

# Muon Collider Task Force

Steve Geer

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# INTRODUCTION

- In January 2006 we began discussing with the Fermilab Director the additional R&D needed to follow up on new Muon Collider developments from Muons Inc. and the NFMCC.
- The Director wanted to enhance the AARD program centered at Fermilab, and wanted that enhanced program to focus on a  $\sqrt{s} \sim 1.5$  TeV Muon Collider.
- 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 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.”*

*From Pierre’s Charge letter*

# CHARGE LETTER

- The July 2006 letter asked Vladimir Shiltsev and SG 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 for a Muon Collider.”*

- Pier requested:

*“A report outlining a plan for developing the Muon Collider concept based on recent ideas in the realm of ionization cooling, and an associated 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.”*

# INITIAL 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: A. Bogacz

LBNL: G. Sabbi

Muons Inc: R. Johnson

Web Page: <https://mctf.fnal.gov/>

# INITIAL MEMBERSHIP

## Names on the MCTF 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<sup>1</sup>, N.Gelfand, E.Gianfelice-  
Wendt, M.Hu, A.Jansson, C.Johnstone, J.Johnstone, VI.Kashikhin,  
V.Kashikhin, M.Lamm, V.Lebedev, N.Mokhov, C.Moore, A.Moretti,  
D.Neuffer, K.-Y.Ng, M.Popovich, I.Rakhno, V.Shiltsev<sup>1</sup>, P.Spentsouris,  
A.Striganov, A.Tollestrup, A.Valishev, A.Van Ginneken, A.Zlobin.

### MuonsInc:

R.Johnson<sup>2</sup>, M.Cummings, S.Kahn, T.Roberts, K.Yonehara

### BNL:

J.S.Berg, R.Gupta, H.Kirk, R.Palmer<sup>3</sup>, R.Fernow, P.Wanderer

### LBNL:

G.Sabbi<sup>4</sup>, P.Ferracin, S.Caspi, M.Zisman

### JLAB:

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

### ANL:

J.Norem

# RELATIONSHIP WITH NFMCC

- The proposed MCTF program has been defined in partnership with some NFMCC institutions ... so we need to have a clear picture of how things get managed.

- Proposed way that groups can participate in the MCTF activities:

1. The NFMCC and its members are invited to participate in the MCTF program.
2. If the mutually agreed upon activities require MCTF resources, the resources, milestones and deliverables would be defined by an MOU between Fermilab and the NFMCC.
3. NFMCC institutions receiving support for MCTF activities would do so within the framework of the NFMCC (i.e., through the process defined in point 2).
4. Institutions participating in the MCTF that are not presently part of the NFMCC would be encouraged to join the NFMCC if this seems appropriate (decided by mutual discussion between the MCTF and NFMCC leadership).

- We want to set things up so that we strengthen the NFMCC, and do not undermine it !

# MCTF R&D PROPOSAL

- In July 2006, The Director requested an R&D plan, that could be transmitted to the DOE, by September 2006.

