Fermilab's Muon Collider Task Force: Status and Plans

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Fermilab

Muon Colider Task Force

- Charge from FNAL Director P.Oddone (July 2006):
  - "…the Muon Collider represents a possible long term path for extending the energy frontier in lepton collisions beyond 1 TeV.
  - "…Task Force to develop a plan for an advanced R&D program aimed at the technologies required to support the long term prospects of a Muon Collider. "
  - requested for September 2006: A report outlining a plan for developing the Muon Collider concept based on recent ideas in the realm of ionization cooling
    - ➢ Initial proposal delivered Sep.2006
  - "…to initiate the Muon Collider study, including the associated cooling channel study and development program, in 2007."
    - ➢ 2007 report and R&D plan in FNAL-TM-2399, Dec'07

Muon Colider Task Force

https://mctf.fnal.gov

FERMILAB-TM-2399-APC 10-Jan-08

MUON COLLIDER TASK FORCE REPORT

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March 2008

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Welcome to The Muon Collider Task Force Web Home

by plone — last modified 2008-01-11 11:15

Muon Colliders offer a possible long term path to lepton-lepton collisions at center-of-mass energies exceeding 1 TeV. In July 2006, Fermilab Director Pier Oddone requested the creation of a Task Force to " develop a plan for an advanced R&D program aimed at the technologies required to support the long term prospects of a Muon Collider". The Muon Collider Task Force (MCTF) produced an initial plan in the Fall of 2006, and began to execute the plan, as resources permitted, in 2007. A report summarizing of the first year of activities was produced at the end of 2007. The MCTF activities complement the overall Neutrino Factory and Muon Collider R&D being pursued by the national *Neutrino Factory and Muon Collider Collaboration* (NFMCC), with an emphasis on those R&D activities which utilize the Fermilab infrastructure and resources.

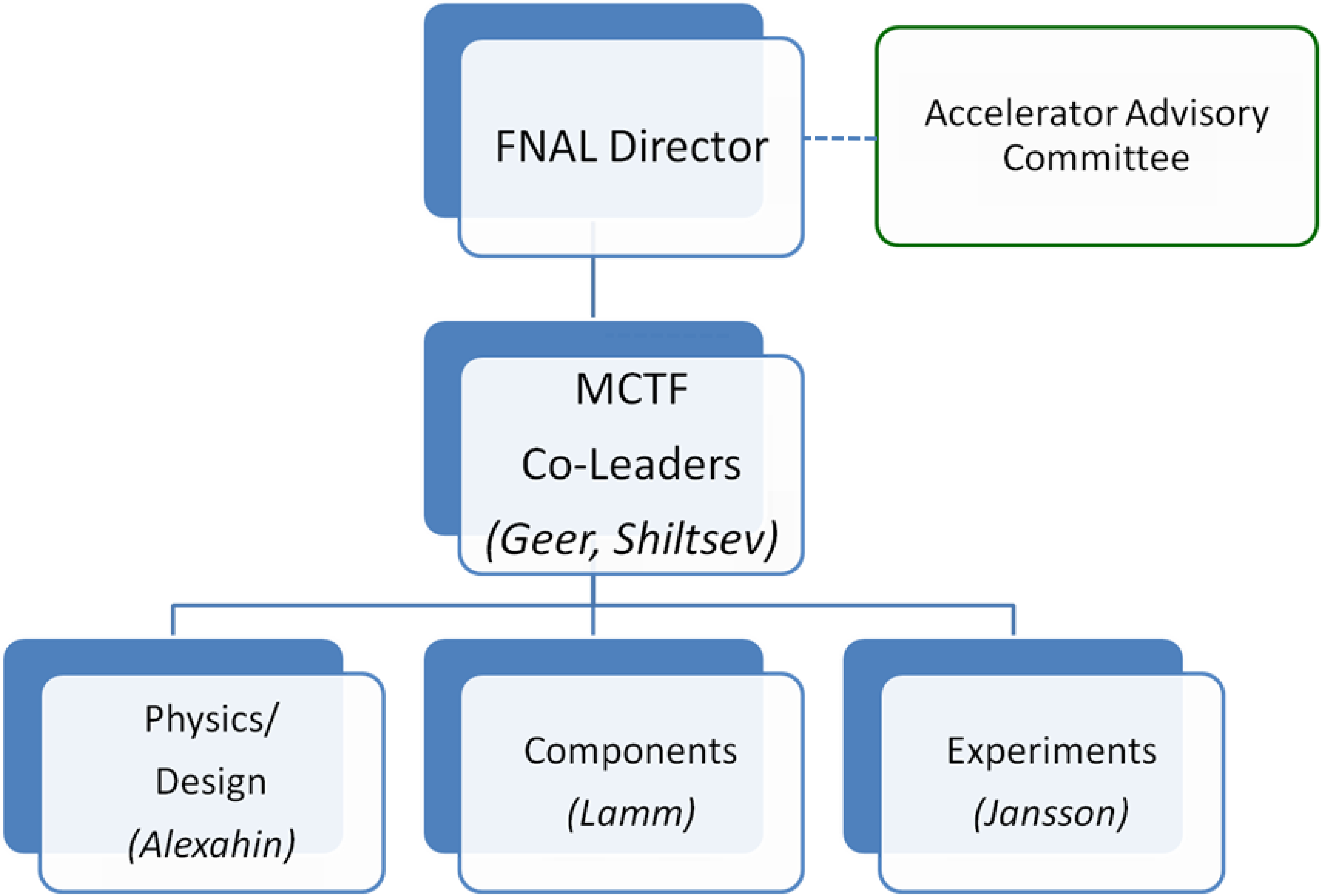
Important Documents

- MCTF 2007 Report (FERMILAB-TM-2399-APC)
- The Muon Collider Task Force R&D Proposal
- The Muon Collider Task Force Charge
- Muon Collider Vision Document

Accelerator Division Document Database

See all the documents in the DocDB that relate to MCTF (password required).

