FOOT: status of the detectors

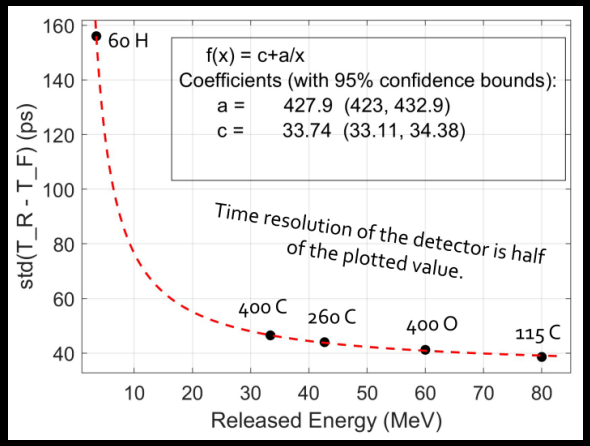
- Start Counter / TofWall
- Beam Monitor
- Emulsions
- Vertex
- MSD
- Inner Tracker
- Magnet
- Calorimeter
- Trigger
- DAQ
- Upgrades

Piergiorgio Cerello – INFN Torino

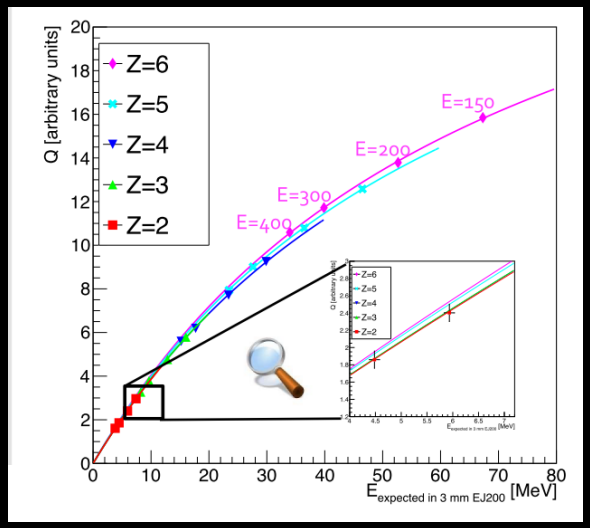
Bologna, August, 31st, 2022

Start Counter + TOF Wall

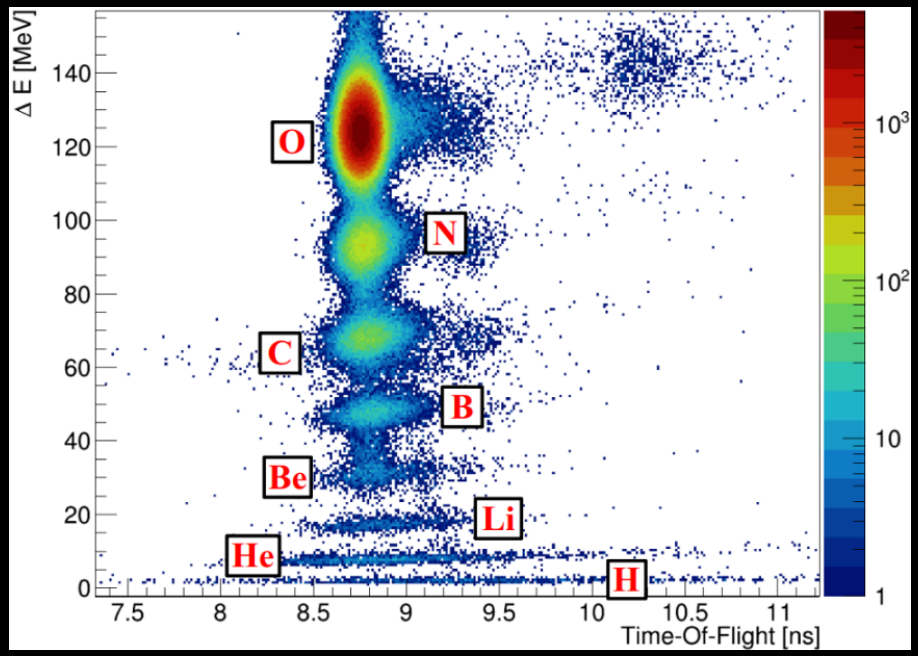
Time resolution



ΔE calibration



GSI 2021 data
400 MeV/u ^{16}O on 5mm carbon



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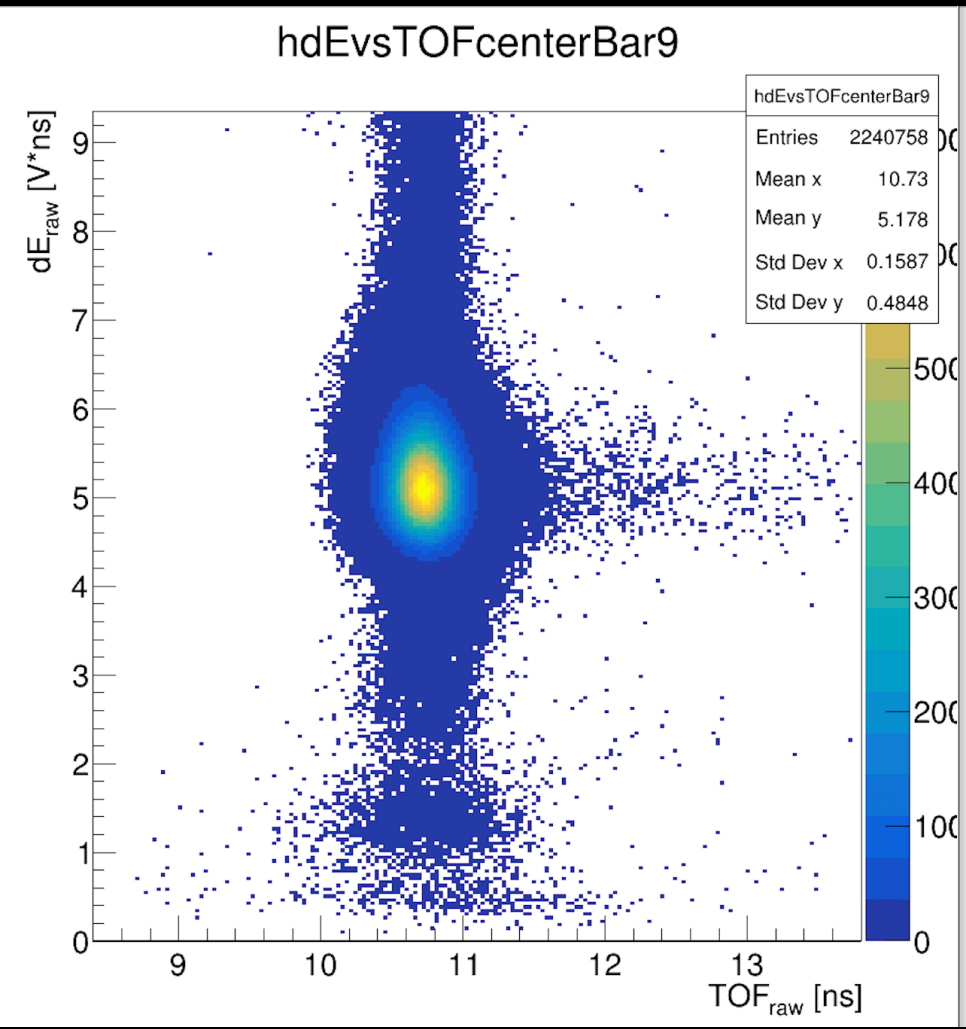
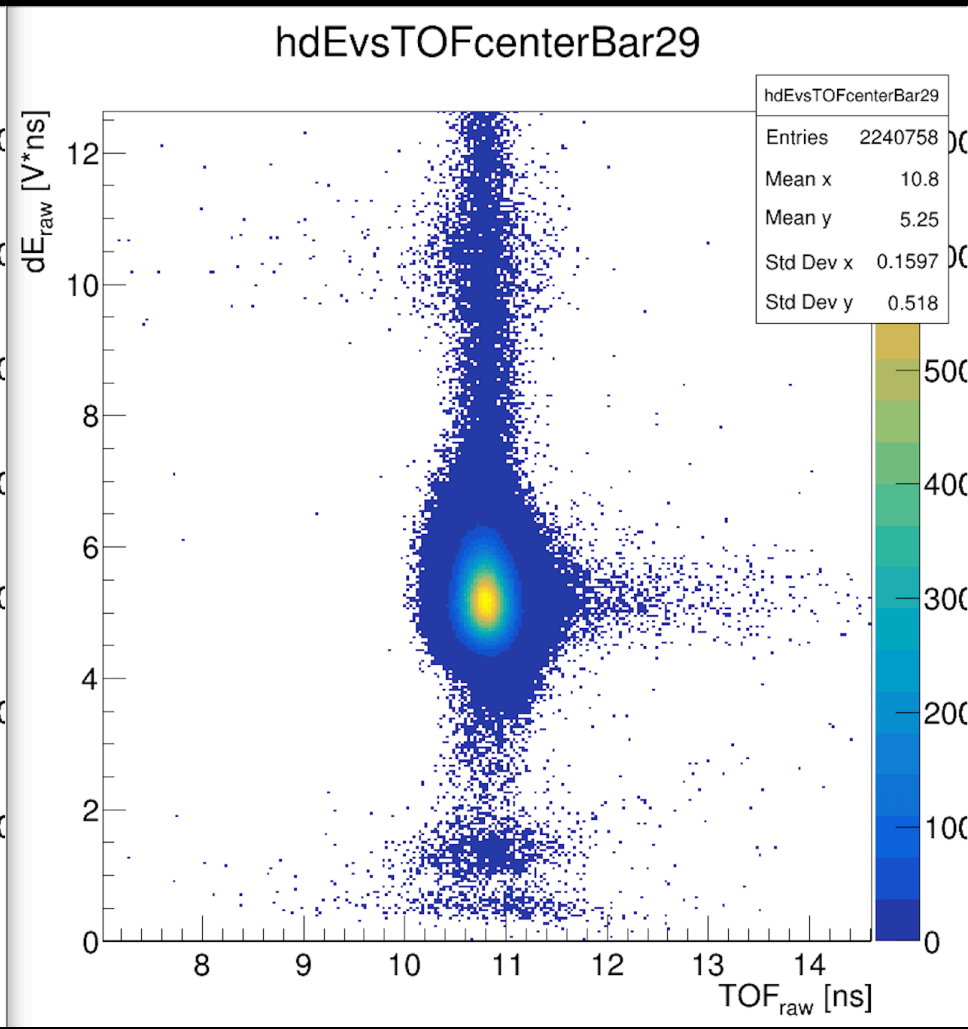
Start Counter + TofWall

