High Intensity Muon Beams at PSI

Giovanni Dal Maso

MidTerm review - Intense

Bachelor and Master degrees

- Born in Cuneo and grown up in Siena, Italy
- Bachelor in Physics at University of Pisa, 2015-2018
- Master in Fundamental Interactions at University of Pisa, 2018-2020. Thesis title: "Beam diagnostic and calibration tools for the MEGII experiment".
- Started Ph.D. at PSI - ETH Zürich on March 2021

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Lectures and teaching

Courses for PhD credits at ETH Zürich:

- autumn 2021:
  - "Learning to Teach": this course imparted a variety of teaching skills that help Doctoral Teaching Assistants with their teaching tasks
  - "Astronomical Observations and Instrumentations": : course focused on the main and recent astronomical observations and description of the most relevant employed instrumentations
- spring 2022:
  - Joint Universities Accelerator School, COURSE 2: technology and applications of particle accelerators
- summer 2022:
  - Engaging Physics Tutoring Summer Camp
  - PSI Particle Physics Summer School - Vision and Precision

Teaching at ETH Zürich:

- autumn 2021: Physics 1 exercise class for Medicine and Health Sciences students
- spring 2022: Physics 2 exercise class for Medicine and Health Sciences students

Conferences and publications

Training:

- 20-21 May 2021: *First Muon Community Meetint* (Muon Collider Workshop), Online
- 2-4 August 2021: *Fermilab 2021 Summer Student School at LNF*, Laboratori Nazionali di Frascati INFN Online
- 6-8 September 2021: *Shedding light on X17*, Centro Ricerche Enrico Fermi, Rome Online
- 24-26 November: *International Workshop on Cosmic-Ray Muography (Muography2021)*, Ghent Online

Conferences and workshops:

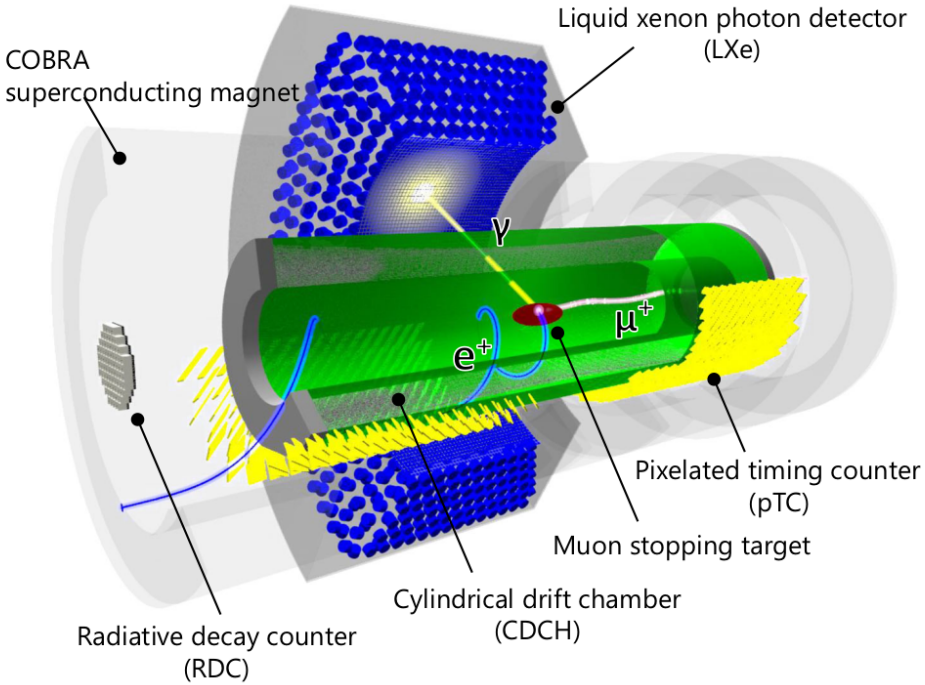
- 6-9 April 2021: *HIMB Physics Case Workshop*, PSI - Paul Scherrer Institut Online
- 10-11 June 2021: *CHIPP Plenary 2021*, Spiez Switzerland. Poster:"High Intensity Muon Beam project(HIMB): how to improve the most intense muon beam in the world"
- 30 August-3 September 2021: *Joint Annual Meeting of the APS SPS*, Universität Innsbruck. Talk: "High Intensity Muon Beam project (HIMB): how to improve the most intense muon beam in the world"
- 22-28 May 2022: *Pisa Meeting on Advanced Detectors - Edition 2022*, La Biodola - Isola d'Elba, Italy. Poster: "Beam monitoring detectors for High Intensity Muon Beams" + proceedings (under preparation)

