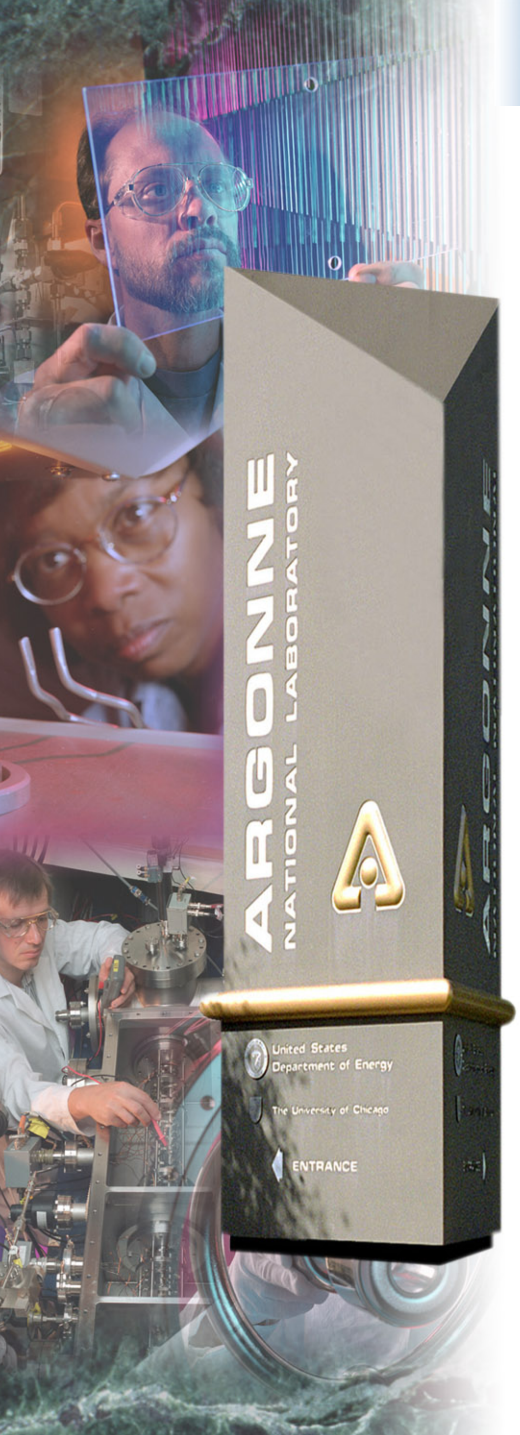

ARGONNE NATIONAL LABORATORY

Material Damage Studies for RIA via Uranium Beam Irradiations

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2nd High-Power Targetry Workshop

Oak Ridge National Laboratory

October 10-14, 2005

THE UNIVERSITY OF CHICAGO

Office of Science
U.S. DEPARTMENT OF ENERGY

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Introduction

- Study radiation damage on potential beam dump materials: 400 kW beam dumps for uranium beams of RIA
- Use 5 MeV/u uranium beams at the ANL ATLAS facility
- Measure hardness changes in Al, Ti, and Cu at peak DPA from 0.001 to 10.
- Irradiate thin samples of Al and Cu for TEM studies of structural damage
- Look for indications of saturation effects in materials properties
- Look for “swift heavy ion effects” (modification of damage due to very high electromagnetic dE/dx)

Proposal for uranium beam irradiations at ATLAS

Measuring Radiation Damage from the Stopping of Uranium Beams in Material

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Proposal for uranium beam irradiations at ATLAS: Abstract

We propose to measure the impact on material properties from the stopping of intense uranium beams in regimes relevant to the primary beam stop of the RIA fragmentation line. Since initial experiments and simulations indicate most of the damage occurs near the end of the uranium beam range, much can be learned from the 6 MeV/A ATLAS that is relevant to 320 MeV/A residual primary beam expected at RIA. We propose to irradiate a number of aluminum samples for various times to study material properties as a function of damage and samples of Be, Ti, and Cu to study the dependence on the choice of the material. After irradiating the samples, nano-indentation tests, which will give hardness as a function of depth in the samples, electrical conductivity tests, and transmission electron microscopy tests will be performed. Much of this post analysis will be done on the ANL site in B212, though some additional testing may require the samples shipped offsite.

