The 2003 Targetry Workshop

High-power Targetry
for
Future Accelerators

Ronkonkoma, NY
September 8-12, 2003

Harold G. Kirk
Brookhaven National Laboratory

Workshop Participation

Over 40 attendees from:

- Argonne
- Brookhaven
- CERN
- Fermilab
- FZ-Julich
- KEK
- Los Alamos
- Michigan State
- Oak Ridge
- Princeton
- PSI-Zurich
- Rutherford Lab
- SLAC

Facilities Represented

- AGS
- ESS
- EURISOL
- IFMIF
- ISIS
- JPARC
- LANCE
- Neutrino Factory
- NUMI
- NLC
- RIA
- SINQ
- SNS

Workshop Organization

Facilities Overview

Summary by John Haines, ORNL

Solid Targets

Summary by Roger Bennett, RAL

Liquid Targets

Summary by Helge Ravn, CERN

Theory/Simulations

Summary by Nikolai Mokhov, FNAL

http://www.cap.bnl.gov/mumu/conf/target-030908/agenda.xhtml

Google: high power targetry

JPARC Targets

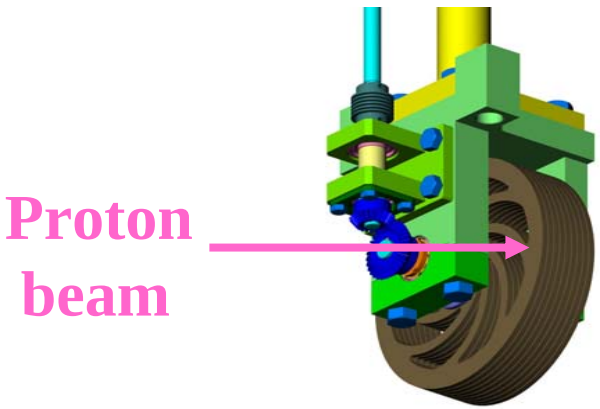
Proton Beam 0.75 MW at 50 GeV

Kaon Production

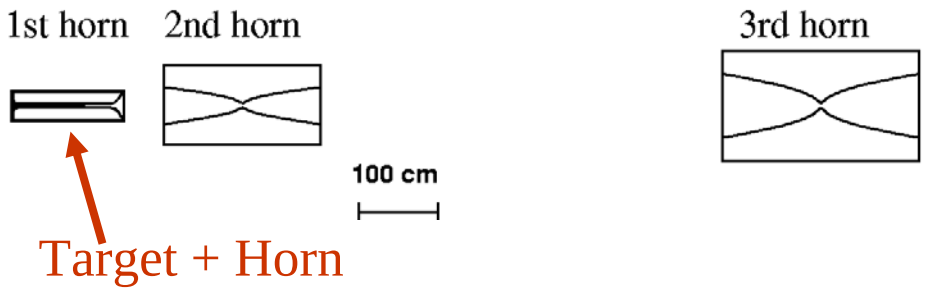
Rotating Ni Disks
Water Cooled
590 J/g

Neutrino Production

Stationary Carbon
Water Cooled
150 J/g

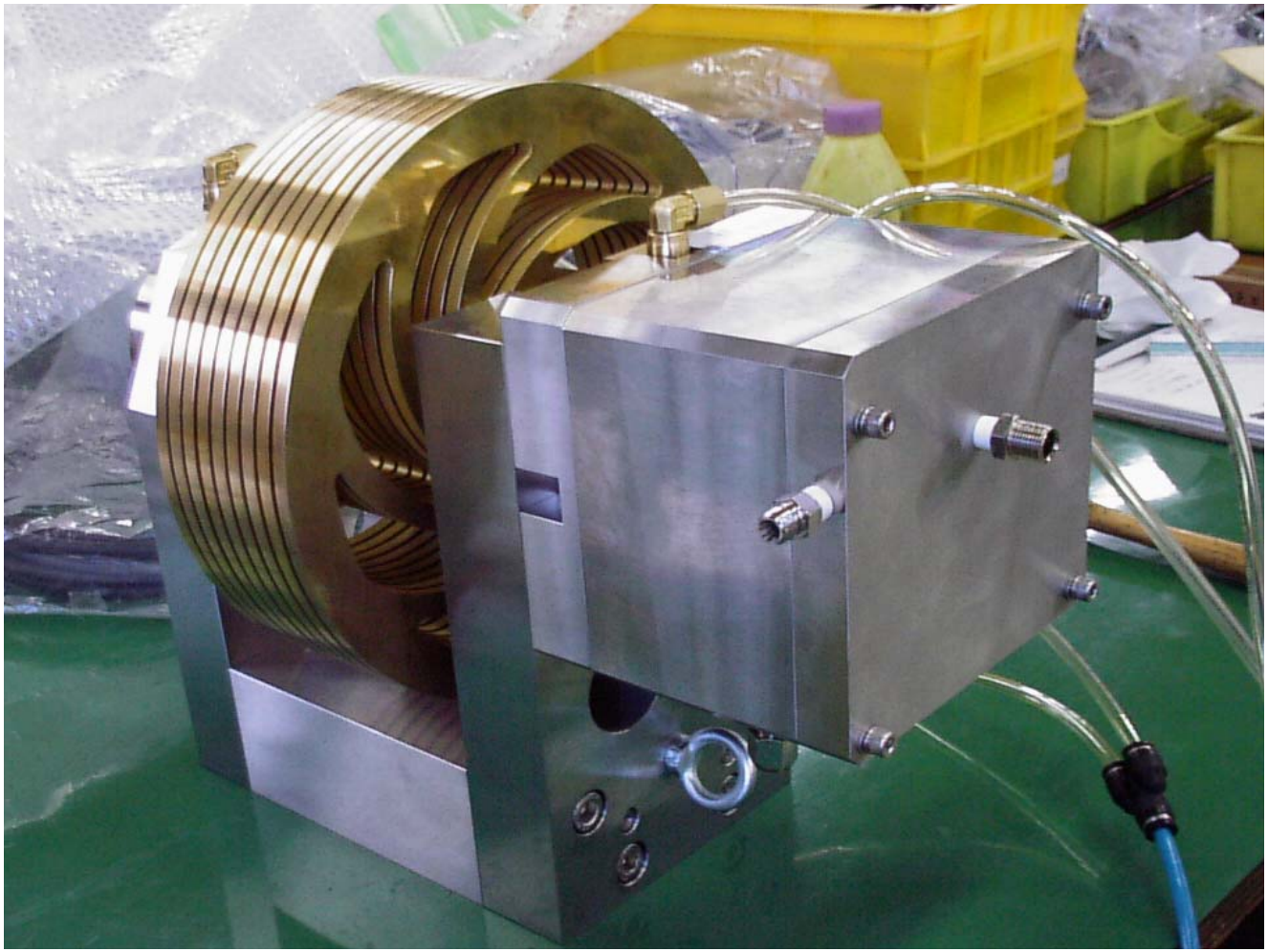


Three Horn System



Muon Collaboration

The T1 Kaon Target Prototype



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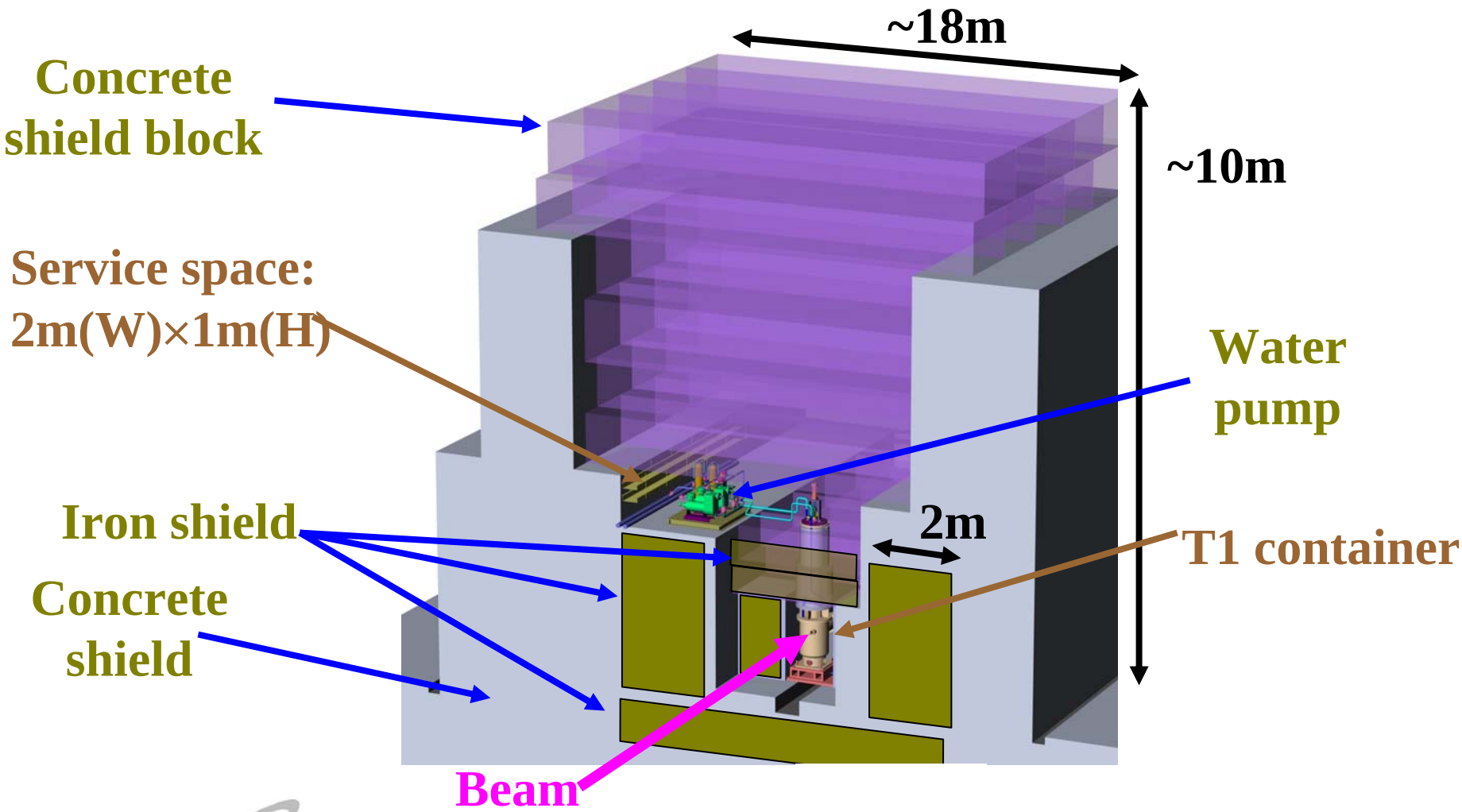
Shielding around the T1 Kaon Target



JPARC neutrino beamline

Proton beam kinetic energy
50GeV (40GeV@T=0)

