Things Bartoszek Engineering has worked on

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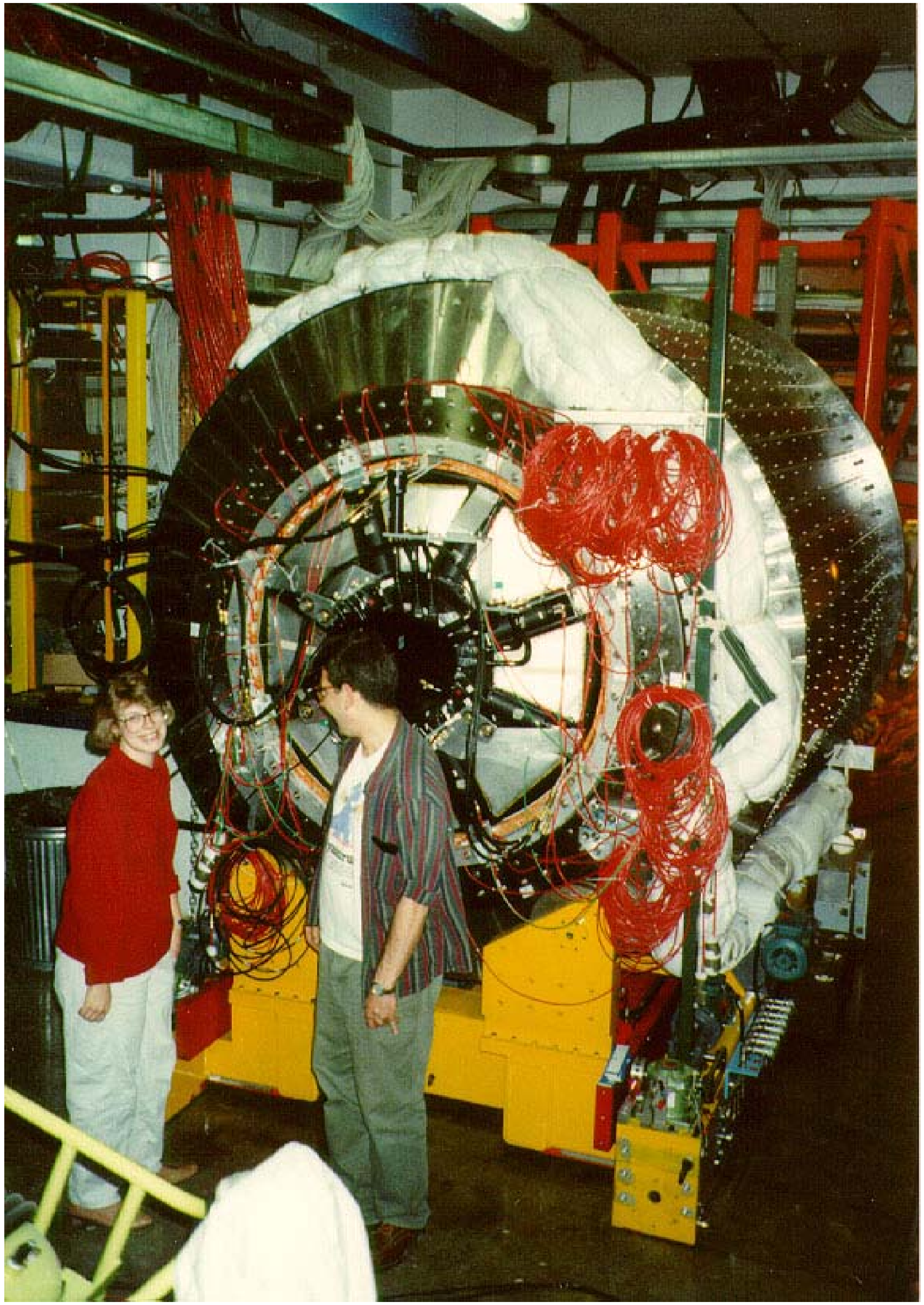
6/16/19

What I hope to accomplish here

- These slides show in a few pictures what Bartoszek Engineering has been doing since its inception in 1990
- Eventually, I would like to include short summaries of what each experiment was looking for and how it all relates to the Big Picture of modern Physics
- I hope you enjoy!

I first designed this one while employed at FNAL. BE was hired to move it a couple of times after I left FNAL.



The E760 calorimeter at Fermilab

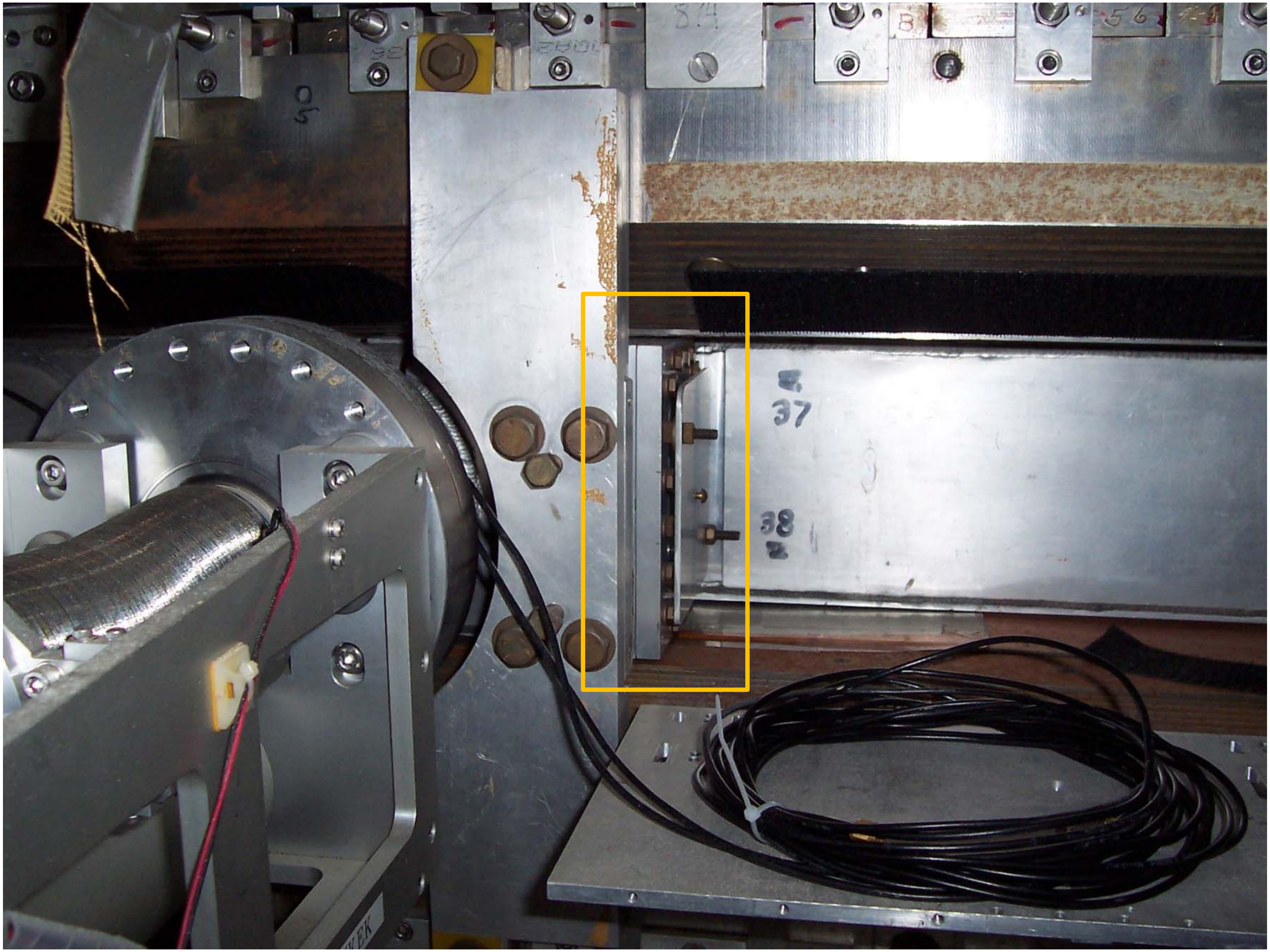
ca 1987

My first big success in building an experiment. $1M of lead glass to measure the charm/anti-charm quark pair

E760/E835

- E760 put a fixed gas jet target of “slushy” hydrogen perpendicular to the stored antiproton beam in the Accumulator at Fermilab
  - Antiprotons collided with the hydrogen atoms in the gas jet
- http://www.e835.to.infn.it/
- “A **charm quark** and an **anti-charm anti-quark** bound together by the strong force makes a **charmonium meson**. Different combinations of quantum numbers (e.g. spin and angular momentum) of the two bound constituents form different **charmonium** particle states. The study of the different states' masses, resonance widths and decay channels increases what is known about the strong force and tests many different theories concerning the strong interaction.”

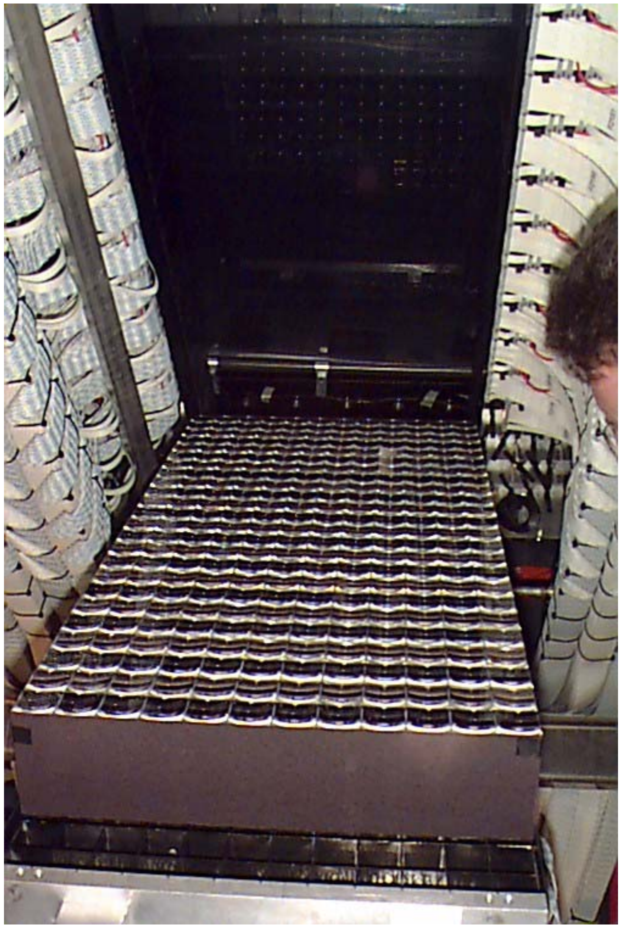
The rectangular Mylar vacuum window for the original G-2 experiment at BNL, 1994

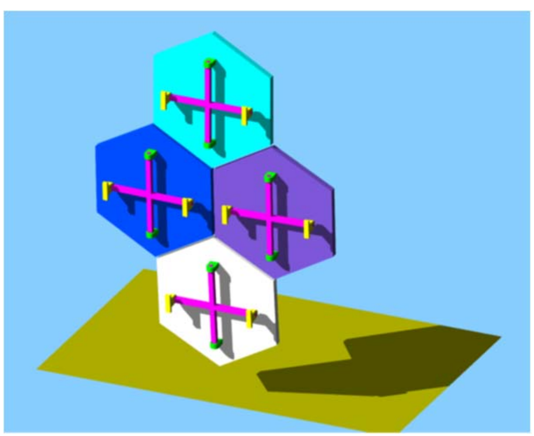


BNL G-2 experiment

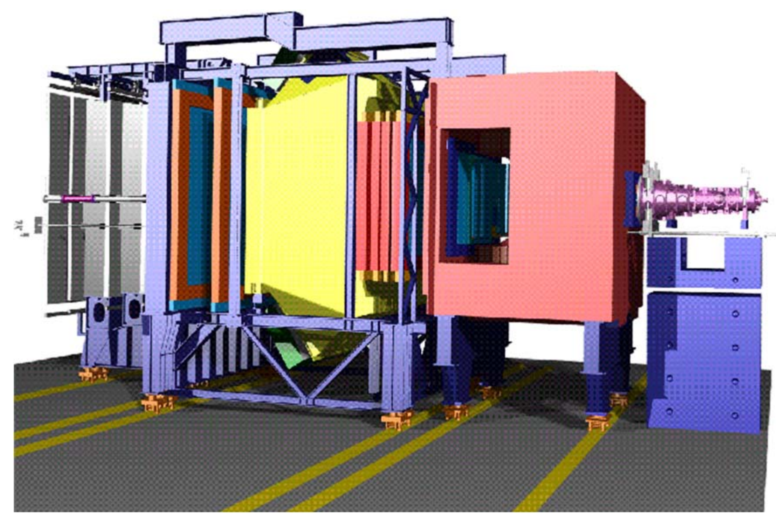
- https://www.g-2.bnl.gov/index.shtml
- "The Muon (g-2) Experiment at Brookhaven National Laboratory is stringently testing the Standard Model by measuring the Anomalous Magnetic Moment of the Muon to unprecedented precision."

The Hera-B RICH optical system, 1995





BE did conceptual design on the mirror mounts and developed the fabrication technique for the PMT lenses.



Hera-B at DESY

- http://www-hera-b.desy.de/

“HERA-B is a large-aperture high-rate spectrometer built for studies of collisions of 920 GeV protons with the nuclei of target wires positioned in the halo of the HERA proton beam. HERA-B was optimized to measure CP-violation in decays of B mesons into the so-called ``golden decay mode'': $B \rightarrow J/\psi K^0$. This ambitious goal required picking each golden-decay event out from a background of 10^{11} hadronic interactions at a rate of 40 million interactions per second. This in turn required advances in radiation-hard technologies, the development of a sophisticated first level trigger and the construction of the first large integrated multi-level switch-based data acquisition and high-level trigger system.”

This report allowed the project to proceed with confidence that the barrel calorimeter would not creep over time. This is one of the largest brass structures in the world.

Report on a Study of Creep and Stress Relaxation in the Bolted Joints of the CMS Hadron Calorimeter

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By Larry Bartoszek, P.E.

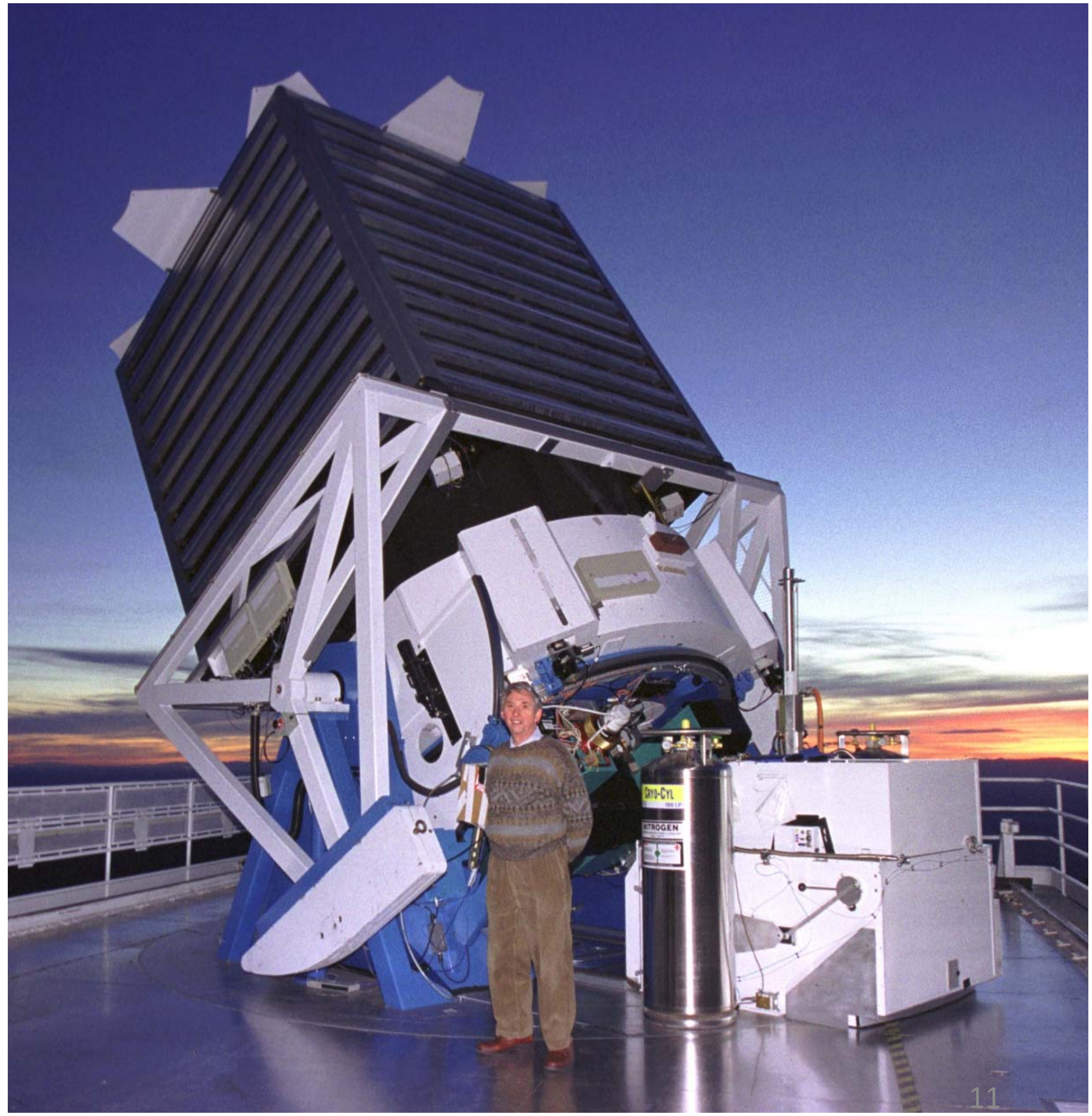
BARTOSZEK ENGINEERING

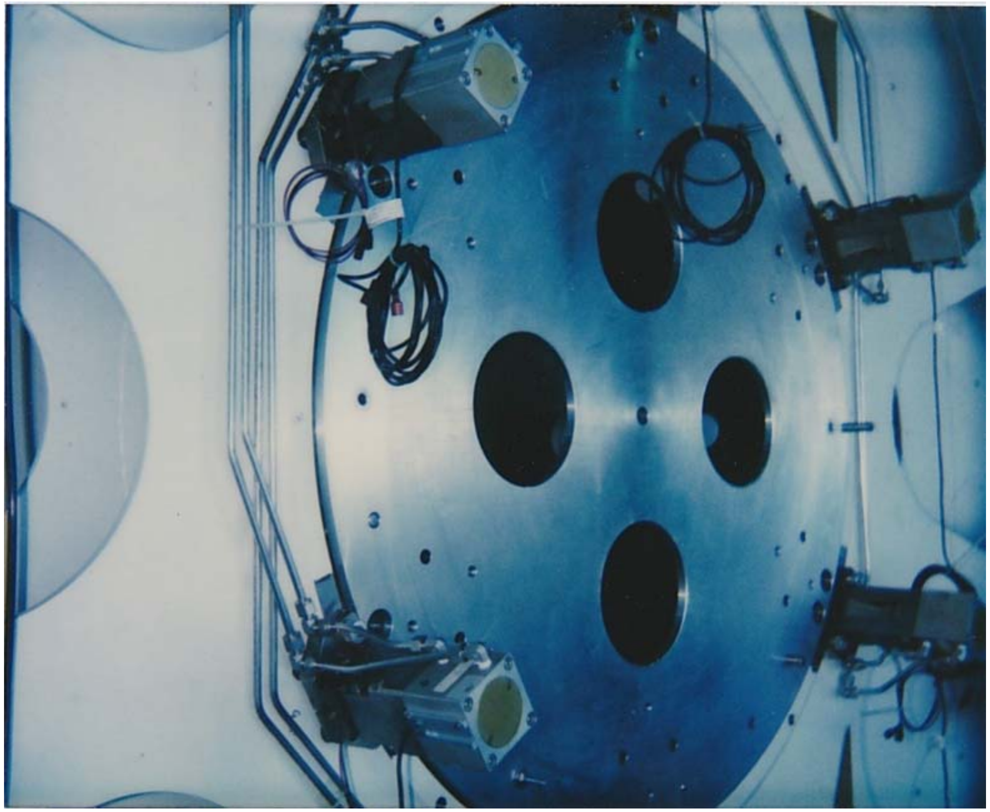
Report #CMS0001, 8/17/97

The CMS Hadron Calorimeter report

This report gave the FNAL CMS collaboration members the confidence to build the CMS calorimeter out of brass. They were worried that the brass would creep over time. I did a lot of research in the behavior of brass at room temperature and convinced myself (and them) that creep was a high temperature phenomenon and that it wouldn’t happen to the calorimeter over any reasonable time scale.

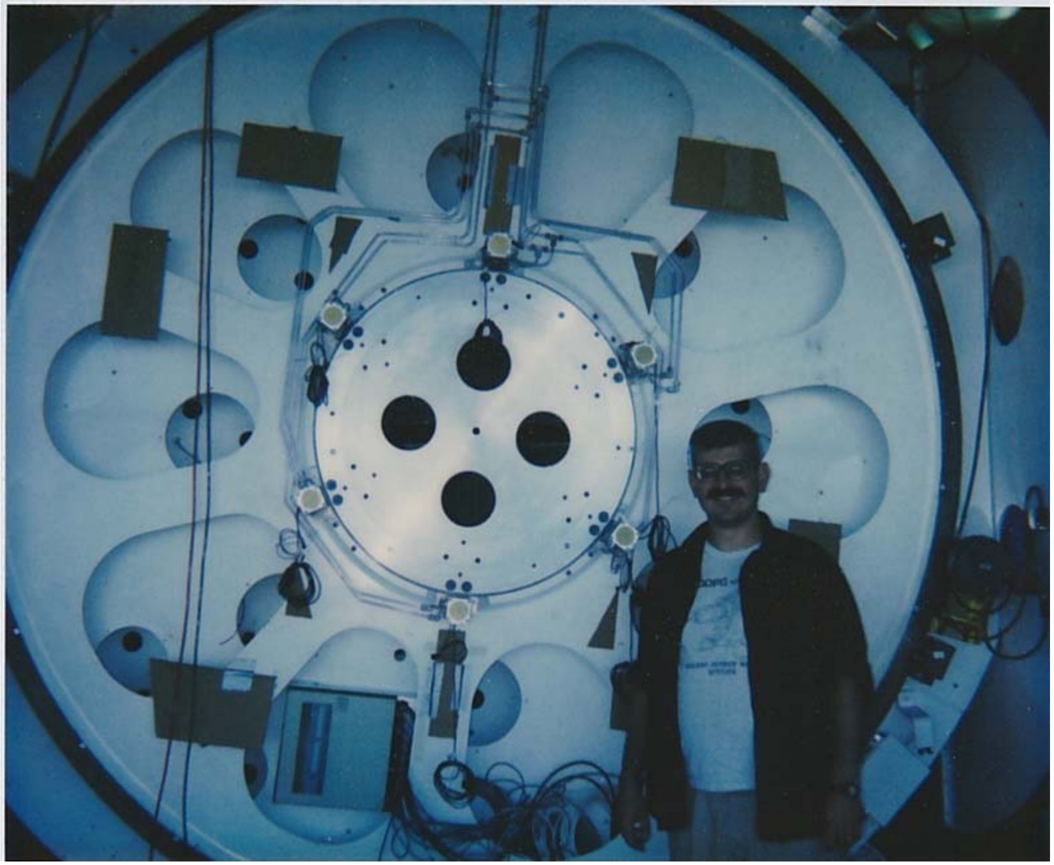
The telescope I helped build:
The 2.5m Sloan Digital Sky Survey Telescope
Apache Point Observatory, NM (1997)





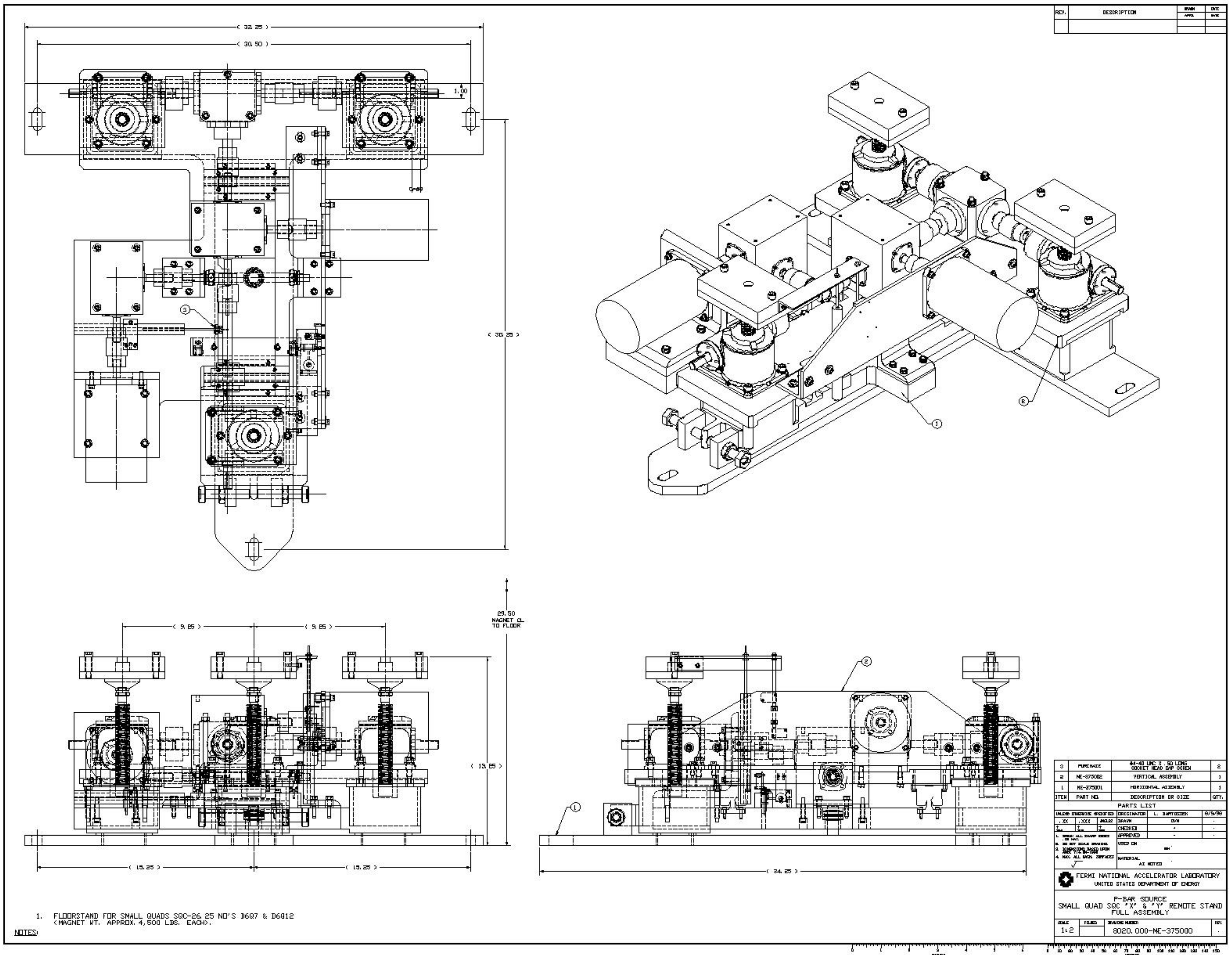
←Closer view of the pneumatic latches I installed to hold the camera and spectroscope on the telescope. They could not ever fail or we would drop a $4 million camera.

I had just spent several days at Apache Point Observatory attaching and installing the pneumatic piping for the latches in 1997 →



I wrote a public talk in 2021 about the amazing impact of SDSS on astronomy and cosmology.
All data is available at
https://www.sdss.org/

The SQC Magnet Stand,FNAL, 1998



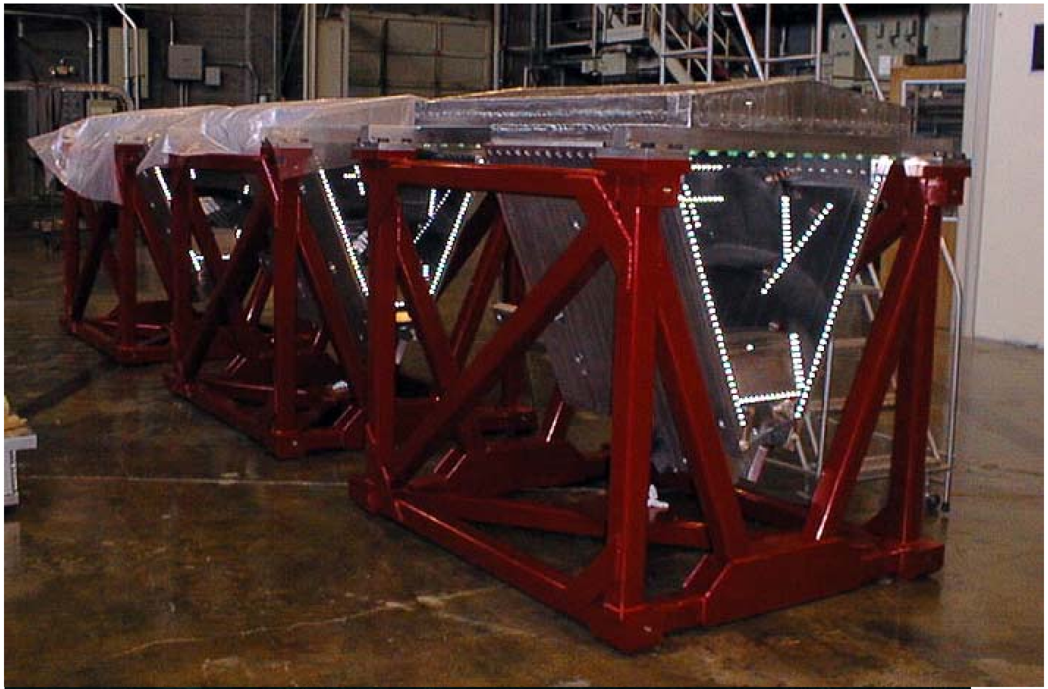
BE was hired to design a new remotely operated magnet stand for SQC magnets at Fermilab.

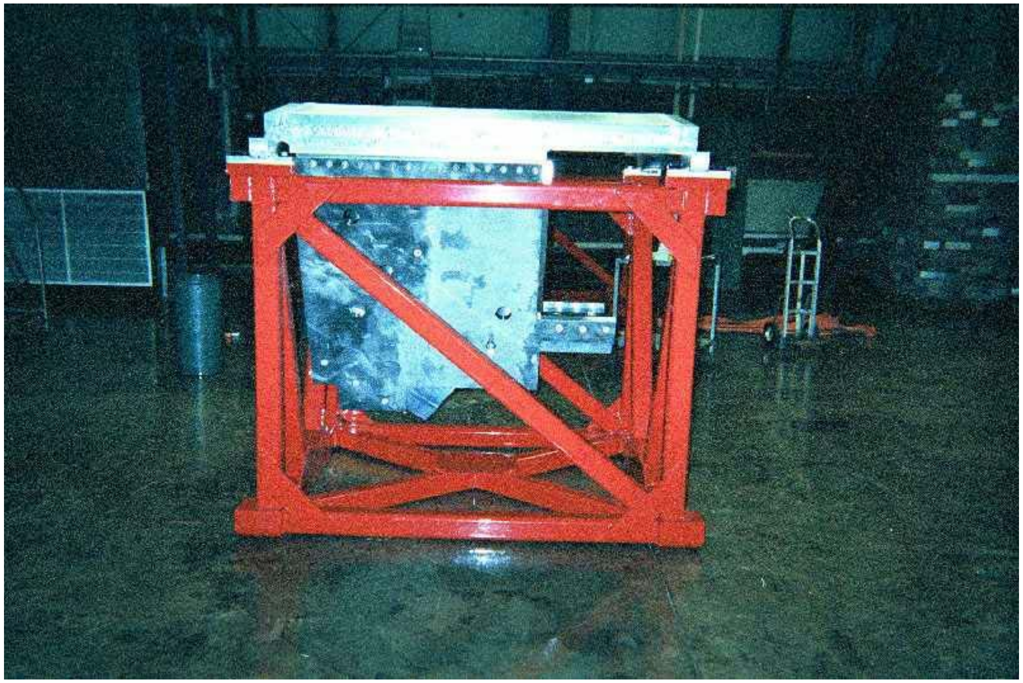
The design is based on designs done previously while I was employed at FNAL.

(This was done in Autodesk's Mechanical Desktop.)

The G0 collimators, UIUC, 1998

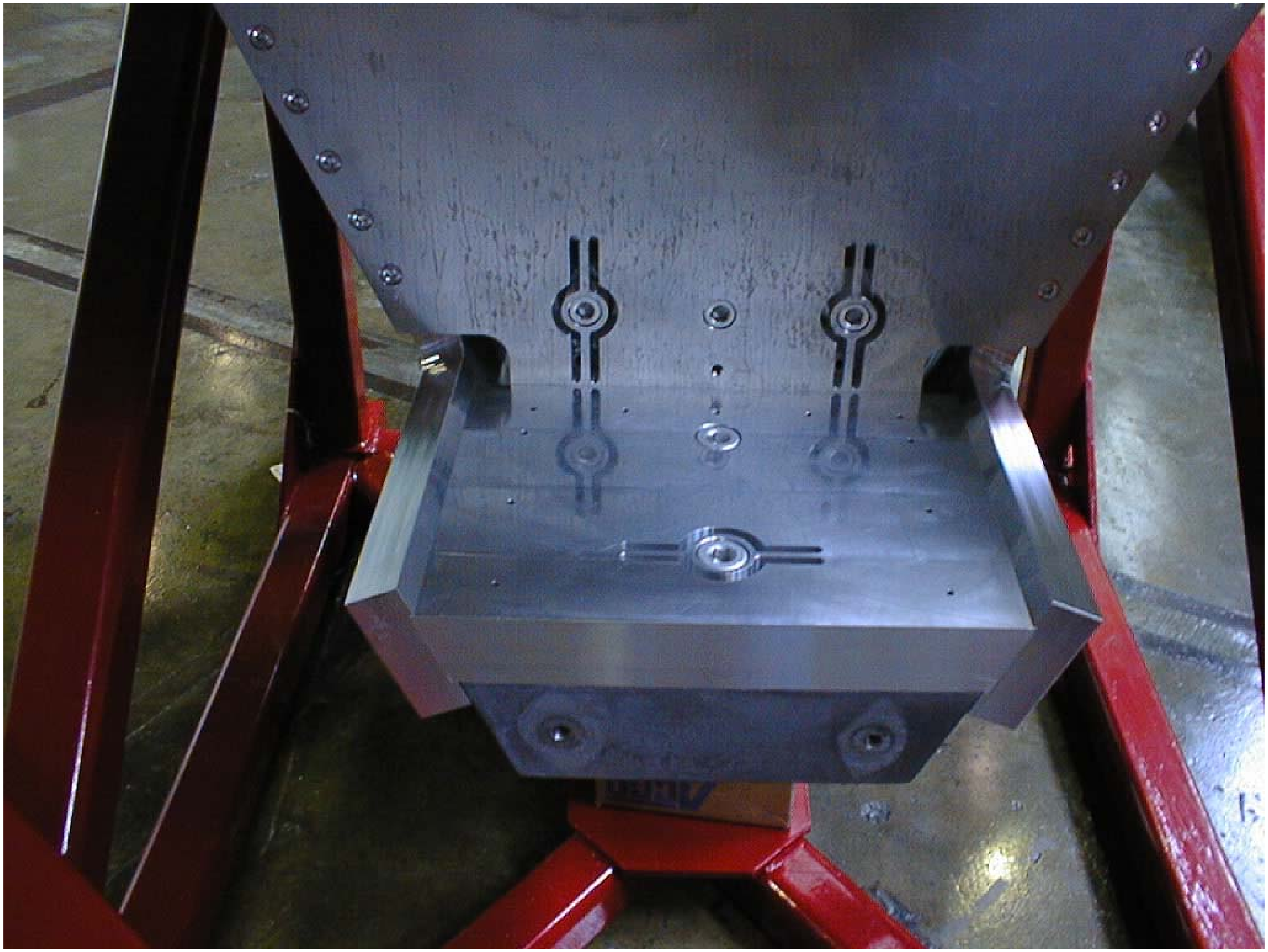
BE designed the 8 2.5 ton collimator modules that fit between the superconducting magnets of the G0 spectrometer. The structures are aluminum with sand cast lead shielding. These structures were cooled to 4K. To allow for differential thermal contraction, BE designed a custom "spring beam" connection to allow the connection of lead and aluminum. BE also designed the red steel frames for lifting and support during assembly of the collimators.





The G0 collimator Spring beam connections, UIUC, 1998

Lead contracts much more than aluminum when cooled to 4K. The cuts in the aluminum structure allowed the bolts and bolt holes in the lead to move without shearing the bolts during cool down and warm up. The connection relies on the stiffness of the plate out of plane to support the weight of the lead.

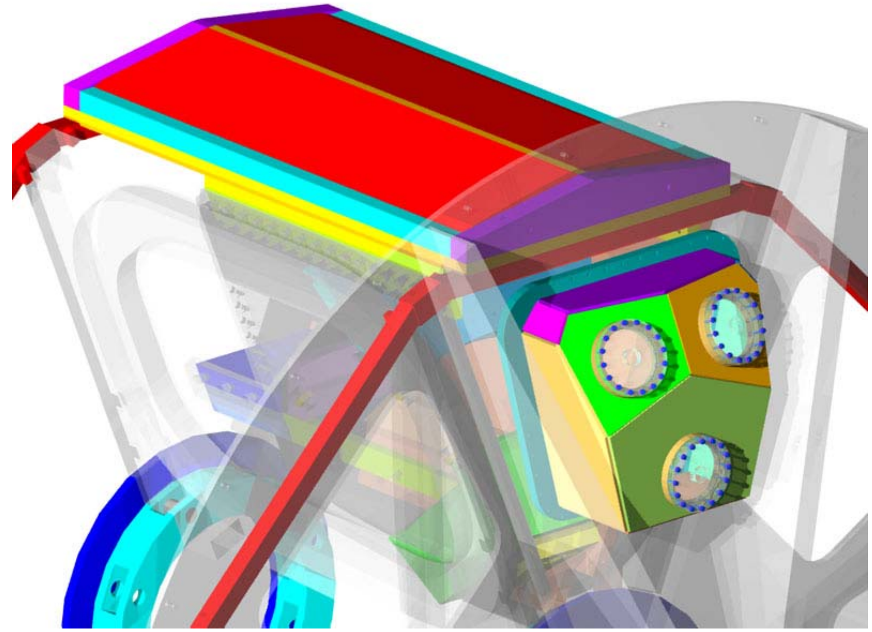


http://bartoszekeng.com/g0/colpics/colassy.htm

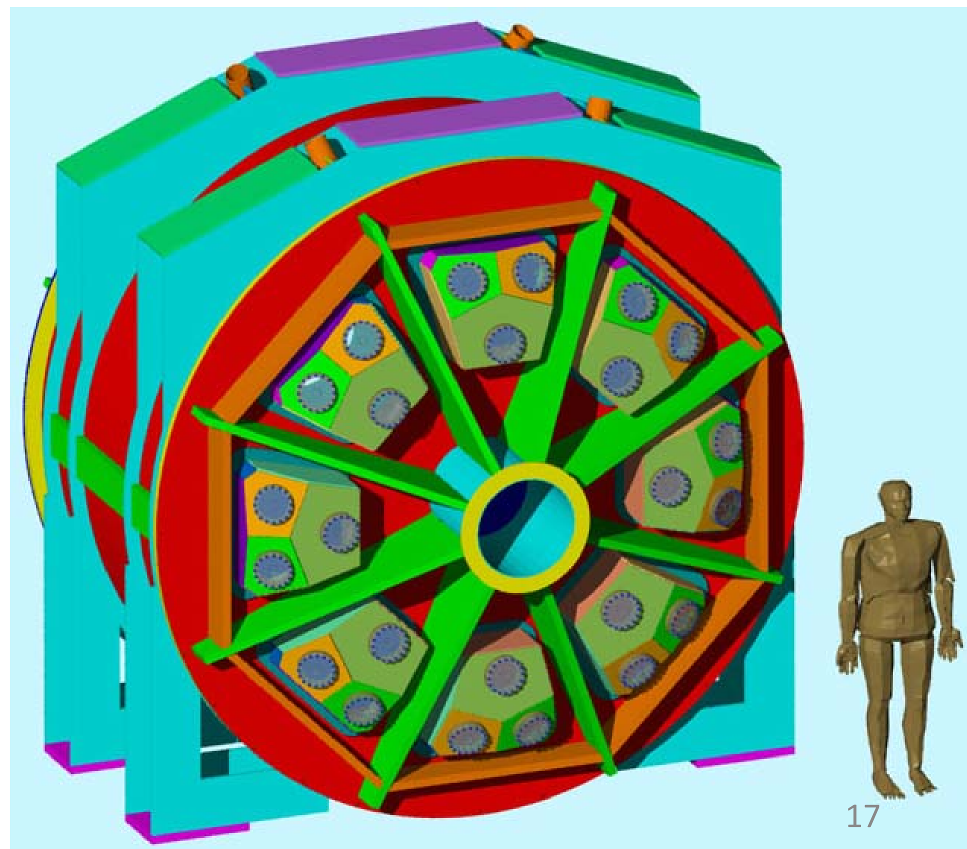
The G0 Vacuum Window Test Fixture, UIUC, 1999

BE designed a test fixture to evacuate or pressurize and puncture a titanium vacuum window to determine its pressure rating and ability to withstand damage under vacuum. The test was enclosed in a metal shell for safety from fragments during testing.

The G0 Optical windows for cold measurement of the collimators, UIUC, 1999



We used photogrammetry to measure the locations of the collimator lead surfaces at 77K to ensure accuracy of collimator assembly and placement.

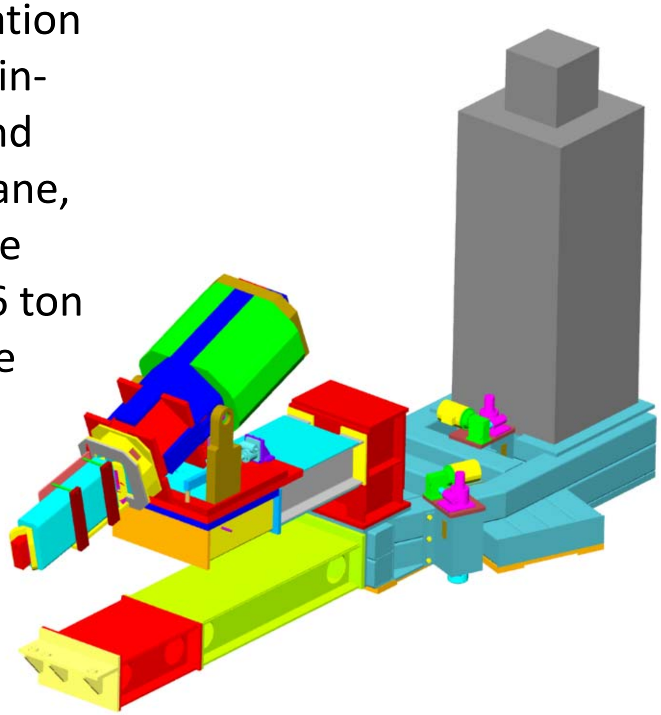


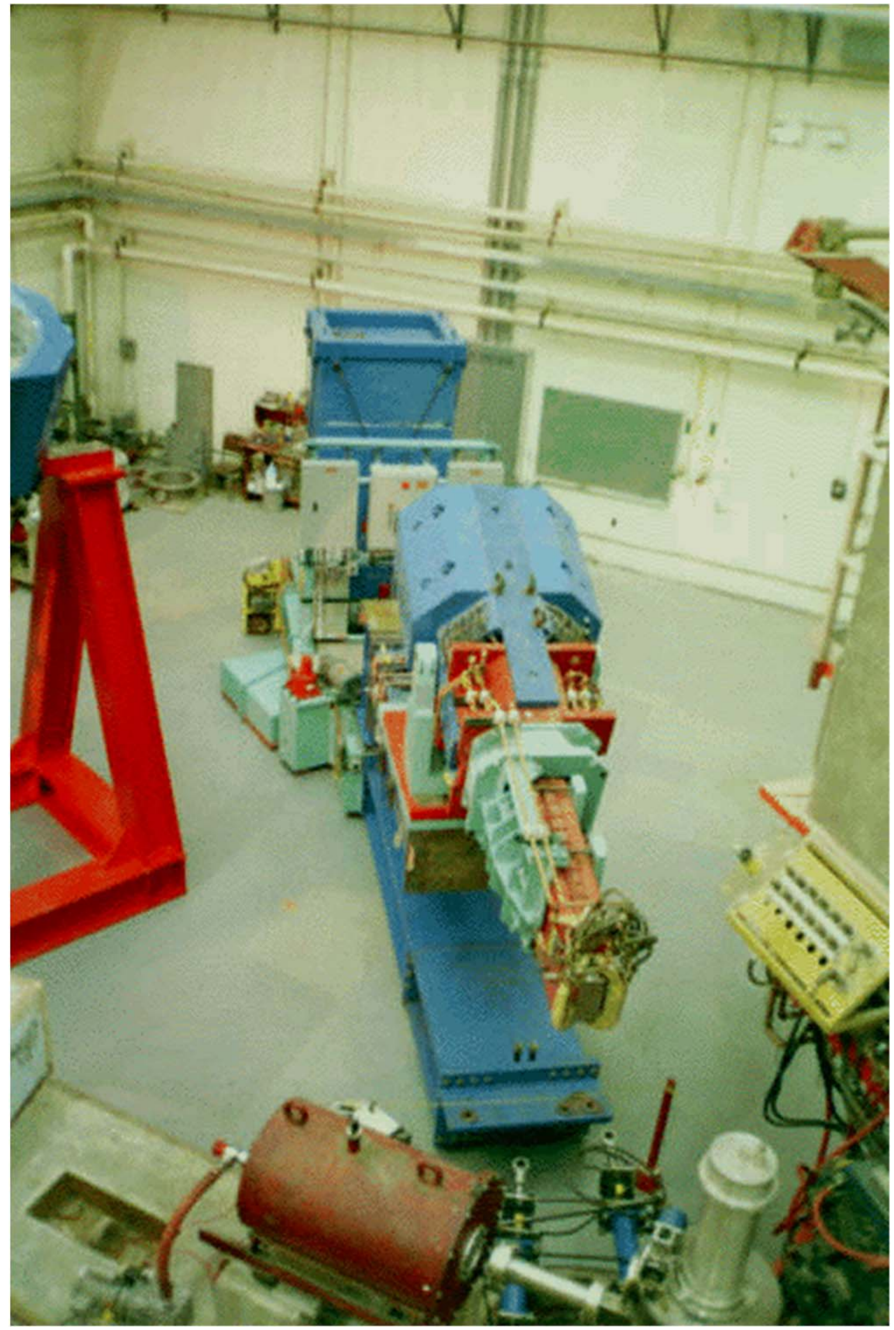
The six-legged walking robot for Scitech, 1999

This is now our outreach robot for Team 2704, Roaring Robotics

The OOPS Satellite support at Bates, 1999

To create a '+' configuration of two OOPS detectors in-plane and one above and below the scattering plane, BE designed the Satellite supports to hold one 16 ton spectrometer each. The blocks on the back are counterweights.





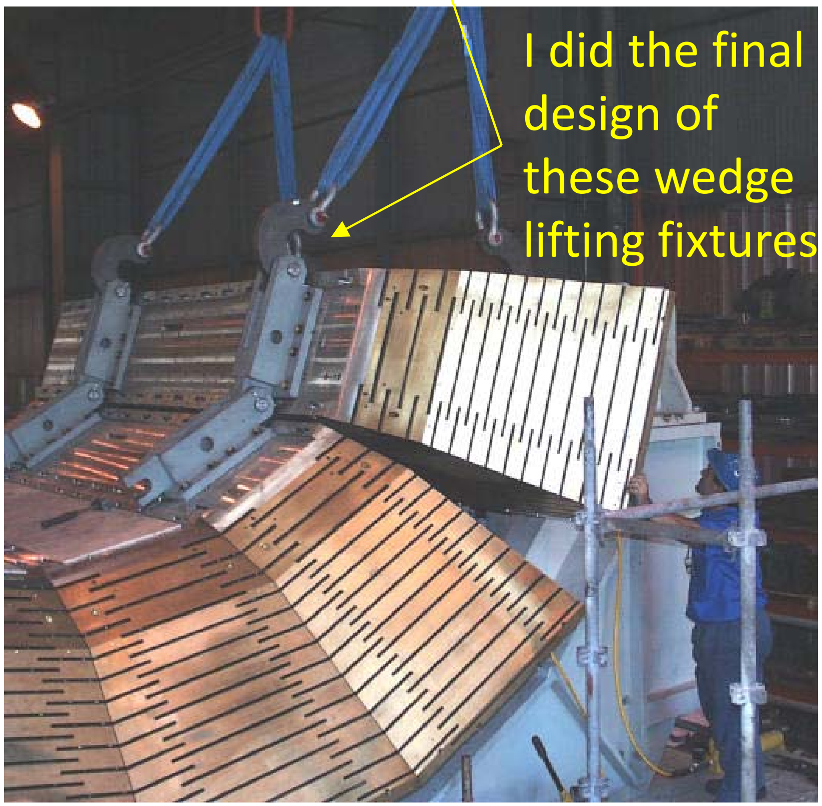
The OOPS Gantry and Satellite supports at Bates, 1999

A three story tall, 120 ton Cartesian robot to point spectrometers at a collision point, with two smaller structures on either side.

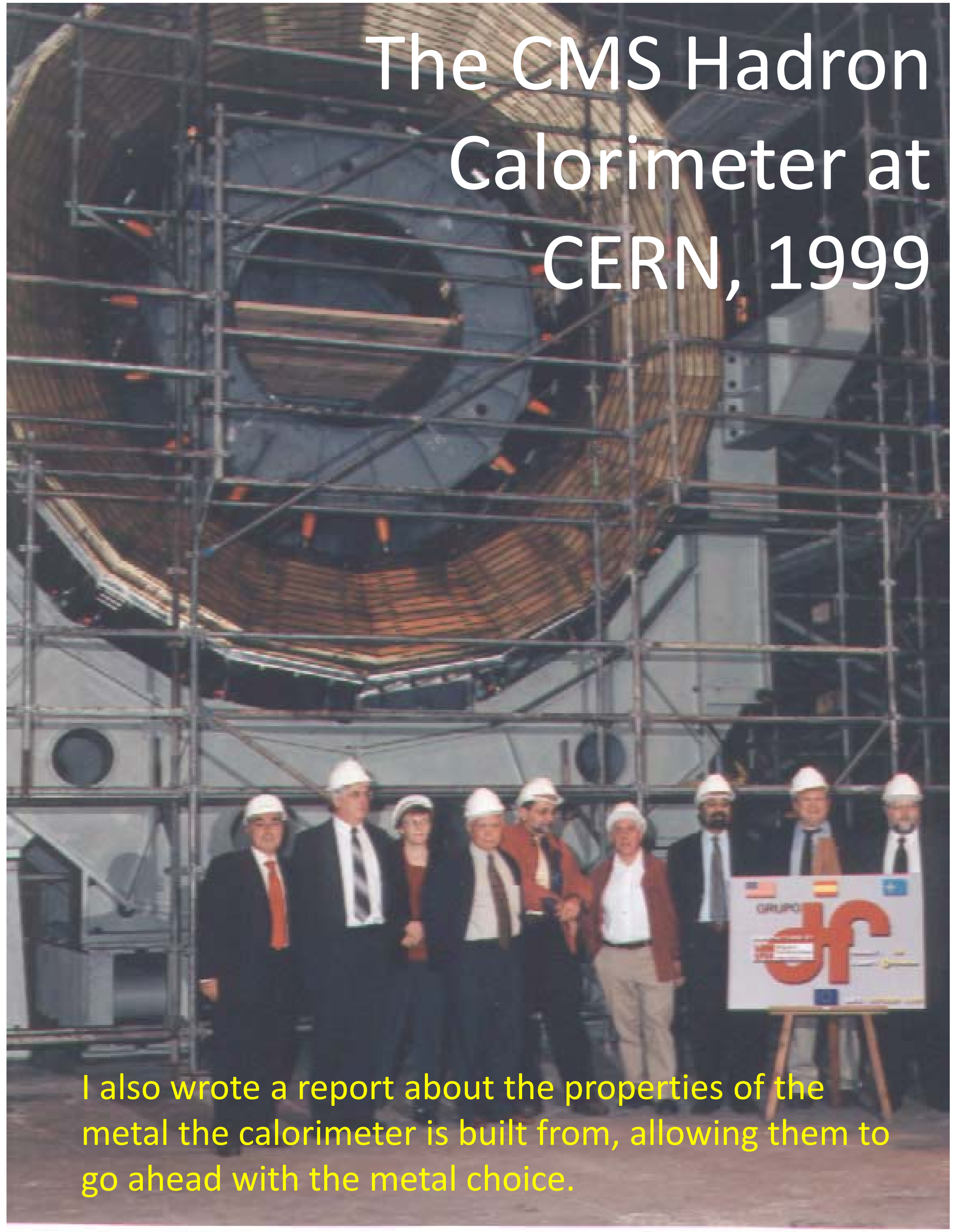
The OOPS experiment

- https://bateslab.mit.edu/projects/oops
- "Another major and pioneering experimental effort at Bates involved the Out-Of-Plane Spectrometer (OOPS). OOPS was a special version of coincidence measurements with magnetic spectrometers. Prior to OOPS coincidence events from electron scattering were carried out with both spectrometers supported in the horizontal plane. This was the case because the problem of detecting one of the particles in an arbitrary direction required a more complicated support system for the spectrometers. The OOPS Collaboration decided that the additional important information that one could gain made the challenging engineering effort worthwhile.
- OOPS took data successfully for a few years, and provided important new information on the structure and reaction mechanisms of nuclei."

The CMS Hadron Calorimeter at CERN, 1999



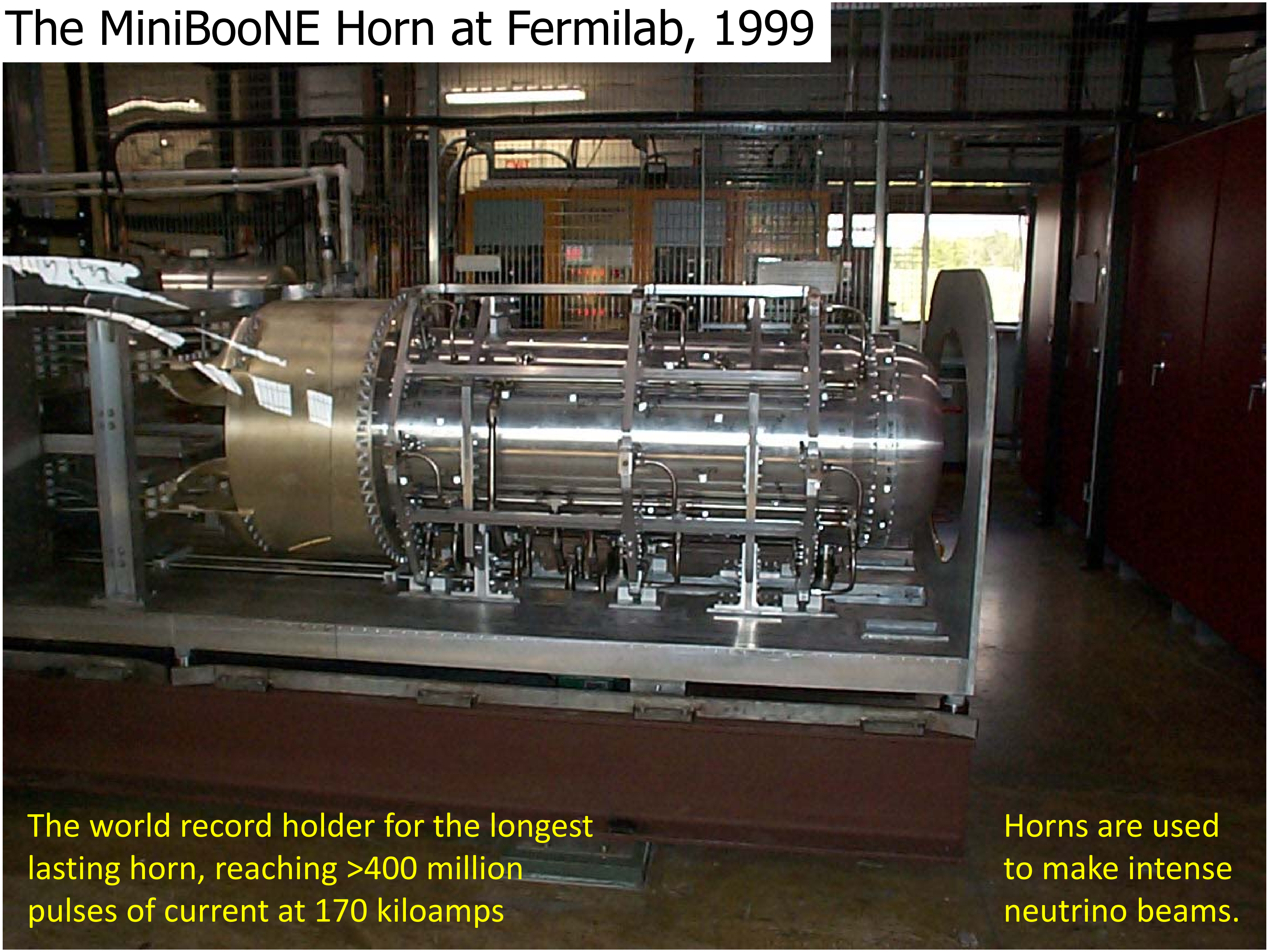
I did the final design of these wedge lifting fixtures



I also wrote a report about the properties of the metal the calorimeter is built from, allowing them to go ahead with the metal choice.

