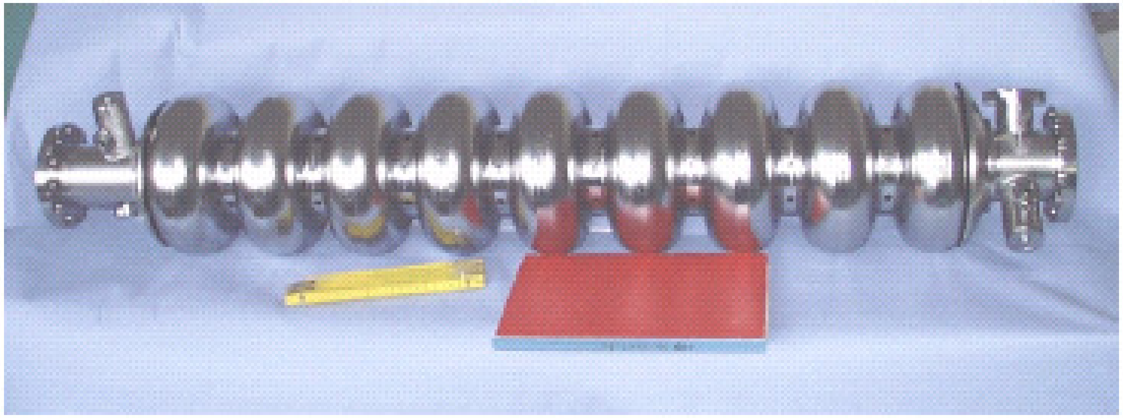
Technology Breakthroughs and International Linear Collider



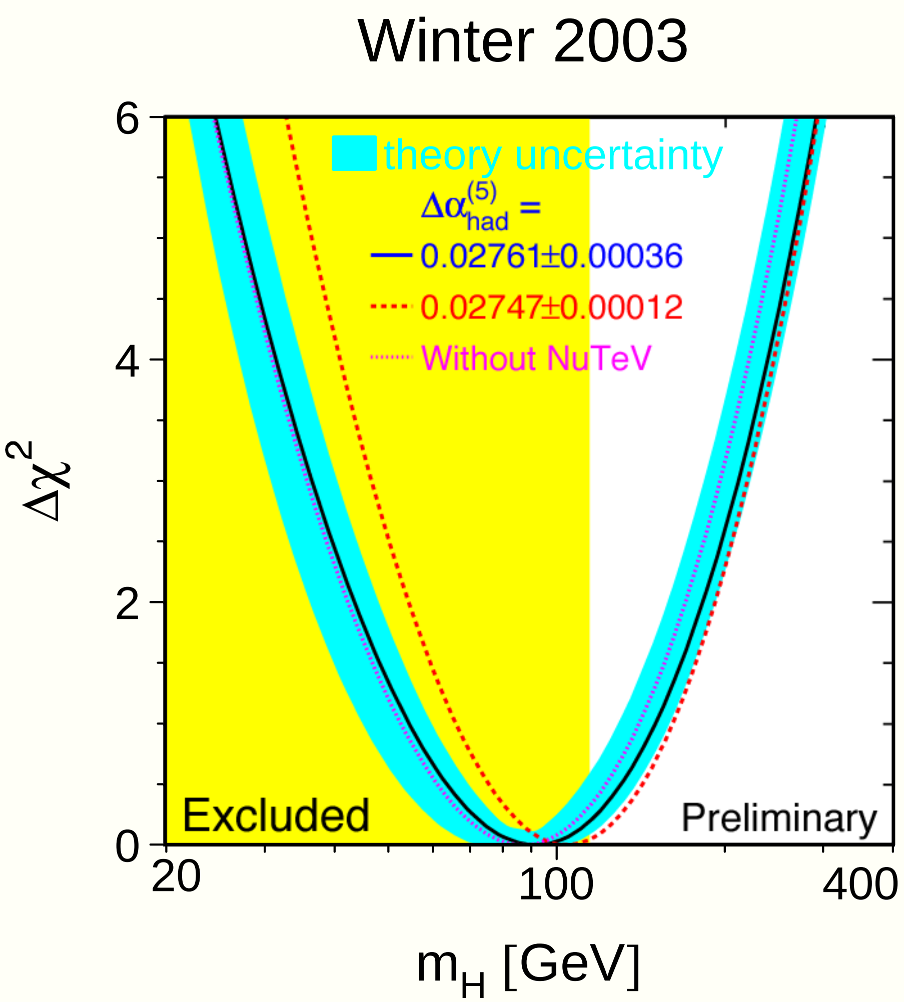
Barry Barish

AAAS Annual Meeting
Washington DC
19-Feb-04

Why a TeV Scale e^+e^- Accelerator?

- **Two parallel developments over the past few years (the science & the technology)**
  - **The precision information e^+e^- and ν data at present energies have pointed to a low mass Higgs; Understanding electroweak symmetry breaking, whether supersymmetry or an alternative, will require precision measurements.**
  - **There are strong arguments for the complementarity between a ~0.5-1.0 TeV ILC and the LHC science.**

Electroweak Precision Measurements



e^+e+ and neutrino scattering results at present energies strongly point to a low mass Higgs and an energy scale for new physics < 1TeV

