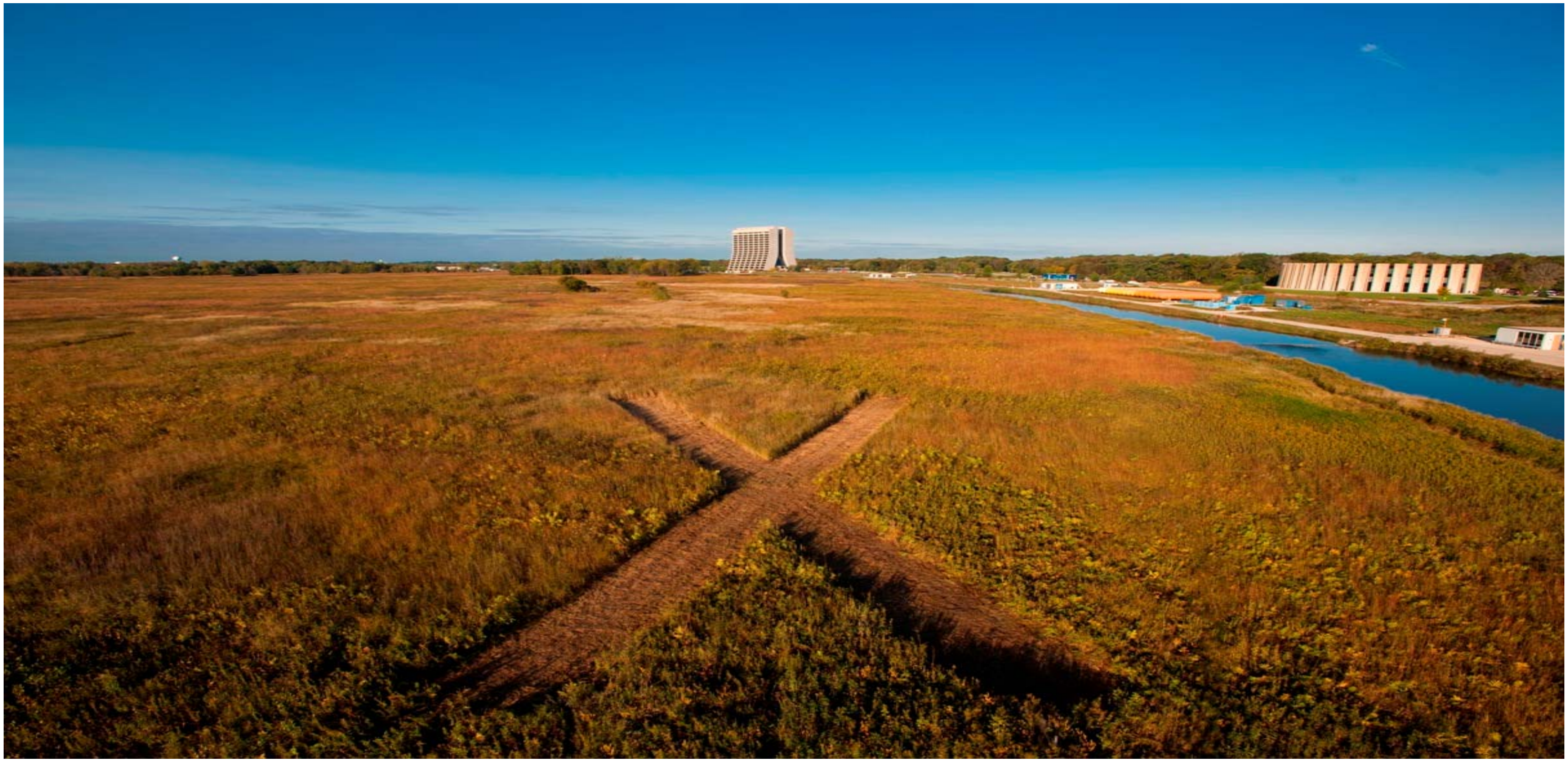
# Project X: A Multi Megawatt Proton Source at Fermilab



