Fermilab's Project X

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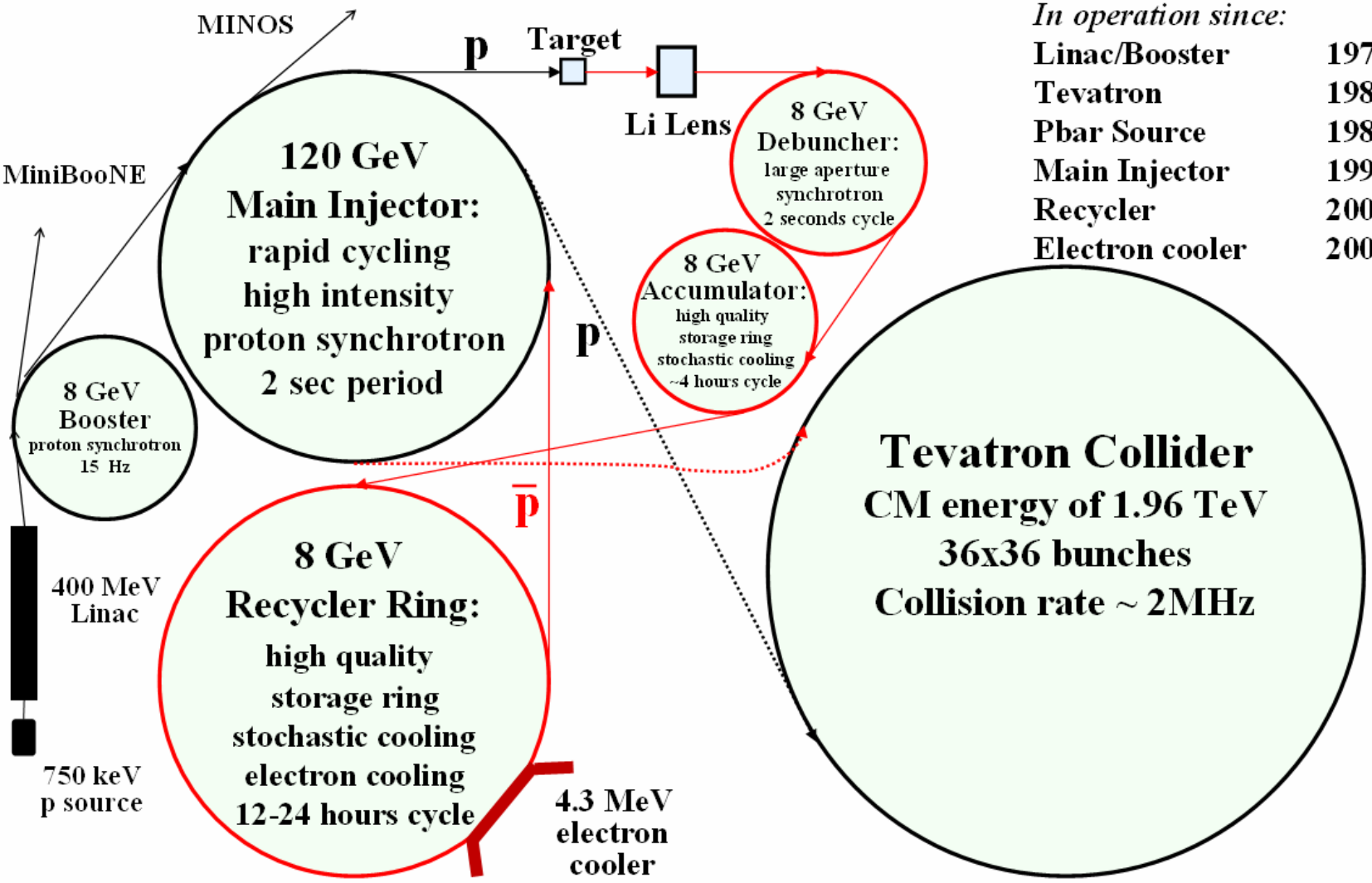
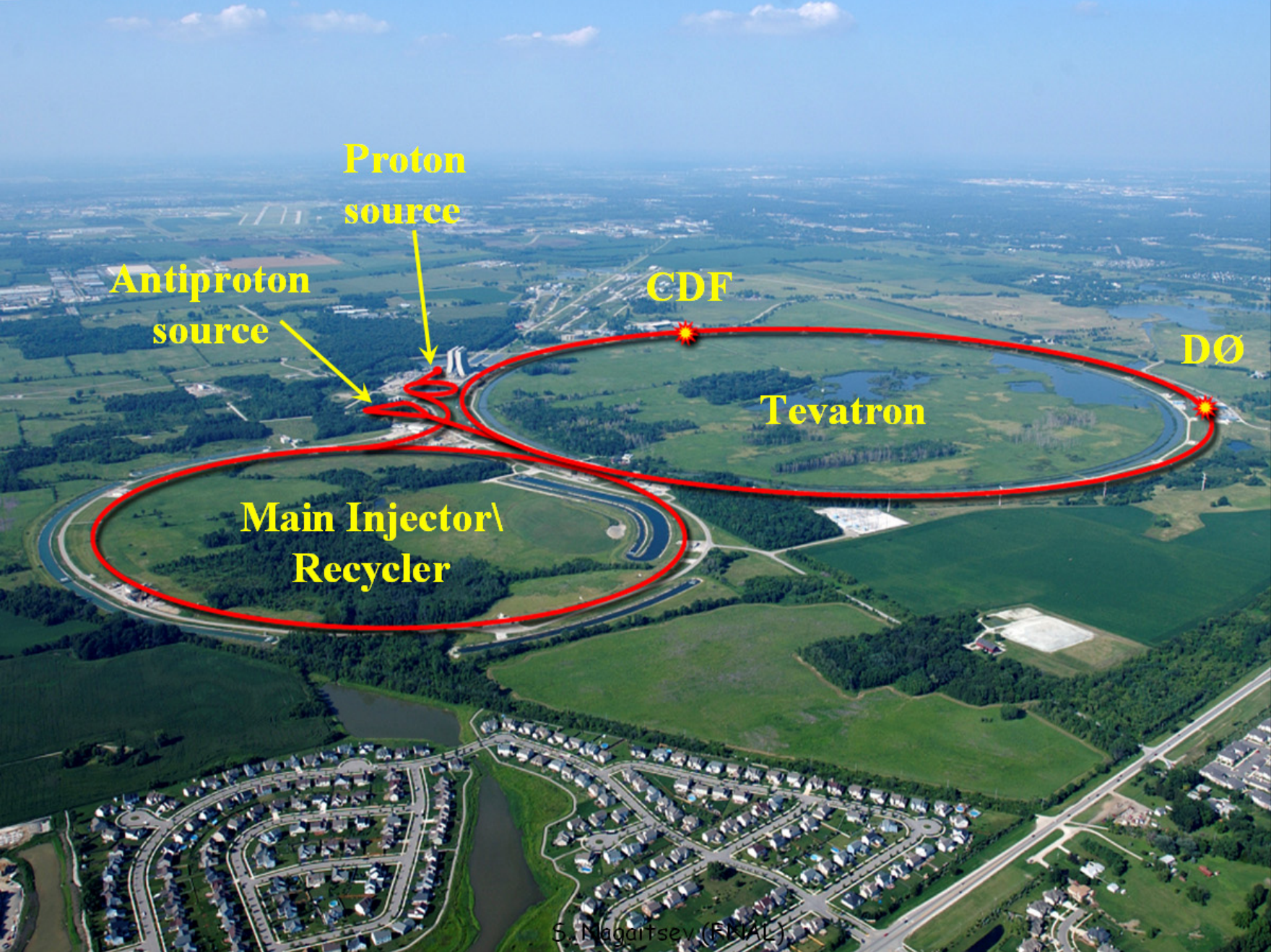
Fermilab accelerator complex: 9 accelerators



