2nd International High-Power Targetry Workshop

AccApp05
Dedicated High Power Target Test Facilities
Summary

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October 10–14, 2005

High Power Target Test Facilities Session

- The purpose of this session was to review some of the recent work on new high power target facilities and to begin discussions to explore the need and potential uses for a test facility
- Presentations on included:
  - G. Bollen – The Rare Isotope Accelerator Project
  - E. Pitcher – LANSCE Materials Test Station for Fast Neutron Irradiations
  - B. Graves – A Free Jet Hg Target Operating in a High Magnetic Field Intersecting a High Power Proton Beam
  - J. Bennett- Some Problems Encountered with High Power Targets and Special Reference to Neutrino Facilities
  - B. Riemer – Requirements for a High Power Target Test Facility
- A round table discussion followed the presentations

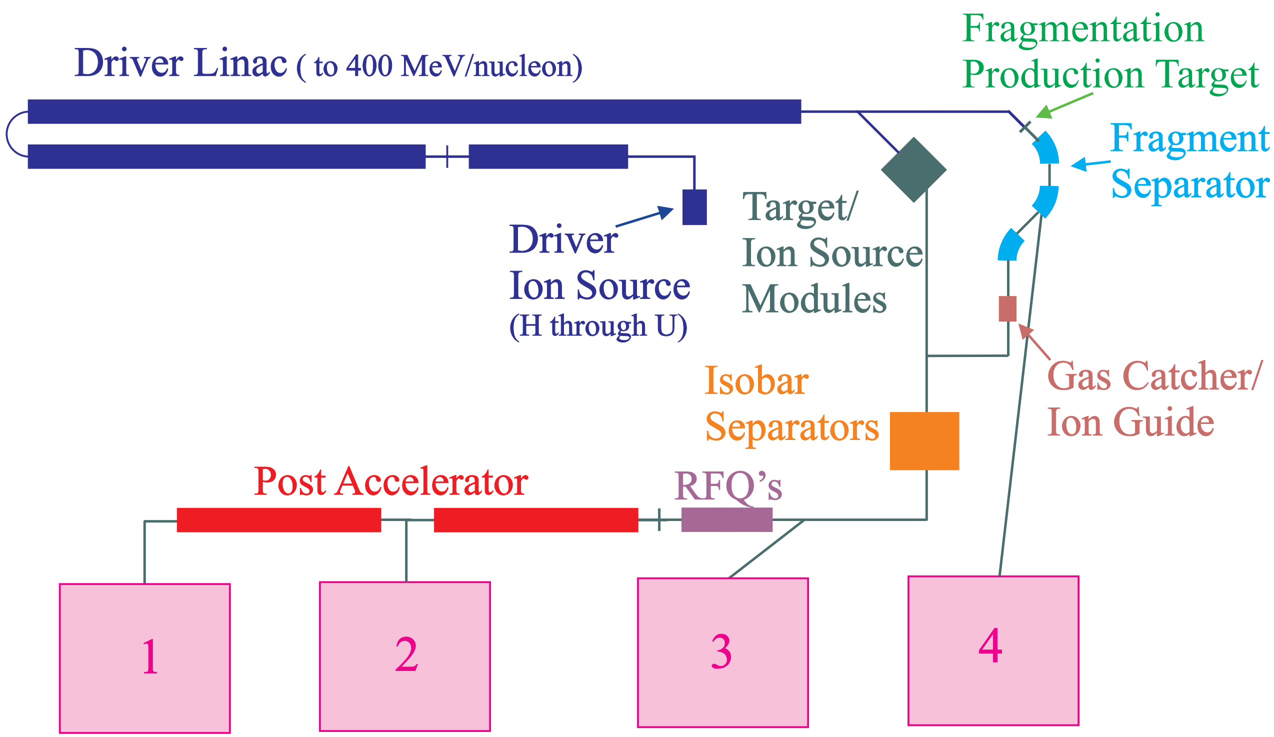
RIA – an intense source of rare isotopes

- **RIA – an overview**
  - RIA-Science
  - Rare Isotope Production
  - RIA Facility
- **RIA target area**
  - Production targets
  - Beam dumps
  - Target area concepts
- **Conclusion**

