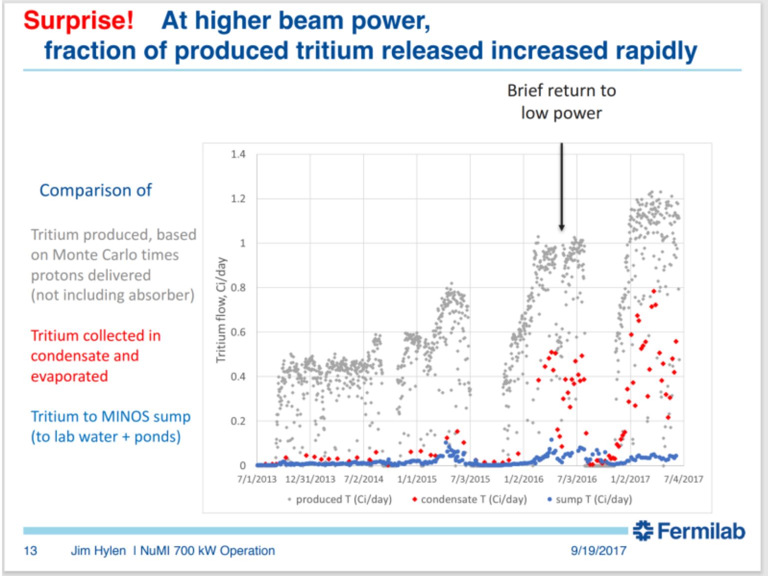
# TSD Slam
# May 2024

# MARS Group

# Tritium production & release
## Dali Georgobiani

## Problem:




Jim Hylen: must be due to temperature increase!
– and he is right.

Work-in-progress...

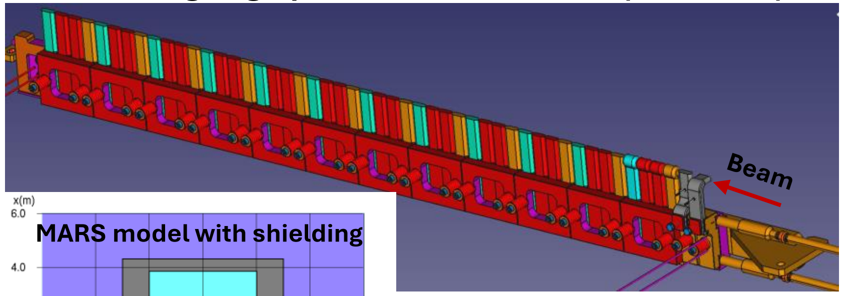
## Solution:

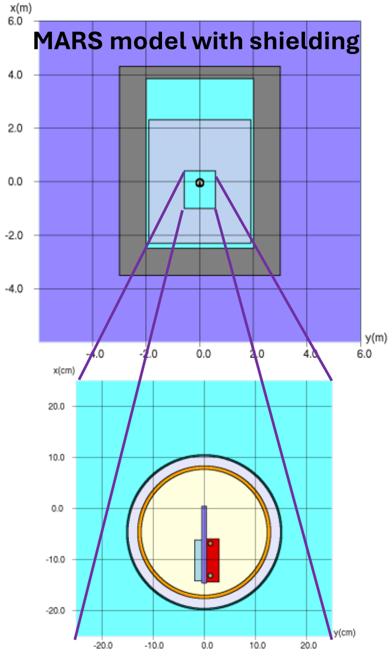
### 1. Tritium production

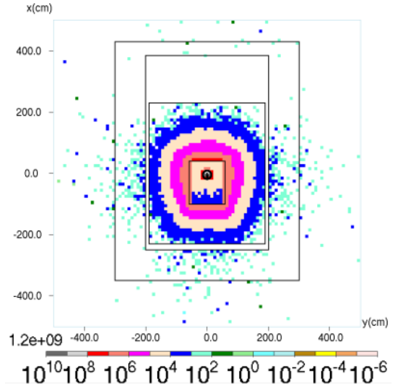
Starting with NuMI target...

- Simple model for 3H production estimate
- Using 3 major Monte-Carlo rad codes: FLUKA (Alajos), MARS (Dali), PHITS (Tom Ginter, FRIB)
- Input: 120 GeV/c protons, 1.1 MW (ideally), effective intensity 5.25e13 pps
- Output: 3H production rates, activation (1y beam on; instant and 1y beam off)

NuMI target: graphite fins in aluminum (ME model)




3H production rate (3H/cm2/s)

| Region | Activity, Ci (1y beam on) | | | Ratio | |
|---|---|---|---|---|---|
| | MARS | FLUKA | PHITS | M/F | M/P |
| Graphite Target | 64.0 | 41.6 | 78.4 | 1.5 | 0.8 |
| Steel shielding | 231 | 383 | 517 | 0.6 | 0.4 |
| Concrete | 0.08 | 0.06 | 0.2 | 1.2 | 0.4 |

***But... not all produced tritium is released instantaneously!***

### 2. Tritium release

In reality, tritium is released from different materials on different diffusion lengths & timescales; diffusion coefficients are strongly temperature-dependent.

Example: for graphite, diffusion coefficients are D=8.0e-35 cm2/s at 50C, and D=1.2e-11cm2/s at 1000C.

We use activation equation to estimate tritium diffusion from the materials in the model.

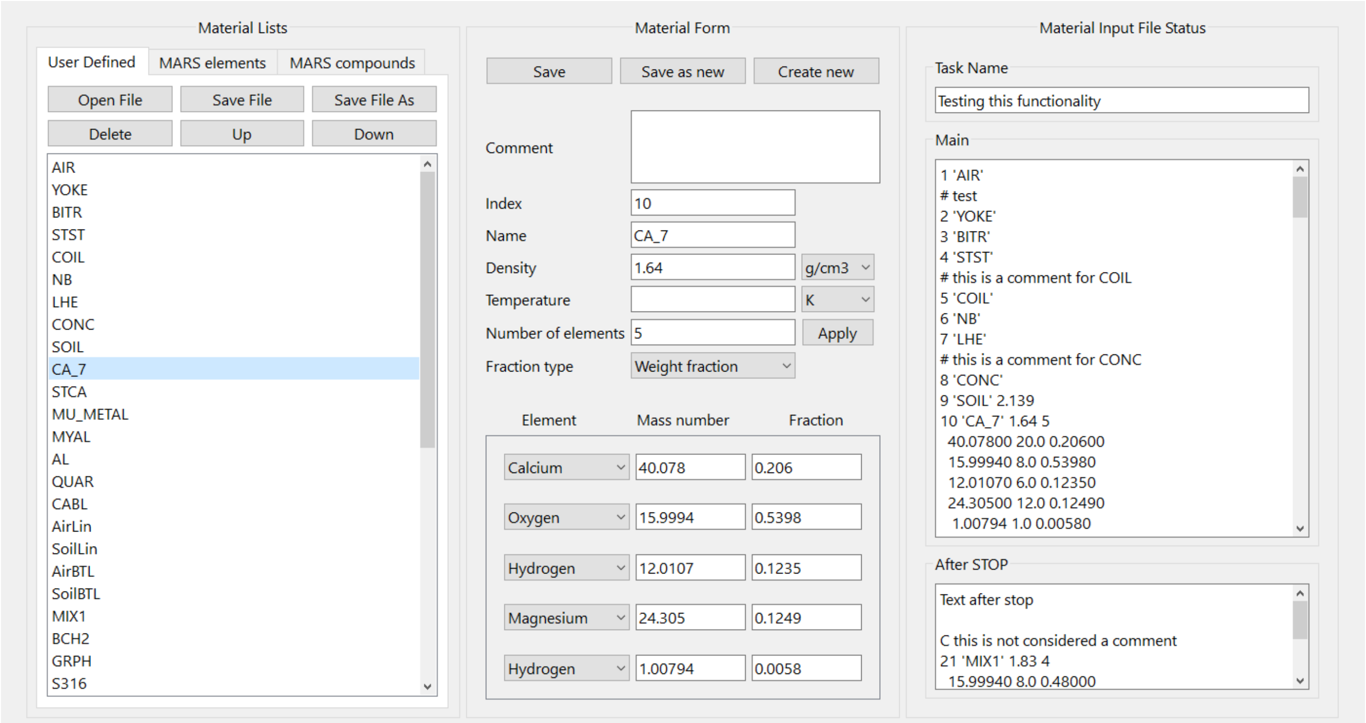
The results will offer a more detailed explanation for the unexpected jump in tritium production with the NuMI beam power increase and will allow us to make predictions on the future tritium releases at Fermilab facilities.

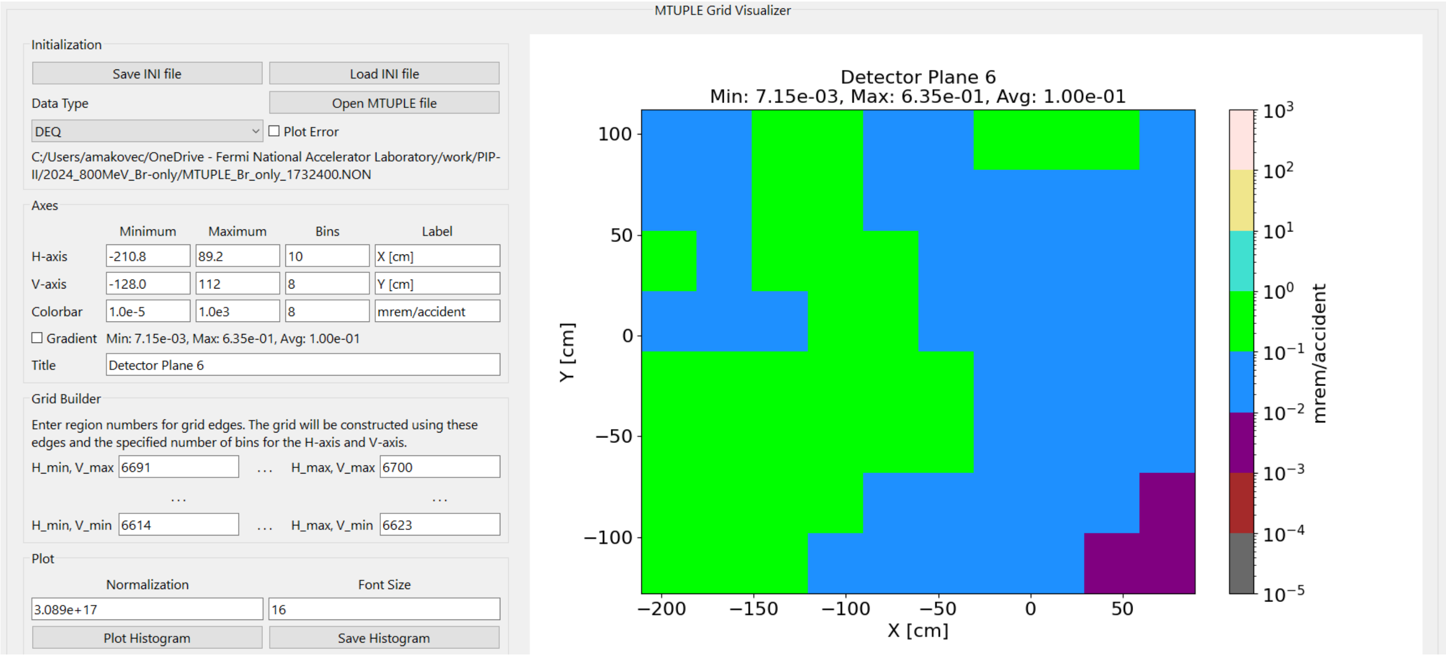
The results will be presented at SATIF-16 workshop (May 28-31, 2024) – we will share the progress and updates afterwards!

