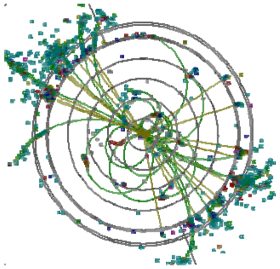
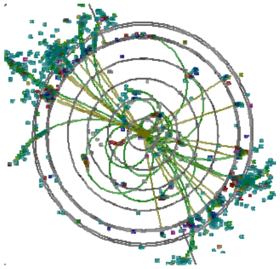


Electroweak Physics and the International Linear Collider

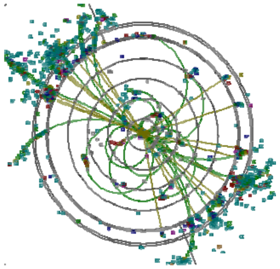
Jim Brau

May 1, 2006



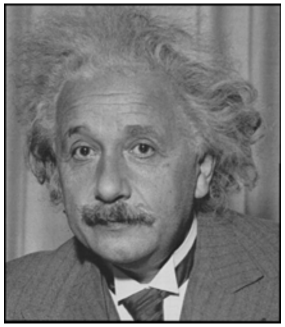
Electroweak Physics and The International Linear Collider

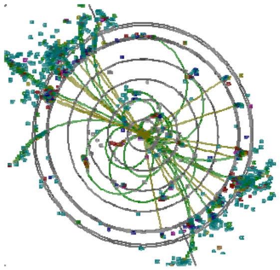
- **Electroweak Physics**
  - **Development of theory**
    - unification of E&M with beta decay (weak interaction)
  - **Predictions**
    - eg. M_W, M_Z, asymmetries....
  - **Missing components**
    - origin of symmetry breaking (Higgs Mechanism)
- **The Hunt for the Higgs Boson**
  - **Limits, indirect constraints and on-going search at TeVatron and LHC**
- **The International Linear Collider**
- **ILC physics program**



Electroweak Symmetry Breaking

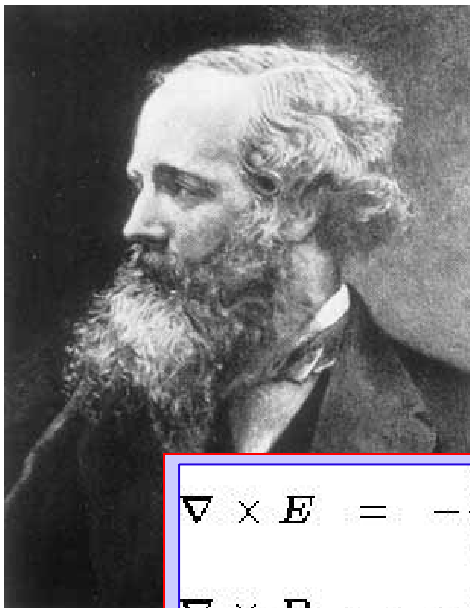
- **A central focus of particle physics research today is the origin of Electroweak Symmetry Breaking**
  - **The weak nuclear force and the electromagnetic force have been unified into a single description SU(2) x U(1)$_Y$**
  - **Why is this symmetry hidden?**
  - **The answer to this appears to promise deep understanding of fundamental physics**
    - the origin of mass
    - supersymmetry and possibly the elements of dark matter
    - additional unification (strong force, gravity)
      and possibly hidden space-time dimensions





Electromagnetism and Radioactivity

- Maxwell unified Electricity and Magnetism with his famous equations (1873)



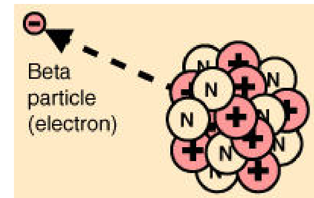
$$\nabla \times E = -\frac{\partial \mathbf{B}}{\partial t}$$

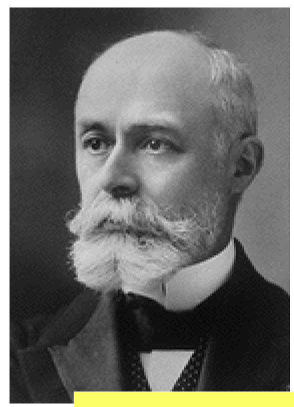
$$\nabla \times B = \mu_0 \mathbf{J} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

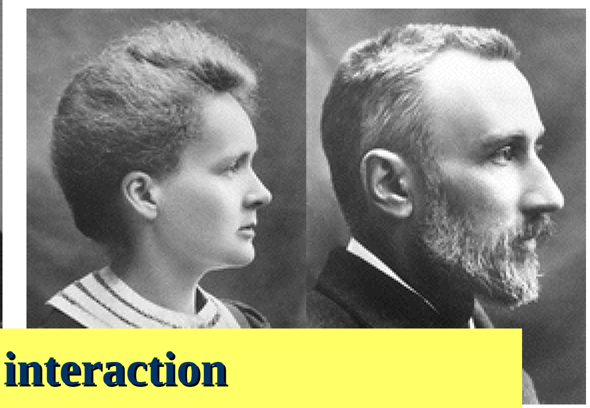
$$\nabla \cdot E = \rho/\epsilon_0$$

$$\nabla \cdot B = 0$$

- Matter spontaneously emits penetrating radiation
  - Becquerel uranium emissions in 1896
  - The Curies find radium emissions by 1898



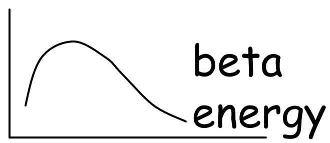




This new interaction (the weak force) is related to E&M

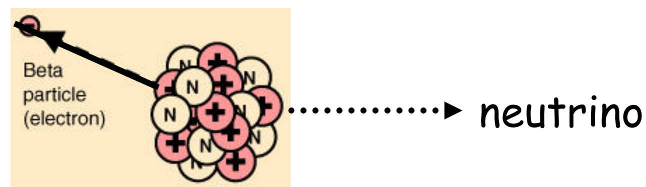
Advancing understanding of Beta Decay

- Pauli realizes there must be a neutral invisible particle accompanying the beta particle:
  - the neutrino



- Fermi develops a theory of beta decay (1934)

  $n \rightarrow p\, e^- \bar{\nu}_e$



- 1956 - Neutrino discovered

  Reines and Cowan

  - Savannah River Reactor, SC

EM and Weak Theory in 1960

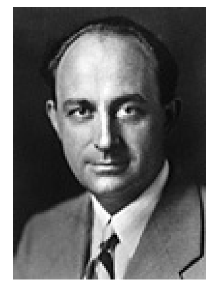
Weak Interaction Theory

- **Fermi's 1934 pointlike, four-fermion interaction theory**

$$M = G J^{\text{weak}}_{\text{baryon}} J^{\text{weak}}_{\text{lepton}} = G(\bar{\psi}_p O \psi_n)(\bar{\psi}_e O \psi_\nu)$$

V-A

$$W = \frac{2\pi}{\hbar} G^2 |M|^2 \frac{dN}{dE_0}$$



- **Theory fails at higher energy, since rate increases with energy, and therefore will violate the "unitarity limit"**
  - **Speculation on heavy mediating bosons but no theoretical guidance on what to expect**

EM and Weak Theory in 1960

Quantum Electrodynamics (QED)

- Dirac introduced theory of electron - 1926
- Through the pioneering theoretical work of Feynman, Schwinger, Tomonga, and others, a theory of electrons and photons was worked out with precise predictive power
- example: magnetic dipole of the electron

  [(g-2)/2] $\mu = g \ (e\hbar/2mc) \ S$

- current values of electron (g-2)/2

theory: $0.5 \ (\alpha/\pi) - 0.32848 \ (\alpha/\pi)^2 + 1.19 \ (\alpha/\pi)^3 + ..$

$= (115965230 \pm 10) \times 10^{-11}$

experiment $= (115965218.7 \pm 0.4) \times 10^{-11}$

The New Symmetry Emerges

VOLUME 19, NUMBER 21 PHYSICAL REVIEW LETTERS 20 NOVEMBER 1967

[11] In obtaining the expression (11) the mass difference between the charged and neutral has been ignored.

[12] M. Ademollo and R. Gatto, Nuovo Cimento 44A, 282 (1966); see also J. Pasupathy and R. E. Marshak, Phys. Rev. Letters 17, 888 (1966).

bra is slightly larger than that (0.23%) obtained from the ρ-dominance model of Ref. 2. This seems to be true also in the other case of the ratio $\Gamma(\eta \to \pi^+\pi^-\gamma)/\Gamma(\gamma\gamma)$ calculated in Refs. 12 and 14.

[14] L. M. Brown and P. Singer, Phys. Rev. Letters 8, ...).

A MODEL OF LEPTONS*

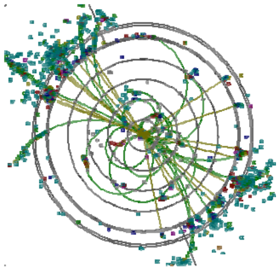
Steven Weinberg†

Laboratory for Nuclear Science and Physics Department, Massachusetts Institute of Technology, Cambridge, Massachusetts

Leptons interact only with photons, and with the intermediate bosons that presumably mediate weak interactions. What could be more natural than to unite[1] these spin-one bosons into a multiplet of gauge fields? Standing in the way of this synthesis are the obvious differences in the masses of the photon and intermediate meson, and in their couplings. We might hope to understand these differences

... a right-handed singlet

$$R = [\tfrac{1}{2}(1-\gamma_5)]e.$$



Enter Electroweak Unification

- Weinberg realized that the vector field responsible for the EM force
  - the photon

  and the vector fields responsible for the Weak force
  - yet undiscovered W^+ and W^-

  could be unified if another vector field, mediated by a heavy neutral boson (Z^0), were to exist

- This same notion occurred to Salam

$$L = g\mathbf{J}_\mu \cdot \mathbf{W}_\mu + g' J_\mu^Y B_\mu$$

$$\tan\theta_W = g'/g$$

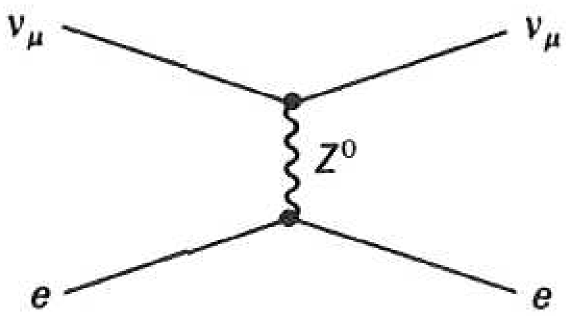
$$\sin^2\theta_W = g'^2/(g'^2+g^2)$$

$$W_\mu^{(3)} = \frac{gZ_\mu + g'A_\mu}{\sqrt{g^2+g'^2}} \qquad B_\mu = \frac{-g'Z_\mu + gA_\mu}{\sqrt{g^2+g'^2}} \longrightarrow e\,J_\mu^{(em)}\,A_\mu$$

$$e = g\sin\theta_W = g'\cos\theta_W$$

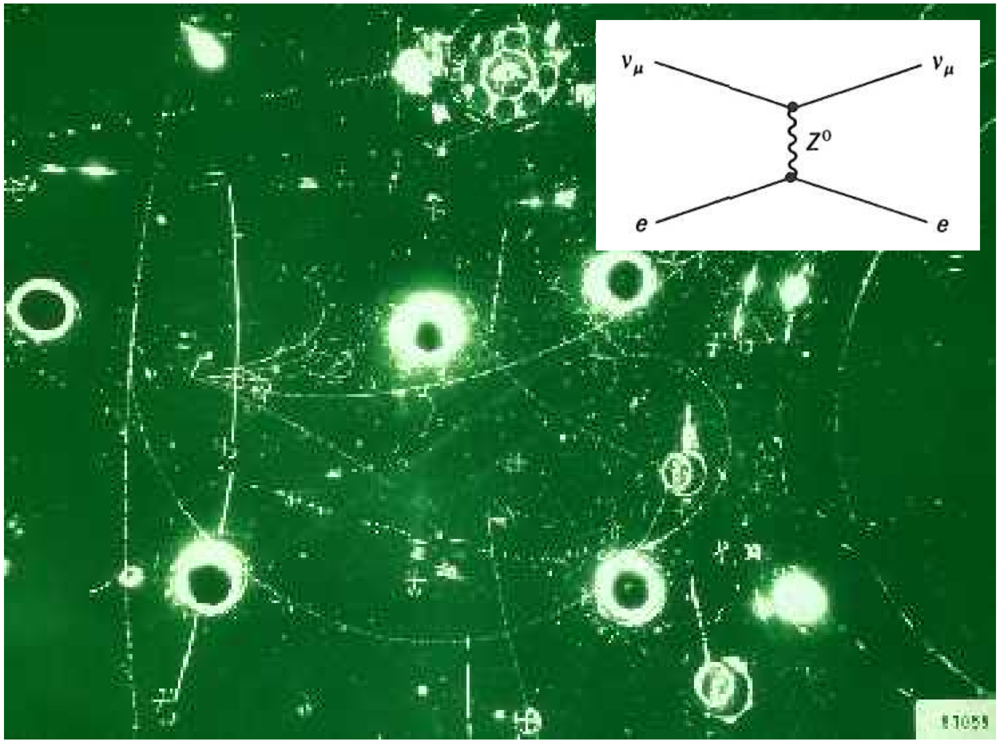
Electroweak Unification

- There remained a phenomenological problem:
  - where were the effects of the Z^0
- These do not appear so clearly in Nature
  - they are small effects in the atomic electron energy level
- One has to look for them in high energy experiments



Neutral Currents Discovered!

