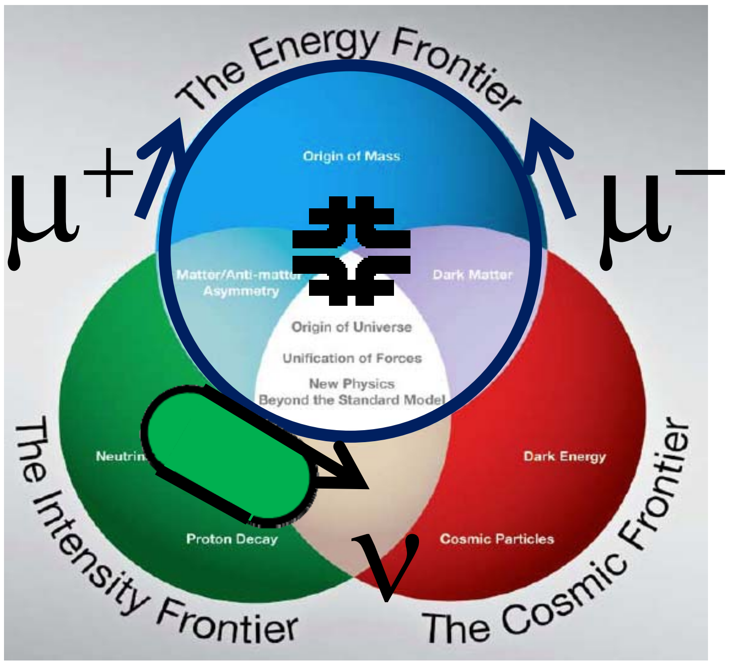


MAP Overview

Steve Geer

Accelerator Physics Center

Fermi National Accelerator Laboratory

Muon Accelerator Program Review

Fermilab, August 24, 2010

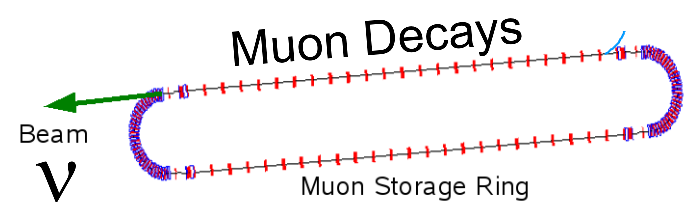
TALKS IN SESSIONS 1 & 2

- THIS TALK: Overview
  - Motivation & Organization
  - Achievements & Challenges
  - Goals & Resources
- Physics Motivation: Eichten
- More detailed R&D Plans & Resources
  - Design & Simulation: Fernow
  - Technology Development: Bross
  - System Tests: Kaplan
- Management Plan: Zisman

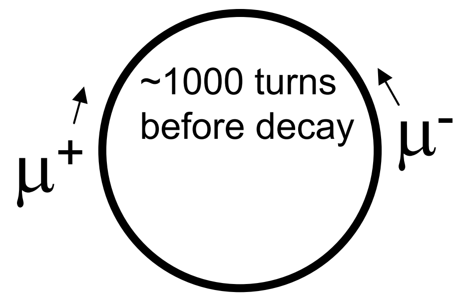
INTRODUCTION

- Over the last decade there has been significant progress in developing the concepts & technologies required to create $O(10^{21})$ muons/year & cool them to fit within an accelerator.

- This enabling R&D opens the way for:
  - NEUTRINO FACTORIES:
    muons decay in the straight section of a storage ring → ν beam with unique properties for precision oscillation measurements.



  - MUON COLLIDERS:
    μ^+ & μ^- collide in a storage ring to produce lepton-antilepton collisions up to multi-TeV energies.



MOTIVATION - COST

- Physics motivation for ν Factories & Muon Colliders
  - see Estia's talk
- There is also a potential cost-effectiveness motivation for a Multi-TeV Muon Collider which arises because muons don't radiate as readily as electrons (m_μ / m_e ~ 207):

- *COMPACT*

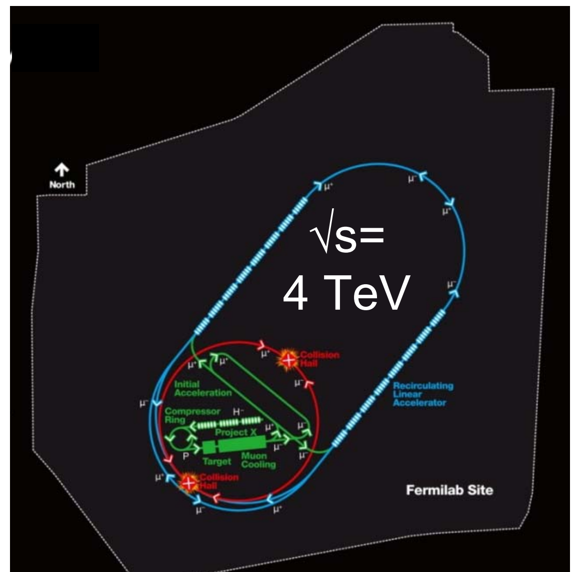
  Fits on laboratory site

- *MULTI-PASS ACCELERATION*

  Cost effective construction & operation

- *MULTIPASS COLLISIONS IN A RING* (~1000 turns)

  Relaxed emittance requirements (& hence relaxed tolerances) c.f. single pass machines

