



**Draft Report**  
**Fermilab Steering Group**  
develop roadmap  
for accelerator-based HEP program at Fermilab

Young-Kee Kim

All Hands Meeting, Fermilab  
August 24, 2007

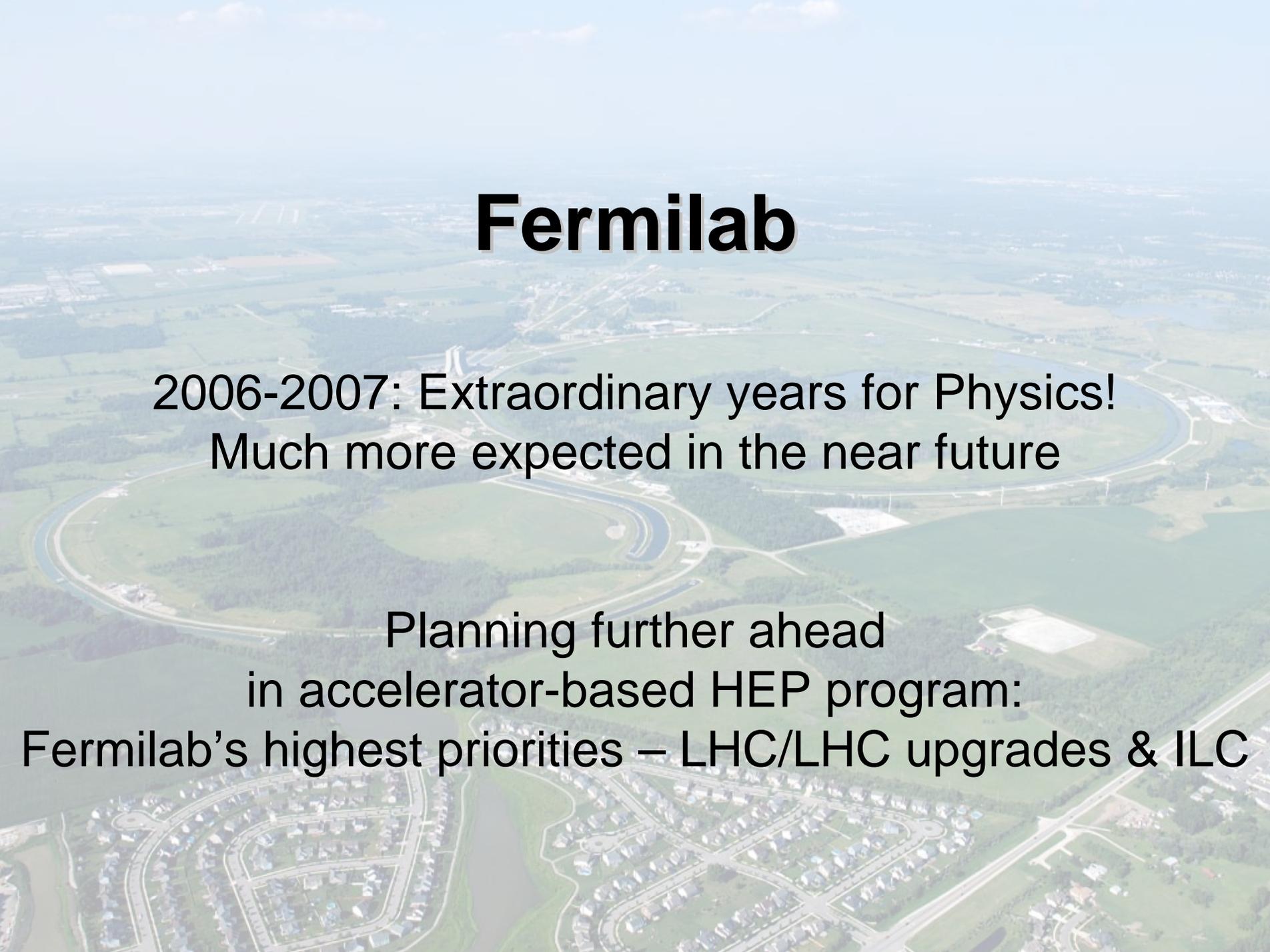
# Fermilab's Scientific Program enables our community to address:

1. Are there undiscovered principles of nature:  
New symmetries, new physical laws?
2. Are there extra dimensions of space?
3. Do all the forces become one?
4. Why are there so many kinds of particles?
5. What happened to the antimatter?
6. What is dark matter?  
How can we make it in the laboratory?
7. How can we solve the mystery of dark energy?
8. How did the universe come to be?
9. What are neutrinos telling us?

From "Quantum Universe"  
and  
"Discovering Quantum Universe"