- **1973 - giant bubble chamber Gargamelle at CERN**
  - **12 cubic meters of heavy liquid**

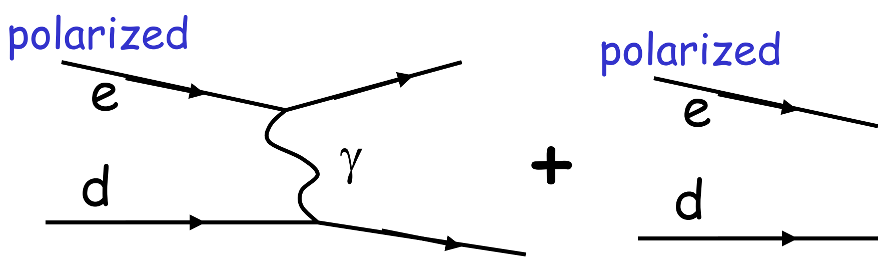


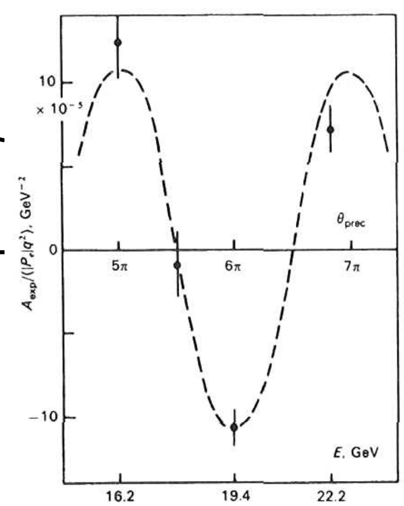
- **Muon neutrino beam**
- **Electron recoil**
- **Nothing else**

- **Neutral Current Discovered**
  that is, the effect of the Z^0

Confirmation of Neutral Currents

- **Weinberg-Salam Model predicts there should be some parity violation in polarized electron scattering**
  - **The dominant exchange is the photon (L/R symmetric)**
  - **A small addition of the weak neutral current exchange leads to an expected asymmetry of $\sim 10^{-4}$ between the scattering of left and right-handed electrons**

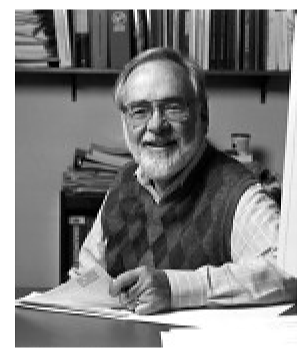




Z^0 exchange violates parity

$g_R \neq g_L$

asymmetry of 10^{-4}



- **Prescott et al. (SLAC) 1978**
- **confirms theory**
- **first accurate measurement of weak mixing angle**

$\sin^2\theta_W = 0.22 \pm 0.02$

W and Z Masses

- **Knowing $\sin^2\theta_W$ allows one to predict the W and Z boson masses in the Weinberg-Salam Model**

$$M_{W^\pm} = \left(\frac{e^2\sqrt{2}}{8G\sin^2\theta_W}\right)^{1/2} = \frac{37.4}{\sin\theta_W}\ \mathrm{GeV} \qquad \sim 80\ \mathrm{GeV}/c^2$$

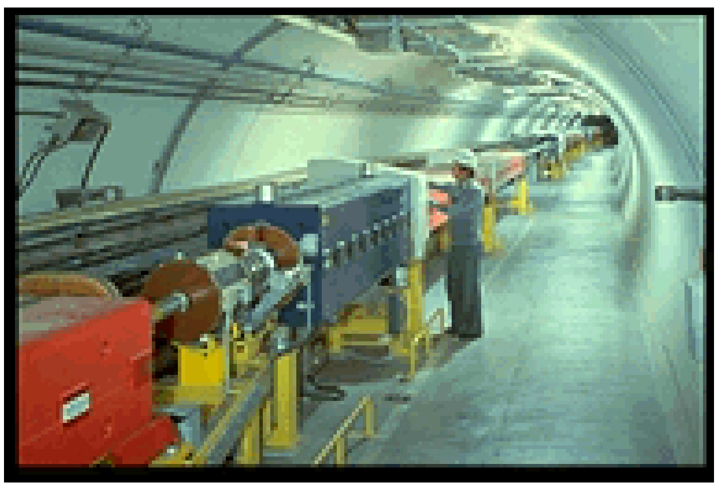
$$M_{Z^0} = \frac{M_{W^\pm}}{\cos\theta_W} = \frac{75}{\sin 2\theta_W}\ \mathrm{GeV} \qquad \sim 90\ \mathrm{GeV}/c^2$$

TREE LEVEL EXPRESSIONS

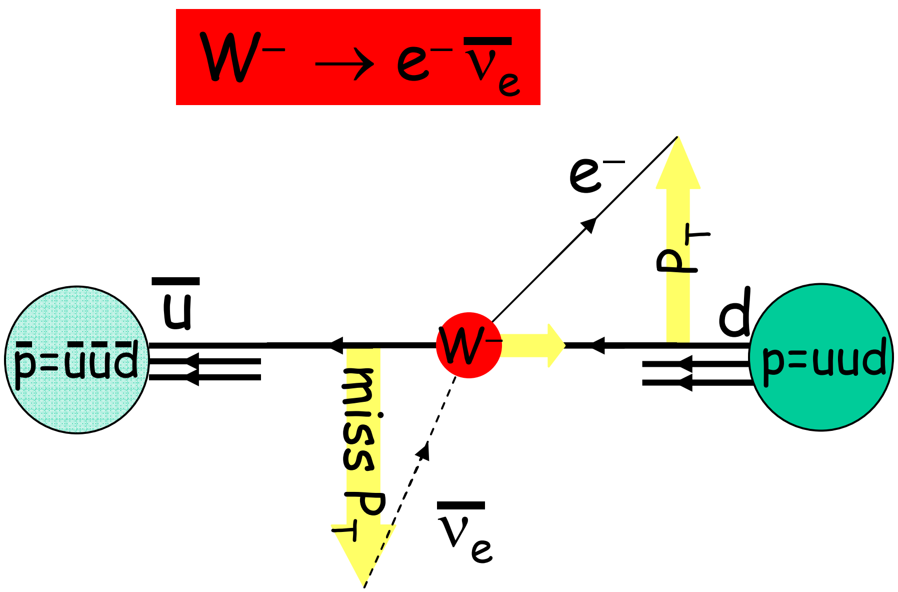
- **Motivated by these predictions, experiments at CERN were mounted to find the W and Z**

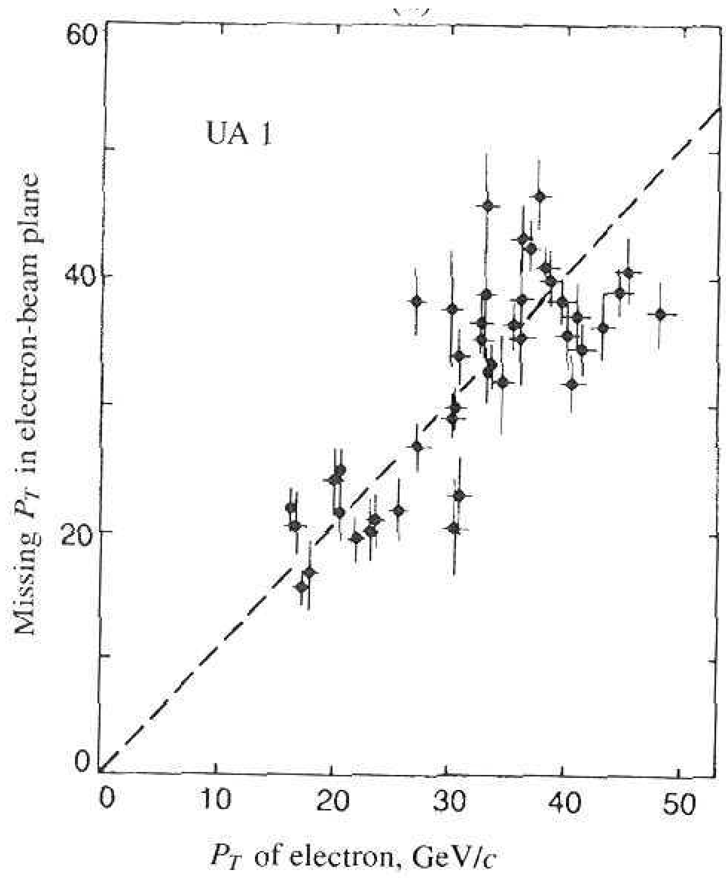
Discovery of the W and Z

- 1981 - antiprotons were stored in the CERN SPS ring and brought into collision with protons

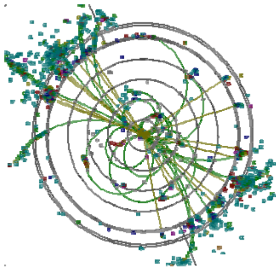


Discovery of the W and Z





UA1 and UA2 discovered the W and the Z bosons



Discovery of the W and Z

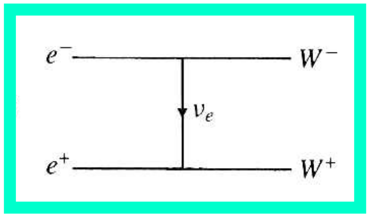
- **That was over 20 years ago**
- **Since then:**
  - **precision studies at Z^0 Factories**
    - LEP and SLC
  - **precision W measurements at colliders**
    - LEP2 and TeVatron

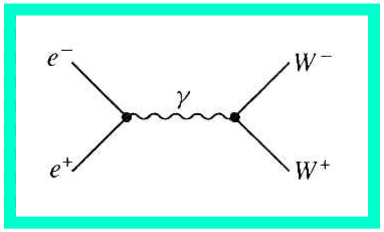
$M_Z = 91187.5 \pm 2.1$ MeV $\qquad M_W = 80404 \pm 30$ MeV/c^2

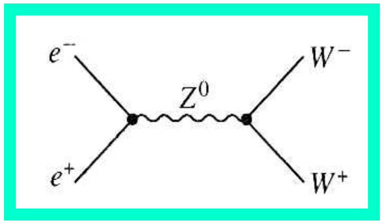
- **These precise measurements (along with other precision measurements) test the Standard Model with keen sensitivity**
  - **eg. are all observables consistent with the same value of $\sin^2\theta_W$**

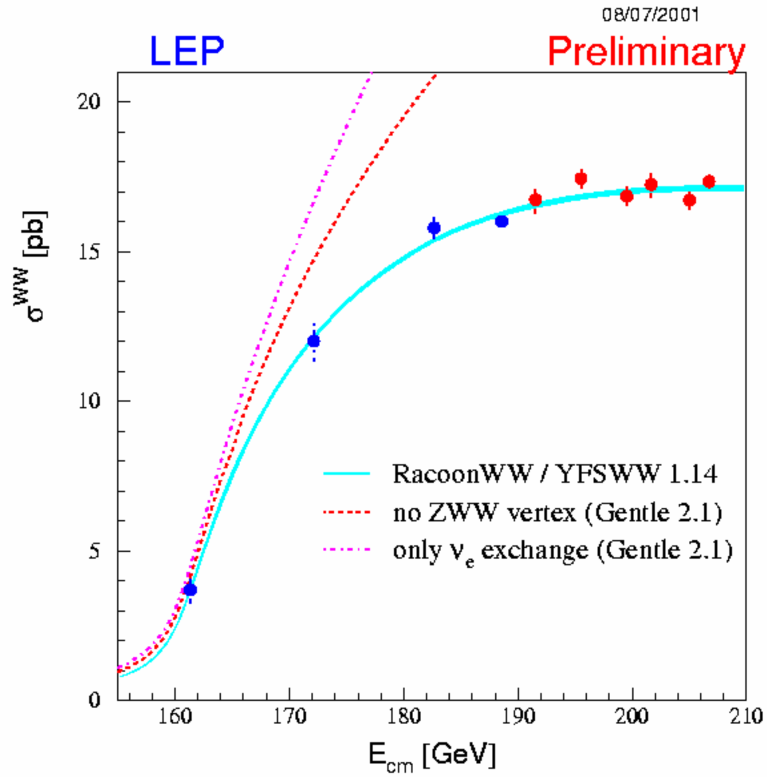
Confirmation of the completeness of the Standard Model

$e^+e^- \rightarrow W^+W^-$ **(LEP2)**









The Higgs Boson

- Why is the underlying SU(2)xU(1) symmetry

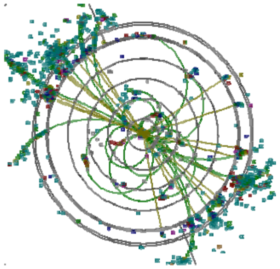
$$L = g\mathbf{J}_\mu \cdot \mathbf{W}_\mu + g' J_\mu^Y B_\mu$$

broken

$$= -\frac{g}{2\sqrt{2}}\sum_i \overline{\psi}_i\, \gamma^\mu\, (1-\gamma^5)(T^+\, W_\mu^+ + T^-\, W_\mu^-)\, \psi_i - e\sum_i q_i\, \overline{\psi}_i\, \gamma^\mu\, \psi_i\, A_\mu - \frac{g}{2\cos\theta_W}\sum_i \overline{\psi}_i\, \gamma^\mu (g_V^i - g_A^i \gamma^5)\, \psi_i\, Z_\mu\,.$$

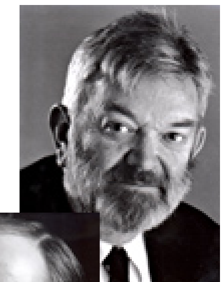
- Theoretical conjecture is the Higgs Mechanism:

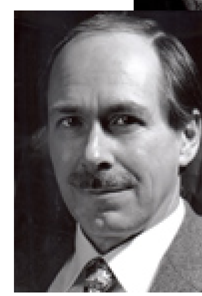
  a non-zero vacuum expectation value of a scalar field, gives mass to W and Z and leaves photon massless

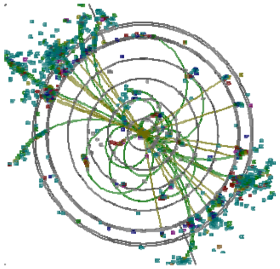


The Higgs Boson

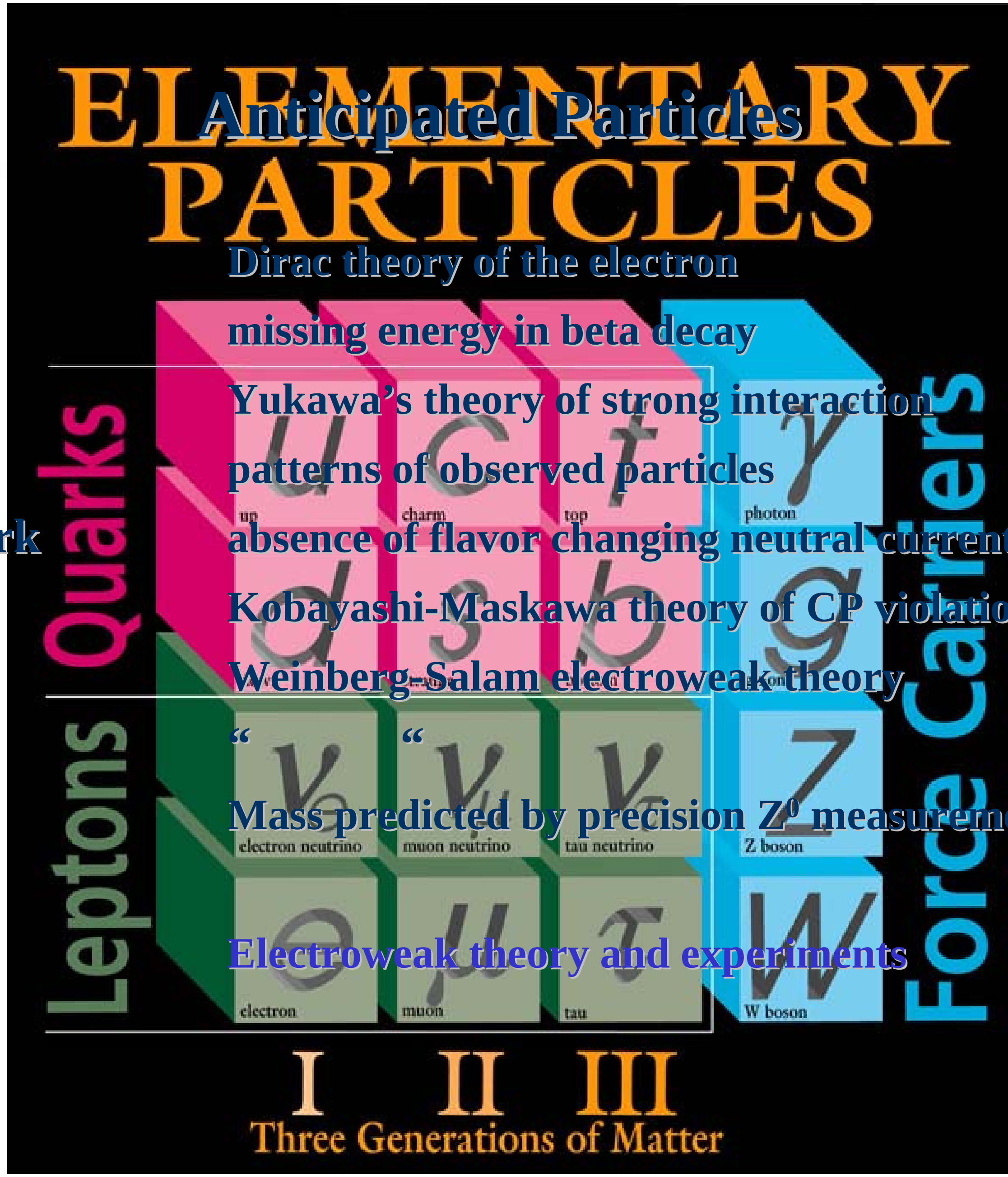
- **This scalar field, like any field, has quanta, the Higgs Boson or Bosons**
  - **Minimal model - one complex doublet $\Rightarrow$ 4 fields**
    - —3 “eaten” by W^+, W^-, Z to give mass
    - —1 left as physical Higgs
- **This spontaneously broken local gauge theory is renormalizable - t’Hooft (1971)**
- **The Higgs boson properties**
  - **Mass < ~ 800 GeV/c^2 (unitarity arguments)**
  - **Strength of Higgs coupling increases with mass**
    - fermions: $g_{ffh} = m_f / v$ $\quad$ v = 246 GeV
    - gauge boson: $g_{wwh} = 2\, m_Z^2/v$



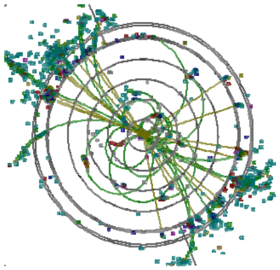




Anticipated Particles

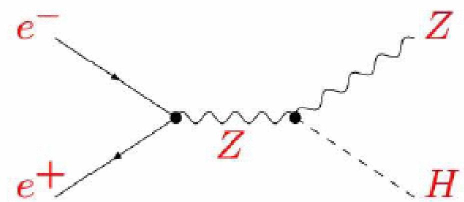


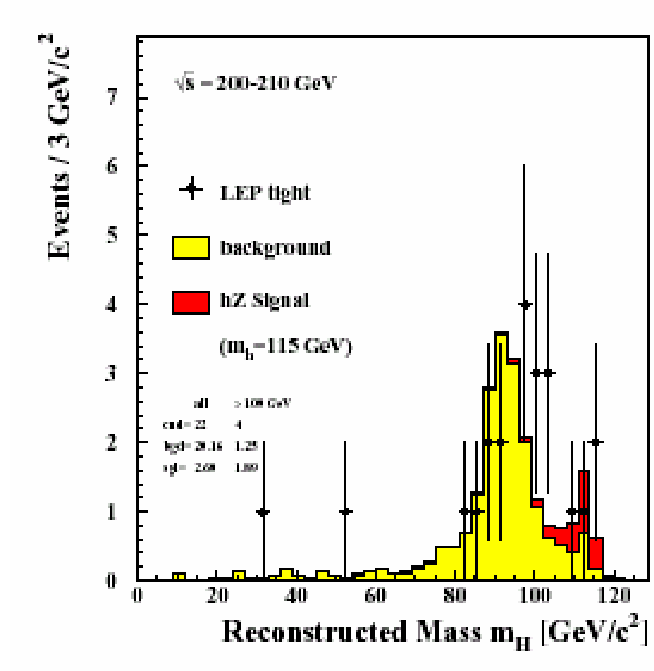
Positron	**Dirac theory of the electron**
Neutrino	**missing energy in beta decay**
Pi meson	**Yukawa's theory of strong interaction**
Quark	**patterns of observed particles**
Charmed quark	**absence of flavor changing neutral currents**
Bottom quark	**Kobayashi-Maskawa theory of CP violation**
W boson	**Weinberg-Salam electroweak theory**
Z boson	**“ “**
Top quark	**Mass predicted by precision Z^0 measurements**
Higgs boson	**Electroweak theory and experiments**



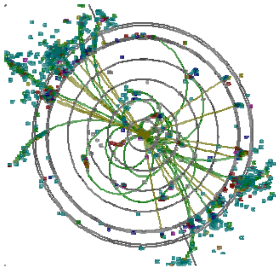
The Search for the Higgs Boson

- LEP II (1996-2000)



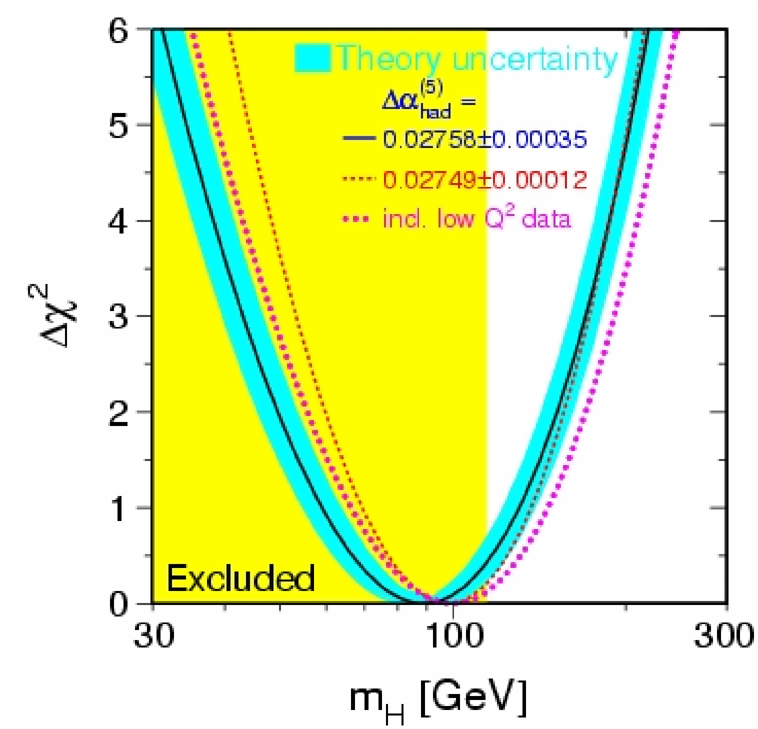


M_H > 114 GeV/c² (95% conf.)

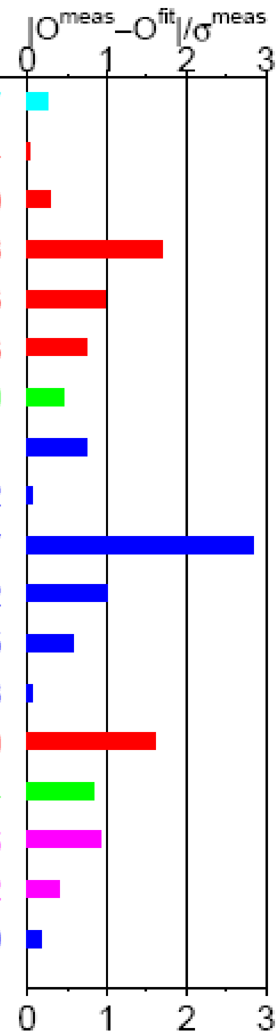


Standard Model Fit

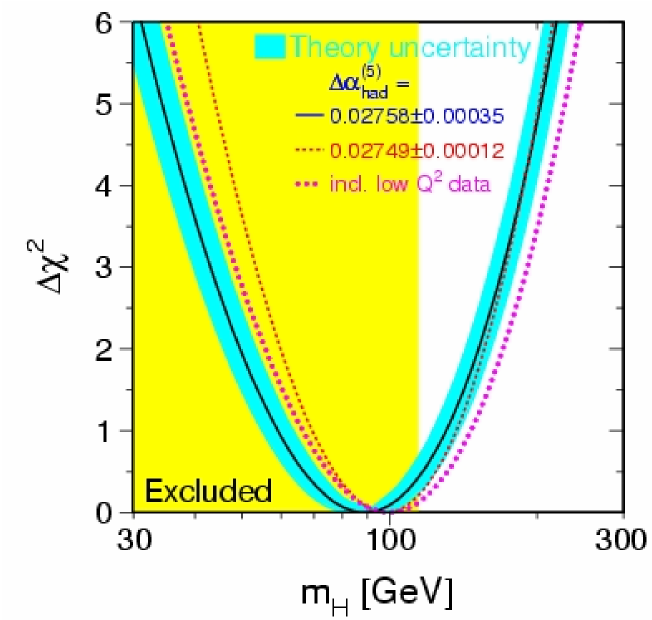
- $M_H = 89^{+42}_{-30}\ \mathrm{GeV}/c^2$

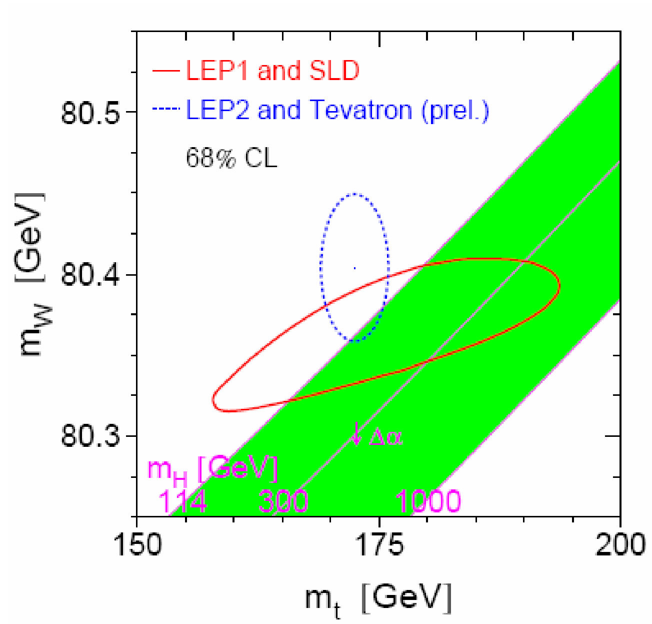


	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4959
σ^0_{had} [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.743
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01643
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21581
R_c	0.1721 ± 0.0030	0.1722
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1037
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.404 ± 0.030	80.376
Γ_W [GeV]	2.115 ± 0.058	2.092
m_t [GeV]	172.5 ± 2.3	172.9



Light Standard Model-like Higgs





(SM) M_{higgs} < 175 GeV at 95% CL.
LEP2 direct limit M_{higgs} > 114.4 GeV.

