Fermilab

Muon Collider R&D Plans & New Initiative

Steve Geer

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INTRODUCTION

- Since 1997, Fermilab has been one of the 3 lead laboratories (with BNL & LBNL) in the Neutrino Factory & Muon Collider R&D Collaboration (NFMCC).

- The muon cooling channel has emerged as the key challenge for a Muon Collider. For several years the NFMCC struggled to produce a viable concept for a complete MC cooling channel, although we succeeded with the much less demanding NF cooling channel.

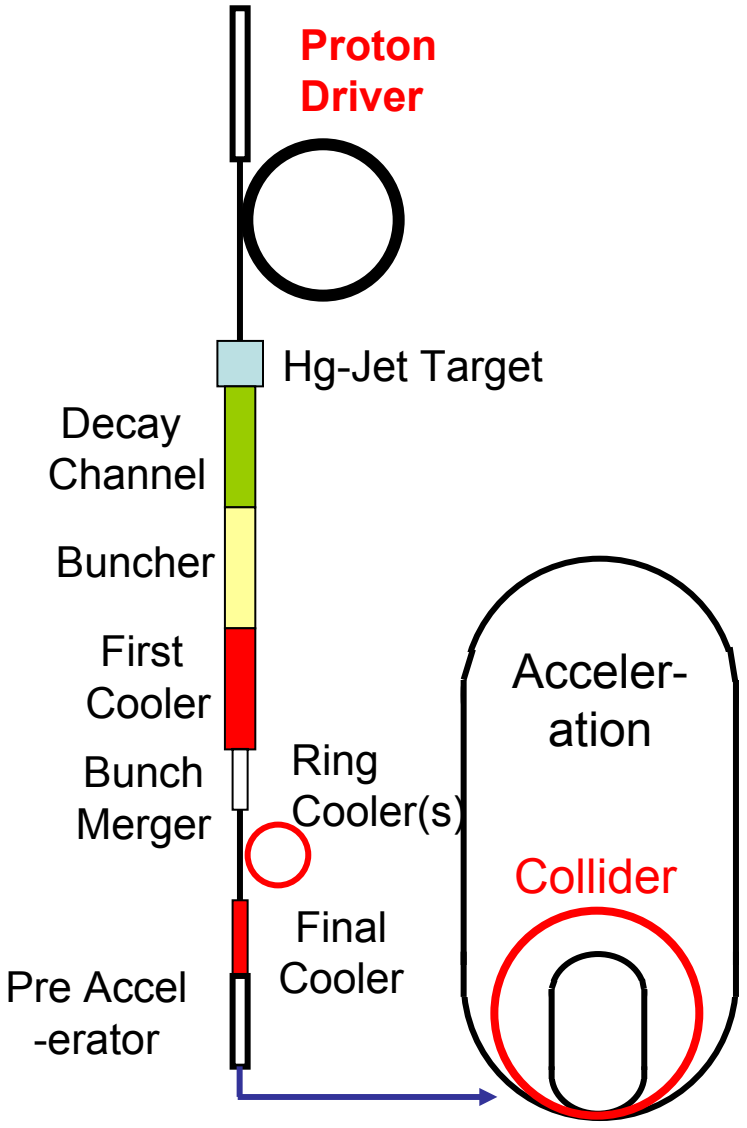
- In last 2 years the NFMCC & Muons Inc. have made a conceptual break-through with MC cooling channel ideas, & new cooling channel component concepts. Also, lots of progress on front-end R&D common to NF & MC.

- We now need an enhanced effort to (i) revisit overall MC design, (ii) ramp up MC cooling channel R&D to see which of the several technical options are viable, & whether we can achieve the required performance.

- The Director has requested the creation of a Muon Collider R&D Task Force & preparation of a proposal for Muon Collider R&D at Fermilab.