The MiniBooNE Detector Tank at Fermilab, 1999

The MiniBooNE Horn at Fermilab, 1999



The world record holder for the longest lasting horn, reaching >400 million pulses of current at 170 kiloamps

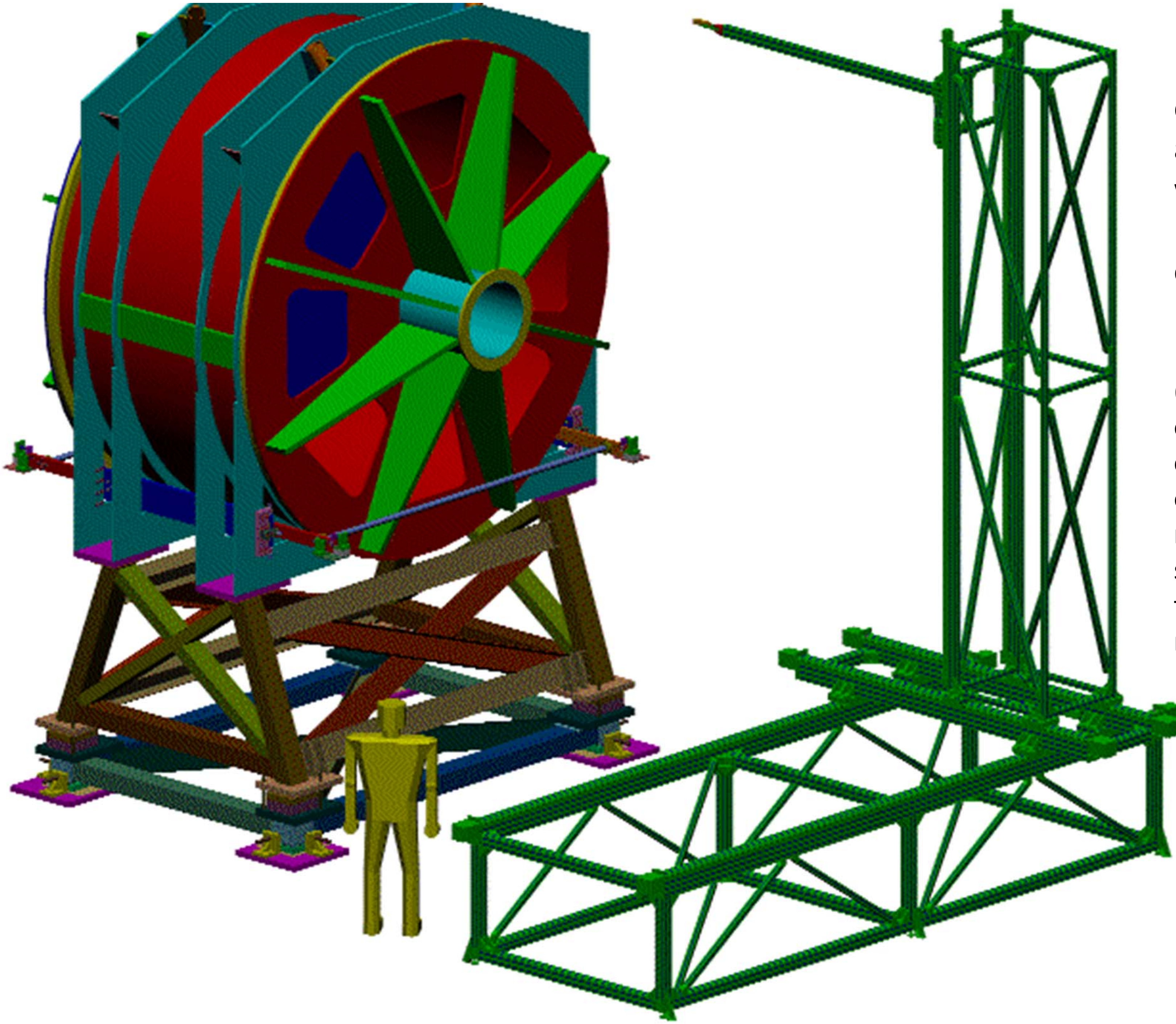
Horns are used to make intense neutrino beams.

MiniBooNE at Fermilab

- https://www-boone.fnal.gov/
- "The primary goal of this experiment is:
  - To test for neutrino mass by searching for neutrino oscillations. Neutrino mass is important because it may lead us to physics beyond the Standard Model. Masses in the range accessible to MiniBooNE will expand our understanding of how the universe has evolved."
- I became "world famous" (to about 40 people) after designing the world-record MiniBooNE horn. No other horn has ever lived through as many pulses as that one. (Still true in 2021.)

The G0 Aluminum End Flanges, UIUC, 2000

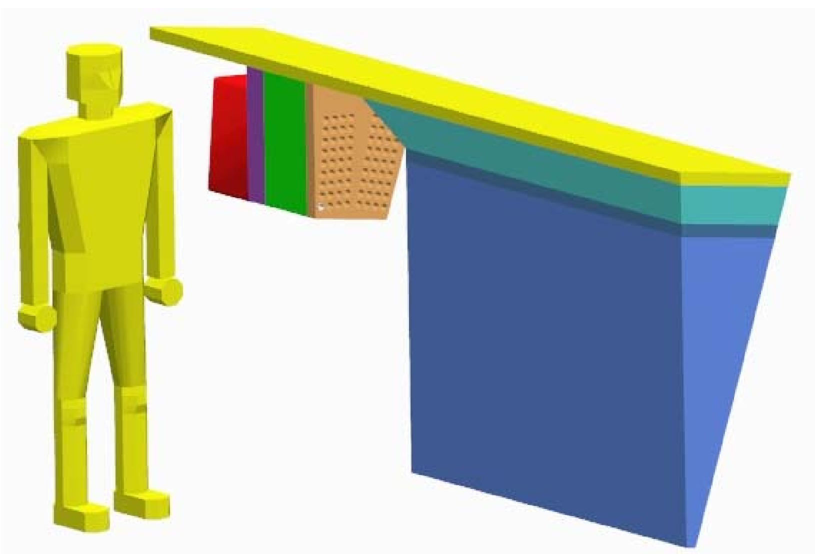
The G0 Magnet Mapper, UIUC, 2000

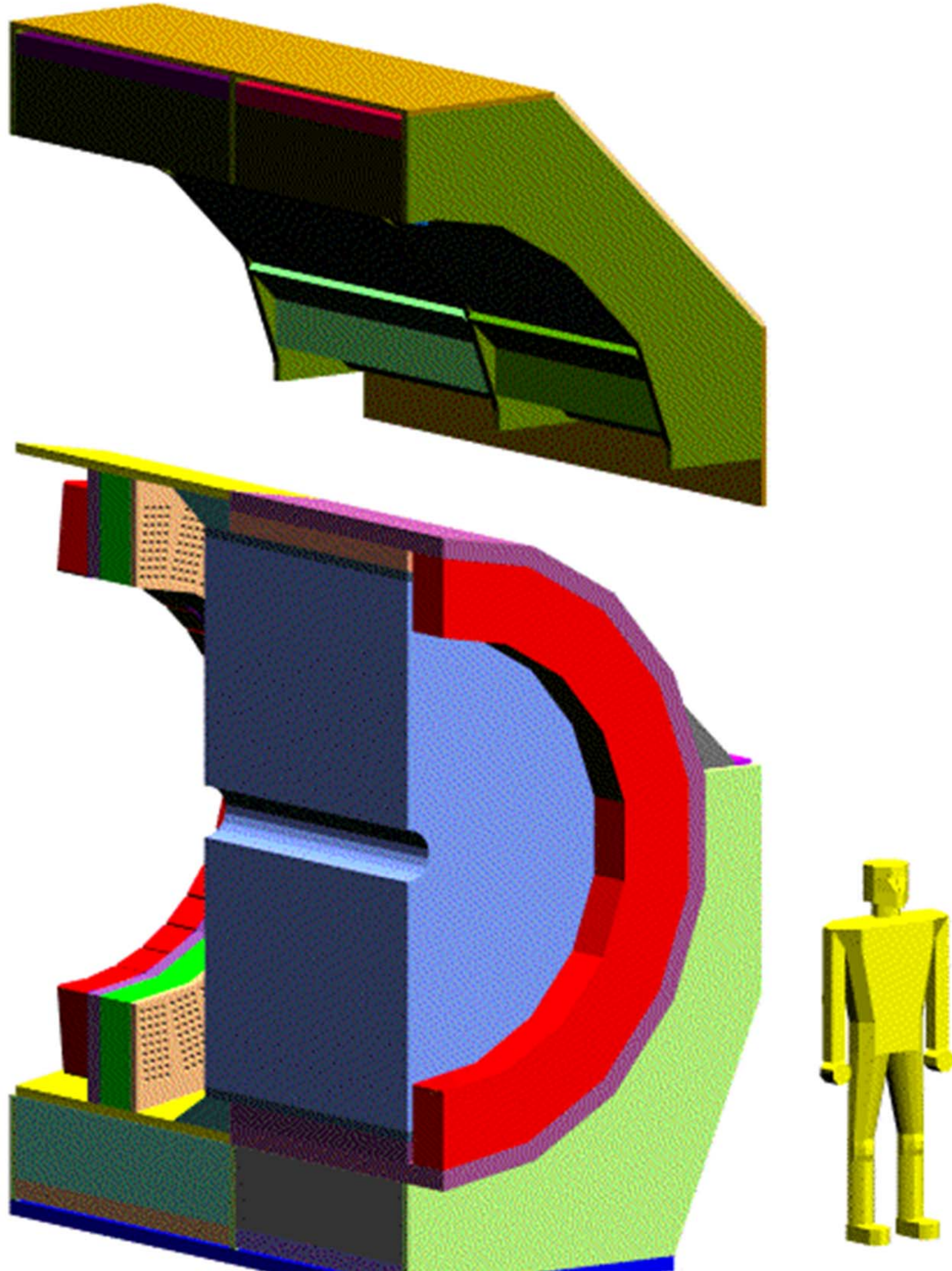


BE contributed the design of the external alignment mechanism wrapped around the bottom of the cryostat for the mapper.

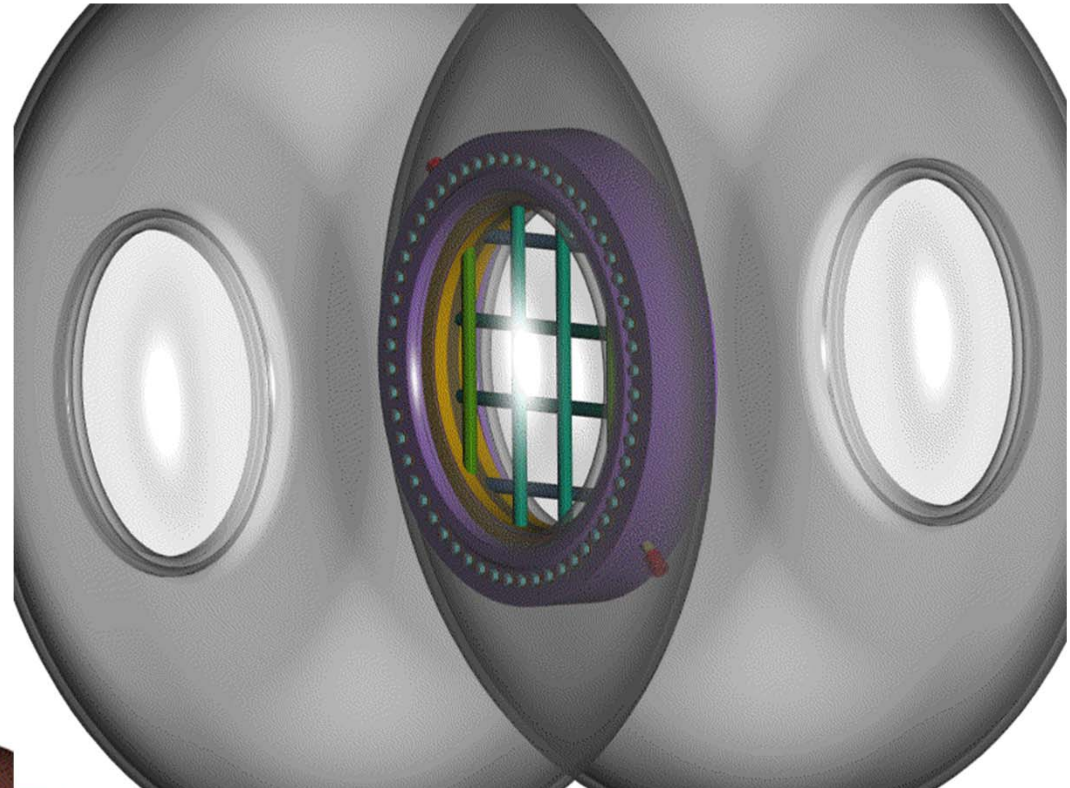
(Sorry about the quality of this image, but I couldn't find any photos of this device to map the magnetic field of the G0 spectrometer. This was the early days of 3D modeling and rendering.)

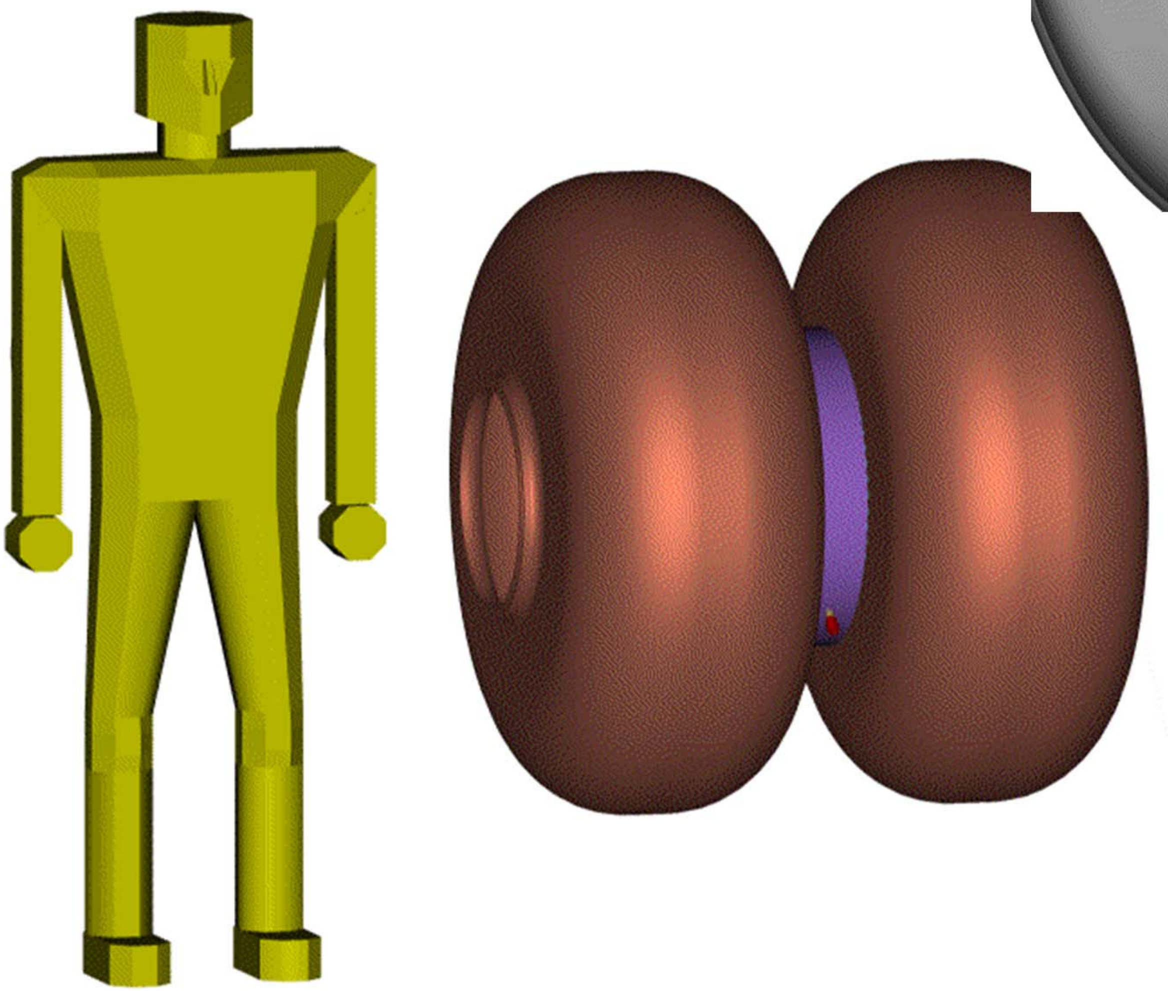
The CMS HF Calorimeter conceptual design, 2000

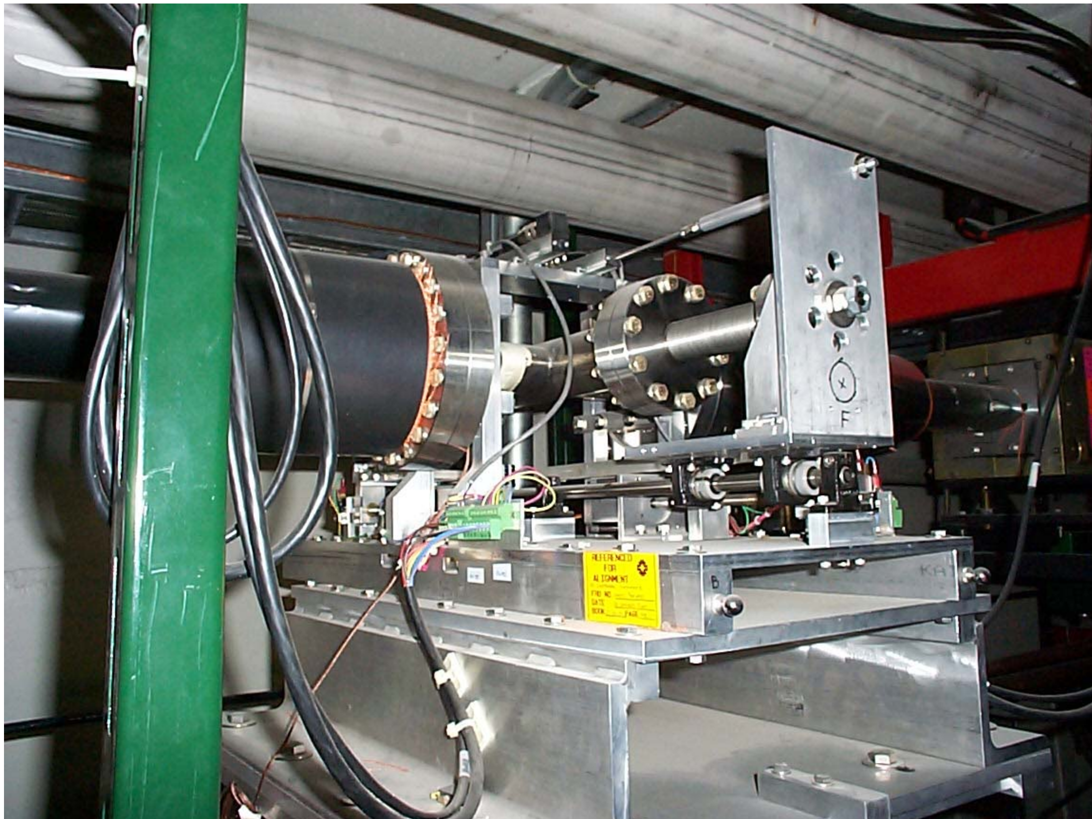




Muon RF Cavity
At FNAL
conceptual design,
2001

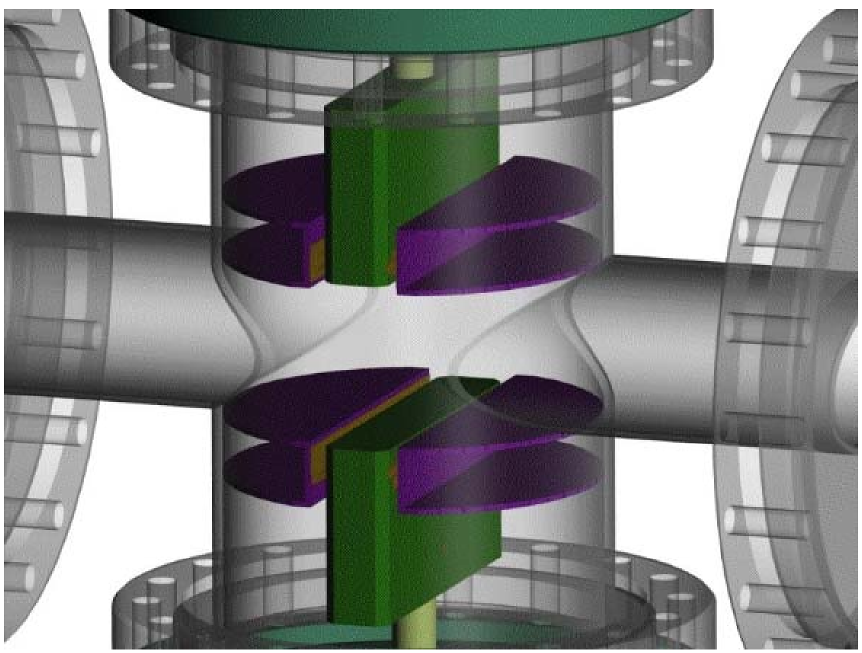






The Recycler Scrapers at Fermilab, 2001

Scrapers are beam diagnostic and shaping tools



The G0 transport fixture, UIUC, 2002

Using the equipment available to Lockwood Brothers, BE designed the entire process and fixtures to lift and rotate the G0 spectrometer to go from inside the lab at NPL to inside Hall C at Jefferson Lab. (There was 1” of clearance to get it through the door at UIUC.)

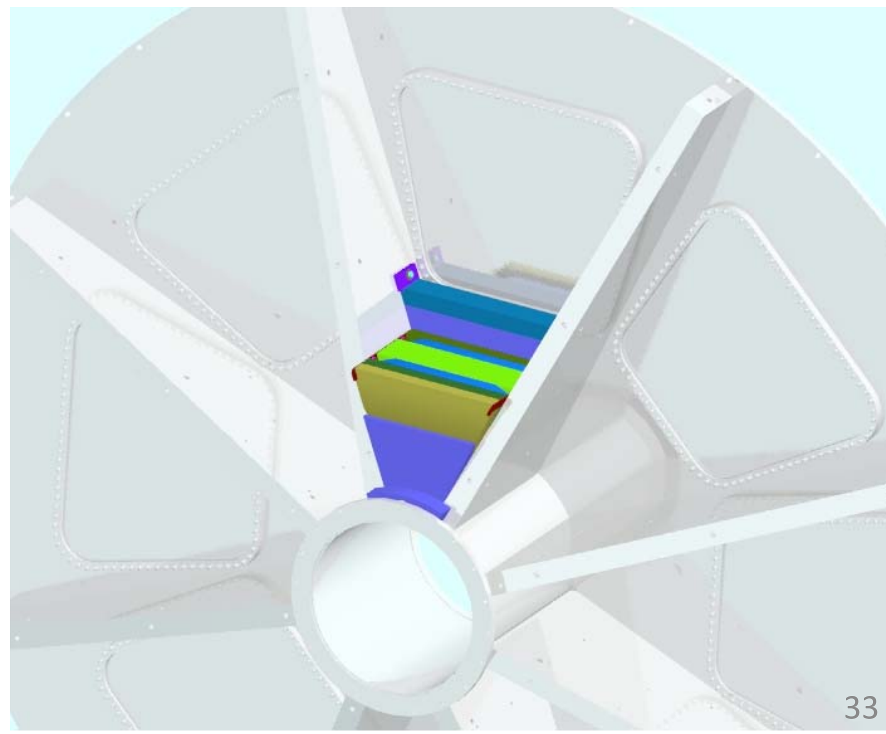
http://bartoszekeng.com/g0/steps/steps.htm

The G0 movable support stand, Jefferson Lab, 2002

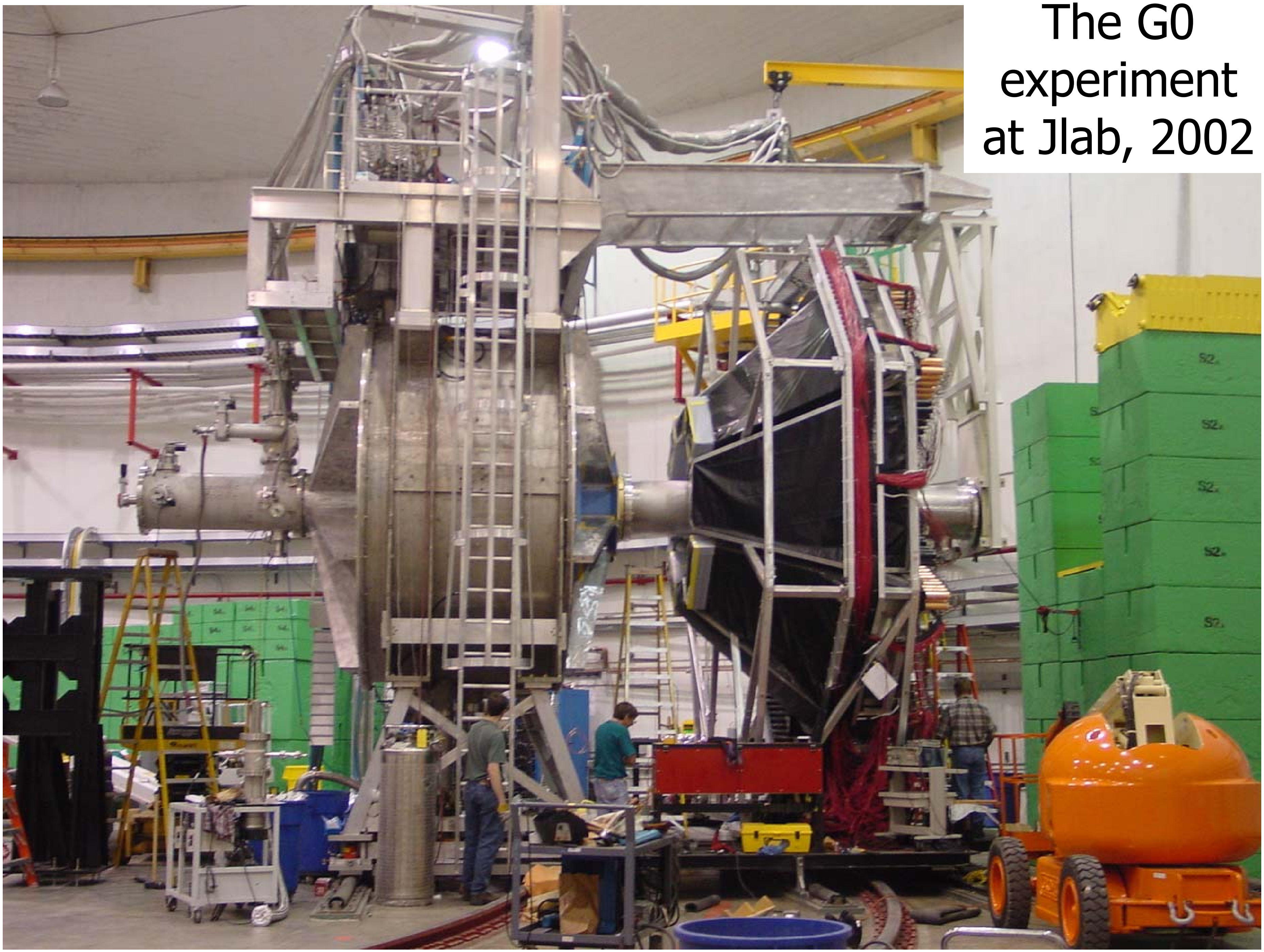
This stand was designed with help from Don Mitchell of 3D Engineering.

The G0 Downstream Head Lead and Borated Poly Shielding, Jefferson Lab, 2002

To reduce background on the G0 detectors, BE designed modules to be assembled under the vacuum windows on the downstream head. BE used sand casting for all the lead shapes of shielding in G0.



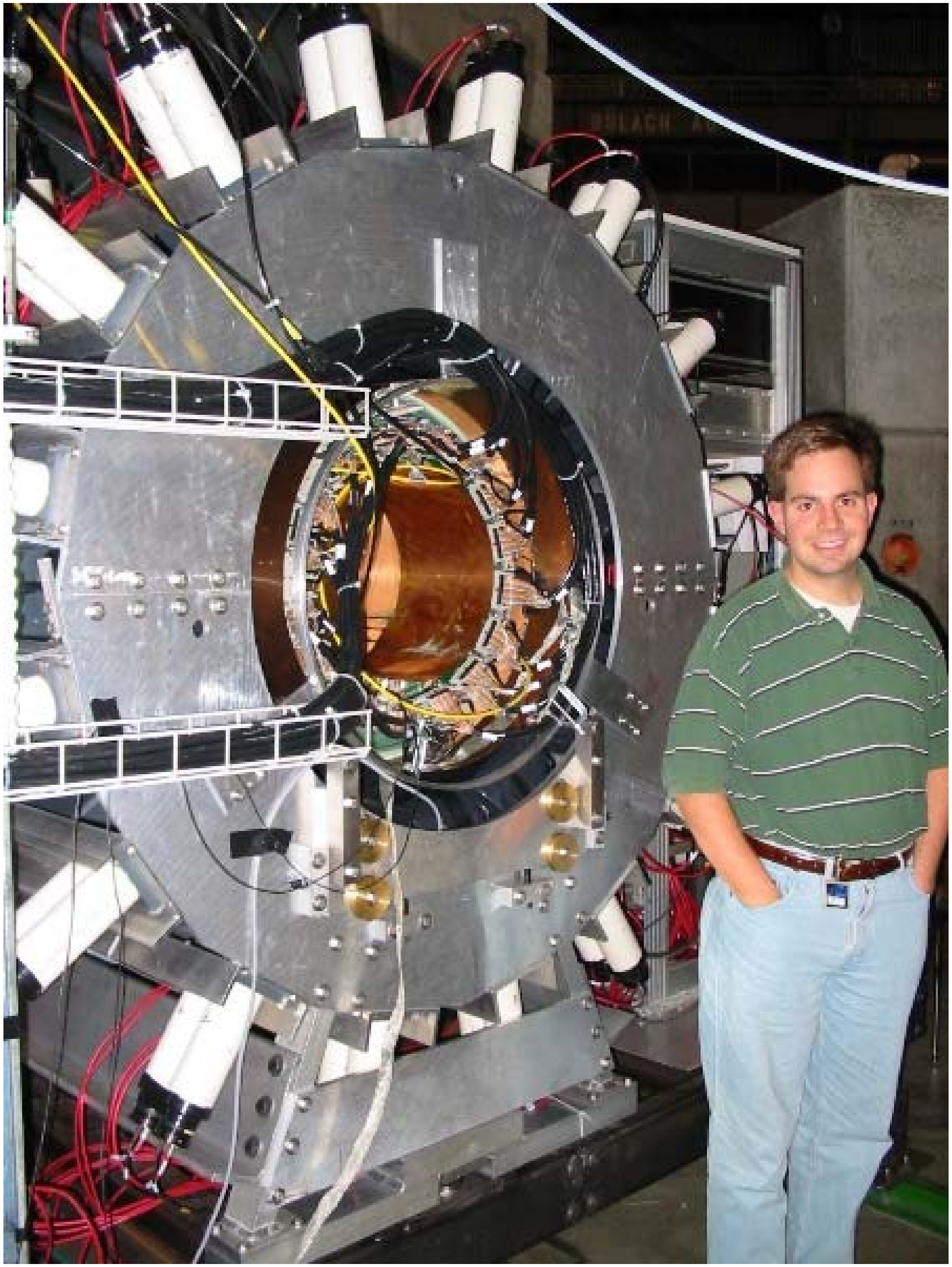
Measuring the amount of "strangeness" in the proton



The G0 experiment at Jlab, 2002

The G0 experiment at JLab

- http://research.npl.illinois.edu/exp/G0/publicWeb/index.html
- "The goal of the G0 experiment is to learn more about the quark substructure of protons and neutrons (nucleons). Our interest is in the distributions of charge and magnetization in the nucleon and how it is built up out of the different types of quarks. We are particularly interested in whether these distributions have any contribution from strange quarks as this type exists only "virtually" in nucleons as the result of the quantum mechanical interplay between mass and energy."



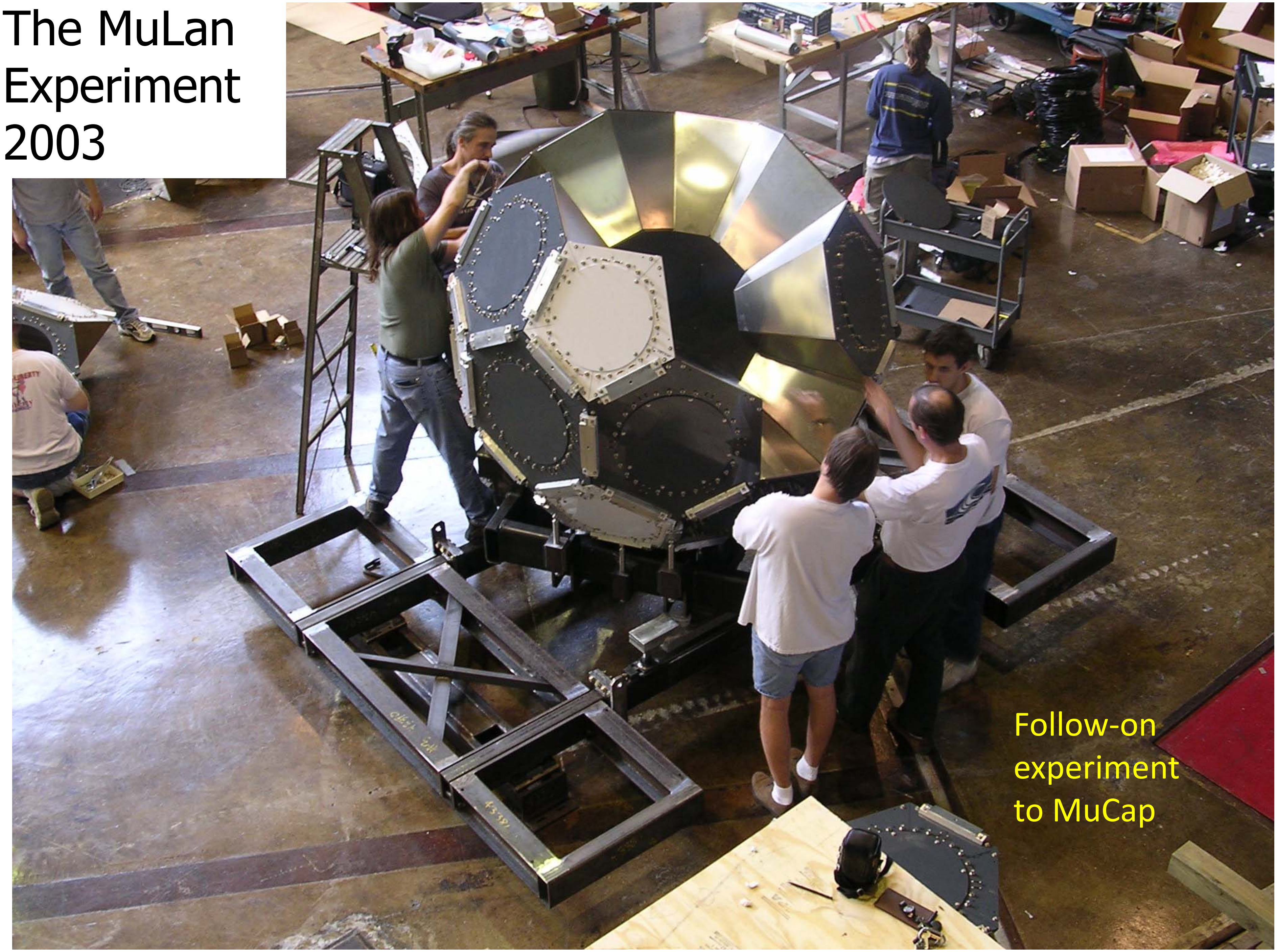
The MuCap experiment at PSI in Switzerland, 2002

Studying the short-lived particle, the muon, heavy cousin to the electron.

MuCap at PSI

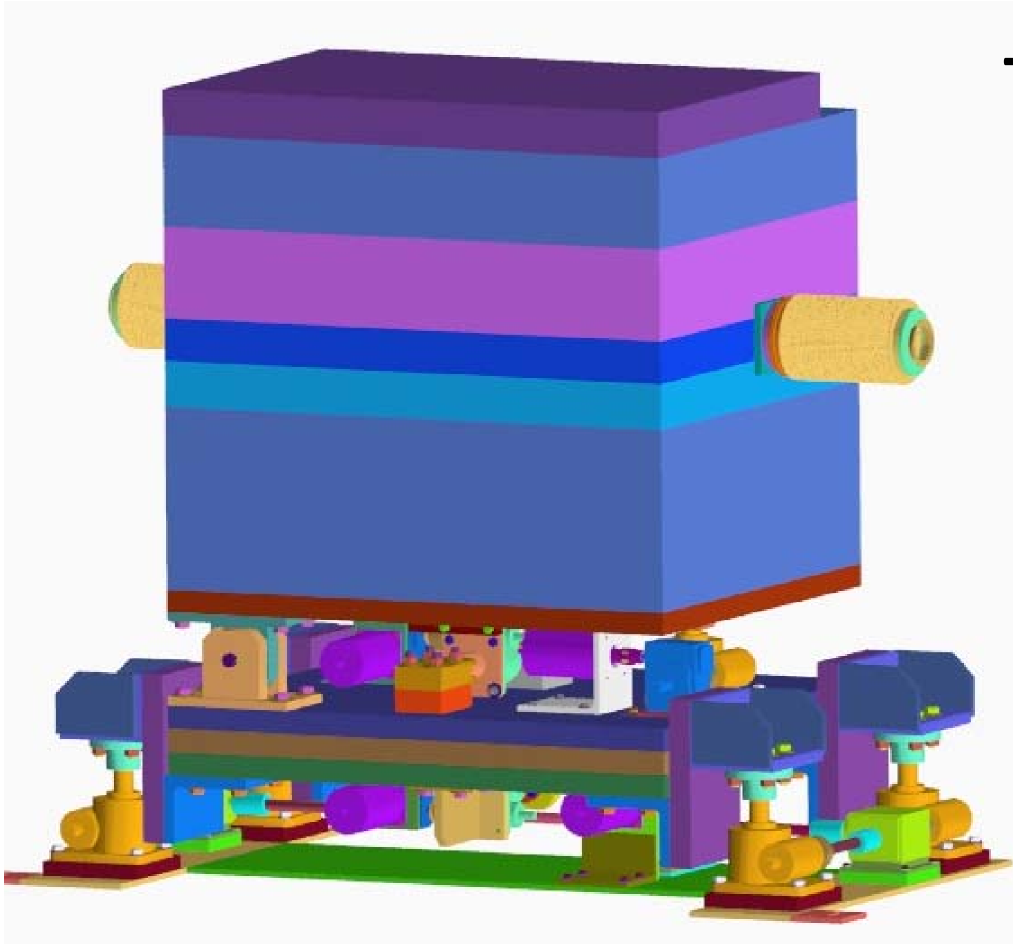
- http://muon.npl.washington.edu/exp/MuCap/
- "MuCap final result precisely tests weak interactions of quarks in the proton, Phys.Rev.Lett. 2013"

The MuLan Experiment 2003



MuLan at PSI

- http://muon.npl.washington.edu/exp/MuLan/
- "The Muon Lifetime Analysis (MuLan) experiment will measure the positive muon lifetime to a precision of one part per million (ppm). The muon lifetime provides the most precise determination of the Fermi coupling constant, which is one of the fundamental inputs to the Standard Model. Recent advances in theory have reduced the theoretical uncertainty on the Fermi coupling constant as calculated from the muon lifetime to a few tenths of a ppm. The remaining uncertainty on the Fermi constant is entirely experimental, and is dominated by the uncertainty on the muon lifetime. The MuLan experiment will use an innovative pulsed beam, a symmetric detector, and modern data-taking methods to reduce the uncertainty on the muon lifetime to 1 ppm."

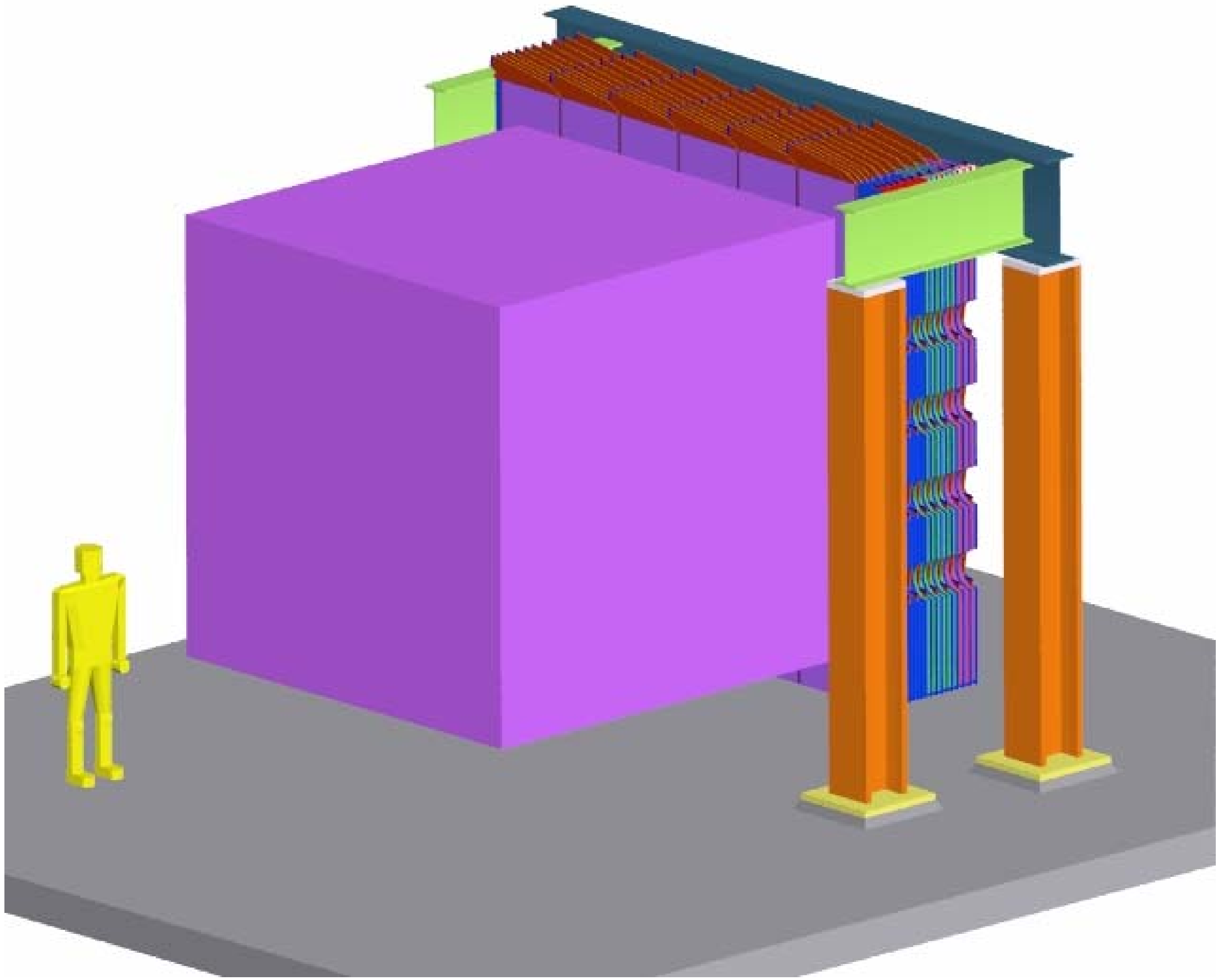


The Booster Collimators at Fermilab, 2003

These 12 ton blocks of steel are motorized and can be positioned precisely to scrape away beam halo. These devices soak up stray radiation in one place so the whole Booster doesn't become too radioactive to work on.

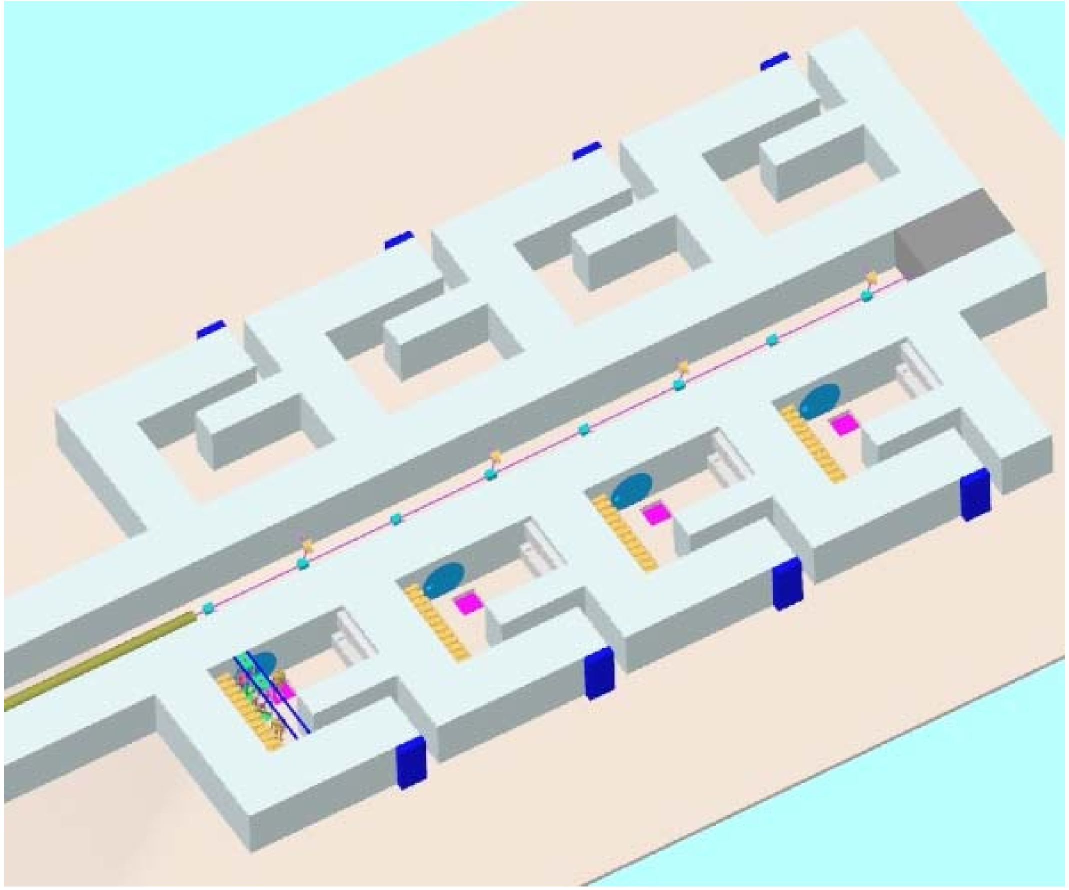
The FINeSSE concept design, 2003

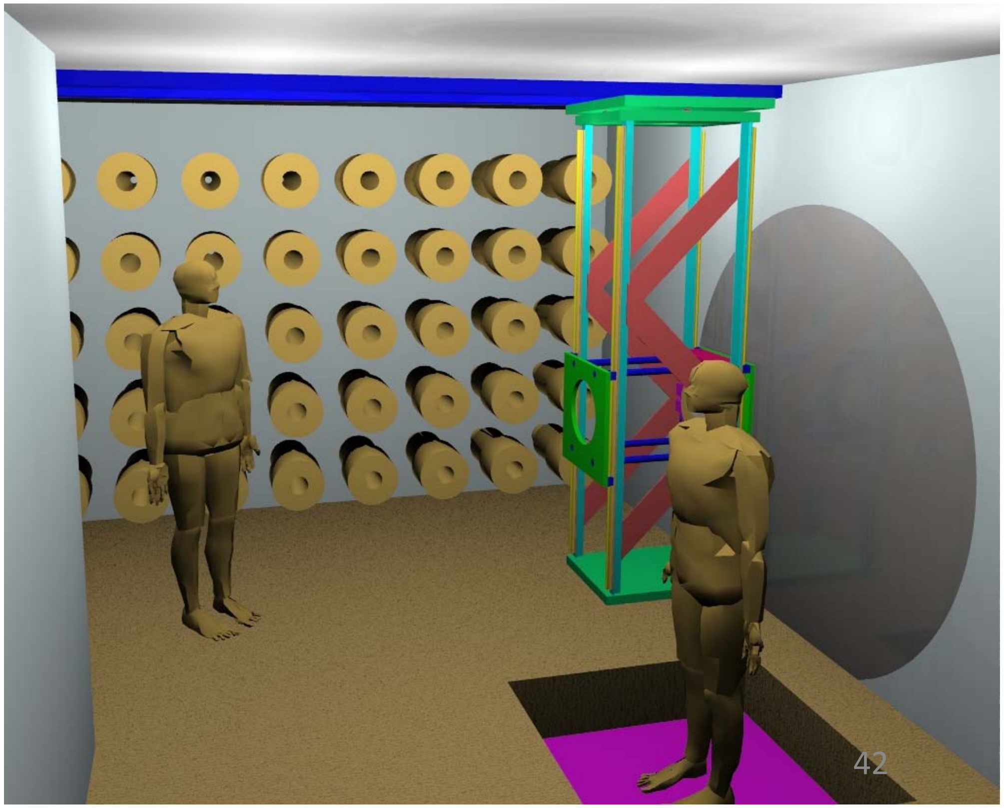
FINeSSE was a proposal for a LAr TPC and scintillator detector. It was not built.



A new Neutron Therapy and Medical Isotope Production Facility (conceptual design) 2004

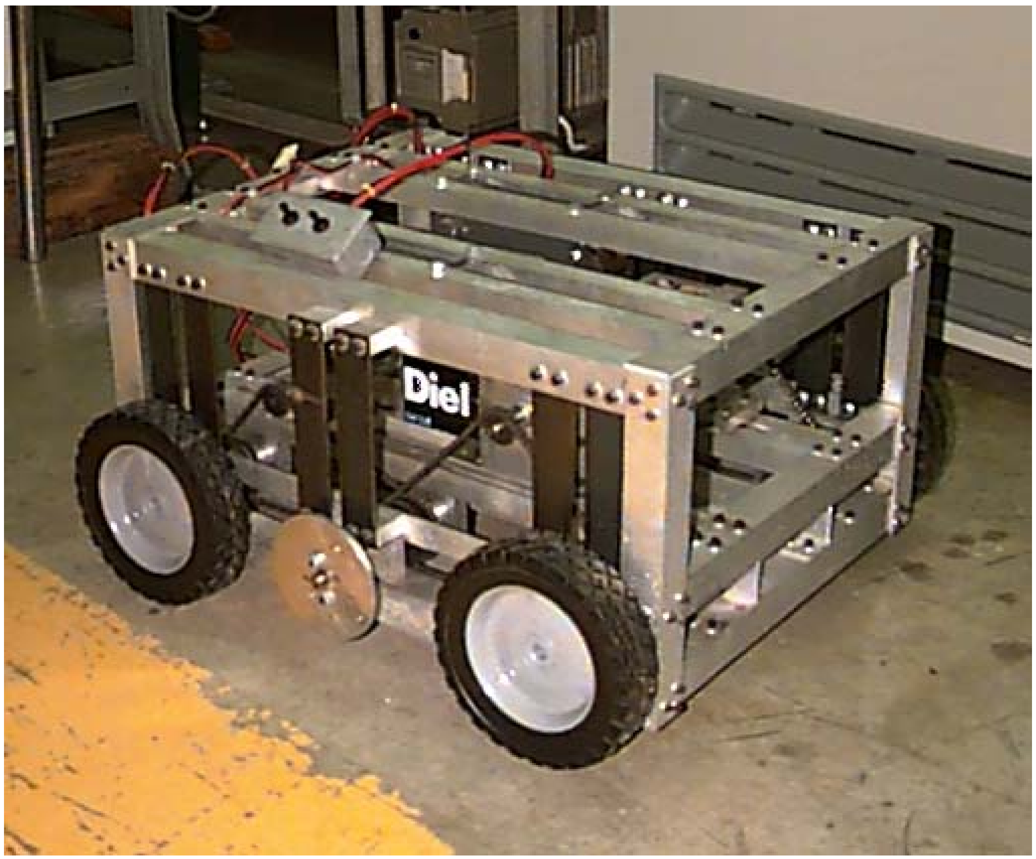
BE worked with Arlene Lennox of FNAL to develop this concept for a new medical facility for neutron therapy. Arlene died before the concept could be commercialized.

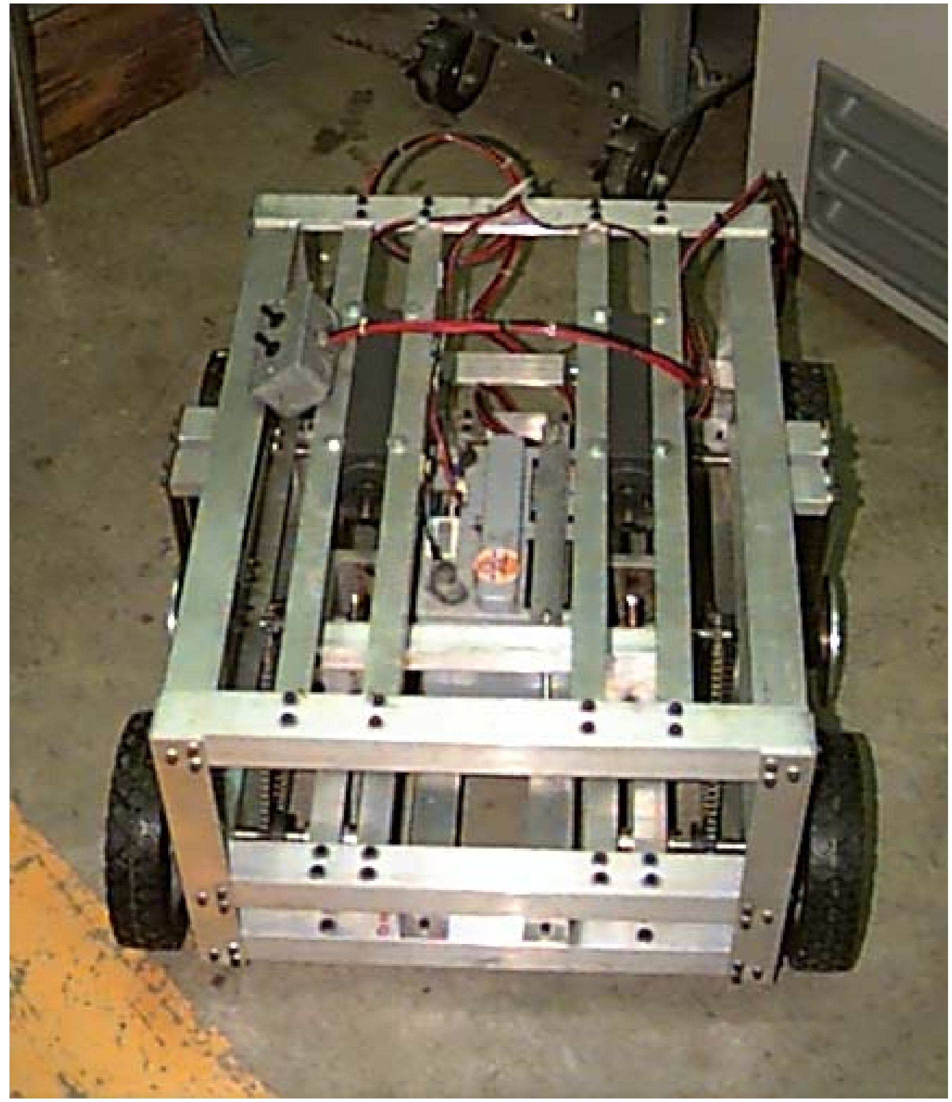




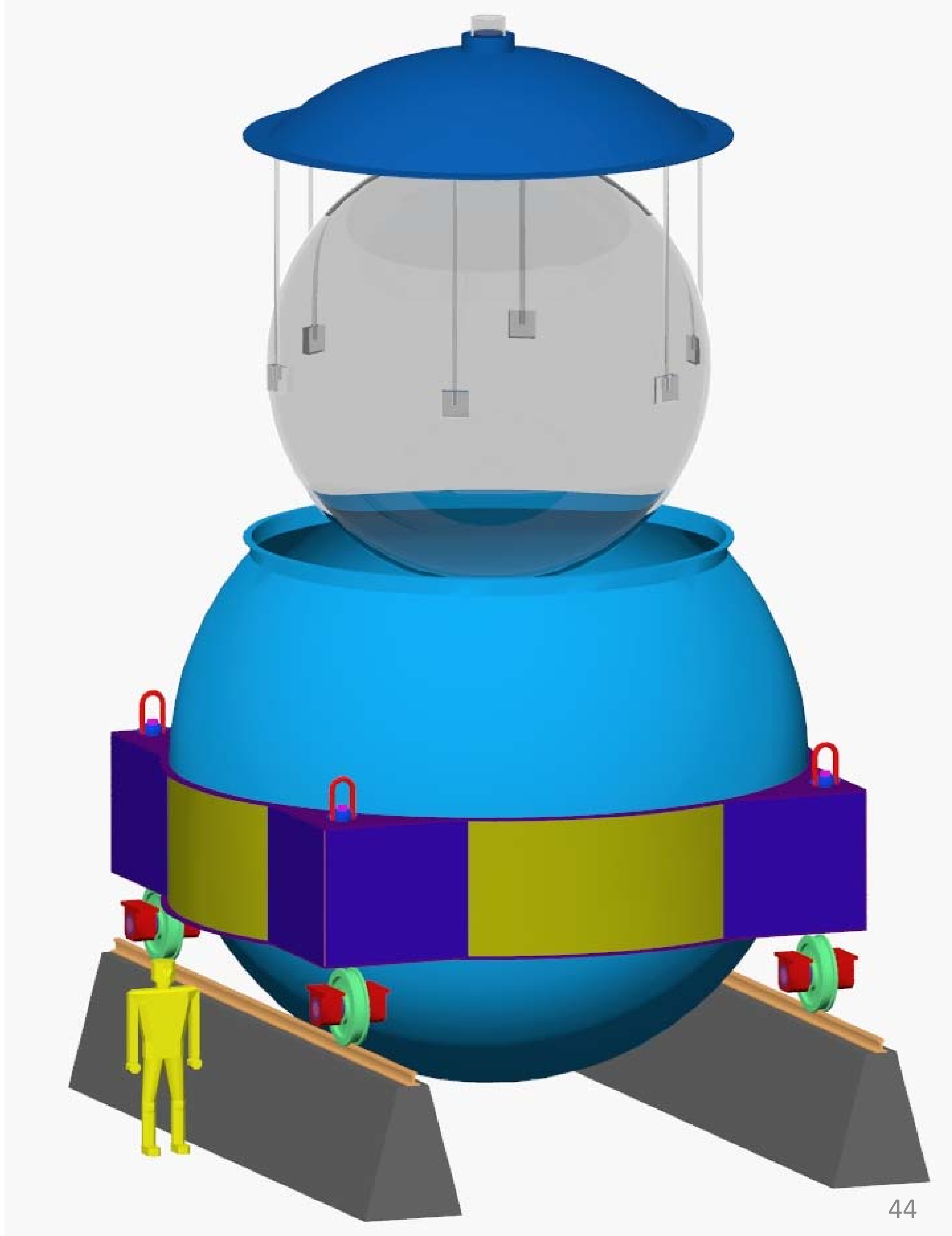
Rosie the Rad Worker Robot at FNAL, 2004

The Scitech robot briefly was a model for a rad worker robot at FNAL. The legs were replaced with wheels.





