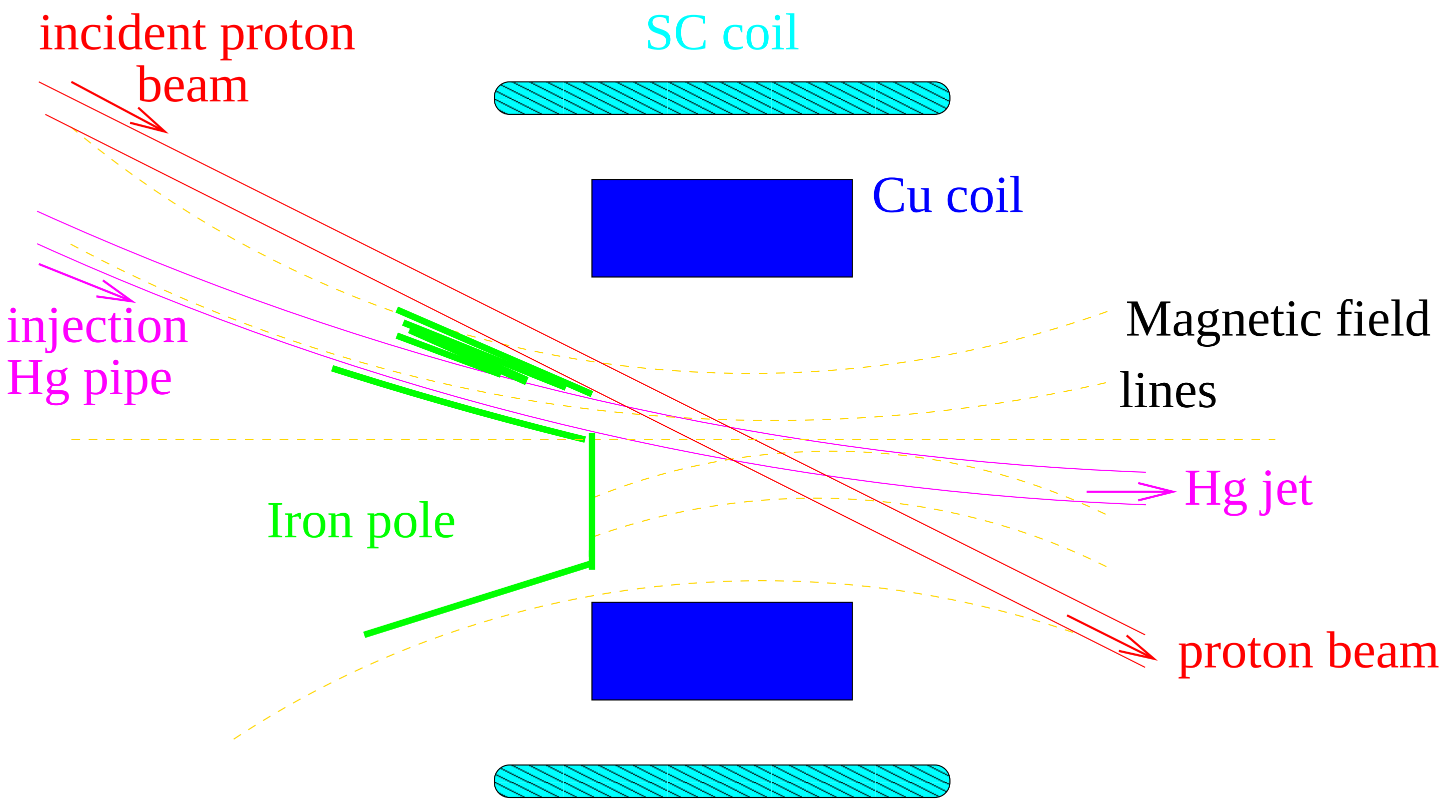
R&D Issues for Targetry and Capture at a Neutrino Factory and Muon Collider Source



K.T. McDonald
Princeton U.

