Large p-p (Lpp), and Target Studies

BNL Meeting with Nigel

R. B. Palmer

1/12/15

1. Intro. to CAD Energy Frontier Accelerator Group
2. Increased Luminosity for 100 TeV p-p Collider (with FNAL)
3. Cost vs. Bending Field for p-p Colliders
4. Target R&D for FNAL Experiments

Intro. to CAD Energy Frontier Accelerator Group

- Group has been studying Muon Colliders
  - as part of the Muon Accelerator Collaboration (MAP)
- Now:
  1. Greatly reducing, or ending, Muon Collider work
  2. Limiting support of Muon Ionization Cooling Exp (MICE) to two years
  3. Increasing study of Large proton proton (Lpp) colliders
  4. Increasing Target R&D for FNAL experiments
- GARD funding will be needed for #3 and #4

2) Study of increased Luminosity of 100 TeV p-p (Lpp)

R. B. Palmer, J. S, Berg, D. Stratakis (BNL)
and Y. Alexahin (FNAL)

Preliminary results presented to R&D Panel

White Paper submitted to R&D Panel

Abstract submitted to IPAC15

Motivation

- CERN 100 TeV 'FCC hh' luminosity is 5 10^{34} cm^{-2}s^{-1}
- Same as in High Luminosity LHC at 14 TeV

- But parton cross sections $\propto\ E^{-2}$
- Luminosity should rise by E^{2}
- Exploring Luminosities 5 to 10 times FCC

Constraints

- Keeping the same average Current, and
- Same number of events per bunch crossing

Example with luminosity 25 10^{34} $cm^{-2}s^{-1}$

- 5 $\times$ bunches to keep events per crossing the same
- Bunch spacing 5 ns instead of 25 ns
- 1/5 charge per bunch to keep the same ave. current

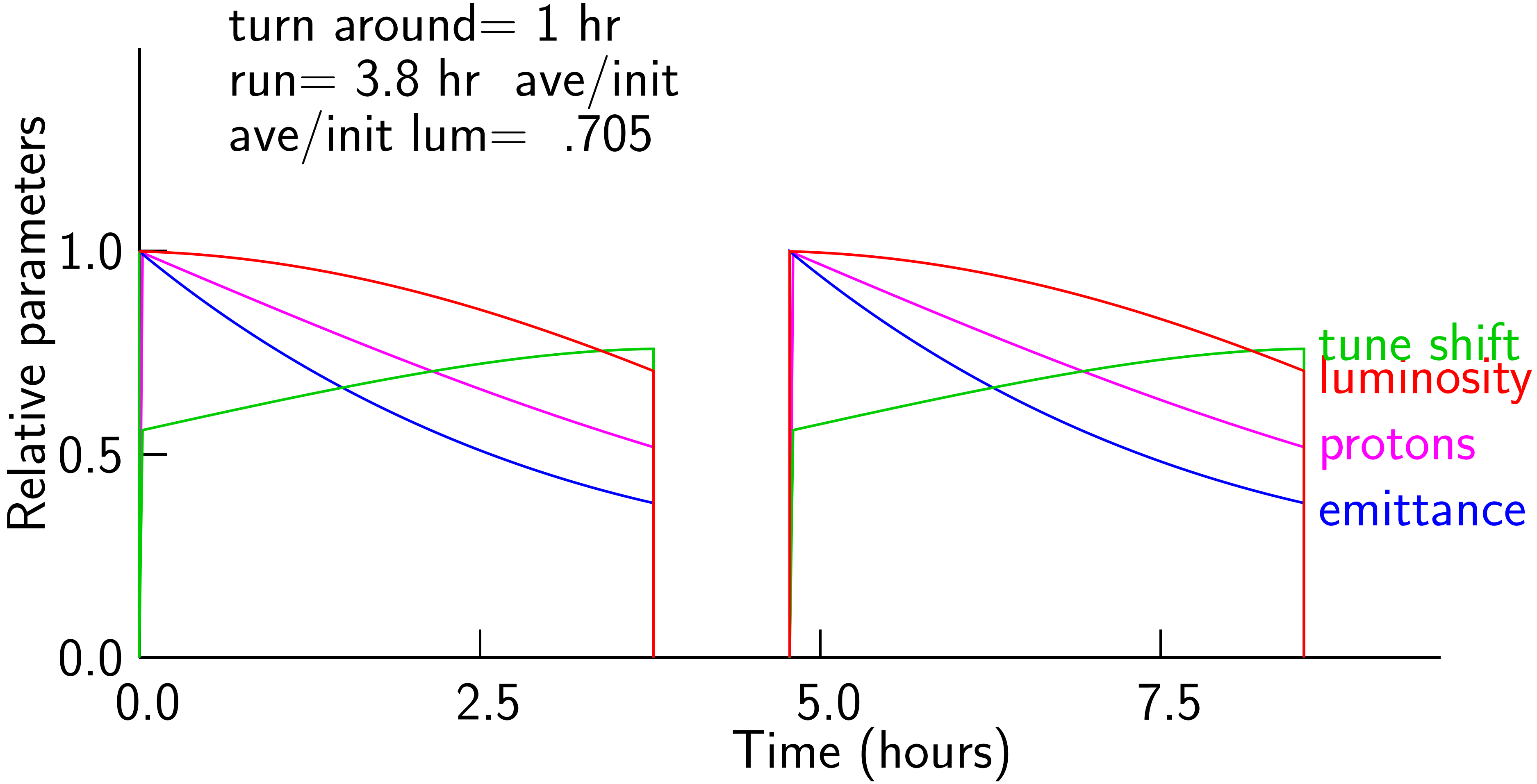
Needs:

