Neutrino Factory and Muon Collider Collaboration

R&D Program

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NUFACT00 Workshop–Monterey
May 17, 2000

Outline

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- R&D activities under way
- R&D plans
- R&D budget
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Introduction

- **Muon beam R&D activities in the U.S. carried out under the auspices of Neutrino Factory and Muon Collider Collaboration (*MC*)**
  - **— broad international community involvement (National Labs, Universities, non-U.S. institutions)**
  - **— reflected in membership of Executive and Technical Boards that guide the R&D program**
    - **o these presently include members from CERN and BINP**
    - **o anticipate expansion of European representatives and addition of representatives from Japan in near future**
- ***MC* has grown to 137 members (+37 in past 6 months)**
  - **— committed to encouraging international cooperation and coordination for Neutrino Factory and Muon Collider R&D**
  - **— this workshop is excellent means to foster such working relationships**
    - **o hope to strengthen R&D ties between the various groups and minimize duplication of effort**

Introduction

- 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
    - o emittance exchange workshop scheduled at BNL in September
      - – contacts here are Rick Fernow (BNL) and Gail Hanson (IU) [talk Wednesday morning in WG-4]
- Change in R&D emphasis not without penalty
  - — initial development based on 805-MHz components
  - — now developing components sized for initial cooling channel parameters
    - o 201 MHz RF cavity, large-bore solenoid, large aperture LH_2 absorber

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 (⇒ready to begin CDR)
- Aim for "ZDR-level" understanding of a Neutrino Factory in ≈ 3–4 years
- If aim to begin CDR at the end of R&D work, it should take ≈ 2 years
  - — implies "prying loose" significant engineering support early
- This is aggressive schedule and requires an augmented funding level

R&D Activities Under Way

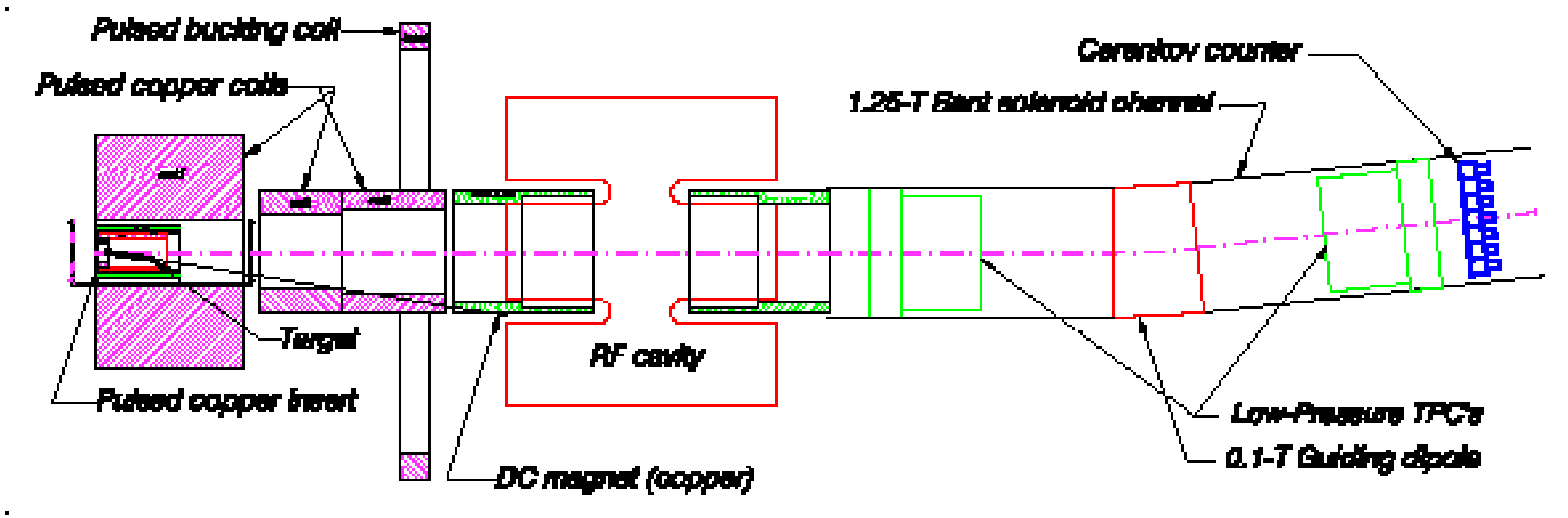
- **R&D activities fall into four main categories**
  - **simulations and theory (Organizer: Jonathan Wurtele, UCB/LBNL)**
  - **targetry experiment (E951 at BNL) to demonstrate technical feasibility of key concepts (Organizer: Kirk McDonald, Princeton U.)**
  - **MUCOOL to demonstrate feasibility of 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)**
- **Significant effort also invested in Feasibility Study activities, drawing other groups into the R&D program**

