The MArEX initiative: First results of test measurements

The n_TOF Collaboration General Meeting 2023
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On behalf of the MArEX collaboration

OUTLINE

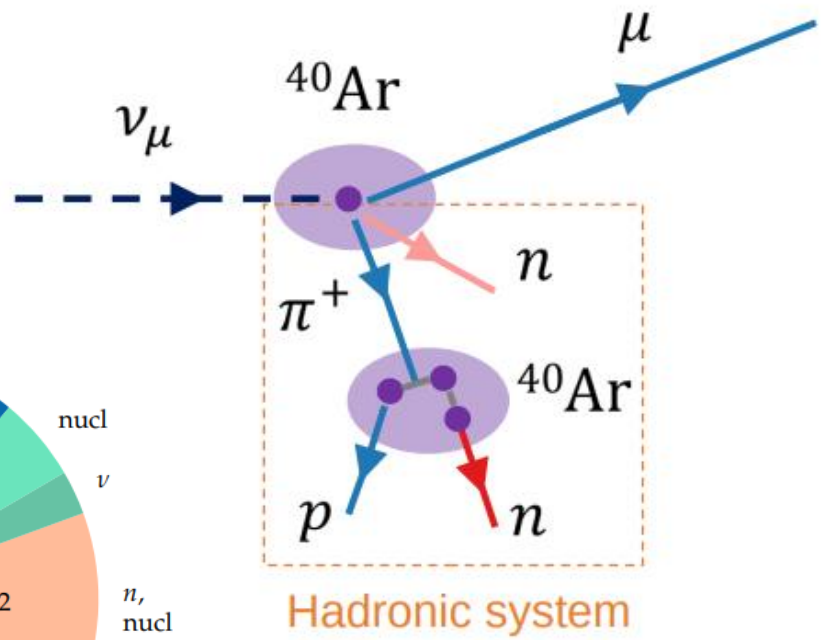
- Importance of Neutrons
- Motivation for MArEX
- Experimental Setup

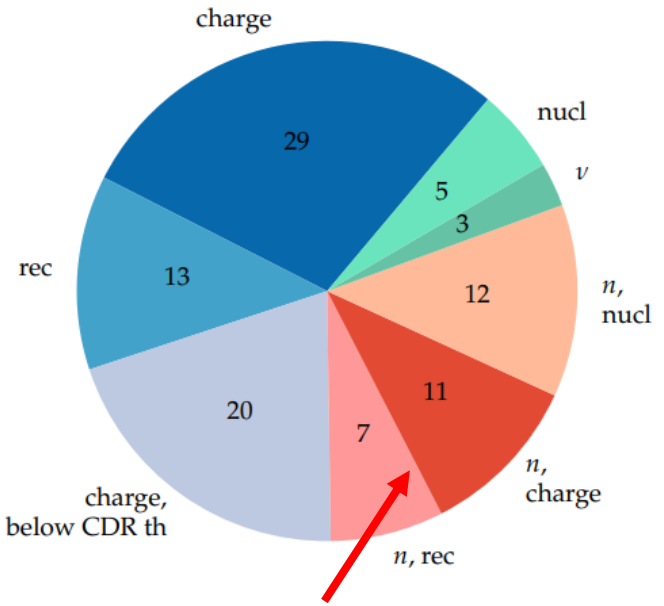
Importance of Neutrons in LAr Experiments

- **Liquid Argon (LAr):** primary detector material in many neutrino and dark matter experiments
  - DUNE, SBND, ICARUS, MicroBooNE, DarkSide, etc.
- Neutron production from neutrino interaction brings a large uncertainty on neutrino energy reconstruction in the form of **missing energy**.
  - Stringent requirements to accurately measure, for example, the neutrino oscillation parameters
  - Need to understand the detector response to neutrons to reduce the systematics
- Neutrons are also useful for **calibrating** multi-kiloton experiments, like DUNE.

$$n + {}^{40}Ar \rightarrow {}^{41}Ar + 6.1\ MeV$$

Fig. (Right) Illustration of a neutrino event in LAr





~ 30% of the final state energy!

Fig. (Left) Energy budget after fully propagating ~10K 4 GeV neutrino events; **Figures from A. Friedland and W. Li (2019).**

Neutron Total Cross Section

- Need to measure the total cross section
  - below 20 keV and between 50-100 MeV (no data in EXFOR)
  - above 100 MeV (current data has large error bars)
- Need a better measurement of the cross section dip in the total cross section at 57 keV
  - Initial effort was made by the ARTIE experiment (https://arxiv.org/abs/2212.05448v3)
  - New experiment, ARTIE-II has been approved

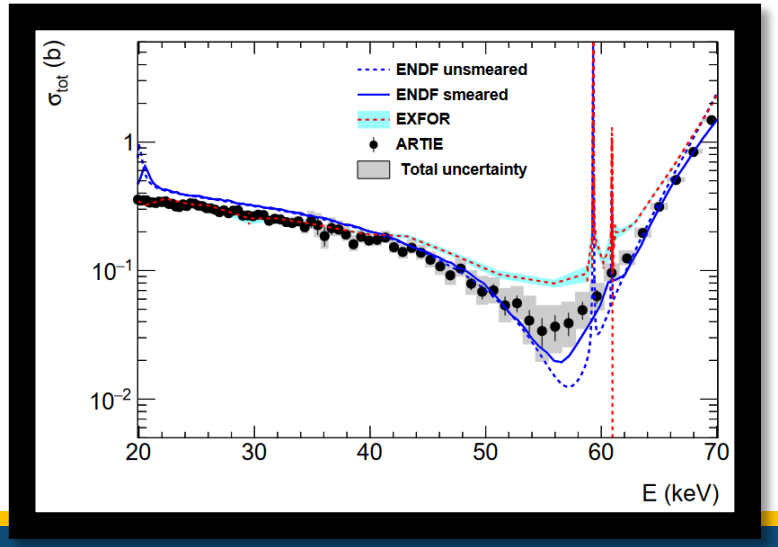


Fig. (Left) Plot shows the measured neutron-argon total cross section, by ARTIE, as a function of energy.

