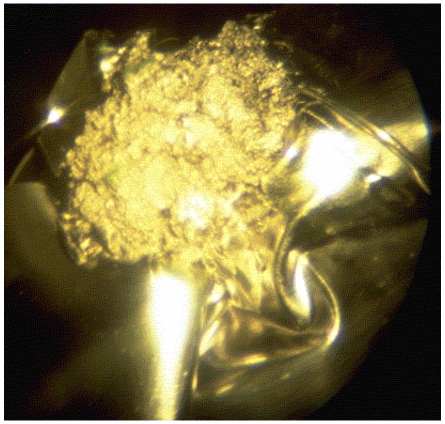
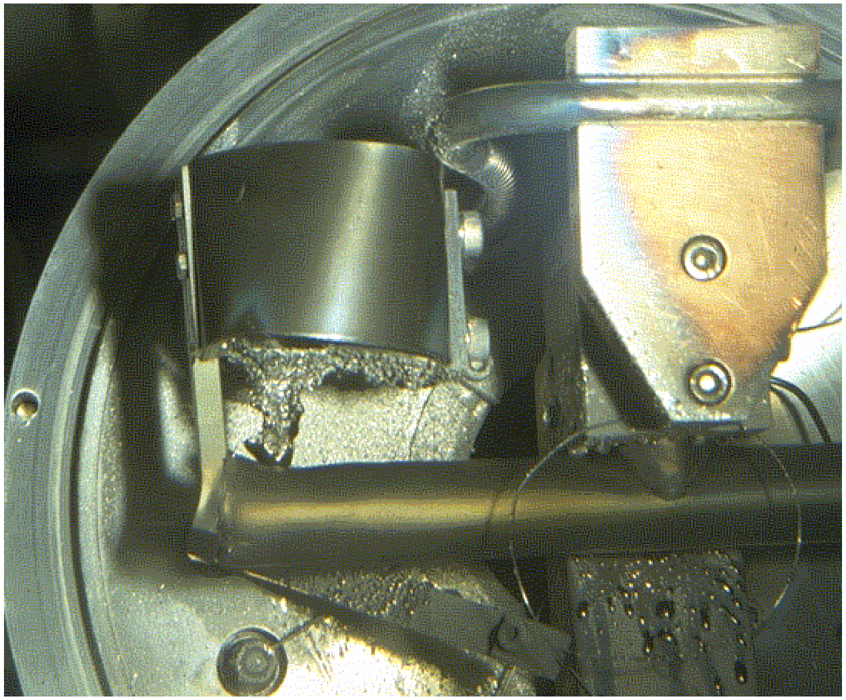
Why are we discussing targets ?

Stress induced plastic deformation



CERN-PS-booster 30 Tp
on ISOLDE targets:

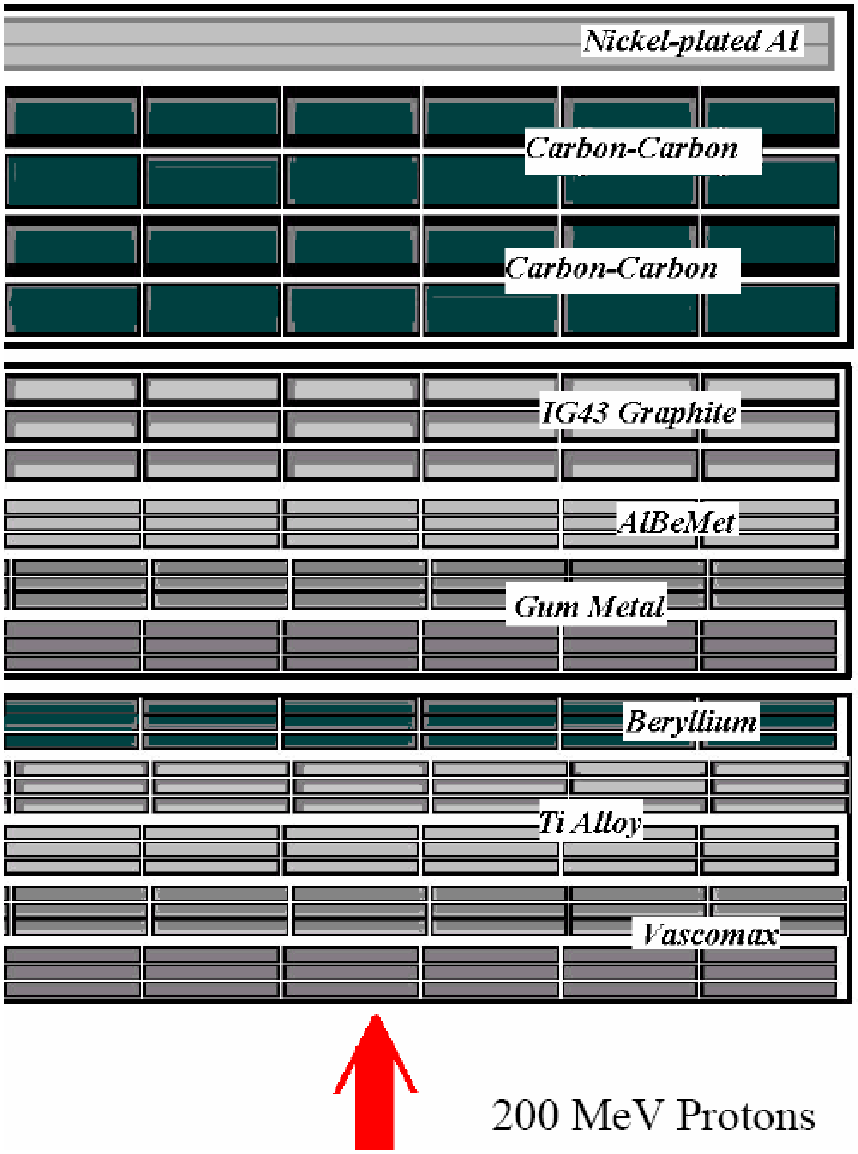
Shock induced rupture of confinement



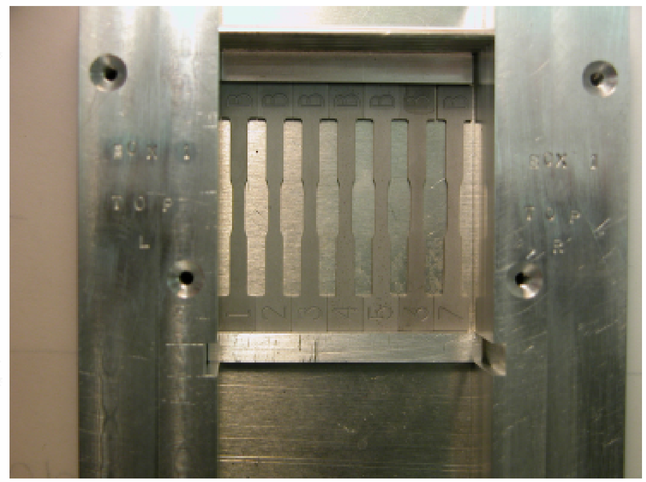
ISS Targetry Status, Issues & Plans

- Solid targets
  - Material studies; properties under irradiation of metals and graphite
  - Shocks and super metals
  - Simulation of the CNGS target response to a p-pulse
  - Measurement of shock waves
- Molten metal jet targets
  - Observation of shock waves
  - Magnetohydrodynamics experiment
  - Cavitation
  - Simulation
- Short intense proton pulses (ns)

Material tests after irradiation



Ref: N.Simos et.at BNL

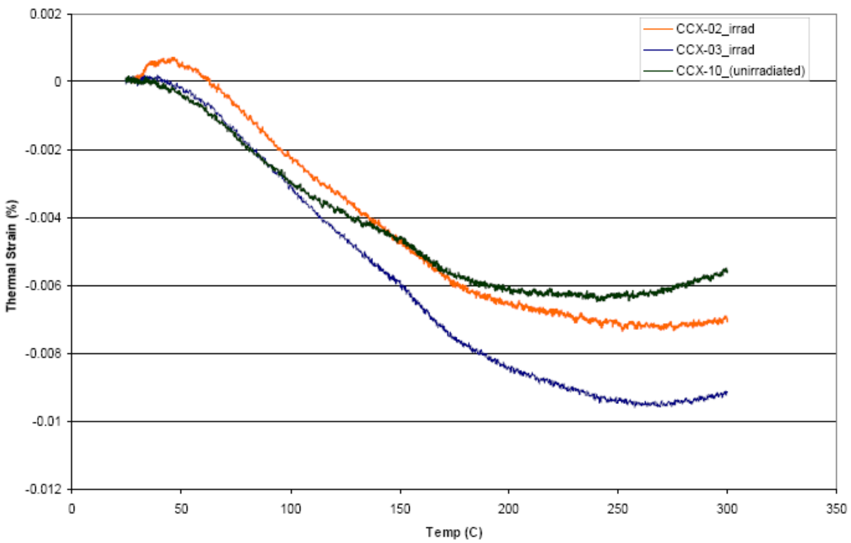


Few dpas (displacement per atom) expected in materials surrounding the target

C-composite

Th-expansion

Ref: N.Simos et.at BNL



Th-conductivity

Ref: J.P. Bonal et C.H. Wu
Nucl. Mat. 277 (2000)

