Fermilab Steering Group

develop roadmap

for accelerator-based HEP program at Fermilab

Young-Kee Kim
Fermilab / University of Chicago

SLAC Users Organization Annual Meeting
June 7, 2007
Energy Frontier Physics at FNAL: Tevatron
Large Hadron Collider
International Linear Collider R&D
Tevatron: close to 2 publications / week

with 0.5 – 1 fb⁻¹

Distance Scale - 10⁻¹⁹ m

B_s−̅B_s Oscillation
Discovery +
Precision Meas.

M_W ~0.05%

M_top ~1%

M_{Higgs} < 144 GeV
at 95% CL

Road to the Higgs!

Total Inelastic
jets (qq, qg, gg)

W
Z

WZ, Single Top, ZZ

Higgs

WH, ZH

jets (qq, qg, gg)

Higgs Mass [GeV/c²]

Low Mass SUSY

100 120 140 160 180 200

σ

mb

μb

nb

pb

fb

observed

100 120 140 160 180 200

Higgs Mass [GeV/c²]
Energy Frontier Physics at FNAL: Tevatron
Large Hadron Collider
International Linear Collider R&D

Integrated Luminosity (pb⁻¹)

FY02 FY03 FY04 FY05 FY06 FY07
Shutdown Shutdown Shutdown

Integrated Luminosity (L/pb)
Energy Frontier Physics at FNAL: Tevatron
Large Hadron Collider (CERN)
International Linear Collider R&D

LHC Accelerator: a leading US institution
CMS: CMS Host Institution → Support US community

Remote Operations Center
Tier-1 Computing Center
LHC Physics Center
Energy Frontier Physics at FNAL: Tevatron
Large Hadron Collider

International Linear Collider R&D

Consensus of HEP Community: ILC is next accelerator.
Highest Priority at FNAL

Detector R&D:
- Vertex Detector
- Muon, Calorimeter

Accelerator R&D:
- Main Linac
- Civil/Site Development
together with ILC institutions

Detector Test Facility (upgraded Fall 2006) for General Use

Accelerator Test Facility (existing building)
Neutrino Physics at FNAL:

MiniBooNE, SciBooNE with 8 GeV Booster protons
MINOS, MINERvA, NOvA with 120 GeV Main Injector protons
Neutrino Physics at FNAL:
MiniBooNE, SciBooNE with 8 GeV Booster protons
MINOS, MINERvA, NOvA with 120 GeV Main Injector protons

Neutrino Oscillation: MiniBooNE, MINOS, NOvA

Neutrino Cross Sections: SciBooNE, MINERvA
Important, yet not very well understood
Accelerator Physics Center

• Launched on June 1, 2007. Led by Vladimir Shiltsev

• R&D aimed at future generations of accelerators

• Educate and train next generation of accelerator scientists and engineers
  • So far, Fermilab has been supporting ~10 Ph.D. students at a given time
  • Enhance this effort
    • more Ph.D. students, undergraduate programs

• Engage university community in accelerator research
Center for Particle Astrophysics

- Theory
- Computational cosmology
- Sloan Digital Sky Survey
- Pierre Auger Observatory
- Cold Dark Matter Search CDMS
- Cold Dark Matter Search COUPP
- Dark Energy Survey
- Supernova Acceleration Project (SNAP) R&D

- World class limits of direct dark matter detection
- SDSS, in combination with WMAP, achieves most precise measurement of cosmological parameters
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”
2006-7 extraordinary years for Particle Physics at FNAL! Much more expected in the near future.

