Report from the LHC/ILC Subpanel

Joe Lykken

HEPAP meeting
19 May 2005

outline

- Charge
- Membership
- Outreach to the larger community
- What we have heard from our customers
- What we think we are producing
- Timeline
- Things we are not going to do
- ILC physics in two minutes

U.S. Department of Energy
and the
National Science Foundation

March 21, 2005

Dear Professor Gilman:

We wish to congratulate you on the widely successful *Quantum Universe* report that with clarity and elegance expresses the great discovery opportunities in particle physics today. It has made a positive impact in Washington, DC, in the Nation, and abroad in conveying the drivers of the coming scientific revolution. As funding agencies and advisors of the Nation's research portfolio in this field, our ability to bring clarity and focus to outstanding scientific issues is an important responsibility. You have succeeded well with *Quantum Universe*.

This brings us to the following. The successful outcome of the International Technology Recommendation Panel, in coming to a clear technology recommendation, was a significant step toward a future Linear Collider. We now ask for your help in addressing another important issue in program planning and public communication. We need to explain clearly to the broad non-scientific community the need for a second large particle accelerator in addition to the Large Hadron Collider (LHC). Inevitably, the question arises as to how a less energetic electron accelerator would work in tandem with a higher energy proton machine in exploring the energy frontier. How would these two accelerators complement one another? What crucial scientific discoveries might not be made without the LC?

To educate us and the public, and to clarify the matter more generally, we would like HEPAP to form a committee to write a document that addresses the following:

- In the context of already known physics, i.e. our current understanding of the electroweak symmetry breaking sector, what are the synergies and complementarities of these two machines? How would an LC be utilized in understanding a Standard Model Higgs, or whatever fulfills its role in the electroweak interaction?

- In the context of physics discoveries beyond the Standard Model (supersymmetry, extra dimensions or other new physics) that are assumed to be made at the Tevatron or early at the LHC, what would be the role of a TeV Linear Collider in making additional and unique contributions to these discoveries, in distinguishing between models, and in establishing connections to cosmological observations?

You may assume that the LHC will be operating over a 15-20 year timeframe with likely upgrades.

We are not asking for any new physics or simulation studies. As you know, there is by now a rather large body of work on this subject. Rather, we are asking for your help in distilling this body of work into a crisp, accessible, and persuasive case. The deliverable should be a short document (10 pages), accessible to knowledgeable non-experts (e.g., members of the EPP2010 Study, OSTP/OMB staff and ourselves). We ask that the report be completed as soon as practical but no later than summer 2005.

Our goal: to deliver a printed report to the EPP2010 committee at their Cornell meeting on 2-3 August 2005

who we are

- Jim Siegrist (LBNL), Joe Lykken (Fermilab) co-chairs
- Jonathan Bagger (JHU, EPP2010)
- Barry Barish (Caltech, GDE)
- Neil Calder (SLAC, ILCCG)
- Albert de Roeck (CERN, CMS)
- Jonathan Feng (Irvine, ILC Cosmo WG)
- Fred Gilman (CMU, HEPAP)
- JoAnne Hewett (SLAC, HEPAP, ALCPGEC)
- John Huth (Harvard, ATLAS)
- Judy Jackson (Fermilab, ILCCG)
- Young-Kee Kim (UC, CDF, HEPAP, ALCPGEC)
- Rocky Kolb (Fermilab, DE Task Force)
- Konstantin Matchev (Florida, CMS, ILC Cosmo WG)
- Hitoshi Murayama (Berkeley, ALCPGEC)
- Rainer Weiss (MIT, CMB Task Force)

outreach to the larger community

- not an advising subpanel, our job is to explain the physics case
- but it doesn't make sense to do this in isolation from the ILC and LHC communities
- we have been in contact with ILC/LHC groups, especially those who are also preparing/sending input to the EPP2010 committee

outreach to the larger community

- JoAnne is a member of the LHC/ILC Study Group
- Jon Bagger is a member of the USLCSG
- we participated in the last ALCPG EC phone meeting
- we are coordinating with the ILC Worldwide Study Group
- Judy, Neil, and Jim are in the ILC Communications Group
- Joe and Hitoshi briefed the rest of the DPF EC in Tampa
- Albert and John will be coordinating with CMS/ATLAS

what we heard from our customers (a sample)

