

FY13 MAP Technology Development: Target and Absorbers Summary

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Chapter 1

Technology Development Summary

1.0.1 Target and Absorbers Overview

The Target and Absorbers Task is to document the technical feasibility of the Target System for a Muon Collider and/or Neutrino Factory. The Target System includes the target itself as well as the surrounding solenoid magnets and their internal shielding, which latter absorbs most of the proton beam power in the form of secondary particles.

In the larger sense, the Target System extends to the end of the Decay Channel in that the latter will absorb a significant fraction of the beam power, which requires magnets with internal shielding using the same technology as for magnets closer to the target.

FY13 Activities

FY13 saw a transition from a Target System based on a 20-T capture solenoid with a 5-T resistive coil insert (Fig. 1.1(left)) to one based on a 15-T solenoid and no resistive insert (Fig. 1.1(right)), as the latter is much more buildable (and compatible with a 3-GeV, 1-MW proton beam in an initial Stage of a Muon Collider). The 20-T option is formally the baseline for the IDS-NF RDR.

1. Beam/Target Optimization

As rather low energy muons are needed for a Muon Collider, it is favorable to use long, thin targets from which particles of interest exit the “sides.” It is then favorable that the target be tilted with respect to the secondary beam axis to minimize reabsorption in the target. Since the target is inside a magnetic field, which deflects the incident proton beam, optimization of the geometry of the incident beam and target is intricate, and must be performed separately for all possible beam energies.

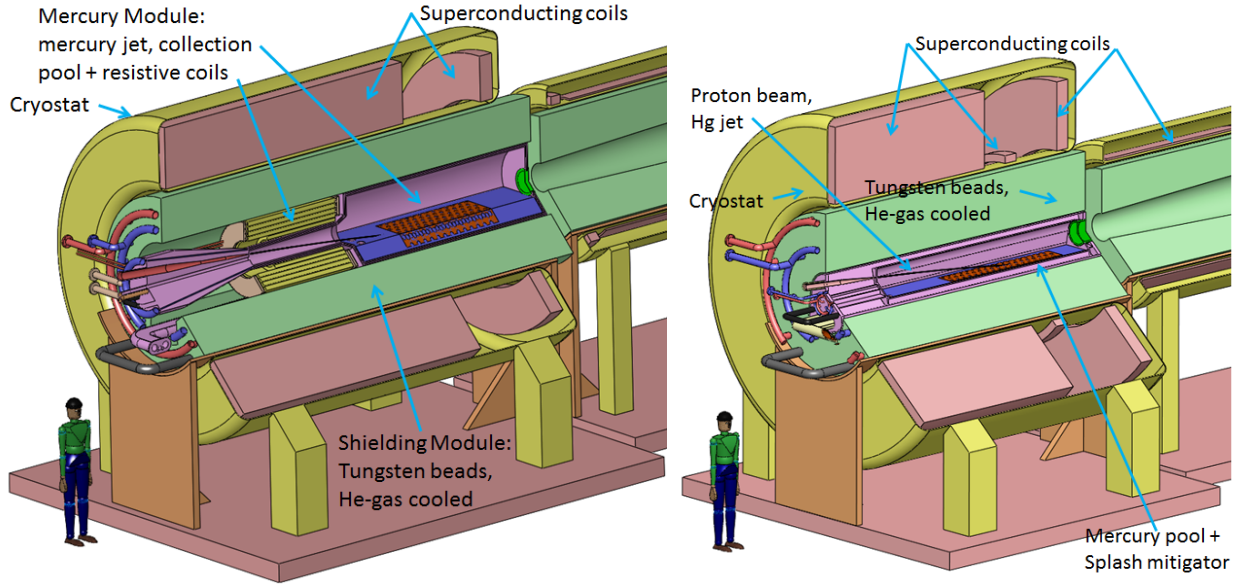


Figure 1.1: Concepts of target systems with a 20-T solenoid (left) and 15-T solenoid (right).

This optimization is performed using the MARS15 code (and occasionally checked against the FLUKA code).