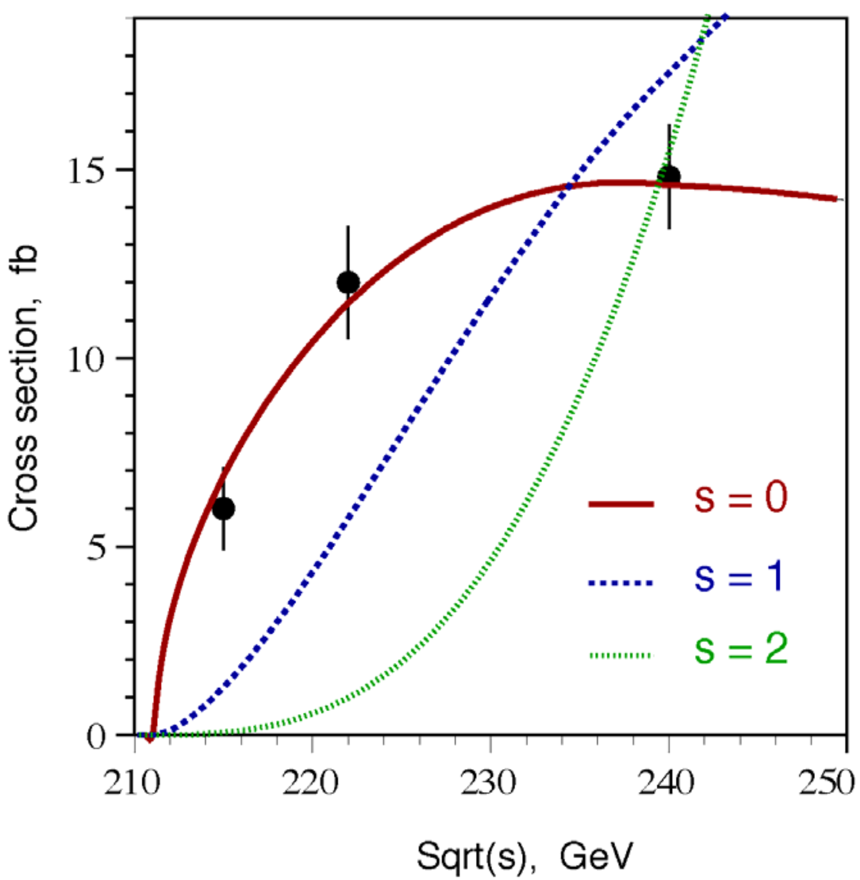
Why a TeV Scale e^+e^- Accelerator?

- **Two parallel developments over the past few years (the science & the technology)**
  - **The precision information from LEP and other data have pointed to a low mass Higgs; Understanding electroweak symmetry breaking, whether supersymmetry or an alternative, will require precision measurements.**
  - **There are strong arguments for the complementarity between a ~0.5-1.0 TeV LC and the LHC science.**

LHC/ILC Complementarity

Linear Collider Spin Measurement

The Higgs must be spin zero



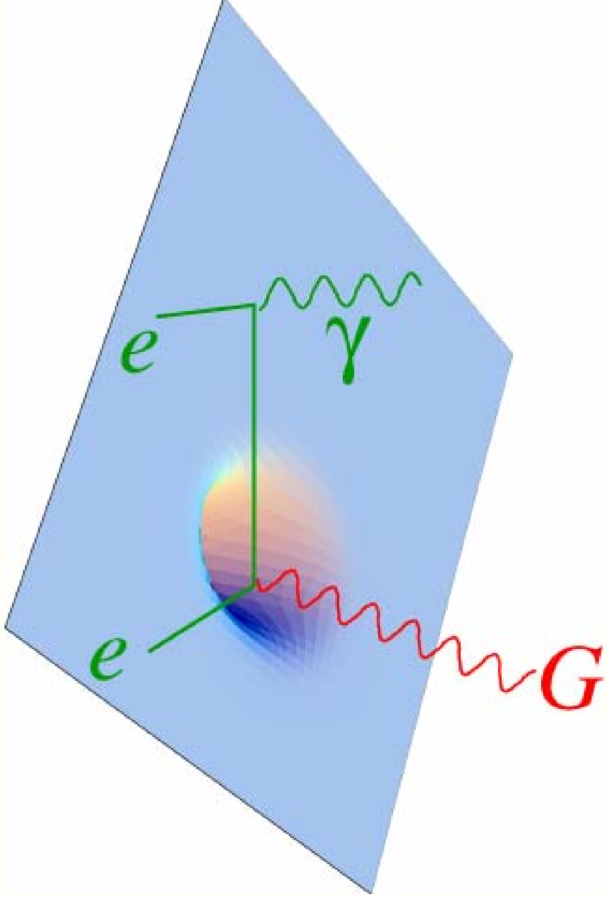
LHC should discover the Higgs

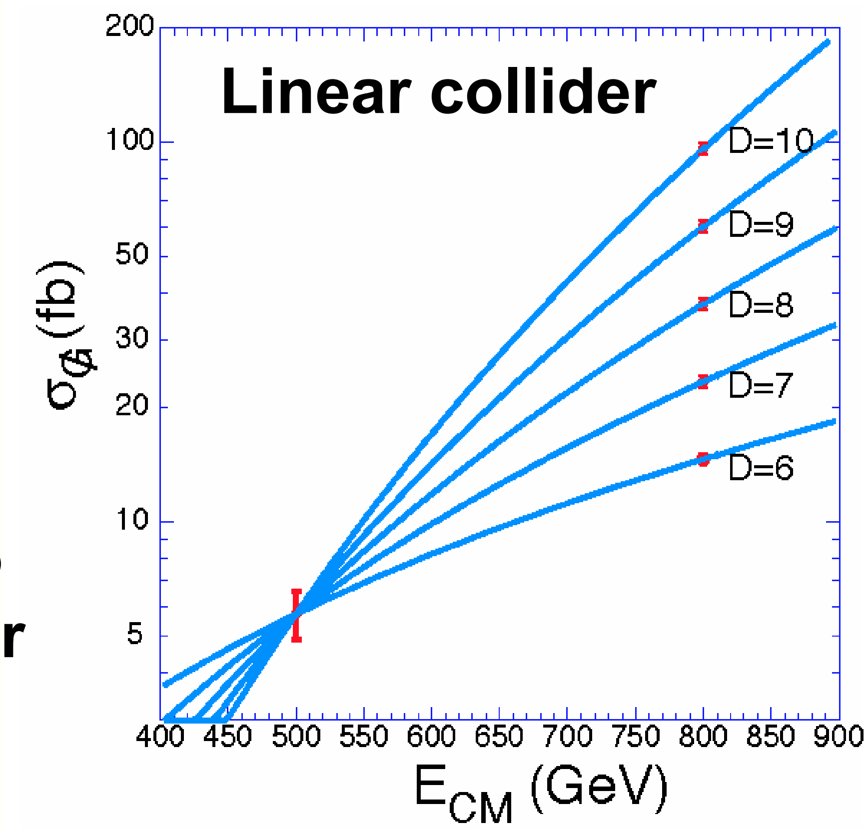
The linear collider should measure its spin

