Updates on Simulation

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Introduction and outline

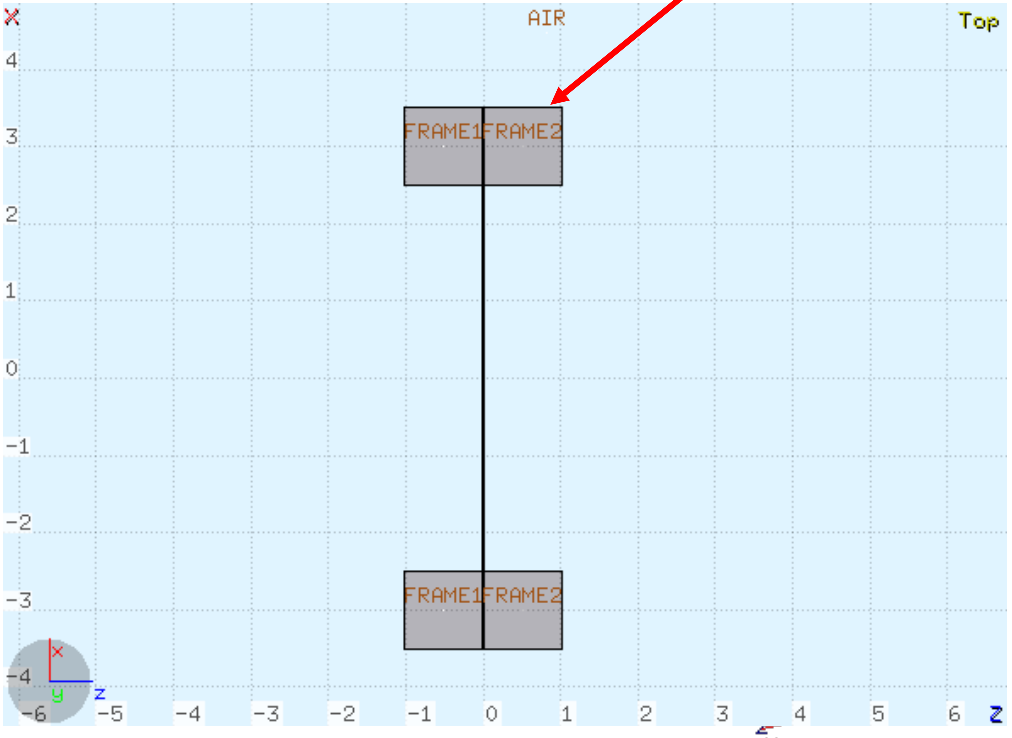
We summarize here the main results concerning MC developments in the last months:

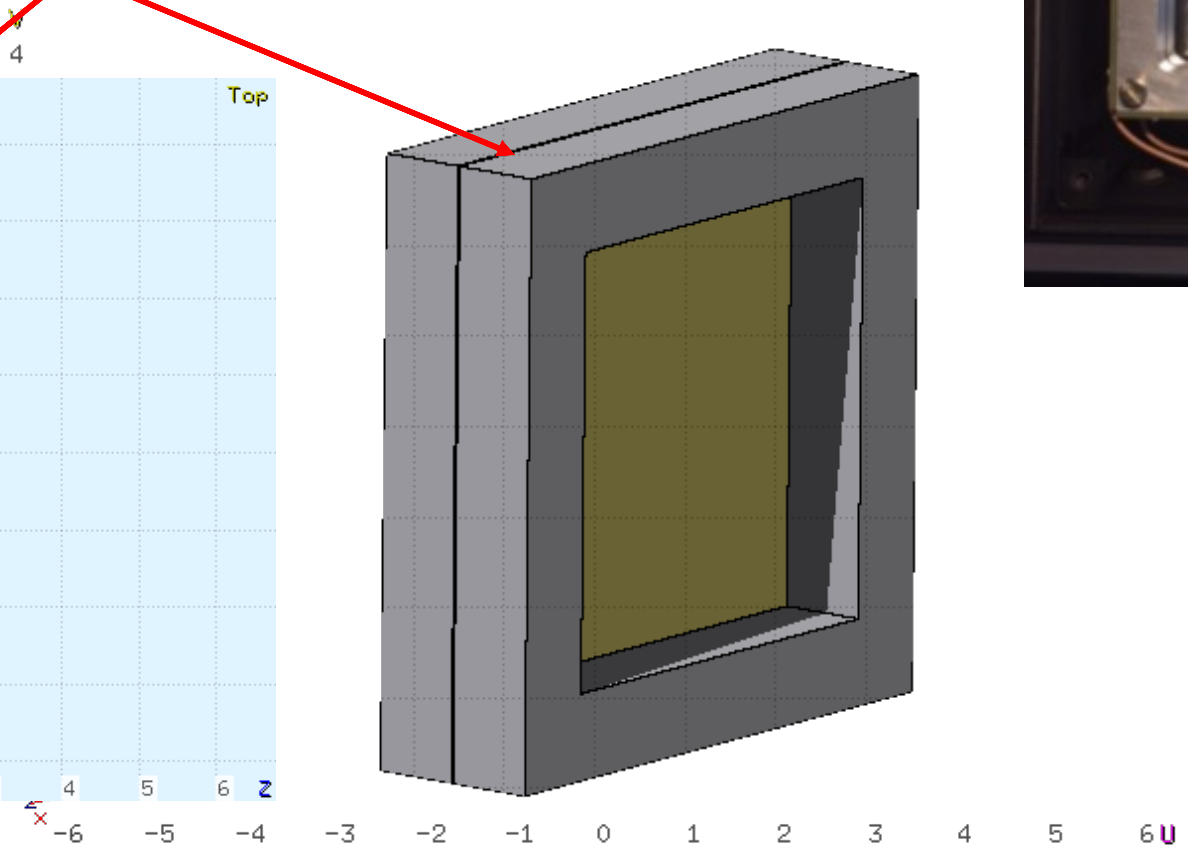
1) Introduction of the most relevant **passive materials** for SC, VT and MSD (IT already had them)
2) Preliminary work for the **2025 GSI campaign** (MAECI project MOFFIITS)
3) Proposal for a **paper on the FOOT simulation**
4) Next developments

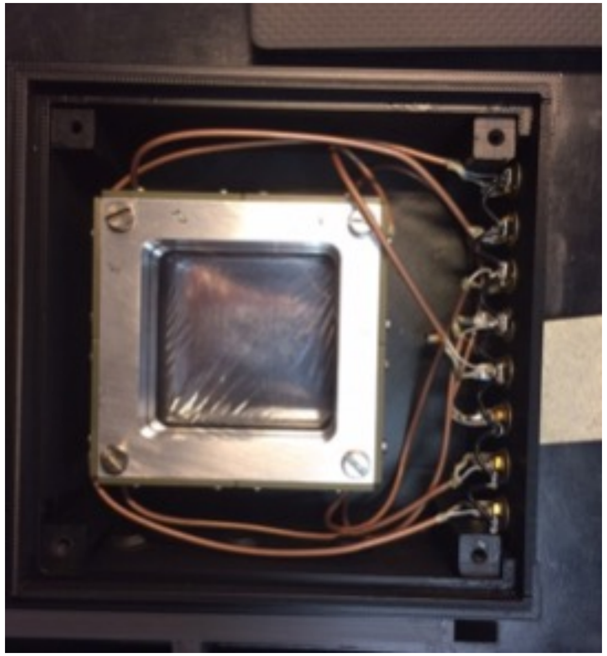
Passive materials

New FLUKA geometry of SC

1 + 1 cm Al frame



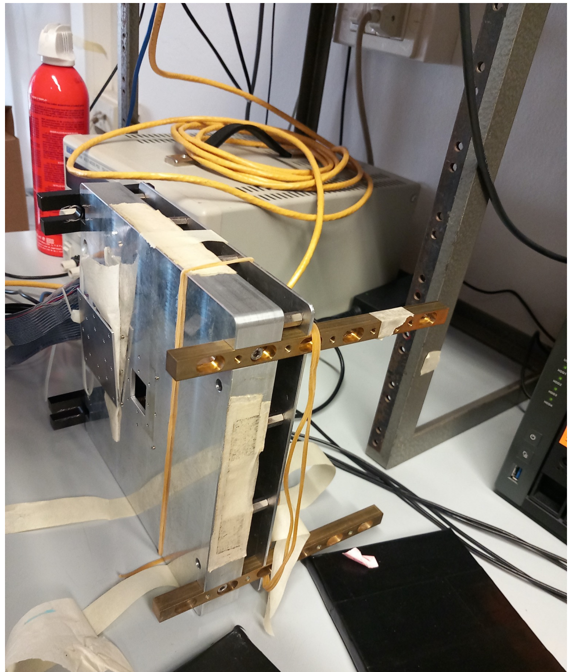




In the case of FOOT, the beam at SC should be sufficiently narrow to avoid hitting the frame

