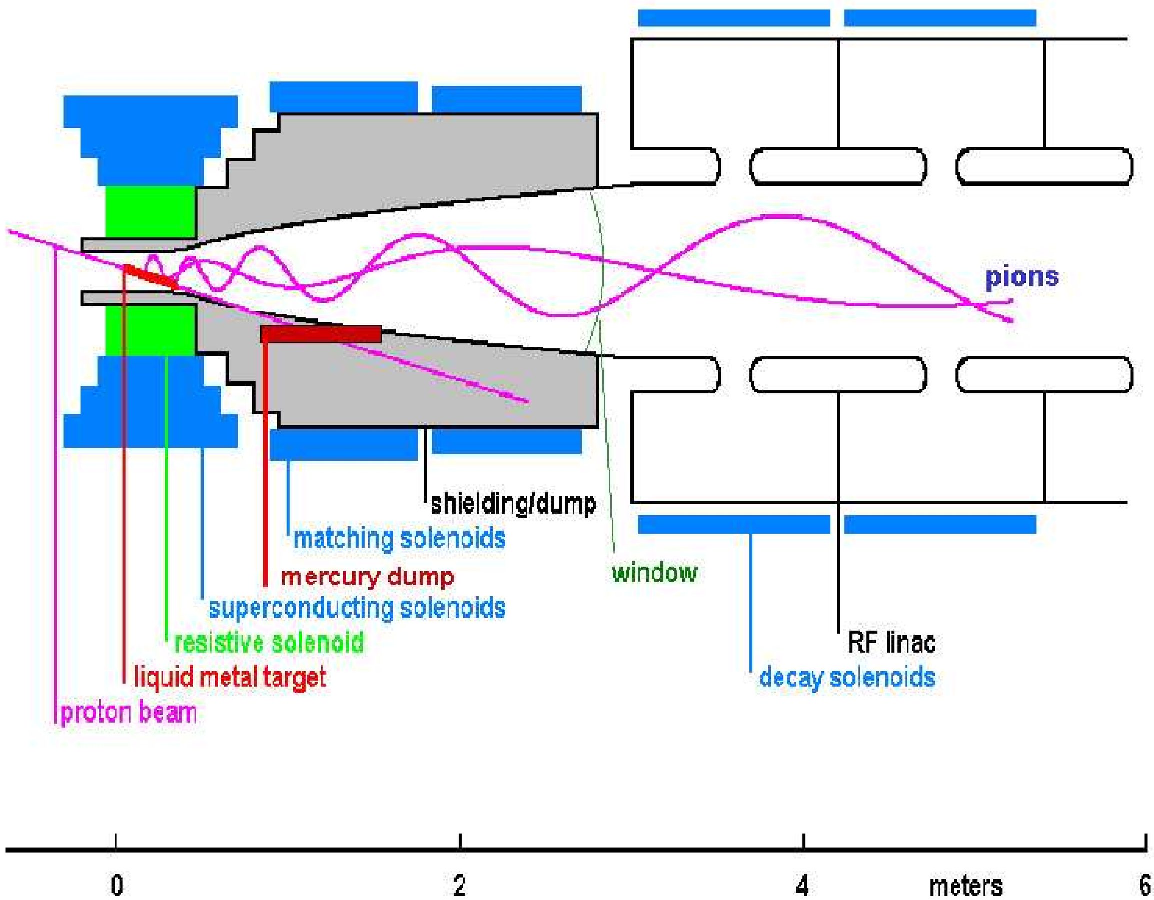
The R&D Program for Targetry and Capture at a Neutrino Factory/Muon-Collider Source



Kirk T. McDonald

Princeton U.

Workshop for a Feasibility Study of a Neutrino Source

Based on a Muon Storage Ring

Fermilab, February, 15, 2000

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

The Opportunity of a Neutrino Factory

- The next generation of neutrino experiments will firm up present indications of couplings of pairs of neutrinos – but will not explore simultaneous effects of 3 neutrinos.
- Many of the neutrino oscillation solutions permit complete study of the couplings between 3 (4?) neutrinos at a neutrino factory.
- But, $> 10^{21}$ ν's/year are needed for this!
- A neutrino factory is a path to a muon collider.

However, there are at present too many explanations of neutrino oscillation data to define an optimal parameter set for a neutrino factory: energy, distance to remote detectors....

