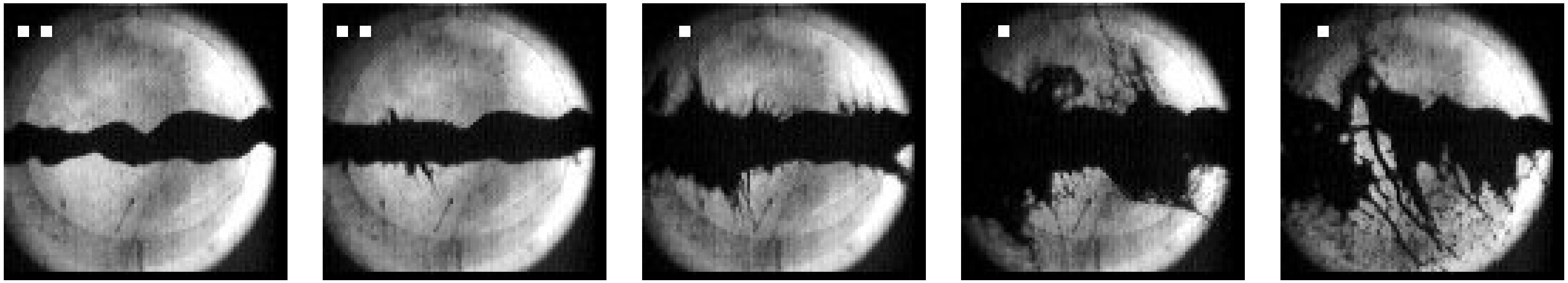
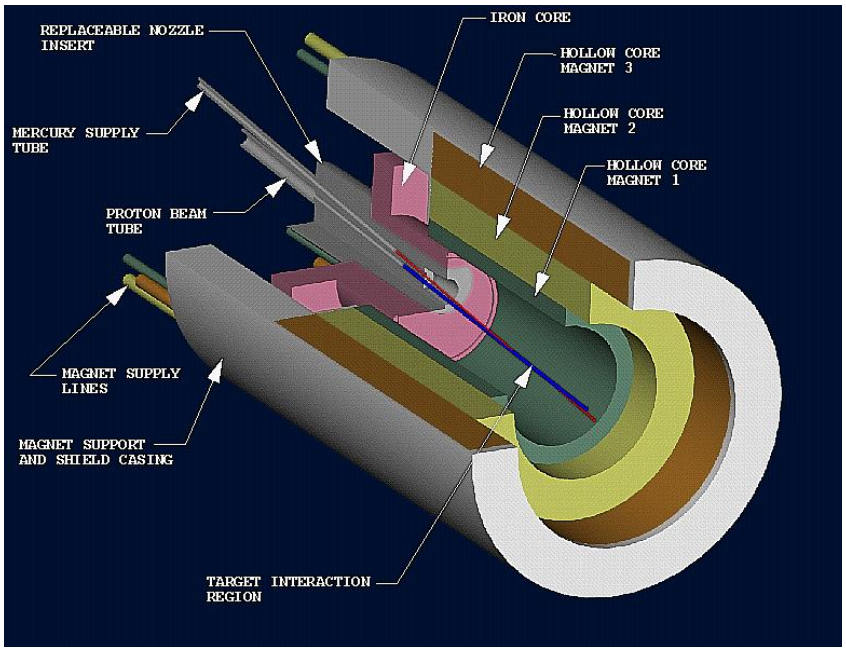
The Targetry R&D Program



