OAK RIDGE National Laboratory

Phase 2 of the FRIB Decay Station initiator (FDSi)

J.M. Allmond – ORNL

On behalf of the FDSi@FRIB Collaboration

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

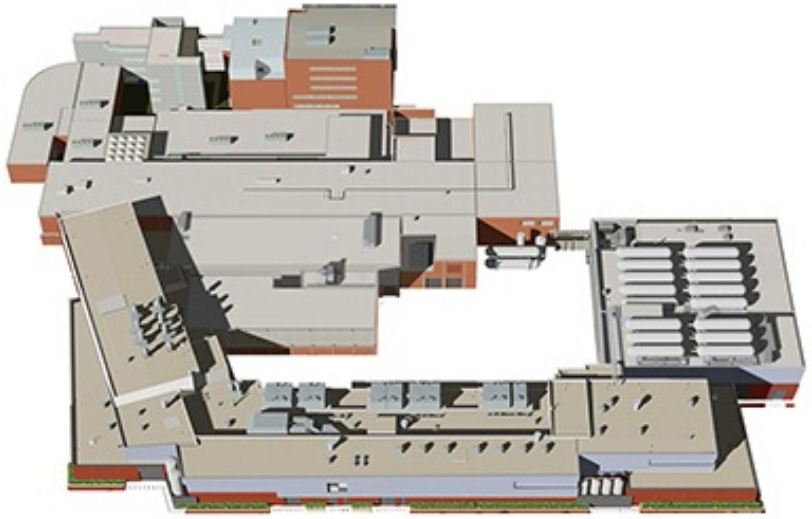
U.S. DEPARTMENT OF ENERGY

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

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

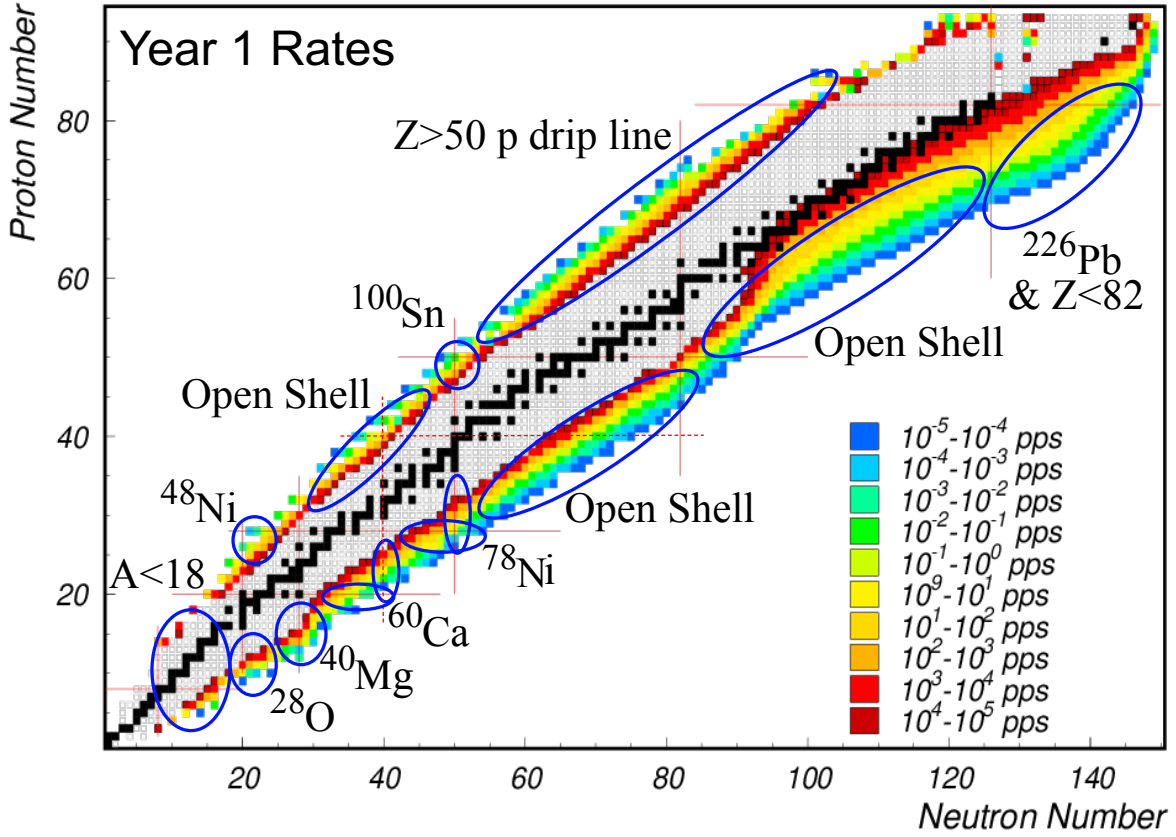
Unprecedented access to exotic nuclei; will produce 80% of isotopes predicted to exist for Z < 93

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



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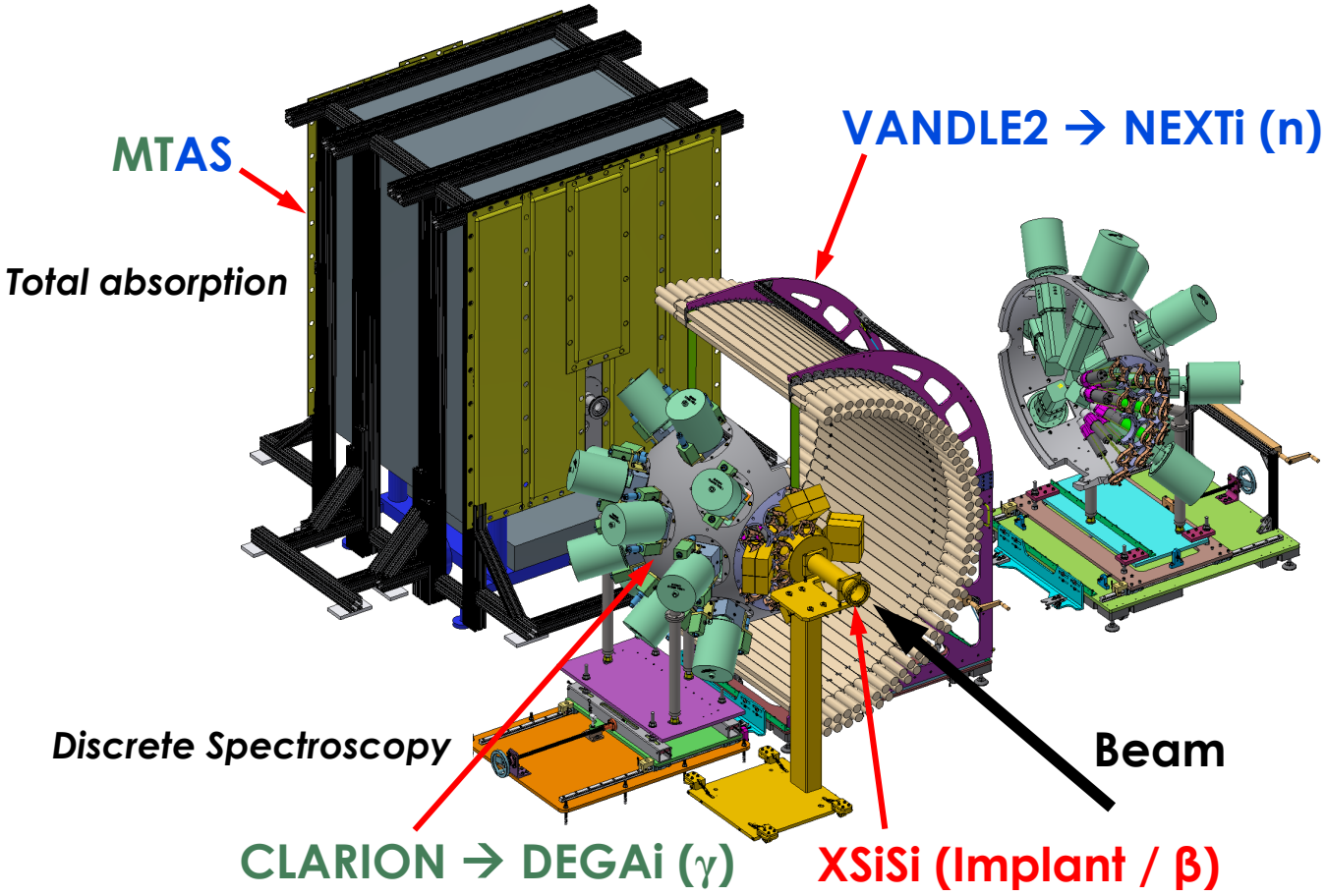
The FRIB Decay Station initiator (FDSi)

- 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 $LaBr_3$ detectors, simulations, machining, Si detectors, and associated electronics

ANL: 8 clovers, 15 $LaBr_3$ detectors, CAGRA (slow beam) frame, HV, engineering

FRIB-MSU: Pixie16 pool (67 modules), GADGET2, 3He tubes and preamps, SUN, PXCT, GeDSSD, 16 $LaBr_3$ detectors, vacuum pumps and gauges, engineering, and machining

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

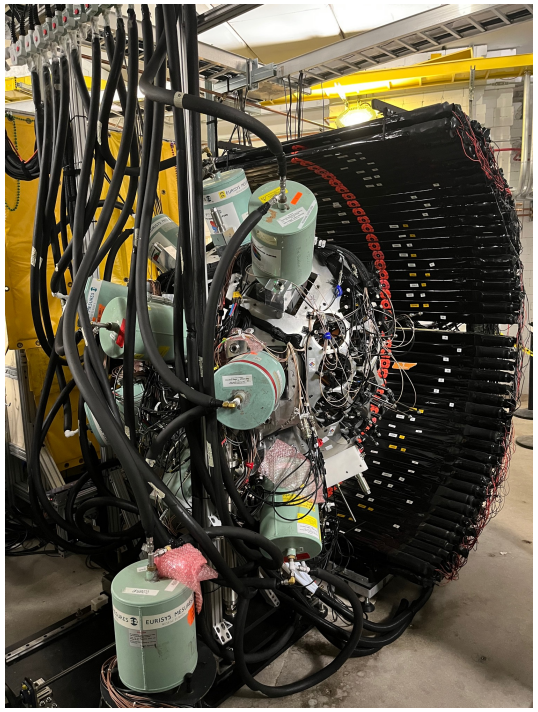
MSU (Mississippi): 4 $CeBr_3$ and 10 $LaBr_3$ detectors, and $CeBr_3$-based implant detector

URSinus: Simulations

UNC: 12 $CeBr_3$ detectors

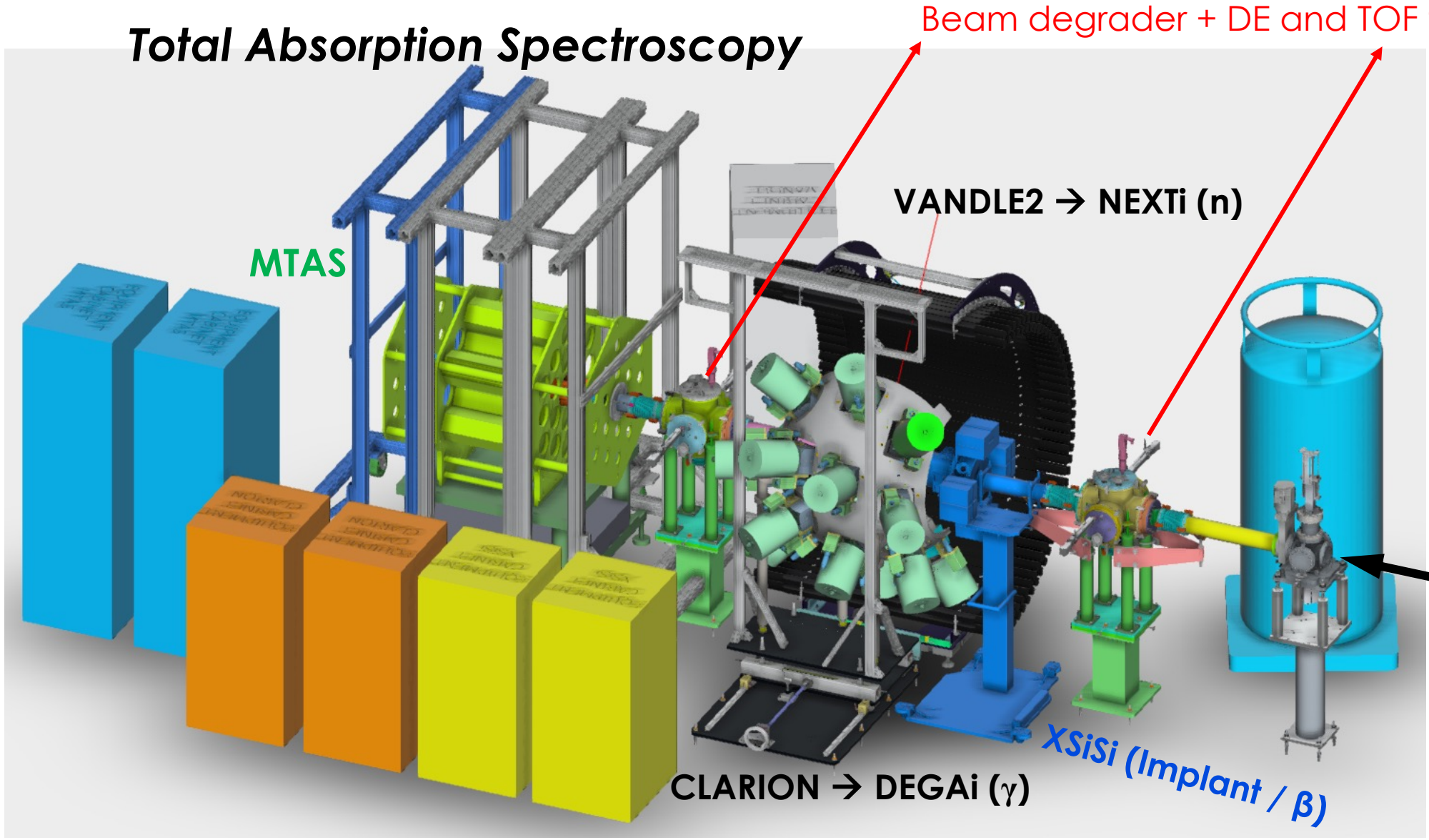
LLNL: 8 clovers (3 are ORTEC), cables, solenoids, and HV

LBNL: 2 clovers**



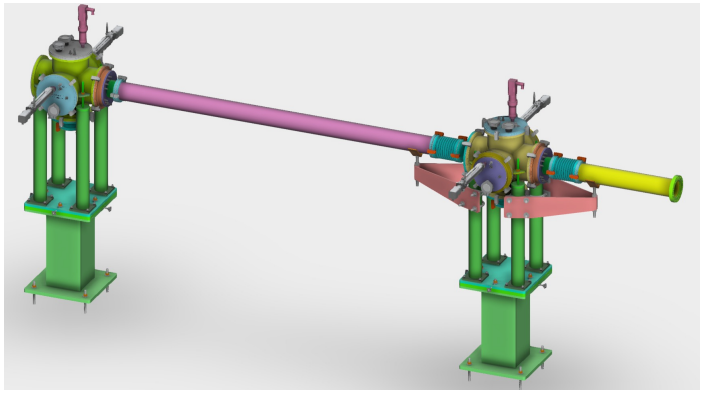
**On limited occasions and contingent on schedule due to local program / facility needs.

