An R&D Program for Targetry at a Muon Collider

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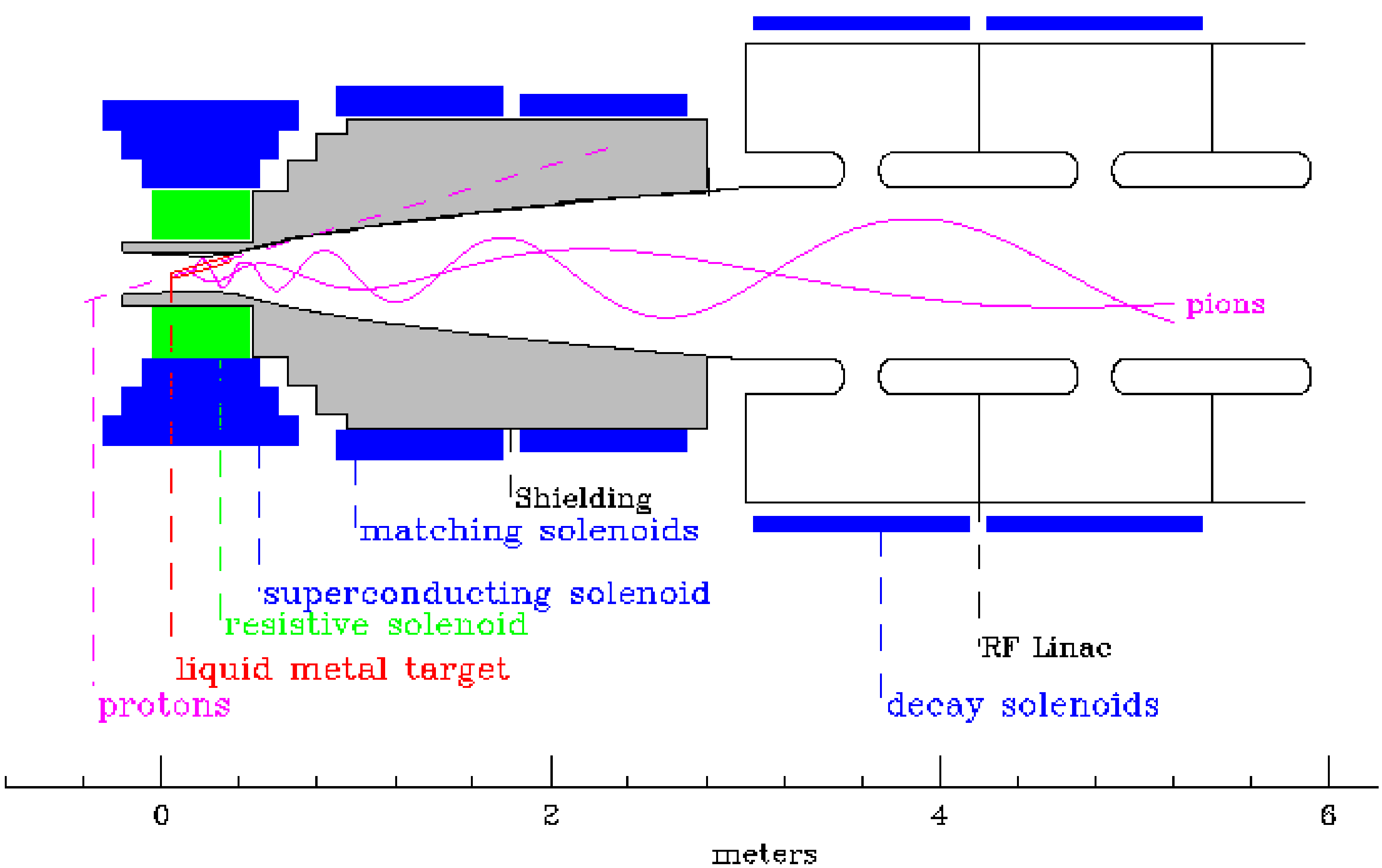
http://puhep1.princeton.edu/mumu/target/

Targetry Challenges

To achieve useful physics luminosity, a muon collider must produce about 10^{14} μ/sec.