W mass (± 30 MeV)
and top mass (± 3 GeV)
consistent with precision measures
and indicate low SM Higgs mass

LEP Higgs search – Maximum Likelihood for Higgs signal at m_H = 115.6 GeV with overall significance (4 experiments) ~ 2σ

The Search for the Higgs Boson

- **Tevatron at Fermilab**
  - **Proton/anti-proton collisions at E_{cm}= 2000 GeV**
  - **Now through 2009**

- **LHC at CERN**
  - **Proton/proton collisions at E_{cm}=14,000 GeV**
  - **First collisions ~2007**

Models of Electroweak Symmetry Breaking

Standard Model Higgs

excellent agreement with EW precision measurements
implies $M_H < 175$ GeV (but theoretically ugly - h'archy prob.- M_h unstable)

MSSM Higgs

expect $M_h < \sim 135$ GeV
light Higgs boson (h) may be very "SM Higgs-like"
(de-coupling limit)

Non-exotic extended Higgs sector

eg. 2HDM

Strong Coupling Models

New strong interaction

The ILC will provide critical data on all of these possibilities

Establishing Standard Model Higgs

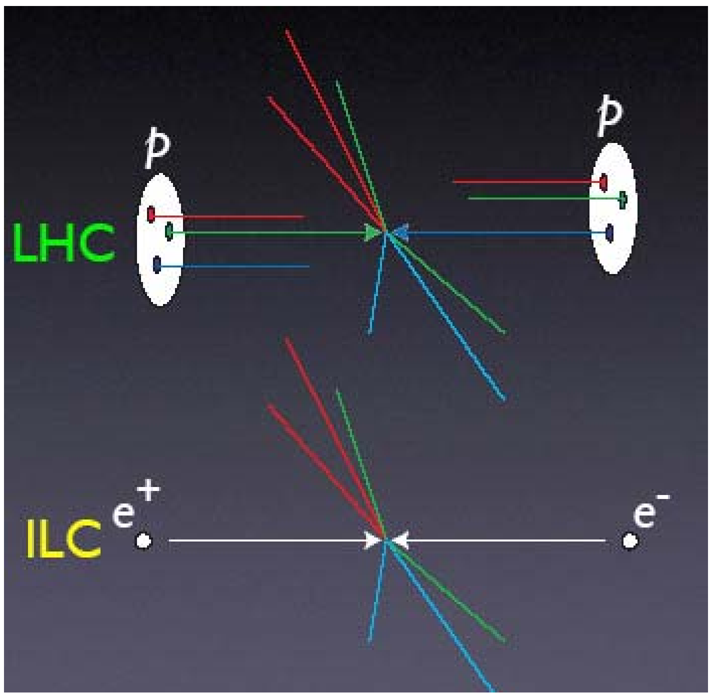
precision **studies of the Higgs boson will be required to understand Electroweak Symmetry Breaking; just finding the Higgs is of limited value**

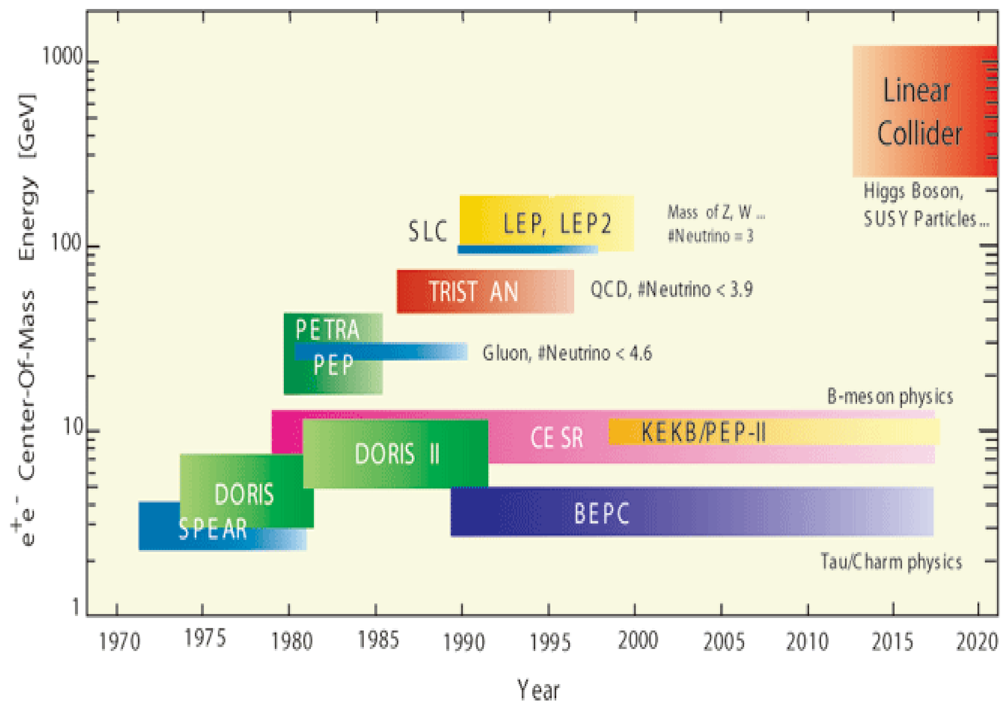
We expect the Higgs to be discovered at LHC (or Tevatron) and the measurement of its properties will begin at the LHC

We need to measure the full nature of the Higgs to understand EWSB

500 GeV International Linear Collider is the tool needed for these *precision* studies

Complementarity of Electron Colliders



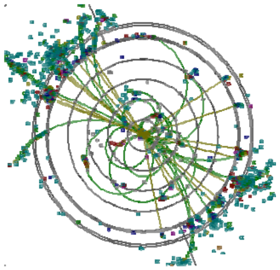


The Large Hadron Collider and the ILC

- LHC at CERN, colliding protons first collisions - 2007
- History demonstrates the complementarity of hadron and electron experiments

discovery	facility of discovery	facility of detailed study
charm	BNL + SPEAR	SPEAR at SLAC
tau	SPEAR	SPEAR at SLAC
bottom	Fermilab	Cornell/DESY ⇒ B Factories
Z^0	SPPS	LEP and SLC

- Electron experiments have frequently provided most precision



Adding Value to LHC measurements

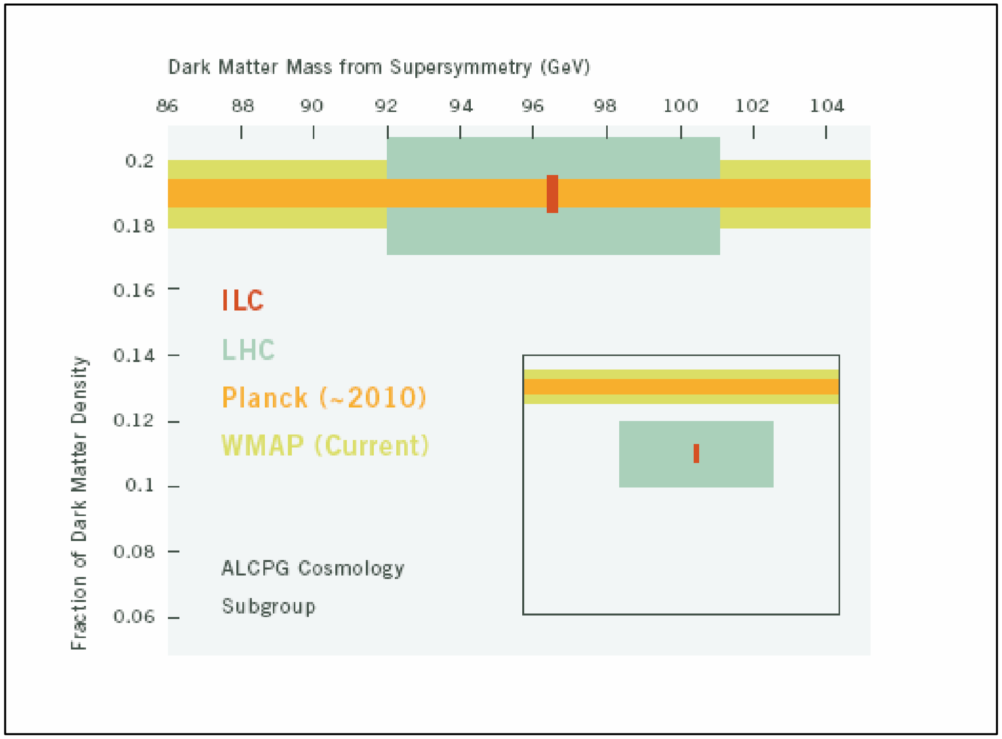
The International Linear Collider will enhance the LHC measurements ("enabling technology")

How this happens depends on the Physics:

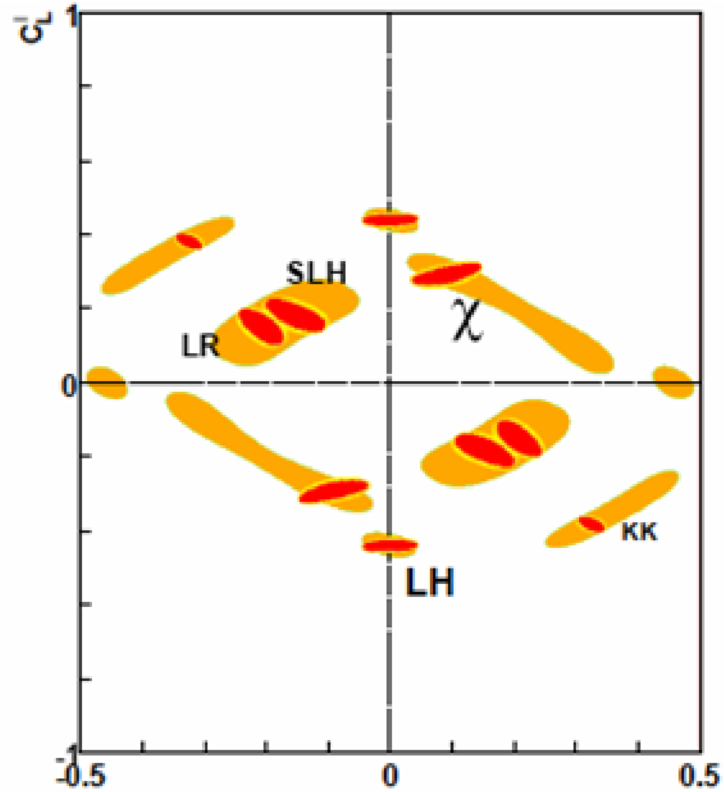
- **Add precision to the discoveries of LHC**
  - **eg. light higgs measurements**
- **Measure superpartner masses and properties**
- **Susy parameters may fall in the tan β /M_A wedge.**
- **Directly observed strong WW/ZZ resonances at LHC are understood from asymmetries at Linear Collider**
- **Analyze extra neutral gauge bosons**
- **Giga-Z constraints**

Complementarity with LHC

SUSY mass and coupling measurements
=> Identification of dark matter



Z′ discovered at LHC
Couplings determined at ILC



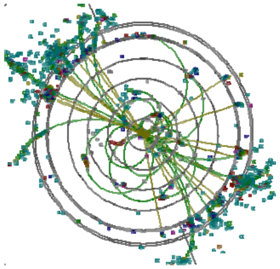
m $_{Z'}$ =2TeV,Ecm=500 GeV, L=1ab^{-1}
with and w/o beam polarization
S.Godfrey, P.Kalyniak, A.Tomkins

Colliders (Circular and Linear)

- **Storage rings have been the optimal facilities for colliding beam experiments for several decades**
  - Developed in 1960's to achieve highest possible center of mass collision energy
  - Particle beams stored for many hours
  - Efficient transfer of beam energy to interactions

- **Electron storage rings have a limited useful energy**

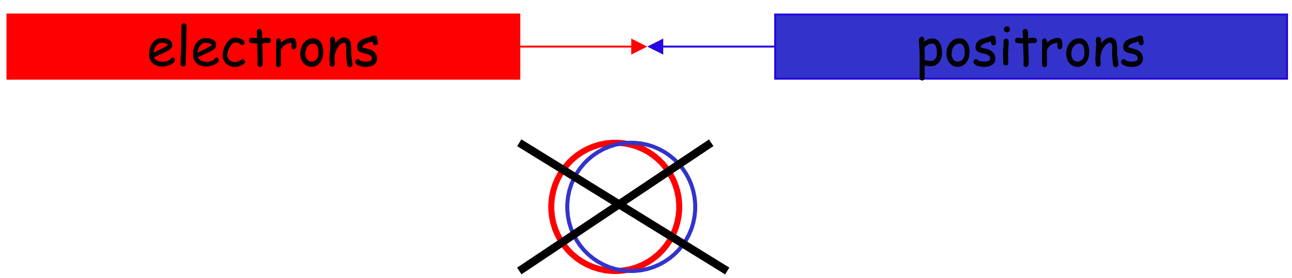
  LEP ~ 100 GeV beam energy



Linear Colliders

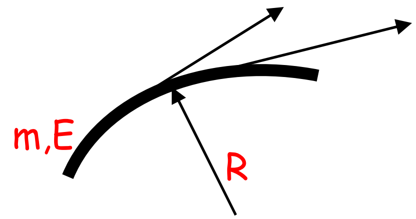
- **Acceleration of electrons in a <u>circular</u> accelerator is plagued by Nature's resistance to acceleration**
  - **Synchrotron radiation**
  - **$\Delta E = 4\pi/3\ (e^2\beta^3\gamma^4 / \underline{R})$ per turn (recall $\gamma = E/m$, so $\Delta E \sim E^4/m^4$)**
  - **eg. LEP2 $\Delta E = 4$ GeV Power ~ 20 MW**