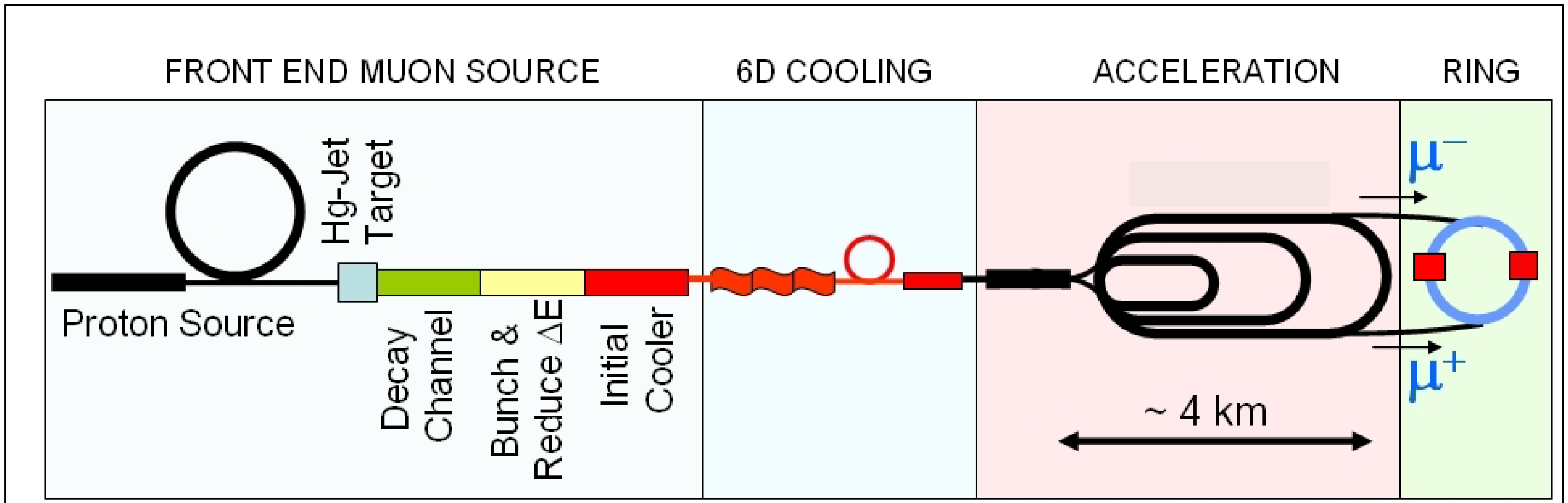


FNAL SITE BOUNDARY

CHALLENGES

- Muons are produced as tertiary particles. To make enough of them we must start with a MW scale proton source & target facility.
- Muons decay $\Rightarrow$ everything must be done fast and we must deal with the decay electrons (& neutrinos for CM energies above ~3 TeV).
- Muons are born within a large 6D phase-space. For a MC we must cool them by O(10^6) before they decay $\Rightarrow$ New cooling technique (ionization cooling) must be demonstrated, and it requires components with demanding performance (NCRF in magnetic channel, high field solenoids.)
- After cooling, beams still have relatively large emittance.

MUON COLLIDER SCHEMATIC

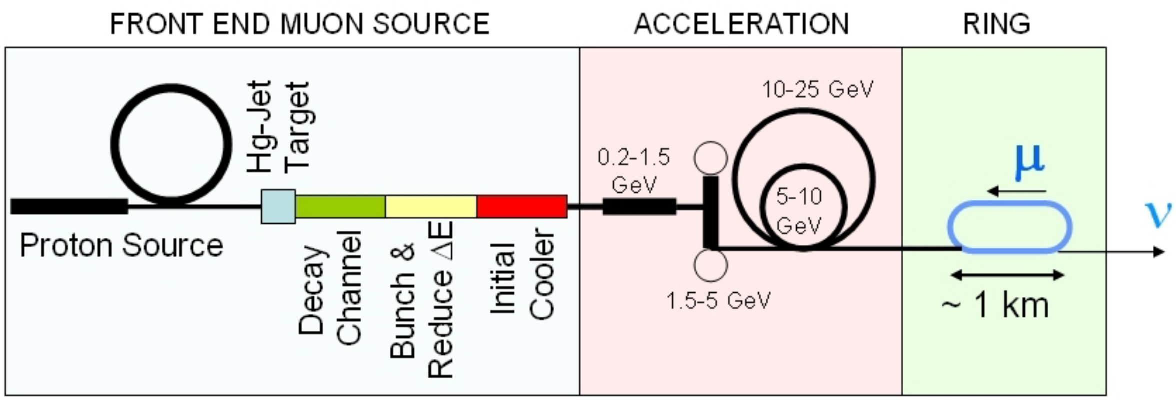


Proton source: Upgraded PROJECT X (~4 MW, 2±1 ns long bunches)

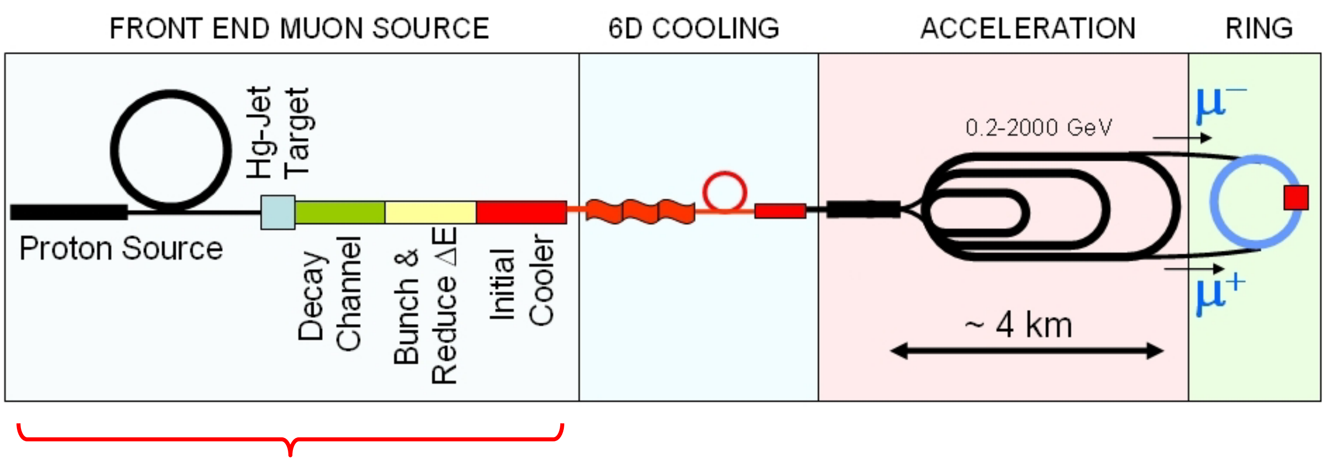
10^{21} muons per year that fit within the acceptance of an accelerator

