A vision for Fermilab

Presentation to the National Academy Panel

EPP 2010: Elementary Particle Physics
In the 21st Century

Pier Oddone, 5/16/05

This will be a personal view….

"If you want to predict the future, help create it"

Bumper sticker

"Make no little plans; they have no magic to stir men's blood"

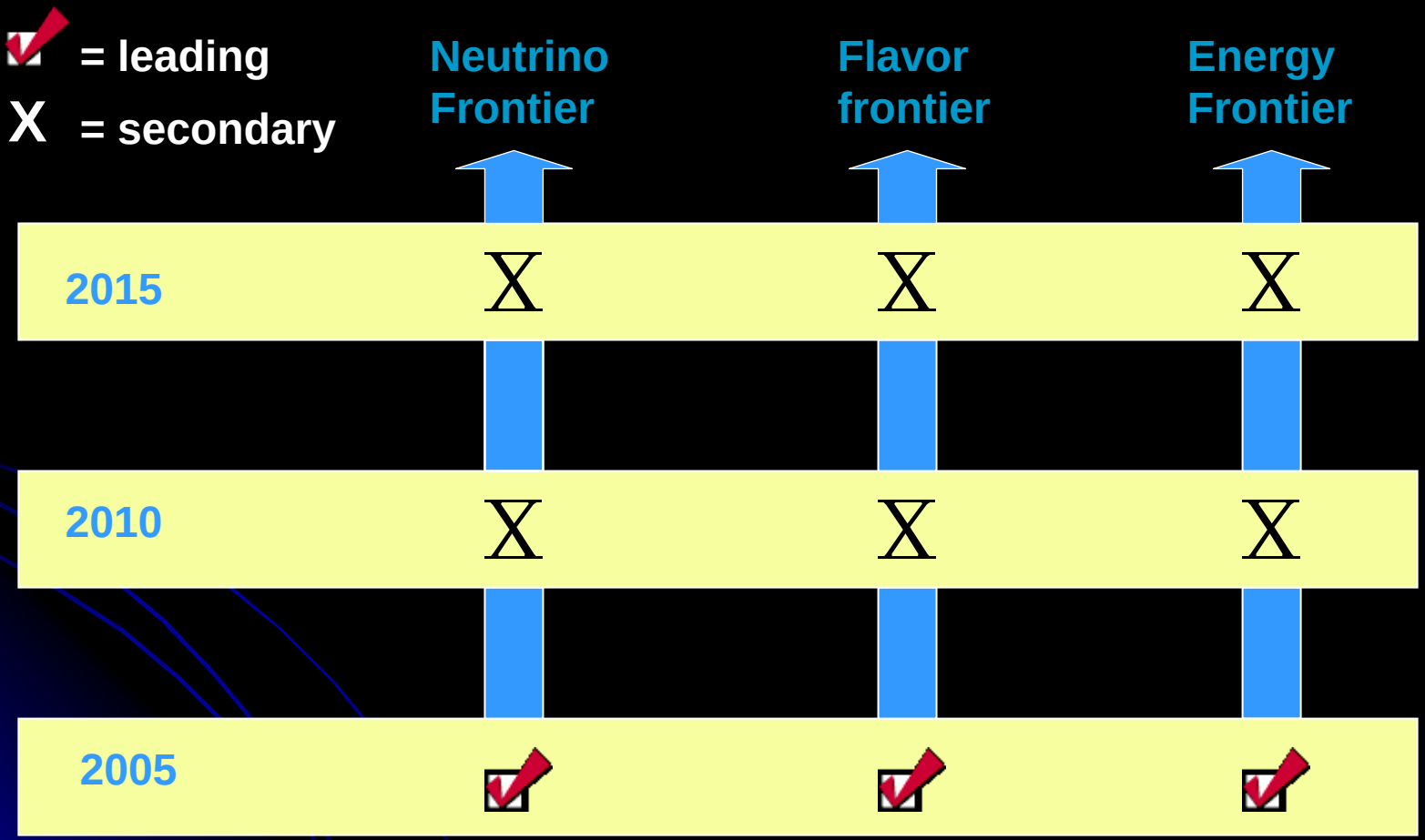
Daniel Burnham, Chicago, circa 1900

Driven by physics

- Where the largest mysteries are:
  - We know next to nothing about the next accessible energy scale: witness the plethora of models
  - We know very little about the world of neutrinos
  - We are ignorant about what dark matter and dark energy are
- We have strong clues that these are the hunting grounds for major new discoveries
- We also believe there is a deep connection between all these areas

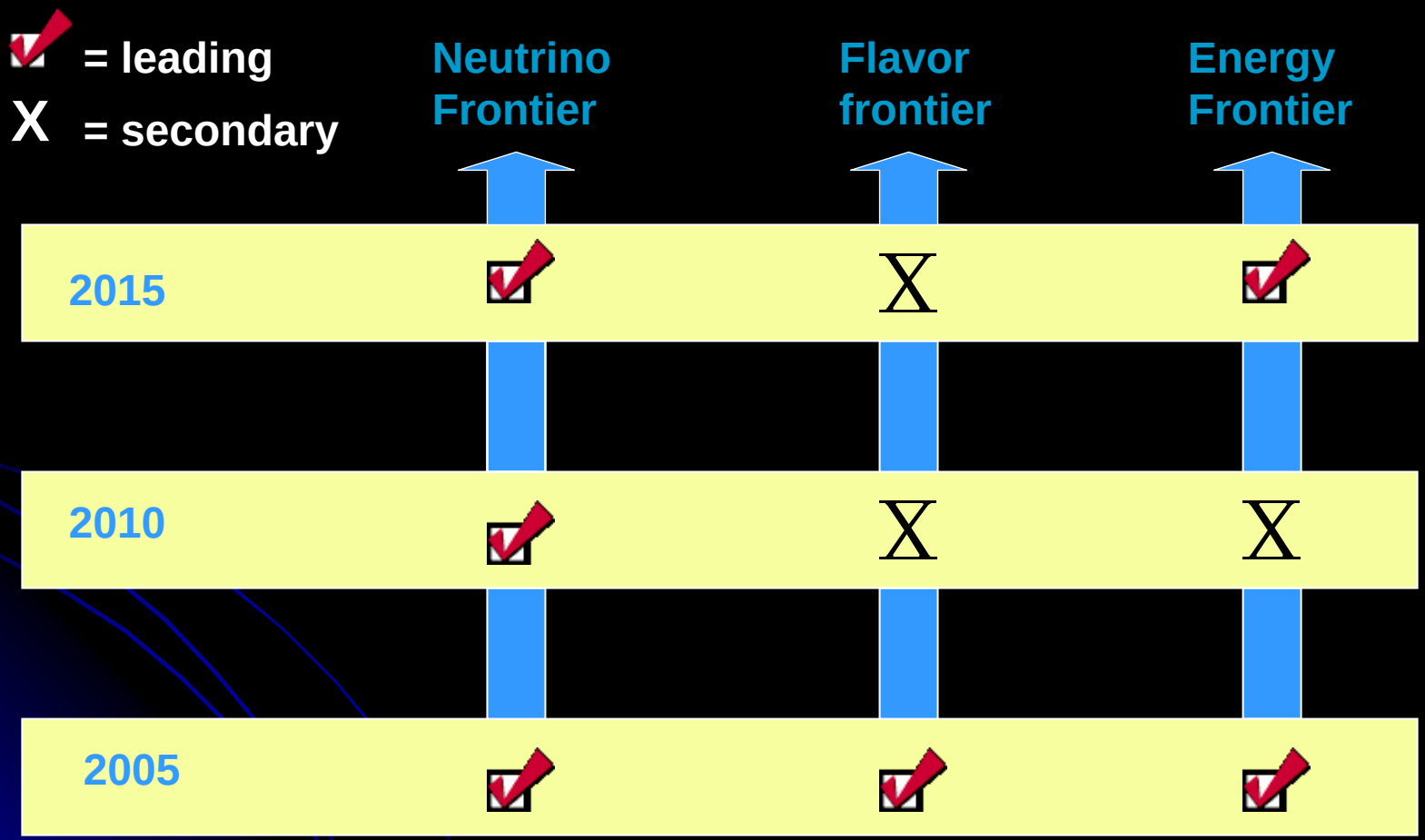
Strategic context: U.S. contribution

Domestic accelerator program with no new investment



Strategic context: U.S. contribution

Domestic accelerator program with new and redirected investment



New Initiatives at Fermilab

Overarching Goals:

Enable the most powerful attack on the fundamental science questions of our time

Provide world class facilities for HEP as part of the global network

Develop science and technology for particle physics and cosmology research

Specific Goal: make vital contributions to particle physics in the next decade by:

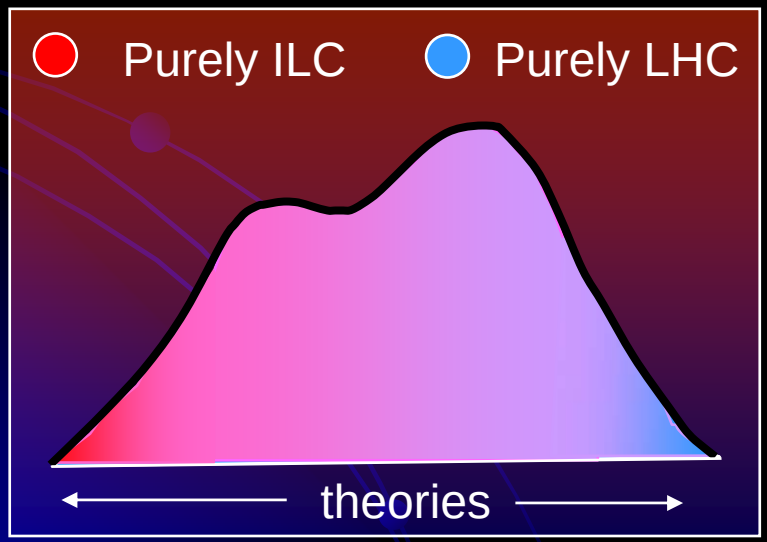
- *Developing a powerful new tool for discovery at the energy frontier (ILC)*
- *Maintaining the foremost neutrino program (NOvA, proton driver(s),+)*

The Energy Frontier (ILC)

- Goals:
  - Establish all technical components, costs, engineering designs, management structures to enable “early” decision (by 2010).
  - Position US (and Fermilab) to host the ILC.
  - Position US (and Fermilab) to play major roles in detector development and physics analysis.
- This is the highest priority initiative for the laboratory

The Energy Frontier: why ILC?

