Neutrino Factory and Muon Collider Collaboration Meeting

Introduction
Fermilab
March, 2007
Alan Bross
Welcome

Collaboration Meeting XII
Well, we are getting older
But still getting Better

- It has been a very productive year with a great deal of progress
  - MuCool (Interesting new results on RF)
  - MERIT (Successful completion of the experiment!)
  - MICE (Beam line commissioning has started)
  - Simulations/Design - International Design Study for a Neutrino Factory has started and work on 1.5–4 TeV MC has accelerated

- The upcoming year is shaping up to be quite exciting
  - First beam experiment in the MTA
  - MICE makes first cooling measurement
  - Neutrino Factory International Design Study
  - Muon Collider Design Effort
To study and develop the theoretical tools, the software simulation tools, and to carry out R&D on the hardware that is unique to the design of Neutrino Factories and Muon Colliders

- Extensive experimental program to verify the theoretical and simulation predictions
Current Organization

Collaboration Spokespersons
A. Bross, H. Kirk

Executive Board

Technical Board

Project Manager
M. Zisman

R&D Tasks

Simul. | µCOOL | Target | MICE | Other

Collaborating Institutions

Neutrino Factory and Muon Collider Collaboration (NFMCC)

DOE/NSF

Laboratories/MCOG
S. Vigdor, S. Holmes, J. Siegrist

MUTAC
R. Kephart

C. Adolphsen
J. Byrd
D. Finley
S. Henderson
M. Lindner
V. Litvinenko
P. McIntosh
L. Merminga
D. Rubin
M. Shaevitz
Collaborating Institutions

US

National Labs
ANL
BNL
FNAL
LBNL
ORNL
TJNAF

Universities
Chicago
Cornell
Illinois
IIT
Indiana
Iowa
Michigan State
Mississippi
Northern Illinois
Princeton
UC-Berkeley
UC-Davis
UC-Los Angeles
UC-Riverside
Wisconsin

International

National Labs
Budker
CERN
DESY
INFN
JINR, Dubna
KEK
RAL
TRIUMF

Universities
Karlsruhe
Imperial College
Lancaster
Max Planck
Osaka
Oxford
Pohang
Tel Aviv

Corporate Partners
Muons Inc.
Tech-X Corporation

Alan Bross  NFMCC Meeting  March 2008
# Executive Board

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Role</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Bross</td>
<td>FNAL</td>
<td>Co-Spokesperson</td>
<td><a href="mailto:bross@fnal.gov">bross@fnal.gov</a></td>
</tr>
<tr>
<td>H. Kirk</td>
<td>BNL</td>
<td>Co-Spokesperson</td>
<td><a href="mailto:kirk@bnl.gov">kirk@bnl.gov</a></td>
</tr>
<tr>
<td>A. Sessler</td>
<td>LBNL</td>
<td>Associate Spokesperson</td>
<td><a href="mailto:amsessler@lbl.gov">amsessler@lbl.gov</a></td>
</tr>
<tr>
<td>I. Ben-Zvi</td>
<td>BNL</td>
<td></td>
<td><a href="mailto:benzvi@bnl.gov">benzvi@bnl.gov</a></td>
</tr>
<tr>
<td>D. Cline</td>
<td>UCLA</td>
<td></td>
<td><a href="mailto:dcline@physics.ucla.edu">dcline@physics.ucla.edu</a></td>
</tr>
<tr>
<td>S. Geer</td>
<td>FNAL</td>
<td></td>
<td><a href="mailto:sgeer@fnal.gov">sgeer@fnal.gov</a></td>
</tr>
<tr>
<td>G. Hanson</td>
<td>UC Riverside</td>
<td></td>
<td><a href="mailto:Gail.Hanson@ucr.edu">Gail.Hanson@ucr.edu</a></td>
</tr>
<tr>
<td>D. Kaplan</td>
<td>IIT</td>
<td></td>
<td><a href="mailto:kaplan@fnal.gov">kaplan@fnal.gov</a></td>
</tr>
<tr>
<td>K. McDonald</td>
<td>Princeton University</td>
<td></td>
<td><a href="mailto:kirkmcd@Princeton.edu">kirkmcd@Princeton.edu</a></td>
</tr>
<tr>
<td>R. Palmer</td>
<td>BNL</td>
<td></td>
<td><a href="mailto:palmer@bnl.gov">palmer@bnl.gov</a></td>
</tr>
<tr>
<td>D. Summers</td>
<td>U. Mississippi</td>
<td></td>
<td><a href="mailto:summers@phy.olemiss.edu">summers@phy.olemiss.edu</a></td>
</tr>
<tr>
<td>A. Tollestrup</td>
<td>FNAL</td>
<td></td>
<td><a href="mailto:alvin@fnal.gov">alvin@fnal.gov</a></td>
</tr>
<tr>
<td>J. Wurtele</td>
<td>LBNL/UC Berkeley</td>
<td></td>
<td><a href="mailto:wurtele@physics.berkeley.edu">wurtele@physics.berkeley.edu</a></td>
</tr>
<tr>
<td>M. Zisman</td>
<td>LBNL</td>
<td>Project Manager</td>
<td><a href="mailto:mszisman@lbl.gov">mszisman@lbl.gov</a></td>
</tr>
<tr>
<td>J. Gallardo</td>
<td>BNL</td>
<td>Scientific Secretary</td>
<td><a href="mailto:gallardo@bnl.gov">gallardo@bnl.gov</a></td>
</tr>
</tbody>
</table>
## Technical Board