$\sqrt{s}$ = 1.5 TeV
Circumference = 2.75 km
$\mathcal{L} = 1\times10^{34}$ $cm^{-2}s^{-1}$
μ/bunch = 2×10^{12}
$\sigma(p)/p$ = 0.1%
$\varepsilon_{\perp N}$ = 25 μm
β^* = 1cm

Muon Collider cf. Neutrino Factory



NEUTRINO FACTORY



MUON COLLIDER

In present MC baseline design, Front End is same as for NF

NFMCC & MCTF

- Muon Collider (MC) & Neutrino Factory (NF) R&D has been pursued in the U.S. by:
  - Neutrino Factory & Muon Collider Collaboration (NFMCC) since 1996
  - Fermilab Muon Collider Task Force (MCTF) since 2006

- The NFMCC & MCTF R&D programs have been coordinated by a committee comprising the NFMCC+MCTF leadership

- NF R&D is international, & is pursued within the context of the International Design Study for a Neutrino Factory (IDS-NF), which aspires to deliver a Reference Design Report by ~2013.

- Our international projects include 2 “systems tests”:
  - MERIT: mercury-jet target experiment (complete)
  - MICE: ionization cooling experiment (ongoing)

ACCOMPLISHMENTS

- Successful completion of NF feasibility studies 1, 2, 2a, & International Scoping Study; launching of the ongoing International Design Study for a NF (IDS-NF)
  - Solid basis for planning the MC Design Feasibility Study (DFS)
- Development of ionization cooling simulation tools and a 6D cooling channel concept.
- Successful completion of MERIT, full engagement in MICE, & establishment of the MuCool Test Area (MTA) facility.
- Establishment of an ongoing technology development program (RF studies, magnet studies, …)
  - Identified issue of RF breakdown in magnetic field

THE MAP INITIATIVE

- Oct 1, 2009 letter from DOE Assoc. Director of Science for HEP to FNAL Director:

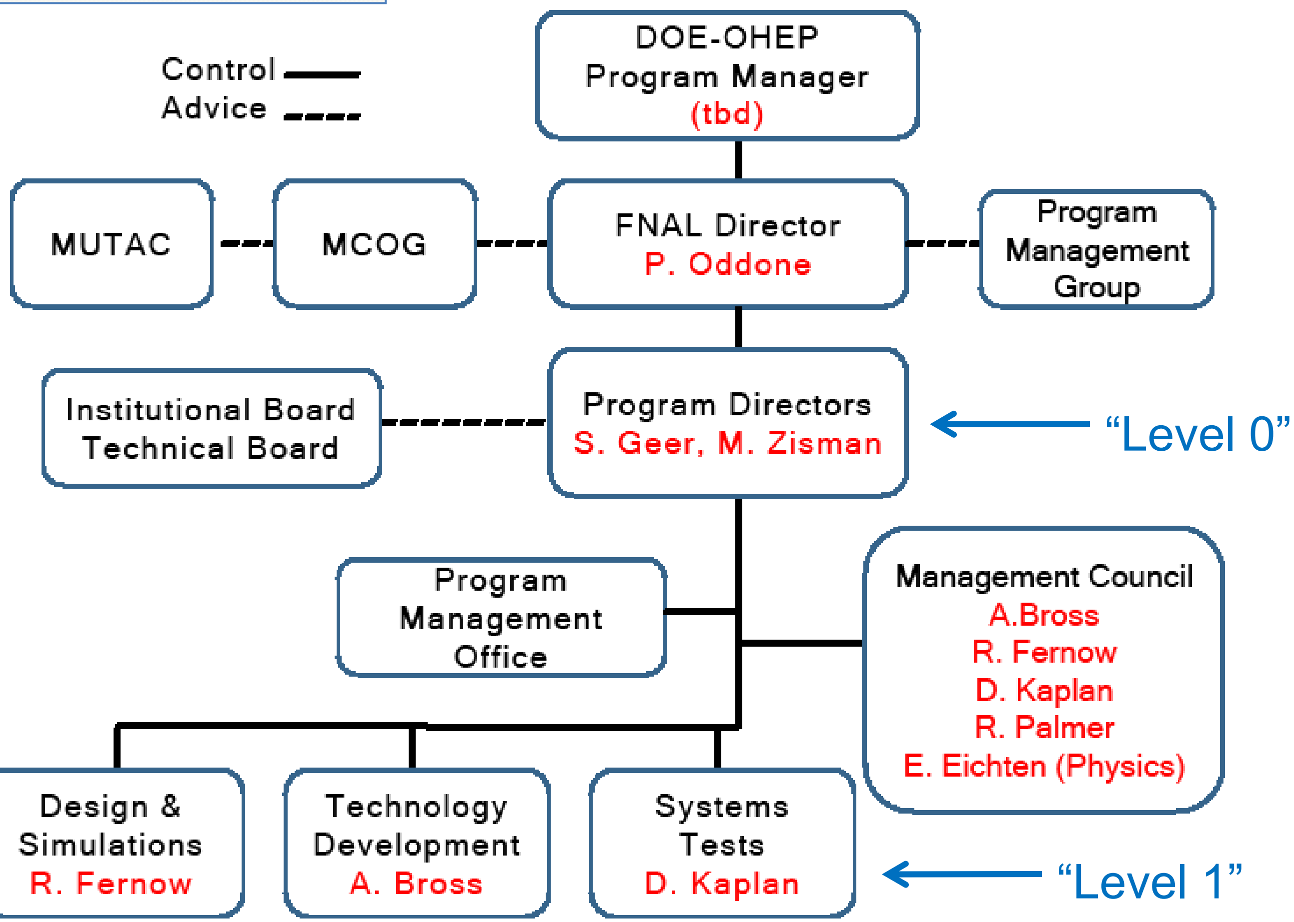
  "Our office believes that it is timely to mount a concerted national R&D program that addresses the technical challenges and feasibility issues relevant to the capabilities needed for future Neutrino Factory and multi-TeV Muon Collider facilities. ..."