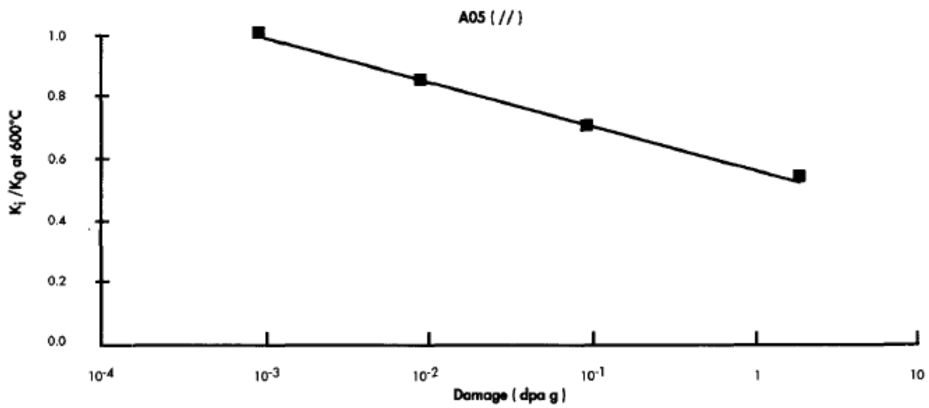
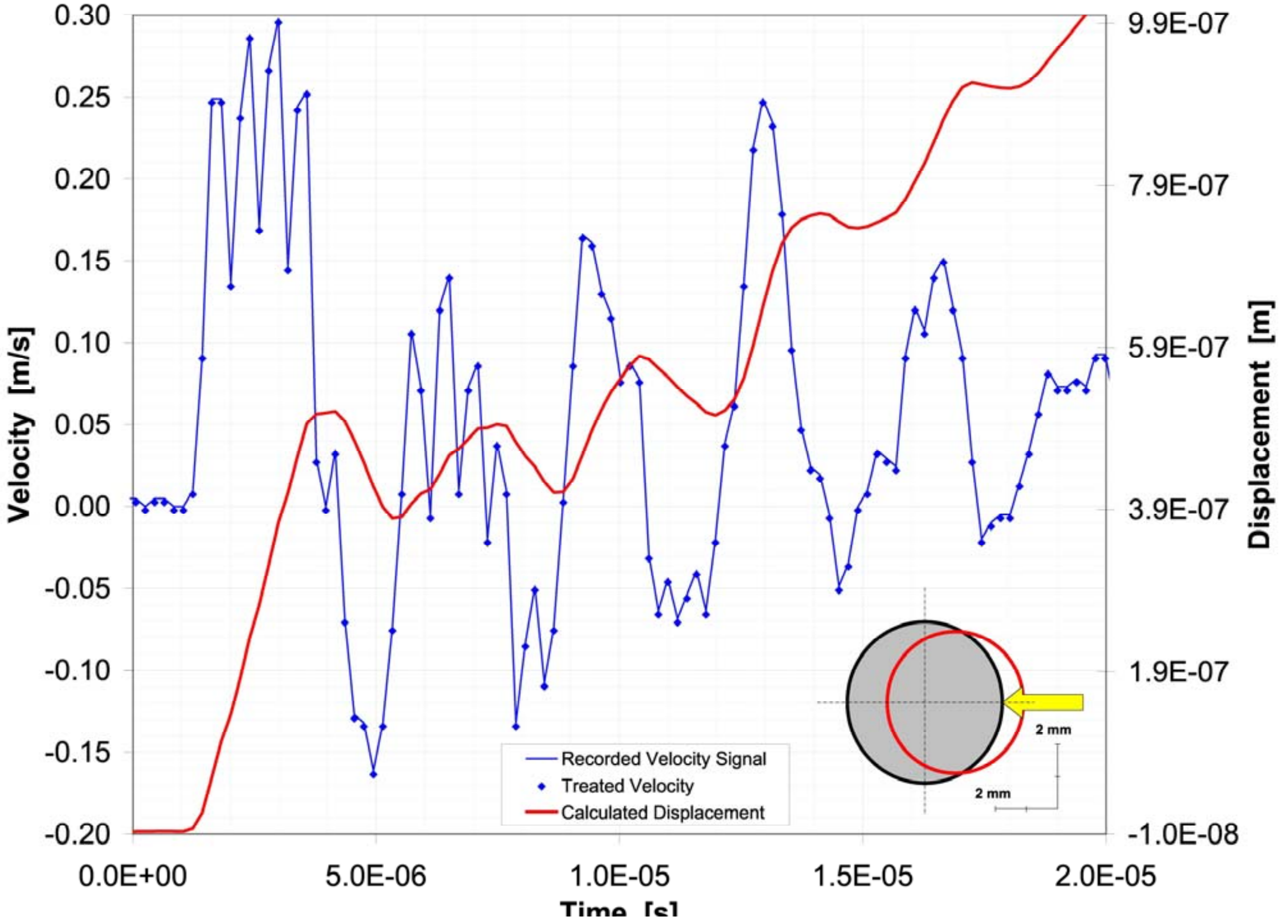


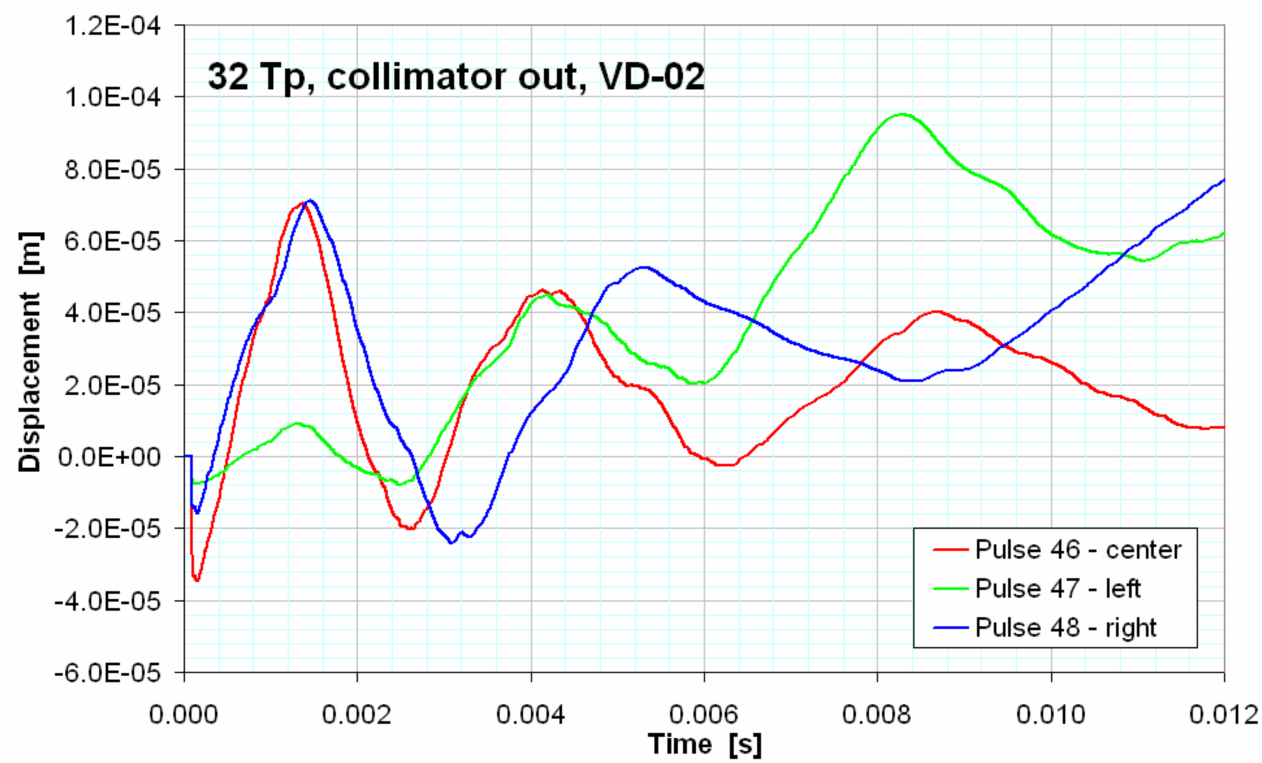
Fig. 4. Thermal conductivity A 05(||) normalized at 600°C as a function of neutron damage.