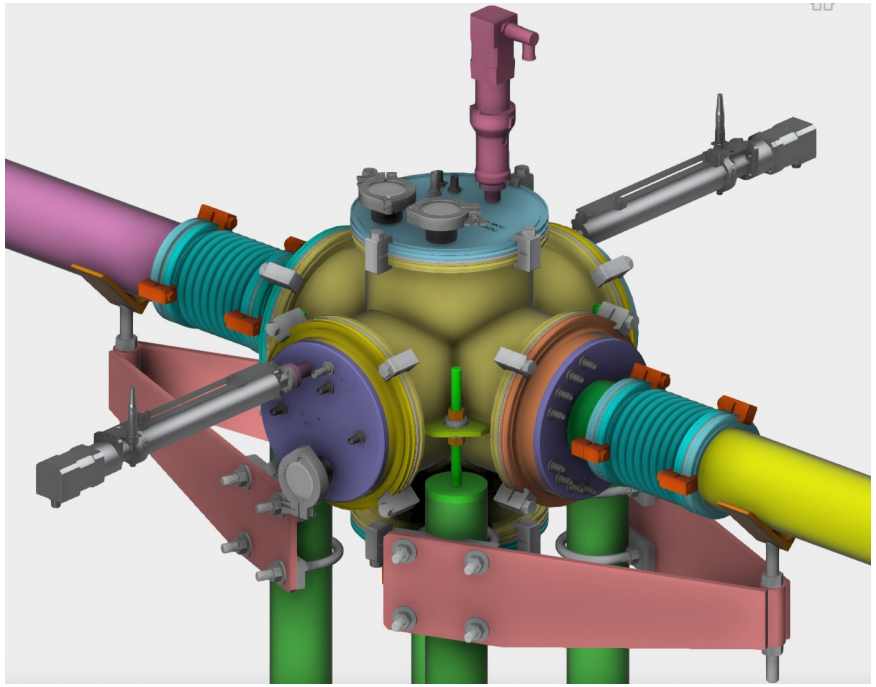
The FDSi: Phase 1 Design

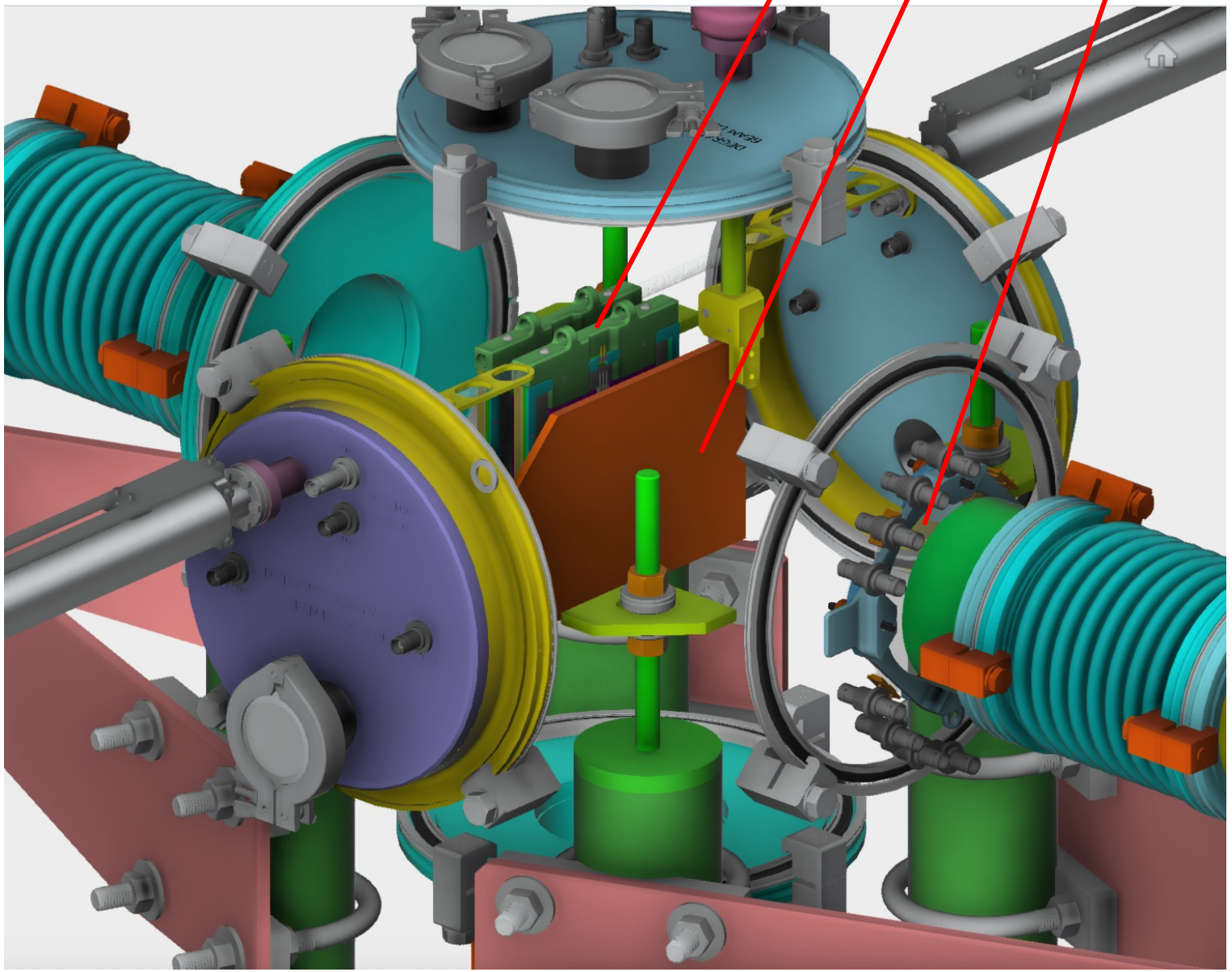


Diagnostic Crosses

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

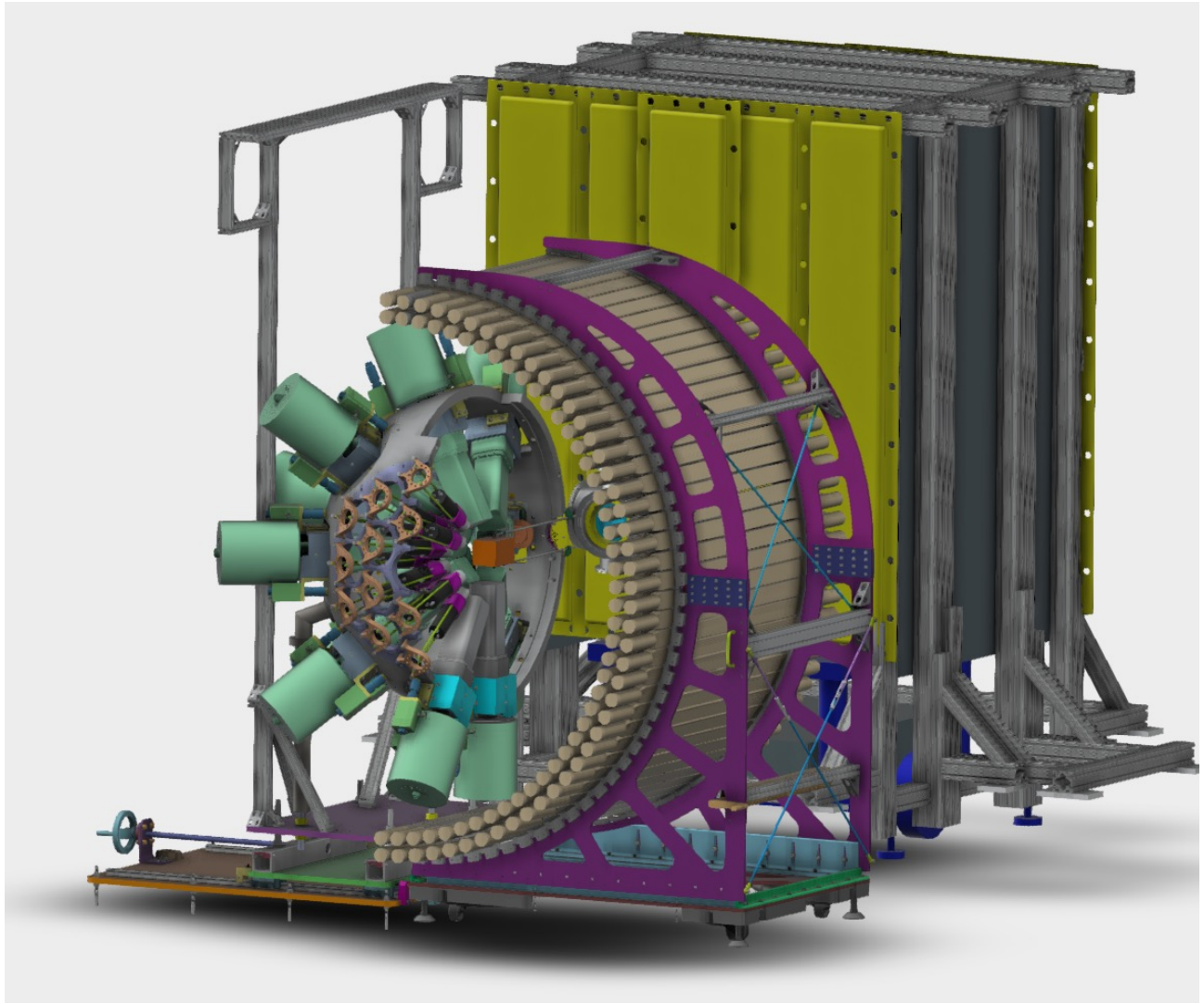


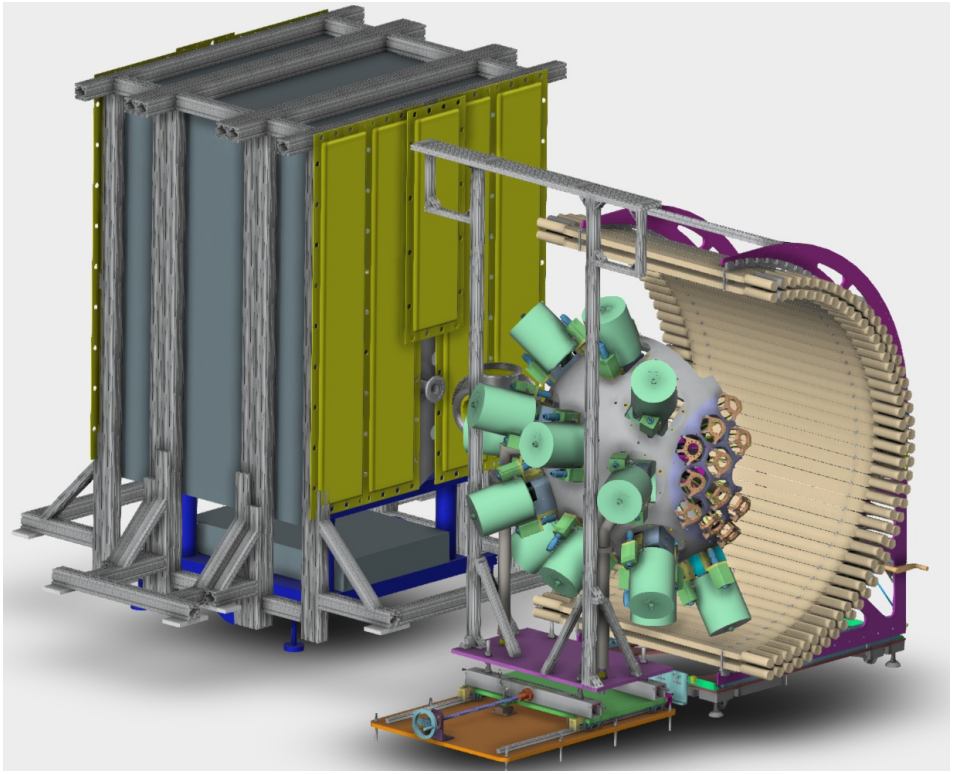


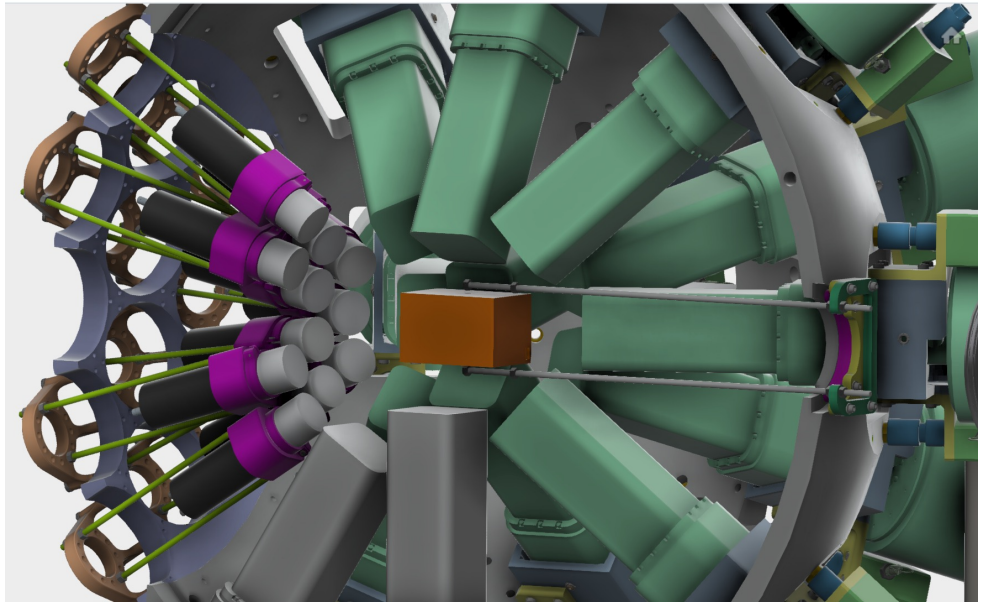


Nominal / Balanced Configuration

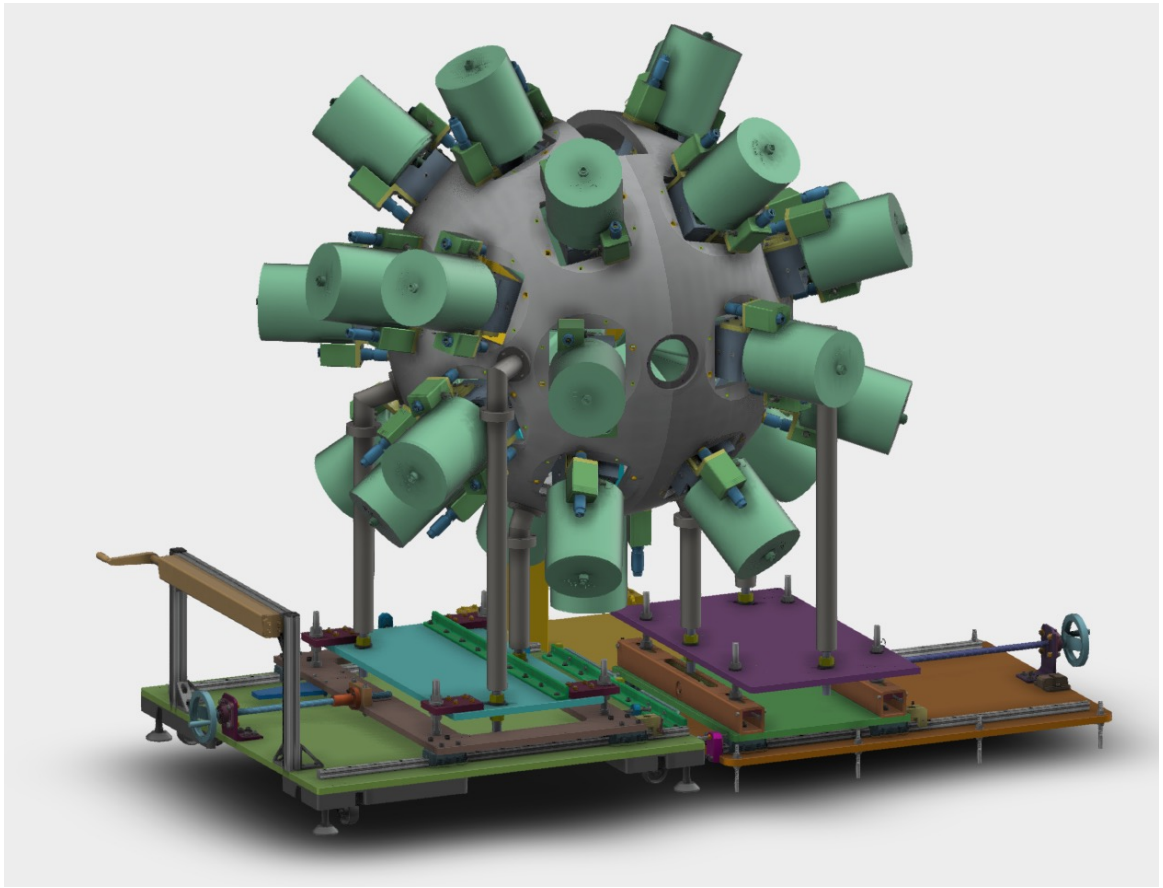
Implant, γ, n (1st focal point) + Total Absorption (2nd focal point)

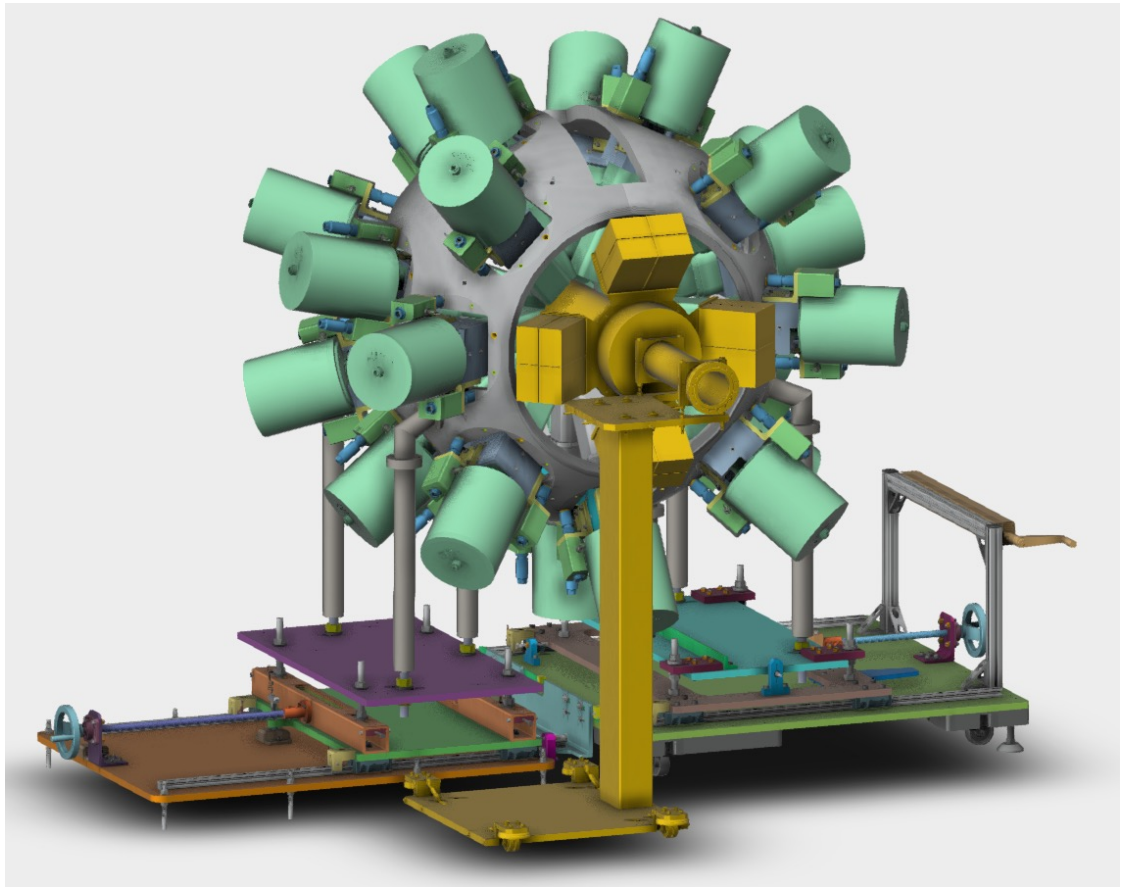




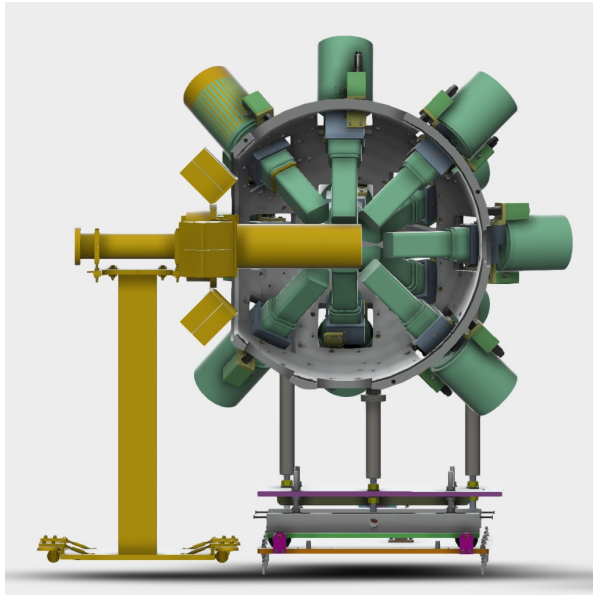


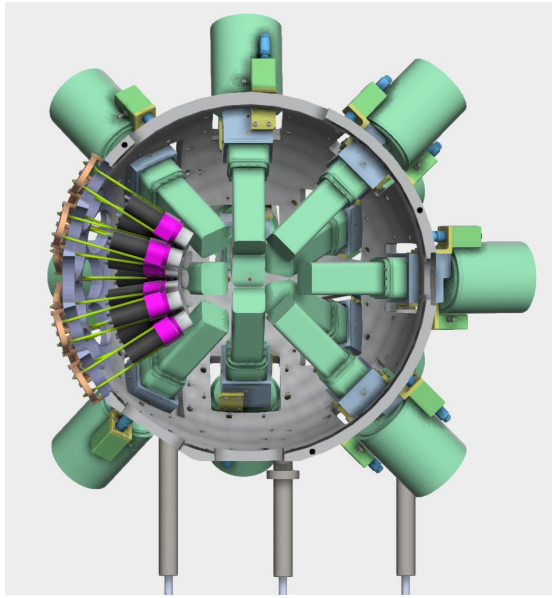
4π High-Resolution γ-Ray Configuration (proton-rich)