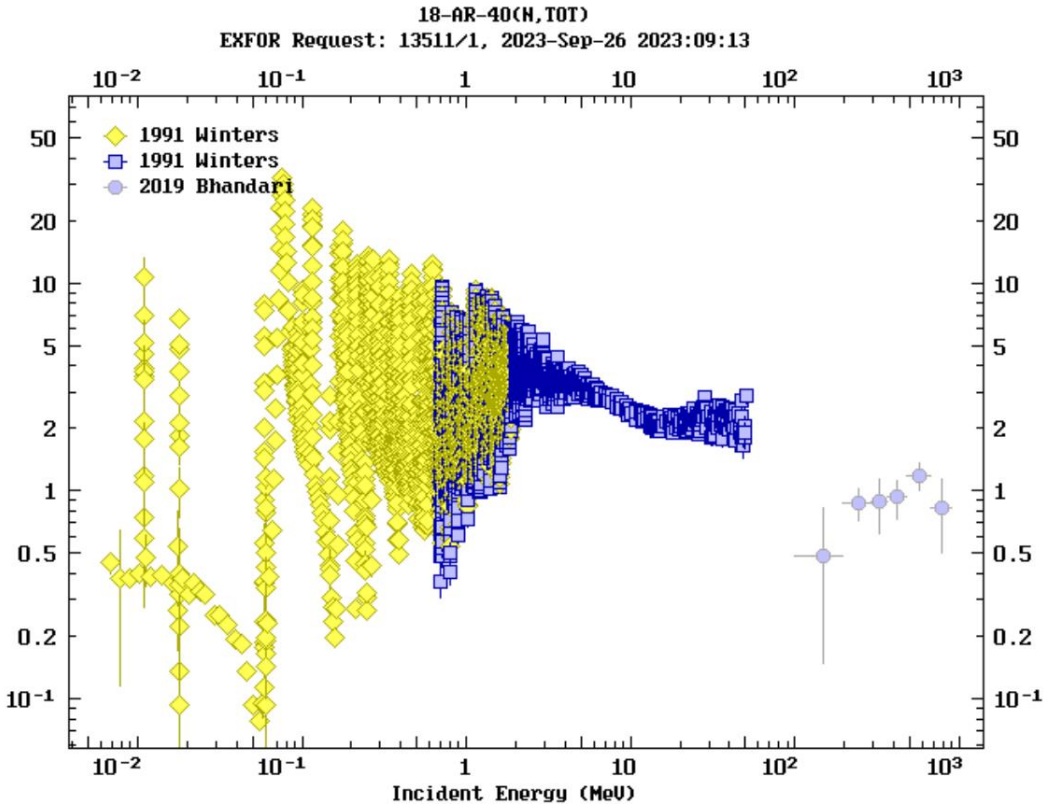


Fig. (Top) Plot of the currently available data of the neutron total cross section on Argon from EXFOR.

n_TOF Facility at CERN

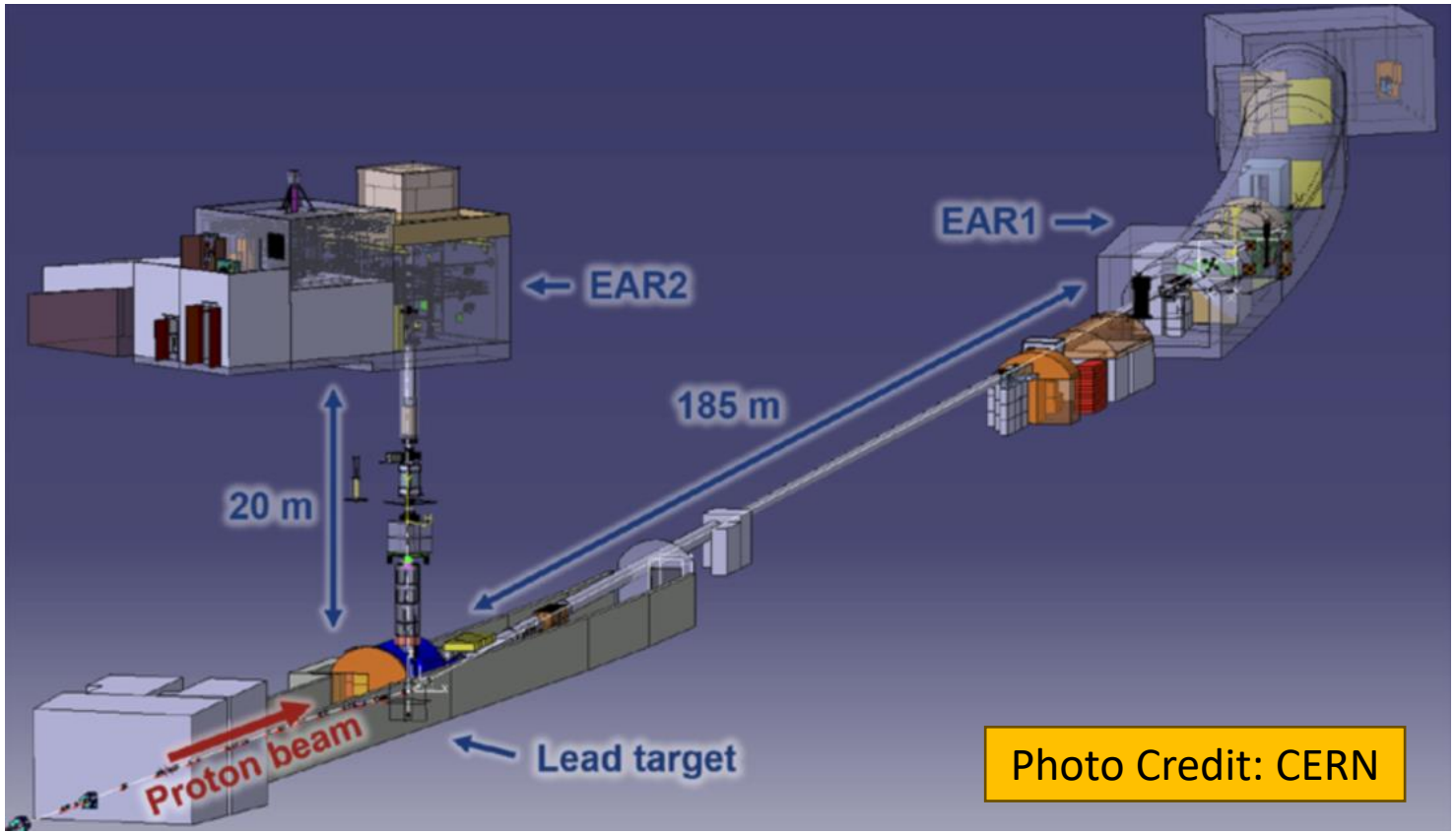
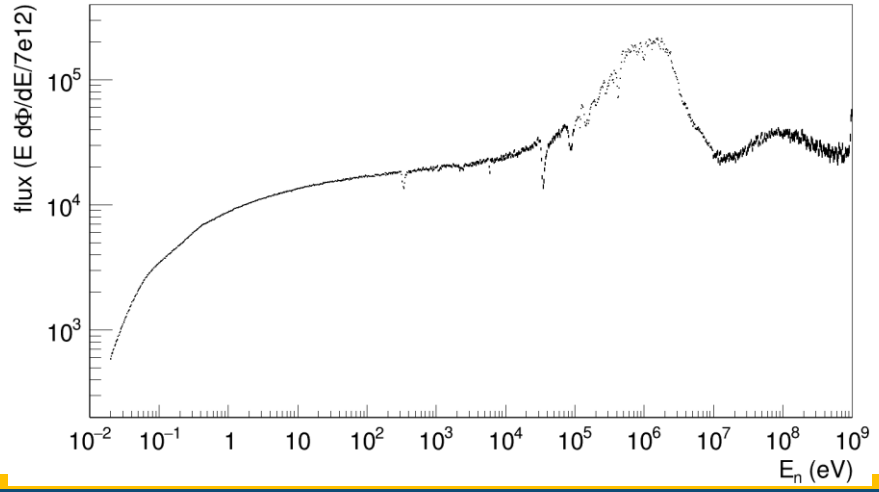


