IRRADIATION EXPERIMENTS & FACILITIES AT BNL: BLIP & NSLS II

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BROOKHAVEN NATIONAL LABORATORY

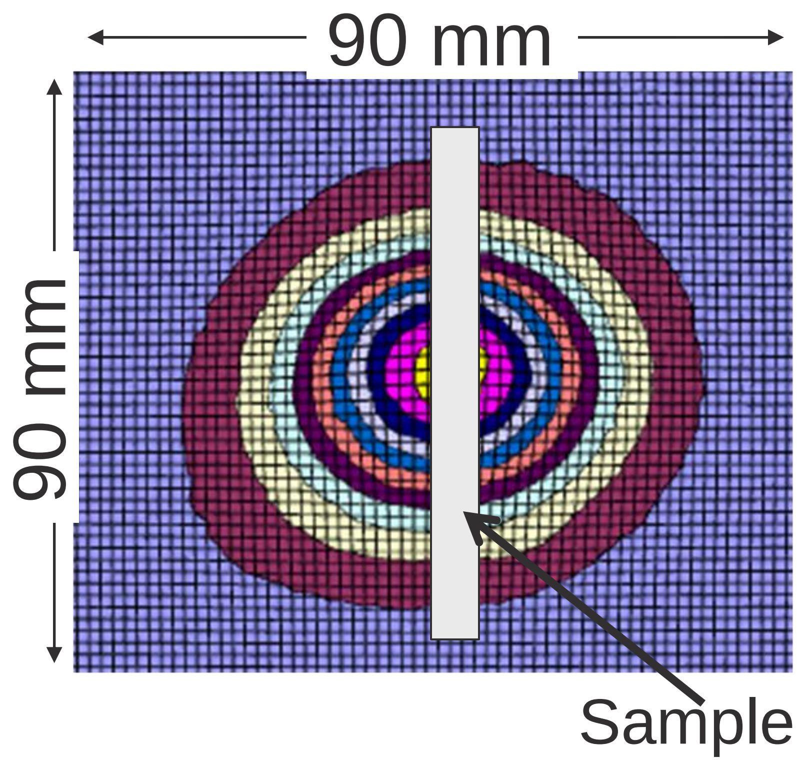
a passion for discovery

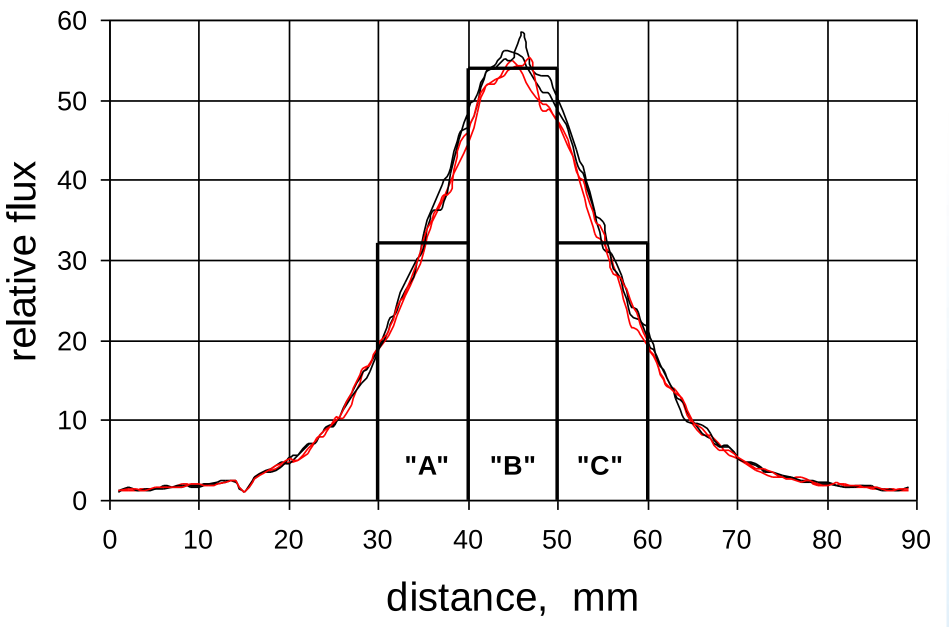
Office of Science U.S. DEPARTMENT OF ENERGY

