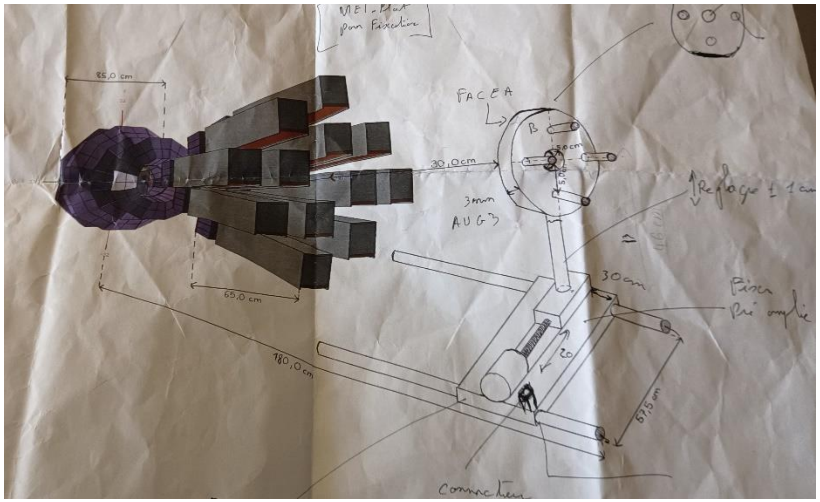
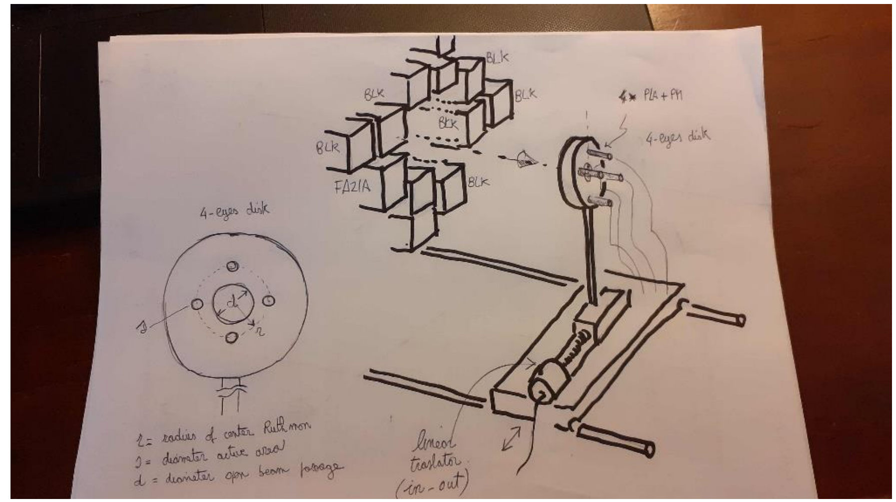
Rutherford detector for beam monitoring

Controlling and monitoring the beam intensity
within the INDRA-FAZIA set-up in D5 at GANIL

Why a new set-up for beam monitoring?
So far (in 2019 & 2022) we used the PICOLIN, a beam profile system with an integrator
It never worked! Even worse it had a leak and sprayed oil in the vacuum chamber everywhere!!
=>forget

After the E818 experiment in 2022 we started thinking about a new system inspired by the one used at Legnaro for Garfield.

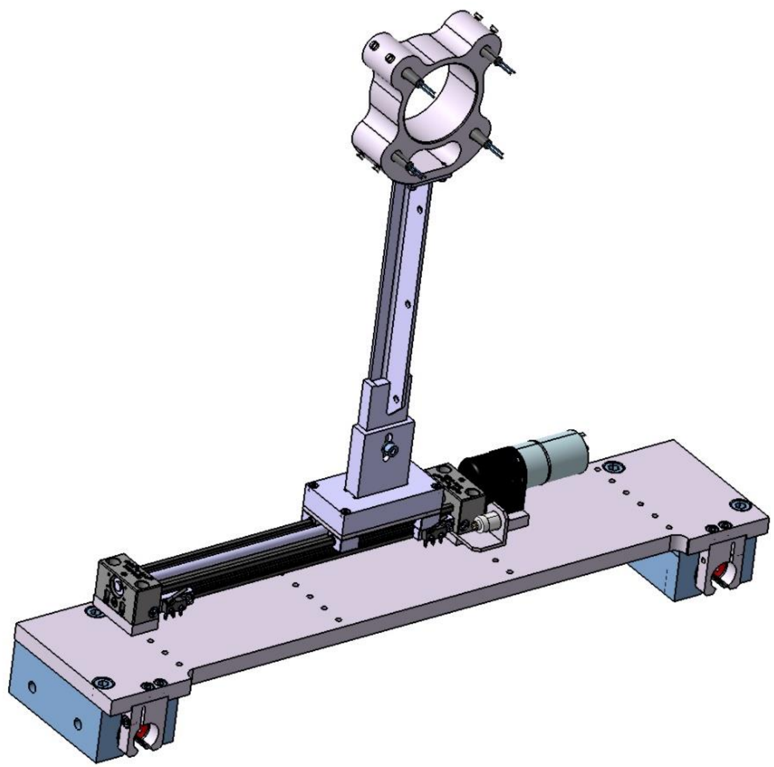


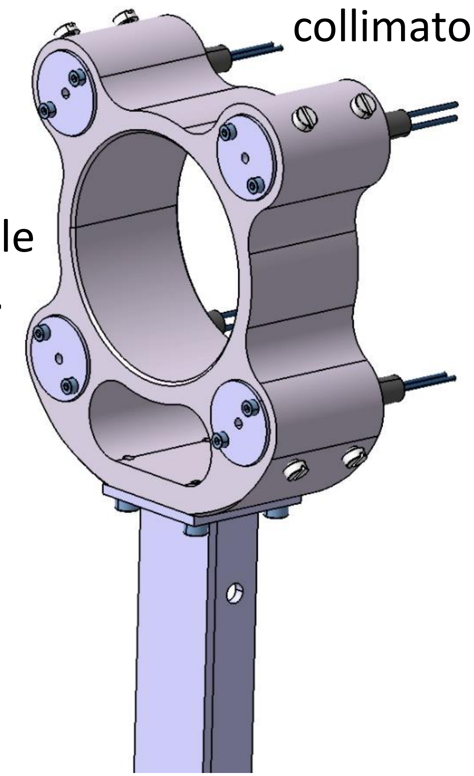


Giovanni designed something on the table and we started
the conception at GANIL.
The goal is to measure the Rutherford elastic diffusion down stream
all along the experiment in parallel with data acquisition.

