International Technology Recommandation Panel
(ITRP)

(January-August 2004)

Annual Meeting
CARE

Coordinated Accelerator Research in Europe
supported by the European Community (FP6 Research Infrastructures Action)

Nov. 2-5, 2004, DESY Hamburg, Germany

Jean-Eudes Augustin
LPNHE-Paris

International Technology Recommandation Panel (ITRP)

The charge was:

- **choose**
  between TESLA & JLC-X/NLC technologies
  assuming construction <2010

based on considerations:
scientific, technical, schedule and cost

- reference: **ILC-TRC** (Loew) 2003 report
- **LC parameters**: ICFA document 9-30-2003
- Recommandation before end of 2004:
  it was issued in August:

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

- **http://www.ligo.caltech.edu/~skammer/ITRP_Home.htm**

Members

Barry Barish(chair)
Jonathan Bagger
Pauk Grannis
Norbert Holtkamp
for North America

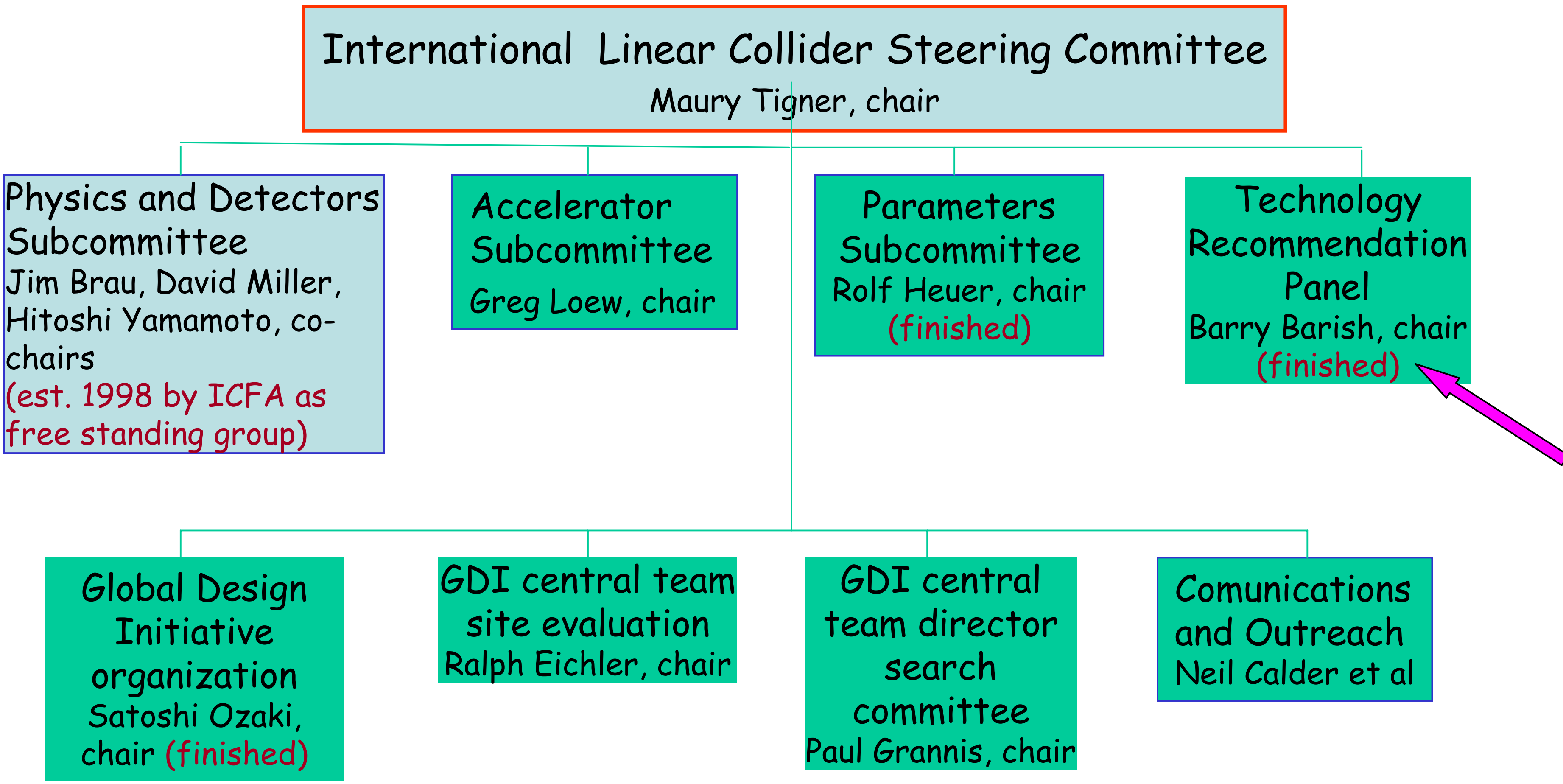
Gyung-Sun Lee
Akira Masaike
Katsunobu Oide
Hirotaka Sugawara
for Asia

Jean-Eudes Augustin
Giorgio Bellettini
George Kalmus
Volker Soergel
for Europe

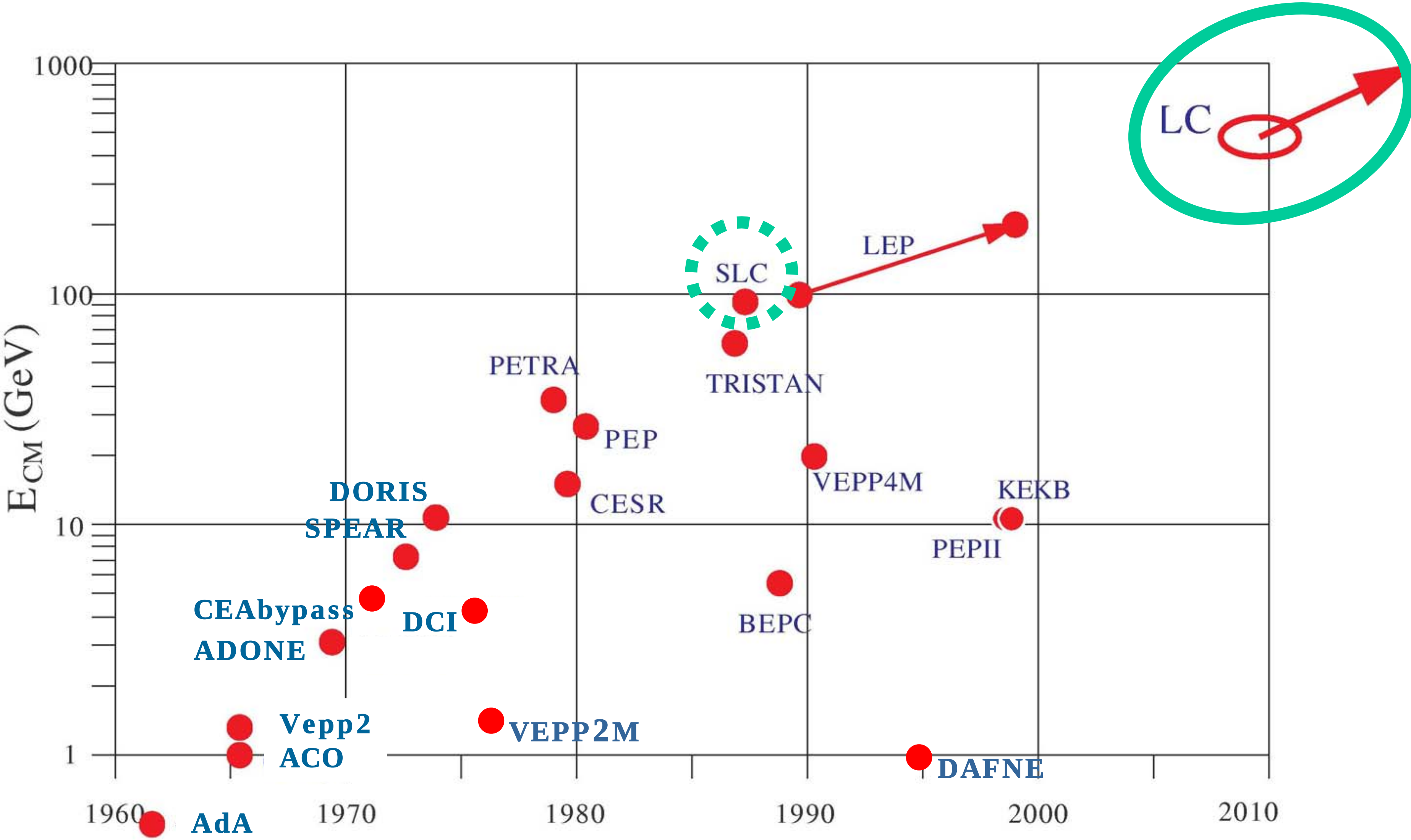
+David Plane secretary

Fall 2002: ICFA created the International Linear Collider Steering Committee (ILCSC) to guide the process for building a Linear Collider.

Asia, Europe and North America each formed their own regional Steering Groups (for Europe: R.Aymar, B.Bertolucci, B.Foster, D.Miller, F.Richard, A.Wagner).



History of e^+e^- Collider



Adapted from Kaoru Yokoya

Remember:

Stanford Linear Collider (1988-1998)

Gave first rate results on Z (80% polarised e-).