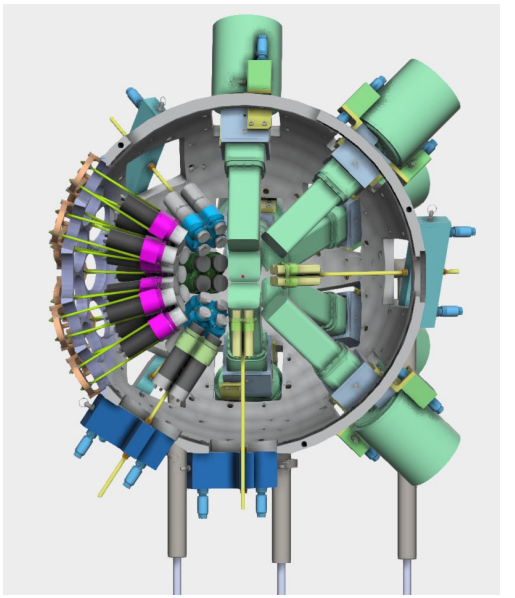


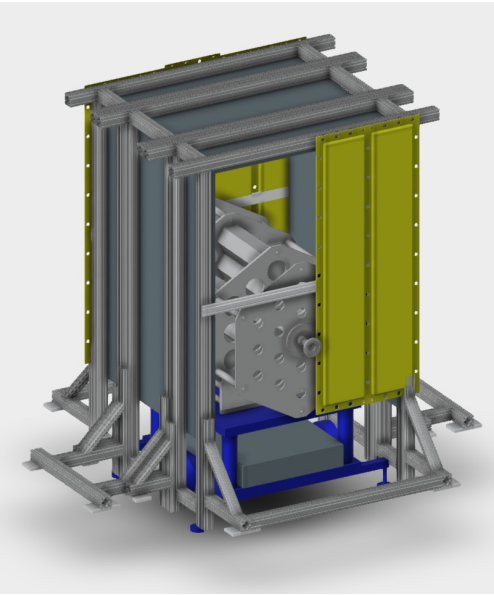


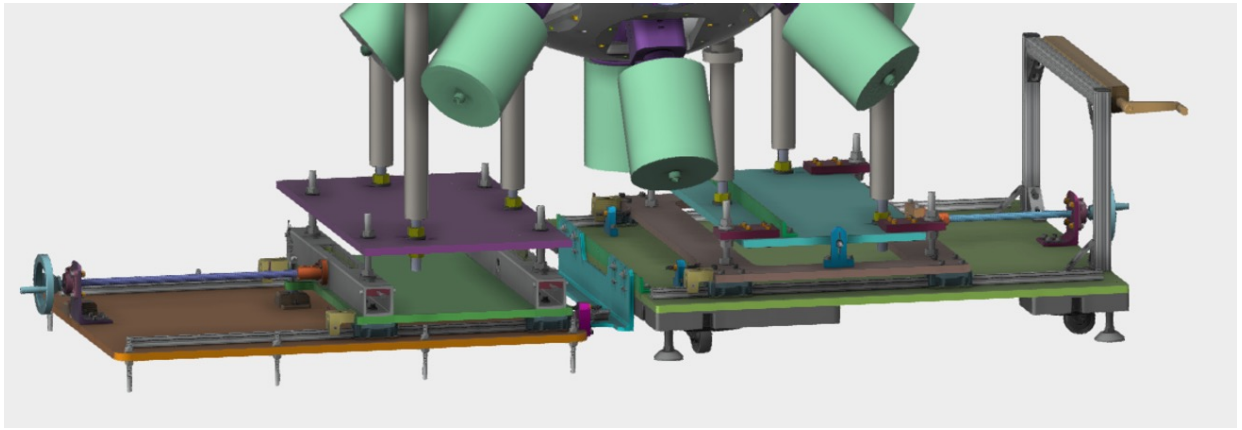
Cross Sections of Mechanical Designs

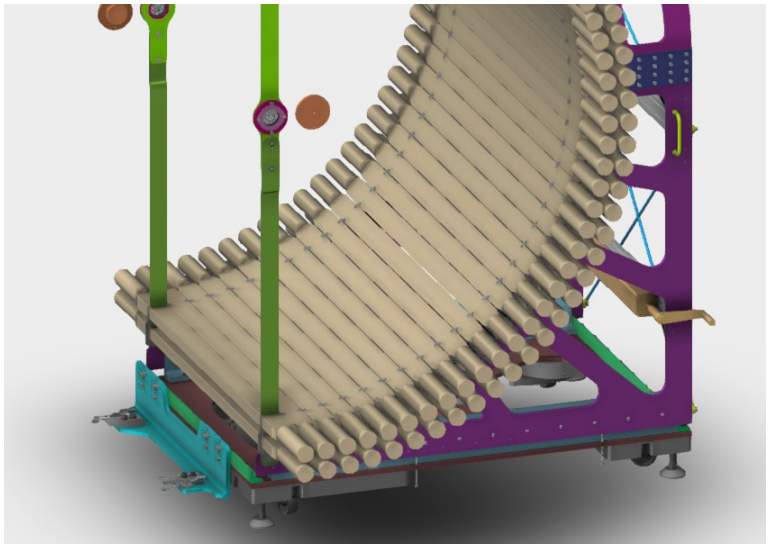




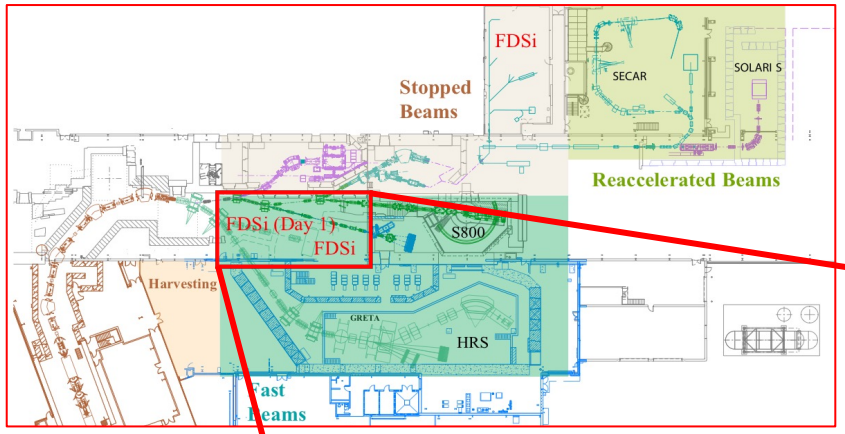








FDSi Locations



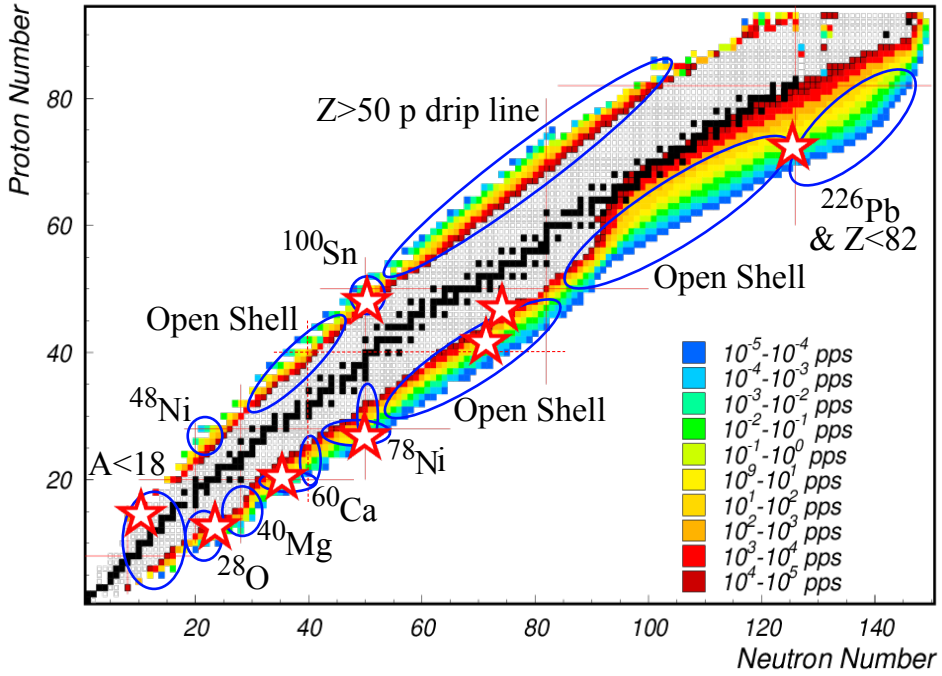
- **Locations and space requirements understood**
- Large doors and crane access required to bring in large and heavy (~tons) equipment
- Storage space required

1st FRIB PAC: Accepted Proposals and POC multiple spokespeople per proposal

First two FRIB experiments executed in May-June 2022 and repeated in Jan-Mar 2024

Third FDSi experiment executed in November 2022

1. "Correlation of Triaxial Deformation with Inertial Dynamics, Masses and r-Process Nucleosynthesis" - J.M. Allmond (**ORNL**)
2. "Decoding the doubly magic stronghold - decay spectroscopy of ^{78}Ni " - Krzysztof Rykaczewski (**ORNL**)
3. "Complete decay spectroscopy of ^{100}Sn and its neighbors" - Robert Grzywacz (**ORNL-UTK**)
4. "Decay spectroscopy of the N=35 nuclei ^{55}Ca, ^{54}K and ^{53}Ar and the search for dripline nucleus ^{50}S" - Wei Jia Ong (**LLNL**)
5. "Decay Spectroscopy Near N=28: Shell Structure, Shapes and Weak Binding" - Heather Crawford (**LBNL**)
6. "Strength of the key ^{15}O(a,g)^{19}Ne resonance in X-ray bursts" - Christopher Wrede (**FRIB-MSU**).
7. "Constraining neutron capture rates for the r-process" - Artemis Spyrou (**FRIB-MSU**)
8. "Decay spectroscopy in the vicinity of the N=126 shell closure" - Jin Wu (**ANL**)



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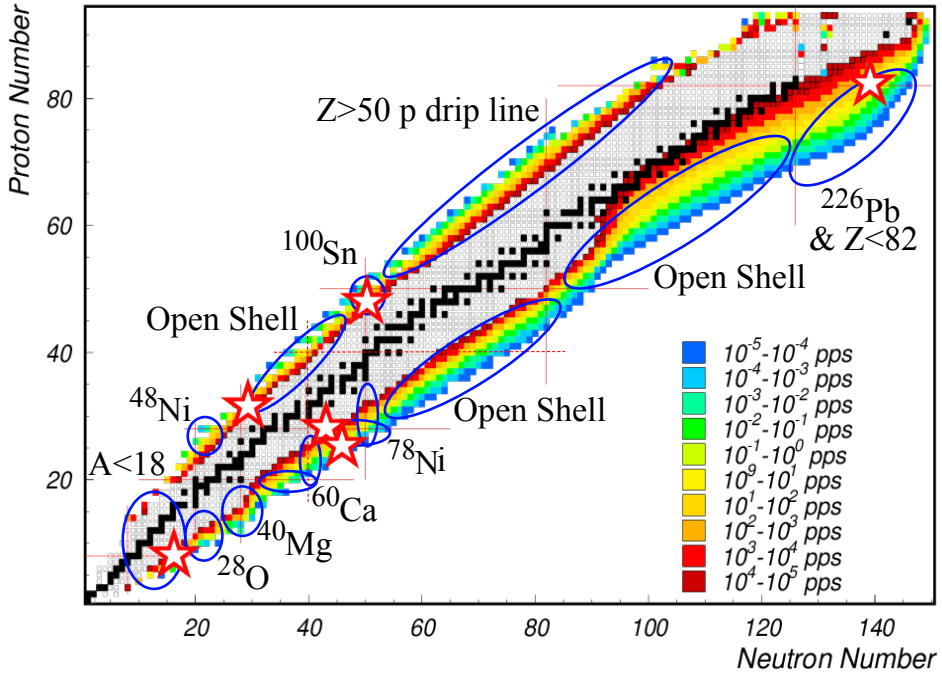
2nd FRIB PAC: Accepted Proposals and POC multiple spokespeople per proposal

Fourth FDSi experiment executed in May 2023

1. "Seniority Isomers and Single-Particle Evolution in $^{218\text{-}222}$Pb Region: New Isotopes, Isomers, and Half Lives" - J.M. Allmond **(ORNL)**
2. "Intersections of nuclear structure and statistical model in βn-decays of cobalt isotopes and isomers" - R. Grzywacz **(UTK, ORNL)**
3. "The Study of Proton-Rich Isotopes Along the Proton Drip-Line above ^{100}Sn" - D. Seweryniak **(ANL)**
4. "Decay Spectroscopy Near N = 40: toward the N = 50 island of inversion near ^{78}Ni" - B. Crider **(Mississippi State University)**
5. "Is there a NiCu Cycle in X-ray Bursts?" - C. Wrede **(FRIB)**

\+ "Beta-delayed neutron spectroscopy of ^{24}O" - R. Grzywacz **(UTK, ORNL)**



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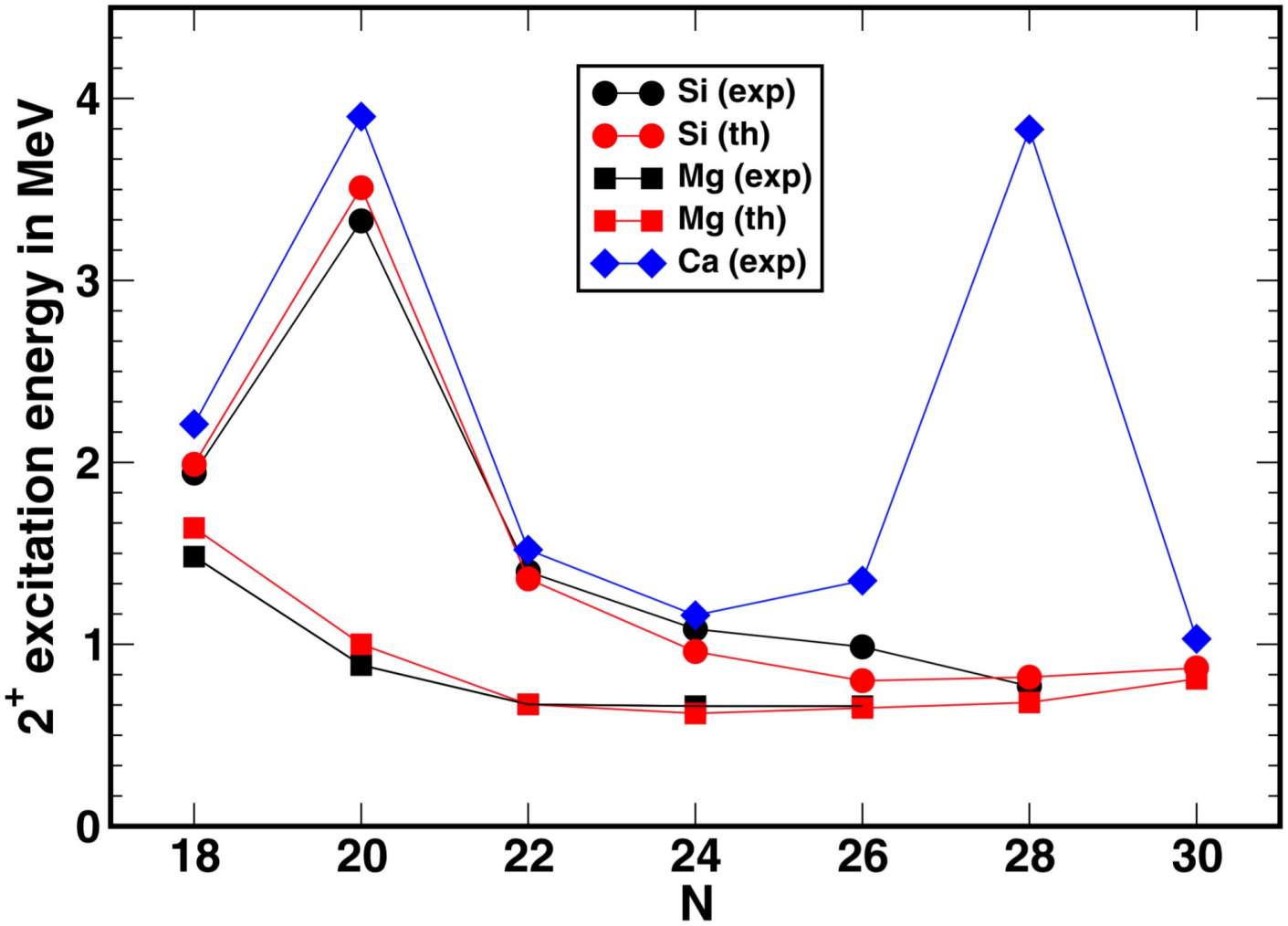
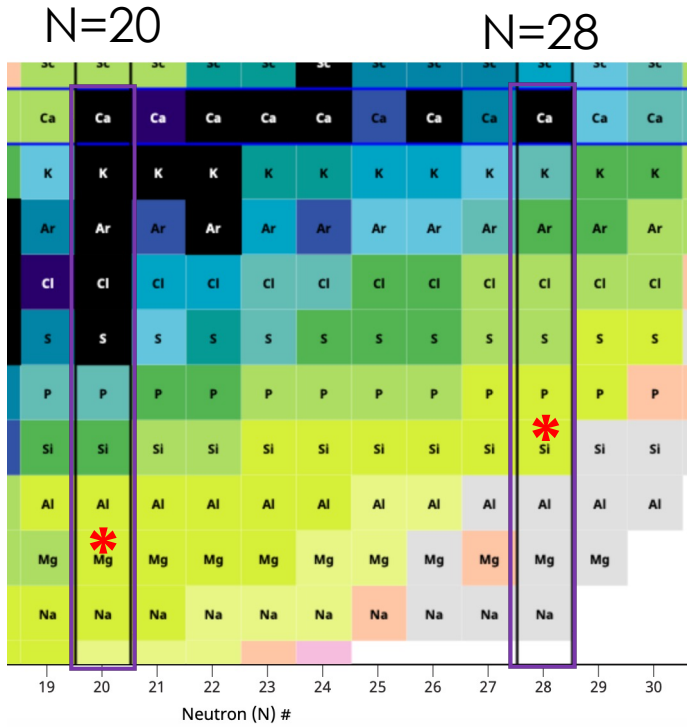
First FRIB Experiment at N=20 and 28 Shell Closures

"Breakdown" of shell closure for n-rich N=20 (^{32}Mg) and N=28 (^{42}Si)

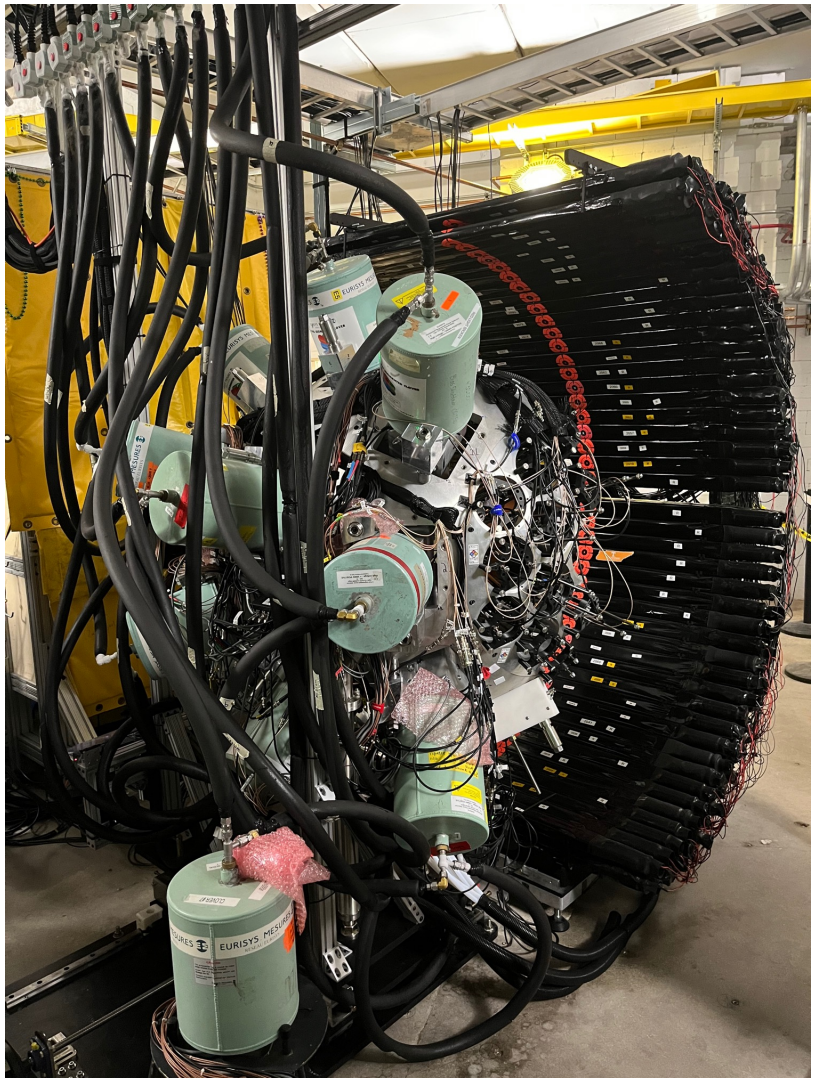


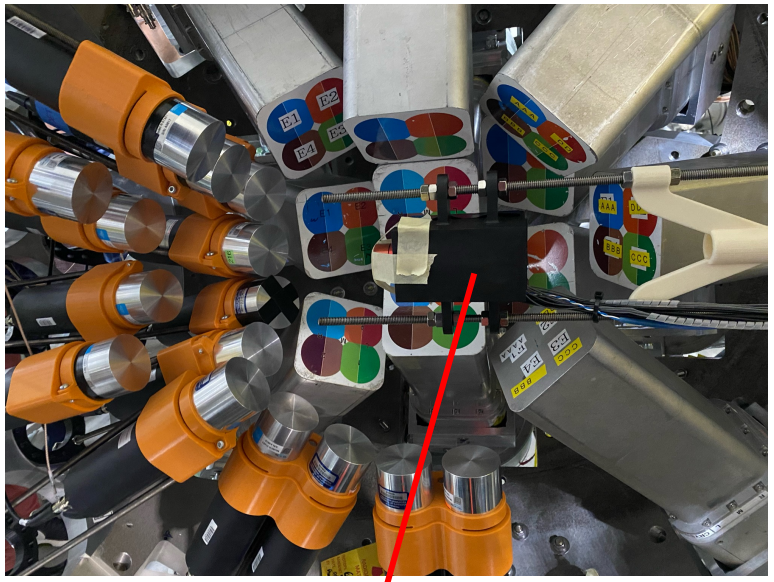


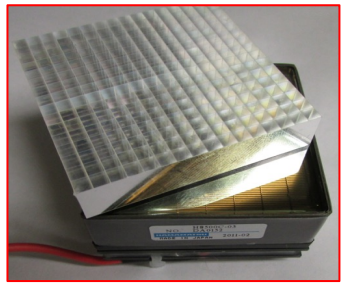
*calculated values with the SDPF-U-MIX interaction.