December 15, 2000

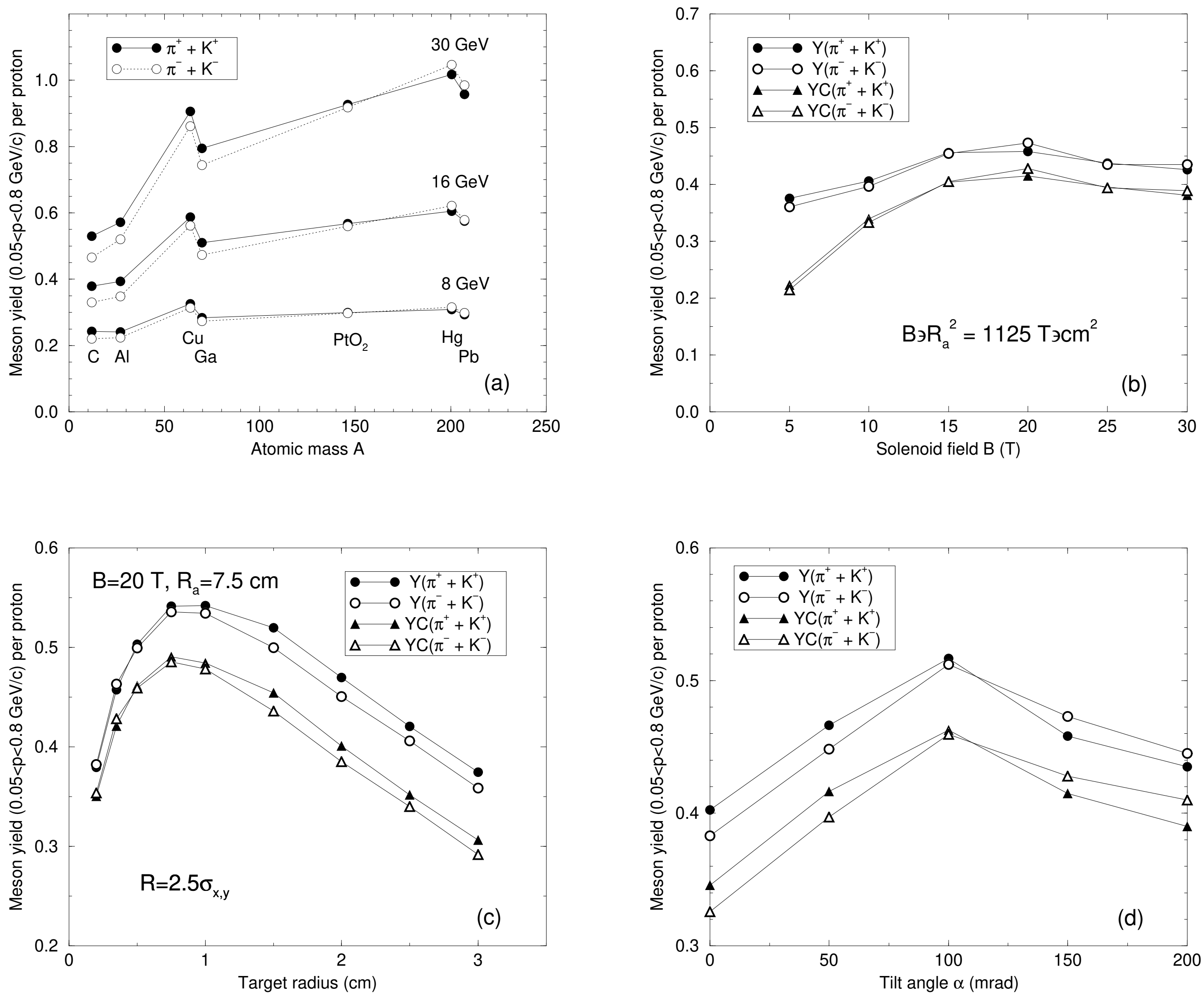
Targetry Workshop, BNL

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

[This is the 26th edition of targetry reviews that began at the Orange Beach meeting, March 1998.]

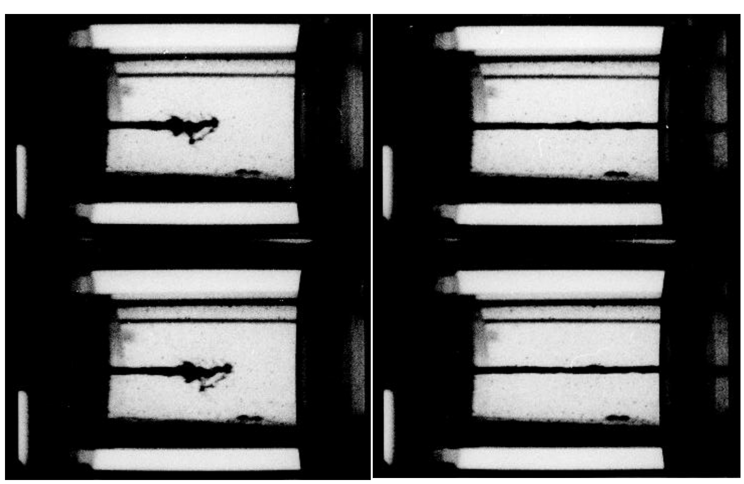
Requirements for Targetry and Capture

- Get muons from pion decay: $\pi^{\pm} \rightarrow \mu^{\pm}\nu$.
- Pions from proton-nucleus interactions in a **target**.
- Goal: 1.2×10^{14} $\mu^{\pm}$/s with a 4-MW p beam (1 MW at t_0).



Baseline Scenario

- High-energy proton beam: 16 or 24 GeV.
- High magnetic field (20 T) around target to **capture** pions with $P_\perp < 220$ MeV/c, $50 < P_\| < 400$ MeV/c.
- Adiabatic reduction of B to ≈ 1 T in decay channel.
- High-Z target.
- Tilt target by ≈ 0.1 rad to maximize pion yield.
- No cooling apparatus near target.
- High power of beam could crack stationary target
- $\Rightarrow$ **Free liquid metal jet** as target: Hg, Pb/Bi, ...

