The ITRP Members

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David Plane - Scientific Secretary

ITRP Schedule of Events

- **Six Meetings**
  - RAL (Jan 27,28 2004) → Tutorial & Planning
  - DESY (April 5,6 2004)
  - SLAC (April 26,27 2004) → Site Visits
  - KEK (May 25,26 2004)
  - Caltech (June 28,29,30 2004) → Deliberations
  - Korea (August 11,12,13) → Recommendation
  - ILCSC / ICFA (Aug 19) → Exec. Summary
  - ILCSC (Sept 20) → Final Report

Our Process

- We studied and evaluated a large amount of available materials
- We made site visits to DESY, KEK and SLAC to listen to presentations on the competing technologies and to see the test facilities first-hand.
- We have also heard presentations on both C-band and CLIC technologies
- We interacted with the community at LC workshops, individually and through various communications we received
- We developed a set of evaluation criteria (a matrix) and had each proponent answer a related set of questions to facilitate our evaluations.
- We assigned lots of internal homework to help guide our discussions and evaluations

What that Entailed

- We each traveled at least 75,000 miles
- We read approximately 3000 pages
- We had constant interactions with the community and with each other
- We gave up a good part of our "normal day jobs" for six months
- We had almost 100% attendance by all members at all meetings
- We worked incredibly hard to "turn over every rock" we could find.

from Norbert Holtkamp

The Charge to the International Technology Recommendation Panel

General Considerations

The International Technology Recommendation Panel (the Panel) should recommend a Linear Collider (LC) technology to the International Linear Collider Steering Committee (ILCSC).

On the assumption that a linear collider construction commences before 2010 and given the assessment by the ITRC that both TESLA and JLC-X/NLC have rather mature conceptual designs, the choice should be between these two designs. If necessary, a solution incorporating C-band technology should be evaluated.

Note -- We have interpreted our charge as being to recommend a technology, rather than choose a design

Evaluating the Criteria Matrix

- We 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

- We evaluated each of these categories with the help of answers to our "questions to the proponents," internal assignments and reviews, plus our own discussions

Evaluation: Scope and Parameters

- The Parameters Document describes a machine with physics operation between 200 and 500 GeV.
  - The luminosity of this machine must be sufficient to acquire 500 fb^{-1} of luminosity in four years of running, after an initial year of commissioning.
  - The baseline machine must be such that its energy can be upgraded to approximately 1 TeV, as required by physics.
  - The upgraded machine should have luminosity sufficient to acquire 1 ab^{-1} in an additional three or four years of running.

- The ITRP evaluated each technology in the light of these requirements, which reflect the science goals of the machine. It examined technical, cost, schedule and operational issues.

Evaluation: Scope and Parameters

- The Panel's general conclusion was that each technology would be capable, in time, of achieving the goals set forth in the Parameters Document.

