Les Rencontres de Physique
de la Vallée d'Aoste

February 27-March 5, 2005

The On-Going Effort towards the International Linear Collider

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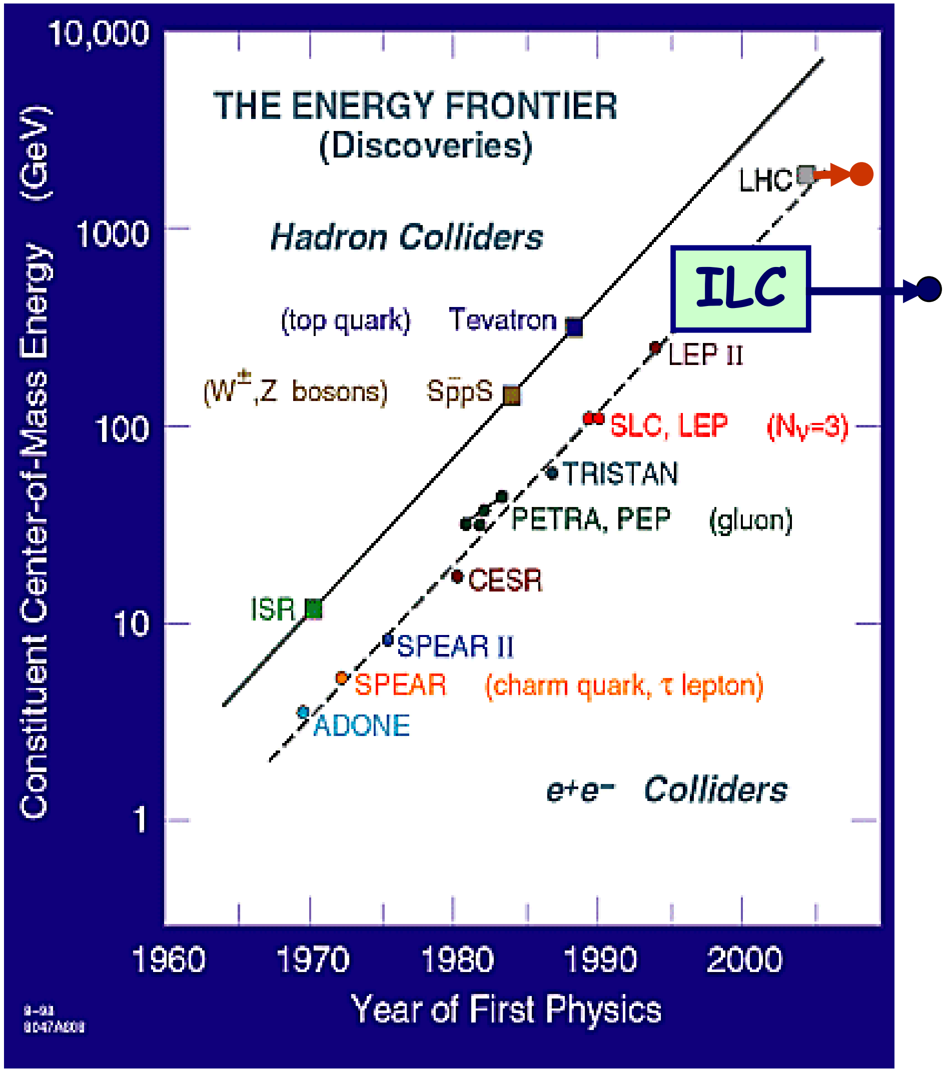
On leave from University of Milano

Energy Frontier and e^+e^- Colliders



LEP at CERN

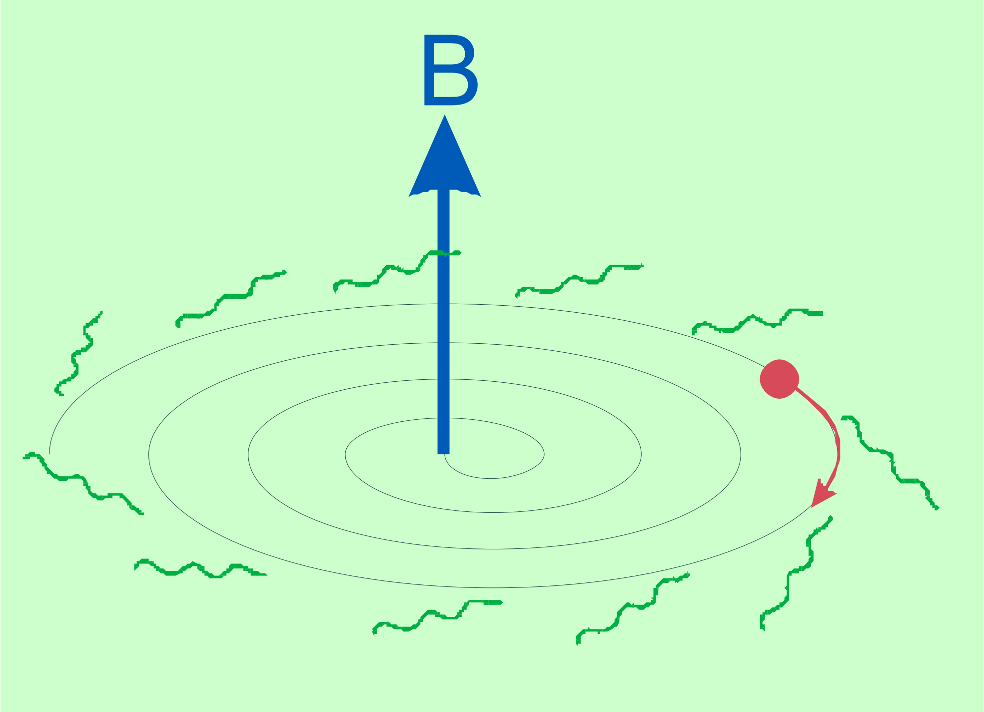
E_{cm} ~ 200 GeV

P_{RF} ~ 30 MW

Why a Linear Collider?

Synchrotron Radiation

From an electron in a magnetic field:



Energy loss must be replaced by RF system

cost scaling $ $\propto E_{cm}^2$

A Simple Exercise

- Synchrotron Radiation (SR) becomes prohibitive for electrons in a circular machine above LEP energies:

$$U_{SR}[\mathrm{GeV}] = 6 \cdot 10^{-21} \cdot \gamma^4 \cdot {}^{1}\!/_{r[\mathrm{km}]}$$

U_{SR} = energy loss per turn
γ = relativistic factor
r = machine radius

- RF system must replace this loss, and r scale as E^2
- LEP @ 100 GeV/beam: 27 km around, 2 GeV/turn lost
- Possible scale to 250 GeV/beam i.e. **E_{cm} = 500 GeV**:
  - **170 km** around
  - **13 GeV/turn** lost

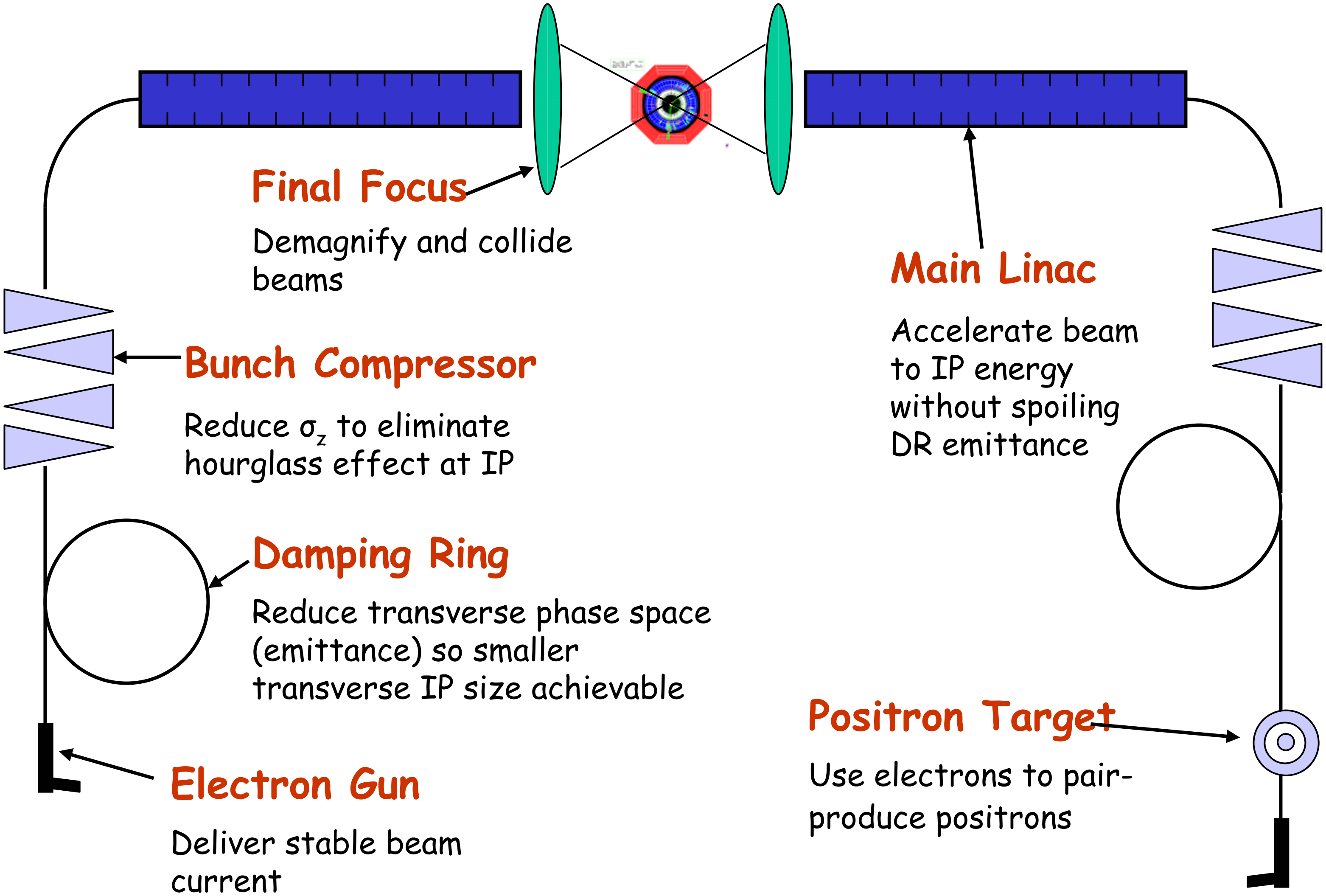
$\gamma_{250GeV} = 4.9 \cdot 10^5$

- Consider also the luminosity
  - For a **luminosity of ~ 10^{34}/cm²/second**, scaling from b-factories gives ~ 1 Ampere of beam current
  - 13 GeV/turn x 2 amperes = **26 GW RF power**
  - Because of conversion efficiency, this collider would consume more power than the state of **California in summer: ~ 45 GW**

Circulating beam power = 500 GW

- Both size and power seem excessive

LC conceptual scheme



Final Focus

Demagnify and collide beams

Main Linac

Accelerate beam to IP energy without spoiling DR emittance

Bunch Compressor

Reduce σ_z to eliminate hourglass effect at IP

Damping Ring

Reduce transverse phase space (emittance) so smaller transverse IP size achievable

Positron Target

Use electrons to pair-produce positrons

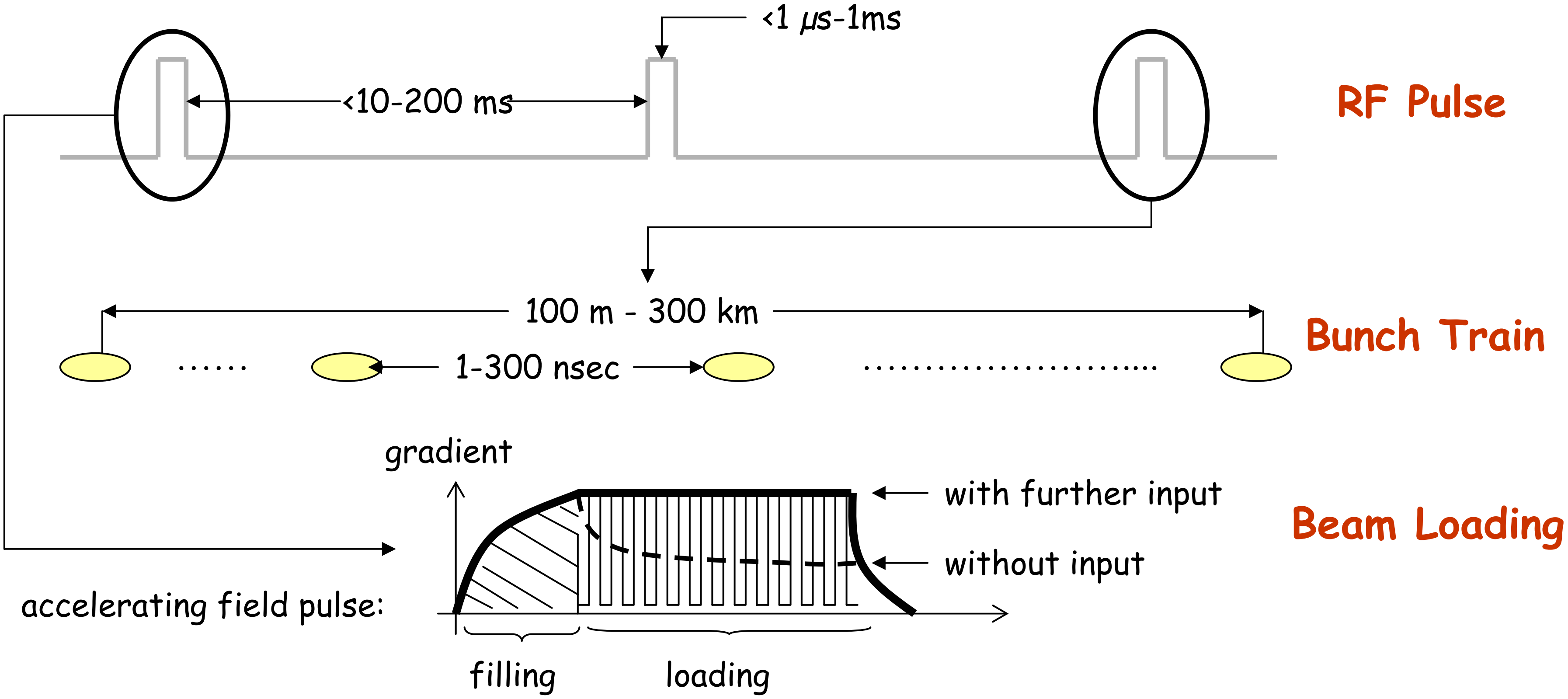
Electron Gun

Deliver stable beam current

Linear Colliders are pulsed

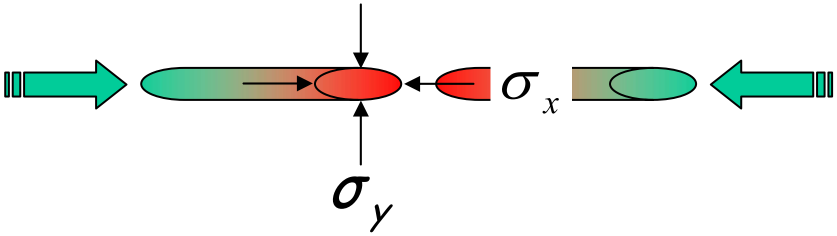
LCs are pulsed machines to improve efficiency. As a result:

- duty factors are small
- pulse peak powers can be very large



Fighting for Luminosity

$$L \propto \frac{N_e^2}{\sigma_x \sigma_y}$$



$$L \propto n_b \times f_{rep}$$

L = Luminosity
N_e = # of electron per bunch
$\sigma_{x,y}$ = beam sizes at IP
IP = interaction point

$$L \propto \frac{P_b}{E_{c.m.}} \times \frac{N_e}{\sigma_x \sigma_y}$$

n_b = # of bunches per pulse
f_{rep} = pulse repetition rate
P_b = beam power
$E_{c.m.}$ = center of mass energy

Parameters to play with

↓ Reduce **beam emittance** ($\varepsilon_x \cdot \varepsilon_y$) for smaller beam size ($\sigma_x \cdot \sigma_y$)
↑ Increase bunch population (N_e)
↑ Increase beam power $\left(P_b \propto N_e \times n_b \times f_{rep}\right)$
↑ Increase **beam to-plug power efficiency** for cost

ILC-TRC (Greg Loew Panel)

International LC Technical Review Committee

- International Collaboration for R&D toward TeV-Scale e^+e^- LC asked for first ILC-TRC in June 1994
- ILC-TRC produced first report end of 1995
- 2001: ICFA requests that ILC-TRC reconvene to produce a second report with the following charge:
  - To assess the present technology status of the four LC designs at hand, and their potential for meeting the advertised parameters at 500 GeV c.m.
  - Use common criteria, definitions, computer codes, etc., for the assessments
  - To assess the potential of each design for reaching higher energies above 500 GeV c.m.
  - To establish, for each design, the R&D work that remains to be done in the next few years
  - To suggest future areas of collaboration
- ILC-TRC produced second report January 2003

http://www.slac.stanford.edu/xorg/ilc-trc/2002/2002/report/03rep.htm

LC status at first ILC-TRC

End 1995 E_{cm}= 500 GeV

	TESLA	SBLC	JLC-S	JLC-C	JLC-X	NLC	VLEPP	CLIC
f [GHz]	1.3	3.0	2.8	5.7	11.4	11.4	14.0	30.0
$\mathcal{L}\times 10^{33}$ [$cm^{-2}s^{-1}$]	6	4	4	9	5	7	9	1-5
P_{beam} [MW]	16.5	7.3	1.3	4.3	3.2	4.2	2.4	1-4
P_{AC} [MW]	164	139	118	209	114	103	57	100
$\gamma\varepsilon_y$ [$\times 10^{-8}$m]	100	50	4.8	4.8	4.8	5	7.5	15
σ_y^* [nm]	64	28	3	3	3	3.2	4	7.4

Tasks to be addressed

Baseline cm Energy stays at 500 GeV

- Push Luminosity to the maximum value
- Technology:
  - Demonstrate that the proposed technology can be pushed to the limits required for a Linear Collider
  - Demonstrate that the proposed technology can be produced in large scale by industry with high reliability and reasonable cost
  - Find solution for all critical items
- Design issues:
  - Demonstrate that very small spot sizes ($\sigma_x \cdot \sigma_y < 1\ \mu m^2$) are possible
  - Investigate all beam physics critical issues
  - Support all design features with cross-checked simulations
  - Address reliability and availability issues
- Roadmap for energy upgrade
- Test Facilities

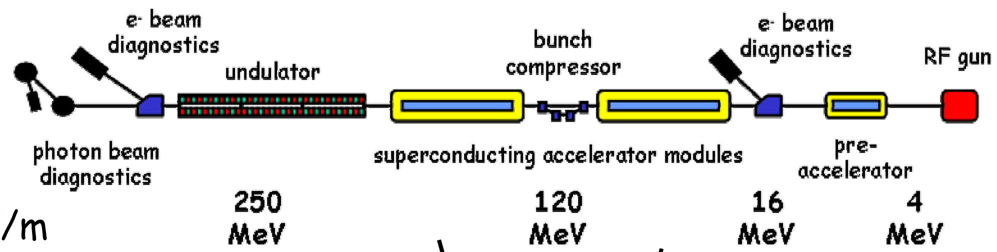
TTF for TESLA

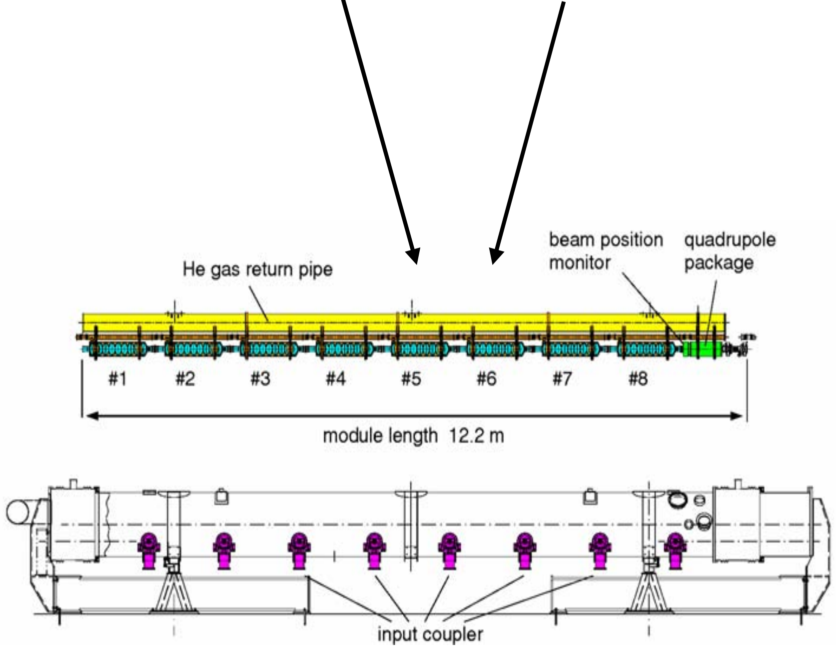
TTF = TESLA Test Facility

TTF Goals:

- Demonstrate that Superconducting RF technology is suitable for LC
- Operate TTF at $E_{acc} > 15$ MV/m
- Develop cavity technology for Eacc > 25 MV/m

TTF as operated for SASE FEL



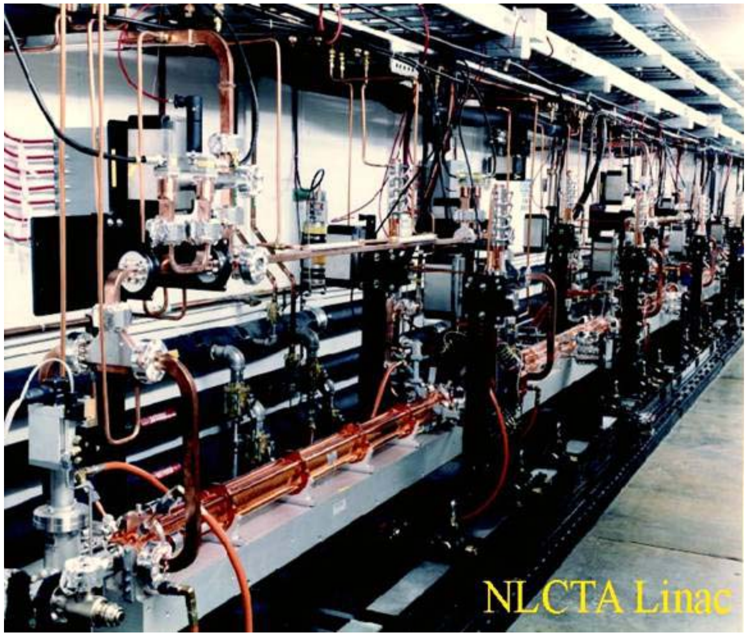


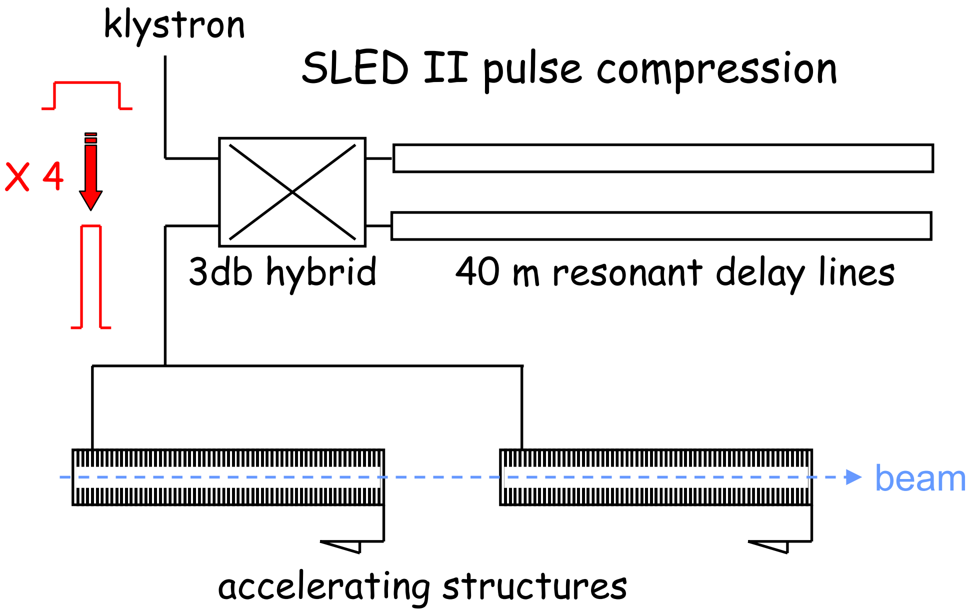
NLCTA for NLC

NLCTA = NLC Test Accelerator

NLCTA Goals:

- RF system integration test of a NLC linac section
- Test efficient, stable and uniform acceleration of a NLC-like bunch train





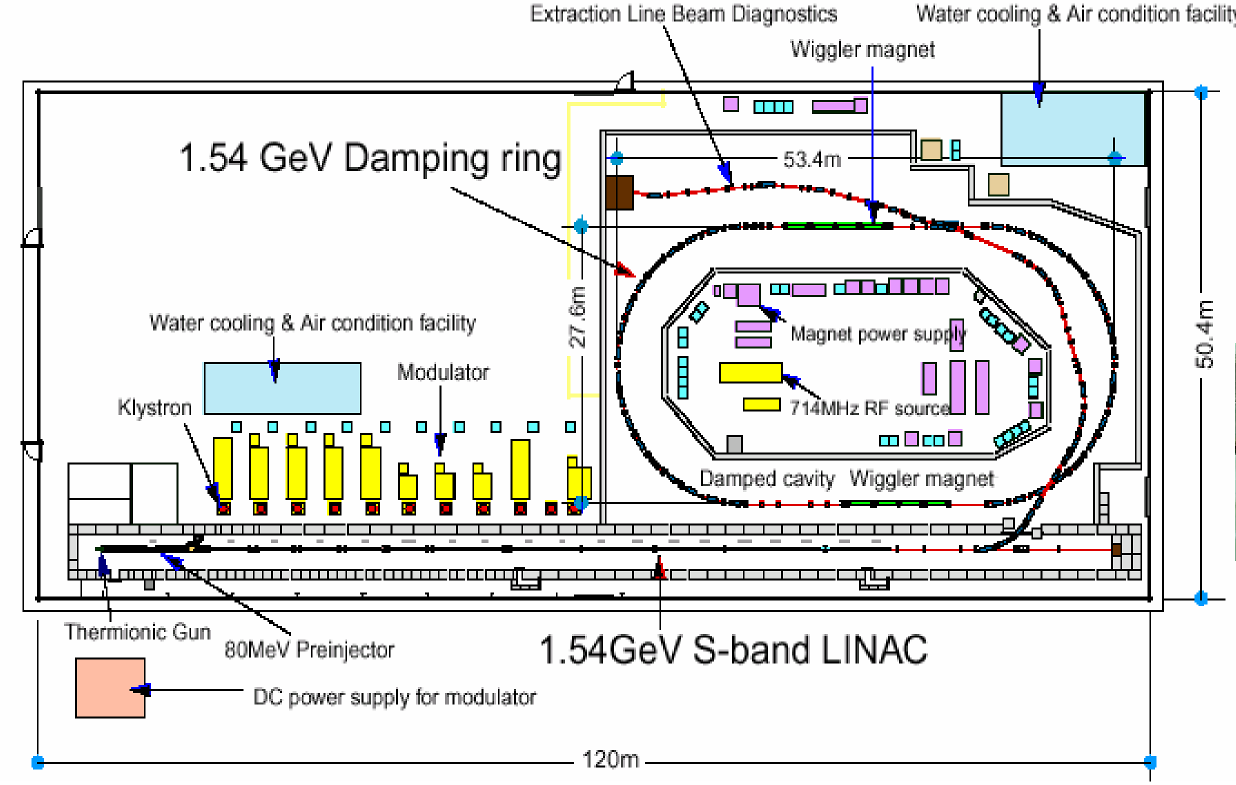
ATF for JLC

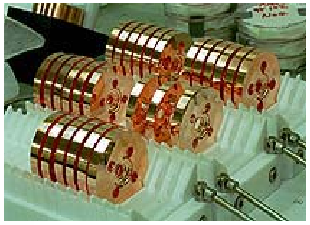
ATF = Accelerator Test Facility

ATF Goals:

- Demonstrate very low beam emittance
- Develop RF technology

Damping ring





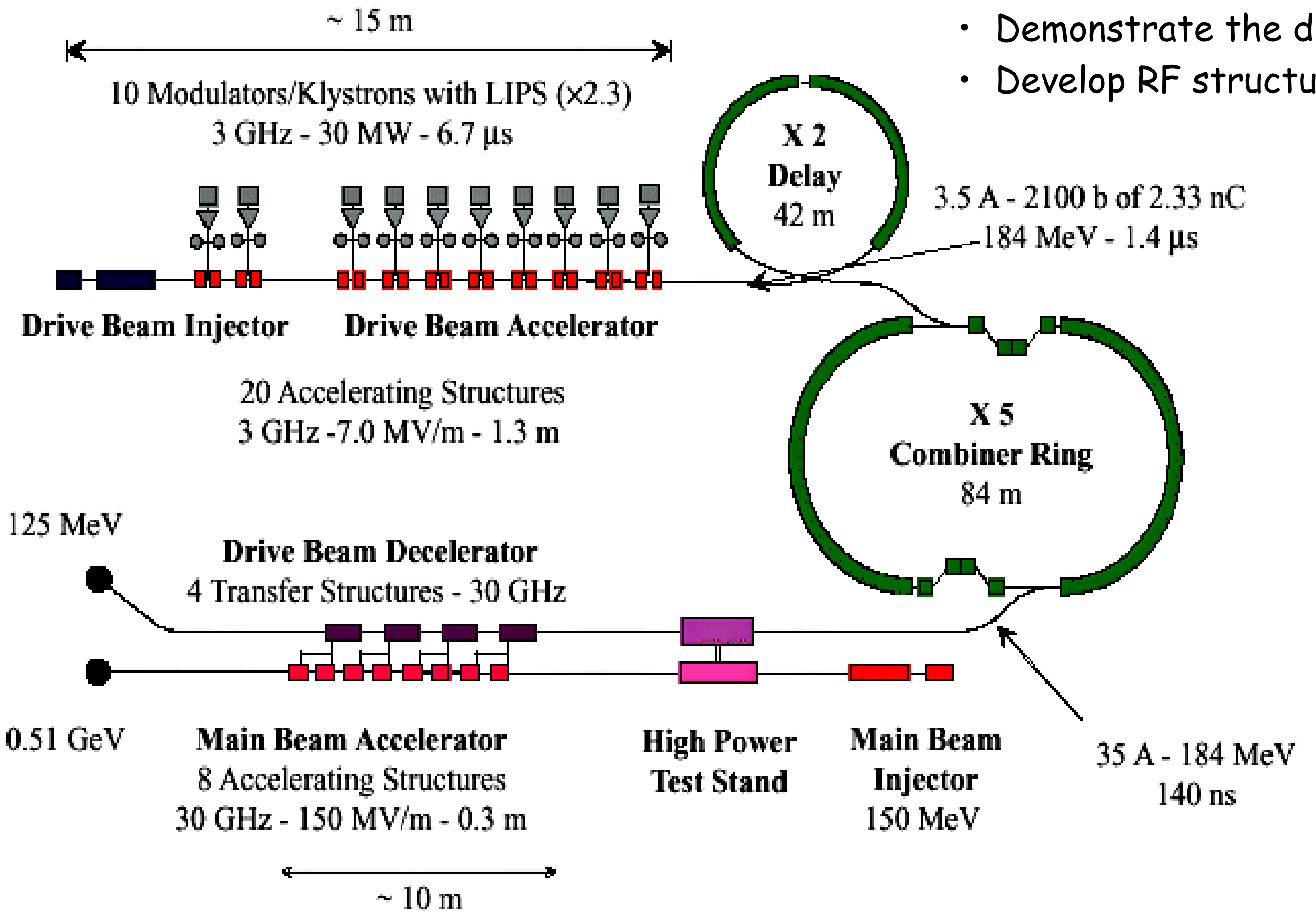
Cavity Production

CTF for CLIC

CTF3 = CLIC Test Facility #3 (Under construction after CTF1 and CTF2)

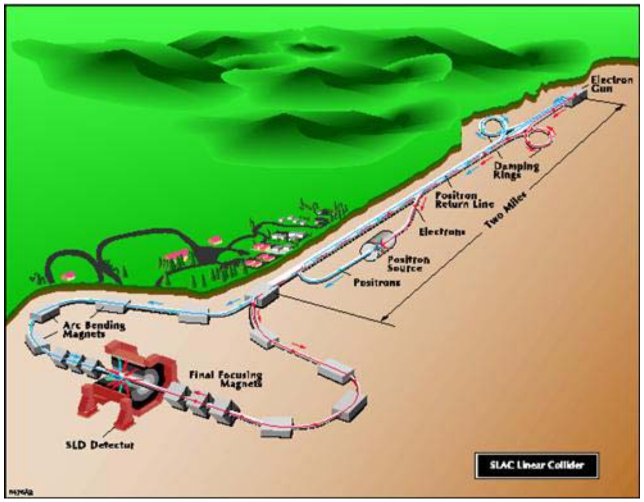
CTF3 Goals:

- Demonstrate the drive beam scheme
- Develop RF structures and technology



Lessons from the SLC

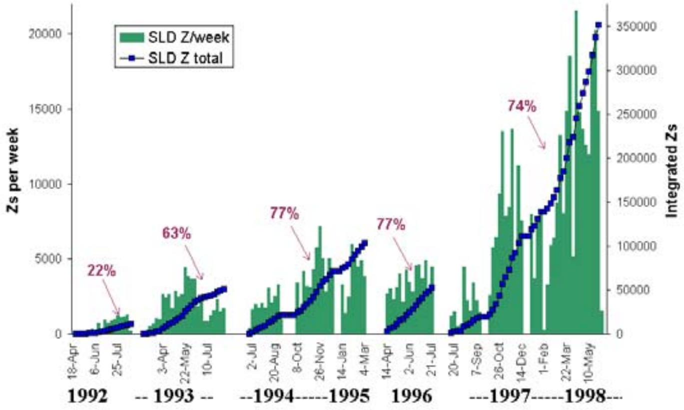
SLC = SLAC Linear Collider



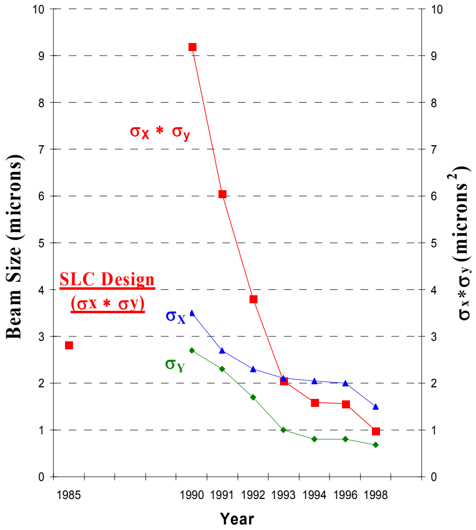
New Territory in Accelerator Design and Operation

- Sophisticated on-line modeling of non-linear beam physics.
- Correction techniques (trajectory and emittance), from hands-on by operators to fully automated control.
- Slow/fast feedback theory and practice.

1992 - 1998 SLD Luminosity



IP Beam Size vs Time



LC status at second ILC-TRC

January 2003 E_{cm}= 500 GeV

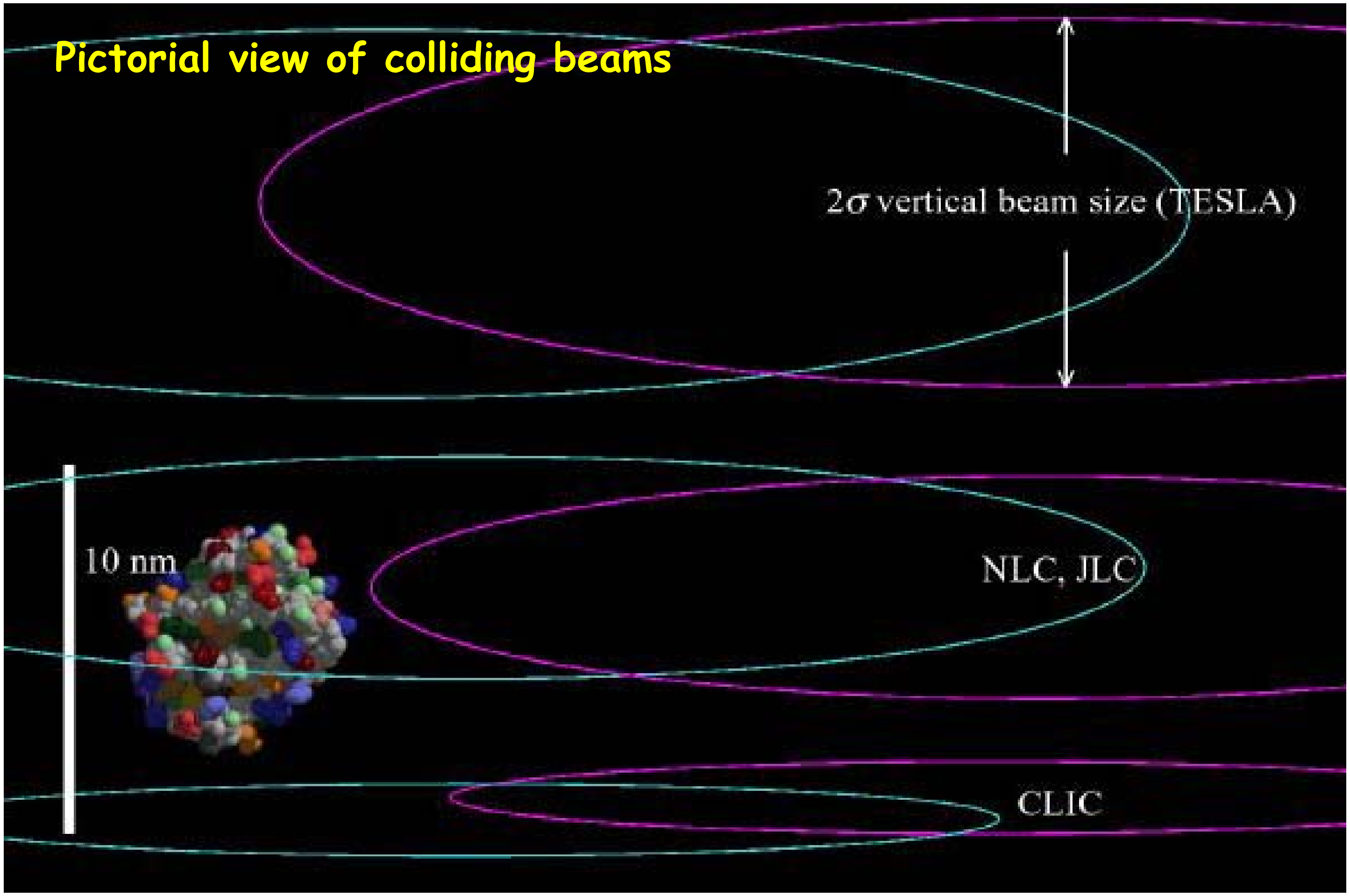
	TESLA	SBLC	JLC-S	JLC-C	JLC-X/NLC	VLEPP	CLIC
f [GHz]	1.3			5.7	11.4		30.0
$\mathcal{L}\times10^{33}$ [$cm^{-2}s^{-1}$]	34			14	20		21
P_{beam} [MW]	11.3			5.8	6.9		4.9
P_{AC} [MW]	140			233	195		175
$\gamma\varepsilon_y$ [$\times10^{-8}$m]	3			4	4		1
σ_y^* [nm]	5			4	3		1.2

Second to first ILC-TRC Comparison

2003 vs. 1995 E_{cm} = 500 GeV

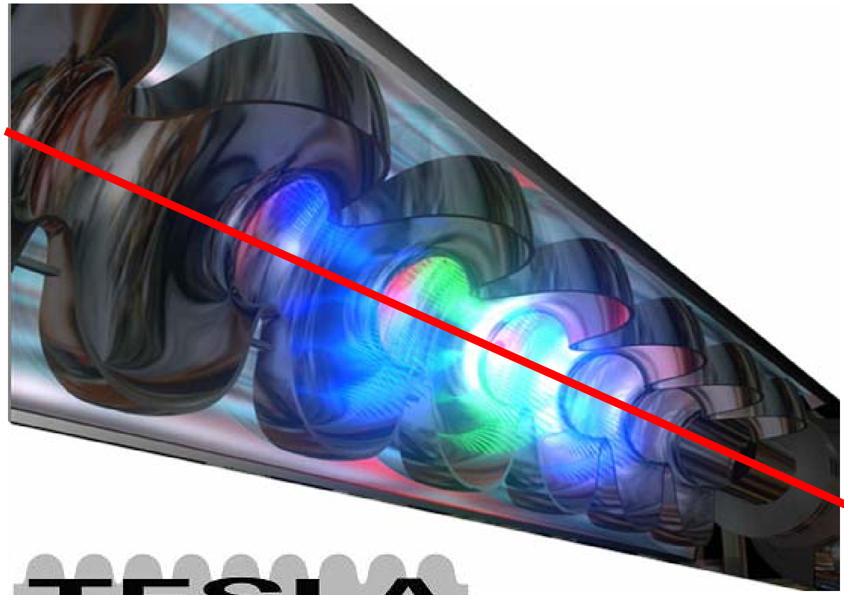
	TESLA 2003	TESLA 1994	JLC/NLC 2003	<JLC/NLC> 1994	CLIC 2003	CLIC 1994
f [GHz]	1.3	1.3	11.4	11.4	30.0	30.0
$\mathcal{L} \times 10^{33}$ [$cm^{-2}s^{-1}$]	34	6	20	6	21	1-5
P_{beam} [MW]	11.3	16.5	6.9	3.7	4.9	1-4
P_{AC} [MW]	140	164	195	110	175	100
$\gamma\varepsilon_y$ [$\times 10^{-8}$m]	3	100	4	5	1	15
σ_y^* [nm]	5	64	3	3	1.2	7.5