1. 1/3 initial emittance
   with coherent electron cooling if needed
2. 1/5 LHC beta* (11 cm vs 55 cm)
   utilizing techniques with $\leq$ 1cm beta*s for muons
3. Fast turn-around
   using full circumference accumulator

Parameters

		LHC	FCC-hh	This
Energy (c of mass)	TeV	14	100	100
Dipole Field B	T	8.3	16 (20)	8.3
Circumference	km	26.7	100 (83)	190
Peak Luminosity	$10^{34}\mathrm{cm}^{-2}s^{-1}$	1	5	25
Ave Luminosity	$10^{34}\mathrm{cm}^{-2}s^{-1}$	1	5	17.5
Init. Protons/bunch	10^{10}	11.5	10	1.9
Bunch sep.	ns	25	25	5
Number of bunches	10^{3}	2.8	10.6(8.9)	102
β^* at IP	cm	55	110	11.2
σ_z bunch length	cm	7.5	7.6	5.5
Init. norm rms trans. emit. $\epsilon_\perp$	μm	3.75	2.2	0.83
Init. beam-beam tune shift		0.01	0.01	0.06
Events/crossing		27	171	171
Synchrotron power	MW	0.0072	4.8	2.5
Turn around time	hr	5	5	1

Parameters vs. time



- Synchrotron cooling is significant
- Keeping Luminosity higher as protons are used up

Conclusions on Lpp Luminosity

- Reason to hope that it is possible to raise luminosities
- Note however that the background will also go up
- Note relationship between luminosity and bending field that:

  keeps luminosity approximately constant
  as the number of muons falls
  because synchrotron radiation reduces the emittance

3) Cost vs. Collider Bending Fields

R. B. Palmer, Brett Parker (BNL),
Bill Foster (FNAL/Congress)

BNL Tech Note 317B/25B, 5/1/84 (1984).