In operation since:

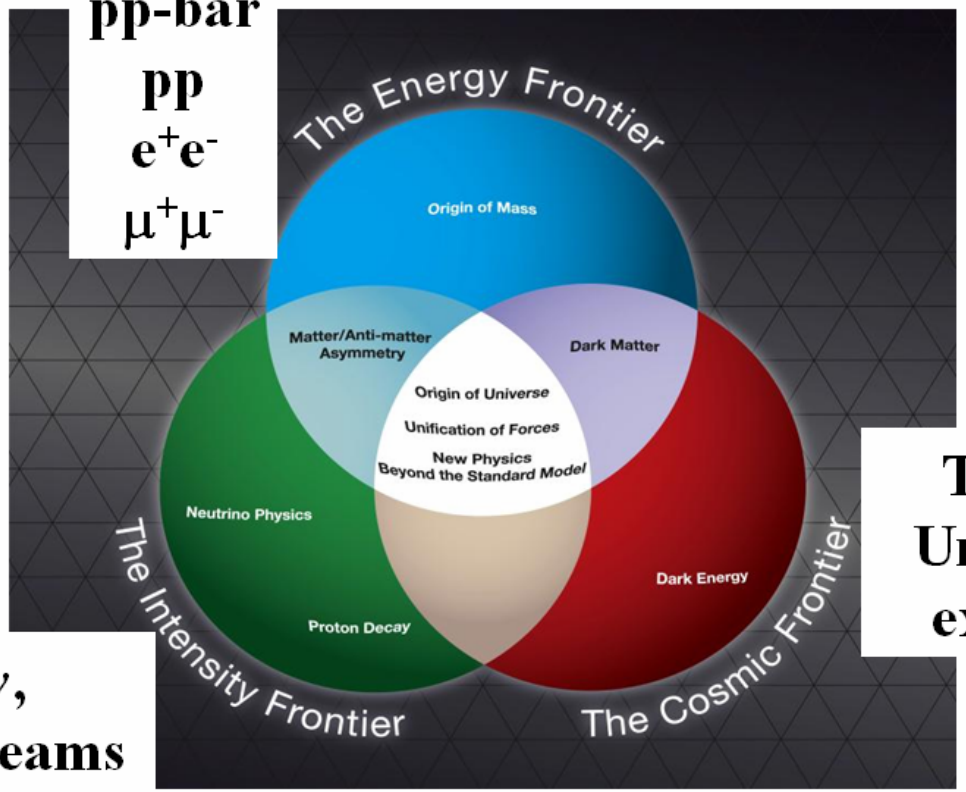
Linac/Booster	1971
Tevatron	1983
Pbar Source	1985
Main Injector	1999
Recycler	2004
Electron cooler	2005


Proton source
Antiproton source
CDF
DØ
Tevatron
Main Injector\ Recycler
S. Nagaitsev (FNAL)

Strategic Context
Fermilab Long Range Plan

The Fermilab long-term plan incorporates three strategic directions:

pp-bar
pp
e^+e^-
$\mu^+\mu^-$

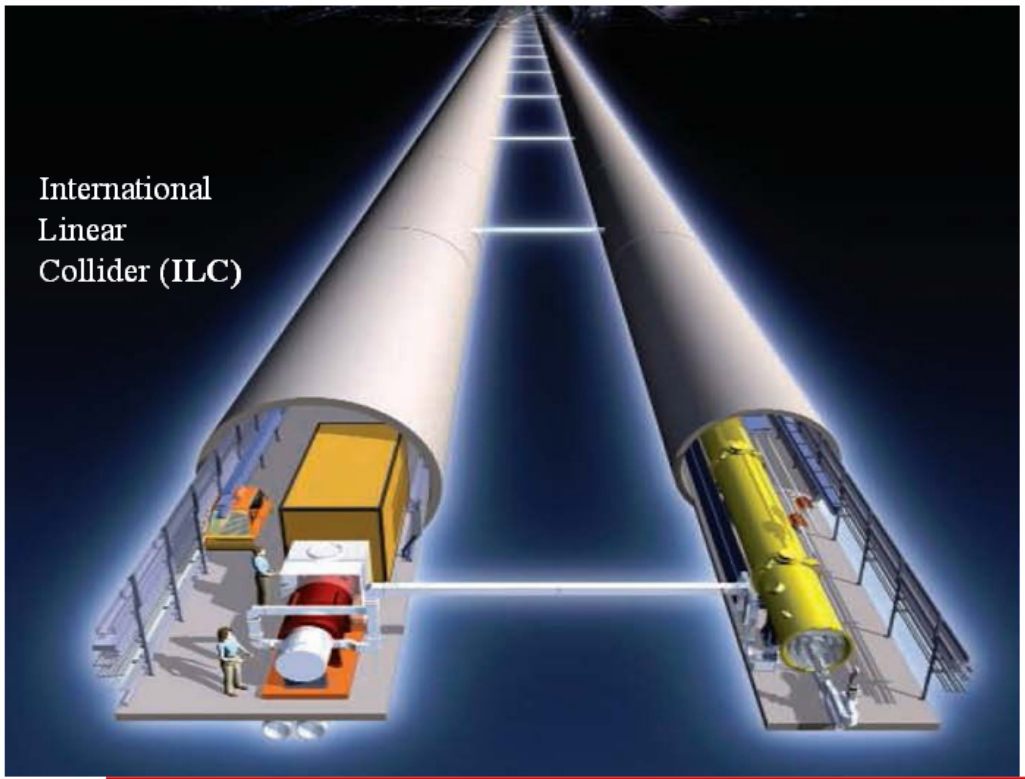


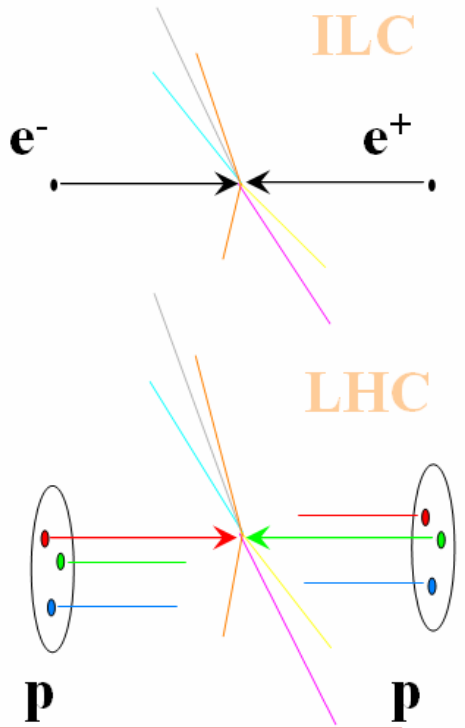
Telescopes; Underground experiments

Intense ν, μ, K, .. beams

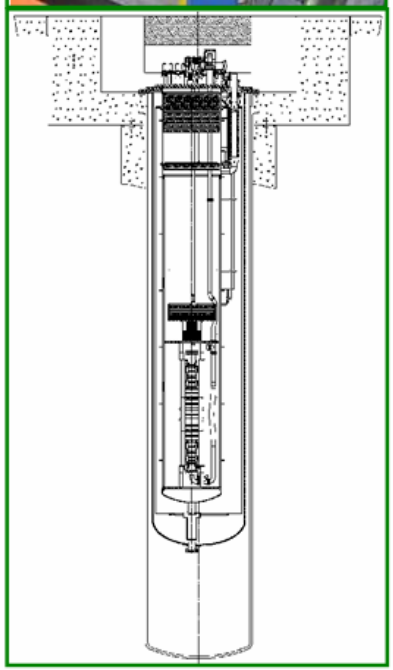
Strategic Context
P5 Recommendations

- Energy Frontier
  - The panel recommends for the near future a broad accelerator and detector R&D program for lepton colliders that includes continued R&D on ILC … The panel also recommends R&D for alternative accelerator technologies, to permit an informed choice when the lepton collider energy is established.

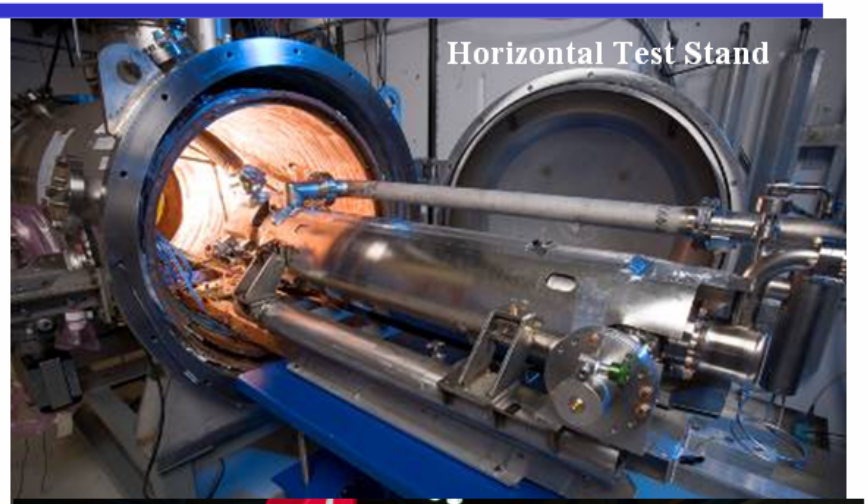




ILC technology at Fermilab



Vertical Test Stand



ILC/SCRF Test facility

Intensity frontier

- The general rule:
  - If the LHC discovers new particles – precision experiments tell about the physics behind through rates/couplings to standard particles
  - If the LHC does not see new particles – precision experiments with negligible rates in the SM are the only avenue to probe higher energies

- Additionally, neutrino oscillations coupled with charged lepton number violating processes constrain GUT model building

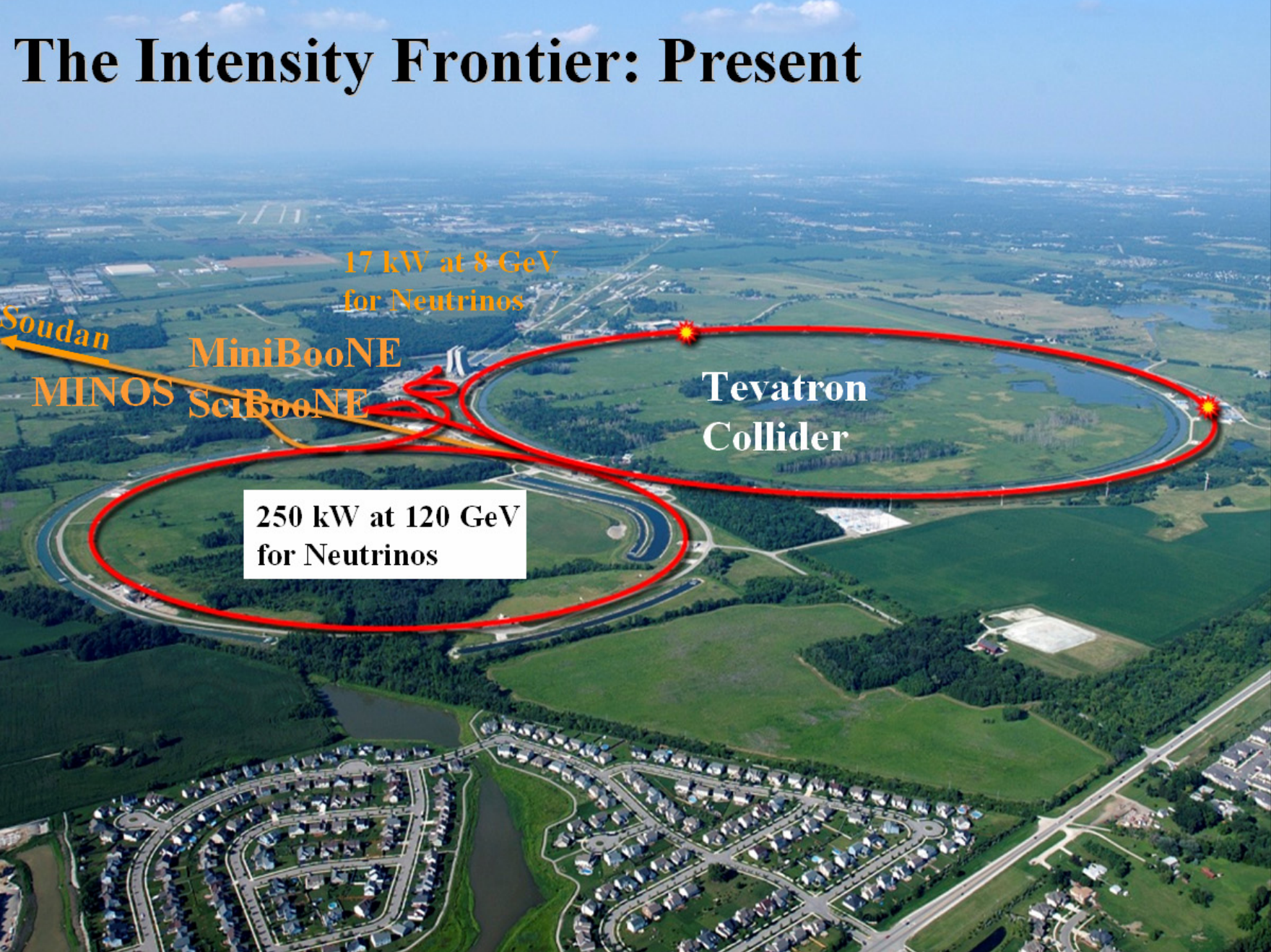
Strategic Context
P5 Recommendations

- Intensity Frontier
  - The panel recommends an R&D program in the immediate future to design a multi-megawatt proton source at Fermilab and a neutrino beamline to DUSEL and recommends carrying out R&D on the technologies for a large multi-purpose neutrino and proton decay detector.
  - A neutrino program with a multi-megawatt proton source would be a stepping stone toward a future neutrino source, such as a neutrino factory based on a muon storage ring… This in turn could position the US program to develop a muon collider as a long-term means to return to the energy frontier in the US.