*AES Site Visit* Jim Kerby *24 February 2010*

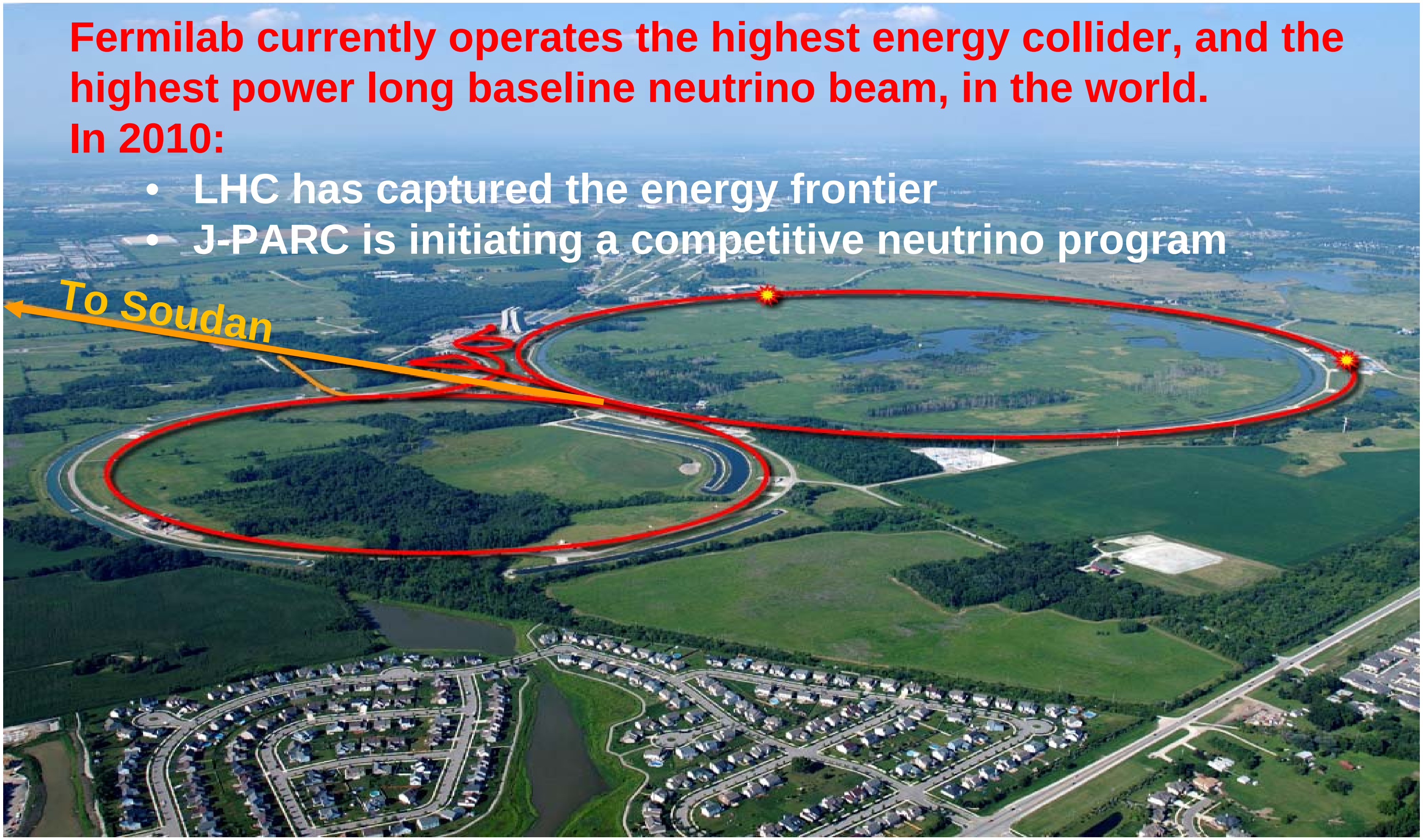
# Project X

# Strategic Context: Fermilab and the World Program

**Fermilab currently operates the highest energy collider, and the highest power long baseline neutrino beam, in the world.**

**In 2010:**

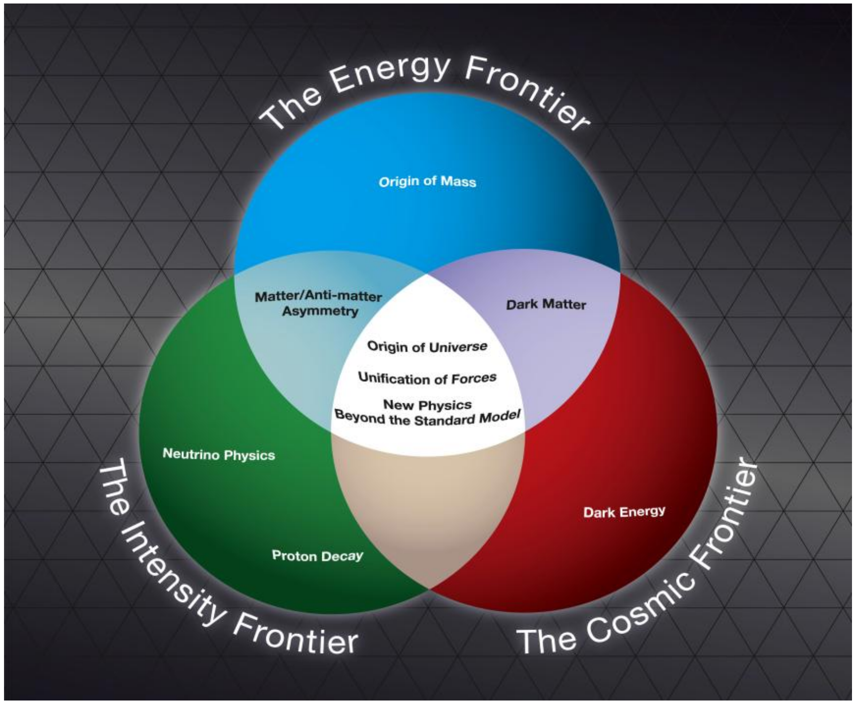
- **LHC has captured the energy frontier**
- **J-PARC is initiating a competitive neutrino program**



# Project X Strategic Context: Fermilab Long Range Plan

- Fermilab is the sole remaining U.S. laboratory providing facilities in support of accelerator-based Elementary Particle Physics.

