Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

BNL Capabilities for Fusion

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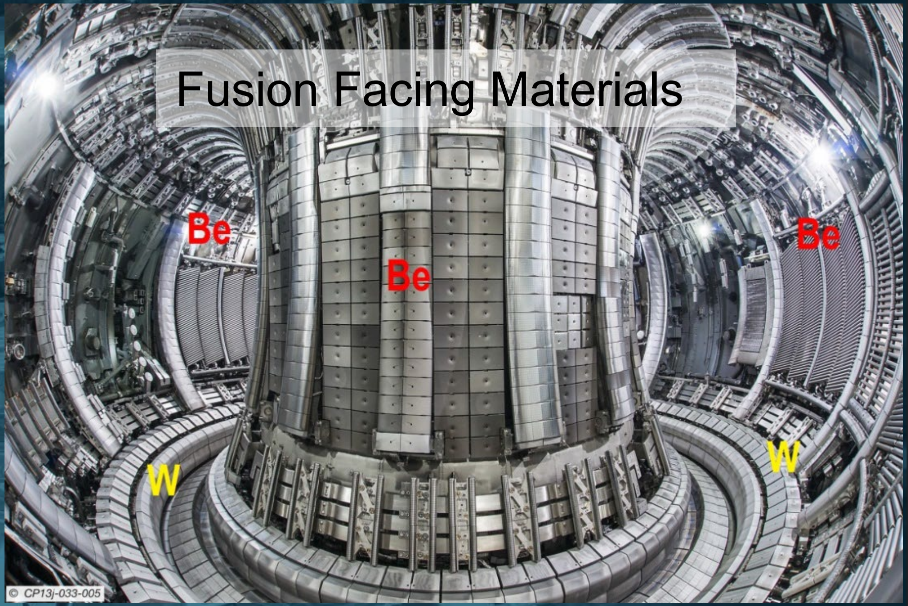
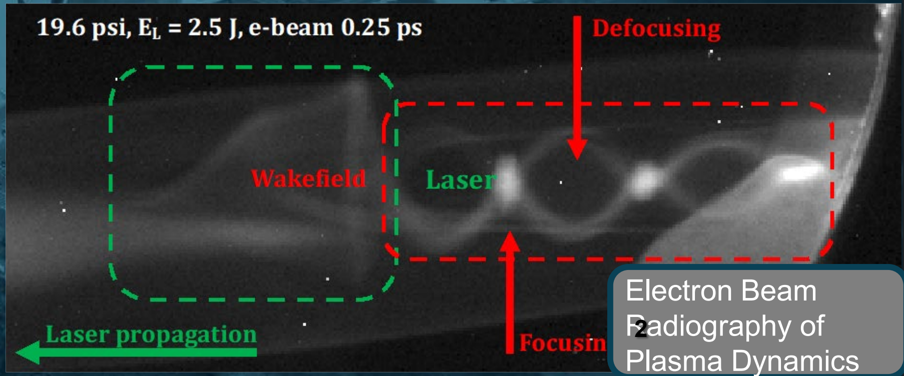
Engagement with the *office of Fusion Energy Sciences & Industrial Initiatives*

What BNL Accelerator Strengths Can Directly Couple to Fusion Needs?

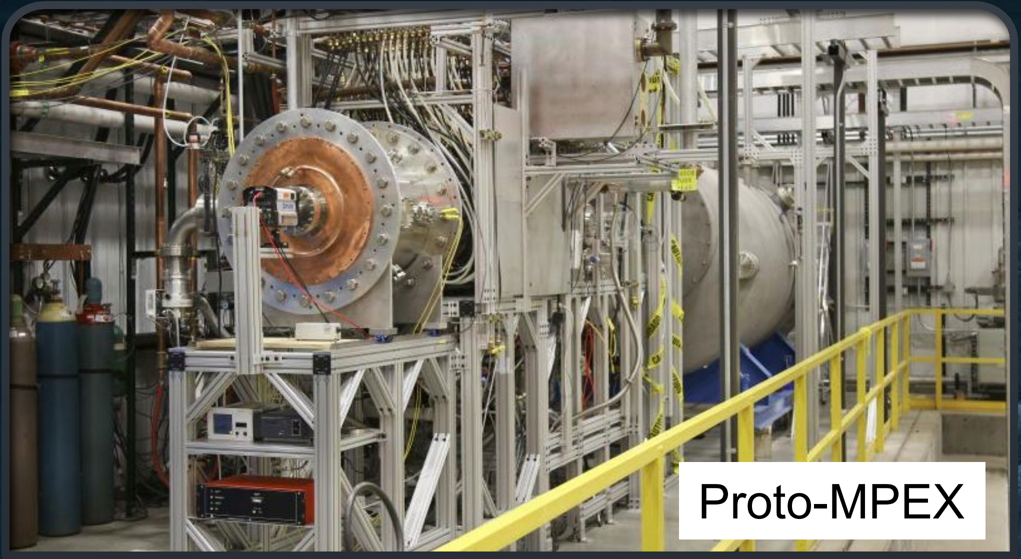
- Superconducting Cable and Magnets, including HTS
- Fusion-Like Neutron Spectra to Bridge the Gap to a Dedicated US Irradiation Facility
- Plasma Science Studies – LWIR Laser-Plasma interactions Offer Different Reach Than NIR Studies
- Can We Contribute to the Particle Sources Needed by the Community?
- What Accelerator Cross-Cuts Can Help Address FES Needs?