Fermilab and the intensity frontier

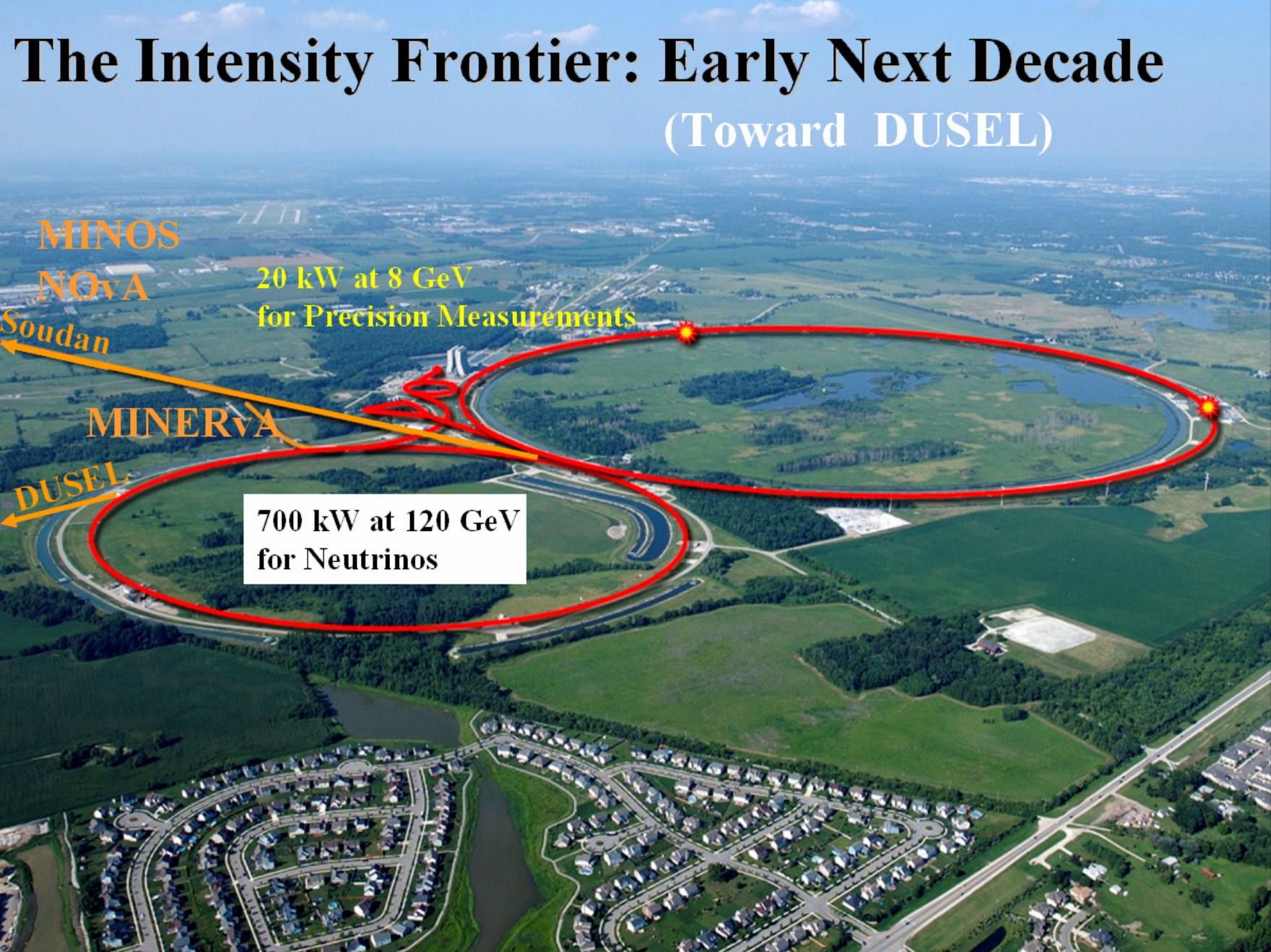
- We have designed a program based on a new injector for the complex.
  - Can exploit the large infrastructure of accelerators: Main Injector (120 GeV), Recycler (8GeV), Debuncher (8 GeV), Accumulator (8 GeV) – would be very expensive to reproduce today
  - New source uses ILC technology and helps development of the technology in the US
  - Provides the best program in neutrinos, and rare decays in the world
  - Positions the US program for an evolutionary path leading to neutrino factories and muon colliders
- Scope of new injector is based on:
  - 2 MW at 120 GeV
  - Affordable
  - Flexible beam delivery at low energy (8 GeV)
  - Upgradable to multi-MW at ~10 GeV