R&D Activities Under Way

- Targetry goals
  - — demonstrate performance of 1-MW 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 solid-target beam test
  - — prepare test of Hg-jet in high magnetic field at NHMFL

R&D Activities Under Way

- **Targetry experimental setup (BNL)**

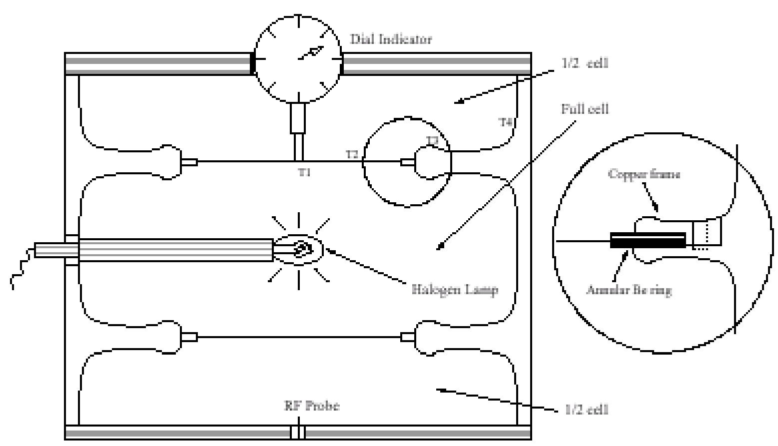


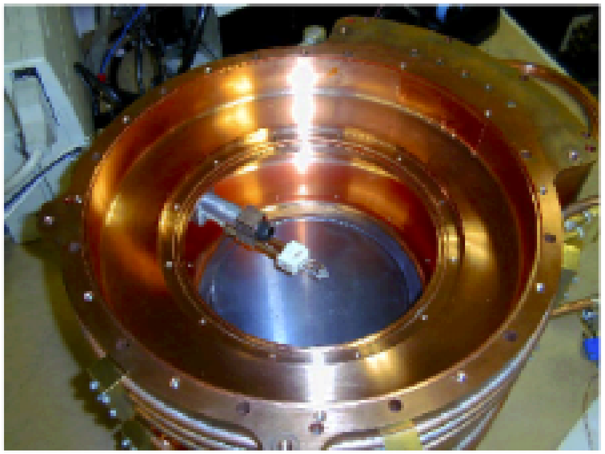
R&D Activities Under Way

- **MUCOOL goals (5-year)**
  - **— build component prototypes and bench test complete cooling cell**
  - **— test cooling channel components in a muon beam…somewhere**
    - **o assume initial portion of channel (⇒201 MHz cavities, big solenoid)**

R&D Activities Under Way

- **MUCOOL activities**
  - **805 MHz RF**
    - **fabricate high-power open cell cavity (high-gradient performance) [A. Moretti]**
    - **fabricate high-power pillbox cavity (multipactor; Be performance) [J. Corlett]**
    - **test Be window deformation [D. Li]**
    - **solenoid for testing cavities [M. A. Green]**