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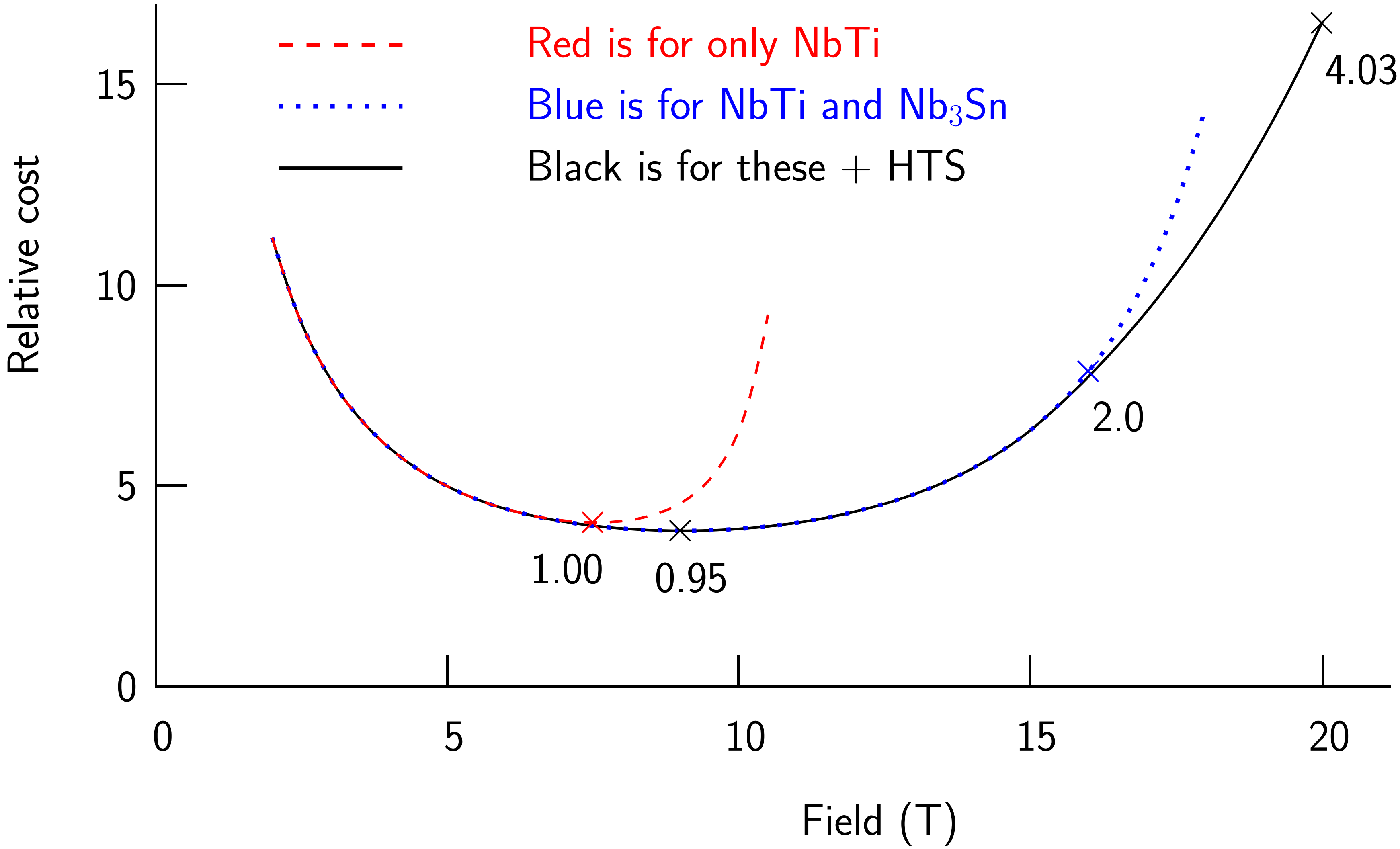
Method

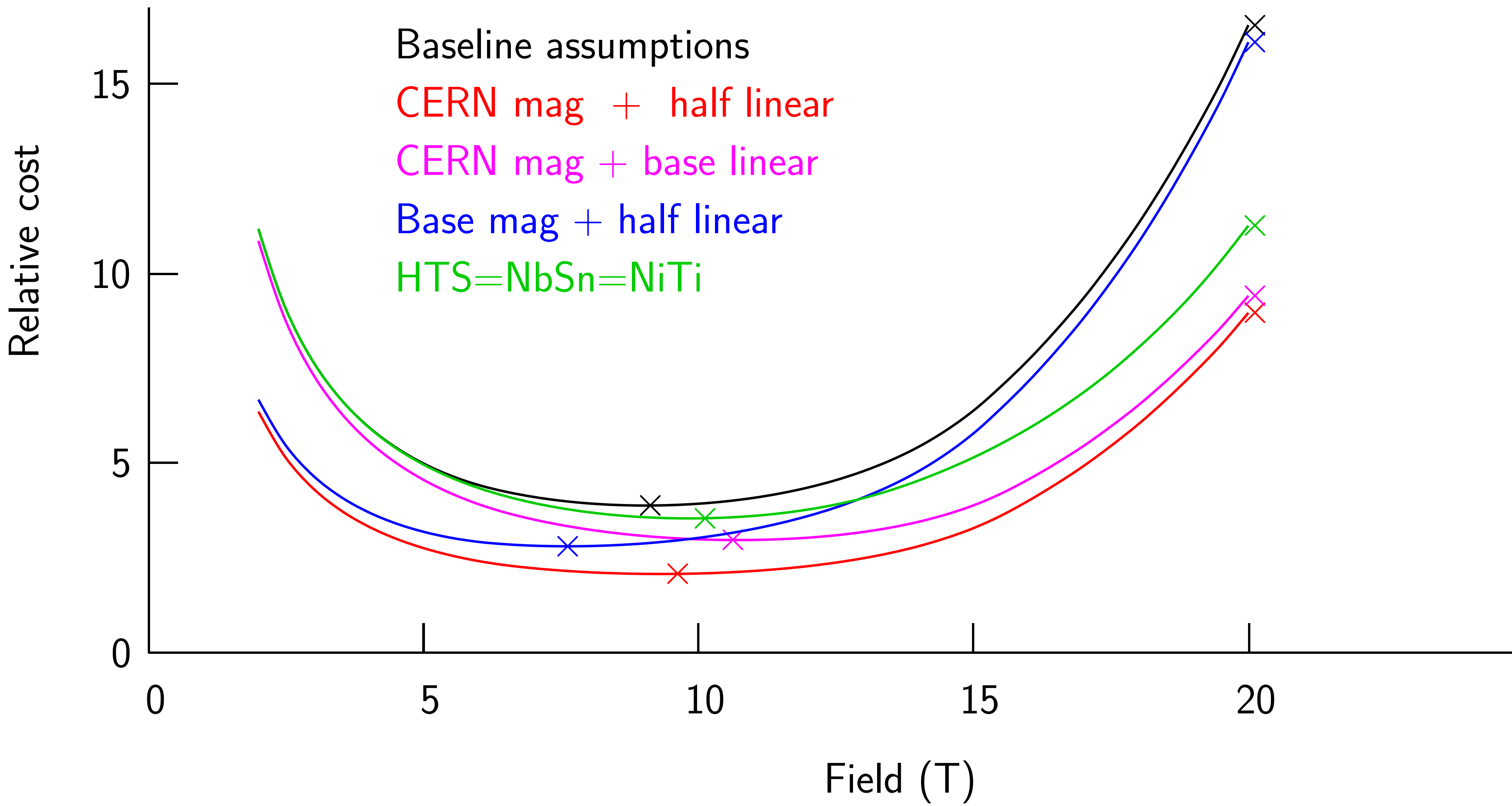
- For different bending fields and different fractions of NbTi, Nb_3Sn, & HTS conductors:
  - Calculate Yoke cross section for minimal saturation
  - Determine dimensions for collars to contain coil forces
  - Use CERN estimated sc costs and SSC data for support, yoke, cryogenic, and tunnel costs
- Find fractions of conductors to minimize magnet costs
- Determine total magnet and tunnel costs vs. field

