



UNIVERSIDAD TECNICA
FEDERICO SANTA MARIA

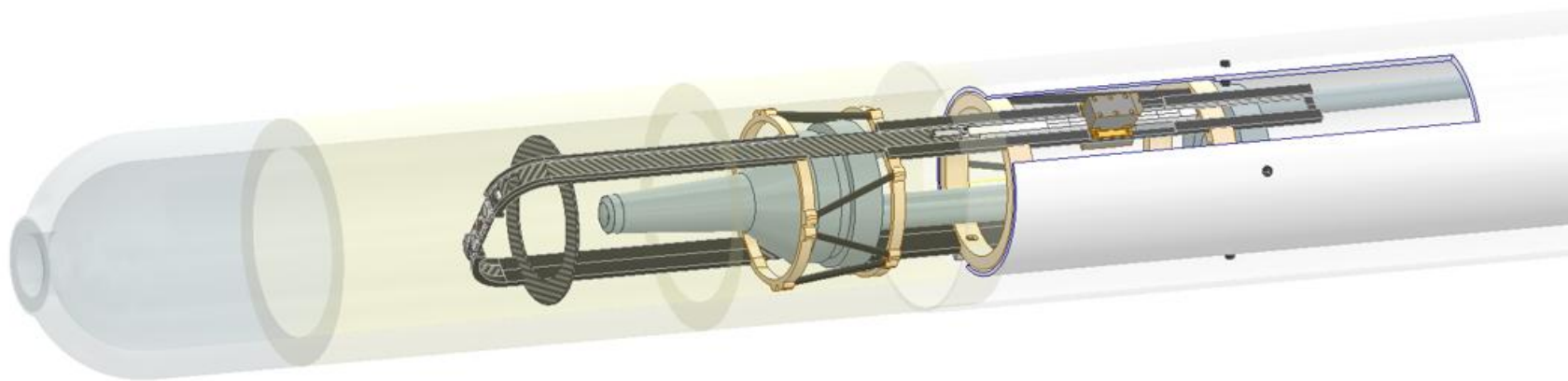


CLAS Collaboration meeting

Run Group E Preparation for Phase 2

Milan Ungerer M.

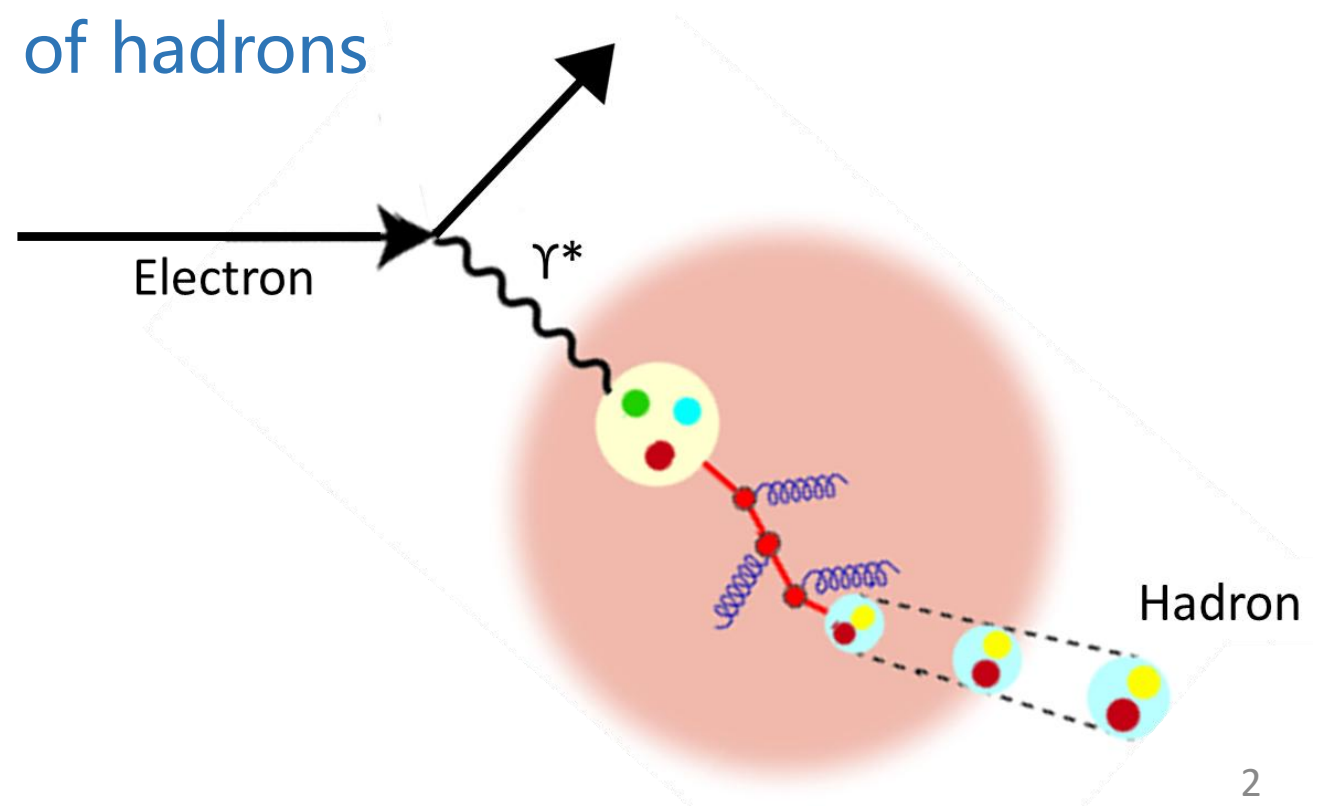
July 1st, 2026



Motivation

Deep inelastic scattering

RGE will provide a comprehensive study of the impact of the nuclear medium on quark hadronization. A multidimensional kinematical analysis of a variety of hadrons is required.



