NanoSonic, Inc.
nanotechnology at work

Long-Term Radiation Rugged Rotary Vacuum and Water Seals in Heavy-Ion Accelerators

PI: Jennifer Lalli

2024 SBIR/STTR Exchange PI Meeting

August 13-15, 2024

Sponsored by the Department of Energy Office of Science, Office of Nuclear Physics

August 15, 2024
11:55 AM
DOE SBIR Phase IIA NP SBIR Exchange

TPOC: Dr. Michelle Shinn

NanoSonic, Inc.
nanotechnology at work

Small Advanced Materials Company
- Incorporated 1998
- Green development and scaled production
- Polymers, composites, and sensors
- Commercialized >15 SBIR derived technologies

Wheatland EcoPark, in Pembroke, VA
LEED certified, energy-efficient, green building

Overview

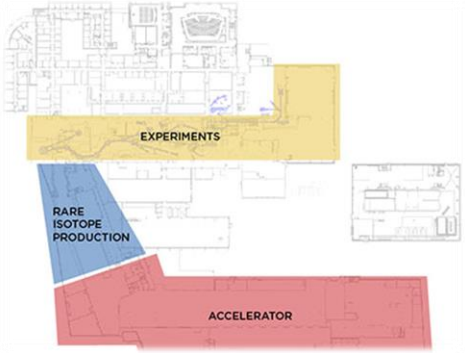
Topic 26f: *Rotary Vacuum and Water Seals in Heavy-Ion Accelerators*

Needed for NP Experiments:

- Ultra-high vacuum and water-cooled seals
- Constant rotation 600 rpm, 5,000 hr, ~1 year
- Extremely high annual radiation dose (~15 MGy)
- Need to change seal as infrequently as possible

Partners:

- BNL - NSRL and MIRP
- MSU - FRIB
- Garlock
- Cardinal Rubber & Seal



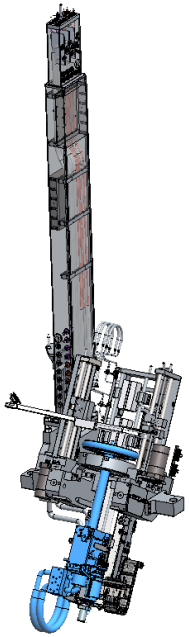
Facility for Rare Isotope Beams
at Michigan State University

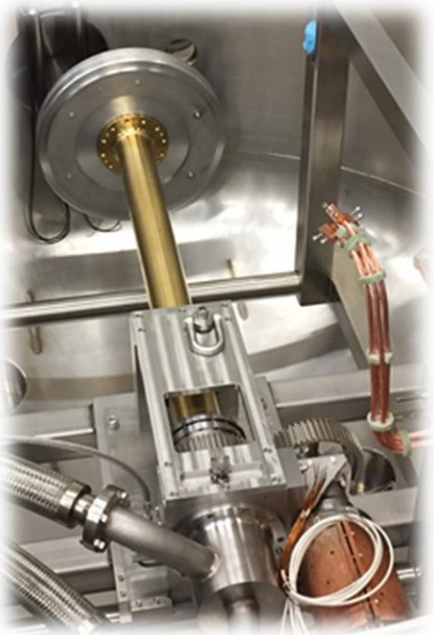
DOE Topic 26f – Technology for High Radiation Environments

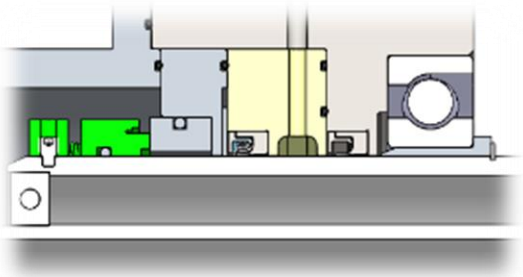
Grant # DE-SC0017107

OBJECTIVE:

- **Develop new rotary vacuum and water seals for rotating targets and beam dumps for rare isotope beam production and beam strippers in high-power heavy-ion accelerators**
- **Durable performance for 0.5 – 1.5 MGy/month, 1 year (5,000 hours), at 600 rpm over 32 °C to 66 °C, water side: 60 gpm (25 psi), vacuum side: $1e^{-5}$ Torr L/s**



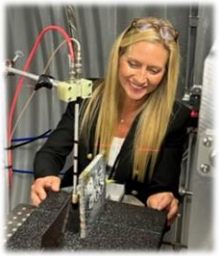




Need mechanical performance of Current Seal with enhanced Radiation & Less Abrasive. Investigating new material for new identified seal design

NanoSonic Team

& Our Commercial Partners/Investors



Dr. Jennifer Lalli, President, FSO, ITPSO
Ph.D. Chemistry, Virginia Tech
- > 20 years of adhesive/sealant and gasket/seal development
- Commercialized 15 SBIR products sold at www.nanosonic.com

Courtnay Brand (PM)
M.S. Chemistry
- NanoSonic's ISO 9001 Quality Management System Representative
- Synthetic Chemist leading foam design and production

Dr. William Harrison, Membrane and Seal Production Lead
Ph.D. Chemistry, Virginia Tech
- >20 years of laboratory safety and production expertise
- Leads NanoSonic scale-up and product certification

