Neutrino Factory and Muon Collider Collaboration (MC) R&D Status and Plans

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FNAL HEPAP Meeting
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Outline

- History
- Collaboration organization
- Neutrino Factory overview
- R&D program goals
- R&D activities and plans
- R&D funding needs
- Summary

History

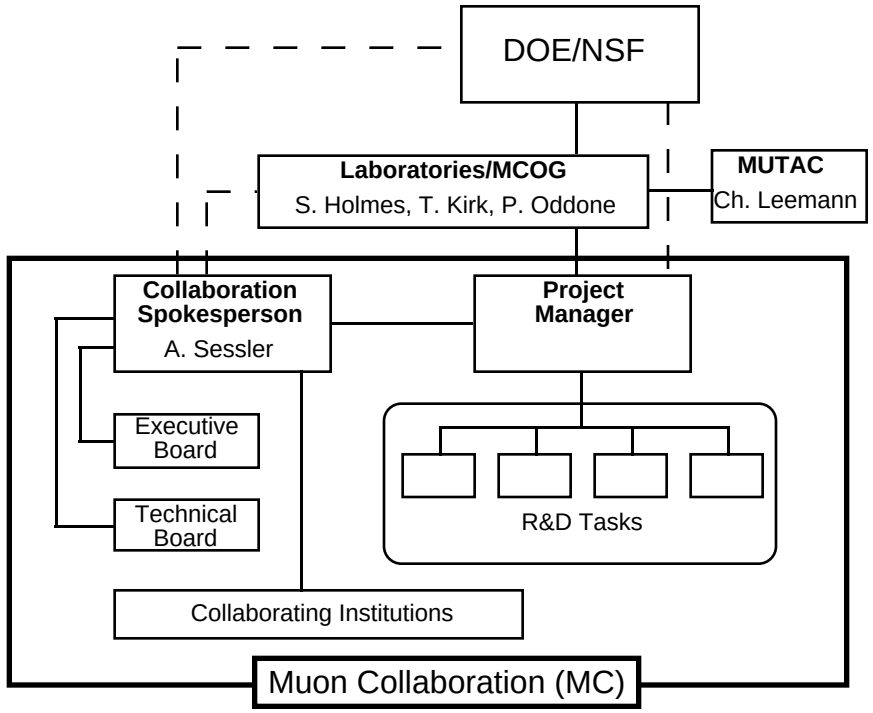
- **History of Muon Collider**
  - **concept of muon collider is not new [Tinlot (1960); Budker (1969); Skrinsky (1971); Neuffer (1979)]**
  - **high-luminosity concepts more recent [Neuffer (1985); Palmer (1994)]**
  - **strong physics interest led to Collaboration (1995) to plan and carry out R&D work aimed at a Muon Collider [see Snowmass report, BNL-52503, Fermilab Conf.-96/092, LBNL-38946, (1996) ed. J. Gallardo; Ankenbrandt *et al.* , Phys. Rev. ST AB 2, 081001 (1999)]**
  - **identified as promising in report of 1998 HEPAP (Gilman) Subpanel on Future of HEP**
- **History of Neutrino Factory based on muon storage ring**
  - **using muon beam from SR: Koshkarev, CERN/ISR-DI/74-62 (1974)**
  - **using muon ring for intense neutrinos from Geer; Phys. Rev. D 57, 6989 (1998)**
- **Collaboration members played seminal role in advancing these ideas**

History

- Many subsequent workshops and meetings held or planned
  - Front End Physics of a Muon Collider, Fermilab (1997)
  - Potential for Neutrino Physics at Future Muon Colliders, BNL (1998)
  - Meeting in Berkeley (April, 1999)
  - Collaboration meeting in St. Croix (May, 1999)
  - NUFACT99 in Lyon (July, 1999), sponsored by ICFA/ECFA http://lyoinfo.in2p3.fr/nufact99/navnu99.html
  - *MC* meeting, Catalina, May 17–19, 2000 and NUFACT00, Monterey, May 22, 2000

Collaboration 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**



Collaboration Organization

- ***MC*** **has broad international community involvement (National Labs, Universities, non-U.S. institutions)**

  — reflected in Board membership

- ***MC*** **has grown (to 133 members) and is ready to expand efforts on Neutrino Factory R&D**

Executive Board:

J. Gallardo, BNL (Secretary)
R. Palmer, BNL (Associate Spokesperson)
S. Geer, Fermilab
A. Tollestrup, Fermilab (Associate Spokesperson)
A. Sessler, LBNL (Spokesperson)
J. Wurtele, LBNL/UC-Berkeley
D. Summers, U. Mississippi
K. McDonald, Princeton U.
D. Cline, UCLA
D. Kaplan, Illinois Institute of Technology
A. Skrinsky, BINP

Technical Board:

A. Sessler, LBNL (Spokesperson)
J. Corlett, LBNL
S. Geer, Fermilab
N. Holtkamp, Fermilab
C. Johnson, CERN
H. Kirk, BNL
K. McDonald, Princeton U.
J. Miller, NHMFL
J. Norem, ANL
R. Palmer, BNL
M. Tigner, Cornell U.
J. Wurtele, LBNL/UC-Berkeley
M. Zisman, LBNL (Observer)