Physics: He + C @ HIT – Jul 2022



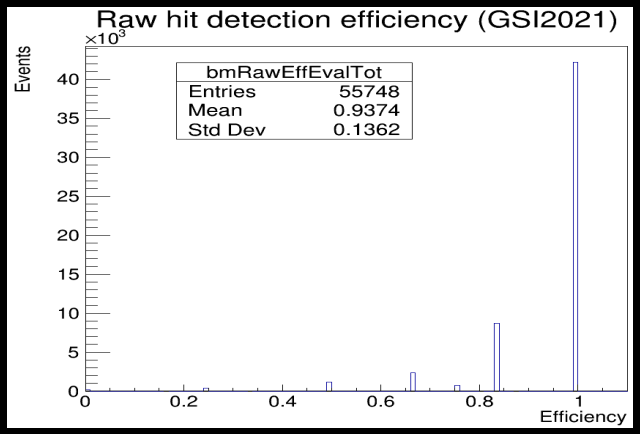


Beam Monitor

Raw hit detection efficency

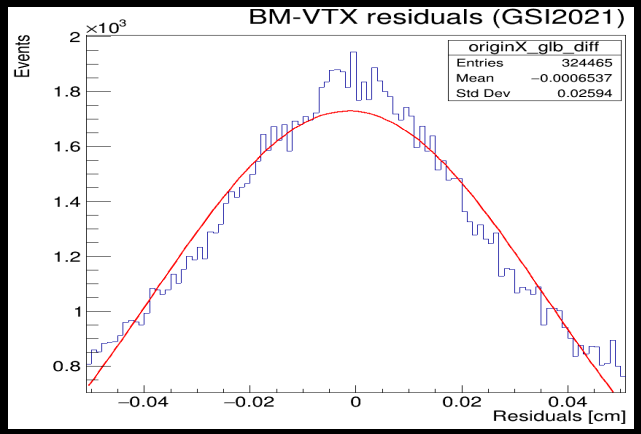
~90% @ GSI2021 - ^{16}O

~80% @ HIT2022 - ^{4}He (to be checked)



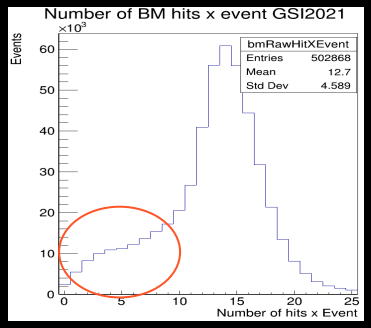
BM - VTX residuals

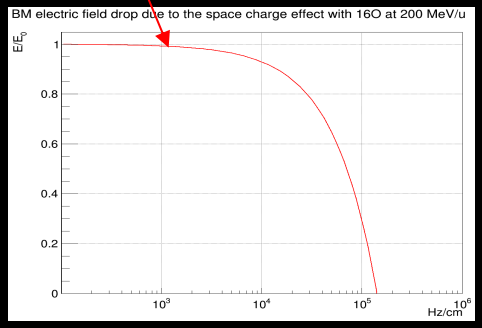
~ 300 μm (GSI2021)

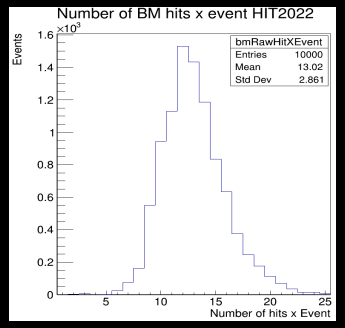


Space-charge effect detected in GSI2021

- inefficiencies at high beam intensity
- rough analytical estimate conducted
- under control at HIT2022
- possibility to measure the BM inefficiency vs beam rate at CNAO with ^{12}C







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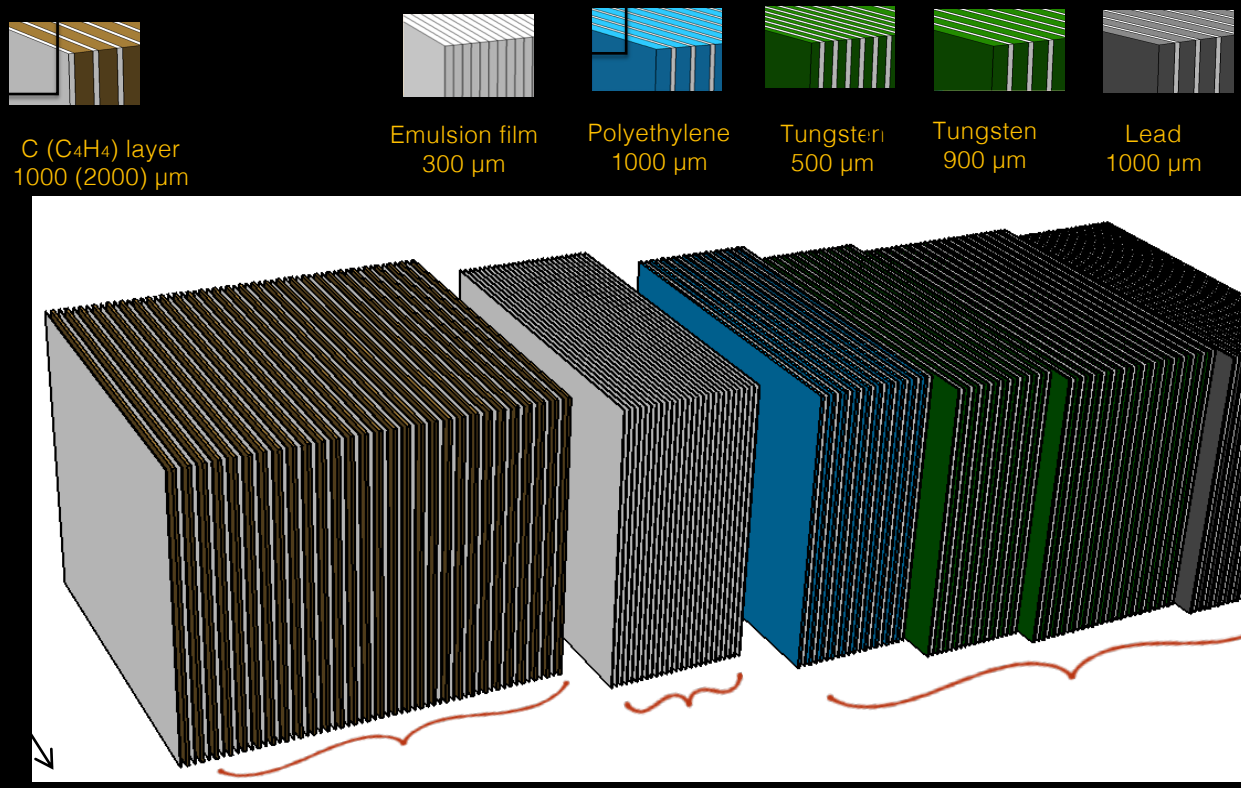
Emulsion spectrometer