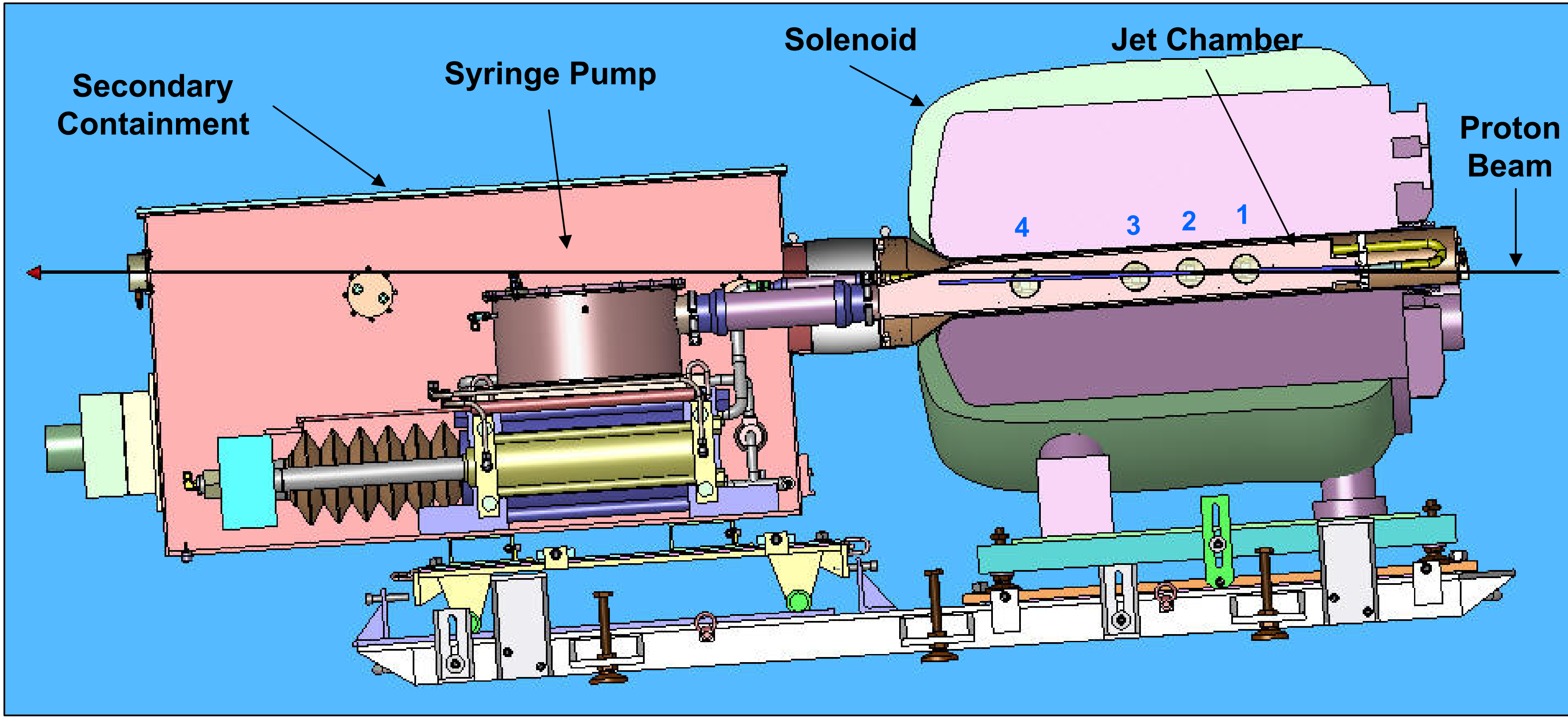


K.T. McDonald
Princeton U.
MUTAC Review
LBNL, April 8, 2008

Targetry Web Page:
http://puhep1.princeton.edu/mumu/target/

MERIT @ CERN was Proof of Principle not a Prototype

MERIT @ CERN used a 180° bend in the mercury delivery path because CERN would not permit any mercury-wetted connections to be made at CERN.



Future Target System R&D

Analysis (and simulation) of MERIT data is ongoing, but the success of the experiment already provides proof-of-principle of a free mercury jet target for megawatt proton beams.

Considerable system engineering is needed before an actual jet target station could be built: 20-T DC magnet, tungsten-carbide(?) shield, mercury delivery and collection system, remote handling system, radioisotope processing, ……..

Desirable to improve jet quality, and to explore viability of jet axis at 100 mrad to magnetic axis, as proposed in Feasibility Study 2. Would also be good to verify feasibility of recovery of the mercury jet in an open pool.

An opportunity exists to conduct non-beam studies with the MERIT equipment after it is shipped from CERN to ORNL ~ Jan 2009.

Such studies would begin with no magnetic field (jet quality, Hg pool), followed by studies with the MERIT magnet powered to 15 (or even 20) T at a new fusion power test facility at ORNL.

Post-MERIT Liquid Target Issues

MHD Simulations

Optimal Nozzle performance

Eliminate 180^0 bend

Hg beam dump

Particle production

Rep-rate delay limits

Target station engineering

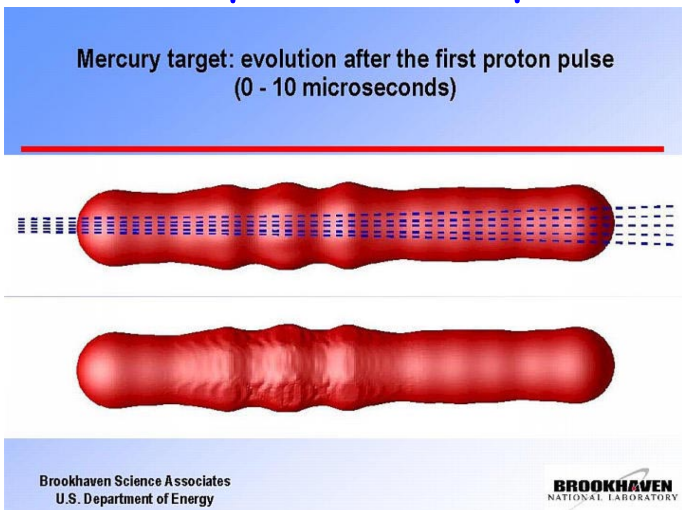
(work with IDS)

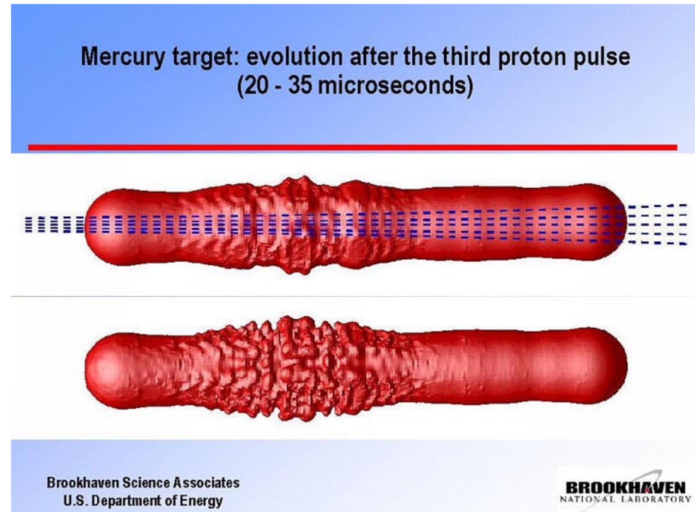
Beam-Induced Effects on a Free Liquid Jet

Beam energy deposition may disperse the jet.