The Braidwood Experiment (conceptual design) 2004

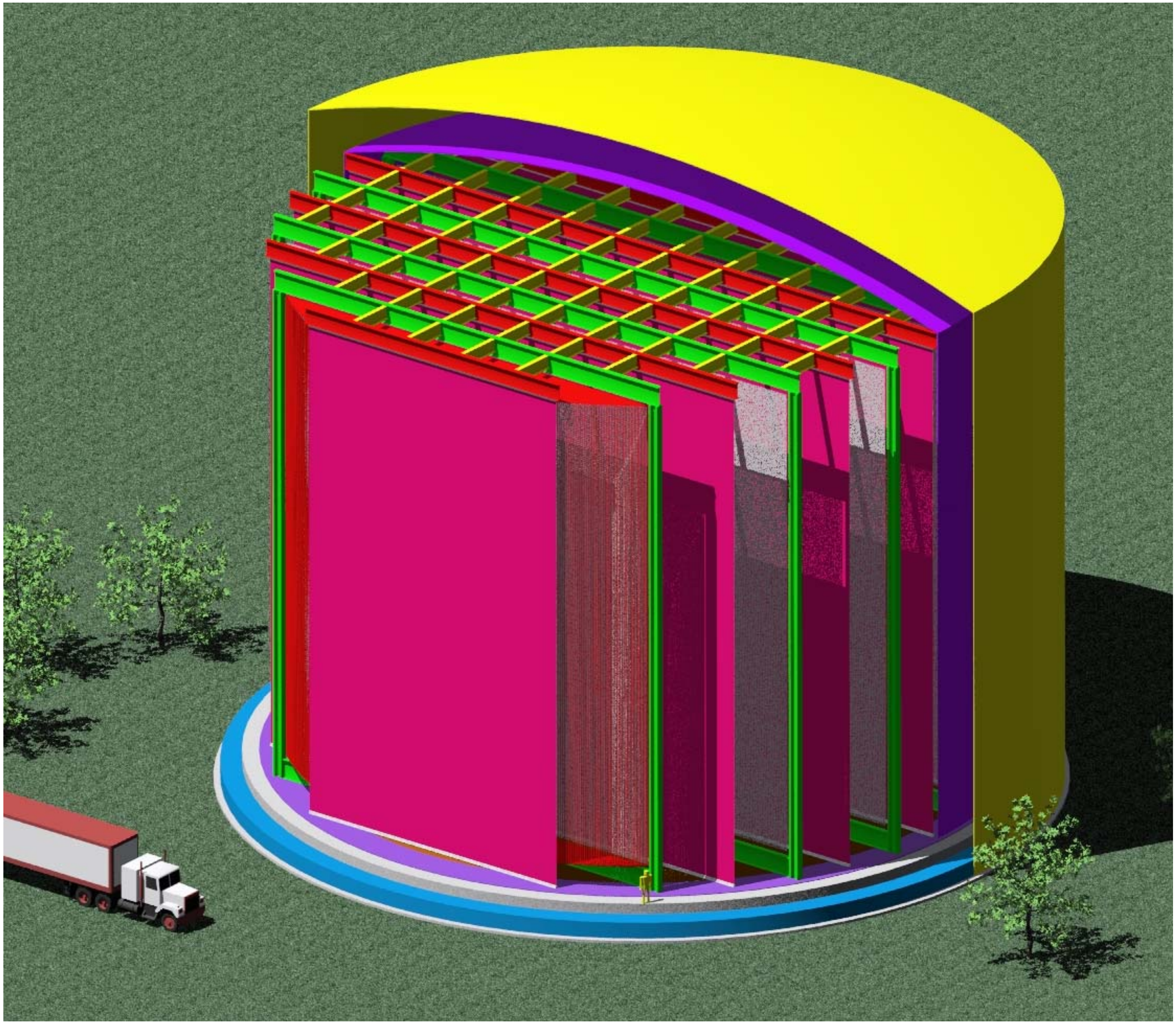


The Braidwood experiment was a reactor based experiment to measure θ_{13}. It was not built.

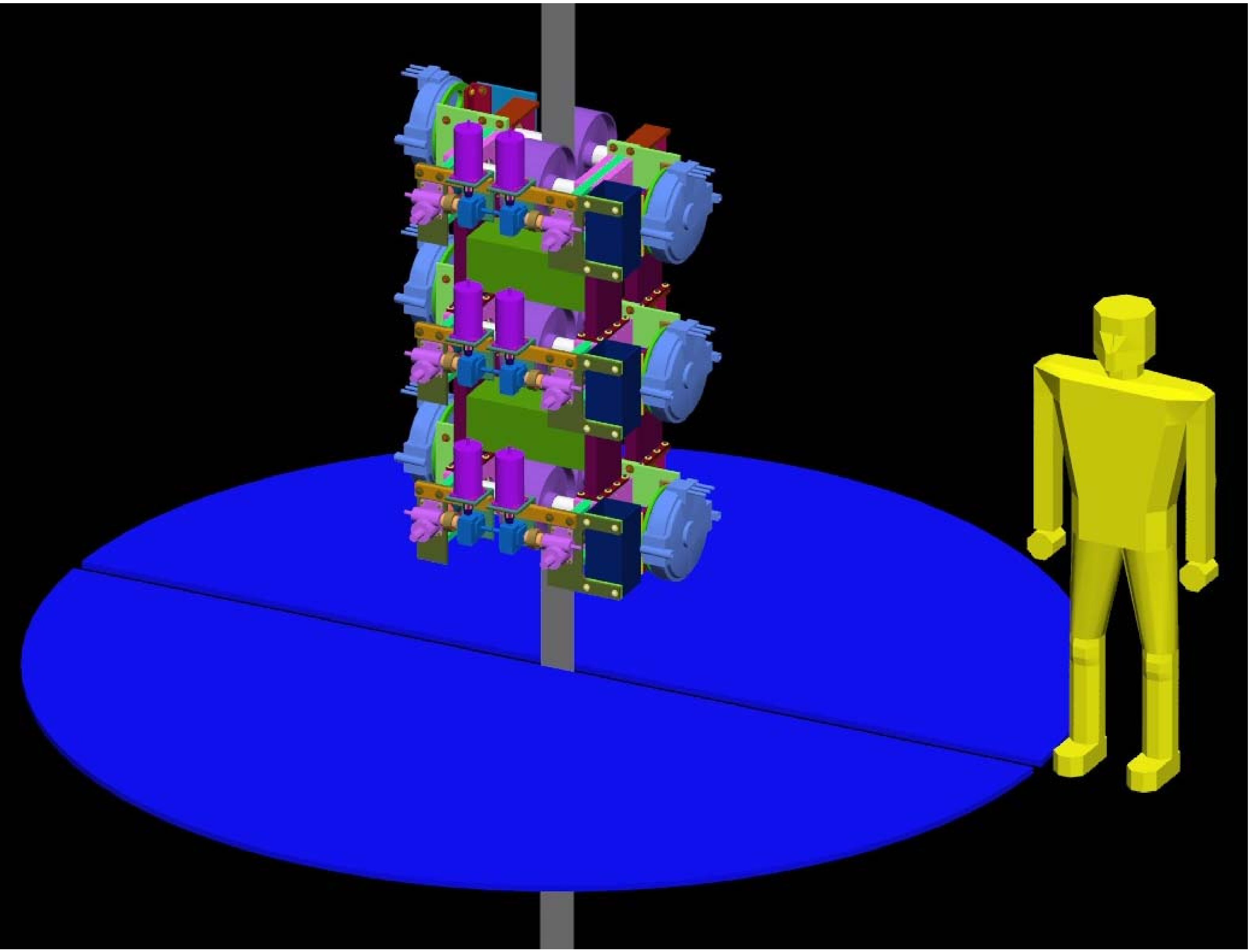
FLARE conceptual design, 2004

BE worked with Adam Para at FNAL to develop the initial concept for a very large liquid argon TPC.

This concept was not built, but was the progenitor of all the new LAr detectors in the US, especially LBNE and DUNE.



Conceptual Design of a 900 kg traction drive for a Space Elevator construction climber, Done for presentation at the Space Elevator Conference in Washington, D.C., 2004

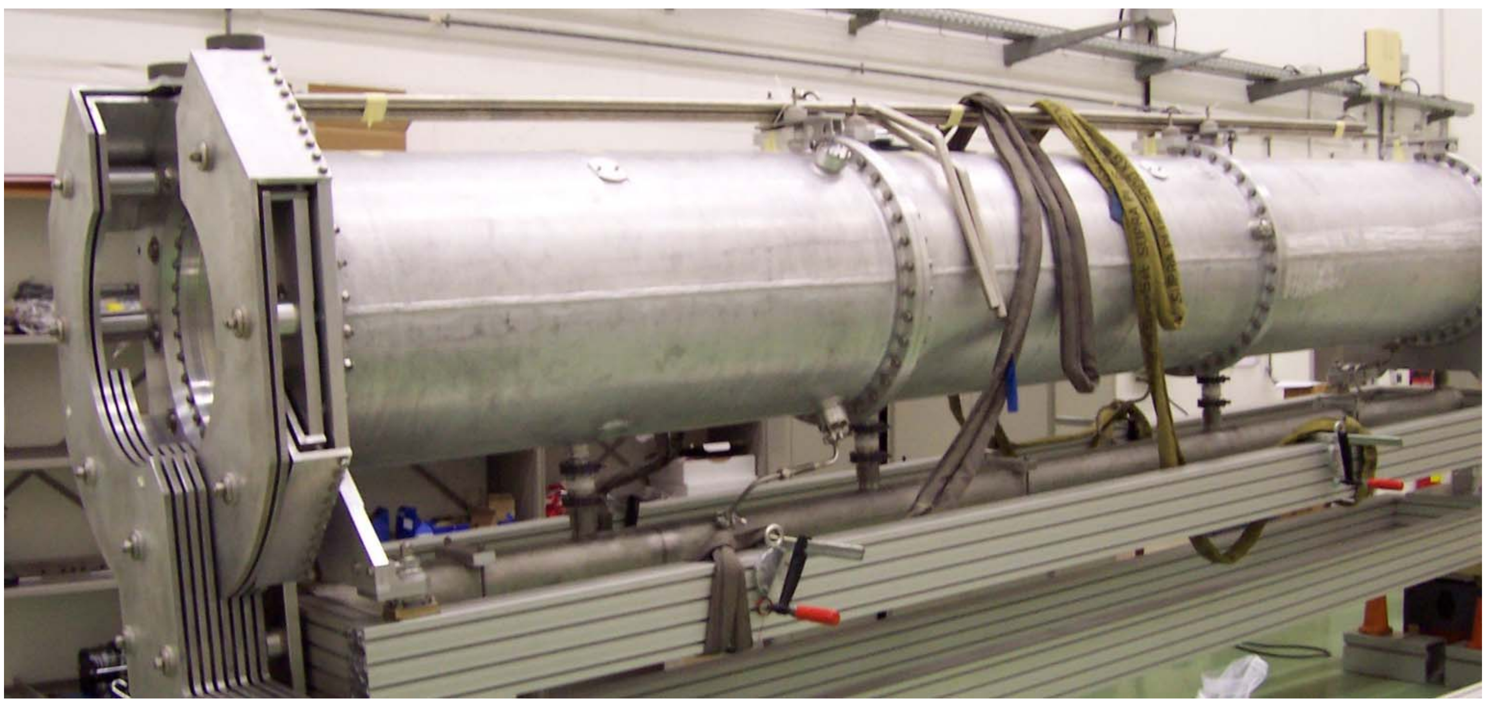


This is technically not a Bartoszek Engineering job,(since there is no money,) but I have been doing it as a “hobby/obsession” since 2004.

Working on the space elevator has been very educational as the machine characteristics are very different than the other projects shown here.

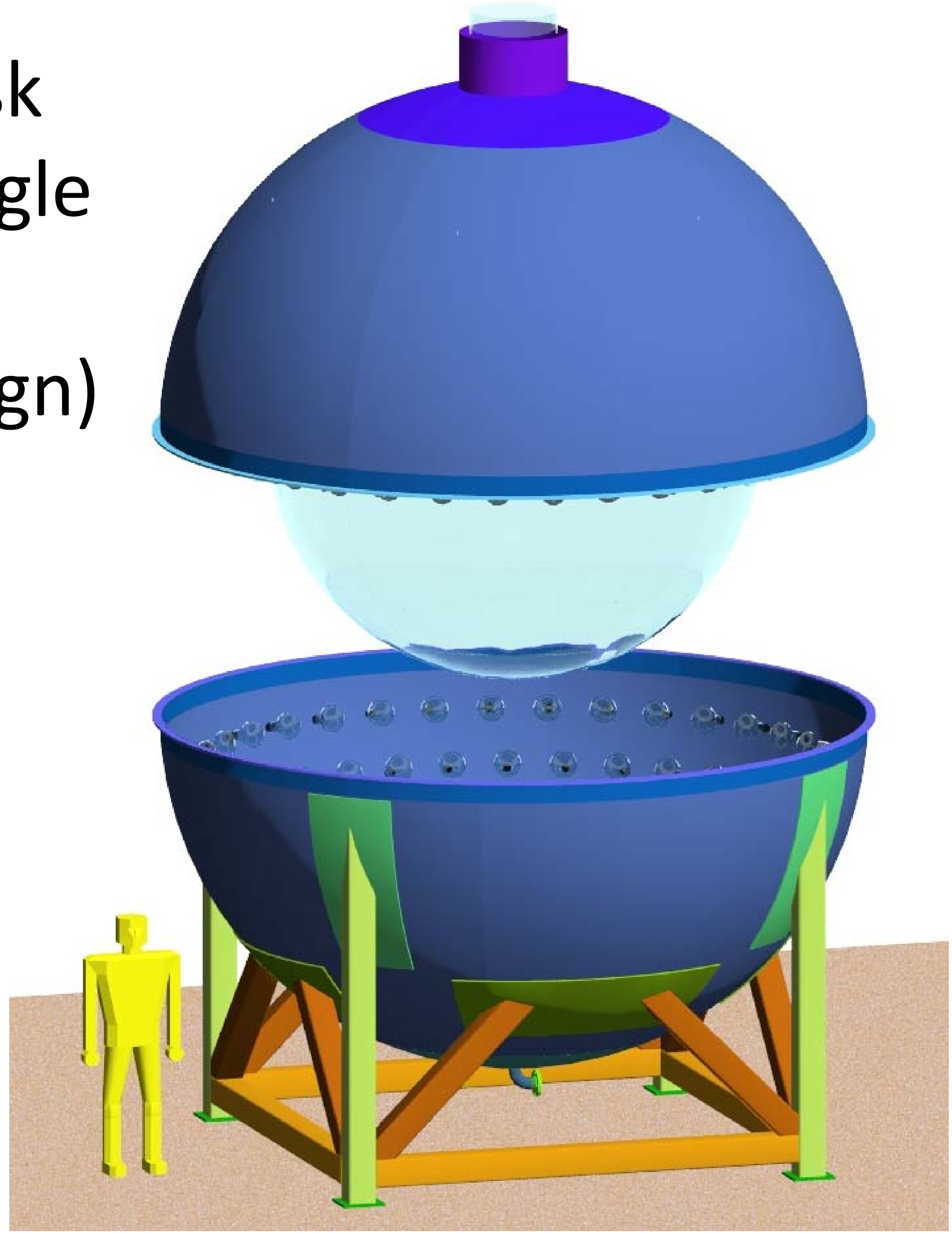
CNGS horn insulator failure review at CERN, 2005

BE was invited to CERN to review some failures of glass ring insulators for the CNGS horns and to advise on whether the proposed fix for the problem was sufficient.

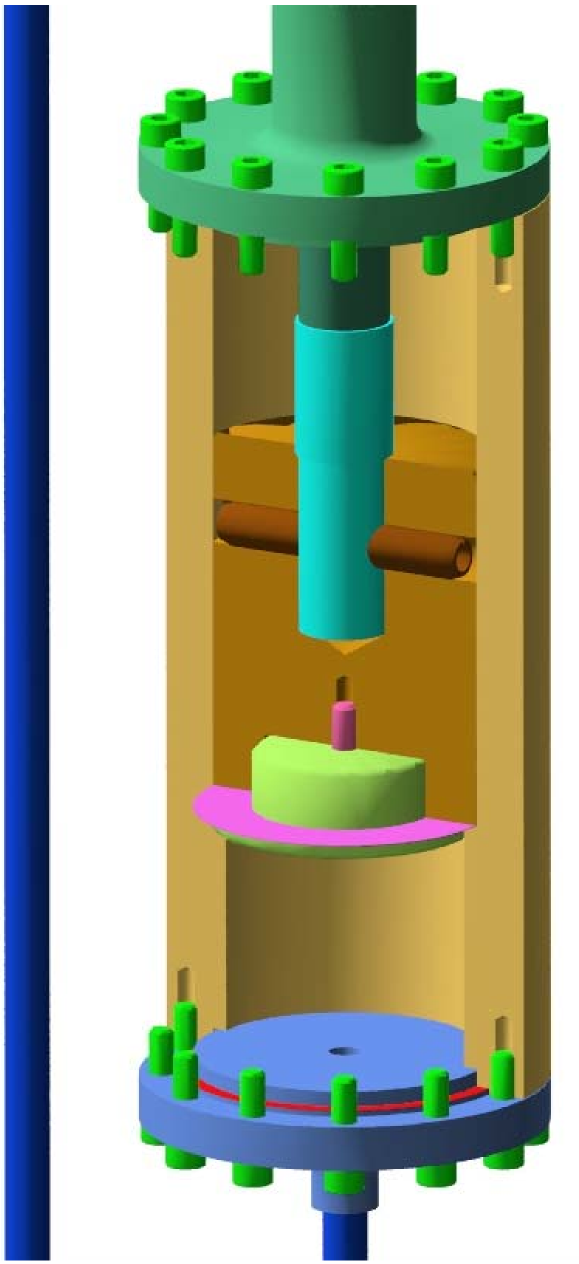


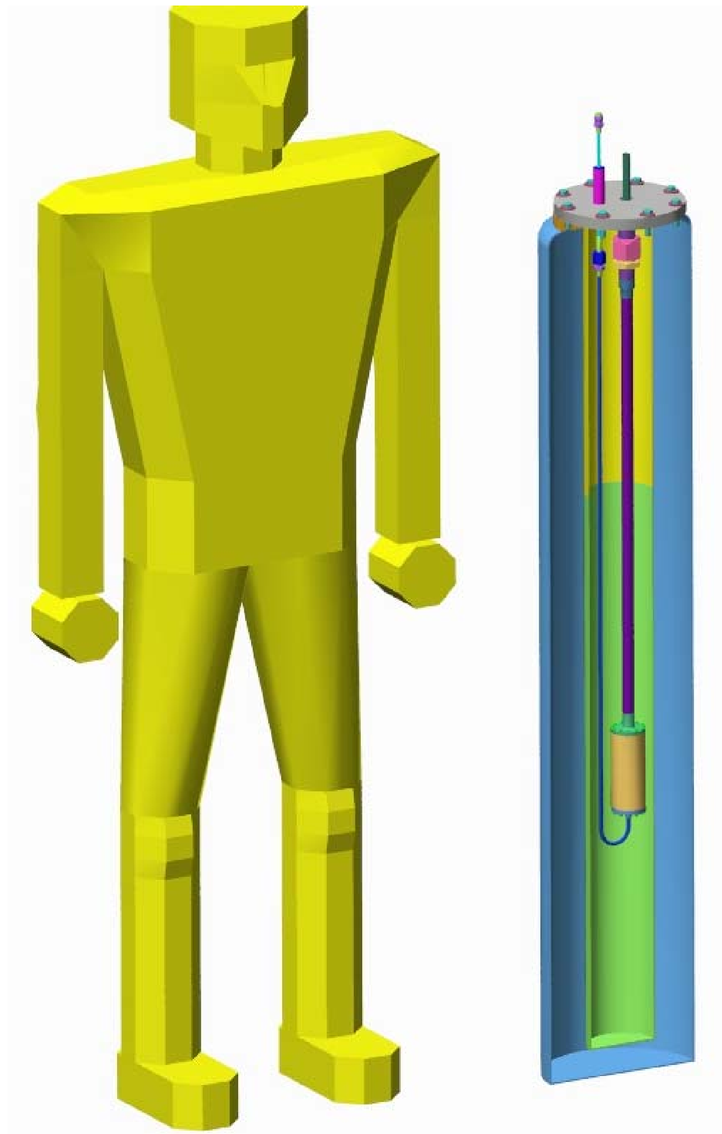
The Krasnoyarsk Weak Mixing Angle Experiment, (conceptual design) 2005

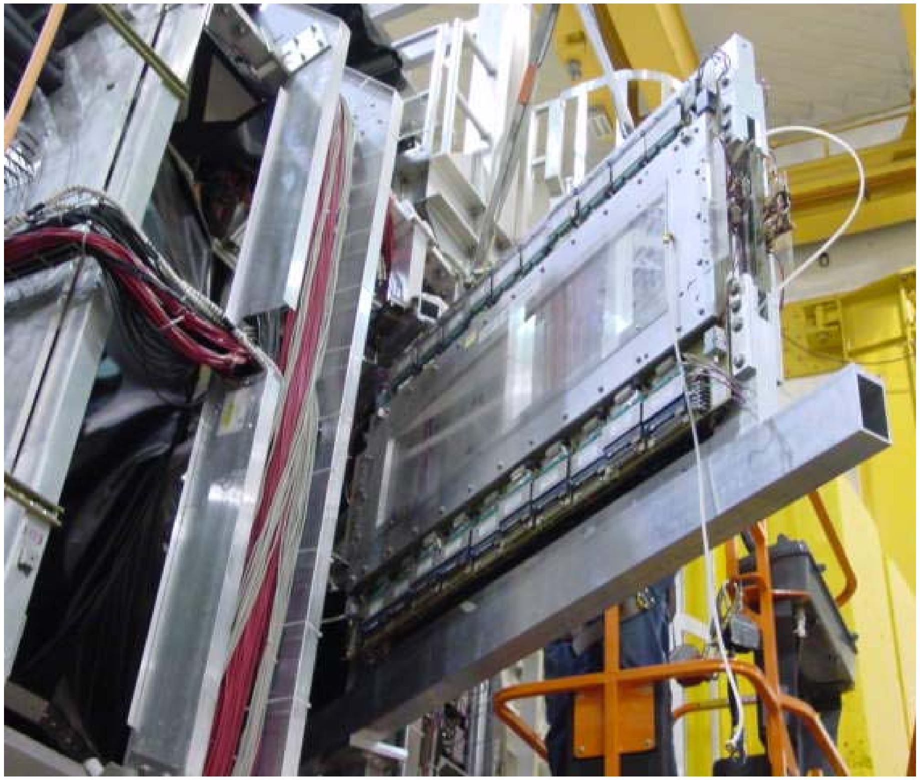
The Krasnoyarsk experiment was a reactor based experiment to measure θ_{13} near a reactor in Russia. This work was done with Janet Conrad at Columbia. It was not built.



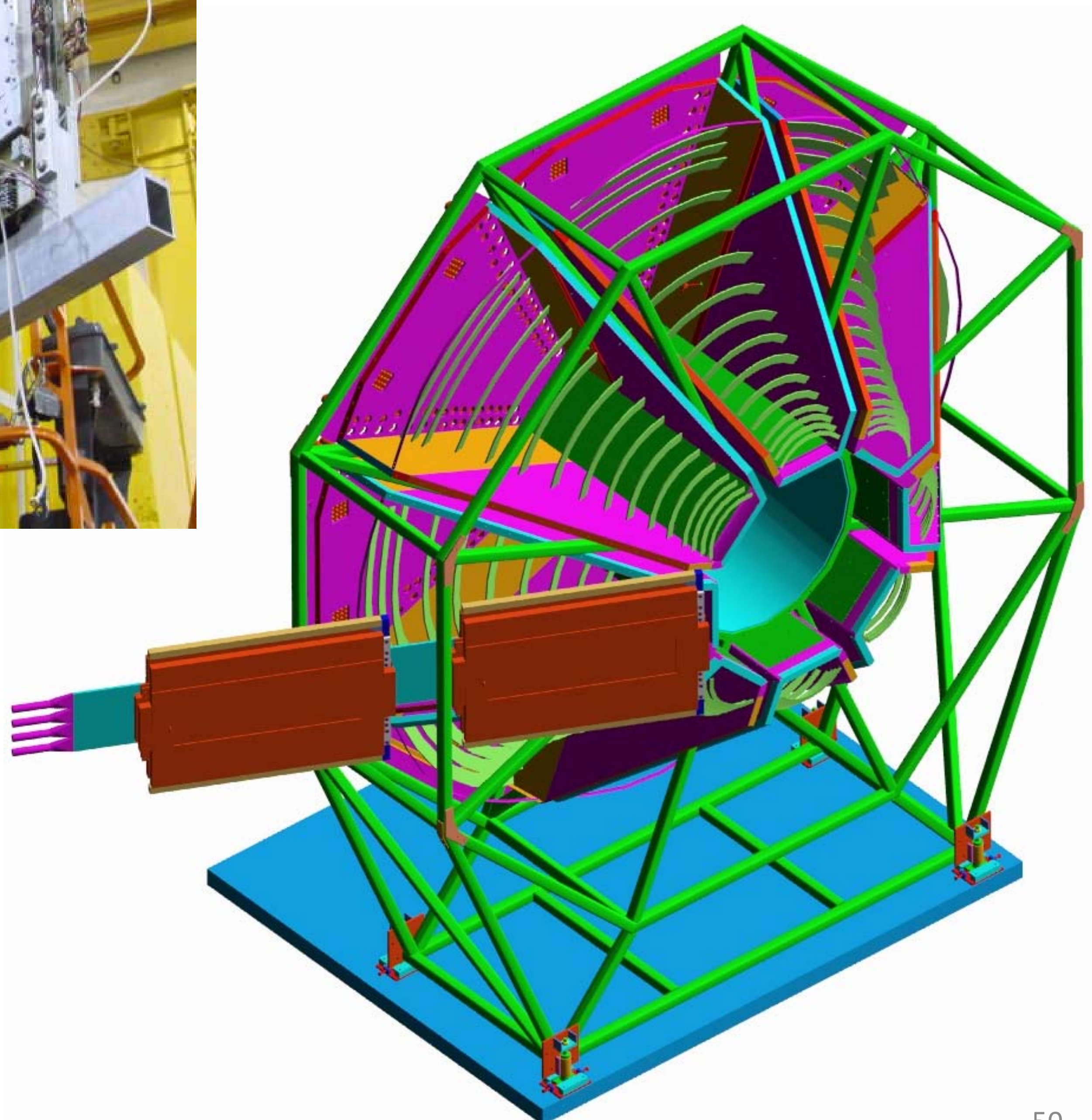
The first large-aperture, all-plastic cryogenic valve for nEDM, 2006





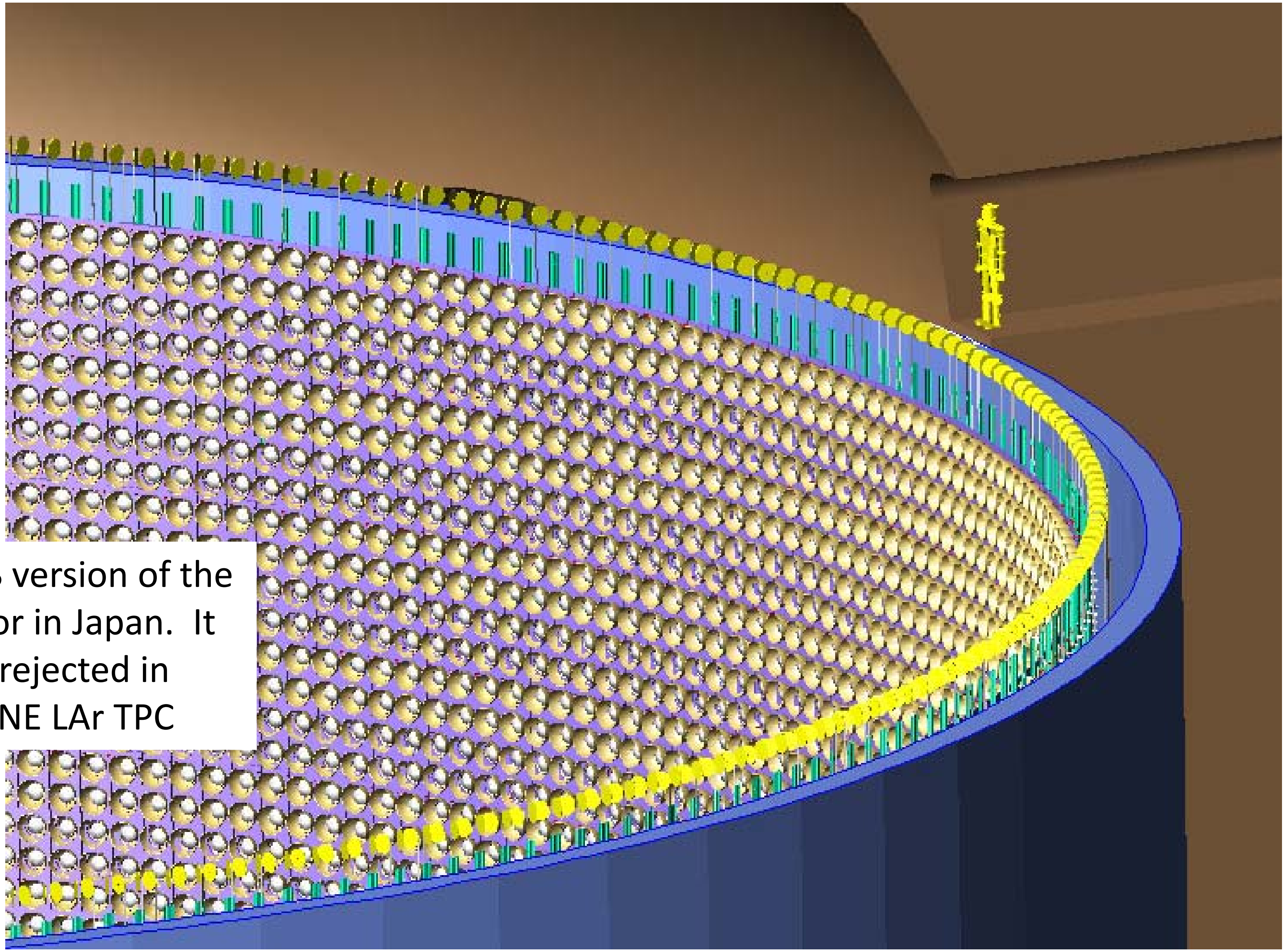


The G0 Wire Chamber at Jlab, 2006



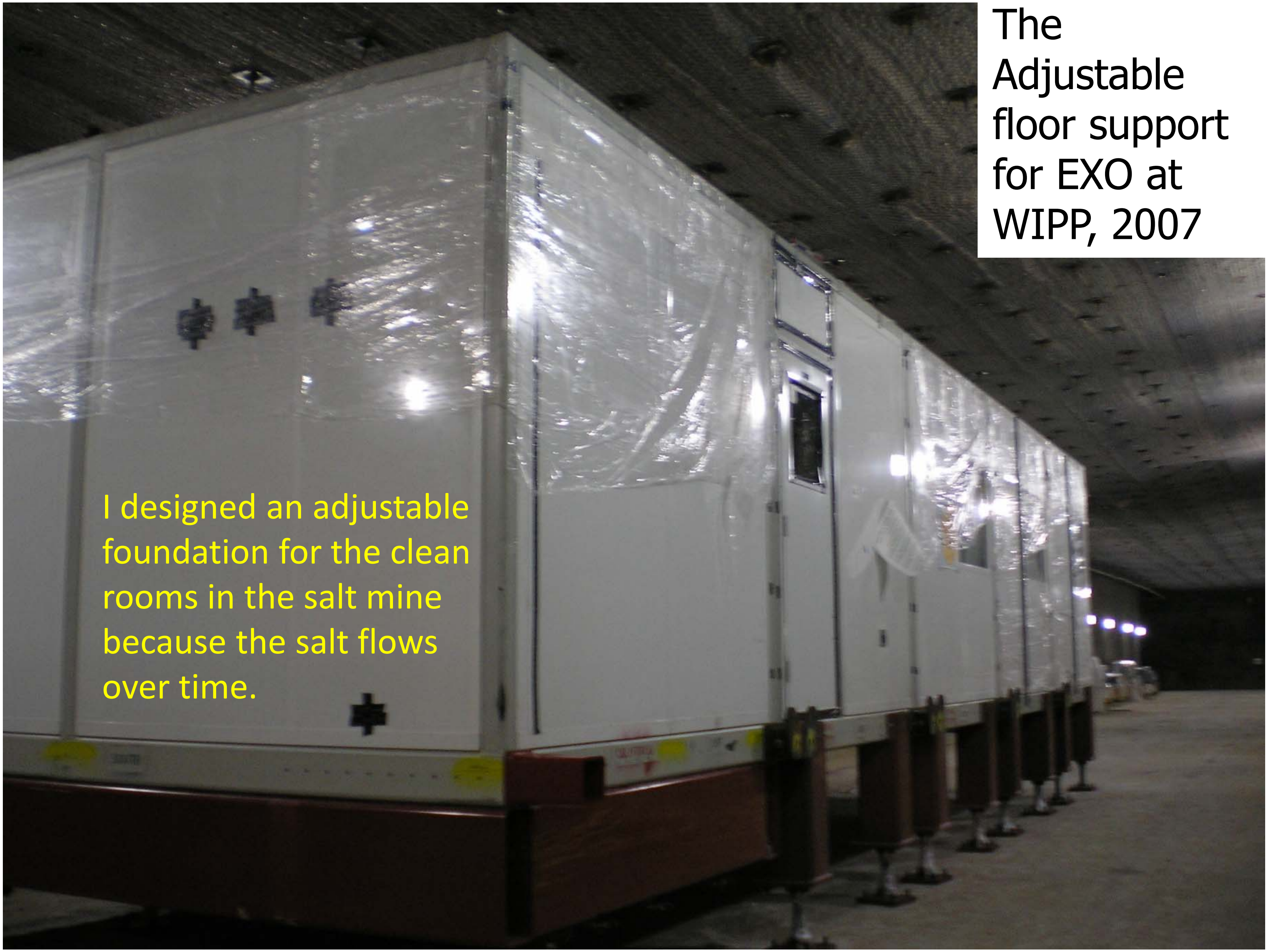
BE designed a supplemental support structure to mount a wire chamber in front of a single G0 detector module. The wire chamber provided higher resolution tracking to check the detector array.

Water Cherenkov in the Homestake Mine, 2007



This was the US version of the Super-K detector in Japan. It was eventually rejected in favor of the DUNE LAr TPC

The Adjustable floor support for EXO at WIPP, 2007



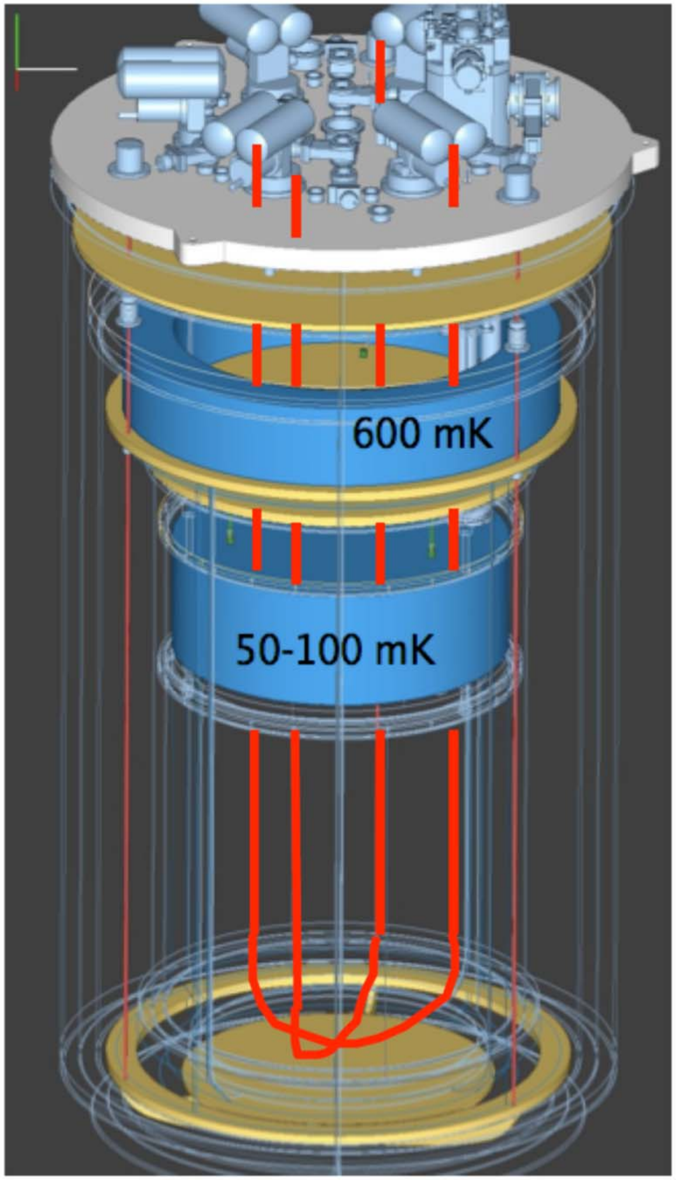
I designed an adjustable foundation for the clean rooms in the salt mine because the salt flows over time.

The EXO IV lifting fixture, WIPP, 2007

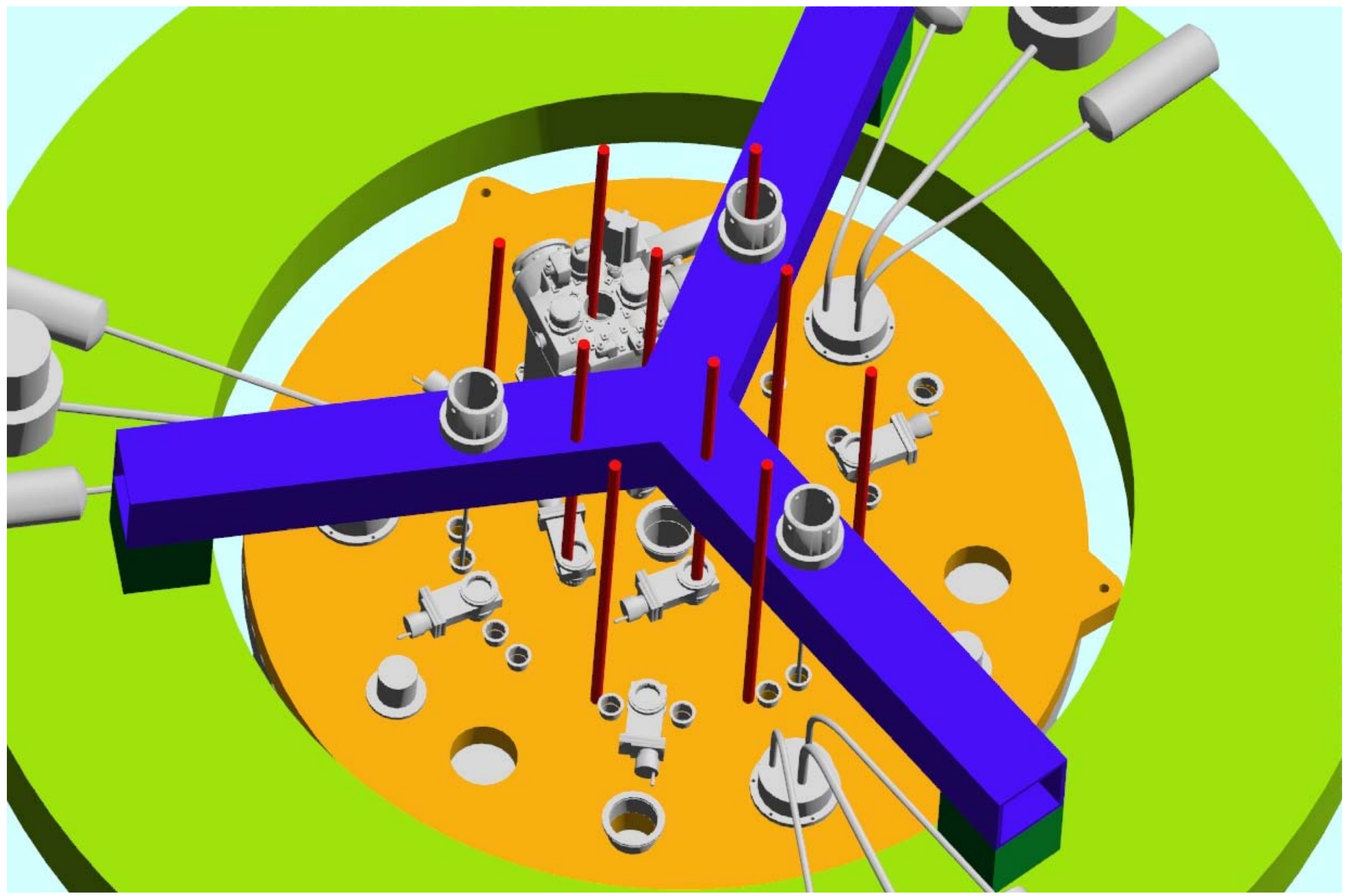
This lifting fixture was designed to lift and remove the inner vessel cryostat so that some pads could be replaced and the inside cleaned.

The concept is similar to an engine hoist, but for a much heavier object.

Conceptual design of a calibration system for Cuore with UWM, 2007



BE was hired to develop a calibration system for Cuore which operates at 10 milliK. CUORE is a large bolometer which operates at Gran Sasso in Italy.



From the CUORE website:

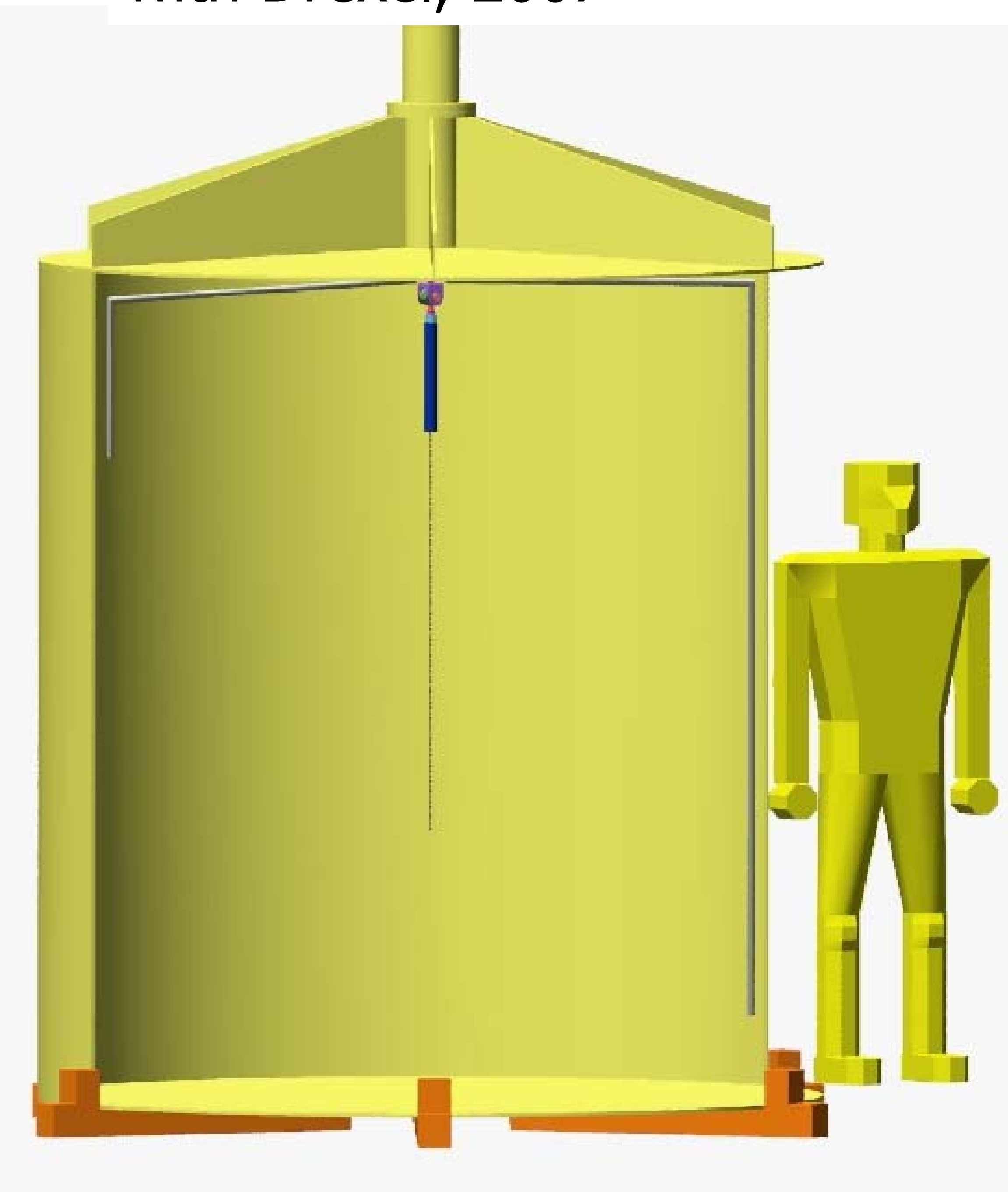
The challenge

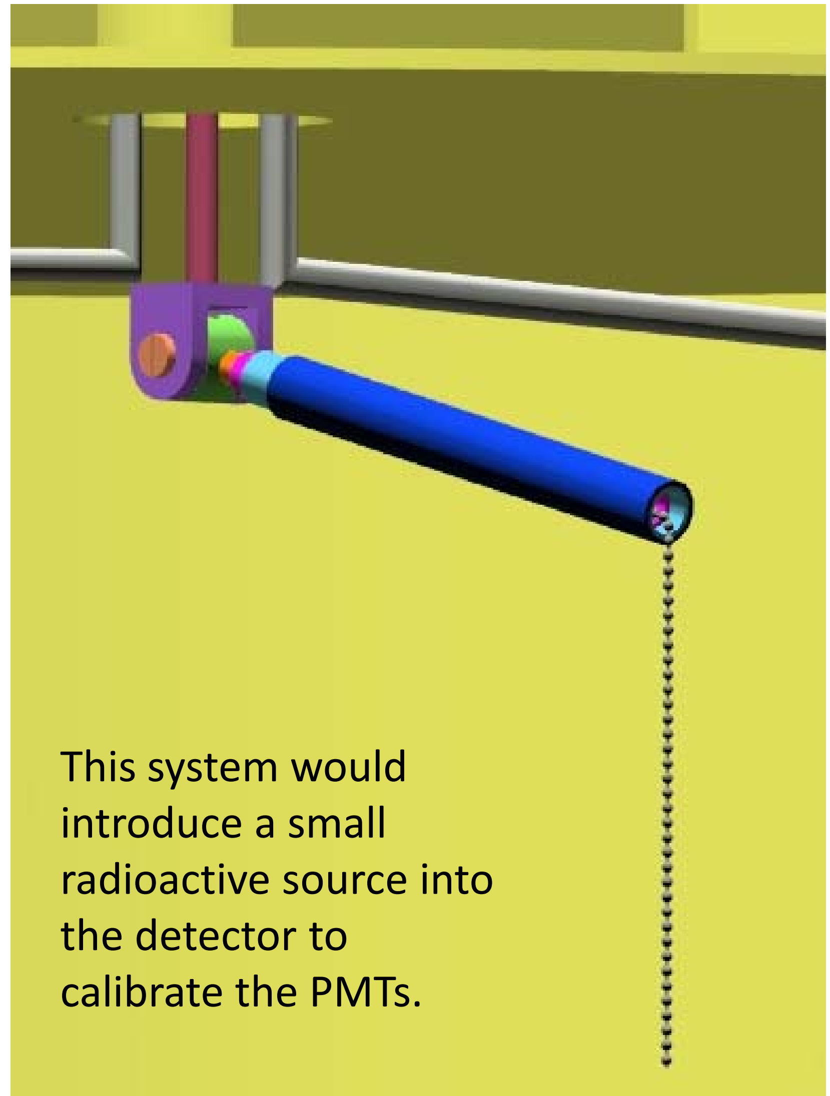
In recent decades, several experiments have searched for 0νββ decay using increasingly advanced technologies. So far, none have seen a clear and reproducible 0νββ decay signal. The next generation of experiments will use ton-scale detectors, with superb energy resolution and exquisitely low backgrounds in the energy region of interest. If observed, the experimental signature would be quite clear but very rare. The signature would be a narrow peak at the energy of the decay, but so rare that we expect to see only a few decays in 5–10 years of data-taking with a ton-scale detector!

The CUORE collaboration has taken up this challenge by studying the 0νββ decay candidate ^{130}Te. In recent years we have built and analyzed data from the prototype bolometric detectors Cuoricino and CUORE-0. The next stage, planned to start operations in 2016, is the largest bolometric detector ever built: CUORE.

https://cuore.lngs.infn.it/en/about/physics

Conceptual design of a calibration system for Double Chooz with Drexel, 2007





This system would introduce a small radioactive source into the detector to calibrate the PMTs.

From the Wikipedia:

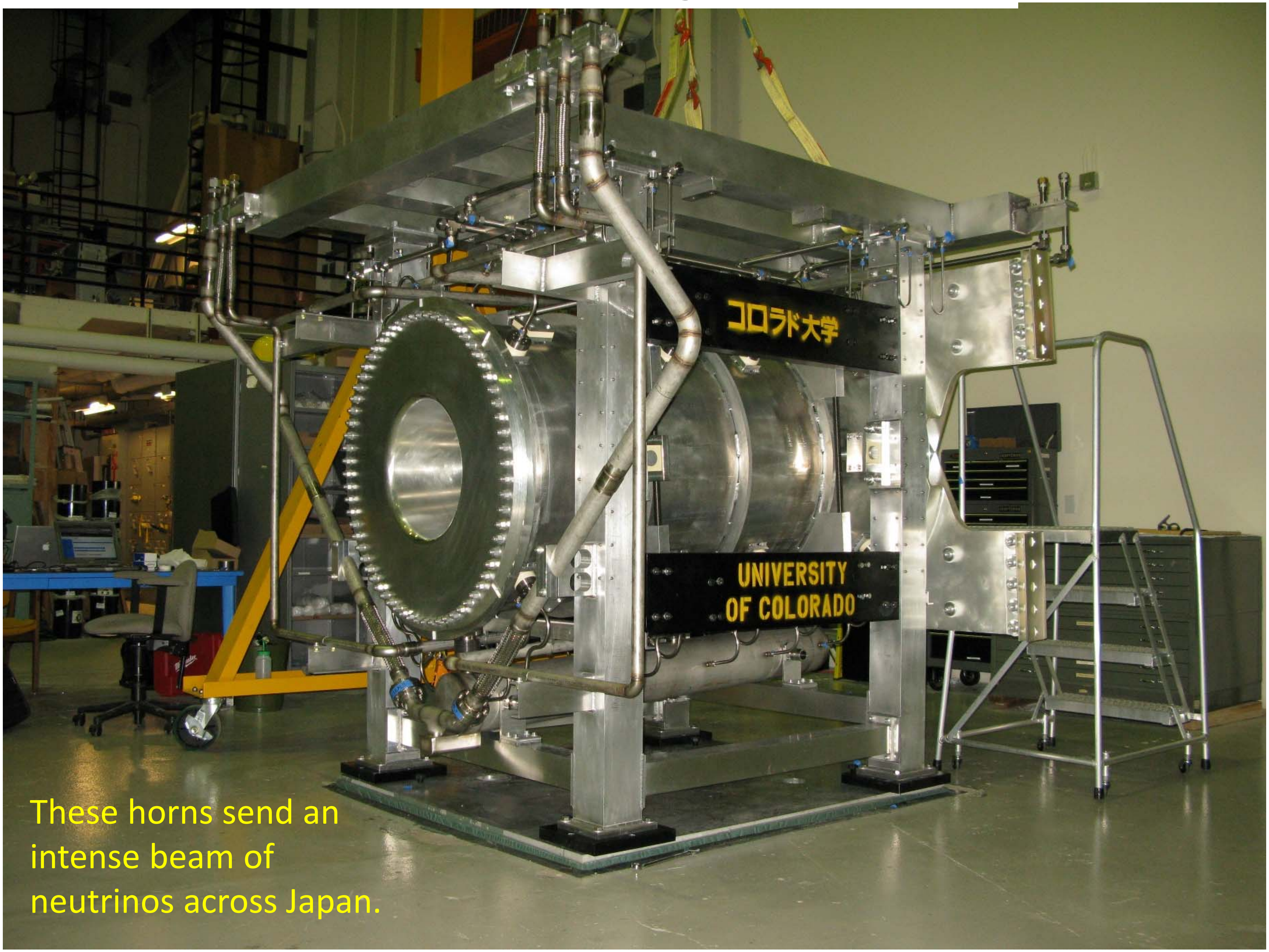
Double Chooz was a short-baseline neutrino oscillation experiment in Chooz, France. Its goal was to measure or set a limit on the θ_{13} mixing angle, a neutrino oscillation parameter responsible for changing electron neutrinos into other neutrinos. The experiment uses reactors of the Chooz Nuclear Power Plant as a neutrino source and measures the flux of neutrinos they receive. To accomplish this, Double Chooz has a set of two detectors situated 400 meters and 1050 meters from the reactors. Double Chooz was a successor to the Chooz experiment; one of its detectors occupies the same site as its predecessor. Until January 2015 all data has been collected using only the far detector. The near detector was completed in September 2014, after construction delays[1] and is taking physics data since beginning of 2015. Both detectors finished taking data at the end of 2017.

https://en.wikipedia.org/wiki/Double_Chooz

The prototype FINeSSE TPC at Yale, 2008

First LAr TPC for Bonnie Fleming at Yale

T2K Horn 2 at CU, 2008 (and again in 2011)



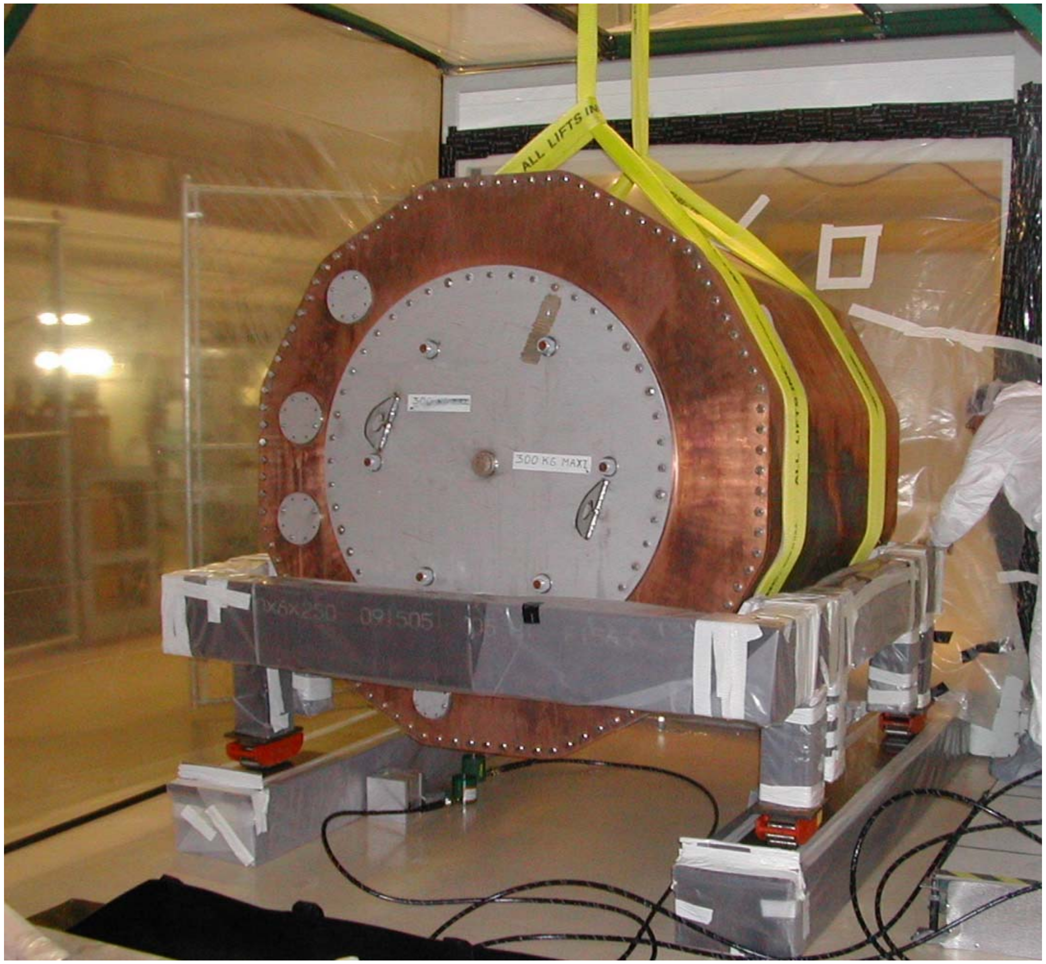
These horns send an intense beam of neutrinos across Japan.