Feasibility proof of linear collider …

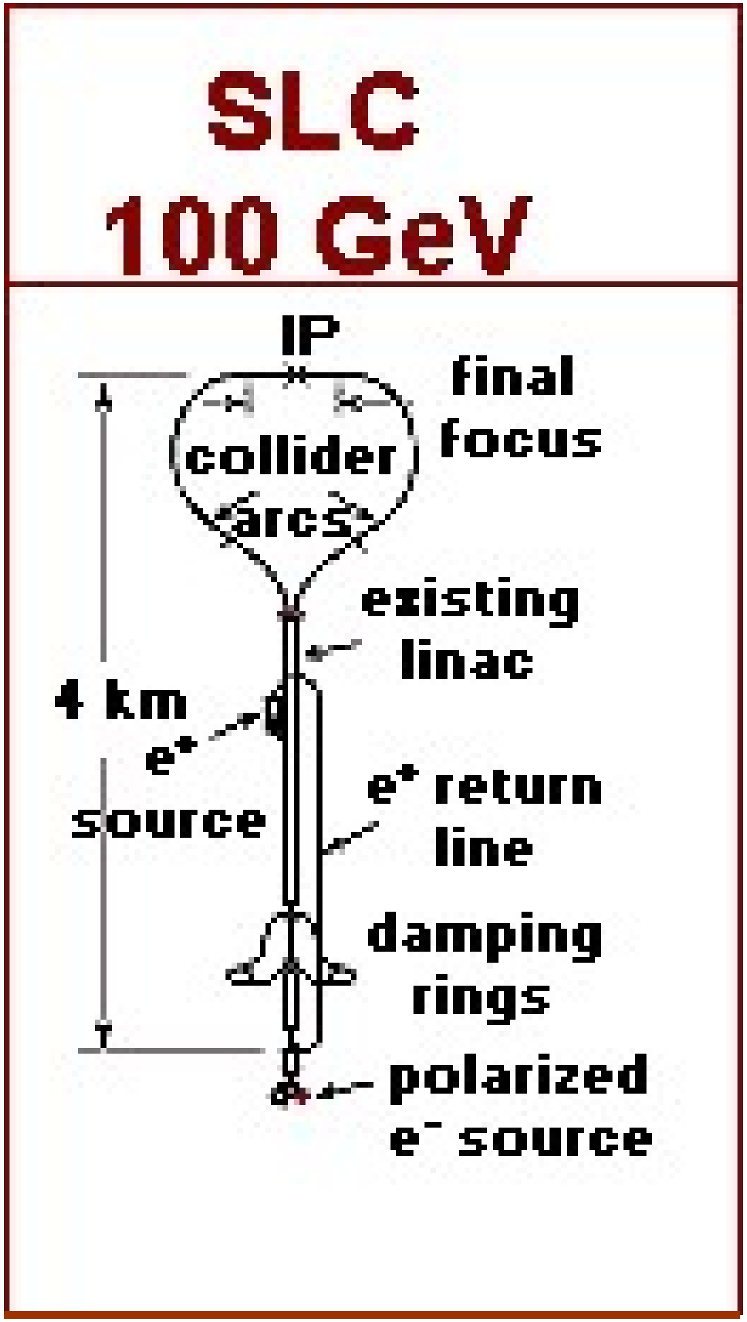
(and training ground of many present day specialists)

In 1998 finally reached

$\mathcal{L}=3.10^{30}\ cm^{-2}\ s^{-1}$

(~50% of the design)

[SLAC, S-band, 2.84GHZ]



Following SLC, in the early 1990's

Several parallel developments, theory and experimental tests towards a "true" linear collider:

- S-Band (2.84 GHz) at DESY (A.Voss), and at SLAC

- C-band (5.7 GHz) in Japan and in Korea

- X-band (11,4 GHz) NLC-X at SLAC (B.Richter,G.Loew)
  and JLC at KEK
  and in Russia at BINP (Balaikin,14 GHz)

  (Note: BNS damping (Balaikin Novokhatski Smirnov) was vital for SLC)

- L-band (1,3 GHz) Superconducting
  TESLA at DESY (Bjorn Wiik)

-30 GHz, beam generated RF: CLIC at CERN (W.Schnell)

→First G.Loew report to ICFA, 1995

March 2003

INTERNATIONAL LINEAR COLLIDER

TECHNICAL REVIEW COMMITTEE

"Greg Loew Committee"

SECOND REPORT

2003

480pp

Validated Readiness of Tesla and NLC-X Concepts

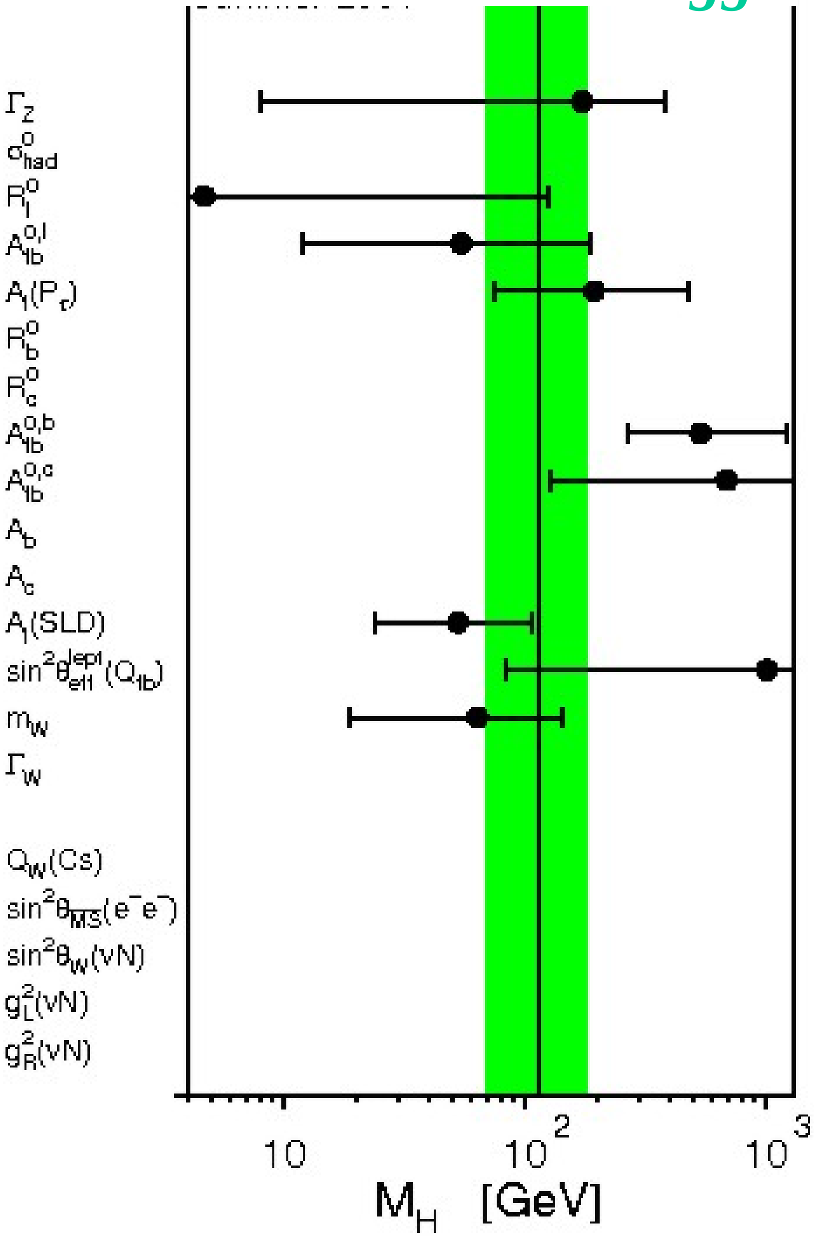
Why ITRP?

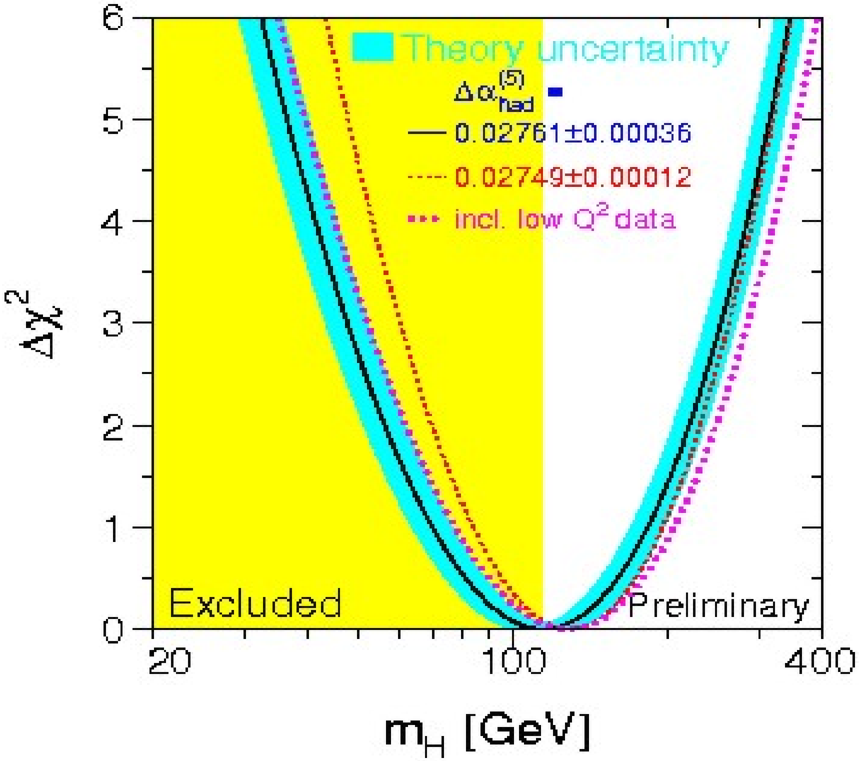
Recommandation!

- 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.
  - 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. (We note that a C-band option could have been adequate for a 500 GeV machine, if NLC/GLC and TESLA were not deemed mature designs).