At low fields tunnel and other 'linear' costs dominate. At high fields super-conductor and other magnet costs dominate. Between these is a minimum

Costs vs. Bending fields



Sensitivity to Assumptions



Conclusion for Bending Fields

- Preliminary result shows cost minimum at relatively low bending fields (Minimum at 9.3 +/- 1.0)
- Cost significantly higher for 16 T ($\times$ 1.7 +/- 0.5)
- Cost much higher for 20 T ($\times$ 3.1 +/- 0.6)

- Proposal now would
  - improve model
  - incorporate RHIC and LHC costs, instead of SSC

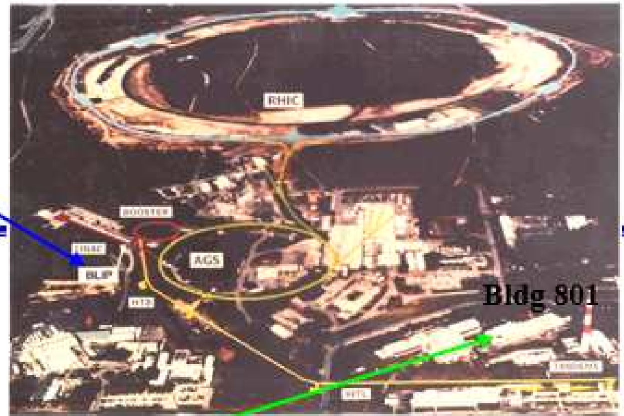
4) Target work in support of FNAL Experiments

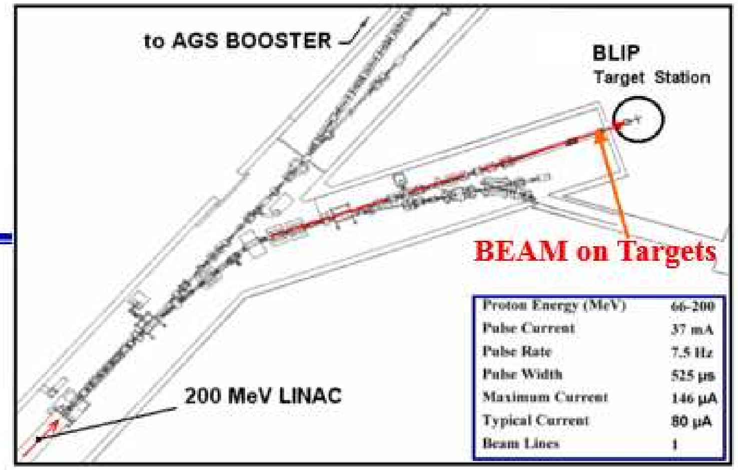
Harold Kirk, Nick Simos, Mary Bishai (BNL),
Kirk McDonald (Princeton), Nikolai Mokhov (FNAL)