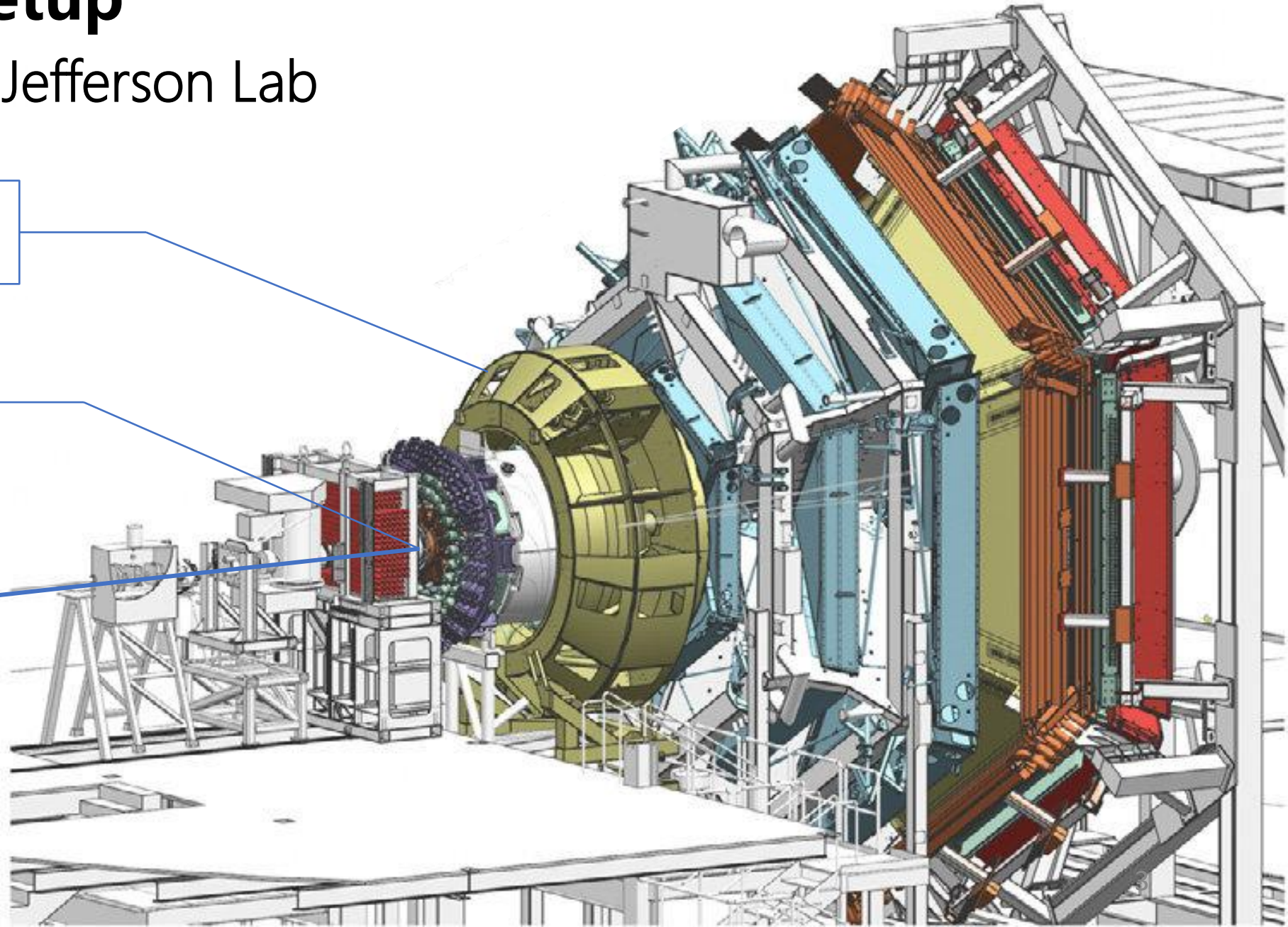
Experimental setup

CLAS12 detector in Jefferson Lab

CLAS12 detector

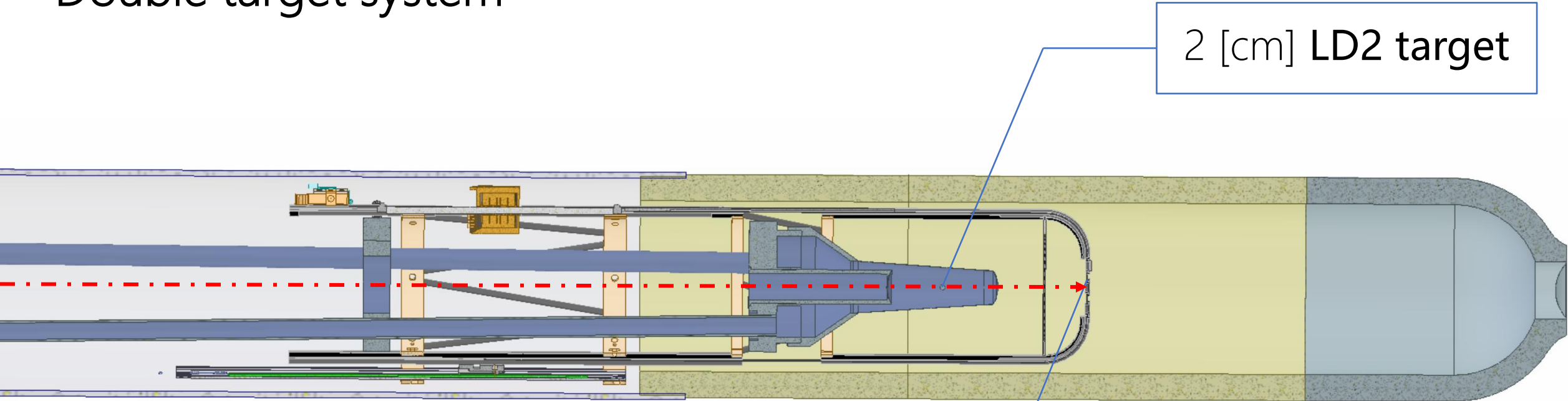
RG-E double-target system

10.5 [GeV]
electron beam



Experimental setup

Double target system



2 [cm] LD2 target

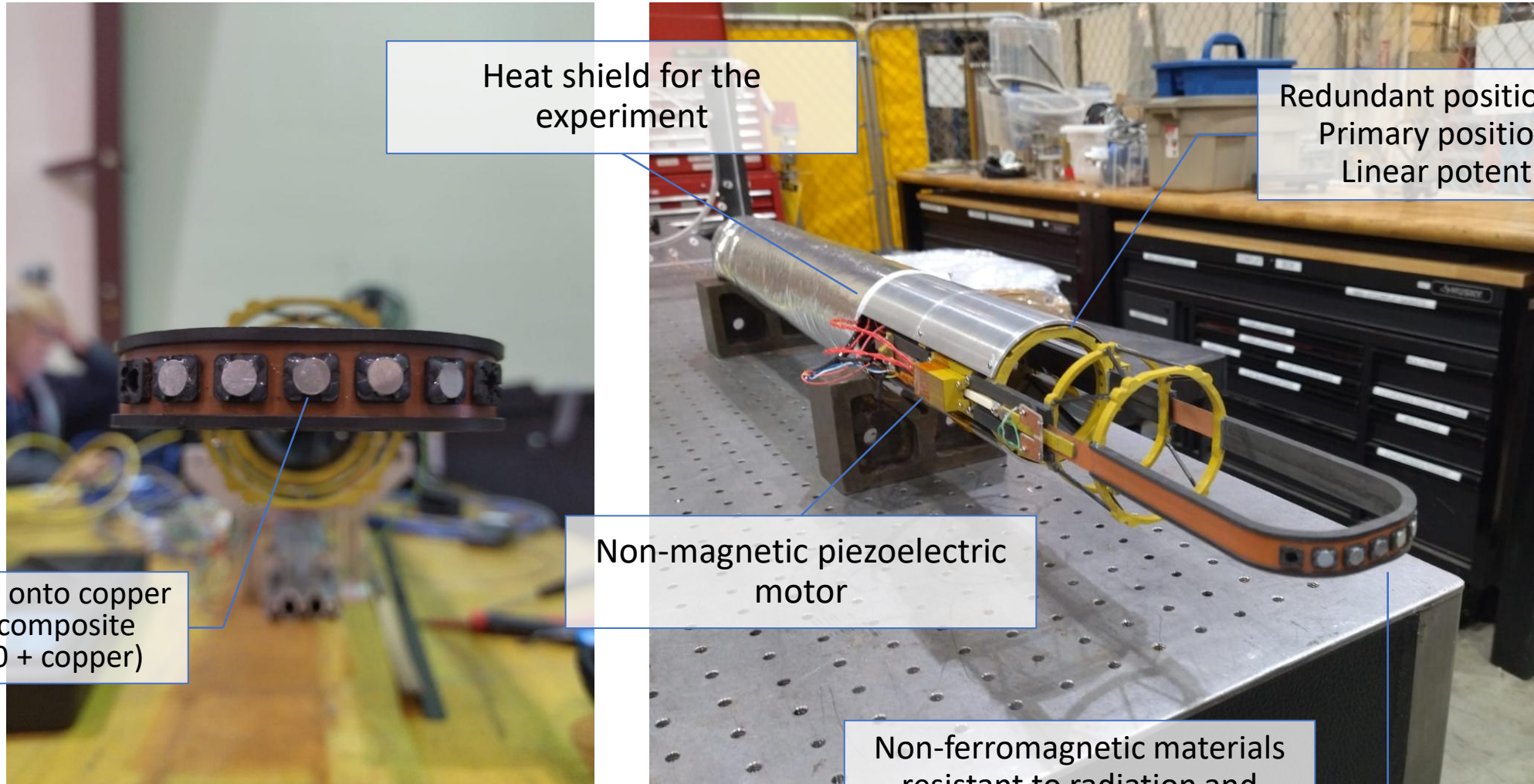
- Carbon (C-12)
- Aluminum (Al-27)
- Copper (Cu-63)
- Tin (Sn-120)
- Lead (Pb-208)

Challenge: extreme conditions

- Ionizing Radiation*: *Neutron* 4,090 [*rem*]
- Magnetic field: 5 [*T*]
- Cryogenic temperatures: 20 [*K*]
- High vacuum: 6×10^{-6} [*mbar*])
- Restricted space: tolerances < 1 [*mm*]
- High precision movement: ± 100 [μm]

How can we meet these requirements to exchange each target remotely under the extreme conditions of the experiment?

Double target system



Heat shield for the experiment

Redundant positioning system
Primary position system:
Linear potentiometer

Glued targets onto copper boxes in a composite ribbon (G10 + copper)

Non-magnetic piezoelectric motor

Non-ferromagnetic materials resistant to radiation and vacuum.

Double target testing

1. Radiation hardness test (JLab 2019)

125 days of operation in Hall A, accumulating a neutron dose of 12,723 rem, more than three times the expected dose.

2. Heat dissipation test (USM 2022)

Laser-heating test: targets stayed below melting point; Pb max: 32 °C.

3. Precision and accuracy of movement test at high vacuum (USM 2023)

Worst-case positioning repeatability: $\pm 52.5 \mu\text{m}$ at 3σ .

