RGE readiness report

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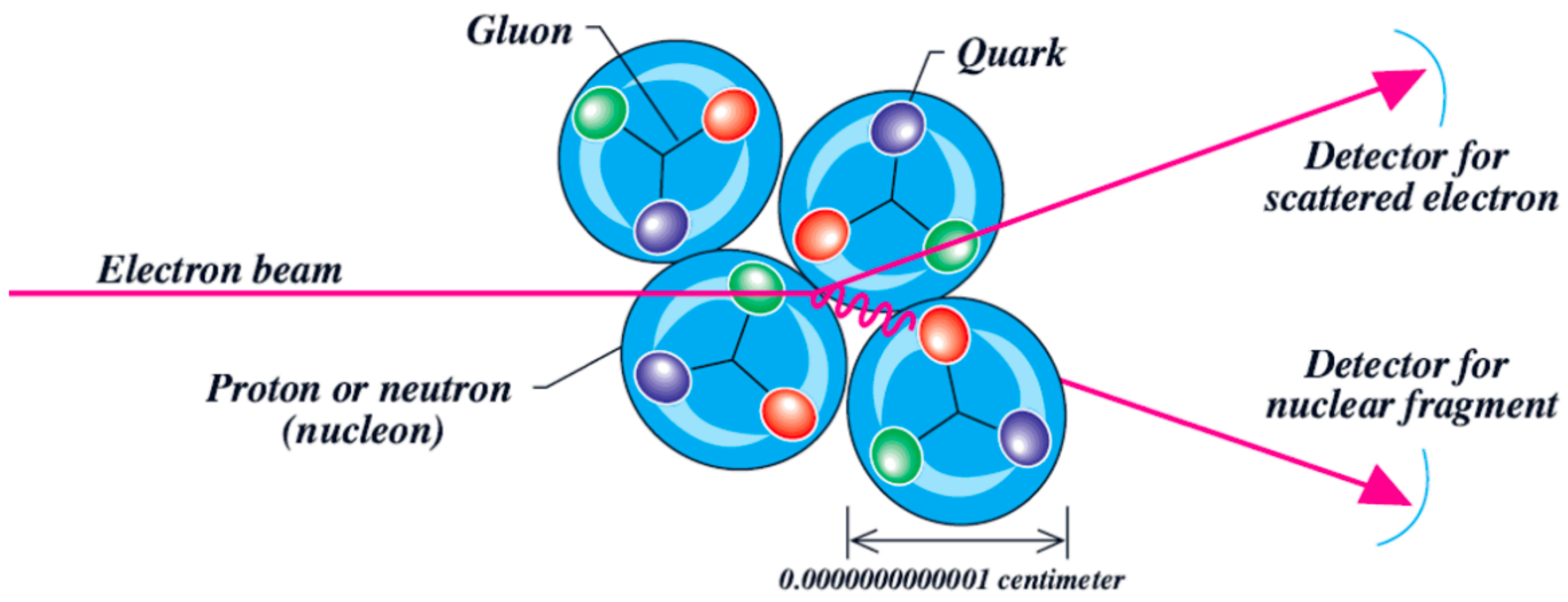
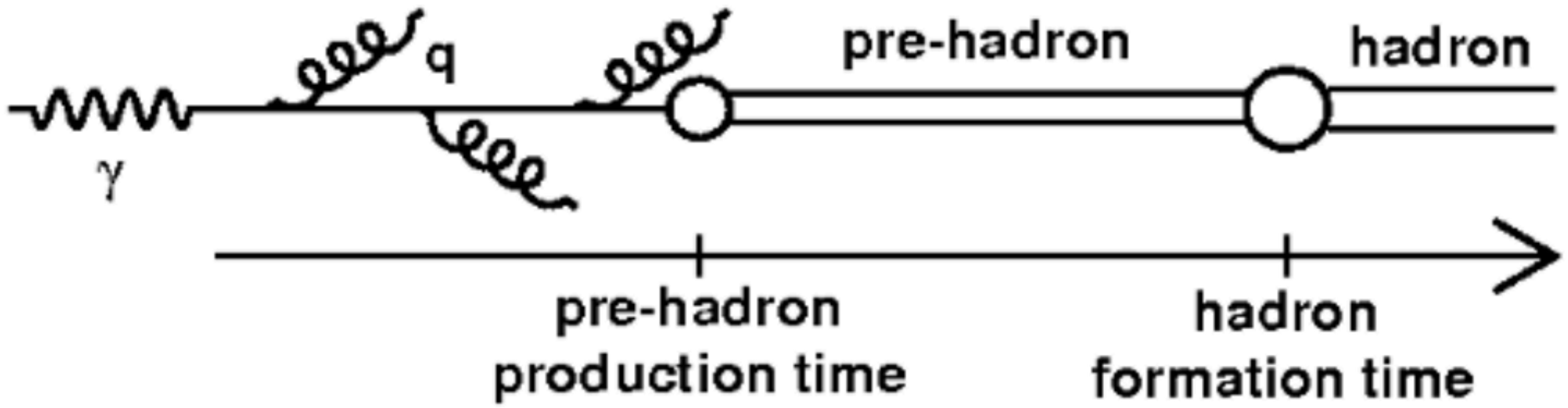
CLAS collaboration meeting
Paris, March, 2023

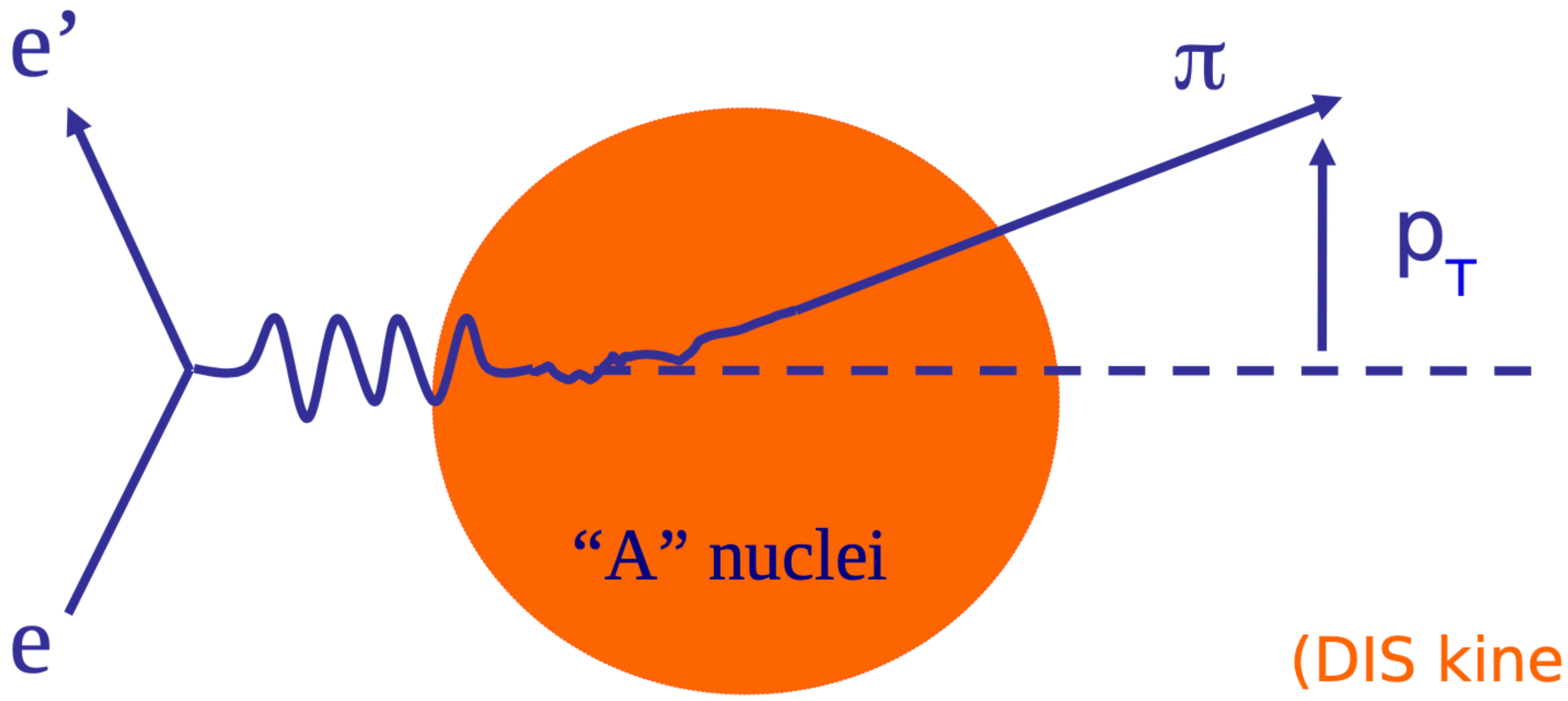


RGE will provide a comprehensive study of the impact of the nuclear medium on quark hadronization. A multidimensional kinematical analysis of a variety of hadrons is required. Thus the color properties of the nuclear medium itself are revealed as well.



Experimental observables

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

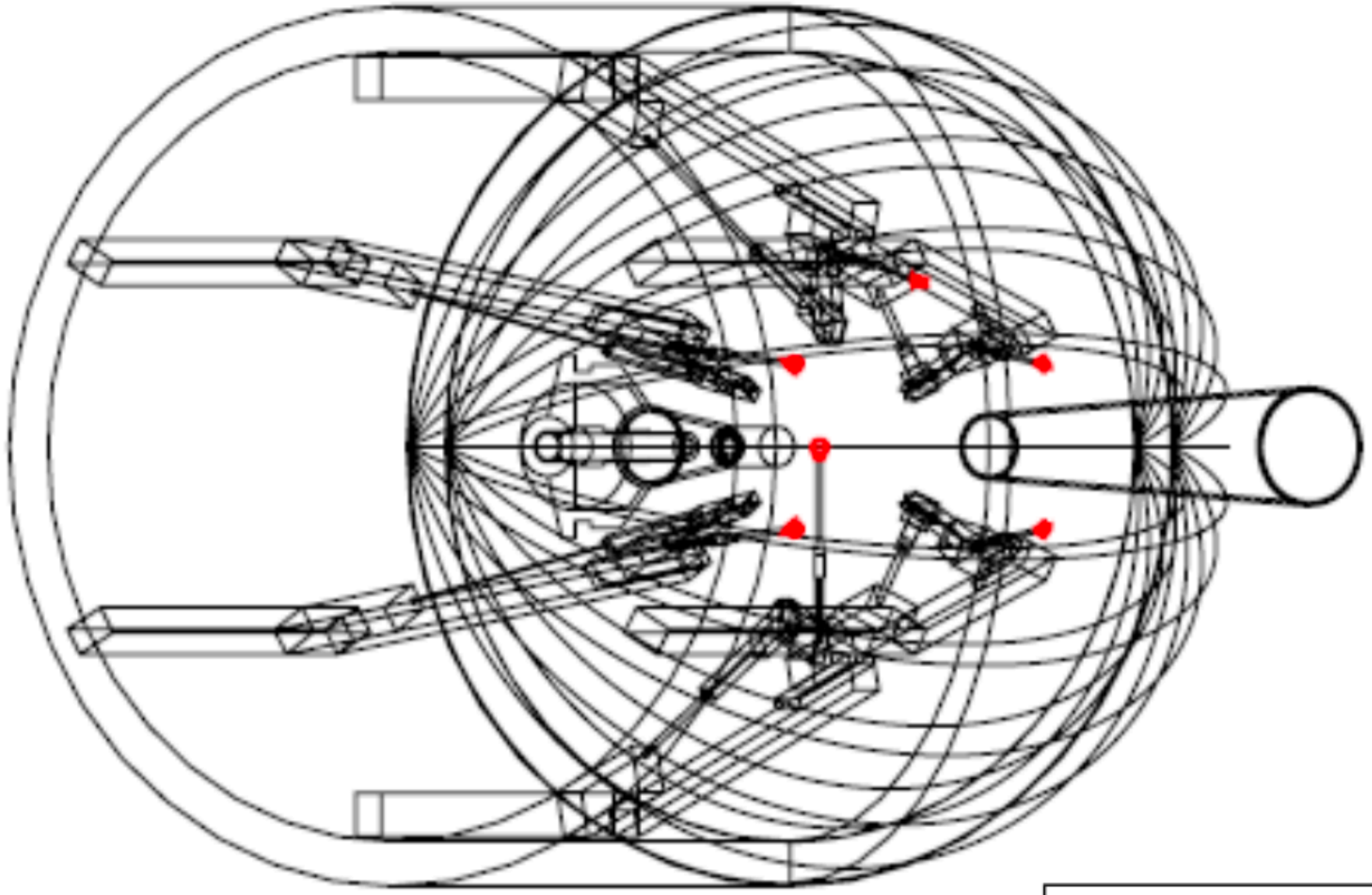


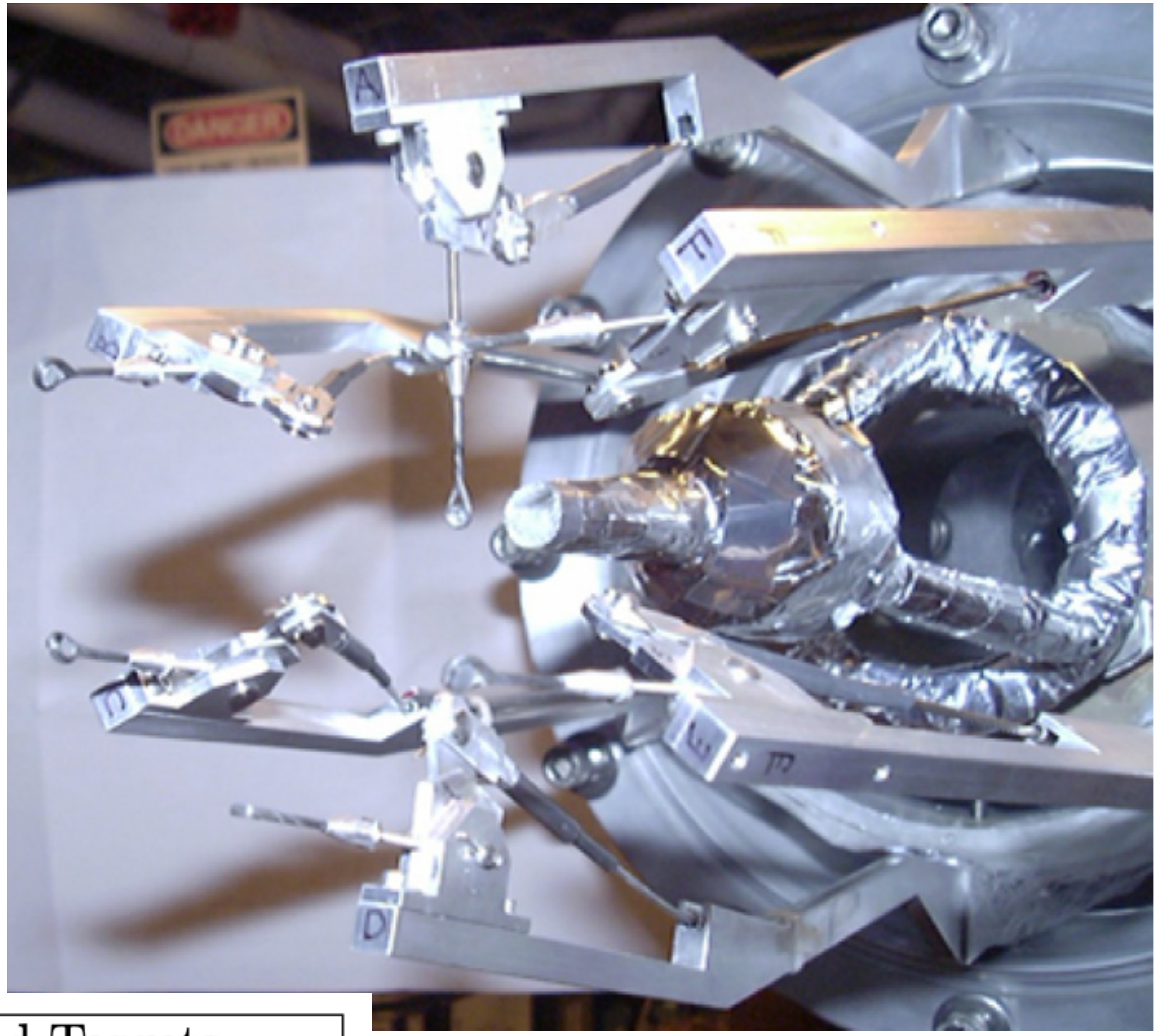
(DIS kinematics)

