Neutrino Factory and Muon Collider Collaboration

R&D Program Plans

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Outline

- Introduction
- Collaboration near-term R&D goals
- R&D plans
- R&D budget
- R&D timelines
- Summary

Introduction

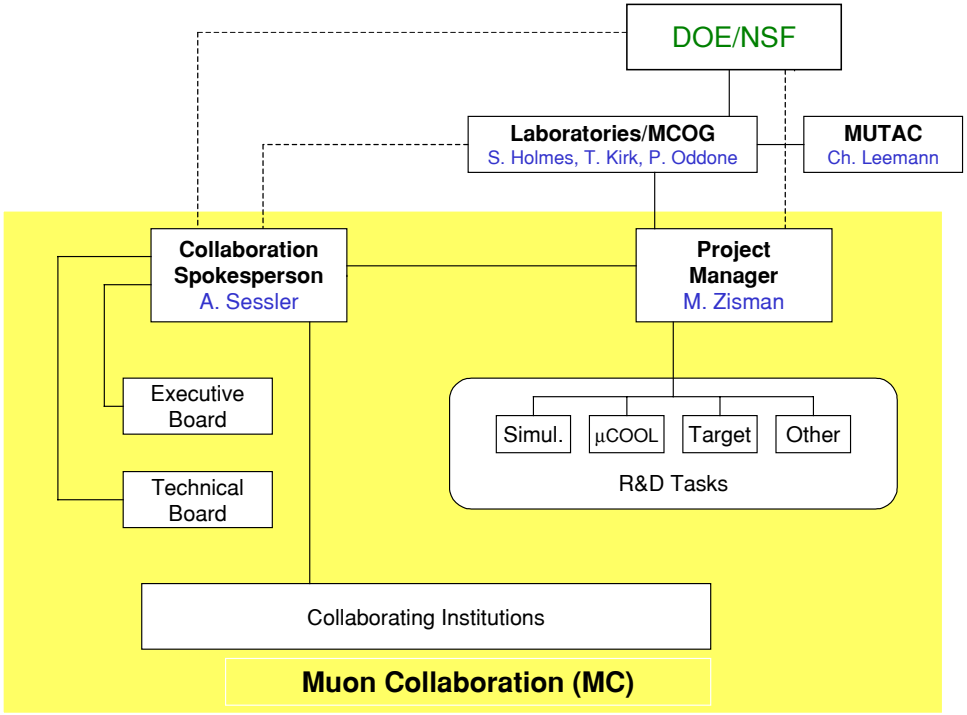
- Since 1999, MC effort focused mainly on Neutrino Factory R&D topics
- Change in emphasis had one R&D implication
  - initial MUCOOL development based on 805-MHz components (RF cavity, power supply, solenoid)
    - work continued to learn about high-gradient performance in the presence of solenoid field
  - now need components sized for initial cooling channel parameters
    - 201 MHz RF cavity, power source, large-bore solenoid
  - R&D on these items is under way
- FNAL Feasibility Study taught us much about Neutrino Factory design
  - technical feasibility established (assuming component specs are met)
  - "cost drivers" were identified
    - R&D to produce cost-effective designs now included in program

Introduction

- MC has 140 members from 30 institutions, including new NSF-sponsored University groups
- We have the scientific personnel to carry out required R&D program in a timely way
- Committed to encouraging international cooperation for Neutrino Factory and Muon Collider R&D
  - coordinate R&D between the various groups
    - Technical Board, Executive Board, NuFACT meetings
    - this is being encouraged from elsewhere also (Maiani letter)
  - a cooling demonstration would be a natural topic for such collaboration
    - there is interest in this in Europe and it will be discussed at NuFACT'01 in May

Introduction

- MC reorganized to improve R&D planning and monitoring
  - added the role of Project Manager (PM) with "line responsibility" for managing MC R&D program
    - MC member, appointed by—and reporting to—MCOG (with DOE-HEP concurrence)



