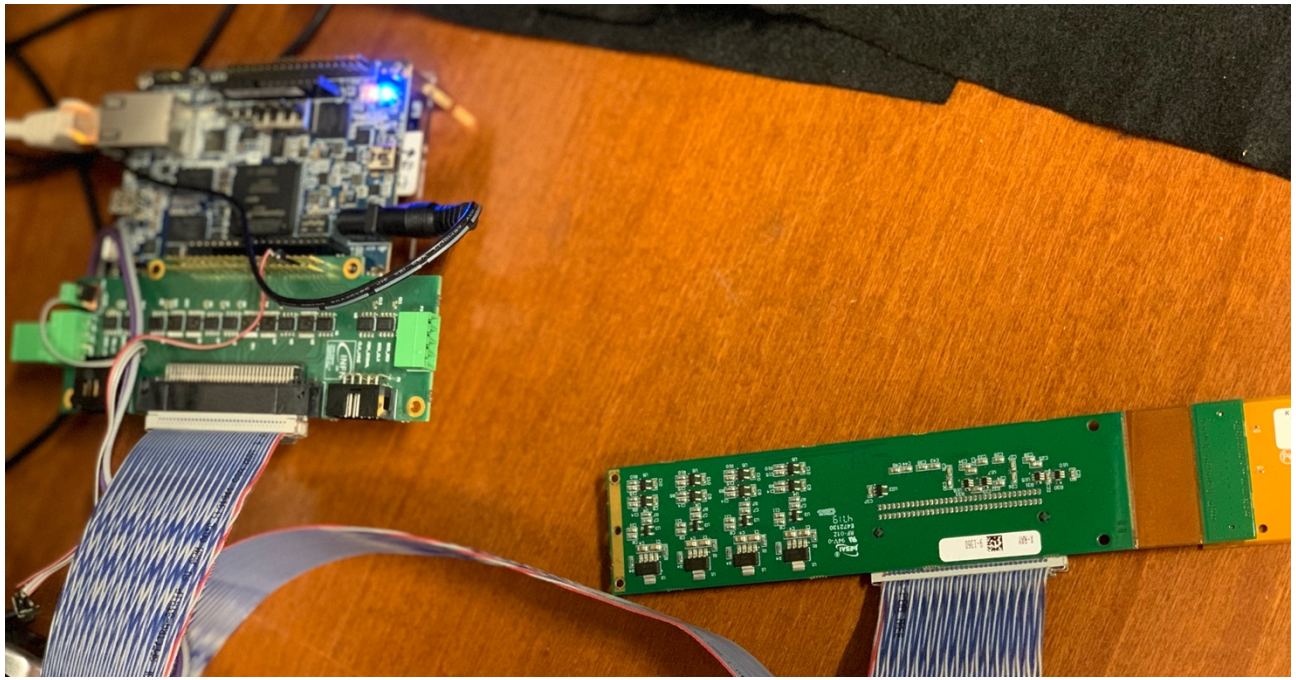
Connector to Trigger system

Connector to Adapter_PlumeM28

Connector to DE0nano_SoC

Inner Tracker (IT) ladder test system

(provided to Strabourg group for ladder production testing)



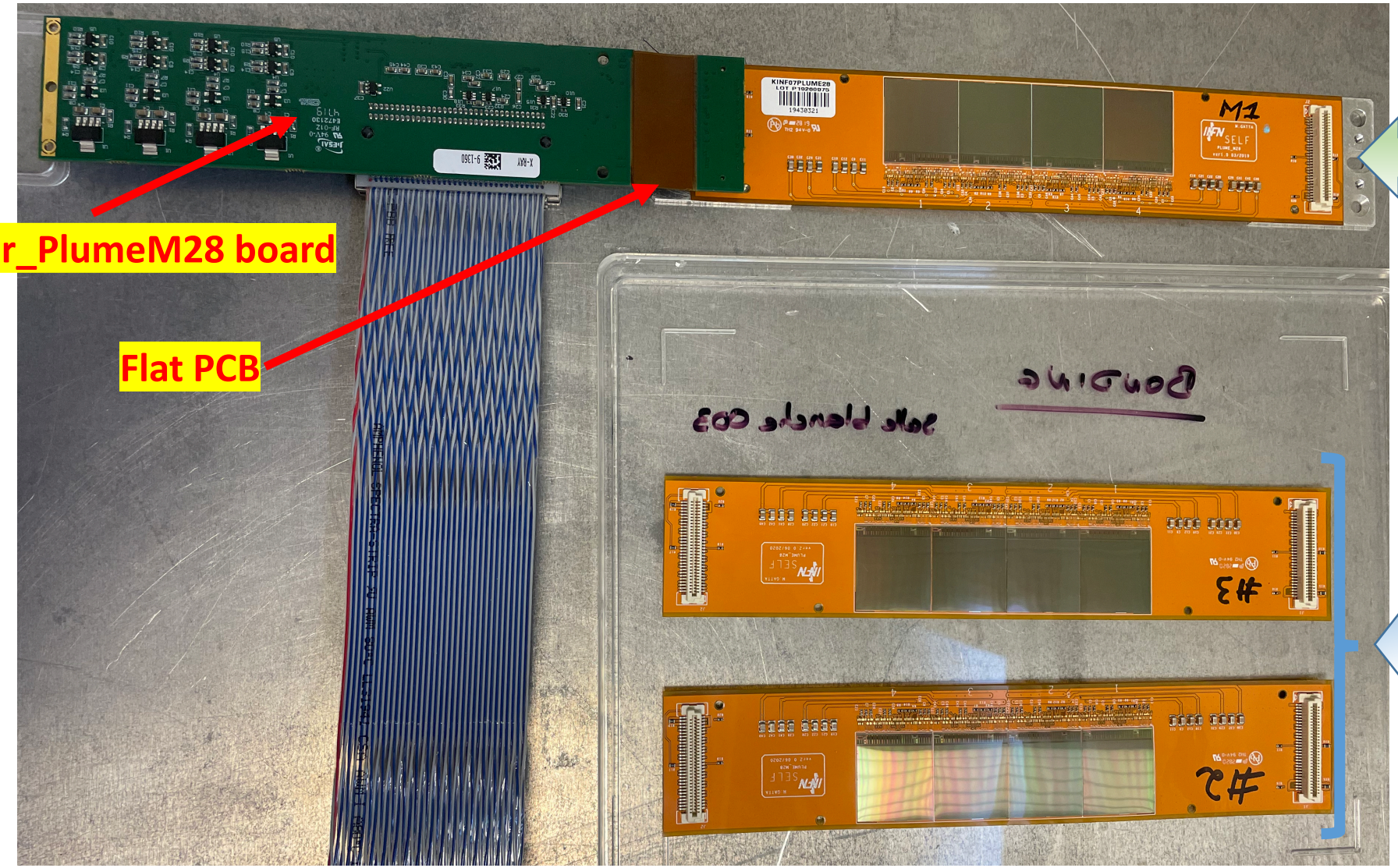
The testing system we used is composed by three different pieces:

- The Terasic DE0 nano board.
- The CableAdapter_plume M28 connected to one of the GPIO connector of the Terasic board.
- The Adapter_PlumeM28 board connected to one of the two 60 pin connectors housing each the signals of 2 M28 sensors.

Test of module 0 in Frascati

Long and deep testing discovered a wrong bonding that prevented the module full functionality.