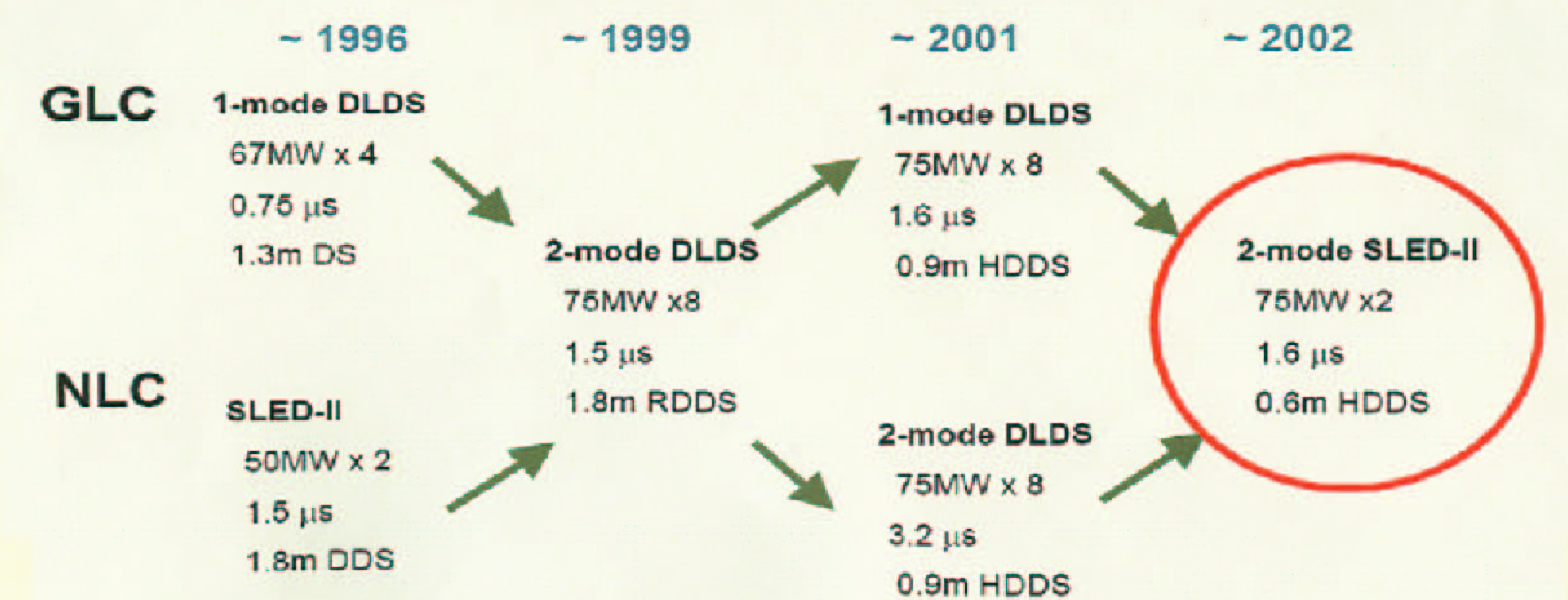
- The Panel felt that the energy goals could be met by either technology.
  - The higher accelerating gradient of the warm technology would allow for a shorter main linac.

- The luminosity goals were deemed to be aggressive, with technical and schedule risk in each case.
  - On balance, the Panel judged the cold technology to be better able to provide stable beam conditions, and therefore more likely to achieve the necessary luminosity in a timely manner.

Evaluation: Technical Issues

- **The Panel evaluated the main linacs and subsystems for X-band and L-band to identify performance-limiting factors for construction and commissioning.**
  - **In general, the Panel found the LC R&D to be far advanced. The global R&D effort uncovered a variety of issues that were mitigated through updated designs.**

Evolution of RF Unit Scheme



Evaluation: Technical Issues

- For the warm technology, major subsystems were built to study actual performance.
  - The KEK damping ring was constructed to demonstrate the generation and damping of a high-intensity bunch train at the required emittance, together with its extraction with sufficient stability.

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

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  - The Final Focus Test Beam at SLAC was constructed to demonstrate demagnification of a beam accelerated in the linac.
  - As a result, the subsystem designs are more advanced for the warm technology.