# of protons / pulse
3.3×10^{14}

Beam power
750kW

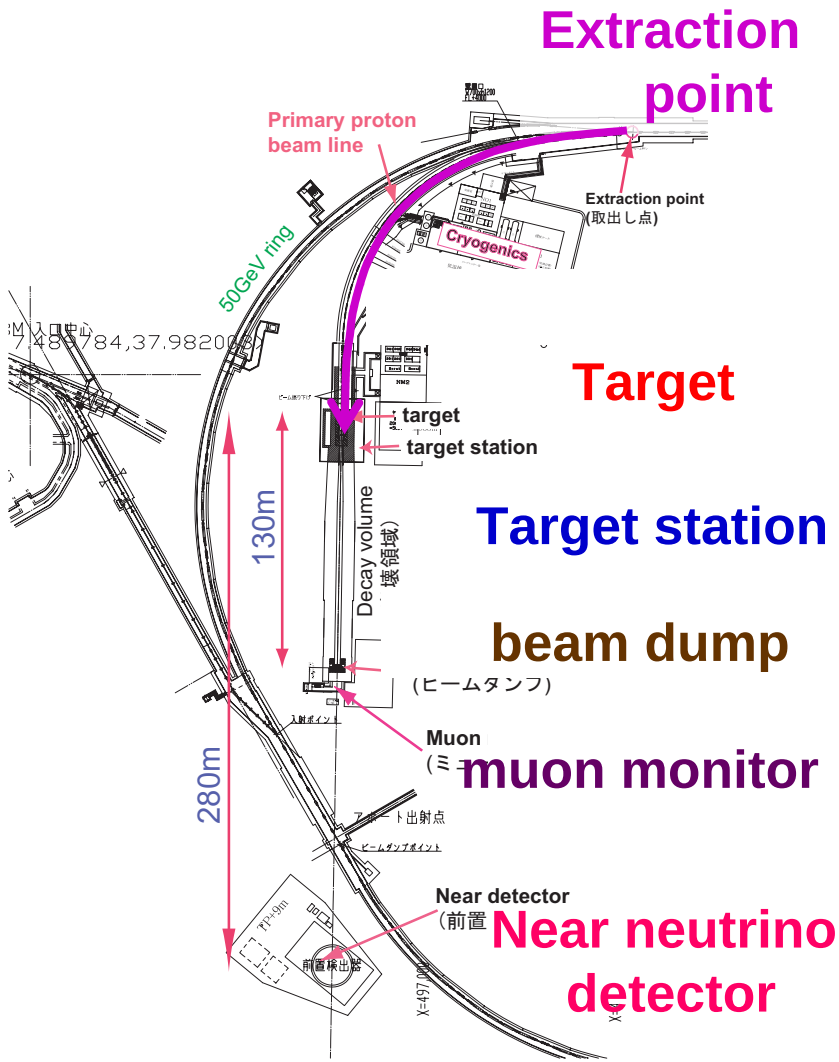
Bunch structure
8 bunches

Bunch length (full width)
58ns

Bunch spacing
598ns

Spill width
~5μs

Cycle
3.53sec



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FNAL Targets

Booster 8 GeV 32 kW

Be 3/8 in diameter segmented
Air cooled
19 J/g

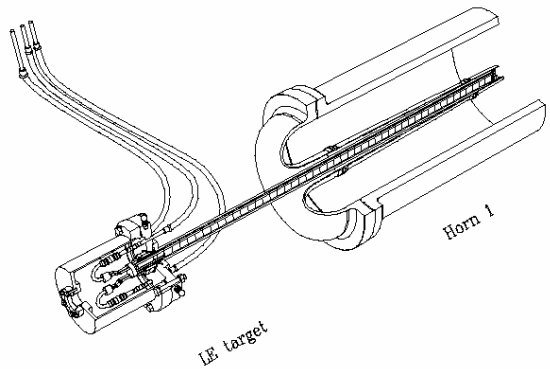
Main Injector 120 GeV 0.4 MW

Pbar Targets

Ni, Cu, W-Re
Air cooled
400 to 1000 J/g

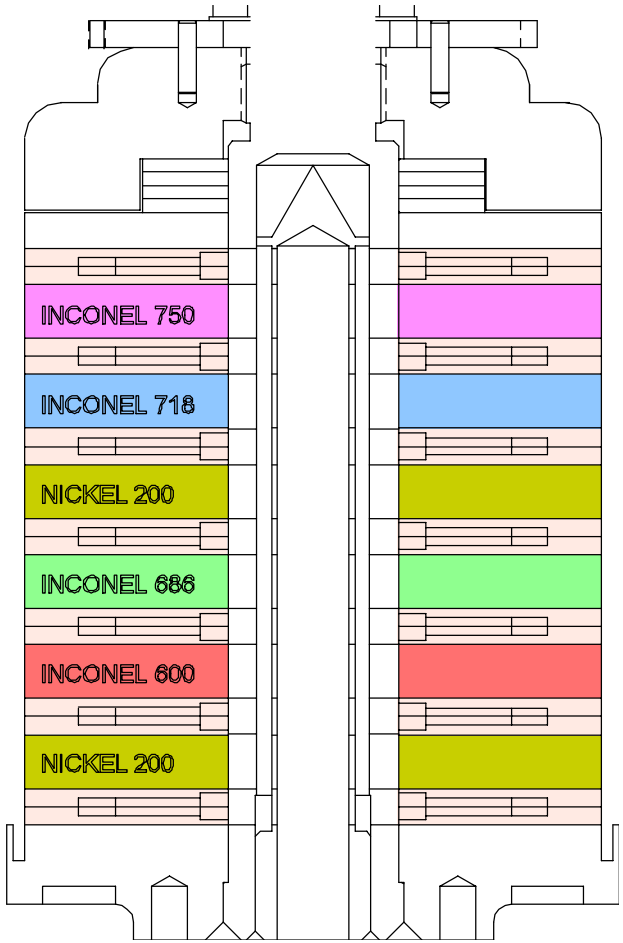
NUMI

Carbon
Water cooled
350 J/g



The assembled Mini-boone Target

The Pbar Target System



W
Target

W-Re
Target

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NuMI Low Energy Target for Minos

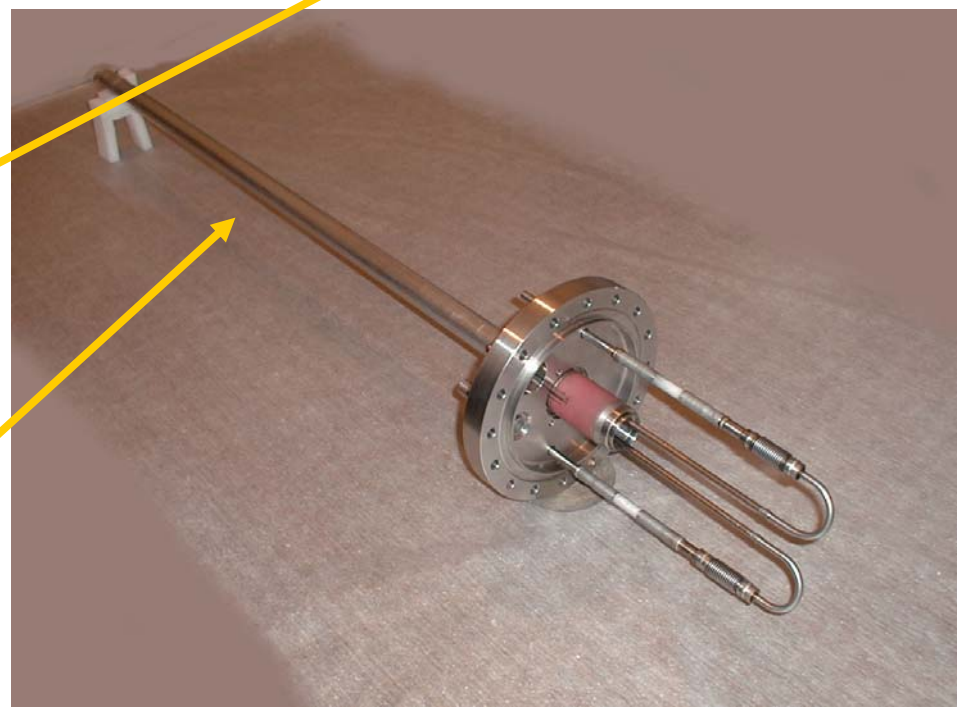
Graphite Fin Core

2 int. len.

Water cooling tube

also provides mechanical support

Aluminum vacuum tube



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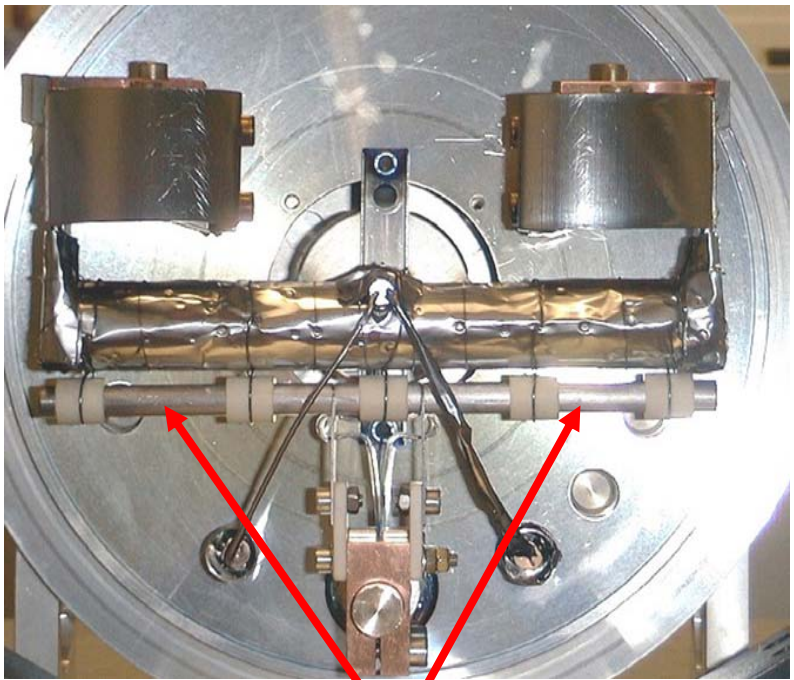
CERN Solid Targets

