# Prioritization of

# Particle Physics

# in the US

- Discussions in P5 -

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# What is P5 ?     P5 in the US HEP landscape

- The US funding agencies:  DoE = Department of Energy
  NSF = National Science Foundation

- HEPAP = High Energy Physics Advisory Panel

- The **P**article **P**hysics **P**roject **P**rioritization **P**anel (P5)

  Charge: "…. *to advise and prioritize specific projects, at the request of the DoE and NSF, and to maintain the roadmap of the field.*"

- The National Academy of Sciences' **EPP2010 committee** (Elementary Particle Physics in the 21st Century) should provide important strategic context to the roadmap.

# Composition of P5

## Chairman:

Abe Seiden, Univ. Santa Cruz

## P5 members:

Hiroaki Aihara, Tokyo Univ.
Andy Albrecht, UC Davis
Jim Alexander, Cornell
Daniela Bortoletto, Perdue Univ.
Claudio Campagneri, UC Santa Barbara
Marcella Carena, Fermilab
Bill Carithers, Berkeley
Dan Green, Fermilab
JoAnne Hewett, SLAC
Karl Jakobs, Freiburg Univ.
Boris Kayser, Fermilab
Ann Nelsen, Univ. of Washington

Harrison Prosper, Florida State Univ.
Tor Raubenheimer, SLAC
Steve Ritz, NASA
Michael P. Schmidt, Yale Univ.
Harry Weerts, Argonne
Stan Wojcicki, Stanford Univ.

Ex officio: Mel Shochet, Univ. Chicago
(HEPAP chair)

# The main Physics Issues

1. ***Physics at the Energy Frontier***
   - Tevatron
   - LHC   (and its upgrade)
   - ILC

2. ***Physics at the Flavour Frontier***
   - B Physics at BaBar
   - Neutrino Physics

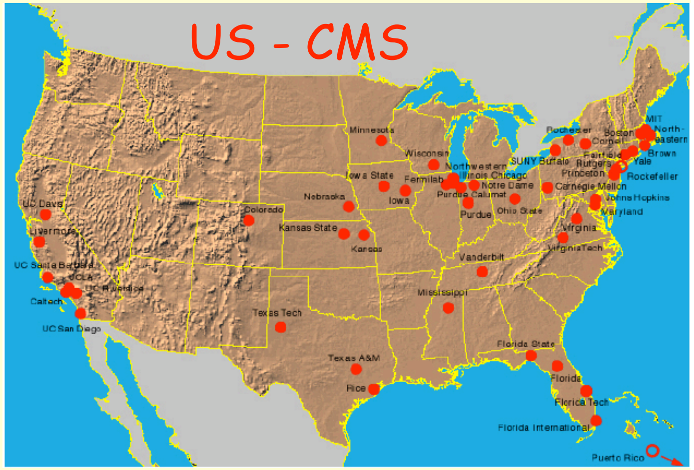
3. ***Physics at the Cosmology Frontier***
   - Dark Matter
   - Dark Energy

# US Involvement in the LHC

- US is strongly involved in the LHC project

ATLAS: 36 institutes (of 153), 272 scientific authors (of 1650)

CMS: 47 institutes, # scientific authors is expected to grow to 500 by the start of data taking



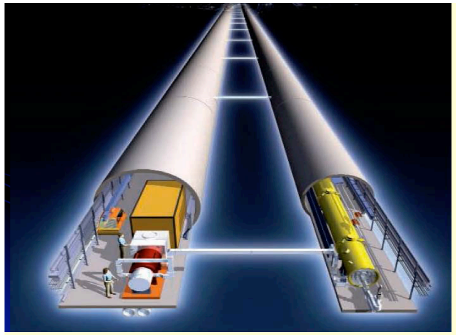

- Involved in many sub-detectors

- Significant contributions to Software and Computing

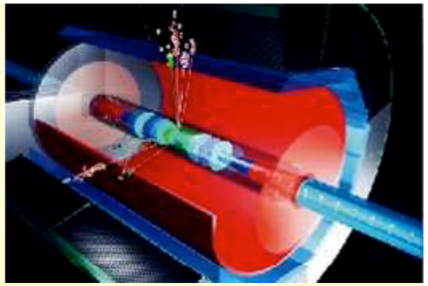
- Strong interest in LHC upgrade projects, R&D activities