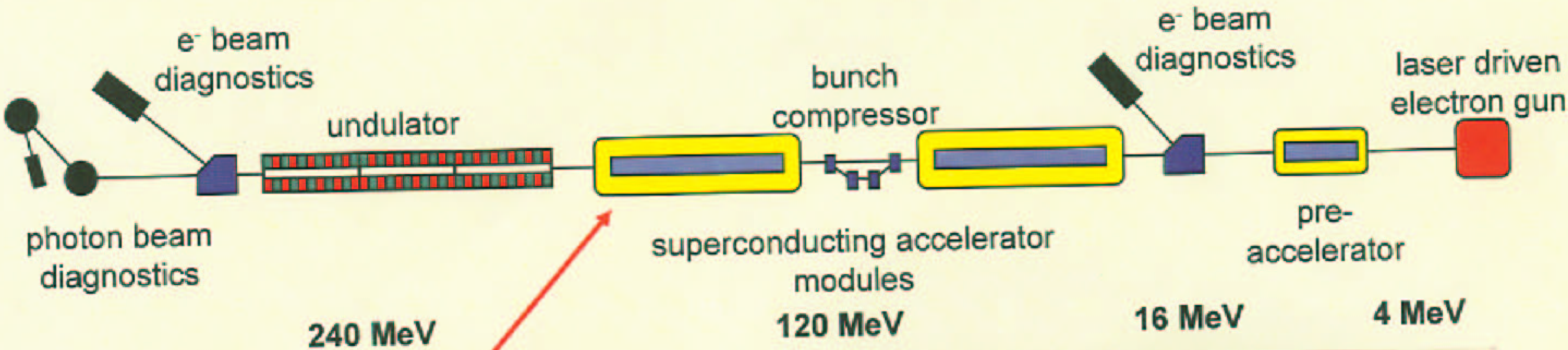
Evaluation: Technical Issues

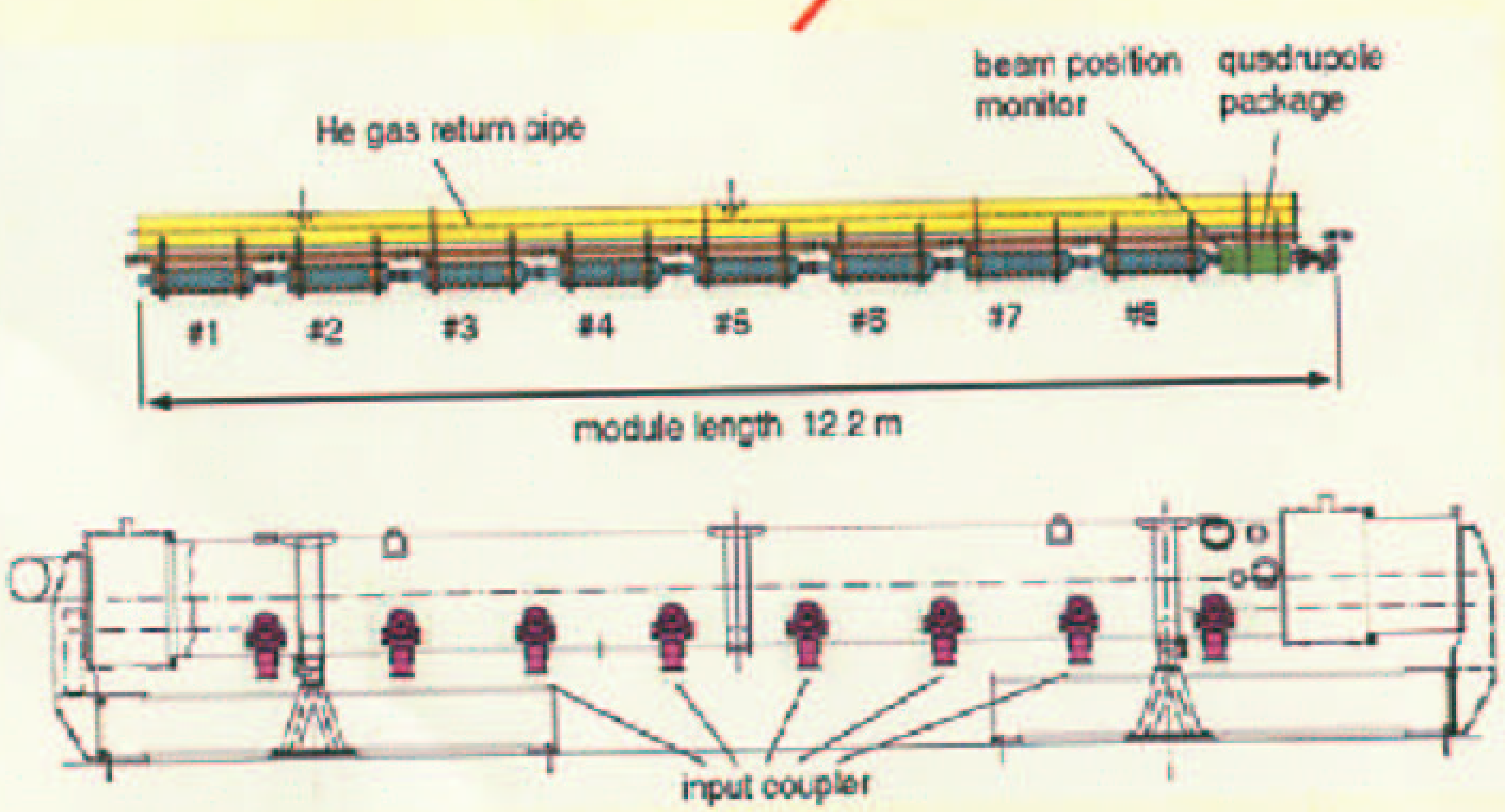
- In general, the cold technology carries higher risk in the accelerator subsystems other than the linacs, while the warm technology has higher risk in the main linacs and their individual components.
- The accelerating structures have risks that were deemed to be comparable in the two technologies.
  - The warm X-band structures require demonstration of their ability to run safely at high gradients for long periods of time.
  - The cold superconducting cryomodules need to show that they can manage field emission at high gradients.
- For the cold, industrialization of the main linac components and rf systems is now well advanced.