The process $e^+e^- \rightarrow HZ$ can be used to measure the spin of a 120 GeV Higgs particle.

LHC/ILC Complementarity

Extra Dimensions





Map extra dimensions: **study the emission of gravitons into the extra dimensions, together with a photon or jets emitted into the normal dimensions.**

Why a TeV Scale e^+e^- Accelerator?

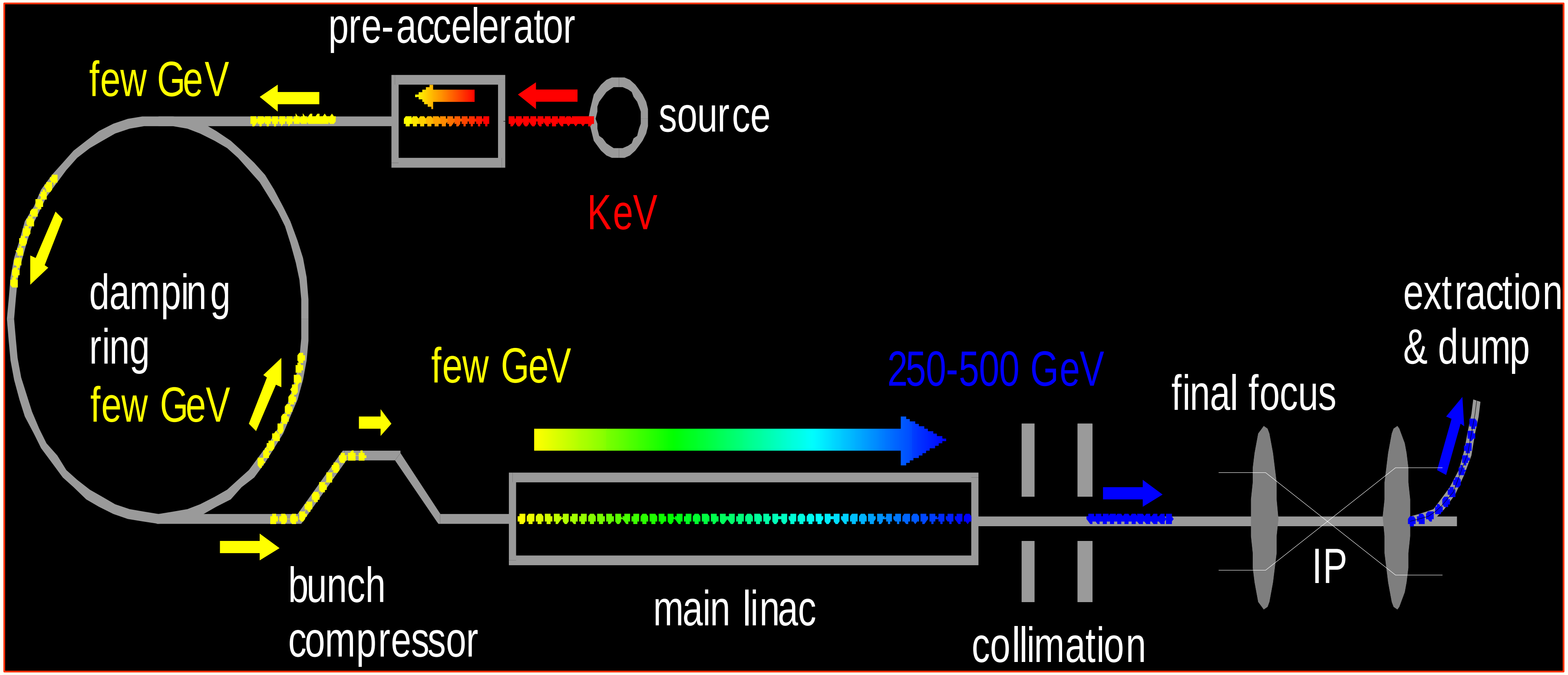
- **Two parallel developments over the past few years (the science & the technology)**
  - **Designs and technology demonstrations have matured on two technical approaches for an e^+e^- collider that are well matched to our present understanding of the physics.**

Parameters for the ILC

- E_{cm} adjustable from 200 – 500 GeV
- Luminosity → $\int L dt$ = 500 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