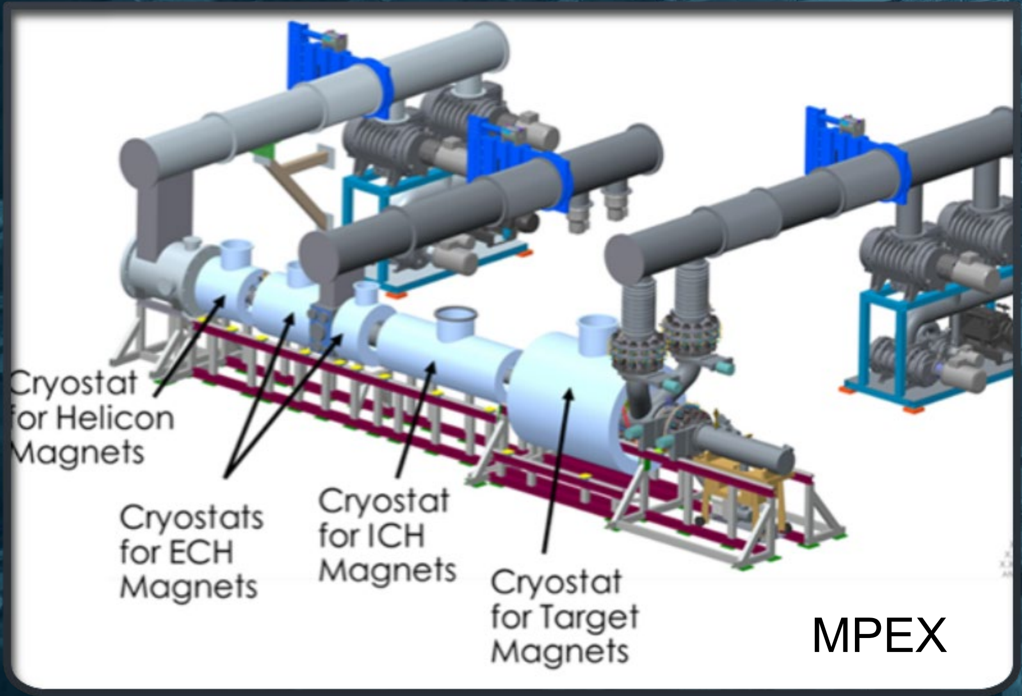


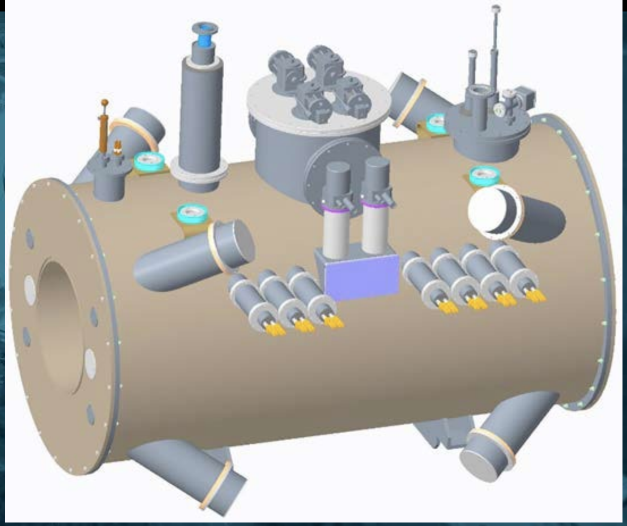
Electron Beam Radiography of Plasma Dynamics

Initial Engagements with DOE Fusion Community

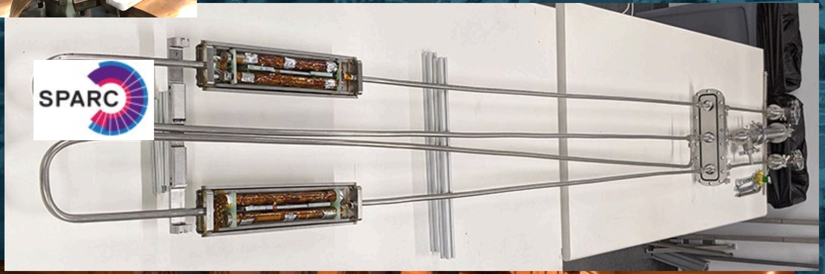


- Material Plasma Exposure Experiment (ORNL)
- Interactions between Large-Scale Volumetric & High-Density Plasmas with Materials
- ORNL connections yield SC Solenoid Design Effort In SMD
  - Magnet conceptual design completed
  - Aiding in procurement