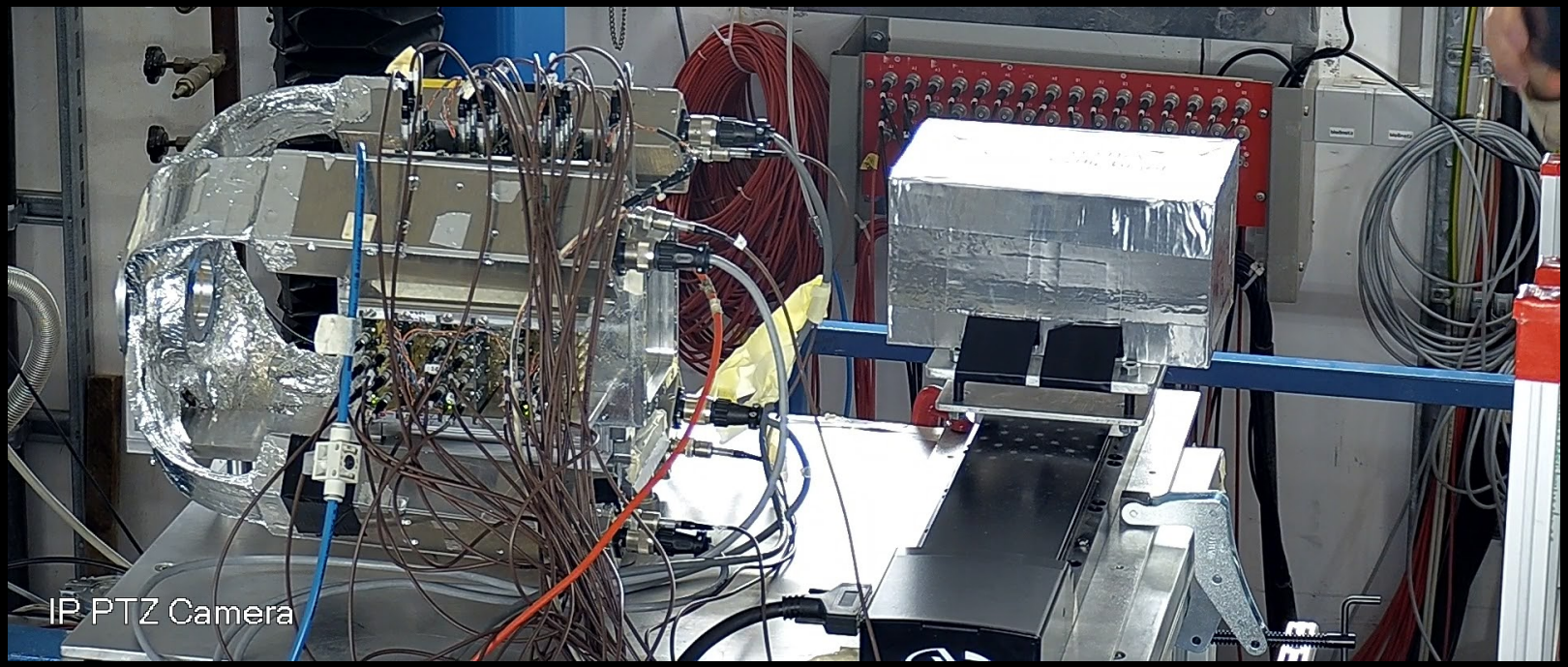


Vertexing
alternated layers of emulsions and target (C or C_2H_4)

Charge identification
only emulsion layers

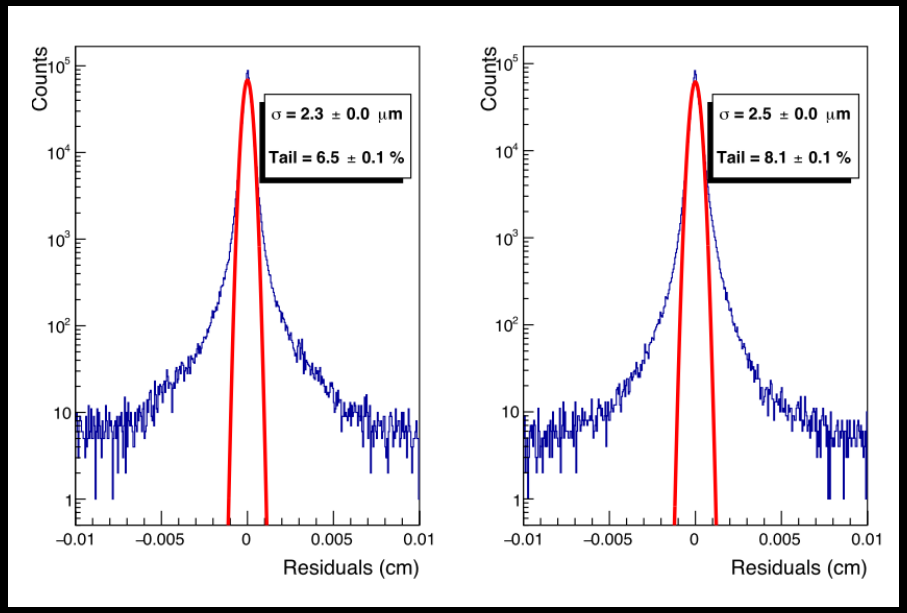
Momentum measurement and isotope identification
alternated layers of emulsions and passive material (plastic, tungsten and lead)

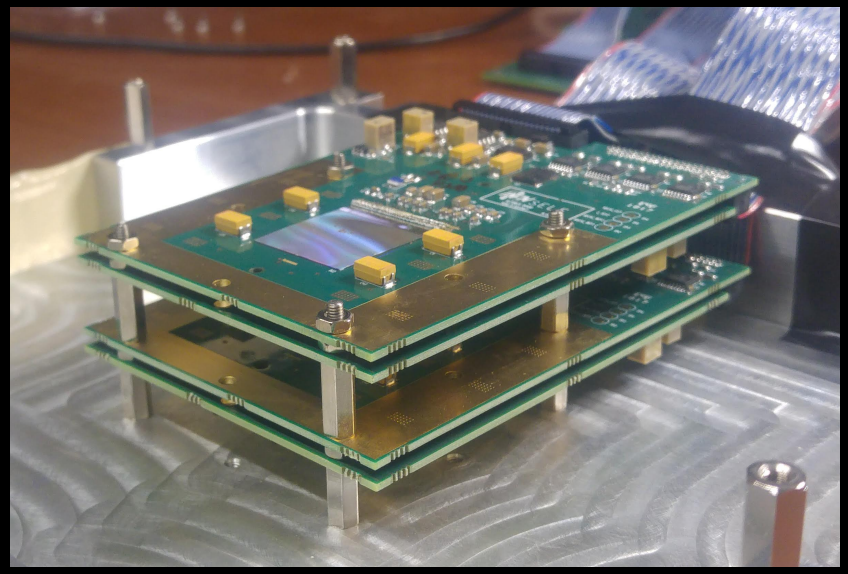
Emulsion spectrometer



Vertex

GSI 2021
Track residuals
(mostly ^{16}O)



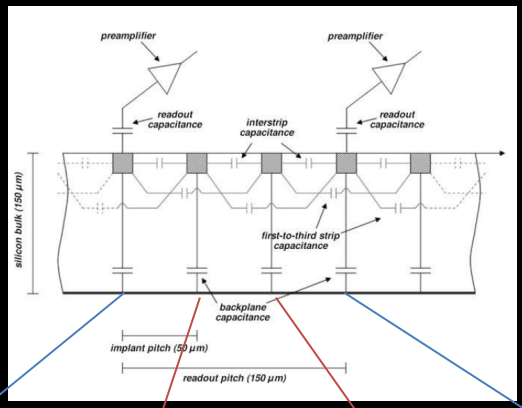


Working almost correctly
- Randomly a trigger is lost
  → resync required

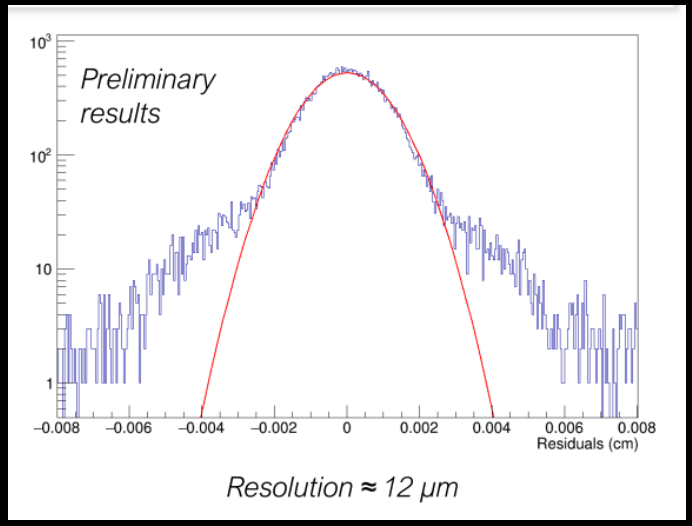
(corrected/addressed in firmware now)
- Good internal alignment
- Max 1 kHz DAQ rate … or pile-up!

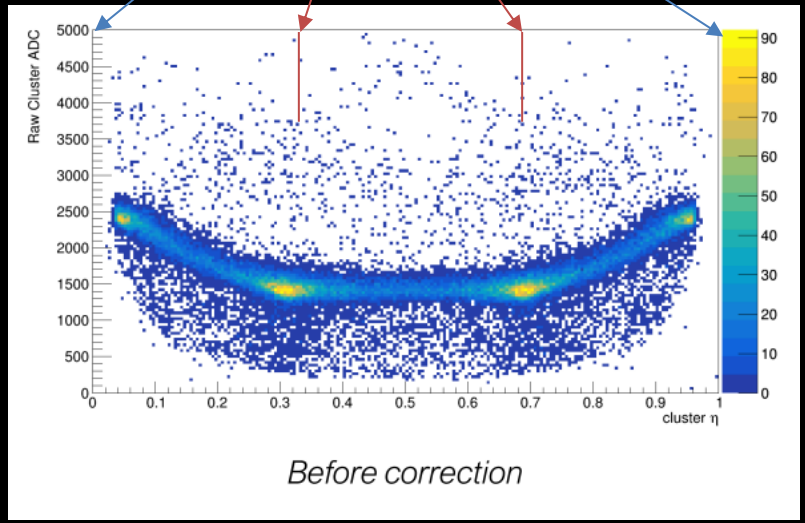
MSDs

3 x-y planes used extensively since Jun 2021
(3 more xy planes available)
50 μm microstrip, 150 μm readout pitch



