Muon Collaboration

The 2003 Targetry Workshop

High-power Targetry for Future Accelerators

Ronkonkoma, NY
September 8-12, 2003

BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk
Brookhaven National Laboratory

Muon Collaboration

Workshop Participation

Over 40 attendees from:

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

Facilities Represented

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

BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

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

Target Parameters from John Haines Summary

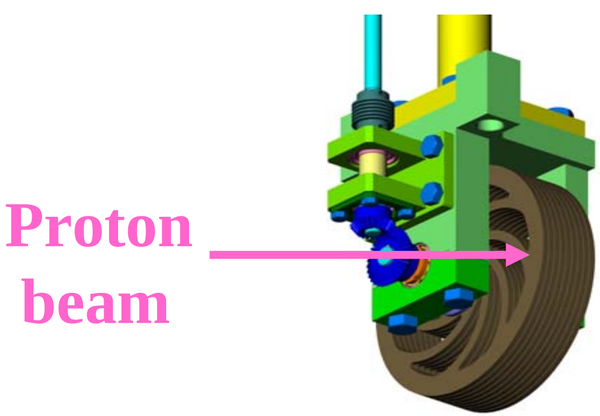
Facility	Status	Target Material	Beam Pulse Duration (ms)	Beam Pulse Rep Rate (Hz)	Energy (GeV)	Time Ave Power in Beam (MW)	Peak Time Ave Power Density (MW/m^3)	Peak Energy Density (MJ/m^3/pulse)
BNL Neutrino Superbeam	Under Study	C-C Composite	2.6	2.5	28	1	4,060	1,630
ESS - short pulse	Under Study	Hg	1.2	50	1.334	5	2,500	50
ESS - long pulse	Under Study	Hg	2,000	16.7	1.334	5	2,500	150
EURISOL	Under Study	Hg	3	50	2.2	4	100,000	2,000
IFMIF	Under Study	Li	CW		0.04 (D_2)	10	100,000	NA
JPARC - Hadron beam line	Under Construc	Ni	7.E+05	0.3	50	0.75	7,600	5,300
JPARC - Neutrino beam line	Under Study	C	5	0.3	50	0.75	83	300
LANSCE - APT irradiation tests	Dismantled	W	1,000	20	0.8	0.8	800	40
LANSCE - Lujan	Existing	W	0.25	20	0.8	0.1	350	18
LANSCE - Mats Test Station	Under Study	Pb-Bi	1,000	120	0.8	0.8	2,400	20
LEDA as fusion mats test facility	Under Study	Li	CW		0.04 (D_2)	2	100,000	NA
MiniBoone	Existing	Be	150	5	8	0.032	120	24
NLC - conventional	Under Study	W Re	0.26	120	6.2	0.086	334,800	2,790
NLC - undulator	Under Study	Ti alloy	0.26	120	0.011	0.126	1,110,000	9,200
NuMI	Existing	C	8.6	0.53	120	0.4	318	600
Pbar	Existing	Inconel 600 + ...	1.6	0.5	120	0.052	7,650	15,300
RIA	Under Study	Li, Be, Hg, W, ...	CW		1-96 (p to U)	0.4	< 4,000,000	NA
SINQ/Solid Target	Existing	Pb, SS-clad	CW		0.575	0.72	720	NA
SINQ/MEGAPIE	Under Construc	Pb-Bi	CW		0.575	1	1,000	NA
SNS	Under Construc	Hg	0.7	60	1	2	800	13
US Neutrino Factory	Under Study	Hg	0.003	15	24	1	3,800	1,080