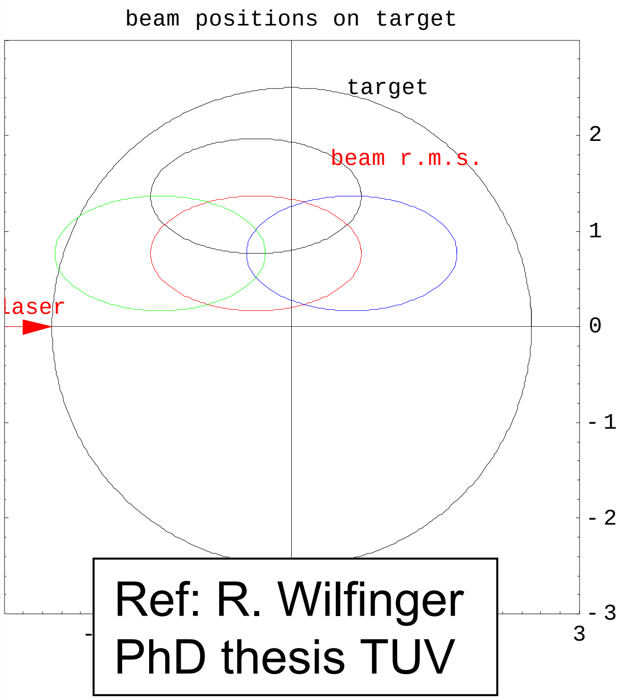
CNGS target test at ISOLDE

ISOLDE PS-booster p-beam
4 bunches of 8 TP within 2.4 μs



CNGS test at the SPS horizontal beam scan



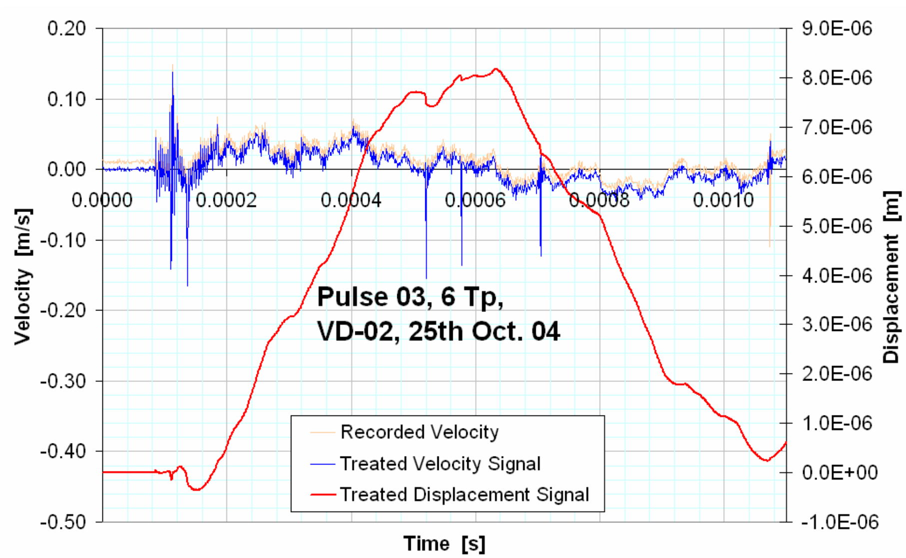


Displaced beam results in bending

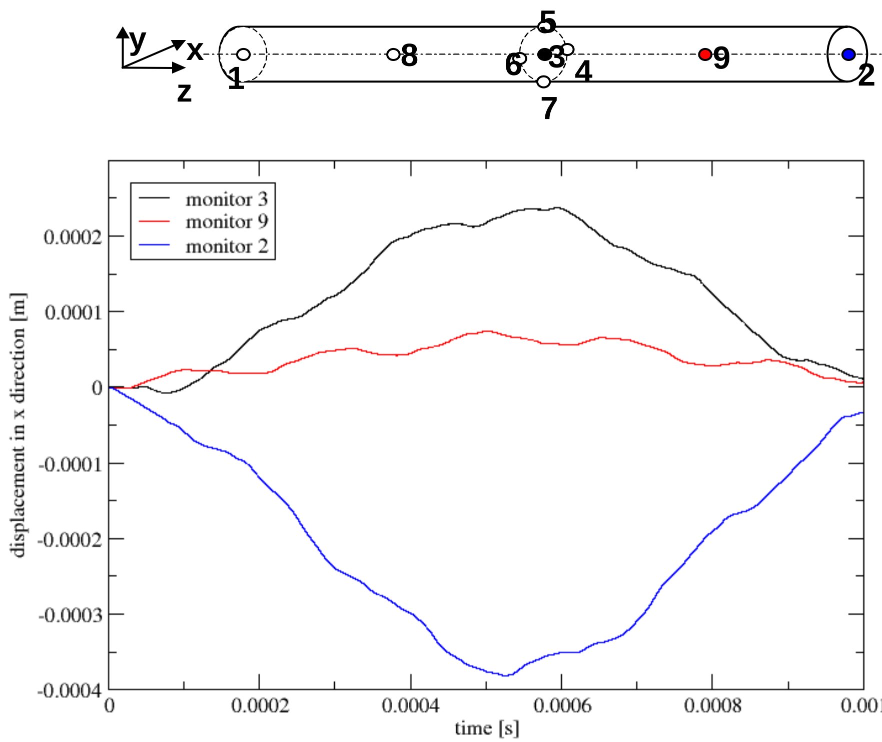
Qualitative Comparison

experiment ↔ simulation

Ref: R. Wilfinger
PhD thesis TUV

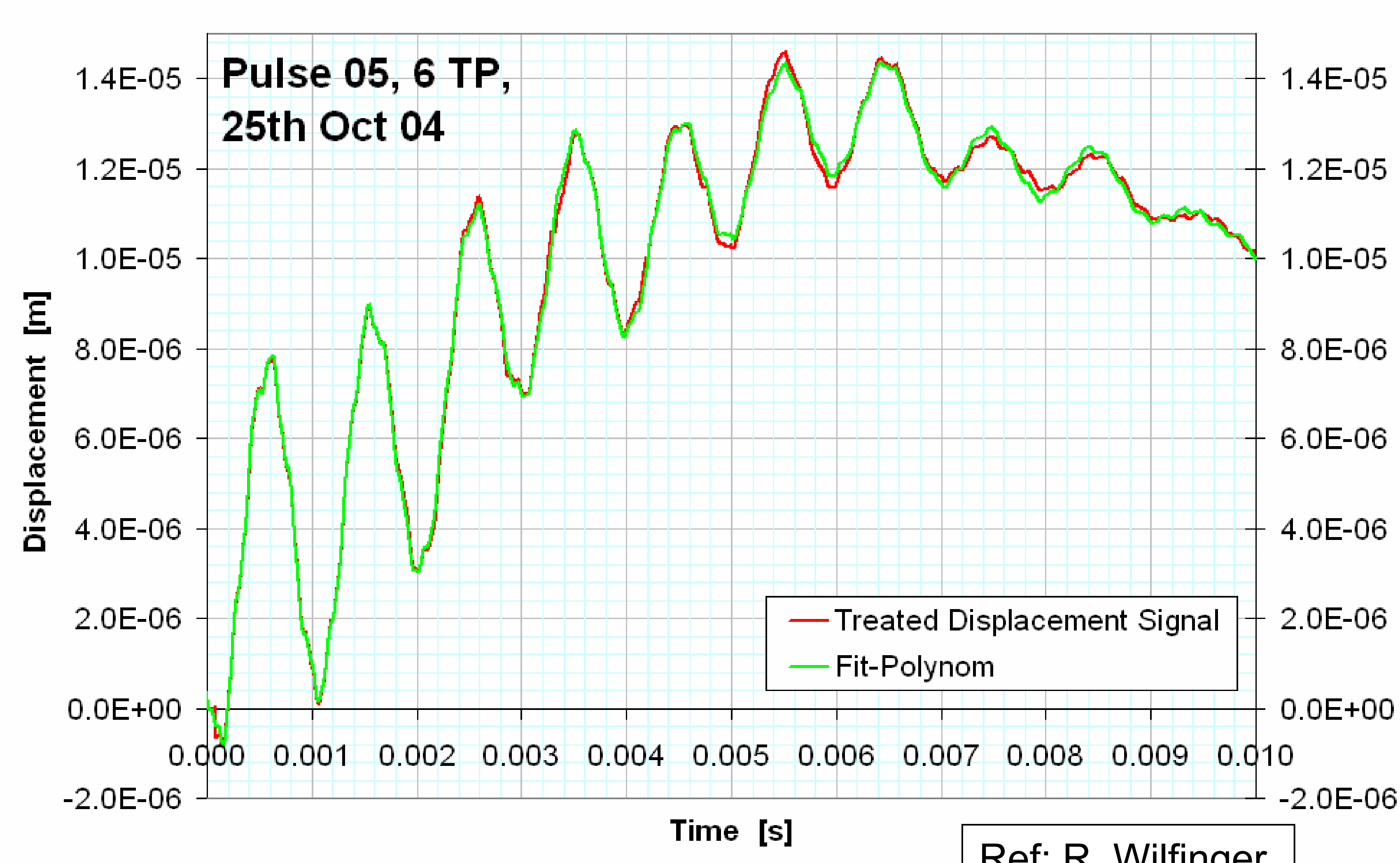


6 x 10^{12} p.o.t.,
CNGS 1st segment
TT40, 25th Oct.



