Neutrino Factory and Muon Collider Collaboration

R&D Program: Present and Future

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Outline

- Introduction
- R&D goals
- Present R&D activities
- R&D plans
- R&D budget
- R&D schedule
- Summary

Introduction

- ***MC*** **R&D program has undergone significant change in direction since last MUTAC meeting**
  - **decision based in part on advice from MUTAC**
- **Since last year, *MC* effort has focused primarily on Neutrino Factory R&D topics**
  - **Muon Collider issues have not been (and should not be) forgotten**
    - **emittance exchange workshop scheduled at BNL in September**
- **Collaboration even changed its name to reflect change in emphasis**

Muon Collider Collaboration $\rightarrow$

Neutrino Factory and Muon Collider Collaboration

Introduction

- Change in R&D emphasis not without penalty
  - initial MUCOOL development based on 805-MHz components (RF cavity, power supply, solenoid)
    - already well along when decision made to change emphasis
    - work continued (to reap benefits of prior investment)
    - we learn about high-gradient performance in the presence of solenoid field
      - at the least, a Muon Collider will require these items
  - now need components sized for initial cooling channel parameters
    - 201 MHz RF cavity, power source, large-bore solenoid
  - R&D on these items was delayed by at least one year
  - other R&D efforts, e.g.,targetry, were unaffected and are proceeding apace

Introduction

- Another significant change resulted from the Fermilab Feasibility Study
  - made visible several aspects of Neutrino Factory design
    - some of the components do not easily "scale" to accommodate 201-MHz dimensions
      - conventional wisdom says that solenoids are easy
      - solenoids with 1.5 m bore diameter and high field (≈3.5 T) are not
    - cooling channel costs have potential for outstripping acceleration costs if cost-effective designs are not found
    - cooling channel performance based on realistic engineering considerations unexpectedly poor
      - believed related to non-optimal upstream channel (phase rotation and bunching)
      - more integrated simulation work is needed

Introduction

- ***MC*** **has grown to 137 members (+37 in past 6 months)**
  - **new NSF-sponsored University groups strengthening us further**
    - **both intellectually and financially**
- **Committed to encouraging international cooperation and coordination for Neutrino Factory and Muon Collider R&D**
  - **expect to strengthen R&D ties between the various groups and avoid unnecessary duplication of effort**
    - **this is being encouraged from elsewhere also (Maiani letter)**
- **We have the personnel to carry out required R&D program in a timely way**

Introduction

- ***MC*** **recently reorganized to improve R&D planning and monitoring**
  - **like any medicine, a bit hard to swallow but will make us healthier**
- **Most significant change was to add the role of Project Manager (PM)**
  - **PM has "line responsibility" for managing *MC* R&D program**
    - ***MC*** **member, appointed by—and reporting to—MCOG (with DOE-HEP concurrence)**
    - **tied administratively to the Labs, not the *MC***
      - **PM can be replaced by Labs (in contrast with Spokesperson)**
    - **PM is *ex-officio* member of Technical Board**
- **"Project" Office will be set up at LBNL**
  - **initially MZ + someone more facile than me at MS Project**
    - **could grow somewhat depending on level of R&D activities managed…and reporting requirements**

Introduction

- **Budgets and schedules will require more formality**
  - **necessary and appropriate when handling $M amounts**
  - **R&D funds will be disbursed only after agreed-upon budget and schedule with auditable milestones are in place**
    - **for major tasks, intermediate milestones will serve to monitor progress**
  - **this will require more engineering involvement in R&D planning**

Introduction

- Setting R&D priorities remains the responsibility of *MC*
  - ensuring that the program is carried out successfully falls to the PM
    - "successful" means "on schedule, within budget, and teaches us something" not that everything works perfectly
- *MC* must plan, schedule, and prepare initial budgets for its activities—R&D leaders are the experts!
  - PM role is to:
    - collect and collate the inputs into a coherent and defensible plan
    - prepare budget submissions to DOE (coordinate with NSF?)
    - verify that the work gets done
    - prepare report on past year's spending and accomplishments for funding agencies and MCOG (as done for FY1999)
- Examples shown later demonstrate start of this process

R&D Goals

- Define where we want to be 5 years from now in all R&D areas, then work backward to see what's needed to get there (funding and effort)
- At the end of 5 years (science/technology-driven schedule)
  - all optics designs completed and self-consistent
  - validation experiments completed or well along
  - know what we want to build
  - know how to build "hard parts" (prototypes completed or designed)
  - ready to design and cost most components ($\Rightarrow$ ready to begin CDR)
- Aim for "ZDR-level" understanding of a Neutrino Factory in $\approx$3 years
- Aim to begin CDR after 5 years of R&D work (complete in $\approx$2 years)
  - implies "prying loose" significant engineering support early
- This is aggressive schedule and requires an augmented funding level