- keep it simple, avoid jargon in the introduction
- take advantage of and credit for the accomplishments of the Standard Model
- connect it to the Quantum Universe brand
- don't sell the LHC short
- more don'ts: precision per se, "new physics"
- don't lead with concurrency, but let the reader draw the conclusion from your examples
- they are interested in dark matter, did not engage with "unification"

what we think we are producing

- a document with four layers
- ~10 pages of text + sidebars + illustrations
- why layers? two reasons:
- (1) need to reach multiple audiences, who have different backgrounds, different levels of awareness of LHC/ILC, and different amounts of time to devote to reading this stuff
- (2) a paradox: crisp implies short, but compelling implies enough detail to back it up

layers

- layer zero: a gemlike, self-contained executive summary, suitable for e-mailing.
  Technical level: USA Today.

- layer one: a crisp, engaging, jargon-free description of the three outstanding discovery opportunities of the ILC, building from the new era of launched by LHC.
  Technical level: New York Times

- layer two: a compelling narrative for each of the three discovery themes, explaining in more detail what ILC experiments could actually do.
  Technical level: Scientific American

layers

- layer three: a whitepaper for the scientific community, the agencies, and the EPP2010 committee, answering questions they have posed + questions in our charge. Includes specific robust scenarios for what LHC and ILC may actually do, orthogonalizing who discovers what. Enough detail to back up claims made in the upper layers, and act as an interface to already existing LHC/ILC studies. Technical level: Physics Dept. Colloquium

timeline

- 25 March: first meeting at LCWS Palo Alto
- 30 March: first weekly telecon
- 22 April: meeting in Washington with J. Marburger, M. Turner, R. Staffin, P. Looney, M. Holland, J. Parriott, K. Carroll
- 23 April: serious writing begins
- 19 May: HEPAP
- 26 May: meeting at Fermilab
- 8 June: complete layers 1+2
- mid-June: meeting, check with customers
- 22 June: complete layers 0+3+sidebars
- 23 June - 4 July: polish, complete graphics, circulate for comments
- 5 July: send to printer
- 2-3 August: unveiling to EPP2010

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Division of Engineering and Physical Sciences
Board on Physics and Astronomy
Elementary Particle Physics 2010 Committee

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1) The physics case for a linear collider
   a. How does a linear collider address the compelling questions of particle physics? Is a linear collider clearly the right machine to address these physics objectives?
   b. What physics does a 500 GeV linear collider address? What are the arguments for going to an energy scale of 1 TeV? How would results from the LHC change these arguments?
   c. What are the physics arguments for operating a linear collider during the same time frame as the LHC?
   d. How would the combination of the LHC and a linear collider answer questions that could not be addressed by either machine alone?
   e. What physics would a linear collider address that would be impossible to probe at the LHC?
   f. How would the physics discoveries from experiments at a linear collider be useful to other branches of science?

things we are not going to do

- downplay the capabilities of the LHC
- guarantee a specific roster of ILC discoveries
- explain why the ILC should be built in the U.S.

what are the science goals of the ILC?