Hadronic multiplicity ratio:

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

Eg2 Double-Target





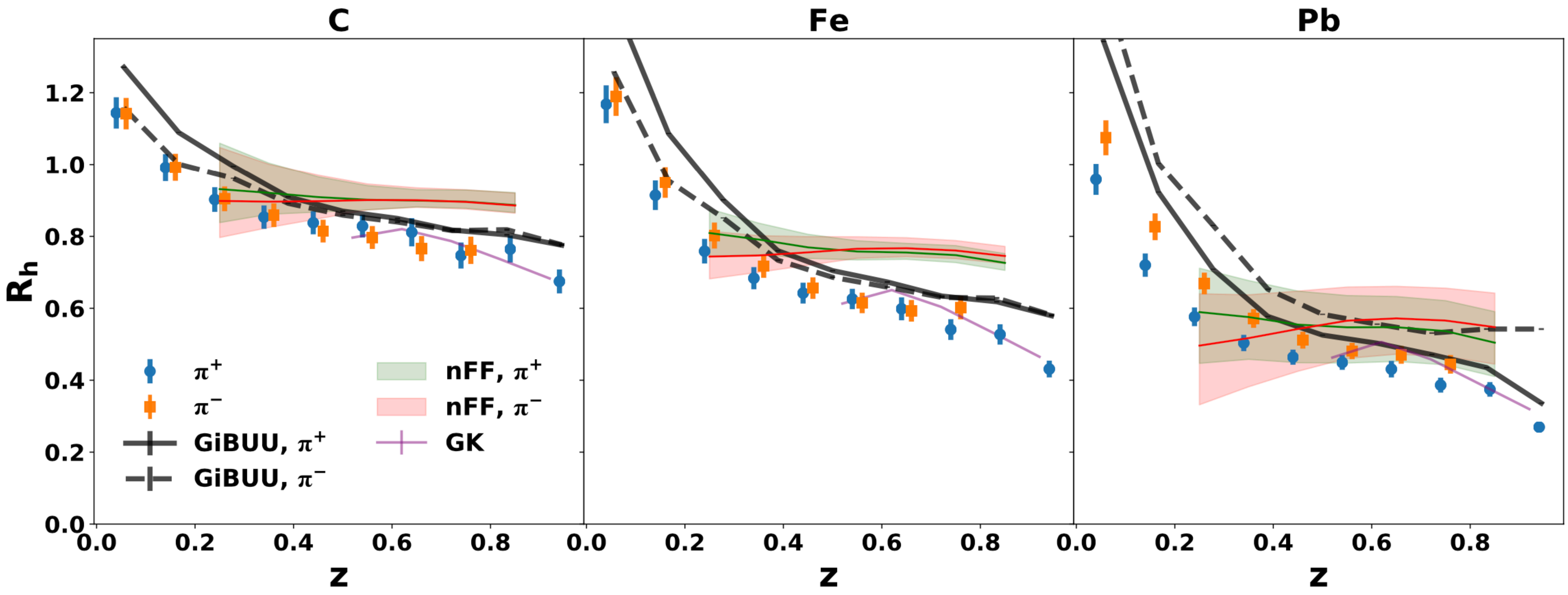
Thickness of Solid Targets		
Target	Thickness (cm)	ρ_A/ρ_D
C	0.17	0.894
Fe	0.04	0.949
Pb	0.014	0.478

H. Hakobyan, W. Brooks et al, Nucl. Instrum. and Meth. A592:218-223, 2008.

Studies performed with EG2 data

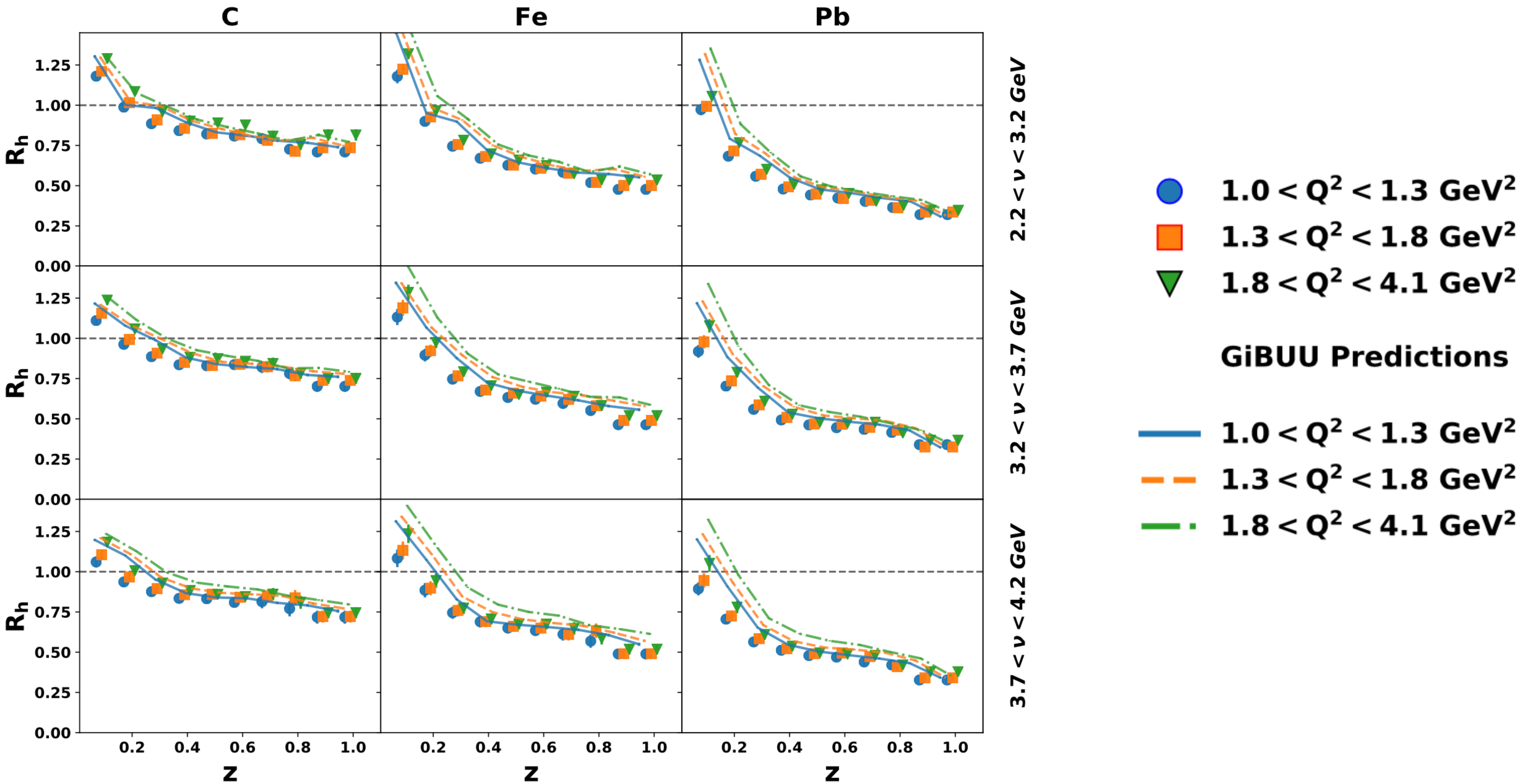
- Hadronization studies in nuclear medium
- Color transparency
- Short-Range Nuclear correlations
- Two-pion BEC correlations
- Dihadron supresión
- Etc.

Charged pions - multiplicity ratio



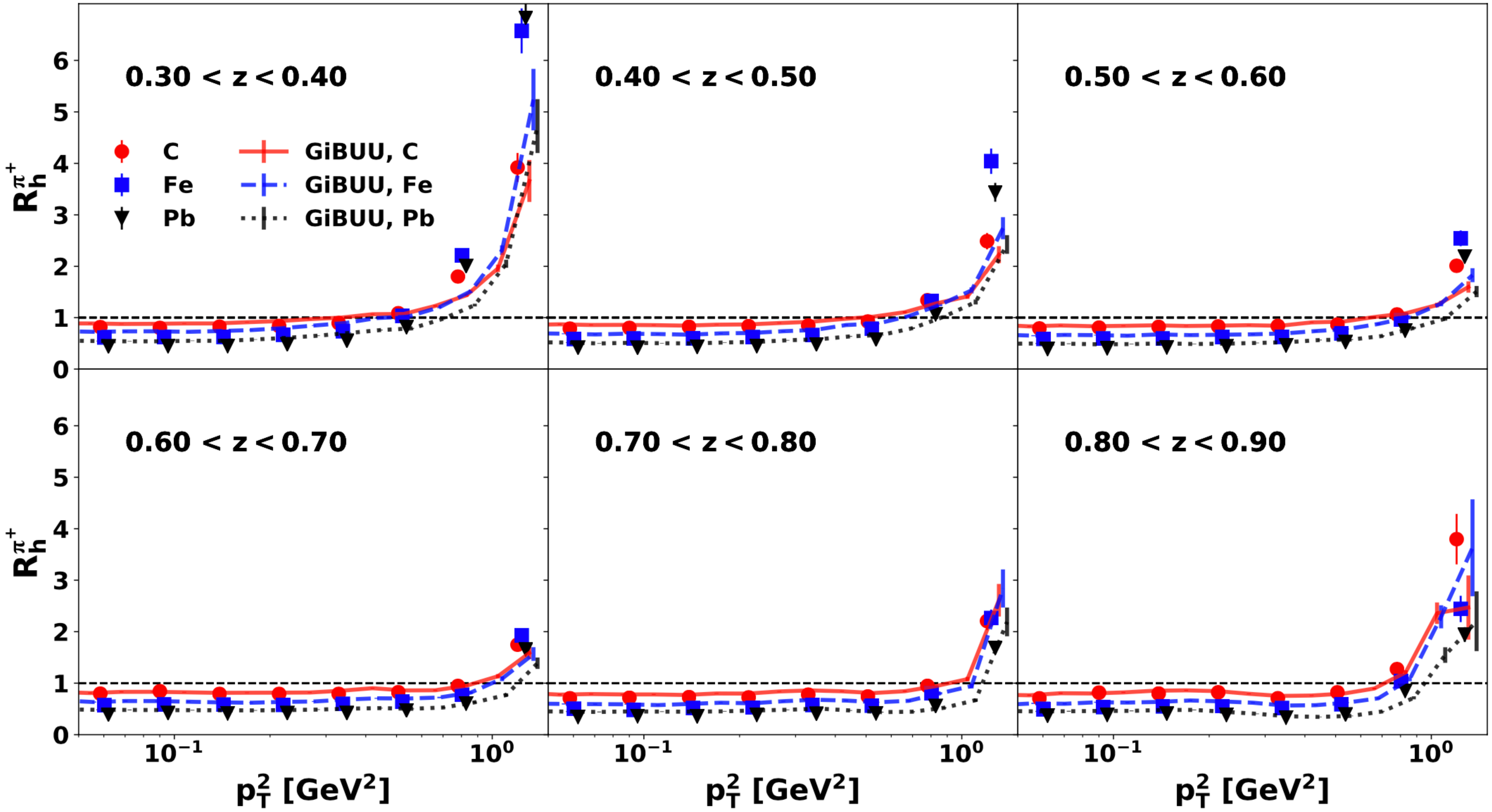
S. Moran, et al. (CLAS collaboration). Phys. Rev. C **105**, 015201 – January, 2022

Charged pions - multiplicity ratio - multidimensional



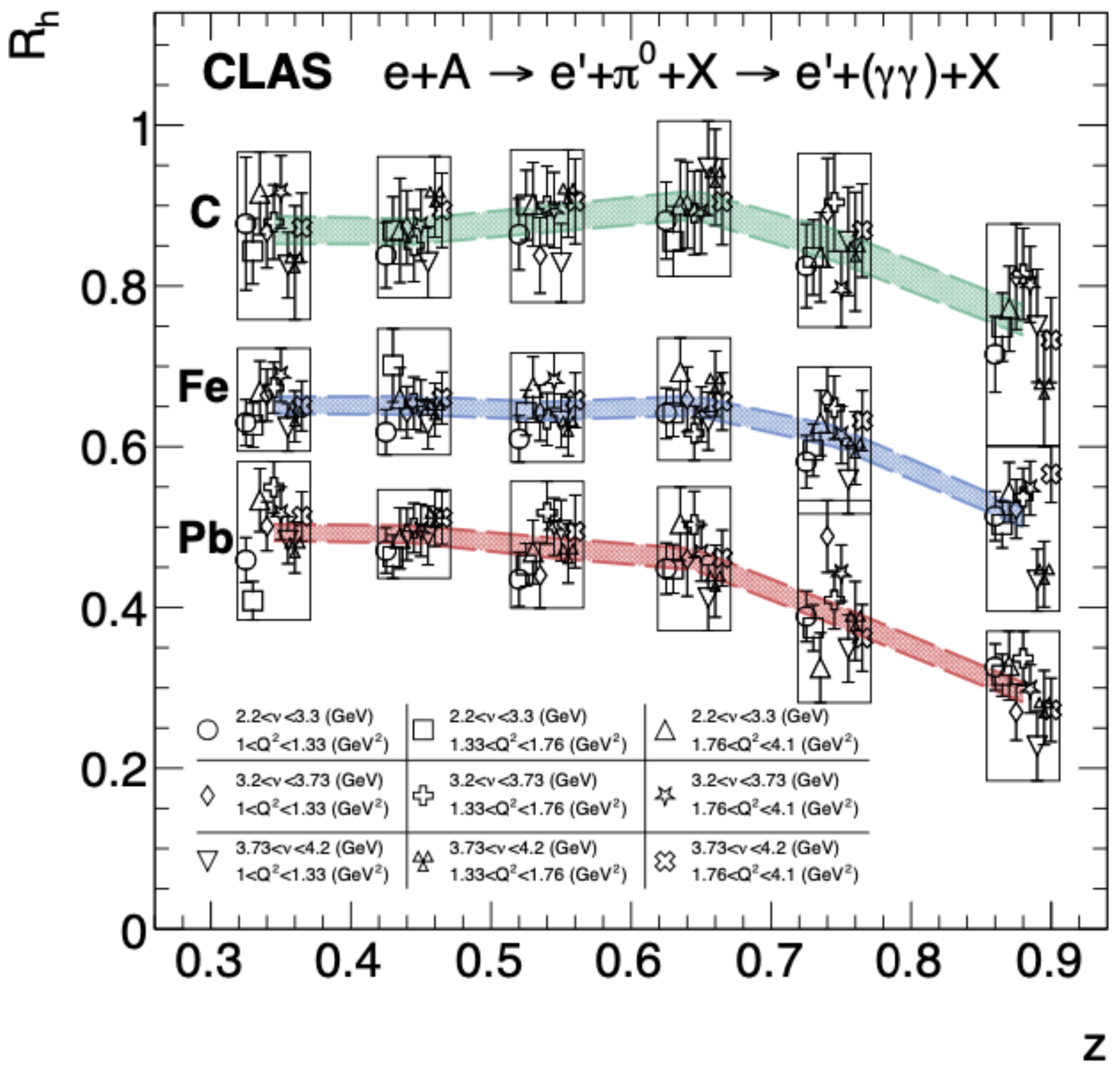
S. Moran, et al. (CLAS collaboration). Phys. Rev. C **105**, 015201 – January, 2022

