The International Linear Collider

Barry Barish
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Why $e^+e^-$ Collisions?

- elementary particles
- well-defined
  - energy,
  - angular momentum
- uses full COM energy
- produces particles democratically
- can mostly fully reconstruct events
Electron Positron Colliders
The Energy Frontier
How do you know you have discovered the Higgs?

Measure the quantum numbers. The Higgs must have spin zero!

The linear collider will measure the spin of any Higgs it can produce by measuring the energy dependence from threshold.
New space-time dimensions can be mapped by studying the emission of gravitons into the extra dimensions, together with a photon or jets emitted into the normal dimensions.
The ILC measures coupling strength of the Higgs with other particles

Higgs Coupling-mass relation

\[ m_i = V \times K_i \]
What can we learn from the Higgs?

Precision measurements of Higgs coupling can reveal extra dimensions in nature

- Straight blue line gives the standard model predictions.
- Range of predictions in models with extra dimensions -- yellow band, (at most 30% below the Standard Model)
- The red error bars indicate the level of precision attainable at the ILC for each particle
Supersymmetry

Supersymmetric Partner

\[
\begin{array}{cccc}
\begin{array}{cccc}
  u & c & t & \gamma \\
  d & s & b & g \\
  \nu_e & \nu_\mu & \nu_\tau & W \\
  e & \mu & \tau & Z \\
\end{array}
\end{array}
\begin{array}{cccc}
  \tilde{u} & \tilde{c} & \tilde{t} & \tilde{\gamma} \\
  \tilde{d} & \tilde{s} & \tilde{b} & \tilde{g} \\
  \tilde{\nu}_e & \tilde{\nu}_\mu & \tilde{\nu}_\tau & \tilde{W} \\
  \tilde{e} & \tilde{\mu} & \tilde{\tau} & \tilde{Z} \\
\end{array}
\end{array}
\]

Spin 1/2  Spin 1  Spin 0  Spin 0  Spin 1/2  Spin 1/2
The JLC-X and NLC essentially a unified single design with common parameters.

The main linacs based on 11.4 GHz, room temperature copper technology.
TESLA Concept

- The main linacs based on 1.3 GHz superconducting technology operating at 2 K.

- The cryoplant, is of a size comparable to that of the LHC, consisting of seven subsystems strung along the machines every 5 km.
The ITRP Recommendation

- We recommend that the linear collider be based on superconducting rf technology

  This recommendation is made with the understanding that we are recommending a technology, not a design. We expect the final design to be developed by a team drawn from the combined warm and cold linear collider communities, taking full advantage of the experience and expertise of both (from the Executive Summary).
The recommendation of ITRP was presented to ILCSC & ICFA on August 19, 2004 in a joint meeting in Beijing.

ICFA unanimously endorsed the ITRP’s recommendation on August 20, 2004.
Parameters for the ILC

- $E_{\text{cm}}$ adjustable from 200 – 500 GeV
- Luminosity $\int L dt = 500 \text{ fb}^{-1}$ in 4 years
- Ability to scan between 200 and 500 GeV
- Energy stability and precision below 0.1%
- Electron polarization of at least 80%

- The machine must be upgradeable to 1 TeV
Global Effort on Design / R&D for ILC

Snowmass
49 GDE members
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Present
GDE Membership
  Americas 22
  Europe   24
  Asia     18

About 30 FTEs

Joint Design, Implementation, Operations, Management
Host Country Provides Conventional Facilities
Global Design Effort

– The Mission of the GDE

• Produce a design for the ILC that includes a detailed design concept, performance assessments, reliable international costing, an industrialization plan, siting analysis, as well as detector concepts and scope.

• Coordinate worldwide prioritized proposal driven R & D efforts (to demonstrate and improve the performance, reduce the costs, attain the required reliability, etc.)
Designing a Linear Collider

Superconducting RF Main Linac
Parametric Approach

- A working space - optimize machine for cost/performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>min</th>
<th>nominal</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunch charge</td>
<td>$N$</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>$n_b$</td>
<td>1330</td>
<td>2820</td>
</tr>
<tr>
<td>Linac bunch interval</td>
<td>$t_b$</td>
<td>154</td>
<td>308</td>
</tr>
<tr>
<td>Bunch length</td>
<td>$\sigma_z$</td>
<td>150</td>
<td>300</td>
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<tr>
<td>Vert. emit.</td>
<td>$\gamma \epsilon_y$</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>IP beta (500GeV)</td>
<td>$\beta_x$</td>
<td>10</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>$\beta_z$</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>IP beta (1TeV)</td>
<td>$\beta_x$</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>$\beta_y$</td>
<td>0.2</td>
<td>0.3</td>
</tr>
</tbody>
</table>
The Key Decisions