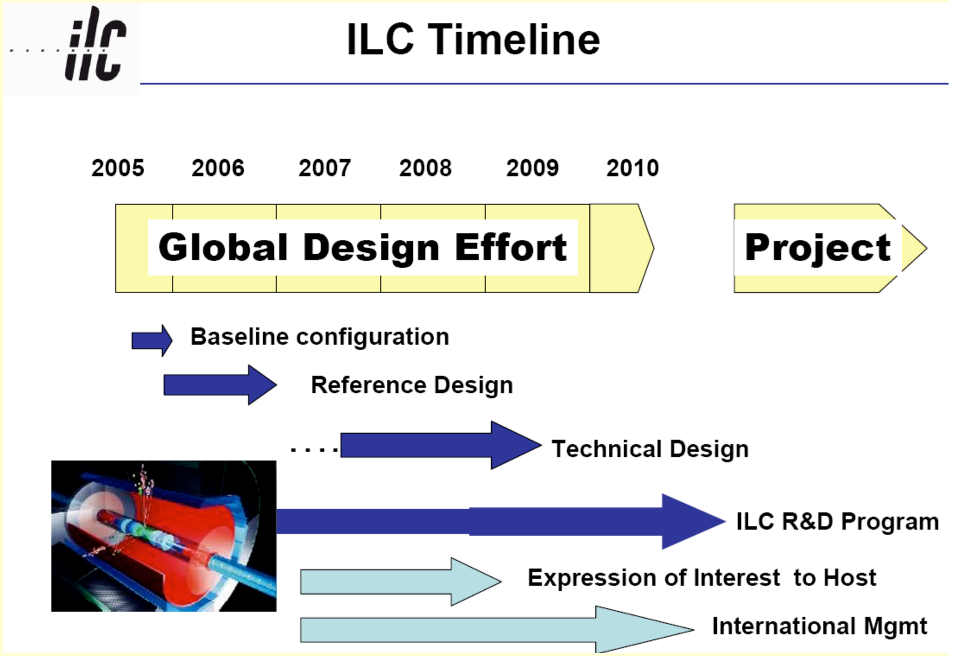
- Strongly involved in LHC Accelerator Research Program (LARP)

LHC is a high priority item for: US physicists, funding agencies, …
…… and P5



# US Involvement in the ILC






- **Strong endorsement by EPP2010**

- **Global Design Effort (GDE)**

- US physics community is strongly involved in accelerator R&D; at National Labs and at universities (major items: damping rings, LINAC beamline instrumentation, ILC cavities and test facilities, high gradient cavity R&D, cryomodule design, beam delivery system, …..,ILC civil designs)

- So far, less strongly involved in Detector R&D; US ILC physicists wish to strengthen this part of the program (to prevent falling further behind partners in Europe (EUDET comparison))

ILC is a high priority item for: US physicists …… and P5

# The $\nu$ physics case

**Reactor Experiments**: measure $\nu_e$-bar disappearance
- sensitive and clean measurement of $\theta_{13}$ (reach: $\sim 0.01 < \theta_{13}$)

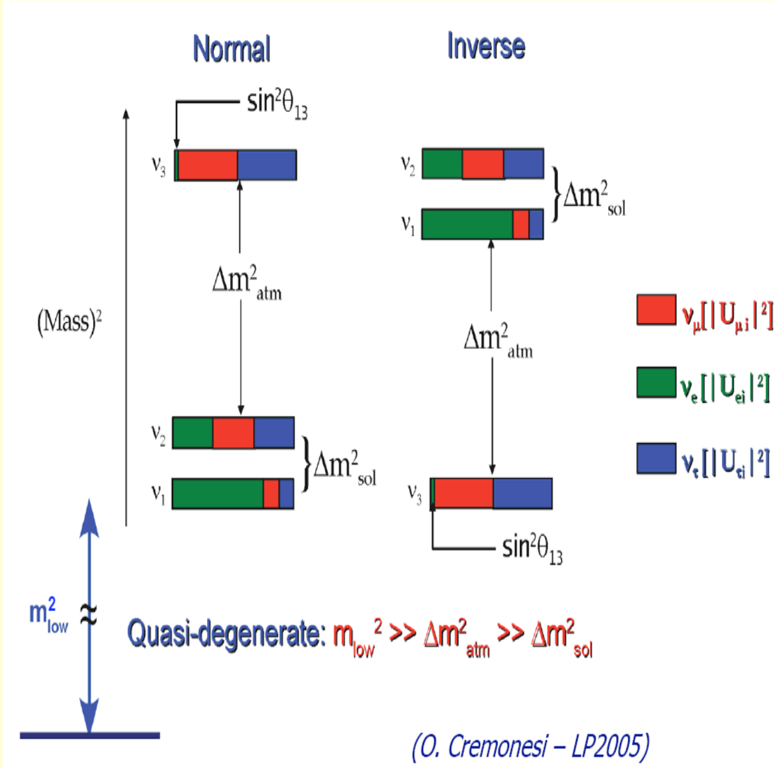
**Accelerator Experiments**:
measure $\nu_\mu \rightarrow \nu_e$ and $(\nu_\mu \rightarrow \nu_e)$bar transitions

- sensitive to $\theta_{13}$

- in addition: sensitive to the atmospheric mixing angle $\theta_{23}$

- sensitive to the $\nu$ mass hierarchy (quark like or inverted)