The T2K Experiment in Japan

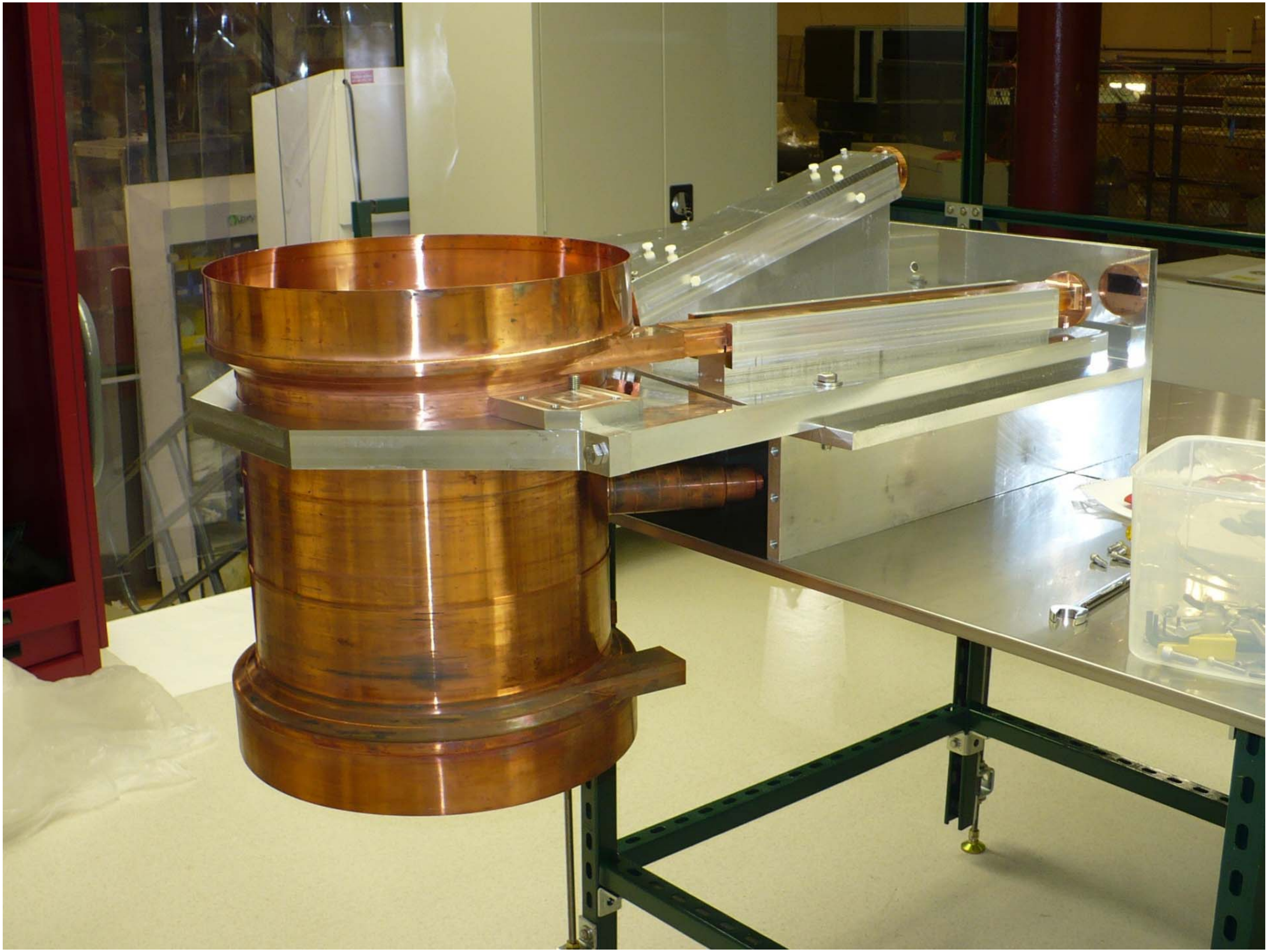
- https://jnusrv01.kek.jp/public/t2k/
- https://en.wikipedia.org/wiki/T2K_experiment
- "T2K was the first experiment which observed the appearance of electron neutrinos in muon neutrino beam,[4] it also provided the world best measurement of oscillation parameter θ_{23} [5] and a hint of a significant matter-antimatter asymmetry in neutrino oscillations.[6][7] The measurement of the neutrino-antineutrino oscillation asymmetry may bring us closer to the explanation of the existence of our matter-dominated Universe."

The EXO cryostat cart at Stanford, 2008

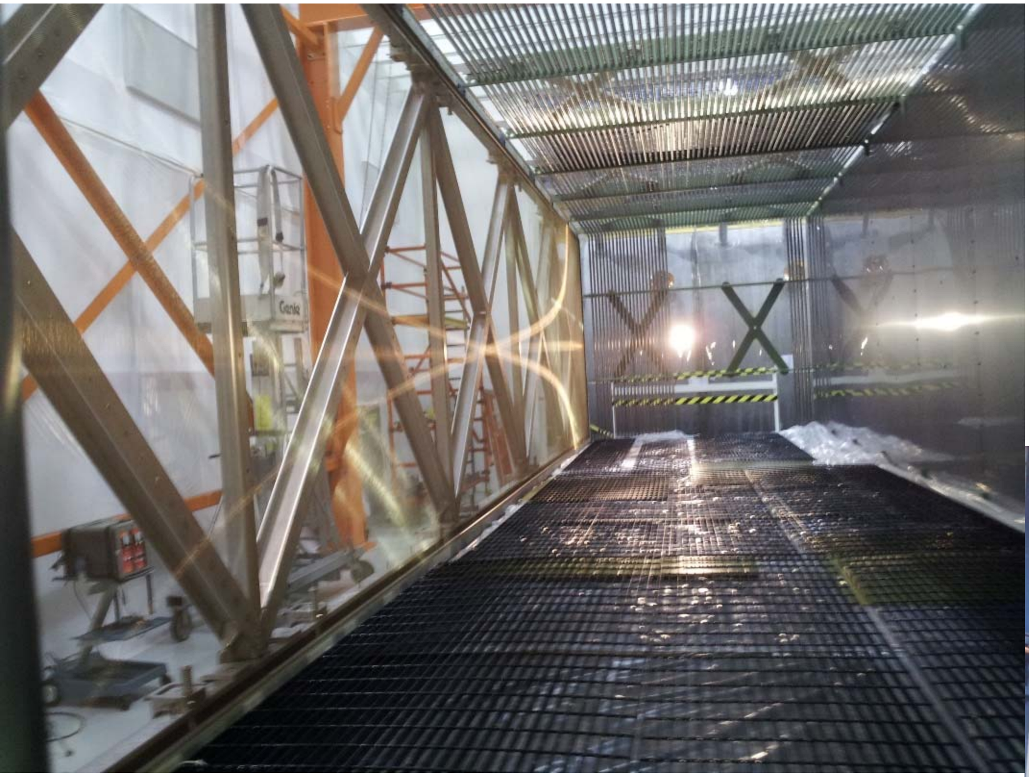
This fixture was needed to lift and roll the cryostat into the clean room at Stanford before the clean rooms were shipped to WIPP.

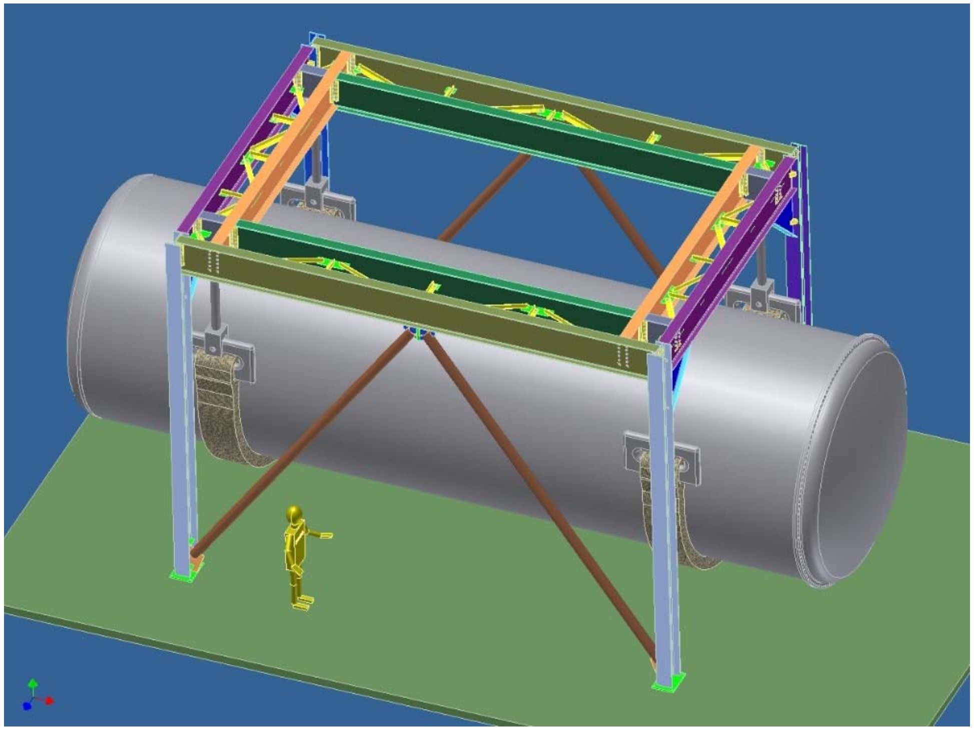


The EXO ebeam welding fixtures at Stanford, 2008



MicroBooNE at FNAL, 2009



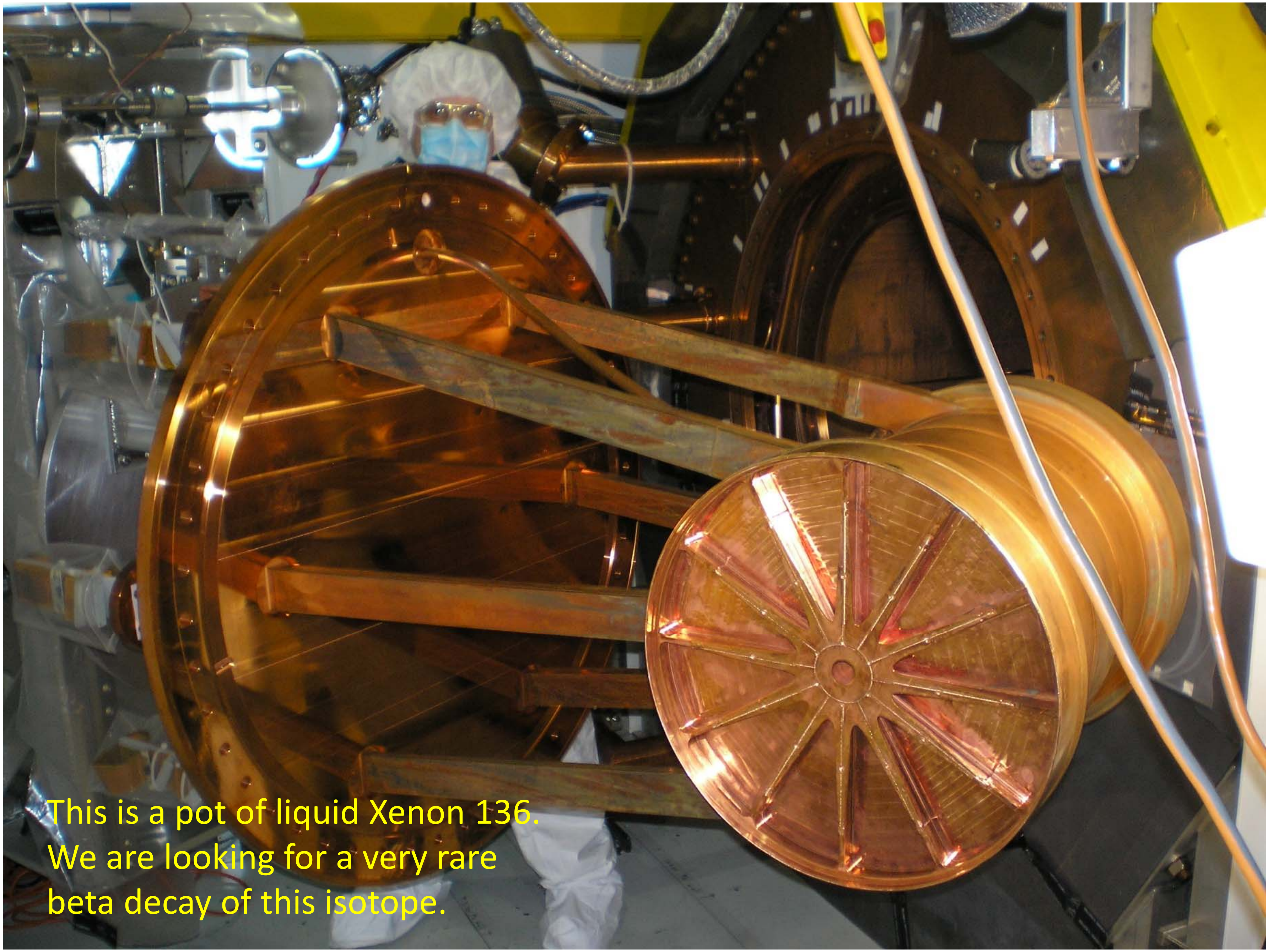


MicroBooNE at FNAL

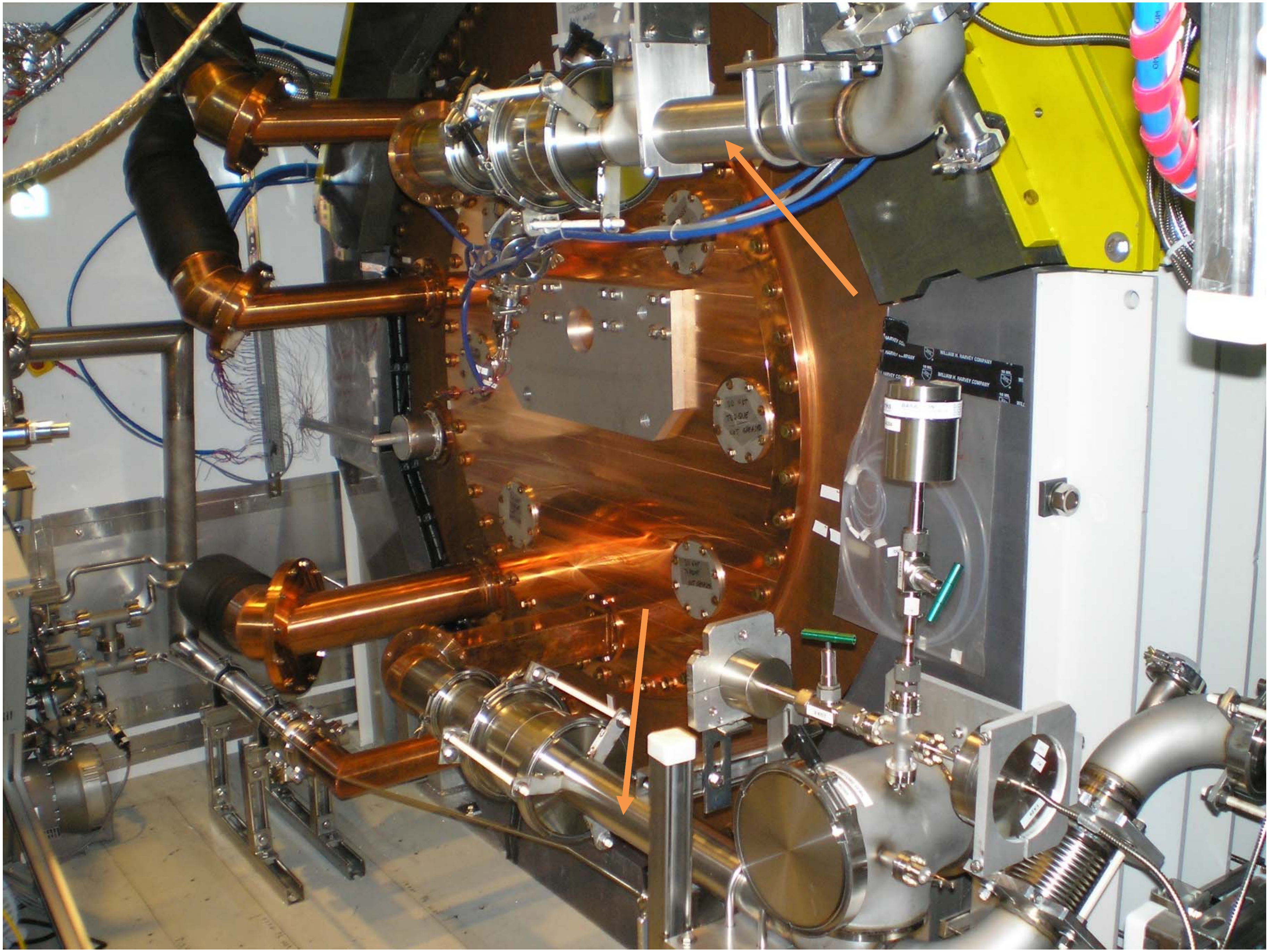
- https://microboone.fnal.gov/
- "MicroBooNE is a large 170-ton liquid-argon time projection chamber (LArTPC) neutrino experiment located on the Booster neutrino beamline at Fermilab. The experiment first started collecting neutrino data in October 2015.
- MicroBooNE will investigate the low energy excess events observed by the MiniBooNE experiment, measure a suite of low energy neutrino cross sections, and investigate astro-particle physics.
- MicroBooNE is also contributing crucial input towards the construction of massive kiloton scale LArTPC detectors for the future Deep Underground Neutrino Experiment (DUNE) and is the first detector in the Short-Baseline Neutrino (SBN) program at Fermilab."

The EXO installation machine at Stanford, 2009

The EXO LXe vessel installation at WIPP, 2009



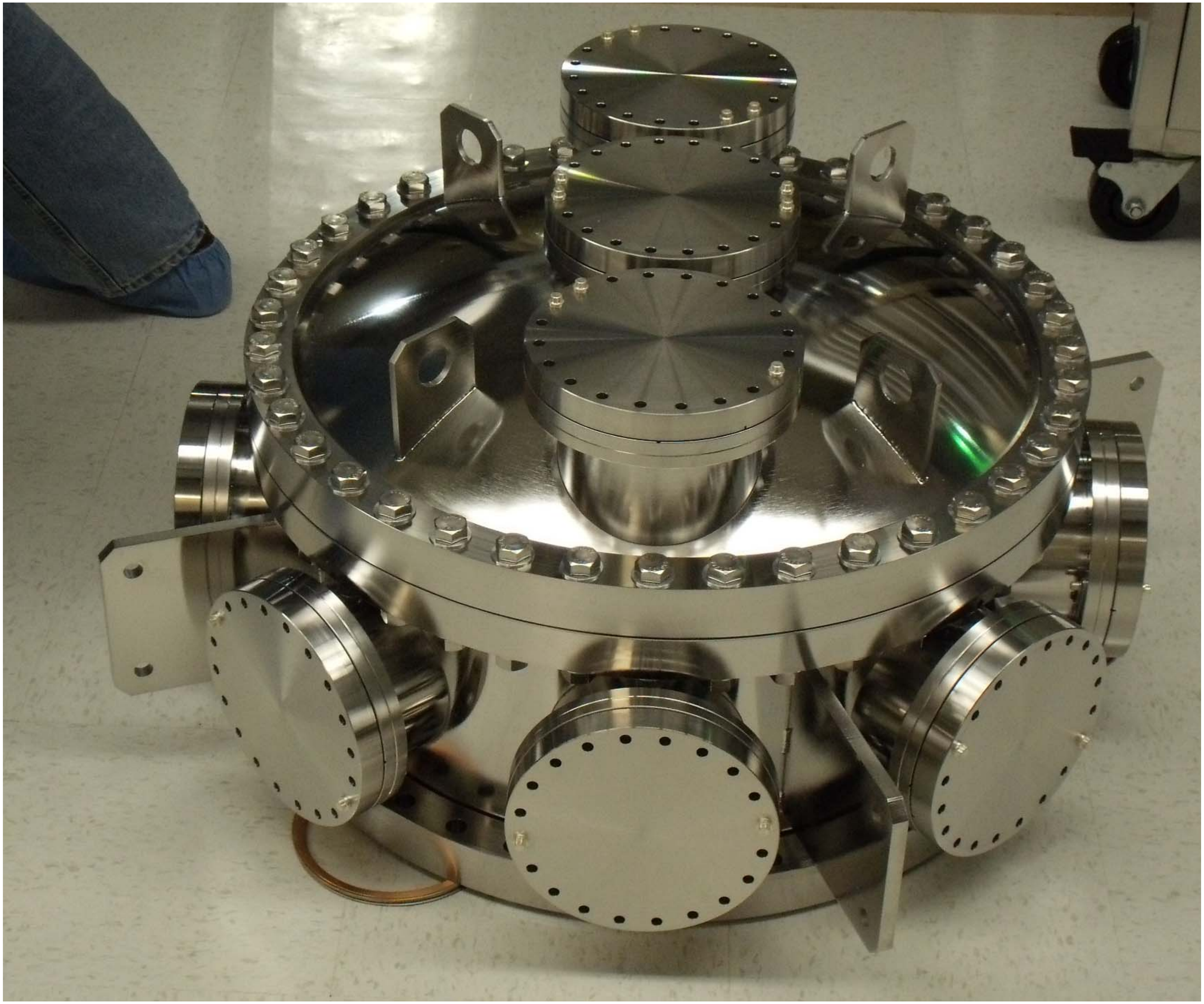
The EXO Xe transfer lines at WIPP, 2009



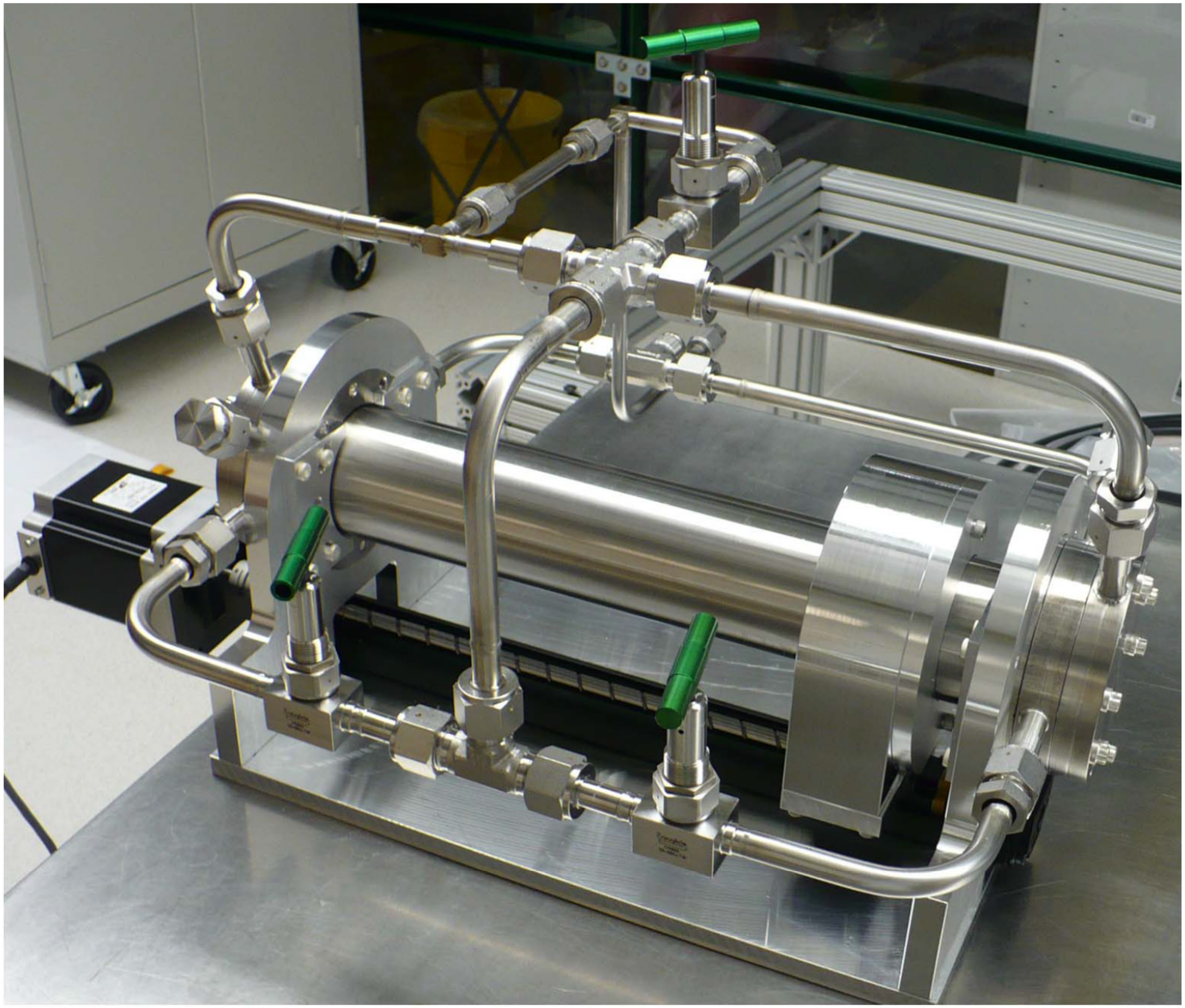
The EXO experiment at WIPP

- https://www-project.slac.stanford.edu/exo/
- “The Enriched Xenon Observatory is an experiment in particle physics aiming to detect "neutrino-less double beta decay" using large amounts of xenon isotopically enriched in the isotope 136. A 200-kg detector using liquid Xe is currently being installed at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Many research and development efforts are underway for a ton-scale experiment, with the goal of probing new physics and the mass of the neutrino.”

Cryopump pressure vessel for EXO, 2010



Magnetically driven Xenon piston pump for EXO, 2010

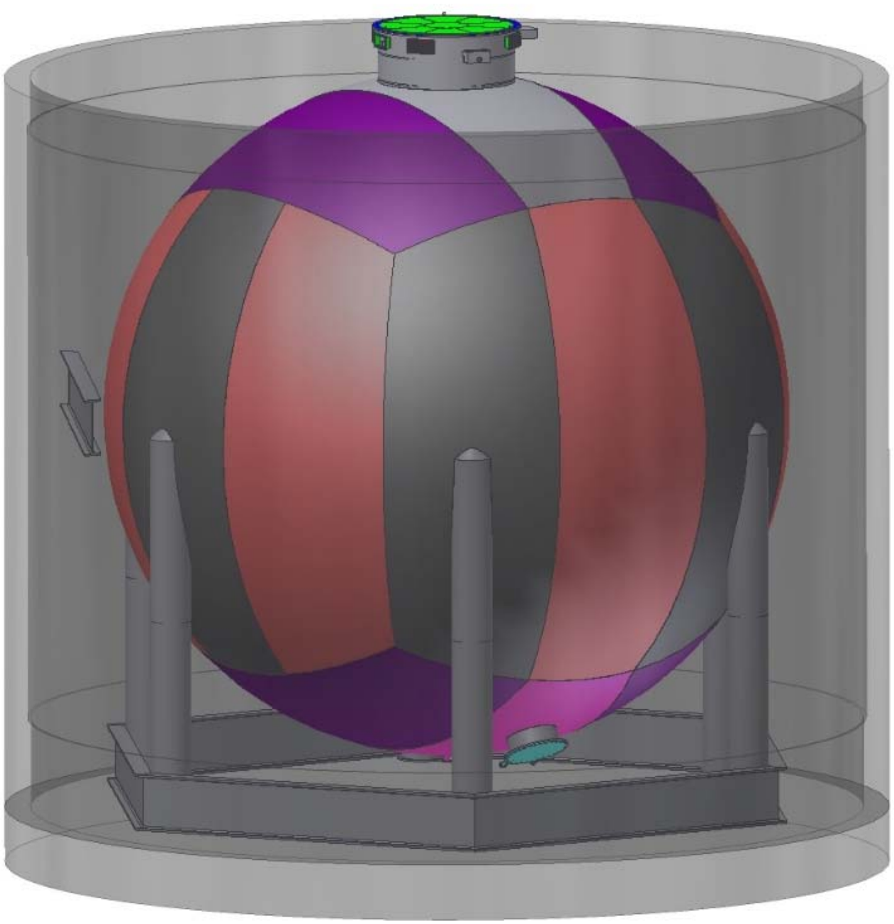


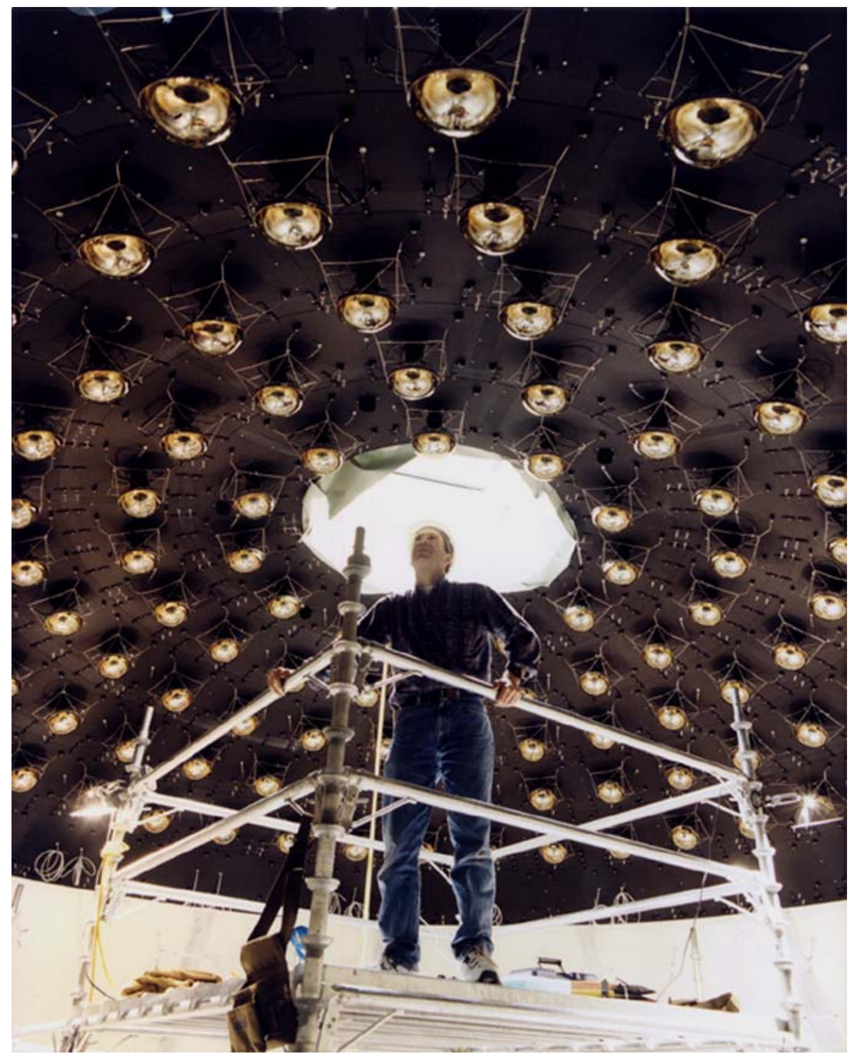
A magnetically-driven piston pump for ultra-clean applications

F. LePort,[1,a)] R. Neilson,[1,b)] P.S. Barbeau,[1] K. Barry,[1] L. Bartoszek,[1] I. Counts,[1] J. Davis,[1] R. deVoe,[1]
M. J. Dolinski,[1] G. Gratta,[1] M. Green,[1,c)] M. Montero Díez,[1] A.R. Müller,[1] K. O'Sullivan,[1] A. Rivas,[1]

Report on Moving the MiniBooNE Detector, 2010

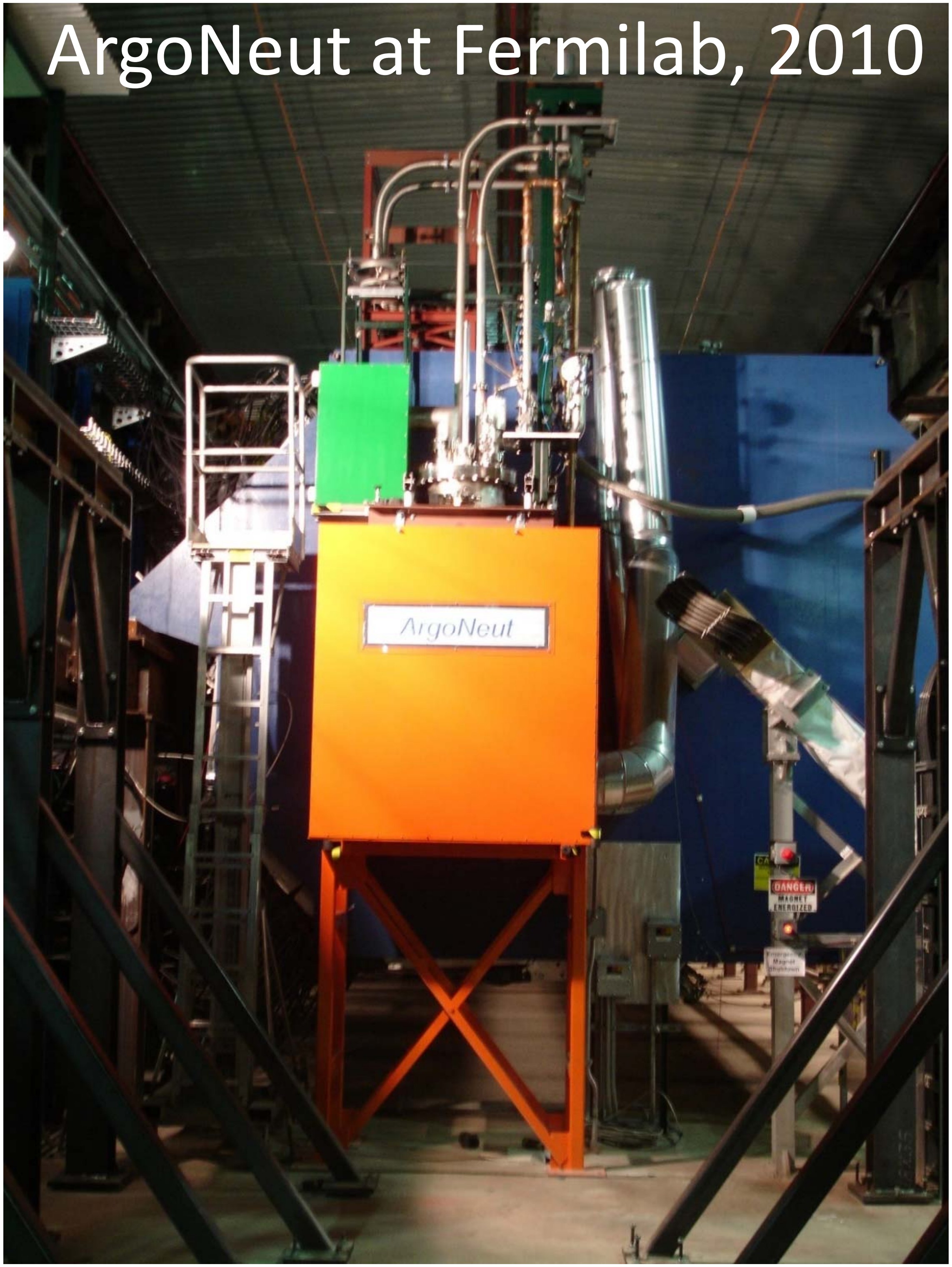
BE was commissioned to write a report about how much money, time and resources would be required to move the 40 foot spherical storage tank which is the MiniBooNE Detector.





ArgoNeut was the first liquid argon TPC detector to detect low energy neutrinos.

Fermilab is working on an enormous scale LAr detector for the DUNE experiment.

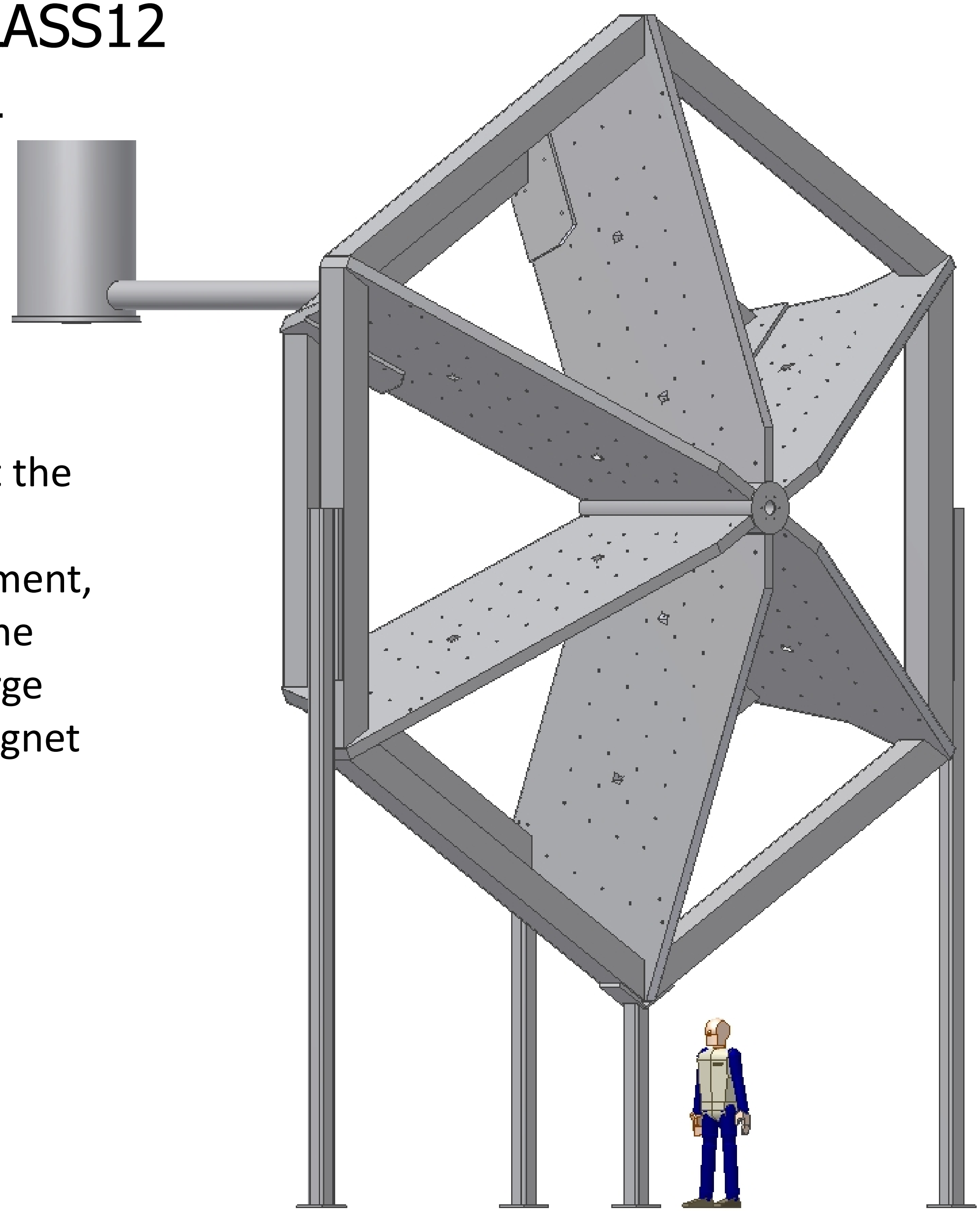


ArgoNeut at FNAL

- https://t962.fnal.gov/index.html
- “ArgoNeuT supplies valuable information about both low energy neutrino interactions and underground detector operations. By taking measurements in the .1 to 10 GeV range, the test provides the first ever data for low energy neutrino interactions within a LArTPC, paving the way for construction of larger detectors. ArgoNeuT also serves as a stepping stone to larger detectors by providing experience in operating underground argon recirculation, trigger, and readout systems.”

Review of the Jlab CLASS12 Torus Structure, 2011

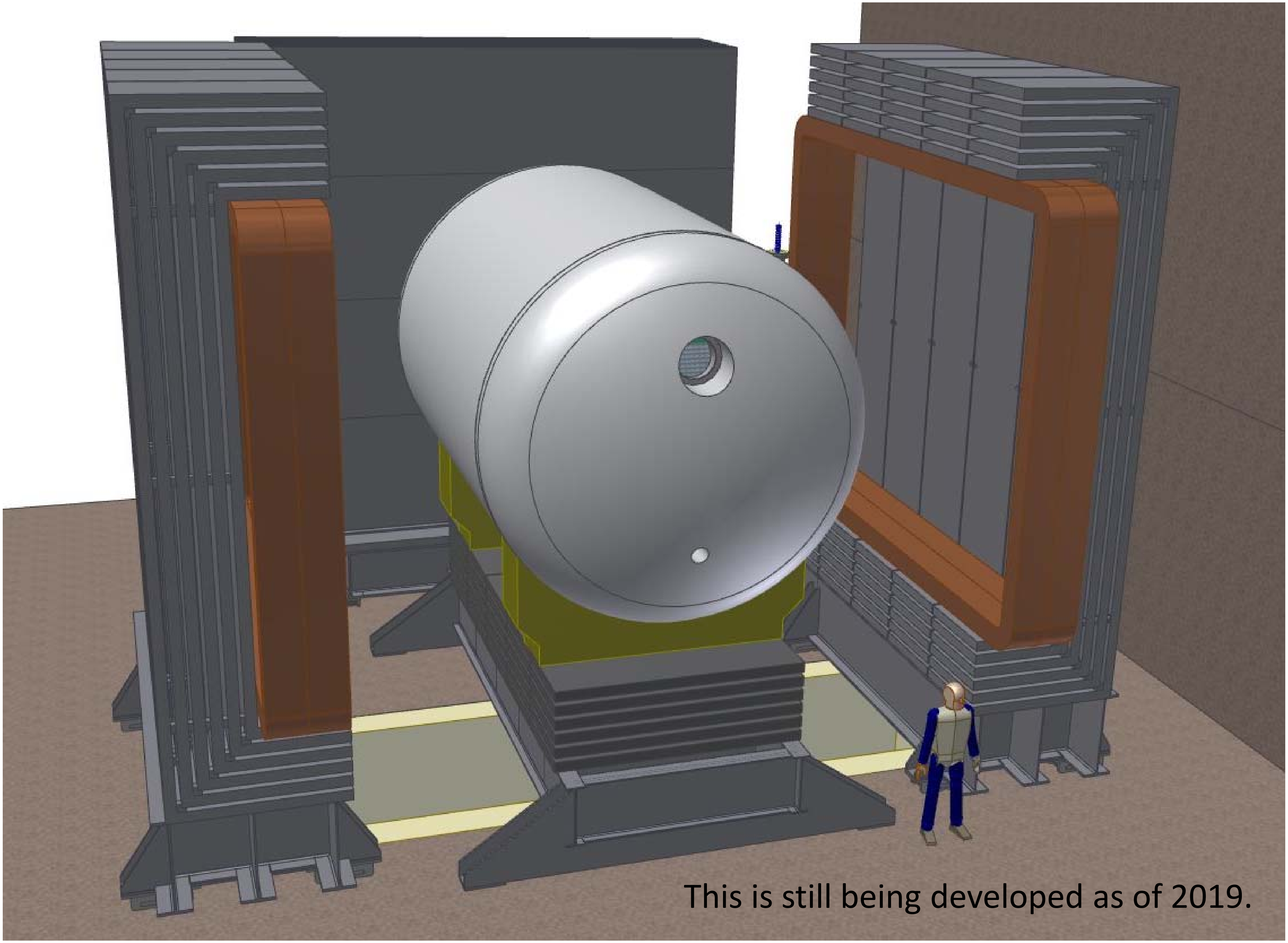
Because of BE's prior work at the Thomas Jefferson National Laboratory on the G0 experiment, Larry was invited to review the design and analysis of the large superconducting toroidal magnet shown here.



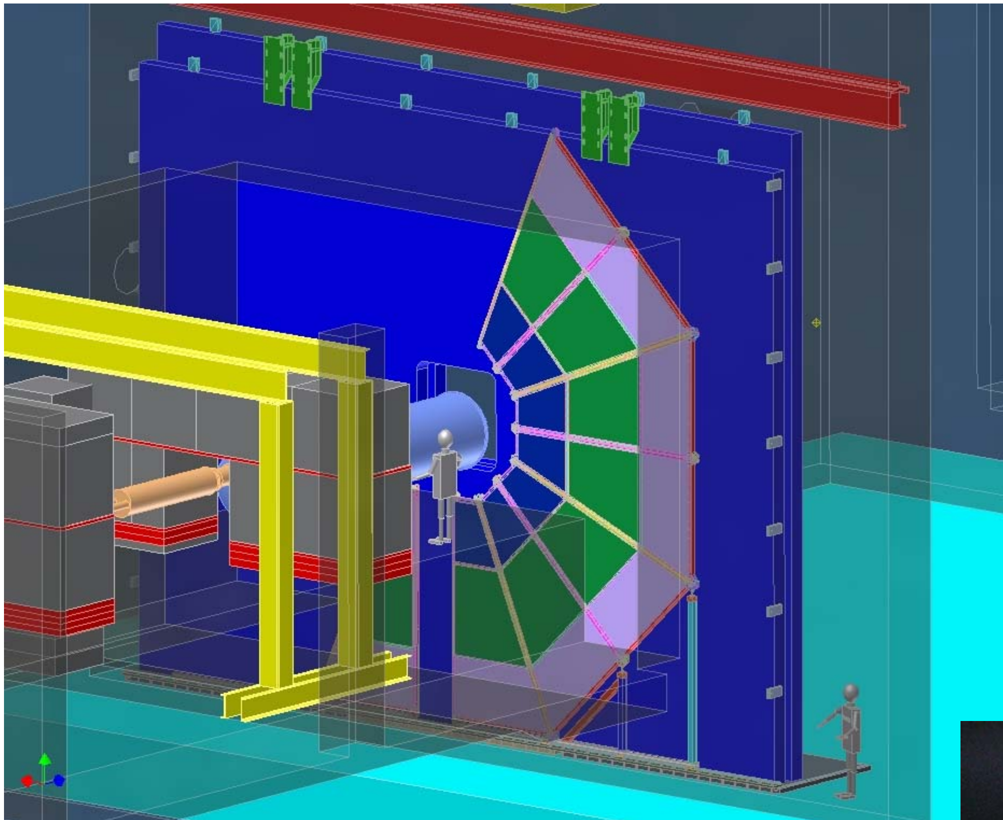
Review of Heliostats in Cyprus, 2011

BE was invited to participate in a design review of large sun-following mirror support structures (heliostats,) intended to be deployed in Cypress.

Concept design for the LBNE Near Detector at FNAL, 2011



This is still being developed as of 2019.



The RPC Upgrade

at the PHENIX Experiment at Brookhaven National Laboratory on Long Island, 2011

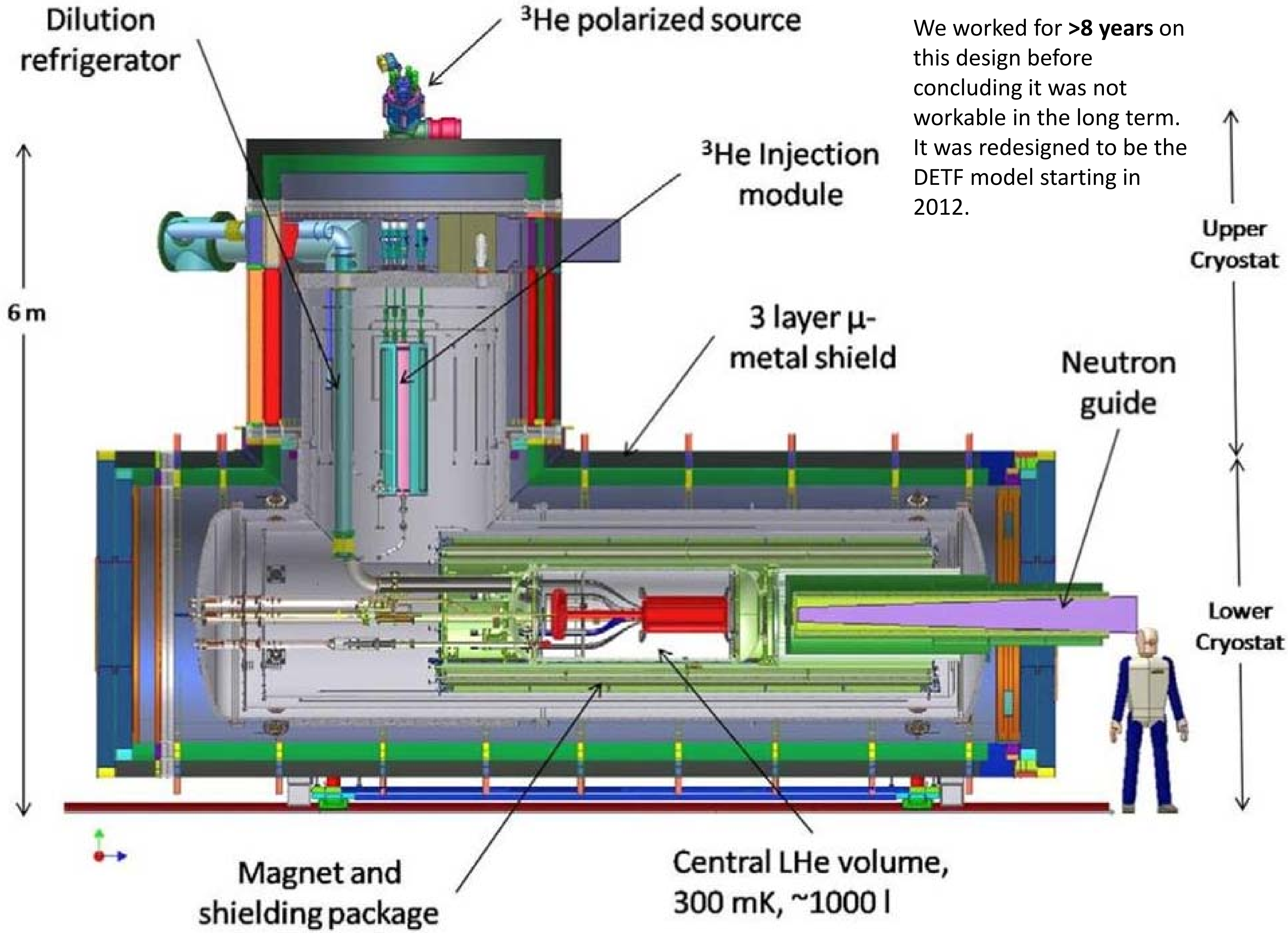
Studying the quark-gluon plasma at RHIC

PHENIX at BNL

- https://www.phenix.bnl.gov/
- "PHENIX, the Pioneering High Energy Nuclear Interaction eXperiment, is the largest of the four experiments that have taken data at the Relativistic Heavy Ion Collider. Data-taking was finished in 2016 and the PHENIX Collaboration is now analyzing large data samples previously collected, prioritizing those with a unique physics reach."

The Vintage nEDM model, 2012

We worked for **>8 years** on this design before concluding it was not workable in the long term. It was redesigned to be the DETF model starting in 2012.



Bartoszek Engineering designed many of the sub-systems for this version.