Evaluation: Technical Issues

- Superconducting RF Linac Concept demonstrated in TESLA Test Facility

TESLA Test Facility Linac



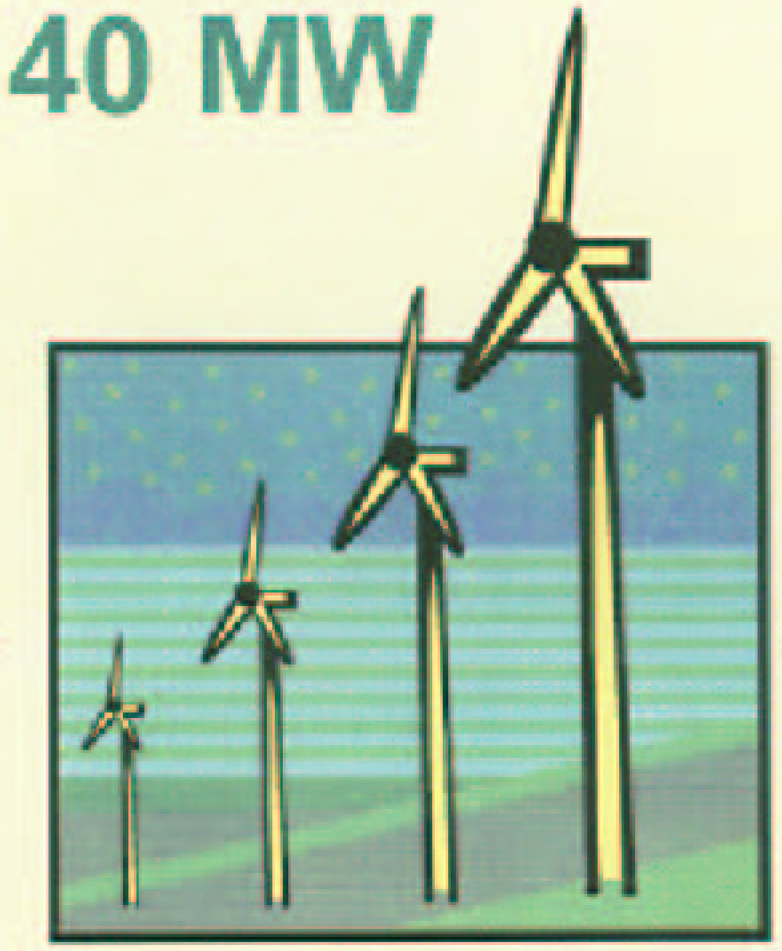


Evaluation: Technical Issues

- Superconducting RF Linac Concept demonstrated in TESLA Test Facility
- Many cold technology components will be tested over the coming few years in a reasonably large-scale prototype through construction of the superconducting XFEL at DESY.
- A superconducting linac has high intrinsic efficiency for beam acceleration, which leads to lower power consumption.