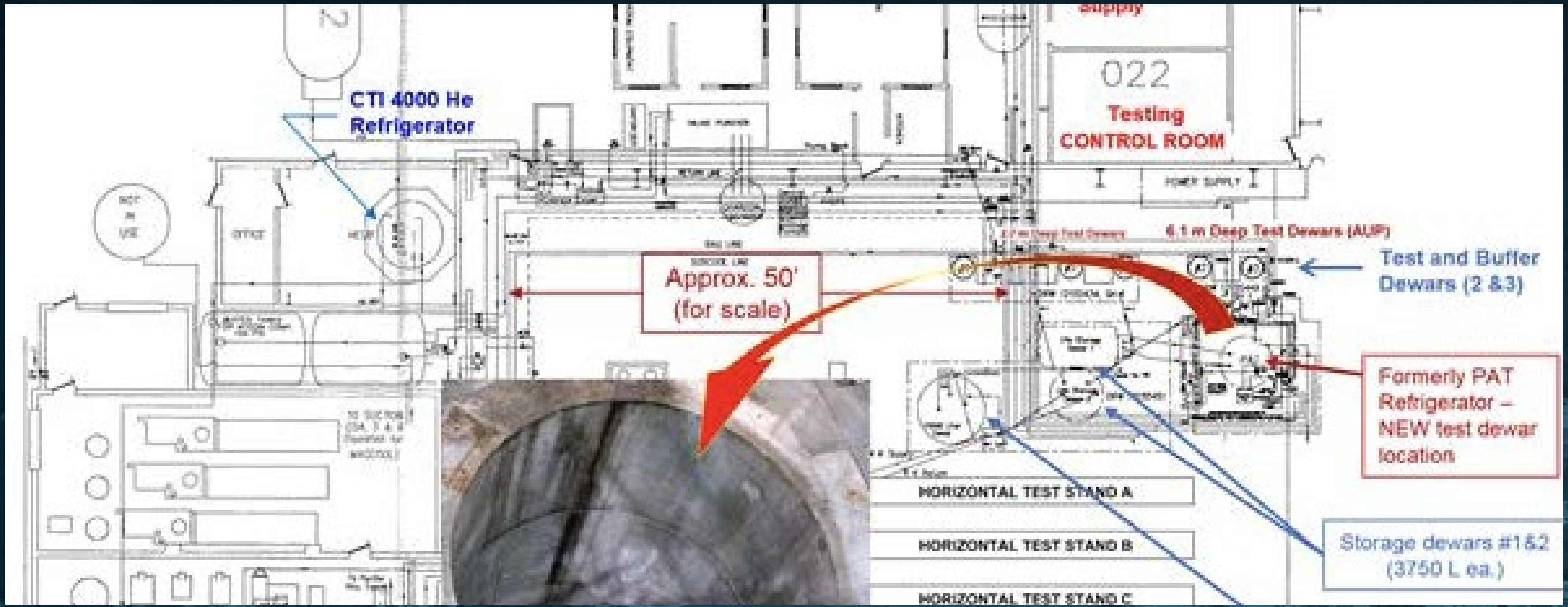


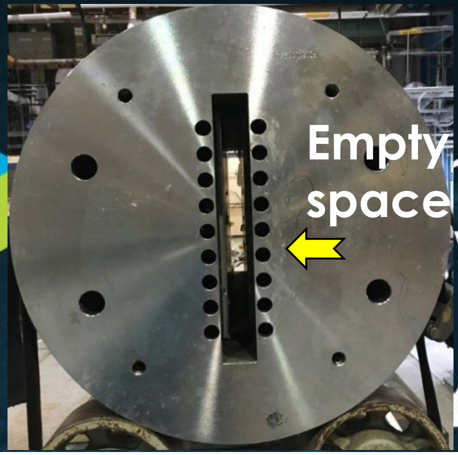



Commonwealth Fusion Systems Founding Partners

INITIAL ENGAGEMENTS WITH INDUSTRY

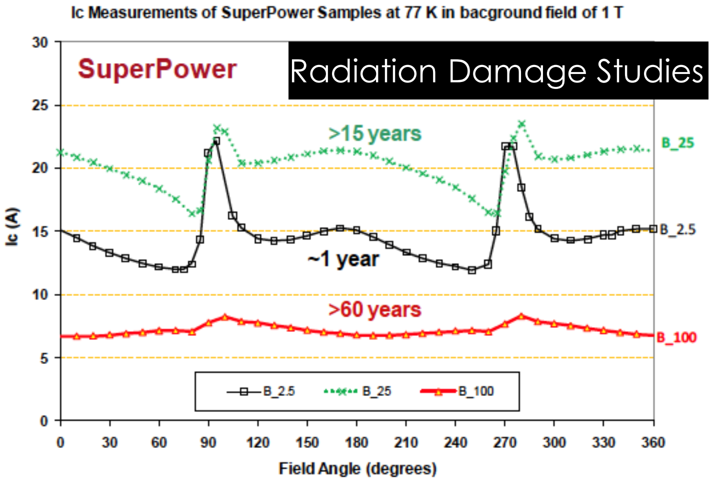
- Strategic Partnership with Commonwealth Fusion Systems (CFS)
  - MIT University Partner
- Initial Cable Samples Tested with Support of BNLFunding
- Internal Funding Also Enabled Engagement with Other Industrial Partners (including International)
  - >$1.5M in additional projects
  - Ongoing Grant Proposals with 6 Partners
- Subsequent INFUSE and ARPA-E Grants with CFS
  - INFUSE - Initial Seed Funding of $170K with CFS
  - ARPA-E - $400K Award with CFS
  - 2 Additional INFUSE Proposals funded with Developed Fusion Partners
  - Multiple proposals in the pipeline
- Industrial Partners Expressed Need For Specific Testing Capabilities
  - 20K Test Stand – under development
  - Conductor Irradiation Studies

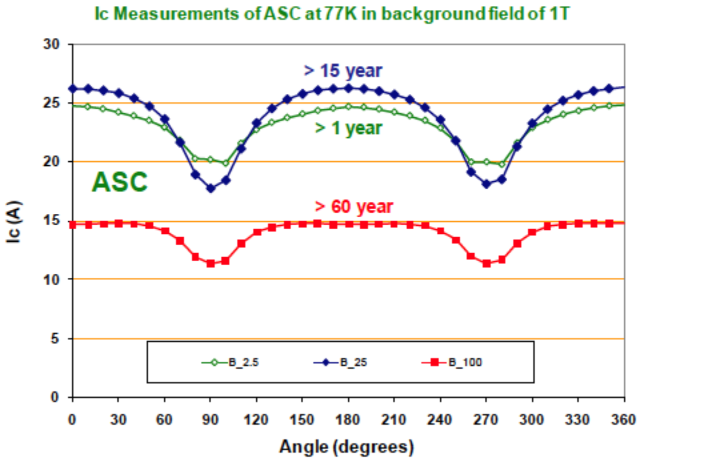




Potential for Expanded Engagement

- Large-Bore Test Pit and Upgraded Magnet Test Facility
  - Ability to carry out these tests independently
  - Quick turn-around and reliable test facility
  - 20K Test Capability with Construction of New Cryostat
  - Ability to test cables at 30-50 kA in short term and ~100 KA in long term
- Conductor Irradiation – Strong HTS Sensitivity of 2G HTS to Proton Irradiation Previously shown – could potentially expand to irradiation during testing at tandem accelerator