Track residuals





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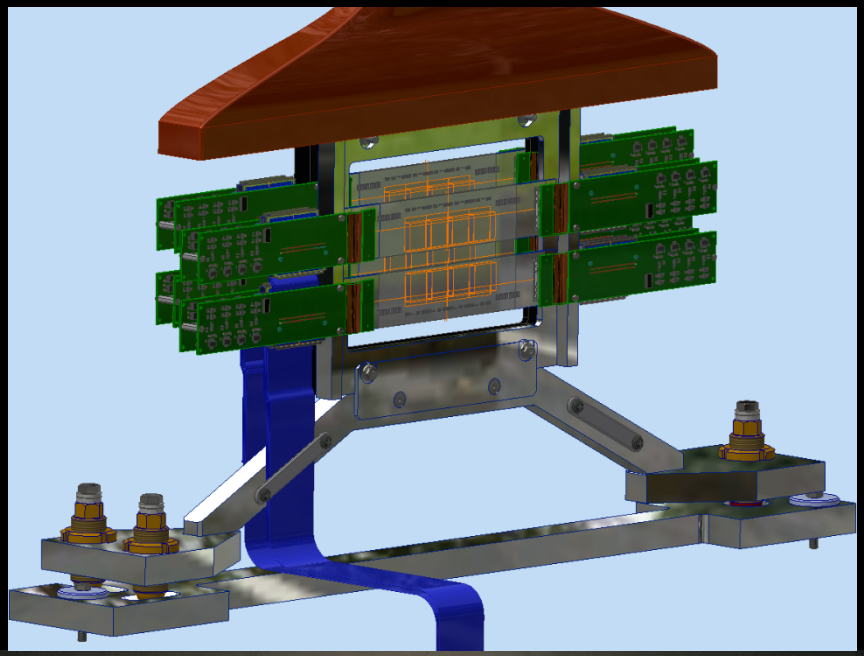
Inner Tracker

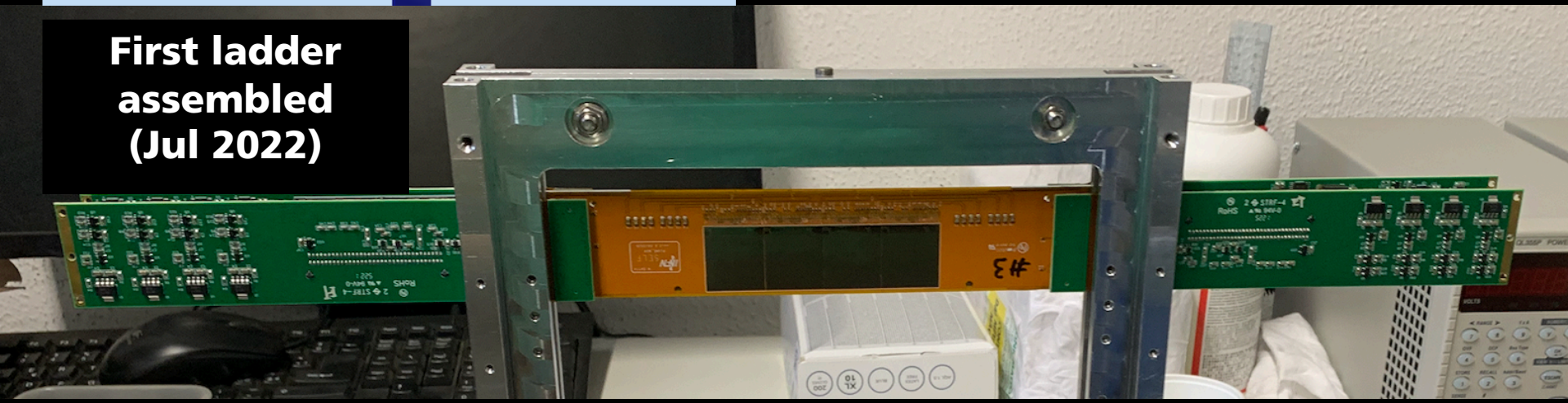


All modules available
1 ladder assembled with 2 test modules
4 to be assembled (now starting)

DAQ test with N>2 ASIC boards soon
DAQ integration test before CNAO data taking

GOAL: assembly by the end of 2022

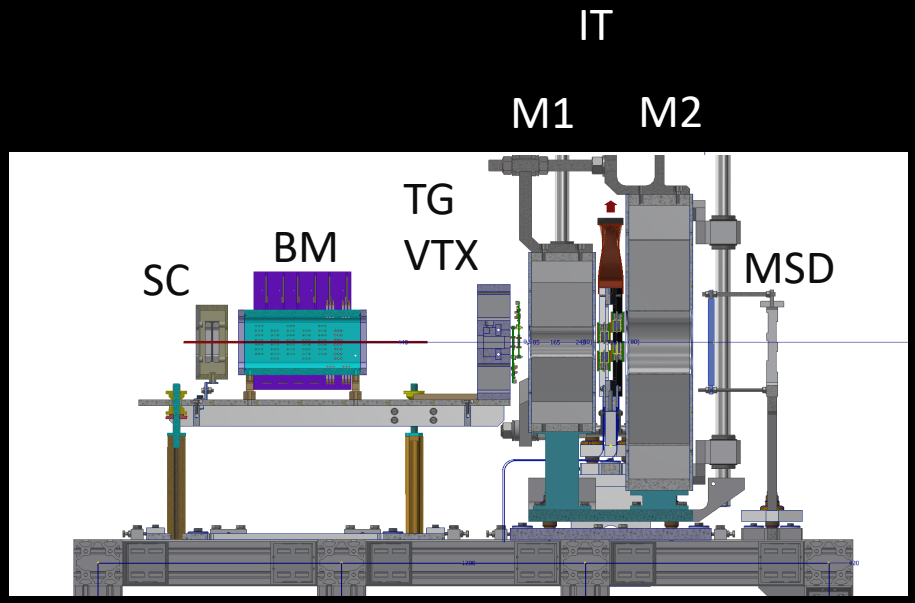
First ladder assembled (Jul 2022)

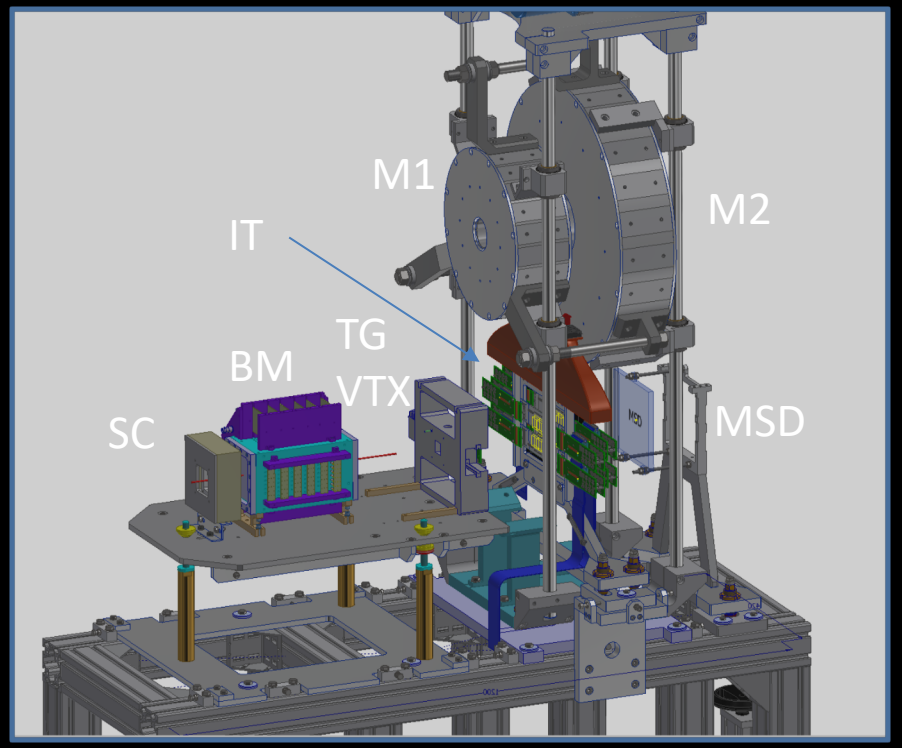


Tracker's Mechanics

Design completed
Tender assigned

Construction on hold!