Planning Farther Ahead:
Fermilab will be solely devoted to Particle Physics.
EPP 2010 Recommendations

1. LHC
2. ILC Global
   ILC Hosting
3. Particle Astrophysics
4. Global Neutrino Program
5. Quark Flavour Physics
P5 Recommendations

• LHC and ILC are highest priorities.
• FY08 - run Tevatron and PEP II and start:
  – Dark Energy Survey (DES)
  – Cold Dark Matter Search Super CDMS-25kg
  – NOvA long baseline neutrino program
  – Daya Bay reactor neutrino experiment
• Longer term - prepare SNAP and LSST
P5 Recommendations (Fermilab)

• **LHC** and **ILC** are highest priorities.
• FY08 - run **Tevatron** and PEP II and start:
  – **Dark Energy Survey (DES)**
  – **Cold Dark Matter Search Super CDMS-25kg**
  – **NOvA long baseline neutrino program**
  – Daya Bay reactor neutrino experiment
• Longer term - prepare **SNAP** and LSST

ILC assumption - early start
Sustain rigorous ILC activities over a possibly longer period. Alternative discovery opportunities that might be needed. Prepare colliders beyond the ILC / LHC.
Fermilab Director Pier Oddone formed Steering Group to develop roadmap for Fermilab’s accelerator-based HEP program. March 22, 2007

Deadline for final report
August 1, 2007
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 Membership

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eugene Beier</td>
<td>U. Penn</td>
</tr>
<tr>
<td>Joel Butler</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Sally Dawson</td>
<td>BNL</td>
</tr>
<tr>
<td>Helen Edwards</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Thomas Himel</td>
<td>SLAC</td>
</tr>
<tr>
<td>Steve Holmes</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Young-Kee Kim (chair)</td>
<td>Fermilab / U.Chicago</td>
</tr>
<tr>
<td>Andrew Lankford</td>
<td>UC Irvine</td>
</tr>
<tr>
<td>David McGinnis</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Sergei Nagaitsev</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Tor Raubenheimer</td>
<td>SLAC</td>
</tr>
<tr>
<td>Vladimir Shiltsev</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Maury Tigner</td>
<td>Cornell</td>
</tr>
<tr>
<td>Hendrick Weerts</td>
<td>ANL</td>
</tr>
</tbody>
</table>
## Steering Group Membership

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eugene Beier</td>
<td>U. Penn</td>
</tr>
<tr>
<td>Joel Butler</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Sally Dawson</td>
<td>BNL</td>
</tr>
<tr>
<td>Helen Edwards</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Thomas Himel</td>
<td>SLAC</td>
</tr>
<tr>
<td>Steve Holmes</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Young-Kee Kim (chair)</td>
<td>Fermilab / U.Chicago</td>
</tr>
<tr>
<td>Andrew Lankford</td>
<td>UC Irvine</td>
</tr>
<tr>
<td>David McGinnis</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Sergei Nagaitsev</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Tor Raubenheimer</td>
<td>SLAC</td>
</tr>
<tr>
<td>Vladimir Shiltsev</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Maury Tigner</td>
<td>Cornell</td>
</tr>
<tr>
<td>Hendrick Weerts</td>
<td>ANL</td>
</tr>
</tbody>
</table>
Neutrino Physics

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eugene Beier</td>
<td>U Penn</td>
</tr>
<tr>
<td>Deborah Harris</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Ed Kearns</td>
<td>Boston Univ.</td>
</tr>
<tr>
<td>Boris Kayser</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Sacha Kopp</td>
<td>UT Austin</td>
</tr>
<tr>
<td>Andrew Lankford</td>
<td>UC Irvine</td>
</tr>
<tr>
<td>Bill Louis</td>
<td>Los Alamos</td>
</tr>
<tr>
<td>(Young-Kee Kim)</td>
<td>UChicago/FNAL</td>
</tr>
</tbody>
</table>

Flavor Physics

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joel Butler</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Brendan Casey</td>
<td>Brown</td>
</tr>
<tr>
<td>Sally Dawson</td>
<td>BNL</td>
</tr>
<tr>
<td>Chris Hill</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Dan Kaplan</td>
<td>IIT</td>
</tr>
<tr>
<td>Yury Kolomensky</td>
<td>UCBerkeley/LBNL</td>
</tr>
<tr>
<td>William Molzon</td>
<td>UC Irvine</td>
</tr>
<tr>
<td>Kevin Pitts</td>
<td>UIUC</td>
</tr>
<tr>
<td>Frank Porter</td>
<td>CalTech</td>
</tr>
<tr>
<td>Bob Tschirhart</td>
<td>Fermilab</td>
</tr>
<tr>
<td>Harry Weerts</td>
<td>ANL</td>
</tr>
<tr>
<td>(Young-Kee Kim)</td>
<td>UChicago/FNAL</td>
</tr>
</tbody>
</table>
Steering Group Activities