# Fermilab

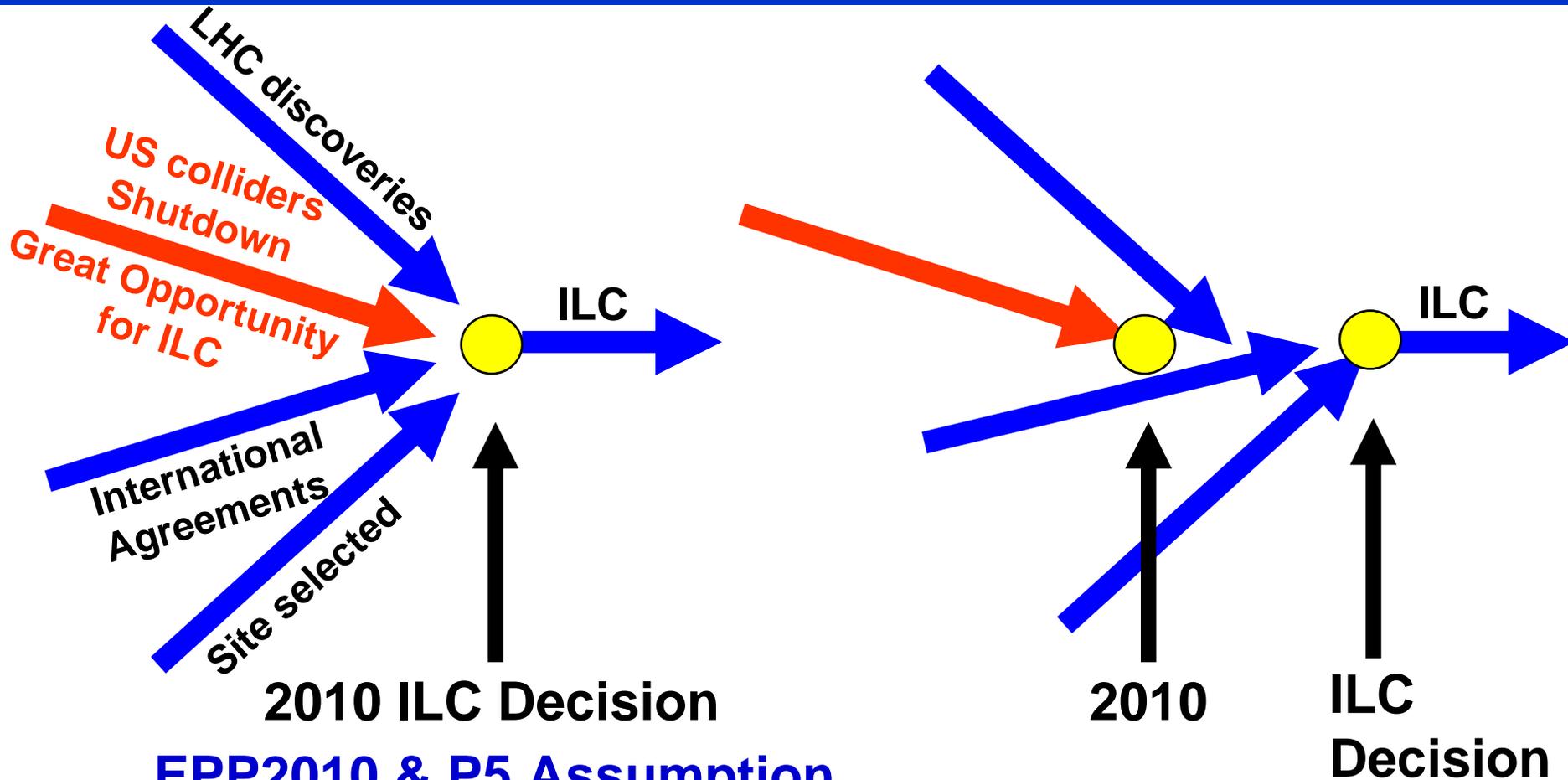
An aerial photograph of the Fermilab facility, showing the large circular accelerator complex in a green, hilly landscape. The complex consists of several concentric rings and various support structures. The surrounding area includes fields, roads, and some residential or commercial buildings in the distance.

2006-2007: Extraordinary years for Physics!  
Much more expected in the near future

Planning further ahead  
in accelerator-based HEP program:

Fermilab's highest priorities – LHC/LHC upgrades & ILC

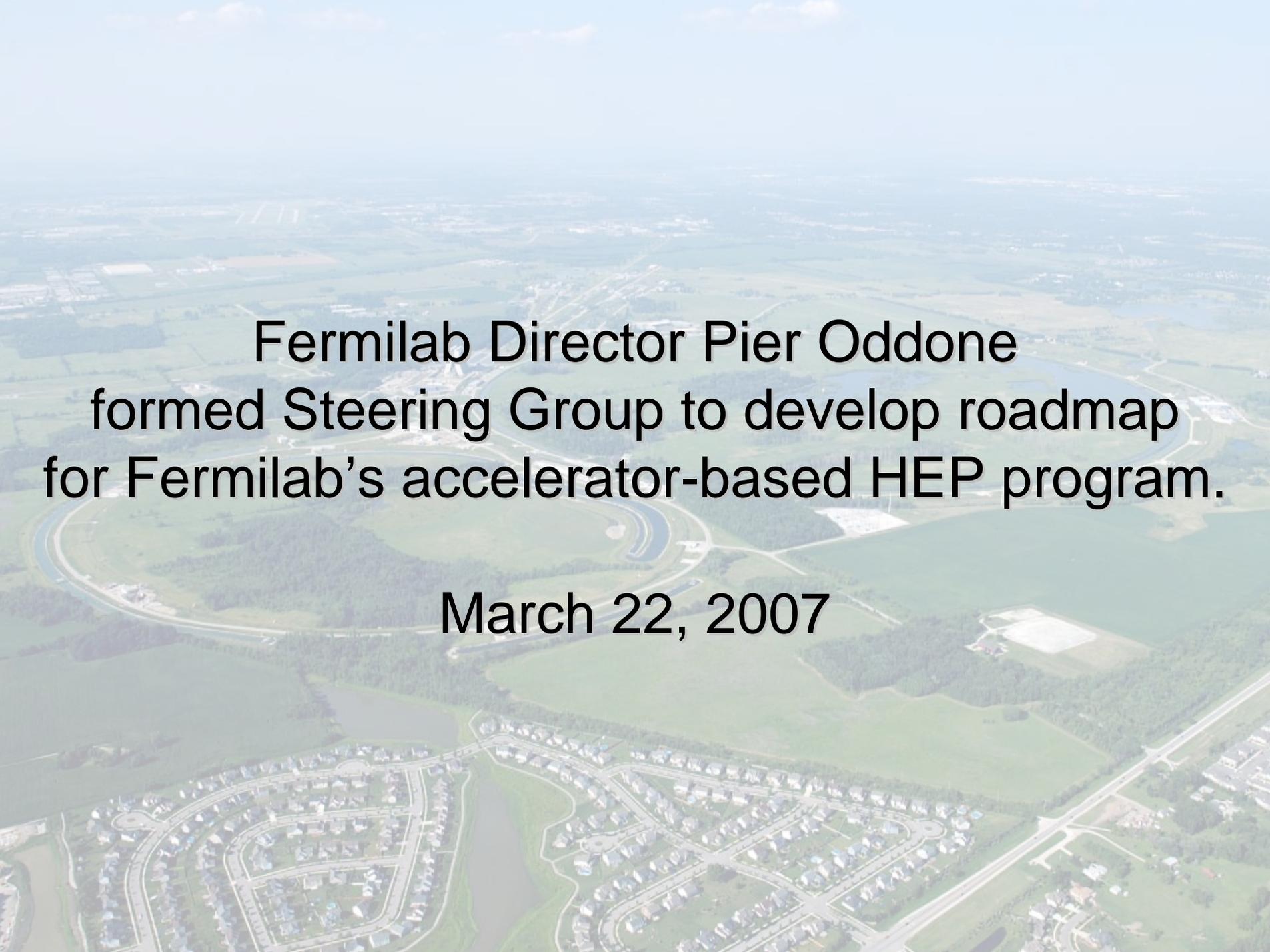
# ILC Decision Timelines



**EPP2010 & P5 Assumption**

**ILC RDR with Cost Estimate in Feb. 2007**

**Possible ILC Decision Timelines**

An aerial photograph showing a large green field with a circular track in the center. In the foreground, there is a residential area with many houses and a road. The background shows a hazy landscape with more fields and some buildings.