- The Fermilab long-term strategy is fully aligned with the HEPAP/P5 plan:
  - Energy and intensity frontiers share strong reliance on accelerators



# Evolution of the Fermilab Accelerator Complex

- A multi-MW Proton Source, Project X, is the linchpin of Fermilab's strategy for future development of the accelerator complex.

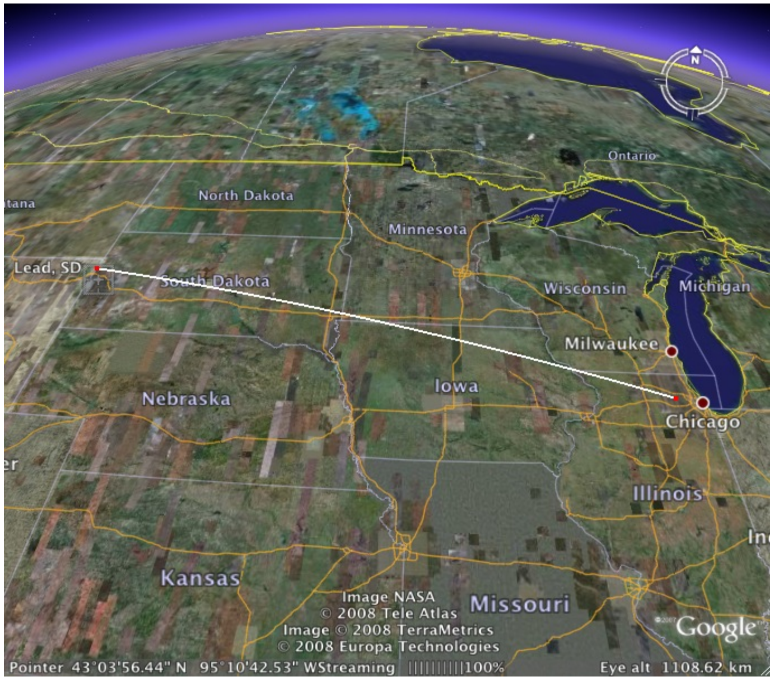
- Project X provides long term flexibility to pursue a variety of scientific opportunities
  - Energy Frontier:

    Tevatron → ILC or Muon Collider
    - Technology alignment
    - Fermilab as host site for ILC or MC
  - Intensity Frontier:

    NuMI→ NOνA→ LBNE/mu2e→ multi-MW Proton Source → NuFact
    - Continuously evolving world leading program in neutrino physics and other beyond the standard model phenomena

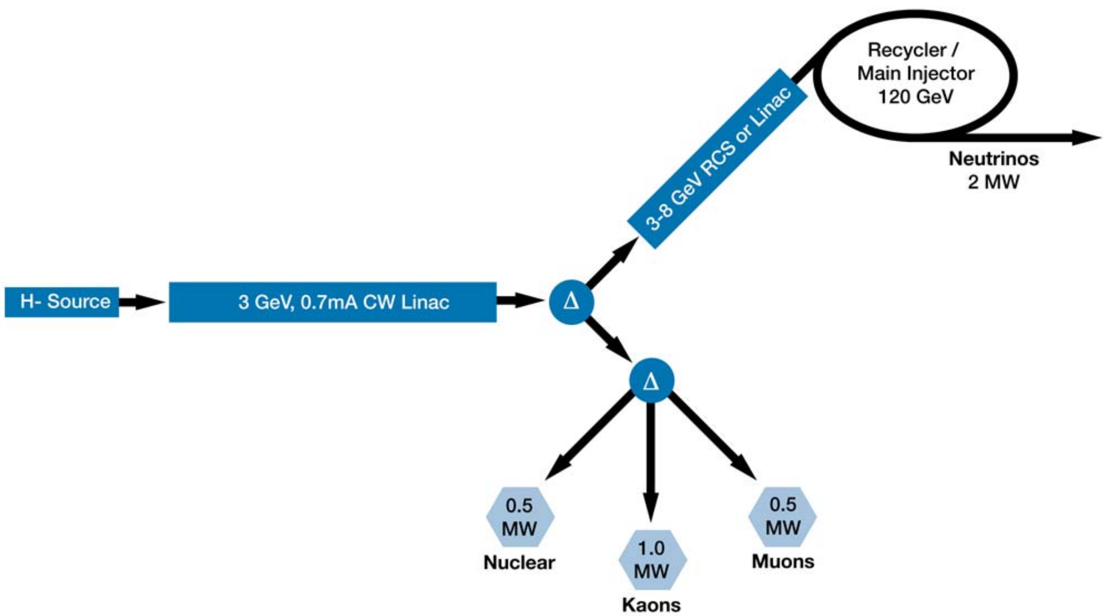
# Mission Need

- The P5 report defines mission need for a multi-MW proton source based on :
  - A neutrino beam for long baseline neutrino oscillation experiments
    - 2 MW proton source at 60 - 120 GeV
  - High intensity, low energy protons for kaon and muon based precision experiments
    - Operations simultaneous with the neutrino program.
  - A path toward a muon source for a possible future neutrino factory and/or a muon collider at the Energy Frontier.
    - Requires upgrade potential to 2-4 MW at ~8 GeV.