Dr. Maggie Bump, Marketing Liaison
Ph.D. Chemistry, Virginia Tech
- New product development, repeatability and scalability
- >20 years of Science Communication
- 17 Teaching Awards - Student Alumni Associates Favorite Faculty

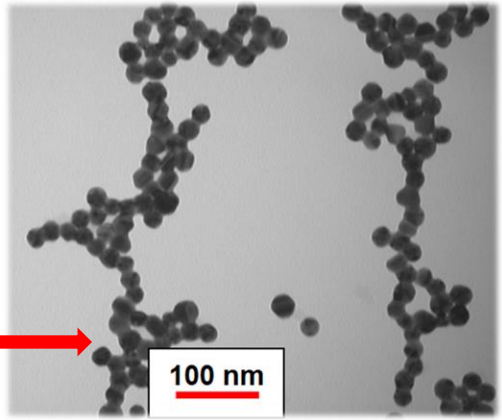
Dr. Eric Gilmer, Chemical Engineering Production Lead
Ph.D. Chemical Engineering, Virginia Tech
- AM prototyping, modeling, and manufacturing expertise
- Leads production of parts for space and aeronautics systems

Dr. Jie Wei, Accelerator Systems Division Director - Michigan State University, **Facility for Rare Isotope Beams**
- Design, fabrication, installation, commissioning, and operations of all aspects of FRIB accelerator systems
- 27 years of research, management, and teaching experience on particle accelerators, major science projects, and major user facilities
- Design, research and development, construction, and commissioning of the Relativistic Heavy Ion Collider (RHIC), the interaction-region design of the Large Hadron Collider (LHC), the design, research and development, and construction of the Spallation Neutrino Source (SNS) ring, and the leadership of the China Spallation Neutron Source (CSNS) project.

Dr. Jeongseog Song, Target and Beam Dump Systems Group Leader
Drs. Philip Morrison, Michael Larmann, and Nicholas Reha

NanoSonic is now ISO 9001:2015 Certified by NSF-ISR

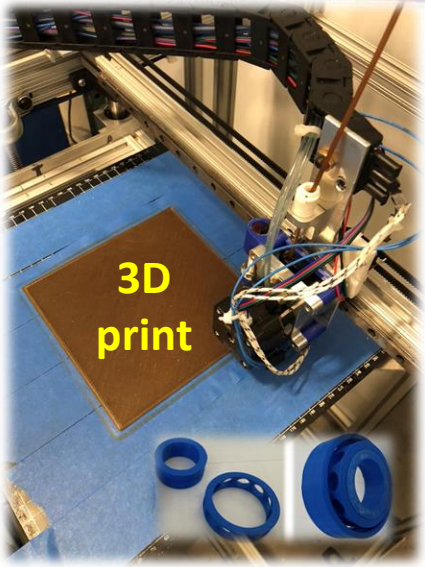
250-gal, 55-gal, 1-10 L in hood, two 20L, and one 100 L reactor

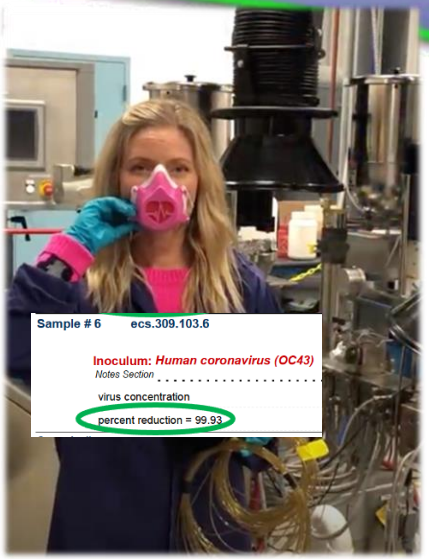


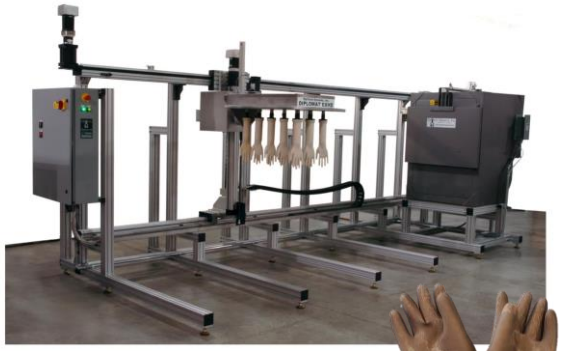
Au from 100 -L

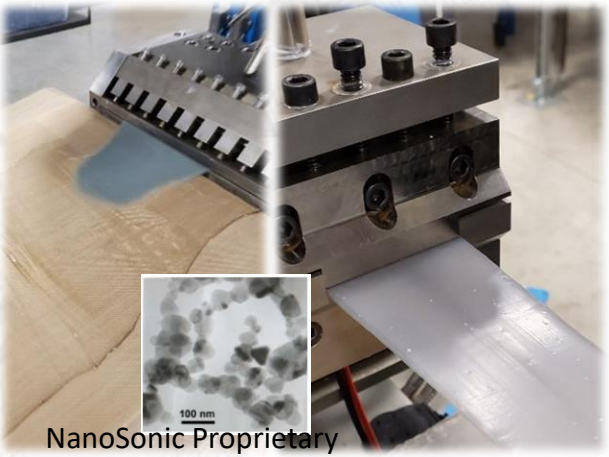
NanoSonic Production Capabilities:

Extrusion and 3D Printing of Radiation Tolerant Polymers, Metals, & Ceramics









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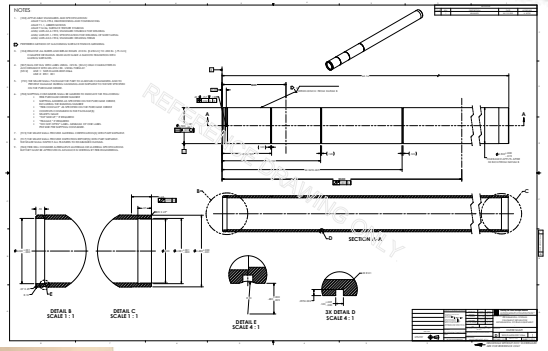
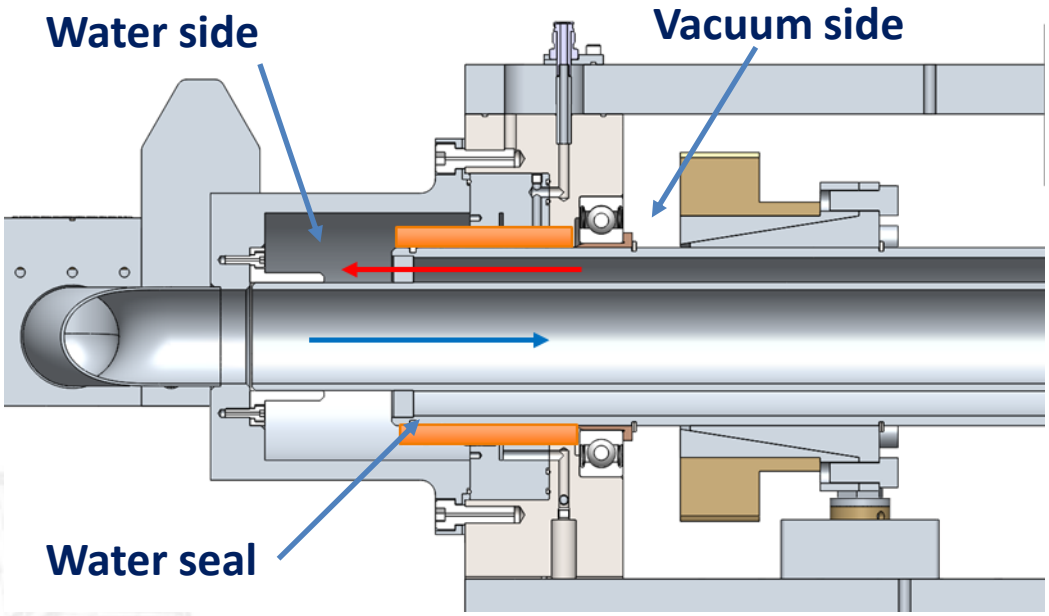
Goal:

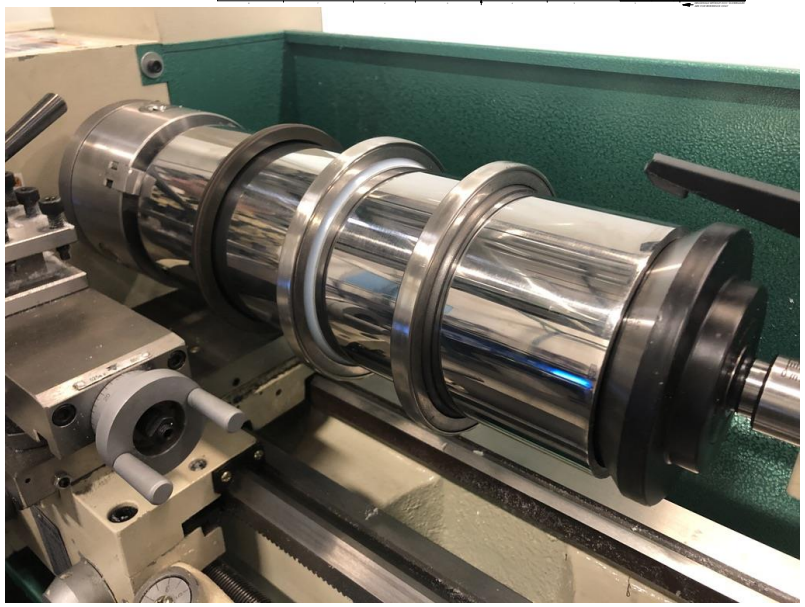
Develop New Materials and Seal Designs for FRIB Beam Dump

GOALS:

- **Develop new polymers with radiation resistance**
- **films not commercially available**
- **Implement new seal design**





