Highlights in liquid metal targets

SNS
ESS
MEGAPIE
LANCE
IFMIF
RIA
BNL
CERN
EURISOL β–ν–beams

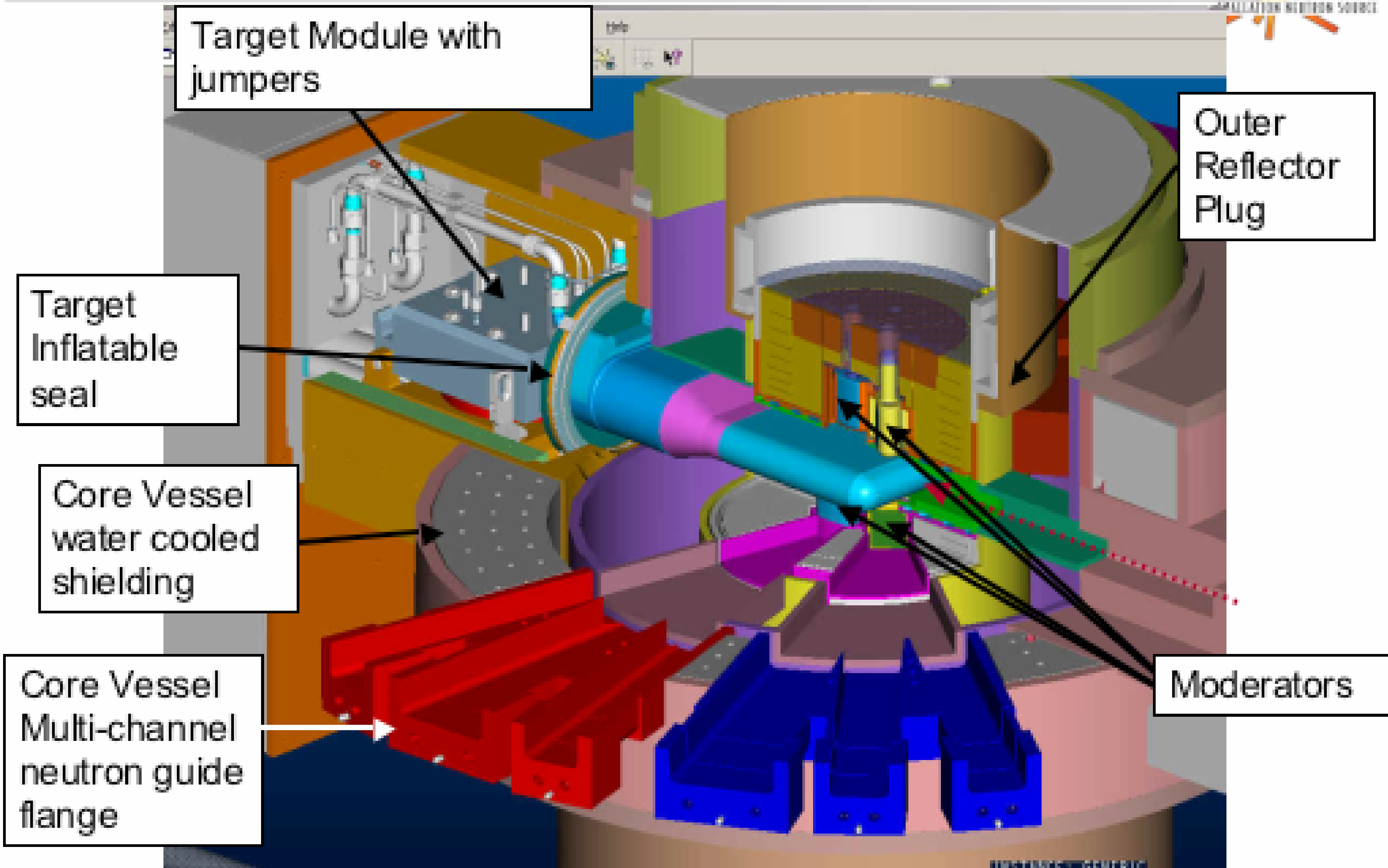
Workshop onHigh-Power Targetry for Future Accelerators
Ronkonkoma, New York, September 8-12, 2003

H. L. Ravn

Target Systems for the Spallation Neutron Source

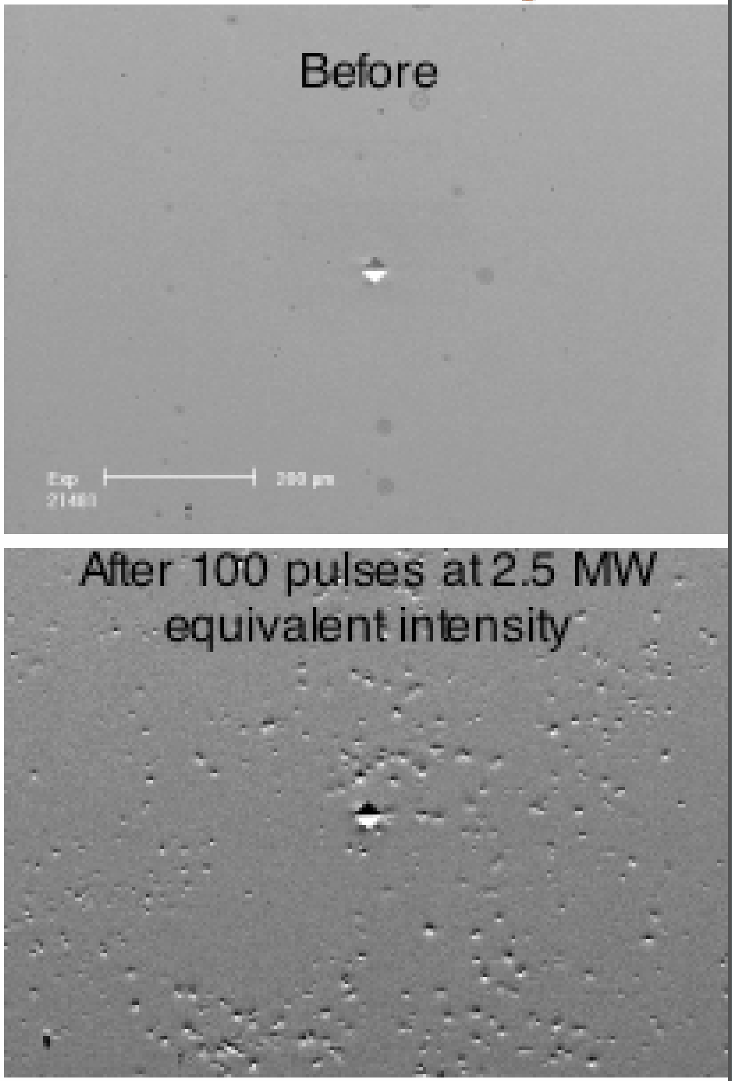
Presented by
John R. Haines
at the
High-Power Targetry for Future Accelerators
September 8-12, 2003

Target Region Within Core Vessel



Cavitation Bubble Collapse Leads to Pitting Damage

- Large tensile pressures occur due to reflections of initial compression waves from steel/air interface.
  - These tensile pressures break (cavitate) the mercury.
  - Damage is caused by violent collapse of cavitation bubbles under subsequent interaction with large compression waves.
- A series of tests were conducted at LANLs WNR facility to examine sensitivity of pitting damage to various parameters, materials, and mitigation schemes
  - 100 - 1,000 pulses
  - Stagnant Hg inside closed targets
  - Examined highly polished surfaces before and after irradiation to quantify damage
- Extrapolation to > 10^8 pulses performed using off-line pressure pulse tests

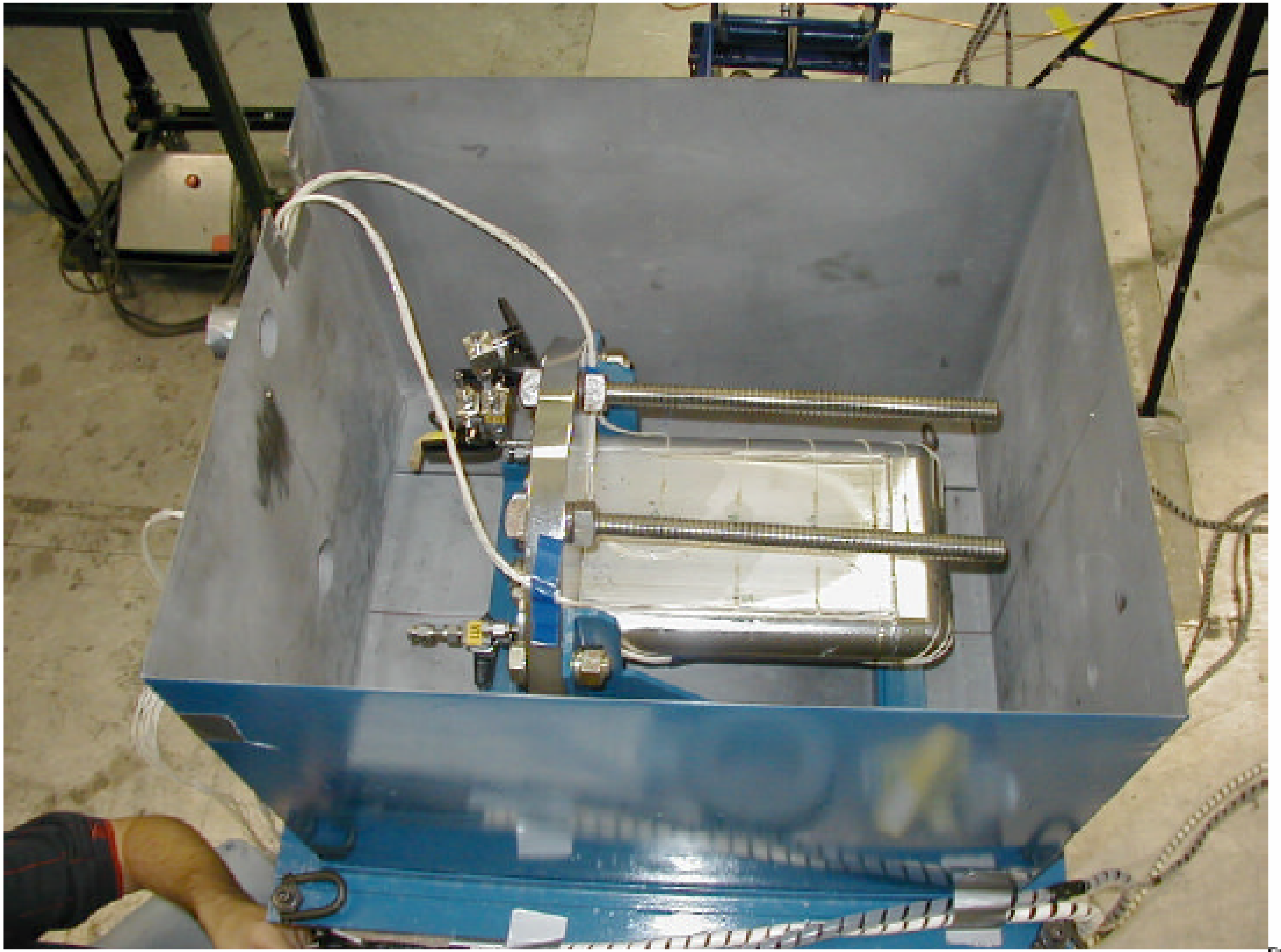


Benchmarking Dynamic Strain Predictions of Pulsed Mercury Spallation Target Vessels

Bernie Riemer

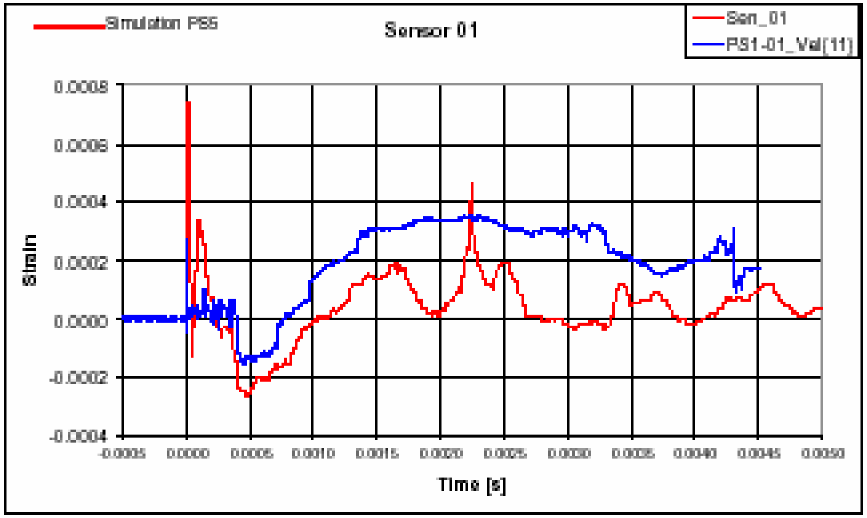
High-power Targetry for Future Accelerators Workshop, Sept. 8-12, 2003

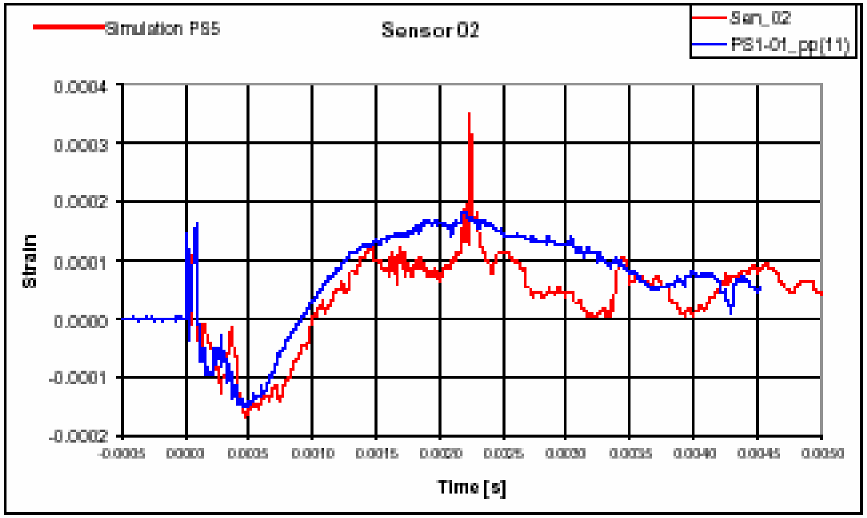
PS target ready for test.