The nEDM experiment at the SNS

- https://nedm.ornl.gov/experiment/
- "The neutron electric dipole moment (or nEDM) was first measured in 1950 by Smith, Purcell and Ramsey at the ORNL's Graphite Reactor – the world's first intense neutron source. This first measurement showed that the neutron was very nearly round (to better than one part in a million)."
- "The goal of the nEDM@SNS experiment at the Fundamental Neutron Physics Beamline at ORNL's Spallation Neutron Source is to further improve the precision of this measurement by two orders of magnitude."
- https://nedm.ornl.gov/neutron-edm-model-scale-model/

nEDM@SNS model as of 2021

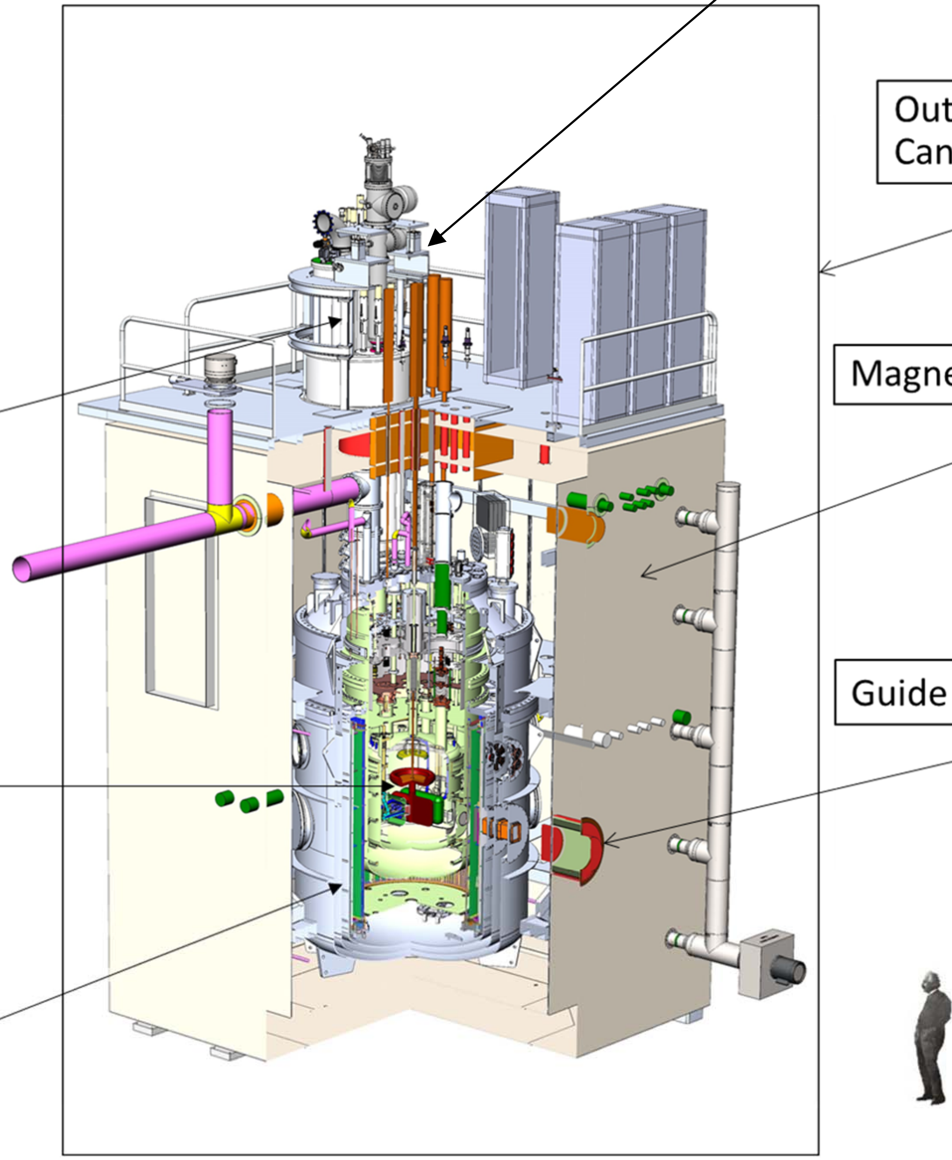
BE is designing the Helium-3 Services cryostat and injection system

Experiment Design

Outer magnetic shielding
Cancellation coils

Helium-3 Services
- Prepare polarized 3He
- Isotopically purify 4He each measurement cycle

Magnetically Shielded Enclosure



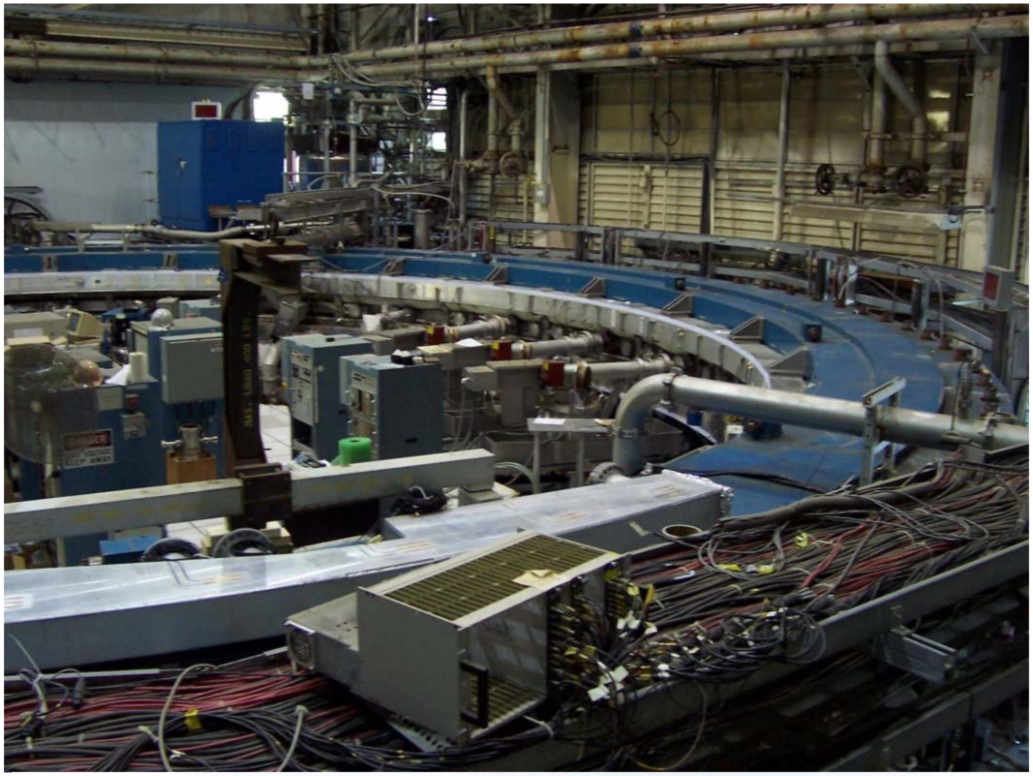
Central Detector System
- Generate electric field
- Store 3He, neutrons
- Monitor 3He, neutron precession frequencies

Guide 8.9Å into apparatus

Magnet Coil Package
- Inner magnetic shielding
- Generate uniform B-field

Image from: https://nedm.ornl.gov/experiment/

The G-2 Experiment at BNL and Fermilab, 2013

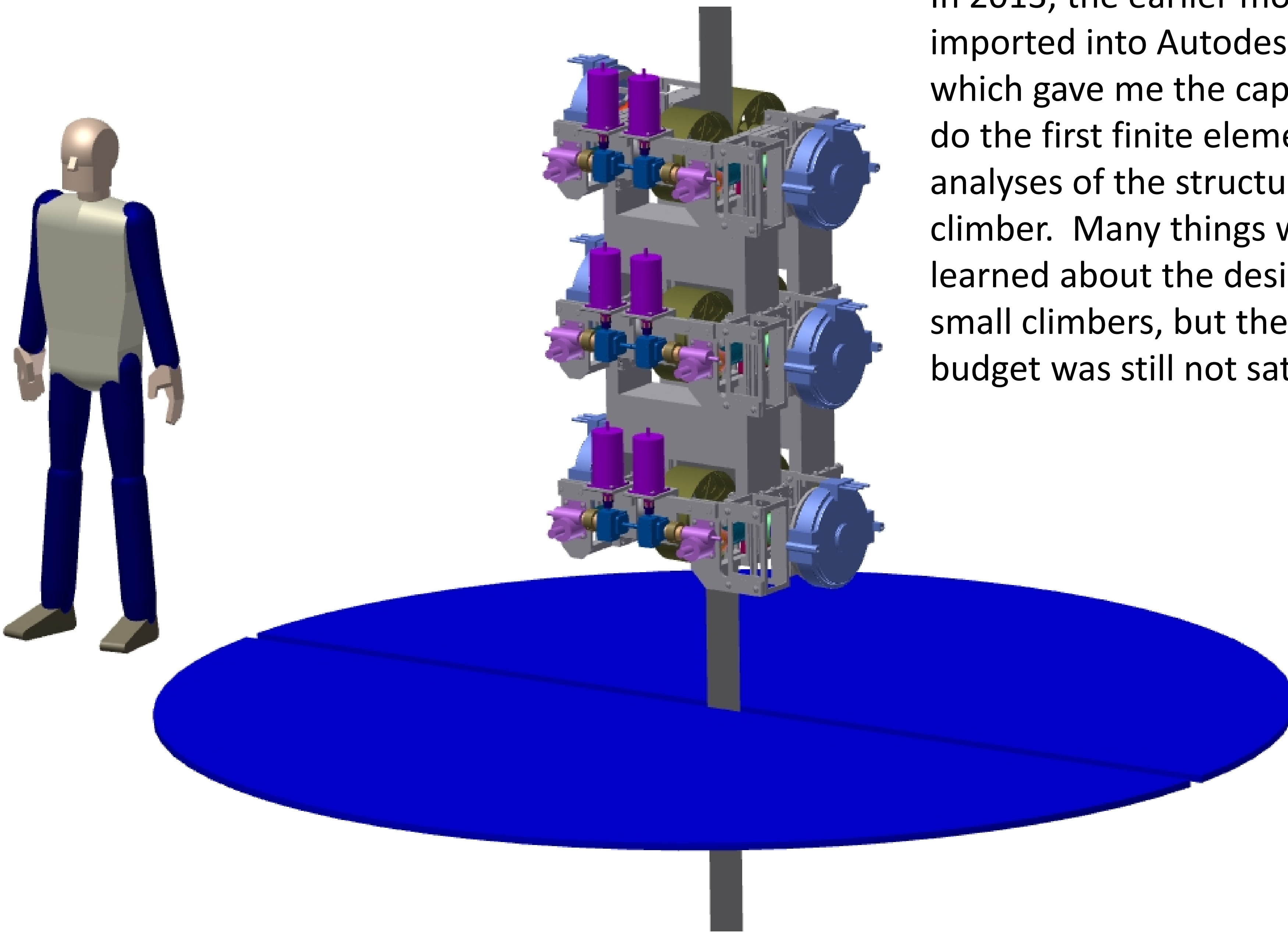


I modeled the original cryostat in 3D so the shipping fixture could be designed.

Muon G-2 at FNAL

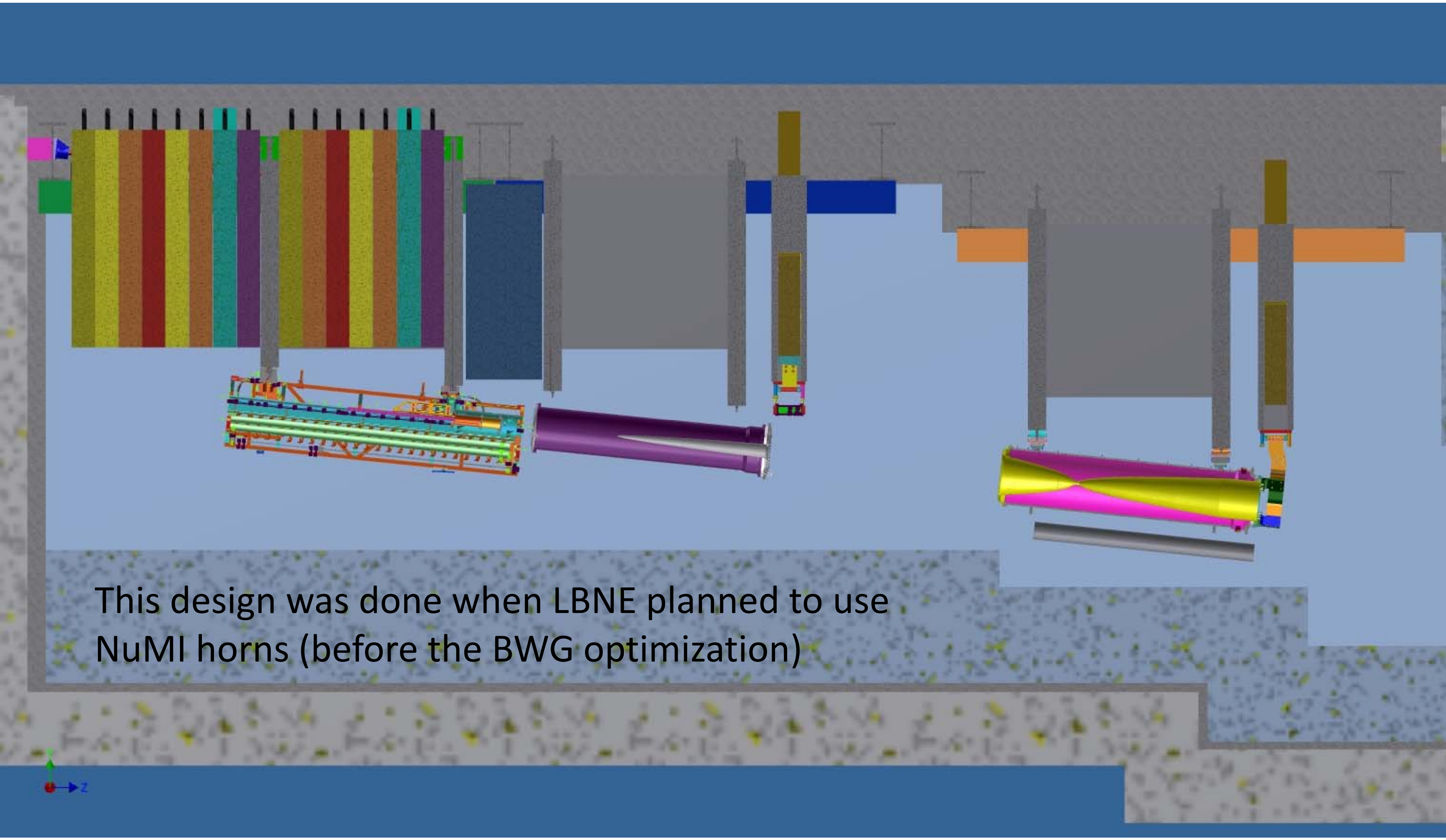
- https://muon-g-2.fnal.gov/
- “Muon g-2 (pronounced gee minus two) uses Fermilab's powerful accelerators to explore the interactions of short-lived particles known as muons with a strong magnetic field in "empty" space. Scientists know that even in a vacuum, space is never empty. Instead, it is filled with an invisible sea of virtual particles that in accordance with the laws of quantum physics pop in and out of existence for incredibly short moments of time. Scientists can test the presence and nature of these virtual particles with particle beams traveling in a magnetic field.”

Redesign of the 900 kg climber for the 2013 Space Elevator Conference, 2013



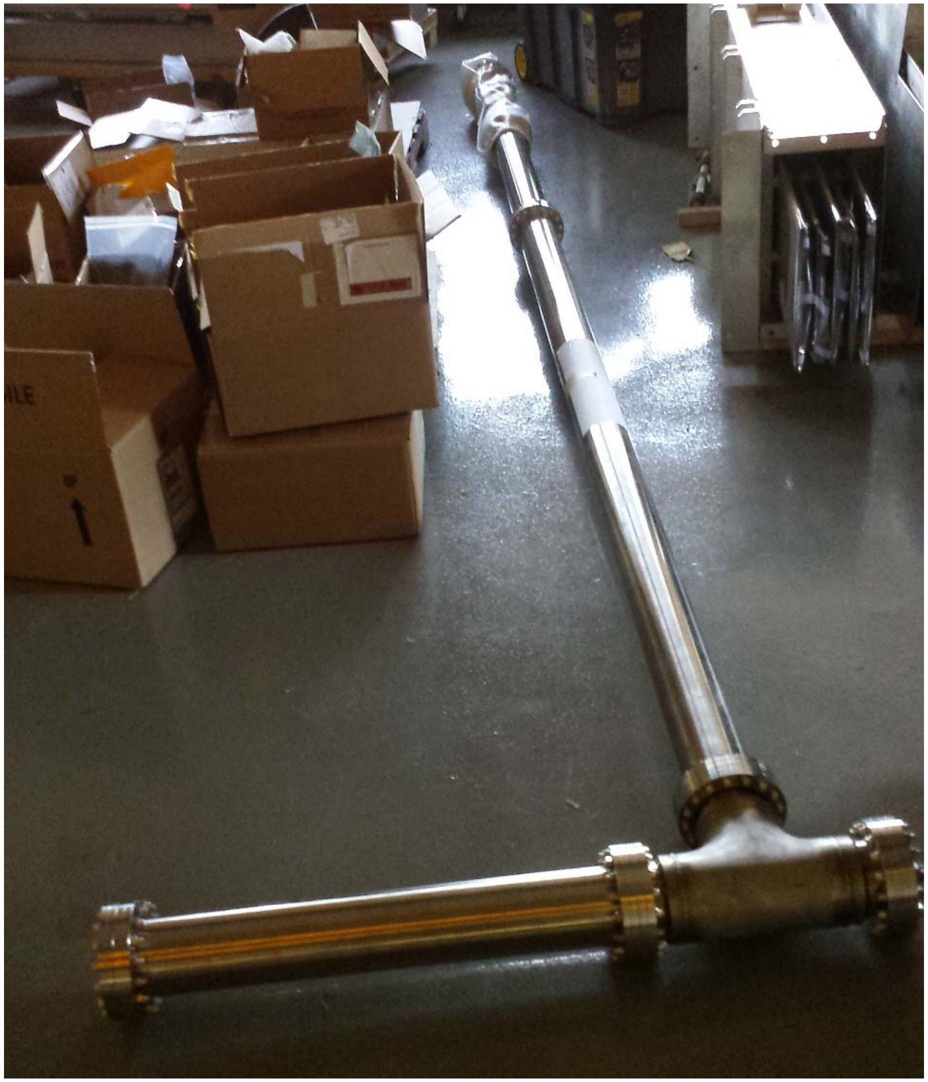
In 2013, the earlier model was imported into Autodesk Inventor which gave me the capability to do the first finite element analyses of the structure of the climber. Many things were learned about the design of the small climbers, but the mass budget was still not satisfied.

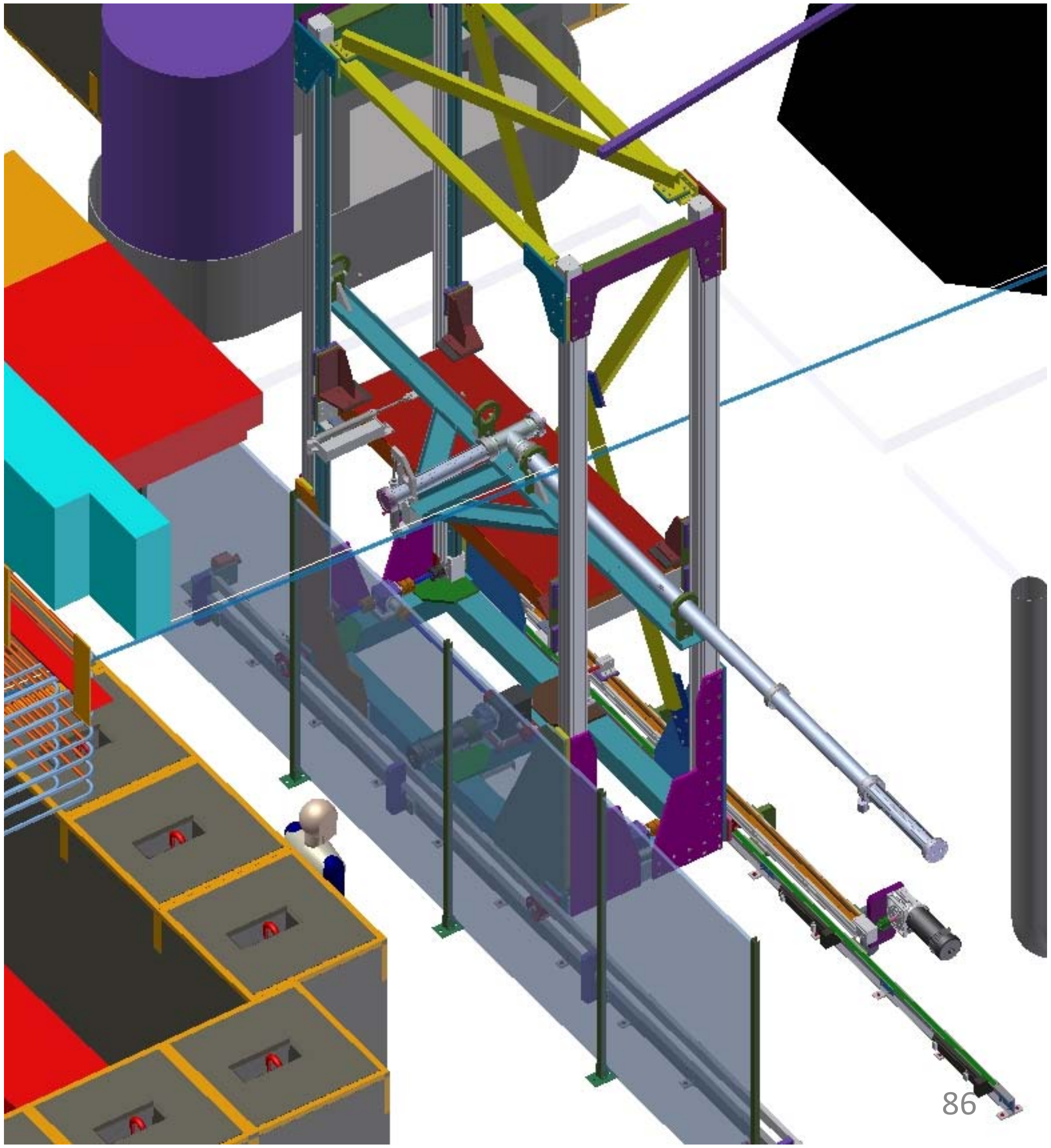
The LBNE Horn Modules and Baffle at Fermilab, 2014



The LBNE Muon Monitor at Fermilab, 2014 (unfinished)

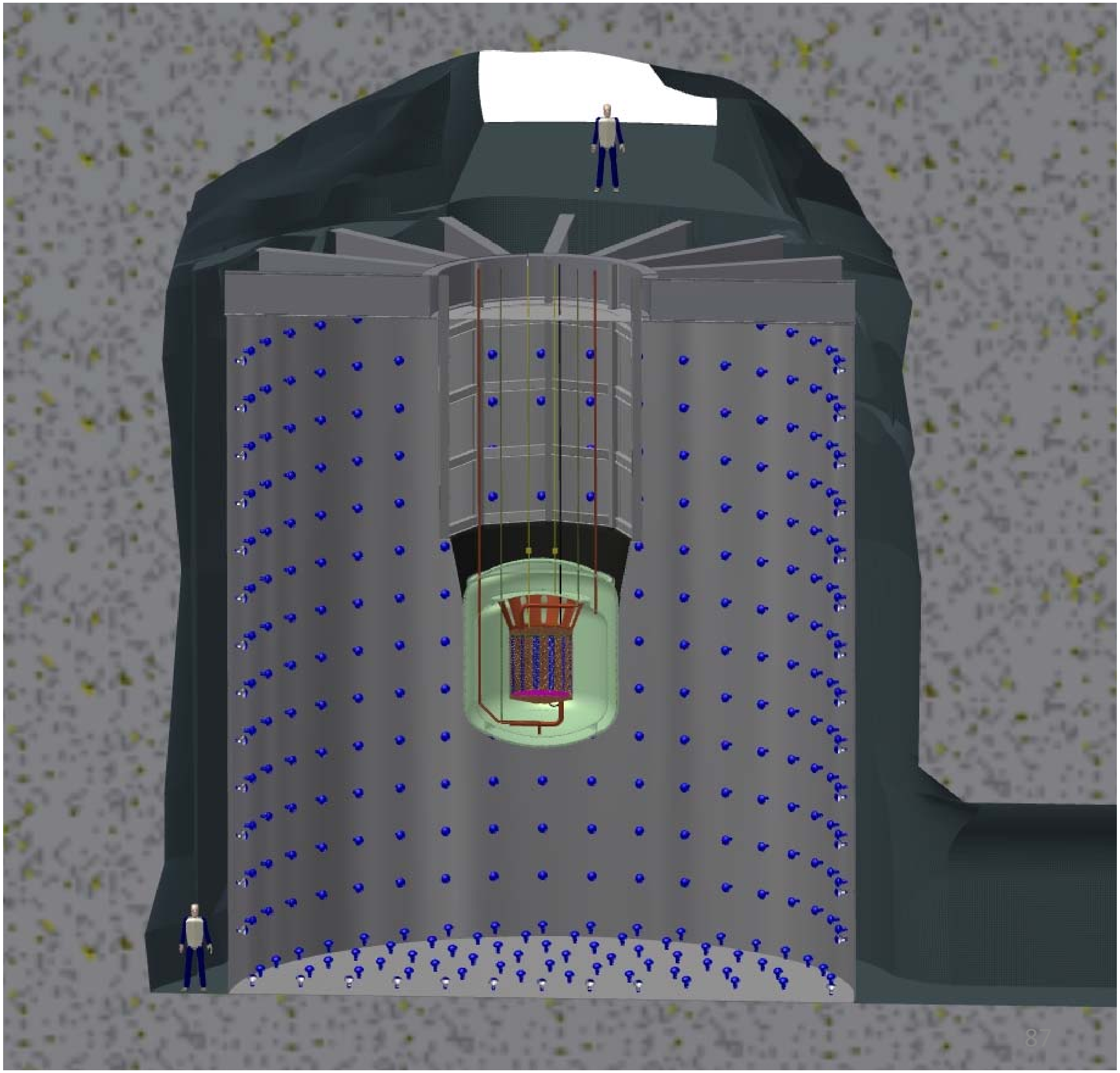
BE designed a movable support for a high pressure gas Cherenkov muon monitor, but the project was abandoned after Geoff Mills died.



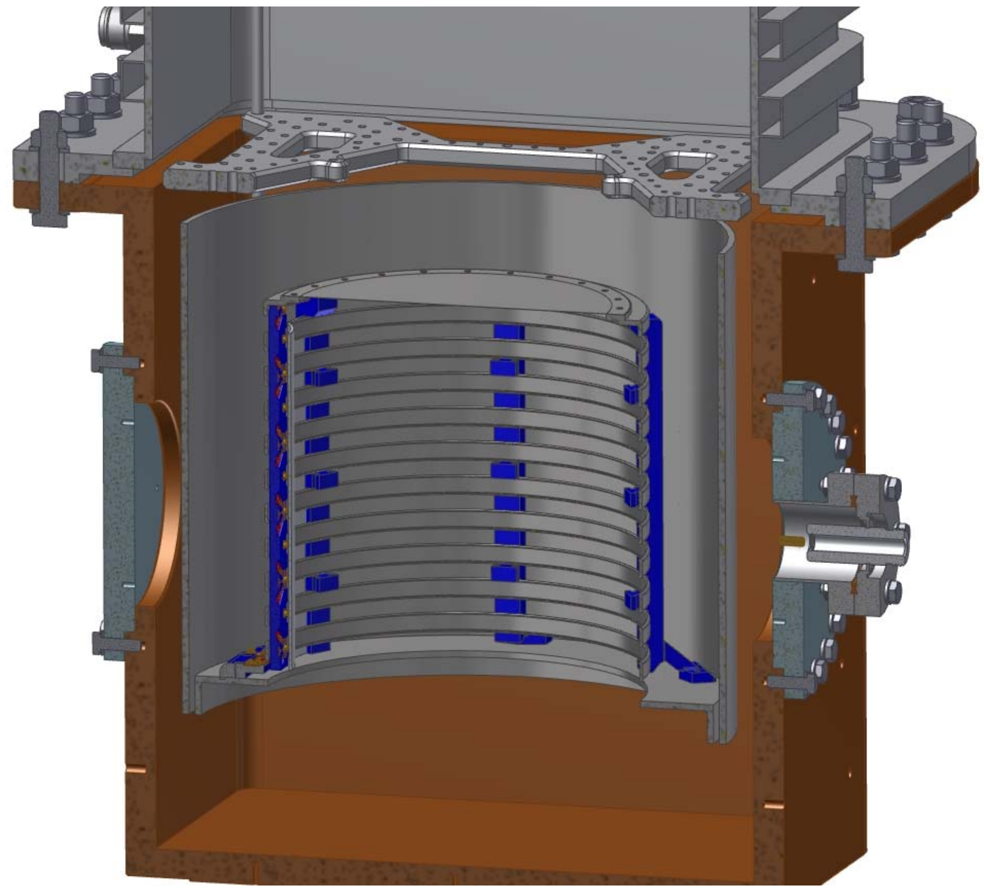


Concept design for nEXO, 2014

BE did the initial design and analysis of a much larger LXe TPC in a deep underground mine. This work is still proceeding as of 2019.



The MiniEXO TPC, 2014



The KPIPE conceptual design, 2015

BE worked with Janet Conrad of MIT to develop a conceptual design for a new neutrino detector.

https://arxiv.org/abs/1510.06994

Thermal Link Clamp test, NCSU, 2015 (part of nEDM)

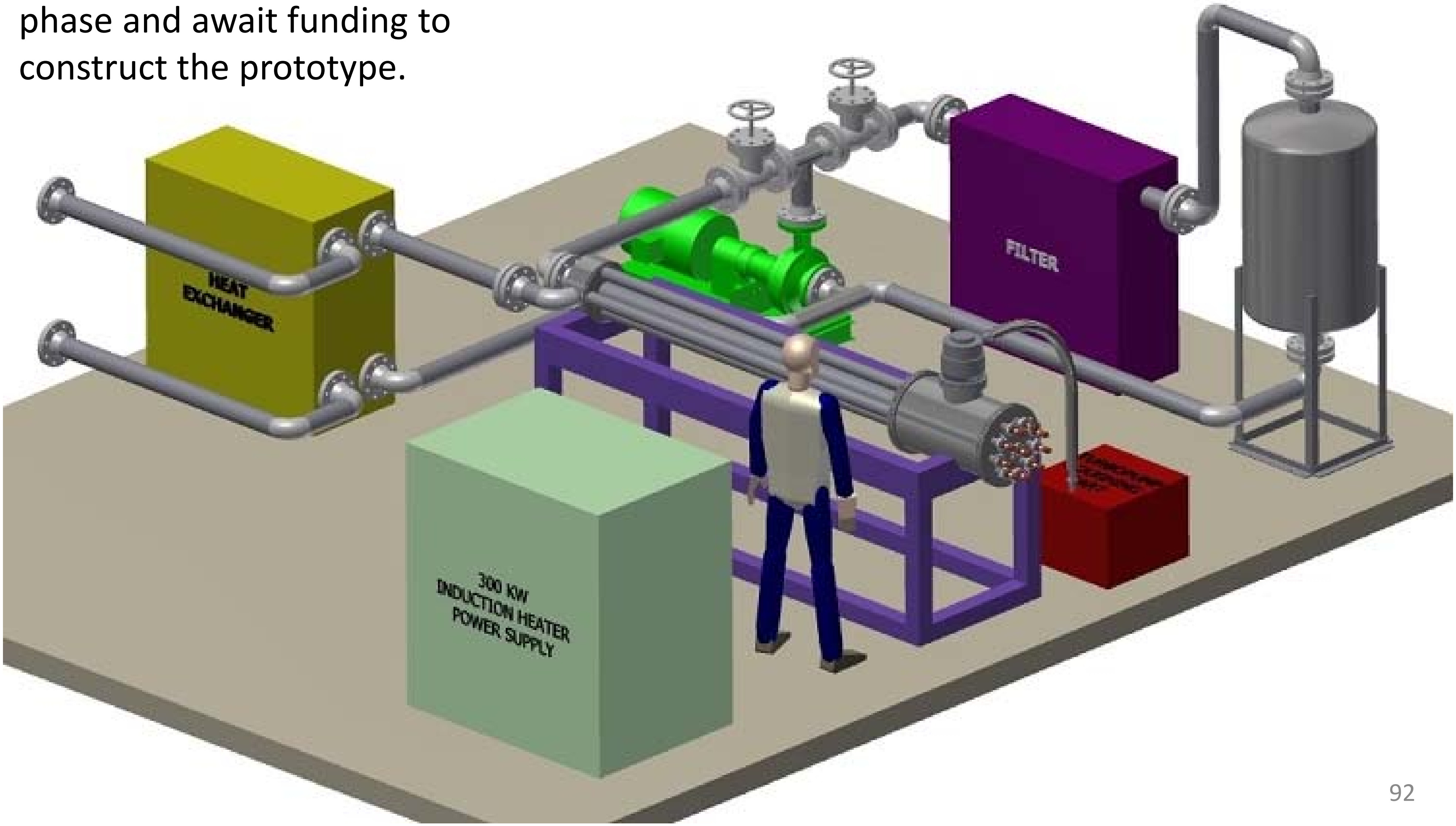
This was a test of a new design for a breakable thermal link. It almost worked but was abandoned for another idea.

DR Pump Cart, UIUC, 2015 (part of nEDM)

The black steel frame supports and vibration isolates the vacuum pumps for the nEDM DR

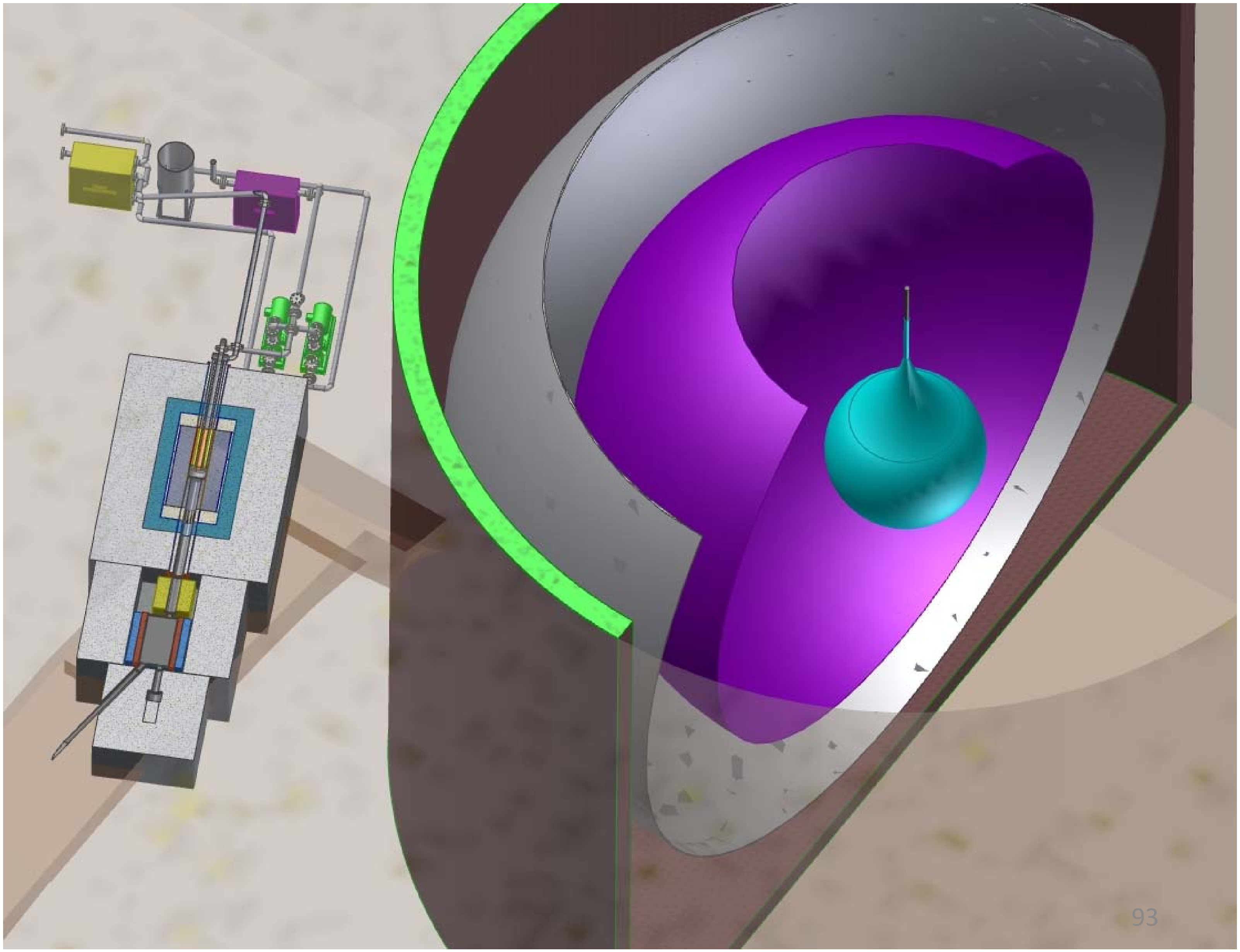
IsoDAR Target Prototype Cooling Test, concept design, 2015

As of 2019 we are in the analysis phase and await funding to construct the prototype.



IsoDAR Target at KAMLAND, concept design, 2015

As of 2019, we are still waiting on funding and approval of this experiment.

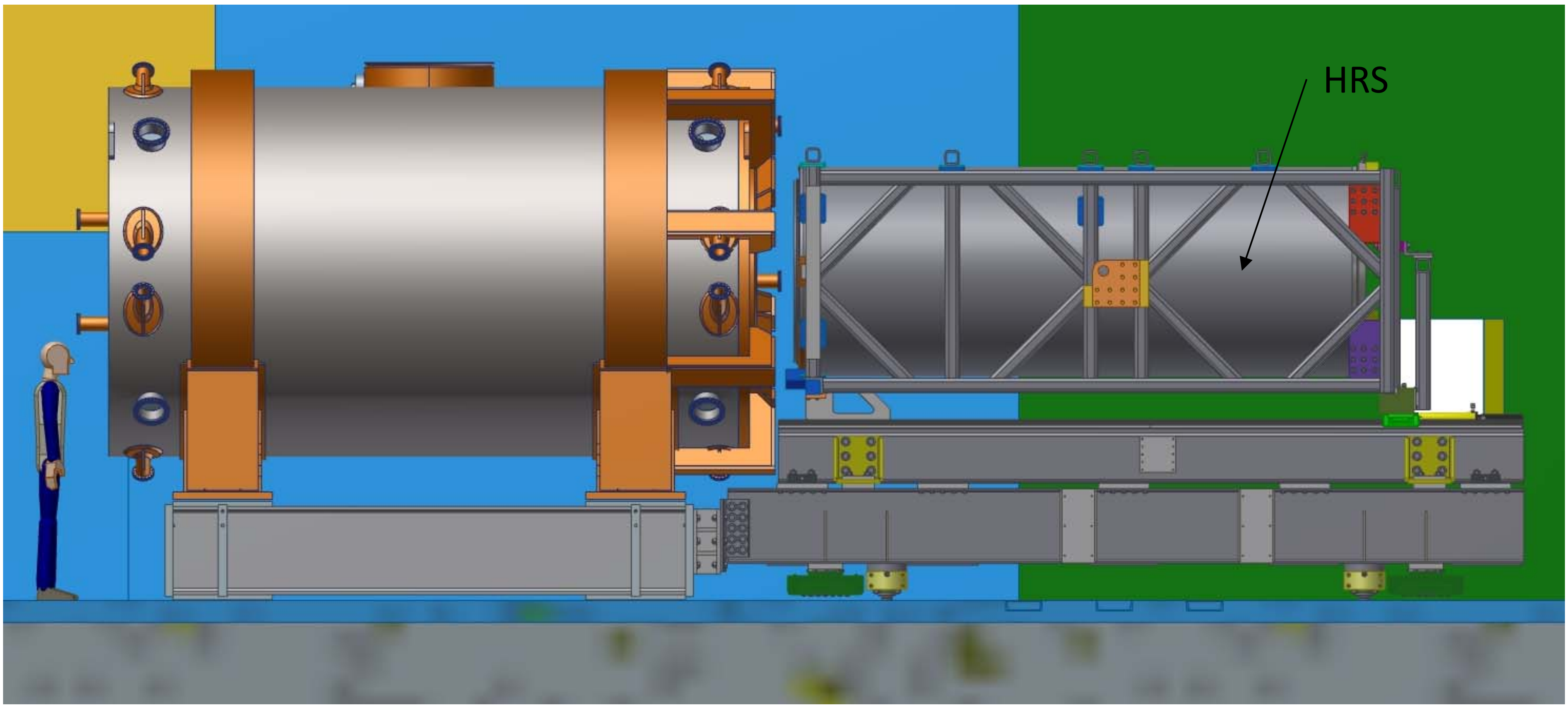


IsoDAR

- https://www.nevis.columbia.edu/daedalus/exp/isodar.html
- "IsoDAR has two primary science goals: sterile neutrino searches using inverse beta decay events and nonstandard interaction searches using electron antineutrino - electron elastic scattering events. With the very large anti-electron event sample, other studies can be considered such as neutrino decay studies, neutrino magnetic moment searches, and precision $_8$Li beta-decay spectrum measurements."

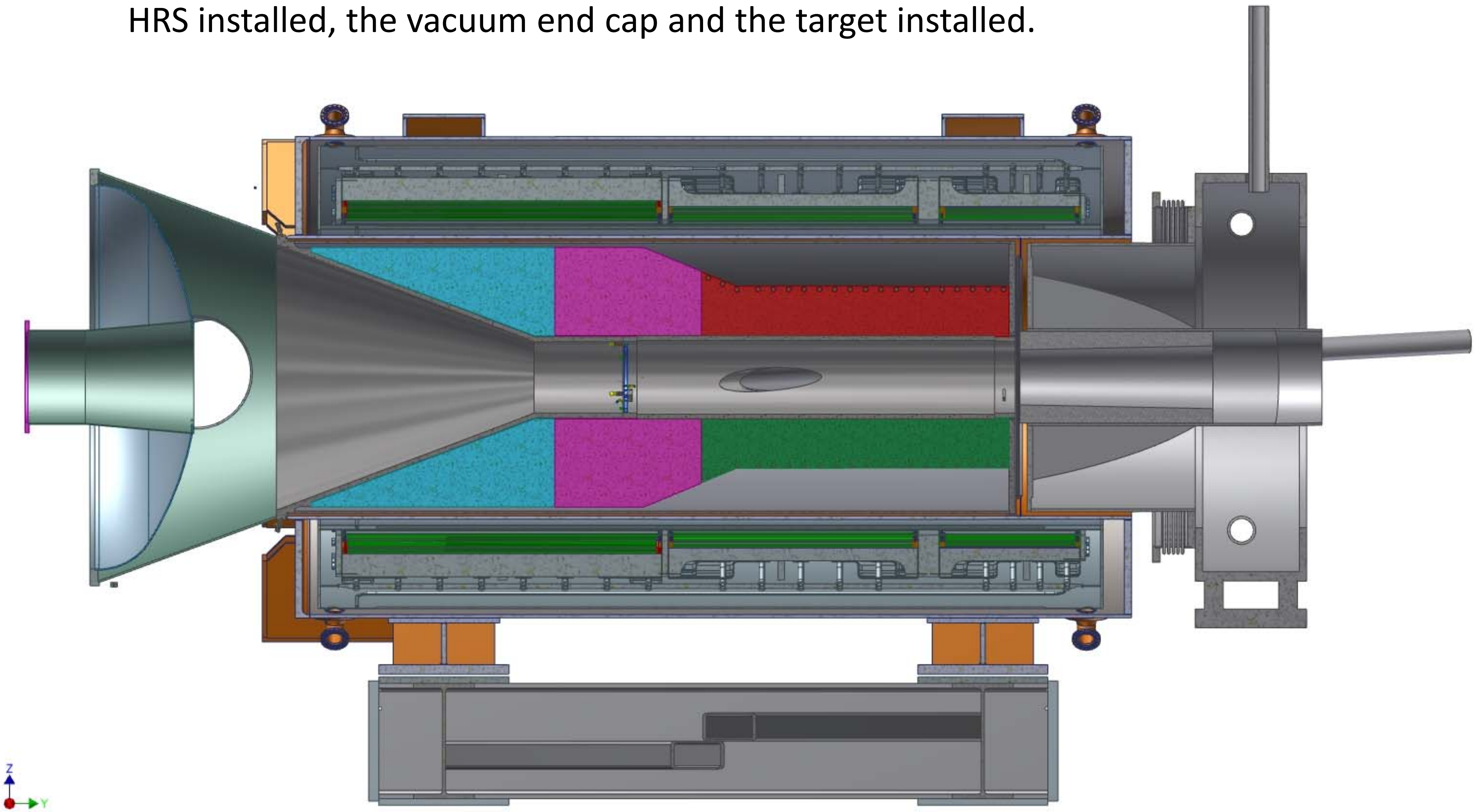
The Mu2e Heat and Radiation Shield (HRS) at FNAL, 2016

The HRS is a 35 ton water-cooled bronze shield encapsulated in a stainless steel jacket to protect the Mu2e Production Solenoid from radiation. This picture shows the HRS and transport frame on the Installation Machine. The HRS is in fabrication as of 2019. The installation process has been redesigned by FNAL.



The Mu2e Heat and Radiation Shield (HRS), 2016

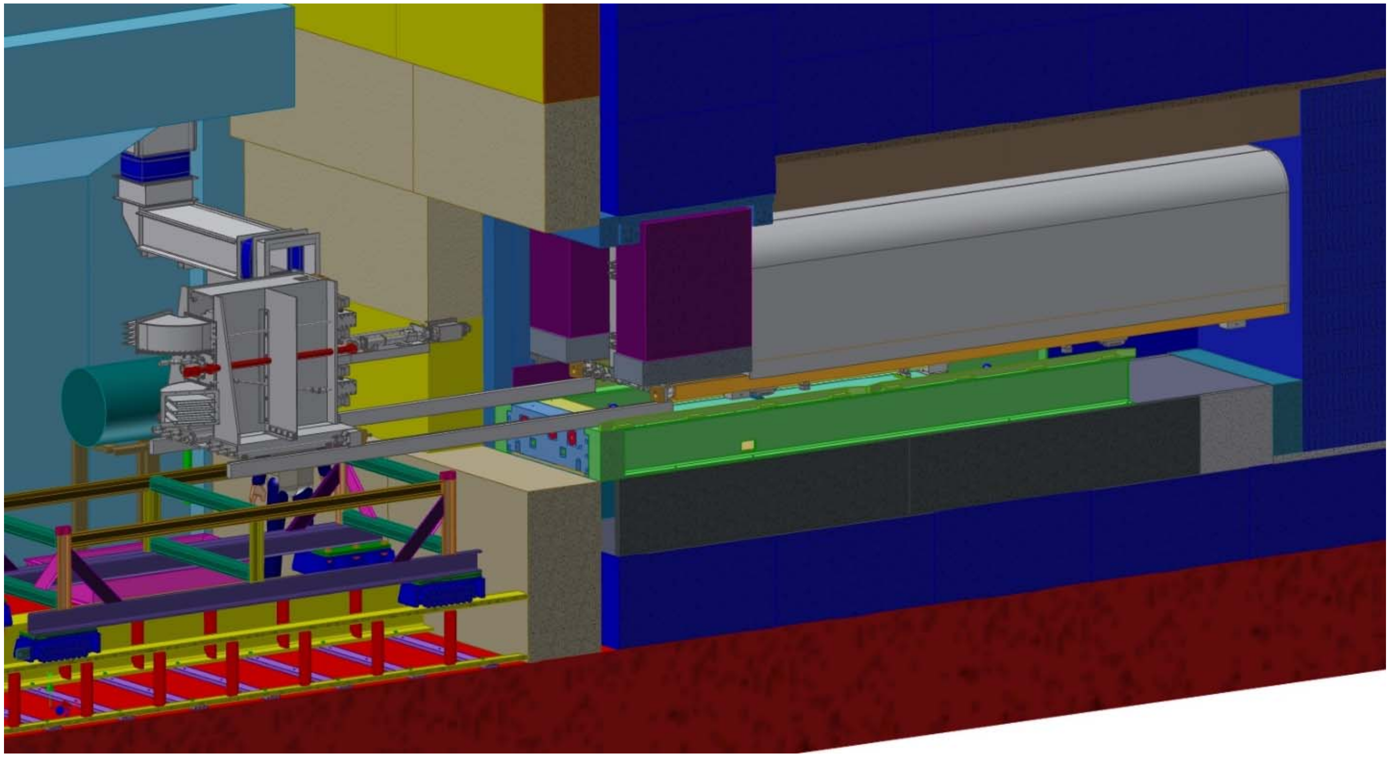
Cross-section through the Production Solenoid (PS) showing the HRS installed, the vacuum end cap and the target installed.



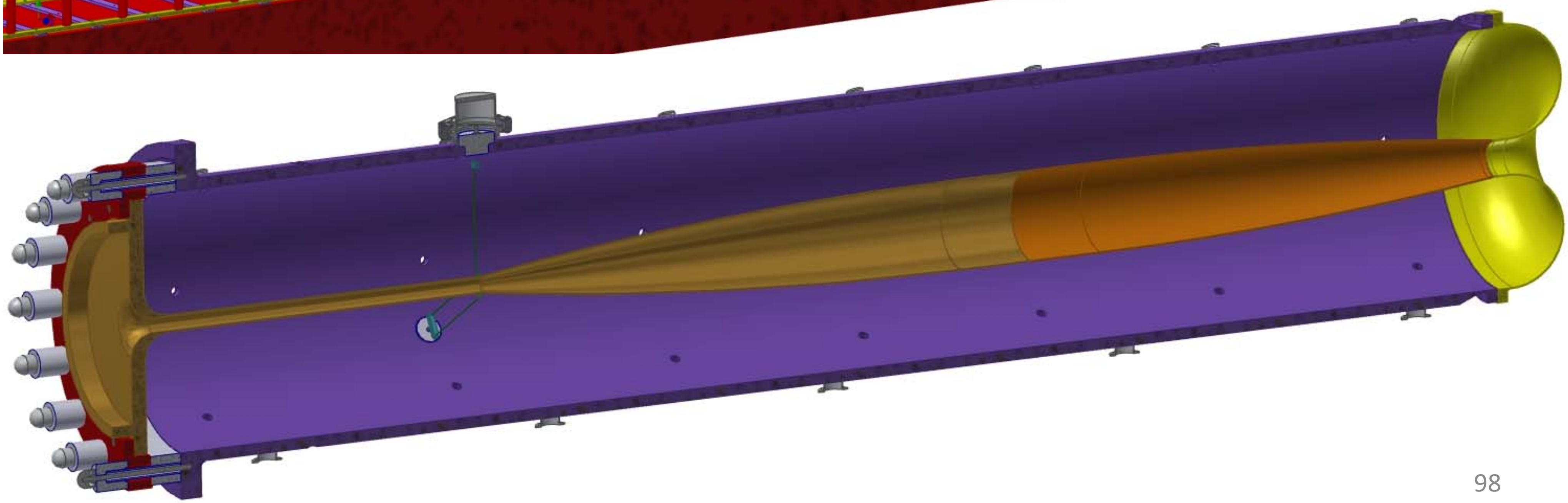
Mu2e at FNAL

- https://mu2e.fnal.gov/
- "Observing muon-to-electron conversion will remove a hurdle to understanding why particles in the same category, or family, decay from heavy to lighter, more stable mass states. Physicists have searched for this since the 1940s. Discovering this is central to understanding what physics lies beyond the Standard Model."

The 3.5m SBND horn upgrade (concept design,) 2017

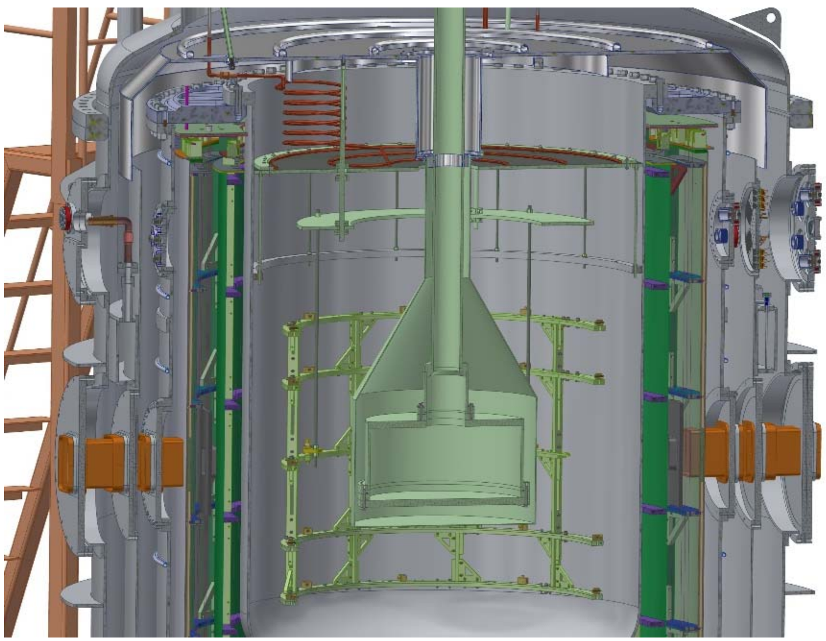


BE designed a replacement for the MiniBooNE horn that would have doubled the neutrino flux of the short baseline neutrino beam at FNAL. The design was shelved by the experiments on that beamline.

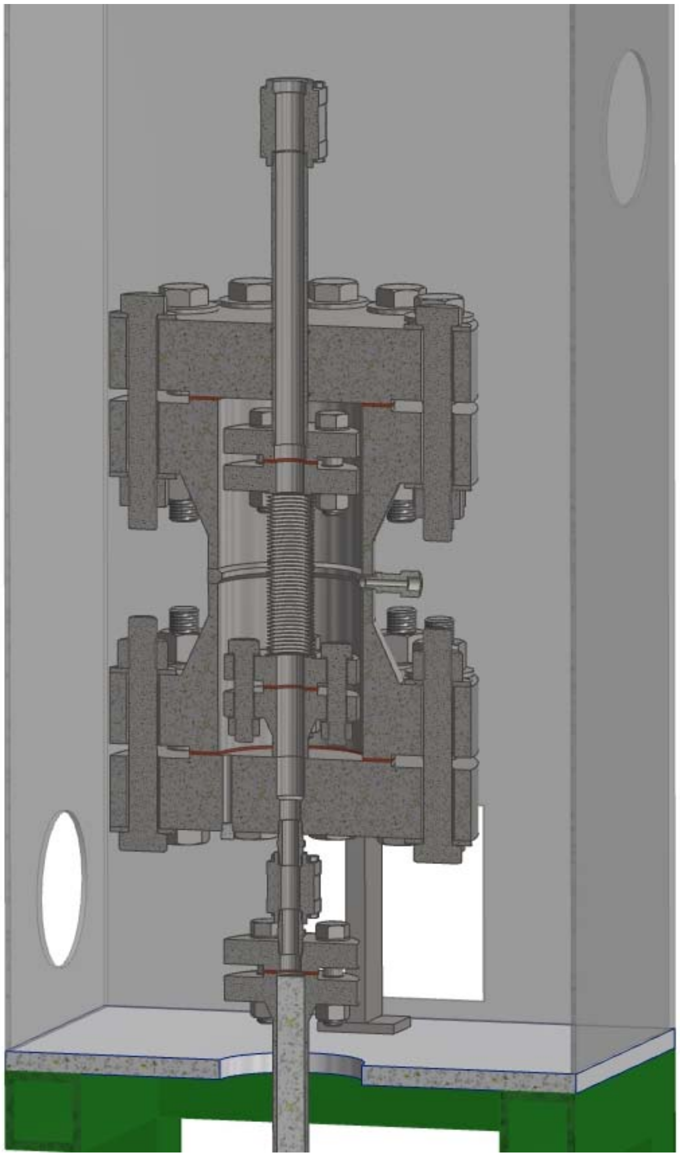


Warm Bore for Caltech Magnet Test, 2017 (part of nEDM)

The warm bore allows magnetic measurements inside a 4K magnet to measure the uniformity of the magnetic field.

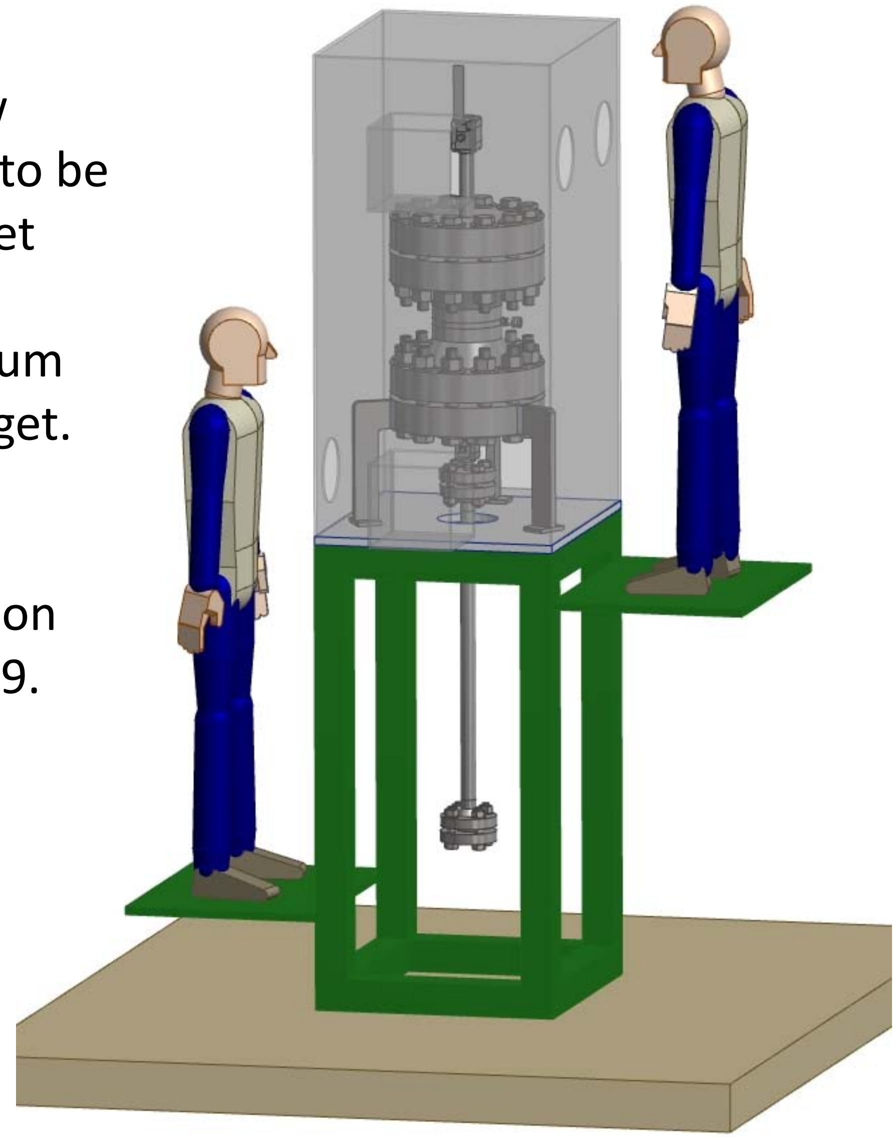


Lithium batch casting machine for IsoDAR, (concept design,) 2018



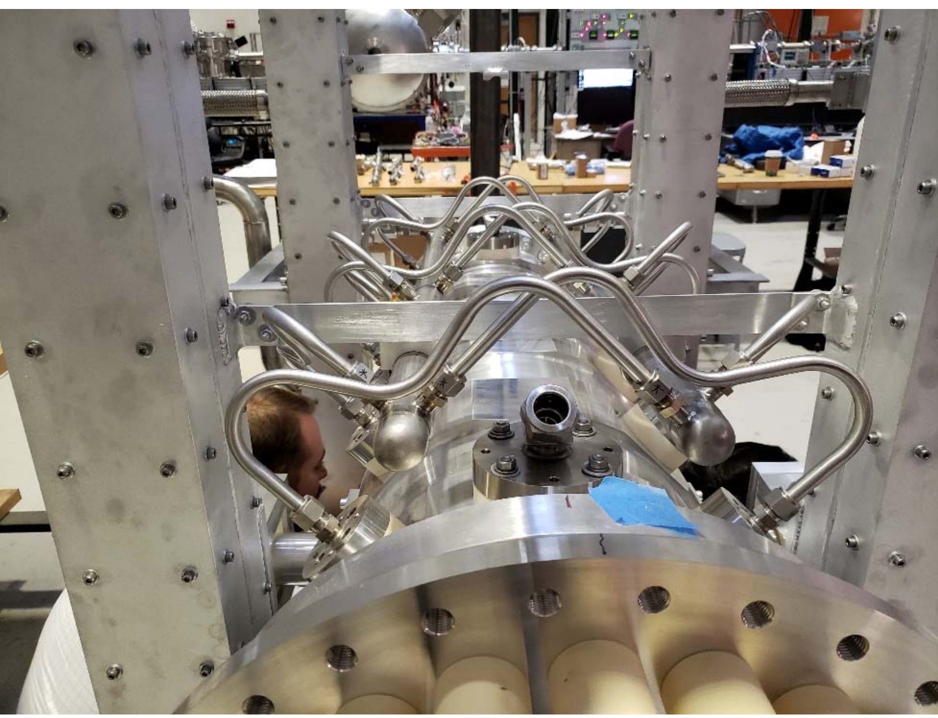
This machine is designed to allow molten lithium 7 to be cast into the target sleeve full of powdered beryllium in the IsoDAR target.