A Unique US HEP/FES Facility at BNL– Status and Proposed Upgrades

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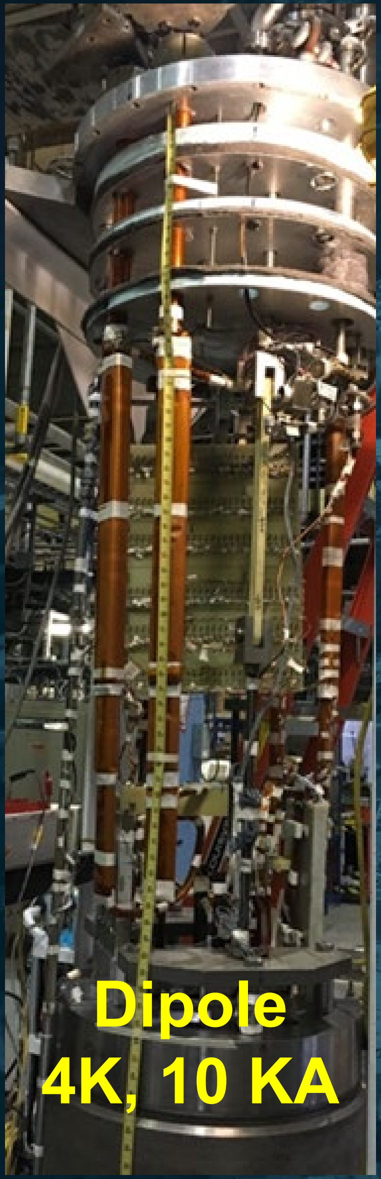
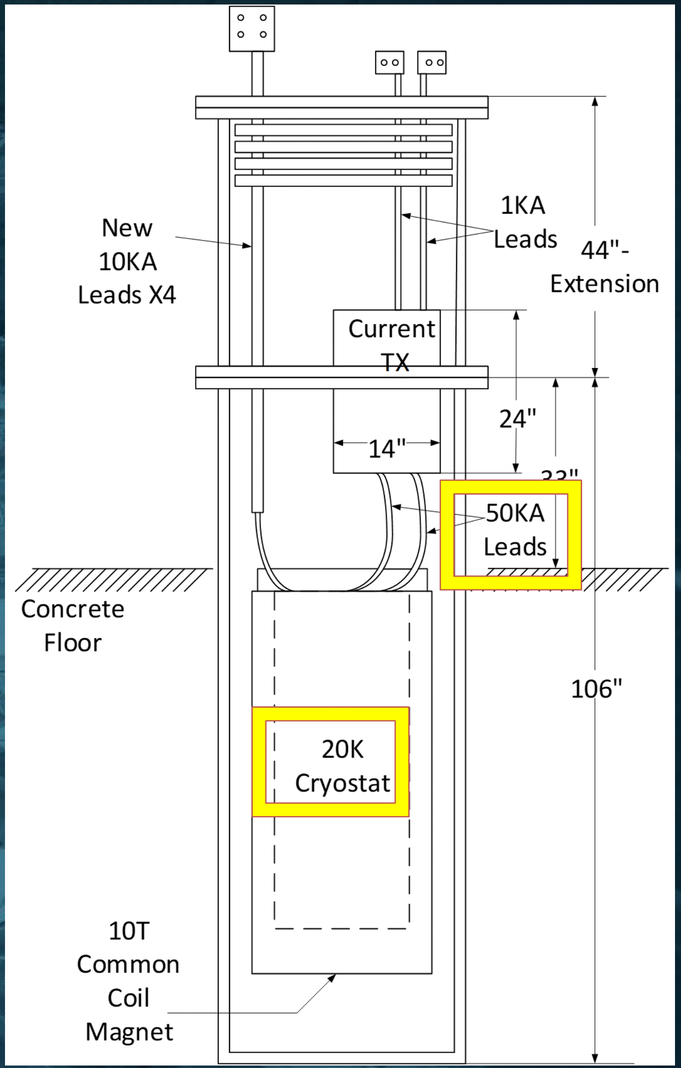
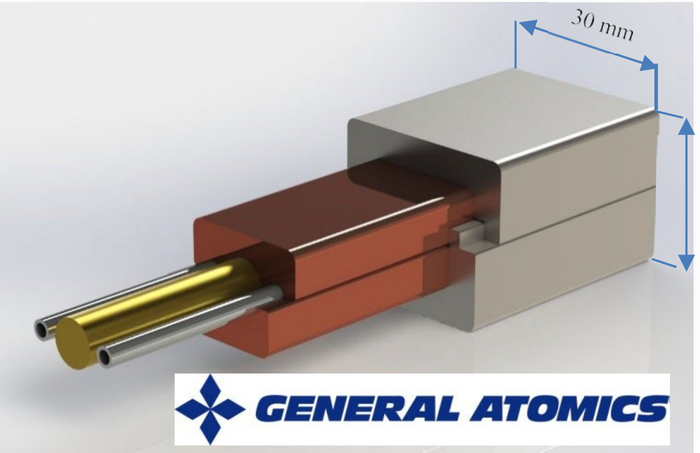


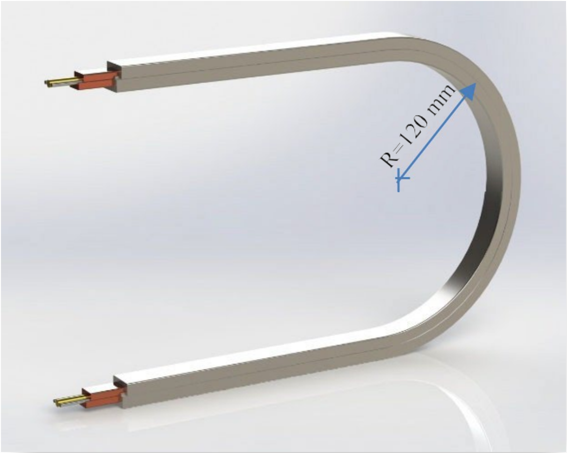
- The current facility provides a field of 0 -10 T at ~4 K and up to 10 kA in cable if connected in series with the magnet
- BNL internal funds are being used to develop
  - 1-50$^+$ kA on cable/joints with superconducting transformer
  - 4-50$^+$ K test temperature for users with a secondary cryostat
  - ~40 m long cable in dipole field, 150-500 mm bend diameter
- This 10 T dipole test facility is complimentary to SULTAN (solenoid-based), and a facility available to users in US now