G. Bollen
National Superconducting Cyclotron Laboratory NSCL
Michigan State University

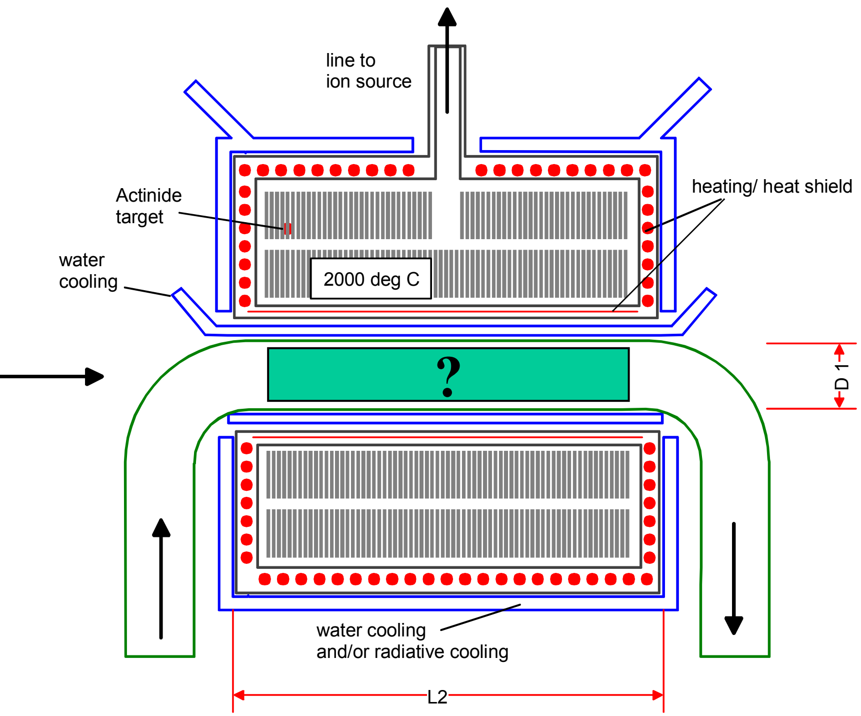
Rare Isotope Accelerator - RIA

- Most intense source of rare isotopes
  - **High power primary beams** protons to U at >100 kW and E > 400 MeV/nucleon.
  - Possibility to **optimize the production method** for a given nuclide.
- Four Experimental Areas (simultaneous users)



Experimental Areas:
1: < 12 MeV/u 2: < 1.5 MeV/u 3: Nonaccelerated 4: In-flight fragments

Two-step fission targets for ≥ 100 kW beam power



Principle of 2-step fission targets:

- Neutron converter for neutron production and dissipation of beam power
- Surrounding blanket of fissionable material for rare isotope production

Original proposal (J. Nolen, ANL):

Li-cooled W converter

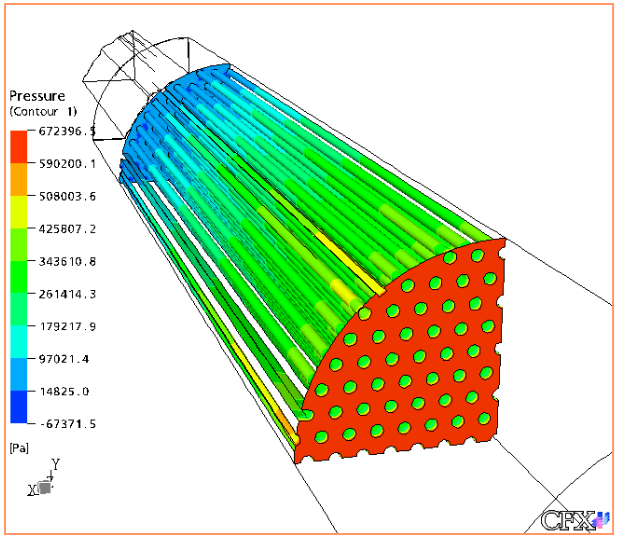
Are there alternatives to Li +W ?

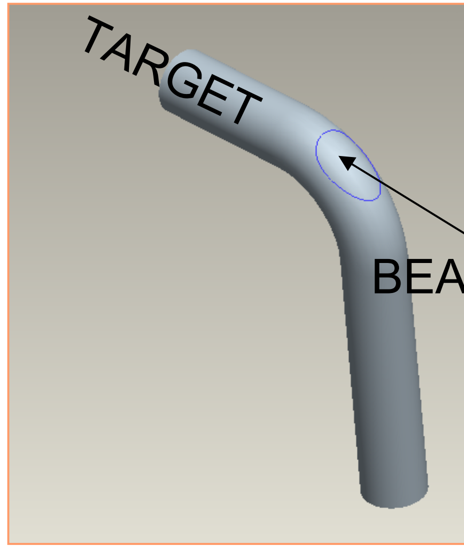
1) **Mercury as target and coolant**
2) **H_2O or D_2O cooled W**

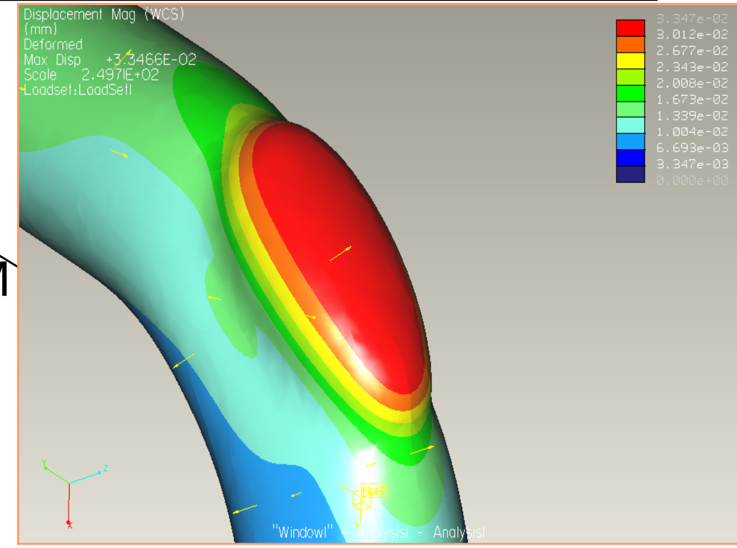
Choice of converter type has impact on design of target area →

- Investigation of neutron/fission yields, beam and decay heating, radiation damage for 400 kW 2-step target
- Conceptual design studies of cooling schemes

Water-cooled tungsten converter target







D. Connor, M. Wendel, A. Carroll/ORNL

Primary target : W (80%) + H_20 or D_2O (20%), 2.5 cm diameter

Temperatures: Tungsten < 225ºC, Water < 140ºC

Water flow of ~ 2 liters/s, Pressure drop ~ 0.7 MPa, Water velocity ~ 18 m/s

Thermal and stress analysis → W converter target can be cooled up to 400 kW
Al and SST for coolant tube – temperatures and stresses not critical