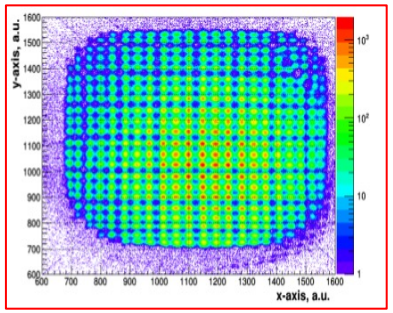
A. Poves, J. Phys. G: Nucl. Part. Phys. **44**, 084002 (2017).

The FDSi Setup in Real Life for 1st FRIB Experiment

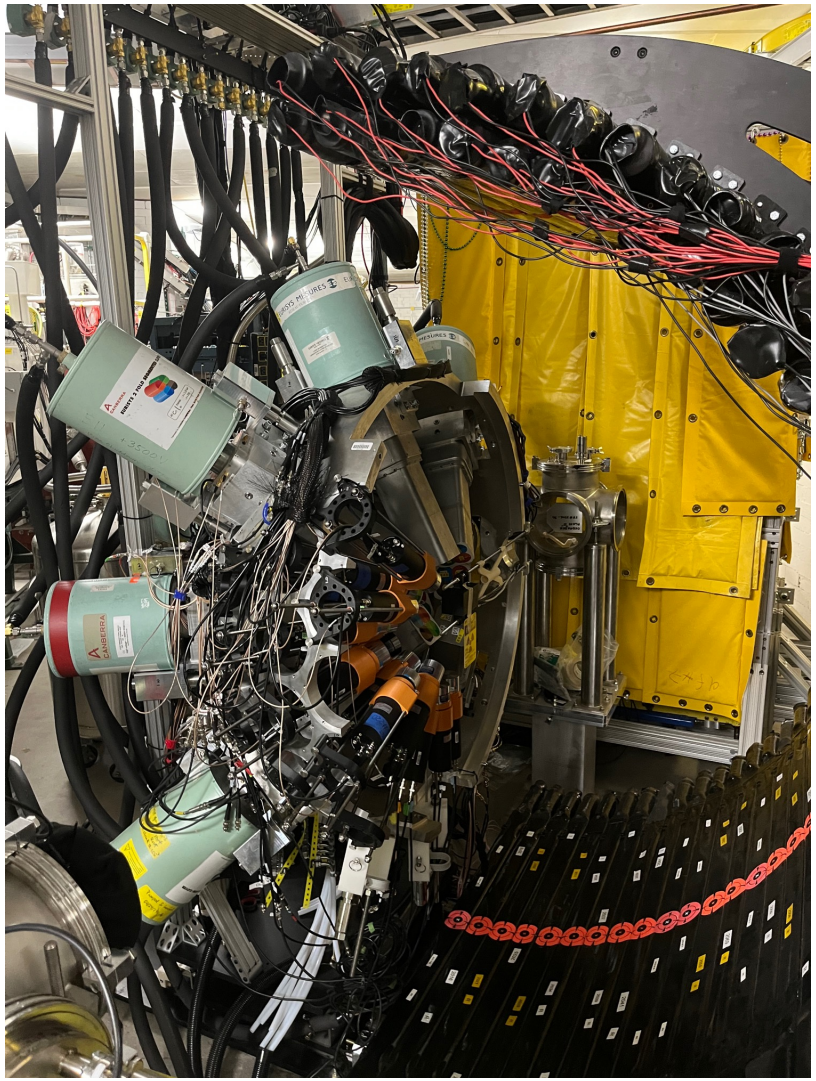






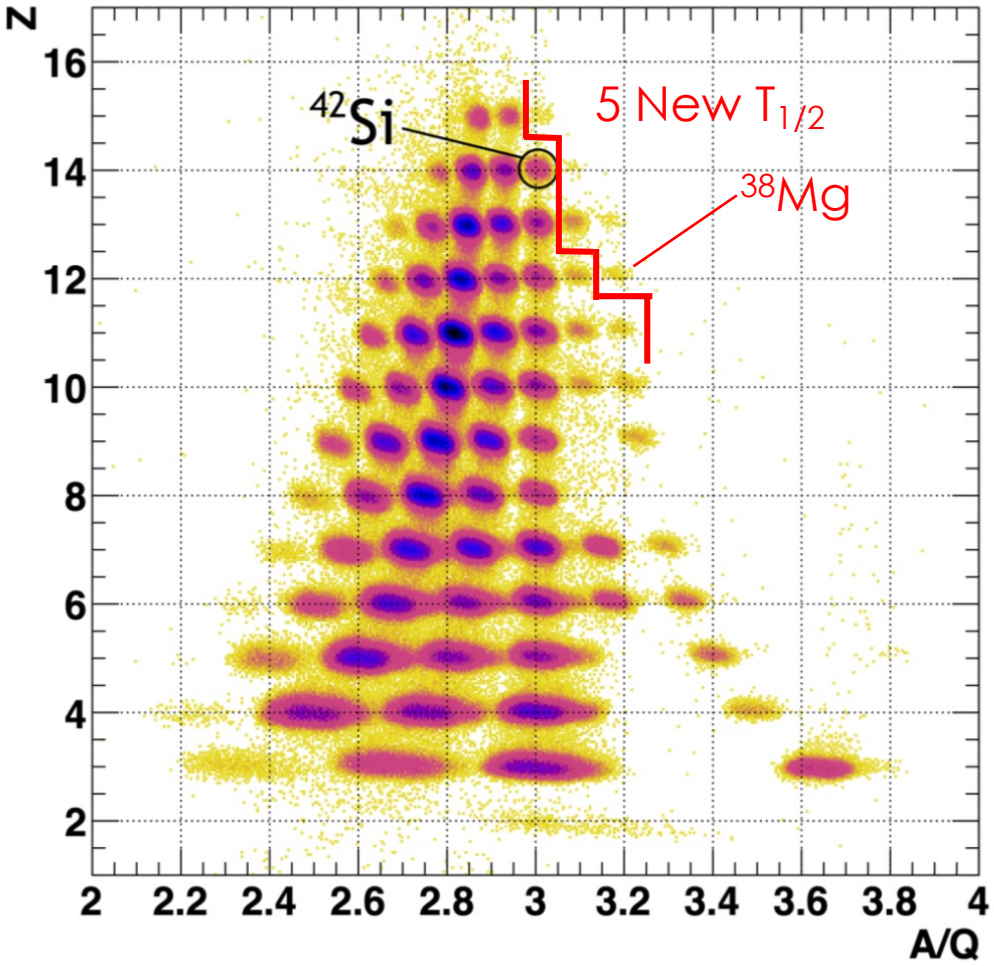


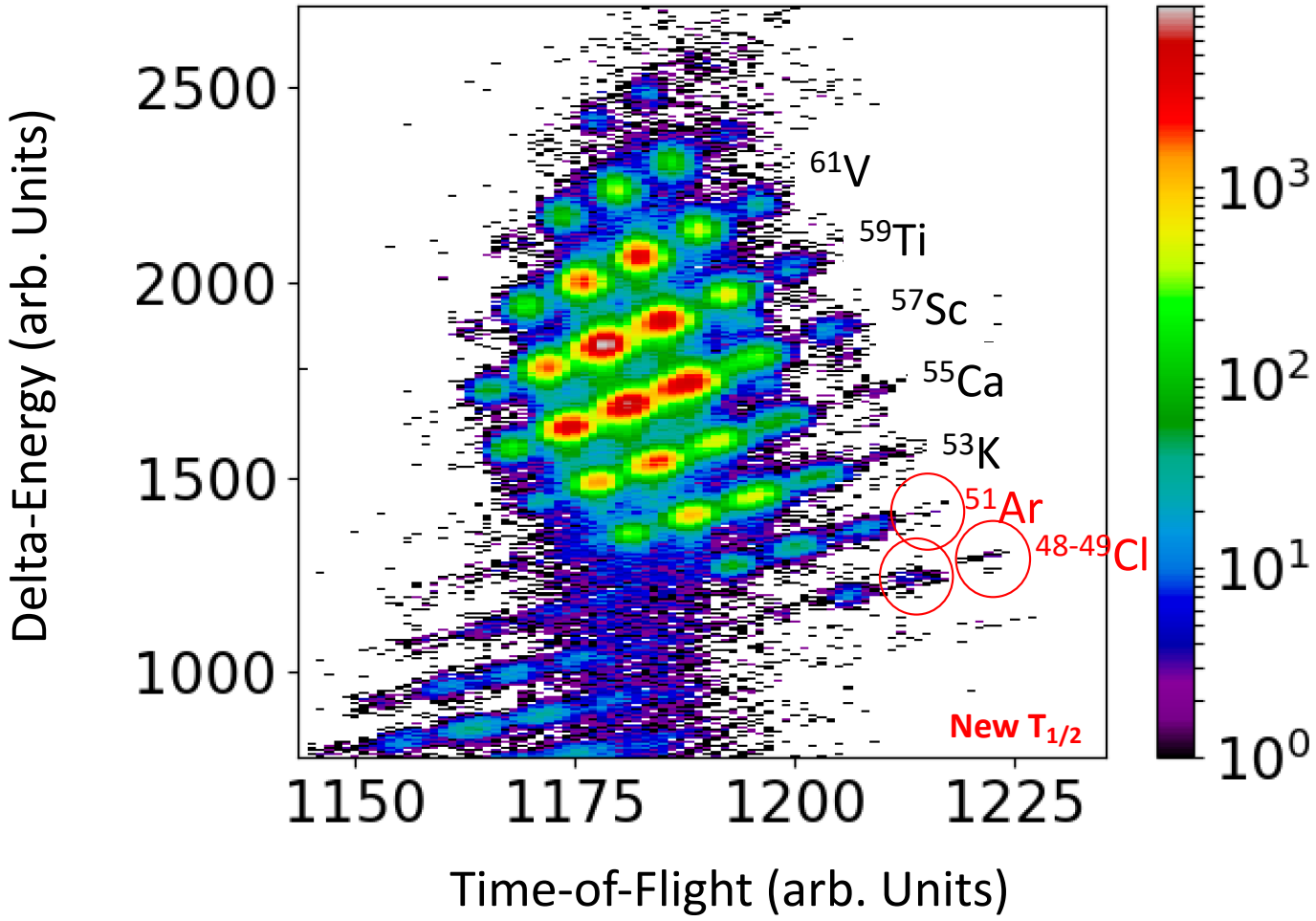
Fast YSO Implant detector from UTK



Particle Identification from First Two FRIB Experiments

Performed with 1kW of primary beam power

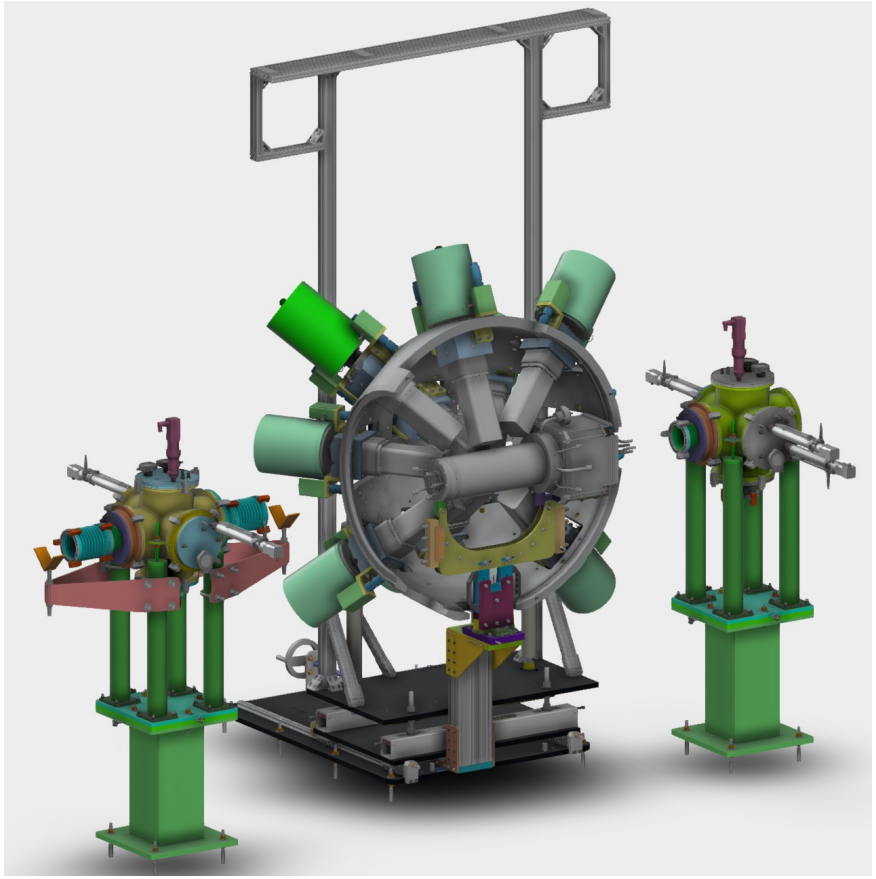


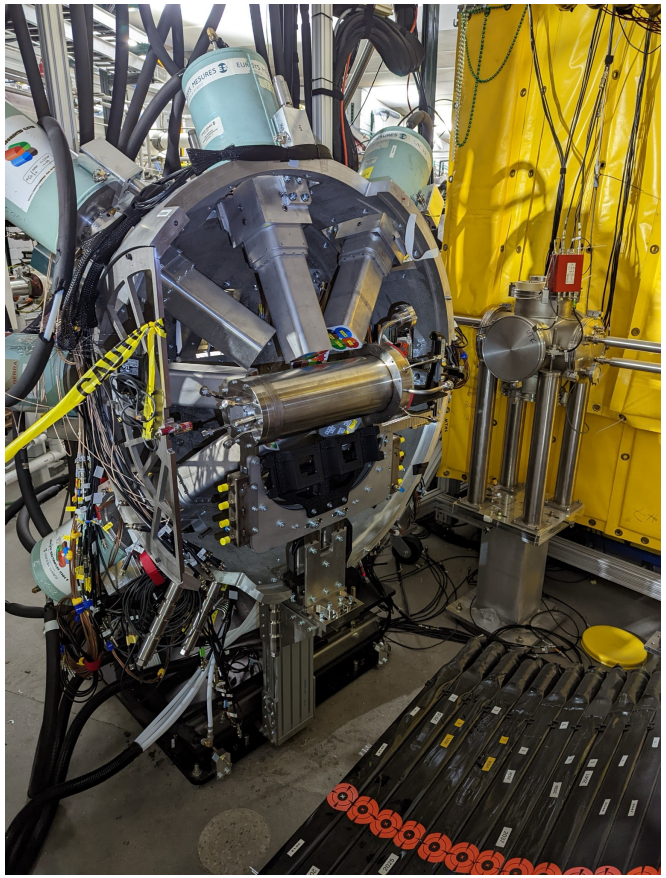


Third FDSi Experiment

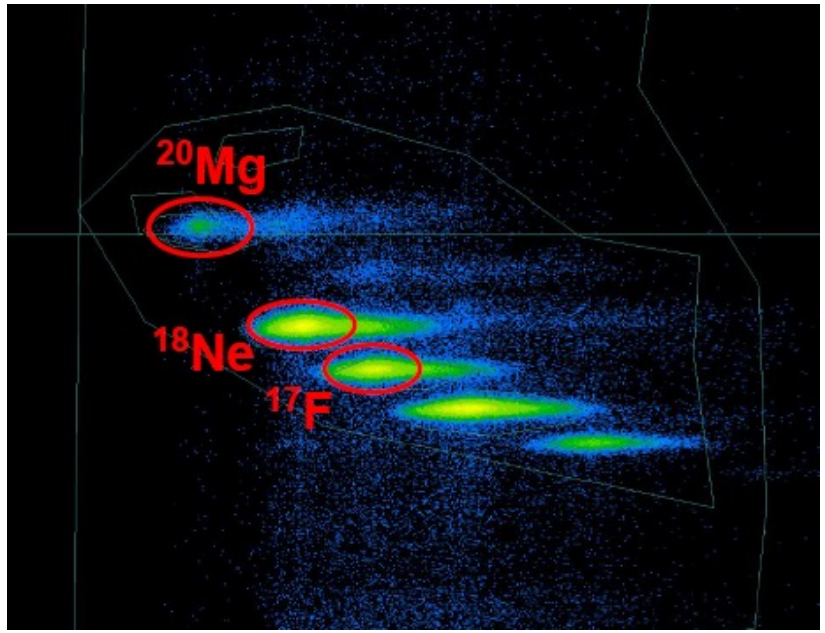
Proton-Rich ^{20}Mg – C. Wrede – FRIB-MSU

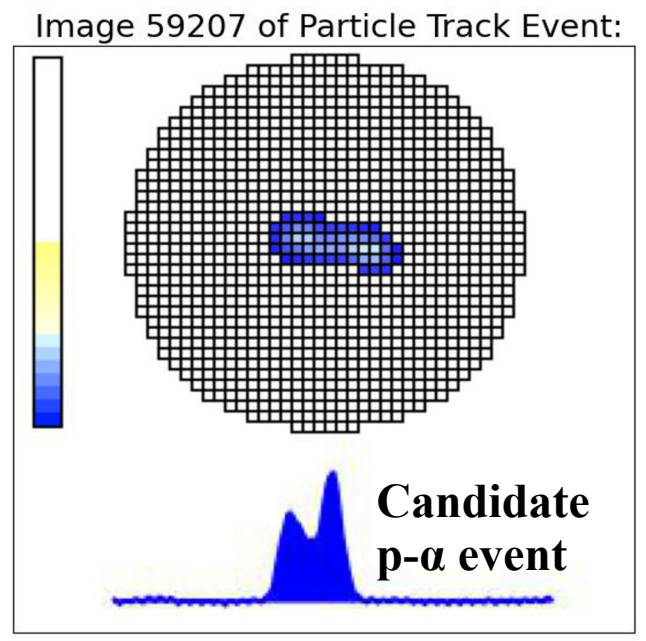
- 4th FRIB experiment, November 2022
- FDSi with GADGET2 (TPC)
- Determine $^{15}O(\alpha,\gamma)^{19}Ne$ resonance in X-ray bursts
- Search for $^{20}Mg(\beta^{+}p\alpha)$ events





