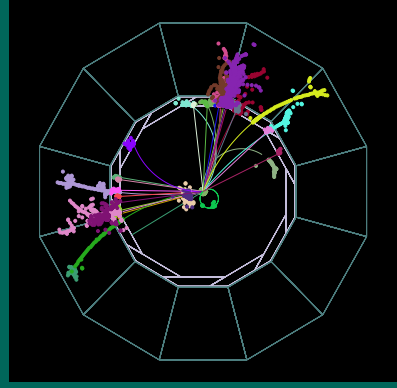


Snowmass 2013 Study

The ILC

Jim Brau

Community Planning Meeting

Fermilab

October 12, 2012

‘Discovery?’ of the First Fundamental Scalar

- Scalar particle(s) have been a central problem of high energy physics for decades
  - Mediate symmetry breaking, Moderate cross sections, Give mass to particles, Violate symmetries
- The newly discovered boson must be examined with great sensitivity – Is it the SM Higgs of EWSB or more? - Does it connect with additional states and processes?
- The LHC will provide some answers
  - Improved measurements – possibly more states– it will take time.
- But, hadron colliders are limited by systematics and model dependencies
- Electron machines (and perhaps future Muon colliders) offer valuable complementarity to our arsenal of instruments
  - Triggerless, bias free & model independent studies

The Lepton Colliders

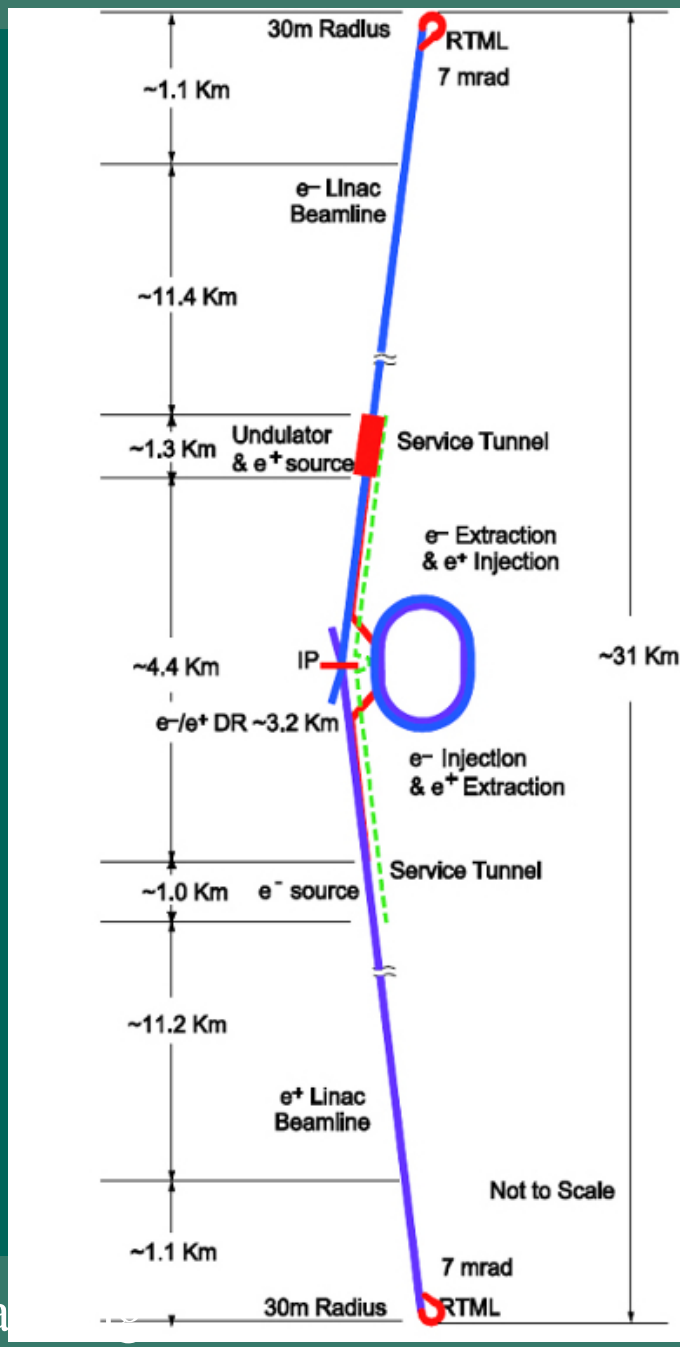
- For many years a world-wide effort has been developing the technology for this TeV class electron-positron collider.
- 2004 – the global community joined forces with a technology decision to pursue the superconducting RF approach, and a large R&D effort has brought this technology to maturity – The Global Design Effort (GDE) was formed by ICFA and the ILC TDR will be <u>completed this year</u>
- CLIC – a parallel effort is underway (completed CDR) to provide the technology to continue to higher energies
- MuC – and muons are being pursued, as well.