Present R&D Activities

- R&D activities fall into four main categories
  - simulations and theory (Organizer: Jonathan Wurtele, UCB/LBNL)
  - targetry experiment (E951 at BNL) to demonstrate technical feasibility of key concepts (Organizer: Kirk McDonald, Princeton U.)
  - MUCOOL to demonstrate feasibility of required components and study cooling effects (Organizer: Steve Geer, Fermilab)
  - component development, e.g.,
    - 201-MHz SCRF cavities for acceleration section (Cornell)
    - induction linac with internal SC solenoid for phase rotation (LBNL)
    - low-frequency, high-gradient proton driver cavity (Fermilab, BNL)
    - 20 T SC solenoid system (NHMFL)
    - muon beam diagnostics (UCLA, U-Mississippi, Northwestern)
- Significant effort also invested in Feasibility Study activities, drawing other groups into the R&D program (FNAL → BNL)

Present R&D Activities

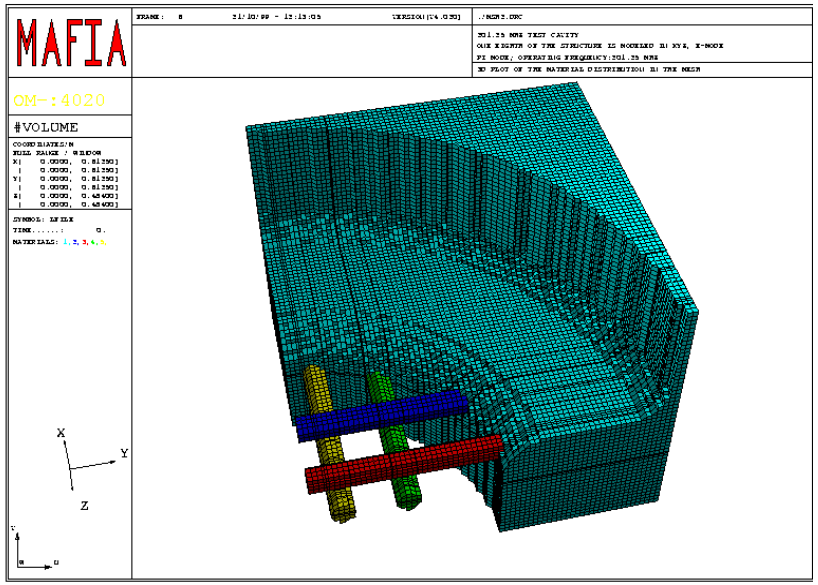
- **Targetry goals**
  - **demonstrate performance of MW-level target in high-field solenoid**
  - **measure pion and neutron yields to benchmark code**
  - **demonstrate lifetime of target (Hg jet and solid)**
- **R&D activities**
  - **complete A3 beam line at BNL**
  - **thermal calculations to assess mechanical behavior of target**
  - **component development for experiment [20-T pulsed solenoid, 70 MHz high-gradient RF cavity]**
  - **prepare for initial target beam test**
  - **prepare test of Hg-jet in high magnetic field at NHMFL**

Present R&D Activities

- **MUCOOL goals**
  - **build component prototypes and bench test complete cooling cell**
  - **test cooling channel components in a muon beam…somewhere**
    - **assume initial portion of channel (⇒ 201 MHz cavities, big solenoid)**
- **MUCOOL activities**
  - **805 MHz RF**
    - **fabricate high-power open cell cavity (high-gradient performance) [A. Moretti]**
    - **fabricate high-power Be-window pillbox cavity (multipactor; Be performance) [J. Corlett]**
    - **test Be window deformation [D. Li]**
    - **solenoid for testing cavities [M. A. Green]**

Present R&D Activities

- 201 MHz RF
  - design high-power cavity suitable for cooling channel [T. Jurgens]
    - Be windows and gridded cell being studied



- design prototype LH_2 absorber [D. Kaplan, M. Cummings]
- define and develop cooling channel diagnostics