Brookhaven Linac Isotope Producer (BLIP)

- Schedule: ~ 6 months/year (during RHIC operation)
- Principal task: isotope production for medical etc. use (proton beam, 117 MeV).
- Simultaneous irradiation and isotope production by increasing beam energy, placing irradiation target ahead of isotope production target
  - 117 Mev → 140, 160, 180, 202 MeV
  - Irradiation at room temperature
- Alternative: irradiation target *behind* isotope target, for irradiation by neutrons and scattered protons.

Proton Beam Profile



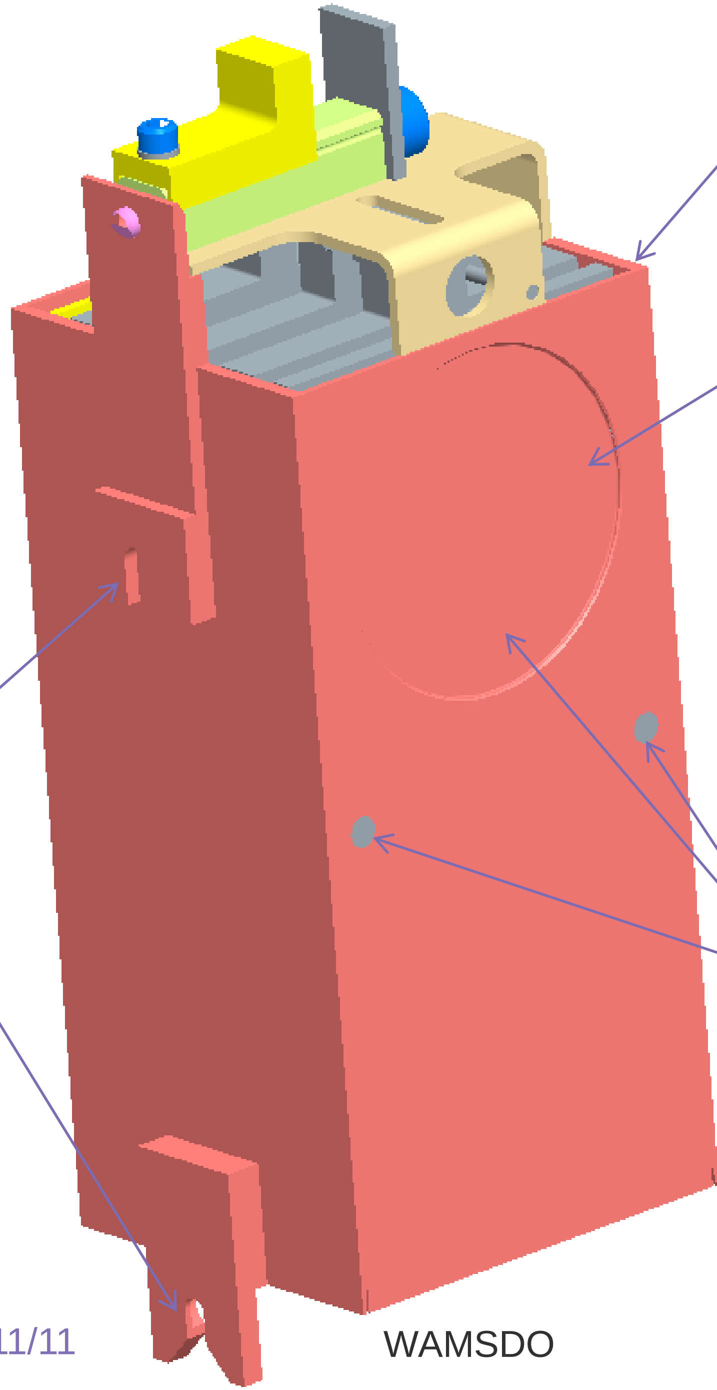


The BLIP proton beam cross-section deduced from a gamma scan of the activation foil irradiated with the samples. The grid is in mm.

