Muon Collaboration

5-Year R&D Plan

Michael S. Zisman
CENTER FOR BEAM PHYSICS

Muon Collaboration Project Manager

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Outline

- Introduction
- R&D goals
- R&D plans
- Assumptions
- Budget scenarios
- Summary

Introduction

- Continued low funding, and launching of MICE and CERN Targetry experiment, pose challenges for the MC
  - MCOG asked us (Geer, Palmer, MZ) to prepare a 5-year R&D plan and indicate the corresponding funding needs
    - realistic plan should assume "flat-flat" funding
    - optimistic plan could perhaps double our "directly funded" program
- MCOG wants evidence that we have a plan and that we have (roughly) the wherewithal to follow it
  - plans presented here are "cautiously optimistic"
    - we continue living close to the edge
- Request is quite timely in view of plans being put in place to have HEPAP subpanel review of DOE's advanced accelerator R&D program
  - MUTAC conclusions today will undoubtedly influence what happens later

R&D Goals

- MC studying issues associated with producing, cooling, accelerating, and storing intense beams of muons
  - key technical challenges of muon beams
    - very short lifetime (2.2 μs at rest)
    - produced as tertiary beam
      - low intensity
      - very large 6D emittance (energy spread, transverse sizes and angles)
  - key non-technical challenge
    - limited availability of funds to carry out R&D in timely way

R&D Goals

- To make a Neutrino Factory a worthwhile option for HEP community, we must address these technical challenges
  - short lifetime puts premium on very rapid beam manipulations
    - requires development of high-gradient NCRF cavities operating in a magnetic field
    - reducing muon beam phase space requires presently untested ionization cooling technique
    - requires fast acceleration having large longitudinal and transverse acceptance
  - low muon production rate requires target that can withstand bombardment by multi-MW proton beam

R&D Goals

- Primary MC R&D thrusts:
  - cooling, including
    - ionization cooling demonstration (MICE, approved at RAL)
      - we participate as part of an international collaboration
    - component R&D (high-gradient cavities operating in magnetic field, LH_2 absorber development)
  - target development, including
    - demonstration of realistic target system under pseudo-operational conditions (Targetry experiment, approved at CERN)
      - McDonald and Kirk co-spokespersons for international effort
    - materials R&D (identify suitably rad-hard materials for targets; study non-standard target implementations, e.g., Hg jet)
      - work of interest to other areas, e.g., LARP/LHC, Superbeams, SNS

R&D Goals

- system studies, including
  - feasibility and cost studies of end-to-end facility configurations (e.g., World Design Study sponsored by RAL)
  - studies of non-standard acceleration systems (FFAG development)
  - involvement in community activities (e.g., NuFact workshops, NuFact Summer Schools, APS Neutrino Study)
- implicit in all this effort is training of new accelerator physicists
  - partnership with particle physicists at universities has been effective
    - accelerator physics "missionary work" ☺

R&D Goals

- **Overarching R&D goal:**
  - provide sufficient information to permit U.S. HEP community to assess whether to include a Neutrino Factory in its long-range construction plans
    - time frame: next 5–10 years
  - develop Neutrino Factory concept to the point where a laboratory can consider adopting it as a future construction project
- **Highest priority items are those critical to reaching this goal**
  - completion of international MICE experiment at RAL
  - development of suitable cooling channel components
  - completion of international Targetry experiment at CERN
  - high level of participation in Neutrino Factory World Design Study
- **R&D plan presented here reflects these priorities**

R&D Plans

- Draft plan is being debuted here
  - hopefully, MUTAC will endorse our vision and recommend MCOG approve the plan
  - after MCOG approval, plan will be given to DOE
    - and likely the HEPAP subpanel will see it as well
- Cooling
  - participate in the MICE experiment at the agreed-upon level ($5–6M hardware costs, plus some operating funds)
    - provide 2 spectrometer solenoids, 1 RFCC module, a Cherenkov detector, a portion of tracker detector, absorber windows
      - hope for additional NSF support for part of this work (MRI submitted, as is University Consortium proposal)
  - continue cavity R&D program at MTA (both 805 and 201 MHz)
    - most critical need is for coupling coil for 201 MHz tests

R&D Plans

- Targetry
  - carry out CERN Targetry experiment (FY07–FY08); thereafter, reduce activity in favor of cooling program
    - H. Kirk managing technical work for the MC
- System studies
  - focus on World Design Study
    - "scoping" part of WDS being organized now by RAL/BENE
    - goal is to launch at NuFact05 and complete by NuFact06
    - second phase: detailed engineering/costing of chosen option
      - request EU "Framework 7" funds for this activity (2007–2008)
  - participation in FFAG electron model initiative also desirable
  - BNL group will carry the main load here (Berg, Fernow, Gallardo, Kahn, Kirk, Palmer)

