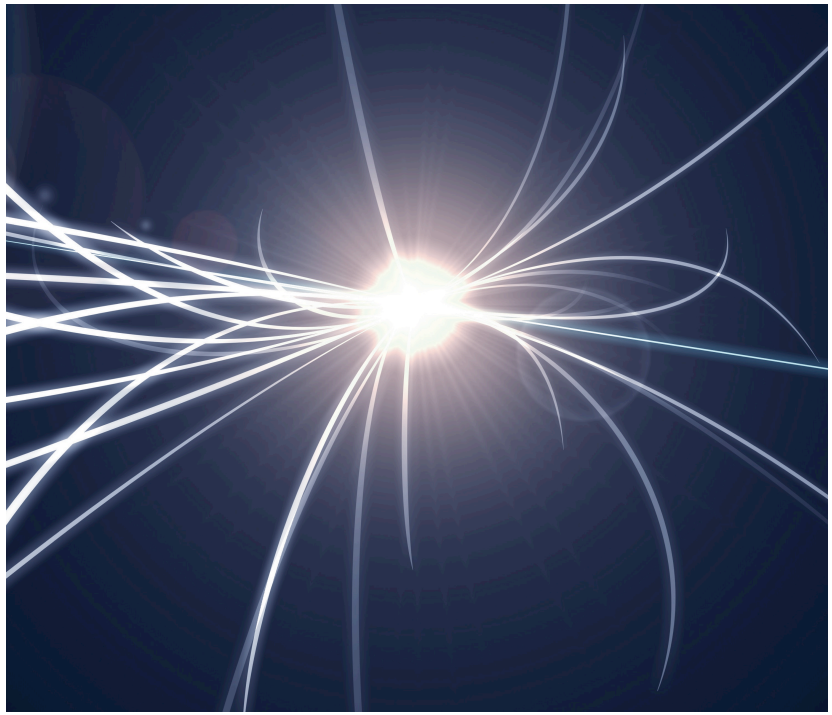
ILC Physics and Detectors: P5 Report



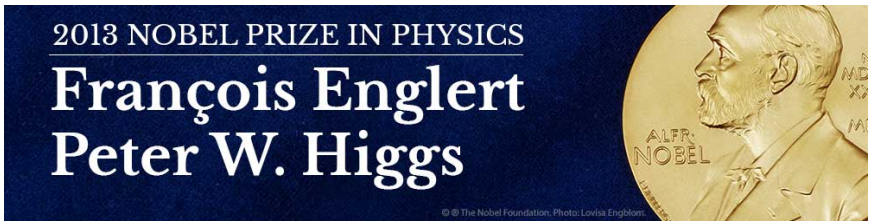
Jonathan Bagger
December 15, 2013
Johns Hopkins University
American Linear Collider Committee

July 4, 2012

- The discovery of a Higgs-like boson marks a turning point for our field
- With the Higgs boson, the Standard Model is complete
  - It provides a consistent explanation of the quarks, leptons and gauge bosons – so far as it goes
- However, there are important phenomena that the Standard Model does not explain, including
  - Dark matter, dark energy, matter/antimatter asymmetry, and even the properties of neutrinos
- The Standard Model offers a firm platform on which to build

The Higgs Boson

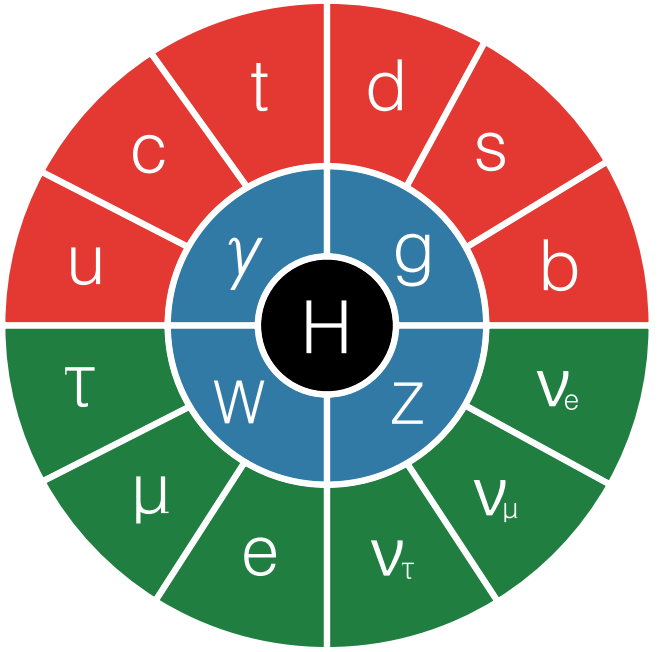
- The Higgs is different. It changes everything
  - It is the first of its kind
  - It is not a quark, a lepton or a gauge boson
  - It is a brand new form of matter – a fundamental spin-zero boson
- As such, it can condense and fill the vacuum, and alter the properties of particles
- The Higgs changes our conception of fundamental physics
  - Is it matter? Is it a force?
  - Or is it both?



The Standard Model

The Higgs changes the picture from this

To this



The Higgs is the linchpin that holds it all together

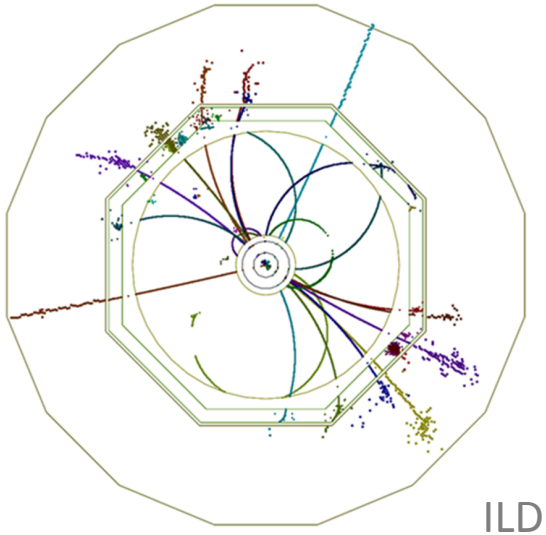
Murch

Precision Higgs Physics

- The case for the ILC starts with the Higgs
  - The Higgs boson has many properties that must be checked
    - Have we found the Higgs or an impostor?
    - Is it a portal to a new world?
  - For example: Models of strong dynamics and extra dimensions contain new electroweak singlet scalars – dilatons and radions. Supersymmetry can contain such particles as well
    - Do they mix with the Higgs and change its properties?
- The Snowmass Energy Frontier group studied these questions
  - They examined precision measurements of the Higgs couplings. Because of decoupling, deviations are expected to be small
  - Their conclusion: We need to measure ZZ, WW, gg, γγ, HH, tt, bb, cc, ττ, μμ, ee – even invisible – couplings to the percent level. We need to detect the pattern of deviations!