The position of the three 1 cm segments in the beam cross section Section B sees a proton flux varying by less than ±5%

More BLIP info

- Target holder interior dimensions ~ 100 mm wide, 100 mm high, 75 mm deep.
- Two target holders per assembly.
- Target assembly immersed in water for cooling (flow: 200 liters per minute).
- Current user: LBNE – materials for Project X.
  - Long Baseline Neutrino Experiment – Abandoned gold mine northwest of Fermilab (DUSEL)
  - Measurements (yield strength, stress, CTE) in hot cell at BNL



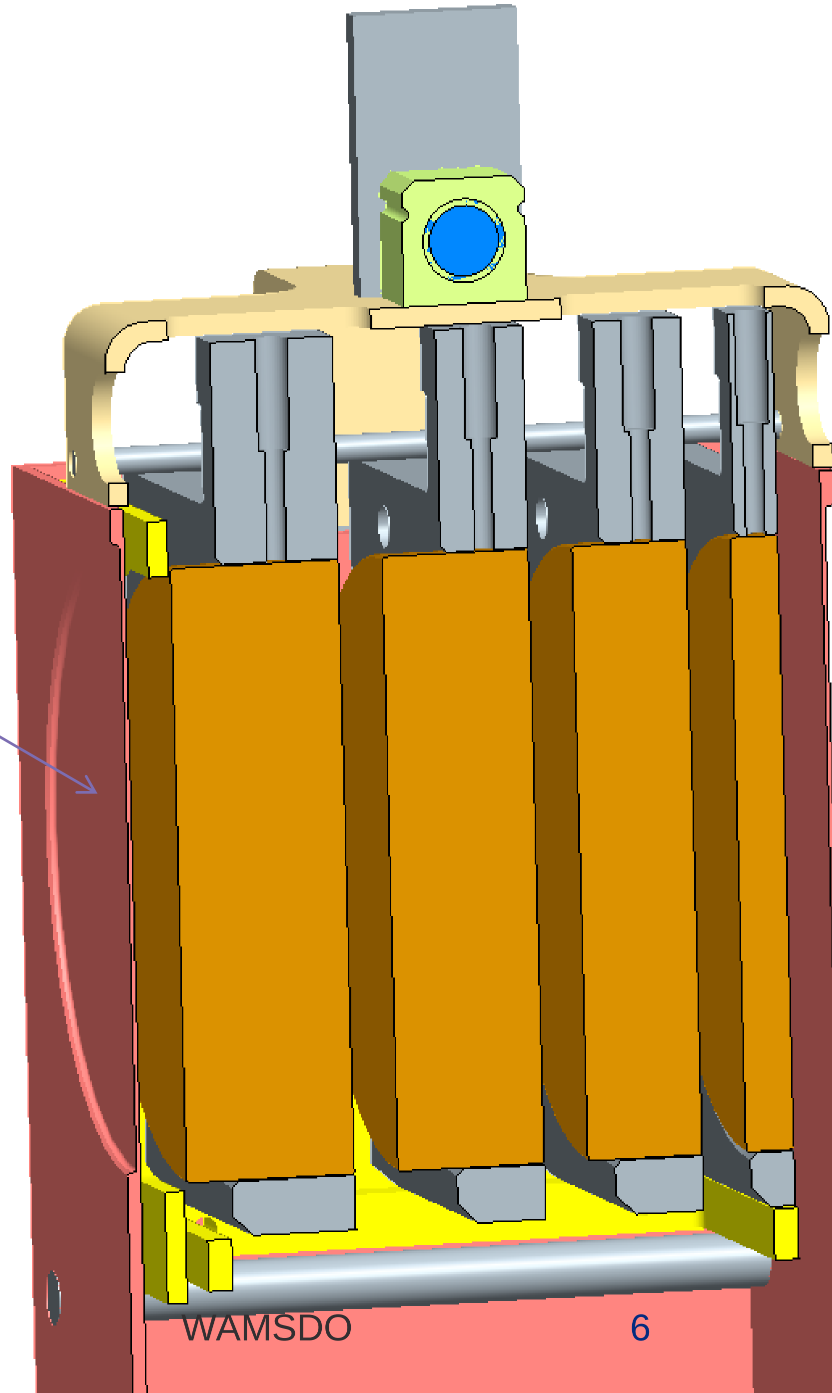
Added .437” of material to this surface

Windows machined integral to box

Basket mounts

Window & basket mounts moved up .437” relative to box mounts for improved beam alignment.

Windows machined integral to box

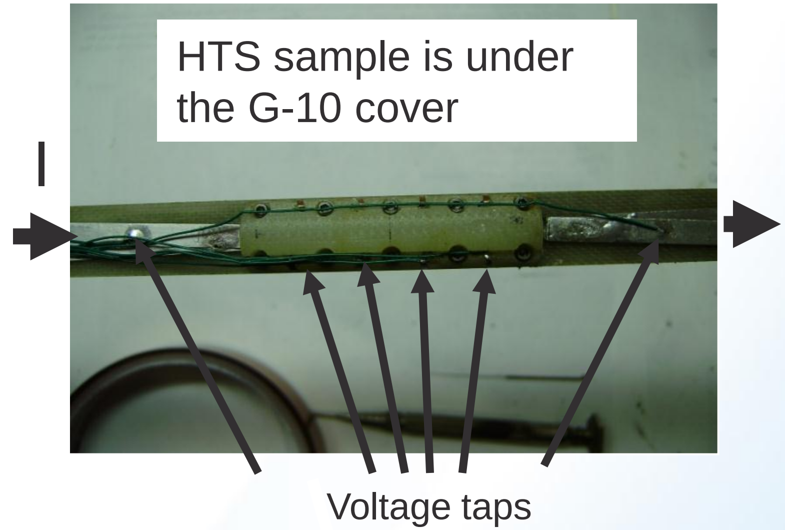


Sample and Irradiation Details of 4 mm wide YBCO conductor

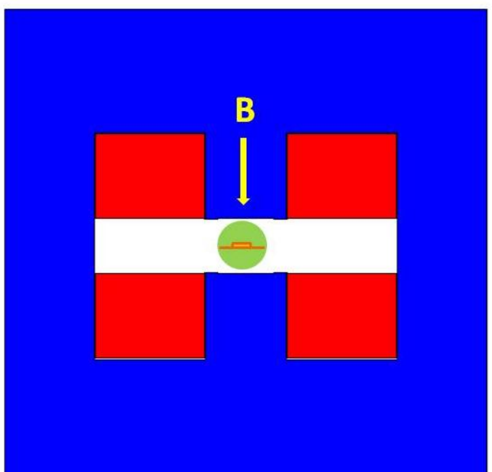
- 7 cm long samples were mounted on five aluminum frames and inserted into the water-filled target tank of the **Brookhaven Linac Isotope Producer (BLIP).**
- The irradiation was done at **142 MeV** with a beam current of 40 µA, and different levels of proton flux were achieved by progressively removing the aluminum frames after specific times to give 2.5, 25, 50, 75, and 100 µA-hrs of irradiation.
- 100 µA-hrs is equivalent to a fluence of $3.4 \times 10^{17} cm^{-2}$