**Fermilab Director Pier Oddone  
formed Steering Group to develop roadmap  
for Fermilab's accelerator-based HEP program.**

**March 22, 2007**

# Steering Group Charge

In his remarks to HEPAP, Undersecretary Orbach requested a dialog with the HEP community:

*"In making our plans for the future, it is important to be conservative and to learn from our experiences. Even assuming a positive decision to build an ILC, the schedules will almost certainly be lengthier than the optimistic projections. Completing the R&D and engineering design, negotiating an international structure, selecting a site, obtaining firm financial commitments, and building the machine could take us well into the mid-2020s, if not later. Within this context, I would like to re-engage HEPAP in discussion of the future of particle physics. If the ILC were not to turn on until the middle or end of the 2020s, what are the right investment choices to ensure the vitality and continuity of the field during the next two to three decades and to maximize the potential for major discovery during that period?"*

# Steering Group Charge (cont.)

With the encouragement of the Office of Science and the support of Professor Mel Shochet, the chair of HEPAP, Fermilab will **develop a strategic roadmap** for the evolution of the accelerator-based HEP program, focusing on facilities at Fermilab **that will provide discovery opportunities** in the next two to three decades. **This roadmap should keep the construction of the ILC as a goal of paramount importance.** To guide this proposal, the Fermilab Director has appointed a Steering Group consisting of members from Fermilab and the national particle and accelerator physics community to insure that the plan serves national needs. The Steering Group will also engage additional constituents in the analysis of the various physics opportunities.

# Steering Group Charge (cont.)

The Steering Group will build the roadmap based on the recommendations of the EPP2010 National Academy report and the recommendations of the P5 subpanel of HEPAP. The Steering Group should consider the Fermilab based facilities in the context of the global particle physics program. Specifically the group should develop a strategic roadmap that:

1. supports the international R&D and engineering design for as early a start of the ILC as possible and supports the development of Fermilab as a potential host site for the ILC;
2. develops options for an accelerator-based high energy physics program in the event the start of the ILC construction is slower than the technically-limited schedule; and
3. includes the steps necessary to explore higher energy colliders that might follow the ILC or be needed should the results from LHC point toward a higher energy than that planned for the ILC.

# Steering Group Charge (cont.)

I am asking Deputy Director Kim to chair the Steering Group.

Any recommendations that might be relevant to the FY09 budget should be transmitted as early as possible.

The Steering Group's final report should be finished and delivered to the Fermilab Director by **August 1, 2007**. This deadline would allow for presentations to **the DOE and its advisory bodies** before the structuring of the FY2010 budget.

# Steering Group Membership

Fermilab and national particle and accelerator physics community

Eugene Beier	U. Penn
Joel Butler	Fermilab
Sally Dawson	BNL
Helen Edwards	Fermilab
Thomas Himel	SLAC
Steve Holmes	Fermilab
Young-Kee Kim (chair)	Fermilab / U.Chicago
Andrew Lankford	UC Irvine
David McGinnis	Fermilab
Sergei Nagaitsev	Fermilab
Tor Raubenheimer	SLAC
Vladimir Shiltsev	Fermilab
Maury Tigner	Cornell
Hendrick Weerts	ANL

# Engaging HEP community in the process

## Formed 2 physics groups (mostly from the University community)

### Neutrino Science

Eugene Beier	U Penn
Deborah Harris	Fermilab
Ed Kearns	Boston Univ.
Boris Kayser	Fermilab
Sacha Kopp	UT Austin
Andy Lankford (chair)	UC Irvine
Bill Louis	Los Alamos

### Precision Physics involving charged leptons and quarks

Joel Butler	Fermilab
Brendan Casey	Brown
Sally Dawson (chair)	BNL
Chris Hill	Fermilab
Dan Kaplan	IIT
Yury Kolomensky	UCBerkeley/LBNL
William Molzon	UC Irvine
Kevin Pitts	UIUC
Frank Porter	CalTech
Bob Tschirhart	Fermilab
Harry Weerts	ANL

# Engaging HEP community in the process

- For all Steering group activities, include
  - Physics group members
  - ILC GDE leaders, HEP / ILC program managers in DOE and NSF
  - HEPAP Chair / Deputy Chair, P5 Chair
  - Chairs of Fermilab/SLAC Users Executive committees
- Public website
  - [http://www.fnal.gov/directorate/Longrange/Steering\\_Public/](http://www.fnal.gov/directorate/Longrange/Steering_Public/)
  - Agendas, presentations, minutes, documents, publicly accessible
- Reach out to HEP community for input / ideas
  - Message sent out to DPF & DPB members
  - Meetings with FNAL staff
  - Meetings with HEP collaborations
  - Presentations at Users meetings at FNAL and SLAC
  - Presentations / Discussions at ANL, BNL, LBNL
  - Many meetings with individuals
  - Fermilab Today articles
  - Meeting with ILC GDE Executive Committee
  - ....

# Letters and Proposals from the Community

- **Letters from the Community**

1. [John Marriner \(May 5, 2007\)](#)
2. [Norman Gelfand \(May 8, 2007\)](#)
3. [Stanley Brodsky \(May 31, 2007\)](#)
4. [Steve Geer et al. \(June 8, 2007\)](#)
5. [Buck Field \(June 12, 2007\)](#)
6. [Chuck Ankenbrandt et al \(June 12, 2007\)](#)
7. [Maury Goodman \(July 7, 2007\)](#)