Summary and Conclusions

- RIA would become the most intense and versatile facility for rare isotope research
- R&D focus has shifted towards beam production areas
  - Some target concepts for up to 100 kW beams for ISOL and fragmentation beam production appear realistic
  - R&D towards > 100 kW looks promising
  - Conceptual design of target area has started

A lot of R&D work ahead but no showstoppers in sight

High-power target testing will be an intrinsic component of RIA

Follow-up on RIA developments at **http://www.orau.org/ria/**

LANSCE Materials Test Station for Fast Neutron Irradiations

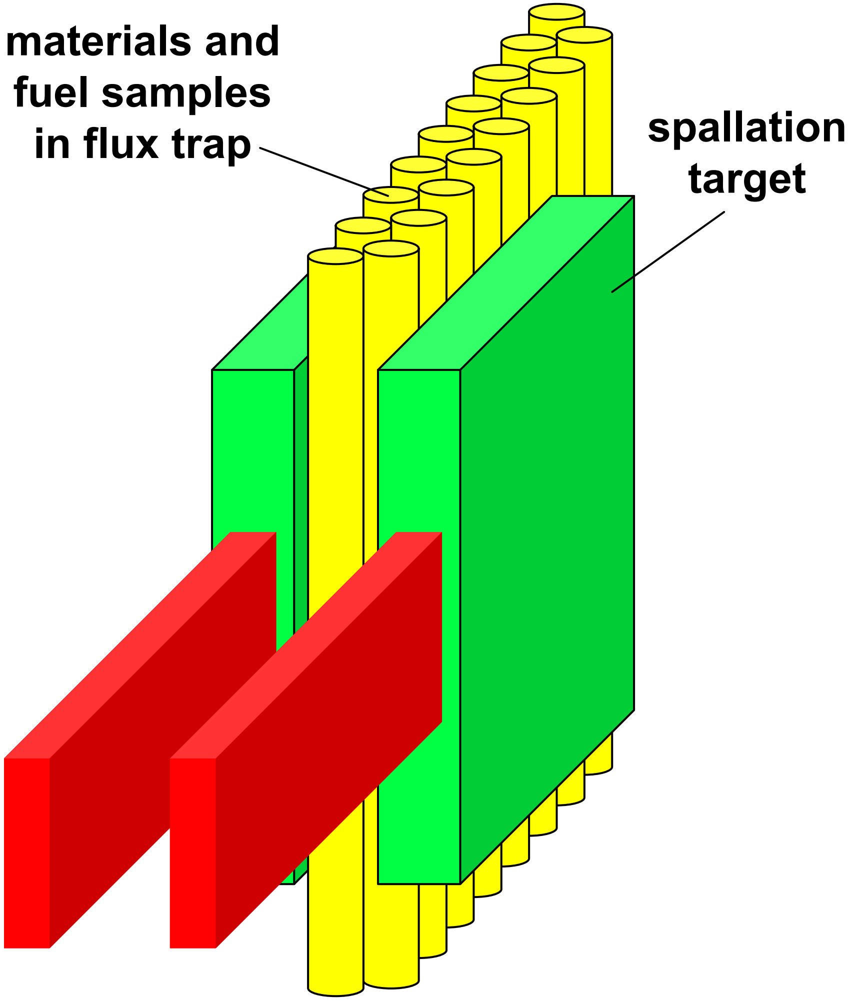
M. Cappiello, R. Wood, E. Pitcher, B. Bergman

Los Alamos National Laboratory

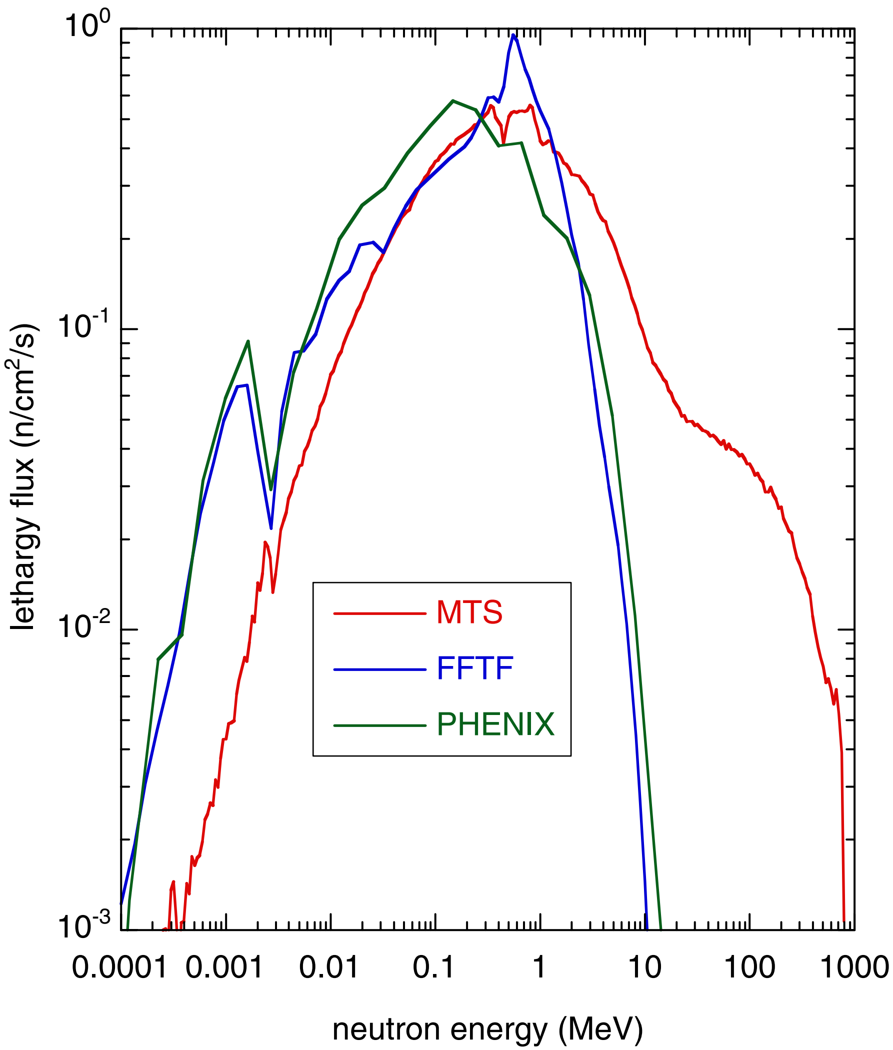
International Conference on Accelerator Applications 2005
Venice, Italy
31 August 2005