- $> 10^{15}$ proton/sec onto a high-Z target.
- Capture pions of $P_\perp \lesssim 200$ MeV/c in a 20-T solenoid magnet.
- Transfer the pions into a 1.25-T-solenoid decay channel.
- Compress π/μ bunch energy with rf cavities and deliver to muon cooling channel.



Targetry Challenges, Cont'd

- Proton beam power $\approx$ 4 MW; 400 kW deposited in target.
- To minimize pion absorption, cannot cool target by thermal bath.
- Radiative cooling is inadequate.
- $\Rightarrow$ Move target material away from beam and cool remotely.
- Even so, target must survive radiation damage (10-100 dpa/year), and the thermal shock of 30 kJ/pulse ($\approx$ 30 J/gm) at 15 Hz.

A moving solid target is very awkward (backup solution).

Pipes with liquid metal (as in future neutron spallation sources) won't survive the pressure wave of thermal shock.

A **free liquid metal jet** is presently the preferred option.

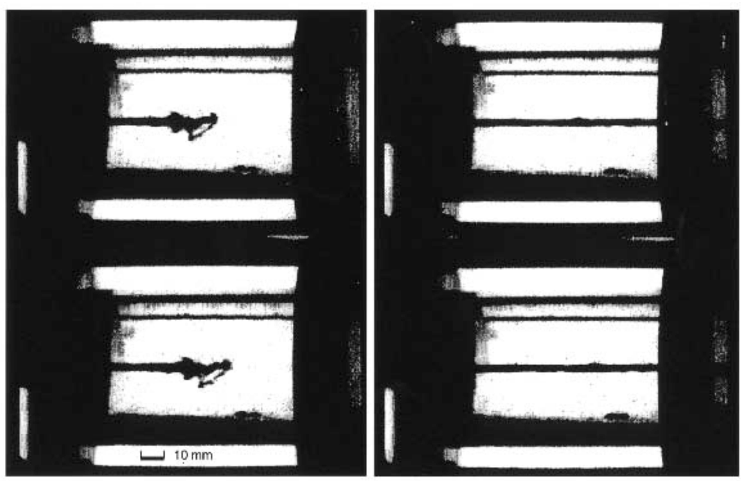
Will it work? Need a **Targetry R&D Program**.

ISOLDE Liquid Targets Damaged by Short Pulses

Cracks developed at braised joints and lead sprayed out.

R&D Issues

- 1-ns beam pulse ⇒ shock heating of target.
  - Resulting pressure wave may disperse liquid (or crack solid).
  - Damage to target chamber walls?
  - Magnetic field will damp effects of pressure wave.
- Eddy currents arise as metal jet enters the capture magnet.
  - Jet is retarded and distorted, possibly dispersed.
  - Hg jet studied at CERN, but not in beam or magnetic field:



High-speed photographs of mercury jet target for CERN-PS-AA. (laboratory test)
4,000 frames per second, Jet speed: 20 ms^{-1}, diameter: 3 mm, Reynold's Number: >100,000
A. Poncet

- Targetry area also contains beam dump.
  - Need 4 MW of cooling.
  - Harsh radiation environment for magnets and rf.

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A Proposal to the BNL AGS Division

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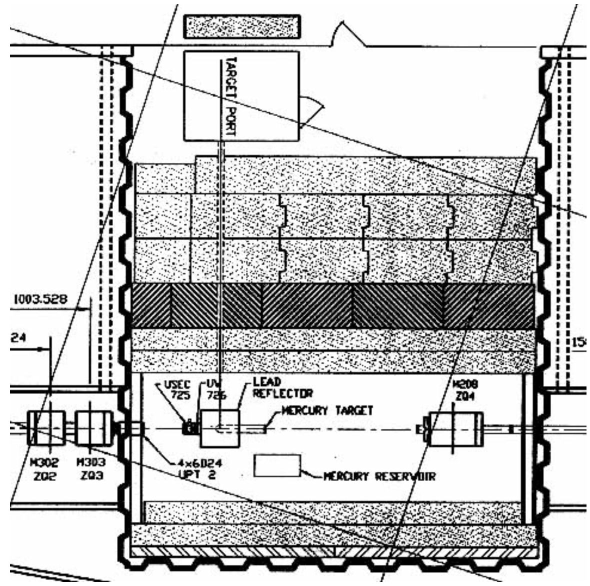
Studies to be performed in the BNL AGS F.E.B. U-line, and at the National High Magnetic Field Laboratory.