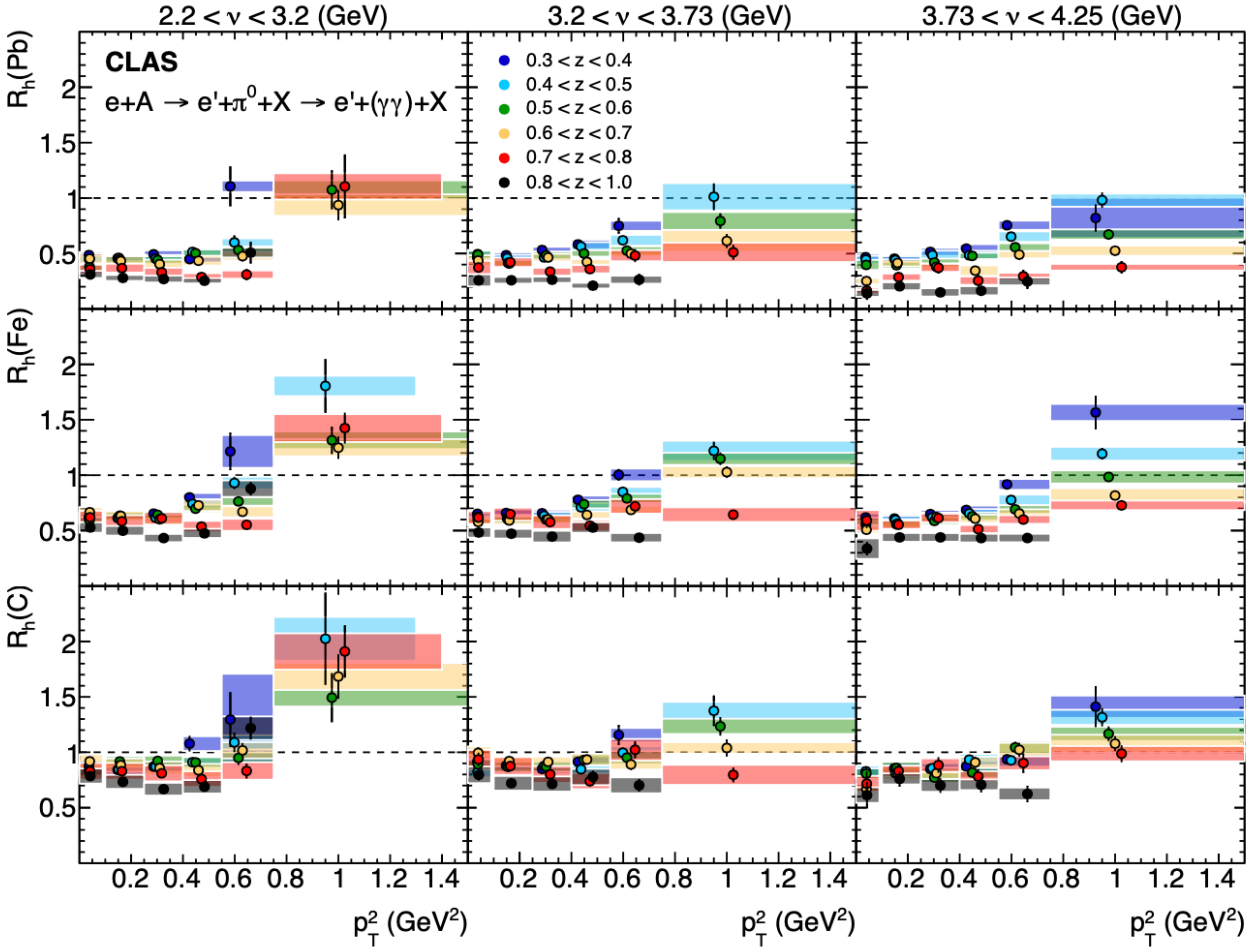
Charged pions - ‘Cronin Effect’ - positive pions



S. Moran, et al. (CLAS collaboration). Phys. Rev. C **105**, 015201 – January, 2022

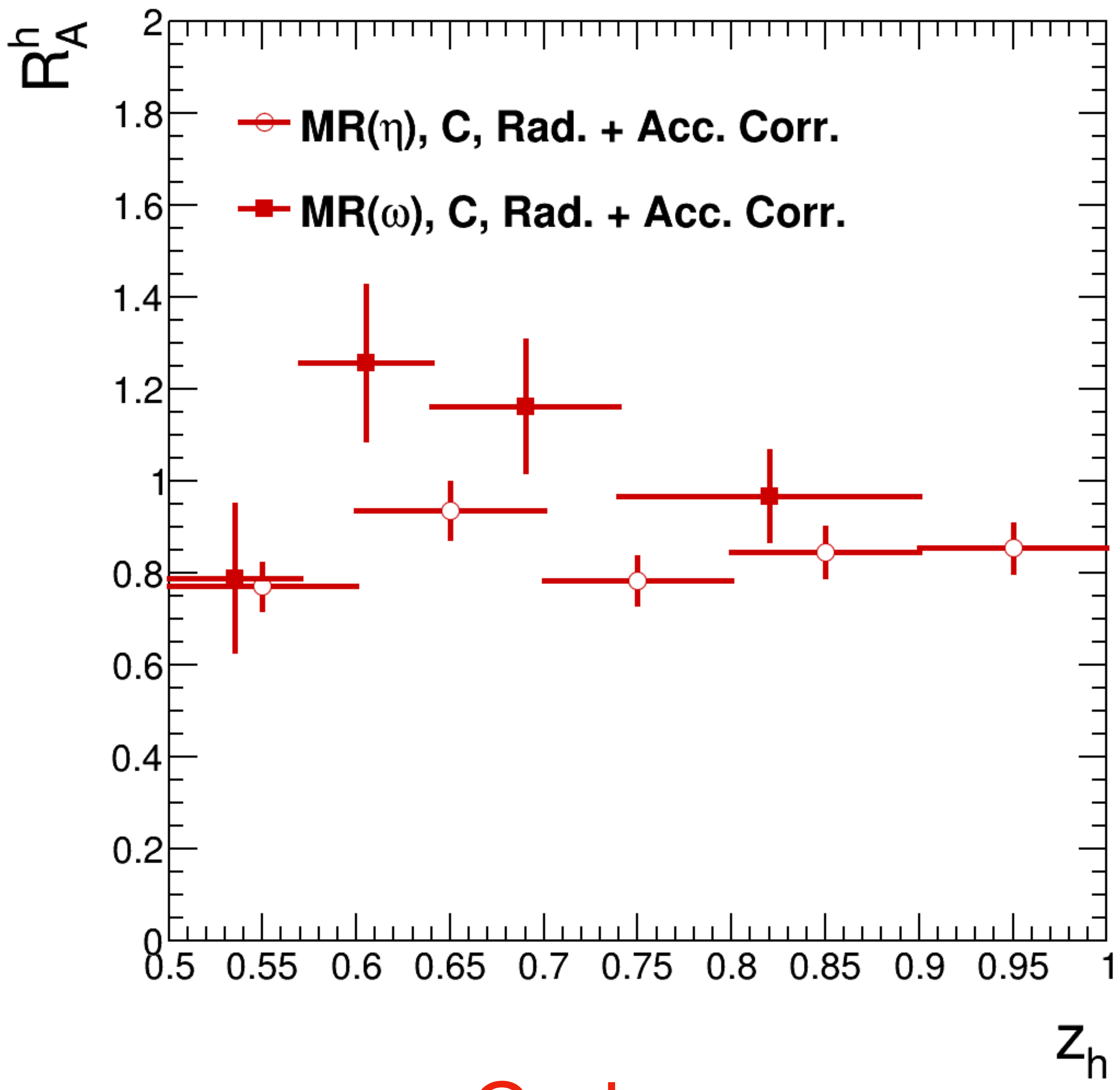
Neutral Pions



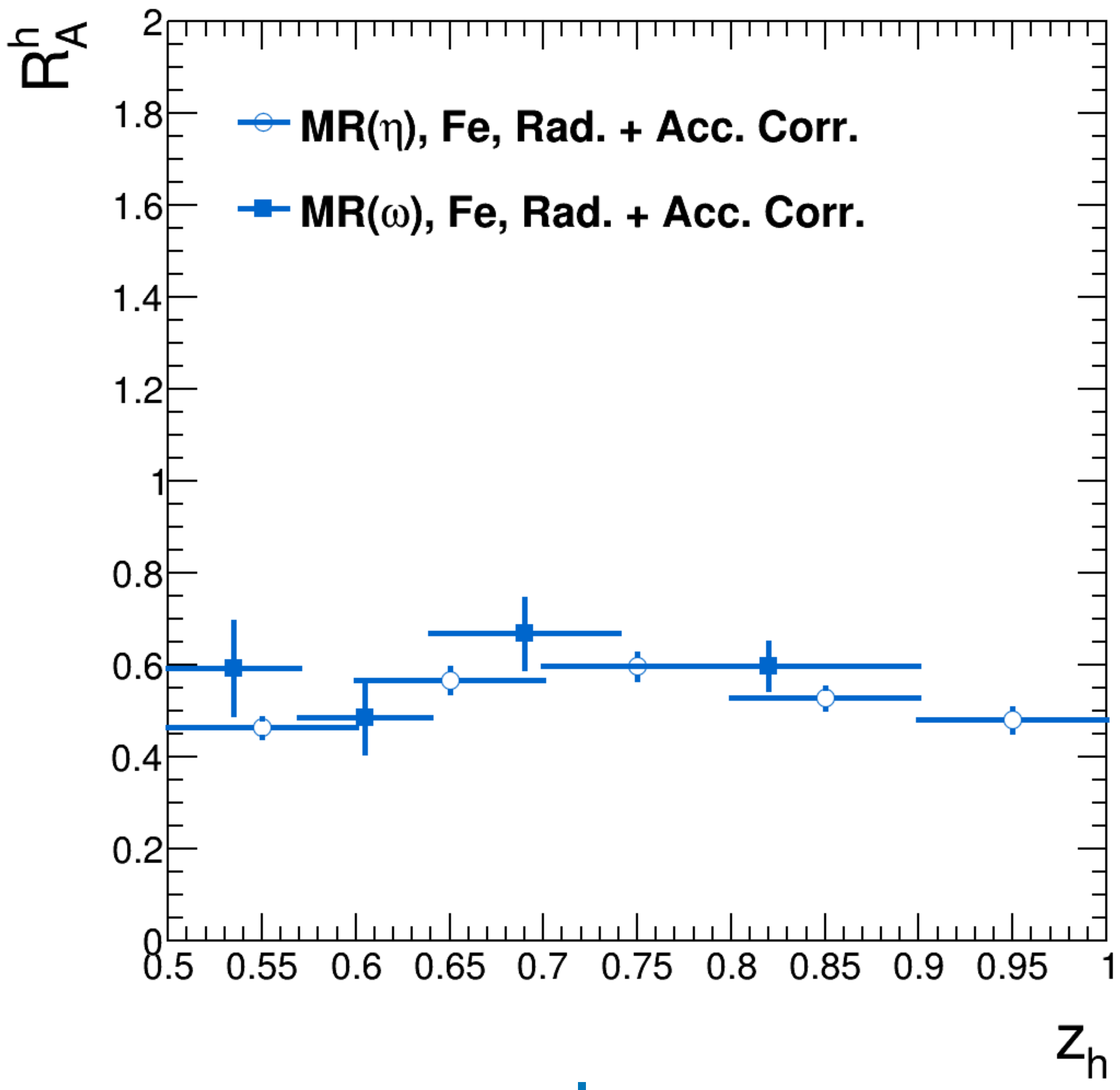


CLAS12 Approved Analysis Note and Publication, see Tayisia Mineeva's talk

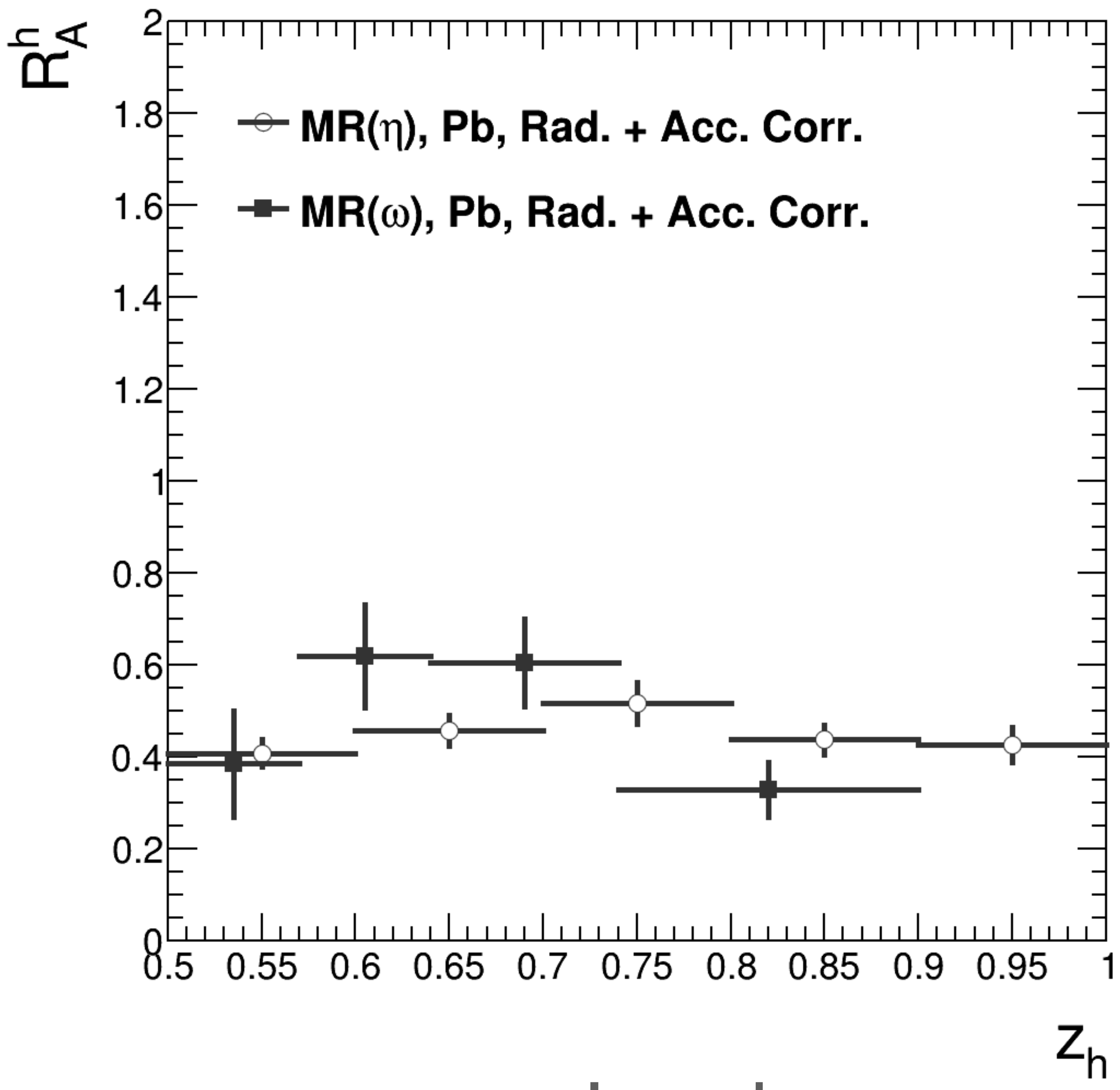
Preliminary results for Etas and Omegas



Carbon



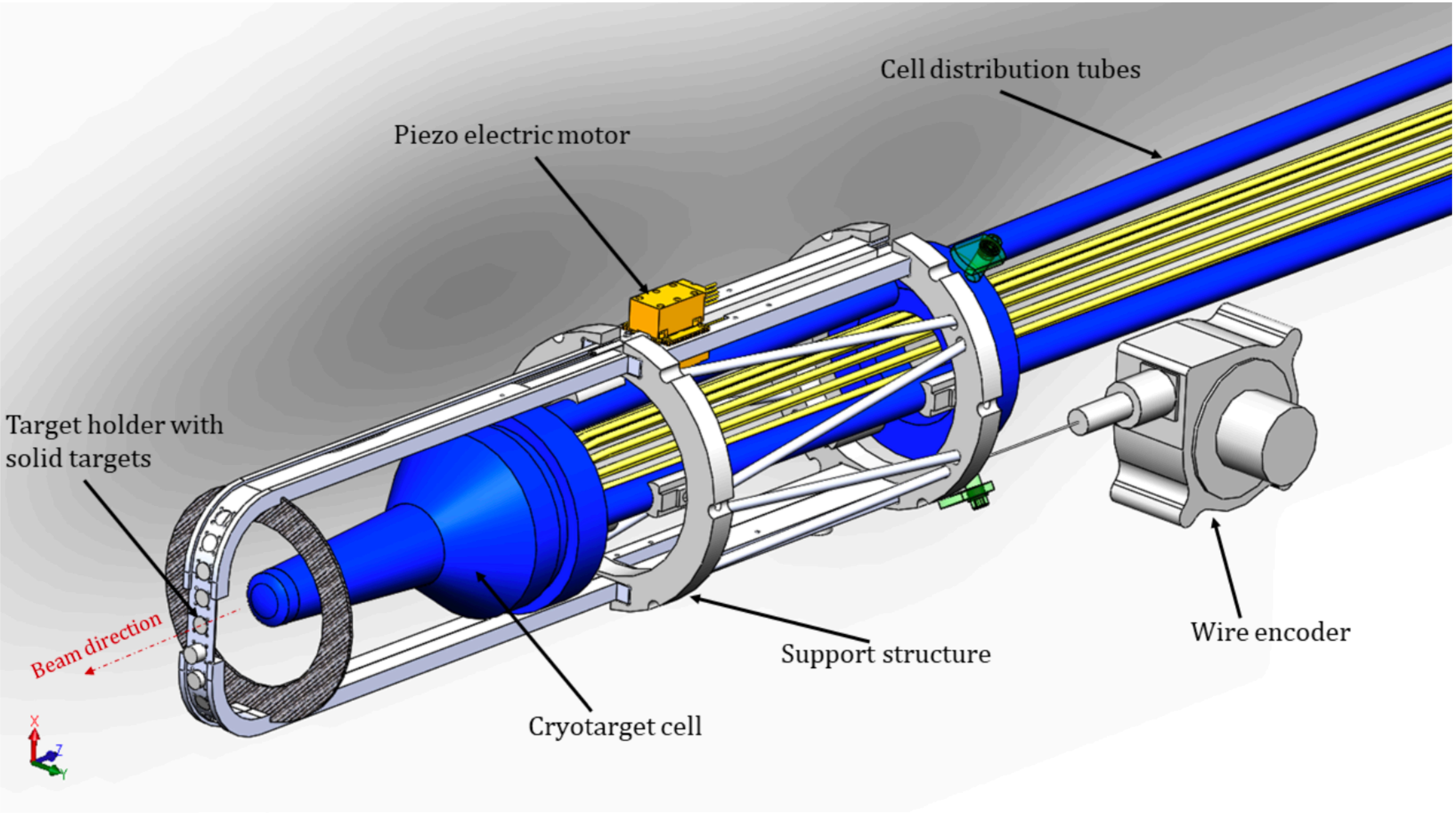
Iron



Lead

Andres Borquez, Orlando Soto et al. analysis note on preparation.