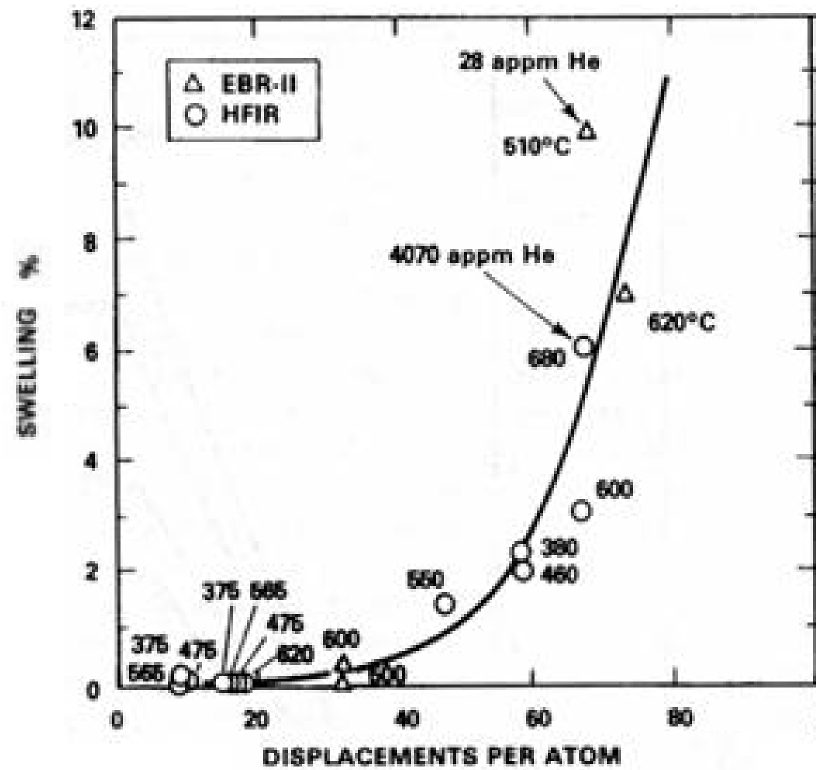
MTS capitalizes on the pulsed nature of the LANSCE beam to illuminate two target halves, thereby creating a "flux trap" in between

- The 1.5-cm-wide by 6-cm-high proton beam spot is directed on to a target half during a 625-μs macropulse
- Between macropulses, the beam is switched to the other target half
- 50 macropulses hit each target half every second



The high-energy tail of the MTS spectrum produces 10x more helium than a FR spectrum

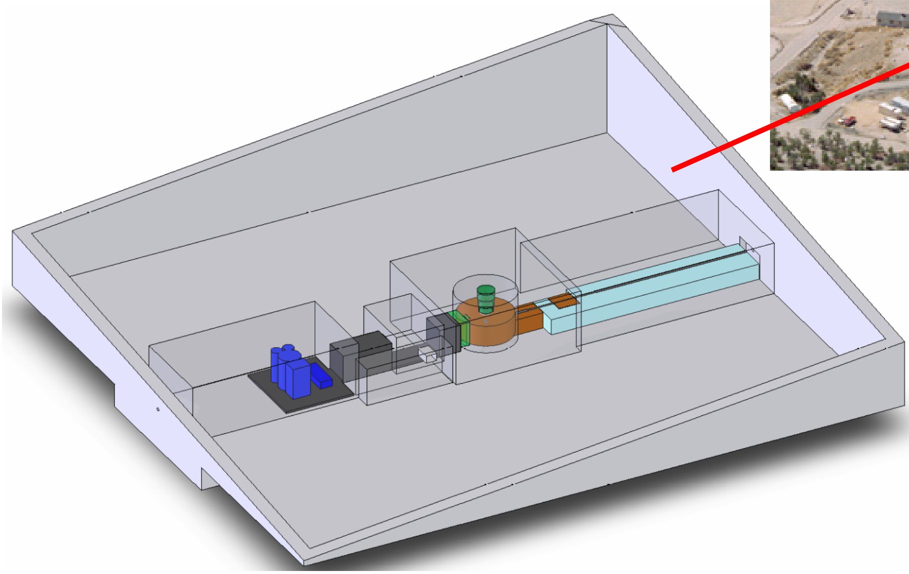




Very little effect of helium is observed on swelling in 316 stainless steel at 500 to 750 ºC (Brager and Garner, JNM, 1983)