Linear Collider Concept



Specific Machine Realizations

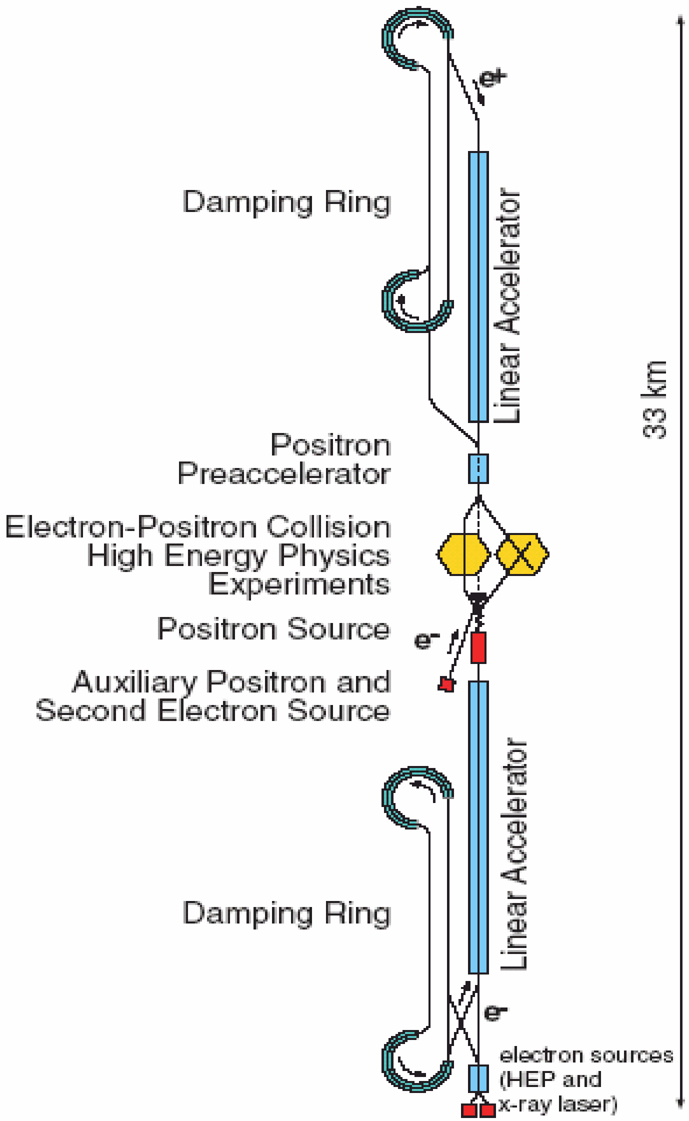
rf bands:

L-band (TESLA)	1.3 GHz	λ =	3.7 cm
S-band (SLAC linac)	2.856 GHz		1.7 cm
C-band (JLC-C)	5.7 GHz		0.95 cm
X-band (NLC/GLC)	11.4 GHz		0.42 cm
(CLIC)	25-30 GHz		0.2 cm

Accelerating structure size is dictated by wavelength of the rf accelerating wave. Wakefields related to structure size; thus so is the difficulty in controlling emittance growth and final luminosity.

- **Bunch spacing, train length related to rf frequency**
- **Damping ring design depends on bunch length, hence frequency**

Frequency dictates many of the design issues for LC

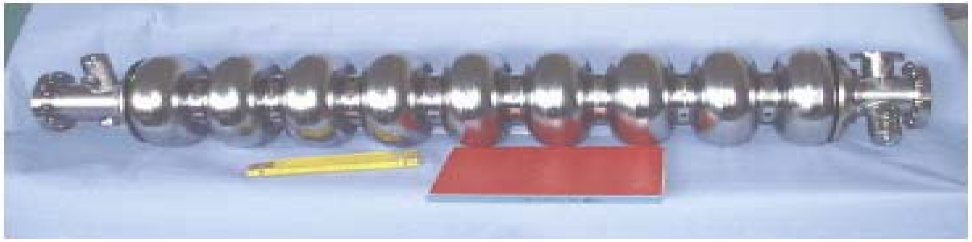


TESLA Concept

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.