- **For this reason, at very high energy it is preferable to accelerate electrons in a <u>linear</u> accelerator, rather than a circular accelerator**

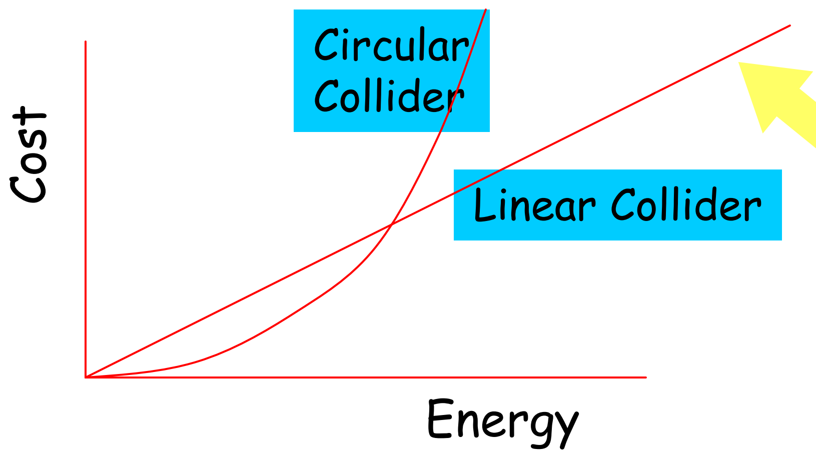


Linear Colliders

- **Synchrotron radiation**
  - $\Delta E \sim (E^4/m^4 R)$



- **Therefore**
  - **Cost (circular)** $\sim a R + b \Delta E \quad \sim a R + b (E^4/m^4 R)$
    - Optimization $R \sim E^2 \quad \Rightarrow$ Cost $\sim c E^2$
  - **Cost (linear)** $\sim a' L$, where $L \sim E$

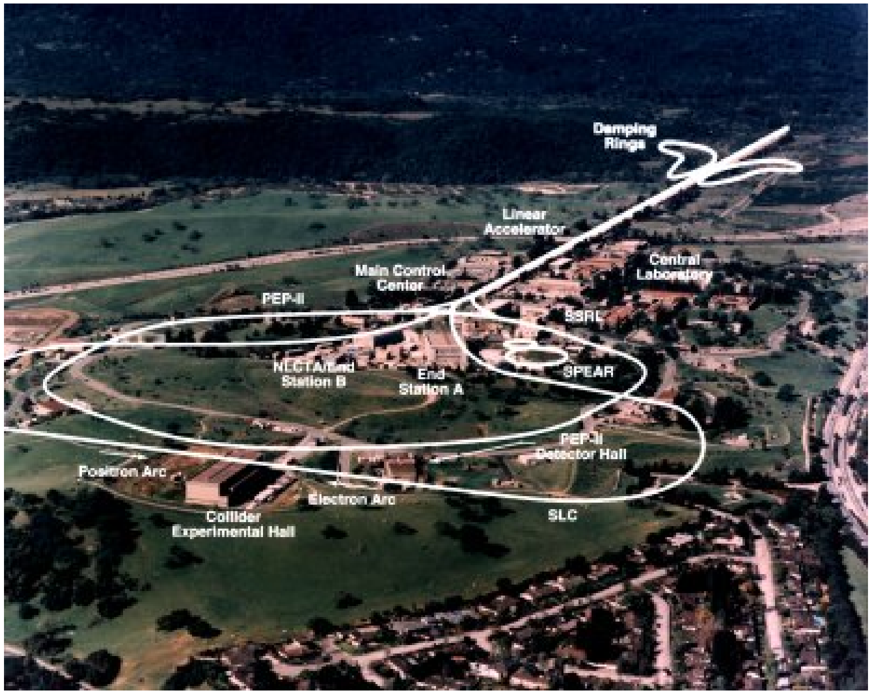


- **At high energy, linear collider is more cost effective**

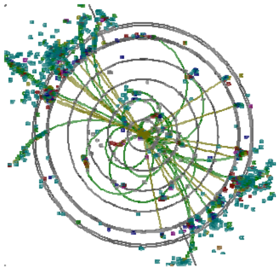
The First Linear Collider

- This concept was demonstrated at SLAC in a linear collider prototype operating at ~91 GeV (the SLC)

- SLC was built in the 80's within the existing SLAC linear accelerator



- Operated 1989-98
  - precision Z^0 measurements
  - established ILC concepts

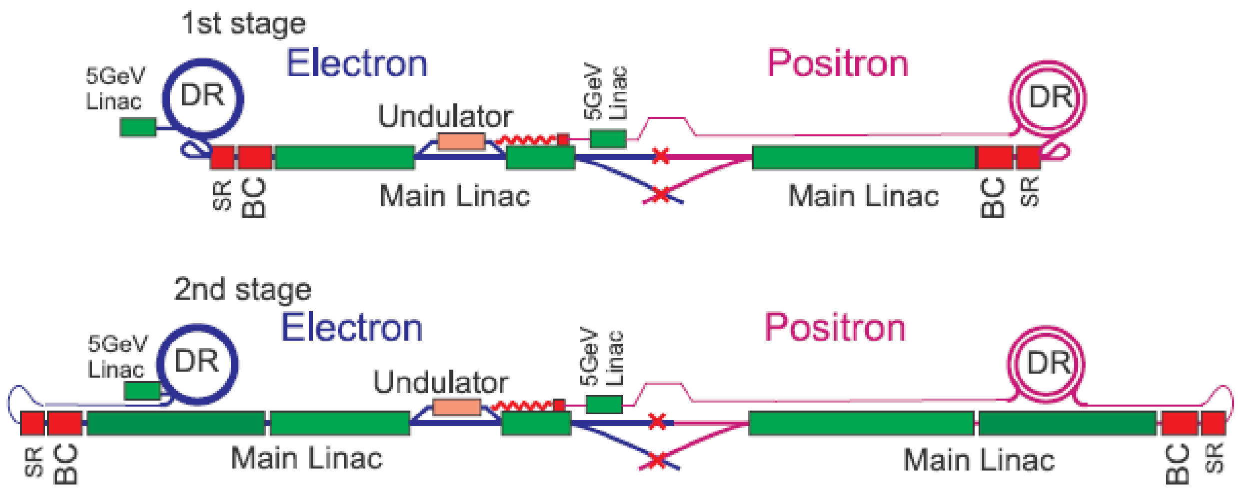


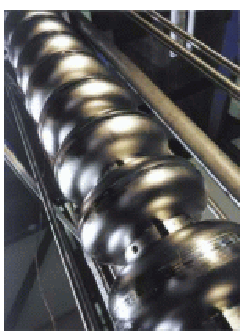
The International Linear Collider

E_{cm} = 500 GeV
- 1000 GeV

Polarized e^-
(~80% and e^+)

Length (500 GeV)
~25 km
~15 miles



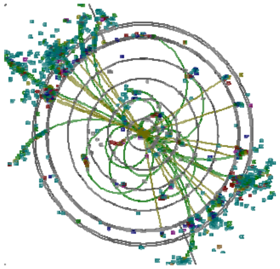


Elucidate Electroweak Interaction

- **precision meas. symmetry breaking**
  - Higgs bosons
  - supersymmetric particles
  - extra dimensions

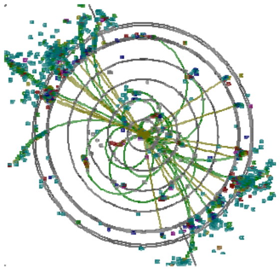
Construction could begin soon after 2010 and operation soon after 2016

- **Intense R&D until 2010**



ILC Accelerator Physics Challenges

- **Develop High Gradient Superconducting RF systems**
  - **Requires efficient RF systems, capable of accelerating high power beams (~MW) with small beam spots(~nm).**
- **Achieving nm scale beam spots**
  - **High intensity beams of electrons and positrons**
  - **Damped beams to ultra-low emittance in damping rings**
  - **Transport beams to collision point without significant emittance growth or uncontrolled beam jitter**
  - **Cleanly dumped used beams.**
- **Reaching Luminosity Requirements**
  - **Designs satisfy the luminosity goals in simulations**
  - **A number of challenging problems in accelerator physics and technology must be solved, however.**



ILC Experimental Advantages

Elementary interactions at known E_{cm}*

eg. $e^+e^- \rightarrow$ Z H * beamstrahlung manageable

Democratic Cross sections

eg. $\sigma(e^+e^- \rightarrow ZH) \sim 1/2\ \sigma(e^+e^- \rightarrow d\bar{d})$

Inclusive Trigger

total cross-section

Highly Polarized Electron Beam

~ 80% (positron polarization? – R&D)

Exquisite vertex detection

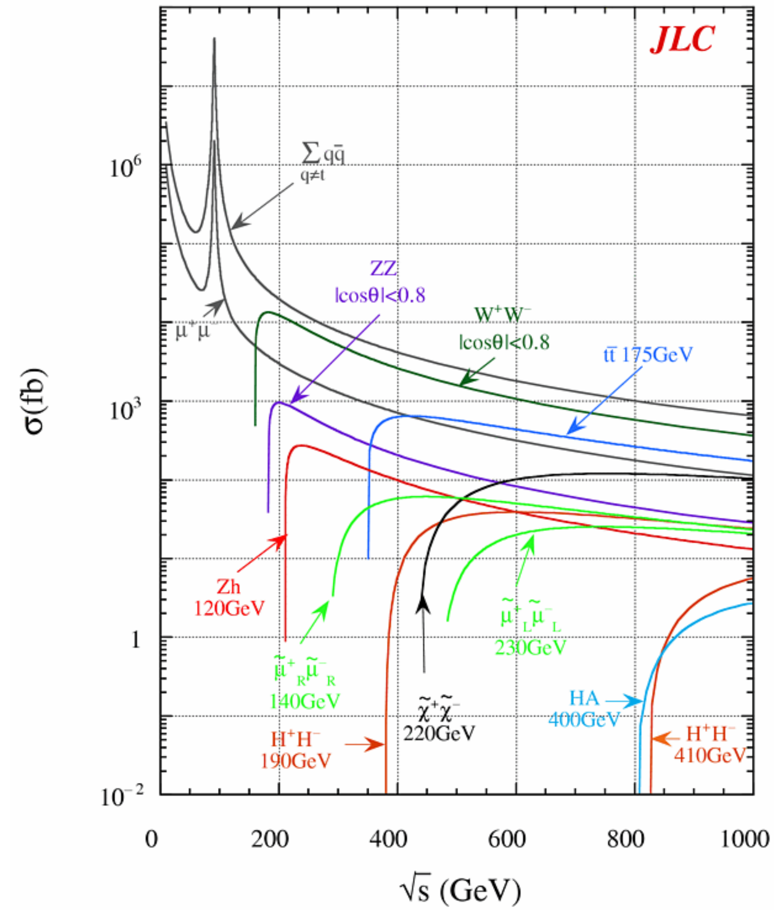
eg. $R_{beampipe} \sim 1$ cm and $\sigma_{hit} \sim 3\ \mu m$

Calorimetry with Particle Flow Precision

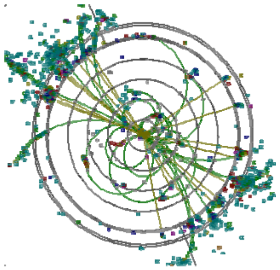
$\sigma_E/E \sim 30\text{-}40\%/\sqrt{E}$

Advantage over hadron collider on precision meas.

eg. $H \rightarrow c\bar{c}$



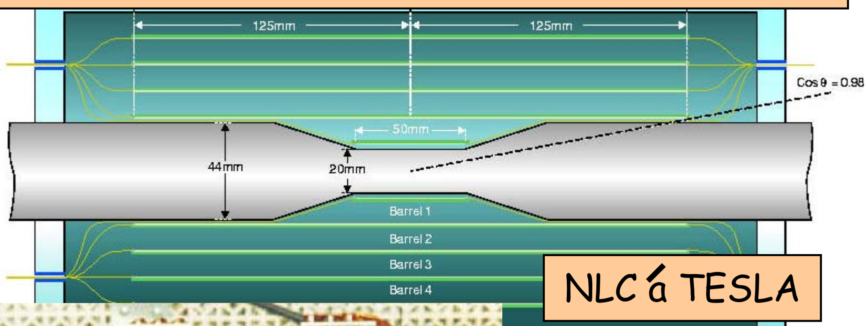
Detector performance translates directly into effective luminosity



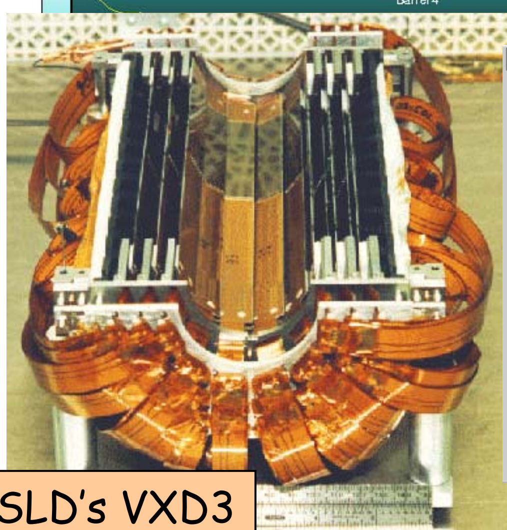
Linear Collider Detectors

The Linear Collider provides very special experimental conditions (eg. superb vertexing and jet calorimetry)