MTS will be located in the 3,000 m^2 LANSCE “Area A” experiment hall

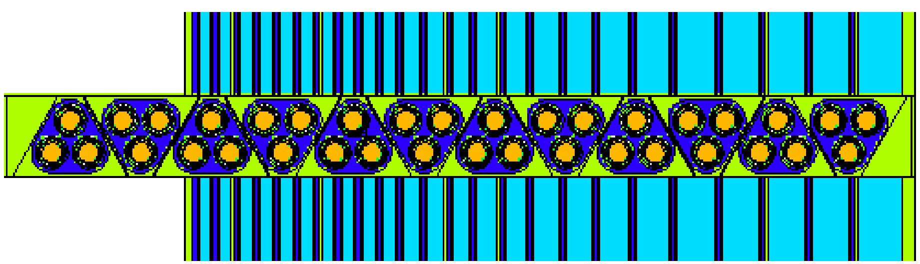
Existing assets include:
800-MeV proton linac
30-T crane
Secondary cooling loops
Back-up generator
Shield blocks
Utilities



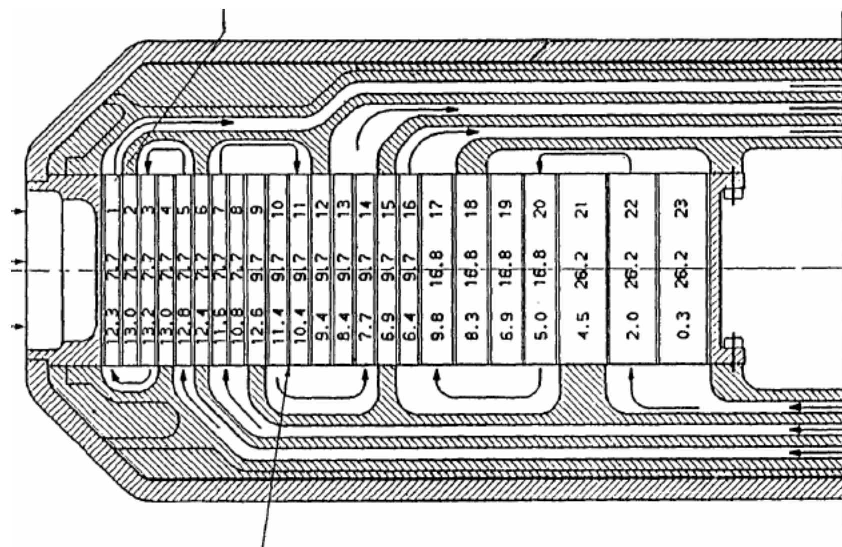
MTS will provide the first fast neutron irradiation capability since the shutdown of the FFTF and EBR-II

The spallation target uses well established technology

	MTS	ISIS	APT
Target material	Ta-clad W	Ta-clad W	SS-clad W
Coolant	D_2O	D_2O	H_2O
Beam energy (MeV)	800	800	800
Beam current (mA)	1	0.2	1



MTS target



ISIS target

Some Problems Encountered with High Power Targets with Special Reference to Neutrino Factories

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Some High Power Accelerator Facilities

Type of Facility	Facility	Beam	Beam Power (mean, approximate)
Spallation Neutron Source	PSI SNS ESS	p, cw p, pulsed p, pulsed	1.1 MW 1-2 MW 5 MW
Neutrino Factory (1-2 MW of circulating muons)	J-PARC SPL USA, EU	p, pulsed p, pulsed p, pulsed	~1 MW 4 MW 4 MW
Transmutation of Nuclear Waste	USA	p, cw/pulsed	50 MW
Tritium Production	USA	p, cw/pulsed	200 MW
Radioactive Beams	RIA, EURISOL	proton, (heavy ions)	5 MW
Neutron Irradiation	IFMIF	deuterons, cw	5 MW
High Energy Physics	SPS (400 GeV, CNGS) SLAC ILC	p, pulse e, pulse e, pulse	170 kW 5 kW

Colour Code: machines in operation   machines being built or proposed

Problem areas:

- **Accelerator:**

The only high power (~1 MW) accelerators are LANL (linac) and PSI (cw cyclotron).

