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

| Nickel-plated Al | Carbon-Carbon | Carbon-Carbon | IG43 Graphite | AlBeMet | Gum Metal | Beryllium | Ti Alloy | Vascomax |

200 MeV Protons

Few dpa\(\text{s}\) (displacement per atom) expected in materials surrounding the target

Ref: N. Simos et. al. BNL
C-composite

Th-expansion

Ref: N. Simos et al. at BNL

Th-conductivity

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

Ref: R. Wilfinger
PhD thesis TUV
Qualitative Comparison
experiment ↔ simulation

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

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

22 September 2005
J. Lettry AB-ATB

Ref: R. Wilfinger
PhD thesis TUV
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

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

24GeV $p^+$

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

8 kHz camera

$V_{\text{splash}} \sim 20-40 \text{ m/s}$

A. Fabich, J. Lettry, H. Kirk, K. Mc Donald, T. Tsang
Hadronic cascade vs. splash velocities

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

Ref: A. Fabich
PhD. thesis TUV
Hg-Jet test
BNL E-951
25th April 2001 #4

p-bunch: $3.8 \times 10^{12}$ 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

~10ms after the tip of the Hg-jet

Ref: A. Fabich
PhD. thesis TUV

22 September 2005       J. Lettry AB-ATB
MHD damping of the instabilities of a Hg-jet

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

Ref: A. Fabich
PhD. thesis TUV

22 September 2005

J. Lettry AB-ATB
Simulation:
R. Samulyak BNL

10 T

Mercury jet entering 20 T solenoid

Mercury jet leaving 20 T solenoid

Brookhaven Science Associates
U.S. Department of Energy
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)
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
  – High 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 environment

• 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?

- $e \sim 10^{-16} s$ - characteristic time of the electron-electron interaction;
- $e_{ph} \sim 10^{-13} s$ - characteristic time of the electron-phonon interaction;
- $ph-ph \sim 10^{-12} - 10^{-11} s$ - 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.

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