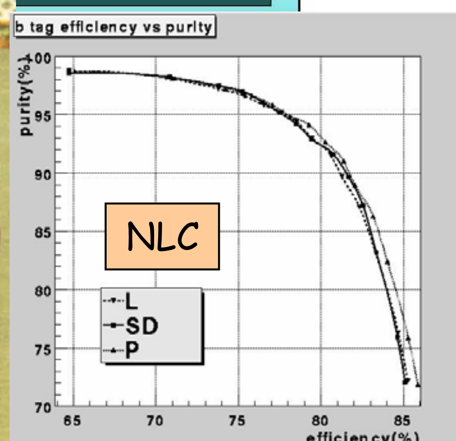
Giga-pixel Vertex Detector



NLC á TESLA



SLD's VXD3

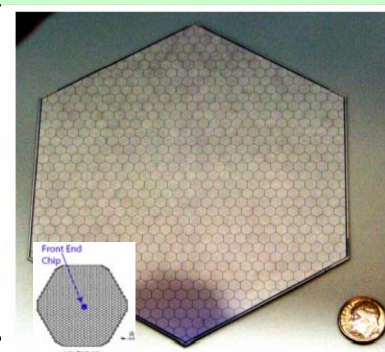


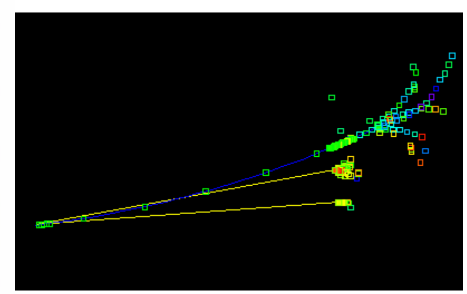
NLC

Silicon-Tungsten EM Calorimetry

SLD Lum (1990)
Aleph Lum (1993)
Opal Lum (1993)

90 Mcell Si/W EM calorimeter central element in particle flow measurement

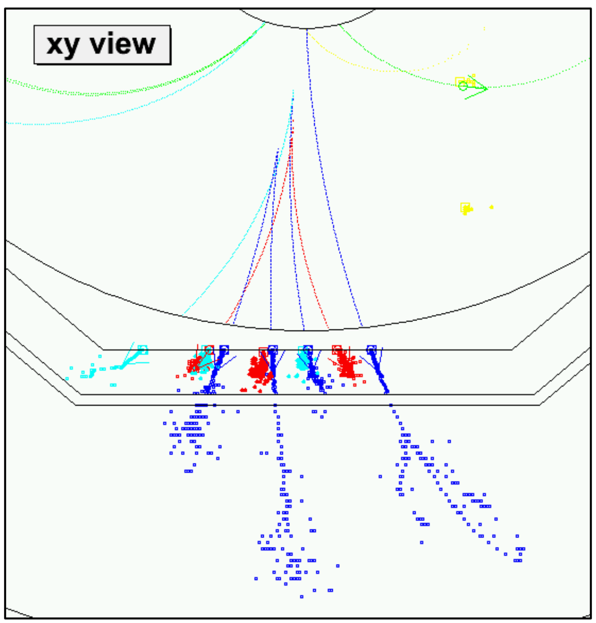




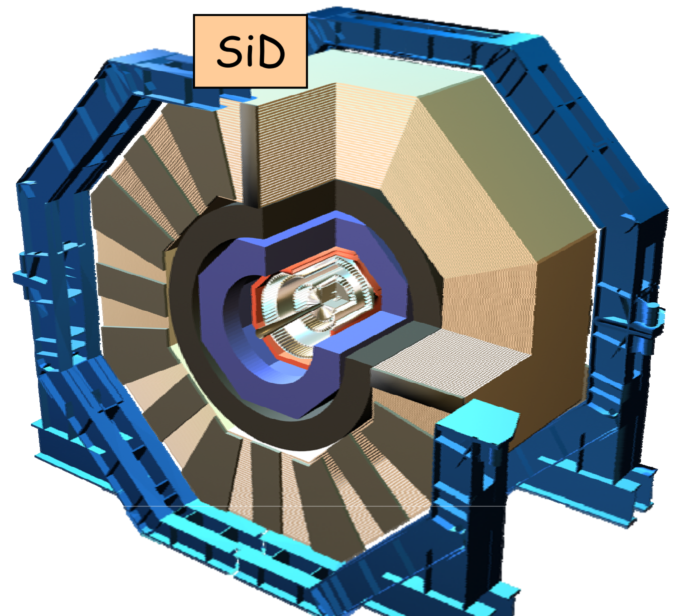
Linear Collider Detectors

Digital Hadron Calorimeter

40 Mcell hadron calorimeter
jet resolution ~30% / $\sqrt{E}$
relies on tracker for charged particles

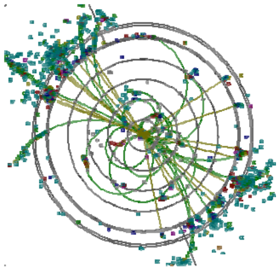


Integrated Detector Designs



Silicon Tracking
5 Tesla Solenoid

Also, GLD, LDC, 4th

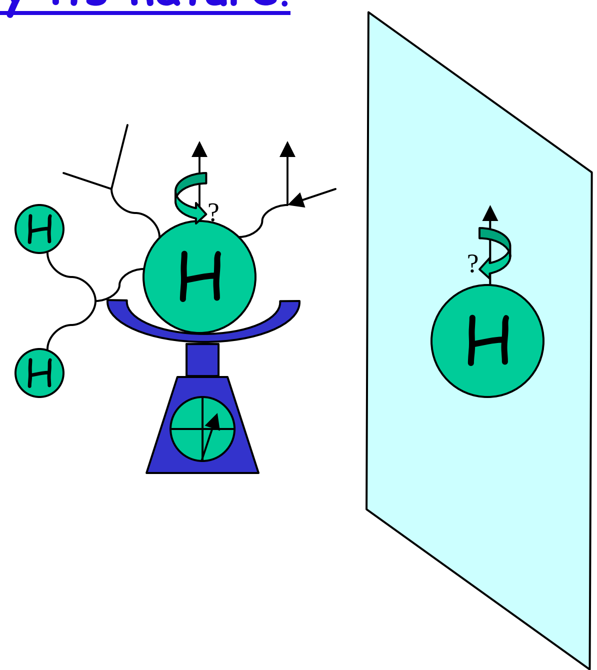


Higgs Physics Program of the ILC

Electroweak precision measurements suggest there should be a relatively light Higgs boson:

When it's discovered, we will want to study its nature. The ILC is essential to this program.

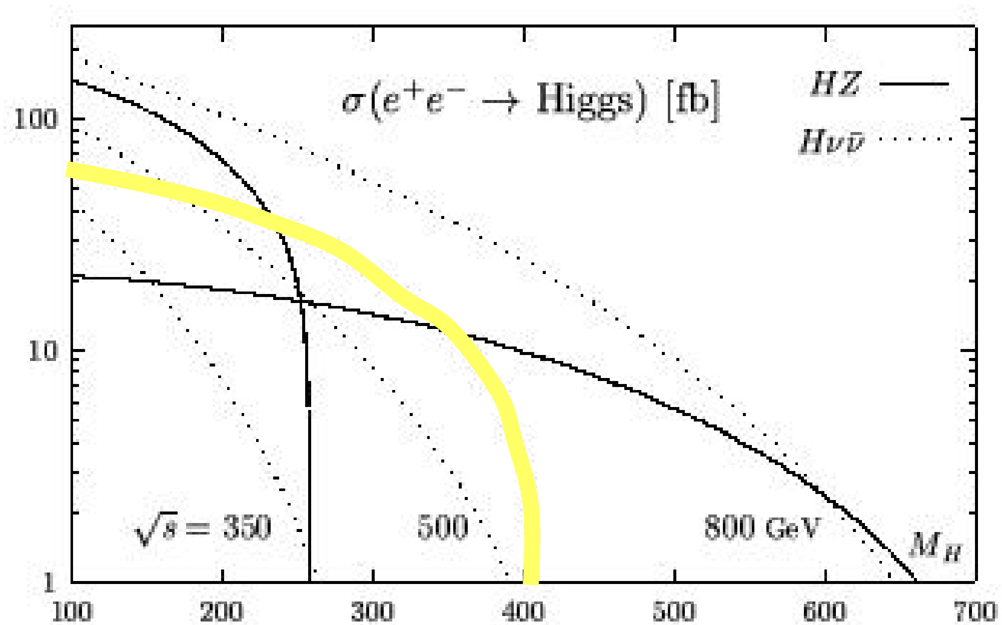
Mass Measurement
Total width
Particle couplings
 vector bosons
 fermions (including top)
Spin-parity-charge conjugation
Self-coupling



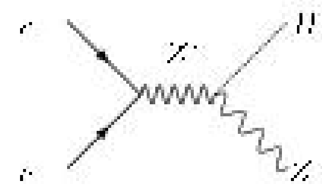
The ILC makes precise measurements

Higgs Production Cross-section

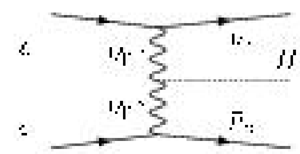
ILC program ~ 500 events / fb



Higgs-strahlung



WW fusion



Recall, $\sigma_{pt} = 87$ nb / $(E_{cm})^2 \sim 350$ fb @ 500 GeV

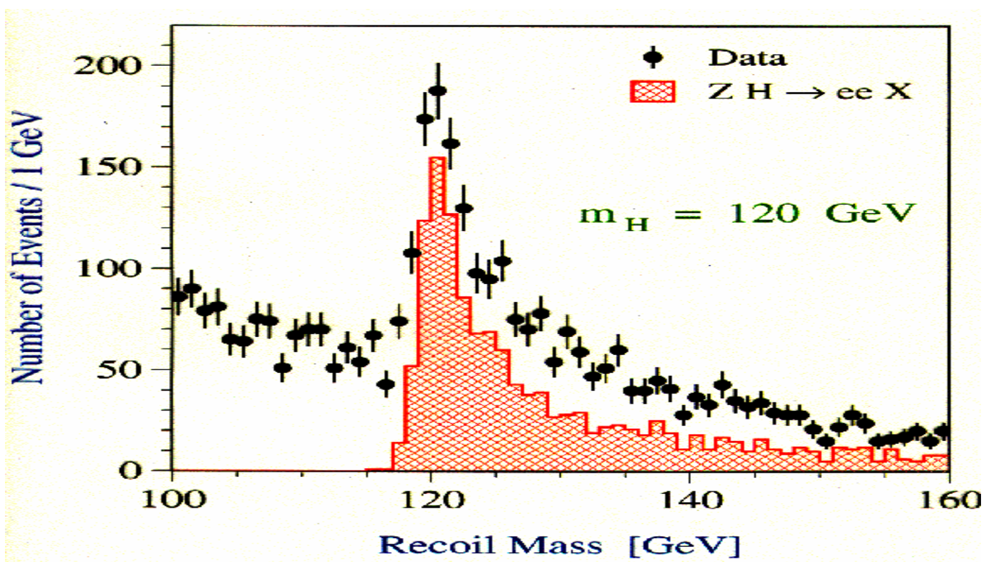
Higgs Studies - the Power of Simple Reactions

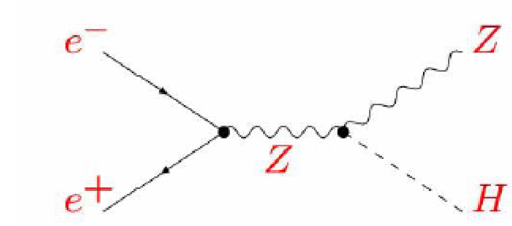
ILC observes Higgs recoiling from a Z, with known CM energy⇓

- powerful channel for unbiassed tagging of Higgs events
- measurement of even invisible decays

(⇓ - some beamstrahlung)

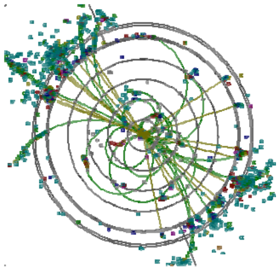
- Tag $Z \rightarrow l^+ l^-$
- Select $M_{recoil} = M_{Higgs}$





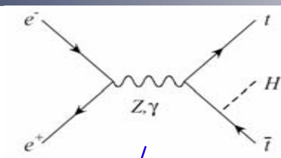
Invisible decays are included

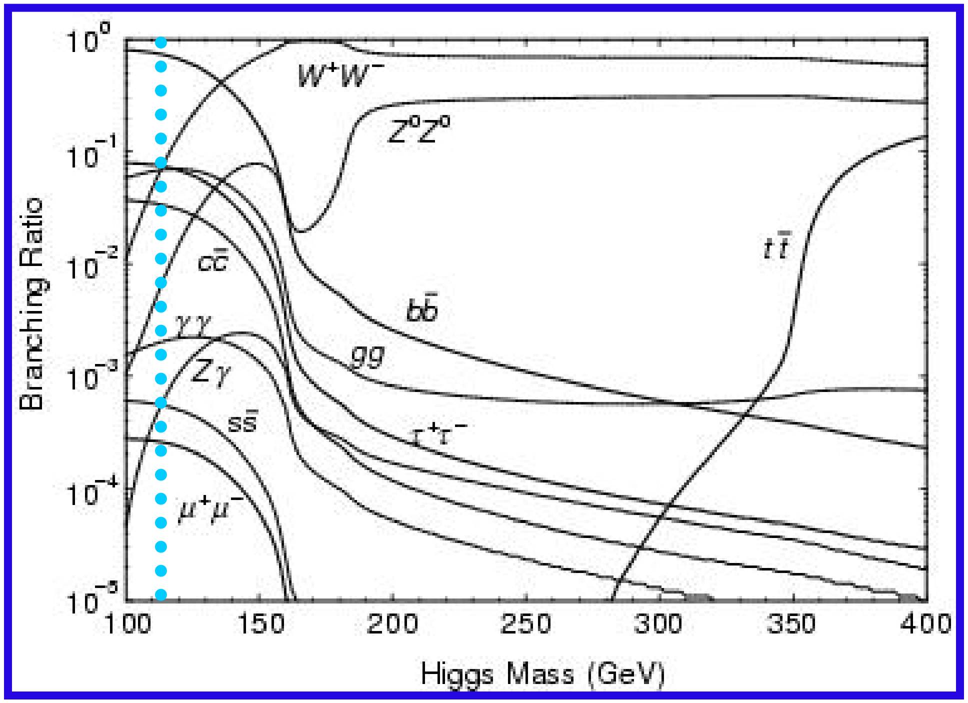
500 fb^{-1} @ 500 GeV, TESLA TDR, Fig 2.1.4