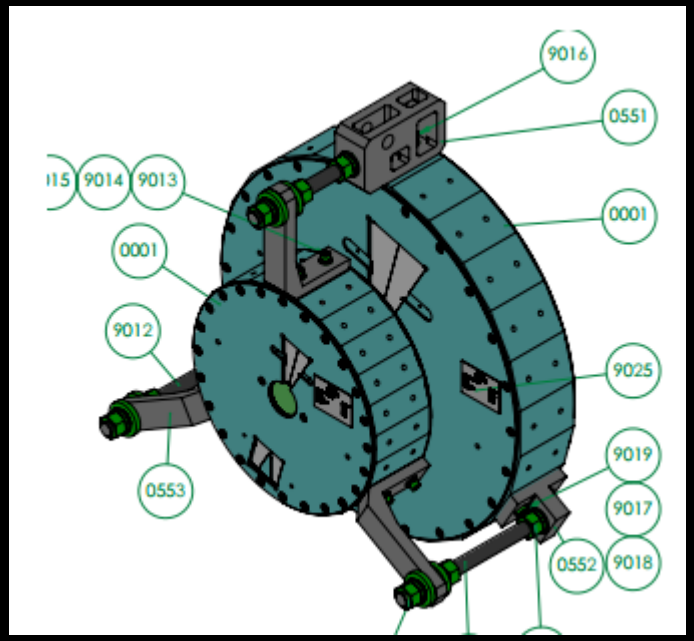


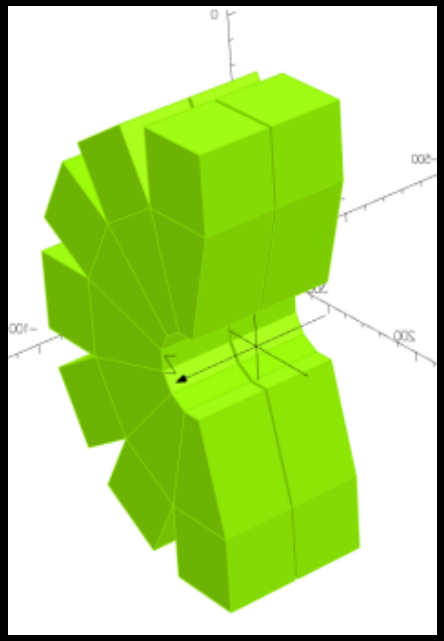
Magnet

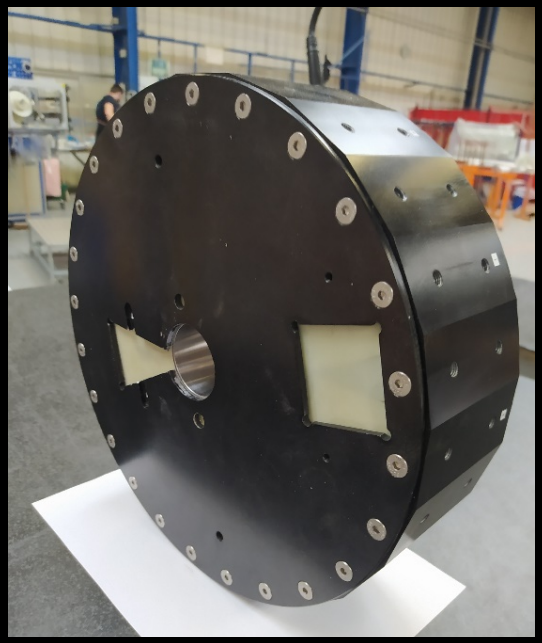
3 firms invited to the bid
1 responded (Sigma Phi)

Choice of NbSm magnetic elements

M1: 96 elements on 2 disks, 2 rings
B max: 1.4 T → strong magnetic forces







Magnet

During assembly many magnetic elements broke.
Front flanges do not look safe!

The firm built also M2 finding the same problems.

Construction failed, new project

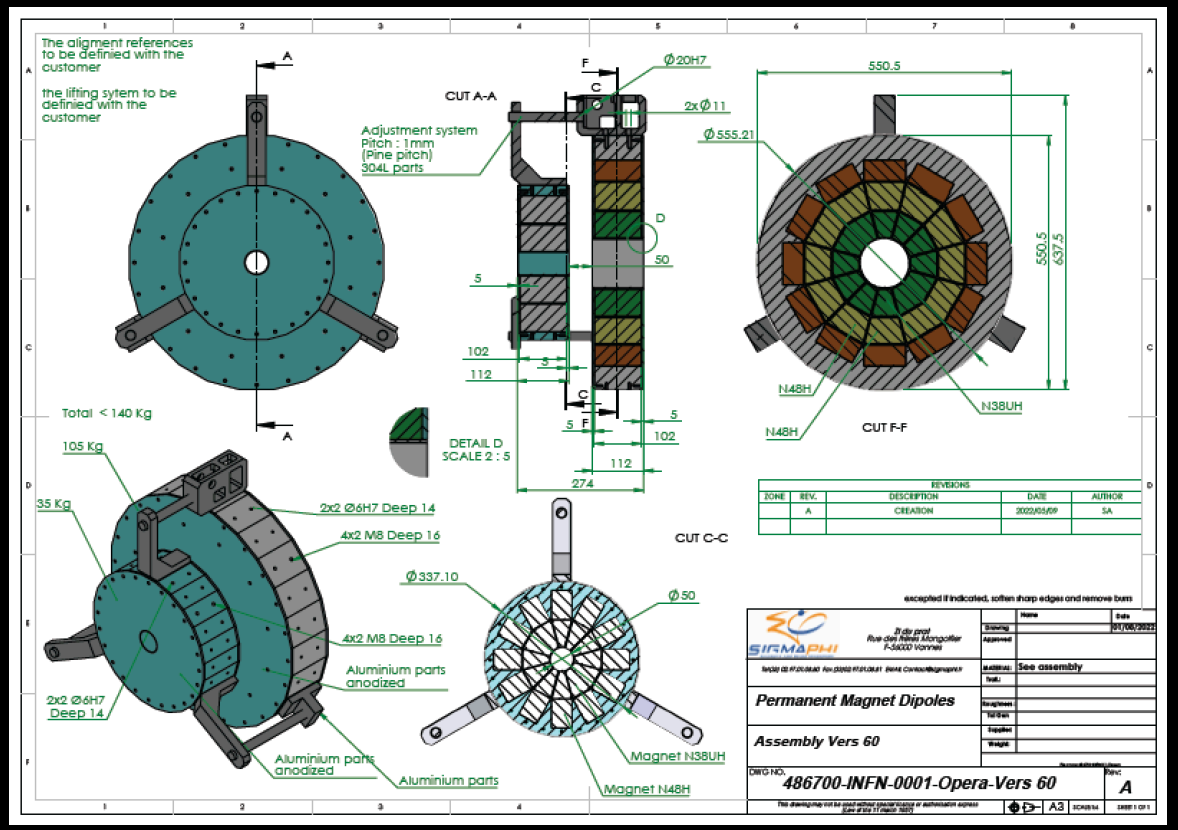
The firm decided to restart the design from scratch using Nd-Fe-B magnetic elements (harder) and avoiding the longitudinal segmentation of magnets.

We are closely following the process (weekly updates), With the help of Lucia Sabbatini (LNF magnet expert - Thanks, Lucia!)

Magnet: new project

Nd-Fe-B
Fewer (-> Longer) magnetic elements – difficult to build
Aluminum cages -> increased depth (100 -> 112 mm)

Project being finalized
Expected delivery: April 2023
Extra costs cannot be excluded



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Calorimeter construction

All components fully delivered except SiPMs

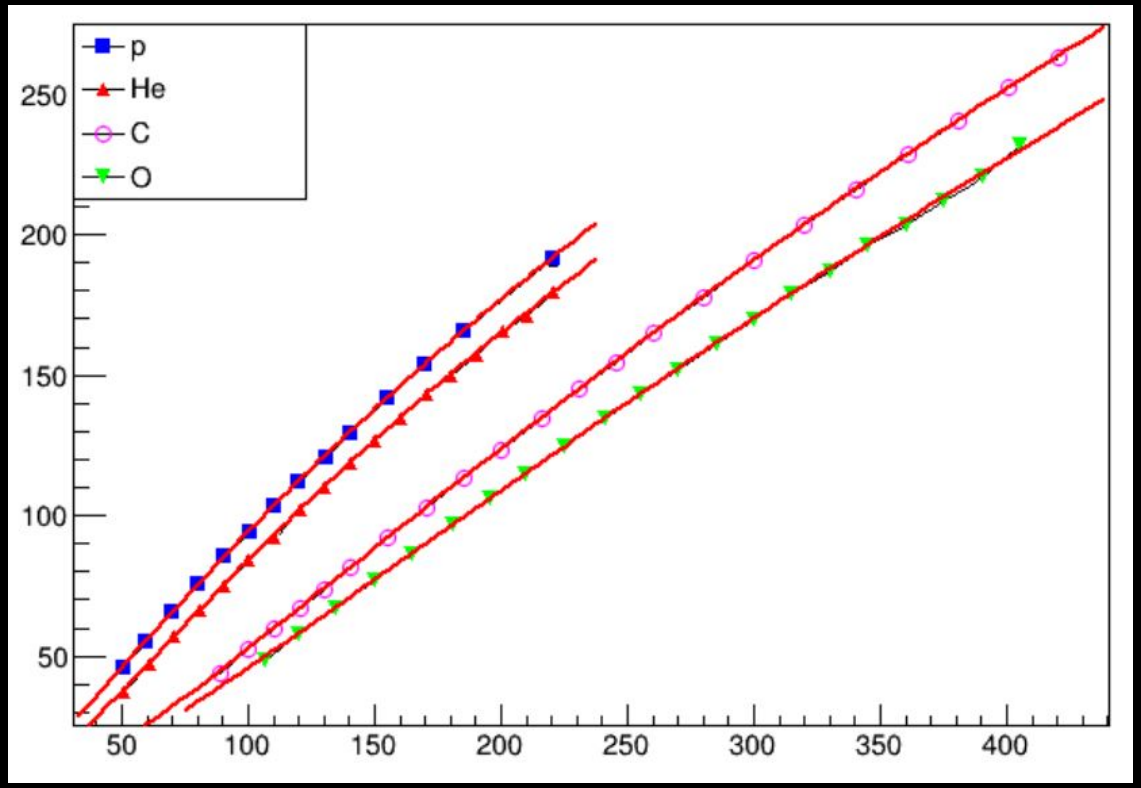
- 63 crystals (7 modules) assembled for HIT data taking (July 2022)
- 200 SiPM to be delivered in 2 weeks
- Final batch at the beginning of October
- Full system assembled by the end of 2022