Precision Higgs Physics

- At LHC, experiments measure σ(H) * BR(H → AA) and the absolute couplings are extracted by global fits
- At ILC, experiments directly measure the couplings
  - The initial state is known
    - The energy is adjustable
    - Electrons and positrons are polarized
    - Events are clean and free from pileup
  - No trigger is required
    - All events are recorded, independent of decay mode

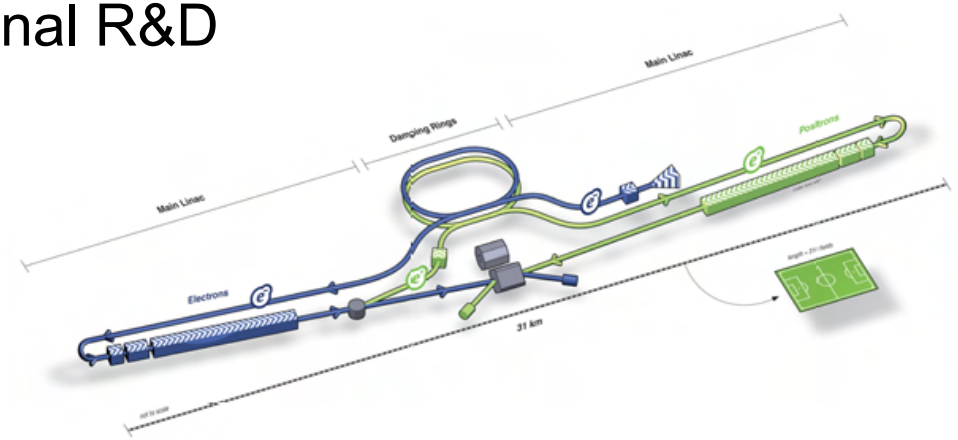


ILD

- ILC detectors are precision instruments, with relatively little material associated with supports, cooling and cabling

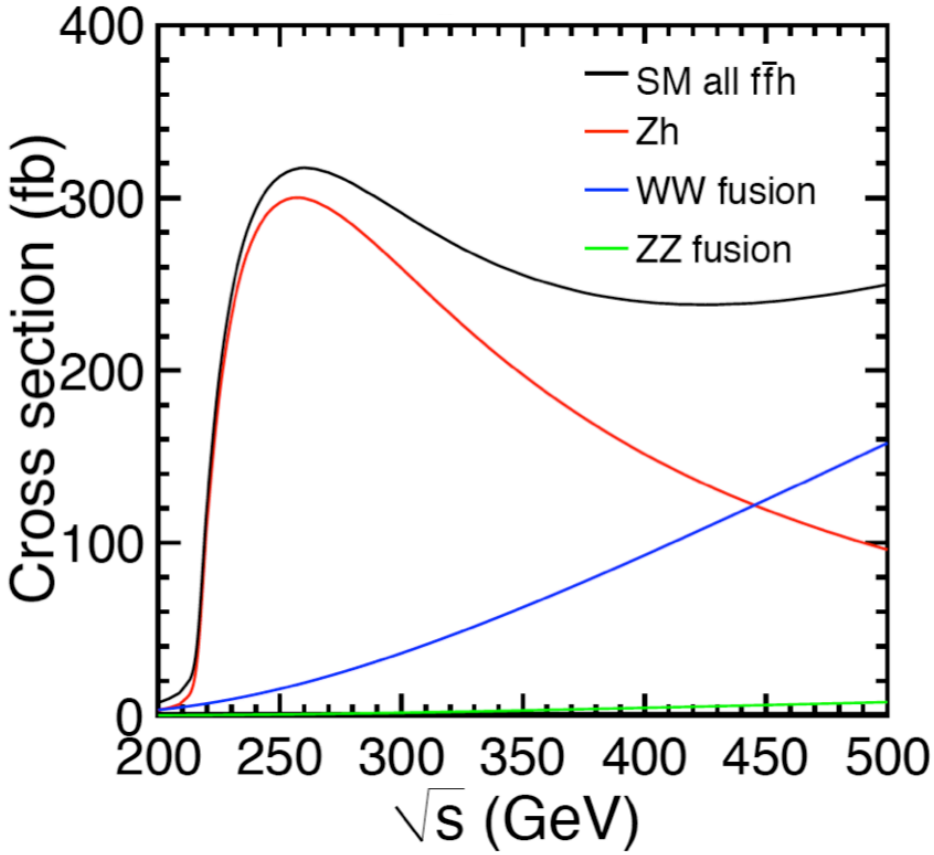
ILC Campaign

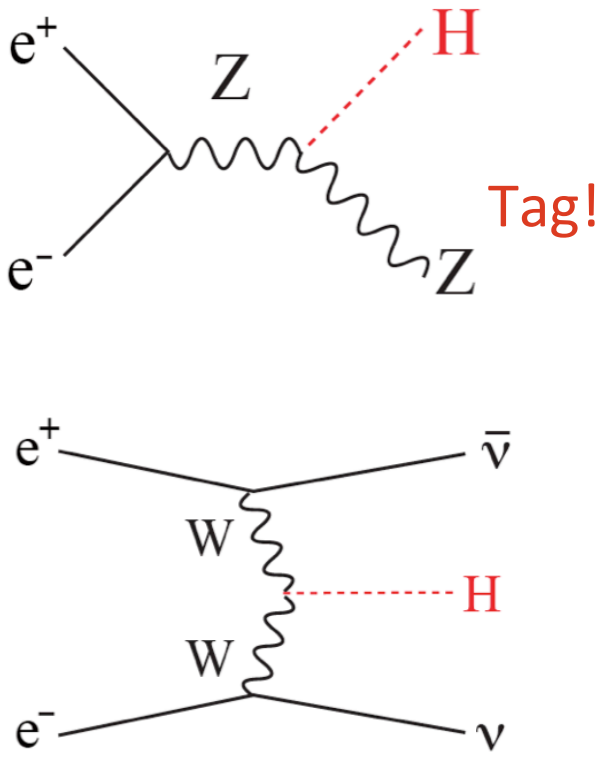
- At ILC, we study the Higgs through a staged campaign with a rich precision physics program at each step
  - Stage 1: Start at 250 GeV in a tunnel sized for 500 GeV
  - Stage 2: Increase energy adiabatically to 500 GeV
  - Stage 3: Extend tunnel and energy to 1 TeV
- Stages 2 and 3 could use higher gradient cavities to be developed through additional R&D