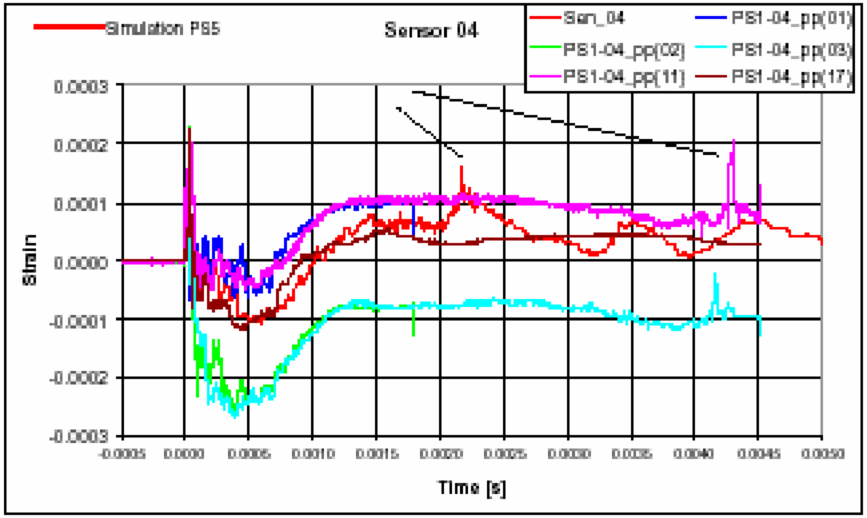


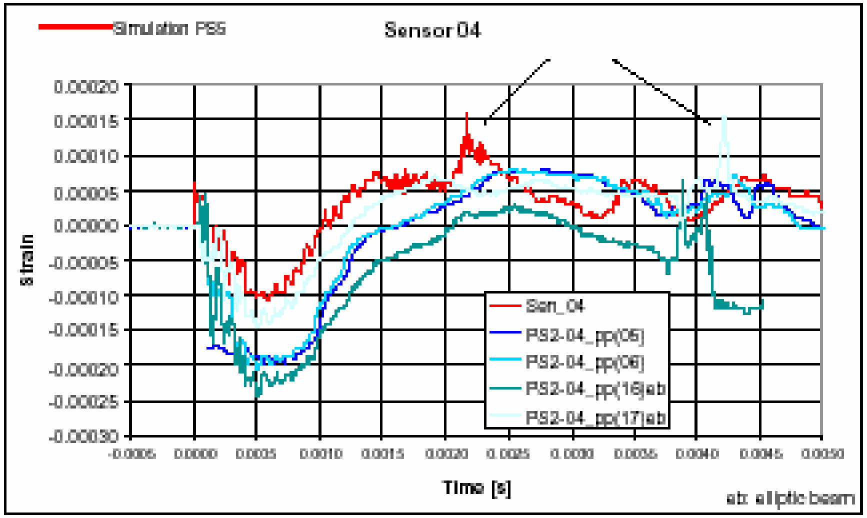
Simulation vs. test data: nose - center

RED = SIMULATION









High Power Targetry for Future Accelerators
September 8-12, 2003
Ronkonkoma, NY

Carrying ESS Forward – R&D on High Power Targets in the EU-FP6

Günter S. Bauer

Forschungszentrum Jülich, Germany
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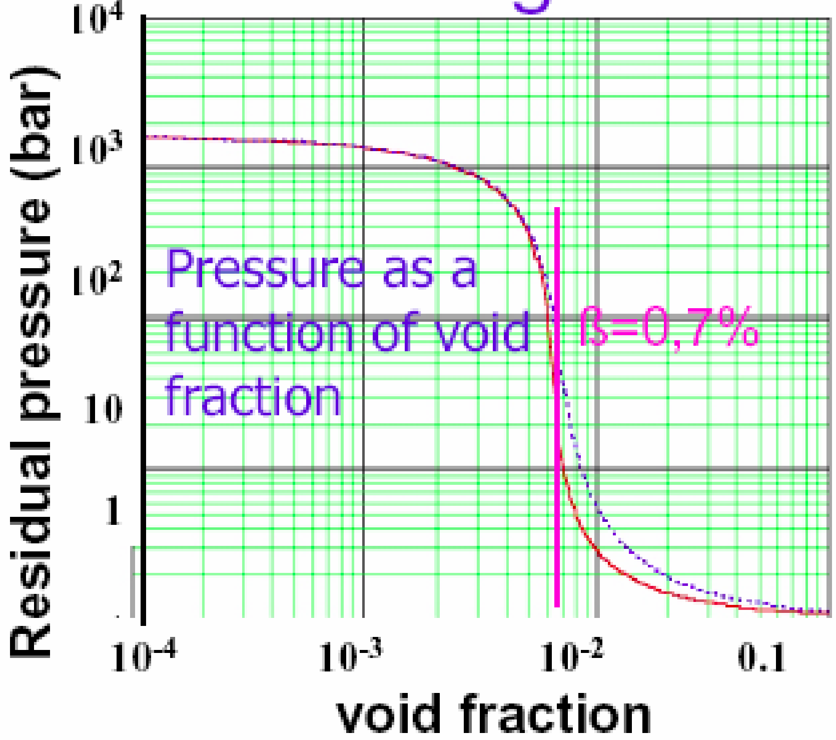
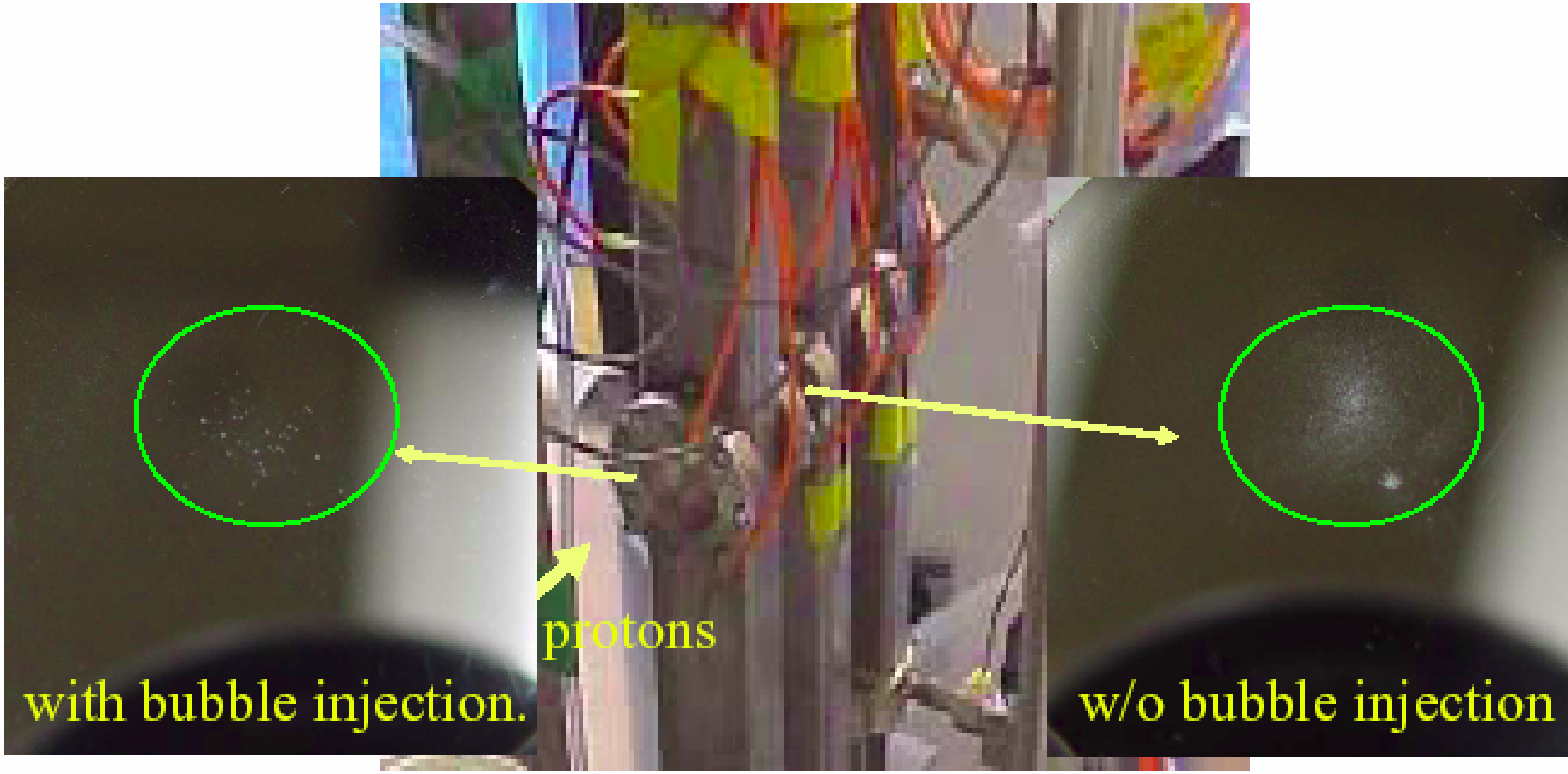
Pressure Pulse Mitigation in Mercury



A volume fraction of ca1% of compressible gas bubbles with about 0.5 mm diameter are expected to reduce pressure buildup by nearly 3 orders of magnitude

Focus of research by the ESS team in collaboration with SNS and JSNS

First PoP-test of Bubble Effect at WNR in June 2002



Maximum energy density in targets was 17.5 J/cc in bubble target and 14.4 J/cc in control target (p^4 = 93789 and 42998 respectively)

⇒ Would expect more than twice the damage in bubble target

⇒ Find significantly less

Topics for R&D on Source Enhancement

Advanced Moderators:

- **There is a prospect to improve long wavelength performance and flexibility of cryogenic moderators significantly by going to a heterogeneously cooled solid moderator material**
  - Coolability and radiation resistance of solid moderators
  - Manufacturing of suitable pellets
  - Transport and annealing
  - Need demonstration of cryogenic system

Targets:

- **To date there is no proven concept for a 5 MW pulsed target**
  - Cavitation erosion by pressure waves is an unresolved issue
  - There remain several materials problems to be investigated
  - Alternative options to the proposed concept need to be qualified
  - Need a prototypic demonstration ready to go in a beam

Preparations for FP6

- Intend to apply for a Design Study: **ADVICES**
  "Advanced Design Validation and Innovative Concepts for a European Spallation Facility"
  with three main topics:
  - *Solid Cold Neutron Moderators at Very Low Temperatures*
    (emphasis on pelletized methane hydrate)
  - *Technology, Safety and Limits of Liquid Metal Targets*
    (emphasis on Hg targets and their structural materials, including hazards and disposal)
  - *Alternative Options for Source Drivers and Targets*
    (emphasis on existing or planned accelerators and materials issues in solid targets)

Workshop on
Target Station and Laboratory Facilities for Eurisol
27.-28.2.2002 CLRC Rutherford Appleton Laboratory

MEGAPIE
A liquid metal target for 1 MW proton beam power

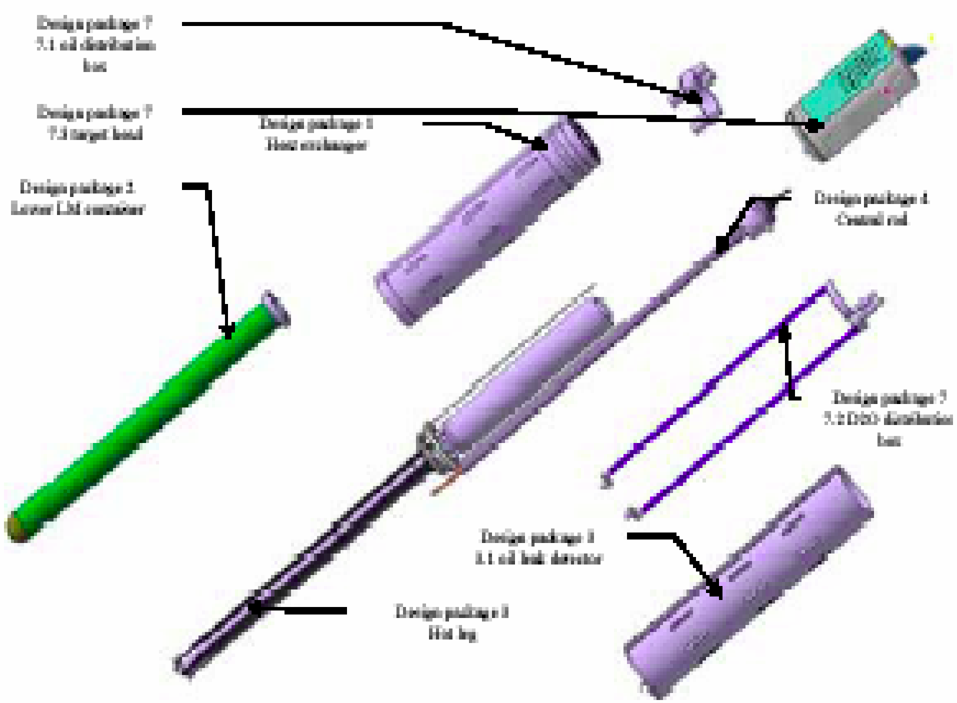
presented by
F. Groeschel

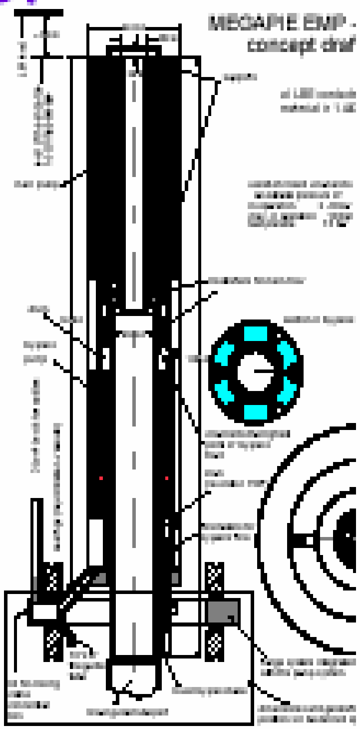
Outline:

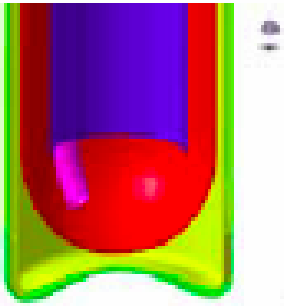
Project Outline
SINQ facility
Target Design
Target Performance
Ancillary Systems
Handling Operations

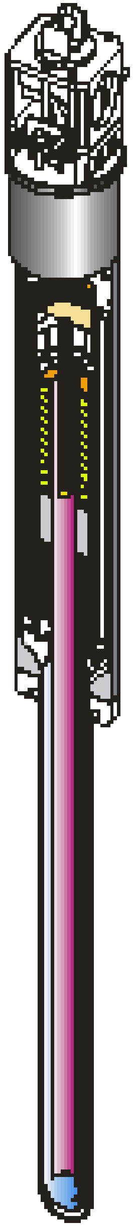
MEGAPIE Target

Overall Length: 5.39 m, Weight: 1.5 to (empty)
LBE volume: 82 l, wetted surface: 8 m²
Deposited Heat 650 kW
LBE T range 240-380°C, max. flow rate ~1 m/s
Beam window T91 steel, T 330-380°C, 20 - 25 dpa

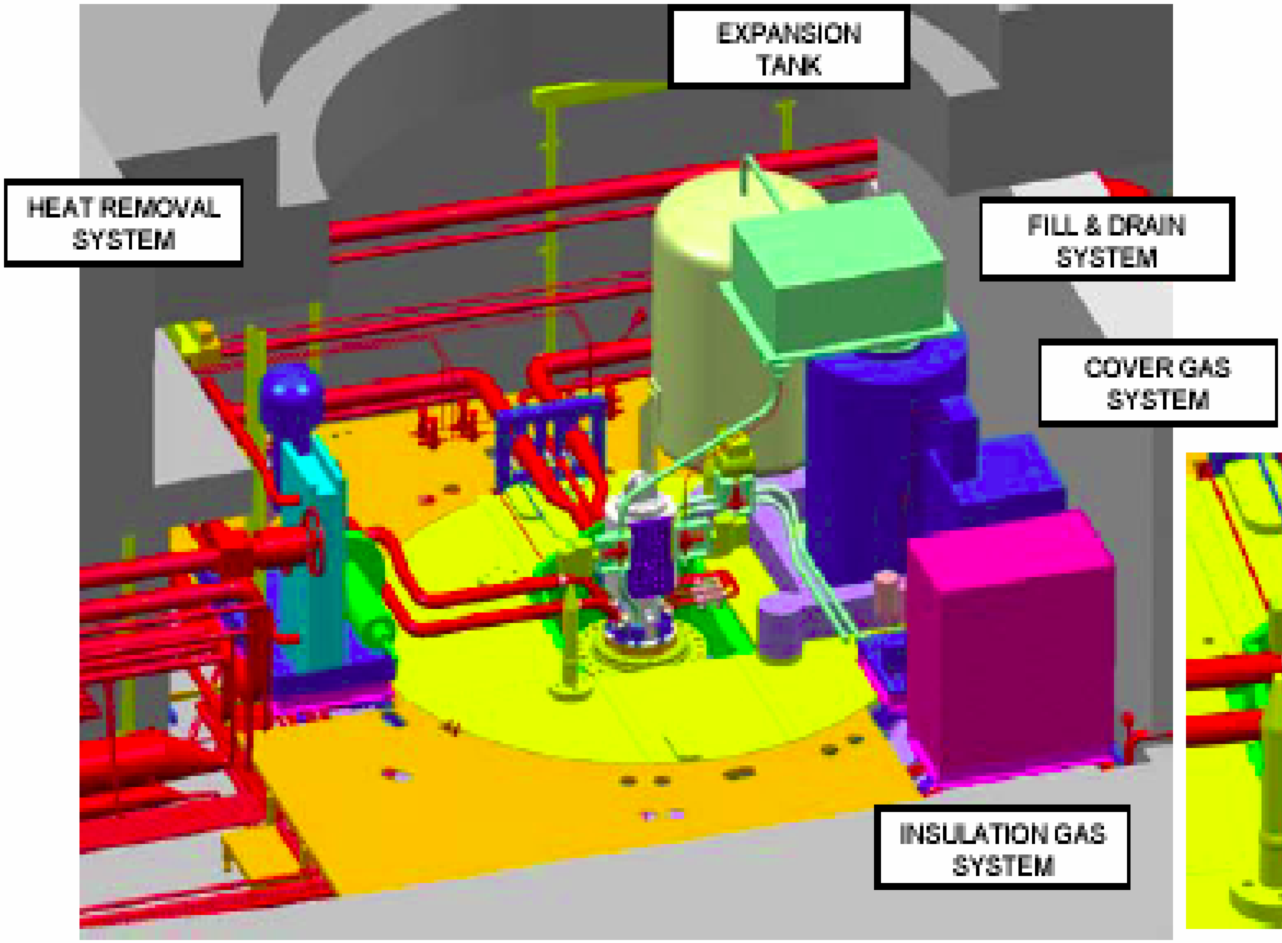


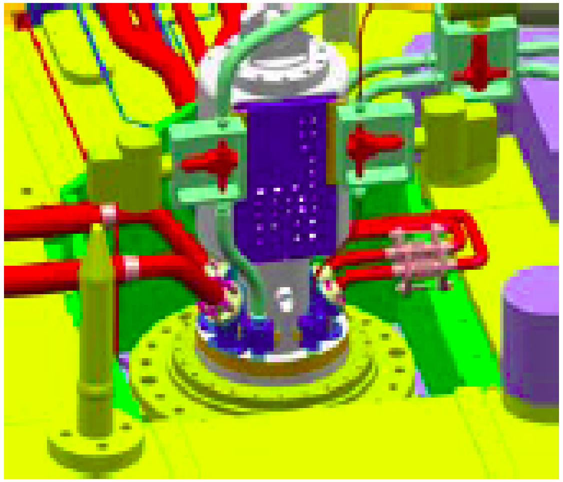






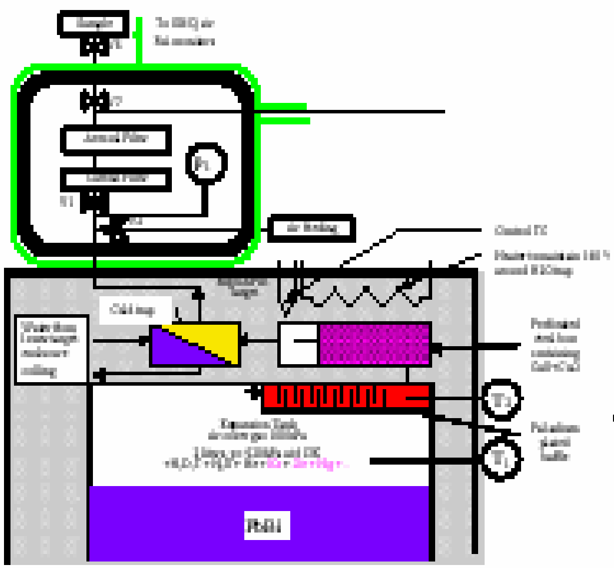
Ancillary Systems

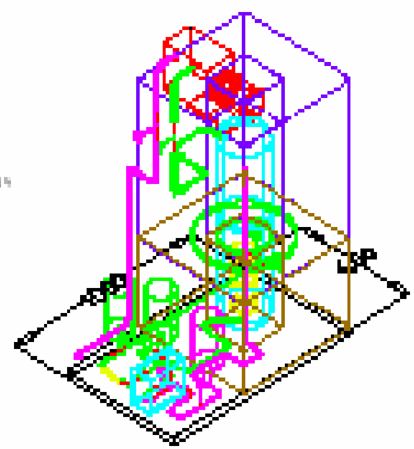


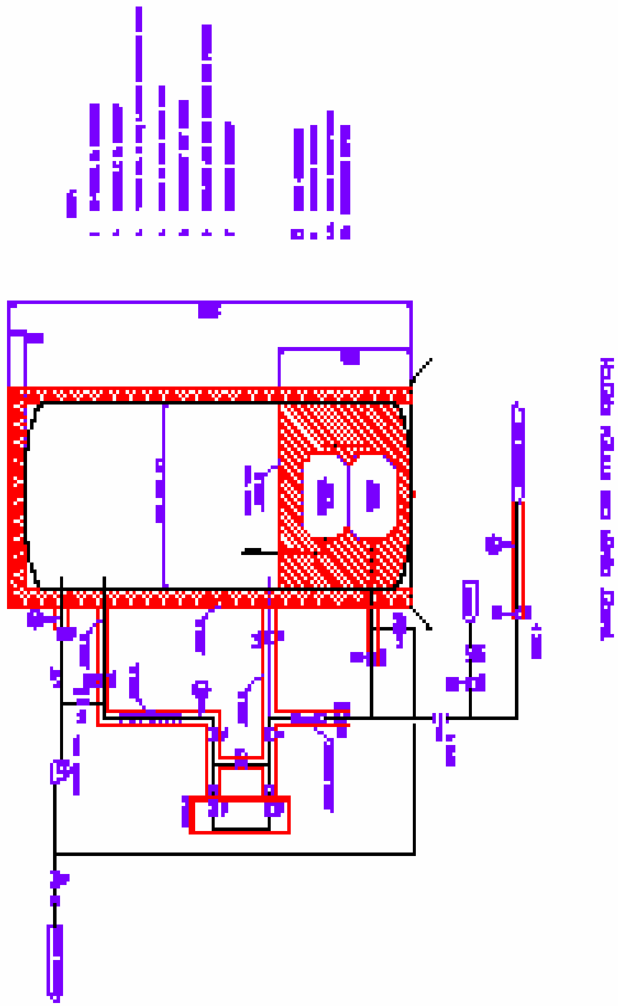


Cover Gas System

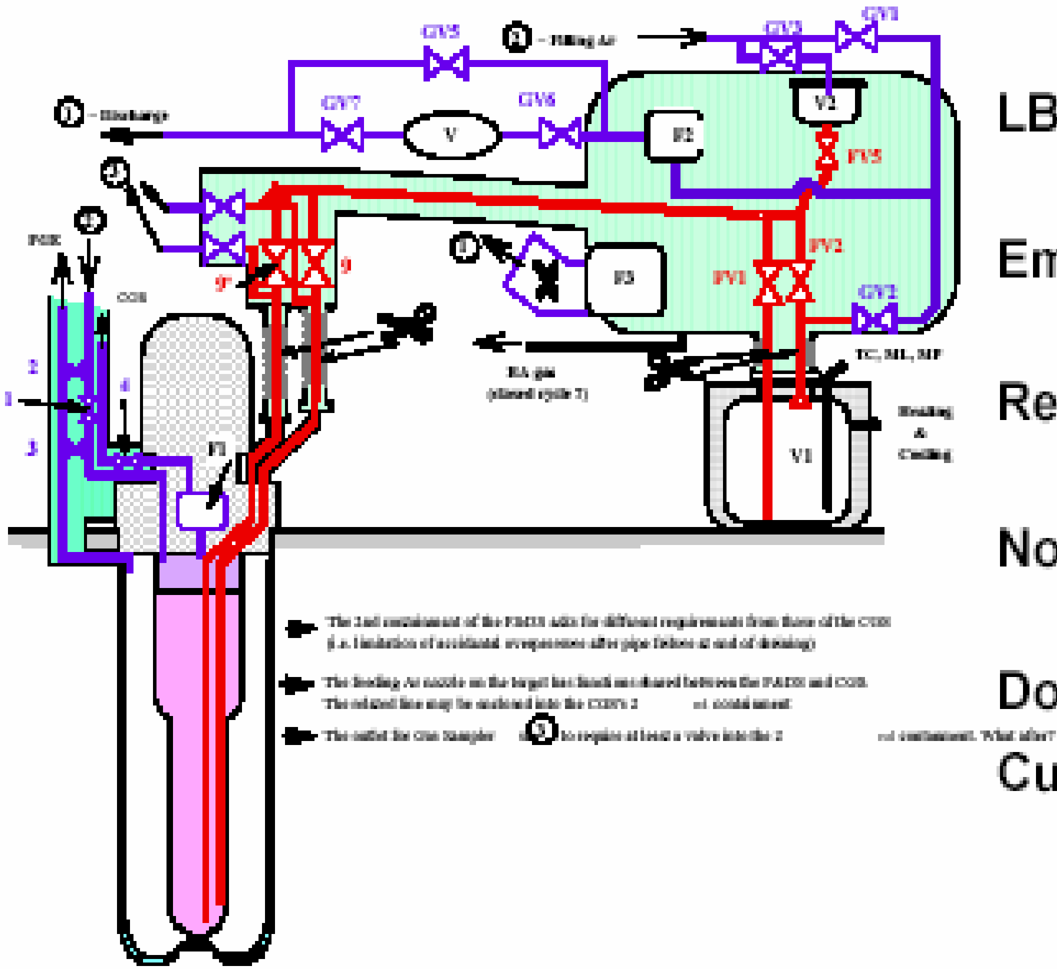
- Operating pressure above 1 bar due to EMP cavitation risk → double containment
- Neutronic calculations yield large uncertainty in He production (0.4 - 4 l)
- Hydrogen will be gettered (Pd, CaO) and Hg will be condensed within target







