Neutrino Factory
and
Muon Collider
Collaboration

R&D Program

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CENTER FOR BEAM PHYSICS

Collaboration Meeting–Catalina
May 17, 2000
Outline

• Introduction
• Collaboration R&D organization
• R&D funding
• R&D activities under way
• R&D plans
• R&D schedule
• Summary
Introduction

• Since our last meeting, there have been changes that will influence how we carry out our R&D program

  — in response to DOE request, MCOG and the MC formalized their mutual interactions

    ○ updated charter for MCOG, some modifications in MC charter
      – to be approved by MC

    ○ even a new Org Chart

• 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 elected Spokesperson, who cannot be)
Introduction

• MCOG has asked me to serve as PM
  — DOE has approved, effective May 2000
  — there will be a “Project” Office set up at LBNL
    o initially MZ + someone more facile than me at MS Project
    o could grow somewhat depending on level of R&D activities managed...and reporting requirements

• Budgets and schedules will require more formality
  — necessary and appropriate when handling $M amounts
  — agreed-upon budget and schedule with auditable milestones should be in place before funds are disbursed
    o for major tasks, intermediate milestones will serve to monitor progress
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
- PM does not eliminate your need to plan, schedule, and prepare budgets for your activities—you 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)
      - please identify our work in talks and papers with official **MC** logo
**Institution:** Argonne National Laboratory

<table>
<thead>
<tr>
<th>Task</th>
<th>Muon Collaboration Funds</th>
<th>Laboratory Funds</th>
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<tr>
<td><strong>Effort ($K)</strong></td>
<td><strong>M&amp;S ($K)</strong></td>
<td><strong>Sum ($K)</strong></td>
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<td><strong>Targetry Studies</strong></td>
<td><strong>Effort ($K)</strong></td>
<td><strong>M&amp;S ($K)</strong></td>
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<td>Liquid Target Studies</td>
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<td><strong>Cooling Studies</strong></td>
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<td>Lithium Lens</td>
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<td>Cavity X-rays</td>
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<td><strong>TOTALS</strong></td>
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Introduction

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
<table>
<thead>
<tr>
<th>Institution</th>
<th>Collaboration</th>
<th>Base Program</th>
<th>Overall</th>
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**NOTES:**

[1] Includes $124K carryover from FY98.
[2] Includes $54.5K carryover from FY98 and $50K uncommitted transferred from BNL.
• To be effective, PM, Spokesperson, and MC must work together to ensure that R&D goals are realized

  — “joint ownership” of the R&D plan is needed

    ○ that’s why PM chosen from ranks of MC

    ○ that’s why PM will be ex-officio member of Technical Board

• Management plan that describes how the R&D will be carried out by the MC and managed by the PM has been formally requested by DOE

  — want input from MC members on what they think should be in the plan

  — expect each participating institution to designate a single contact person responsible for all MC R&D activities undertaken there

  — whether process functions effectively depends on the people, not the document
Collaboration R&D Organization

- Oversight role of “sponsoring” Labs (≡ BNL, Fermilab, LBNL) via MCOG (Directorate level)
  - MCOG appoints Technical Advisory Committee (MUTAC)
  - Project Manager has line responsibility for R&D implementation, working closely with Spokesperson on planning
### R&D Funding

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

<table>
<thead>
<tr>
<th>Institution</th>
<th>MUCOOL Expt. &amp; Generic Studies</th>
<th>TARGETRY Expt.</th>
<th>SALARY</th>
<th>RESERVE</th>
<th>TOTAL ($K)</th>
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<td><strong>TOTAL ($K)</strong></td>
<td><strong>2047</strong></td>
<td><strong>2073</strong></td>
<td><strong>550</strong></td>
<td><strong>15</strong></td>
<td><strong>4685</strong></td>
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*MC funds are “leveraged” since the sponsoring Labs cover physics staff costs*