Higgs at ILC

- At ILC, the Higgs is produced by two main processes





ILC TDR

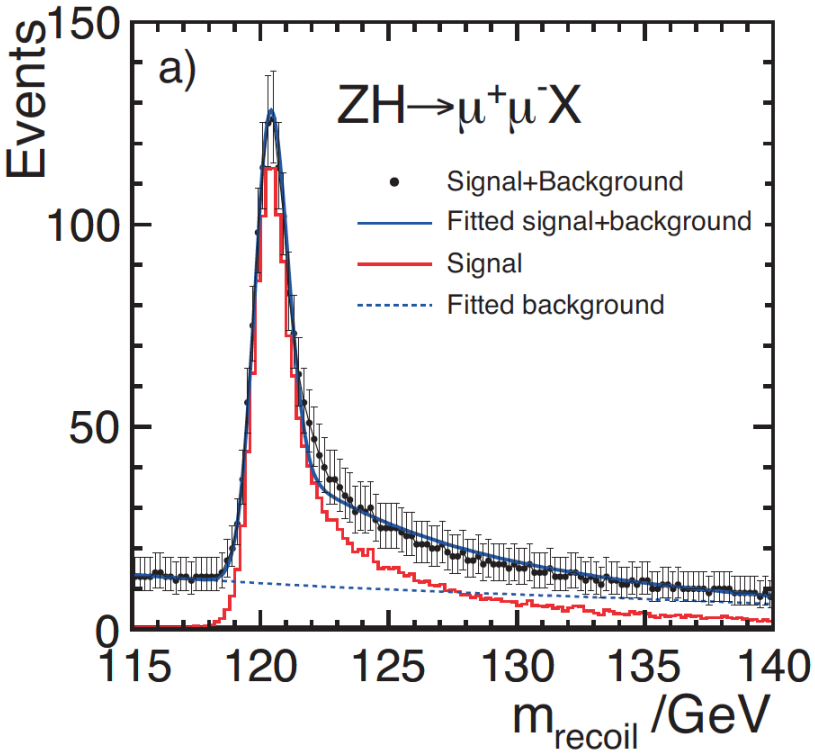
Higgs at ILC

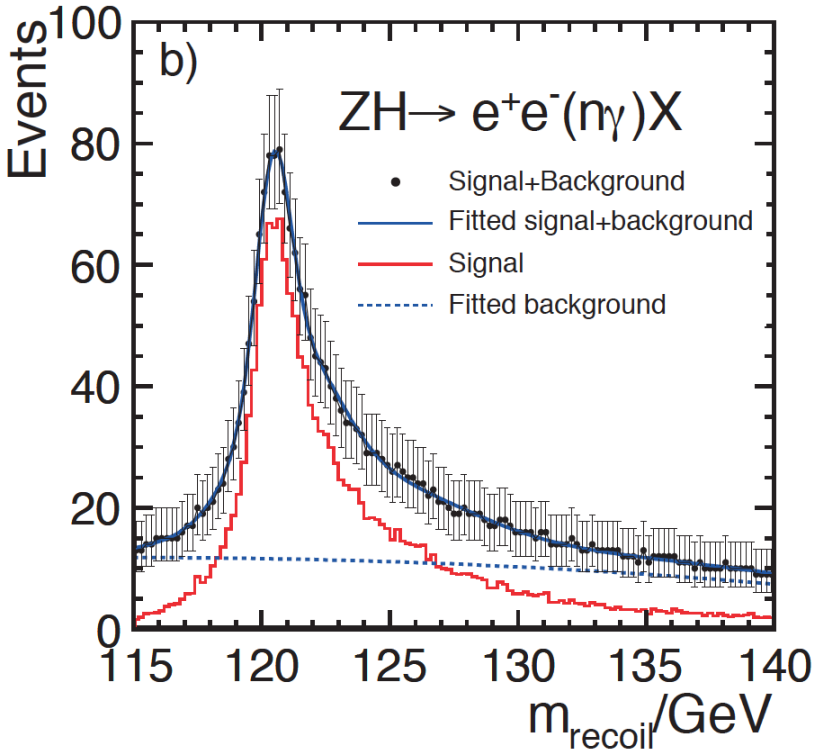
- At 250 GeV, ZH production provides tagged Higgs source
  - Measure
    - Higgs mass and total width
    - Relative BFs, including invisible modes
    - Absolute ZZ partial width (but statistics limited)
      - Allows normalization of all partial widths
- Above 250 GeV, WW fusion becomes increasingly important
  - Measure
    - Absolute WW partial width
      - Allows a reduction in errors for all the absolute widths
    - Top quark Yukawa
    - Triple Higgs coupling
    - All are important!

ILC is a precision Higgs machine!