- Spare components (~ 10%: boards, SiPMs) needed

Calorimeter response

S22007 - July 17th
S08358 - July 24th

p, ^{4}He, ^{12}C, ^{16}O beams
About 80 (!) energies



$ADC(E) = ax^2 / (1 + bx + cx^2)$

Calorimeter response

S22007 - July 17th
S08358 - July 24th

p, ^{4}He, ^{12}C, ^{16}O beams
About 80 (!) energies

$$ADC(E) = ax^2 / (1 + bx + cx^2)$$

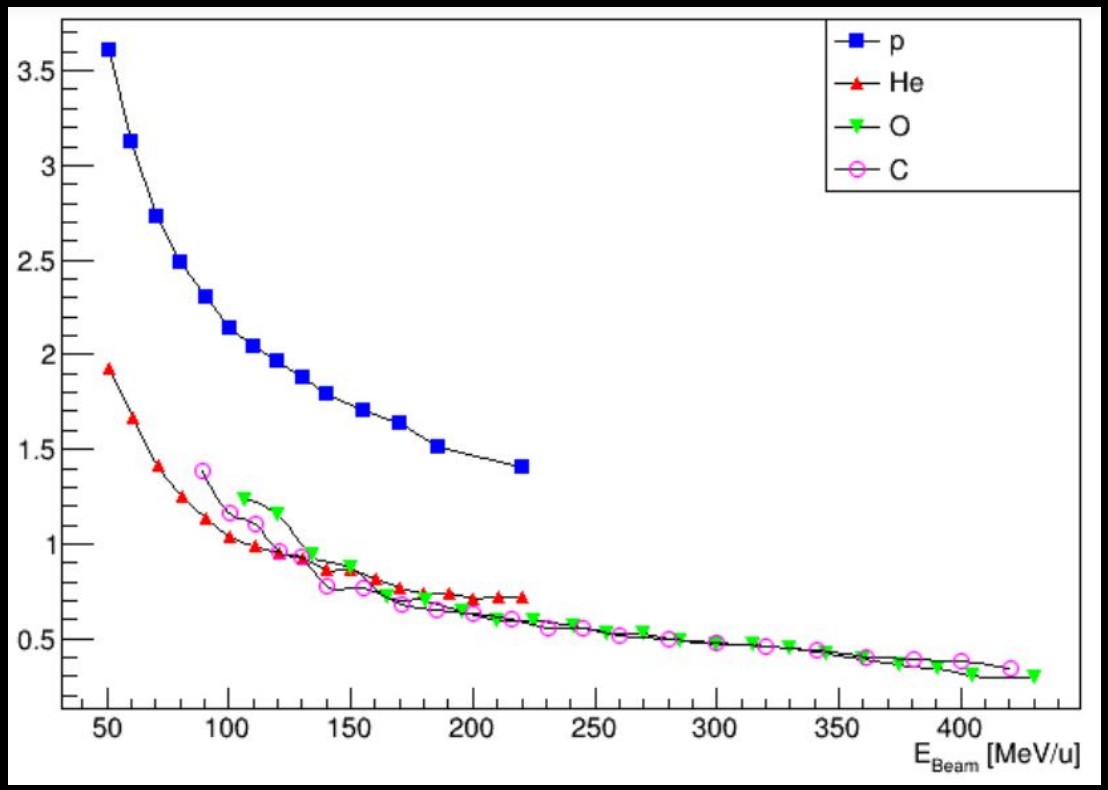
	p	He	C	O
a	0.109	0.044	0.013	0.011
b	9.42e-02	3.71e-02	1.46e-02	1.29e-02
c	12.3e-05	5.83e-05	1.06e-05	0.88e-05

$$|E_{fit} - E_{ADC}| < 1\%$$

Calorimeter resolution

S22007 - July 17th
S08358 - July 24th

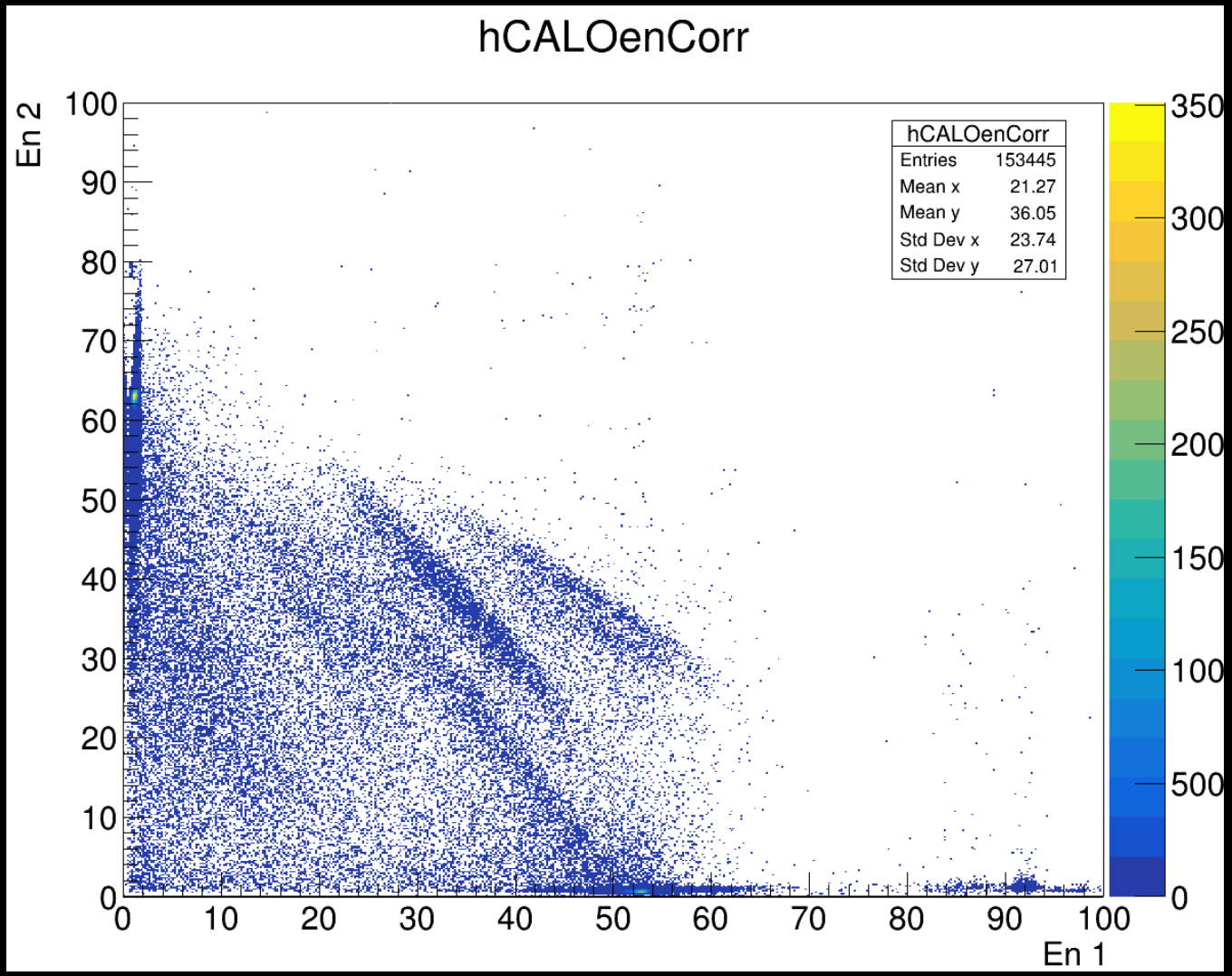
p, ^{4}He, ^{12}C, ^{16}O beams
About 80 (!) energies



E (MeV/u)