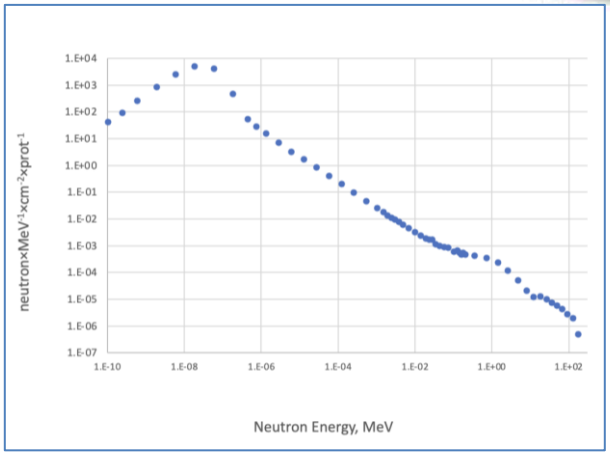


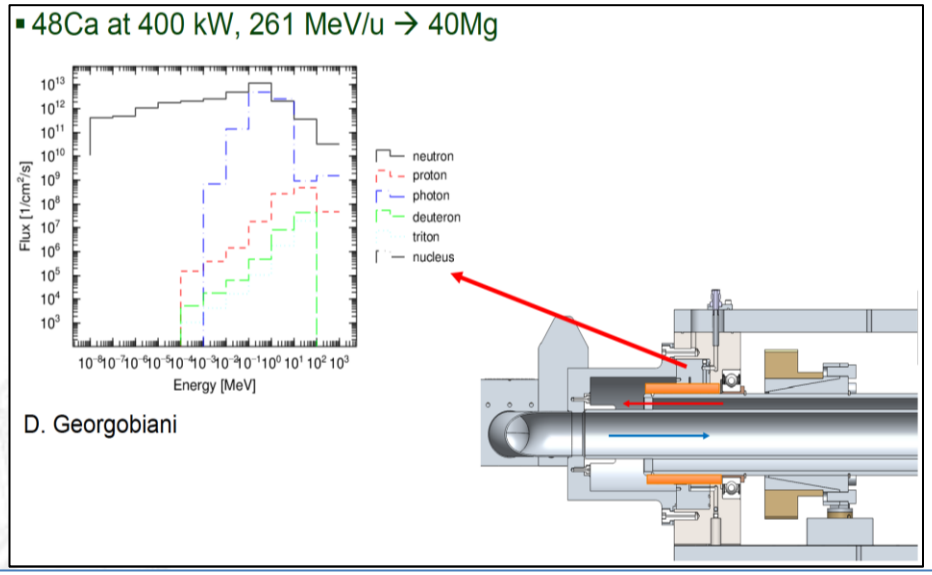
Reproduced 4.5" SS Shaft for Abrasion Testing of New Seal Materials to Mimic Beam Dump Water Seal

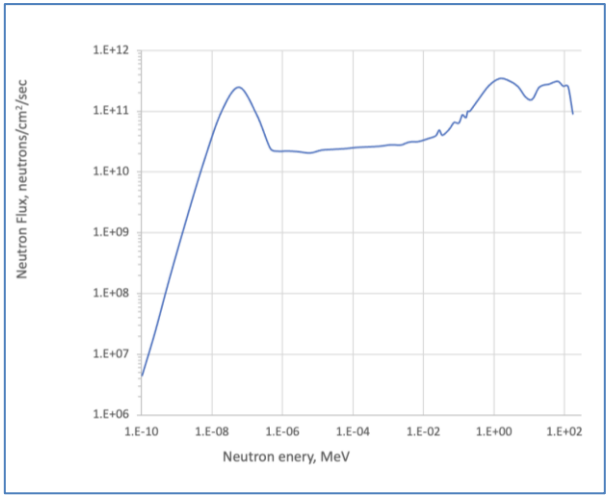
Goal: Survive High Dose Exposure

Particle Energy Spectra for Beam Dump's Rotating Water Seal

Energy, MeV		Flux, particles/cm2/second				
E_low	E_high	Neutrons	Protons	Photons	Deuterons	Tritons
1.0E-09	1.0E-08	5.1E+06	0.0E+00	0.0E+00	0.0E+00	0.0E+00
1.0E-08	1.0E-07	1.9E+08	0.0E+00	0.0E+00	0.0E+00	0.0E+00
1.0E-07	1.0E-06	2.3E+08	0.0E+00	0.0E+00	0.0E+00	0.0E+00
1.0E-06	1.0E-05	4.9E+08	0.0E+00	0.0E+00	0.0E+00	0.0E+00
1.0E-05	1.0E-04	8.3E+08	0.0E+00	0.0E+00	0.0E+00	0.0E+00
1.0E-04	1.0E-03	9.7E+08	6.8E+01	0.0E+00	2.4E+00	5.0E-01
1.0E-03	1.0E-02	1.2E+09	1.8E+02	3.2E+05	8.3E+00	2.0E+00
1.0E-02	1.0E-01	2.3E+09	6.7E+02	6.7E+07	3.0E+01	7.9E+00
1.0E-01	1.0E+00	5.3E+09	8.2E+03	2.3E+09	2.3E+02	4.8E+01
1.0E+00	1.0E+01	9.5E+08	1.2E+05	1.2E+09	3.8E+03	8.1E+02
1.0E+01	1.0E+02	1.6E+08	2.3E+05	4.3E+05	2.0E+04	9.3E+03
1.0E+02	1.0E+03	1.5E+07	2.1E+04	7.3E+05	0.0E+00	0.0E+00