- Letter requested that FNAL Director put in place a new organization for a national Muon Collider & Neutrino Factory R&D program, hosted at FNAL, and designate the program director.

- MAP Organization is now in place and is functioning.
- 214 MAP participants at birth (~31 FTE) from 14 institutions:
  – ANL, BNL, FNAL, Jlab, LBNL, ORNL, SLAC, Cornell, IIT, Princeton, UCB, UCLA, UCR, U-Miss
- MAP R&D proposal submitted by FNAL Director on March 1st
- MAP Website: http://map.fnal.gov

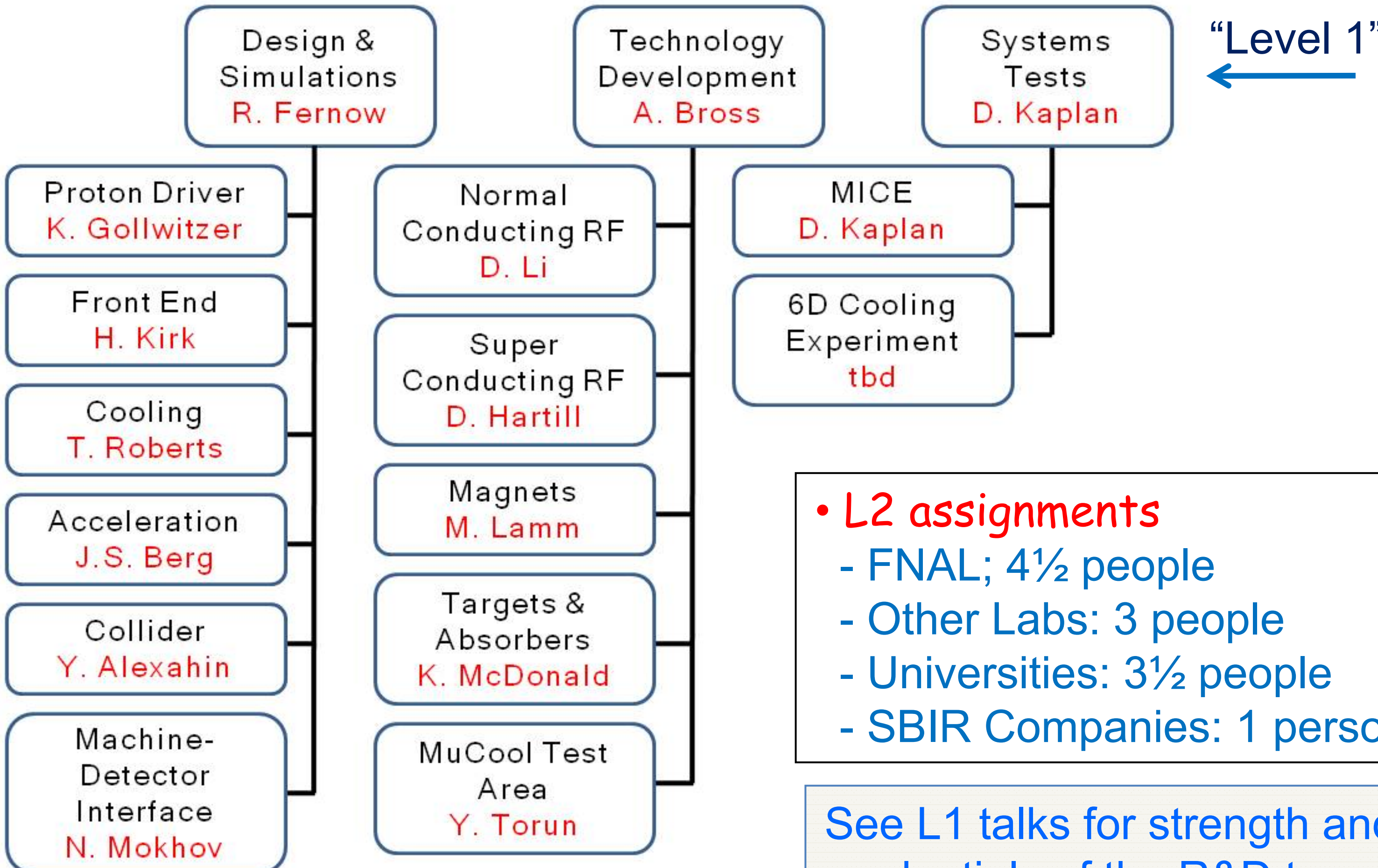
MAP ORGANIZATION

See M. Zisman's talk on the Management Plan



ORGANIZATION: L1 & L2

Organization populated down to L2, and is functioning



- *L2 assignments*
  - FNAL; 4½ people
  - Other Labs: 3 people
  - Universities: 3½ people
  - SBIR Companies: 1 person

See L1 talks for strength and credentials of the R&D teams

MAP GOALS

- MC: To significantly advance the R&D from its present level (exploring technical concepts) to the next level (establishing feasibility by performing end-to-end simulations based upon hardware that is in-hand or under development).