- **One Page Proposals from the community**

1. [6GeV ILC Test Linac - Giorgio Apollinari and Bob Webber \(May 7, 2007\)](#)
2. [LAr TPC in FNAL's Neutrino Beams - David Finley \(May 29, 2007\)](#)
3. [Precision Neutrino Scattering at Tevatron - Janet Conrad and Peter Fisher \(May 29, 2007\)](#)
4. [Very Large Cherenkov Detector - Milind Diwan et al \(June 5, 2007\)](#)
5. [From Tevatron to Muon Storage Ring - Terry Goldman \(June 6, 2007\)](#)
6. [Antimatter Gravity Experiment - Thomas Phillips \(June 7, 2007\)](#)
7. [Neutrino Oscillation with high energy/intensity beam - Henryk Piekarz \(June 10, 2007\)](#)
8. [Space-Time Ripples Study - Nikolai Andreev \(June 11, 2007\)](#)
9. [Fixed Targer Charm Expt - Jeff Appel and Alan Schwartz \(June 11, 2007\)](#)
10. [Stopped Pion Neutrino Source - Kate Scholberg \(June 11, 2007\)](#)
11. [UNO Experiment - Change Kee Jung \(June 11, 2007\)](#)
12. [n-nbar Transition Search at DUSEL - Yuri Kamyshkov \(June 11, 2007\)](#)
13. [8GeV cw Superconducting Linac - Ankenbrandt et al. \(June 12, 2007\)](#)
14. [Neutrino Expt with 5kton LAr TPC - Fleming and Rameika \(June 12, 2007\)](#)
15. [MicroBooNE - Fleming and Willis \(June 12, 2007\)](#)
16. [delta s - Rex Tayloe \(June 14, 2007\)](#)

- **Expression of Interest (EOI)**

1. [mu to e conversion - William Molzon \(May, 2007\)](#)
2. [me to e conversion - E.J. Prebys, J.P. Miller et al \(May, 2007\)](#)
3. [Klong to pi0 nu nu - D. Bryman et al \(June 11, 2007\)](#)

- **Letter of Intent (LOI)**

1. [Low- and Medium-Energy Anti-Proton Physics - D. Kaplan et al \(June 1, 2007\)](#)

# Guidelines in forming the plan

# Guidelines in forming the plan

1. The LHC program is our most important near-term project given its broad science agenda and potential for discovery. It is essential to support the physics analysis, computing, and accelerator and detector upgrades.

# Guidelines in forming the plan

2. The particle physics community's highest priority for investment toward the future is the ILC, based on our present understanding of its potential for breakthrough science.

Fermilab will continue to participate vigorously in the international R&D program for the ILC and to be one of the leaders in the global ILC effort. The laboratory will strive to make the ILC at Fermilab a reality by accomplishing the preparatory work required for the U.S. to bid to host the ILC.

# Guidelines in forming the plan

3. There must be an intermediate science program in case the timeline for ILC is stretched out.

This program will be an opportunity to do exciting physics that complements discoveries at energy frontier facilities, and to make further progress on ILC technology. The program should provide great discovery potential, support ILC R&D and industrialization as well as R&D on future accelerators beyond the ILC and LHC, and strengthen ties with the university community and with other laboratories. The plan must be robust and flexible.

# Guidelines in forming the plan

4. Fermilab will continue a phased program to study dark matter and dark energy through astrophysical observations. The program will allow complementary discoveries to those expected at the accelerator-based particle physics programs. These non-accelerator-based efforts are outside the Steering Group's charge, and not included in the plan.

# Plan (Roadmap) for Fermilab

# Plan for Fermilab (1)

- Fermilab's highest priority is discovering the physics of the Terascale by participating in LHC, being one of the leaders in the global ILC effort, and striving to make the ILC at Fermilab a reality.
- Fermilab will continue its neutrino program with NOvA as a flagship experiment through the middle of the next decade.

# Plan for Fermilab (2): ILC Onshore

- If ILC remains near the GDE-proposed timeline, Fermilab will focus on the above programs.
- If ILC departs from the GDE-proposed timeline, Fermilab should pursue additional neutrino science and precision physics opportunities by upgrading the proton accelerator complex.
  - If ILC start must wait for a couple of years, the laboratory should undertake the SNuMI (an upgrade of NuMI) project.
  - If ILC postponement would accommodate an interim major project, the laboratory should undertake Project X for its science capability and ILC alignment.

# Plan for Fermilab (3): ILC Offshore

- If ILC is constructed offshore, Fermilab should pursue additional neutrino science and precision physics opportunities by upgrading current proton facilities while supporting the ILC as the highest priority.
  - The laboratory should undertake SNuMI at a minimum.
  - Or the laboratory should undertake Project X if resources are available and ILC timing permits.

# Plan for Fermilab (4)

- In all scenarios,
  - R&D support for Project X should be started now, emphasizing
    - expediting R&D and industrialization of ILC cavities and cryomodules
    - overall design of Project X
  - R&D for future accelerator options concentrating on neutrino factory and muon collider should be increased.
  - The laboratory should support detector R&D and test beam efforts for effective use of future facilities.