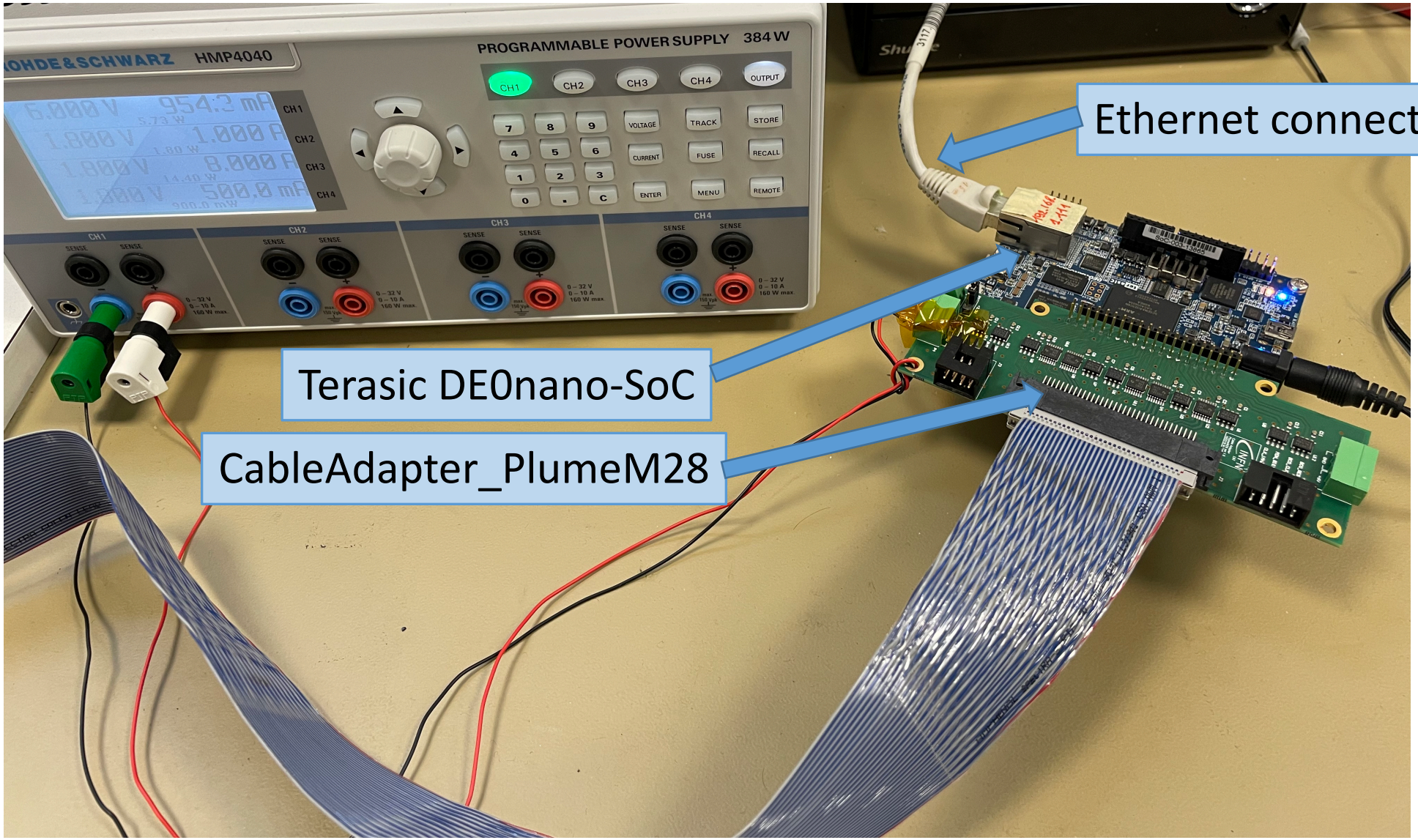
Inner Tracker (IT) status (pictures from Strasbourg)



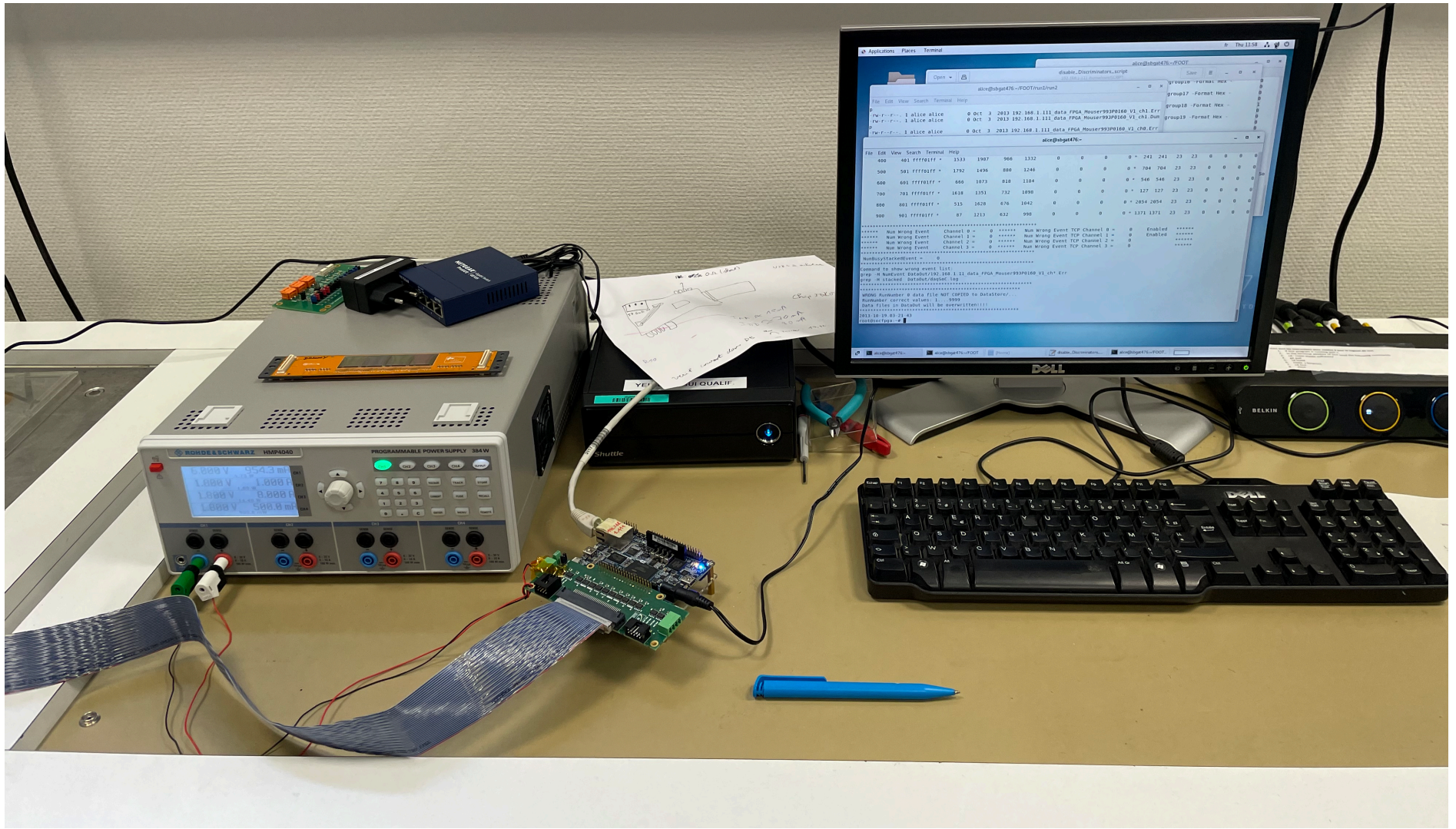
First module assembled
(used for test system qualification in Frascati.
Now back in Strasbourg)

Two new modules ready to be qualified (tested) before first ladder assembly.

