Muon Collaboration

Post-Irradiation Properties of Candidate Materials for High-Power Targets

PAC05

Knoxville, TN

May 16-20, 2005

BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk
Brookhaven National Laboratory

Pressure Wave Amplitude

$$\text{Stress} = Y\,\alpha_T\,U / C_V$$

Where Y = Material modulus

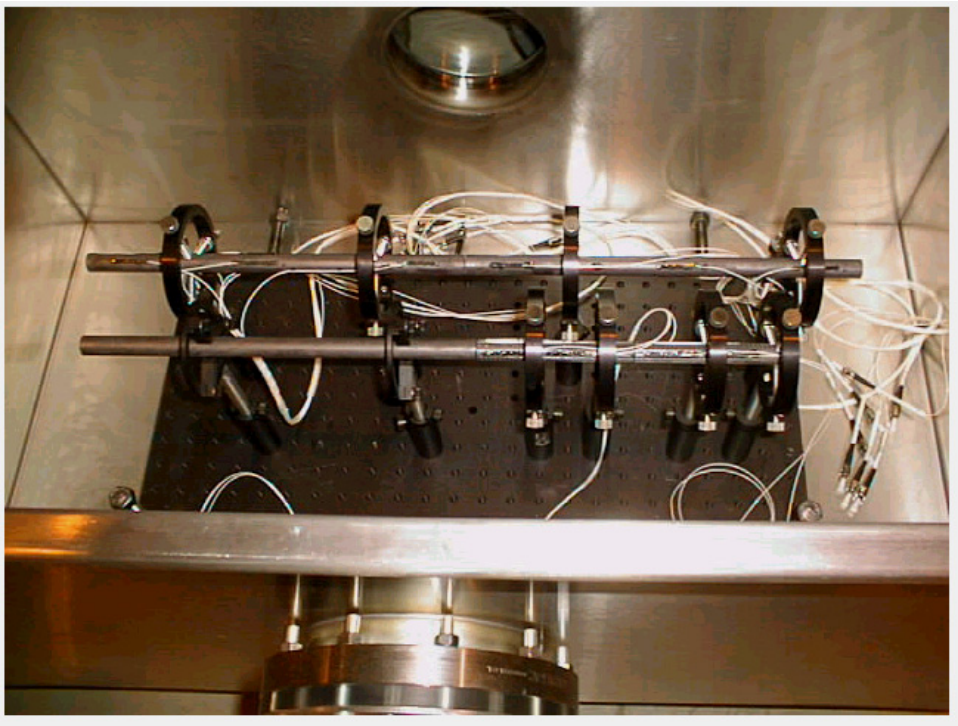
α_T = Coefficient of Thermal Expansion

U = Energy deposition

C_V = Material heat capacity

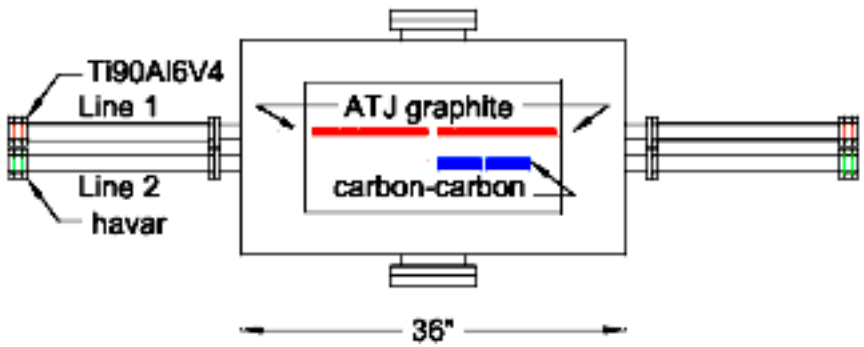
When the pressure wave amplitude exceeds material tensile strength then target rupture can occur. This limit is material dependant.

E951: Graphite & Carbon-Carbon Targets



Key Material Properties

	ATJ	CC X/U
Y, GPa	10	54/5.3
α_T , $10^{-6}/^0K$	2.5	~0
Tensile Strength, MPa	15	182/44