# Intensity Frontier, Project X

# Project X: Properties

~2.3 MW at 120 GeV for Neutrino Science  
Initially NOvA, Possibly DUSEL later

120 GeV fast extraction  
1.7E14 protons/1.4 sec  
2.3 MW

8 GeV slow or fast spill  
1 second x 2.25E14 protons/1.4 sec  
200 kW

200 kW at 8 GeV for  
Precision Physics

ILC Style 8 GeV H Linac:  
9mA x 1 msec x 5 Hz

Single turn transfer  
@ 8 GeV

Main Injector  
1.4 sec cycle

Recycler  
3 linac pulse/fill

Stripping Foil

8 GeV H<sup>-</sup> Linac with ILC Beam Parameters  
(9mA x 1msec x 5Hz)

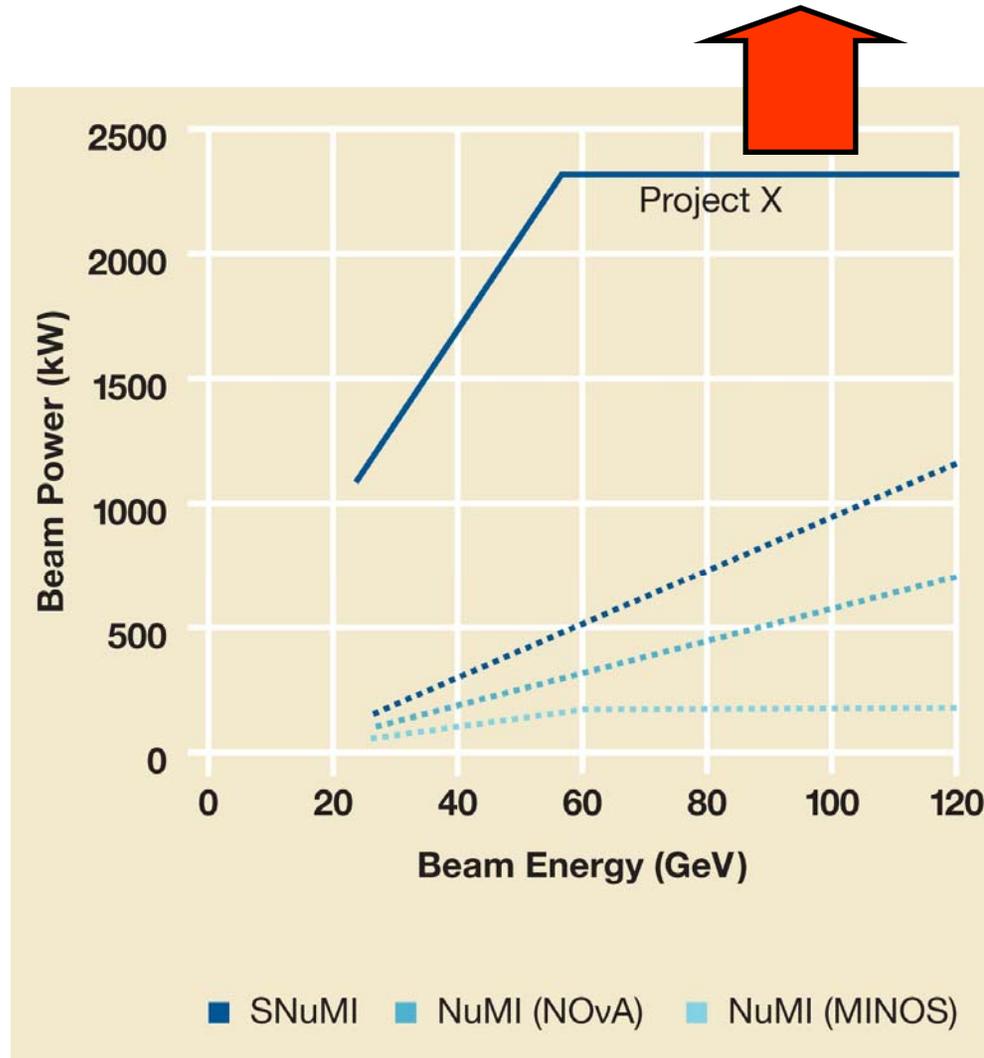
$v < c$

$v = c$  (ILC Linac)



# Project X: Proton Beam Power

with Main Injector Upgrade



Inject into  
Main Injector

sNuMI

NuMI (NOvA)

NuMI (MINOS)

# Project X: Accelerator Issues

An internal team (“Project X team”) was formed late June to evaluate the basic concept of Project X.

Document (early August)

<http://www-bdnew.fnal.gov/hq/mcginnis/ProjectX/Report/ProjectX.pdf>

Heroic Efforts by the team!!

- G. Apollinari
- D. Bogert
- A. Burov
- J. Carneiro
- B. Chase
- C. Gattuso
- P. Hurh
- J. Hysten
- D. Johnson
- J. Johnstone
- A. Klebaner
- I. Kourbanis
- J. Lackey
- V. Lebedev
- A. Leveling
- M. Martens
- D. McGinnis (chair)
- S. Nagaitsev
- E. Preby
- P. Ostroumov
- A. Valishev
- L. Vorobiev
- R. Webber
- D. Wildman
- R. Zwaska

# Possible Physics Opportunities with Project X

# Neutrino Science

- **Ultimate goal**

- use neutrinos to find answers to big questions like “Did we all come from neutrinos?” (leptogenesis) and “Do all forces and masses become one?” (unification)

- **Neutrinos are different!**

- They may be their own antiparticles or obey a different set of rules with respect to matter-antimatter (CP) asymmetry. Their tiny masses suggest a “see-saw” with superheavy partner  $\nu$ 's not yet detected.