3.5 x 10^{13} p.o.t.
CNGS 2nd segment
L. Massidda and F. Mura, CRS4

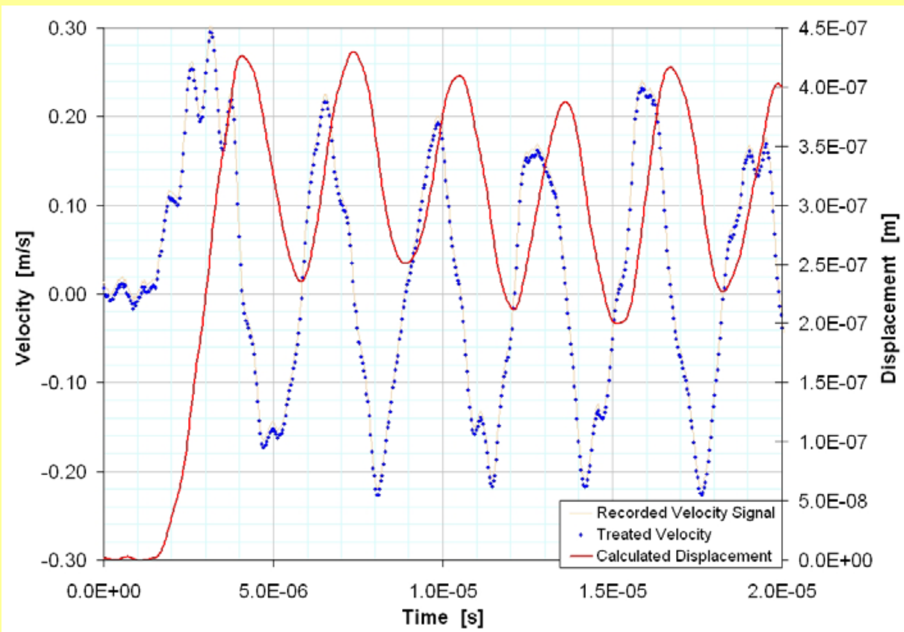
Damping constants of each eigen-modes

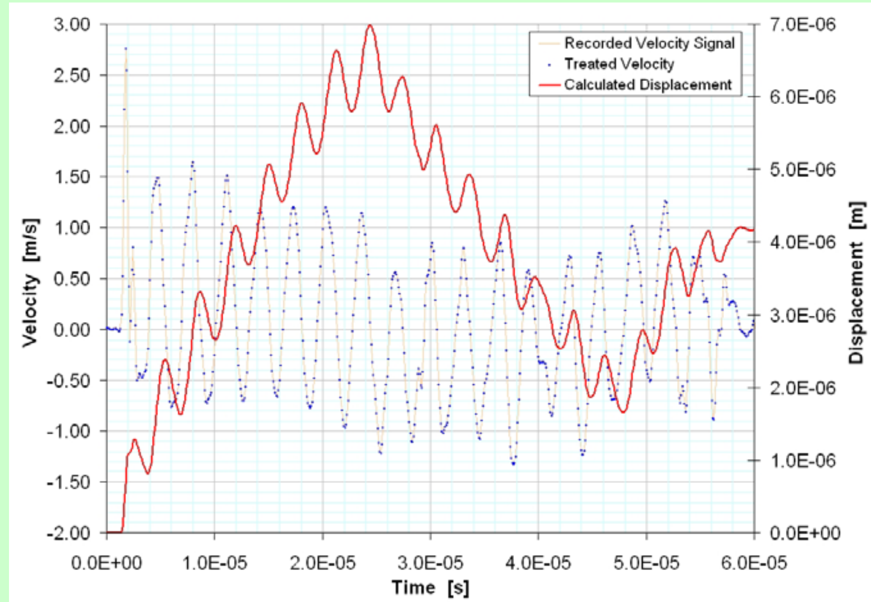


Ref: R. Wilfinger
PhD thesis TUV

Thermal Stress Waves in INVAR-36

Radial





Longitudinal

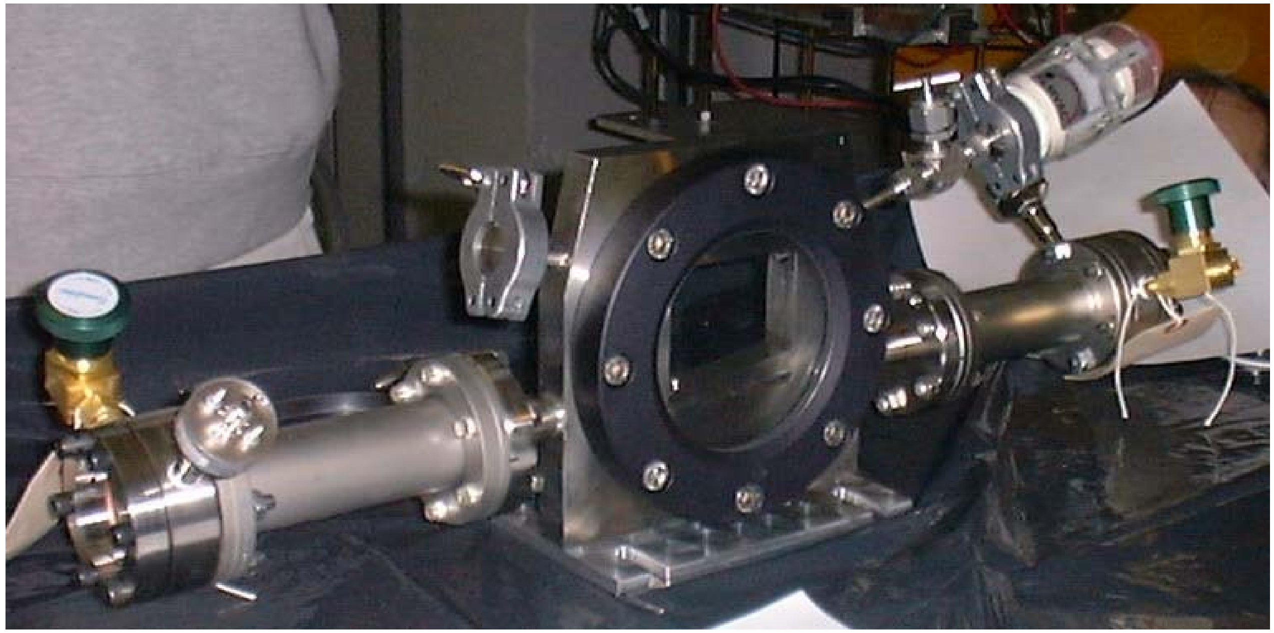
Ref: R. Wilfinger
PhD thesis TUV

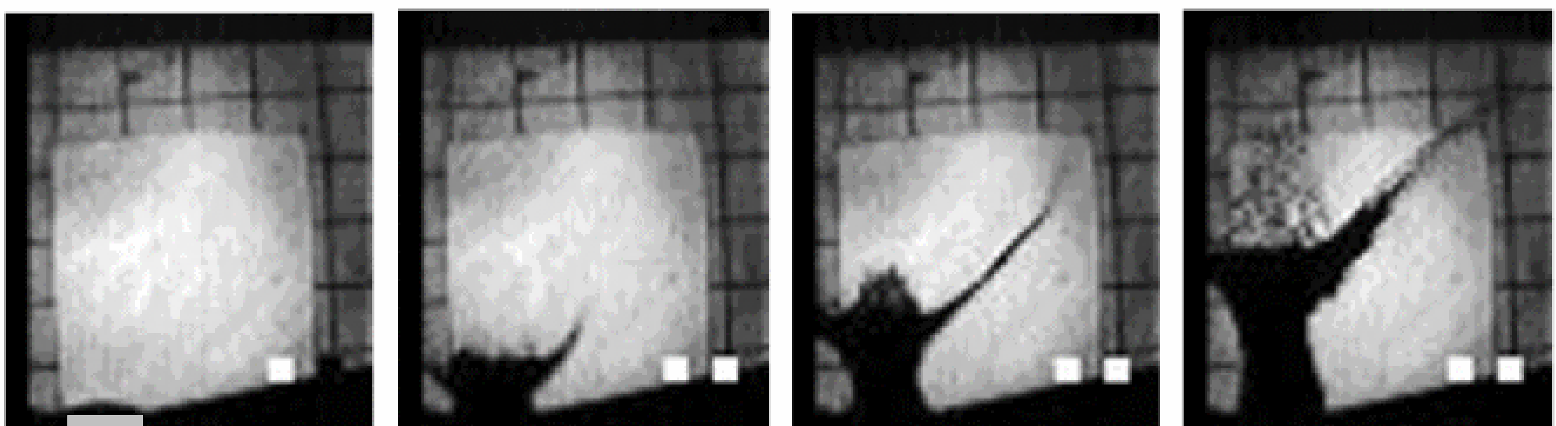
BNL-CERN thimble test

A. Fabich, J. Lettry, H. Kirk, K. Mc Donald, T. Tsang

1st P-bunch
1.8×10^{12} ppb
dt: 100 ns

24GeV p^{+}





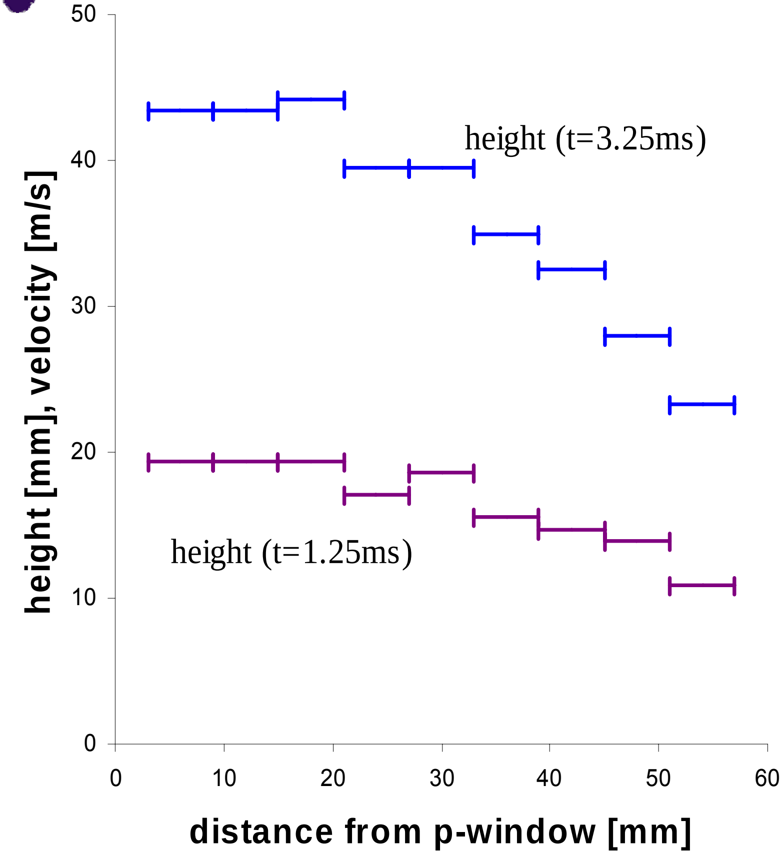
Hg

Timing : 0.0, 0.5, 1.6, 3.4 ms, shutter 25 μs

V_{splash} ~20-40 m/s