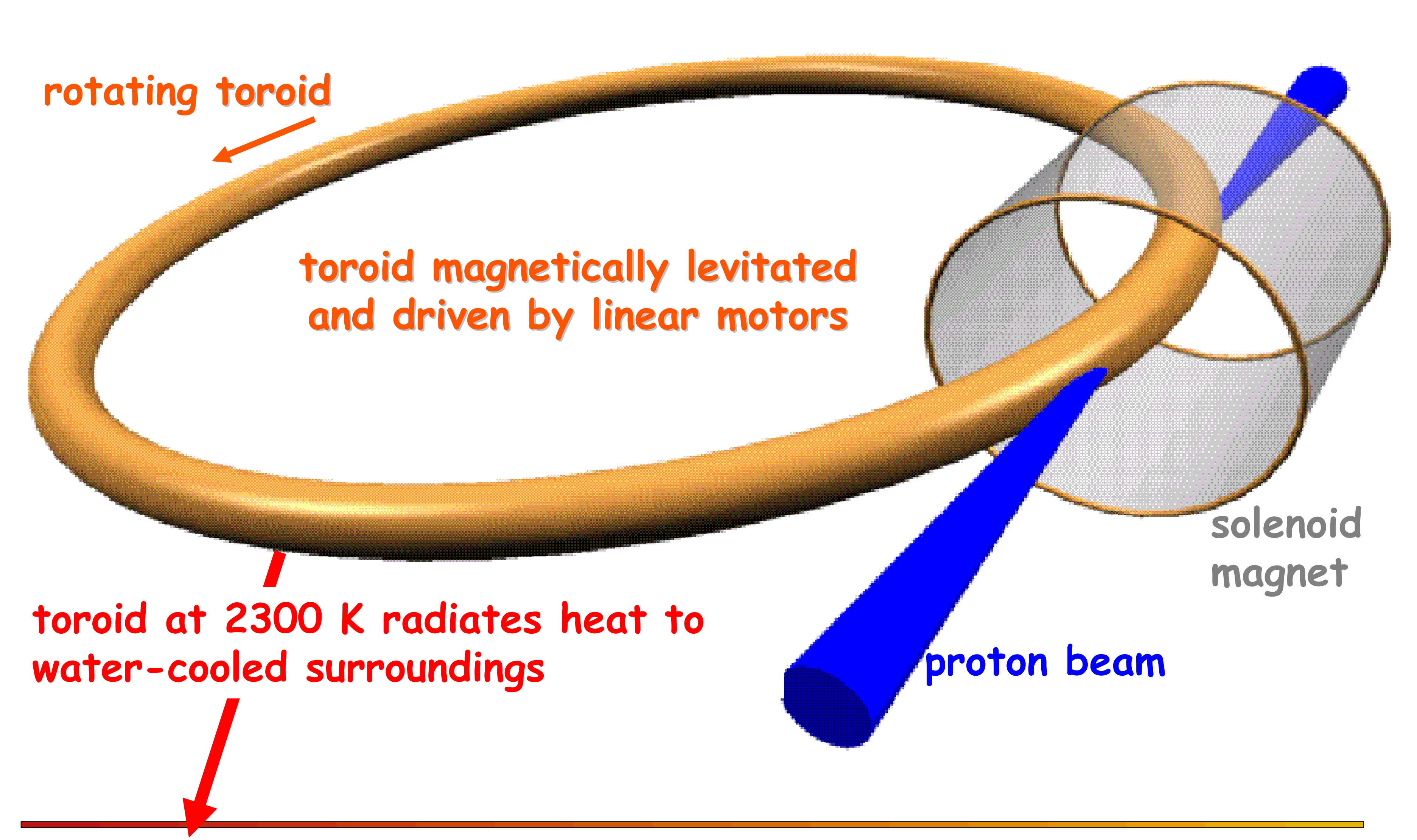
Short pulse machines - synchrotrons and accumulator rings - may give problems at high charge density - ep instability.

- **Target:**

Heat Dissipation Thermal Shock (pulsed beams) Radiation Damage	} DEPENDENT ON ENERGY DENSITY

If the beam is spread over a large volume the temperature rise is correspondingly small; it is easier to remove the heat and the thermal shock and radiation damage is less.

The Radiation Cooled Rotating Toroid
RAL, UK



Vital to test the target in the beam to assess radiation damage, shock - and possibly the cooling.

Hence, need a

Test Facility

Consisting of

✓Accelerator (cost of order £1000 M)

✓Target Station(s); **with hot cells, analysis equipment, specialist staff.** (cost of order £100 M)

Conclusions

- ✓ NEED a Test Facility – long term, in particular for solid targets with pulse beams
- ✓ Very Expensive
- ✓ Unlikely to be funded (my view)
- ✓ Each facility will have to do its own tests.

A Free Jet Hg Target Operating in a High Magnetic Field Intersecting a High Power Proton Beam