Assumptions

- MUCOOL R&D will require modest support except for the provision of a coupling coil
  - other pieces all exist now
- MICE hardware is costly and requires the bulk of MC funds after completing Targetry experiment
  - NSF has been asked for support for MICE and has provided a small amount ($100K/yr for 3 years)
    - we requested additional $2M via MRI, for one spectrometer solenoid and the U.S. portion of tracker detector
      - presently out for review
    - to be conservative, only partial MRI funding ($0.5M) from NSF was assumed, even in the baseline budget scenario
  - operating funds must include "common fund" contribution (author tax)
    - not clear how to get DOE portion funded in early years

Assumptions

- **System studies will involve mostly effort and will be accommodated in "base program" funds**

  — **NSF support has been requested to augment this effort along with support for cooling and for MICE activities**

University Consortium Funding Needs from NSF

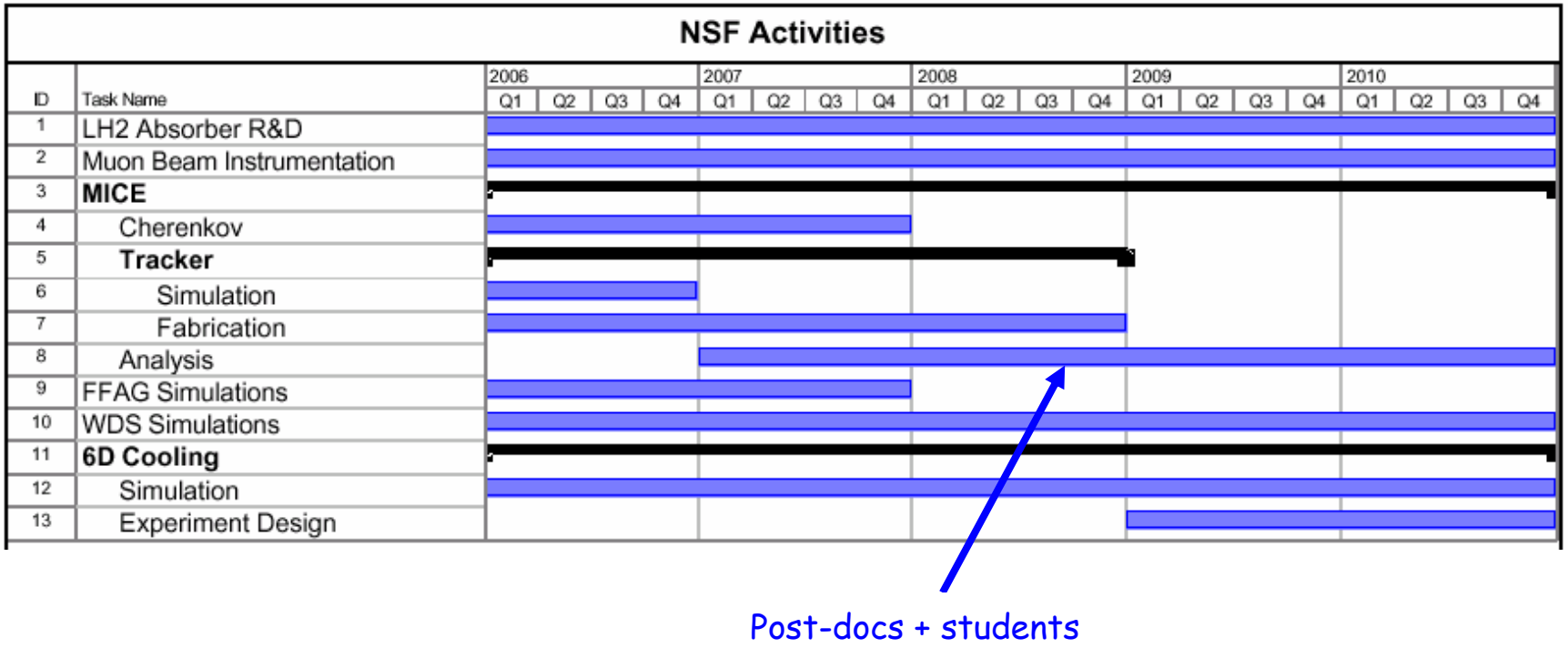
Activity	Funding ($K)	Institution(s)
Absorbers	116	UIUC, NIU, IIT
Instrumentation	66	NIU, NWU
Acceleration	40	MSU
Cooling/Emittance exchange	200	UIUC, MSU, U-Miss, UC-R
MICE	128	U-Miss, UC-R
TOTAL (annual)	550	

  — **in a minimum budget scenario, much of this effort would need to be deferred should NSF fail to support it**

  ⇒ **other MICE groups will then be exploiting what we conceived, designed, and built** ☹