laboratoire commun CEA/DSM spiral2 CNRS/IN2P3

CAD from GANIL workshop

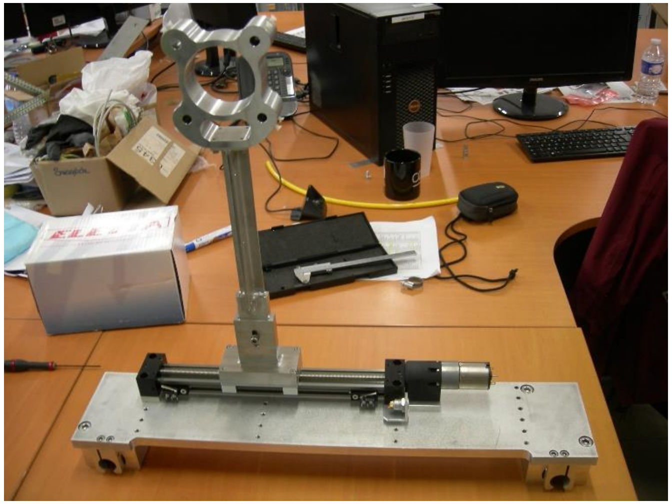


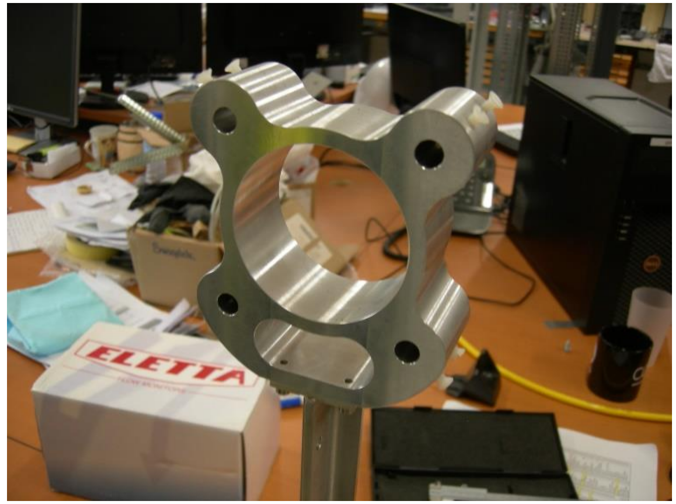


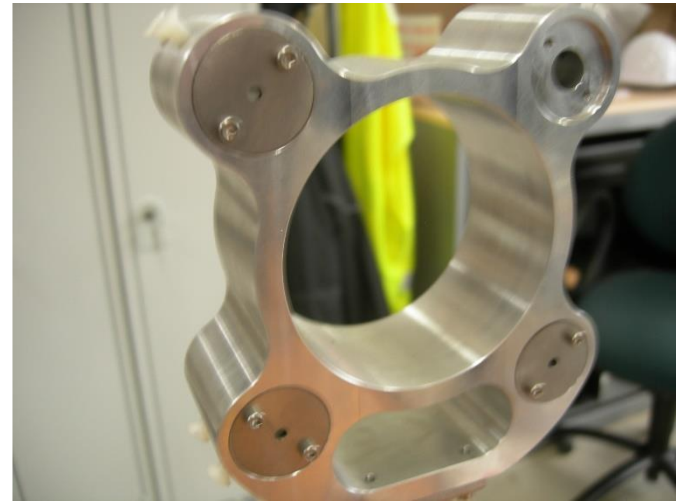
Four holes to mount the detectors. Some collimators too.

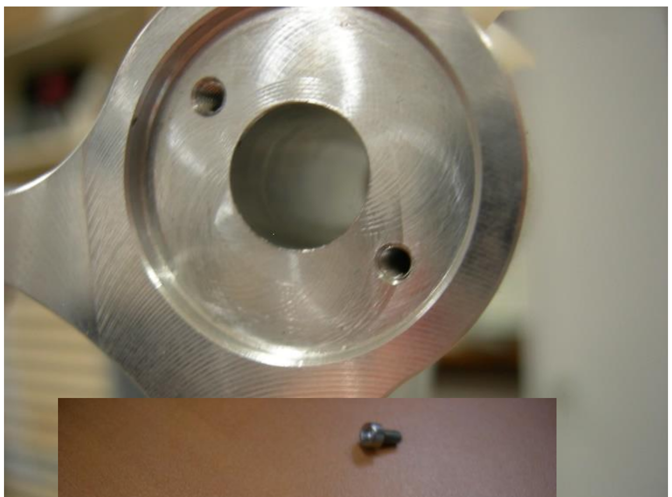
Big central hole for beam line.

Remote control to be able to remove it from the beam stream.
Adjustable distance from target and height.



