

The FDSi and its Active Stoppers

J.M. Allmond – ORNL

Ian Cox – UTK

On behalf of the FDSi Group

ORNL is managed by UT-Battelle, LLC for the US Department of Energy



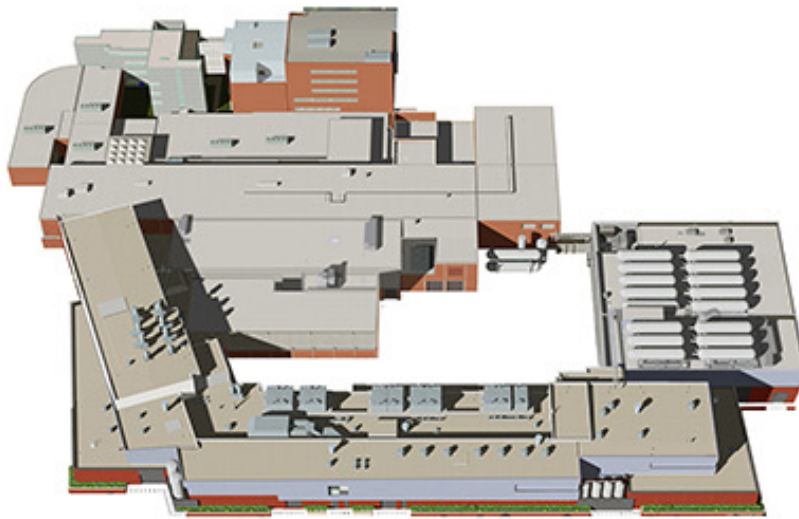
U.S. DEPARTMENT OF
ENERGY

Facility for Rare Isotope Beams (FRIB) – A DOE User Facility

Exotic nuclei from Intense stable beams at > 200 MeV/u + separator

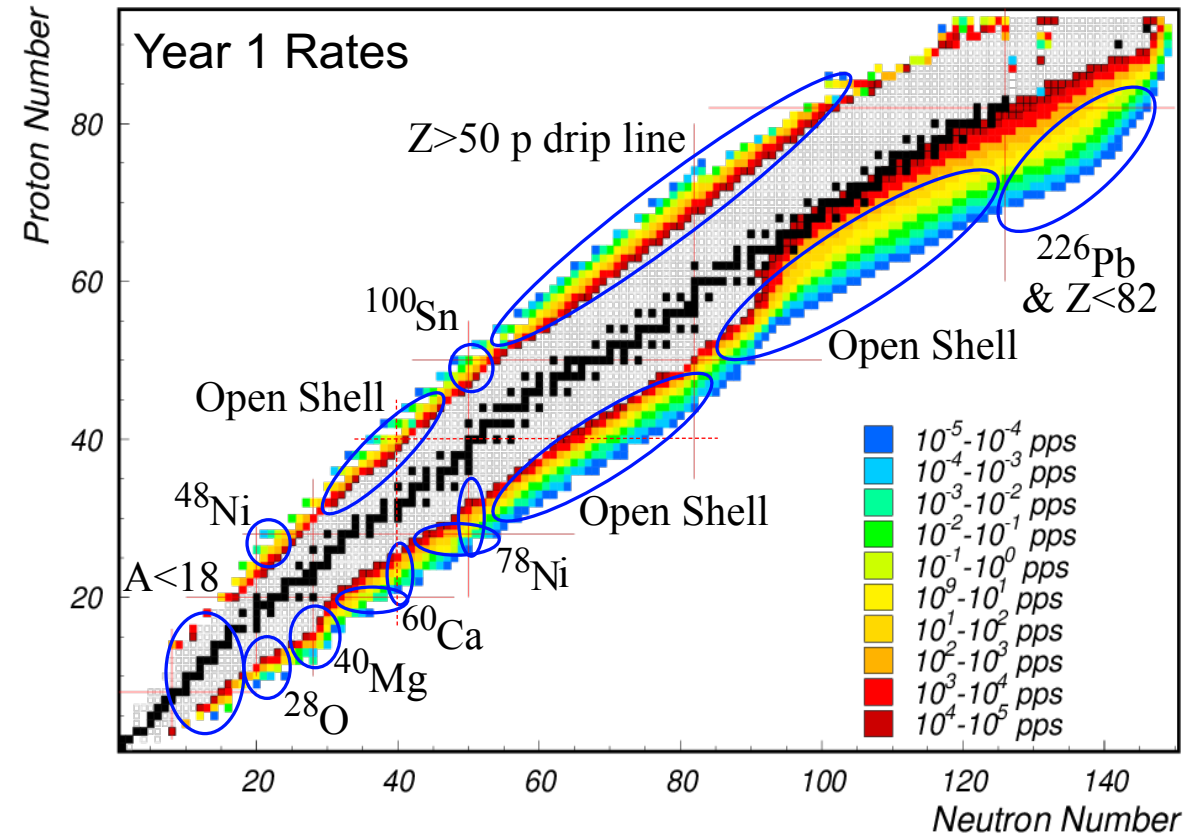
Unprecedented access to exotic nuclei; will produce 80% of isotopes predicted to exist for $Z < 93$

<https://frib.msu.edu>



- Properties of rare isotopes
- Nuclear astrophysics
- Fundamental interactions
- Applications for society, including in medicine, homeland security, and industry.

1st FRIB experiment in May 2022

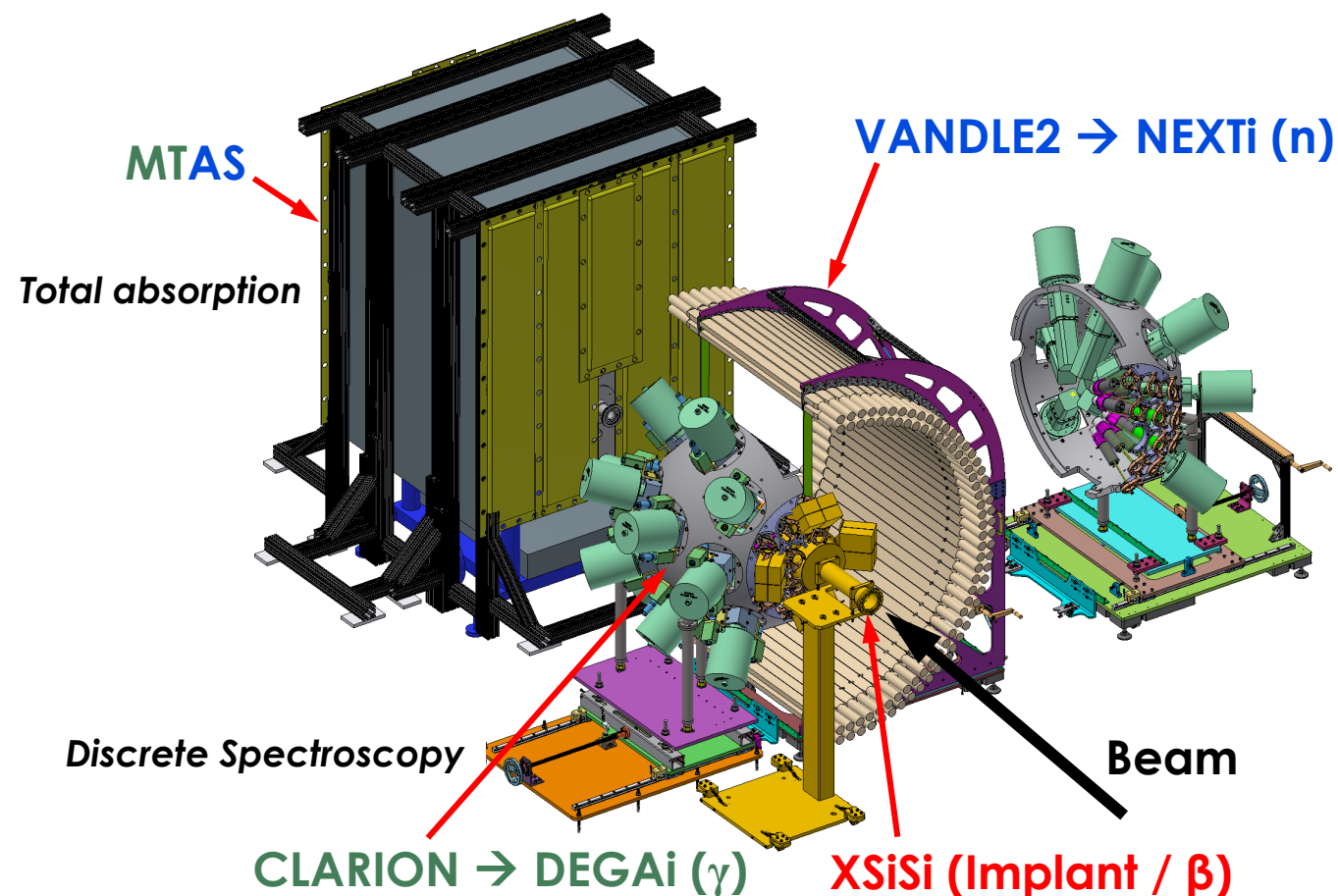


The FRIB Decay Station initiator (FDSi)

- Integration of community detectors
- Reconfigurable infrastructure
- Complete / Tandem measurements

Phase 1 of project completed in Spring 2022
First FRIB experiment completed in May 2022

<https://fds.ornl.gov/initiator/>



FDSi Relies on Community Contributions (~\$10M+ worth of existing resources)

ORNL: 11 Clovers, MTAS, 3He tubes and preamps, CLARION / DEGAi frame, simulations, electronics, and engineering

UTK: VANDLE / NEXTi, segmented scintillator-based implant detectors, 30 LaBr₃ detectors, simulations, machining, Si detectors, and associated electronics

ANL: 8 clovers, 15 LaBr₃ detectors, HV, engineering

FRIB-MSU: Pixie16 pool (67 modules), GADGET2, 3He tubes and preamps, 16 LaBr₃ detectors, vacuum pumps and gauges, engineering, materials, and machining

FSU: 3 clovers**, HV, and prototype machining

MSU (Mississippi): 4 CeBr₃ and 10 LaBr₃ detectors, and CeBr₃-based implant detector

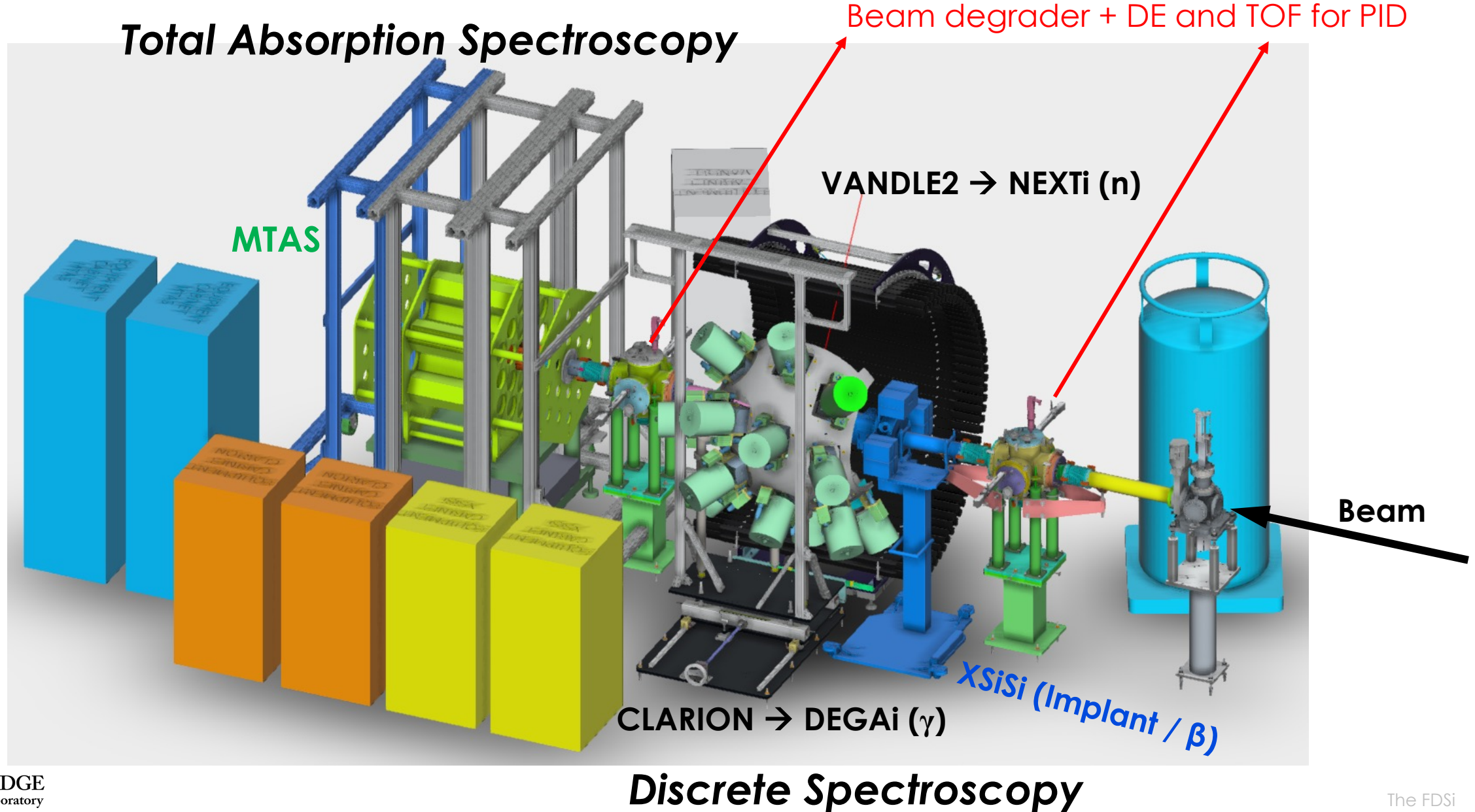
URSinus: Simulations

UNC: 12 CeBr₃ detectors

LLNL: 8 clovers (3 are ORTEC), cables, solenoids, and HV

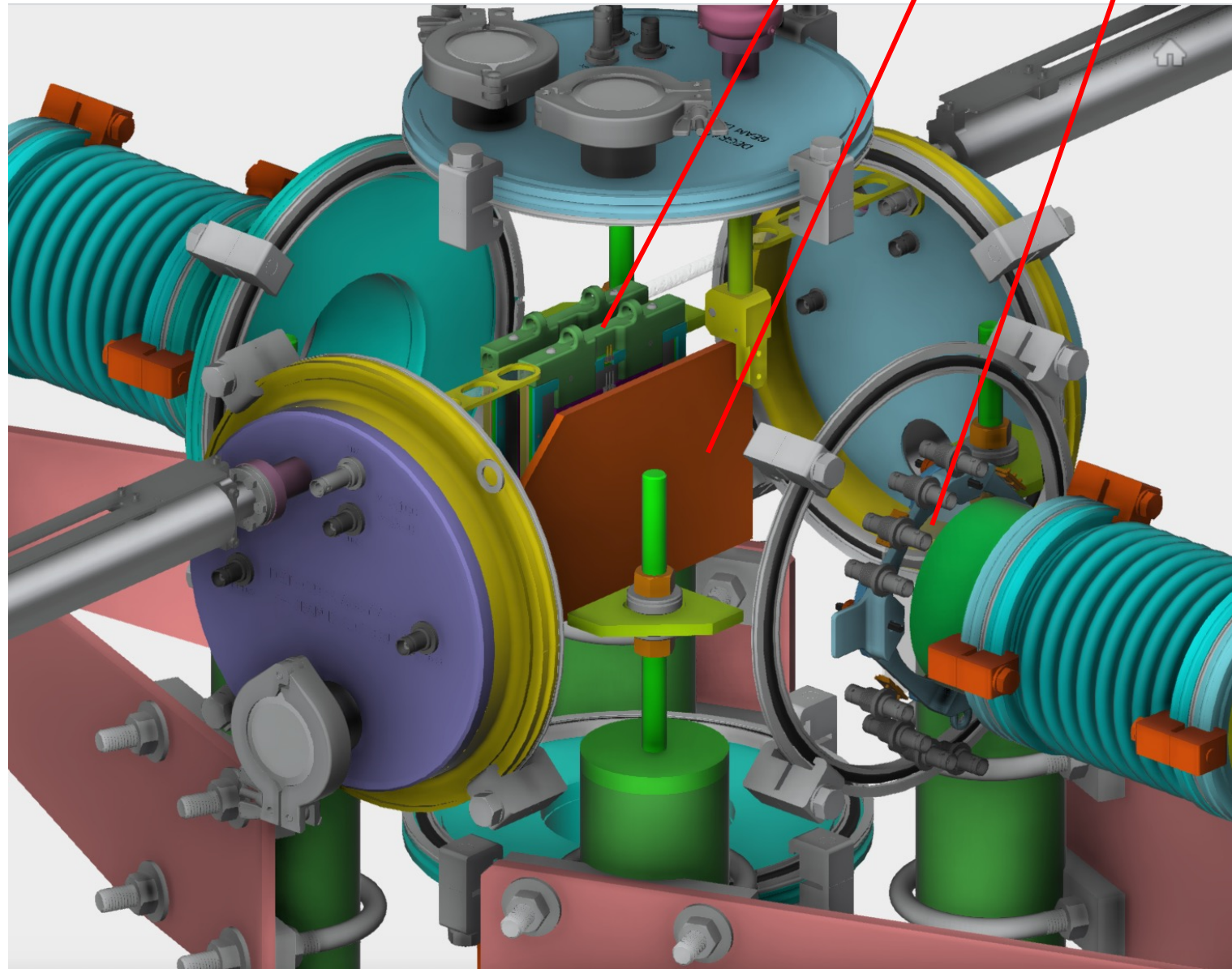
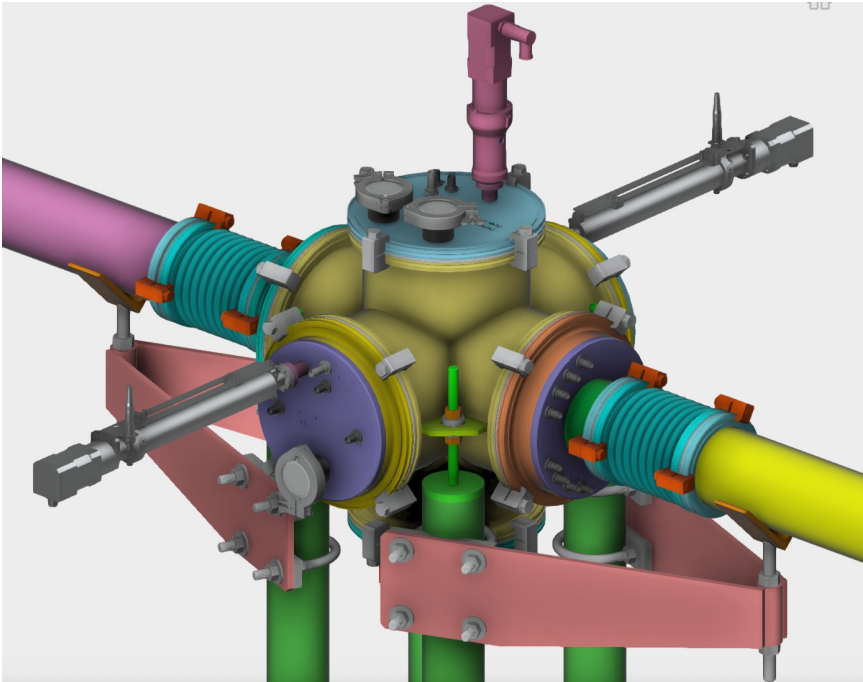
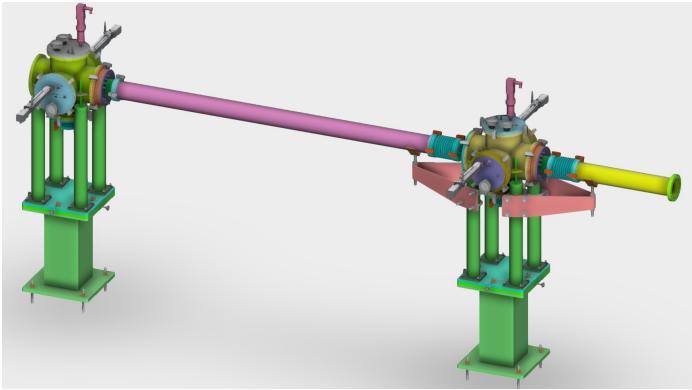
LBNL: 2 clovers**

