Muon Colliders: Tough Questions

Muon colliders have been promised for many years but muon cooling still has not delivered more than 10% phase space reduction. A muon collider needs phase space reduction by 10^6.

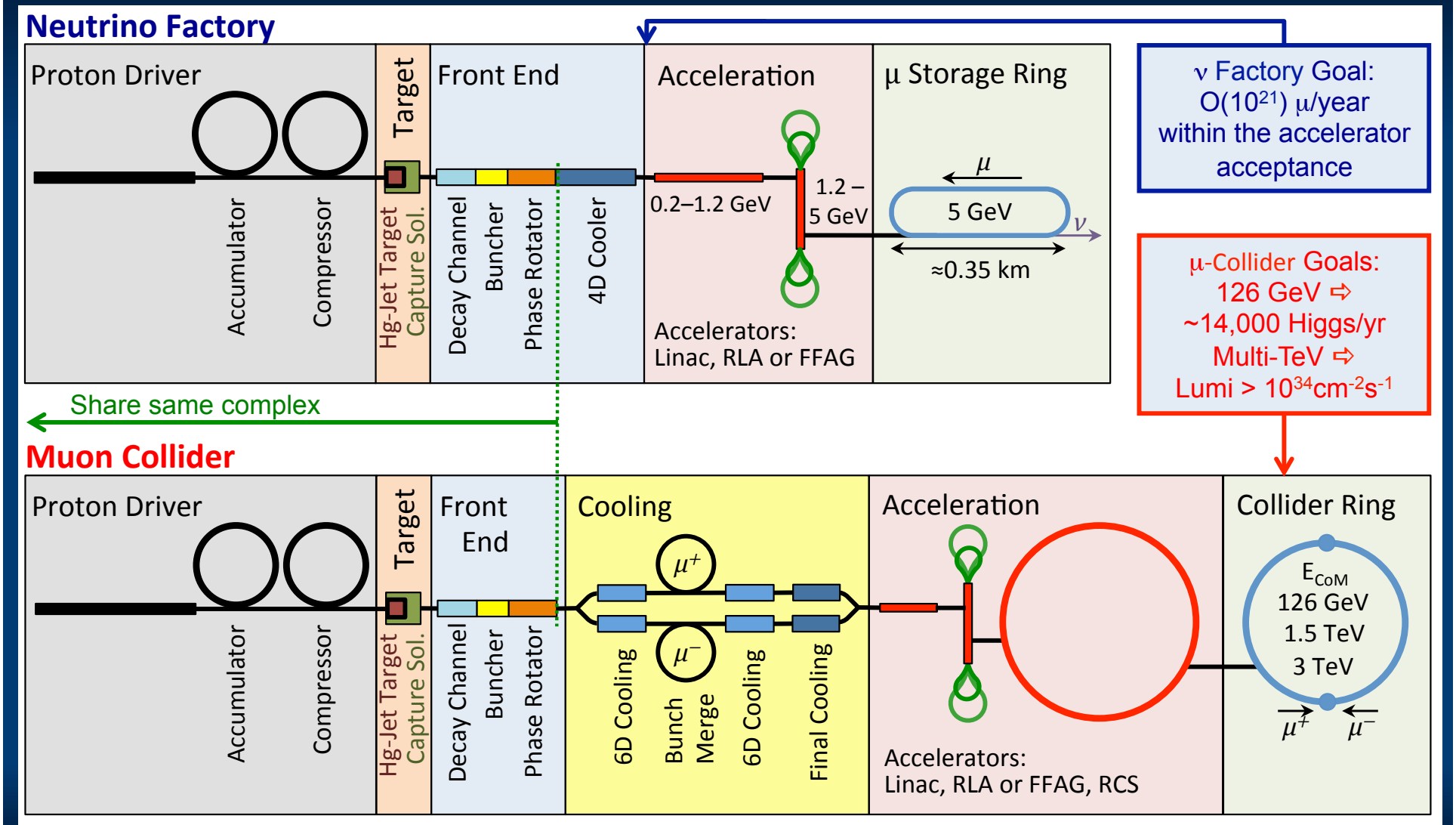
What is the path to get there?