Fill & Drain System



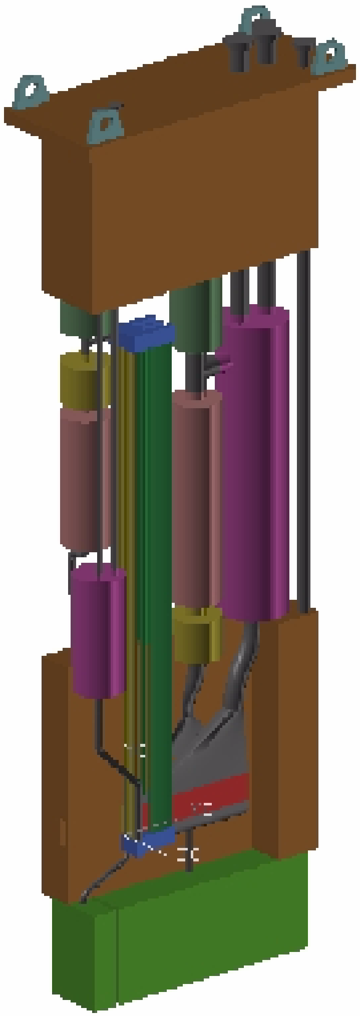
- LBE expansion during freezing
- Empty target during standby and repairs
- Reduce activity during transport
- No draining as an option and after target damage
- Double containment
- Cut & Squeeze System to separate installation from target

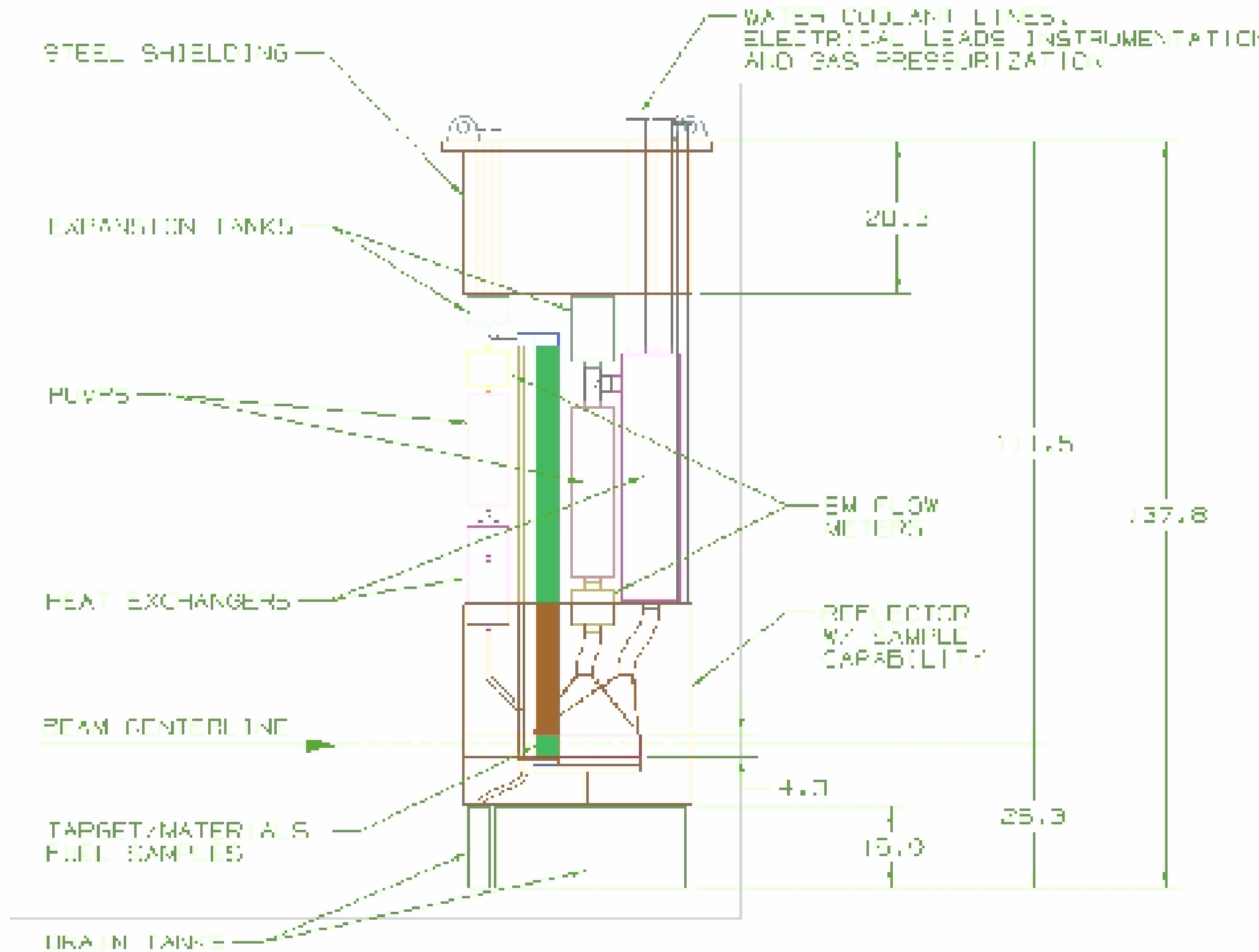
The Proposed Materials Test Station at LANSCE

Eric Pitcher
Los Alamos National Laboratory

Presented at the Workshop on
High-Power Targetry for Future Accelerators
Brookhaven National Laboratory
September 8, 2003

A conceptual design of a flowing Pb-Bi target has been developed





The A-1 target, shown here during construction in 1973, is the proposed location for the MTS

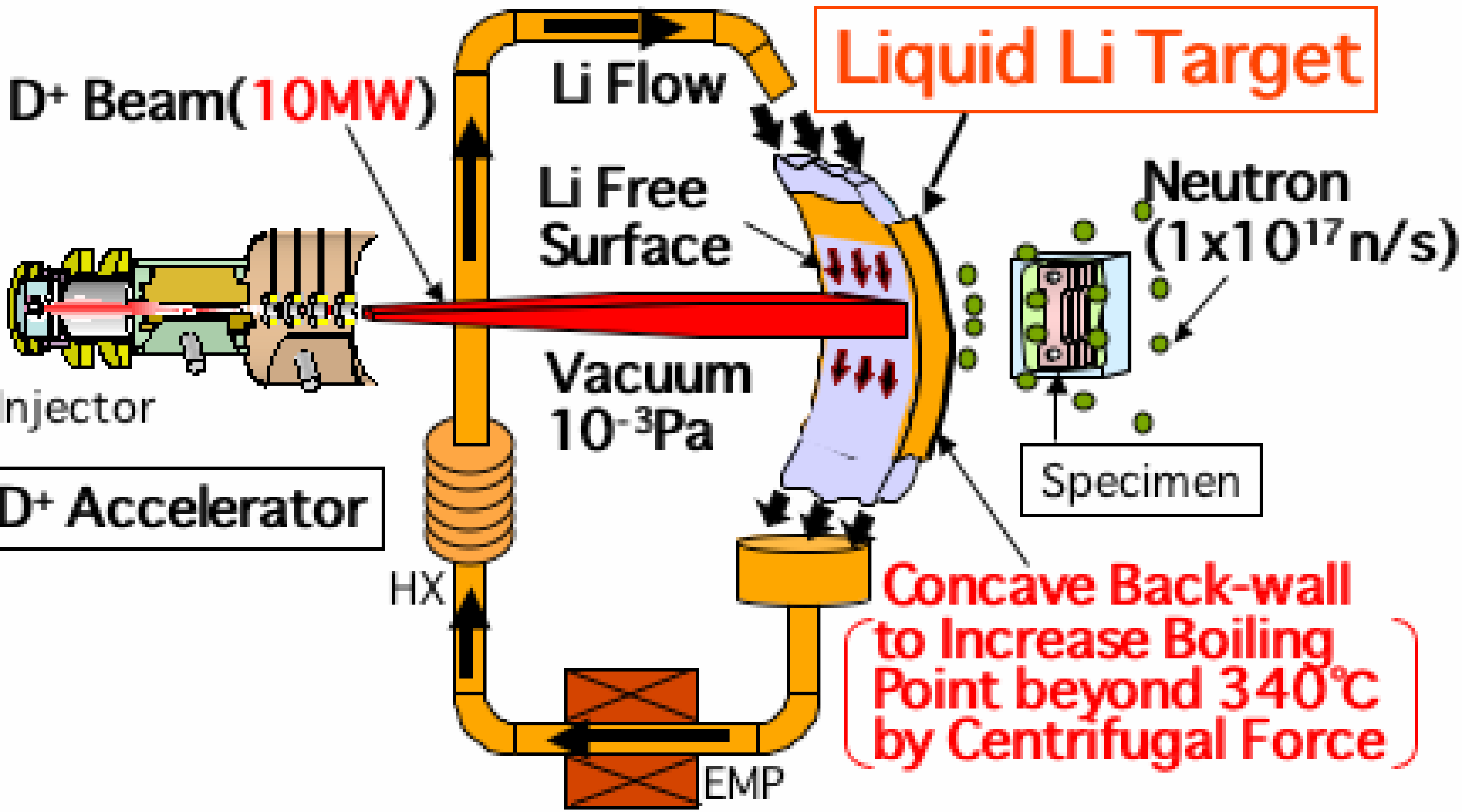
Liquid lithium Target in IFMIF (International Fusion Materials Irradiation Facility)

Hiroo Nakamura
Japan Atomic Energy Research Institute

WS on High-power Targetry for Future Accelerators
September 8–12, 2003, Marriott Courtyard, NY