- in answering, focus on discovery opportunities, not just measurements
- use the Quantum Universe big questions as guide and motivation
- make the relationship to LHC clear

ILC physics in two minutes:

science goals of the ILC

- discover the identity of dark matter
- resolve the mysteries of the Higgs
- connect the laws of the large to the laws of the small

discover the identity of dark matter

- determine what dark matter particles can be produced in the laboratory (LHC+ILC)
- discover their identity
- connect the dark side to the bright side

resolve the mysteries of the Higgs

- reveal the nature of the universal energy field that creates mass (LHC+ILC)
- determine if Higgs is connected to the dominance of matter over antimatter
- discover secrets of the quantum vacuum

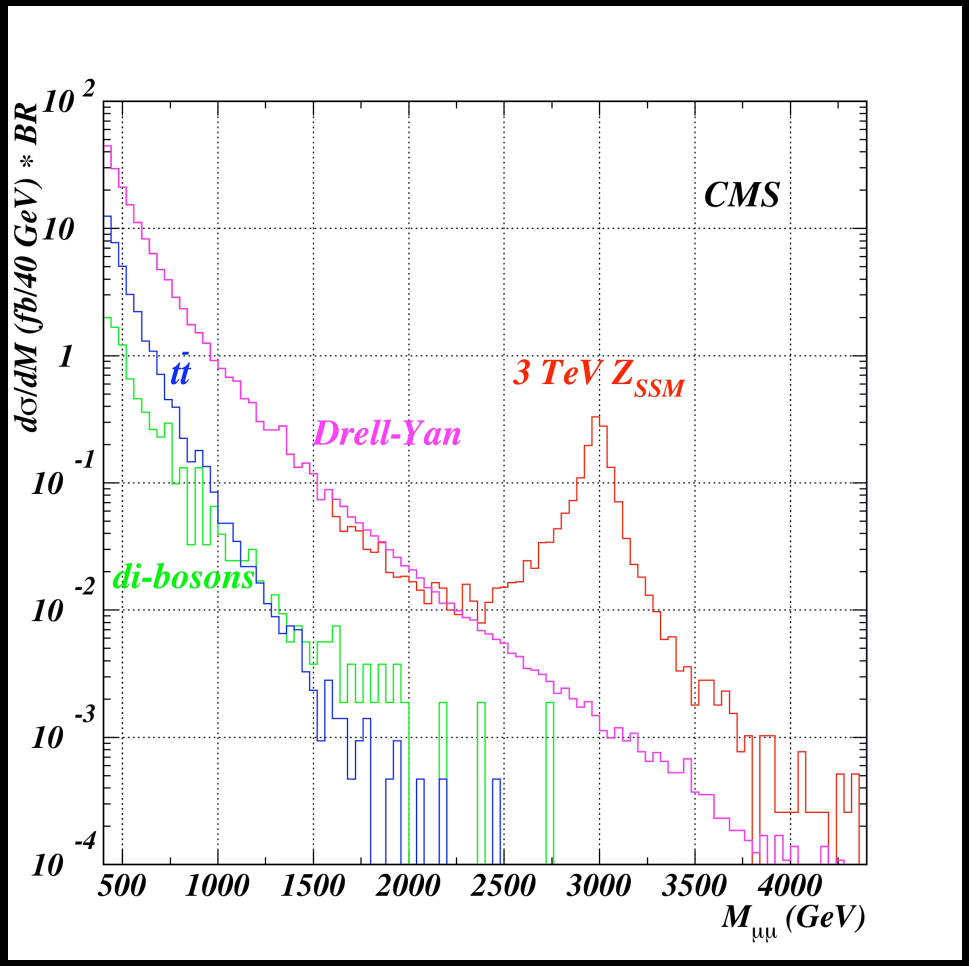
connect the laws of the large to the laws of the small

- discover how supersymmetry is hidden (LHC+ILC)
- bring into focus Einstein's vision of an ultimate unified force
- detect the quantum signals of extra dimensions