RGE Experiment (12 GeV)



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Requirements for it (targets + luminosity)

Target	PAC days	Beam current (nA) calculated by Milan U.	Luminosity (/cm²s)	Backup target in case of melting
Deuterium	4	32	1.00E+35	
Carbon	6	31	1.00E+35	
Aluminum	7	45	1.00E+35	
Copper	8	83	1.00E+35	
Tin	15	72	6.00E+34	Ag; 83*0.60 = 50 nA
Lead	18	108	6.50E+34	Au; 99*0.65 = 64 nA

JLab Target group are working on the new cryotarget,
our engineers are on touch with them to adapt to new geometry requirements if necessary

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Hadrons in CLAS12

hadron	$c\tau$	mass (GeV)	flavor content	detection channel	Production rate per 1k DIS events
π^0	25 nm	0.13	$u\bar{u}d\bar{d}$	$\gamma\gamma$	1100
π^+	7.8 m	0.14	$u\bar{d}$	direct	1000
π^-	7.8 m	0.14	$d\bar{u}$	direct	1000
η	0.17 nm	0.55	$u\bar{u}d\bar{d}s\bar{s}$	$\gamma\gamma$	120
ω	23 fm	0.78	$u\bar{u}d\bar{d}s\bar{s}$	$\pi^+\pi^-\pi^0$	170
η'	0.98 pm	0.96	$u\bar{u}d\bar{d}s\bar{s}$	$\pi^+\pi^-\eta$	27
ϕ	44 fm	1.0	$u\bar{u}d\bar{d}s\bar{s}$	K^+K^-	0.8
$f1$	8 fm	1.3	$u\bar{u}d\bar{d}s\bar{s}$	$\pi\pi\pi\pi$	-
K^+	3.7 m	0.49	$u\bar{s}$	direct	75
K^-	3.7 m	0.49	$\bar{u}s$	direct	25
K^0	27 mm	0.50	$d\bar{s}$	$\pi^+\pi^-$	42
p	stable	0.94	ud	direct	530
$\bar{p}$	stable	0.94	$\bar{u}\bar{d}$	direct	3
Λ	79 mm	1.1	uds	$p\pi^-$	72
$\Lambda(1520)$	13 fm	1.5	uds	$p\pi^-$	-
Σ^+	24 mm	1.2	us	$p\pi^0$	6
Σ^0	22 pm	1.2	uds	$\Lambda\gamma$	11

With new Double-Target, designed and built in UTFSM

Experiment Context: CLAS12 Conditions

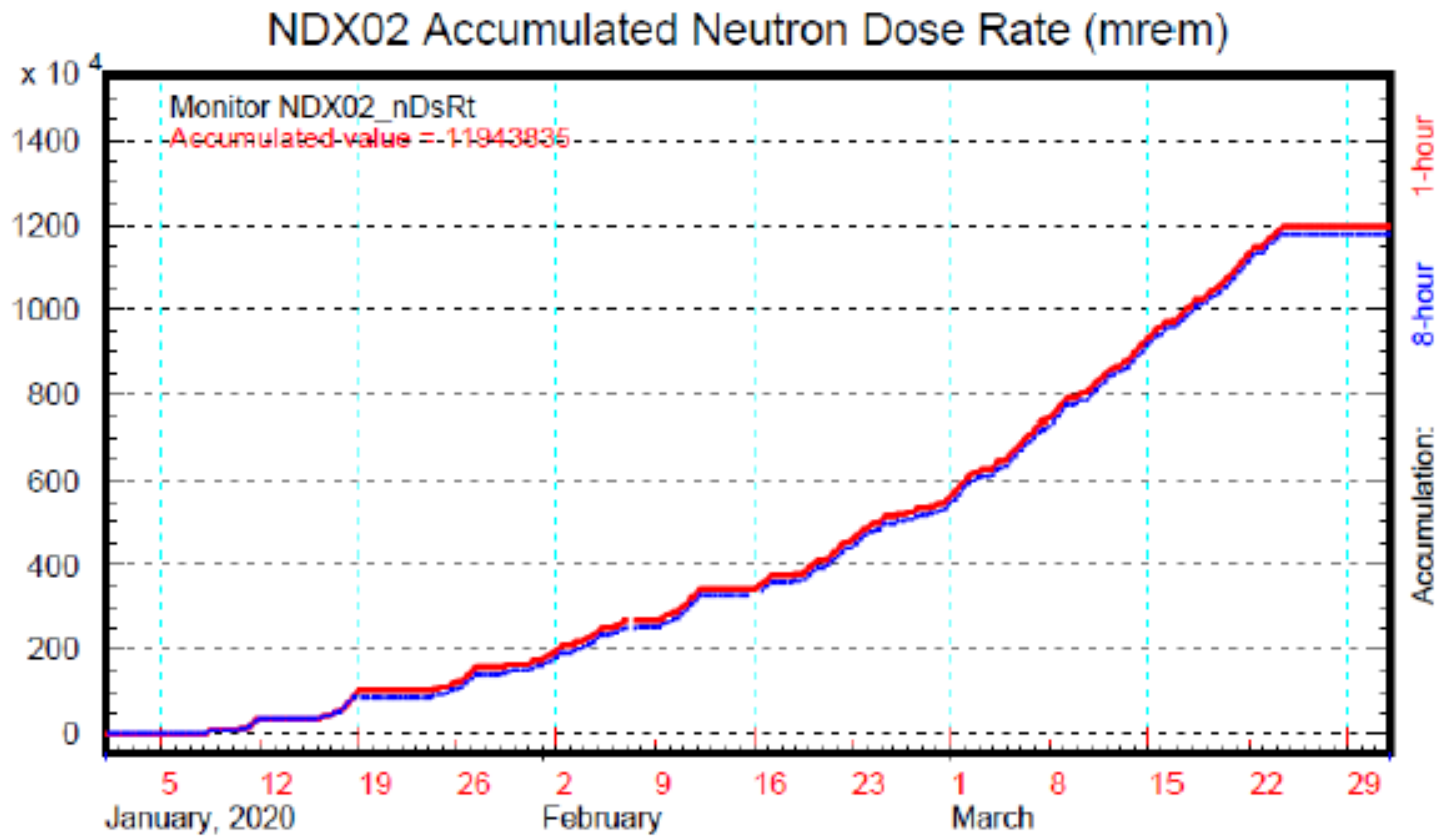
1. Reduced Space in Beamline, 85mm
2. High Vacuum, 10-6 mbar
3. Strong Magnetic Field, 5 Tesla
4. Cryogenic Temperatures, 22 Kelvin cryo-cell
5. 11 GeV Beam energy

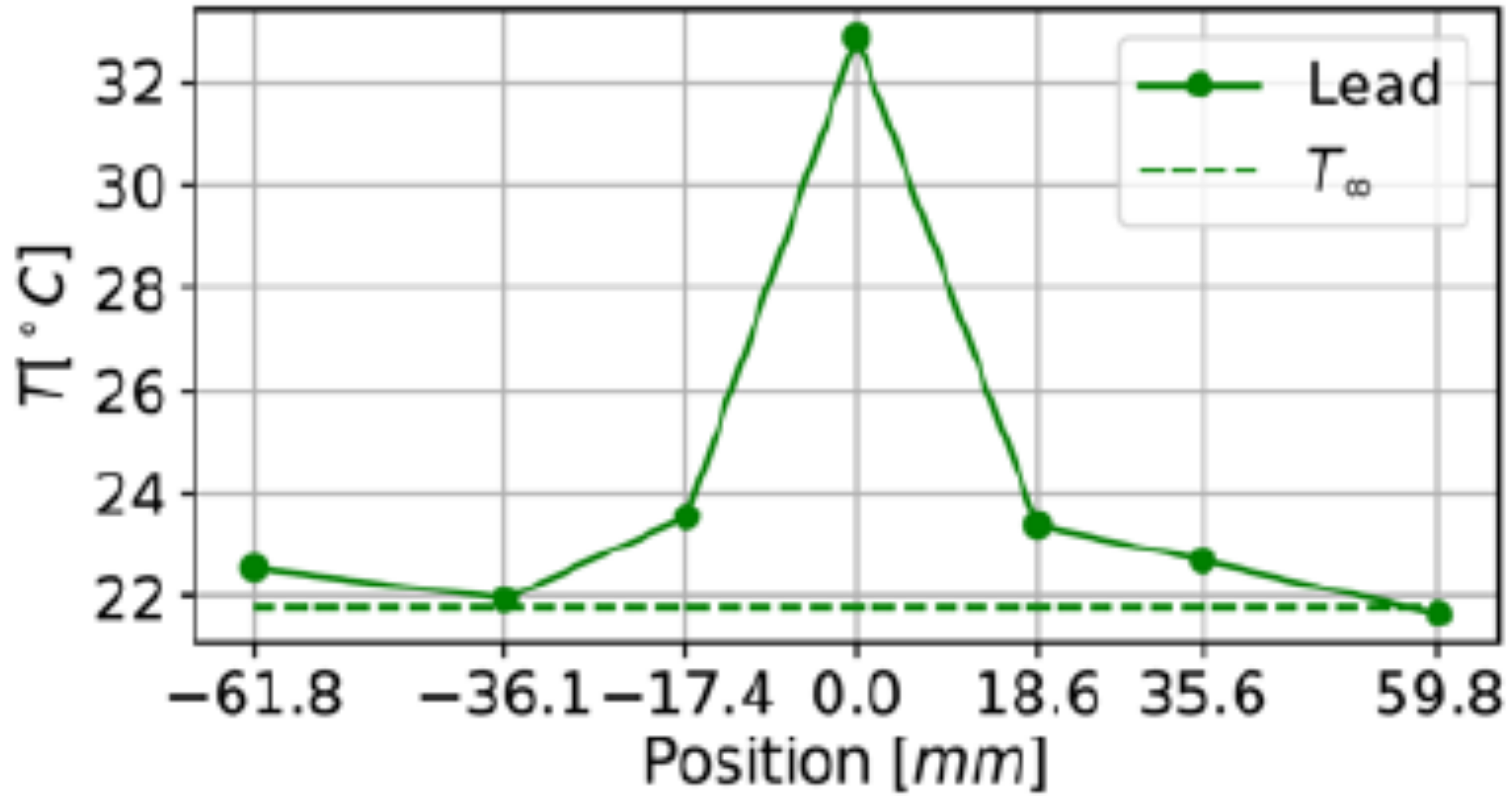
- Interchangeable solid targets system in high vacuum
- Remote control system
- Resistant to high radiation
- Non-magnetic materials
- High vacuum resistant materials (no out-gassing)
- Fit in a 85mm diameter, cylindrical room
- Estimation of temperature in targets and devices

Double target system

Tests of the double target system into extreme conditions

- Radiation hardness test ✓
- Operation in vacuum test ✓
- High temperature test ✓
- Low temperature test
- Repetitiveness and precision test
- **Commissioning**





Engineering Tests Report

Double Target Engineering Notes

Engineers: Bruno Benkel, Sebastián Gálvez, Jairo González, Alonso Lepe, René Ríos, Milan Ungerer, Vicente Saona, Eduardo Valdivia, Juan (Iñaki) Vega.
Physicist: Claudio González, Esteban Molina
RGE spokepersons: William Brooks, Hayk Hakobyan, Taisiya Mineeva