PHITS simulations of damage

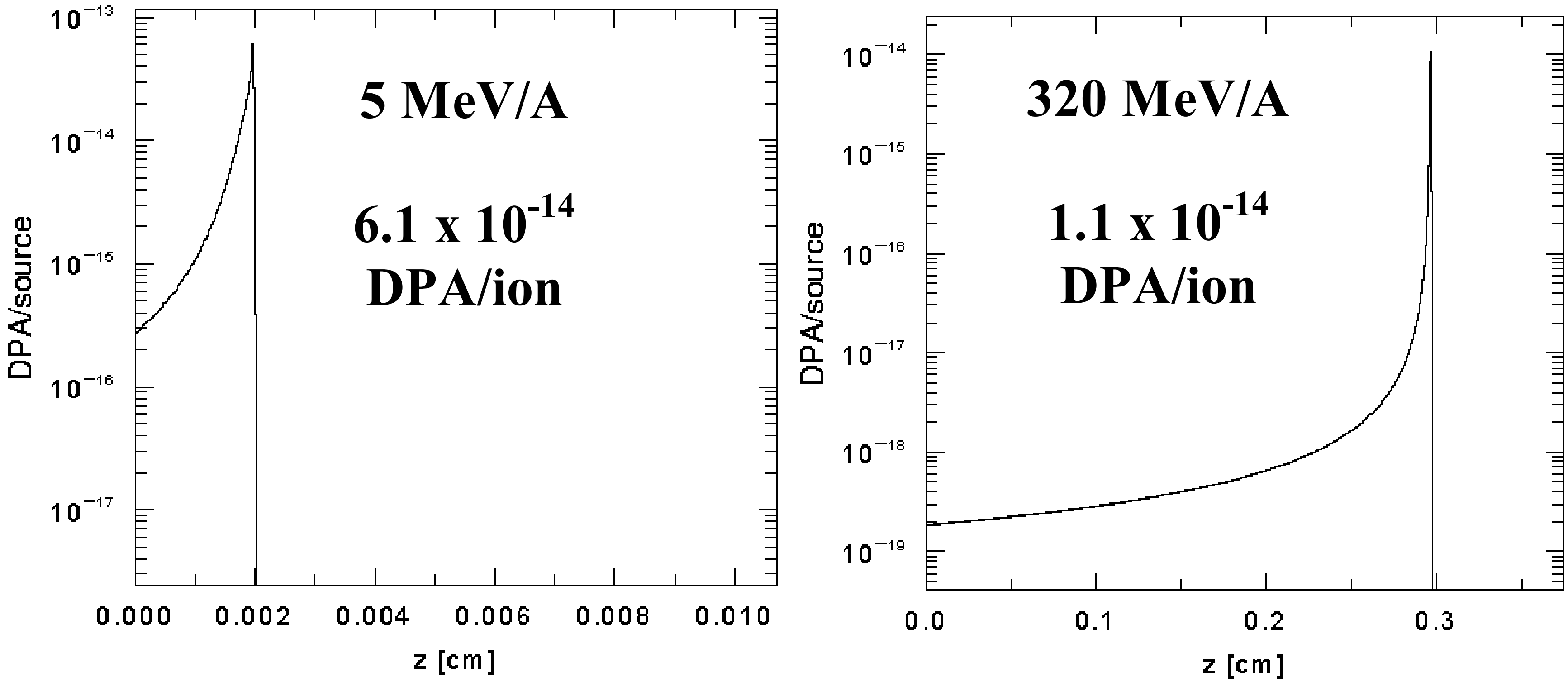


Figure 1: PHITS simulations showing DPA/source particle as function of depth for uranium beams of two different energies on copper.