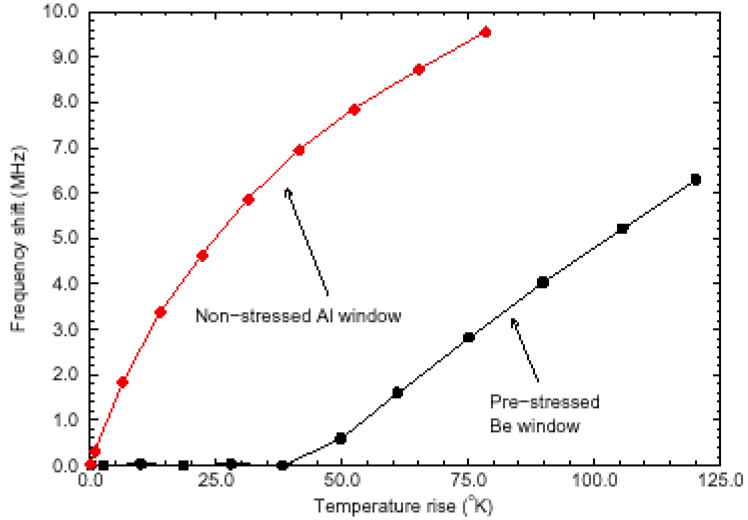




R&D Activities Under Way

— frequency shift vs. temperature rise for Al and Be windows

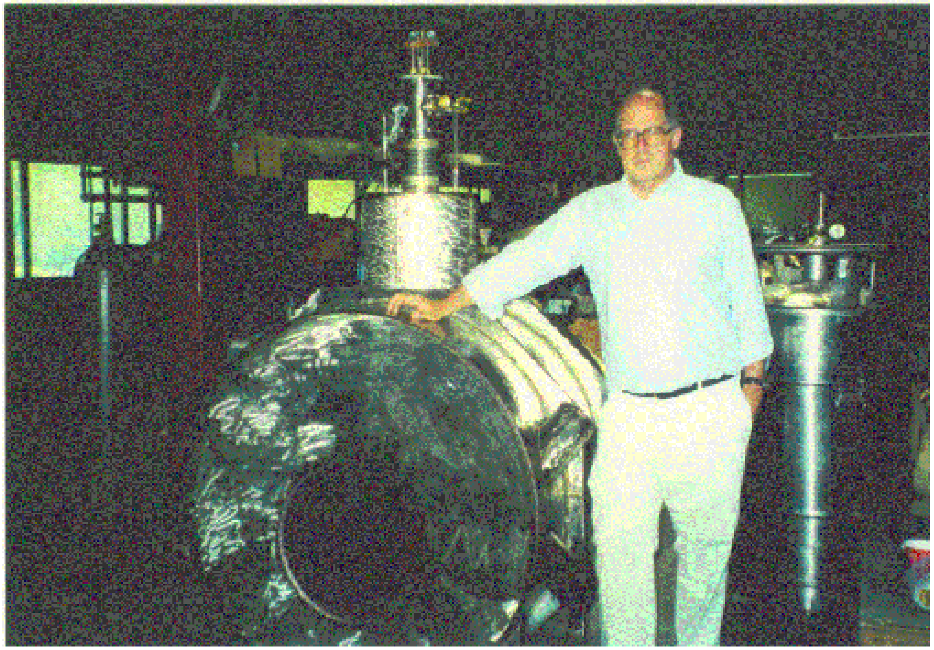
- Be (pre-stressed) shows improved performance

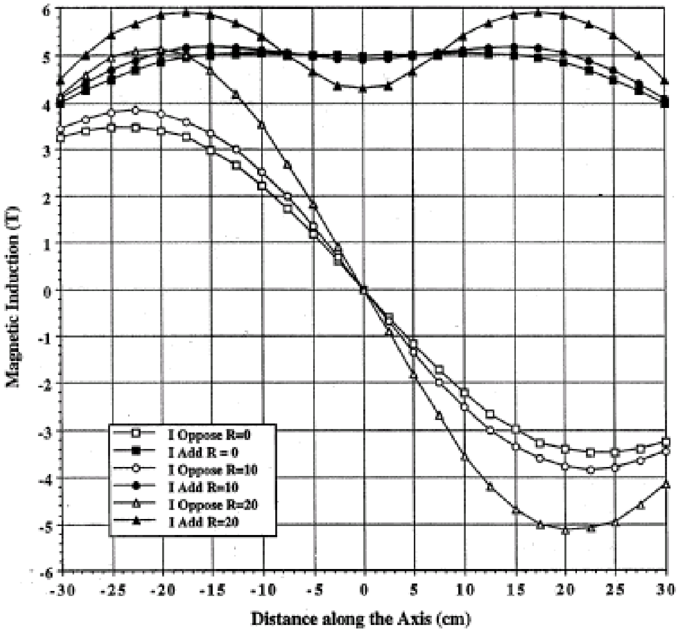


R&D Activities Under Way

— solenoid for cavity tests has been completed

- **test solenoid has two independent coils**
  - **operates in "solenoid" or "gradient" mode (5 T peak field)**
  - **meets design specifications**
- **shipped to FNAL to be installed in Lab G test area**