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

• Guidance is to expect same amount from DOE in FY2001
  — request made (through Cornell) for NSF funds to support MC R&D activities
    o development of 201 MHz SCRF cavity (Cornell)
    o front-end design (Columbia)
    o target-related studies and beam dynamics (MSU)
    o cooling channel apparatus and instrumentation (IIT, Northwestern)
    o ionization cooling theory (Chicago)

• Flat budgets for next few years looks like maximum-likelihood scenario
  — but we must keep asking for what we need to make reasonable progress
R&D Activities Under Way

- Primary activities this year are Targetry and MUCCOL experiments
  - these took 88% of this year’s funding

- Goals of Targetry experiment
  - demonstrate performance of 1-MW target in a high-field solenoid
  - measure pion and neutron yields to benchmark MARS code
  - demonstrate target lifetime (Hg-jet and solid)
  - study performance of high-gradient RF cavity in high radiation environment

- Targetry activity this year aimed at making BNL A3 beamline operational
  - expected to be ready for beam by October
  - work under way to refurbish 70-MHz power supply for RF cavity test
  - other activities have lagged (by design) in order to complete “facility”
    - this must be addressed next year to take advantage of facility
R&D Activities Under Way

• MUCCOL goals (as reported to HEPAP in March 2000)
  — create FNAL muon test beam facility
  — build component prototypes and bench test complete cooling cell
  — define, realistically simulate, carry out phased experiment ultimately showing significant cooling (ideally 2x emittance reduction)
    ○ verify multiple scattering and energy straggling estimates, test one cell, then replicate
    ○ assume initial portion of channel (⇒ 201 MHz cavities, big solenoid)
R&D Activities Under Way

• MU Cool activity this year
  — design and fabricate high-power open cell 805 MHz test cavity
  — design and fabricate high-power 805 MHz pillbox cavity to test Be window behavior
  — develop 5-T solenoid suitable for 805 MHz cavity tests ✓
  — develop Lab G facility for testing (utilities, RF power source) ✓
  — design and fabricate LH₂ absorber for testing
  — carry out conceptual engineering design of example cooling cell ✓
  — carry experiment design to level sufficient to get MUTAC approval to embark on this path
    ○ work on instrumentation development in support of experiment

• These activities have suffered (but also benefited) from the Feasibility Study effort
R&D Plans

• Many discussions recently about R&D plans and priorities

• MUCOOL goals now being revisited
  — what changed?
    o Feasibility Study did not make a convincing case for cooling channel benefits
      – insufficient cooling, intensity increase marginal, magnets very challenging, … and it’s not exactly cheap
    o Physics Study indicated that much lower intensity (~$10^{19}$ neutrinos per year) was enough for initial physics program
      – gives possibility to start without cooling channel and upgrade
R&D Plans

- there is no consensus on what the experiment should be (well, maybe this one is not such a recent change)
  - measure only straggling and/or multiple scattering
  - measure cooling by tracking single-particles and reconstructing phase space (standard or “pencil” beam variants)
  - measure cooling with an intense bunched beam
    ♦ most realistic but likely most expensive and difficult
- there is a concern that the funds to do any but the simplest experiment envisioned will not be available
R&D Plans

— my take on the situation

  o items driving the present debate:
    – it’s too expensive and the money isn’t available; we can start without it
  o there are different judgments on a key question
    – “Must we demonstrate up front that cooling works to convince the community to invest in a Neutrino Factory?”
  o *MC* must reach consensus on this point...the rest is details
    – implicit assumption: cooling will be required eventually ⇒ inertia
    – MC must also decide what it means to “demonstrate” cooling
      ♦ we need to convince ourselves that we know how to do it
      ♦ necessary...is it sufficient?
R&D Plans

- one school argues that we build an “entry level” facility (no cooling) and do the cooling experiment at the facility (as part of an upgrade R&D program) afterwards

  - predicated on:

    ♦ existence of a world-class physics program at the entry level machine

    ♦ the community having confidence that a suitable upgrade path exists without a cooling demonstration prior to construction