B.Barish

Constraints on m_{Higgs}





$\log(m_{Higgs}) = 2.06 \pm 0.21$

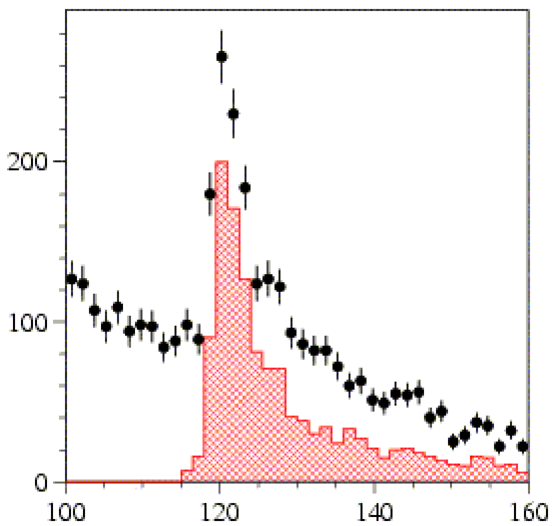
$m_{Higgs} = 114^{+69}_{-45}$ GeV

$m_{Higgs} < 260$ GeV @95% c.l.

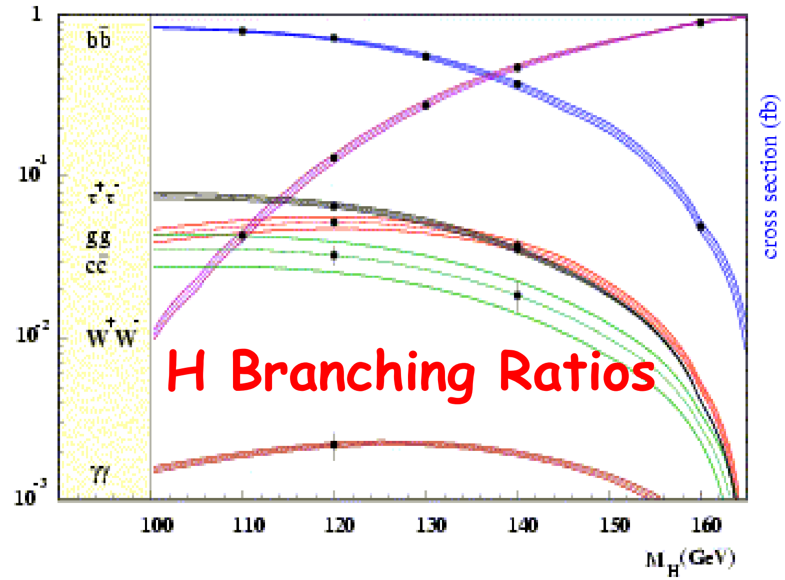
$m_{Higgs} > 114$ GeV @95% c.l.

Teubert, IHEP 2004 Beijing

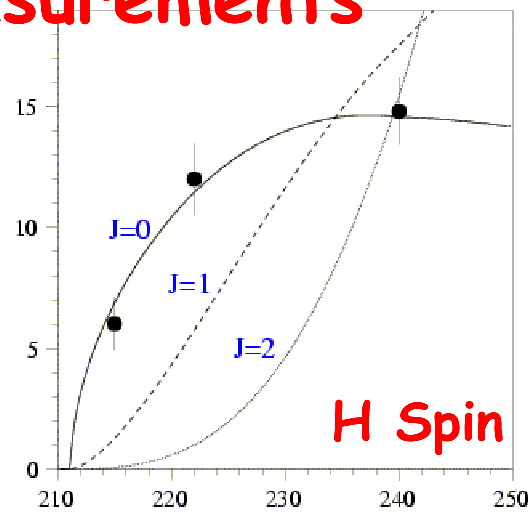
Linear Collider Physics: Precision measurements