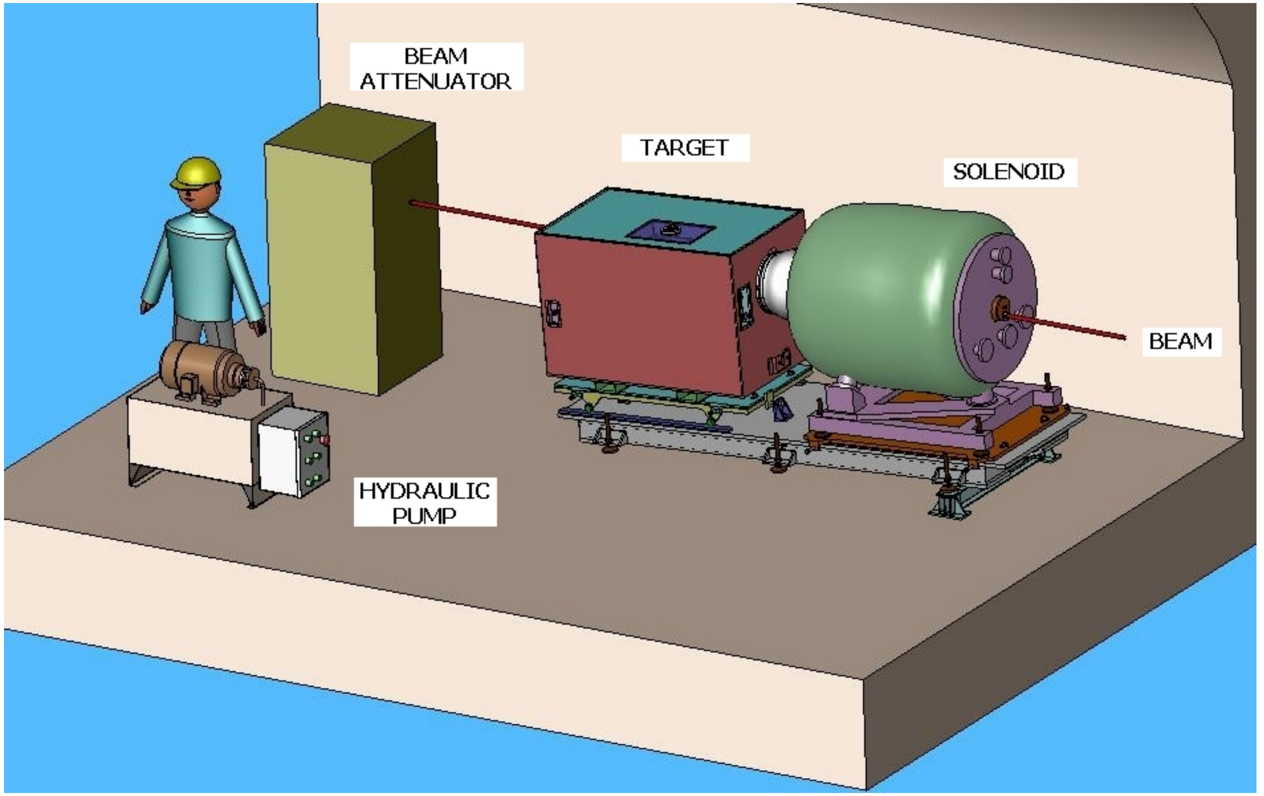
Van Graves, ORNL

P. Spampinato,T. Gabriel, *ORNL*
H. Kirk, N. Simos, T. Tsang, *BNL*
K. McDonald, *Princeton*
P. Titus, *MIT*
A. Fabich, H. Haseroth, J. Lettry, *CERN*

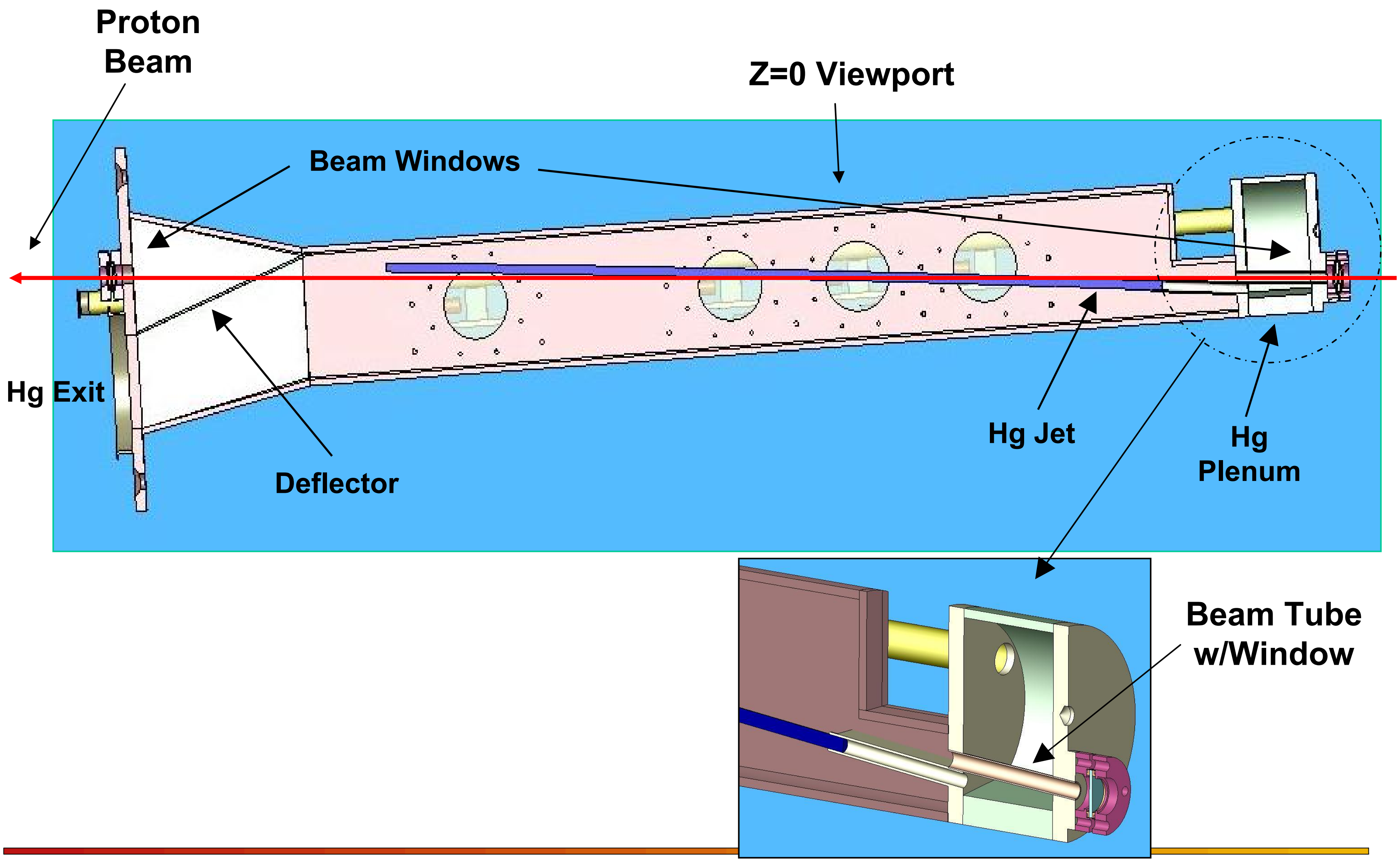
International Conference on Accelerator Applications 2005
Venice, Italy
August 29 – Sept 1, 2005

Experiment Layout

- Hg target is a self-contained module inserted into the magnet bore
- Two containment barriers between the Hg and the tunnel environment