The FDSi: Phase 1 Design



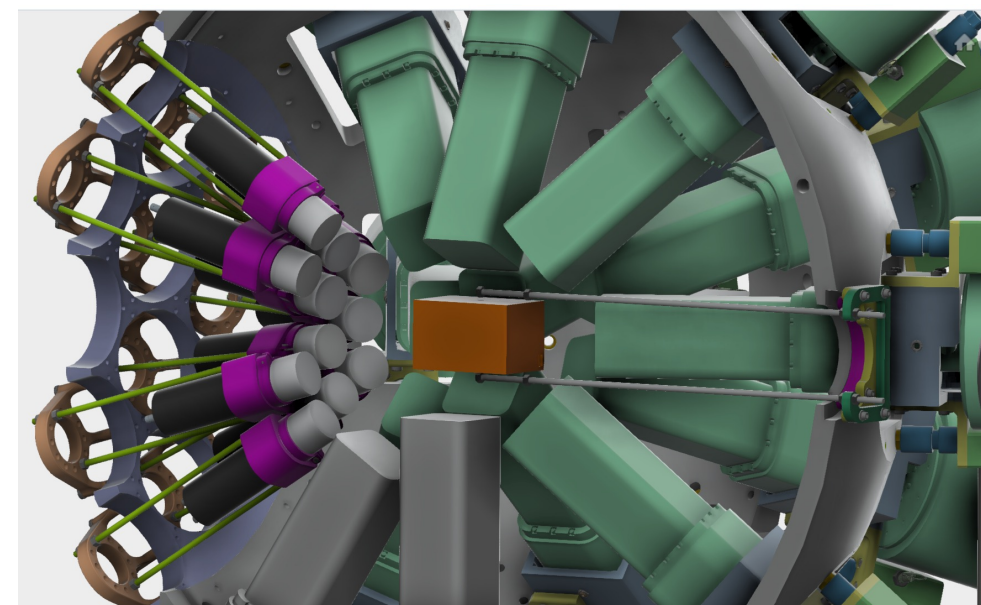
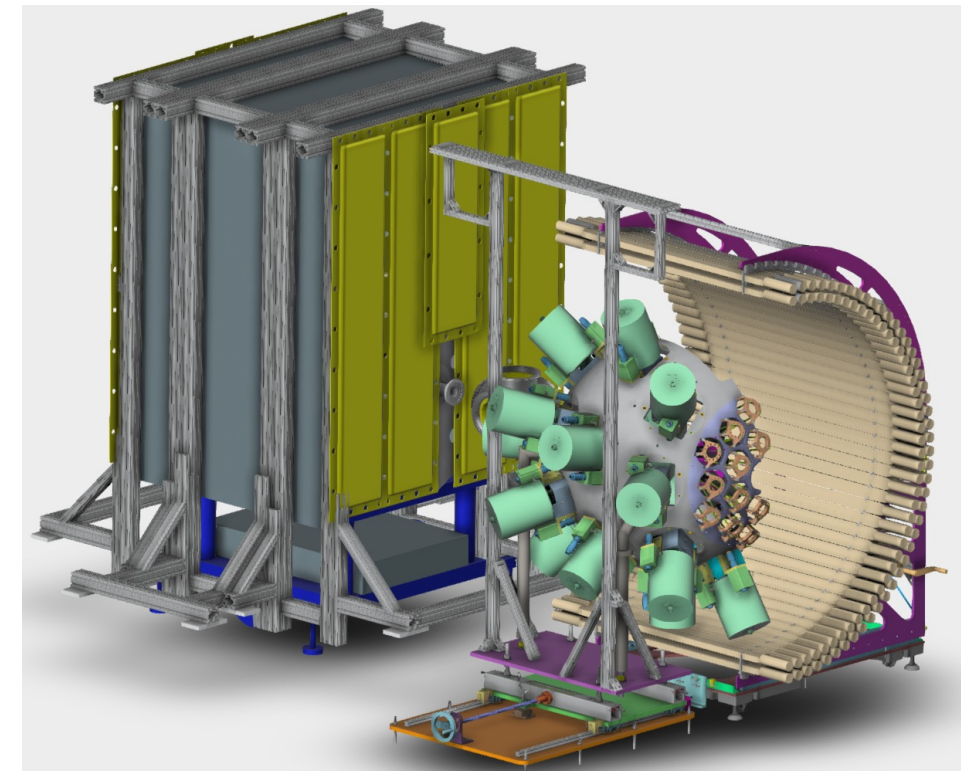
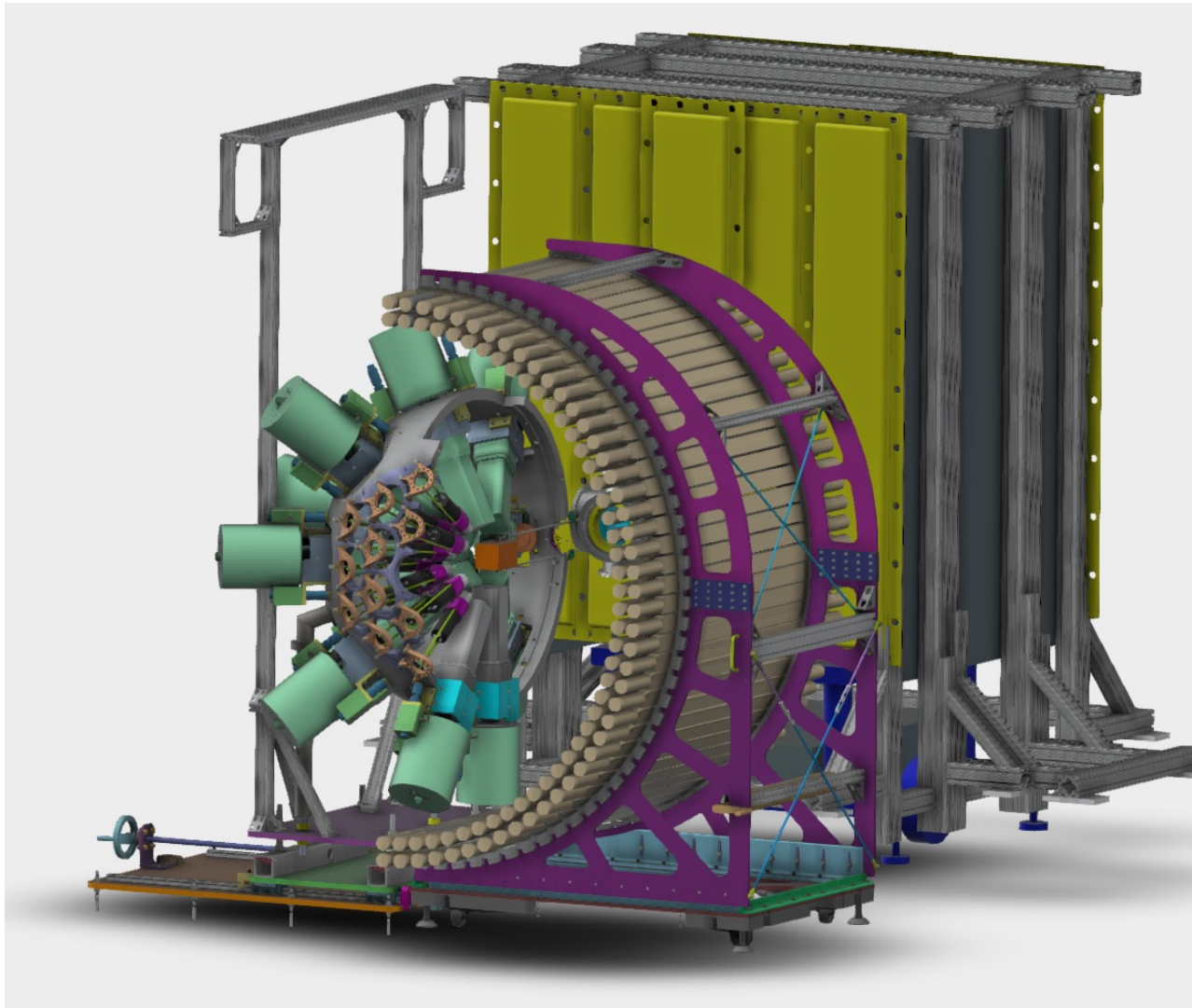
Diagnostic Crosses

Degraders, Si and fast plastic for PID, segmented scintillators for beam tuning, and vacuum service

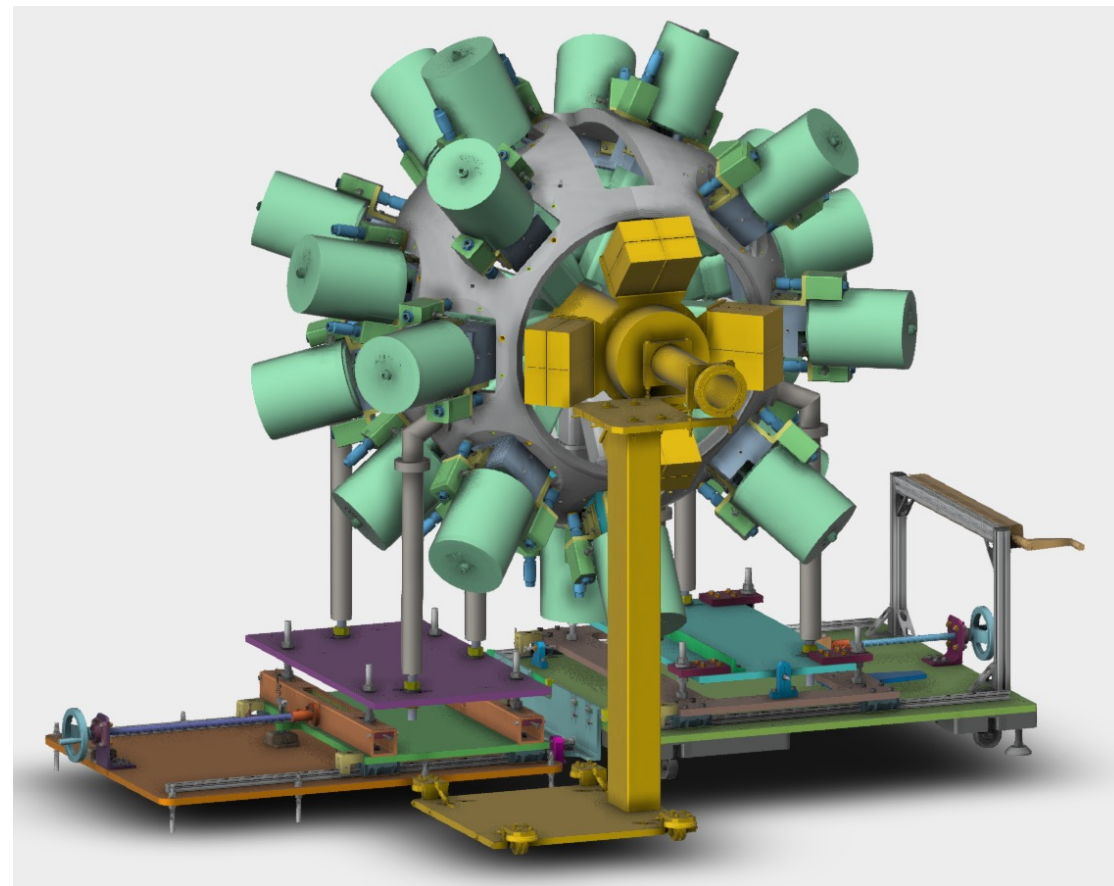
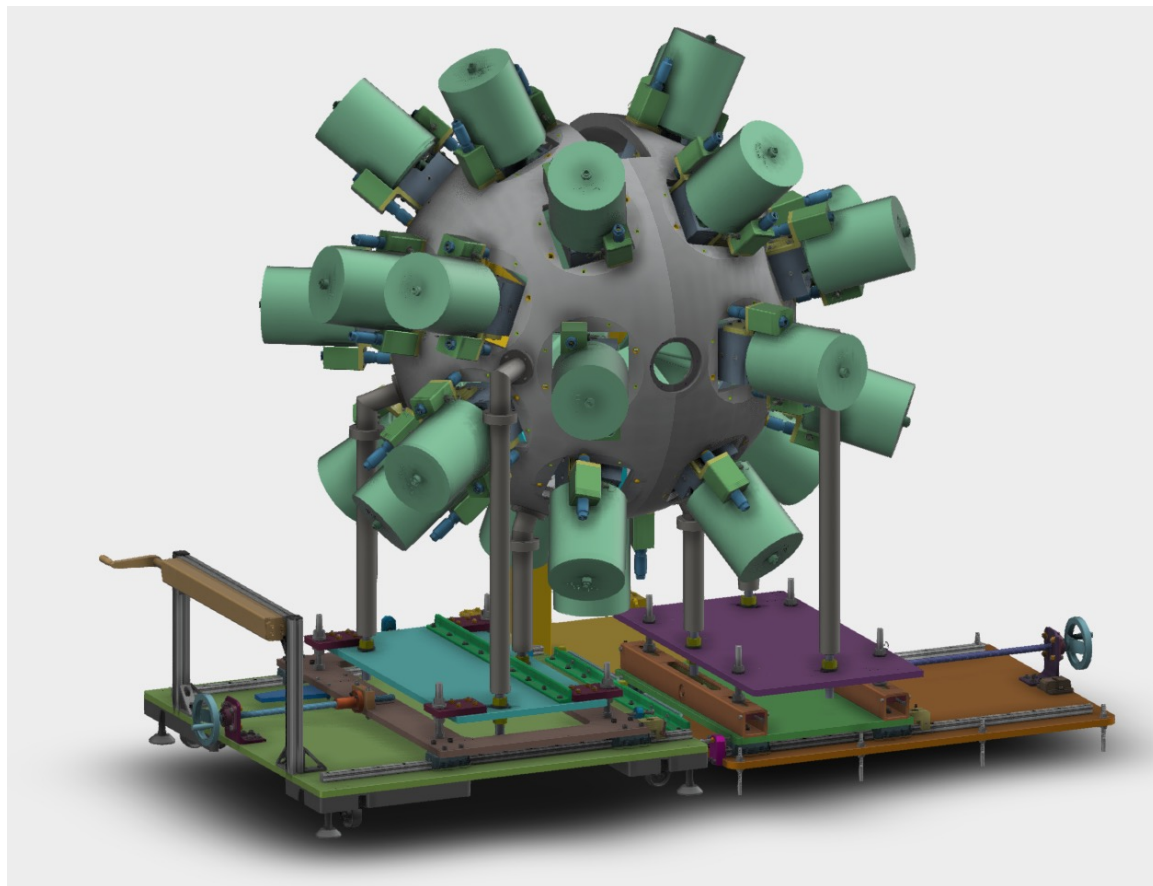


Nominal / Balanced Configuration

Implant, γ , n (1st focal point) + Total Absorption (2nd focal point)

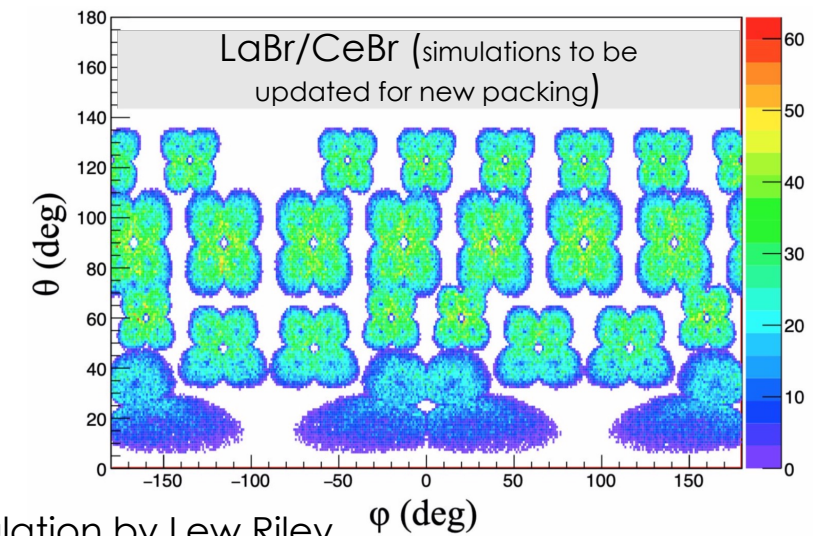
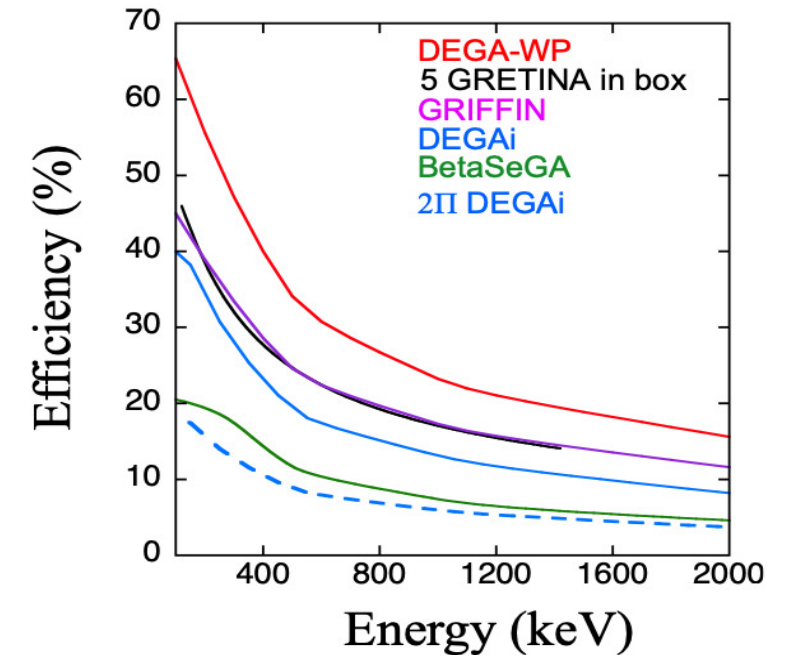
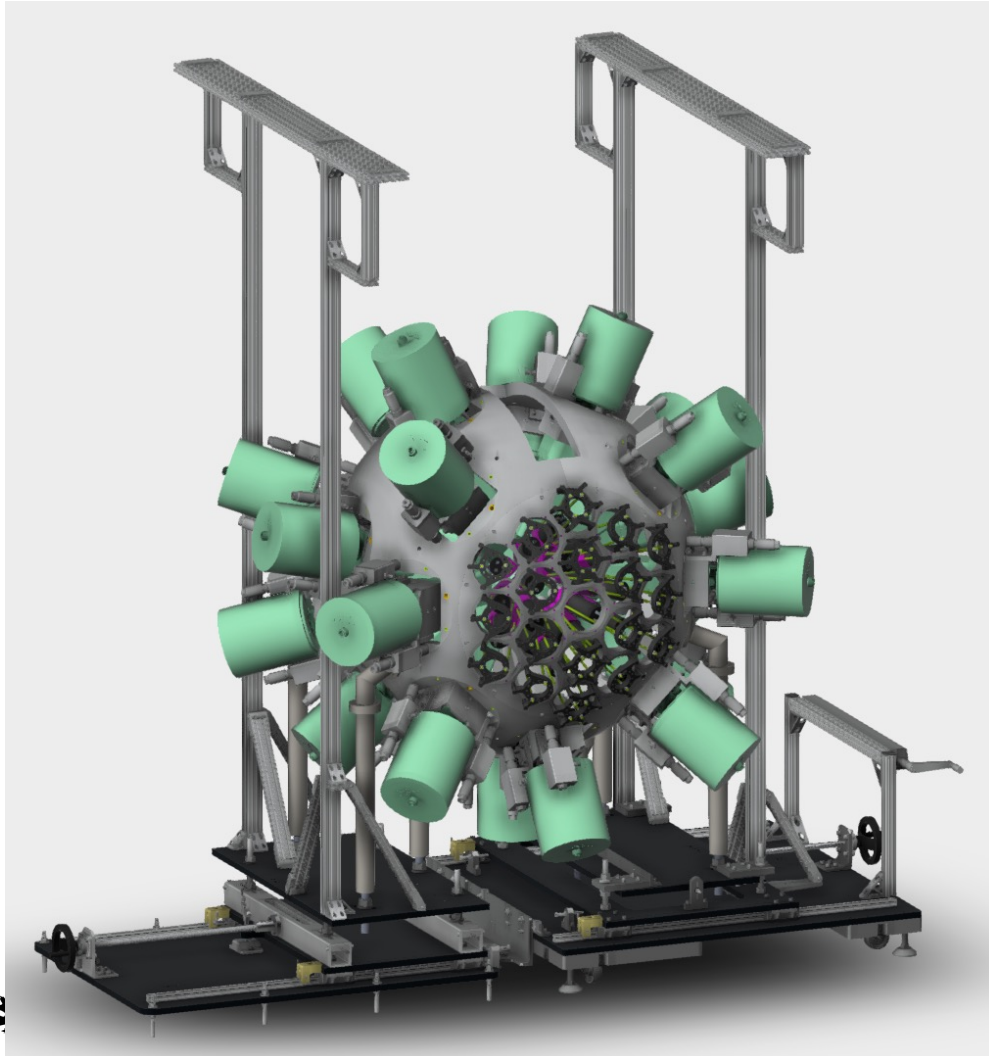