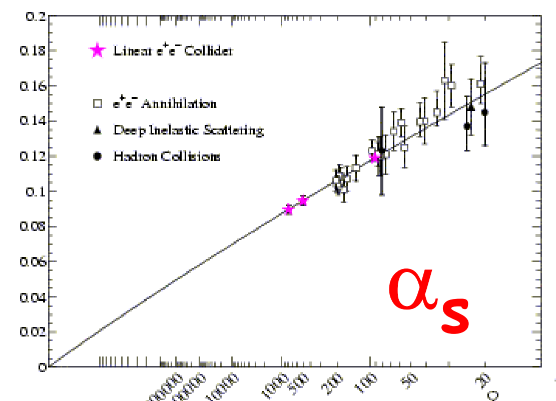
Inclusive Higgs:
Z Recoil mass



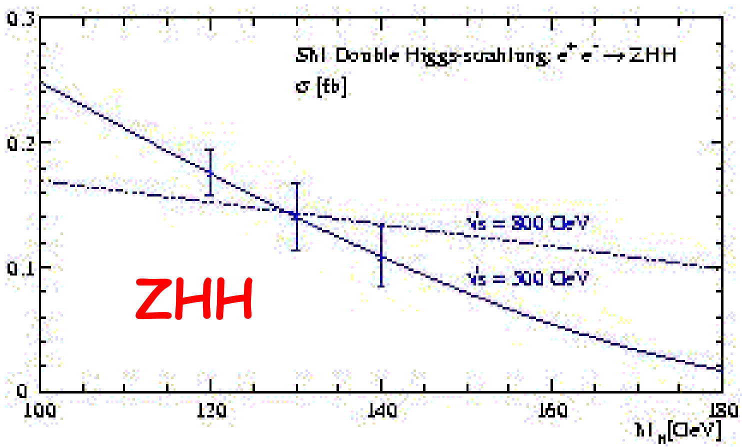
H Branching Ratios



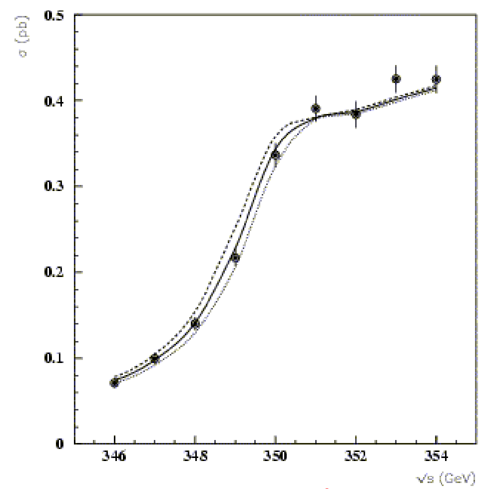
H Spin



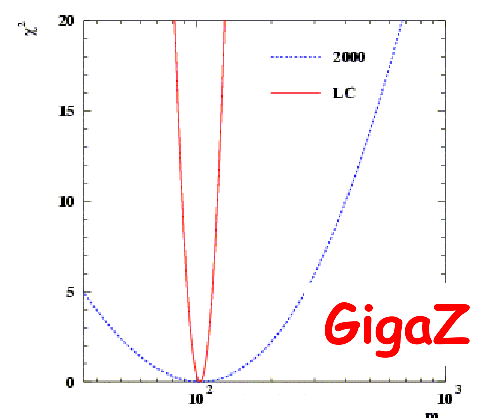
α_s



ZHH



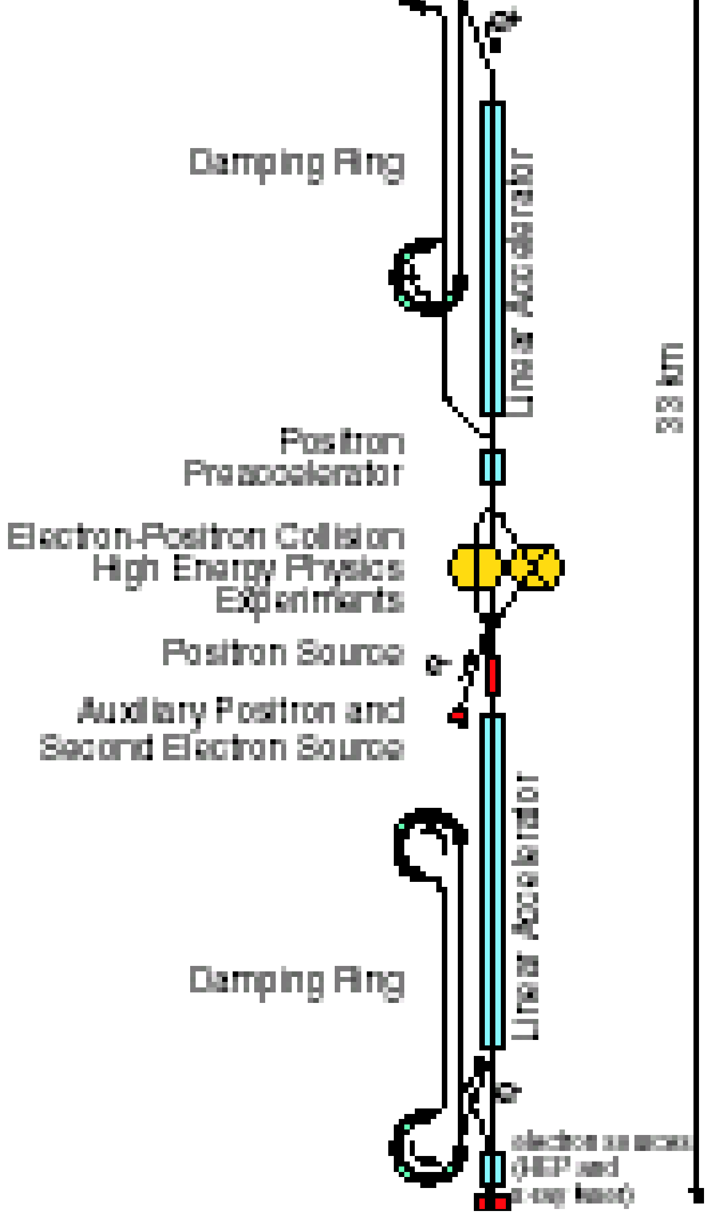
Top quark mass



GigaZ

... and much more beyond SM

TESLA



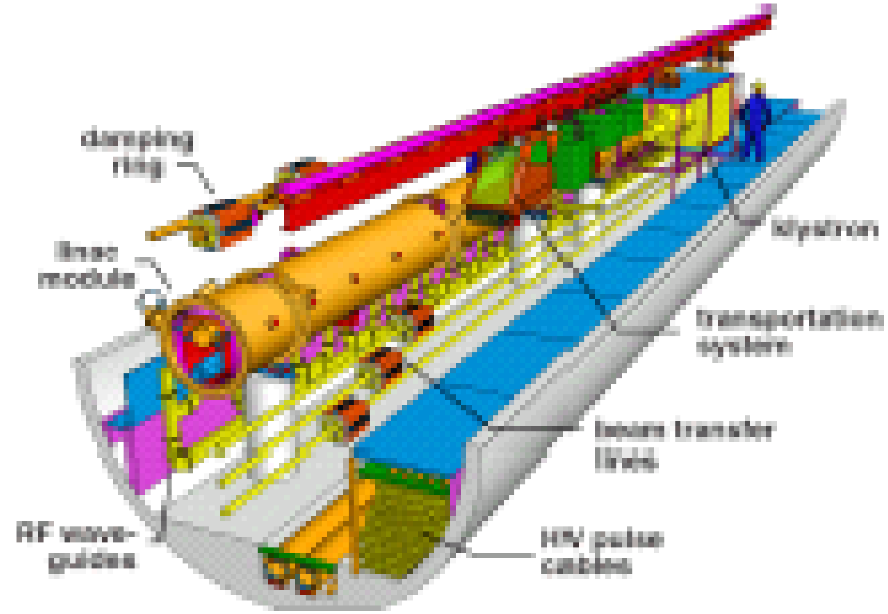
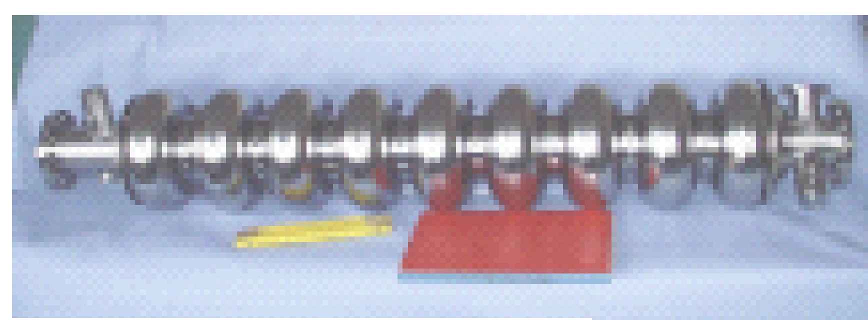


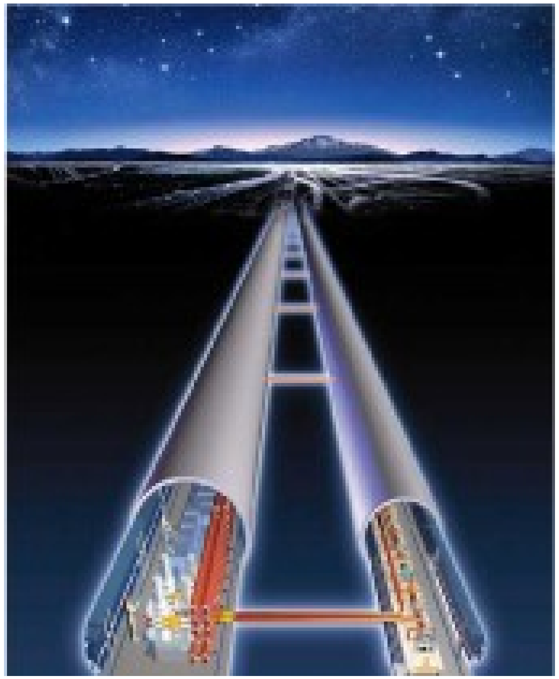
FIGURE 2. Sketch of the 5 m diameter TESLA linac tunnel

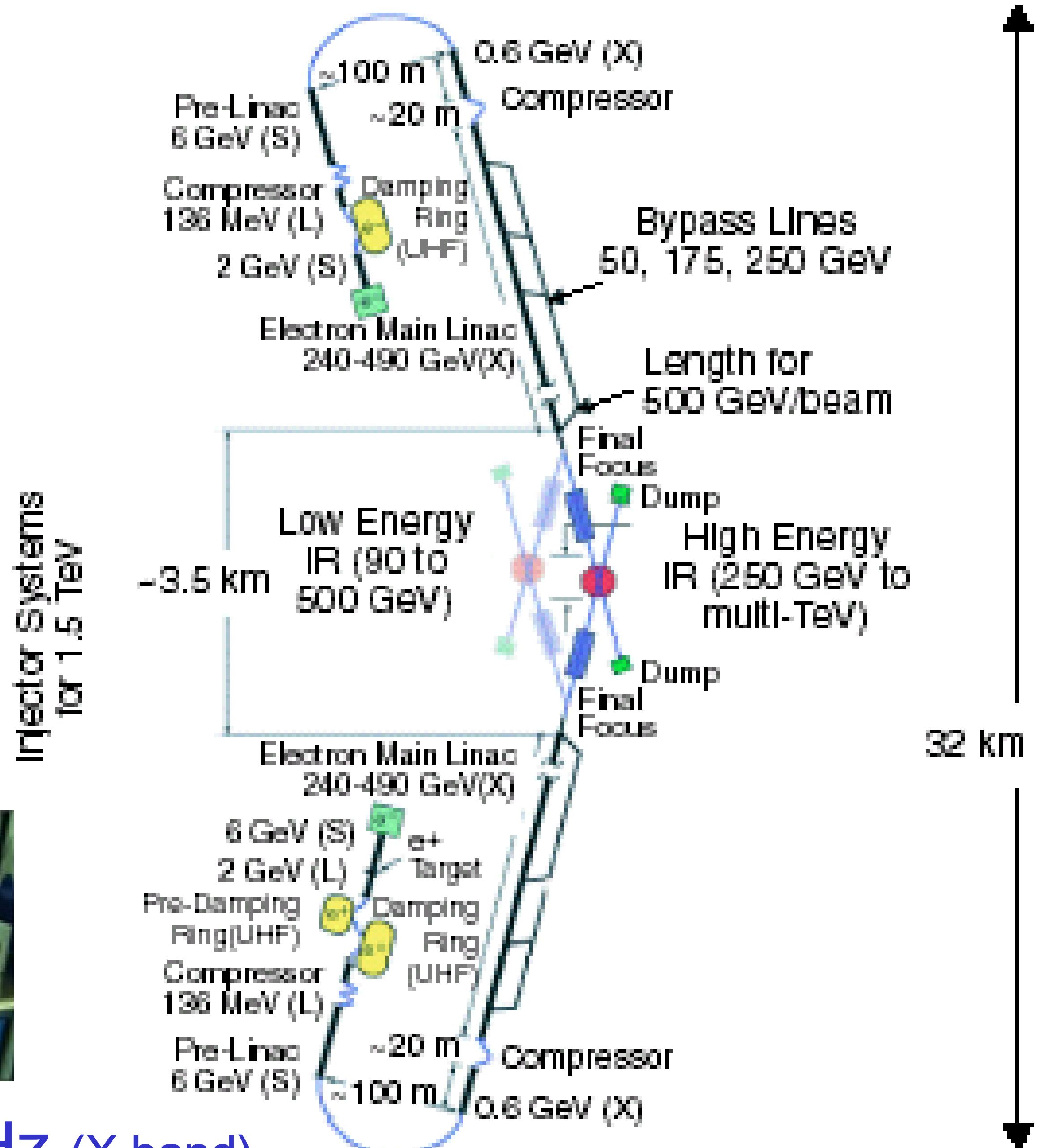


Superconducting RF , 1,3 GHz

Niobium Cavities

NLC-X





Copper, 11,4 GHz (X band)

Main Collider Parameters

	TESLA		NLC/JLX(X)	
c.m energy ***GeV***	500	800	500	1000
RF frequency ***GHz***	1.3		11.4	
Luminosity $10^{34}/cm^2/s$	3.4	5.8	2.5	
nb bunches/pulse	2820	4500	192	
$N^{\pm}$ /bunch (10^{10})	2	4	0.75	
Bunch separation ***ns***	337	176	1.4	
Repetition rate ***Hz***	5	4	150	100
σ_y at Xing point **nm**	5	2.8	3	2.1
$\Delta E/E$ beamstrahlung	3.2%	4.3%	4.6%	7.5%
Accel. Gradient **MV/m**	23.4	35	65/52*	
Total AC power **MW**	140	200	243	292
Site length **km**	33		32	

* loaded

Parameters for the Linear Collider

Parameters for the Linear Collider

September 30, 2003

Parameter Sub-committee

(S.Komamiya, Dongsul Son, R.Heuer(Chair), F.Richard, P.Grannis, M.Oreglia)

- Baseline machine: $\sqrt{s}$ = 500 GeV, 500 fb^{-1} (in 4 yrs)
  - Scans 200 to 500 GeV, - E stable to 0.1%,
  - Two Int. Regions, at least one with Xing angle ($\gamma\gamma$)
  - Calibn at 91 GeV (Z0), - e^- Polarisation 80%
- Energy Upgradeable to about 1 TeV, 1 at^{-1} in 3-4 yrs
- 6 Options:

  1 at^{-1} in next 2 yrs,

  e^-e^- collisions,

  positron polarisation to 50%, (helicoidal undulator)

  "Giga Z" $\mathcal{L}$ several 10^{33} cm^{-2} sec^{-1}, E to 0.1%,

  WW threshold, $\mathcal{L}$ several 10^{33} cm^{-2} sec^{-1}, **E to 10^{-5}**,

  and $\gamma\gamma$ from backscattered laser beams in one IR.