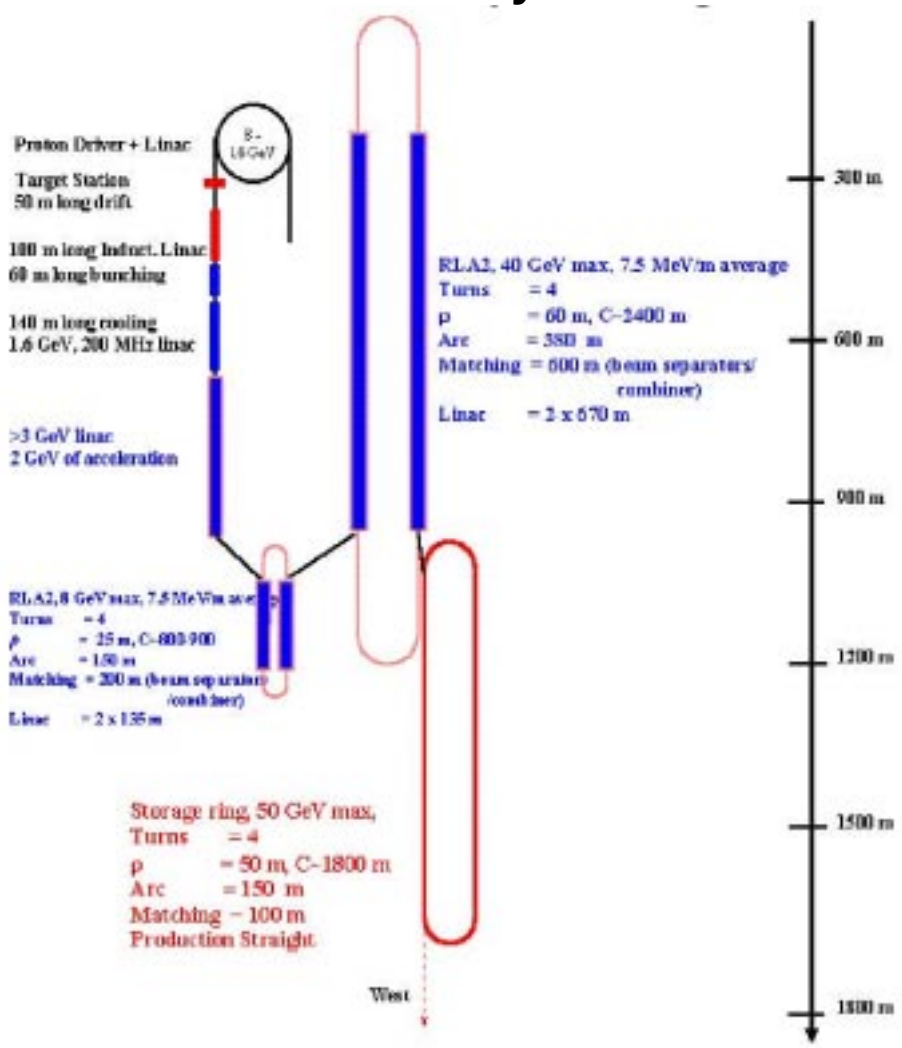
Neutrino Factory Overview

- **Neutrino Factory comprises these sections (*MC* doing R&D on all)**
  - **Proton Driver (primary beam on production target)**
  - **Target and Capture (create pions and capture into decay channel)**
  - **Phase Rotation (induction linac to reduce energy spread of bunch)**
  - **Cooling (reduce transverse emittance of beam)**
  - **Acceleration (raise energy from 200 MeV to 20–50 GeV with RLAs)**
  - **Storage Ring (store muon beam for ≈1000 turns; optimize yield with long straight section aimed in desired direction)**

    NOTE: design dominated by diffuse phase space and rapid decay of muons
- ***MC* participating in Neutrino Factory Feasibility Study at Fermilab (N. Holtkamp, D. Finley); brings additional groups into the endeavor**
  - **identify for *MC* R&D program technologies required for feasibility demonstration (credibility) and associated with "cost drivers" (need to improve technology)**
- **Expect to participate similarly in future feasibility study at BNL**
- **Envision summary of feasibility studies at Snowmass '01**
- **Not an easy project, but no fundamental problems found**