R. Samulyak, BNL

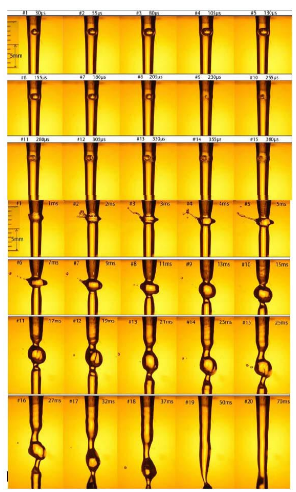
FRONTIER simulation predicts breakup via filamentation on mm scale:





Laser-induced breakup of a water jet:

(J. Lettry, CERN)



Water jet ripples generated by a 8 mJ Laser cavitation bubble

Issues from MERIT: Jet Quality, Vertical Height

Jet quality poor in zero magnetic field, and improves (as expected) with increasing field.

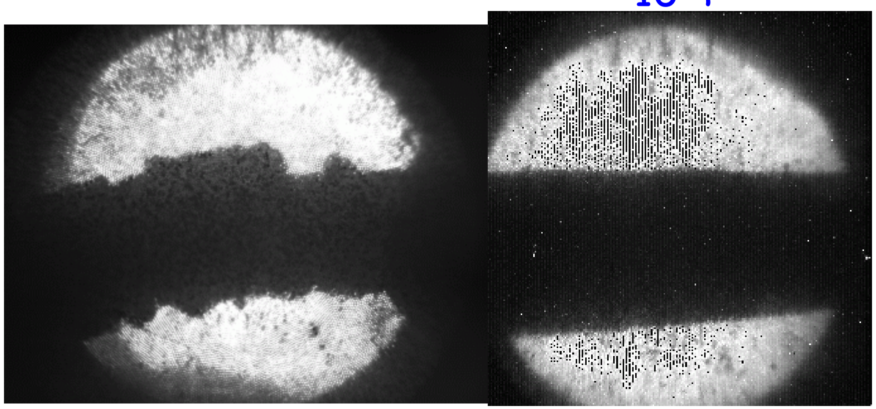
Jet vertical height 1.5-2.4 times nozzle diameter, and little affected by magnetic field.

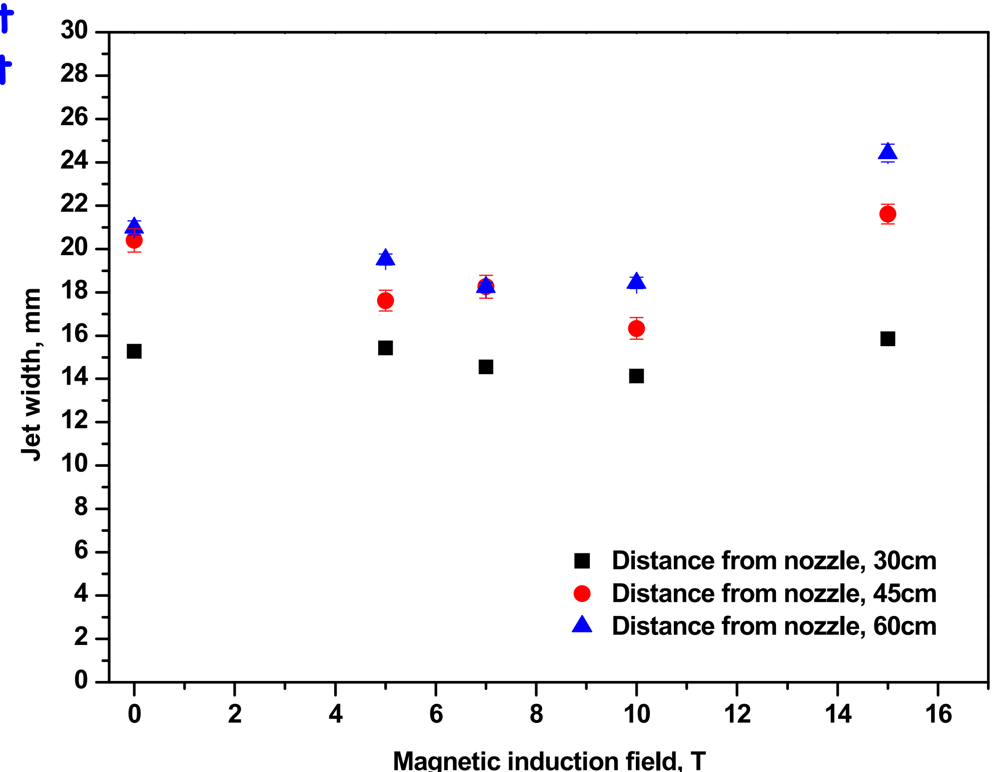
Simulations predict that vertical expansion of jet would be small, and would vary as B^2.

Suggests that 180° bend before nozzle leads to vertical expansion of jet.