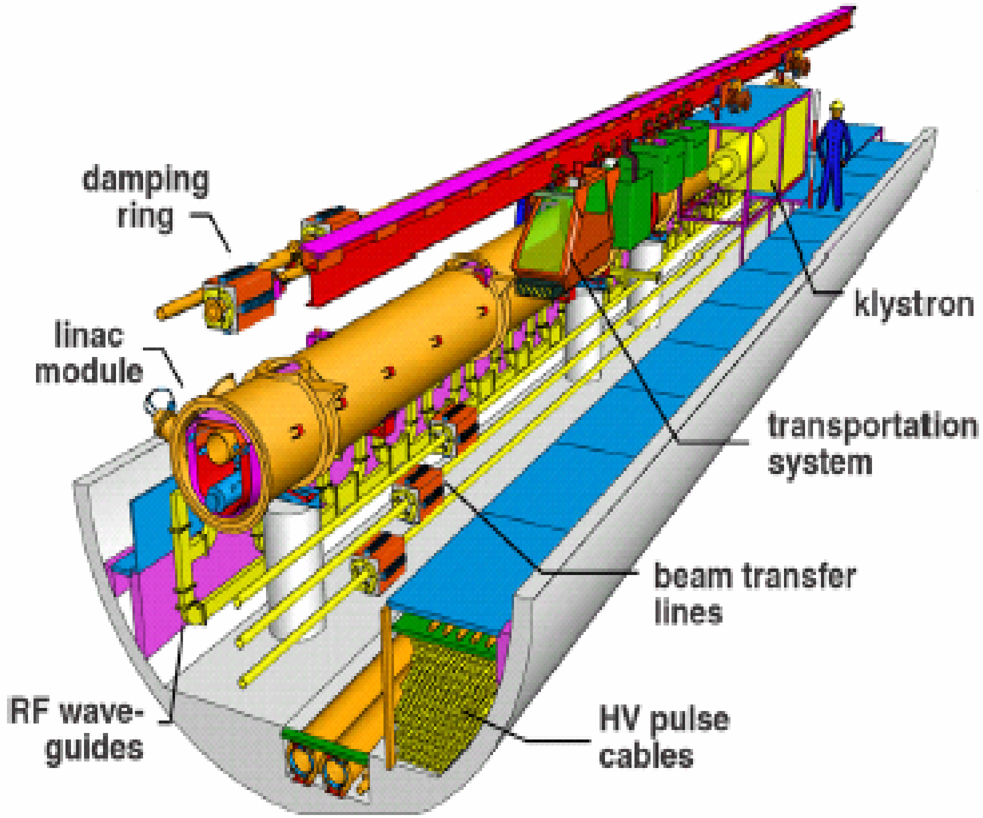
TESLA Cavity



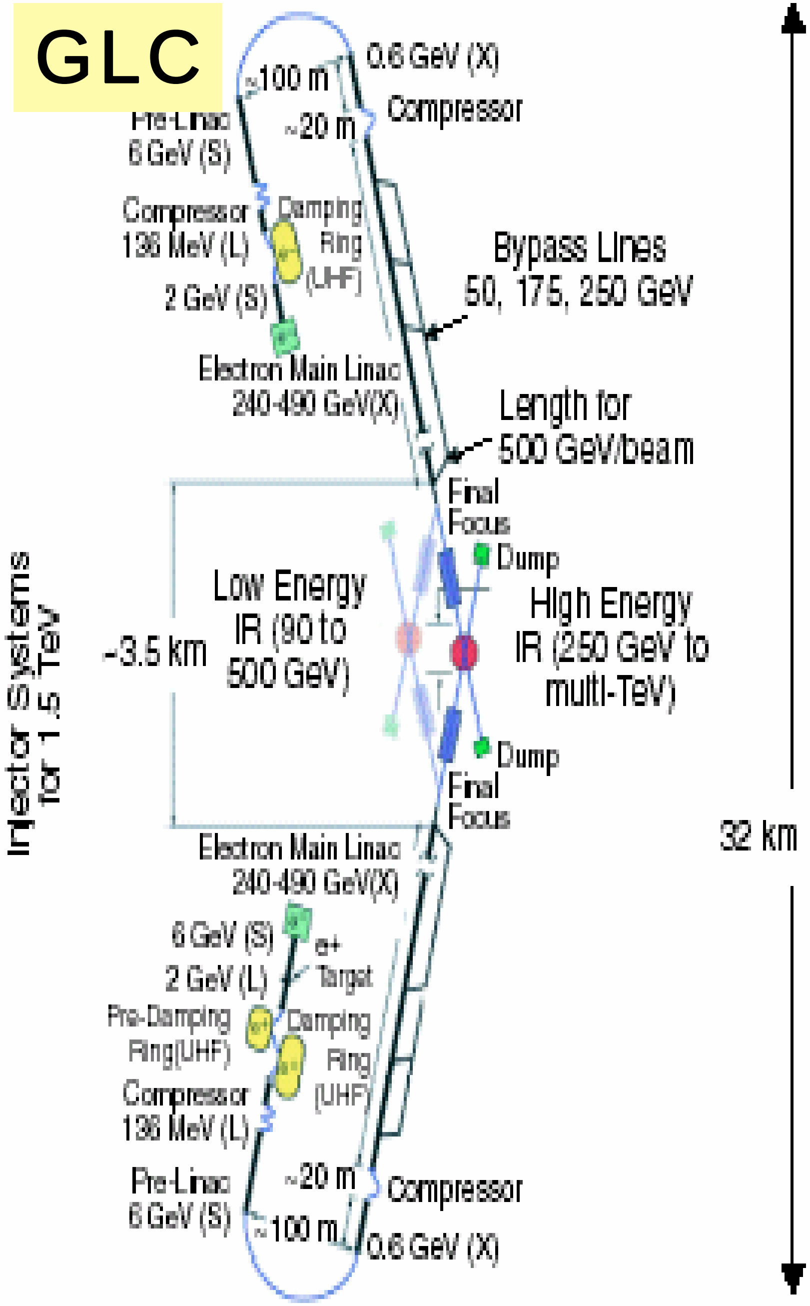
- **RF accelerator structures consist of close to 21,000 9-cell niobium cavities operating at gradients of 23.8 MV/m (unloaded as well as beam loaded) for 500 GeV c.m. operation.**
- **The rf pulse length is 1370 μs and the repetition rate is 5 Hz. At a later stage, the machine energy may be upgraded to 800 GeV c.m. by raising the gradient to 35 MV/m.**

TESLA
Single Tunnel Layout

- **The TESLA cavities are supplied with rf power in groups of 36 by 572 10 MW klystrons and modulators.**