4. Magnetic field test (JLab August 2023)

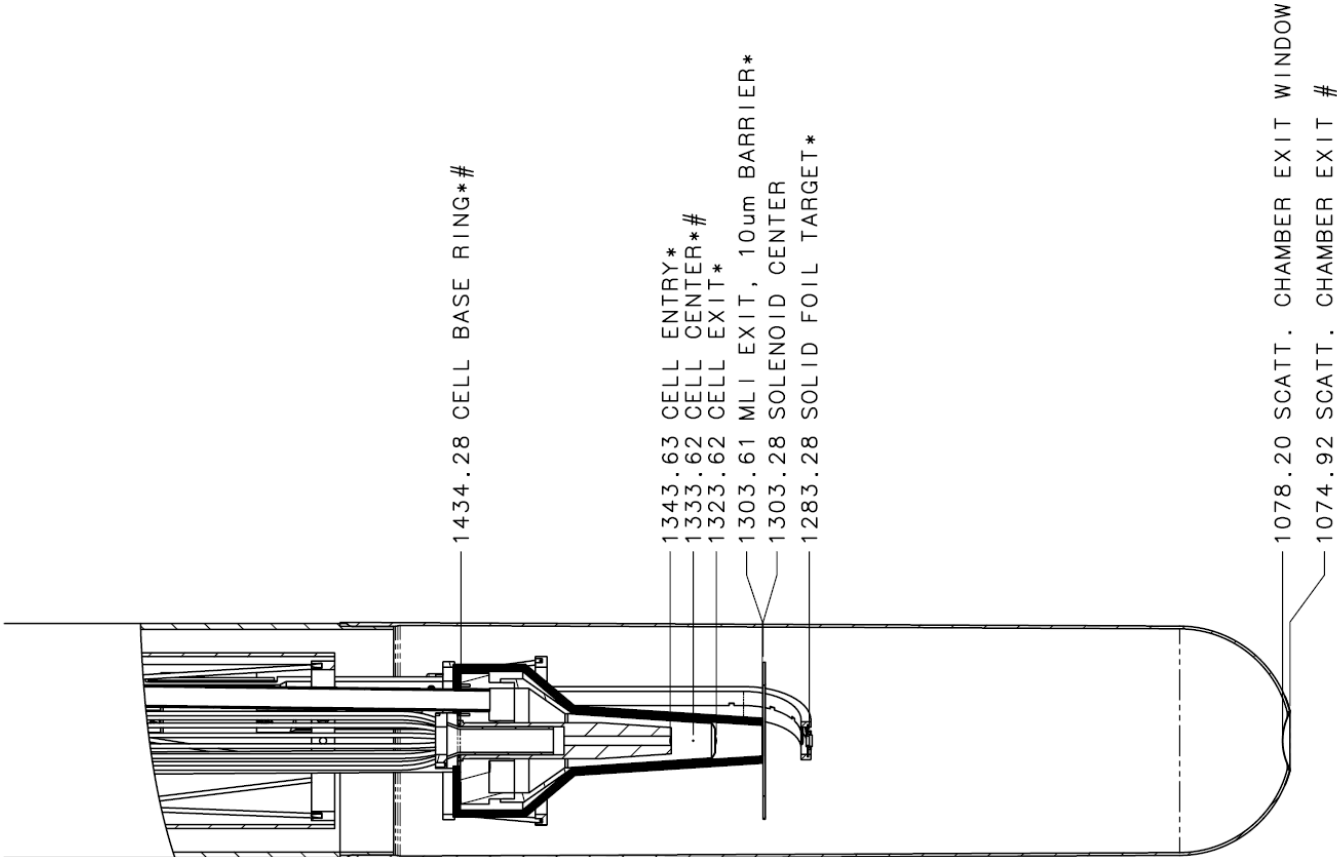
Motion system validated in a 5 T solenoid magnetic field with no issues.

5. Low temperature test (JLab October 2023)

Motion system validated at cryogenic temperature ($\sim 40 \text{ K}$) with $< 500 \text{ mW}$ heat load.

Double target installation

2024 Phase



* WHEN AT OPERATING TEMPERATURE, CELL AND FOIL LOCATIONS MOVE UPSTREAM APPROXIMATELY 5 [mm] DUE TO THERMAL CONTRACTION



Special thanks to:

Hall B engineering team
Scientific staff
Target Group
Alignment Group

Run Configuration and Data Collected

2024 Phase

- Data taken in [Spring 2024](#) from March 15th to May 19th
- [10.5 GeV](#) electron beam
- [Standard CLAS12](#) configuration with FT-OFF
- Three layers of FMT
- ~ 93% of data has [inbending torus polarity](#)

Target	Production Current (nA)	Accumulated Charge (mC)	Integrated Luminosity (1/fb) (Solid Target)	Events
LD2+C	85	25.24	24.38	3,391,704,235
LD2+Al	70	20.53	24.23	2,445,718,954
LD2+Cu	75	21.46	22.42	2,488,996,497
LD2+Sn	65	27.6	21.58	2,754,243,416
LD2+Pb	70	46.84	26.76	4,631,998,074
C only	85	2.29	3.79	148,150,553
Pb only	160	4.98	2.84	23,516,294

Pass1 Cooking summary

2024 Phase

Dates:

- Pass1 review on December 12th 2025
- Pass1 cooking started on April 1st 2026
- Pass1 finished cooking on May 11th 2026

Data:

- 381 Runs cooked with coatjava 13.8.2
- Three trains included in the cooking:
 - Anti-proton
 - Lambda
 - Jpsi/TCS
- Data location in tape: /mss/clas12/rg-e/production/spring2024/pass1/

*Courtesy of Antonio Radic

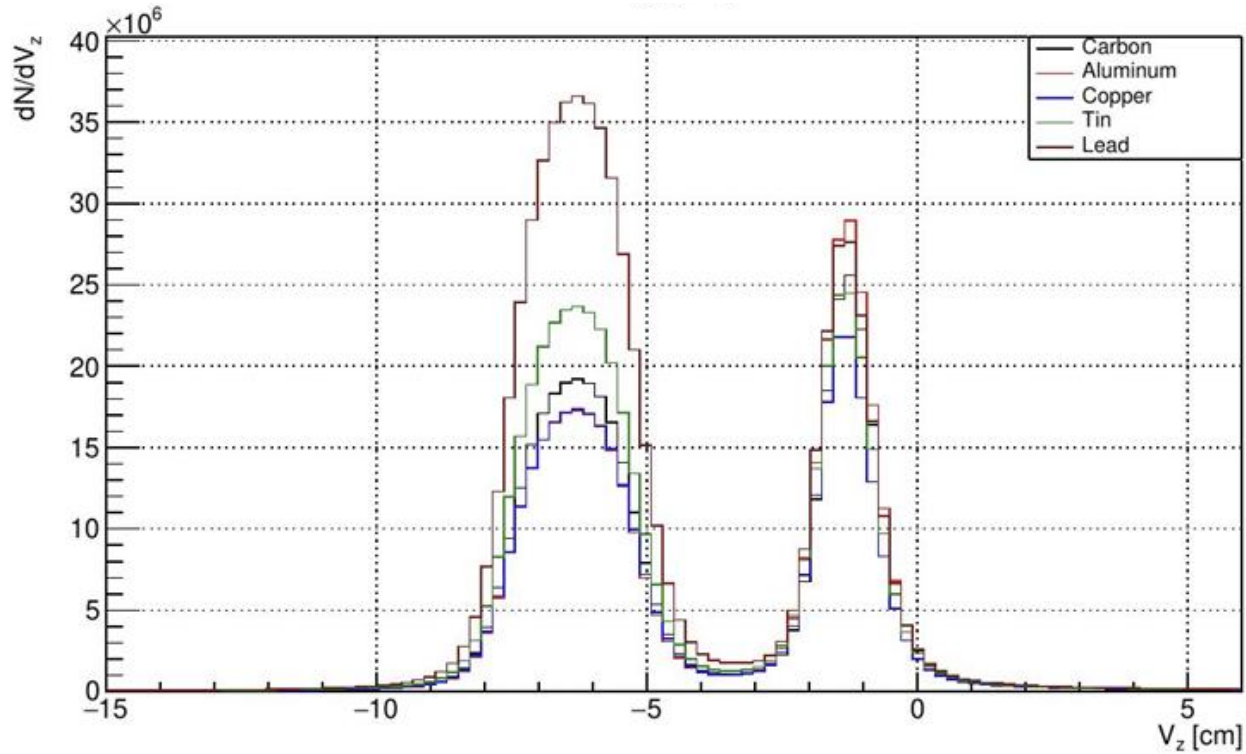
```
.  
└─ pass1/  
    └─ torus-1/  
        └─ C_D2  
        └─ Al_D2  
        └─ Cu_D2  
        └─ Sn_D2  
        └─ Pb_D2  
        └─ C_only  
        └─ Al_only  
        └─ Pb_only  
        └─ empty  
    └─ torus+1/  
        └─ C_D2  
        └─ Pb_D2  
    └─ zero/  
        └─ empty
```