MCTF Organization



Muon Collider Design Options

Low emittance option

Very challenging option so far:

- need convincing ideas of how to incorporate RF into HCC

- need proof that HPRF will work under ionizing beam

- needs viable design for the next cooling stages – PIC/REMEX

- needs collider lattice design with necessary parameters

High emittance option

a rather solid ground under the feet, but not without its risks and deficiencies:

- high muon bunch intensity $2{\cdot}10^{12}$

- slow cooling resulting in poor muon transmission

- high p-driver bunch intensity

MCTF scenario

tries to alleviate the shortcoming of the high emittance option by borrowing some ideas from the low emittance option:

- faster 6D cooling by using HCC and/or FOFO snake

- bunch merging at high energy (20-30GeV)

- additional cooling using Fernow lattice or PIC (may become possible due to later bunch merging and lower total intensity)

- increased rep-rate to compensate for reduction in peak luminosity

FY08 MCTF Design & Simulations Plan

Collider ring:

- Optimization of the collider ring design
- Study of implications of the “dipole first” option for detector protection
- Beam-beam simulations
- Detailing of the design with corrector circuits, injection and collimation systems

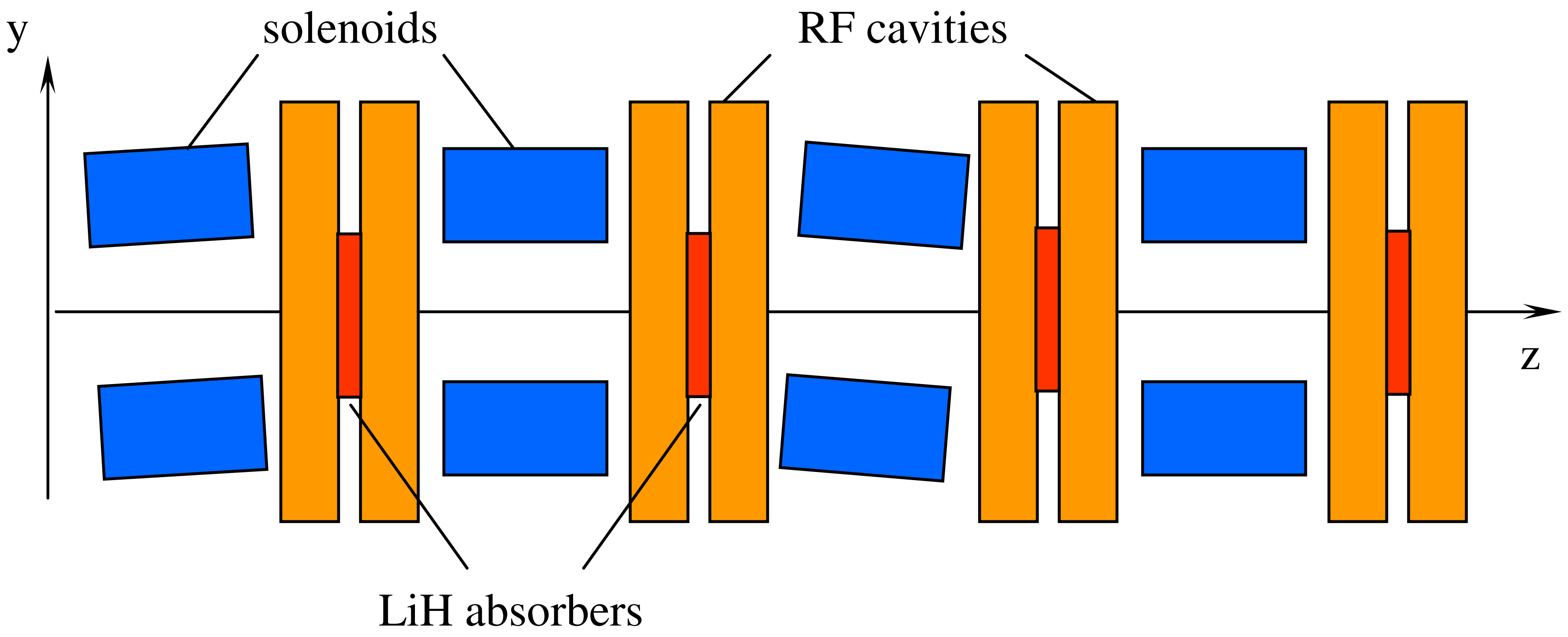
Basic 6D ionization cooling:

- **“Guggenheim” RFOFO channel:**
  - More realistic modeling of the magnetic field
  - Alternative design with open cell RF cavities with solenoids in the irises
- **Helical cooling channel**
  - Design of RF structure which can fit inside the “slinky” helical solenoid
  - Design and simulation of the segmented channel
- **FOFO snake:**
  - tracking simulations and optimization
- **Side-by-side comparison of the three structures to choosing the baseline scheme**

Final cooling:

- **Complete design of the 50T channel with required matching between the solenoids**
- **Channel design incorporating Fernow’s lattice with zero magnetic field in RF**
- **Feasibility study of the PIC/REMEX scheme**