Fig. (Top) Schematic of the n_TOF facility; (Right) Neutron Flux at EAR 1 (Credit: n_TOF)

- Two experimental areas (EAR) with different flight paths for time-of-flight measurements
  - EAR 1: 182.3 - 190.2 m
  - EAR 2: 18.16 - 23.66 m
- EAR 1:
  - Wide energy range neutron beam
  - Long flight path; High energy resolution



Motivation for the MArEX Initiative

- Multiple Argon Experiments (MArEX) initiative
  - perform accurate measurements for the transmission and capture reaction channels for neutron interactions in LAr at the n_TOF facility
- To test the feasibility of transmission measurements
  - Transmission experiments haven't been performed previously at n_TOF
  - Measure the cross section of known materials like Bi, Al, and C.
- To test the feasibility of transmission measurements on Ar
  - Carbon fiber SCUBA tank filled with gaseous Argon
  - Measure the argon cross section
  - Proof of concept for a transmission measurement with LAr

Transmission Measurement

Transmission is given by

$$T(E) = \frac{N_{in} - B_{in}}{N_{out} - B_{out}} \frac{Q_{out}}{Q_{in}}$$

- E – Energy of the neutron (converted from the measured time of flight)
- N – Number of neutrons reaching the detector
- B – Number of background events
- $\frac{Q_{out}}{Q_{in}}$ - Beam flux normalization for target in and target out

Cross section is given by

$$\sigma(E) = -\frac{1}{n}\ln[\mathrm{T(E)}]$$

- n – Number density of the target sample (atoms/barn)