That's what we have to do…



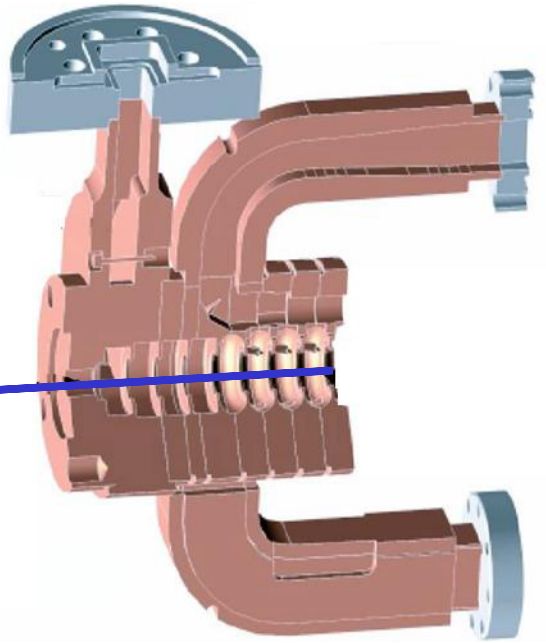
From Hasan Padamsee

Competing technologies



TESLA

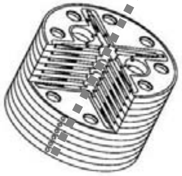
1.3 GHz - Cold



NLC

JLC

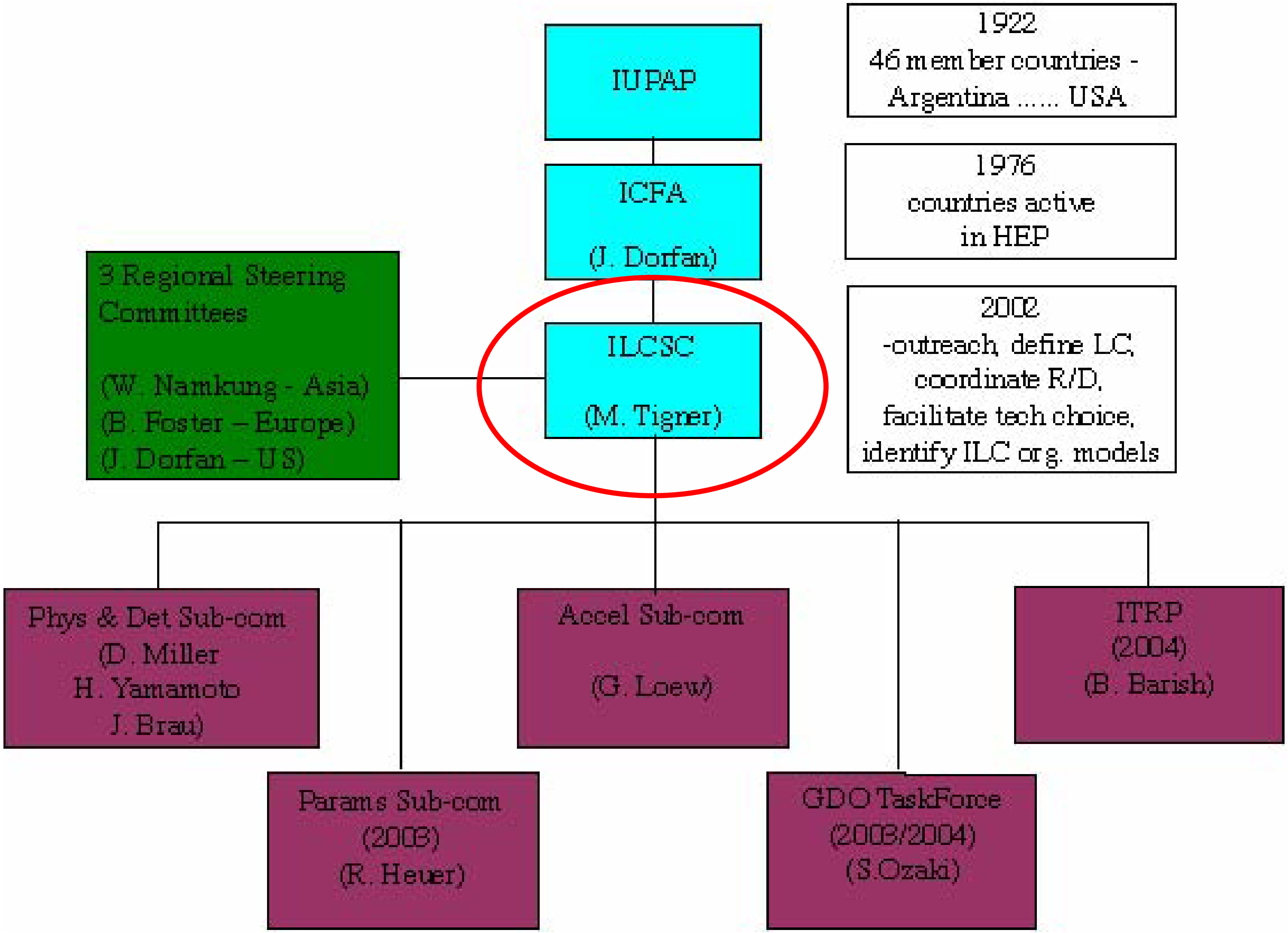
11.4 GHz - Warm



CLIC

30 GHz-Warm

LC Organisation up to August 2004



IUPAP

1922
46 member countries -
Argentina …… USA

ICFA
(J. Dorfan)

1976
countries active
in HEP

3 Regional Steering
Committees

(W. Namkung - Asia)
(B. Foster – Europe)
(J. Dorfan – US)

ILCSC
(M. Tigner)

2002
-outreach, define LC,
coordinate R/D,
facilitate tech choice,
identify ILC org. models

Phys & Det Sub-com
(D. Miller
H. Yamamoto
J. Brau)

Accel Sub-com
(G. Loew)

ITRP
(2004)
(B. Barish)

Params Sub-com
(2003)
(R. Heuer)

GDO TaskForce
(2003/2004)
(S.Ozaki)

ILCSC as in 2002

International Linear Collider Steerng Committee

Membership of the ILCSC in 2002

H. Chen (IHEP, Beijing)
J. Dorfan (SLAC)
B. Foster (Bristol, UK)
C. Garcia Canal (La Plata, Argentina)
P. Grannis (Stony Brook, US)
S. Komamiya (Tokyo)
L. Maiani (CERN)
D. Miller (UCL, UK)
W. Namkung (POSTECH, Korea)
A. Skrinsky (BINP)
H. Sugawara (KEK)
M. Tigner (Cornell) – Chair
Y. Totsuka (Tokyo)
A. Wagner (DESY)
M. Witherell (Fermilab)

First proposed on Feb. 2002 (J. Dorfan), very active since Aug. 2002

Extract from the mandate of the ILCSC

- Engage in outreach, explaining the intrinsic scientific and technological importance of the project.
- Based upon the extensive work already done in Asia, Europe and N. America, engage in defining the scientific roadmap, the scope and primary parameters for machine and detector.
- Monitor the machine R&D activities and make recommendations on the coordination and sharing of R&D tasks as appropriate.
- Identify models of the organizational structure, based on international partnerships, adequate for constructing the LC facility.
- Carry out such other tasks as may be approved or directed by ICFA.

Technology Choice: NLC/JLC or TESLA

The International Linear Collider Steering Committee (ILCSC) selected the twelve members of the International Technology Recommendation Panel (**ITRP**) at the end of 2003:

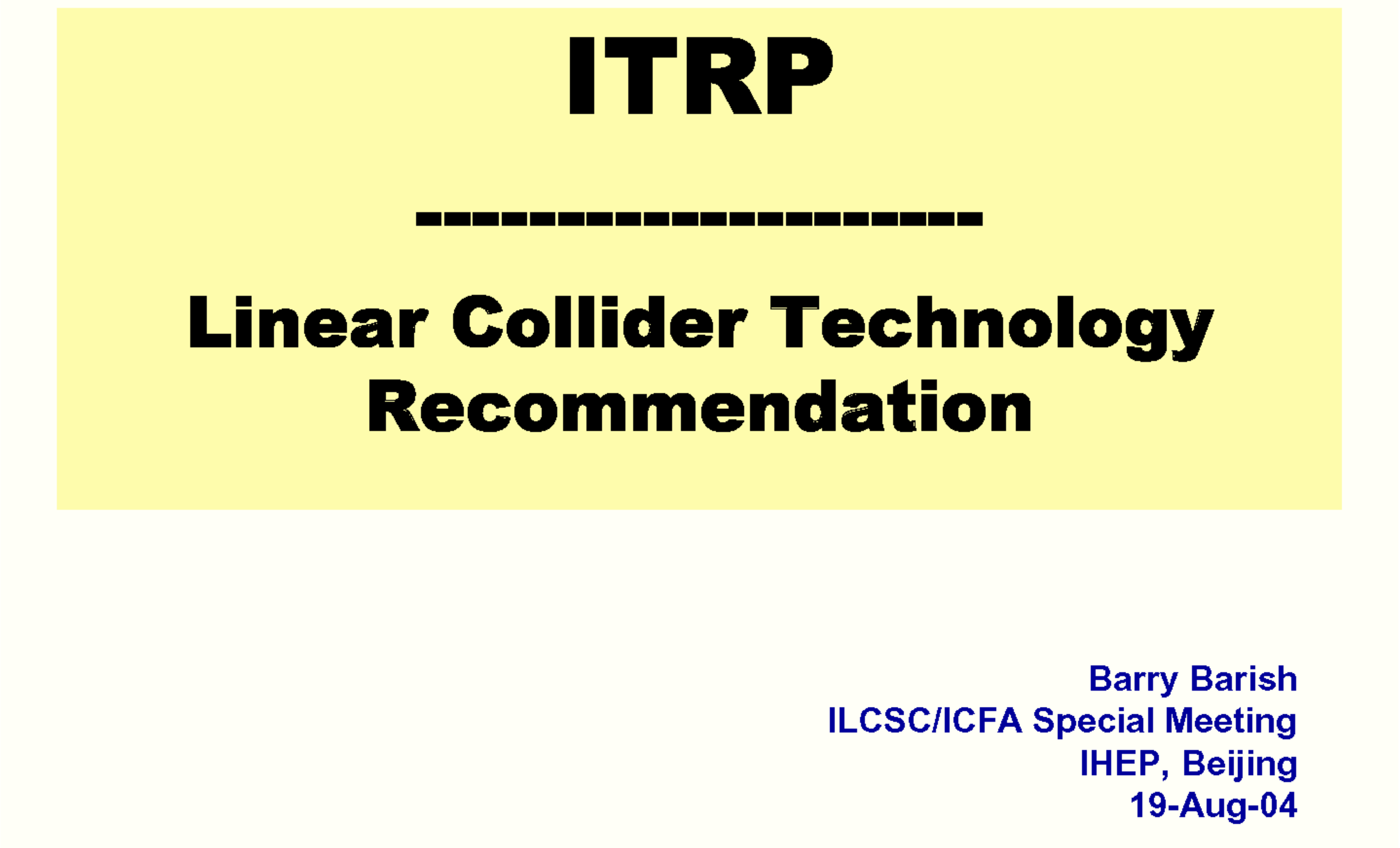
Asia:	**Europe:**	**North America:**
G.S. Lee	J-E Augustin	J. Bagger
A. Masaike	G. Bellettini	**B. Barish (Chair)**
K. Oide	G. Kalmus	P. Grannis
H. Sugawara	V. Soergel	N. Holtkamp

First meeting end of January 2004 at RAL

Mission: one technology by end 2004

Result: recommendation on 19 August 2004

From the ILC Birthday



ITRP

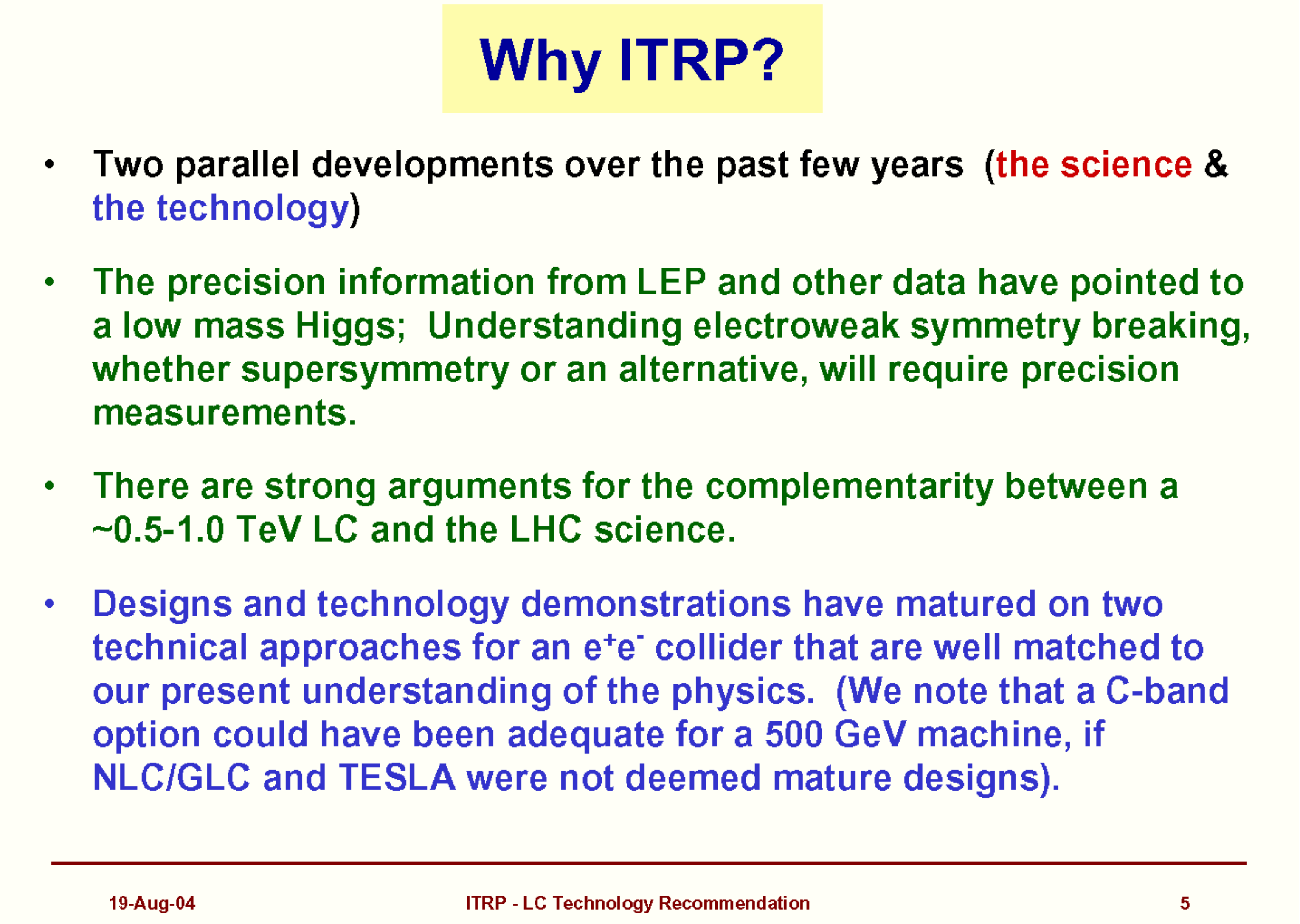
Linear Collider Technology Recommendation

Barry Barish
ILCSC/ICFA Special Meeting
IHEP, Beijing
19-Aug-04

From the ILC Birthday

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

From the ILC Birthday

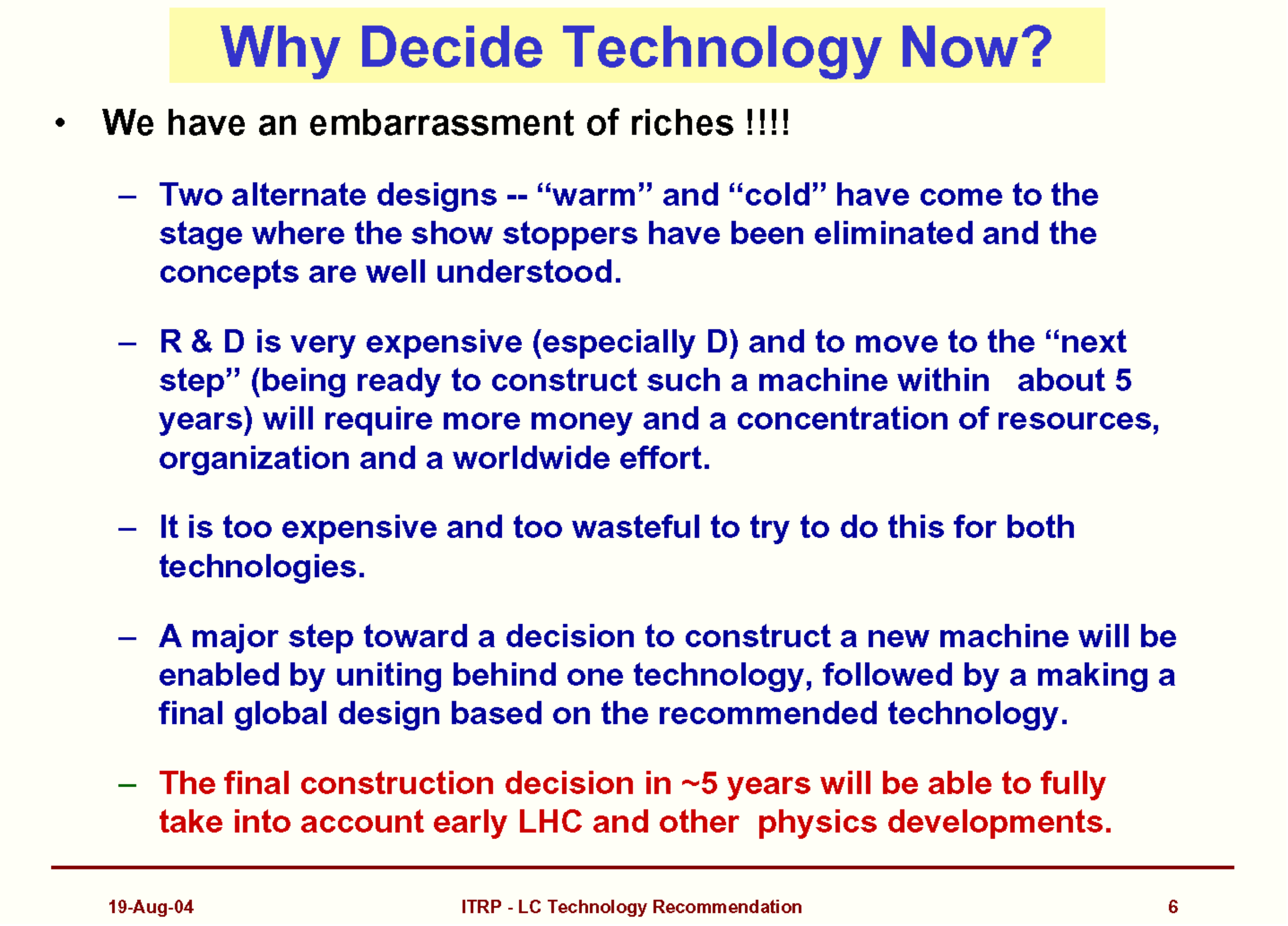


Why ITRP?

- 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).