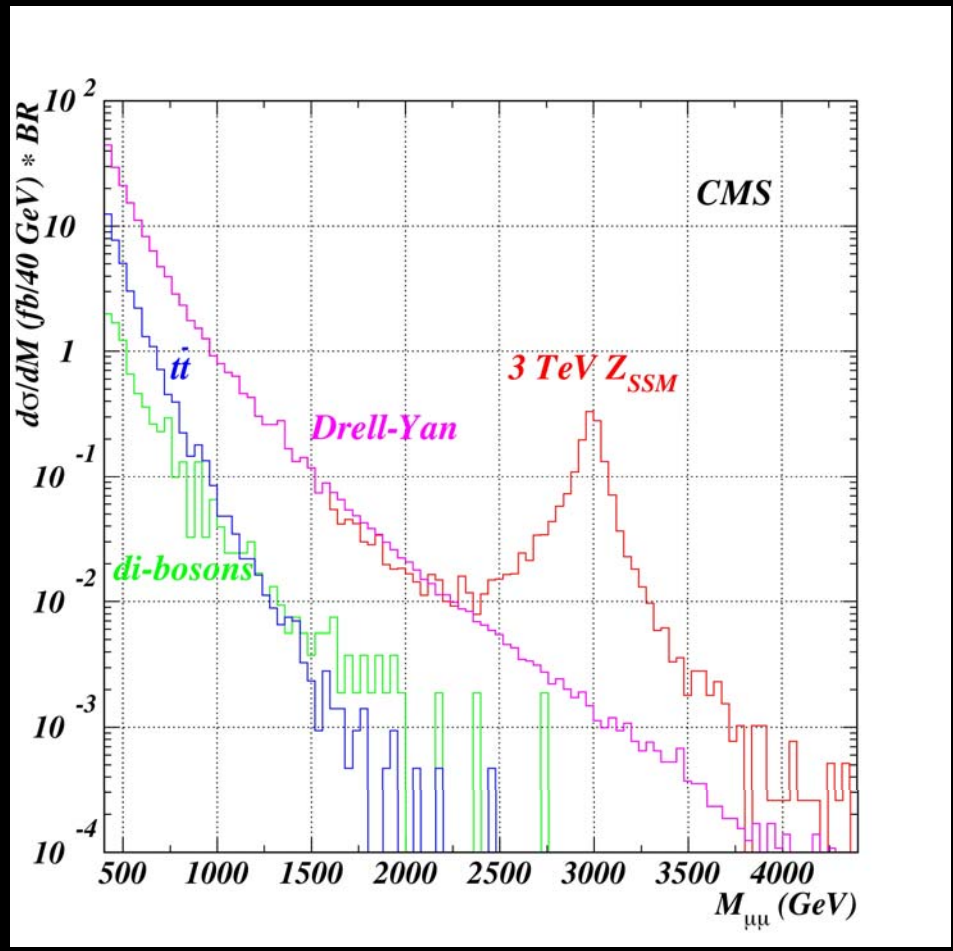
- We expect the greatest richness at the energy frontier
- Few phenomena will manifest themselves in only one machine



- We will build on the foundation of LHC to make major discoveries at ILC

ILC/LHC Physics: new particle

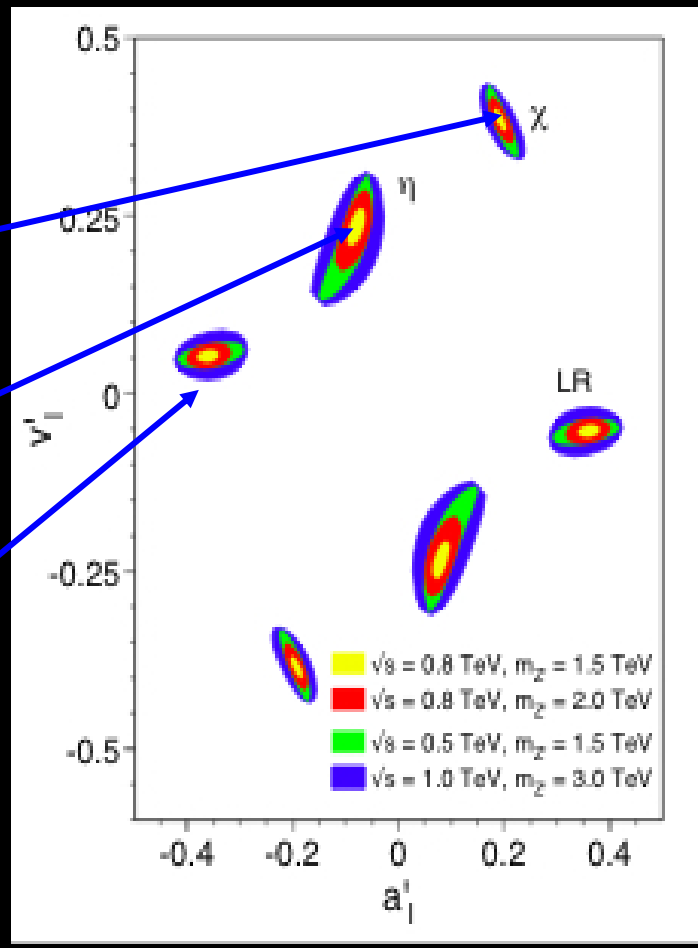
- LHC experiments find a new heavy particle, Z'
- Able to show that Z' mediates a new force of nature
- This is a great discovery



Notice peak is ½ event per bin per fb^{-1}

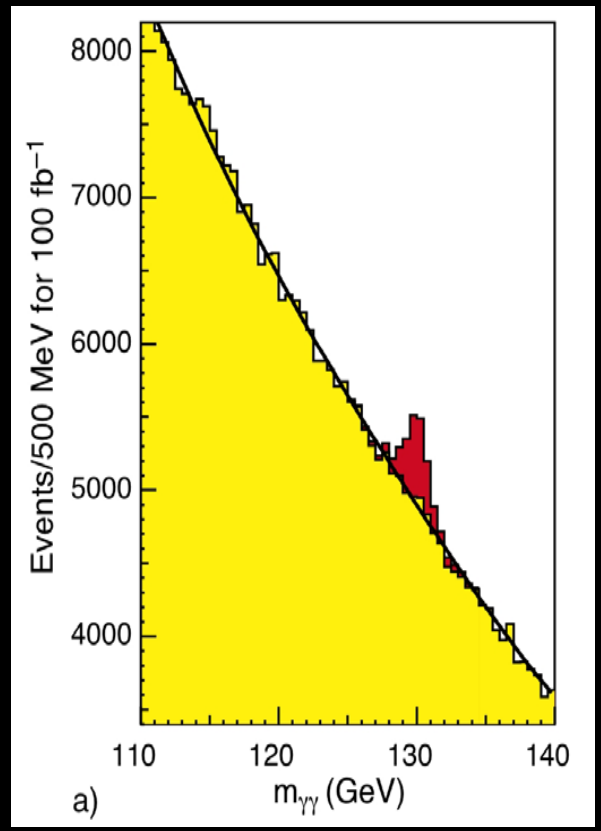
LHC/ILC Physics: new particle

- ILC measures couplings of Z' to find out what it means
- If here, related to origin of neutrino masses
- If here, related to origin of Higgs
- If here, Z' comes from an extra dimension of space
- These are great discoveries!