Fabrication and testing is waiting on funding as of 2019.

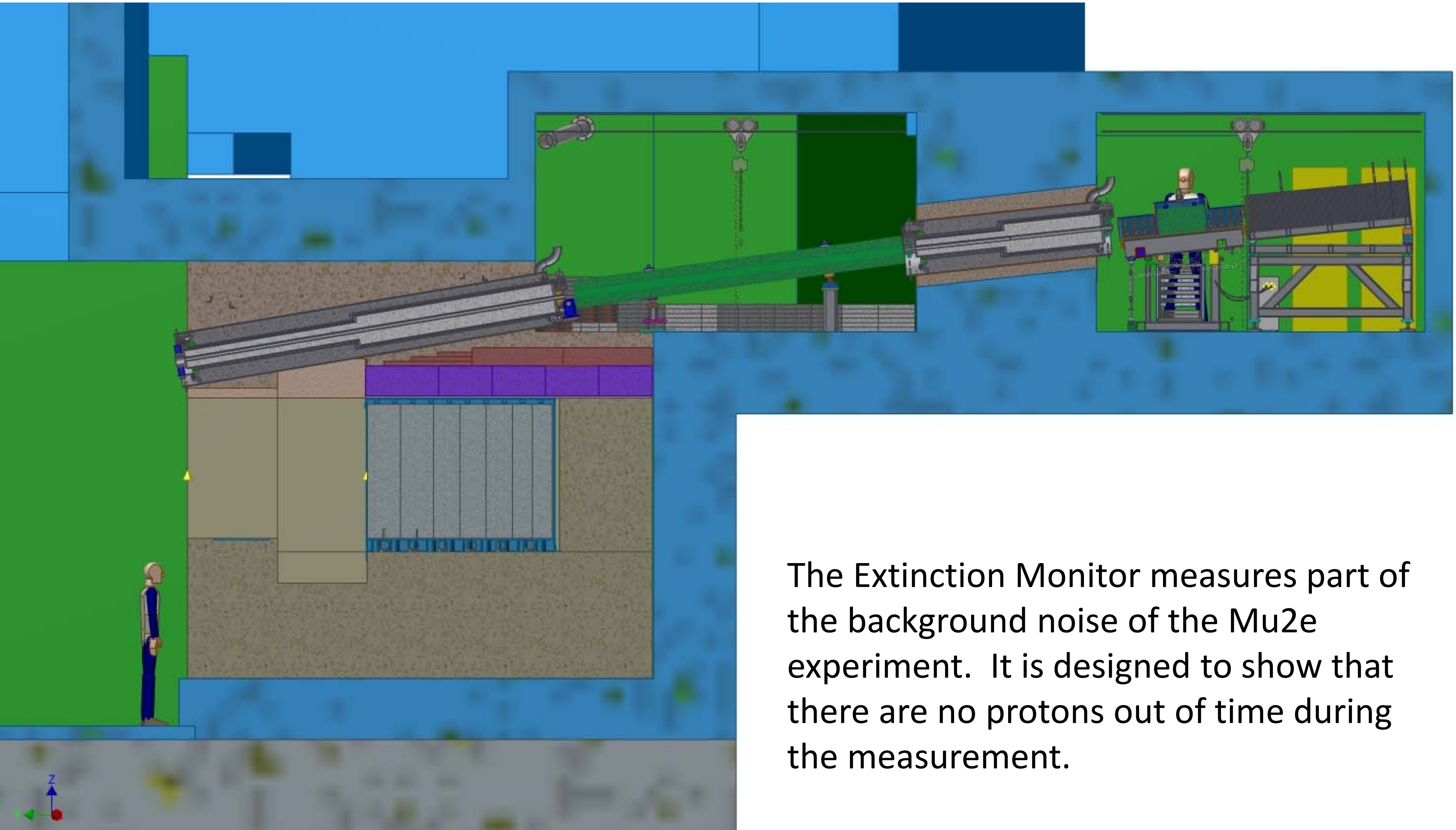


T2K Horn 1 at CU, 2018

BE did the original design on all three T2K horns. We then did the manufacturing of horn 2 at Boulder first. Horn 1 was built in Boulder after the second Horn 2 was built.



The Mu2e Extinction Monitor at FNAL, 2018

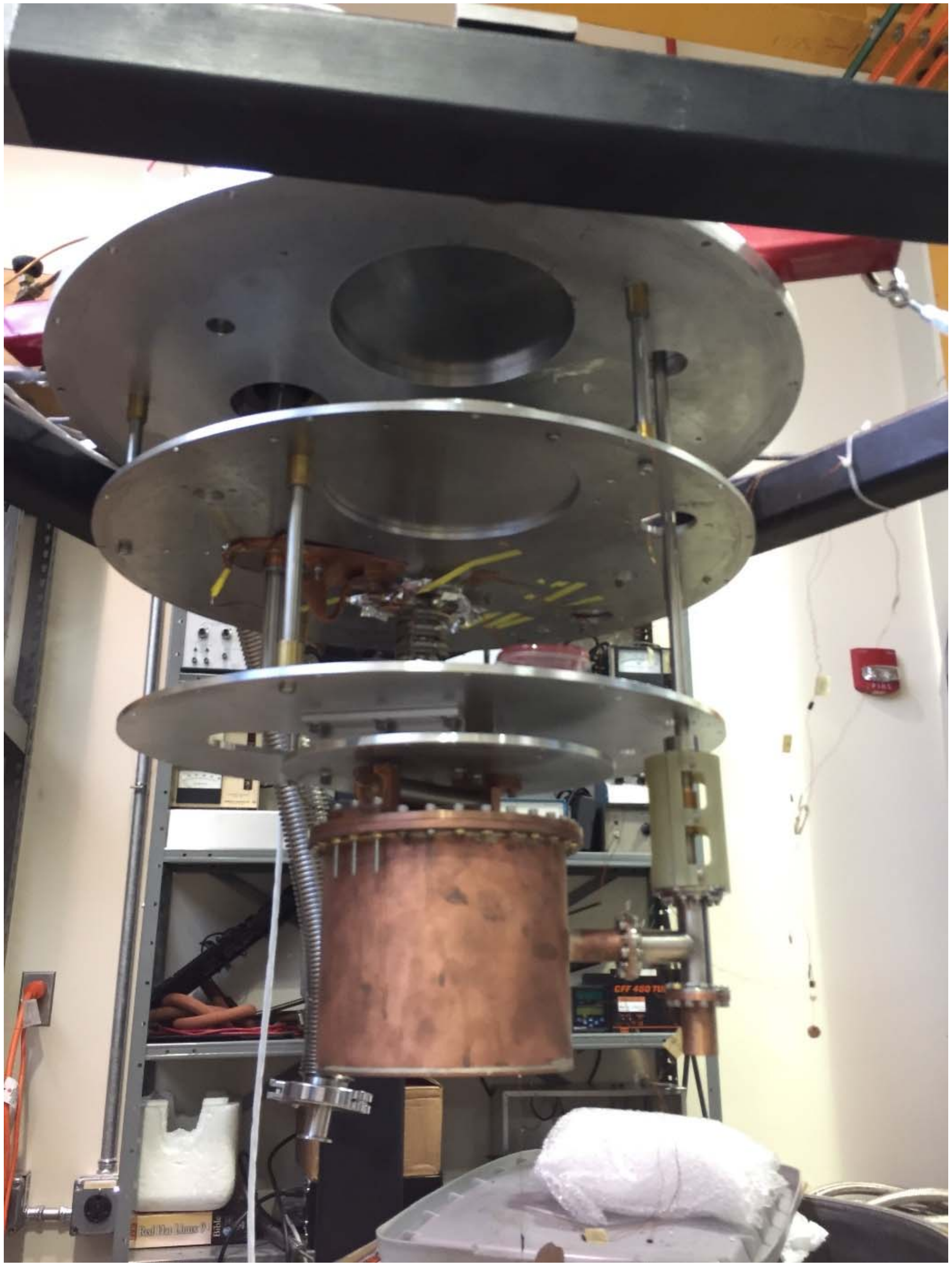


The Extinction Monitor measures part of the background noise of the Mu2e experiment. It is designed to show that there are no protons out of time during the measurement.

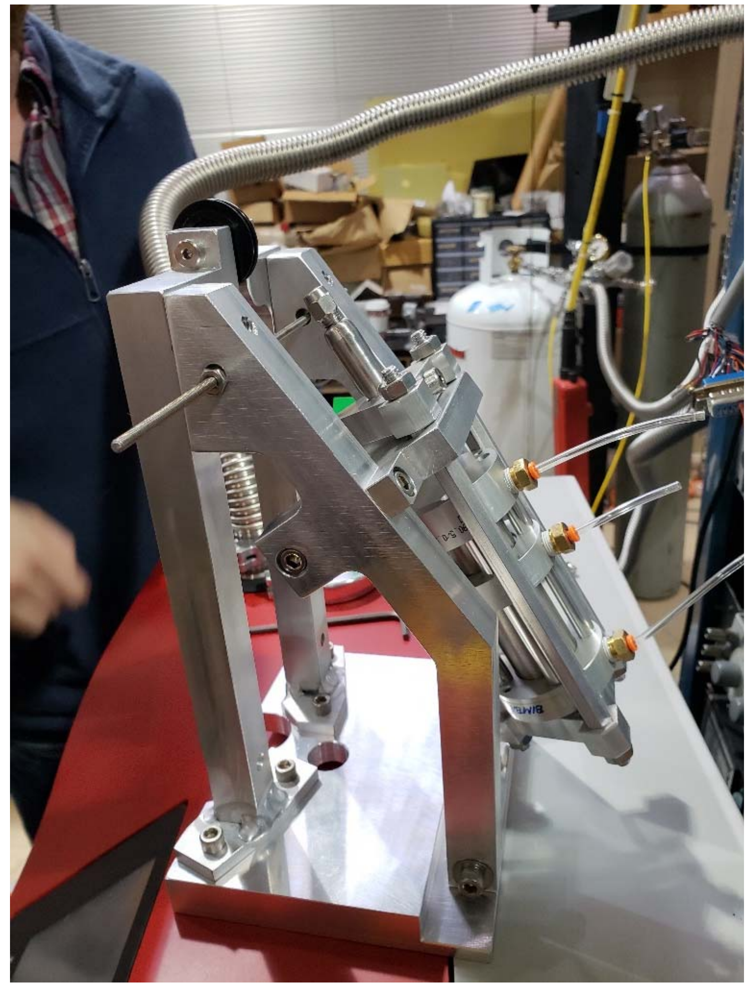
It is still in production as of 2019.

Mu2e Extinction Monitor parts at FNAL, 2021

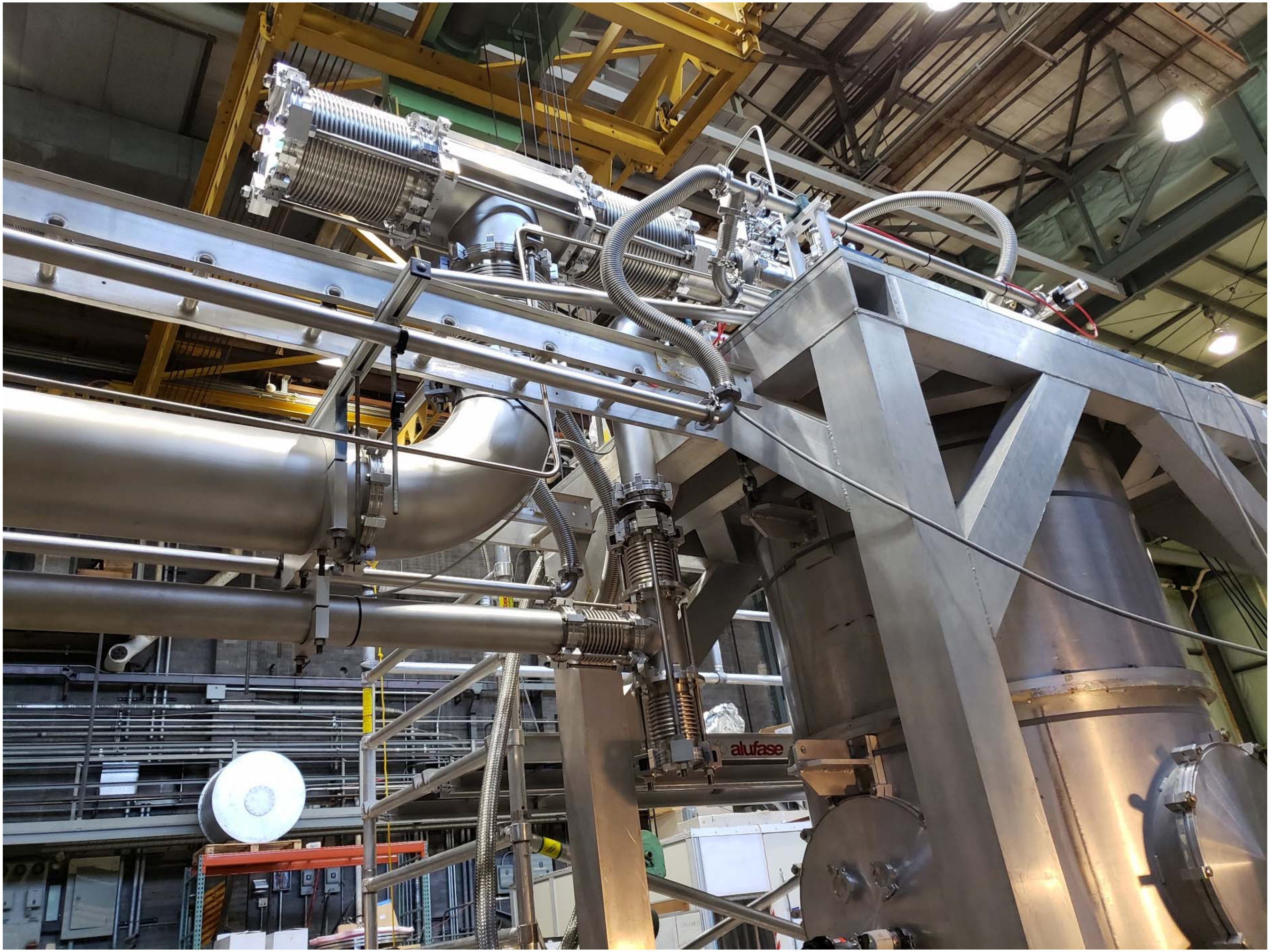
PULSTAR Charcoal Pump, 2018 (part of nEDM)



The PULSTAR Cryostat at NCSU, 2018 (part of nEDM)



DR Test Stand, UIUC, 2018 (part of nEDM)



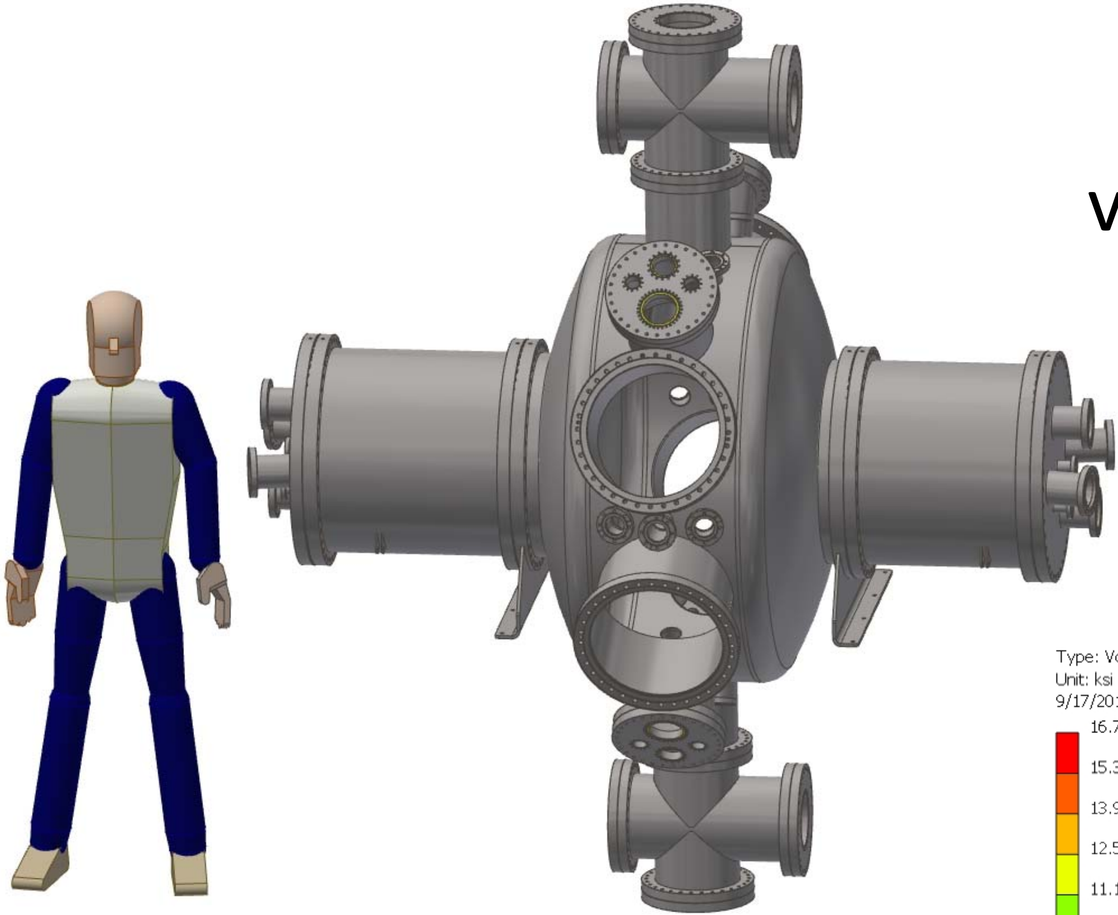
Cryogenic valve actuator, UIUC, 2019 (part of nEDM)

This room temperature actuator actuates the cryogenic valves in nEDM

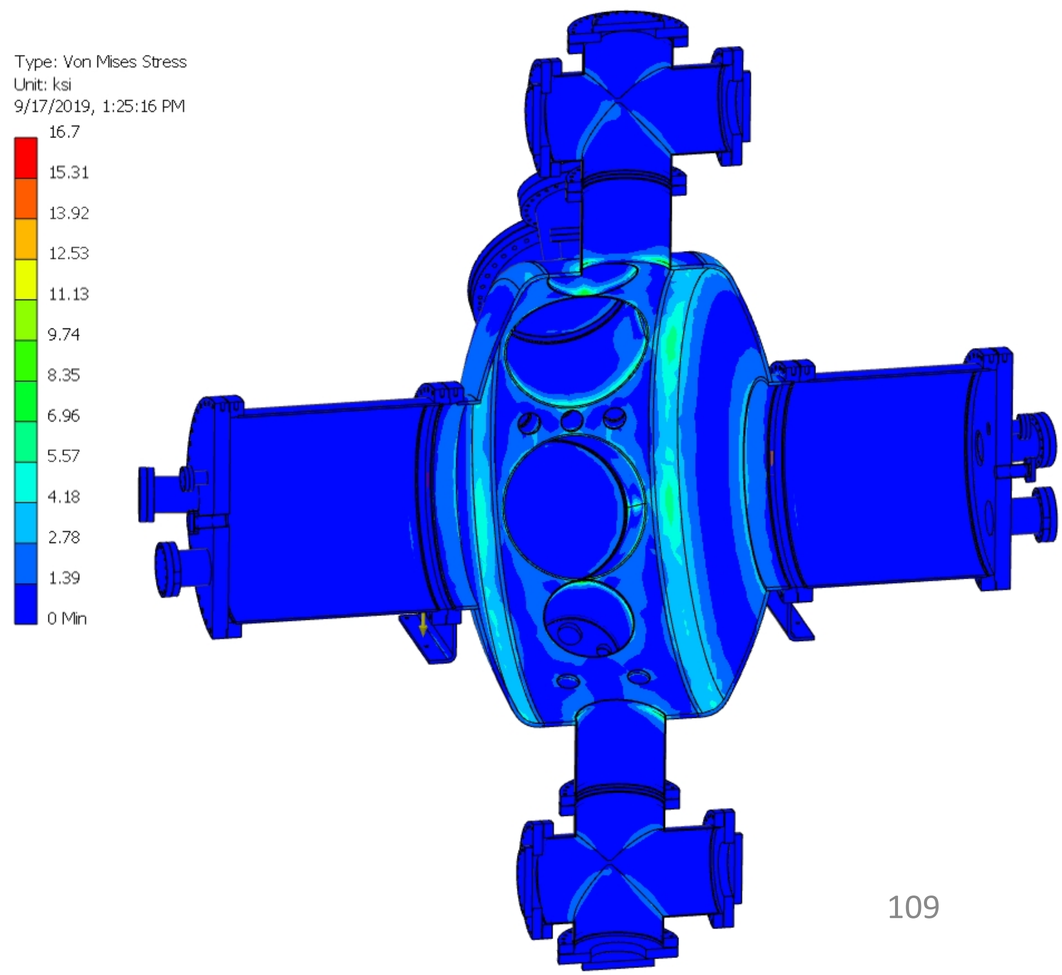
NPD Gamma magnet supports, UIUC, 2019 (part of nEDM)

The 80-20 structures support the coils that will surround the DR test cryostat.

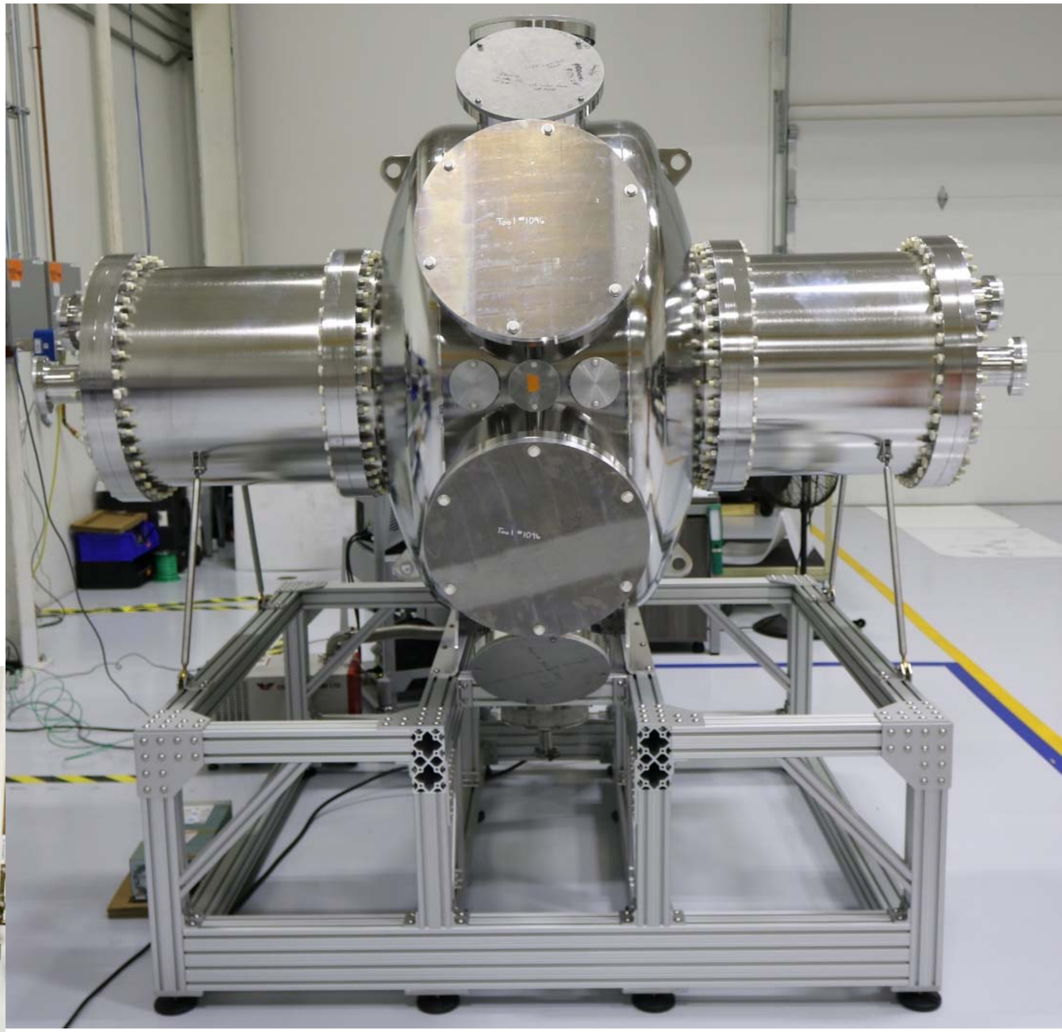
FEA of the Hunter Vacuum vessel for Temple University 2019

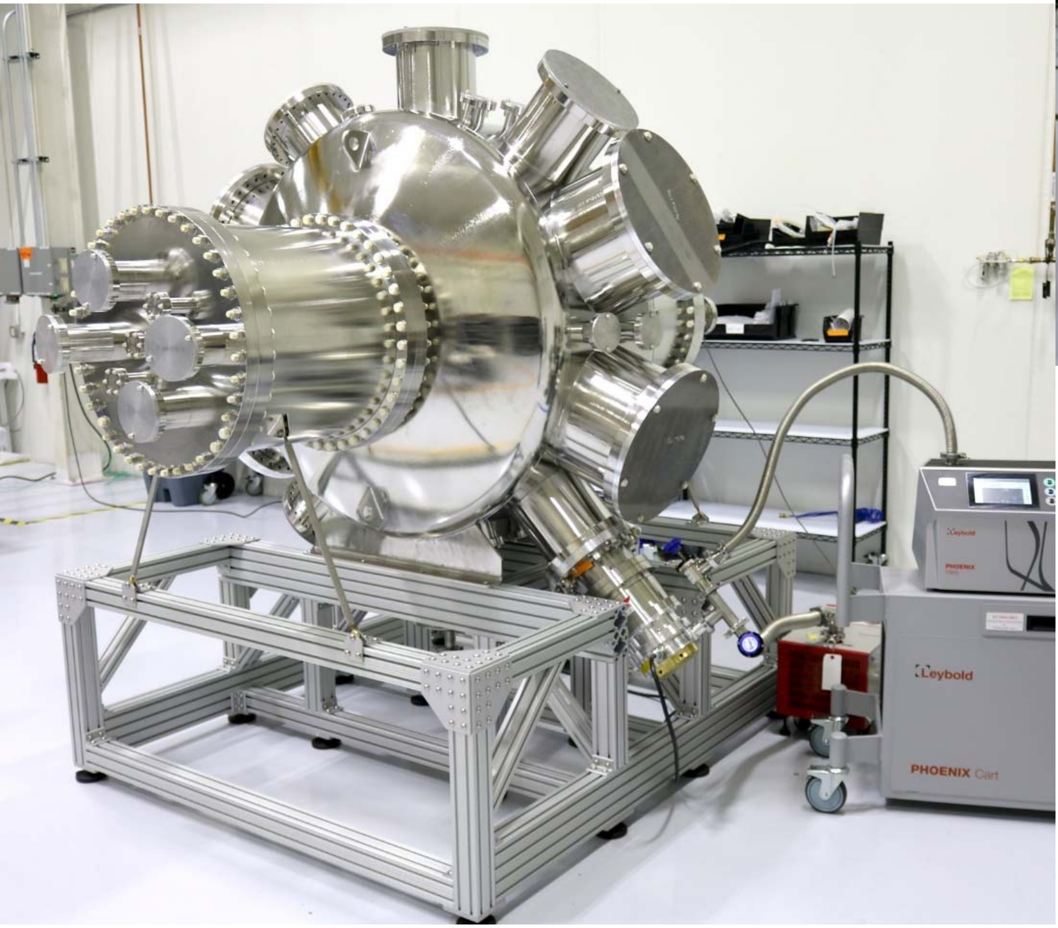


BE was asked to analyze this vessel because the manufacturer had done an inadequate job of analysis. I found an interference in the model between two tubes that no one had noticed before.



Photos of the Hunter vacuum vessel
from 7/20

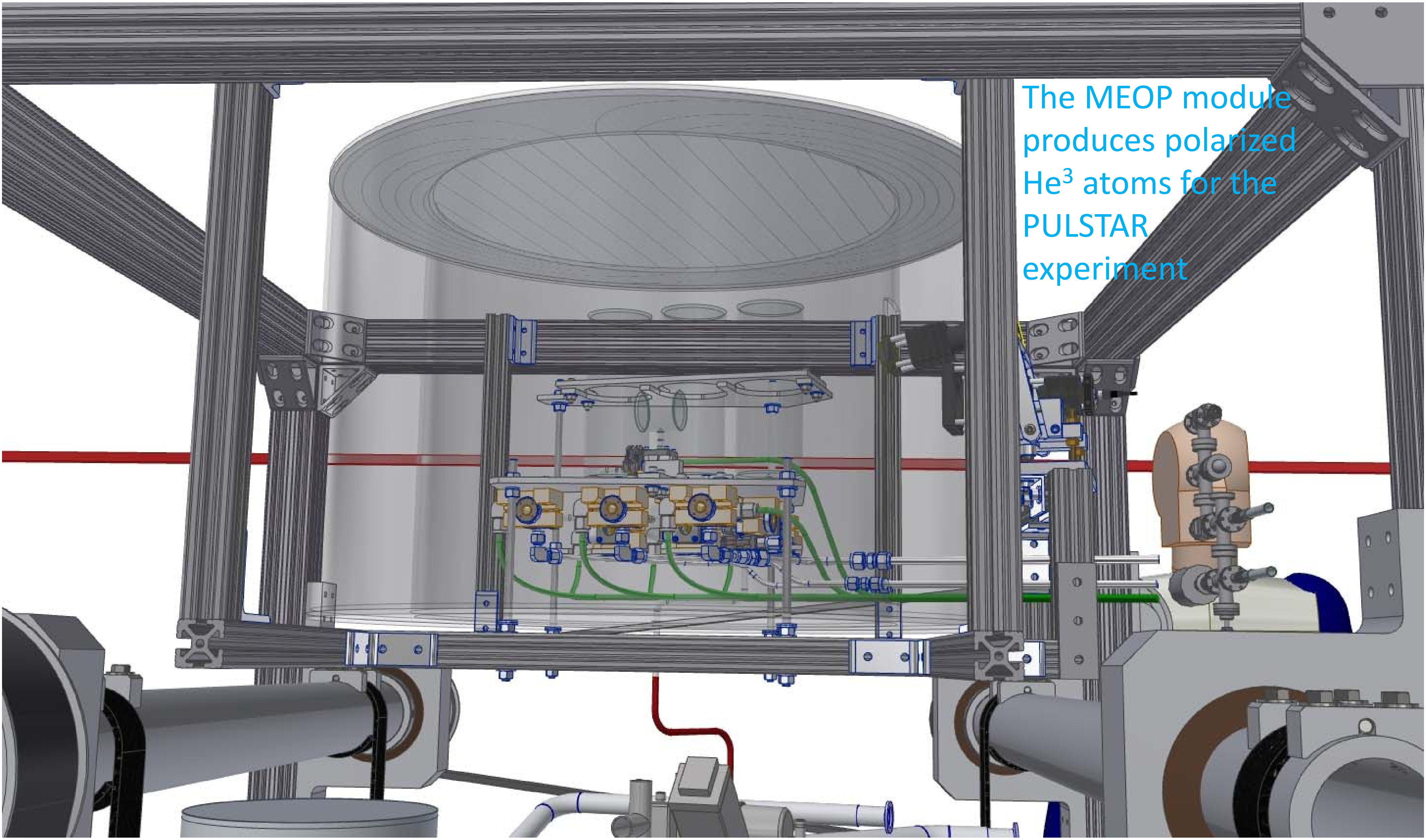




The HUNTER Experiment

- https://phys.cst.temple.edu/hunter/
- “The HUNTER (Heavy Unseen Neutrinos from Total Energy-momentum Reconstruction) collaboration brings together AMO, NP and HEP researchers to search for additional “sterile” neutrinos beyond the Standard Model of particle physics. HUNTER is an apparatus for radioactive atom trapping and high resolution decay-product spectrometry. It is built around a high occupancy, low temperature Magneto-Optical Trap (MOT), loaded from a source of radioactive 131 Cs through a subsidiary loading MOT. The MOT is viewed by large acceptance, high resolution electrostatic spectrometers (“Reaction Microscope”) to detect the recoil ions and Auger electrons from electron-capture (EC) decays in the trap, plus a position-sensitive scintillator array measuring vector momentum of atomic x-rays. HUNTER will allow event-by-event missing mass reconstruction of EC decays, seeking a separated nonzero mass peak from massive sterile neutrinos.”

MEOP Module, NCSU, 2019 (part of nEDM)

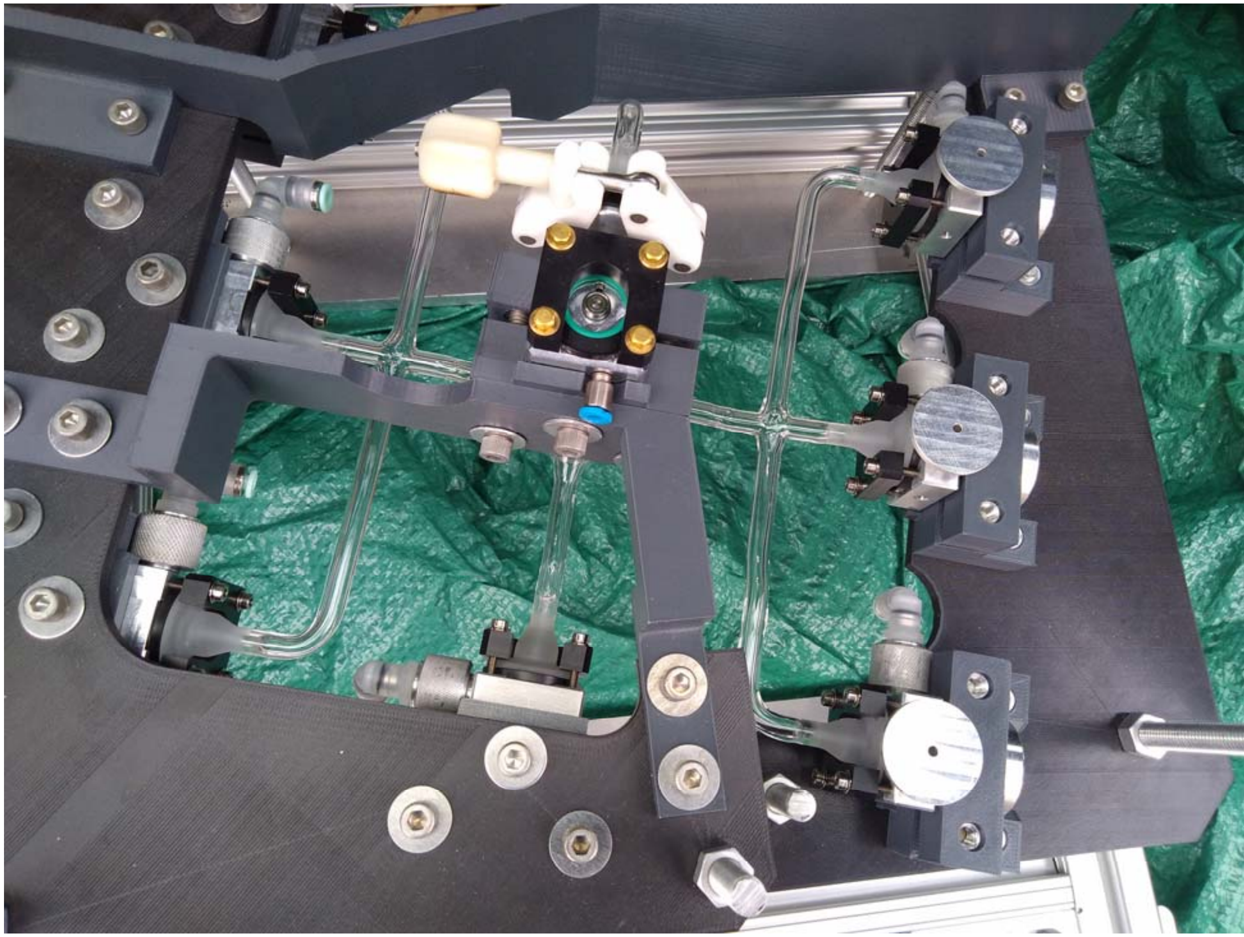


The MEOP module produces polarized He^3 atoms for the PULSTAR experiment

^{3}He Injection System MEOP Manifold

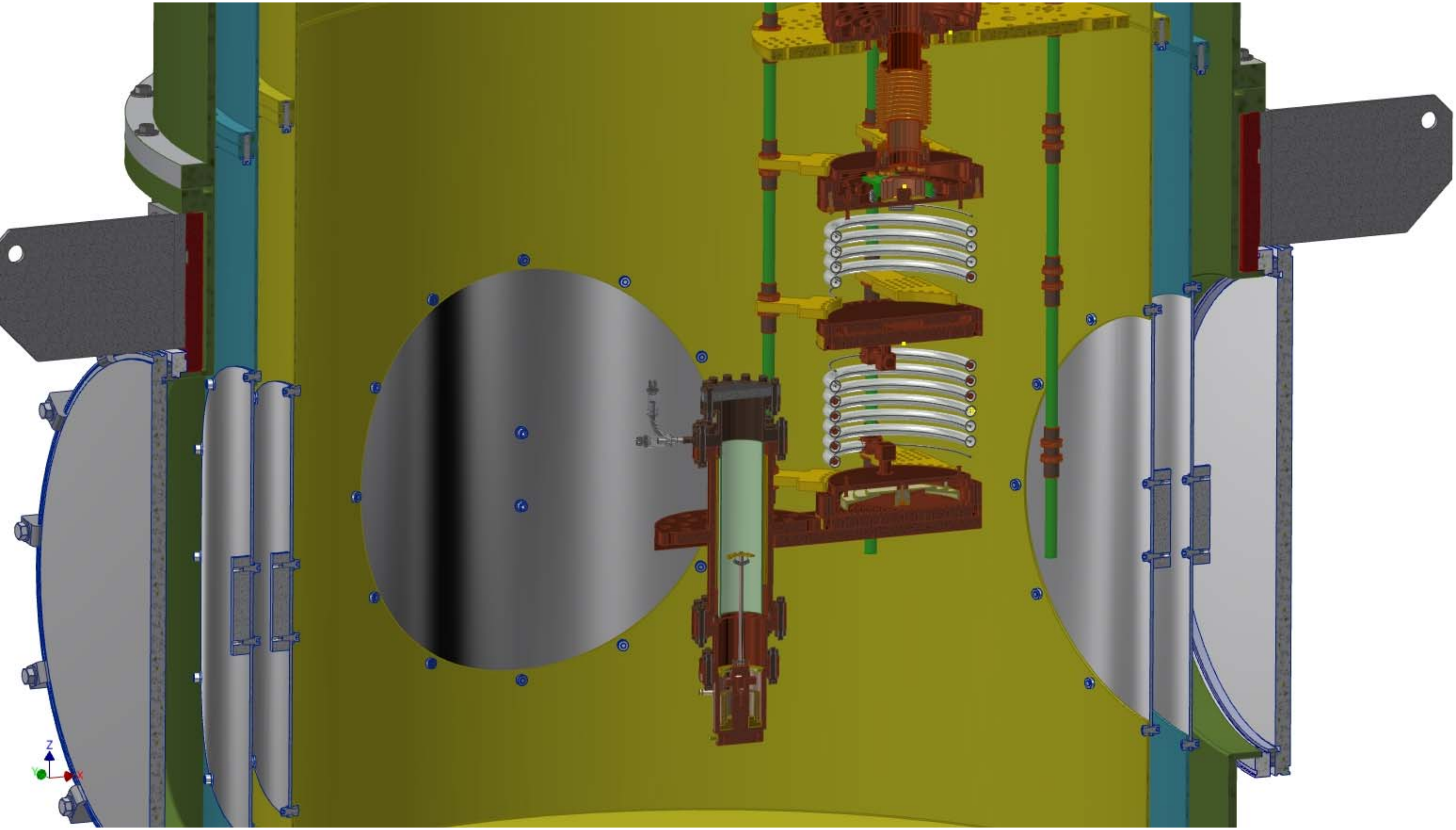
from Tom Rao's presentation to the nEDM Collaboration meeting, 2/9/22

Glass manifold fabricated in frame to ensure good fit and reduce chance of cracking from stress



The gray support parts were 3D printed from my design.

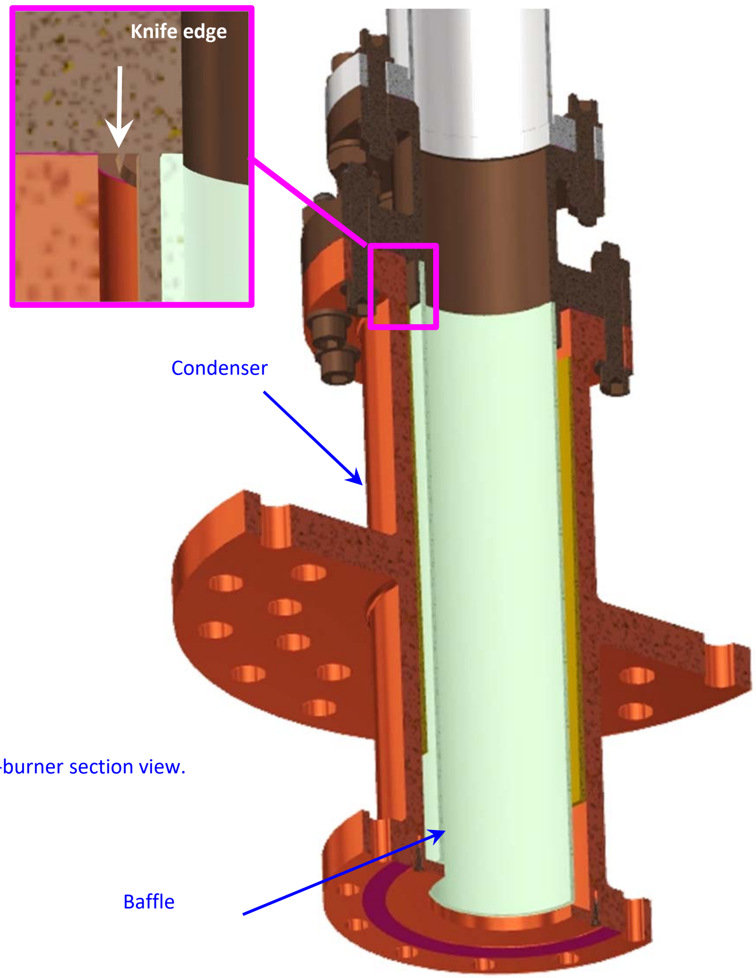
He3 Film Burner test, UIUC, 2019 (part of nEDM)



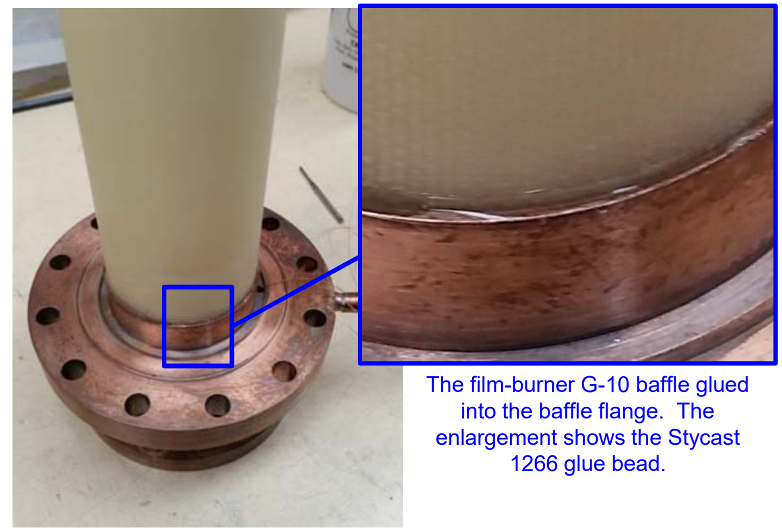
This is one of the first components of the He3 beam line to be fabricated. Testing in 2020.

Pictures of the Film-Burner parts from Steve Williamson's talk at the nEDM collaboration meeting, 2/2/22 (part of nEDM)

BE designed all of the parts shown here.

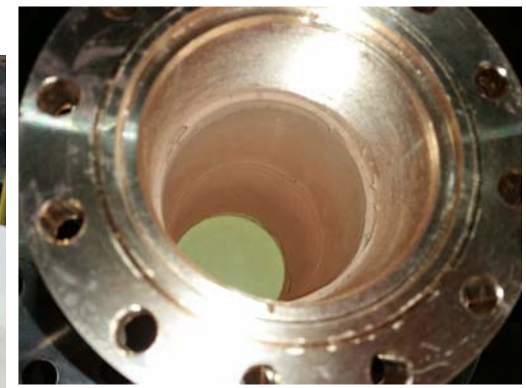


Film-burner section view.

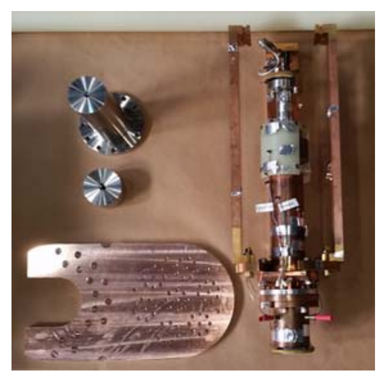


The film-burner G-10 baffle glued into the baffle flange. The enlargement shows the Stycast 1266 glue bead.

The completed film-burner condenser after gold plating of the cold plate.



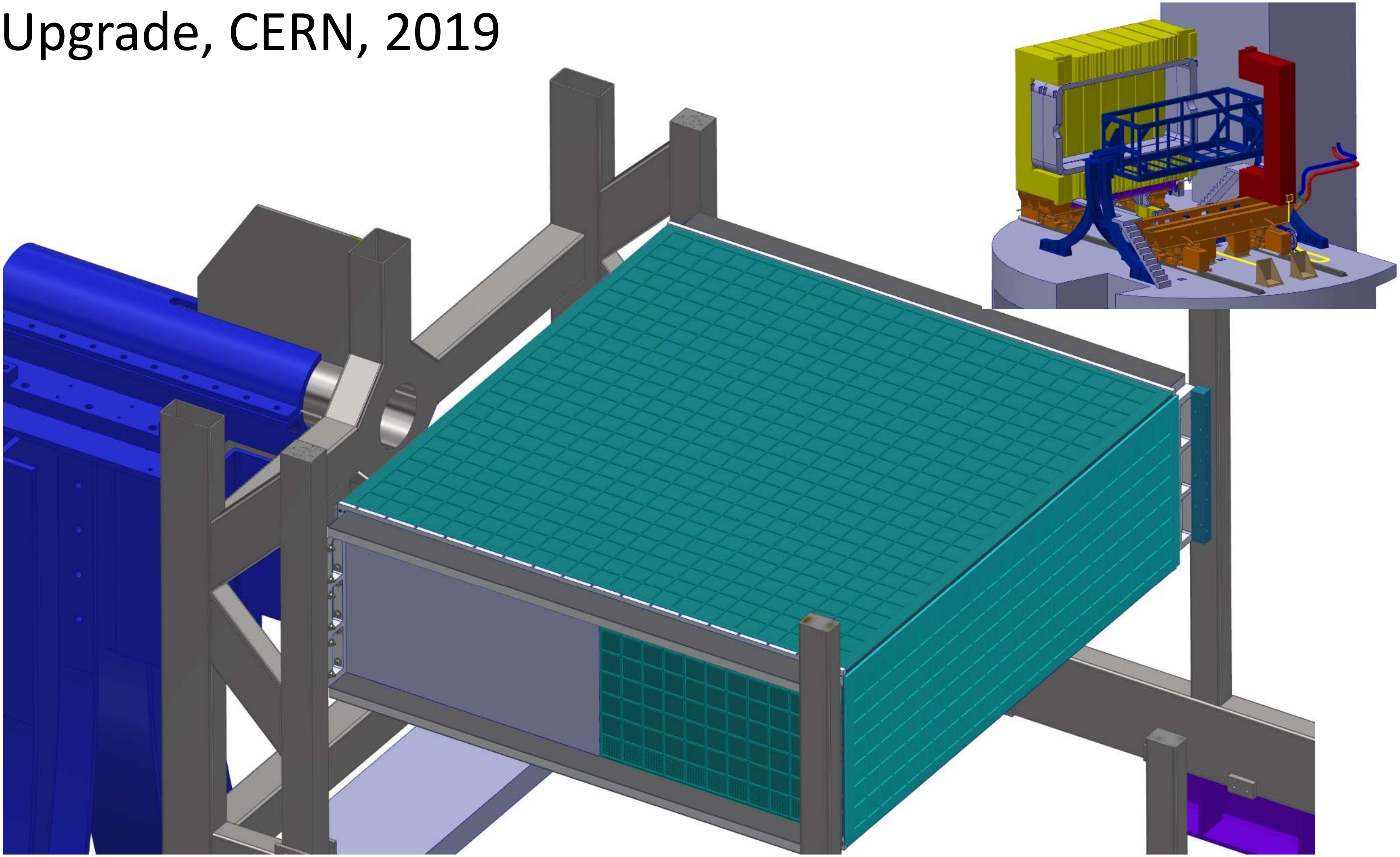
The sintered copper on the interior surface of the film-burner condenser.



Components for film-burner test.

Film-burner test setup.

Super Fine Grained Detector, T2K Near Detector Upgrade, CERN, 2019



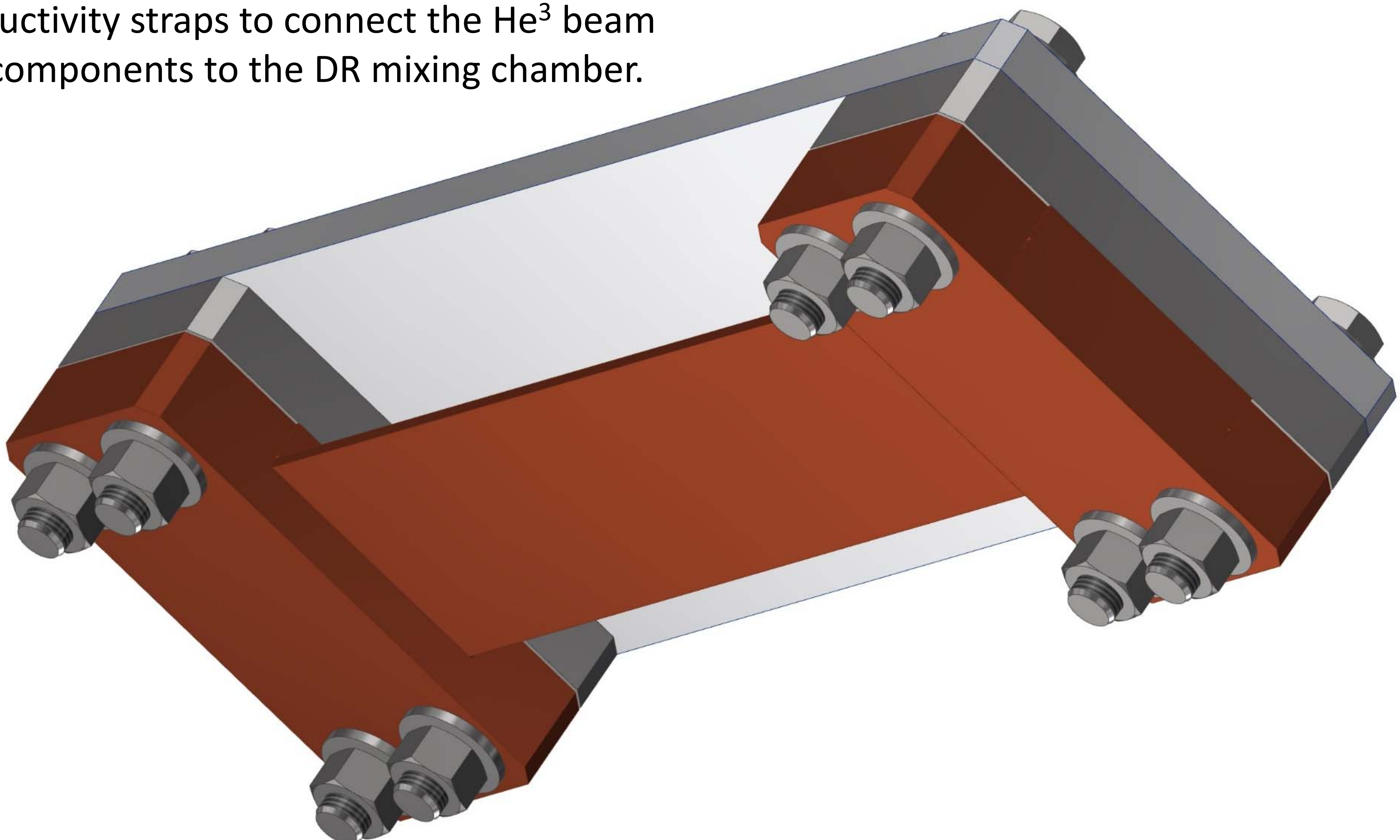
BE is currently doing the box design and its method of attachment to the ND280 basket.