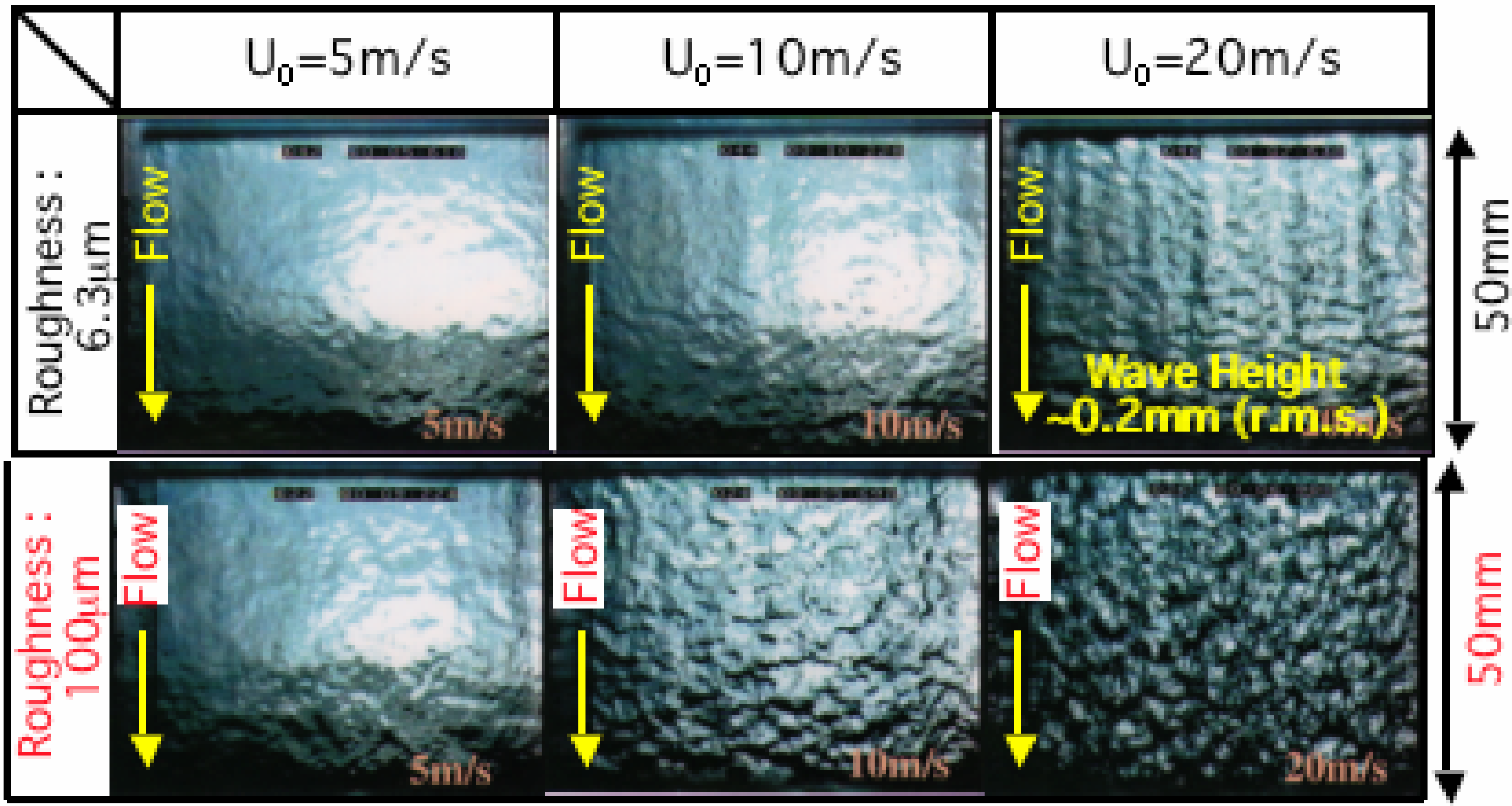
Concept of D-Li Neutron Source

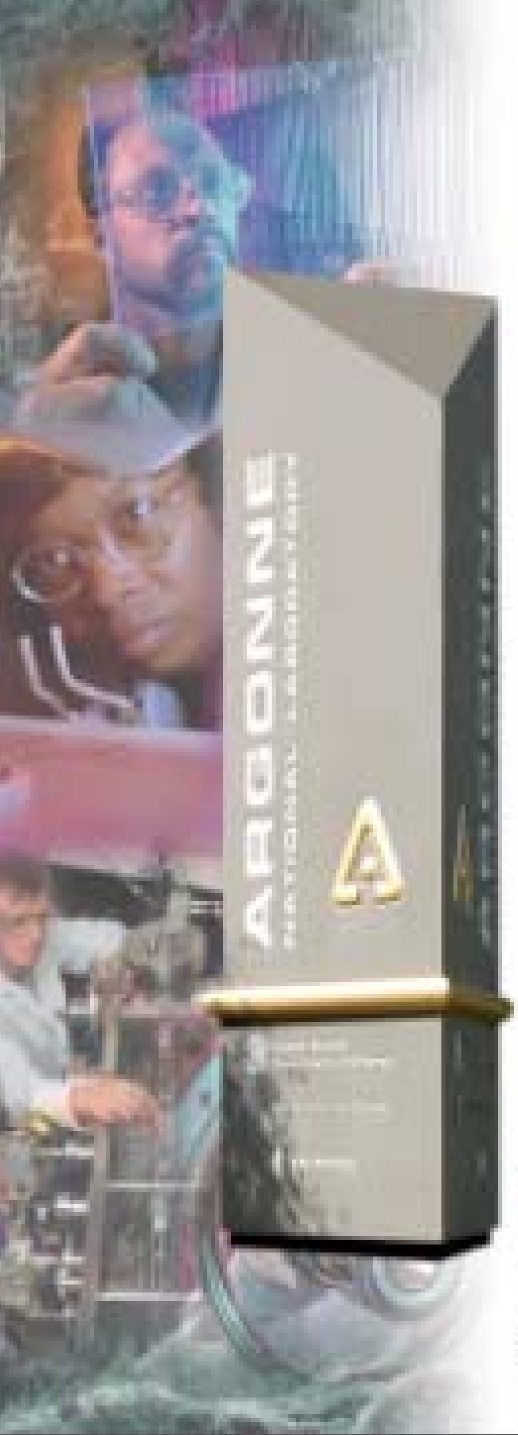
High-speed liquid Li flow along concave back-wall is selected as Li target to handle high heat load ($1GW/m^2$) of 10MW D^+



Flow velocity & Roughness

- Double reducer nozzle generates stable flows with surface deviation < 1mm.
- Rough (100μm) wall nozzle generated waves in IFMIF velocity range of 10-20m/s





Target Developments for the U.S. Rare Isotope Accelerator

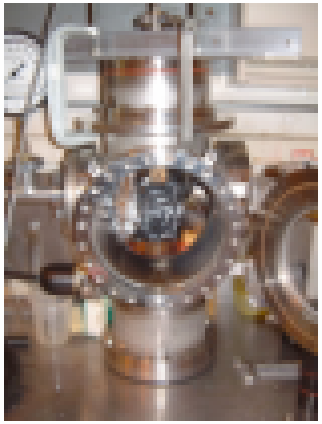
Conference on High Power Targetry
For Future Accelerators

Jerry Nolen
Physics Division
September 11, 2003

Argonne National Laboratory

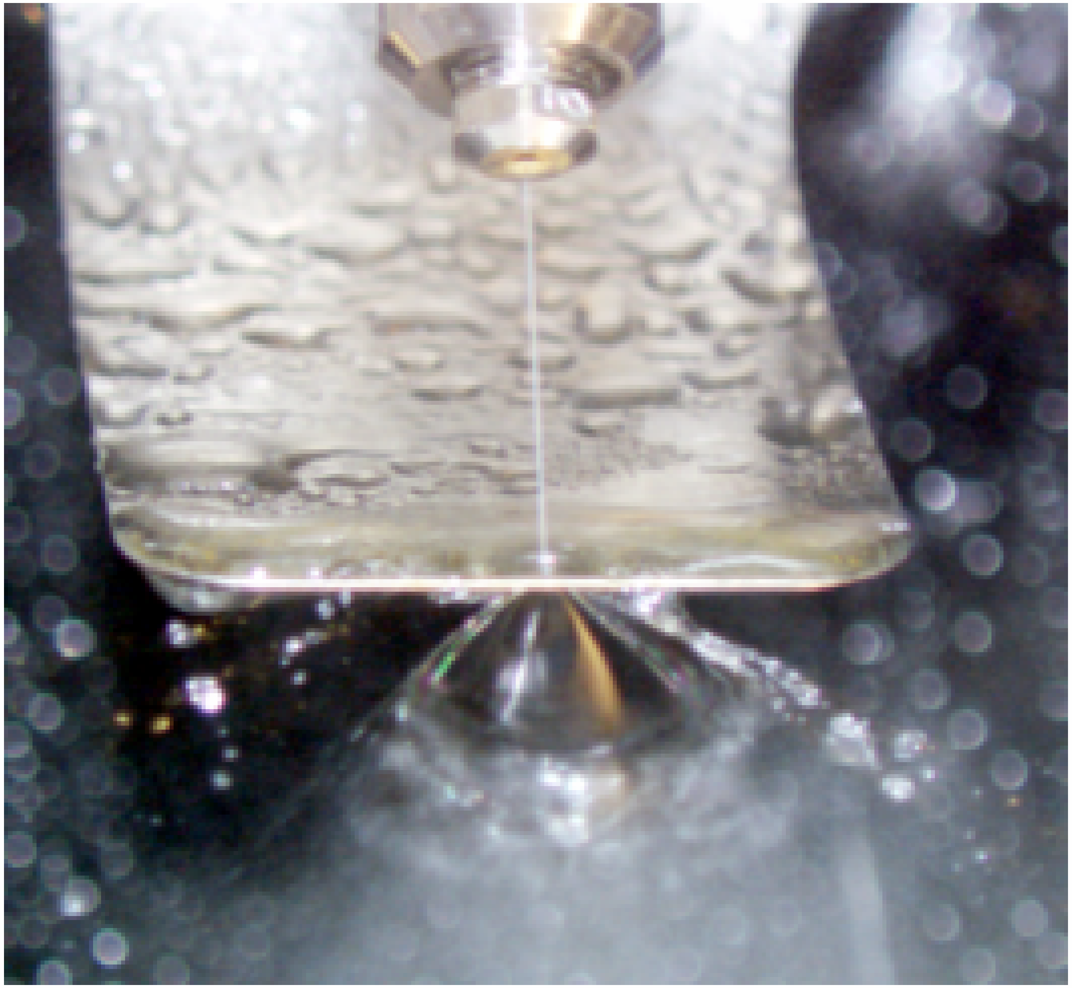
A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

RIA Thin Film Strippers

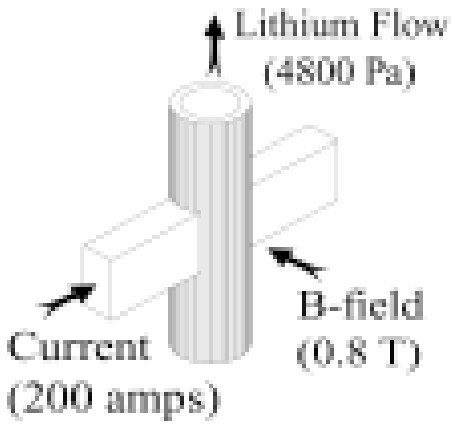


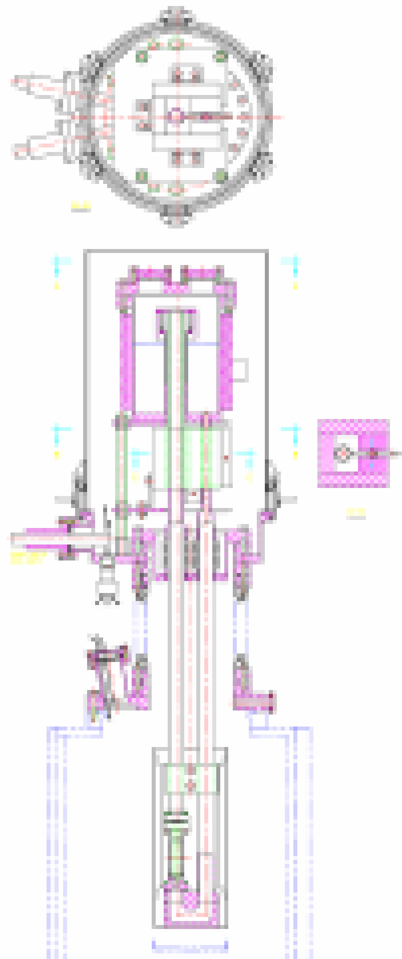
To date:

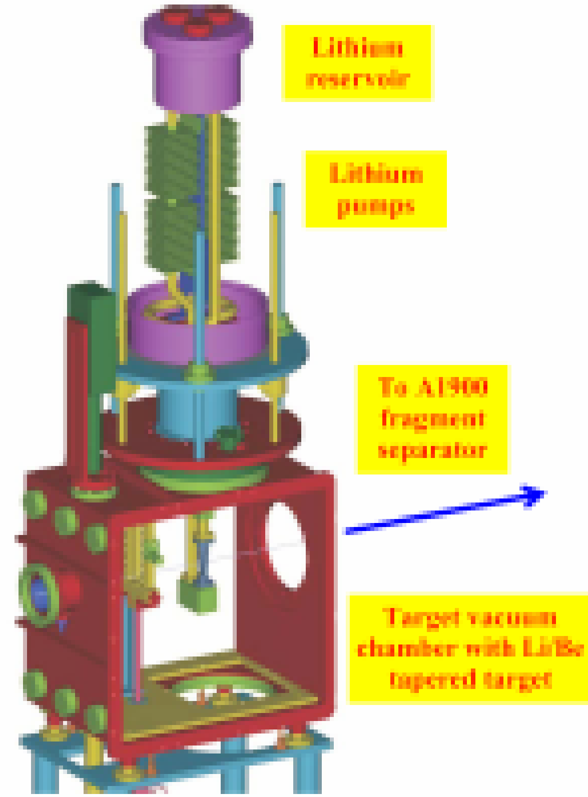
- Water film
- 0.25 mm diameter orifice
- 33 m/s jet velocity
- 15 atmospheres driving pressure
- >2 micron film thickness
- Under partial vacuum
- Film area ~ 1 cm diameter



Hybrid Be/Li Target for 4-kW Heavy-ion Beams

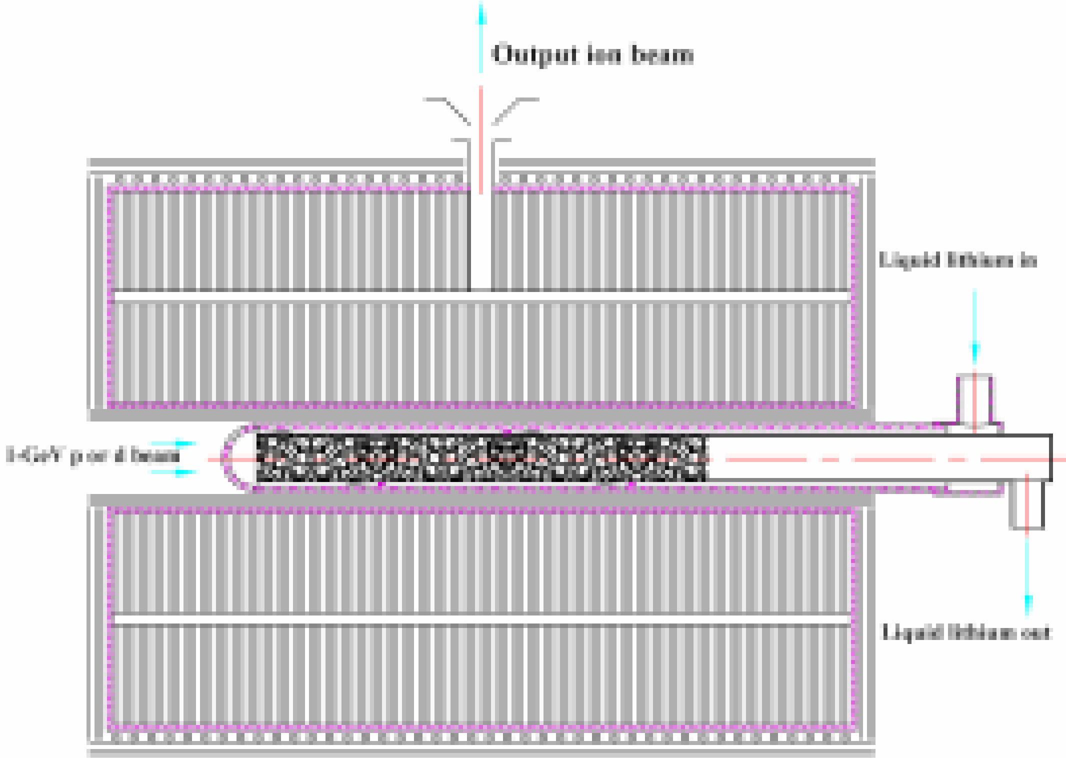






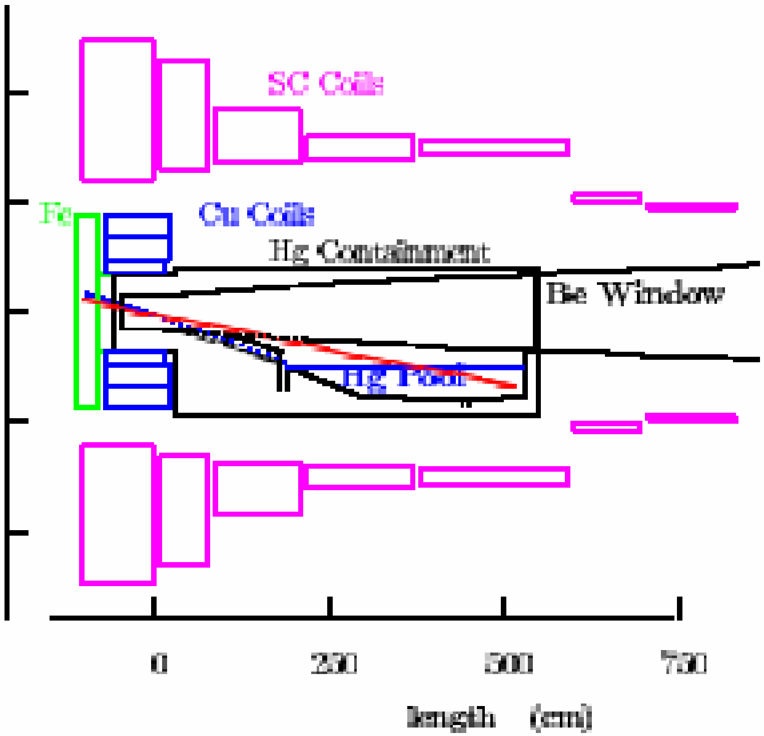
An ANL/MSU collaboration for use at NSCL