Present R&D Activities

- **Simulation goals**
  - **complete end-to-end simulations, including effects of errors**
    - **Target/Capture, Front End, Acceleration, Storage Ring**
  - **develop concept for emittance exchange (longitudinal £ transverse)**
  - **develop analytical tools for understanding front-end performance**
  - **support MUCOOL demonstration design**
- **Simulation/theory activities**
  - **studying front-end solution with/without initial phase rotation**
    - **still to be optimized in terms of performance**
  - **analytical tools being developed**
  - **holding emittance exchange workshop in September**
  - **working on acceleration system and storage ring designs**

Present R&D Activities

- Component development goals
  - demonstrate high-gradient 201-MHz SCRF cavity (acceleration)
  - demonstrate induction linac cell with internal SC solenoid operating at 2 MV/m (phase rotation)
    - demonstrate realistic pulser system to drive it
  - demonstrate high-gradient, low frequency RF cavity for proton driver
  - identify and demonstrate other critical technologies
- Component development activities
  - design and test 201-MHz SCRF cavities (work at Cornell supported by NSF)
  - develop test cavity and inductive inserts for proton driver

R&D Plans

- **Simulations**
  - **Feasibility Study cooling channel performance unexpectedly poor**
    - **believed related to poorly optimized upstream beamline (too much energy spread) so upstream front end must be reexamined**
      - **must understand this to demonstrate better cooling performance**
    - **error sensitivity of cooling channel must be understood**
      - **solenoid strength and multipole errors; RF cavity *V*, ϕ, and HOMs; absorber variations; energy straggling, multiple scattering tails,…**
    - **only from these studies can we define**
      - **component specifications to compare with what we build**
      - **diagnostics that can measure what we need to control**
      - **the need for, and plans for, experimental tests of key issues**

R&D Plans

- **Targetry**
  - **solid-target effort will be augmented (FNAL, ORNL)**
    - **consider also "facility" issues (shielding, remote handling, radioactive storage)**
  - **first beam tests will take place at BNL A3 line (Princeton, BNL)**
    - **plan for measurements of neutron yield and of pion yield (MSU *et al.*; Princeton, BNL)**
  - **work on target solenoid will proceed (NHMFL)**
    - **evaluate rad-hard materials and robust coil designs (MSU)**
  - **E951 program is proceeding on schedule**

R&D Plans

- **MUCOOL**
  - **carry out high-power tests on 805-MHz cavities (FNAL, LBNL)**
    - **see what limits gradient; study multipactor and Be window behavior**
      - **this will take us through FY01**
  - **build prototype LH_2 absorber and test with beam (IIT *et al.*, FNAL)**
  - **shift focus to 201-MHz development (FNAL, LBNL)**
    - **cavity design is under way (delivery and testing will take 3 years)**
    - **must decide on Be-window or gridded version**

R&D Plans

- solenoid to test cavity must also be designed and fabricated
  - Feasibility Study showed that this magnet is not easy
    - explore idea of initial testing with scale-model magnets
      - like NASA ("faster, cheaper, almost as good")
- definition of demonstration awaits guidance from simulation effort

R&D Plans

- Proton driver (FNAL, BNL)
  - develop and test high-gradient pulsed RF cavity
  - demonstrate intense, short proton bunches (≈1 ns)
- Component development
  - SCRF cavity program getting 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 design gradient

R&D Plans

- induction linac prototype development
  - verify gradient performance, pulser design with reset feature, effect of internal SC solenoid
    - begin with engineering study, then fabricate prototype cell
  - CERN approach, using RF cavities, will be watched carefully
- do engineering design of suitable power source, e.g., multibeam klystron
- diagnostics
  - begin consideration of "operational" diagnostics (ANL, U-Miss, UCLA, Princeton, Northwestern)
    - what is needed to transport beam, characterize beam, maintain beam properties during storage

R&D Plans

- **Feasibility study**
  - **BNL has requested *MC* participation in study of "high-end" Neutrino Factory design**
    - **estimate performance and identify R&D needs and cost drivers, building upon previous Fermilab study**

R&D Budget

- **Funding has been increasing**
  - — ***MC*** **funds are "leveraged" since the sponsoring Labs cover physics staff costs**
    - o **more like "European" accounting**

Year	DOE ($M)	NSF ($M)	TOTAL ($M)
FY99	2.2	––	2.2
FY00	4.7	1.2	5.9

  - — **additional funds contributed by Fermilab and BNL in support of feasibility study activities**
- **We hope for more support in FY01**
- **Accounting activity has been increased (*MC* + base program funds)**
  - — **complete accounting of FY99 funds has been prepared for MCOG and DOE**
  - — **YTD accounting of FY00 has been prepared for this review**