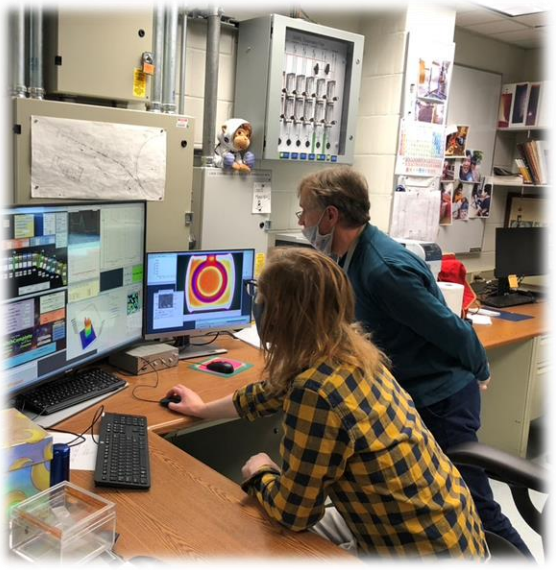




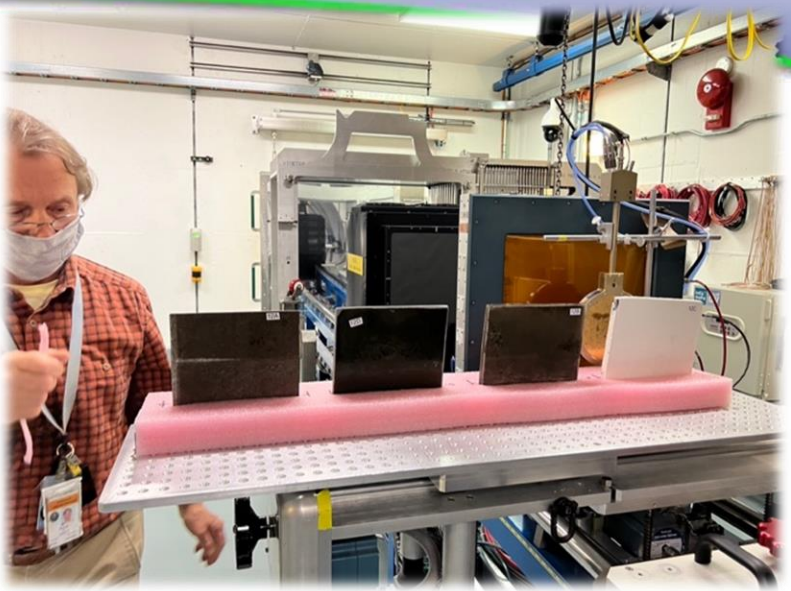


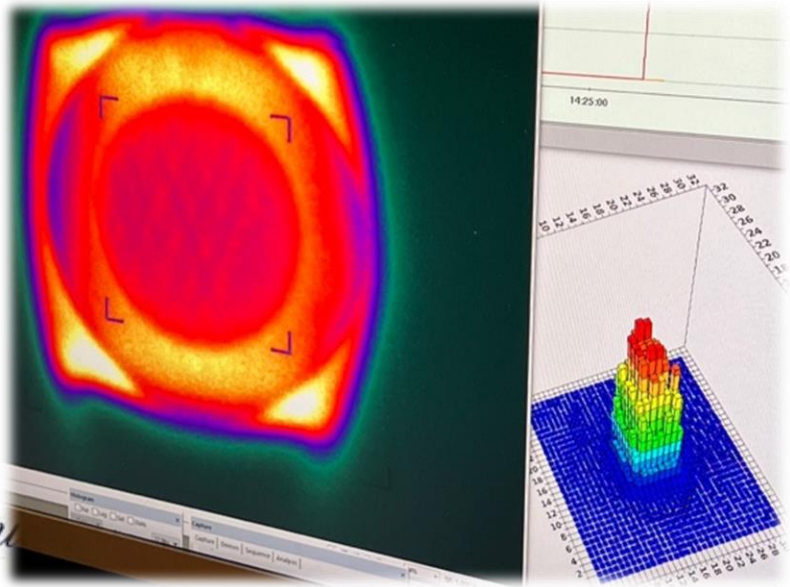
High Energy 260 MeV when operated at 400 kW, Estimated Beam Flux based on typical irradiation: 150 uA (9.3 x 1014 protons/sec) assuming secondary neutron flux to be homogeneous and crossing a 50 x 50 mm area at 90 deg

Radiation Exposure Run 1 - May 7, 2021
High Energy – 1 GeV Fe / 1 GeV proton



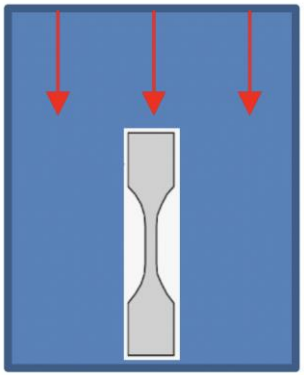
Radiation Exposure Run 2 - June 13, 2022
Lower Energy – 400 MeV Fe / 100 MeV proton