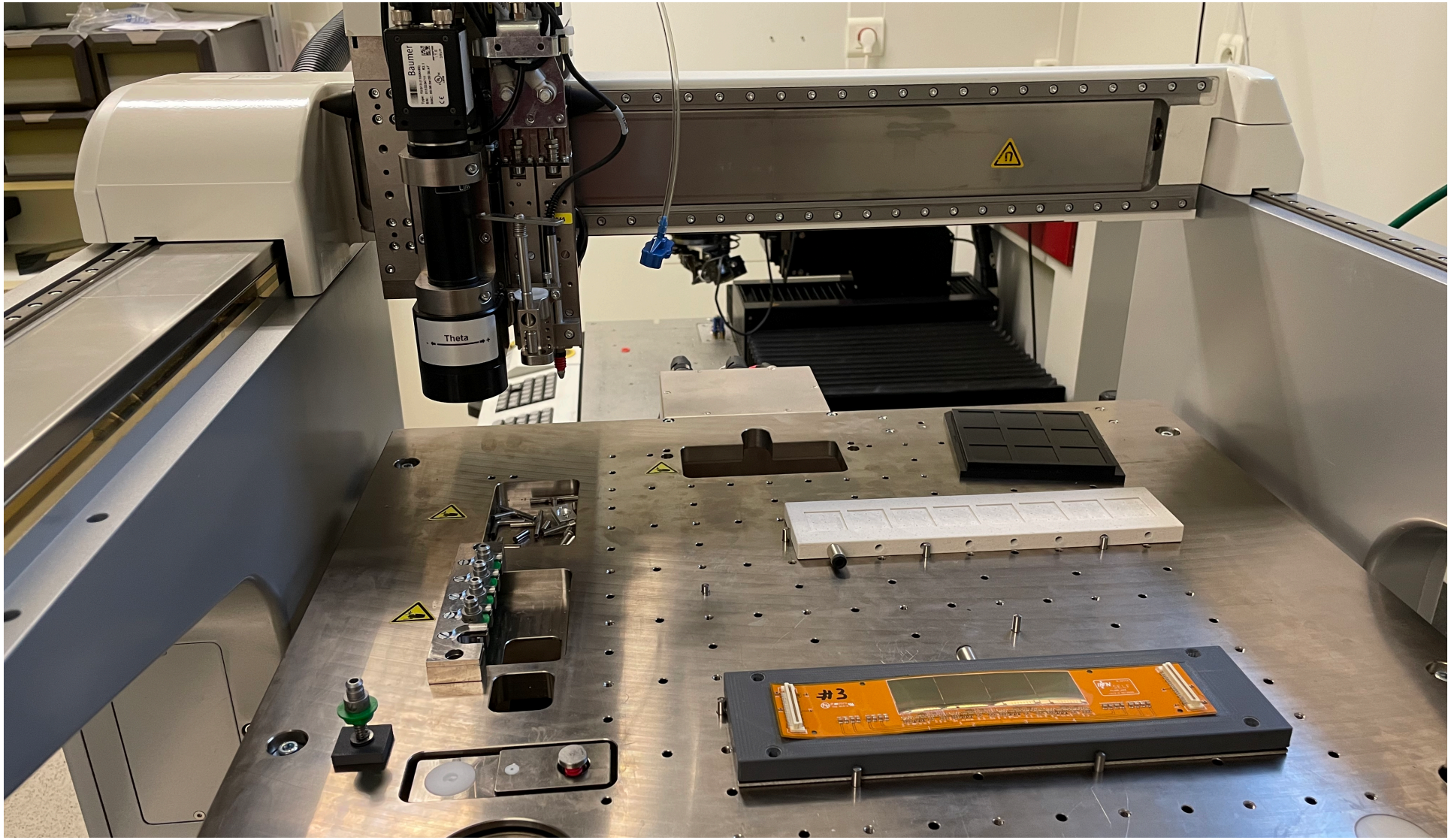
Inner Tracker (IT) status (pictures from Strasbourg)



Inner Tracker (IT) status (pictures from Strasbourg)



Inner Tracker (IT) status (pictures from Strasbourg)

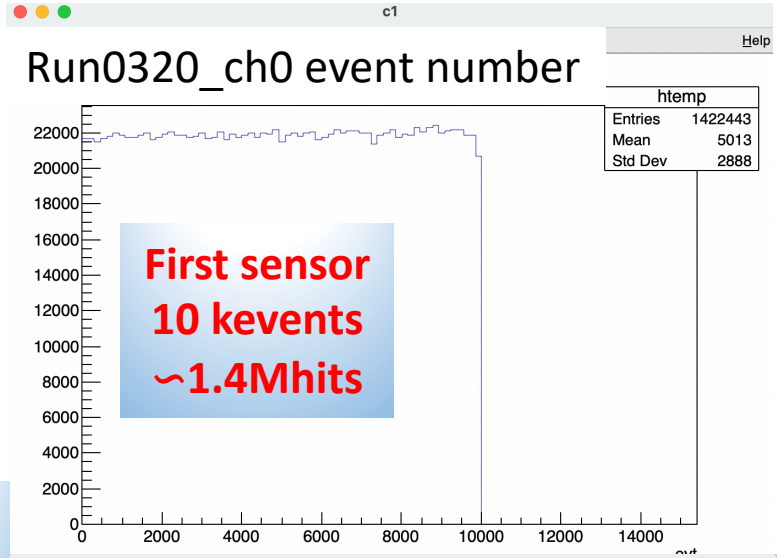


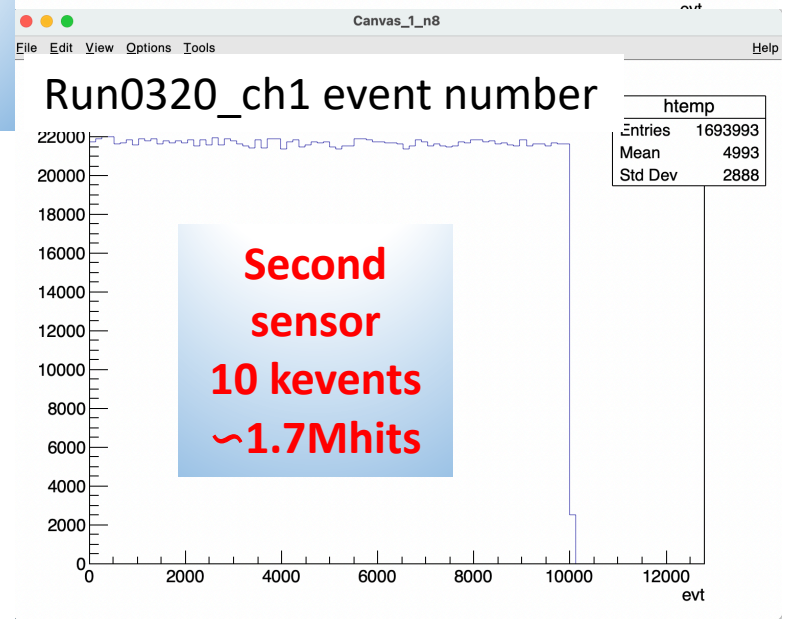
Inner Tracker (IT) status (test preliminary results)

```
[espiriti@sbgli2 ~/data]$ ll
totale 32
-rw-r--r--. 1 espiriti uetiimm  369 26 nov 12.20 README.txt
drwxr-xr-x. 2 espiriti uetiimm 4096 26 nov 12.20 run0011
drwxr-xr-x. 2 espiriti uetiimm 4096 26 nov 12.19 run0012
drwxr-xr-x. 2 espiriti uetiimm 4096 26 nov 12.20 run0021
drwxr-xr-x. 2 espiriti uetiimm 4096 26 nov 12.19 run0022
drwxr-xr-x. 2 espiriti uetiimm 4096 26 nov 12.20 run0031
drwxr-xr-x. 2 espiriti uetiimm 4096 26 nov 12.20 run0032
drwxr-xr-x. 2 espiriti uetiimm 4096 26 nov 12.20 run0320
[espiriti@sbgli2 ~/data]$ cat README.txt
Record of RUNs

* Module 1
 run0011 sideA, 10k evts, no source, no mask
 run0012 sideB, 10k evts, no source, no mask

* Module 1
 run0021 sideA, 10k evts, no source, no mask
 run0022 sideB, 10k evts, no source, no mask

* Module 3
 run0031 sideA, 10k evts, no source, no mask
 run0032 sideB, 10k evts, no source, no mask
 run0320 sideB, ? evts, beta source, no mask

[espiriti@sbgli2 ~/data]$
```

