

# Muon Collider R&D Plans

1. Marching Orders
2. MC Schematic – Reminder
3. Task Force Charge
4. Proposal
  - Scope
  - R&D Plan
  - Status
5. What's Next

# CHARGE LETTER

## Cover Letter

July 12, 2006

To: Vladimir Shiltsev and Steve Geer

From : Pier Oddone

Subject: Muon Collider Task Force

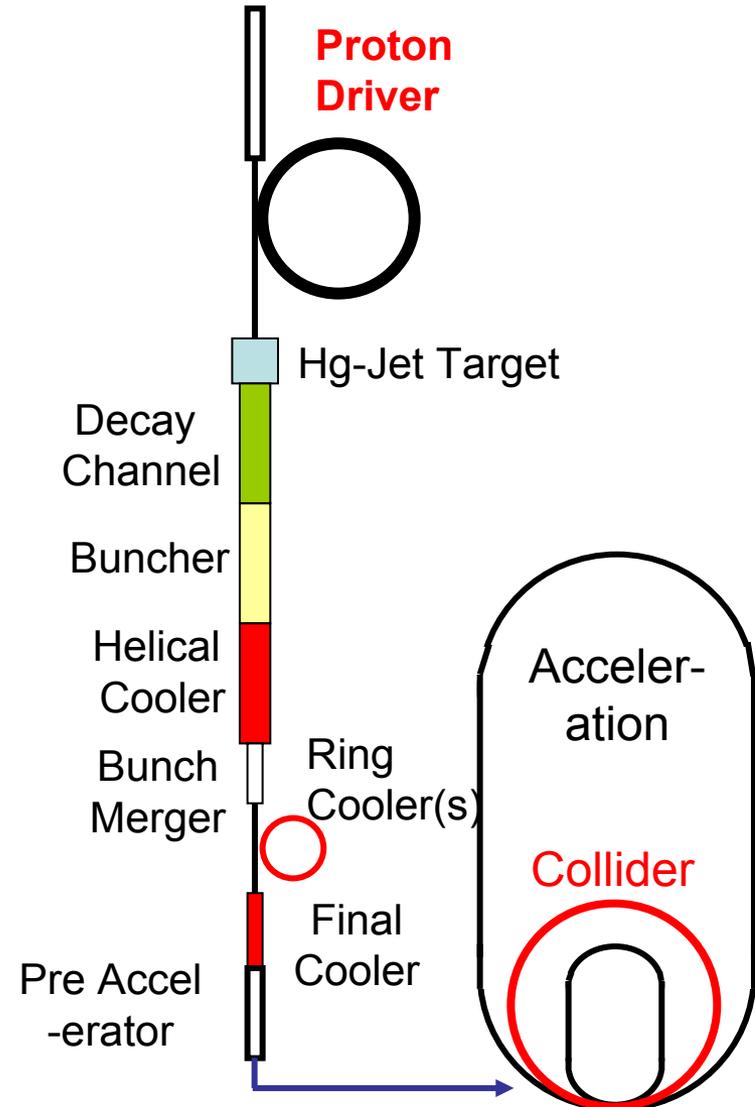
I would like to ask the two of you to form and lead a Task Force to develop a plan for an advanced R&D program aimed at the technologies required to support the long term prospects of a Muon Collider. In doing so I would ask that you operate in consideration of the attached charge, taking special note 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.

# Muon Collider Schematic

## MUON COLLIDER SCHEME

- **Proton Driver (e.g. HINS)**
  - primary beam on production target
- **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