# Ongoing development of a new, more user-friendly Graphical User Interface (GUI) for MARS


## Alajos Makovec

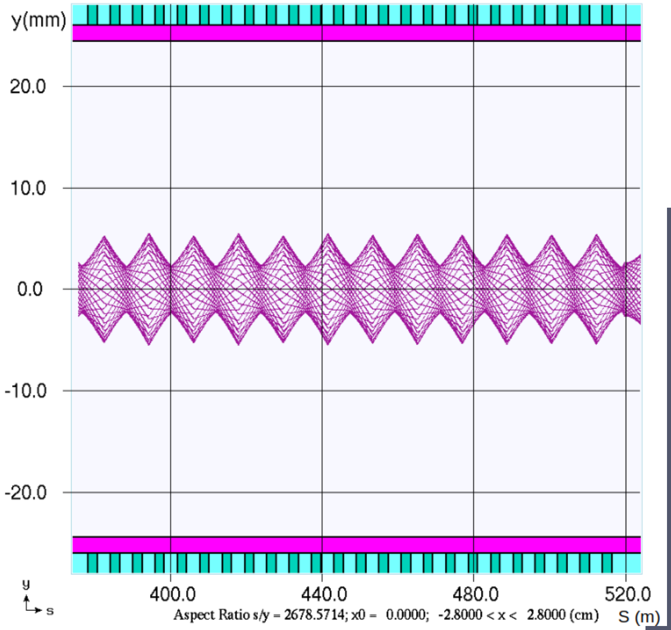

- The Main Window was created to facilitate switching among different features.
- The first fully realized feature is the Material Window, which allows users to:
    - Browse predefined MARS elements and compounds.
    - Clone or copy these into the current material input.
    - Import and export material input files.
    - GUI features include visualization and editing of compounds, with conversions between mass and atomic ratios, and temperature conversions between Kelvin and Celsius.
- Additional tools developed:
    - MTUPLE Grid Visualizer: A tool for visualizing detector plane scoring results from MTUPLE simulation output files.
    - Particle Distribution Analyzer (PDA): For visualizing particle distributions from source files.
    - Energy Spectra Analyzer (ESpA): For visualizing energy spectra from various sources.
- Demonstrated features, to be added:
    - Fast (real-time) 2D visualization of geometry for interactive cross-sectional views.



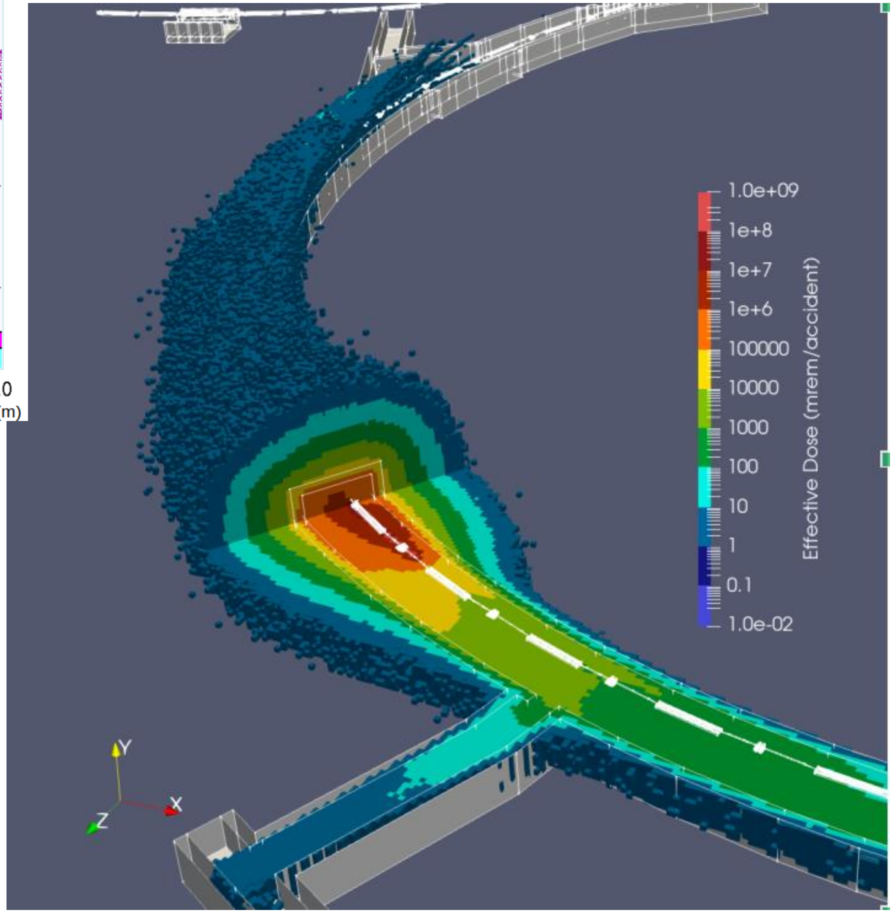



# MARS support
# Igor Tropin, Igor Rakhno

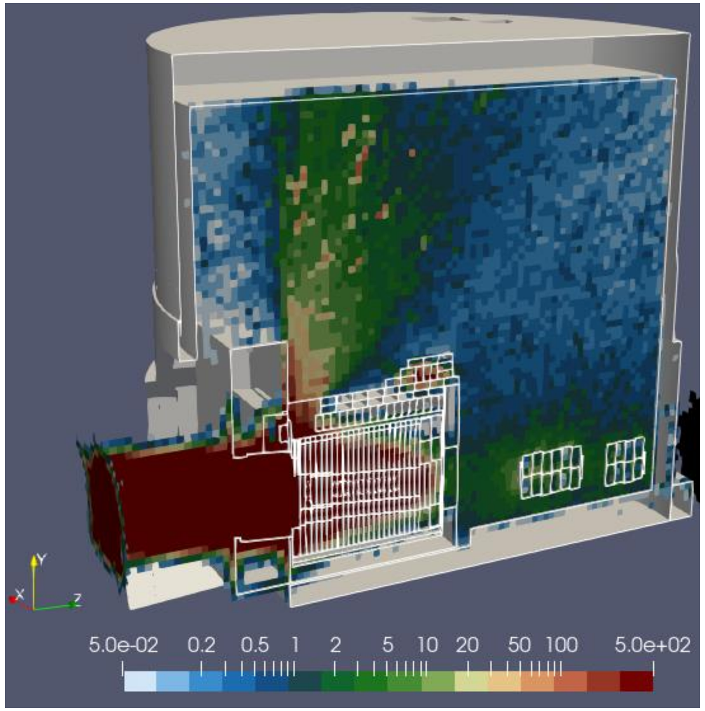
- Replacing obsolete dependencies (CERNLIB → ROOT/VTK)
- Adoption to HPC/HTC environments
- Introducing new features according to needs of various projects.
- Improvement and verification of physics models.



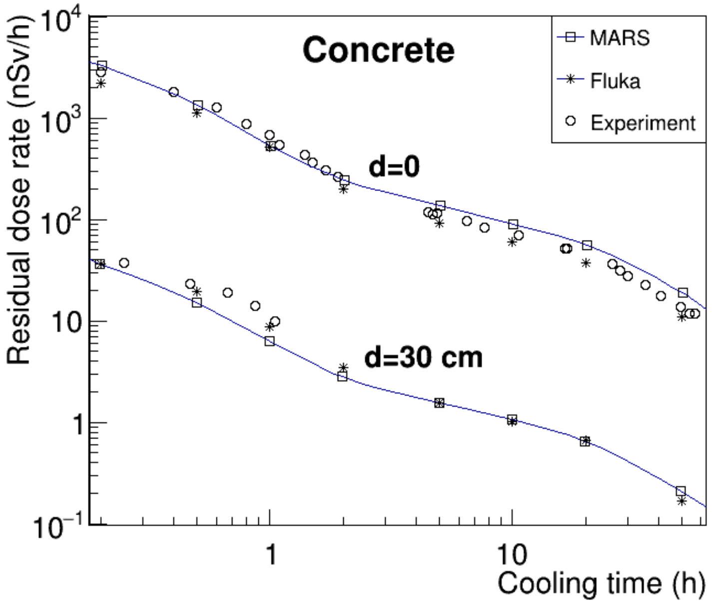

3σ Beam Envelope in PIP2 BTL Arc2




Effective dose induced by beam accident in PIPII BTL analyzed in ParaView toolkit