ΔE-ToF





R. Mahajan, T. Wheeler *et al.* (to be submitted)

3 FDSi Publications from First FRIB Experiment (4th just accepted as PRL)

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

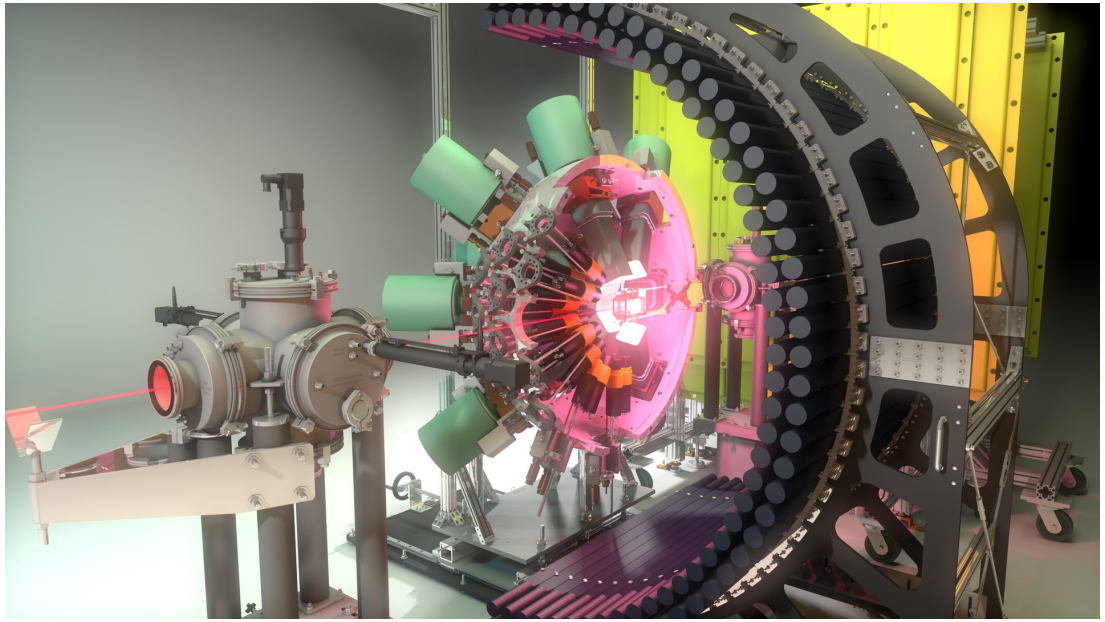
12 citations

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**

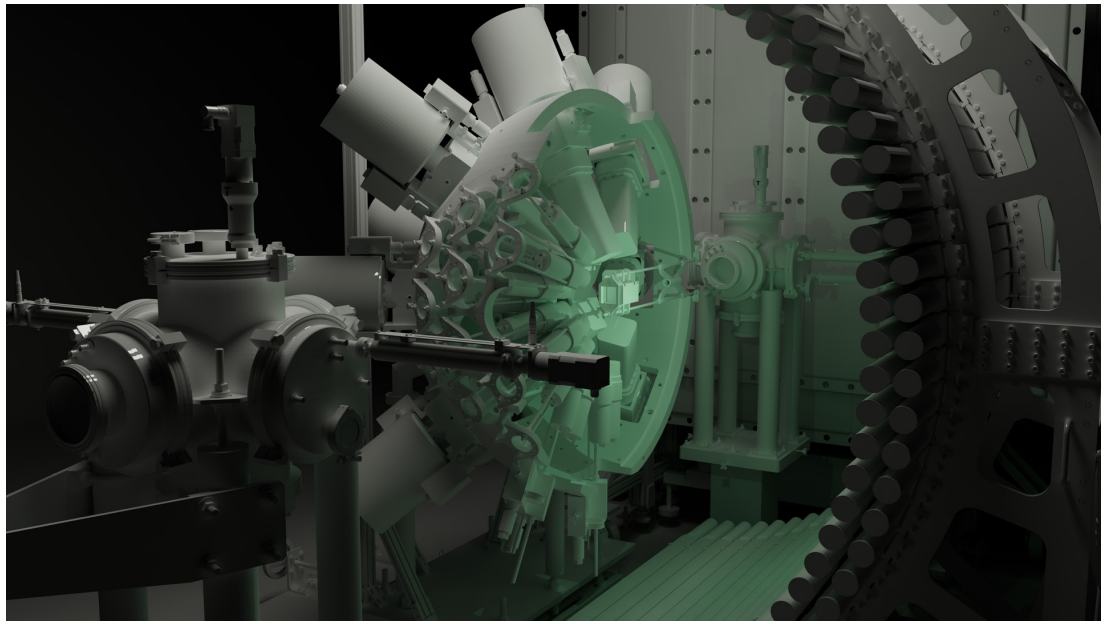
4 citations

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

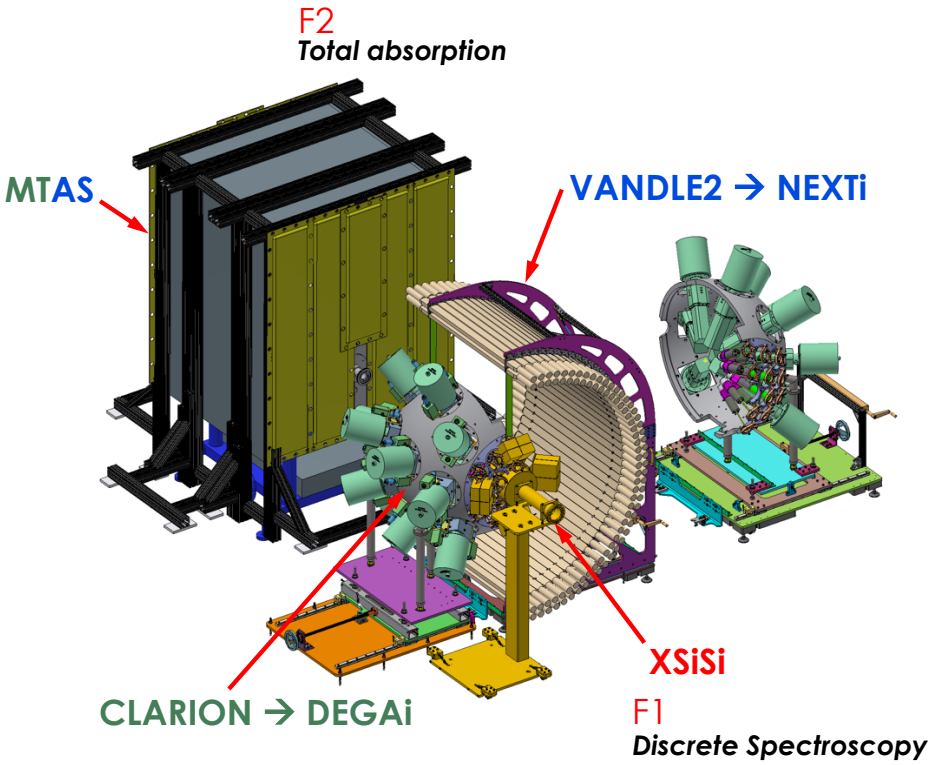
β decay of ^{36}Mg and ^{36}Al: Identification of a β-decaying isomer in ^{36}Al

R. S. Lubna *et al.*

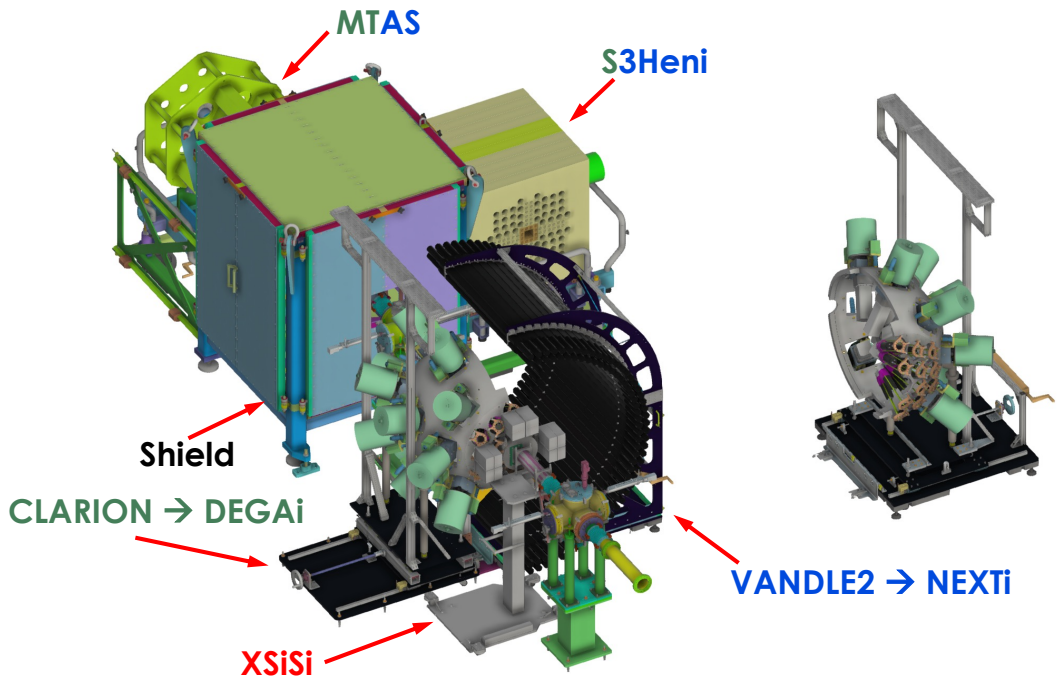
Phys. Rev. C **108**, 014329 (2023) - Published 31 July 2023

FDSi – Transition to Phase 2

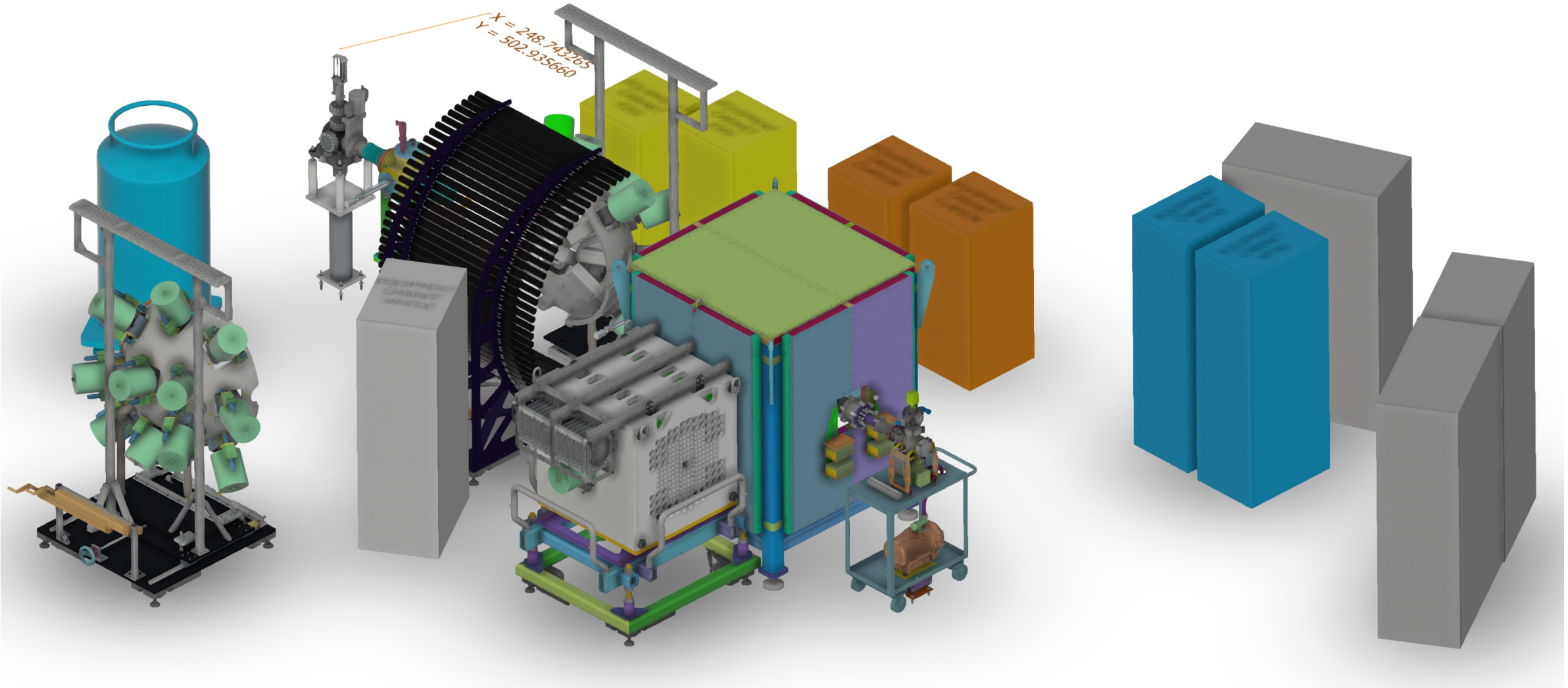
Phase 1



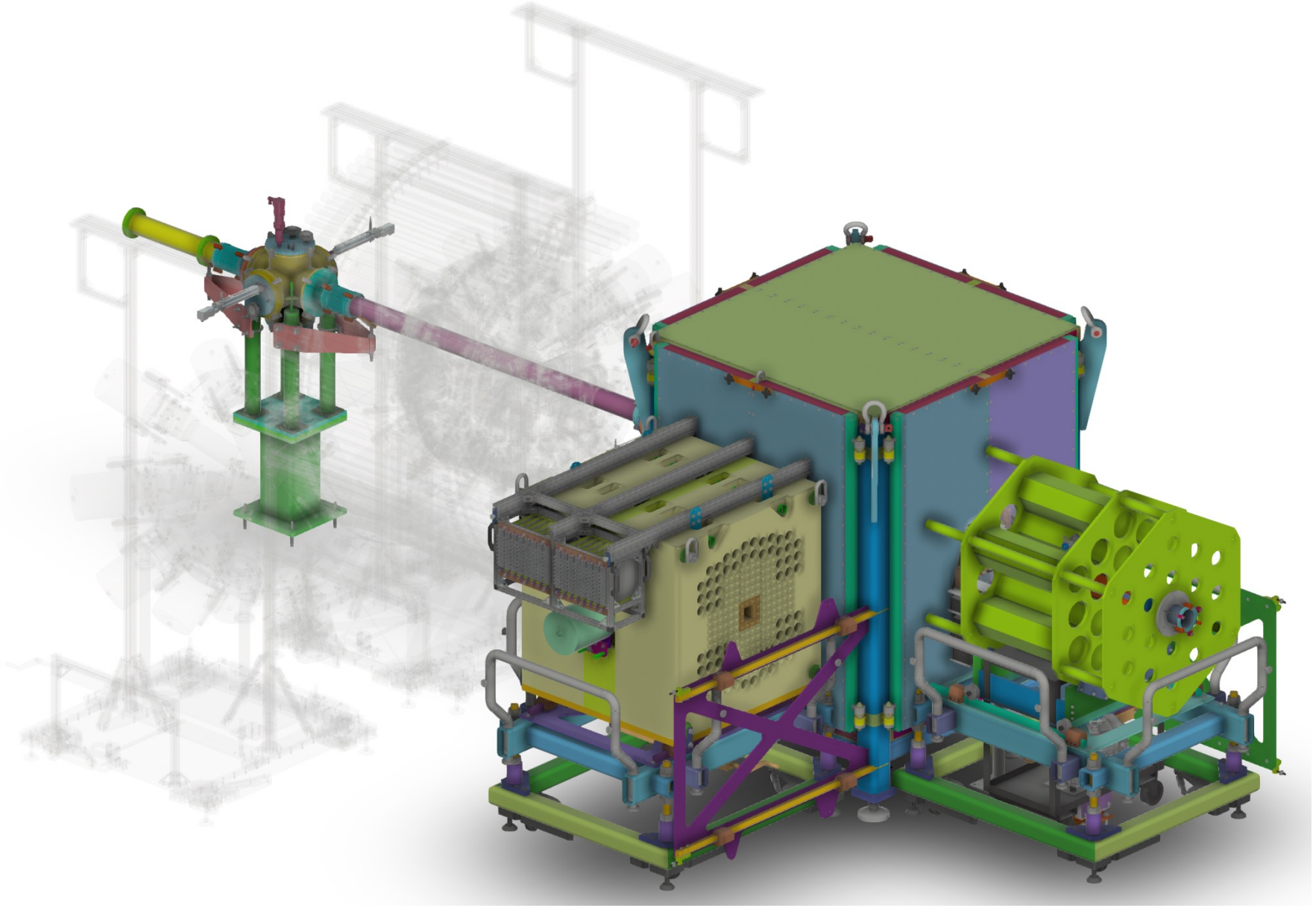
Phase 2



FDSi - Phase 2 Design



Phase 2 – New Switchyard Shielding, Carts, and S3Heni



Switchyard Shield

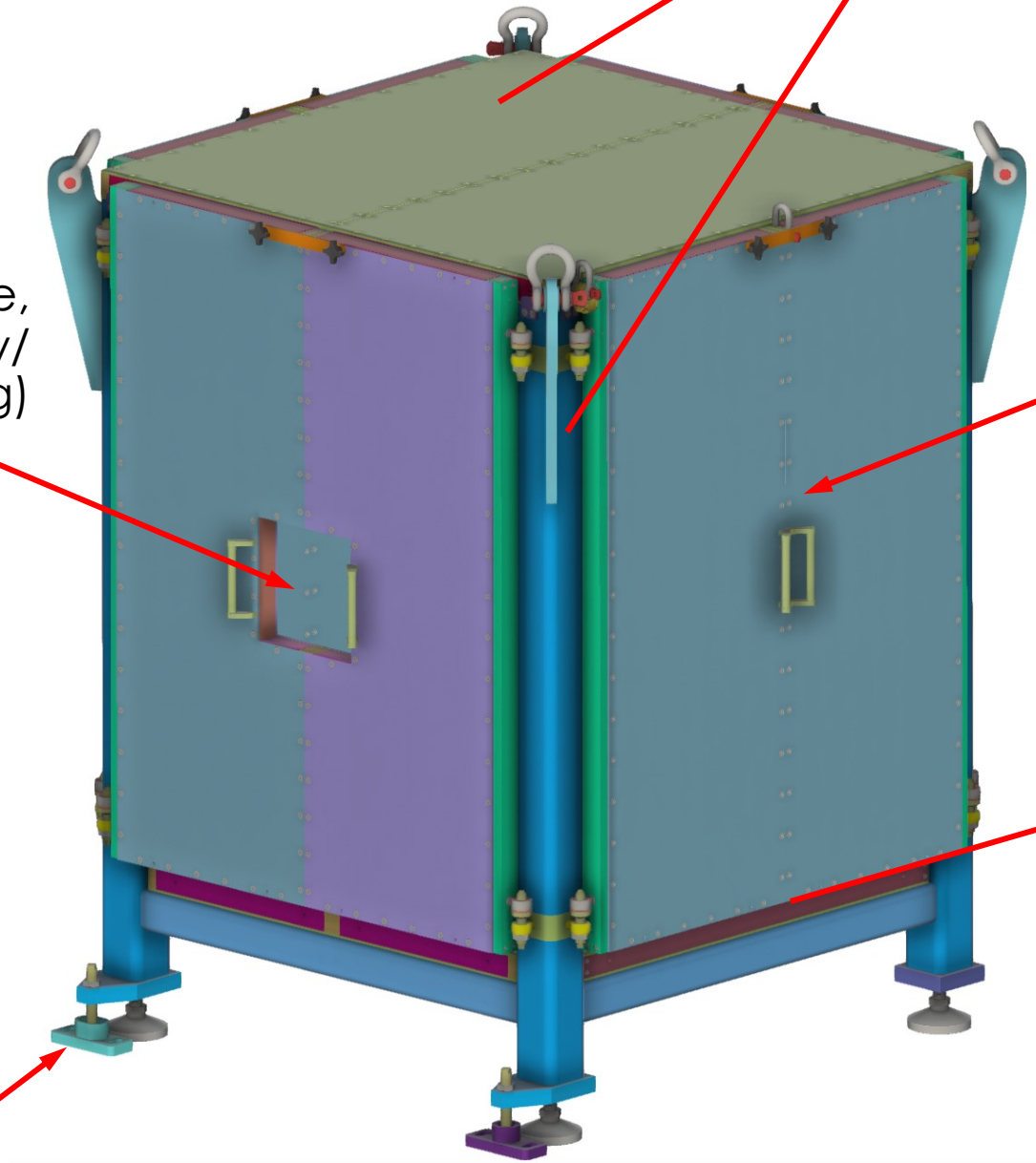
- *2-Inch lead shielding in all skins*
- *Lead-filled support frame columns*

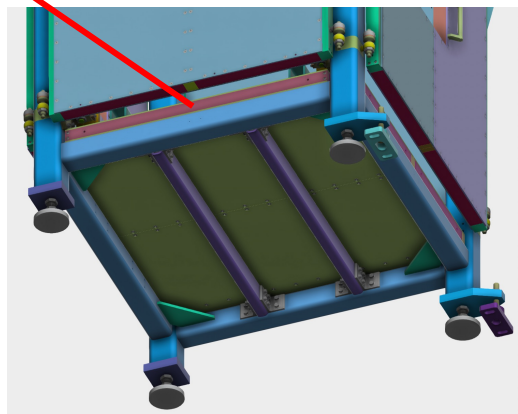
Cut out for Beam, Pipe, and Implant Detector (w/ cabling)

French doors on all 4 sides

Gap for PMT cables
(bed skirts / blankets will be hung from hooks at bottom of door)