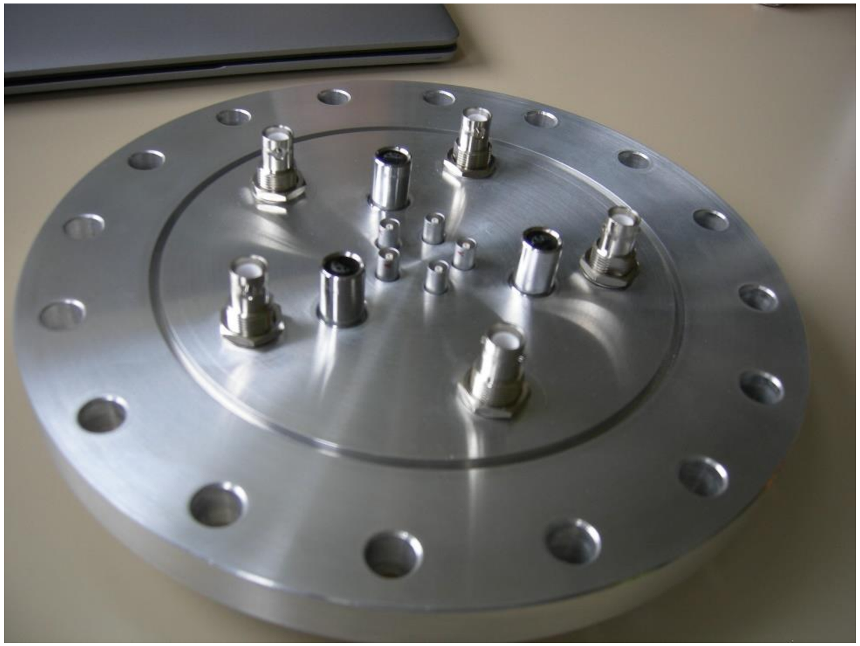


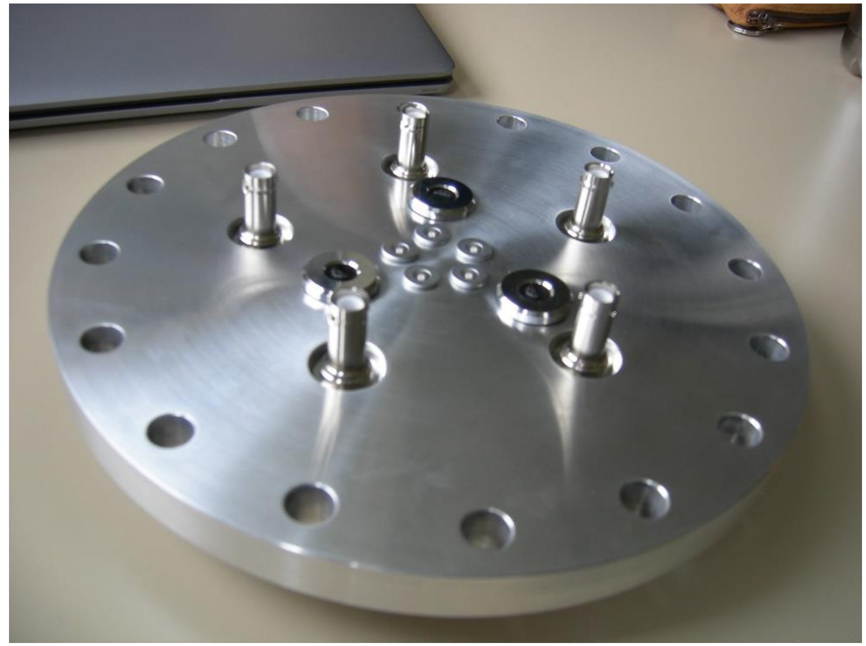




The mechanical frame is now built and installed in D5

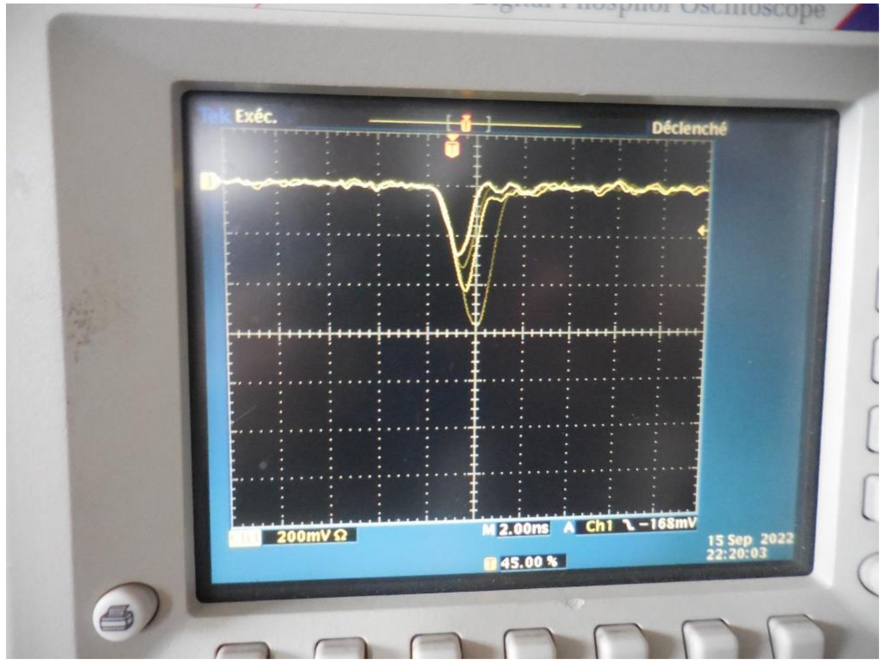
We have a new flange too, to cope with the new needs of the Rutherford monitor, 5 SHVs, 5 Lemos, 3 connectors for monitoring





The detectors are a small plastic (4-5 mm thick) read by Hamamatsu Photo Multipliers Ref. H3164-14. We bought 5 of them in 2022.

Negative polarity -1250 V

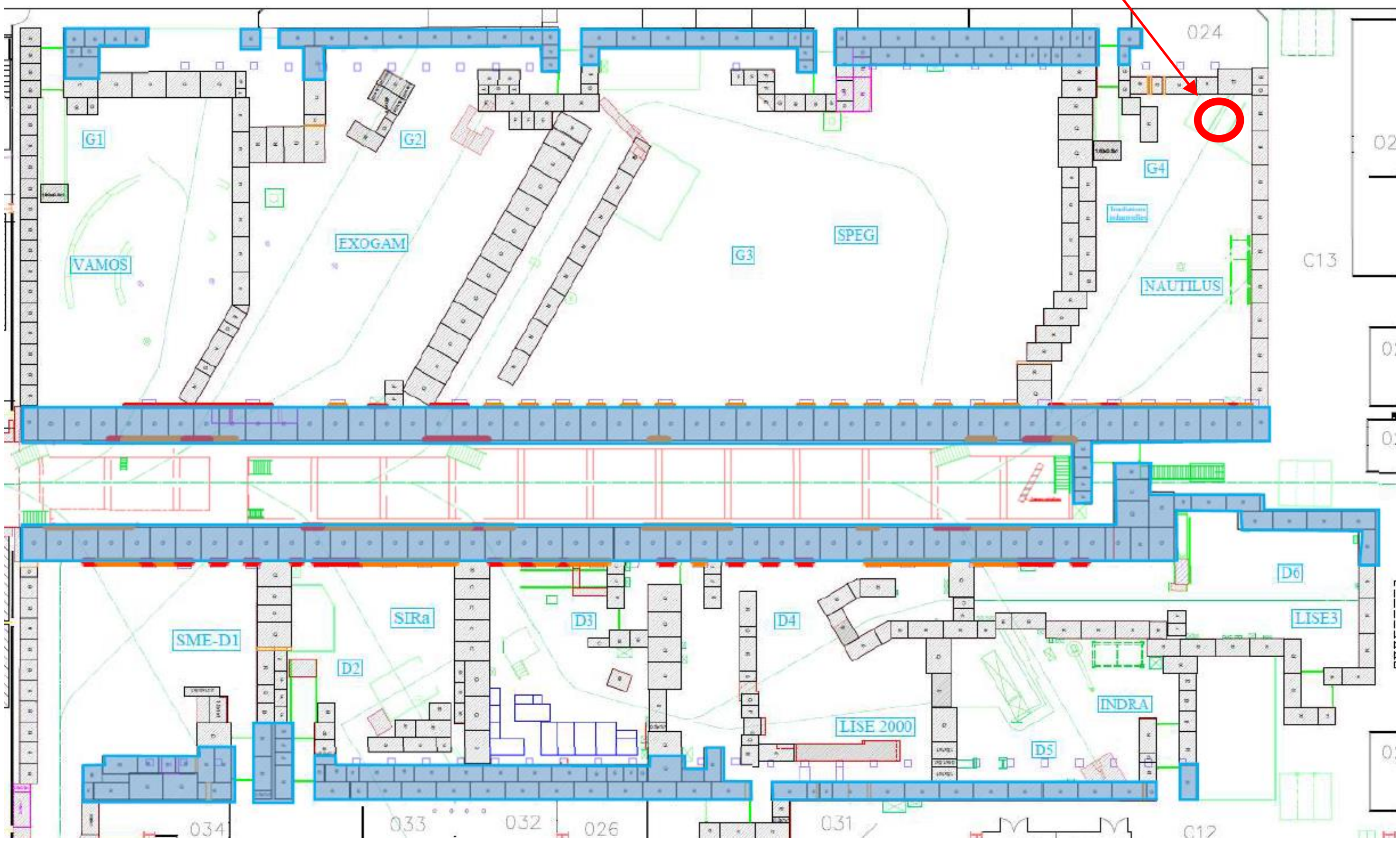


Even in vacuum and in the dark, once polarized the detector have (big) signals. With Alpha sources we just infer something! We need beams to test them properly.

