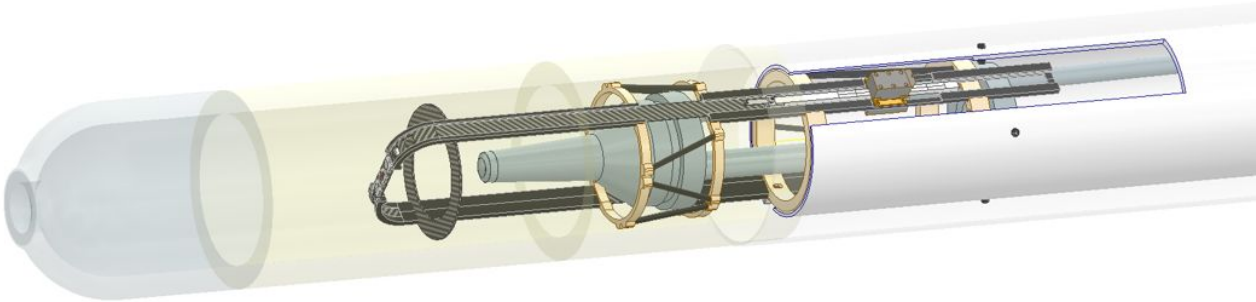
UNIVERSIDAD TECNICA
FEDERICO SANTA MARIA

CCTVal
CENTRO CIENTÍFICO
TECNOLÓGICO
DE VALPARAÍSO

Jefferson Lab

CLAS Collaboration meeting

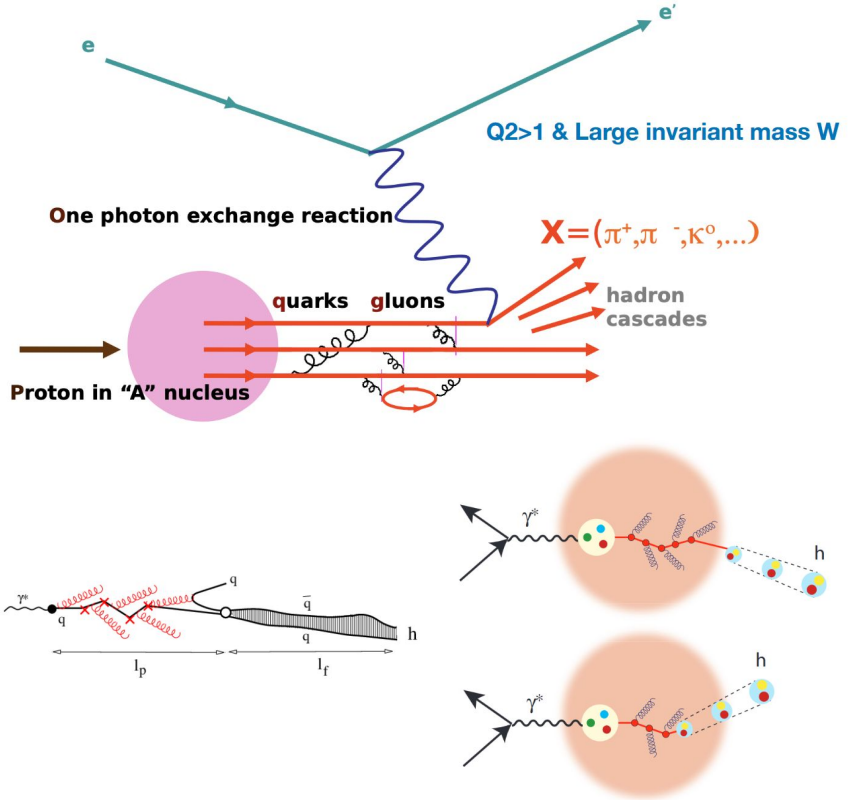
Run Group E Preparation for Phase 2



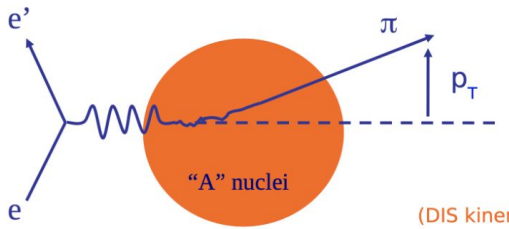
Hayk Hakobyan

11/19/2026

Semi-Inclusive Deep Inelastic Scattering on Nuclear Targets (SIDIS)



Transverse momentum broadening: $\Delta p_T^2 = p_T^2(A) - p_T^2(^2H)$



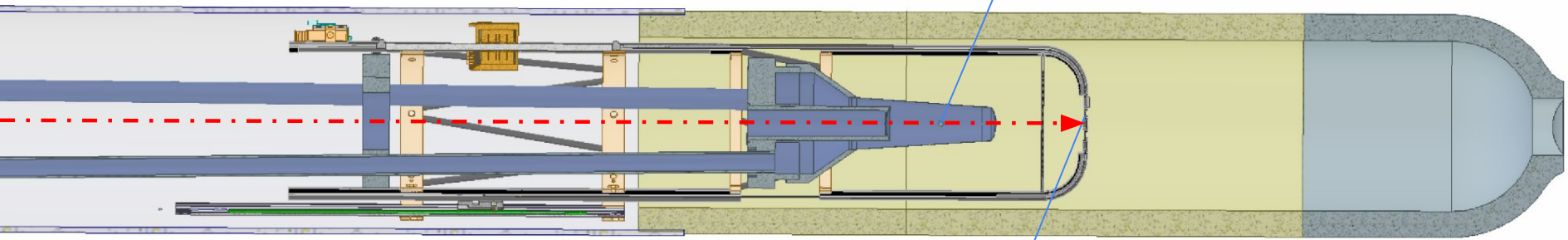
(DIS kinematics)

Hadronic multiplicity ratio:

$$R_M^h(z,\nu,p_T^2,Q^2,\phi) = \frac{\left\{\frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_A}{\left\{\frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_D}$$

Experimental setup

Double target system



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

Solid Target System Design and Fabrication Coordinator: Milan Ungerer.

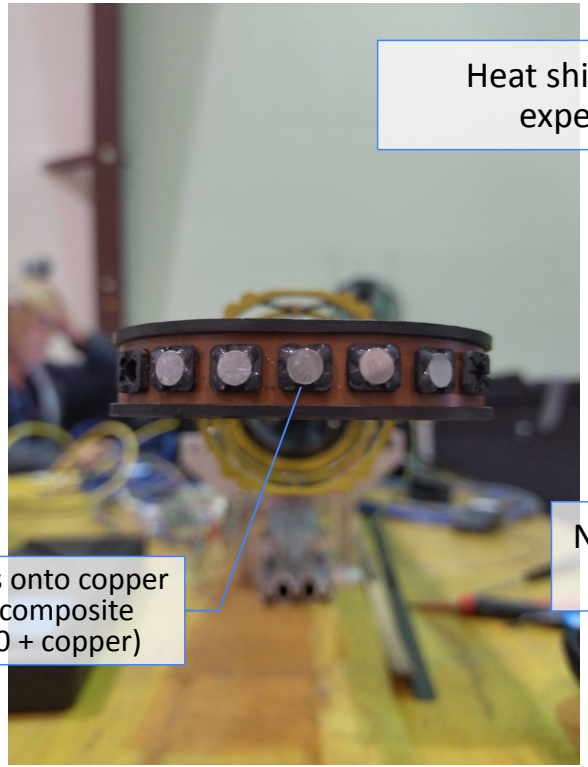
Challenge: extreme conditions

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

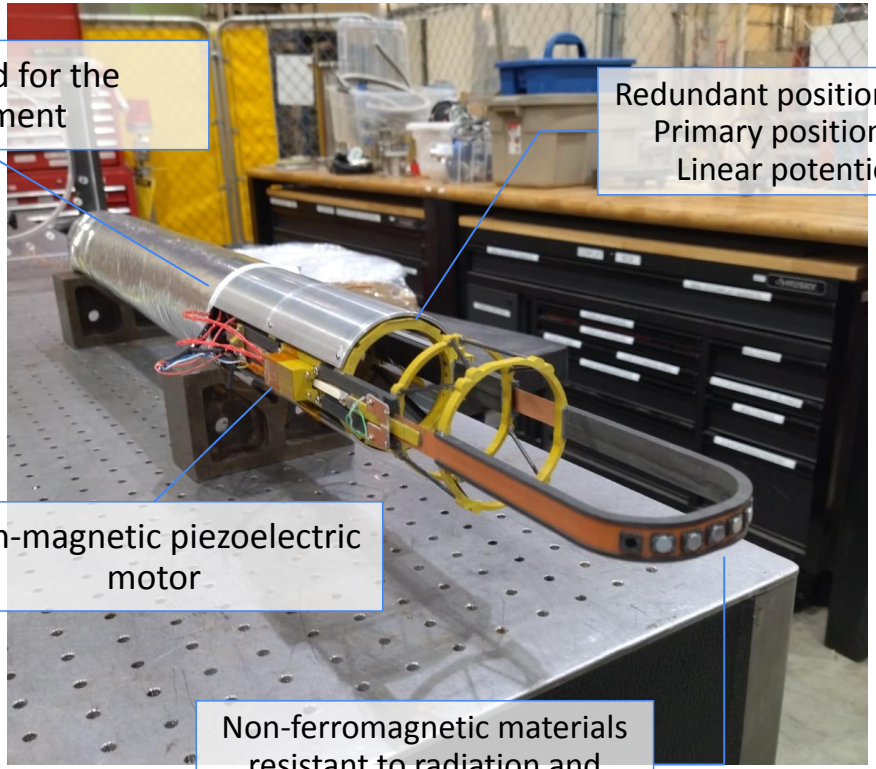
How can we meet these requirements to exchange each target remotely under the extreme conditions of the experiment?