three examples of
LHC/ILC discovery scenarios
that may actually happen

ILC/LHC Physics: new particle

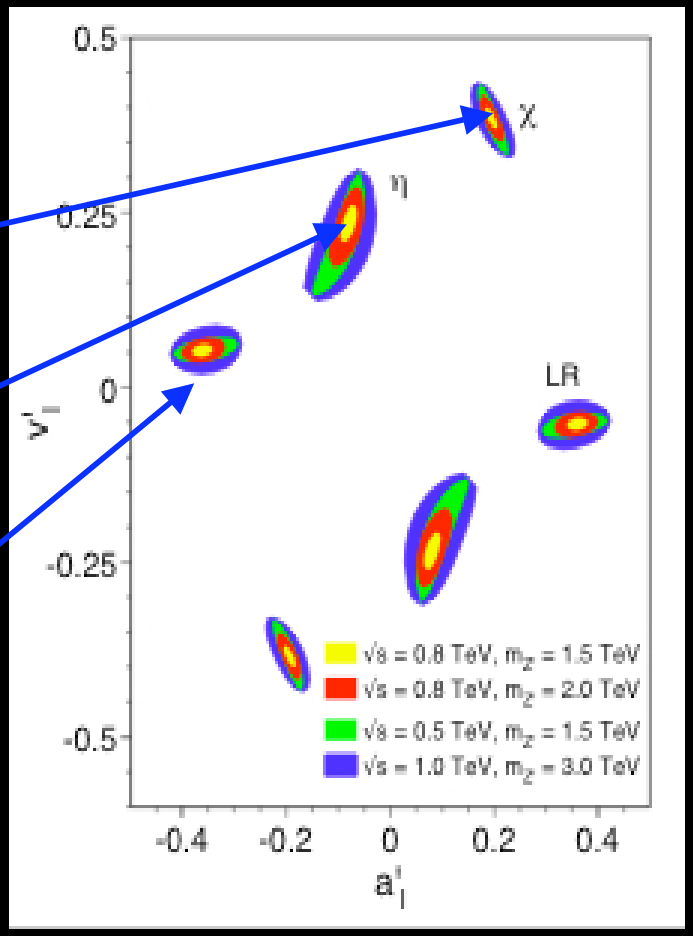
- LHC experiments find a new heavy particle, Z'
- Able to show that Z' mediates a new force of nature
- This is a great discovery