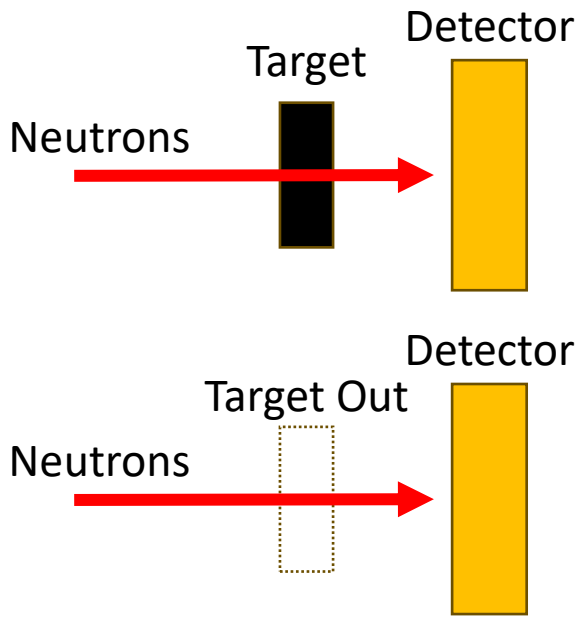
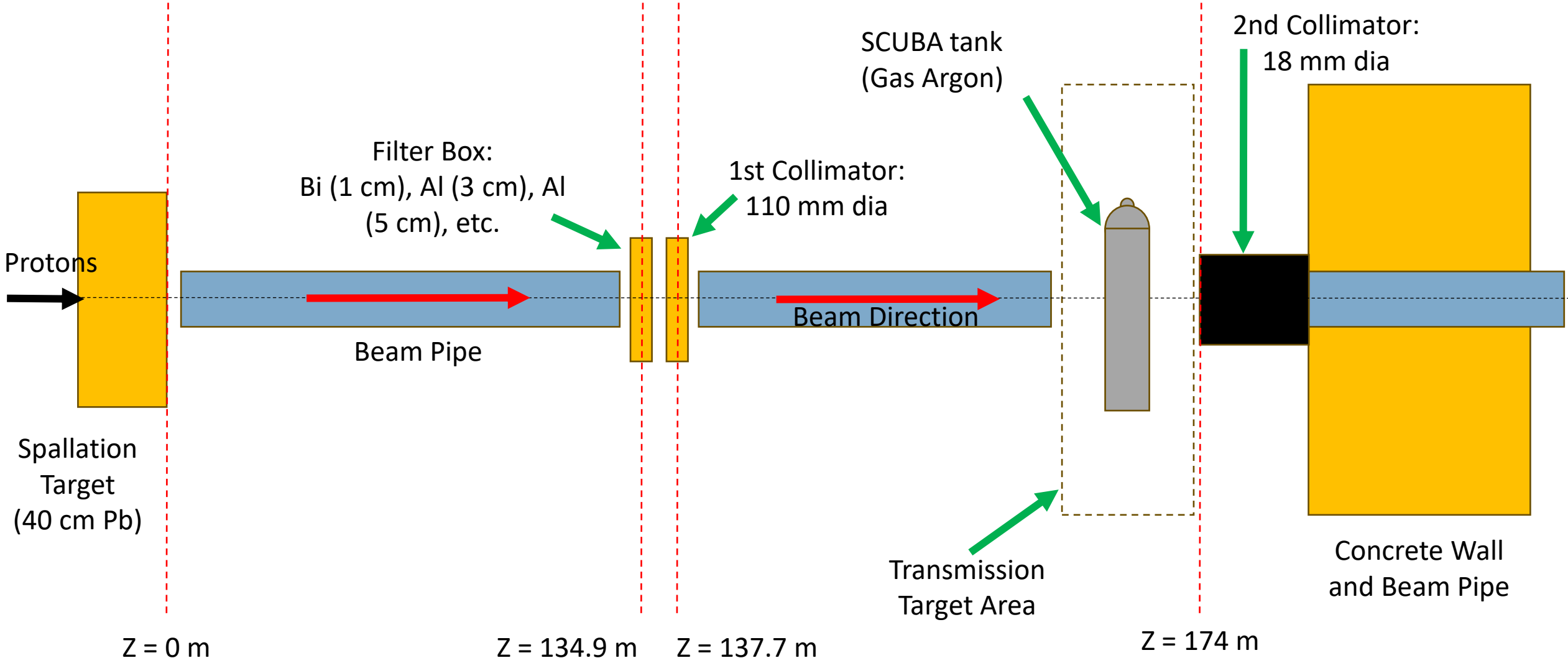
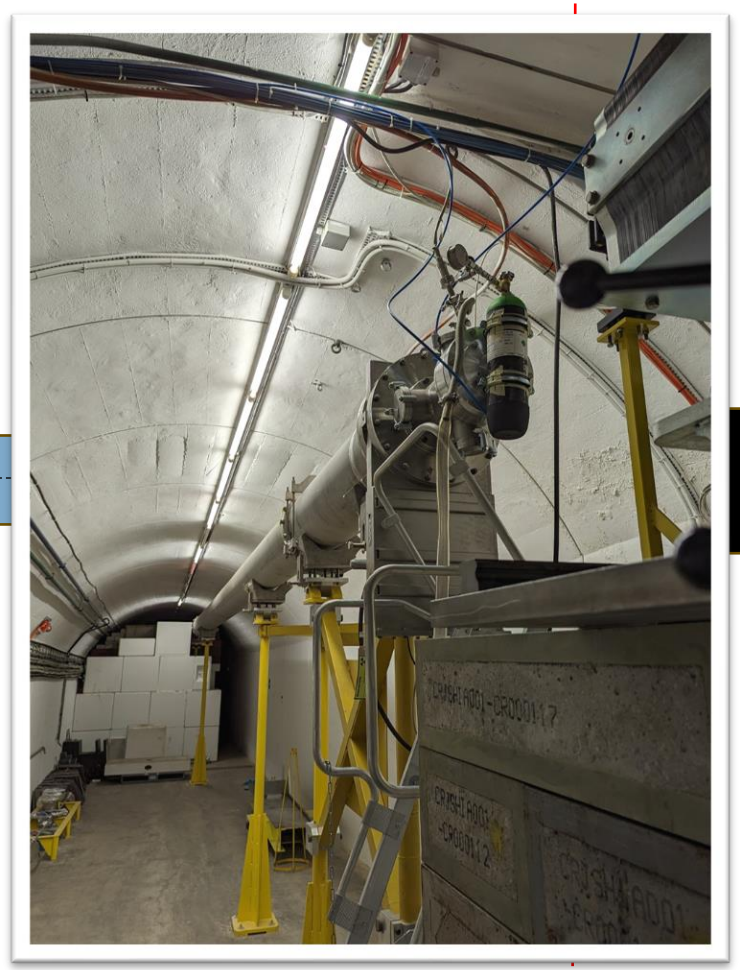


Fig. (Top) Target in measurement; (Bottom) Target out measurement. Ideally should be vacuum in place of target.

Experimental Setup – Beam Line Area



Experimental Setup – Beam Line Area



Protons

Spallation Target (40 cm Pb)

