Project X Strategy and Status: A Discussion

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Accelerator Physics & Technology Seminar

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Outline

- Goals
- Constraints
- Evolution of Project X & Strategy

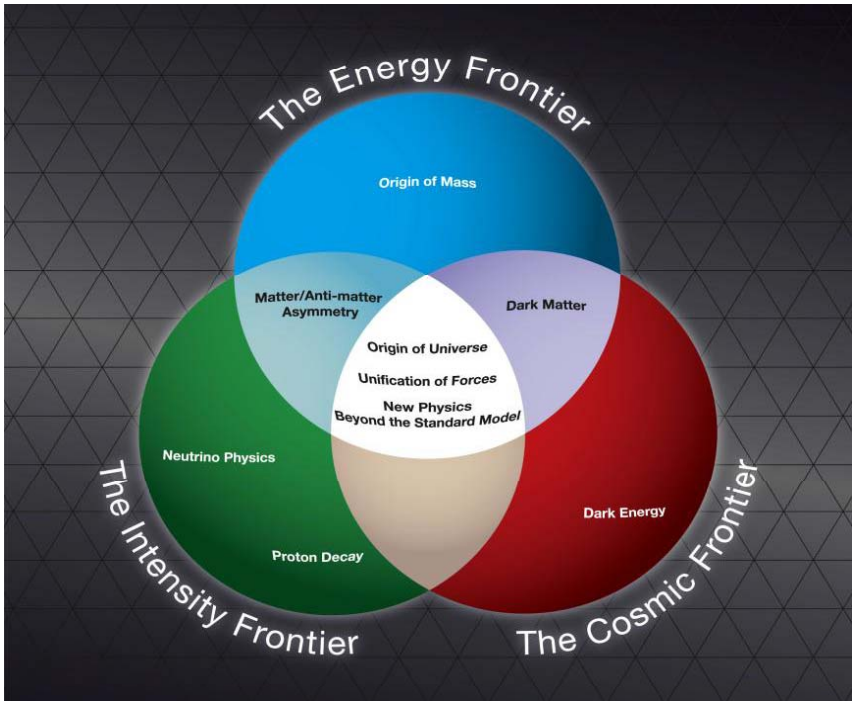
- Discussion

Goals

Reconfigure the Fermilab accelerator complex to support a world-leading elementary particle physics program over the next >2 decades.

⇒Establish a world-leading intensity frontier program at Fermilab

⇒Use this program as a bridge to recapturing the energy frontier



Goals

- The most reliable path toward meeting these goals is via the construction of a multi-MW Proton Source, Project X, at Fermilab

- Intensity Frontier:

  NuMI→ NOνA→ LBNE/mu2e→ Project X→ Rare Processes→ NuFact

  – Continuously evolving world leading program in neutrino and rare processes physics

- Energy Frontier:

  Tevatron → ILC or Muon Collider

  – Technology alignment

  – Fermilab as host site for ILC or MC

Constraints
Physics

- Project X in its initial configuration must support a compelling physics program, and this program must have the strong endorsement of the U.S. elementary particle physics community
- The P5 report, accepted by HEPAP, defines a mission with strong community support:
  - Long baseline neutrino beam
    - 2 MW proton source at 60 - 120 GeV
  - High intensity, low energy protons for kaon and muon based precision experiments
    - Several hundred kWs
    - Operations simultaneous with the neutrino program.
  - A path toward a future muon facility – neutrino factory or muon collider
    - Requires upgrade potential to 2-4 MW at ~5-15 GeV.

⇒ **We have (and will) preserved these three elements as the central mission definition for Project X.**

Constraints
Physics Uncertainties

- Neutrinos: Value of $\sin^2 2\theta_{13}$
  - This parameter is the key to the reach of the long baseline neutrion program
    - Determines the ability to measure the mass hierarchy and CP violation
  - It has not been measured, but it is known to be <0.2
  - It needs to be >0.005 to give access to CP violation based on a very massive detector at DUSEL and 2 MW beam from Fermilab over 5 years.
  - We will know by around 2012 if $\sin^2 2\theta_{13}$ is greater than or less than ~0.02

$\Rightarrow$ **What total investment in LBNE and Project X makes sense before we know what this number is?**

Constraints
Physics

- Rare Process: Must provide an appropriate beam energy, beam power, and duty factor

	Proton Energy (kinetic)	Beam Power	Beam Timing
Rare Muon decays	2-3 GeV	>500 kW	1 kHz – 160 MHz
(g-2) measurement	8 GeV	20-50 kW	30- 100 Hz.
Rare Kaon decays	2.6 – 4 GeV	>500 kW	20 – 160 MHz. (<50 psec pings)
Precision K^0 studies	2.6 – 3 GeV	> 100 mA (internal target)	20 – 160 MHz. (<50 psec pings)
Neutron and exotic nuclei EDMs	1.5-2.5 GeV	>500 kW	> 100 Hz

⇒Need a compelling physics case that will be embraced by the community

Constraints
Department of Energy

- Policy
  - Energy strategy is the priority within the Department of Energy
- DOE 413.3
  - Project X is subject to the standard CD-0, 1, 2, 3, 4 process; however…
  - Project X is a "Major System" (>$750M), requiring higher level of approval and scrutiny than, e.g. NOvA, MicroBoone, Mu2e (LBNE is also a Major System)
- DOE wants/expects an integrated strategy for the laboratory
  - The DOE strategy puts Project X in line after Mu2e and LBNE
  - Both Mu2e (Nov. 2009) and LBNE (Jan. 2010) have received CD-0
  - DOE has told us that Project X is at least one year behind LBNE
- Fiscal
  - Mu2e + LBNE + Project X is of order $2B.
  - The DOE has not expressed a willingness to increase the HEP budget significantly

  ⇒ DOE has expressed a desire to keep Project X < $1B, or to develop staging options with an initial phase <$1B

Constraints
Resources

⇒ **While we would have preferred to have received CD-0 at this point, we are receiving very substantial financial support from DOE for Project X and SRF development (not including ILC):**

- $39M in FY10
- $50M in FY11

- However, there remain severe (people) resource constraints within the laboratory
  - The DOE does not want to see the laboratory staff grow
  - Several major projects underway at the lab (NOvA, DECam, MicroBoone, Mu2e, LBNE, (APUL))
  - This will be ameliorated somewhat once Run II ends

Constraints
Relationships

- Relationship to other programs
  - We are in the process of reorienting SRF development activities toward Project X.
    - This must be done without compromising commitments to the ILC/GDE: ILCTA_NML rf unit test
  - We must develop a sufficient understanding of Muon Accelerator requirements to build and site Project X in a manner that allows utilization (after upgrades) as a muon front end.