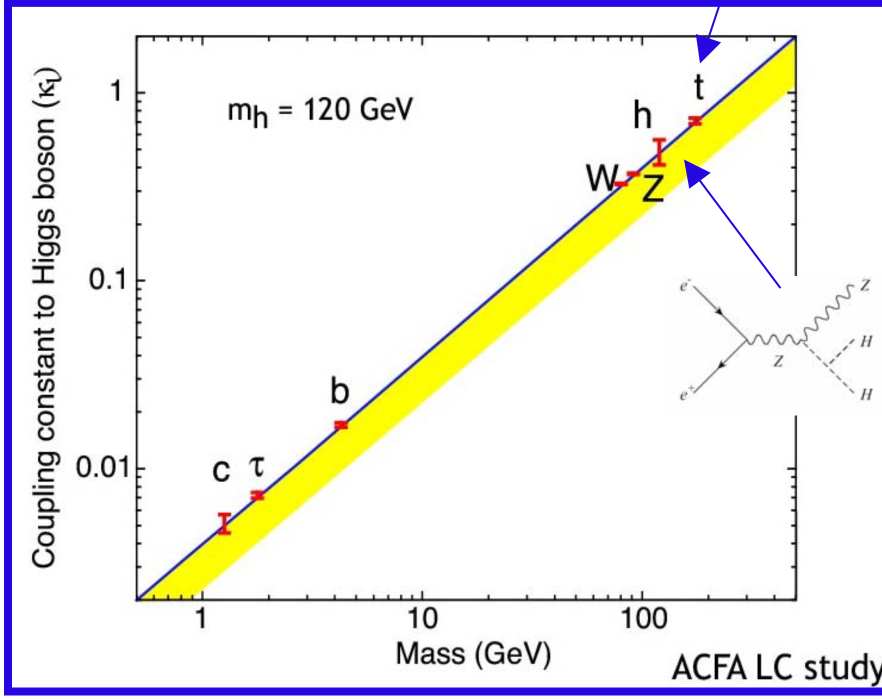


Higgs Couplings - the Branching Ratios

$g_{ffh} = m_f / v \qquad v = 246$ GeV







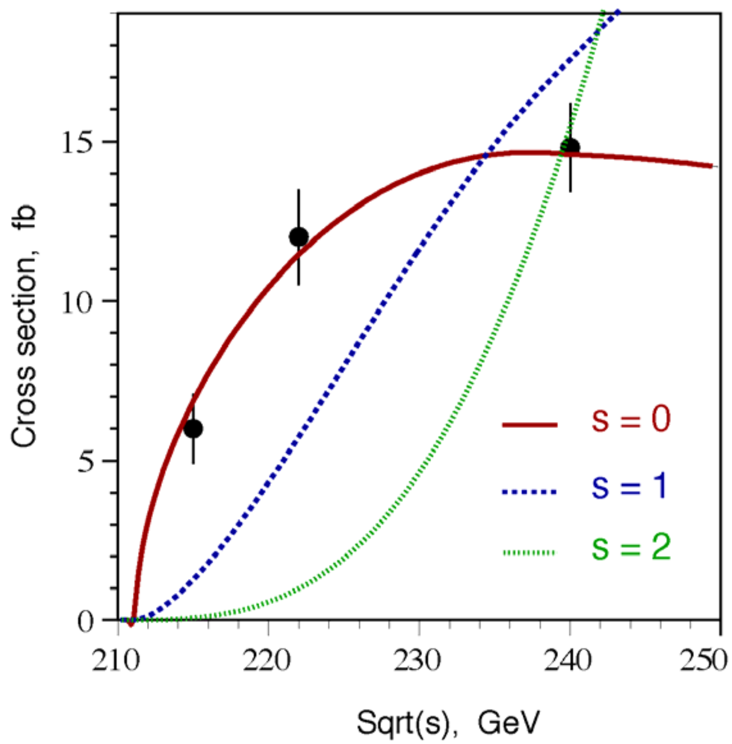
Measurement of BR's is powerful indicator of new physics

e.g. in MSSM, these differ from the SM in a characteristic way.

Higgs BR must agree with MSSM parameters from many other measurements.

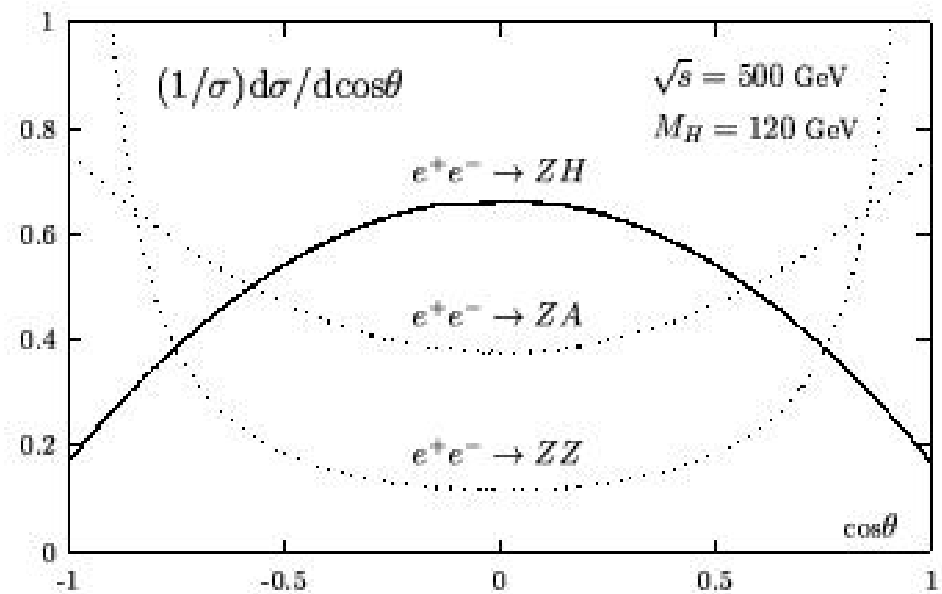
Higgs Spin Parity and Charge Conjugation (J^{PC})

$H \to \gamma\gamma$ or $\gamma\gamma \to H$
rules out J=1 and indicates C=+1

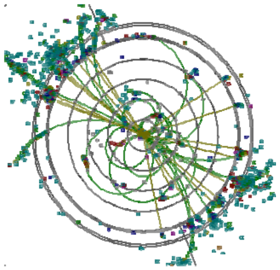


LC Physics Resource Book,
Fig 3.23(a)

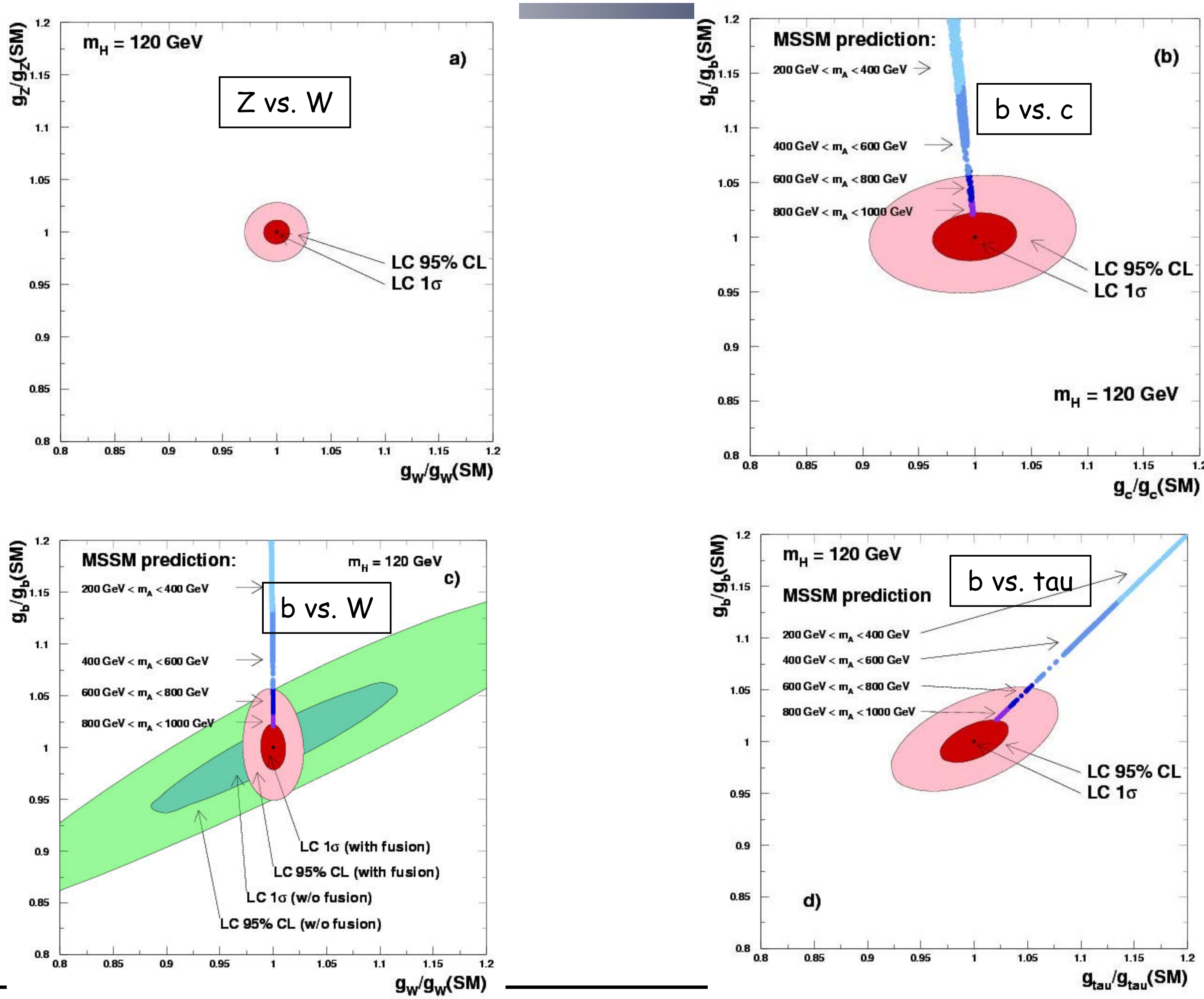
Production angle (θ) and Z decay angle in Higgs-strahlung reveals J^P ($e^+e^- \to Z\,H \to f\bar{f}H$)



TESLA TDR, Fig 2.2.8



Is This the Standard Model Higgs?



Arrows at:
- M_A = 200-400
- M_A = 400-600
- M_A = 600-800
- M_A = 800-1000

HFITTER output

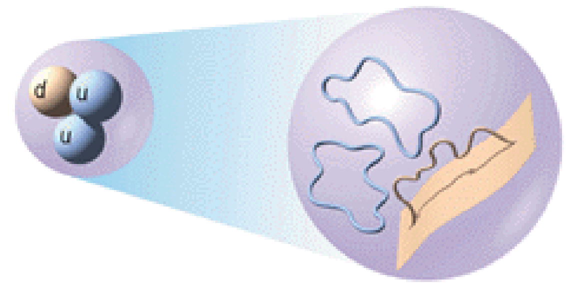
conclusion:
for M_A < 600, good sensitivity