Goals

Long Term: Provide a facility to test key components of the front-end of a muon collider in realistic beam conditions.

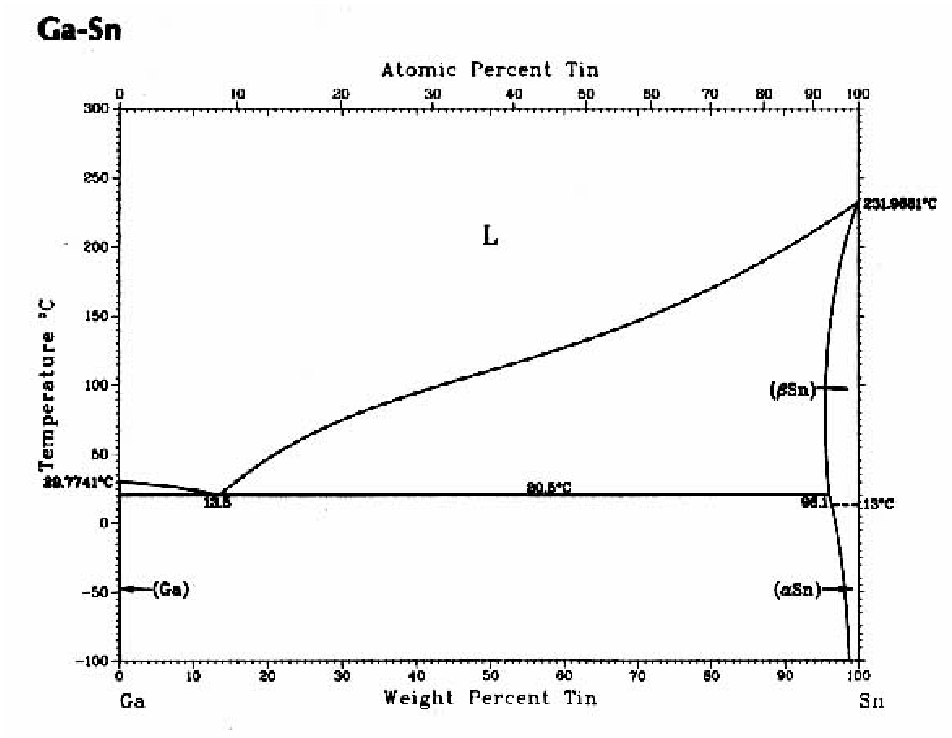
Near Term (1-2 years): Test effects of intense, short proton pulses and magnetic fields on liquid metal targets.
(Change target technology if encounter severe difficulties.)

Mid Term (3-4 years): Add 20-T magnet to liquid target tests;
Test 70-MHz rf cavity (+ 1.25-T magnet) downstream of target;
Characterize pion yield.

The 8 Steps in the R&D Program

1. Simple tests of liquid (Ga-Sn) targets in the AGS FEB U-line.
2. Test of liquid jet entering a 20-T magnet (20-MW cw Bitter magnet at the National High Field Magnet Laboratory).
3. Test of liquid jet in the FEB U-line (without magnet).
4. Add 20-T pulsed magnet (4-MW peak) to the FEB U-line.
5. Add 70-MHz rf cavity downstream of target in FEB U-line.
6. Surround rf cavity with 1.25-T magnet.
7. Characterize pion yield from target + magnet system in FEB U-line.
8. Ongoing simulation of the thermal hydraulics of the liquid-metal target system.