Mark Palmer

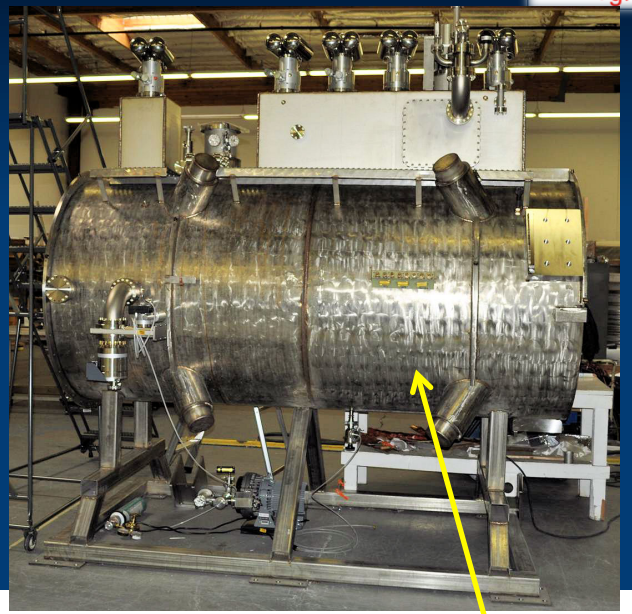
August 2, 2013

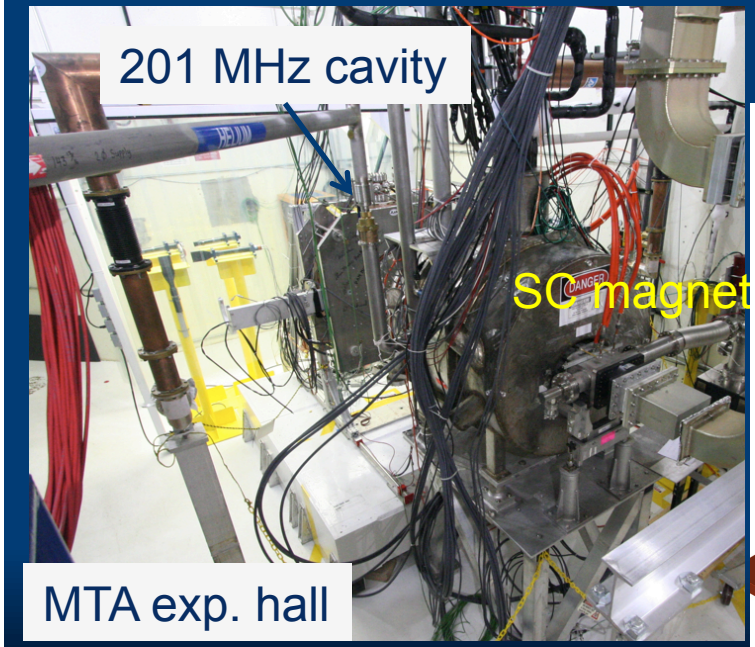
Fermilab

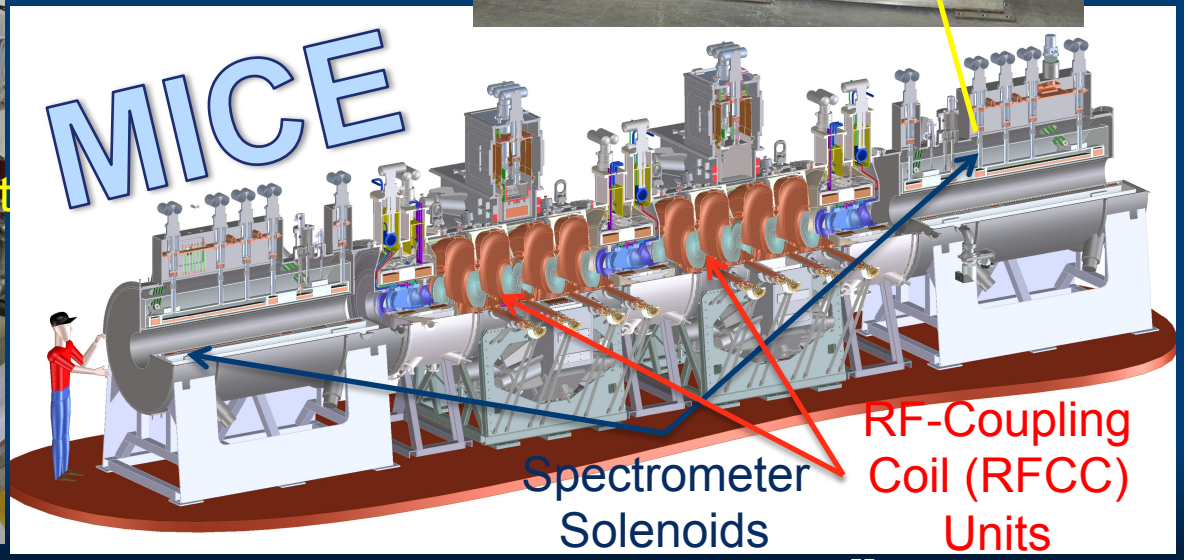
The U.S. Muon Accelerator Program



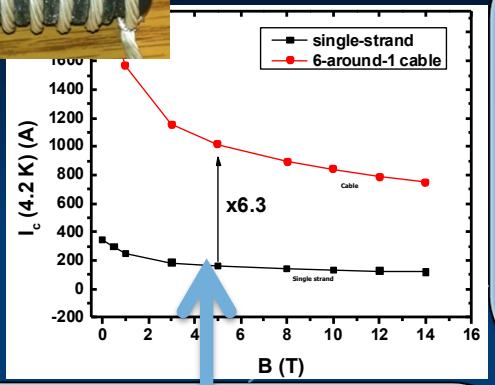
Elements of the R&D Program





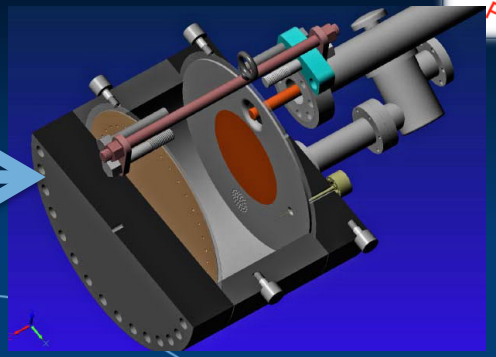


Cooling Channel R&D Effort



Successful Operation of 805 MHz "All Seasons" Cavity in 3T Magnetic Field under Vacuum

MuCool Test Area/Muons Inc



Breakthrough in HTS Cable Performance with Cables Matching Strand Performance

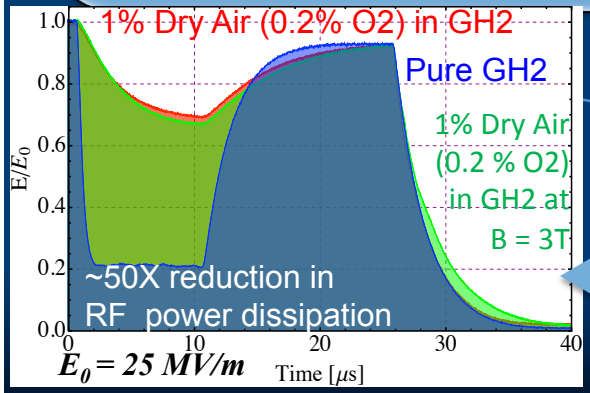
FNAL-Tech Div
T. Shen-Early Career Award