- NF: To complete MICE*), and make those significant U.S. contributions to the IDS-NF that are needed to ensure success (delivering an RDR by ~2013).

*) Also important for MC

PROPOSAL STRATEGY

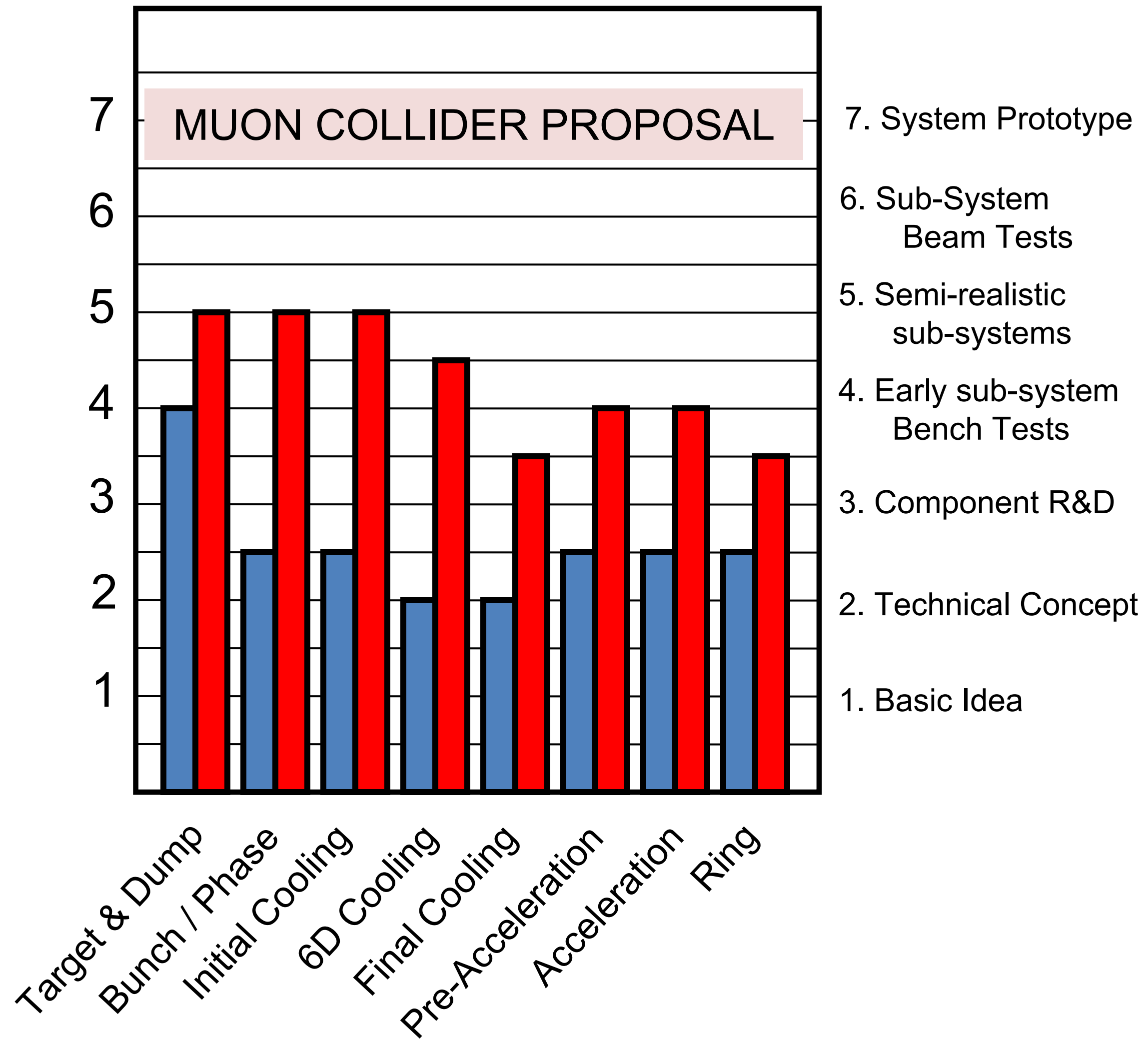
- Identify the required R&D deliverables.
- Make an R&D plan that respects initial funding guidelines and achieves the deliverables.
- Make an augmented plan that speeds things up by 1 year (i.e. assess how much it costs to go faster).
  - Important if future developments (e.g. LHC results) motivate speeding things up
- In both nominal and augmented plans, Year 1 = now (FY10) with the current funding level.
  - The MAP organization is presently executing Year 1 of the MAP plan

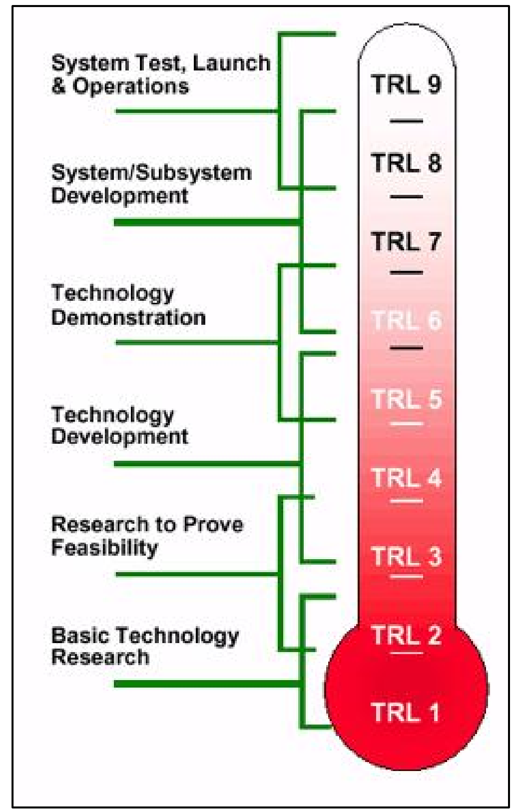
MILESTONES & DELIVERABLES

- Muon Collider Design Feasibility Report (FY16)
  - Based on end-to-end simulation of MC complex which uses components that are in-hand or can be developed with a specified R&D program
- Hardware R&D results → technology choice
- MC Cost range (FY16)
- Contributions to the IDS-NF RDR (FY14)
- R&D plan for longer-term activities (including 6D cooling experiment)