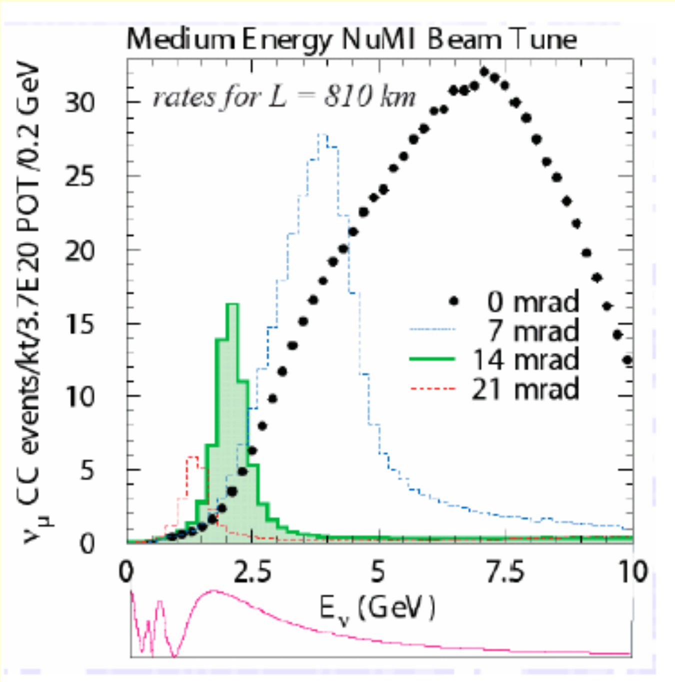
- sensitive to CP violation parameter $\delta$, if $\theta_{13}$ large enough



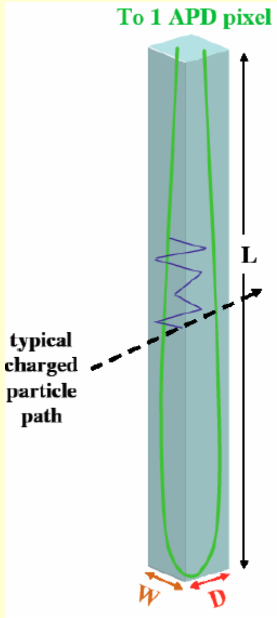

accelerator measurements will typically involve several $\nu$ properties at once; reactor measurement of $\theta_{13}$ would help to disentangle the properties

# NOνA : NuMI Off-axis $\nu_e$ Appearance experiment

- A proposed 2nd generation experiment on the NuMI beamline
- Far detector: 25 kt, totally active tracking liquid scintillator calorimeter
- located 810 km from Fermilab (Ash River), 12 km off NuMi beamline
- physics requires $6.5 \times 10^{20}$ protons/y on NuMI target (~0.6 MW)
  (with main injector → proton driver → increase to ~2 MW)
- unique characteristics: long baseline → access to matter effects
  → can be used to determine the ordering of ν mass states








15.7 m long basic det. element

# US Activities and Plans on Dark Matter Search

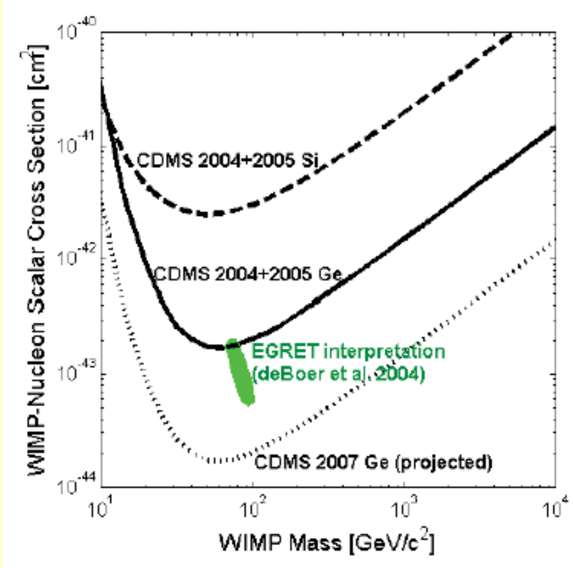
CDMS-II: Soudan mine
Si + Ge detectors,
Measure heat + ionization
Phase II, ~1 kg