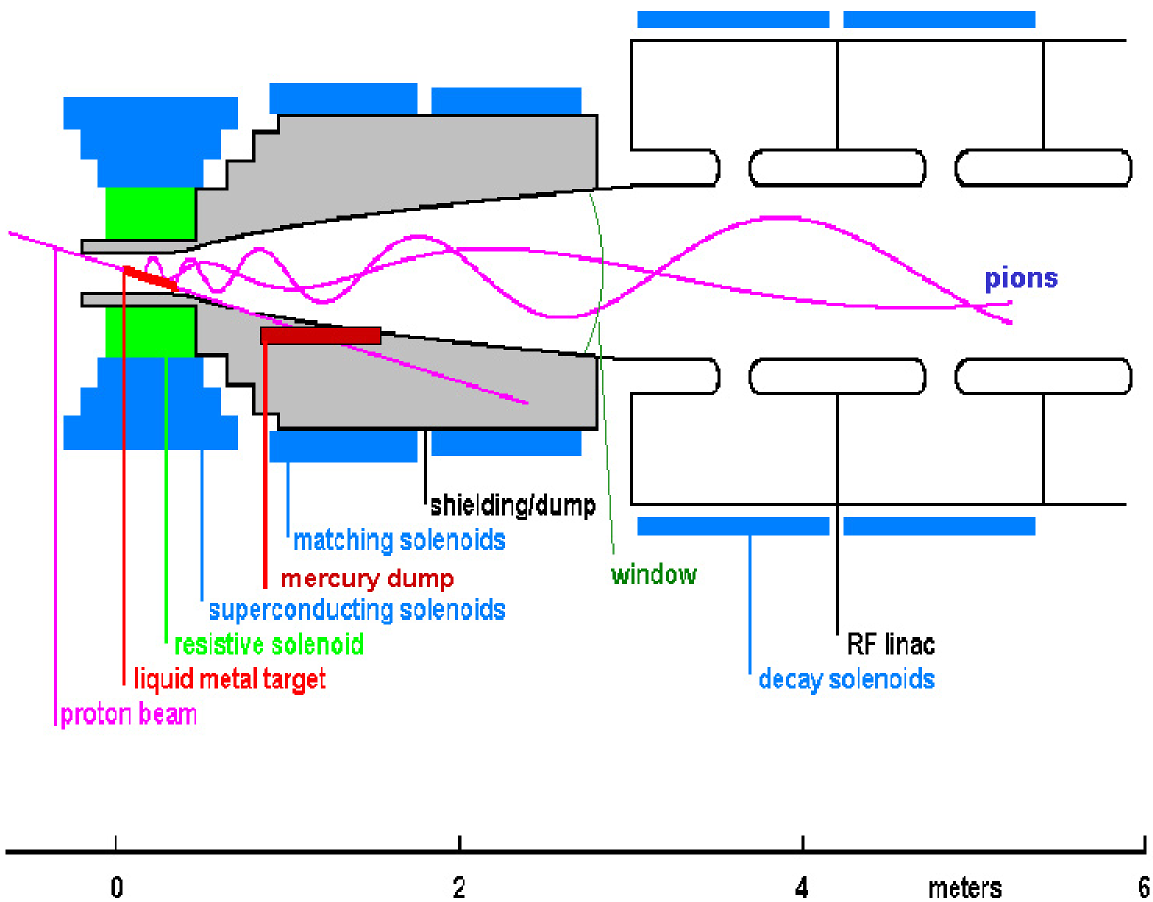


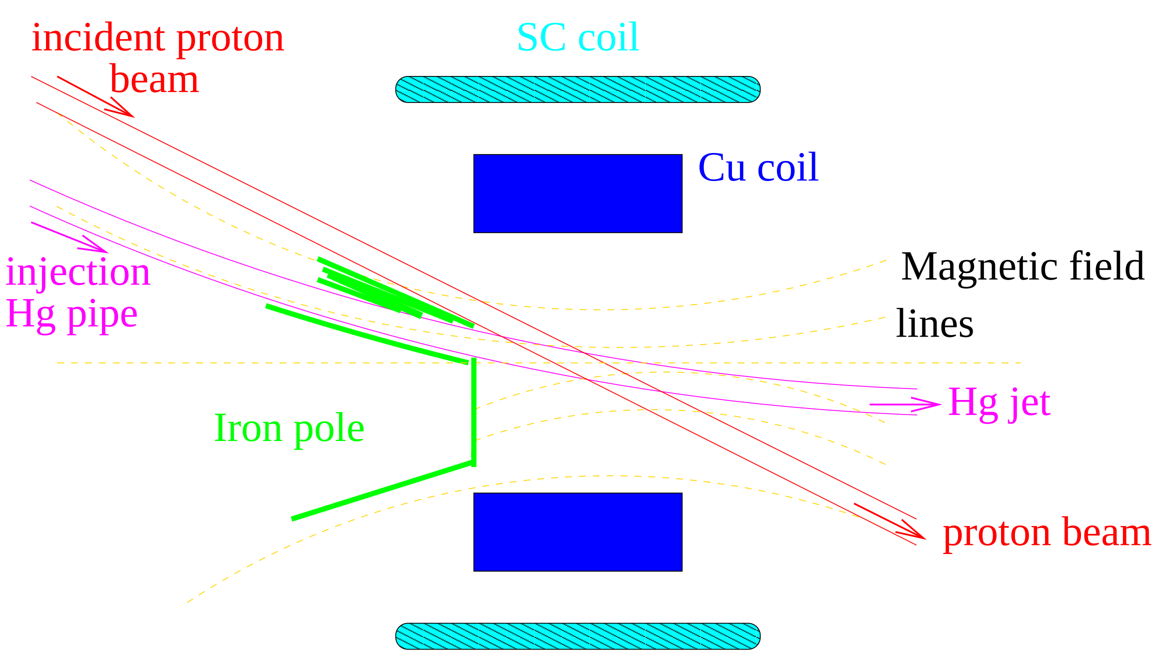
High-speed photographs of mercury jet target for CERN-PS-AA (laboratory tests)