*Lorenzo Zana (Radcon) simulations

Double target system



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



Heat shield for the experiment

Redundant positioning system
Primary position system:
Linear potentiometer

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: ±52.5 μm at 3σ.

4. Magnetic field test (JLab August 2023)

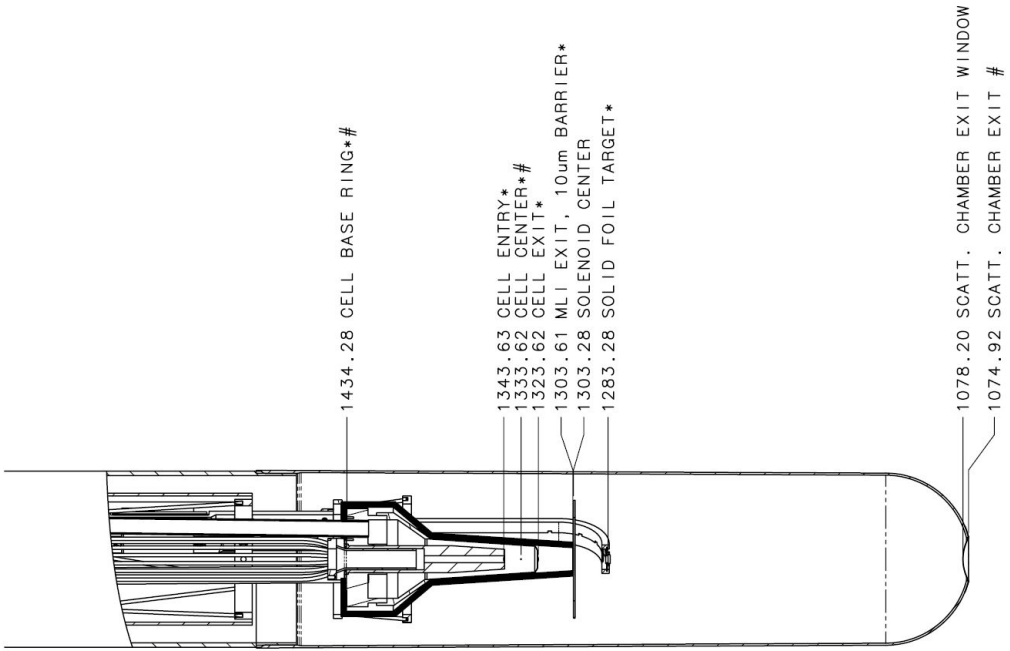
   Motion system validated in a 5 T solenoid magnetic field with no issues.

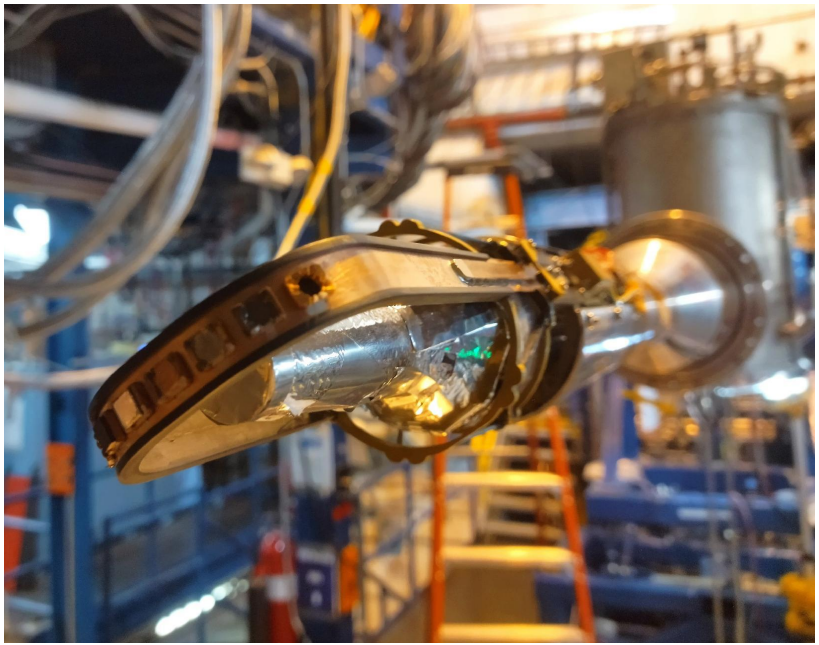
5. Low temperature test (JLab October 2023)

   Motion system validated at cryogenic temperature (~40 K) with <500 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

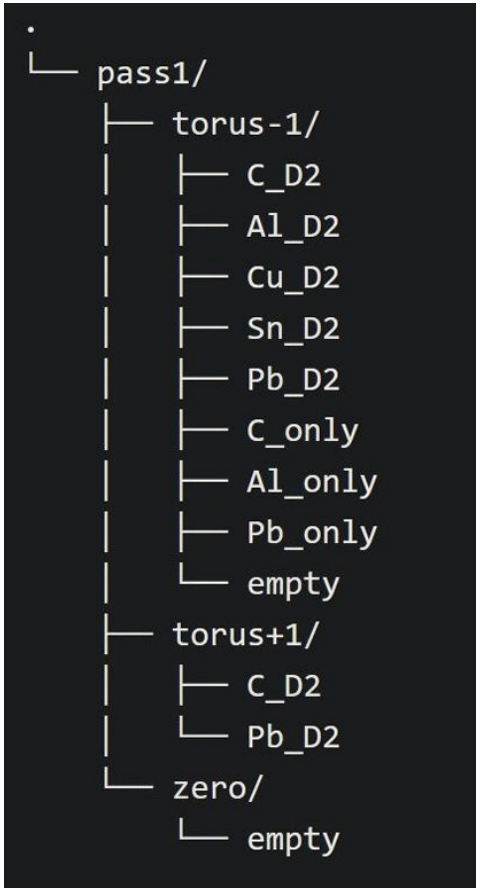
2024 Phase

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/

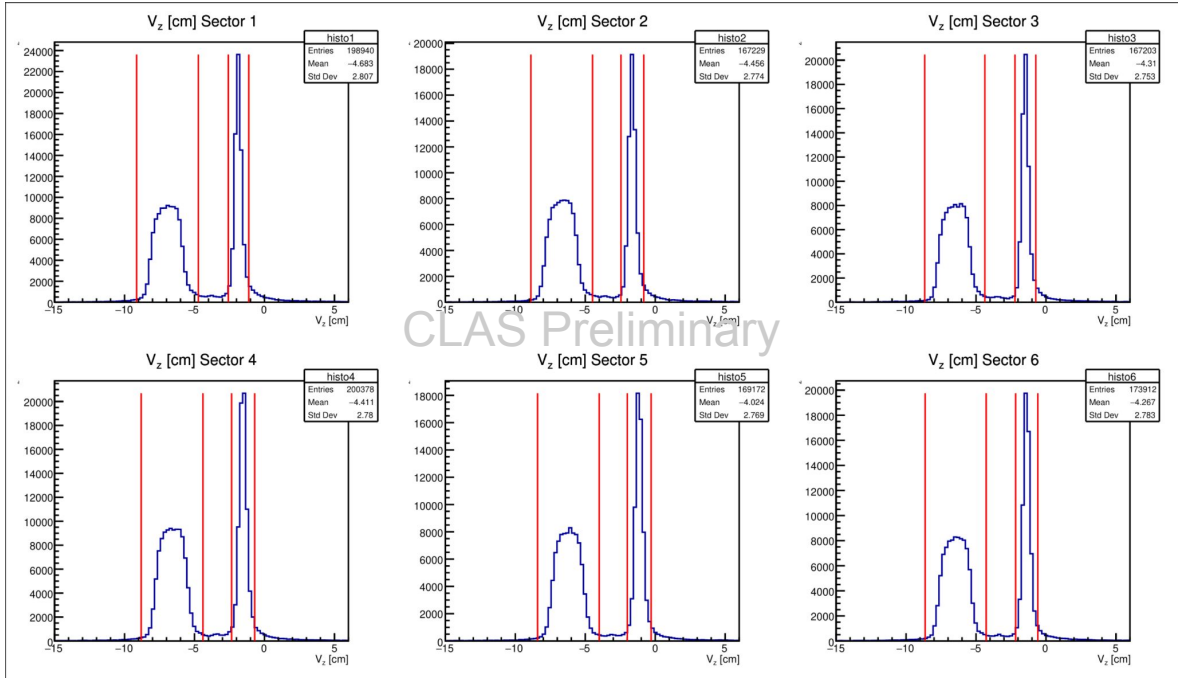


Coordination of cooking and calibration activities from RG-E: Antonio Radic.