Concrete Wall and Beam Pipe

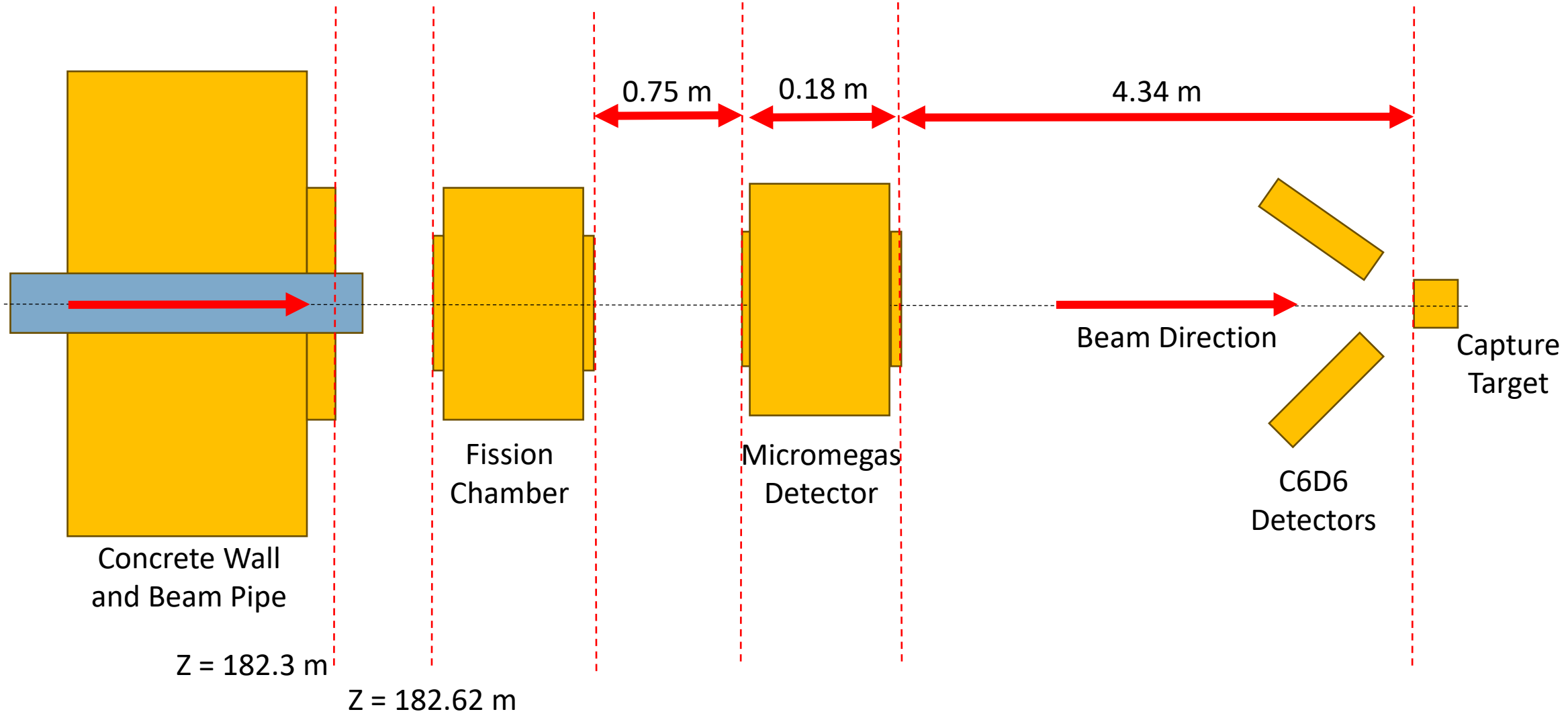
Z = 0 m

Z = 134.9 m

Z = 137.7 m

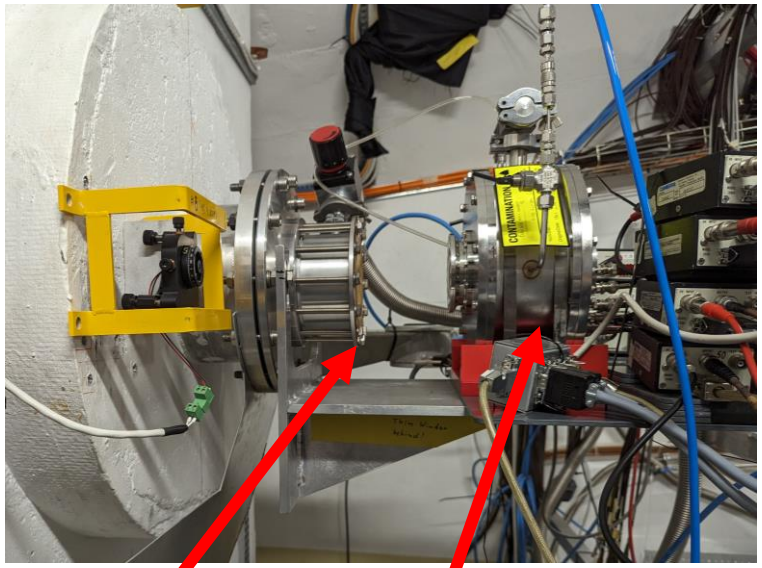
Z = 174 m

Experimental Setup – Detector Area



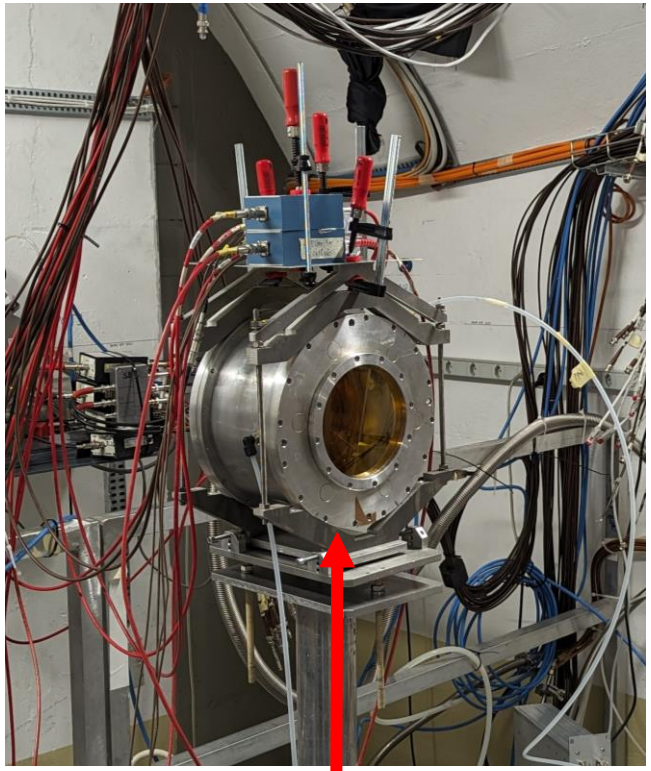
Experimental Setup - Detectors

Beam Direction

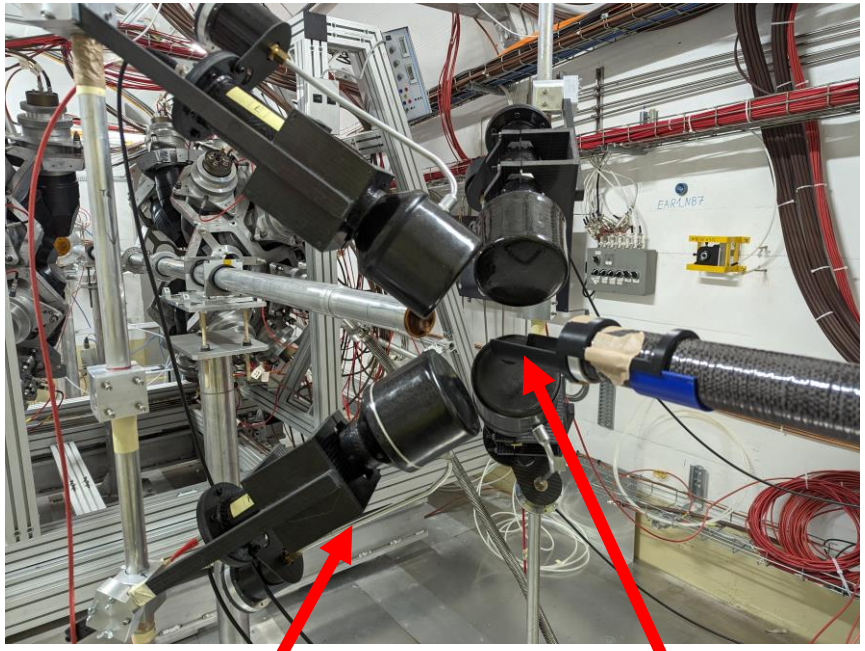


Beam Pipe End

U235 Fission Chamber (PTBC)
- 8 Detectors in the chamber
- 42 mm diameter U235 sample



Micromegas (FIMG)
- 2 detectors with B10 samples