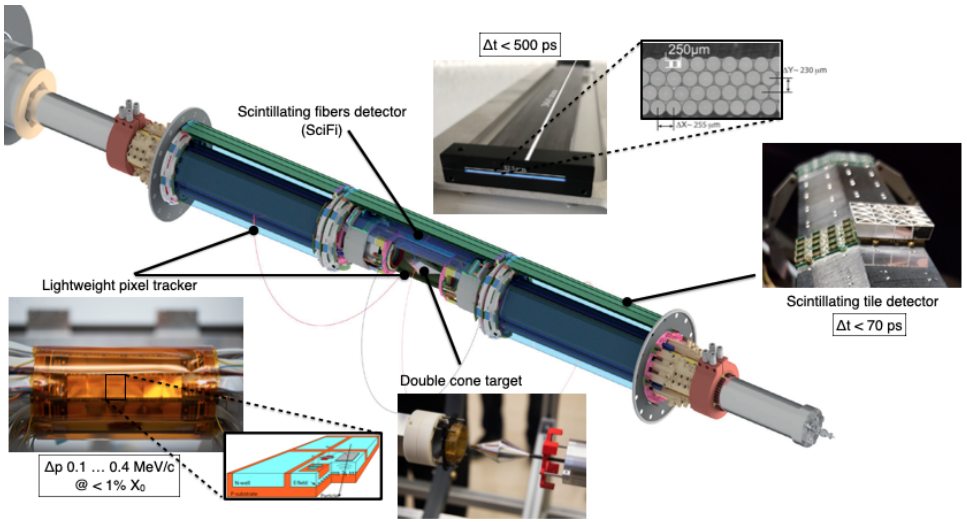
Publications:

- A. Baldini et al., "The Search for $\mu^+ \to e^+\gamma$ with 10–14 Sensitivity: The Upgrade of the MEG Experiment", Symmetry 2021, 13(9), 1591 (https://doi.org/10.3390/sym13091591);
- M. Aiba et al., "Science Case for the new High-Intensity Muon Beams HIMB at PSI", arXiv:2111.05788.
- Eichler, R. et al. "IMPACT conceptual design report", (PSI Bericht, Report No.: 22-01). Paul Scherrer Institut.

MEG II and Mu3e experiments

The goal of the MEG II experiment is to measure the decay $\mu^+ \to e^+ \gamma$. The current limit on this process - most stringent upper limit on any particle decay - was set by the MEG collaboration at PSI to B($\mu^+ \to e^+ \gamma$) $< 4.2\ 10^{-13}$ (90 % CL). The upgrade aims at reaching a sensitivity of $6\ 10^{-14}$ (90 % CL).





The goal of the Mu3e experiment is to measure the decay $\mu^+ \to e^+ e^- e^+$. The current limit on this process was set at $1.0\ 10^{-12}$ (90 % CL) by the SINDRUM II collaboration at PSI. The Mu3e collaboration aims at reaching a sensitivity of $2\ 10^{-15}$ (90 % CL) in its first phase, and 10^{-16} (90 % CL) in the second one.

MEG II and Mu3e: beams

For both MEG II and Mu3e I work on the beamlines in the πE5 experimental area. For the Mu3e Compact Muon Beam Line we successfully finished our 2022 commissioning campaign obtaining better result than foreseen in the Mu3e TDR: 7 10^7 μ^+/s $\rightarrow$ 10^8 μ^+/s. For both the experiment I work on the development of new beam monitoring tools and on the simulation of the particle beams.