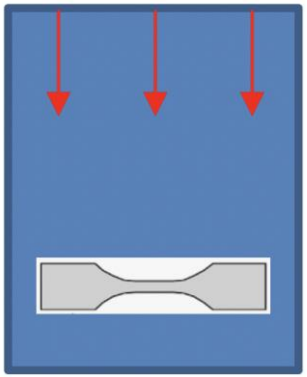


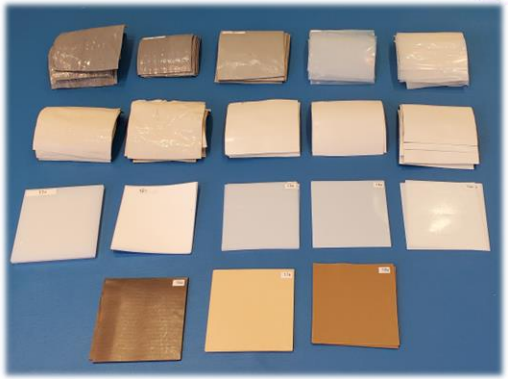


Increased Dose – 214 Gy

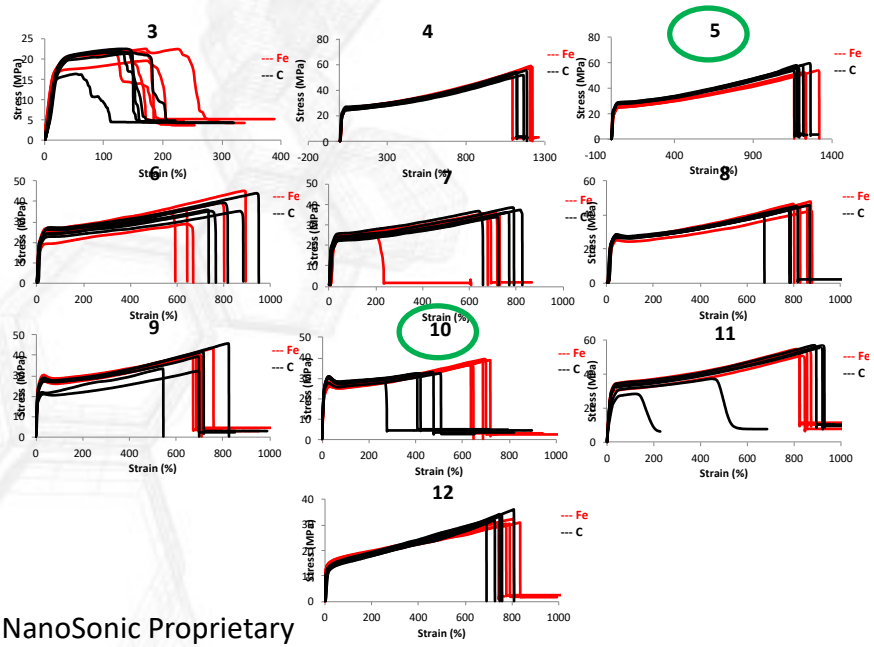
Exposure at NSRL to Fe 1 GeV for Down-Selection – Chain Scission vs. Embrittlement