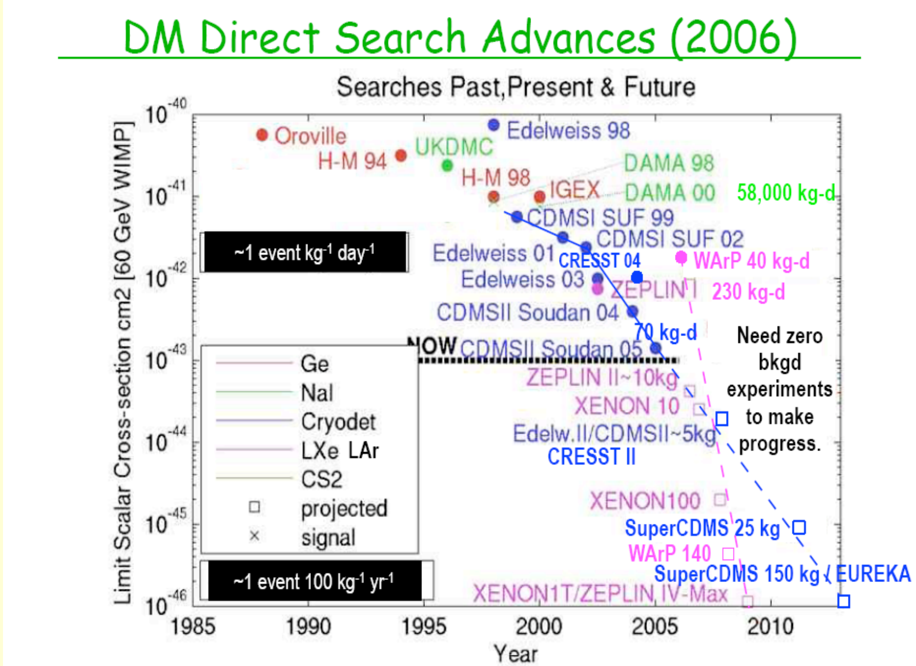
Short term proposal:
upgrade to Super CDMS
→ 25 kg Si/Ge detector mass
→ SNO-lab (reduced background)
Project cost ~ $16M

→ Establish technology (towards 1 ton projects)
→ allow for comparisons with other technologies
(Liquid detectors)

Construction: 2007 – 2009
Operation: 2009 – 2011

Future 1-ton projects:
Super-CDMS (1.000 kg) or
Liquid Argon/Xenon detectors



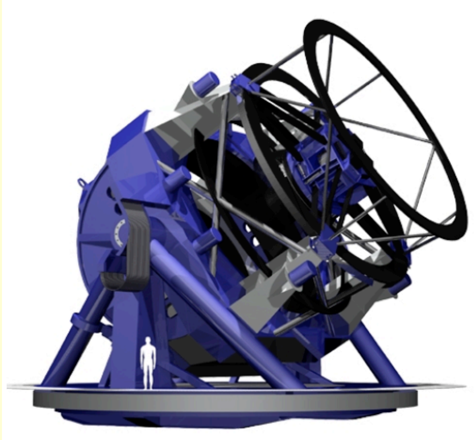

Plot updated from that in DM Review Article: Gaitskell, Ann. Rev. Nucl. and Part. Sci. 54 (2004) 315-359

# A few selected Dark Energy Projects

- Many proposals, ground-based and space-based-

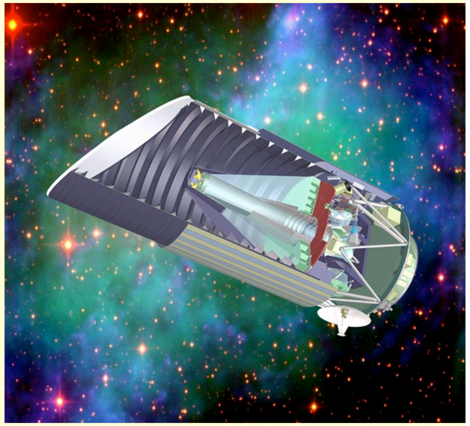
Strategy: extract pressure to energy density (equation of state)
$w(z) = P(z) / \rho(z)$ from influence on large scale structure formation

- study Dark Energy through supernovae, weak-lensing and spatial distribution of galaxies



(i) Dark Energy Survey (DES):
- 520 Mega-pixel wide-field camera (2.2 square degrees) mounted on the CTIO-observatory in Chile.

(ii) Large Synoptic Survey Telescope (LSST):
- proposal to construct a new 8.4 m telescope and a 3 Giga-pixel camera



(iii) Joint Dark Energy Mission (JDEM):
Planned joint DoE / NASA space mission to investigate Dark Energy
Example: SNAP (Supernova Acceleration Probe)
(2 m telescope in space, 0.7 $deg^2$ field of view)

- LSST and SNAP are very challenging, large scale future projects (~ $400M), calls for international collaboration (physics labs or space agencies)

# P5 Recommendations, planning guidelines (2006)

1) *The **LHC program** is our **most important near term project** given its broad science agenda and potential for discovery. It will be important to support the physics analysis, computing, maintenance and operations, upgrade R&D and necessary travel to make the U.S. LHC program a success. The level of support for this program should not be allowed to erode through inflation.*

2) *Our **highest priority for investments toward the future is the ILC** based on our present understanding of its potential for breakthrough science. We need to participate vigorously in the international R&D program for this machine as well as accomplish the preparatory work required if the U.S. is to bid to host this accelerator.*