slides from Pier Oddone talk to EPP2010

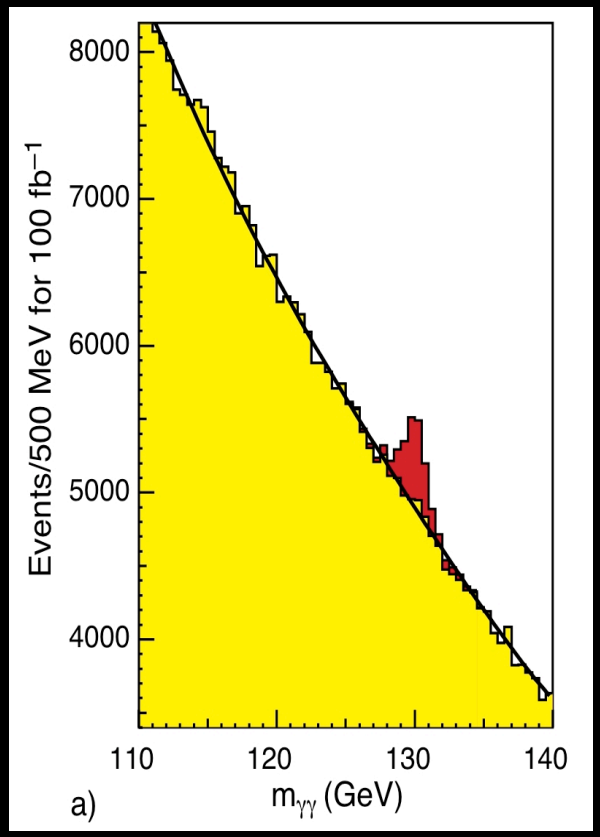
LHC/ILC Physics: new particle

- 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

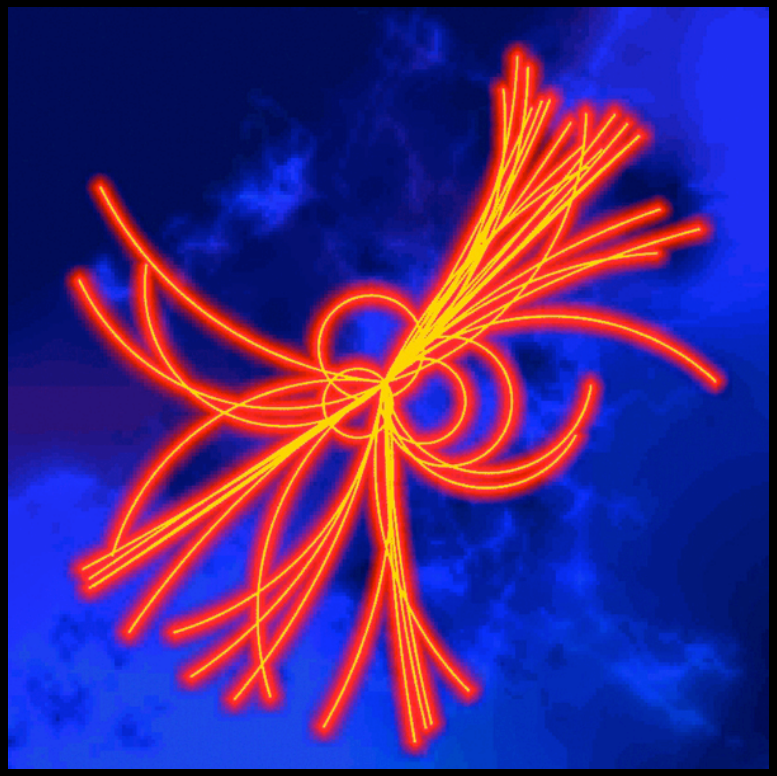


Signal

M_H = 130 GeV

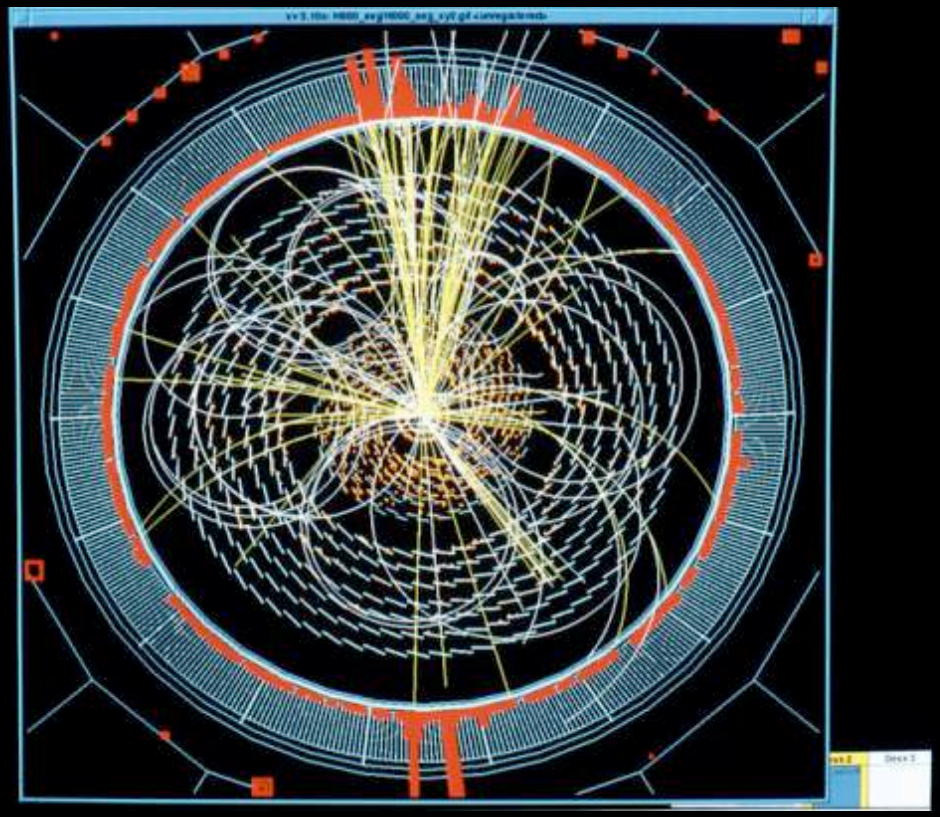
LHC/ILC: CP violation

- From decays of Higgs, ILC experiments discover a new source of CP violation
- Solves the mystery of why matter dominates over antimatter