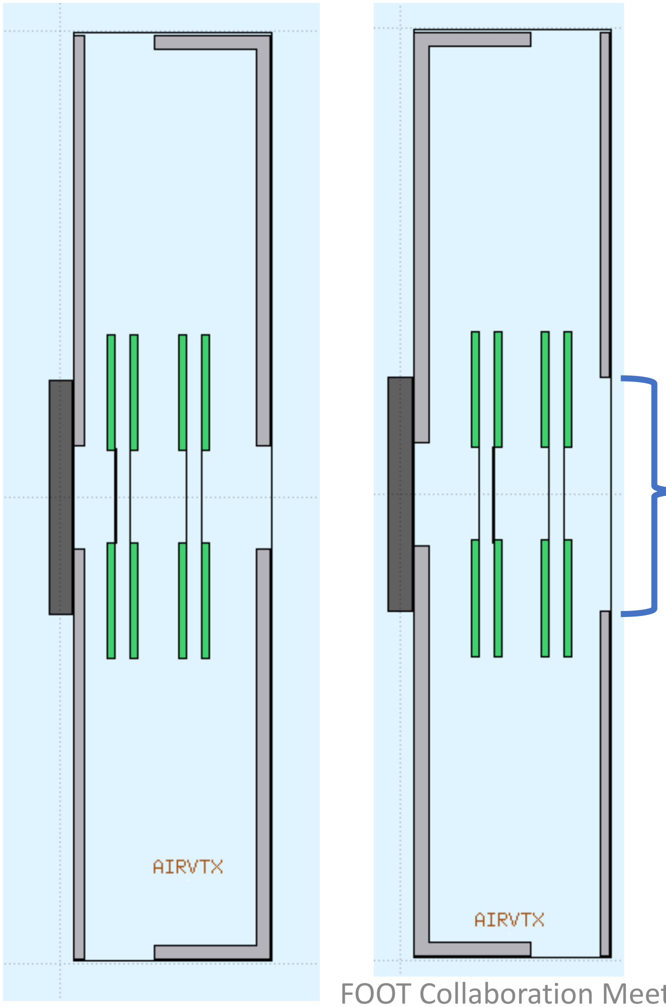
VTX geometry

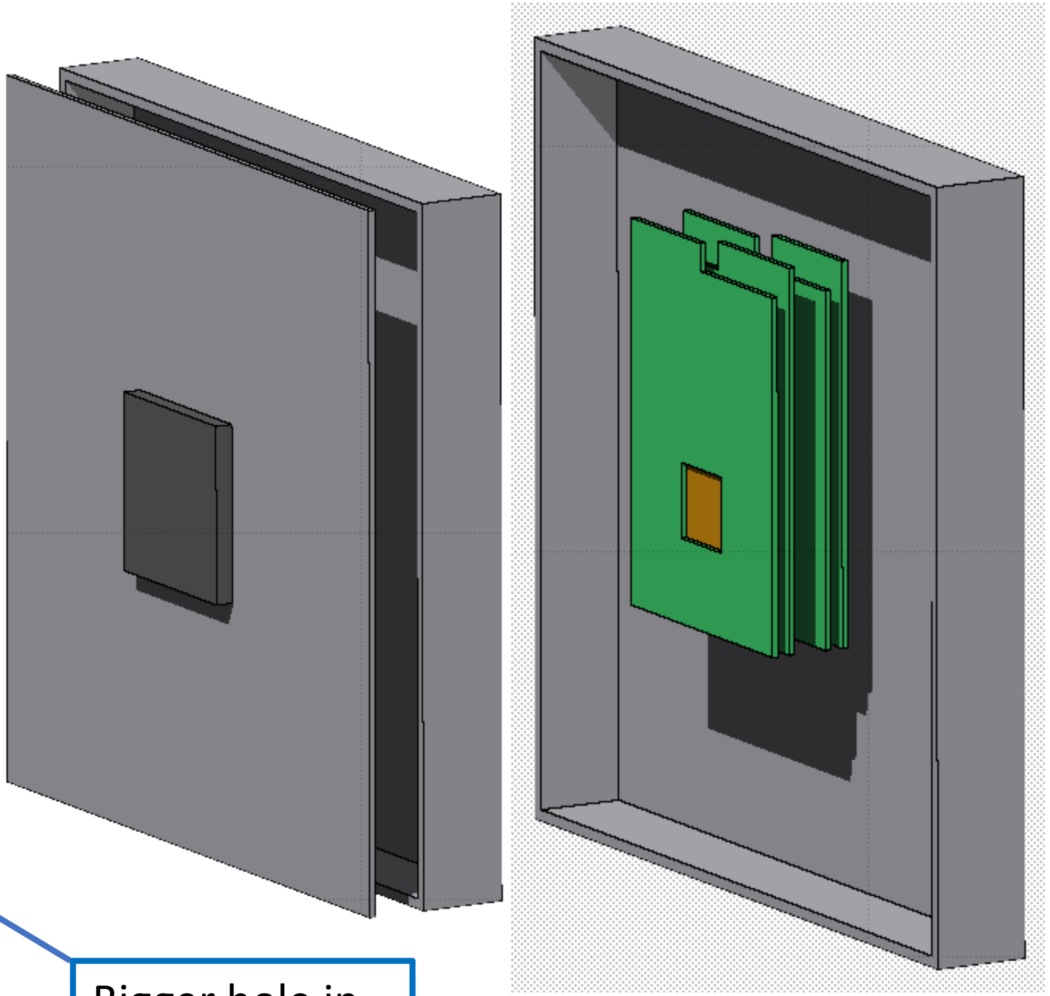
In the last campaigns it has changed.
Possible new changes are expected in the future



GSI2021
CNAO2022

CNAO2023



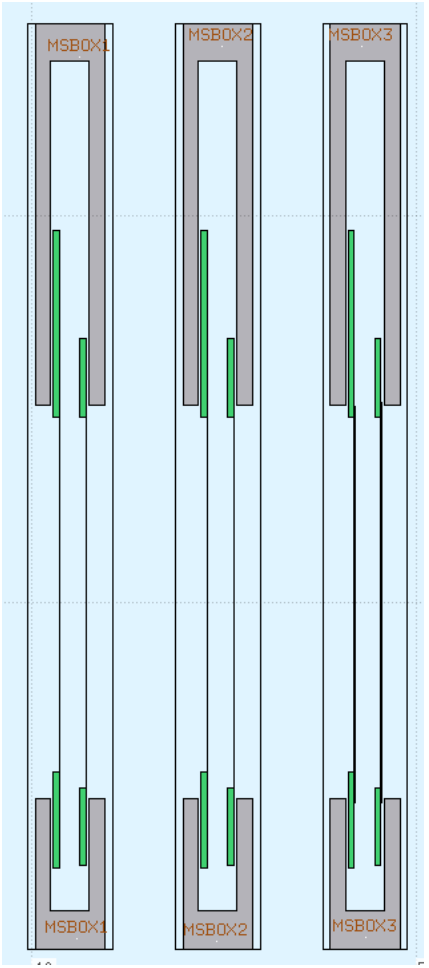


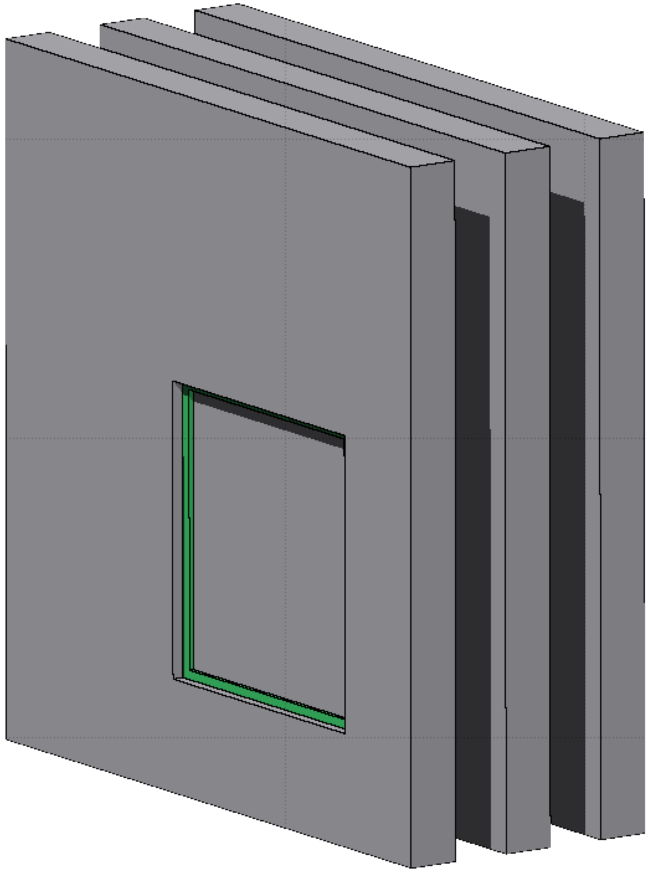
Bigger hole in the back layer

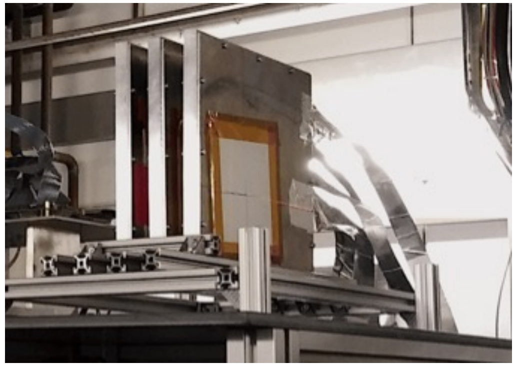
Printed board material:
- Elemental composition is an average of the existing ones in literature. Used also for MSD.

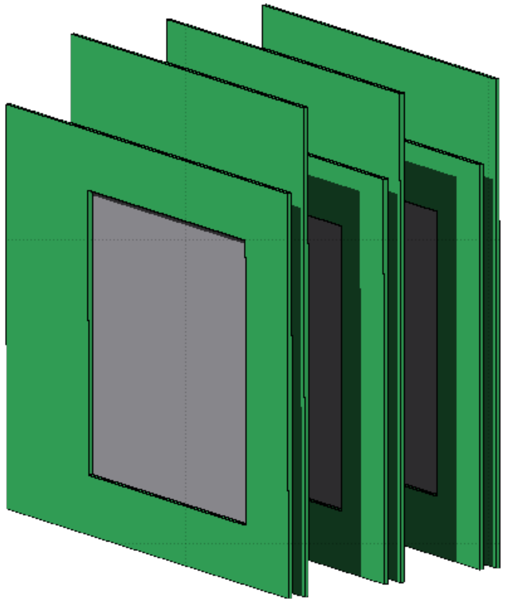
MSD: GSI2021/HIT2022/CNAO2022

3 boxes (3 different AIRMSD)