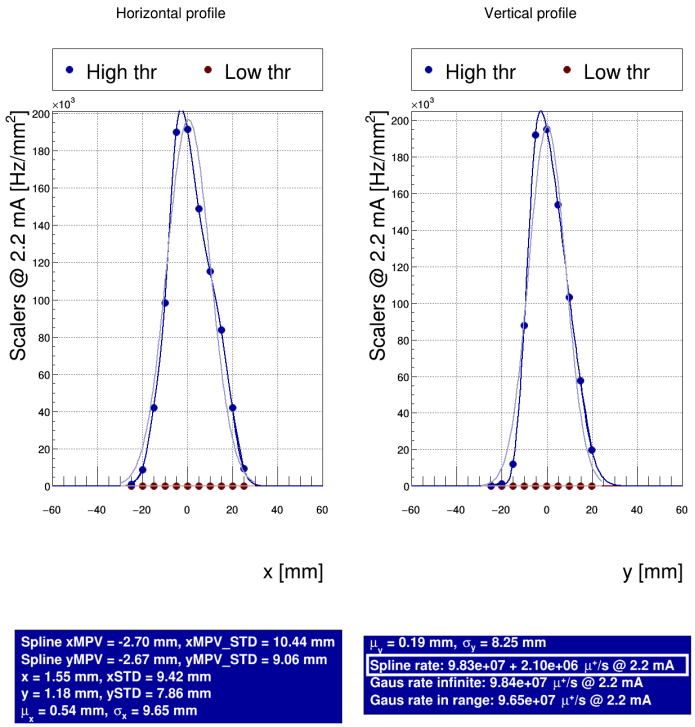


Figure: Mu3e beam after 2022 commissioning campaign.

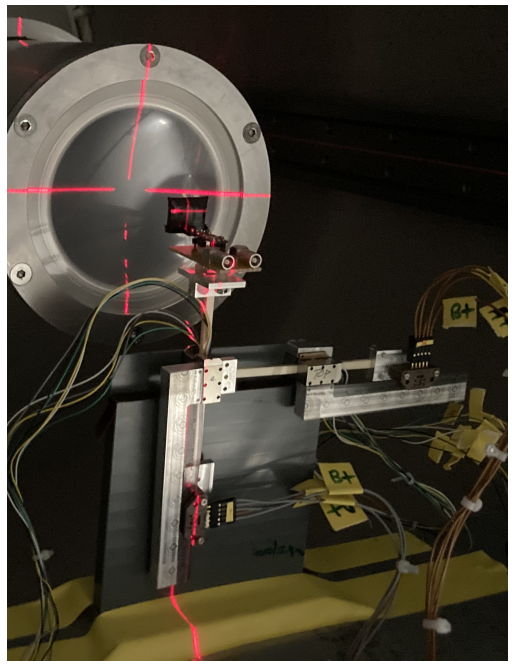
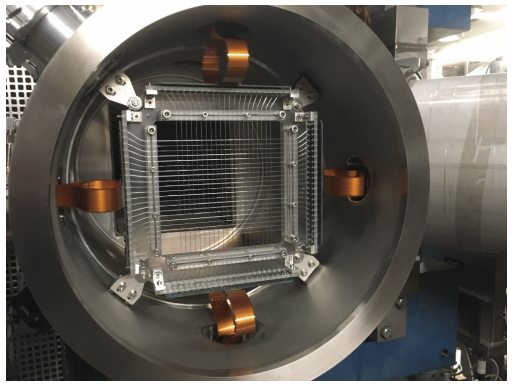
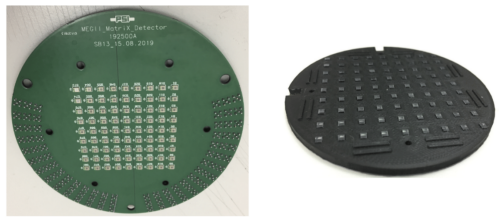


Figure: Mu3e beam monitor.



(a) SciFi detector



(b) MatriX detector

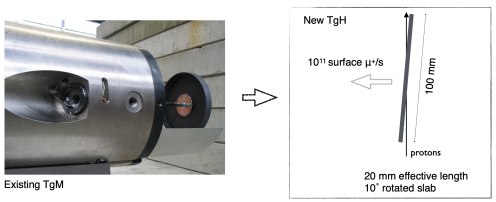
Figure: MEG II beam monitors

The High Intensity Muon Beam project

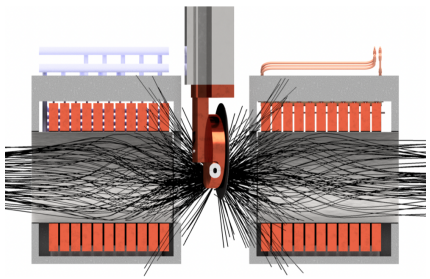
PSI aims at increasing by two orders of magnitude the muon beam rate, from 10 ^{8} μ^+/s to 10 ^{10} μ^+/s.