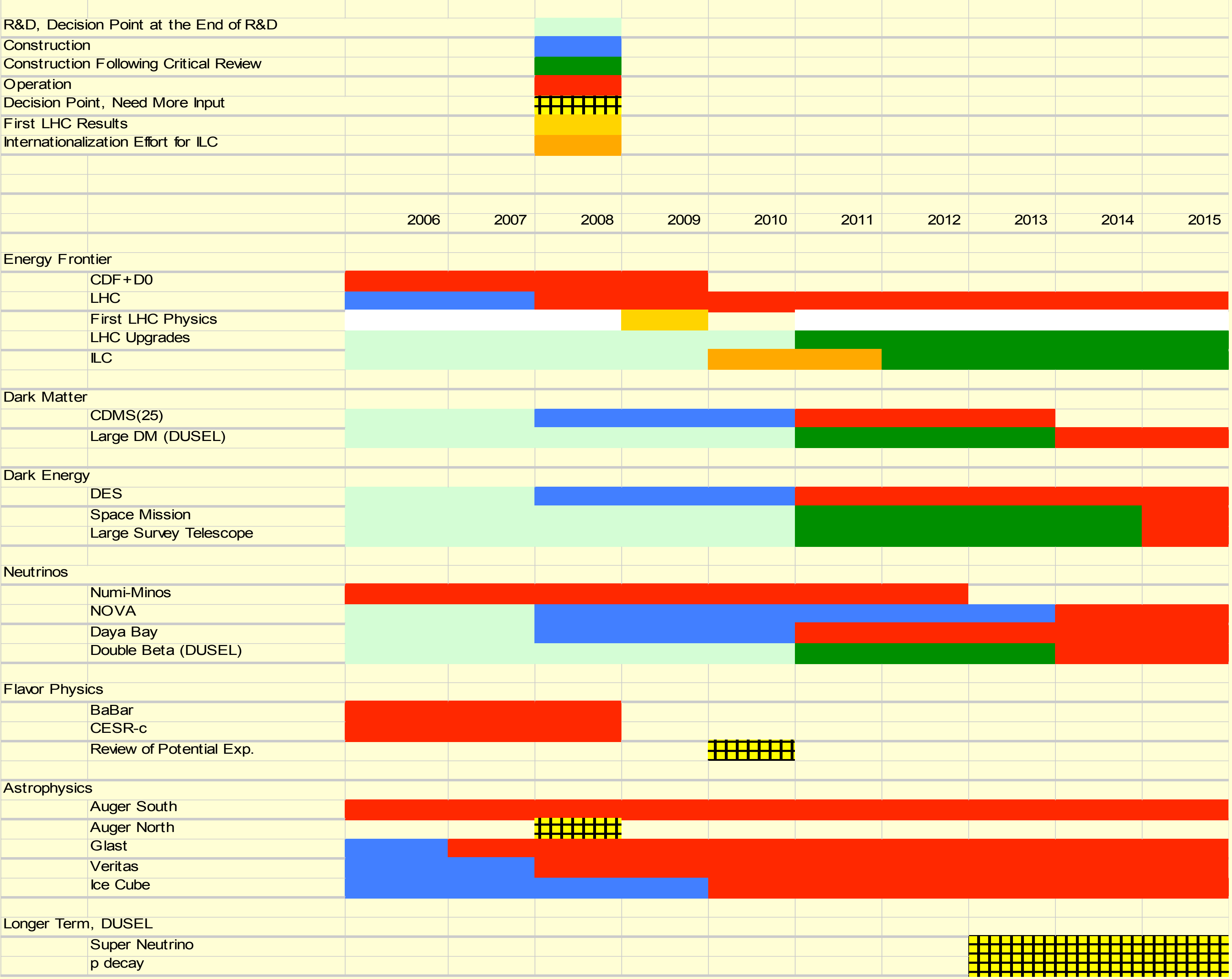
3) *Investments in a **phased program to study dark matter, dark energy, and neutrino interactions are essential** for answering some of the most interesting science questions. This will allow complementary discoveries to those expected at the LHC or the ILC. A phased program will allow time for progress in our understanding of the physics as well as the development of additional techniques for making the key measurements.*

## P5 Recommendations, planning guidelines (2006) (cont. )

4) *In making a plan, we have arrived at a* ***budget split for new investments of about 60% toward the ILC and 40% toward the new projects in dark matter, dark energy, and neutrinos through 2012.*** *The budget plan expresses our priority for developing the ILC but also allows significant progress in the other areas. We feel that the investments in dark matter, dark energy, and neutrino science in our plan are the minimum for a healthy program.*

5) ***Recommendations for construction starts on the longer-term elements*** *of the Roadmap should be made* ***toward the end of this decade by a new P5 panel****, after thorough review of new physics results from the LHC and other experiments.*