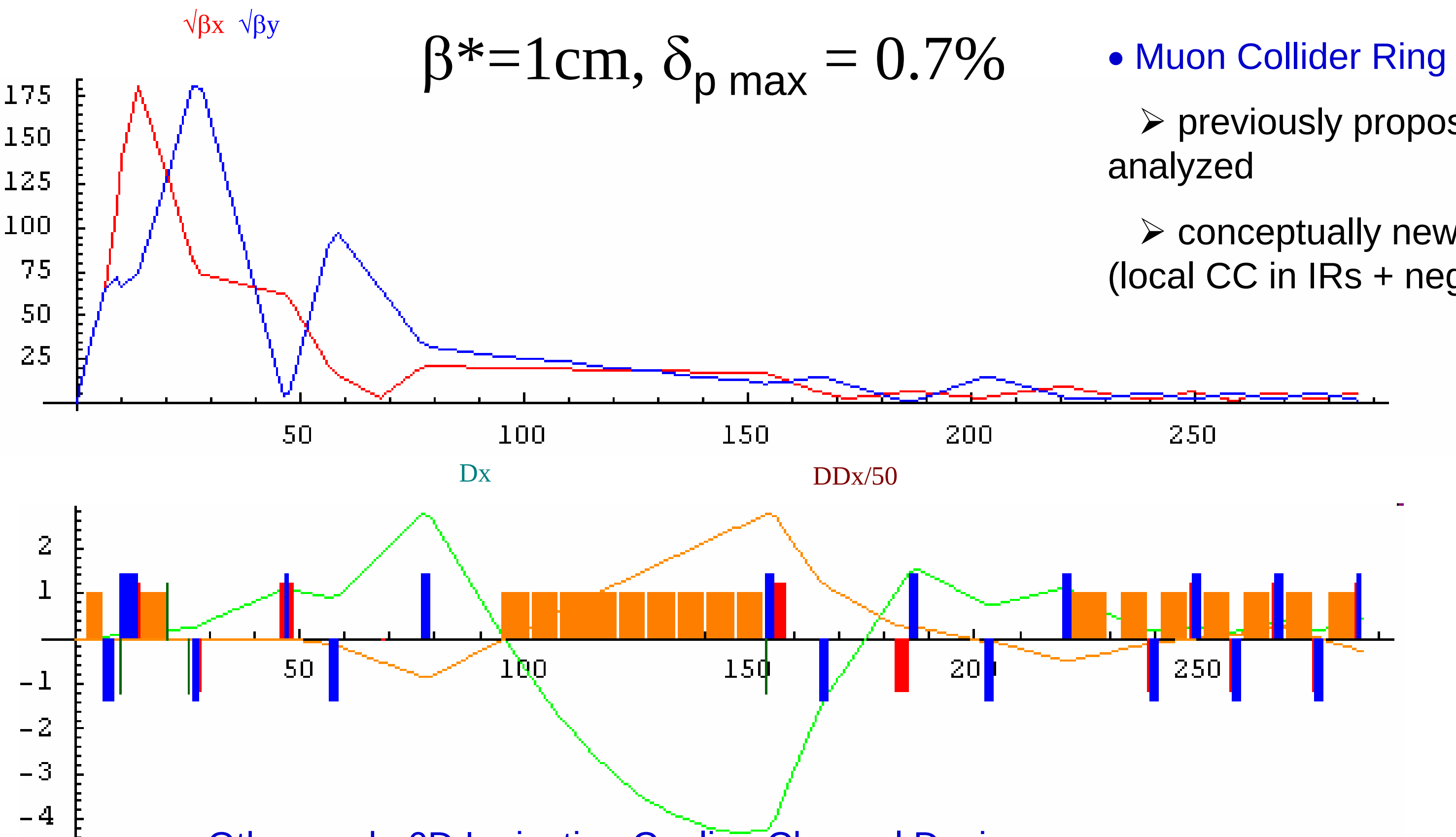
201 MHz FOFO snake



Cell length =3.2 m, solenoid inner radius = 40cm, Bmax=2.4 T at p=100MeV/c
HPRF cavities 2×16cm long, E=25MV/m, GH2 fill with density 10% of LH2
Emittance decrement 1/25m, equilibrium emittances ~1.5 π·mm