Interesting hydrodynamic issues, but may be best to focus of aspects relevant to ν Factory/Muon Collider – where no 180° bend is contemplated.

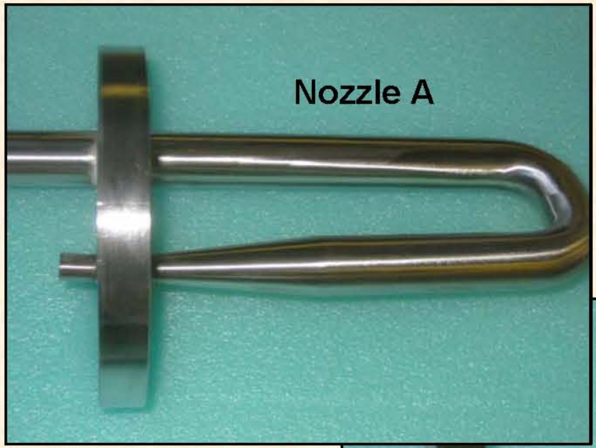
0 T 10 T

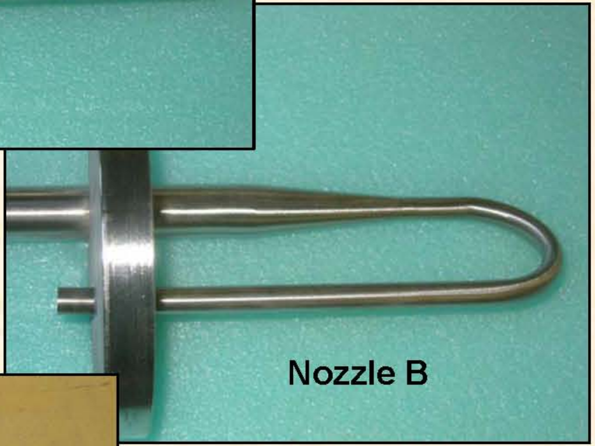




SS Water Test Nozzles

- Nozzle A – diameter reduction after bend, 2.5° nozzle angle
- Nozzle B – reduction before bend, 2.5° nozzle angle
- Nozzle C – test nozzle with reduction after bend, straight nozzle tip, internally similar to nozzle A
- Nozzle D – nozzle A after reaming out the tip





New Capabilities at ORNL

- **Considering pursuit of other liquid targets (LBE) or additional Hg-related R&D with MERIT equipment**
  - Performing integrated system testing (no-beam) at ORNL would be beneficial
- **Discussions with Tim Bigelow, ORNL Fusion Energy Division, indicate some existing experimental power supplies will be moved from Y-12 to ORNL this year**
  - Had considered this option prior to CERN experiment but could not pursue due to schedule constraints
- **Some of the power supplies will have capability to power MERIT solenoid**

7627 Power Supply Building

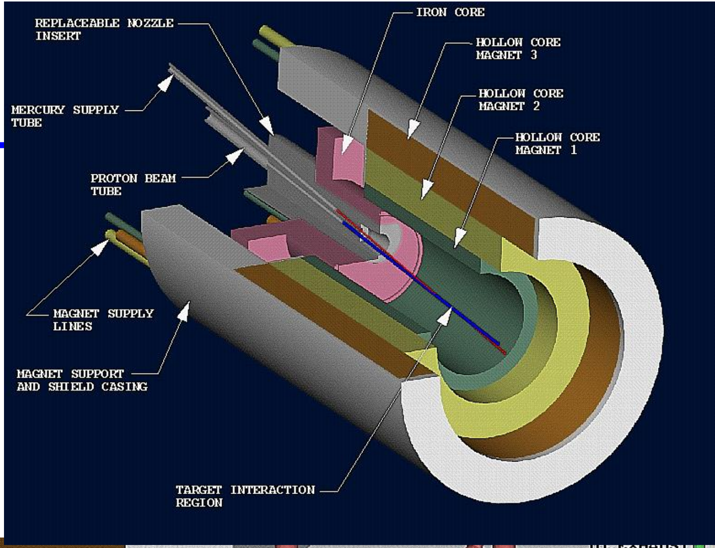
- **New facility to be located near SNS Target Test Facility bldg**
- **Construction has started**
  - **Schedule completion: Sept 2008**
- **Several power supplies will be installed**