4π High-Resolution γ -Ray Configuration (proton-rich)



DEcay Germanium Array initiator (DEGAi)

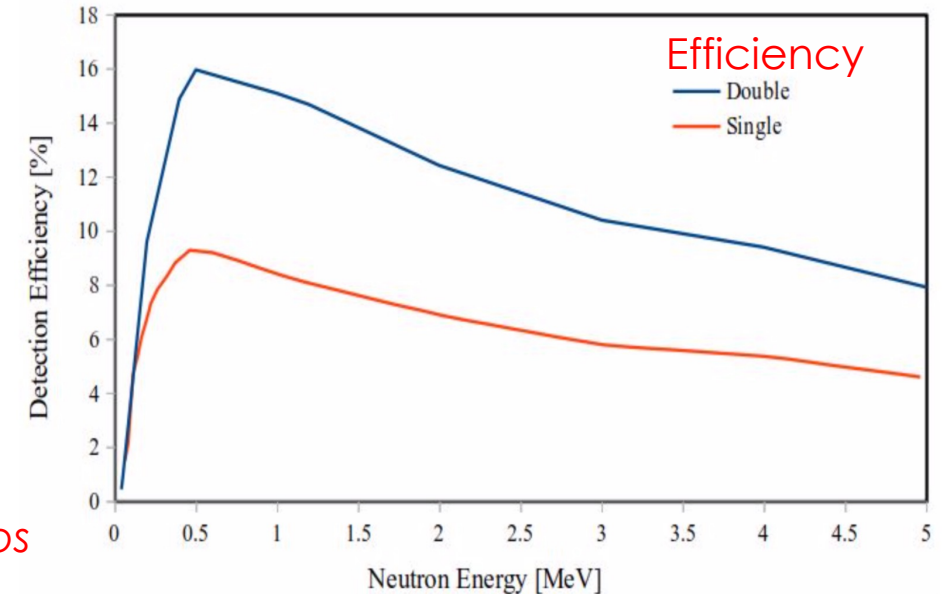
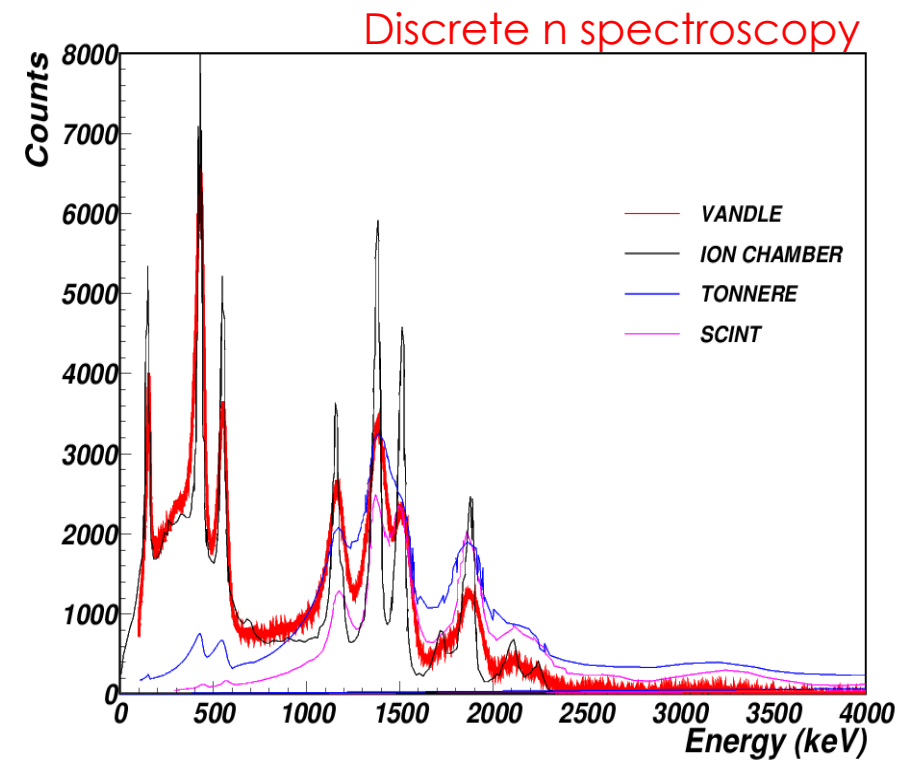
Working group led by J.M. Allmond (ORNL)



*simulation by Lew Riley ϕ (deg)

NEutron Xn Tracking initiator (NEXTi)

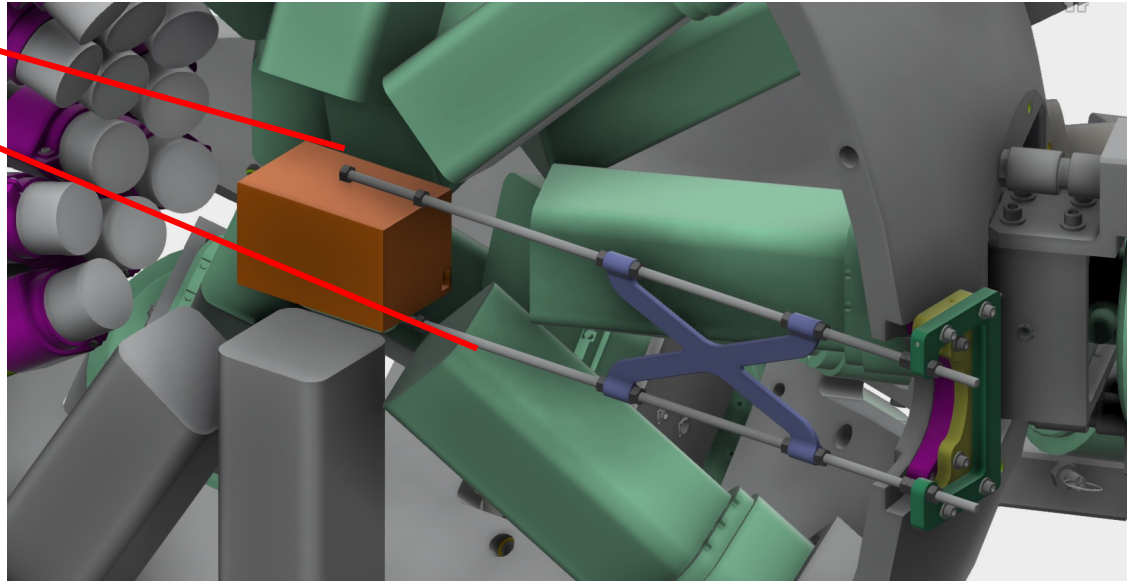
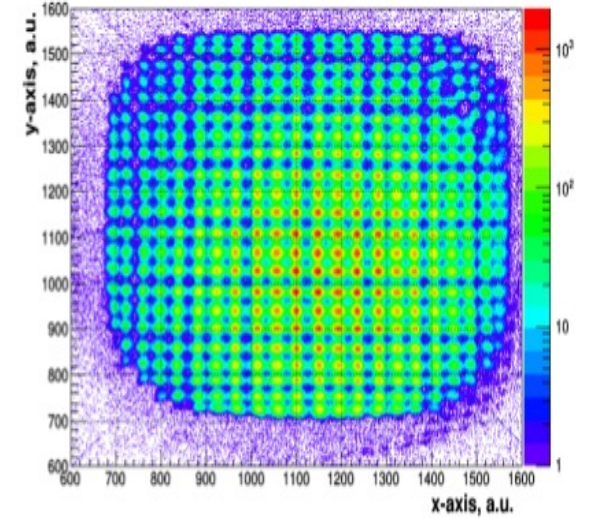
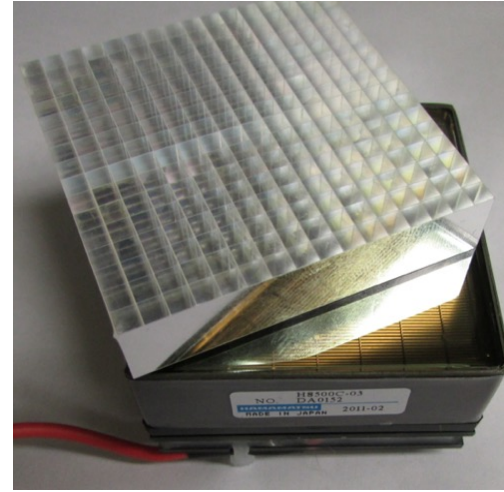
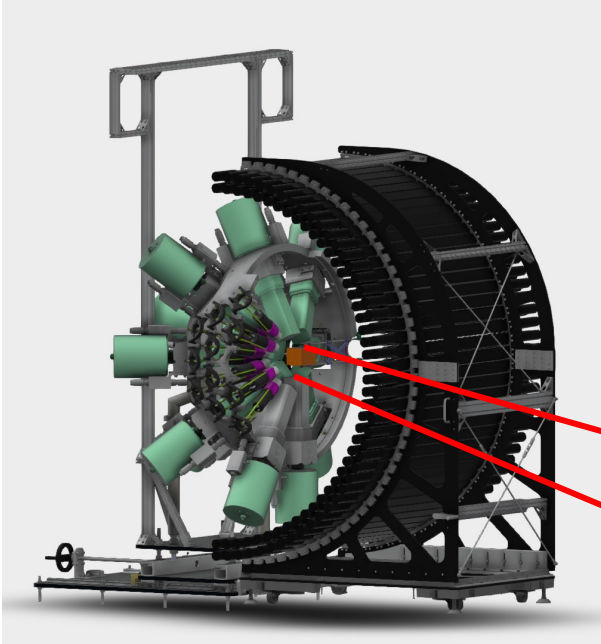
Working group led by Robert Grzywacz (UTK)



XScintillator and Si initiator (XSiSi)

High stopping power and fast

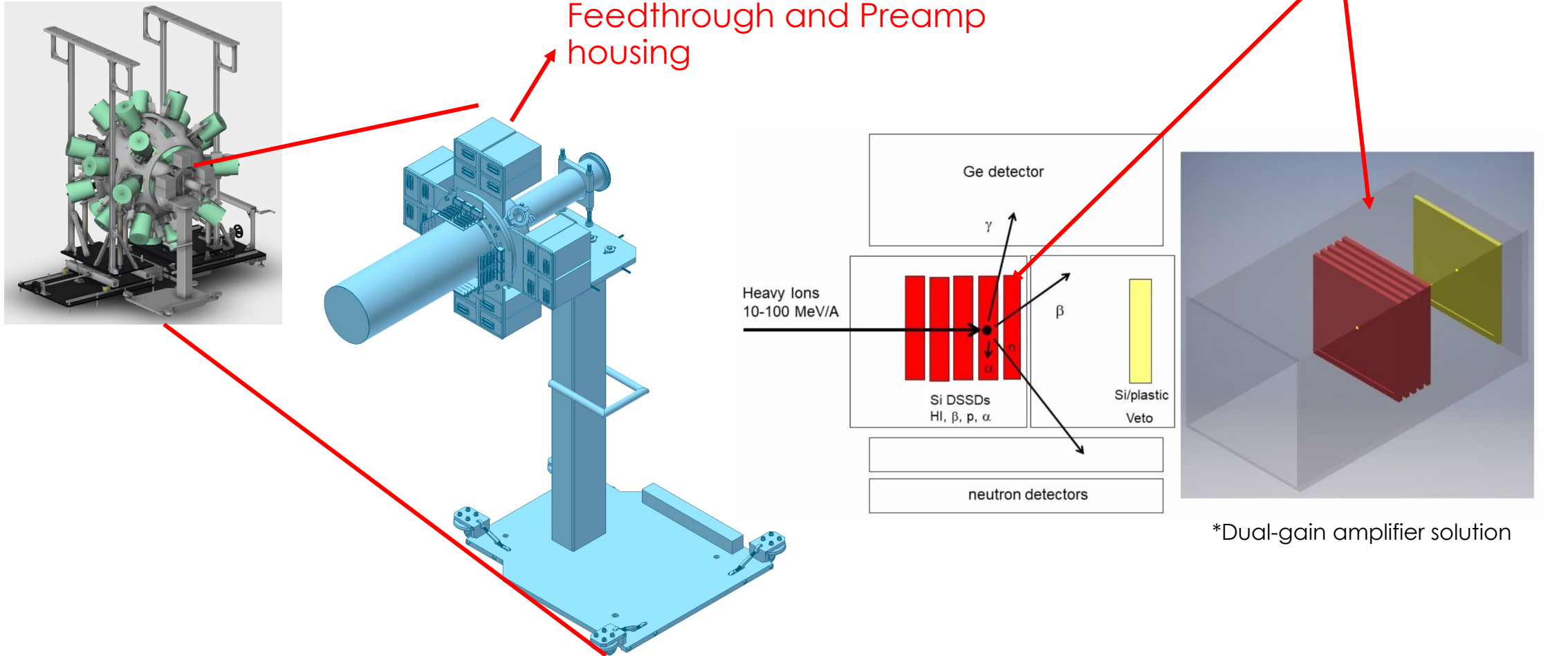
XScintillator (e.g., YSO, CeBr for n-tof)



XScintillator and Si initiator (XSiSi)

Si stack detector

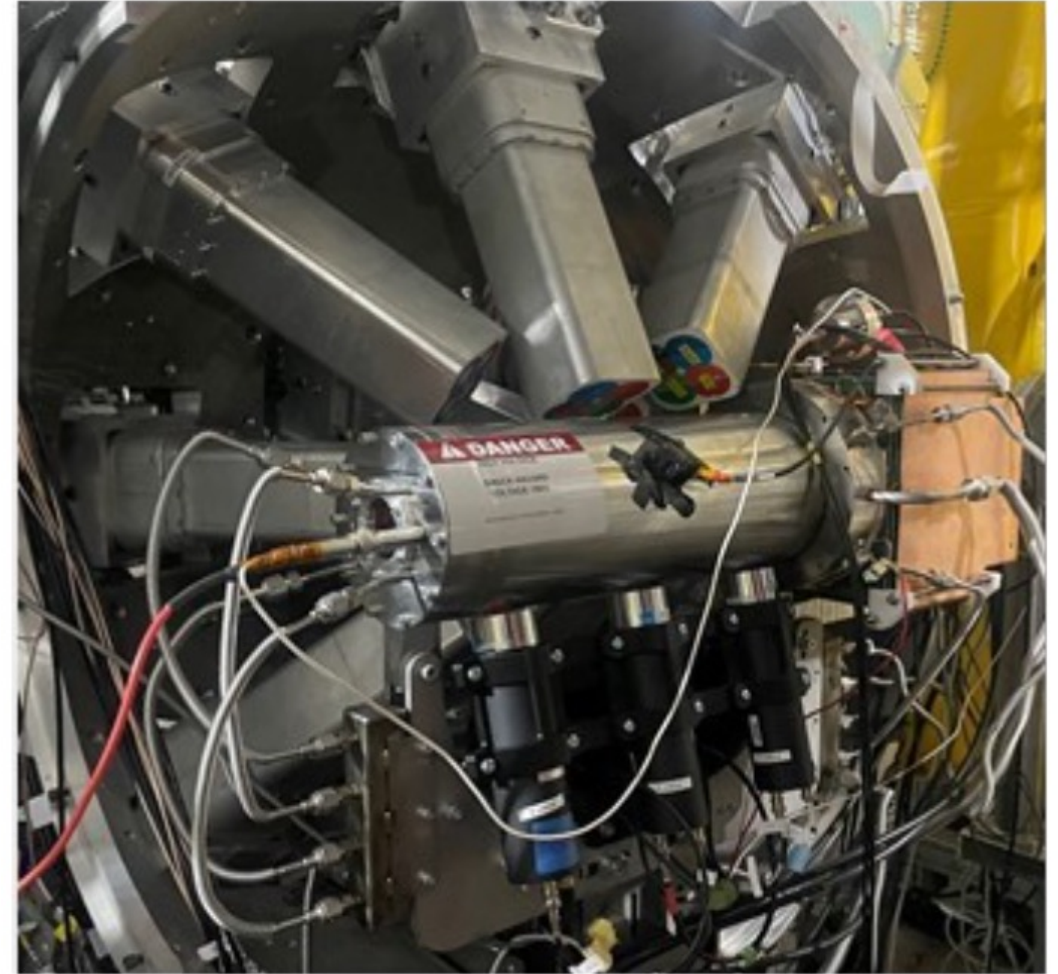
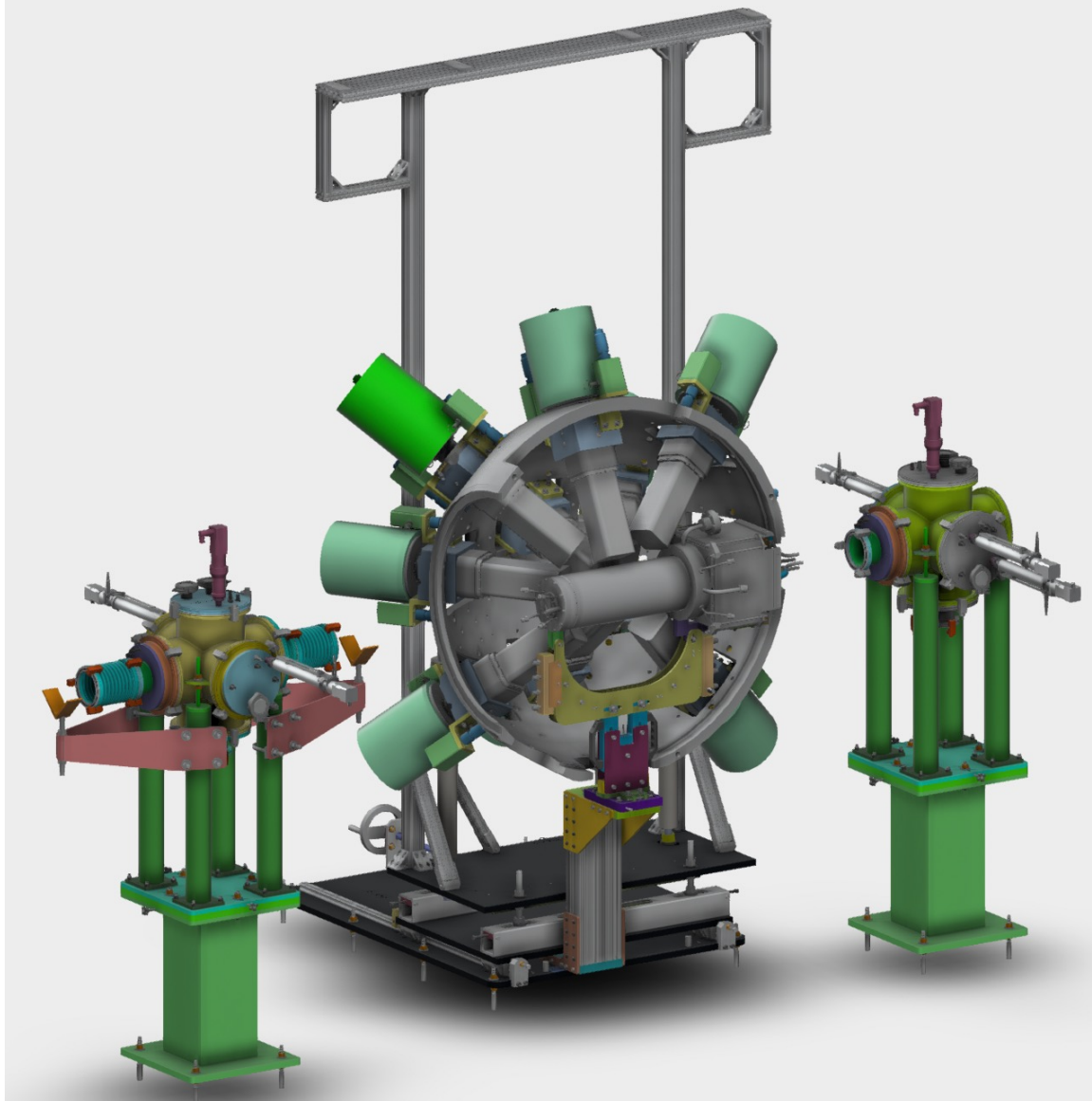
Working group led by Darek Seweryniak (ANL)



**Critical for enabling high-rate, p-rich, and $Z > 50$ (multi-charge state) studies; also expands overall coverage per experiment*