ISOLDE

PS-Booster 1-1.4 GeV 0.005 MW

Various targets/materials



Tantalum Target

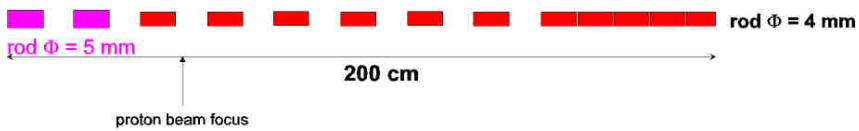
CNGS

SPS proton beam 400 GeV 0.25 MW

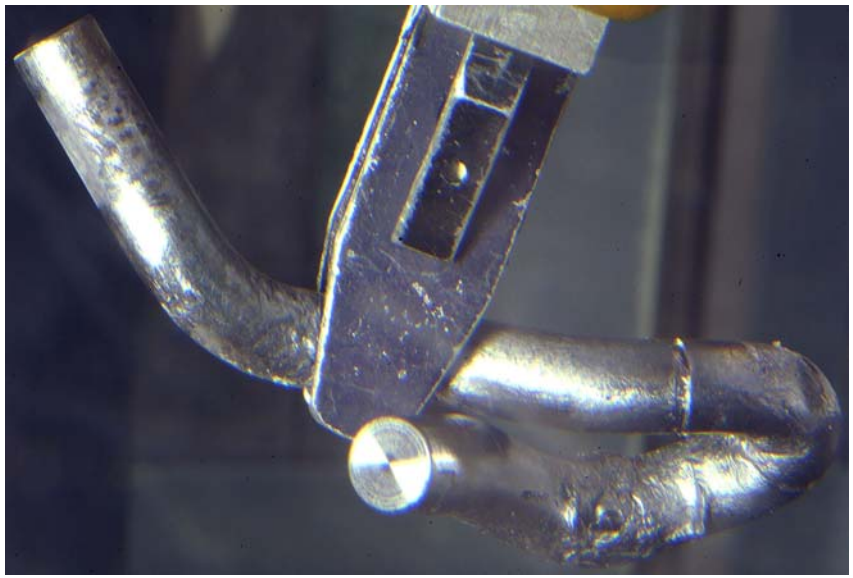
Segmented carbon

He cooled

750 J/g

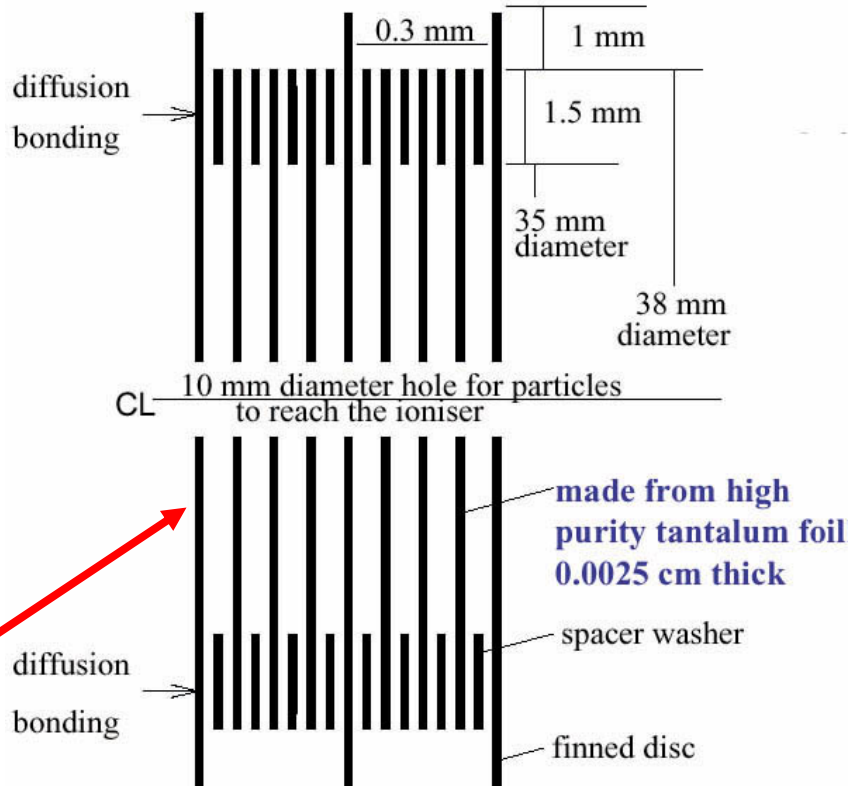


Experience with Tantalum

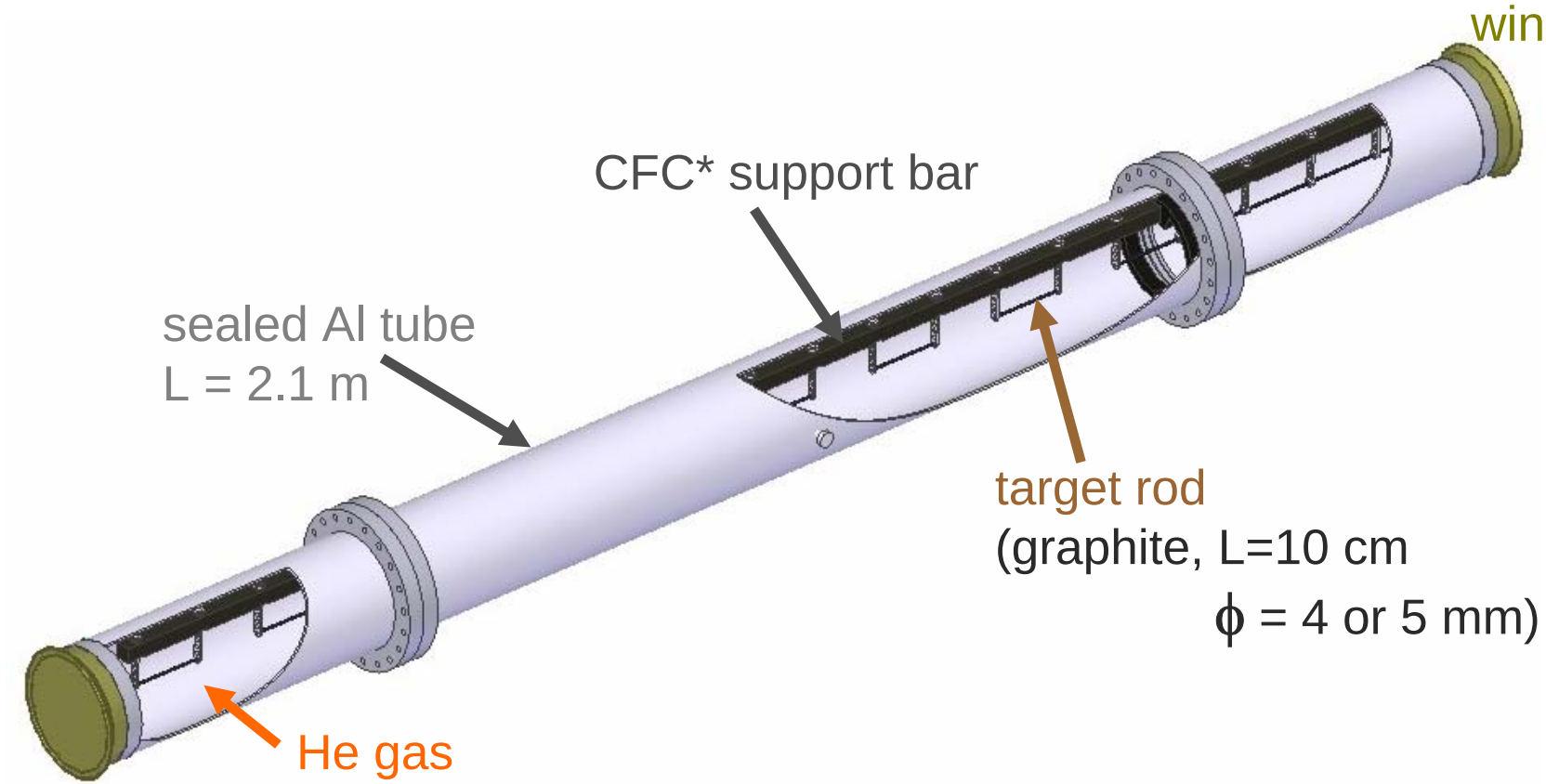


Tantalum rod after one week of ISOLDE running

The radiantly cooled RIST tantalum target



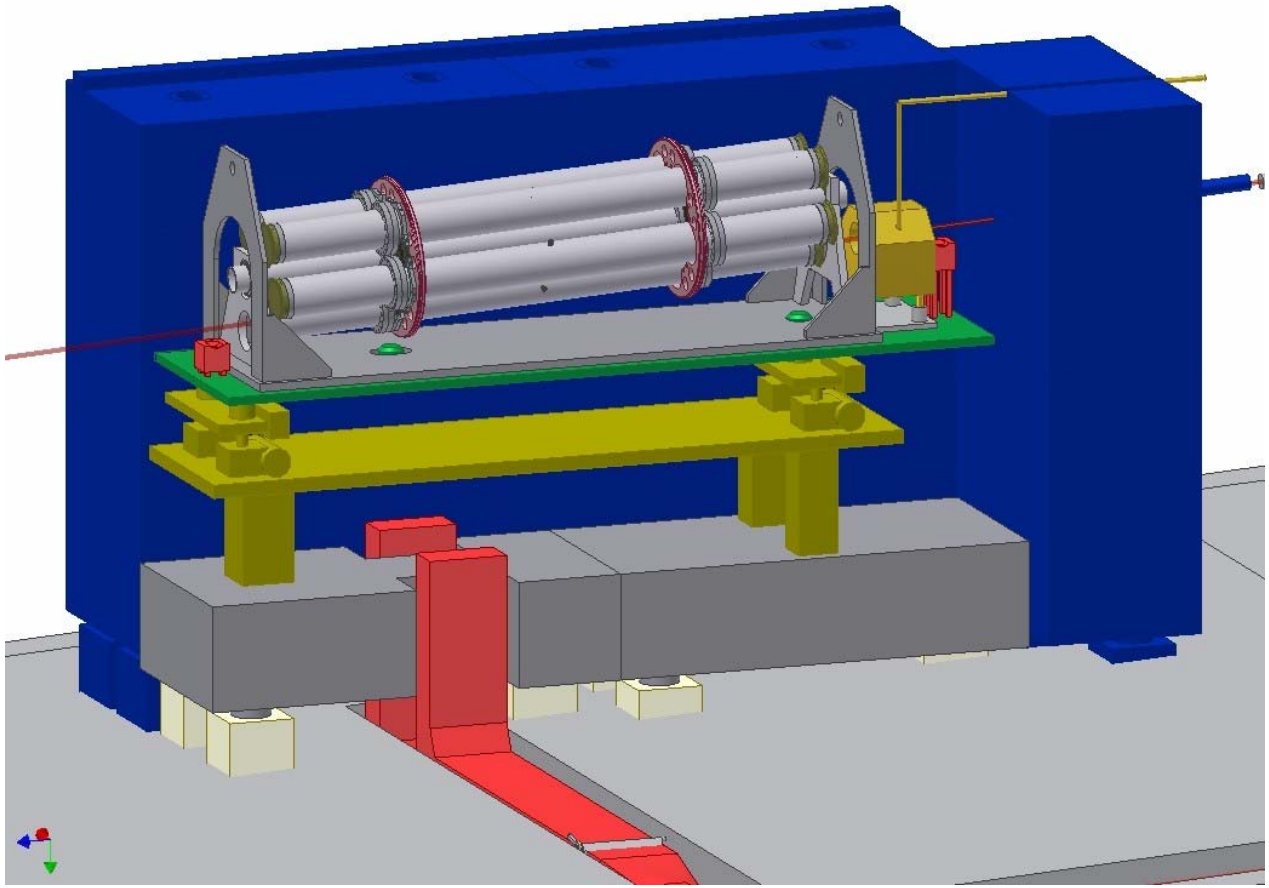
The CNGS Target



*CFC=Carbon-Fiber reinforced Carbon

The CNGS Target Station

CNGS Target Station (4 in-situ spare targets)



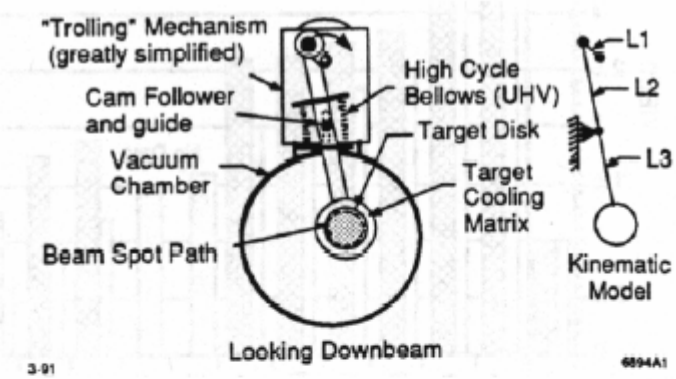
SLAC Positron Target

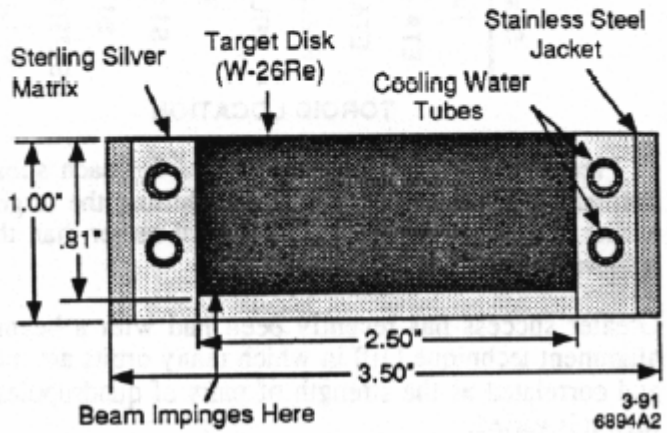
The SLC e- drive beam 30 GeV 24 kW

Target is W-Re Water cooled 28 J/g

Factor of 2 safety margin—Failed after 5 years running.

For NLC e- drive beam 6 GeV 339 kW





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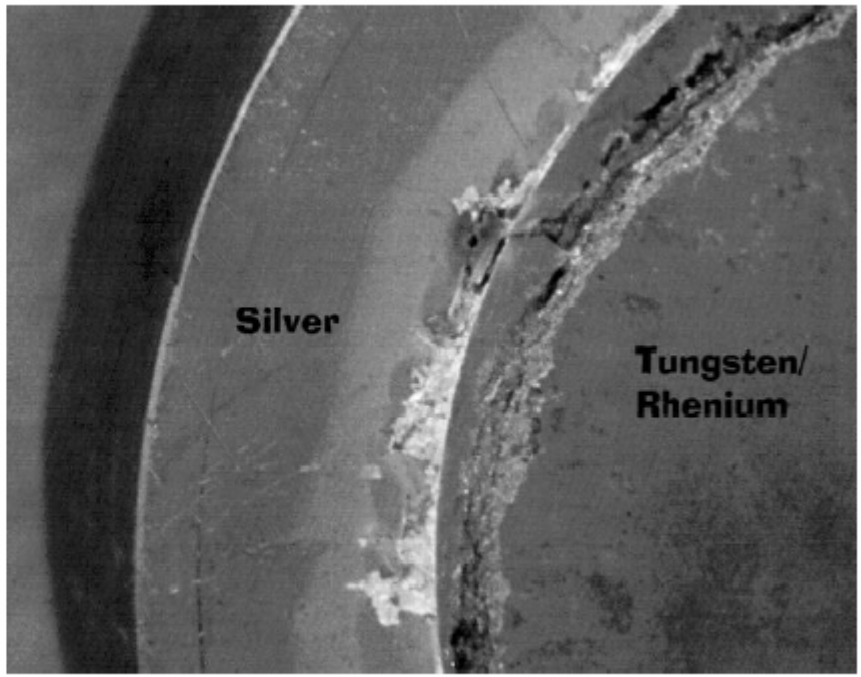
SLC Target Damage



SLC target damage studies were done at LANL. Results show evidence of cracks, spalling of target material and aging effects.

Los Alamos Solid Target R&D

Neutron source production

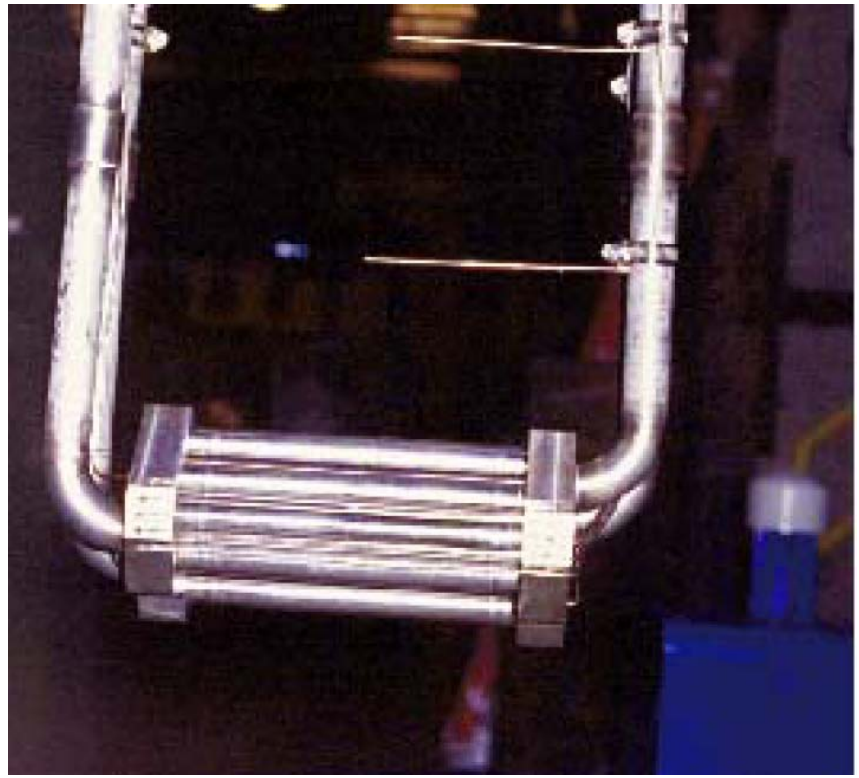
Lance p beam 0.8 GeV 0.8 MW

Stainless Steel Cladded Tungsten

Water Cooled 100 W/g

Results: 2 Months successful running

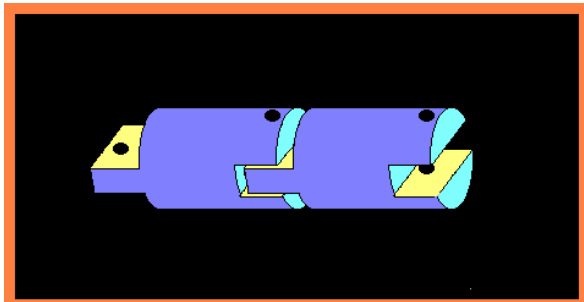
Post-irradiation studies confirm that the target integrity is uncompromised.