## **Muon Collider Advanced Accelerator R&D Proposal**

### Abstract

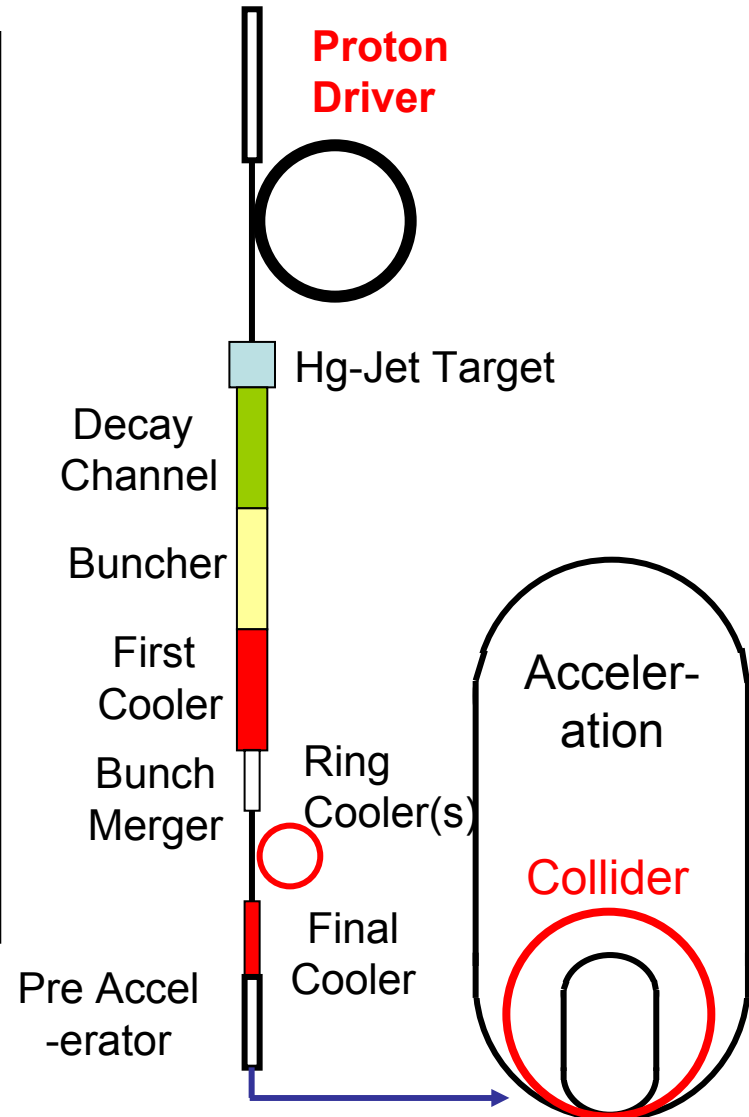
Muon Colliders offer a possible long term path to lepton-lepton collisions at center-of-mass energies  $\sqrt{s} \geq 1$  TeV. We propose a program of advanced accelerator R&D aimed at developing the Muon Collider concept. The proposed R&D program is motivated by recent progress on Muon Collider design in general, and in particular, by new ideas that have recently emerged on muon cooling channel design. We request support to complement and extend the ongoing Muon Collider R&D studies. This additional R&D will enable the development of a complete 6D cooling channel scheme for a Muon Collider with  $\sqrt{s} = 1.5$  TeV, including design, component prototyping and testing, and demonstration in a muon beam. In addition, in the light of recent developments, we propose to take a fresh look at the overall design for a 1.5 TeV Muon Collider, identify the outstanding R&D issues not being addressed by the ongoing R&D program, and formulate a longer term R&D plan to address these issues. This proposal describes plans and deliverables for FY07, FY08 and beyond, and preliminary budget requests.