# Initial Configuration-2

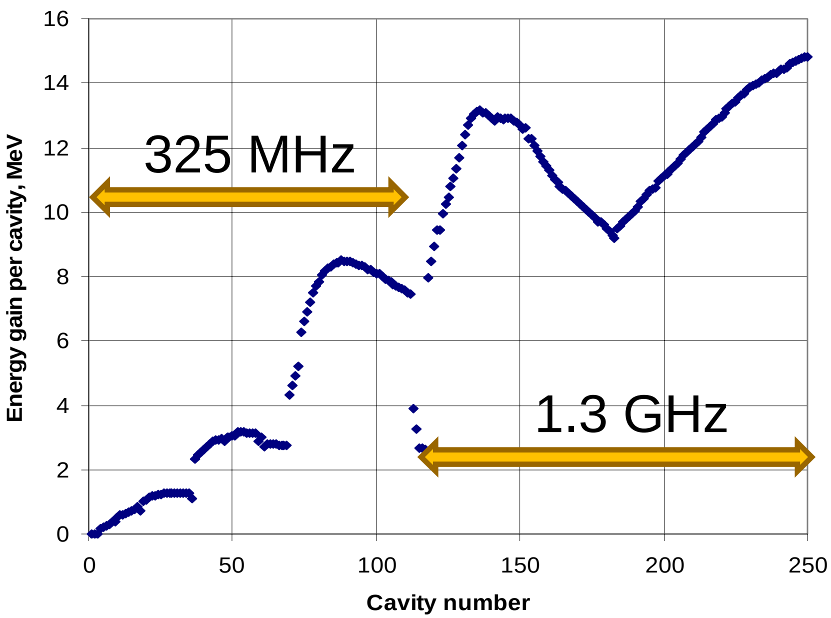
- Project X Design Criteria
  - 2 MW of beam power over the range 60 – 120 GeV;
  - Simultaneous with 2 MW beam power at 3 GeV;
  - Compatibility with future upgrades to 2-4 MW at 8 GeV