Deliverable	Nominal schedule	Augmented schedule
MC DFS		
Interim	FY14	——
Final + cost range	FY16	FY15
MICE hardware completion	FY13	
RF studies (down-select)	FY12	
IDS-NF RDR	FY14	
6D cooling definition	FY12	
6D cooling section component bench test	FY16	FY15
6D demonstration proposal	FY16	FY15

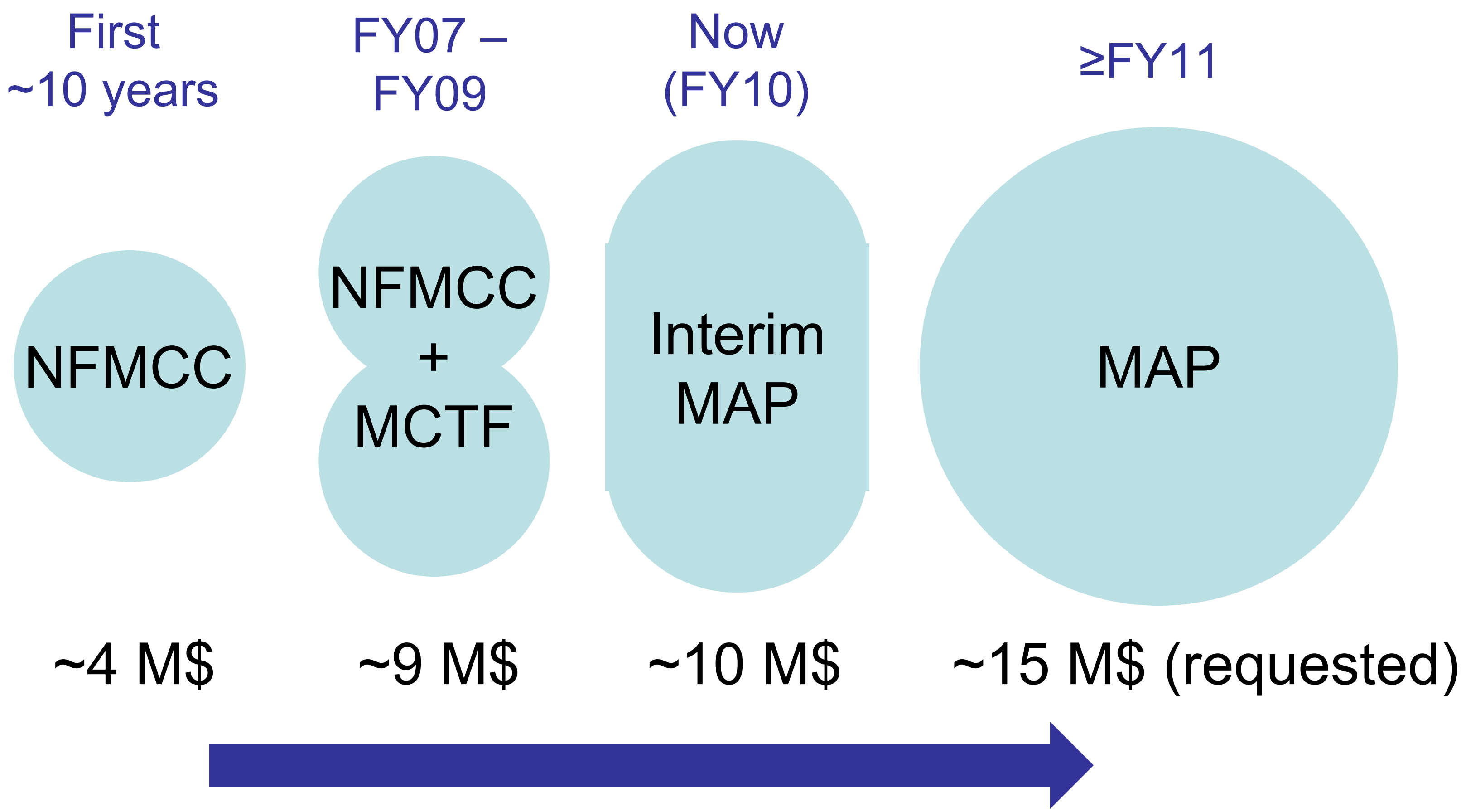
R&D PROGRESS TOWARDS THE PROPOSED MC-DFS