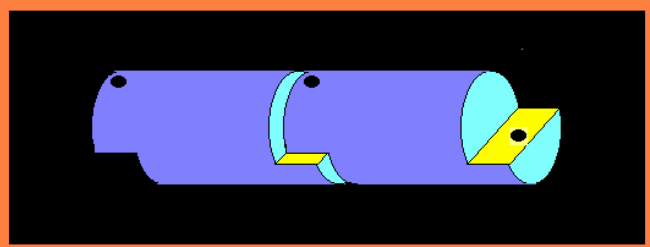


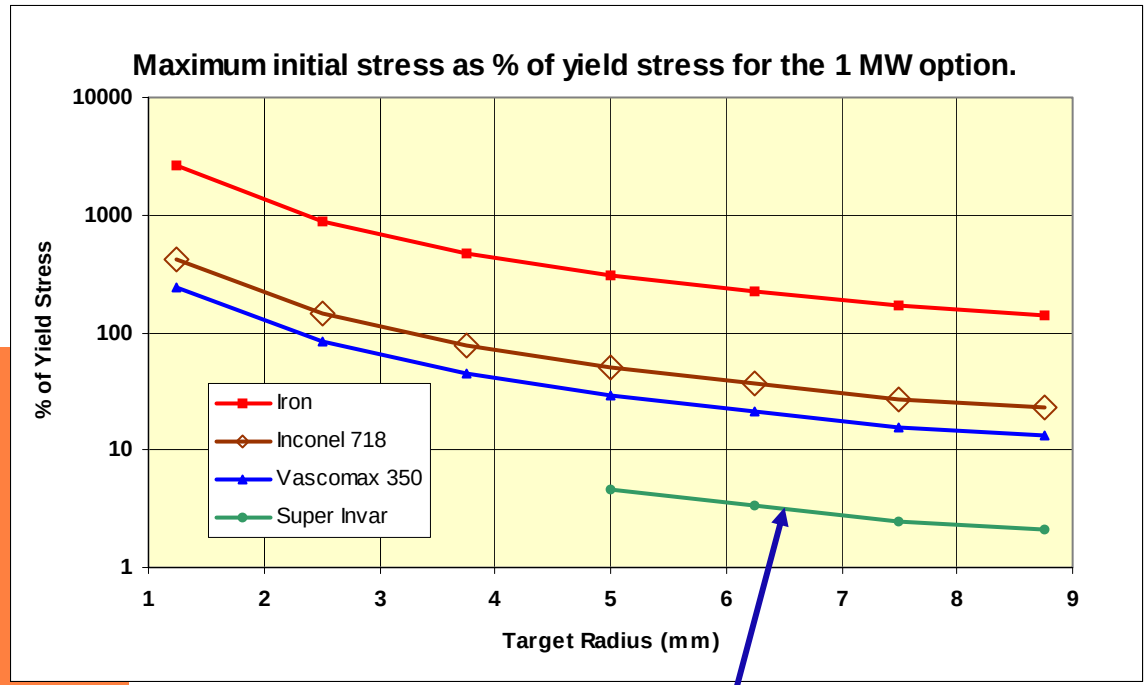
Solid Target Studies at BNL

Examine iron based alloys for candidate target material.

Suggest moving chains



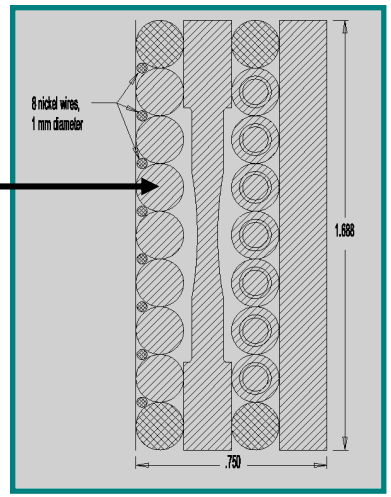




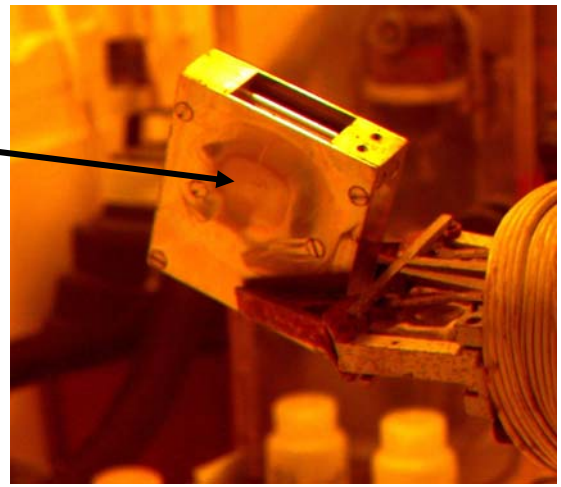
Super Invar looks promising, due to its low coefficient of thermal expansion, BUT

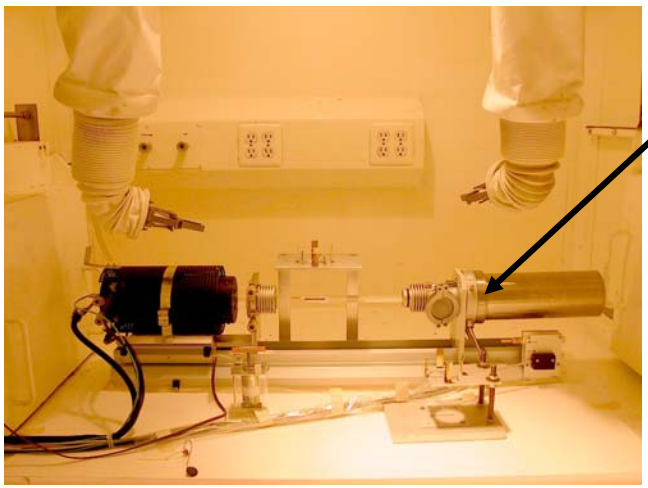
Super-invar Irradiation at BNL

The cylindrical samples of super-invar.



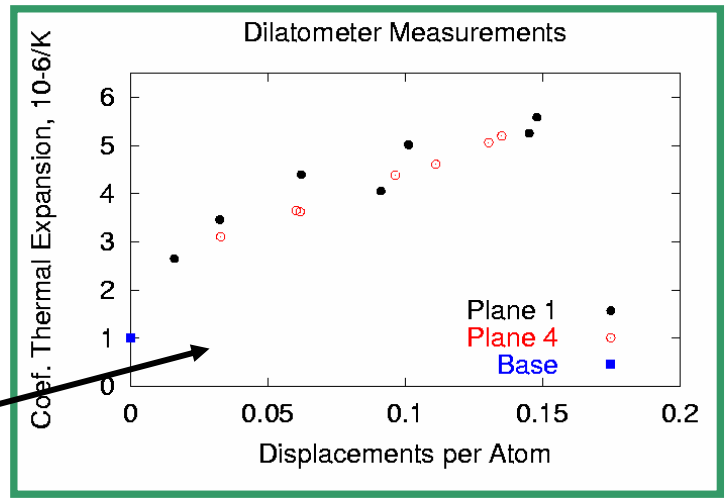
The target basket after irradiation





Dilatometer in Hot cell

Results of coefficient of thermal expansion measurements



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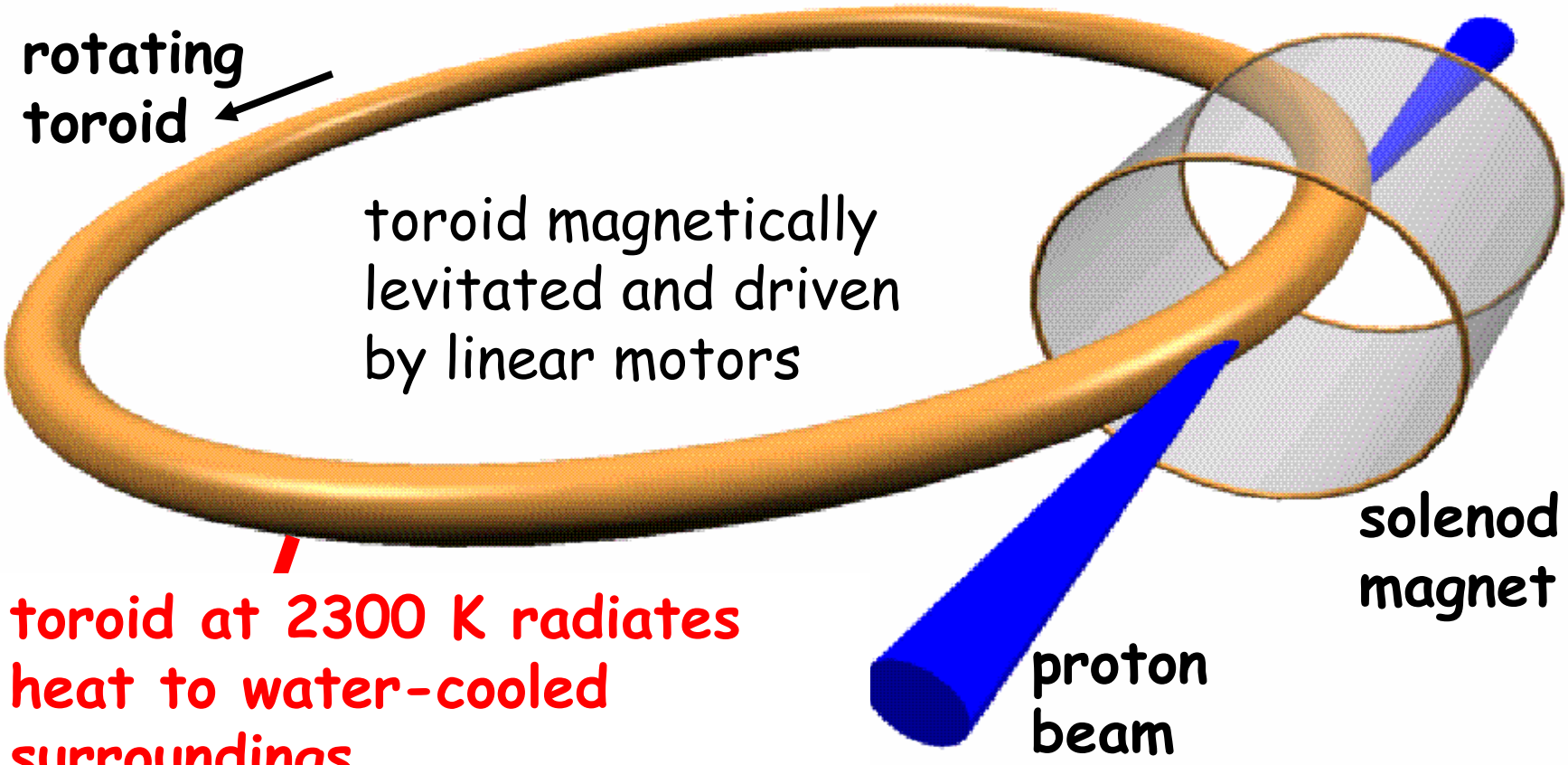
Schematic of a rotating tantalum target

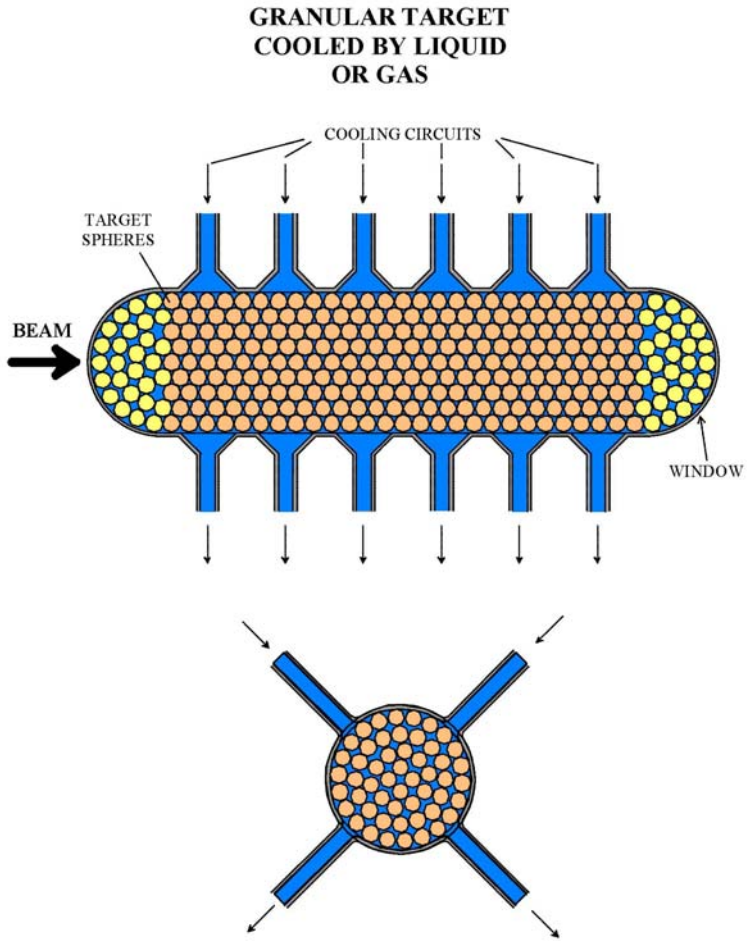


Roger Bennett, RAL

Granular Solid Target

Advantages for a granular approach

- Reduced sample volume results in reduced sample thermal gradient
- Large surface/volume ration leads to better heat removal
- Better liquid or gas conduction through the target
- Simpler stationary solid target approach
- Could utilize high-Z target material