8 kHz camera

Hadronic cascade vs. splash velocities



Ref: A. Fabich
PhD. thesis TUV

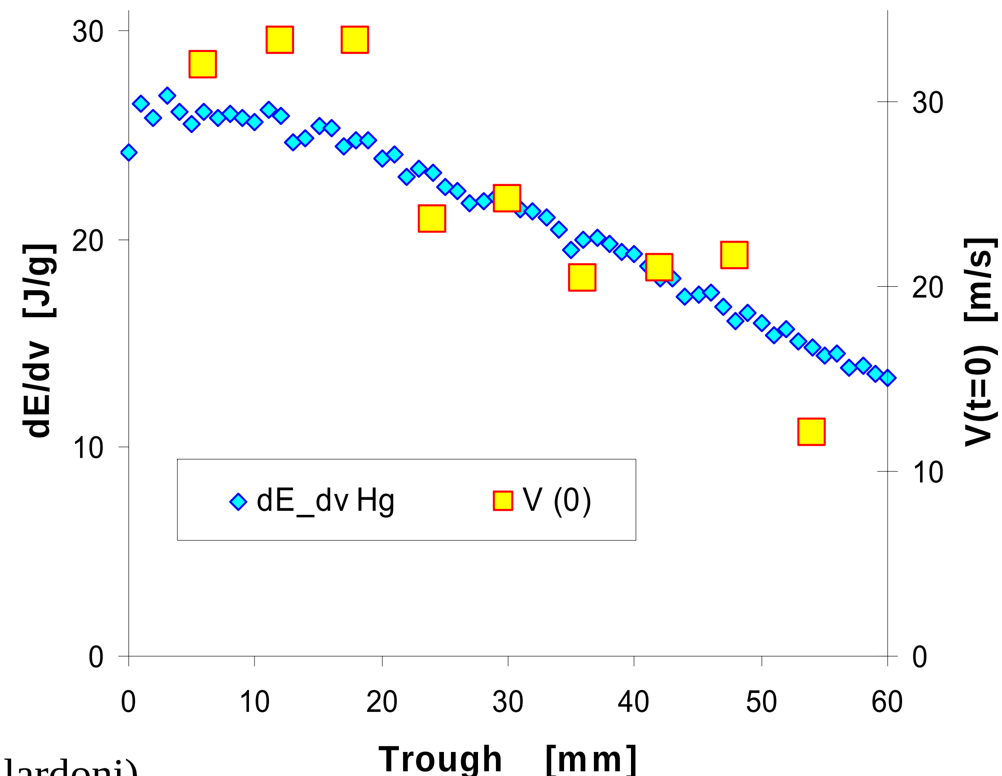
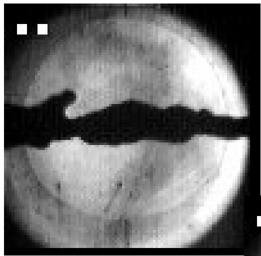


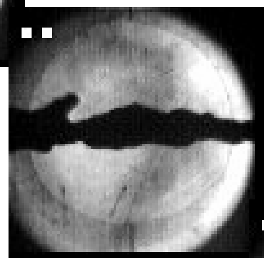
Image processing (6mm binning) by A. Fabich)
Energy deposition computed with MARS by S. Gilardoni)

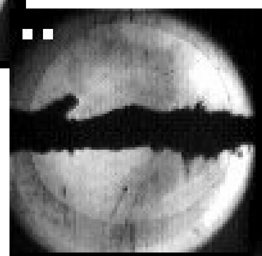
Hg-Jet test
BNL E-951

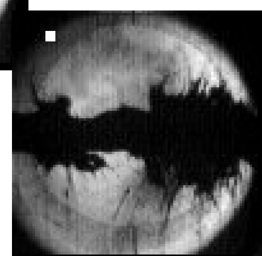
25th April 2001 #4

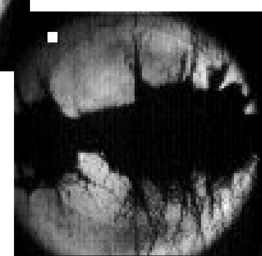
A. Fabich, H. Kirk, K. Mc Donald

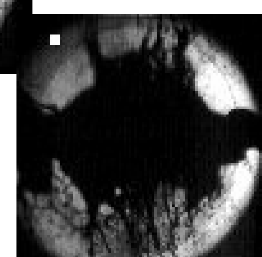


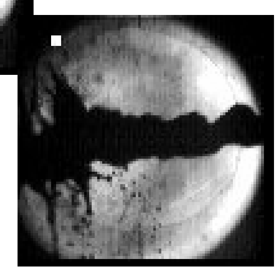












Pictures timing [ms]