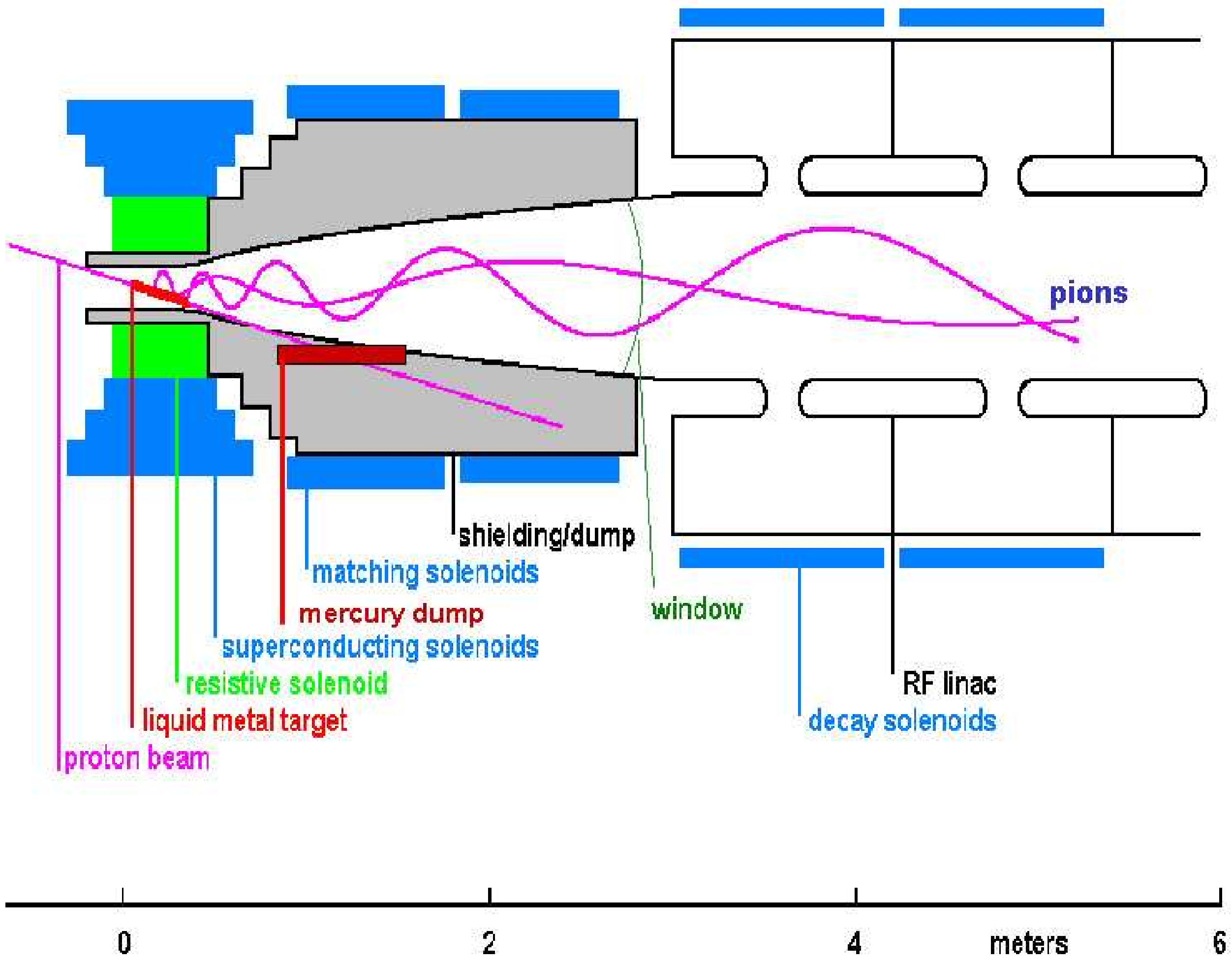
It will take several years for the physics to be clarified enough to make a wise choice of parameters for an initial neutrino factory.

These facts afford both an opportunity and a need for an ambitious R&D program.

We Need a High Performance Source

- We need lots of protons: several megawatts desired, perhaps only 1 MW initially.
- We need to maximize the yield of ν's, and hence μ's per proton.
- For advanced neutrino studies (ν_e in final state), and for a muon collider, we desire controlled muon polarization.
- High yield seems best accomplished in a solenoidal capture system with a dense target and little support structure.
- Solid targets extremely marginal in multimegawatt beams with 10^8 cycles/year.
- A "disposable" target may be preferable; use once and throw away.
- $\Rightarrow$ Mercury jet target.
- Maximal capture + polarization control
  $\Rightarrow$ High-gradient, low-frequency rf close to target.

The Baseline Targetry/Capture Scenario



Choices:

- Liquid or solid target?
- Phase rotation or drift after target?

High performance neutrino factory and muon collider favor the first choices.

May be expedient to start with the second choices.

Two Classes of Issues

1. Viability of targetry and capture for a single pulse.
   - Effect of pressure wave induced in target by the proton pulse.
   - Interaction of a moving metal target with the solenoid field.
   - Operation of the first rf cavity in a magnetic field and in large particle flux.
2. Long-term viability of the system in a high radiation area.

   [Issues for solid target & magnet coils are of this type.]

The most novel issues (1) are addressable in studies with low rep. rate but a large number of protons/pulse (up to 10^{14} $p$pp in BNL E951).

Long-term issues, including solid targets, may require study in a high-rep.-rate, high-average-power beam (Los Alamos Spallation Radiation Damage Facility, 0.8 MW, 20 Hz; a DOE Category 3 Nuclear Facility).