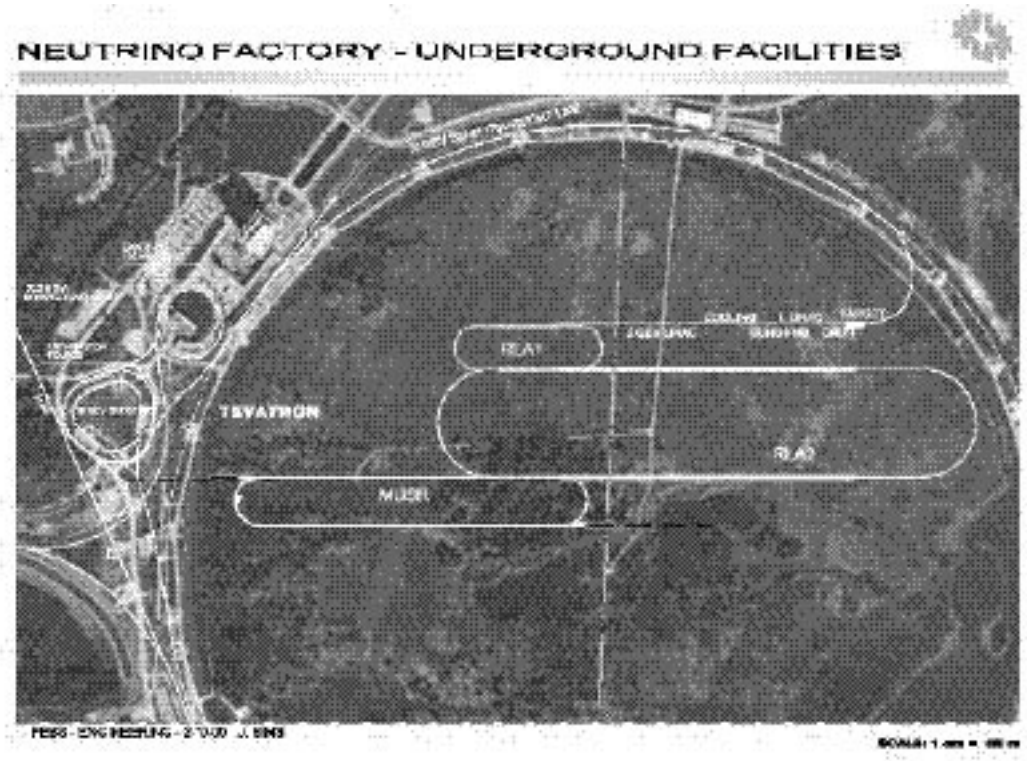
Neutrino Factory Overview

- **Generic elements of a neutrino factory**



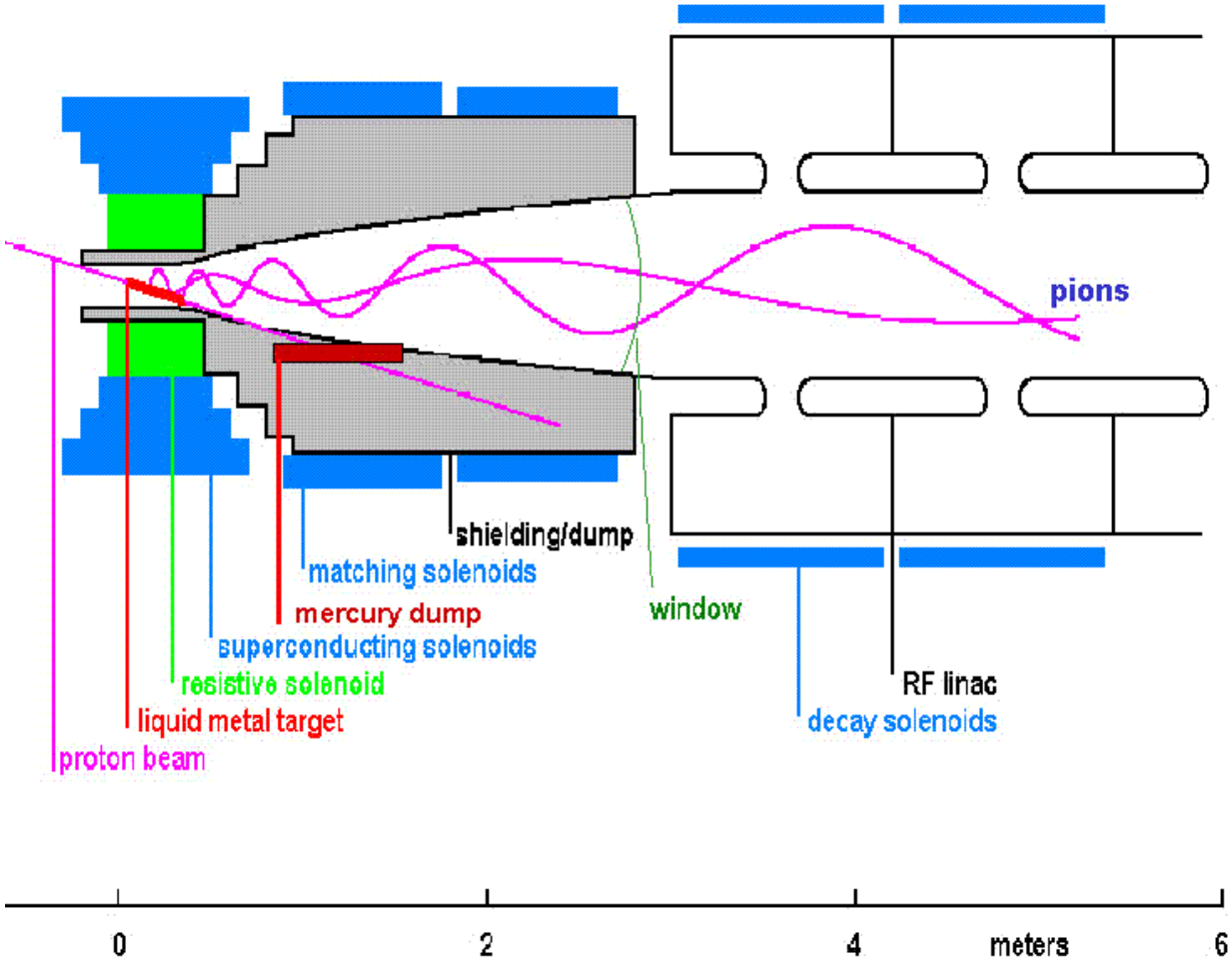
Neutrino Factory Overview

- **Footprint on Fermilab site**



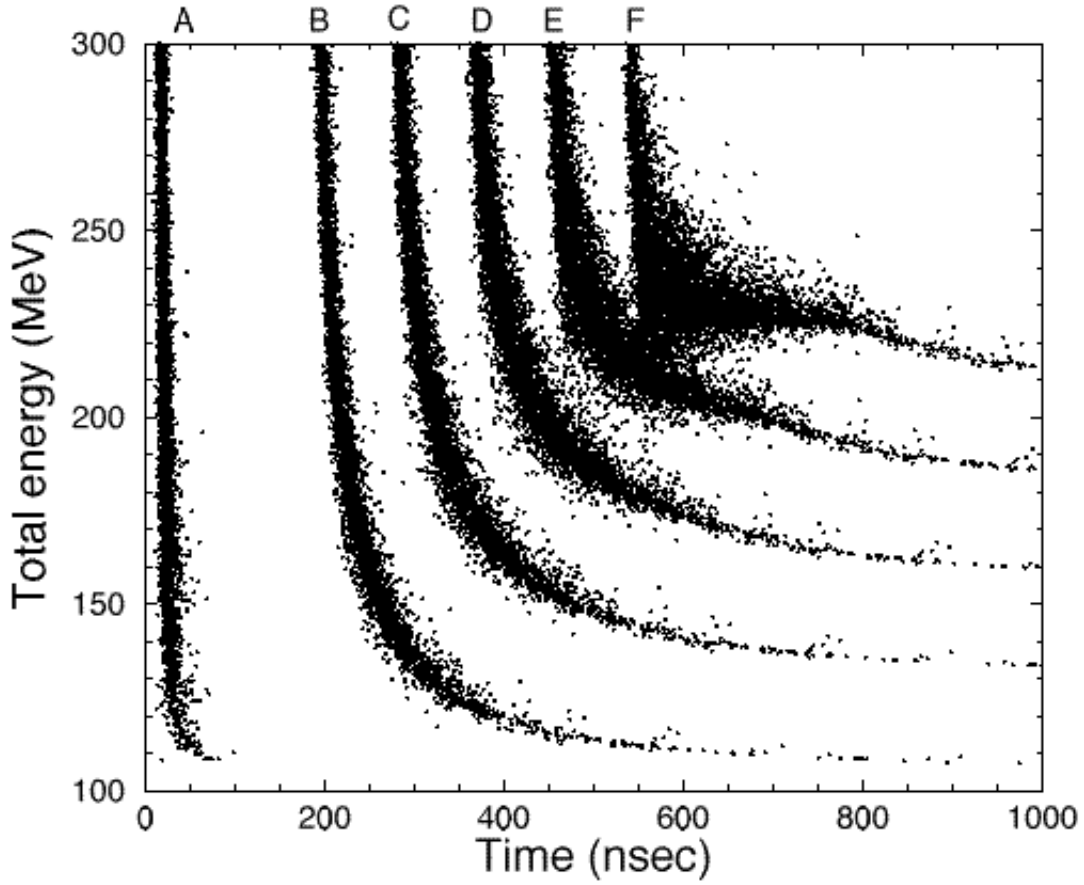
Neutrino Factory Overview

- **Target and capture section**



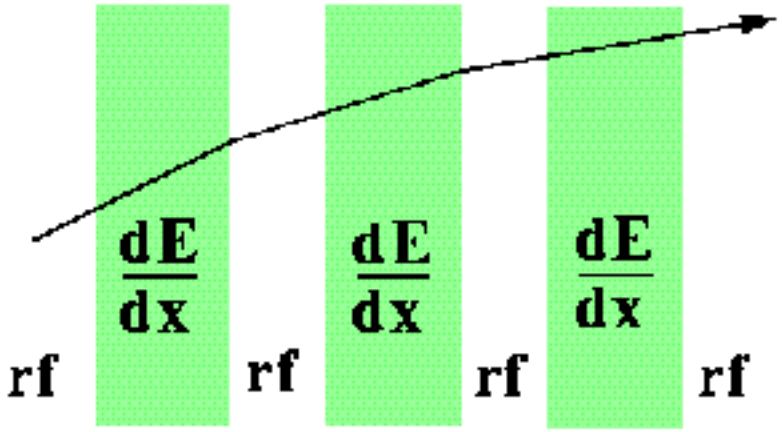
Neutrino Factory Overview

- **Effect of phase rotation on energy spread of muon bunch**
  - **A is after target; B is after drift; C–E inside induction linac; F is linac exit**