Assumptions

- **Time line for University Consortium activities, if funded by NSF**



Assumptions

- Cost of items needed for MICE/MUCOOL
  - "ingredients" for the budget scenarios presented here
  - all costs without contingency; contingent events will require schedule stretch-out

Item	No. (5)	No. (6)	Cost (1) ($K)	Cost (2+) ($K)	Total (5) ($K)	Total (6) ($K)
CC-MUCOOL	n/a	n/a	970	n/a	970	n/a
Spectr. sol.	2		1200	800	2000	
RF module	1	1	1400	900	1400	900
CC-MICE	1	1	n/a	560	560	560
Tracker	1		625		625	
TOTAL					5555	1460

NOTE: Step 5 tests one half-cell of cooling channel; Step 6 tests one full cell

Budget Scenarios

- Two strawman plans considered for hardware costs
  - "baseline" (flat-flat, $3.6M/yr) and "incremental" ($4M/yr)
  - base program funds: BNL ($1.0M); FNAL ($0.6M); LBNL ($0.3M)
    - "threat" to BNL base program adds uncertainty to plan
  - then, MC funds of $1.7M available each year in baseline case
- Summary of baseline case is

Activity	FY05	FY06	FY07	FY08	FY09	FY10
Cooling	492	245	345	705	615	225
Targetry	713	640	625	100	100	100
System Studies	195	195	195	295	295	195
MICE	300	620	535	600	690	1180
TOTAL	1700	1700	1700	1700	1700	1700

  - amounts for Targetry and System Studies are assigned first
  - remaining funds available for MUCOOL + MICE

Budget Scenarios

- priorities in FY05–07 are CERN Targetry experiment and first MICE spectrometer solenoid
- specific allocation of MICE funding depends on fate of NSF MRI proposal
- require help in obtaining 1 CC and tracker hardware from elsewhere (iMICE and/or NSF)

Budget Scenarios

- **Hardware requirements (Step 5) differ in the two scenarios**

Funding source	Baseline ($K)	Incremental ($K)
MUCOOL	970	970
MICE-US	3400	4410
MICE-international	560	—
NSF	625	175
TOTAL-DOE	*4370*	*5380*
TOTAL	5555	5555

  - **to reach Step 6 in either scenario requires an additional RFCC module (⇒+$1460K)**
    - **cannot reach Step 6 by FY10; need two more years (baseline) or one more year (incremental)**
- **Note that both plans require some financial help from others**
  - **intentionally pessimistic assumptions made to show that there is still a solution; we hope to do better**
- **Either plan would benefit from front-loaded (cf. flat) funding profile (not considered yet, for simplicity)**

Budget Scenarios

- **Budget details for baseline case**

	FY06 ($K)	FY07 ($K)	FY08 ($K)	FY09 ($K)	FY10 ($K)	Sum ($K)
Available	865	880	1305	1305	1405	5760
Cooling	245	345	705	615	225	2135
staff	180	180	180	180	180	900
absorber	20	20				40
MTA ops.	45	45	45	45	45	225
CC-MUCOOL		100	480	390		970
MICE	620	535	600	690	1180	3625

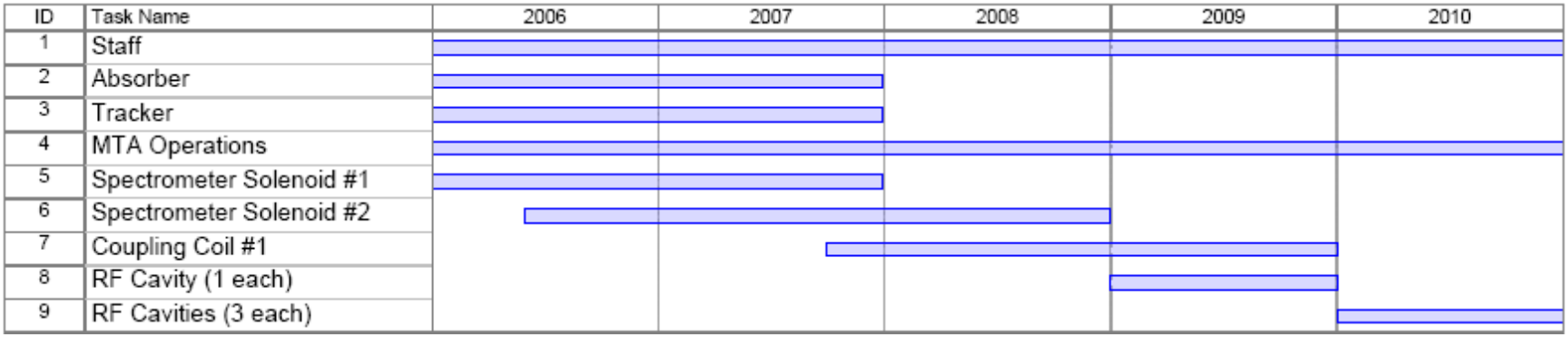
- **MICE needs only $3.4M for Step 5, so extra funds are available**