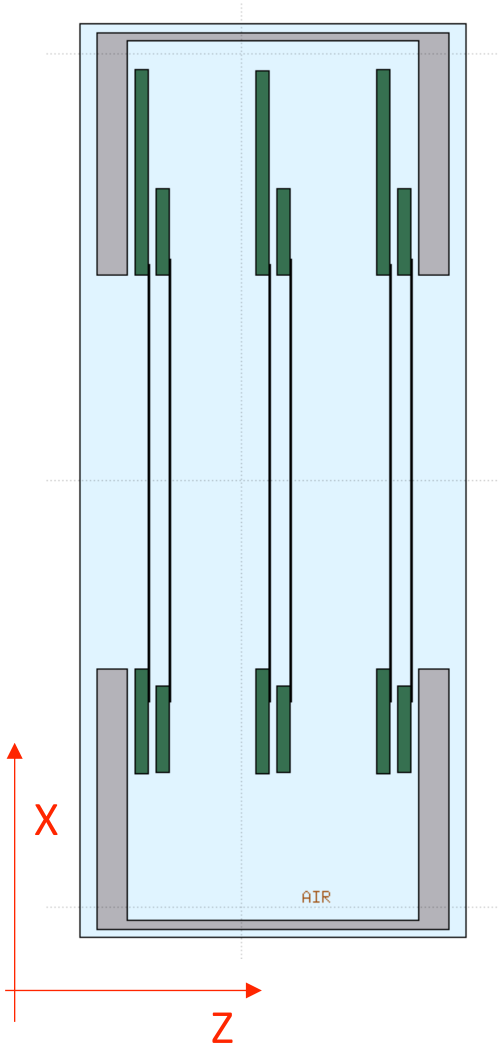


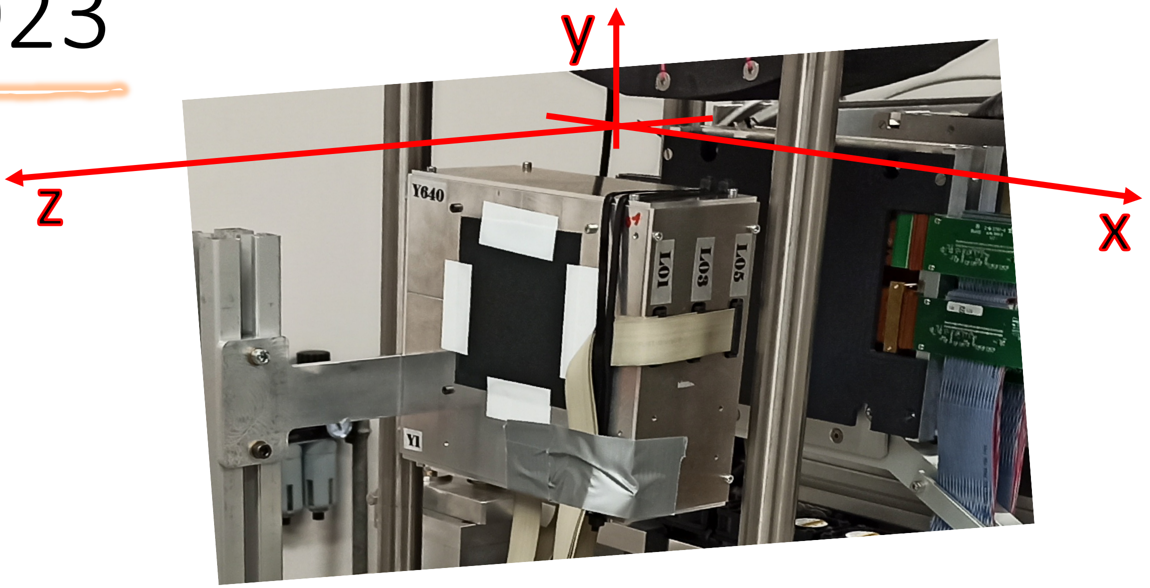


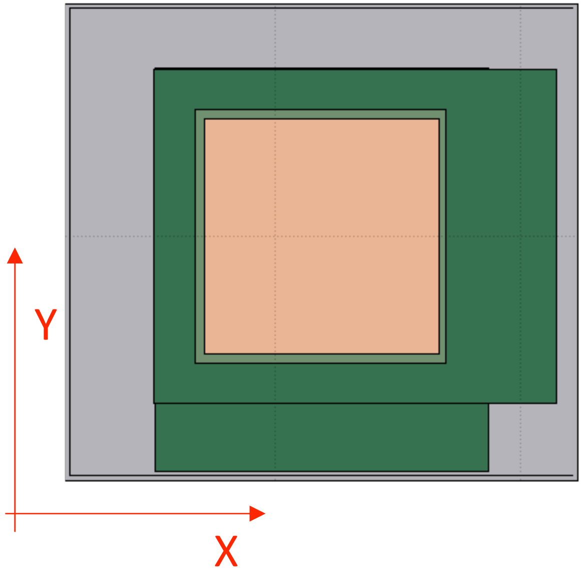


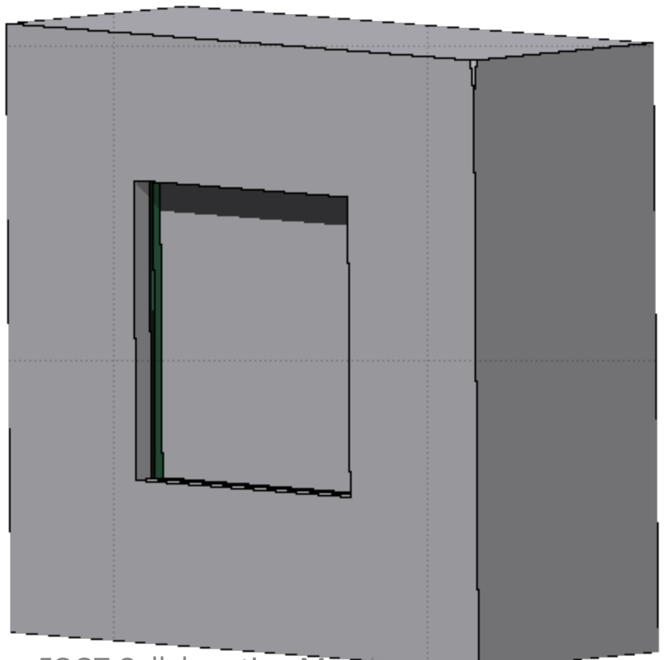


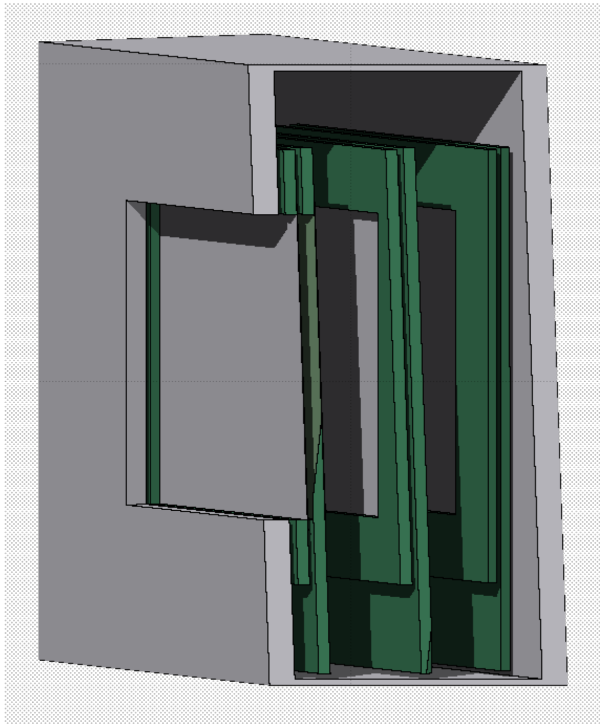
MSD: CNAO2023



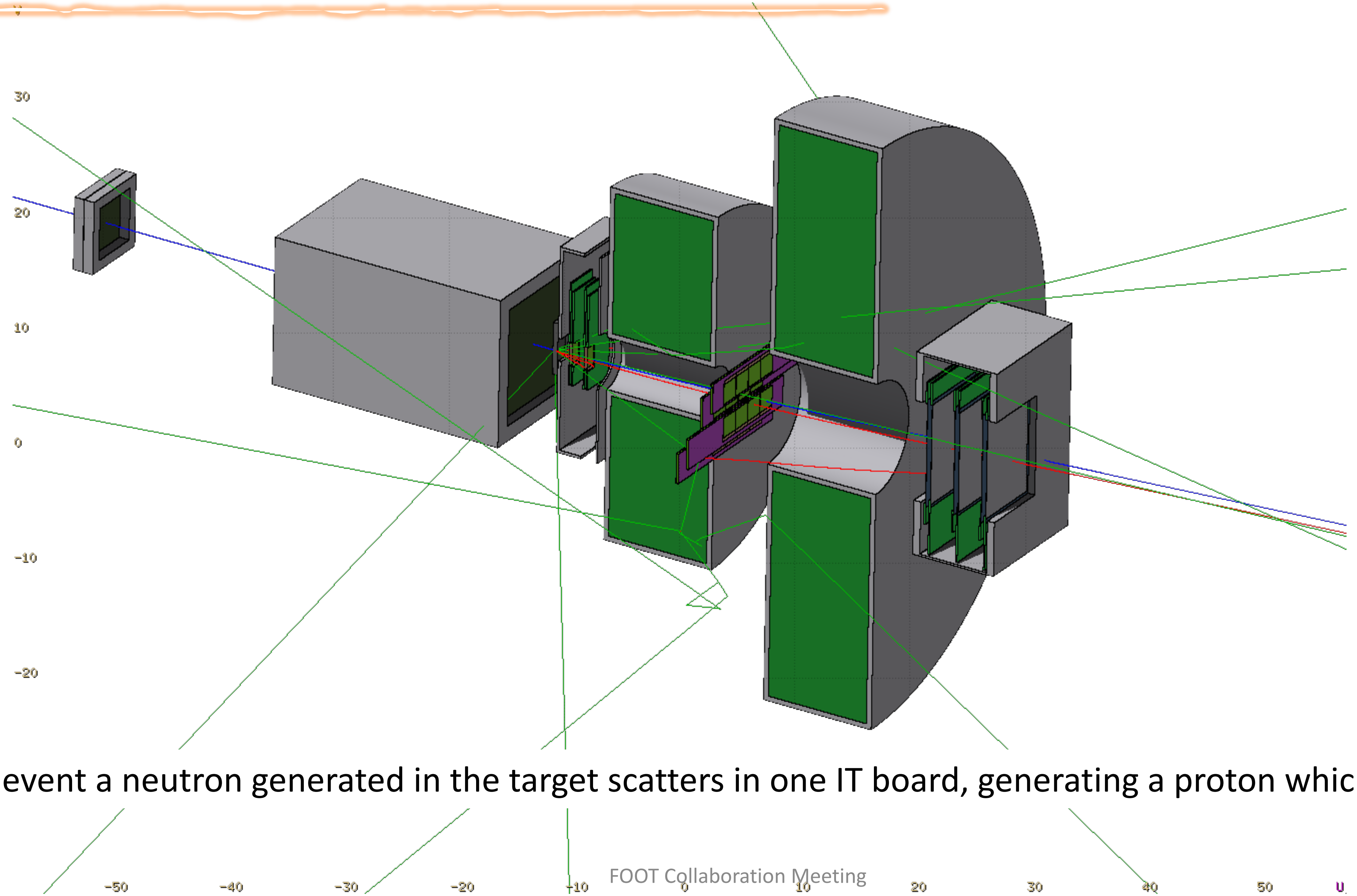








IT already had the main passive elements



In this event a neutron generated in the target scatters in one IT board, generating a proton which hits MSD

New separate MC campaigns with passive materials

To keep them separate from the old ones and make the comparison easier:

GSI21PS_MC (to be compared with GSI2021_MC)

run: 400 (^{nat}C), 401 (C_2H_4), 402 (AIR), 200, 201, 202

HIT22PS_MC (to be compared with HIT2022_MC)

run: 100, 140, 200, 220

CNAO22PS_MC (to be compared with CNAO2022_MC)

run: 200 (^{nat}C), 201 (C_2H_4)

CNAO23PS_MC (to be compared with CNAO2023_MC)

run: 200 (^{nat}C), 201 (C_2H_4), 202 (AIR)

Warning: so far in MC campaigns run number was just set to 1.

We prefer, from now on, to use by convention in MC a run number that remembers the *energy of the beam* and the *composition of the target*

For analysis purposes: details on the name and number of new regions are contained in the **FOOT.reg** file in the **geomaps** directories

The new MC productions:

We have produced GSI21PS_MC and CNAO23PS_MC

- **GSI21PS_MC**:

  5 Millions of primaries, ^{nat}C target (run 400), C_2H_4 target (run 401) and no target (run 402), 1 sigle file for each run

  Tier1: /storage/gpfs_data/foot/shared/SimulatedData/GSI21PS_MC

- **CNAO23PS_MC**:

  5 Million of primaries (run 200, ^{nat}C target) in 5 files

  Tier1: /storage/gpfs_data/foot/shared/SimulatedData/CNAO23PS_MC

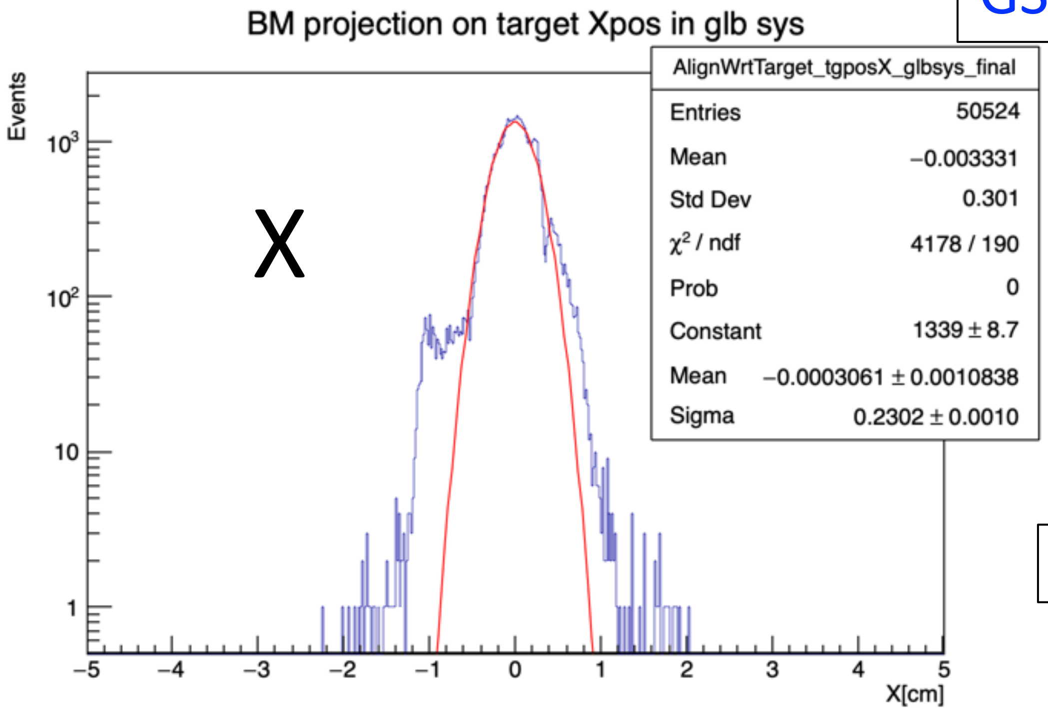
Geometry for the new GSI21PS_MC campaign

run 400 (^{nat}C target), 401 (C_2H_4 target), 402 (No target)