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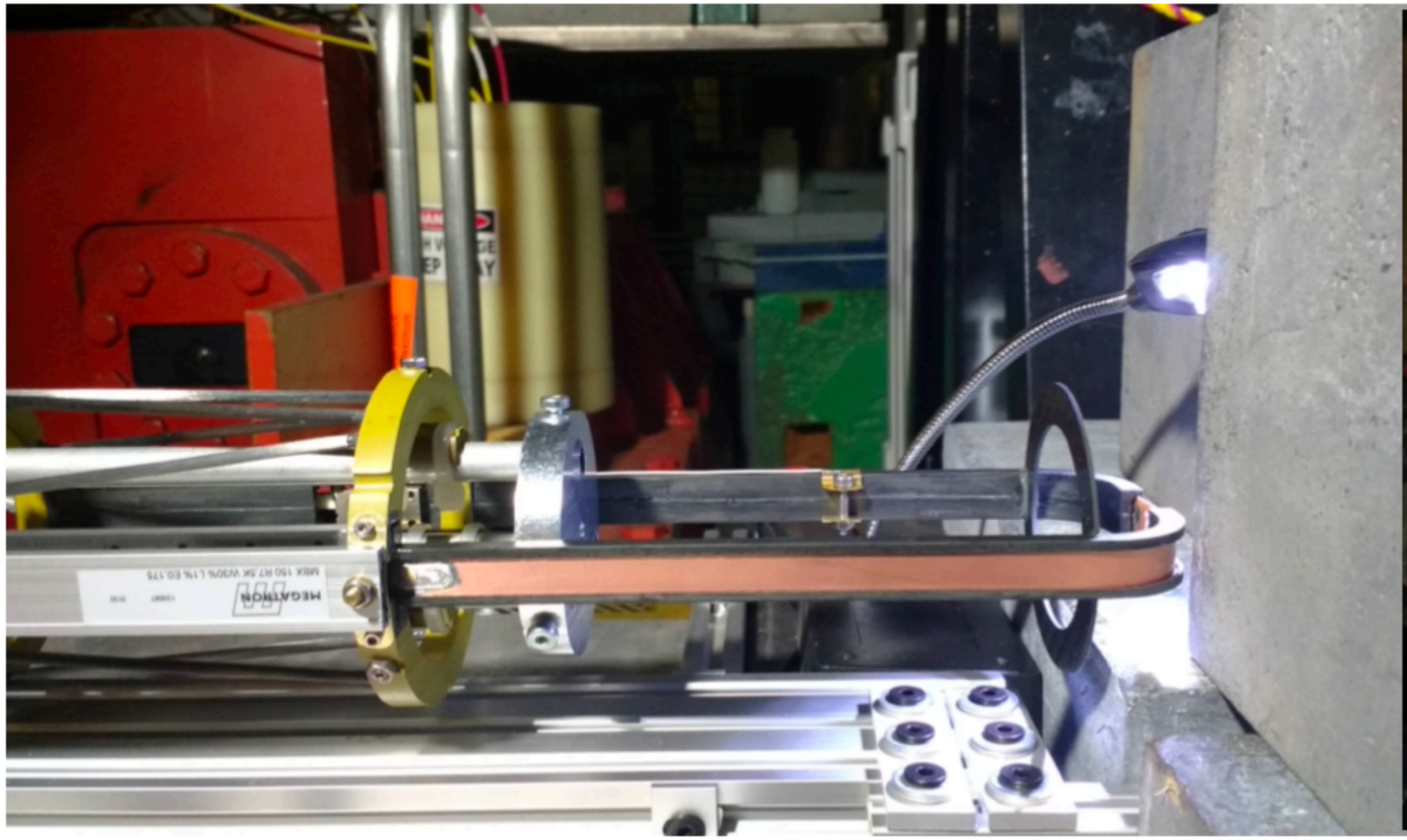
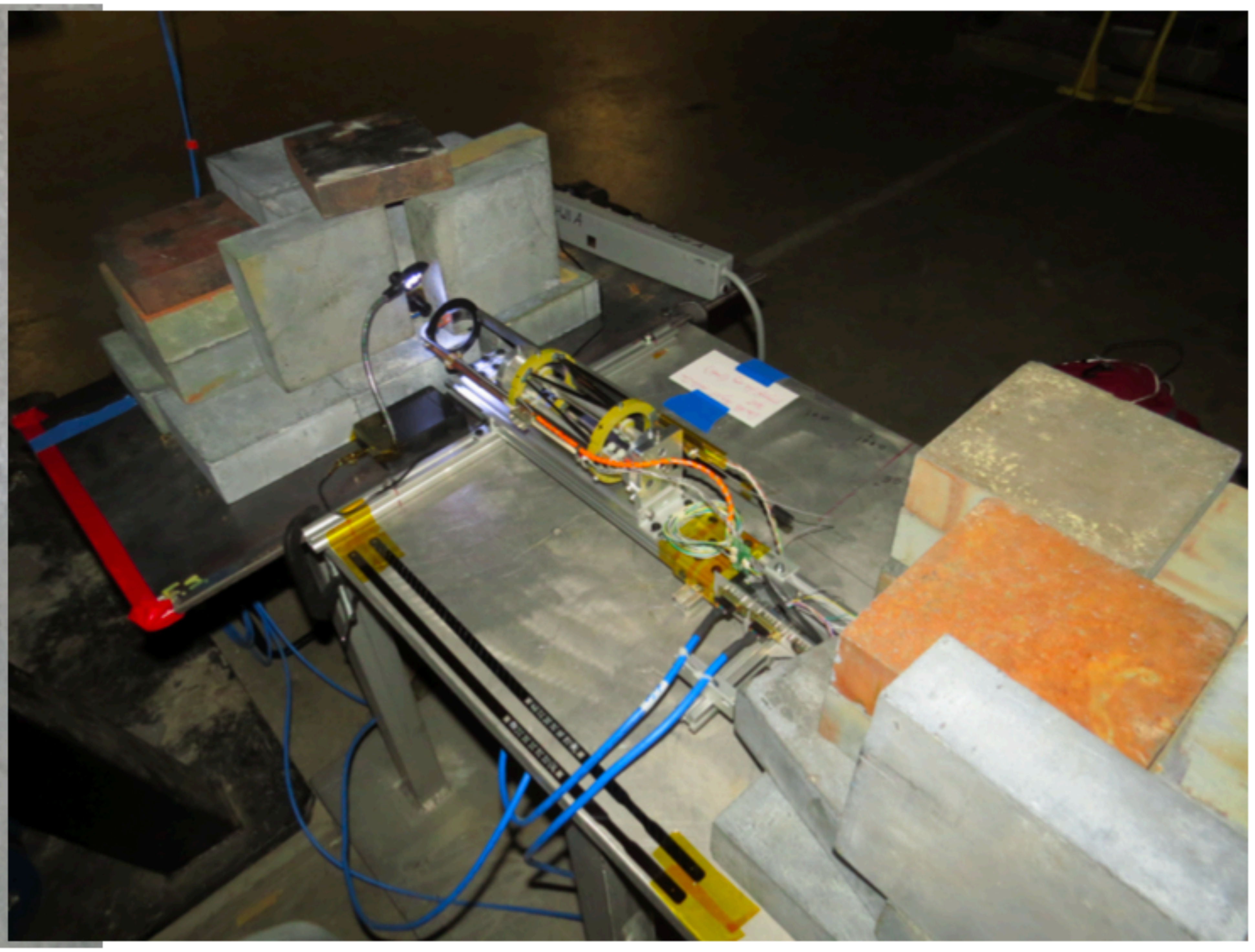
Radiation Hardness test of the Double-target in Hall-A

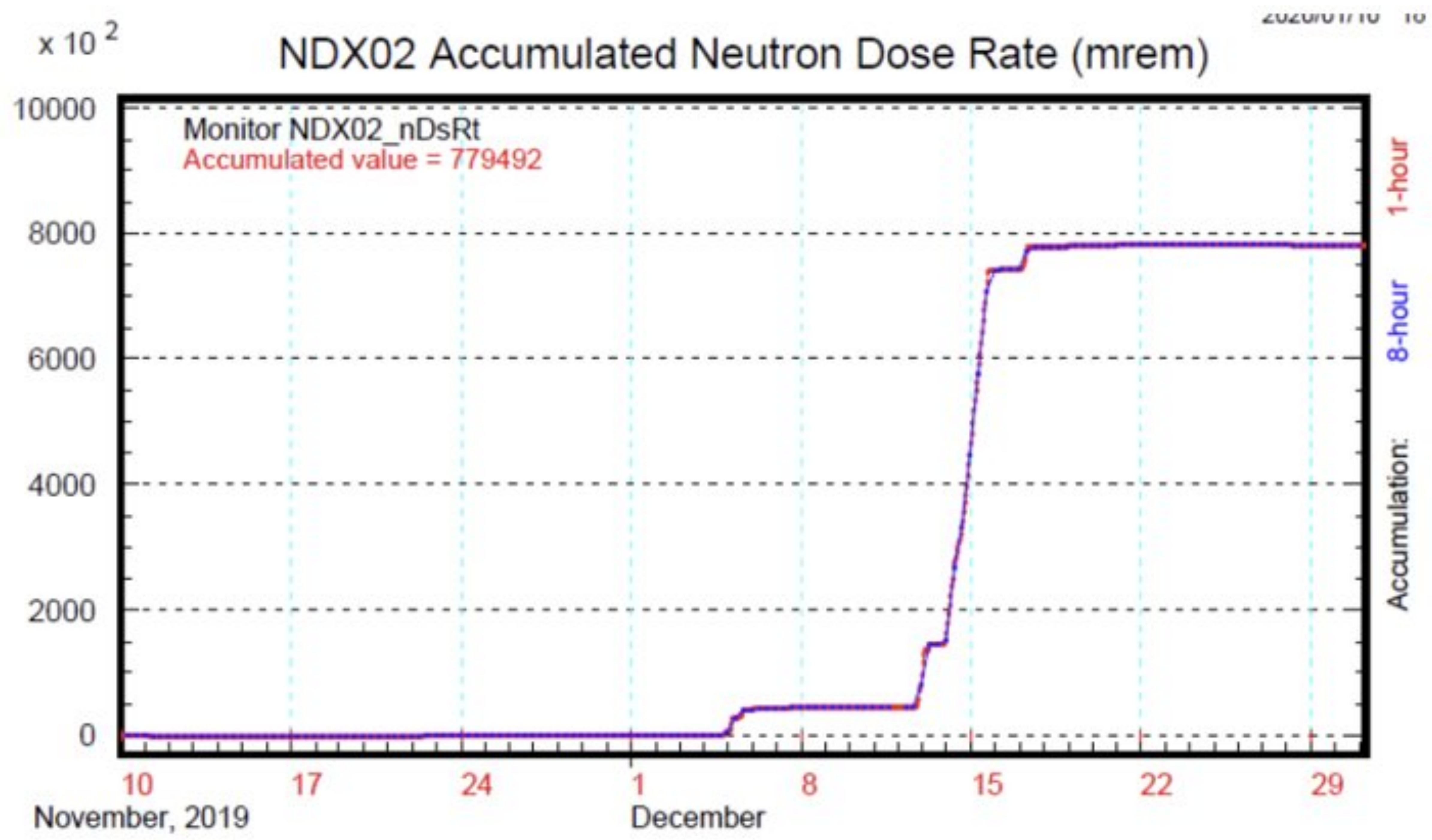


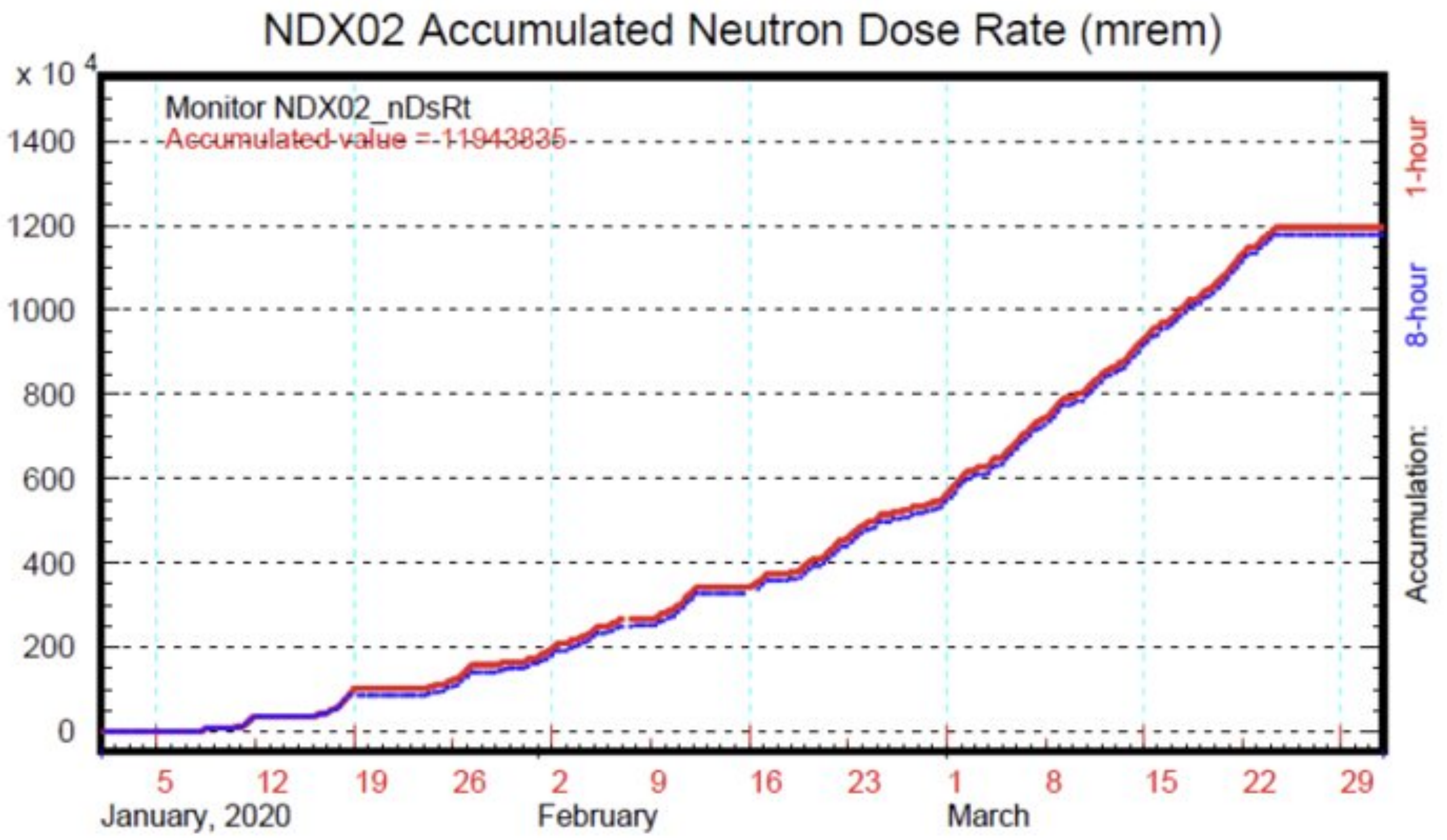


Milan Unegerer’s Master’s thesis “New Double-Target for CLAS12 experiment” includes detailed description of radiation hardness test; detailed thermal analysis via simulations; background studies with GEMC

Neutron radiation of the target during Hall-A test was 336% of the estimated dose. The target used in the test is currently in UTFSM and is fully operational.