Iron 55 radioactive source

Data shown in the following

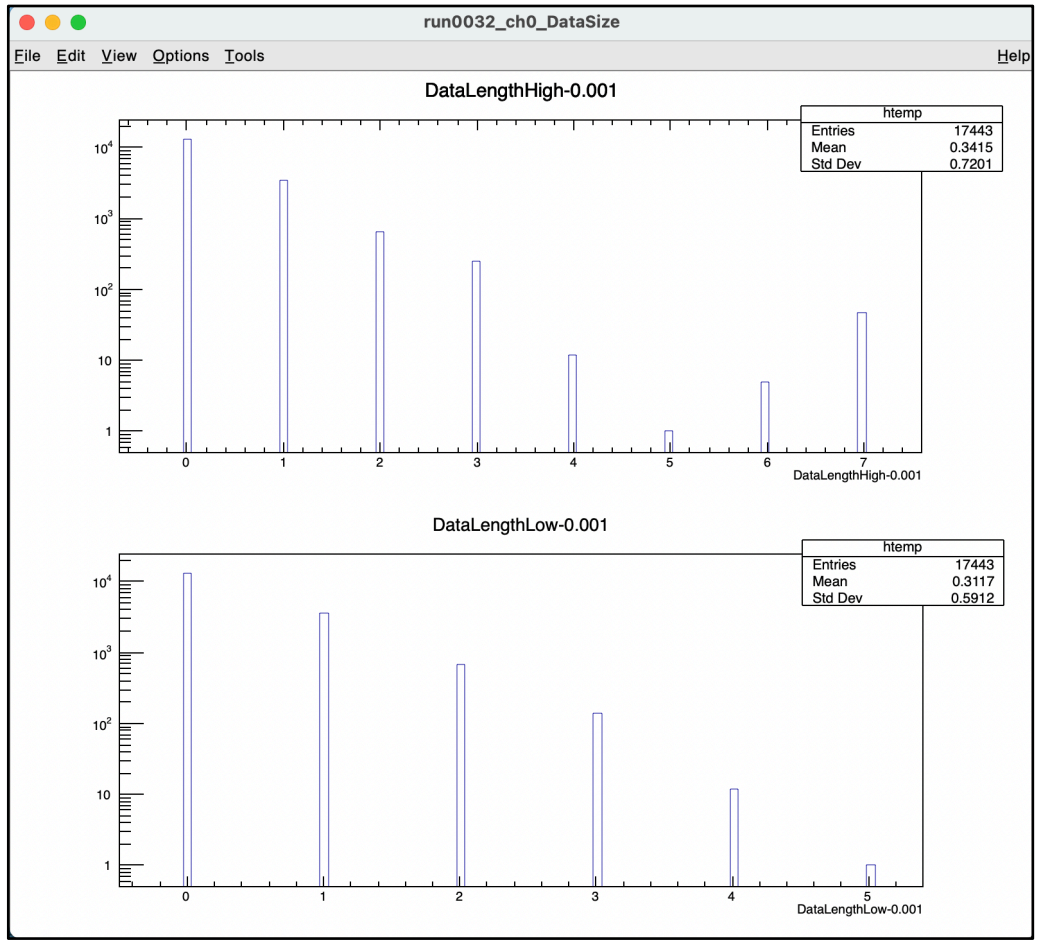




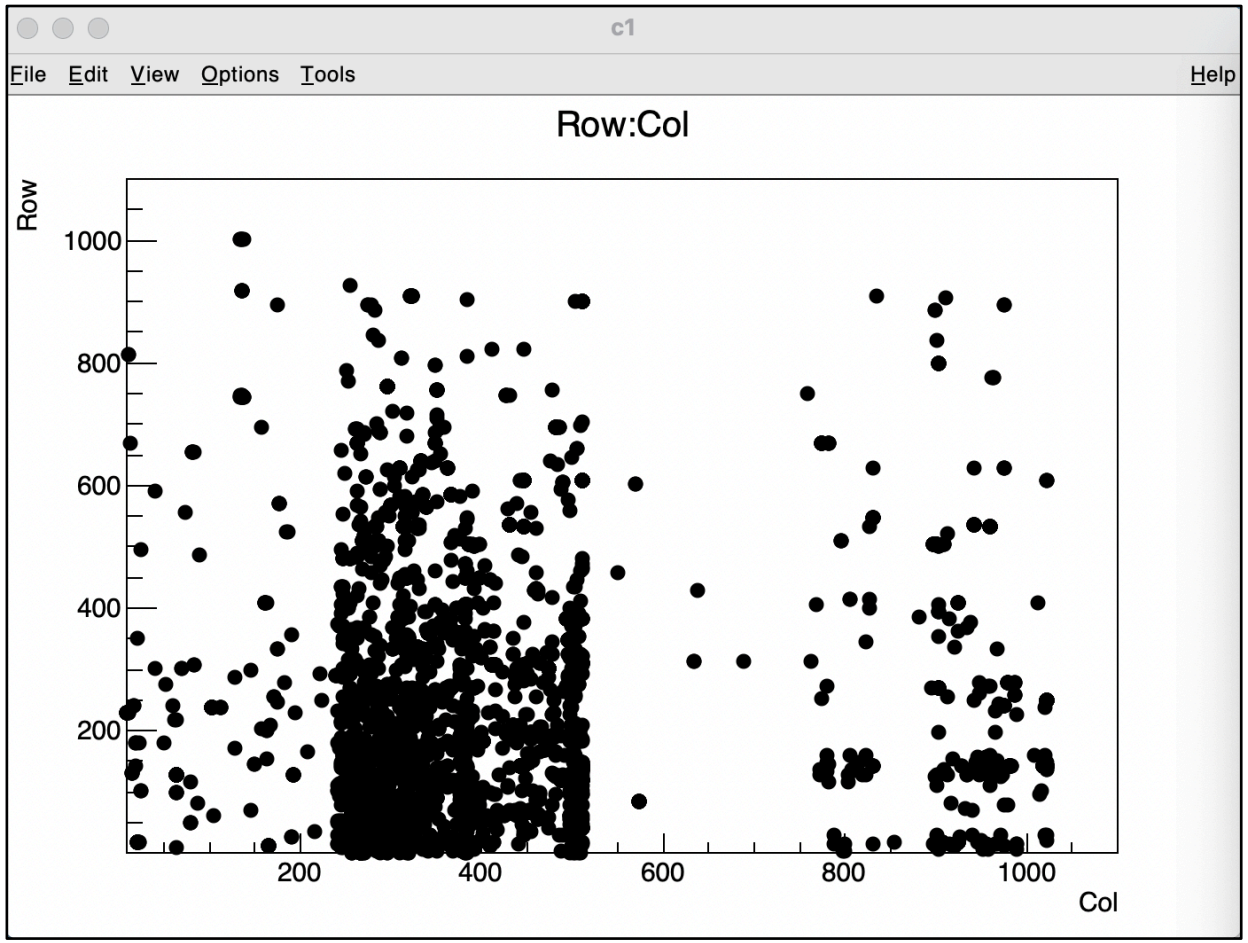
Inner Tracker (IT) status (test preliminary results)

«Pedestal» run (run0032) first sensor

Data size (num. of long words)



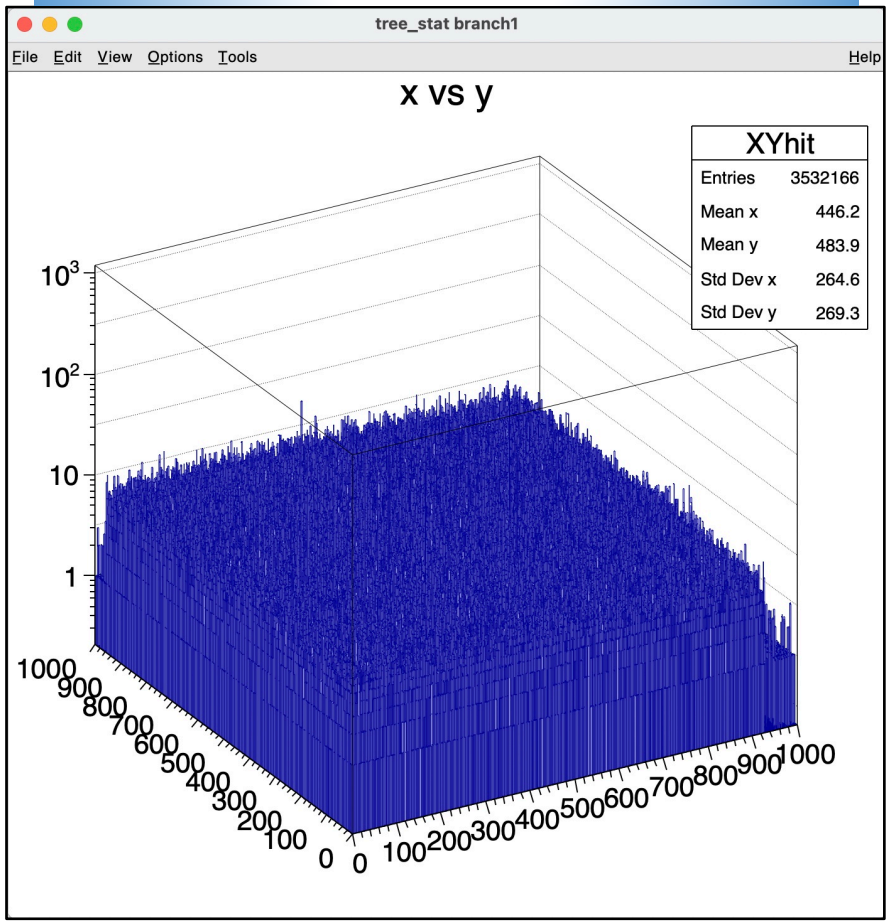
Hit map. Clear thresholds (4 regions) non-uniformity