Collaboration Near-Term R&D Goals

- Defined where we want to be in 2005 in all R&D areas, then determined what's needed to get there (funding and effort)
- By 2005 (science/technology-driven schedule)
  - all optics designs completed and self-consistent
  - validation experiments planned or under way
  - know what we want to build
  - know how to build "hard parts" (prototypes completed or designed)
  - ready to design and cost most components (⇒ ready to begin CDR)
- Aim for "ZDR-level" understanding of Neutrino Factory in 2003–2004
- Aim to begin CDR in 2005 (complete in 1–2 years)
- This aggressive schedule requires a reasonable funding level
  - which we not quite getting! (0.1 FTE × 10 years ≈ 0 FTE)

R&D Plans

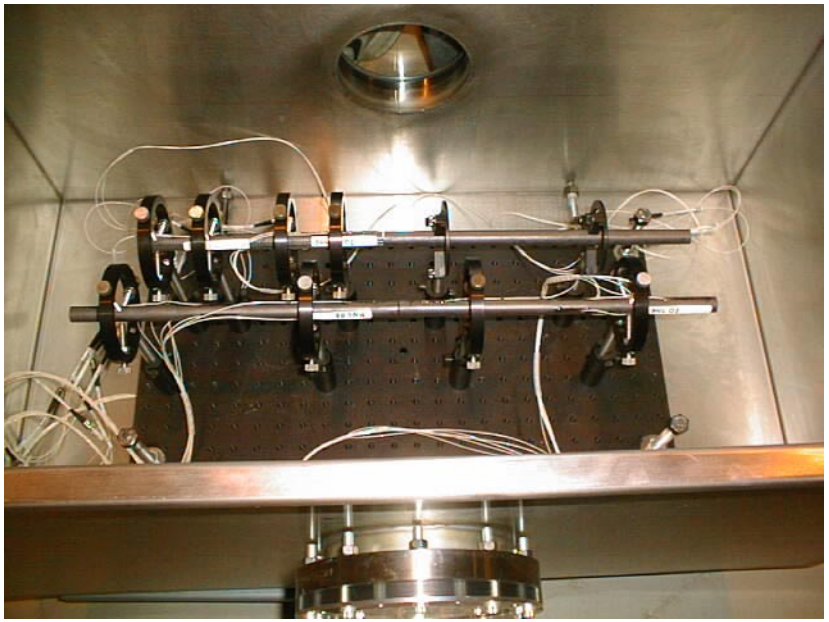
- Beam simulations
  - study alternative bunching and phase rotation schemes
  - continue error sensitivity studies
  - complete "interface" studies between cooling, acceleration, and storage ring sections
  - provide support for MUCOOL program
    - especially, planning and analyzing cooling experiment
  - develop scheme(s) for longitudinal cooling ("emittance exchange")

R&D Plans

- Targetry
  - E951 program is proceeding on schedule
    - make neutron yield and pion yield measurements to benchmark codes (MSU *et al.*; Princeton, BNL)
  - develop pulsed target solenoid for E951 tests (MIT, BNL)
    - evaluate rad-hard materials and robust coil designs (MSU)
  - study "facility" issues (shielding, remote handling, radioactive storage) (ORNL, BNL)
  - explore other target options, e.g., "band" targets
  - evaluate target performance at 4 MW power level
  - tests of Hg jet in high magnetic field (13 T) started by CERN colleagues at Grenoble