Special thanks to:
CALCOM

RG-E Experiment Phase 1 preliminary results

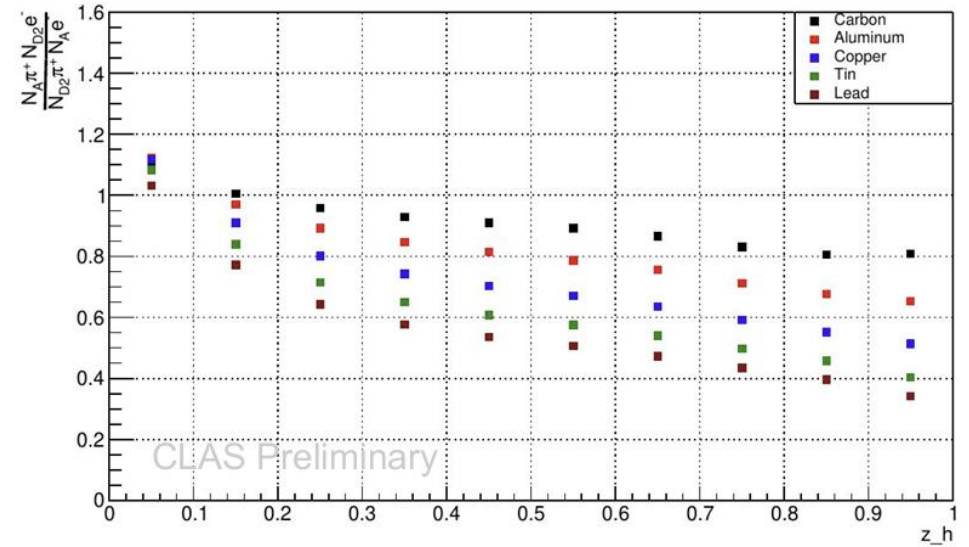
Vertex and integrated MR

V_z [cm] of electrons using only DC

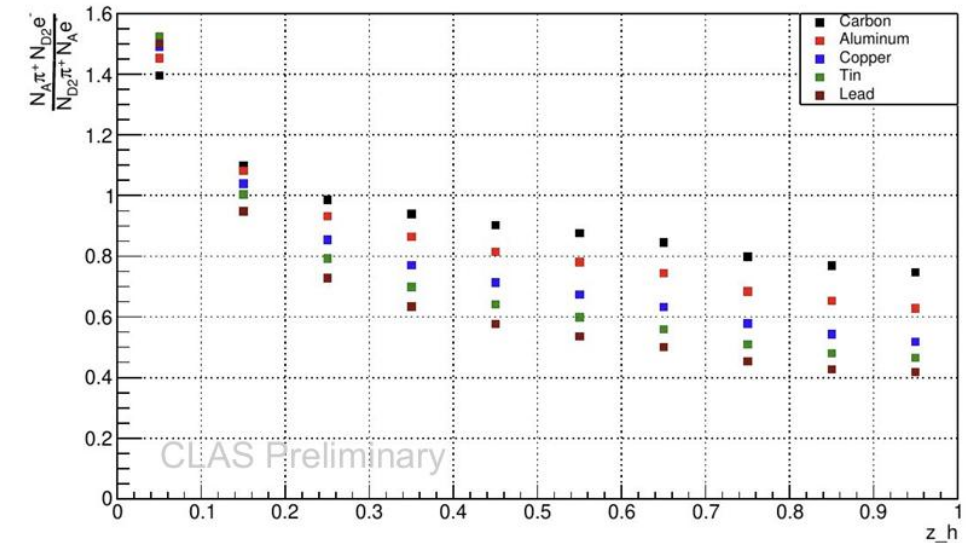


*Courtesy of Antonio Radic

Multiplicity Ratio



π^+

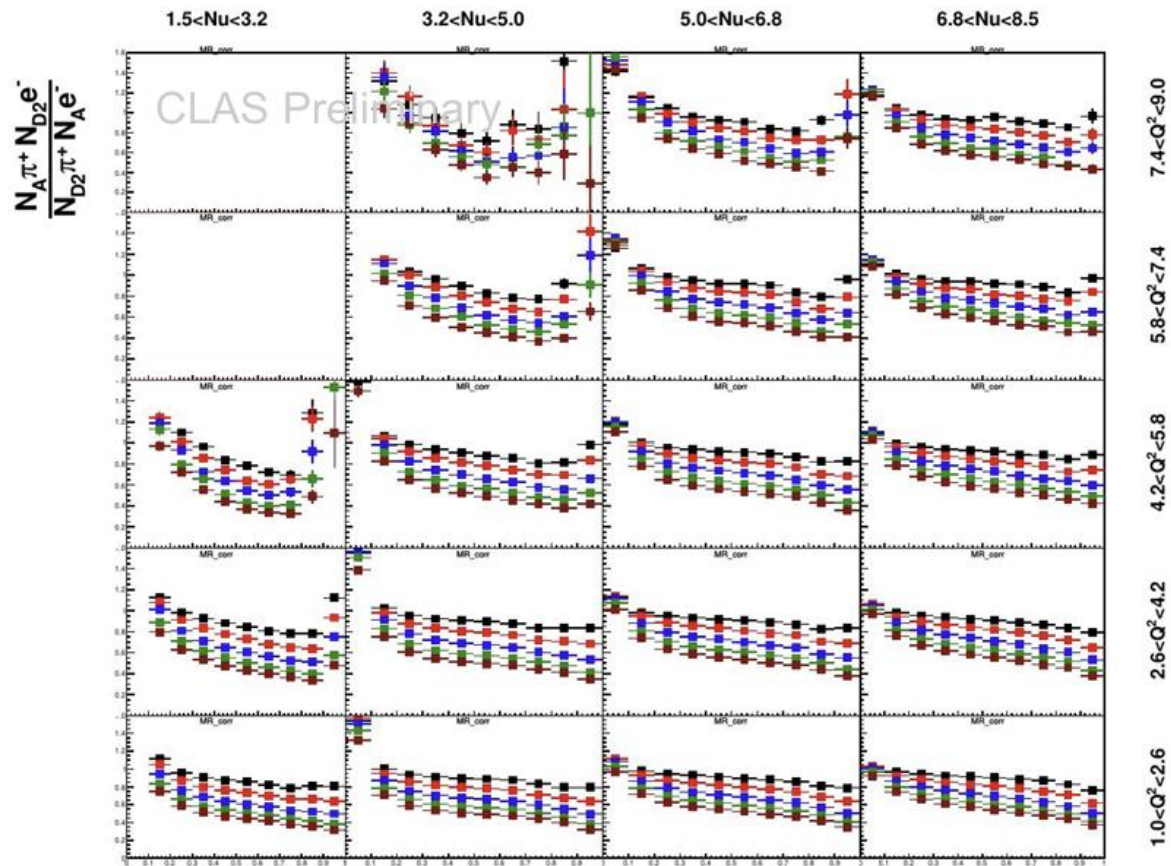


π^-

RG-E Experiment Phase 1 preliminary results

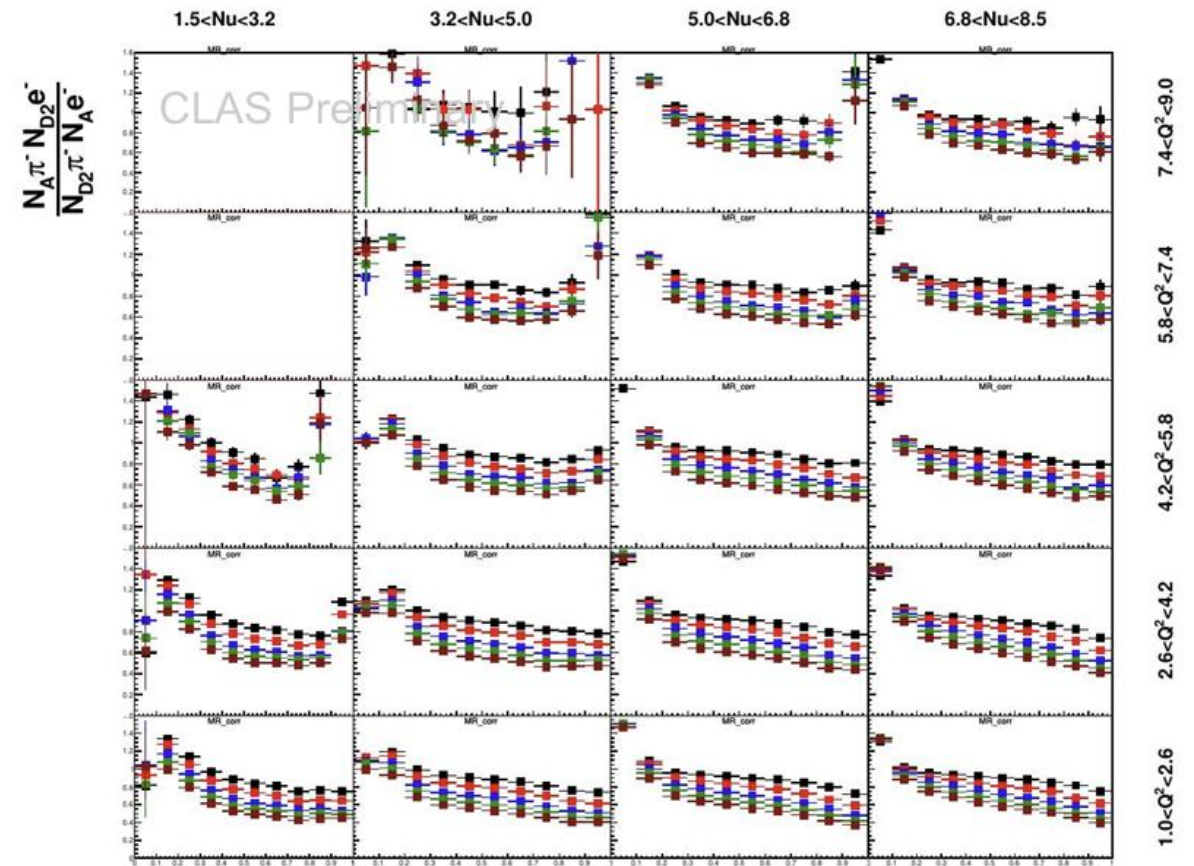
Multibinning Zh Multiplicity Ratio

π^+



Zh

π^-



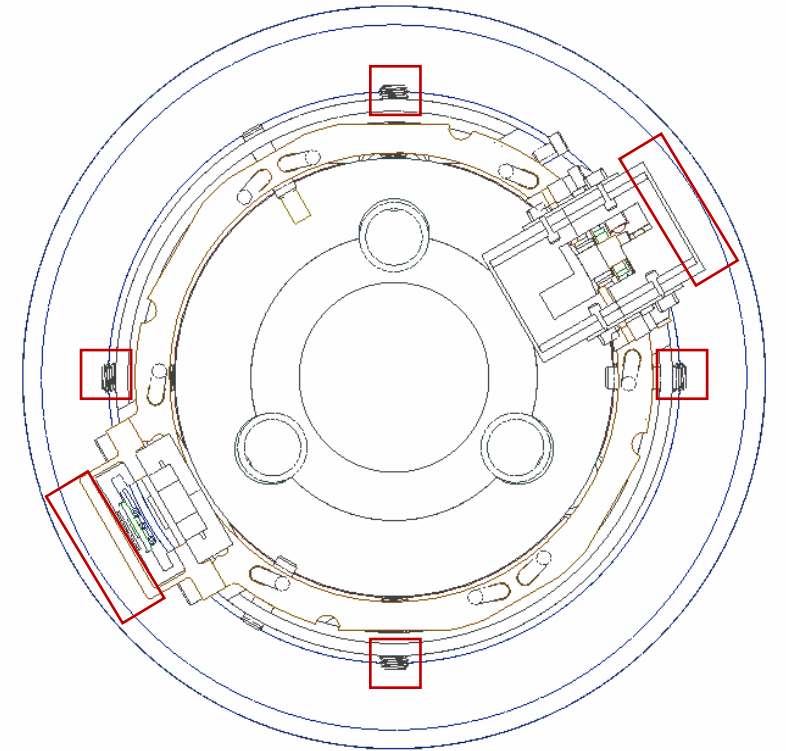
Zh

Double target improvements

RG-E 2027 Phase

Installation and operation were successful, with only minor improvements identified:

- **Increase assembly tolerances** by reducing tracks and structural rings.
- Improve **limit-switch** performance at **low temperatures**.
- Strengthen the **redundant position** measurement system.
- Improve solid-target **alignment system** within the heat shield.



Experimental setup

RG-E 2027 Phase

- 10.5 GeV electron beam
- Standard CLAS12 configuration with FT-OFF
- Three layers of FMT
- ~ 93% of data has inbending torus polarity

Target	Length (mm)	Production Current (nA)	Integrated Luminosity (1/cm ²) (Assuming 50% beam efficiency)	Total days
LD2+C12	20 + 1.51	85	7.92E+40	10.1
LD2+Al27	20 + 1.21	70	7.92E+40	10.8
LD2+Cu63	20 + 0.34	75	7.92E+40	10.5
LD2+Sn120	20 + 0.29	65	7.92E+40	14.3
LD2+Pb208	20 + 0.14	70	7.92E+40	14.4
Total				60

RG-E pasc 2 experiment scheduled for 2027 (Remaining 50% of PAC days)

Preparation Plan for RG-E Phase 2

- Double-target Phase 1 assessment trip and coordination of next steps to prepare the target for the 2027 experiment — June 2026