Saturation effect observed in copper with protons and neutrons

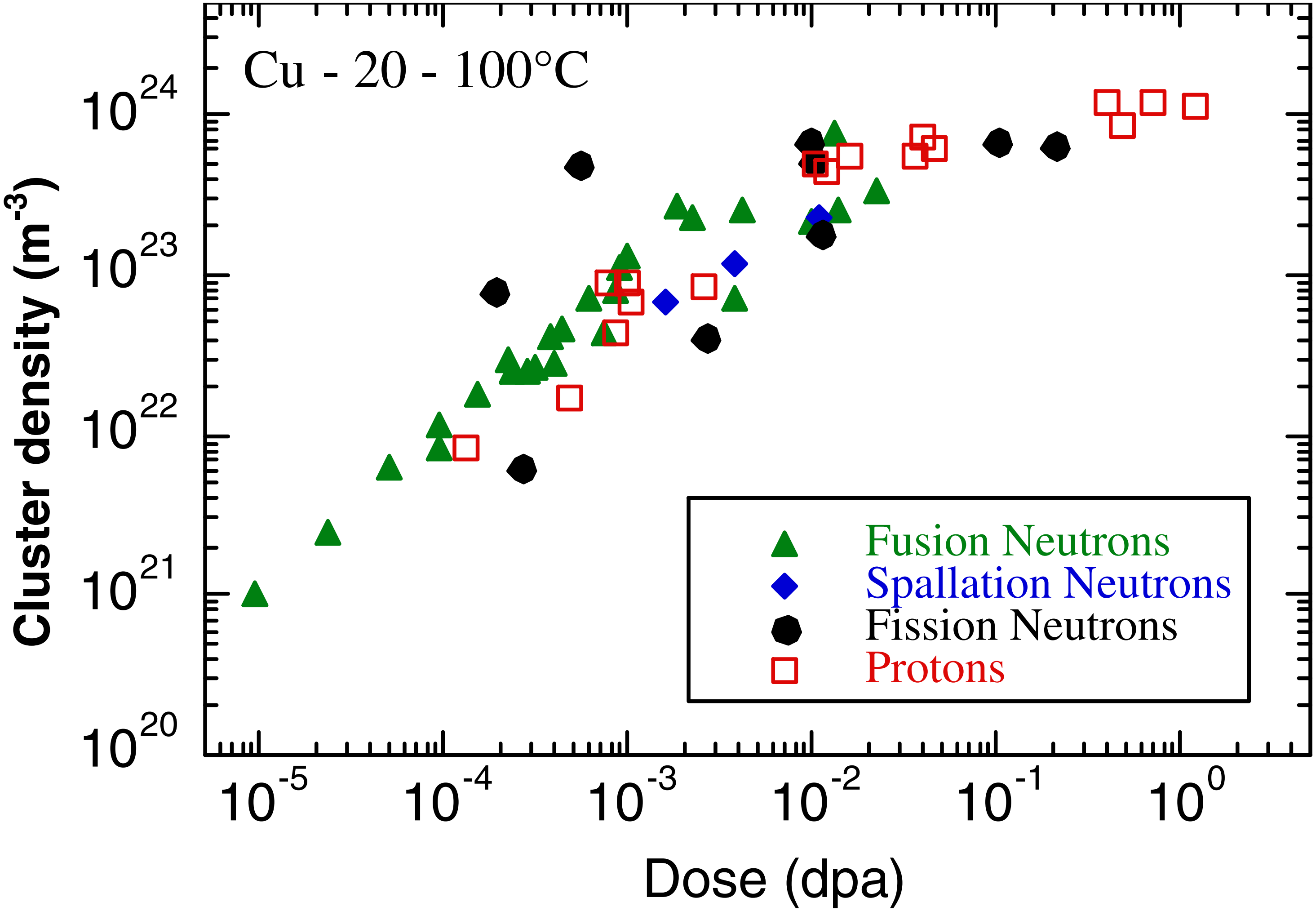
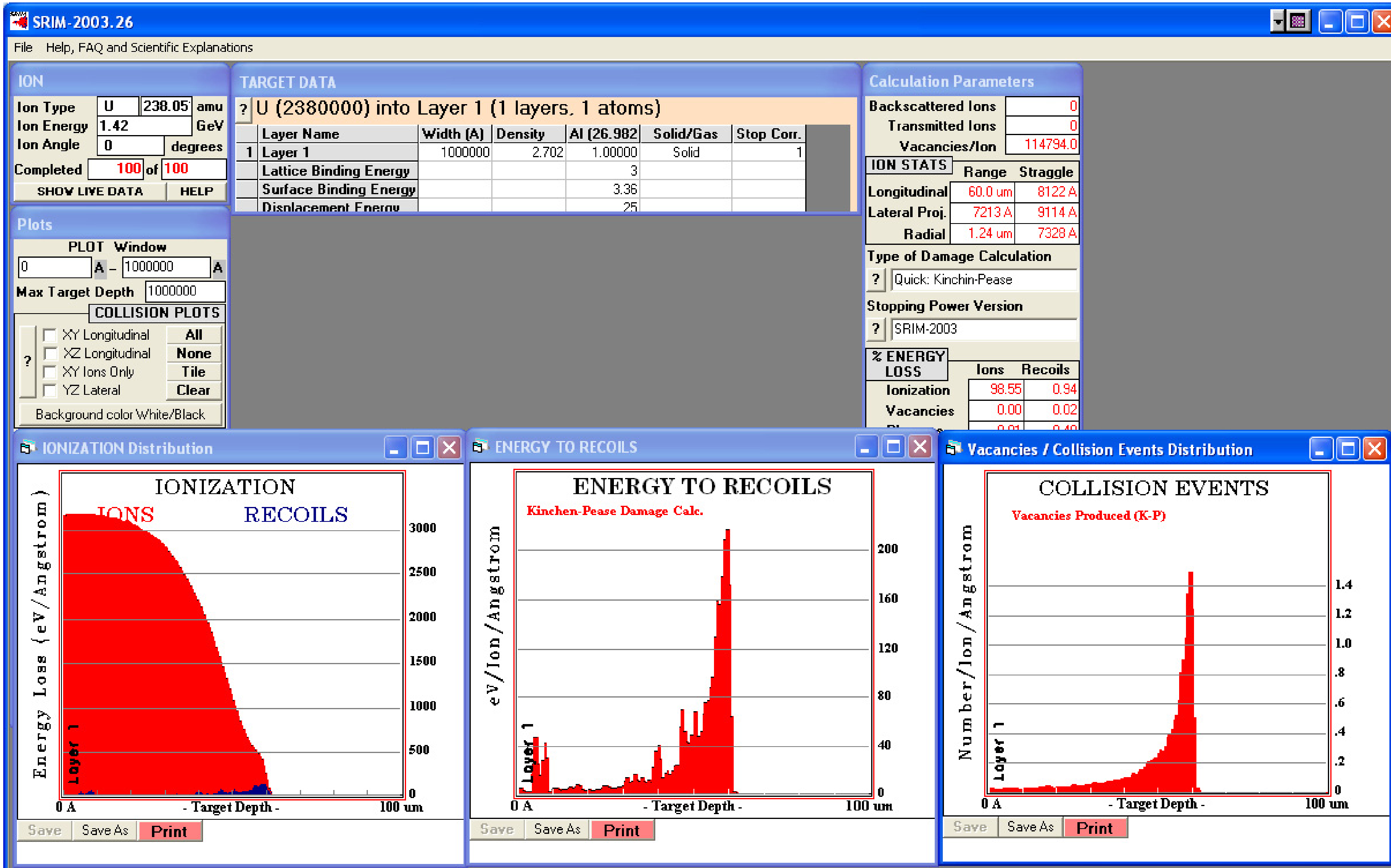