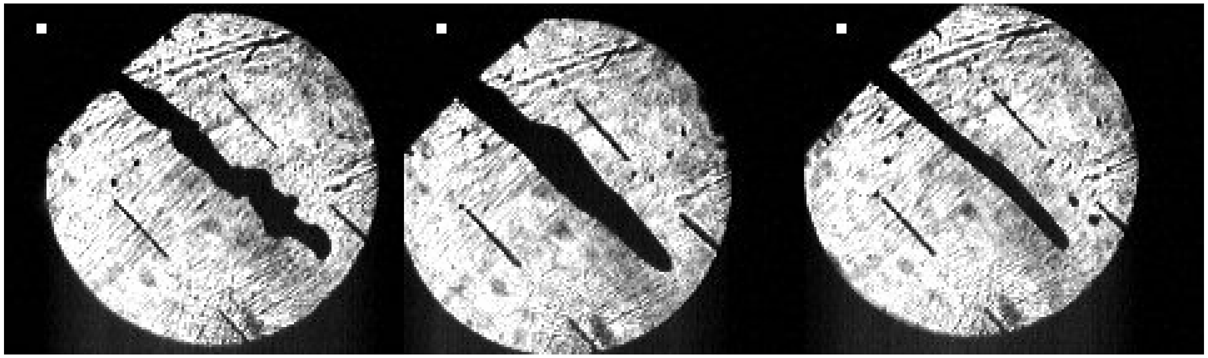
0.00
0.25
0.50
1.75
4.50
10.75
29.75

p-bunch: 3.8×10^{12} ppb, 26GeV
150 ns

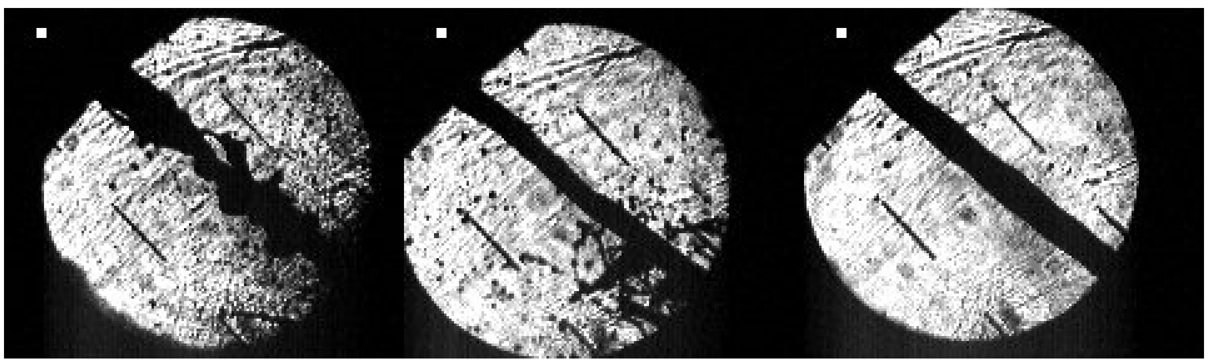
Hg- jet : diameter ~ 1cm
jet-velocity ~ 2.5 m/s
“explosion” velocity ~ 10 m/s

Jet velocities and shapes, injection at 6°, P(Hg) = 64 bar

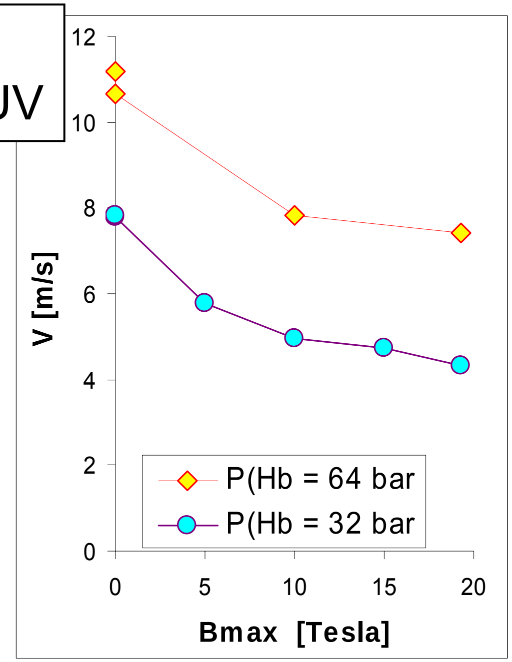
Ref: A. Fabich
PhD. thesis TUV

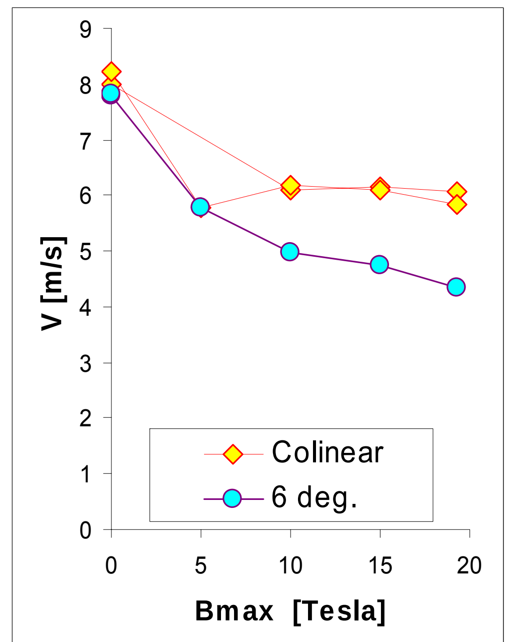


0 T **10 T** **19.3 T**



~10ms after the tip of the Hg-jet

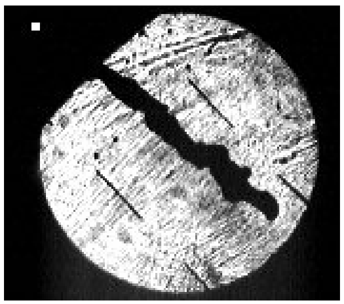


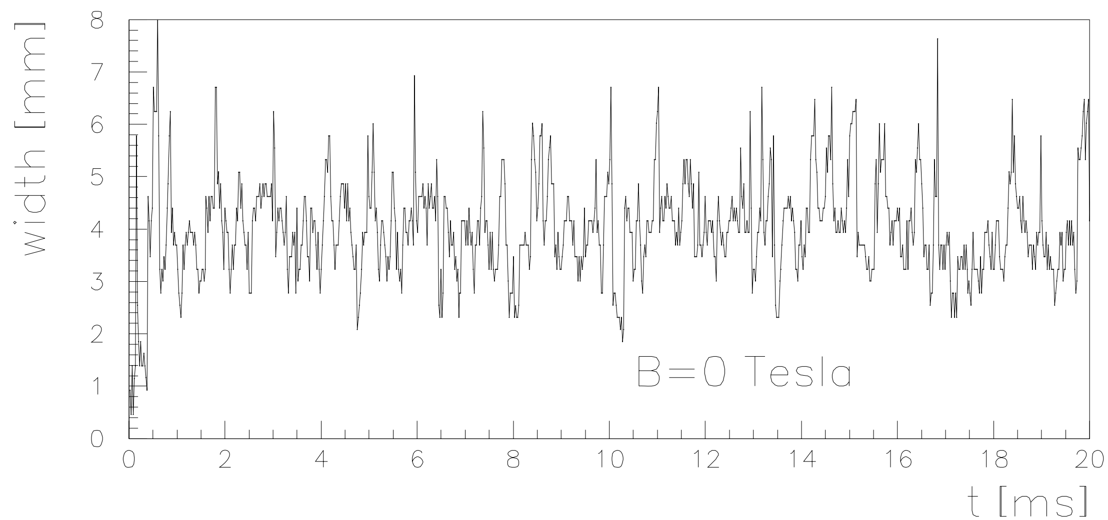


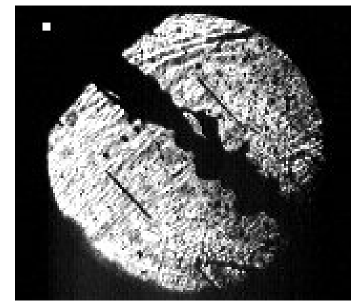
MHD damping of the instabilities of a Hg-jet