Brings shield back into proper alignment if moved

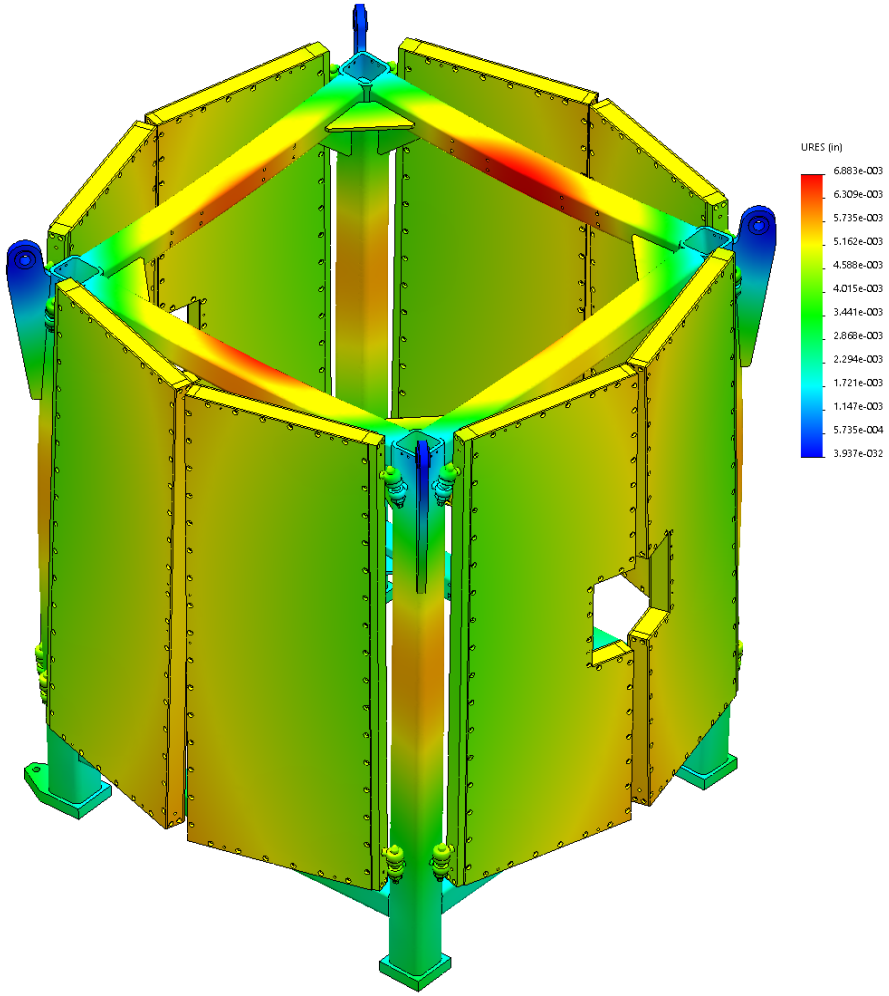




Stress Analysis of New Pb Shielding

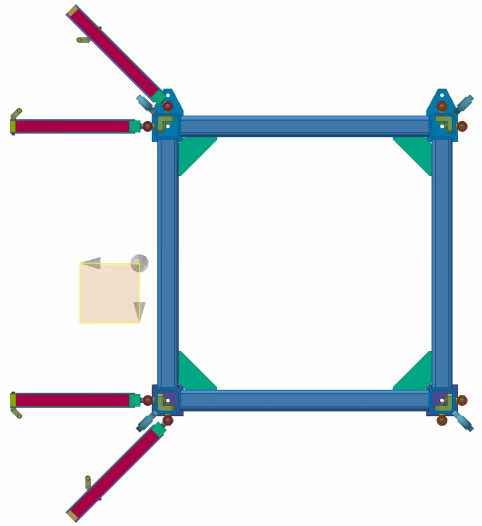
- **Stress analysis, rigidity, and stability understood**
- **Full Summary:** **MTAS shield FEA results 20221213.pdf**

MTAS Frame Assy
Scenario 1 -- Lifted
(no detector)

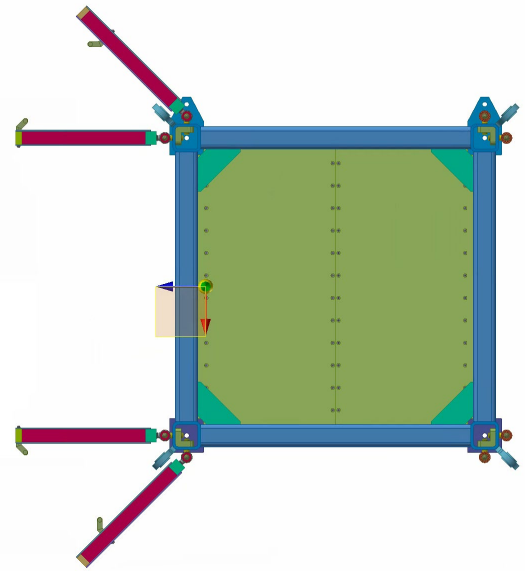


The max deflection is 0.006883 in. The deflection scale is exaggerated 250x.

If the doors shown are assembled and positioned with no internal assemblies (or other means of counterbalance), the CG is outside the stand.



If the only added counterbalance is the bottom shielding, the CG moves back inside the stand footprint.



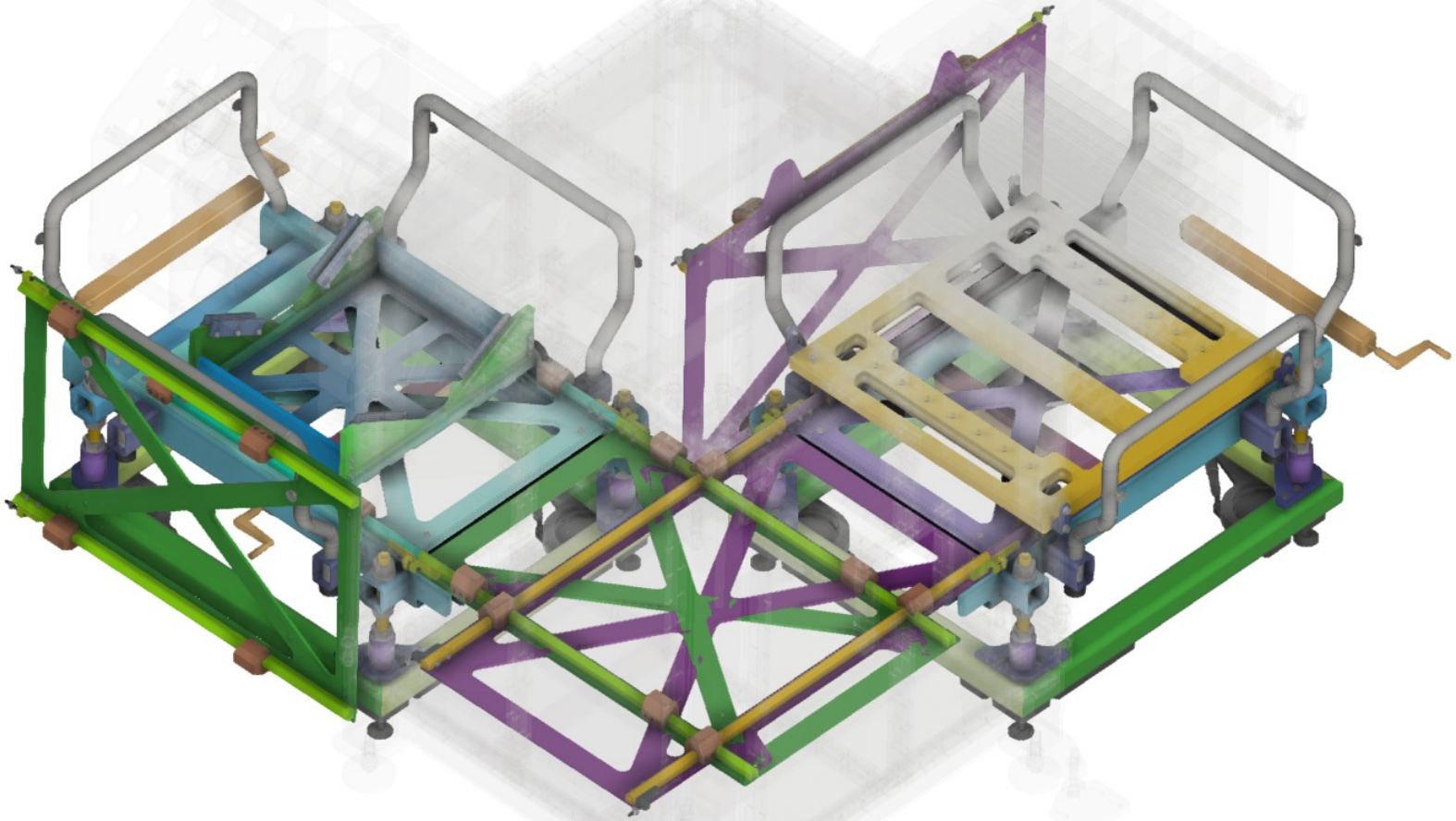
Switchyard Shield

- March 12, 2024
- Fully Assembled

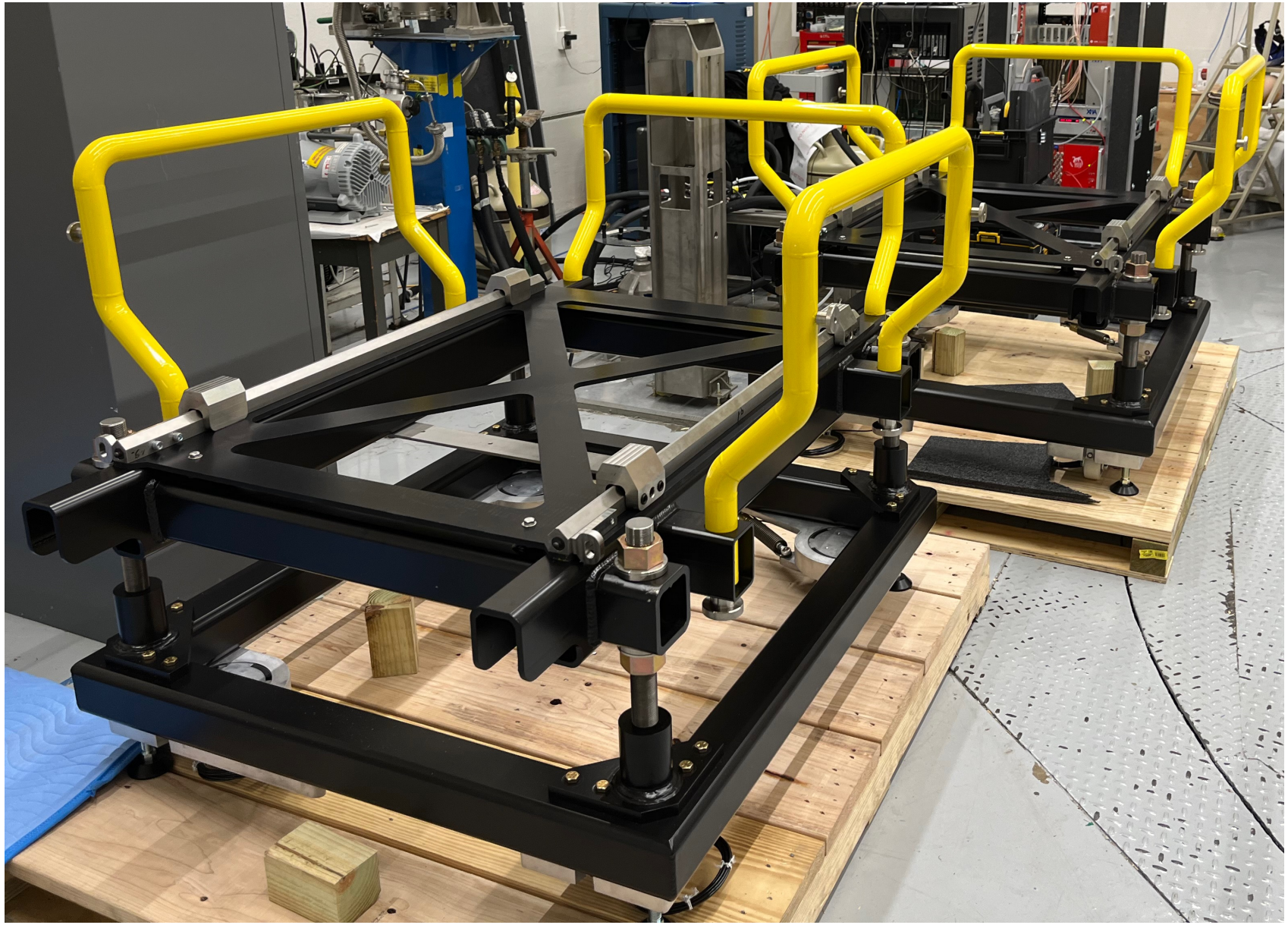
Switchyard Shield

- March 28, 2024
- Lift test 125% (15 tons) for 15 minutes
- To be painted next and then shipped to FRIB

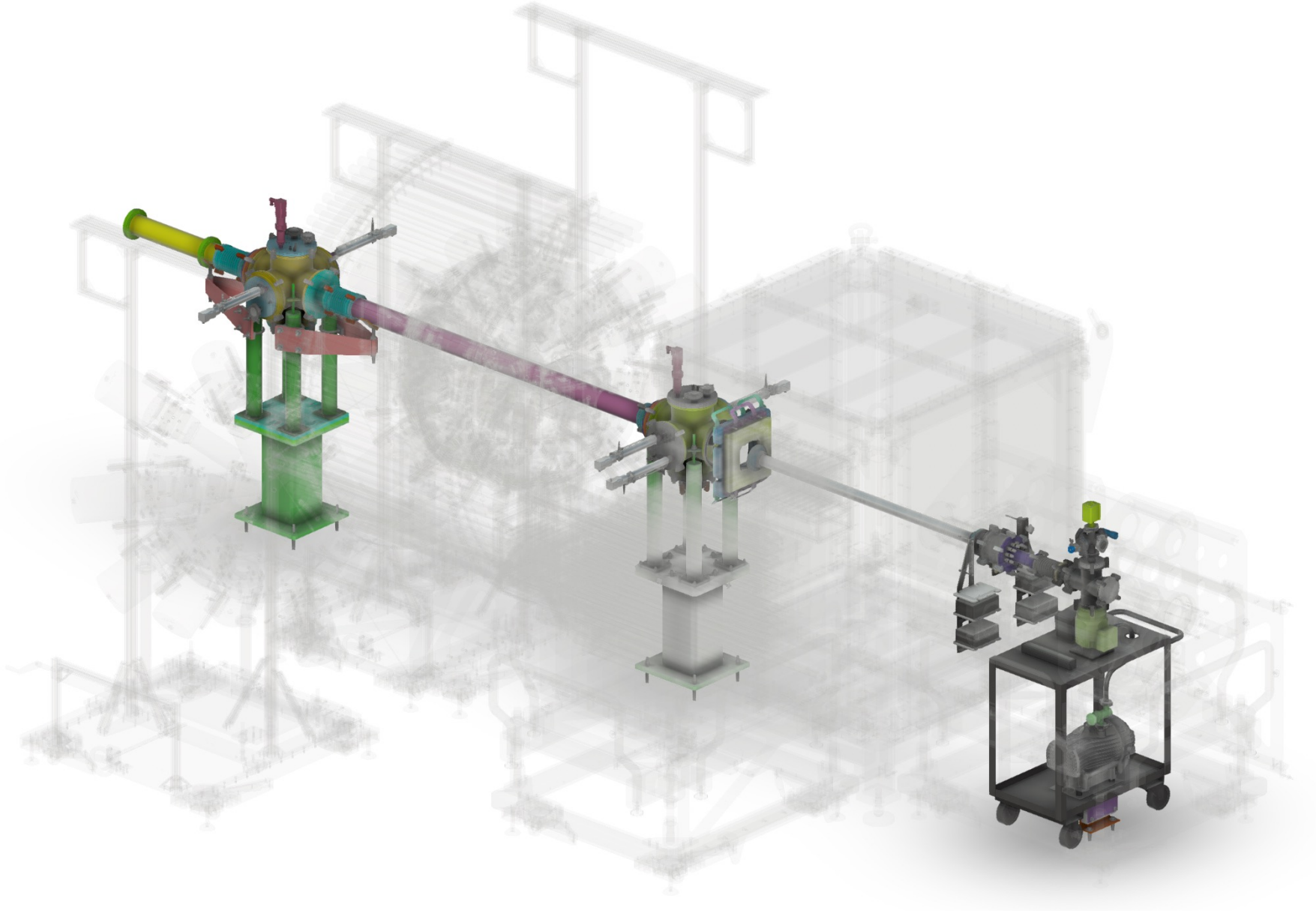
S3Heni and MTAS Carts and Rails – Shield Compatible



S3Heni and MTAS Carts and Rails – Shield Compatible



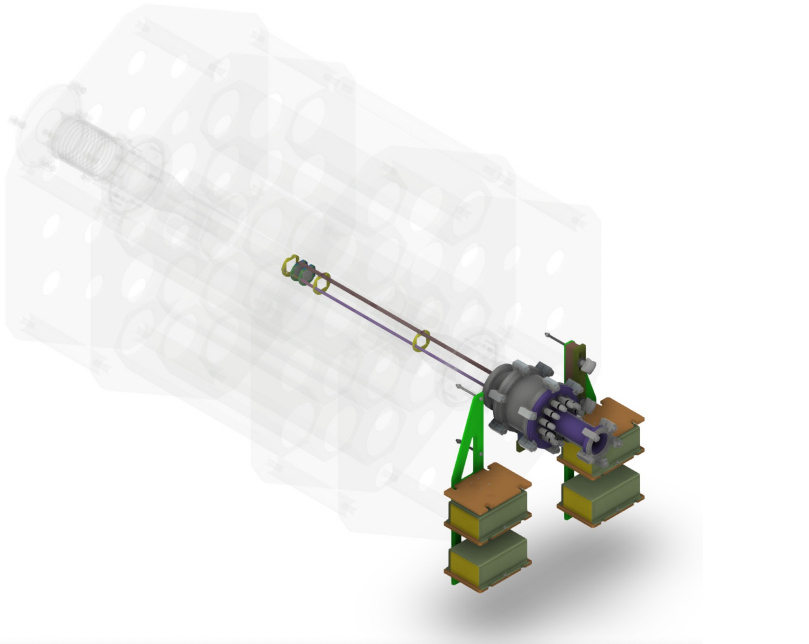
Phase 2 – New Beamline, Feedthroughs, Pump Station