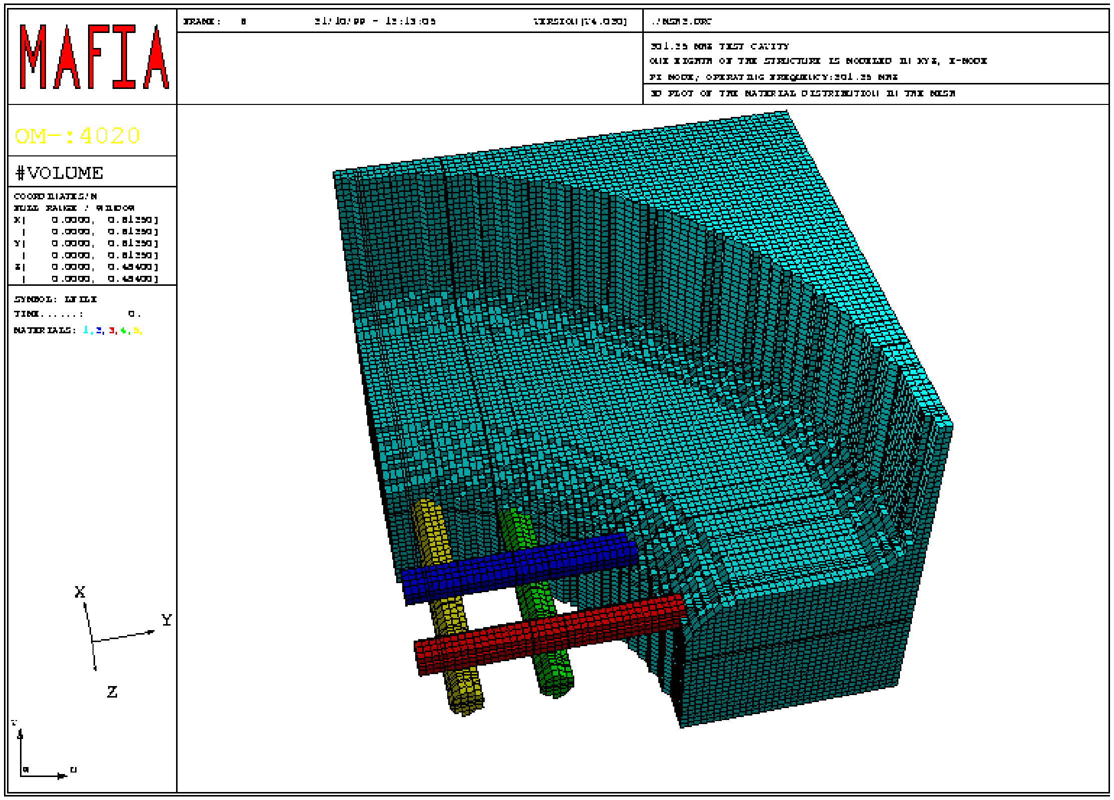




R&D Activities Under Way

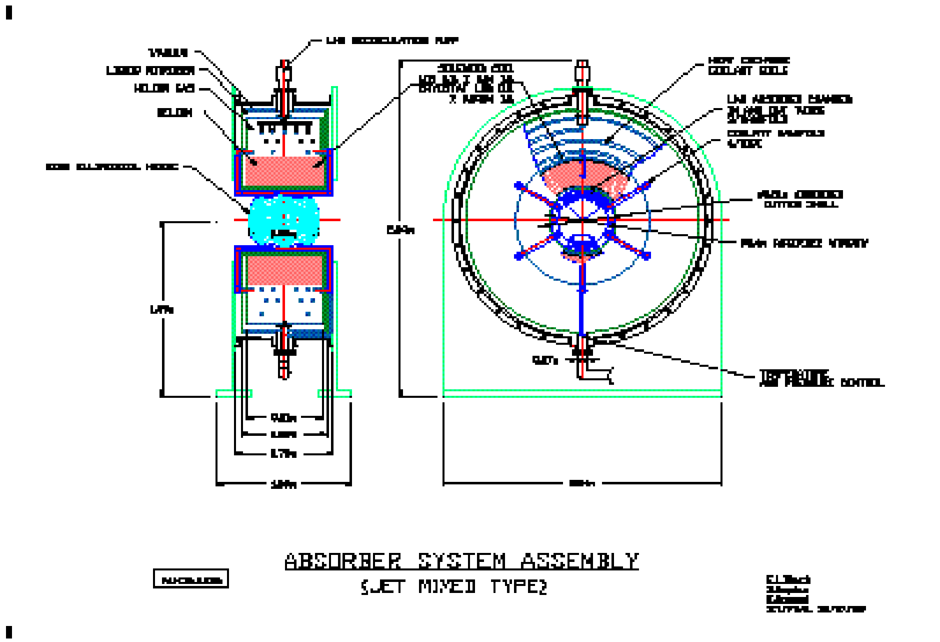
— 201 MHz RF

- **design high-power cavity suitable for cooling channel [T. Juergens]**
