Theory and Simulation: Overview and Plans

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MUTAC Review
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Outline

• overview of simulation activities in NFMCC
• present some neutrino factory front-end results
• discuss our near-term simulation plans
NFMCC simulation activities (1)

(1) perform design simulations for future muon-based facilities
- neutrino factory
- muon collider

major facility design areas
- proton driver
- target
- front-end
- acceleration
- storage or collider ring
NFMCC simulation activities (2)

(2) related simulation efforts inside the collaboration
• MICE experiment (ionization cooling)
• MERIT experiment (liquid targetry)
• RF breakdown
• solid target shock
• small ring coolers

(3) Muons Inc
• separate effort funded by SBIR
• main focus on low-emittance muon colliders
• active collaboration within NFMCC
Study 2a

• Study 2a = design written up in APS Joint Study on the Future of Neutrino Physics (2004)
• this is an update on NFMCC Neutrino Factory Study 2 (2001) contained some BNL site-specific aspects
• new front end design
  adiabatic RF bunching and phase rotation
  simplified cooling channel
• new accelerator design with $A_T = 30$ mm rad
  dog-bone RLA
  FFAG accelerators
• Study 2b = design written up in PRSTAB 9,011001 (2006)
Recent simulation highlights

● participation in International Scoping Study
  aim to focus and consolidate neutrino factory machine options
  workshops
  CERN in September 2005
  BNL in December 2005
  KEK in January 2006

● enhanced interest in muon colliders
  successful LEMC workshop February 2006
  two new schemes based on bunch coalescence

● machine design publications in Phys. Rev. STAB
  RFOFO cooling ring  http://prst-ab.aps.org/abstract/PRSTAB/v8/i6/e061003
  Study 2a neutrino factory design  http://prst-ab.aps.org/abstract/PRSTAB/v9/i1/e011001
MUTAC meeting simulation guide

- many simulation topics will be covered at this review
- ISS neutrino factory results to date
  - comparison of neutrino factory schemes (R. Palmer)
  - $\pi$ production (H. Kirk)
  - phase rotation & bunching (D. Neuffer)
  - acceleration (S. Berg)
  - storage rings (C. Johnstone)
- muon collider
  - collider schemes with bunch merging (R. Palmer)
  - collider simulations (D. Summers)
  - Muons Inc. (R. Johnson)
- experiment-related simulations
  - targetry (R. Samulyak, N. Simos)
  - MICE (A. Blondel)
  - RF breakdown (J. Norem)
ISS front-end tasks

1. compare performance of existing neutrino factory schemes
   overview (R. Palmer)
2. evaluate implications of reduced rf gradient ←
3. search for optimized front-end systems
   optimum beam-target combination (H. Kirk)
   combined phase rotation and cooling (D. Neuffer)
   spiral cooling channel (D. Summers)
   effect of curved rf windows ←
   Study 2a missing cavity sensitivity ←
4. trade-off of cooling versus accelerator acceptance
5. evaluate suitability of windows/absorbers for 2 signs, 4 MW ←
Effect of reduced rf gradient

- what if we can’t achieve 15.25 MV/m in a magnetic field?
- operation with 2/3 gradient reduces performance by 20% compensated by adjusting amount of absorber and rf phase
- another study assumed construction gives distribution of gradients best to put highest gradients at start of channel 12 full gradient cavities restored performance loss

(J. Gallardo)
Effect of curved rf windows

- Study 2a used flat rf windows
- Actual curved windows introduce radial electric fields
  - Peak $E_R$ is 17% of peak $E_Z$ near corner of the window
- Used SuperFish fields with real curved windows
- Saw no significant change in front-end performance
  - 6% loss reducing window radius from 25 → 21 cm
  (Study 2a → MUCOOL cavity shape)
Failure of an rf cavity in Study 2a

- looked at failure of single cavities in rotator or cooling channel
- find \( \sim 3\% \) loss in \( \mu_A/p \)

(J. Gallardo)
Heating in Study 2a absorber window

- Study 2a neutrino factory design keeps both μ signs
- gives more heating in absorber windows
- this 1-D calculation shows design with conduction cooling possible for 1 MW p beam
- 3-D finite element analysis will be done
- have scheme with flowing He gas if additional cooling needed
- experimental measurements on LiH proposed at MTA

(not to scale)
Near-term plans

- neutrino factory
  - continue investigating refinements to Study 2a
  - finish work on International Scoping Study (NuFact06)
  - begin new design work based on ISS conclusions?

- muon collider
  - continue investigation of more NF-compatible schemes
    - bunch coalescence
    - spiral cooling channels and cooling rings
    - final cooling using 50 T solenoids
  - collaborate with Muons Inc on the very low emittance approach
Summary

• have active program of simulation work
• our major emphasis has been neutrino factory
  – Study 1 → Study 2 → Study 2a → Study2b → ISS
• longer term interest in a muon collider
• continued to make progress in all areas last year
• plan to continue this work in the coming year