R&D Goals

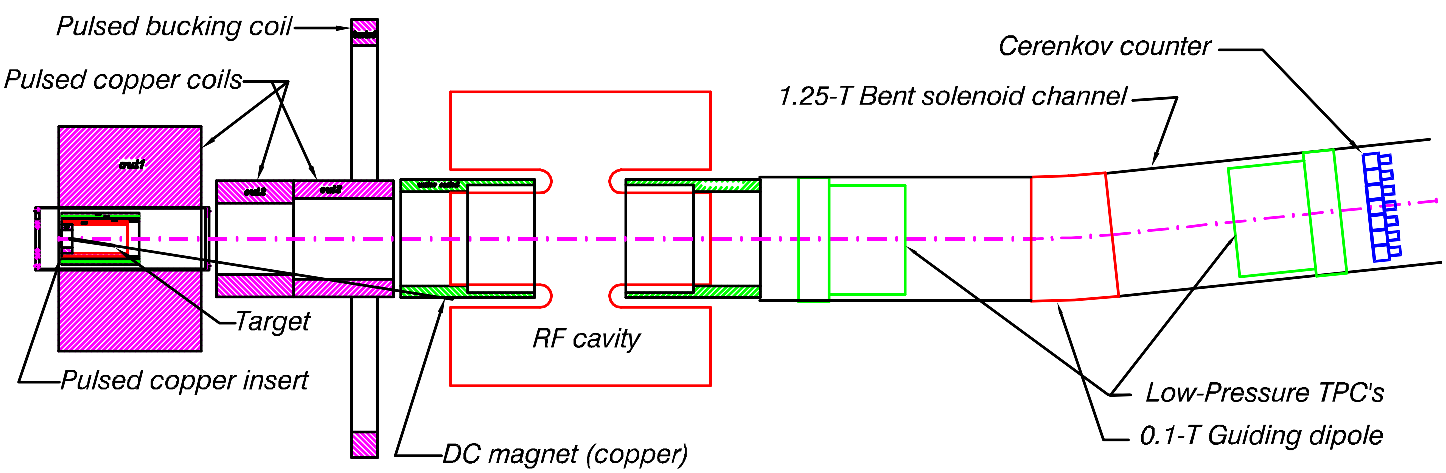
1. Single pulse studies (BNL E951).

   Overall: Test key components of the front-end of a neutrino factory in realistic single-pulse beam conditions.

   Near Term (1-2 years): Explore viability of a liquid metal jet target in intense, short proton pulses and (separately) in strong magnetic fields.

   (Change target technology if encounter severe difficulties.)

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



2. Long Term Survivability

Define needed R&D program during 2nd half of FY00.

Example: survival of a carbon target (Sam Childress):

- Cylindrical geometry focuses reflected pressure wave to very high values on axis, even for diffuse energy deposition.
- 10-100 J/gm/pulse, $> 10^8$ pulse/year, $\Rightarrow > 10^5$ eV/atom/yr.
- $\Rightarrow$ Every interatomic bond broken $\gtrsim 10^3$ times/year.
- 4 MW $\Rightarrow 10^{22}$ p/year $\approx$ 30 dpa/year.
- Graphite lifetime is about 10 dpa.

90% of beam energy deposited in the liner of the superconducting magnets. (Nikolai Mokhov)

Is a solid liner viable; should the beam hit a mercury pool?

Are the superconducting coils viable? (Al Zeller)

We must operate a high-radiation facility. (Phil Spampinato)

E951 Schedule

- FY99:
  Prepare A3 area;
  Begin work on liquid jets, magnet systems, and rf systems.
- FY00:
  Complete A3 line;
  Continue work on magnet and rf systems;
  Begin work on extraction upgrade.
- FY01:
  First test of targets in A3;
  Liquid jet test in 20-T magnet at NHMFL;
  Continue work on extraction magnet and rf systems.
- FY02:
  Complete extraction upgrade, magnet and rf systems;
  Test targets with 10^{14} *p*pp;
  Begin work on pion yield diagnostics;
  Option to study mercury dump in vertically pitched beam.
- FY03:
  Beams tests of target + 20-T pulsed magnet + rf cavity;
  Complete pion detectors; test yield with low intensity SEB.

Targetry/Capture R&D Summary

- Continue the BNL E951 R&D program on issues of intense single pulses.

  1. Activate R&D with industry into a high-power, low-frequency source.

- Expand R&D into long-term issues.

  1. Evaluate radiation hardness of target materials.
     Perform experiments if present data insufficient.
     Coordinate with design of 20-T magnet/dump.
  2. Evaluate the radionucleide inventory for various targetry scenarios.
     Can we stay below threshold for a Category 3 Nuclear Facility?
  3. Extend studies of systems issues of the target station.
     How much remote handling? How frequently?...
  4. Conduct tests as necessary in a high-power beam, such as the 1-MW Spallation Radiation Damage Facility at LANL.