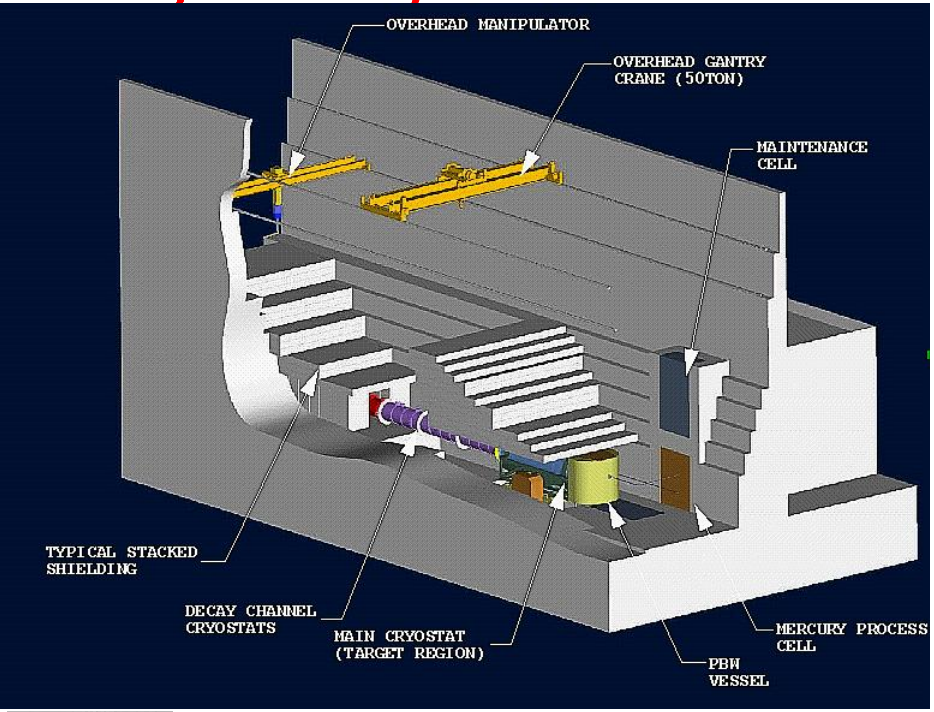
Bldg 7625

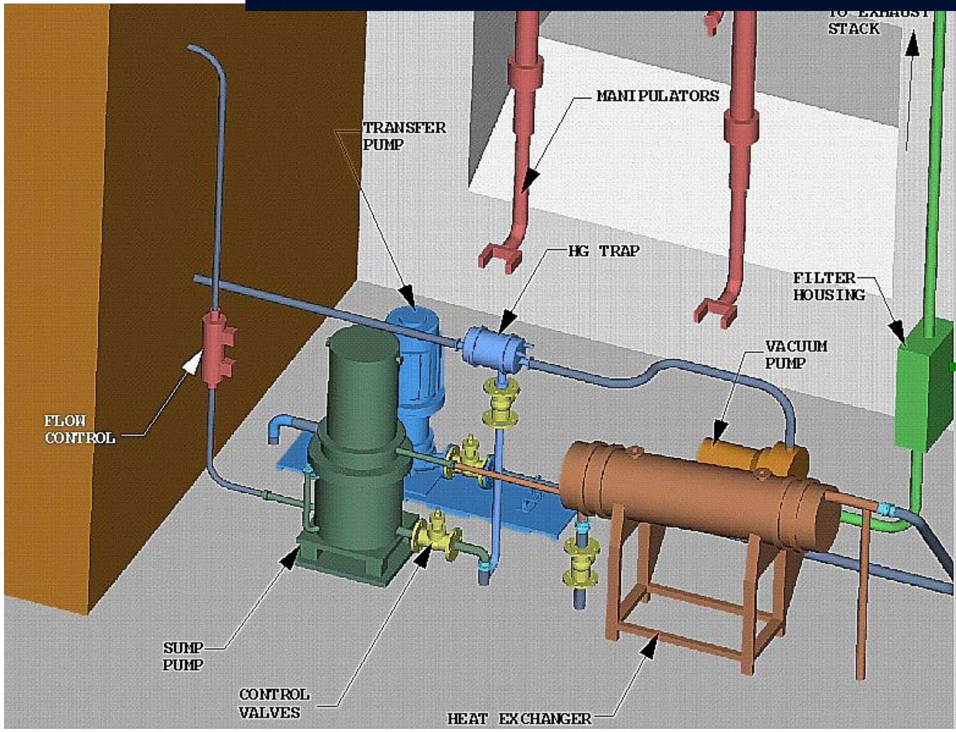
- **Pit capable of housing MERIT experimental equipment**
  - Approximately 40ft x 15ft x 12ft deep
- **5000-gal LN2 dewar in place**
- **20T overhead crane**

Neutrino Factory Feasibility Study 2

- Infrastructure studies based on SNS mercury target experience.
- Should be extended during the International Design Study.
- Considerable engineering support needed to go beyond Study 2.







Features of the Study 2 Target Design

Mercury jet with 1-cm diameter, 20 m/s velocity, at 100 mrad to magnetic axis.

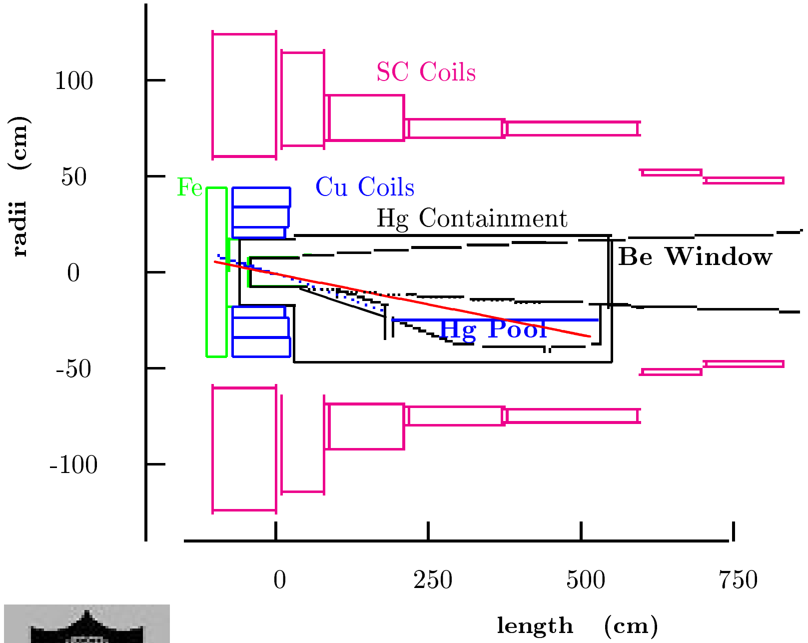
Proton beam at 67 mrad to magnetic axis.