Residual dose (200d/1d) in LBNF Absorber Building

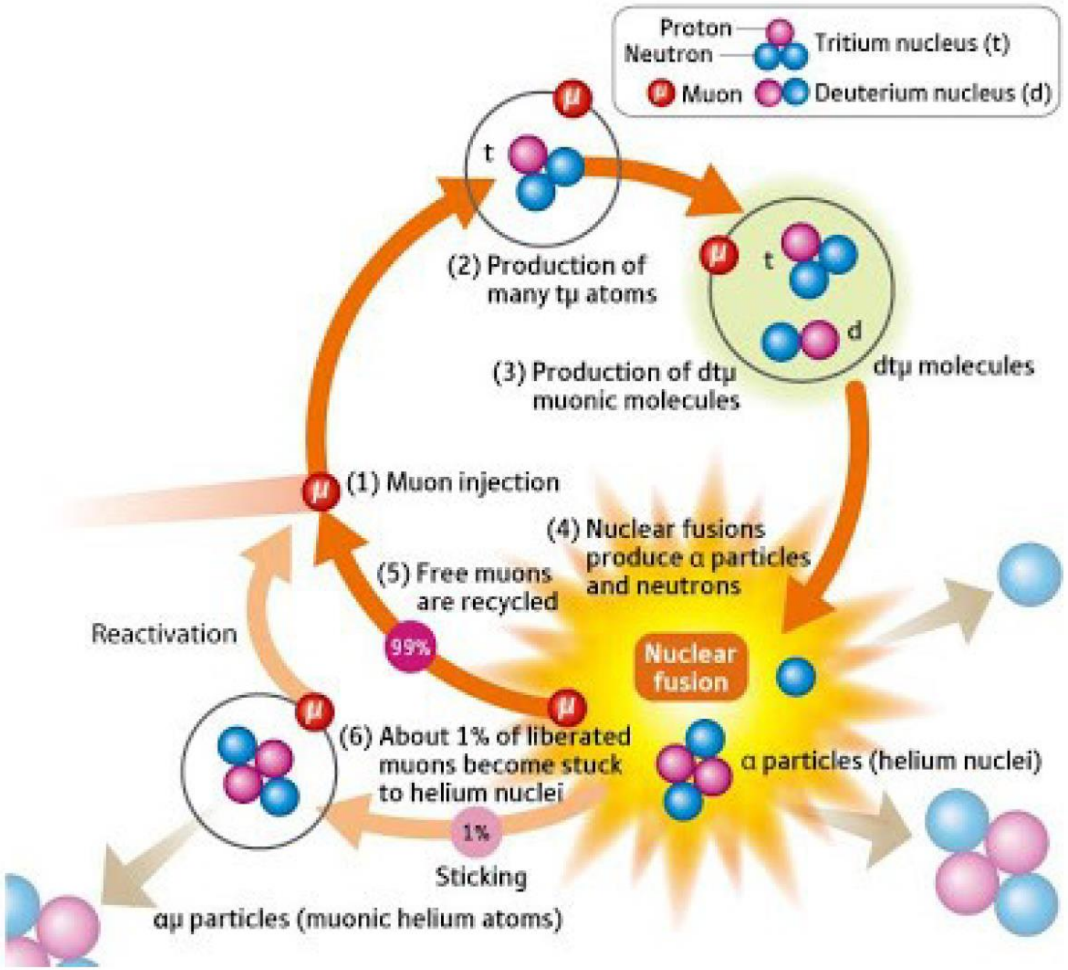


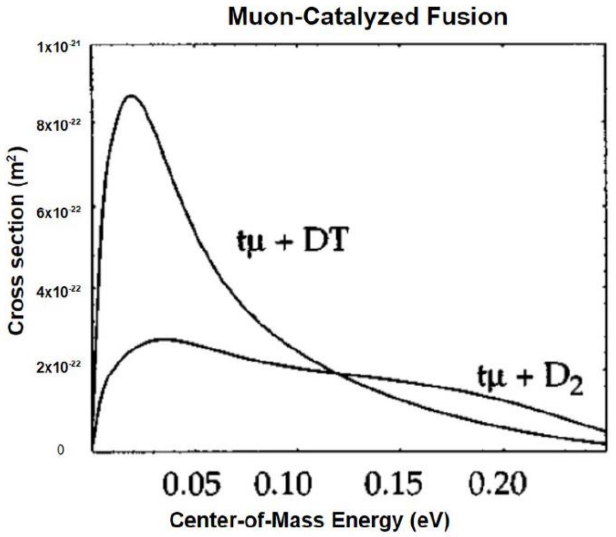

On validation estimators for residual dose – comparison with SINBAD benchmark data

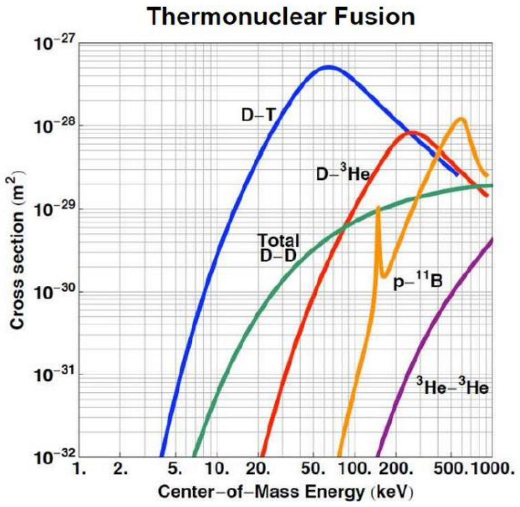
# TSD: Top dog

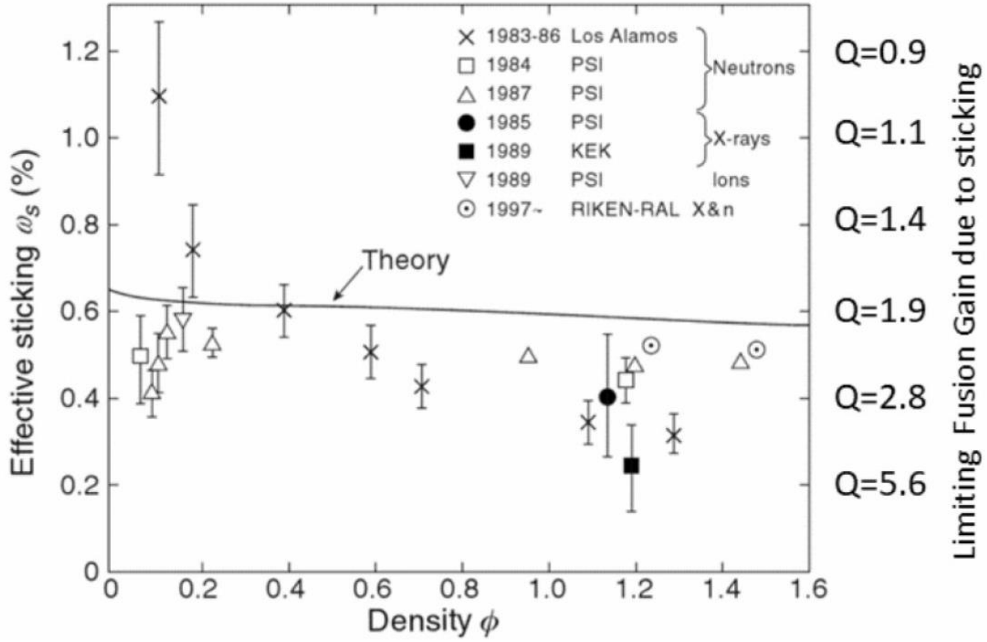
# Kevin Lynch – Non-Mu2e Muon Physics (G4, Muonium, muCF*)

## Muon Catalyzed Fusion



# Science group

## LBNF Neutrino Beam Instrumentation L4

- ***Goal: To achieve DUNE physics goals, constrain beam systematics → requires well controlled & stable beam***
- LBNF
  - Prototype Horn Location Sensor
  - Muon Beam Permit system
    - TDR, Publication

SUDESHNA

## NuMI/LBNF Simulations

- ***Goal:***
  - ***Immense need for radiation-hard real-time target health monitor***
  - ***ML application → new way of anomaly detection/monitoring***
  - ***Requires simulation***
- Neutrino beam simulations, e.g., new simulation technique, understanding beam behavior
- Neutrino/Muon beam timing → precision timing in beam delivery, pico-second detectors etc.
  - All these work → Proposal writing, Conference talks/lectures, Publication

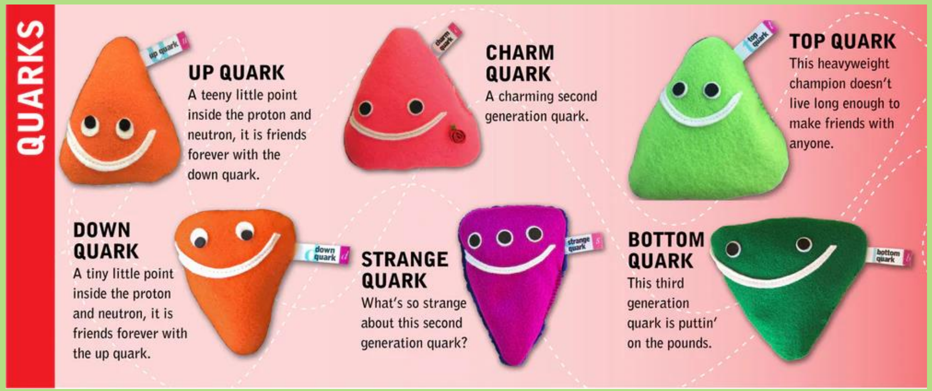
## Miscellaneous

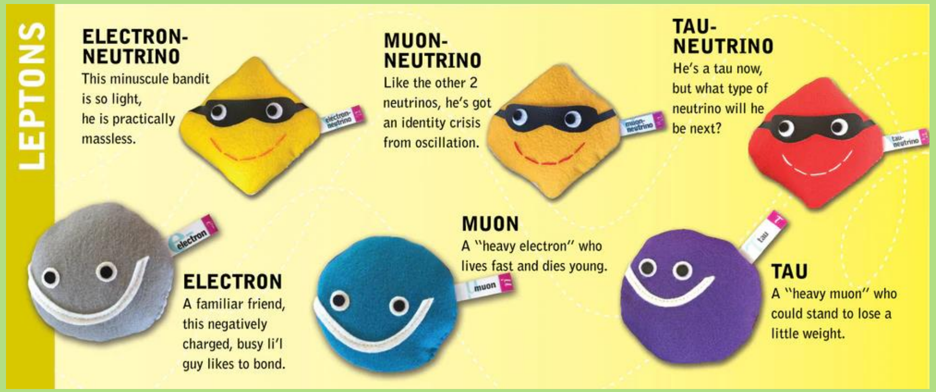
- ***Goal: Grow as a person***
  - EDIA work: FAPA LRG leader, EDIT task force member, Broader Engagement task force member
  - Like giving outreach talks/tours to members of community, both within US & outside
  - Current SAC member
  - Assistant to Kevin
  - Started TSD Early Career Group (ECG)
  - SPIN 2023 cohort alumnus
  - Served as one of 2 run-cos in 2022

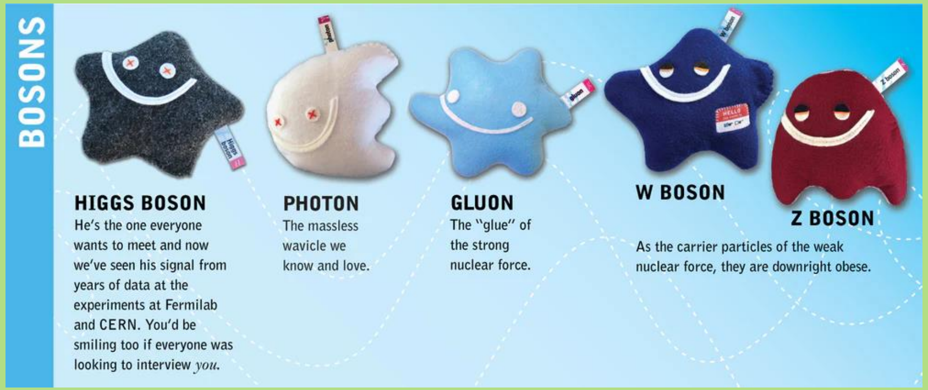
**Katsuya**

Standard model

# Hunting weird particles





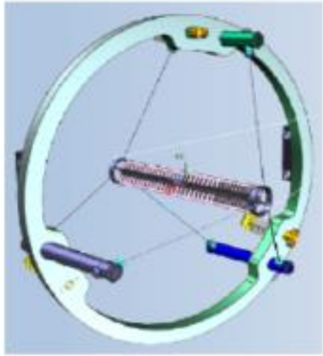

X particles
(just example)