Calorimeter calibration

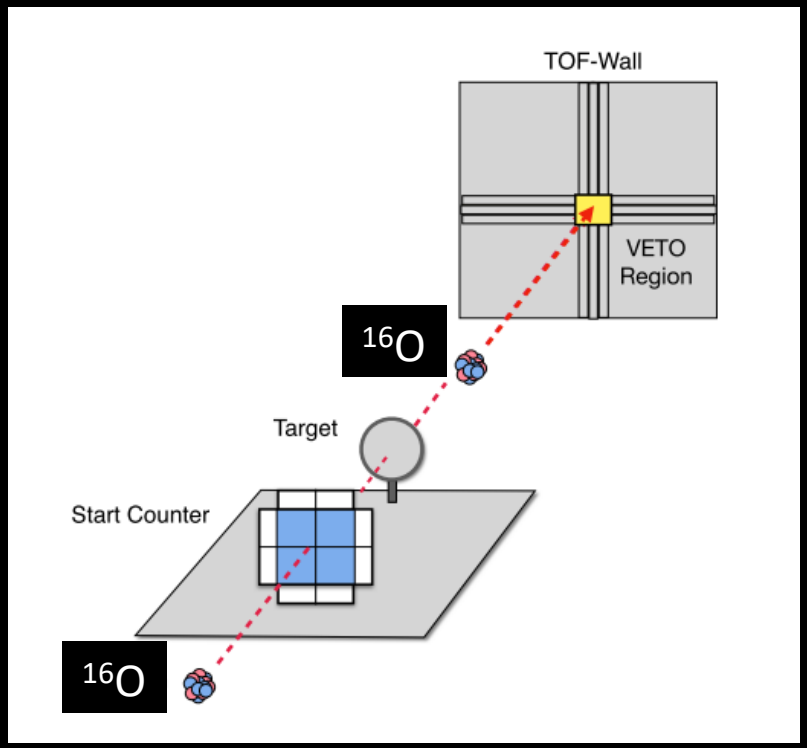
Physics: He + C

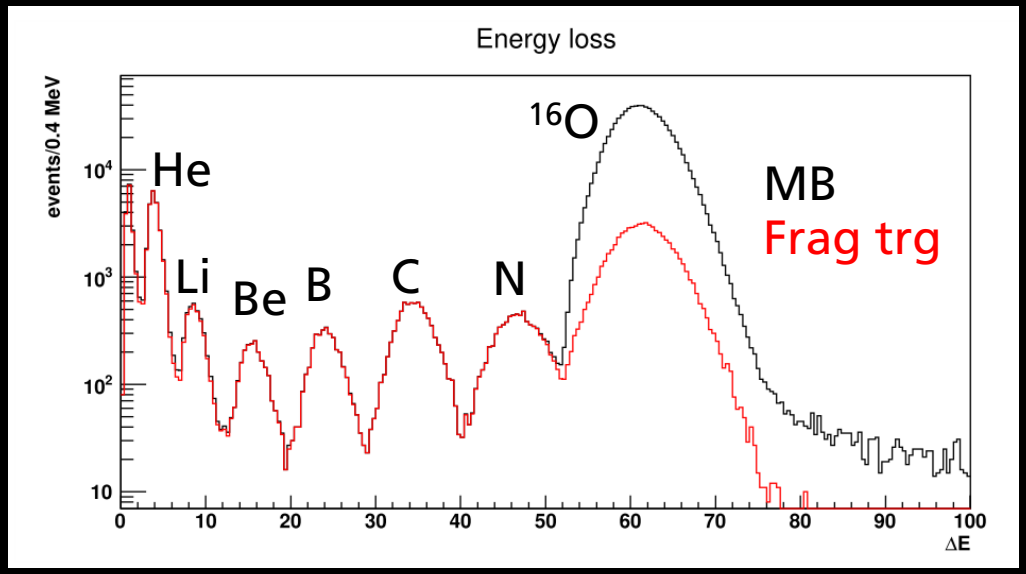


Trigger

Fragmentation events are at a level of few %

→ Better to implement a trigger logic to select them!





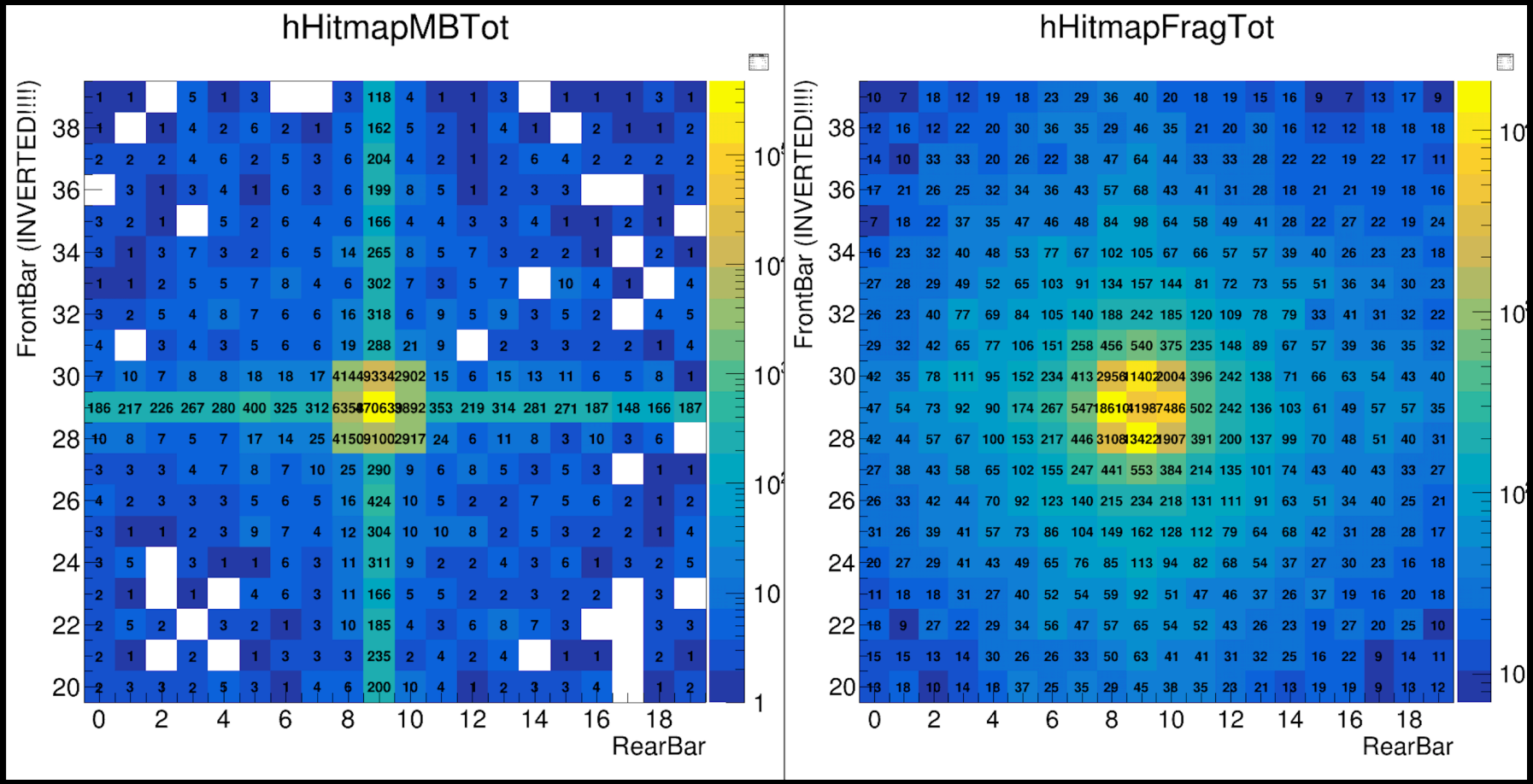
Trigger efficiencies (%)

^{16}O rejection factor: 11,8

H	He	Li	Be
95.7 ± 0.2	98.2 ± 0.1	99.1 ± 0.2	99.3 ± 0.2
B	C	N	O
99.6 ± 0.1	99.8 ± 0.1	98.2 ± 0.1	8.46 ± 0.03

Trigger

Physics: He + C @ HIT – Jul 2022



DAQ

Detector integration in DAQ has been tested extensively

- > 40 Mevents acquired at GSI in 2021 in different trigger configurations
- ~ 98 Mevents acquired at HIT in 2022 in different trigger configurations

- SC+BM+TW+Calo. DAQ rate up to 2.1 kHz.
  Very long tests (>12h) without any problem.

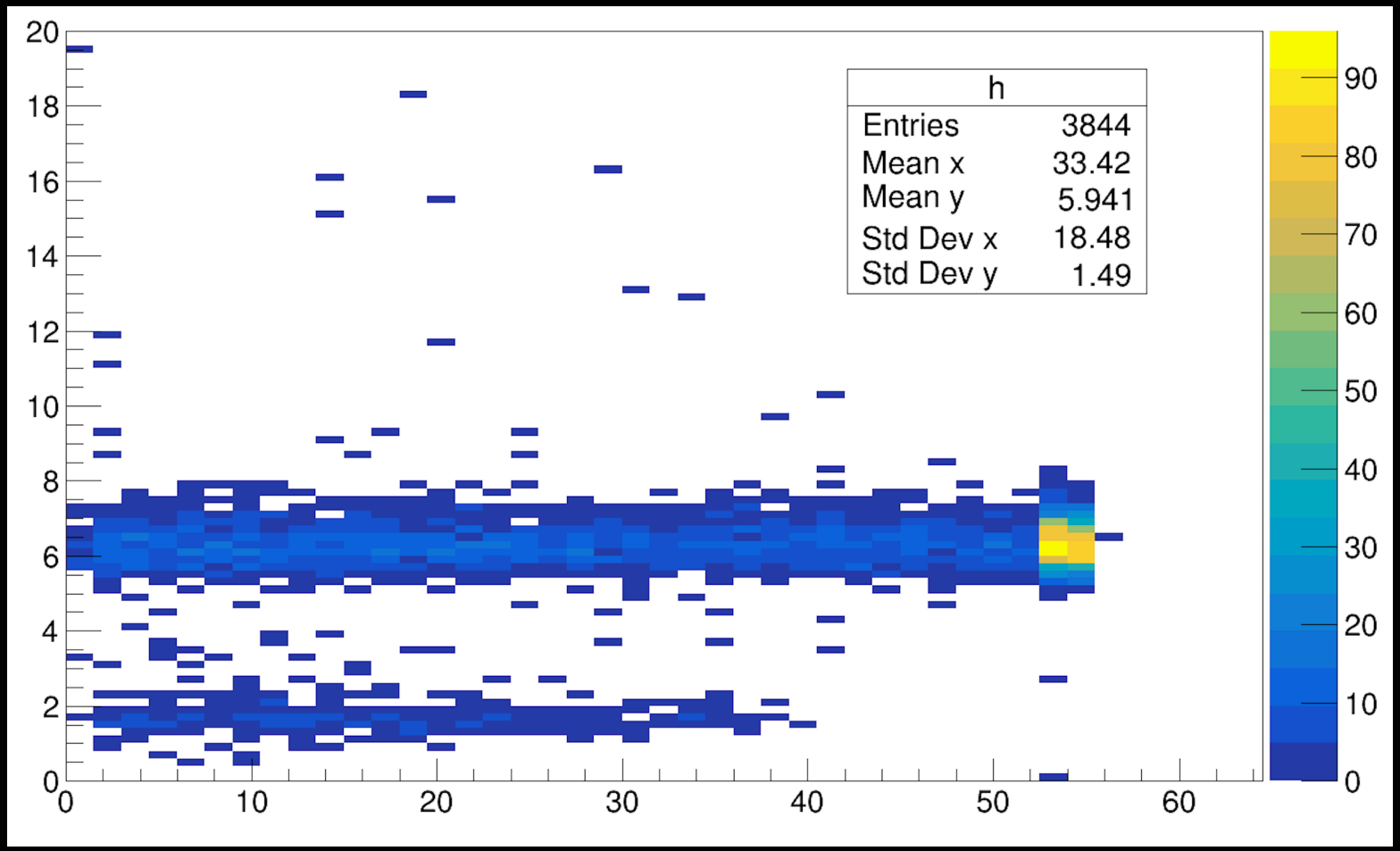
- MSD (6 xy planes).
  DAQ rate up to 2.4 kHz; long test (>4h) with no problems.