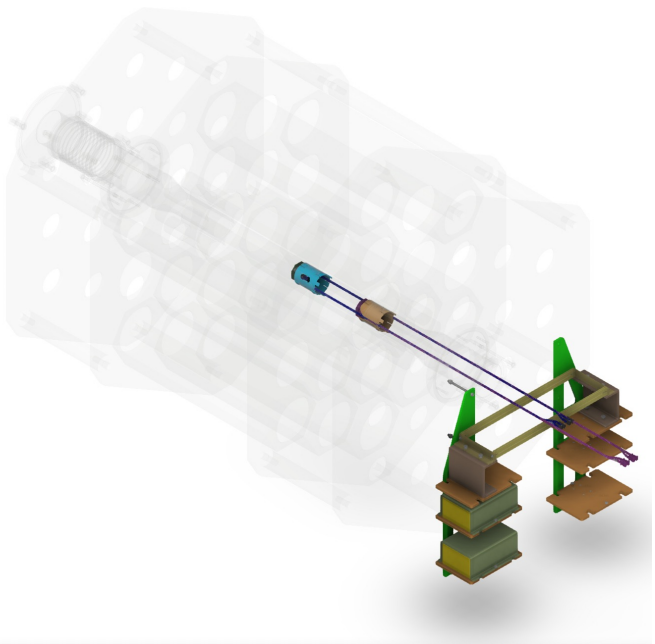
Beamline + Pump Cart Configurations

In Air configurations, when possible, maximize implant surface

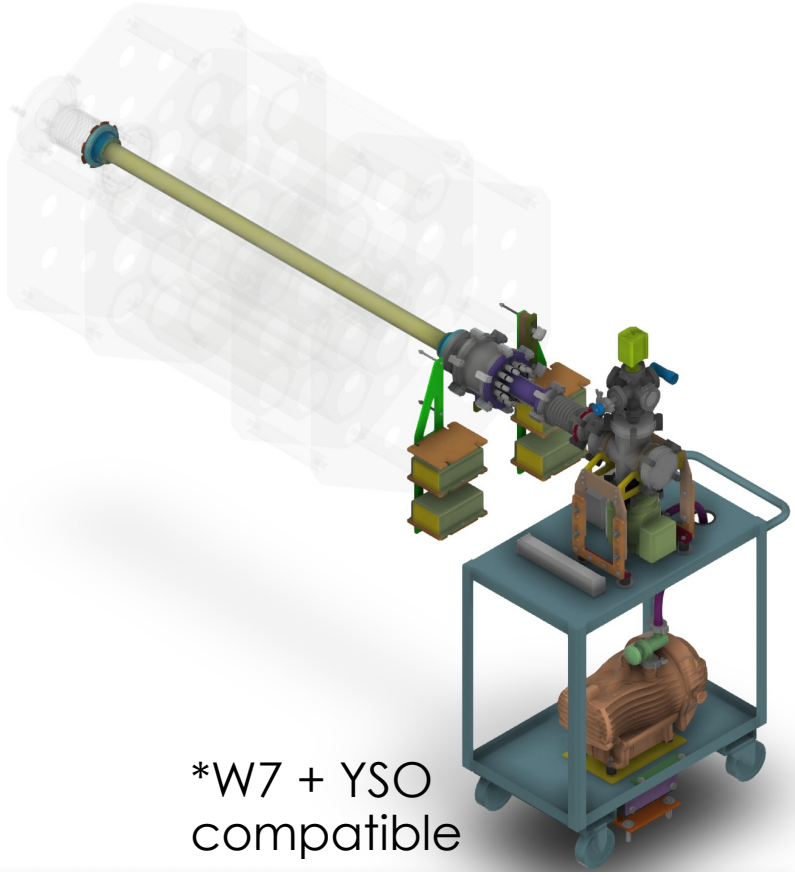
W5 IN AIR CONFIGURATION



YSO IN AIR CONFIGURATION

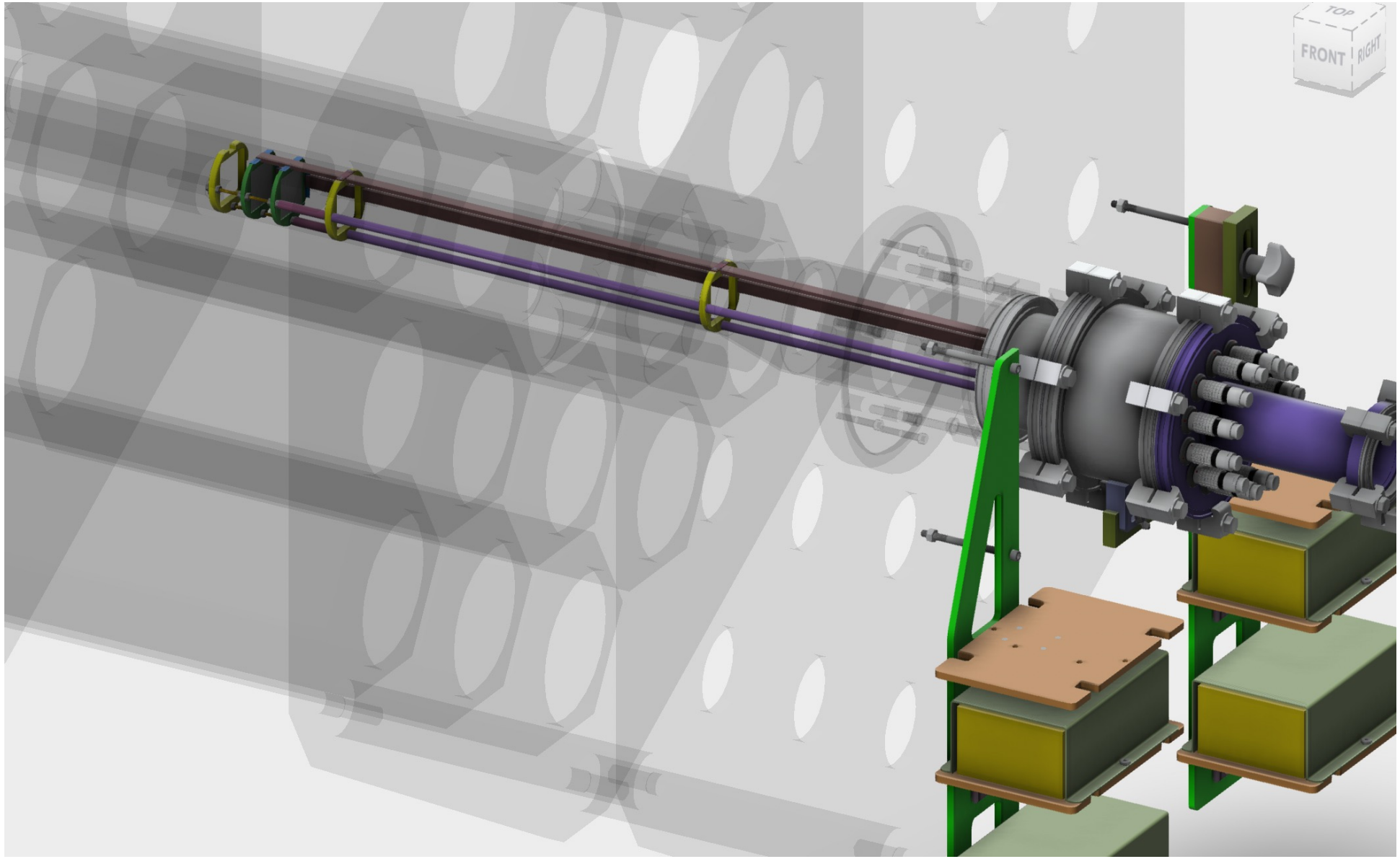


W7 IN VACUUM CONFIGURATION

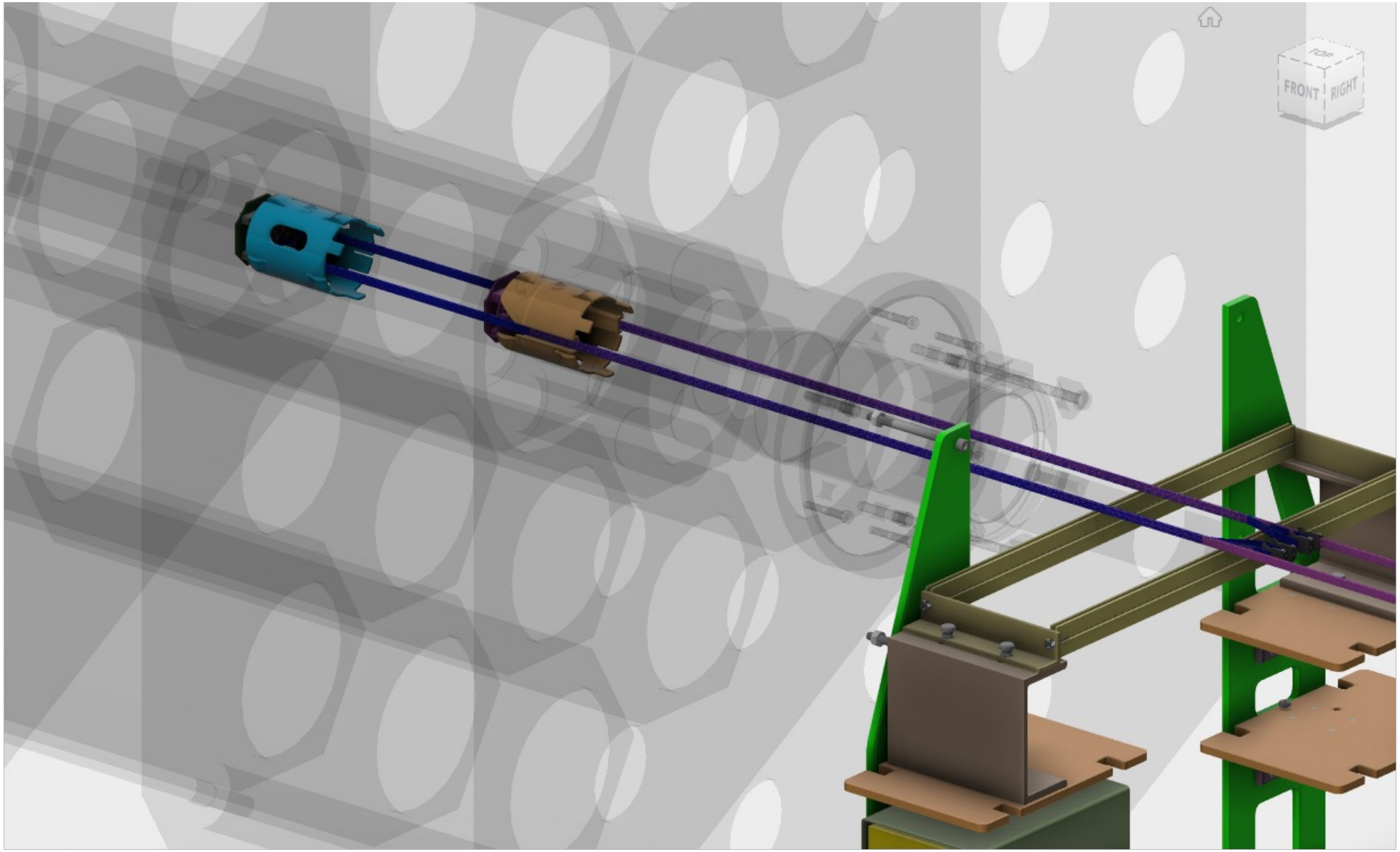


*W7 + YSO compatible

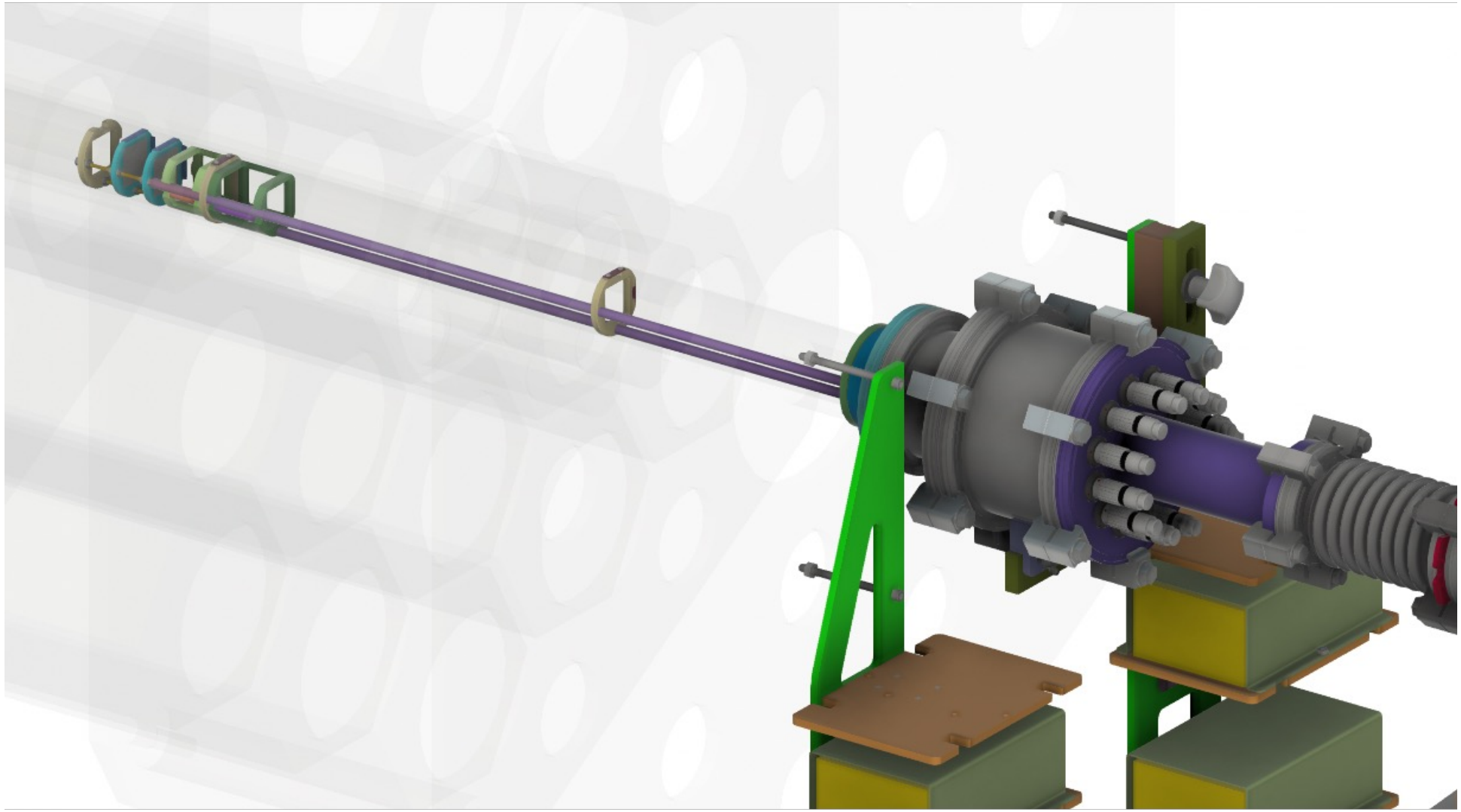
W5 IN AIR CONFIGURATION



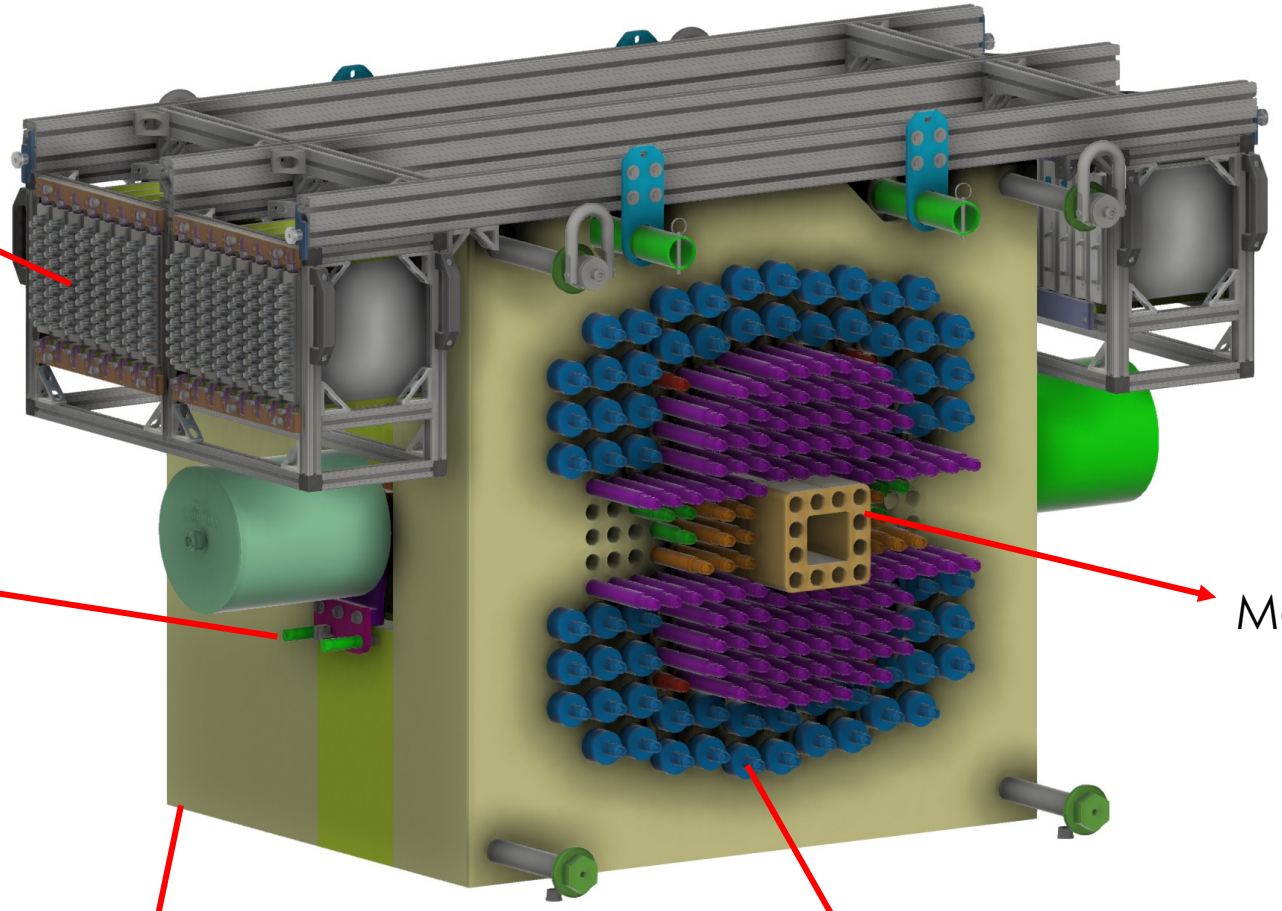
YSO IN AIR CONFIGURATION



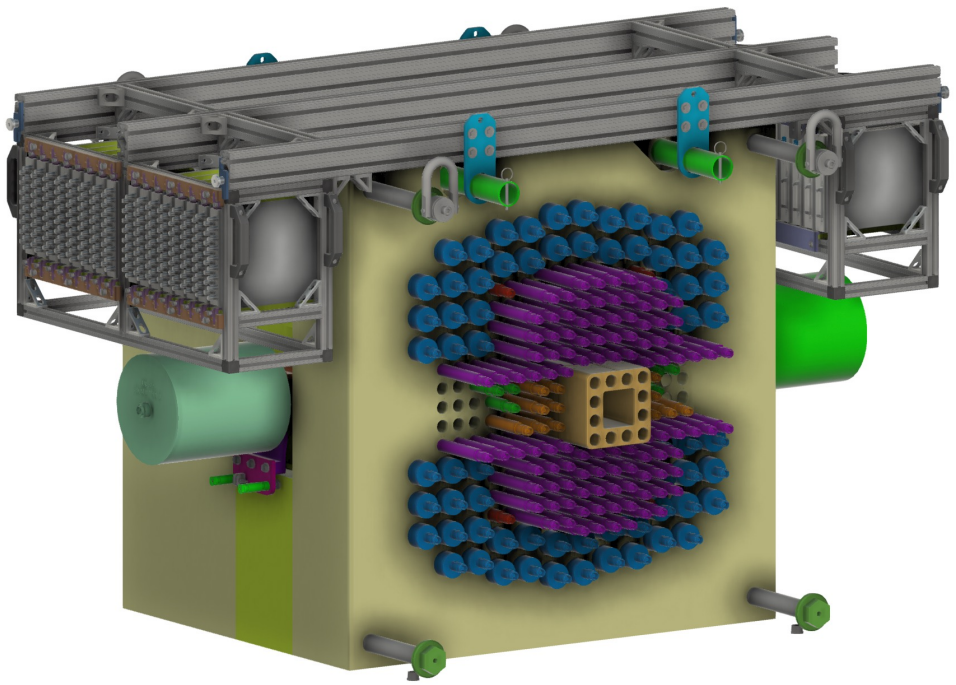
W7 IN VACUUM CONFIGURATION (+YSO Compatible)