  - **Be windows and gridded cell being studied**



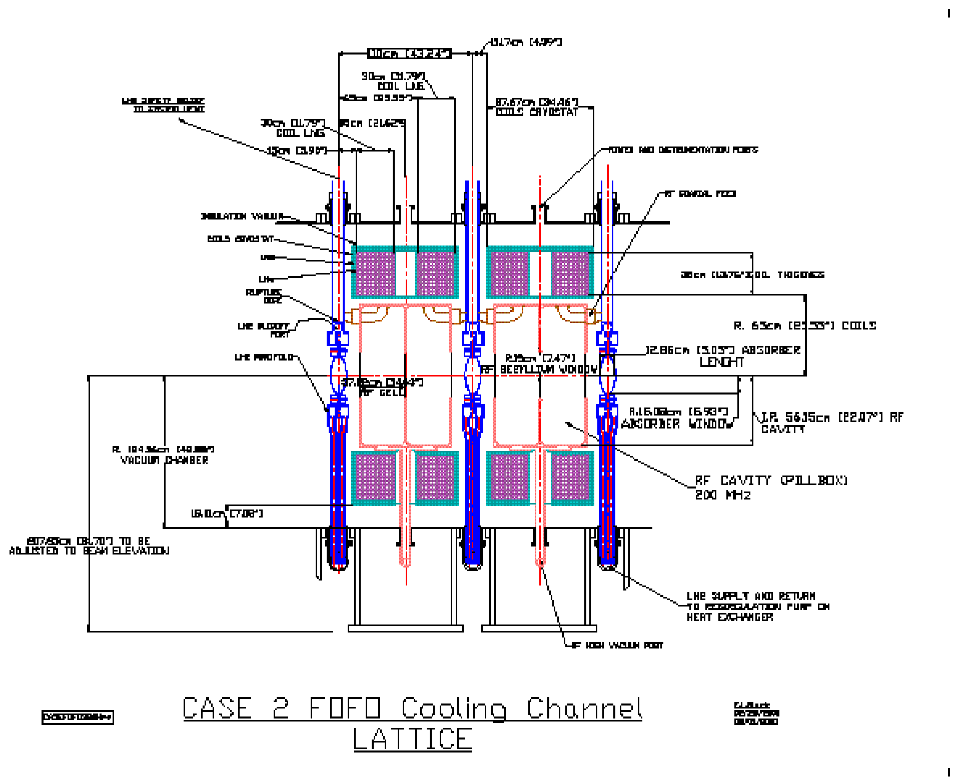
R&D Activities Under Way

— design prototype LH_2 absorber [D. Kaplan]