Optimization for 8-GeV proton beams was completed in FY13, and work has begun for 3 GeV (where the particle production models are less robust).

2. Target System/Front End Global Optimization

An important development in FT13 was the understanding that the longitudinal-transverse emittance exchange performed by the “tapering” field in the Target System (from 15-30-T peak down to ≈ 1.5 in the subsequent Decay Channel) affects the Buncher, and that a shorter field taper is preferred, as illustrated in Fig. 1.2. A consequence is that the Target System effort needs to include participation in the global optimizations being carried out in the Front End Design and Simulations group.

3. Energy-Deposition Simulations

FY13 saw the completion of the energy-deposition studies in the nominal Target System, which studies have identified the minimum configuration of shielding of the superconducting coils against radiation damage. The figure of merit here is that the energy deposition be everywhere less than 0.1 mW/g to permit a 10-year operational lifetime (the so-called ITER limit).

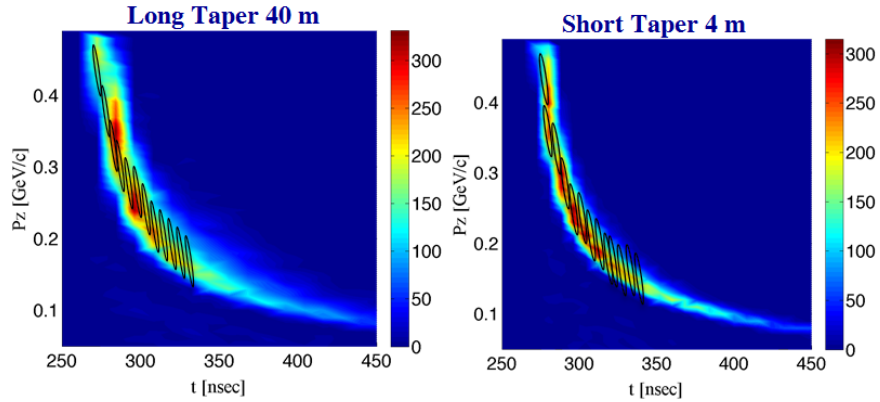


Figure 1.2: Longitudinal phase-space distributions at the beginning of the Buncher for long and short tapers in the Target System, overlaid with the acceptance of the Buncher.

About 10% of the proton beam energy is transported into the Decay Channel, and most of this energy would be transported into the subsequent Buncher and Phase Rotator if it were not somehow removed from the nominal muon beam. The Front End group proposes a chicane (+ Be absorber, (Fig. 1.3(left)) to mitigate this issue. Studies of energy deposition in the Decay Channel magnets (Fig. 1.3(right)) were begun in FY13, and need to be continued in FY14.

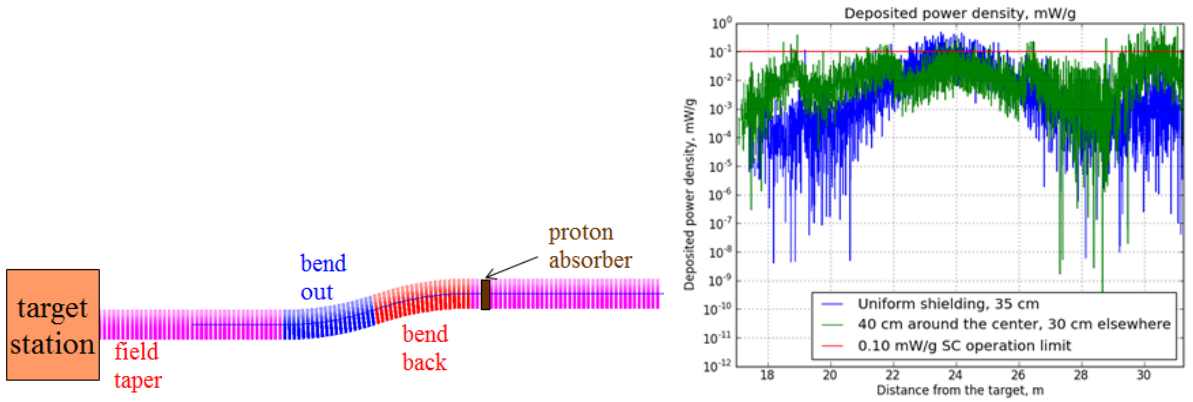


Figure 1.3: Decay Channel with chicane (left), and a preliminary study of energy deposition in the chicane magnets (right).