That is obtained by:

1. substituting TgM, 5-mm thick, with TgH 20-mm thick 10-deg slanted. The slanting angle increases surface muon yield relative to other particles, in this case the increase is near to 100 %

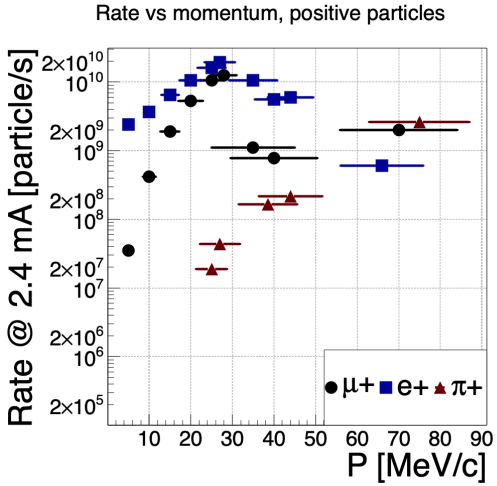


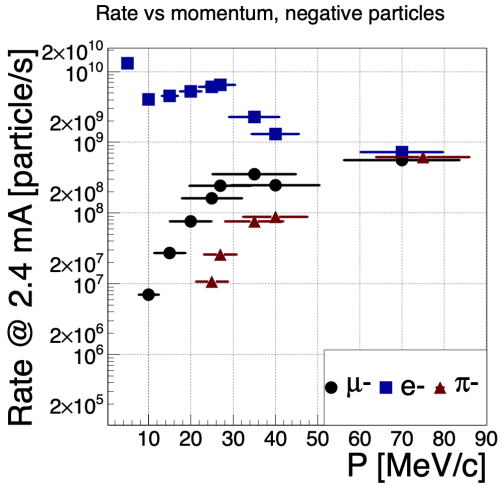
2. using split radiation hard capture solenoid to allow the proton beam travelling to the spallation target and increase muon capture

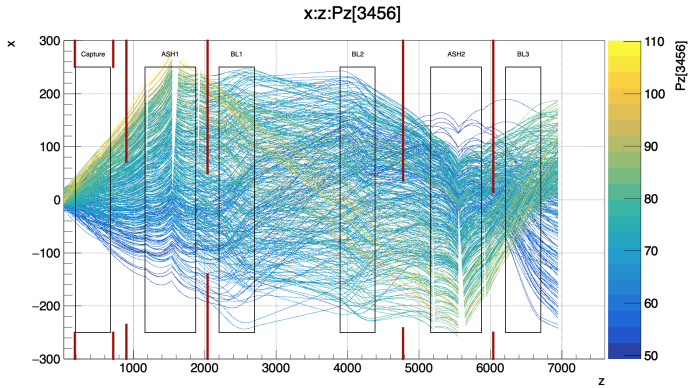


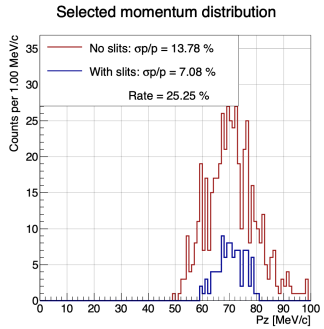
3. using solenoidal beamlines for maximum transmission

I'm working on the simulation of the non-surface muon beams and on the slits system optimization.









Next steps

I'm currently half-way through my Ph.D. Below is a list of the steps foreseen for the remainder of the grant period:

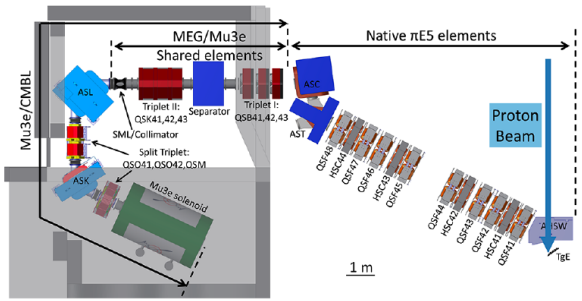
- 2022:
  - MEG II beam tuning campaign
  - MEG II data taking
  - MEG II & Mu3e Beam monitors
  - X17 data taking with the MEG II apparatus (see backup)
  - HIMB simulations
- 2023:
  - X17 data analysis
  - last CMBL commissioning campaign
  - Full Mu3e detector commissioning
  - MEG II beam tuning and data taking
  - Beam monitoring upgrade for HIMB
  - HIMB simulations