- another argues that we must design and propose a fully functional facility at the outset...this presumably requires cooling

  - predicated on:

    ♦ there being no world-class physics program accessible at a scaled down facility, or only one that could be accomplished more cost-effectively with a fixed-target program
R&D Plans

• Where does that leave us?
  — we do not presently have enough simulation work completed to have a solid cooling channel design
    ○ and certainly not enough done to present a defensible experiment to MUTAC in June
      – so, we cannot propose an experiment now

• What should we do now?
  — we must decide as a group whether we think a cooling demonstration is needed
    ○ if we decide it is, we must define it and create a plan to get there
  — a related, but different, question is whether we need a cooling experiment
    ○ this is to test the physics more than the technology
R&D Plans

- How are our R&D plans impacted by these considerations?
  - Targetry is not changed much
    - solid-target testing has been added to the list without any adjustments of money or effort level
      - augment solid-target effort, which is too thin (as part of Targetry program)
  - shift MUCOOL focus mainly to simulation effort until we have a credible design
    - Feasibility Study cooling channel performance unexpectedly poor
      - believed related to poorly optimized upstream beamline (too much energy spread) so entire front end must be reexamined
      - must understand this to demonstrate better cooling performance
R&D Plans

- error sensitivity of cooling channel must be understood
  - solenoid strength and multipole errors; RF cavity \( V, \phi \), and HOMs; absorber variations; energy straggling, multiple scattering tails,…

- only from these studies can we define
  - component specifications against which to compare 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

— reorient and reprioritize component development

  o RF cavity development

    – do development with “quarter-scale models” (805 MHz) until sure we have a cavity design that we want to build

    ♦ confirm features needed for full-size version with existing power source and test solenoid (windows, grids, tuner, coupler, gradient, multipactor properties, fabrication techniques, operability at LN temperature)

    ♦ this program could easily take another year or more

    – person to take responsibility for this work should be identified

  o power source (201 MHz) still needed and is a long lead time effort

    ♦ not a crash program, but it should be worked on to demonstrate an approach with a well-defined cost
R&D Plans

- magnet development
  - transport solenoids must be taken more seriously based on Feasibility Study results
  - explore possibility of testing most of the technical issues with scale-model magnets
    - like NASA ("faster, cheaper, almost as good")
    - cost of full size magnets will be high and fabrication time long
    - save this until we’re reasonably confident design will work
      - ...but, we will have to cross this bridge eventually
      - work on target solenoid is ongoing and needed
      - remember the SR and RLA magnets
      - person to take responsibility for this work should be identified
R&D Plans

- absorber development would focus on mini-cooling needs until a cooling channel configuration has been defined
  - this would not change the near-term plans much, if at all

- instrumentation development aimed at MUCOOL should be deferred until there is a defined goal
  - thought should be given instead to “operational” diagnostics
    - what is needed to transport beam, characterize beam, maintain beam properties in the SR during the coast

- start induction linac R&D aimed at developing prototype
  - performance is critical to preparing the beam properly for cooling
  - need to verify gradient performance, pulser design with reset feature, and ability to include solenoid in the structure
  - begin with engineering study, then fabricate prototype cell
R&D Plans

- **R&D focus**
  - Long-term focus: continue to aim R&D program toward development of a CDR for a Neutrino Factory
  - Immediate focus: upcoming MUTAC review (June 15–16 at BNL)
  - Near-term focus: HEPAP review of HEP plans (if this happens)
  - Intermediate focus: Snowmass ’01
Summary

• *MC* R&D program is healthy
  — clear directions to proceed on all hardware fronts
  — clear challenges identified for simulation group

• We must work hard to convince community and Labs to support adequate funding for our R&D effort

• We also need a plan to make reasonable technical progress even with flat budgets

• Biggest challenge to our success is lack of fully dedicated people
  — 100 names x 0.1 effort ≠ 10 FTE