Recent Design work

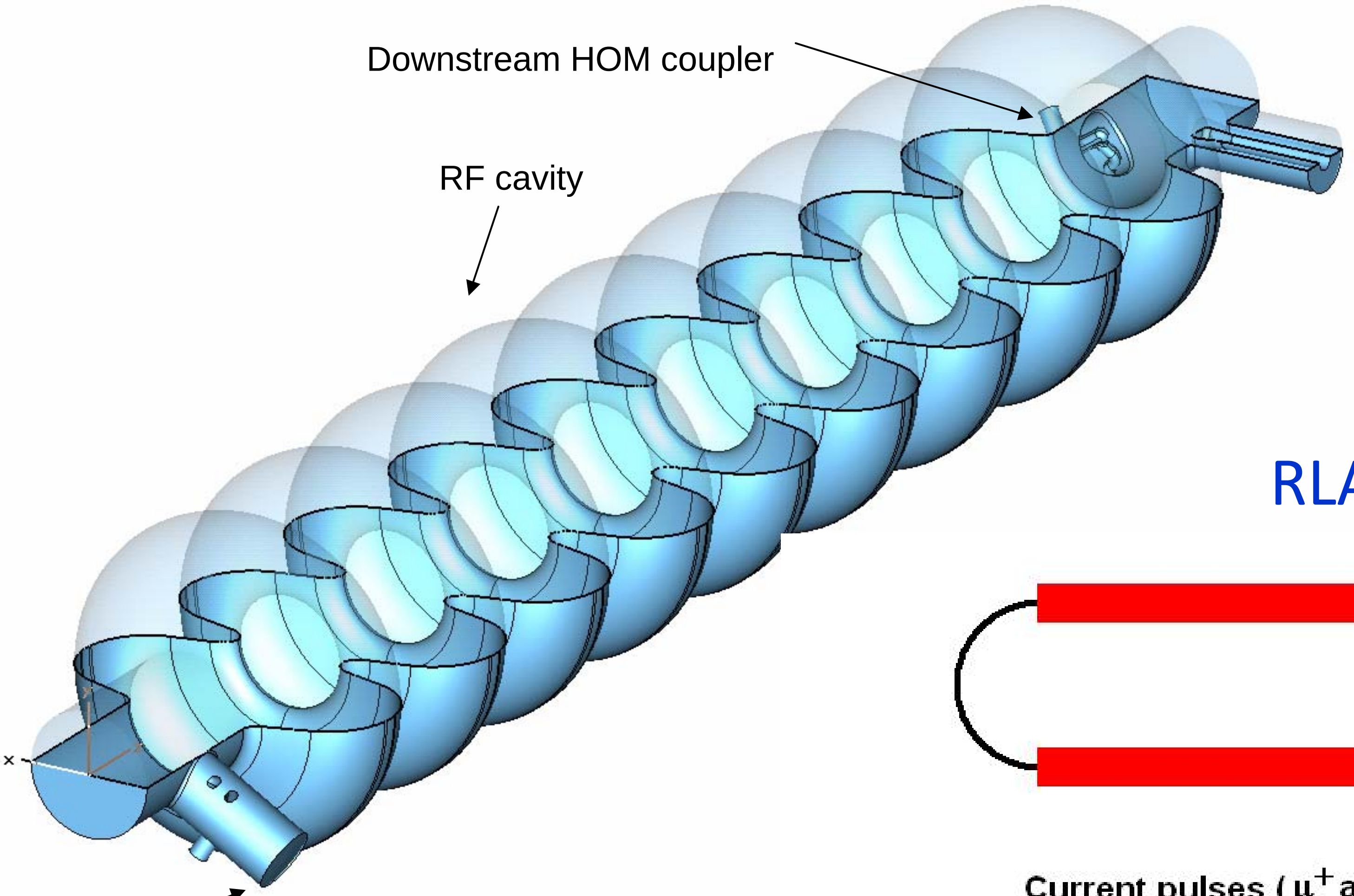
β^*=1cm, $\delta_{p\ max}$ = 0.7%



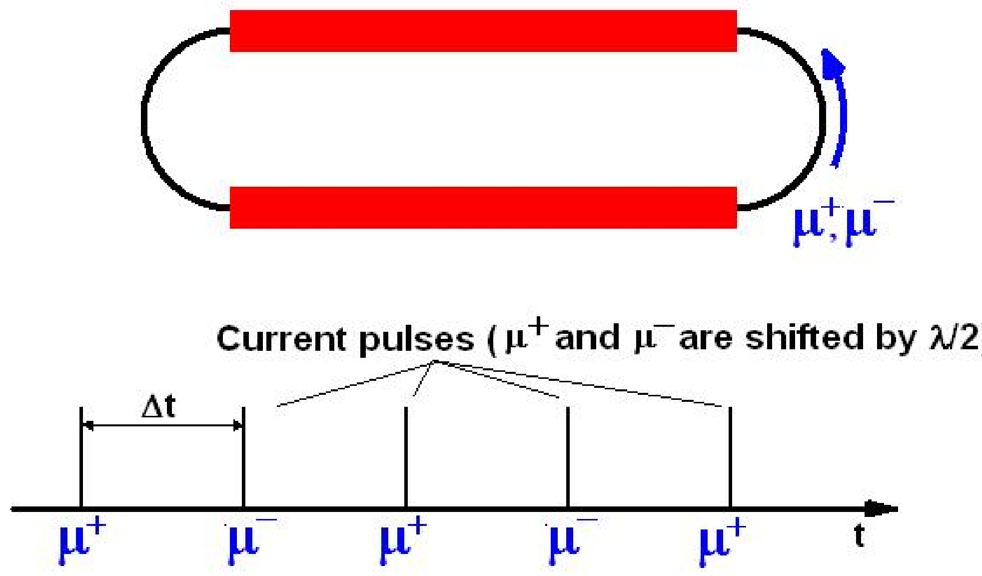
- Muon Collider Ring Design
  - ➢ previously proposed lattice designs analyzed
  - ➢ conceptually new design proposed (local CC in IRs + neg. dispersion section)

- Other work: 6D Ionization Cooling Channel Design
  - ➢ theory of HCC with distributed RF revisited
  - ➢ new principle of resonant dispersion generation proposed
  - ➢ schemes for PIC in achromatic ring and HCC analyzed
  - ➢ effect of SC in PIC and “super-Fernow” channels clarified