NASA Technology Readiness Levels

ORGANIZATION/FUNDING EVOLUTION

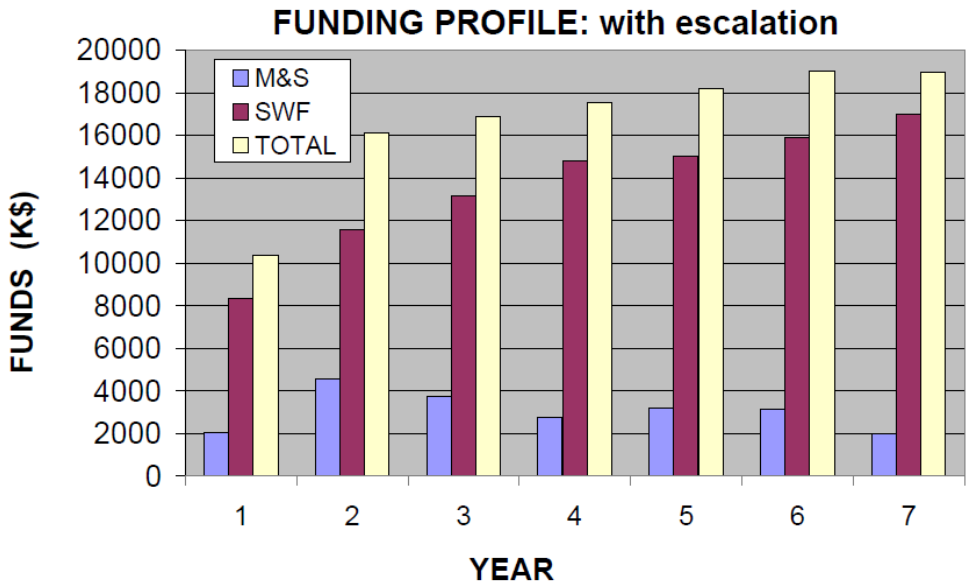


COMPLEMENTARY EFFORTS

- International partners (see talk by Blondel)
  - MICE
  - IDS-NF
- Activities funded by NSF
  - Contributions to MICE
  - Proposed low frequency SCRF R&D (Cornell).
- DOE support for VHFSMC R&D on HTS conductor
- DOE supported SBIR funded activities. Examples:
  - 40T solenoid (PBL)
  - G4BEAMLINE (Muons Inc.)

DOE FUNDING REQUEST

- Requested funding profile respects an initial guideline of ~15 M$/yr (FY10 dollars)
- More details in L1 talks



FY10

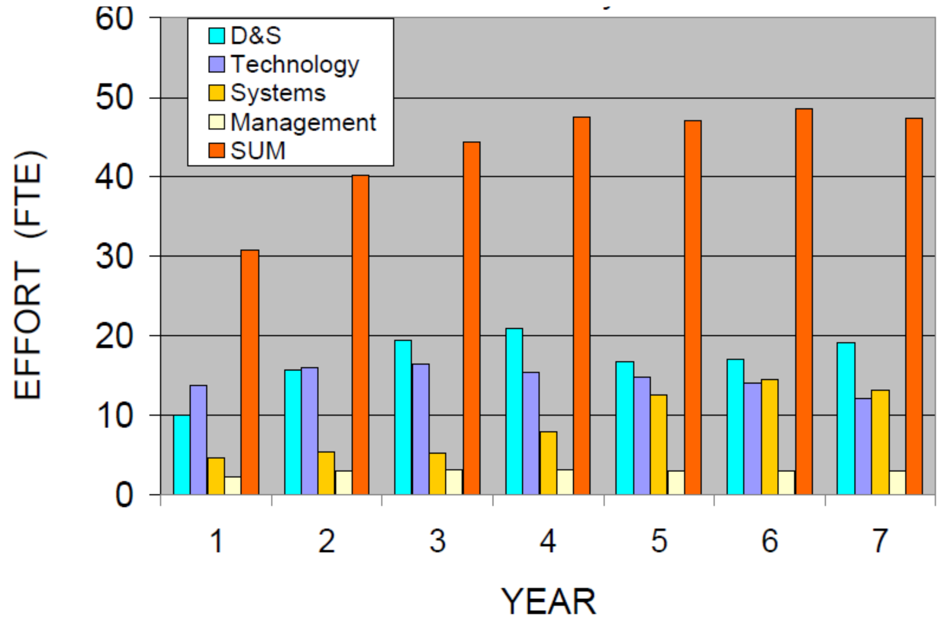
	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Effort (FTE)	31	40	44	48	47	49	47
SWF ($M)[a)]	8.3	11.2	12.2	13.2	12.9	13.0	13.4
M&S ($M)[a)]	2.0	4.2	3.3	2.3	2.6	2.5	1.5
Total ($M)[a)]	10.3	15.4	15.5	15.5	15.5	15.5	14.9
Total ($M)[b)]	10.3	16.1	16.9	17.5	18.2	19.0	19.0

a) FY10 dollars. b) Then-year dollars, assuming 4% annual escalation.

EFFORT

More details in L1 talks

- Proposed effort levels agreed on with BNL, FNAL & LBNL management



FY10

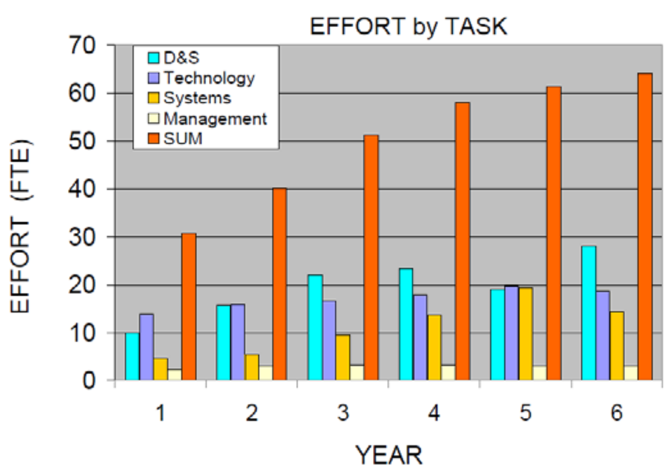
	Y1	Y2	Y3	Y4	Y5	Y6	Y7
BNL	5	7	8	8	8	8	6
FNAL	20	23	25	28	31	33	30
LBNL	3	4	5	5	4	3	5
Other[a)]	3	6	6	7	4	5	6
TOTAL	31	40	44	48	47	49	47