Peter Sievers, CERN

Liquid Metal Targets--Hg

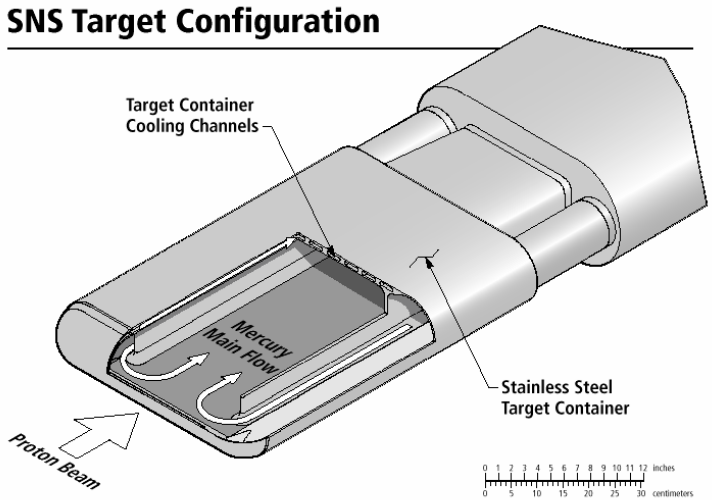
Neutron Sources – SNS and ESS

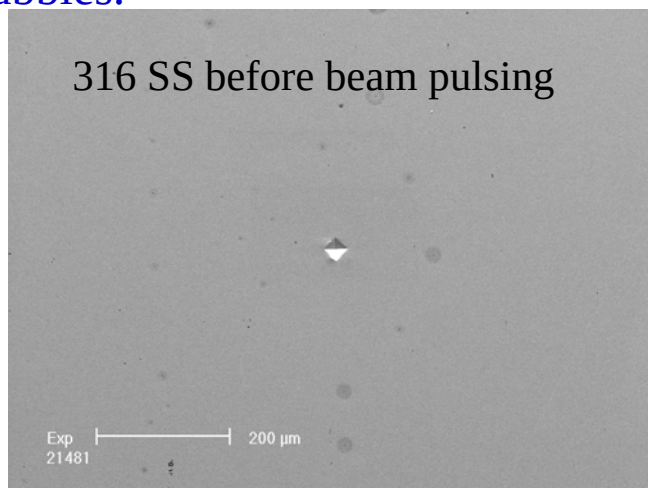
Proton beam 1 GeV and 1 MW

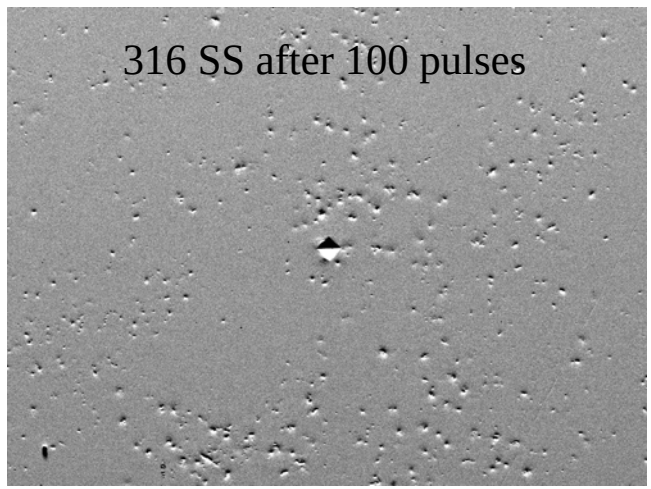
60 Hz operation with large beam spot

Peak energy deposition ~ 1 J/g

Pitting of stainless steel containment vessel significant issue. Pitting results from collapsing cavitation induced bubbles.







R&D on the Pitting Issue

Feature	Normalized Erosion*
Gas layer near surface	0.06
Bubble Injection	0.25
Kolsterized surface	0.0008
1/2 Reference Power	0.09

* Erosion relative to reference (2.5 MW) case

ESS team has been pursuing the Bubble injection solution. SNS team has focused on Kolsterizing (nitriding) of the surface solution. SNS team feels that the Kolsterized surface mitigates the pitting to a level to make it marginally acceptable. Further R&D is being pursued.

Liquid Metal Targets—PbBi Eutectic

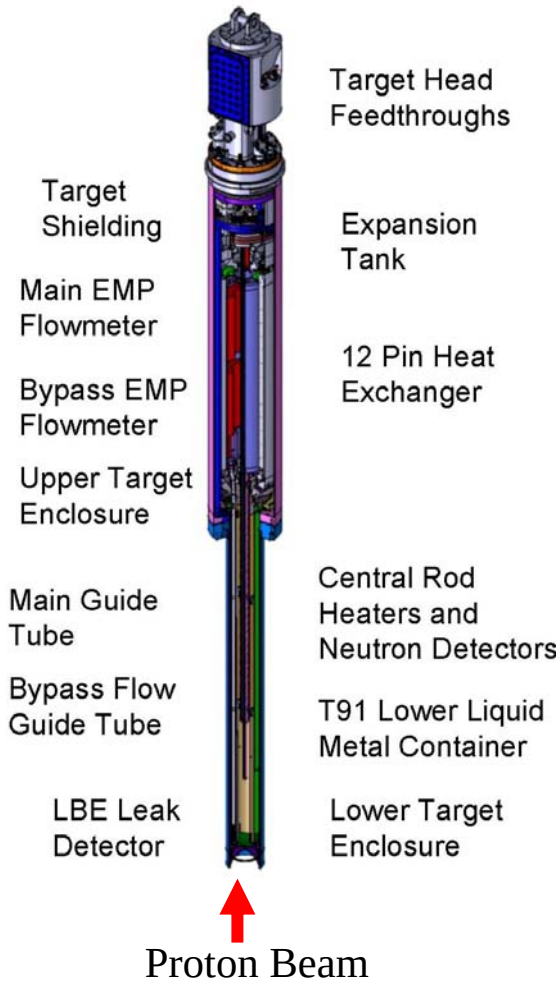
MEGAPIE Project at PSI

0.59 GeV proton beam

1 MW beam power

Goals:

- Demonstrate feasablility
- One year service life
- Irradiation in 2005



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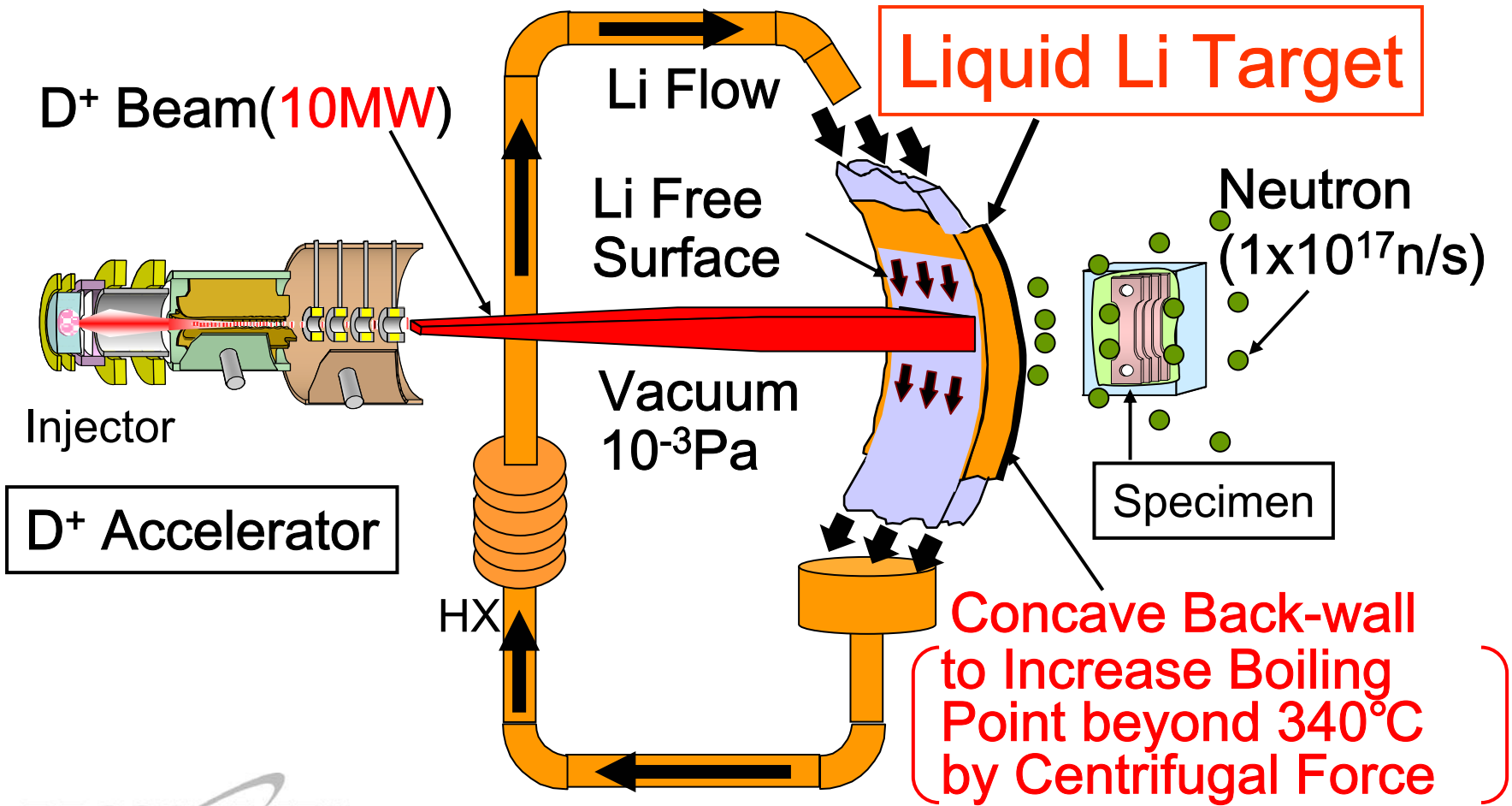
The IFMIF Liquid Li Target

Fast Neutron Source -- Operations in 2017

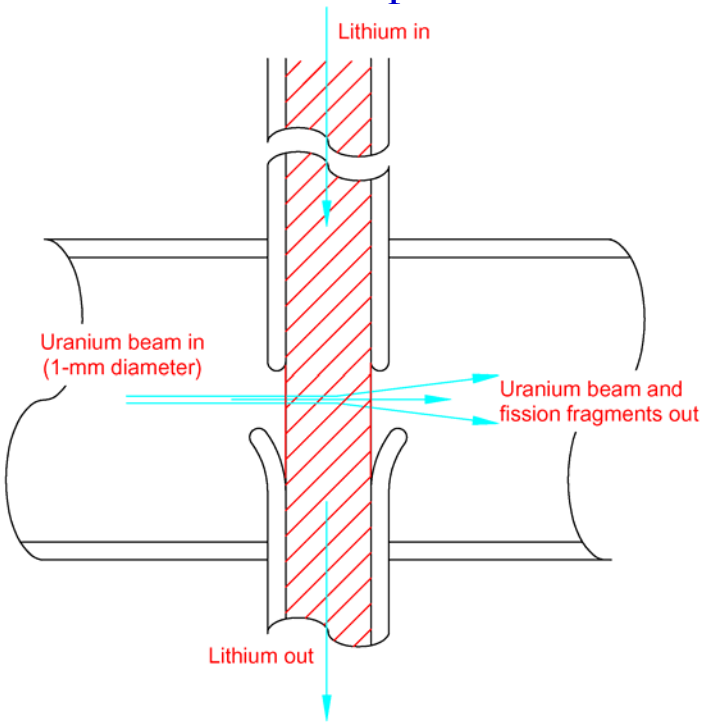


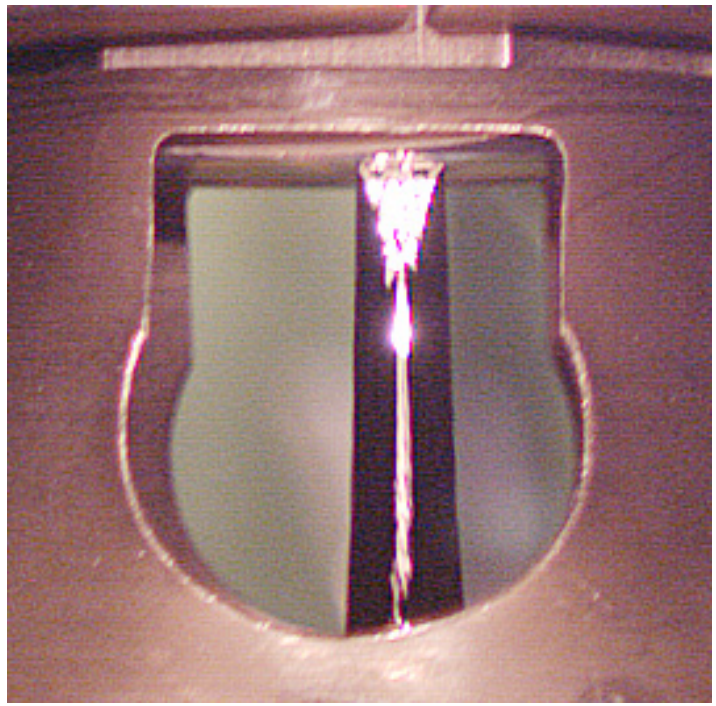
RIA Windowless Liquid Li Target

Rare Isotope Accelerator

Production of rare isotopes by ISOL method and target fragmentation method.

A windowless liquid Li sheet is proposed as a target for heavy ion projectiles. This method also show promise as a thin film stripper.