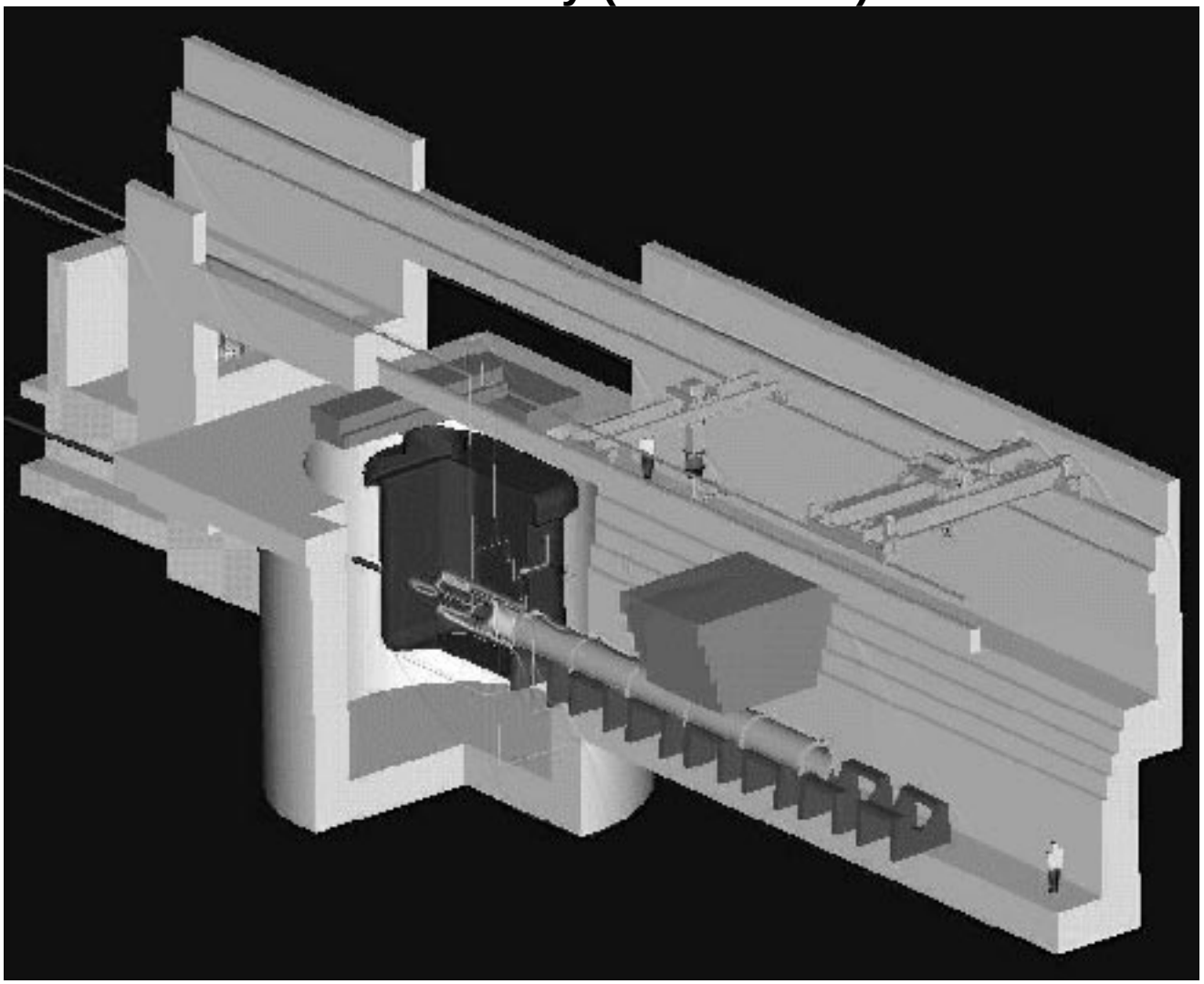
Neutrino Factory Overview

- **Ionization cooling…analogous to radiation damping**



Neutrino Factory Overview

- **Target station of Neutrino Factory (from ORNL)**



R&D Program Goals

- Define where we want to be 5 years from now in all R&D areas, then work backwards to see what's needed to get there ($ 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 ($\Rightarrow$ ready to begin CDR)
- If aim to begin CDR at the end of R&D work, it should take $\approx$2 years
  - implies "prying loose" significant engineering support early
- This aggressive schedule requires an augmented funding level
  - HEPAP endorsement to funding agencies and Laboratory management is needed to maintain our momentum

R&D Activities and Plans

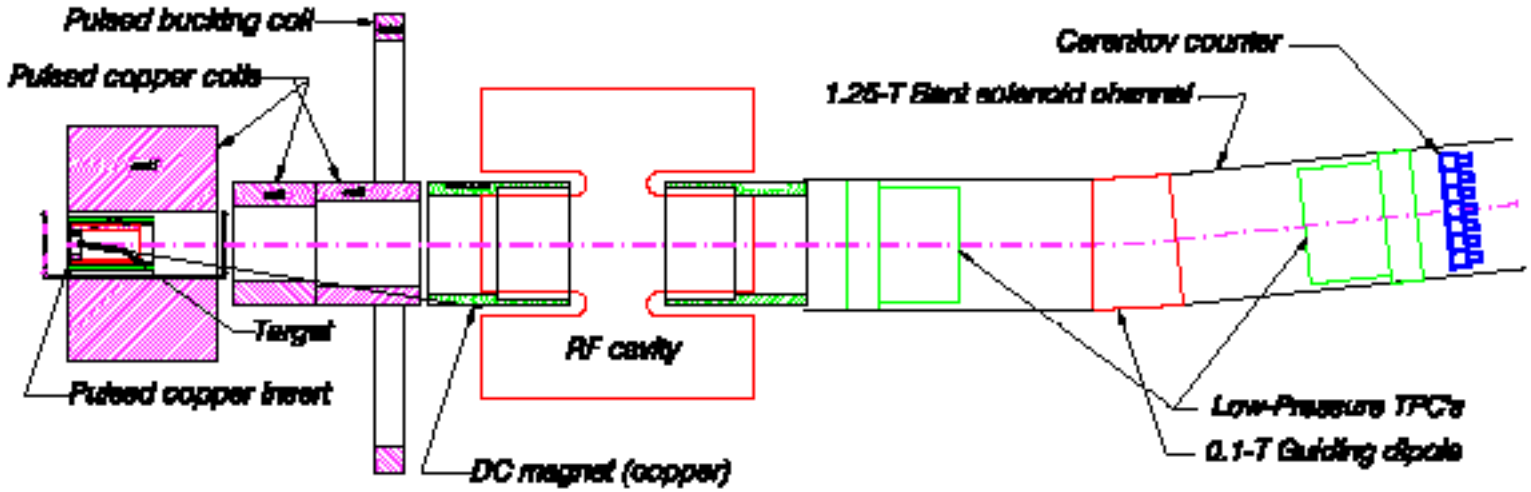
- **R&D activities fall into four main categories**
  - **simulations and theory (Organizer: Jonathan Wurtele, UCB/LBNL)**
  - **targetry experiment (E951 at BNL) to demonstrate technical feasibility of key concepts (Organizer: Kirk McDonald, Princeton U.)**
  - **cooling experiment (MUCOOL) to demonstrate feasibility of required components and cooling effects (Organizer: Steve Geer, Fermilab)**
  - **special hardware components development, e.g.,**
    - **200 MHz SC RF cavities for acceleration section (JLab, Cornell)**
    - **induction linac with internal SC solenoid for phase rotation (LBNL)**
    - **low-frequency, high gradient cavity and power source for proton driver (Fermilab, BNL)**
    - **20 T SC solenoid system (NHMFL)**
- **Significant effort also invested in Feasibility Study activities, drawing other groups into the R&D program**