Super Fine Grained Detector for T2K

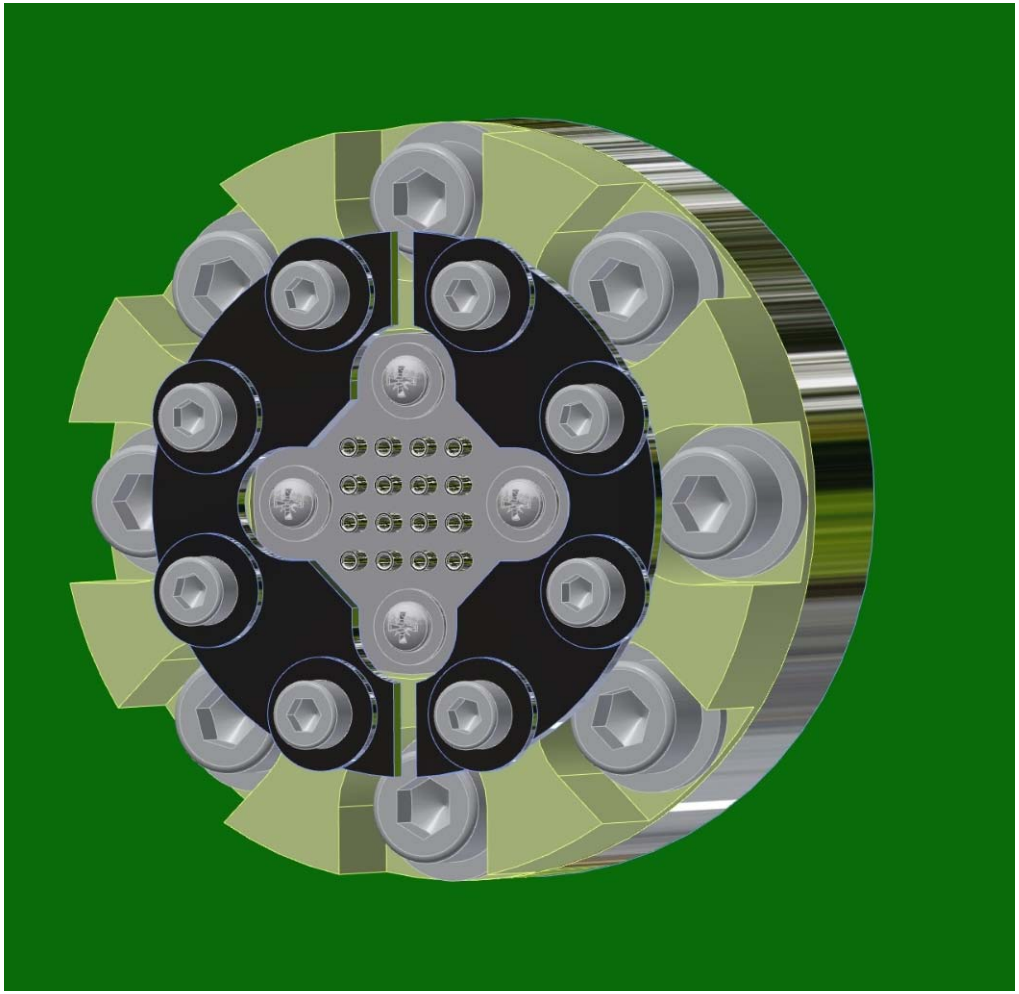
- https://pos.sissa.it/369/118
- "The T2K-II program will upgrade the beam power of the main ring at J-PARC to 1.3 MW and will also renovate the T2K near detector ND280. With these two components the T2K collaboration will establish the value of leptonic CP violation at the 3σ level for a significant fraction of the possible δCP values. An upgrade of the near detector is essential to achieving this goal as it can be used to reduce the overall statistical and systematic uncertainties to the level of less than 4%. We have developed an innovative concept for this neutrino detection system, comprising the totally active Super-Fine-Grained-Detector (SuperFGD), two High Angle TPC (HA-TPC) and six TOF planes. The SuperFGD, a highly segmented scintillator detector, acting as a fully active target for the neutrino interactions, is a novel device [1]"

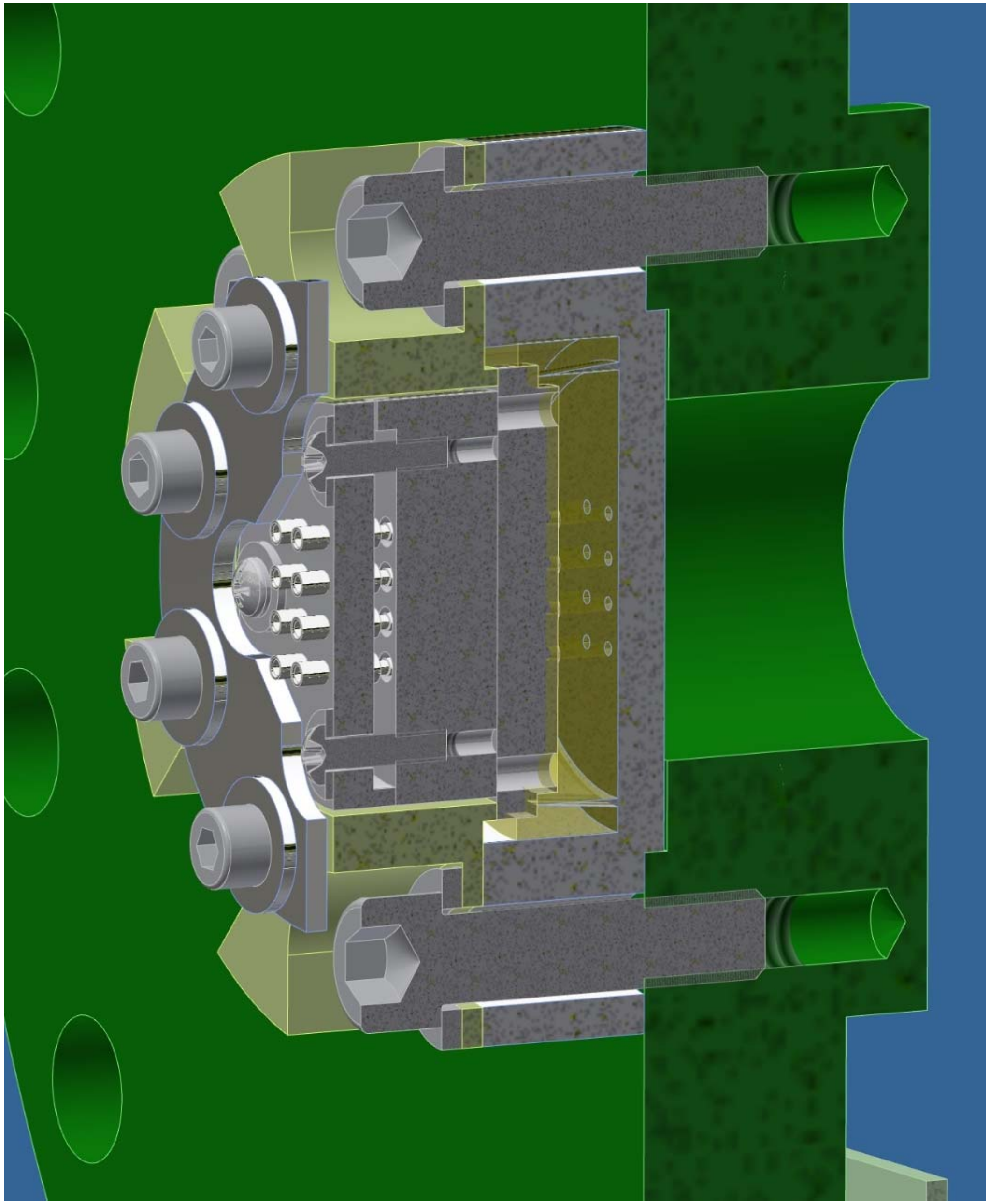
Thermal strap E-beam weld fixture, UIUC, 2019 (part of nEDM)

BE is developing the high thermal conductivity straps to connect the He^3 beam line components to the DR mixing chamber.



Magnet wire feedthrough design, NCSU, 2019 (part of nEDM)

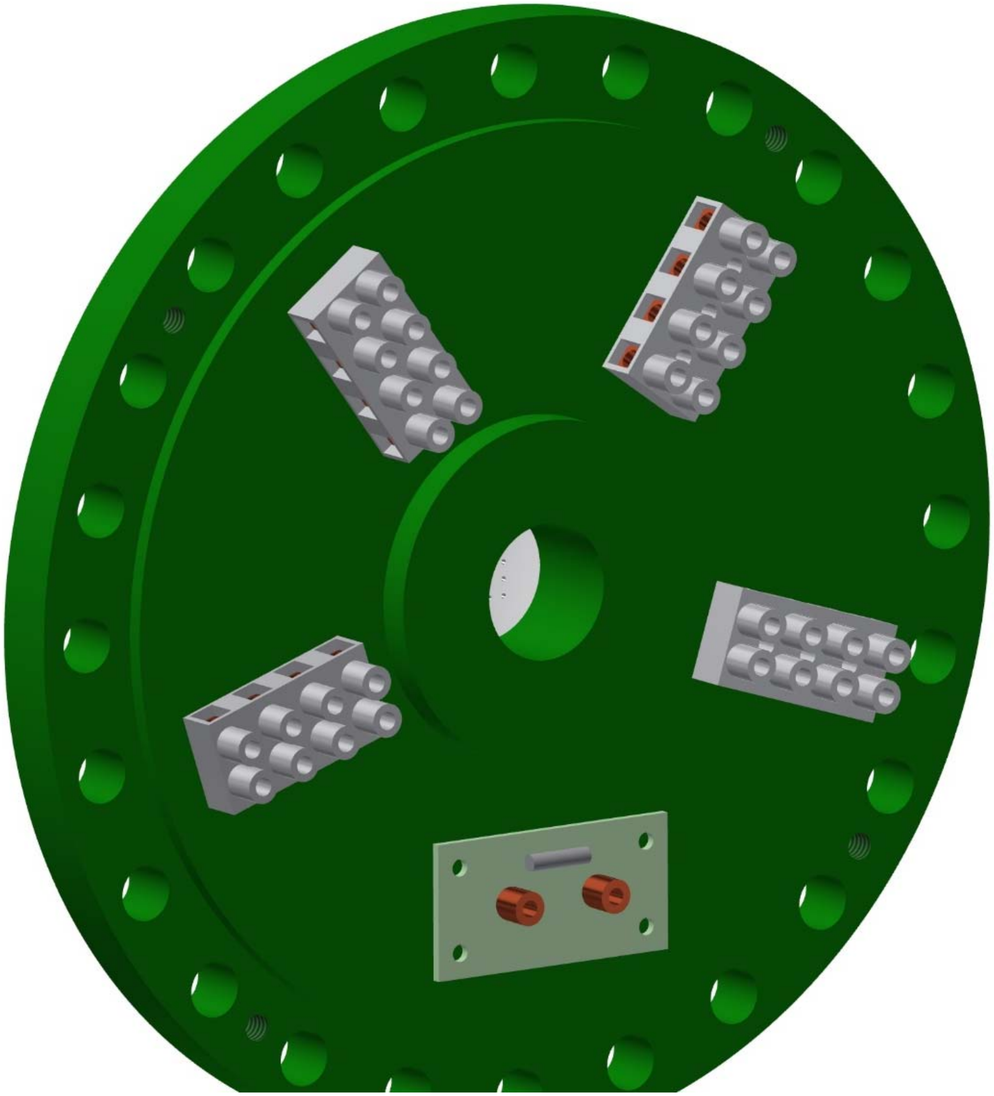


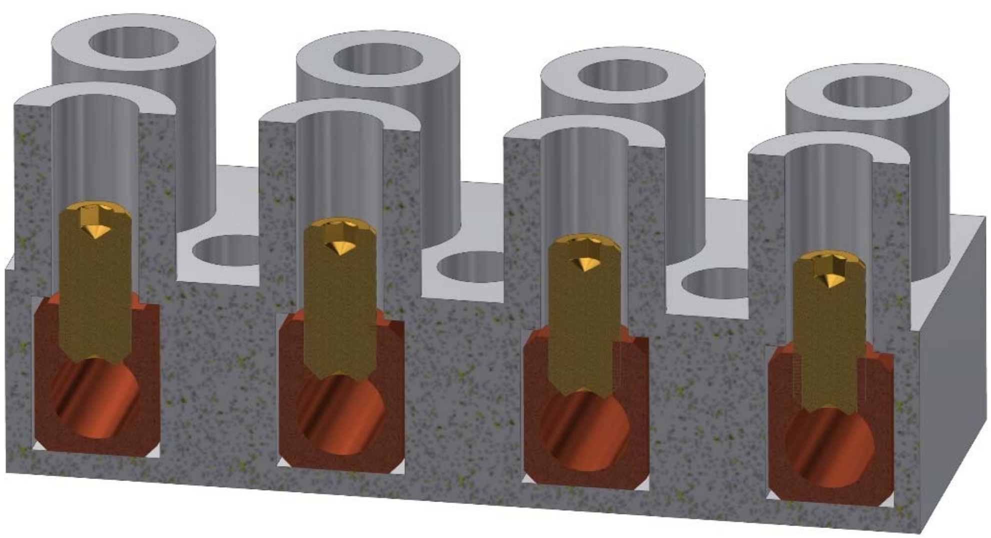


These will be used to connect magnets at 4K to room temperature power supplies.

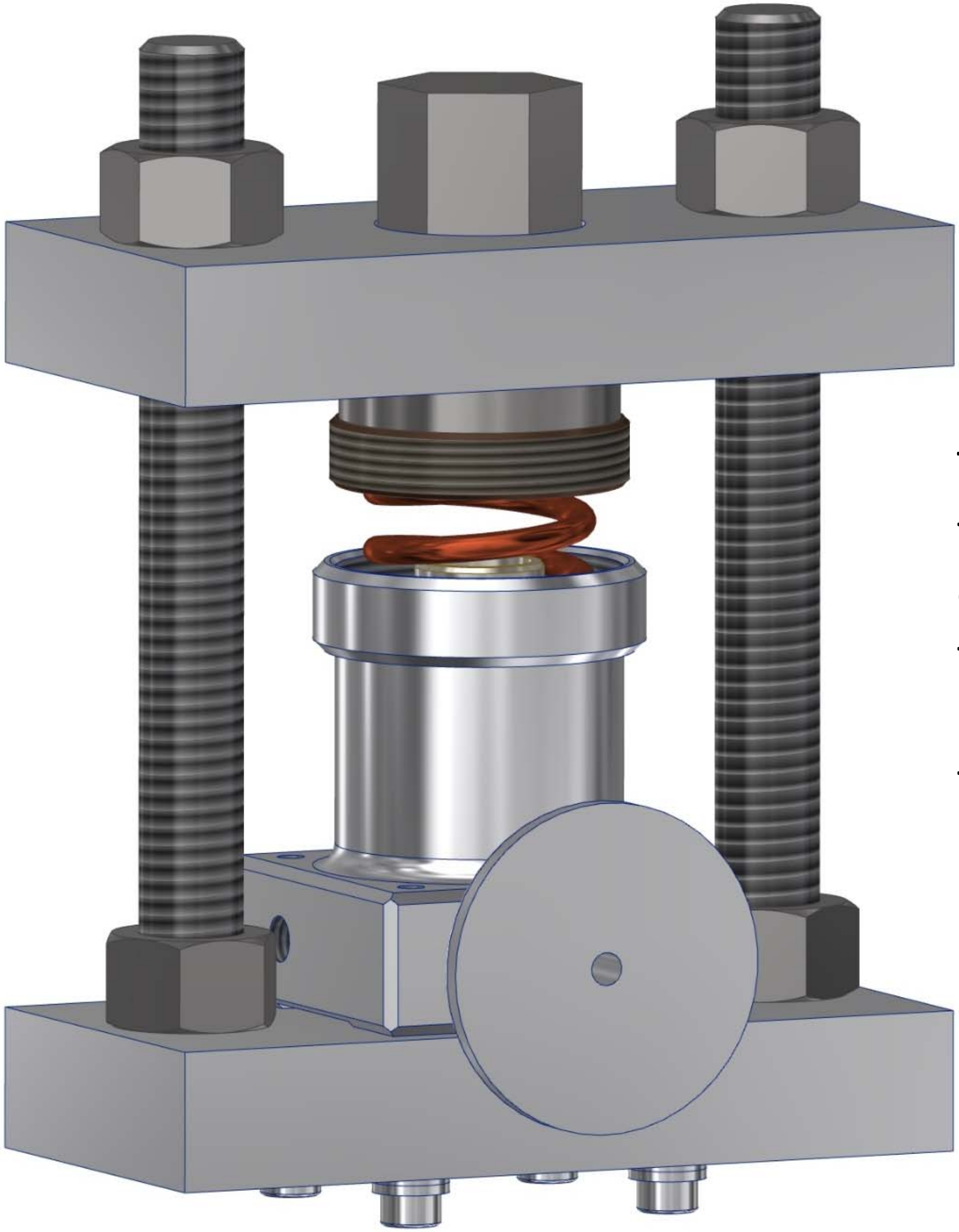
Custom nonmagnetic terminal blocks, PULSTAR, (part of nEDM), 2020

BE designed these terminal blocks for PULSTAR because commercially available ones are magnetic. We need them close to the PULSTAR measurement cell where magnetic materials are not allowed.

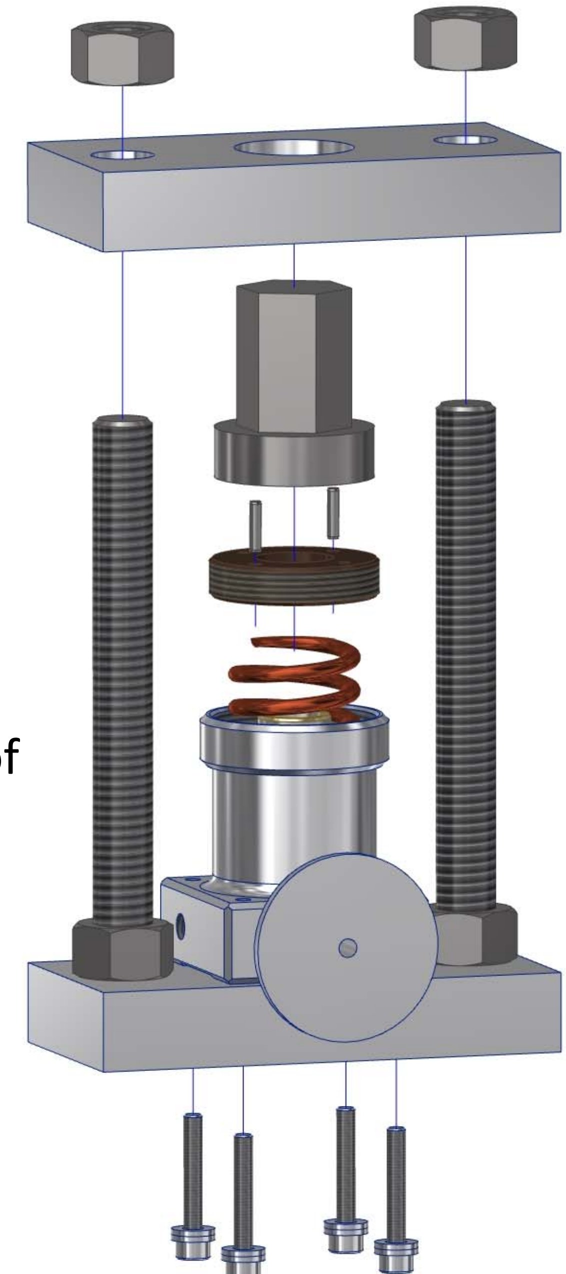




MEOP valve spring installation fixture, (part of nEDM,) 2020

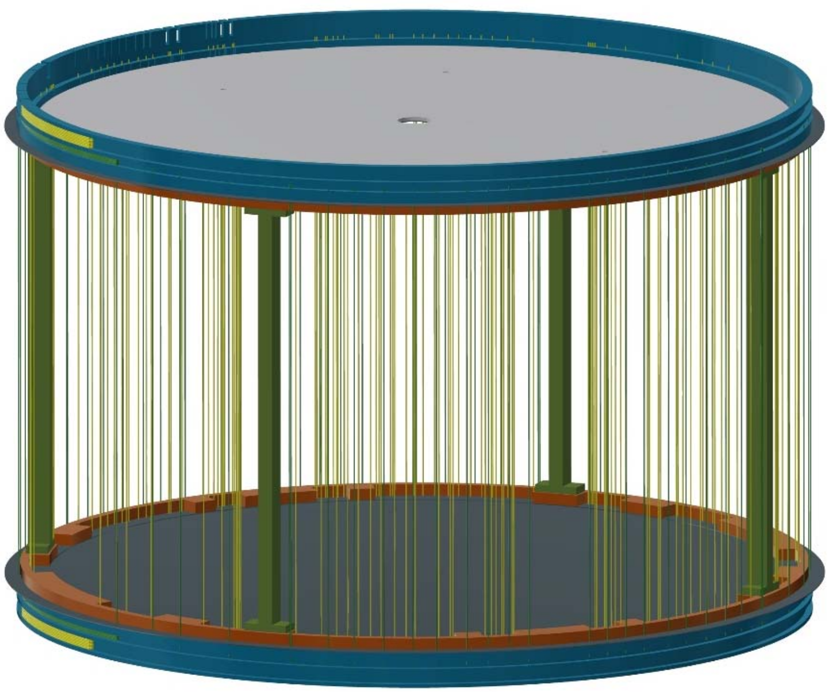


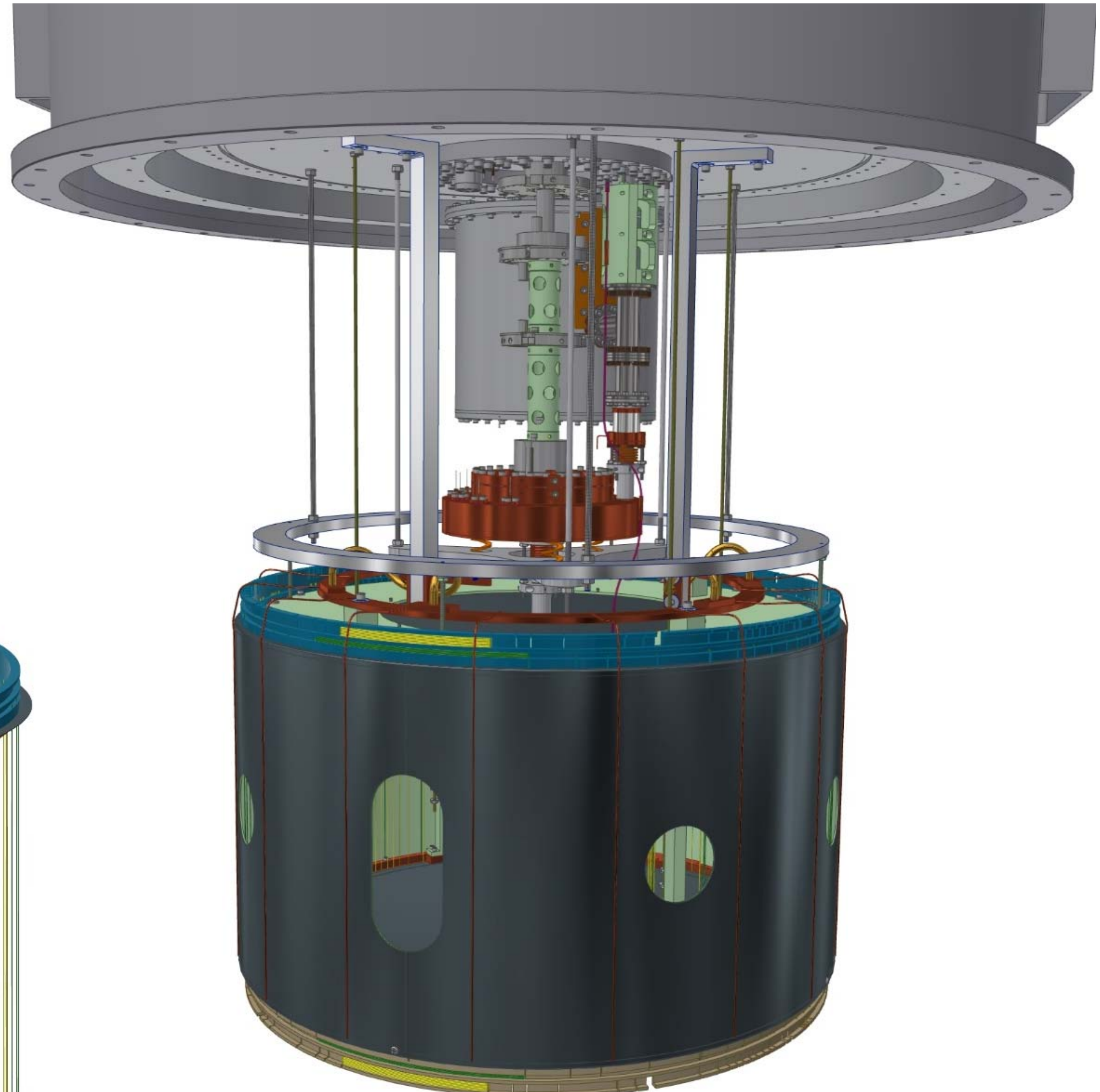
This device allows the springs to be compressed into the ILL-style pneumatic valves of the MEOP system.

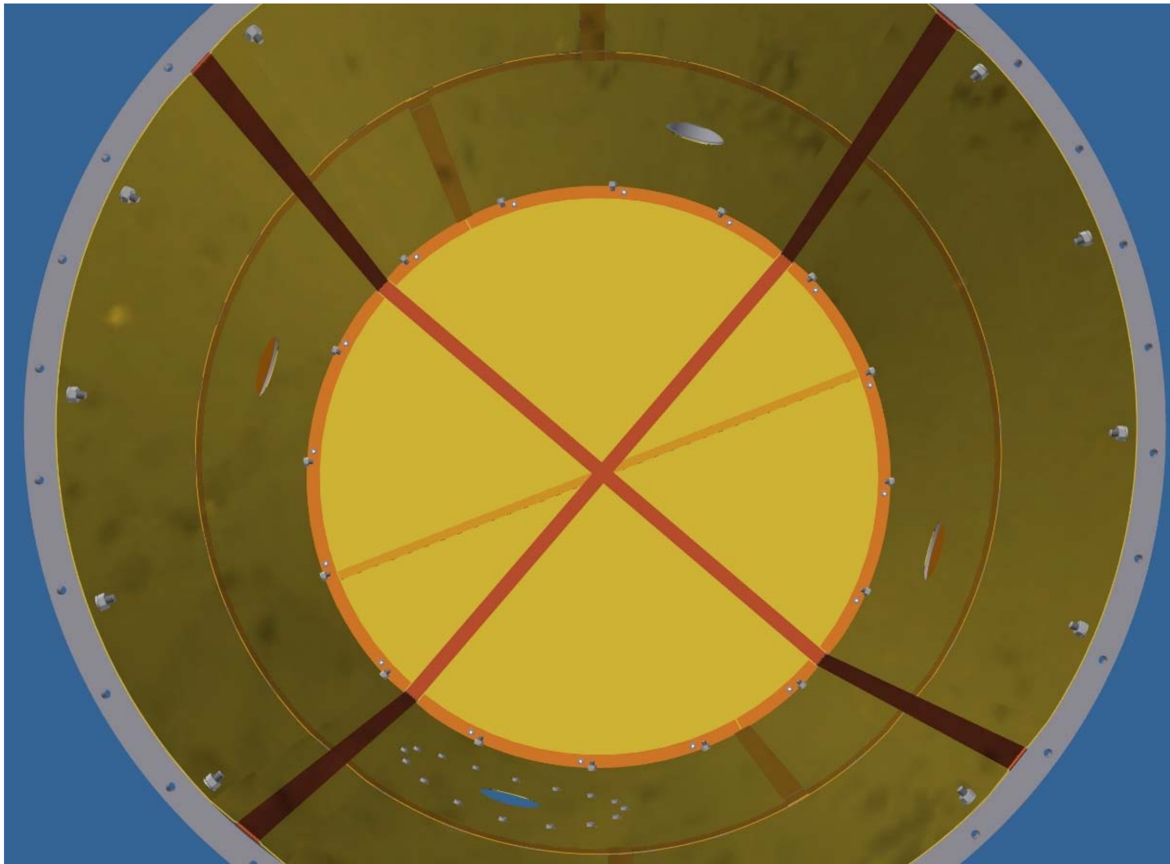


First pass at the PULSTAR internal magnet, (part of nEDM,) 2020

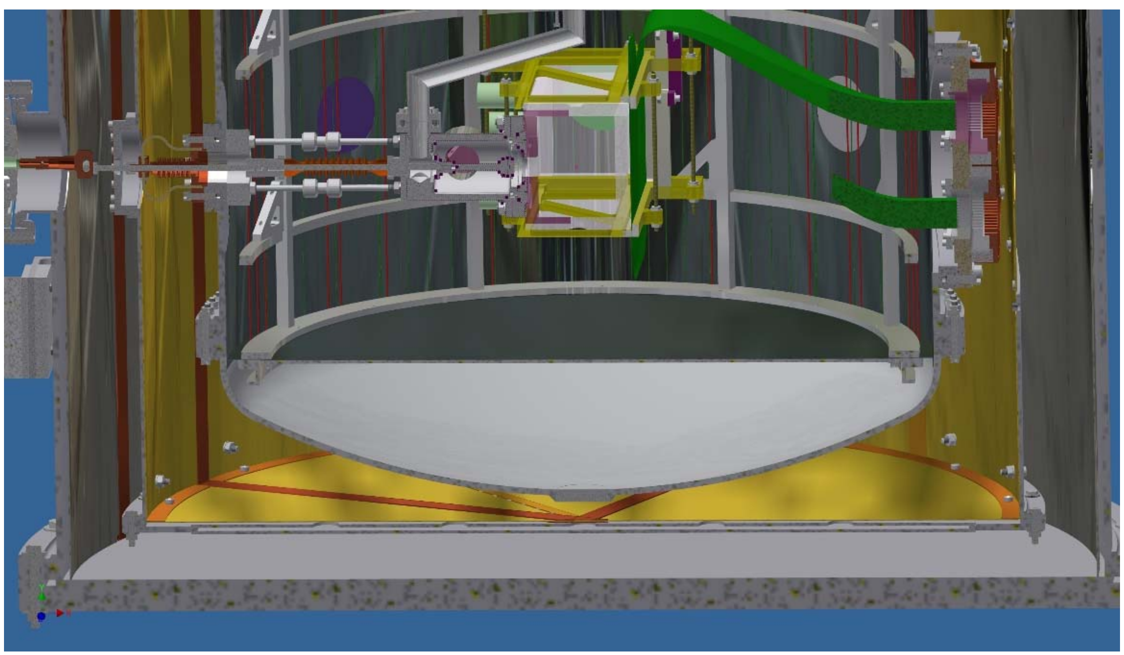
This was the first fully developed magnet design, but it will be redone in 2021 because of new placement of the wires to reduce magnetic field gradients.

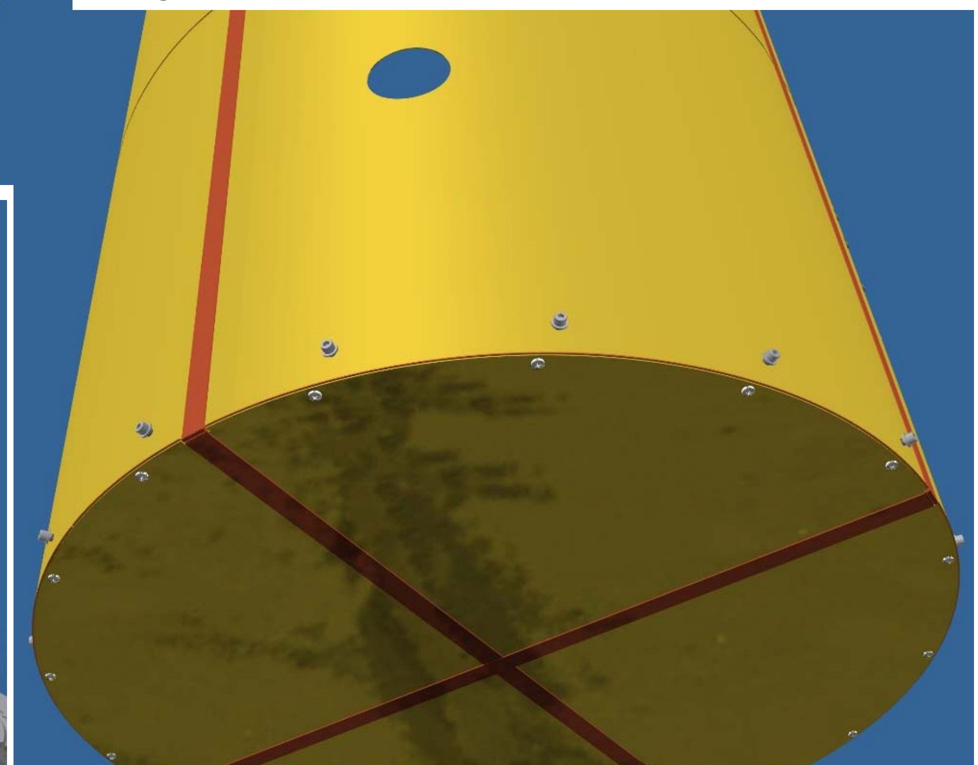


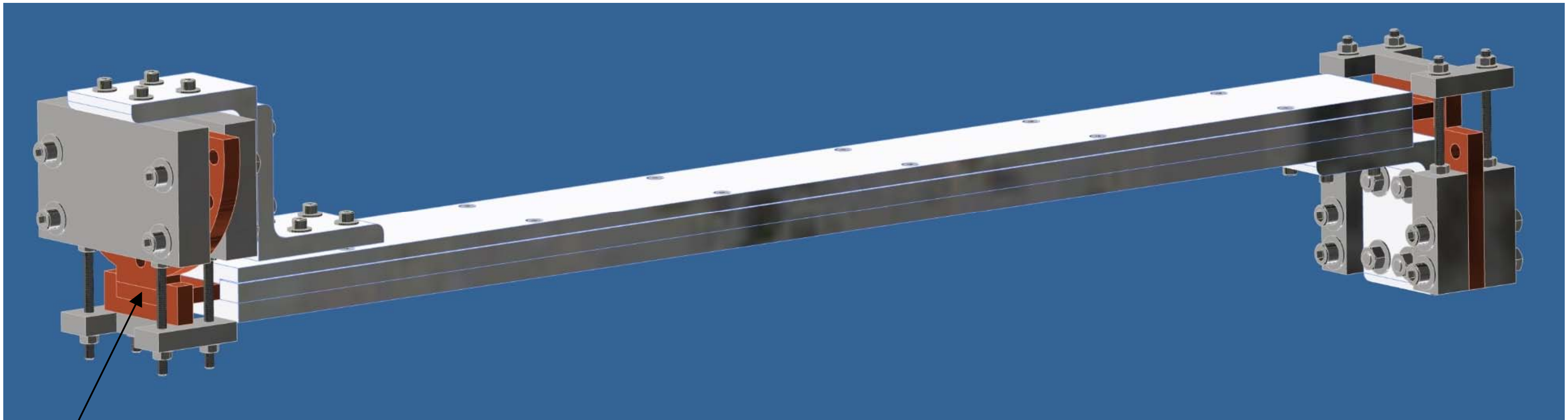




Cryonetic magnetic shield mounted on the LN shield for the PULSTAR cryostat, NCSU, 2019 (part of nEDM)





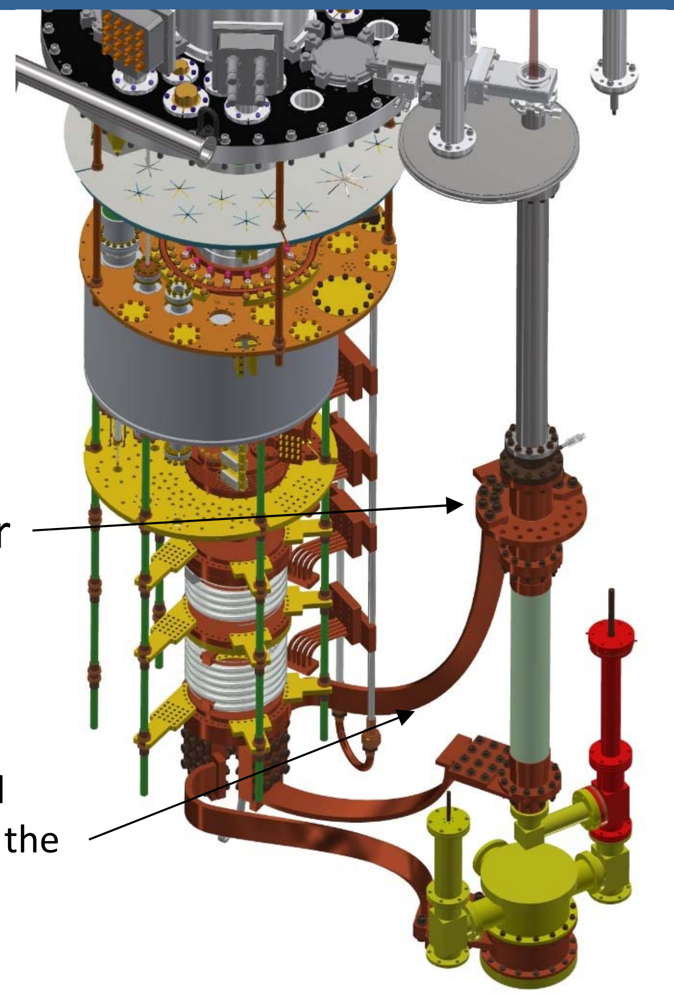


E-beam welds
(both ends)

Welding Fixture for the full length thermal strap for the Phase 2 Film Burner test, 2020 (part of nEDM)

This welding fixture allows us to assemble 200 copper foils together, .002” thick each, and e-beam weld the bolted flanges onto the ends. The foil is heat treated to increase its thermal conductivity dramatically.

The cold end of the thermal strap will be at 250 mK, the warm end only about 300 mK.



Film burner

Film burner thermal strap connection to the DR mixing chamber

Pictures of Faux Beam Line Components from Steve Williamson's talk at the nEDM collaboration meeting on 2/2/22 (Part of nEDM)

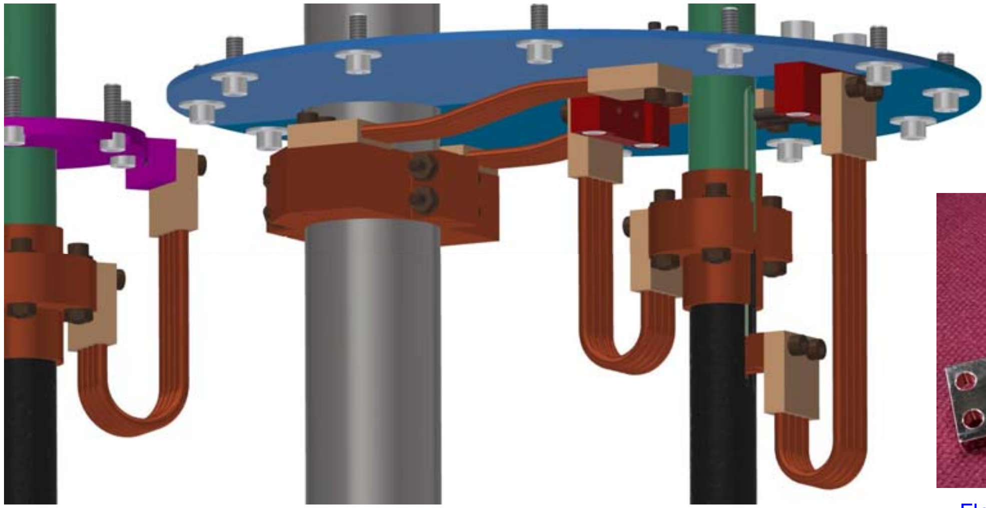
BE designed all of the parts shown on this page. (We always love to see things get built.)

Stainless beam-line tubes after fabrication.

Completed beam-line vacuum top flange

Brazed copper spool piece. This connects the inj. volume to the film burner. Note wiring feed-through bushing for level sensor (see arrow).

Nut and washer plates used to bolt together soft copper flanges



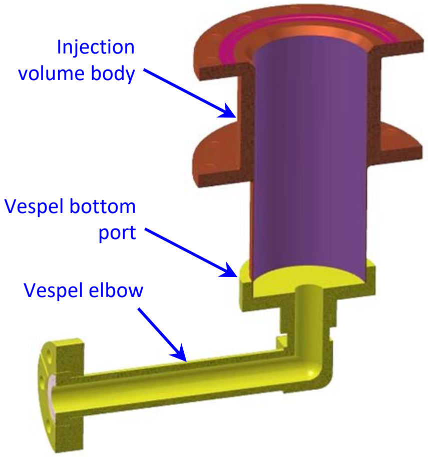
The design of thermal anchoring of the faux beam line to one of the shield plates. The inner actuator tube, which moves up and down, is shown in the "down" position

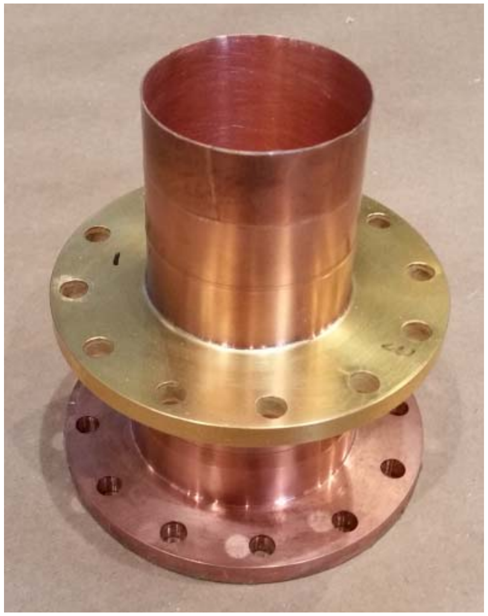
Flexible anchor straps made by Technology Applications, Inc. (TAI) were received. They will be used to anchor the Phase 2 injection beam line.

Copper clamps for thermally anchoring the beam line tube to the thermal shields.

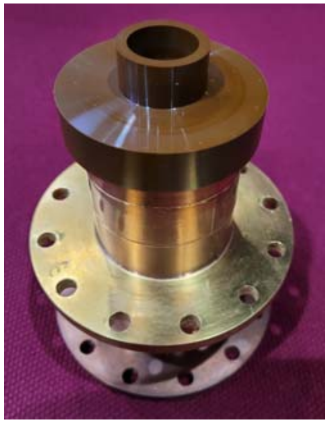
Pictures of the Injection Volume for Helium 3 Services from Steve Williamson's talk at the nEDM Collaboration meeting on 2/2/22 (Part of nEDM)

More stuff for the Helium 3 services testing at UIUC built.





Completed 1-piece copper inj. vol. copper body. Note gold-plated anchor plate (shown upside-down).

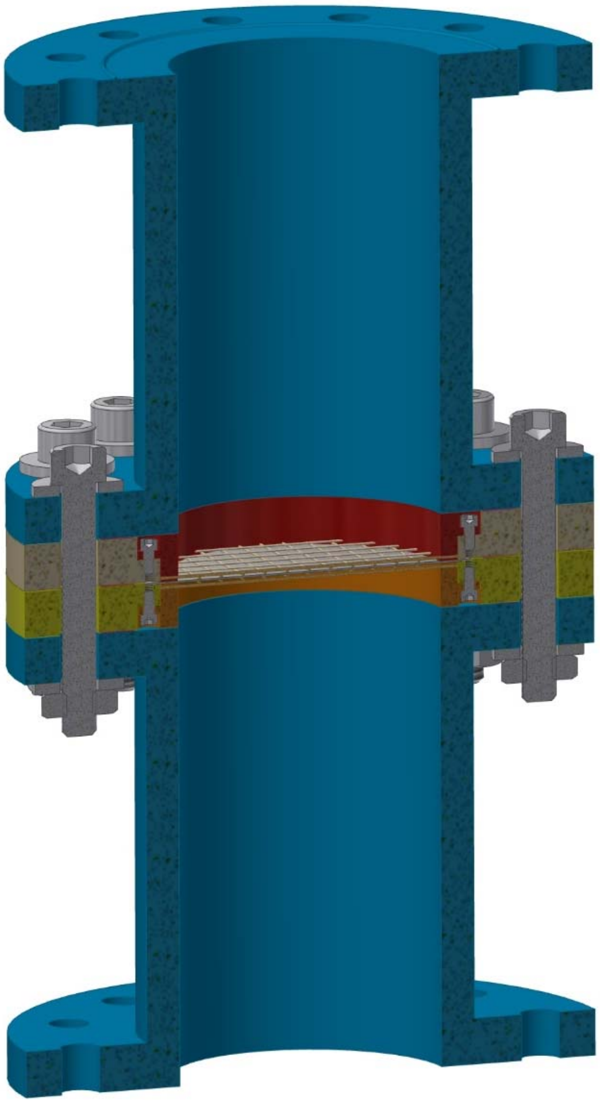


The Vespel bottom port test fit to the bottom of the injection volume.

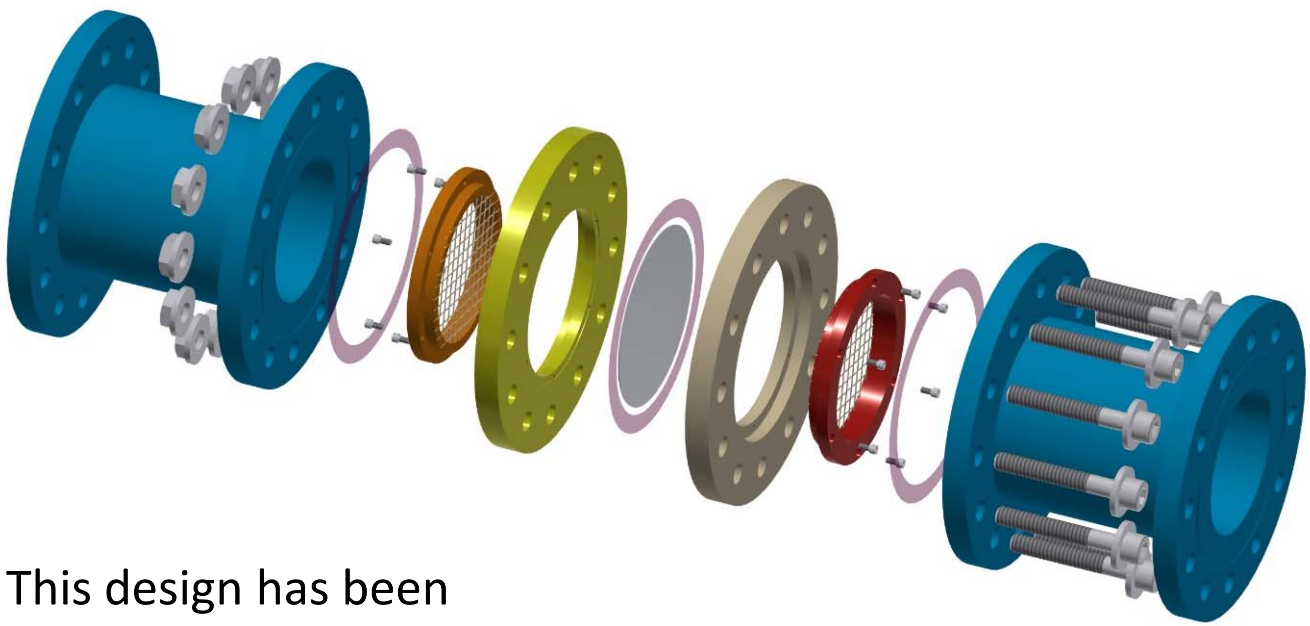
The injection volume body after seamless Kapton tubing was bonded to the inside surface.

Left: CAD model of the level sensor (light blue) mounted in the injection volume. The small red "dots" are bare ROX sensors. **Below:** the completed Vespel support rod.

Nuclepore filter for the He3 lines of nEDM, 2020



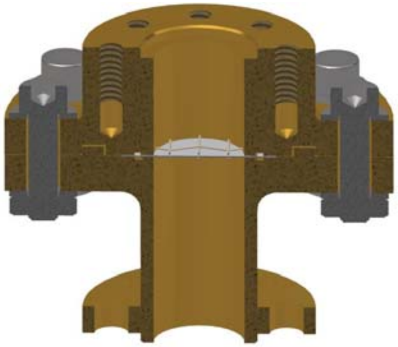
The Nuclepore filter is designed to prevent magnetic particles from reaching the nEDM measurement cell. These particles could compromise the nEDM measurement.
It has Kevlar threads to support the delicate filter material during cool-down



This design has been updated to use fewer seals.

Pictures of the Heat flush through Nuclepore Filter test from Steve Williamson's talk at the nEDM Collaboration meeting, 2/2/22, (Part of nEDM)

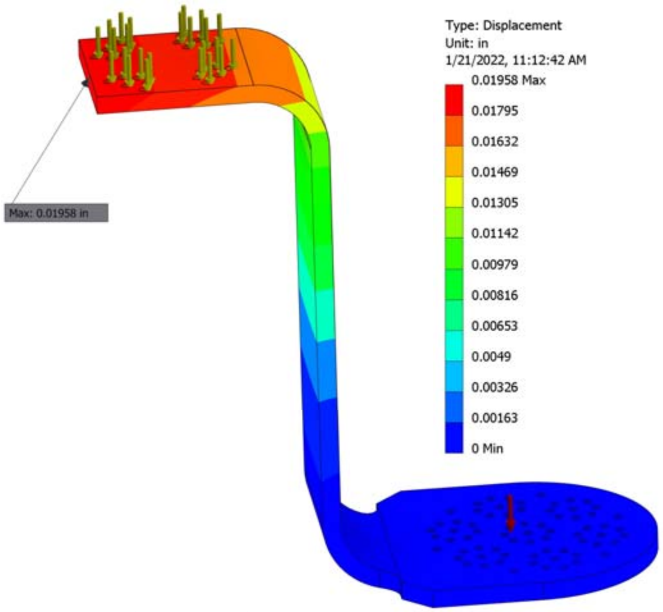
The Harvard heat-flush test hardware disassembled to install Nuclepore membrane



Section view detail of the Nuclepore membrane holder.

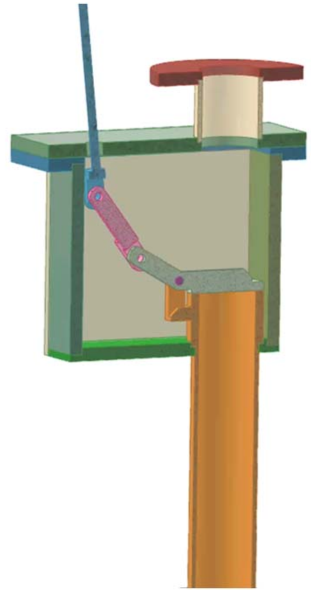
The heat-flush with Nuclepore membrane holder mounted on DR.

Fabricated components for the Nuclepore mebrane holder.



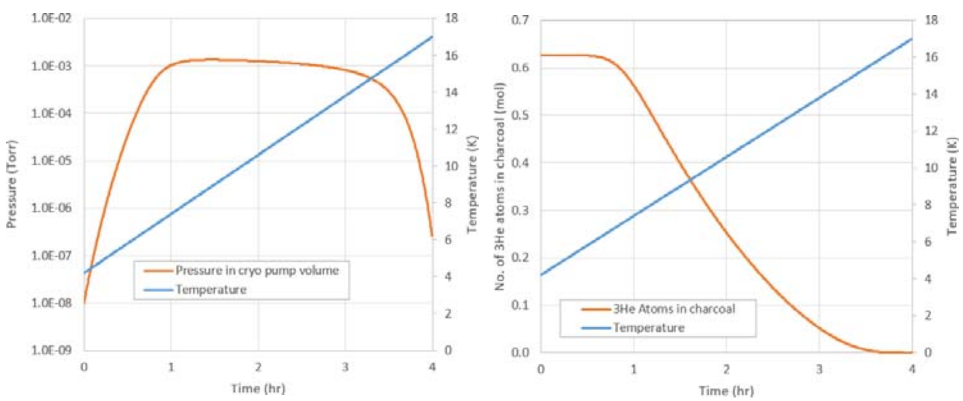
FEA deflection of anchor under gravity load of assembly. Max is 0.020"

Preliminary design of the ABS Interface regeneration valve from Steve Williamson's talk to the nEDM collaboration meeting on 2/2/22 (part of nEDM)

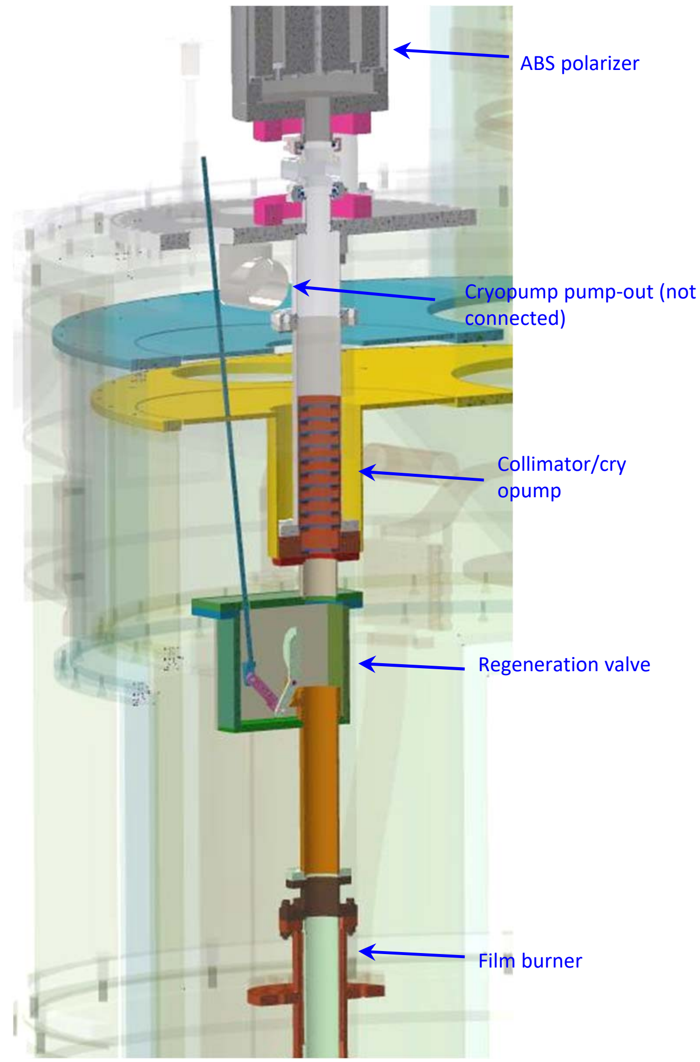


Animation showing the regeneration valve mechanism

This work was started in October of 2021.

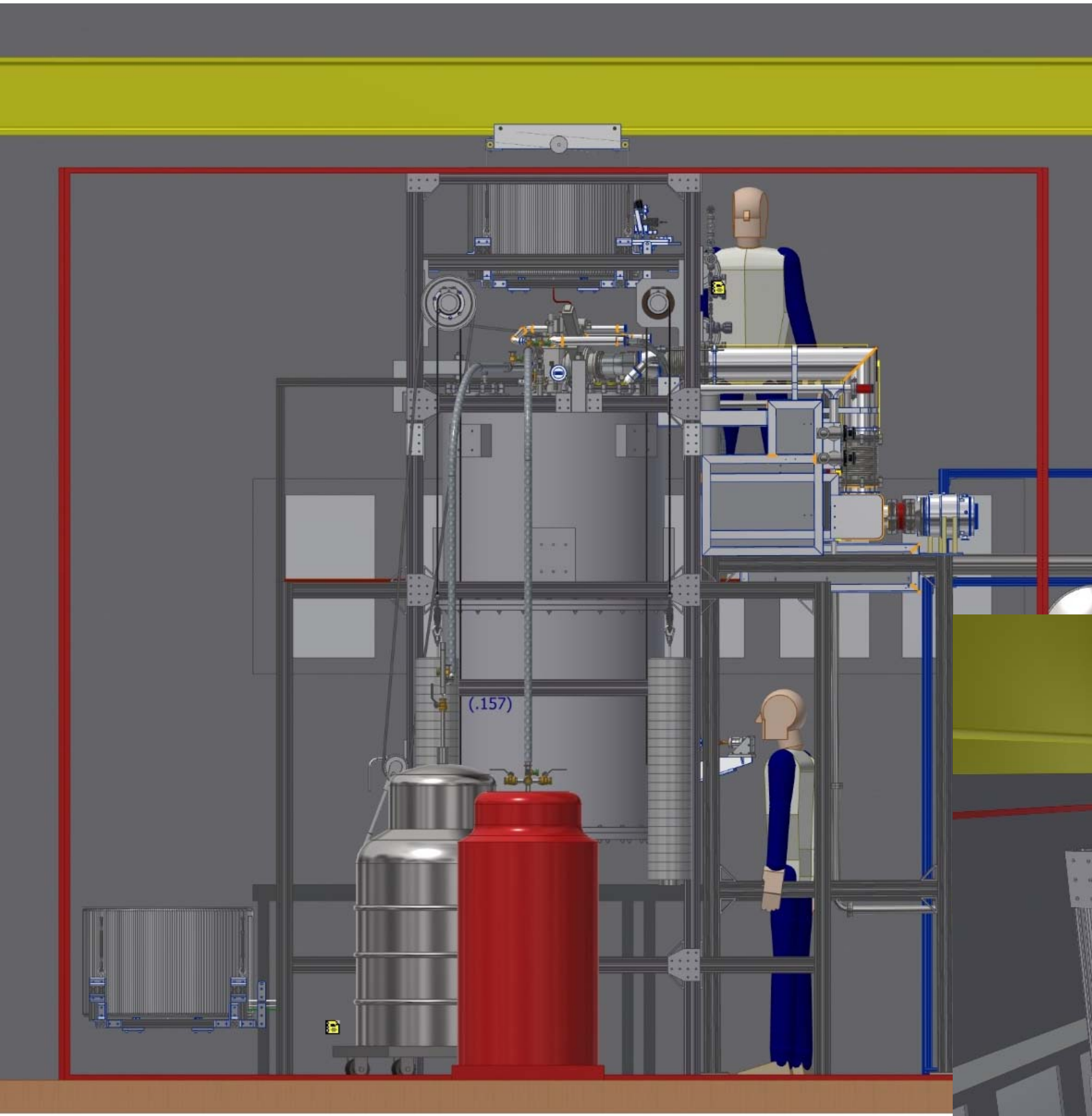


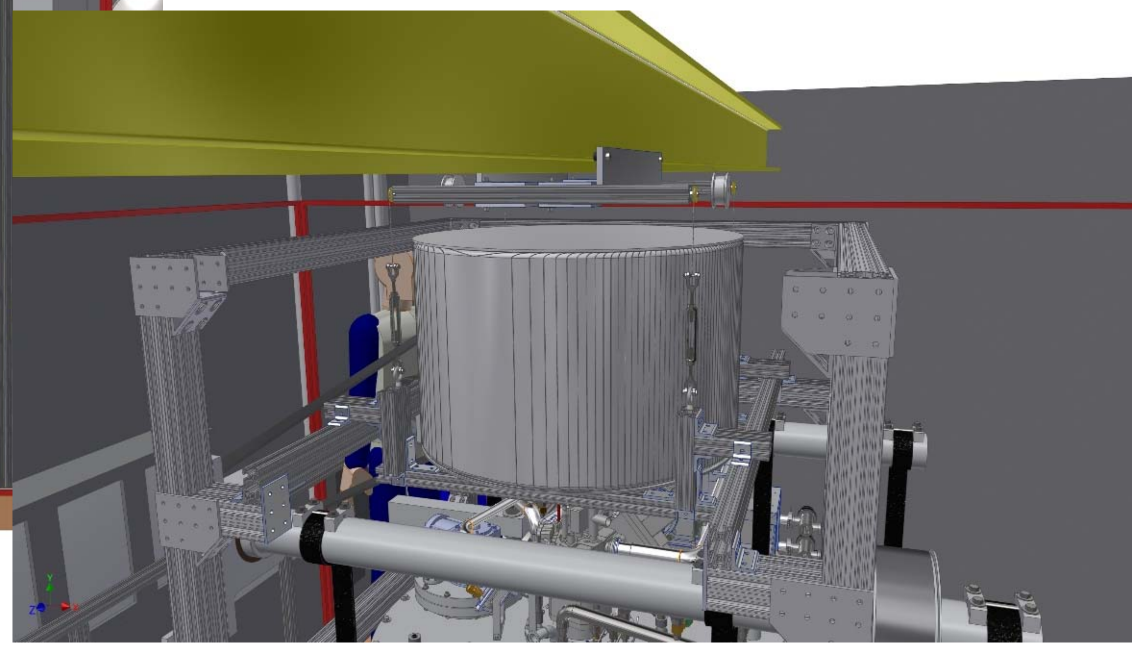
Simulated pressure and remaining ^{3}He in cryopump during regeneration for a linear rise in temp. from 4.2 to 17K. For this model, the allowed leak rate through the closed regen valve came to 0.25 Torr-l/s (huge).