- Proposal can be found on the MCTF web page: <https://mctf.fnal.gov/>

# MUON COLLIDER SCHEMATIC

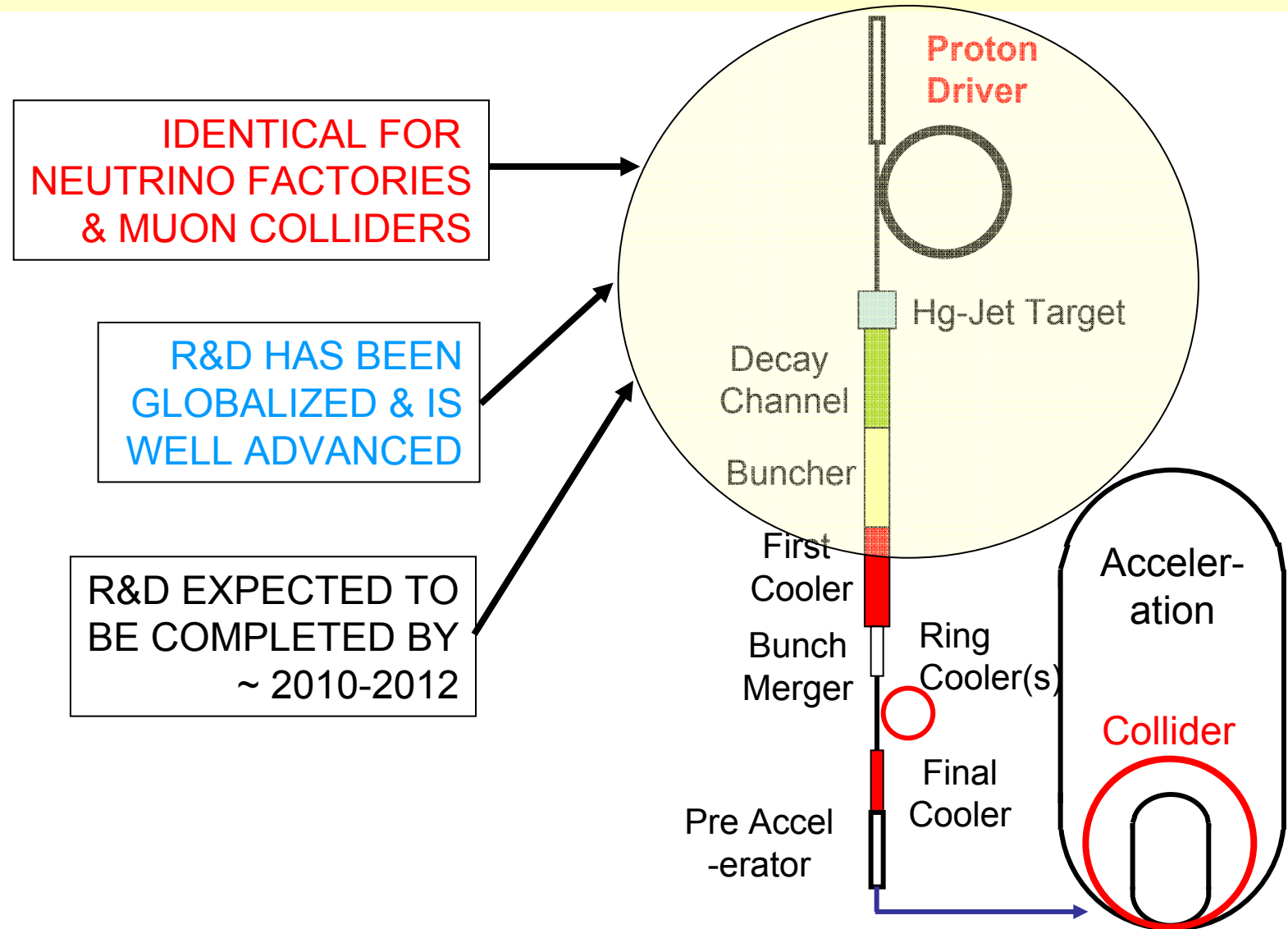


- Proton Driver (e.g. HINS)
- Target, Capture, and Decay
  - create  $\pi$ ; decay into  $\mu$
- Bunching & Phase Rotation
  - reduce  $\Delta E$  of bunch
- Cooling
  - reduce 6D emittance
- Acceleration
  - 130 MeV  $\rightarrow$  up to 1.5 TeV
- Storage Ring
  - store for  $\sim 1000$  turns
  - One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