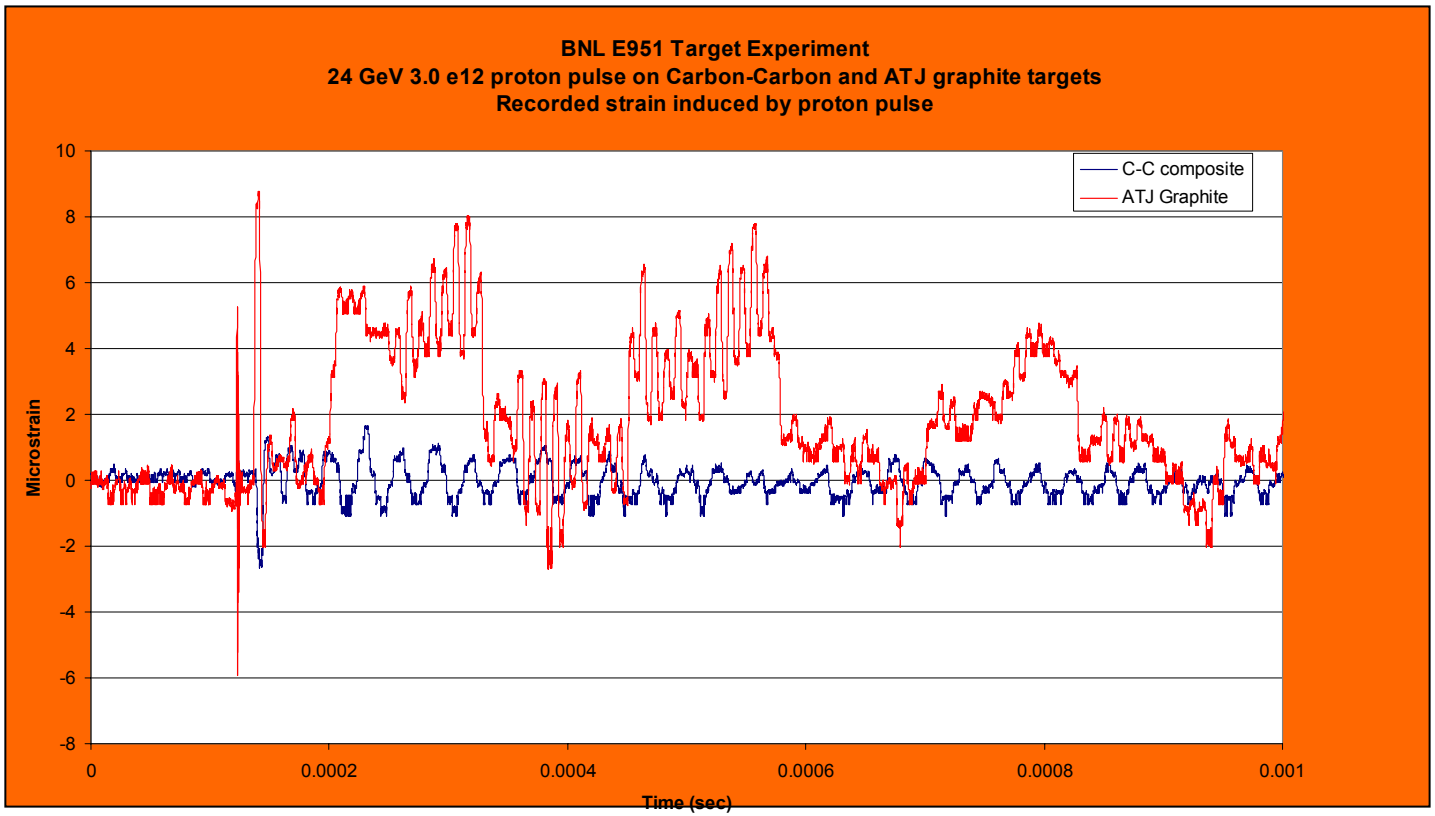


BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

E951: Strain Gauge Measurements

24 GeV, 3 x 10^{12} protons/pulse



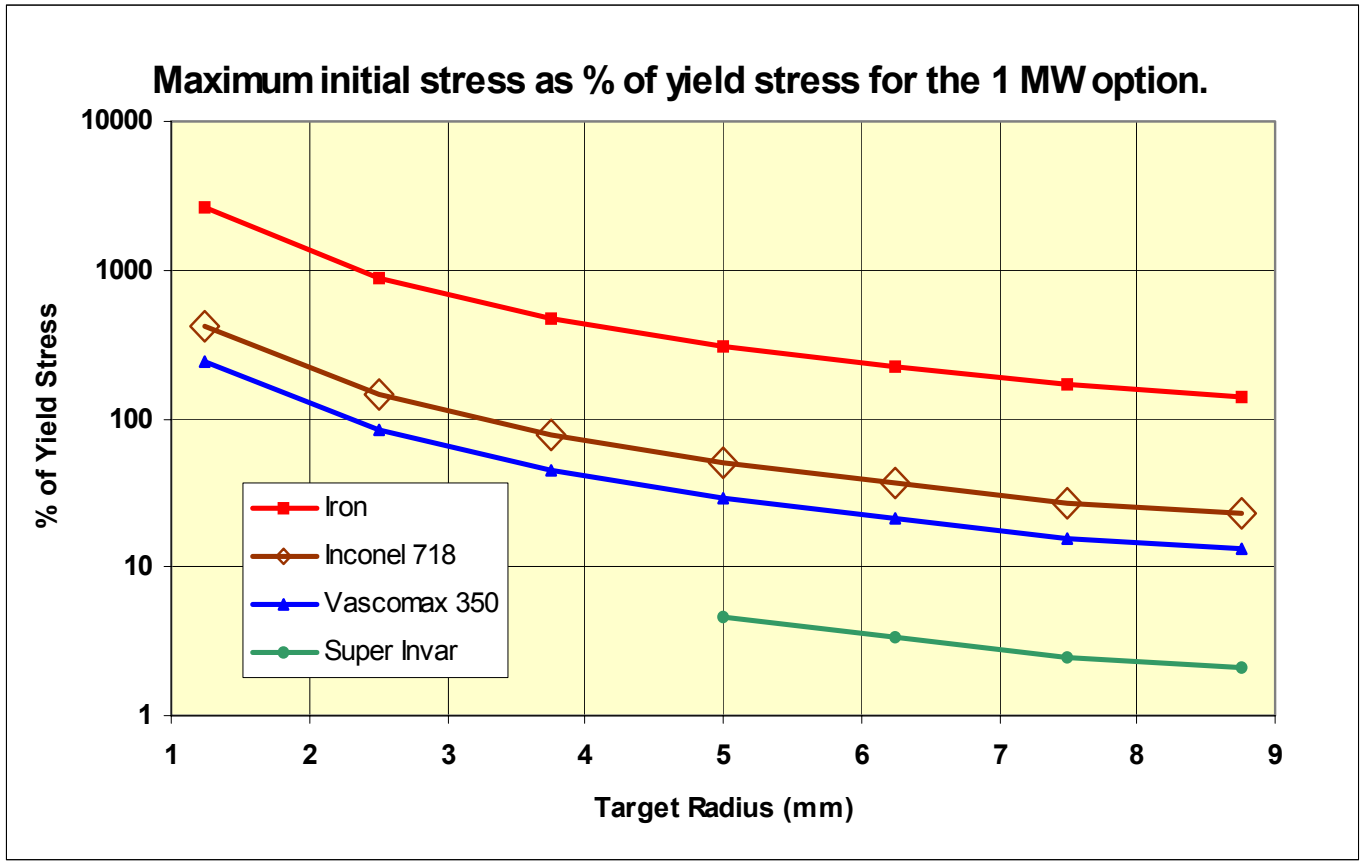
Target Material Examples

Peter Thieberger, BNL

Consider the case of a 16 x 10^{12} , 3ns , 24 GeV proton pulses