LC: Machine Components:

Energy: RF cavities, pulse compression, klystrons, modulators

Energy dispersion: flat beams $\sigma_y \ll \sigma_x$

Intensity: e+ sources, undulator vs. conventional

Luminosity: damping rings, bunch compressors

Beam delivery system & final focus σ_y = 5to3 nm

$$\mathcal{L} = \frac{f_{rep}\, n_b\, N_+ N_-}{4\pi\sigma_x\sigma_y} H_D$$

(H_D pinch enhancement factor)

Extraction & Dump

- Emittance & **preservation**: Source, Damping Ring, Linac, BDS
- $$\mathcal{L} = \eta\, P_{AC} \left(\frac{1}{E_{cm}}\right) \left(\frac{N_\pm}{\sigma_x}\right) \left(\frac{1}{\sigma_y}\right) H_D \propto_{\beta_y \approx \sigma_z} \frac{\eta_{RF} P_{RF}}{E_{cm}} \sqrt{\frac{\delta_{BS}}{\varepsilon_{n,y}}} H_D$$

Efficiency AC Power

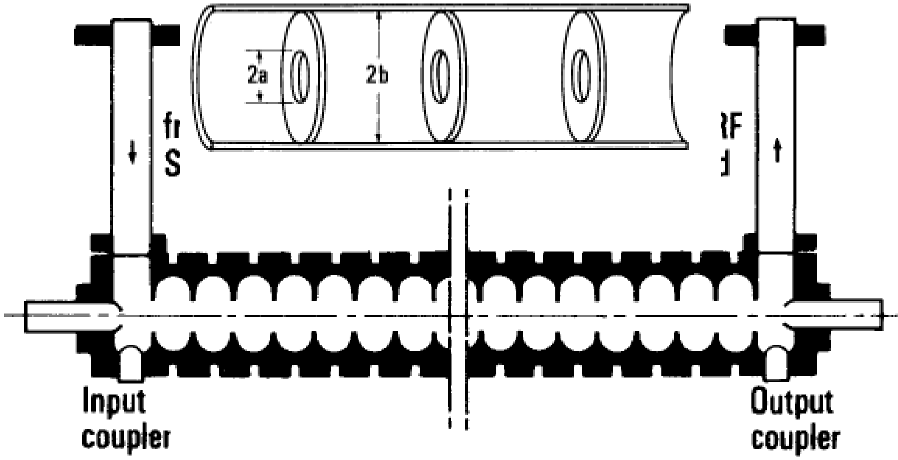
and integrated $\mathcal{L}$: **reliability**

(Nice tutorials in **http://www.desy.de/~njwalker/uspas/**)

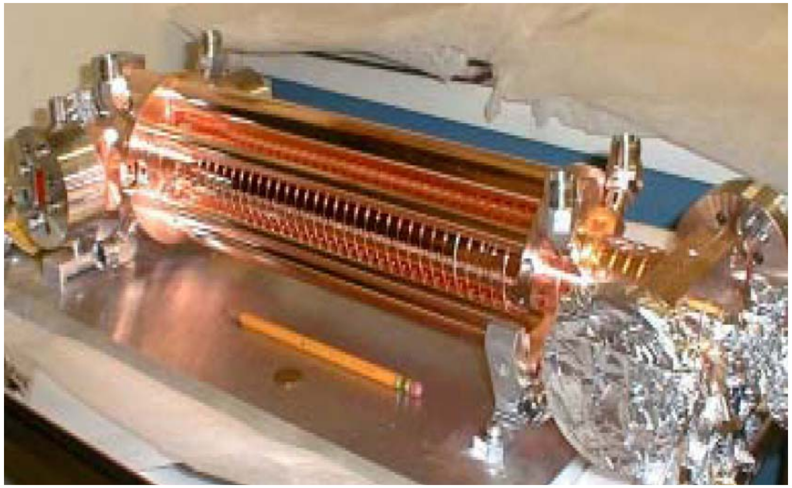
LC Components

Energy: RF cavities

X-band

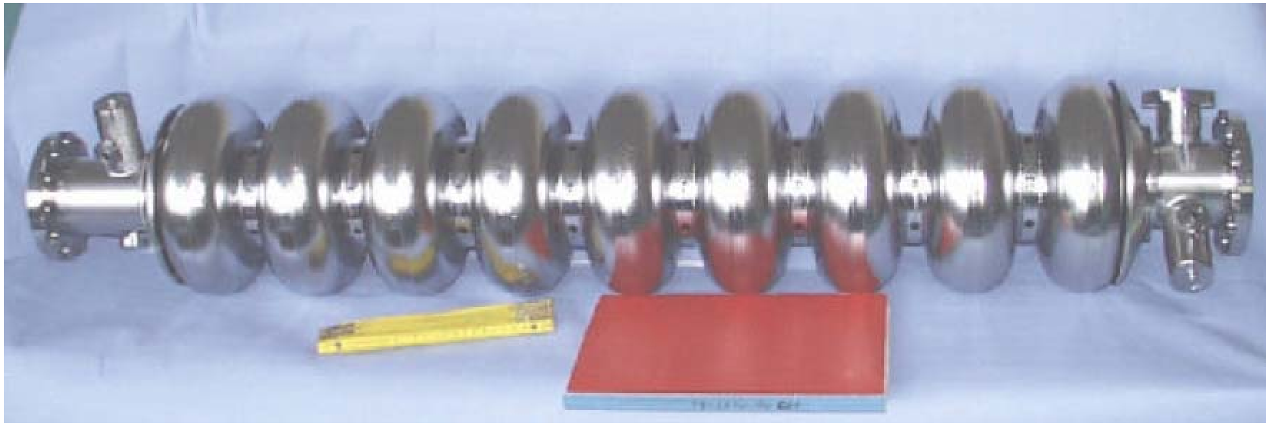


Copper, 60cm,
65MV/m unloaded,
52MV/m at nominal intensity
Length reduced from 1,8m to 0,6m
due to breakdowns: <0,1/hour/section
$\Rightarrow$ 1/2sec which is tolerable (?)
Micron precision machining



TESLA

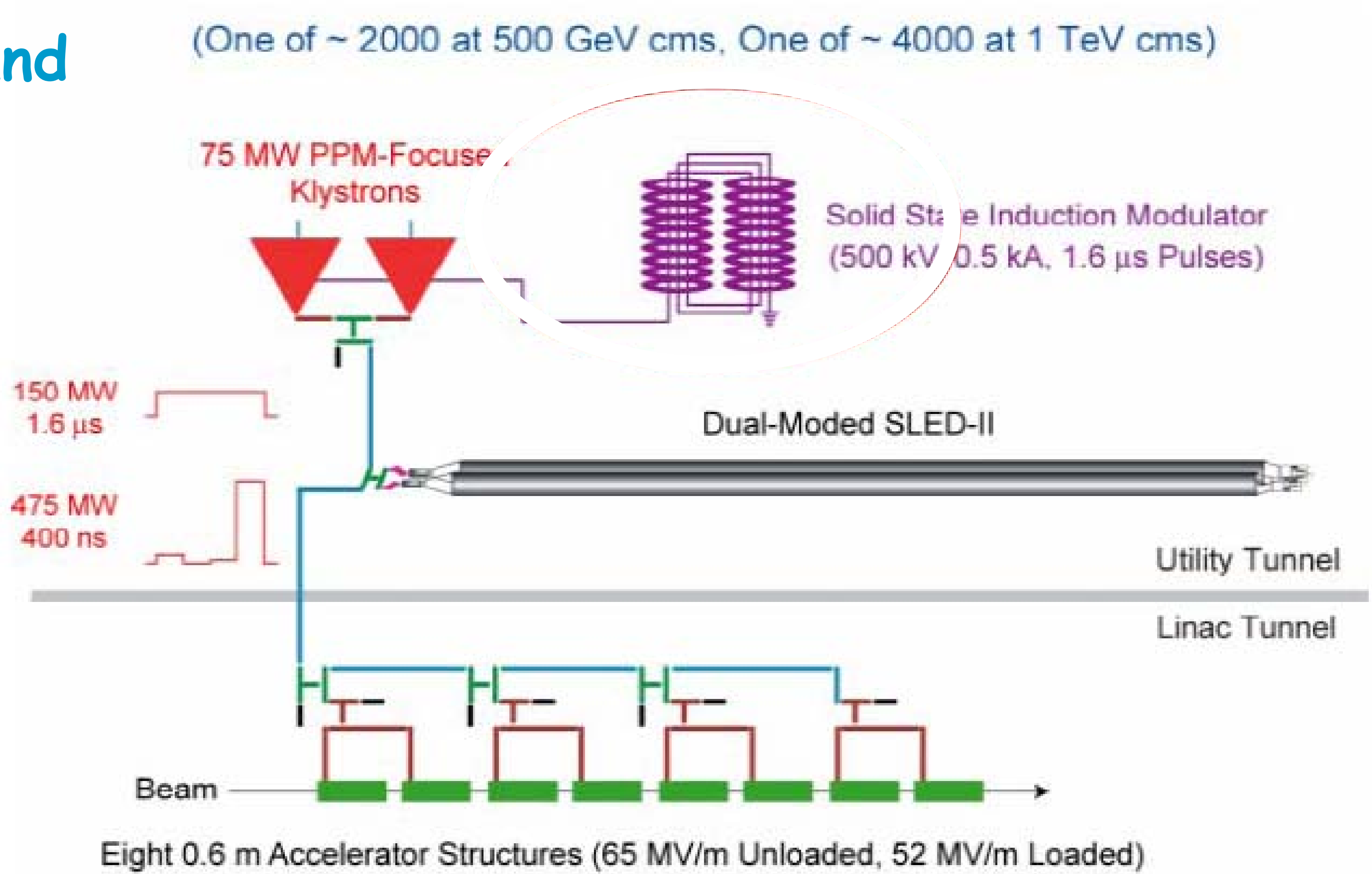
Niobium, 35MV/m
Complex RF Coupler
Dark current under control (?)
Clean rooms, strict quality control