4. Magnet Conceptual Design

The evolution of the coil configurations of the Target System (and beginning of the

Decay Channel) for a 15-T capture solenoid followed by a shorter “taper” is illustrated in Fig. 1.4.

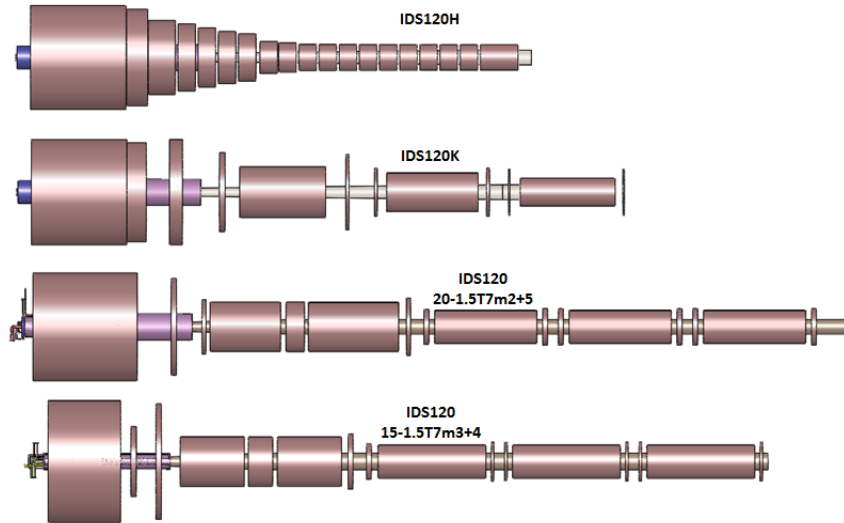


Figure 1.4: Four versions of the Target System magnets. The “taper” is clearest in the topmost version.

5. Target-Handling-System Design

Only rather preliminary efforts have been made on the design of the mercury-handling system (for options with a mercury target). Some of this effort is visible in Fig. 1.1.

If a first stage of a Muon Collider does not use a mercury target, but is to be upgradeable to one later, some of the interconnection infrastructure for an eventual liquid target must be installed initially.

6. Beam/Liquid Jet Interaction Simulations

Simulations of the disruption of a liquid mercury jet by a proton beam inside a magnetic field were originally beyond the state of the art in magnetohydrodynamics, but advances in such simulations are reaching the point of good representation of the complex physical processes involved, as illustrated in Fig. 1.5.

7. Liquid-Jet Nozzle Simulations

The poor quality of the free mercury jets in the CERN MERIT experiment has sensitized use to issues of nozzle design. A simulation effort is underway, beginning with the turbulent flow in the pipe leading to the nozzle, and then of the free jet which emerges from the nozzle. In FY13 the simulation of the turbulent pipe flow

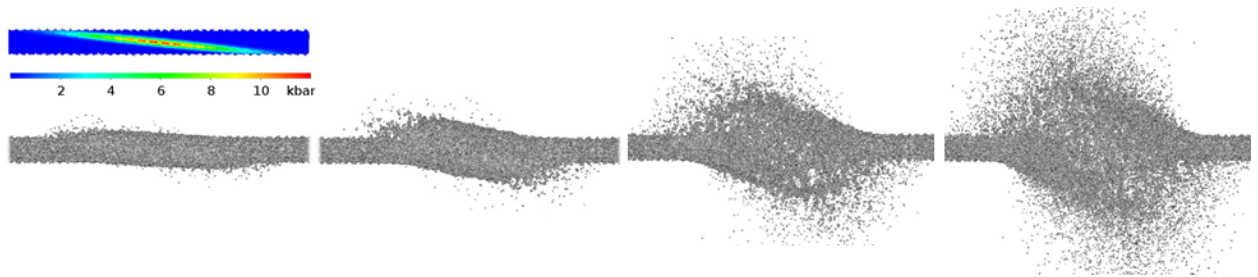


Figure 1.5: Numerical simulations of the interaction of a 1-cm-diameter mercury jet with a proton beam incident at an angle.