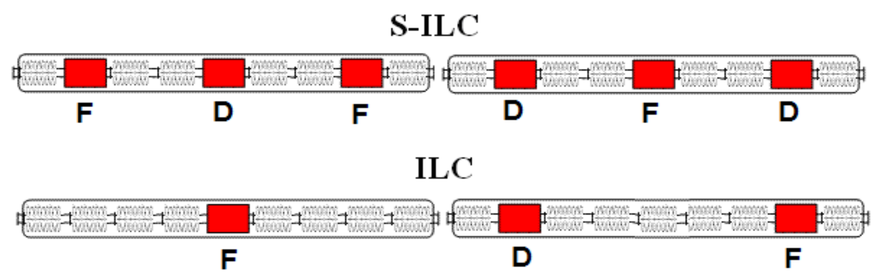


# Accelerator Requirements:
## Rare Processes

| | 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 |

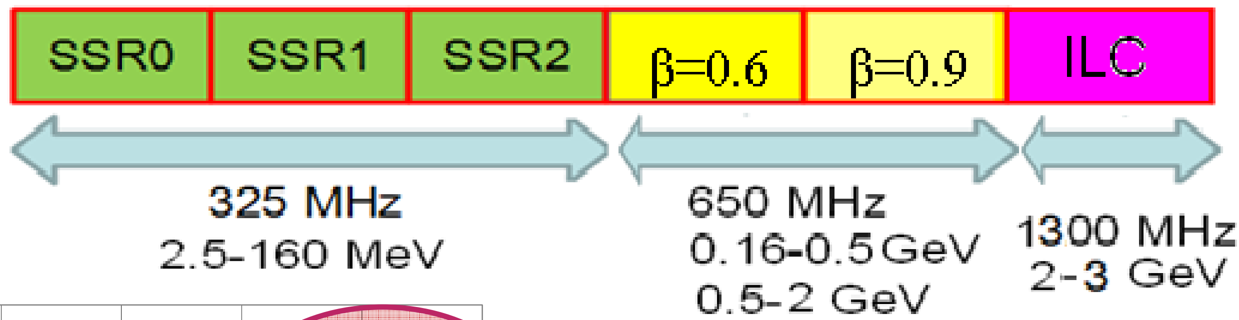
# IC-2v1.0
# Technology Map to 2GeV

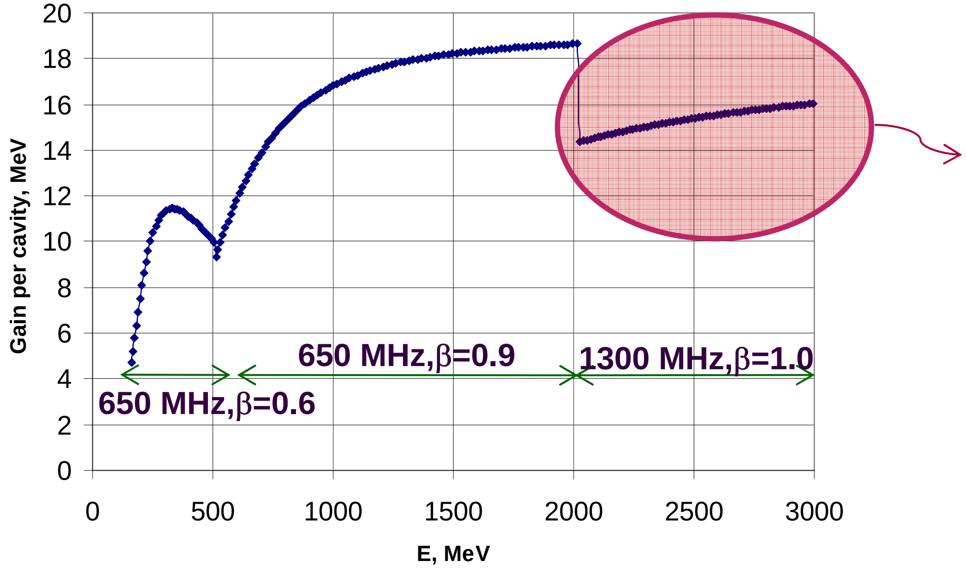



# IC-2v2.0
## Technology Map to 3GeV

- Current configuration under consideration:



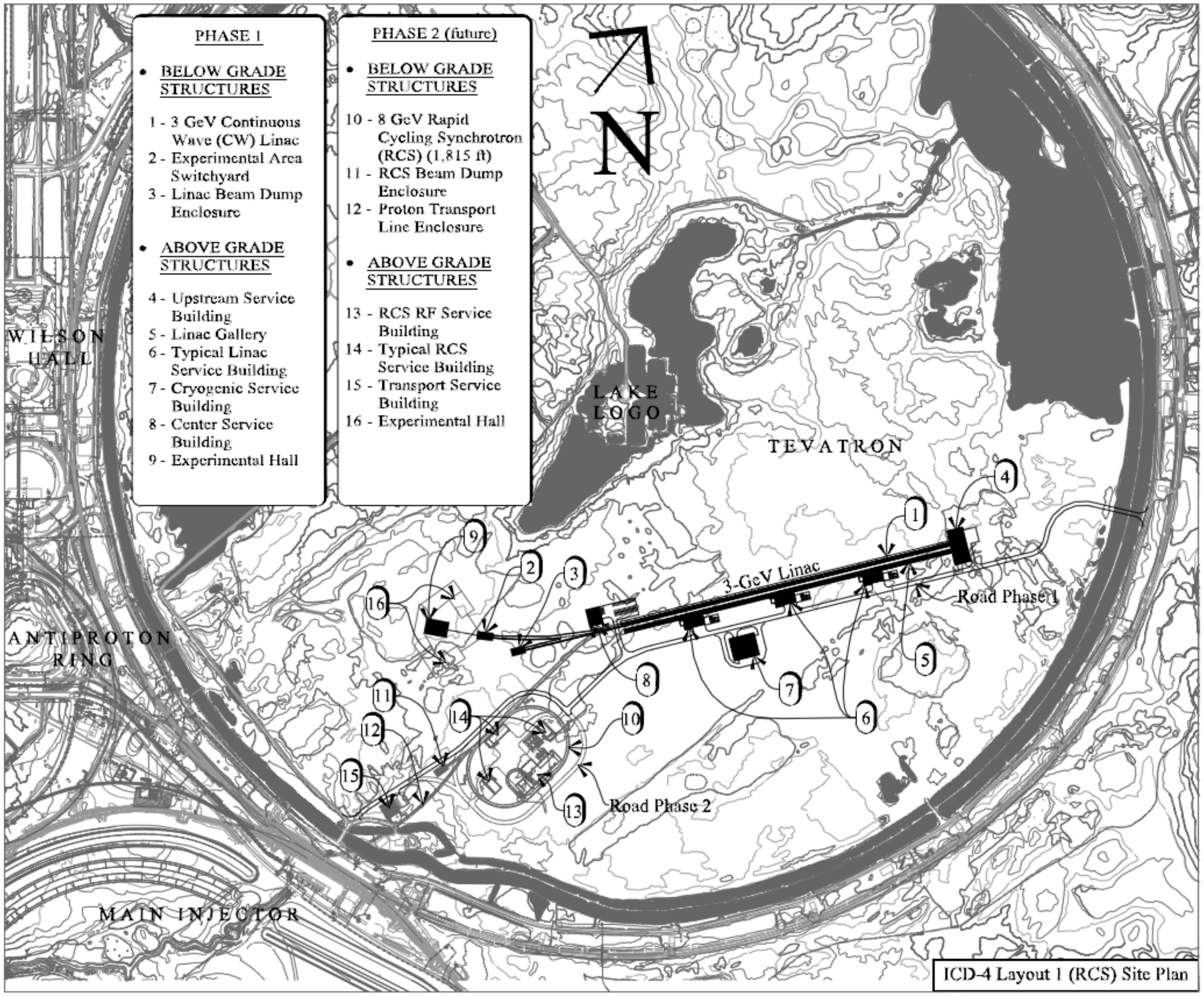




Notes:

Discontinuity effectively eliminated with β=0.95, low loss cavity design

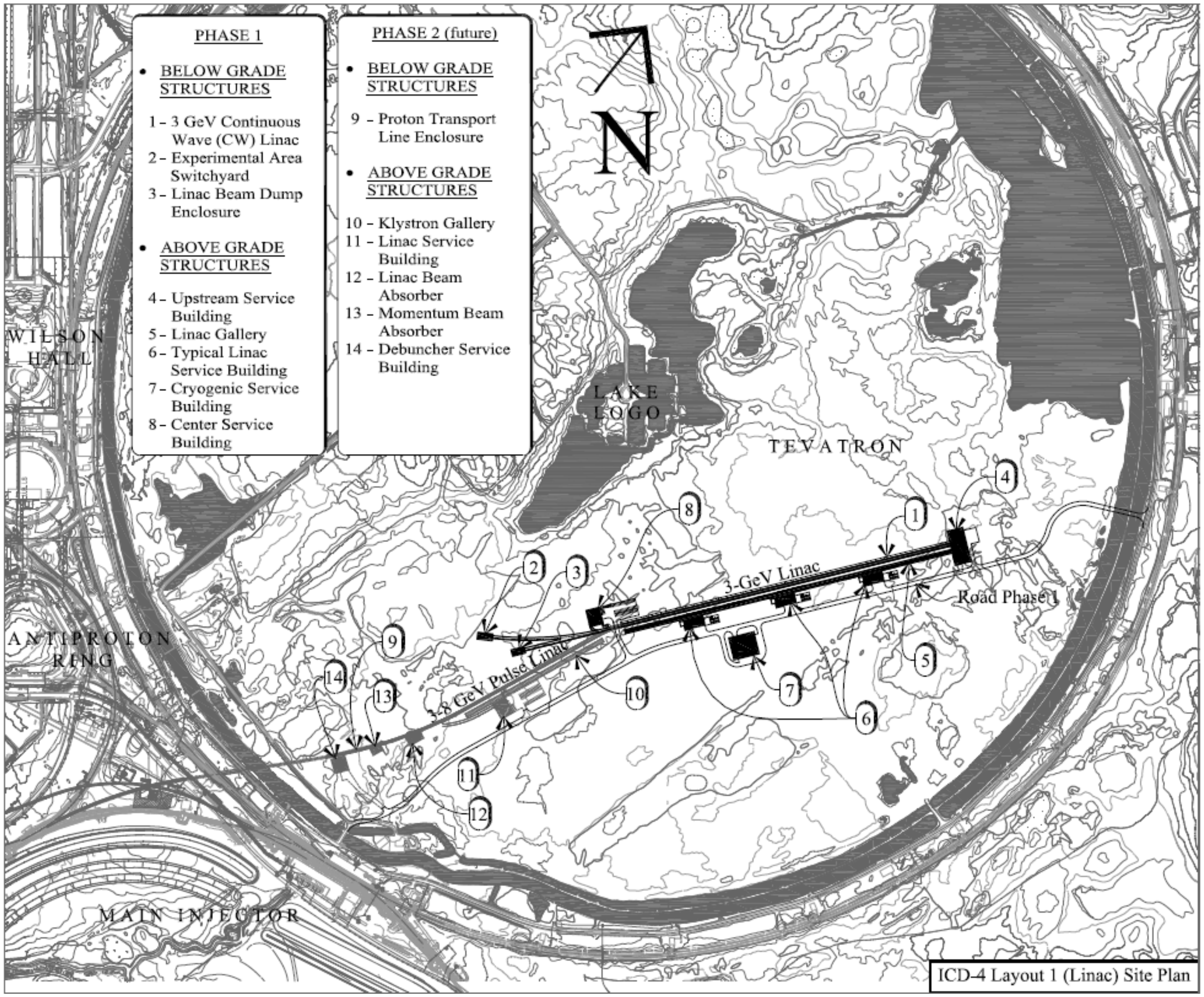
650 MHz, β=0.9, 5-cell cavities are same physical length as 1300 MHz, β=1.0, 9-cell cavities

# IC 2v2



PHASE 1
BELOW GRADE STRUCTURES
1 - 3 GeV Continuous Wave (CW) Linac
2 - Experimental Area Switchyard
3 - Linac Beam Dump Enclosure
ABOVE GRADE STRUCTURES
4 - Upstream Service Building
5 - Linac Gallery
6 - Typical Linac Service Building
7 - Cryogenic Service Building
8 - Center Service Building
9 - Experimental Hall
PHASE 2 (future)
BELOW GRADE STRUCTURES
10 - 8 GeV Rapid Cycling Synchrotron (RCS) (1,815 ft)
11 - RCS Beam Dump Enclosure
12 - Proton Transport Line Enclosure
ABOVE GRADE STRUCTURES
13 - RCS RF Service Building
14 - Typical RCS Service Building
15 - Transport Service Building
16 - Experimental Hall
N
WILSON HALL
LAKE LOGO
TEVATRON
3-GeV Linac
Road Phase 1
Road Phase 2
ANTIPROTON RING
MAIN INJECTOR
ICD-4 Layout 1 (RCS) Site Plan