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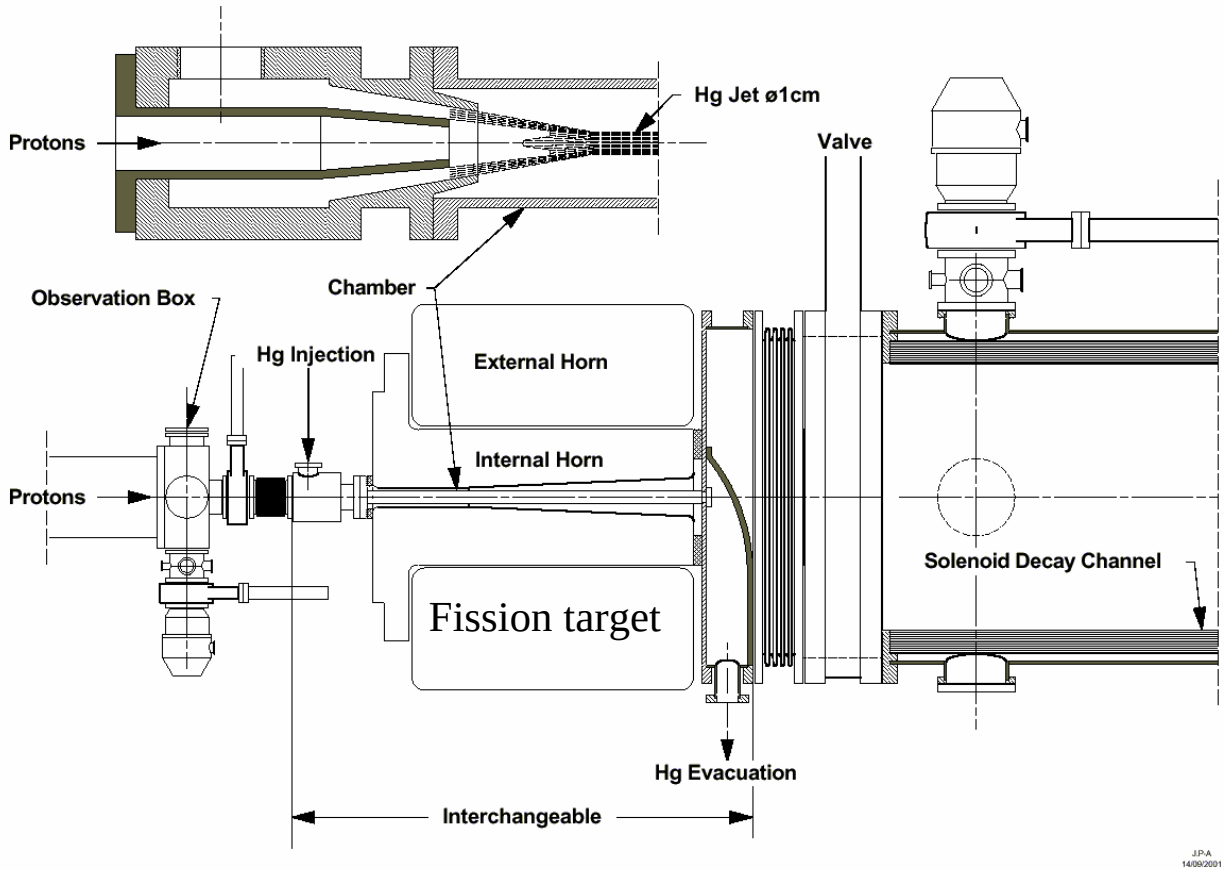
EURISOL Target Development

Proposed ISOL method target based on proton-Hg jet generation of neutrons which subsequently lead to fission product ions in the surrounding material.

Concept to be tested at ISOLDE.

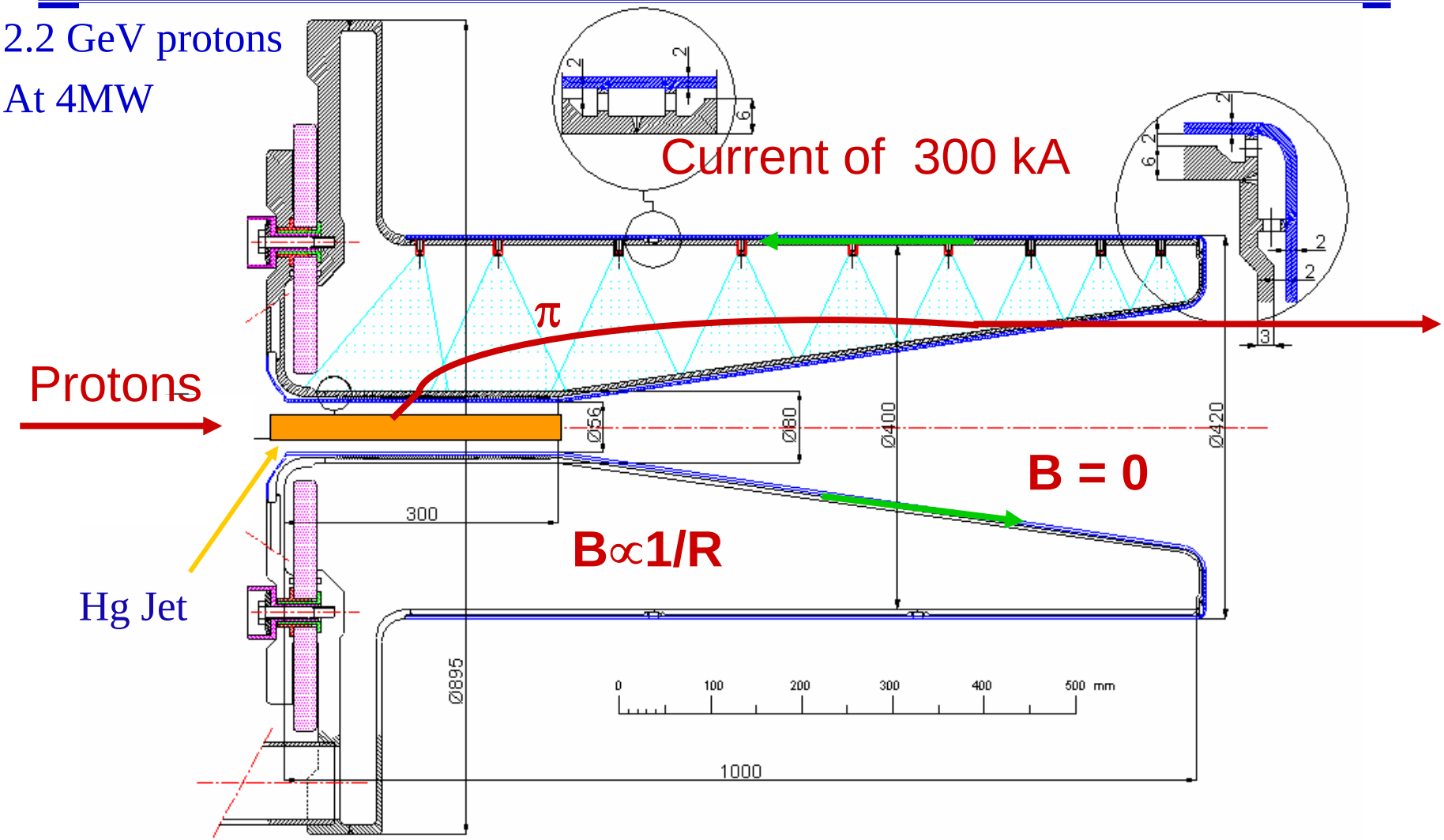
Method also has possible applications as a source for β–ν beams.



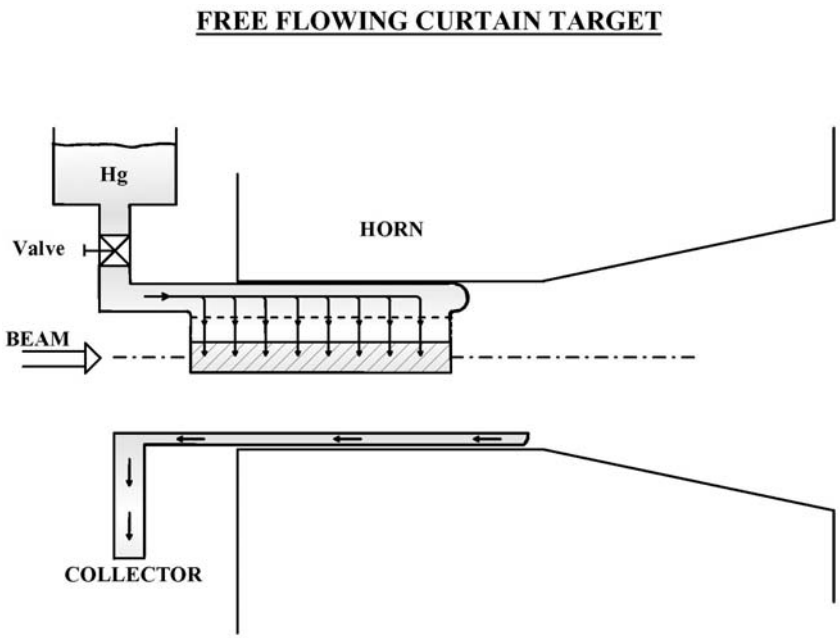
The CERN SPL Target Development

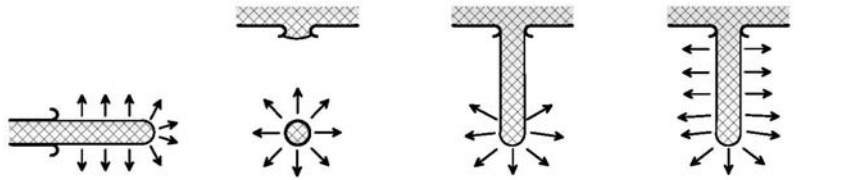
2.2 GeV protons

At 4MW



Siever's Liquid Hg Curtain





	Free Jet	Pulsed Curtain	Continuous Curtain Tip explodes	Continuous Curtain Curtain explodes
Volume Flow (cm^3/s)	2000.	2000.	2000.	5000.
Velocity at nozzle (m/s)	>20.	1.25	0.5	1.25

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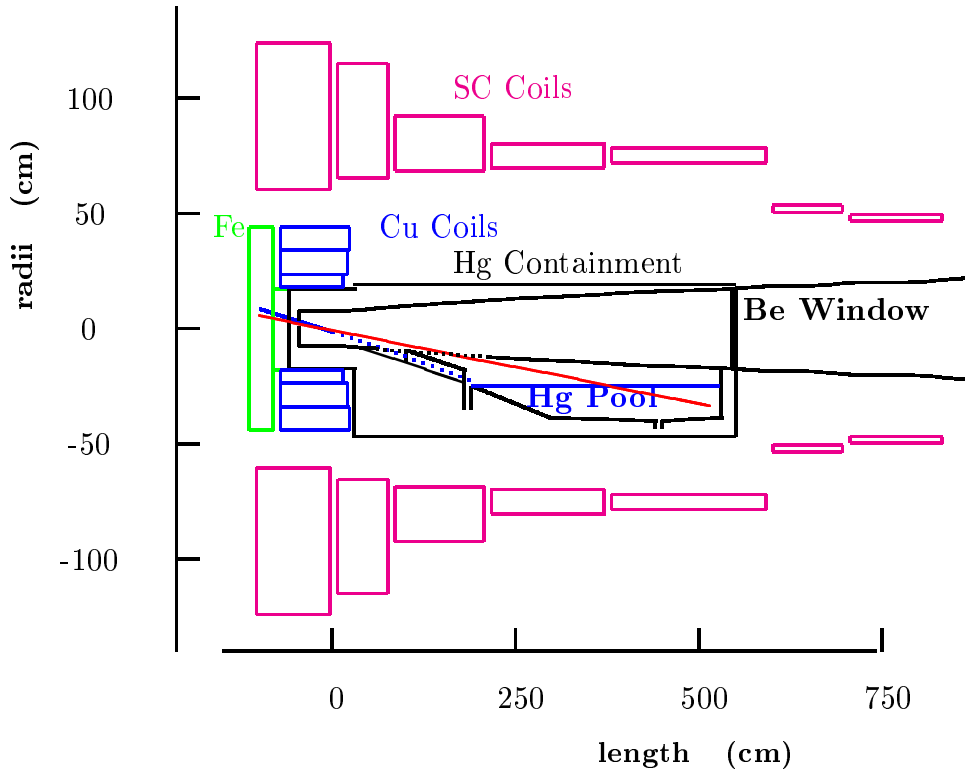
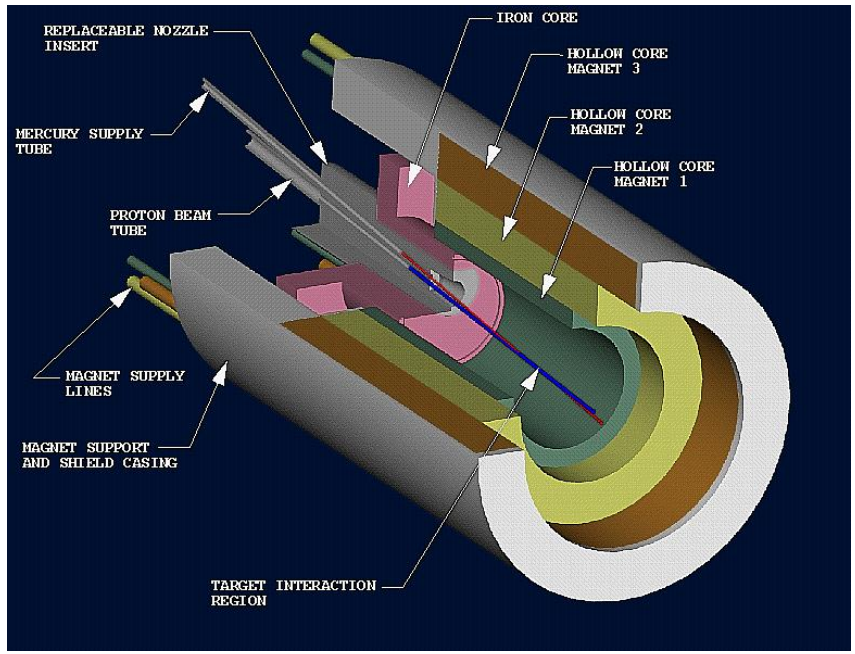
Neutrino Factory Targetry Concept





Capture low P_T pions in high-field solenoid
Use Hg jet tilted with respect to solenoid axis
Use Hg pool as beam dump