Primary Containment Xsec



Requirements for a High Power Target Test Facility

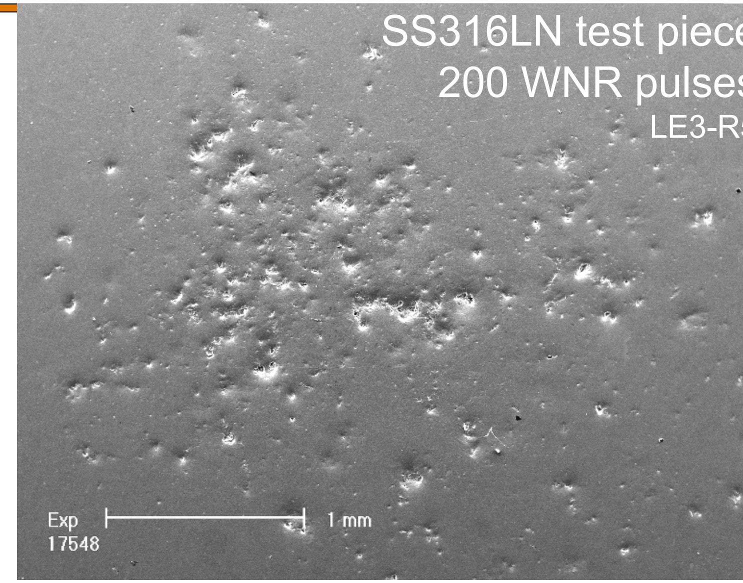
Bernie Riemer
T. A Gabriel, J. R. Haines, T. J. McManamy

August 29 - September 1, 2005
Venice, Italy

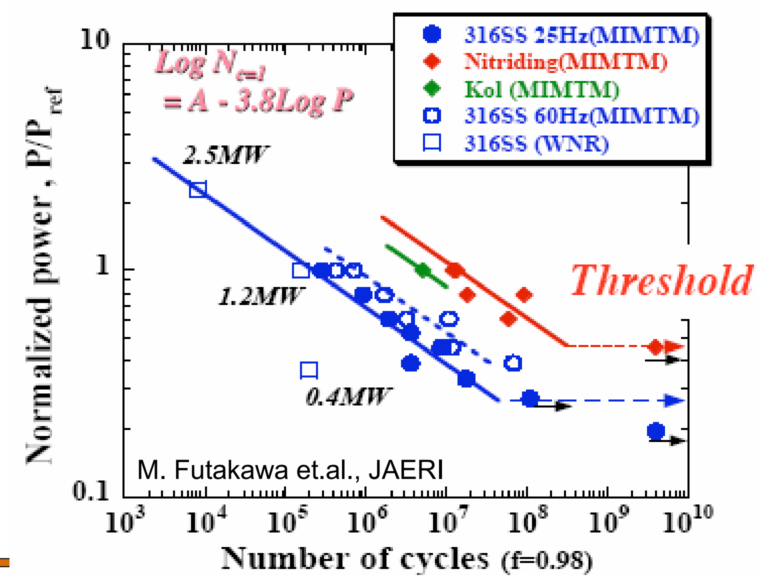
Why talk about a High Power Target Test Facility?

- The SNS foresees the need for a test facility to develop technology that increases the neutron brightness *and* lifetime of its short pulse liquid metal spallation target.
  - Users of neutron sources are expected to demand brighter source performance.
  - Brightness (driven by beam power) and lifetime are strongly coupled.
- What other research areas might also be interested in such a facility?
  - Long pulse or solid spallation targets
  - Neutrino factory targets
  - Rare isotope production targets
  - Accelerator transmutation of waste
  - Material irradiation
  - Advanced moderator material radiation effects
  - Semiconductor neutron radiation effects
- Are there sufficiently common requirements for multi-purpose test facility?

What will limit the power capacity and lifetime of short pulse liquid metal spallation targets?



- Cavitation Damage Erosion (CDE) has been observed in tests of mercury target hit with prototypically intense beam pulses.



- Considerable research has been done including both in-beam and off-line testing to improve understanding and explore directions for solving the problem.

Current knowledge and strategy

- CDE *rate* is strongly sensitive to beam power; *perhaps* $\propto P^4$.
- Pulse frequency effect on CDE has been demonstrated in MIMTM but remains unknown for in-beam conditions.
- Alternate materials and surface hardening treatments can provide only modest potential for extending target life.

- Required improvements in target life and power capacity must come by mitigation of the damage mechanism, either by:
  - Reducing pressure wave magnitude at generation, e.g. through gas bubble injection.
  - Isolating the vessel wall from damaging bubble collapse by creating a layer of gas between it and the mercury.

- New bubble generation and gas wall technologies will need:
  - Off-line R&D for fundamental development.
  - Testing under more prototypic flow, beam and target geometry conditions than currently is possible.

Discussion topics

- Where can commonality be found between various research areas interests in terms of:
  - Required beam parameters?
  - Test cell size and required utilities?
  - Shielding?
  - Remote handling requirements?
  - PIE infrastructure?
- What are the possibilities for locating a facility?
  - Addition or modification to existing facility.
  - Green field construction.
- Does phased construction make sense?
- How to fund such a facility, considering:
  - Substantial construction cost
  - Substantial operating cost
- Cooperation and commitment from multiple agencies and / or multiple governments.

Summary

- There currently exists no test facility with sufficient beam performance and infrastructure necessary for advancement of short pulse liquid metal spallation targets.
- Such a facility could potentially serve other research areas that utilize high power targets.
- Although there are challenges, it is hoped discussion and consensus can lead to a dedicated high power test facility that will push target development into the multi-megawatt range.

Session Conclusion

- Round table discussions were held after the presentations
- Some preliminary observations included:
  - No single project is likely to fund such a facility
  - The facility must be able to satisfy multiple different users
  - Areas of common interest should be found with radiation damage identified as one potential area
  - Post Irradiation Examination (PIE) should be give a high priority
  - Some capability may exist at current facility such as at LANSCE
  - An agreement was made to circulate a form to poll the attendees and others to find the desired beam and support facility characteristics