Test at GANIL in G4 room

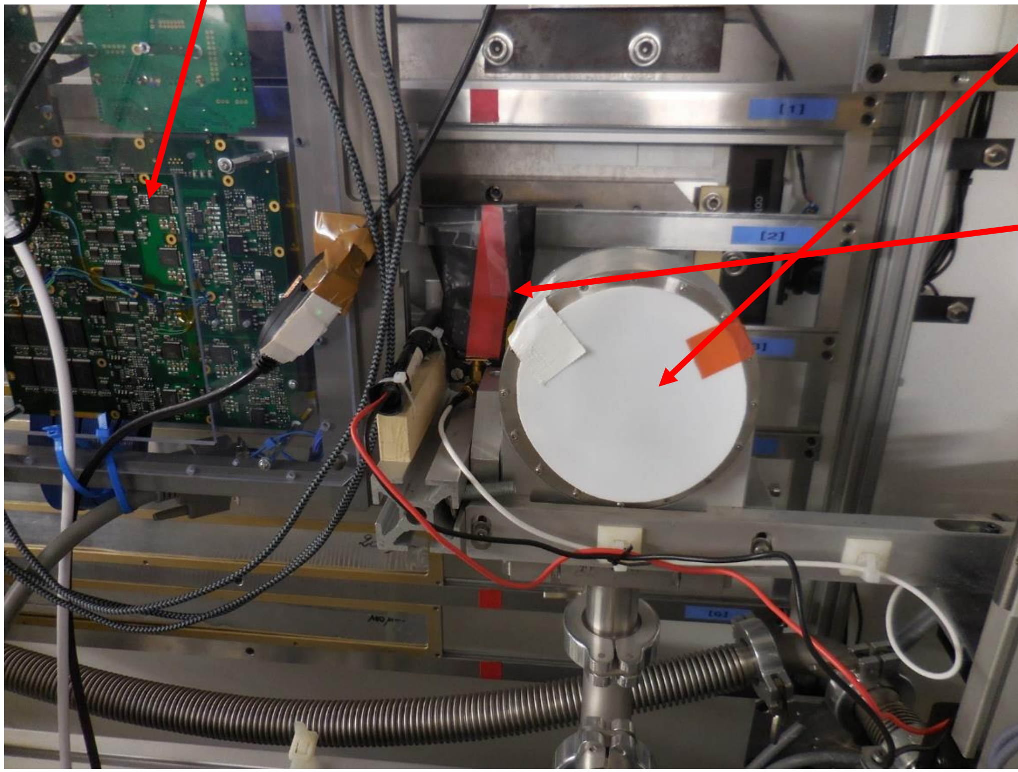
28-31 mars 2023: ^{136}Xe @ 49 A MeV
9-12 mai 2023: ^{86}Kr @ 46,5 A MeV