R&D Budget

- **Summary of FY99 spending**

Institution	Collaboration		Base Program	Overall
	Committed ($K)	Uncommitted ($K)	Committed ($K)	Committed ($K)
ANL	150		100	250
BNL	462.1	102.9	1264	1726.1
FNAL [1]	834		965	1799
LBNL [2]	274.2	115.3	123.3	397.5
Princeton U.	90	40	135	225
UC-Berkeley	50		125	175
UCLA	60		47.9	107.9
Mississippi	50		83	133
TOTALS	**1970.3**	**258.2**	**2843.2**	**4813.5**

NOTES:

[1] *Includes $124K carryover from FY98.*

[2] *Includes $54.5K carryover from FY98 and $50K uncommitted transferred from BNL.*

R&D Budget

- **Representative details**

Institution: Argonne National Laboratory

Task	Muon Collaboration Funds			Laboratory Funds		
	Effort ($K)	M&S ($K)	Sum ($K)	Effort ($K)	M&S ($K)	Sum ($K)
Targetry Studies						
Liquid Target Studies	$ 65.000	$ 5.000	$ 70.000			
Cooling Studies						
Lithium Lens				$10.000		$10.000
Cavity X-rays					$10.000	$10.000
Physics Salaries						
Cooling (Bent Solenoid, Cav. X-rays)	$ 75.000		$ 75.000	$75.000		$75.000
Administration and Travel		$ 5.000	$ 5.000		$5.000	$5.000
SUBTOTALS	**$ 140.000**	**$ 10.000**		**$85.000**	**$15.000**	
TOTALS			**$ 150.000**			**$100.000**

R&D Budget

- **Representative accomplishments**

Argonne National Laboratory
(Accomplishments–FY1999)

- Developed theory of bent solenoid channel and identified specific aberrations and emittance growth mechanisms
- Explored methods of producing small emittance from low momentum muons in a lithium lens, with the aim of defining an optimum lens configuration
- Began measurements of the x-ray spectrum from an RF cavity to assess its effect on the diagnostics envisioned for the proposed FNAL muon cooling experiment
- Developed code for liquid metal magneto-hydrodynamics that is being used to predict heating, pressure, and mechanical deformation of a liquid-metal jet injected into a 20-T solenoid and heated by an intense proton beam
- Quantified slow (Joule) and fast (beam) pressure pulses in a liquid-lithium cell and carried out preliminary analysis of thermal, pressure, and mechanical response

R&D Budget

- **FY00 funding distribution (all DOE funds)**

Institution	MUCOOL Expt. & Generic Studies	TARGETRY Expt.	SALARY	RESERVE	TOTAL ($K)
BNL		1818			1818
FNAL	1229		90		1319
LBNL	438	75		15	528
ANL	25	80	200		305
IIT	157				157
Mississippi	68				68
Princeton	80	100	60		240
UCB			120		120
UCLA	50		80		130
TOTAL ($K)	**2047**	**2073**	**550**	**15**	**4685**

— **NSF has recently provided $1.2M for muon-related R&D**

R&D Budget

- **FY00 year-to-date summary**

Institution	Collaboration		Base Program	Overall
	Year To Date ($K)	Uncommitted ($K)	Year To Date ($K)	Year To Date ($K)
ANL	230	75	0	230
BNL	1028	790	1549	2577
FNAL [1]	1162	157	1257	2419
LBNL	211.2	316.8	125.6	336.8
Princeton U. [2]	174	106	200	374
UC-Berkeley	75	45	24	99
UCLA	63.0	67.0	16.0	78.9
Mississippi	50	18	83	133
Cornell + NSF Contract	0	1193.6	0	0
TOTALS [3]	**2993.2**	**1574.8**	**3254.569**	**6247.7**
		2768.4		

NOTES:

[1] *Includes $157K IIT subcontract.*

[2] *Includes $40K carryover from FY99.*

[3] *DOE totals in black; additional NSF funding shown in blue .*

R&D Budget

- **Budgets based on technology-limited schedule prepared (FY01–FY05)**
  - **FY01 (*MC* + base) is reasonably well defined**