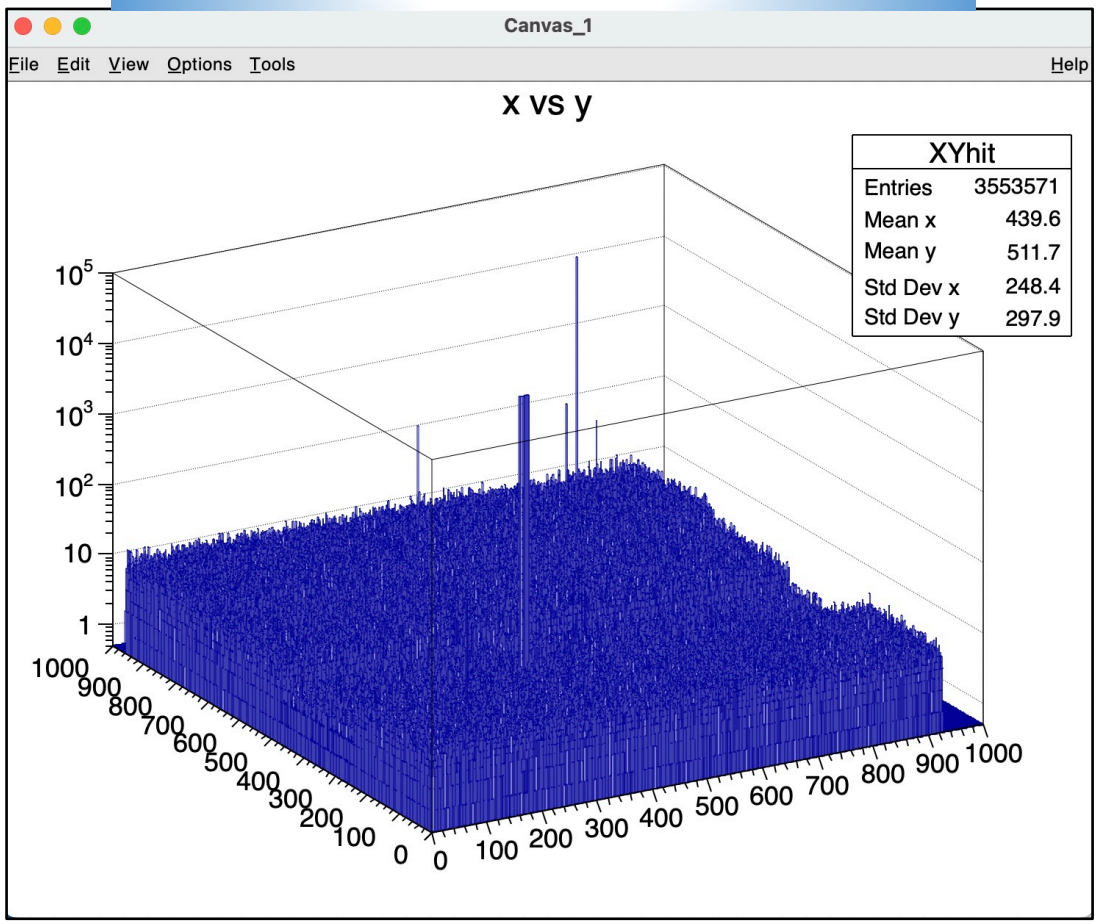
Inner Tracker (IT) status (test preliminary results)

Iron 55 radioactive source run hit maps (run0320)