The Intensity Frontier: Present



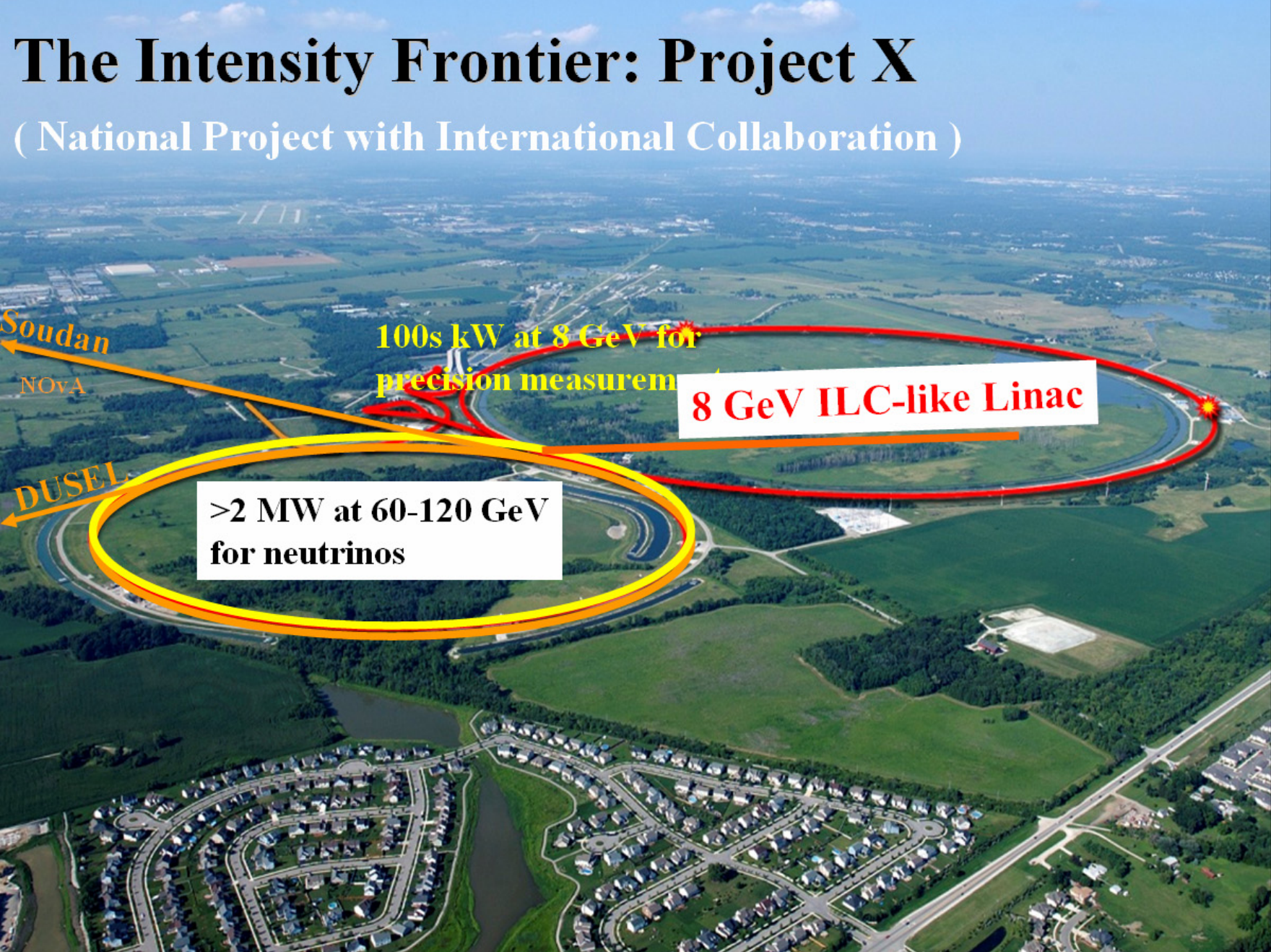
The Intensity Frontier: Early Next Decade

(Toward DUSEL)



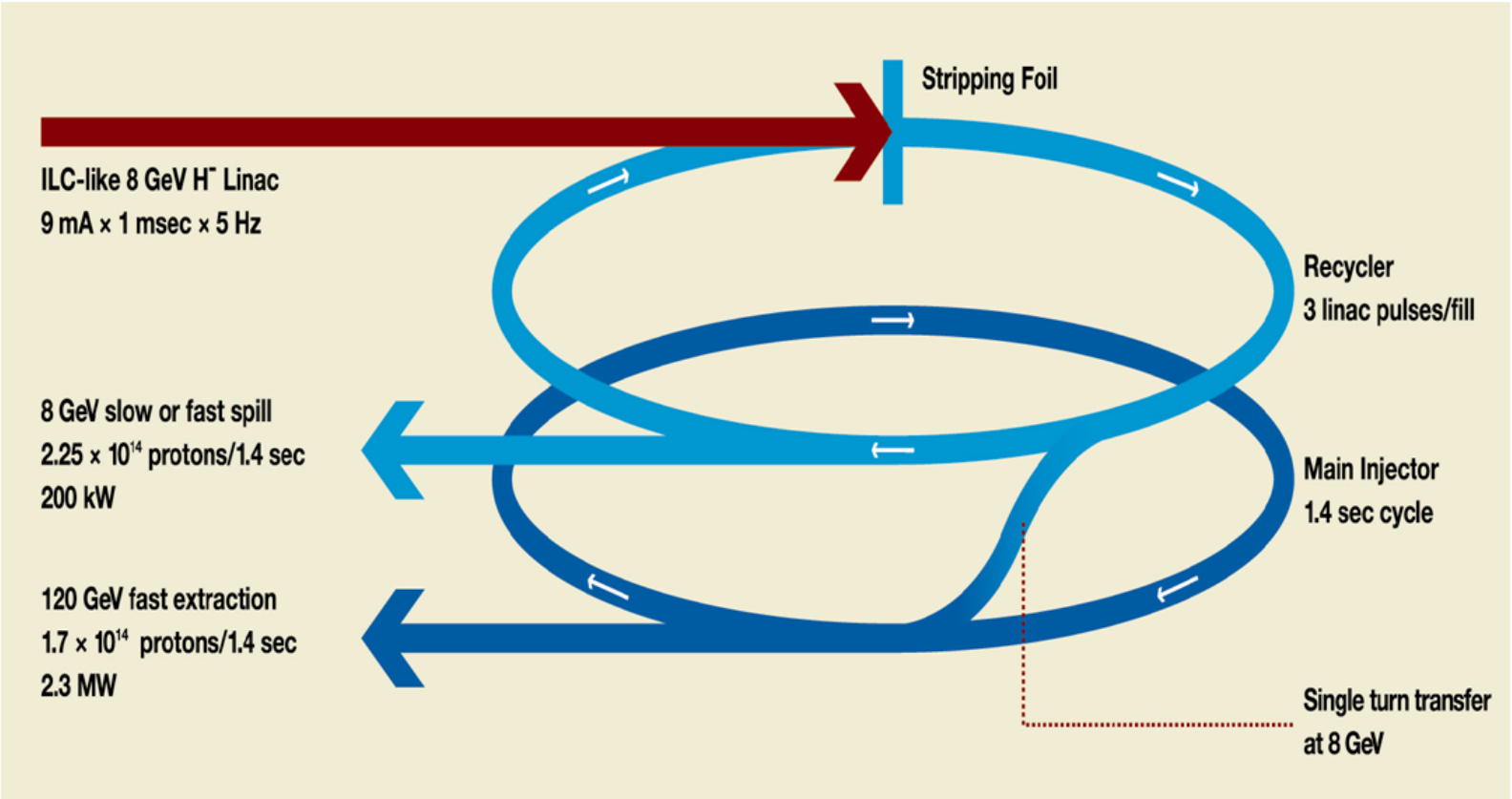
The Intensity Frontier: Project X

(National Project with International Collaboration)