LHC/ILC physics: CP violation

- LHC experiments discover several kinds of Higgs particles

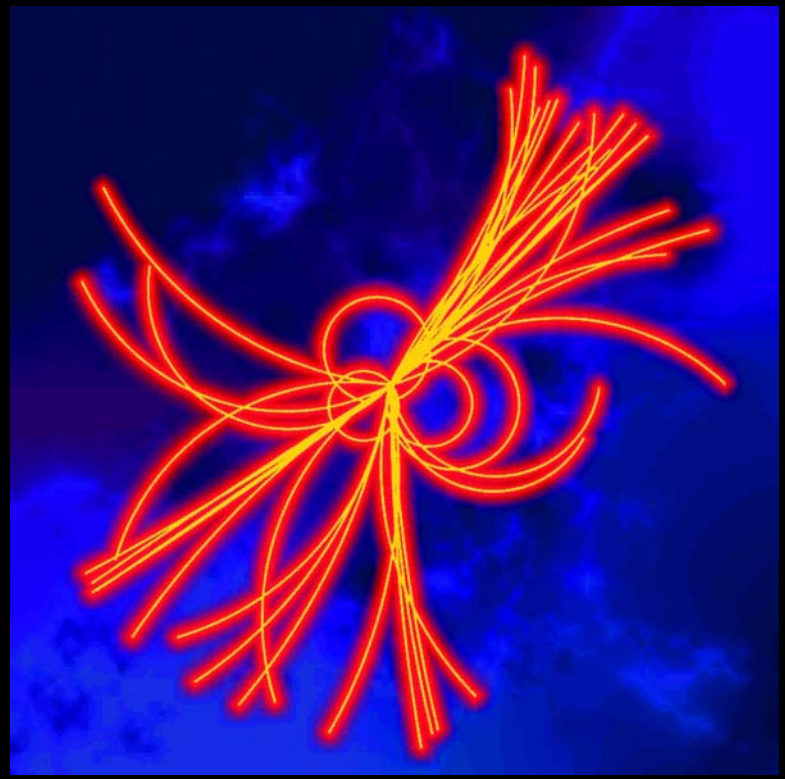


Example Signal

M_H = 130 GeV

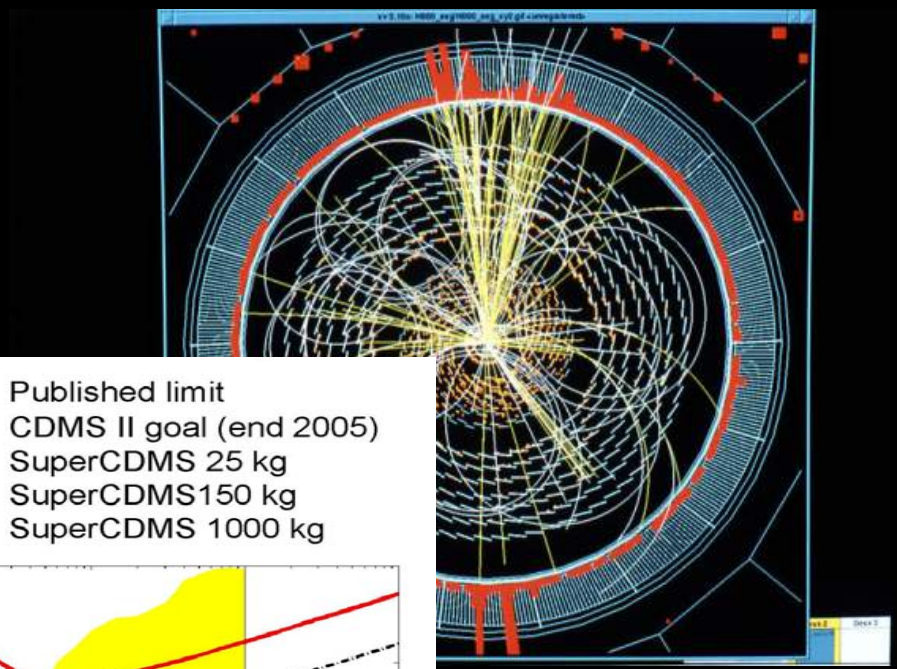
LHC/ILC: CP violation

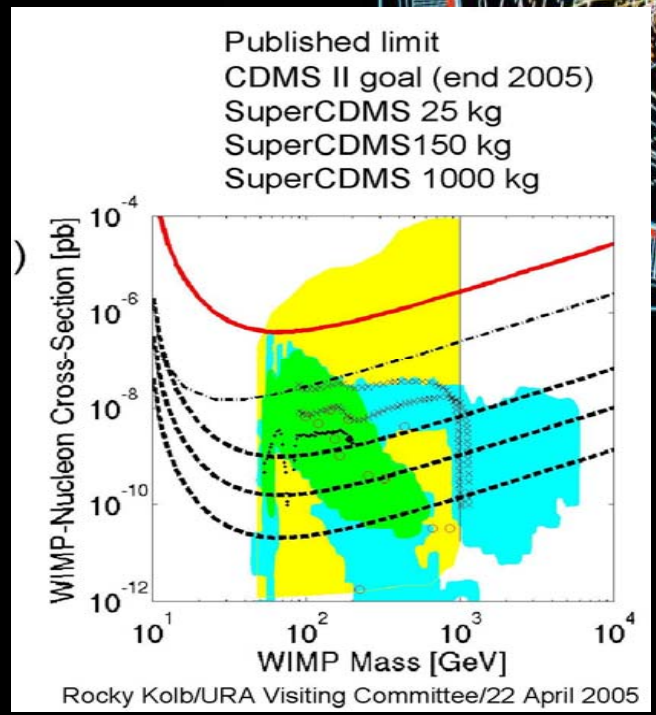
- From decays of Higgs, ILC experiments discover a new source of CP violation (e.g. angular correlations to specific decays)
- Solves the mystery of why matter dominates over antimatter



LHC/ILC physics: dark matter

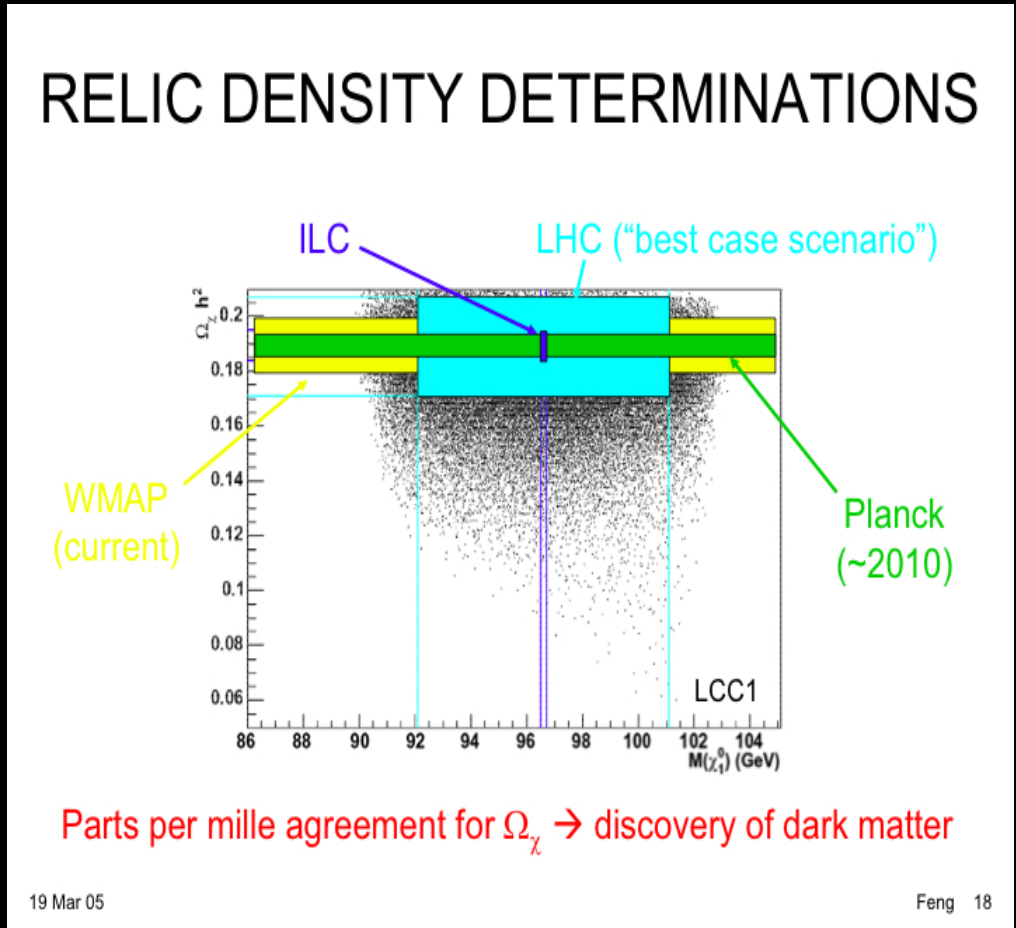
- CDMS detects WIMPS from the galactic halo
- LHC discovers a neutralino
- Dark matter?





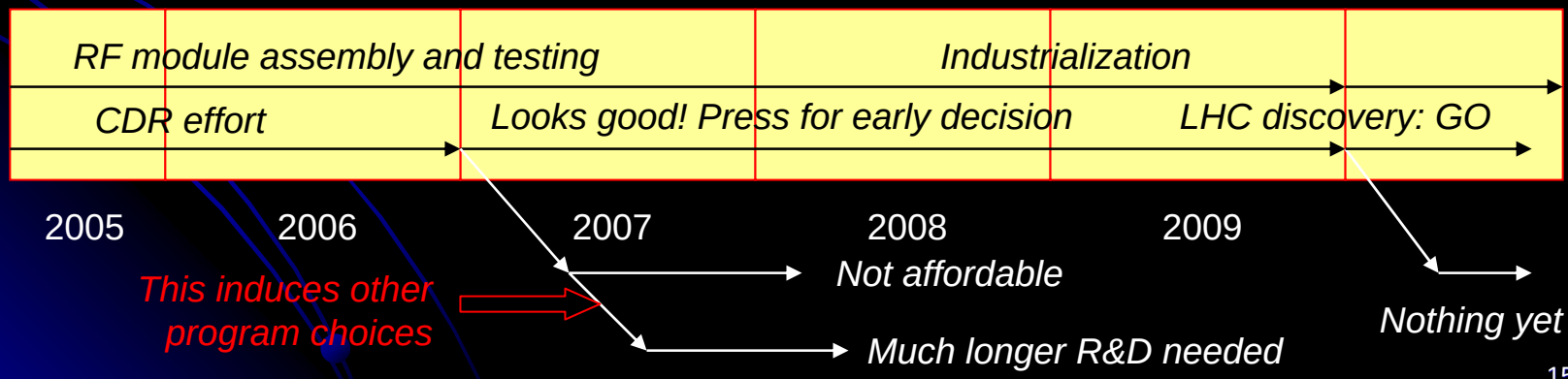
LHC/ILC Physics: dark matter

- ILC sparticle measurements determine relic density
- Show that the neutralino really is dark matter
- And discover that it is only 2/3 of the total!



ILC Research and Development

- Most critical need: establish world class expertise in SC RF technology in the US: human and physical resources
- Facilities at Fermilab: buildings exist, need to beef up infrastructure (power,cryo,RF) for cryomodule assembly and testing.
- Integrate this work into global effort.