Experiment

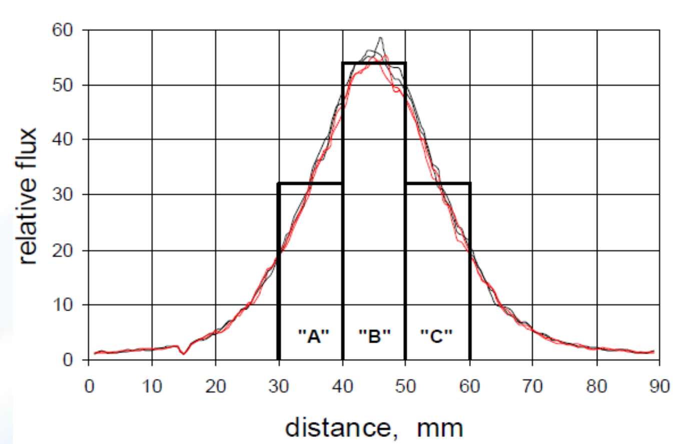
- Three 1cm sections of each conductor are measured.
- YBCO samples are irradiated at the Brookhaven Linac Isotope Producer (BLIP) (G.Greene)
- Levels of proton fluence are 2.5, 25, 100 mA hrs.
- B is positioned to be at the center of the beam.
- Open cryostat. Samples are directly cooled by LN2.
- Magnetic field (0.25T, 0.5T,0.75T, 1.0T and 1.25T) are provided by a non-superconducting magnet.



Angle=0:



The normal to the tape plane is parallel to the external magnetic field



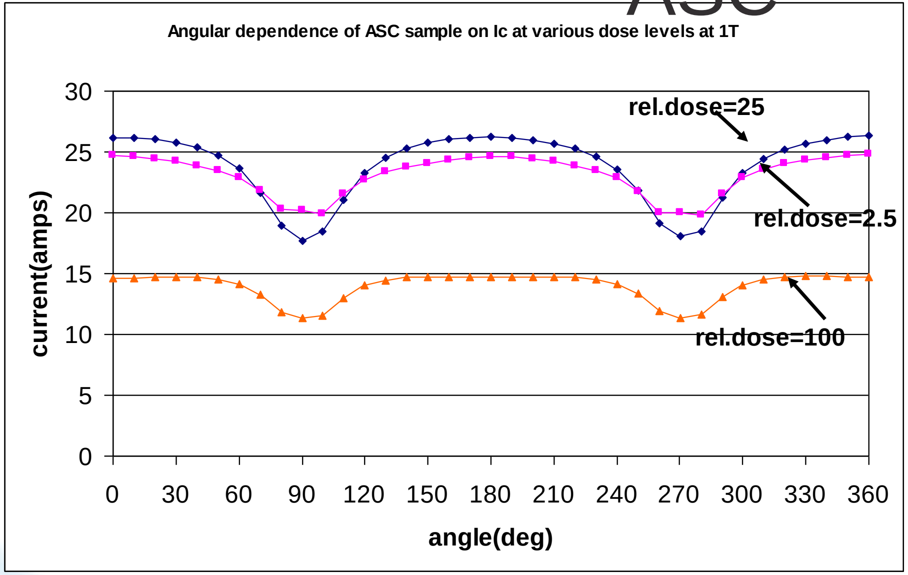
courtesy G.Greene and B.Sampson

Rel.dose=25

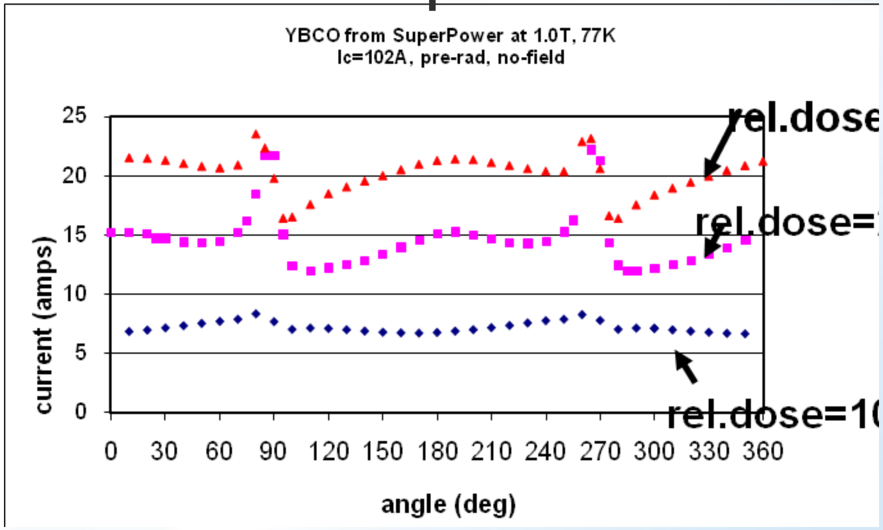
- In actual FRIB system, estimated rel.dose would be ~10. rel.dose=25 is close to the actual dose.
- I_c of rel.dose=25 was expected to be between I_c of rel.dose=100(highest) and rel.dose=2.5 (lowest).

However…

ASC