R&D Activities and Plans

- **Targetry goals (5-year)**
  - **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 [FY00]**
  - **thermal calculations to assess mechanical behavior of target [FY00]**
  - **component development for experiment [20-T pulsed solenoid, 70 MHz high-gradient RF cavity] [FY01]**
  - **initial solid-target beam test [FY01]**
  - **test of Hg-jet in high magnetic field at NHMFL [FY01]**
  - **complete high intensity proton beam tests (10^{14} ppp) [FY02]**

R&D Activities and Plans

- **Targetry experimental setup (BNL)**

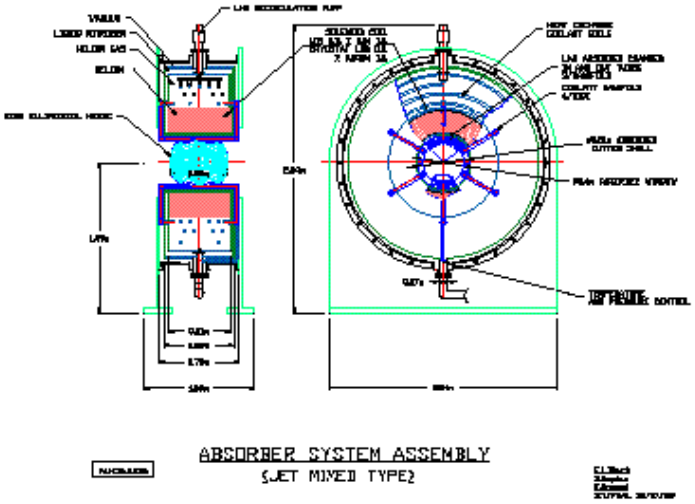


R&D Activities and Plans

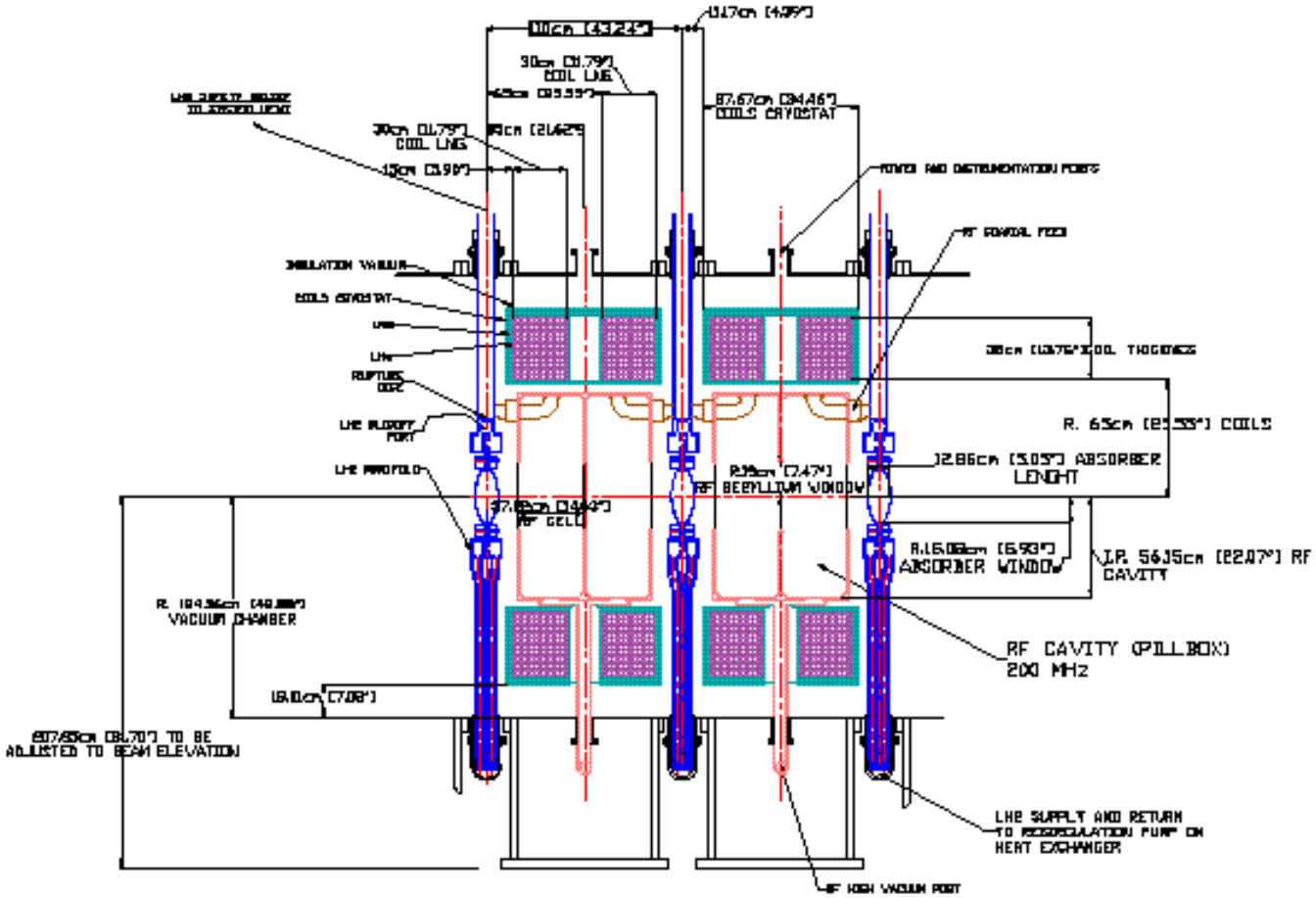
- MUCOOL goals (5-year)
  - create FNAL muon test beam facility (need MCOG buy-in + Lab support)
  - build component prototypes and bench test complete cooling cell
  - define, realistically simulate, carry out phased experiment ultimately showing significant cooling (ideally 2x emittance reduction)
    - assume initial portion of channel (⇒ 201 MHz cavities, big solenoid)
    - verify multiple scattering and energy straggling estimates, test one cell, then replicate
- MUCOOL activities
  - 805 MHz RF
    - high-power pillbox cavity (multipactor; Be performance) [FY00]
    - test solenoid [FY00]
    - high-power open cell cavity (high gradient performance) [FY00]