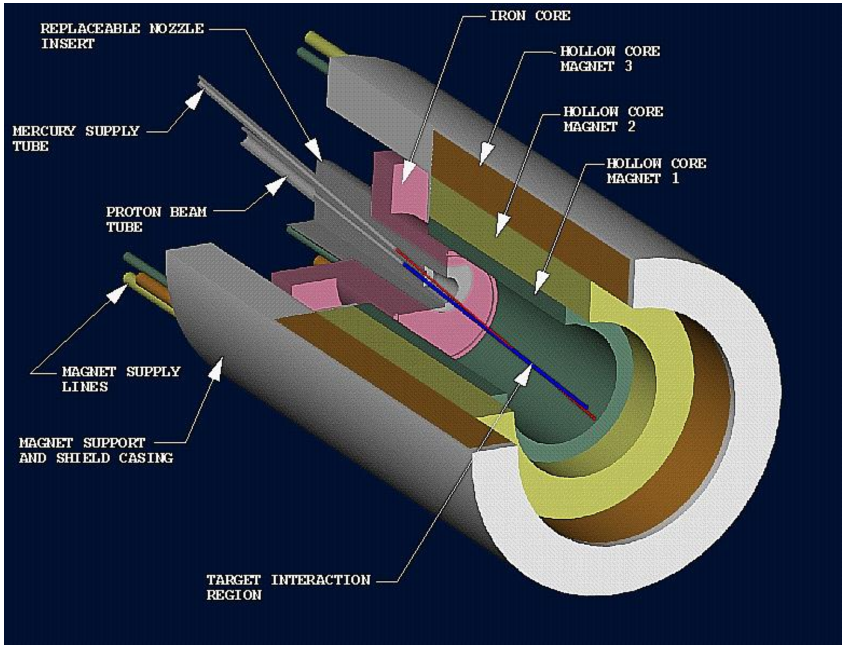
Iron plug at upstream end of capture solenoid to reduce fringe-field effect on shape of free jet.

Mercury collected in a pool in ~ 4 T magnetic field.

Issues:

- Jet quality after emerging from long cylindrical nozzle in iron plug.
- Splash in mercury pool should not extend up into nominal beam region.





Could Reuse MERIT Equipment to Study Jet Issues without Beam

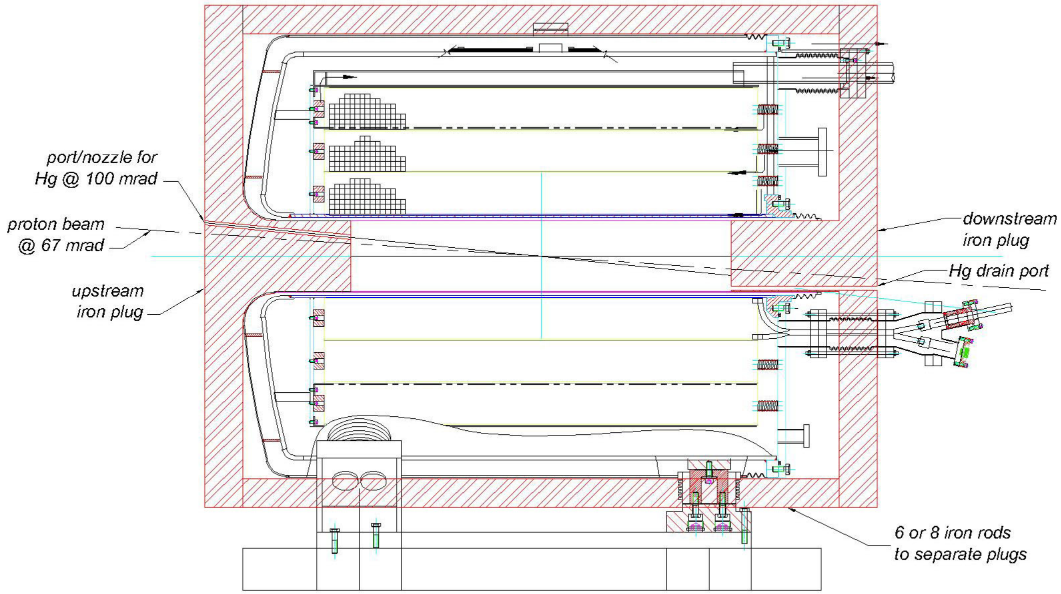
At a facility suitable for more general handling of mercury, could connect the mercury test volume to the mercury pump by hoses so that mercury enters at one end of magnet and exits at the other.