Material Yield Strength

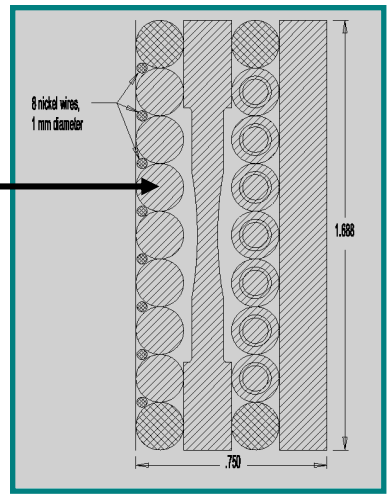
Beam Induced Stress



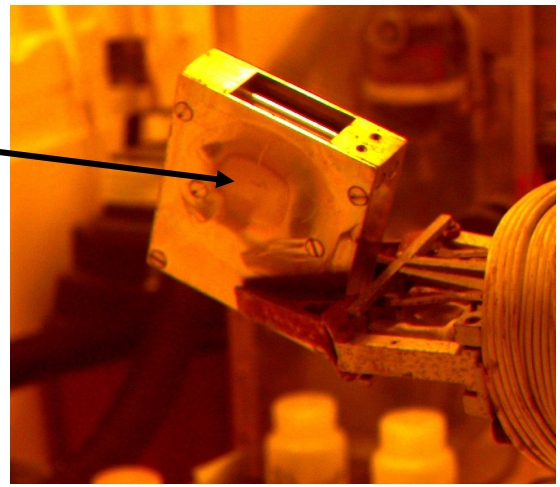
Harold G. Kirk

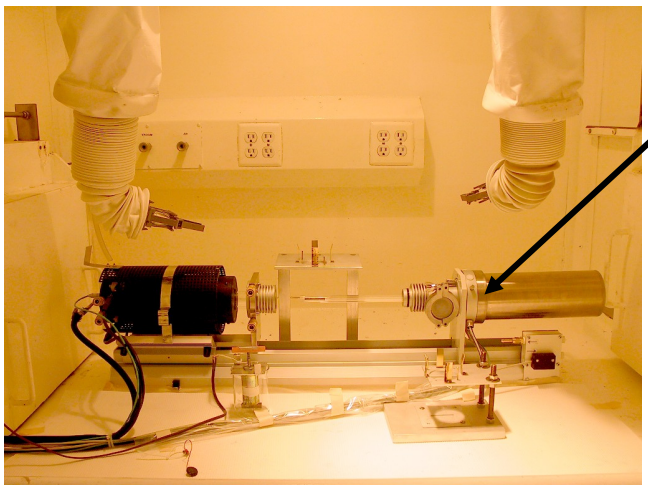
Super-Invar Irradiation at BNL (2002)

The cylindrical samples of super-invar.