MUCOOL

	Required Funds			
	M&S ($K)	**Effort** (FTE)	**Labor** ($K)	**Total** ($K)
Lab G	*480.0*	*6.90*	*587.0*	*1,067.0*
805 MHz				
Setup	195.0	1.60	136.0	331.0
Testing	110.0	1.20	102.0	212.0
200 MHz				
Setup	175.0	4.10	349.0	524.0
Cooling Components	*2,230.0*	*6.20*	*625.0*	*2,855.0*
200 MHz cavity	345.0	2.60	221.0	566.0
Be window cavity	155.0	1.20	120.0	275.0
Solenoid for 200 MHz	830.0	0.40	34.0	864.0
LH_2 absorber test area	850.0	2.00	250.0	1,100.0
Instrumentation	50.0			50.0
General	*180.0*	*0.00*	*0.0*	*180.0*
Consultants	75.0			75.0
Travel	80.0			80.0
Supplies & expenses	25.0			25.0
TOTAL	**2,890.0**	**13.10**	**1,212.0**	**4,102.0**

	Required Funds			
	M&S ($K)	**Effort** (FTE)	**Labor** ($K)	**Total** ($K)
GRAND TOTAL	**7,358.0**	**50.3**	**7,385.0**	**14,743.0**

R&D Budget

— "out-years" (*MC* + base) will require iteration

MUCOOL

Item	FY02 ($K)	FY03 ($K)	FY04 ($K)	FY05 ($K)	Sum ($K)
Solenoid for 201 MHz					
First Model	1000	1000	500		2500
Second model		250	1500	250	2000
TOTAL	**1000**	**1250**	**2000**	**250**	**4500**
201 MHz NCRF cavity					
Lab G prep	500				500
Be window tests	300				300
LN temperature study	100	500			600
First cavity fab and test	345	455			800
Second cavity fab and test			785	135	920
TOTAL	**1245**	**955**	**785**	**135**	**3120**
LH_2 Absorber					
Second cell design, fab, test	250	750			1000
TOTAL	**250**	**750**			**1000**
Instrumentation					
Development and testing	200	200	200	200	800
TOTAL	**200**	**200**	**200**	**200**	**800**
Supplies and expenses					
Travel and supplies	100	100	100	100	400
TOTAL	**100**	**100**	**100**	**100**	**400**
Test cell assemblies					
Ten cells for demonstration			8000	12000	20000
TOTAL			**8000**	**12000**	**20000**
TOTAL (no demo)	**2795**	**3255**	**3085**	**685**	**9820**
TOTAL (with demo)	**2795**	**3255**	**11085**	**12685**	**29820**
TOTAL to ZDR		**17423**			
TOTAL to CDR					**21193**
TOTAL to CDR (with demo)					**41193**

R&D Budget

— total cost to reach ZDR (or CDR) is obtained from these estimates

Source	FY99 ($M)	FY00 ($M)	FY01 ($M)	FY02 ($M)	FY03 ($M)	FY04 ($M)	FY05 ($M)	Sum ($M)
MC	2.0	4.7						
Base	2.8	*5.0*						
NSF	---	1.2						
TOTAL	4.8	*10.9*						
REQUIRED (no demo)	4.8	*10.9*	*14.7*	*13.2*	*15.3*	*9.8*	*3.8*	*72.6*
REQUIRED (with demo)						*17.8*	*15.8*	*92.6*
							TOTAL to ZDR:	59.0

- reaching the ZDR stage will require about $59M ($43M beyond FY00)
- reaching CDR stage requires ≈$14M more without a cooling demo (or ≈$34M with a $20M cooling demo “placeholder”)

- With present funding levels, shortfall next year would be about $3M

— with hoped for NSF increase, we’re pretty close to what we need

- but no flexibility for alternatives (e.g., band targets) or collider work

R&D Schedule

- **Focus on three-year period (FY2001, FY2002, FY2003)**
  - **categorize program as follows**
    - **simulations**
    - **targetry**
    - **MUCOOL**
    - **proton driver**
    - **components**
    - **feasibility studies**

R&D Schedule

- **Simulations**
  - **FY01**
    - **complete front-end simulations of FOFO and single-flip channels**
    - **add features to ICOOL for error studies and optimization**
    - **continue error sensitivity studies**
    - **complete study of multiple scattering and straggling issues**
      - **sensitivity of results to model assumptions**
      - **ability of simulation code to reproduce measured data**
    - **begin assessment of polarization preservation**
    - **continue simulations of acceleration and storage ring performance**

R&D Schedule

- **FY02**
  - **iterate channel design based on realizable components**
  - **complete acceleration and storage ring simulation studies including errors and fringe fields**
  - **define initial component specifications from error studies**
- **FY03**
  - **integrate simulations end-to-end (target to storage ring)**
    - **with realistic errors and component specifications**