  —for contingency, if needed; for Step 6, if not

- **With our pessimistic scenario, Step 6 requires about 2 more years, depending on contingency experience**

Budget Scenarios

- **Baseline** plan gives
  - first spectrometer solenoid, end of FY07
  - second spectrometer solenoid, end of FY08
  - 1 coupling coil and first RF cavity, end of FY09
  - 3 RF cavities, end of FY10



- **Issues**
  - long hiatus for RF cavity fabrication
  - delay between first and second spectrometer solenoids
- Associated with "cash-flow problem" due to Targetry support in FY06-07

Budget Scenarios

- In incremental scenario, assume DOE MC funds of $2.1M/yr available
  - amounts for Targetry and System Studies again assigned first
  - remaining funds available for MUCOOL + MICE
- Summary of incremental case is

Activity	FY05	FY06	FY07	FY08	FY09	FY10
Cooling	492	260	590	970	320	320
Targetry	713	640	715	190	100	100
System Studies	195	195	195	195	195	195
MICE	300	1005	600	745	1485	1485
TOTAL	1700	2100	2100	2100	2100	2100

  - base program funds remain as now: BNL ($1.0M); Fermilab ($0.6M); LBNL ($0.3M)
  - assumes DOE pays for all required U.S. components except for small NSF contribution to tracker (i.e., no MRI funding)
    - even with this very pessimistic assumption, hardware requirements can be met with $400K/yr incremental funds

Budget Scenarios

- **Budget details for incremental case**

	FY06 ($K)	FY07 ($K)	FY08 ($K)	FY09 ($K)	FY10 ($K)	Sum ($K)
Available	1265	1190	1715	1805	1805	7780
Cooling	260	590	970	320	320	2460
staff	180	180	180	180	180	900
absorber	20	20	20			60
MTA ops.	60	50	50	50	50	260
CC-MUCOOL		340	630			970
Post-doc			90	90	90	270
MICE	1005	600	745	1485	1485	5320

- **MICE needs $4.4M for Step 5, so additional funds are available**
  - **—for contingency, if needed; for Step 6, if not**
  - **—Step 6 requires about 1 more year**

Budget Scenarios

- **Incremental** plan gives
  - both spectrometer solenoids, end of FY07
  - first coupling coil and first RF cavity, end of FY08
  - second coupling coil, end of FY09
  - 3 RF cavities, early in FY10

- **Issues**
  - first RF cavity still comes somewhat late
  - first coupling coil still comes somewhat late

Summary

- We have presented two funding scenarios for carrying out the MC R&D program in the next 5 years
  - baseline, flat funding at $3.6M total, $1.7M MC-direct funds
  - incremental, flat funding at $4.0M total, $2.1M MC-direct funds
  - both cases are well below the funding level recommended for our program of $8M/yr
- For both scenarios we developed a budget consistent with achieving our programmatic goals
  - conservative assumptions made about additional funding sources
    - with luck, we'll do better than estimated here
  - contingent events, especially in the baseline case, would result in modest delays to the program (1–2 years)
- MC R&D program is ambitious, but can be accomplished with steady funding support and careful prioritization of the effort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NO, I DON'T WANT YOU TO LOSE HOPE.

Cost Reconciliation

- NSF proposal made very conservative assumptions about costing
  - resulted in a fairly high cost estimate
- We have now revisited all estimates, with more realistic assumptions
  - magnets and RF assumed to be vendor fabrication, not done at Lab
    - reduces both ED&I costs and overhead
  - 7:1 multiplexing confirmed to be acceptable via simulations
  - experience gained from fabrication of prototype RF cavity
    - considerable ED&I now done, but "off the books" as R&D
  - development of less expensive implementation of Be windows
  - elimination of contingency (not a real savings; increases risk of schedule delays)

Cost Reconciliation

- **Comparison of costs**

Item	Old estimate ($K)	Revised estimate ($K)
RF cavities (2 x 4-cavity)	3240	2300
CC (2 ea.)	3240	1120
Tracker items (2 ea.)	2560	625
TOTAL	9040	4045

  - **new estimates do not require 20% miscellaneous "correction"**
  - **new estimates include required ED&I and overhead explicitly**
  - **ED&I reduced based on simpler fabrication model and engineering effort accomplished since original estimates prepared**
  - **corrections in proposal for ED&I, overhead, contingency effectively doubled estimated cost used for proposal (⇒ $18M)**
  - **correction for new estimate (contingency) only ≈$1M, as other items accounted for properly**
  - **"exploitation costs" from NSF proposal (post-docs, students, travel) not included**