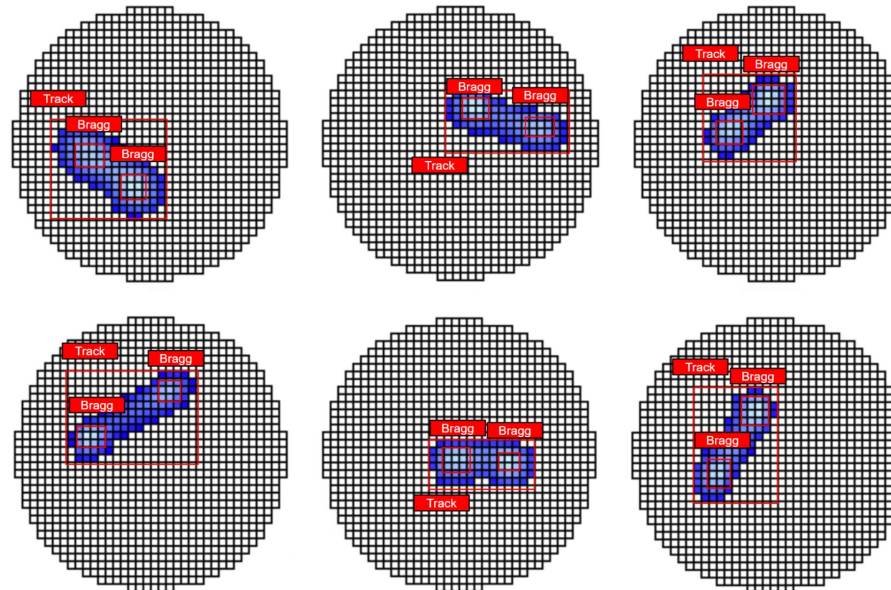
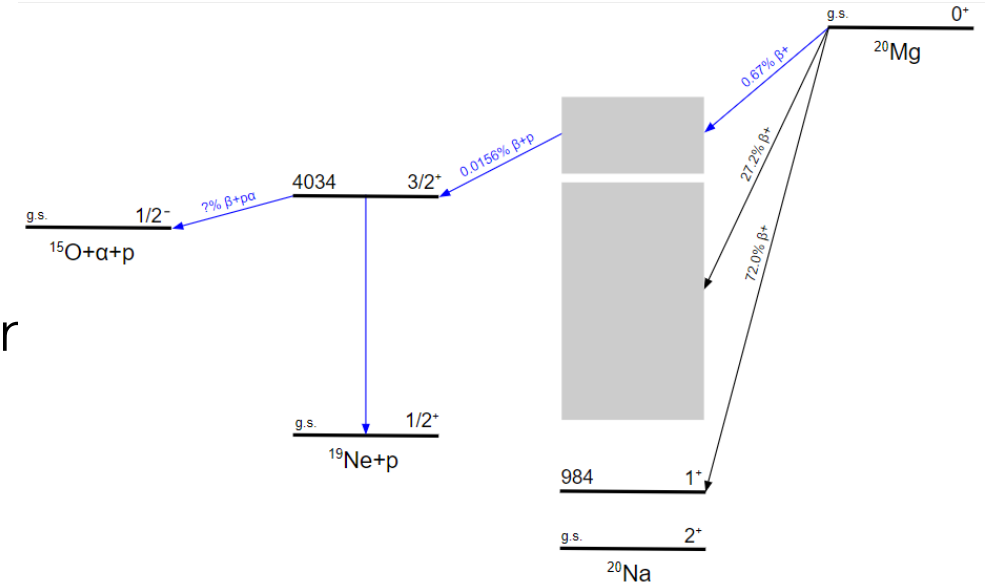
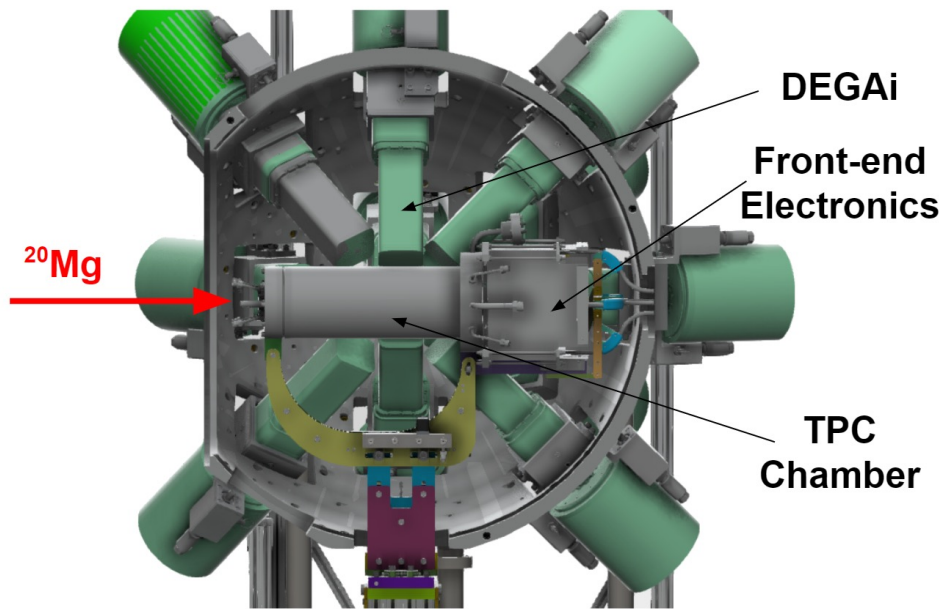
GADGET2 - TPC

Working group led by Chris Wrede (MSU)



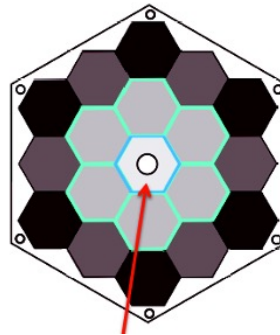
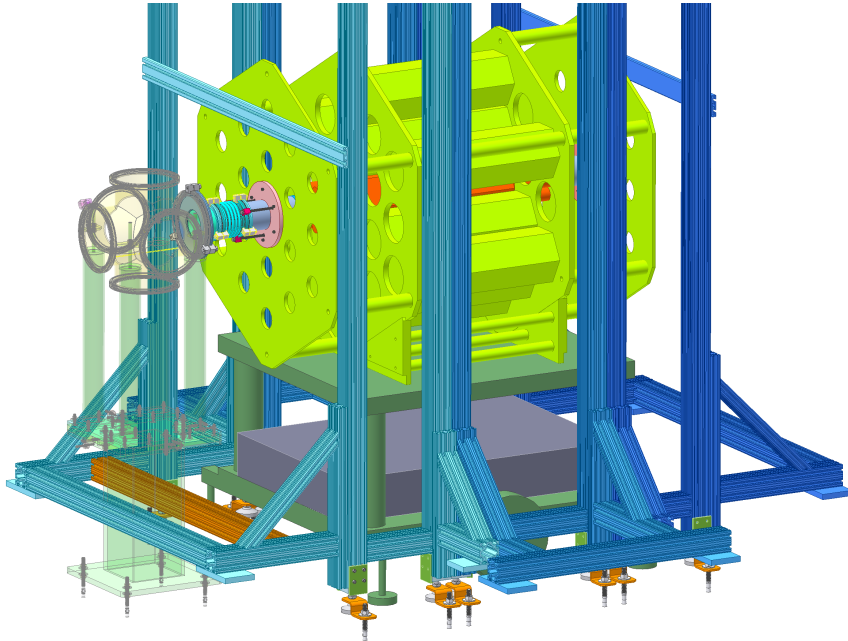
GADGET2 - TPC

- arXiv:2501.17892v1 [physics.ins-det] 28 Jan 2025
- Employing machine learning for event identification

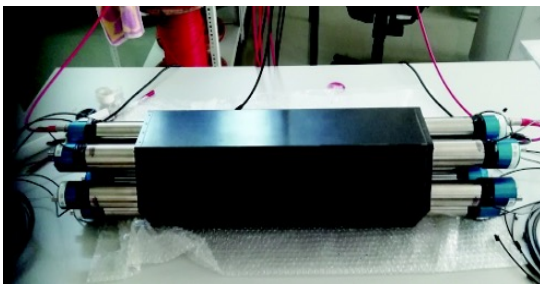


Modular Total Absorption Spectrometer (MTAS)

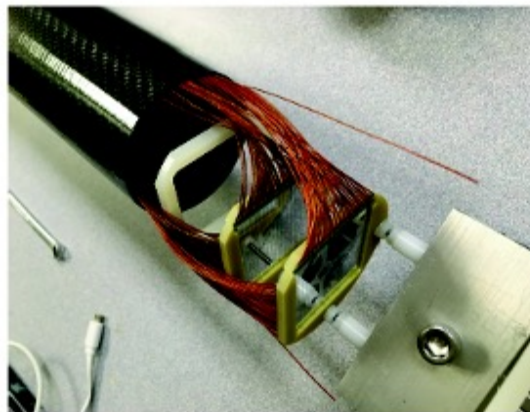
Working group led by Krzysztof Rykaczewski (ORNL)



**Radial segmentation*



**New central module,
angular segmentation*

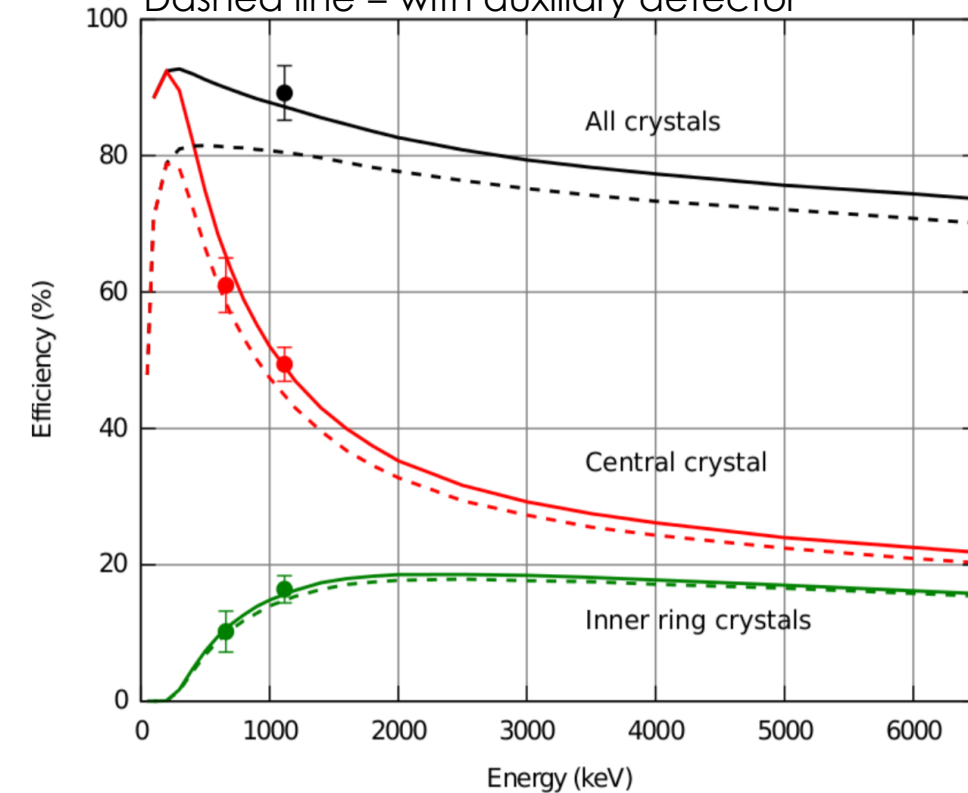


**Implant similar to XSiSi*

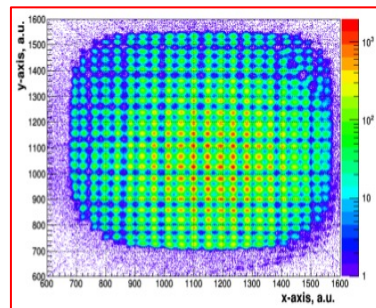
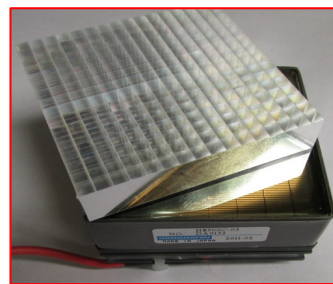
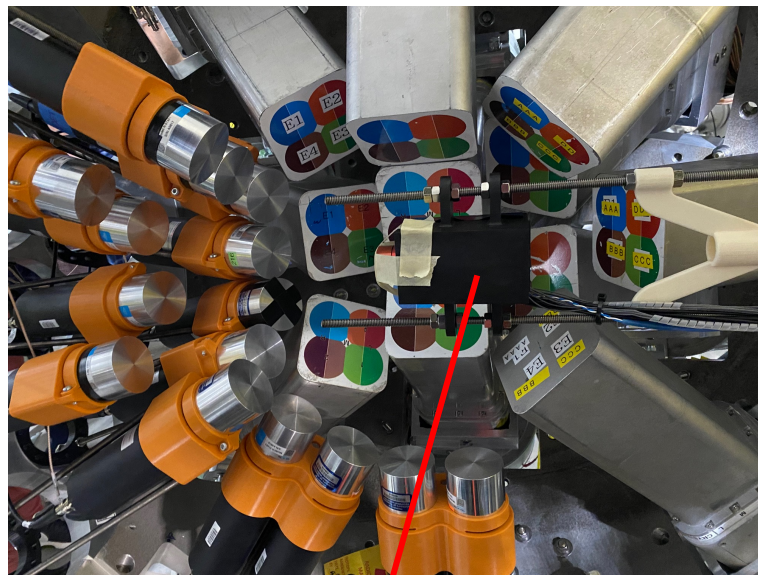
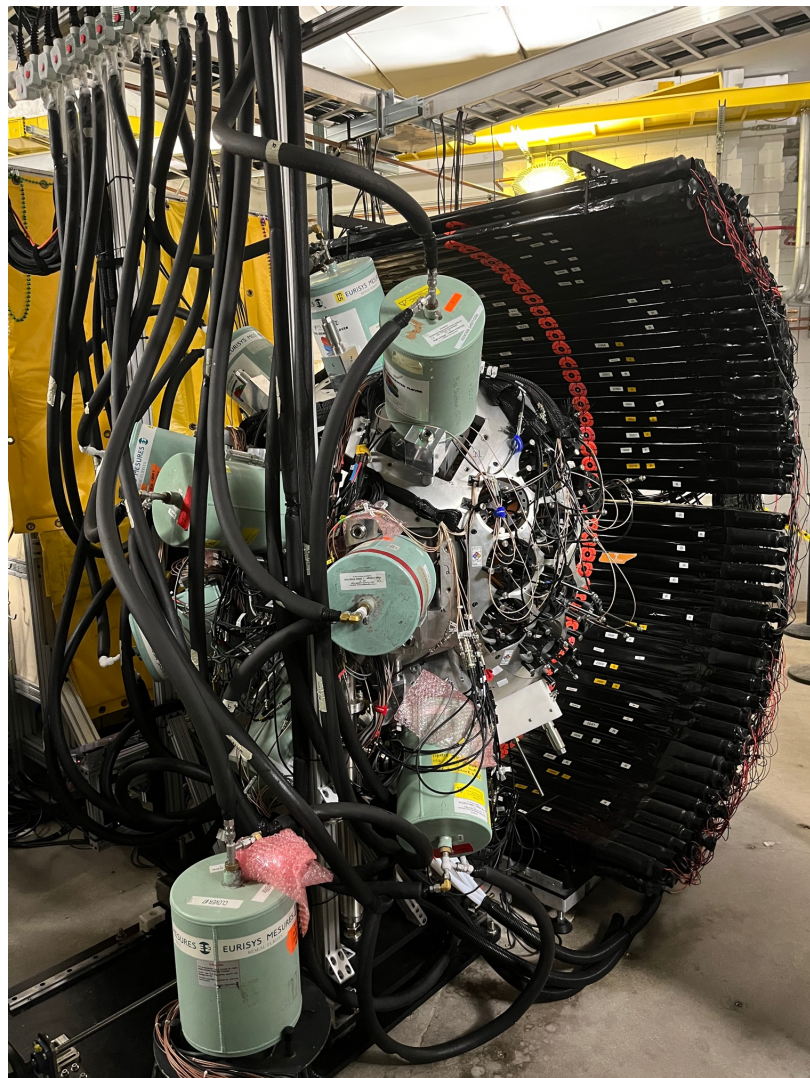
**Largest TAS in the world and with shielding*

Solid line = no auxiliary detector

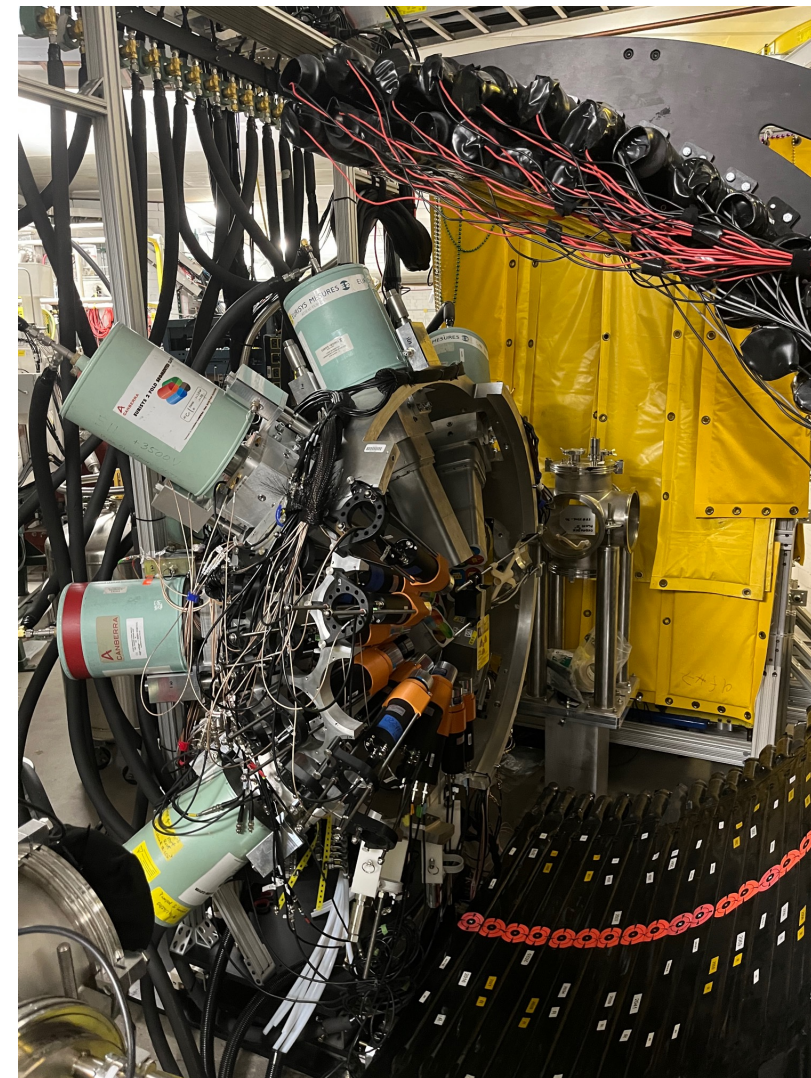
Dashed line = with auxiliary detector



The FDSi Setup in Real Life for 1st FRIB Experiment



Fast YSO Implant detector from UTK



4 FDSi Publications from First Two FRIB Experiments



PRL **Featured in Physics** **Editors' Suggestion**

13 citations

Crossing $N = 28$ Toward the Neutron Drip Line: First Measurement of Half-Lives at FRIB

H. L. Crawford *et al.*

Phys. Rev. Lett. **129**, 212501 (2022) - Published 14 November 2022

Physics Viewpoint : Probing the Limits of Nuclear Existence

PRL **Featured in Physics**

6 citations

Microsecond Isomer at the $N = 20$ Island of Shape Inversion Observed at FRIB

T. J. Gray *et al.*

Phys. Rev. Lett. **130**, 242501 (2023) - Published 13 June 2023

Physics Synopsis : Excited Sodium-32 with a Spherical Wave Function

PRC

1 citation

β decay of ^{36}Mg and ^{36}Al : Identification of a β -decaying isomer in ^{36}Al