SuperPower



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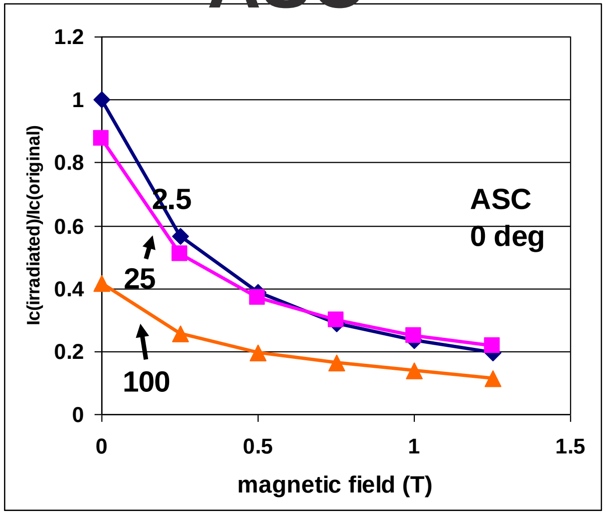
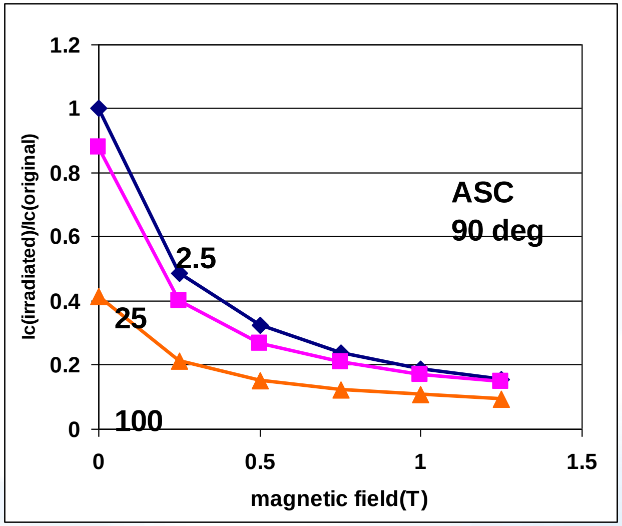
I_c vs magnetic field

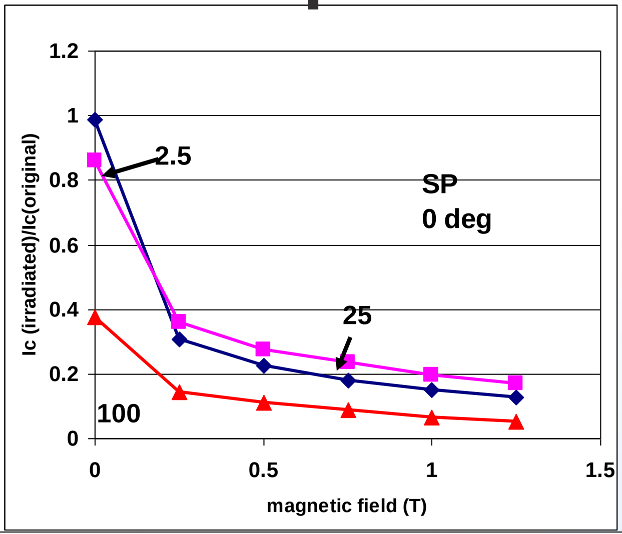
- As field increases, Ic decreases monotonically for any radiated samples.
- Rel.dose=25 gives slightly higher Ic than rel.dose=2.5 in
- some magnetic fields. This effect is clear in SuperPower sample but not in ASC sample.