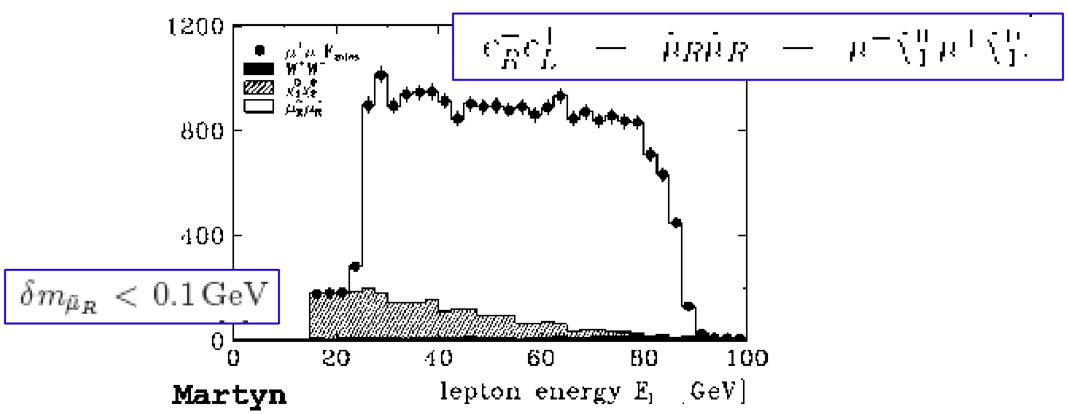
TESLA TDR, Fig 2.2.6

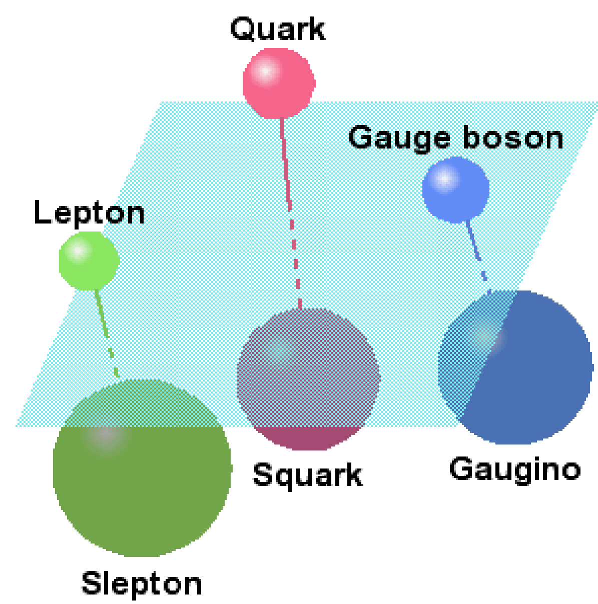
Supersymmetry

- **Supersymmetry**
  - **particles matched by super-partners**
    - super-partners of fermions are bosons
    - super-partners of bosons are fermions
  - **inspired by string theory**
  - **cancellation of divergences**
  - **dark matter?**
  - **many new particles**
    - ILC could detail properties

c

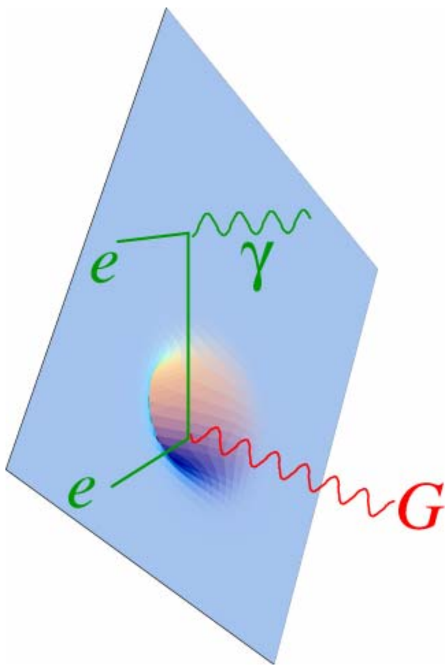


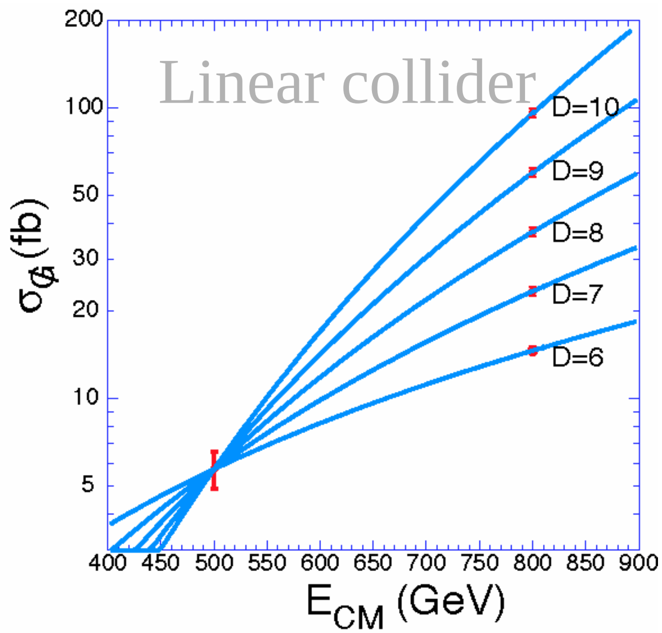




Extra Dimensions

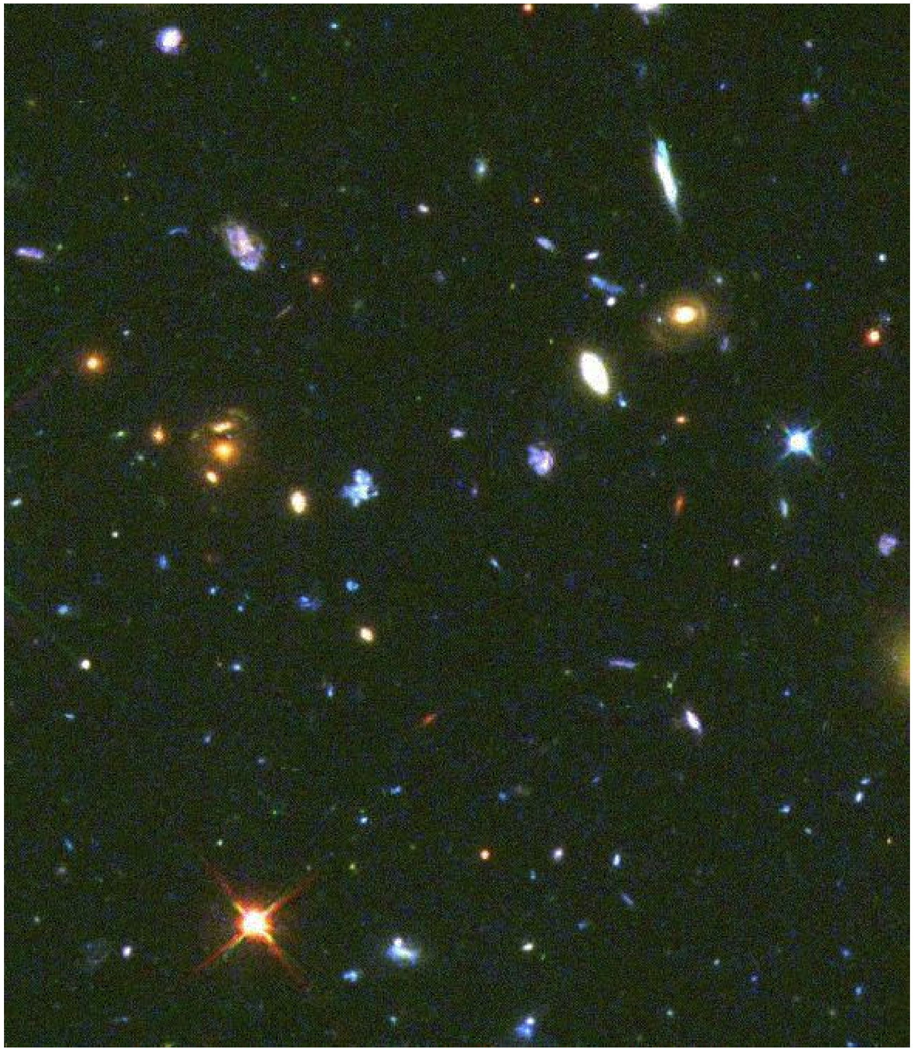
- **Extra Dimensions**
  - **string theory inspired**
  - **solves hierarchy problem ($M_{planck} >> M_{EW}$)**
    - if extra dimensions are large
  - **large extra dimensions observable at ILC**





Cosmic connections

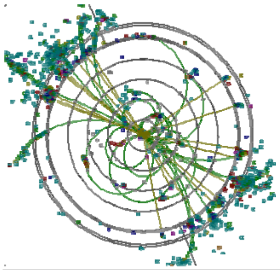
- Early universe
- GUT motivated inflation
- Dark matter
- Accelerating universe
- Dark energy



Some Steps Toward the ILC

- **2002- DOE/NSF High Energy Physics Advisory Panel**
  - **Subpanel on Long Range Planning for U.S. High Energy Physics**
  - **A high-energy, high-luminosity electron-positron linear collider should be the <u>highest priority</u> of the US HEP community, preferably one sited in the US**
  - **Similar statements in other regions $\Rightarrow$ global consensus on next collider**
- **2003- DOE Office of Science Future Facilities Plan**
  - **Linear Collider is ranked first among mid-term projects**
- **2004 – Technology choice by ICFA (Superconducting RF)**
- **2005 – Global Design Effort formed**
  - **Baseline Configuration Document**
- **Apr. 26, 2006 – NRC Report on the Future of Particle Physics**

- **end of 2006 – GDE Reference Design Report (w/ cost)**



Revealing the Hidden Nature of Space and Time

March 26, 2006

Charting the Course for Elementary Particle Physics

EPP 2010: Elementary Particle Physics in the 21st Century

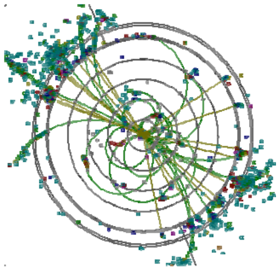
- Given the excitement of the scientific opportunities in particle physics, and in keeping with the nation's broader commitment to research in the physical sciences, the committee believes that the United States should continue to support a competitive program in this key scientific field.

- **Action Item 1: The highest priority for the U.S. national effort in elementary particle physics should be to continue to be an active partner in realizing the physics potential of the LHC experimental program.**

- **Action Item 2: The United States should launch a major program of R&D, design, industrialization, and management and financing studies of the ILC accelerator and detectors.**

- **Action Item 3: The United States should announce its strong intent to become the host country for the ILC and should undertake the necessary work to provide a viable site and mount a compelling bid.**

ILC Timeline

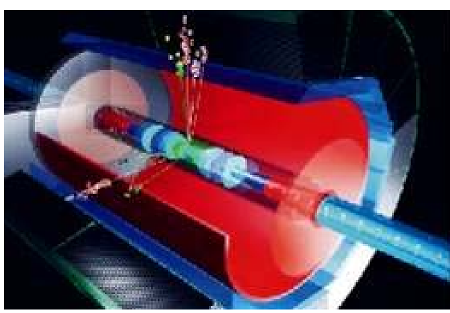


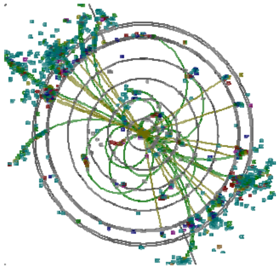
B. Barish

2005 2006 2007 2008 2009 2010

Global Design Effort → Project

- Baseline configuration
- Reference Design
- .... Technical Design
- ILC R&D Program
- Expression of Interest to Host
- International Mgmt





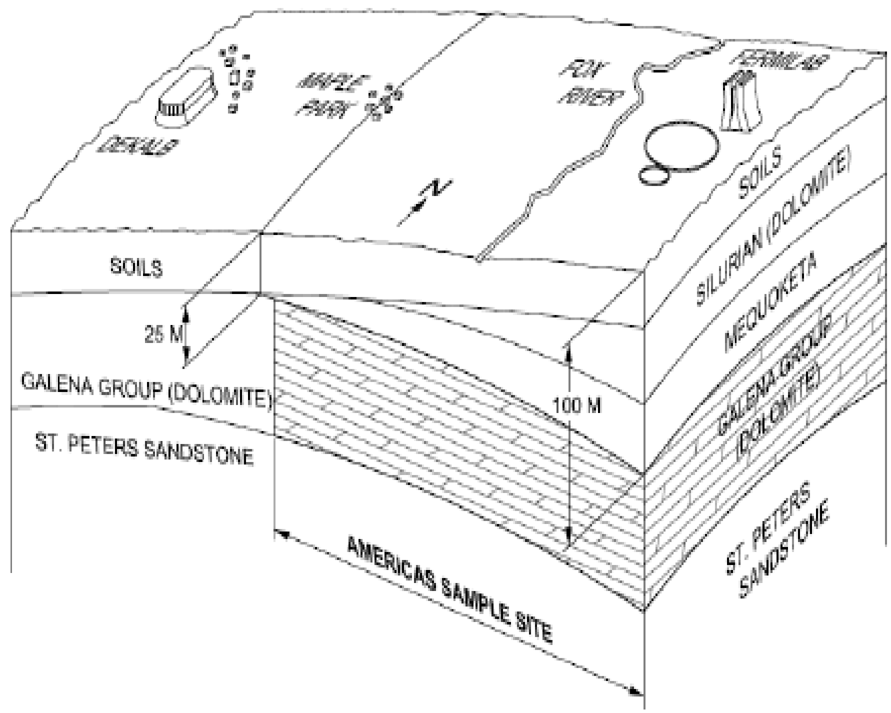
Americas Sample Site

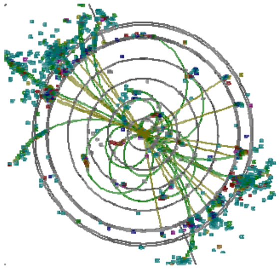
B. Barish

- **Design to "sample sites" from each region**
  - **Americas – near Fermilab**
  - **Japan**
  - **Europe – CERN & DESY**

- **Illinois Site**
  - **– depth 135m**
  - **Glacially derived deposits overlaying Bedrock.**
  - **The concerned rock layers are from top to bottom**
    - the Silurian dolomite,
    - Maquoketa dolomitic shale,
    - the Galena-Platteville dolomites.

Americas Sample Plan / Section





Conclusion

- Current status of Electroweak Precision measurements indicates the physics at the ILC will be rich
- The International Linear Collider will be a powerful tool
  - Electroweak Symmetry Breaking
  - origin of mass
  - other fundamental physics
  - advance understanding of LHC discoveries
- This physics follows a century of unraveling the mystery of the electroweak interaction
- We can imagine future discoveries may further our knowledge of fundamental physics in unanticipated ways