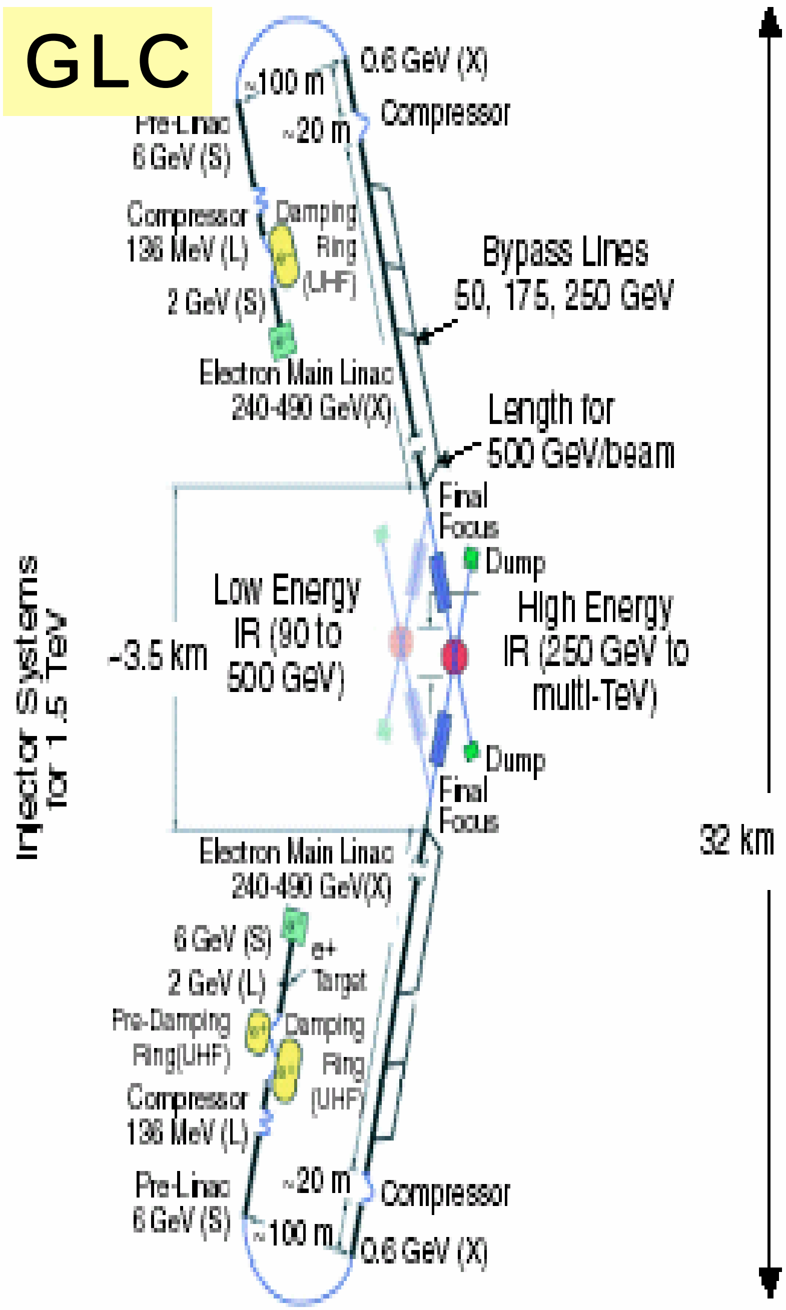


GLC



GLC/NLC Concept

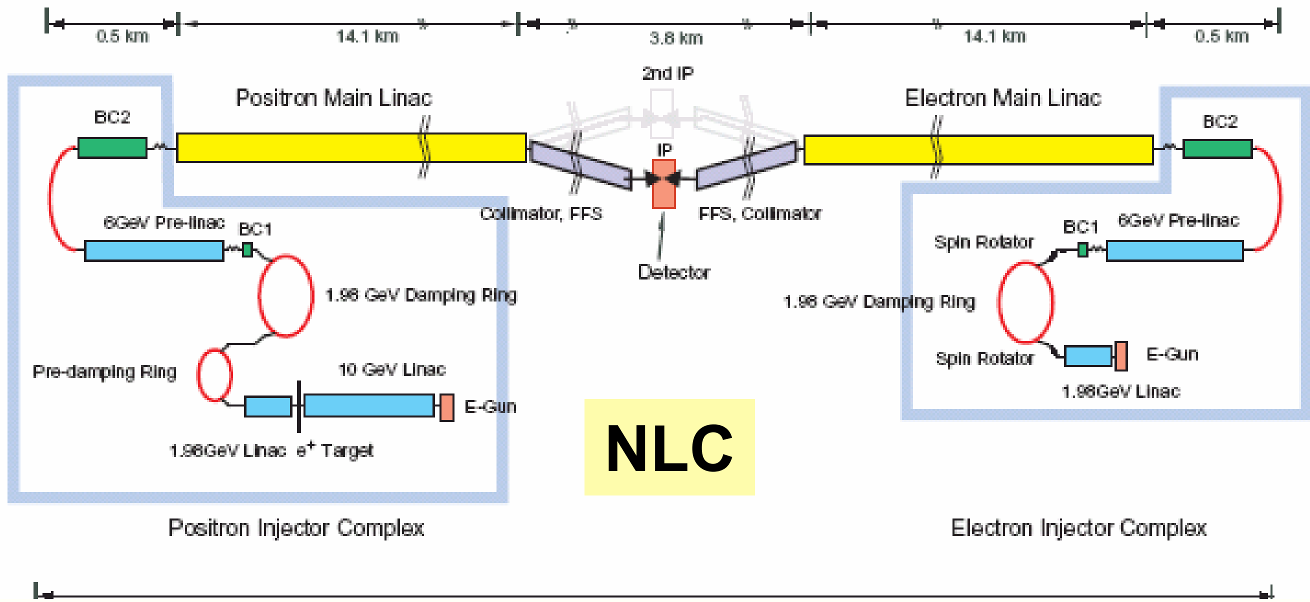
- **The JLC-X and NLC are essentially a unified single design with common parameters**
- **The main linacs are based on 11.4 GHz, room temperature copper technology.**



GLC/NLC Concept

- **The main linacs operate at an unloaded gradient of 65 MV/m, beam-loaded to 50 MV/m.**
- **The rf systems for 500 GeV c.m. consist of 4064 75 MW Periodic Permanent Magnet (PPM) klystrons arranged in groups of 8, followed by 2032 SLED-II rf pulse compression systems**

GLC / NLC Concept



- **Two parallel tunnels for each linac.**
- **For 500 GeV c.m. energy, rf systems only installed in the first 7 km of each linac.**
- **Upgrade to 1 TeV by filling the rest of each linac, for a total two-linac length of 28 km.**

Which Technology to Chose?