R. S. Lubna *et al.*

Phys. Rev. C **108**, 014329 (2023) - Published 31 July 2023

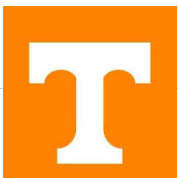
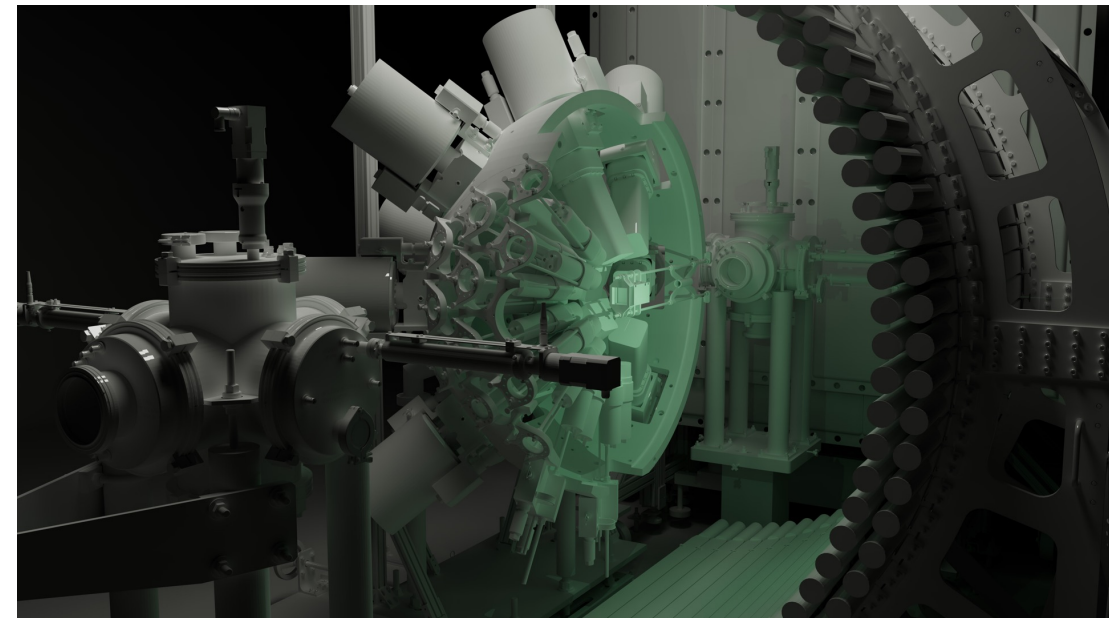
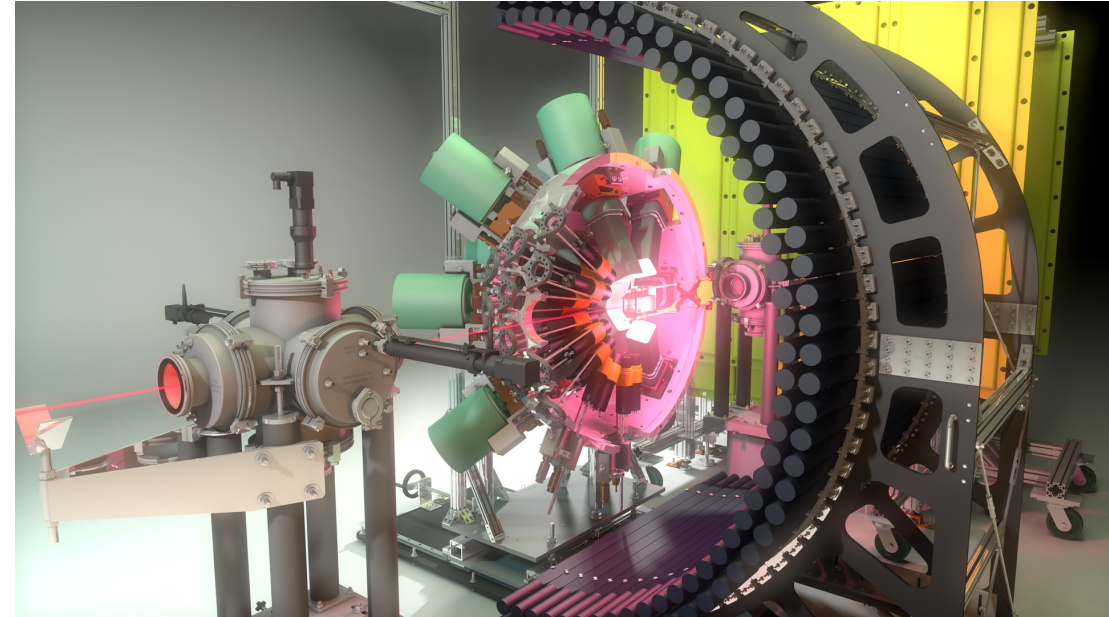
PRL

Proton Shell Gaps in $N = 28$ Nuclei from the First Complete Spectroscopy Study with FRIB Decay Station Initiator

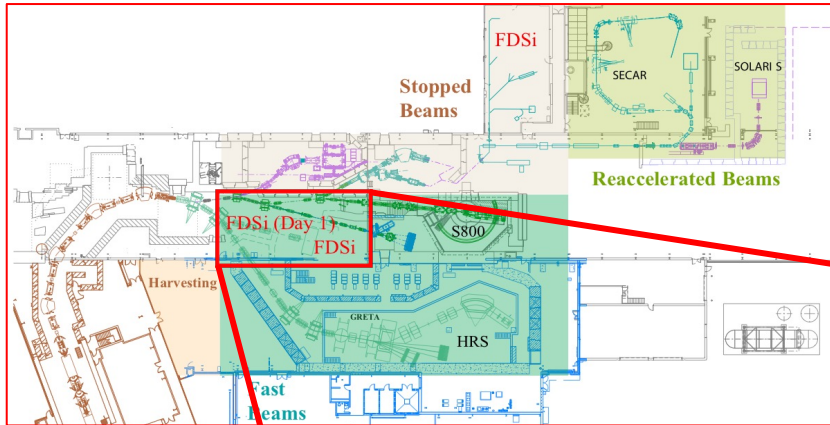
I. Cox *et al.*

Phys. Rev. Lett. **132**, 152503 (2024) - Published 12 April 2024

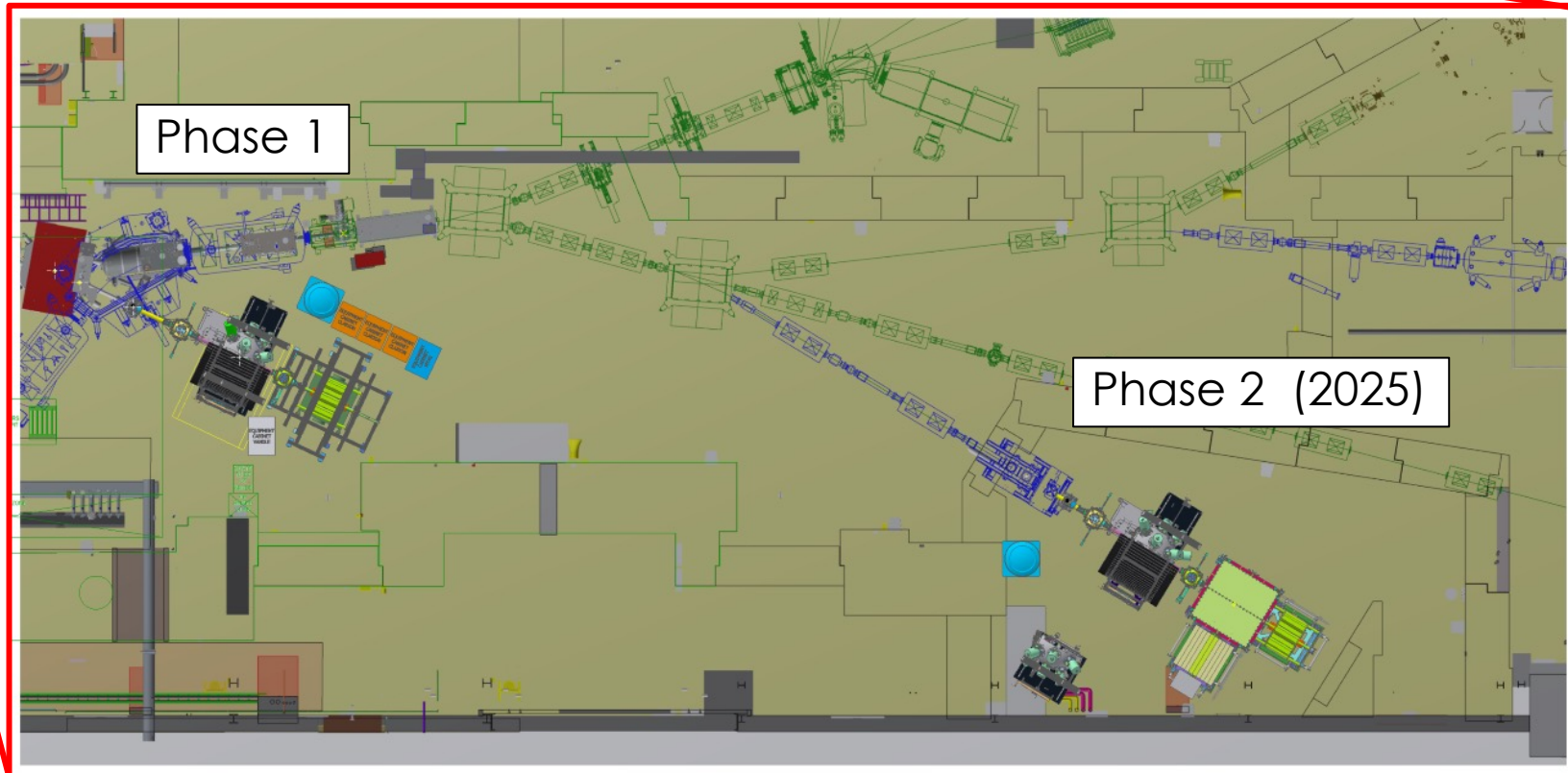
[Show Abstract](#) +



FDSi Locations

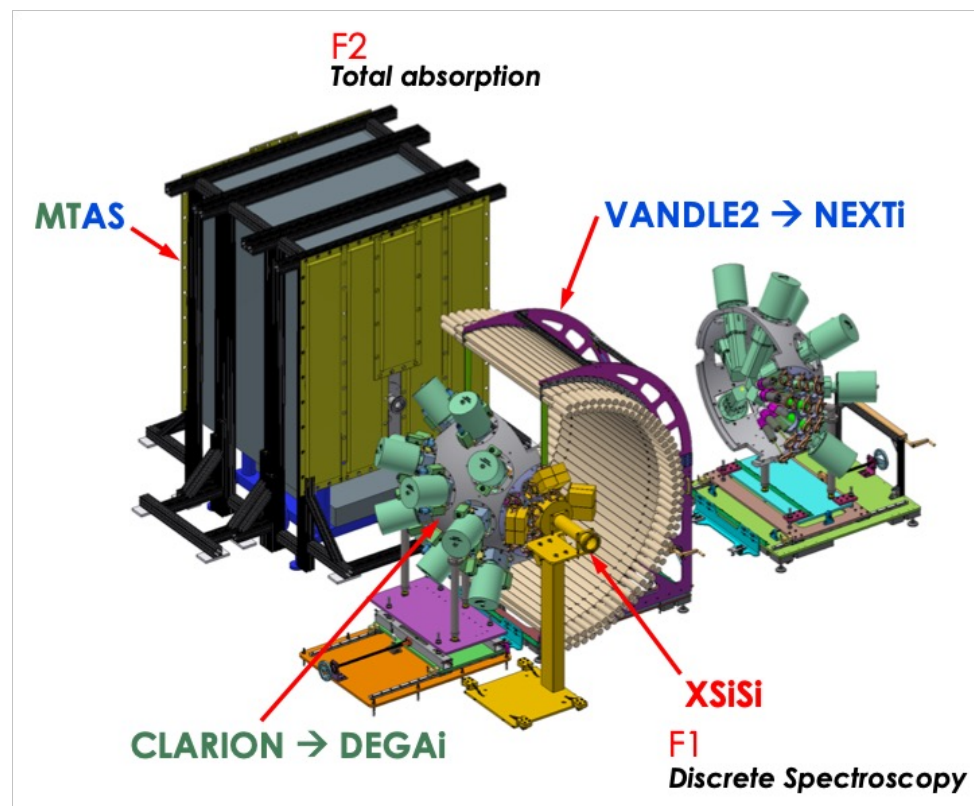


- **Locations and space requirements understood**
- Large doors and crane access required to bring in large and heavy (~tons) equipment
- Storage space required



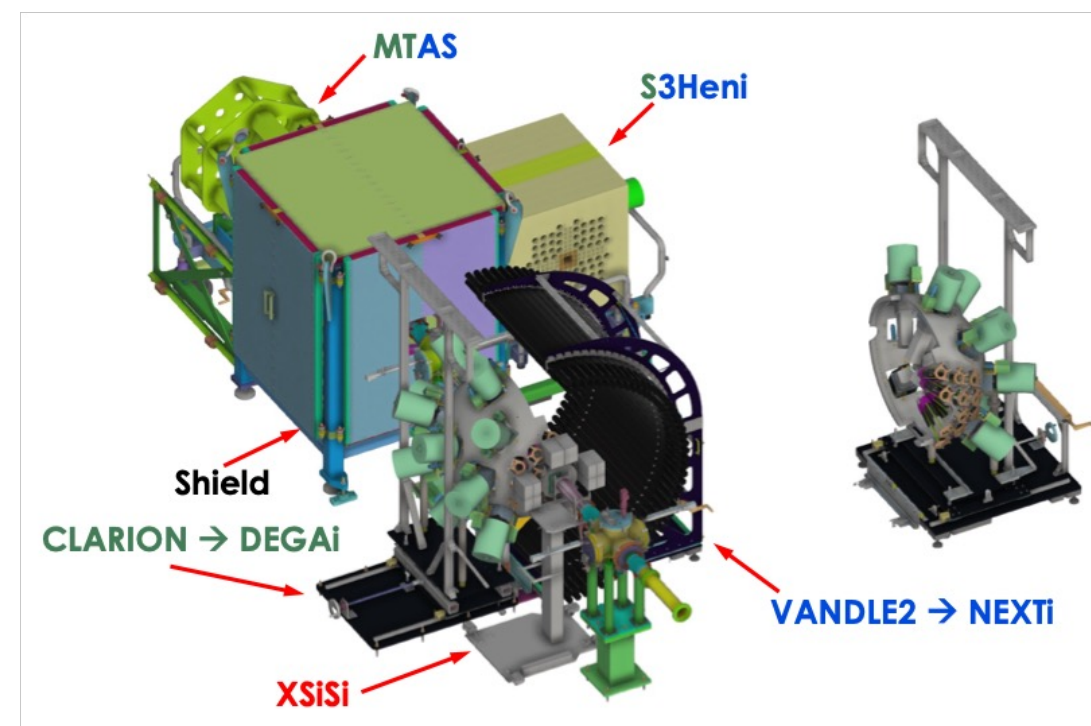
FDSi – Transition to Phase 2

Phase 1

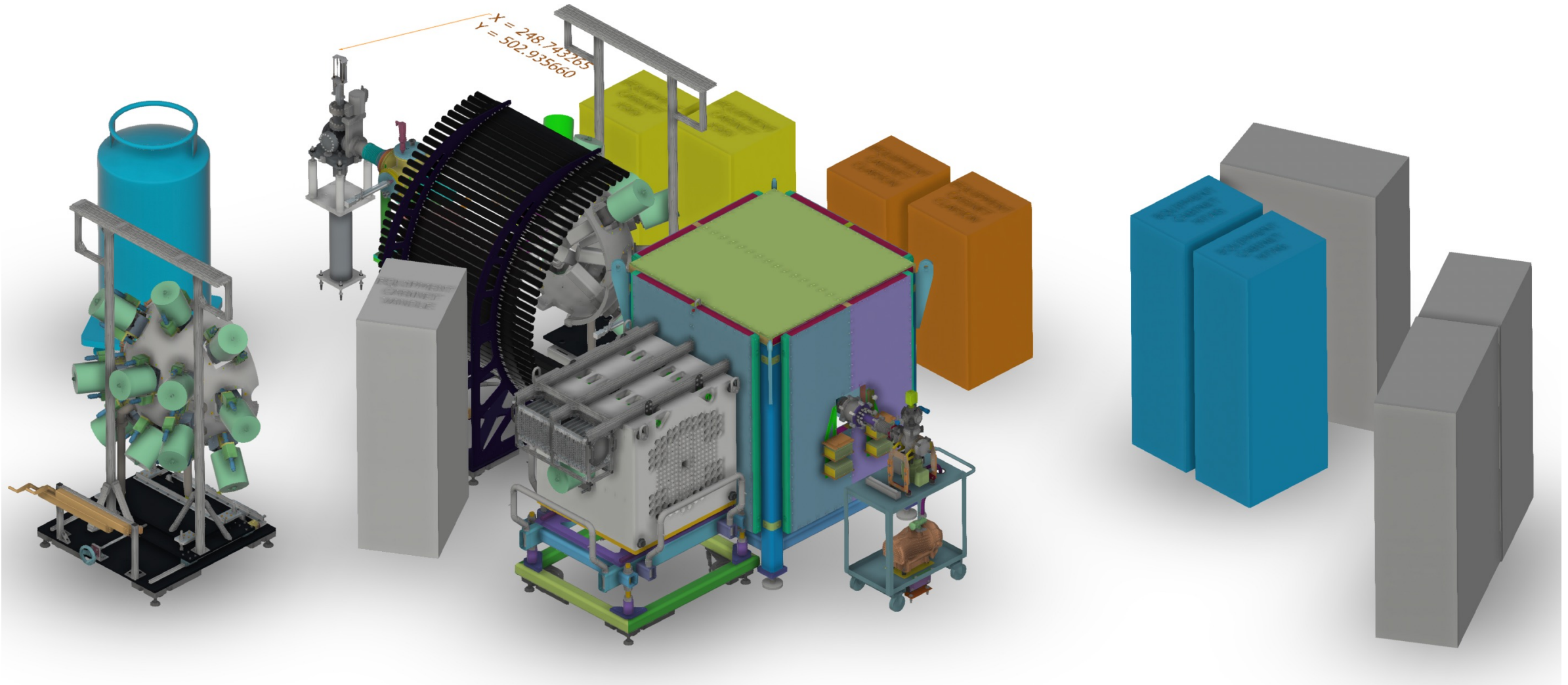


Phase 2

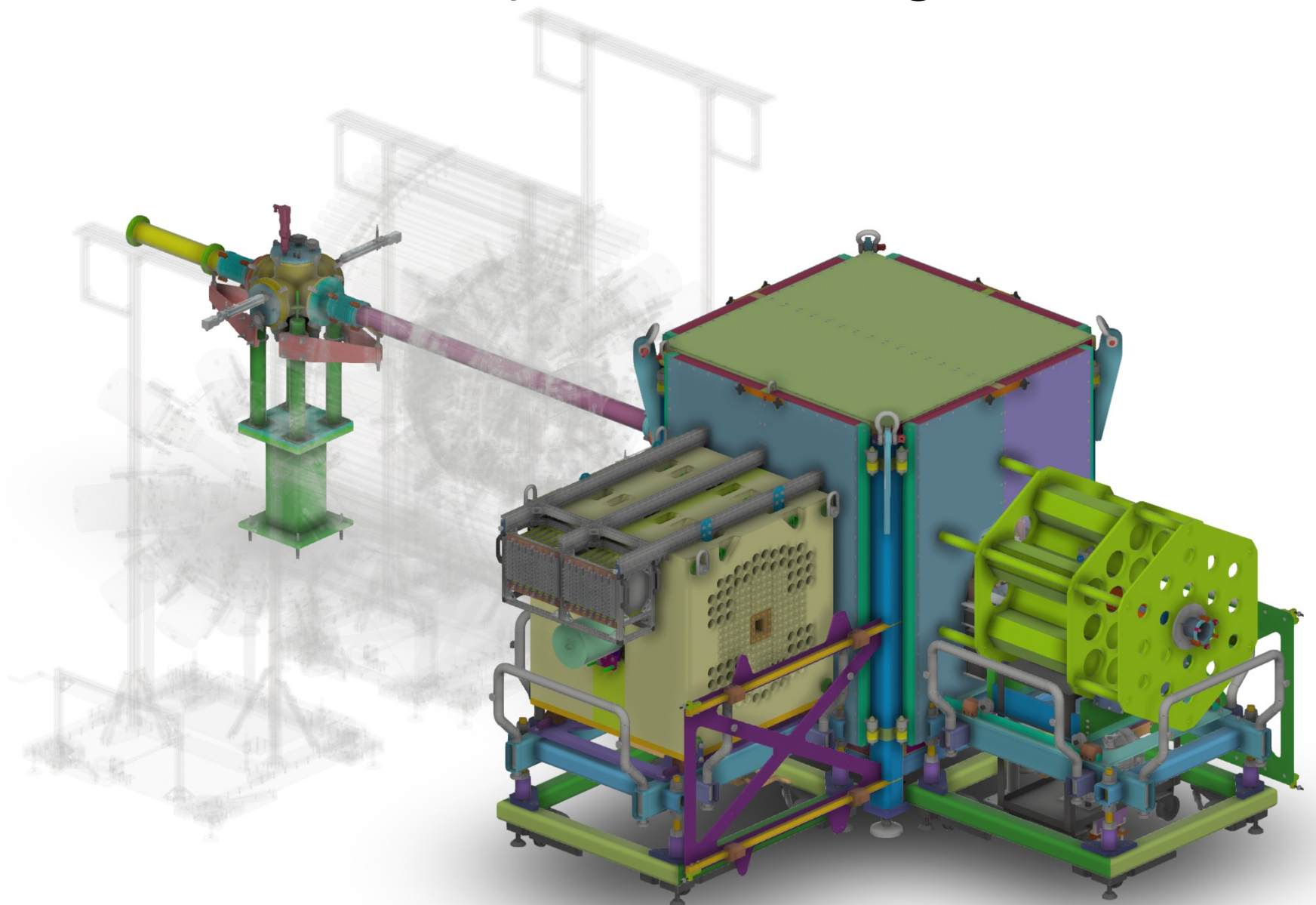
Completed in March 2025!