# CHARGE-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-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).

# R&D PROPOSAL

- “DRAFT” given to Pier end of September

<p style="text-align: right;"><i>DRAFT</i></p> <p style="text-align: center;"><b><u>Muon Collider</u></b> <b>Advanced Accelerator R&amp;D Proposal</b></p> <p style="text-align: center;">Abstract</p> <p><u>Muon Colliders</u> offer a possible long term path to lepton-lepton collisions at center-of-mass energies <math>\sqrt{s} \geq 1</math> TeV. We propose a program of advanced accelerator R&amp;D aimed at developing the <u>Muon Collider</u> concept. The proposed R&amp;D program is motivated by recent progress on <u>Muon Collider</u> design in general, and in particular, by new ideas that have recently emerged on <u>muon cooling channel design</u>. We request support to complement and extend the ongoing <u>Muon Collider</u> R&amp;D studies. This additional R&amp;D will enable the development of a complete 6D cooling channel scheme for a <u>Muon Collider</u> with <math>\sqrt{s} = 1.5</math> TeV, including design, component prototyping and testing, and demonstration in a <u>muon beam</u>. In addition, in the light of recent developments, we propose to take a fresh look at the overall design for a 1.5 TeV <u>Muon Collider</u>, identify the outstanding R&amp;D issues not being addressed by the ongoing R&amp;D program, and formulate a longer term R&amp;D plan to address these issues. This proposal describes plans and deliverables for FY07, FY08 and beyond, and preliminary budget requests.</p>	<p><u>FNAL:</u> <u>C. Ankenbrandt</u>, <u>Y. Alexahin</u>, <u>V. Balbekov</u>, <u>E. Barzi</u>, <u>C. Bhat</u>, <u>D. Brommelsiek</u>, <u>A. Bross</u>, <u>A. Burov</u>, <u>A. Drozhdin</u>, <u>D. Finley</u>, <u>S. Geer</u><sup>1</sup>, <u>N. Gelfand</u>, <u>E. Gianfelice-Wendt</u>, <u>M. Hu</u>, <u>A. Jansson</u>, <u>C. Johnstone</u>, <u>J. Johnstone</u>, <u>VI Kashikhin</u>, <u>V. Kashikhin</u>, <u>M. Lamm</u>, <u>V. Lebedev</u>, <u>N. Mokhov</u>, <u>C. Moore</u>, <u>A. Moretti</u>, <u>D. Neuffer</u>, <u>K.-Y. Ng</u>, <u>M. Popovich</u>, <u>I. Rakhno</u>, <u>V. Shiltsev</u><sup>1</sup>, <u>P. Spentsouris</u>, <u>A. Striganov</u>, <u>A. Tollestrup</u>, <u>A. Valishev</u>, <u>A. Van Ginneken</u>, <u>A. Zlobin</u>.</p> <p><u>MuonsInc:</u> <u>R. Johnson</u><sup>2</sup>, <u>M. Cummings</u>, <u>S. Kahn</u>, <u>T. Roberts</u>, <u>K. Yonehara</u></p> <p><u>BNL:</u> <u>J. S. Berg</u>, <u>R. Gupta</u>, <u>H. Kirk</u>, <u>R. Palmer</u><sup>3</sup>, <u>R. Fernow</u>, <u>P. Wanderer</u></p> <p><u>LBNL:</u> <u>G. Sabbi</u><sup>4</sup>, <u>P. Ferracin</u>, <u>S. Caspi</u>, <u>M. Zisman</u></p> <p><u>JLAB:</u> <u>K. Beard</u>, <u>A. Bogacz</u>, <u>Y.-C. Chao</u>, <u>Y. Derbenev</u>, <u>B. Rimmer</u></p> <p><u>ANL:</u> <u>J. Norem</u></p>
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- Pier requested some additional text be added ... we are about to give him the updated document, after which we believe it will be given to Staffin.

# 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.

# PROPOSED R&D PLAN

- 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

# REQUESTED SUPPORT

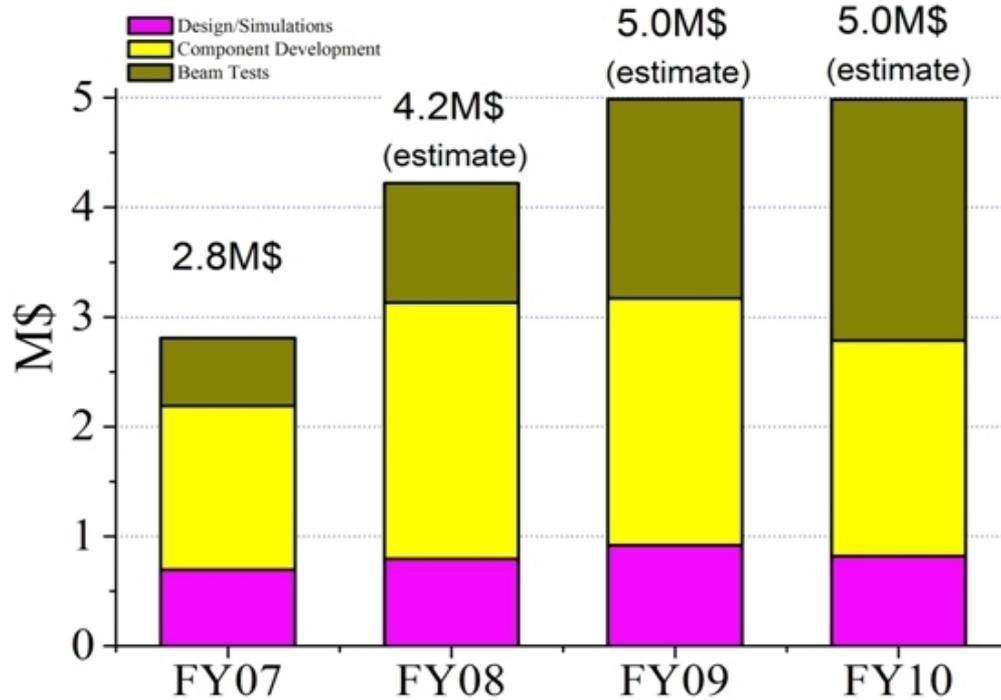


Figure 5: Estimated Muon Collider AARD budget profile.

# What's Next

1. The R&D Proposal is done ... so now we are charged with beginning to execute the plan.
2. It may be some time before we know the fate of the proposal, and/or the level of support for our activity. We believe that in the Labs 07 request there is 2M\$ for MC R&D ... but this does not mean we will get it.
3. We (Vladimir, SG, Alvin, ... ) will be meeting with Holmes soon to discuss the interim plan ... but I think we should proceed as fast as we can with the activities that do not require immediate M&S.
4. In the immediate future we need to consolidate on some organizational things ... regular meetings, co-ordination group, web pages and notes, email lists, ....

**THERE ARE MANY INTERESTING R&D THINGS TO DO & WE NEED ALL THE HELP WE CAN GET ... PLEASE JOIN IN !**