4,000 frames per second, Jet speed: 20 ms-1, diameter: 3 mm, Reynold's Number:>100,000

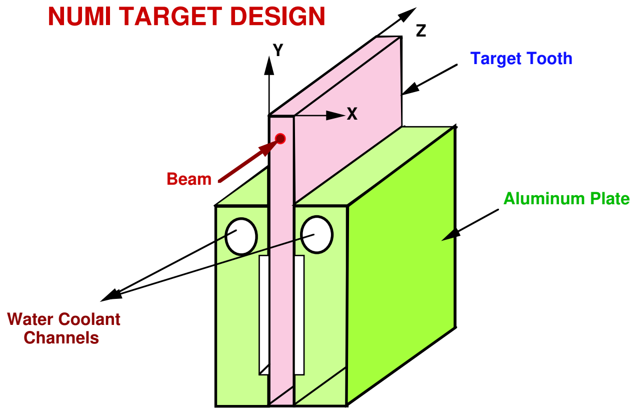
A. Poncet

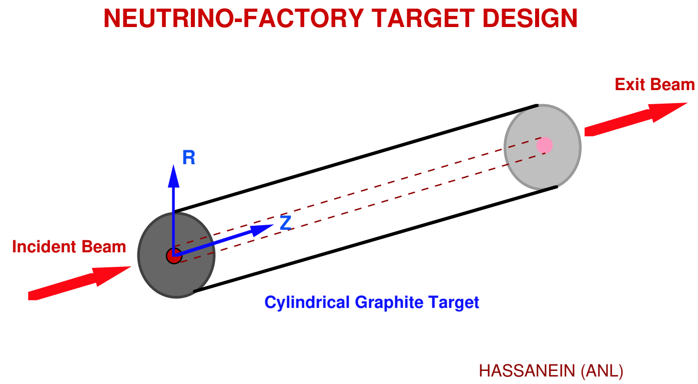
Baseline Scenario



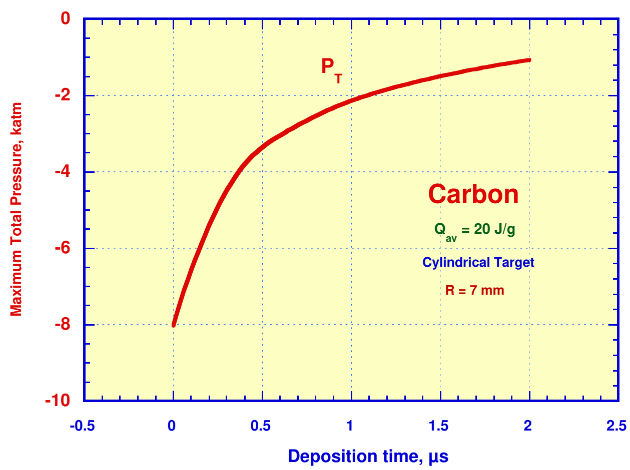


A Carbon Target is Feasible at 1-MW Beam Power

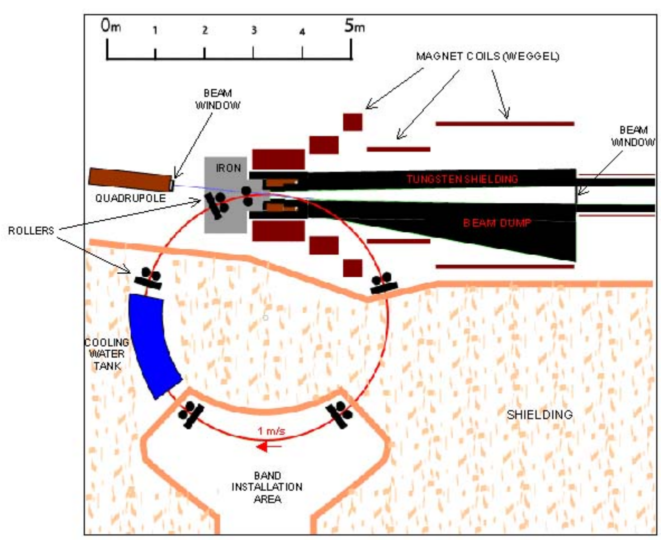




But a few-nsec beam pulse causes severe pressure waves.