R&D Schedule

- **Targetry**
  - **FY01**
    - **commission A3 beamline (~6 weeks parasitic operation)**
    - **test liquid-metal jet at NHMFL**
    - **identify suitable carbon material, carry out finite-element analysis, measure sublimation rate**
    - **begin design of radiatively cooled solid target**
    - **complete target-solenoid and PS design**
    - **begin fabrication of pulsed solenoid + 5 MW PS**
    - **begin materials tests of radiation hardness**
    - **design fast kicker for AGS intensity upgrade**
    - **initial beam test of target (liquid-metal or solid)**

R&D Schedule

- **FY02**
  - **complete carbon sublimation tests**
  - **construct prototype carbon target**
  - **complete fabrication of target-solenoid and PS**
  - **continue target tests with beam (both solid and liquid-metal)**
  - **complete AGS intensity upgrade**
  - **begin yield measurements to benchmark MARS (π, n)**
  - **continue radiation hardness tests**
  - **test 70 MHz RF cavity in high-radiation environment**

R&D Schedule

— **FY03**

- **test target with 20 T solenoid at 10^{14} ppp (~6 weeks parasitic beam)**
- **test target with solenoid and RF cavity at 10^{14} ppp (~6 weeks parasitic beam)**
- **complete radiation tests and begin resistive test coil design**
- **begin design of proton beam dump**
- **develop proton beam window mockup**
- **complete pion diagnostics and begin pion yield tests (~6 weeks parasitic beam)**

R&D Schedule

- **MUCOOL**
  - **FY01**
    - **complete high-power tests of 805-MHz open cell cavity**
      - **measure HOMs; gradient limits; multipactor; thermal behavior**
    - **continue Be window testing program**
    - **complete low-power tests of 805-MHz Be-window pillbox cavity**
    - **complete high-power tests of 805-MHz Be-window pillbox cavity**
    - **complete design of prototype absorber**
    - **get safety approval and begin thermal tests of prototype absorber**
    - **design and begin scale-model tests of cooling channel solenoid**
    - **continue design of high-power 201-MHz NCRF cavity**

R&D Schedule

- **FY02**
  - **begin fabrication of high-power 201-MHz NCRF cavity**
  - **begin setup of 201-MHz test area**
  - **complete design and begin fabrication of 201-MHz test solenoid**
  - **complete LH_2 absorber tests with beam**
- **FY03**
  - **complete 201-MHz test area setup**
  - **complete fabrication of high-power 201-MHz NCRF cavity**
  - **complete fabrication of 201-MHz test solenoid**
  - **begin high-power tests of 201-MHz components**

R&D Schedule

- **Proton Driver**
  - **FY01**
    - **test loaded cavity with beam**
    - **begin high-current bunch compression tests**
    - **design high-gradient pulsed cavity (~1 MV/m)**
    - **design ramped power supply**
  - **FY02**
    - **test inductive inserts with beam**
    - **fabricate high-gradient cavity**
    - **continue bunch compression tests aimed at 1-ns bunches**
  - **FY03**
    - **test high-gradient RF cavity with beam**

R&D Schedule

- **Components**
  - **FY01**
    - **fabricate 201 MHz SCRF cavity**
    - **complete processing facilities upgrade for 201 MHz cavity**
    - **complete conceptual design of induction linac module with internal solenoid and multipulse power supply**
    - **develop concepts for front-end, acceleration, storage ring diagnostics**
  - **FY02**
    - **test 201-MHz SCRF cavity (CW and pulsed)**
    - **design prototype high-power 201-MHz RF power source**
    - **begin fabrication of induction linac module and associated pulser**
    - **fabricate prototype diagnostics devices**

R&D Schedule

- **FY03**
  - **fabricate second SCRF prototype**
  - **complete and test induction linac module**
  - **begin beam tests of diagnostics**