19-Aug-04 ITRP - LC Technology Recommendation 5

From the ILC Birthday

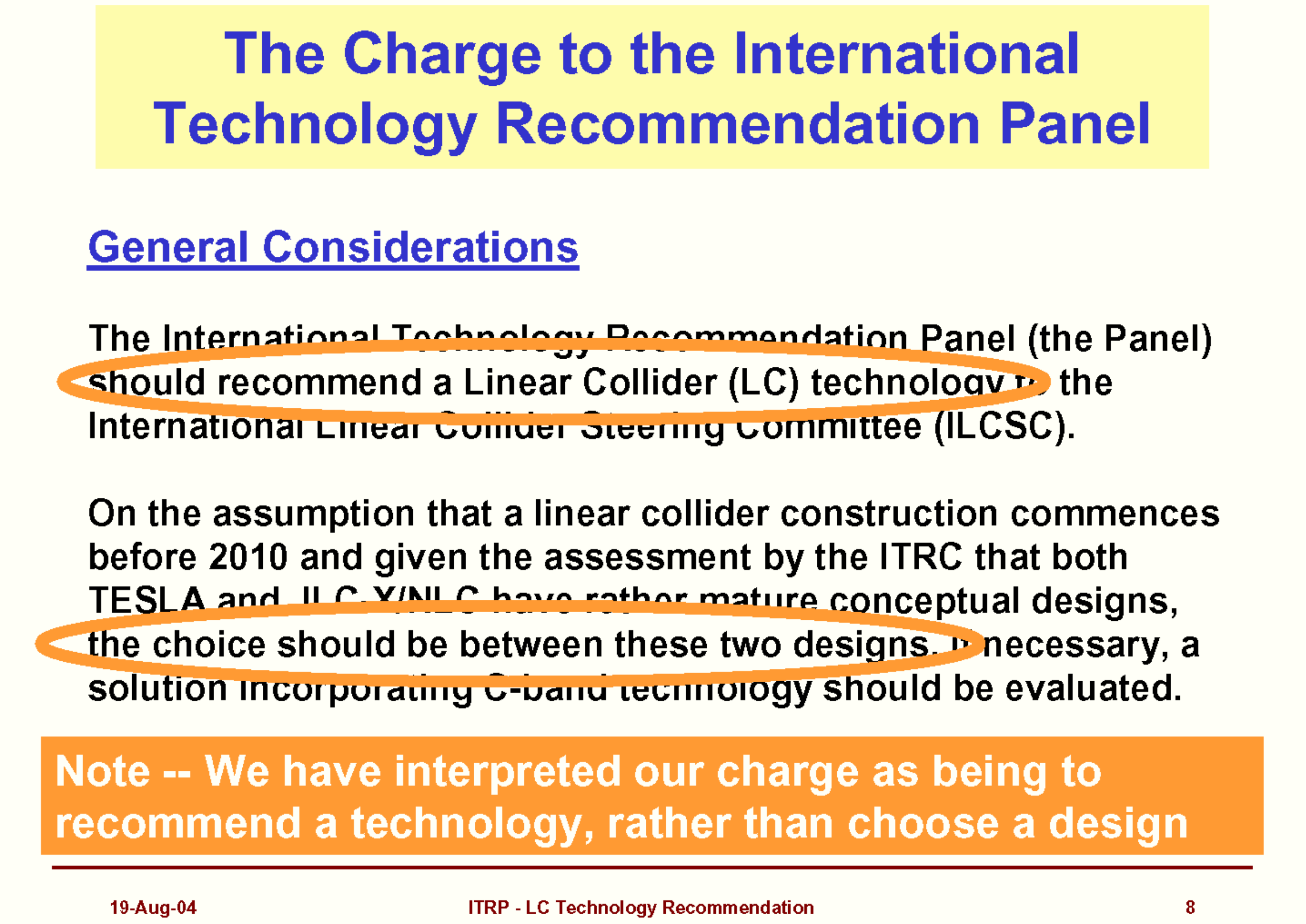


Why Decide Technology Now?

- We have an embarrassment of riches !!!!
  - Two alternate designs -- “warm” and “cold” have come to the stage where the show stoppers have been eliminated and the concepts are well understood.
  - R & D is very expensive (especially D) and to move to the “next step” (being ready to construct such a machine within about 5 years) will require more money and a concentration of resources, organization and a worldwide effort.
  - It is too expensive and too wasteful to try to do this for both technologies.
  - A major step toward a decision to construct a new machine will be enabled by uniting behind one technology, followed by a making a final global design based on the recommended technology.
  - The final construction decision in ~5 years will be able to fully take into account early LHC and other physics developments.

19-Aug-04 ITRP - LC Technology Recommendation 6

From the ILC Birthday



The Charge to the International Technology Recommendation Panel

General Considerations

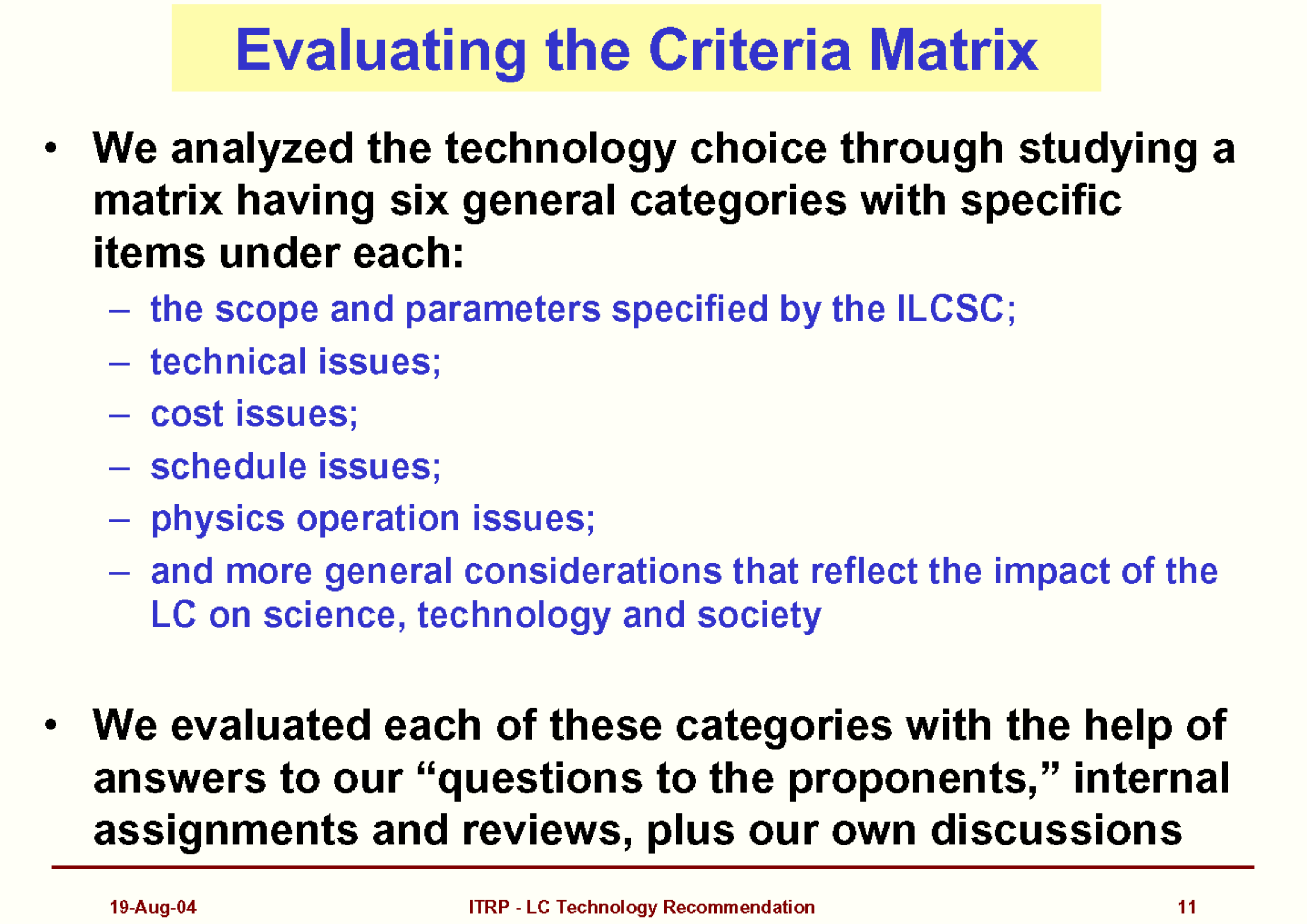
The International Technology Recommendation Panel (the Panel) should recommend a Linear Collider (LC) technology to the International Linear Collider Steering Committee (ILCSC).

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

19-Aug-04 ITRP - LC Technology Recommendation 8

From the ILC Birthday

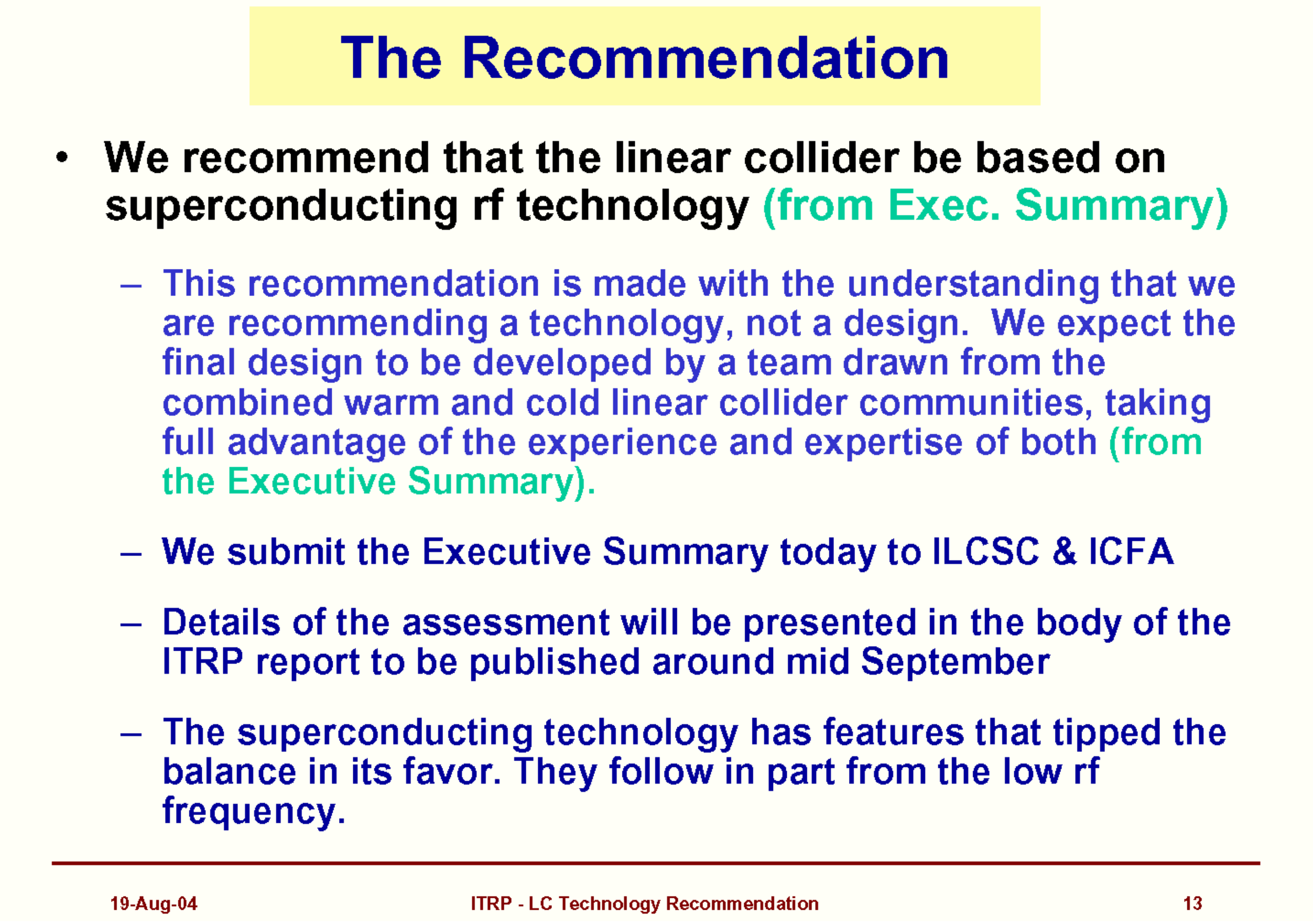


Evaluating the Criteria Matrix

- 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

19-Aug-04 ITRP - LC Technology Recommendation 11

From the ILC Birthday

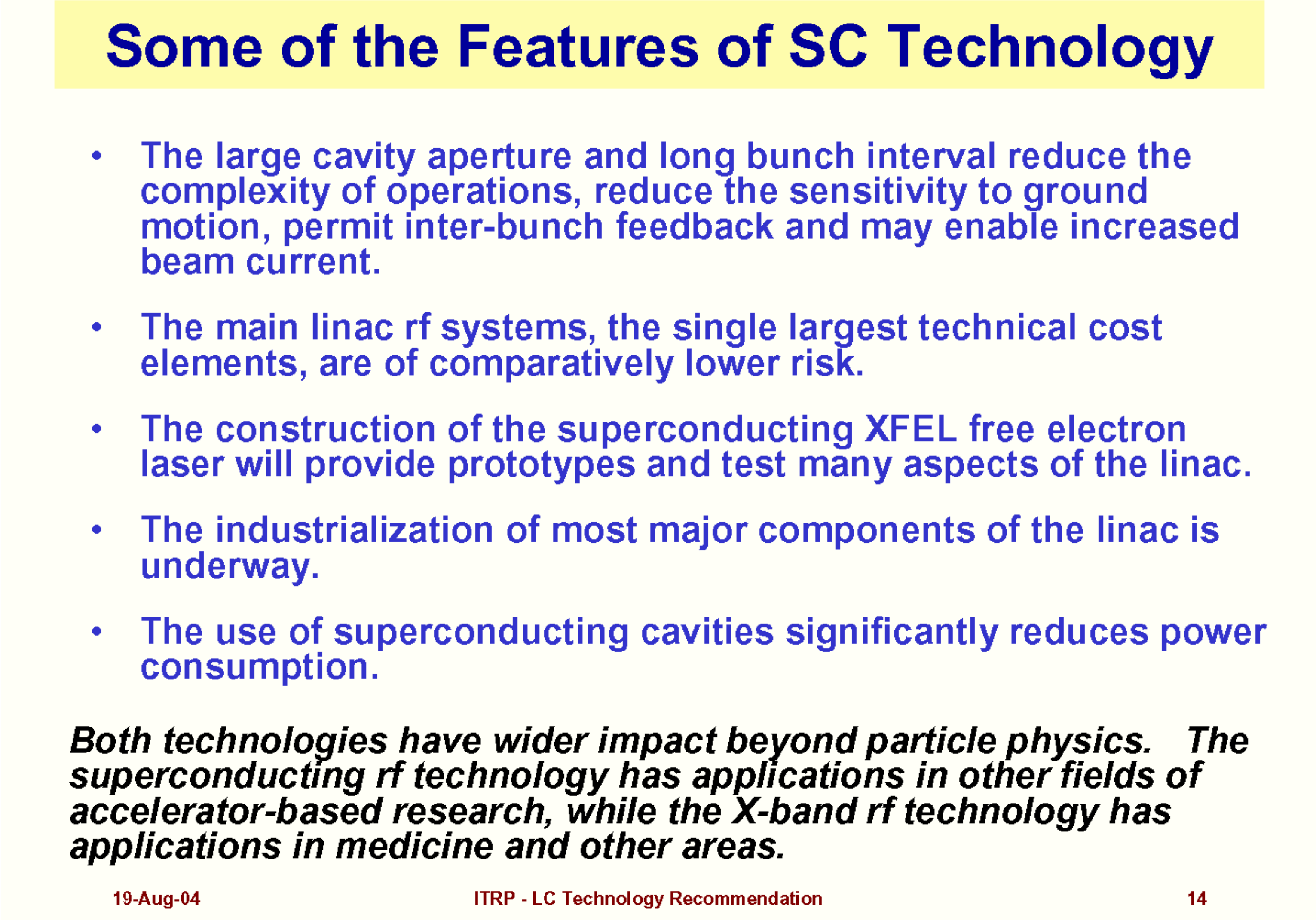


The Recommendation

- **We recommend that the linear collider be based on superconducting rf technology** (from Exec. Summary)
  - 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).
  - We submit the Executive Summary today to ILCSC & ICFA
  - Details of the assessment will be presented in the body of the ITRP report to be published around mid September
  - The superconducting technology has features that tipped the balance in its favor. They follow in part from the low rf frequency.

19-Aug-04 ITRP - LC Technology Recommendation 13

From the ILC Birthday



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.
- 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.

Both technologies have wider impact beyond particle physics. The superconducting rf technology has applications in other fields of accelerator-based research, while the X-band rf technology has applications in medicine and other areas.

19-Aug-04 ITRP - LC Technology Recommendation 14

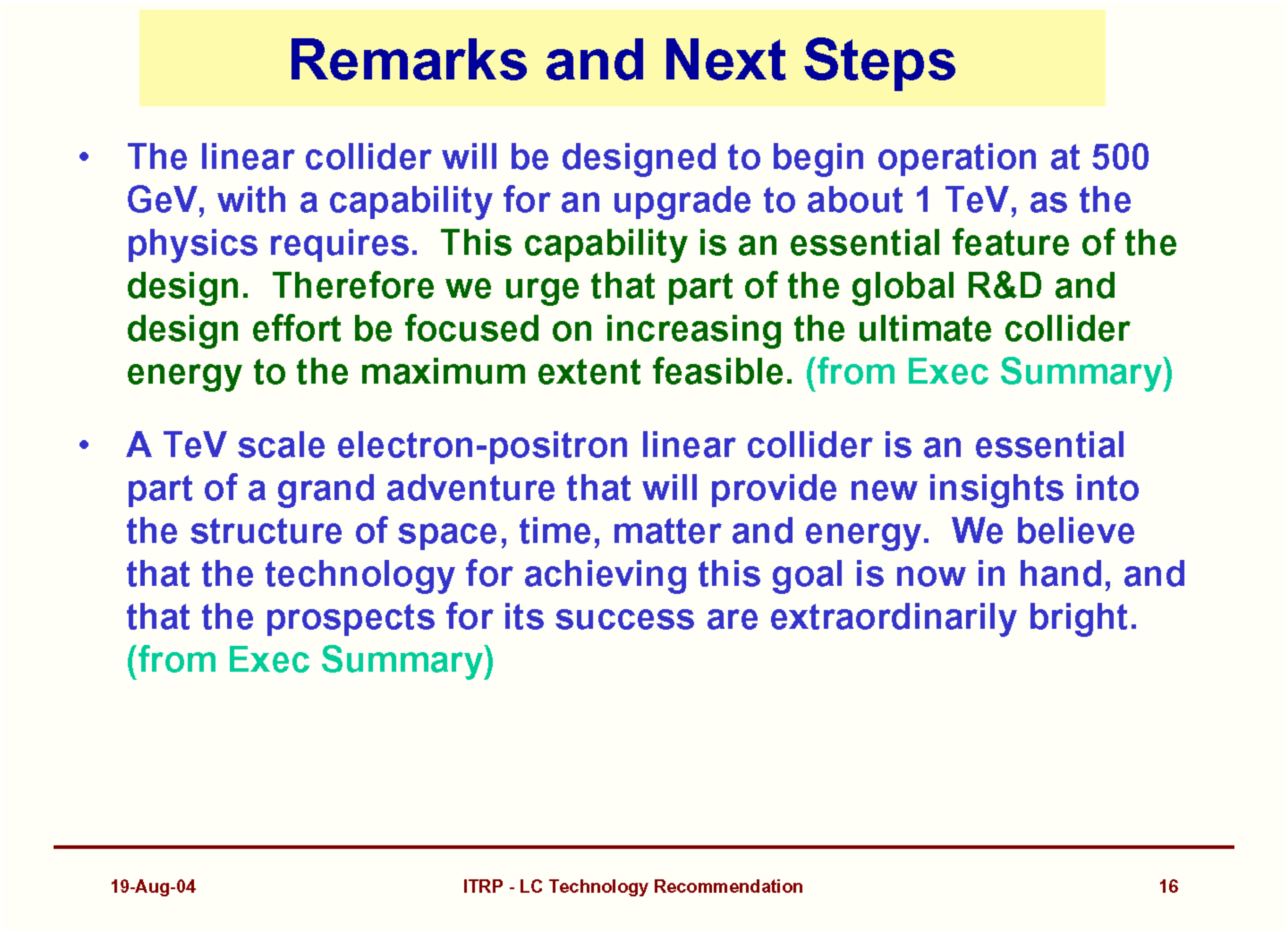
From the ILC Birthday

Remarks and Next Steps

- CLIC, C-Band, GLC/NLC and TESLA researchers have done a fantastic job bringing these technologies to the point where we can move forward toward making a next generation linear collider a reality.
- We especially want to note the importance of the the work that has been done on the warm technology. 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.
- We endorse the effort now underway to establish an international model for the design, engineering, industrialization and construction of the linear collider. Formulating that model in consultation with governments is an immediate priority. Strong central management will be critical from the beginning.