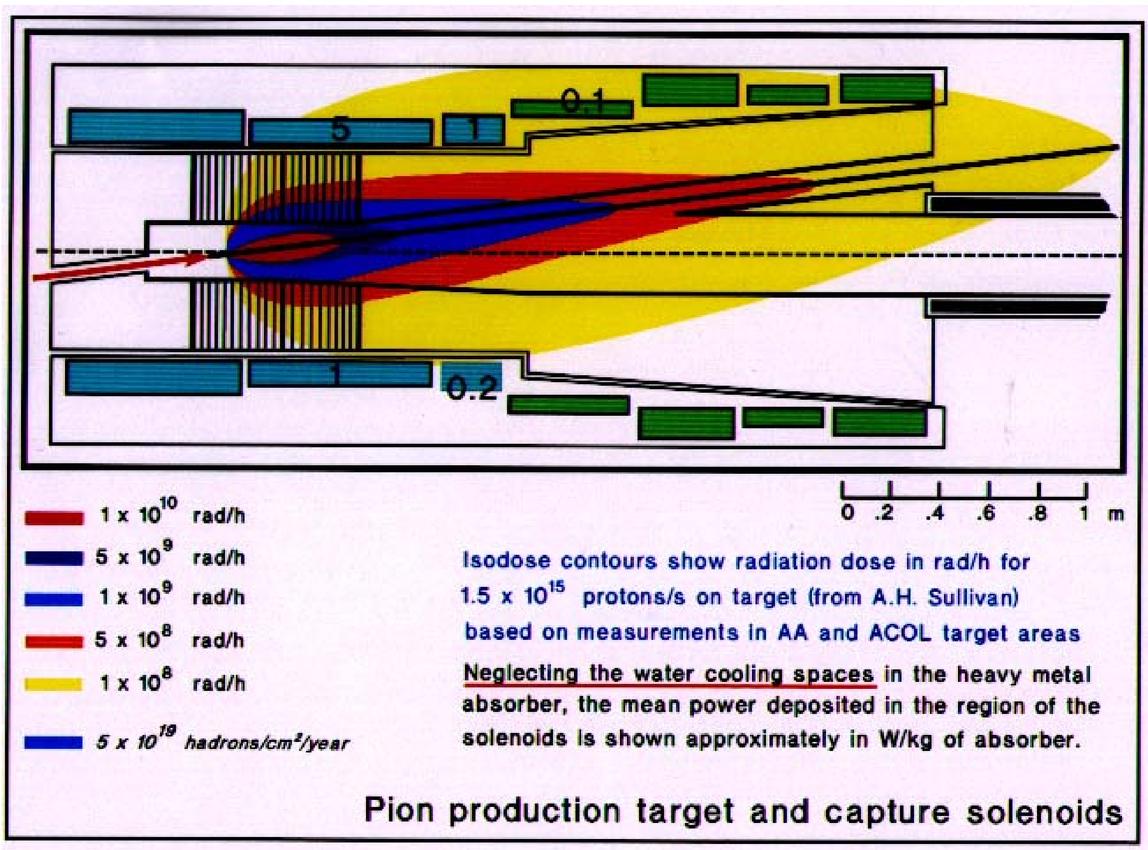


A rotating band target is another option:



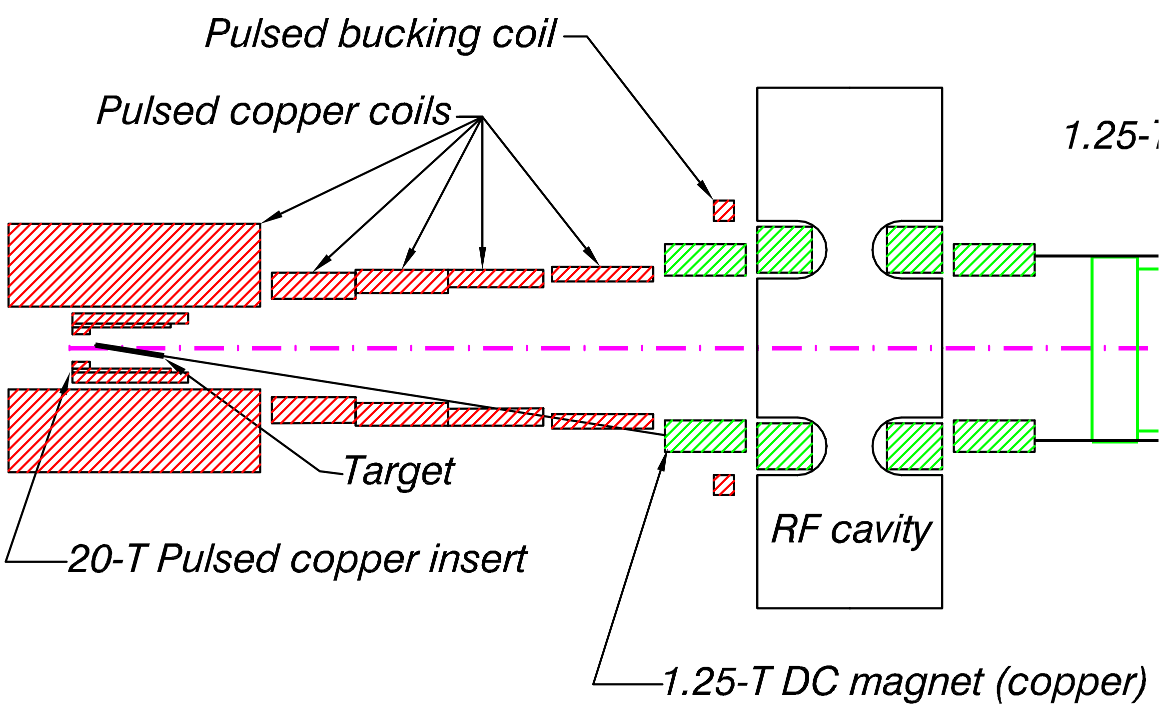
Two Classes of Issues

1. Viability of targetry and capture for a single pulse (E951).
   - Beam energy deposition may disperse the jet.
   - Eddy currents may distort the jet as it enters the magnet.
2. Long-term viability of the system in a high radiation area (Feasibility Study 2).



The First Three Stages of E951

1. Tests of targets in an intense beam (without magnetic field).
   - In the BNL A3 beamline: 24 GeV p's, up to 1.5e13 p/bunch, up to 6 bunches spaced by 20 ms.
   - Targets: carbon, mercury, Wood's metal, inconel, ...
2. Tests of liquid metal entering a magnet (without beam).
   - At the 20-T hybrid magnet facility of the NHMFL (Florida).
3. Tests of liquid target + beam + 20-T pulsed magnet.



Agenda, E951 Workshop, Dec. 15

Overview

08:30-09:00	K. McDonald (Princeton)	

A3 beamline

09:00-09:20	K. Brown (BNL)	Beam Optics
09:20-09:40	K. Brown (BNL)	Beam Instrumentation
09:40-10:00	R. Prigl (BNL)	Beam Shielding Design
10:00-10:20	Coffee Break	
10:20-10:40	N. Simos (BNL)	Beam Windows
10:40-11:00	J. Scaduto (BNL)	Status of Construction

A3 Target Tests

11:00-11:20	K. McDonald (Princeton)	Target Test Program
11:20-11:40	C. Finfrock (BNL)	Mercury Jets, Horizontal & Vertical
11:40-12:00	H. Wang (BNL)	High-Speed Camera System
12:00-13:00	Lunch	

Agenda, E951 Workshop, Dec. 15, Continued

A3 Target Tests, cont'd.

13:00-13:20	J. Haines (ORNL)	Carbon, Room Temp, Strain Sensors
13:20-13:40	G. Greene (BNL)	Carbon, High Temperature
13:40-14:00	J. Norem (ANL)	Schlieren Photography
14:00-14:20	A. Zeller (MSU)	Neutron Studies

A3 Safety Committee Issues

14:20-14:50	H. Kirk (BNL)	Safety Committee Issues
14:50-15:10	Coffee Break	

NHMFL Mercury Test

15:10-15:30	K. McDonald (Princeton)	Goals
15:30-15:50	J. Miller (NHMFL)	20-cm Bore, 20-T Hybrid Magnet

20-T Pulsed Magnet Design

15:50-16:10	B. Weggel (BNL)	System Requirements
16:10-16:30	P. Hwang (Everson Electric)	System Design
16:30-16:50	Steve Van Sciver (NHMFL)	System Design