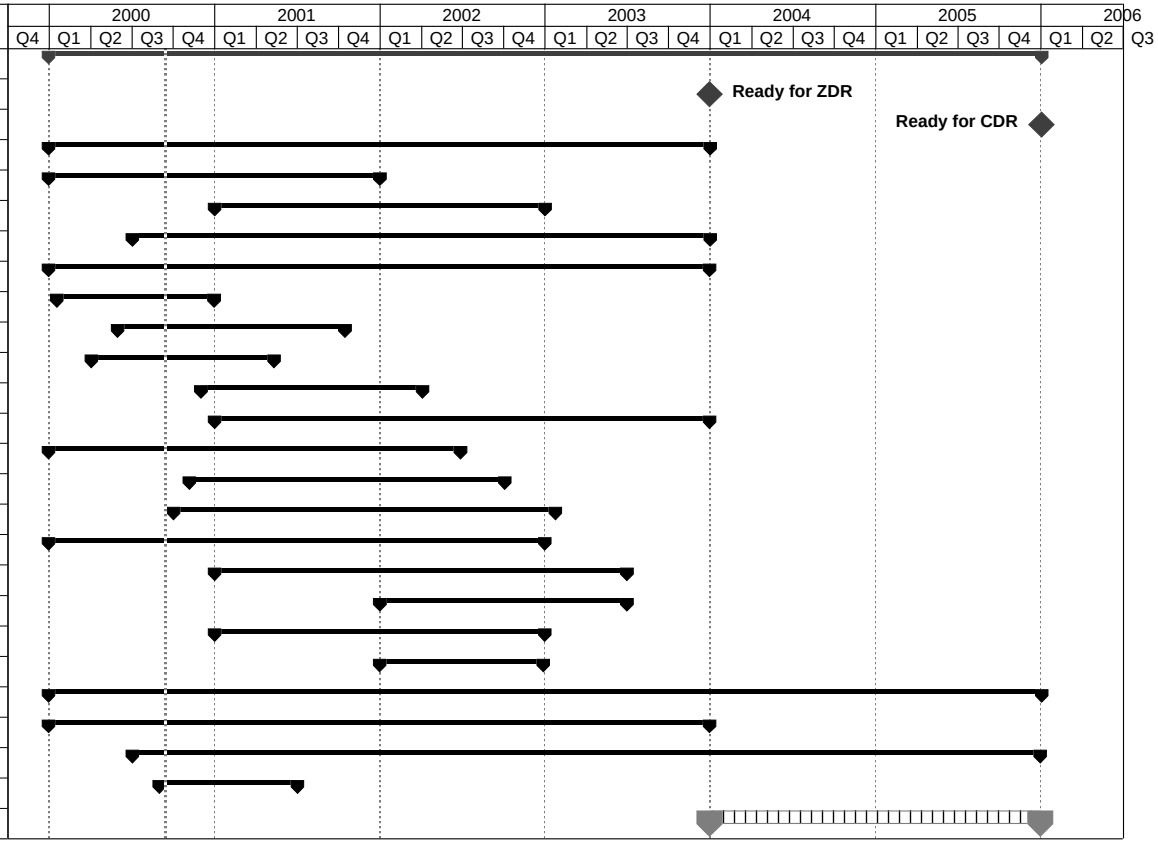
R&D Schedule

- **Feasibility studies**
  - **FY01**
    - **complete study of high-end facility and write report**
    - **prepare report summarizing facility design and physics reach for Snowmass ’01**