MUON COLLIDER SCHEMATIC

- Proton Driver (e.g. HINS)
- Target, Capture, and Decay
  - create π; decay into μ
- Bunching & Phase Rotation
  - reduce ΔE of bunch
- Cooling
  - reduce 6D emittance
- Acceleration
  - 130 MeV $\rightarrow$ up to 1.5 TeV
- Storage Ring
  - store for ~1000 turns
  - One IP

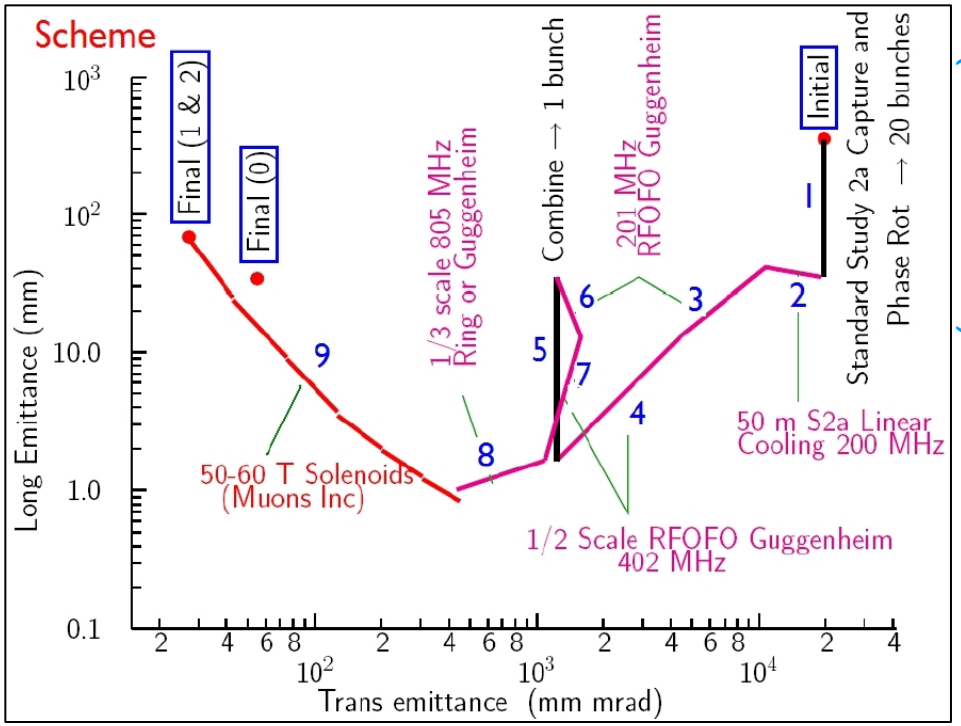


CONCEPTUAL BREAKTHROUGH

- Want to end up with 1 or 2 muon bunches / cycle to maximize luminosity. Old concept: make 1 bunch at the beginning & keep hold of it through the entire front-end → requires low frequency rf systems. We did not succeed in producing a practical, self-consistent cooling channel that reduced the emittance by the required factor of O(10^6).

- In the last 2 years it has been realized that it is easier to start with many bunches, & combine them in the middle of the cooling scheme → first complete self-consistent MC cooling channel designs.

- The MC & NF front-ends (up to the beginning of the cooling) are now the same !