Site power: 140 MW

Power Usage TESLA Design



Linac: 97MW

Sub-systems: 43MW

RF: 76MW

78%

Cryogenics: 21MW

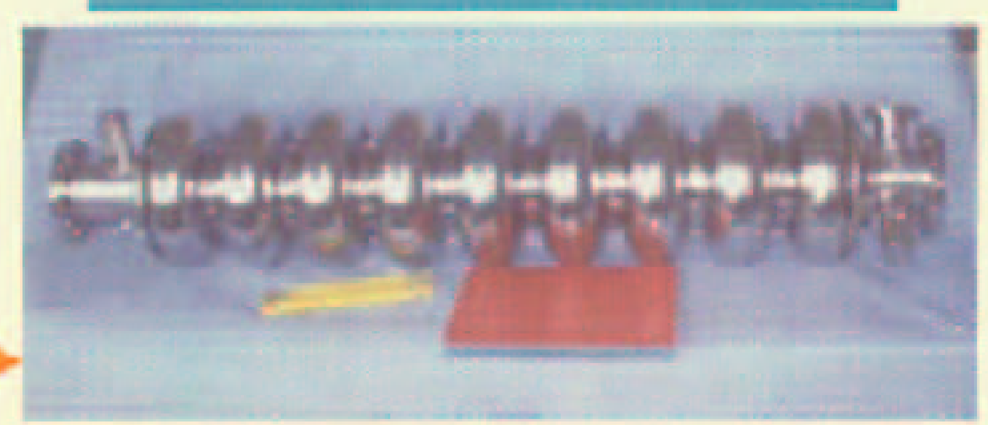
Injectors

Damping rings

Water, ventilation, …

65%

Beam: 22.6MW



60%

Evaluation: Technical Issues

- In a superconducting rf structure, the rf pulse length, the length of the bunch train, and interbunch time interval are all large. This offers many advantages.
- The disadvantages are mainly related to the complex and very long damping rings, and the large heat load on the production target for a conventional positron source, which might require a novel source design.
  - Storage rings are among the best-understood accelerator subsystems today, and much of this knowledge can be transferred to the linear collider damping rings.
  - Beam dynamics issues such as instabilities, ion effects, and intrabeam scattering have been well studied in those machines.

Evaluation: Technical Issues

- Achieving design luminosity will be a critical measure of the collider's success. A number of arguments indicate it will be easier with the cold technology.
  - The cold technology permits greater tolerance to beam misalignments and other wakefield-related effects.
  - Natural advantage in emittance preservation because the wakefields are orders of magnitude smaller
  - The long bunch spacing eliminates multi-bunch effects and eases the application of feedback systems.
  - This feedback will facilitate the alignment of the nanometer beams at the collision point.
- For these reasons, we deem the cold machine to be more robust, even considering the inaccessibility of accelerating components within the cryogenic system.

Evaluation: Cost Issues

- The Panel spent considerable effort gathering and analyzing all information that is available regarding the total costs and the relative costs of the two options.
- At the present conceptual and pre-industrialized stage of the linear collider project, uncertainties in estimating the total costs are necessarily large.
- Although it might be thought that relative costing could be done with more certainty, there are additional complications in determining even the relative costs of the warm and cold technologies because of differences in design choices and differences in costing methods used in different regions.