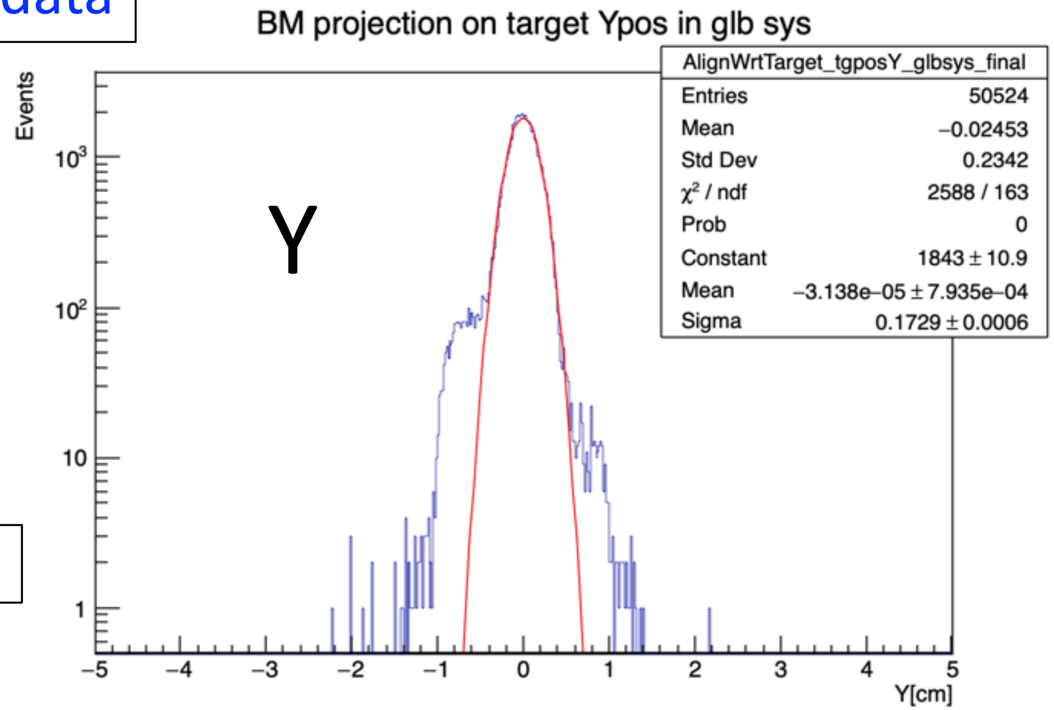
Towards a meaningful simulation

The main issue is the Beam Model and its lateral structure (otherwise the addition of passive material might be not considered in the correct way)

GSI2021 exp data



Raw BM map

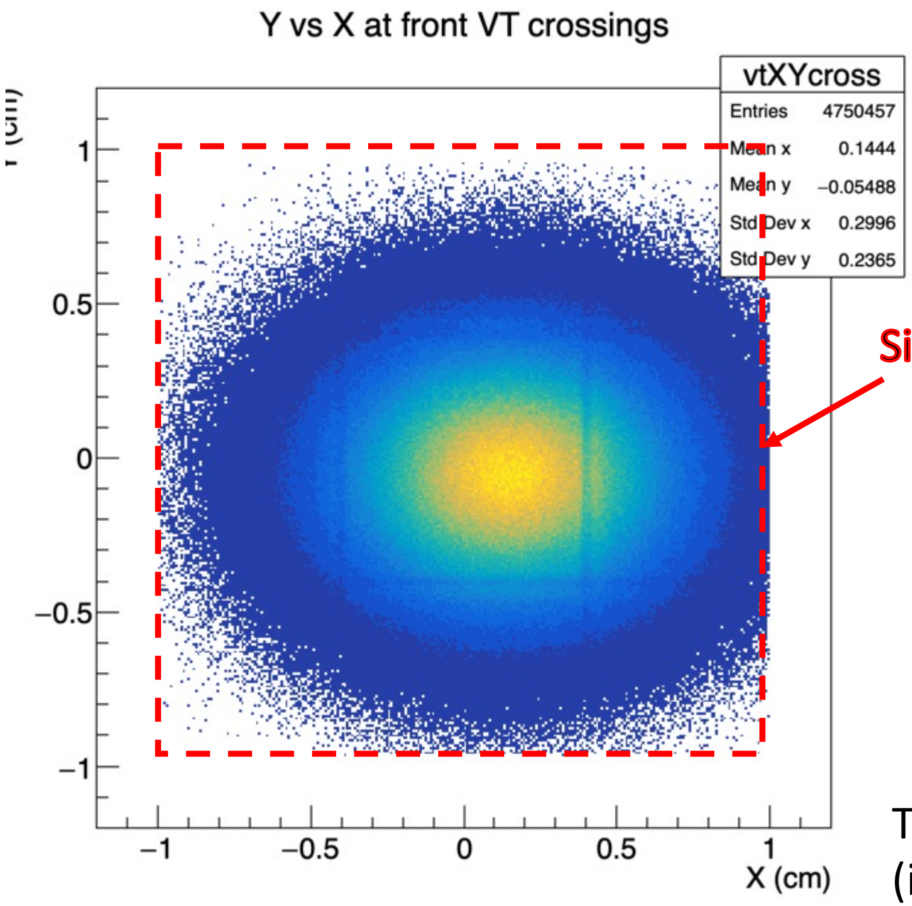


Discussed with Physics coordinator and others: the beam is centred according to the translation of the VTX in FOOT.geo **AFTER** alignment. This means to take the position of the beam from NO-TG run for clean events in VTX with one single track.

2 independent X-Y gaussians having FWHM of 0.7104 and 0.5527 cm respectively, and slightly off-centered:
<x> = +0.147 cm;   <y> = -0.055 cm

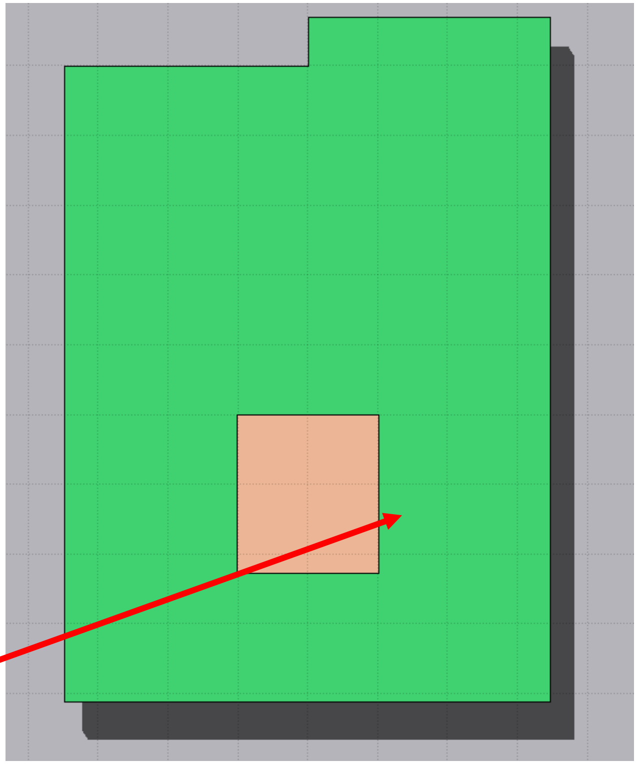
Interaction of primaries in passive materials:

No interactions on the SC frame (beam width is not so large)
The main effects have to be expected by interactions on the VT (<u>although still small</u>)



Size of active region

Tails of the beam hit the Printed Circuit Board



The number of primary interactions in the VT increases by ~13% (in absolute it remains a small number as compared to interaction in air)

Some numbers for GSI21PS_MC run 400

Interaction of primaries: (^{16}O 400 MeV/u on graphite target)

Total no. of Processed Events: 5000000

No. of interactions in Air: 64761 Before TG: 20408 After TW: 44353

No. of interactions in STC: 8352 (STC passive mat: 0)

No. of interactions in BMN: 7057 (shield: 3; mylar wind.: 1709; sense wires: 33; field wires: 624; gas: 4688)

No. of interactions in TGT: 200458 (~**4%**)

No. of interactions in VTX: 7267 (VTX passive mat: 791)

No. of interactions in MSD: 29407 (MSD passive mat: 25)

No. of interactions in TW : 169690

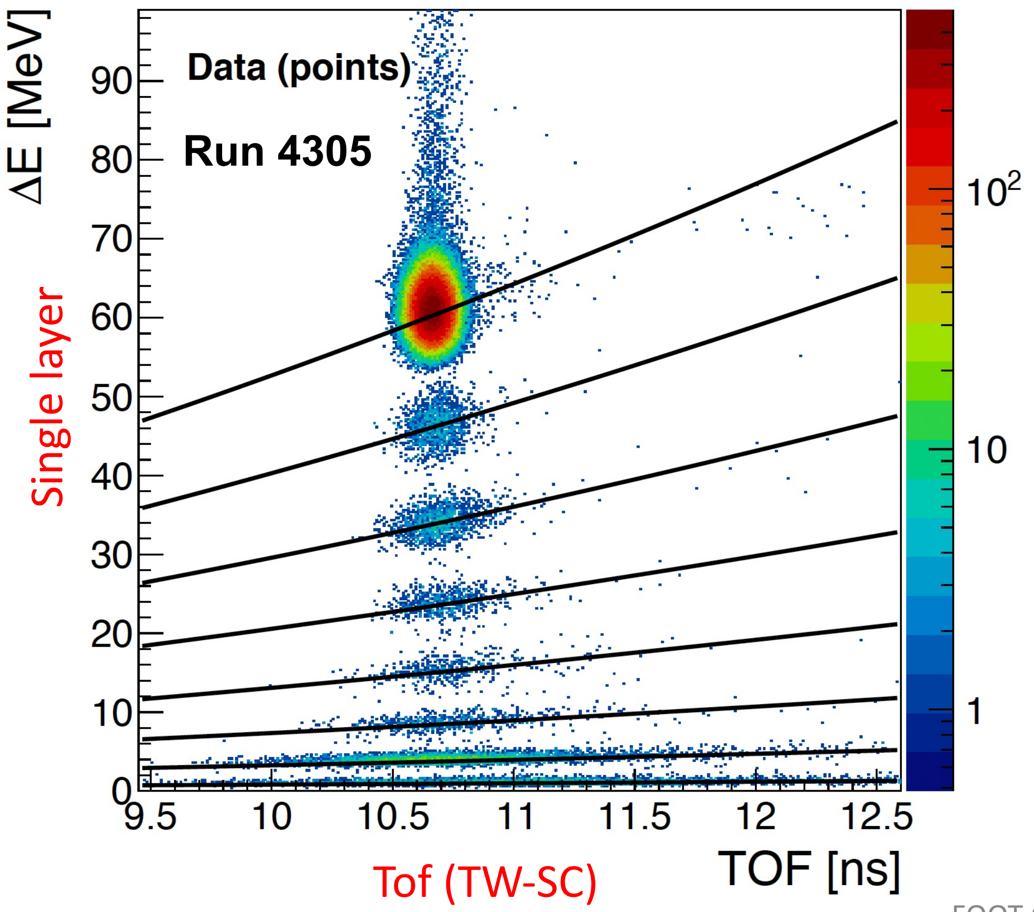
^{16}O @ 400 MeV/u + ^{nat}C target

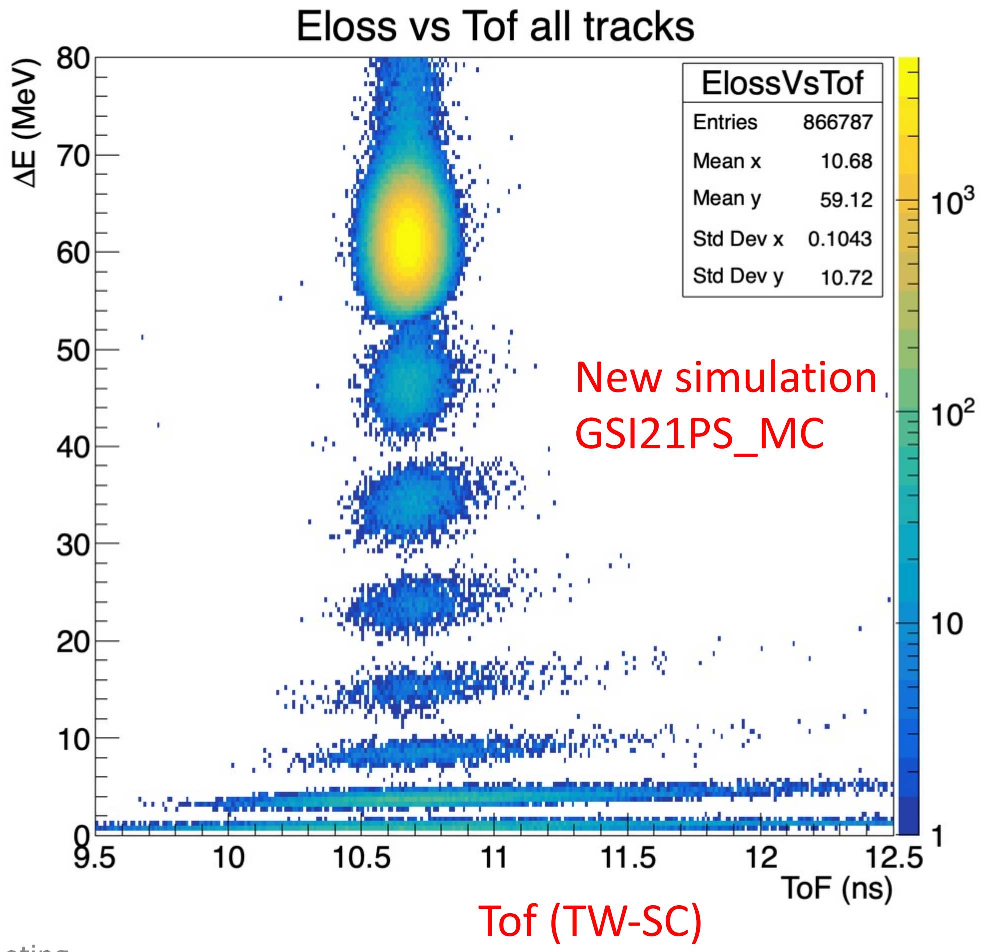
$$ToF\left(400\frac{MeV}{u}\ Target - TW\right) = \frac{L}{\beta\ c} \sim \frac{189.15\ cm}{0.71\ \cdot\ 29.979\frac{cm}{ns}} \sim 9\ ns$$