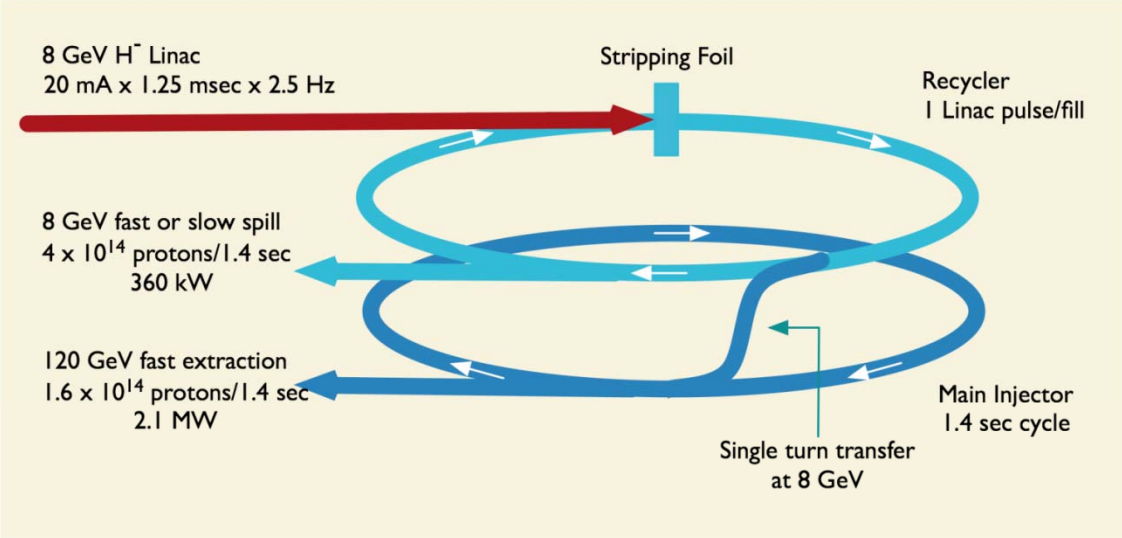
- Collaborators
  - We are currently collaborating with nine national and four international institutions during the R&D phase
  - The potential role of India may be critical to establishment of PX
    - Strong interest in applications of this technology to ADS
  - Potential interest from other offices within DOE?

Constraints
Bottom Line

⇒ **There are many constraints and uncertainties; and dealing with them requires a flexible strategy**

Strategy and Evolution
Initial Configuration-1 (IC-1)

- Initial Configuration-1



- Strong alignment with ILC technologies
- Initial Configuration Document-1 V1.1 released March 2009
  - Accompanying cost estimate $1.5B
  - Subject of Director's Review March 2009

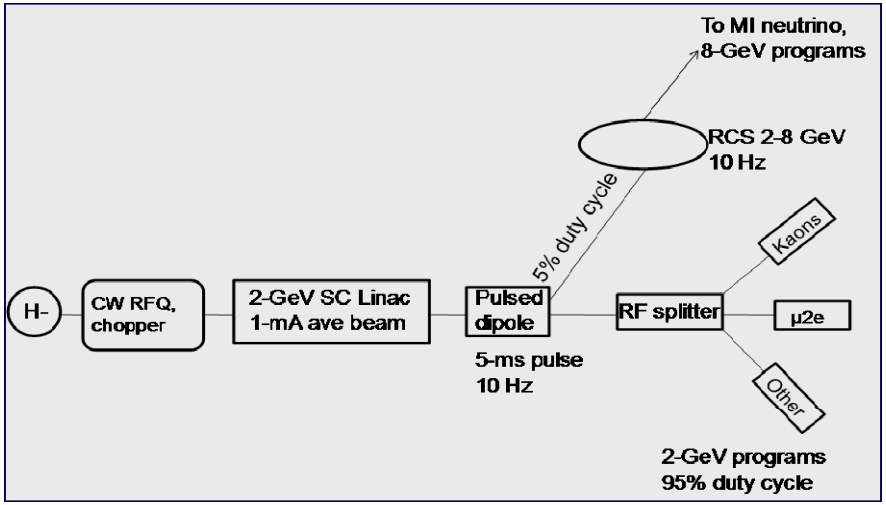
Strategy and Evolution
Initial Configuration-1

- Issue: IC-1 does not provide a strong platform for mounting a low energy rare processes program
  - These programs require high duty factor beams with varying bunch structures
  - The Recycler is ill-suited to providing high intensity slow spilled beam
  - The Debuncher appears limited to <150 kW in this mode
  - We believe there is a fundamental limit on the amount of beam power that can be delivered via a resonant extraction system.
  - Difficulties supporting multiple users