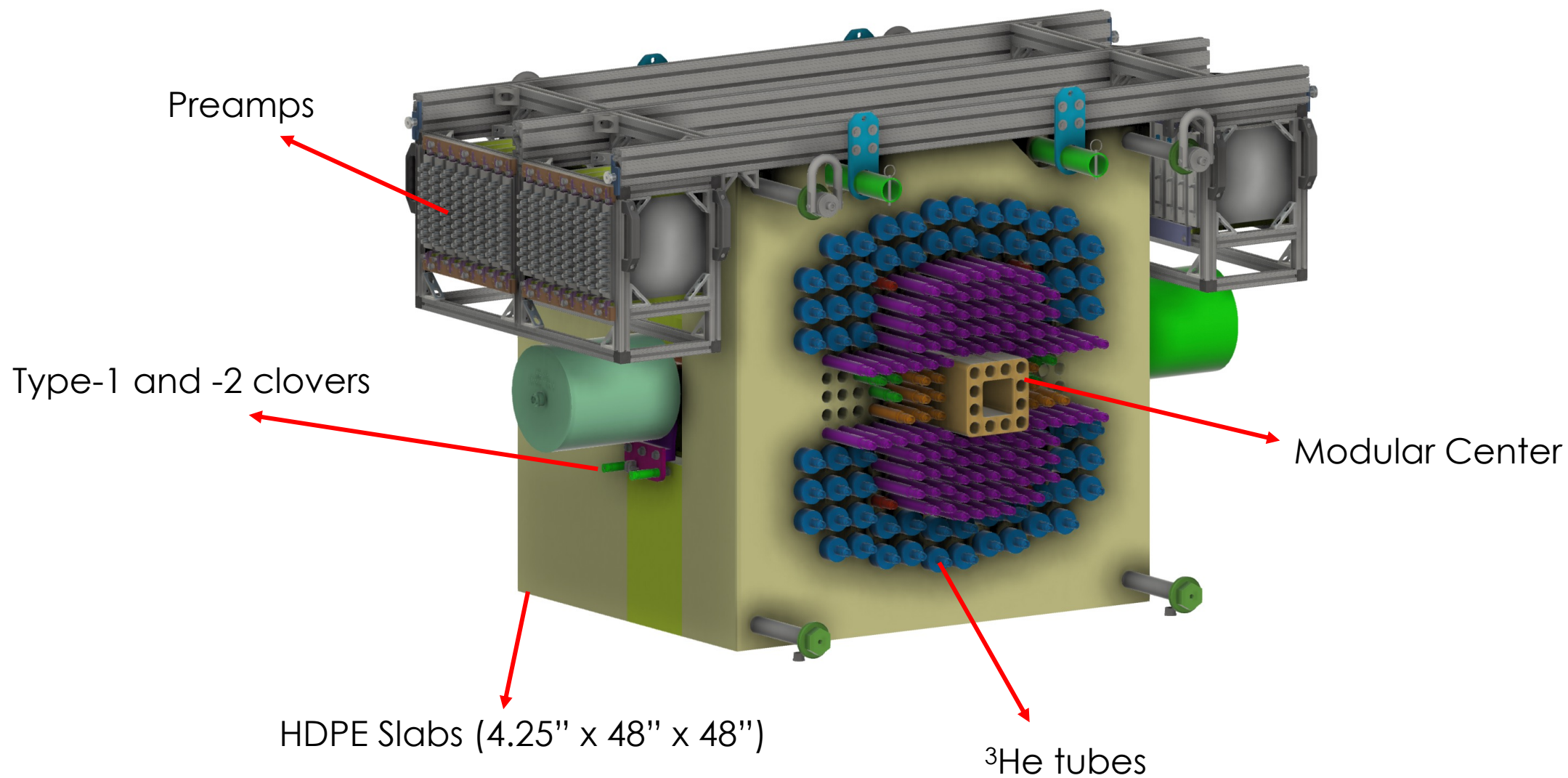
FDSi - Phase 2 Design



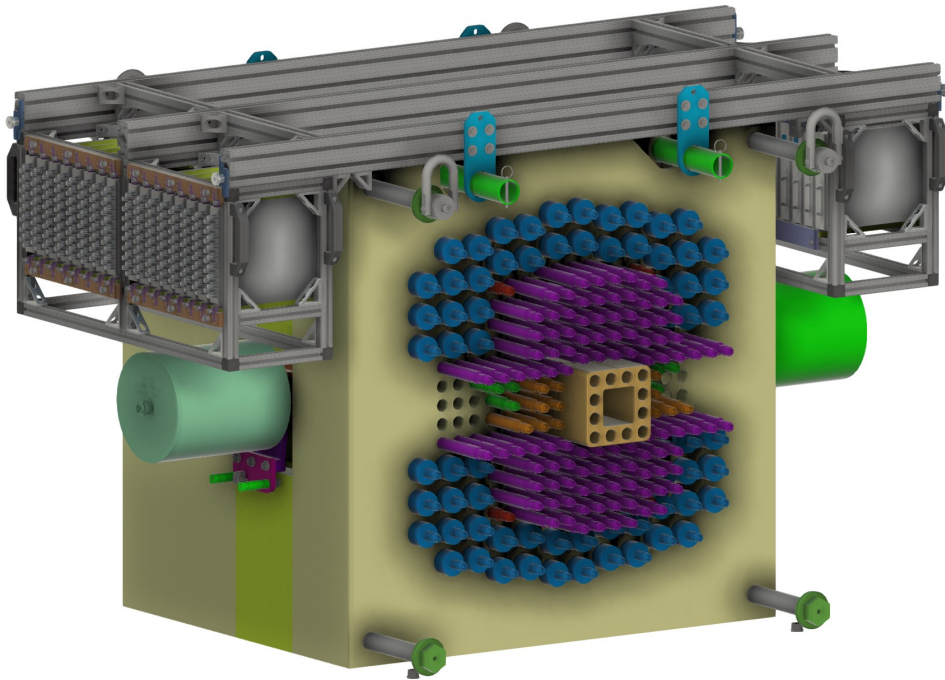
Phase 2 – New Switchyard Shielding, Carts, and S3Henri



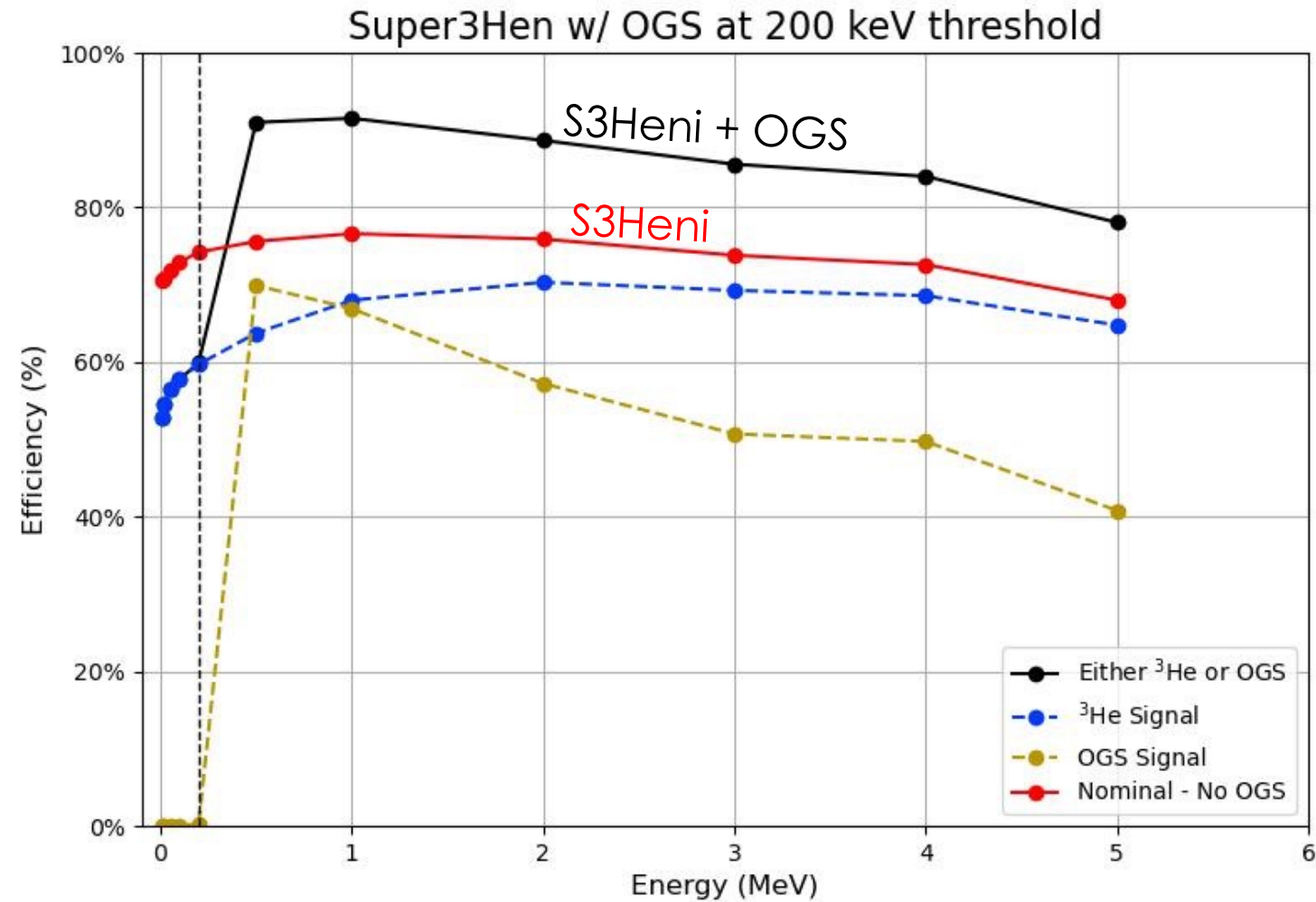
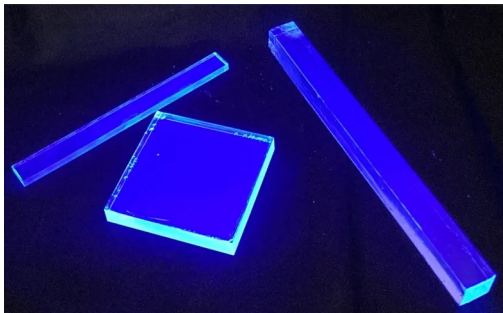
Phase 2 – S3Henri



Phase 2 – S3Henri with OGS Central Module

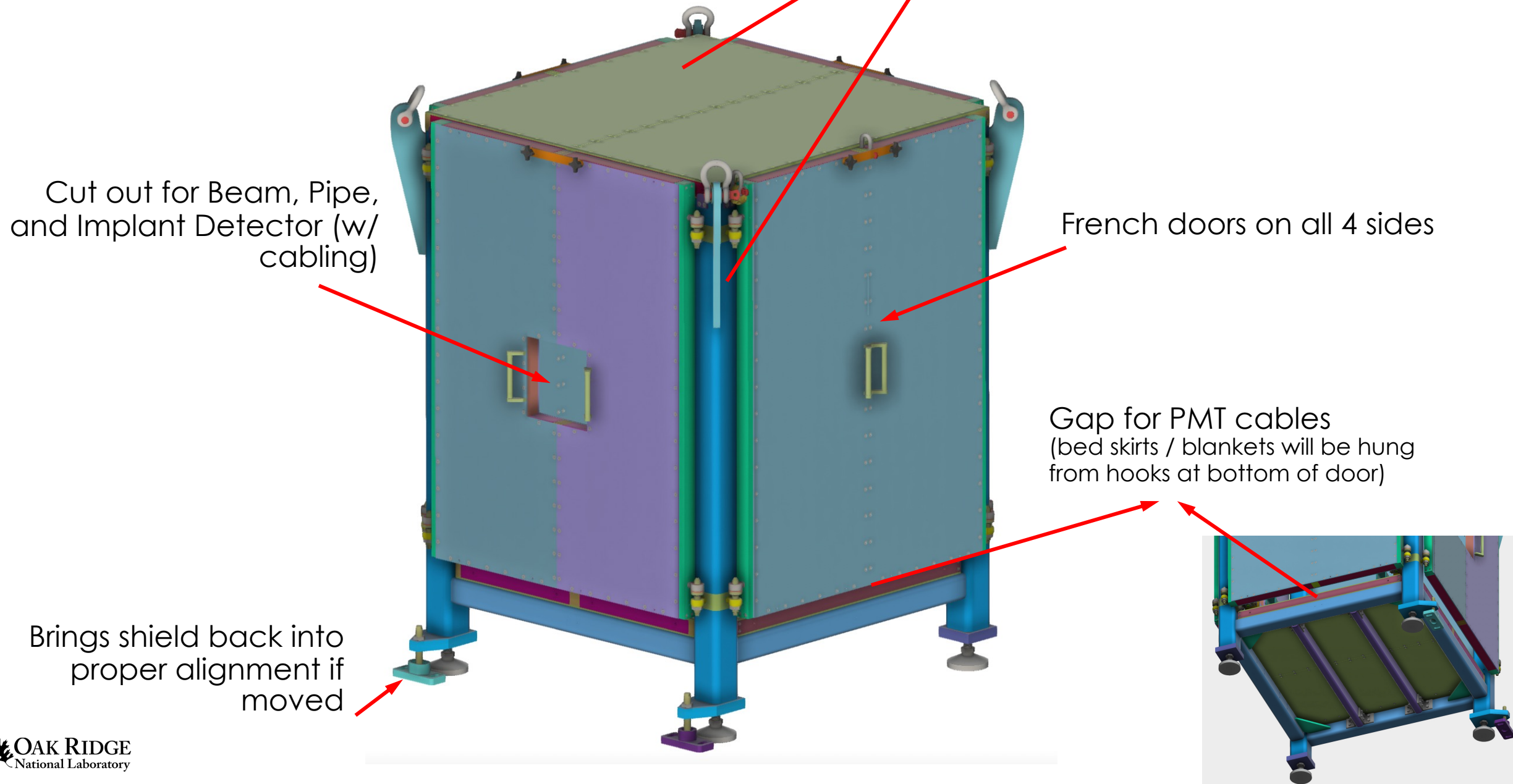


OGS solutions by UTK, Grzywacz

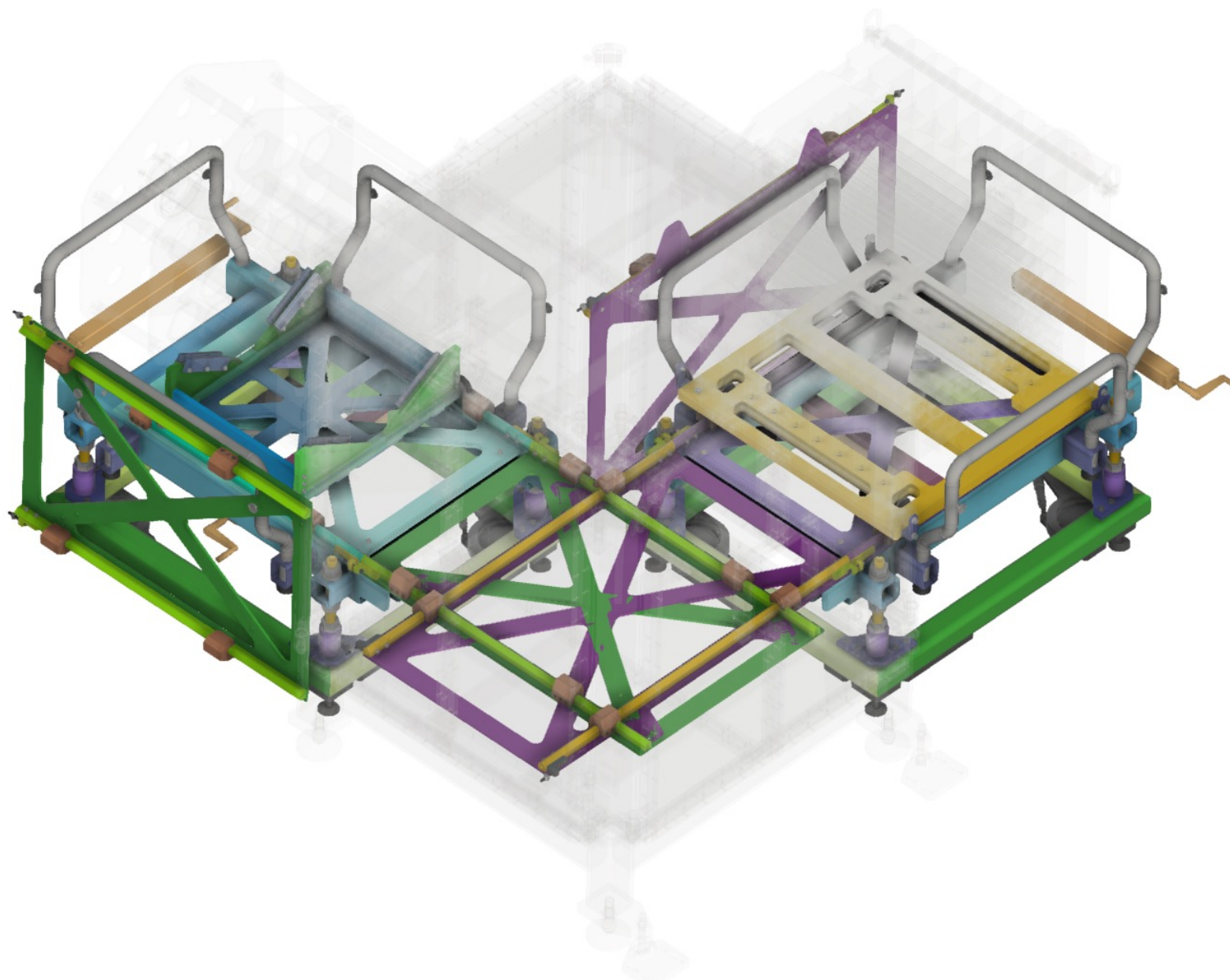


Parallel simulations:
MCNP - James Huffman (MSU)
GEANT4 - Charlie Rasco (ORNL)