Irradiation room for industrial applications

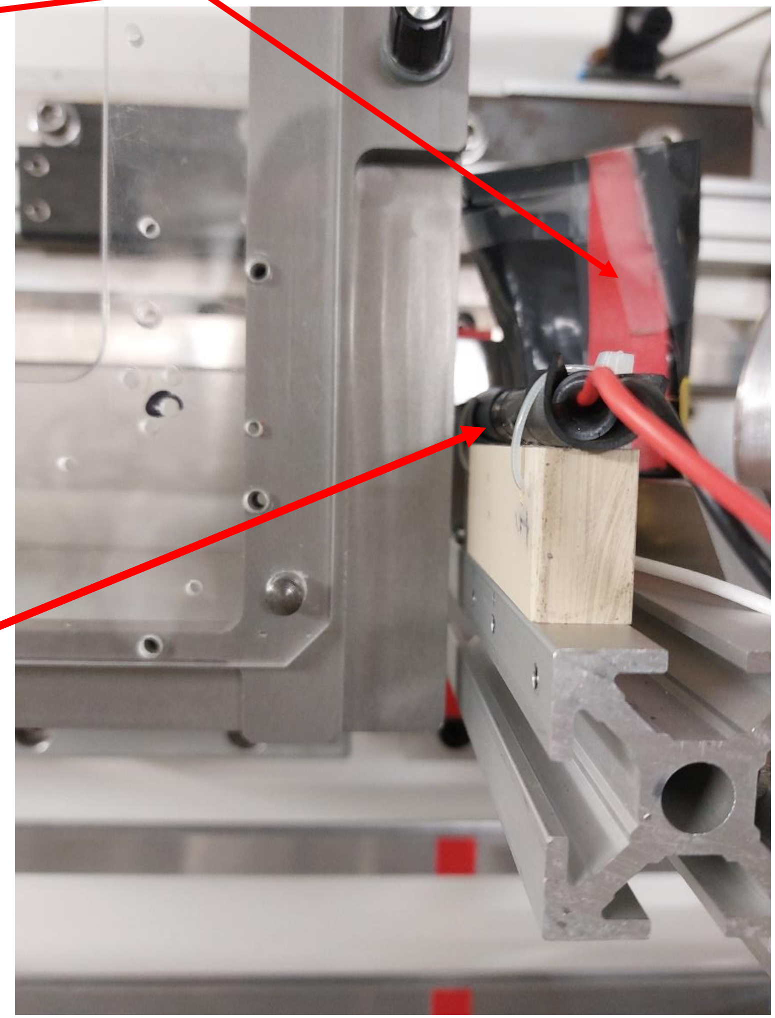


Mother board to be irradiated

Detector profiler for beam focusing and settingsG4

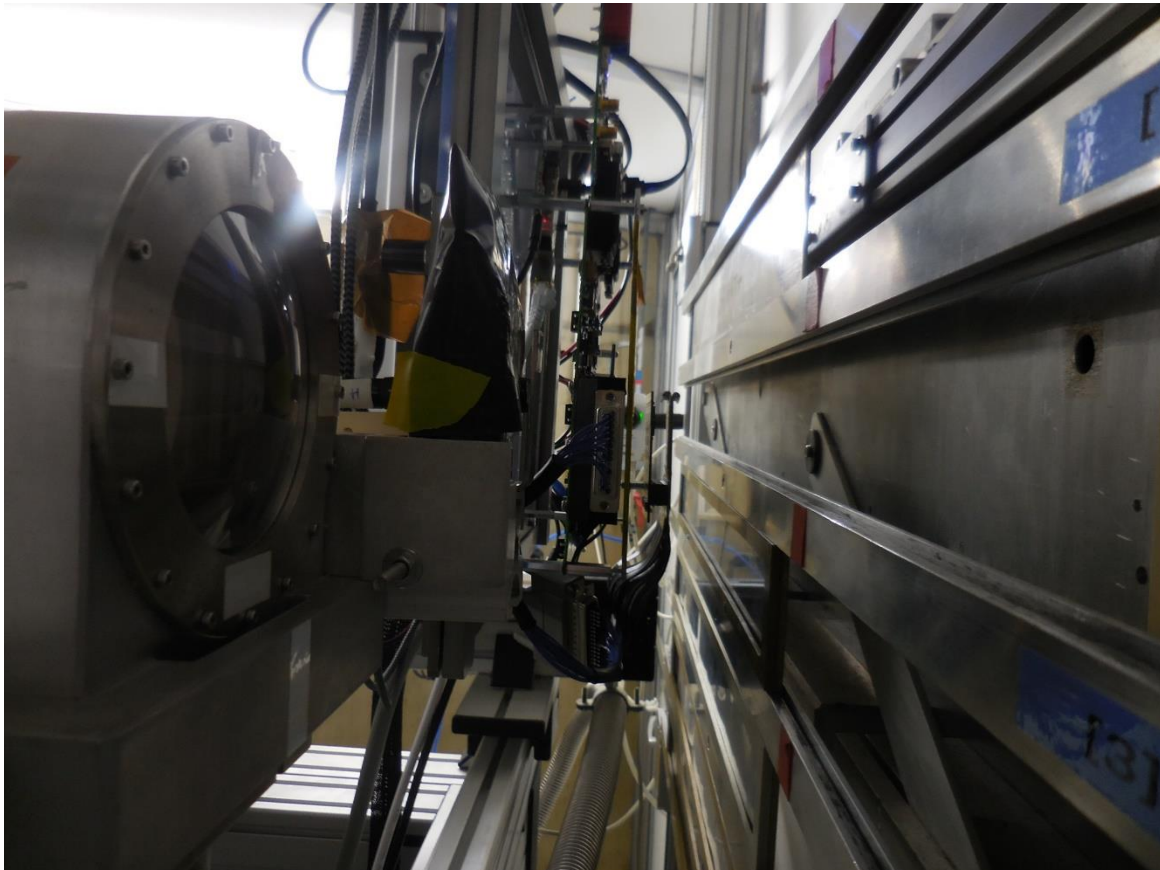


Silicon detector for beam monitoring (flux and dose)

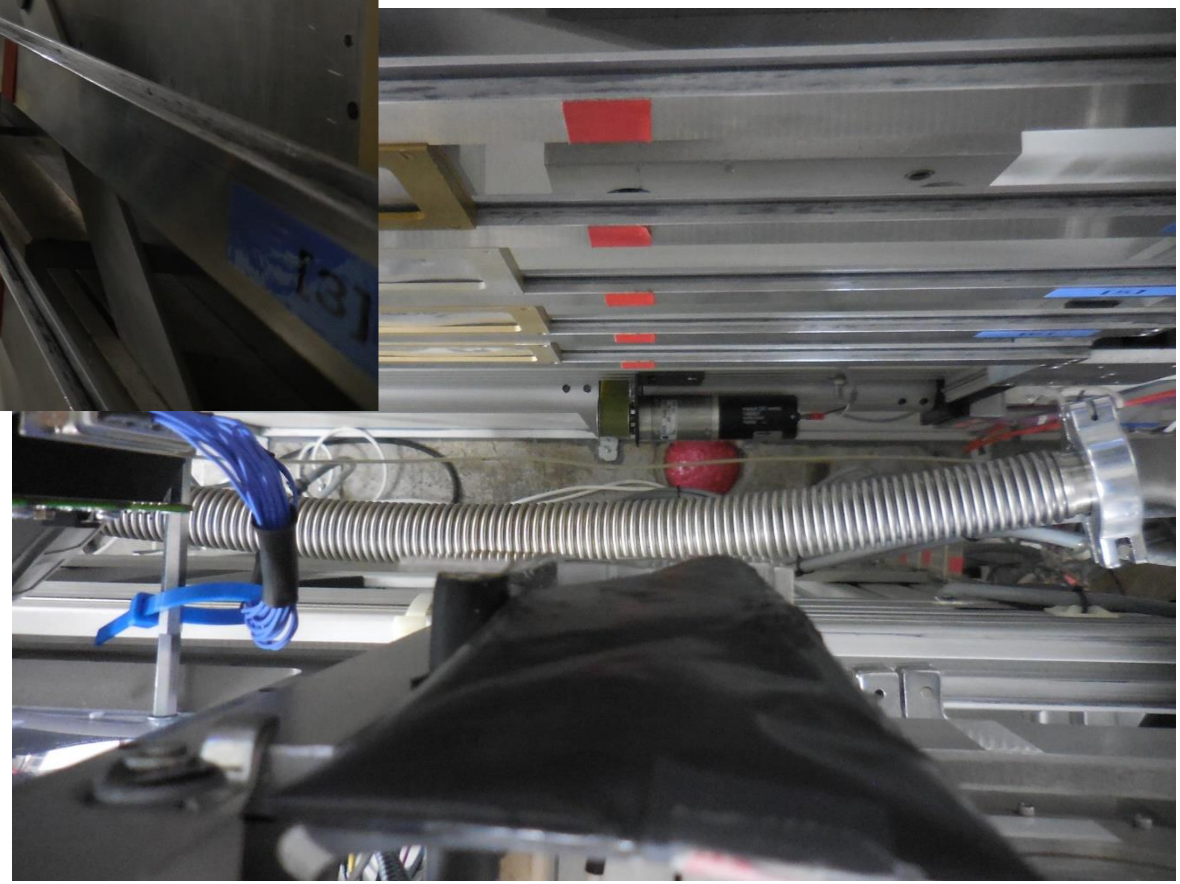


<u>Our set-up:</u>

- Photomultiplier Hamamatsu H3164-14
- Fast Plastic (thickness 3-4 mm)
- collimator inox (thickness 2 mm, ø 0,8 mm)
- Power supply 1200 V
- Oscilloscope
- Discri QUAD CFD 7174
- DAQ Mesytec MVLC module from the new INDRA electronics



Irradiation in air.
De-focalized beam.
Swept beam (156 MHz) on many cm.
Transition vacuum-air through a stainless steel window of 50x5 cm, thickness 10 µm.
We are in the dark, but there is still some parasitic light and we depend (a lot) from the various industrial set-ups.



Distance from the window from 5 to 15 cm in air according to the industrial team (monitoring system, adjustable in 3D)