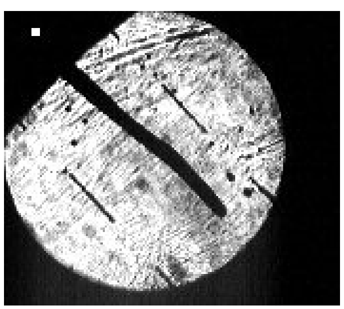
Ref: A. Fabich
PhD. thesis TUV

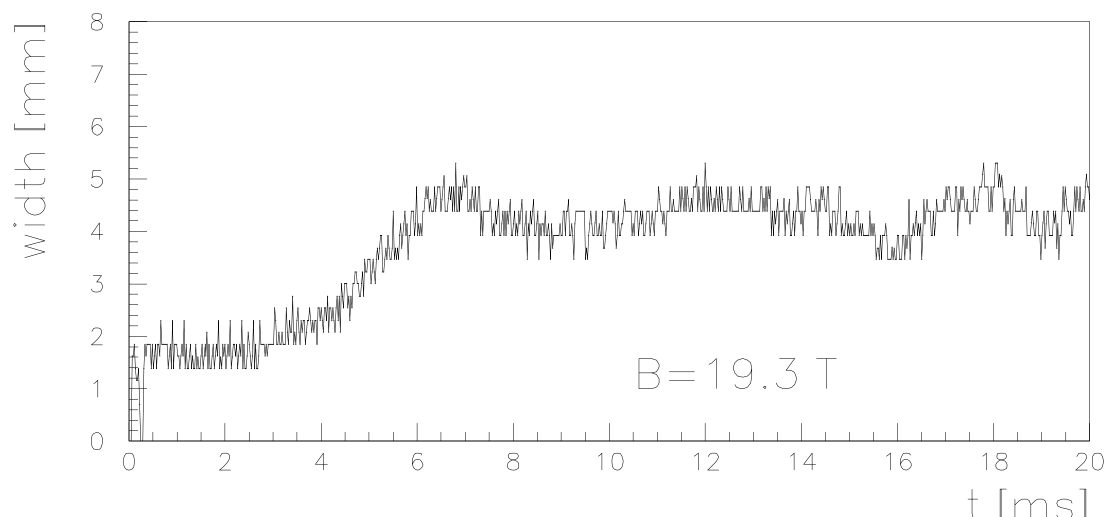
The radius is measured at a fixed position, the jet velocity is 11 m/s