ToF (SC-Target) $\sim 1.74\ ns$

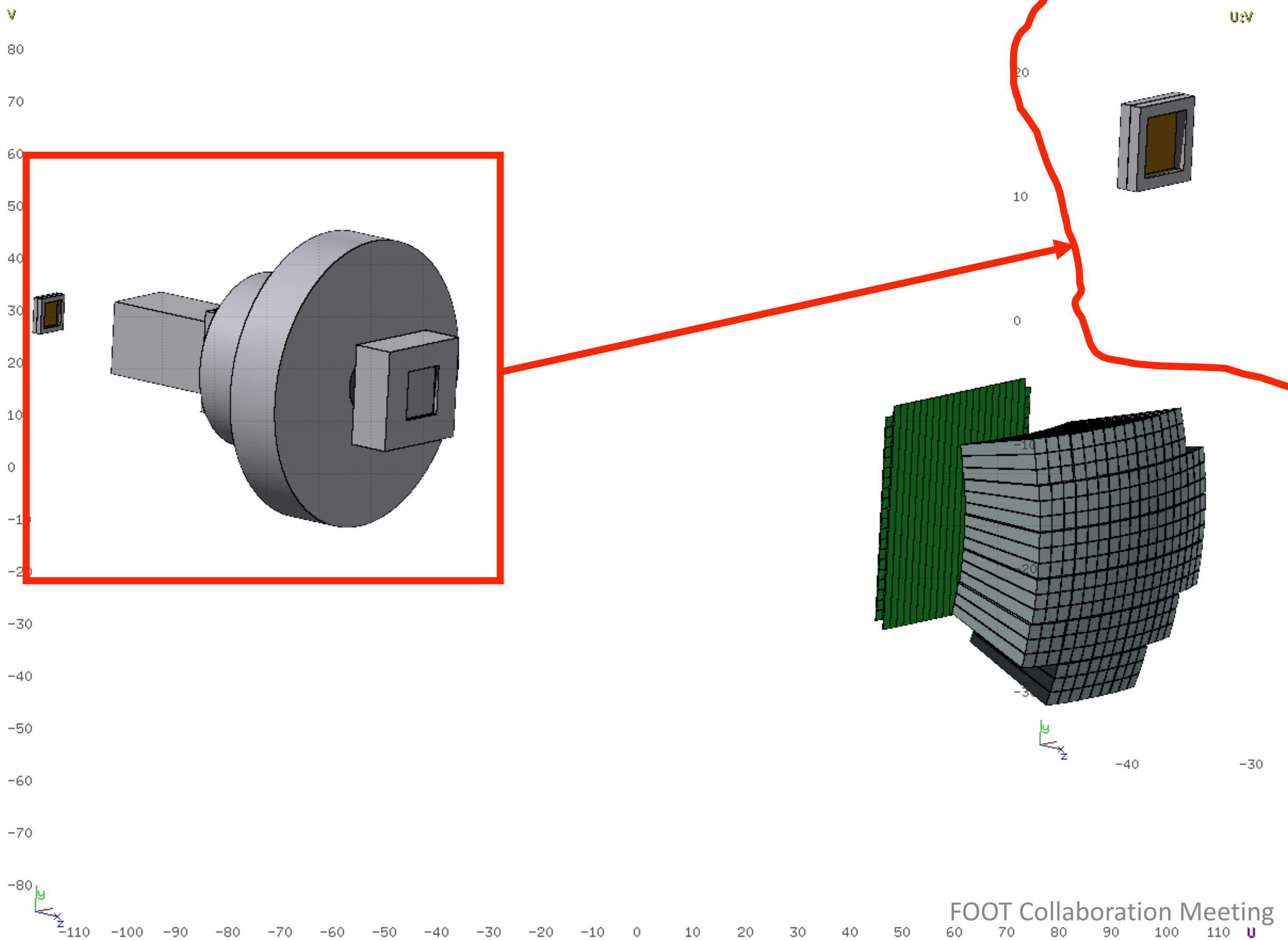
ToF (SC-TW) $\sim 10.7\ ns$

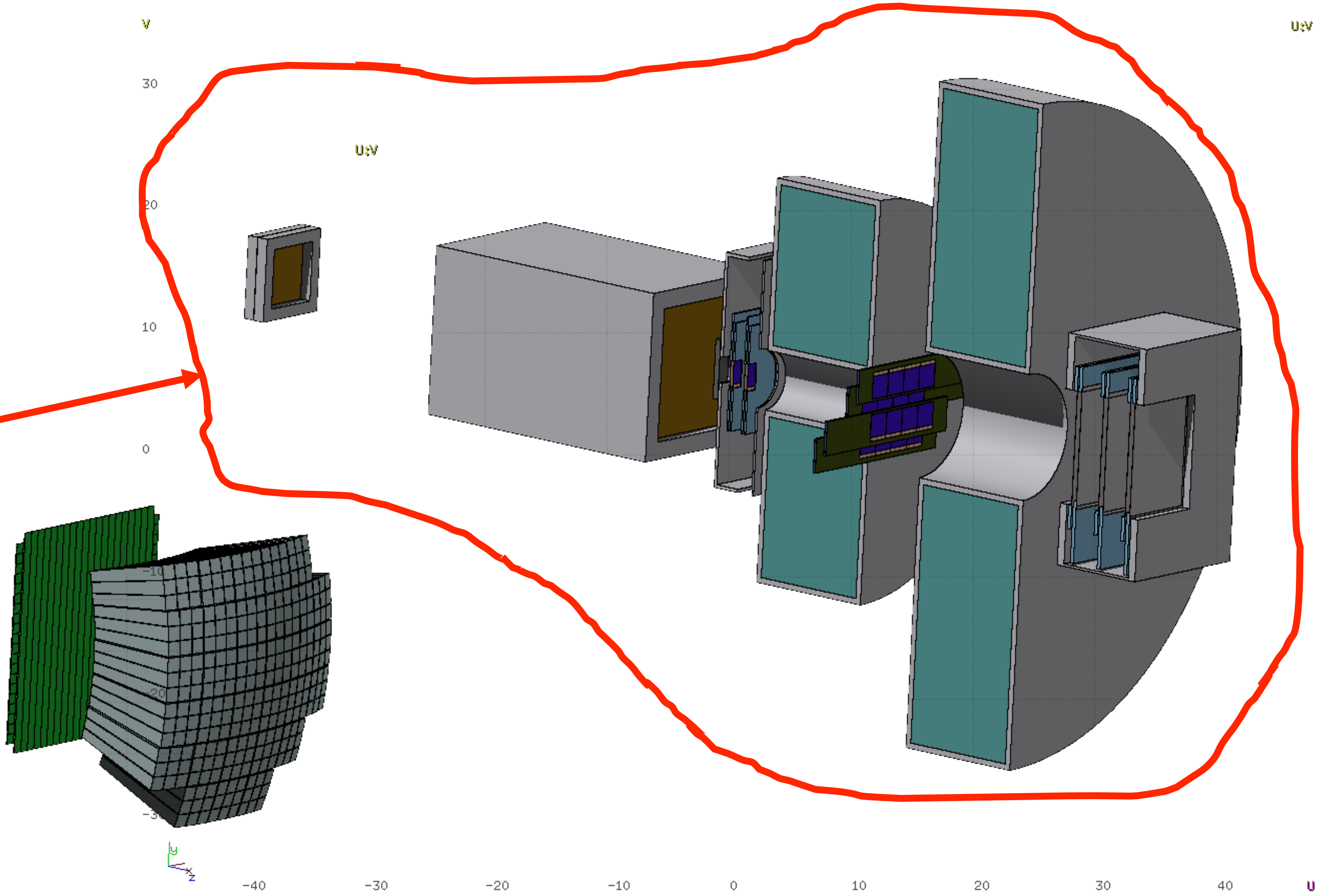
$$\frac{dE}{dx}\left(^{16}O\ @\ 400\ \frac{MeV}{u}\right) \sim 0.020\frac{GeV}{mm}$$