was completed, including the effect of perturbations due to weld beads some 10 cm upstream of the nozzle, as illustrated in Fig. 1.6. Work is underway to validate the codes updates to simulate a free liquid jet.

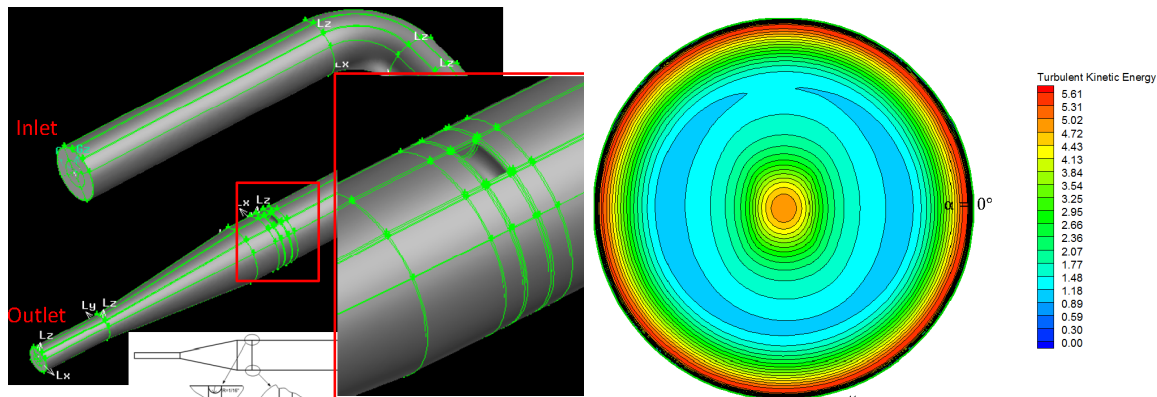


Figure 1.6: The model for the nozzle of the MERIT experiment, including a weld-bead perturbation (left), and results of the simulation at the nozzle exit that indicate the effect of the perturbation is largely damped there.

8. Final-Focus Interface

A first look at the interface between an 8-GeV proton beam and the Target System was made in FY13. The proton beam transport is sketched in the left of Fig. 1.6, and candidate final-focus optics are sketched in the right figure.

The more challenging case of a 3-GeV proton beam, possibly requiring multiple beams to maintain sufficiently small beam emittance, needs to be addressed in FY14.

9. IDS-NF Reference Design Report (RDR)

A section describing the Target System was contributed to the IDS-NF RDR.

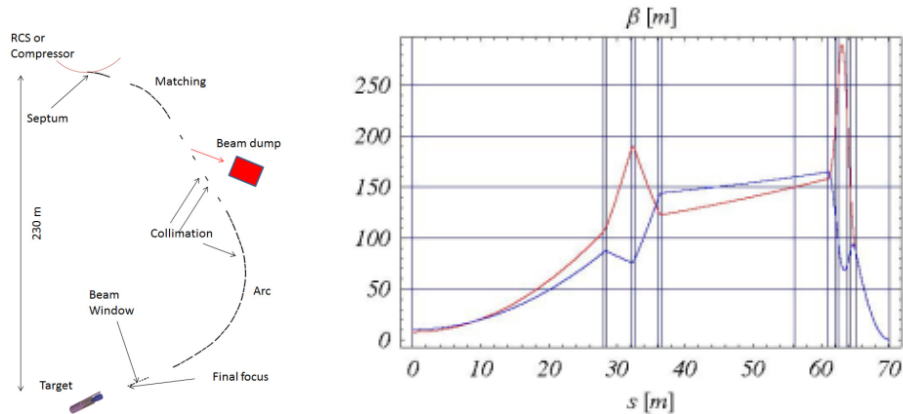


Figure 1.7: Left: An 8-GeV proton beam scenario; right: candidate optics for the final-focus quadrupole triplet.