Higgs at ILC

Example: At 250 GeV, Higgs mass from Z recoil to ± 32 MeV
and the Higgs width to ± 500 keV

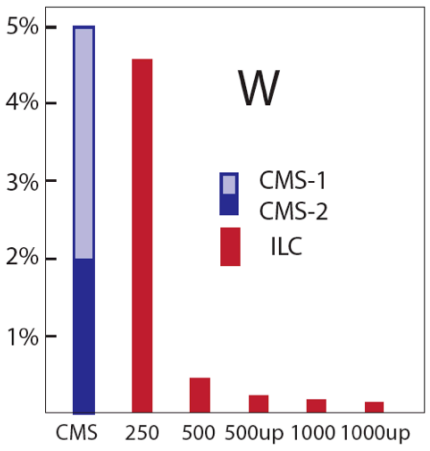


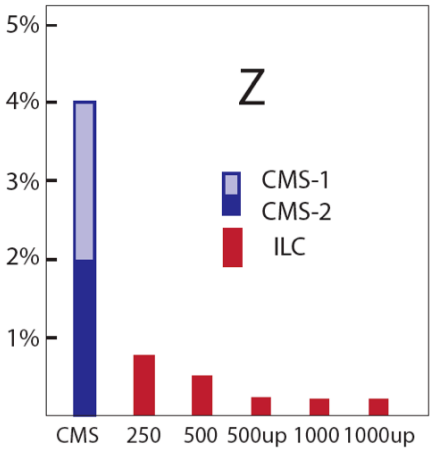


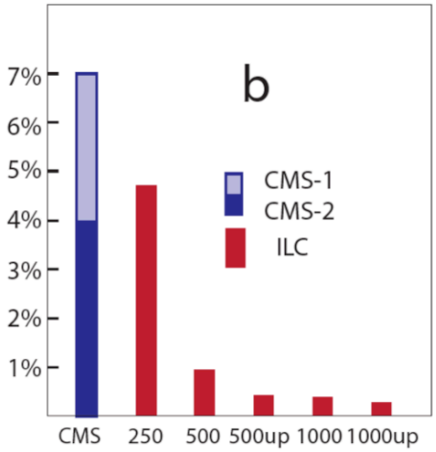
Also: ZH cross section to percent level

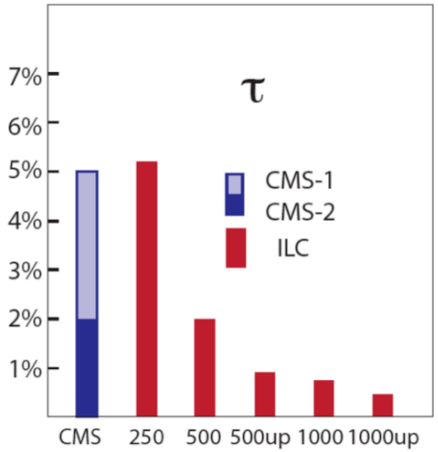
ILC TDR

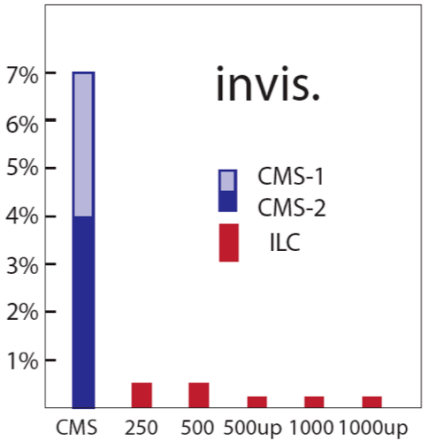
Higgs at ILC

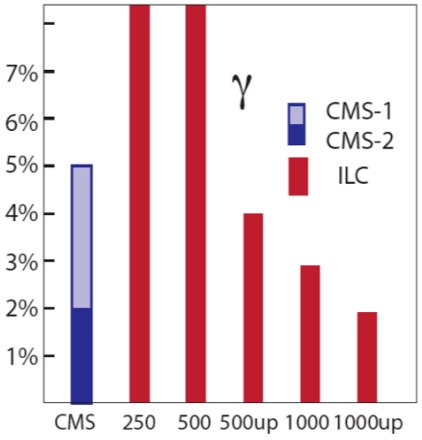


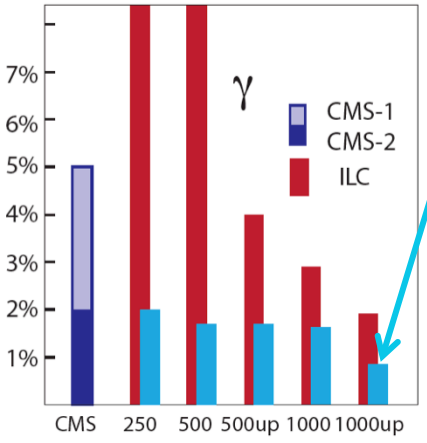












Using BR(γγ)/BR(ZZ*) from LHC

250 GeV:	250 /fb
500 GeV:	500 /fb
250up GeV:	1150 /fb
500up GeV:	1600 /fb
1000 GeV:	1000 /fb
1000up GeV:	2500 /fb

Peskin (Snowmass)