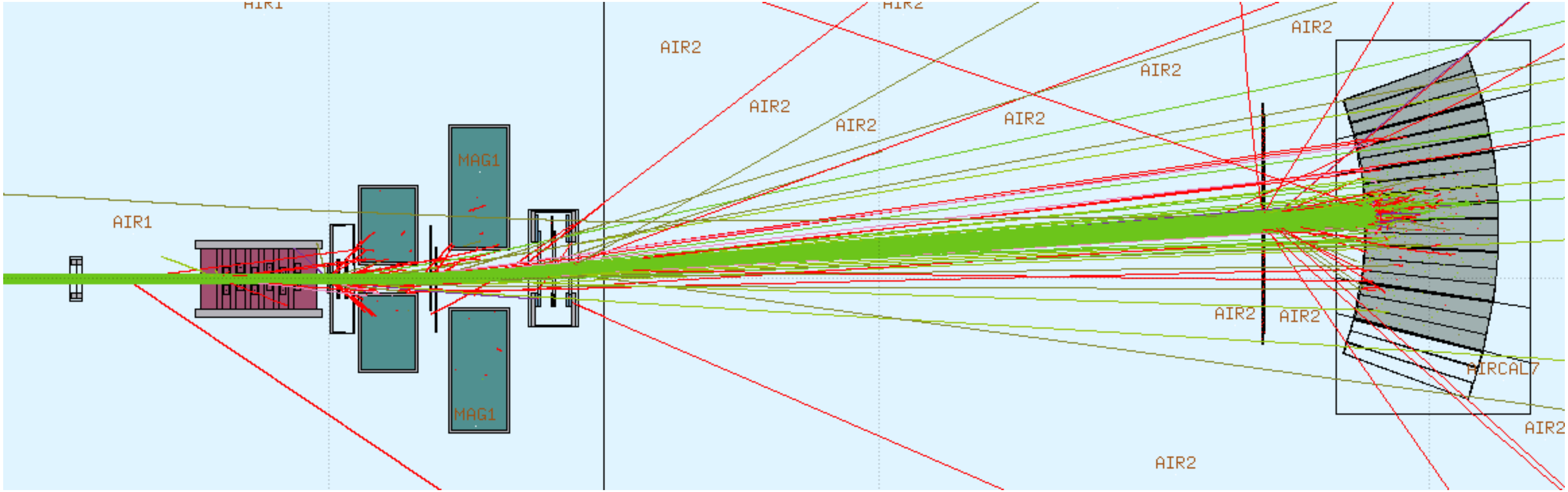


The new CNAO23PS_MC geometry





The new CNAO23PS_MC geometry



500 primary events overlapped

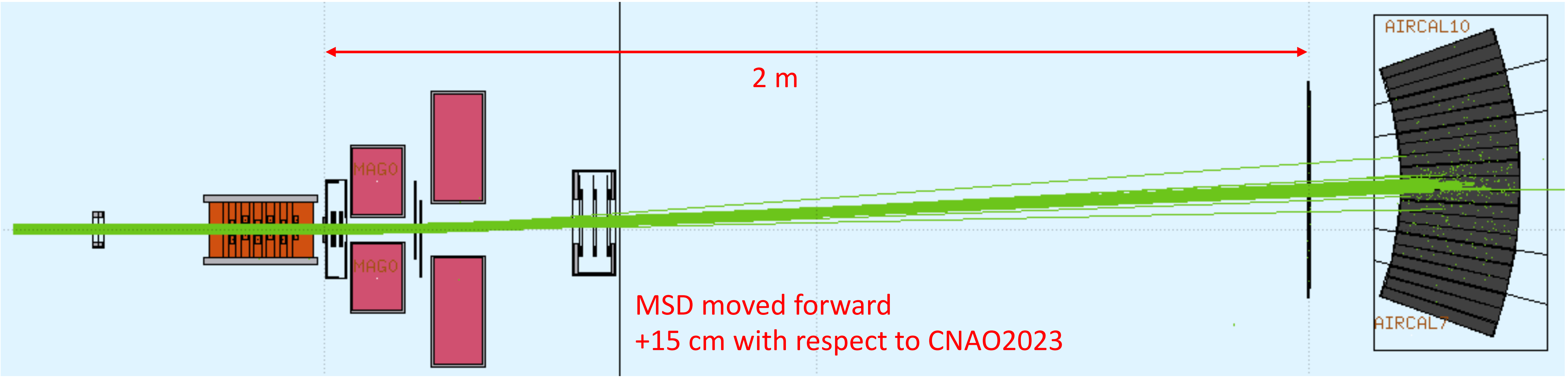
Not yet analyzed

2025 GSI campaign
(MAECI project MOFFIITS)

A new campaign: **GSI25PS_MC** for MAECI project

^{16}O @ 500 MeV/u ^{nat}C target

Cloned from CNAO23PS_MC with few differences



10^6 events - Shoe Genfit reconstruction

Warning: Z-id calibration not yet available

Work in progress

- Positioning of all detectors is still provisional:

  we have to understand better the available space in cave A.

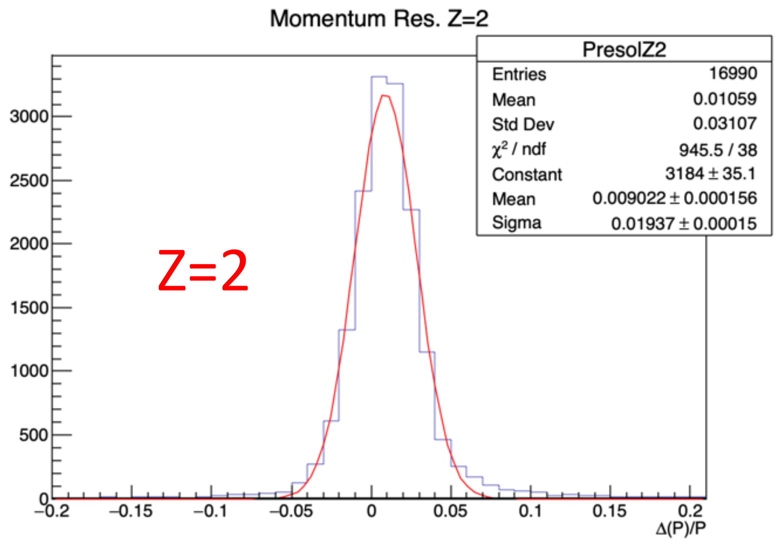
- Studies:
  - Momentum resolution as a function of spacing between the different tracking detectors
  - Mass resolution from P-ToF combination

- Preliminary results are obtained in an optimistic approach:

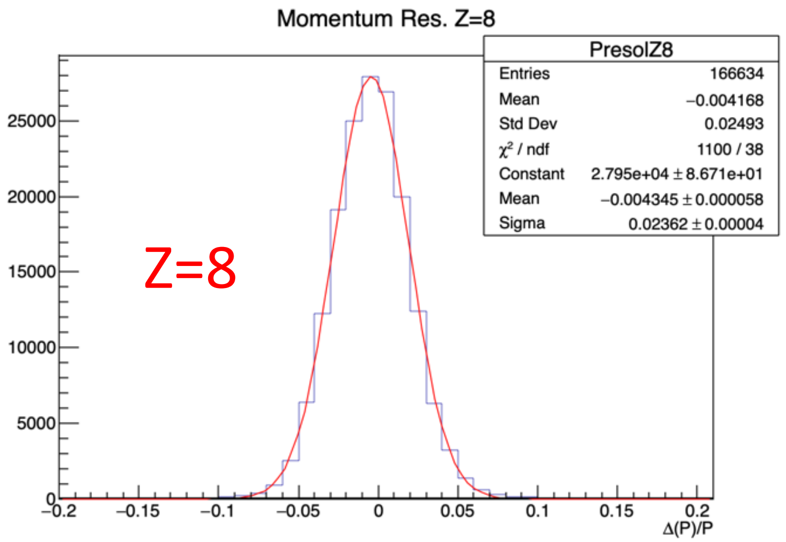
  in order to reduce CPU time and the size of the output file, the production of particles in the calorimeter has been switched off (too many neutrons)

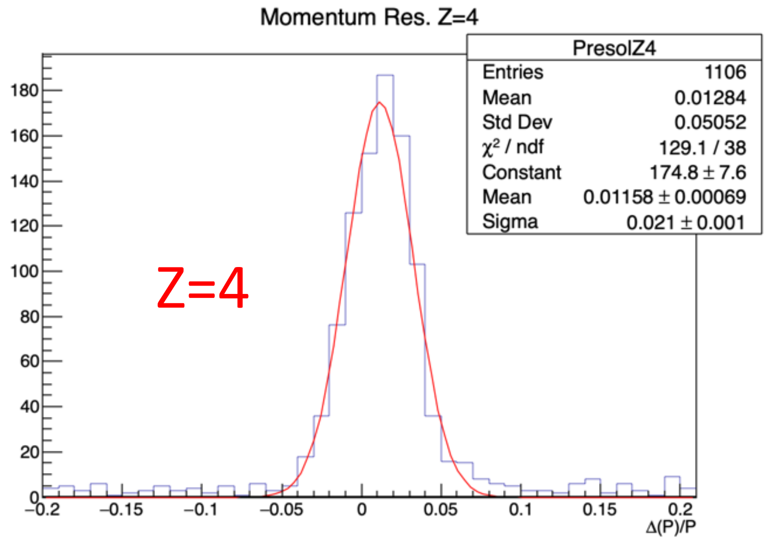
Momentum Resolution

glbtrack->GetTgtMom() to obtain P from reconstructed track evaluated at production in target



$$\frac{\Delta P}{P} = \frac{(P_{rec} - P_{true})}{P_{true}}$$





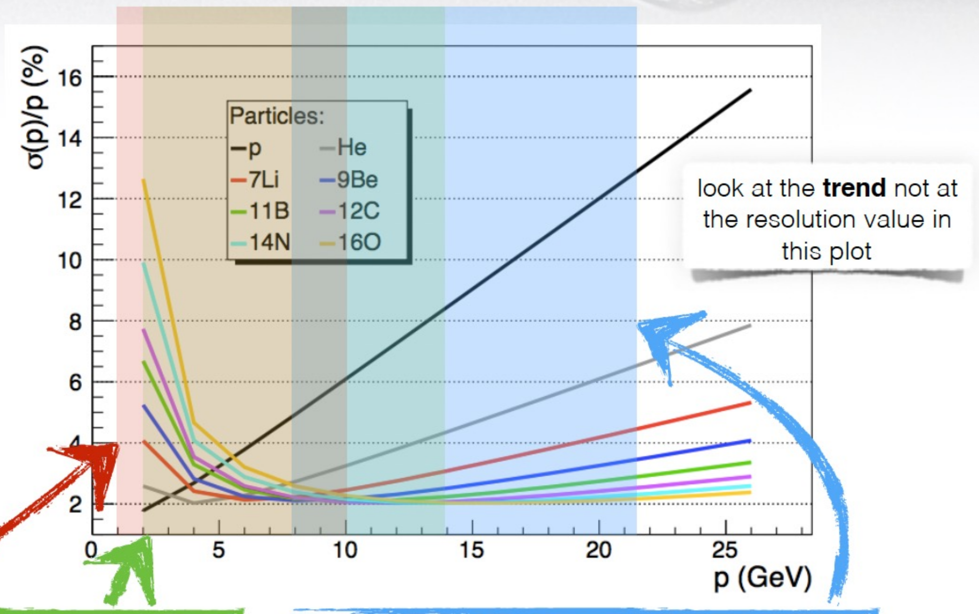
Here Z = Ztrue (MC)

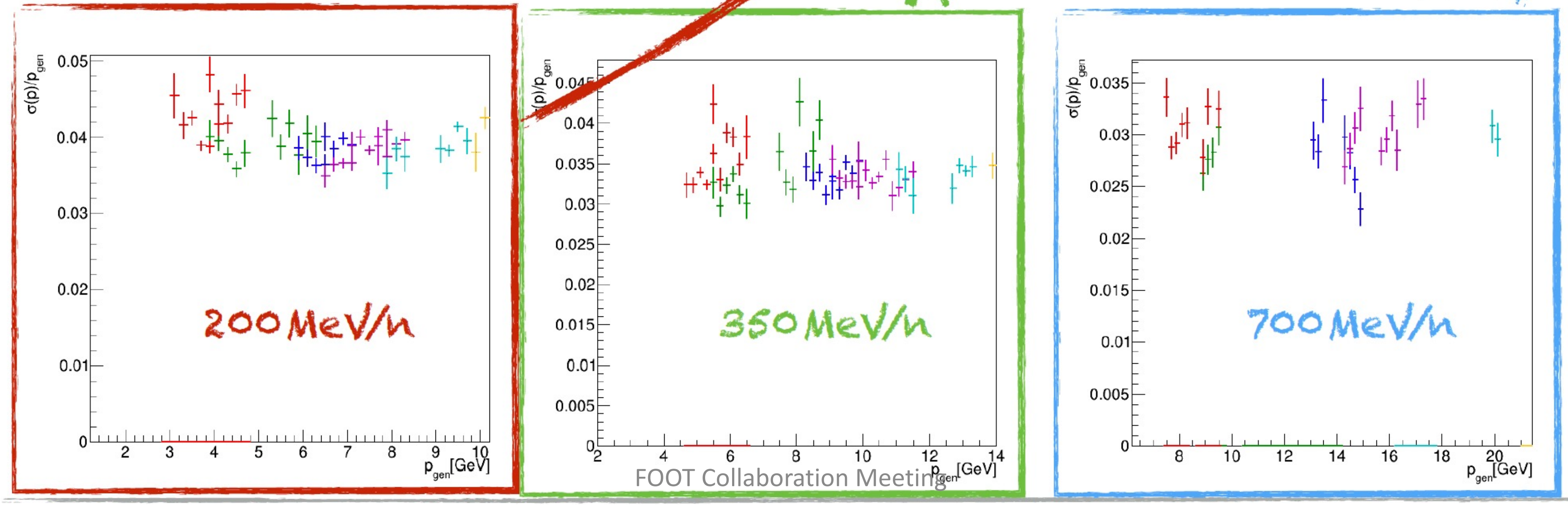
$\sigma_P/P < 3\%$

Preliminary

From a study presented by M. Franchini at FOOT Meeting June 2018

- **At 200MeV/n**, all elements are in the “decreasing” part, dominated by ***MS contribution***;
  - **light elements** have *lower p*: MS contribution fall earlier;
  - **heavy-elements** have *higher p*: approaching minimum, MS not so high anymore;
- **At 700MeV/n**, all in region dominated by ***spatial resolution***;
  - **light elements** (steeper growth, lower-p minimum) have low p; still close to the minimum
  - **heavy elements** (grows slower, higher-p minimum) have higher p but still close to the minimum