Special thanks to:
CALCOM

Electron vertex cuts

- Vertex cuts depending on sector and target

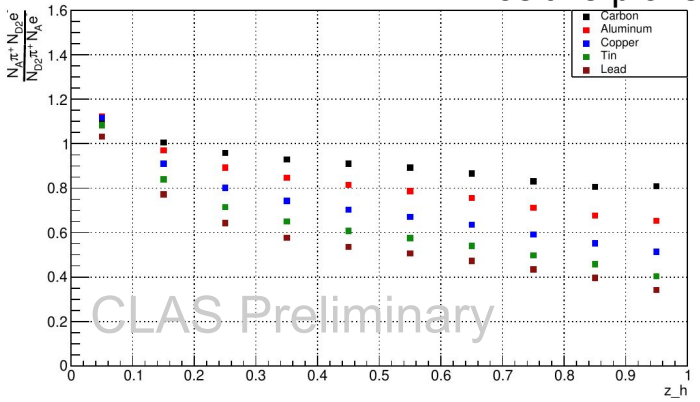


Z-vertex by sector

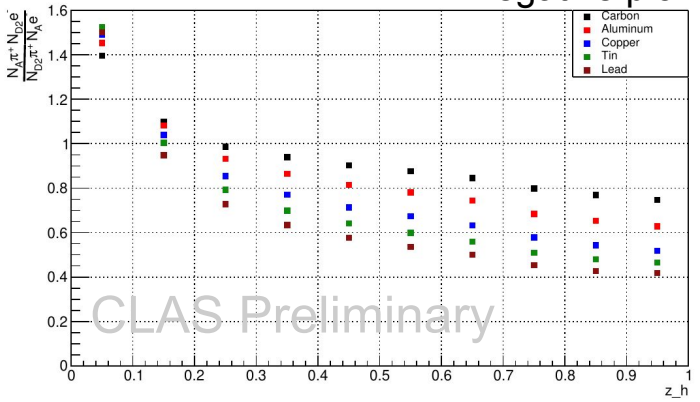
*Cuts developed by Uditha

Multiplicity Ratio studies - Z_h

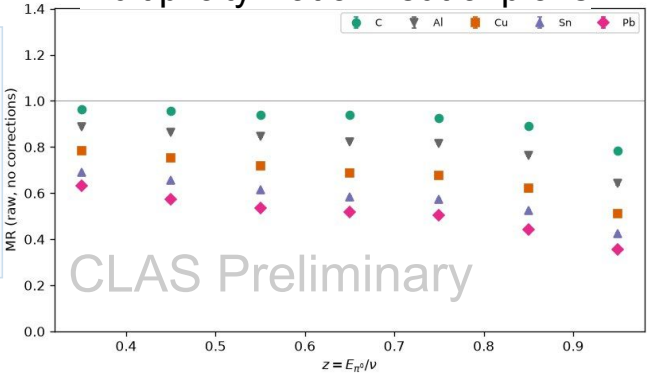
Multiplicity Ratio Positive pions



Multiplicity Ratio Negative pions

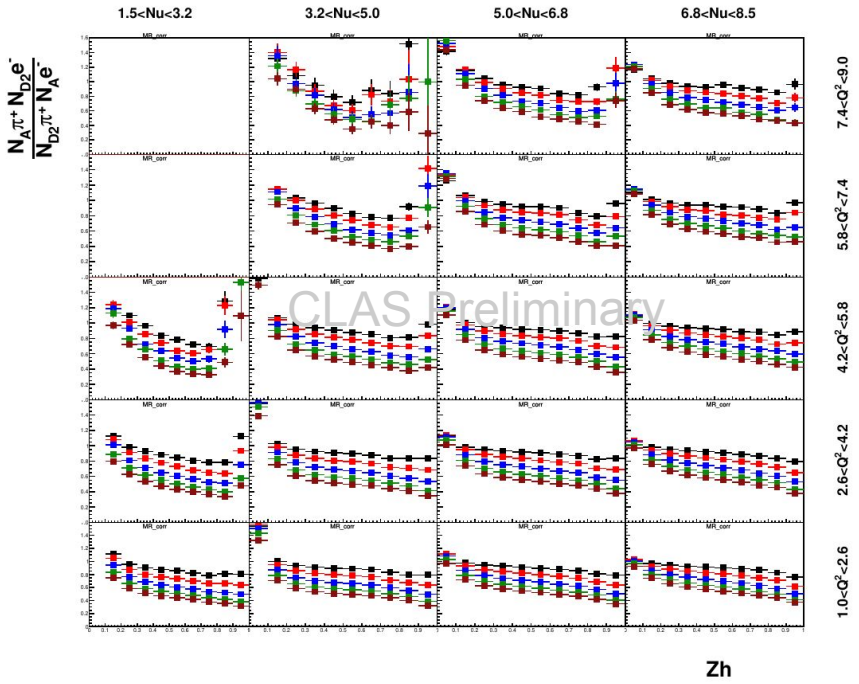


Multiplicity Ratio Neutral pions

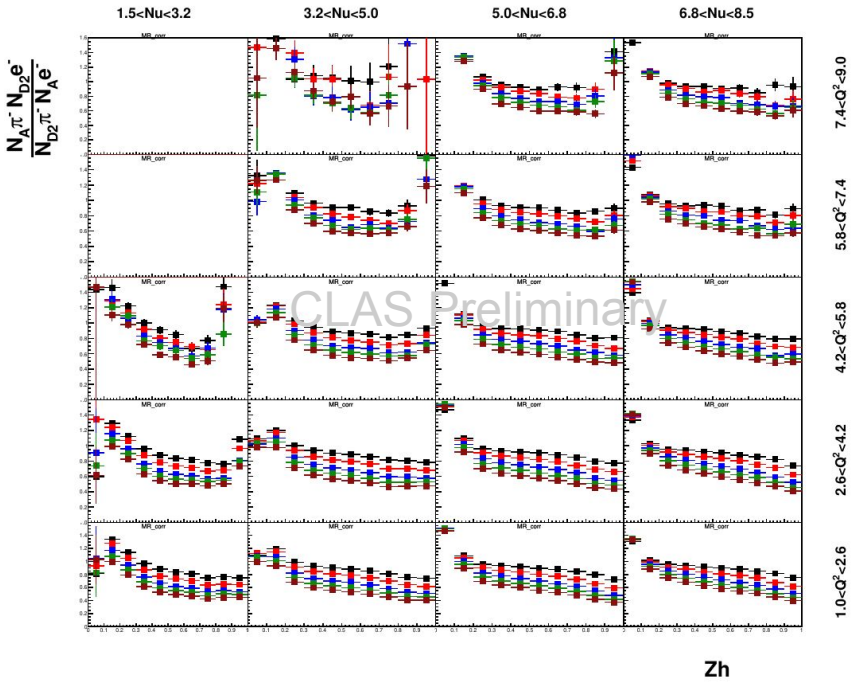


For preliminary results on Lambda and antiproton analyses, see Udi's and Sebouh's talks.