- Finalize design improvements for double-target assembly tolerances and alignment — August 2026
- Finish the design of the new limit-switch system — August 2026
- Replicate and implement minor corrections to the electronic system — August 2026
- Manufacture, assembly and test of the new double-target models — November 2026
- Installation and data taking — First half of 2027

Summary

- The [double-target system operated successfully](#) during the first phase of the RG-E experiment.
- RG-E Phase 1 achieved the [expected integrated luminosity](#).
- Pass-1 [cooking](#) of the RG-E spring 2024 dataset has been [completed](#).
- The [available statistics](#) enable multiplicity-ratio studies using both one-dimensional and multidimensional binning.
- [Minor improvements](#) have been identified in the double-target system and are expected to be completed this year.
- The second phase is planned to [replicate the configuration used in the first phase](#).
- The next phase will approximately double the dataset, enabling [improved precision and opening opportunities for additional studies](#).



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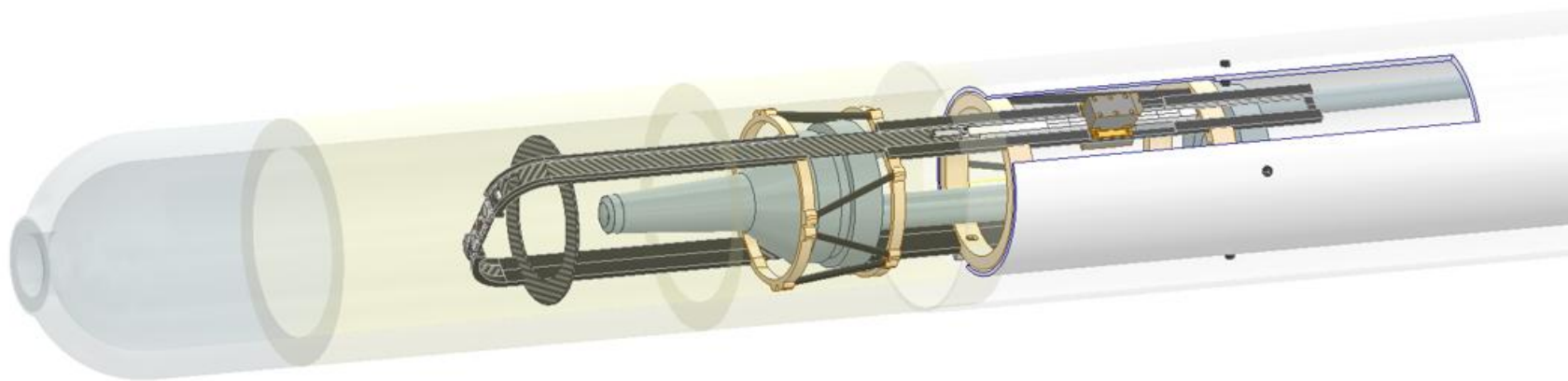


CLAS Collaboration meeting

Run Group E Preparation for Phase 2

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July 1st, 2026



Backup slides

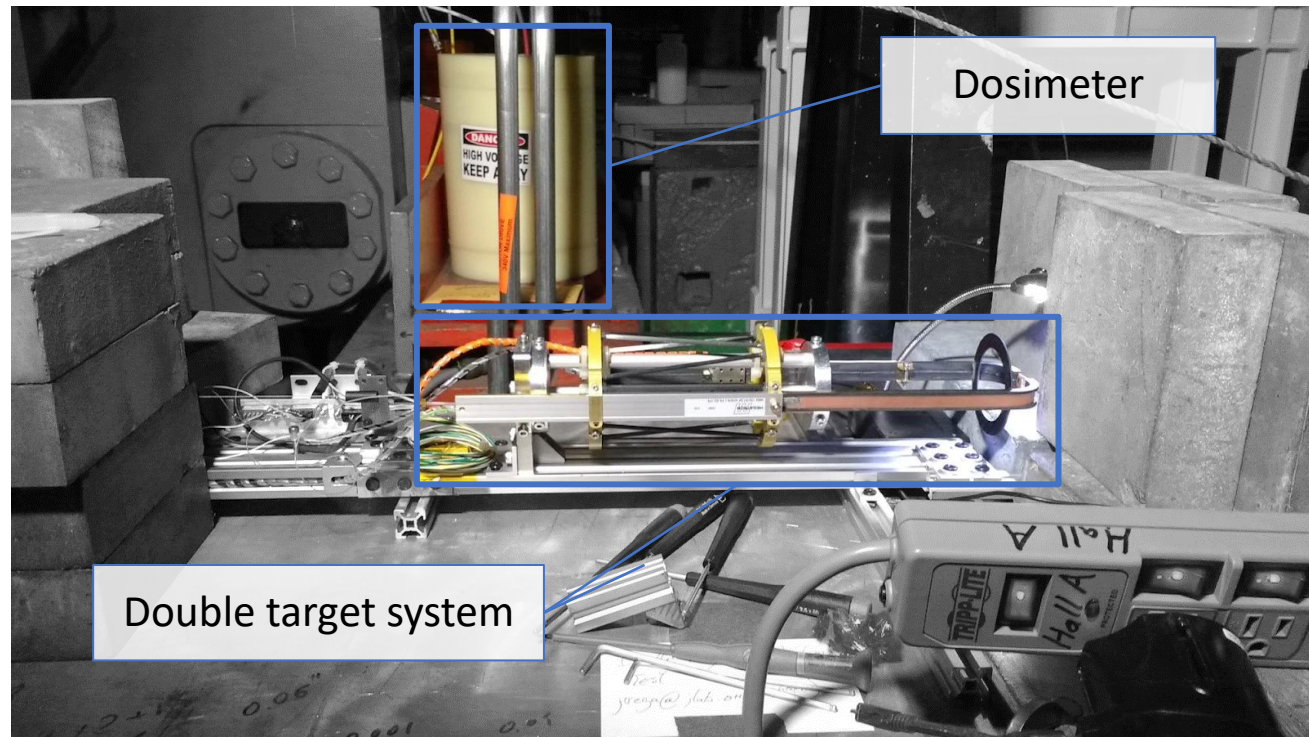
Radiation hardness test

Jefferson Lab's Hall A provides an ideal environment for conducting radiation resistance tests due to its **accessibility** to high radiation rates and **constant monitoring**.