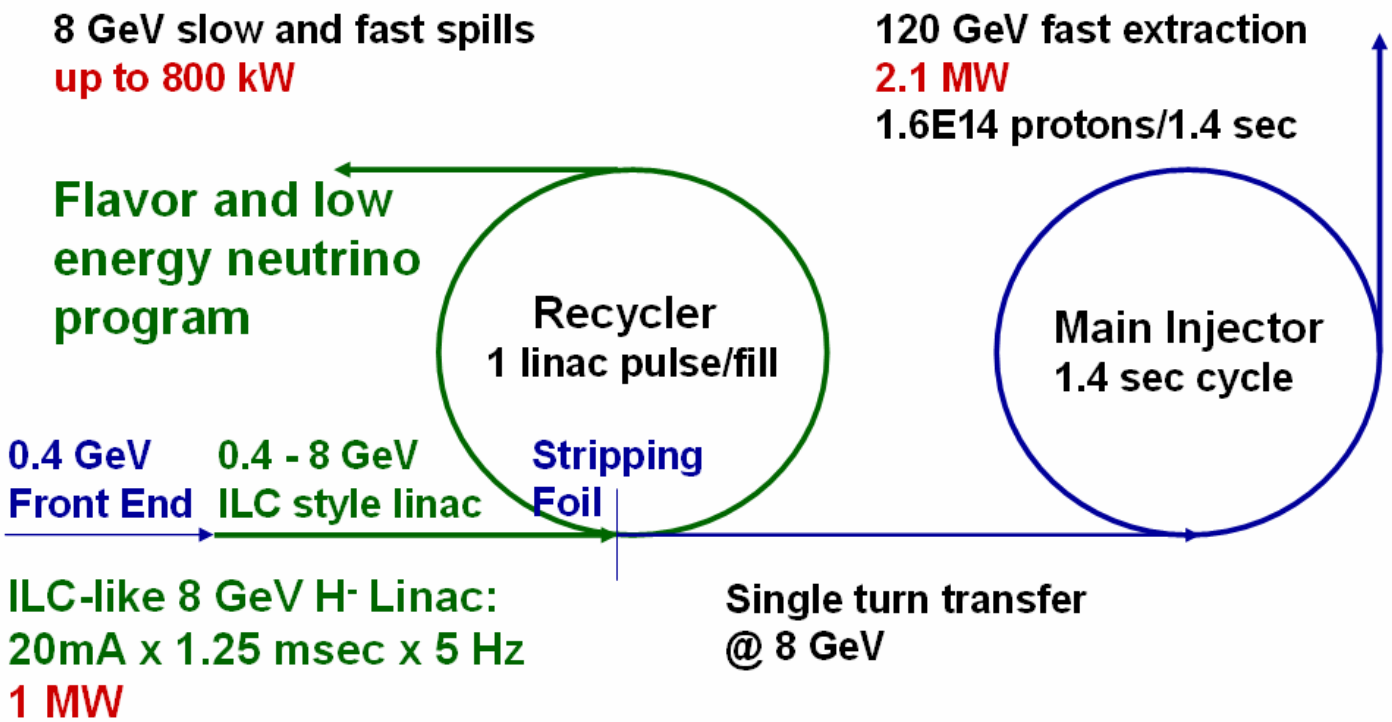
Project X: early concept

Concept (Nov, 2007)



Project X: present concept (Sep 08)

Project X is a high intensity proton facility aimed at supporting a world leading program in neutrinos and rare decays.



The beams of the linacs

	Proton Driver Phase 1 Design	Proton Driver Phase 2 Design	HINS capability	Project X Base Design (Nov-07)	Project X ICD (Sep-08)	
Particle	H-	H-	H+ then H-	H-	H-	
Nominal Bunch Frequency/Spacing	325 3.1	325 3.1	325 3.1	325 3.1	325 3.1	MHz nsec
Particles per Pulse	15.6	15.6	37.5 *	5.6	15.6	E13
Pulse Length (beam)	3	1	3/1	1	1.25	msec
Average Pulse Current	8.3	25	~20	9	20	mA
Pulse Rep. Rate	2.5	10	2.5/10	5	5	Hz
Chopping -6% @ 89KHz and 33% @ 53MHz	37.5%	37.5%	0 - 37.5%	37.5%	37.5%	
Bunch Current	13.3	39.8	32	14.3	32	mA
Bunch Intensity	2.5 41	7.6 122	6.1 98	2.7 ** 44	6.1 98	E8 pCoul

* full un-chopped 3 msec pulse at klystron-limited 20 mA

** ILC bunch intensity is 2E10 (electrons)

Project X Facility Overview

Scope

- A new 8 GeV, superconducting, H^- linac capable of delivering 1 MW of beam power;
- A new beamline for transport of 8 GeV H^- from the linac to the Recycler Ring;
- Modifications to the Recycler required for 8 GeV H^- injection, accumulation, and delivery of protons to the Main Injector;
- Modifications to existing beamlines to support transfer of 8 GeV protons from the Recycler to the Main Injector;
- Modifications to the Main Injector to support acceleration and extraction of high intensity proton beams over the range 60-120 GeV;
- Modifications to the Recycler to support a new extraction system for delivery of 8 GeV protons in support of a dedicated flavor program.

Project X: High Level Performance Goals

Linac		
Particle Type	H^-	
Beam Kinetic Energy	8.0	GeV
Particles per pulse	1.6×10^{14}	
Pulse rate	5	Hz
Beam Power	1	MW
Recycler		
Particle Type	protons	
Beam Kinetic Energy	8.0	GeV
Cycle rate	5	Hz
Particles per cycle	1.6×10^{14}	
Beam Power to 8 GeV program	850	kW
Main Injector		
Beam Kinetic Energy (maximum)	120	GeV
Cycle time	1.4	sec
Particles per cycle	1.6×10^{14}	
Beam Power at 120 GeV	2.1	MW