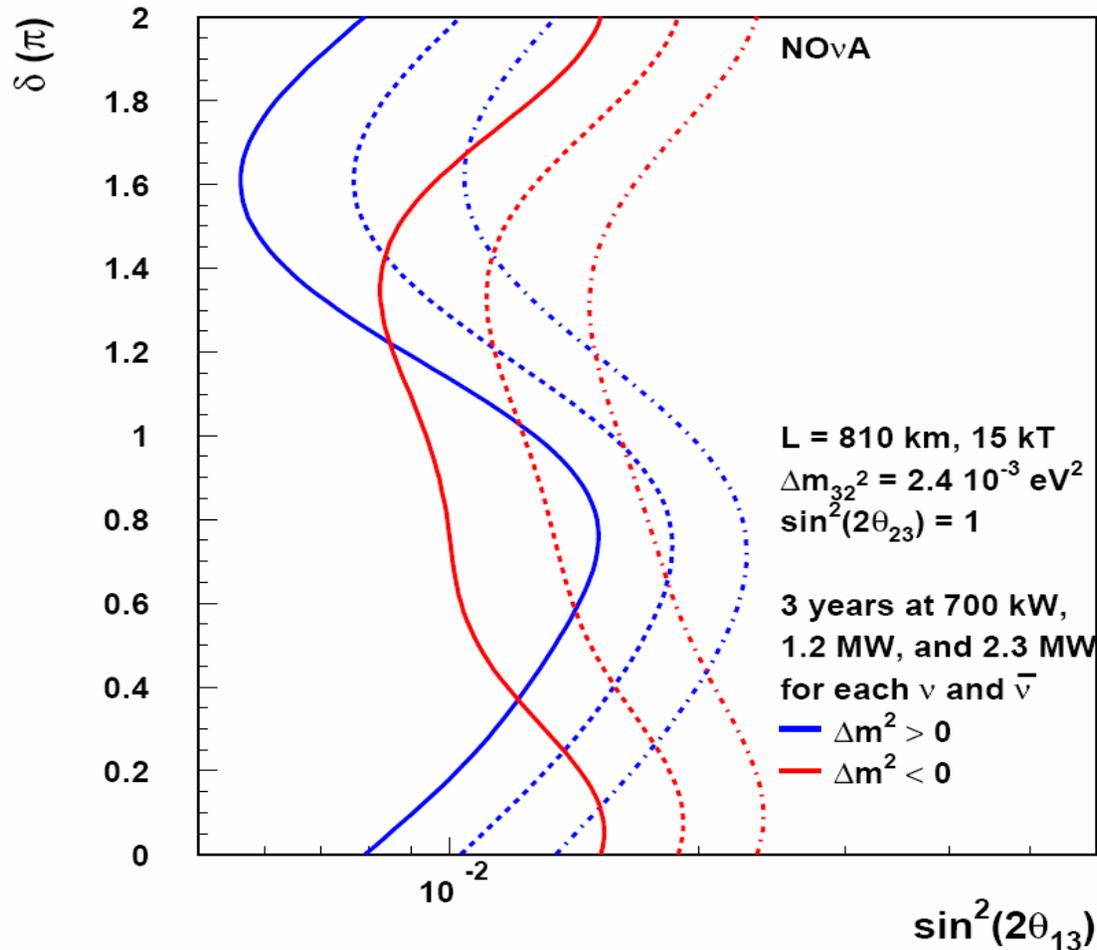
# Neutrino Science

- Re-running the Big Bang with all these  $\nu$  properties gives leptogenesis
  - creation of matter from decay of superheavy  $\nu$ 's
- These  $\nu$  properties may fit into a larger picture including the **unification and supersymmetry**
- This **requires a broad ambitious program** to detect CP violation in  $\nu$ 's, determine their mass hierarchy, the Majorana nature of  $\nu$  mass, and how  $\nu$ 's mix.

# Neutrino Science

e.g. Sensitivities with NOvA Detector

$3\sigma$  Sensitivity to  $\sin^2(2\theta_{13}) \neq 0$



# Precision Physics

- Ultraprecise experiments with high intensity sources of muons and quarks provide unique discovery potential.
  - The discovery of Lepton Flavor Violation (muon to electron conversion) could probe unification physics complementary to neutrinos and ILC.
  - Precise measurements of quark flavor violation with kaons could complement LHC and probe even higher energy scales ( $\sim 1000$  TeV in some models).

# Project X – Alignment with ILC and Future Accelerators

# Aligned to ILC

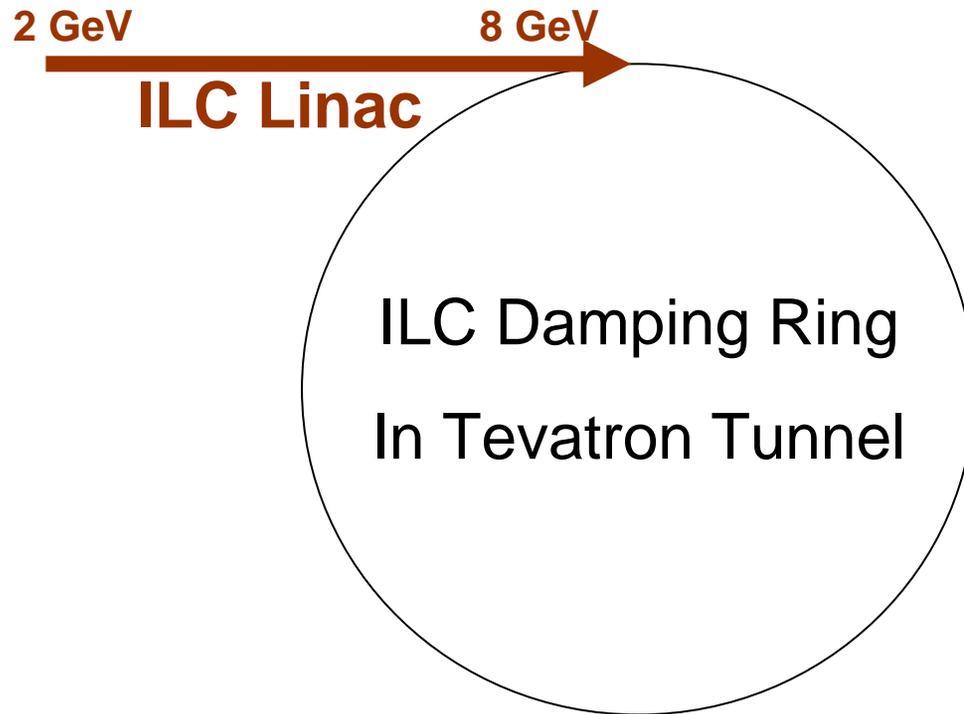
6 GeV  $e^-$  Linac with  
ILC Beam parameters (9mA x 1msec x 5Hz)



- Same as ILC:
  - 36 Cryomodules
  - RF distribution
  - Cryogenic distribution
  - Beam parameters
- Cryomodule Industrialization
  - ILC RDR Regional Profile
    - Doubling time = ~1 year
    - Year 1: 3 cryomodules / year
    - Year 4: 25 cryomodules / year
  - Advancing technology
    - Find cheaper ways to produce in large quantities