Some energy loss calculation

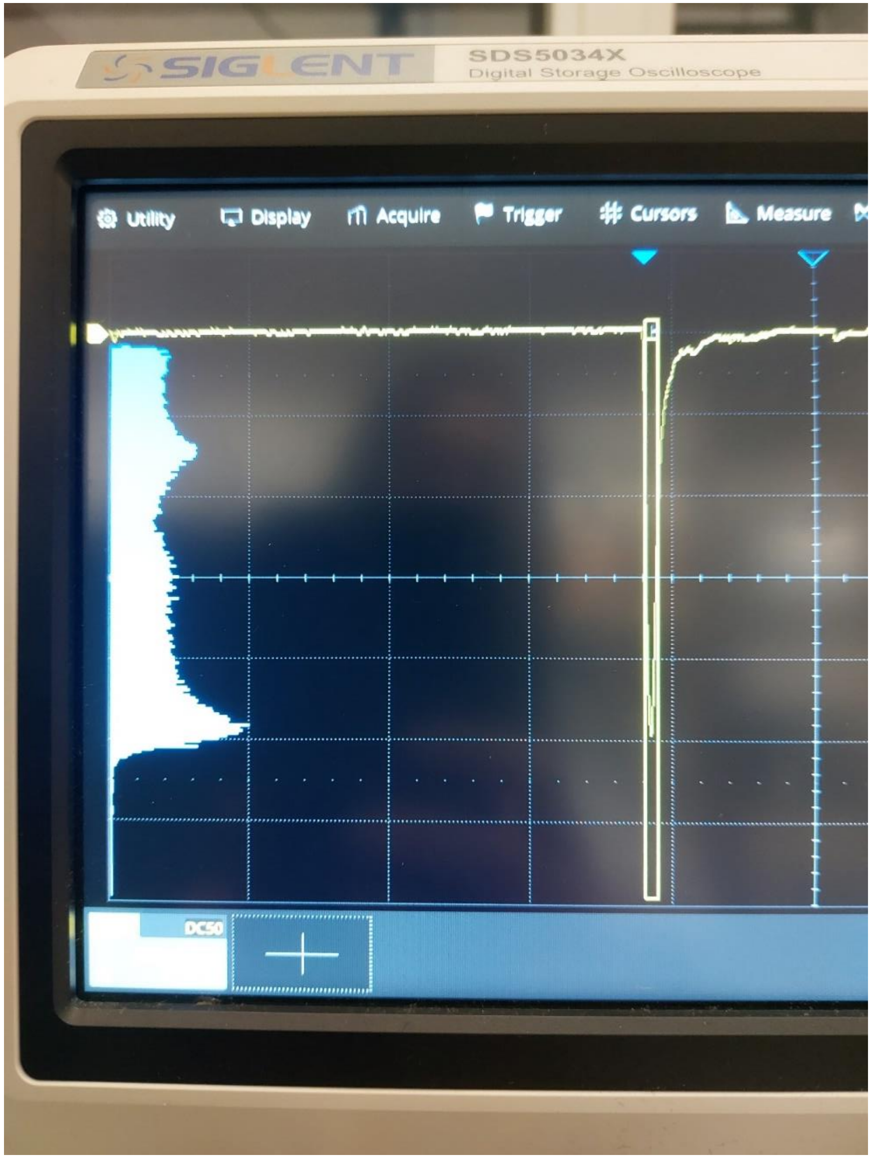
```
###############################################
Pour le materiel Inox d epaisseur:  10 um
Particle Z, A, Ei = 54,   136,   49
Energie totale = 6664 MeV
Perte dans la premiere fenetre = 172.217 MeV
Energie de la particule a la sortie de la fenetre =  6491.78 MeV
E/A de la particule a la sortie de la fenetre =  47.7337 A MeV
###############################################
Epaisseur de la zone d air = 13 cm
Perte dans la zone d air = 439.738 MeV
Energie de la particule a la sortie de la zone d air =  6052.04 MeV
E/A de la particule a la sortie de la zone d air =  44.5003 A MeV
###############################################
Materiel 2 = Al
Epaisseur materiel 2 = 300 um
Perte dans le materiel 2 = 2422.81 MeV
Energie de la particule a la sortie du materiel 2 =  3629.24 MeV
E/A de la particule a la sortie du materiel 2 =  26.6856 A MeV
kaliveda [3]
```

Energy loss in entrance window

Energy loss in 13 cm of air

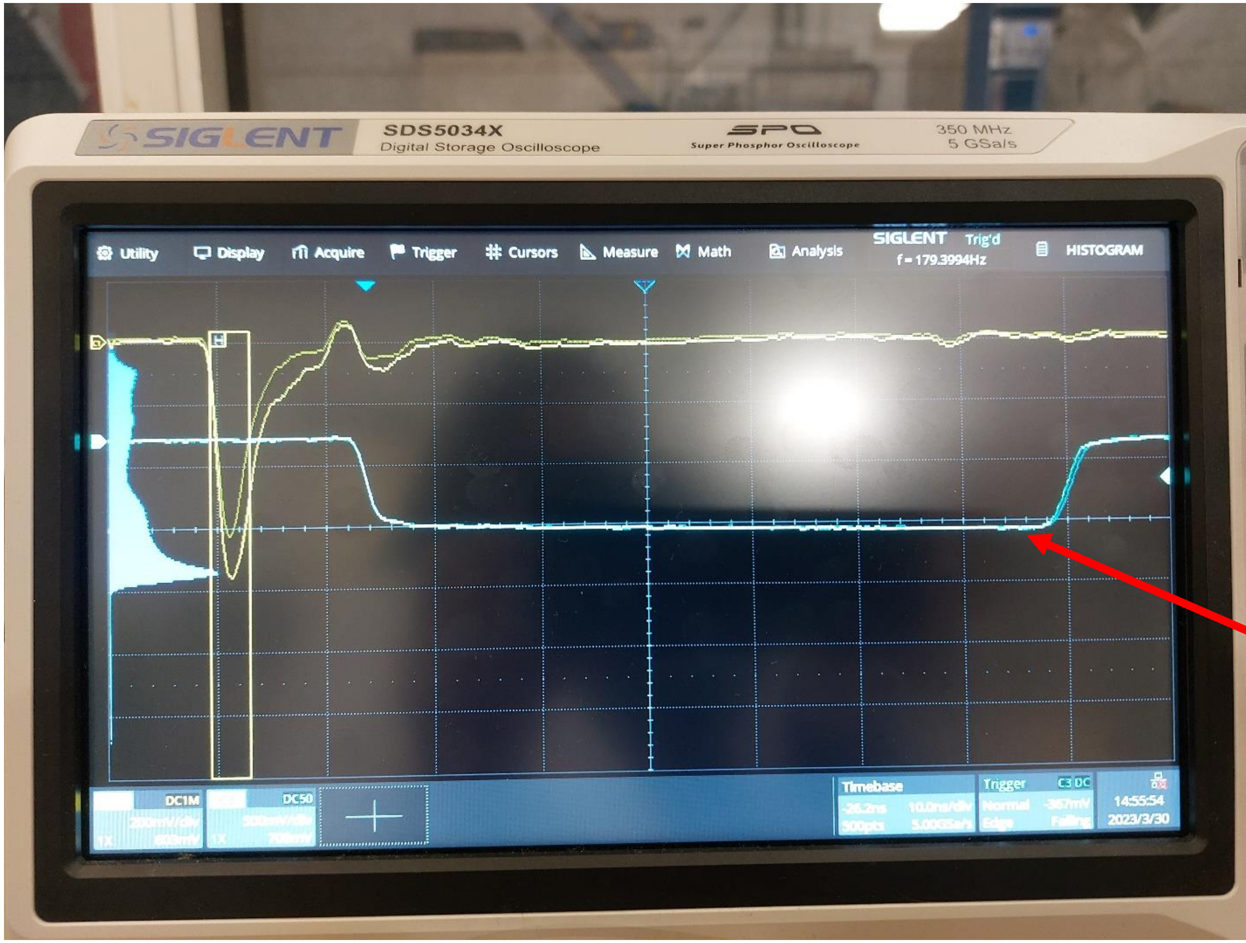
Energy deposited in the plastic

With a ^{136}Xe beam at 49 A MeV, we stop it in the plastic.
We deposit 6 GeV in the plastic (compare to 5.5 MeV for alphas source)!