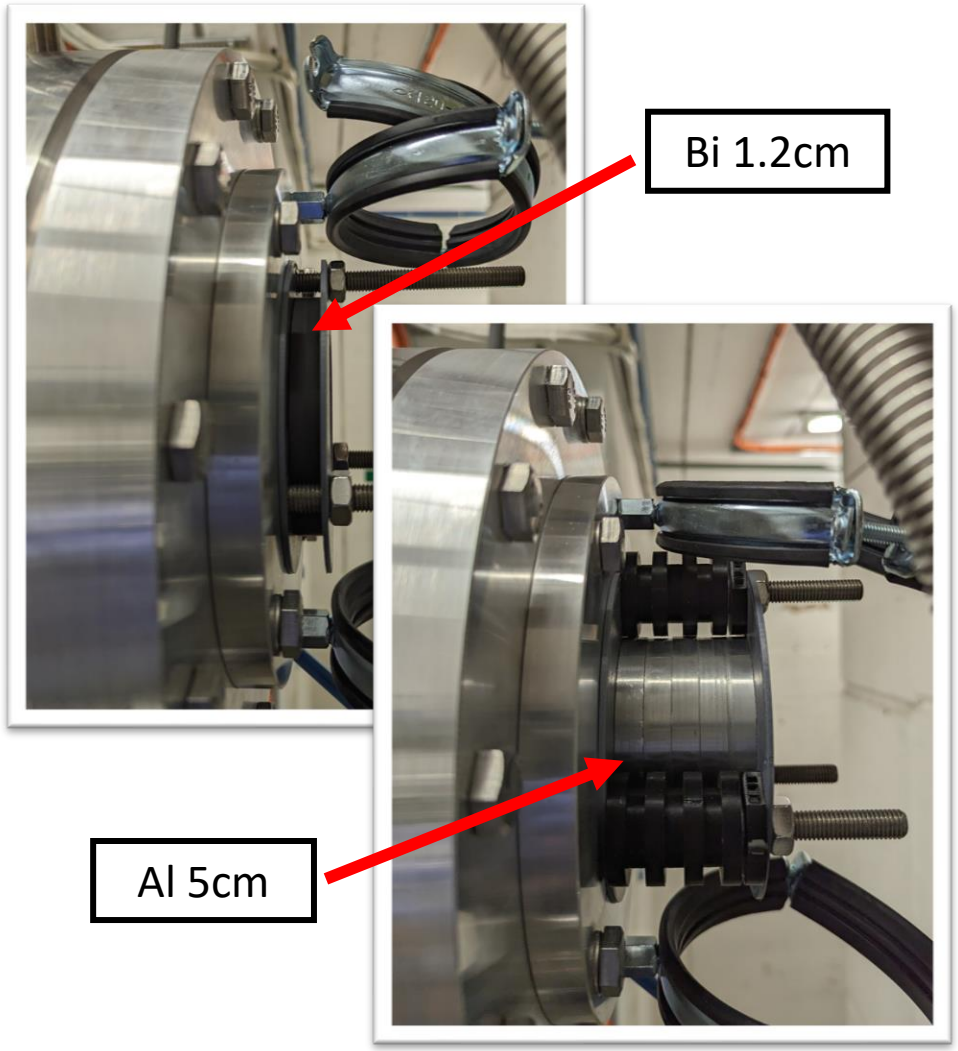


Capture Target Stand

C6D6 Capture Setup
- 4 scintillation detectors
- Placed 125º wrt the beam line

Data Taking

- We finished data taking on October 26th; About 50 days for beam time
- An average of 1.1e17 protons per day
- Took data with the following materials as targets
  - Al: 3cm, 5cm, 8cm
  - Bi: 1cm, 1.2cm
  - C: 1.2cm
  - Empty carbon fiber SCUBA tank
  - SCUBA tank filled gaseous argon at 200 bar
  - SCUBA tank filled gaseous argon at 1 atm