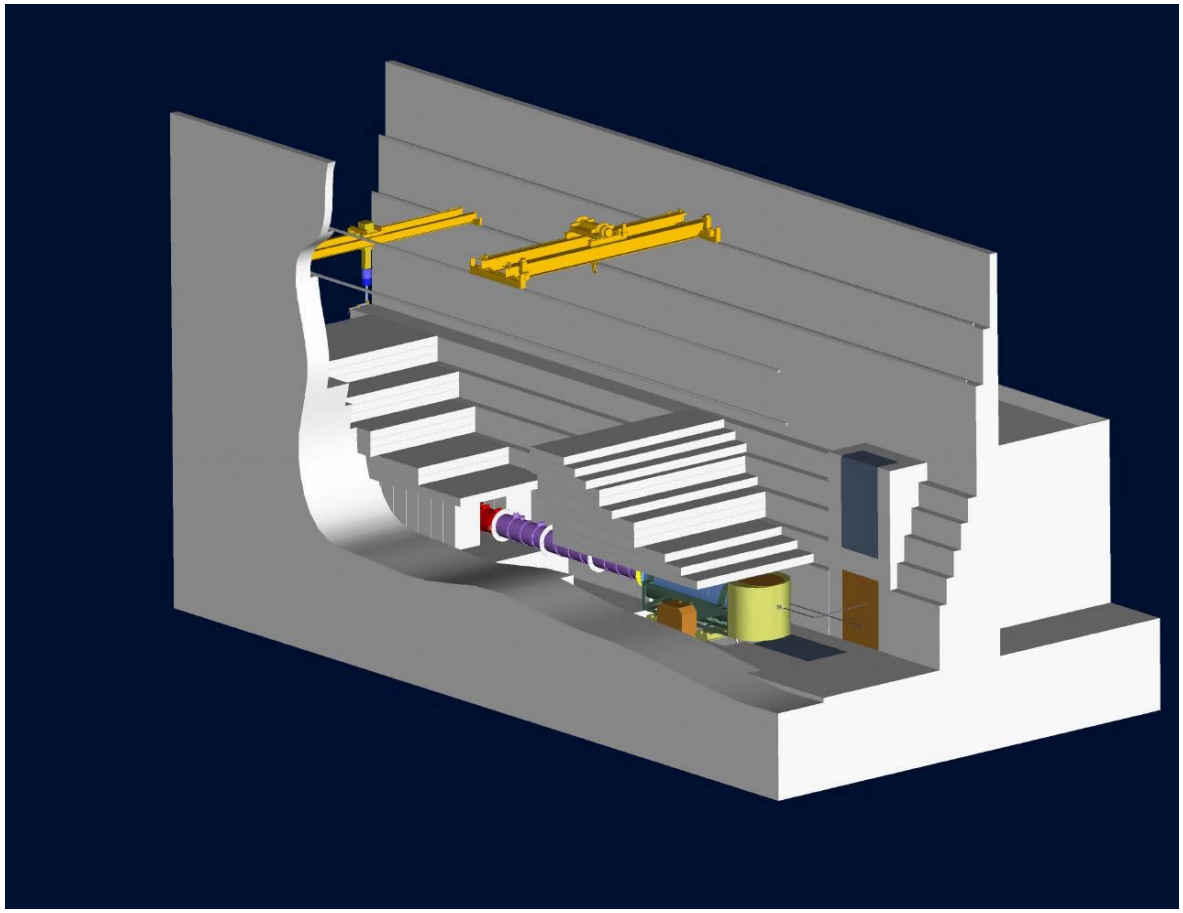
R&D Plans

- Target mover and C target assembly in the A3 line at BNL



R&D Plans

- Target facility is a significant aspect of the project



R&D Plans

- MUCOOL
  - complete high-power tests on 805-MHz cavities (FNAL, LBNL)
    - see what limits gradient; study multipactor and Be window behavior
  - build prototype LH_2 absorber and test with beam (ICAR, FNAL)
  - shift focus to 201-MHz RF development (FNAL, LBNL)
    - cavity design is under way (delivery and testing take 2–3 years)
    - Be window and/or grid design for large aperture cavity must be developed
  - design and fabricate solenoid to test cavity

R&D Plans

Open-cell cavity being tuned
(Fermilab)

Test solenoid in Lab G
(LBNL)

R&D Plans

- prepare string test (3 cells)
  - assemble a single cell from the individual components (cavity, solenoids, absorber)
    - test it as a unit [FY02–FY04]
      - expose to 400 MeV proton beam at FNAL
  - design power source (MBK) during this period
  - fabricate two more prototype cells and assemble with first cell for 3-cell string test [FY04–FY05]
    - fabricate RF power source for cavity test during this period
  - carry out proton beam tests with 3-cell string [FY05–FY06]