Scale 200 mV & 50ns/div
^{136}Xe 49 A MeV
10µm Inox & ~10 cm air

The signal height is ~1 V is far above the background around 300 mV



Scale 200 mV & 10ns/div
^{136}Xe 49 A MeV
10µm Inox & ~13 cm air

With a quad CFD module set by Roman above the background
We build a logical signal of adjustable length (here 65 ns).
Without beam ~1 trigger/5 s
With beam 180 Hz

We also tried a fast amplifier, but the signal is too short, not conclusive.

A 6 GeV Xe is a lot!

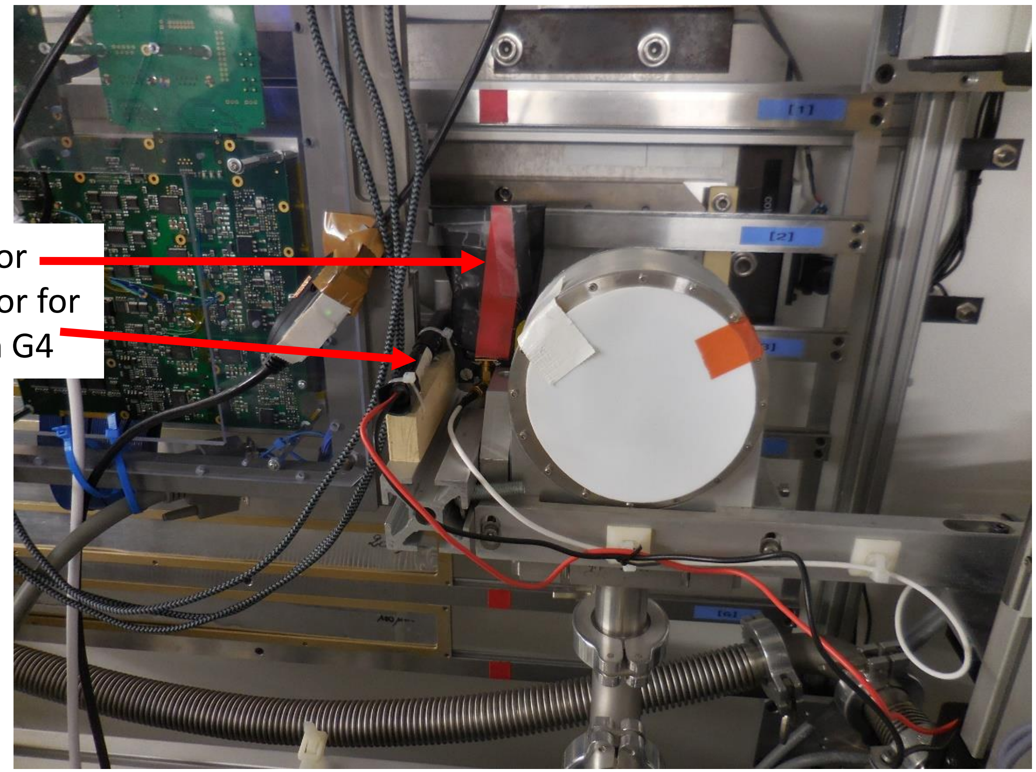
⇒ We tried also various degraders, Al or brass, to get Energies from 1,4 to 3,6 GeV.

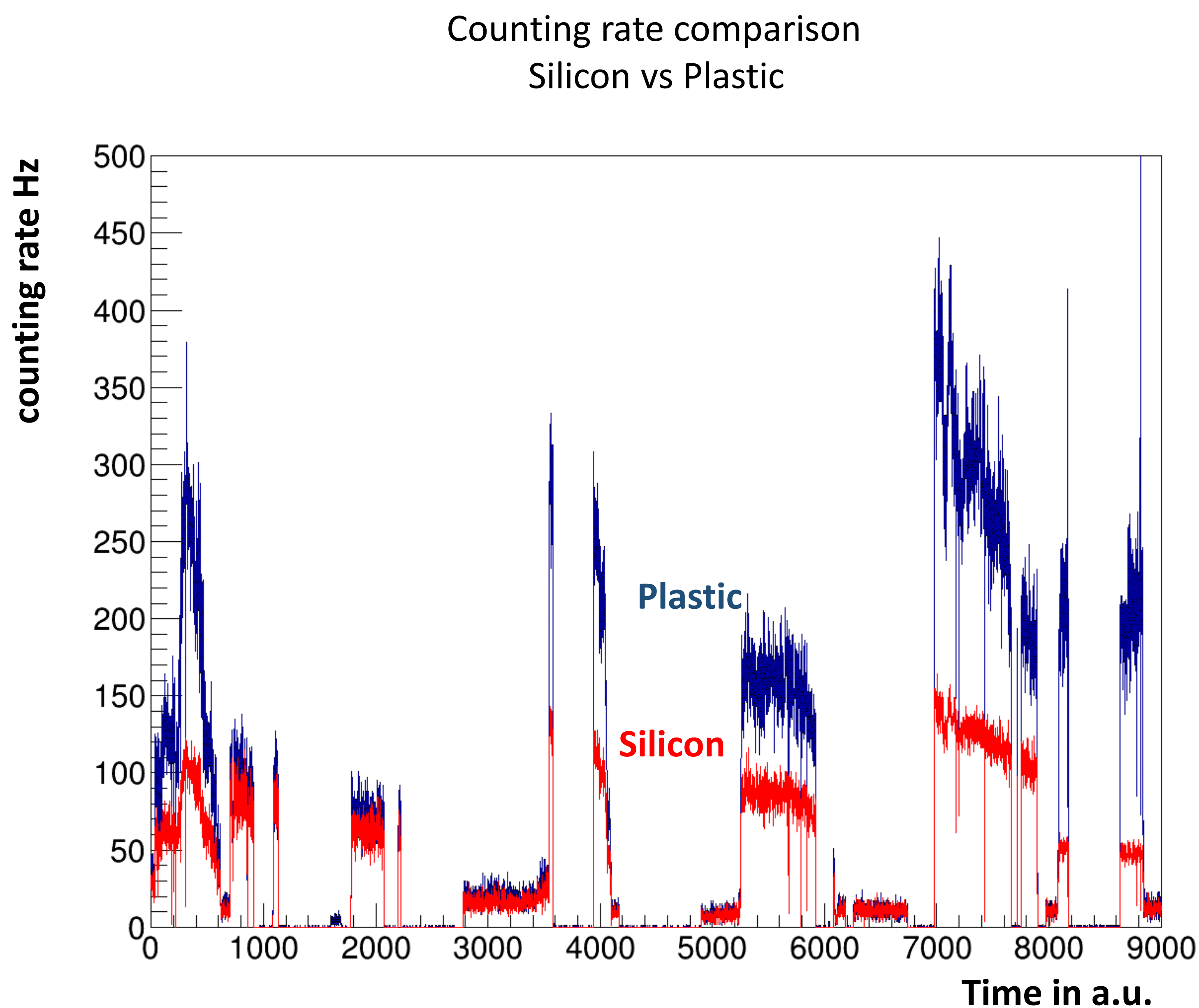
⇒ We still trig above the background.