R&D Activities Under Way

— **example of cooling cell [E. Black]**

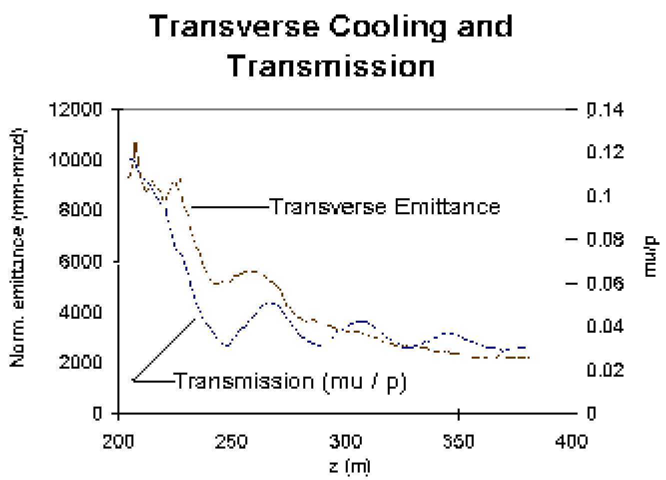


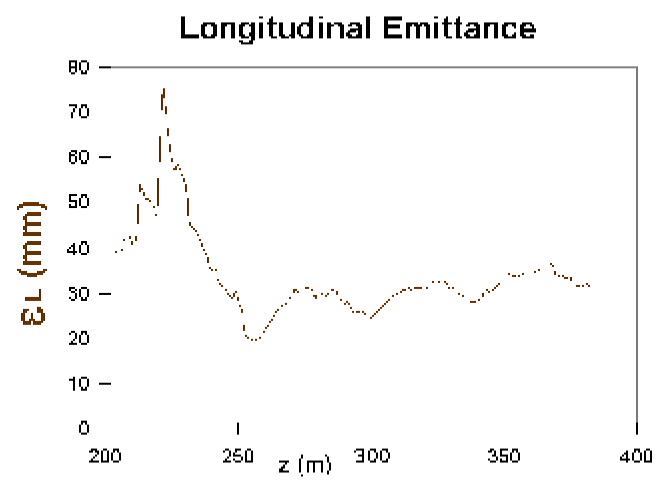
R&D Activities Under Way

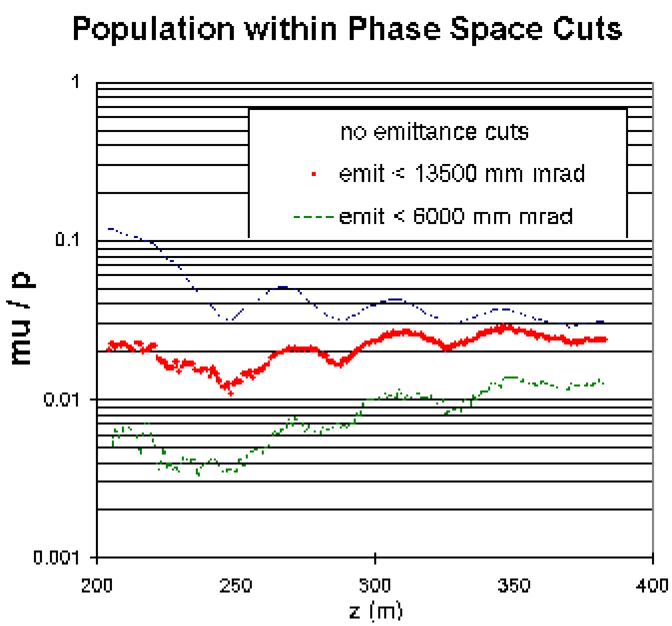
- **Simulation goals**
  - **— complete end-to-end simulations, including effects of errors**
    - **o Target/Capture, Front End, Acceleration, Storage Ring**
  - **— develop concept for emittance exchange (longitudinal £ transverse)**
- **Simulation/theory activities**
  - **— completed front-end solution with/without initial phase rotation**
    - **o still to be optimized in terms of performance**
  - **— study front-end error sensitivities**
  - **— have emittance exchange workshop**
  - **— work on acceleration system and storage ring designs**

R&D Activities Under Way

- Simulation beginning from induction linac (175 MHz RF) [C. Kim]







Lattice Properties:

Peak Field on Axis	3.4 T
Peak Field at Coils	12 T
Current Density	132 A/mm2
LH length	12.6 cm --> 13.2 cm
LH radius	15 cm --> 10 cm
Al wall thickness	400 μ --> 200 μ
Be window thickness	125 μ
Be window radius	19 cm
RF	175 MHz, 14 MV/m

total transmission, 0.03 mu/p at 2100 mm mrad

within 6000 mm mrad cut, 0.014 mu/p

momentum cut, 0.15 < Pz < 0.25 GeV/c

R&D Activities Under Way

- **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)**
    - o **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)**
    - o **expand cleaning and processing facilities**
    - o **order first test cavity**
  - — **develop test cavity and inductive inserts for proton driver**