Multiplicity Ratio studies - Multibinning Z_h

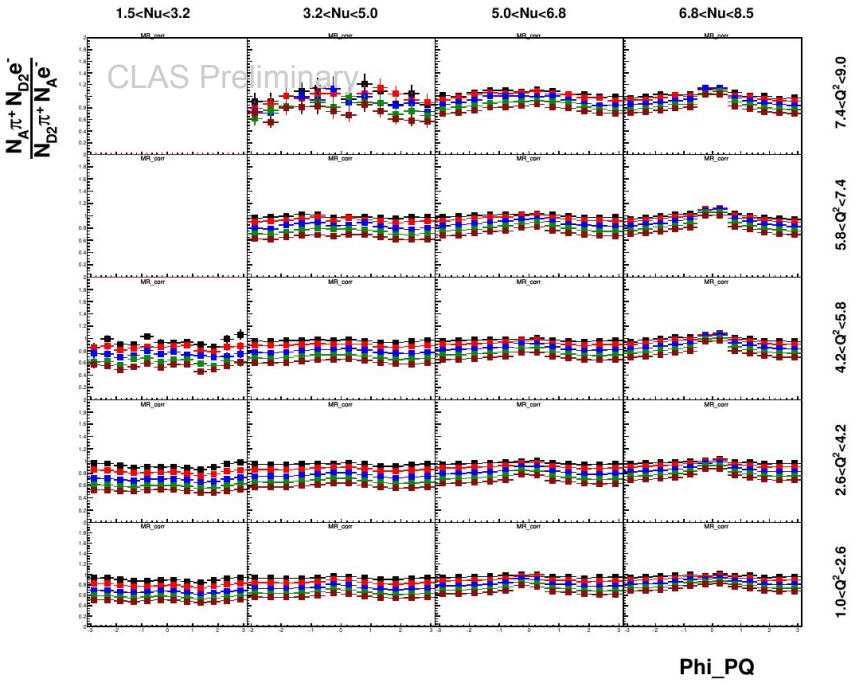


Positive pions

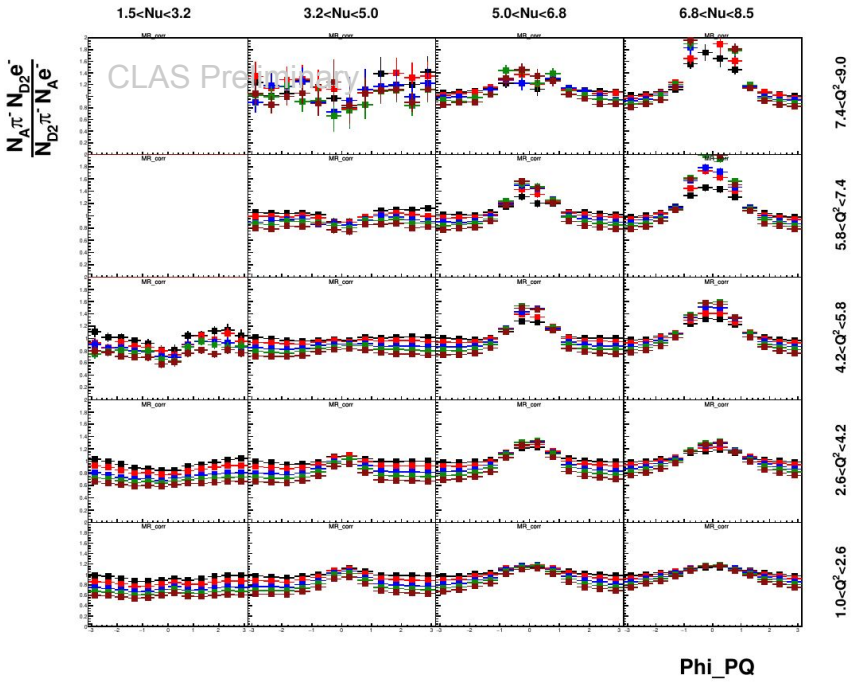


Negative pions

Multiplicity Ratio studies - Multibinning PhiPQ



Positive pions



Negative pions

Simulations status

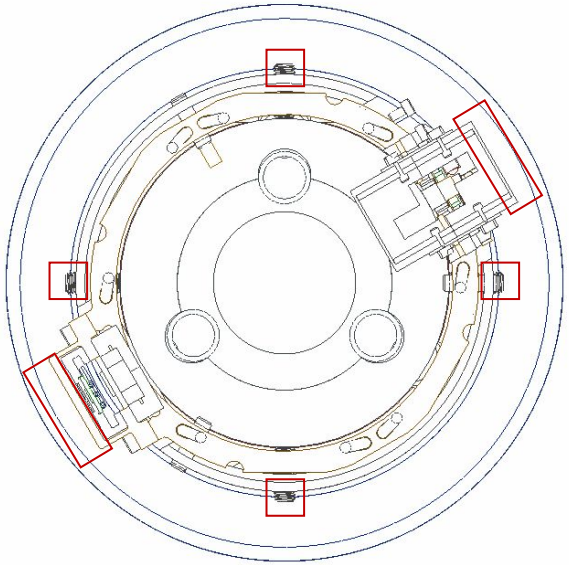
- 7 target configurations in GEMC (5 inbending and 2 outbending)
- Solid and D2 target vertex generation per configuration
- Plan to run **GiBUU** or **nucsidisgen** as main generator
- Latest GiBUU version with **5 different PDFs** close to be installed in OSG
- Planned to run **one D2 configuration**.
- Planned to run **5 solid configurations**, one at a time.

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**.
- Improve solid-target **alignment system** within the heat shield.



Double target improvements

RG-E 2027 Phase

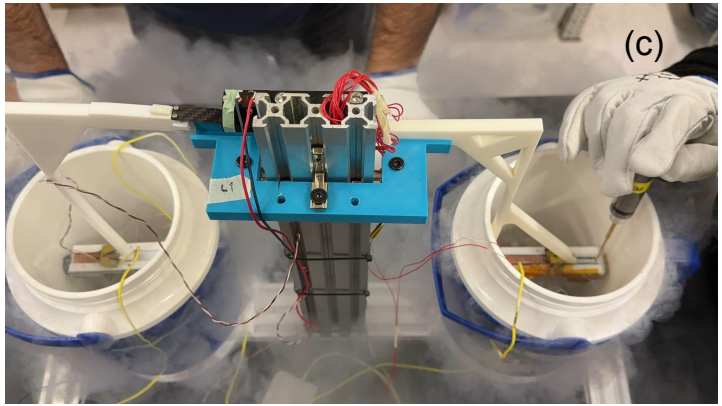
(a) CCTVal engineers taking measurements on the Solid Target System in the TED High Bay Area, Room 1603 (Rad Cage), in July 2026.

(b) Manufactured components for the construction of an upgraded version of the Solid Target System.

(c) Cryogenic performance tests for the limits switches







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 **COMPLETED**
- Finalize design improvements for double-target assembly tolerances and alignment — August 2026 **COMPLETED**
- Finish the design of the new limit-switch system — August 2026 **COMPLETED**
- Replicate and implement minor corrections to the electronic system — August 2026 **COMPLETED**
- Manufacture, assembly and test of the new double-target models — December 2026
- Installation and data taking — First half of 2027

Experimental setup

RG-E 2027 Phase

- **10.5 GeV** electron beam
- **Standard CLAS12** configuration with FT-OFF and three layers of FMT
- % of data **inbending and outbending** torus polarity **to be defined**

Target	Length (mm)	Production Current (nA)	Integrated Luminosity (1/cm2) (Assuming 50% beam efficiency)	Total PAC days
LD2+C12	20 + 1.51	85	8E+40	5
LD2+Al27	20 + 1.21	70	8E+40	5
LD2+Cu63	20 + 0.34	75	8E+40	5
LD2+Sn120	20 + 0.29	65	8E+40	7
LD2+Pb208	20 + 0.14	70	8E+40	7
H2+C12	20 + 1.51	85	2E+40	1
Total				30

hadron	cτ	mass	flavor content	limiting error (60 PAC days)
π^0	25 nm	0.13	$u\bar{u}d\bar{d}$	5.7% (sys)
π^+, π^-	7.8 m	0.14	$ud, d\bar{u}$	3.2% (sys)
η	170 pm	0.55	$u\bar{u}d\bar{d}s\bar{s}$	6.2% (sys)
ω	23 fm	0.78	$u\bar{u}d\bar{d}s\bar{s}$	6.7% (sys)
η'	0.98 pm	0.96	$u\bar{u}d\bar{d}s\bar{s}$	8.5% (sys)
ϕ	44 fm	1	$u\bar{u}d\bar{d}s\bar{s}$	5.0% (stat)*
$f1$	8 fm	1.3	$u\bar{u}d\bar{d}s\bar{s}$	-
K^0	27 mm	0.5	$d\bar{s}$	4.7% (sys)
K^+, K^-	3.7 m	0.49	$u\bar{s}, \bar{u}s$	4.4% (sys)
p	stable	0.94	uud	3.2% (sys)
$\bar{p}$	stable	0.94	$\bar{u}\bar{u}\bar{d}$	5.9% (stat)**
Λ	79 mm	1.1	uds	4.1% (sys)
$\Lambda(1520)$	13 fm	1.5	uds	8.8% (sys)
Σ^+	24 mm	1.2	uus	6.6% (sys)
Σ^-	44 mm	1.2	dds	7.9% (sys)
Σ^0	22 pm	1.2	uds	6.9% (sys)
Ξ^0	87 mm	1.3	uss	16% (stat)*
Ξ^-	49 mm	1.3	dss	7.8% (stat)*

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 allow multiplicity-ratio studies with both one-dimensional and, at least for light hadrons, multidimensional binning.
- Minor improvements have been identified in the double-target system and are expected to be completed this year.
- The next phase will approximately double the dataset, enabling improved precision and opening opportunities for additional studies.

HEPNP 2027

10th International Conference on
High Energy, Particles and Nuclear Physics
in the LHC Era

18–22 January 2027

Universidad Técnica Federico Santa María

Valparaíso, Chile

Registration and abstract submissions are open

indico.hpc.utfsm.cl/event/2/



UTFSM · CCTVAL

SCAN FOR DETAILS

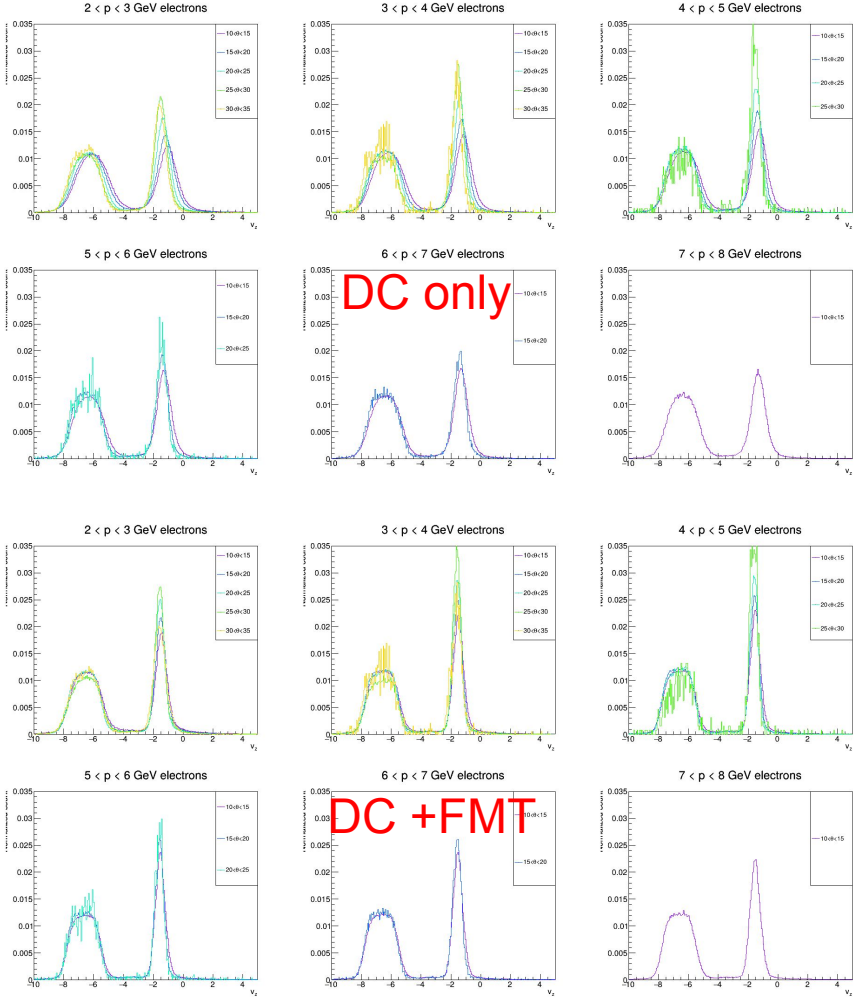
#HEPNP2027

Backup slides

Tracking bank used

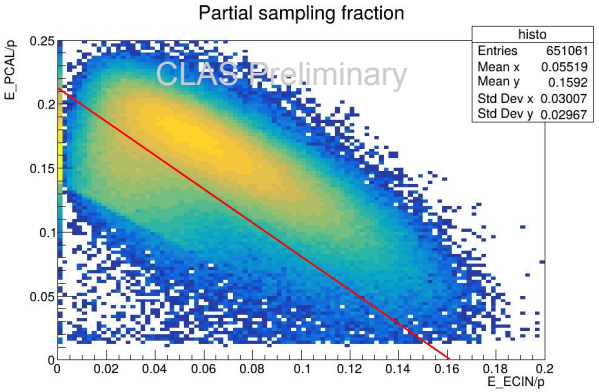
1. Using Tracks with FMT+DC information from REC::FTrack when available
2. If particle has no entry in REC::FTrack, using DC only tracking information from REC::Particle.