# P5 Roadmap - 2006, US Program



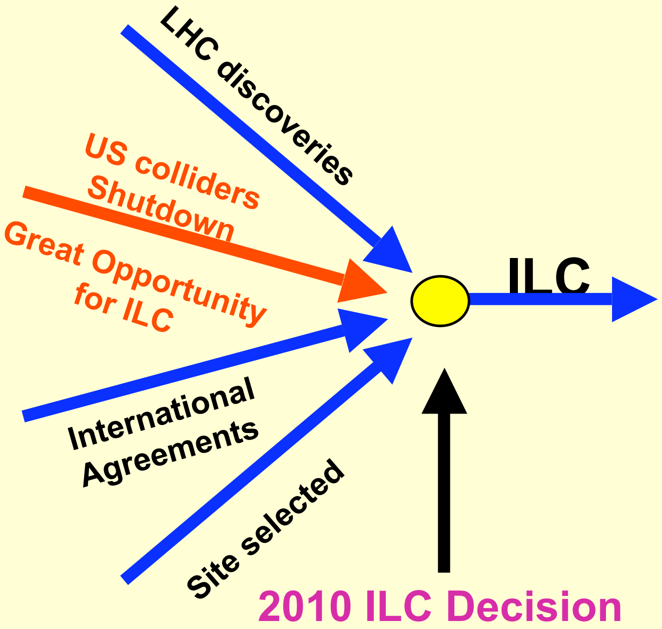
# P5 Questions in 2007

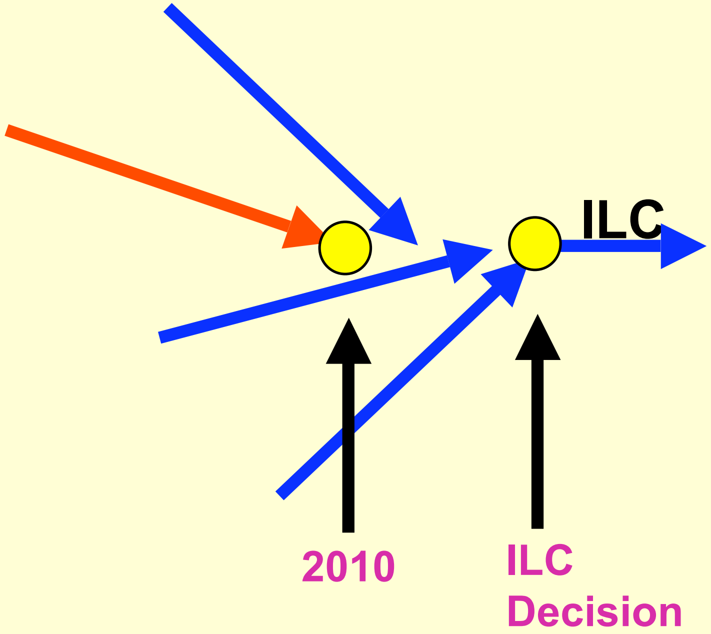
- Fermilab running in 2010 ??

  Delay of the LHC, or slow start-up of the LHC

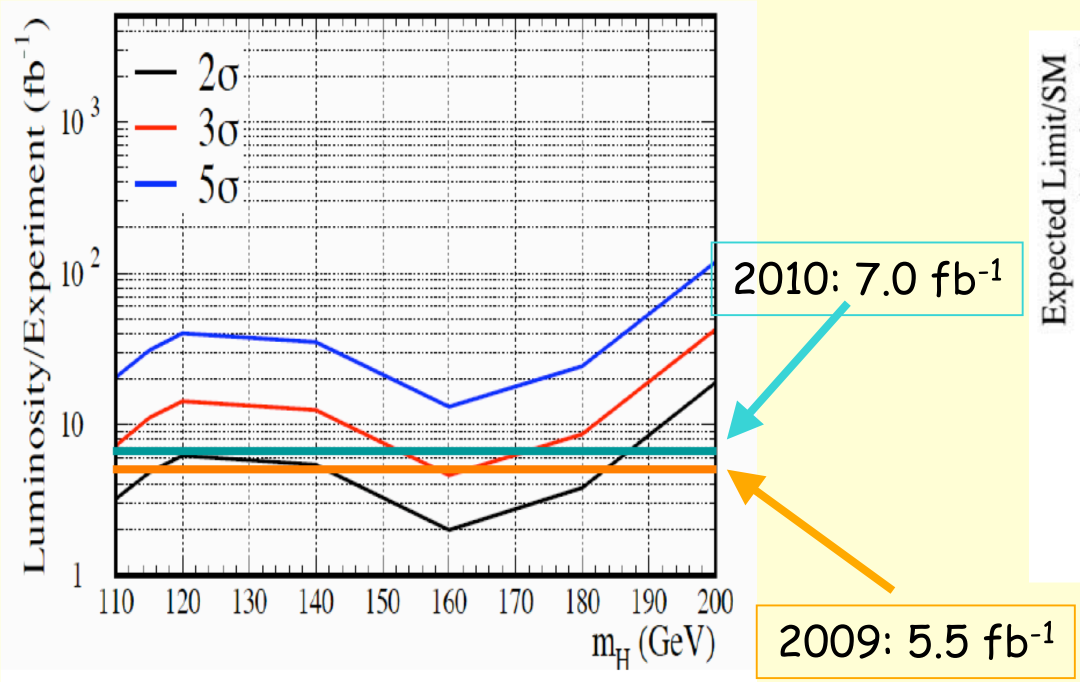
  First evidence for Higgs at the Tevatron ?