JPARC Targets

Proton Beam 0.75 MW at 50 GeV

Kaon Production

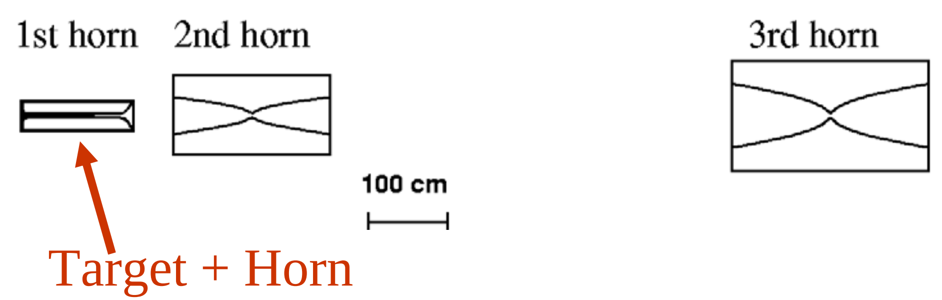
Rotating Ni Disks
Water Cooled
590 J/g



Neutrino Production

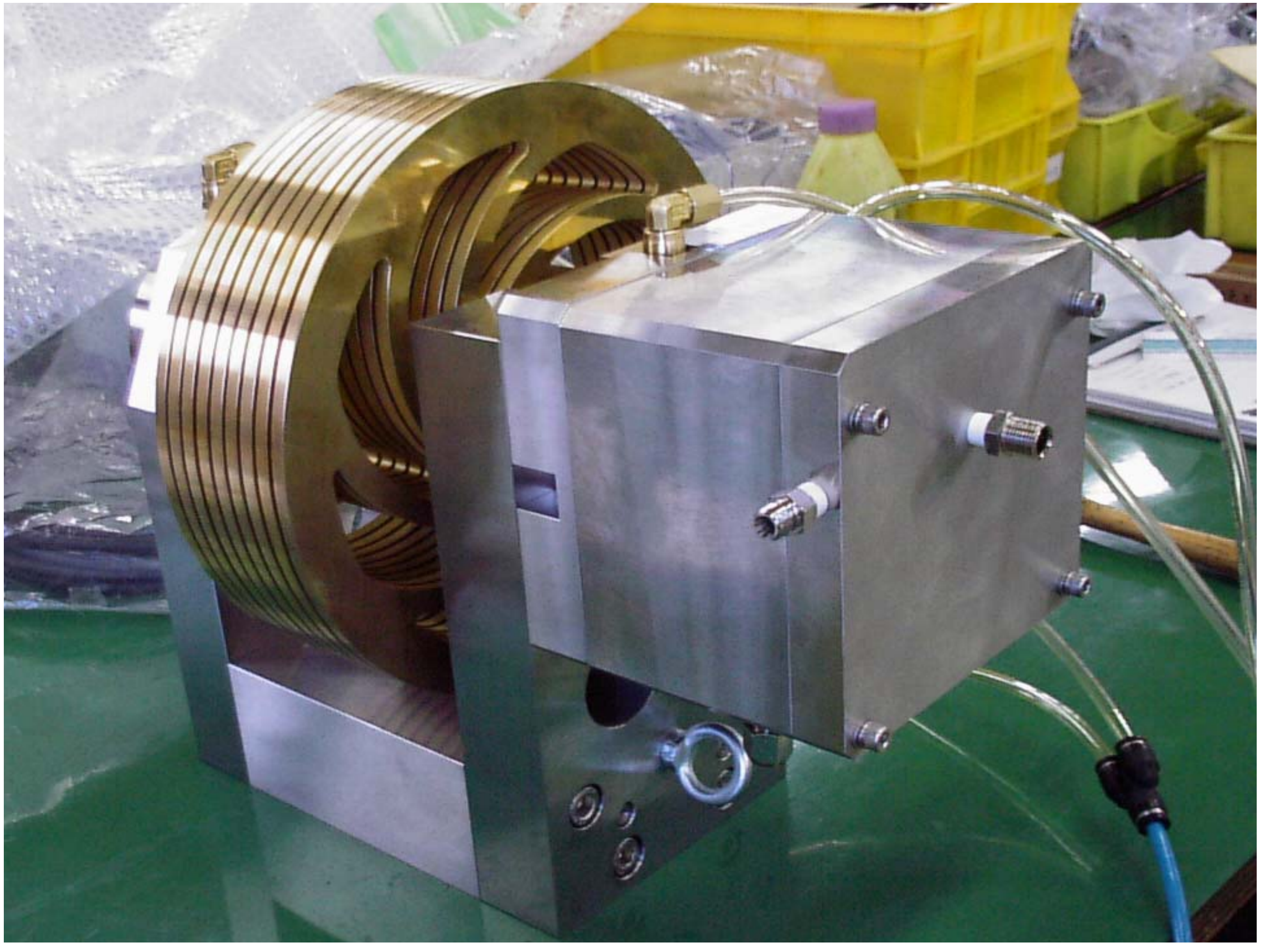
Stationary Carbon
Water Cooled
150 J/g

Three Horn System

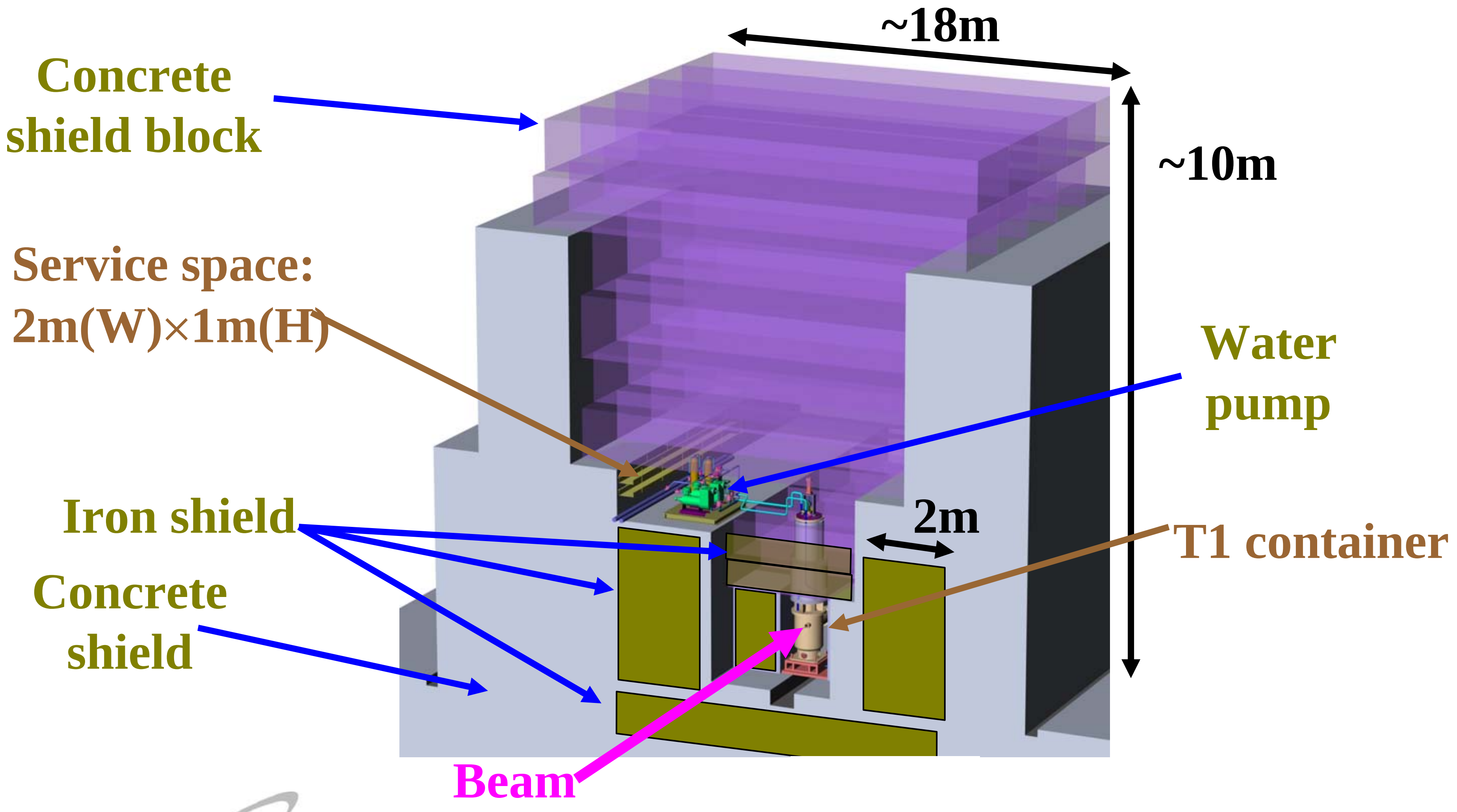


Harold G. Kirk

The T1 Kaon Target Prototype



Shielding around the T1 Kaon Target



FNAL Targets

Booster 8 GeV 32 kW

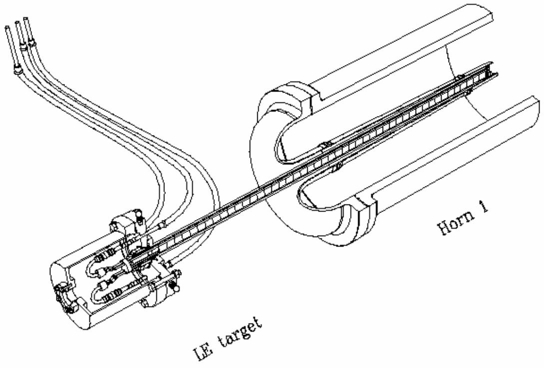
Be 3/8 in diameter segmented

Air cooled

19 J/g

Main Injector 120 GeV 0.4 MW

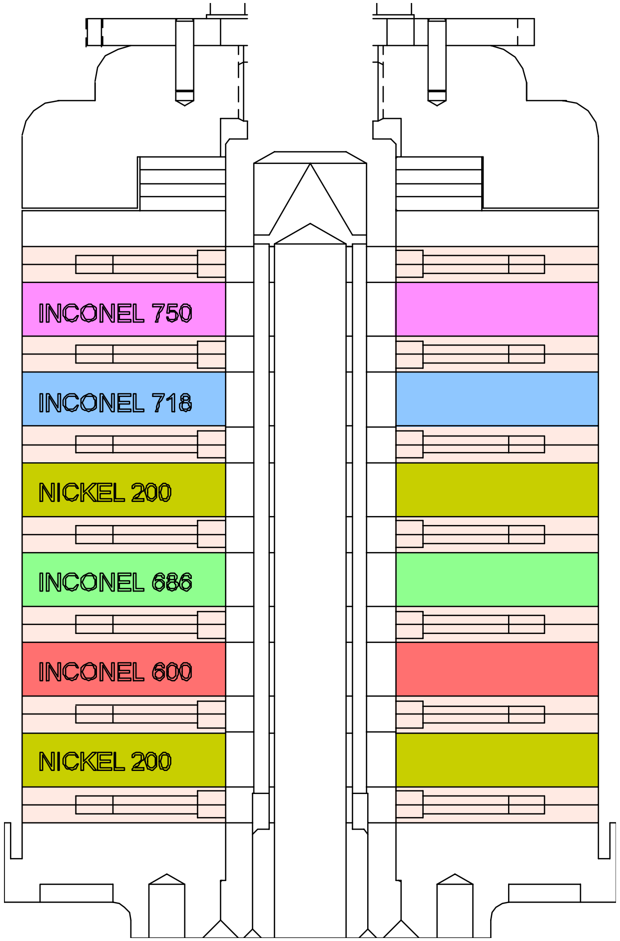
Pbar Targets	NUMI
Ni, Cu, W-Re	Carbon
Air cooled	Water cooled
400 to 1000 J/g	350 J/g



Harold G. Kirk

The assembled Mini-boone Target

The Pbar Target System



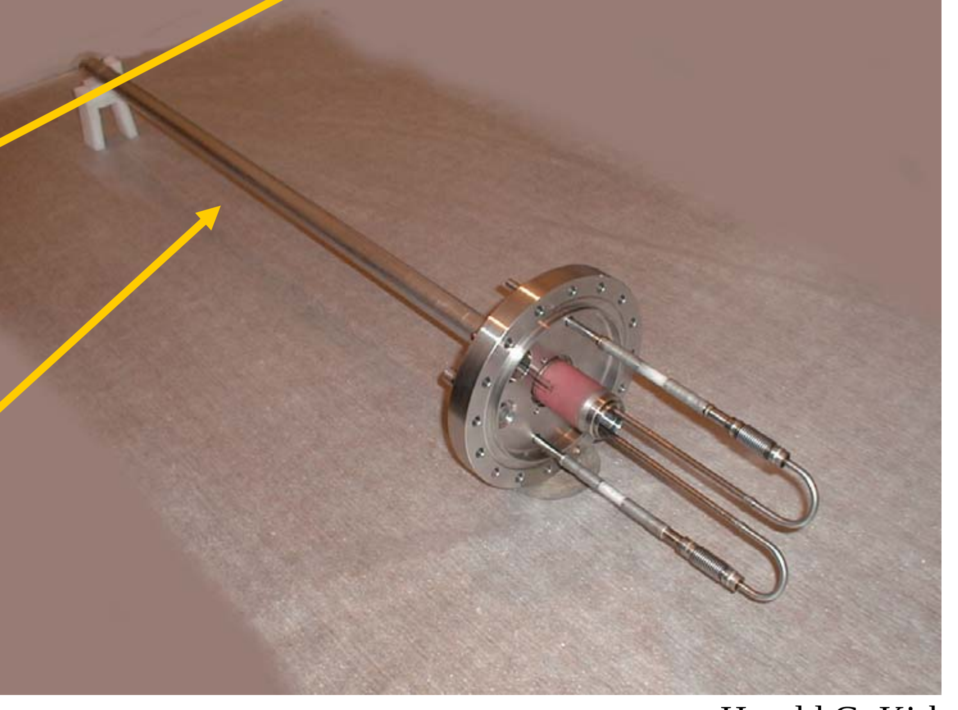
W Target

W-Re Target

BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

NuMI Low Energy Target for Minos



Graphite Fin Core
2 int. len.