⇒ **These considerations led to the development of IC-2**

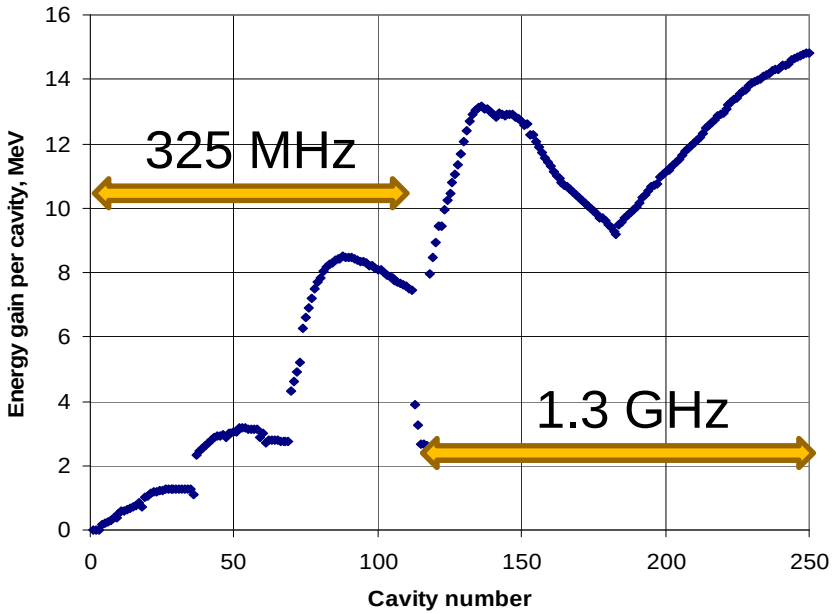
Strategy and Evolution
Initial Configuration-2v1

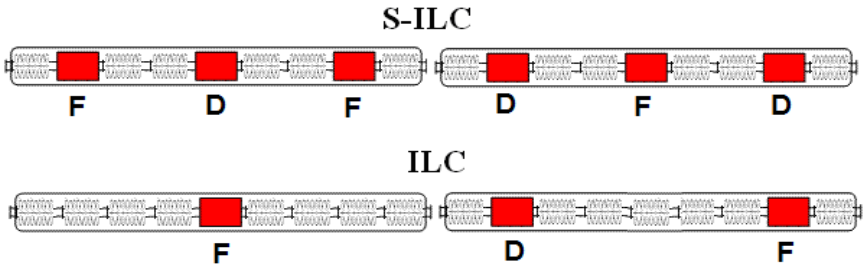
- Initial Configuration-2, version 1



- Linac configuration (to 2 GeV) unchanged except for CW
- Greatly enhanced capabilities for rare process program
  - 2 MW and flexible provision for beam requirements
  - Supports multiple users
- Initial Configuration Document-2V1.0 released March 2010
  - Accompanying cost estimate $1.6B (unreviewed)

Strategy and Evolution
Initial Configuration-2v1





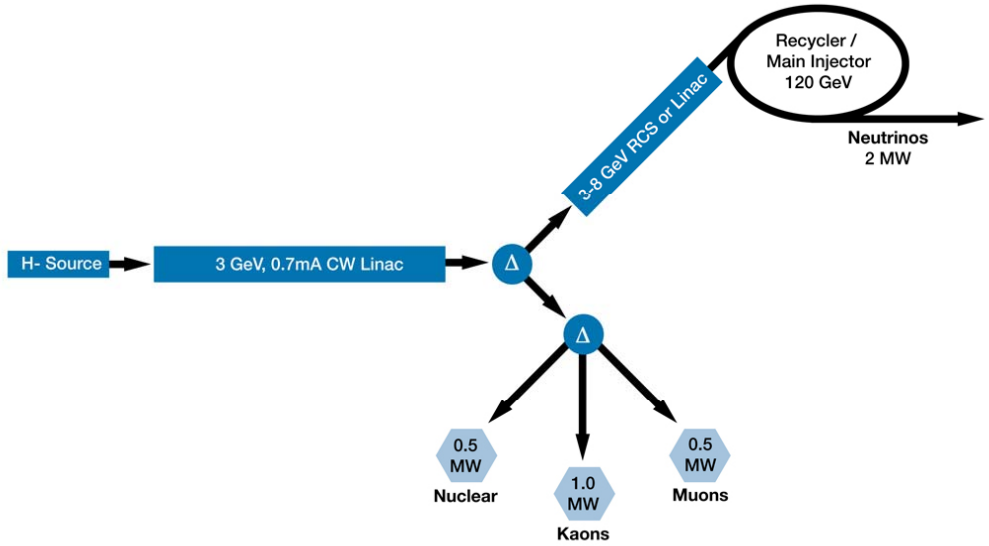
Strategy and Evolution
Initial Configuration-2v1

- Issue: IC-2v.1 does not provide a particularly efficient accelerator
  - The issue is primarily related to transit time effects in the lower beta sections
  - A secondary issue is that we would probably prefer a larger beam aperture in the lower energy sections of the linac than provided by a β=0.8, 1300 MHz structure
- Issue: Still less than optimum beam energy for rare processes program
  - Physics task force identified optimum energy range as 2.6-4 GeV for the rare process program (other than g-2)