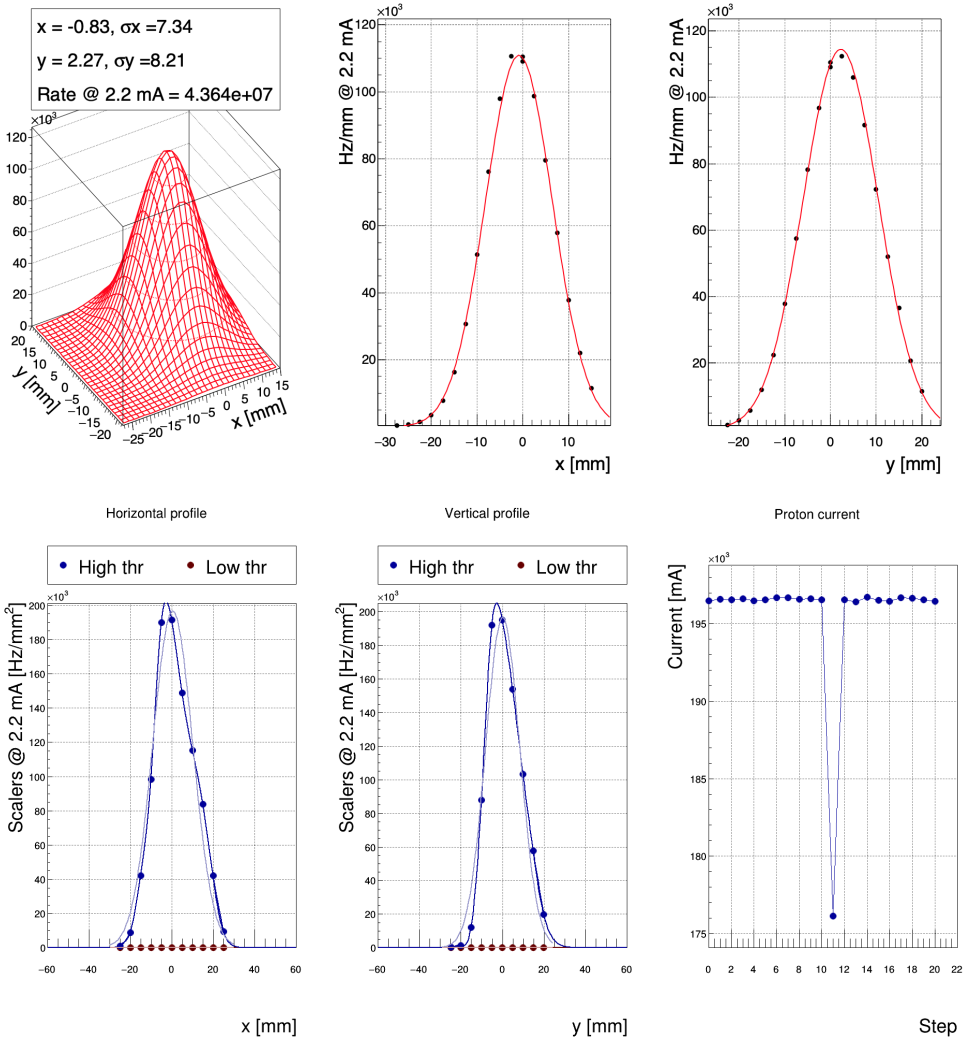
Back-up

Compact Muon BeamLine commissioning

During spring 2021 and 2022 we commissioned the CMBL for the Mu3e experiment:

- within the 2021 beam campaign we managed to deliver muons at the center of Mu3e magnet: 4.4 10^7 μ^+/s. Transmission was not yet optimal.
- within the 2022 beam campaign we managed to exceed TDR estimates: 7 10^7 μ^+/s $\rightarrow$ 10^8 μ^+/s





Beam Monitors

I'm involved in the preparation of new beam monitoring tools for muon beams. I work on the front-end and analysis tools for all of them. All of them can operate in high magnetic field environments 1 T.

Mu3e beam scanner: APD mounted on a stage moved by piezo-electric motors. Upgraded stage to be assembled this year.