Evaluation: Cost Issues

- Some of the important contributors to the uncertainties are:
  - Design and implementation plans for important technological components of each machine are in a preliminary state.
  - Differences in design philosophy by the proponents lead to differences in construction cost, as well as final performance. These cannot be resolved until a global and integrated design exists.
  - Assumptions about industrialization/learning curves for some key components have large uncertainties at this early stage in the design.
  - Present cost estimates have some regional philosophies or prejudices regarding how the project will be industrialized. Contingency accounting, management overheads, staff costs for construction and R&D costs for components are all treated differently; this adds uncertainty to cost comparisons.

Evaluation: Schedule Issues

- In accordance with our charge, we assumed that LC construction would start before 2010, and that it would be preceded by a coordinated, globally collaborative effort of research, development, and engineering design.

- Based on our assessment of the technical readiness of both designs, we concluded that the technology choice will not significantly affect the likelihood of meeting the construction start milestone.

- We believe that the issues that will drive the schedule are primarily of a non-technical nature.

Evaluation: Physics Operations Issues

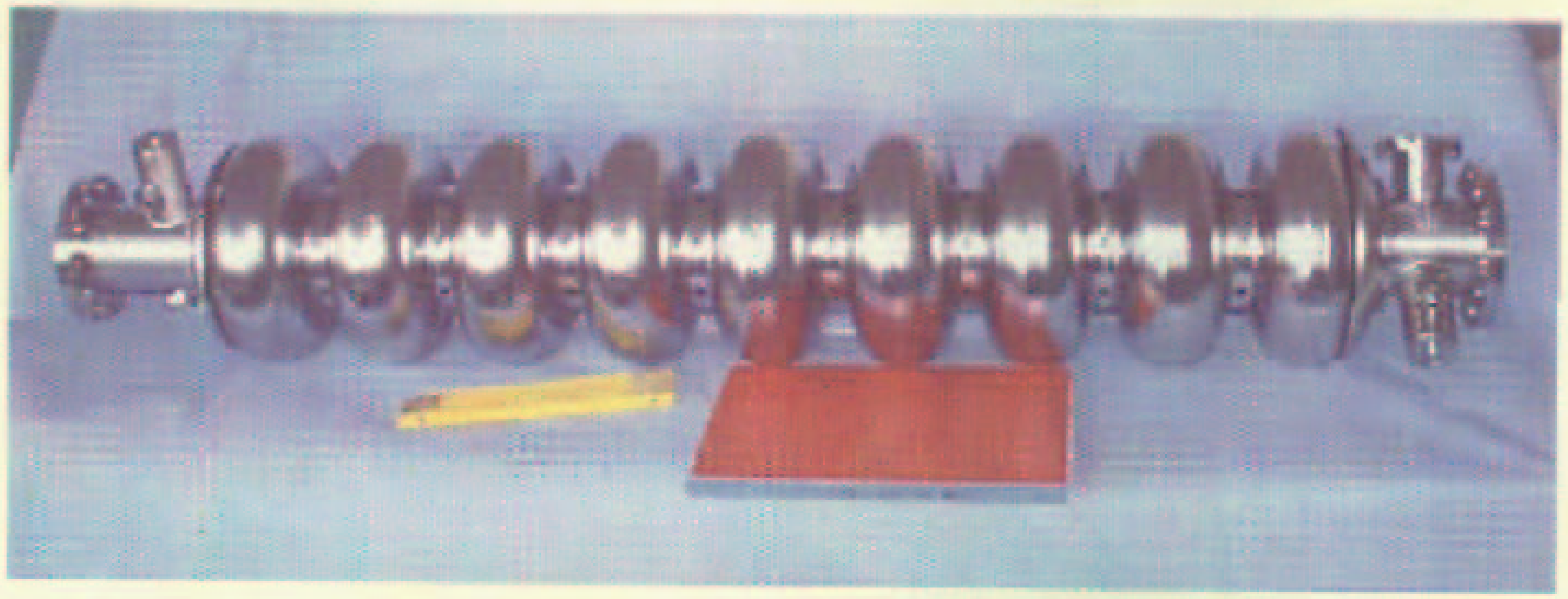
- **Several factors favor the cold machine:**
  - The long separation between bunches in a cold machine allows full integration of detector signals after each bunch crossing. In a warm machine, the pileup of energy from multiple bunch crossings is a potential problem, particularly in forward directions.
  - The energy spread is somewhat smaller for the cold machine, which leads to better precision for measuring particle masses.
  - If desired, in a cold machine the beams can be collided head-on in one of the interaction regions. Zero crossing angle might simplify shielding from background.
  - a nonzero crossing angle permits the measurement of beam properties before and after the collision, giving added constraints on the determination of energy and polarization at the crossing point.