- Radiation Damage of Materials
- Design and Simulation:
  - For LBNE baseline
  - Hybrid Target

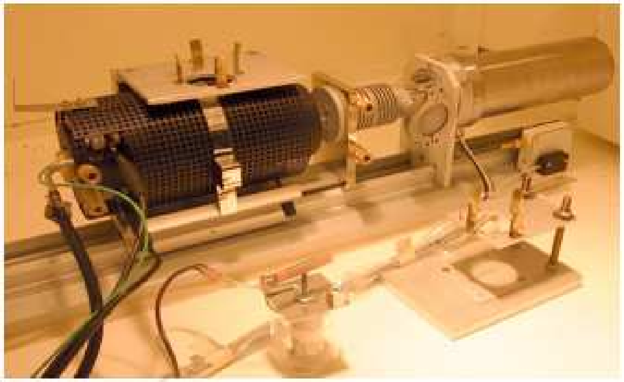
Radiation damage studies using BLIP

Irradiation takes place at BLIP using 200 MeV or 117 MeV protons at the end of Linac





Post irradiation analysis at BNL Hot Labs



Thermal Expansion/Heat Capacity Measuring System

Remotely controlled tensile strength testing

Unique role of BLIP

"One needs high intensity/current in a beam spot with enough irradiation volume to do meaningful Post-Irradiation-Examinations (PIE)."

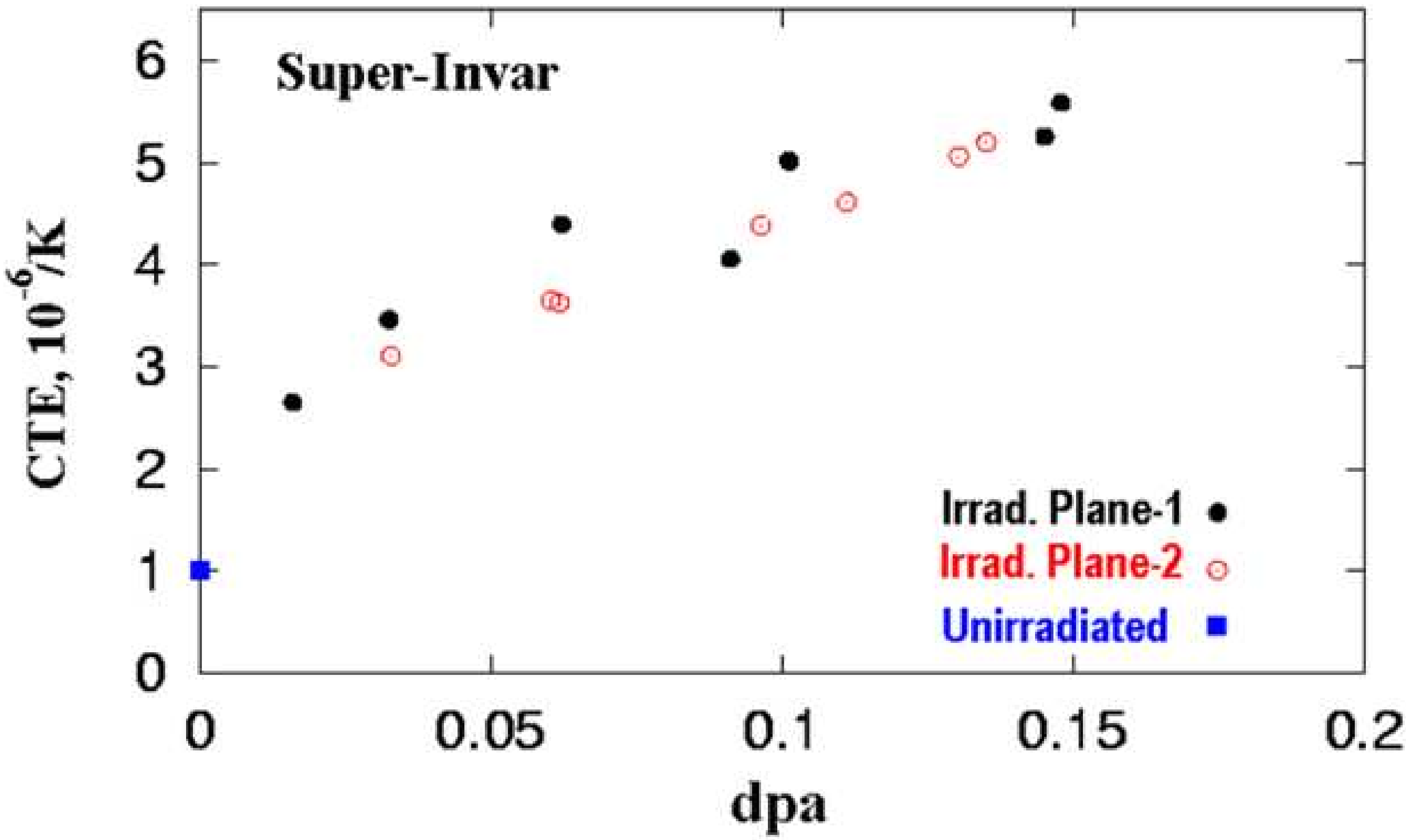
"At energies high enough to get transmutation and high current enough to irradiate a sizable volume to do bulk tensile testing. BLIP is currently the only facility identified that partially fills that need"