The Path to a Viable Muon Ionization Cooling Channel

World Record HTS-only Coil

15T on-axis field
16T on coil

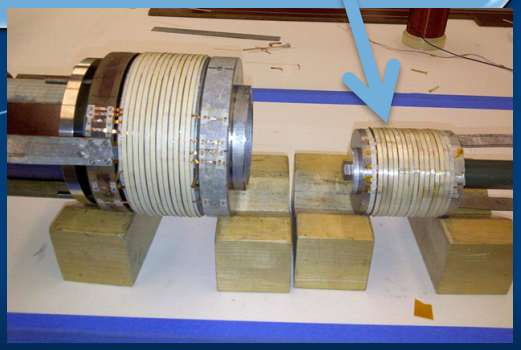
PBL/BNL



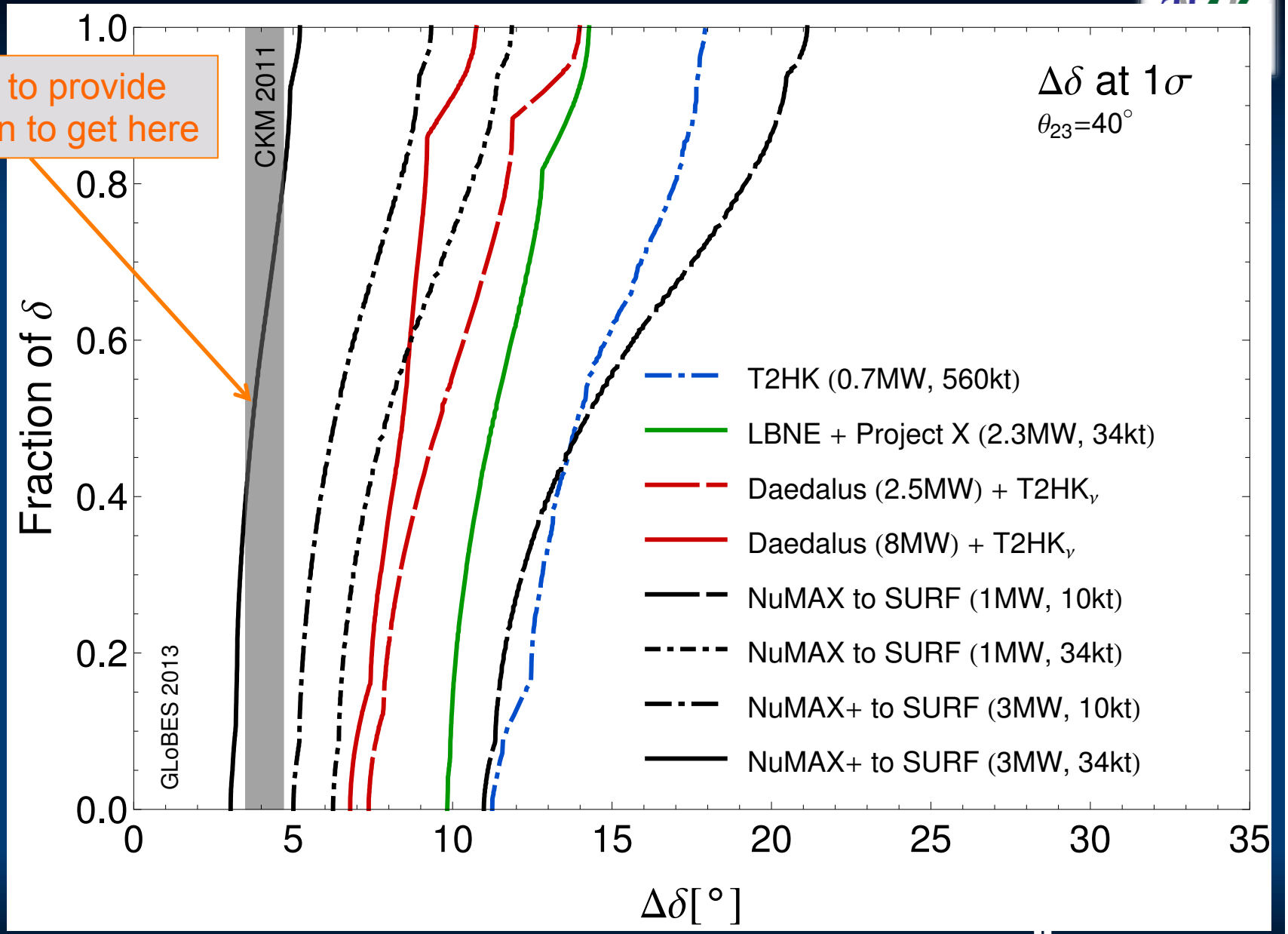
Demonstration of High Pressure RF Cavity in 3T Magnetic Field with Beam