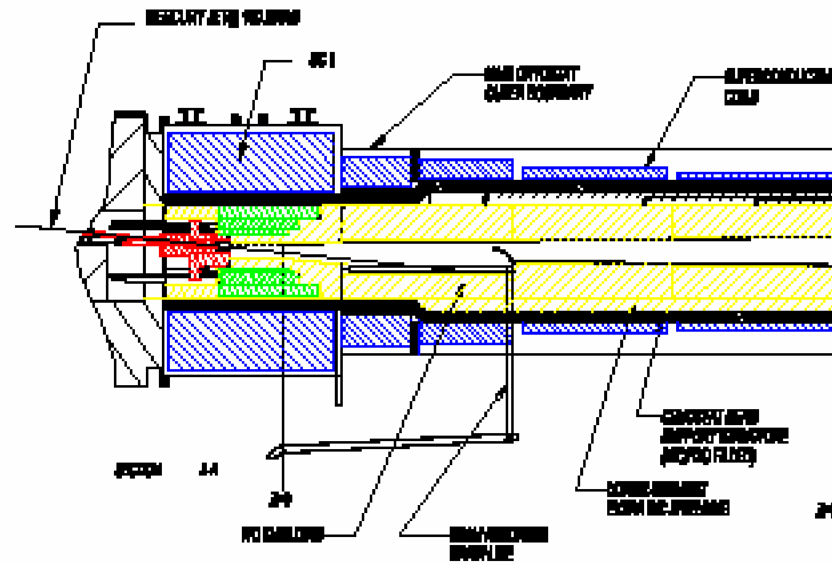
Two-step, n-generator target concept

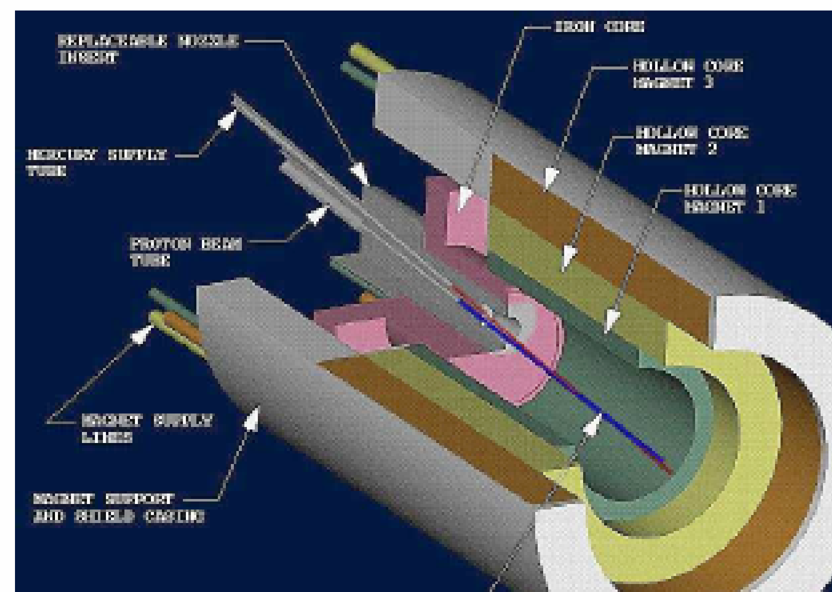


Prototype being developed by W. Talbert, et al., TechSource, Inc. (SBIR Grant)
Fine-grained, higher thermal conductivity UC being developed at ANL.

Sketches of a 4-MW Target Sta







K.T. McDonald

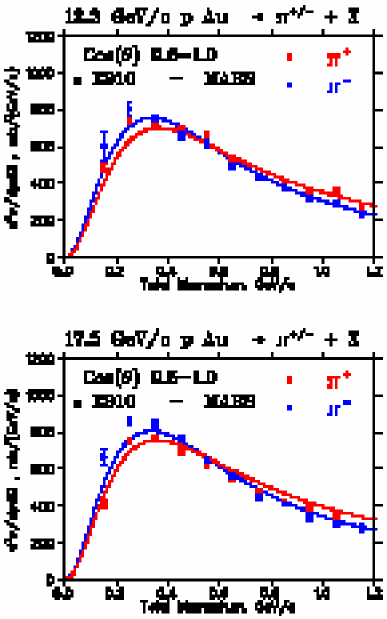
Princeton U.

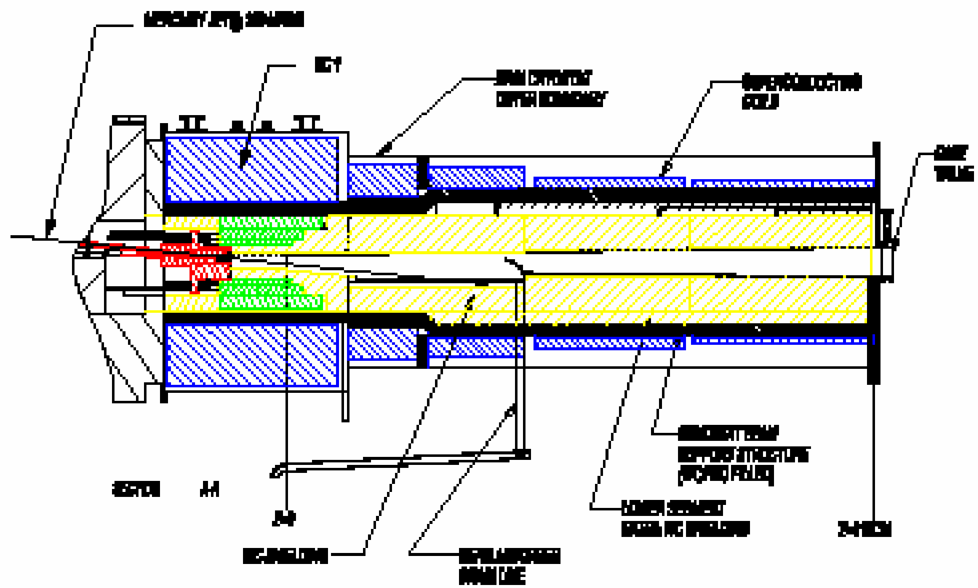
shop on High-Power Targets for
Future Accelerators

nkoma, NY, September 10, 2003

Targetry Challenges for Intense Muon and Neutrino Beams

- Use of a multimegawatt proton beam for maximal production of soft pions → muons.
- Capture pions in a 15-20-T solenoid, followed by a 1.25-T decay channel (with beam and target tilted by 100 mrad w.r.t. magnetic axis).





- A carbon target is feasible for 1.5-MW proton beam power.
- For $E_p \gtrsim 16$ GeV, factor of 2 advantage with high-Z target.
- Static high-Z target would melt, ⇒ **Moving target**.
- A free mercury jet target is feasible for beam power of 4 MW (and more).

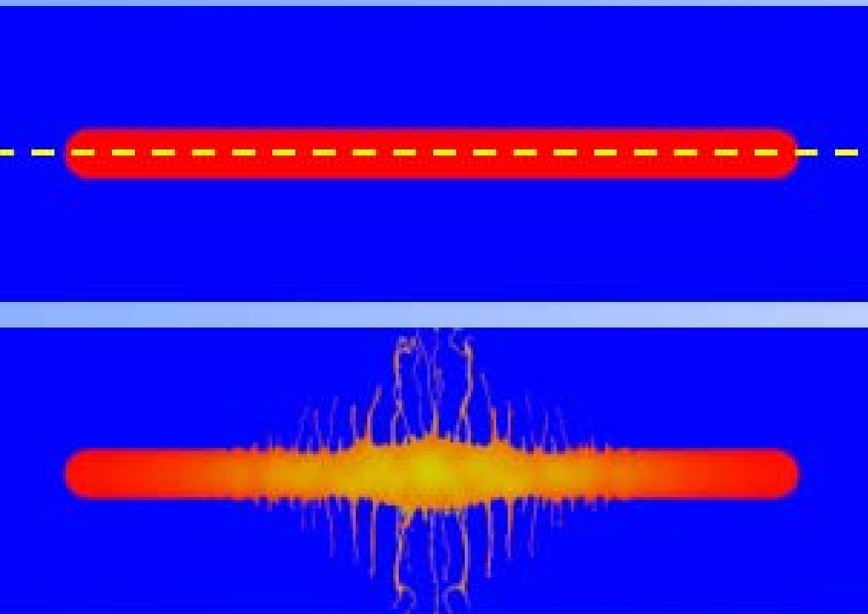
Modeling of Free Surface MHD Flows and Cavitation

Roman Samulyak

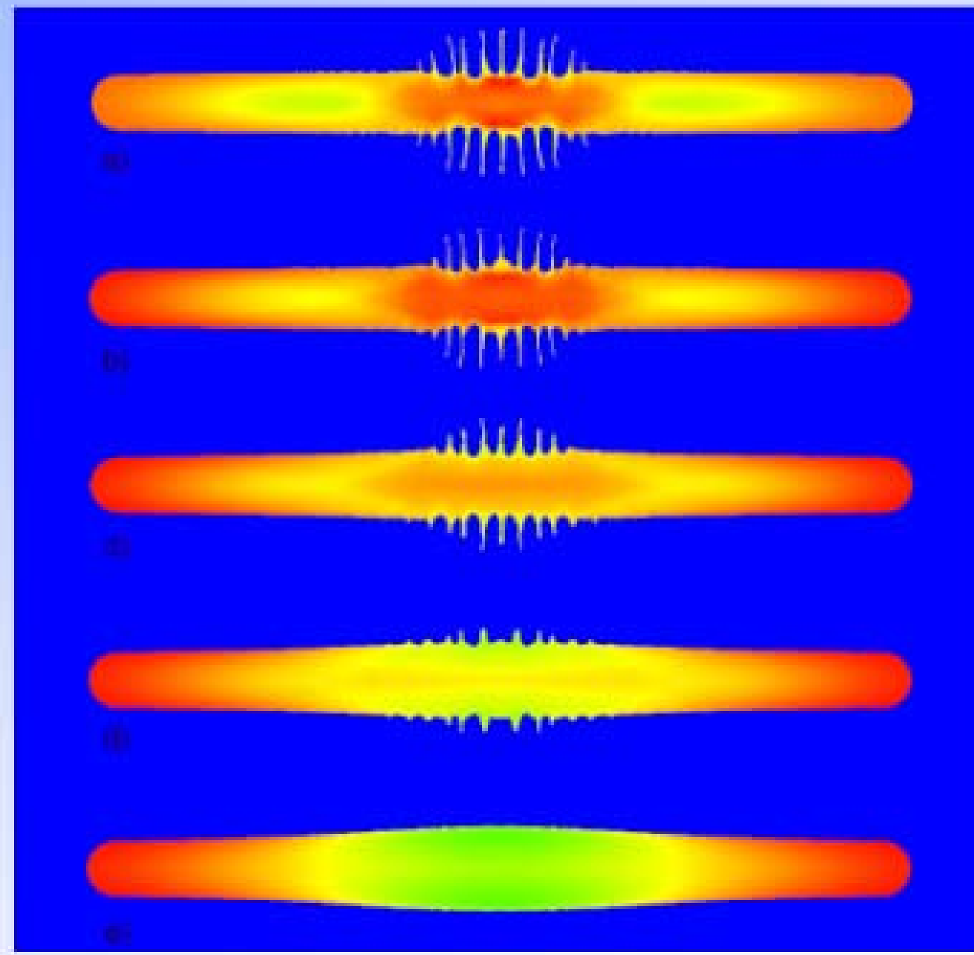
Center for Data Intensive Computing
Brookhaven National Laboratory
U.S. Department of Energy

rosamu@bnl.gov

Richtmyer-Meshkov instability and MHD stabilization



Simulation of the mercury jet – proton pulse interaction during 100 microseconds, B = 0