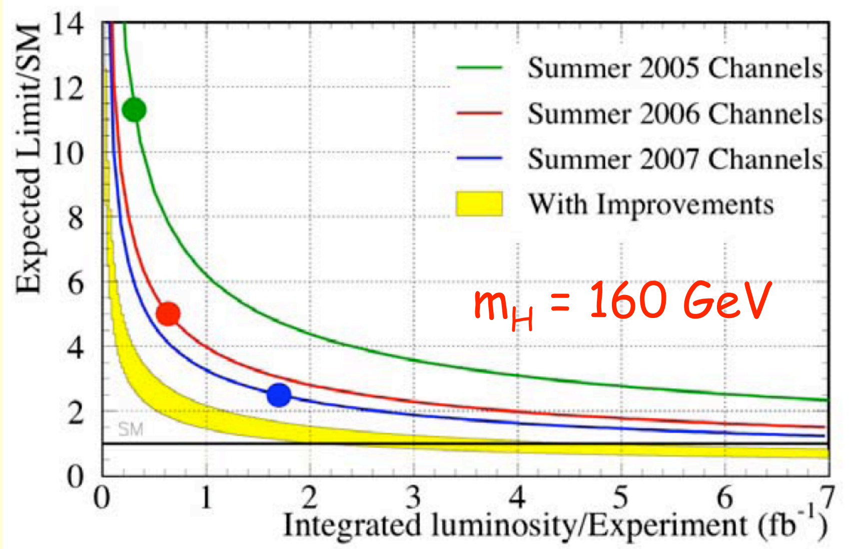
- Future of Fermilab, Project X



# Projected Tevatron Higgs mass reach




P5 Recommendations:

- The option of continued running past 2009 should be held open as a possibility and revisited in Fall 2008
- FERMILAB management should work with DOE on implications of additional running
- Funding for additional running should not come at the expense of two highest priority areas in the P5 roadmap
- Criteria for decision making in 2008: examination of the manpower (dep. on LHC schedule), demonstration of sig. progress in analysis techniques

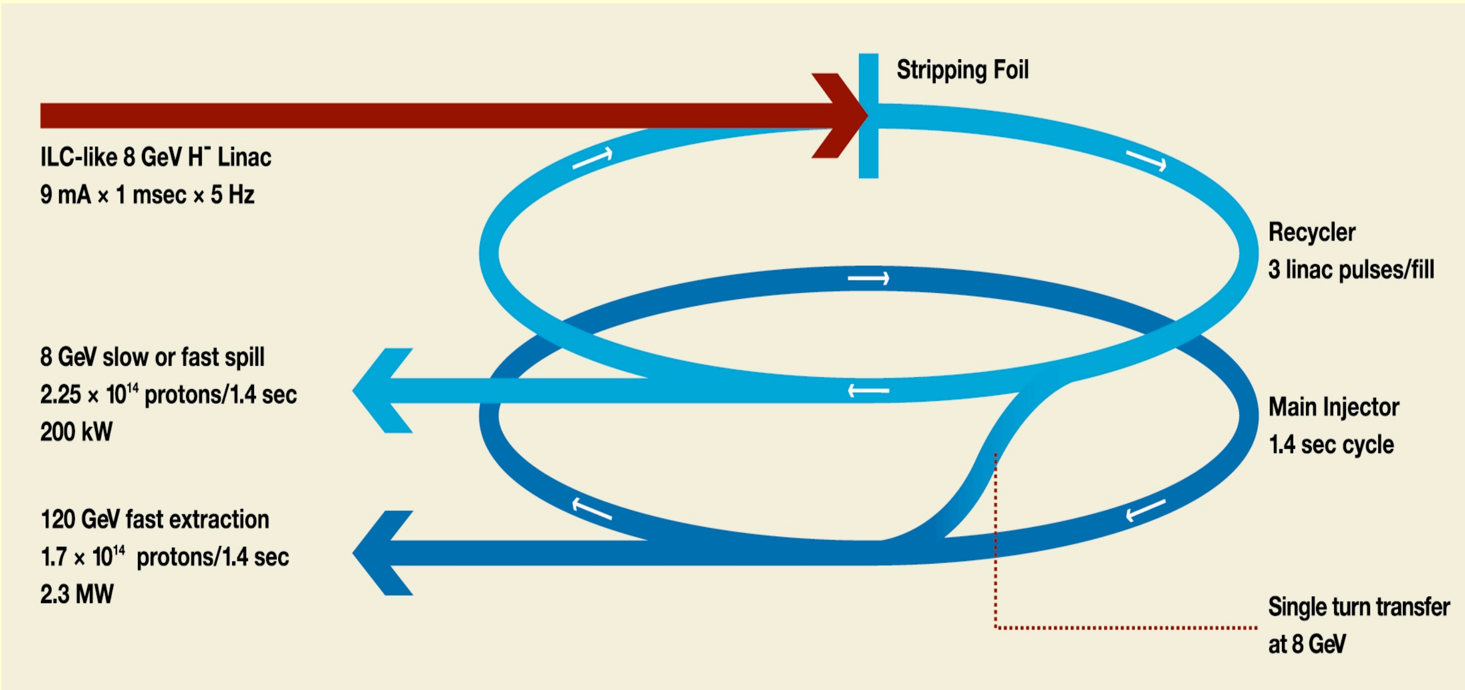
In his remarks to HEPAP, Undersecretary Orbach requested a dialog with the HEP community (Feb 2007):