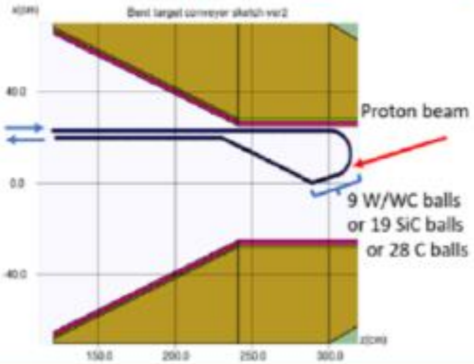
My missions are…

- produce weird particles
- detect them

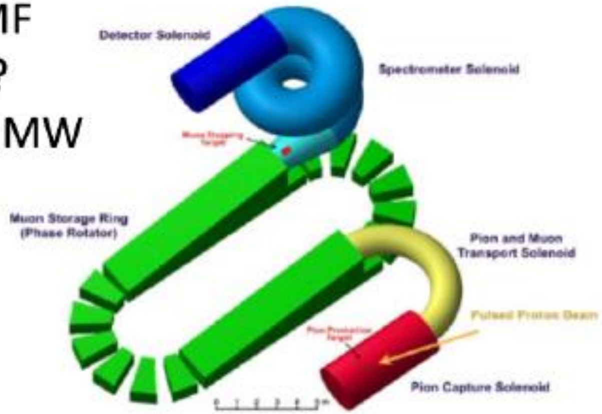
Mu2e
Tungsten, 6.3 mm x 220 mm
8 kW beam in 4.5 T



Mu2e-II
R = 1 cm W/WC spheres
100 kW




AMF
???
~1 MW

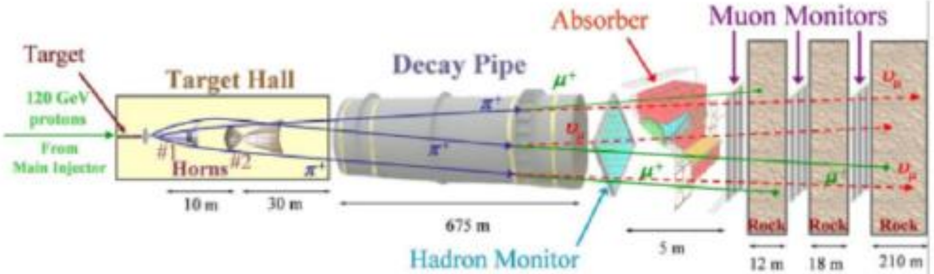



Compact, high-power targets and accompanying beam-intercept devices inside extraction solenoid

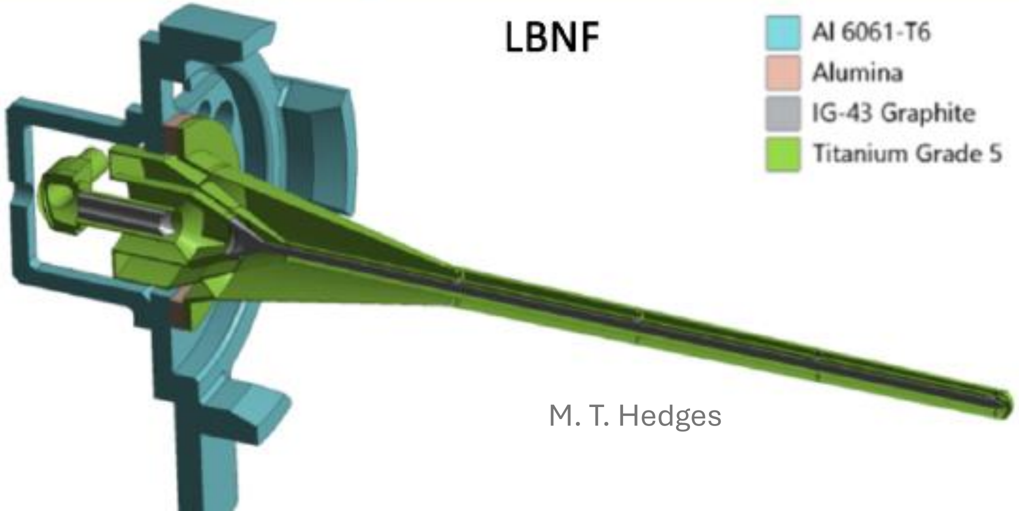
Muon collider
?????????????????????
***Multi-MW in 20 T!!!***

Short → Near → Long

NuMI




LBNF



# HPT R&D Group

# High-Power Targetry R&D Team

## In-Beam Studies

*Evaluate in-beam performance of candidate materials*

- **Irradiated Material Studies**
  - high energy proton irradiation
  - Low energy ion irradiation
- **Thermal Shock Studies**
  - HiRadMat facility at CERN

## Novel Target Materials

*New materials with enhanced thermal shock and radiation damage resistance*

- **High-Entropy Alloys**
- **Nanofibers**
- **Composite materials**
- **Heat treatment**


## Material Characterization

*Evaluate performance of candidate materials before and after irradiation*

- **MI-8 Lab**
- **Many Collaborations and subcontracts**
  - RaDIATE
  - UCSB

## Develop Modeling

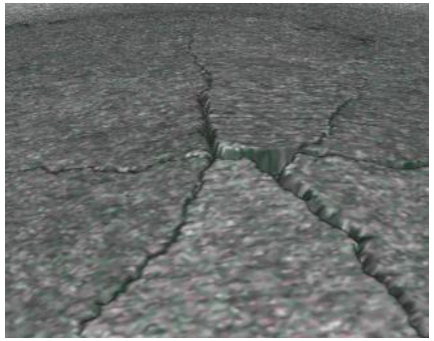
*Prediction of fundamental response of various materials to irradiation and thermal shock*

- **Helium gas bubbles** formation and segregation
- **Radiation damage effects**
- **Heat transfer mechanism** in nanofiber media

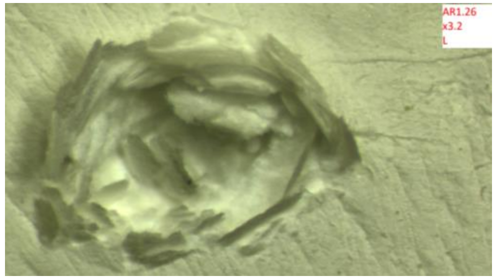
# Challenges associated with Beam Intercepting Devices

**Radiation damage**

*Physical property changes*



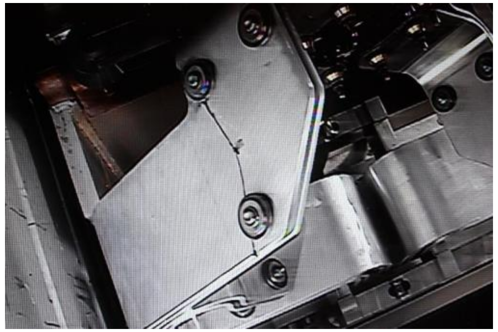
Be window embrittlement (FNAL)



Thermal shock damage on $ZrO_2$ nanofiber (HRMT test)

**Thermal shock**

Stress wave, plastic deformation, cracking



Horn stripline fatigue failure (FNAL)

**Thermal Fatigue**

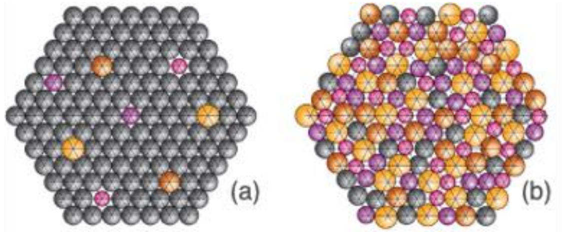
Microstructure damage

# Novel materials development - Kavin

Advance the state-of-the-art in target materials for enhanced thermal shock and radiation damage resistance

- Enable future multi-MW accelerator target facilities
- Maximize particle production efficiency and improve reliability

## High-Entropy Alloys for beam window applications




(a) Conventional alloy, (b) High-entropy alloy (Miracle & Senkov, 2016)

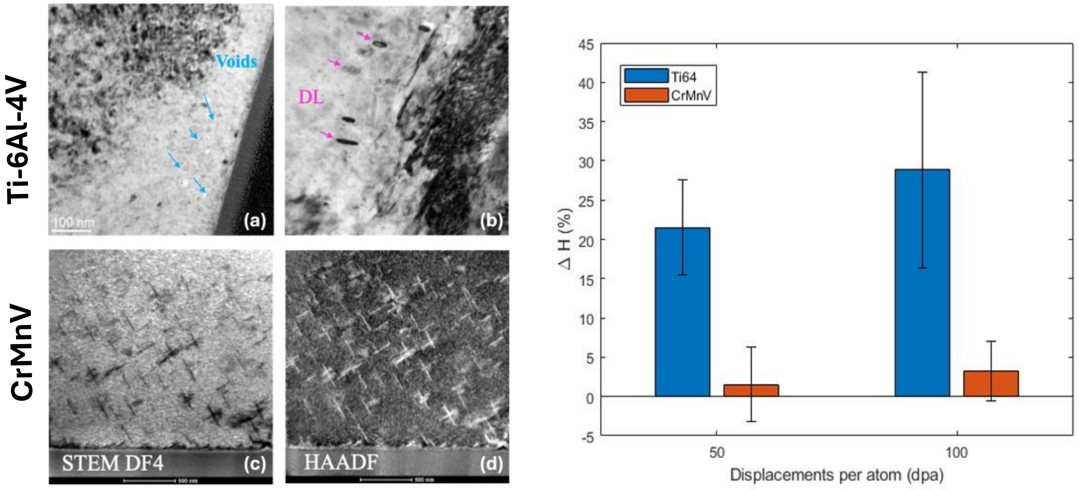
Studies have shown promising properties and remarkable radiation damage resistance


Sectioned arc-melted ingots (UW-Madison)

Larger plates fabrication by Sophisticated Alloys

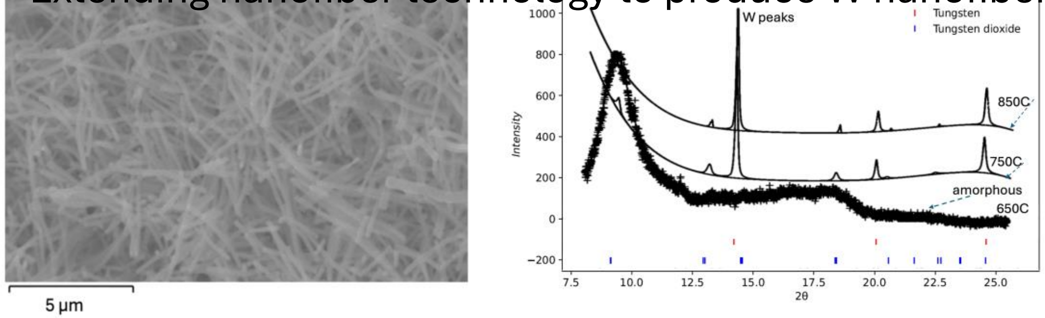
- Successfully produced AlCoCrMnTiV alloy systems
- Achieved target compositions
- SEM, EDS, XRD confirmed homogeneity and BBC phase

Irradiation with $V^{2+}$ ions up to 100 DPA at 500 C indicates superior radiation damage resistance of CrMnV compared to Ti-6Al-4V (FNAL, UW-Madison)