Figure 2: Plot of observed material damage as a function of dpa for neutrons and protons on copper [11].

S.J. Zinkle, communication with B.D. Wirth

Will we see a "swift heavy ion effect?" SRIM simulation



6 MeV/u uranium in Al.

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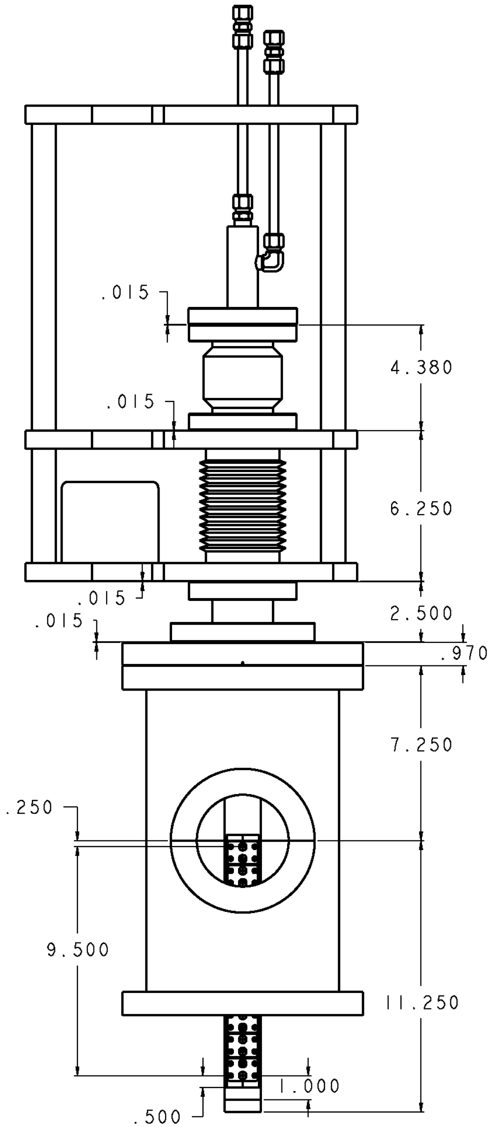
Irradiation plan:

Material	Damage Level (peak dpa)	Test	Current Density (pnA/cm^2)	Estimated Time	Total particle Density ($1/cm^2$)
Al	0.001	Hardness	0.4	20 minutes	3.0e12
Al	0.005	Hardness	4	10 minutes	1.5e13
Al	0.01	Hardness	4	20 minutes	3.0e13
Al	0.05	Hardness	40	10 minutes	1.5e14
Al	0.1	Hardness	40	20 minutes	3.0e14
Al	0.5	Hardness	400	10 minutes	1.5e15
Al	1	Hardness	400	20 minutes	3.0e15
Al	5	Hardness	400	2 hours	1.8e16
Al	10	Hardness	400	4 hours	3.6e16
Al	.01	TEM	4	20 minutes	3.0e13
Al	.05	TEM	40	10 minutes	1.5e14
Ti	0.5	Hardness	400	8 minutes	1.2e15
Ti	10	Hardness	400	3 hours	2.7e16
Cu	0.5	Hardness	400	7 minutes	1.0e15
Cu	10	Hardness	400	3 hours	2.7e15
Cu	.01	TEM	4	14 minutes	2.1e13
Cu	.05	TEM	40	7 minutes	1.0e14
Be	0.5	Hardness	400	50 minutes	7.5e15
Be	10	Hardness	400	20 hours	1.8e17

Apparatus


.015
.015
4.380
6.250
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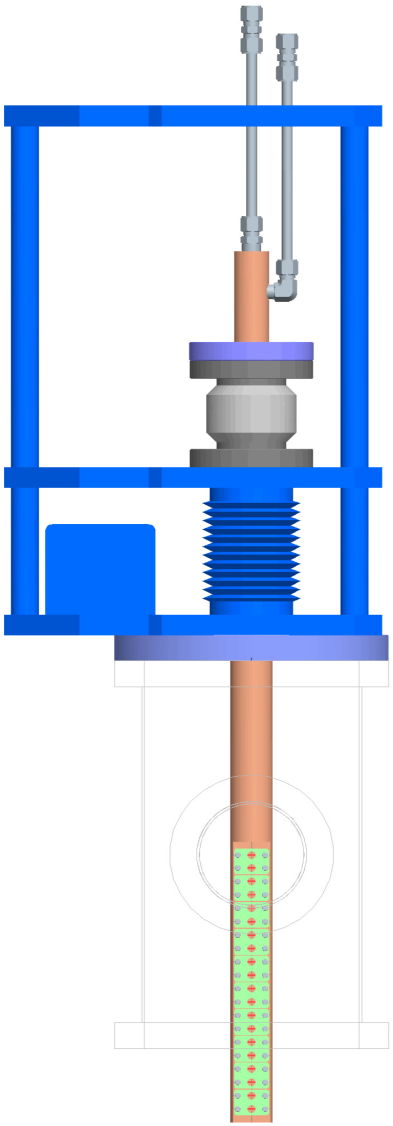
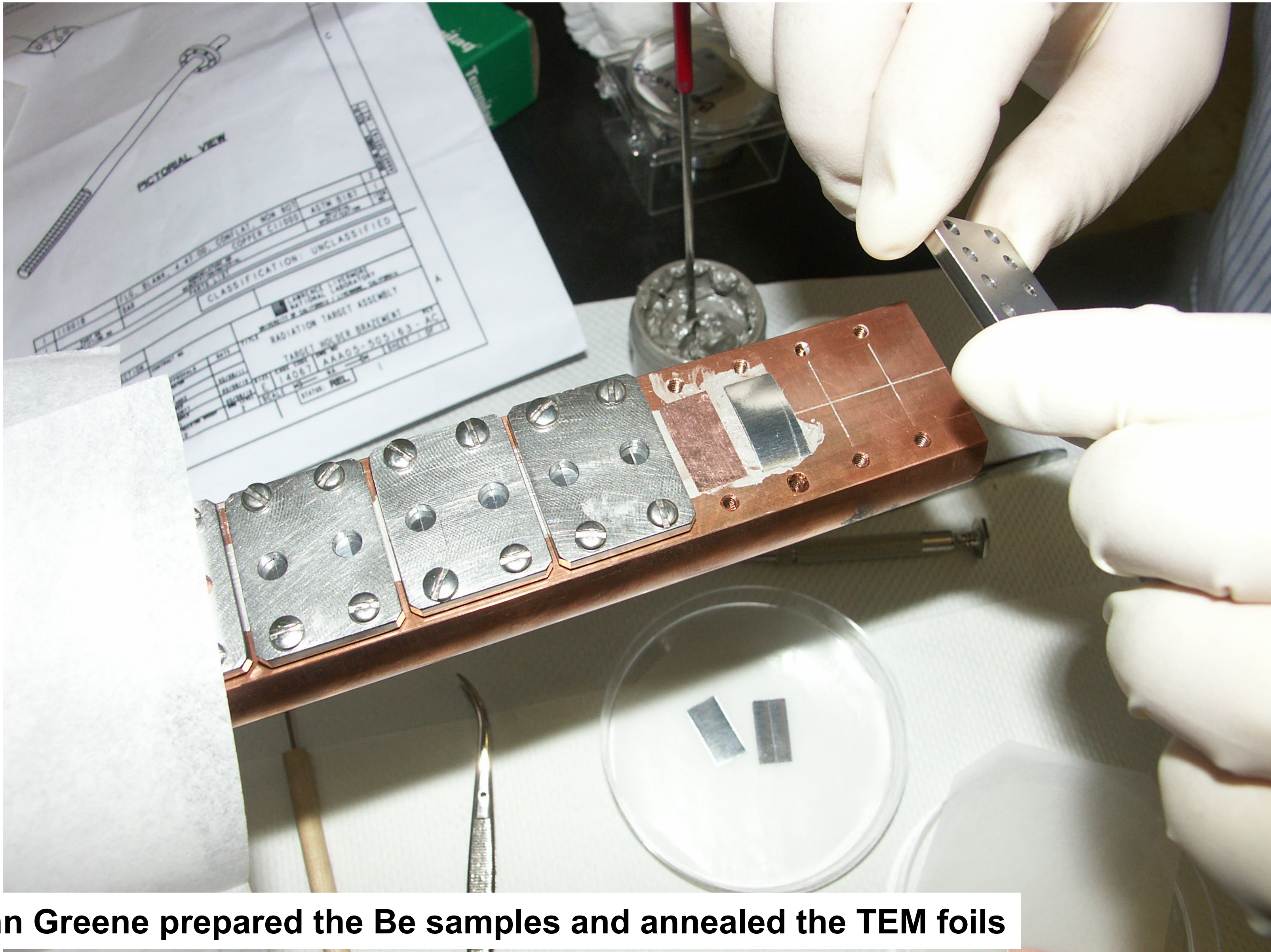