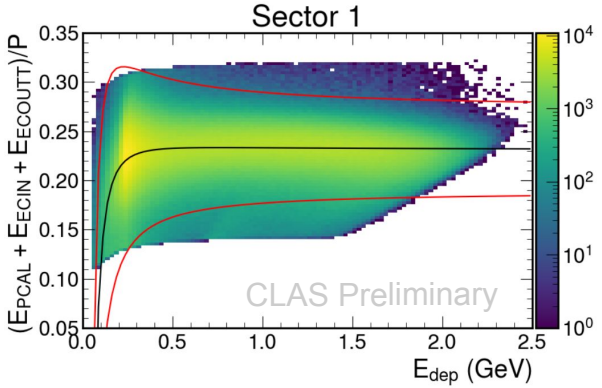
➔ Improvement of vertex resolution
➔ Maintains full statistics
➔ Reduced z-vertex θ dependence



Electron identification

- Start from particles reconstructed as electrons in reconstruction software.
- DIS cuts:
  - $Q2 > 1\ GeV^2$
  - $W > 2\ GeV$
  - $y < 0.85$
- Electron Fiducial cuts
  - PCAL V > 9 cm
  - PCAL W > 9 cm
  - DC R1 to edge > 4.5 cm
  - DC R2 to edge > 3.5 cm
  - DC R3 to edge > 7.5 cm
- Partial sampling fraction cuts per sector
- Sampling fraction cuts cuts per sector





Pion ΔT cut refinement

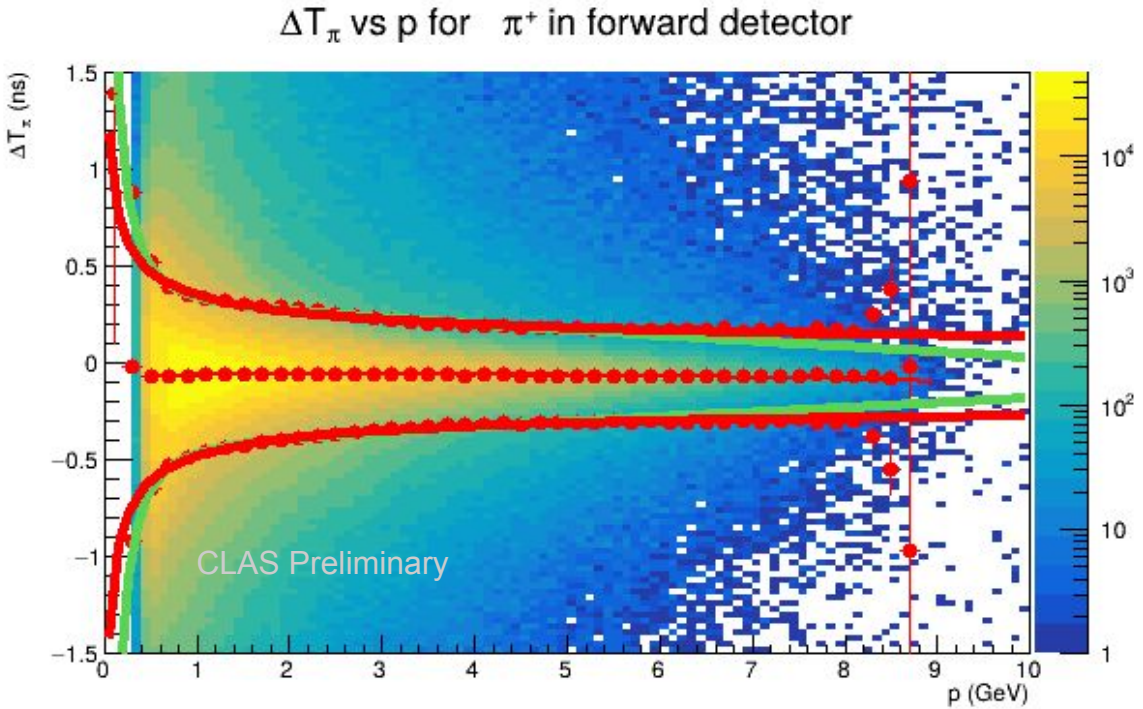
$$\Delta T_{\pi+} = (T_{FTOF} - T_{start}) - (l_{path}/c \cdot \beta_{\pi+}) \qquad \beta_{\pi+} = p/\sqrt{(p^2+m^2_{\pi+})}$$

measured time — theoretical time

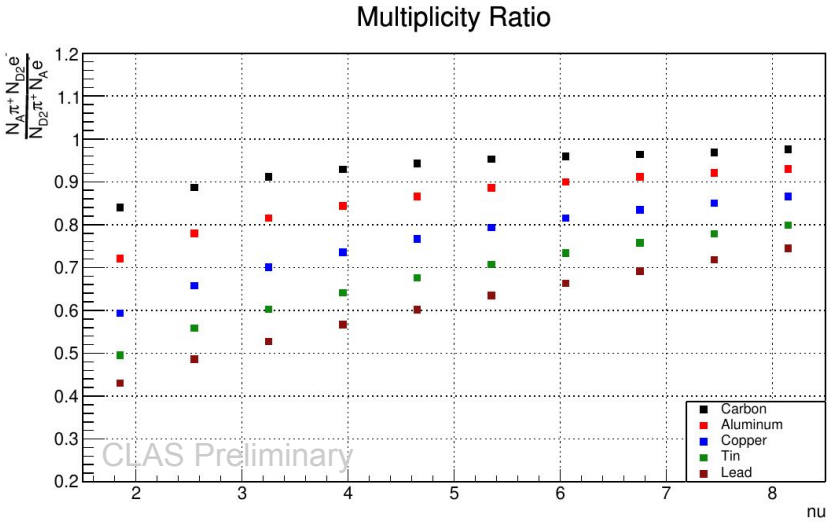
- Divide $\Delta T_{\pi+}$ vs p in 45 bins from 0 to 9 GeV
- Fit each bin with a gaussian fit
- In each p bin sum $\mu \pm 3\sigma$
- Fit upper and lower points with function:

$$(-)\sqrt{a^2 + \left(\frac{b}{p^a}\right)^2}$$

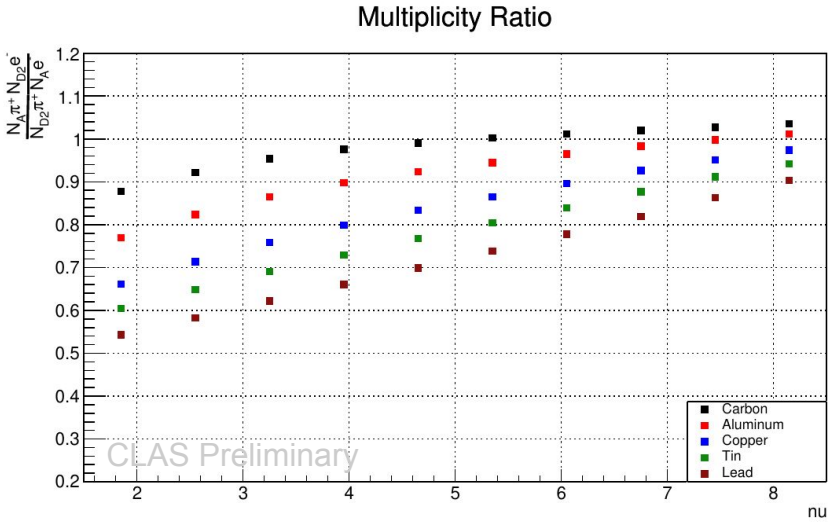
- Where (-) is for lower bound



Multiplicity Ratio studies - Nu

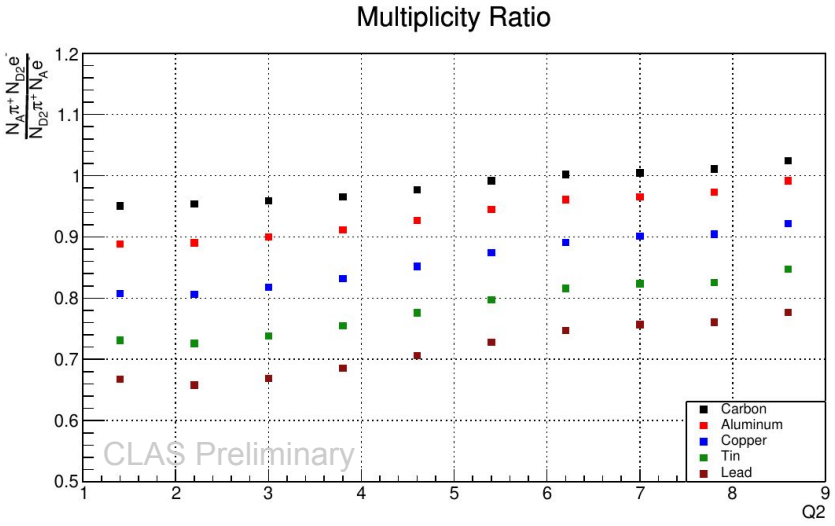


Positive pions

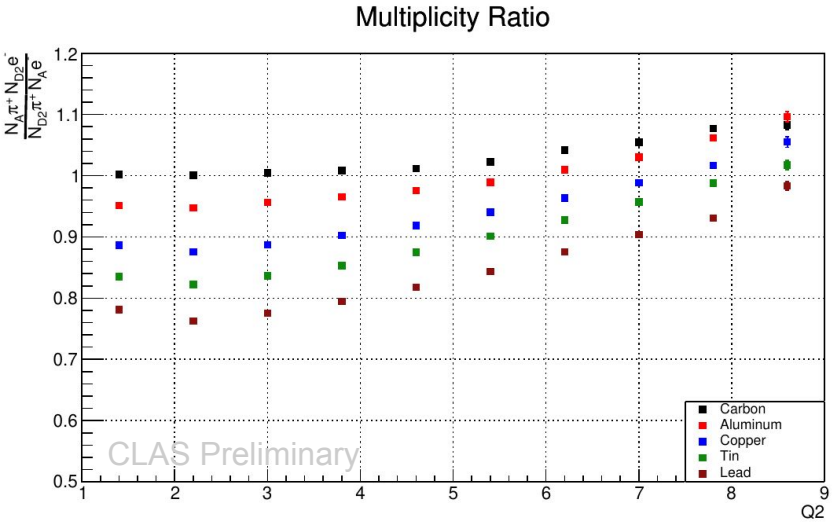


Negative pions

Multiplicity Ratio studies - Q2

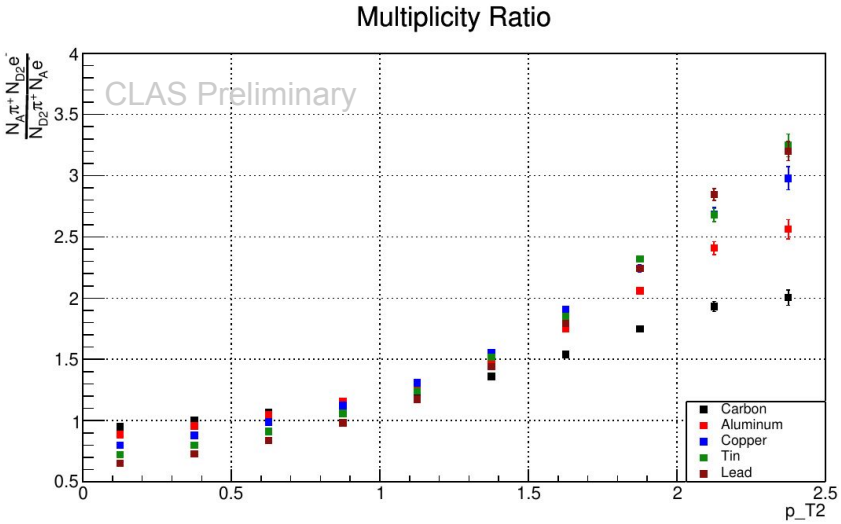


Positive pions

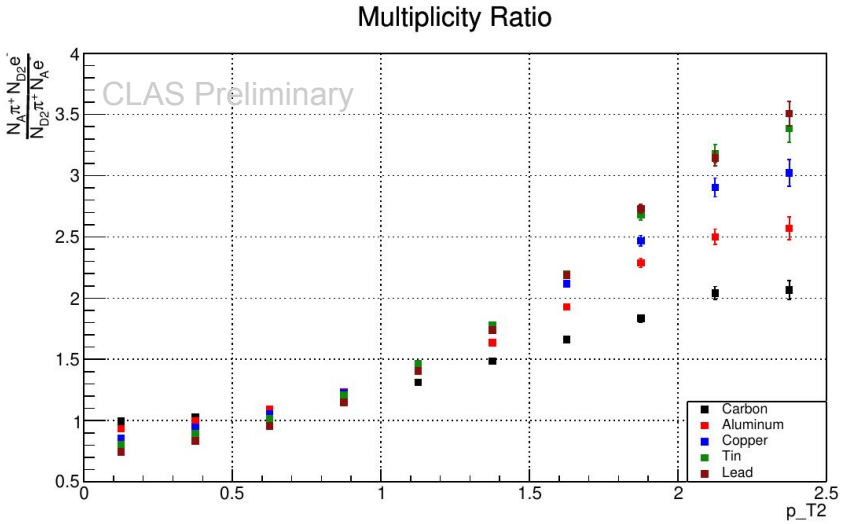


Negative pions

Multiplicity Ratio studies - Pt2

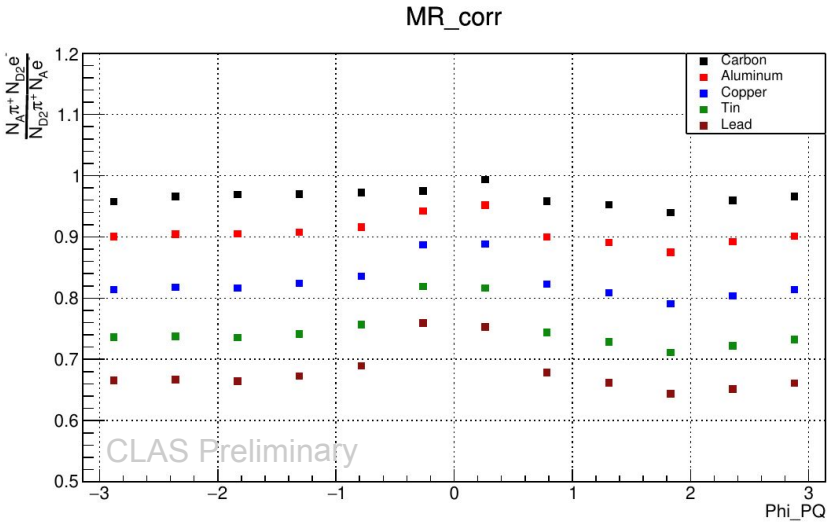


Positive pions

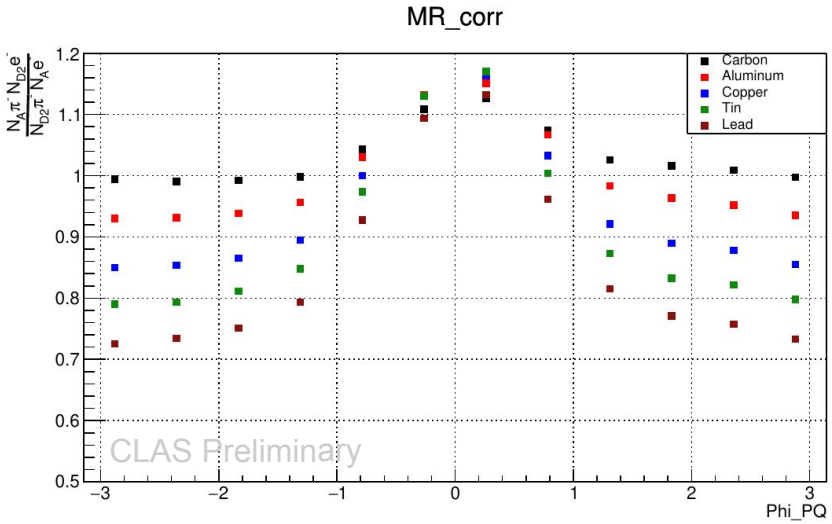


Negative pions

Multiplicity Ratio studies - PhiPQ



Positive pions



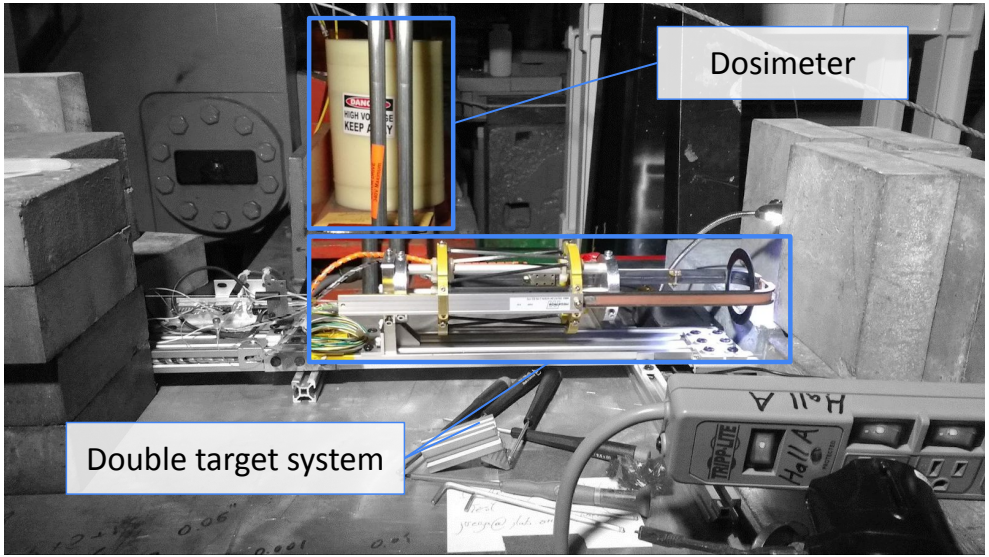
Negative pions

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]