Estimation of accumulated dose through **simulations***:

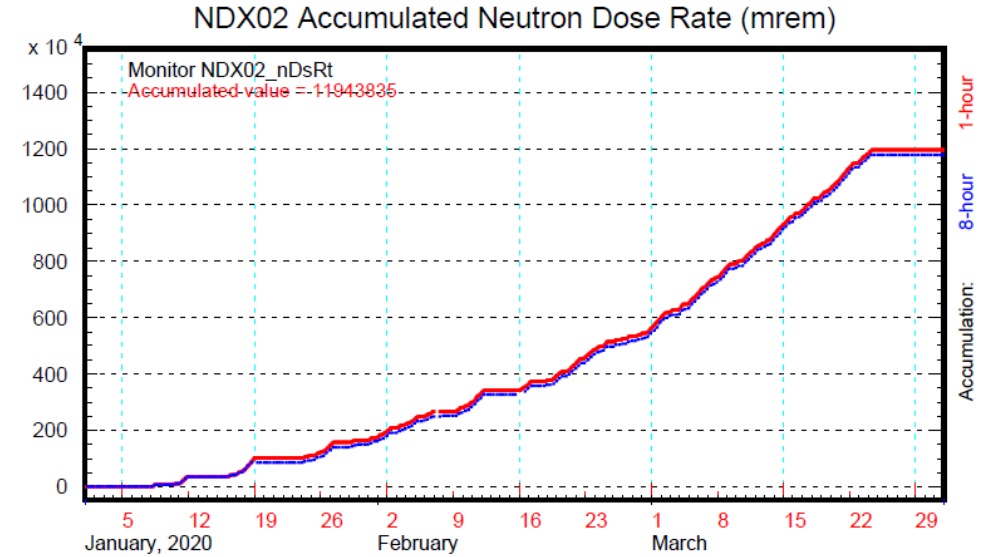
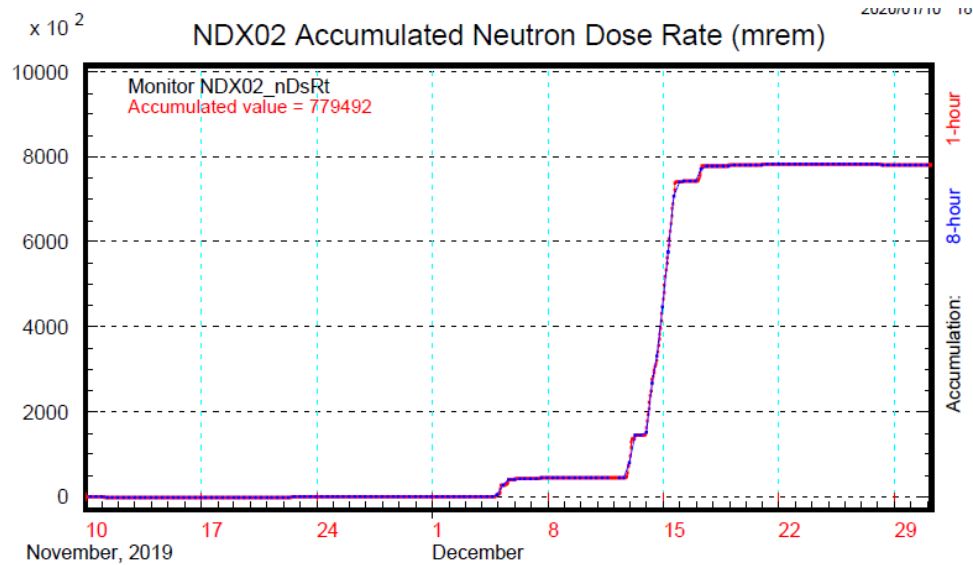
- **Neutron: 3,780 [rem]**
- Photon: 367 [rem]
- Proton: 92 [rem]
- Electron: 3,958 [rem]

*Lorenzo Zana (Radcon) simulations

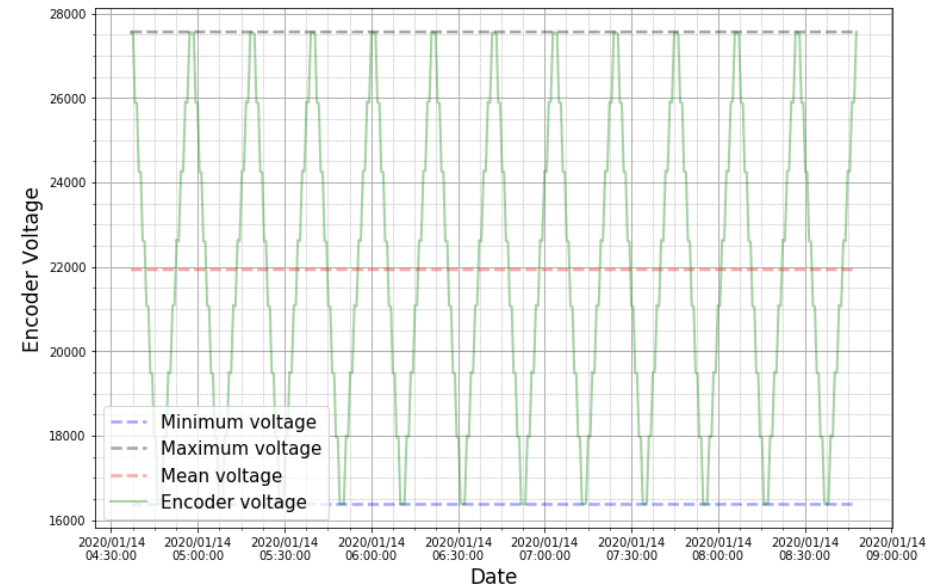


Accumulated dose during 4 months of testing

Neutron dose
12,723 [rem]
337%!

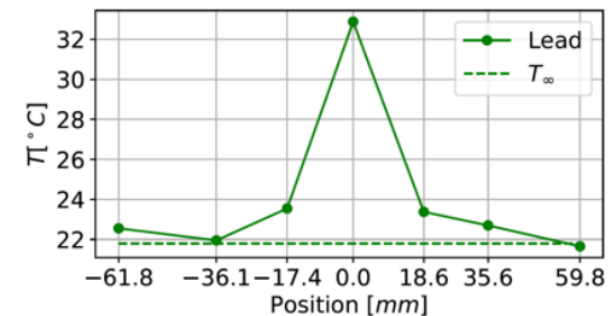
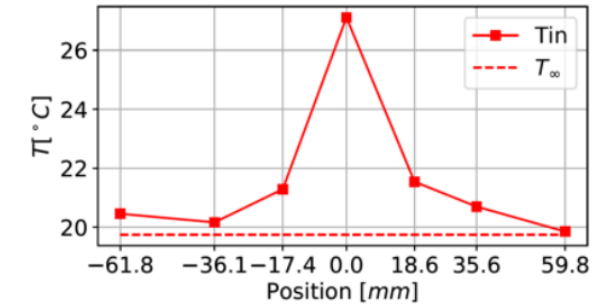
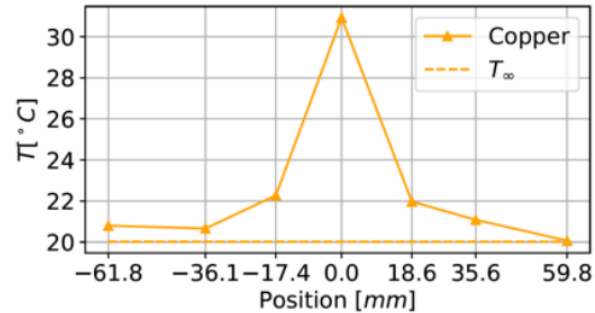
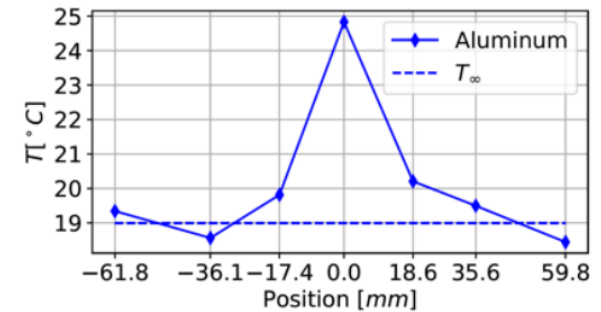
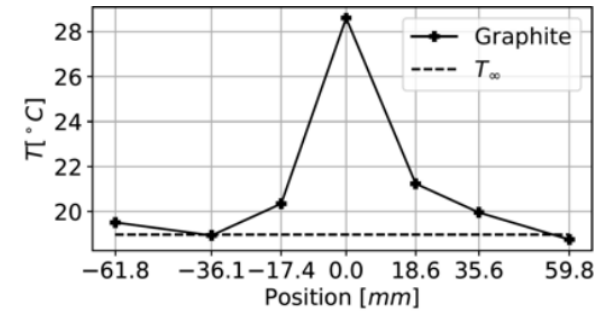
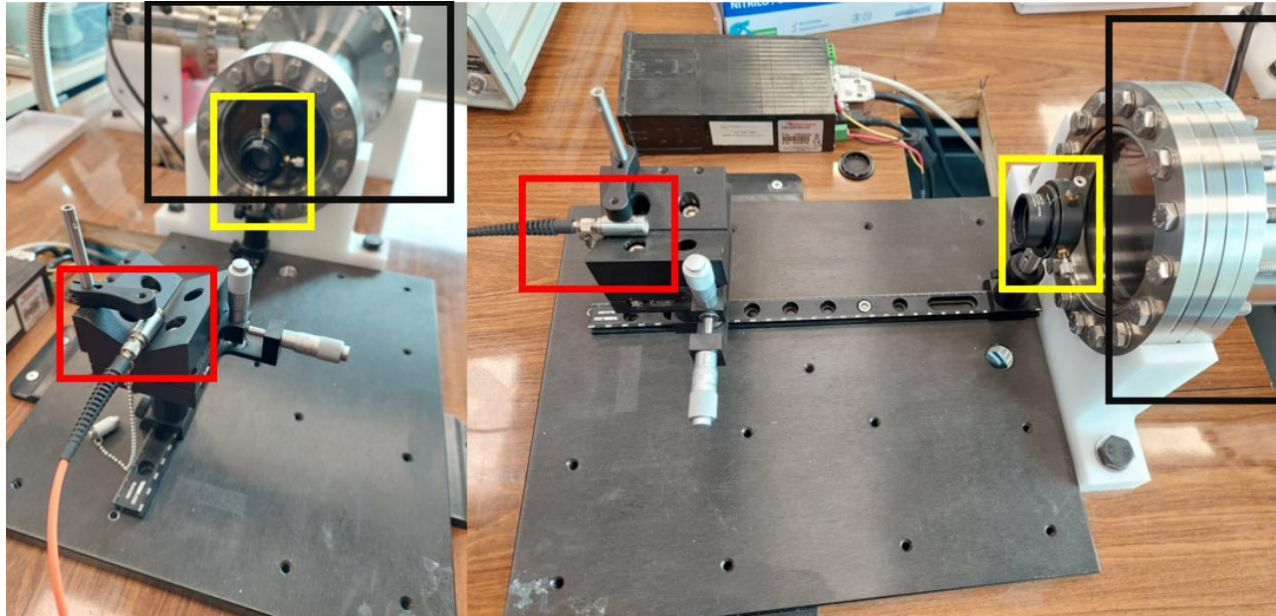