Water cooling tube
also provides mechanical support

Aluminum vacuum tube

BROOKHAVEN NATIONAL LABORATORY

Muon Collaboration

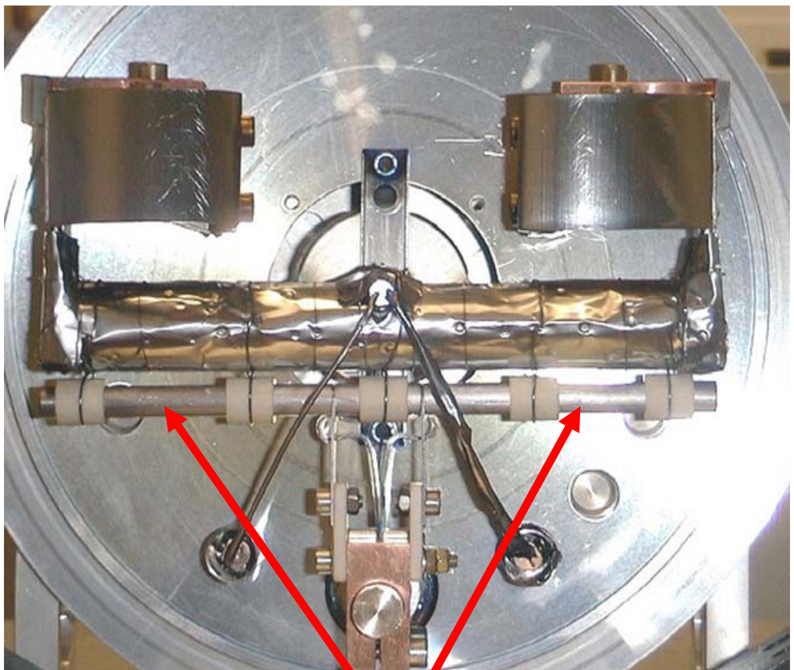
Harold G. Kirk

CERN Solid Targets

ISOLDE

PS-Booster 1-1.4 GeV   0.005 MW

Various targets/materials



Tantalum Target

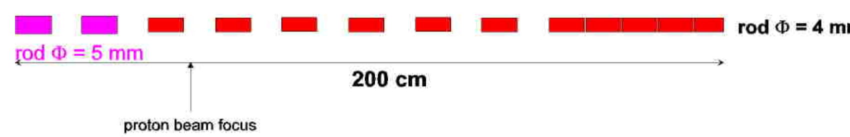
CNGS

SPS proton beam 400 GeV 0.25 MW

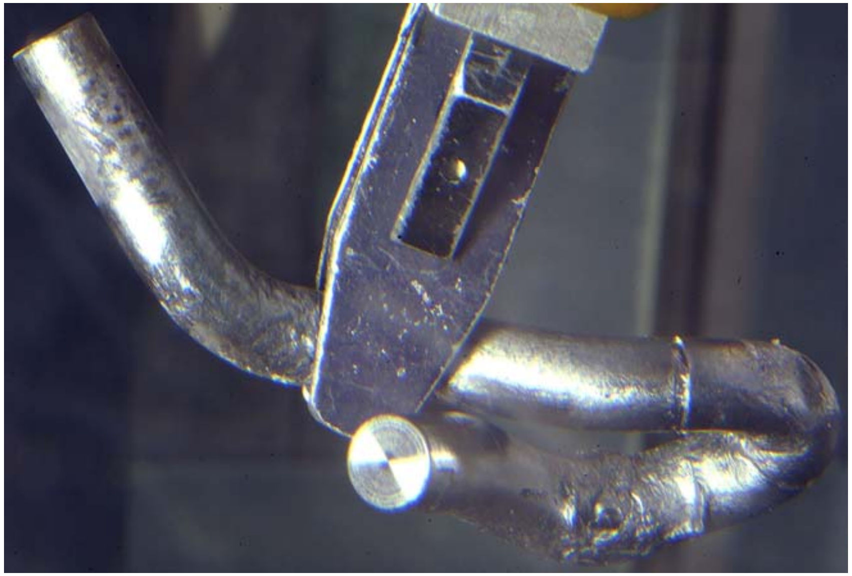
Segmented carbon

He cooled

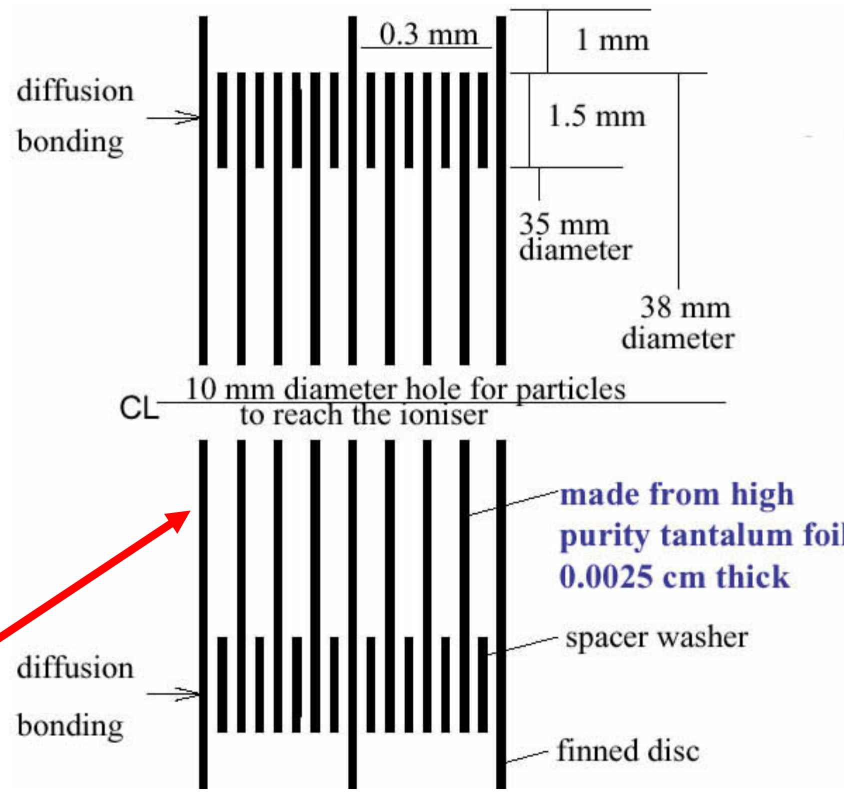
750 J/g



Experience with Tantalum

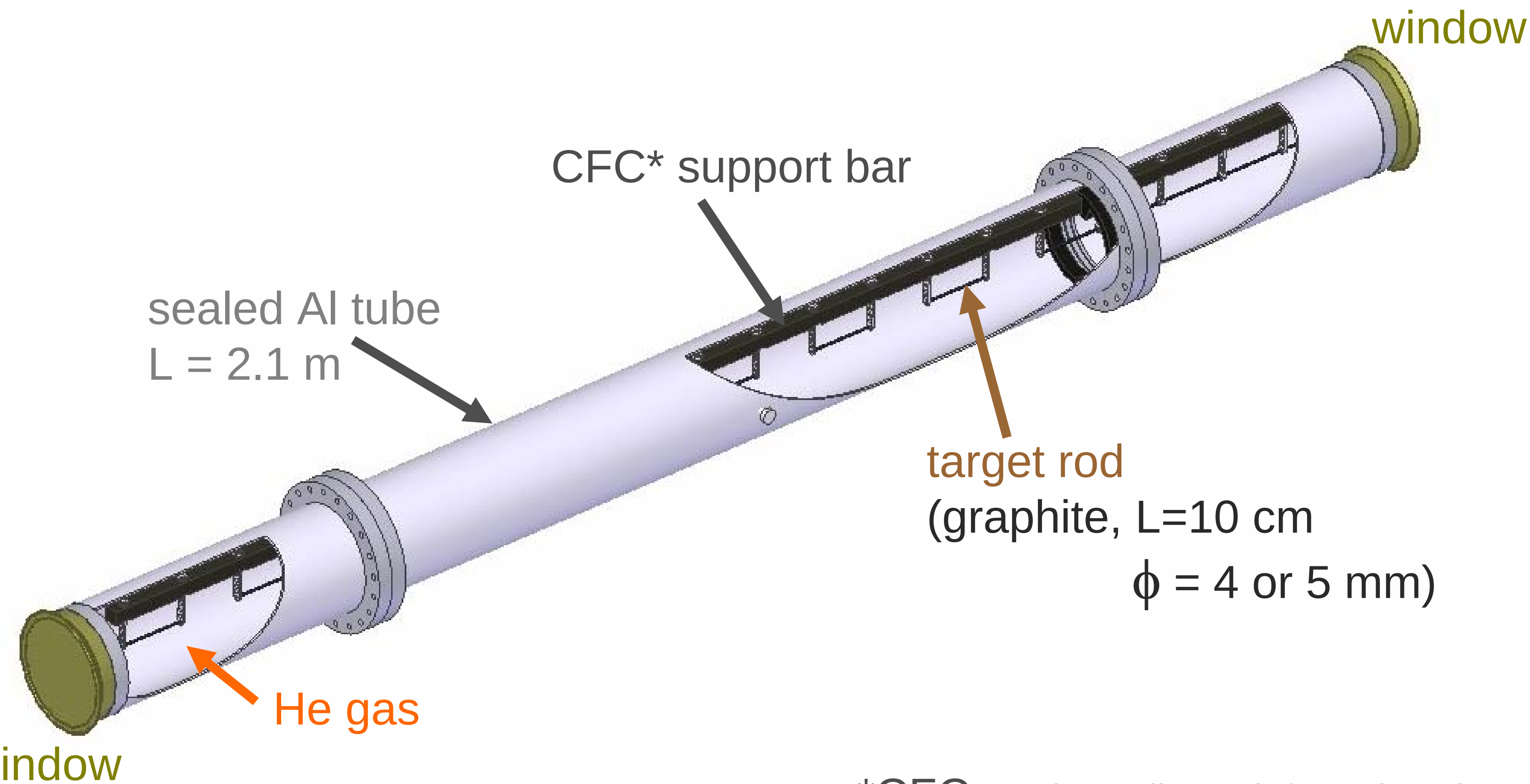


Tantalum rod after one week of ISOLDE running



The radiantly cooled RIST tantalum target

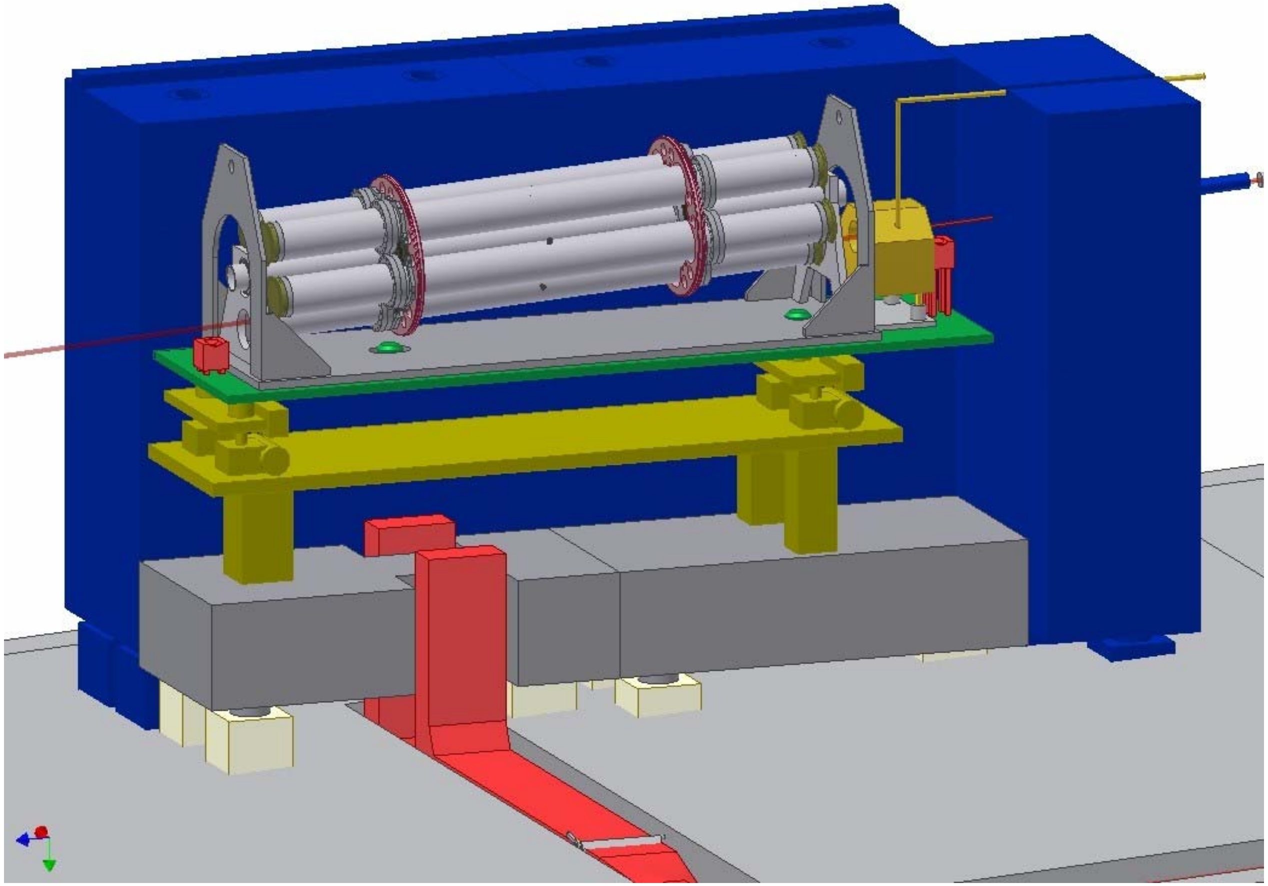
The CNGS Target



*CFC=Carbon-Fiber reinforced Carbon

The CNGS Target Station

CNGS Target Station (4 in-situ spare targets)



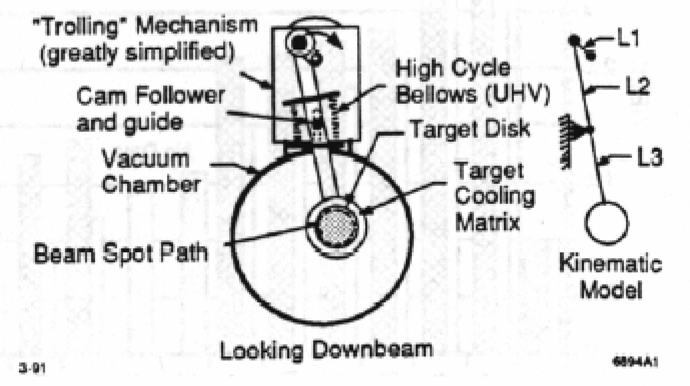
SLAC Positron Target

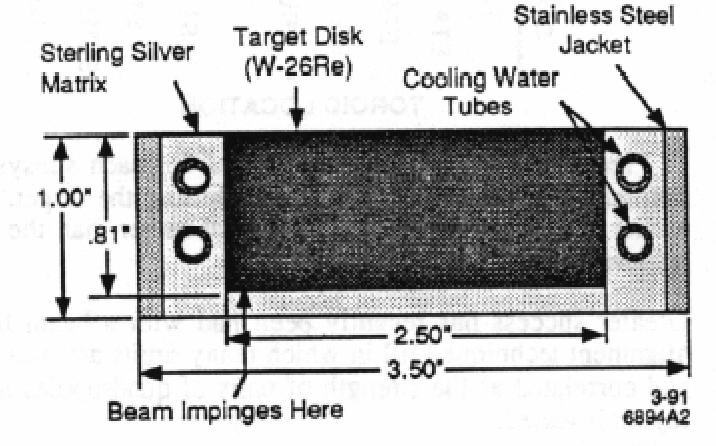
The SLC e^- drive beam 30 GeV 24 kW

Target is W-Re   Water cooled   28 J/g

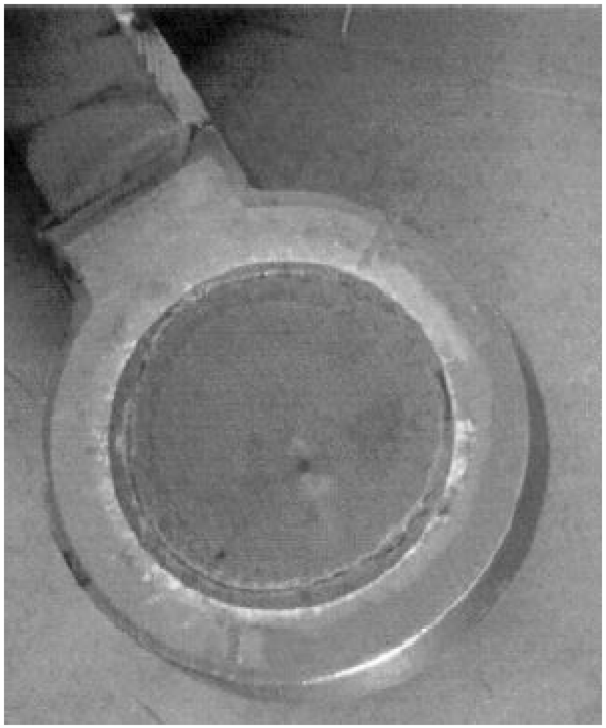
Factor of 2 safety margin—Failed after 5 years running.