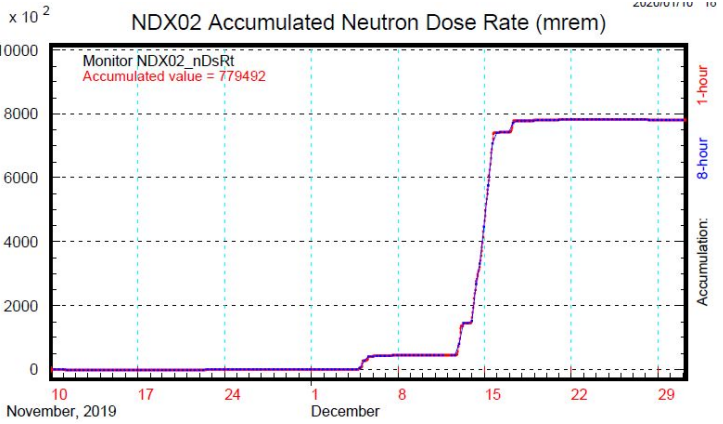
*Lorenzo Zana (Radcon) simulations

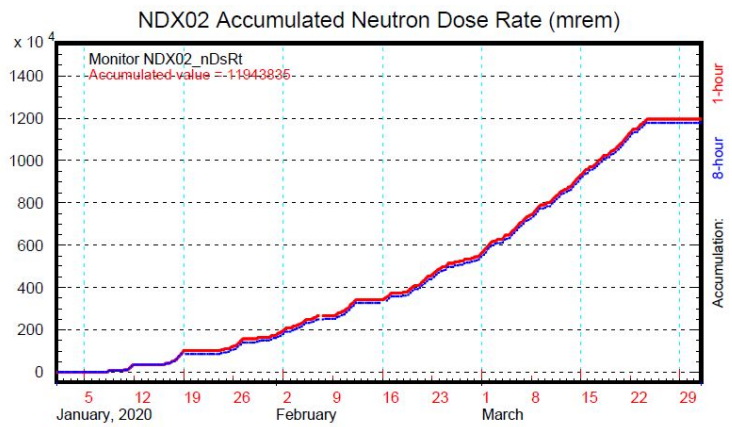
Accumulated dose during 4 months of testing

Neutron dose

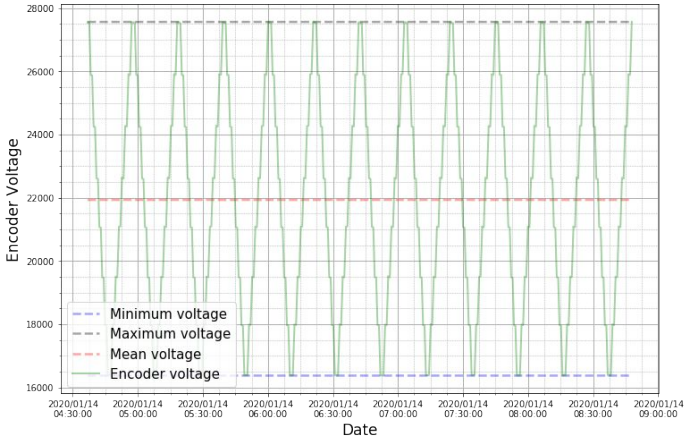
12,723 [rem]

337%!



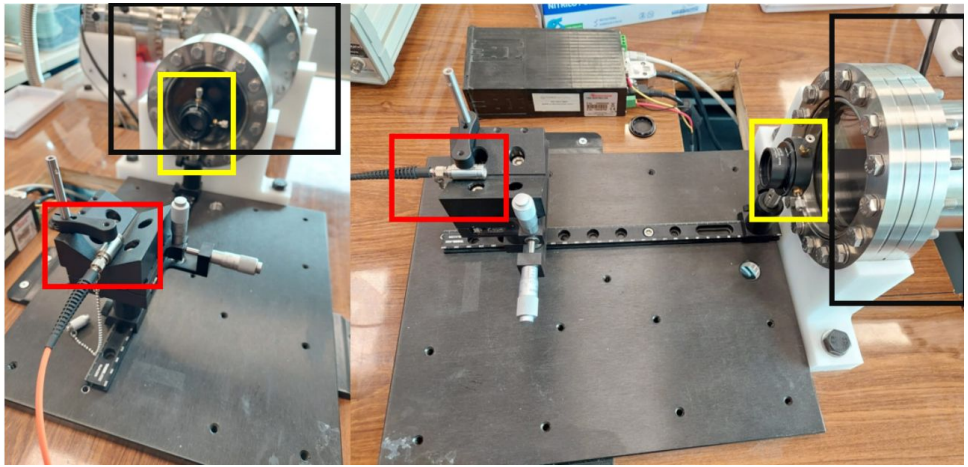


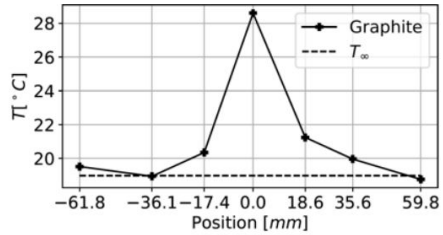
Measurement of position for **125 days without appreciable changes.**

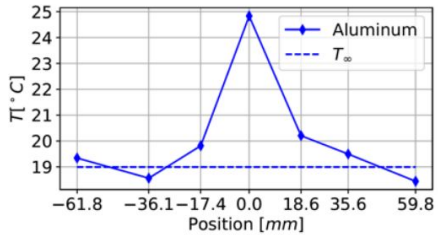


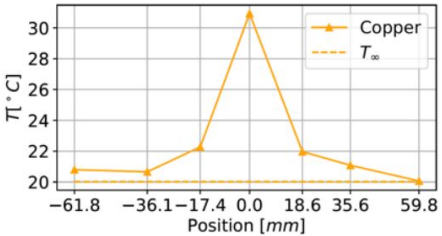
Heat dissipation test

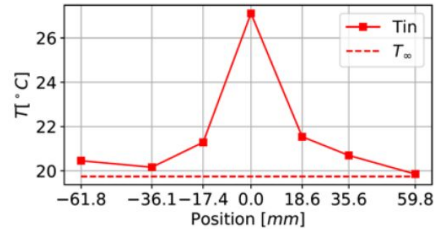
Heat extraction capacities of the Double-Target