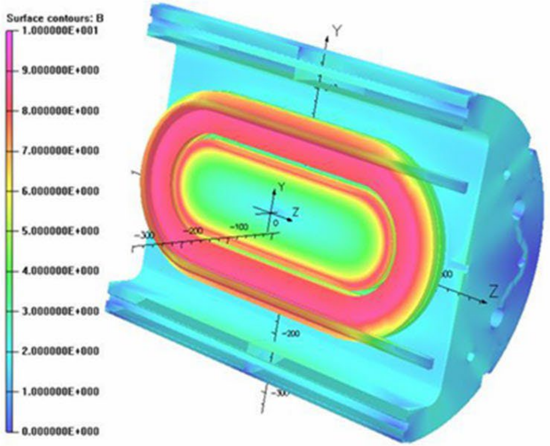


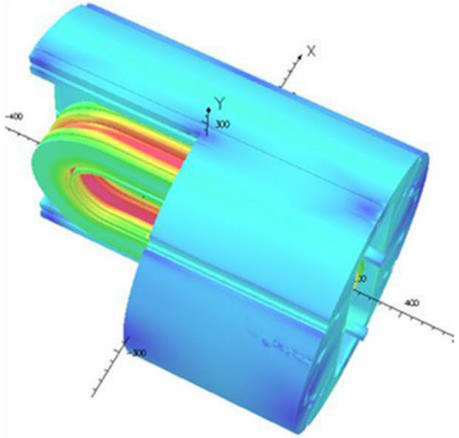
Variety of Upcoming Cable Tests

- ✓ Twisted Stacked/Viper from CFS (INFUSE) - two tests completed
- ✓ Magnum NX™ from SMS (INFUSE) – Performance under field - funded
- ➢ Two tests of Viper cable from CFS (arpa-e) – completed
- ➢ CORC from ACT (MDP) – Quench and technology studies – funded (also ACT/BNL STTR)
- ➢ Cable-in-conduit for fusion magnets from BTG (SBIR) – Phase I funded
- ➢ CICC from GA (INFUSE) – proposal submitted



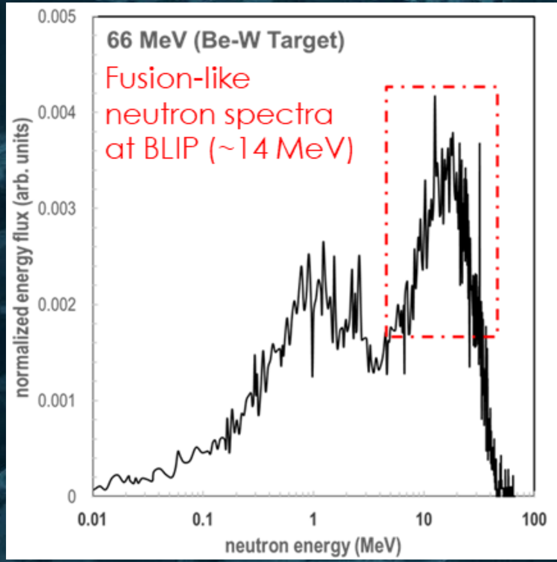






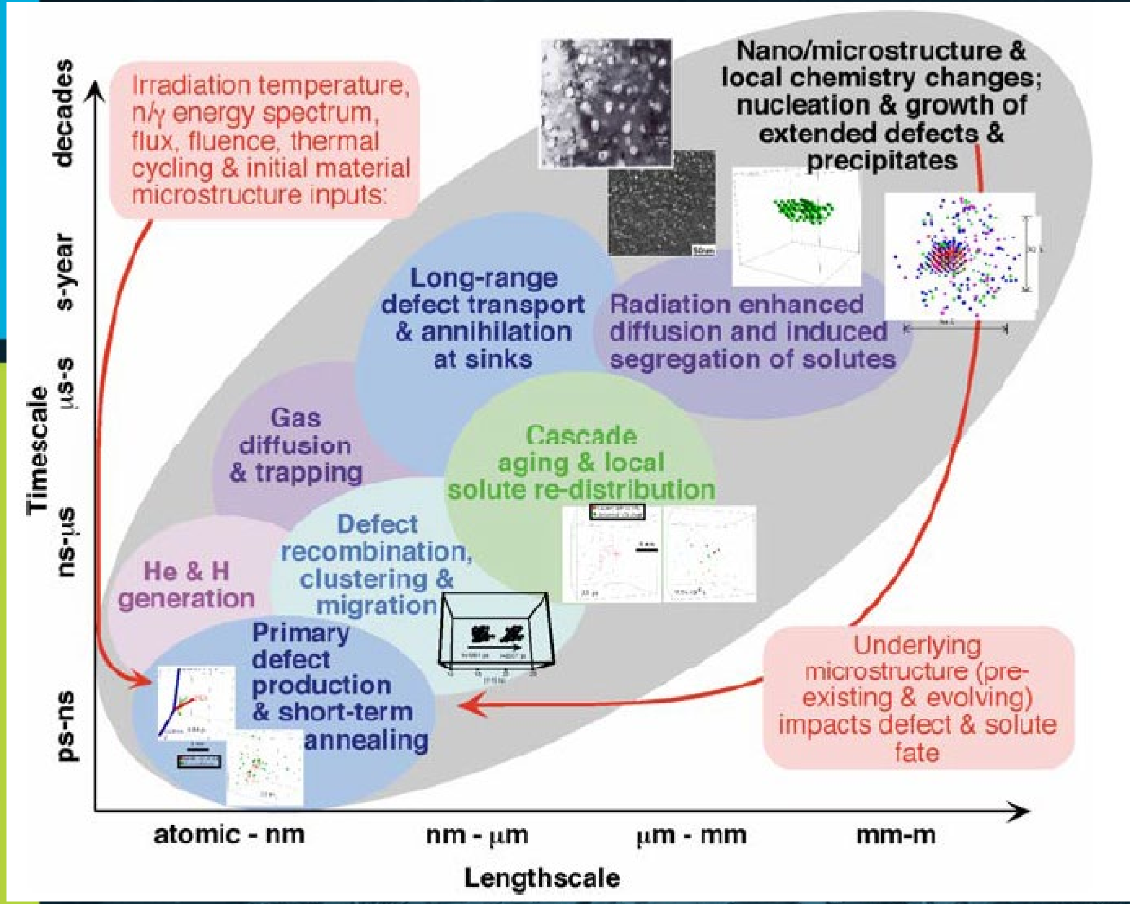
Extreme Environments for Structural Materials:

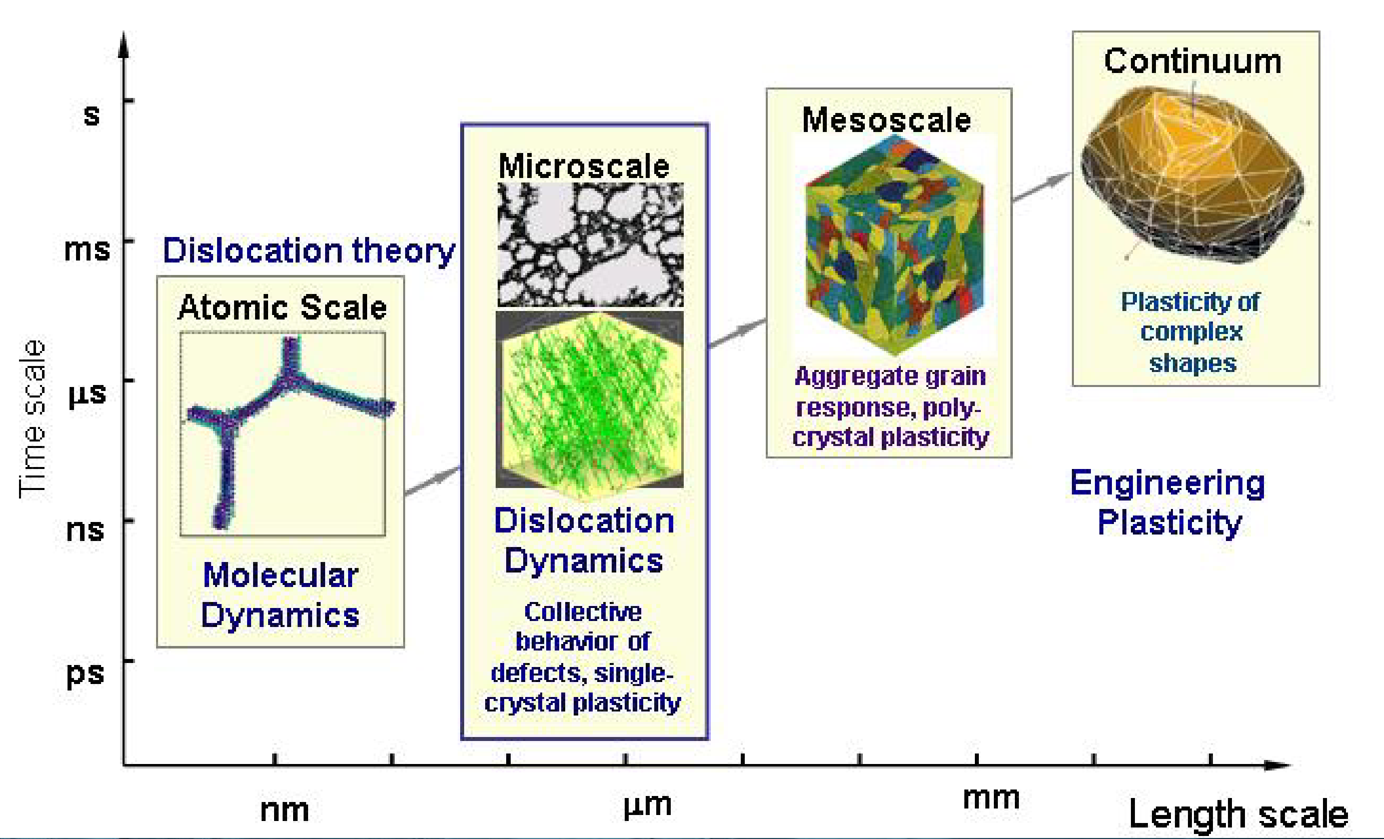
- Fission Reactors and Magnetic Fusion Systems



	Fission reactors			Magnetic Fusion	
	Commercial light-water reactors	Gas-cooled thermal reactors	Liquid metal fast reactors	Tritium breeding blanket and first wall	Divertor system
Structural Materials	Zirconium alloys, stainless steel, Incaloy	Graphite	Martensitic steels	Advanced ferritic steels, V alloys, SiC/SiC composites, refractory alloys (Ta, Nb, Mo, W)	Tungsten, graphite
Maximum thermal power load				5–7 MW/m^2	15–20 MW/m^2
Structural alloy maximum temperature	<300°C	~1000°C	<600°C	550–700°C (1000°C for SiC)	>1000°C
Maximum radiation dose	~1 dpa	~1–2 dpa	~30–100 dpa	~150 dpa	~150 dpa
Maximum transmutation helium concentration	~0.1 appm	~0.1 appm	~3–10 appm	~1500 appm (~10,000 appm for SiC)	~1500 appm (~10,000 appm for SiC)
D,T ion flux				1 W/cm^2 (at 10 kev/ion	~2–3 W/cm^2 (at 10 kev/ion
Magnetic field strength				~6–7 T	~6–7 T

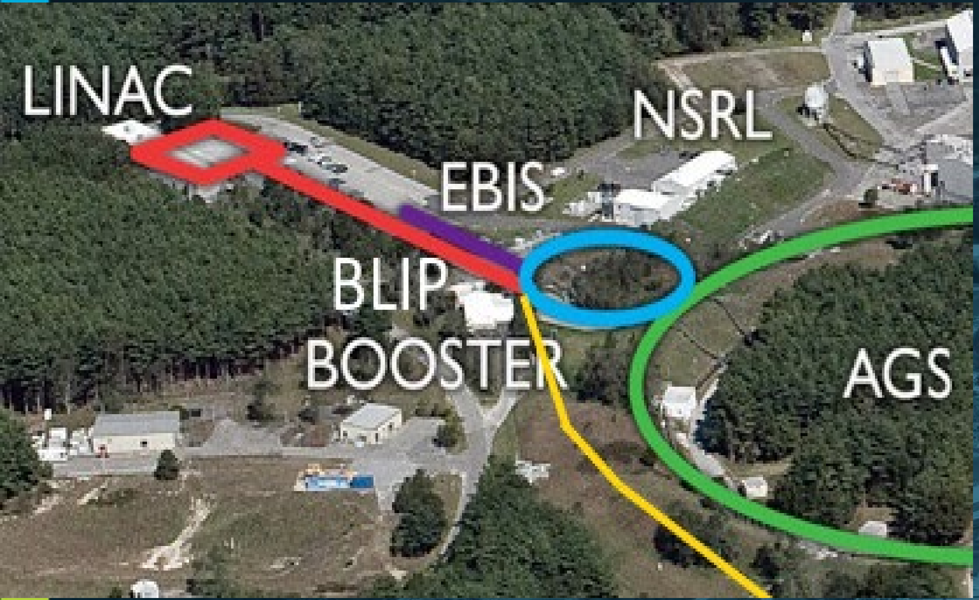
Challenges of Connecting Scales: Materials in Extreme Conditions