- BUT – the ILC is the only one of these technologies <u>ready for a start</u>

The ILC

- ✱ 500 GeV E_{cm}
  - Two 11 km SuperRF linacs at 31.5 MV/m
  - Centralized injector (***polarized electrons >80%***)
  - Undulator based positron source (***polarized***)
  - Variable E_{CM} (200 GeV – 500 GeV)
- ✱ Upgradable to 1 TeV
- ✱ Unprecedented detectors with low backgrounds
  - Democratic cross-sections

    eg. $\sigma(e^+e^- \rightarrow ZH) \sim 1/2\ \sigma(e^+e^- \rightarrow d\ d)$
  - Inclusive trigger (ie. NO TRIGGER)
- ✱ Options (for the future)
  - Hi luminosity at M_Z (***GigaZ***) / W pair threshold
  - $\gamma\gamma$, $e\gamma$, e^-e^-



ILC Plan in Japan

M. Yamauchi (KEK) - ESPP Open Symposium, Krakow - 12 Sep 12

- Japanese HEP community proposes to host ILC based on the "staging scenario" to the Japanese Government.
  - ILC starts as a 250GeV Higgs factory, and will evolve to a 500GeV machine.
  - Technical extendability to 1TeV is to be preserved.
- It is assumed that one half of the cost of the 500GeV machine is to be covered by Japanese Government. However, the share has to be referred to inter-governmental negotiation.