Critical choices: luminosity parameters & gradient
Making Choices – The Tradeoffs

Many decisions are interrelated and require input from several WG/GG groups.
Superconducting RF Cavities

High Gradient Accelerator
35 MV/meter -- 40 km linear collider
Gradient

Results from KEK-DESY collaboration

After Standard etch Average
28.9 +/- 1.1 MV/m

After EP Average
35.6 +/- 2.3 MV/m

must reduce spread (need more statistics)
# SRF Cavity Gradient

<table>
<thead>
<tr>
<th>Cavity type</th>
<th>Qualified gradient</th>
<th>Operational gradient</th>
<th>Length*</th>
<th>energy</th>
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<tbody>
<tr>
<td>initial TESLA</td>
<td>35 MV/m</td>
<td>31.5 MV/m</td>
<td>10.6 Km</td>
<td>250 GeV</td>
</tr>
<tr>
<td>upgrade LL</td>
<td>40 MV/m</td>
<td>36.0 MV/m</td>
<td>+9.3 Km</td>
<td>500 GeV</td>
</tr>
</tbody>
</table>

Total length of one 500 GeV linac $\approx 20$km

* assuming 75% fill factor
The Baseline Machine (500GeV)

- RTML ~1.6km
- BDS 5km
- ML ~10km (G = 31.5MV/m)

20mr
2mr

R = 955m
E = 5 GeV

e+ undulator @ 150 GeV (~1.2km)

e+ Linac

not to scale
From Baseline to a RDR

Jan
Frascati
Freeze Configuration
Organize for RDR

Bangalore
Review Design/Cost Methodology

Vancouver
Review Initial Design / Cost

Valencia
Review Final Design / Cost
RDR Document

Design and Costing

2006
Preliminary RDR Released
The Main Linac Configuration

- Klystron – 10 MW (alternative sheet beam klystron)
- RF Configuration – 3 Cryomodules, each with 8 cavities
- Quads – one every 24 cavities is enough
ILC Cryomodule

Increase diameter beyond X-FEL

Review 2-phase pipe size and effect of slope
RF Power: Baseline Klystrons

Thales  
CPI  
Toshiba

Specification:
10MW MBK
1.5ms pulse
65% efficiency
Linear Collider Facility

Main Research Center

Particle Detector

~30 km long tunnel

Two tunnels
- accelerator units
- other for services - RF power
Tunnel Diameter

- Both tunnels are 5 meter diameter (Fixed)
- 5 meters in Asia & 7.5 meters elsewhere between tunnels (for structural reasons)
- 5 meters between tunnels required for shielding
Baseline Features – Electron Source

- Electron Source – Conventional Source using a DC ----- Titanium-sapphire laser emits 2-ns pulses that knock out electrons; electric field focuses each bunch into a 250-meter-long linear accelerator that accelerates up to 5 GeV
Baseline Features – Positron Source

- **Positron Source – Helical Undulator with Polarized beams** – 150 Gev electron beam goes through a 200m undulator ing making photons that hit a 0.5 rl titanium alloy target to produce positrons. The positrons are accelerated to 5-GeV accelerator before injecting into positron damping ring.
6 Km Damping Ring

Requires Fast Kicker 5 nsec rise and 30 nsec fall time

The damping rings have more accelerator physics than the rest of the collider
Beam Delivery System

• Requirements:
  – Focus beams down to very small spot sizes
  – Collect out-going disrupted beam and transport to the dump
  – Collimate the incoming beams to limit beam halo
  – Provide diagnostics and optimize the system and determine the luminosity spectrum for the detector
  – Switch between IPs
Cost vs Performance

- We obtained our first ILC costing in July
- We are validating those costs and studying areas where different costing disagree
- We are studying areas where costs appear larger than expected for requirements, value engineering, etc.
- Our aim is to produce a reference design, which has taken into account major cost vs performance optimization – examples
  - 2mr x 20 mr compared to 14mr x 14 mr
  - One positron damping ring
  - Optimizing size of tunnels
  - Position of damping ring
Final Remarks

• Design Status and Plans
  – Baseline was determined and documented at end of 2005
  – Plan to complete reference design / cost by the end of 2006
  – Technical design by end of 2009

• R & D Program
  – Support baseline: demonstrations; optimize cost / performance; industrialization
  – Develop improvements to baseline – cavities; high power RF

• Overall Strategy
  – Be ready for an informed decision by 2010
  – Siting; International Management; LHC results; CLIC feasibility etc