Argon Transmission Setup

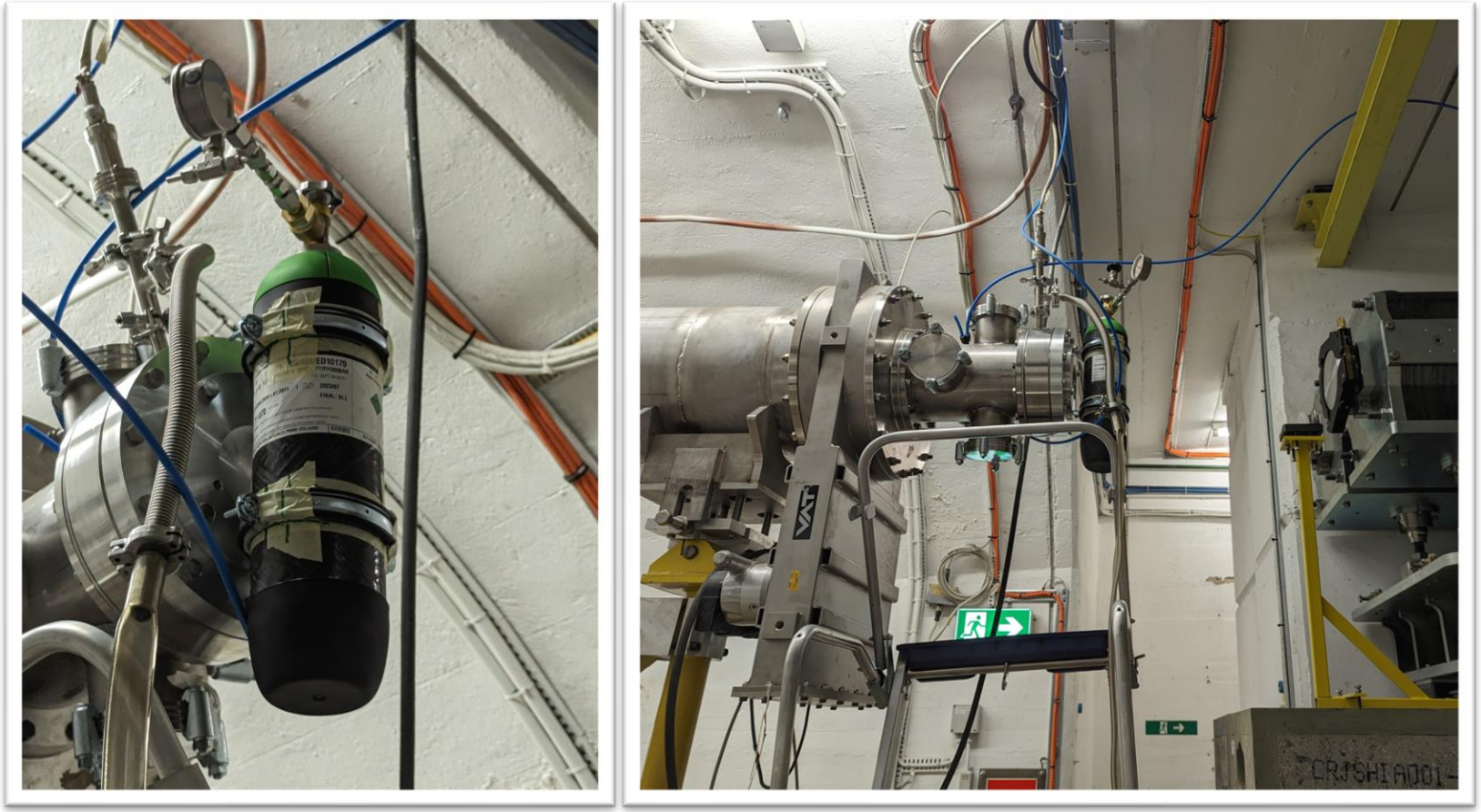


Fig. Argon tank in the transmission station

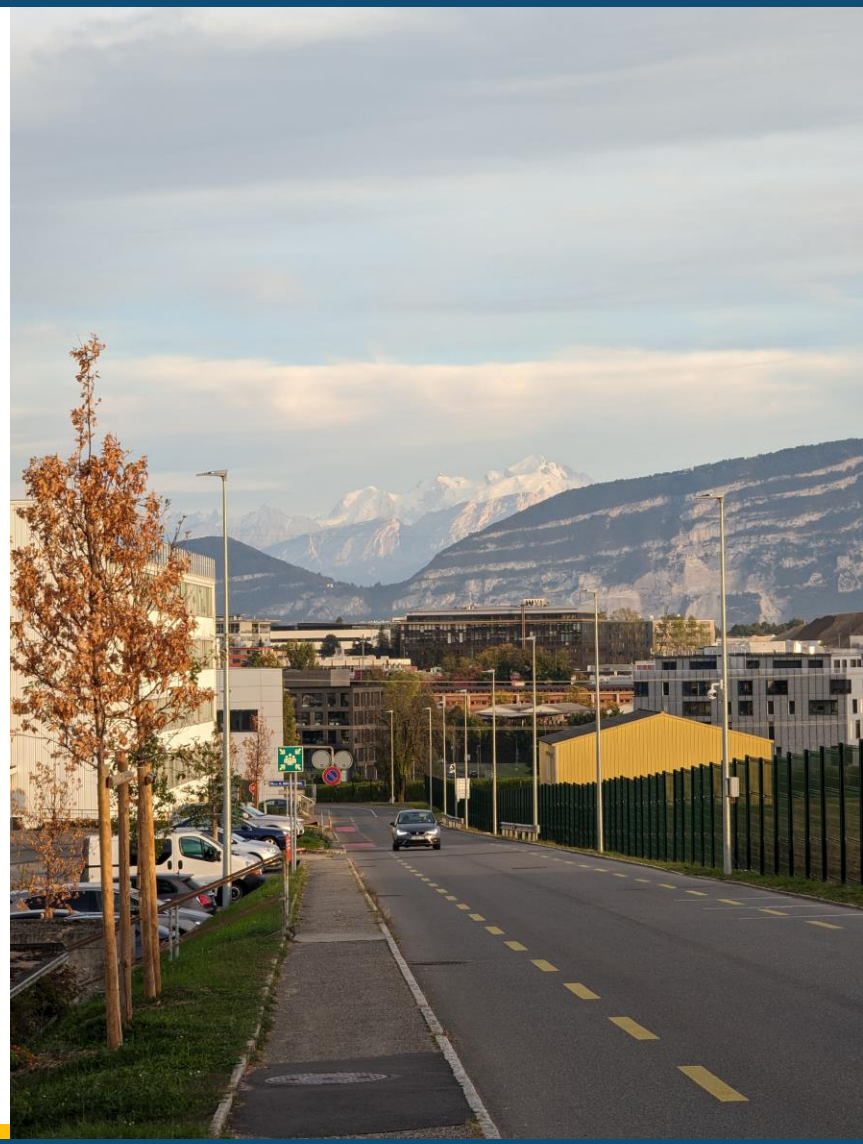
Argon tank specifics

- Carbon fiber tank
- 3 L volume
- 200 bar pressure
- ~ 10 cm of Ar gas in the neutron path
- ~ 0.05 atoms/barn

Conclusion

- Important to understand neutron propagation and capture in LAr
  - Measure the neutron total cross section over a wide energy range