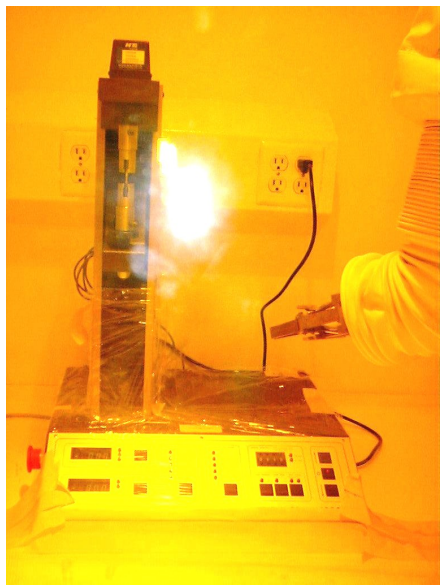
The target basket after irradiation





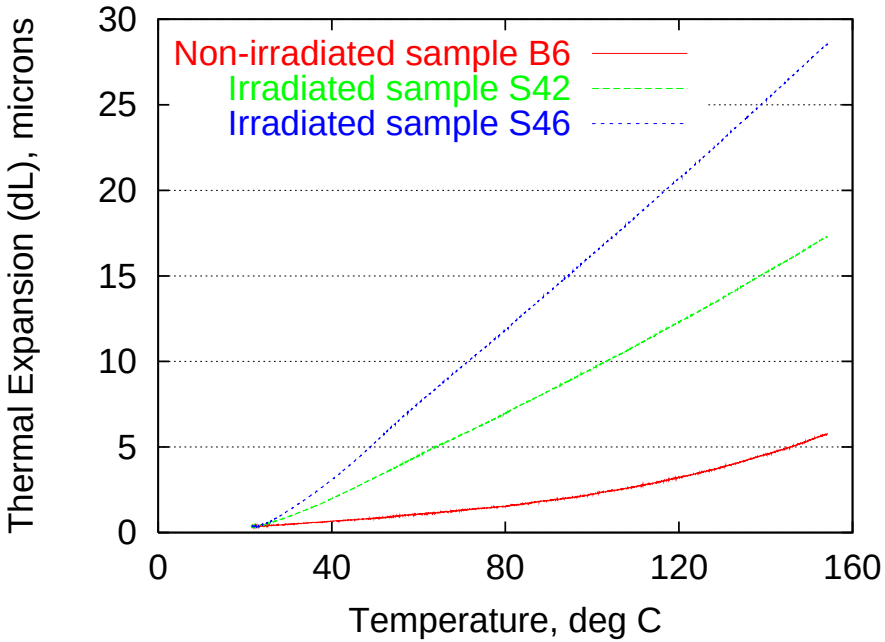
Dilatometer in Hot Cell

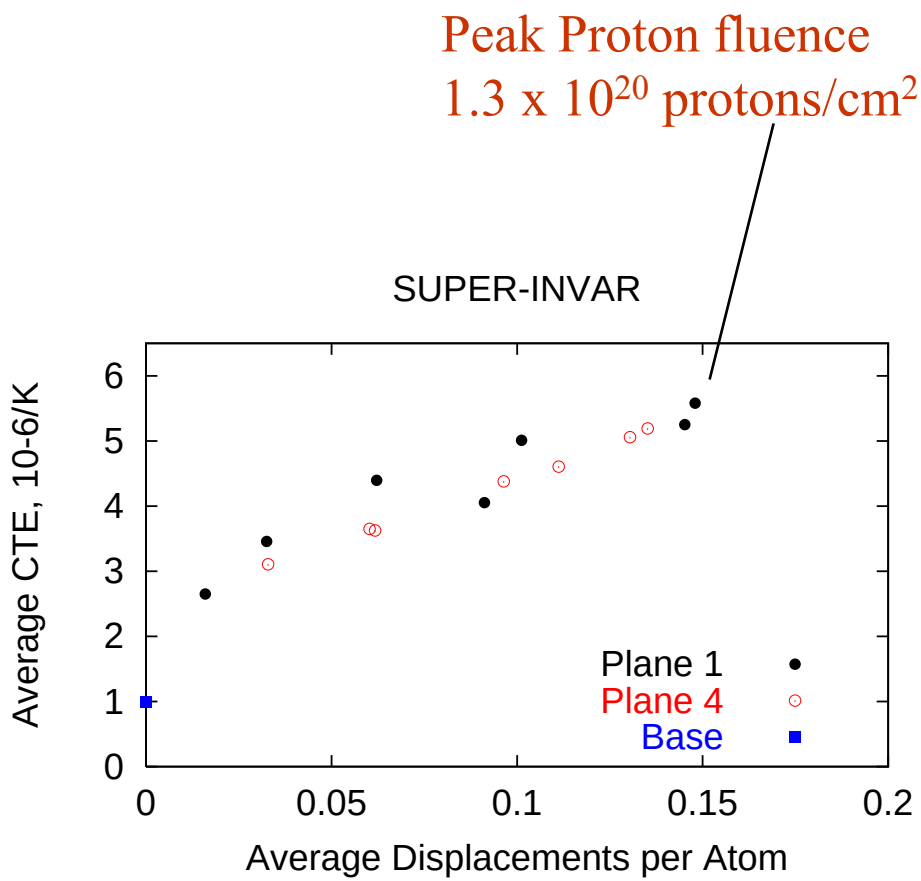
Tensile Tester in Hot Cell



BROOKHAVEN NATIONAL LABORATORY

Super-Invar CTE measurements

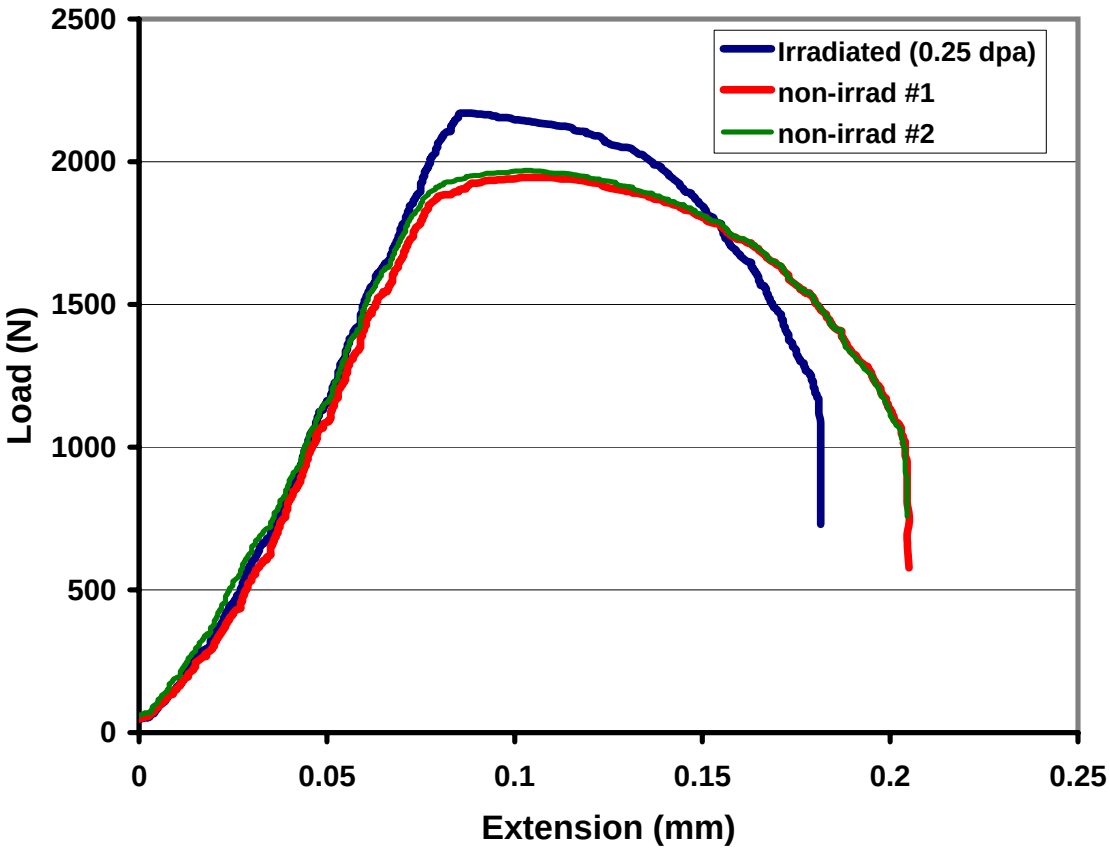




BROOKHAVEN NATIONAL LABORATORY

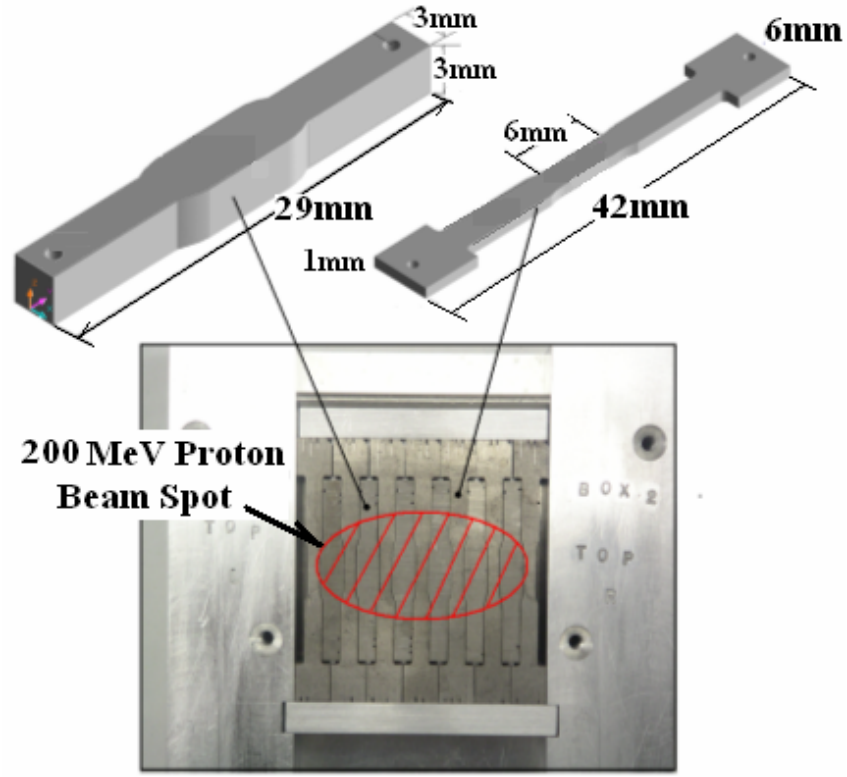
Harold G. Kirk

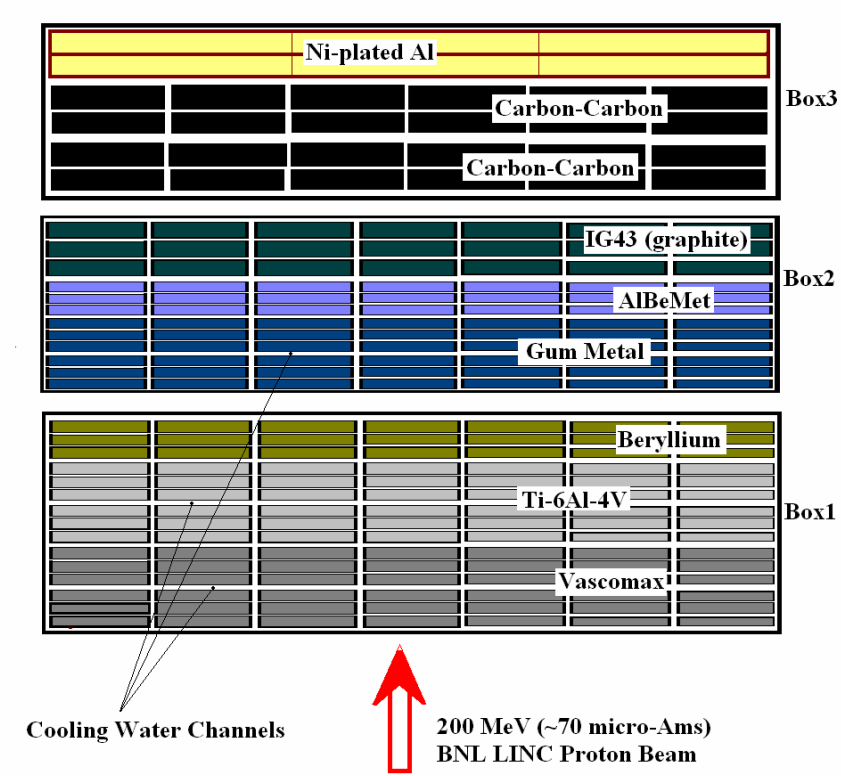
Super-Invar Tensile Testing



Tensile testing shows that Super-Invar strengthens while remaining ductile (at the 0.25 dpa level)

Irradiation at BNL (2004)





Material Test Matrix

Carbon-Carbon composite: Low-Z, low CTE composite that may potentially minimize thermal shock and survive high intensity pulses.

Graphite (IG43) : Different graphite grades respond differently to irradiation

Titanium Ti-6Al-4V alloy: Irradiation effects on fracture toughness of alloy that combines good tensile strength and relatively low CTE are sought

Toyota's "Gum" Metal : "Super" alloy exhibiting ultra-low elastic modulus, high strength , super-elastic like nature and near-zero linear expansion coefficient for the temperature range -200 C to +250 C

Vascomax: High-strength, high-Z alloy. Irradiation effects on CTE, fracture toughness and ductility loss are sought.