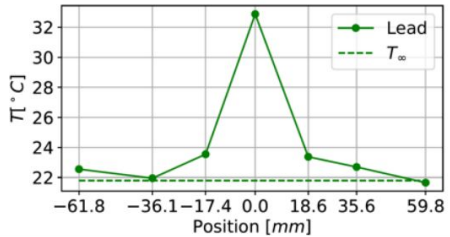






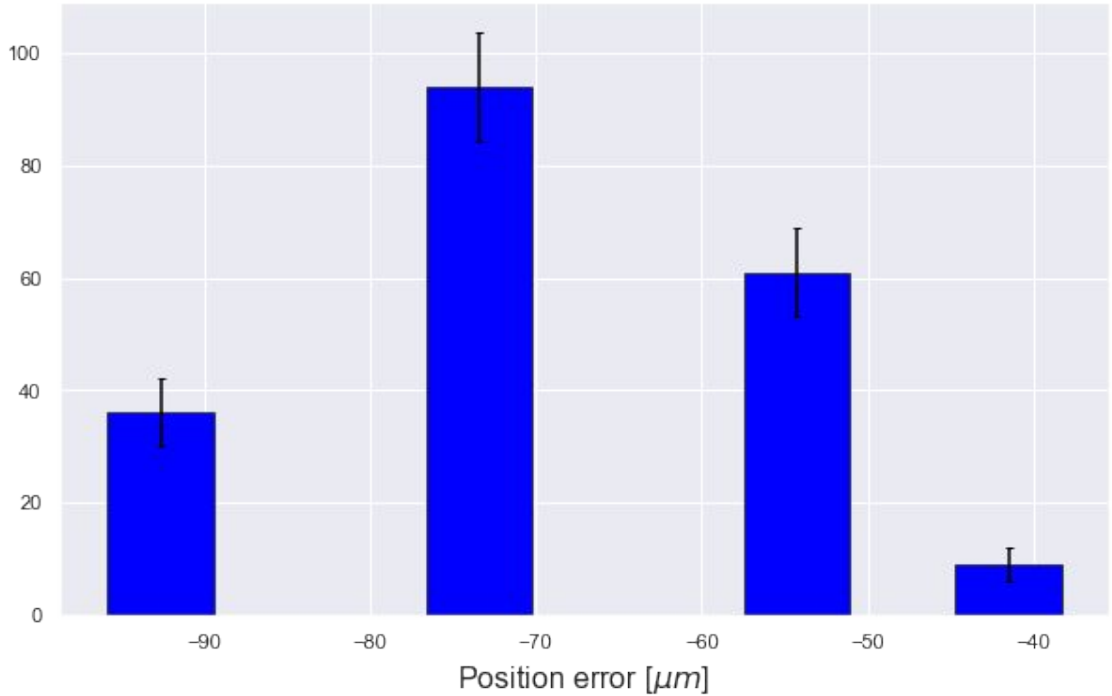






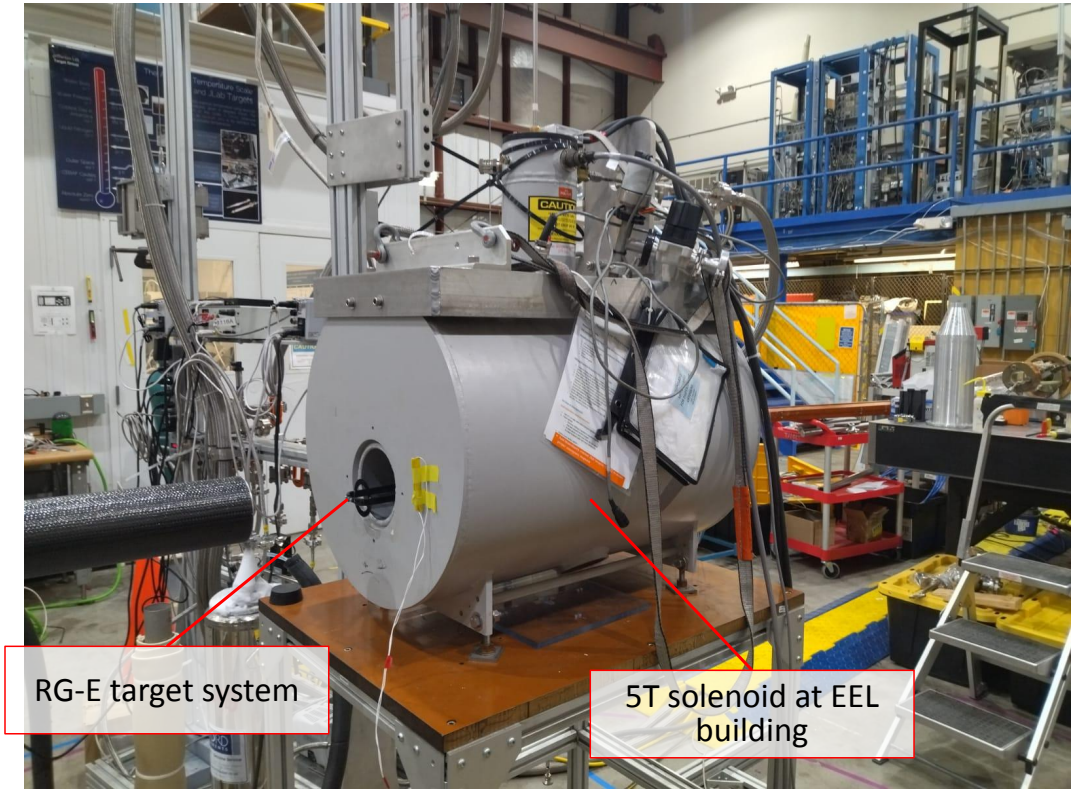
The experimental setup consists of a laser with sufficient power to **deposit 60 [mW]** on each target under vacuum conditions and a measurement of temperature at various points near the heat flow. The objective is to ensure that the solid targets **do not reach their melting point.**

Precision and accuracy of movement in high vacuum conditions



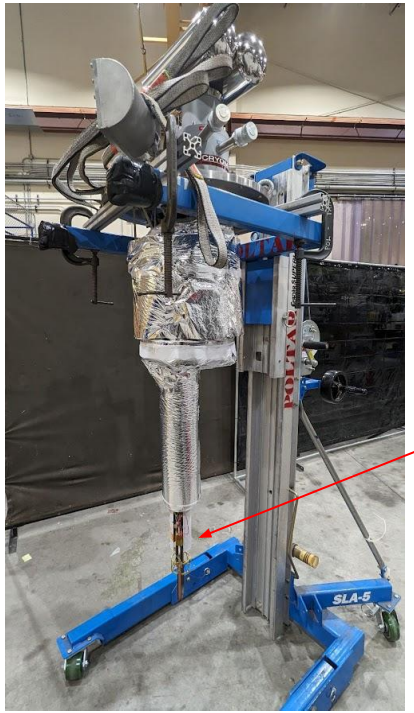
- Measurement instrument resolution: 20 [μm]
- Number of samples: 200
- 3σ (99.7%) = ± 70 [μm]

High magnetic field test at Jlab (August 2023)



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

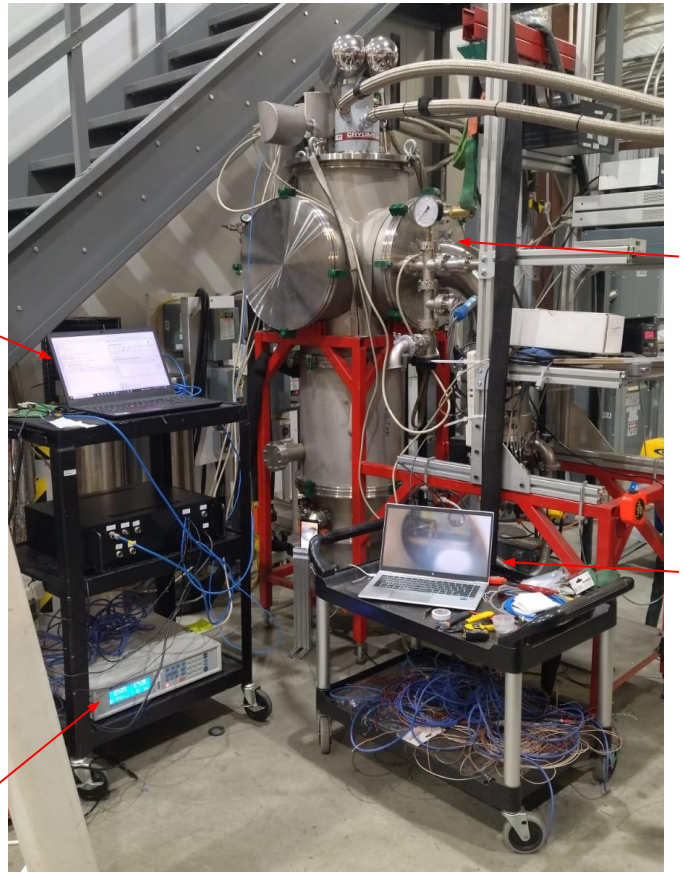
Low temperature test at Jlab (October 2023)



Target ready to be installed

Movement control system

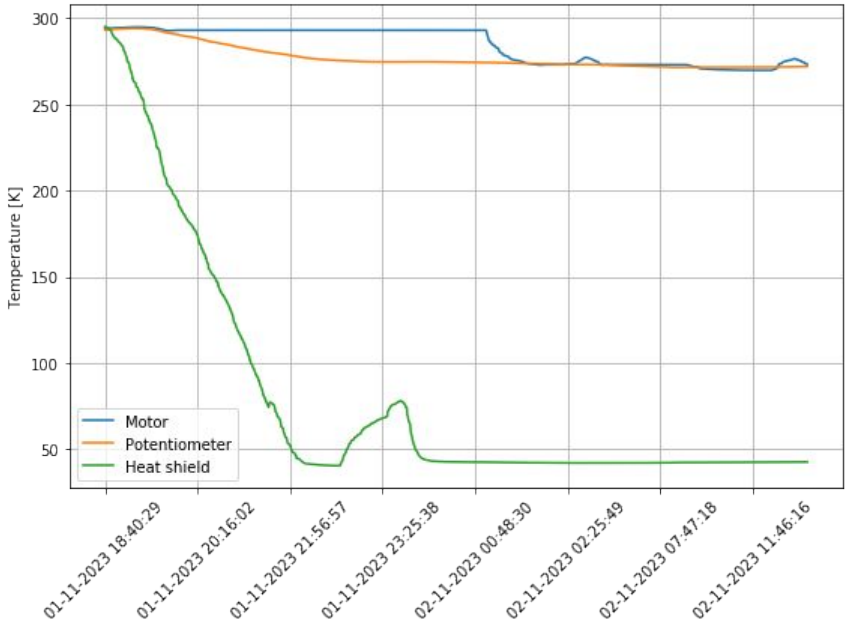
Temperature control system



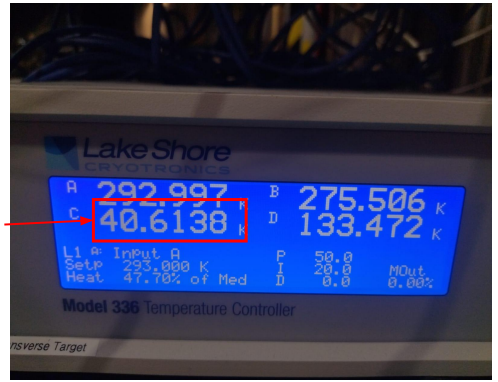
Pulse tube – Cryogenic equipment capable to achieve below 40 K

Visual inspection

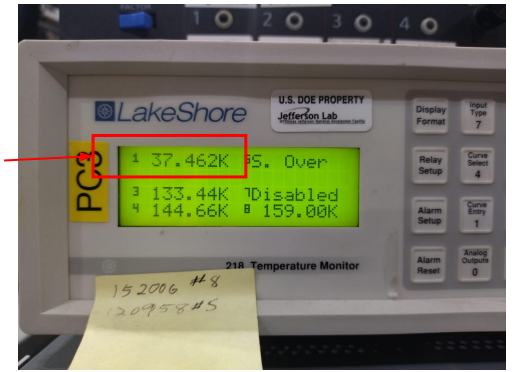
Low temperature test at Jlab (October 2023)



Heat shield temperature



Pulse Tube temperature



The heating power of the system is less than 500 mW

The movement system worked properly during the whole test