## Nanofibers as particle production targets

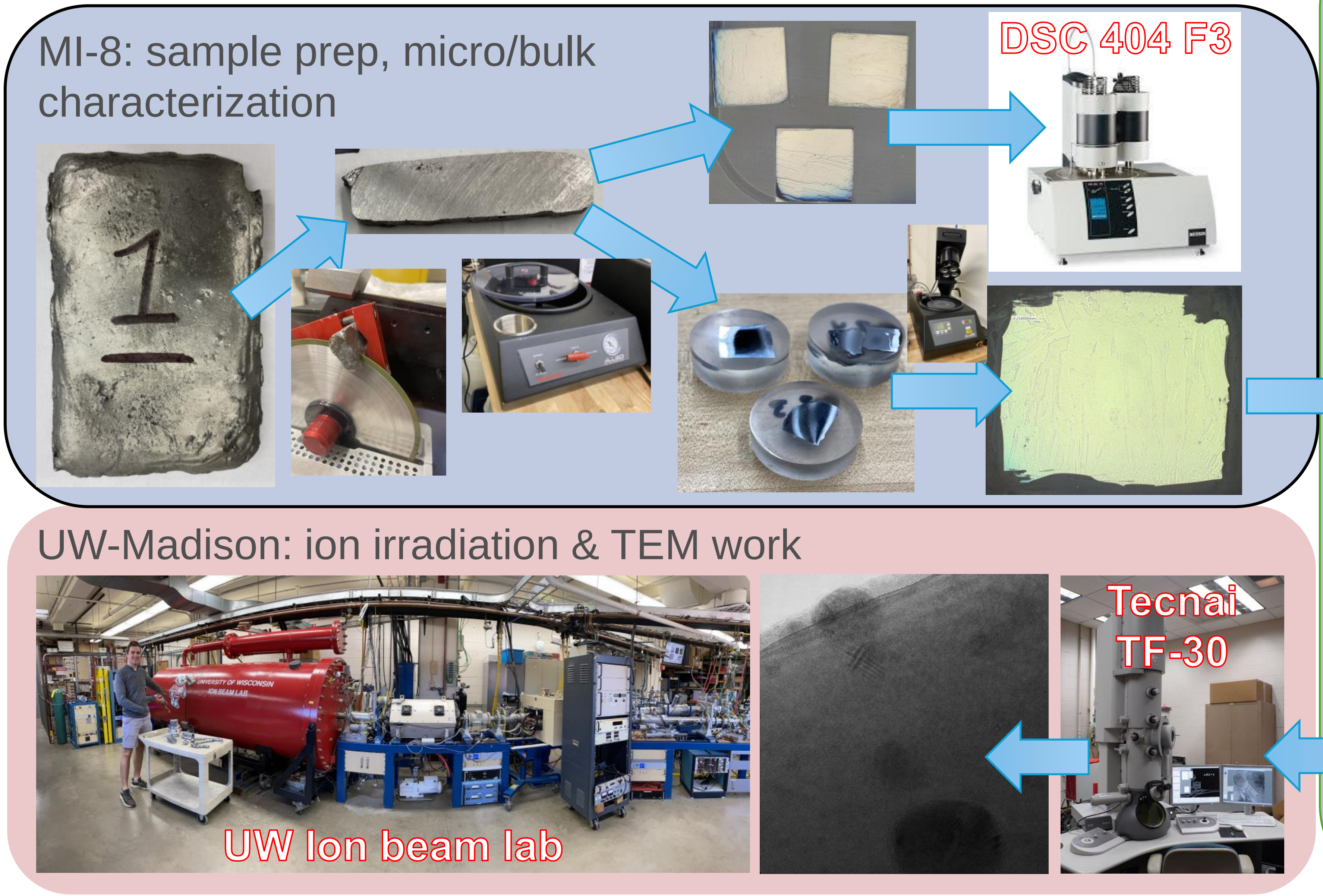
- Offers intrinsic resilience to thermal shock and radiation damage
- Extending nanofiber technology to produce W nanofibers

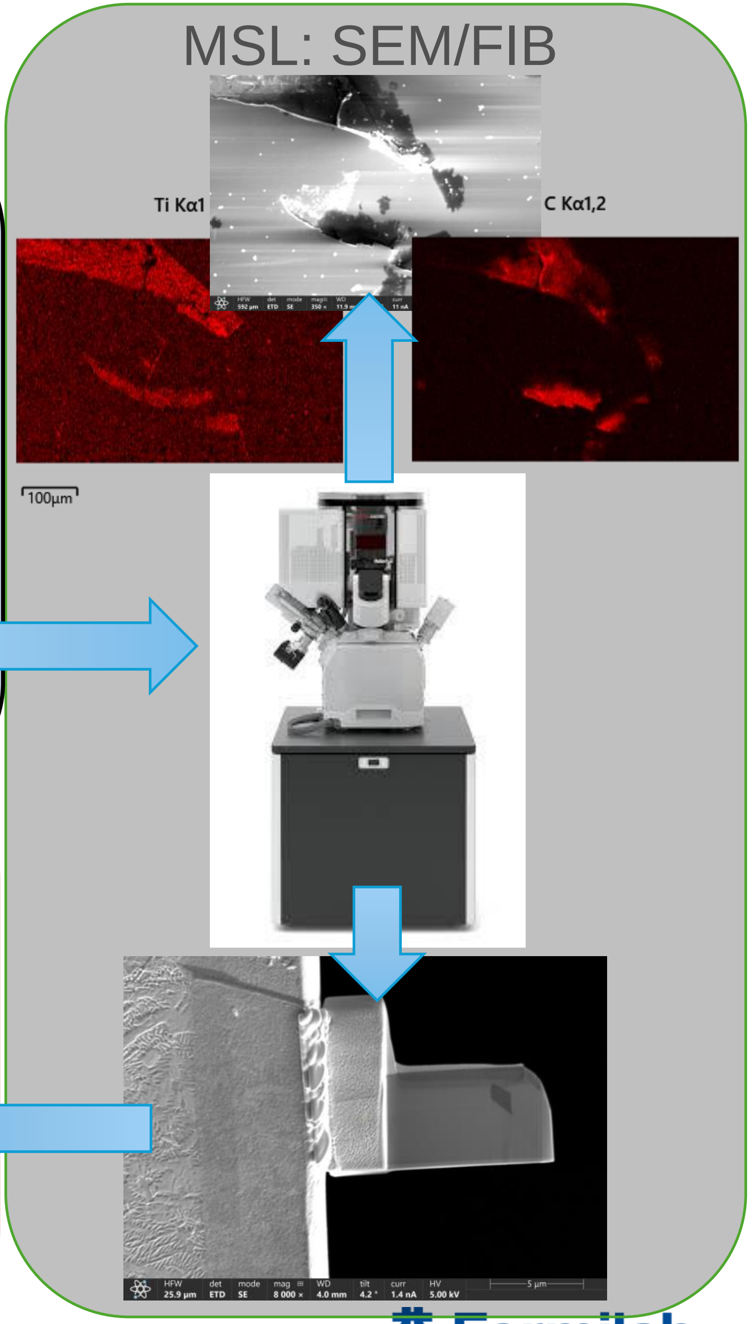



In-situ XRD informed optimal heat treatment (850 C) to obtain almost pure Tungsten nanofibers (99%)