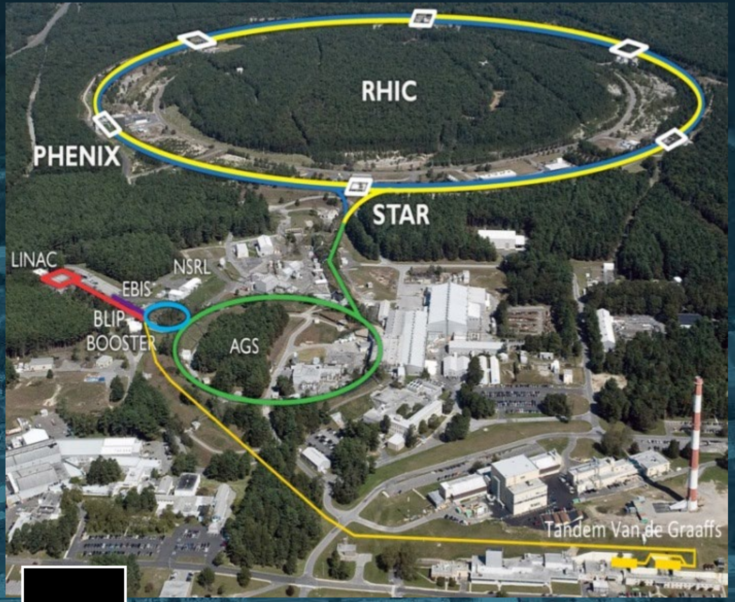




Irradiation to Microstructural Analysis
⇨ A Unique BNL Accelerator Cross-Cut

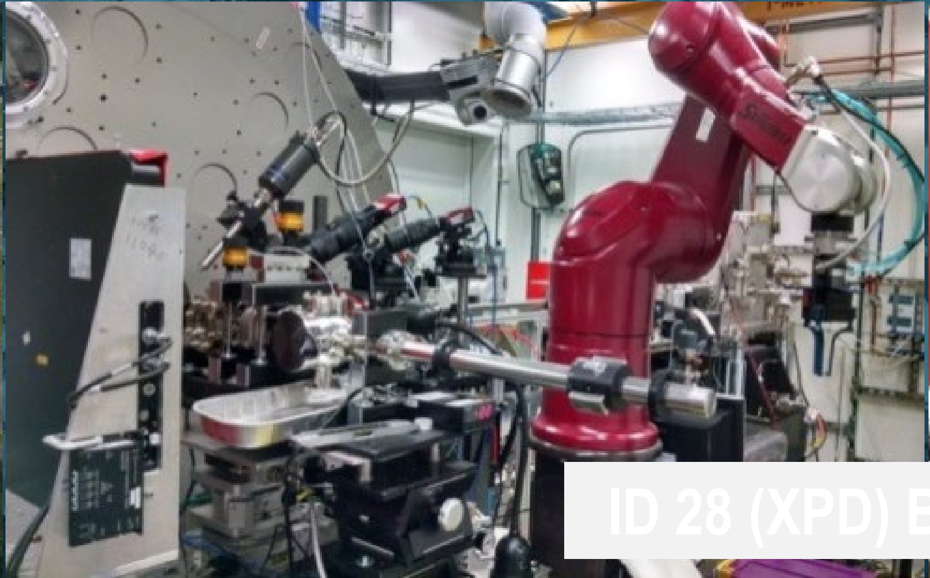
Synergies with the BNL Accelerator Complex