Absolute Higgs couplings at LHC and ILC, from Snowmass

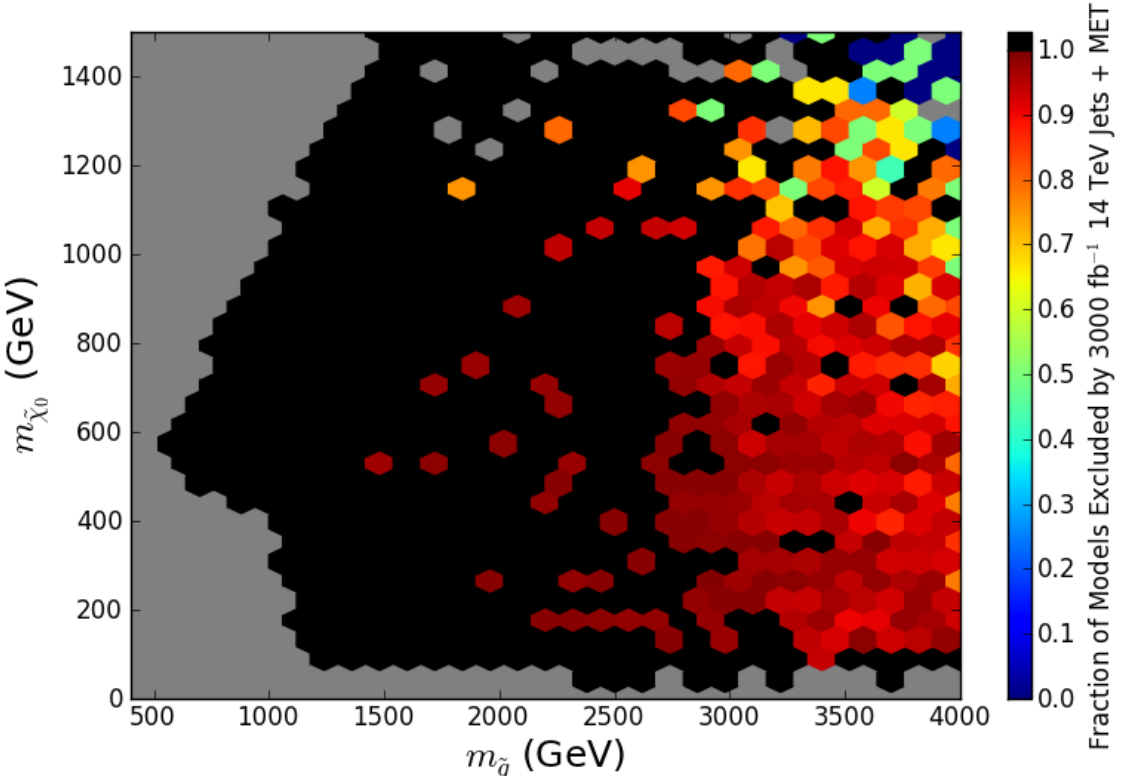
Beyond the Higgs

- Of course, the ILC is much more than a Higgs factory. With its adjustable energy and polarization, and its clean and controlled initial state, the ILC is capable of a variety of precision measurements
  - For example, studies at top-quark pair production threshold will measure the top quark mass to 100 MeV, and the helicity structure of the top-quark Z boson couplings to the percent level. The top quark is the heaviest quark, so it must couple most strongly to the EWSB sector
  - Precision studies of $e^+e^- \rightarrow f\bar{f}$ and WW provide another example. They have great reach (~ 40-100 TeV at 500 GeV) for new physics that couples through the s or t channels, and through precision and polarization, experiments can begin to determine its nature

Supersymmetry

- A Snowmass supersymmetry study found models with heavy colored sparticles, and light uncolored ones, that remain undetected at the high luminosity LHC

(Jets + MET analysis only)

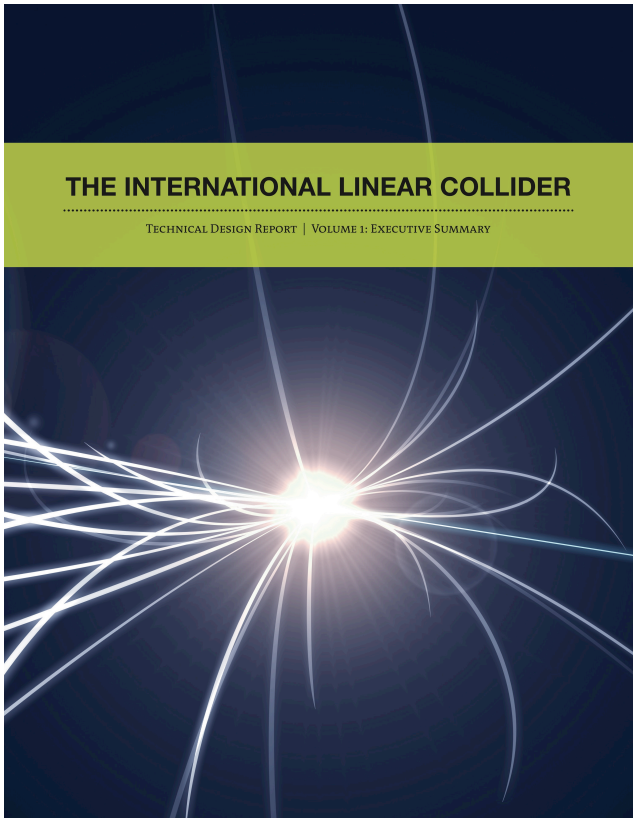


Cahill-Rowley, Hewett, Ismail, Rizzo (Snowmass)

- These sparticles are targets for the ILC!

ILC TDR

- The ILC physics case is sufficiently compelling that 2400 physicists from 392 institutes in 48 countries signed its Technical Design Report
  - Including 387 physicists from 78 institutions in the United States
- Over the past ten years, US universities and laboratories participated in the global detector R&D program, validated by test beam results, that realized the capabilities needed for the exceptional precision of the ILC detectors



ILC TDR

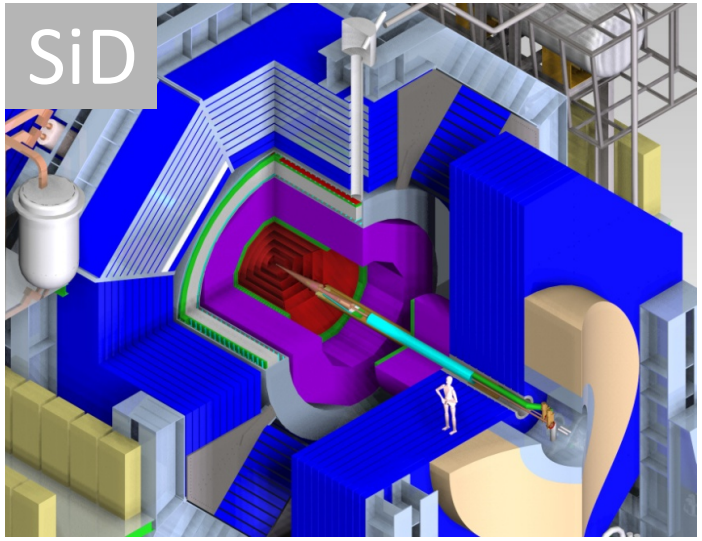
- The Technical Design Report was completed in mid 2013
  - The TDR was prepared by the Global Design Effort, an international team led by Barry Barish
  - Costs were validated by an international review committee, chaired by Norbert Holtkamp
- With the completion of the TDR, a new group, the LCC – Linear Collider Collaboration – was formed under ICFA to realize the machine
  - Also a global effort, the LCC is led by Lyn Evans, former CERN LHC project leader. His team includes Mike Harrison from BNL as associate director for ILC
- The bottom line is that the ILC design is *complete* and the project is *good to go*