a) B = 0 b) B = 2T c) B = 4T
d) B = 6T e) B = 10T

Brookhaven Science Associates
U.S. Department of Energy

BROOKHAVEN NATIONAL LABORATORY

Simulation of Muon Collider Target Experiments

Yarema Prykarpatskyy

Center for Data Intensive Computing

Brookhaven National Laboratory

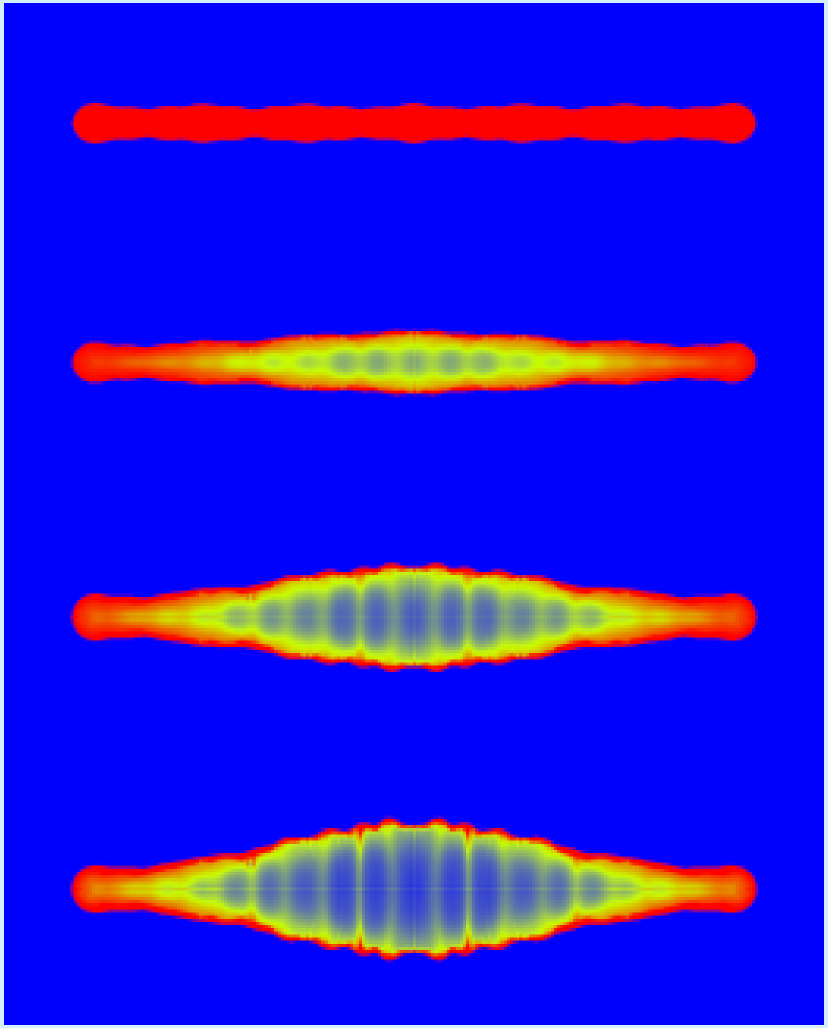
U.S. Department of Energy

yarpry@bnl.gov

Muon Collaboration

BROOKHAVEN NATIONAL LABORATORY

Numerical simulation of the interaction of a free mercury jet with high energy proton pulses using two phase EOS