R&D Activities and Plans

- 201 MHz RF
  - high-power cavity suitable for cooling experiment [FY01]
    - Be windows and gridded cell being studied [choose FY00]
  - solenoid (≈4 T) [test June '01]
  - high-power klystron or other power source [FY01]
- test prototype LH_2 absorber with beam [FY01]



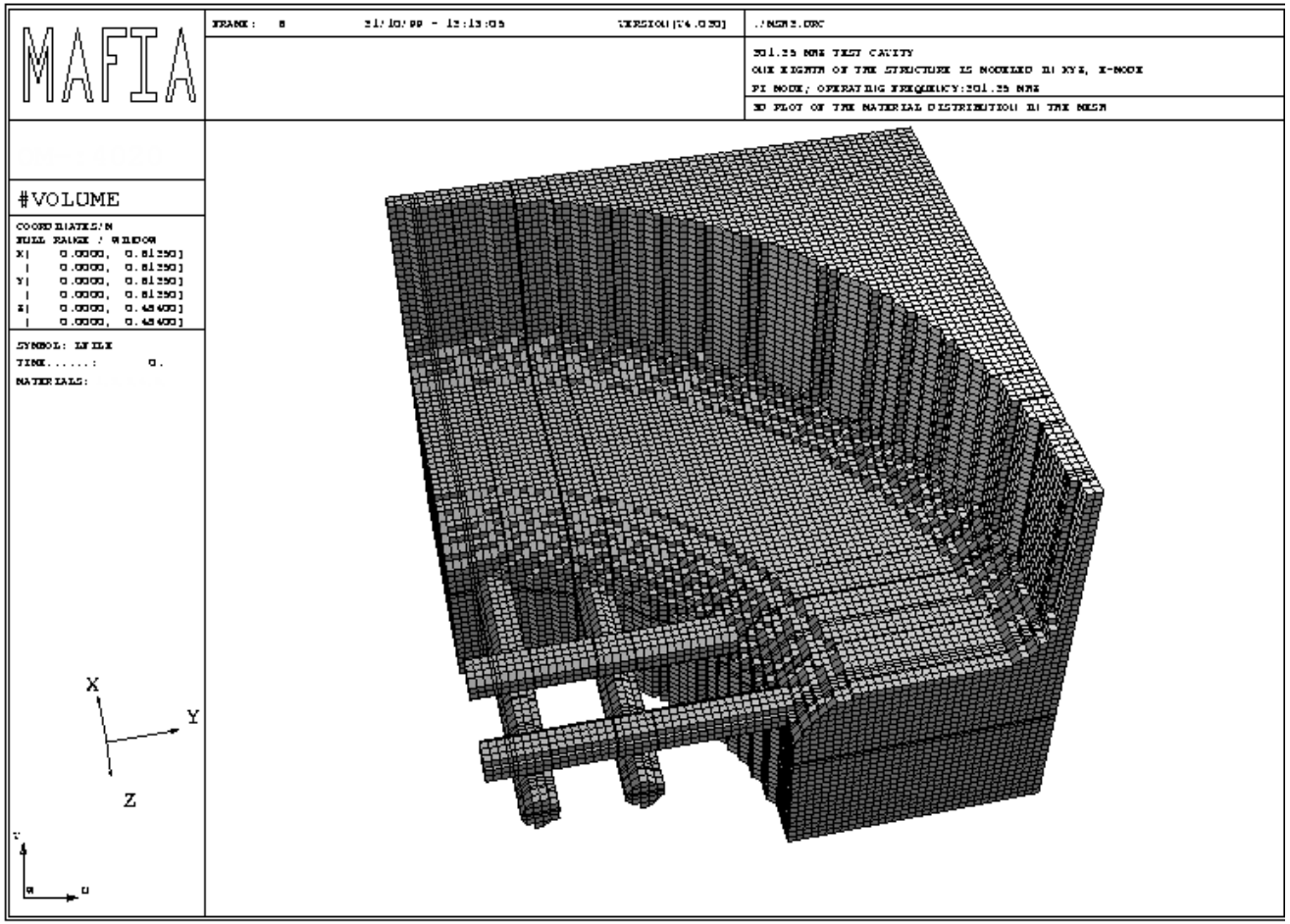
R&D Activities and Plans



CASE 2 FOFO Cooling Channel
LATTICE

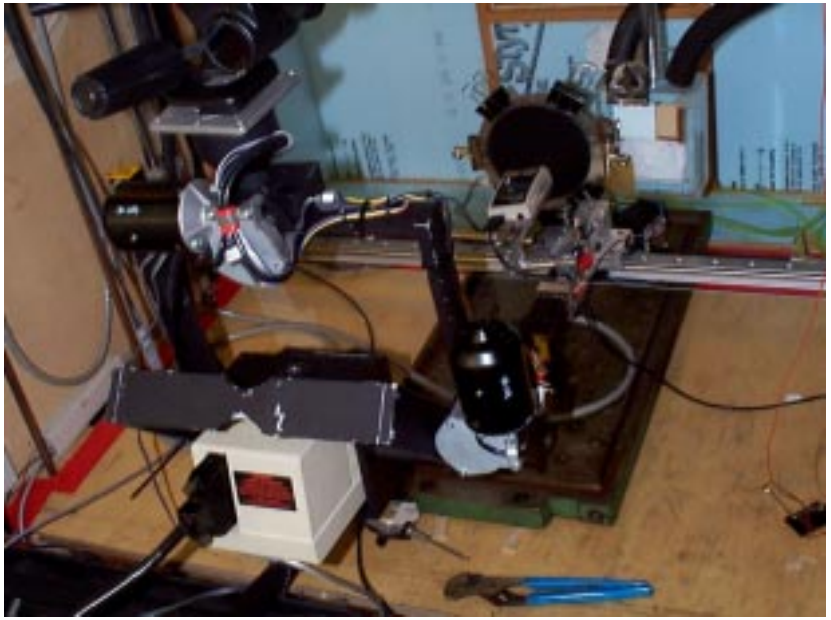
R&D Activities and Plans

- **Gridded cavity model**



R&D Activities and Plans

- **Be window thermal testing**



R&D Activities and Plans

- **Be window ready for low-power RF testing**

R&D Activities and Plans

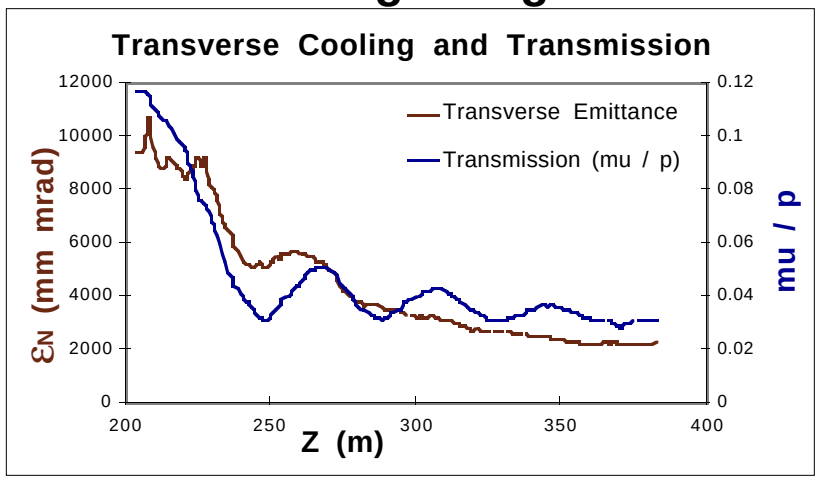
- **Low-power Be window test cavity at LBNL**

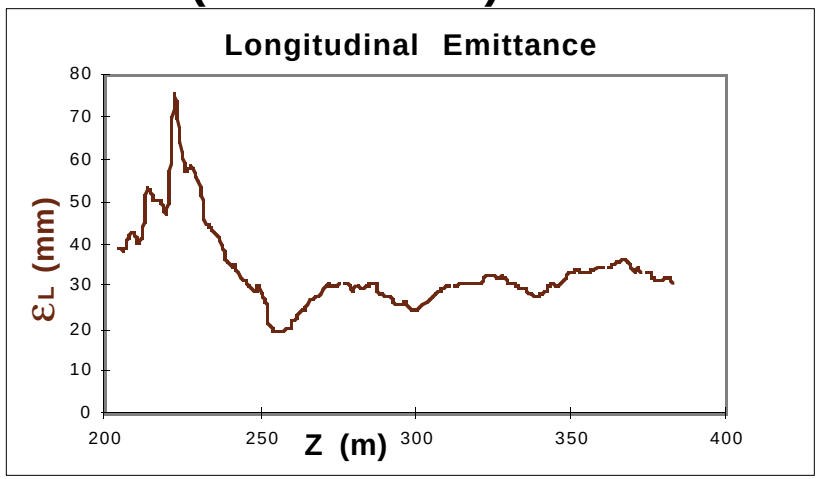
R&D Activities and Plans

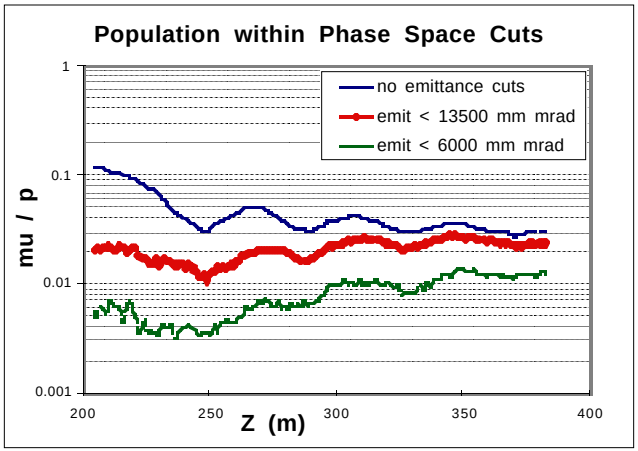
- **Simulation goals (5-year)**