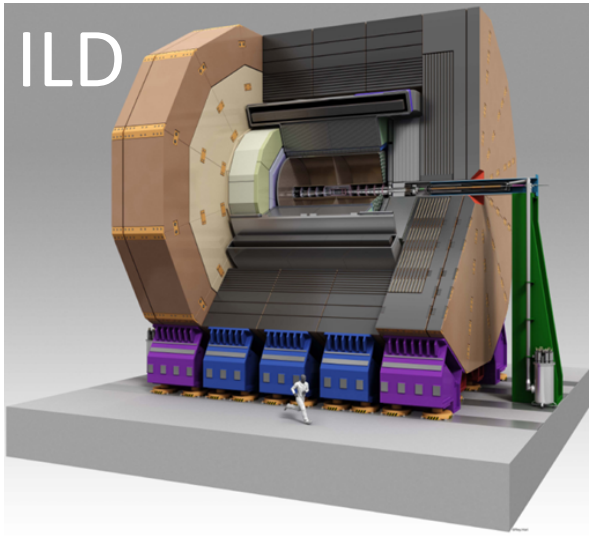
ILD and SiD: Precision Detectors

- ILC physicists have collected themselves into two nascent detector collaborations: ILD and SiD. Each of the two detectors enjoys
  - superb momentum resolution to measure the Higgs recoil
  - high efficiency flavor tagging to measure branching ratios with precision
  - excellent jet energy resolution to separate W, Z and Higgs bosons
- SiD is based on 100% silicon tracking, while ILD employs a state-of-the-art TPC
- The detector groups require engineering and prototyping to finalize their designs before construction