Acceleration of Muons by ILC-type SC RF



RLA

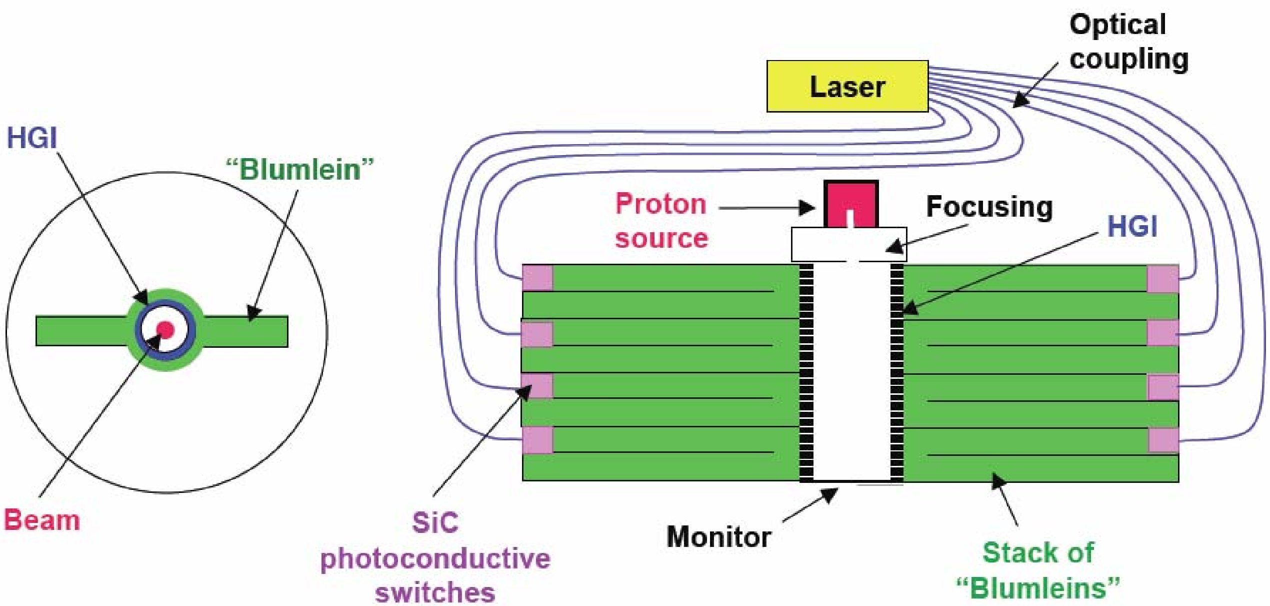


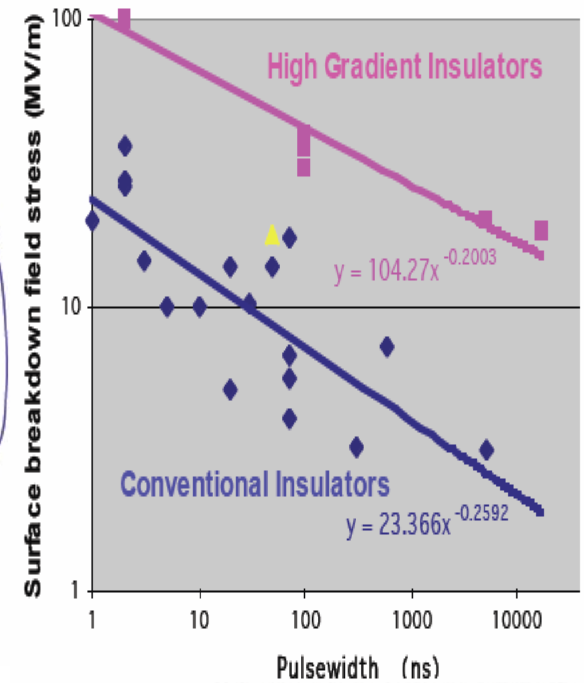
Wall plug power estimates

	MC1999	HE2008	HE2008	LE2008	LE2008
Collider cm Energy (TeV)	3	1.5	3	1.5	3
Luminosity (1e34)	7	1	3	3	3.5
Emittance (pi mm mmrad)	50	25	25	2.1	2.1
Rep rate (Hz)	15	13	8	65	32
Muons/beam (1e12)	8	2	2	1	1
PD beam power (MW)	4	4	2	3.6	8
Muon beam power (MW)	57.6	6.24	7.68	15.6	15.36
TOTAL wall plug power (MW):	**204**	**60**	**83**	**166**	**158**
PD (MW)		16	11	68	35
Bunching Ring(s) (MW)		4	4	4	4
Target station (MW)		1	1	1	1
Collection system (MW)		4	4	4	4
Cooling system (MW)		4	12	2	2
Acceleration (MW)	130	25	32	81	93
Beamlines		2	4	2	4