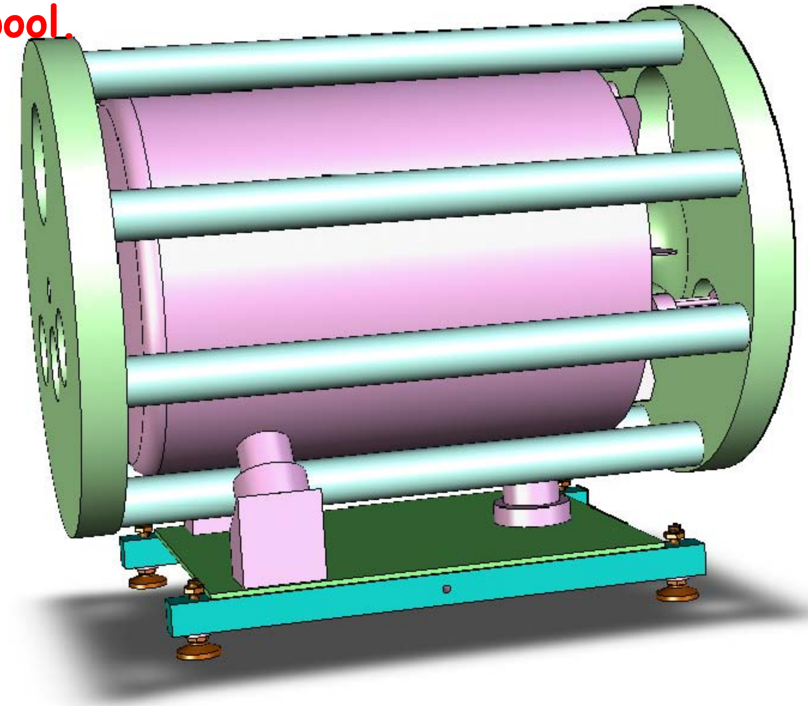
Could study jet quality in nozzles with no sharp bends.

Could use optical diagnostics with both side and top views.

Could add iron plugs to the MERIT magnet to study effect of field on a jet at 100 mrad (instead of 33 mrad as in MERIT @ CERN).

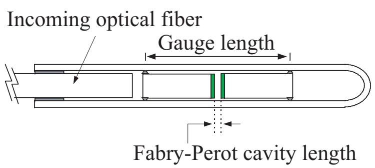
Could also study collection of the jet in a mercury pool.

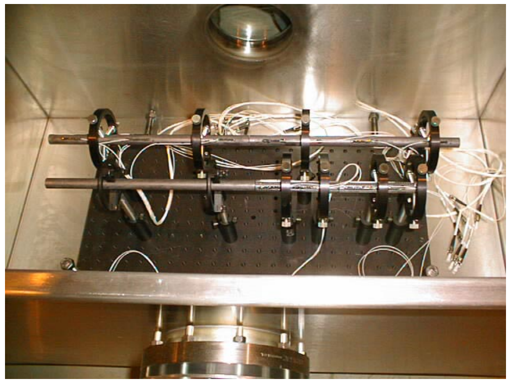




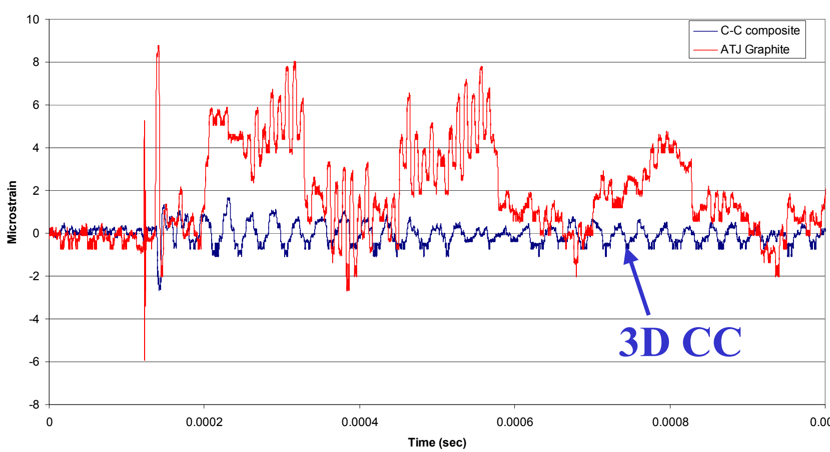
Irradiation Studies

ATJ graphite and a 3-D weave of carbon-carbon fibers instrumented with fiberoptic strain sensors, and exposed to pulses of 4×10^{12} protons @ 24 GeV.





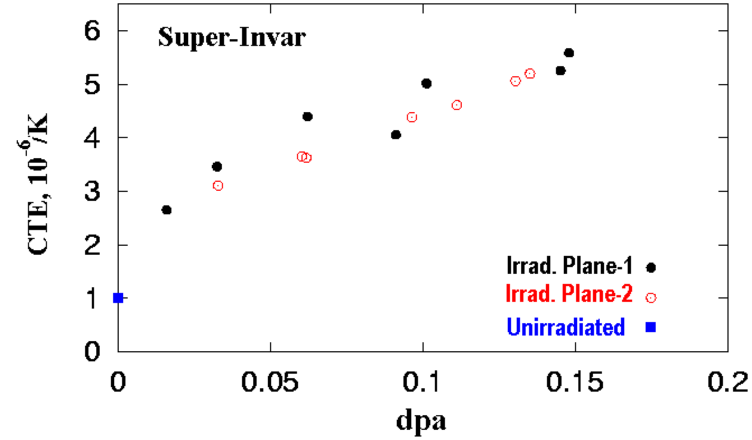
BNL E951 Target Experiment
24 GeV 3.0 e12 proton pulse on Carbon-Carbon and ATJ graphite targets
Recorded strain induced by proton pulse