First sensor - 10 kevents - ∽3.5 Mhits



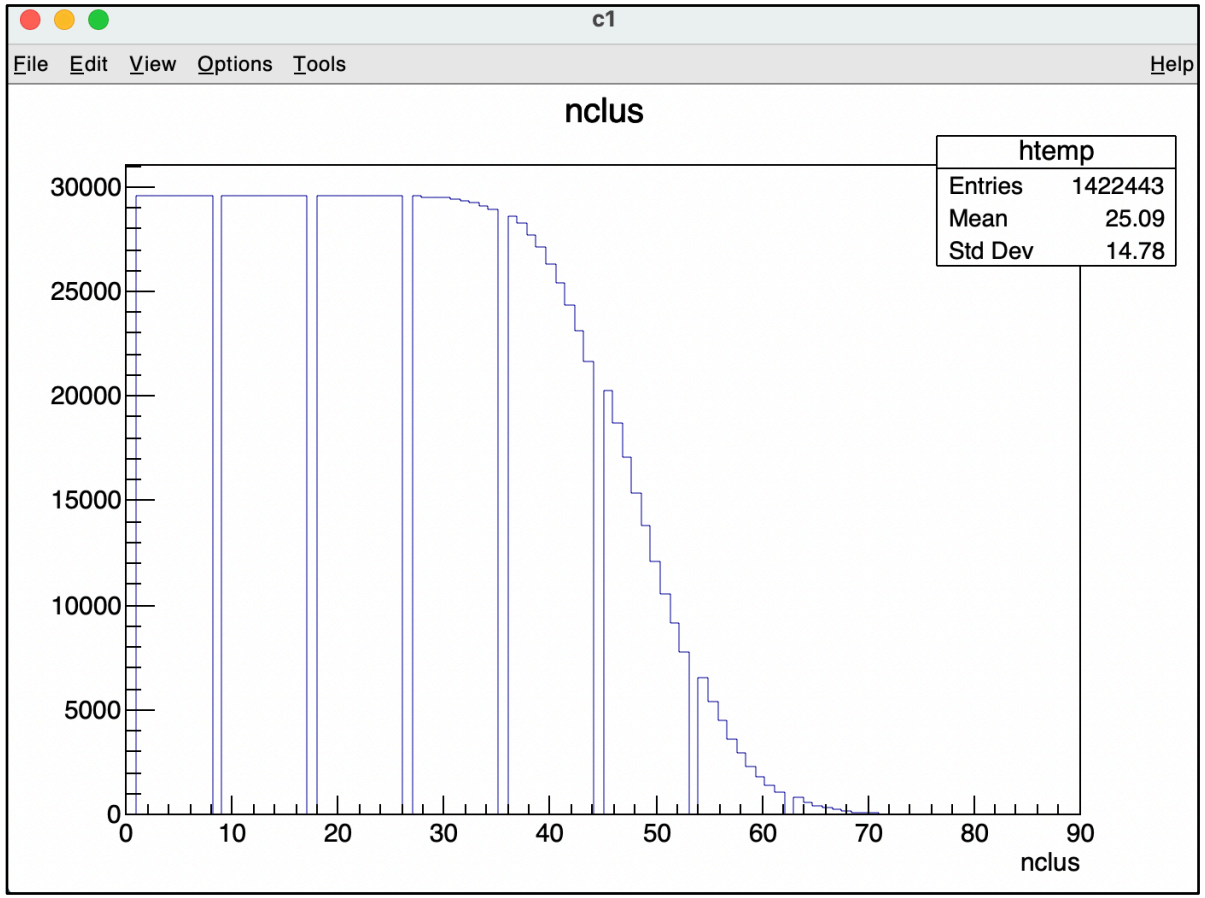
Second sensor - 10 kevents - ∽3.5 Mhits



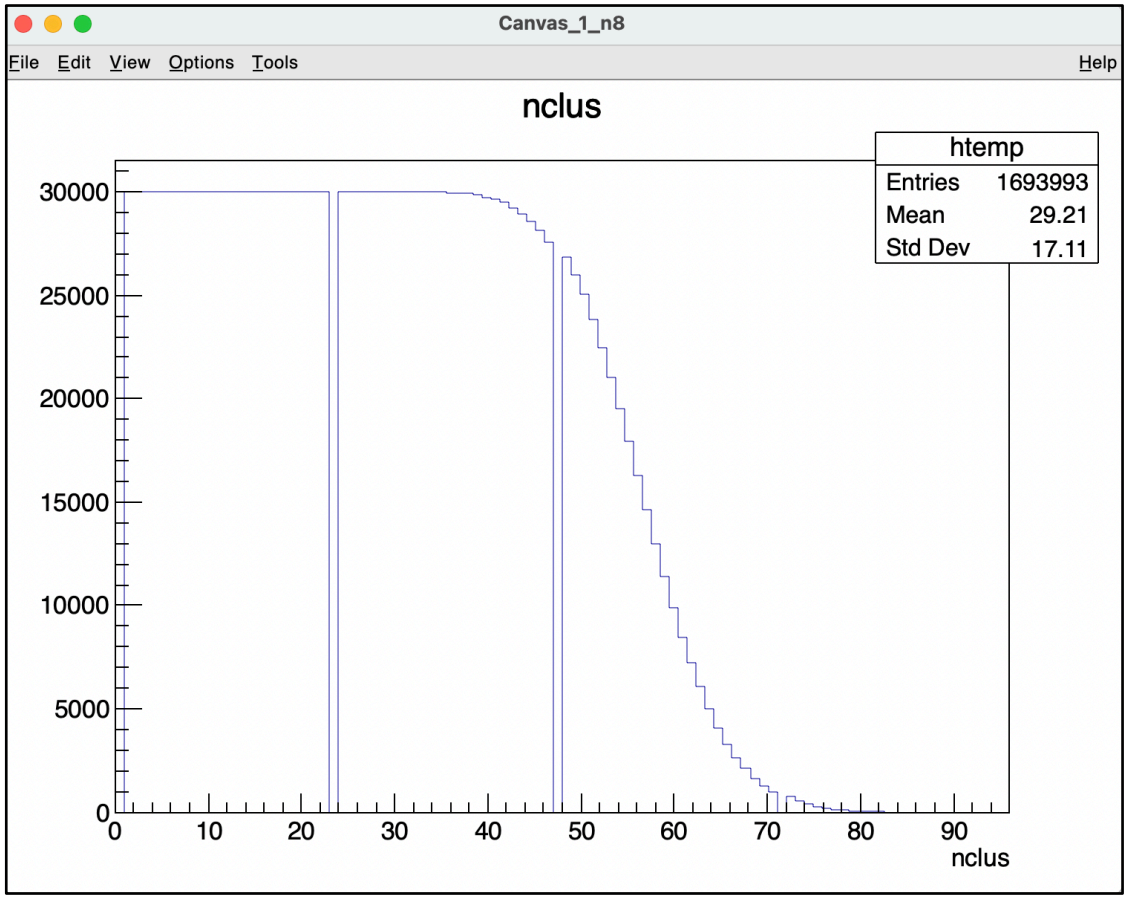
Inner Tracker (IT) status (test preliminary results)

Iron 55 radioactive source run (run0320) – cluster number per event

First sensor - 10 kevents - ∽1.4 Mcluster



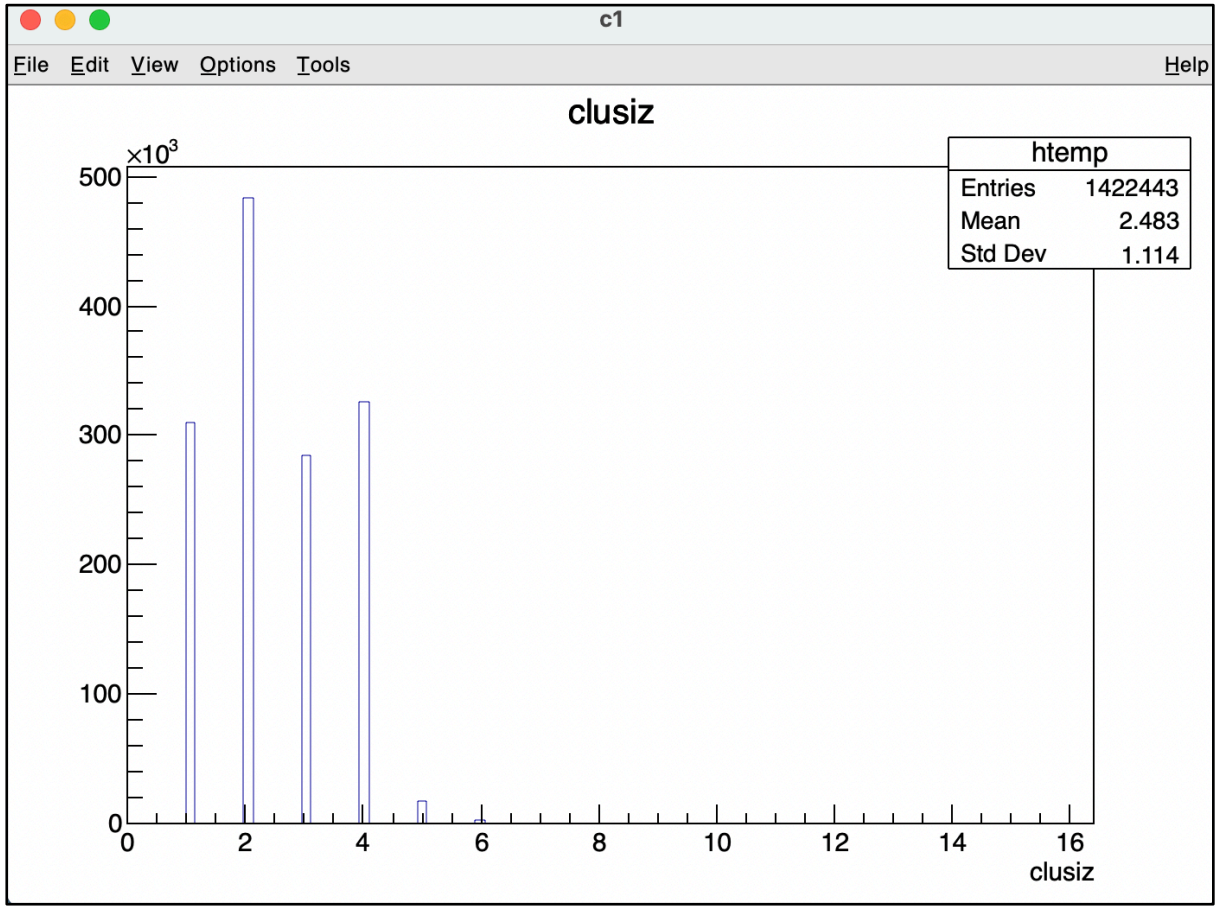
Second sensor - 10 kevents - ∽1.7 Mcluster



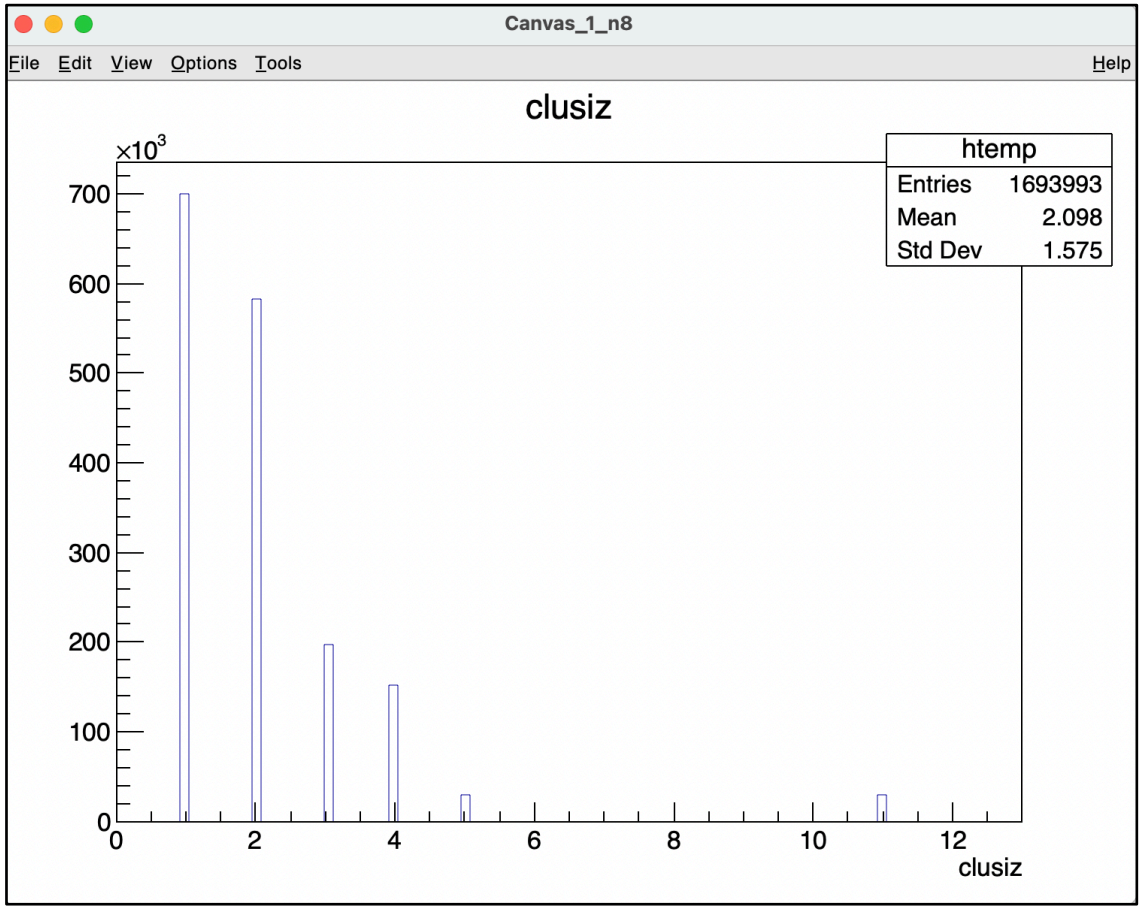
Inner Tracker (IT) status (test preliminary results)