  - **complete end-to-end simulations, including effects of errors**
    - **Target/Capture, Front End, Acceleration, Storage Ring**
  - **develop concept for emittance exchange (longitudinal ↔ transverse)**
- **Simulation/theory activities**
  - **completed front-end solution with/without initial phase rotation**
    - **still to be optimized in terms of performance**
  - **study front-end error sensitivities [December ’00]**
  - **study effects that might limit high-intensity in proton driver [FY00]**
  - **have emittance exchange workshop [Fall ’00]**
  - **extend particle simulations through acceleration system [FY01]**
  - **complete storage ring design [FY01]**

R&D Activities and Plans

- **Simulation beginning from induction linac (175 MHz RF)**







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

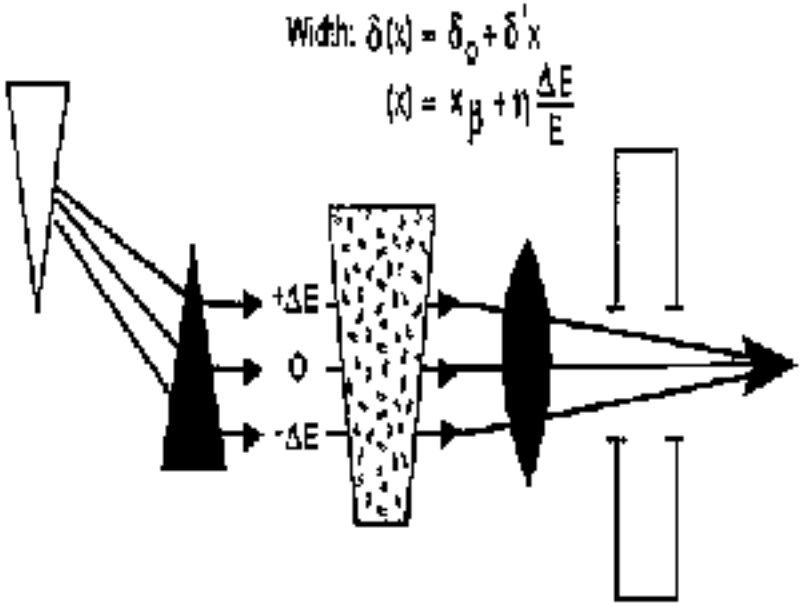
total transmission, 0.03 mu/p at 2100 mm mrad