Measurement of position for **125 days without appreciable changes.**



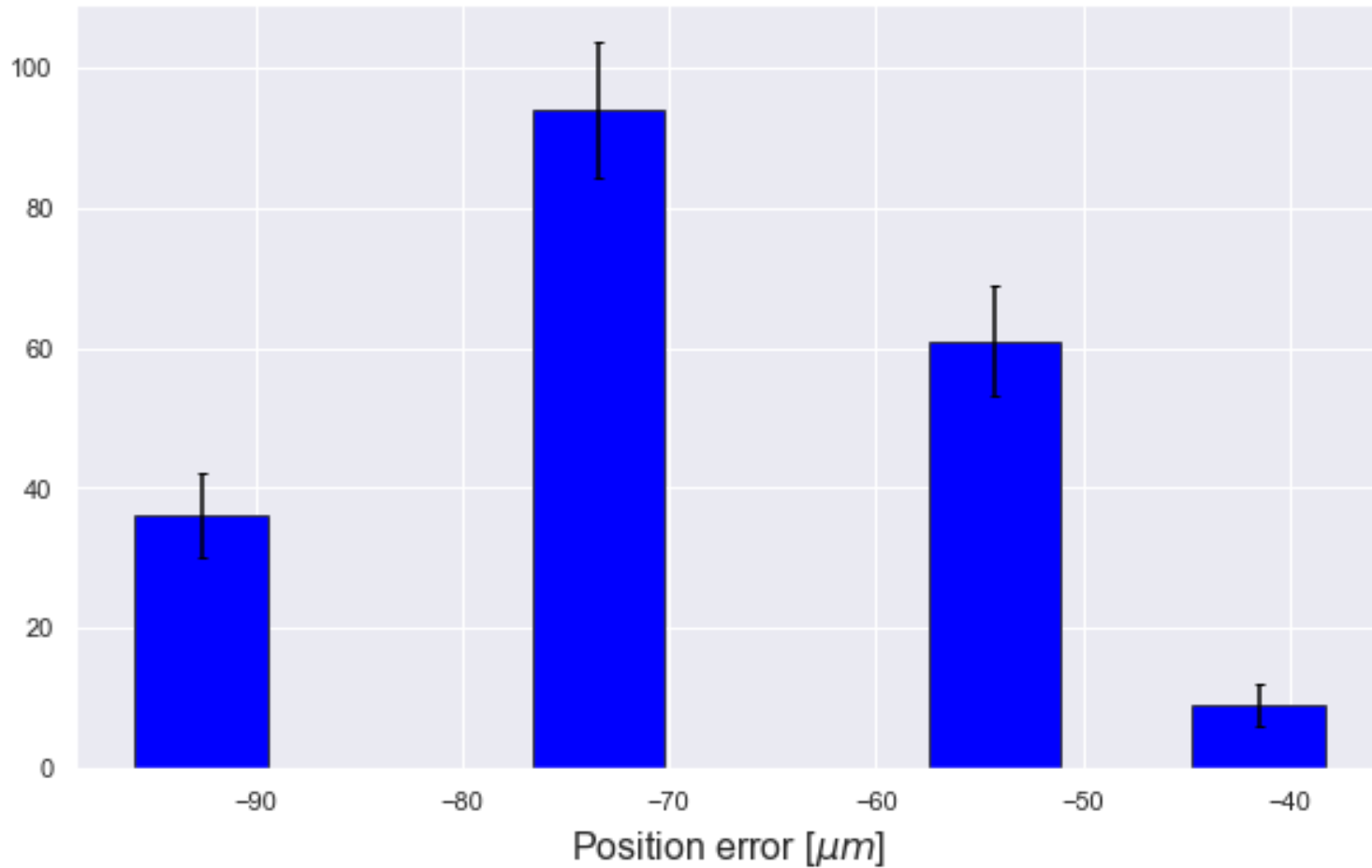
Heat dissipation test

Heat extraction capacities of the Double-Target



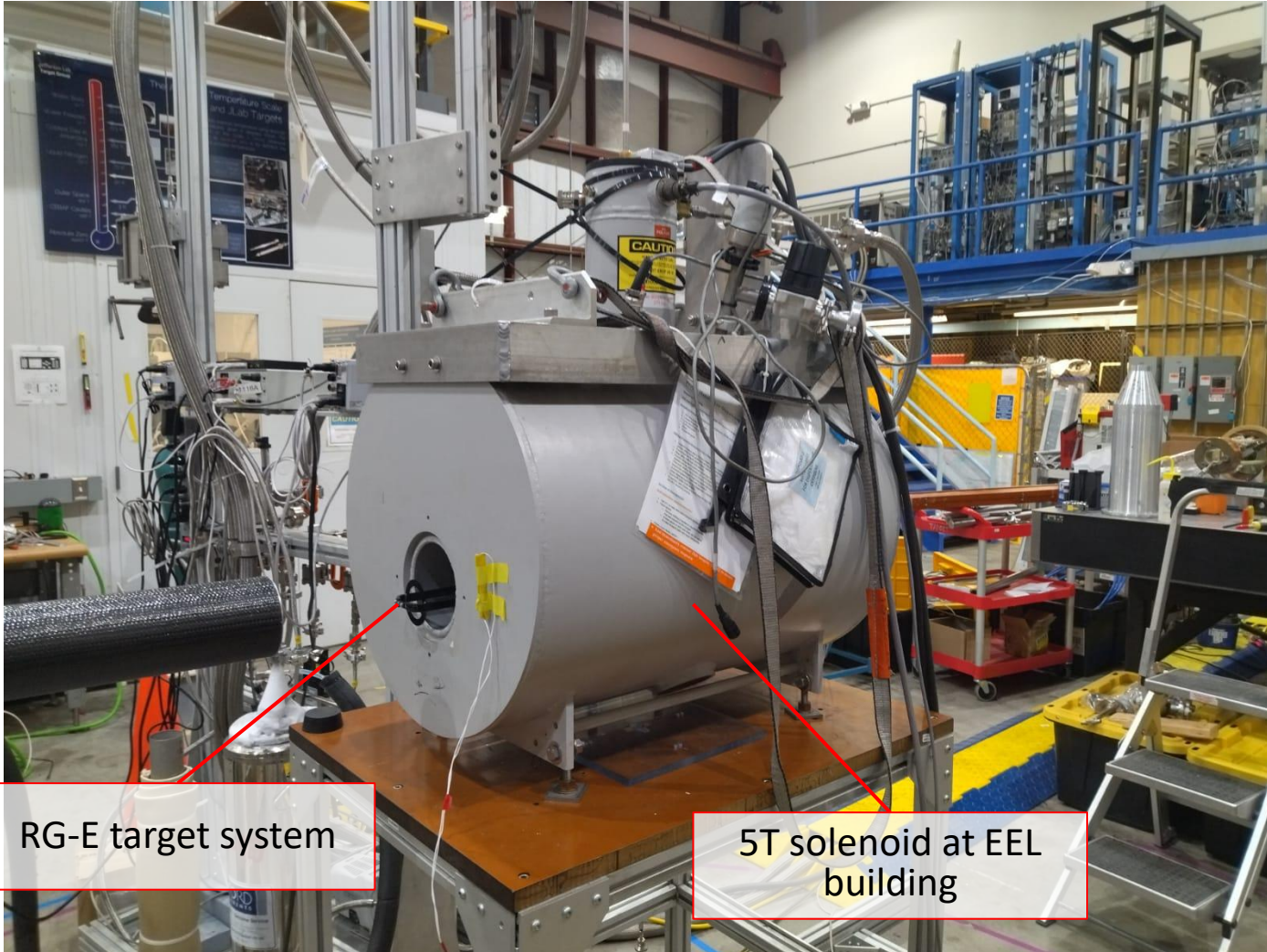
The experimental setup consists of a laser with sufficient power to **deposit 60 [mW]** on each target under vacuum conditions and a measurement of temperature at various points near the heat flow. The objective is to ensure that the solid targets **do not reach their melting point**.