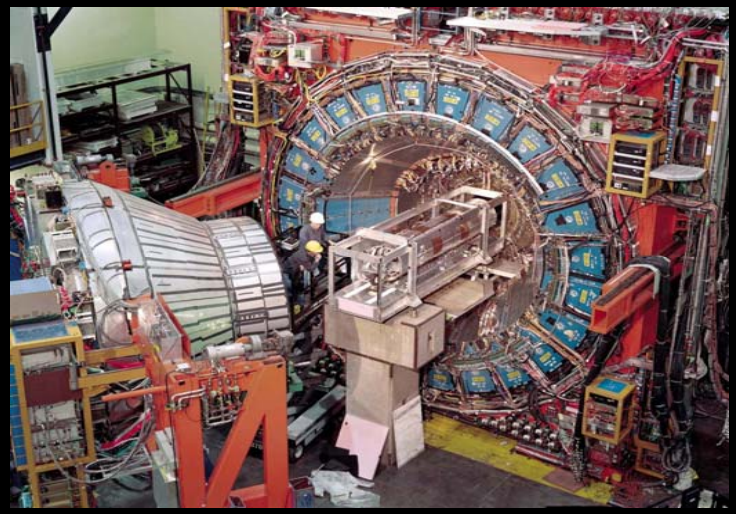


While we develop the ILC….

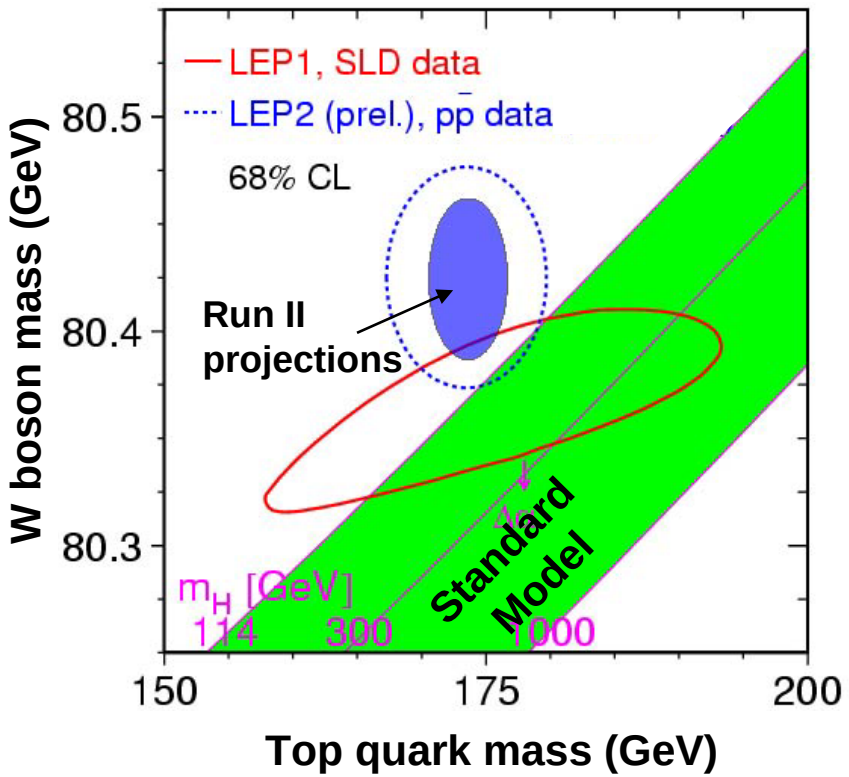
- We must deliver on our “ships of the line”:
  - The Tevatron Program: CDF and D0
  - LHC and CMS
  - The neutrino program: Minos and MiniBoone
- and maintain scientific vitality with a diverse program that includes:
  - Particle astrophysics
  - Theory and computing
  - Technology development

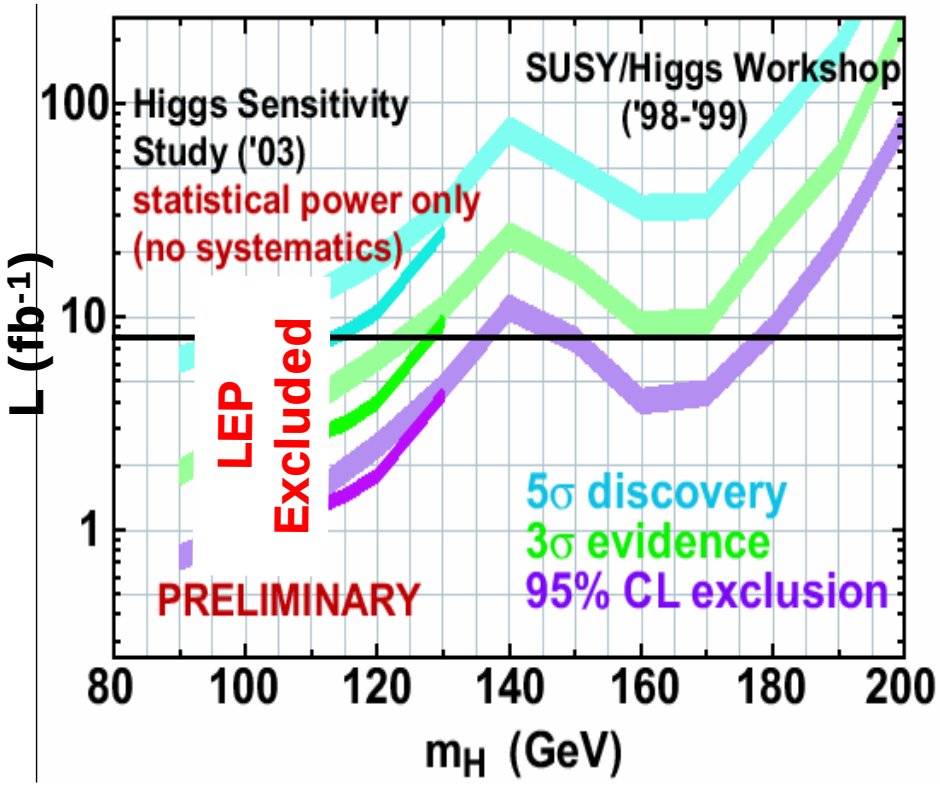
Tevatron Program

- Greatest window into new phenomena until LHC is on
- 1500 collaborators, 600 students + postdocs
- Critically dependent on Luminosity
- Doubling time a major consideration



