The Coming Particle Physics Revolution
FNAL Long Range Plan:
Progress Report

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(From) Charge to the FNAL Long Range Planning Committee

• The committee should develop scenarios for each of the two cases spelled out by the HEPAP Subpanel.

  – A linear collider project will be built here, starting late in this decade with international support and organization.

  – The linear collider will be built offshore with substantial participation from U.S. High Energy Physics.
Membership

- Hugh Montgomery (Chair)
- Steve Holmes (Deputy)
- Jeff Appel
- Joel Butler
- Marcela Carena
- Josh Frieman
- Steve Geer
- Chris Hill
- Bob Kephart
- Sergei Nagaitsev
- Jim Strait
- John Womersley
- Gary Feldman, Harvard
- Young-Kee Kim, Chicago
- Peter Meyers, Princeton
- Angela Olinto, Chicago
- Ritchie Patterson, Cornell
Chronology

- January, February, 2003
  - Committee approached, charge drafted and circulated
- Spring and Summer, 2003
  - Sub-committees formed, programs of presentations in committee and discussions
  - Layout of report discussed, space assigned
- Fall, 2003
  - Open Sessions
  - Drafts of sections of the report
  - Plenary Meetings
- January 9,10 ----
  - Retreat
- January- February 2004
  - Circulate Drafts of sections and complete report
- February-March 2004, converge, make presentations

- March-April, complete report (Exec Summary + Rep. ~75 pages)
Current Fermilab Accelerator Complex

• Present Local Accelerator Based Physics Program:
  • Tevatron: CDF, D0 → BTeV
  • Booster: MiniBooNE
  • Main Injector: NuMI-MINOS
  • Main Injector: E907(MIPP), E906(Drell-Yan), (Kaons)

  – Energy Frontier, Discovery
  – Strong Neutrino Component
  – Strong Quark Flavor Component
  – QCD

• Provides Basis for Future Flexibility
• Provides Ability to respond to Physics demands

We are regularly receiving proposals
Program lasts into next decade
Coming Revolution in Particle Physics

- The standard model is starting to give way to something new.
  - neutrinos have mass and mixing
    - window on a new phenomenon at the Grand Unification Scale?
  - Tevatron?, LHC, will pull back the curtain on the origin of mass, or electroweak symmetry breaking,
    - SUSY?
    - Strong Dynamics
    - Extra Dimensions
Coming Revolution in Particle Physics

• new physics questions
• exploration of new worlds:
  – A new world of phenomena at the electroweak symmetry breaking scale and beyond;
  – A new world of neutrino masses and mixings, which may address the matter-antimatter asymmetry of our universe;
  – A new world of cosmological and particle astrophysics.
• new ways of working
• new connections
Vision I: FNAL hosting Linear Collider

• Linear Collider under construction near Fermilab
  – Fermilab at the center of future discoveries and understanding
  – Major part of Lab activity

• Neutrino Program
  – Based on improvements to the accelerator complex and the experiments over the next ten years

• Large Hadron Collider Program
  – Accelerator and experiment: Fermilab leading center for CMS physics

• Other experiments at FNAL
  – As physics demands
  – Quark Flavor may still be key
  – Other programs

• Astroparticle physics, Accelerator R&D

• Non-particle science
Vision II: FNAL with Linear Collider Offshore

- **Fermilab Neutrino Program**
  - World leading long baseline program
  - New accelerator: Proton Driver

- **Linear Collider offshore**
  - Significant Lab resources in this activity

- **Large Hadron Collider Program**
  - Accelerator and experiment: Fermilab leading center for CMS physics

- **Other experiments at FNAL**
  - As physics demands
  - Quark Flavor may still be key
  - Other programs

- **Astroparticle physics, Accelerator R&D**

- **Non-particle science**
The Linear Collider

• Physics of Electroweak Symmetry breaking
  – Elucidation of Higgs field/particle
    • What are its couplings to different fermions
  – New degrees of freedom
    • SUSY
    • Extra Space Dimensions
  – Precision discrimination between candidate descriptions
  – Detection and identification of dark matter

• A window to even higher energies

• Exciting Physics of the highest quality
Linear Collider Status

- International Linear Collider Steering Committee under ICFA
  - Regional Committees
- Governance documents complete or in draft.
- US LC Accel Committee has completed study of Cold & Warm options “as if sited in US”, not yet released.
- Technologies
  - R1s supposed to be resolved this year
    - Power distribution was met in December for warm.
- Technology Choice
  - Committee in place,
  - 1st Meeting in UK in January.
  - Report by end of 2004
Linear Collider Actions

• Fermilab should initiate efforts to coordinate development of design studies for both warm and cold ETFs, in collaboration with international partners, with a goal of siting the ETF for the chosen technology at Fermilab.