R&D Plans

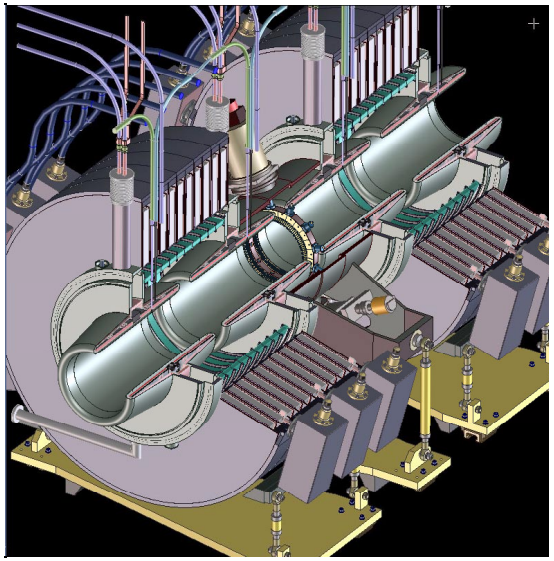
- carry out cooling demonstration as an international effort
  - finalize plans for muon beam demonstration test [FY03]
  - begin experiment in collaboration with other groups [FY06-...]
    - could be based on "string" or other components
- in the longer term, plan for emittance-exchange test system

R&D Plans

- Component development
  - SCRF cavity program now under way at Cornell (NSF supported)
    - upgrade processing facilities; set up 201-MHz power source
    - explore cost-effective fabrication techniques
    - develop method to provide adequate mechanical stiffness
    - demonstrate high-power pulsed operation (at FNAL)
  - begin consideration of "operational" diagnostics (ANL, U-Miss, UCLA, Princeton, Northwestern, IIT)
    - what is needed to transport beam, characterize beam, maintain beam properties during storage
    - also must define and develop diagnostics for string test and/or cooling demo

R&D Plans

- induction linac prototype development
  - verify gradient performance, pulser design, internal SC solenoid
- engineering design of 201-MHz power source, e.g., multibeam klystron



Induction linac concept

TESLA 7-beam 1.3-GHz MBK

R&D Budget

- Funding was increasing, but now is decreasing
  - direct MC funds "leveraged" by base program funds
    - sponsoring Labs cover physics staff costs

Year	DOE-base ($M)	DOE-MC ($M)	NSF ($M)	ICAR ($M)	TOTAL ($M)
FY99	2.8	2.2	--	--	5.0
FY00	3.3	4.7	1.2	--	9.2
FY01	2.1	3.2	1.2	2.1	8.6
FY02[a]	2.2	2.8	1.2	2.1	8.3

[a]Present guidance from funding agencies.

- We need increased funds to build components (NCRF cavity, target solenoid, absorber, klystron, induction linac module, SCRF cryomodule)
  - these are all expensive items

R&D Budget

- **FY01 funding plan (only DOE-MC funds)†**

Institution	MUCOOL Expt. & Generic Studies	TARGETRY Expt.	SALARY	RESERVE	TOTAL ($K)
BNL	130	880	50		1060
FNAL	845				845
LBNL	180	30		180	390
ANL		25	180		205
IIT			60		60
Mississippi	70				70
Princeton		145			145
UCB			90		90
UCLA	65		30		95
ORNL	50	50			100
NHMFL	100				100
JLab			5		5
Cornell			5		5
Iowa	10				10
TOTAL ($K)	**1450**	**1130**	**420**	**180**	**3180**

†NSF has provided $1.2M for muon R&D (mainly SCRF at Cornell) and ICAR has provided $2.1M for muon R&D (mainly cooling)

R&D Budget

- **Budgets based on technology-limited schedule prepared (FY01–FY05)**

R&D area	FY01 ($M)	FY02 ($M)	FY03 ($M)	FY04 ($M)	FY05 ($M)	Sum ($M)
MUCOOL	4.9	3.8	4.3	11.3	11.2	35.4
Targetry	4.7	3.8	4.1	3.5	2.1	18.2
Beam Simulations	2.3	2.0	2.0	2.0	2.0	10.3
Acceleration/Storage Ring	1.0	0.7	0.7	0.7	0.7	3.6
Components	1.9	4.5	7.5	4.3	4.0	22.2
ZDR Preparation				4.0	6.0	10.0
TOTAL	15	15	19	26	26	100