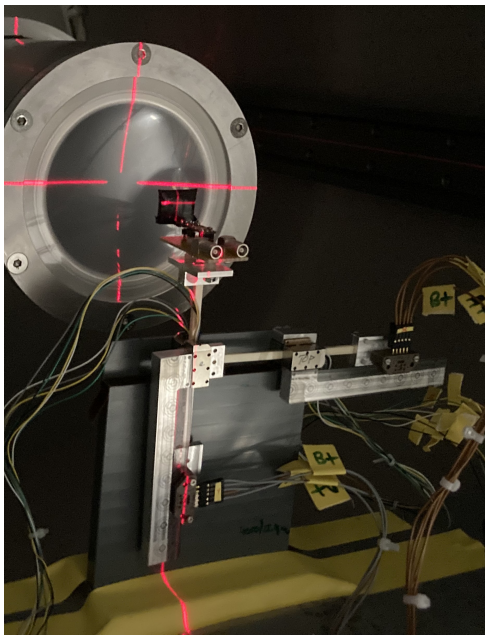


Figure: Mu3e beam scanner

SciFi: a grid of scintillating fibers coupled to SiPMs. Upgrade to be assembled this year including a moving stage for beam measurements on demand during beam time.

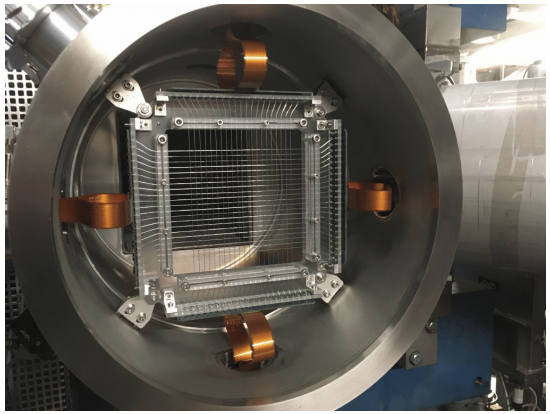


Figure: SciFi detector

MatriX: a matrix of scintillating elements coupled to SiPMs. We are going to assemble the upgraded version, with improved particle ID by the end of this year.

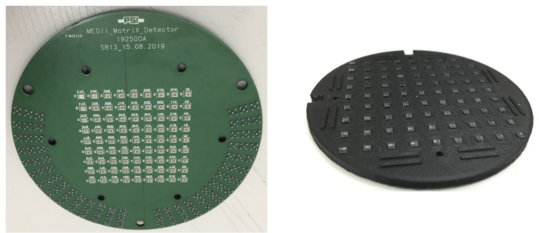
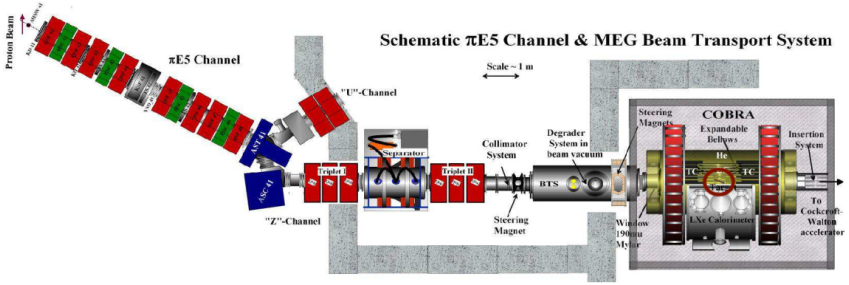
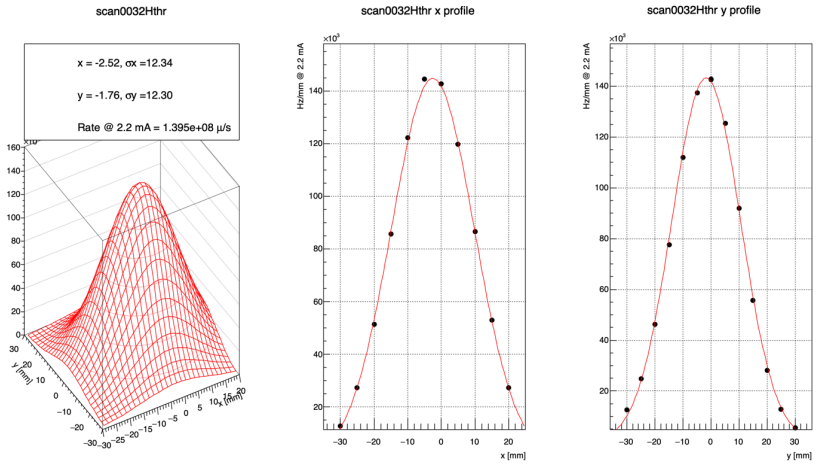