$\Rightarrow$ **These considerations led to the development of IC-2v2**

Strategy and Evolution
Initial Configuration-2v2

- Initial Configuration-2, version 2

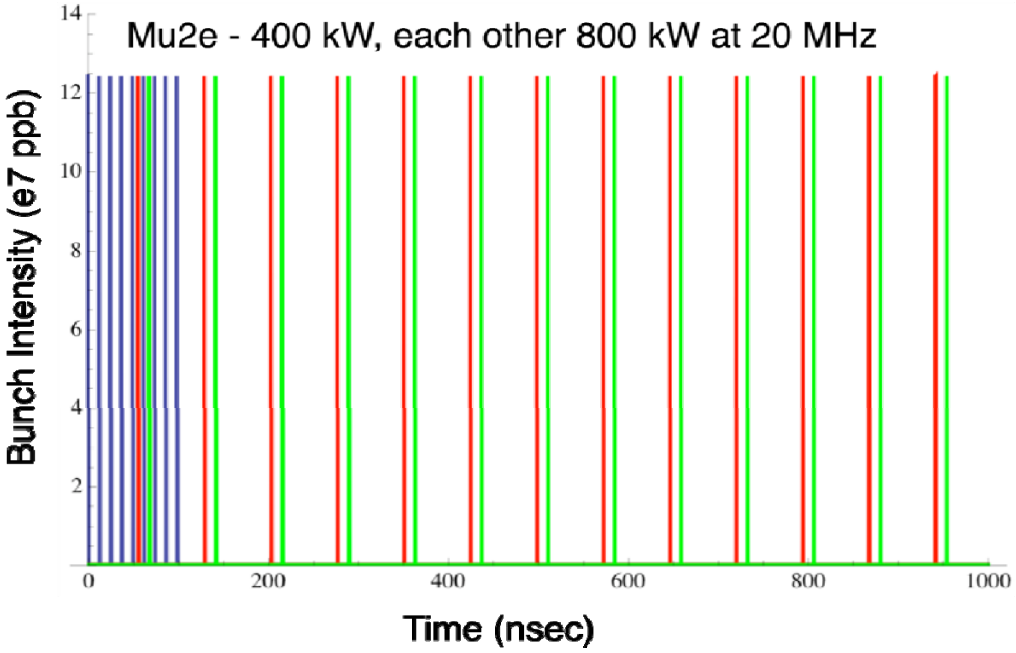


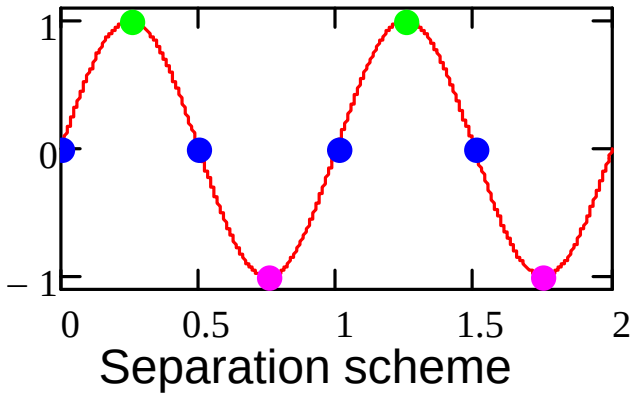
- More efficient linac configuration
- Enhanced capabilities for rare process program
  - 2-3 MW at 3 GeV
- Initial Configuration Document-2V2.0 targeting April 2010 release
  - Accompanying cost estimate targeting April 2010 release

Strategy and Evolution
Initial Configuration-2v1 (IC-2v1)

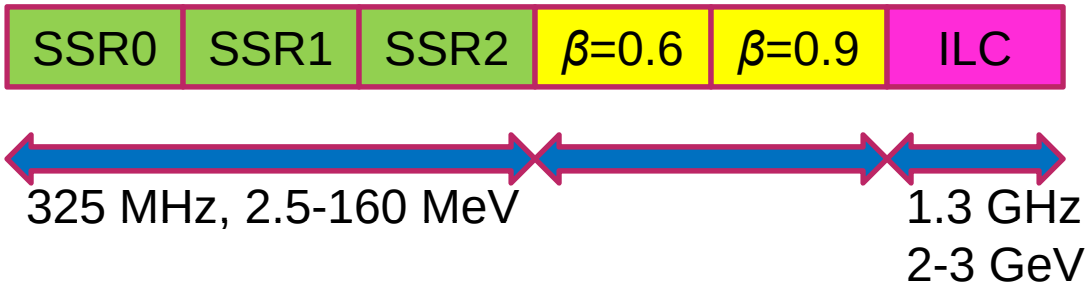
1 μsec period at 2 GeV

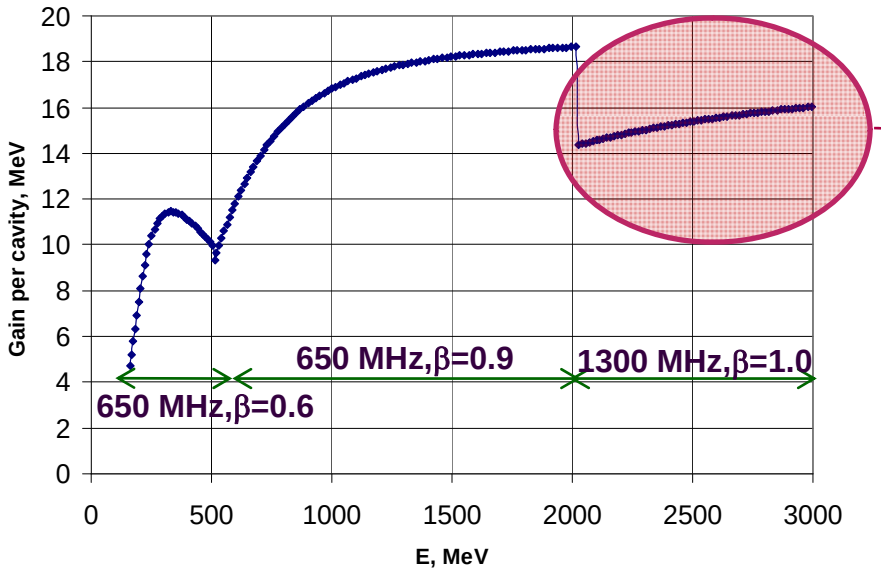
mu2e pulse (9e7) 162.5 MHz, 100 nsec	400 kW
Kaon pulse (9e7) 27 MHz	800 kW
Other pulse (9e7) 27 MHz	800 kW





Strategy and Evolution
Initial Configuration-2v2 (IC-2v2)