Iron 55 radioactive source run (run0320) – cluster size per event

First sensor - 10 kevents - ∽2.48 hits/cluster

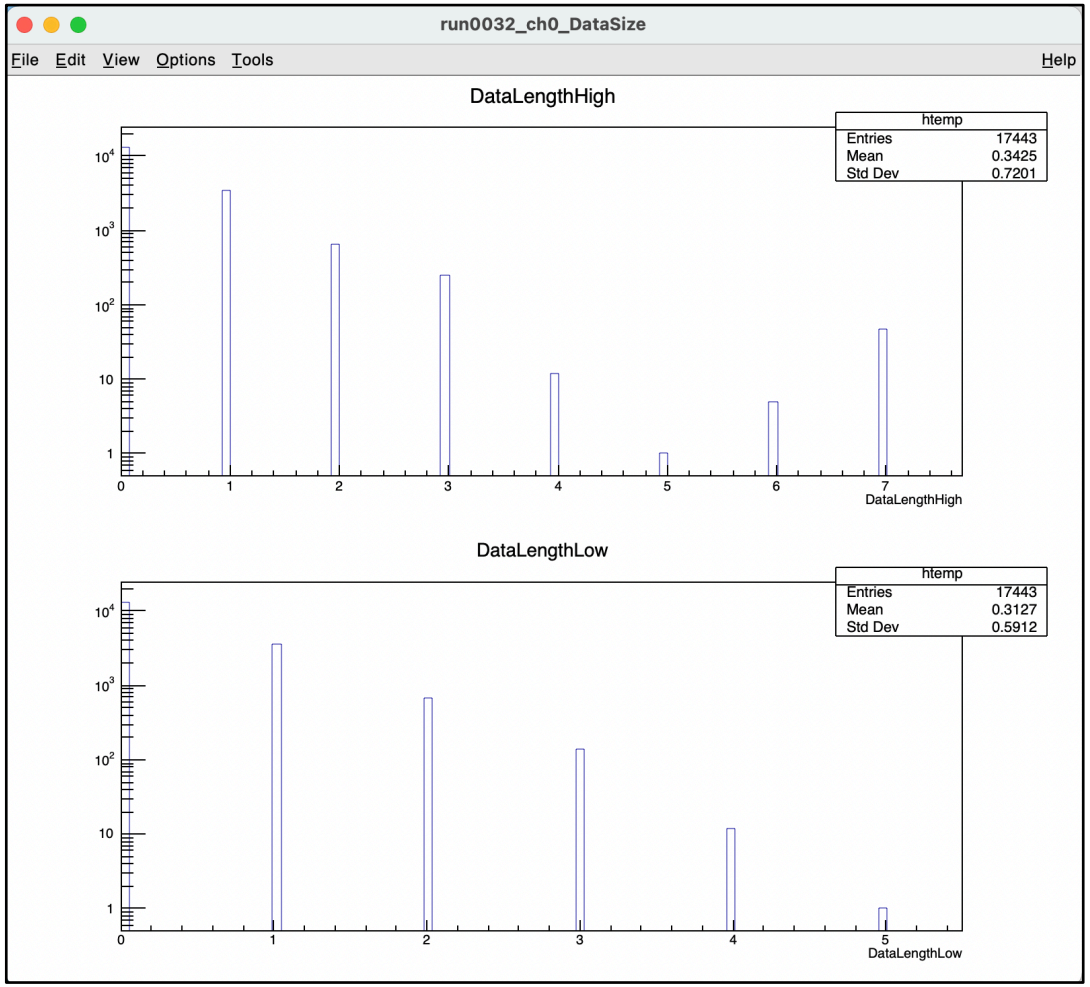


Second sensor - 10 kevents - ∽2.10 hits/cluster

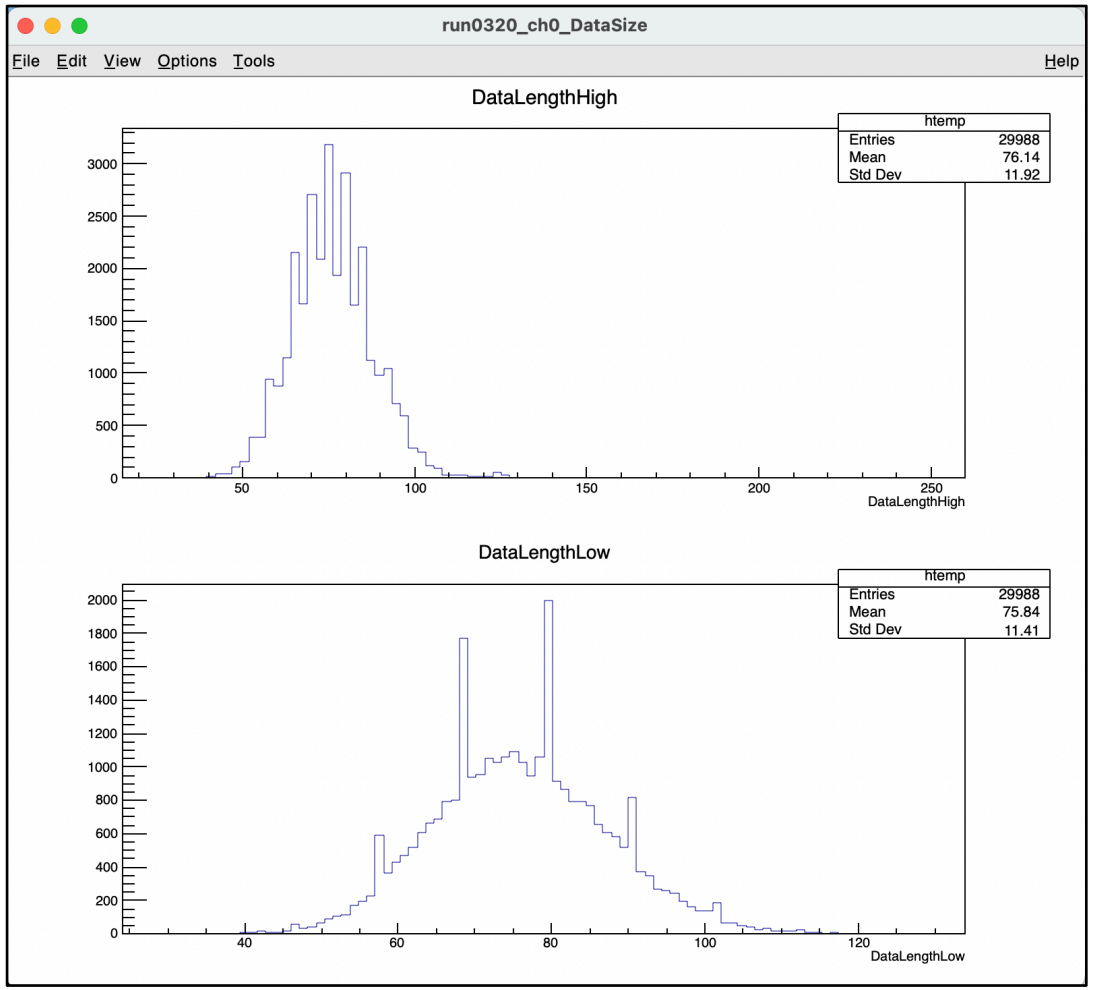


Inner Tracker (IT) status (test preliminary results)