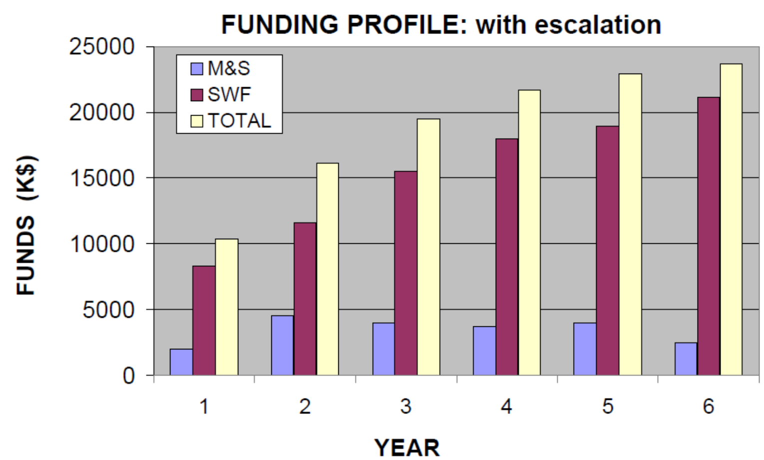
[a)] Includes SBIR companies, universities, other laboratories, additional engineering from the main laboratories and/or external vendor contracts.

AUGMENTED PLAN

What it takes to speed up by 1 year

	Y1	Y2	Y3	Y4	Y5	Y6
Effort (FTE)	31	40	51	58	61	64
SWF ($M)[a)]	8.3	11.2	14.4	16.0	16.2	17.4
M&S ($M)[a)]	2.0	4.2	3.5	3.2	3.3	2.0
Total ($M)[a)]	10.3	15.4	17.9	19.2	19.5	19.4
Total ($M)[b)]	10.3	16.1	19.5	21.7	22.9	23.7





	Y1 (FTE)	Y2 (FTE)	Y3 (FTE)	Y4 (FTE)	Y5 (FTE)	Y6 (FTE)
BNL	5	7	8	9	9	10
FNAL	20	23	30	34	37	37
LBNL	3	4	5	6	6	6
Other[a)]	3	6	8	9	9	11
TOTAL	31	40	51	58	61	64

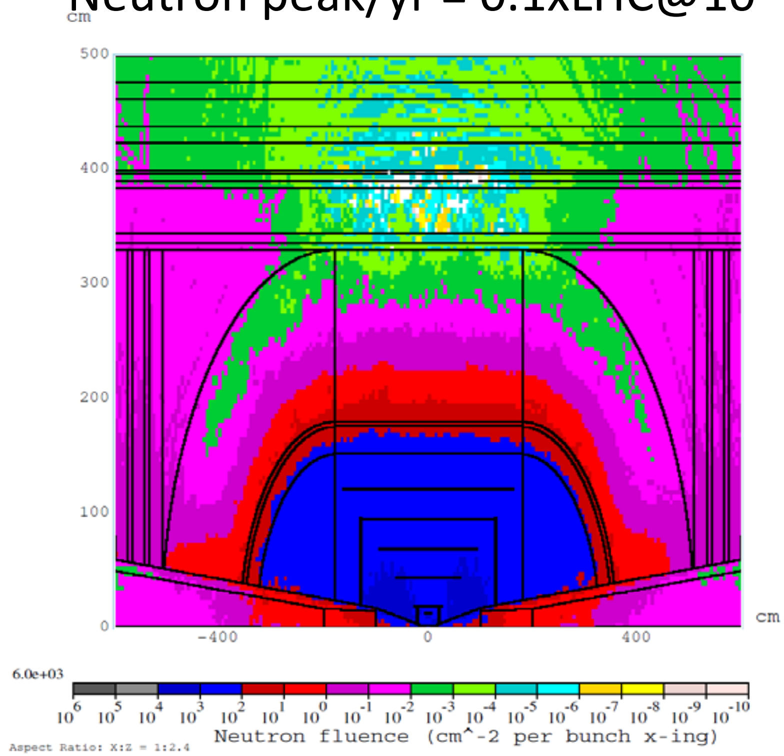
RELATIONSHIP WITH PHYSICS STUDIES

- Physics & detector background studies are outside the scope of MAP but …
  – Within MAP we have a machine-detector interface group that optimizes final focus & shielding, and provides background files for physics studies
  – We are actively engaged in helping to set up and drive forward a parallel physics-detector study effort.
    - See talk by Estia
  – Leader for physics/backgrounds studies will participate in the "MAP Management Council" which provides week-by-week advice to the MAP Director(s)
  – The physics/background studies will deliver a report to community on detector design & physics capabilities.

DETECTOR SHIELDING PROGRESS

- Illustrative example: MARS map of background neutrons for a 1.5 TeV Muon Collider

Neutron peak/yr = 0.1xLHC@10^{34}



Total absorbed dose from all background particles in Si detector

Peak at r=4 cm:

MC: 0.1 MGy/yr

LHC: 0.2 MGy/yr @10^{34}

FINAL REMARKS

- The proposed MAP R&D plan is built upon the experience and success from the last decade.
- The proposed plan interfaces seamlessly with the ongoing R&D (Year 1 = FY10), and the MAP organization is in place and functioning.
- The plan would deliver a NF-RDR by ~2013, and by ~2016 advance MC R&D from early component R&D to sub-system bench tests, MICE completion, an end-to-end simulation of a MC complex, and a MC feasibility assessment and cost range.
- The R&D is challenging, and we will have to adjust the plan along the way, but we believe that with appropriate support we will succeed.

A MUON-BASED VISION

Muon Collider Conceptual Layout

Project X
Accelerate hydrogen ions to 8 GeV using SRF technology.

Compressor Ring
Reduce size of beam.

Target
Collisions lead to muons with energy of about 200 MeV.

Muon Capture and Cooling
Capture, bunch and cool muons to create a tight beam.

Initial Acceleration
In a dozen turns, accelerate muons to 20 GeV.

Recirculating Linear Accelerator
In a number of turns, accelerate muons up to 2 TeV using SRF technology.

Collider Ring
Bring positive and negative muons into collision at two locations 100 meters underground.