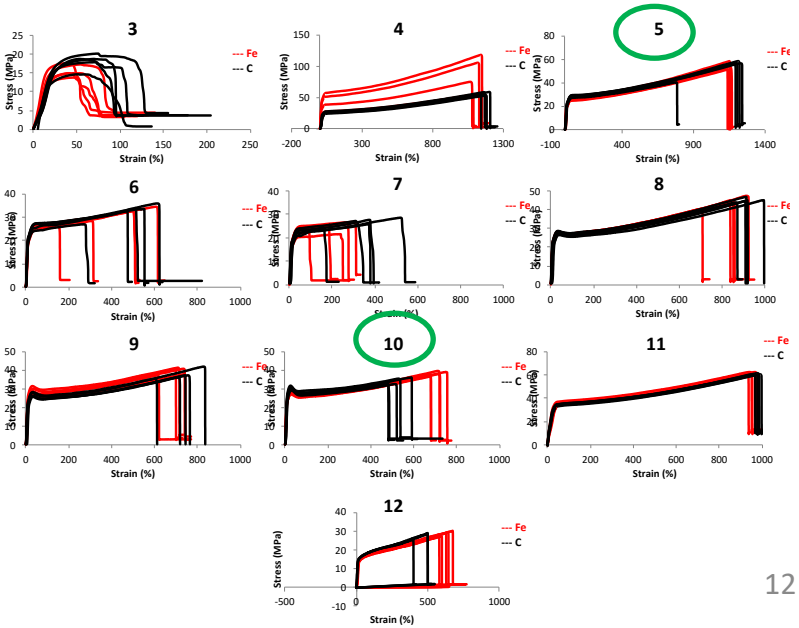




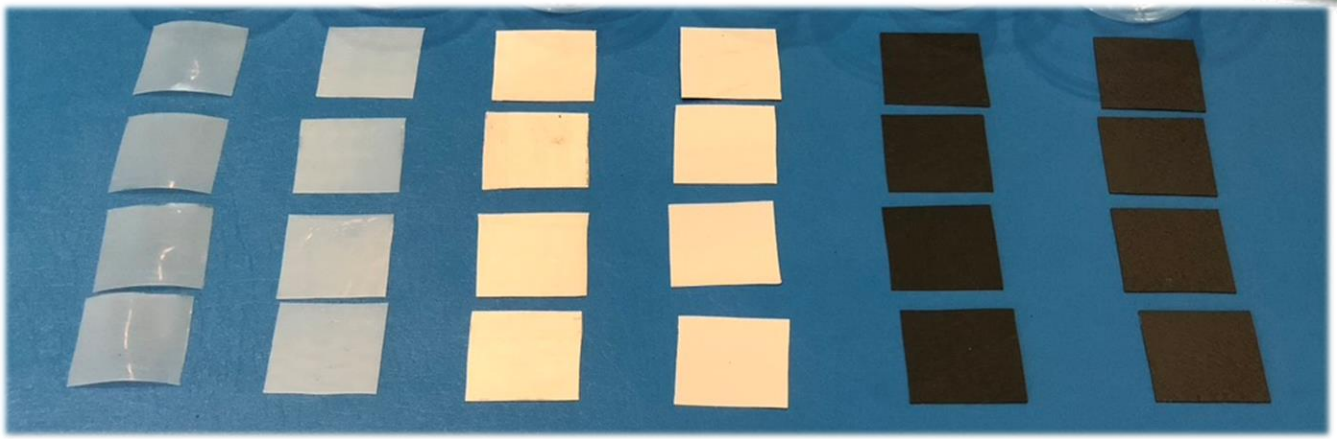


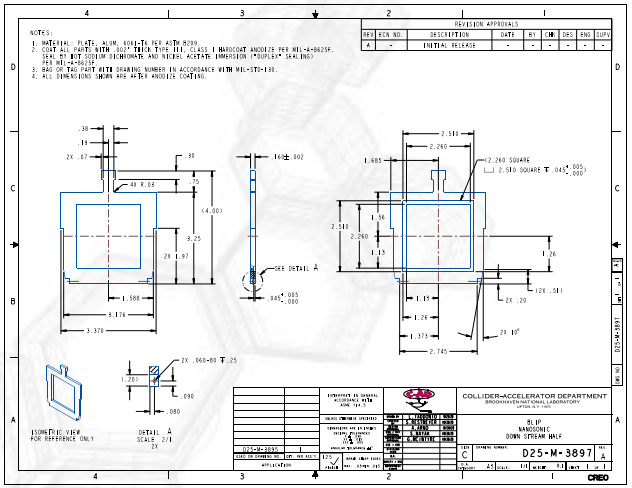
Mechanical Properties for All NanoSonic Films in Parallel and Perpendicular Directions