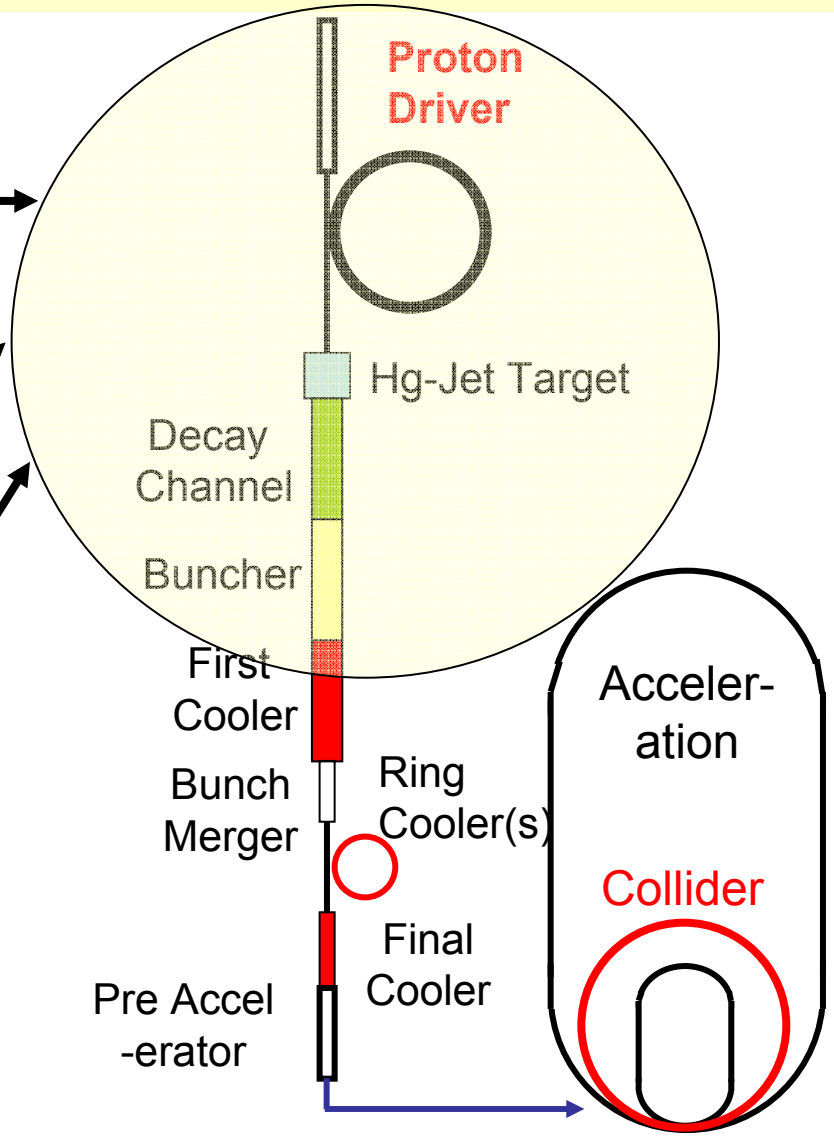
(Palmer et al)