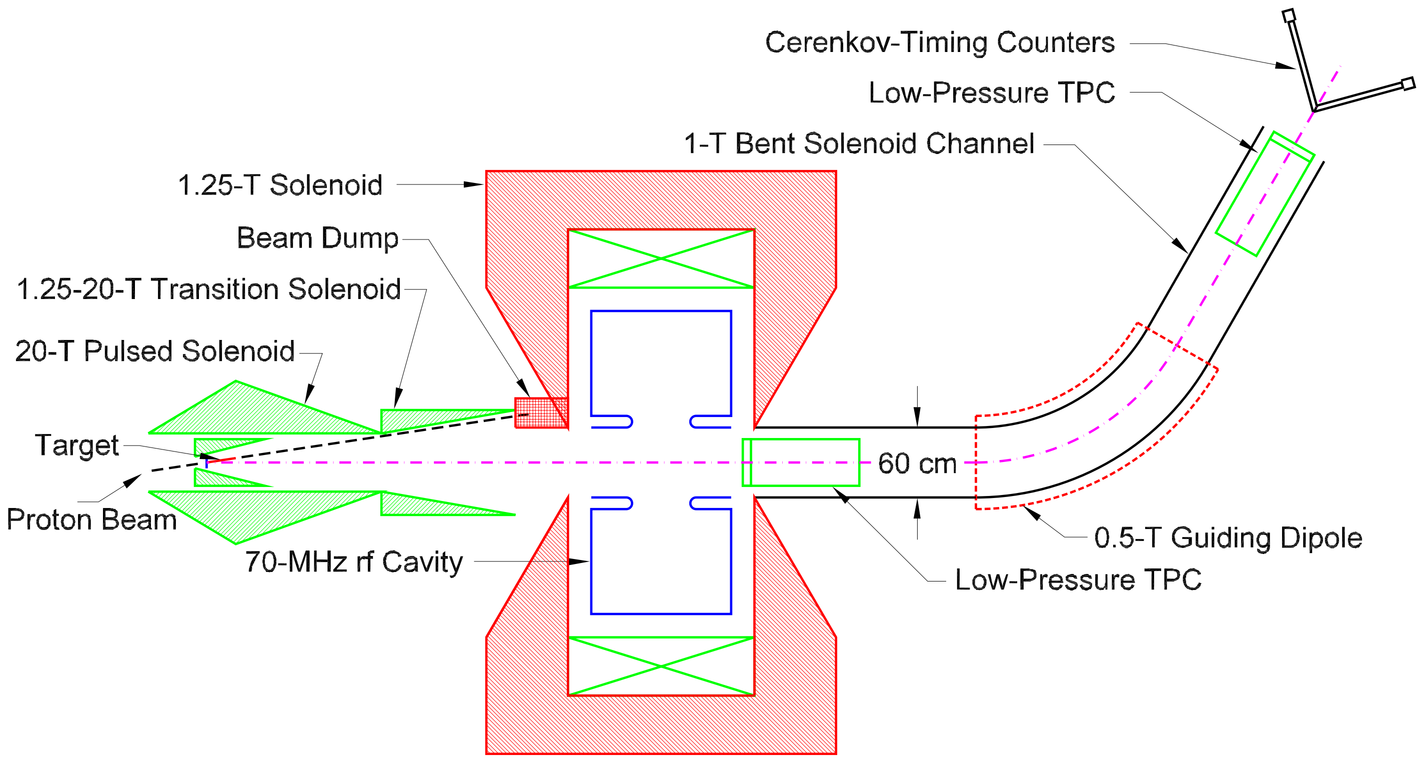
Begin with Ga/Sn Liquid-Metal Alloy



Eutectic Ga/Sn alloy melts at 20C. Density = 6 g/cm^3.

Easy to make and handle; very low viscosity.

Overall Configuration of the Experiment



What Next?...

Heavier, higher-Z liquid metals: mercury, lead/bismuth...

Systems issues for long life, high rep. rate.

Hybrid DC 20-T magnet: superconducting outer, resistive inner.

Superconducting magnets around rf cavities.

Budget and Schedule by Fiscal Year

(In units of 1M$)

Program Step	FY99	FY00	FY01	Total
1. Simple beam tests	0.12	–	–	0.12
2. Jet in 20-T magnet	0.08	–	–	0.08
3. Jet in beam	0.20	0.20	–	0.40
4. Add 20-T pulsed magnet	0.20	≈0.60	–	≈0.80
5. Add 70-MHz rf cavity	0.15	≈0.80	–	≈0.95
6. Add 1.25-T magnet	0.05	0.15	≈1.00	≈1.20
7. Characterize pion yield	0.05	0.10	≈1.85	≈2.00
8. Simulations	0.15	0.15	0.15	0.45
Total	1.00	≈2.00	≈3.00	≈**6.00**