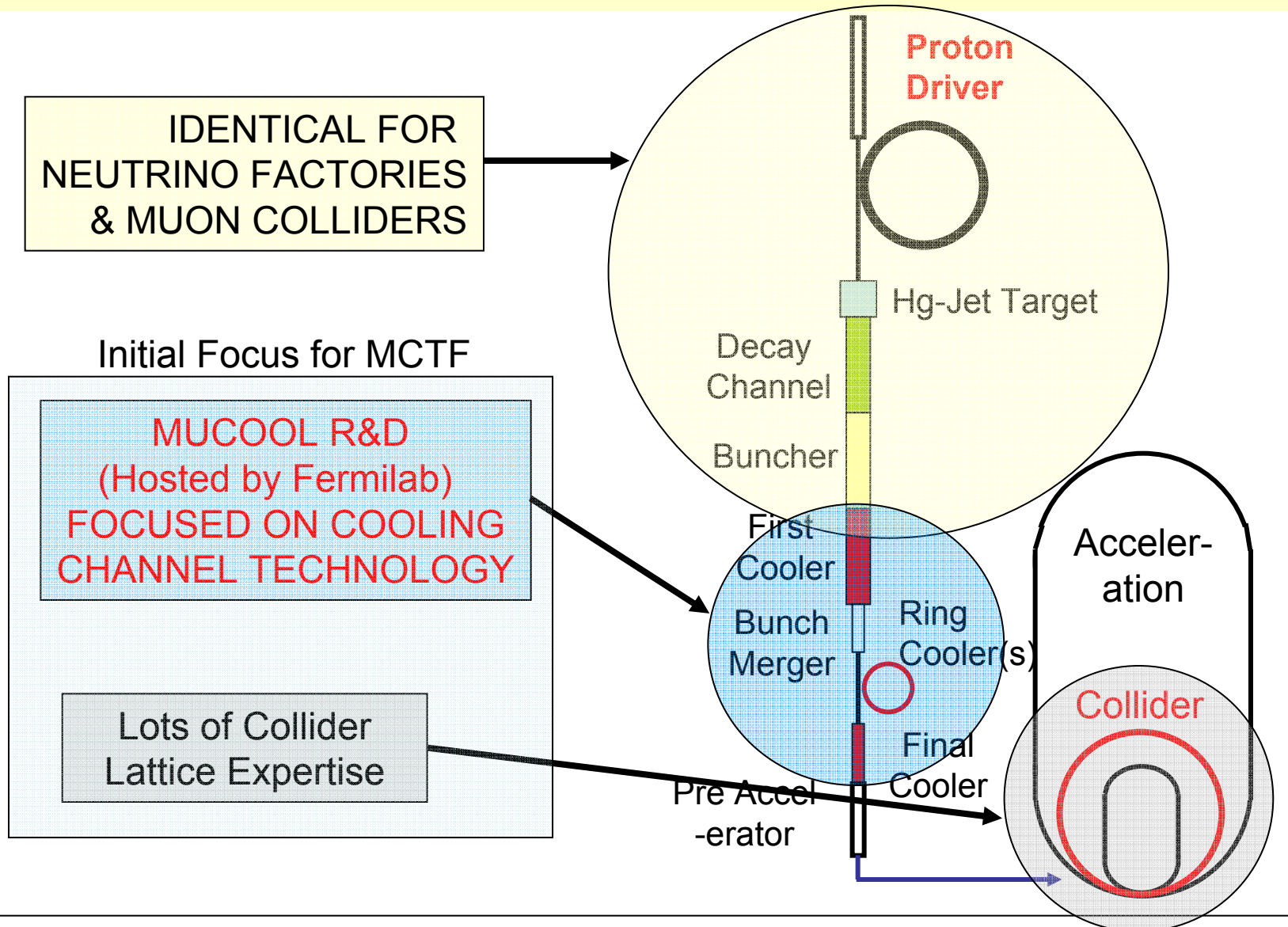




# IMPLICATIONS: NF vs MC R&D



# IMPLICATIONS: MC R&D at FERMILAB

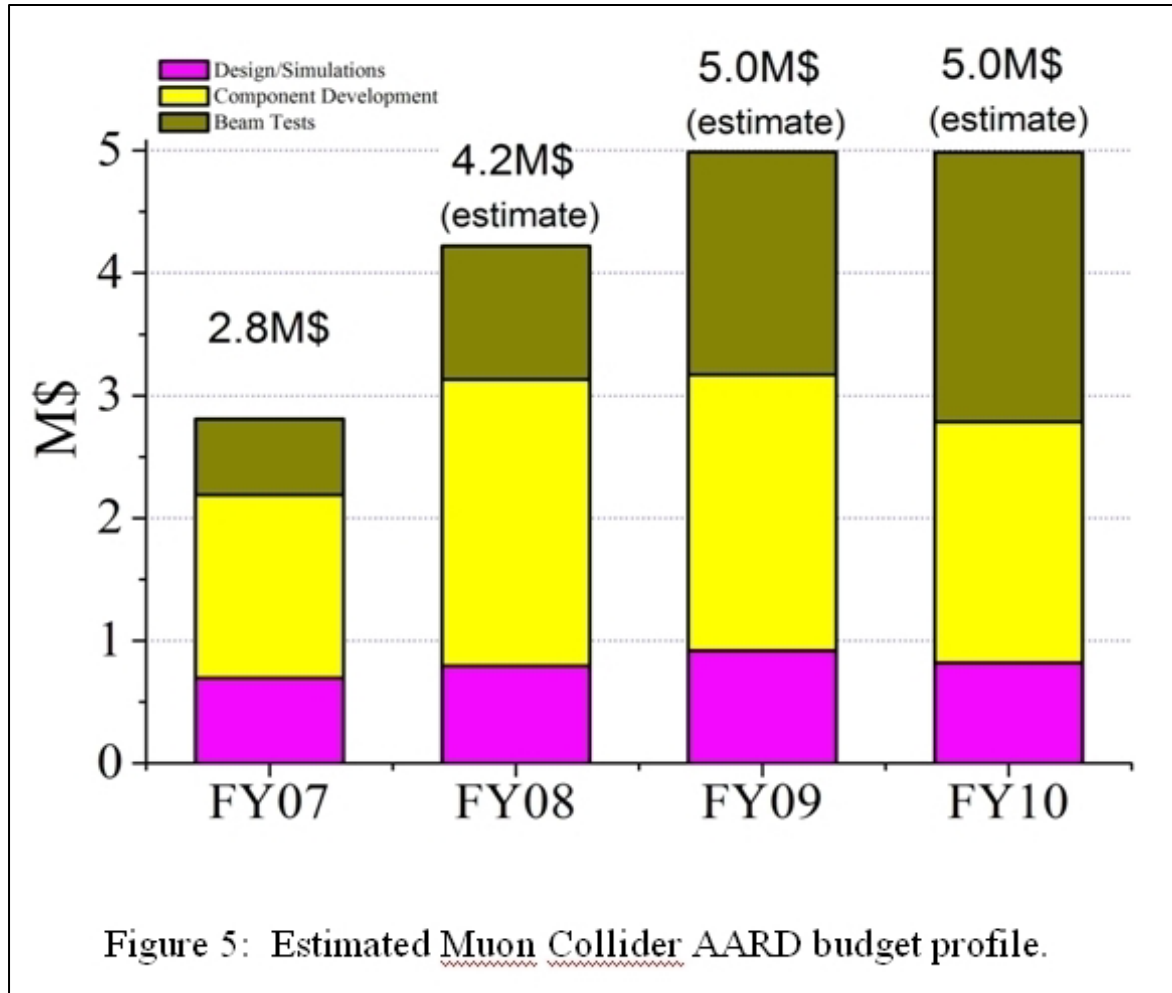


# PROPOSED MCTF ACTIVITIES

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

# REQUESTED SUPPORT



ESTIMATE  
CORRESPONDING  
TO INITIAL PLAN

# PROPOSED R&D PLAN

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

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

# ACTIVITIES THIS YEAR

- Minimal M&S this year, but some effort, and lots on enthusiasm. We have been asked to produce an interim report in September 2007.
- **Muon Collider Design Study Goals for FY07:**
  - ◆ Optics Design: Dynamic aperture assuming LHC upgrade magnets; beam-beam effects; stability analysis
  - ◆ Cooling Channel: 50T Solenoid Channel
- **HTS R&D Goals for FY07**
  - ◆ Conceptual design work (Kahn & Palmer)
  - ◆ Material Testing: Acquire HTS strand+some measurements; acquire YBCO tape coil+some measurements
- **HCC R&D Goals for FY07**
  - ◆ Determine parameters (for helical magnet & matching sections)
  - ◆ Design & construct 3-coil test (LHC conductor in hand)
  - ◆ Information to make decision to build (or not) helical magnet
- **Test Beam Goals for FY07**
  - ◆ MTA High Power Proton Beam Implementation Plan

# MORE DETAILS

## See Following Talks:

Muon Collider R&D at the MUCOOL Test Area [Andreas Jansson](#)

50 T Solenoid [Bob Palmer](#)

Magnet R&D [Mike Lamm](#)

High Field Magnet Quench [Steve Kahn](#)

MCTF Design and Simulation Plans [Yuri Alexahin](#)

# SUMMARY

- The Fermilab Director requested formation of a Muon Collider R&D Task Force & preparation of an appropriate R&D proposal ... done.
- 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.
- We have a tentative mechanism for NFMCC groups to participate in the MCTF activity ... intention is to enhance the NFMCC in the process.



# 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.

# 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).