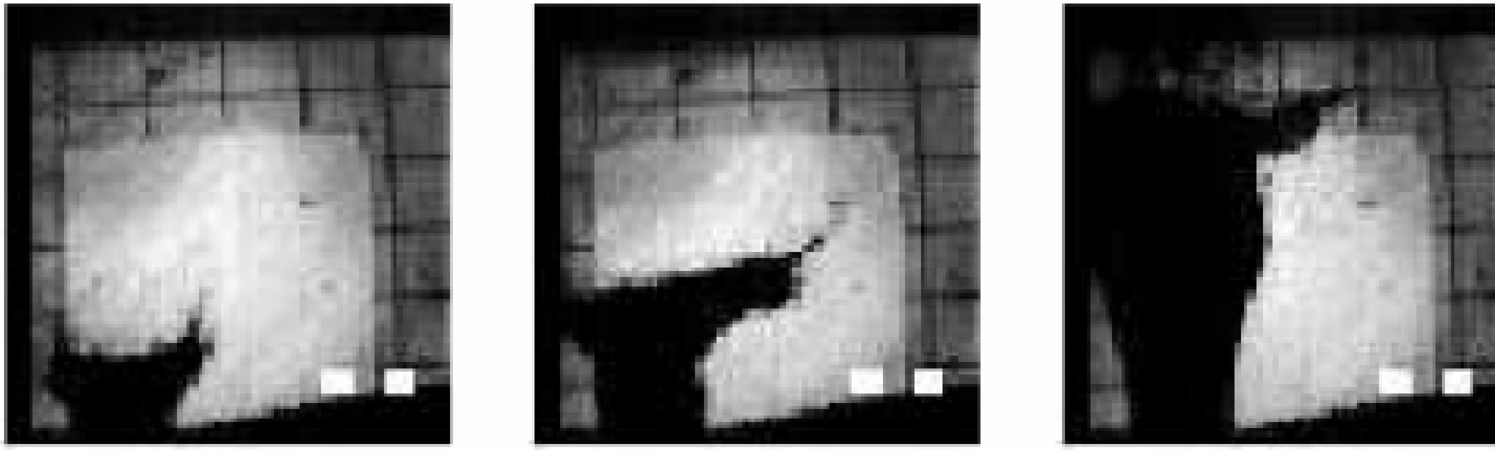


Evolution of the mercury jet after the interaction with a proton pulse

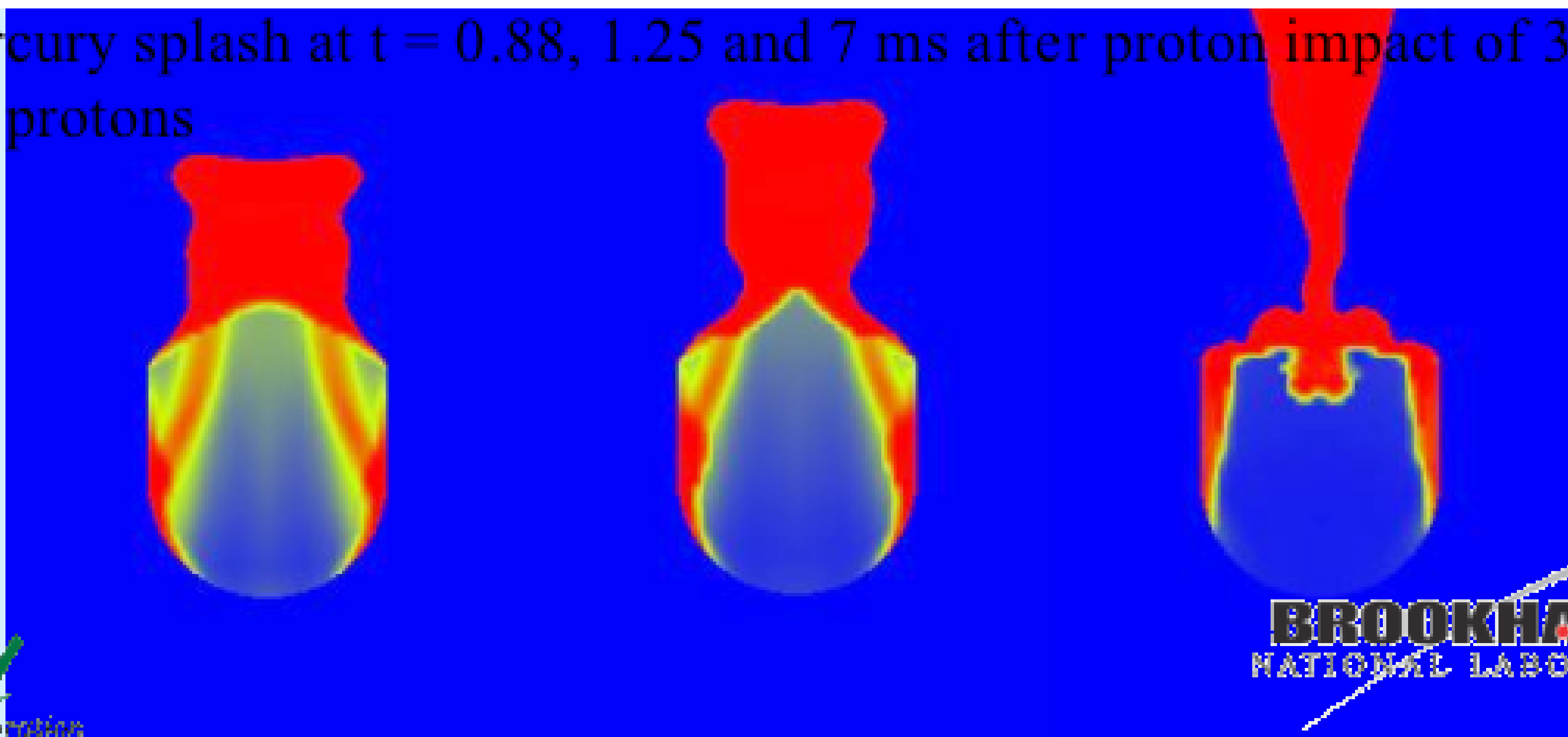
Muon Collaboration

BROOKHAVEN NATIONAL LABORATORY

Mercury splash (thimble): experimental data



Mercury splash at t = 0.88, 1.25 and 7 ms after proton impact of 3.7 e12 protons



Muon Collaboration

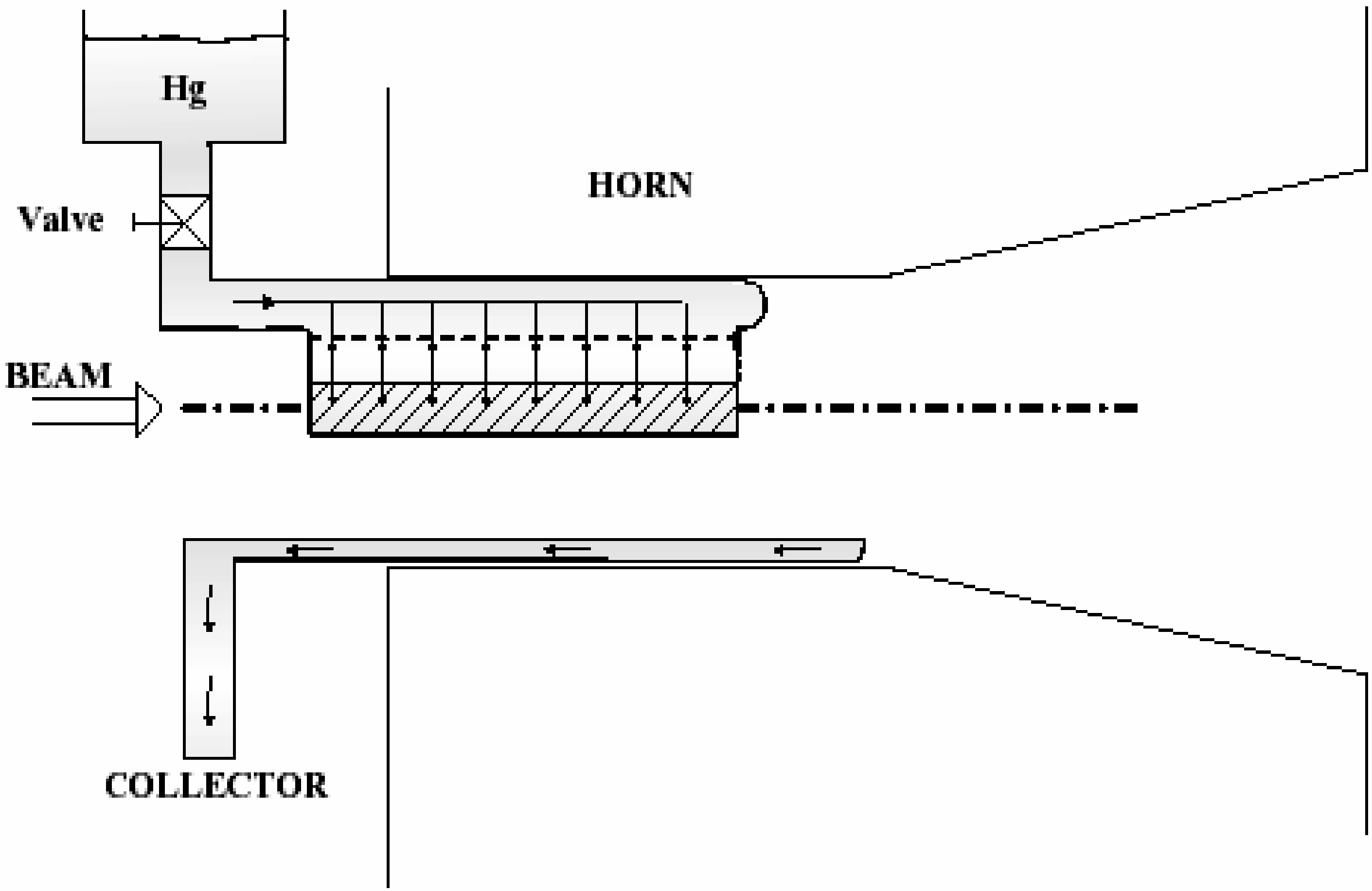
BROOKHAVEN NATIONAL LABORATORY

High-power Targetry for Future Accelerators
September 8-12, 2003
BNL

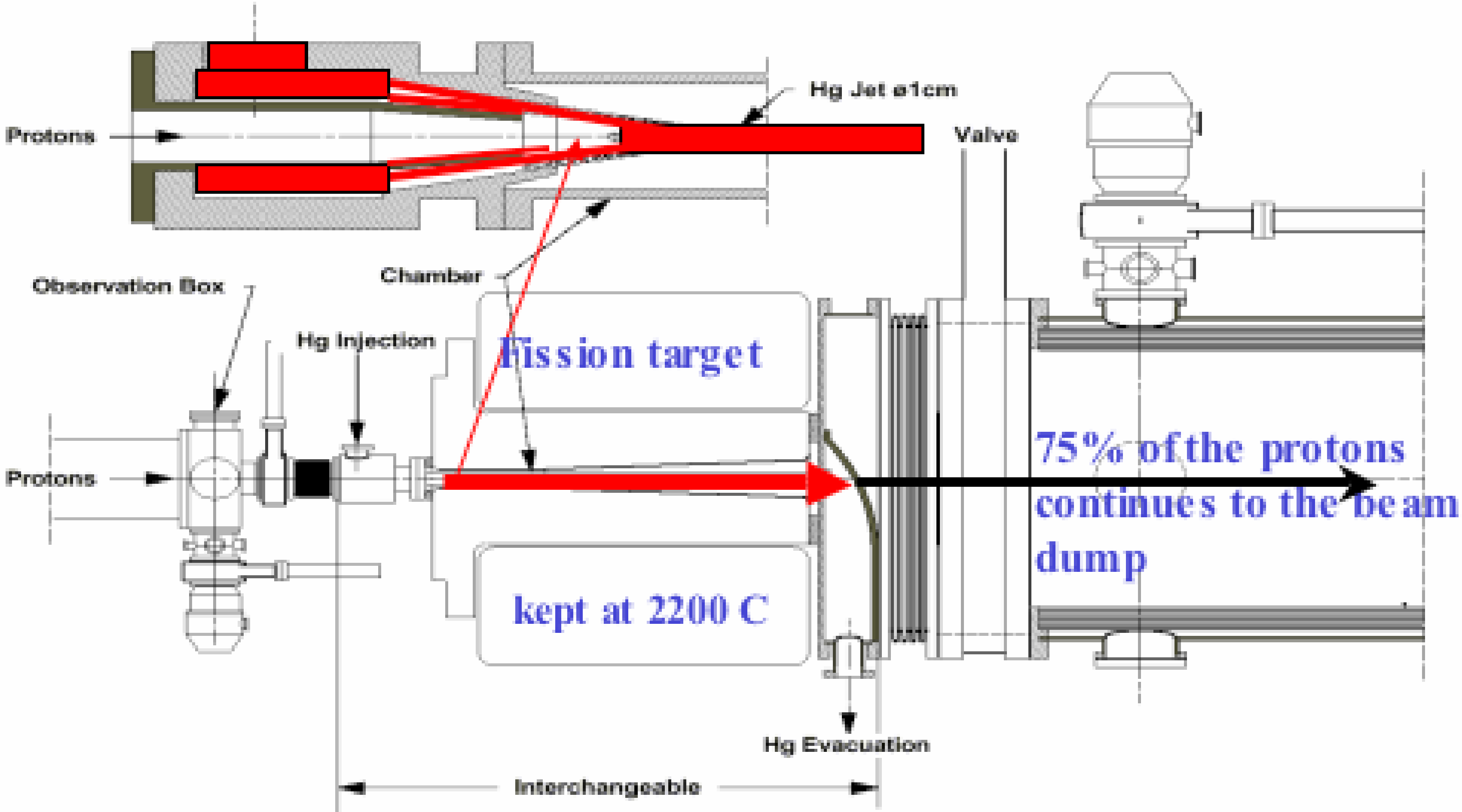
Freely Dropping Mercury Curtains

P. SIEVERS
CERN

FREE FLOWING CURTAIN TARGET



High power targets for EURISOL and Beta ν-beams



EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

CERN INTC-2003-xxx
INTC-I-xxx
Geneva, 12 August, 2003

Letter of Interest to the INTC

HIGH POWER MERCURY TARGET TESTS AT THE CERN-ISOLDE TARGET STATIONS

FZJ-SNS-RAL-ISOLDE-CERN Collaboration

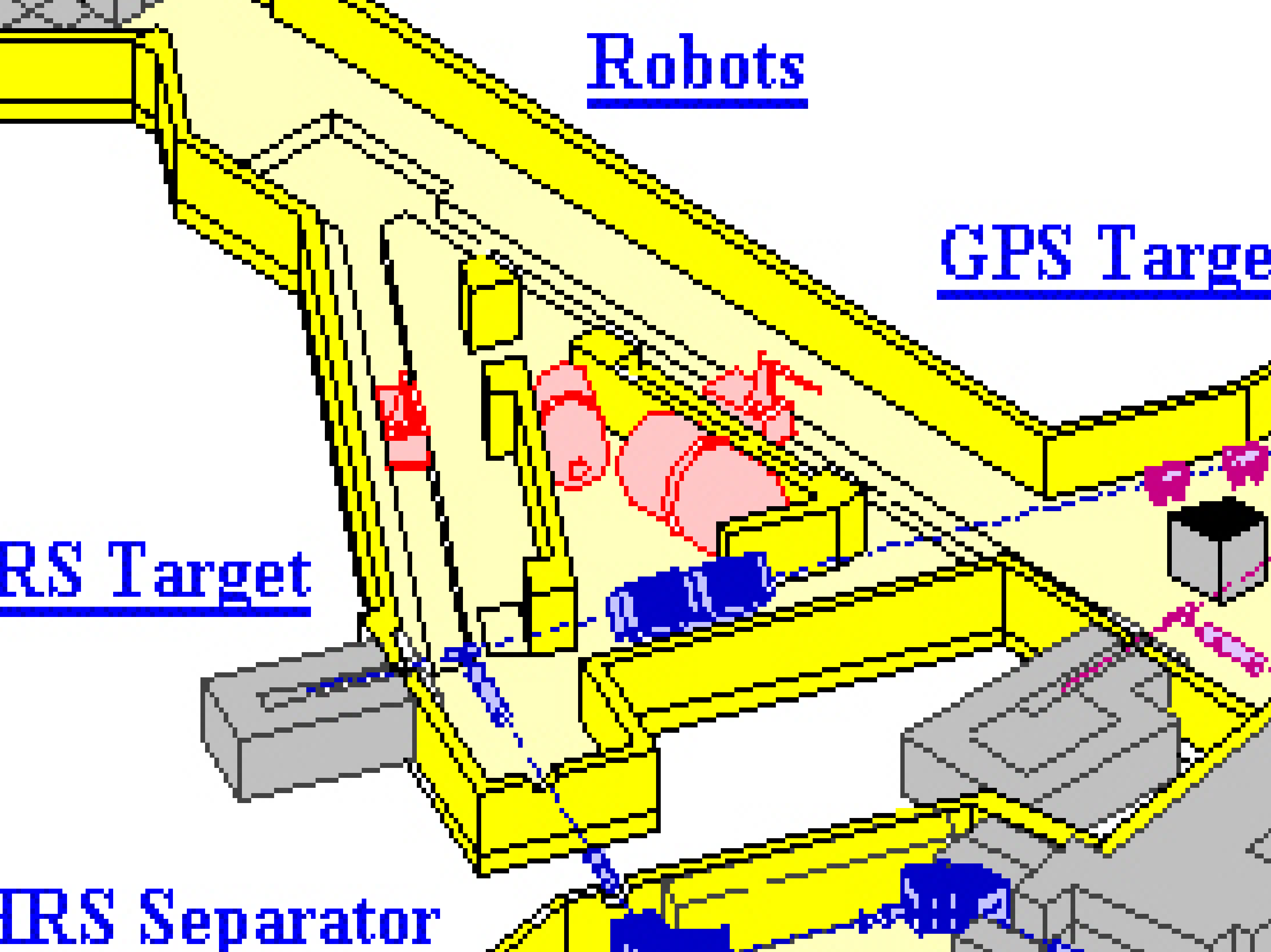
Guenter S. Bauer[1] J.R. Bennett[2], Tim A. Broome[2], Adrian Fabich[3], Simone Gilardoni[3], John Haines[4], Ulli Köster[3], Jacques Lettry[3] and Helge L. Ravn[3]

1. Forschungszentrum Juelich, D-52425 Juelich, Germany
2. CCLRC, Rutherford Appleton Laboratory, Chilton, Oxon., OX11 0QX, UK
3. CERN CH-1211, Geneva 23 Switzerland
4. ORNL/SNS, Oak Ridge, TN, USA

Spokesperson: G. S. Bauer
Contact person: H. L. Ravn

Abstract

A proposal for MEGAPIE gas production studies at ISOLDE approved


Robots
GPS Targe
RS Target
IRS Separator

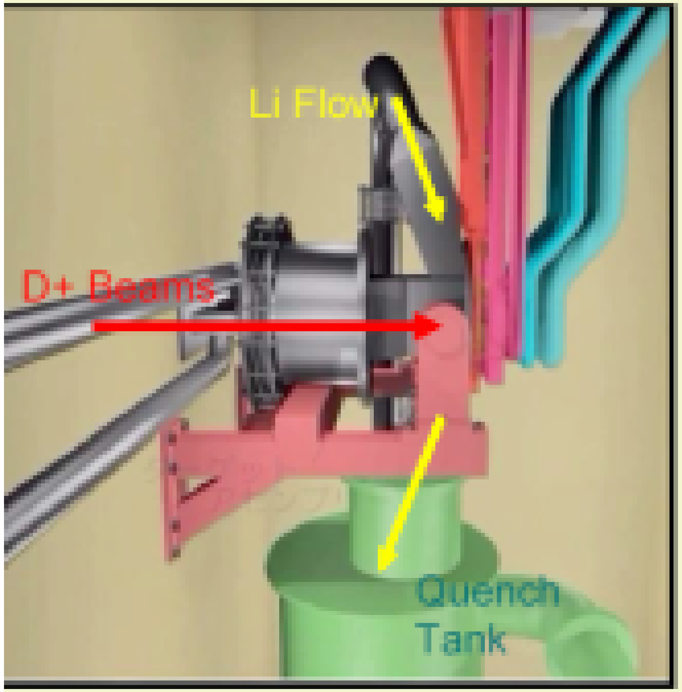
The End

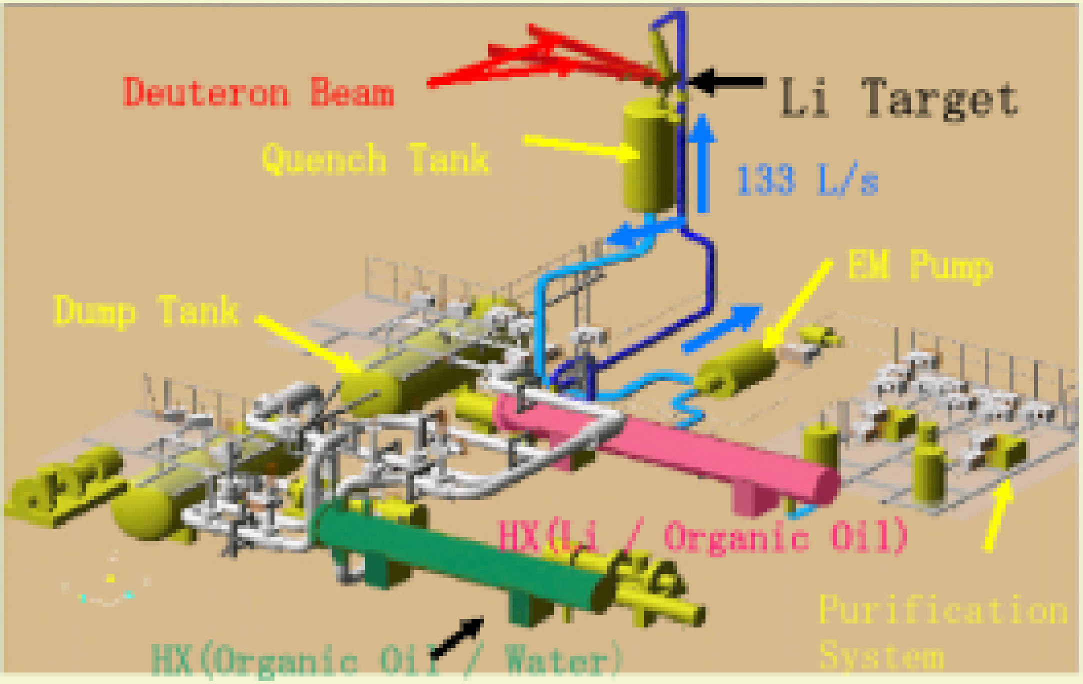
I wish to thank the chairman of the the workshop Harold Kirk and his team for the initiative of bringing together high power target specialists from widely different fields of science.

I found the workshop very well organised with plenty of time for both instructive and constructive discussions.

I will go back with the hope that someone in due time will organise a similar follow up workshop.

IFMIF Target System Design





Function:
Obtain stable and high speed
Li flow under 10 WM D+ beam

Major Specifications:

- Heat flux by beam: 10MW/100 cm^2
- Li-flow: 15 (range 10-20) m/s
- Width/Thickness of Li: 26cm/ 2.5 cm
- Inlet, Outlet, Peak Li Temp: 250, 300, 450 °C
- Tritium Generation rate: 7 gr/yr
- Impurity contents: 10 wppm (C, N, O, each)

Mercury Loop Parameters @ 2 MW

• Power absorbed in Hg	1.2 MW
• Nominal Operating Pressure	0.3 MPa (45 psi)
• Flow Rate	340 kg/s
• Vmax (In Window)	3.5 m/s
• Temperature	
– Inlet to target	60°C
– Exit from target	90°C
• Total Hg Inventory	1.4 m^3 (20 tons)
• Pump Power	30 kW
• Reynolds Number	1.4×10^6 bulk flow
• Pr	0.014

SNS Hg Target operates at low temperature and pressure