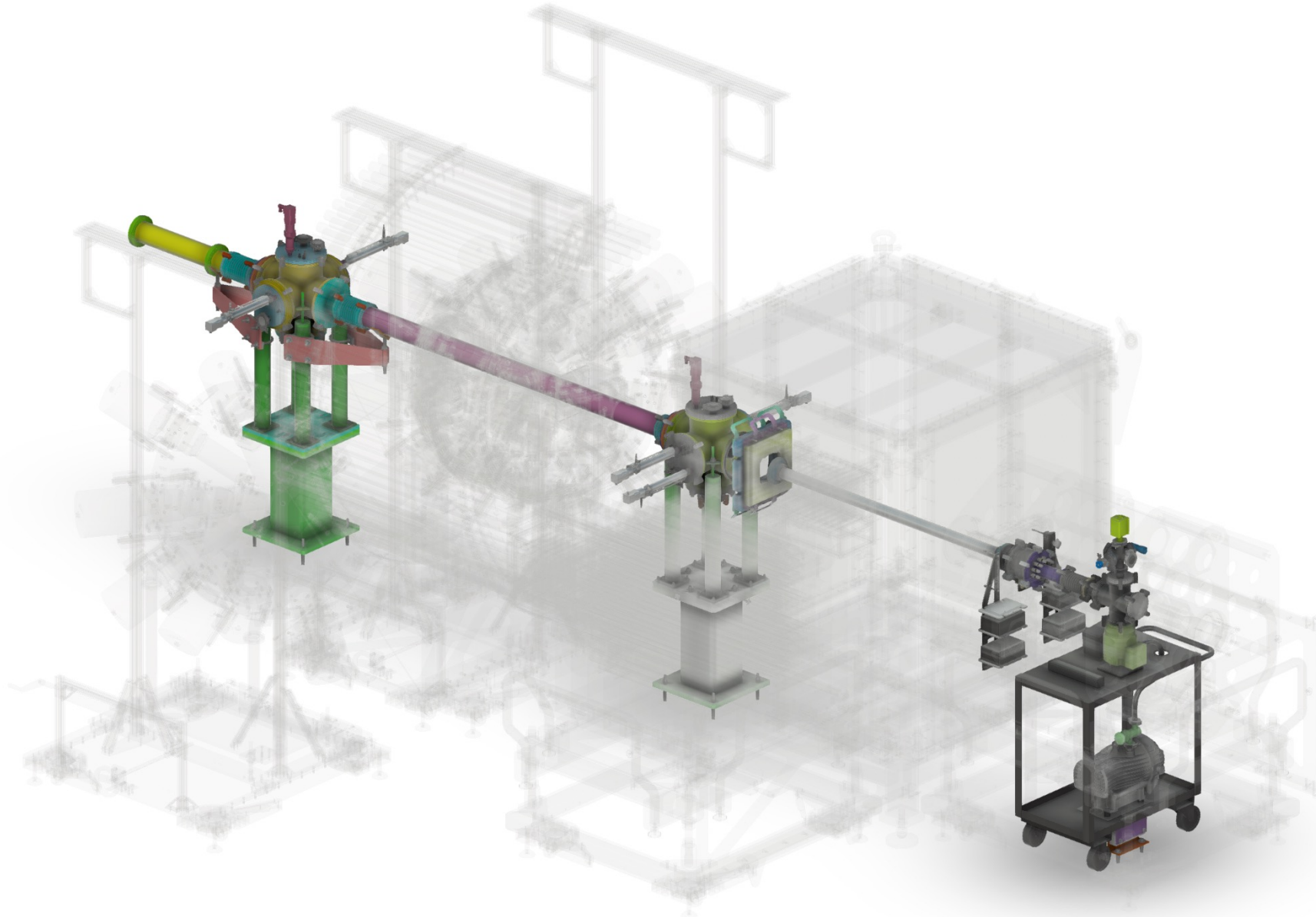
Switchyard Shield



S3Heni and MTAS Carts and Rails – Shield Compatible



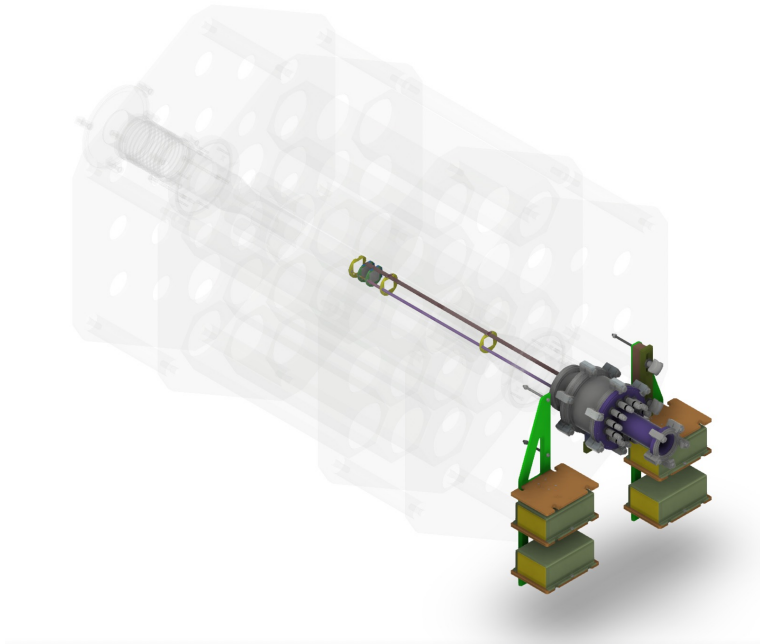
Phase 2 – New Beamline, Feedthroughs, Pump Station