ILD and SiD: Precision Detectors

Both detectors have unprecedented tracking, vertexing and jet performance

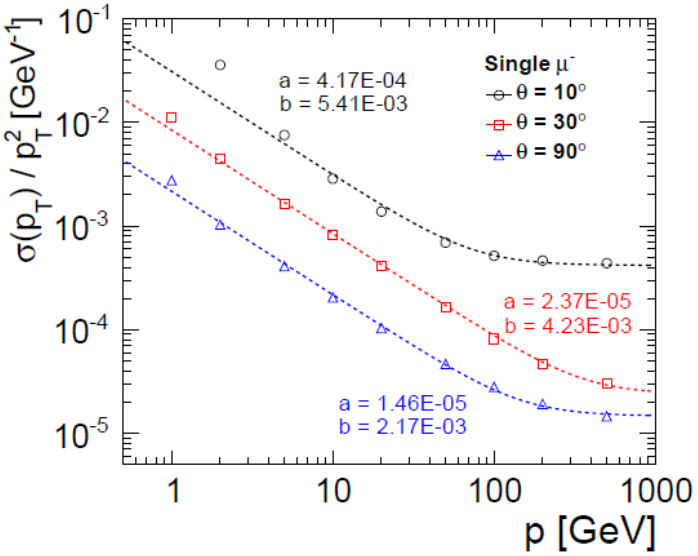


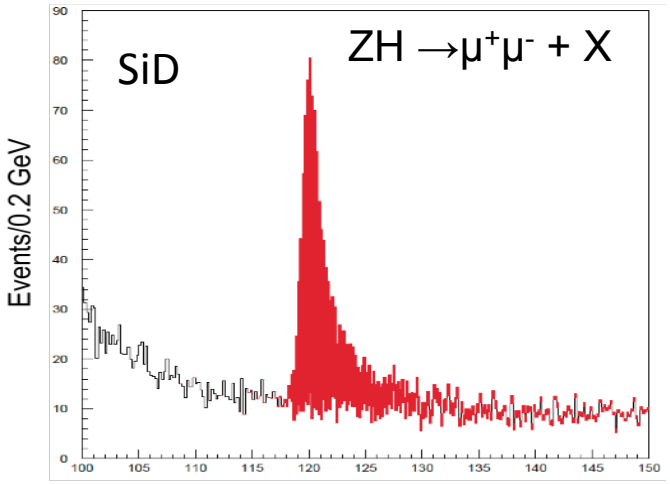


Superb momentum resolution aides in measuring Higgs recoil

$\sigma(p_T)/p_T^2$ ~

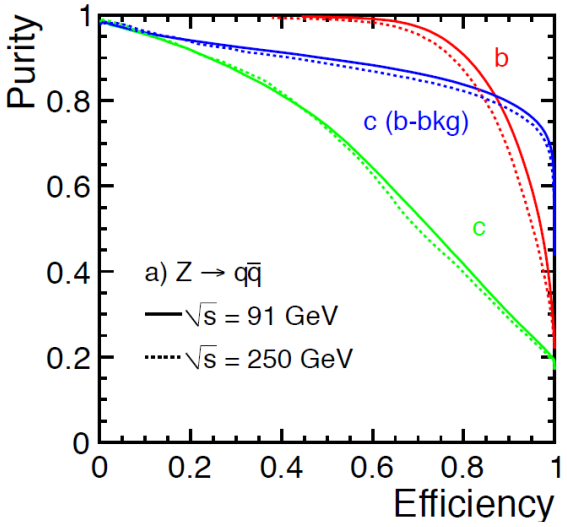
2-5 x 10^{-5} GeV^{-1}

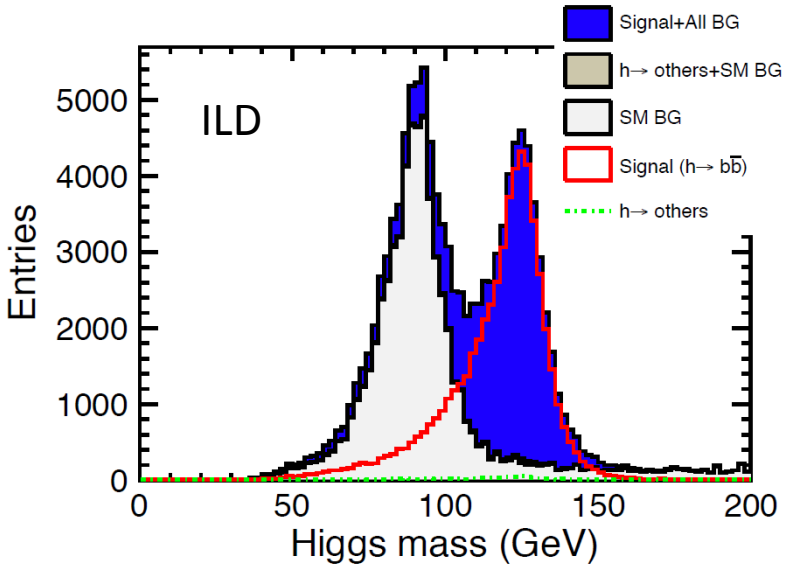




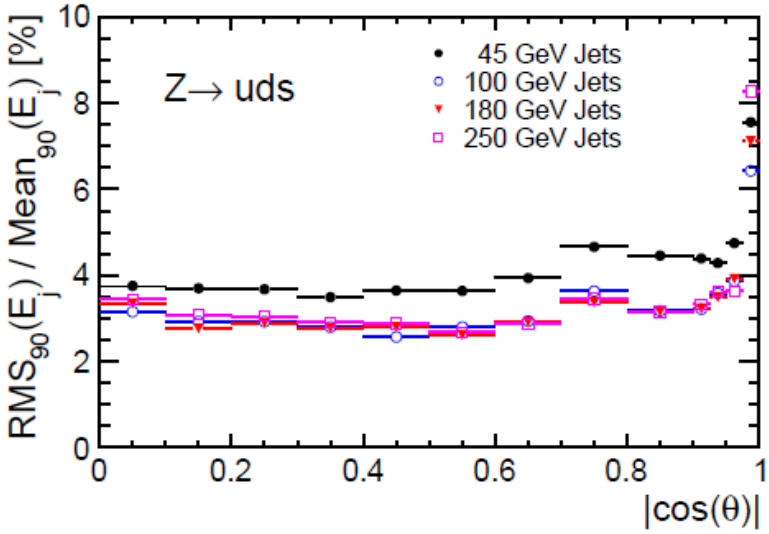
ILD and SiD: Precision Detectors

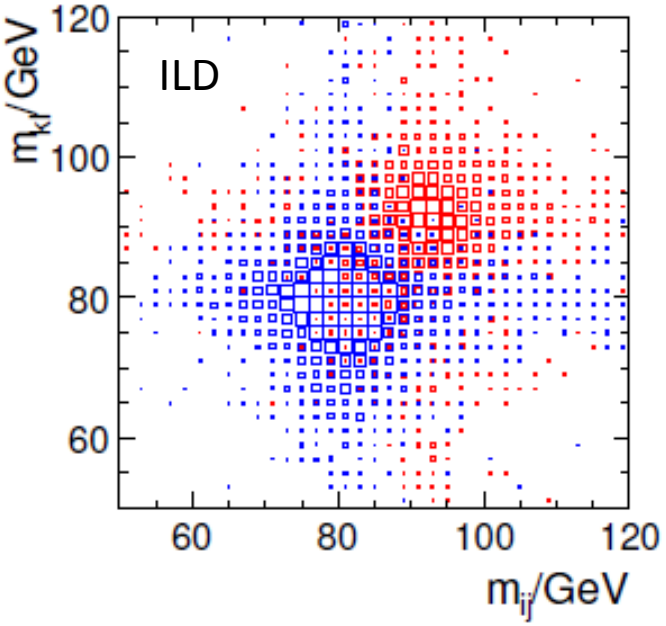
Efficient flavor tagging allows robust $H \rightarrow b\bar{b}$ reconstruction





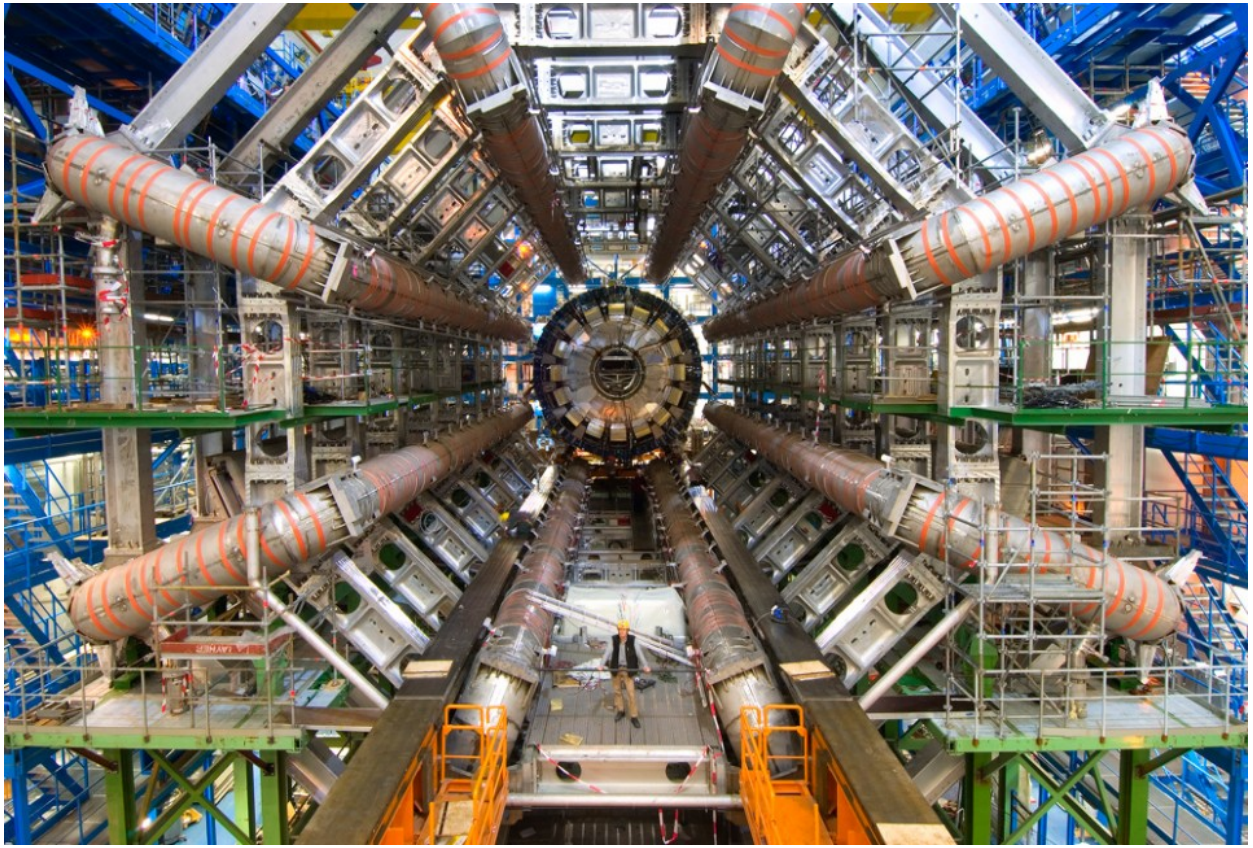
Excellent jet energy resolution separates ZZ (red) from WW (blue) final states in Higgs decay





Proof of Principle

- The LHC experience demonstrates that our field knows how to build and operate complex facilities



So where do we stand?