Phase 2 – S3Heni

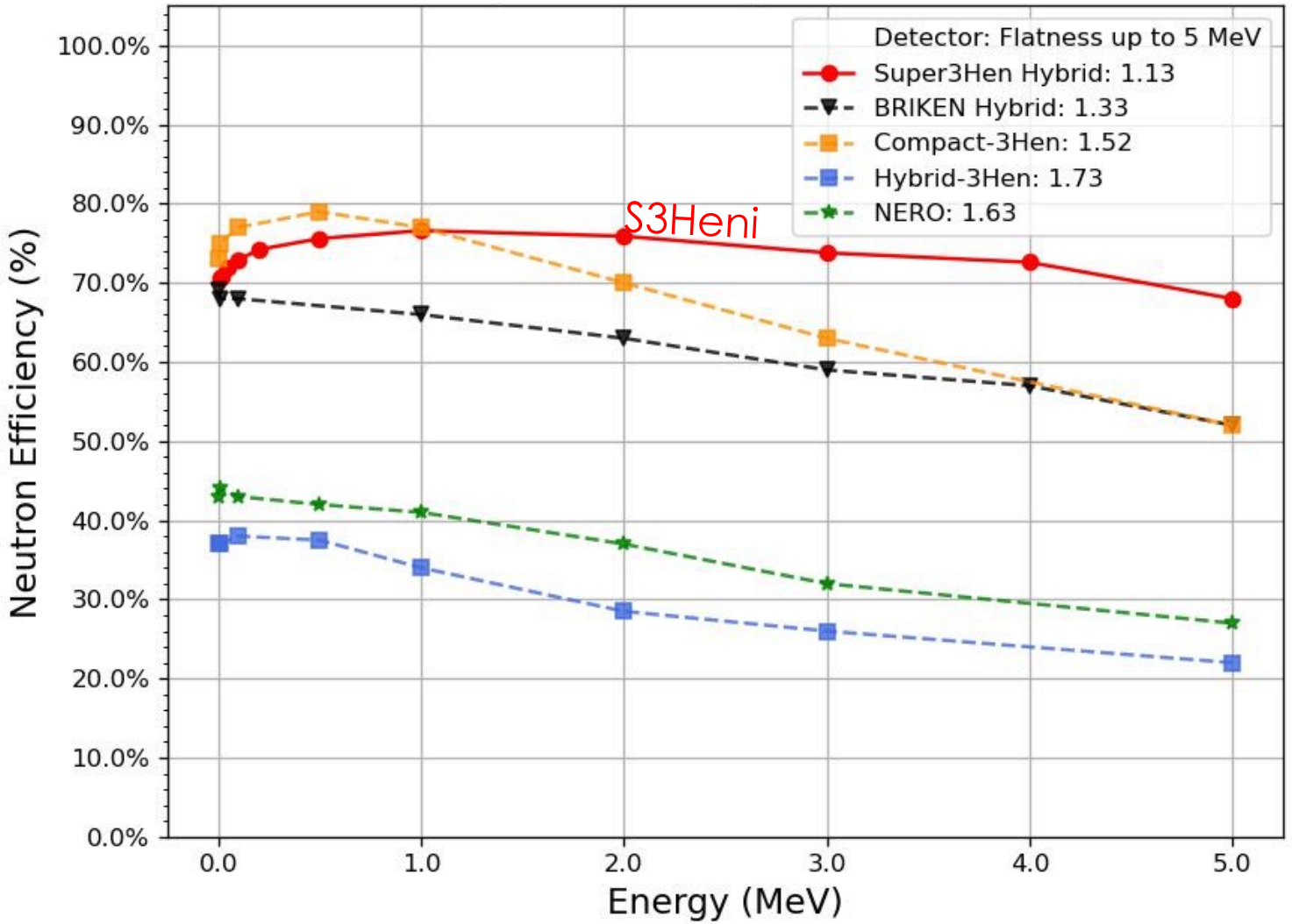


Phase 2 – S3Heni



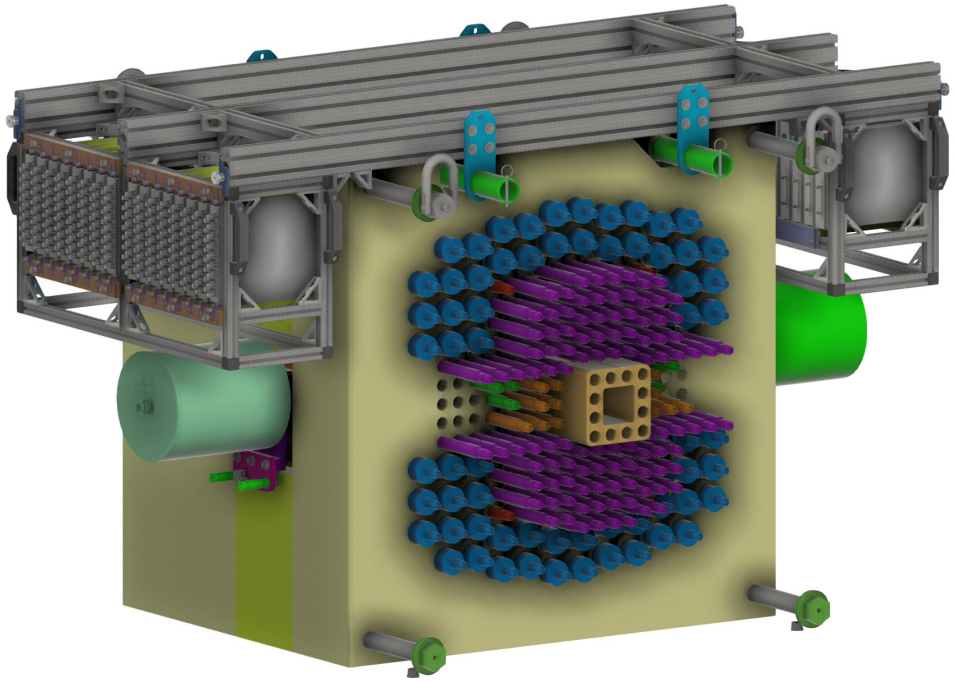
^{3}He tubes (240-264):

69	- 2” x 24” (ORNL)
16	- 1” x 24” (ORNL)
47	- 1” x 12” (ORNL)
96-120	- 1” x 32” (ORNL-NNSA)
12	- 1” x 10” (FRIB-MSU)

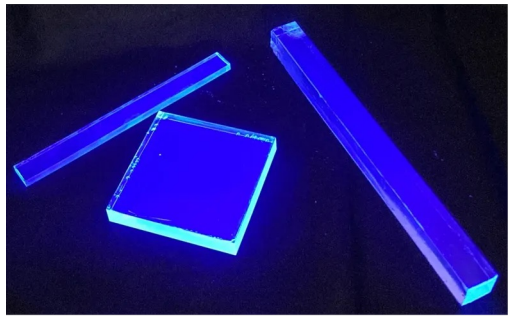


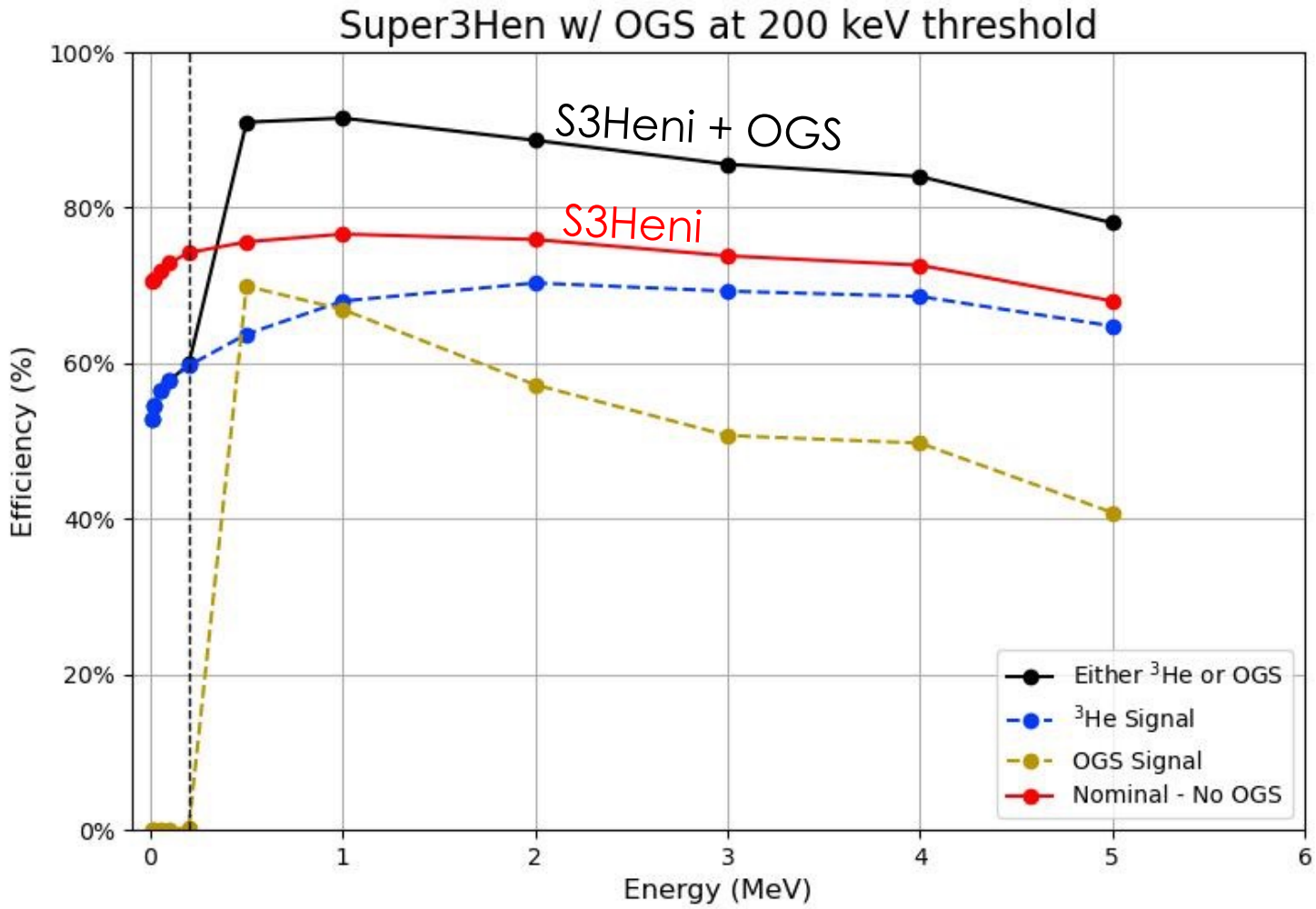
Parallel simulations:
MCNP - James Huffman (MSU)
GEANT4 - Charlie Rasco (ORNL)

Phase 2 – S3Heni with OGS Central Module



OGS solutions by UTK, Grzywacz

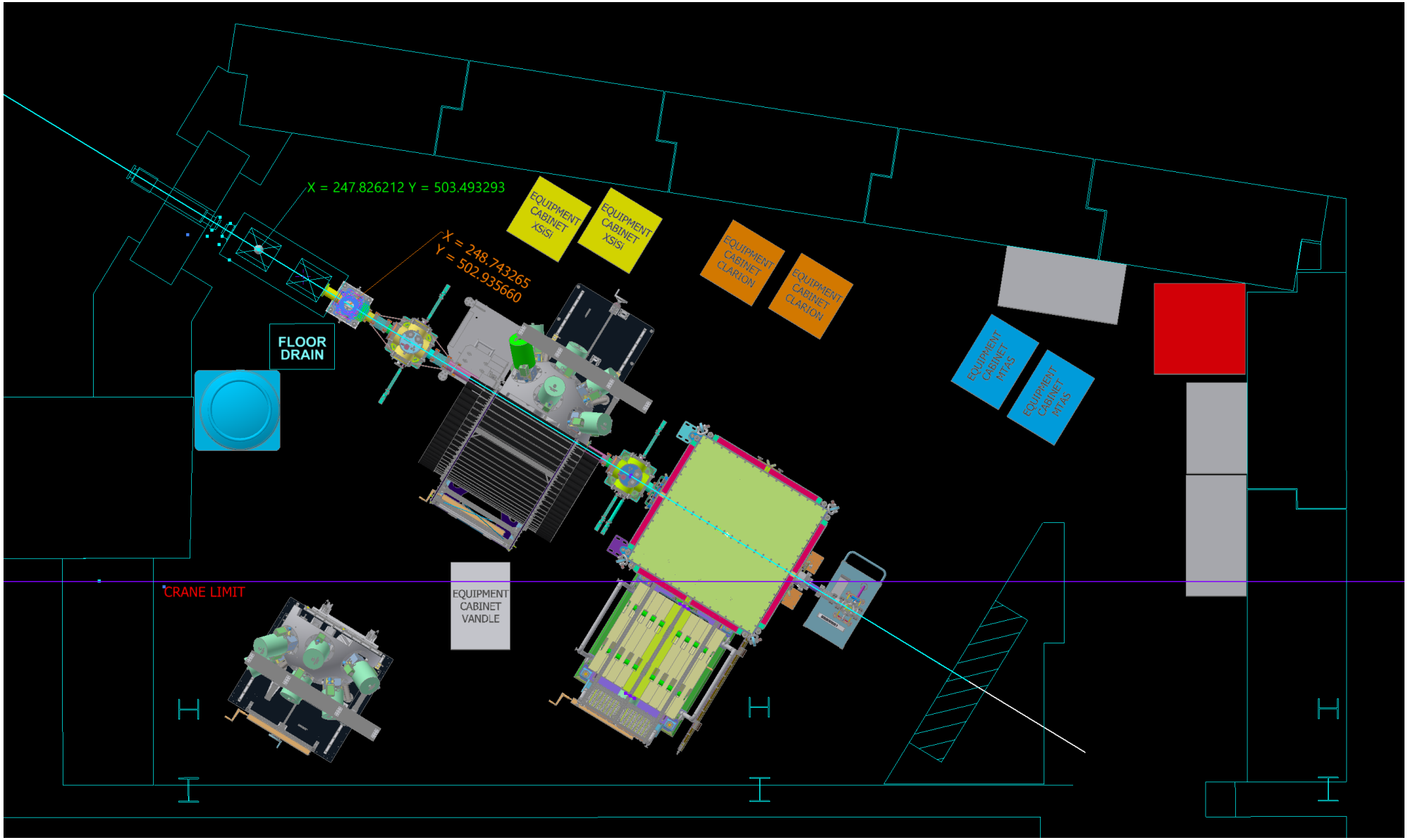




simulation:
MCNP - James Huffman (MSU)

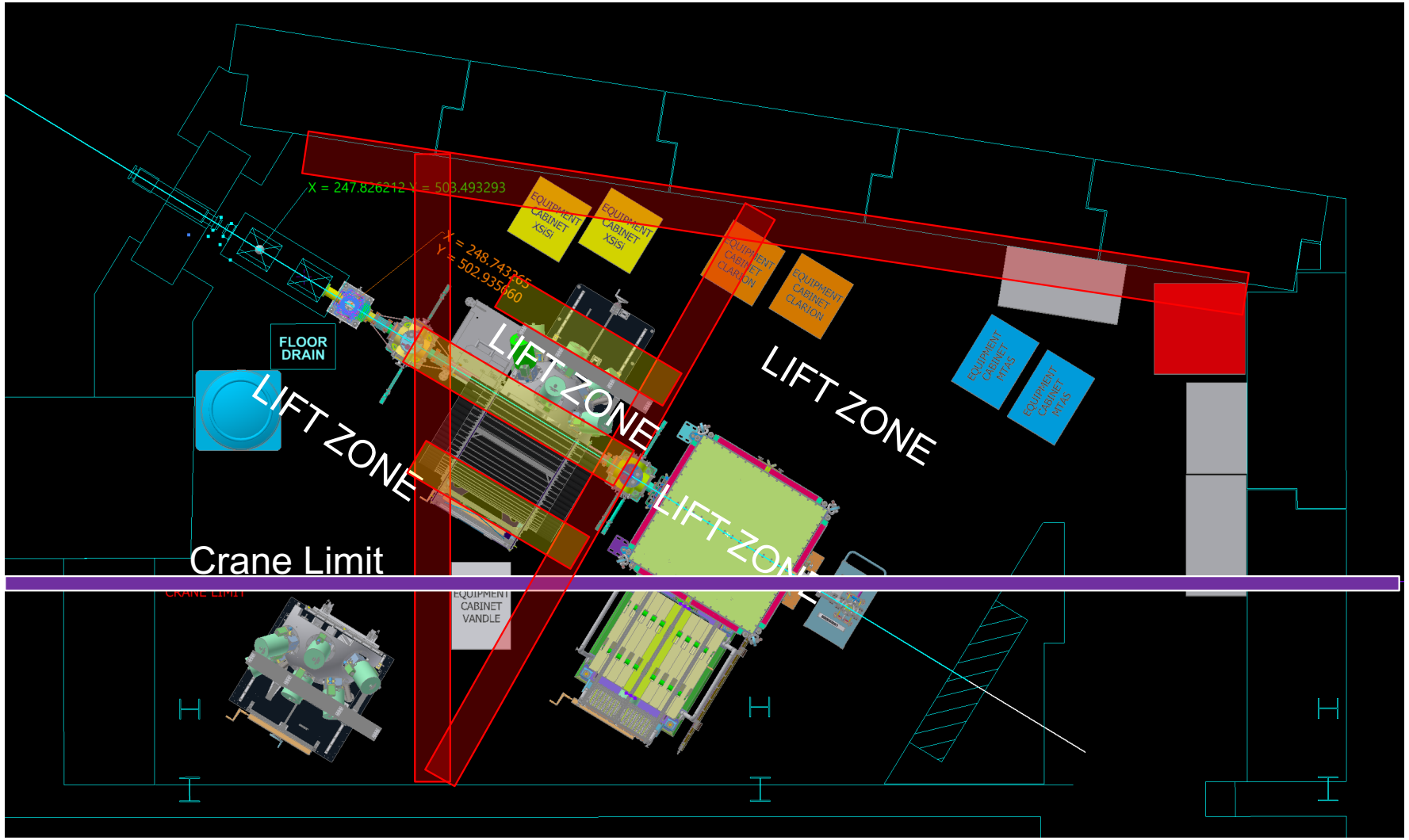
OAK RIDGE National Laboratory

Phase 2 – Room Layout



OAK RIDGE National Laboratory

Preliminary: Utility and Cable Tray Layout



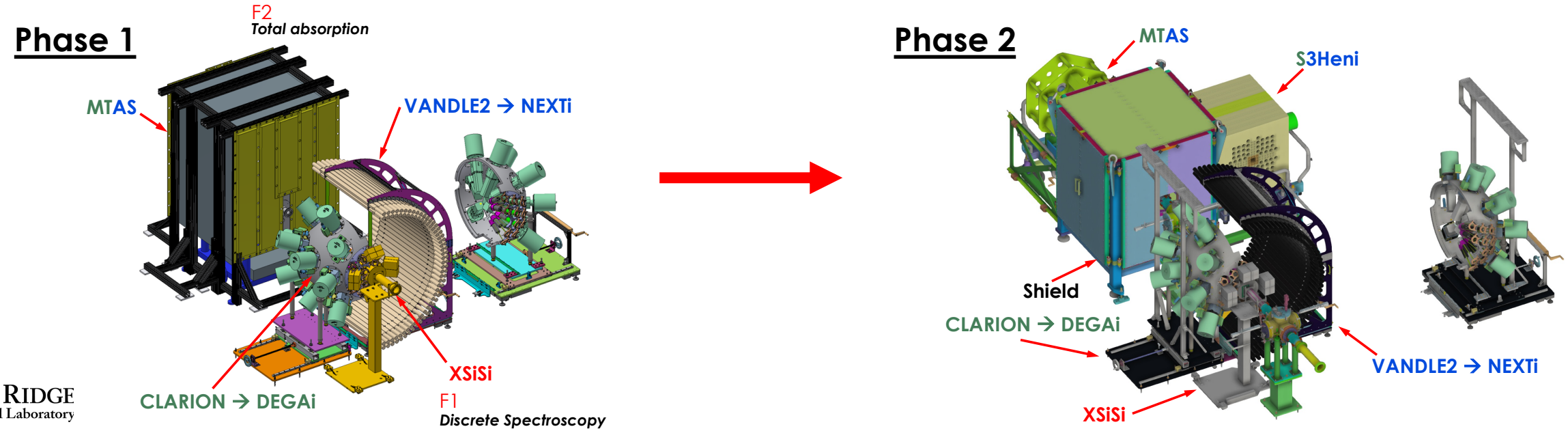
*Post free cable trays

*Utilities accessible from trays

Cable tray at 10'-11', FDSi interference at ~ 9.5'
Bottom of tray currently at 119" in transfer hall which is good

FDSi - Phase 2 Progress and Schedule

- Integrate GADGET2 - completed
- Extra DEGAi, XSiSi, MTAS, and Cross electronics & Si detectors - ordered
- Misc. Honeycomb and YSO extension-alignment parts - completed
- New shield structure with switchyard compatibility - Assembly finished
- Switchyard compatible carts for S3Heni and MTAS - Assembly finished
- Shield compatible beamline + pump cart for MTAS and S3Heni - In fabrication
- New Super 3Heni (S3Heni) neutron-counter array - in fabrication
- Utility and cable tray layout - in progress
- Misc. small parts - in progress
- Installation in permanent vault - Fall 2024



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

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Project Management:	Mitch Allmond
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FDSi Coordination:	Robert Grzywacz (Spokesperson) Sean Liddick Darek Seweryniak Mitch Allmond
Facility Engineer:	Ben Arend
Alignment Engineer:	Dave Sanderson
FDSi Engineer:	Gary Hollenhead
XSiSi Engineer:	Russ Knaack
Engineer Support	Toby King

FDSi Group:

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•**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!