IMPLICATIONS: NF vs MC R&D

IDENTICAL FOR NEUTRINO FACTORIES & MUON COLLIDERS

R&D HAS BEEN GLOBALIZED & IS WELL ADVANCED

R&D EXPECTED TO BE COMPLETED BY ~ 2010-2012

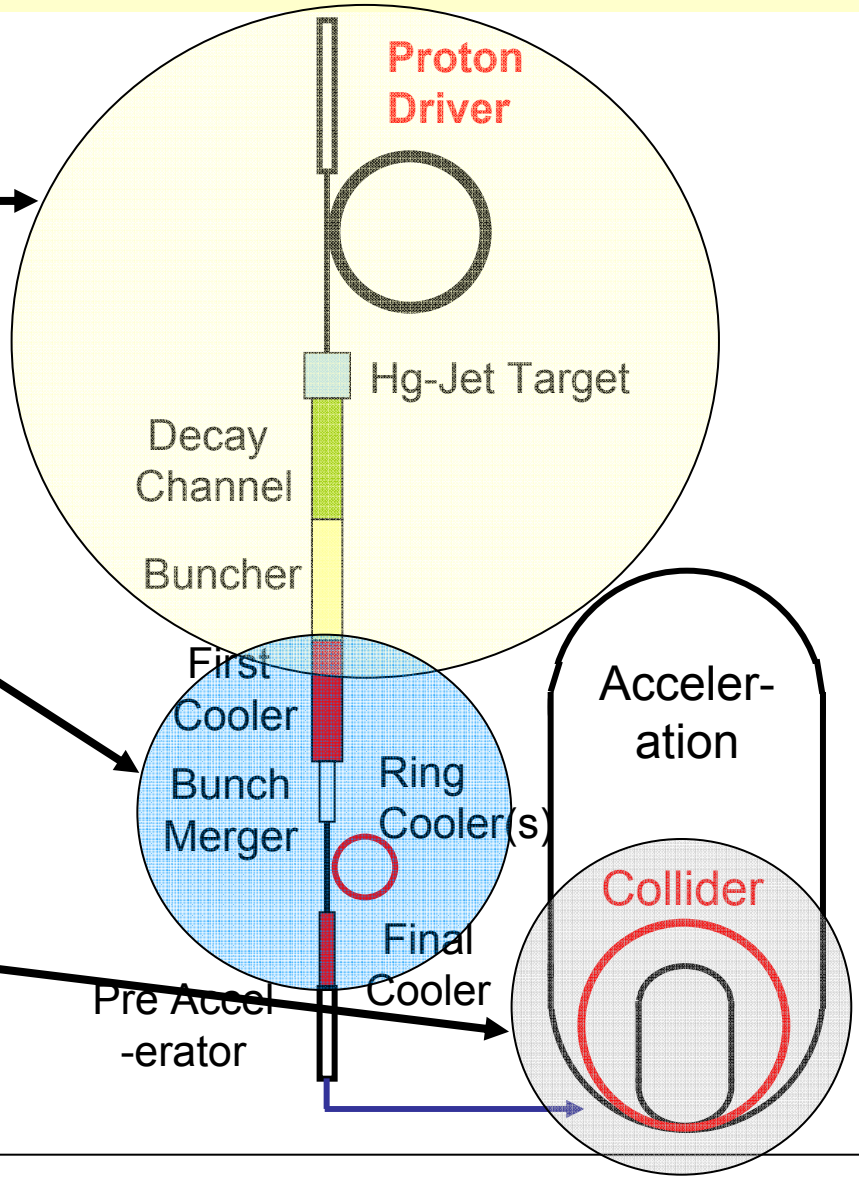


IMPLICATIONS: MC R&D at FERMILAB

IDENTICAL FOR NEUTRINO FACTORIES & MUON COLLIDERS

MUCOOL R&D (Hosted by Fermilab) FOCUSED ON COOLING CHANNEL TECHNOLOGY

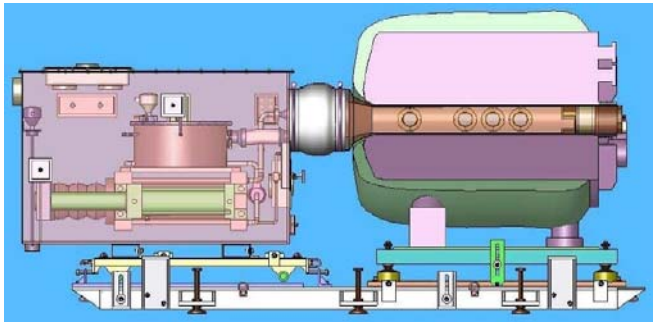
Lots of Collider Lattice Expertise



ONGOING FRONT-END R&D
(Common to Neutrino Factories and Muon Colliders)

- MERIT: International Target Experiment

Location: CERN
Run Date: Late 2007
Goal: Test Hg-jet injected into 15T solenoid with high intensity proton beam.

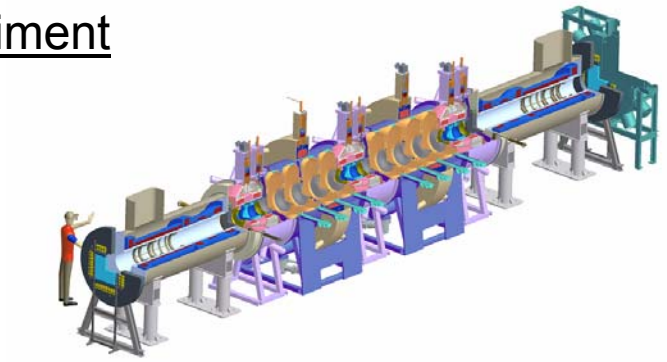


- MUCOOL: Cooling channel component prototyping & testing

Location: Fermilab
Run Date: Ongoing
Goal: Develop & bench test all components for muon cooling channels.

- MICE: International Muon Coolong Experiment

Location: RAL
Run Date: Phase 1 Starts Late 2007
Goal: Test short cooling channel section in a muon beam



MUON COLLIDER TASK FORCE

- In July 2006, the Fermilab Director requested a Task Force be formed to develop an R&D plan aimed at the technologies needed for a Muon Collider.

- The first short-term goal for the task force was to prepare an R&D proposal… first version was completed end-September.

- The next task is to begin to execute the R&D plan … as resources permit.