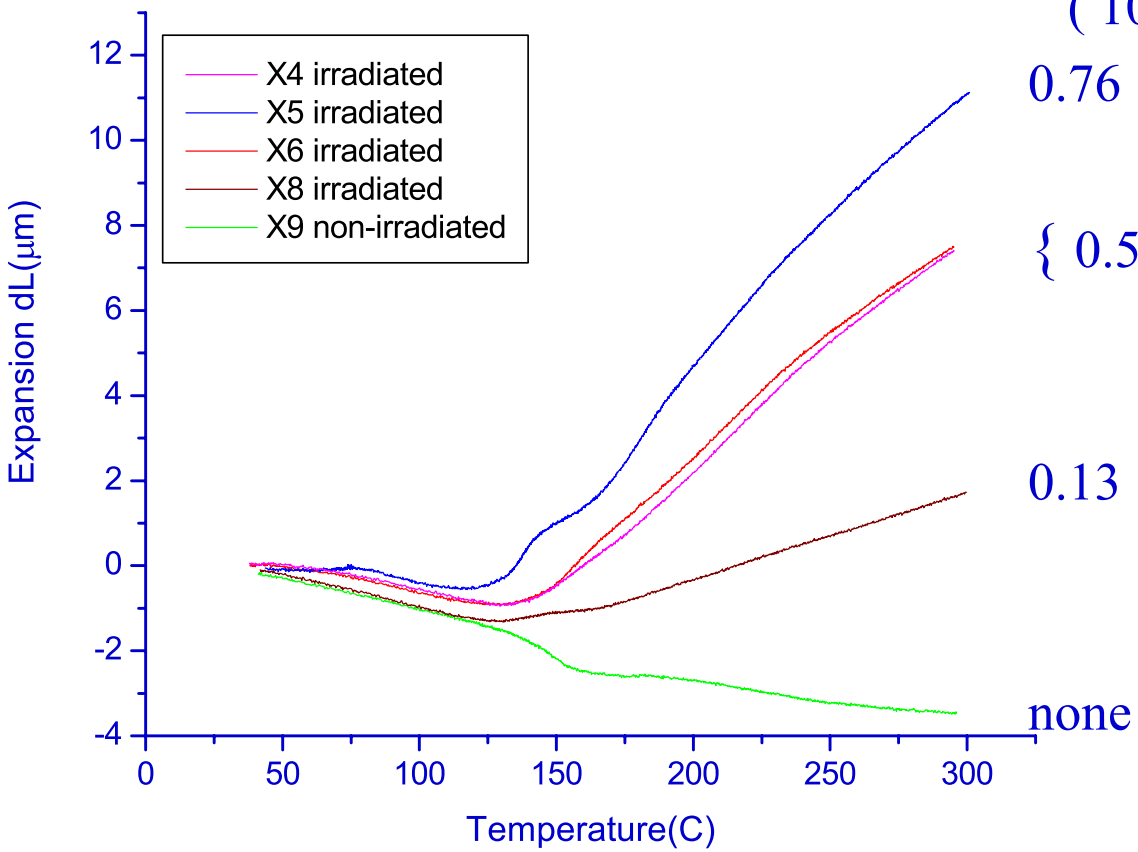
Beryllium: Known material examined closer for irradiation damage

AlBeMet: Low-Z composite combining good properties of Be and Aluminum.

Nickel-plated Aluminum (NUMI horn) : Assess how bonding between the layer and the substrate survive irradiation in the presence of water

Super-Invar: Re-examination of previously tested material for effects of temperature induced annealing

Carbon-Carbon Composite



Average Proton Fluence

(10^{20} protons/cm^2)