Fermilab

# HEA characterization and irradiation: Abe

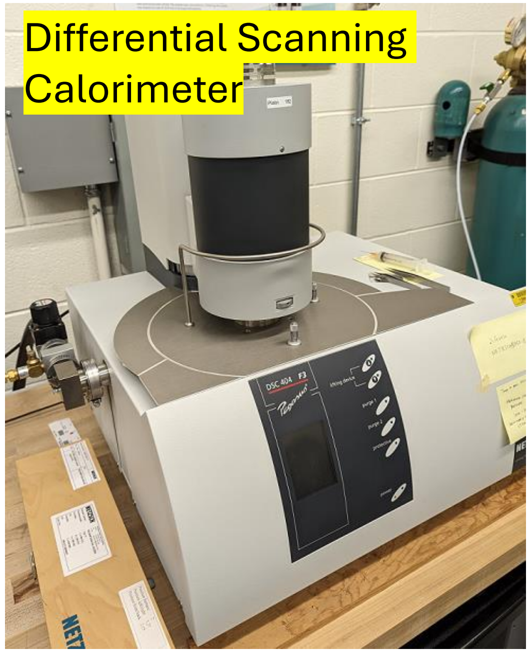




Fermilab

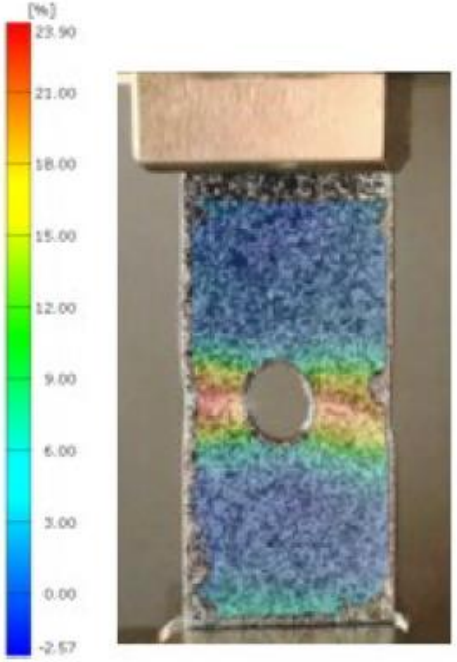
# Material Testing at MI-8

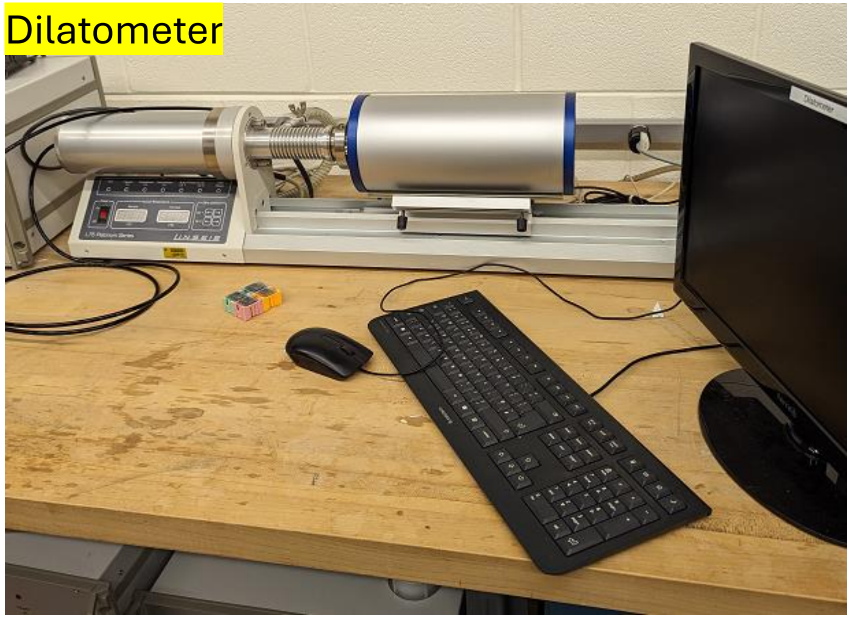


Differential Scanning Calorimeter


Nano-indenter

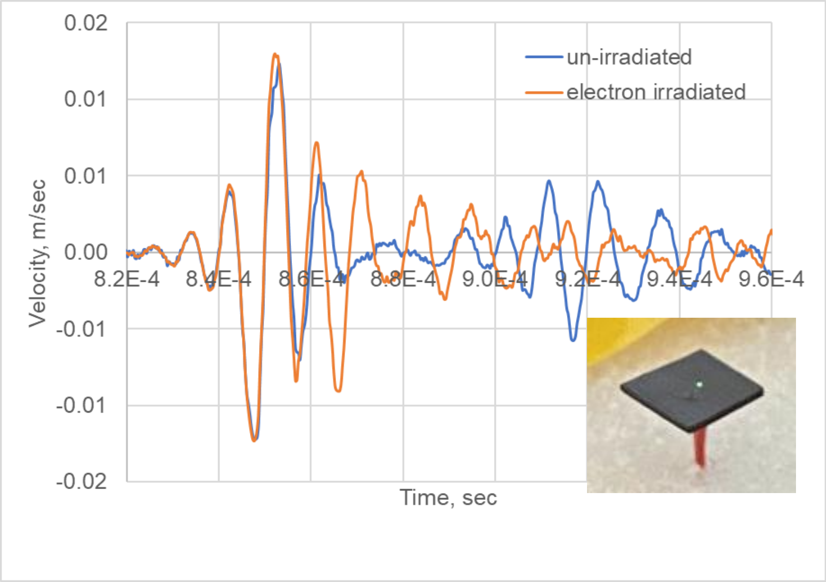

Tensile tester- DIC



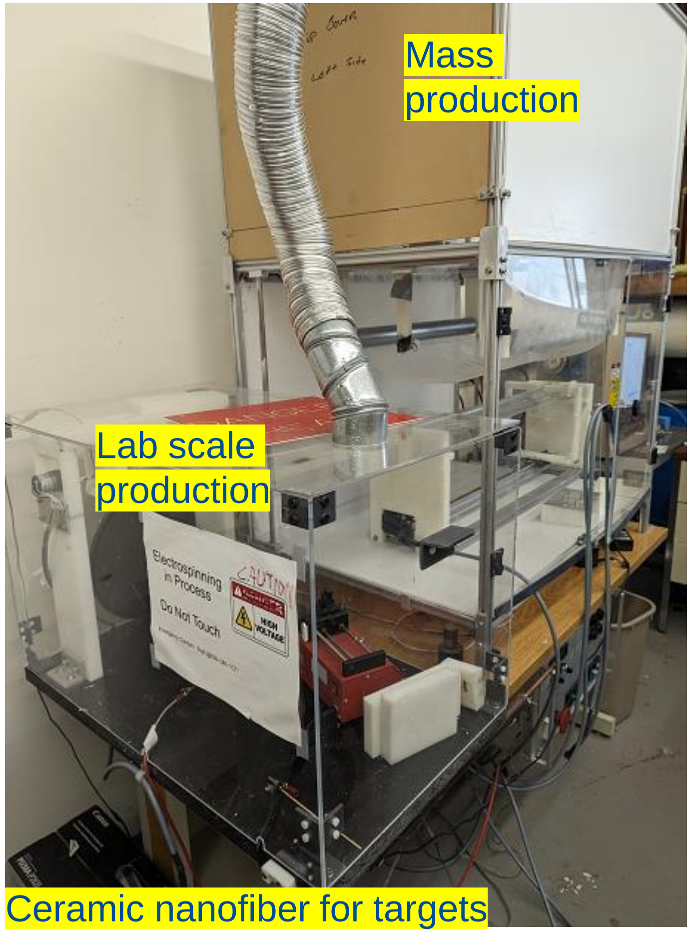
Dilatometer


LDV

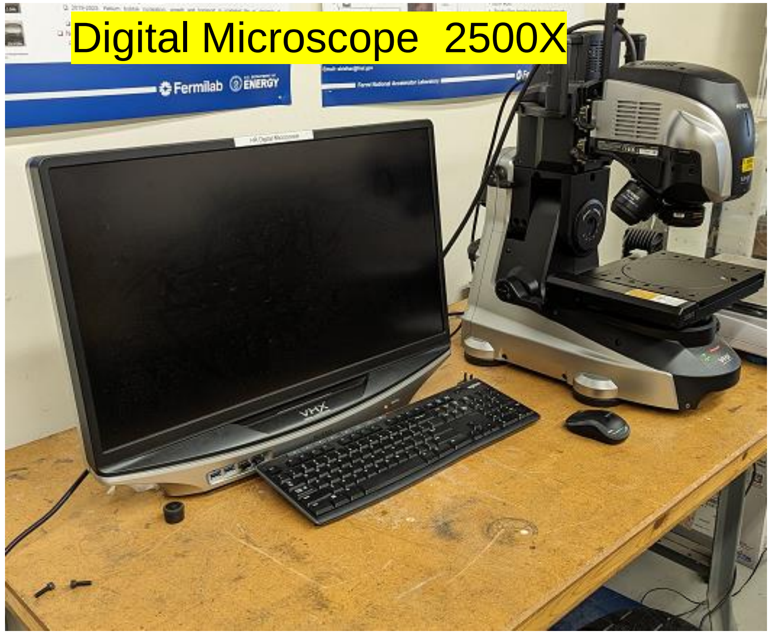


New Fatigue tester –US-JP

Nano-fiber production unit

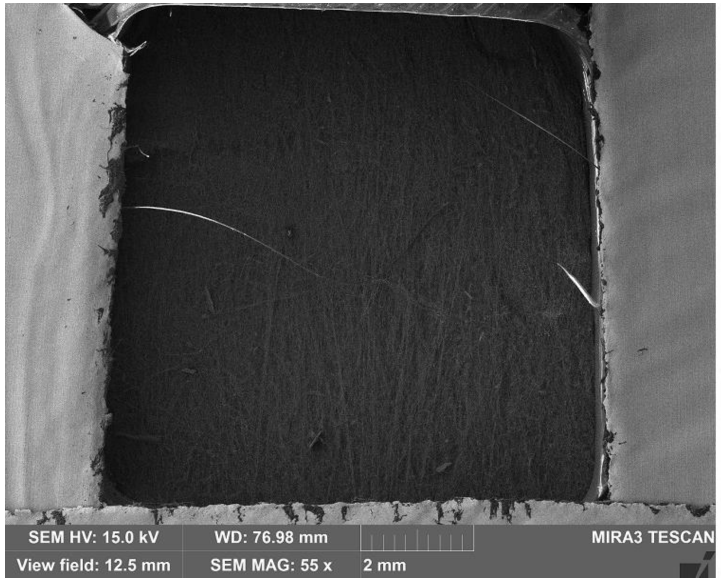


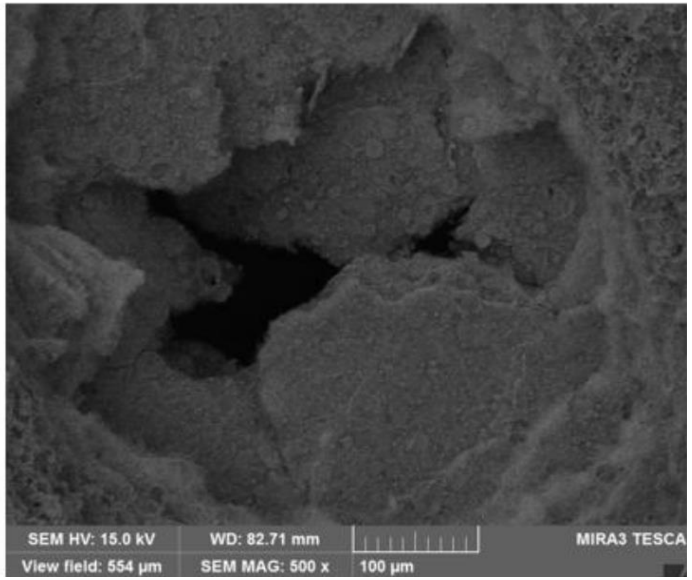

Cutter and Polisher

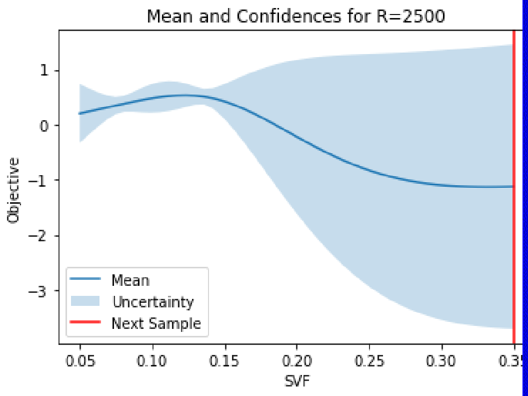


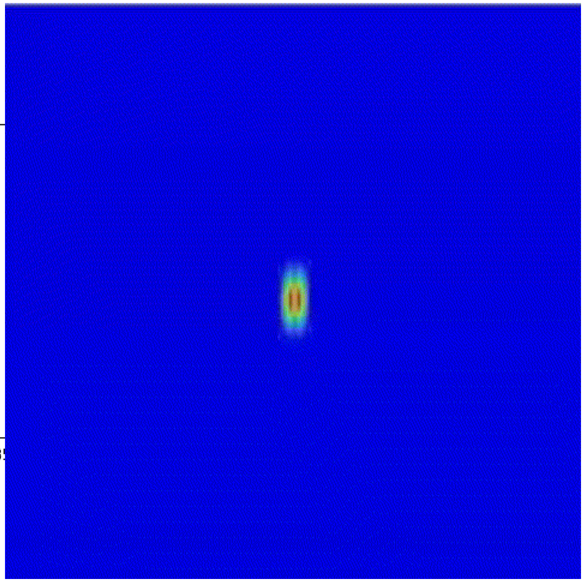
# Will – Multiphysics simulations to study heat transfer in nanofiber

- Nanofibers---good because they might mitigate thermal stress waves, radiation resistance, gas cooling but HRM (2018) test showed packing density is important
- I do multiphysics simulations and mathematical modeling to understand heat transfer and fluid dynamics in NF targets, especially as functions of construction parameters
- PhD student at IIT, advisor is Yagmur Torun (NOvA). Working in person since April. Hi!



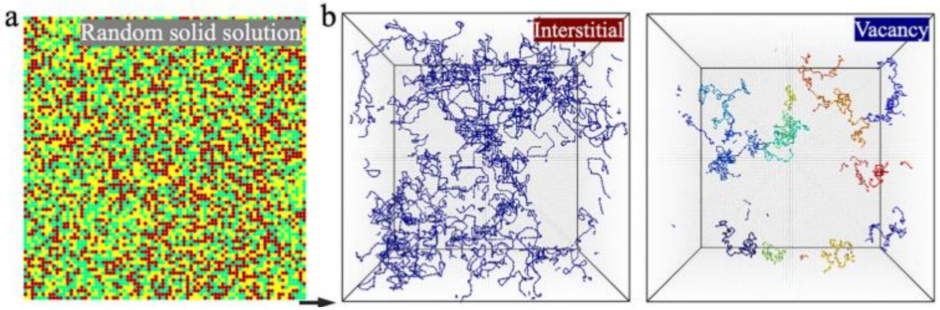



# Studying radiation damage in high entropy alloys (HEAs) using simulations

Goal: Simulate radiation damage in HEAs and study defect properties under different radiation conditions.