- VTX: 4 planes, 1 board. DAQ rate up to 1.2 kHz; safe rate at 0.75 kHz
  - Observed problems (lost triggers) under scrutiny;
  - changes in the firmware to address this problem
  - Rate limited by the rolling shutter mode of M28 (185 us x 3)

- IT: same architecture of VTX.

Fragment identification (TofWall + CALO)

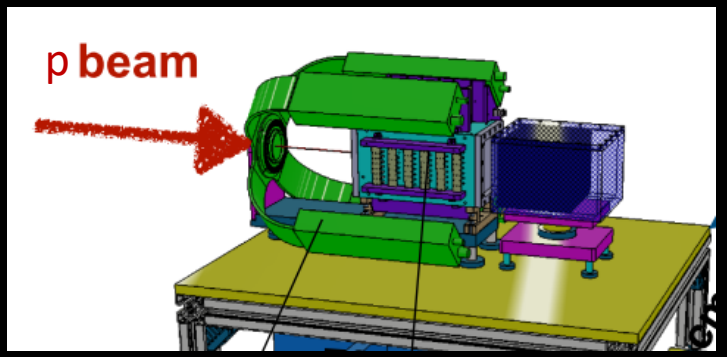
Physics: He + C



Emulsion spectrometer

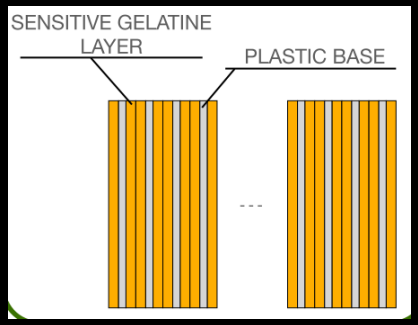
Upgrade: Nano Imaging Tracker emulsion for direct fragmentation measurements

NIT emulsions able to see
track length shorter than 100 μm;
better spatial resolution

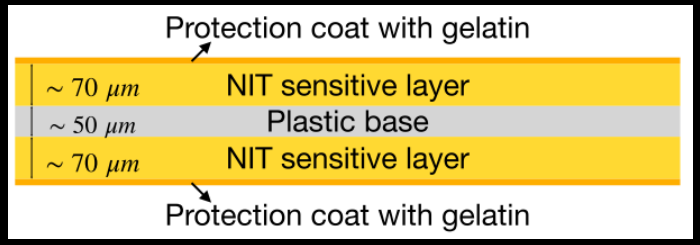


Direct fragmentation of target

cross section measurements become feasible



4% interactions in the detector, of which:
- 81% in emulsion gel (C, O, H, N, Ag, Br)
- 19% in plastic base $(C_8H_8)_n$

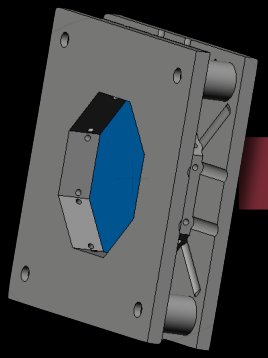


Production possible at LNGS!!!

Start Counter upgrade

MARGARITA 2.0 (Battistero)

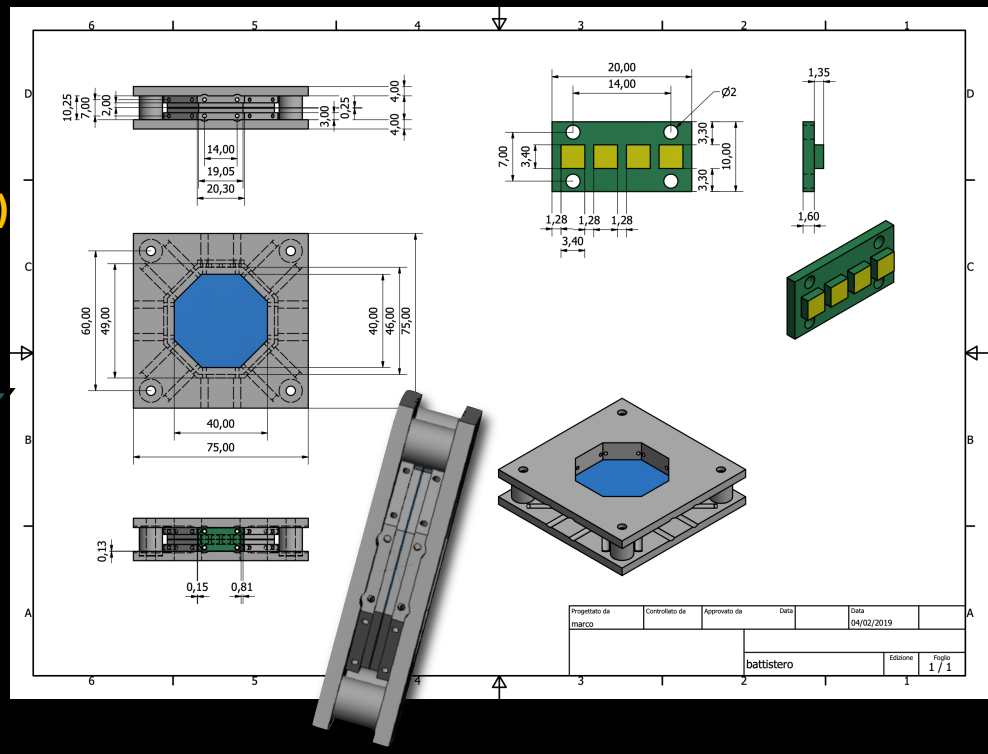
In order to maximize the light collection and improve the readout efficiency we intend to build a MARGARITA 2.0 with an optimized shape.



- 8 Boards (1 per face)
- 4-6 SiPMs per Board
- 32-48 SiPMs in total
- EJ-232 (Commercial)
  - or **2N** (SBAI+CREF **Patent!) plastic scintillator**.. thickness to be defined according to performance.

MARGARITA 1.0

- 8 Boards (2 per face)
- 6 SiPMs x 8 Boards
- 48 SiPMs in total
- EJ-232 Fast Plastic Scintillator, 250μm



June 2022 test beam with electrons (mip) at BTF with 5 mm samples and PMTs:

- 2N => 110 ± 10 ps
- EJ-232 => 160 ± 10 ps

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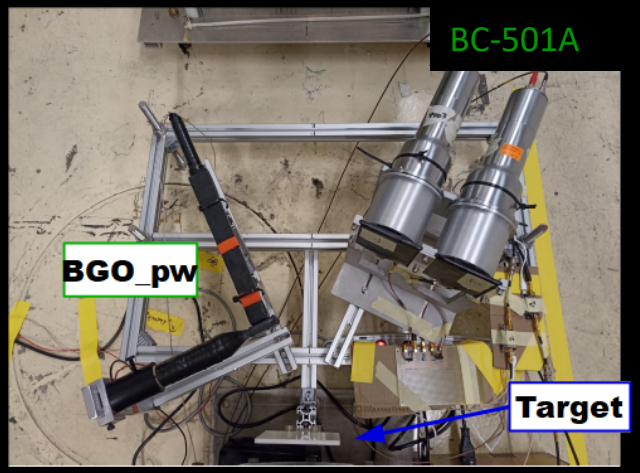
Neutron detection

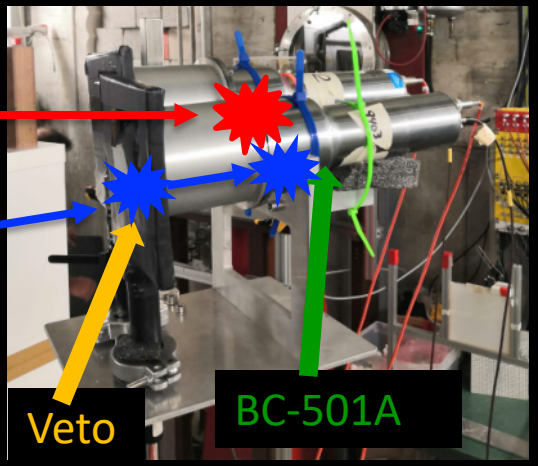
BC501 and BGO
being tested NOW



N-TOF
Neutron
beam

Neutral particles:
anticoincidence event

Charged particles:
coincidence event



GSI July 2021

^{16}O, 200 MeV/u, $(C_2H_4)_n$, 0.5 cm

^{16}O, 400 MeV/u, $(C_2H_4)_n$, 1 cm

$$\frac{d^2\sigma}{dEd\vartheta}$$