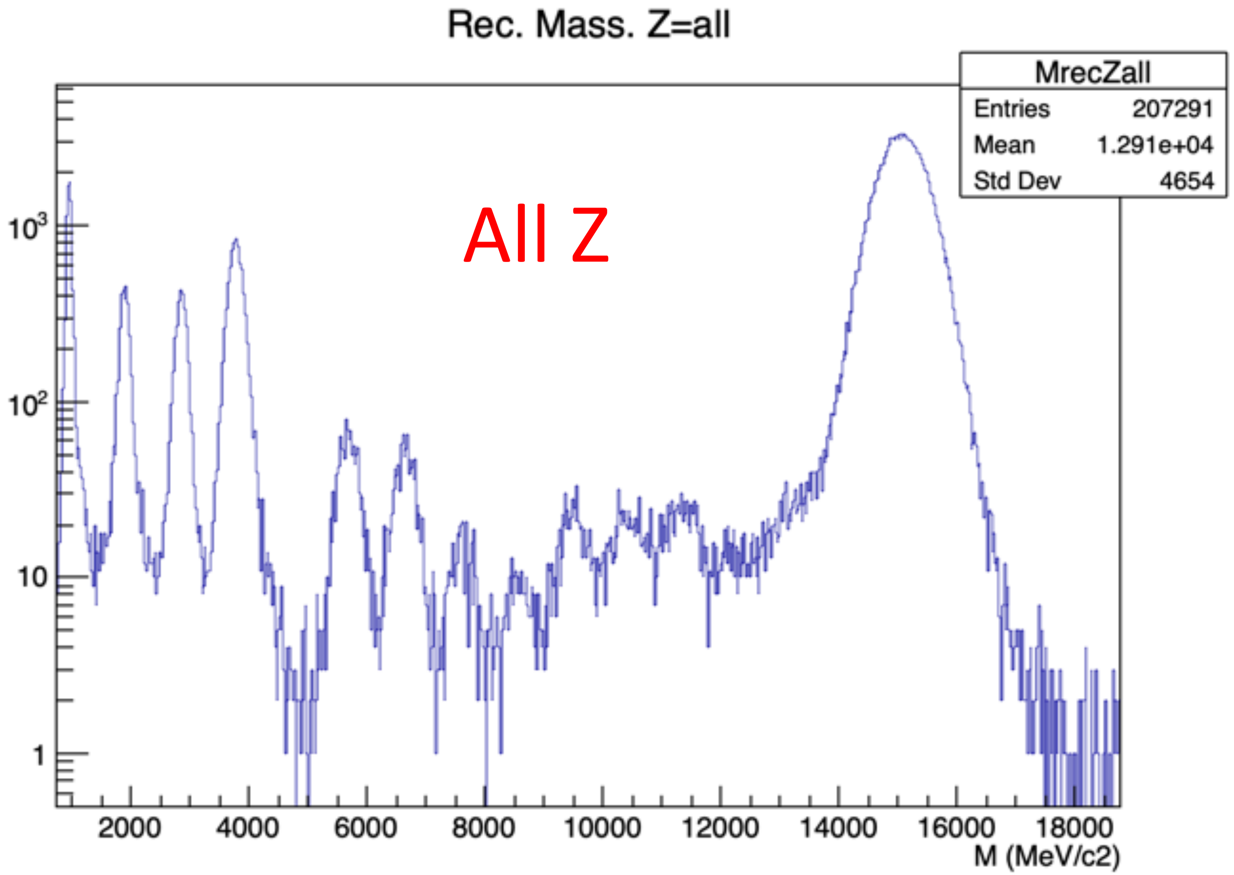




Isotopic Mass-Id using P and ToF

glbtrack->GetTwTof() to obtain Tof resolution in MC from the parametrization of exp. data

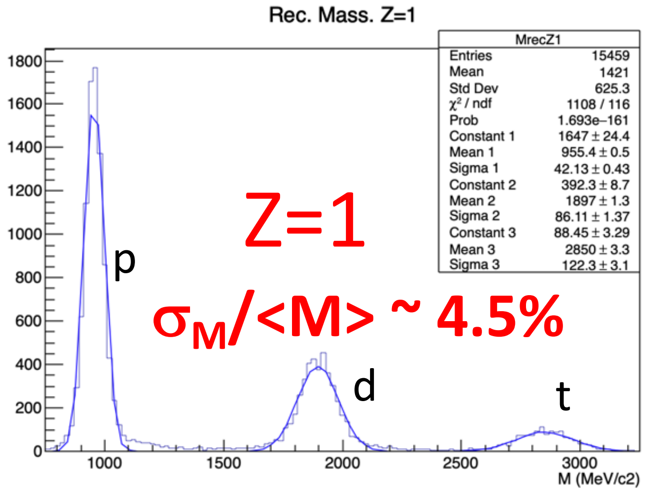
$$M = \frac{P}{c\beta\gamma}$$

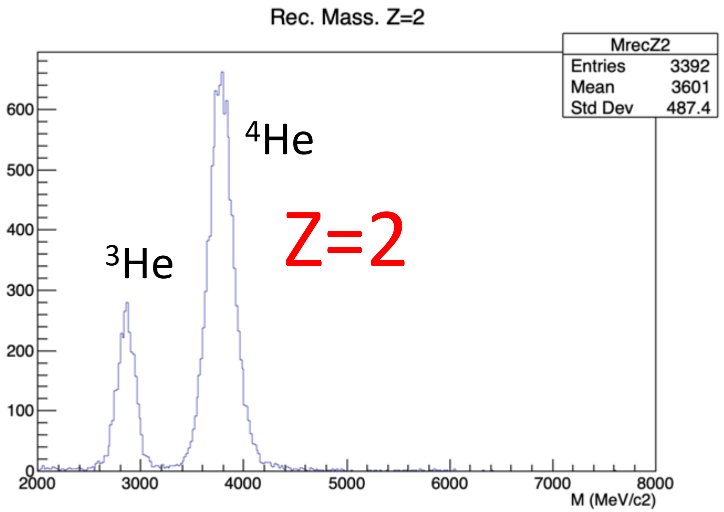


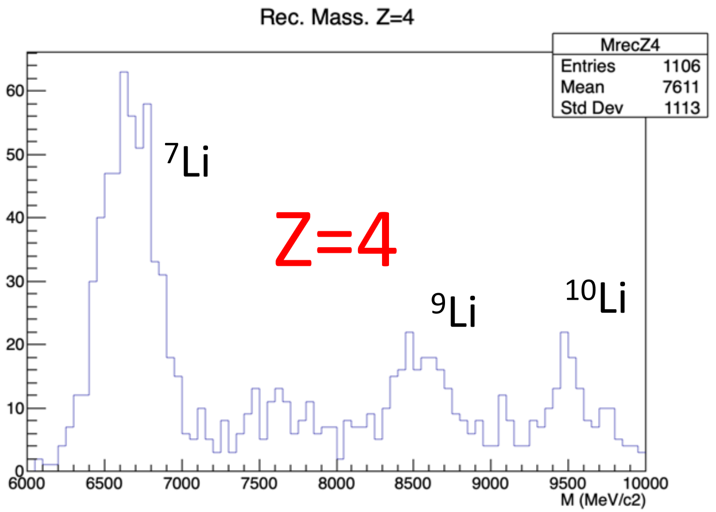
Preliminary

Mass reconstruction using P and ToF

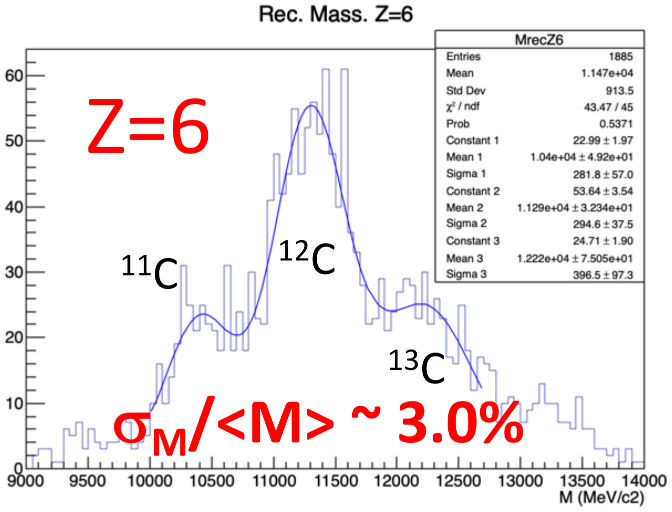
Preliminary

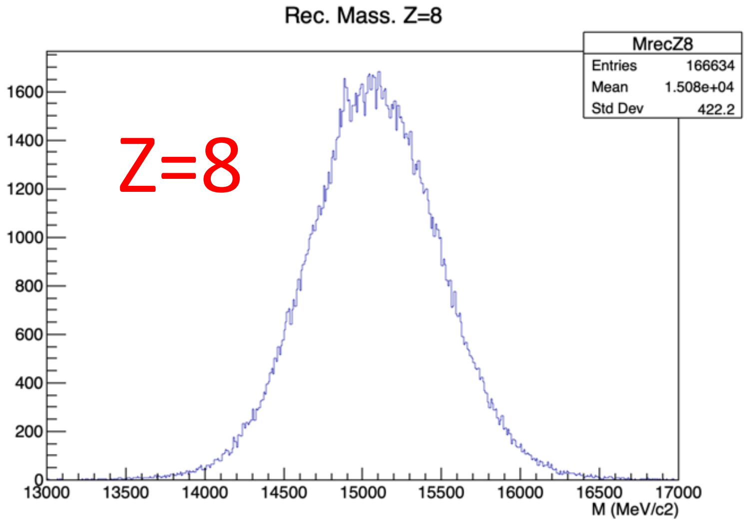






Z = Ztrue (MC)





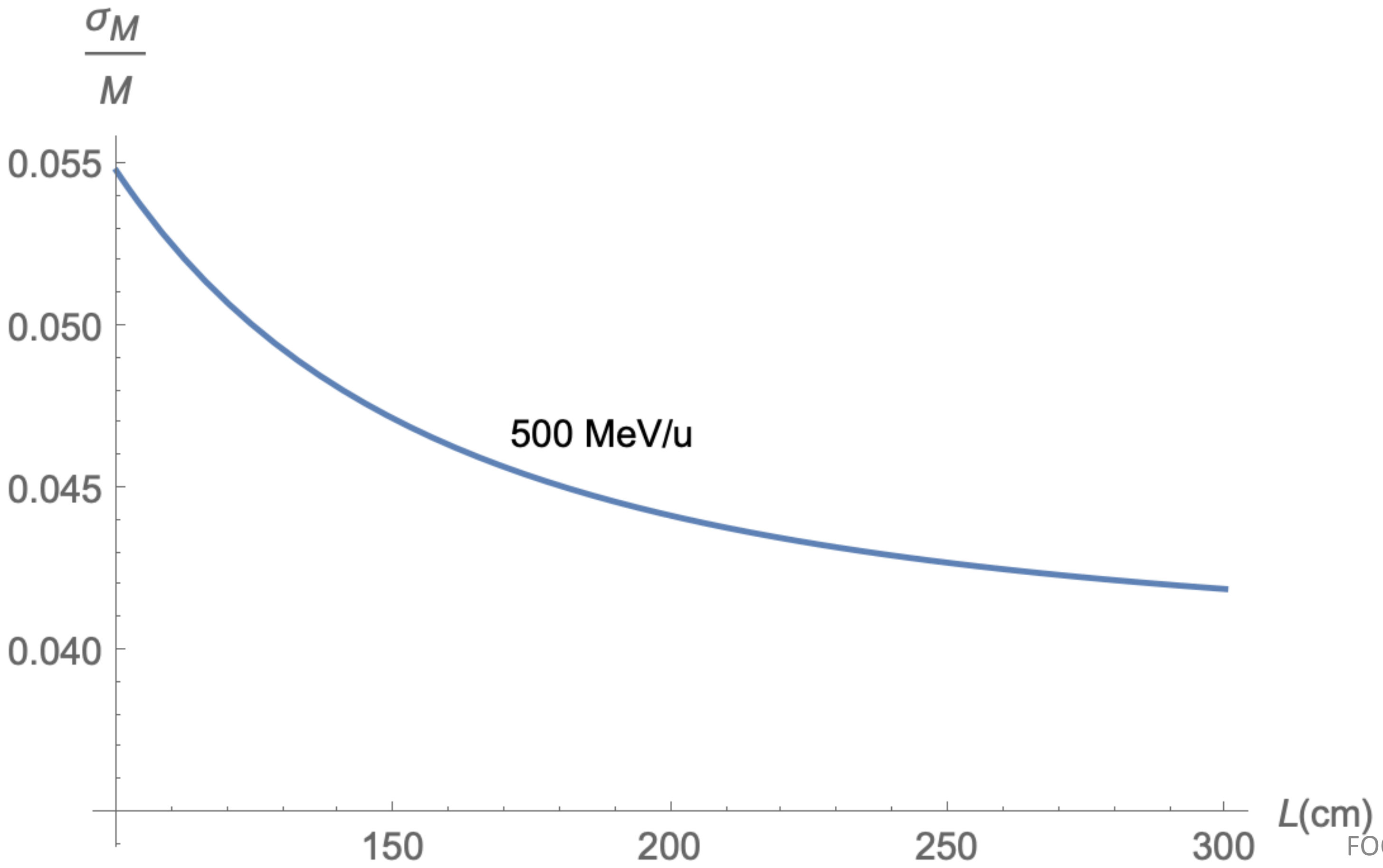
<M> in excess of ~1.5-2% for Z=1 and ~1% for Z = 6 with respect to true value