NiCoCr (from literature)

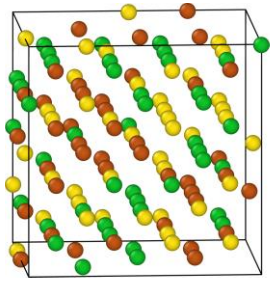



**CALPHAD**
- Used for predicting phase diagram
- Fast and GUI based package
- In this work: Used for scanning vast phase-space and shortlisting compositions for further investigation

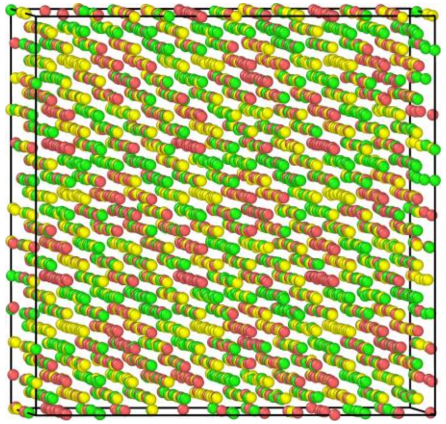
**Density functional theory (DFT)**
- Used for studying electronic structure
- Very accurate but limited by system size
- In this work: Used for collecting high-quality data

**Molecular dynamic (MD)**
- Used for studying time and temperature dependent properties
- Need force-field to simulate and is as accurate as defined force-field
- In this work: Will be used to simulate and study mechanical and defect properties under different radiation conditions


DFT structure (128 atoms)



MD structure (3456 atoms)



Current status
- In process of validating the accuracy of first version of force-field
- Running more DFT simulations to add on to current force-field

Cao, Penghui. "How does short-range order impact defect kinetics in irradiated multiprincipal element alloys?." *Accounts of Materials Research* 2.2 (2021): 71-74.

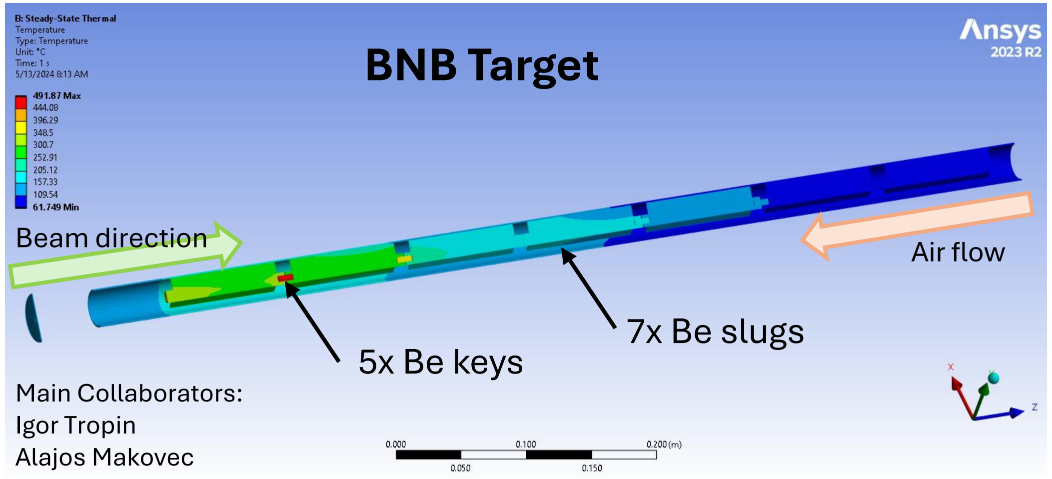
# Engineering: operations & projects

# TSD Slam

May 16 2024

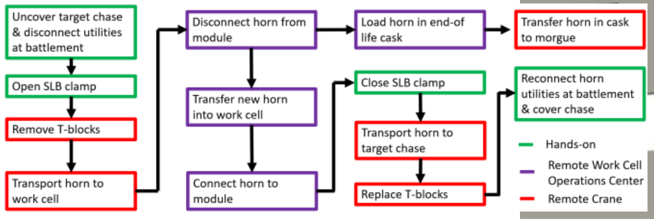
Bill Paley

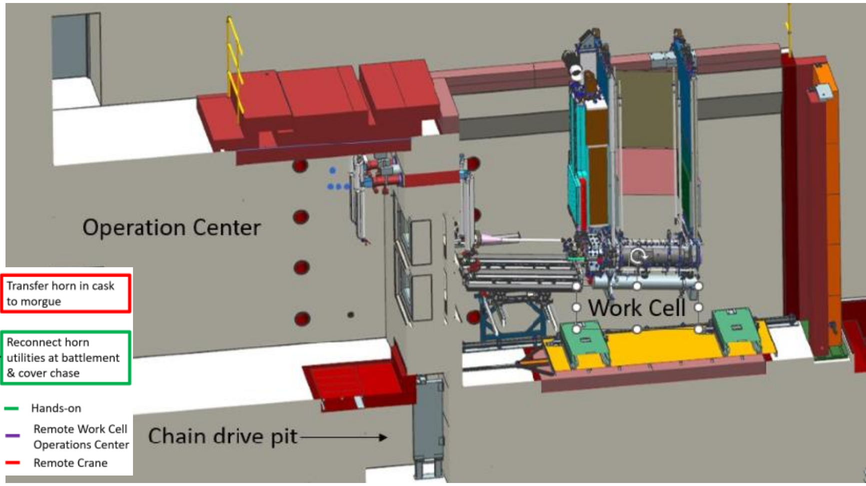
## BNB Target




Main Collaborators:
Igor Tropin
Alajos Makovec

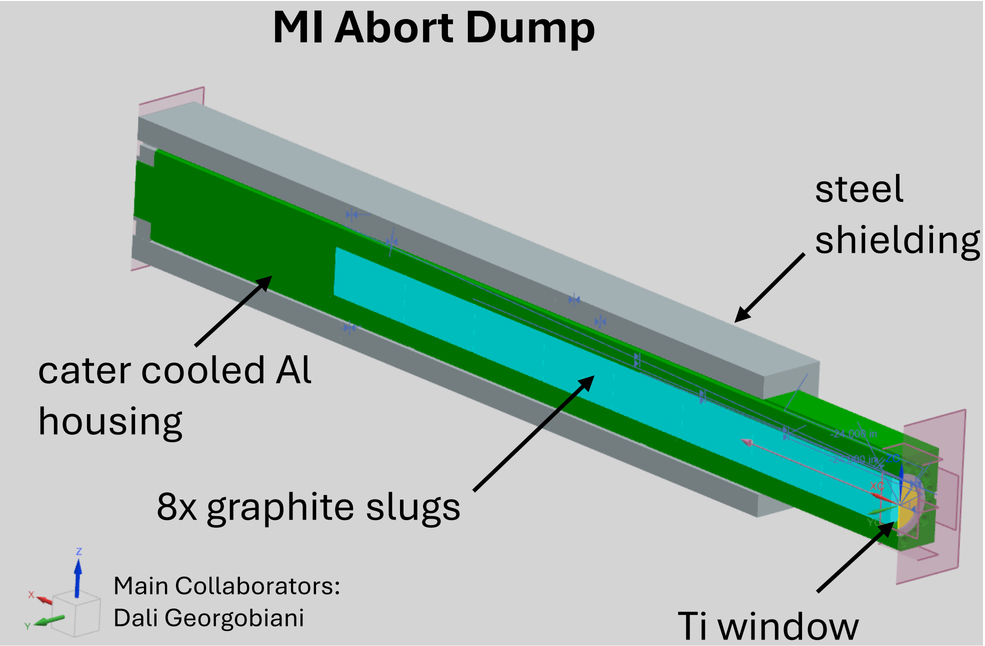
## LBNF Remote Handling




Main Collaborators:
Vladimir Sidorov
Patrick Hurh
Keith Anderson

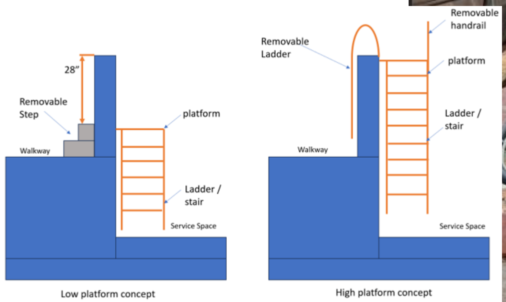
## MI Abort Dump

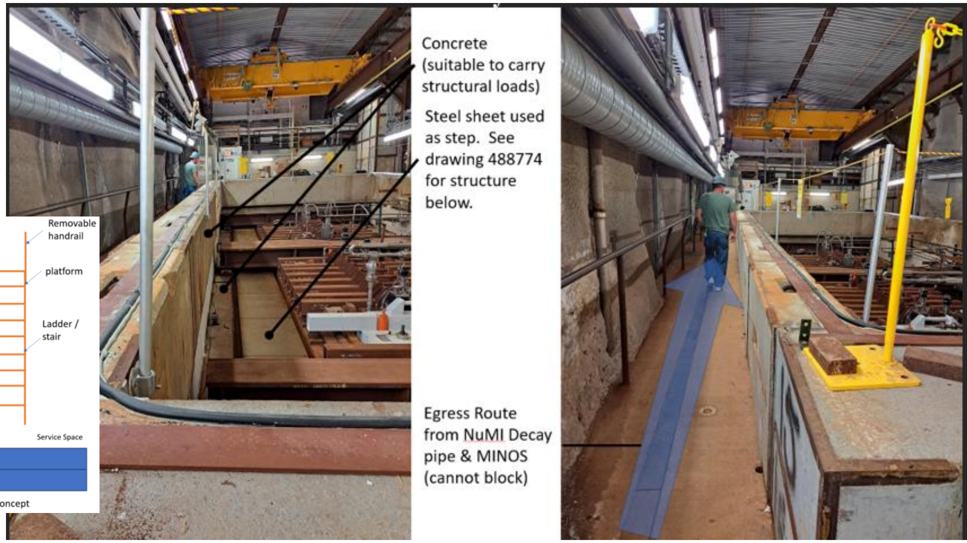



Main Collaborators:
Dali Georgobiani

Will they survive PIP-II rep rate & energy deposition?