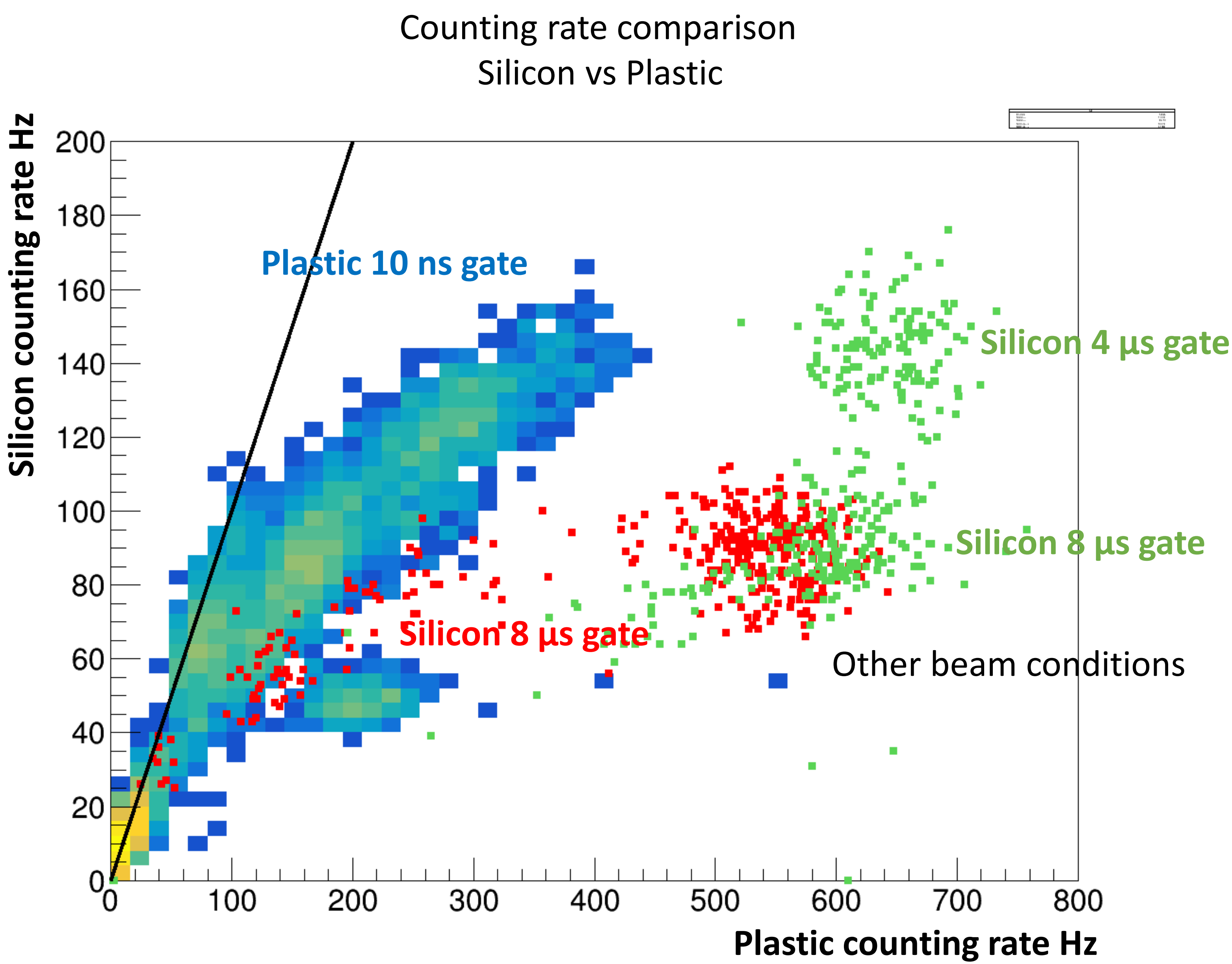
According to the environment we have more or less noise.
Diffused particles (p), gamma…??
PM directly fired?
We tried various shielding but still we can have parasitic noise.
But anyway we proved the working principle.

During the second test in May: we sent the logical signal in the INDRA acquisition system via a Mesytec MVLC controller.

Mesytec FPGA-based VME Controller




Counting rate comparison
Silicon vs Plastic
counting rate Hz
Time in a.u.
Plastic
Silicon
0
50
100
150
200
250
300
350
400
450
500
1000
2000
3000
4000
5000
6000
7000
8000
9000


Counting rate comparison
Silicon vs Plastic
Silicon counting rate Hz
Plastic counting rate Hz
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
Plastic 10 ns gate
Silicon 4 µs gate
Silicon 8 µs gate
Silicon 8 µs gate
Other beam conditions

We are know looking for « our own » discriminator:
The cost is about 5-6 k€

MSCF-16 PMT

(Data sheet V5.1_02)

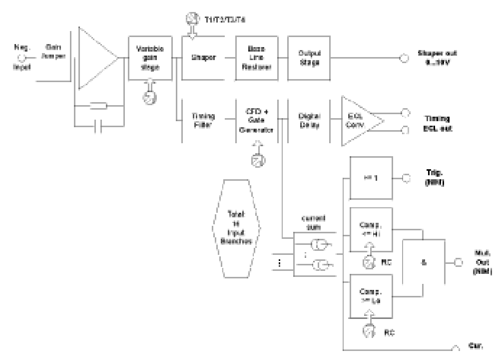
16 fold Spectroscopy Amplifier with CFDs and Multiplicity Trigger

mesytec **MSCF-16-PMT** is an integrating shaping / timing filter amplifier with constant fraction discriminator and multiplicity trigger. It provides 50 Ω terminated Lemo 00 inputs, and directly processes fast **negative signals** from PMTs or other charge sources.

Features:

- 16 channel NIM module, low power design
- directly interfaces to anode signals from photo multipliers
- Shaping amplifiers with active baseline restorer
- Timing filter amplifiers
- CF discriminators (opt.: leading edge)
- ECL timing output with digital delay of 400 ns
- Trigger output
- Multiplicity trigger
- Remote control of discriminator thresholds, shaping time, gains and PZ
- 4 shaping times
- Gain adjustable from 100 pC to 20 nC for max range
- 50 Ω terminated Lemo 00 input.
- Low noise (0.2 pC rms / 2 pC rms)
- Mostly controllable via front panel
- Remote control via USB and mesytec control bus
- 4 selectable timing filter integration times
- ECL timing delay can be switched off

Schematics:



Conclusions

- For low counting rate both detectors give similar results.
- But soon the silicon use in G4 for irradiation measurements saturates.
- We discovered that they use a 8 µs gate! Too large for DAQ.
- Then the silicon is aging, they use it for a while and it stops the Xe-Kr beam!
- They were guessing this problem without been able to quantify it.
- Now they ask for our help!
- They would keep the silicon for E measurements and a plastic for fast counting.

- There is another beam time period in G4 beginning of July, ^{129}Xe @ 49.6 A MeV.
- Four other plastic have been prepared, we can check them.
- Then we will mount them in D5 on there frame to be tested under beam in real condition (in 2024?).

So far we think the idea and the set-up are operational.