LC Components

Energy: cavities, klystrons, modulators, compressors

X-band

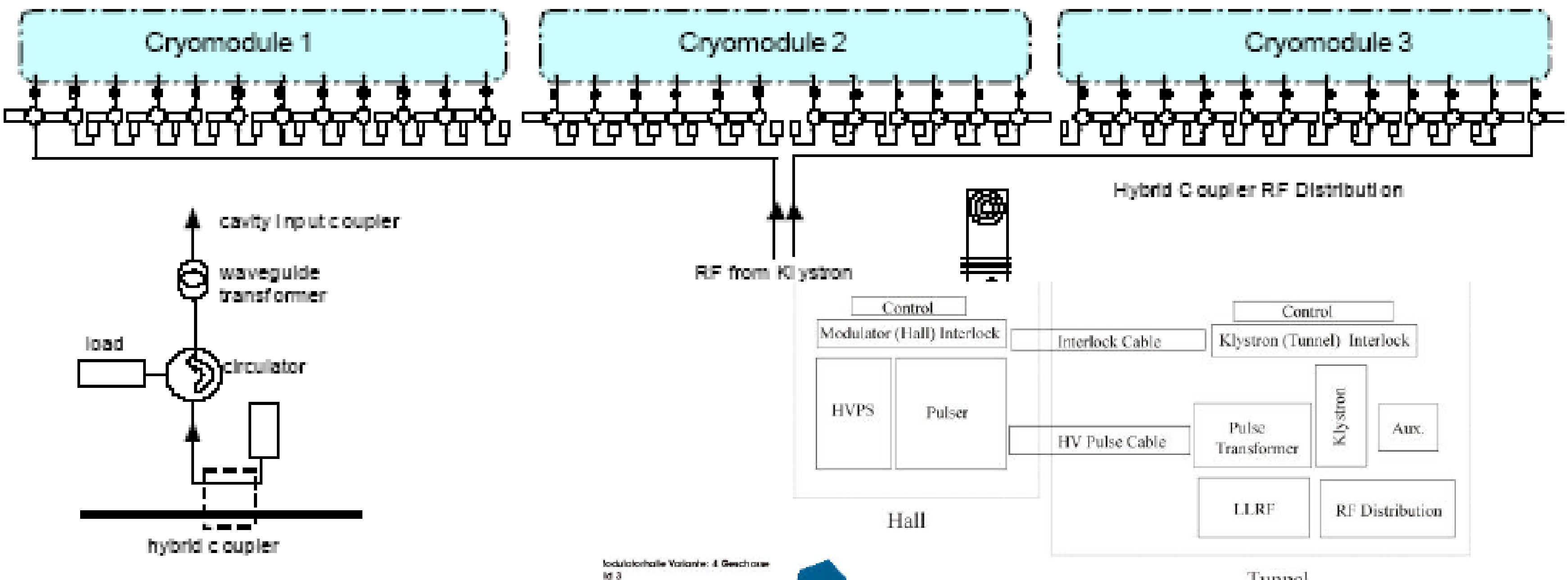


LC Components

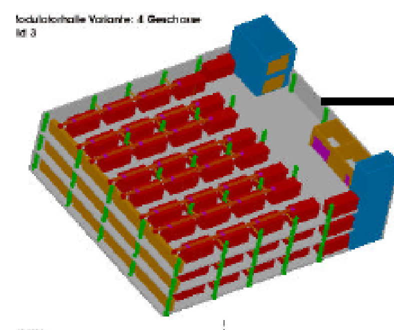
Energy: cavities, klystrons, modulators

TESLA RF organisation

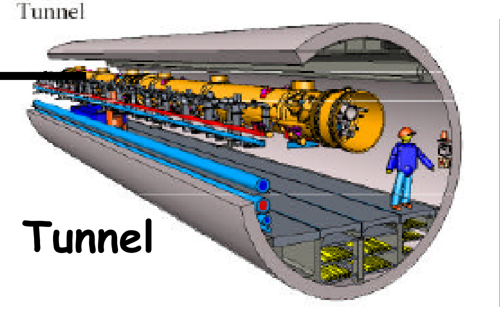
21024 cavities, 36 per klystron → 584 klystrons of 10MW at 500 GeV
and twice as much at 1 TeV



Modulators Hall



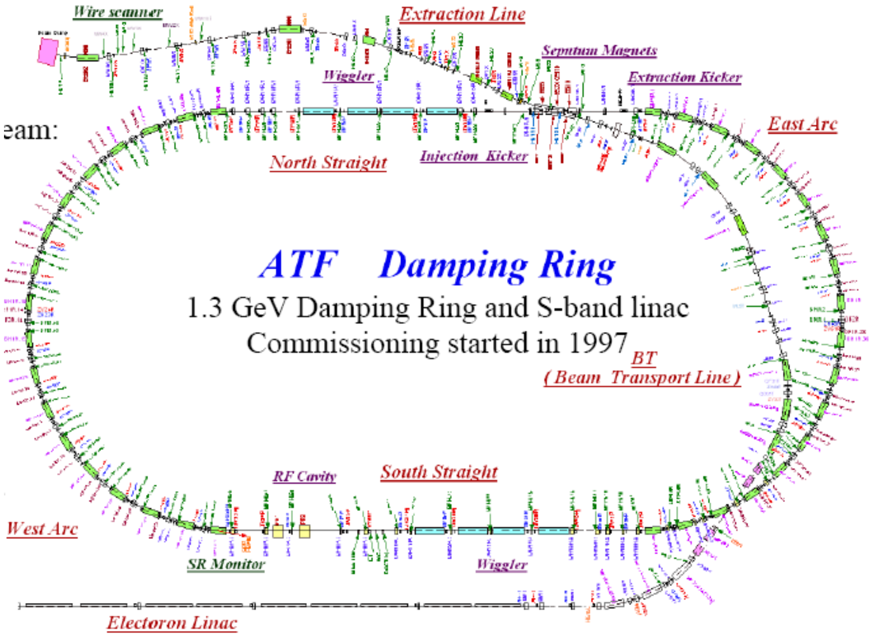
HV Cables



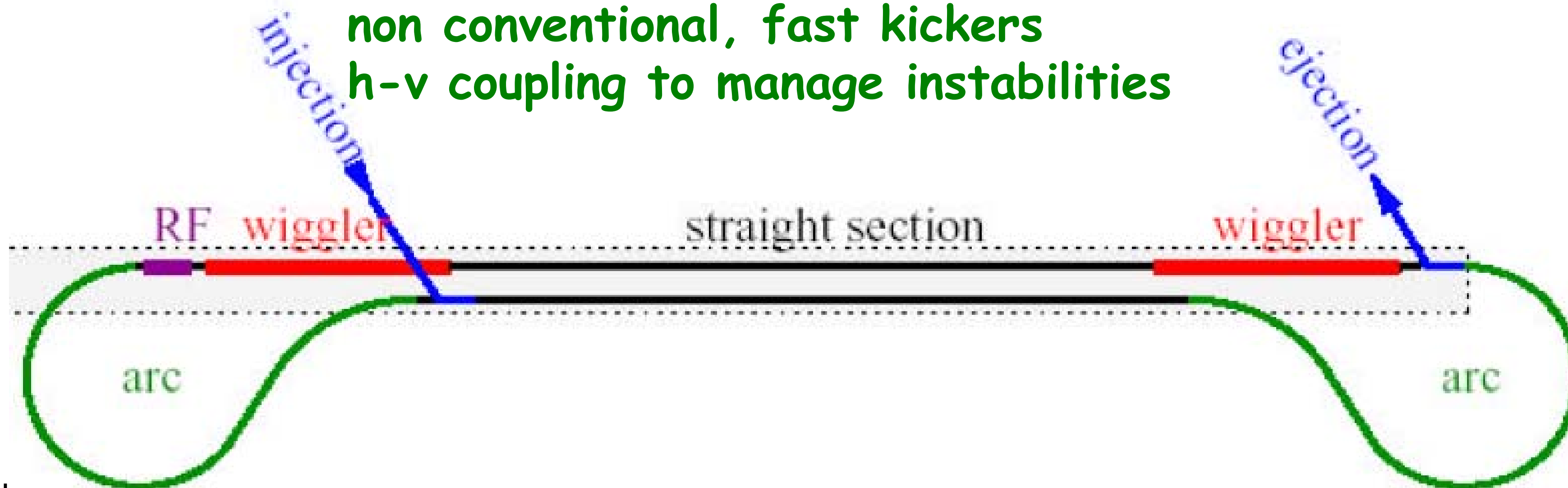
Tunnel

LC Components
Damping Rings

X-band
2GeV Damping Rings, L=300m
prototype: ATF at KEK



TESLA: 5GeV Damping Rings, L=17 km « dog-bone »
non conventional, fast kickers
h-v coupling to manage instabilities



USLC report

…new info since beginning of ITRP

availability, cost, schedule, site, risk assessment

U.S. Linear Collider
Technology Options Study
U.S. Linear Collider Steering Group
Accelerator Sub-committee
Linear Collider Option Task Forces
March 4, 2004