19-Aug-04 ITRP - LC Technology Recommendation 15

From the ILC Birthday



Remarks and Next Steps

- The linear collider will be designed to begin operation at 500 GeV, with a capability for an upgrade to about 1 TeV, as the physics requires. This capability is an essential feature of the design. Therefore we urge that part of the global R&D and design effort be focused on increasing the ultimate collider energy to the maximum extent feasible. (from Exec Summary)
- A TeV scale electron-positron linear collider is an essential part of a grand adventure that will provide new insights into the structure of space, time, matter and energy. We believe that the technology for achieving this goal is now in hand, and that the prospects for its success are extraordinarily bright. (from Exec Summary)

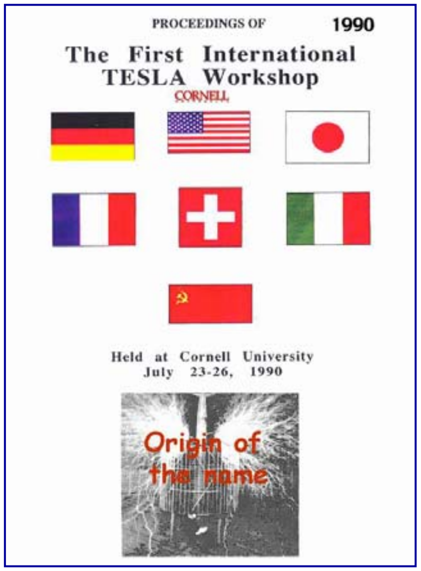
19-Aug-04 ITRP - LC Technology Recommendation 16

From the Day After

- Robert Aymar (CERN): “A linear collider is the logical next step to complement the discoveries that will be made at the LHC. The technology choice is an important step in the path towards an efficient development of the international TeV linear collider design, in which CERN will participate.”
- Yoji Totsuka (KEK): “This decision is a significant step to bring the linear collider project forward. The Japanese high-energy community welcomes the decision and looks forward to participating in the truly global project.”
- Jonathan Dorfan (SLAC): “Scientific discovery is the goal. Getting to the physics is the priority. The panel was presented with two viable technologies. We at SLAC embrace the decision and look forward to working with our international partners.”
- Similar Declarations from: Albrecht Wagner (DESY), Hesheng Chen (HEP), Michael Witherell (FNAL) et al.

From the ICFA press release, Beijing, 20 August 2005

The TESLA Collaboration

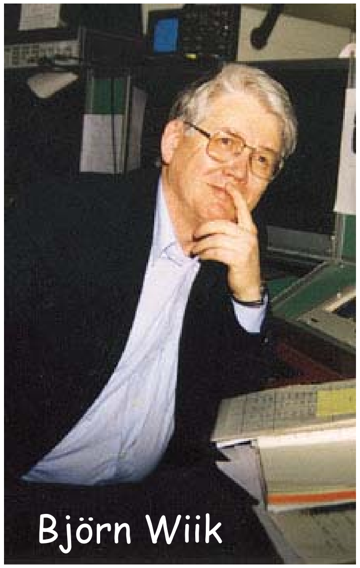


PROCEEDINGS OF 1990

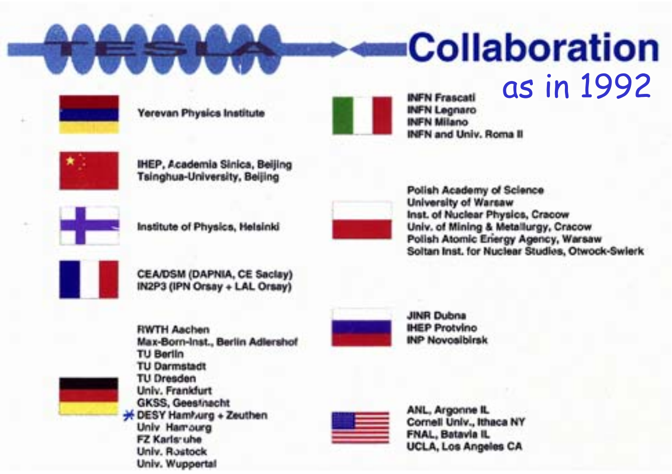
The First International
TESLA Workshop
CORNELL

Held at Cornell University
July 23-26, 1990

Origin of the name



Björn Wiik



TESLA Collaboration
as in 1992

Yerevan Physics Institute

IHEP, Academia Sinica, Beijing
Tsinghua-University, Beijing

Institute of Physics, Helsinki

CEA/DSM (DAPNIA, CE Saclay)
IN2P3 (IPN Orsay + LAL Orsay)

RWTH Aachen
Max-Born-Inst., Berlin Adlershof
TU Berlin
TU Darmstadt
TU Dresden
Univ. Frankfurt
GKSS, Geesthacht
* DESY Hamburg + Zeuthen
Univ Hamburg
FZ Karlsruhe
Univ. Rostock
Univ. Wuppertal

INFN Frascati
INFN Legnaro
INFN Milano
INFN and Univ. Roma II

Polish Academy of Science
University of Warsaw
Inst. of Nuclear Physics, Cracow
Univ. of Mining & Metallurgy, Cracow
Polish Atomic Energy Agency, Warsaw
Soltan Inst. for Nuclear Studies, Otwock-Swierk

JINR Dubna
IHEP Protvino
INP Novosibirsk

ANL, Argonne IL
Cornell Univ., Ithaca NY
FNAL, Batavia IL
UCLA, Los Angeles CA

Develop SRF for the future TeV Linear Collider

Basic goals

- **Increase gradient by a factor of 5** (Physical limit for Nb at ~ 50 MV/m)
- **Reduce cost per MV by a factor 20** (New cryomodule concept and Industrialization)
- **Make possible pulsed operation** (Combine SRF and mechanical engineering)

Major advantages vs NC Technology

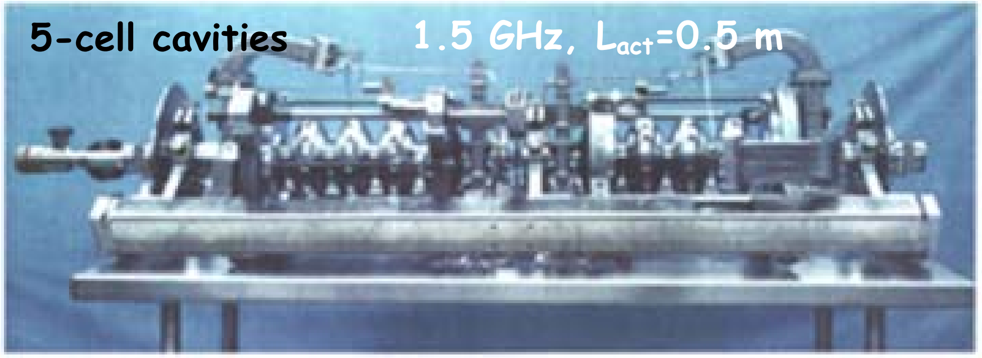
- **Higher conversion efficiency**: more beam power for less plug power consumption
- **Lower RF frequency**: relaxed tolerances and smaller emittance dilution

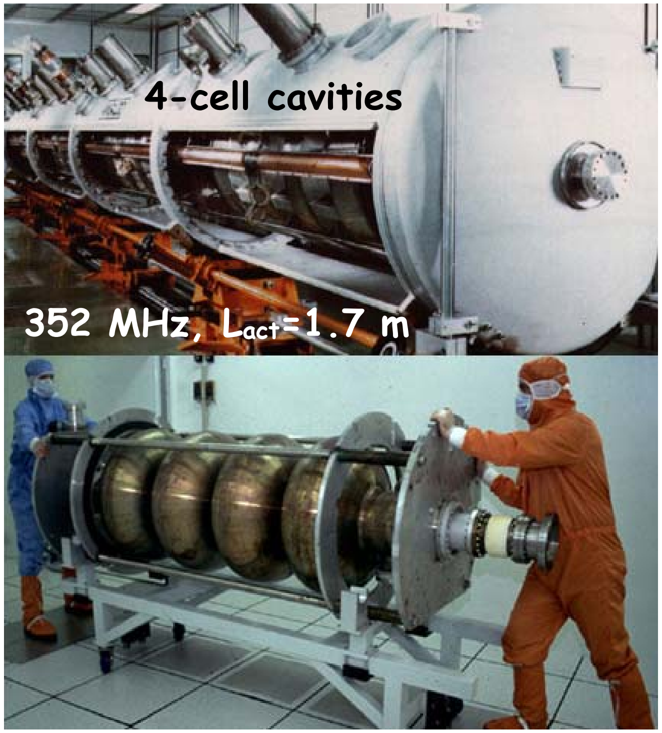
References for TESLA Technology

CEBAF at TJNAF

338 bulk niobium cavities

- Produced by industry
- Processed at TJNAF in a dedicated infrastructure





LEP II at CERN

32 bulk niobium cavities

- Limited to 5 MV/m
- Poor material and inclusions

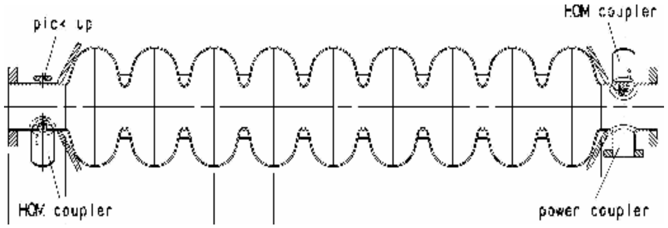
256 sputtered cavities

- Magnetron-sputtering of Nb on Cu
- Completely done by industry
- **Field improved with time**
  $\langle E_{acc} \rangle$ = 7.8 MV/m (Cryo-limited)

Optimized cavity design and rules

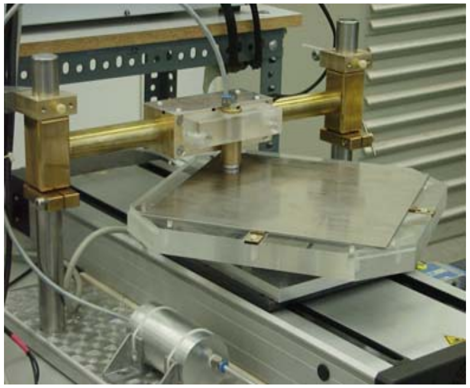
Major contributions from: CERN, Cornell, DESY, CEA-Saclay

- 9-cell, 1.3 GHz



TESLA cavity parameters

R/Q	1036	Ω
E_{peak}/E_{acc}	2.0	
B_{peak}/E_{acc}	4.26	mT/(MV/m)
Δf/Δl	315	kHz/mm
$K_{Lorentz}$	≈ -1	$Hz/(MV/m)^2$



Eddy-current scanning system for niobium sheets

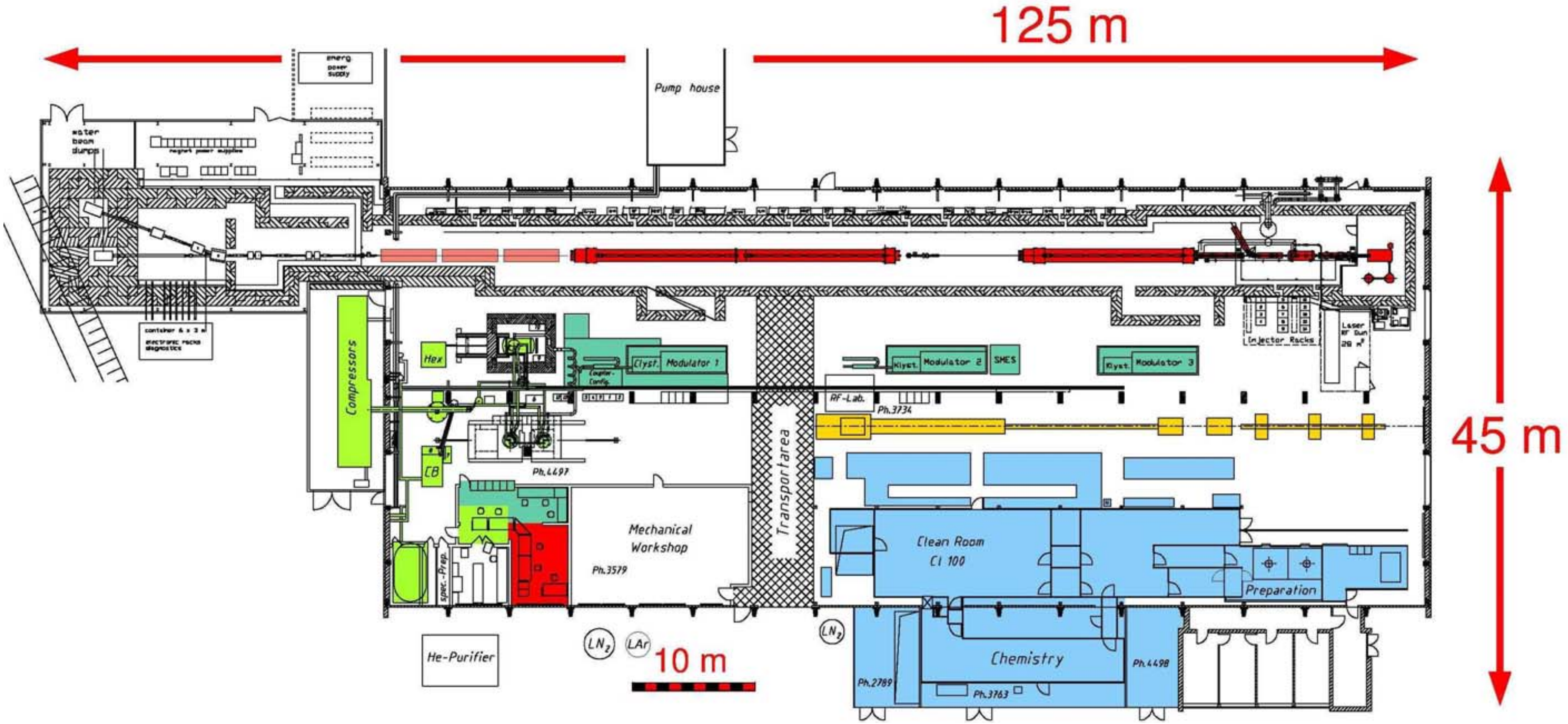
Cleanroom handling of niobium cavities

Preparation Sequence

- Niobium sheets (RRR=300) are scanned by eddy-currents to detect avoid foreign material inclusions like tantalum and iron
- Industrial production of full nine-cell cavities:
    - Deep-drawing of subunits (half-cells, etc.) from niobium sheets
    - Chemical preparation for welding, cleanroom preparation
    - Electron-beam welding according to detailed specification
- 800 °C high temperature heat treatment to stress anneal the Nb and to remove hydrogen from the Nb
- 1400 °C high temperature heat treatment with titanium getter layer to increase the thermal conductivity (RRR=500)
- Cleanroom handling:
    - Chemical etching to remove damage layer and titanium getter layer
    - High pressure water rinsing as final treatment to avoid particle contamination

A dedicated new infrastructure at DESY

- Scanning niobium material for inclusion
- Clean closed loop chemistry (Buffer Chemical Polishing – BCP)
- High Pressure Rinsing, HPR, and clean room drying
- Clean Room handling and assembling (Class 10 and 100)



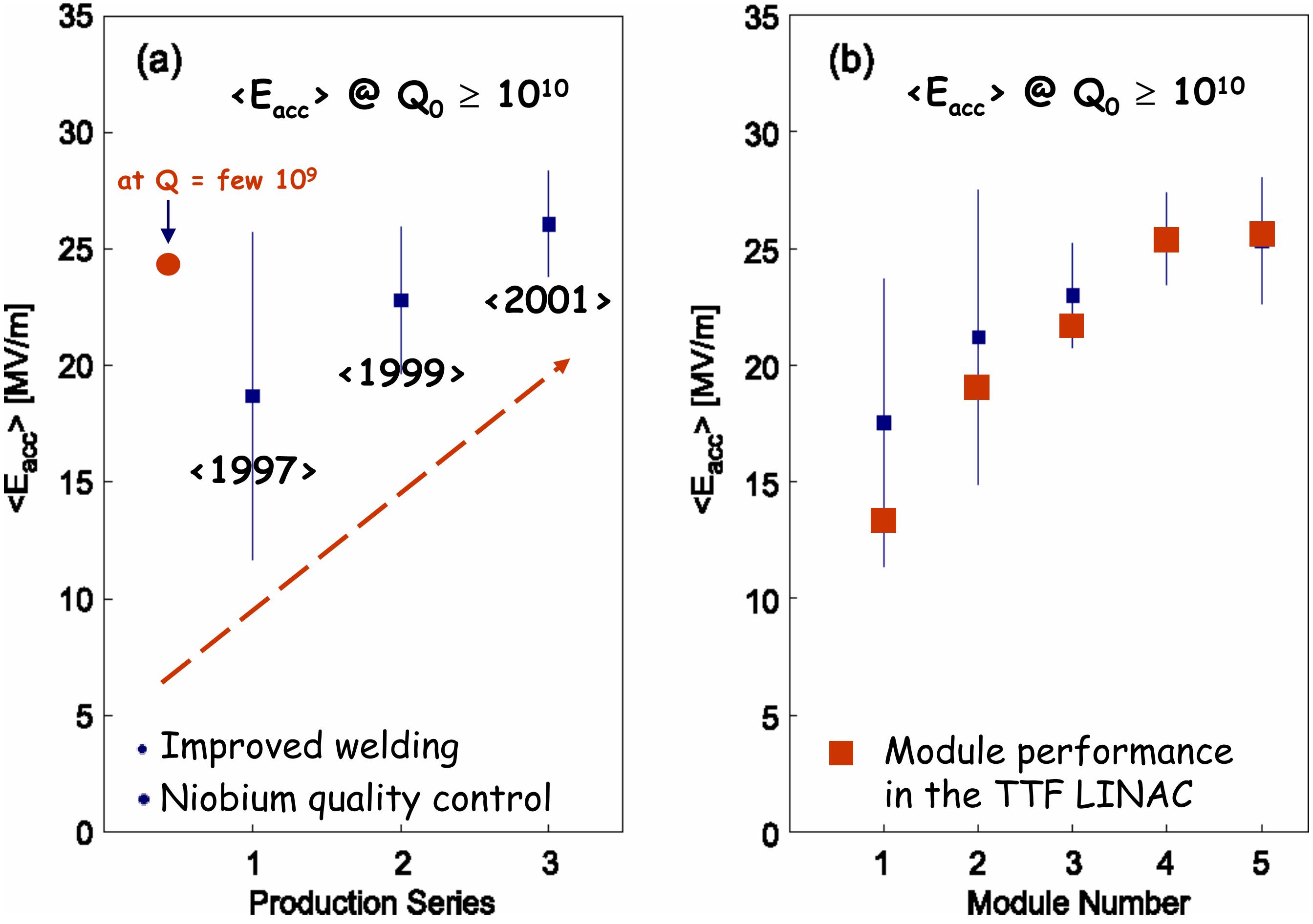
Learning curve with BCP

BCP = Buffered Chemical Polishing

3 cavity productions from 4 European industries: Accel, Cerca, Dornier, Zanon

Cornell ●
1995

5-cell



Electro-Polishing & Baking for 35 MV/m

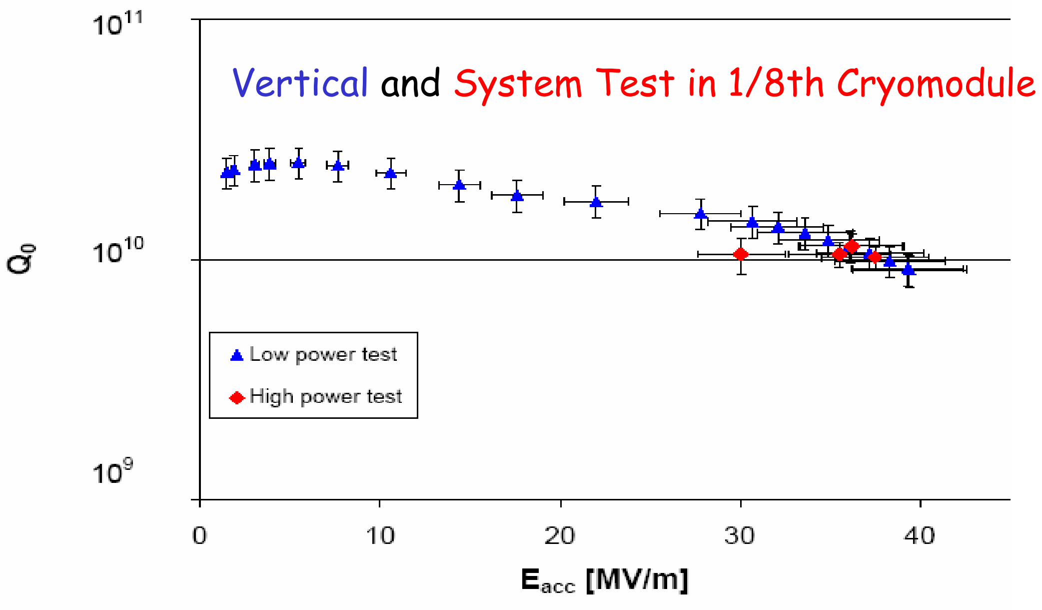
The AC 70 example

EP at the DESY plant
- **Low Field Emission**

800°C annealing

120°C, 24 h, Baking
- high field Q drop cured

High Pressure Water Rinsing



Electro-Polishing (EP)

instead of

Buffered Chemical Polishing (BCP)