«Ped» run, NO source (run0032)
First sensor – data size- ∽0.3 long word/event

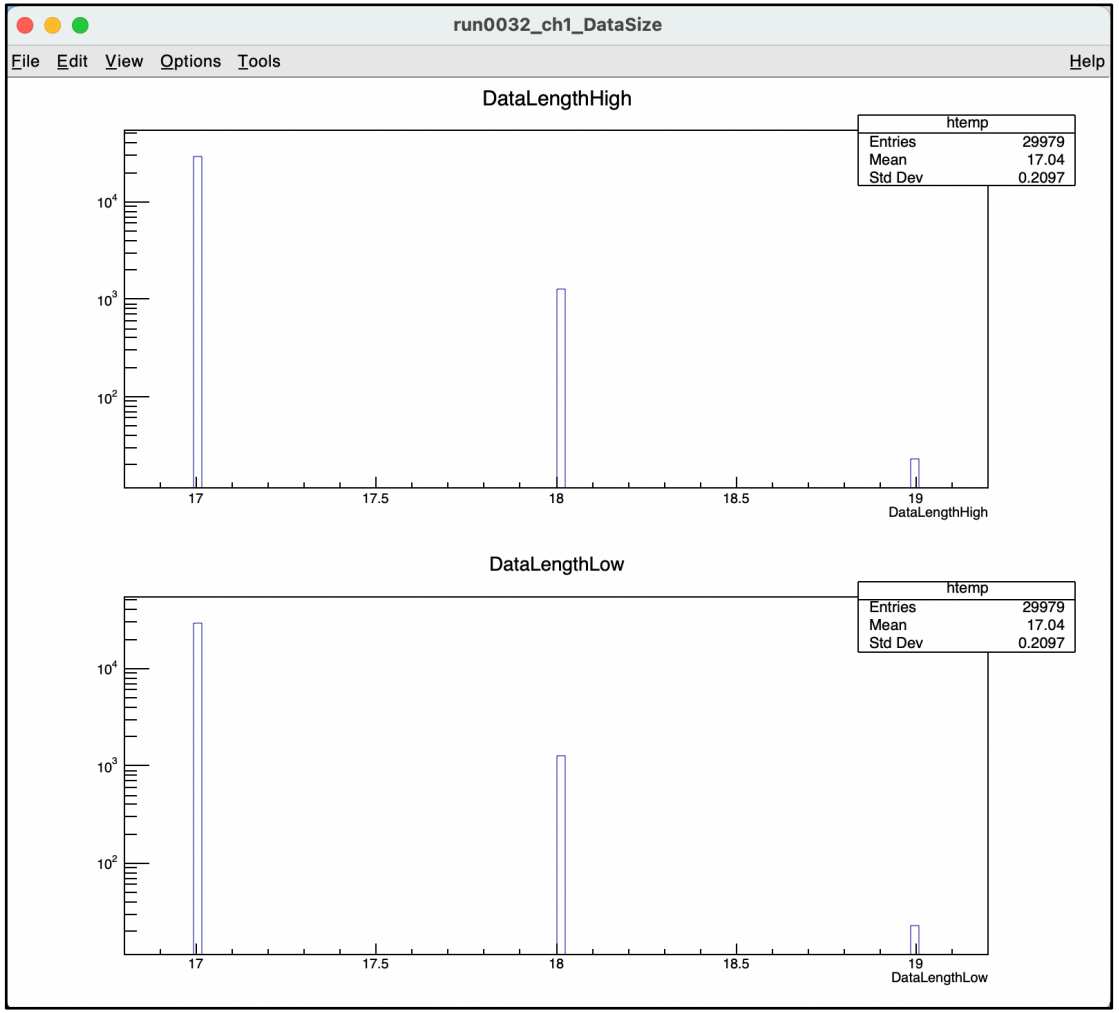


Iron 55 radioactive source (run0320)
First sensor – data size- ∽90 long word/event

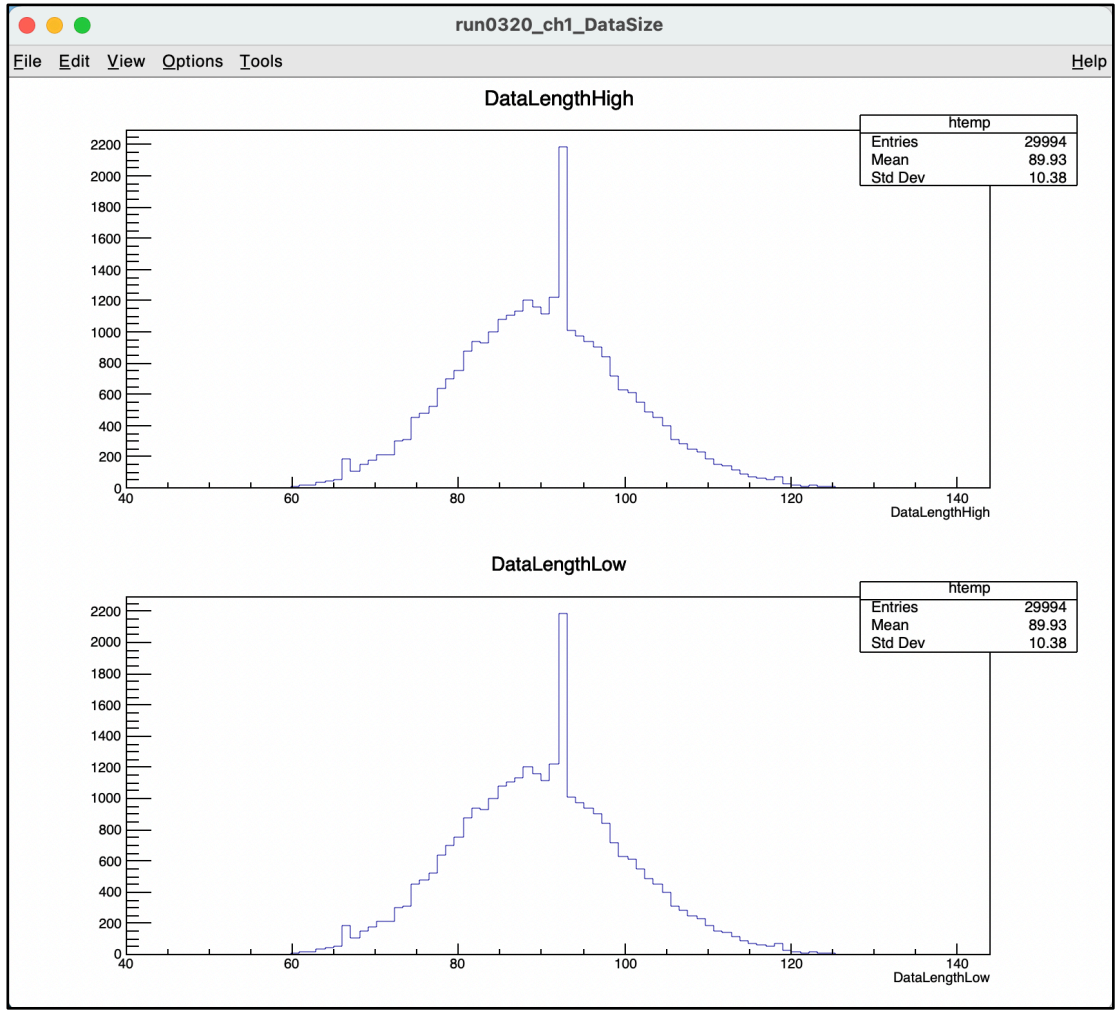


Inner Tracker (IT) status (test preliminary results)

«Ped» run, NO source (run0032)
Second sensor – data size- ∽17 long word/event



Iron 55 radioactive source (run0320)
Second sensor – data size- ∽90 long word/event



Conclusions

FOOT tracker mechanical setup:

- Final mechanical design
- Funds available 2022
- Order will be issued january 2022

Magnet system:

- Delivery foreseen beginning february 2022

Pixel vertex detector:

- Used at GSI (collected 40 Mevents)
- Slow control firmware under development

Inner Tracker:

- Plume ladder assembly process definition concluded in Strasbourg
- All production tools available
- **First module tested at LNF, wrong bonding discovered (bonding plan modified)**
- Missing Adapter_PlumeM28 boards production started beginning november 2021
- Two more module assembled in Strasbourg
- Modules testing system (finale readout chain) qualified and available in Strasbourg
- Inner tracker fanout board firmware to be written (hardware available)