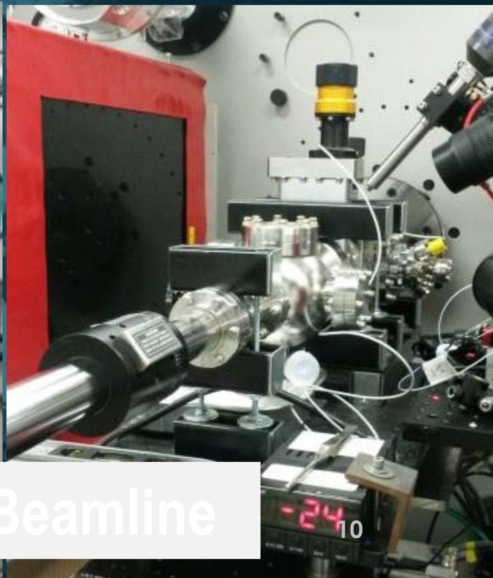




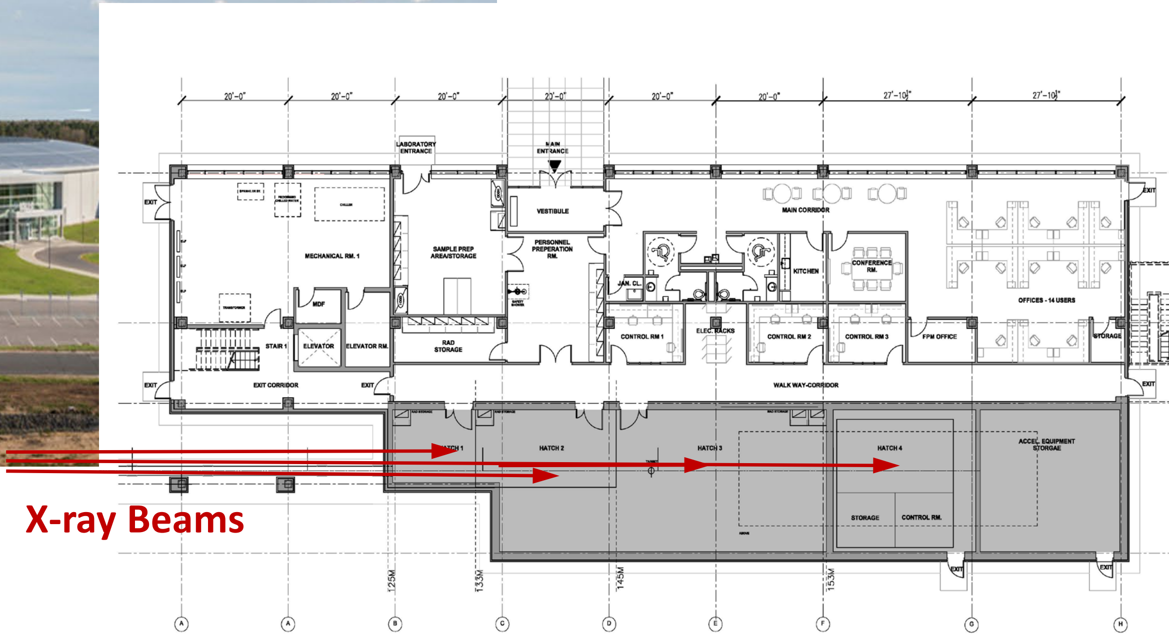
Collider Complex

NSLS II Synergy





Vision: Materials in a Radiation Environment Facility



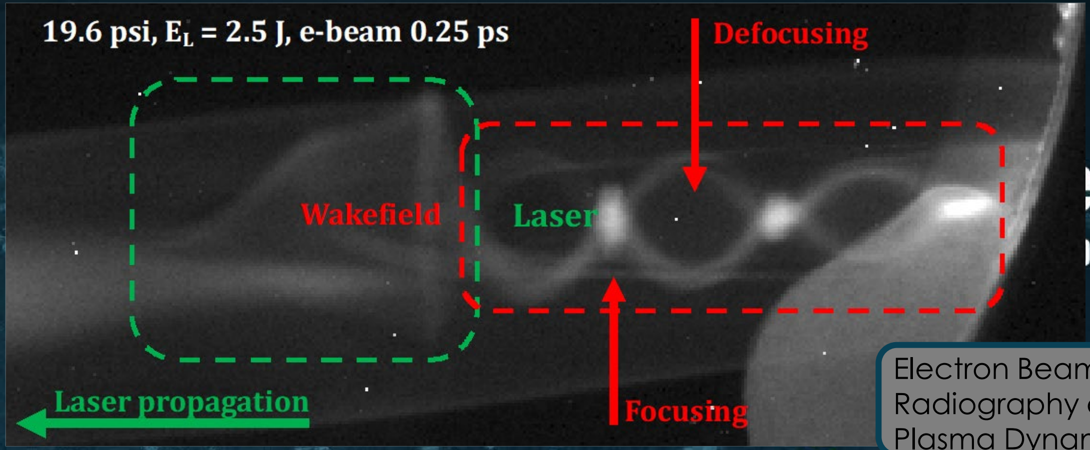
MRE will be an external facility optimized for Post Irradiation Examination research with higher dose limits and provision for particle accelerators

- Up to three independently operating hard X-ray branch beamlines
- *In situ* characterization capabilities (P, T, stress, electric field)
- Radioactive samples: fuel, dispersibles, transuranics, nondestructive, minimal sample preparation, bulk samples for real interfaces

A world-leading synchrotron facility for the nuclear and fusion material science community

Plasma Science in the LWIR Laser Driver Regime

- Multi-Beam Studies of Plasma Dynamics
- studies of plasma response to intense, relativistic laser pulses @100x lower target densities than can be utilized at NIR facilities
  - wake fields
  - particle beam generation
    - Protons, Ions, neutrons
  - plasma instabilities (e.g. Weibel instability)



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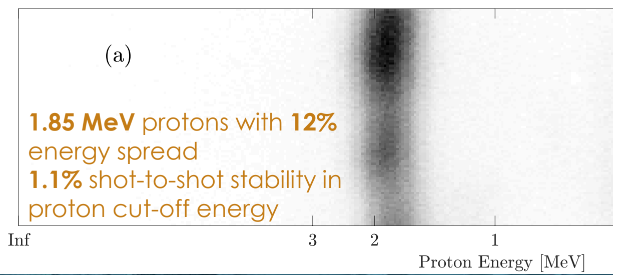
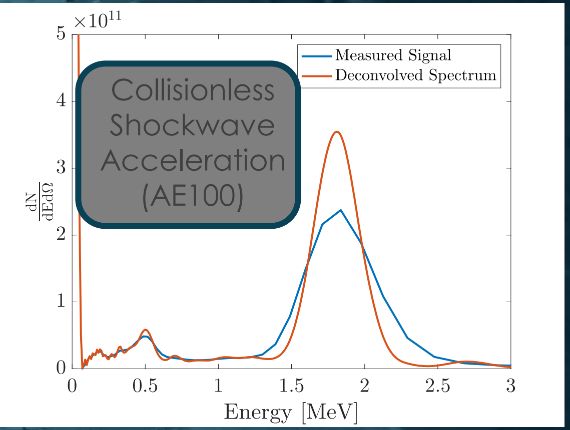
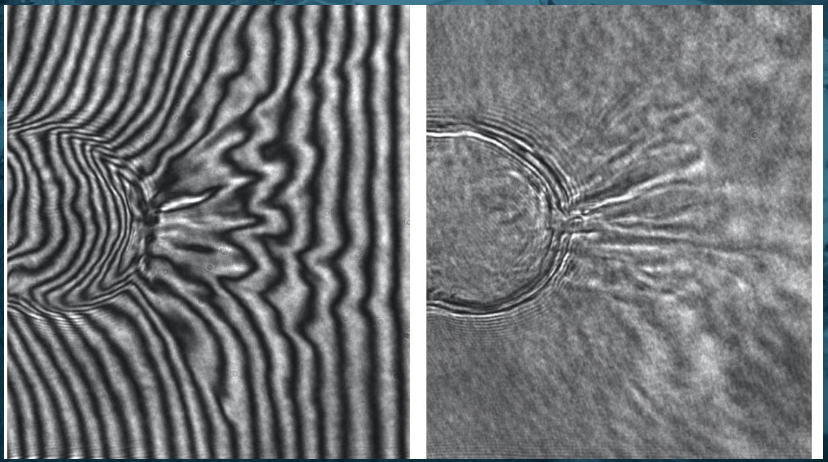




Collisionless Shockwave Acceleration (AE100)

LWIR ⇨ Flexible Gaseous Target Capability



Concluding remarks

BNL is utilizing its strengths in the accelerator technology space to contribute to fusion development

We are partnering with LBNL/ONRL/PPPL/ASC and others on fusion technology development with monthly calls to develop collaborations

We welcome collaboration with companies, academia and other national labs in the fusion space