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alan Bross</td>
<td>Co-Spokesperson</td>
<td><a href="mailto:bross@fnal.gov">bross@fnal.gov</a></td>
</tr>
<tr>
<td>Rick Fernow</td>
<td></td>
<td><a href="mailto:fernow@bnl.gov">fernow@bnl.gov</a></td>
</tr>
<tr>
<td>Michael Green</td>
<td></td>
<td><a href="mailto:magreen@lbl.gov">magreen@lbl.gov</a></td>
</tr>
<tr>
<td>Don Hartill</td>
<td></td>
<td><a href="mailto:dlh@lns.cornell.edu">dlh@lns.cornell.edu</a></td>
</tr>
<tr>
<td>Dan Kaplan</td>
<td></td>
<td><a href="mailto:kaplan@fnal.gov">kaplan@fnal.gov</a></td>
</tr>
<tr>
<td>Harold Kirk</td>
<td>Co-Spokesperson</td>
<td><a href="mailto:kirk@bnl.gov">kirk@bnl.gov</a></td>
</tr>
<tr>
<td>Kirk McDonald</td>
<td></td>
<td><a href="mailto:kirkmcd@Princeton.edu">kirkmcd@Princeton.edu</a></td>
</tr>
<tr>
<td>Jim Norem</td>
<td></td>
<td><a href="mailto:norem@anl.gov">norem@anl.gov</a></td>
</tr>
<tr>
<td>Bob Rimmer</td>
<td></td>
<td><a href="mailto:rarimmer@jlab.org">rarimmer@jlab.org</a></td>
</tr>
<tr>
<td>Mike Zisman</td>
<td>Project Manager</td>
<td><a href="mailto:MSZisman@lbl.gov">MSZisman@lbl.gov</a></td>
</tr>
</tbody>
</table>
# Theory & Simulation Board

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. Fernow (BNL)</td>
<td>Chair</td>
<td><a href="mailto:fernow@bnl.gov">fernow@bnl.gov</a></td>
</tr>
<tr>
<td>H. Kirk (BNL)</td>
<td>Targetry Simulation Co-ordinator</td>
<td><a href="mailto:kirk@bnl.gov">kirk@bnl.gov</a></td>
</tr>
<tr>
<td>D. Neuffer (FNAL)</td>
<td>Front-End Systems Co-ordinator</td>
<td><a href="mailto:neuffer@fnal.gov">neuffer@fnal.gov</a></td>
</tr>
<tr>
<td>R. Fernow (BNL)</td>
<td>Emittance Exchange/Ring Cooler Coordinator</td>
<td><a href="mailto:fernow@bnl.gov">fernow@bnl.gov</a></td>
</tr>
<tr>
<td>S. Berg/ C. Johnstone (BNL)/(FNAL)</td>
<td>Acceleration Simulation Coordinators</td>
<td><a href="mailto:jsberg@bnl.gov">jsberg@bnl.gov</a>, <a href="mailto:cjj@fnal.gov">cjj@fnal.gov</a></td>
</tr>
<tr>
<td>A. Sessler (LBNL)</td>
<td>Theory Co-ordinator</td>
<td><a href="mailto:amsessler@lbl.gov">amsessler@lbl.gov</a></td>
</tr>
<tr>
<td>M. Berz (MSU)</td>
<td></td>
<td><a href="mailto:berz@msu.edu">berz@msu.edu</a></td>
</tr>
<tr>
<td>G. Hanson (UCR)</td>
<td></td>
<td><a href="mailto:Gail.Hanson@ucr.edu">Gail.Hanson@ucr.edu</a></td>
</tr>
<tr>
<td>E. Keil (FNAL)</td>
<td></td>
<td><a href="mailto:Eberhard.Keil@t-online.net">Eberhard.Keil@t-online.net</a></td>
</tr>
<tr>
<td>S. Koscielniak (Triumf)</td>
<td></td>
<td><a href="mailto:shane@triumf.ca">shane@triumf.ca</a></td>
</tr>
<tr>
<td>R. Palmer (BNL)</td>
<td></td>
<td><a href="mailto:palmer@bnl.gov">palmer@bnl.gov</a></td>
</tr>
</tbody>
</table>
Core Program

Targetry R&D: Mercury Intense Target Experiment (MERIT)
Co-Spokespersons: Kirk McDonald, Harold Kirk

Ionization Cooling R&D: MuCool and MICE
MuCool Spokesperson: Alan Bross
US MICE Leader: Dan Kaplan

Simulations & Theory
Coordinator: Rick Fernow

Fermilab Muon Collider Task Force
Design Studies

• Muon Collider Design and Simulation work has reached a new level of intensity this year
  ✦ Work in all areas
    ▲ Cooling
    ▲ Acceleration
    ▲ Ring and IR
    ▲ Start on Detector design considerations