Extrapolates to
μ-Collider Parameters

MuCool Test Area



The ν Sector


We want to provide the option to get here
CKM 2011
GLoBES 2013
$\Delta\delta$ at 1σ
θ_{23}=40°
Fraction of δ
$\Delta\delta$[°]
T2HK (0.7MW, 560kt)
LBNE + Project X (2.3MW, 34kt)
Daedalus (2.5MW) + T2HK$_\nu$
Daedalus (8MW) + T2HK$_\nu$
NuMAX to SURF (1MW, 10kt)
NuMAX to SURF (1MW, 34kt)
NuMAX+ to SURF (3MW, 10kt)
NuMAX+ to SURF (3MW, 34kt)
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30
35

Muon Collider Parameters

Muon Collider Parameters								
		Higgs Factory		Top Threshold Options		Multi-TeV Baselines		
Parameter	***Units***	*Startup Operation*	*Production Operation*	*High Resolution*	*High Luminosity*			*Accounts for Site Radiation Mitigation*
CoM Energy	TeV	0.126	0.126	0.35	0.35	1.5	3.0	6.0
Avg. Luminosity	$10^{34}cm^{-2}s^{-1}$	0.0017	0.008	0.07	0.6	1.25	4.4	12
Beam Energy Spread	%	0.003	0.004	0.01	0.1	0.1	0.1	0.1
Higgs* or Top$^+$ Production/10^7sec		3,500*	13,500*	7,000$^+$	60,000$^+$	37,500*	200,000*	820,000*
Circumference	km	0.3	0.3	0.7	0.7	2.5	4.5	6
No. of IPs		1	1	1	1	2	2	2
Repetition Rate	Hz	30	15	15	15	15	12	6
β^*	cm	3.3	1.7	1.5	0.5	1 (0.5-2)	0.5 (0.3-3)	2.5
No. muons/bunch	10^{12}	2	4	4	3	2	2	2
No. bunches/beam		1	1	1	1	1	1	1
Norm. Trans. Emittance, ε_{TN}	π mm-rad	0.4	0.2	0.2	0.05	0.025	0.025	0.025
Norm. Long. Emittance, ε_{LN}	π mm-rad	1	1.5	1.5	10	70	70	70
Bunch Length, σ_s	cm	5.6	6.3	0.9	0.5	1	0.5	2
Proton Driver Power	MW	4$^\#$	4	4	4	4	4	1.6