DWA-ILA for Muon Acceleration

Mini-Workshop at FNAL, Feb 28. 2008

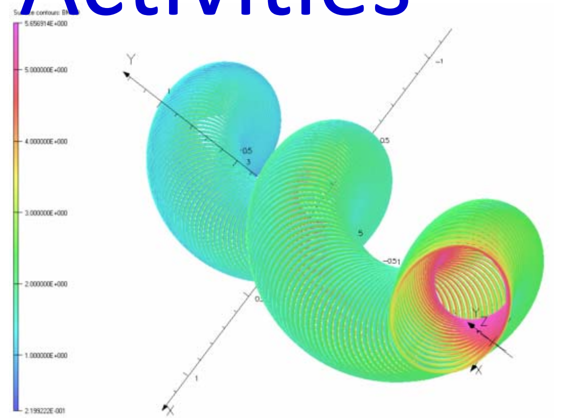


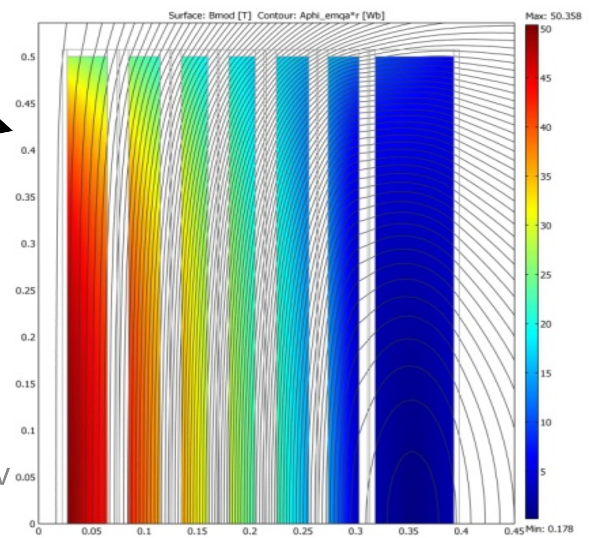


- Dielectric Wall Acceleration (no ferrite) promises gradients ~100MV/m; novelties:
  - ➢ SiC photo-switches
  - ➢ PFL with dielectrics >400MV/m
  - ➢ High gradient vacuum insulators >100MV/m
- 10 cm 10 MeV section test expected in CY08 (G.Caporaso, LLNL)

FY08 MCTF Magnets Activities

- Magnet System Concepts for 6-D Cooling in Muon Collider.
  - ➢ Superconducting Helical Solenoids
  - ➢ Multi-stage magnet system from 6T to 20 T on conductor
  - ➢ Magnet system and RF cavities integration
- Small scale Helical Solenoid demonstration magnet
  - ➢ **Four coils magnet design, fabrication and test**
- HTS High Field Solenoids Concepts for Muon Cooling Channels
- HTS superconductor properties





MCTF Magnets Status and Plans

- Significant progress this year, largely through magnet program base support, Muons Inc. collaboration and support from MCTF/APC
- Helical cooling channel design for 6-D cooling advances
- Short demonstration HCC magnet will be built and tested in 2008 with support from Muons Inc. and MCTF/APC
- HTS conductor studies continue at Fermilab (and elsewhere) on a range of materials, as a function of field, field angle, temperature
- Paper studies of High Field Solenoids show feasibility and difficulties in building magnets beyond the 40 T range
- Plans for a National Program for HTS High Field Conductor development have begun
- Results will be presented at EPAC08 and ASC08 Conferences

HCC experimental goals

- The current focus is on
  - Develop and simulate a HCC design including RF cavities, with realistic engineering constraints
  - Test high pressure RF cavity with beam
  - Build and test a 4 coil HCC model magnet
- The aim is to establish the usefulness of a HCC and define a prototype HCC section to build and test in the next few years.
- Desired deliverable by MUTAC time – cost estimate of the HCC section
  - a small group is set up