within 6000 mm mrad cut, 0.014 mu/p

momentum cut, 0.15 < Pz < 0.25 GeV/c

R&D Activities and Plans

- **Schematic view of emittance exchange**

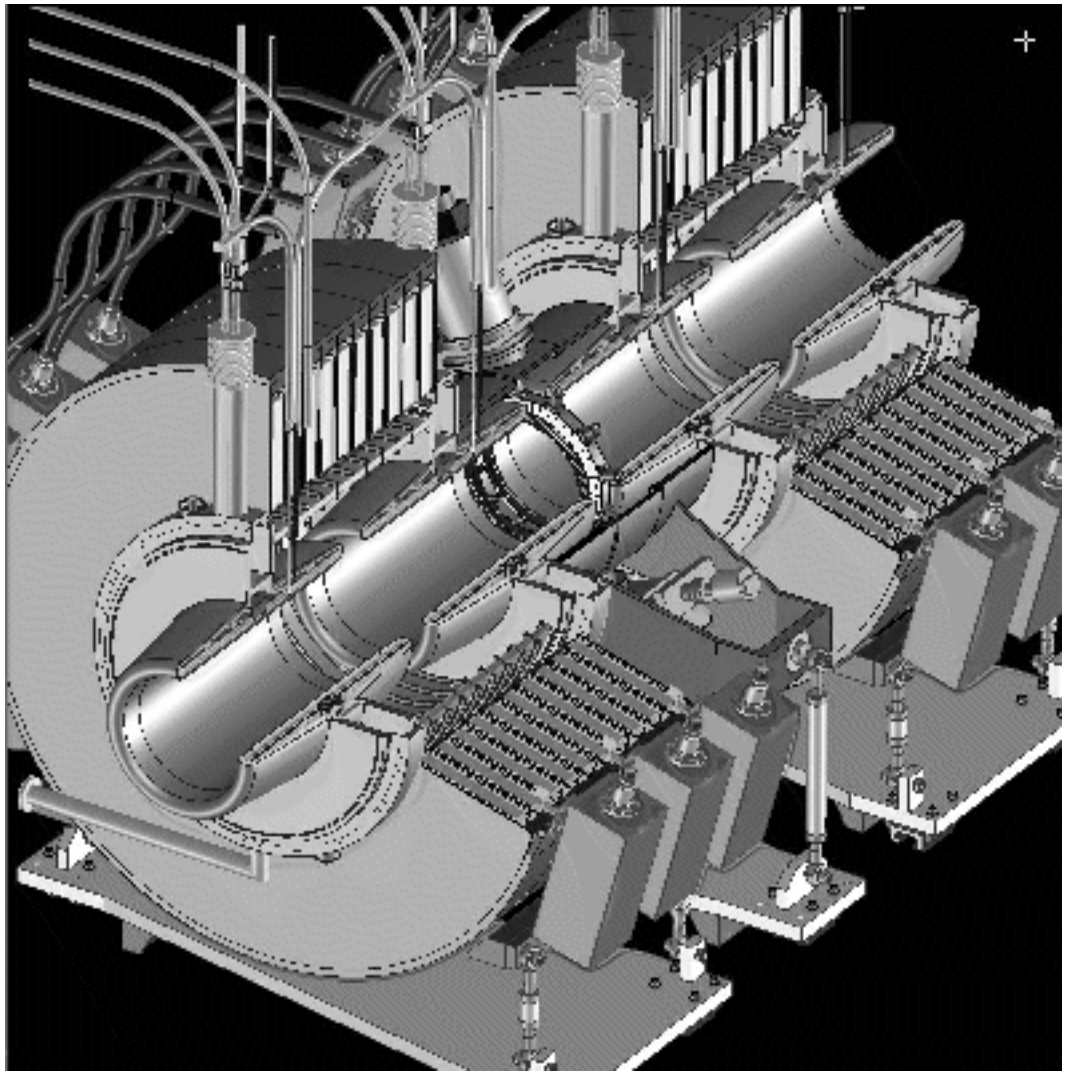


R&D Activities and Plans

- **Component development goals (5-year)**
  - **demonstrate high-gradient 200 MHz SCRF cavity (acceleration)**
  - **demonstrate induction linac cell with internal SC solenoid operating at 2 MV/m (phase rotation)**
    - **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**
  - **build and test prototype induction linac + solenoid module [FY01]**
  - **design and test 200- and 400-MHz SCRF cavities [FY02]**
  - **identify storage ring components needing R&D and/or prototyping, e.g., superconducting magnets [FY02]**

R&D Activities and Plans

- **Induction linac cell with internal SC solenoid**



R&D Funding Needs

- **FY00 funding distribution**

Institution	MUCOOL Expt. & Generic Studies	TARGETRY Expt.	SALARY	RESERVE	TOTAL ($K)
BNL		1818			1818
FNAL	1229		90		1319
LBNL	438	75		15	528
ANL	25	80	200		305
IIT	157				157
Mississippi	68				68
Princeton	80	100	60		240
UCB			120		120
UCLA	50		80		130
TOTAL ($K)	**2047**	**2073**	**550**	**15**	**4685**

R&D Funding Needs

- **Anticipated R&D funding**
  - **in process of refining costs and schedules for 5-year period (evaluation not complete)**

	Collaboration ($M)	Base Program ($M)
FY99	2.2	2.8
FY00	4.7	≈5
FY01	≈16	
FY02	≈22	
FY03	≈32	
FY04	≈32	

- **Breakdown (anticipate both DOE and NSF contributions)**
  - **Targetry: $2–5M/yr**
  - **Cooling: $2→20M/yr**
  - **Simulations: $1–2M/yr**
  - **Components: $2→5M/yr**

Summary

- ***MC*** **has made good progress in R&D activities and feasibility studies aimed at initial goal of νF**
  - **— hardware is being built and tested!**
- ***MC*****, MCOG, sponsoring Labs, funding agencies working together to maintain focused, well-managed R&D program (internationally coordinated)**
- **Must get long lead time items under way**
  - **— muon beam test facility at FNAL**
  - **— high-power RF sources for MUCOOL experiment**
    - **significant "up-front" costs for industrial development**
- **Need aggressive program of component development**
  - **— SC solenoid, SCRF cavity, induction linac module,…are expensive**
- **We hope HEPAP helps make this a priority with funding agencies**
- **More support ($) needed to make R&D progress in a timely way**