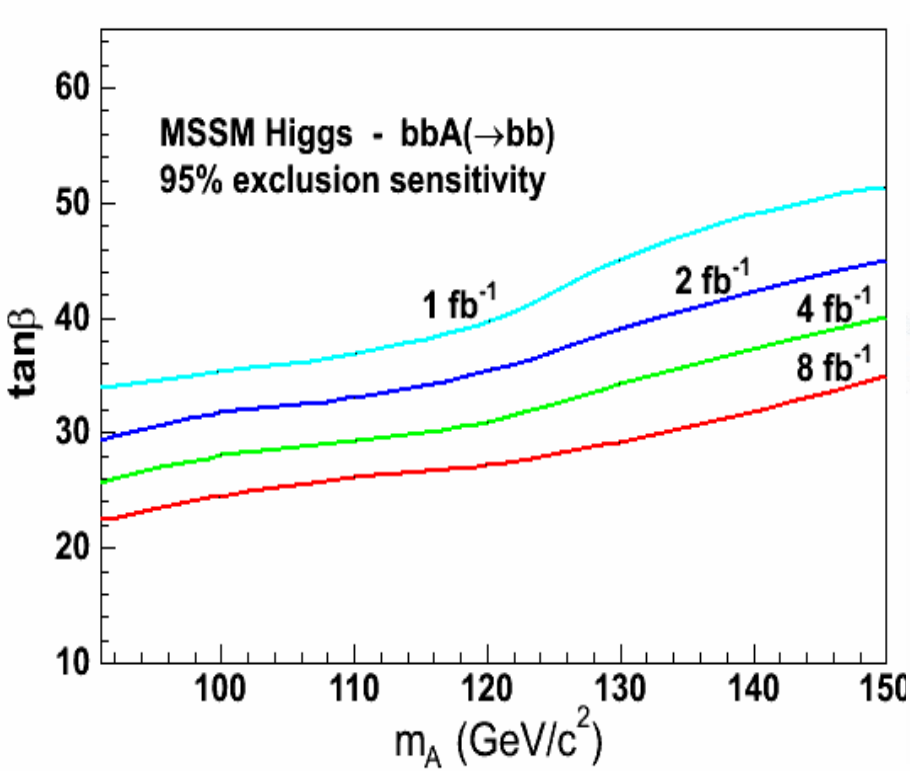
Closing in on the the SM Higgs

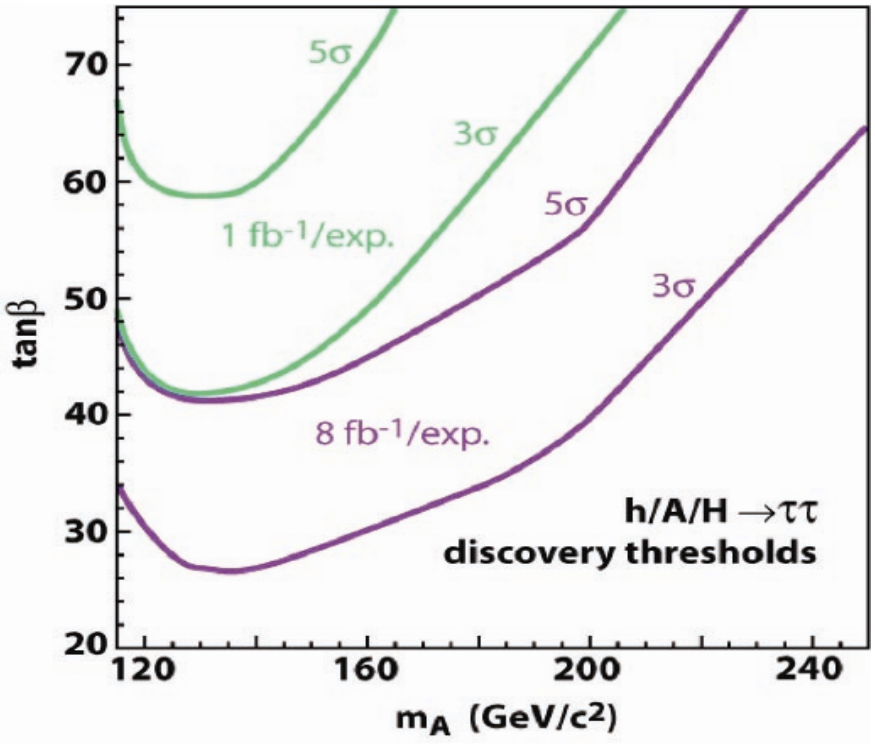




- Sensitivity to low mass Higgs, or
- Severely constrain mass

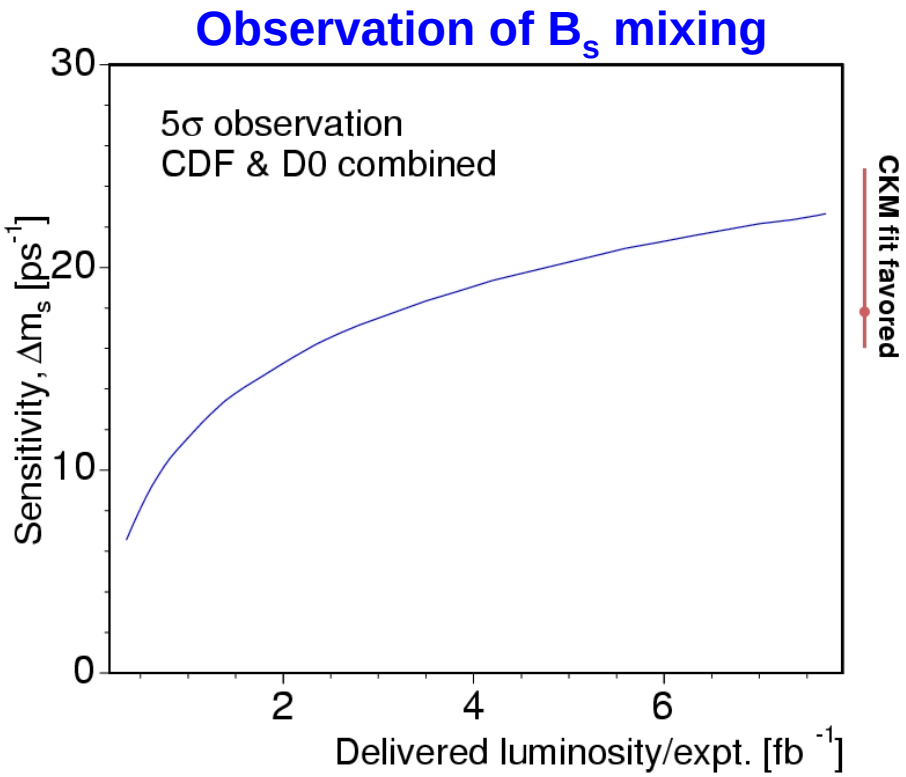
And the non-SM Higgs

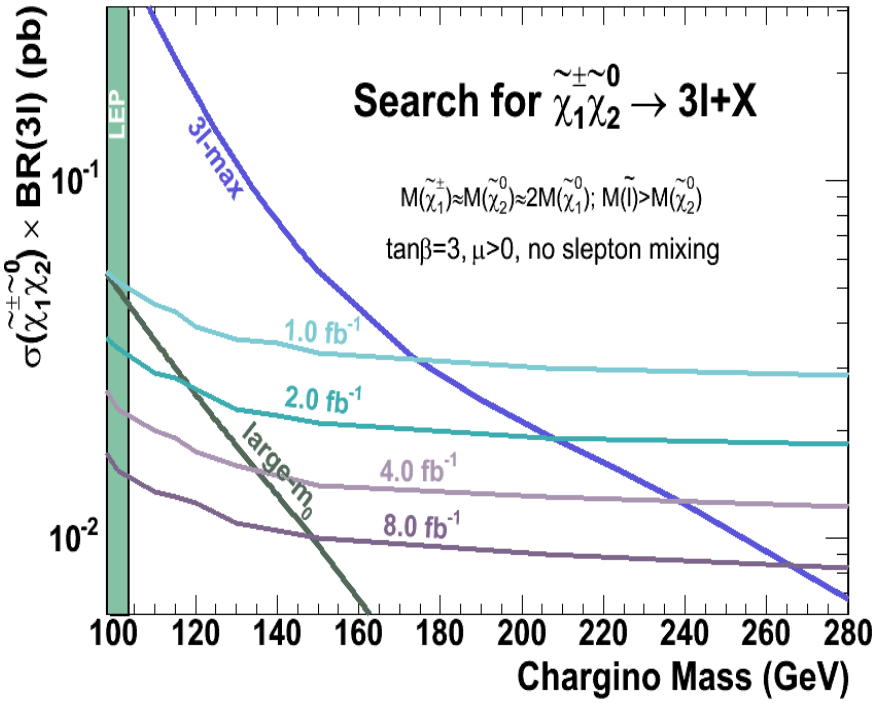




Explore the majority of allowed parameters for the lightest supersymmetric Higgs

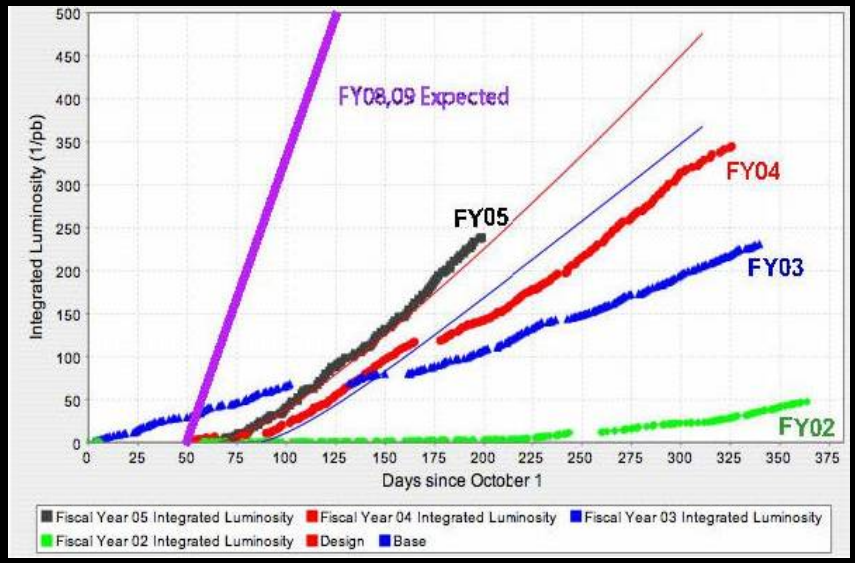
Other Windows to New Physics



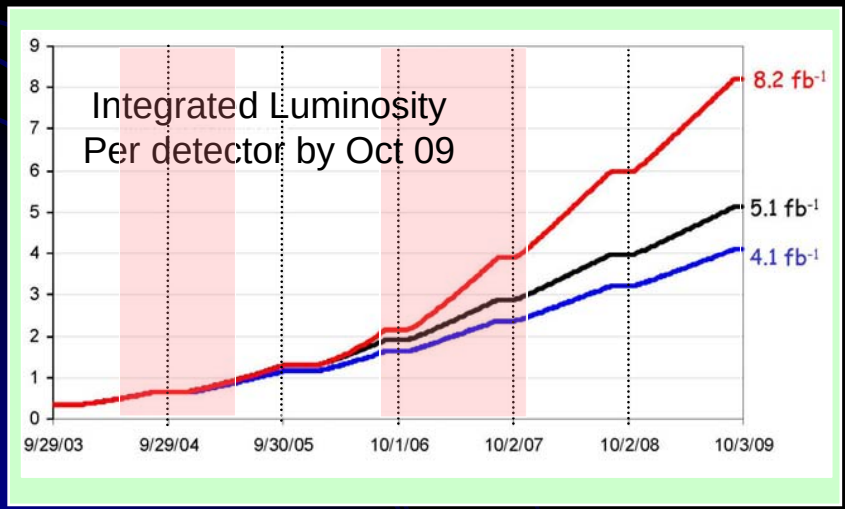


- Discovery Potential over most of B_s mixing expected region
- SUSY Chargino Sensitivity to 270 GeV!