- less local field enhancement
- High Pressure Rinsing more effective
- **Field Emission onset at higher field**

In Situ Baking

@ 120-140 ° C for 24-48 hours

- to re-distribute oxygen at the surface
- **cures Q drop at high field**

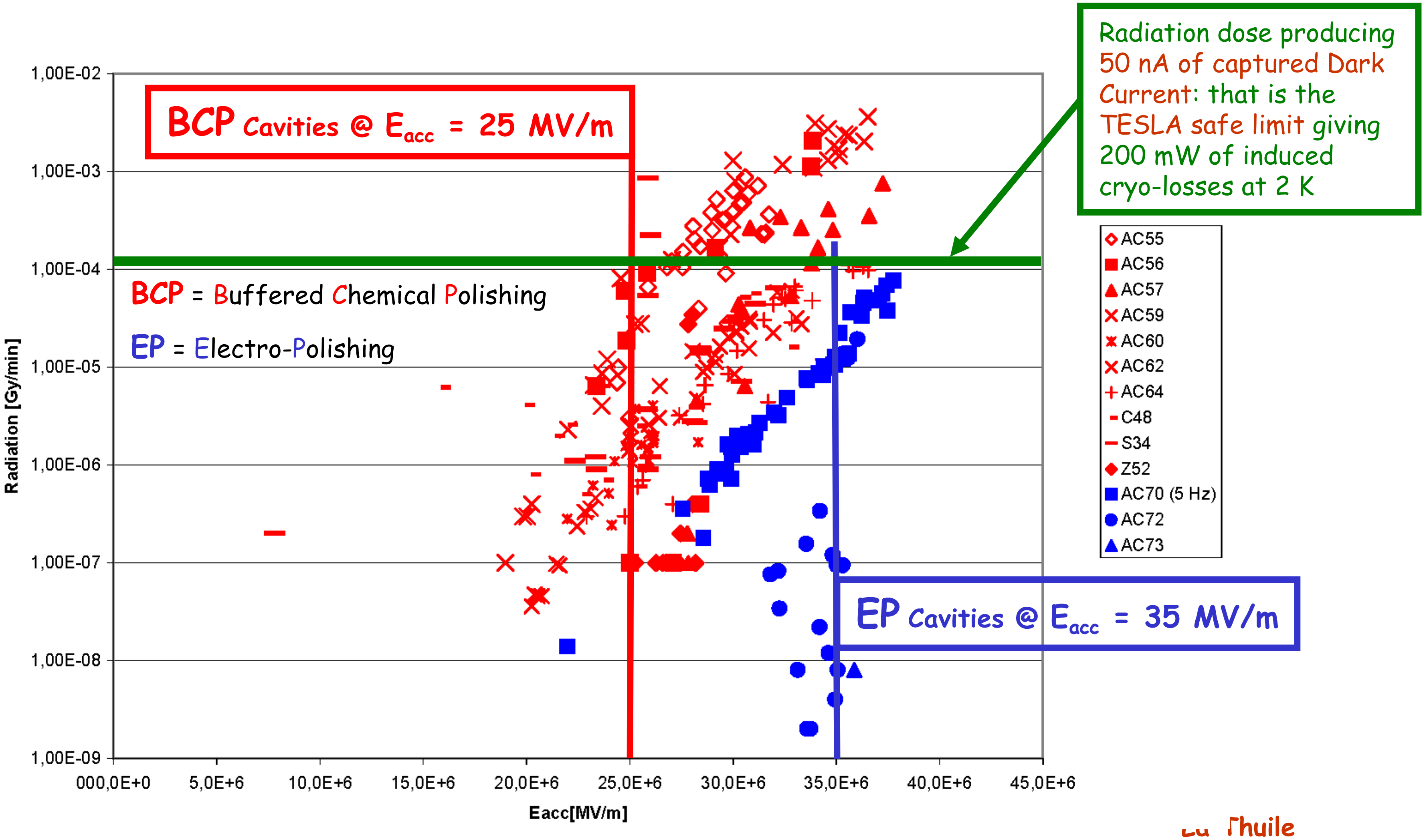
Field Emission pushed to very high field

BCP Cavities used in Modules 4 & 5 are in red, EP cavities in blue

---

Radiation Dose from the fully equipped cavities while High Power Tested in "Chechia"

"Chechia" is the horizontal cryostat equivalent to 1/8 of a TTF Module



BCP Cavities @ E_{acc} = 25 MV/m

BCP = Buffered Chemical Polishing

EP = Electro-Polishing

EP Cavities @ E_{acc} = 35 MV/m

Radiation dose producing 50 nA of captured Dark Current: that is the TESLA safe limit giving 200 mW of induced cryo-losses at 2 K

Cryomodule Design Ratinales

High Performance Cryomodule was central for the TESLA Mission

  - More then one order of magnitude was to be gained in term of capital and operational cost

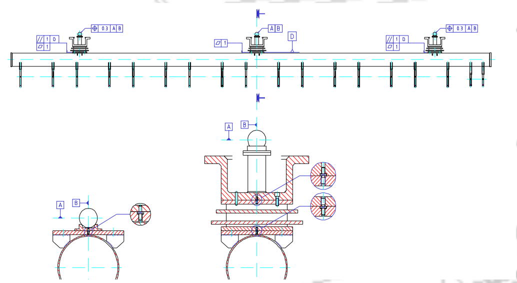
- High filling factor: to maximize real estate gradient
  - Long sub-units with many cavities (and quad): cryomodules
  - Sub-units connected in longer strings
  - Cooling and return pipes integrated into a unique cryomodule
- Low cost per meter: to be compatible with a long TeV Collider
  - Cryomodule used also for feeding and return pipes
  - Minimize the number of cold to warm connections for static losses
  - Minimize the use of special components and materials
  - Modular design using the simplest possible solution
- Easy to be alligned and stable: to fullfil beam requirements

Performing Cryomodules

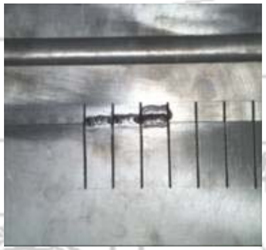
Three cryomodule generations to:

- improve simplicity and performances
- minimize costs

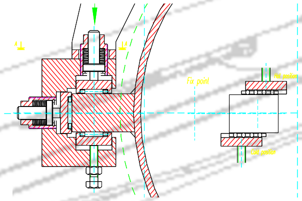
Reliable Alignment Strategy



"Finger Welded" Shields



Sliding Fixtures @ 2 K

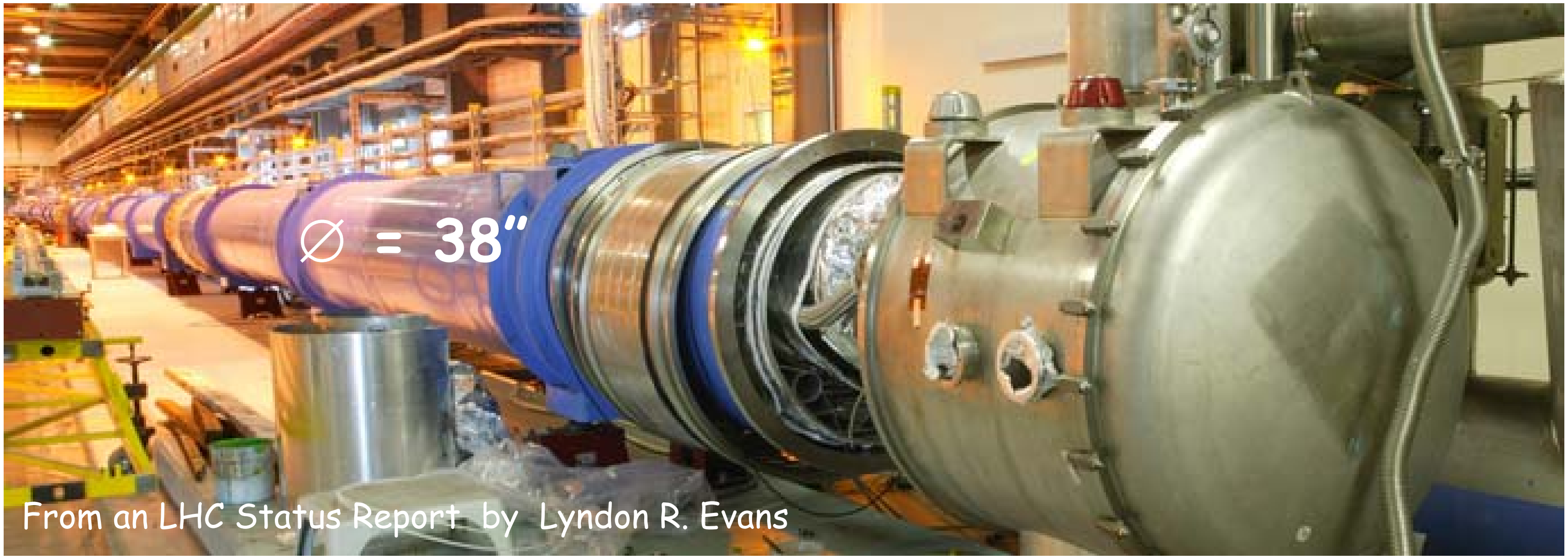


Required plug power for static losses < 5 kW/(12 m module)

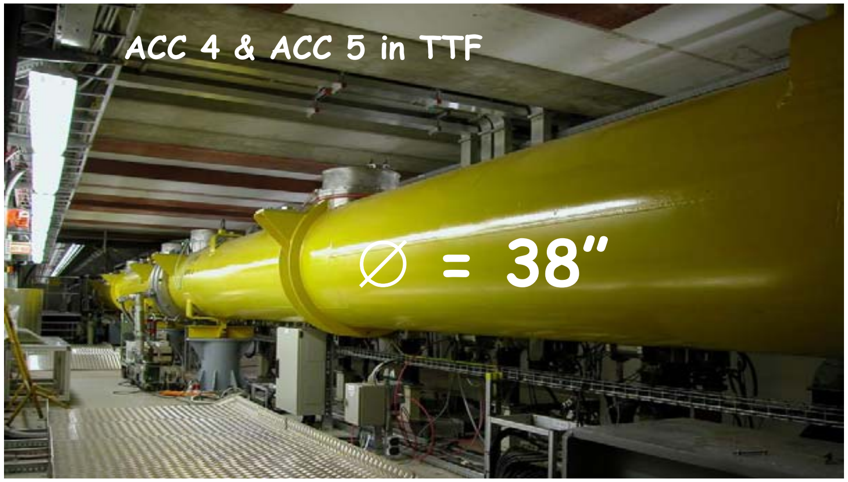
TTF Module Installation

	Type	Installation date	Cold time [months]
CryoCap		Oct 96	50
M1	1	Mar 97	5
M1 rep.	2	Jan 98	12
M2	2	Sep 98	44
M3	2	Jun 99	35
M1*	2	Jun 02	25
MSS	2		8
M3*	2	Apr 03	14
M4	3		14
M5	3		14
M2*	2	Feb 04	11

LCH and TESLA/ILC Module Comparison



From an LHC Status Report by Lyndon R. Evans


ACC 4 & ACC 5 in TTF

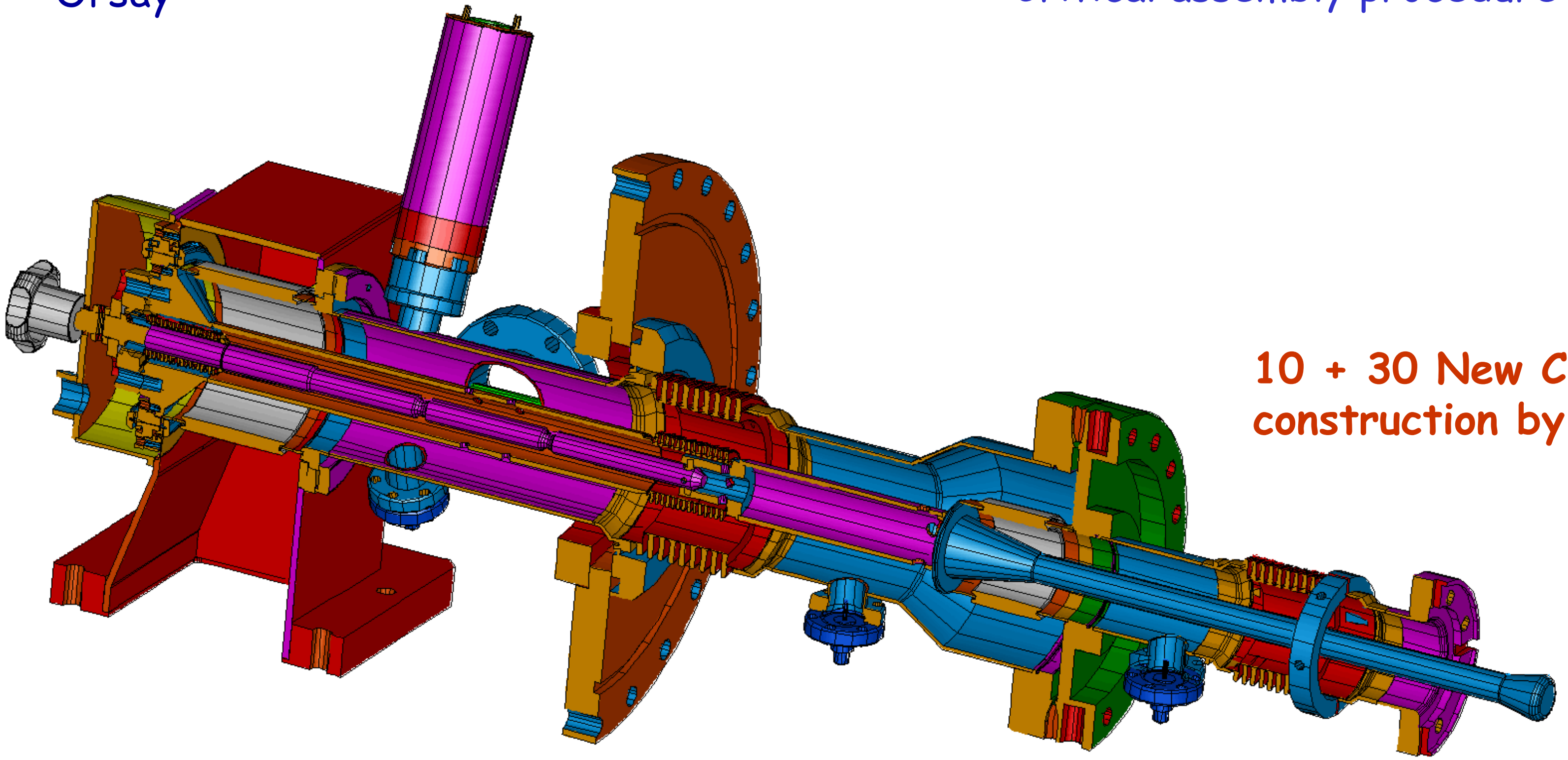

ACC 2 & ACC 3 in TTF

Power Coupler

- TTF III Coupler has a robust and reliable design.
- Extensively power tested with significant margin
- New Coupler Test Stand at LAL, Orsay

Pending Problems

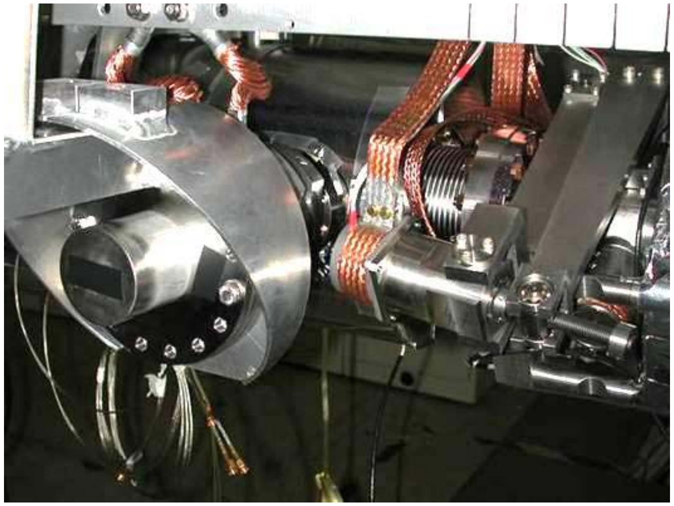
- Long processing time: ~ 100 h
- High cost (cavity/2)
- Critical assembly procedure

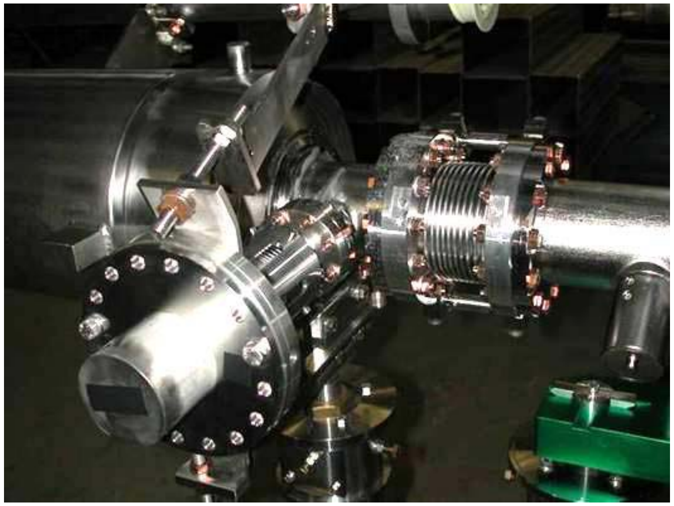


10 + 30 New Couplers in construction by industry

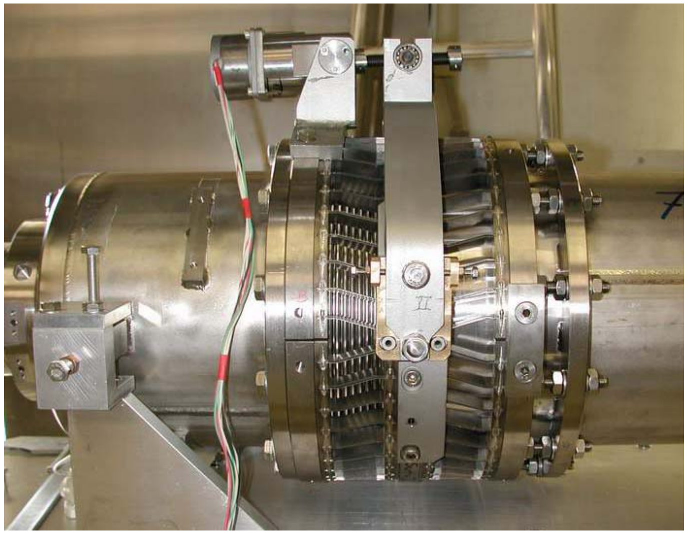
SC Cavity Tuners

TTF Tuner

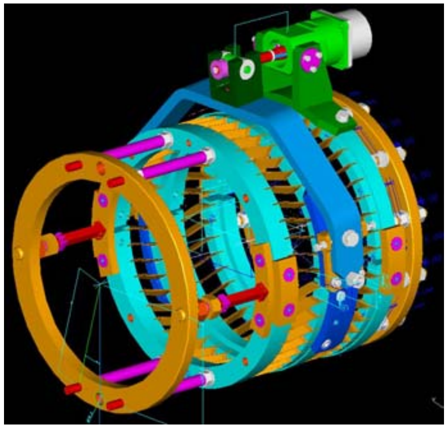




INFN Blade-Tuner for ILC



Successfully operated with superstructures

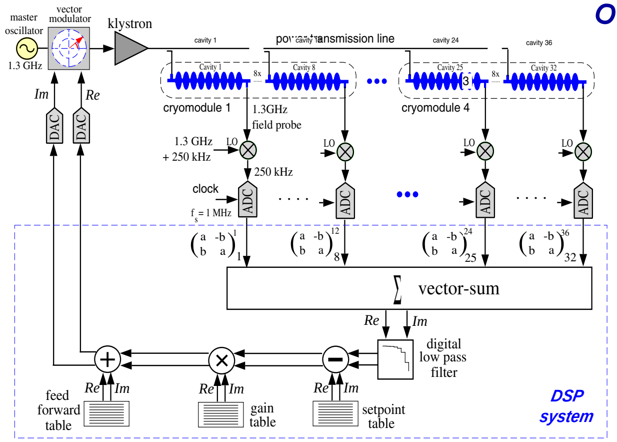


Integration of piezos completed for Lorentz force compensation and microphonics.