- Conducted a feasibility test for transmission measurements at n_TOF
  - Measured the cross section of known materials like Bi, Al, and C.
  - Took data with a carbon fiber SCUBA tank filled with gaseous Argon

Riccardo and Zina will present the first results of the measurement!



Thank You!

MArEX Collaboration:

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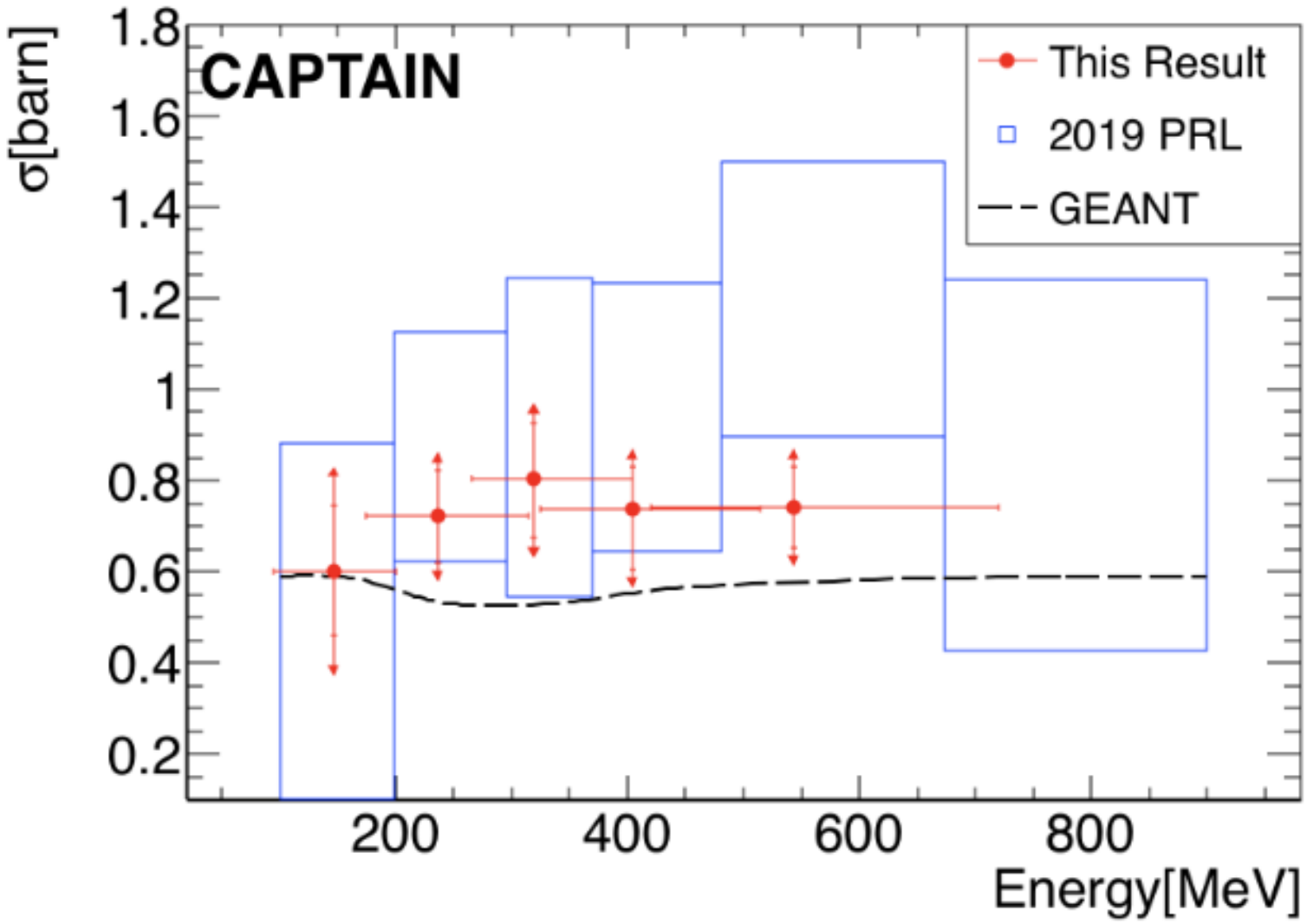
Back Up Slides

Mini-CAPTAIN Measurement



https://arxiv.org/abs/2209.13488v3