Radiation Hardness Test

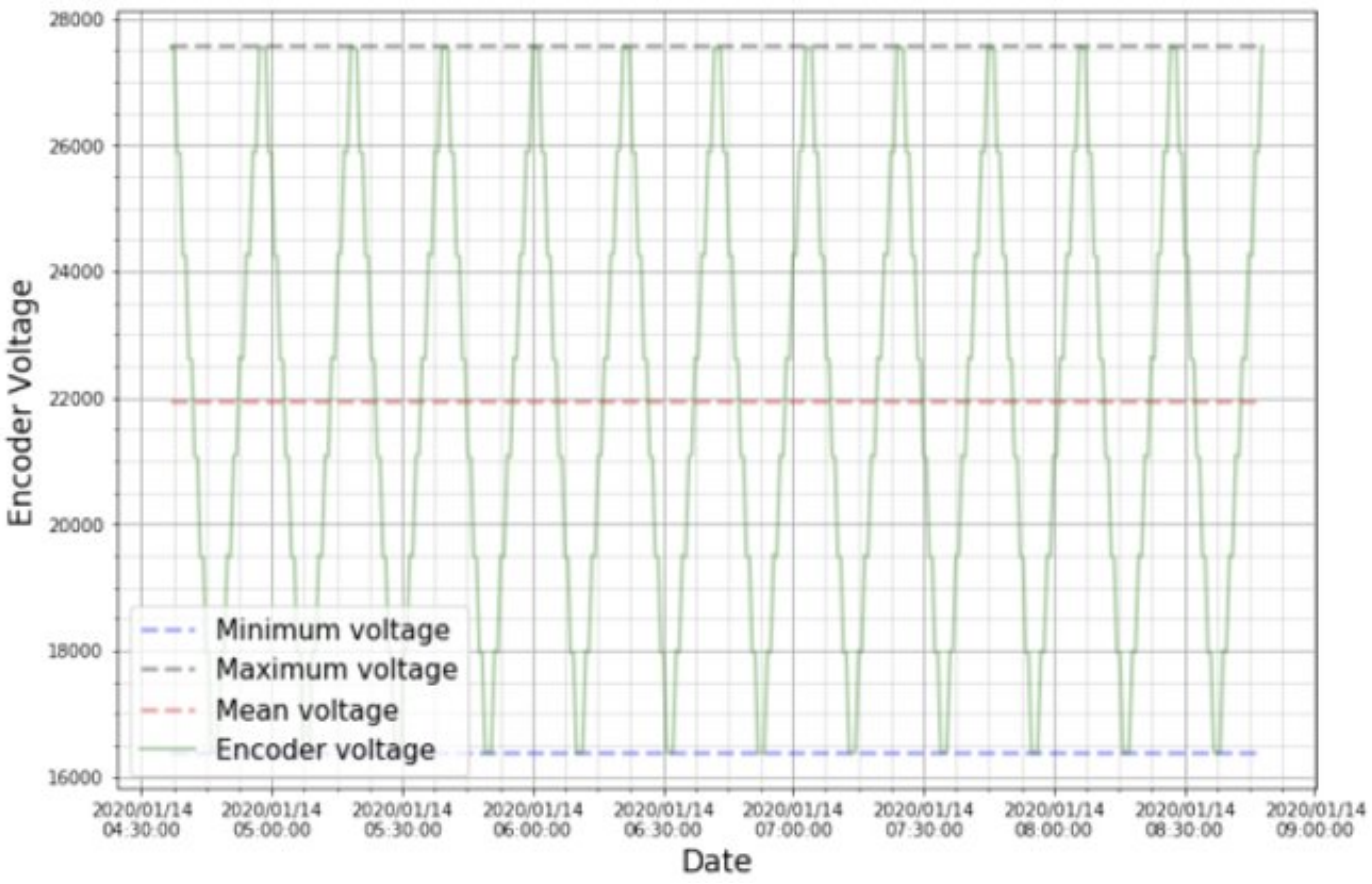




Accumulated Neutron dose from November 2019 until March 2020

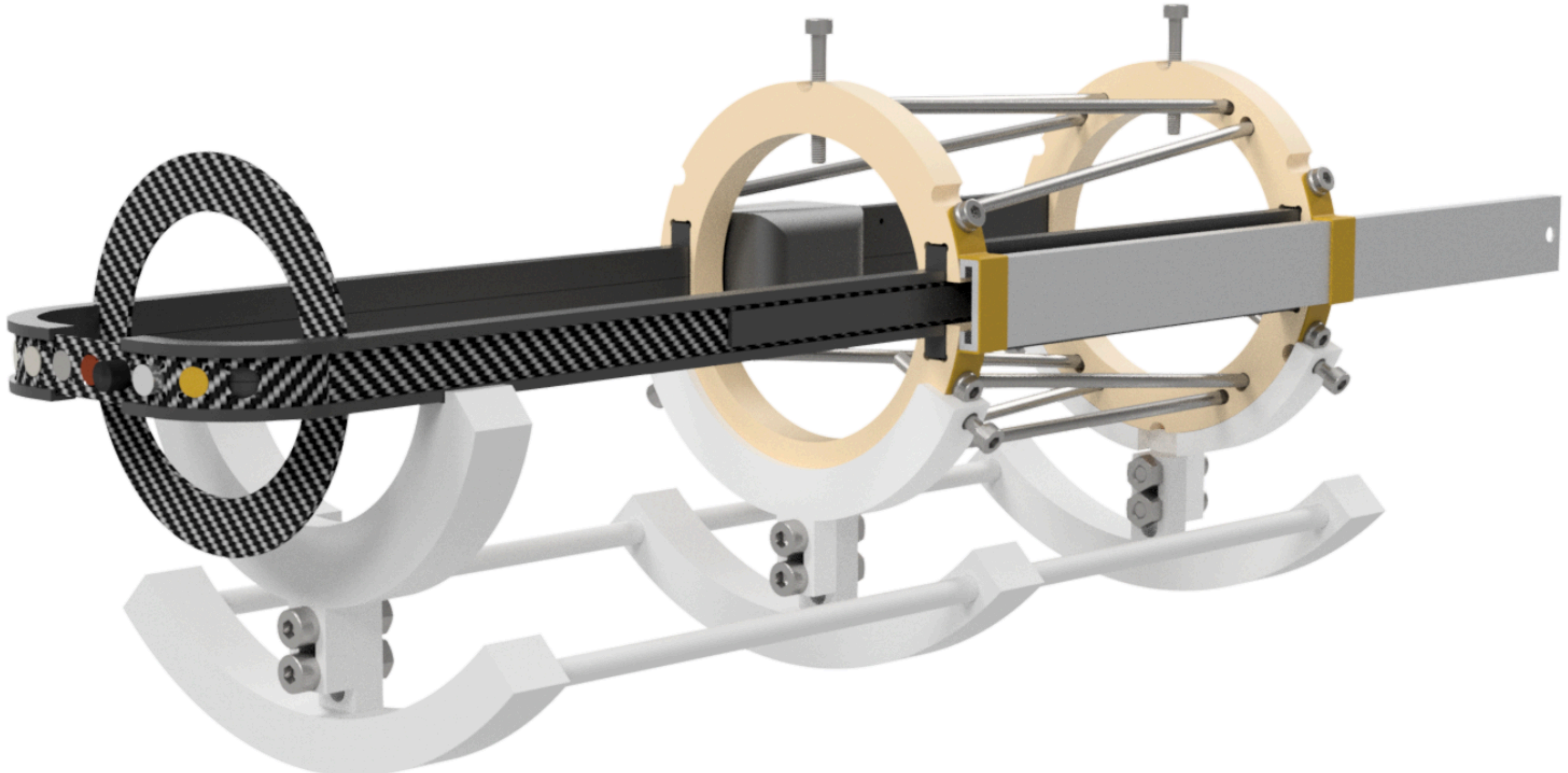
Photon dose was monitored as well.

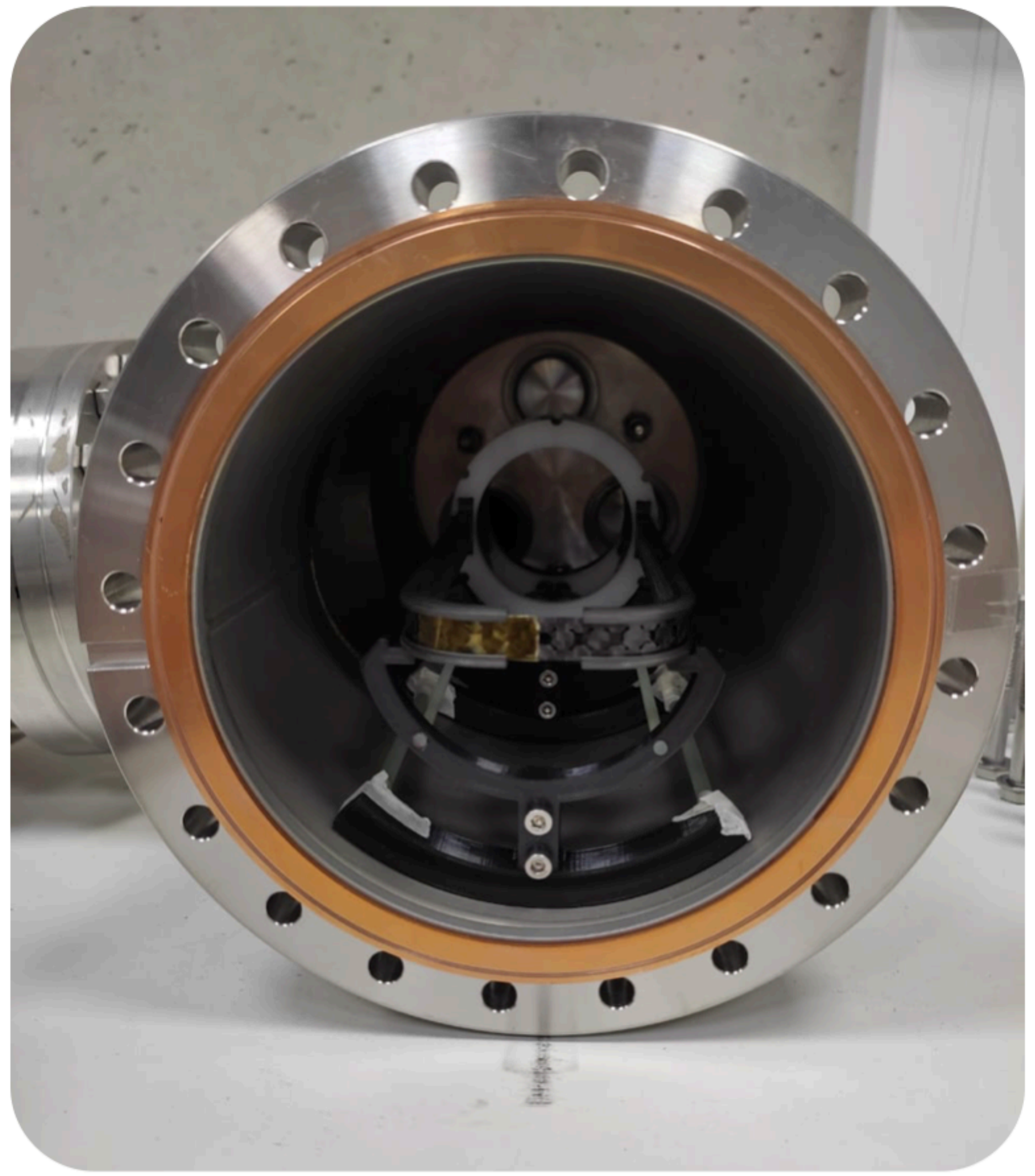
Radiation Hardness Test



Encoder voltage reading under high radiation for 4.5 hrs

Vacuum Chamber (10-7 mbar vacuum pressure)

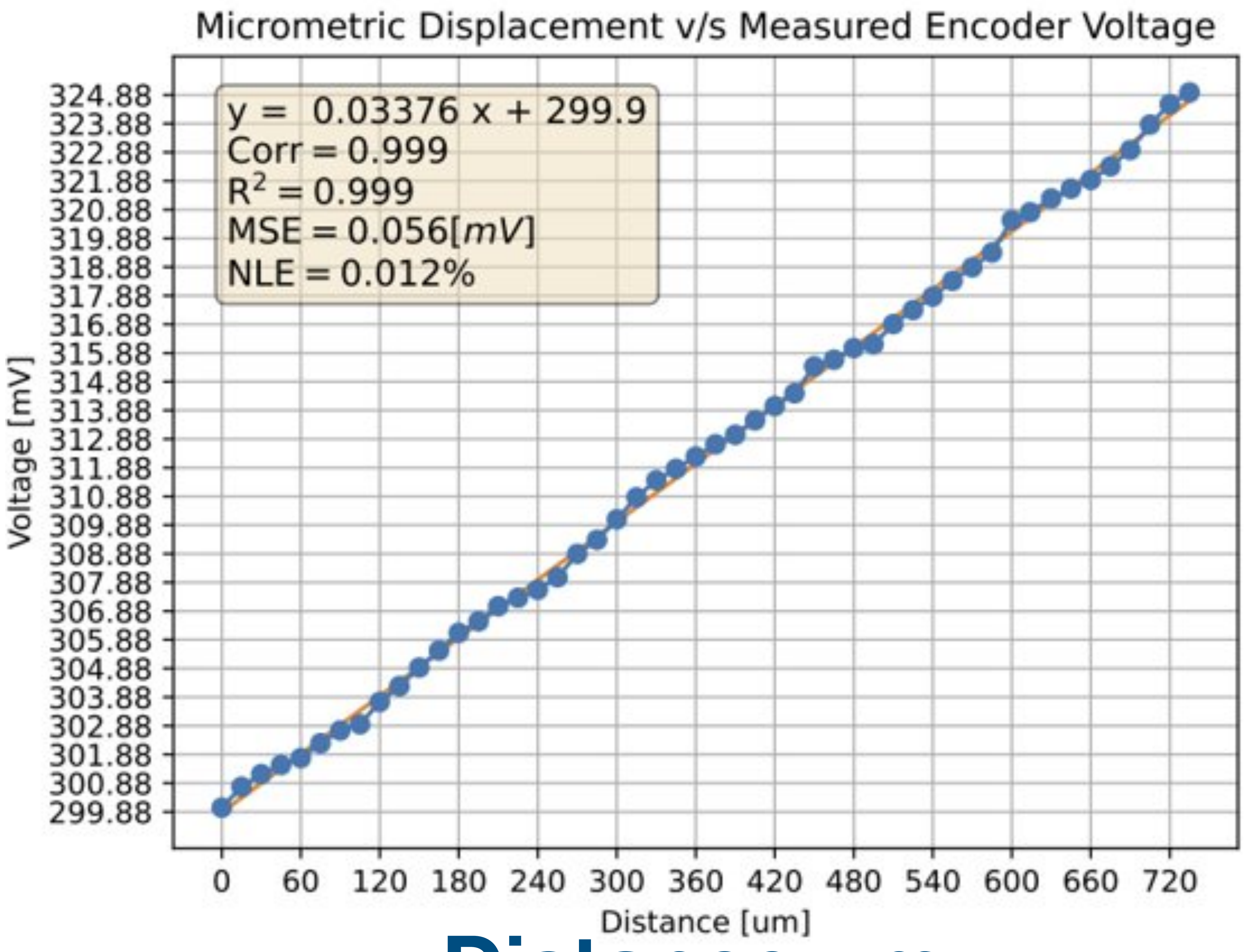




Movement inside the Vacuum

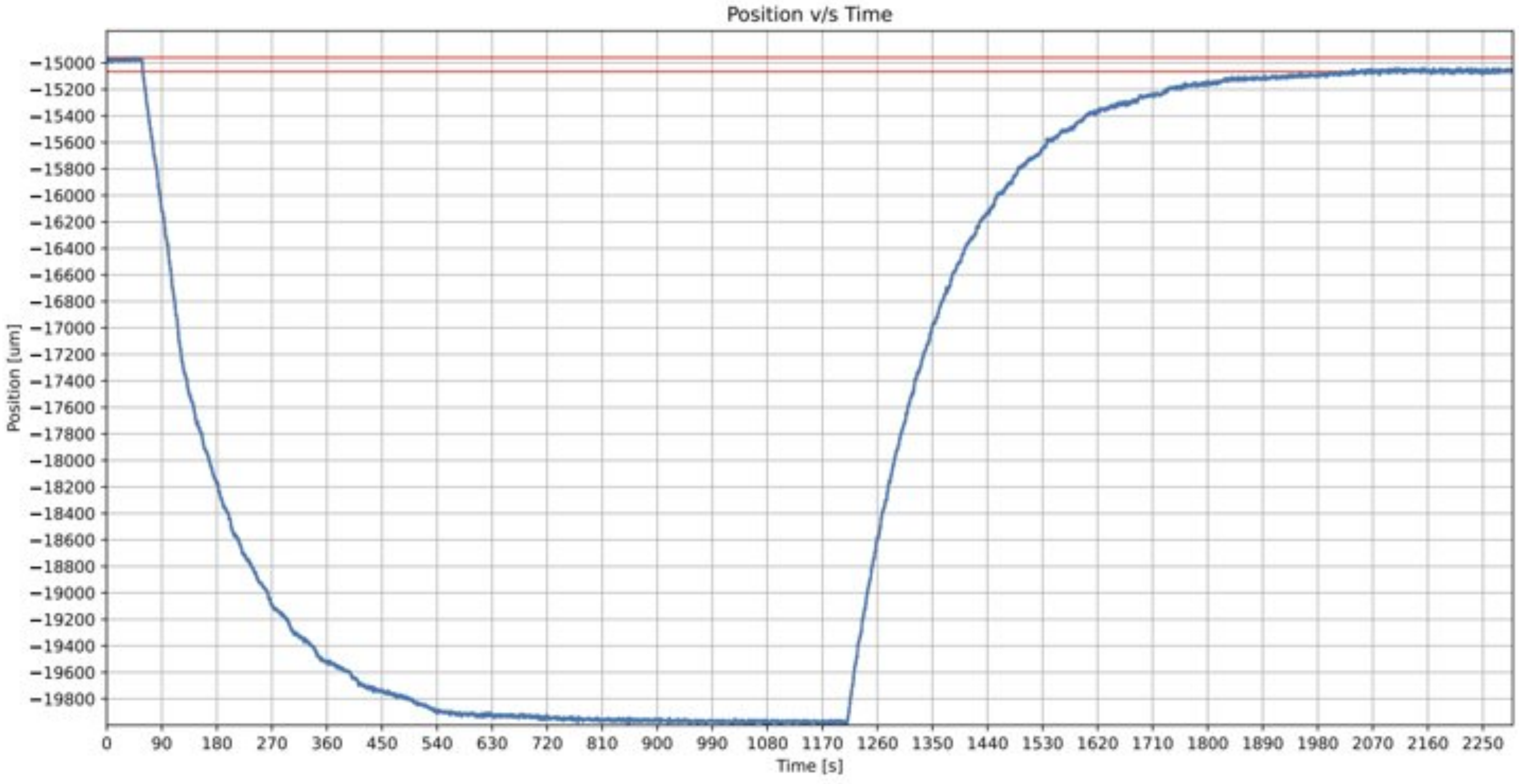
- *Accuracy of 50 um*
- *Speed up to 3.2 mm/s*
- *Control with EPICS*