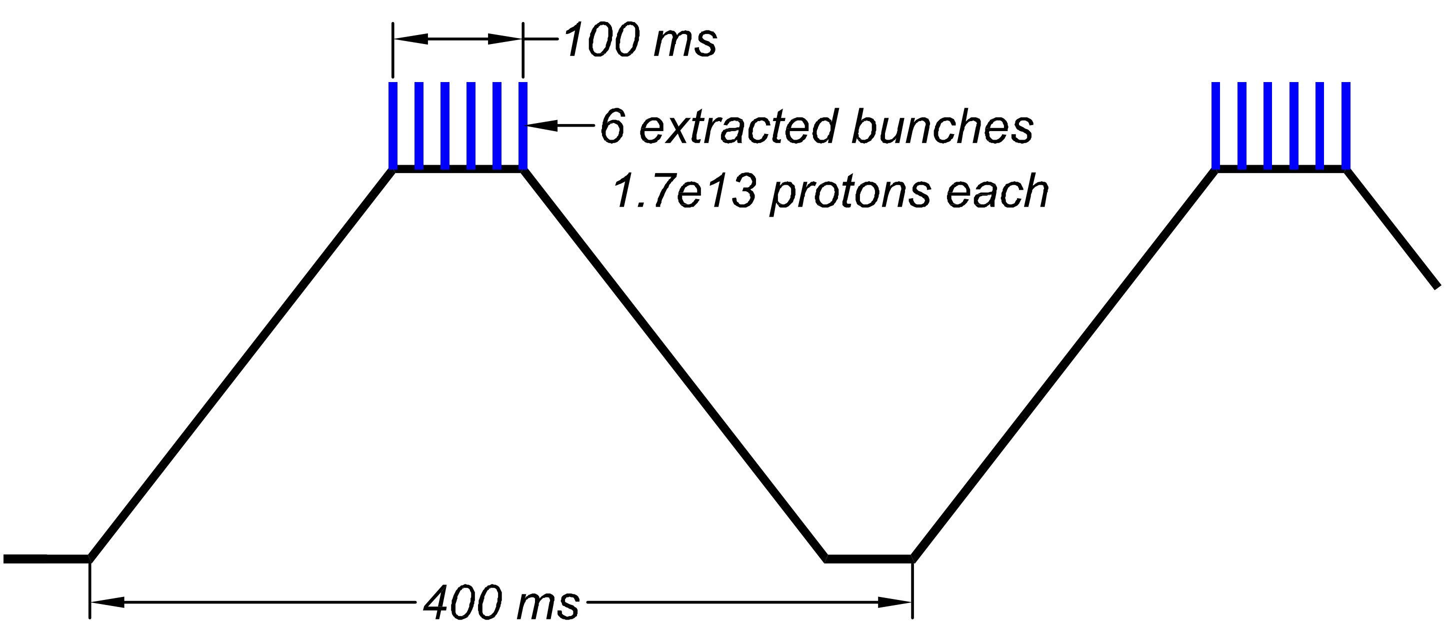
Summary

16:50-17:10	H. Kirk (BNL)	Action Items

Feasibility Study 2, Target-related Parameters

Proton Driver:

Energy	24 GeV
p per bunch	$\approx 1.7 \times 10^{13}$
Bunches per cycle	6
Time between extracted bunches	20 ms
Average repetition rate	2.5 Hz
Peak repetition rate	50 Hz
Beam power	$\geq$ 1MW
rms bunch length	$\leq$ 3 ns



Feasibility Study 2, Target-related Parameters

Target:

Material	mercury
Velocity	$\approx$ 30 m/sec
Diameter	1 cm
Angle: target axis to magnet axis	100 mrad
Angle: beam axis to target axis	33 mrad
Interaction region	60 cm
Displacement of front from axis	$\approx$ 1 cm

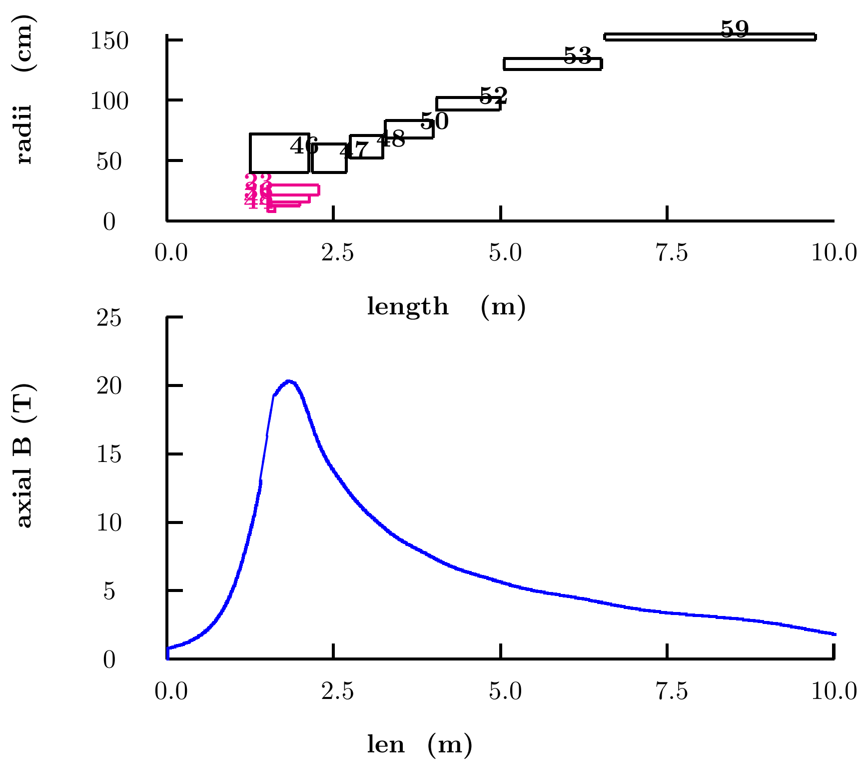
Issues:

- How to get the jet into the magnet?
- Will the first of 6 beam pulses disrupt the whole jet?

Feasibility Study 2, Issues

Capture and Matching Solenoids

The 20 T capture solenoid would be a hybrid, with copper (insert) and superconducting (outsert), magnet similar to that discussed in Feasibility Study 1. However, it is proposed here to use hollow copper conductor for the insert, rather than a Bitter style magnet in Study 1. The choice is aimed at achieving longer magnet life and avoiding any problems with highly irradiated water insulation. It is understood that the initial cost will be higher.