Section view of the Phase 4 injection beam line showing the conceptual design for a flap-type regeneration valve (shown open)

PULSTAR MEOP Trolley, part of nEDM, 2020





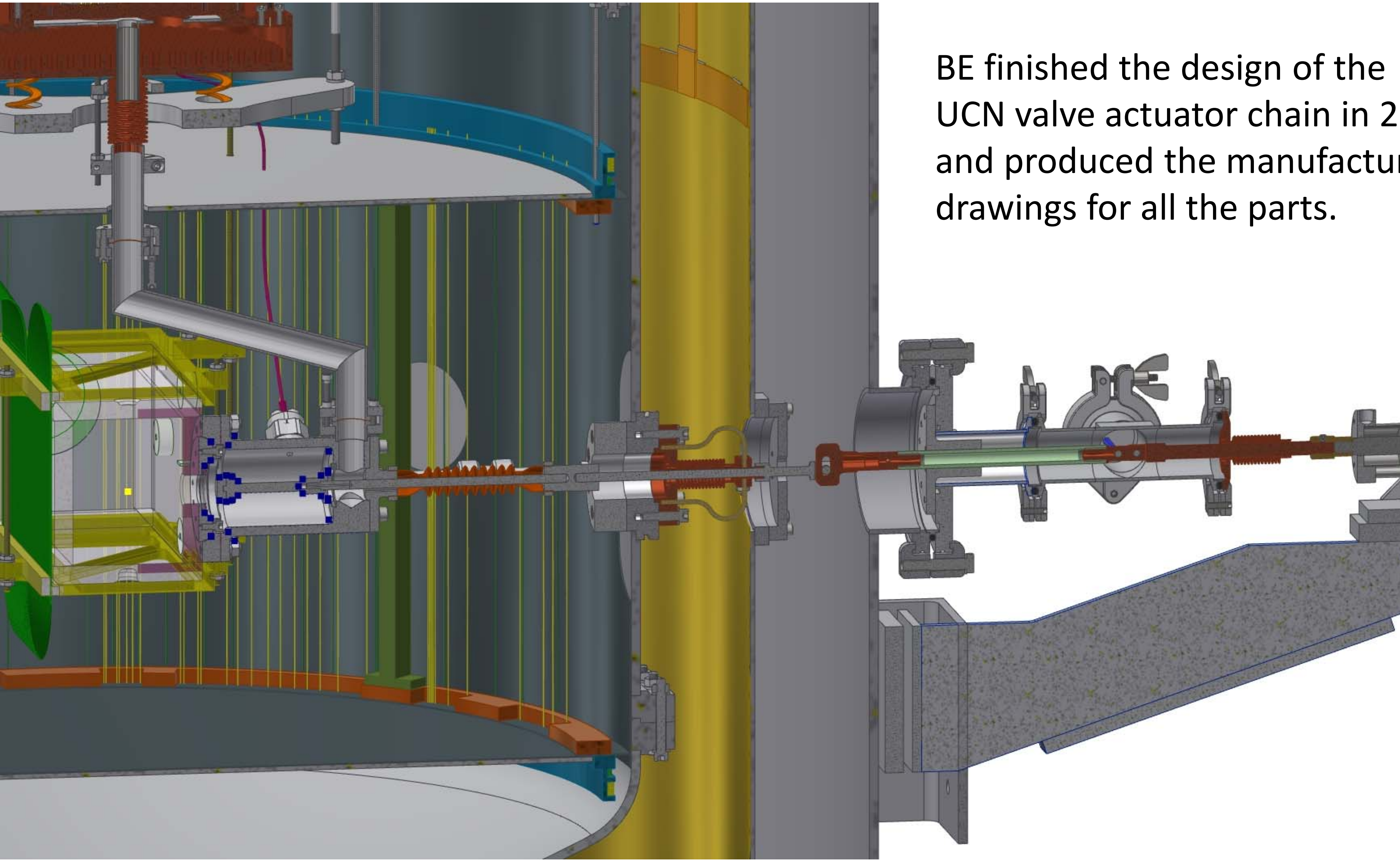
BE designed a simple and cheap trolley system to install the PULSTAR MEOP. The trolley greatly simplified the installation process.

MEOP Lifting Mechanism Test

from Tom Rao's presentation at the 2/9/22 nEDM Collaboration meeting

- Mechanism needed to lift MEOP frame on top of cryostat
- MEOP trolley that will be used to lift the MEOP frame has been installed
- To test the frame the MEOP frame was lifted a few feet
- After the test, the wire ropes used to attach the frame to the trolley were removed
- The chain used to operate the lifting mechanism was also removed

UCN Valve actuator chain, PULSTAR, (part of nEDM,) 2020

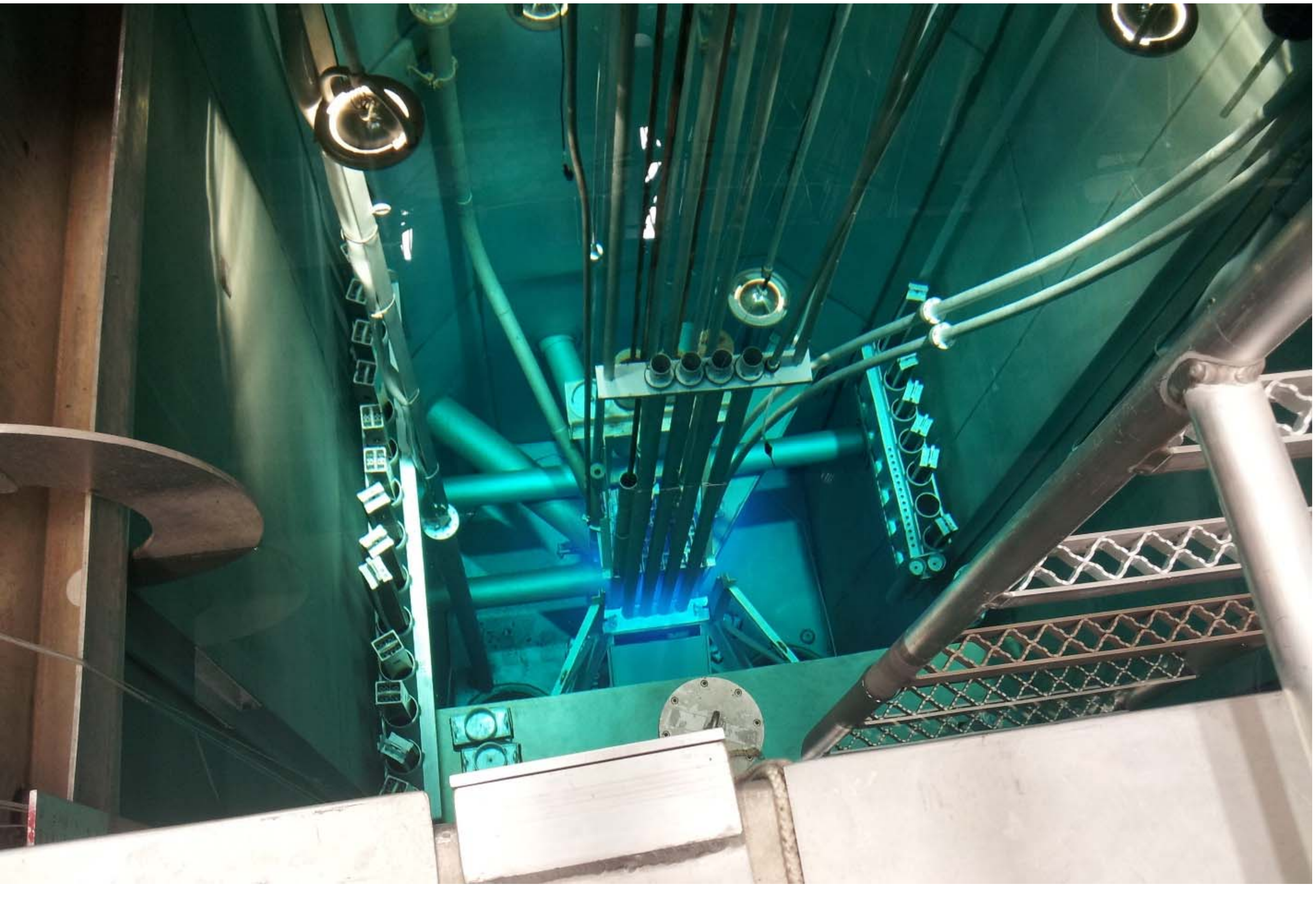


BE finished the design of the UCN valve actuator chain in 2020 and produced the manufacturing drawings for all the parts.

PULSTAR, (part of nEDM,) 2020 and beyond

https://nedm.ornl.gov/sos-pulstar/

•The main nEDM@SNS apparatus will take 2-3 months to cooldown and warm back up again.
•A number of development efforts (quality tests of production measurement cells, development of spin dressing operational techniques, and study/optimization of several systematic effects) require frequent thermal cycles.
•These efforts can be carried out much more expeditiously at a smaller satellite apparatus being constructed at the North Carolina State University PULSTAR reactor.



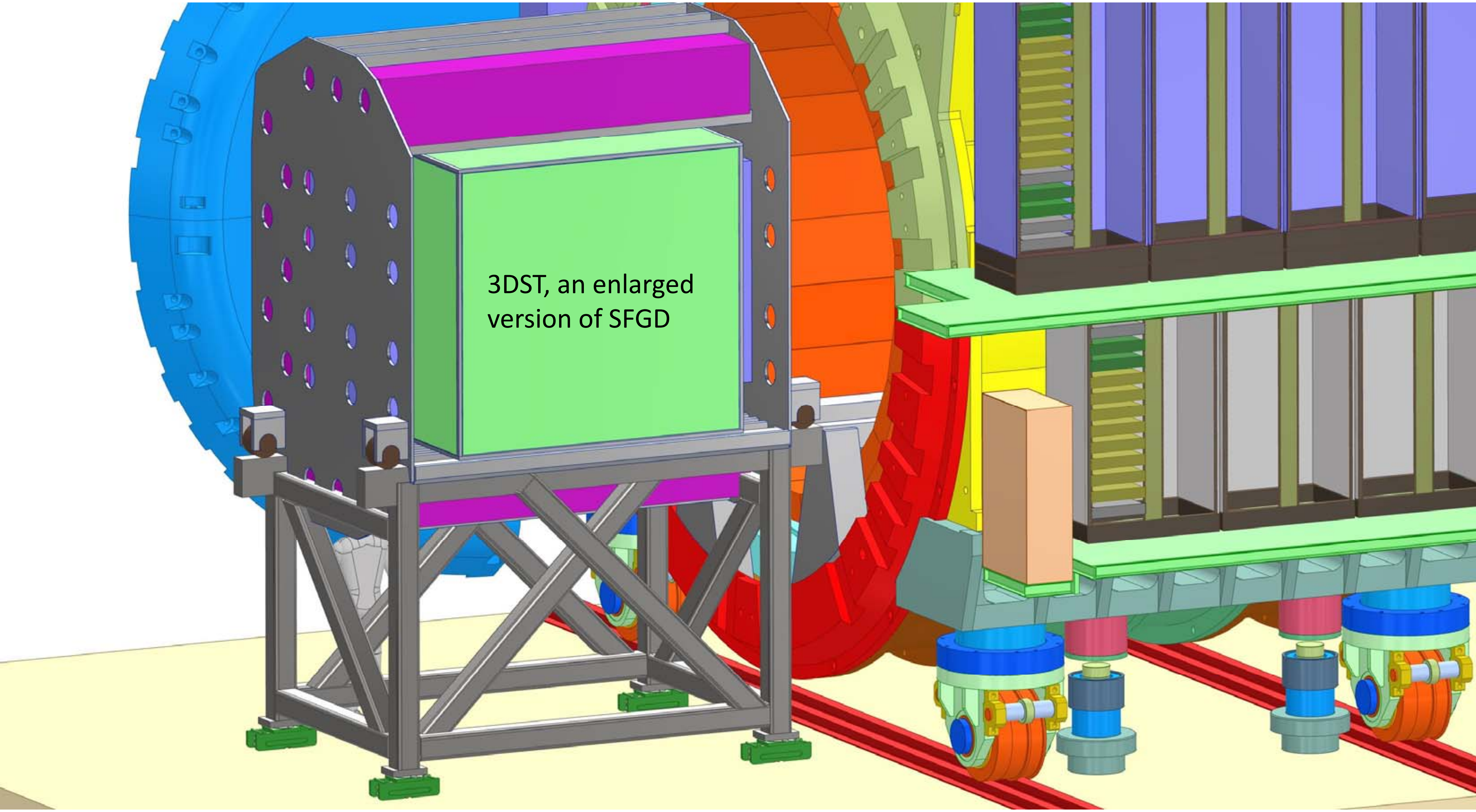
This is a look into the PULSTAR reactor at NCSU in Raleigh. This reactor will produce thermal neutrons that will be slowed down until some of them become ultracold neutrons. Those will be introduced into the PULSTAR cryostat shown on other slides for the studies needed to make the main nEDM apparatus work.

MIT SPARC fusion reactor, 2020

BE was hired by MIT to help develop the toroidal field magnets for the SPARC reactor (picture from https://www.psfc.mit.edu/sparc)

I can't post any pictures of the work BE did because it is covered by an NDA.

3DST+TPC detector inside KLOE, DUNE ND, 2021

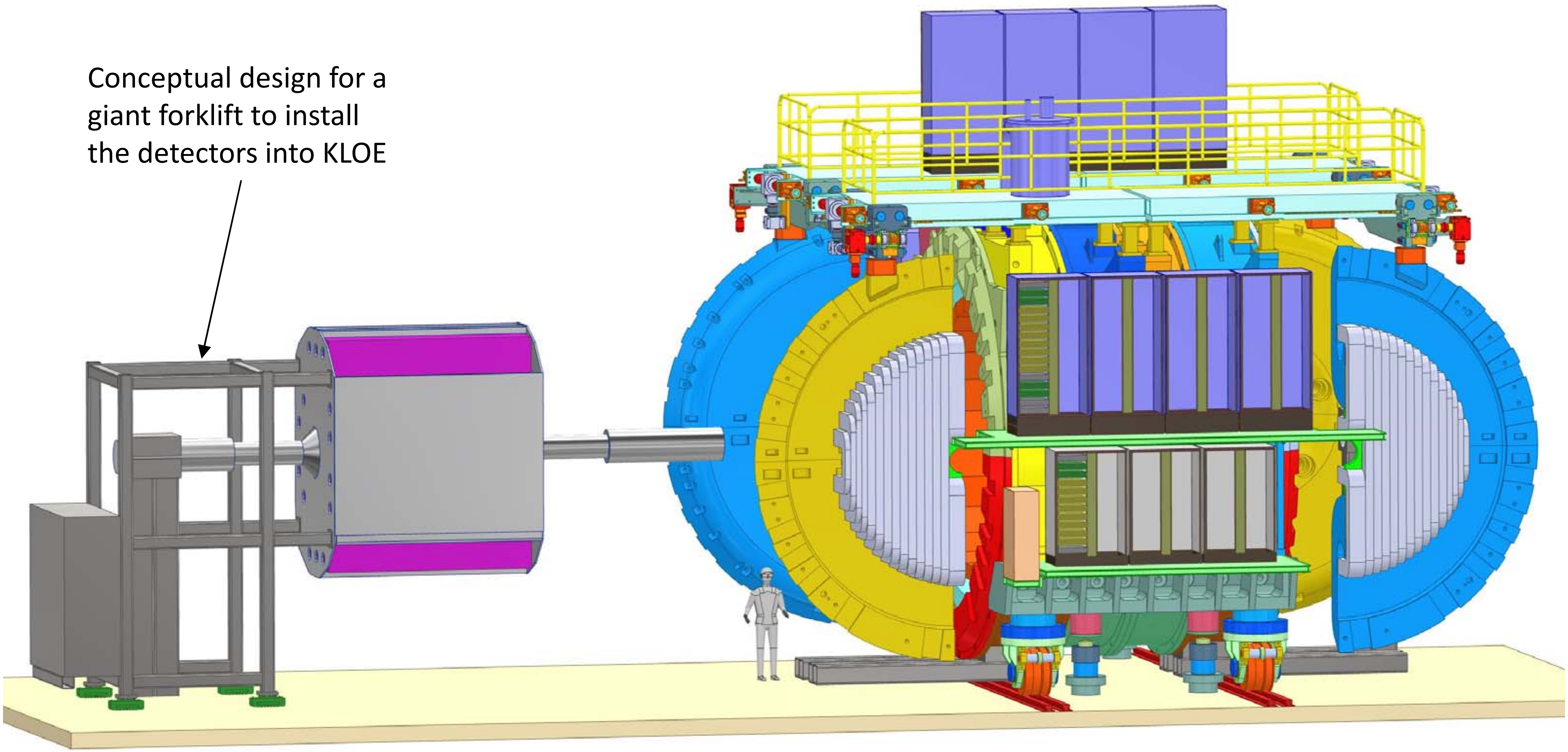


BE was hired to design a new support scheme for a new set of detectors as part of SAND, one of the detectors in the DUNE Near Detector Hall at FNAL

SAND repurposes the KLOE magnet

3DST+TPC detector inside KLOE, DUNE ND, 2021

Conceptual design for a
giant forklift to install
the detectors into KLOE

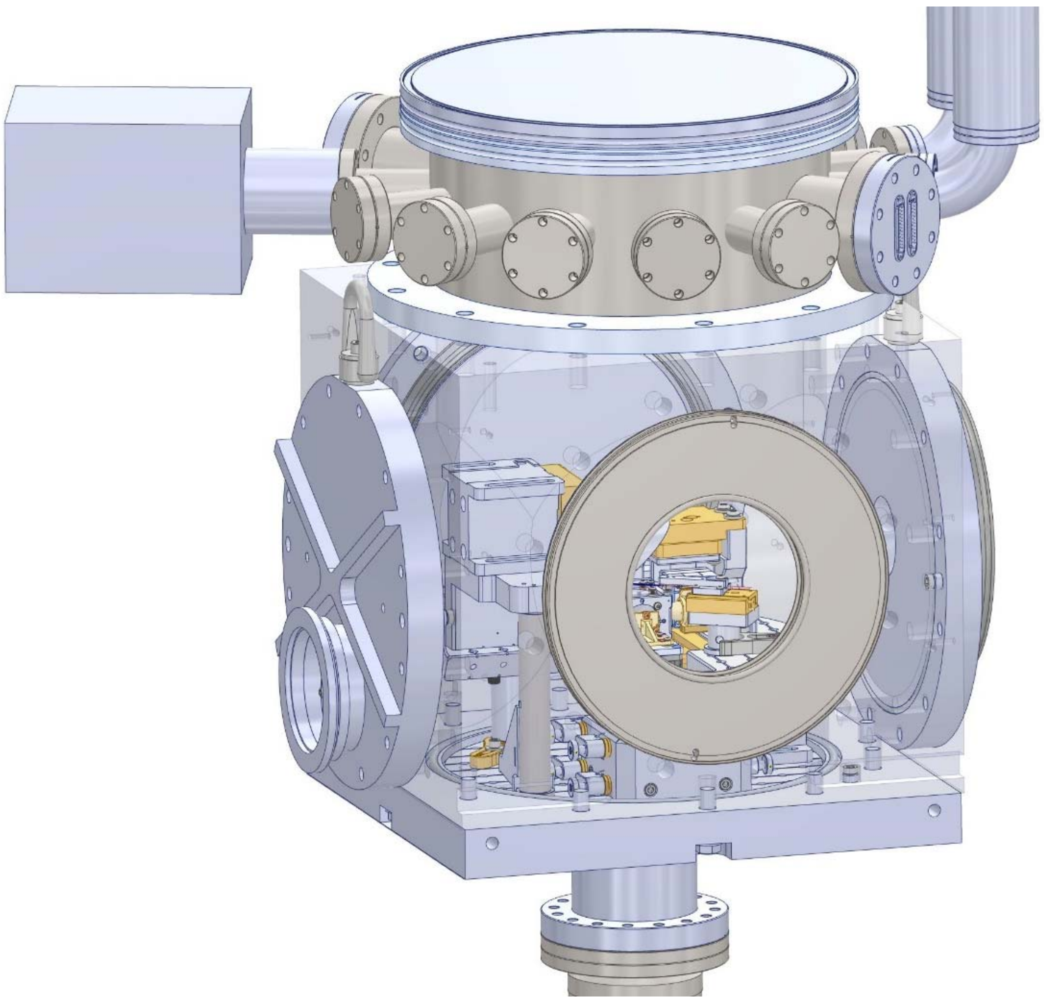


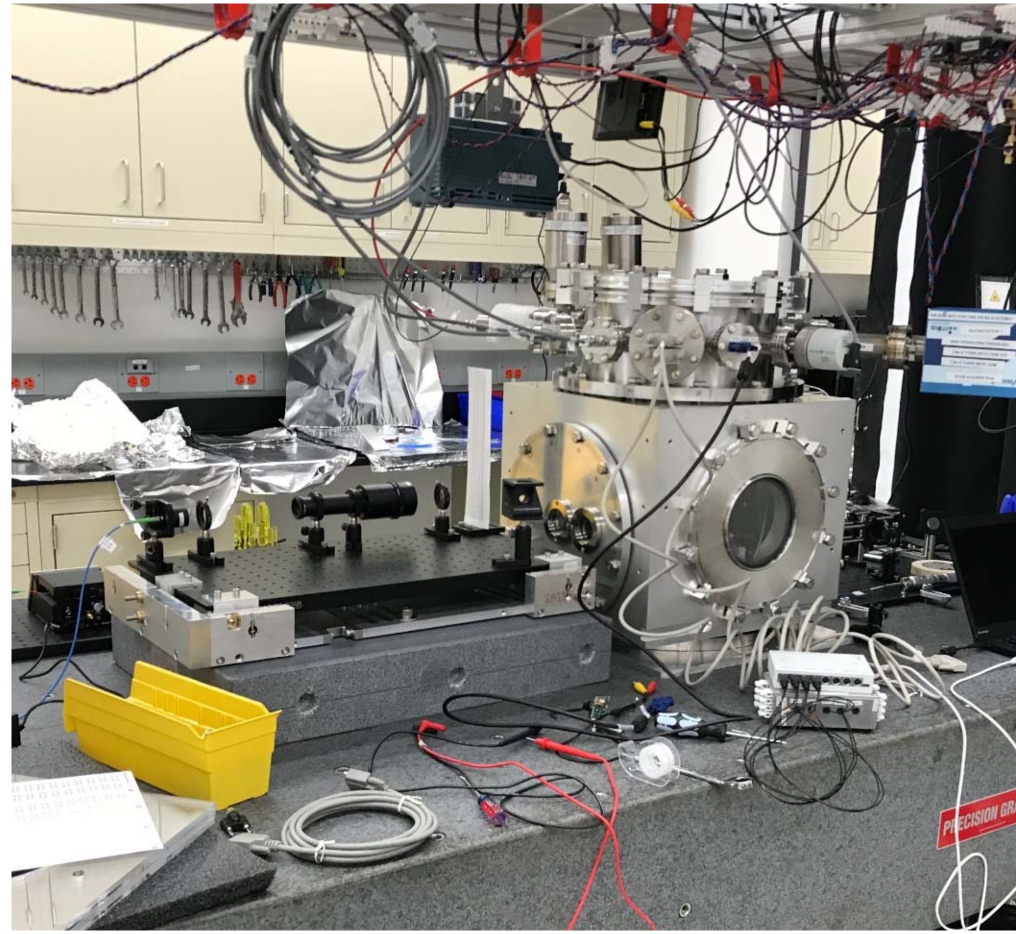
This is the second conceptual design produced for SAND@DUNE. This one is more problematic than the previous one. This work is in preparation for a design shootout in March, 2021. The alternative detector package we are competing against is a straw tube tracker by INFN.

3DST+TPC in SAND for DUNE ND

- 3DST is a larger version of the T2K SFGD
- https://indico.cern.ch/event/835190/contributions/3613904/attachments/1941278/3218893/KLOE3DST-NNN2019-Martinez.pdf
- A decision was made that 3DST will not be the chosen technology inside KLOE.

Gratta Gravity experiment, Stanford, 2021





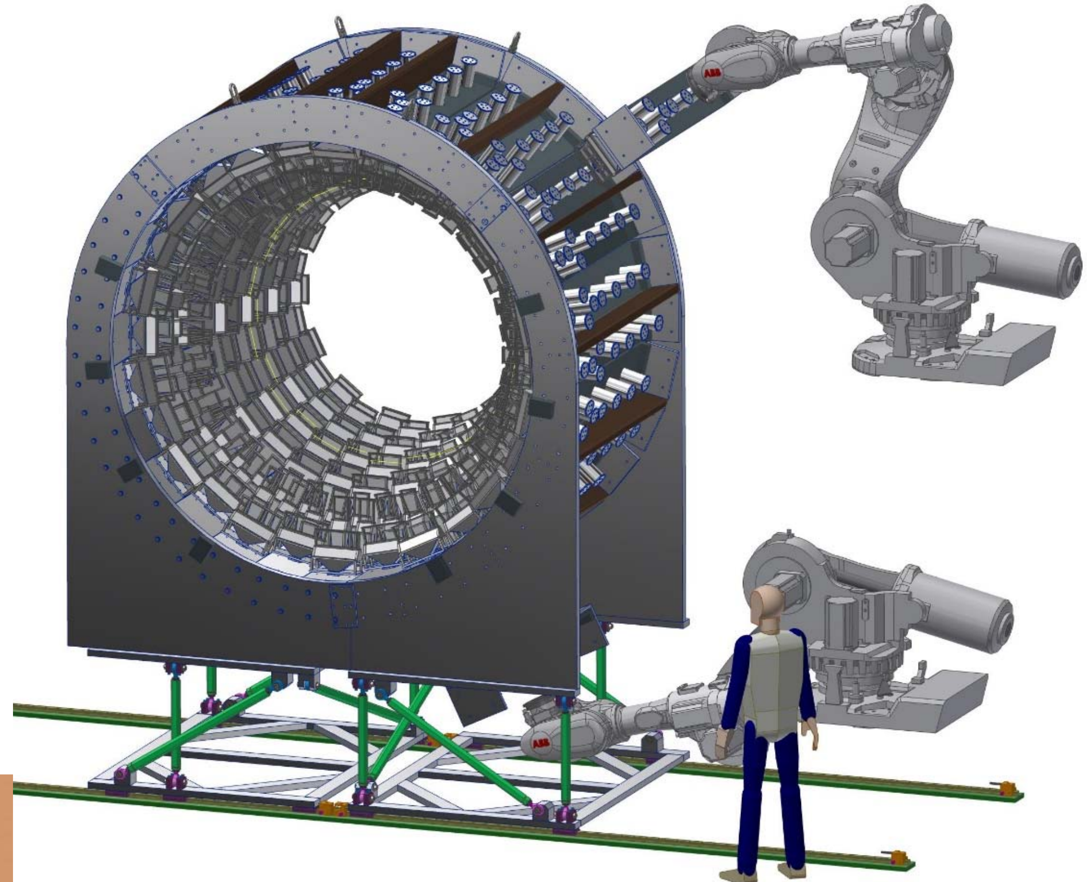
Giorgio Gratta's Gravity Experiment is looking for deviations from the $1/r^2$ law of gravity for very small objects like laser suspended microspheres.
BE helped with an upgrade to that experiment and produced new part drawings for several of the flanges.

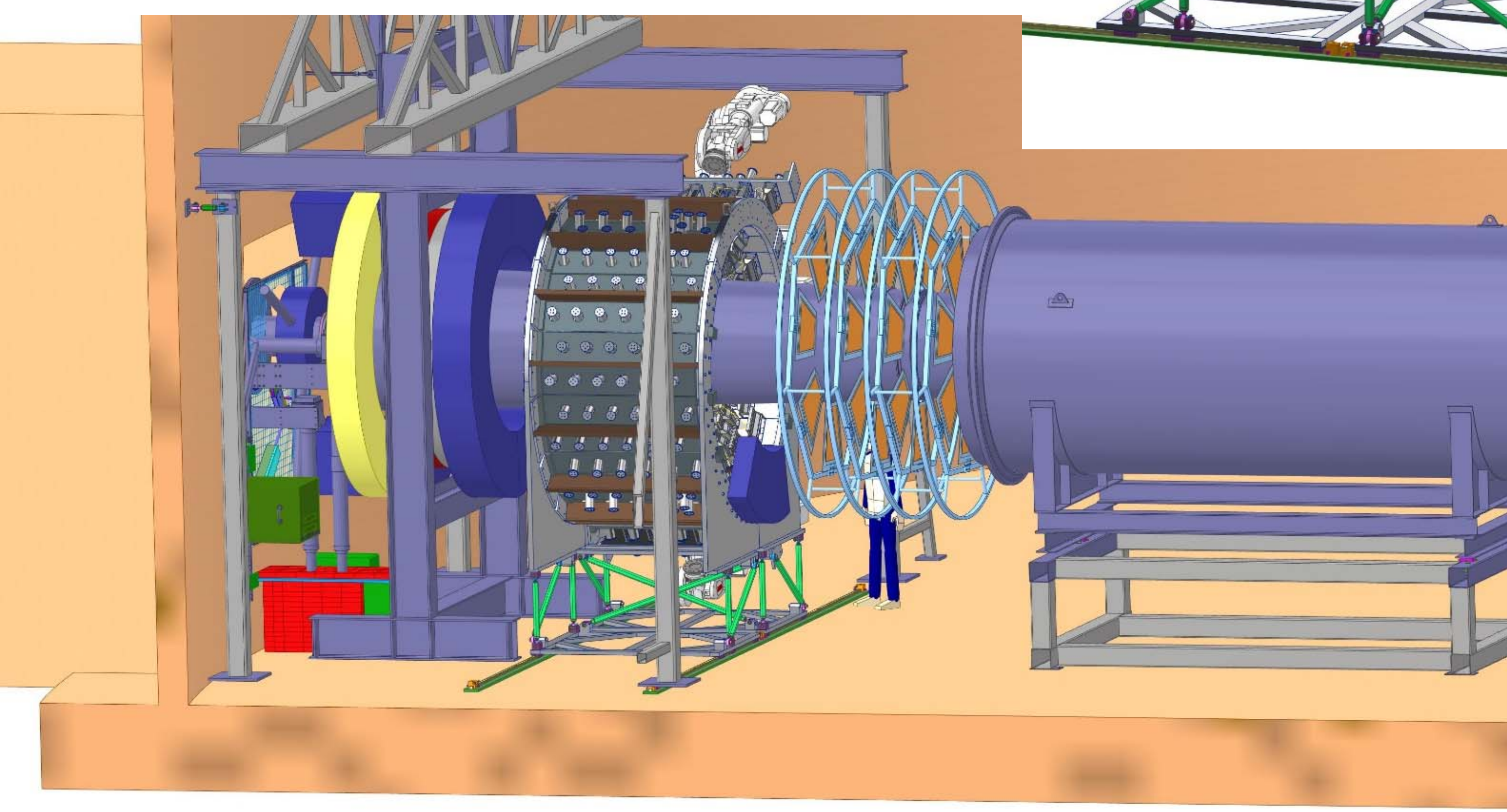
Testing gravity at micron scales

- http://grattalab3.stanford.edu/gravity/index.html
- “Theories that attempt to unify gravity with the Standard Model or to explain the nature of dark energy suggest that gravity may deviate from the Newtonian form $1/r^2$ at micron length scales. We use mesoscopic optomechanical systems to measure sub-attonewton forces at micron length scales to test these theories. Our current work uses optically levitated microspheres to measure gravitational interactions between masses separated by less then 20 microns. Optically levitated microspheres provide a powerful probe for short-range forces because they can be precisely controlled with optics and do not need to be mechanically coupled to the surrounding environment. We are also exploring the use of mesoscopic optomechanical force sensors to search for other new particles and interactions. Recently, we have used optically levitated microspheres to search for millicharged particles (charged particles with much less than an electron's charge) bound in the bulk of the microspheres. Mesoscopic optomechanical systems are an important tool for probing new physics that may be most easily observed at the length scales between subatomic and laboratory length scales.”

MOLLER Experiment at Jefferson Lab Hall A, 2021

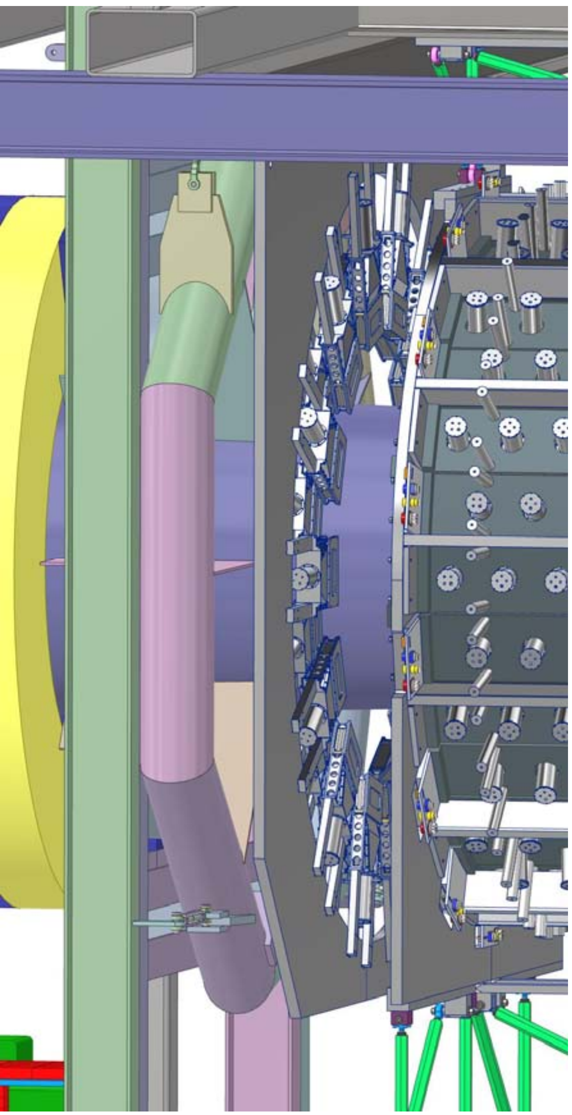
BE was hired to develop the conceptual design of the support structure for the quartz crystal detectors. We will eventually do the final design.

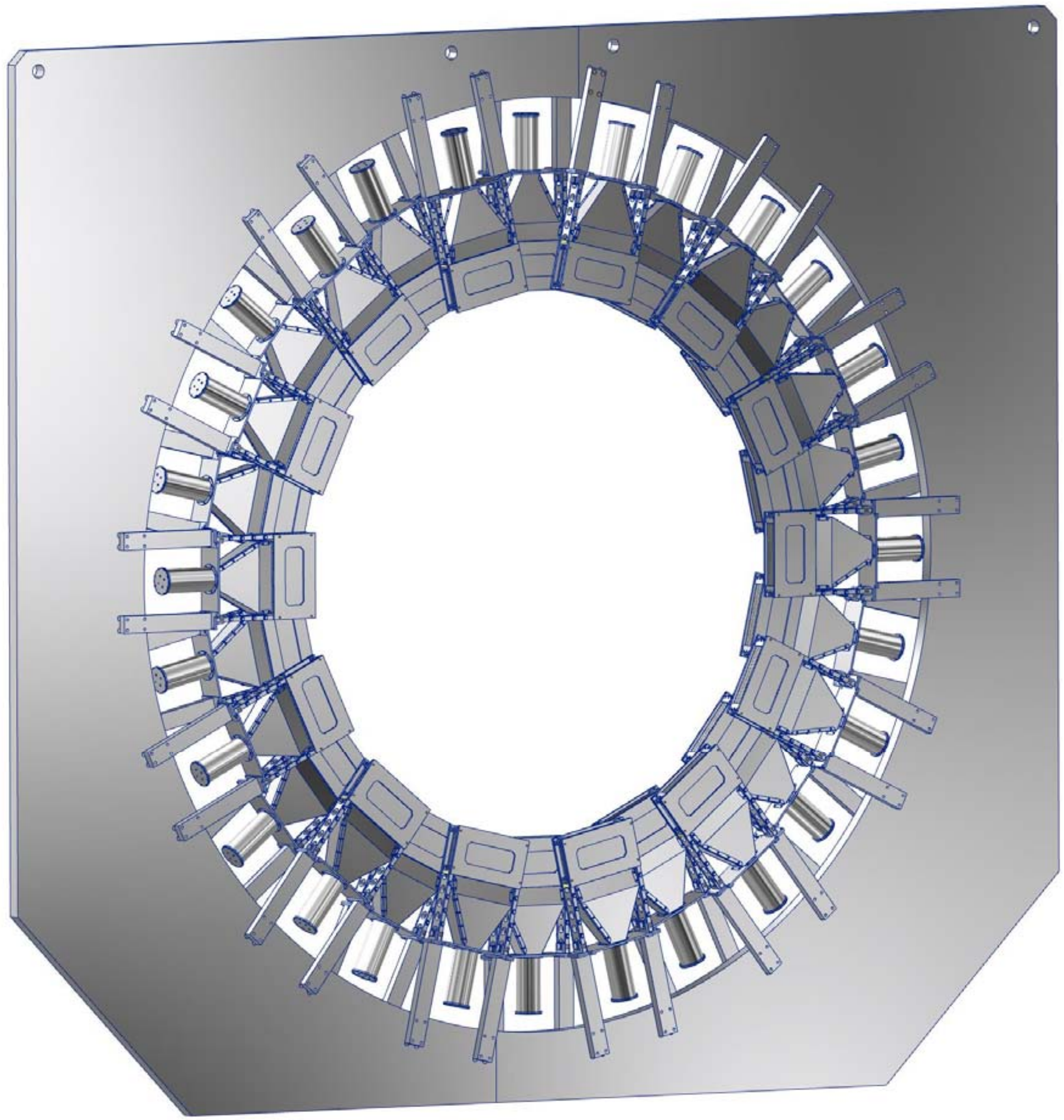




MOLLER Shower Max detector support, 2021

Shower Max in its location downstream of the main detector



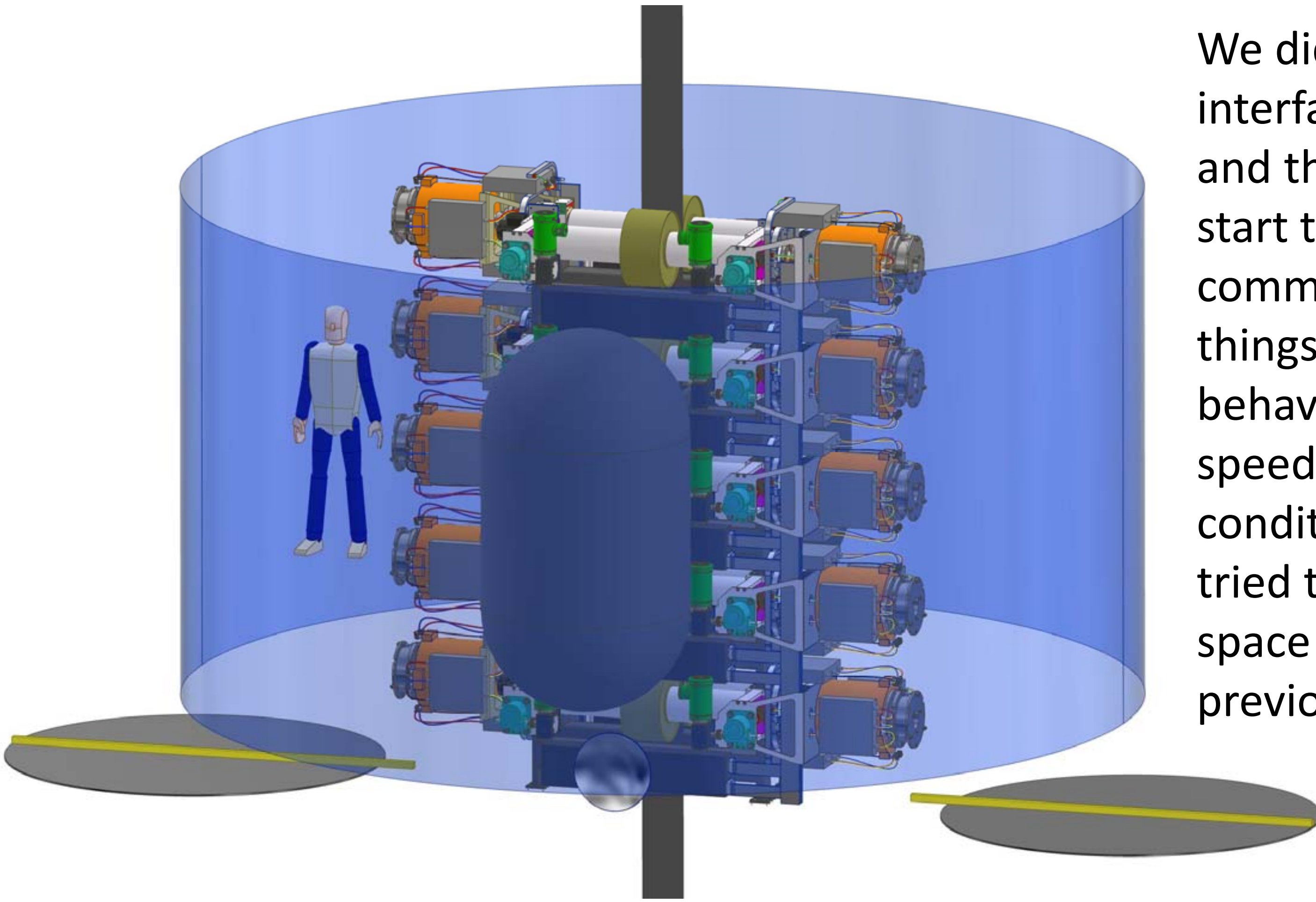


BE was tasked with making the preliminary design of the shower max support for the MOLLER experiment.

MOLLER experiment at JLab

- https://moller.jlab.org/moller_root/
- "The Measurement of a Lepton-Lepton Electroweak Reaction (MOLLER) experiment proposes to measure the parity-violating asymmetry in electron-electron (Møller) scattering. The measurement will be carried out at Jefferson Laboratory's state-of-the-art accelerator by rapidly flipping the longitudinal polarization of electrons that have been accelerated to 11 GeV and observing the resulting fractional difference in the probability of these electrons scattering off atomic electrons in a liquid hydrogen target. This asymmetry is proportional to the weak charge of the electron, which in turn is a function of the electroweak mixing angle, a fundamental parameter of the electroweak theory. The accuracy of the proposed measurement allows for a low energy determination of the mixing angle with precision on par with the two best measurements at electron-positron colliders."

Reference Conceptual Design of the First 20 tonne Commercial Climber of the Space Elevator, 2021



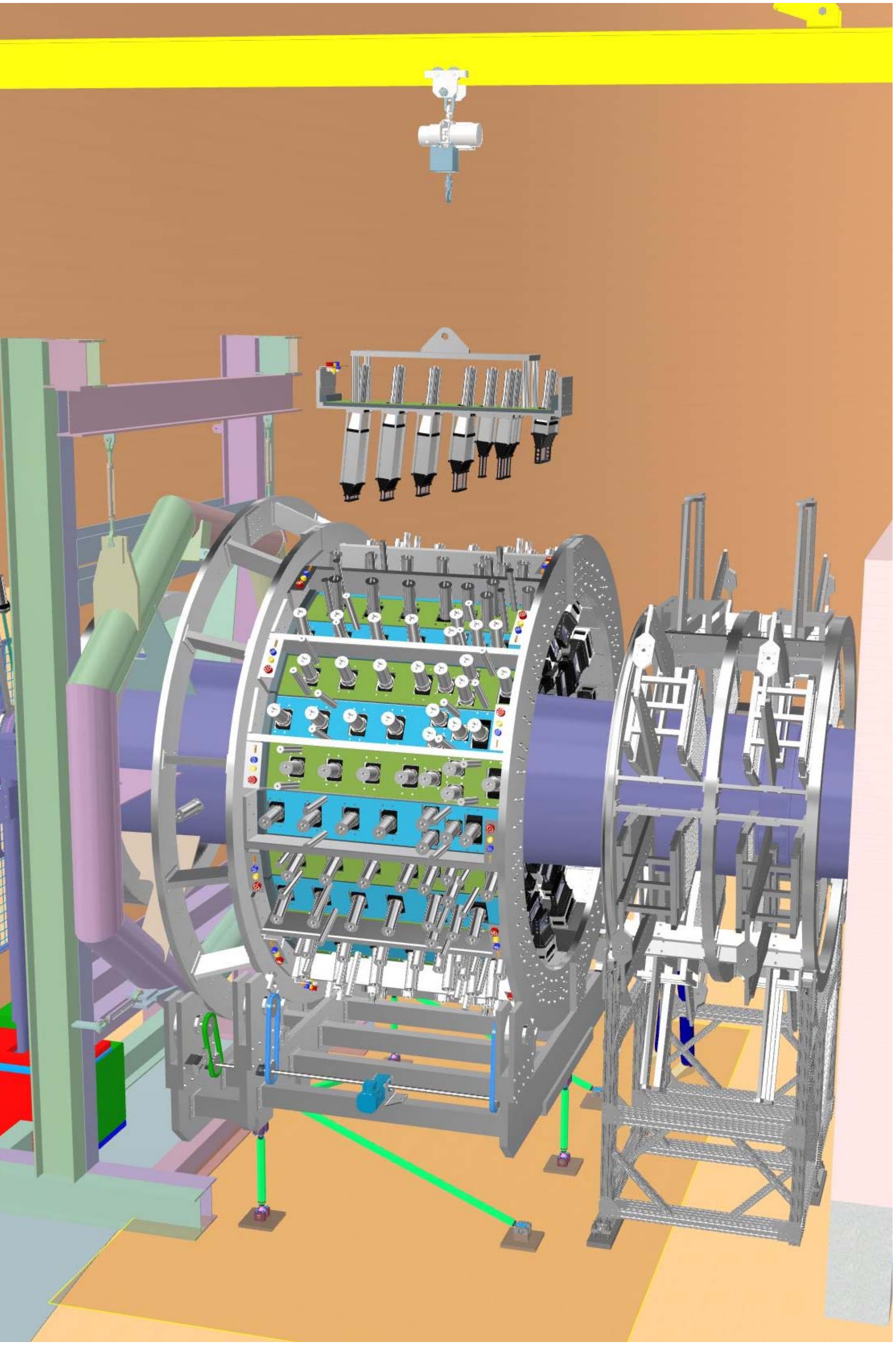
In 2021, I was elected as a Director on the Board of the International Space Elevator Consortium.

We did a two-year study of the interface between the climber and the tether, and I was able to start the conceptual design of the commercial climbers. Many new things were learned about the behavior of components at high speed, high load and space conditions. The primary thing we tried to learn was whether the space elevator was as scalable as previously claimed.

Sizing the Beams to support helium tanks at UIUC, 2022

BE was tasked with sizing the wide flange beams to allow stacking of one set of helium tanks on another of different length.

The key with any beam sizing is to check the requirements of the AISC Handbook of Steel Construction. The allowed unbraced length of these beams had to be larger than the spacing between the supports. BE found a more economical beam size than was originally specified by others.



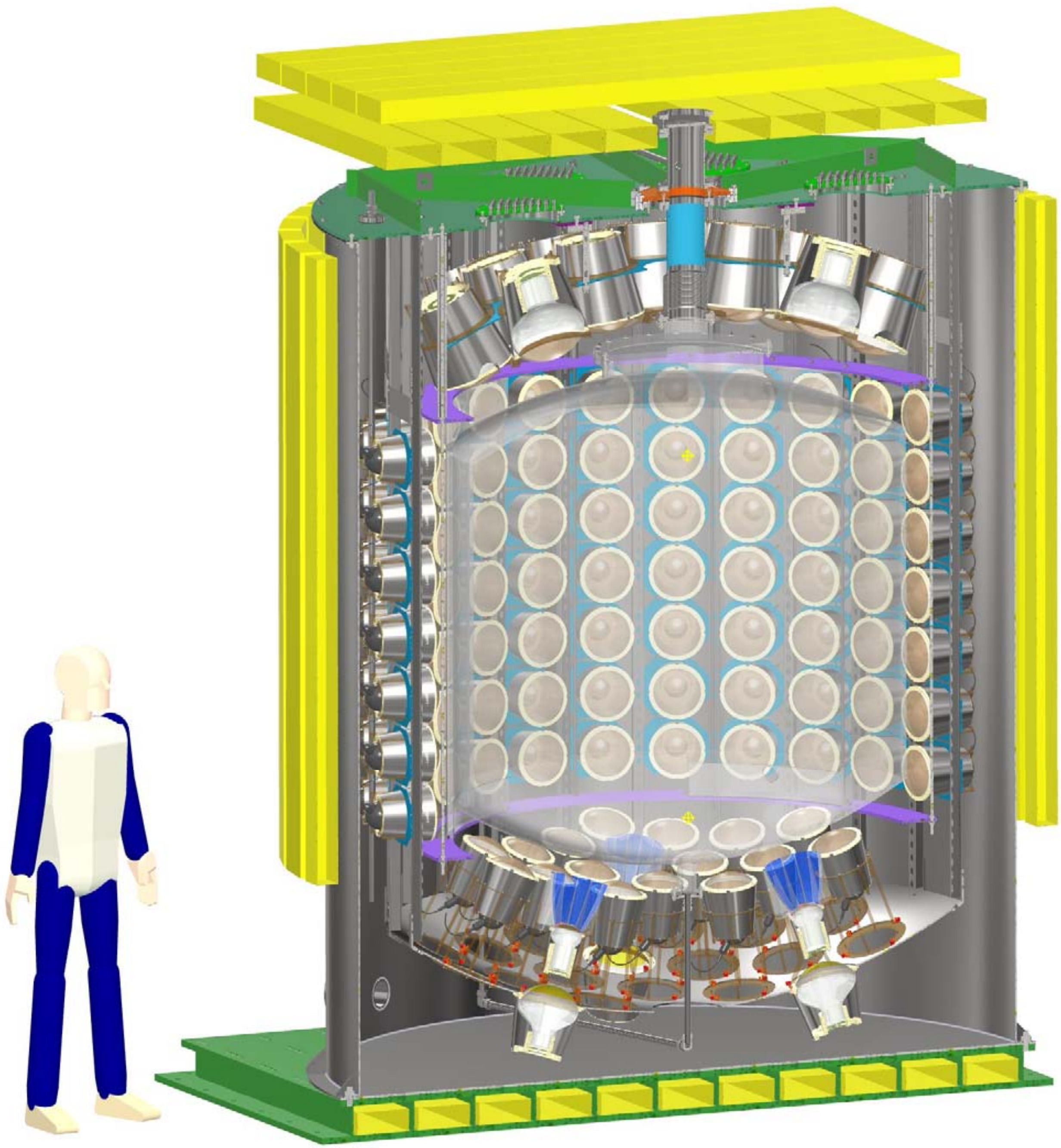
Redesign of the MOLLER Experiment at Jefferson Lab Hall A, 2022

The original design involving robots to install the segments in the main detector was rejected on safety and complexity grounds and the support structure was redesigned for a much more traditional installation technique reminiscent of E760.

The Shower Max detector was integrated into the same support structure as the main detector.

BE also consulted on the support structure for the GEMS detector immediately US of the main detector.

Eos Demonstrator Project, LBL, 2022

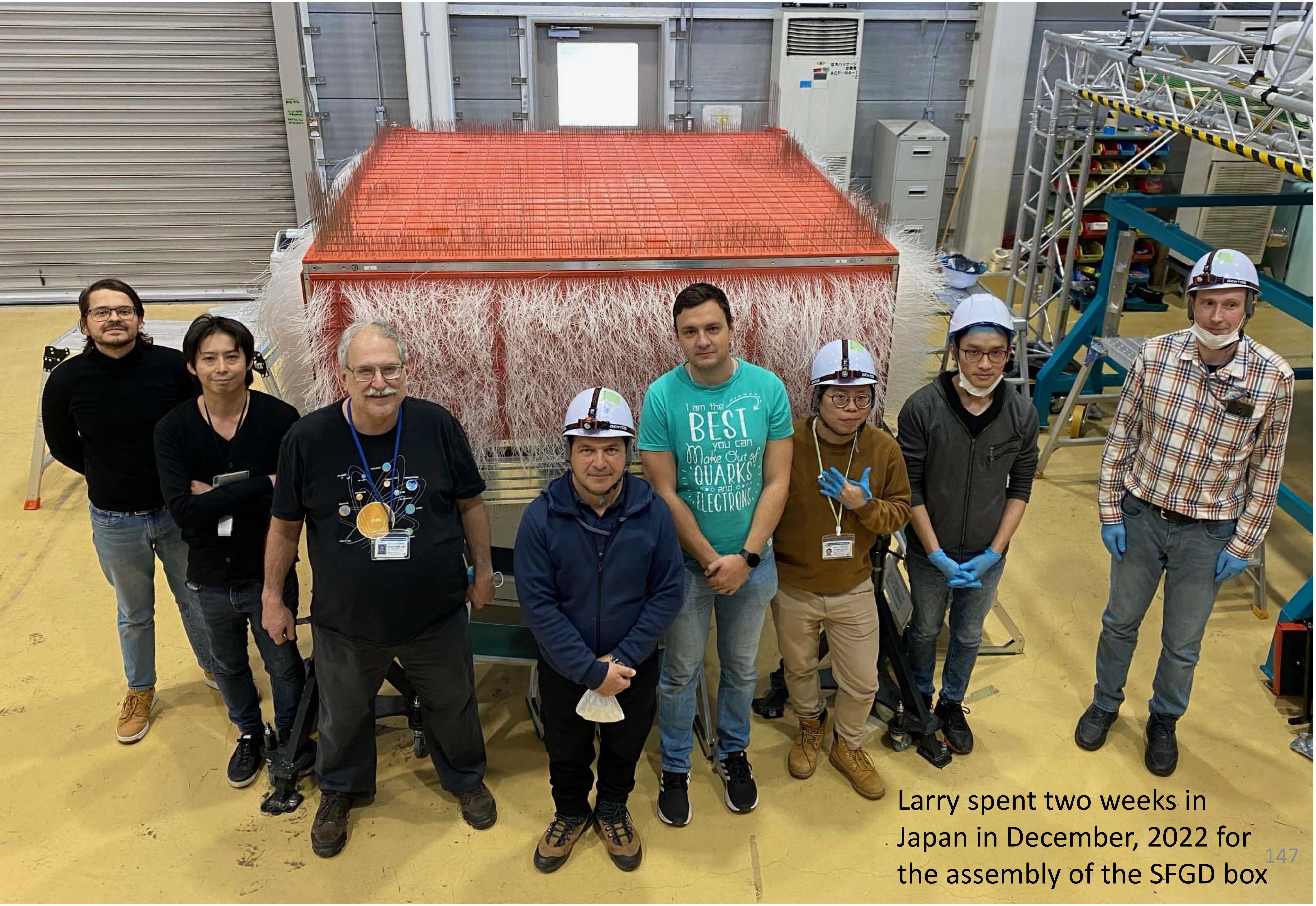


Eos is a new neutrino detector using water-based scintillator and dichroicon light sensors. It is a demonstrator project for the much larger Theia experiment.

BE was hired to do the calibration system originally, but was switched to design of the outer water tank (taking into account the seismic requirements at Berkeley,) and the photomultiplier support structure.

BE will also design some assembly fixtures.

Final Assembly of the SFGD Box at J-PARC, 12/22



Larry spent two weeks in Japan in December, 2022 for the assembly of the SFGD box