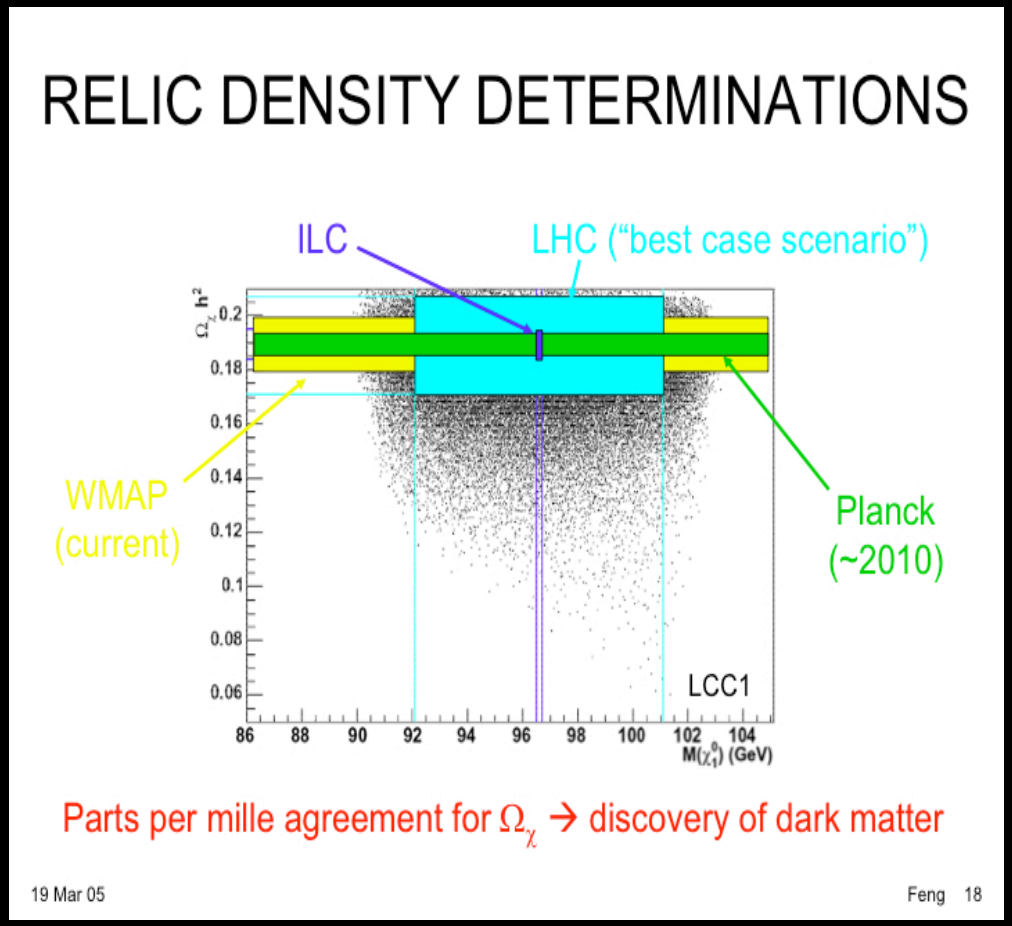
LHC/ILC physics: dark matter

- 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!



communication is hard

- it is very challenging to dejargonize our standard arguments
- but we, as a community, are improving
- “if you can’t explain it simply, then you don’t understand it”