Voltage uV



Distance um

Position um



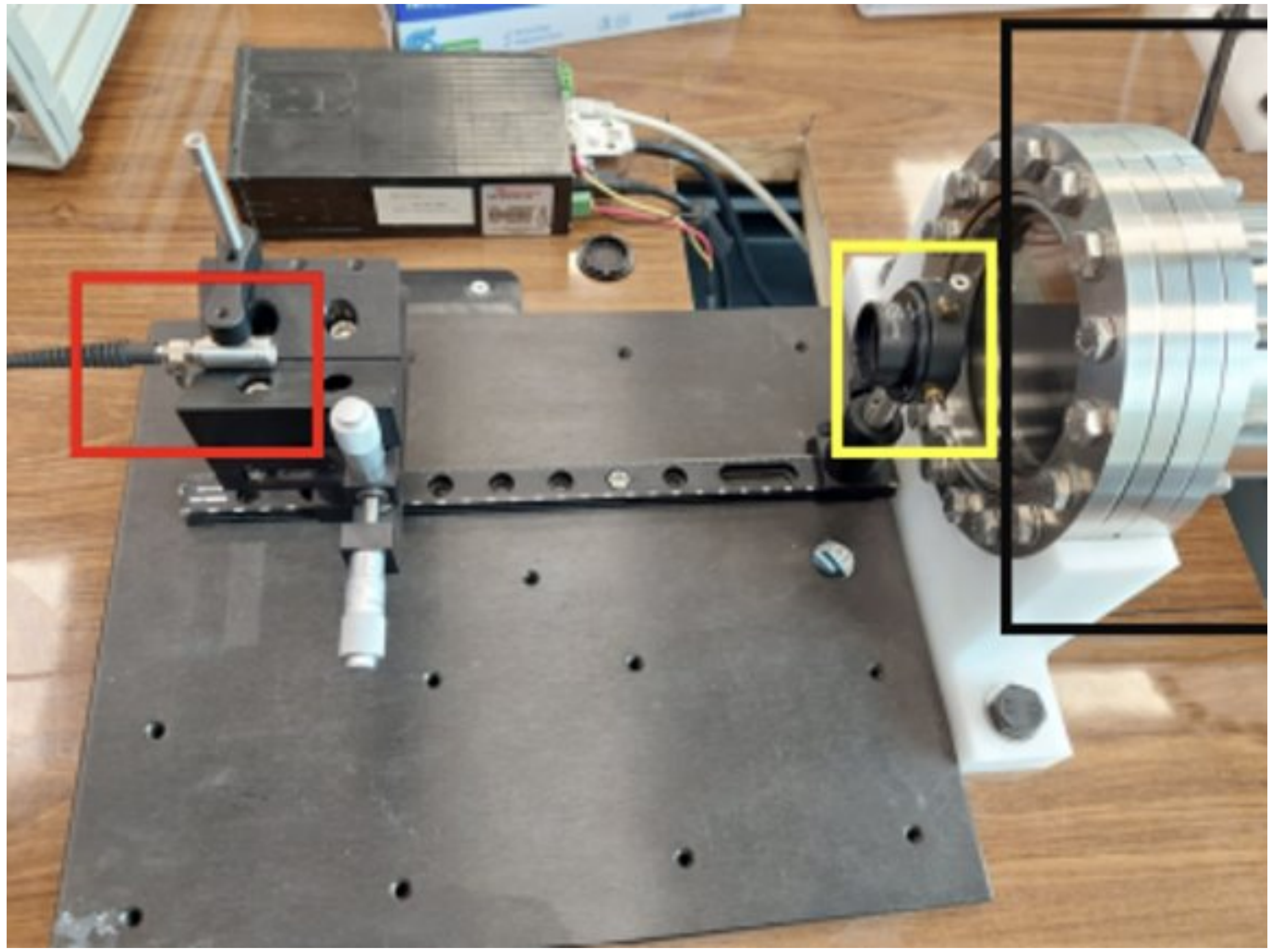
Time s

Correlation between encoder's displacement and voltage reading

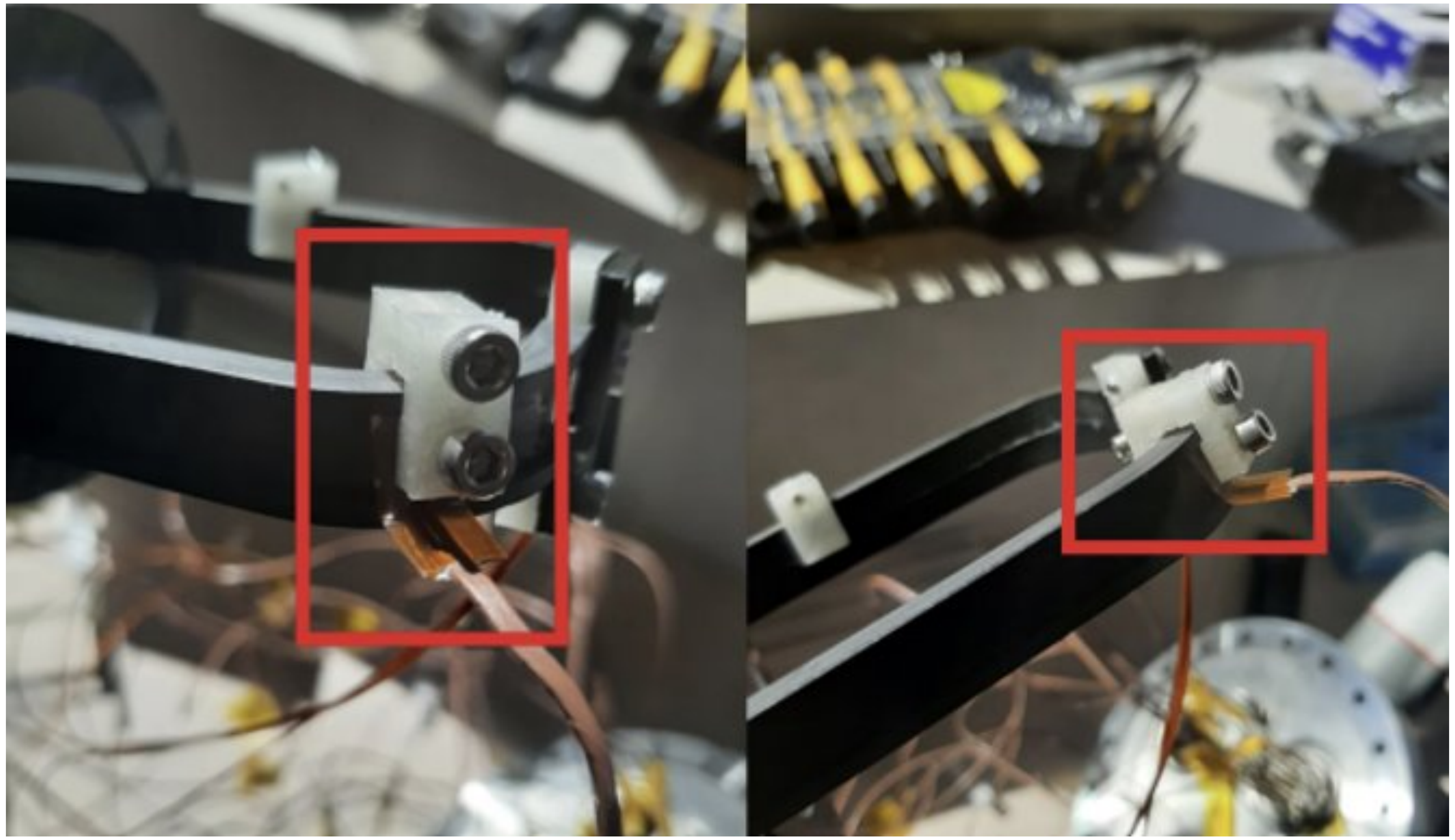
Position in time of a solid target. Complete cycle run