  - **reaching the CDR stage will require about $100M**

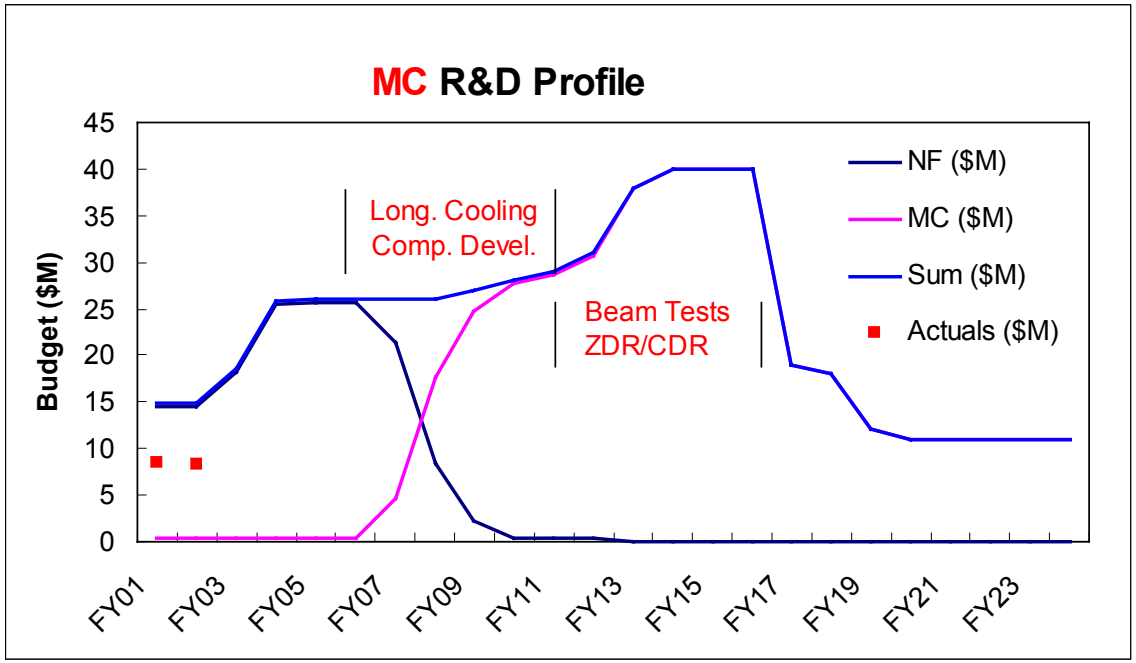
- **Difficult to sustain component development program at funding level well below $10M/yr**

  - **below a certain threshold, R&D produces only "paper and plastic"**

R&D Budget

- Budgets projected into the out-years (basis: SWAG)
  - actuals for FY01 (and expectations for FY02) are indicated
  - decrease in FY17 and beyond would be filled in with R&D effort for MC-II

    ...if I had the nerve to draw it!



R&D Timelines

- The technology-limited schedule to start a Neutrino Factory physics program is expected to be:

2000-2003	R&D activities (ongoing)
2003-2004	Prepare Zeroth-Order Design Report (ZDR); continue R&D; cooling string tests begin
2005-2006	Prepare Conceptual Design Report (CDR)
2007-2012	Construct Neutrino Factory (assume 6 years)
2013	Experiments begin

R&D Timelines

- The schedule to start a Muon Collider physics program is expected to be much later:

2000-2006	R&D activities (ongoing; mainly theory and simulation effort)
2007-2012	Develop and bench test components for longitudinal cooling (bent solenoid, wedge absorber, diagnostics, ring cooler)
2010	Feasibility Study for Muon Collider
2013-2015	Beam tests of 6D cooling system
2013-2016	Prepare Zeroth-order Design Report (ZDR), followed by Conceptual Design Report (CDR)
2017-2024	Construct Muon Collider (assume 8 years)
2025	Experiments begin

Summary

- MC R&D program has clear directions to proceed on all fronts
- Long-range planning of R&D program has been done
- MC membership provides sufficient manpower to carry out our program
- Subpanel endorsement of MC R&D plan is critical to increasing financial support from Labs (base program) and funding agencies (DOE, NSF)
  - strong R&D support is a prerequisite to having good technical options from which to choose