Evaluation: General Considerations

- Linear collider R&D affects other scientific areas
  - the development of high-gradient superconducting cavities is a breakthrough that will find applications in light sources and X-ray free electron lasers, as well as in accelerators for intense neutrino sources, nuclear physics, and materials science.
  - New light sources and XFELs will open new opportunities in biology and material sciences.
  - The superconducting XFEL to be constructed at DESY is a direct spin-off from linear collider R&D.
  - the R&D work done for the X-band rf technology is of great interest for accelerators used as radiation sources in medical applications, as well as for radar sources used in aircraft, ships and satellites, and other applications.

The Recommendation

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



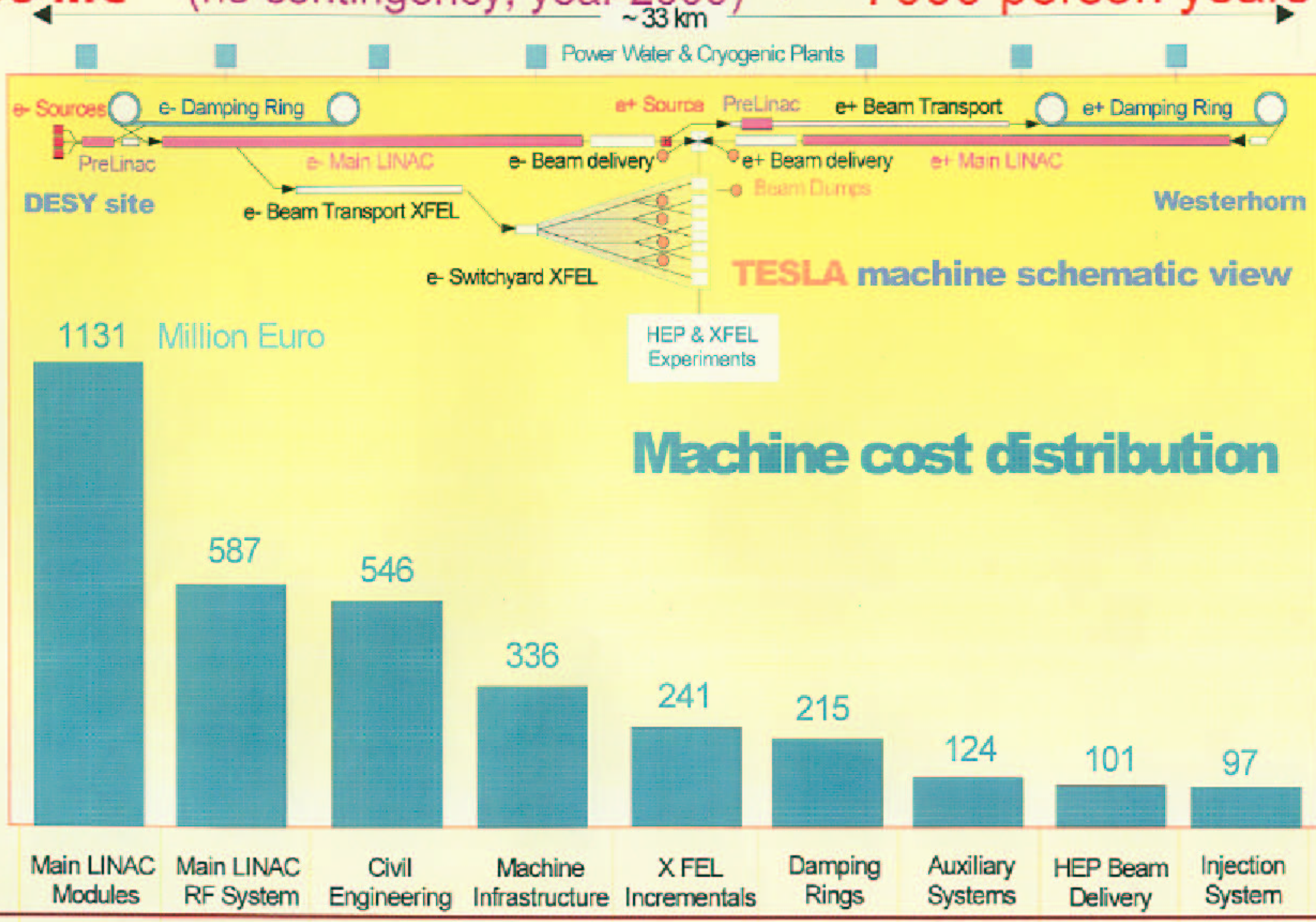
  - This recommendation is made with the understanding that we are recommending a technology, not a design. We expect the final design to be developed by a team drawn from the combined warm and cold linear collider communities, taking full advantage of the experience and expertise of both (from the Executive Summary).
  - The superconducting technology has several very nice features for application to a linear collider. They follow in part from the low rf frequency.