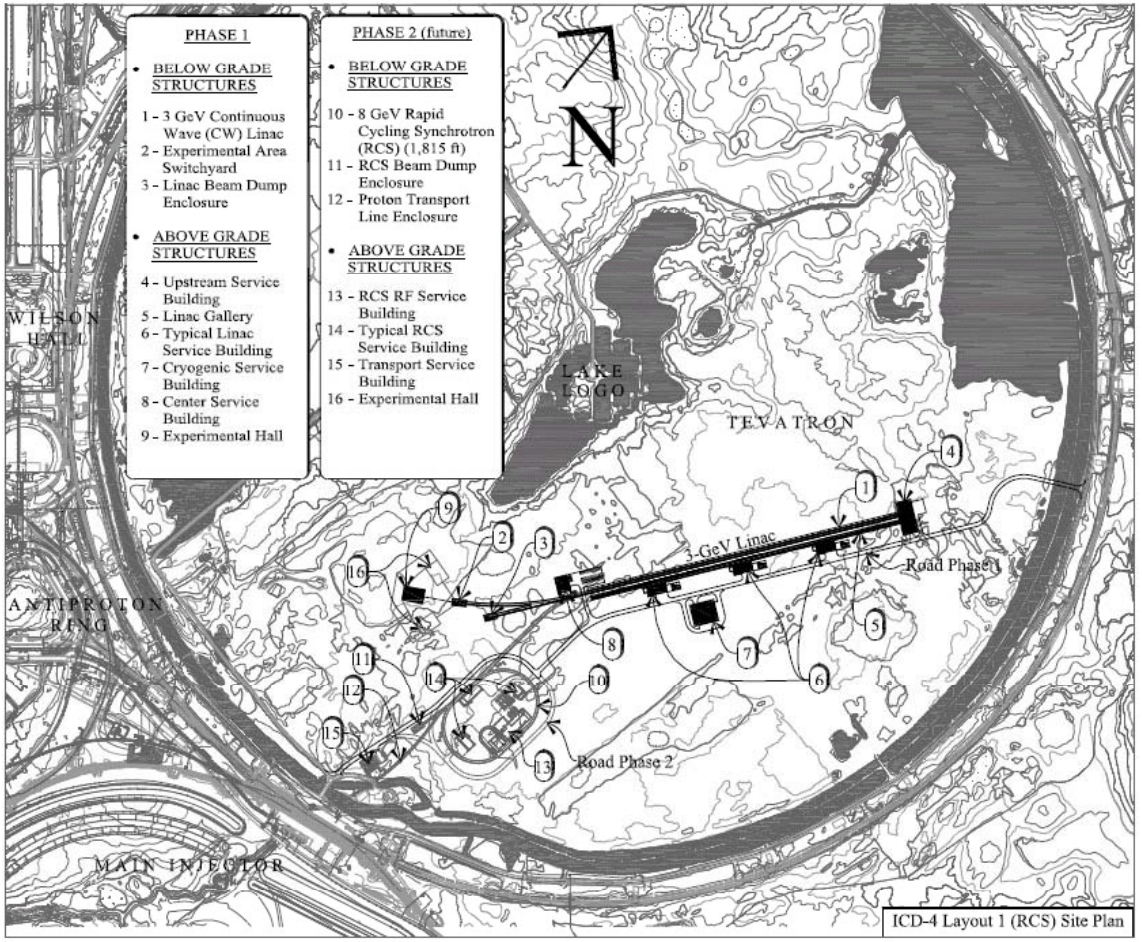


Notes:

Discontinuity may be eliminated with β=0.95, low loss cavity design

650 MHz, β=0.9, 5-cell cavities are same physical length as 1300 MHz, β=1.0, 9-cell cavities

Initial Configuration-2
Provisional Siting



Strategy
SRF Development

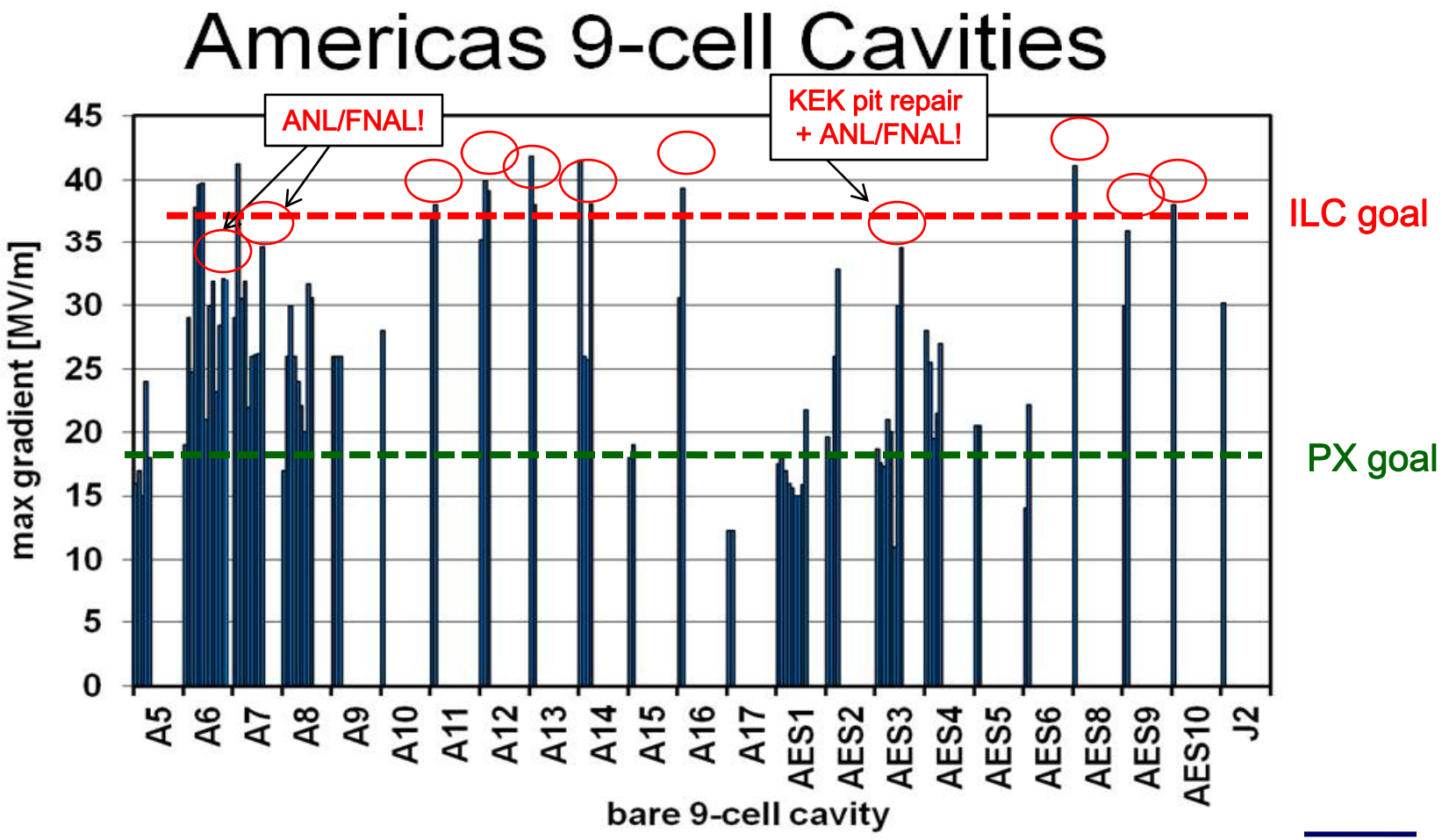
- We are in the process of integrating all srf development activities at Fermilab under a single management team
  - Project X, ILC, HINS, SRF infrastructure
  - Program is now targeting Project X needs, while retaining commitments to ILC
  - Plan has been discussed withh DOE
  - Program under the management of Bob Kephart