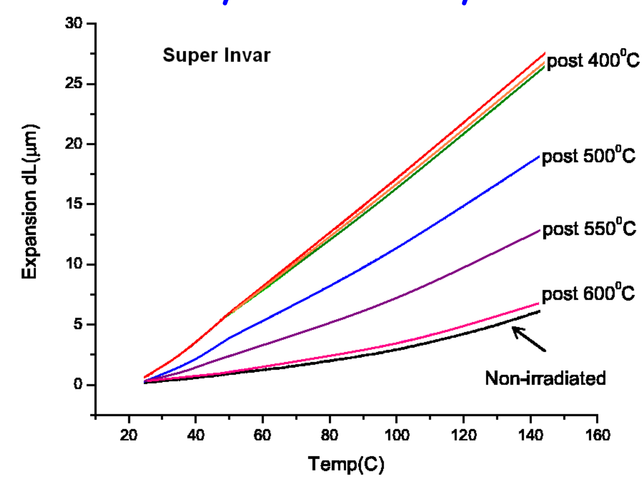
Carbon-carbon composite showed much lower strains than in the ordinary graphite -- but readily damaged by radiation!

Thermal-expansion coefficient of engineered materials is affected by radiation.

Super-Invar: CTE \vs\ dose:

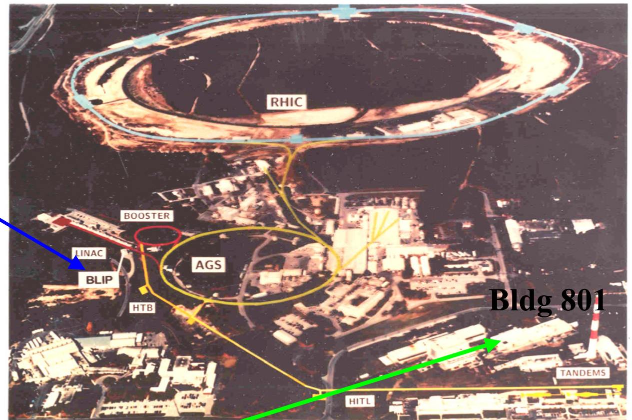


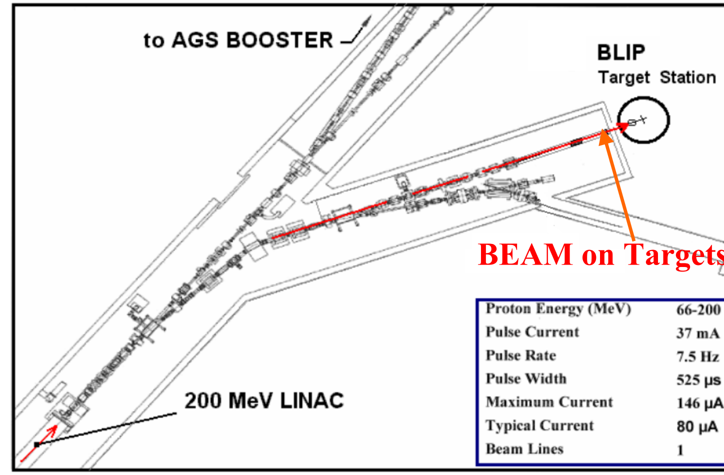
Super-Invar: recovery of the CTE by thermal annealing:



Experimental Process
Utilizing BNL Accelerator Complex

Irradiation takes place at BLIP using 200 MeV or 117 MeV protons at the end of Linac

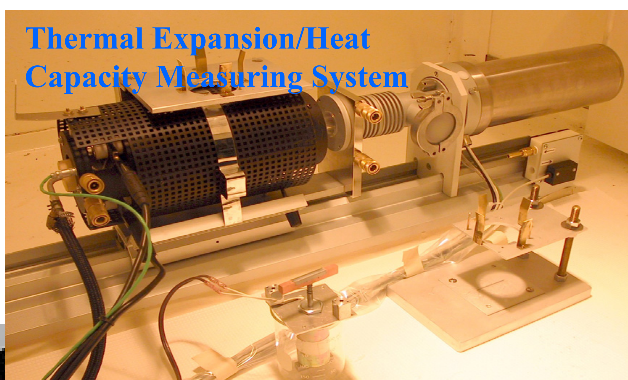




Proton Energy (MeV)	66-200
Pulse Current	37 mA
Pulse Rate	7.5 Hz
Pulse Width	525 μs
Maximum Current	146 μA
Typical Current	80 μA
Beam Lines	1

Post-irradiation analysis at BNL Hot Labs

Remotely operated mechanical testing system



Summary

Liquid-target MHD simulations are ongoing and should continue to be supported.

Hardware studies of jet (and splash) quality in configurations close to those of Feasibility Study 2 could be performed with MERIT equipment at ORNL.

Systems engineering of a 4 MW target facility should be supported in the context of the IDS or other muon-based accelerator feasibility study.

Studies of radiation damage of solid-target candidates are ongoing, largely without NFMCC support.

Next Targetry Workshop: 1-2 May, 2008, Oxford, UK

http://www.physics.ox.ac.uk/users/peachk/HPT/