- We are proposing to pursue this R&D in collaboration with groups from the NFMCC, Muons Inc., LBNL, BNL, ANL, JLAB.

CHARGE COVER LETTER

July 12, 2006

To: Vladimir Shiltsev and Steve Geer

From : Pier Oddone

Subject: Muon Collider Task Force

I would like to ask the two of you to form and lead a Task Force to develop a plan for an advanced R&D program aimed at the technologies required to support the long term prospects of a Muon Collider. In doing so I would ask that you operate in consideration of the attached charge, taking special note of the deliverables requested for September 2006: A report outlining a plan for developing the Muon Collider concept based on recent ideas in the realm of ionization cooling, and an associated cooling R&D plan that can be implemented starting in FY2007. Following receipt of this report I will expect to initiate the Muon Collider study, including the associated cooling channel study and development program, in 2007.

The Muon Collider represents a possible long term path for extending the energy frontier in lepton collisions beyond 1 TeV. It is important to establish the possibilities and to outline the R&D program that will be necessary to develop the underlying technology base. I look forward to working with you to formulate and execute a plan to explore these possibilities and to provide options for Fermilab and the world HEP program in the future.

COLLABORATION

Muon Collider
Advanced Accelerator R&D Proposal

FNAL:
C.Ankenbrandt, Y.Alexahin, V.Balbekov, E.Barzi, C.Bhat, D.Brommelsiek, A.Bross, A.Burov, A.Drozhdin, D.Finley, S.Geer[1], N.Gelfand, E.Gianfelice-Wendt, M.Hu, A.Jansson, C.Johnstone, J.Johnstone, Vl.Kashikhin, V.Kashikhin, M.Lamm, V.Lebedev, N.Mokhov, C.Moore, A.Moretti, D.Neuffer, K.-Y.Ng, M.Popovich, I.Rakhno, V.Shiltsev[1], P.Spentzouris, A.Striganov, A.Tollestrup, A.Valishev, A.Van Ginneken, A. Zlobin.

MuonsInc:
R.Johnson[2], M.Cummings, S.Kahn, T.Roberts, K.Yonehara

BNL:
J.S.Berg, R.Gupta, H.Kirk, R.Palmer[3], R.Fernow, P.Wanderer

LBNL:
G. Sabbi[4], P.Ferracin, S.Caspi, M.Zisman

JLAB:
K.Beard, A.Bogacz, Y.-C.Chao, Y.Derbenev, B.Rimmer

ANL:
J.Norem

TASK FORCE
35 members

MUONS INC.
5 collaborators

BNL
6 collaborators

LBNL
4 collaborators

ANL
1 collaborator

Note: membership has healthy overlap with NFMCC

PROPOSED ACTIVITIES

The plan focuses on revisiting the overall Muon Collider design, and on developing and testing the cooling channel components that are needed (beyond those needed for a Neutrino Factory).

1. Muon Collider Design and Simulations
   - to establish the required cooling parameters.

2. Component Development.
   - Helical Magnets (Muons Inc. concept)
   - HTS High-Field Solenoids (NFMCC & Muons Inc Designs)
   - Pressurized rf Cavities (Muons Inc. concept)

3. Beam tests and Experiments.
   - High Intensity proton beam tests
   - Muon beam tests

ORGANIZATION

Task Force Leaders: V. Shiltsev, S. Geer

Sub-Task Leaders:
Muon Collider Design Studies: Y. Alexahin
Magnet Development: M. Lamm
Beam Tests and Experiments: A. Jansson

Contacts:
ANL: J. Norem
BNL: R. Palmer
JLAB: ???
LBNL: ???
Muons Inc: R. Johnson

Web Page: https://plone4.fnal.gov/P0/MCTF.

PROPOSED R&D PLAN

- We have an initial plan (assuming instantaneous support at requested level):

FY07:	a) initial design report for a 1.5 TeV low emittance muon collider; b) MTA high power proton beam implementation plan; c) HTS material studies report and development plan for a very high-field solenoid for muon cooling; d) HCC design and utility report, decision to prototype;
FY08:	a) pressurized RF cavity and absorber tests in the MTA with high-intensity proton beam; b) development and installation of muon target, transport line and diagnostics in MTA; c) 5T HTS insert built and tested at 15T and test report; d) HCC and matching sections design finished, prototypes built;
FY09:	a) muon beam commissioned, start of muon diagnostics tests; b) HCC magnets construction starts; c) 50T HTSC solenoid engineering design finished;
FY10:	a) HCC magnets competed and 6D cooling experiment starts; b) high-field HTSC solenoid prototype built. c) Muon Collider cooling channel report

- We will need to update the plan once the level of support is known.