Error propagation on *m(p-ToF)*

$$m = \frac{p}{\beta\gamma}$$

$$\sigma_p = kp \qquad k = 4\ \%$$

$$\sigma_{ToF} = 0.07\ ns$$



$$\sigma_m^2 = \left(\frac{\partial m}{\partial p}\right)^2 \sigma_p^2 + \left(\frac{\partial m}{\partial \beta}\right)^2 \sigma_\beta^2$$

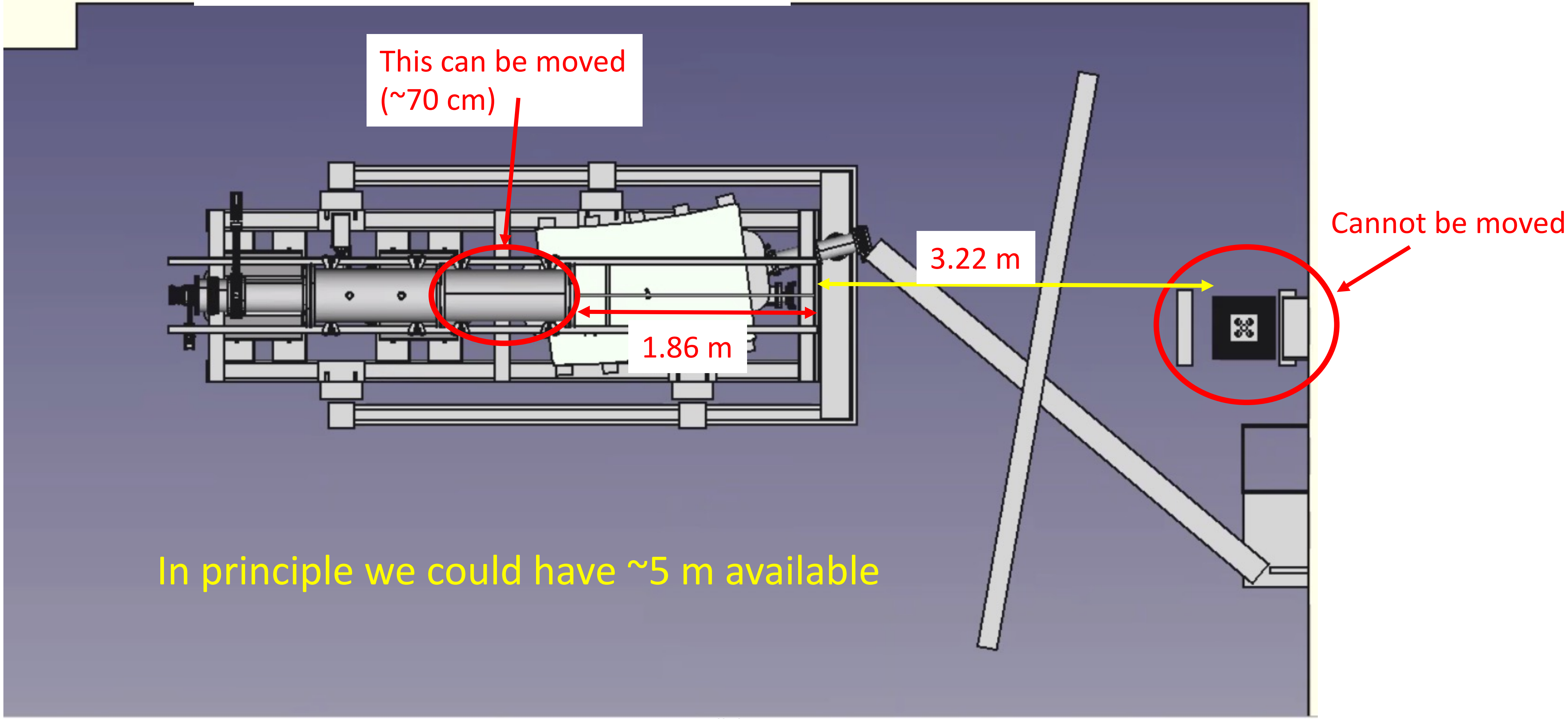
$$\sigma_m = p\sqrt{\frac{(1-\beta^2)}{\beta^2}k^2 + \frac{c^2\sigma_{ToF}^2}{(1-\beta^2)L^2}}$$

$$= p\sqrt{a(\beta) + b(\beta)\frac{\sigma_{ToF}^2}{L^2}}$$

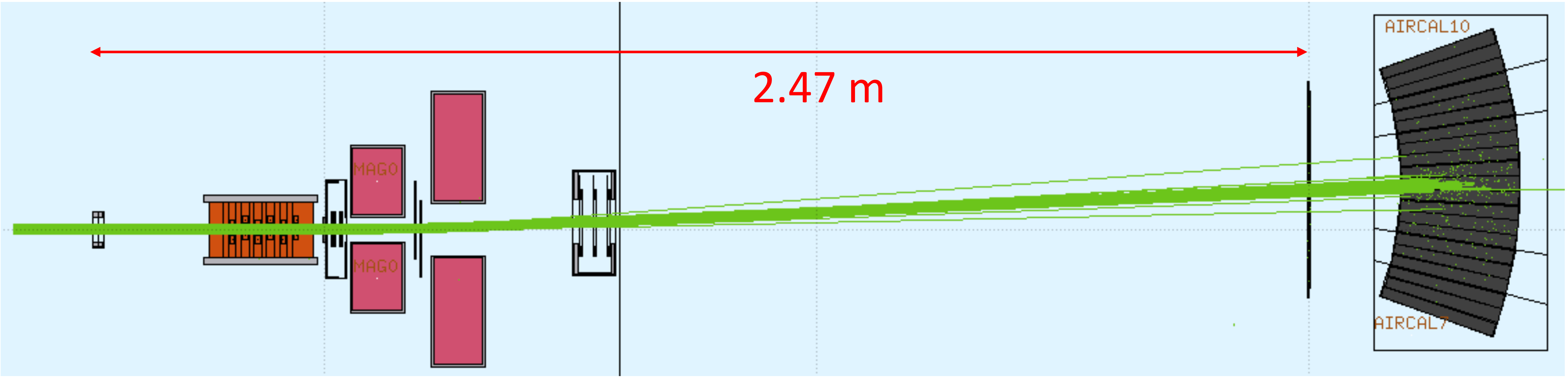
$\frac{\sigma_m}{m}$ does not depend on m

Is there enough room in Cave A?

From a meeting with C. Schuy on June 20th



Overall size of GSI2025 detector hypothesis

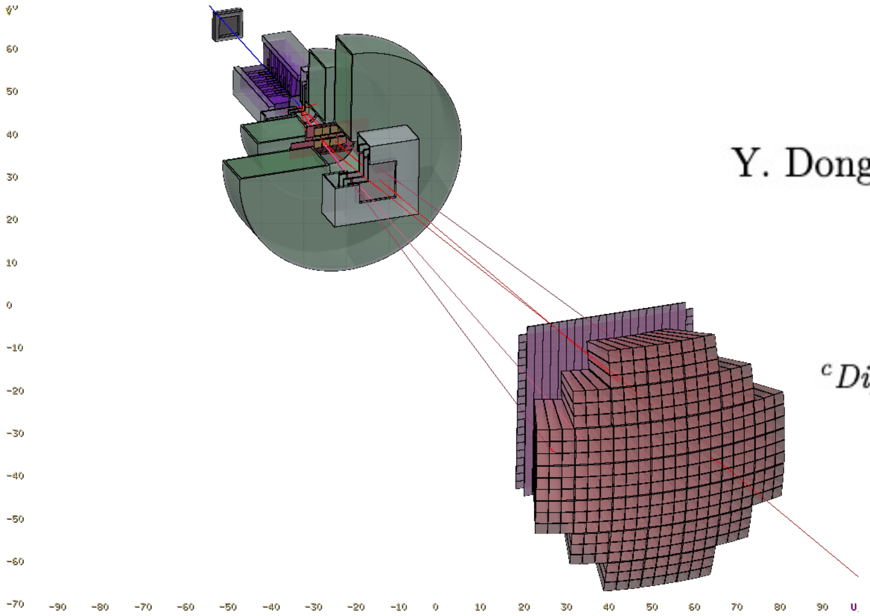


Calo needs
2 m of total space

Paper on FOOT simulation

Under consideration by the Editorial Board

Possible Journals: Computer Physics Communication, Monte Carlo Methods and Applications (https://www.degruyter.com/journal/key/mcma/html). Less probably NIM, JINST…



The FLUKA Monte Carlo Simulation of the magnetic spectrometer of the FOOT experiment

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and the FOOT Collaboration

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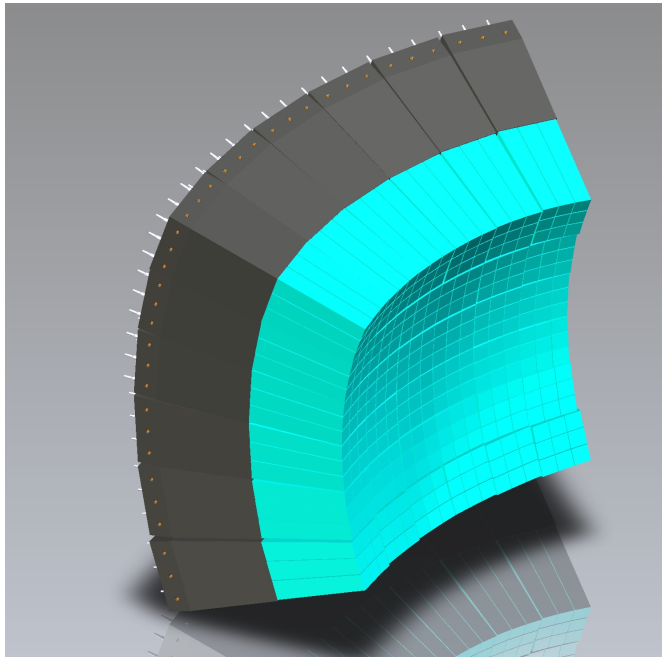
Conclusions

- The inclusion of important passive elements in simulation has been succesfully accomplished and new simulated data sets are available
- GSI21PS_MC simulation should be ready to be used successfully
- CNAO23PS_MC simulation has to be checked and analyzed
- A new GSI25PS_MC campaign (preliminary for MAECI project) is available, and preliminary studies are under way
- A new paper describing the simulation of the Magnetic Setup of FOOT has been proposed

Next steps in MC development



1. New Calo geometry (in preparation by E. Lopez Torres).

   The development of the flexible python tool to manage Calorimeter geometry, by Alessio Mereghetti (CNAO), is in progress

2. Analysis of CNAO23PS_MC campaign
3. New VTX24 configurations test
4. Insertion of the measured Magnetic Map
5. Investigation of GSI2025 setup:

   resolutions achievable as a function of relative distaces of tracking devices,

   Target-TW distance etc.

Thanks for your attention