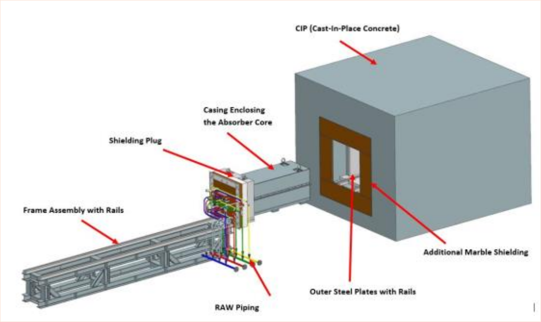
## NuMI Personnel access

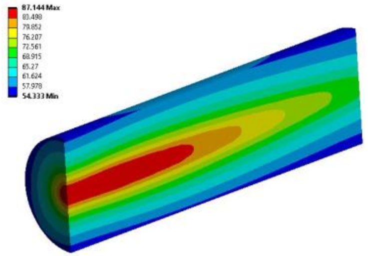


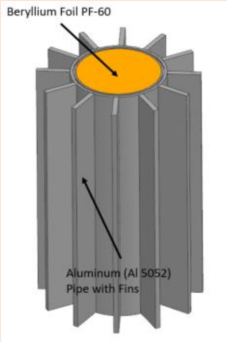

Main Collaborators:
Jimmy Zahurones

## PIP-II Beam Transfer Line (BTL) Absorber (25kW)

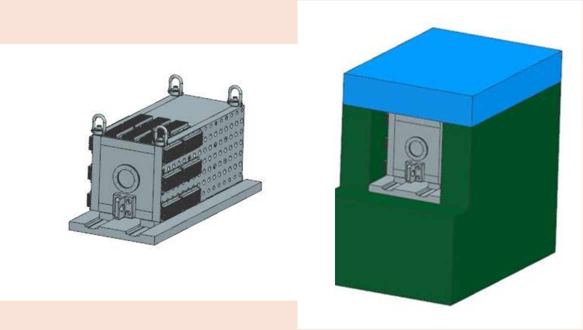


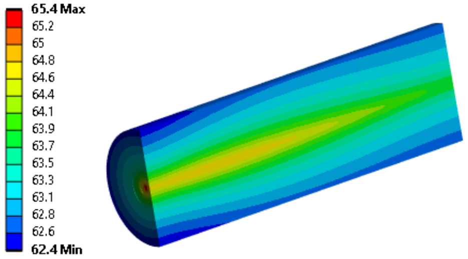



EBW for 25 kW Absorber



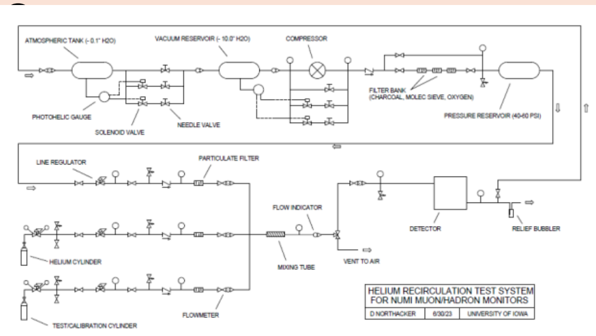

## PIP-II LINAC Absorber (2kW) - Portable






Machined Ti Gr2 for 2kW Absorber

## Helium Gas System for NuMI: R&D at MI-8




- Team Katsuya Y, Dave N, Yun He and Nandhini D.
- Goal of the project is to reduce the Helium gas consumption used for the NuMI Hadron and Muon Monitors.
- Upgrading the existing system. Leaky relief valve fix resulted in one bank surviving extra 3.5 days.
- Recirculation R&D setup at MI-8 to test the recirculation system at a small scale.

## TSD Relief Valve Replacement

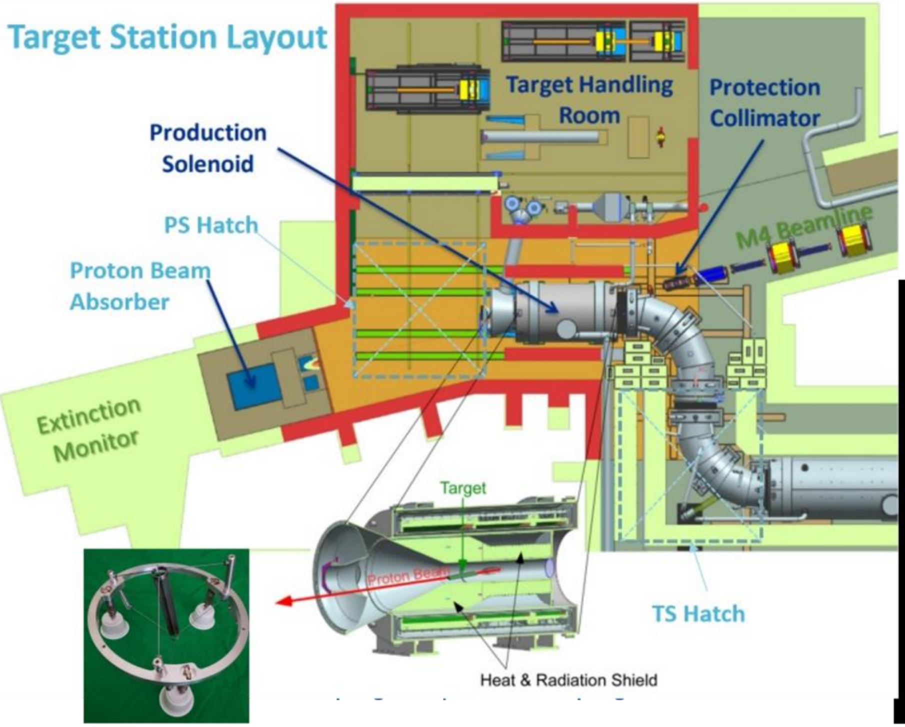
**Time to Replace Relief Valves !!!**

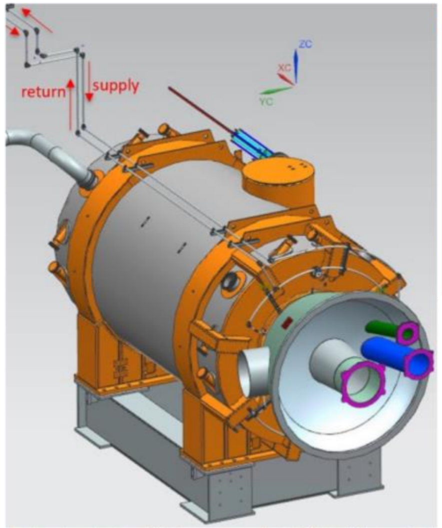
- Currently in the process of replacing all relief valves under the purview of TSD.
- Team consists of Kevin P, Jimmy Z, John A III and Zunping L and Nandhini D.
- Task involves reviewing the ENs and adding missing info, create HAs, procure the correct relief valves, changeout and update the FNAL Pressure Relief Database.

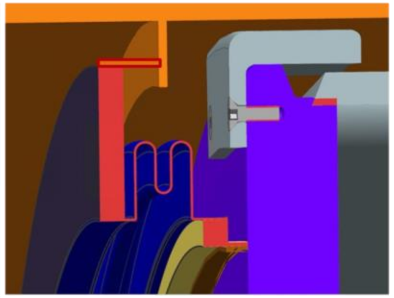
- **Member of FNAL Vacuum Window Safety Panel**

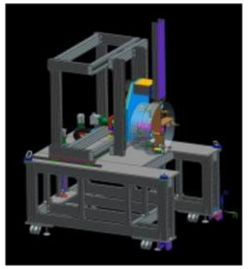
# Introduce Mu2e Target Station at TSD slam, Zunping Liu, 5/16/2024

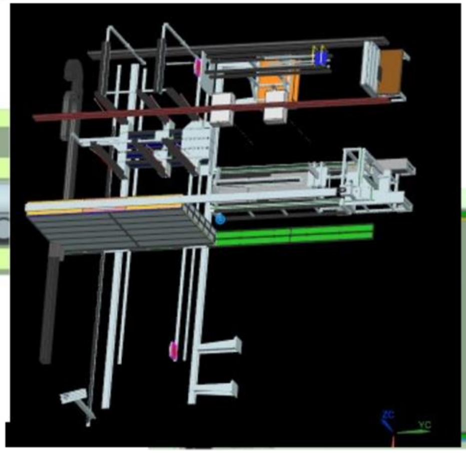


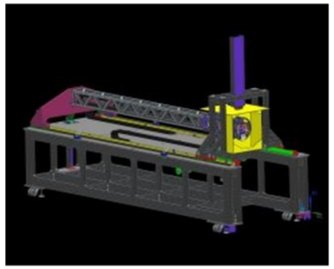


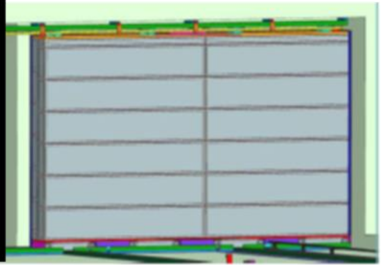





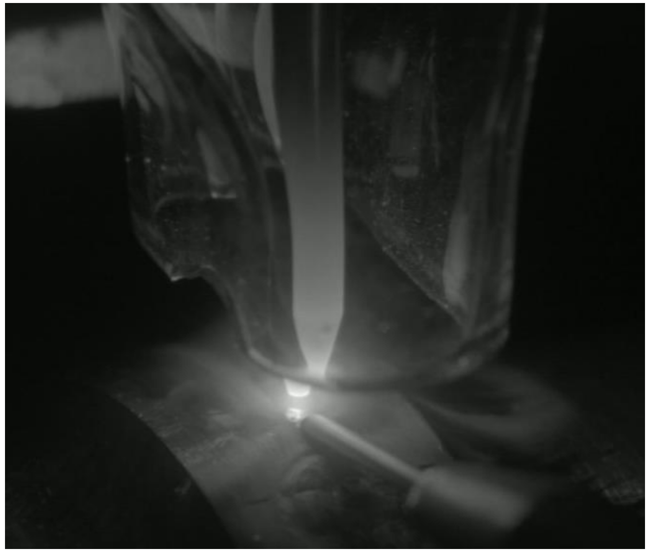


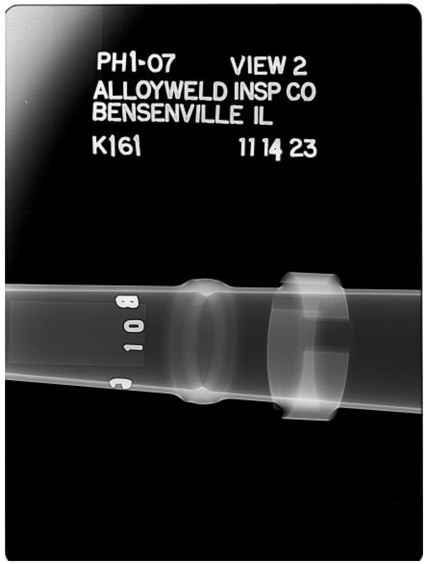


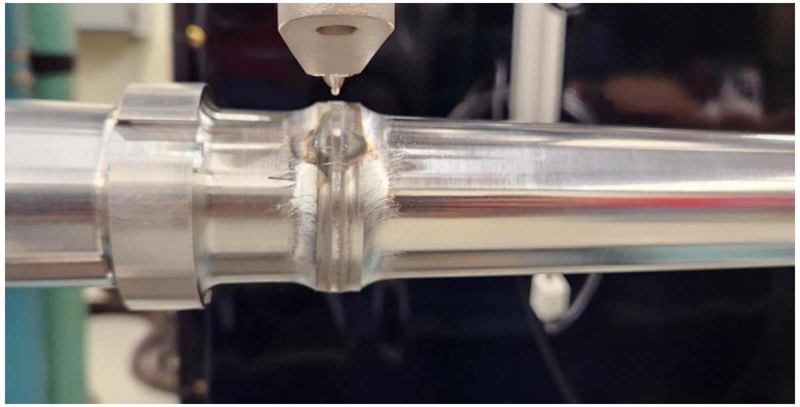


# Adrian Orea

- NuMI Inner conductor welds
- PH1-07 Fabrication and QA
- LBNF Striplines
- EMPHATIC
- SLB-11 Fabrication







Fermilab

# Quinn Peterson

Mechanical Engineer

- LBNF
  - Beam Windows
  - Decay Pipe
  - Remote Handling
- Hi-Rad-Mat
- FEA Users Group
- Co-op Co-Manager