FY13 Deliverables and Status The effort on Targets and Absorbers in FY13 was entirely in design and simulation. The most tangible deliverables have been 12 papers presented at IPA13 and NAPAC13, and a section to the IDS-RDR.

1. IPAC13: TUPFI067, *Energy Deposition and Shielding Study of the Front End for the Neutrino Factory*, P. Snopok *et al.*
2. IPAC13: TUPFI069, *Influence of Proton Beam Emittances on Particle Production off a Muon Collider Target*, X. Ding *et al.*
3. IPAC13: TUPFI073, *Design of Magnets for the Target and Decay Region of a Muon Collider/Neutrino Factory*, R.J. Weggel *et al.*
4. IPAC13: TUPFI074, *Design of the Final Focus of the Proton Beam for a Neutrino Factory*, J. Pasternak *et al.*
5. IPAC13: TUPFI075, *Optimizing Muon Capture and Transport for a Neutrino Factory/Muon Collider Front End*, H.K. Sayed *et al.*
6. IPAC13: THPFI092, *Design of the Mercury Handling System for a Neutrino Factory/Muon Collider Target*, V.B. Graves *et al.*
7. NAPAC13: TUPBA09, *Simulation of High Power Mercury Jet Targets for Neutrino Factory and Muon Collider*, R. Samulyak *et al.*
8. NAPAC13: TUPBA10, *Impact of the Initial Proton Bunch Length on the Performance of the Muon Front End*, H.K. Sayed *et al.*

9. NAPAC13: TUPBA11, *Towards a Global Optimization of the Muon Accelerator Front End*, H.K. Sayed *et al.*
10. NAPAC13: THPHO11, *Optimization of the Capture Section of a Staged Neutrino Factory*, H.K. Sayed *et al.*
11. NAPAC13: THPMA10, *Energy Deposition in Magnets and Shielding of the Target System of a Staged Neutrino Factory*, P. Snopok *et al.*
12. NAPAC13: THPMA11, *Optimization of Particle Production for a Staged Neutrino Factory*, X. Ding *et al.*
13. *The Target System*, sec. for the IDS-NF RDR,
http://www.hep.princeton.edu/~mcdonald/mumu/target/IDS-NF/RDR/IDS-NF-RDR_target_system.pdf

FY13 Participants

List of activities and participants, by institution.

| Activity | Institution | Participants |
|---|--------------------|--|
| L2 Management | Princeton | K.T. McDonald |
| Beam/Target Optimization | UCLA | X. Ding (+ H.G. Kirk, BNL, J. Back, Warwick) |
| Target System/Front End Global Optimization | BNL | H.K. Sayed, H.G. Kirk |
| Energy-Deposition Simulations | PBL | N. Souchlas (+ P. Snopok, IIT) |
| Magnet Conceptual Design | PBL | R.J. Weggel |
| Target-Handling-System Design | ORNL | V.B.Graves |
| Beam/Liquid Jet Interaction Simulations | SUNY Stony Brook | R.V. Samulyak |
| Liquid-Jet Nozzle Simulations | SUNY Stony Brook | F. Ladiende, Y. Zhan |
| Final-Focus Interface | (Imperial College) | (J. Pasternak) |

FY13 Summary

Conceptual designs for a Target System for an 8-GeV, 4-MW Muon Collider were largely completed in FY13, and work has begun on a 3-GeV, 1-MW scenario.

FY14 Plans

The major emphasis of effort on Targets and Absorbers in FY14 will be development of a scenario for an initial stage of a Muon Collider with a proton beam of 3-GeV kinetic energy and 1-MW beam power, such that the initial Target System can be upgraded to eventual operation at 4-MW, perhaps with an 8-GeV proton beam.