- As P5 heard from Atsuto Suzuki at Fermilab, Japan is considering hosting the ILC as a global project

Lyn Evans and
PM Shinzo Abe

Japan is serious. Very serious

Japan

- From the Science Council of Japan:
  - "We endorse the scientific significance of the ILC project within particle physics"
  - "There are uncertainties and risk factors concerning the project organization within Japan and the availability of researchers from other countries"
  - "We recommend intensive investigation and discussions on various issues for two to three years to make the decision on execution of the ILC project"
  - "In parallel with the above investigations, negotiations should be conducted with research laboratories and responsible funding authorities of primary countries and regions to clarify the prospects for the international cost sharing"
  - "SCJ is willing to help the government for the final decision by making recommendations from the academic viewpoint"

Japan

- From Takeo Kawamura, chair of the bipartisan Federation of Diet Members in support of ILC:
  - "It is certain that the ILC will bring about a dramatic advance in science"
  - "From now on, we should move towards forming the framework for an international partnership which goes beyond simple cooperation between researchers, towards one to which governments commit"
  - "We would like to proceed in an orderly manner and with a large-scale view, by building an international network base for researchers and engineers with our partner nations, reinforcing cooperation in the fields of science, technology, and economics"
  - "It is our duty to realize this ILC project"

This sounds serious to me!

www.icepp.s.u-tokyo.ac.jp/lcws13/Mr_Kawamura_LCWS13_Speech_English_Translation.pdf

Japanese Media

NHK「かぶん」ブログ

Science & Culture

NHK科学文化部(かぶん)のブログです。
科学と文化の専門記者が取材した最新の話題をお伝えします。

<< 前の記事 | トップページ | 次の記事 >>

2013年06月14日（金）

ILC誘致すべきか検討始まる

日本が有力な候補地となっている最先端の実験施設、ILC＝国際リニアコライダーを誘致すべきかどうかの検討が、国から依頼を受けた日本学術会議で始まり、巨額の運営費用は日本だけで負担するのか、などといった質問が出されました。

Europe and Asia

- The 2013 European Strategy for Particle Physics states:
  - "The initiative of the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. Europe looks forward to a proposal from Japan to discuss a possible participation"
- A 2013 report from the Asian High Energy Physics Community states:
  - "AsiaHEP/ACFA welcomes the proposal by the Japanese HEP community for the ILC to be hosted in Japan. [It] looks forward to a proposal from the Japanese Government to initiate the ILC project"

United States: HEPAP and Snowmass

- From HEPAP Facilities Panel:
  - "The ILC accelerator and detectors enable a research program that will address questions of very great scientific importance, and both the accelerator and the detectors are absolutely central"
- From Snowmass Energy Frontier group, reporting to P5
  - "There is a compelling case for a lepton collider beyond LHC"
    - "Theory sets the goal in Higgs, top quark couplings as discovery of deviations from the SM at the few-percent level. ILC, on the table now, can meet this goal"
  - "We will realize these goals through global collaboration"
    - "We are fortunate that other regions of the world agree with our goals and are providing high-energy colliders with impressive capabilities"
    - "It is important the US physicists can participate in these programs"

United States: P5

- The question before P5 is: What will the US say?
- At Snowmass, the community found that the physics case is compelling, and that it is important for the US to participate
  - Participating in the ILC will develop core competencies that will strengthen US industry and the DOE laboratory complex
  - US laboratories bring essential skills to bear, especially in superconducting RF technologies
  - US university groups are carrying out critical detector R&D in preparation for TDRs
- We need to place the project in a very broad context…

Leadership

- Remember, we are the most international field of science
  - Our science demands a global approach
  - We can have impact far beyond our field
- CERN was founded by visionary physicists who brought together former enemies and laid a cornerstone for modern Europe
  - We are the beneficiaries of their foresight
- Today, physicists at SESAME are attempting something similar in the Mideast
  - With Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestinian Authority, and Turkey

Leadership

- Might the ILC spark new collaboration and cooperation, both in Asia and across the globe?
  - And bring benefits far beyond science?
- Kawamura again:
  - “The scientific innovation of this large international collaborative project is an important opportunity for the improvement of culture, education, economy and social life throughout the world”
  - “Above all, the international process for the realization of ILC is a new challenge. ILC is a project that can serve as a model for worldwide collaboration, not only in science and technology, but also in many other fields”

www.icepp.s.u-tokyo.ac.jp/lcws13/Mr_Kawamura_LCWS13_Speech_English_Translation.pdf

Leadership

- We ask that P5 recall Harold Shapiro's words in the National Academies' EPP2010 report…
  - "In the flat world that is taking shape, leadership … no longer consists of single-handed efforts to maintain dominance in a particular field. Rather, leadership emerges from the creativity and initiative needed to organize international teams of collaborators to pursue projects that are beyond the capability of any one country"
- And Rolf Heuer's more pointed comment
  - "Global collaboration = Global partnership with long term support"

Bottom Line

- My bottom line: Our facilities are of such a scale that we need a global approach – one that leverages new sources of funding
- Japan is in the process of deciding that it is in its national interest to host the ILC
  - This would inject new money into the field, towards an exciting project, in a global partnership
- It is in all of our interests to make sure that this global effort succeeds
  - And for that, we need P5

Summary

- With the ILC, we have
  - A strong physics case
  - A machine we can build
  - An experienced design team
  - A nation moving to host
- The world is watching

ALCC Membership

Jonathan Bagger	Johns Hopkins
Jim Brau	Oregon
Dmitri Denisov	Fermilab
Paul Grannis	Stony Brook
Mike Harrison	BNL
Nigel Lockyer	Fermilab
Joe Lykken	Fermilab
David MacFarlane	SLAC
Lia Merminga	TRIUMF
Hugh Montgomery	Jefferson Lab
Marc Ross	SLAC
David Rubin	Cornell
Director of TRIUMF	TRIUMF
Harry Weerts	ANL (Chair)
Andy White	UT Arlington
Graham Wilson	Kansas