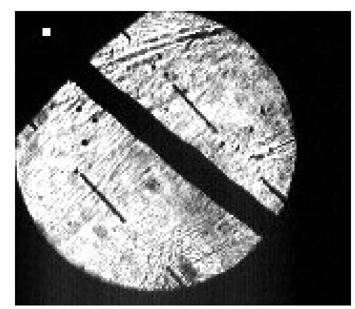






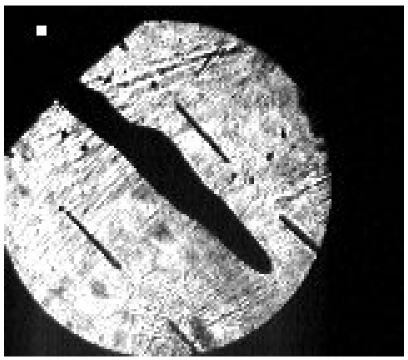


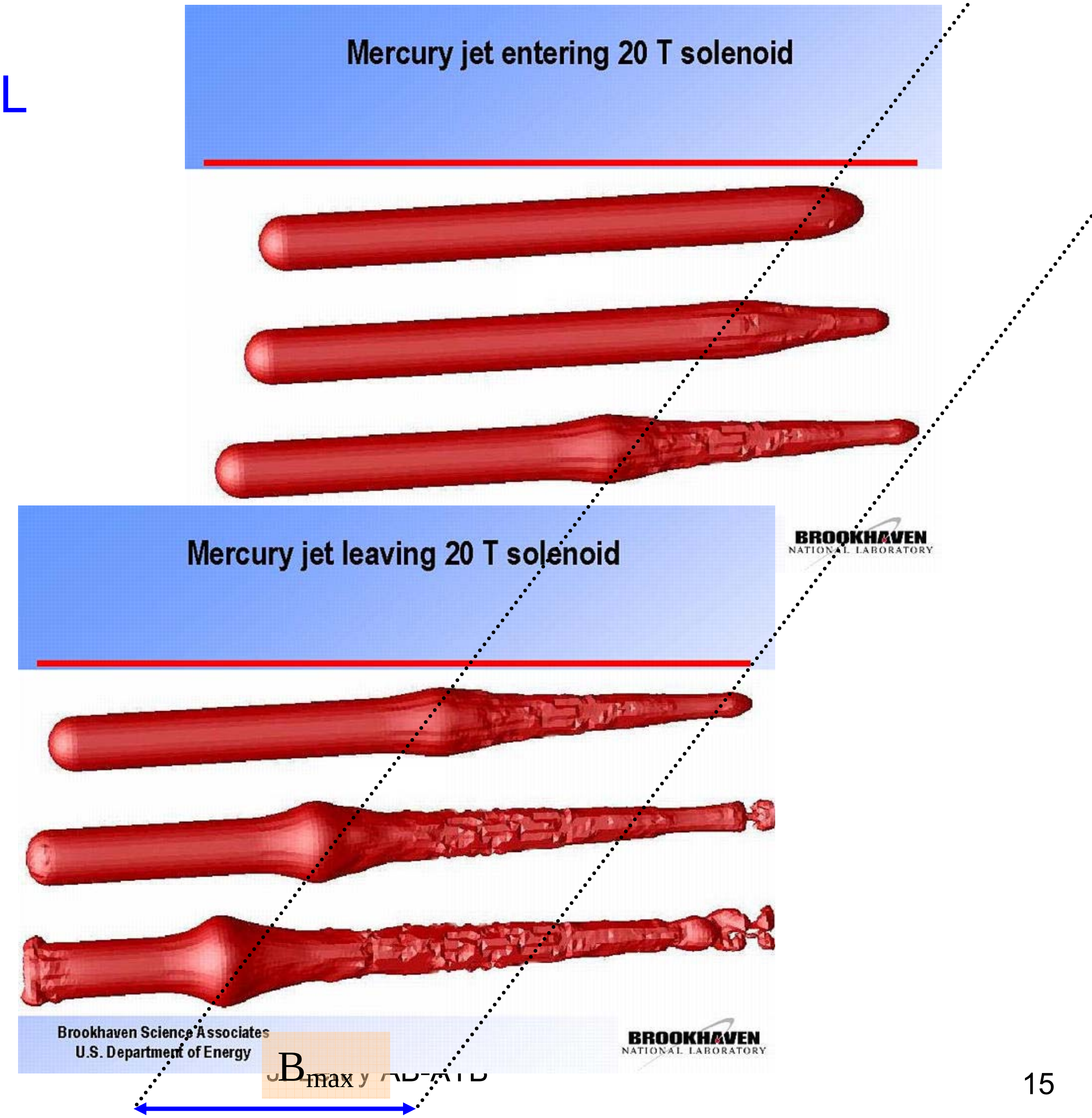




Simulation:
R. Samulyak BNL

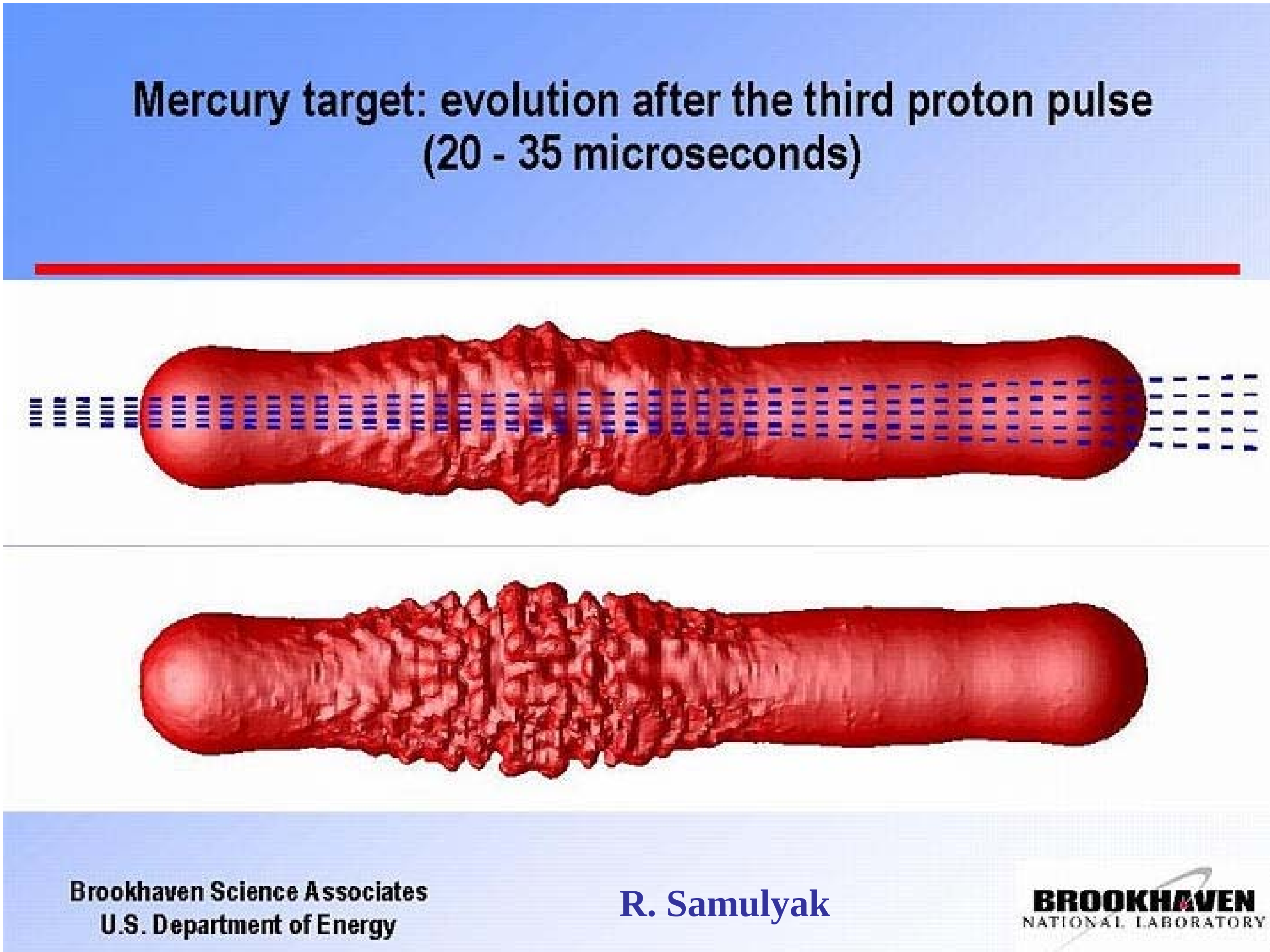
10 T





Water jet ripples generated by a 8 mJ Laser cavitation bubble (~50 μs after collapse)

Ref: E. Robert
Dipl. thesis EPFL


Mercury target: evolution after the third proton pulse
(20 - 35 microseconds)
Brookhaven Science Associates
U.S. Department of Energy
R. Samulyak
BROOKHAVEN
NATIONAL LABORATORY

Heat flow, mass flow

- He-cooling forced convection
  - Ta-beads
- Radiation cooling
  - Levitating ring
- New material for each proton pulse (20-40 kg/s)
  - Chain saw, bullets and molten metal Jets

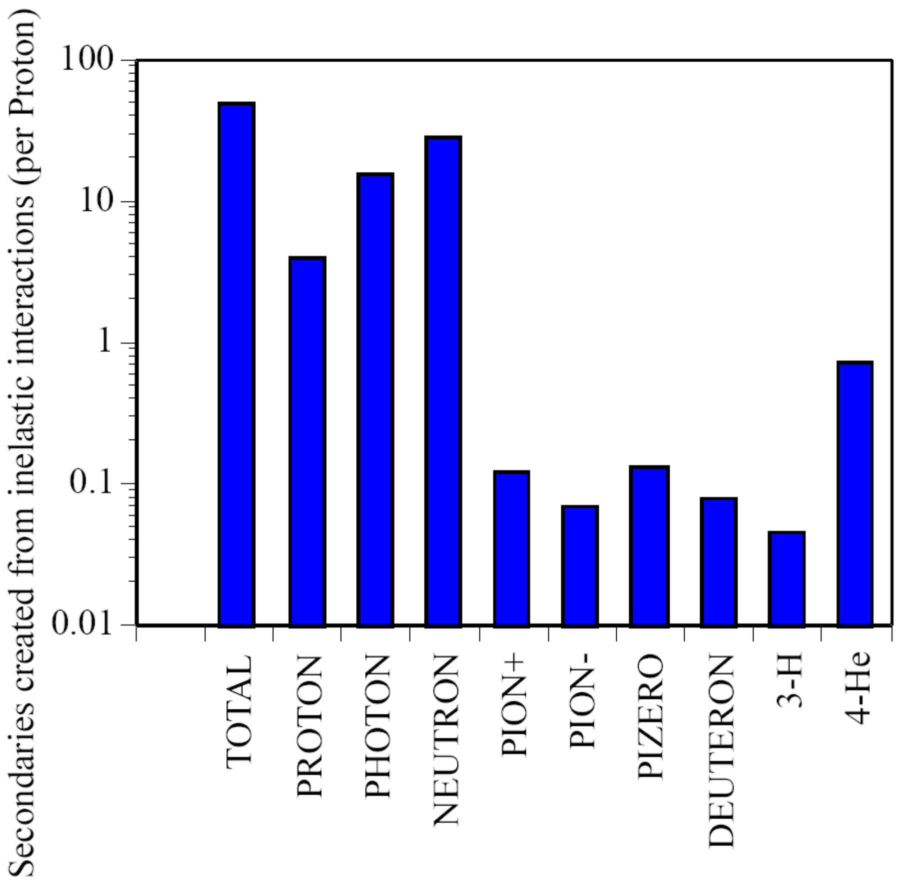
Molten metal jets were proposed to:
a) Avoid deformation of solids or high speed mechanics under vacuum
b) Reduce the effects of modification of the material constants with irradiation
c) Attempt to increase the power density of the beam beyond any solid.

Issues or new technologies to be established

- Molten metal targets
  - Hight pressure high velocity molten metal fluid dynamics
    - Cavitation in the piping
    - Corrosion
    - Recuperation of high velocity splashes
  - Purification of the molten metal circuits
- Solid targets
  - Effect of chemical impurities on material properties
  - High velocity mechanics under vacuum
  - Compaction of beads
- Component reliability or life time vs. exchange time
  - Horns
  - 20 T magnets
- Simulation codes
  - Beyond simple Energy deposition FLUKA,
  - Shock transport Kurchatov
  - 3d-Shocks with MHD BNL
  - Shocks CRS4
- Optical measurement techniques in high radiation environement
- MHD of MERIT's injector
- Activation of components, inventory of specific activities vs. time
  - Radioactive waste handling
  - Internal transport, intermediate storage
  - End disposal
- Experimental areas dedicated to target tests (highest radiotoxicity)

Particle multiplicity: 1 GeV protons in Hg

50.00% BY IONISATION,
21.80% BY EM-CASCADE,
9.50% BY LOW ENERGY NEUTRONS,
2.60% BY NUCLEAR RECOILS AND HEAVY FRAGMENTS,



Ref: Y. Kadi, A. Herrera

Short time scale ns pulses

For ns-pulse duration, all protons are within a 30 cm target.
The multiplicity of secondaries is ~few hundred particles above keV and few millions electron – ion pairs
Even if generated within 1 ns by 10^{14} GeV protons the particle density is still very small ppM compared to the atomic one.
However, is this charge state distribution within the solid / liquid negligible in view of the respective mobilities of ions and electrons that are quite different ?
What differs in the response of metals (conduction band) and moderate density graphite ?

$\_{e}$ ~ 10^{-16} s - characteristic time of the electron - electron interaction;

$\_{e\text{-}ph}$ ~ 10^{-13} s - characteristic time of the electron - phonon interaction;

$\_{ph\text{-}ph}$ ~ $10^{-12} \div 10^{-11}$ s - characteristic time of phonon - phonon interaction;

A.I. Ryazanov Kurchatov Inst.

Plans (and wishes that may only become true with adequate funding)

- Experiments:
  - MERIT (n-ToF-011)
  - P-induced shock on high temperature Ta-cylinder with a VISAR (RAL)
- Material studies
  - Irradiation at high temperature (EURISOL DS)
  - Mechanical tests of irradiated materials …
  - Material tests via eigen-frequencies …
- Simulation codes BNL, FLUKA, Kurchatov,CRS4
- High power target test station …

High Powered Target Test Facility (HPTTF).
The HPTTF will be discussed, in detail, at the upcoming High Power Targetry Workshop in October 2005 at ORNL/SNS.

Thanks to all contributors