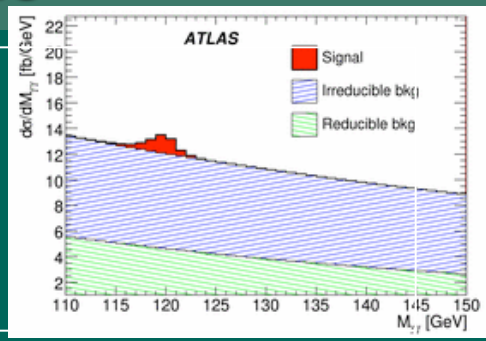
ILC Higgs Studies

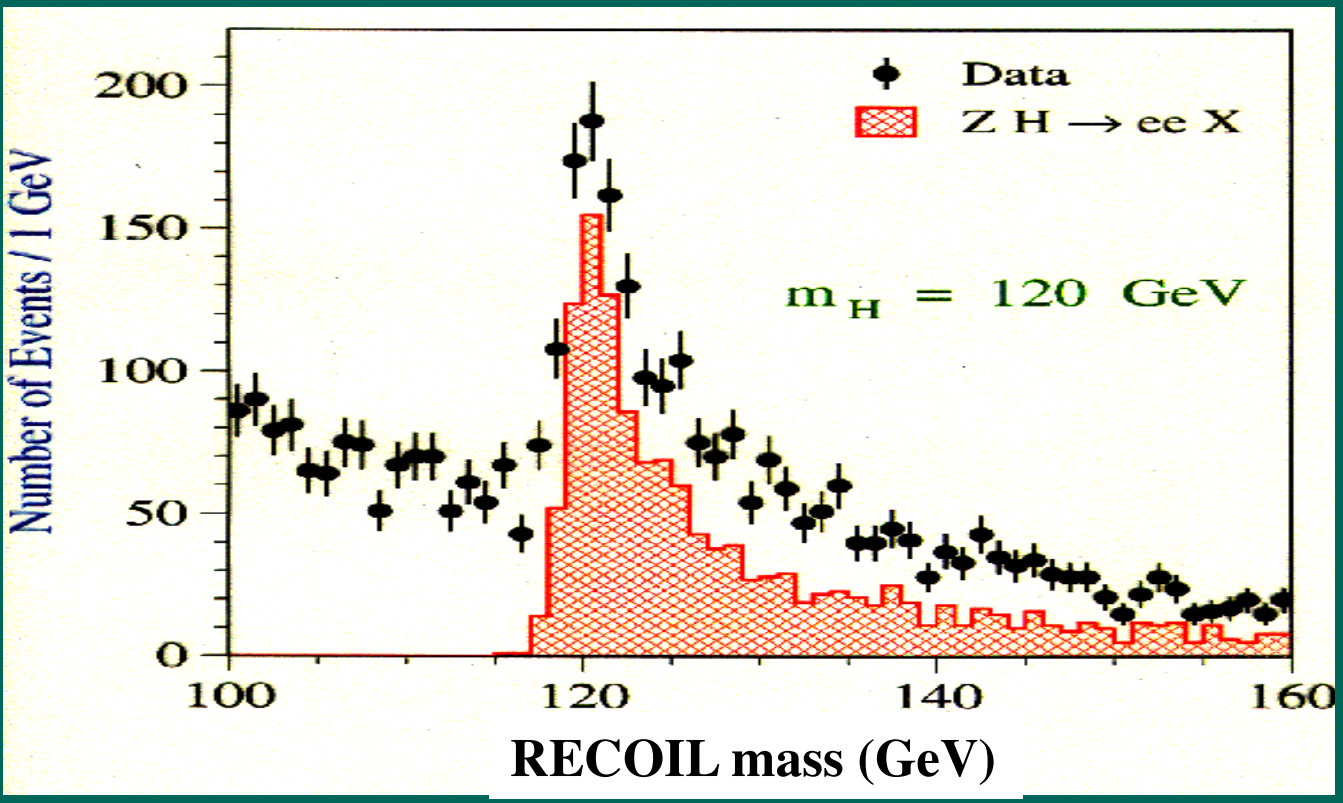
- the Power of Simple Interactions

ILC observes Higgs recoiling from a Z, with known CM energy⇓

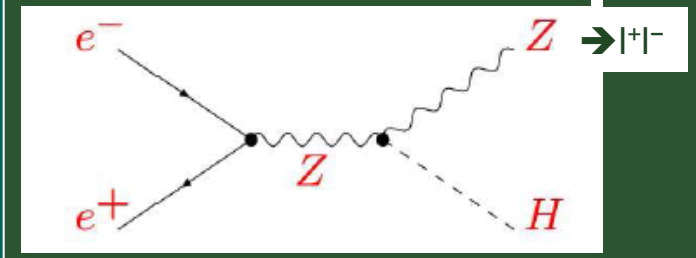
- powerful channel for unbiassed tagging of Higgs events
- measurement of even <u>invisible decays</u>

(⇓ - some beamstrahlung)