Some of the 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.

TESLA Cost estimate500GeV LC, one e+e- IP

3,136 M€ (no contingency, year 2000) + ~7000 person years



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- 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.

The ITRP Recommendation

- The ITRP 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 and J. Dorfan announced the result at the IHEP Conference
- The ITRP recommendation was discussed and endorsed at FALC (Funding Agencies for the Linear Collider) on September 17 at CERN.

Meeting of Funding Agencies to discuss the status and funding prospects for a linear collider of 0.5 to 1TeV. Fourth meeting held at CERN on 17 September 2004

1. The fourth meeting of representatives from CERN (President of Council and DG), Canada (NSERC), France (CNRS), Germany (BMBF), India (DAE, DST), Italy (INFN), Japan (MEXT), Korea (MOST), UK (PPARC) and the US (DOE, NSF) was held at CERN on 17 September 2004.

2. The Group received a presentation from Professor Barish, chair of the International Technology Review Panel (ITRP). He outlined the process followed to reach a recommendation on the technology for a 0.5 to 1TeV linear collider and the primary reasons for the choice of the superconducting rf technology. The Funding Agencies praised the clear choice by ICFA. This recommendation will lead to focusing of the global R& D effort for the linear collider and the Funding Agencies look forward to assisting in this process. The Funding Agencies see this recommendation to use superconducting rf technology as a critical step in moving forward to the design of a linear collider.

What's Next?

- A new global design based on superconducting rf technology will be initiated by the combined warm and cold experts.
- We need to fully capitalize on the experience from SLC, FFTB, ATF and TTF as we move forward. The range of systems from sources to beam delivery in a LC is so broad that an optimized design can only emerge by pooling the expertise of all participants.
- The R&D leading to a final design for the ILC will be coordinated by an International Central Design Team, which the ITRP endorses.
- The first collaboration meeting will be at KEK in November.

Is global collaboration possible?

Two disturbing facts

1. Failure of ITER
2. CERN attitude

Regional machine may be an alternative with other regions' participation

1. Asia-pacific
2. US

Global center may become rather week unless we have a strong leadership

Personal Impression

1. It is hard to make a purely scientific and technological judgment but we did it, sort of.
2. It is hard to compare cost estimation done in different culture and we did not do it.
3. Is ICFA constraint that energy is 0.5 Tev extendable to ~1Tev reasonable? We thought it is, sort of.
4. Energy extendability is important but did we agree on how much? Well?
5. Do I think this recommendation will push the global collaboration? Next transparency .


Arriving in Korea