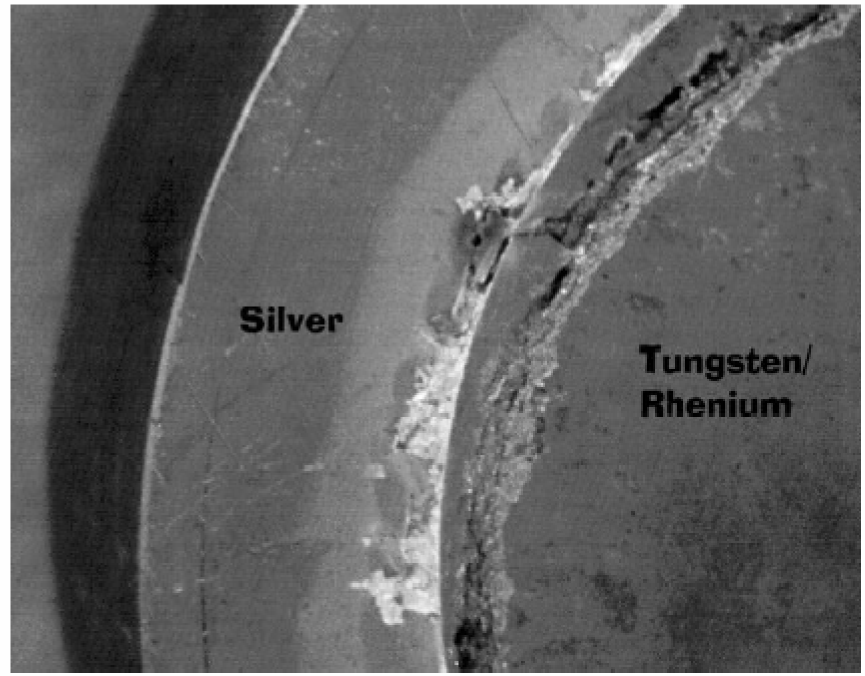
For NLC e^- drive beam 6 GeV 339 kW





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

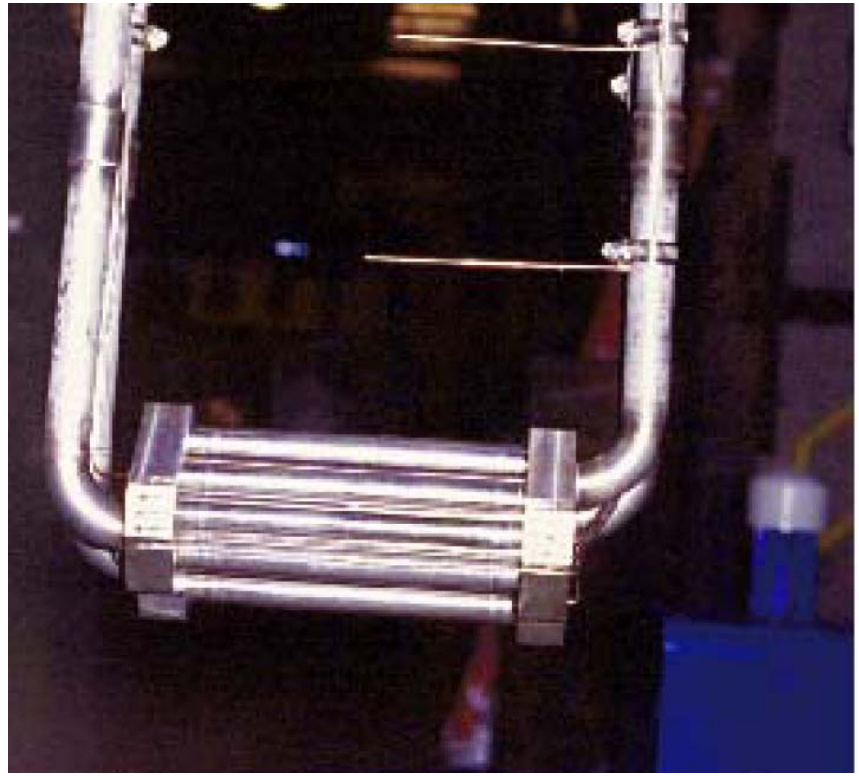
Lance p beam 0.8 GeV 0.8 MW

Stainless Steel Claded Tungsten

Water Cooled 100 W/g

Results: 2 Months successful running

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

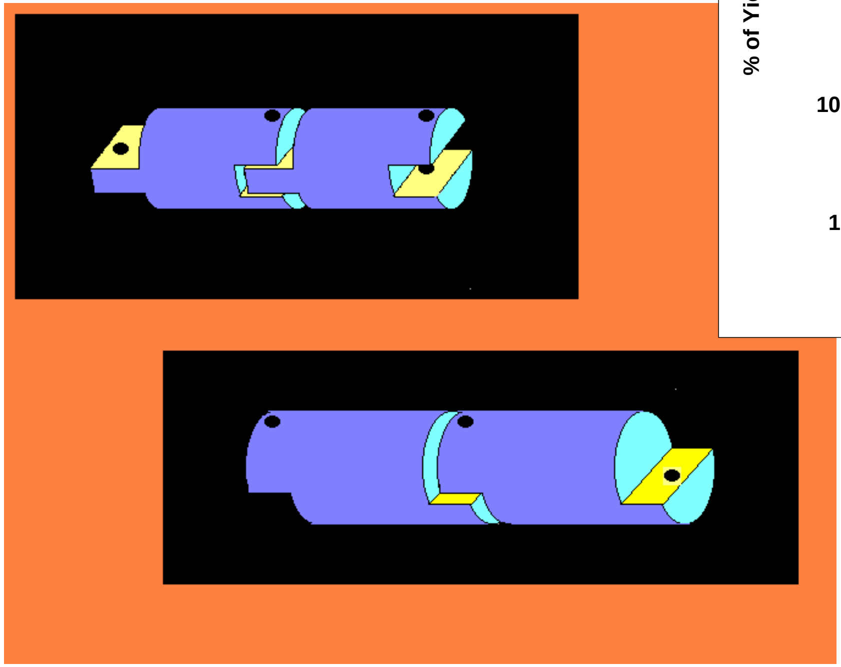


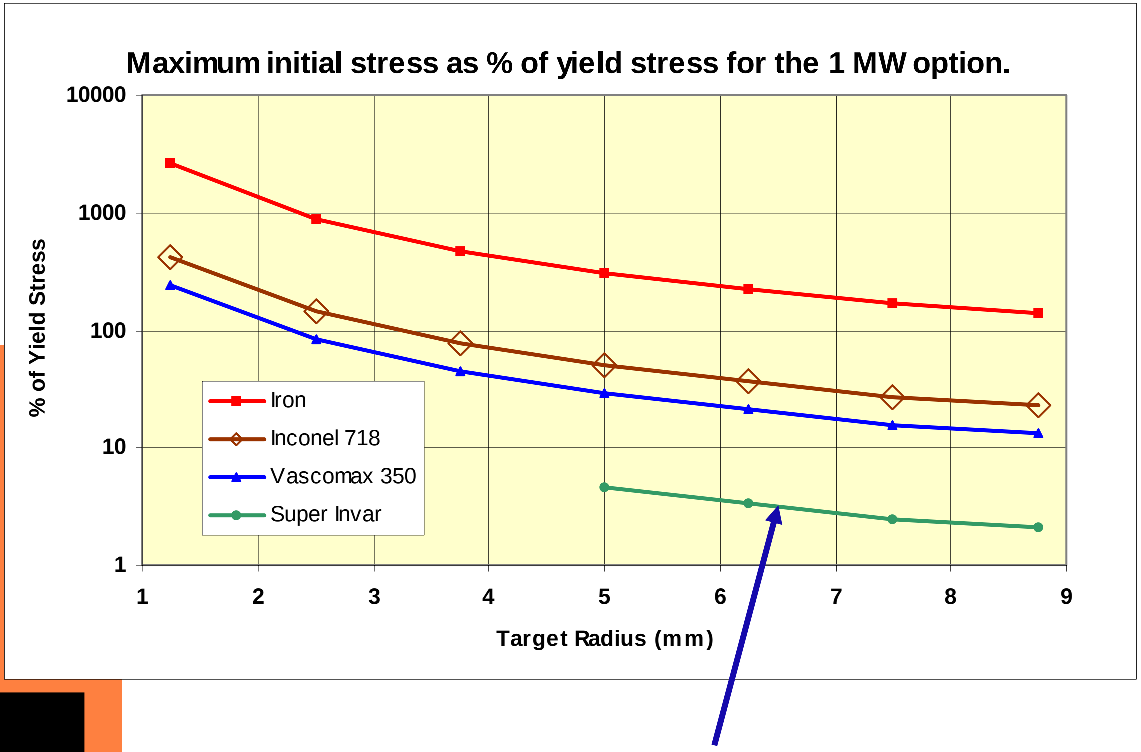
fact Muon Collaboration

Solid Target Studies at BNL

Examine iron based alloys for candidate target material.