- Two alternate designs -- “warm” and “cold” had come to the stage where the show stoppers had been eliminated and the concepts were well understood.
- A major step toward a new international machine requires uniting behind one technology, and then make a unified global design based on the recommended technology.

International Technology Review Panel

International Technology Recommendation Panel Meeting
August 11 ~ 13, 2004. Republic of Korea

ITRP Schedule of Events

- **Six Meetings**
  - **RAL (Jan 27,28 2004)** → **Tutorial & Planning**
  - **DESY (April 5,6 2004)**
  - **SLAC (April 26,27 2004)**
  - **KEK (May 25,26 2004)**

    (DESY, SLAC, KEK) → **Site Visits**
  - **Caltech (June 28,29,30 2004)** → **Deliberations**
  - **Korea (August 11,12,13)** → **Recommendation**
  - **ILCSC / ICFA (Aug 19)** → **Exec. Summary**
  - **ILCSC (Sept 20)** → **Final Report**

Evaluate a Criteria Matrix

- **The panel analyzed the technology choice through studying a matrix having six general categories with specific items under each:**
  - **the scope and parameters specified by the ILCSC;**
  - **technical issues;**
  - **cost issues;**
  - **schedule issues;**
  - **physics operation issues;**
  - **and more general considerations that reflect the impact of the LC on science, technology and society**

Experimental Test Facility - KEK

- **Prototype Damping Ring for X-band Linear Collider**
- **Development of Beam Instrumentation and Control**

	ATF	GLC/NLC-DR	
E_b	1.28 (1.54 max)	1.98	GeV
N_e	~ 10^{10}	0.75 10^{10}	e-/bunch
S_b	2.8	1.4	ns
N_b	20	192	/pulse
$\gamma\varepsilon_x$	~4	3	μm.rad
$\gamma\varepsilon_y$	~0.015	0.02	μm.rad

Final Focus Test Faclity - SLAC

Final Focus Test Beam Collaboration

BINP (Novosibirsk)

DESY

Fermilab

IBM

Kawasaki

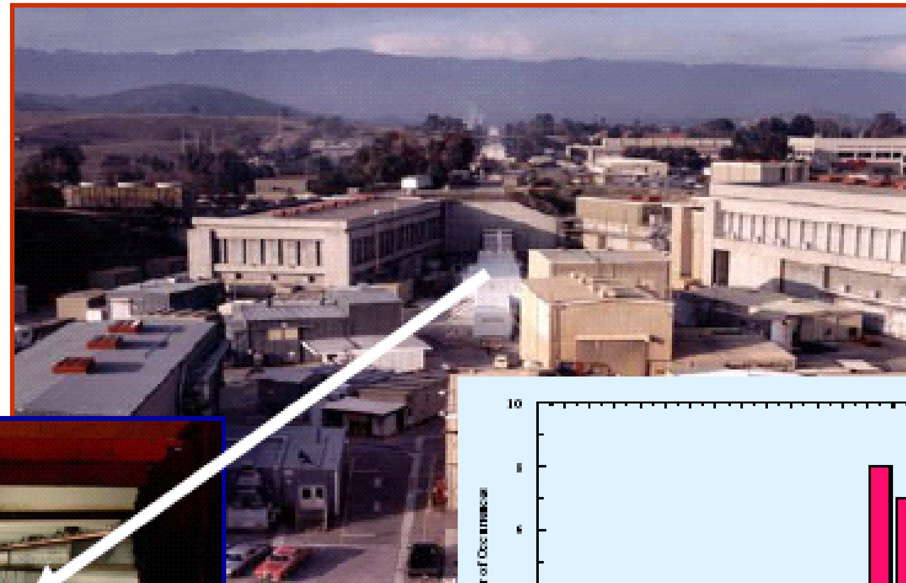
KEK

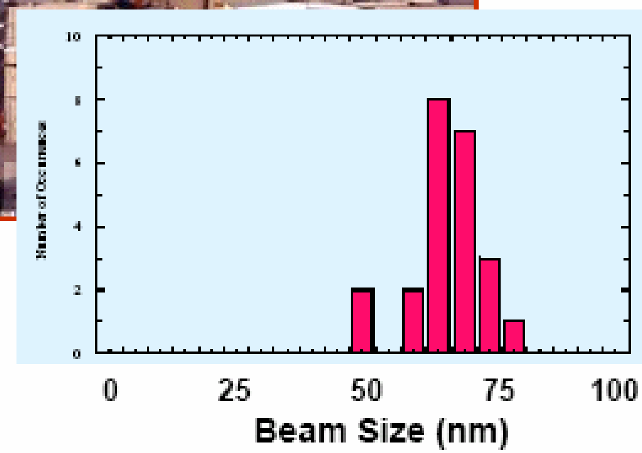
LAL (Orsay)

MPI(Munich)