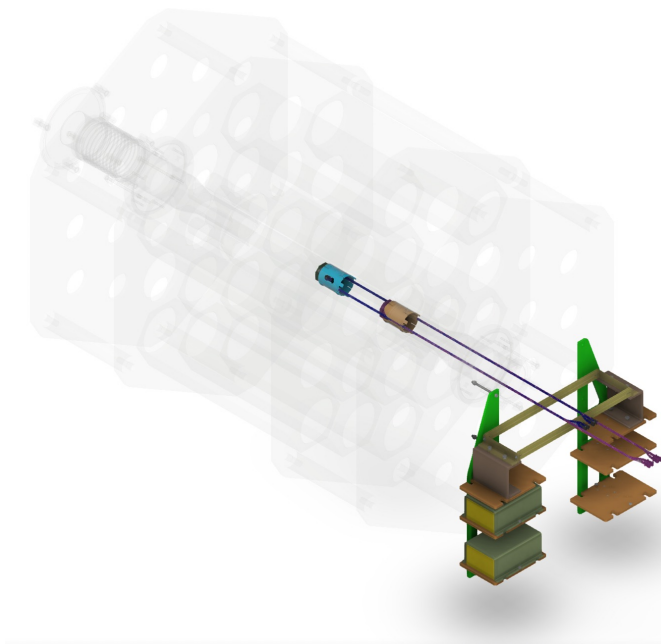
Beamline + Pump Cart Configurations

In Air configurations, when possible, maximize implant surface

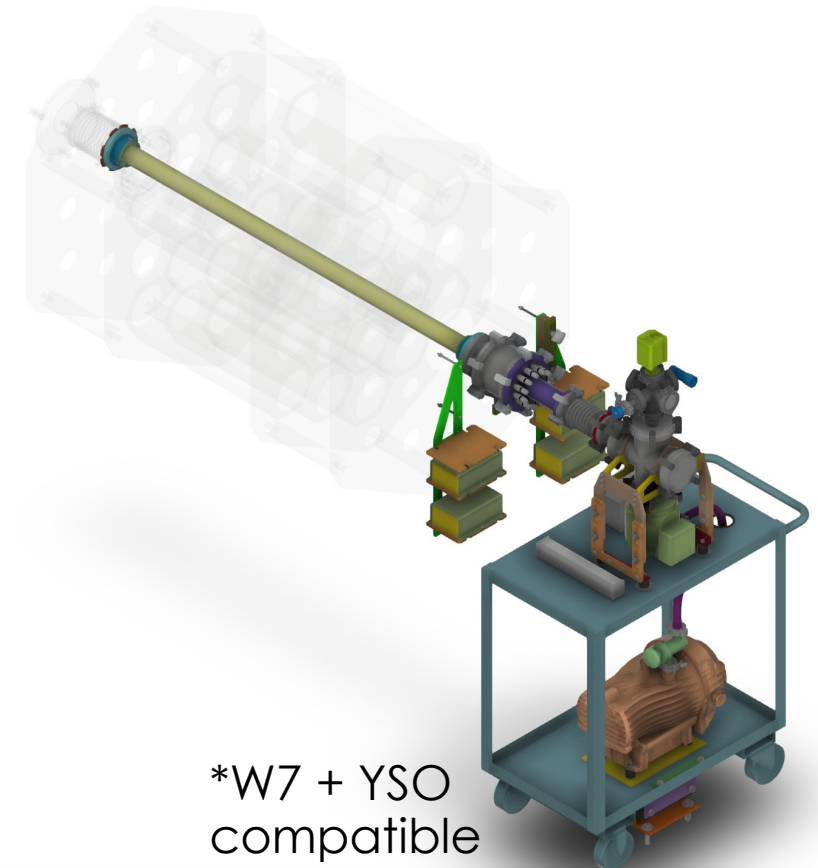
W5 IN AIR CONFIGURATION



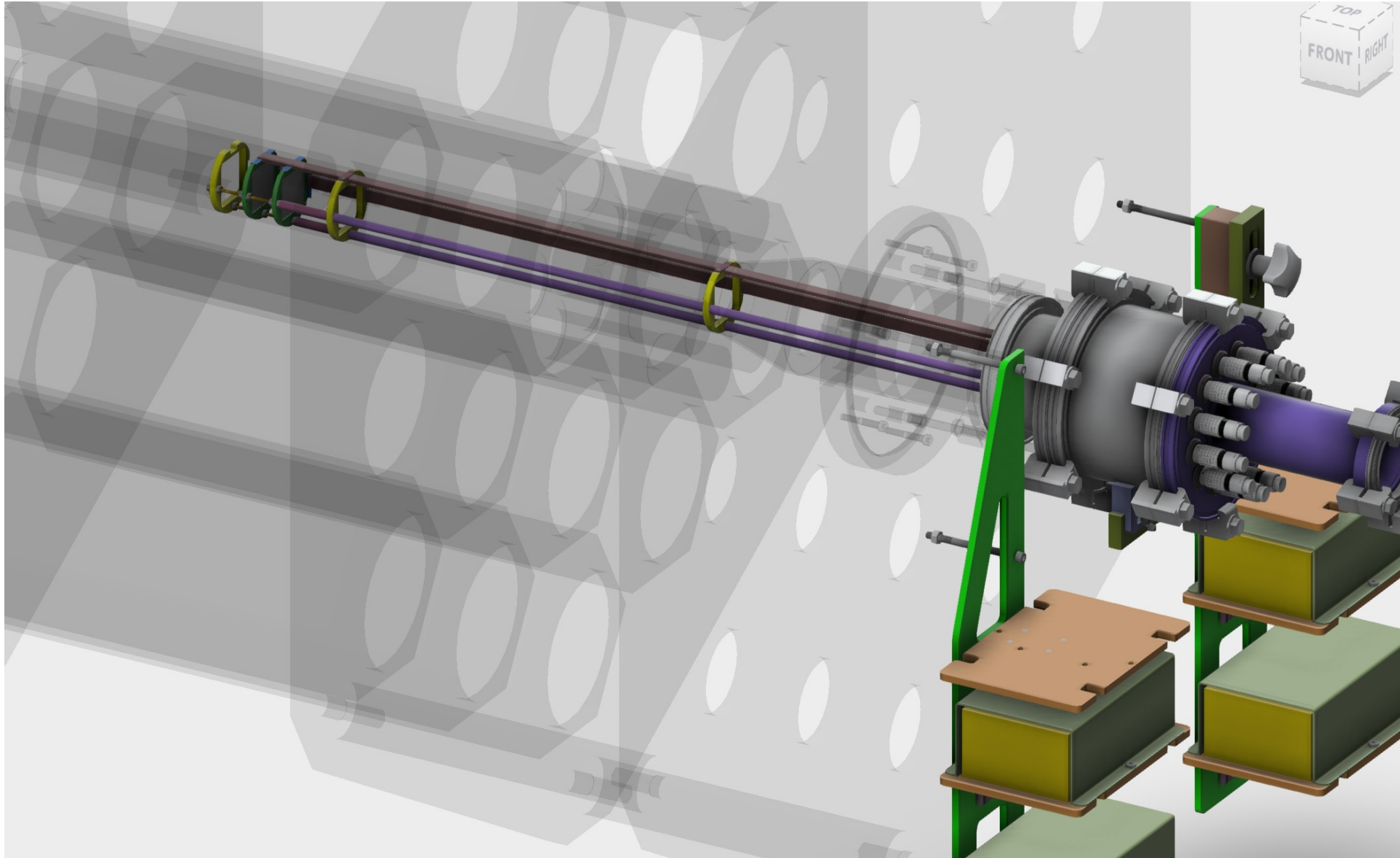
YSO IN AIR CONFIGURATION



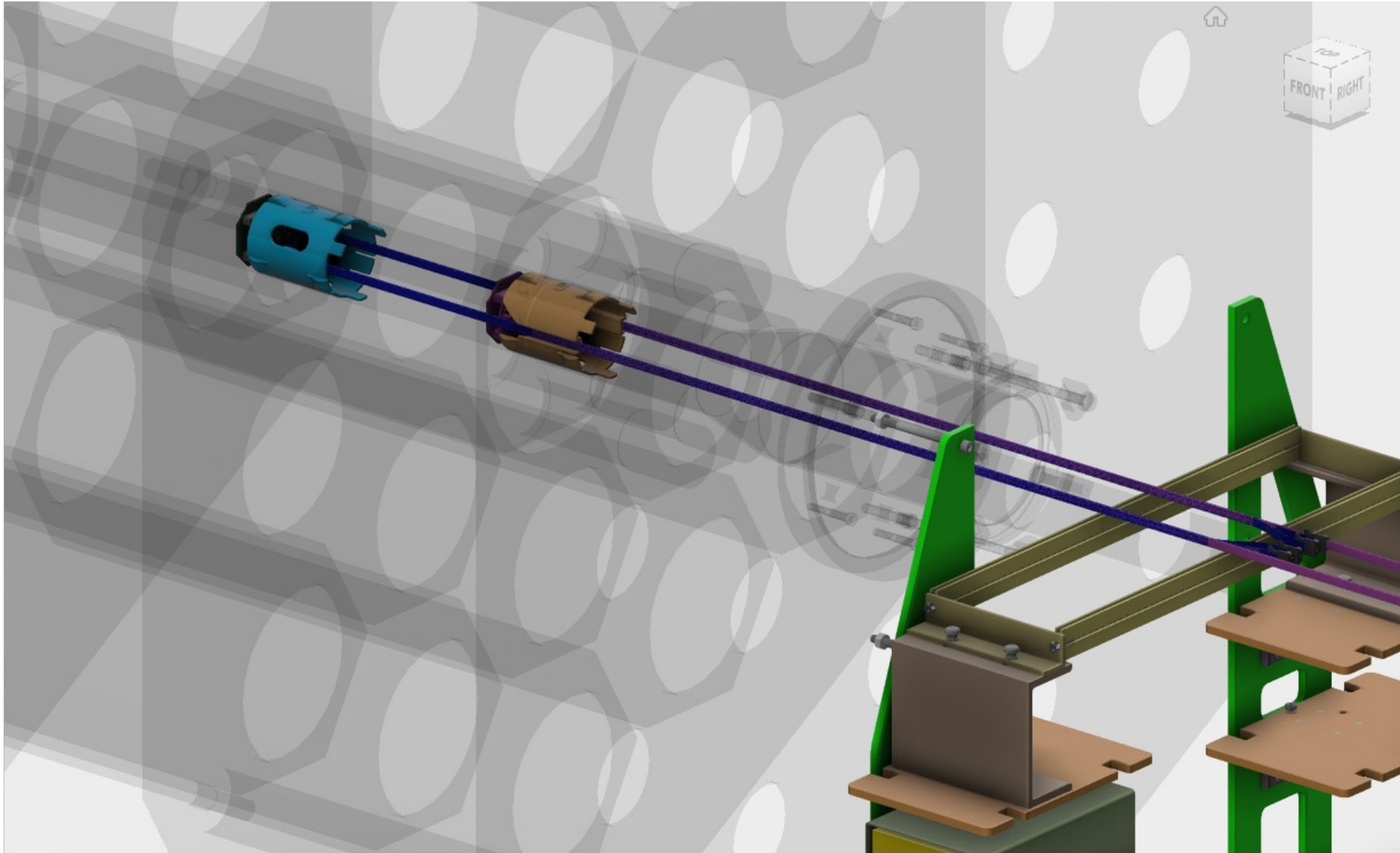
W7 IN VACUUM CONFIGURATION



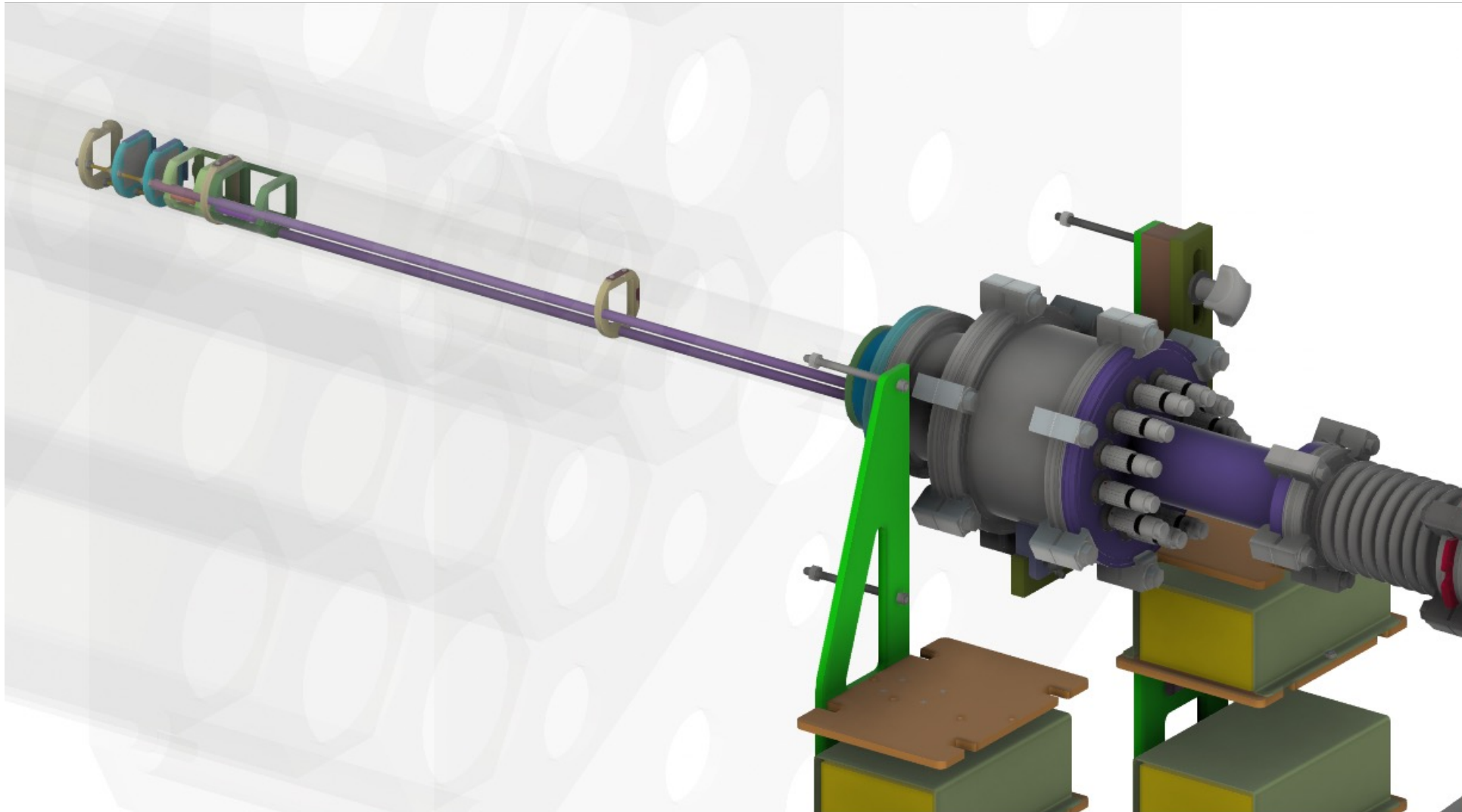
W5 IN AIR CONFIGURATION



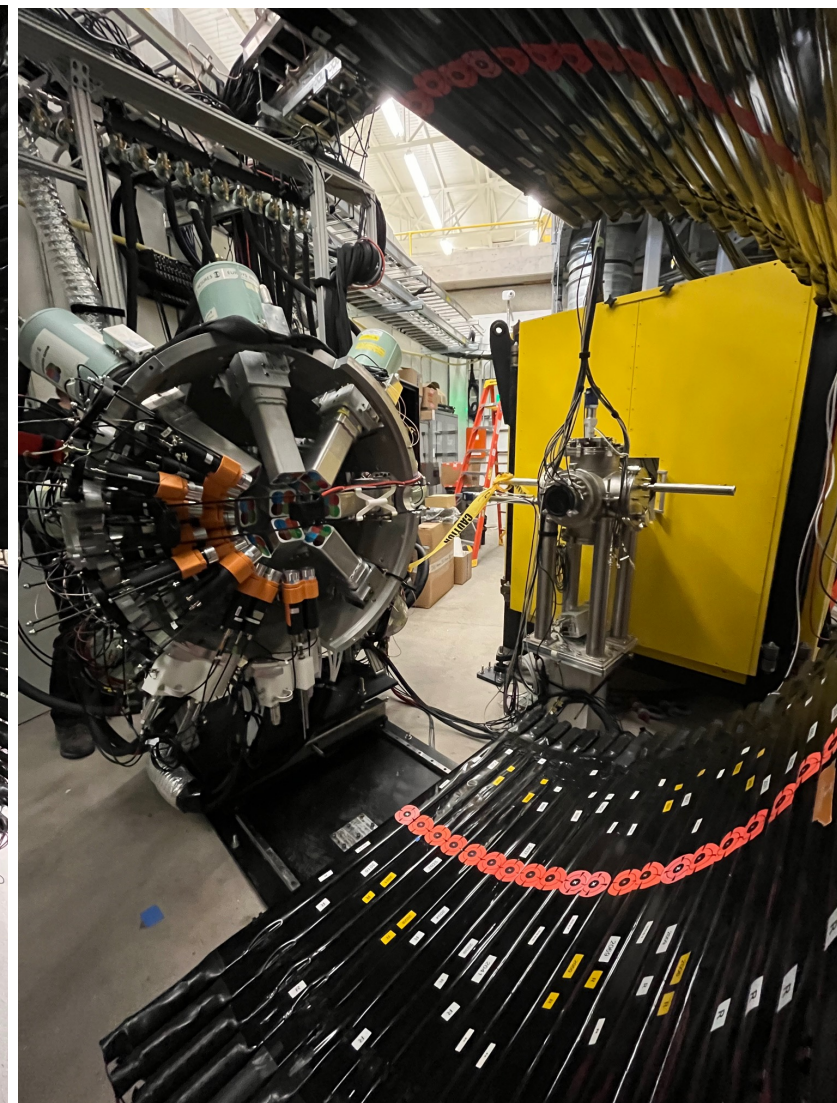
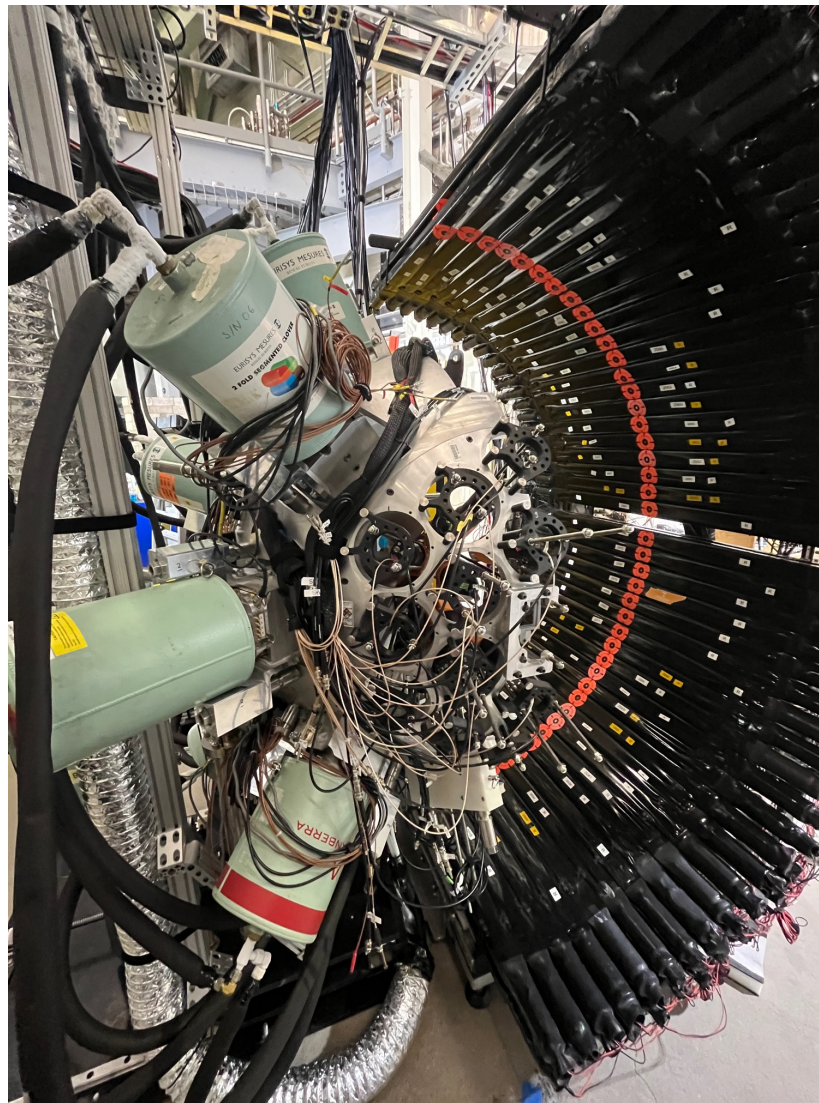
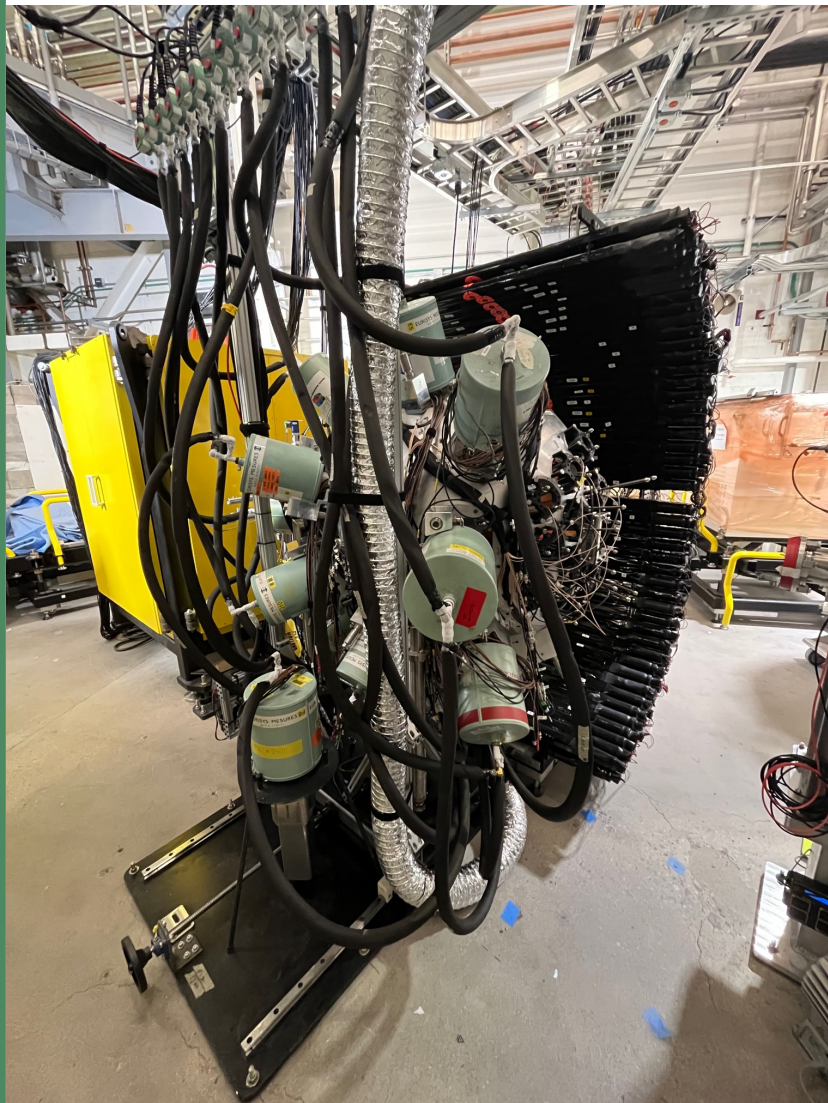
YSO IN AIR CONFIGURATION



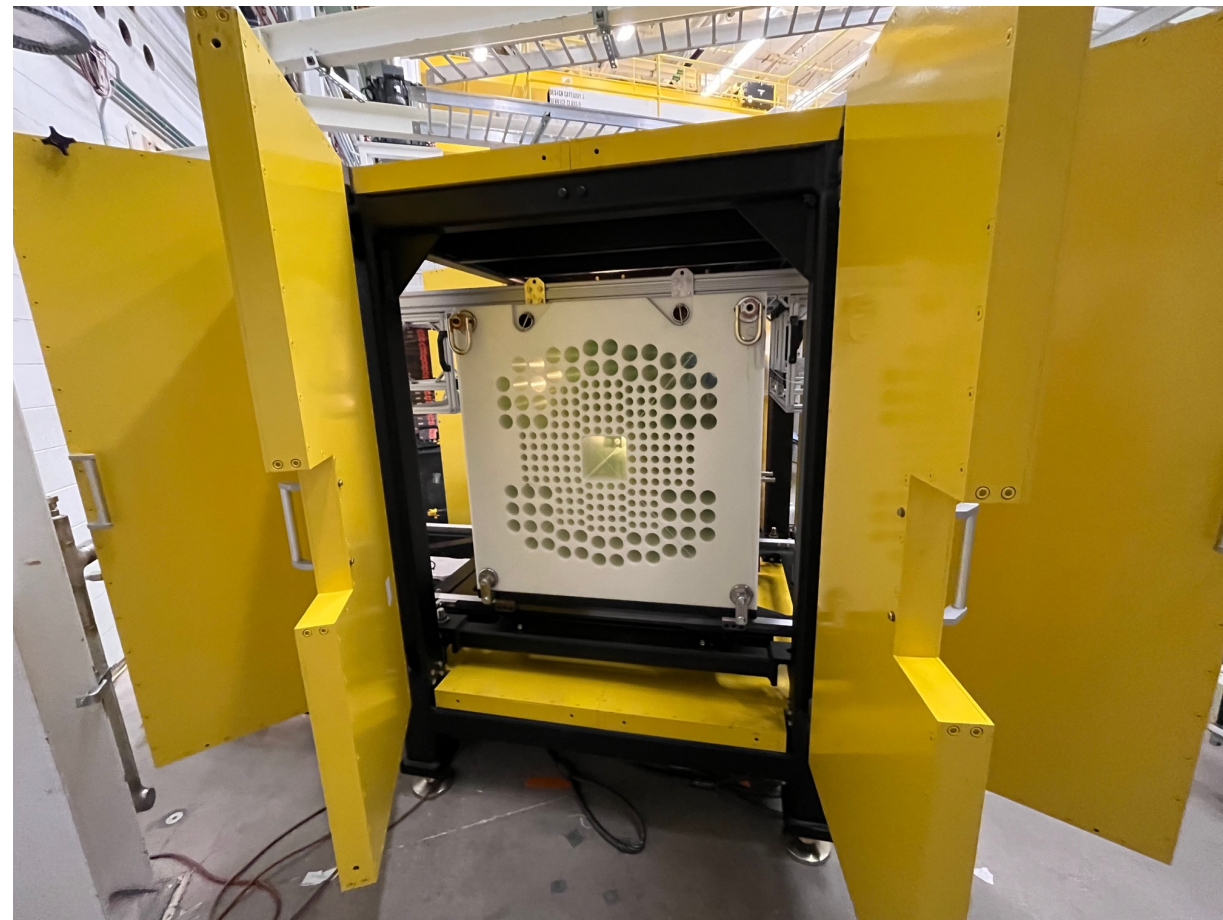
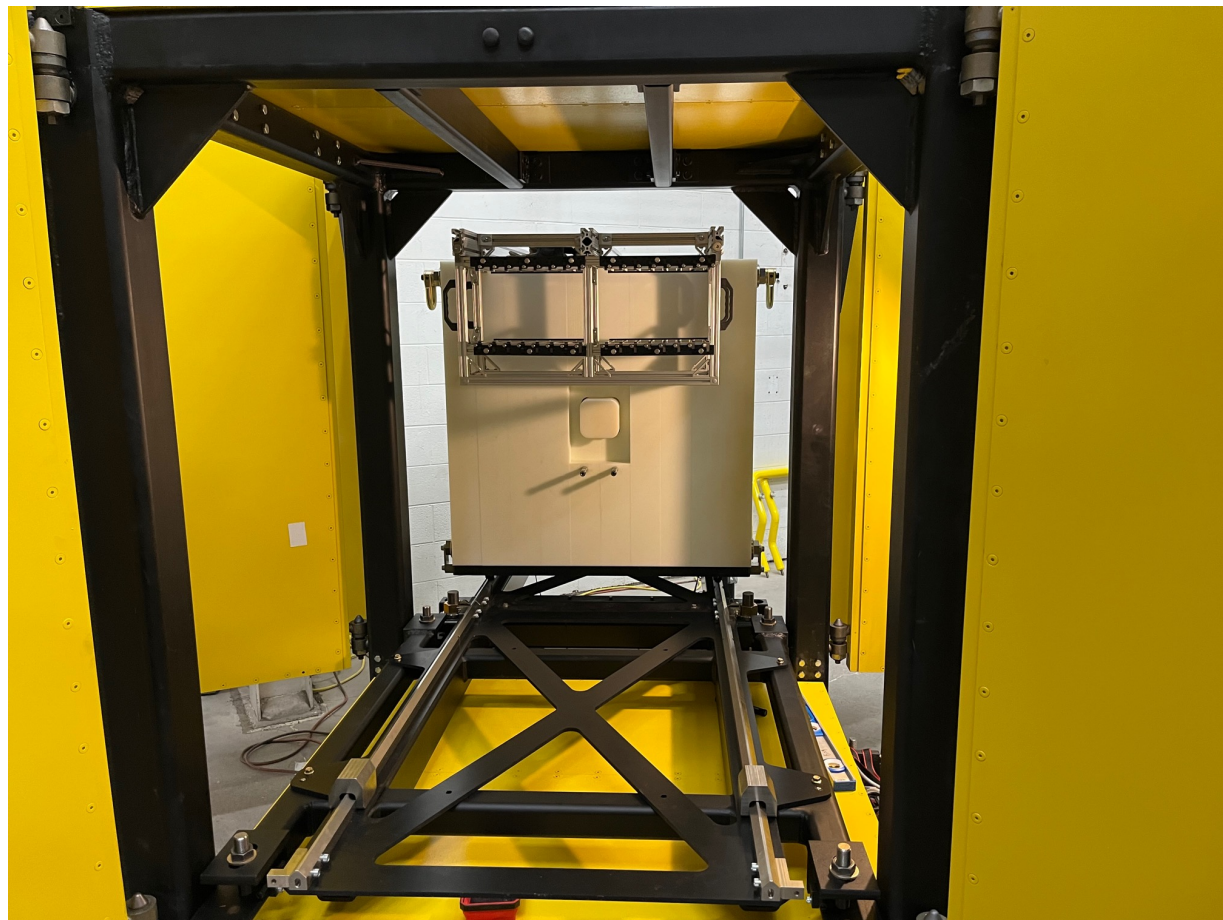
W7 IN VACUUM CONFIGURATION (+YSO Compatible)



The FDSi Setup in Real Life for Phase 2



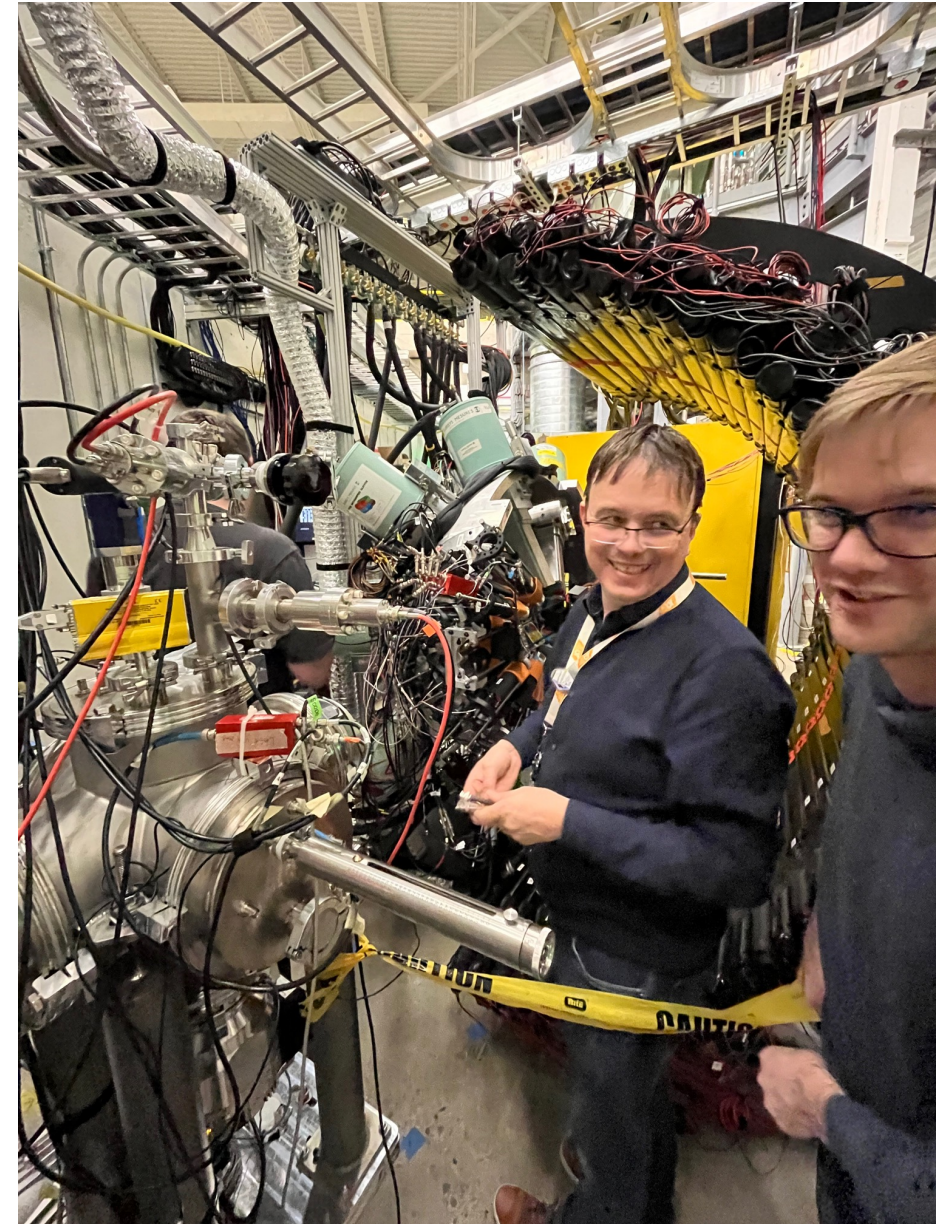
The FDSi Setup in Real Life for Phase 2



The FDSi Setup in Real Life for Phase 2



The FDSi Setup in Real Life for Phase 2



Acknowledgements and Contacts

(+ many students/postdocs)

FDS Users Executive Committee (2024):

- M. Madurga (Chair) – UTK
- H. Crawford (Secretary) – LBNL
- Wei Jia Ong – LLNL
- Andrea Richard – Ohio University
- H. Schatz – FRIB

FDSi Project

Project Oversight:
Project Management:
FRIB technical contact:

Georg Bollen
Mitch Allmond
Sean Liddick

FDSi Coordination:

Robert Grzywacz (Spokesperson)
Sean Liddick
Darek Seweryniak
Mitch Allmond

Facility Engineer:
Alignment Engineer:
FDSi Engineer:
XSiSi Engineer:
Engineer Support
Device Support

Ben Arend
Dave Sanderson
Gary Hollenhead
Russ Knaack
Toby King
Rebecca Lubna

FDSi Group:

J. M. Allmond, R. Grzywacz, K. Rykaczewski, C. Rasc, A. Macchiavelli (**ORNL**), D. Seweryniak, M.P. Carpenter (**ANL**), S.N. Liddick, A. Spyrou, C. Wrede, H. Schatz, F. Montes (**FRIB**), R. Grzywacz, K.L. Jones, M. Madurga (**UTK**), V. Tripathi (**FSU**), B. Crider (**MSU (Mississippi)**), H.L. Crawford (**LBNL**), L. Riley (**URSinus**), R.V.F. Janssens (**UNC**), A. Rogers (**UML**), K. Kolos, J.T. Harke (**LLNL**), M. Karny (**Warsaw**)

FDSi Working Groups:

- **DEGAi** – J.M. Allmond, M.P. Carpenter, A. Macchiavelli, V. Tripathi, M. Madurga, R.V.F. Janssens, B. Crider, S.N. Liddick, K. Kolos, J.T. Harke, H.L. Crawford
- **NEXTi** – R. Grzywacz, M. Madurga, M. Rajabali, A. Fijalkowska
- **TAS** – K. Rykaczewski, A. Spyrou, C. Rasco, M. Karny, S. Lyons, R. Grzywacz
- **XSiSi** – D. Seweryniak, R. Grzywacz, A.M. Rogers, J. Wu, A. Estrade Vaz, K. Rykaczewski, B. Crider
- **S3Heni** – K. Rykaczewski, C. Rasco, F. Montes, J. Huffman, H. Schatz, A. Estrade, K. Kolos, W.-J. Ong, A. Spyrou, M. Rajabali
- **GADGET2 (TPC)** – C. Wrede

Thank you!