R&D Schedule

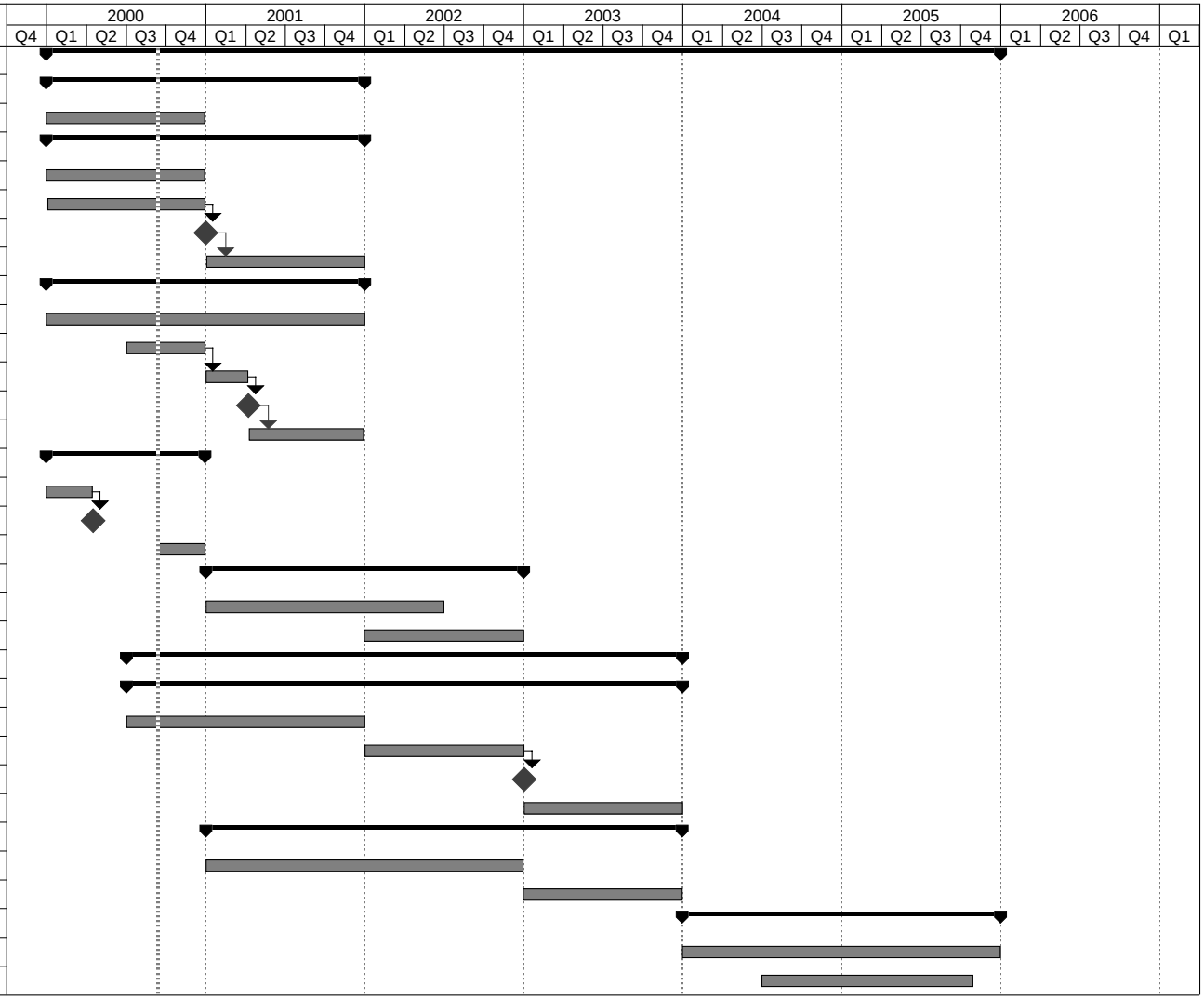
- **Preliminary schedule based on the above plan has been developed**
  - **— not resource loaded yet, nor fully linked (plan and schedule will be iterated this summer)**

ID	Task Name
1	**Neutrino Factory R&D**
2	Ready for ZDR
3	Ready for CDR
4	**MUCOOL**
5	**805 MHz RF**
22	**Liquid hydrogen absorber**
25	**201 MHz RF**
34	**Targetry**
35	**AGS extraction prep**
38	**Liquid metal jet**
59	**AGS extraction upgrade**
63	**Pulsed solenoid**
75	**Solid target studies**
79	**RF systems**
106	**Cavity solenoid**
118	**Capture experiment**
133	**Simulation and validation**
146	**Proton Driver**
147	**High-gradient RF**
150	**Inductive inserts**
153	**Short bunch tests**
155	**Beam simulations**
162	**Acceleration and storage ring**
166	**Components**
180	**Feasibility study II**
186	**Cooling demonstration**



R&D Schedule

ID	Task Name
1	**MUCOOL**
2	**805 MHz RF**
3	Lab G preparation
4	**Open cell cavity fab**
5	Design
6	Fabricate
7	Cavity complete
8	Test
9	**Be window cavity**
10	Be window testing
11	Pillbox cavity design
12	Pillbox cavity fab
13	Cavity complete
14	Test
15	**805 MHz test solenoid**
16	Design and fab
17	Solenoid complete
18	Make operational in Lab G
19	**Liquid hydrogen absorber**
20	Design and prototype
21	Beam tests
22	**201 MHz RF**
23	**RF cavity**
24	Design
25	Fab
26	Cavity complete
27	Test
28	**201 MHz test solenoid**
29	Design and fab
30	Test
31	**Cooling demonstration**
32	Fab components
33	Install components



Summary

- *MC* R&D program is vigorous and healthy
  - clear directions to proceed on all hardware fronts
  - clear challenges identified for simulation group
- Long-range planning of R&D program is in progress
- *MC* membership and funding both growing at healthy rate
  - we have the manpower to carry out our program
- Involvement of NSF institutions and groups strengthens the effort
  - involvement of international institutions and groups would strengthen the R&D effort even more
- MUTAC endorsement of *MC* R&D plan is critical to increasing financial support from Labs (base program) and funding agencies (DOE, NSF)
  - a good showing at Snowmass '01 will garner community support
- We look forward to these positive trends continuing