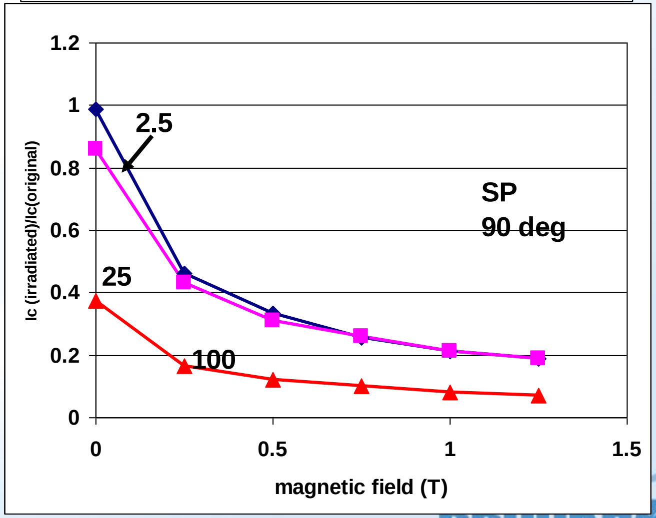
ASC





SuperPower

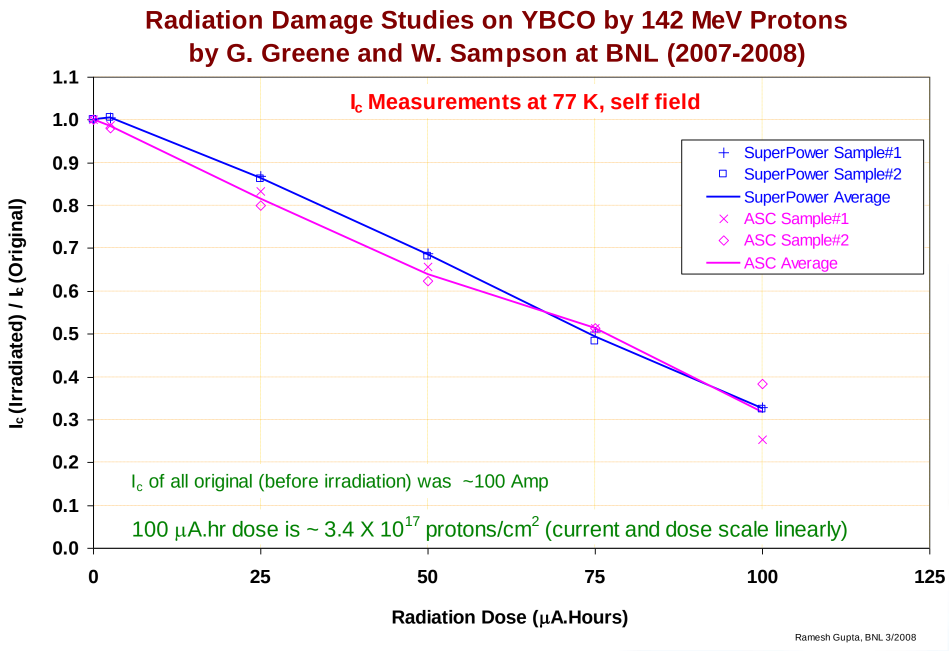




Measured I_c at 77K, self field

Critical current (I_c) of samples was measured before and after irradiation at 77 K, self field.