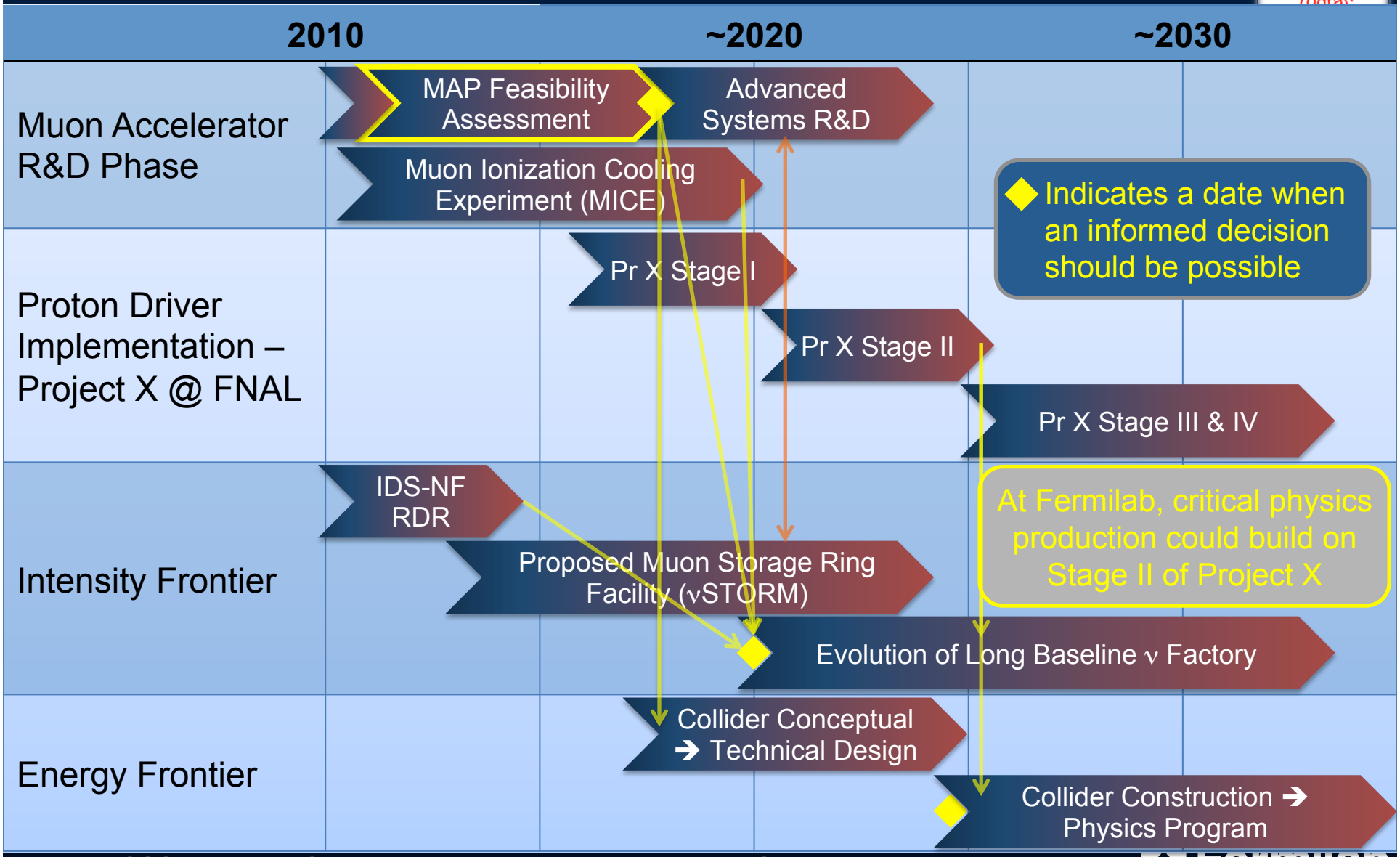
$^\#$ Could begin operation with Project X Stage II beam

Exquisite Energy Resolution Allows Direct Measurement of Higgs Width

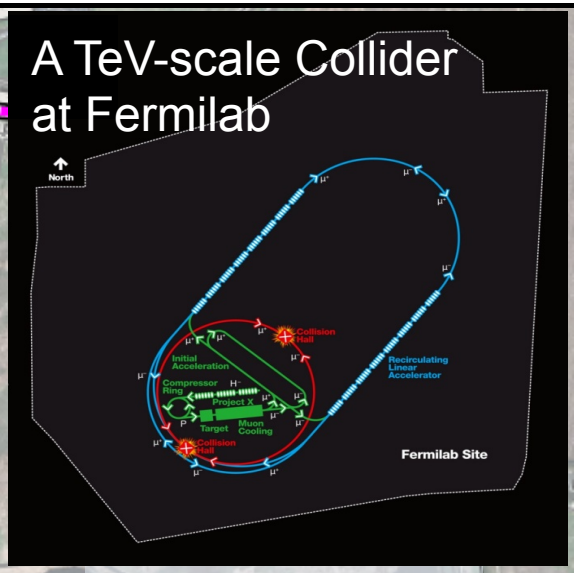
Success of advanced cooling concepts ⇨ several × 10^{32}

Site Radiation mitigation with depth and lattice design: ≤ 10 TeV

MAP Timeline



A Muon Accelerator Facility for Cutting Edge Physics on the Intensity and Energy Frontiers Based on Project X Stage II