0.76

{ 0.52 and 0.36

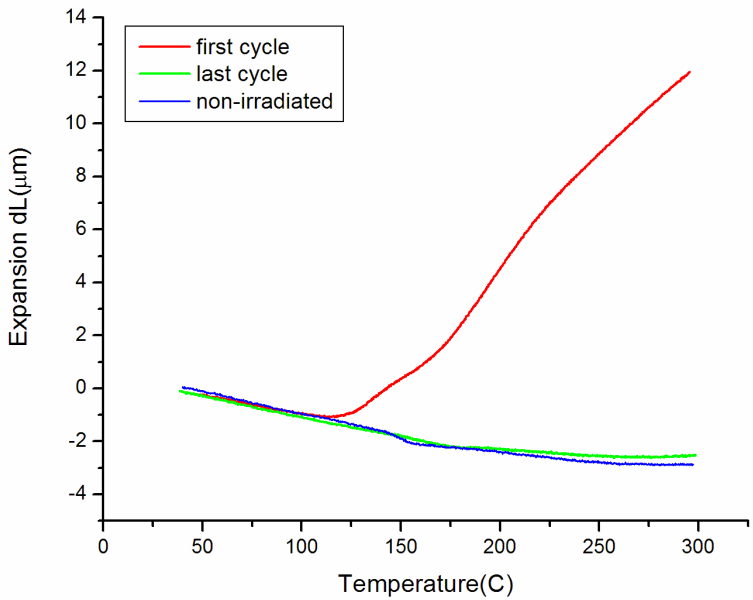
0.13

none

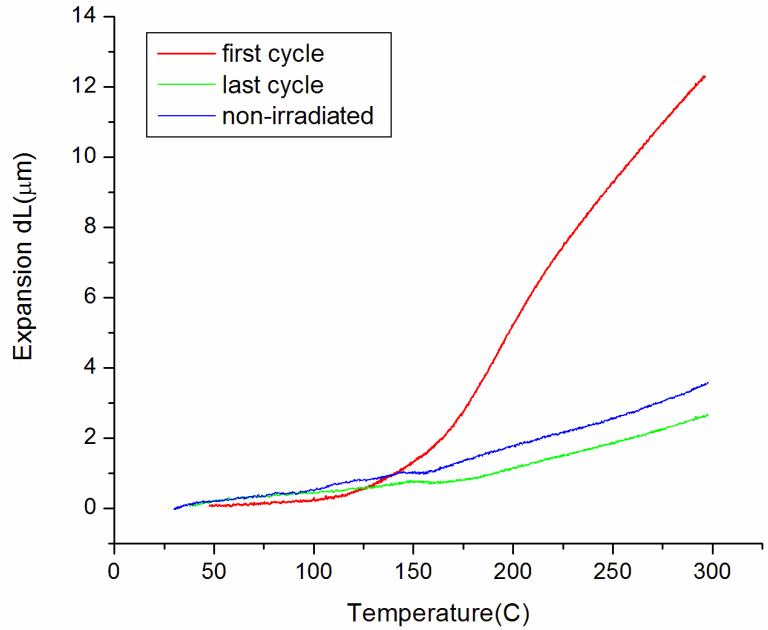
BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