SRF Infrastructure

- **Steady progress on SRF infrastructure at FNAL**
  - Several new SRF facilities now in full operation
- **Vertical Test Stand; tests bare cavities**
  - Works! 60 tests so far, 40 in FY09 (achieved design test rate of 5/month)
  - Civil construction complete for 2 more VTS systems (325 and 650 MHz capability)
- **Cryomodule Assembly Facility**
  - Works! 2 CM assembled in MP9 & ICB: CM1(1.3 GHz) & FLASH(3.9 GHz)
  - Completed cavity dressing infrastructure ➔ dressed 7 cavities so far
- **Horizontal Test Stand**; tests dressed cavities (unique in U.S.)
  - Works ! Five 3.9 GHz tests + Five 1.3 GHz cavities tested so far (faster than DESY!)
  - Two high gradient (> 30 MV/m) dressed "S1-global" cavities shipped to Japan
- **ANL/FNAL Joint EP Processing; commissioning**
  - ~Works ! Excellent results with single and nine cells (two ~ 35 MV/m)
  - 6 nine cell EP cycles, 38 High Pressure rinse and assembly cycles!
- **Excellent progress on RF unit test facility at New Muon Lab**

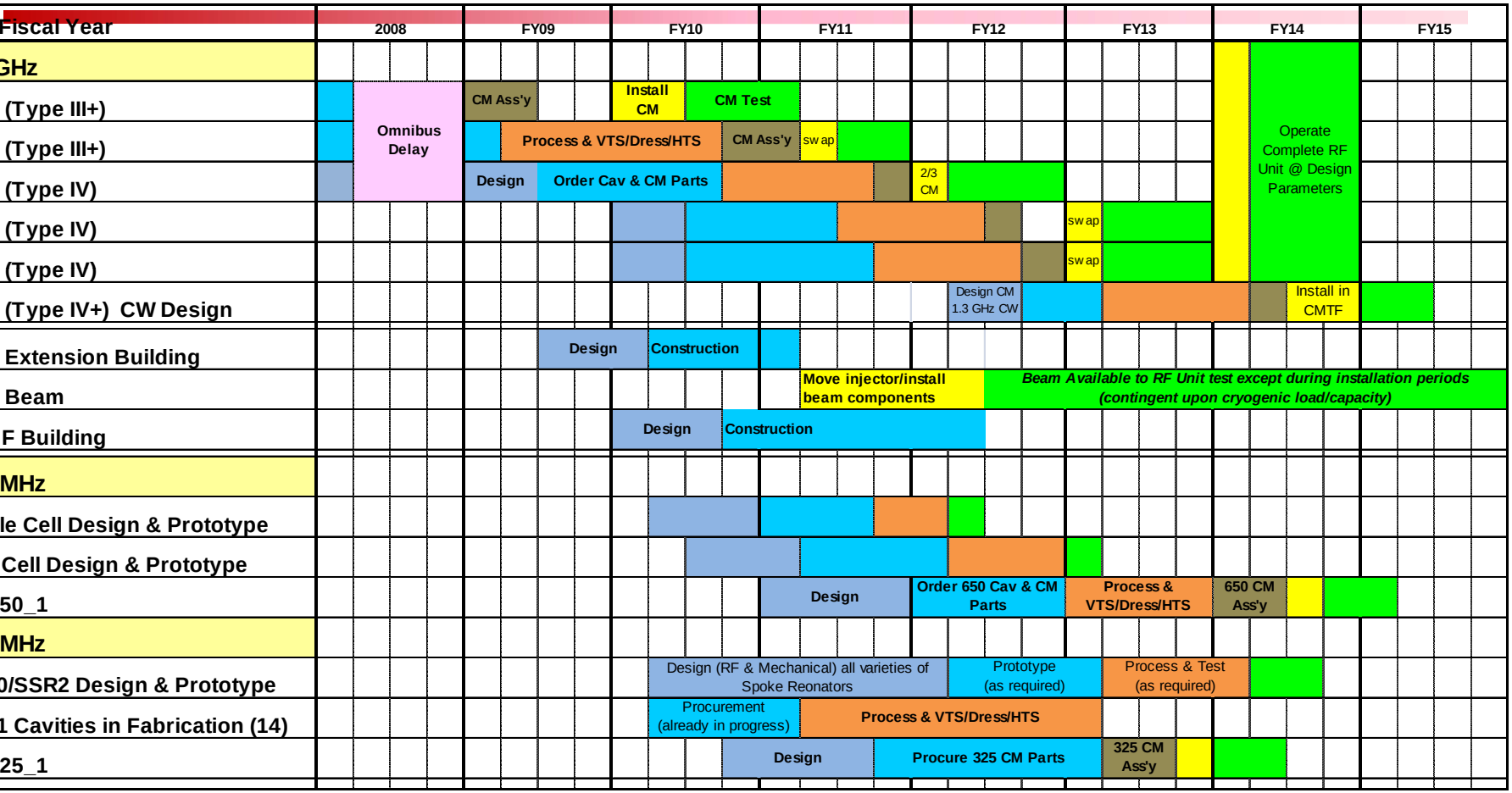
Project X

ILC Cavity Gradient



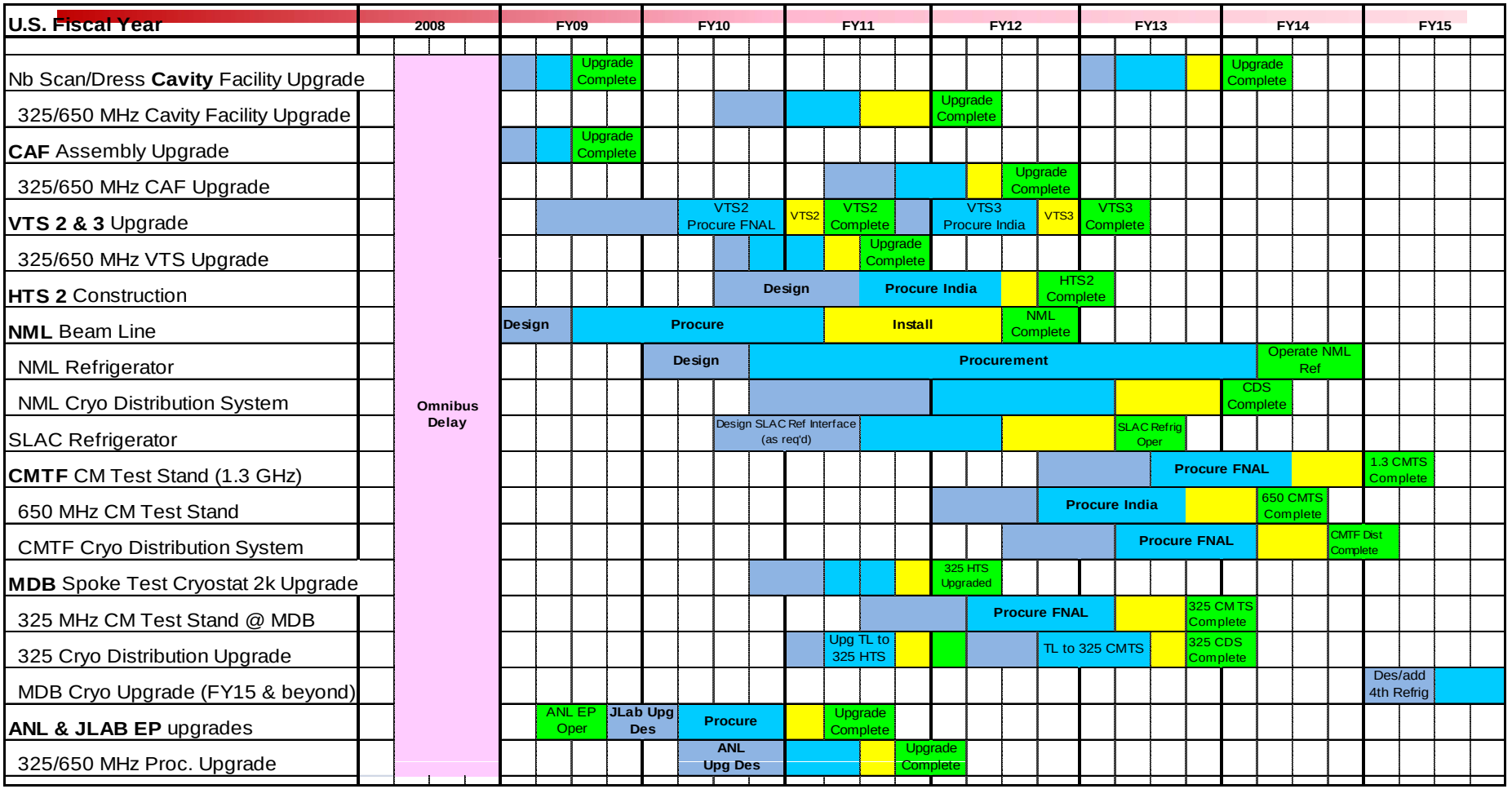
Integrated SRF Plan

Cryomodules



Design	Procure	Process & VTS Dress & HTS	Assemble	Install	Commission & Operate

Integrated SRF Plan
Infrastructure



Design | Procure | Process & VTS Dress & HTS | Assemble | Install | Commission & Operate

Near Term Strategy (~Next 6 months)

- Complete the IC-2v2.0 documentation:
  - ICD-2v2.0
  - Accompanying cost estimate
  - Targeting late April for release
- Update R&D plan to configuration IC-2
- Concentrate RCS effort on critical issues
  - Injection
- Continue work on outstanding technical questions
  - Identify a baseline concept for the chopper
  - Concepts for marrying a 3-8 GeV pulses linac to CW front end
- Establish cost range based on IC-1, IC-2, and identification of cost reduction opportunities
- Conduct Director's Review

$\Rightarrow$ **All cost range/configuration info. available for CD-0 by summer**