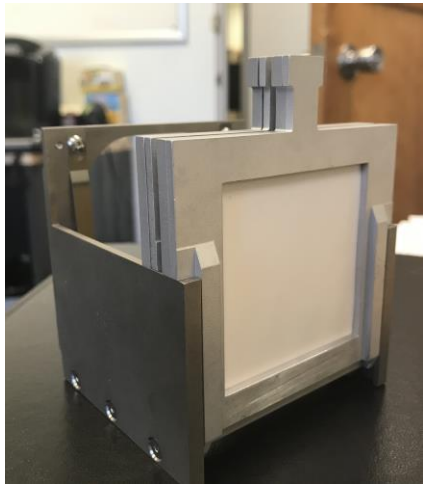


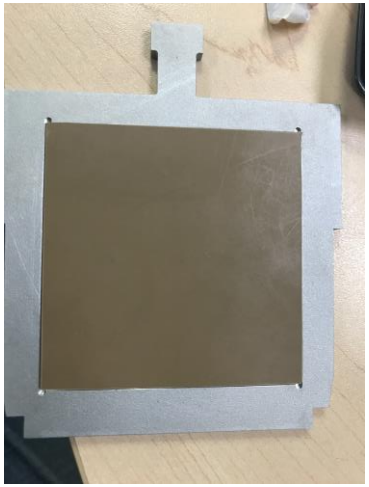


High Dose Exposure at BNL BLIP
Delivered Films





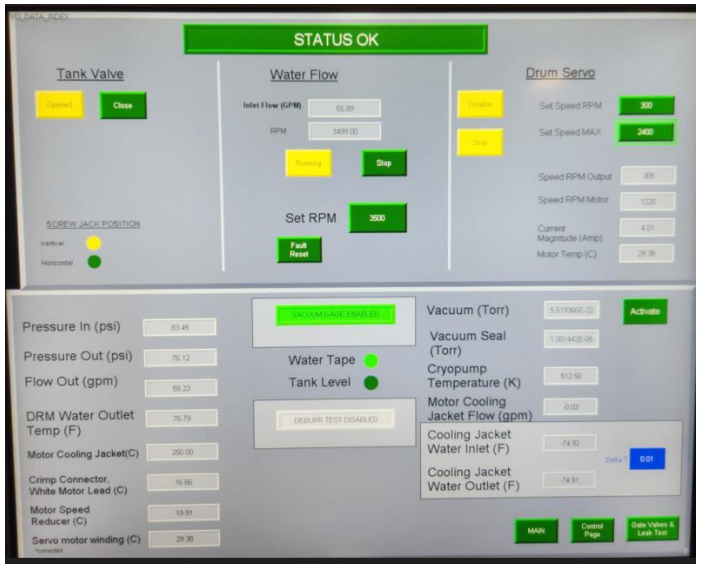




First Run in 2022 – New Run Pending

DRM test

- Rotating and water flow test at target truck bay area on 6/28/2023
  - Water flow rate for DRM
  - Inlet: 57.5 gpm
  - Outlet:62.81 gpm
  - Water pump rotating speed: 3500 rpm
  - Flowmeter not exactly in center
  - Water cooling for motor, ~ 2 gpm



Rot speed (rpm)	Time	Motor current (A)	Δp (psi)	Motor temp (C)	Flow (gpm)	Water leak
200	10:30 – 10:50					X
300	10:50 – 11:10	3.85	7 (83-76)	29.11	In:55.3 out:59.26	O

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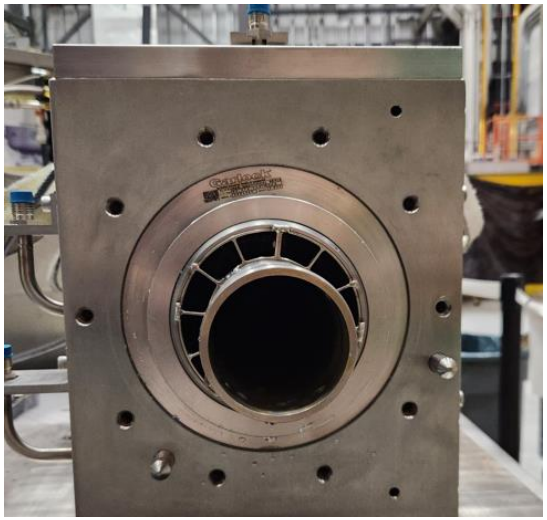
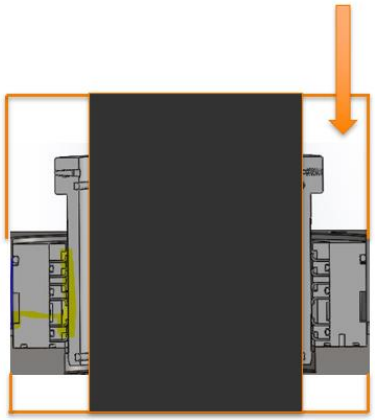
J. Song, HPT, DRM test, 6/2023

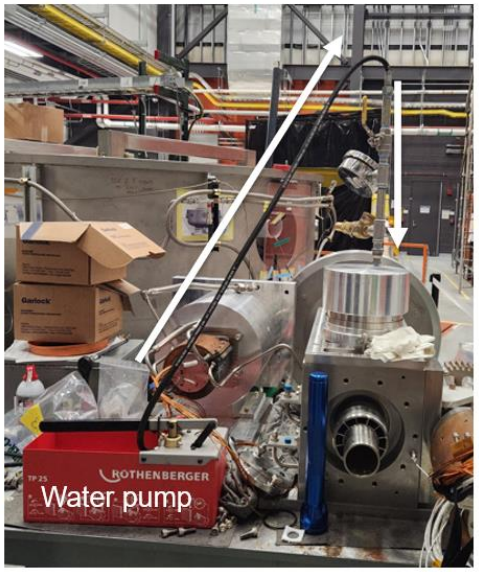
Water seal
Hardness Testing

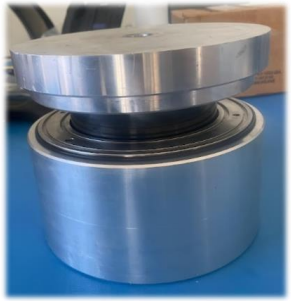


Status of Down-Selected Seal Material

Air pressure: ~ 80 psi,
with water







- Static test
  - Seal arrived here (5/16)
  - Tested at Target lab
  - Water pressure: ~ 75 psi
  - After 10 mins of pressurization:
    - No leak found

MSU Test Rig and Leak Path Findings Highlighted in Yellow
NanoSonic's Test Fixture and Seal Tested at MSU
Seal Passing at ~45 psi, and Seal with a Small Leak at 50 psi Indicated by Bubbles

Acknowledgements

Dr. Michelle Shinn
Dr. Elizabeth Bartosz, Brenda May, John Motz, Christine Grady, Cassie Dukes, Linda Severs, Dr. Manouchehr Farkhondeh, and Dr. Manny Oliver

Dr. Jie Wei, Dr. Jeongseog Song, Dr. Frederique Pellemoine and Dr. Georg Bollen MSU FRIB
Garlock

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NanoSonic