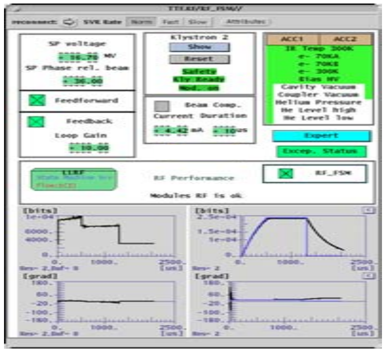
Cold tests by fall 2005 (DESY, BESSY, Cornell)

LLRF performance in TTF

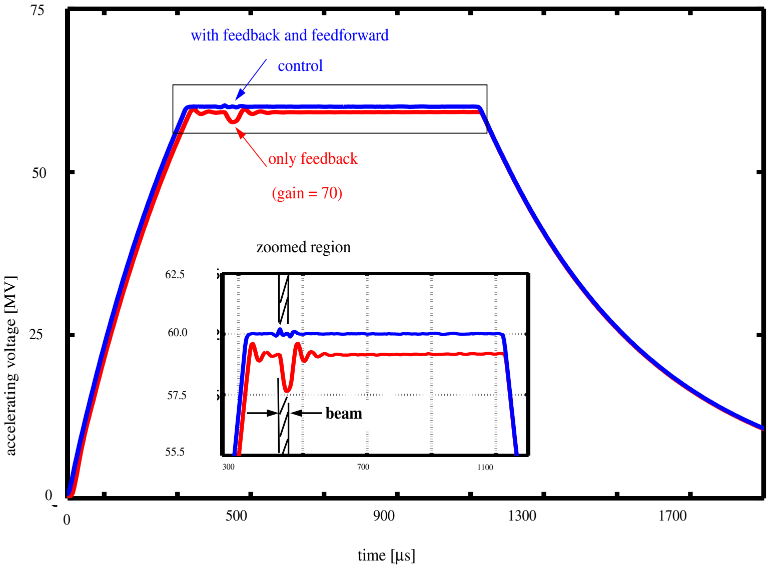
Principle of RF Control



Operation with Final State Machine



from TTF Console in Milano



Contributions to Energy Fluctuations

1. Lorentz Force
2. Microphonics
3. Bunch-to Bunch Charge Fluctuations
4. Calibration error of the vector-sum
5. Phase noise from master oscillator
6. Non-linearity of field detector
7. Klystron Saturation
8. RF curvature (finite bunch length)
9. Wakefield and HOMs

Microphonics

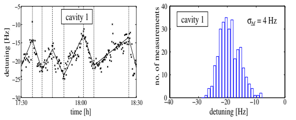


Figure 2: Fluctuations of the cavity resonance frequency. a) Slow drifts over a period of one hour and b) probability density of the cavity resonance frequency with an rms width of 2Hz - 7Hz.

Lorentz Force Detuning

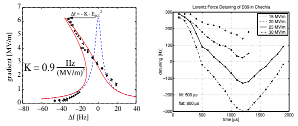
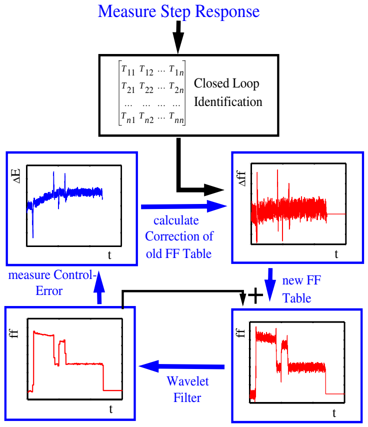


Figure 3: Influence of radiation pressure on the resonance curve of a sc cavity. a) Static detuning during cw operation and b) dynamical detuning during nominal TESLA pulse.

Adaptive Feedforward



Measure Step Response

$$\begin{bmatrix} T_{11} & T_{12} & \cdots & T_{1n} \\ T_{21} & T_{22} & \cdots & T_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ T_{n1} & T_{n2} & \cdots & T_{nn} \end{bmatrix}$$

Closed Loop Identification

ΔE

Δff

calculate Correction of old FF Table

measure Control-Error

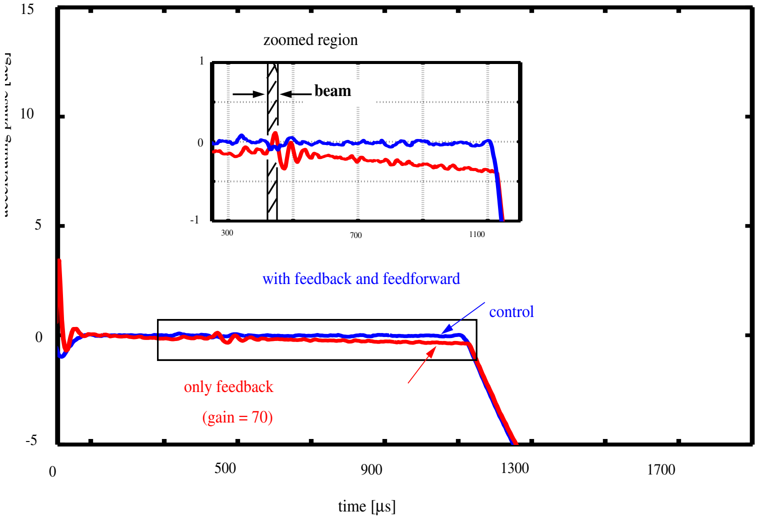
new FF Table

ff

Wavelet Filter

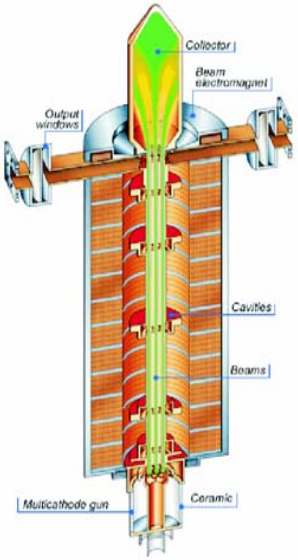
Adaptive Feed Forward can handle nonlinear systems through linarisation around the operating point.

The calculation of a new feed forward table needs only a few seconds.



Multi Beam Klystrons

Three **Thales** TH1801 Multi Beam Klystrons produced and tested



Achieved efficiency	65%
RF pulse width	1.5 ms
Repetition rate	5 Hz
Operation experience	> 5000 h

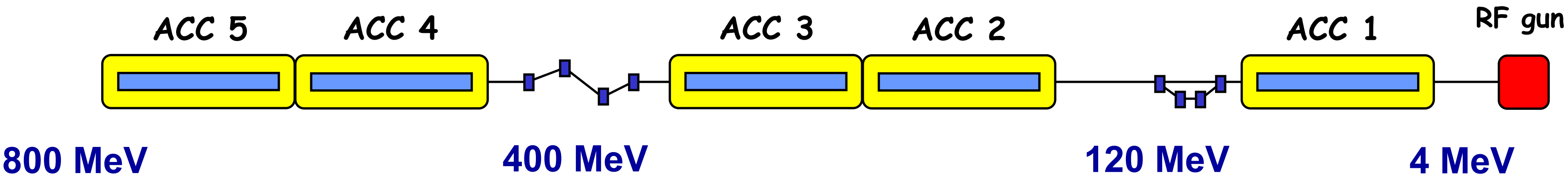
10% of operation time at full spec's

Indipendent beam design proposed and built by **CPI**. Prototype on test.

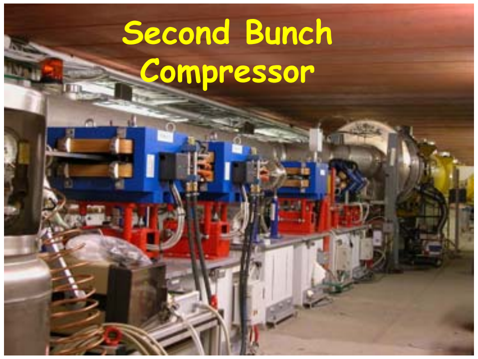
A new design proposed by Toshiba looks robust and should reach 75% efficiency

First prototype successfully test - Cathode loading < 2.1 A/cm^2

TTF II under Commissioning




TESLA like tunnel for ACC 6 & ACC 7


Second Bunch Compressor

VUV FEL User Facility

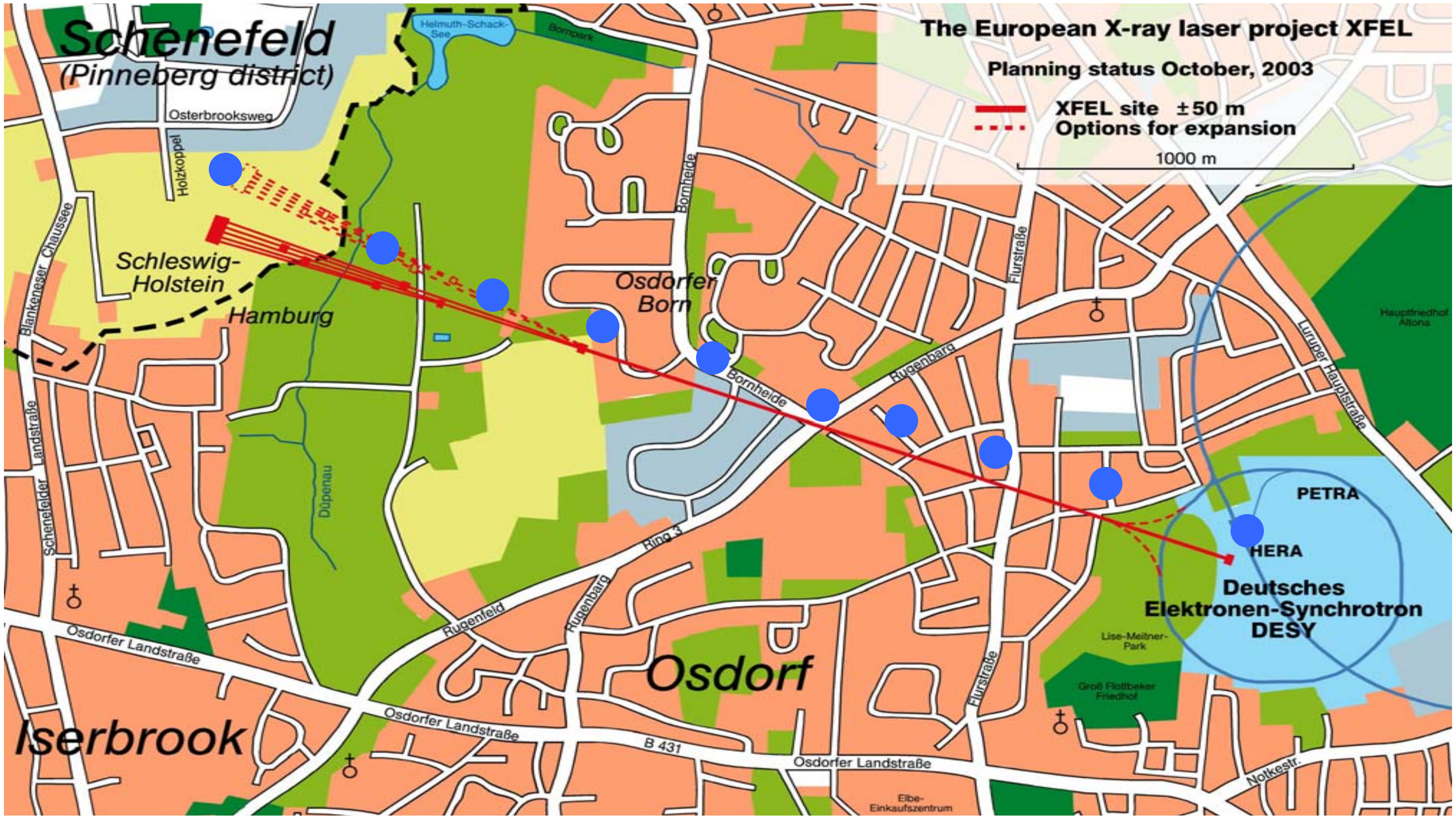
- Linac Commissioning under way
- SASE FEL Commisssioning by September this year


ACC 4 & ACC 5

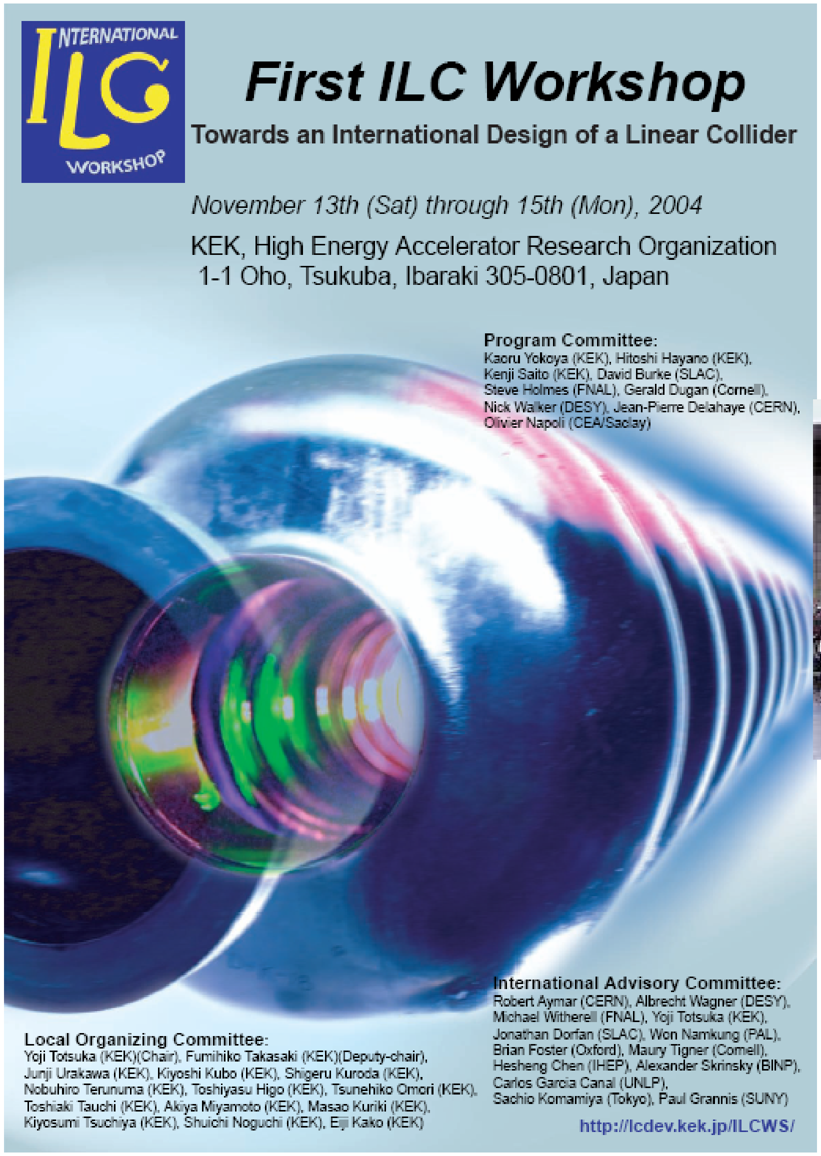

ACC 2 & ACC 3

X-FEL coming soon

- 50% funded by the German Government - European consensus being established
- **Great opportunity for ILC**
  - Machine reliability according to SRL standards
  - Industrial mass production of cavities (~ 1000) and modules (> 120)



Start of the Global Design Initiative



INTERNATIONAL ILC WORKSHOP

First ILC Workshop

Towards an International Design of a Linear Collider

November 13th (Sat) through 15th (Mon), 2004

KEK, High Energy Accelerator Research Organization
1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan

Program Committee:
Kaoru Yokoya (KEK), Hitoshi Hayano (KEK),
Kenji Saito (KEK), David Burke (SLAC),
Steve Holmes (FNAL), Gerald Dugan (Cornell),
Nick Walker (DESY), Jean-Pierre Delahaye (CERN),
Olivier Napoli (CEA/Saclay)

International Advisory Committee:
Robert Aymar (CERN), Albrecht Wagner (DESY),
Michael Witherell (FNAL), Yoji Totsuka (KEK),
Jonathan Dorfan (SLAC), Won Namkung (PAL),
Brian Foster (Oxford), Maury Tigner (Cornell),
Hesheng Chen (IHEP), Alexander Skrinsky (BINP),
Carlos Garcia Canal (UNLP),
Sachio Komamiya (Tokyo), Paul Grannis (SUNY)

Local Organizing Committee:
Yoji Totsuka (KEK)(Chair), Fumihiko Takasaki (KEK)(Deputy-chair),
Junji Urakawa (KEK), Kiyoshi Kubo (KEK), Shigeru Kuroda (KEK),
Nobuhiro Terunuma (KEK), Toshiyasu Higo (KEK), Tsunehiko Omori (KEK),
Toshiaki Tauchi (KEK), Akiya Miyamoto (KEK), Masao Kuriki (KEK),
Kiyosumi Tsuchiya (KEK), Shuichi Noguchi (KEK), Eiji Kako (KEK)

http://lcdev.kek.jp/ILCWS/

~ 220 participants from 3 regions

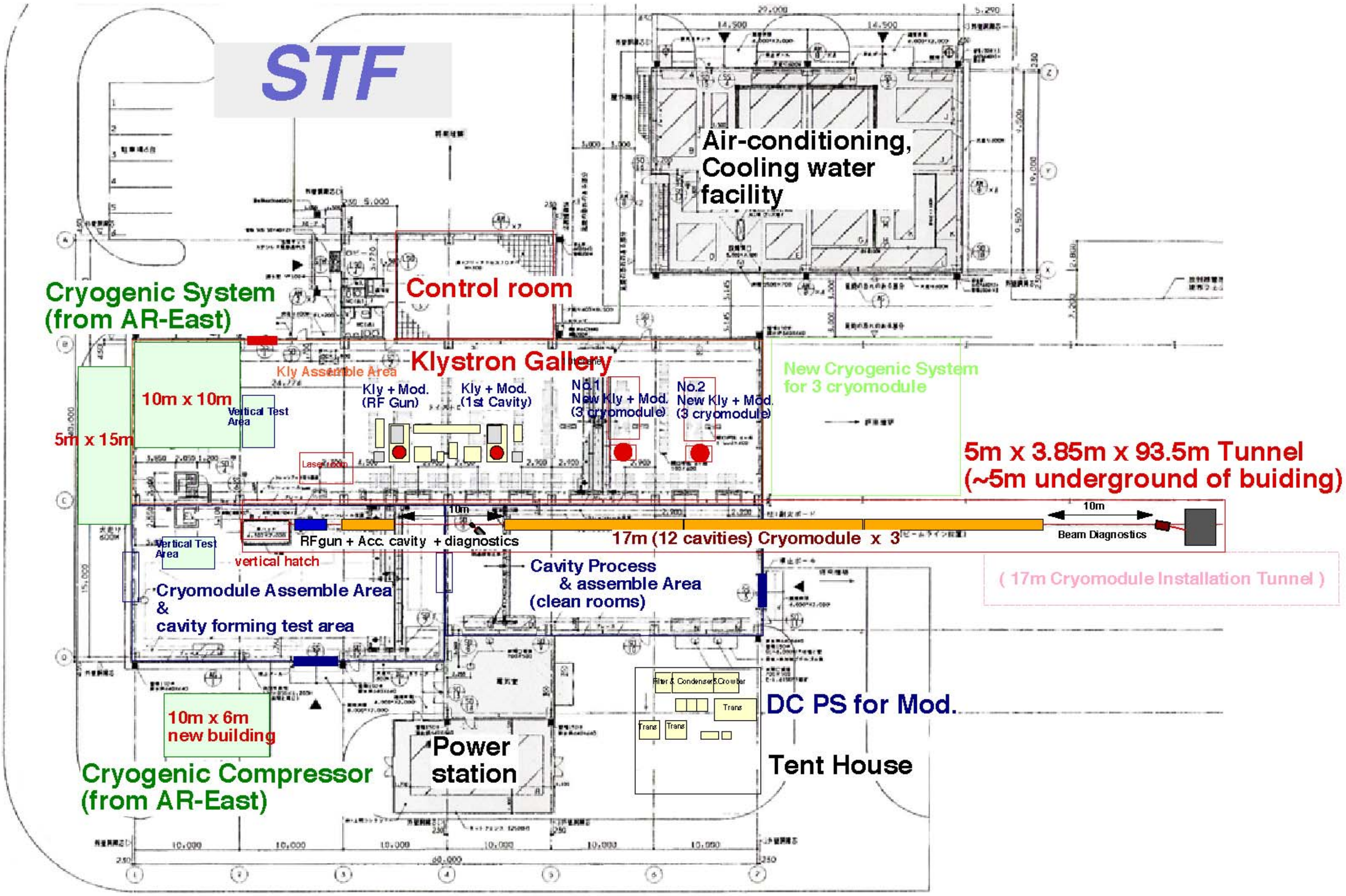
most of them accelerator experts

Global SCRF Test Facilities

- **TESLA Test Facility (TTF) @ DESY**
  currently unique in the world
  VUV-FEL user facility
  test-bed for both XFEL & ILC
- US proposed **SMTF @ FNAL**
  Cornell, JLab, ANL, FNAL, LBNL, LANL, MIT, MSU, SNS, UPenn, NIU, BNL, SLAC
  currently requesting funding
  TF for ILC, Proton Driver, RIA (and more)
- **STF @ KEK**
  aggressive schedule to produce high-gradient (45MV/m) cavities / cryomodules
- **Others (UK?)**