- We will also need to revise the plan after the first year of studies, once we have better evaluated component issues and R&D costs.

REQUESTED SUPPORT

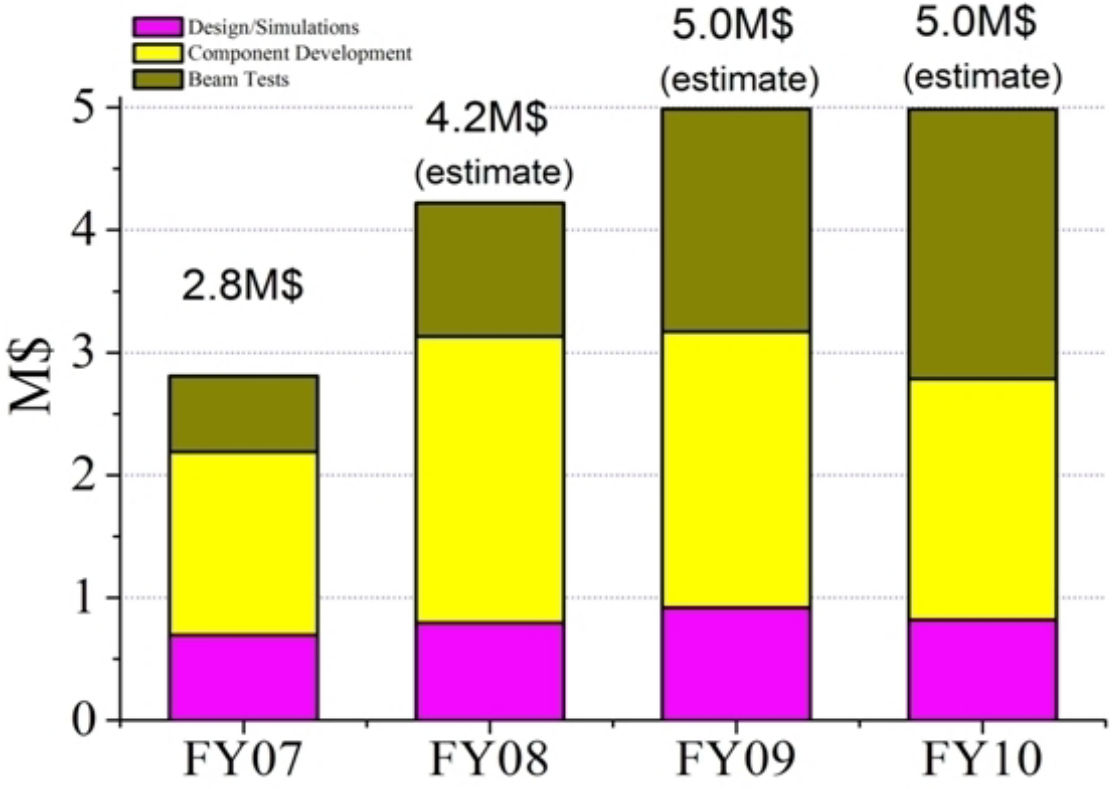


Figure 5: Estimated Muon Collider AARD budget profile.

ESTIMATE CORRESPONDING TO INITIAL PLAN

SUMMARY

- Progress in cooling channel ideas motivate an enhanced push on Muon Collider R&D.

- The Fermilab Director has requested formation of a Muon Collider R&D Task Force & preparation of an appropriate R&D proposal.

- We are proposing to revisit the overall Muon Collider design (in the light of recent progress) to re-establish the cooling channel requirements, and to develop and test the various new cooling channel component concepts to see which are viable and whether they can meet the required performance.

- We believe the scope of the require R&D corresponds to about 5M$/year for a number of years … the estimate needs to be revised after the first year of activity.