1. KNOWN INTIAL STATE
2. MEASURE Z→ l^+l^-



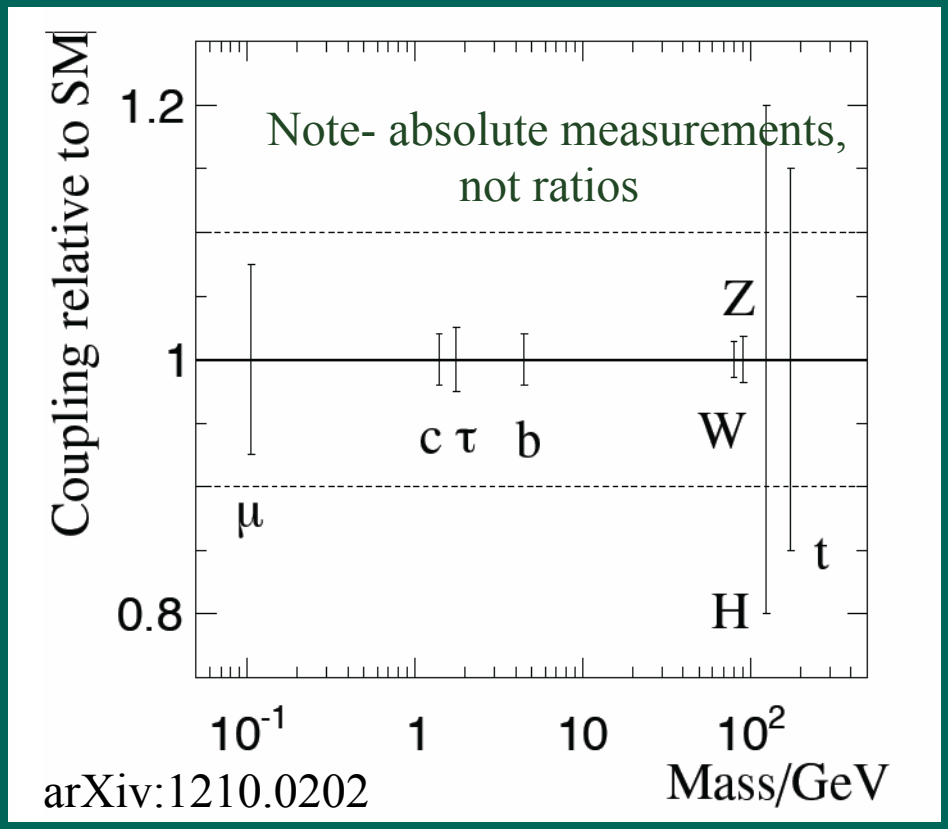
3. CALCULATE RECOIL

Invisible decays are included

500 fb^{-1} @ 500 GeV, TESLA TDR, Fig 2.1.4

ILC Couplings

- Linear Collider physics program will sharpen view of underlying physics of EWSB
  - Does Higgs boson carry Standard Model properties?
  - ILC offers very precise coupling measurements



Invisible and unexpected decay modes are also measured through Higgs-strahlung process

What can the LHC do with 3000 fb^{-1}?

Need 1-2 % Precision on Couplings

- Recall "Decoupling Limit" – deviations of coupling from SM could be quite small – Haber arxiv:9501320
- SUSY

$$g(\tau)/SM = 1 + 10\% \left(\frac{400\ \mathrm{GeV}}{m_A}\right)^2$$

$$g(b)/SM = g(\tau)/SM + (1-3)\%$$

Peskin arxiv:1208.5152

- Little Higgs

$$g(g)/SM = 1 + (5-9)\%$$

$$g(\gamma)/SM = 1 + (5-6)\%$$

- Composite Higgs

$$g(f)/SM = 1 + (3-9)\% \cdot \left(\frac{1\ \mathrm{TeV}}{f}\right)^2$$

f = fermion flavor

f = Goldstone boson decay constant

Note – each coupling channel can have independent variation

More ILC Physics

HIGGS - in addition to precision coupling measurements

Higgs mass – better than 50 MeV; Higgs width – 4-5%

Sensitive to mixing of CP-even and CP-odd to 3-4%

TOP Top quark mass ~100 MeV (statistical precision of 20 MeV)

Top quark width ~30 MeV

Asymmetries ~5%

Precise tests of Top couplings to Gauge bosons

SEARCH FOR LOW MASS DARK MATTER CANDIDATE

- -

REFINING LHC DISCOVERIES

Precision probe in clean environment reveals underlying physics

NEW DIRECT DISCOVERIES

Color neutral states

Higgs sector

NEW DISCOVERIES THROUGH PRECISION MEASUREMENTS

Precision tests of SM particles highly sensitive to new physics

The Snowmass Study

- Clarify the physics capabilities
  - What can the LHC achieve finally?
  - What are the relative capabilities of the ILC?
  - What are the implications for elucidating underlying physics?
- European Strategy Process already working on these issues
- On the ILC side, the upcoming workshop in Arlington, TX (LCWS12) will provide an opportunity
- Beyond that, the Snowmass planning process is organizing meetings on Higgs and on New Particles and Interactions in April/May 2013
  - These meetings will be good opportunities to advance and coordinate the studies
- If ILC importance is confirmed (I expect it to be, again), Then

  US community must endorse & support the Japanese initiative