Precision and accuracy of movement in high vacuum conditions



- Measurement instrument resolution: 20 [μm]
- Number of samples: 200
- 3σ (99.7%) = ± 70 [μm]

High magnetic field test at Jlab (August 2023)



The movement system worked under **5T magnetic field without any problem**

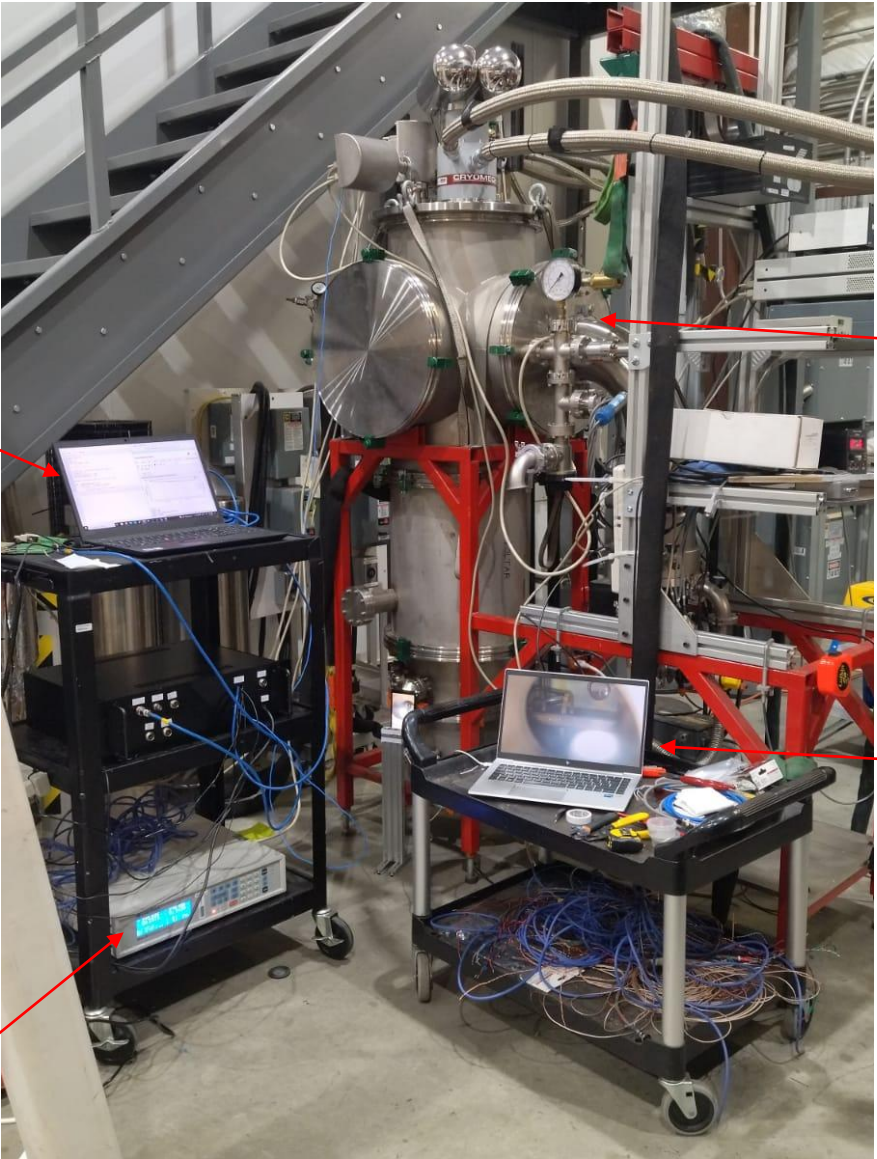
Low temperature test at Jlab (October 2023)



Movement control system

Target ready to be installed

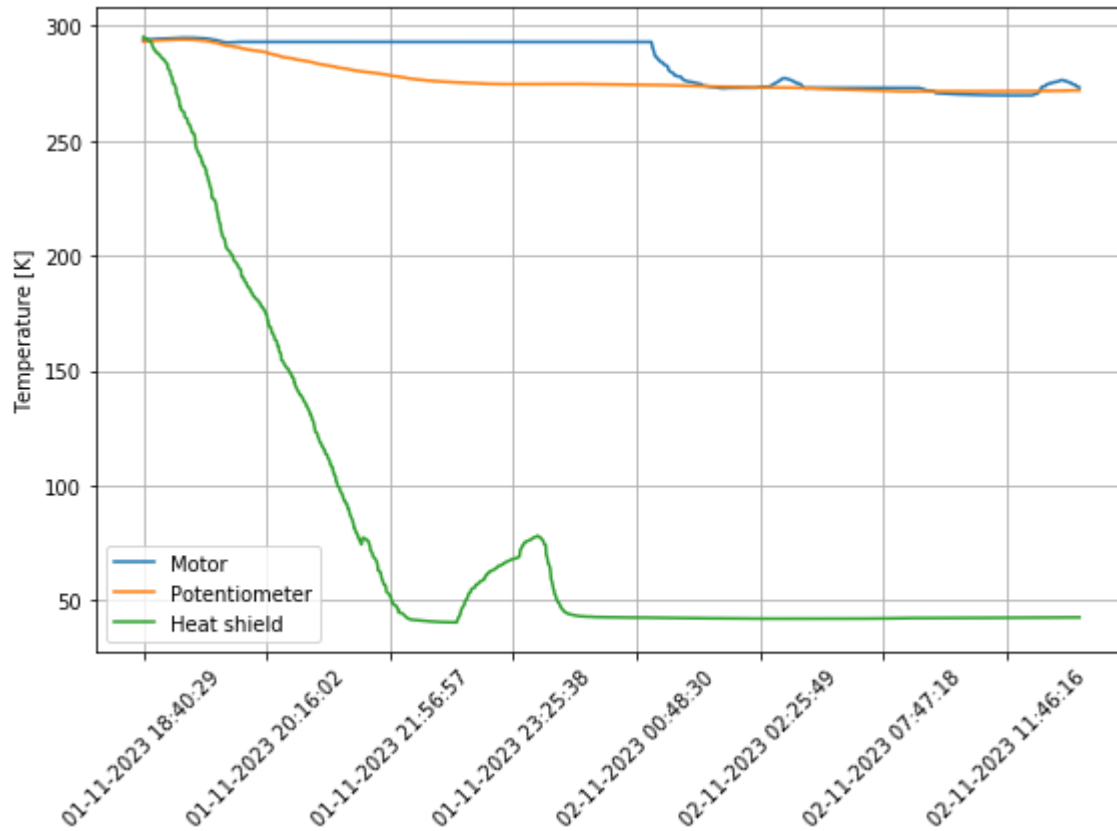
Temperature control system



Pulse tube – Cryogenic equipment capable to achieve below 40 K

Visual inspection

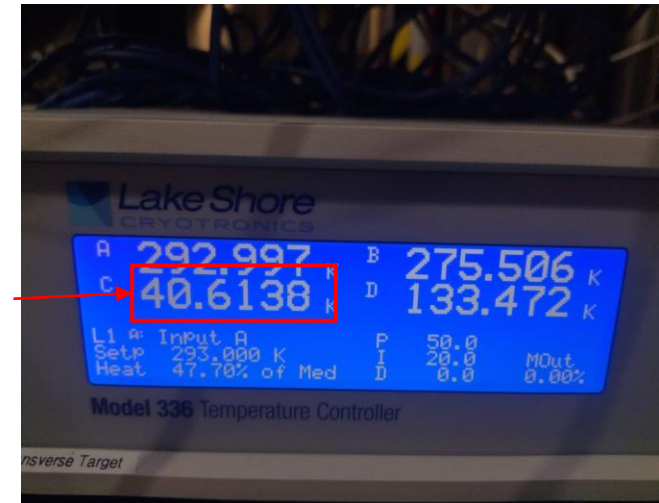
Low temperature test at Jlab (October 2023)



The heating power of the system is less than 500 mW

The movement system worked properly during the whole test

Heat shield temperature



Pulse Tube temperature