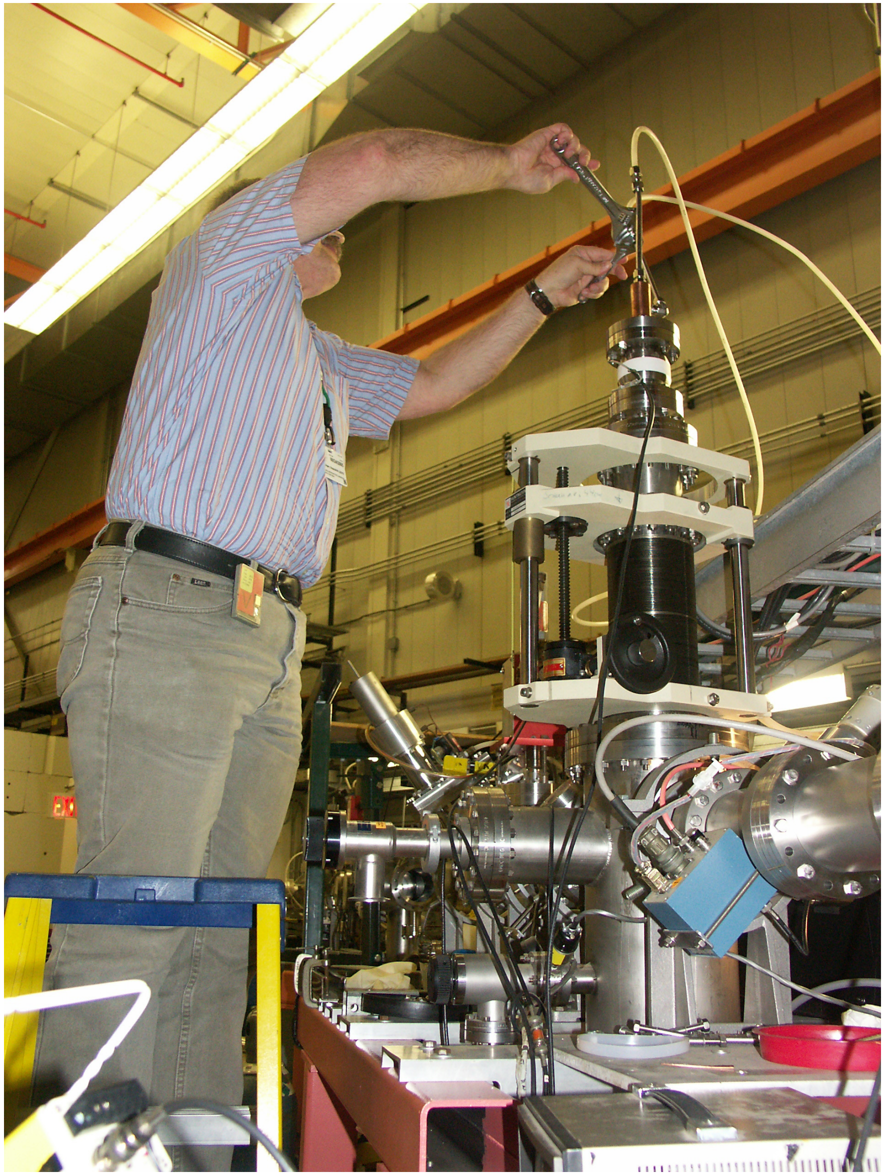
Mounting samples on the ladder

Mounting samples



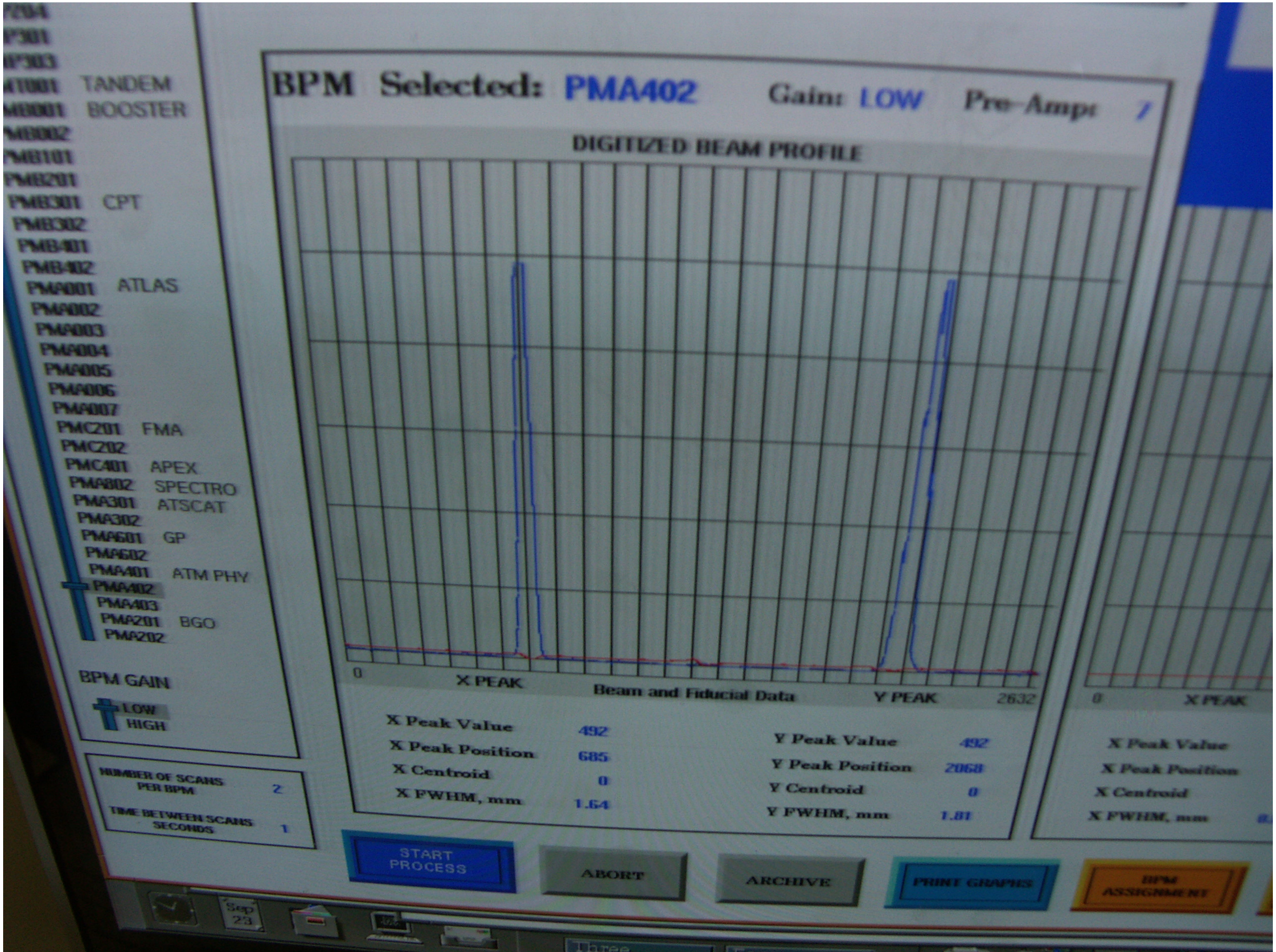
John Greene prepared the Be samples and annealed the TEM foils