- The deliverable would be a complete MC cooling channel design together with prototype cooling channel components tested on the bench and in a beam.

PROPOSED ACTIVITIES

1. Collider Design and Simulations to establish the muon cooling requirements: Given the recent progress on Muon Collider cooling channel design, proton driver designs, target R&D, and the MUCOOL and MICE programs, we will take a fresh look at the overall Muon Collider scheme. In addition to establishing the ionization cooling requirements, we will also identify the remaining muon source and collider design and performance issues.

2. Component Development: We will develop and bench test the components needed for the 6D cooling channel. In particular, we propose hardware R&D plan to prototype and test Helical Cooling Channel magnets, very high field HTS solenoids and pressurized RF cavities for the cooling channel. This hardware R&D is essential to guide further Muon Collider design studies.

3. Beam Tests and Experiments: We will perform beam tests of the components. For that we will build a proton beam line for high-intensity tests of LiH absorbers and pressurized RF cavities. Later, we will design and build a muon production, collection and transport system. 250-300 MeV/c muons will be used in the 6D ionization cooling demonstration experiment.

CHARGE- page 1

Muon Collider Task Force Charge

1. Introduction

The Muon Collider represents a potential long term path to lepton-lepton collisions at center-of-mass energies beyond 1 TeV. Recent progress in 6-dimensional (6D) muon cooling concepts hold promise for preparing an intense muon beam with an emittance small enough for acceleration and injection into a Muon Collider. Several new, innovative, cooling ideas deserve evaluation to (i) identify which ideas are the most promising, (ii) identify the main technical questions that must be addressed before a 6D cooling channel could be built, and (iii) formulate the R&D path that is needed for their development. In addition, a fresh look at a Muon Collider design by accelerator experts would establish the ionization cooling requirements, and identify the remaining muon source and collider design and performance issues.

2. Charge

i) **Cooling Channel and Collider Design Concept**.
Taking into account recent developments in muon cooling ideas, develop a plan to form a design and simulation study group that will develop a coherent concept for a Muon Collider with a center-of-mass energy of 1.5 TeV, based upon a low emittance parameter set. The group's focus should be to outline the general scheme, the parameter choices, and the 6D ionization cooling channel requirements to support a usable luminosity, and in addition identify the primary design challenges beyond the 6D cooling systems. Progress should be documented in reports in September 2007 and September 2008. The initial plan for creating the study group should include an estimate of the required Fermilab effort and the expected contributions from outside of Fermilab, and should be documented in a brief report in September 2006.

CHARGE- page 2

ii) **Cooling Channel R&D**.
Prepare a one year study plan to (a) evaluate the technical feasibility of the components (rf cavities, magnets, absorbers, etc) needed for a muon collider class 6D cooling channel as identified in i), (b) identify the technical issues that must be addressed before a 6D cooling channel could be built, and (c) formulate a plan for the associated component R&D and 6D cooling tests that must be performed to establish basic viability of the cooling channel. The study plan should be documented in a short report in September 2006. The results of the one year study should be documented in a more detailed report in September 2007.

iii) **Component Development and Testing.**
(a) Prepare a plan to implement, in FY07, the beam and experimental setup required to test the high-gradient operation of a high-pressure gas-filled rf cavity operated in a multi-Tesla magnetic field and exposed to an ionizing beam. The implementation plan should be documented in a short report made available in September 2006. This plan should include a description of the measurements to be made, should be formulated in collaboration with Muons Inc, and should document the connection between these activities and charge elements i) and ii)
(b) Design, and prepare a plan to build, a helical solenoid suitable for a 6D cooling channel section test. The implementation plan should be described in a short report made available in September 2006, developed in collaboration with Muons Inc. and documenting the connection between this activity and charge elements i) and ii). A complete prototype design and fabrication plan should be described in a concise report in September 2007.
(c) Prepare an R&D plan to explore the feasibility of building a very high field (~50Tesla) high-Tc superconducting solenoid suitable for the final stages of a muon cooling channel for a Muon Collider. The R&D plan should be documented in a short report made available in September 2006, including documenting the connection between this activity and charge elements 1) and ii).