Table 3.2.0.1: US Linear Collider: overall parameters

Parameter	X-band ***(warm)*** Reference design	***(cold)*** L-band Reference design	X-band **upgrade**	L-band **upgrade**
Beam Energy [GeV]	250	250	500	500
Loaded RF gradient[MV/m]	52	28	52	35
Two-Linac total length[km]	15.94	27.00	29.36	42.54
Bunches/pulse	192	2820	192	2820
Electrons/bunch[10^{10}]	0.75	2	0.75	2
Pulse/s[Hz]	120	5	120	5
$\gamma\varepsilon x$(IP)[μm-rad]	3.6	9.6	3.6	9.6
$\gamma\varepsilon y$(IP)[μm-rad]	0.04	0.04	0.04	0.04
βx(IP)[mm]	8	15	13	24.4
βy(IP)[mm]	0.11	0.4	0.11	0.4
σx(IP)[nm]	243	543	219	489
σy(IP)[nm]	3.0	5.7	2.1	4.0
σz(IP)[mm]	0.11	0.3	0.11	0.3
Dy	12.9	22.0	10.1	17.3
H_D	1.46	1.77	1.41	1.68

USLC report

Parameter	X-band ***(warm)*** Reference design	***(cold)*** L-band Reference design	X-band **upgrade**	L-band **upgrade**
$\mathcal{L}_{geom}[10^{33}cm^{-2}\ s^{-1}]$	14.2	14.5	22.2	22.7
$\mathcal{L}[10^{33}cm^{-2}\ s^{-1}]$	20.8	25.6	31.3	38.1
N γ/e	1.19	1.48	1.24	1.58
δE_b[%]	4.6	3.0	8.2	5.9
Average power/beam [MW]	6.9	11.3	13.8	22.6
Peak beam current in pulse [mA]	855	9.51	855	9.51
Beam pulse length [μs]	0.270	950	0.270	950
Total number of klystrons ➡	4520	603	8984	1211
Peak RF power per klystron [MW]	75	10.0	75	9.7
Total number of structures ➡	18080	18096	35936	29064
Peak RF power per structure [MW]	56	0.276	56	0.345
Linac AC power [MW] ➡	207.6	132.7	389.9	295.9
Linac AC to beam efficiency [%]	6.6	17.0	7.1	15.3

http://www.slac.stanford.edu/xorg/accelops/

ITRP

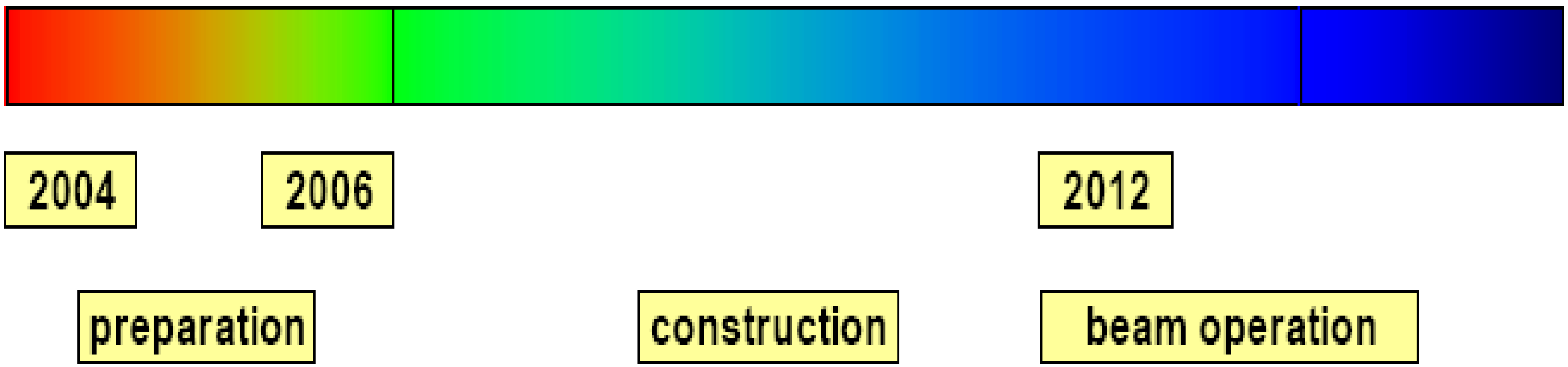
- Six Meetings
  - RAL (Jan 27,28 2004) → **Tutorial and organization**
  - DESY (April 5,6 2004)
  - SLAC (April 26,27 2004) → **Site Visits**
  - KEK (May 25,26 2004)
  - Caltech (June 28,29,30 2004) → **Deliberations Begin**
  - Korea (August 11,12,13) → **Recommendation**

Tesla Test Facility (in DESY)

Installing an 8 SC Cavities module cryostat

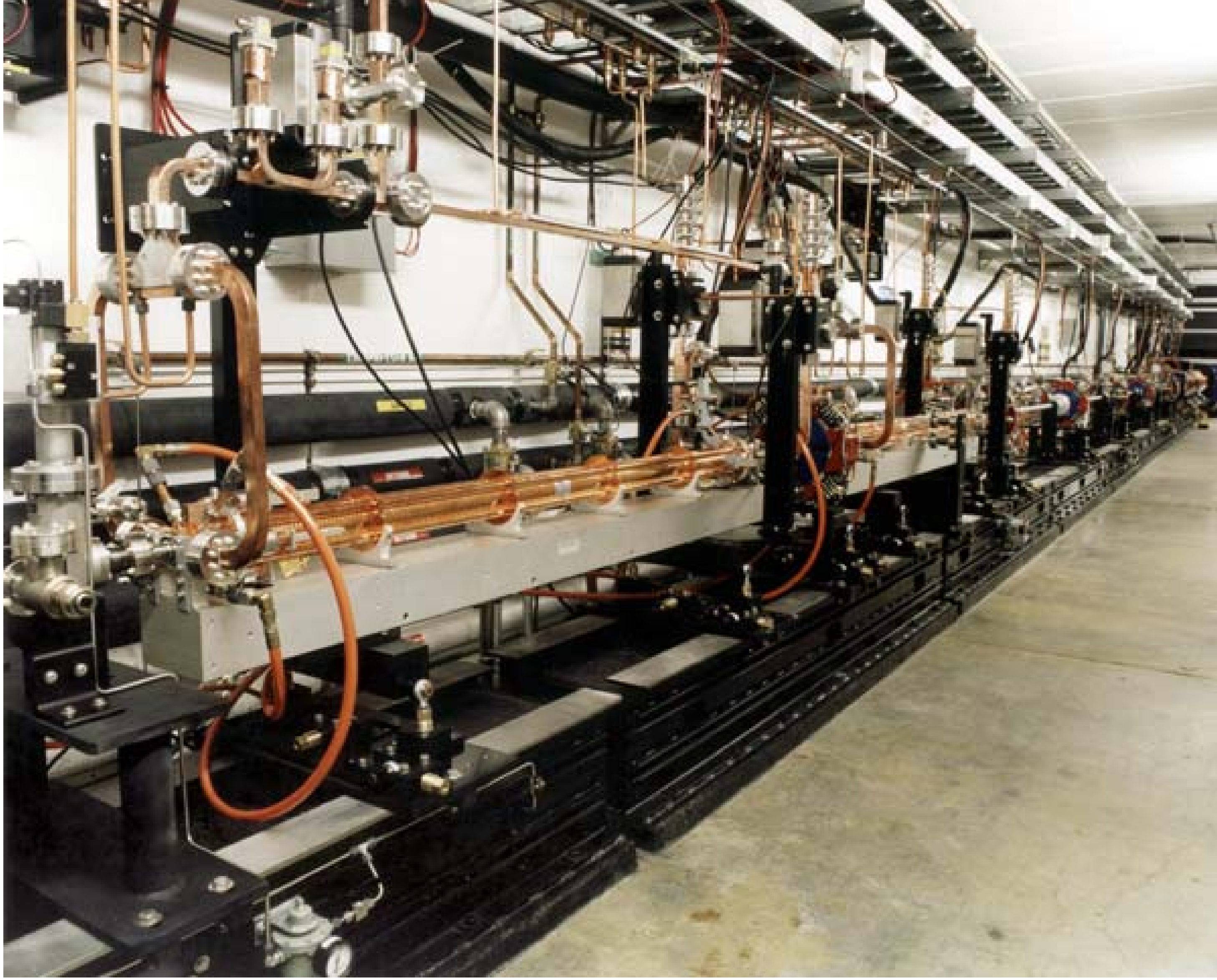
XFEL in DESY

1,5 km Linac in TESLA technology,
17,5 GeV @ 23Mv/m and up to 28 MV/m for 25 GeV



Construction in industry of 120 accelerating modules (~100 cavities) and 32 RF stations, pratically requiring **ALL** components necessary for the Collider main accelerator.
The cryogenic plant is 1/6 of what is needed for TESLA500.
Operation of an undulator.