Tevatron: key is luminosity



Luminosity history
for each fiscal year



Integrated luminosity
for different assumptions

Top Line: all run II upgrades work

Bottom line: none work

(pink/white bands show the doubling times for the top line)

LHC: delivering on the promise

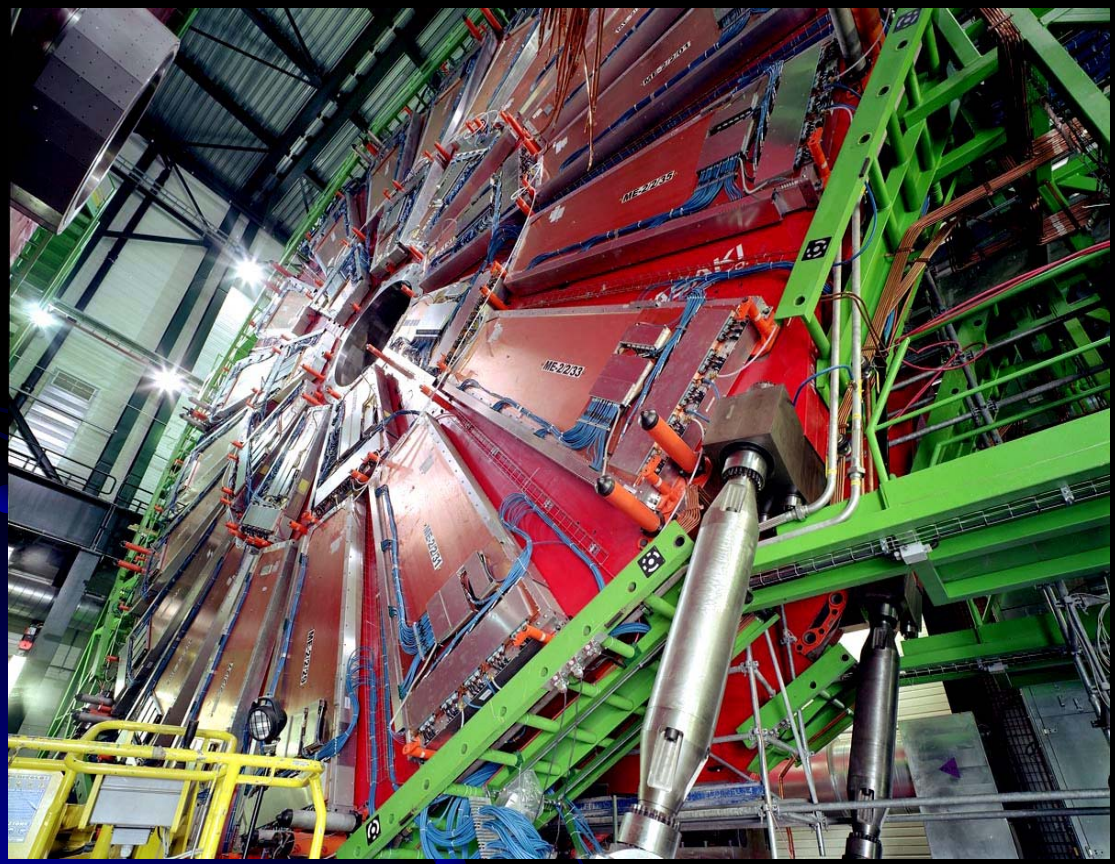
- Huge increase in physics reach: 7 times the energy, 100 times the luminosity of the Tevatron
- US Construction Collaboration has been successful: Fermilab + LBNL + BNL.
- With increase in energy and luminosity come special challenges (e.g., 300 Megajoules of stored energy in the beam!)

LHC: delivering on the promise

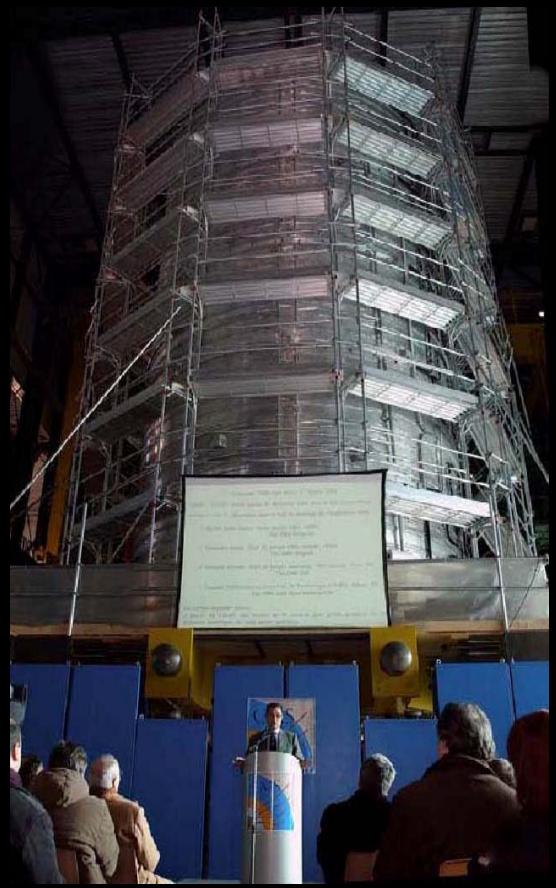
- US LHC Accelerator R&D Program = LARP: Fermilab + LBNL + BNL +SLAC
  - Commissioning: bring huge FNAL experience to LHC
  - Technology for upgrades: once again, luminosity will be key
- FNAL will have presence at CERN but also develop remote “operations” center at FNAL.
- Important step in the development of future “global” machines like the ILC

CMS: Compact Muon Detector

- Coming together: aimed at completion by end of 2007



Muon detectors



Magnet cold mass

CMS: Compact Muon Detector

- US collaboration doubled in the last three years

>300 Collaborators

41 Institutions

US CMS: and Fermilab's role

- Only major US lab associated with CMS: a central support role for the US community
- This was the case during construction
- Attention now to huge data and physics discovery challenge: the LHC Physics Center (LPC)

Summary for LHC and CMS

- Fermilab will be a vital partner to CERN in making the LHC and CMS a success

- Our ambition is to contribute with:
  - Presence at CERN as necessary
  - Remote control/monitoring/data centers at Fermilab for both accelerator and detector(s)
  - Technical support and critical mass: such that being at FNAL will be nearly “as good” as being at CERN for all our University partners!

Present Neutrino Program

Minos Far detector

Minos near detector

- MINOS program is just starting:

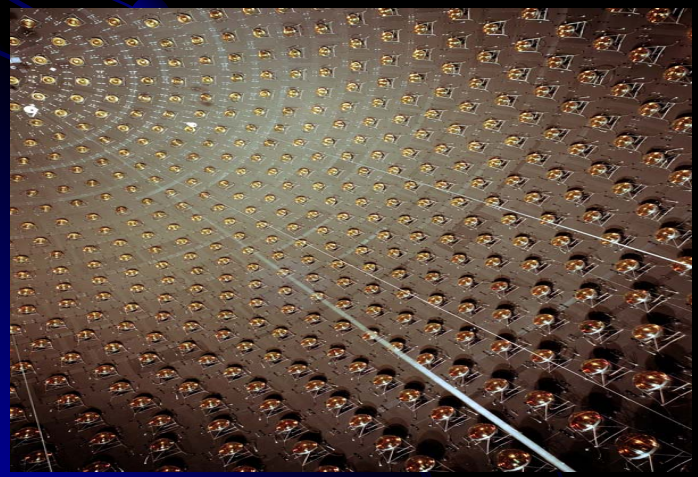
  - 2 GeV neutrinos

  - 5.4 Kiloton far detector and 1.0 Kiloton near detector

  -Most precise measurements in the atmospheric region

  -ν_μ disappearance

Present Neutrino Program



- MiniBooNE

  - 1 GeV neutrinos (Booster)

  - 800 ton oil cerenkov

  - Operating since 2003

  - $\nu_\mu \rightarrow \nu_e$ appearance

  - first results this fall: all hell will break loose if positive signal

New Initiatives: neutrinos

- Understanding the Neutrino matrix:
  - What is $sin^2 2\theta_{13}$
  - What is the Mass Hierarchy
  - What is the CP violation parameter δ
- Fermilab is in the best position to make vital contributions to answer these questions

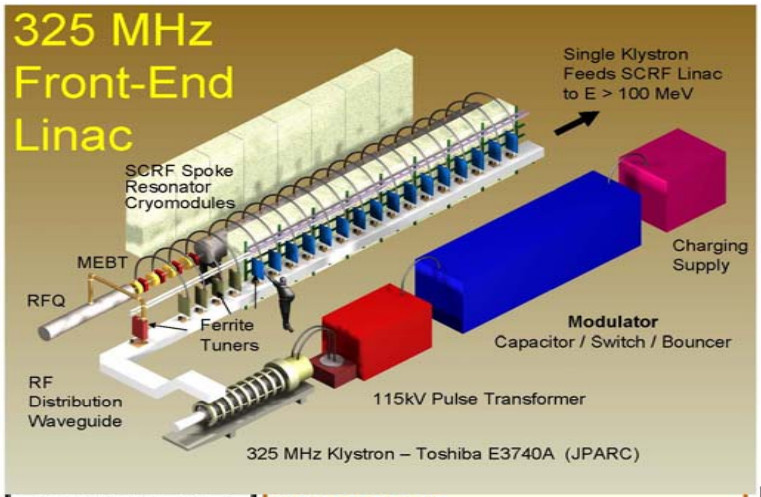
New Initiatives: neutrinos

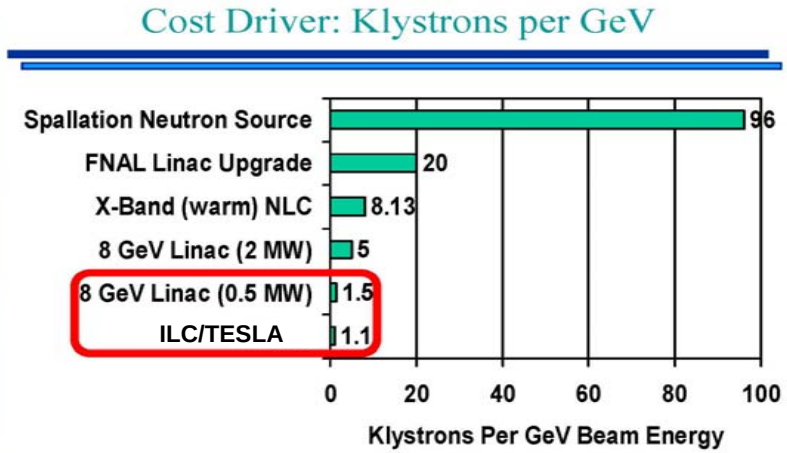
- Most powerful beam in the world at 200 KW
- Upgrades (by 2008) would give 440 KW
- When we stop the Tevatron, we'll have 600+ KW, the same as JPARC after 2010+
- Further improvements: aimed at 2 MW proton beam power