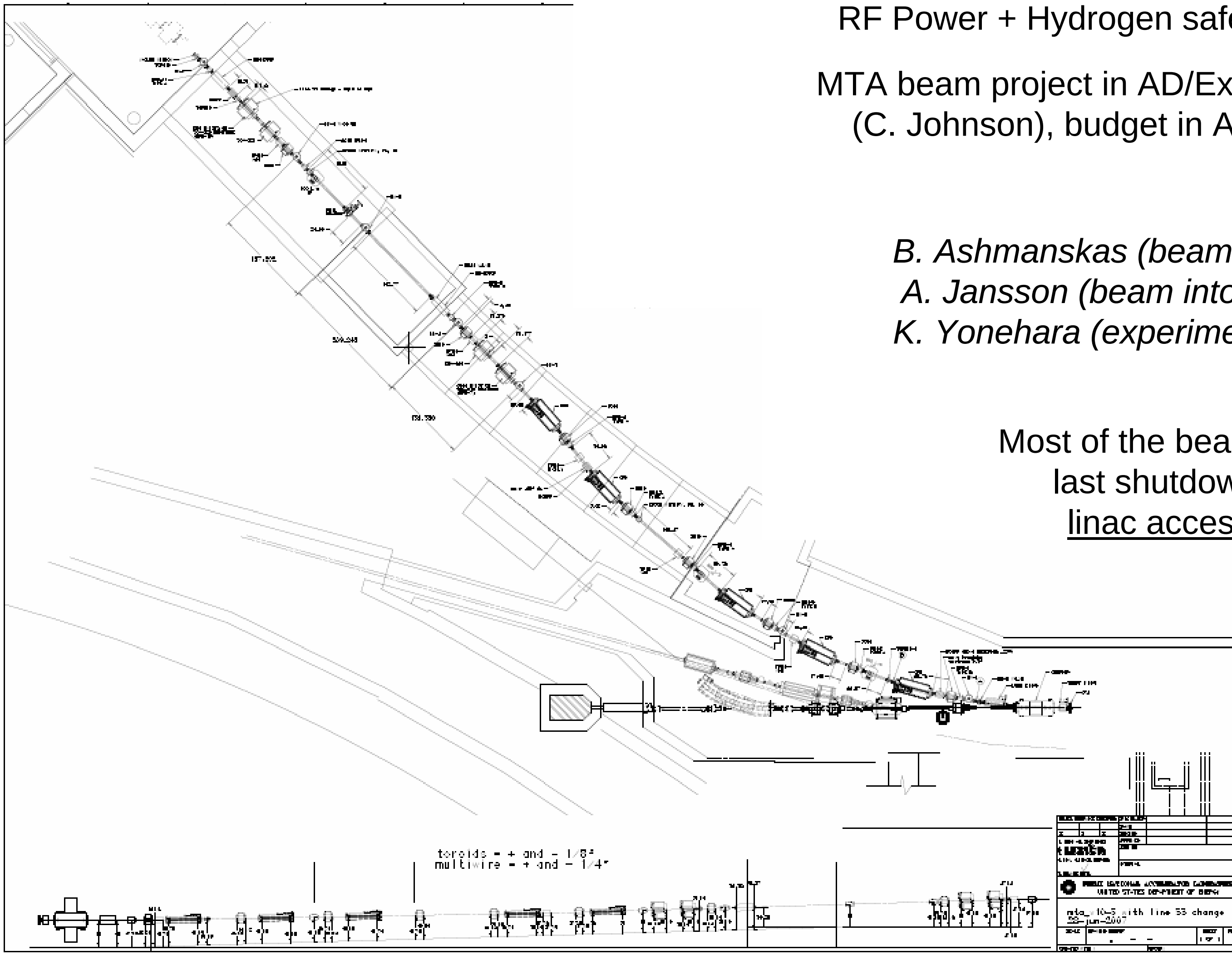
MTA Beamline

RF Power + Hydrogen safety + **Beam** needed.

MTA beam project in AD/External Beams (C. Johnson), budget in APC (A. Bross)

APC coordinators:
B. Ashmanskas (beam to first beam stop)
A. Jansson (beam into hall+ RF re-route)
K. Yonehara (experimental requirements)

Most of the beamline was installed last shutdown *(F Garcia)*, need linac access to finish this year!



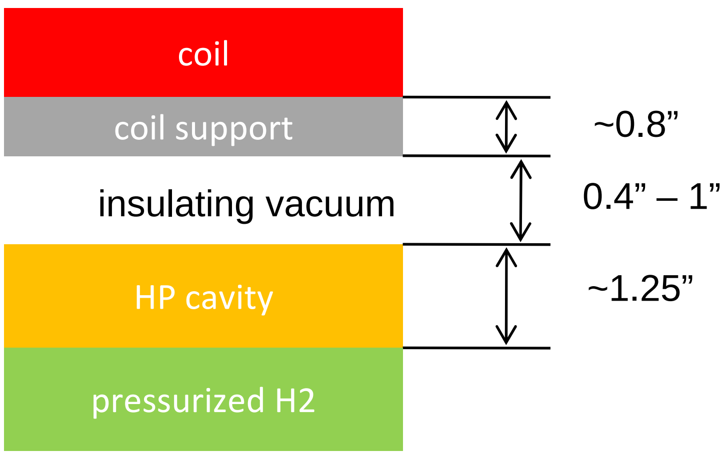
RF in HCC

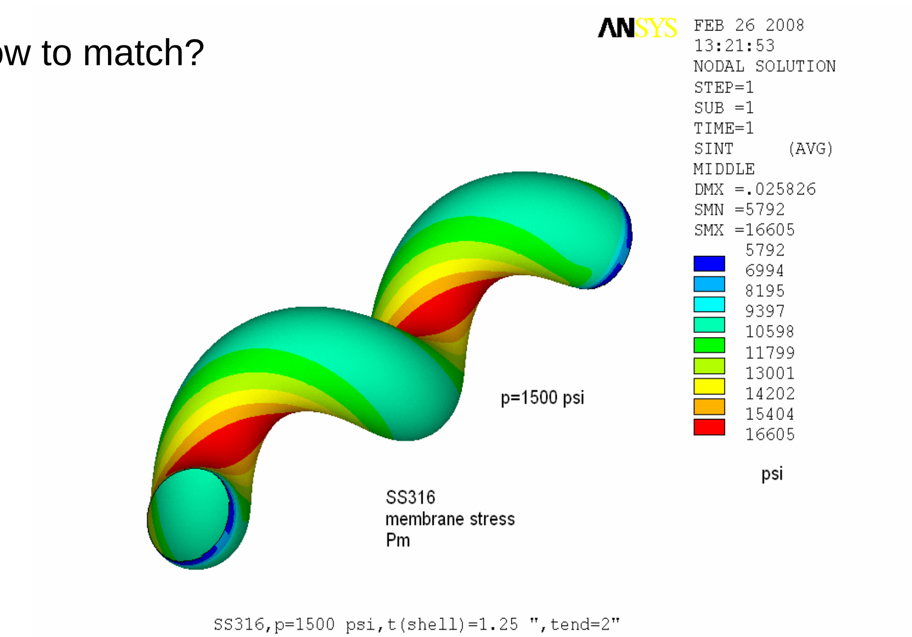
$1M Question:How to include RF?

1. RF inside coils?
2. RF in between coils?
3. RF and HCC separate?

How much space is needed between coil and cavity?

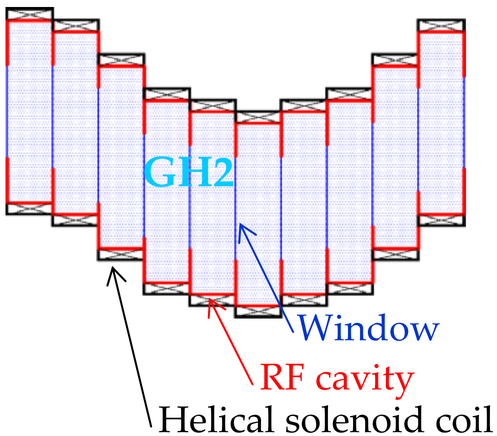
How to match?