Project X
1000 kW 8GeV Linac

28 Klystrons (2 types)
461 SC Cavities
58 Cryomodules

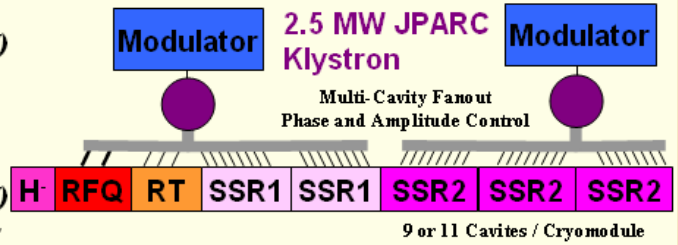
Front End Linac

325 MHz 0-10 MeV

1 Klystron (JPARC 2.5 MW)
16 RT Cavities

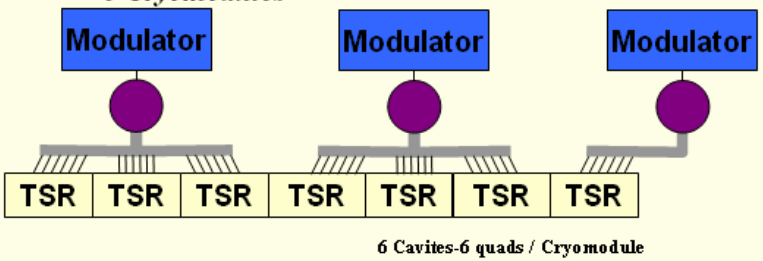
325 MHz 10-120 MeV

1 Klystron (JPARC 2.5 MW)
51 Single Spoke Resonators
5 Cryomodules



325 MHz 0.12-0.42 GeV

3 Klystrons (JPARC 2.5 MW)
42 Triple Spoke Resonators
7 Cryomodules



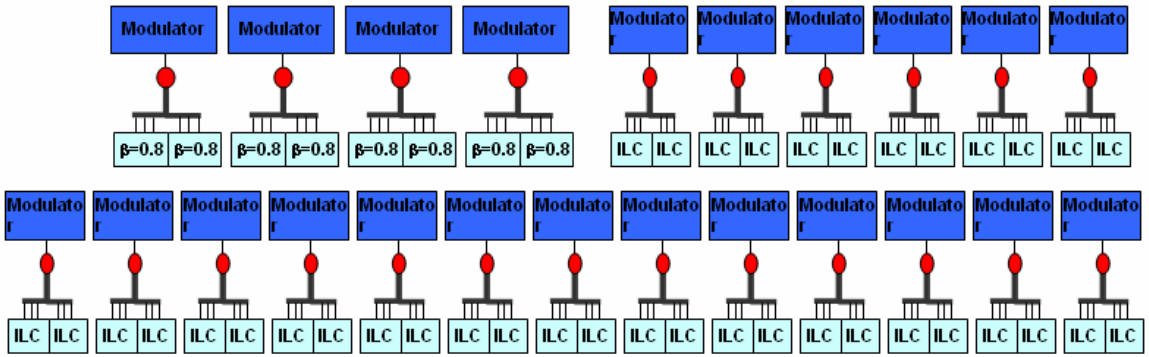
1300 MHz LINAC

1300 MHz 0.42-1.3 GeV

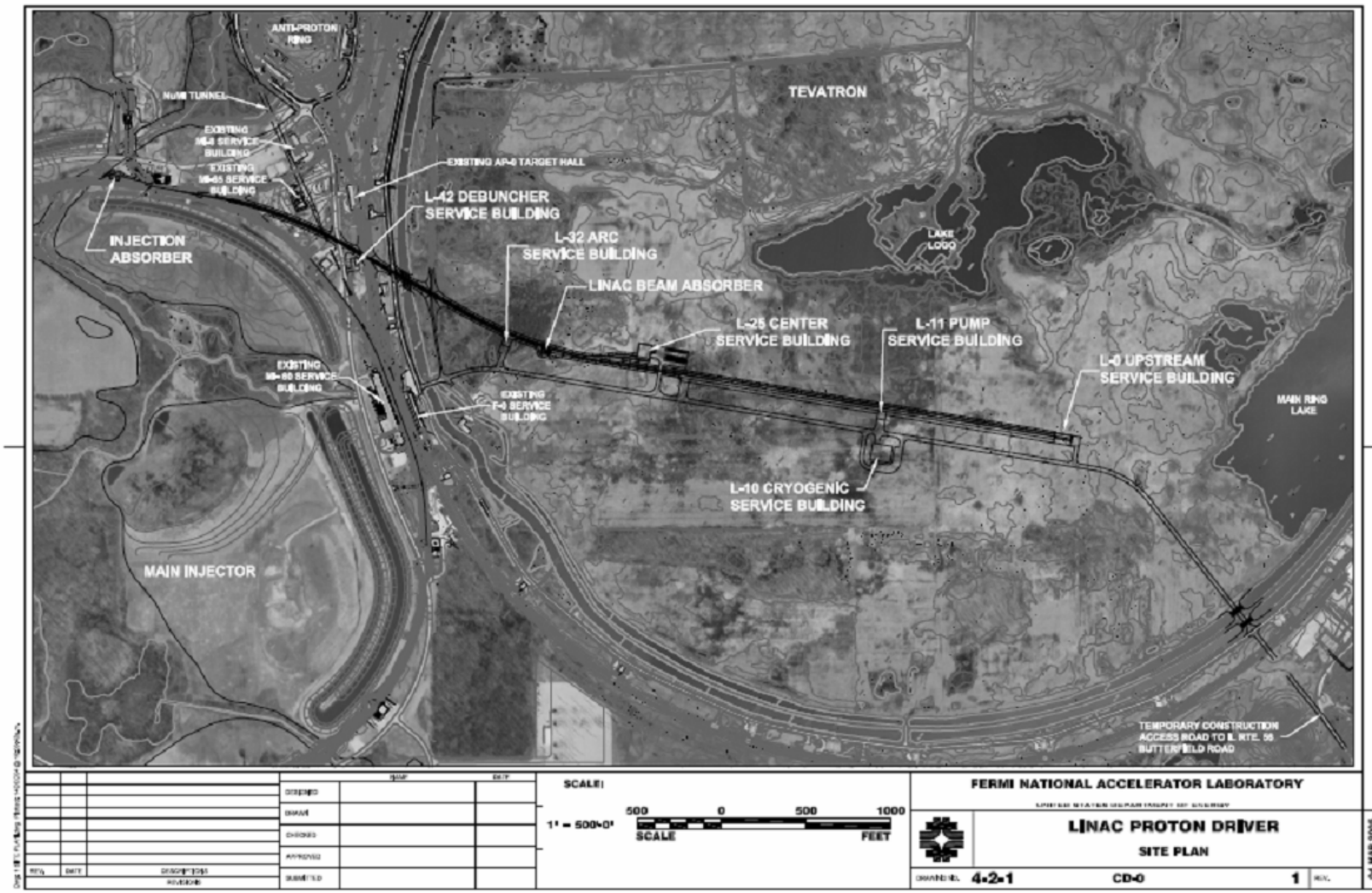
4 Klystrons (ILC 10 MW MBK)
64 Squeezed Cavities (β=0.81)
8 Cryomodules

1300 MHz 1.3-8.0 GeV

19 Klystrons (ILC 10 MW MBK)
304 ILC-identical Cavities
38 ILC-like Cryomodules



Project X: Provisional Site



Project X: Alignment with future accelerator facilities

- ILC and SRF programs:
  - Development of shared technologies to the benefit of both efforts
  - Project X linac designed to accommodate accelerating gradients in the range 23.6 – 31.5 MV/m (XFEL – ILC)
    - Initial configuration is based on 25 MV/m
- Muon facilities
  - Develop upgrade concept for the Project X linac aimed at >2 MW
  - Develop a performance specification for a Proton Source supporting a Neutrino Factory and Muon collider, consistent with Project X concepts.

Project X timeline

- Working backwards:
  - 2013: CD-3 – Start Construction
  - 2012: CD-2 – Establish Baseline
  - 2011: CD-1 – Establish Baseline Range
    - Requires a complete Conceptual Design Report
  - 2009: CD-0 – Approve mission need
    - Requires new cost (range) estimate which will be reviewed by DOE . Based on Initial Configuration Document (nearing completion).

(CD = Critical Decision)