• Neutrino Factory
  ✦ Start of the International Design Study for a Neutrino Factory

• First International Workshop on NF & MC
  ✦ Synergy between the Physics and R&D programs
    ▲ Hosted by the UK Science and Technology Facilities Council

The Collaboration’s Focus has shifted somewhat to the MC
Muon Collider - Motivation

Reach Multi-TeV Lepton-Lepton Collisions at High Luminosity

Muon Colliders may have special role for precision measurements.
Small $\Delta E$ beam spread – Precise energy scans

Small Footprint - Could Fit on Existing Laboratory Site
Fermilab Muon Complex - Vision
Muon Complex Evolution

1. 8 GeV SC Linac
   PROJECT X

2. Muon Collider
   Test Facility
   - Rebunch
   - R&D Hall
   - Decay
   - Cool
   - Target
   - Phase Rot.
   - & Bunch

3. Neutrino Factory Project
   - Pre-Accel
   - 0.2–0.8 GeV
   - RLA
   - (1–4 GeV)
   - 4 GeV Ring

4. 1.5 TeV
   Muon Collider
   - 6D Cooling
   - Final Cooling
   - Muon Acc
   - Collider Ring

5. 4 TeV
   Muon Collider
   - More Acc
   - Larger ring

6. EXISTING FACILITIES
Muon Collider

• Exploring 2 approaches

Palmer et al:
- RFOFO Ring
- Guggenheim
- 50-60T Solenoid Channel

Muons Inc.^
- High pressure gas-filled cavities
- Helical Cooling Channel
- Reverse Emittance Exchange
- Parametric Resonance Induced Cooling

• Ingredients needed in Collider cooling scenario include:
  - Longitudinal cooling by large factors ...
  - Transverse cooling by very large factors
  - Final beam compression with reverse emittance exchange
  - Improvements in bunch manipulations (bunch recombination?)
  - Reacceleration and bunching from low energy

*Sign up for LE MC Workshop April 21-25: http://www.muonsinc.com/Lemc2008
Neutrino Factory - IDS Starting Point

- **Proton Driver**
  - 4 MW, 2 ns bunch

- **Target, Capture & Phase Rotation**
  - Hg Jet
  - 200 MHz train

- **Cooling**
  - 30 pmm (⊥)
  - 150 pmm (L)

- **Acceleration**
  - 103 MeV → 25 GeV

- **Storage/Decay ring**
The Neutrino Factory – The first Step in Muon Complex Vision?

- Neutrino Physics is at the Forefront of HEP and will remain so for years to come
- The Big Questions:
  - What is the origin of neutrino mass?
  - Did neutrinos play a role in forming galaxies?
  - Did neutrinos play a role in birth of the universe?
  - Are neutrinos telling us something about unification of matter and/or forces?
  - Will neutrinos give us more surprises?

Big questions ≡ Hard/Important questions to answer

Is a Neutrino Factory needed in order to answer these questions?
ISS - NF Physics Reach

- What we do know is that the NF gives the best Physics Reach
  - $\text{NF} \equiv \text{PRECISION}$

\[
\sin^2 2\theta_{13}
\]

**Hierarchy**

**$\delta CP$**

**SPL:** 4MW, 1MT H$_2$OC, 130 km BL
**T2HK:** 4 MW, 1MT H$_2$OC, 295 km BL
**WBB:** 2MW, 1MT H$_2$OC, 1300 km BL

**NF:** 4MW, 100KT MIND, 4000 & 7500 BL
**BB350:** $\gamma=350$, 1MT H$_2$OC, 730 km BL
Neutrino Factory - The Physics Case

We Don't Know - But
There is a Natural Decision Point \( \approx 2012 \)

After NOvA and T2K
If \( \theta_{13} \) not seen or seen at \( 3\sigma \)
Consider New Facility

In order to make an informed decision whether or not a NF is this new facility - Will need a CDR ready at this time
This defines the R&D Program
Conclusions

We Find Ourselves in Interesting Times

- The Muon Collider as a mid-Term Priority for DOE?
  - The MC may be the way towards Lepton-Lepton collisions at the Energy Frontier
  - Will require increased effort on our part to make the technical case and increased support
    - Design and Simulation
    - Experimental verification of the many emerging new ideas
  - Synergy with the Neutrino Factory remains
    - Phased Approach to a Muon Complex looks promising

- Neutrino Factory
  - Compelling case for a precision neutrino program remains
    - With present assumptions Neutrino Factory out-performs other options. However, more is needed before concluding this is the right path
      - What the on-going Neutrino Physics program tells us
      - Must Remain an Option – IDS delivered CDR by 2012
Outlook

• As you are all aware, this has been a very tough year and next year looks scary
  ✷ We still have managed to make good progress, but this situation is certainly limiting what we can do

• There is also a great deal of uncertainty (and opportunity)
  ✷ P5 Report
  ✷ HEPAP’s Reaction to P5 Report
  ✷ DOE’s Reaction to HEPAP Reaction to P5 Report

• And There will be more reviews
  ✷ Horizontal AARD DOE review this summer