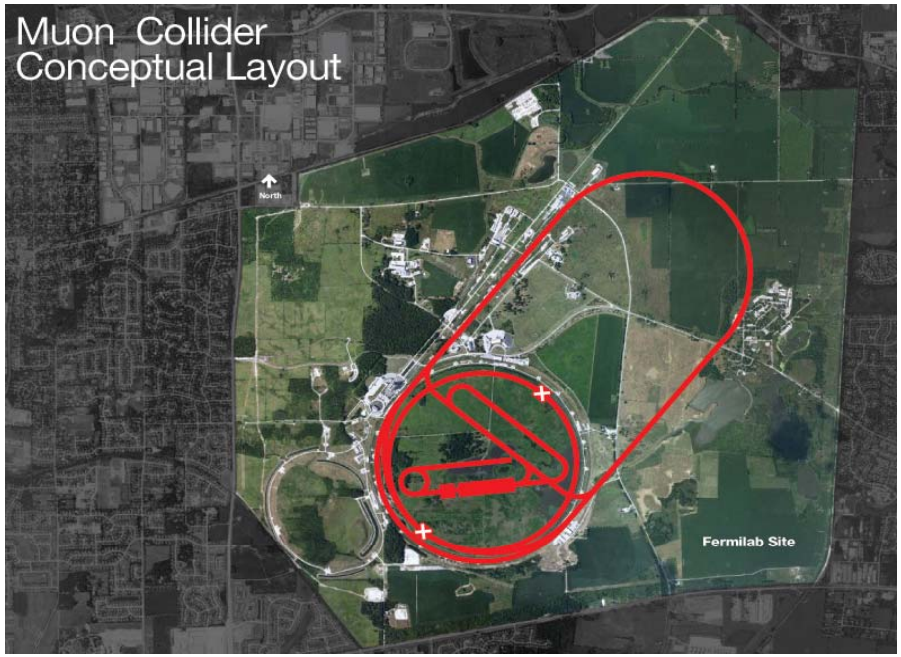
Strategy
(Longer Term)

- Get R&D reoriented toward the IC-2 configuration
  - Emphasis of srf development at all relevant frequencies
  - Consolidation of Project X and SRF infrastructure efforts into common organization with rationalized funding sources
  - Engagement of collaborators
- Identify/engage external collaborators
- Identify/engage stakeholder outside of HEP
- DOE has advised us that the earliest possible dates are:
  - PED funding: FY2012
  - Construction start: FY2015
- We believe that we could construct Project X over a five year time period, assuming a commensurate funding profile

$\Rightarrow$Project X could be up and running ~2020

Muon Facilities

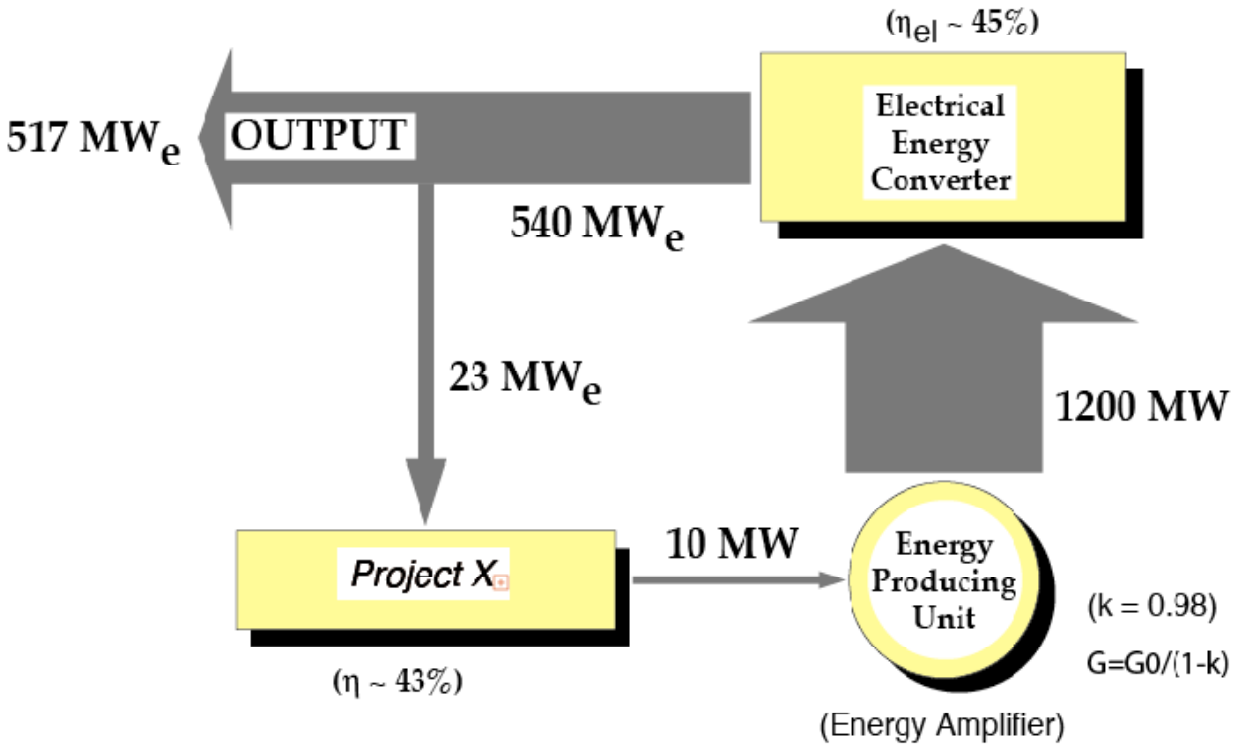
- Project X shares many features with the proton driver required for a Neutrino Factory or Muon Collider
  - NF and MC require ~4 MW @ 10± 5 GeV
  - Primary issues are related to beam "format"
    - NF wants proton beam on target consolidated in a few bunches; Muon Collider requires single bunch
  - Project X linac is not capable of delivering this format



⇒ It is inevitable that a new ring(s) will be required to produce the correct beam format for targeting.

Potential for ADS

Opportunity to align with energy development initiatives in DOE?



Summary

- Project X is the centerpiece of Fermilab's plan for future development of the accelerator complex.
- We are following a strategy for Project X appropriate to a highly constrained environment
  - The evolution of the design has provided significantly enhanced physics capabilities
  - Work remains in selling the physics program to the community
- Despite the lack of CD-0 we are receiving strong support from DOE for PX and SRF R&D
  - We have an accelerator design which is already quite advanced for CD-0
  - The virtues of the CW linac are apparent to all involved, including DOE
- **The CW linac concept will remain the core of the Project X concept as it develops further**
  - We will not have a final configuration for Project X until CD-1 (2012?)
  - Need to develop a plan for utilization as a muon facility front end
- Project X will be a unique facility in the world and will give the U.S. ownership of the Intensity Frontier for decades.
- Project X could be constructed over the period ~2015 - 2019