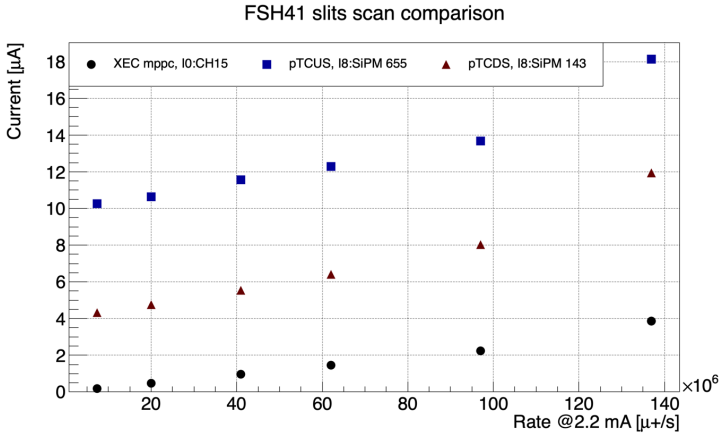
Figure: MatriX detector

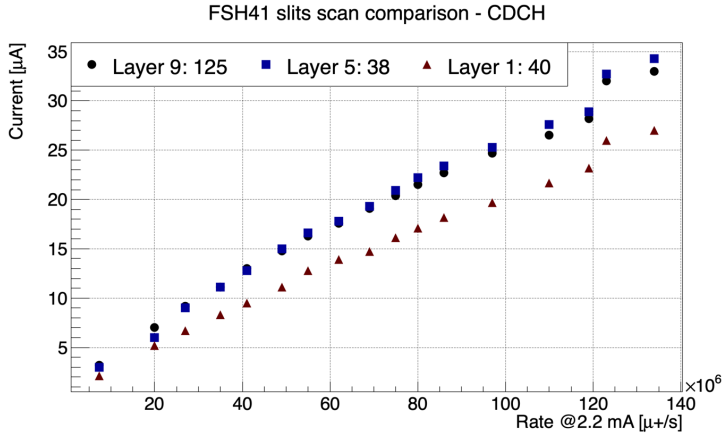
MEG II

For MEG II I contribute to the yearly beam tuning campaign and to the detector calibrations. In 2021 we studied the detector response at different muon rates, started the physics run and collected pure radiative muon decay data sets to check reliability and quality of the experiment.









X17 measurement

I'm contributing to the measurement of the anomaly in the Lithium to Beryllium process with the MEG II apparatus. This measurement can be performed during the HIPA service days as we already have a Cockroft-Walton in the experimental area to calibrate our calorimeter.
The Cylindrical Drift Chamber of the MEG II apparatus can provide a measurement of this anomaly based on a different detection method then that used by the ATOMKI collaboration.
We assembled the target chamber last september for first tests and tested our DAQ last January.
We plan on doing data taking by February 2023.

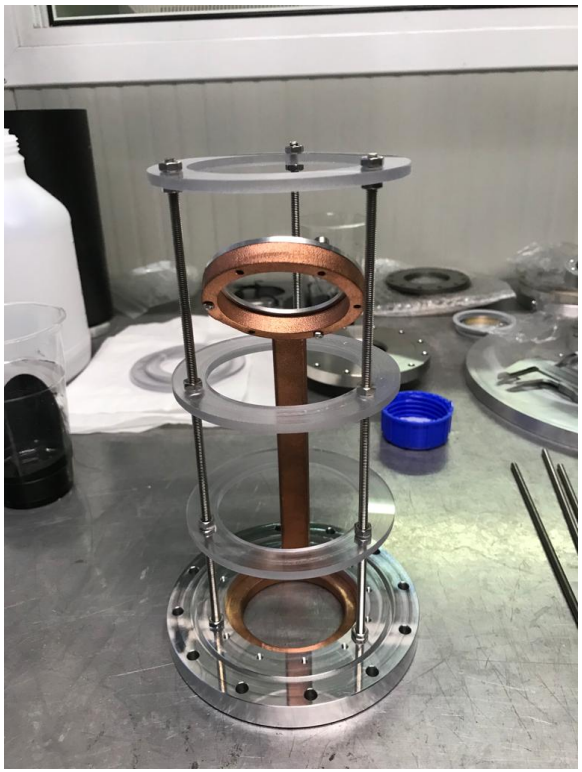


Figure: Carbon vacuum chamber + target