Suggest moving chains





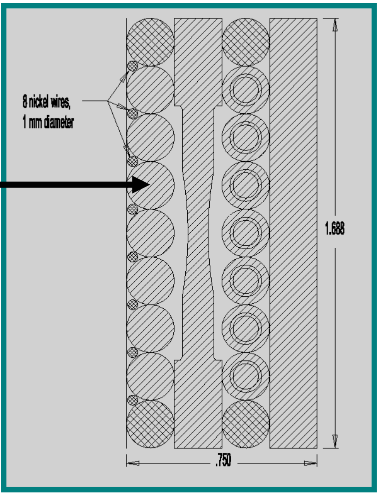
Super Invar looks promising, due to its low coefficient of thermal expansion, BUT

BROOKHAVEN NATIONAL LABORATORY

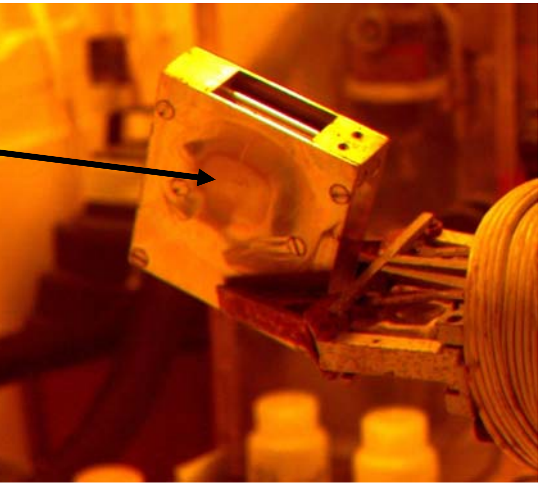
Harold G. Kirk

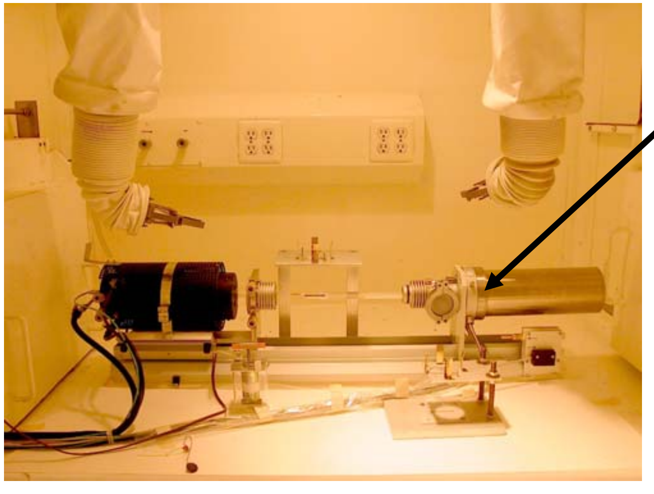
Super-invar Irradiation at BNL

The cylindrical samples of super-invar.



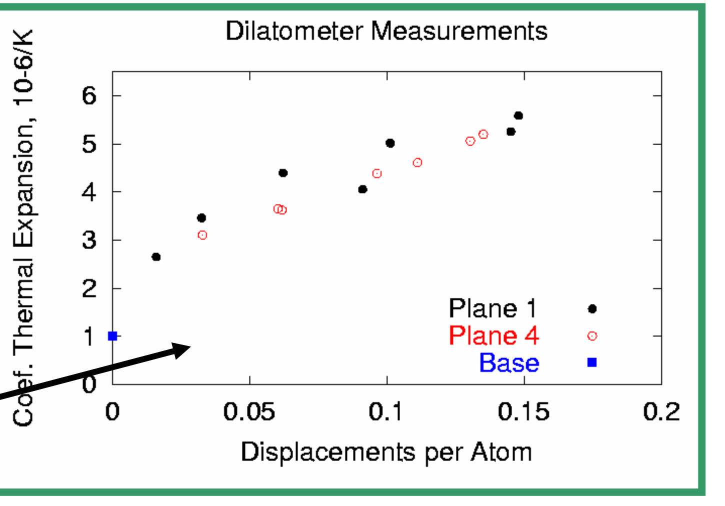
The target basket after irradiation





Dilatometer in Hot cell

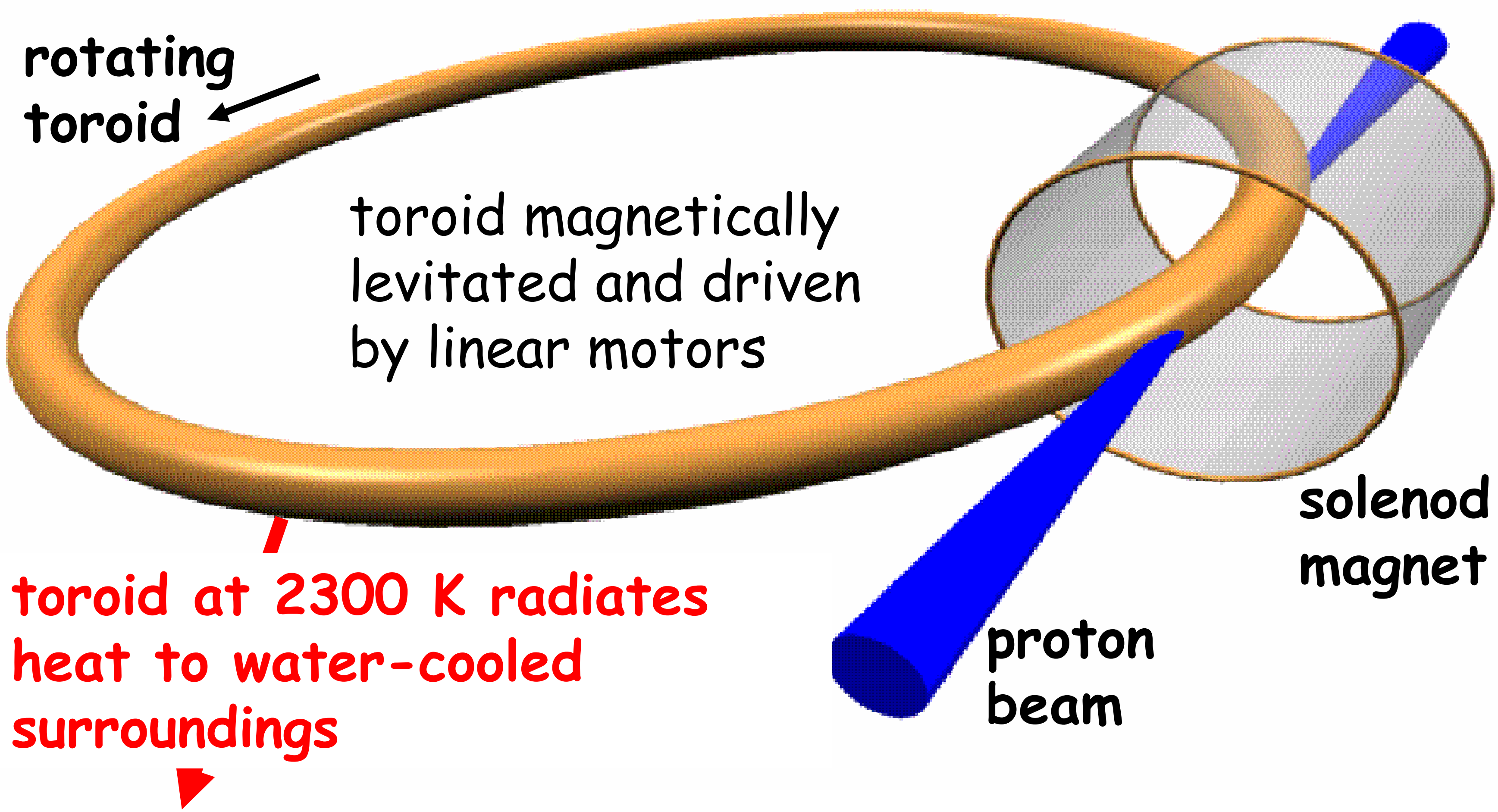
Results of coefficient of thermal expansion measurements



BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

Schematic of a rotating tantalum target

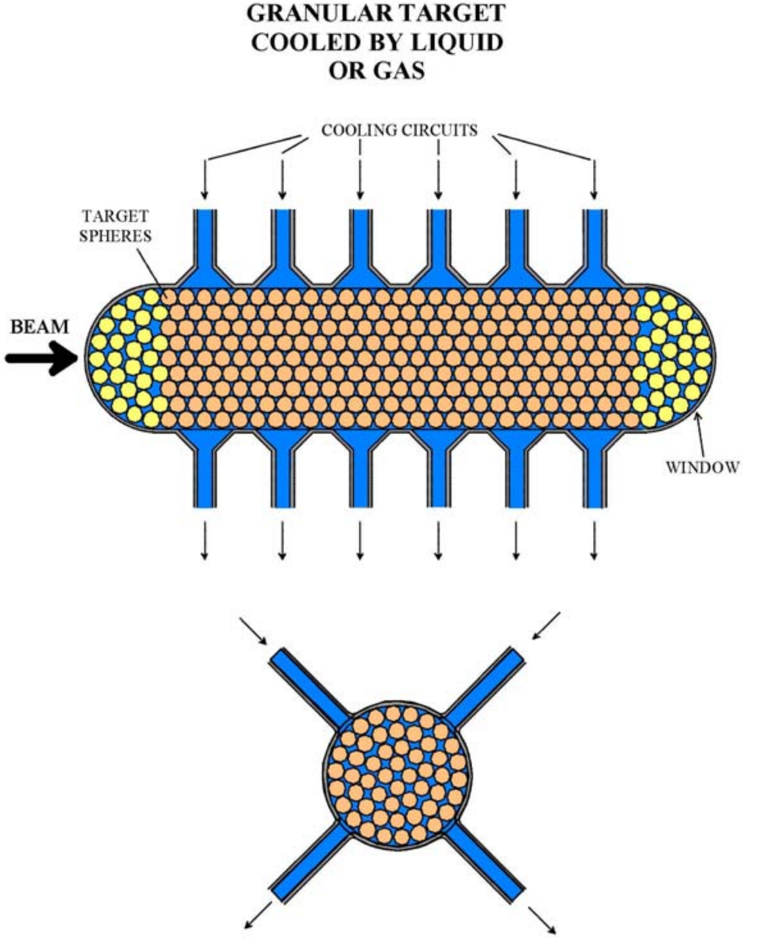


Roger Bennett, RAL

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

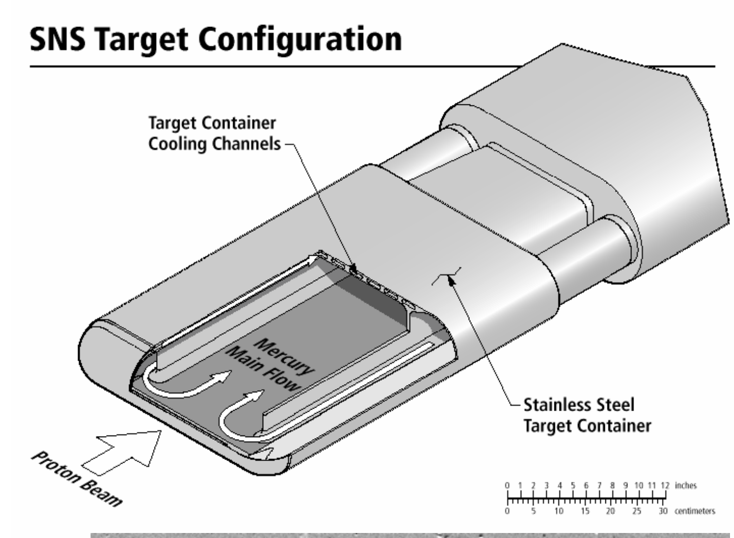
Neutron Sources – SNS and ESS

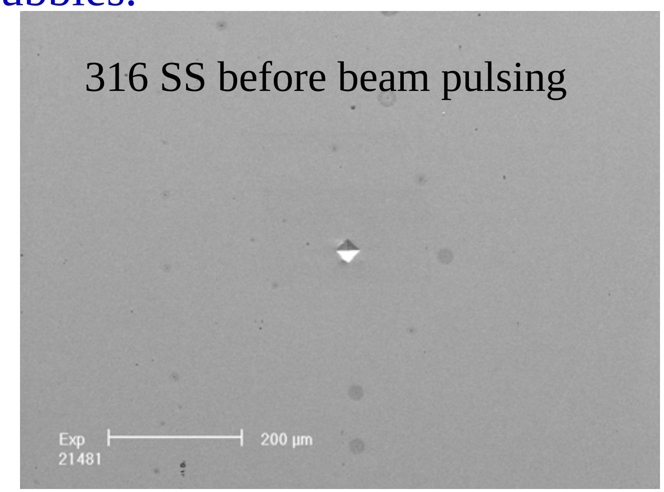
Proton beam 1 GeV and 1 MW

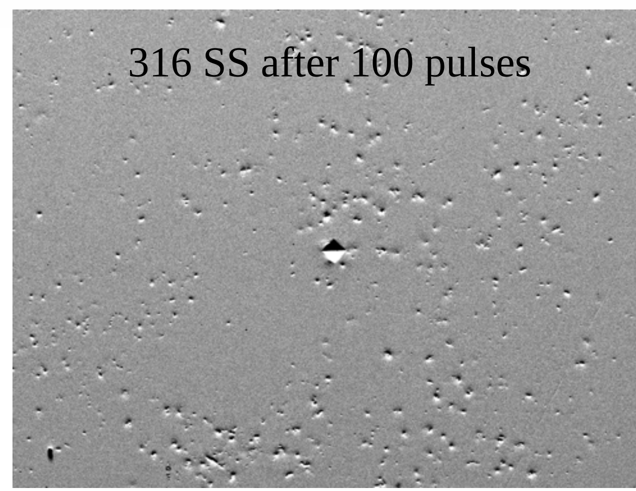
60 Hz operation with large beam spot

Peak energy deposition ~ 1 J/g

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







Harold G. Kirk

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

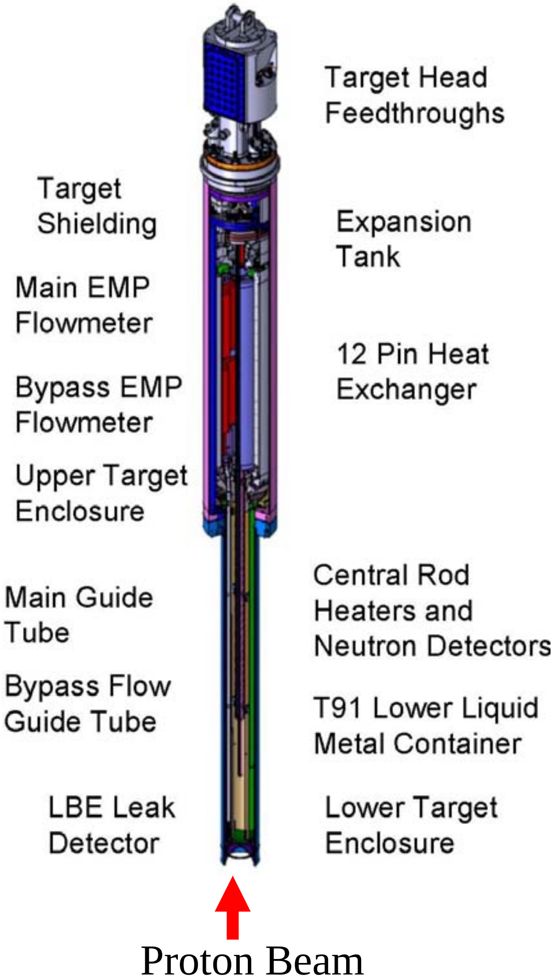
MEGAPIE Project at PSI

0.59 GeV proton beam

1 MW beam power

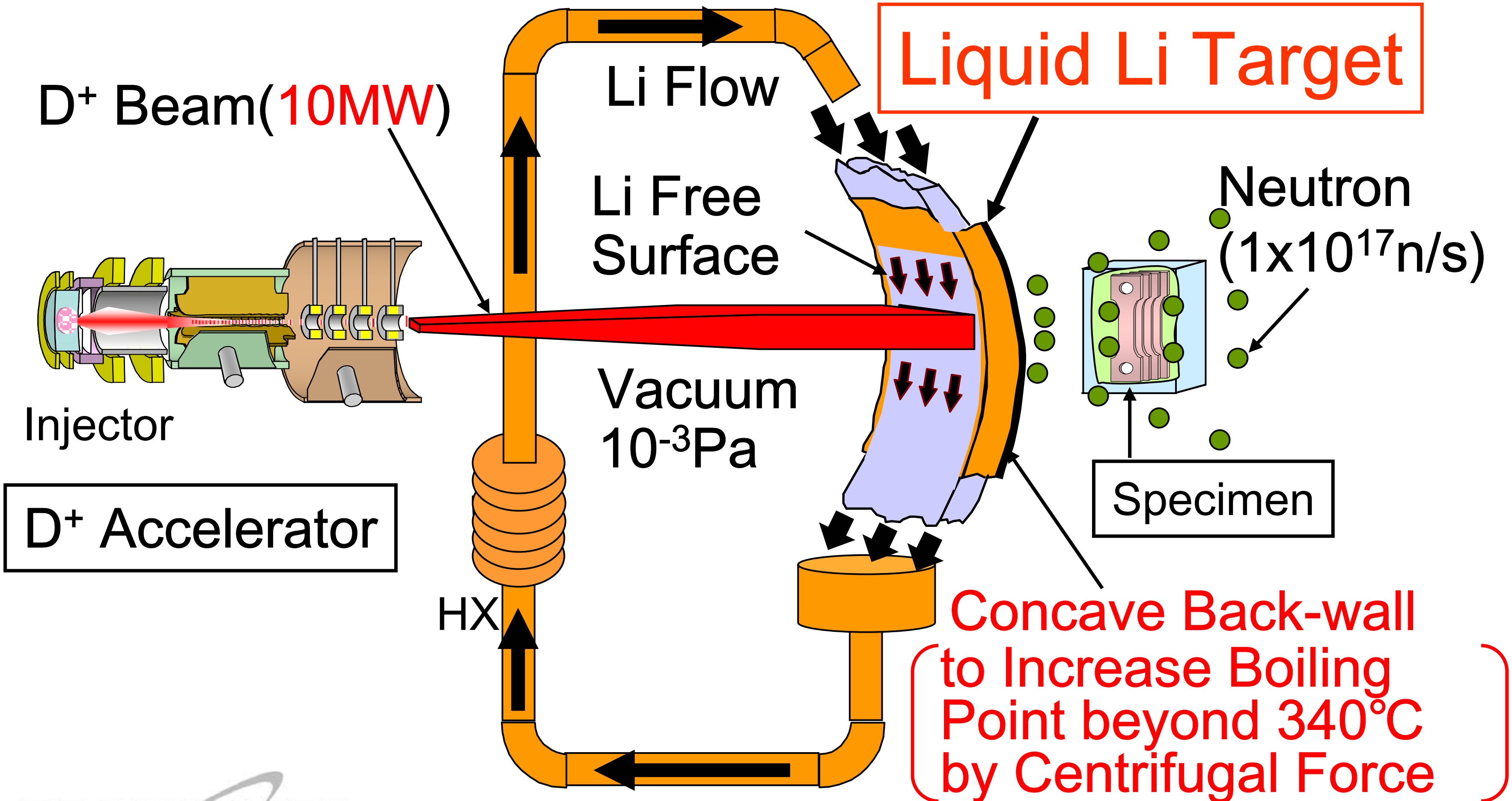
Goals:

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



The IFMIF Liquid Li Target

Fast Neutron Source -- Operations in 2017

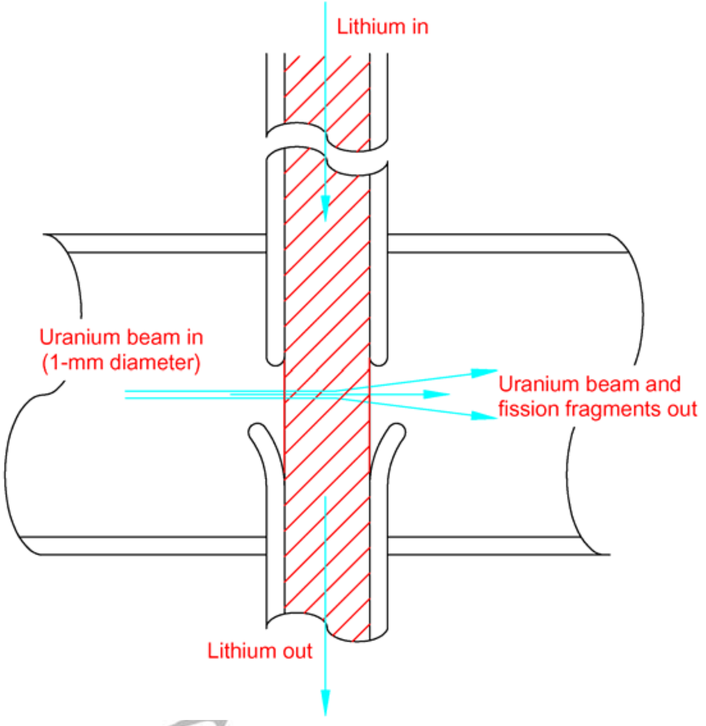


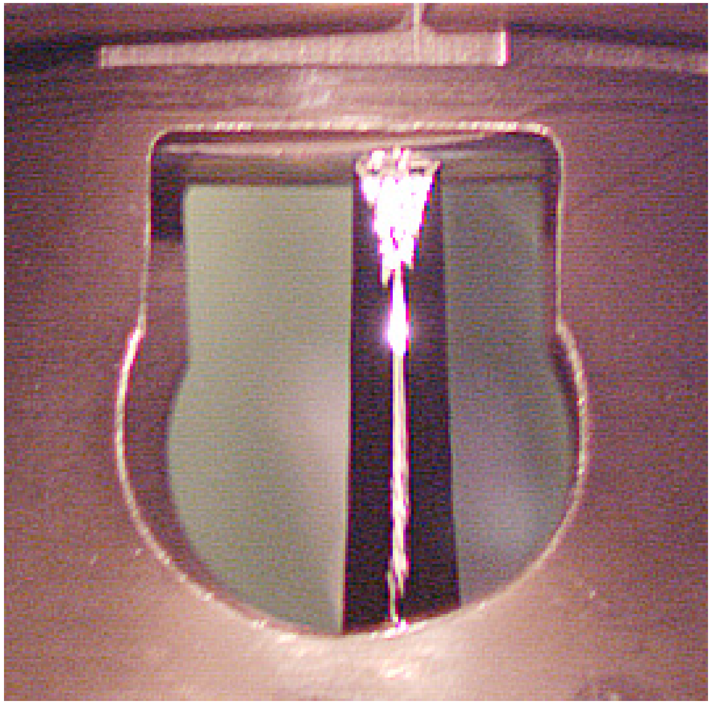
RIA Windowless Liquid Li Target

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 producing heavy ion projectiles. This method also show promise as a thin film stripper.