To SURF

LBNE

Buncher/ Compressor Rings

NF Decay Ring: νs to SURF

RLA to 63 GeV + 300m Higgs Factory

Front End +4D +6D

Linac + RLA to ~5 GeV

Project X Stage II

Project X Stage I

N

1500 ft 0 1500 ft

νSTORM + Muon Beam R&D Facility

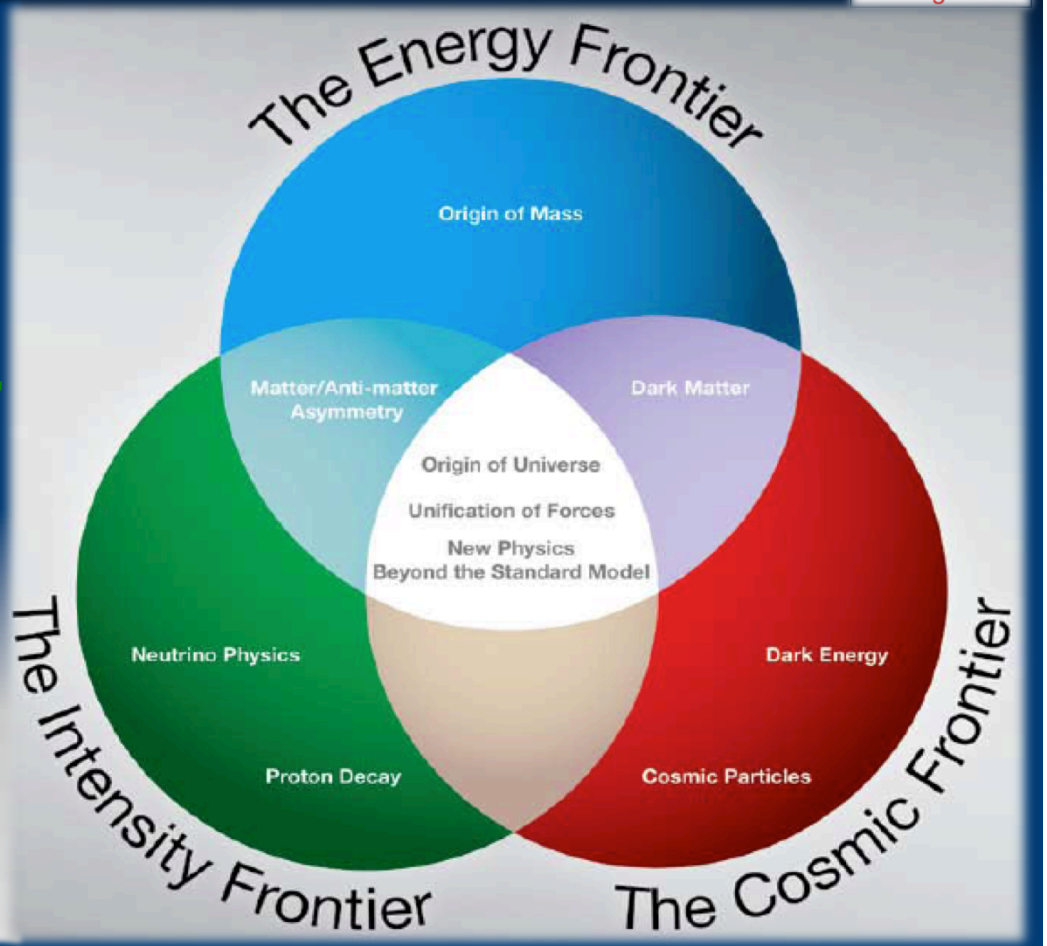
A 1.5 TeV collider would fit within the Tevatron ring

The Aims of the Muon Accelerator Program

Muon accelerator R&D is focused on developing a facility that can address critical questions spanning two frontiers…

The Intensity Frontier:
with a ***Neutrino Factory*** producing well-characterized ν beams for precise, high sensitivity studies

The Energy Frontier:
with a ***Muon Collider*** capable of reaching multi-TeV CoM energies
and
*a **Higgs Factory** on the border between these Frontiers*



The unique potential of a facility based on muon accelerators is physics reach that SPANS 2 FRONTIERS