Patrick G. Hurh (FNAL)

Nikolai Mokhov & Mary Bishai established that radiation damage in 4 weeks at BLIP $\equiv$ 0.4 MW yr at NuMI

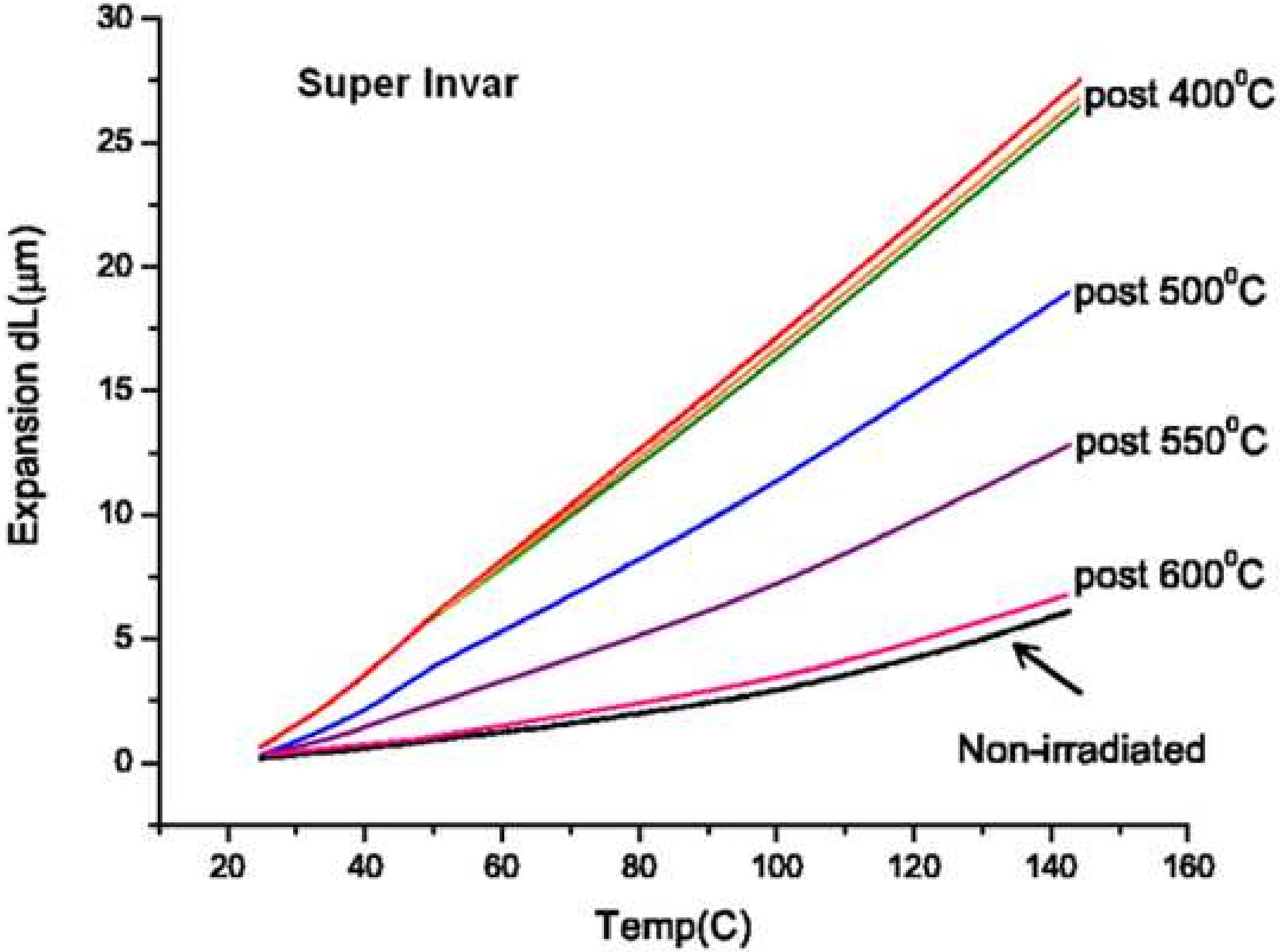
An Example: Study of Super-Invar

Low coefficient of expansion good for shock heating



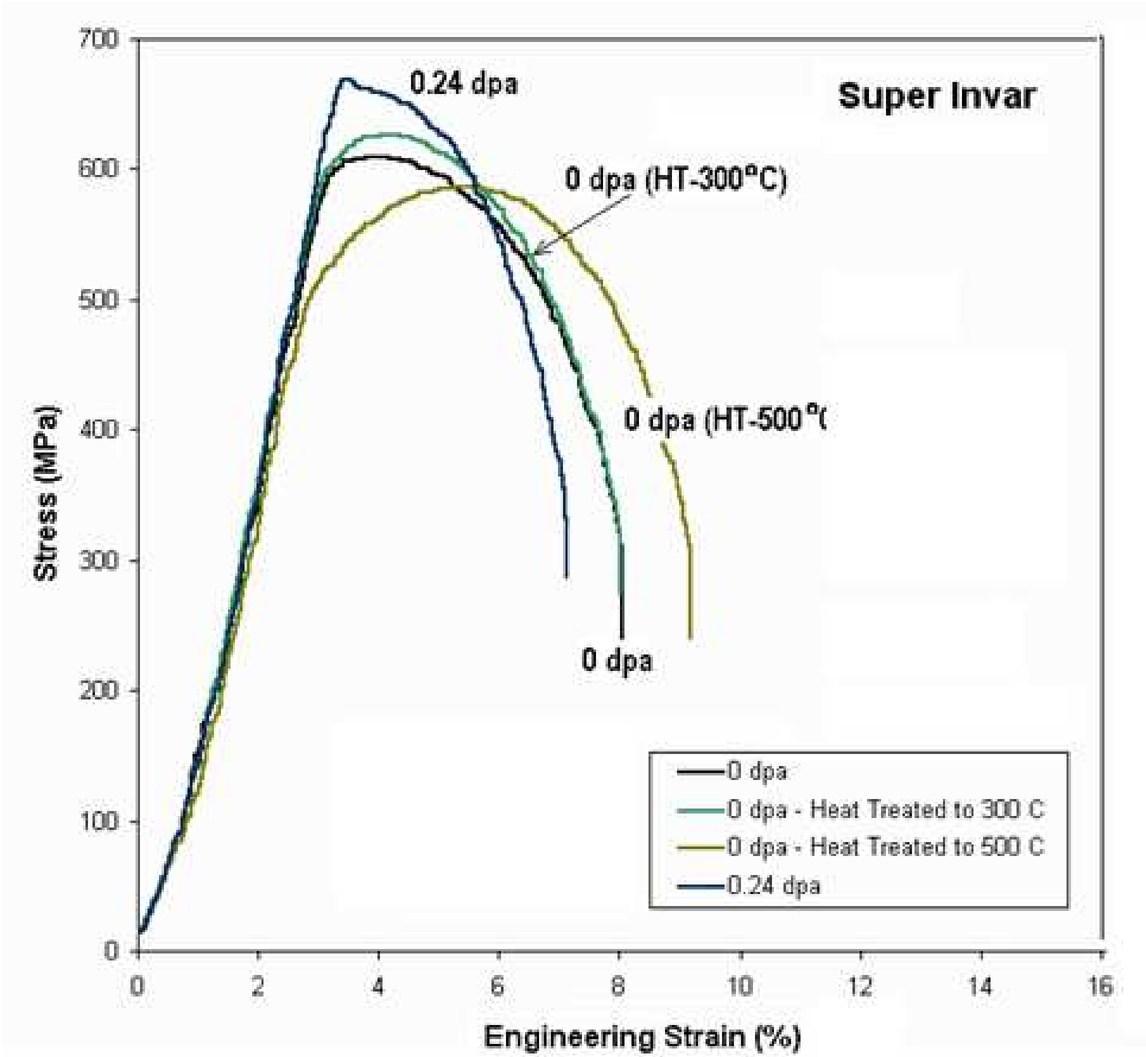
But radiation increases coefficient

Effect of Annealing



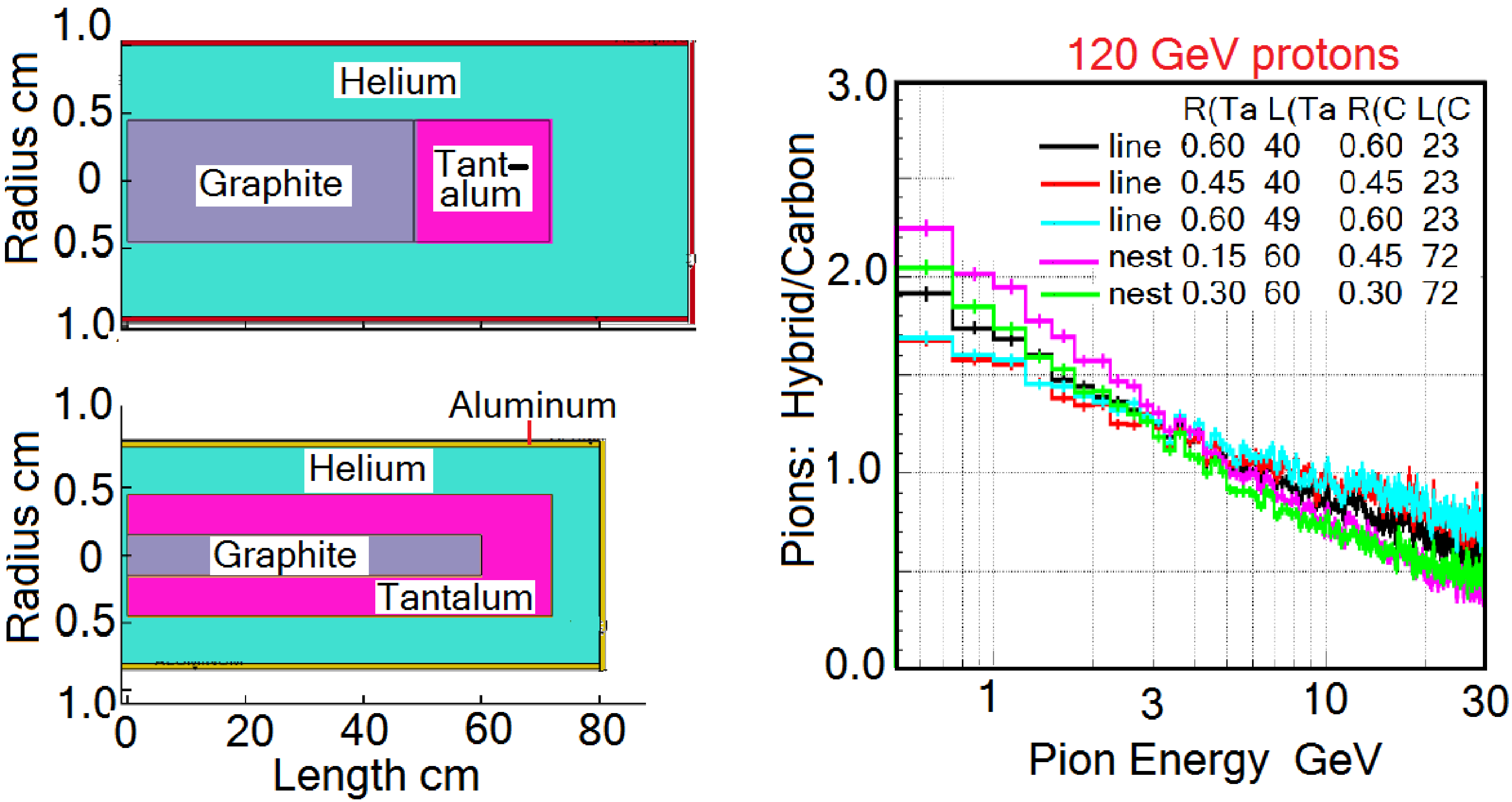
Annealing restores the low coefficient
If run hot the coefficient should remain low

Strength



- Maximum stress increased by radiation
- But made less ductile
- Annealing restores ductility

Hybrid Target for LBNE



Hybrid Target Continued

- Idea proposed by Mary Bishai and Nick Simos
- Being studied by Chris Densham in UK
- A factor of two at low energy for the 2nd maximum
- With no sacrifice of medium energy for first maximum
- Cuts off the high energy tail that produces backgrounds from Neutral Currents (NC) at lower energy
- Reduce the wrong-sign contaminant in the anti-neutrino beam (factor of 2!)

- We would like to contribute to this study.

Conclusions for Target Studies

- BLIP is a unique resource for target material studies
  - Graphite & tantalum should be studied for targets
  - Aluminum and AlBemet for possible use in horns
- Super Invar and Carbon-Carbon are best operated hot
- A hybrid low density followed by high density target has many advantages and shoild be studied further