• It is imperative that Fermilab prepare a bid to host the electron-positron Linear Collider
  – With Broad US LC accelerator collaboration

• The challenge is worthy of Fermilab.

• Fermilab planning should be based upon the host laboratory/international project model.
Neutrinos

- Neutrinos appear to mix, to have mass
  - Some explanations of light neutrino mass involve heavy states “at the GUT scale”

- Pattern of observations is not understood
  - Intrinsically exciting

- Assume three flavors (doesn’t fit the data but….)
  - Mass Hierarchy? CP Violation
    - Matrix Element $\theta_{13}$
      - $\nu_e$ appearance
      - Matter effects
    - Different experiments have sensitivity to different aspects
      - Reactor, JPARC to SuperK are sensitive to just magnitude of $\theta_{13}$
      - NuMI baseline and energy $\rightarrow$ sensitivity to
        - magnitude of $\theta_{13}$
        - Mass hierarchy
        - CP violation
Neutrinos

• Neutrinos
  • Fermilab’s capabilities provide unique opportunity
  • neutrino physics forms an exciting program
  • Fermilab should pursue vigorously

• Intense Neutrino Beams
  • a superconducting linear accelerator or new synchrotron
    plus Main Injector improvements

• Prepare CDR for SC LINAC + Mission Need (CD0) for Proton Driver
Proton Driver – SC Linac

March 13, 2004
URA Visiting Committee
Large Hadron Collider

• Role commensurate with the size of Fermilab
• CMS Physics Analysis Center
  – A (or perhaps The) place to do physics
  – Enhance US physics potential
  – Improve return on investment
  – (some) resources have been planned, the trick is to make it happen
• Phenomenology
• Detector Development for higher luminosity
• LHC Accelerator Research Program
Accelerator R&D

• Most of our science is dependent on accelerator R&D done many years ago.

• The future of that science depends on the R&D we do today.

• Lots of the work is immensely interesting physics

• Committee would like to support an increase in resources

• Committee feels we could systematically improve the way we treat this part of the program.
Particle Astrophysics

- Already have strong astrophysics program (FNAL was the pioneer among HEP labs)
  - Dark Matter (SDSS, CDMS, SUSY searches)
  - Dark Energy (SNAP/JDEM nascent)
  - Ultra high energy cosmic rays (Auger)

- Current Discussions of new initiatives.
  - SDSS Program considering an extension.
  - Fermilab Technical Expertise significant (Focal Plane Arrays)
  - To list above, add CTIO/DECAM
  - PAC augmented to handle the discussion.

- Committee feels Astroparticle physics should grow.

- Committee recommends FNAL find mechanism to help manage and provide coherence in expanding program
  - Astro Center or Institute is one option being explored
Interdisciplinary Science

• application of accelerators to the benefit of society.
  – for example, support the proposed Hadron Therapy Facility in DuPage Technology Park to the north of the site
  – R&D in Computing Science and Technology

Detector R&D

• Todays experiments enabled by earlier work
• Modest but focused program
Resources

- Start from 6 year model being used for discussions with DOE now.
- Extend for a further few years to include 2017.
- Use 2% increase per year to inflate individual items (if know no better)
- Make a few intelligent moves, for example recognize that when BTeV stops there is a drop in the accelerator operation costs.
- Add in a profile corresponding to the desired new initiative.
  - Linear Collider
  - Proton Driver
- Not well done
  - Delve into the large parts of the operations, and the support to see what can be redirected.
  - Scrub for double counting between existing elements and elements added
- Balancing is only broad brush
Conclusions

We expect a revolution in physics

We see an exciting future for Fermilab

If we work together, we can make it happen!

The work is of the whole committee, the MANY participants in the subcommittees, and of the many who have attended the open sessions.