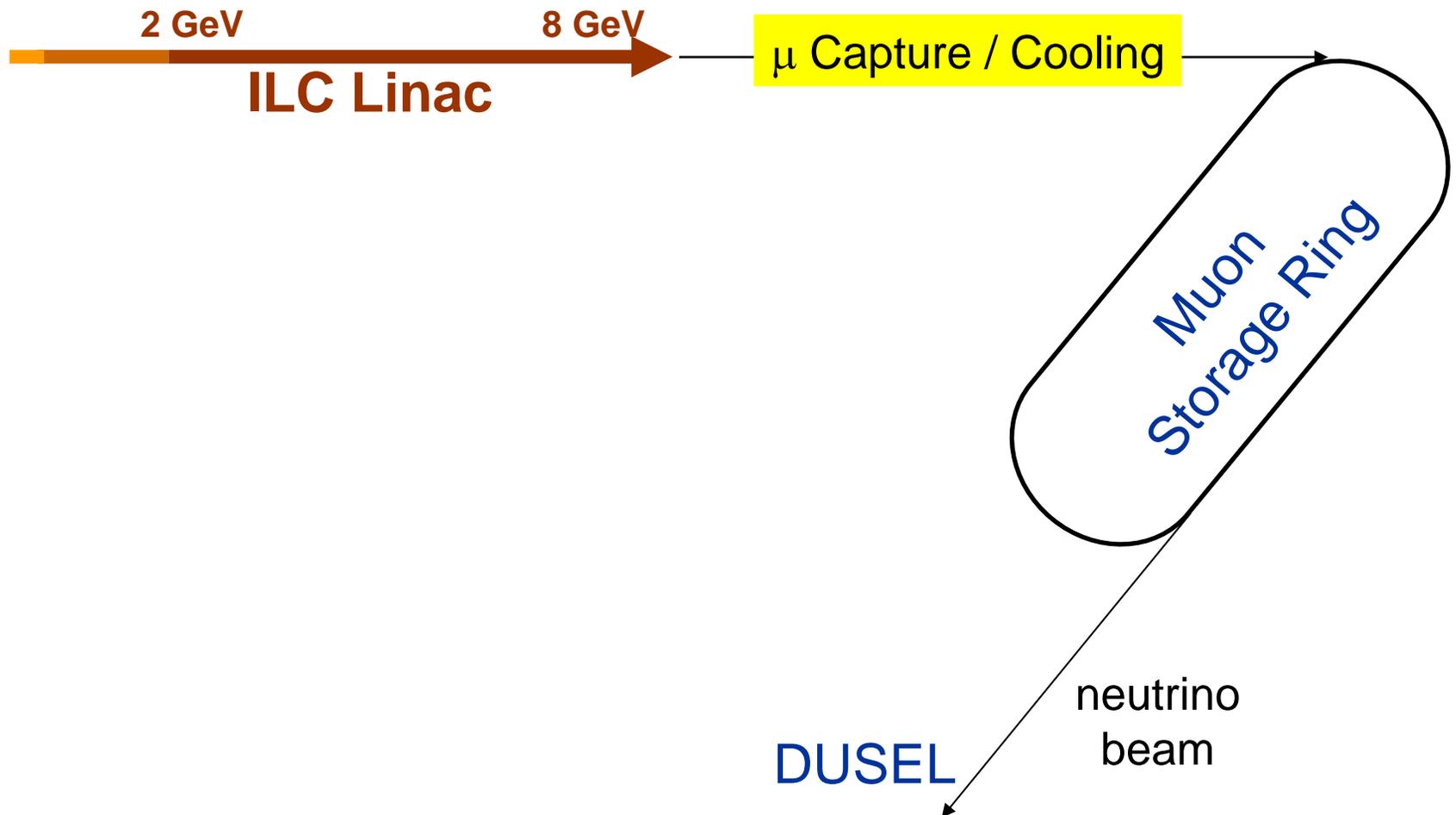
# Aligned to ILC

6 GeV  $e^-$  Linac with  
ILC Beam parameters (9mA x 1msec x 5Hz)

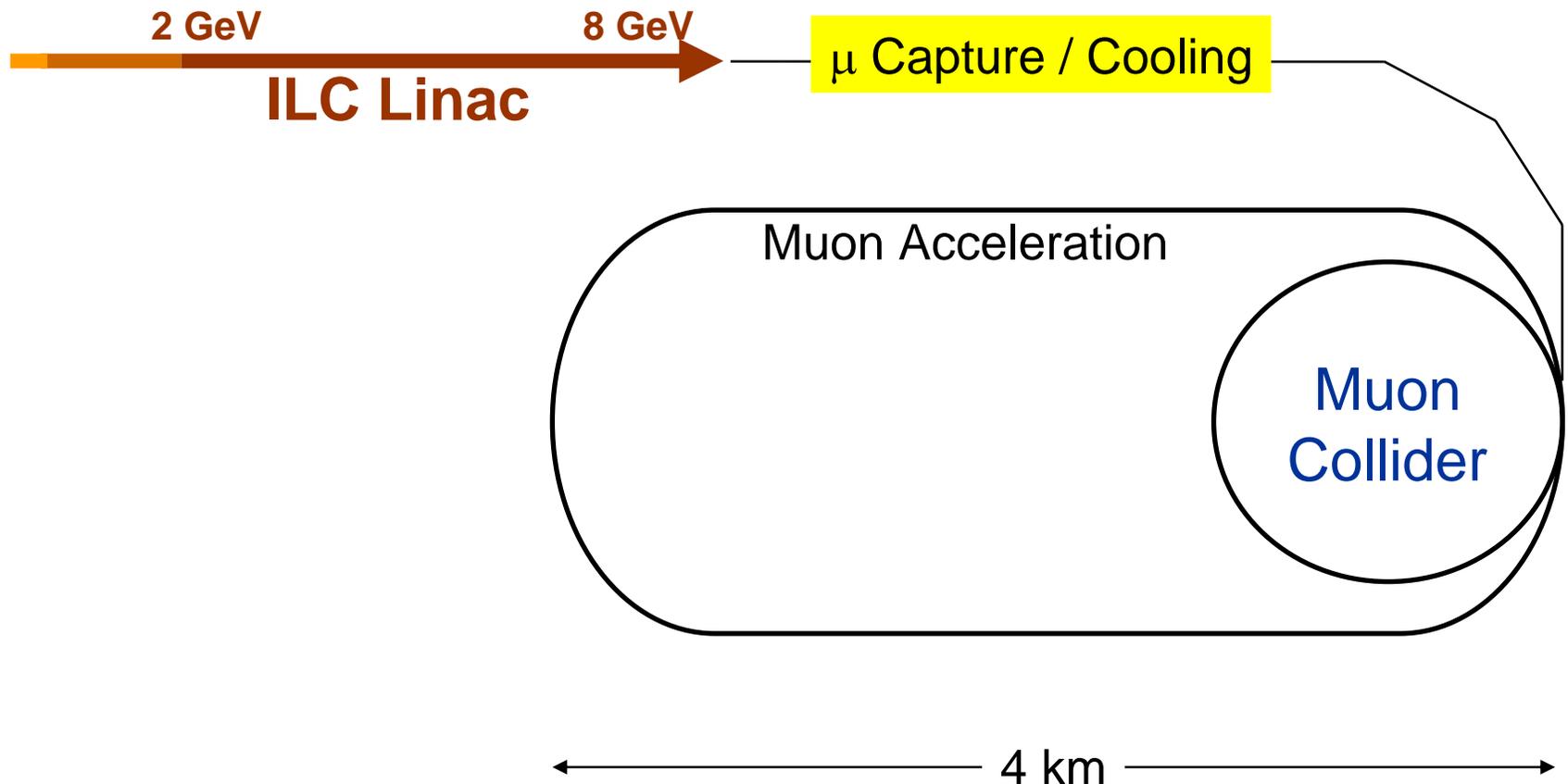


Preassemble and test the ILC Damping Ring

# First Stage of Future World Facilities



# First Stage of Future World Facilities



# Vehicle for National & International Collaboration

8 GeV H<sup>-</sup> Linac with  
ILC Beam parameters (9mA x 1msec x 5Hz)



## 0 → 0.12 GeV

- Modest increase from current 60 MeV R&D program
- Collaboration with ANL, BNL, LBNL

## 0.12 → 2 GeV Linac

- Potential strong international collaboration (e.g. India)

## 2 → 8 GeV ILC-like Linac

- SLAC, ANL, Cornell, JLab, DESY, KEK, TRIUMF, ...