Very clear synergy with LC



Next
Linear
Collider
Test
Accelerator (in SLAC)

Complete RF system

Accelerator Test Facility:

Damping Ring

(in KEK)

Reaches the required emittance

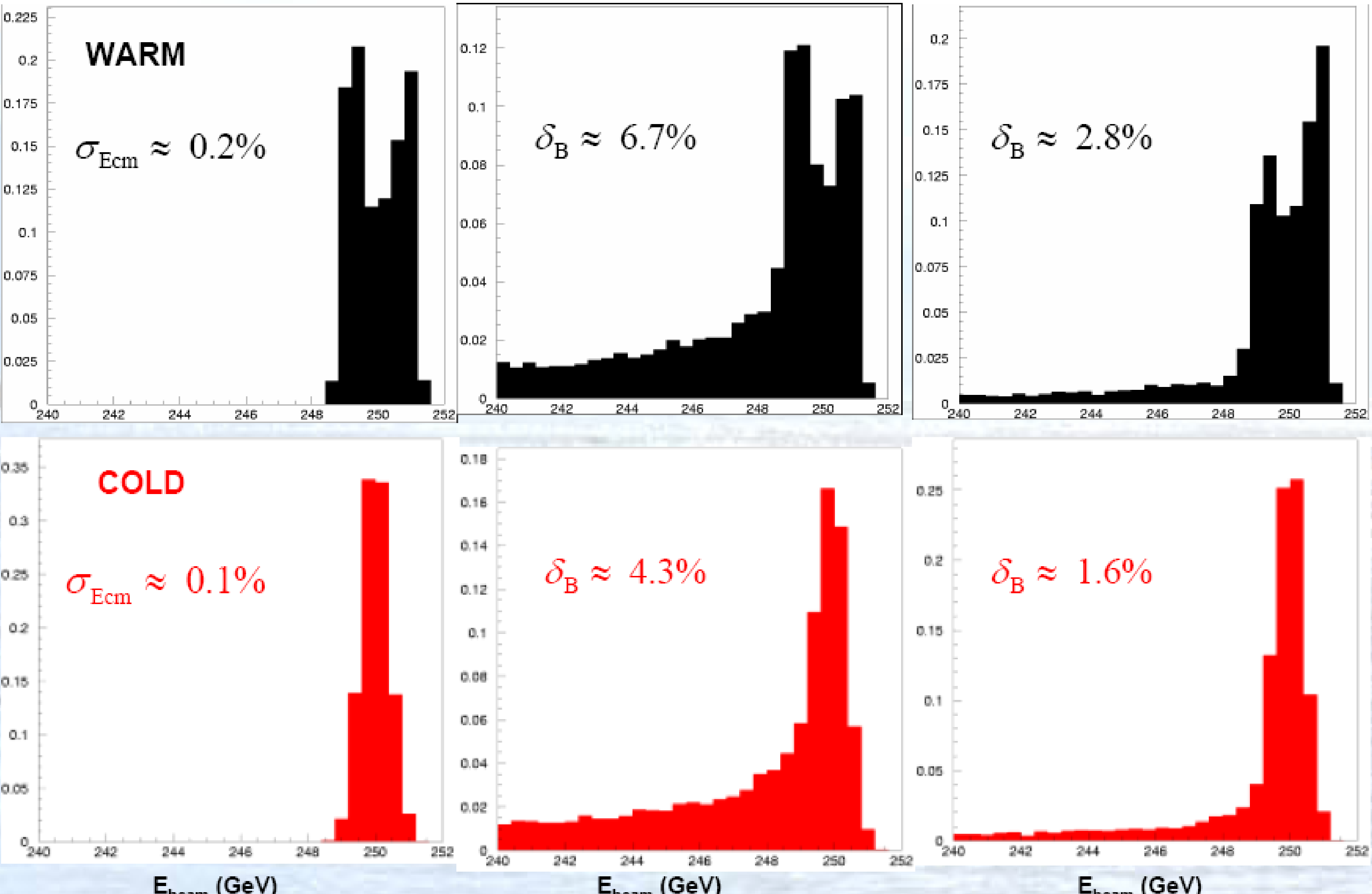
Study of multibunch,
electron clouds,
fast ion instability

Instrumentation

Beam Energy Profiles

$\langle E_{beam\ (incoming)} \rangle = 250$ GeV

Before Collision | After Collision | Lumi Weighted



Final

International Technology Recommendation Panel

Report

Submitted to the International Linear Collider Steering Committee (ILCSC) and the International Committee on Future Accelerators (ICFA)

September 2004

(Executive summary issued 19 August 2004)

http://www.ligo.caltech.edu/~skammer/ITRP_Home.htm

3.1 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.. …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.

3.2 Technical Issues

The factors were characterized in terms of risk…

The experience gained from the SLC…will be of utmost importance.

We found that, generally speaking, 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.

For the cold, industrialization of the main linac components and rf systems is now well advanced. Furthermore, many cold technology components will be tested through construction of the superconducting XFEL at DESY.

A superconducting linac has a high intrinsic efficiency for beam acceleration, which leads to lower power consumption.

…future R&D must stress ways to **extend the energy reach** to 1 TeV, and even somewhat beyond.

…The *(cold)* disadvantages are mainly related to the complex and very long damping rings, and the positron source, which might require a novel source design.

The ability to achieve design luminosity in the shortest possible time will be easier with the cold technology …we deem the cold machine to be more robust, even considering the inaccessibility of accelerating components within the cryogenic system.

. …the cold technology is better suited for intensity upgrades and smaller-emittance beam transport. The long bunch spacing in the cold technology …lowers the overall risk.

Our recommendation is for the cold rf technology, but not a specific design.

… the combined experience of the warm and cold collaborations will be essential to develop the best possible design.

3.3 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 stage of the linear collider project, uncertainties in estimating the total costs are necessarily large.

…the Panel concluded that comparable warm and cold machines, in terms of energy and luminosity, have total construction and lifetime operations costs that are within the present margin of errors of each other.

3.4 Schedule Issues

The ITRP analyzed schedule issues to assess the effect of each technology on industrializing, constructing and commissioning the linear collider.

we assumed that LC construction would start before 2010…we concluded that the technology choice will not significantly affect the likelihood of meeting the construction start milestone. The construction of the superconducting XFEL free electron laser will provide prototypes …which gives the superconducting technology some advantage.

3.5 Physics Operation Issues

…it was felt that several factors favor the cold machine:

The long separation between bunches

The energy spread is somewhat smaller.

In a cold machine the beams can be collided head-on

It is important that the final design allows maximum flexibility for physics

3.6 General Considerations

The ITRP decision should allow the linear collider to move forward quickly, so the two machines *(ILC and LHC)* can have some period of concurrent operation…

Linear collider R&D is sufficiently advanced for the project to move to design, engineering, industrialization, and construction. The technology is in hand.

The technology recommendation presented here is just one step in a coordinated effort by the worldwide particle physics community to develop a unified plan for the next large particle accelerator, the **International Linear Collider**.

- In Beijing, the ILCSC and ICFA met to review the ITRP recommendation.

ITRP Chair made a presentation accompanied by a 2.5 page Executive Summary that encapsulates the recommendation

ICFA/ILCSC
unanimously
endorsed the recommendation

J.Dorfan, ICFA Chair, Beijing 2004

First ILC Workshop

Towards an International Design of a Linear Collider

KEK, 13-15 Novembre 2004

The goal of this Workshop is to facilitate the world-wide formation of an international design team of a linear collider.

Work Group Conveners:

WG1 Overall Design

Kiyoshi Kubo (KEK) Daniel Schulte (CERN) Tor Raubenheimer (SLAC)

WG2 Main linacs

Hitoshi Hayano(KEK) Terry Garvey (IN2P3/LAL) Chris Adolphsen (SLAC)

WG3 Injector

Masao Kuriki (KEK) Susanne Guiducci (INFN) Gerry Dugan (Cornell)

WG4 Beam Delivery

Tomoyuki Sanuki(Tokyo) Graham Blair (RHUL,UK) Andrei Seryi (SLAC)

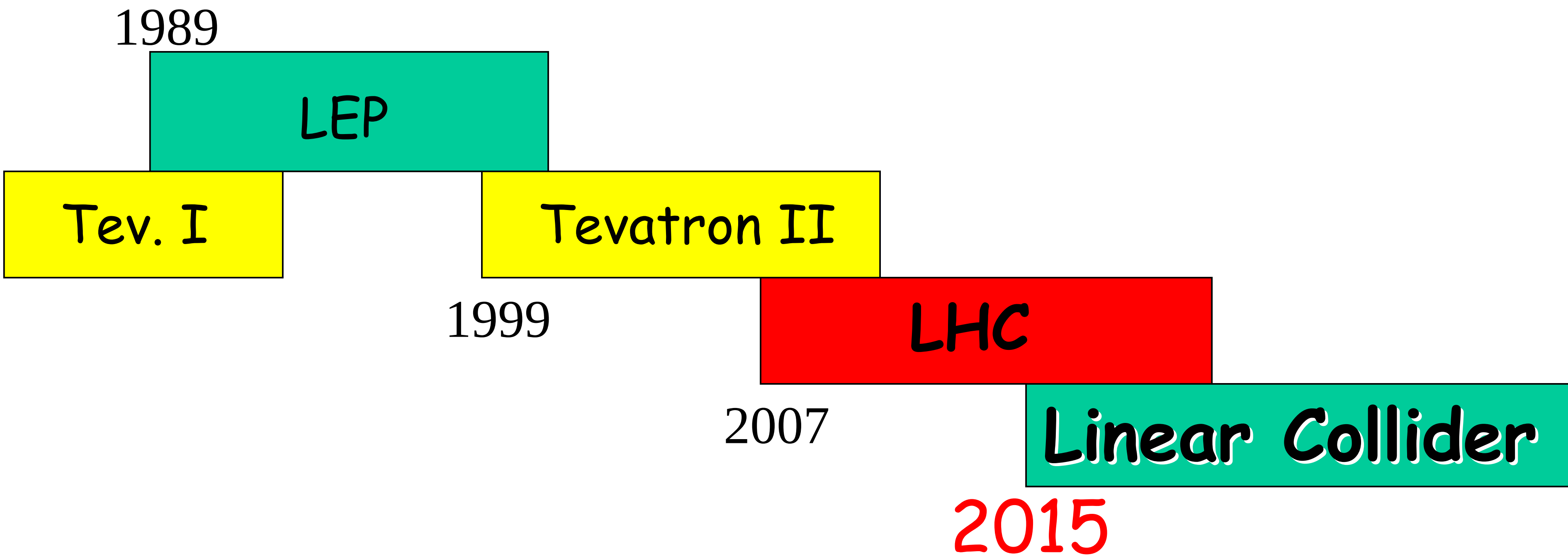
WG5 High gradient cavities

Kenji Saito (KEK) Dieter Proch (DESY) Helen Edwards (FNAL)

Tentative Schedule

2004	√	Technology recommendation, and formation of international project team.
2005		Start of work on international proposal (CDR).
2007		Completion of international engineering design (TDR).
2008		International project agreements and site selection.
2009		Start of on-site construction.
2015		End of construction.

Conclusion (sort of)



The future of particle Physics!