# IC 2v2



PHASE 1
• BELOW GRADE STRUCTURES
1 – 3 GeV Continuous Wave (CW) Linac
2 – Experimental Area Switchyard
3 – Linac Beam Dump Enclosure
• ABOVE GRADE STRUCTURES
4 – Upstream Service Building
5 – Linac Gallery
6 – Typical Linac Service Building
7 – Cryogenic Service Building
8 – Center Service Building
PHASE 2 (future)
• BELOW GRADE STRUCTURES
9 – Proton Transport Line Enclosure
• ABOVE GRADE STRUCTURES
10 – Klystron Gallery
11 – Linac Service Building
12 – Linac Beam Absorber
13 – Momentum Beam Absorber
14 – Debuncher Service Building
N
WILSON HALL
LAKE LOGO
TEVATRON
3-GeV Linac
Road Phase 1
3-8 GeV Pulse Linac
ANTIPROTON RING
MAIN INJECTOR
ICD-4 Layout 1 (Linac) Site Plan

# Joint PX/ILC/SRF Strategy

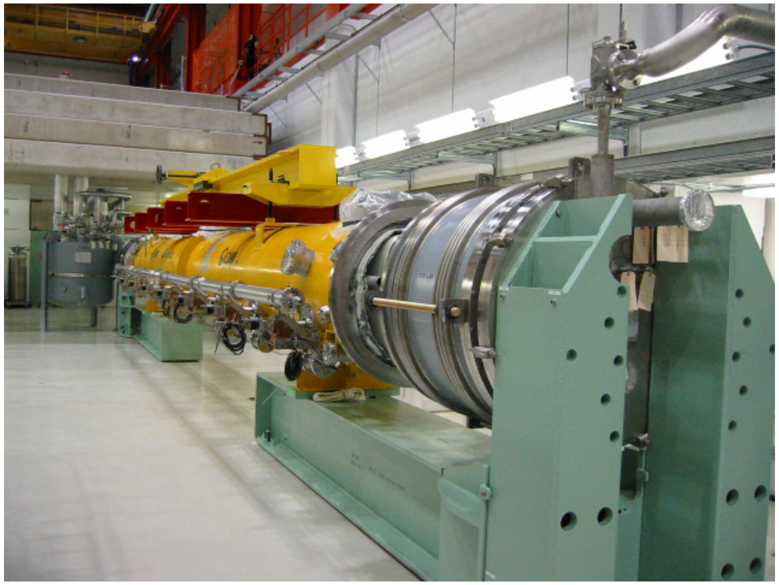
- Project X shares 1.3 GHz technology with the ILC
  – Project X requires 9-20 ILC-like cryomodules, depending upon the final frequency configuration
    - Design is migrating at the detail level from the ILC
      – CW vs pulsed
      – 18 MV/m vs 31.5 MV/m
      – Perhaps lower beta and lower loss cavity shape
- However, there is very significant infrastructure and expertise on the ILC program that can be applied
  – Close coordination between Project X and GDE
    - Common development effort
    - Shared facilities for assembly and testing
    - Yield vs gradient remains a key metric

# Joint PX/ILC/SRF Strategy

- Industrialization
  - Production of 1.3 GHz CMs for Project X over a~4 year period represents a significant step beyond current capabilities; however, the production rate remains well below that required by ILC.

  ⇒This activity could represent the initial phase of an industrialization buildup for ILC (in the U.S.).

- Cryomodule Assembly Plan
  - CM1: TESLA Type III (2009)
    - Based on DESY supplied cavities
  - CM2: TESLA Type III (2010)
    - Based on U.S. supplied cavities
  - CM3: Type IV.1 (2011)
    - U.S. supplied cavities
  - CM4: Type IV.2 (2012)
    - Project X prototype



# Near Term Strategy
## (~Next 6 months)

- Establish a cost-range for Project X based on variations in configuration and performance
- Update R&D plan to configuration IC-2v2
- Retain RCS within the estimate but limit work to critical issue(s)
- Continue work on outstanding technical questions
  - Identify a baseline concept for the chopper
  - RCS injection
  - Identification of the cost breakpoint between RCS and pulsed linac
- Investigate options for pairing a 3-8 GeV pulsed linac to CW front end