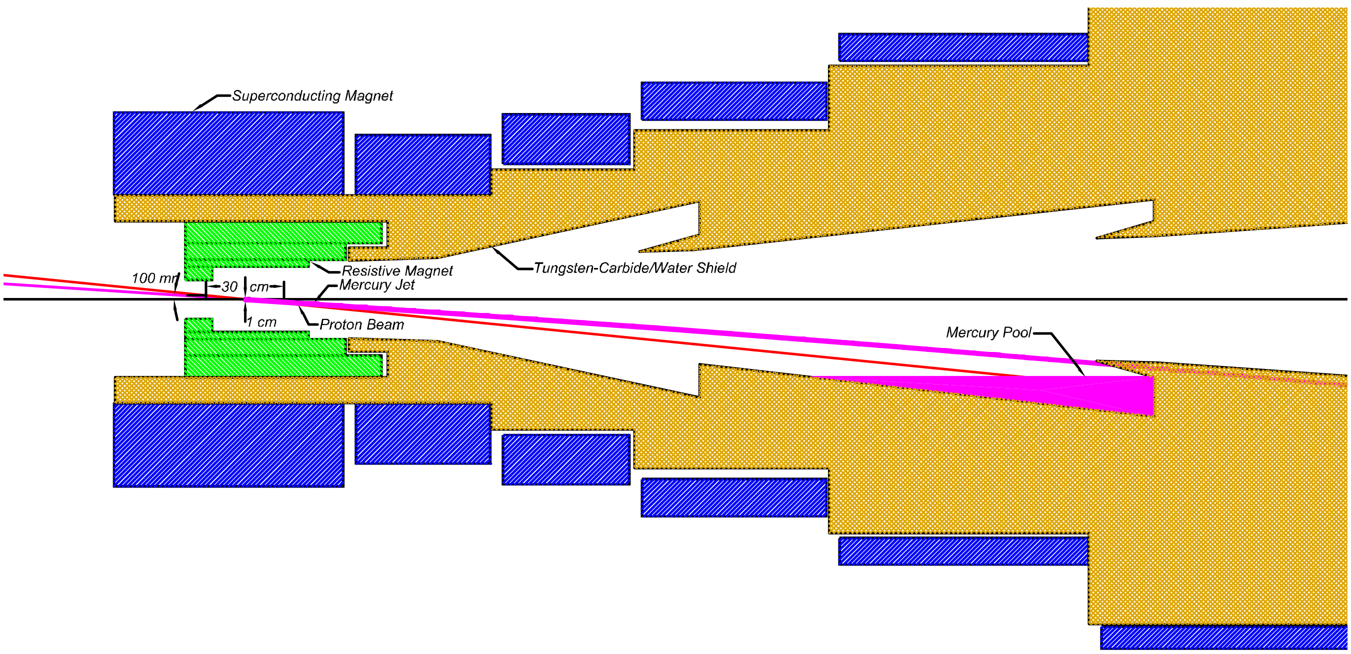


After the 20 T magnet, coils are designed to taper the axial field down slowly to 1.25 T over a distance of approximately 18 m. The form of the tapered field is approximately $B(z) \approx 20/(1 + k\, z)$. The final design will have to include space for the beam dump and shielding.

Feasibility Study 2, Issues

Beam Dump

The proton beam is dumped, and the mercury jet collected, several meters downstream of the interaction region:



Agenda, Feasibility Study 2 Workshop, Dec. 16

Phase Rotation

08:30-08:55	L. Reginato (LBNL)	Induction Linac: Baseline Design
08:55-09:20	Y. Fukui (UCLA)	Option C Modifications

Target Station and Decay Channel

09:20-09:45	P. Spampinato (ORNL)	Decay Channel Systems Issues
09:45-10:10	N. Mokhov (FNAL)	Prompt & Residual Radiation Environment
10:10-10:30	Coffee Break	
10:30-10:55	H. Ravn (CERN)	Targetry R&D at CERN
10:55-11:20	J. Haines (ORNL)	Mercury Target Issues
11:20-11:45	J. Cline (ANL)	Radiation Chemistry of Cooling Water
11:45-13:00	Lunch	

Agenda, Feasibility Study 2 Workshop, Dec. 16, Cont'd.

	Liquid Metal Jet – Magnet Interaction	
13:00-13:25	K. McDonald (Princeton)	Review of Analytic Studies
13:25-13:50	S. Kahn (BNL)	Analytic Studies
13:50-14:15	R. Samulyak (BNL)	Numerical Studies with the Frontier Code
	20-T Solenoid – Hollow Conductor Option	
14:15-14:45	J. Miller (FSU)	Issues and Criteria
14:45-15:10	B. Weggel (BNL)	Design Concept
15:10-15:30	Coffee Break	
	Beam Simulation Issues	
15:30-15:55	I. Stumer (BNL)	GEANT Studies
15:55-16:20	Y. Torun (BNL)	Comparison with E910
	Discussion	
16:20-17:00	All	Discussion