Temperature Test

Red Laser Beam
Lens
Vacuum Chamber

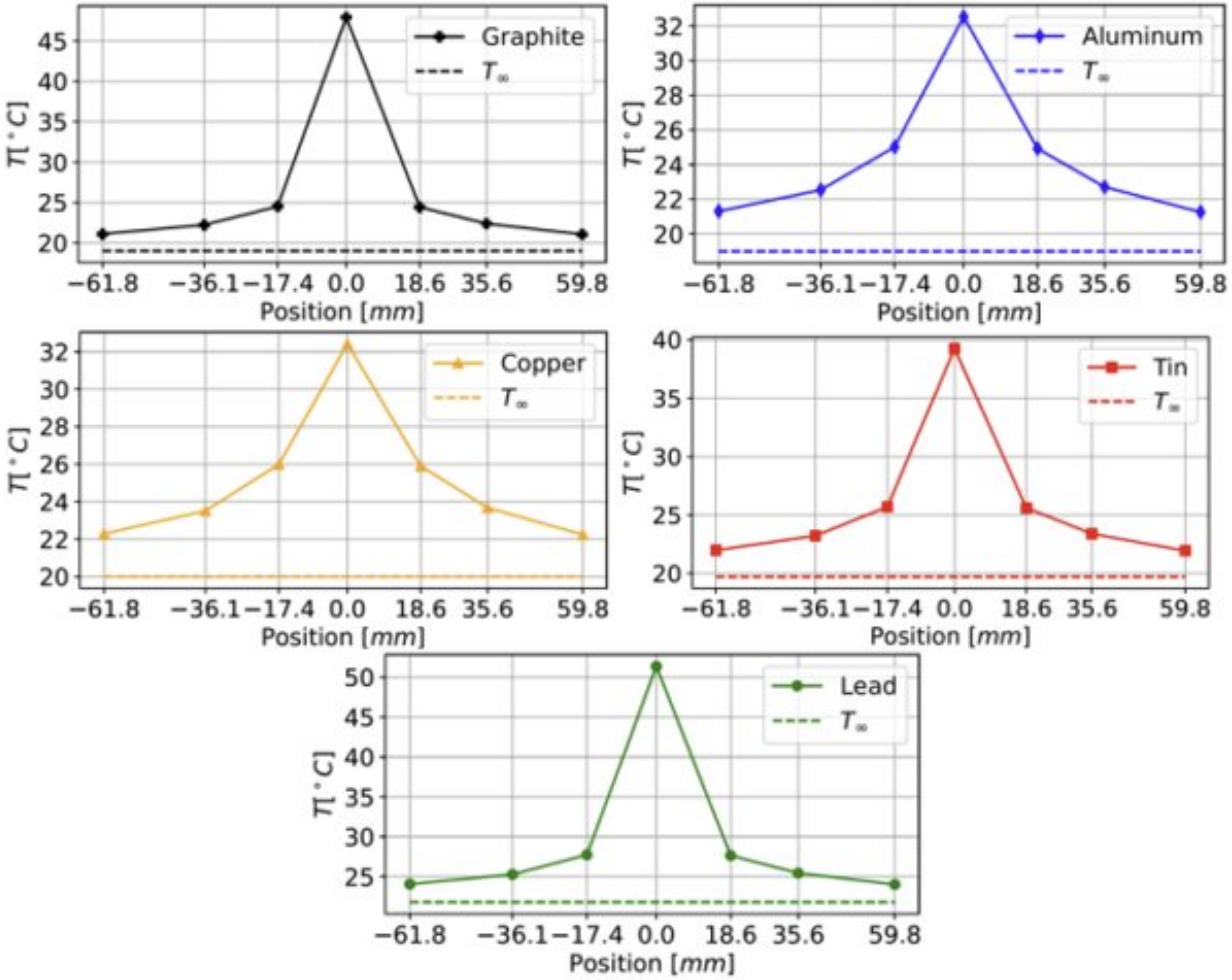


Thermo-couple Holders

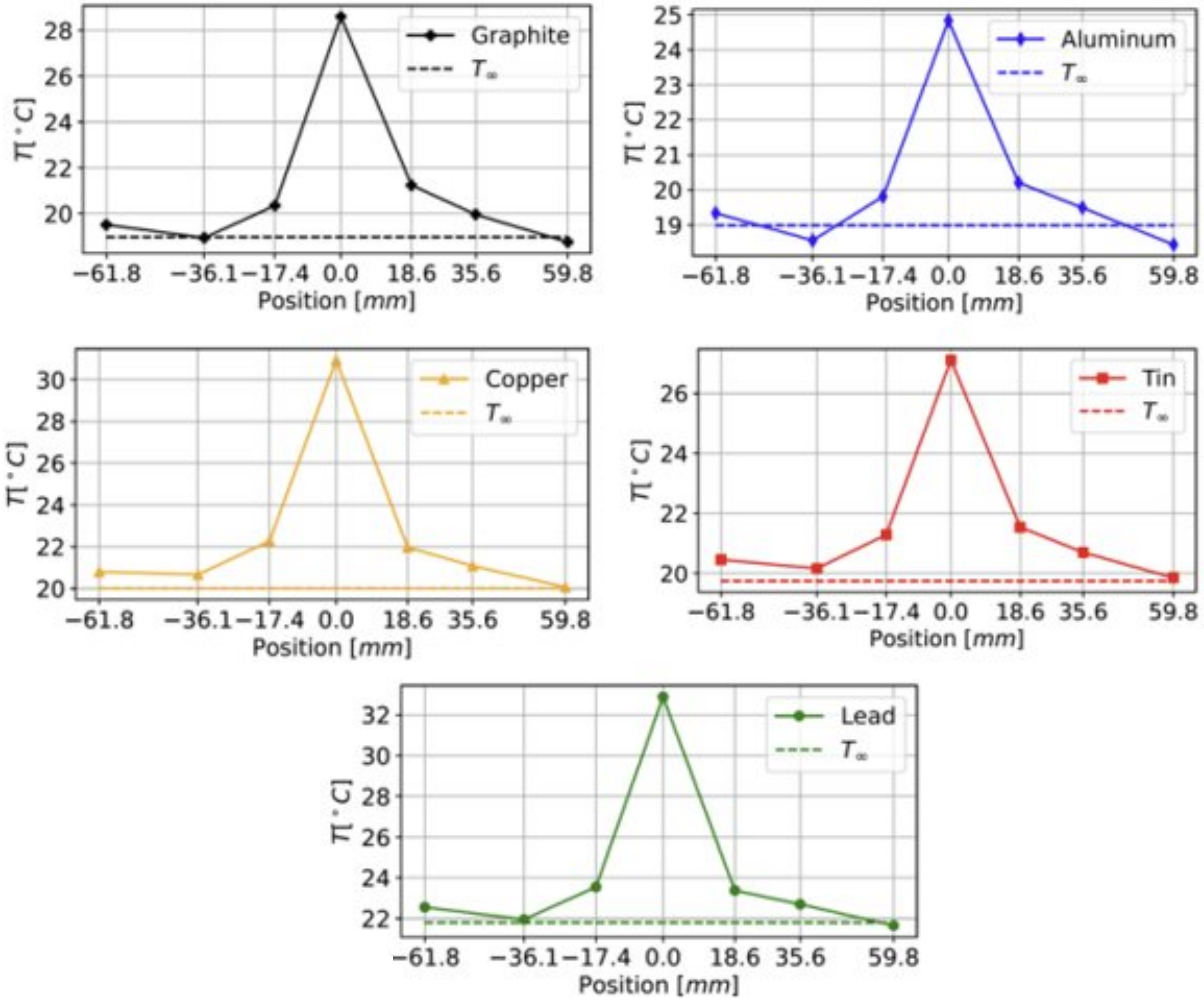


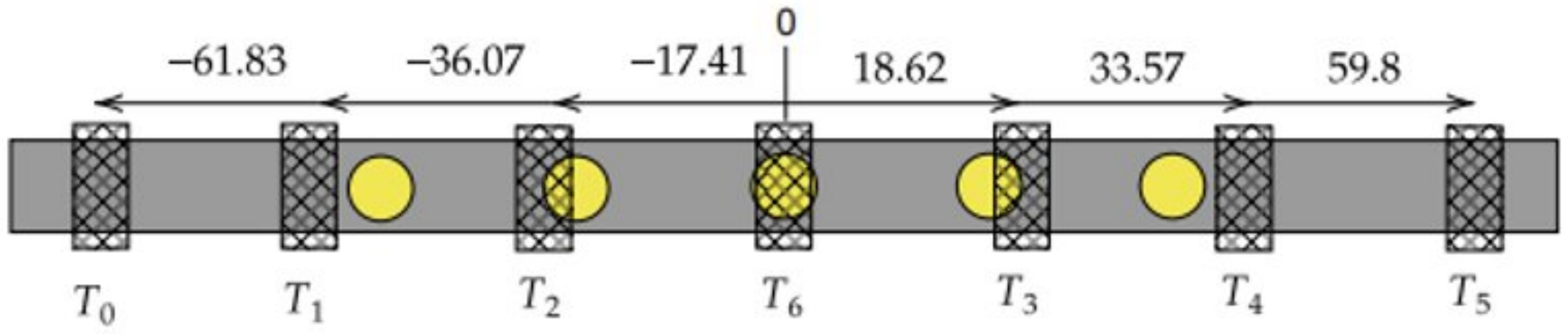
Temperature Test

Numerical Simulations



Lab Measurements





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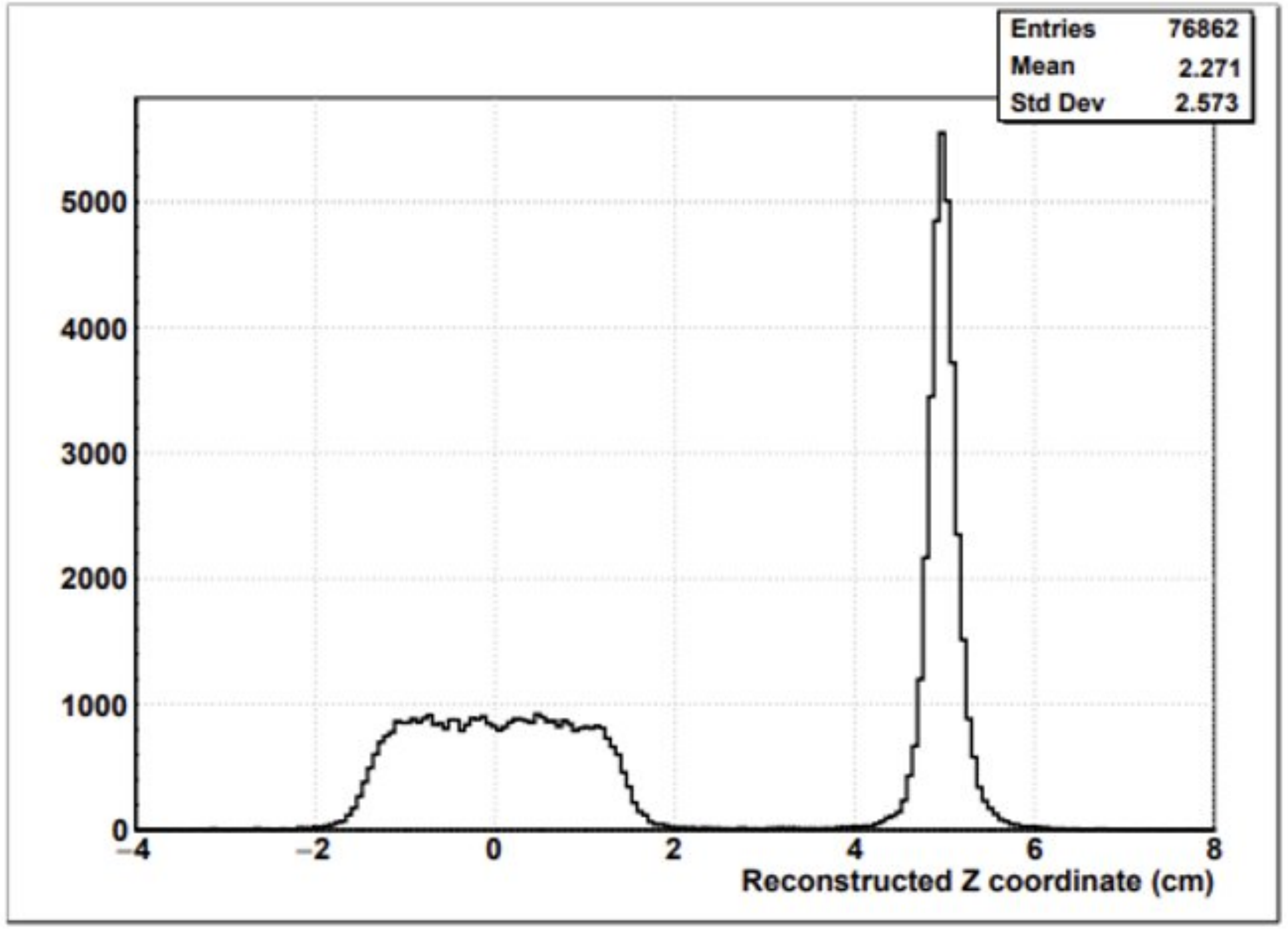
Temperature Test Results

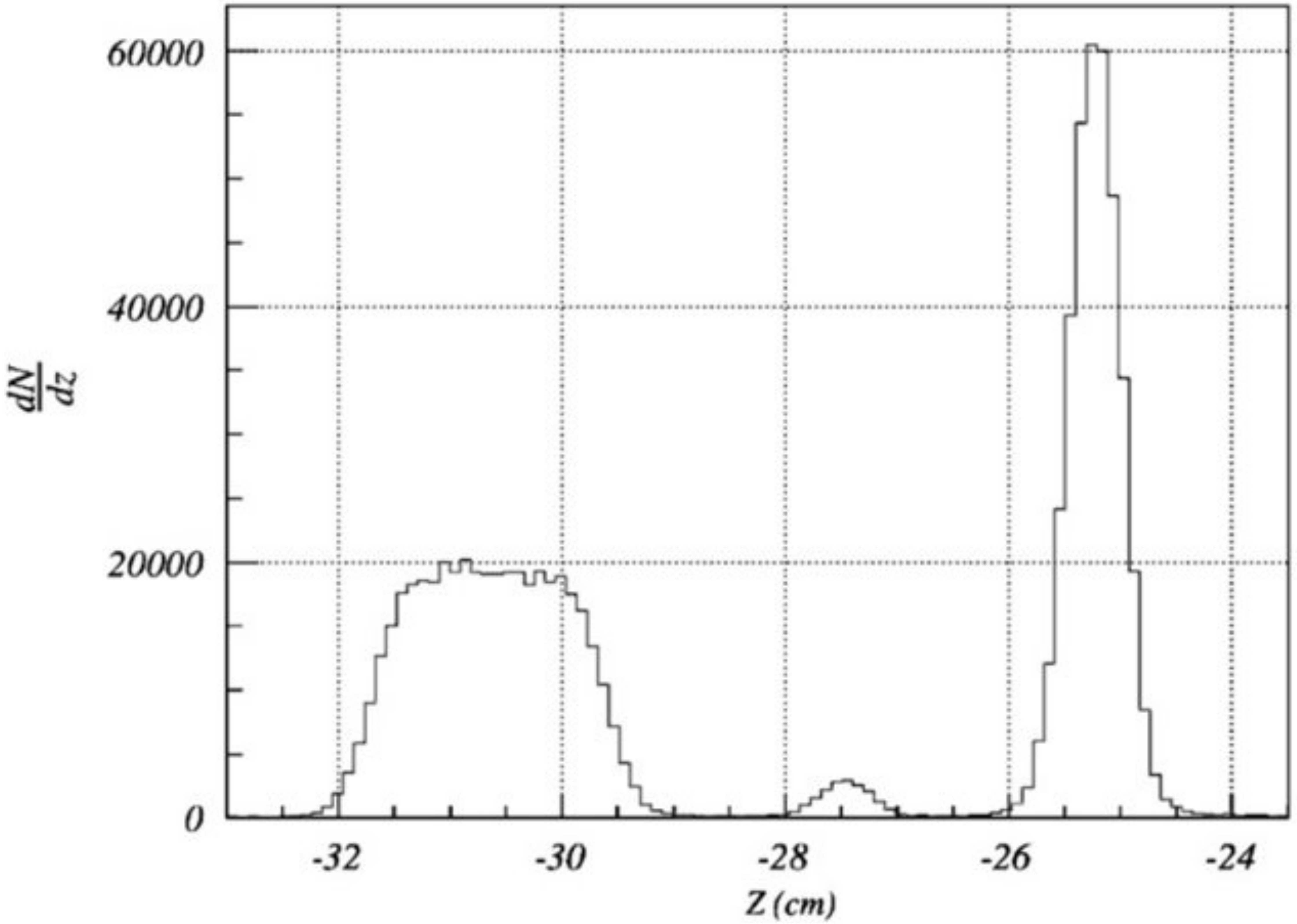
Target	Experiment $T_{max} K$	Simulation $T_{max} K$	Melting point K
C	301.75	321.06	4098
Al	297.98	305.68	934
Cu	304.08	305.56	1358
Sn	300.26	312.39	505
Pb	306.03	324.49	601

Maximum temperatures reached in physical experiment and numerical experiment compared to the melting point of the corresponding solid target

Vertex Reconstruction with GEMC



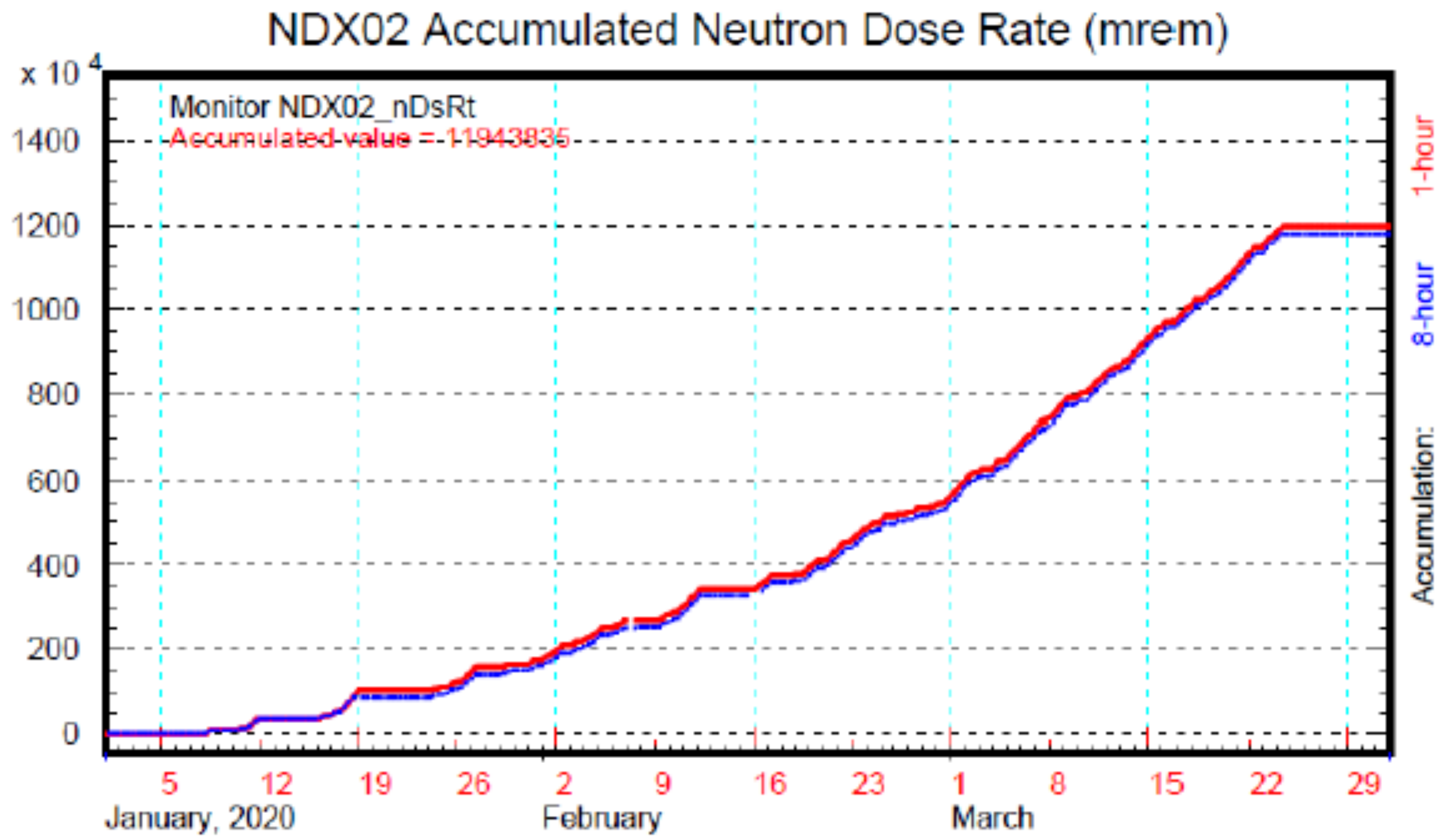
CLAS12 Simulation

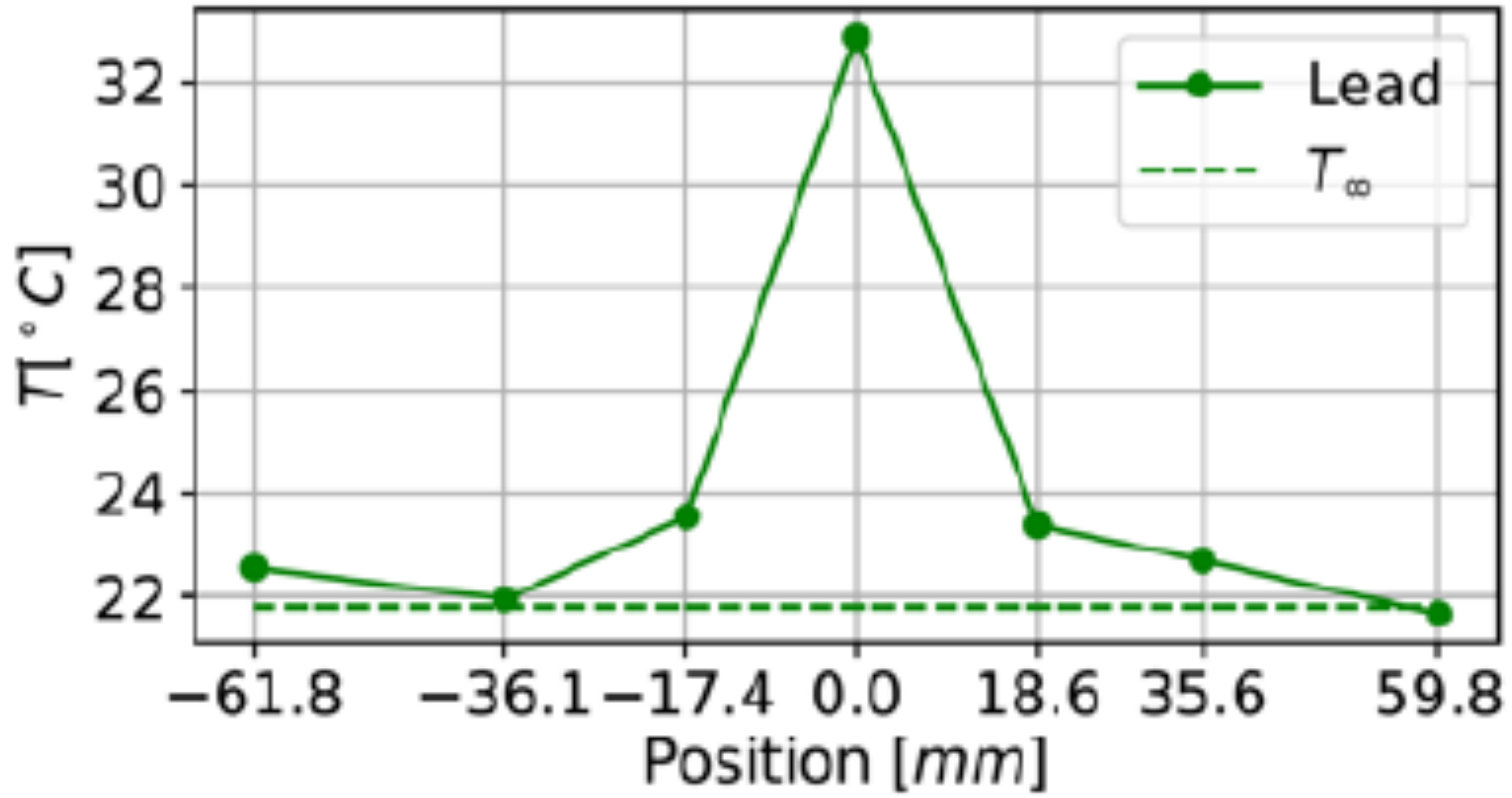


Data CLAS

Tests of the double target system into extreme conditions

- Radiation hardness test ✓
- Operation in vacuum test ✓
- High temperature test ✓
- Low temperature test
- Repetitiveness and precision test
- **Commissioning**





Some current highlights …

- The new Hall-B cryo-target is in the process of building.
- Details should be worked out to fit the design of the Hall-B cryo-target and double-target to each other.
- Double-target will be mounted on the new heat shield, eliminating increased heat load on the target cell. The new heat shield surrounding the target will be cooled independently from the target with temperatures ranging from target temp and up (*message from James Brock*).
- A scattering chamber's design and material composition should be worked out to maintain a 4 mm clearance between the target and the scattering chamber.
- In UTFSM, the target will be tested for liquid nitrogen temperatures.
- A repetitiveness test is on way to confirm the target's positioning precision after hundreds/thousands of movements.
- Preparation and execution of the commissioning this year is on way.

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Current USM Work Team

Researchers	Design and manufacturing	Digital transformation	Physics
Hayk Hakobyan	Alonso Lepe	Jairo González	Esteban Molina
Will Brooks	Miguel Martinez	Eduardo Valdivia	Bruno Benkel
Taisiya Mineeva		Vicente Saona	Milan Ungerer

**And in addition, all the team that supports every specific task that we require*

In JLab special thanks to CLAS Cryotarget building engineering team - James Brock, Bob Miller, Cris Keith and others, Stepan Stepanyan, Nathan Baltzell, Xiangdong Wei, Florian Hauenstein for collaboration and support

Final remarks

- Double-Target building includes technical challenges that require substantial engineering development
- Multidisciplinary work (electronic, mechanical, and physics)
- We have a tight schedule to prepare the system for commissioning (2023), before January 2024 when RGE is scheduled to run