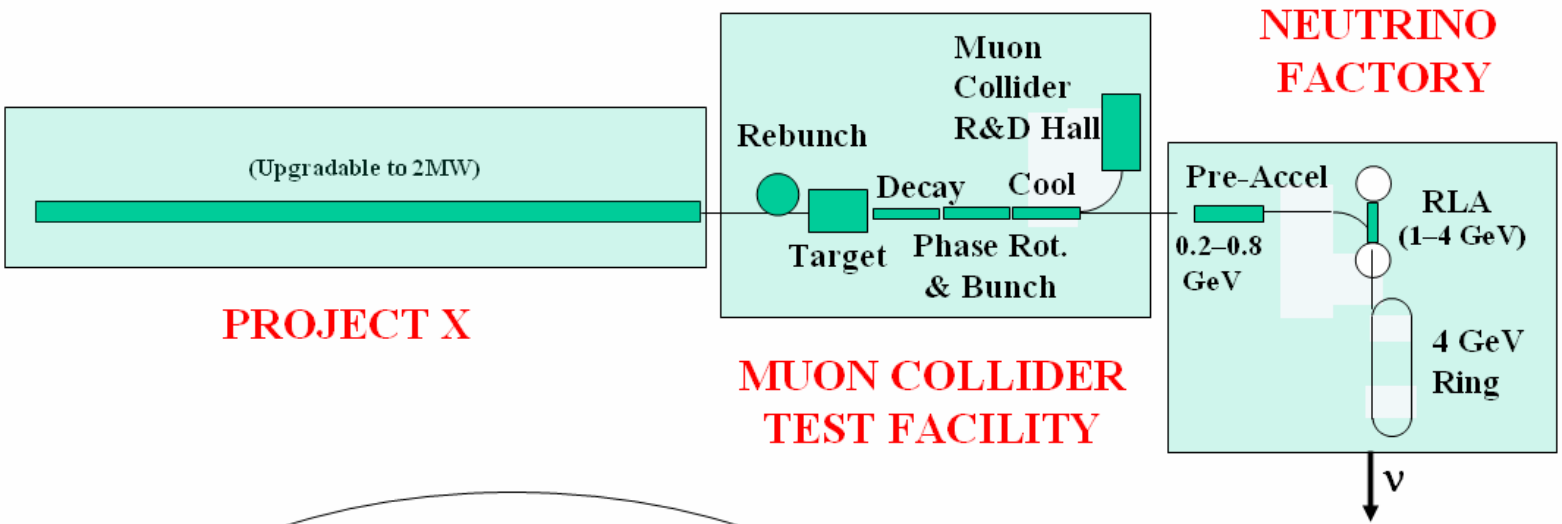
Collaboration plan

- A draft MOU covering the period through CD-2 is currently circulating for comment among the management of the following potential U.S. collaborators:
  - ANL
  - BNL
  - Cornell
  - LBNL
  - ORNL/SNS
  - MSU
  - TJNAF
  - SLAC
- Several non-US labs have expressed interest in participating in Project X R&D (& construction)
- Initial collaboration meeting: Nov 21-22, 2008

Project X: expandability

- Initial configuration exploits alignment with ILC
- But it is expandable:
  - increase the rep rate
  - increase the pulse length
  - increase the beam current
- Would position the program for a multi-megawatt (2-4 MW) source for intense muon beams at low <8 GeV energies – very difficult with a synchrotron.
- We can develop existing 8 GeV rings (Recycler, Debuncher, Accumulator) to deliver and tailor beams, allowing full duty cycle for experiments with the correct time structure: *K* decays, $\mu \rightarrow e$ conversion, *g-2*.

Example: evolutionary path muons

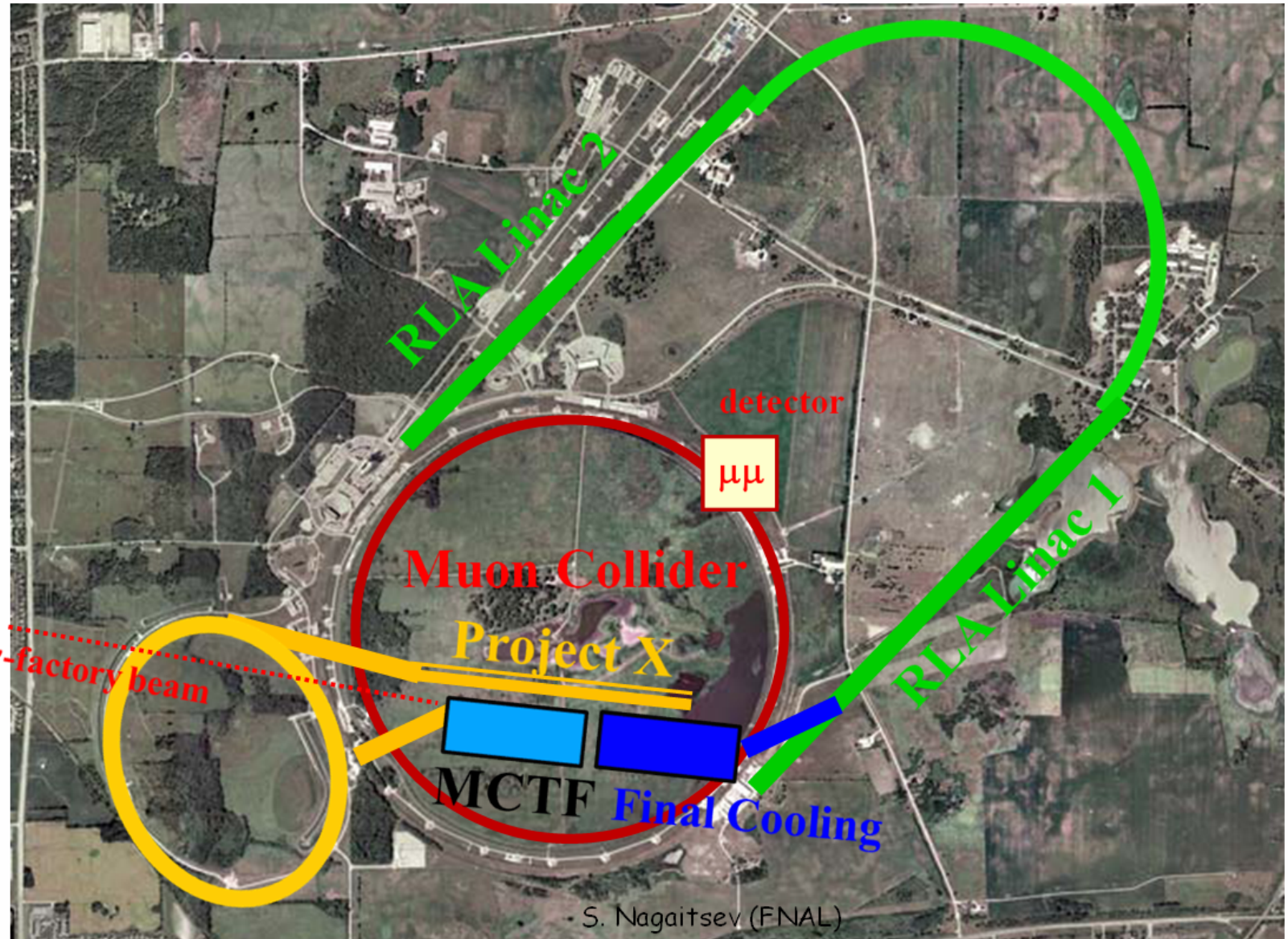


Illustrative Vision

Three projects of comparable scope:

- **Project X (upgraded to 2MW)**
- **Muon Collider Test Facility**
- **4 GeV Neutrino Factory**

1.5-4 TeV Muon Collider at Fermilab



S. Nagaitsev (FNAL)

Summary

- The Project X design concept supports a long term future for Fermilab based on world leading facilities at the:
  - Energy Frontier
  - Intensity Frontier
- Design concept exists for a facility with >2 MW beam power at 120 GeV, simultaneous with 800 kW at 8 GeV.
  - Major sub-system performance goals established
  - Supports world class program in neutrino physics and rare processes
- Design provides flexibility to support a long-term future for accelerator based physics at Fermilab
  - Potential upgrade paths to multi-MW at 8 GeV exist
  - Design aligned with needs of ILC technology development
  - Design concept supports future development of muon facilities