*"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?"*

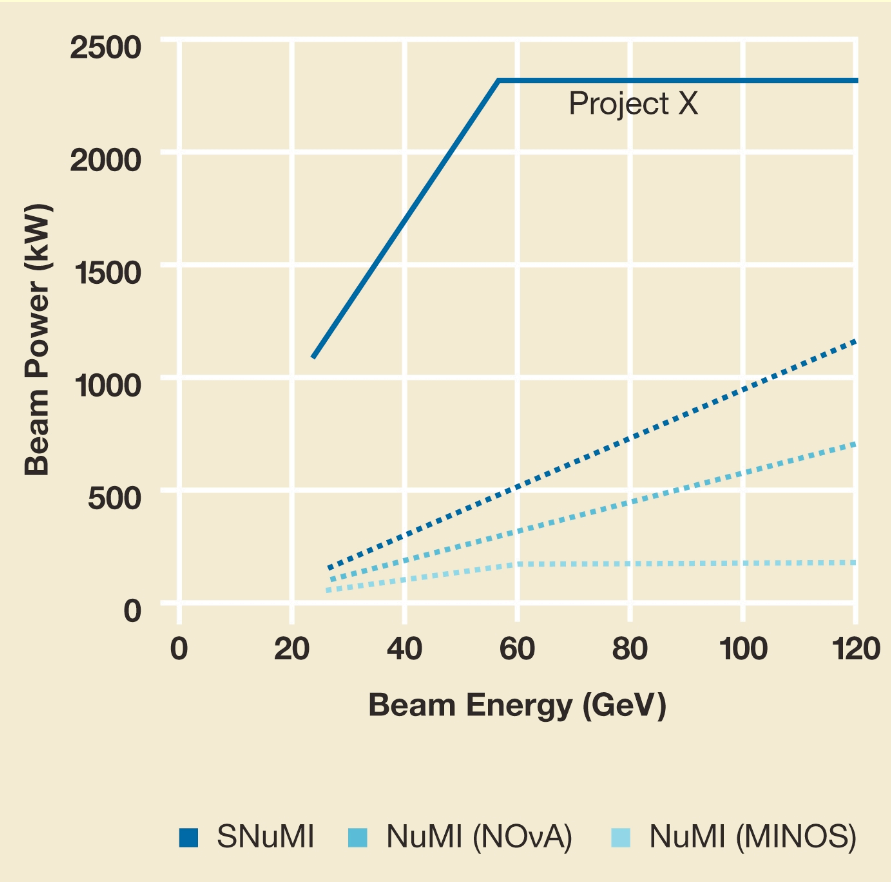
⇒ Fermilab Strategy Group
chaired by Fermilab Deputy Director Young-Kee Kim
guidelines: EPP2010 + P5 recommendations

# Project X = Intense Proton Facility at FNAL

- 8 GeV linear accelerator
- Characteristics similar to that of the ILC
  → accelerating industrialization of ILC components in the US,
  creating an engineering opportunity for ILC cost reduction and early risk mitigation
- Combined with the existing Recycler Ring and the Main Injector
- Intense proton beams from 8 to 800 GeV



# Proton beam power of Project X and Physics Opportunities




Physics Opportunities:

- Neutrino Oscillations (mass ordering, CP violation)
- High intensity $\mu$ source study of $\mu \to e$ transitions
- Precision physics with Kaons e.g. $K \to \pi \nu\nu$ rare decays
- …..

**Workshop is planned to explore the Utilization of Project X capabilities**

Decision on Project X: early in the next decade

# Recommendations from Fermilab Strategy Group

- 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.
- If the ILC remains near the timeline proposed by the Global Design Effort, Fermilab will focus on the above programs.
- If the ILC departs from the GDE-proposed timeline, in addition Fermilab should pursue neutrino-science and precision-physics opportunities by upgrading the proton accelerator complex.
- If the ILC is constructed offshore, in addition Fermilab should pursue neutrino-science and precision-physics opportunities by upgrading current proton facilities while supporting the ILC as the highest priority.
- In all scenarios: R&D support for Project X should be started now