BROOKHAVEN NATIONAL LABORATORY

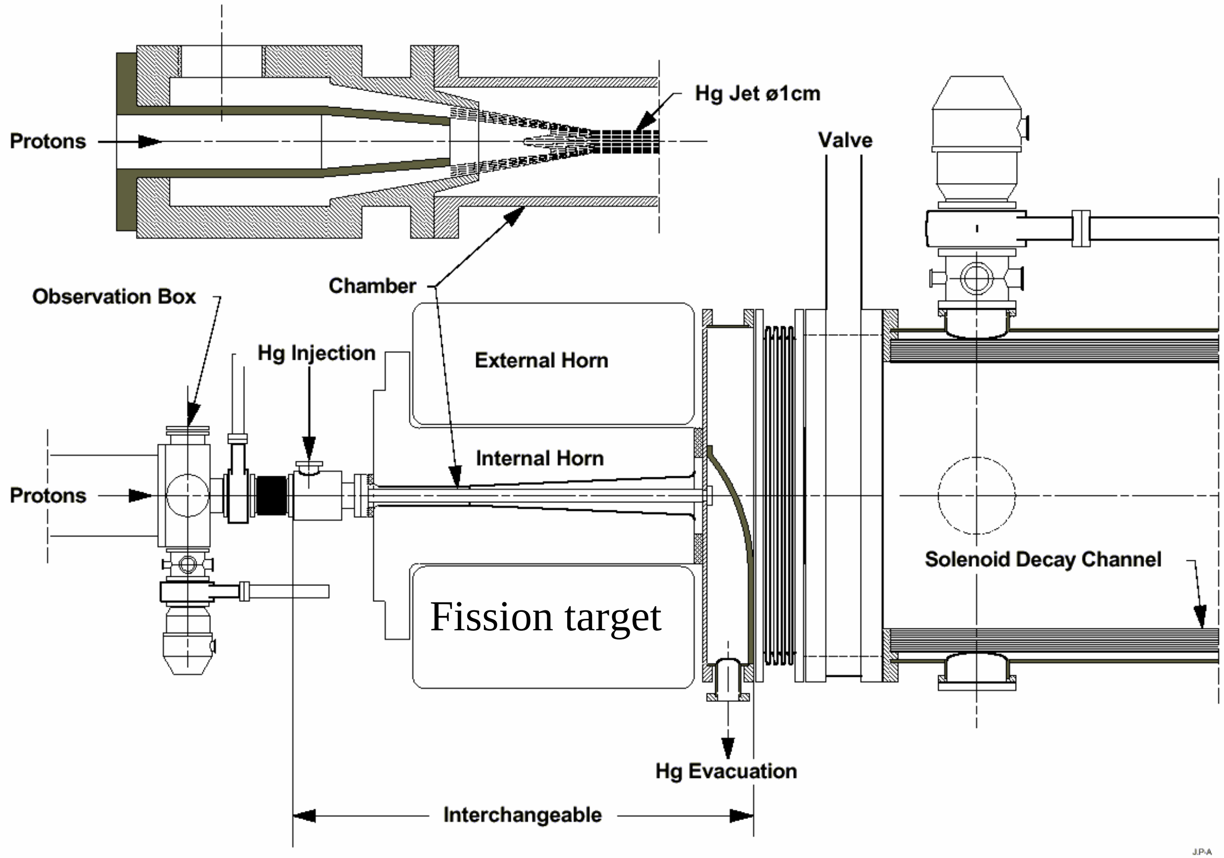
Harold G. Kirk

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.

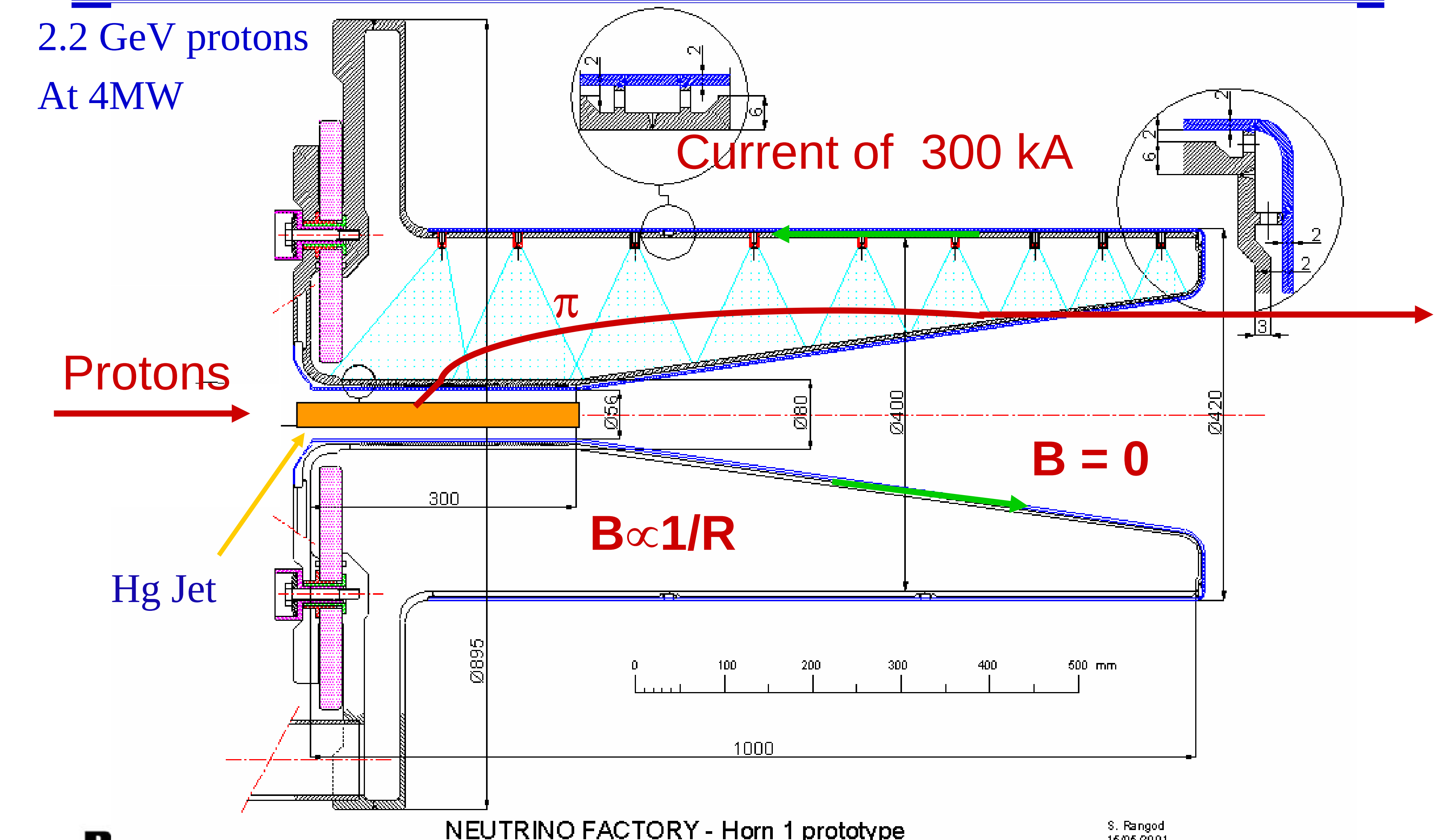
Method also has possible applications as a source for $\beta-\nu$ beams.