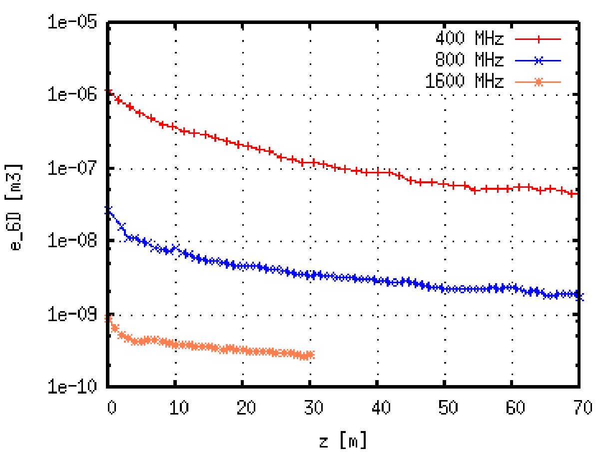




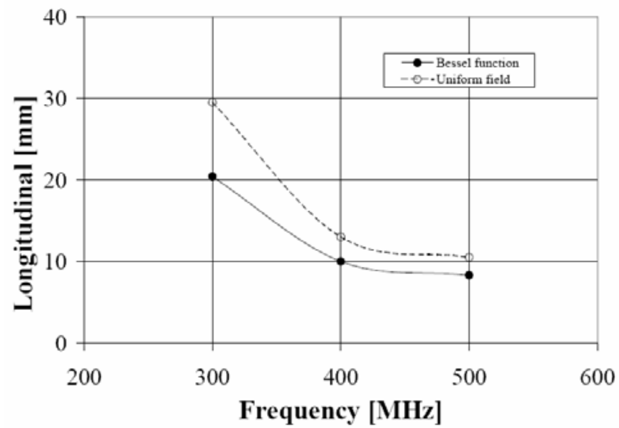
A Jansson, K Yonehara, V Kashikin, M Lamm, J Theilacker, A Klebaner, D Sun, A Lee, G Romanov, D Broemmelsiek, G Kutznetsov, A Shemyakin, …

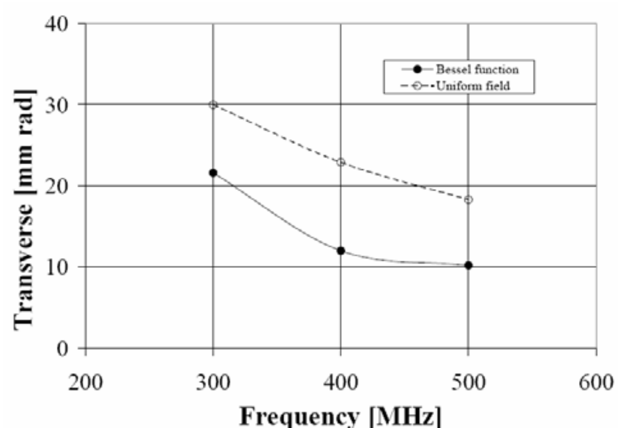
HCC simulations





K Yonehara





$R_{coil}=R_{cavity}$

- Early simulations ignored the geometric constraints on cavity size, then assumed $R_{cavity}=R_{coil}$
- Recent simulations indicate that R_{cavity} can be reduced further without much loss of acceptance!
- Need to explore the limits further
- Also need simulations of "separated function" HCC

Current Budget (M$, fully loaded)

	FY07 Spent	FY08 Allocated *
MCTF	4.4	4.1
M&S	1.1	0.9
SWF	3.3	3.2

**DoE specified funding cap on all muon accelerator R&D at Fermilab*

FY08 M&S (direct) vs Request

Activity	FY07 Spent	FY08 Allocated	FY08 Request
Travel	91	30	80 [1)]
HCC Magnet	58	60	230 [2)]
HTS	0	50	200 [3)]
MTA Beamline	573	220	300 [4)]
MUCOOL	50	160	280 [5)]
MICE	160	60	60
MCTF RF			120 [6)]
6D HCC Section			100 [7)]
Mu2e Accel R&D			50 [8)]
TOTAL	**932**	**580**	**1420**

Scope of Initial Requests

1) Needed to meet travel needs associated with MICE
2) To move beyond initial “4 coil test” towards building an HCC section.
3) to exploit HTS conductor R&D momentum initiated with SBIR, and to push ahead with initiating a national HTS magnet collaboration needed to get our feet on the ground with this technology.
4) The MTA beamline estimate is 300k$. Completing the beamline so that the first HPRF test can be made in FY08 is a priority.
5) Needed to complete the presently planned MUCOOL RF R&D in FY08 before the MICE solenoid arrives early FY09 (→ scheduling conflict)
6) Needed to extend the RF R&D to explore “magnetic insulation” against RF breakdown.
7) Needed to begin work towards bench testing an HCC 6D cooling section … first step towards a 6D cooling experiment.
8) Beginning – smth that can grow in coming years, and establishes that accel R&D for expts (as well as machines) is supported by APC

Summary

- Good news – FY08 budget for Muon R&D has not vanished under severe budget constraints
- Lab's Major Muon R&D goals in FY08 are :
  - continue design/simulation efforts;
  - get 400 MeV beam in MTA;
  - start high-pressure RF studies with beam;
  - carry out MUCOOL tests (RF in B-field);
  - support MICE as planned;
  - design 6D HCC experiment;
  - construct 4 test coils;
  - develop HTS collaboration;
  - develop a 10+ yr plan that fits FNAL roadmap

Future

- Lab's desired roadmap to intensity and/or energy frontier :
  - Tevatron (-2010) and NOvA (2011-2016)
  - Project-X
    - R&D 2008-2011, constr 2012-2016
    - operation >2017 (to DUSEL?)
  - ~2012-13 make a choice for either 4 GeV NF or MC as next big machine
    - do muon accel R&D till 2012-13