⇒All info. available for CD-0 by late spring

Project X

# Long-Term Strategy

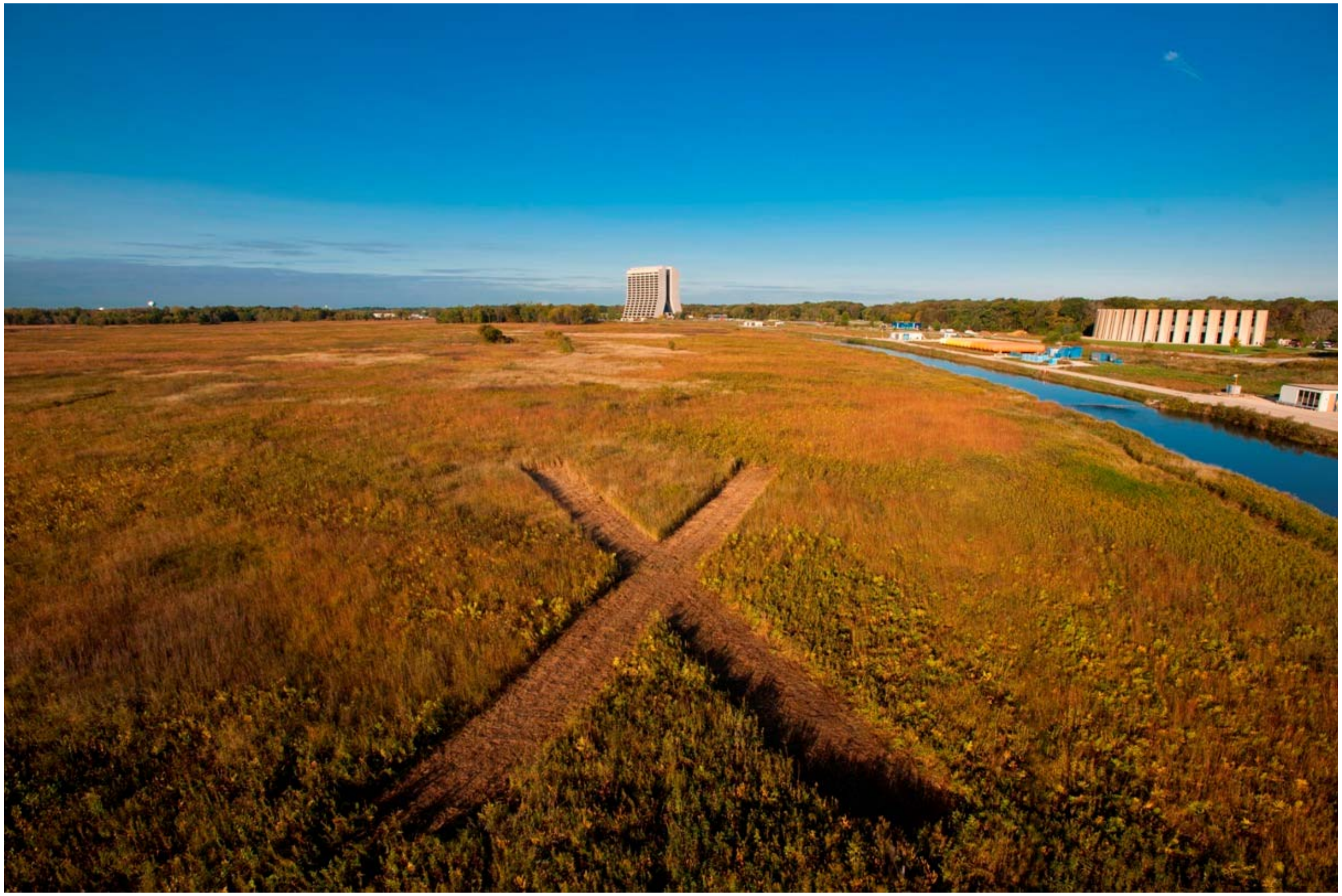
- DOE has advised us that the earliest possible dates are:
  - PED funding: FY2012
  - Construction start: FY2015
- We believe that we could construct Project X over a five year time period, assuming a commensurate funding profile

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

# Summary

- Project X is central to Fermilab's strategy for future development of the accelerator complex:
  - Intensity Frontier: World leading program in neutrinos and rare processes; Fermilab as potential Neutrino Factory site
  - Energy Frontier: Aligned with ILC technology development; Fermilab as potential site for ILC or a Muon Collider
- Initial configurations, and preliminary cost estimates, established
  - >2 MW at 60-120 GeV, simultaneous with up to 2 MW for rare processes program
  - Upgradable to 2-4 MW at 8 GeV
- Integrated effort on Project X, ILC, and Muon Facilities
- Project X could be constructed over the period ~2015 - 2019
- Collaboration formed to undertake the R&D program

# Backup Slides



Project X

# Initial Configuration-2
## Performance Goals

| | | |
|---|---|---|
| **Linac** | | |
| Particle Type | $H^-$ | |
| Beam Kinetic Energy | 3.0 | GeV |
| Average Beam Current | 0.67 | mA |
| Linac pulse rate | CW | |
| Beam Power | 3000 | kW |
| Beam Power to 3 GeV program | 1920 | kW |
| **RCS** | | |
| Particle Type | protons | |
| Beam Kinetic Energy | 8.0 | GeV |
| Cycle time | 0.1 | sec |
| Particles per cycle to MI | $2.6\times10^{13}$ | |
| Beam Power to 8 GeV program | 190 | kW |
| **Main Injector/Recycler** | | |
| Beam Kinetic Energy (maximum) | 120 | GeV |
| Cycle time | 1.4 | sec |
| Particles per cycle | $1.6\times10^{14}$ | |
| Beam Power at 120 GeV | 2100 | kW |

simultaneous