The CERN SPL Target Development

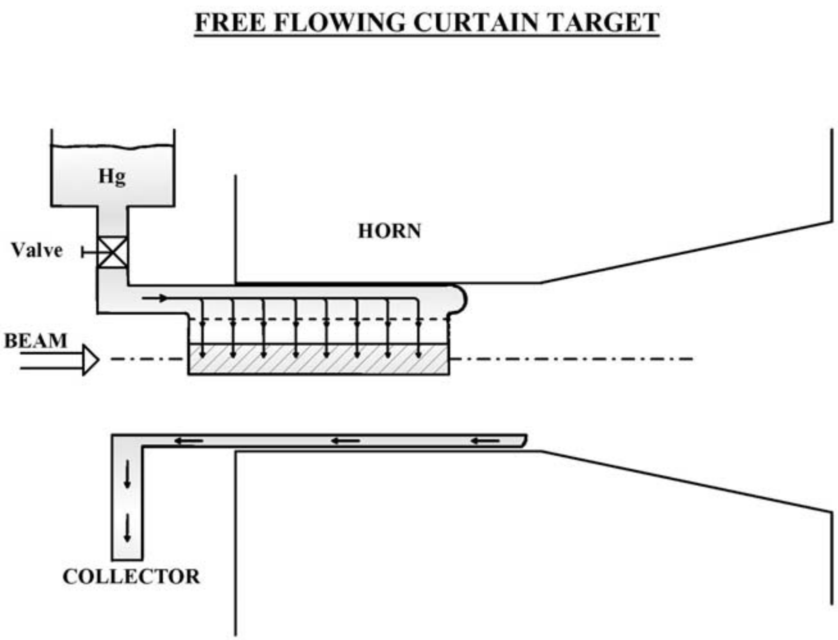
2.2 GeV protons

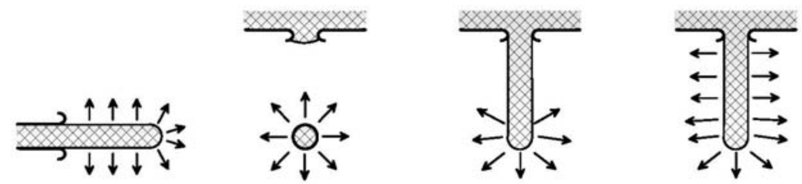
At 4MW



Harold G. Kirk

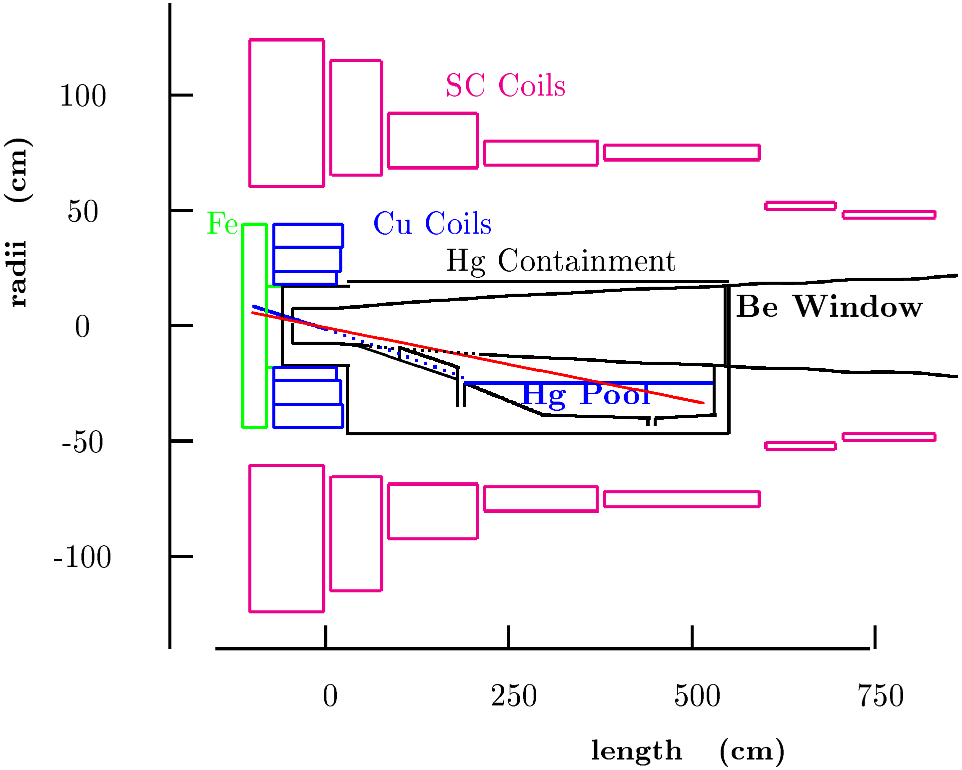
Siever's Liquid Hg Curtain

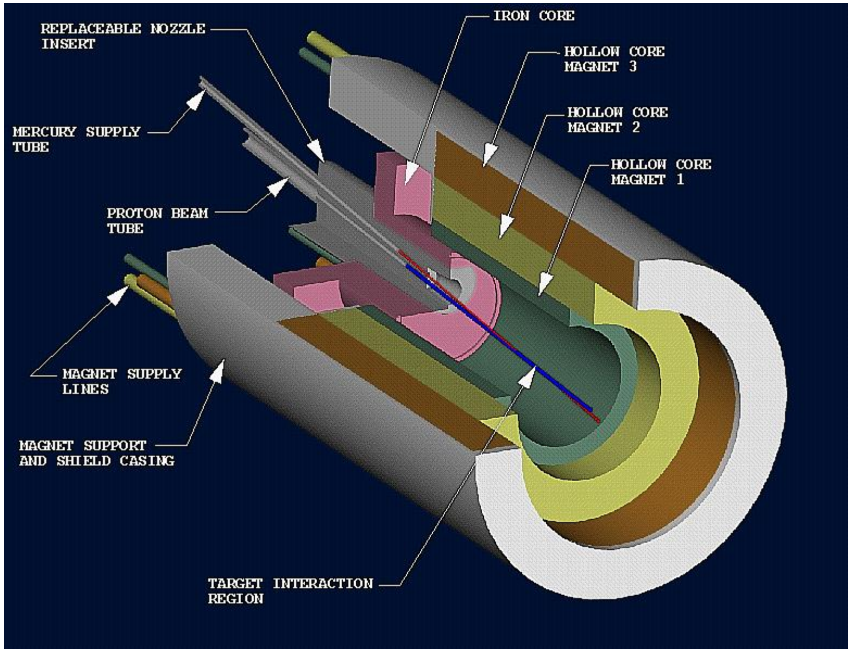




	Free Jet	Pulsed Curtain	Continuous Curtain: Tip explodes	Continuous Curtain: Curtain explodes
Volume Flow (cm^3/s)	2000.	2000.	2000.	5000.
Velocity at nozzle (m/s)	>20.	1.25	0.5	1.25

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

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

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

J. Roger J. Bennett[1], Luca Bruno[2], Chris J. Densham[1], Paul V. Drumm[1],
T. Robert Edgecock[1], Helmut Haseroth[2], Yoshinari Hayato[3], Steven J. Kahn[4],
Jacques Lettry[2], Changguo Lu[5], Hans Ludewig[4], Harold G. Kirk[4],
Kirk T. McDonald[5], Robert B. Palmer[4], Yarema Prykarpatskyy[4],
Nicholas Simos[4], Roman V. Samulyak[4], Peter H. Thieberger[4],
Koji Yoshimura[3]

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

Participating Institutions

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

Harold G. Kirk

Simulation and Theory Summary

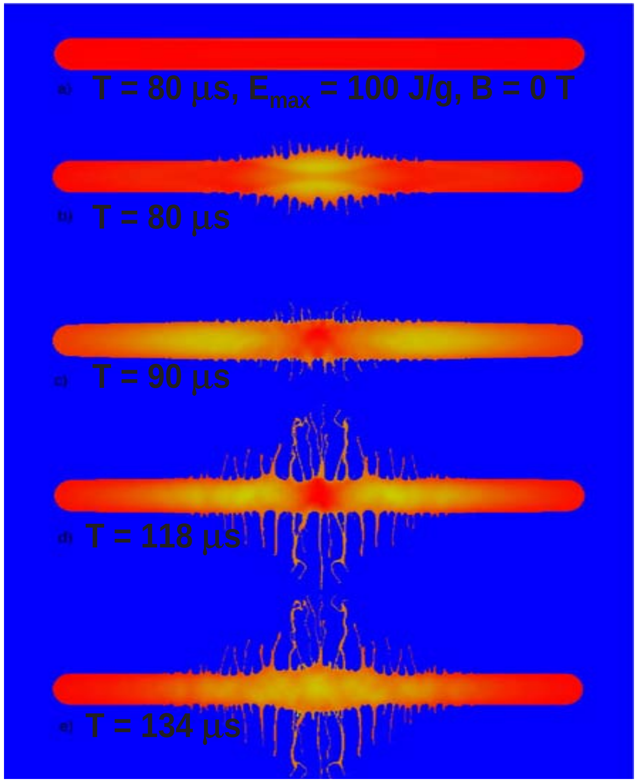
1. **Particle Yields, Energy Deposition and Radiation (N. Mokhov, L. Waters)**
   - Needs and Specs
   - Codes
   - Uncertainties
   - Benchmarking
   - Future Work

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

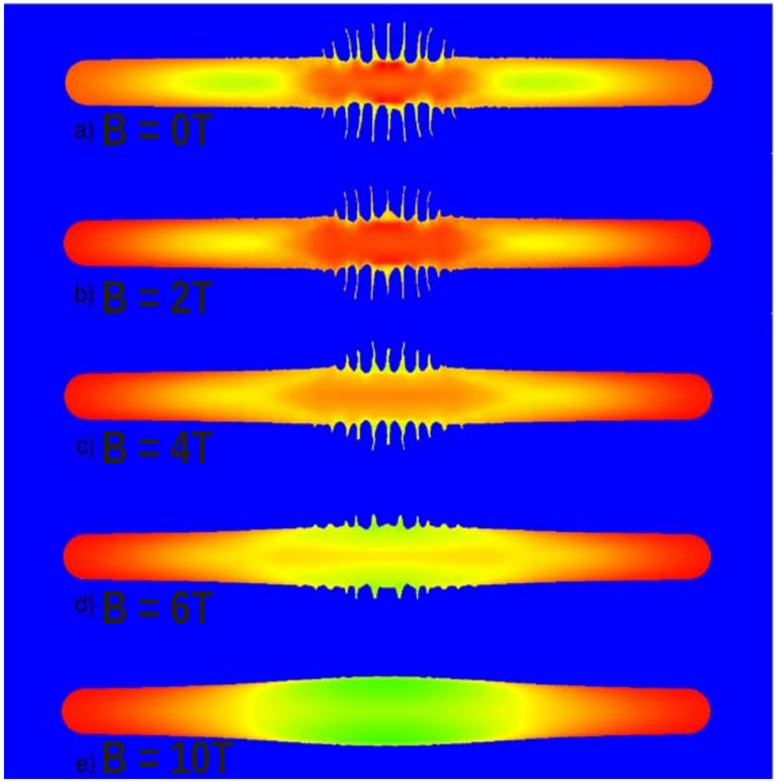
3. **Magnetohydrodynamics in Liquid Targets (R. Samulyak, Y. Prykarpatskyy)**

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

Simulations at BNL (Samulyak)

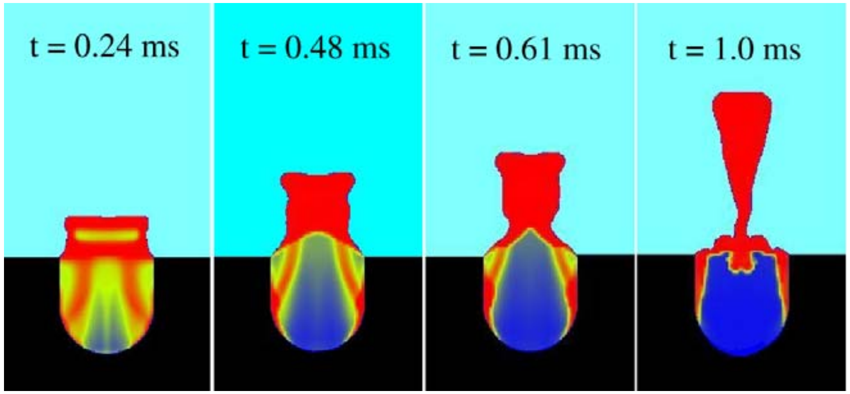


Gaussian energy deposition profile
Peaked at 100 J/g. Times run from
0 to 124 μs.



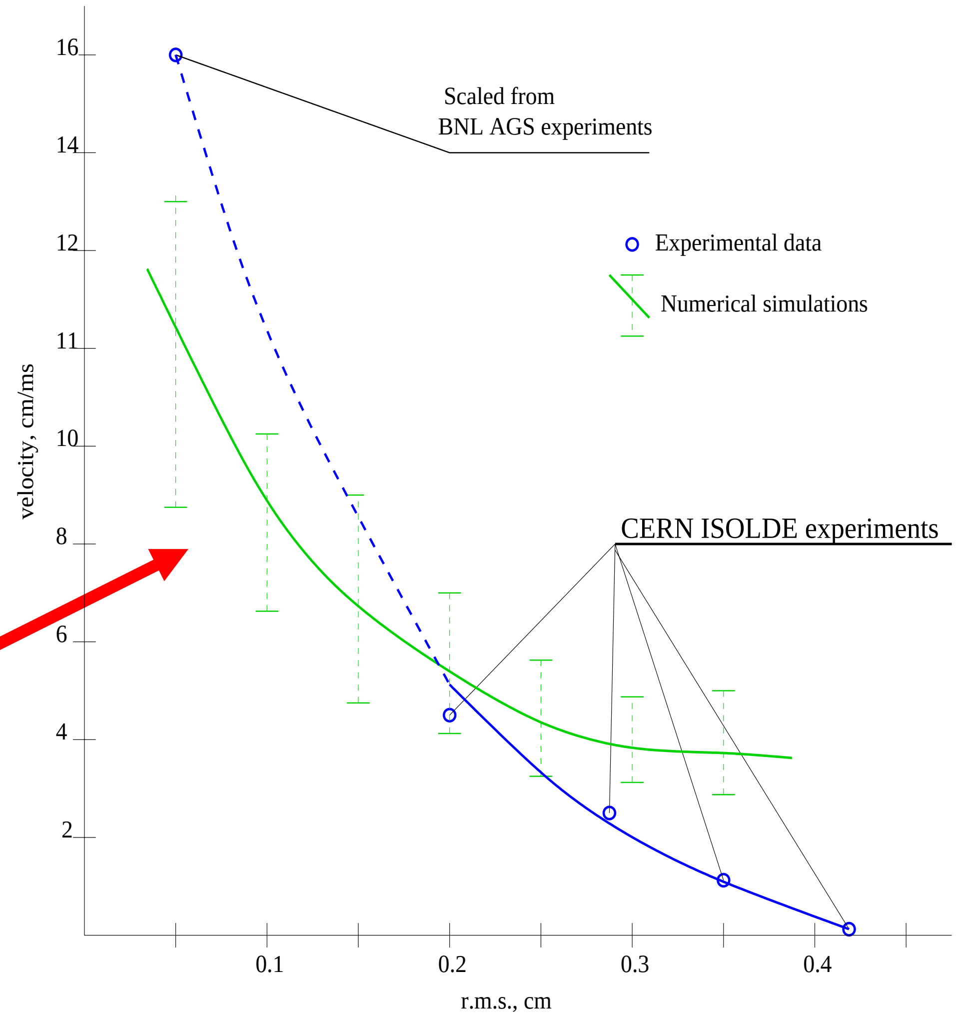
Jet dispersal at t=100 μs with magnetic
Field varying from B=0 to 10T

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.