C-C Composite Thermal Cycles



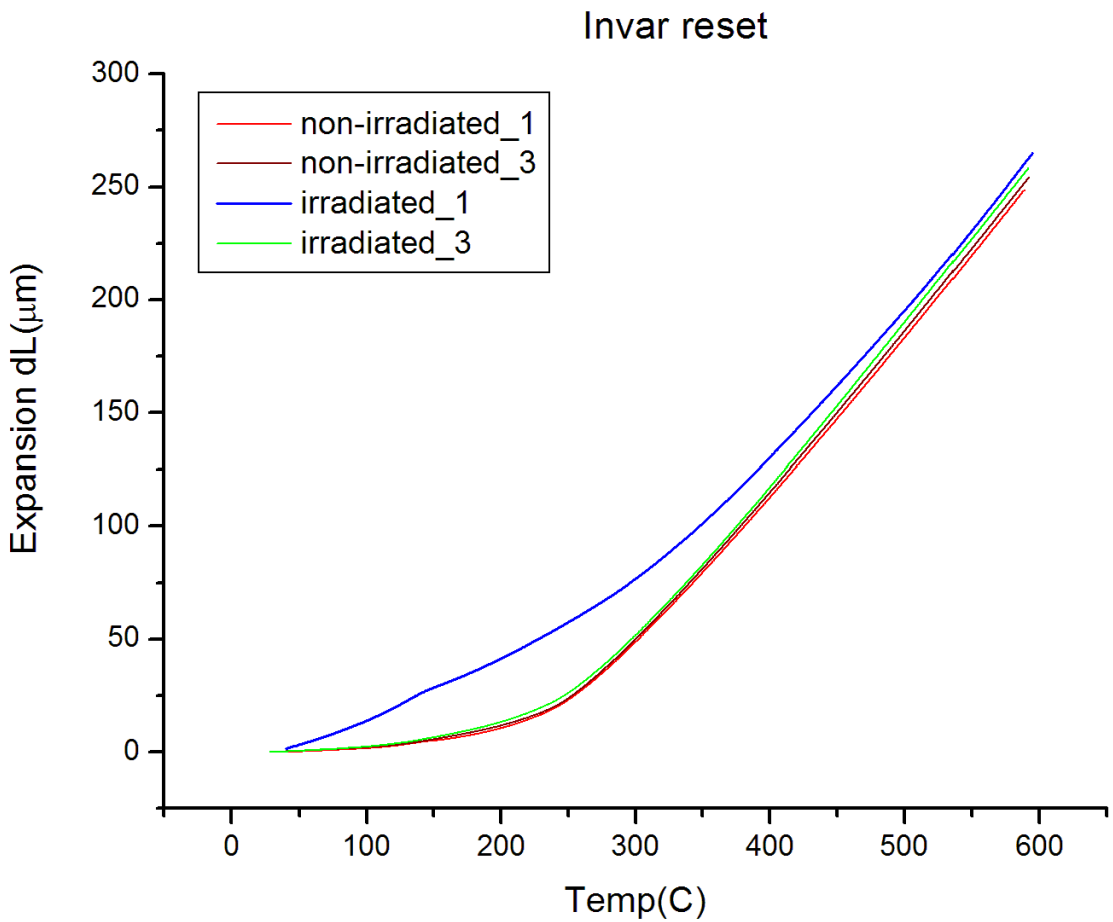
XYZ Orientation



UV Orientation

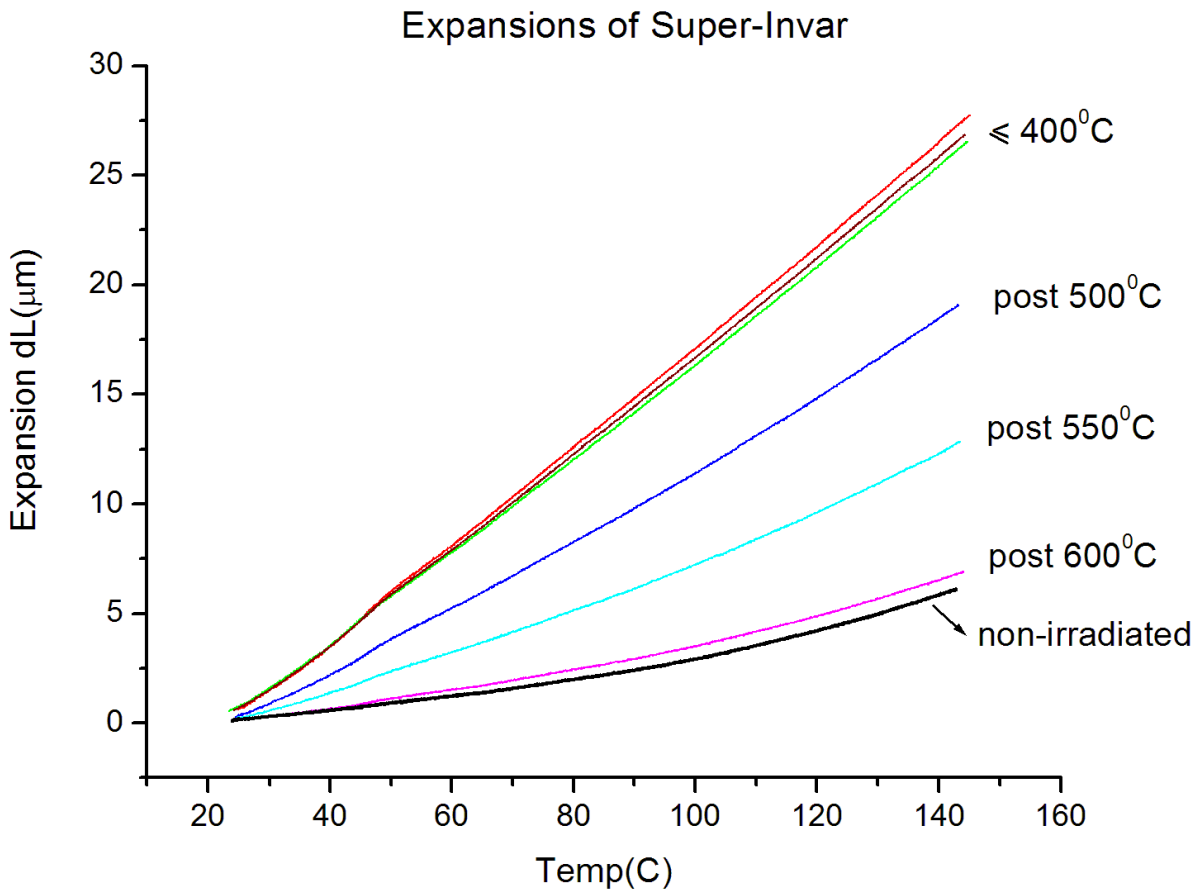
BROOKHAVEN NATIONAL LABORATORY

CTE resetting of Super-Invar

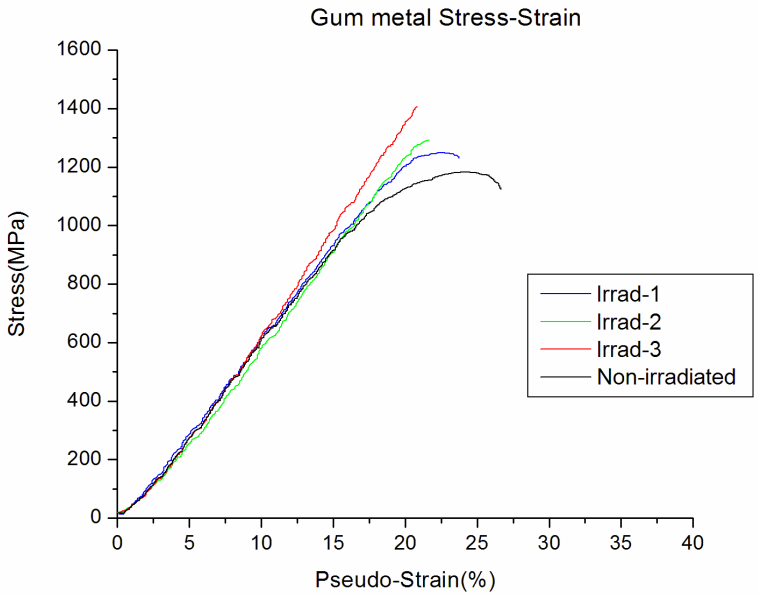


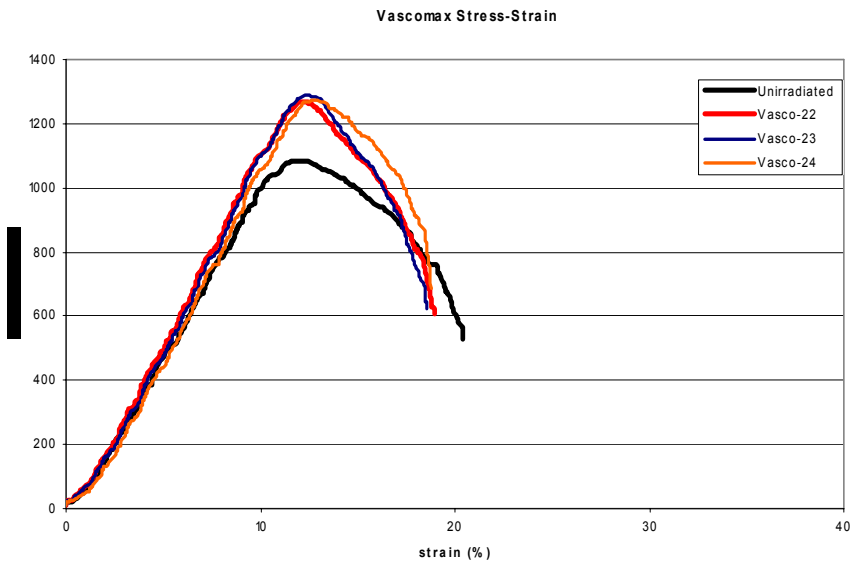
Invar resets its CTE after a 600^0C thermal cycle

Super-Invar thermal cylcles



Initial Tensile Results





Gum Metal strengthens but turns brittle

Vascomax strengthens **without** turning brittle.

The Collaborators

H. Kirk, H. Ludewig, L. Mausner, N. Simos, P. Thieberger

Brookhaven National Laboratory

K. McDonald

Princeton University

J. Sheppard

Stanford Linear Accelerator Center

L. P. Trung

Stony Brook University

Y. Hayato, K. Yoshimura

KEK