Rochester

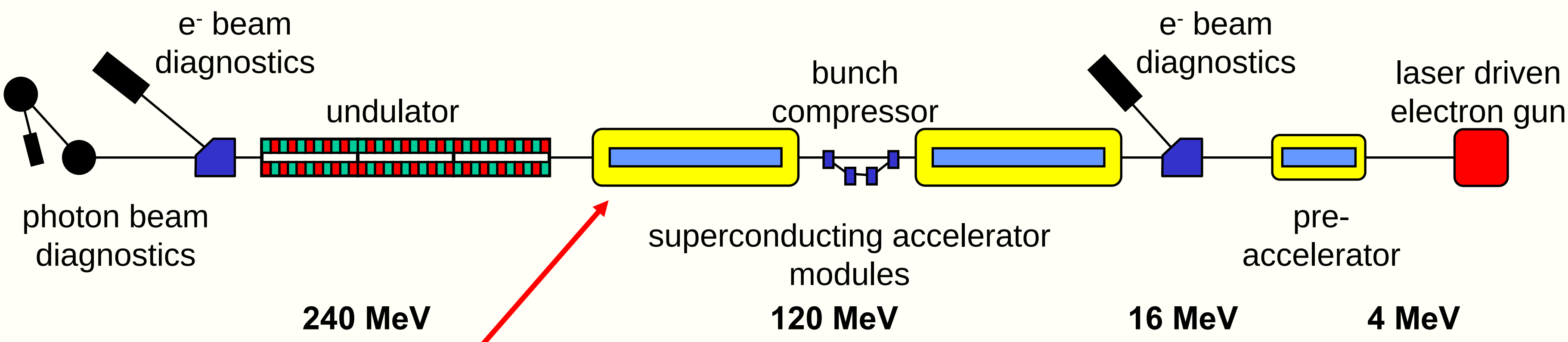
SLAC

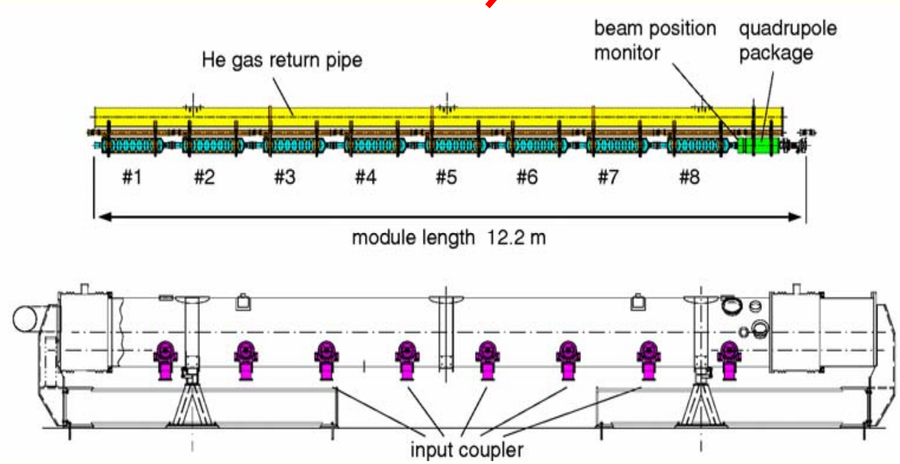




Vertical beam size of 60-70 nm … the needed demagnification.

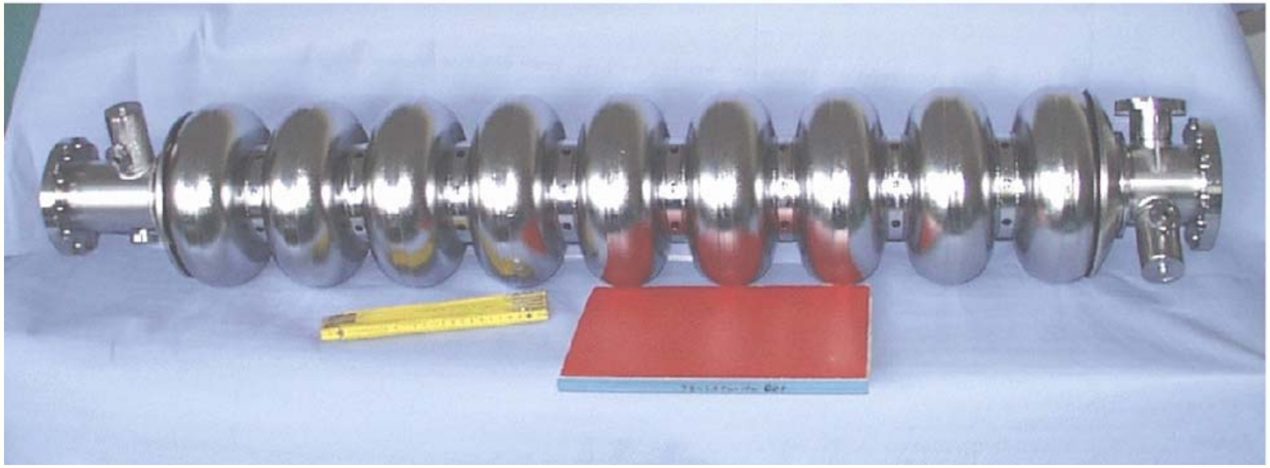
TESLA Test Facility Linac - DESY





Technology Recommendation

- **The Panel recommended that the linear collider be based on superconducting rf technology**



  - **The superconducting technology has several very nice features for application to a linear collider. They follow in part from the low rf frequency.**

Some Features of SC Technology

- The large cavity aperture and long bunch interval reduce the complexity of operations, reduce the sensitivity to ground motion, permit inter-bunch feedback and may enable increased beam current.
- The main linac rf systems, the single largest technical cost elements, are of comparatively lower risk.
- The construction of the superconducting XFEL free electron laser will provide prototypes and test many aspects of the linac.
- The industrialization of most major components of the linac is underway.
- The use of superconducting cavities significantly reduces power consumption.

Technology Recommendation

- **The recommendation was presented to ILCSC & ICFA on August 19 in a joint meeting in Beijing.**

- **ICFA unanimously endorsed the ITRP's recommendation on August 20**

What's Next

- **Organize the ILC effort globally (Wagner)**
  - **Coordinate worldwide R & D efforts, in order to demonstrate and improve the performance, reduce the costs, attain the required reliability, etc.**
  - **Undertake making a "global design" over the next few years for a machine that can be jointly implemented internationally.**
  - **These goals are within reach and we fully expect to have an optimized design within a few years, so that we can undertake building the next great particle accelerator.**