Engineered solution--P. Spampinato, ORNL

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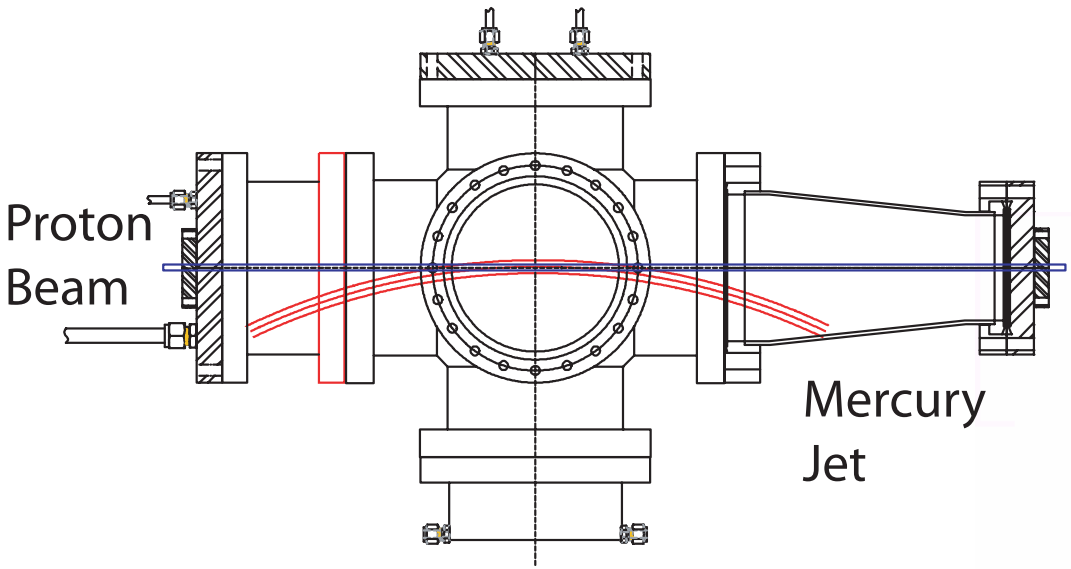
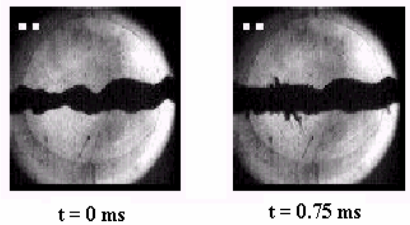
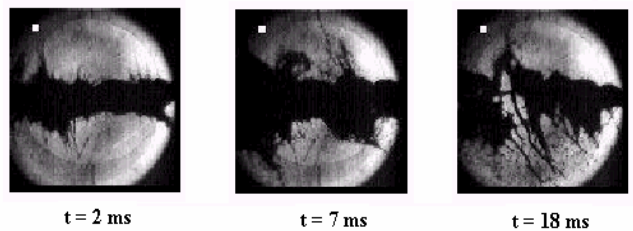
E951 Hg Jet Tests

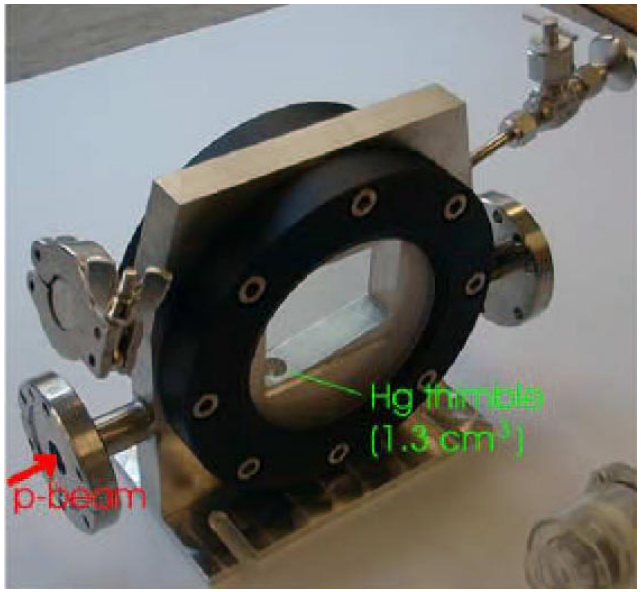


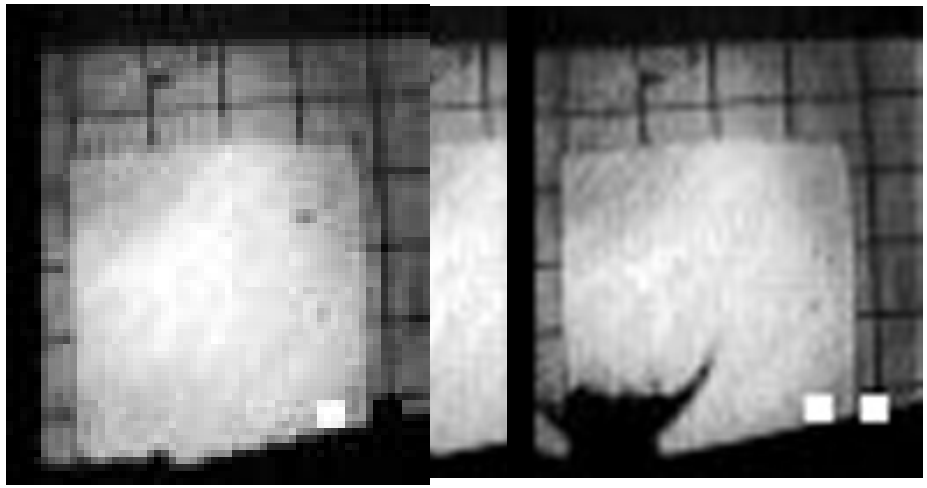
- 1cm diameter Hg Jet
- 24 GeV 4 TP Proton Beam
- No Magnetic Field

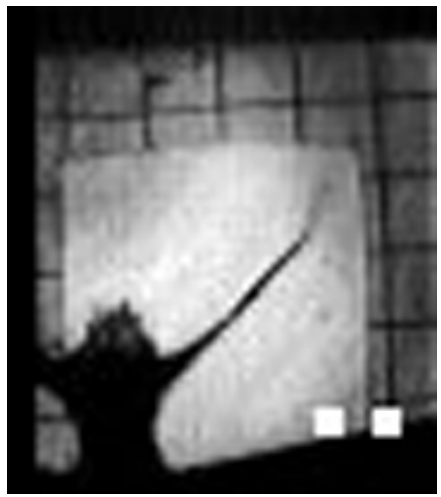


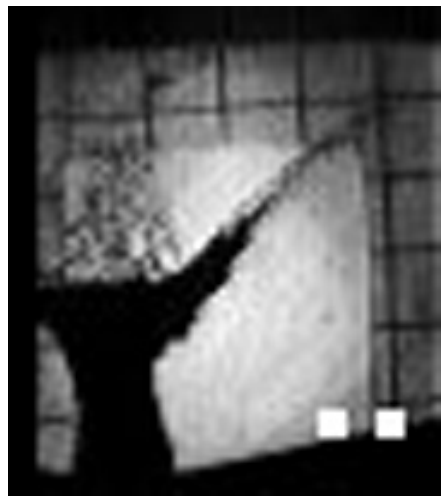


CERN Passive Hg Thimble Test







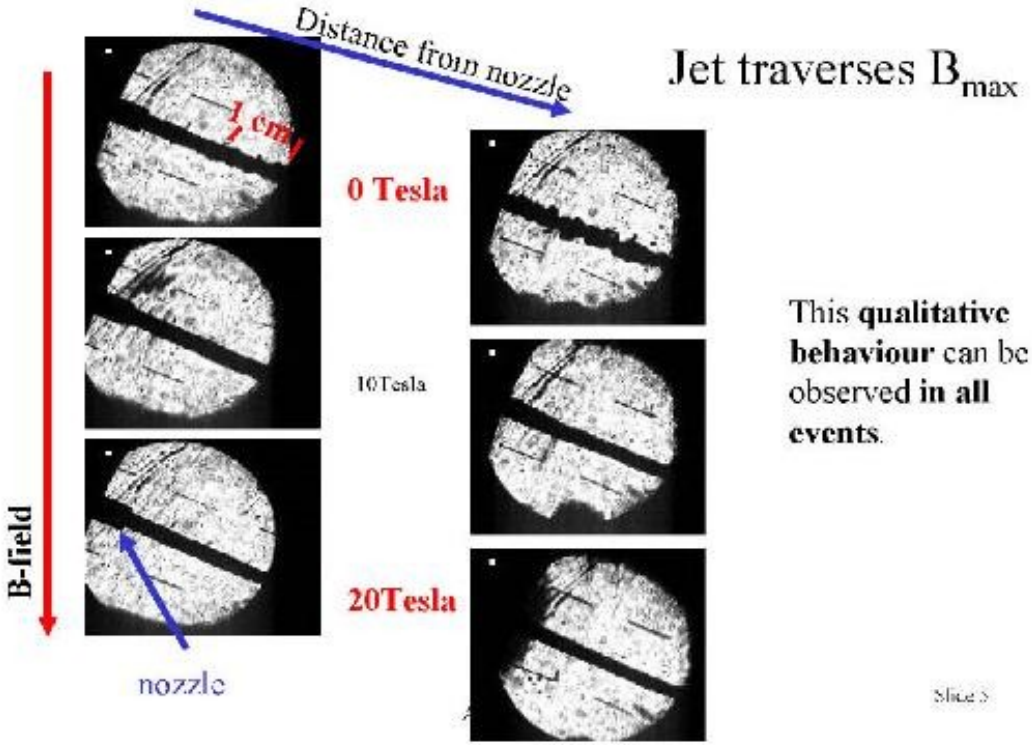


Exposures to a BNL AGS 24 GeV
2 TP beam. T=0, 0.5 , 1.6 and 3.4 ms.

Key E951 Results

- Hg jet dispersal proportional to beam intensity
- Hg jet dispersal ~ 10 m/s for 4 TP 24 GeV beam
- Hg jet dispersal velocities ~ ½ times that of "confined thimble" target
- Hg dispersal is largely transverse to the jet axis -- longitudinal propagation of pressure waves is suppressed
- Visible manifestation of jet dispersal delayed 40 μs

CERN/Grenoble Hg Jet Tests



- **4 mm diameter Hg Jet**
- **v = 12 m/s**
- **0, 10, 20T Magnetic Field**
- **No Proton Beam**

A. Fabich, J. Lettry
Nufact'02

Key Jet/Magnetic Field Results

- The Hg jet is stabilized by the 20 T magnetic field
- Minimal jet deflection for 100 mrad angle of entry
- Jet velocity reduced upon entry to the magnetic field

Bringing it all Together

We wish to perform a proof-of-principle test which will include:

- A high-power intense proton beam (16 to 32 TP per pulse)
- A high (> 15T) solenoidal field
- A high (> 10m/s) velocity Hg jet
- A ~1cm diameter Hg jet

Experimental goals include:

- Studies of 1cm diameter jet entering a 15T solenoid magnet
- Studies of the Hg jet dispersal provoked by an intense pulse of a proton beam in a high solenoidal field
- Studies of the influence of entry angle on jet performance
- Confirm Neutrino factory/Muon Collider Targetry concept

Letter of Intent-- Isolde and nToF Committee

CERN-INTC-2003-033
INTC-I-049
23 October 2003
Updated: 31 Oct 2003

A Letter of Intent to
the ISOLDE and Neutron Time-of-Flight
Experiments Committee

Studies of a Target System for a 4-MW, 24-GeV Proton Beam

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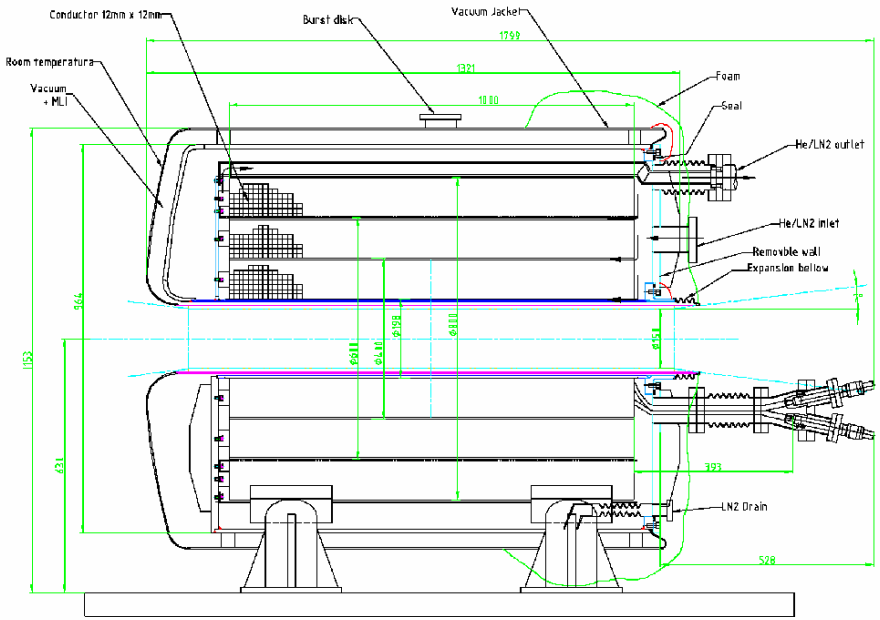
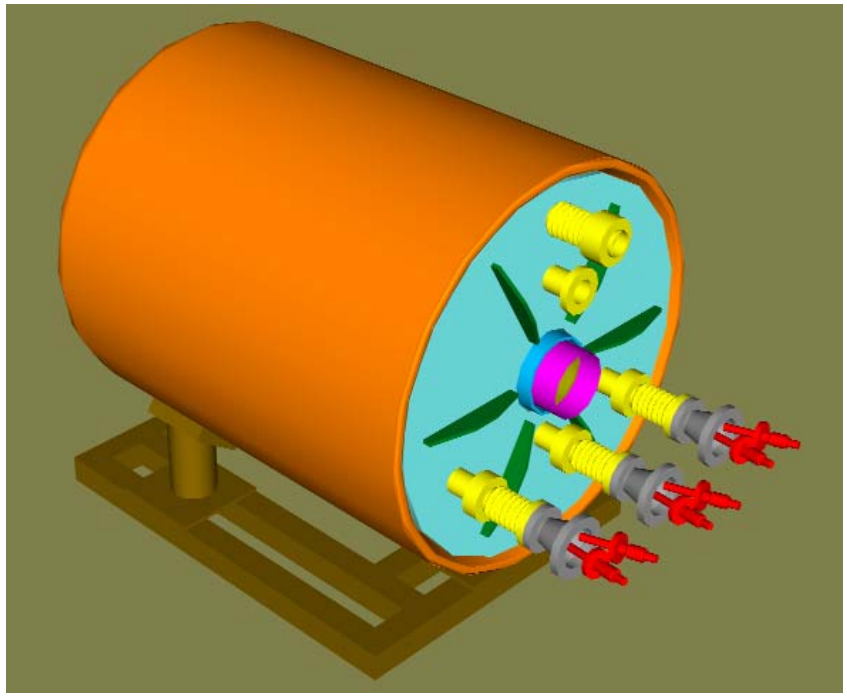
Spokespersons: H.G. Kirk, K.T. McDonald
Local Contact: H. Haseroth