• Weekly Telephone Meeting (Kick-off meeting on April 2\textsuperscript{nd})
• Fact findings
  – EPP2010 and P5 assumptions
  – ILC R&D needs, needs as a host country / host laboratory
  – LHC Upgrades
  – Physics and Facility Opportunities: near, med, long term
    • Physics; $\nu$, $\mu$, K, p-bar, B, …
    • reconfiguring existing accelerator complex, and new facilities
• Formed 5 subgroups – analysis done through subgroups
• Reach out to community for input
• For all activities, we include
  – ILC GDE leaders, HEP / ILC program managers in DOE and NSF
  – Chairs of Fermilab/SLAC Users Executive committees
  – HEPAP Chair / Deputy Chair, P5 Chair
• Steering Group Webpage: publicly accessible by anyone
  – \texttt{http://www.fnal.gov/directorate/Longrange/Steering_Public/}
  – Agendas, presentations, minutes, documents, etc.
Subgroups

- **Oversight (additional constituents)**
  - To make sure that roadmaps being developed are consistent with EPP2010 and P5 recommendations (Mel Shochet, Jon Bagger, Abe Seidan, Sally Dawson)

- **Neutrino Physics (additional constituents)**
  - Develop roadmap for neutrino physics based on NuSAG studies

- **Flavor Physics: quarks, charged leptons, ... (additional constituents)**
  - Develop 10-year plan with reconfiguring existing accelerator complex

- **Accelerator Facilities (based on technical and resources feasibilities)**
  - Develop options of a roadmap that supports ILC R&D for early start, supports Fermilab as a potential host site, and provides an accelerator-based high energy physics program in case of delayed start

- **High Energy Colliders beyond the ILC**
  - Develop steps necessary to explore higher energy colliders that might follow ILC or be needed should results from LHC point toward a higher energy than that planned for ILC.
### Tentative Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 – 12:00</td>
<td><strong>Energy Frontier</strong>&lt;br&gt;ILC: What is needed for early decision and construction?&lt;br&gt;LHC accelerator upgrades&lt;br&gt;R&amp;D steps for colliders beyond ILC and LHC</td>
</tr>
<tr>
<td>1:00 – 2:30</td>
<td><strong>Intensity Frontier - Protons</strong>&lt;br&gt;Reconfiguration of the existing accelerator complex&lt;br&gt;Toward higher intensity proton sources</td>
</tr>
<tr>
<td>2:30 – 3:30</td>
<td><strong>Luminosity Frontier - Electrons</strong>&lt;br&gt;Super B factory, Giga-Z</td>
</tr>
<tr>
<td>4:00 – 600</td>
<td><strong>Sketching Possible Roadmaps</strong></td>
</tr>
<tr>
<td>6:00 – 6:30</td>
<td><strong>Discussion for Final Report Writing</strong></td>
</tr>
<tr>
<td>7:00 – 9:00</td>
<td><strong>Dinner Discussion</strong></td>
</tr>
</tbody>
</table>
Example of Possible Fermilab Roadmap

Energy Frontier:
- Tevatron Running
- Tevatron Physics
- LHC
- LHC Upgrade
- ILC EDR + R&D
- ILC System Test
- 1-2 RF Units
- Beyond ILC/LHC Reach: R&D for higher energy lepton and hadron colliders

Intensity Frontier: High Intensity Protons
- ν beams from Booster, Main Injector protons
  - MiniBooNE, SciBooNE, MINOS, MINERvA, NOvA
- ν, μ, K, p beams
- Reconfiguring Accelerator Complex
- 2 GeV + 6 GeV Linac + Recycler + Main Injector
- Running
- ILC Cryomodules
  - (Cavities, Couplers, …)
  - ILC RF Distribution
- Running
ILC Style 6 GeV Linac → High Intensity Proton Sources

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

Recycler
3 linac pulse/fill
Stripping Foil

Main Injector
1.4 sec cycle

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

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

Single turn transfer @ 8 GeV