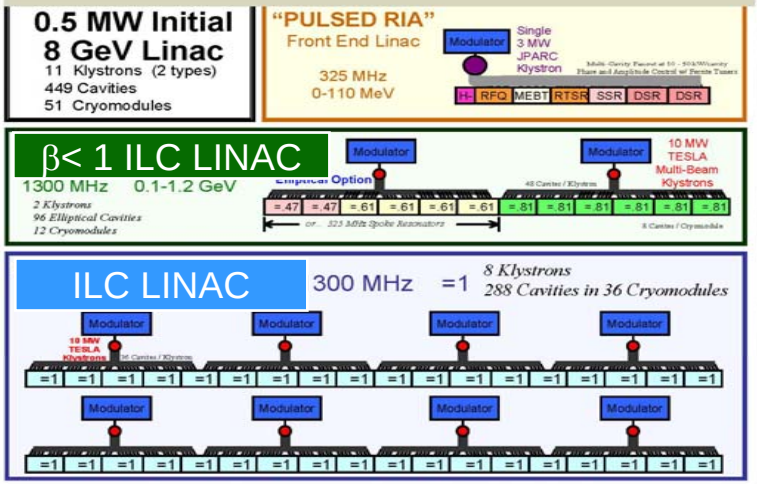
Neutrino Program: accelerators

- Develop Proton Driver
  - R&D helps develop base of SC RF technology
  - Extremely flexible operations = much simplified complex
  - Accelerator energy is 2% of ILC
- Also develop alternatives
  - No Tevatron means we have recycler, accumulator and debuncher to play with
  - We have VERY EARLY creative ideas on how to deliver 1-2 MW at 120 GeV.

Neutrino Initiative – Proton Driver



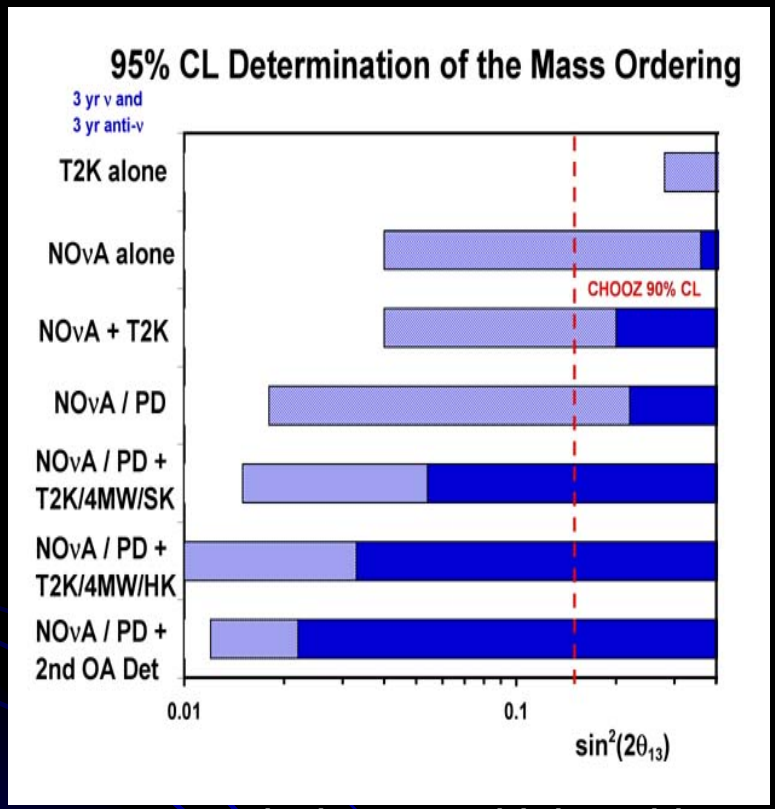




Neutrino Initiative: NOvA

- In addition to Beam power: detector mass and detector sensitivity: NOvA is 30 ktons, totally active
- NOvA is the only experiment sensitive to matter effects (hence the mass hierarchy).
  - We want to start a long term R&D program towards massive totally active liquid Argon detectors for extensions of NOvA.
  - Improvement is proportional to (Beam power) x (detector mass) x (detector sensitivity)