Participating Institutions

1) RAL
2) CERN
3) KEK
4) BNL
5) Princeton University

High Field Pulsed Solenoid

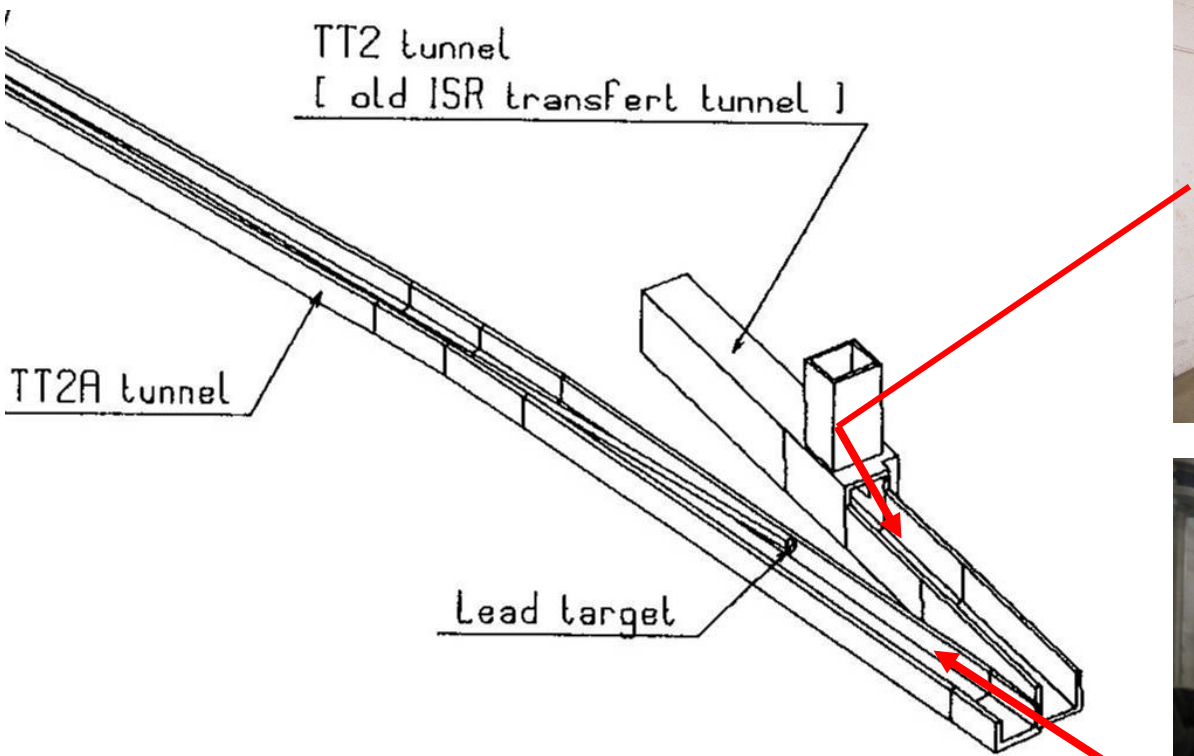




- 70^{o} K Operation
- 15 T with 4.5 MW Pulsed Power
- 15 cm warm bore
- 1 m long beam pipe

Peter Titus, MIT

Possible Experiment Location at CERN



Letter of Intent to submitted Oct. 23, 2003

Simulation and Theory Summary

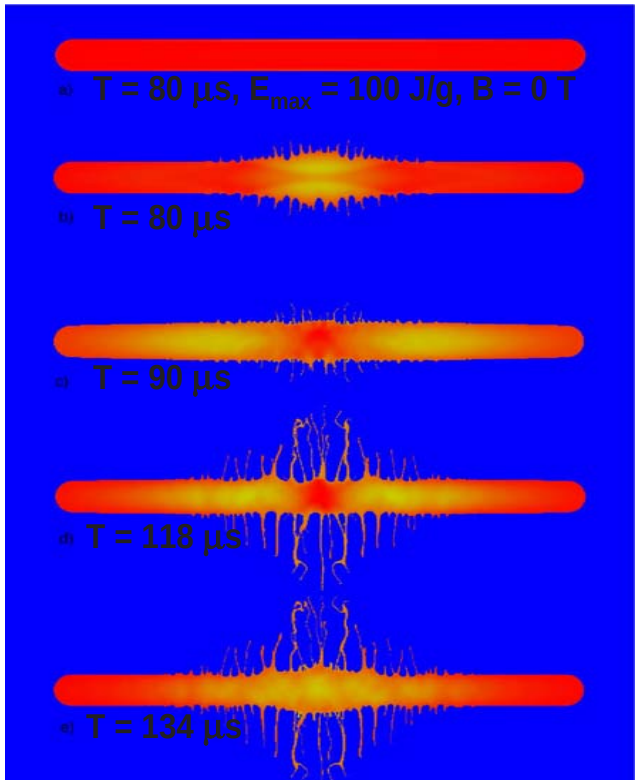
1. **Particle Yields, Energy Deposition and Radiation (N. Mokhov, L. Waters)**
   - Needs and Specs
   - Codes
   - Uncertainties
   - Benchmarking
   - Future Work

2. **Structural Analyses of Solid Targets and Li-lenses (N. Simos, P. Hurh, B. Riemer)**

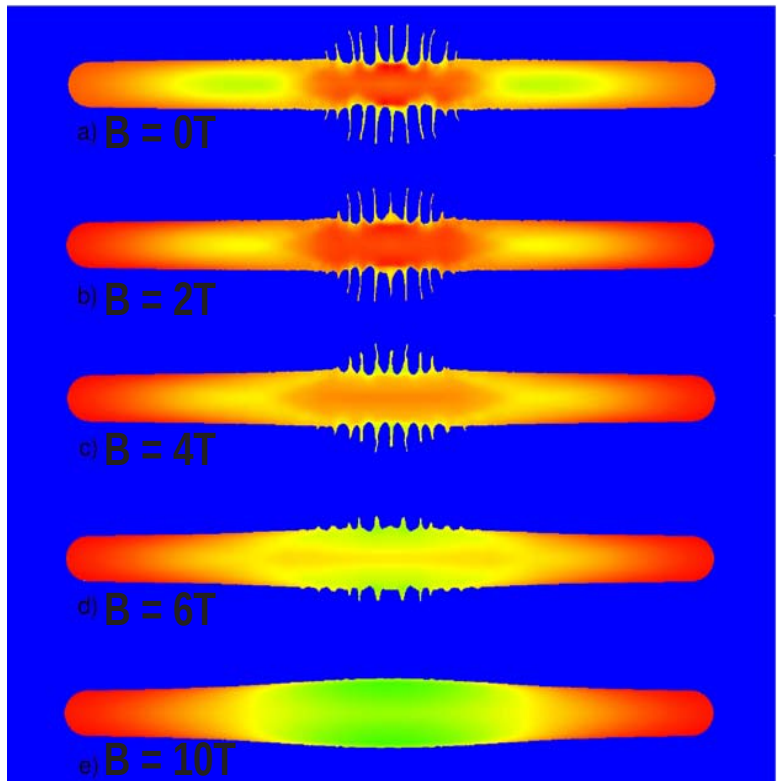
3. **Magnetohydrodynamics in Liquid Targets (R. Samulyak, Y. Prykarpatskyy)**

4. **Misc (L. Waters)**
   - Materials Handbook
   - Hydraulics

Simulations at BNL (Samulyak)

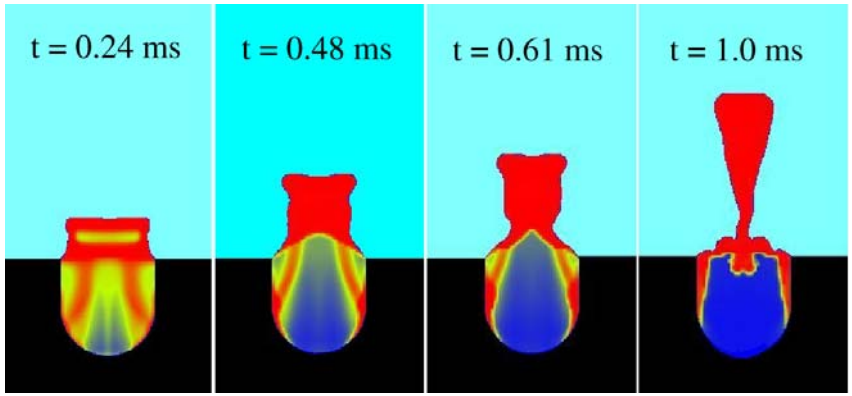


Gaussian energy deposition profile Peaked at 100 J/g. Times run from 0 to 124 μs.



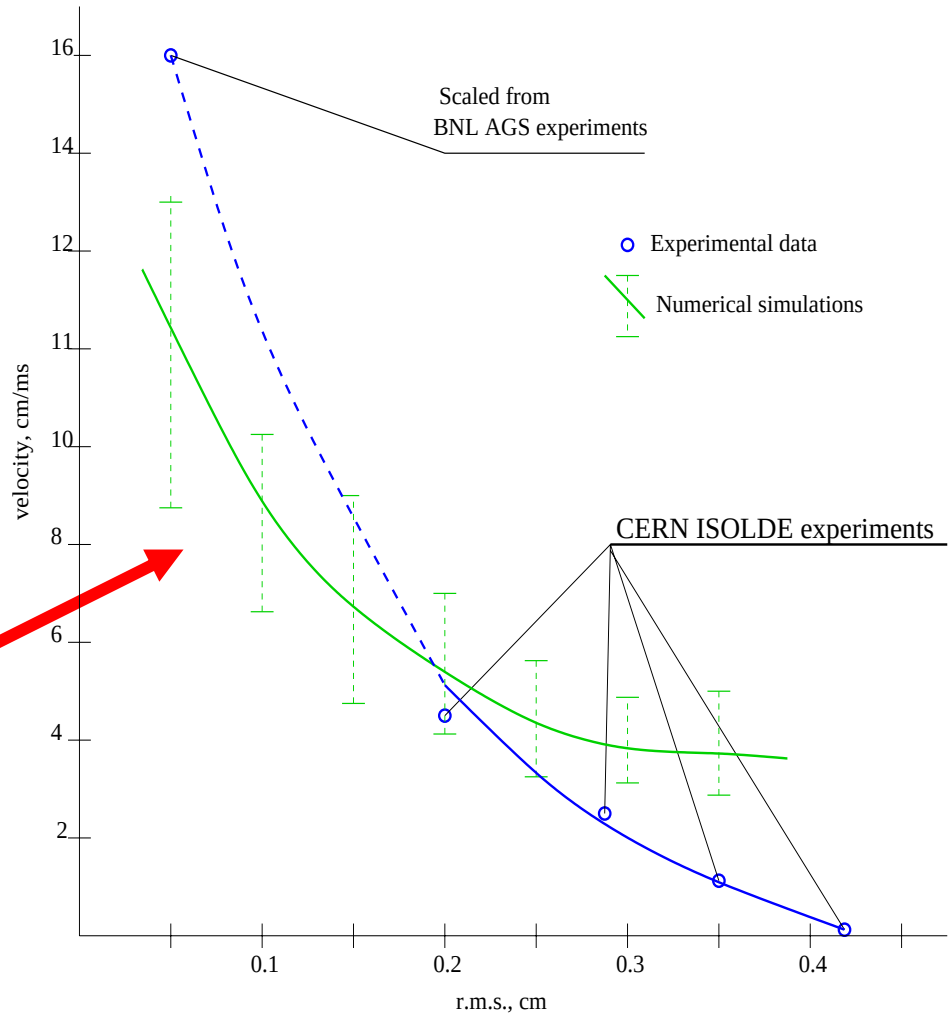
Jet dispersal at t=100 μs with magnetic Field varying from B=0 to 10T

CERN Hg Thimble Results



Simulations—Prykarpatskyy, BNL

Bulk ejection velocity as a function Of beam spot size. ISOLDE data is 17 TP at 1.4 GeV.



Harold G. Kirk

Conclusions

- New physics opportunities are demanding more intense proton drivers.
- 1 MW machines are almost here! 4 MW machines are planned.
- Targets for 1 MW machines exist but are unproven.
- But no convincing solution exists yet for the 4 MW class machines.
- Worldwide R&D efforts underway to develop targets for these new machines.
- A key workshop concern was the lack of worldwide support facilities where promising new ideas can be tested.