R&D Plans

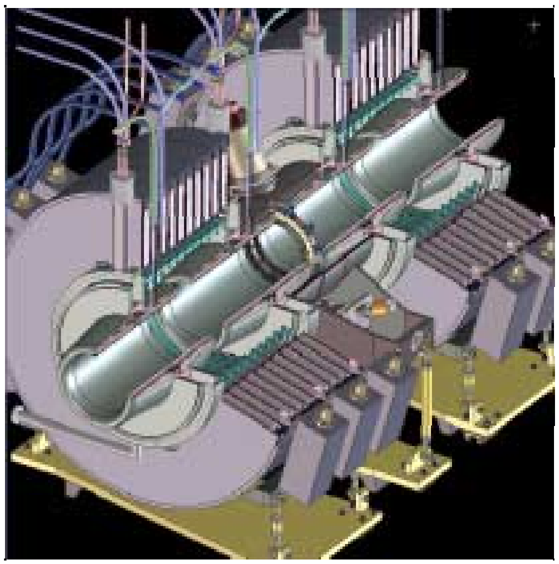
- **Simulations**
  - **Feasibility Study cooling channel performance unexpectedly poor**
    - **believed related to poorly optimized upstream beamline (too much energy spread) so upstream front end must be reexamined**
      - **must understand this to demonstrate better cooling performance**
    - **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**

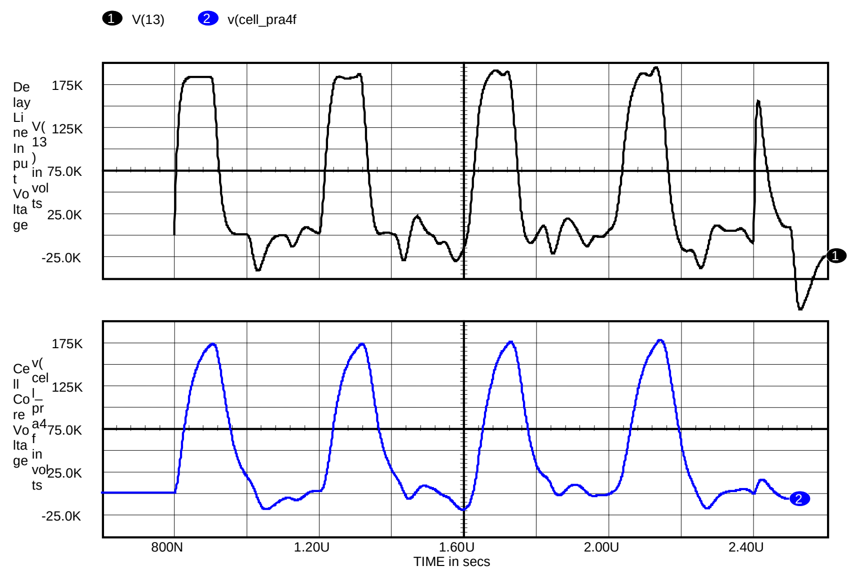
R&D Plans

- **Targetry**
  - — **solid-target effort will be augmented**
  - — **first beam tests will take place at BNL A3 line**
  - — **work on target solenoid will proceed**
- **MUCOOL**
  - — **shift focus to 201-MHz development starting next year**
    - o **cavity design is under way (delivery and testing will take 2–3 years)**
  - — **solenoid to test cavity must also be designed and fabricated**
    - o **Feasibility Study showed that these magnets are 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

- **Component development**
  - **— induction linac prototype will be developed**
    - **o verify gradient performance, pulser design with reset feature, effect of internal SC solenoid**
      - **– begin with engineering study, then fabricate prototype cell**
  - **— alternative CERN approach using RF cavities will be watched carefully**





R&D Plans

— diagnostics

- begin consideration of "operational" diagnostics
  - what is needed to transport beam, characterize beam, maintain beam properties during storage

— 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

• Proton driver

— develop and test high-gradient pulsed RF cavity

— demonstrate intense, short proton bunches ($\approx$ 1 ns)

R&D Budget

- **Work reported here is not free**
- **Funding has been increasing each year**
  - — ***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**

Summary

- *MC* R&D program is vigorous and healthy
  - — clear directions to proceed on all hardware fronts
  - — clear challenges identified for simulation group
- We will continue to coordinate closely with European and Japanese colleagues to maximize R&D output and minimize duplication
  - — a shared muon beamline would be a valuable resource
- *MC* membership and funding have both grown at a healthy rate in the past few years
  - — involvement of NSF institutions and groups strengthens the effort
  - — involvement of international institutions and groups would strengthen the muon-beam R&D effort even more
- We look forward to these positive trends continuing