I_c of all samples before radiation was ~100 A.



As radiation dose increases, I_c decreases monotonically for both ASC and SuperPower YBCO samples (courtesy G. Greene and W. Sampson)

YBCO and Nb_3Sn

- YBCO (High Temperature Superconductor)
  - Target cooled off to “no detectable radioactivity”. Had surface contamination. → Test in dewar in “clean” area, behind “caution” tape and sign (i.e., not in hot cell)
  - Annealing varied with dose (low dose → no anneal)
  - Not production material.
- Nb_3Sn – ITER material
  - Annealing at room temperature not significant.
- Nb – “pure Nb has 600 ppm Ta – long-lived radioisotopes after irradiation.

PROPOSED ENDSTATION FOR NEW BNL LIGHT SOURCE, NSLS II

- Endstation for radioactive materials
  - 30 – 80 keV monochromatic photons
  - Beam diameter: 10 μm
  - Techniques: Diffraction, imaging
- Endstation for real-time, in situ studies w. photons
  - 1 MeV tandem for heavy ions
  - 200 kV accelerator for H, He
  - Ion beam diameter: μm to mm
  - Time resolution: μs to ms
- Supporting infrastructure
- Presentation to Advisory Committee 17 Nov.

Credits

- BLIP: L. Mausner, A. Ghosh
- YBCO measurements: R. Gupta, G. Greene, W. Sampson, Y. Shiroyanagi
- NSLS II: A. Ghosh, L. Ecker

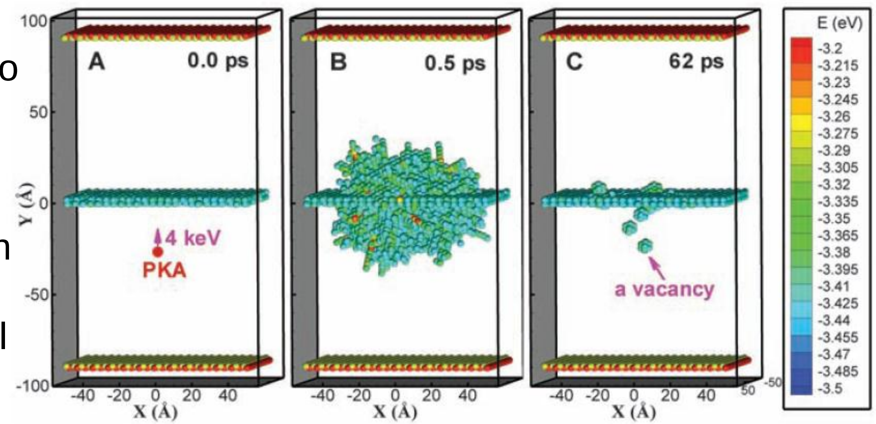
Real time and in-situ studies of Materials in a Radiation Environment (MRE)

MRE at NSLS II

- Ion accelerators for in situ experiments of radiation effects and mesoscale microstructural changes due to radiation
- Separate endstation for radioactive materials
- Will enable studies of new materials for reactors, nuclear fuels and structural materials in high radiation environments
- Data for verification of computer simulations, material performance during off-nominal conditions, and licensing

Examples of Science Areas & Impact

- NUCLEAR STRUCTURAL MATERIALS: Role of interfaces in radiation resistant materials
- NUCLEAR FUELS: Characterization of spent fuel, metal fuels, and new synthesis routes for oxide fuels
- NATIONAL SECURITY: material characterization for nuclear forensics
- SEMICONDUCTOR FABRICATION: Understand the effect of doping induced defects on semiconductor performance



Displacement Cascade Near a Grain Boundary
Bai, et al. Science, 2010

Beamline Capabilities
Techniques: Diffraction, Imaging, Spectroscopy
Source: Damping or superconducting wiggler
Energy range: 10-90 keV
Time resolution: msec-µsec
Beam Size: > 1 µm

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