**New conceptual design by Project X team:  
ILC like Linac even below 1 GeV**

# Draft Report

submitted to Pier Oddone  
on August 7, 2008

Accelerator Advisory Committee  
(Fermilab External Committee)  
Review  
on Accelerator Part of the Plan/Roadmap

August 8-10, 2007

Fermilab

# AAC Membership

- John Corlett (LBNL), Chair
- Swapan Chattopaddhyay (TJNAF)
- Gunther Geschonke (CERN)
- Georg Hoffstaetter (Cornell)
- Kwang-Je Kim (ANL)
- Shin-ichi Kurokawa (KEK)
- Michiko Minty (DESY)
- Hasan Padamsee (Cornell)
- Stephen Peggs (BNL)
- Tor Raubenheimer (SLAC)
- Hans Weise (DESY)

(Michiko and Hasan were not able to attend this meeting)

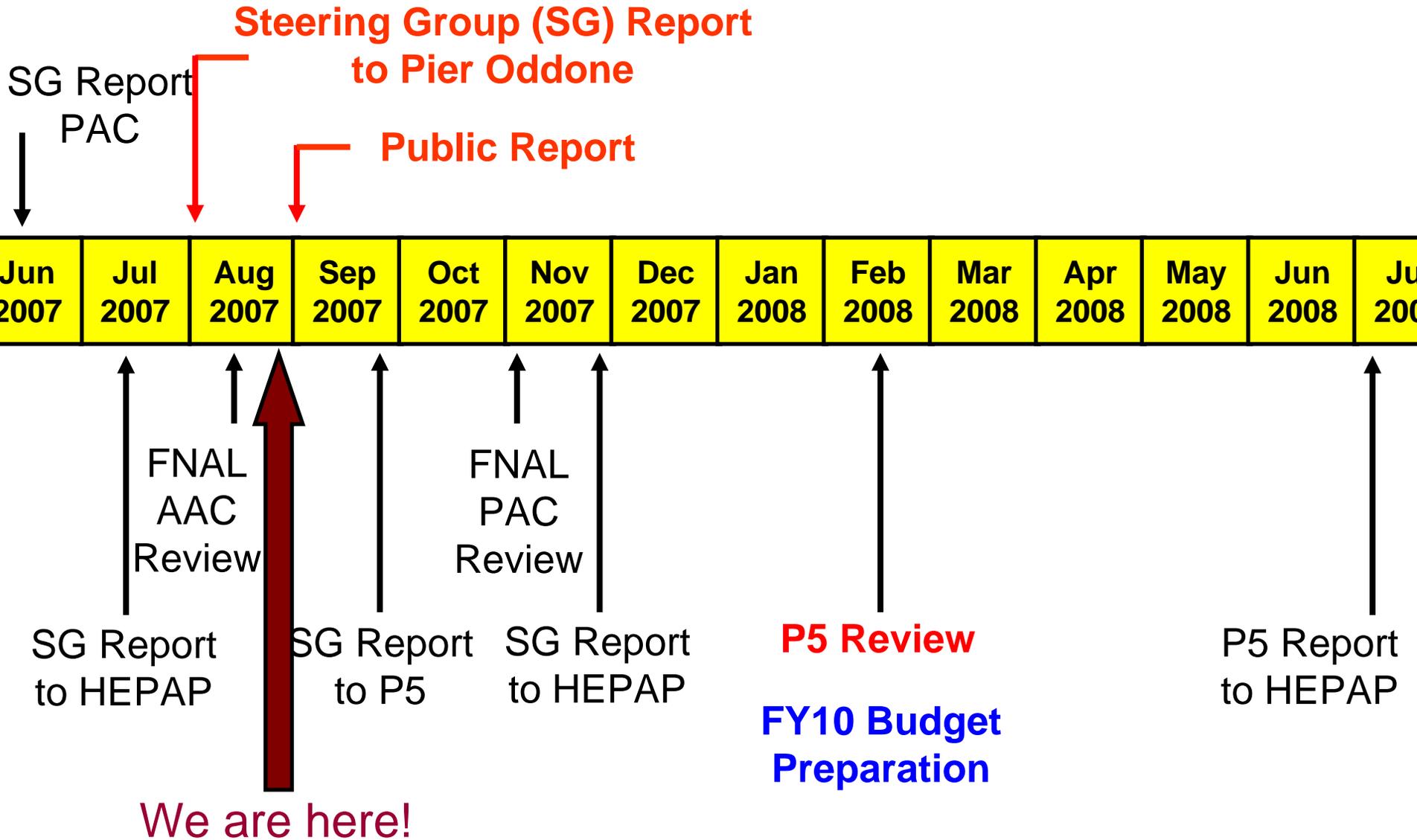
# AAC Comments

- The committee strongly supports the plan presented
  - Provides options for the future of accelerator based HEP at Fermilab
  - Has broad scope, addresses near and far-term activities
    - Critical for healthy future of HEP in the U.S.
- Evolution of the plan has benefited from Fermilab leadership in pursuing options
  - Establishment of processes leading to strong alignment of Project X with ILC
- The committee strongly supports plans for Project X
  - needs to be ready with an engineering design in the 2010 timeframe
  - An immediate strong start is recommended.
- We congratulate the Project X team on an innovative design
  - Supportive of ILC, neutrino sector, muon collider
  - A prudent backup in case of delay to the ILC
- We recommend that Fermilab be considerate of potential misinterpretations of the priority of ILC wrt Project X.

# In Progress

- Physics studies
  - Details with Project X
  - Comparison in the global context
- Resource Planning for Project X

# Next Steps



This plan is to keep Fermilab  
on the pathway to discovery  
no matter what happens!