The birthday of Larry's twins

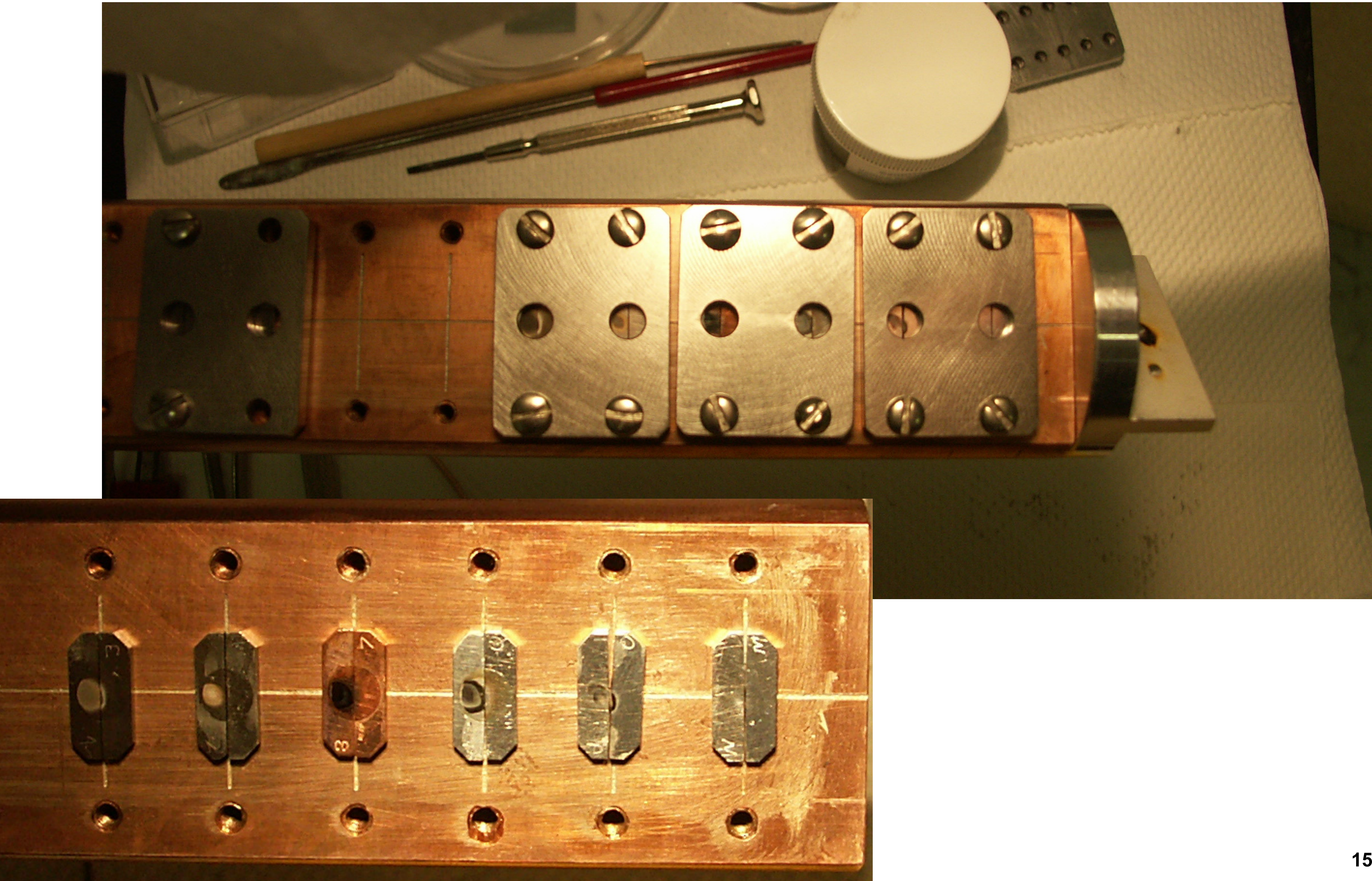


Tuning beam in the ATLAS control room

On-line display of beam profile monitor



Visible beams spots on samples after irradiation



Status

- All irradiations were completed except for the Be samples
- Uranium beam currents up to 20 particle nanoamperes were used in 2-mm diameter beam spot
- Sample temperatures during the irradiations were 20-100 C
- The samples were activated up to ~40,000 decays per minute of betas near contact; now decayed to ~1000 dpm for the 10 DPA samples
- Prompt radiation was minimal except for the Be samples
- Samples are being mounted for micro-hardness measurements in a hot lab at ANL
- A proposal has been submitted by M. Kirk and Y. Yan (ANL/MSD) for TEM studies at the ANL electron microscope facility. Samples will be etched at that facility
- Future studies will be planned based on the results of the upcoming analysis; could be more studies at ATLAS (~5 MeV/u) and/or studies at NSCL (~80 MeV/u)