Neutrino Initiative: Physics Reach

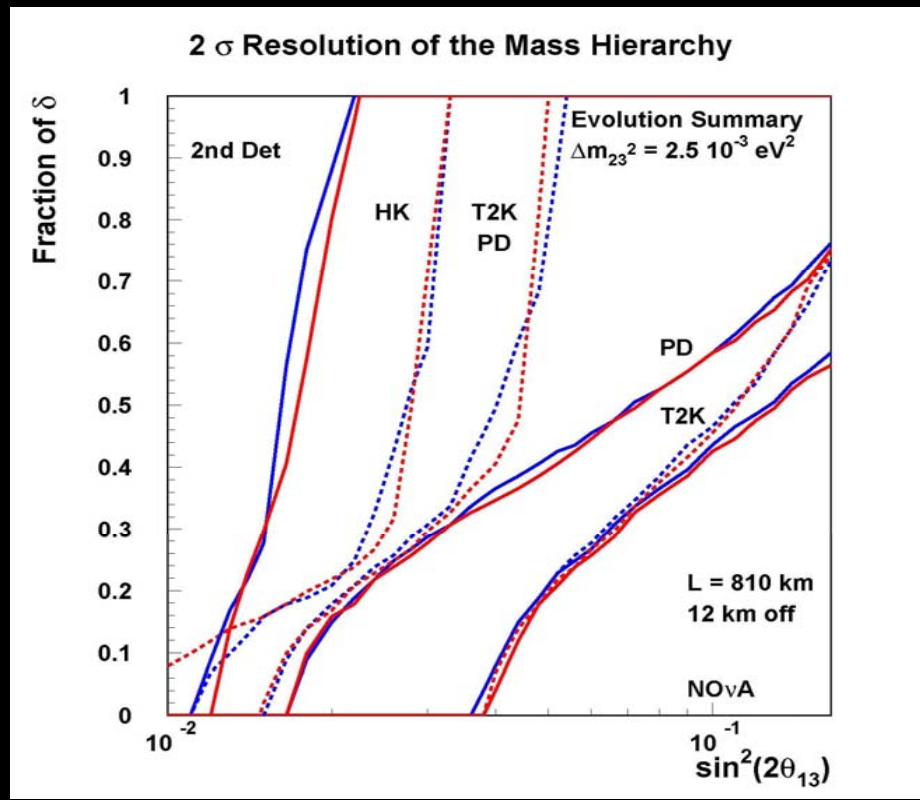


Mass ordering sensitivity with several evolutionary paths

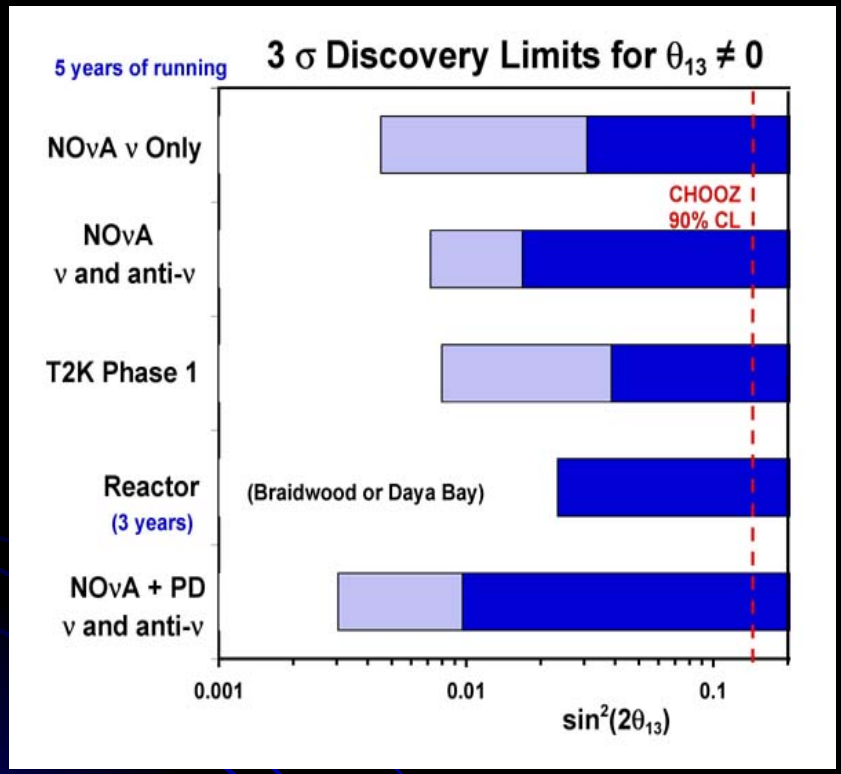
Sensitivity for some values of δ

Sensitivity for all values of δ

NOvA sensitivity as other experiments (T2K,HK) or accelerators (PD) are added

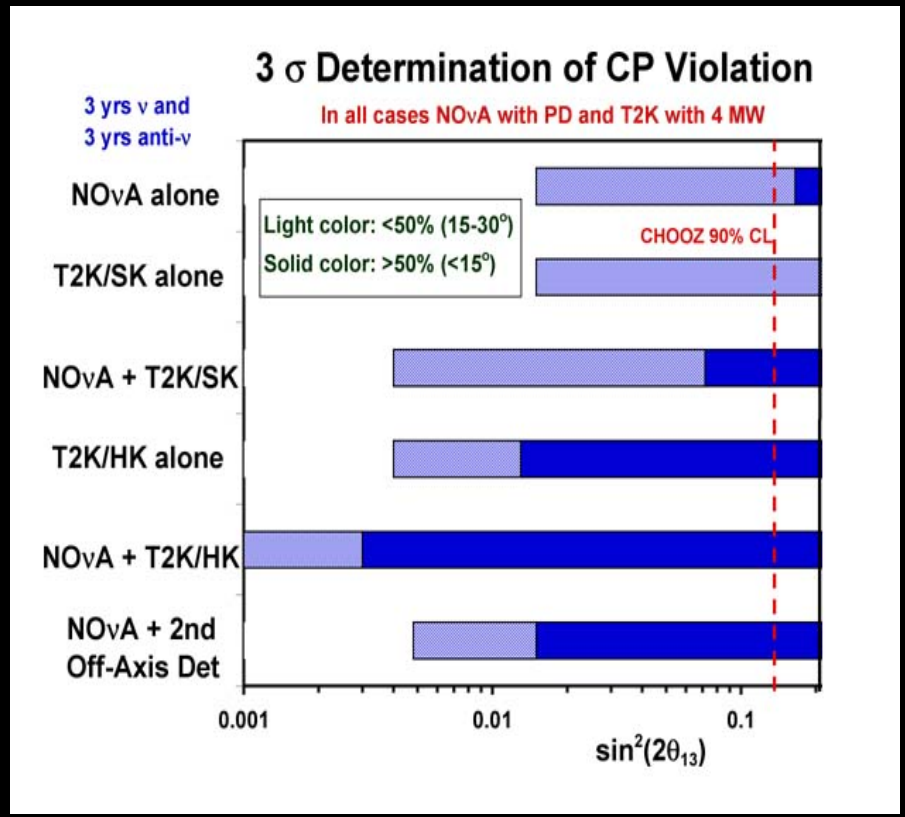


Neutrino Initiative: Physics Reach

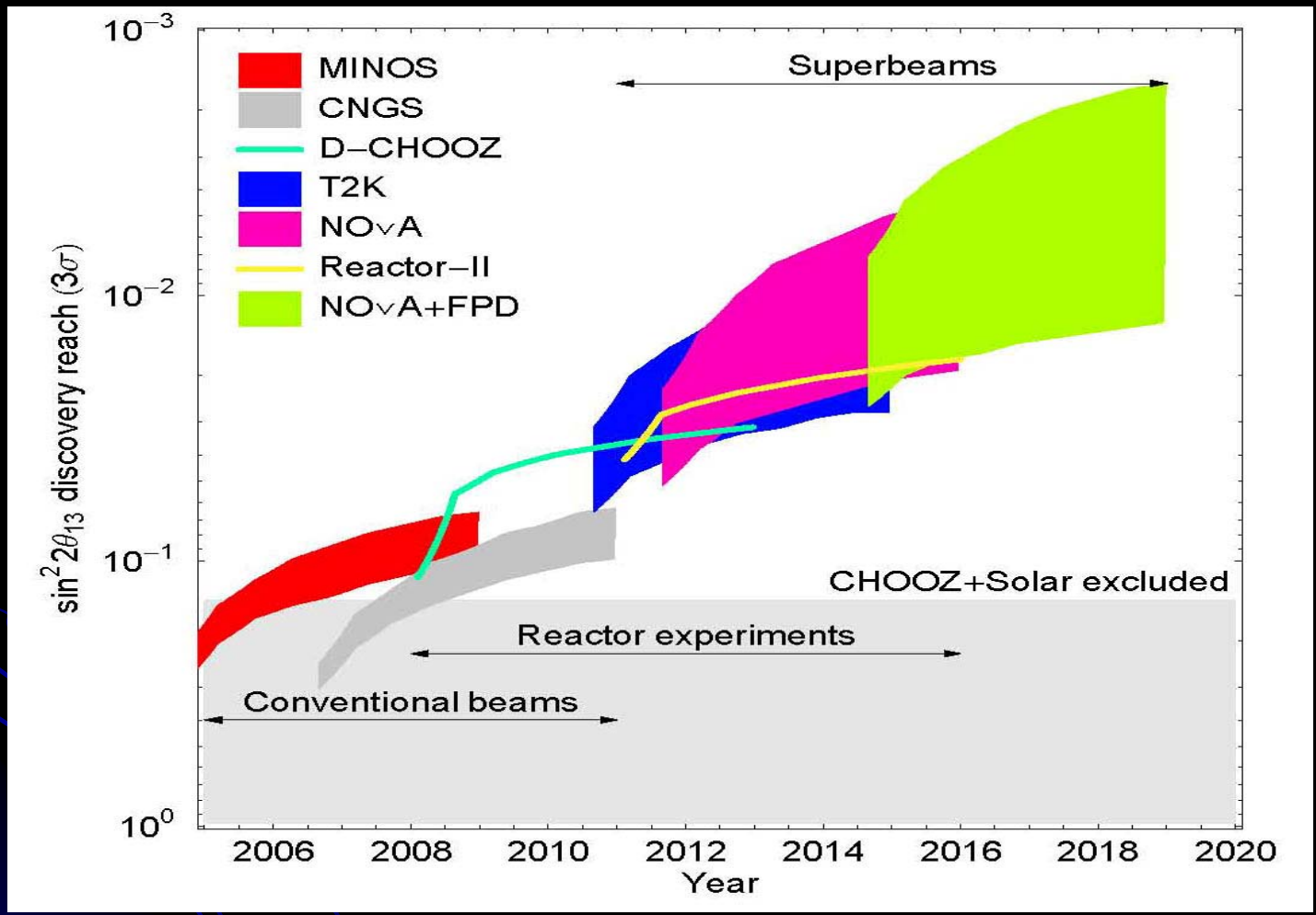


θ_{13} { Sensitivity for some values of δ / Sensitivity for all values of δ

CP violation reach for evolutionary path

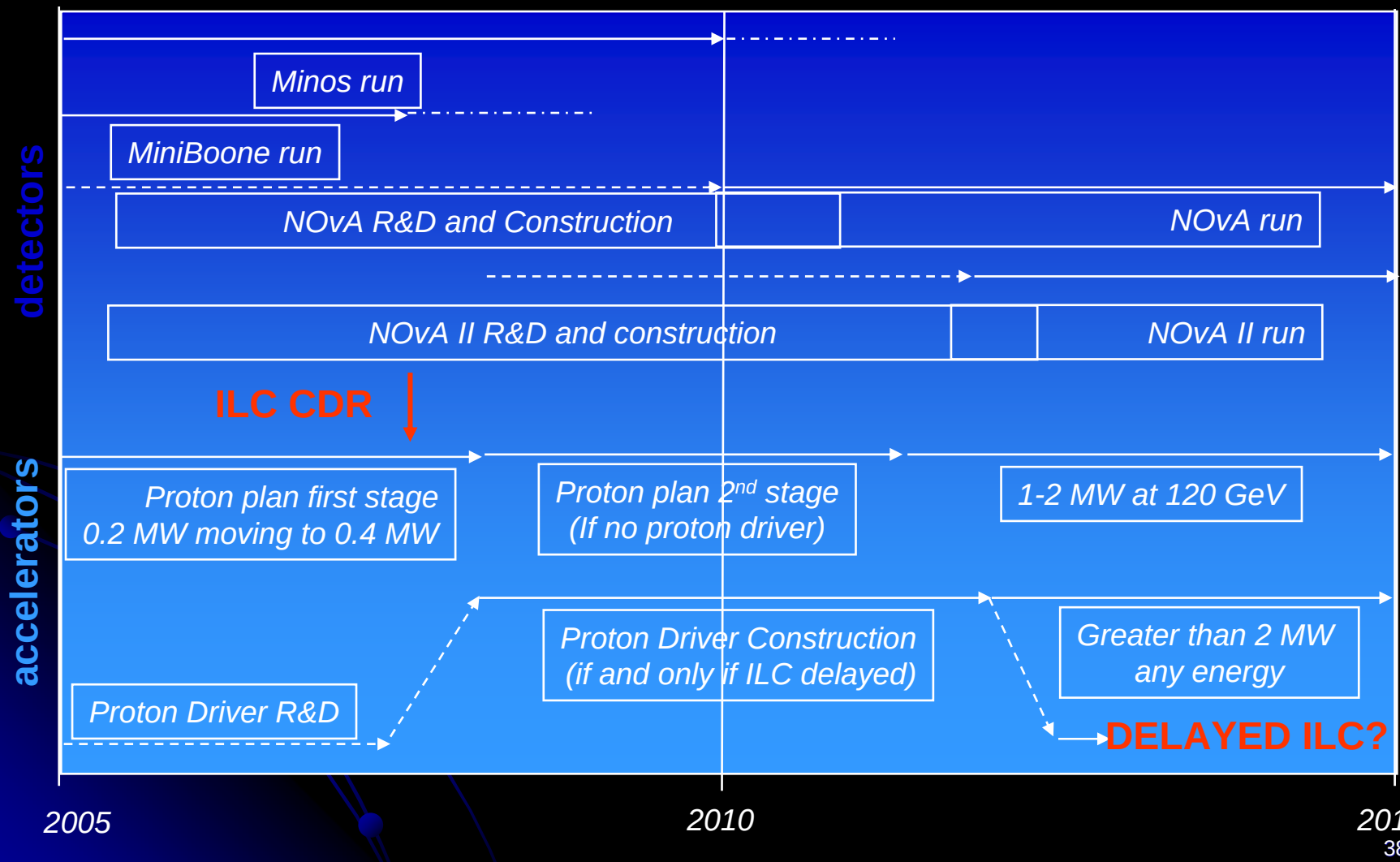


Neutrino Initiative: Physics Reach



A possible evolution of the neutrino world program

Neutrino Program (delayed ILC)



Interlinked Roadmap

- The immediate decisions are: NOvA, and support of ILC R&D and proton driver R&D
- Options get looked two years down the line after ILC CDR: decision to go for early ILC decision precludes proton driver
- LHC input will determine branch points at the end of the decade

Interlinked Roadmap

- Establishes the main trunk and branches for the laboratory.
- It supports a vital role for the US community in the global program
- Requires “strong focusing” now, which narrows the program….
- But it establishes the strong base on which breadth and “texture” can flourish as we move forward.