All facilities will be discussed at **TESLA Collaboration Meeting** 30/3-1/4 at DESY

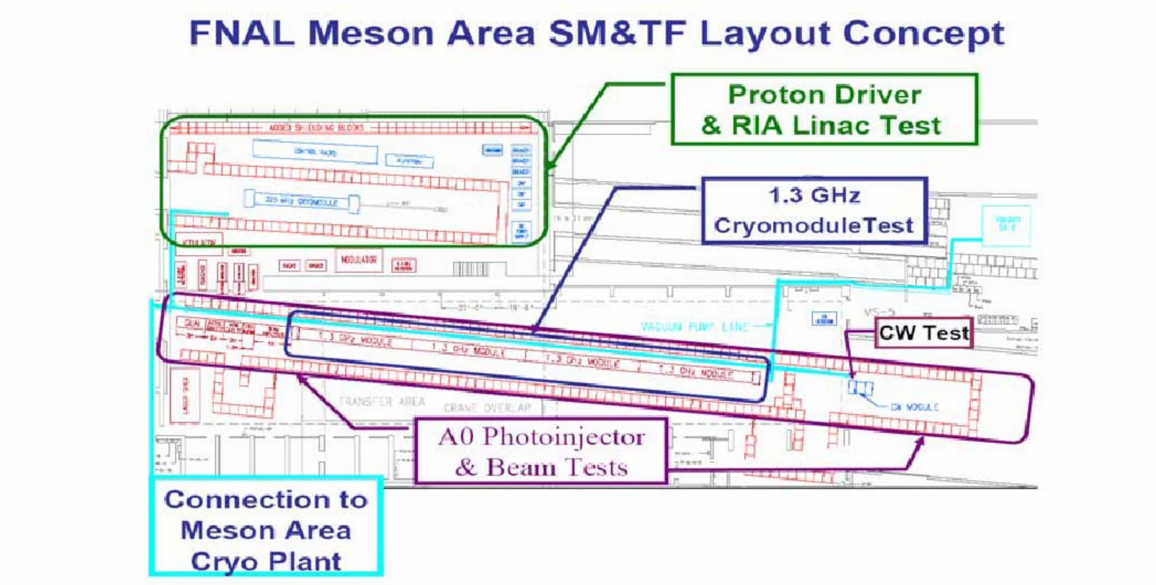
STF @ KEK

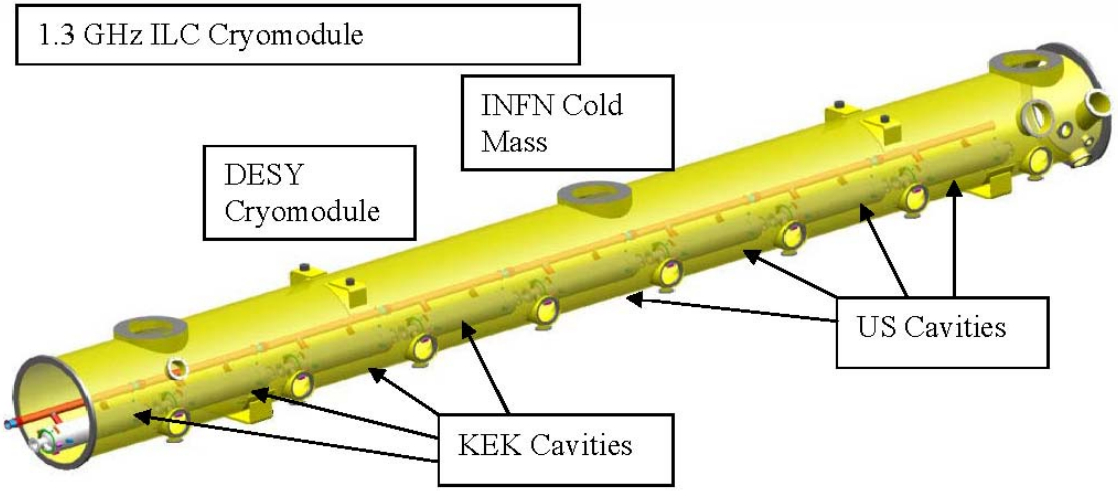


Plan of Superconducting Cavity Test Facility (STF)

V2.1 Hitoshi Hayano, 11/03/2004

SMTF @ FNAL as presented to DOE



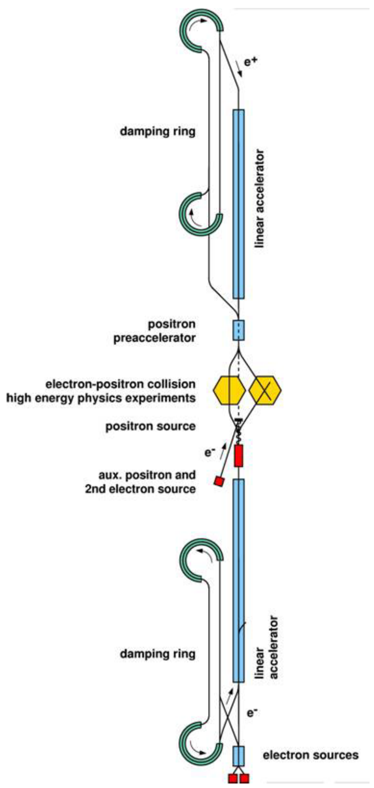


"The **SMTF proposal is to develop U.S. Capabilities** in high gradient and high Q superconducting accelerating structures

in support of

International Linear Collider
Proton Driver
RIA
4th Generation Light Sources
Electron coolers
lepton-heavy ion collider
and other accelerator
projects of interest to U.S
and the world physics
community."

ILC Possibilities

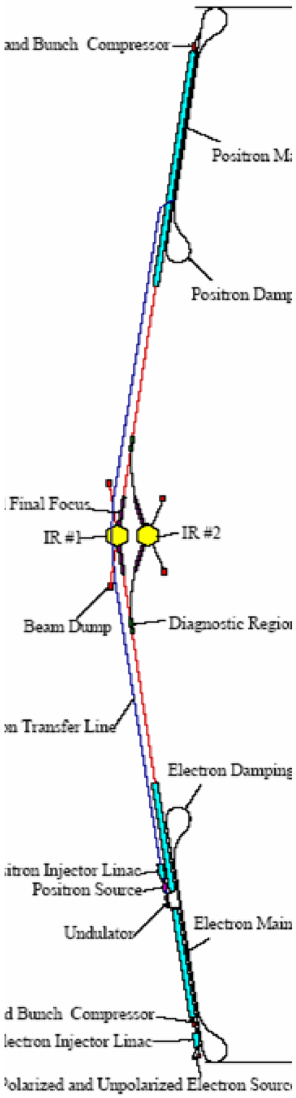


33km

TESLA TDR (2001)
500 GeV (800 GeV)

US Options Study (2003)
500 GeV (1.3 TeV)

47 km

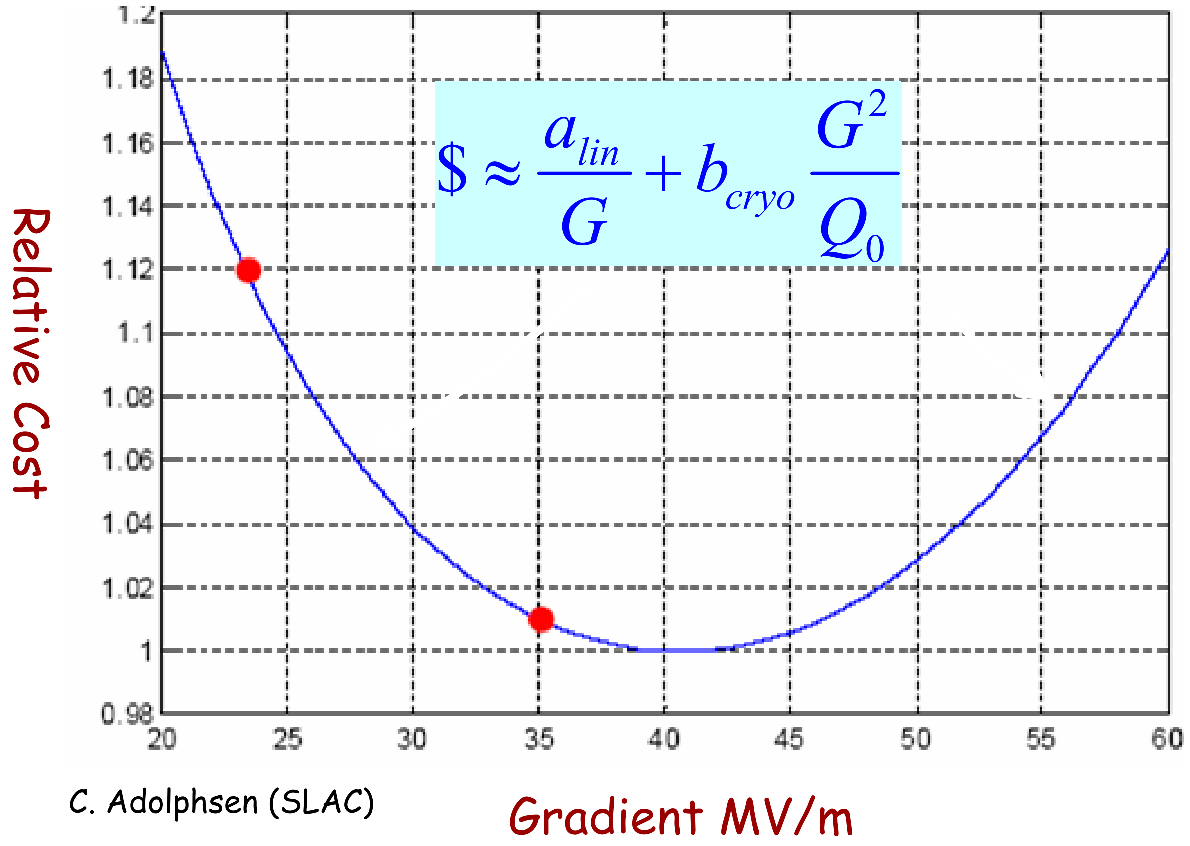


Main Linac: The Cost Driver

- Main Linacs are the biggest single cost item
- 10 years of R&D by the TESLA collaboration has produced a mature technology
  - But we're not quite there yet…
- Primary focus of future R&D *should* be
  - successful tech. transfer to industry
  - cost reduction through industrialisation
  - need extensive effort to achieve high reliability !!!
- XFEL project is already doing much of this within Europe
- Within 'brave new ILC world', there is still room for discussion
  - One important question:
    "What should the design gradient be?"

About the Gradient for ILC

- 35MV/m is close to optimum
- 30 MV/m would give safety margin



$$\$ \approx \frac{a_{lin}}{G} + b_{cryo}\frac{G^2}{Q_0}$$

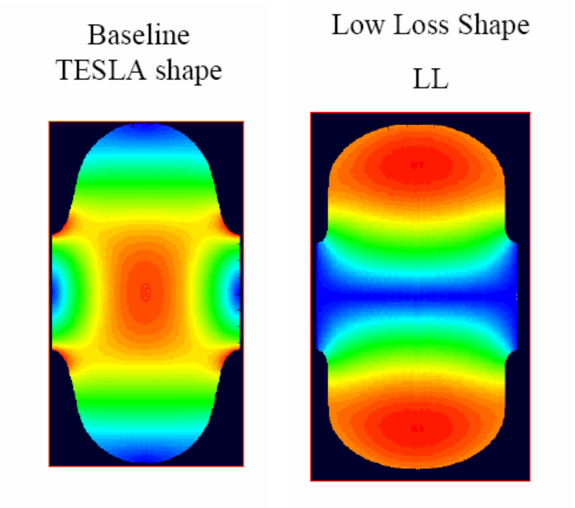
C. Adolphsen (SLAC)

Japanese are pushing for 40-45MV/m

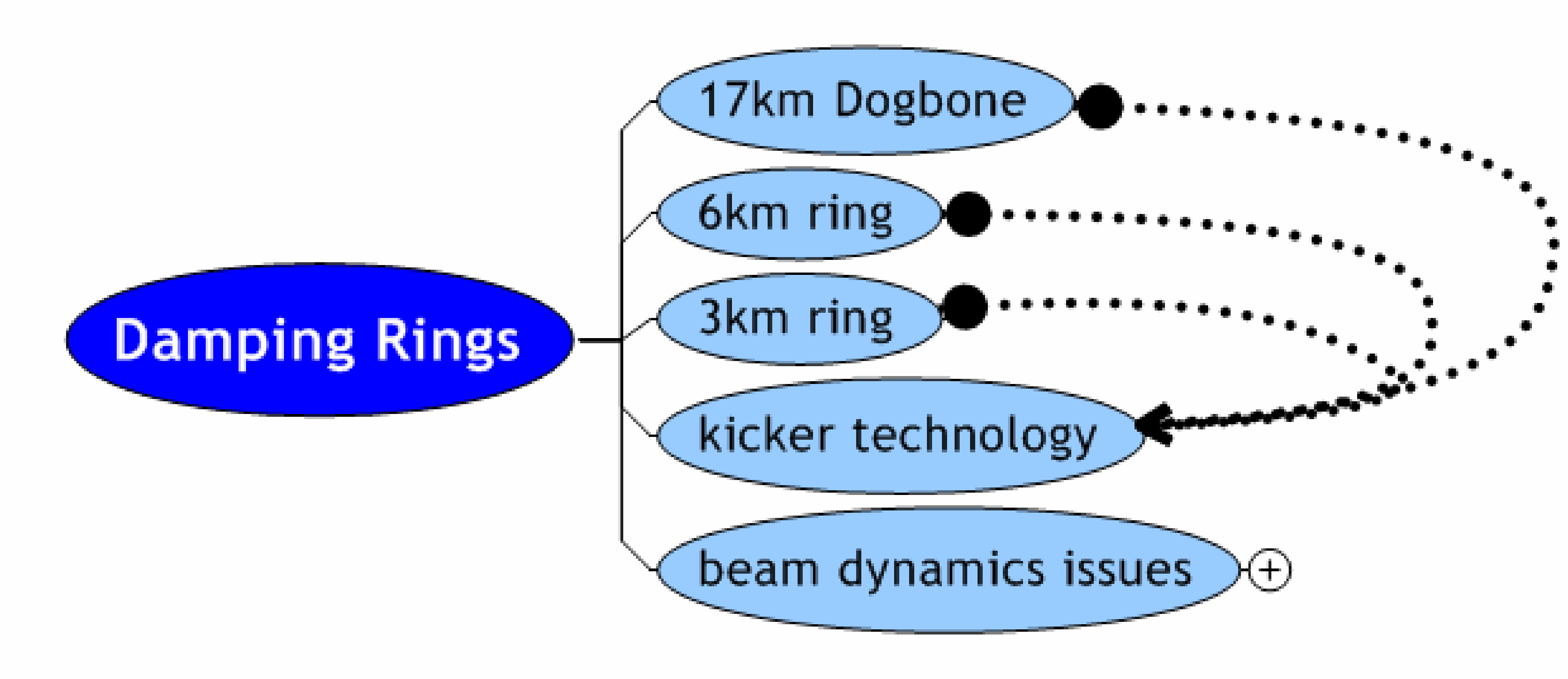
"ICHIRO" cavity

Larger magnetic volume

Lower peak magnetic field



Damping Rings



Need to compress 300 km (~1ms) bunch train into ring

Compression ratio (i.e. ring circumference) depends on **speed of injection/extraction kicker**.

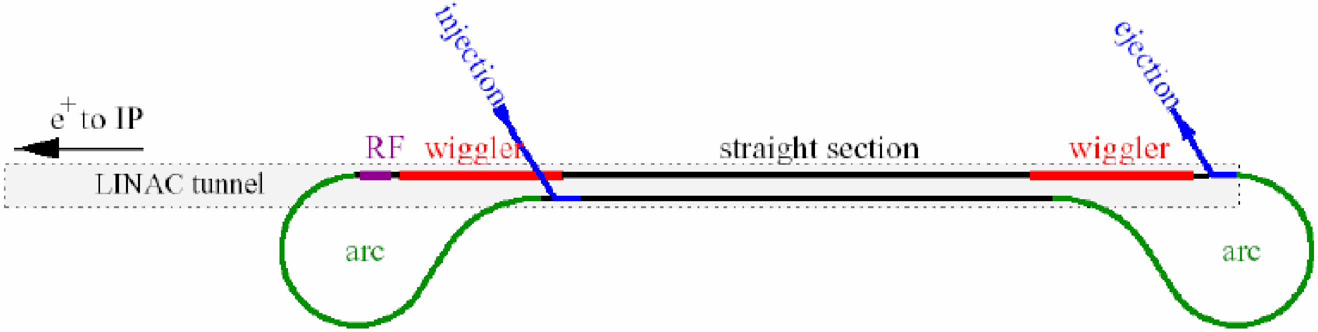
DR Design Approaches: Example # 1

The TESLA TDR lattice

5 GeV, 17 km lattice (arcs 1 km each, straights 15 km total).

Bunches spaced by 20 ns, injected and extracted individually.

Positron damping ring requires 440 m of wiggler to achieve damping time of 27 ms.



Schematic of Dogbone Damping Ring from TESLA TDR

Strengths:

- Relatively small amount of extra tunnel required.
- Large circumference reduces average current, and helps mitigate some instabilities.
- Flexibility in modes of operation (e.g. could double number of bunches)

Weaknesses:

- Large space-charge tune shift needs to be corrected using coupling-bumps.
- Sensitive to stray magnetic fields.

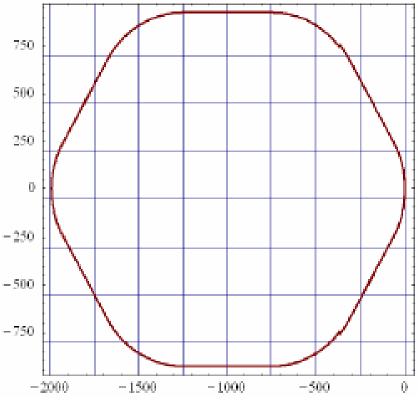
DR Design Approaches: Example # 2

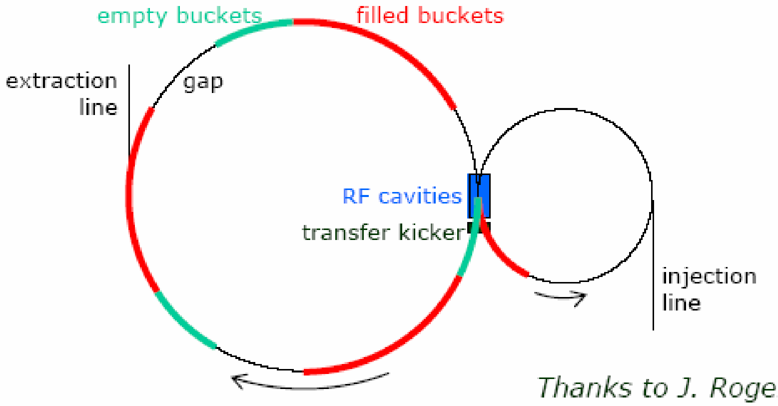
The FNAL 6 km Lattice

5 GeV, 6 km lattice (six-fold symmetry).

Injection/extraction scheme uses 6 ns rise-time, 60 ns fall-time kicker.

Lattice documented in FERMILAB-TM-2272-AD-TD
http://www.hep.uiuc.edu/home/g-gollin/linear_collider/Fermilab_damping_ring_report.pdf





Thanks to J. Rogers and G. Dugan (Cornell)

Strengths:

- Relatively small circumference reduces space-charge effects.
- Reduced amount of wiggler needed to achieve required damping rate.
- Injection/extraction scheme allows use of slow fall-time kicker.

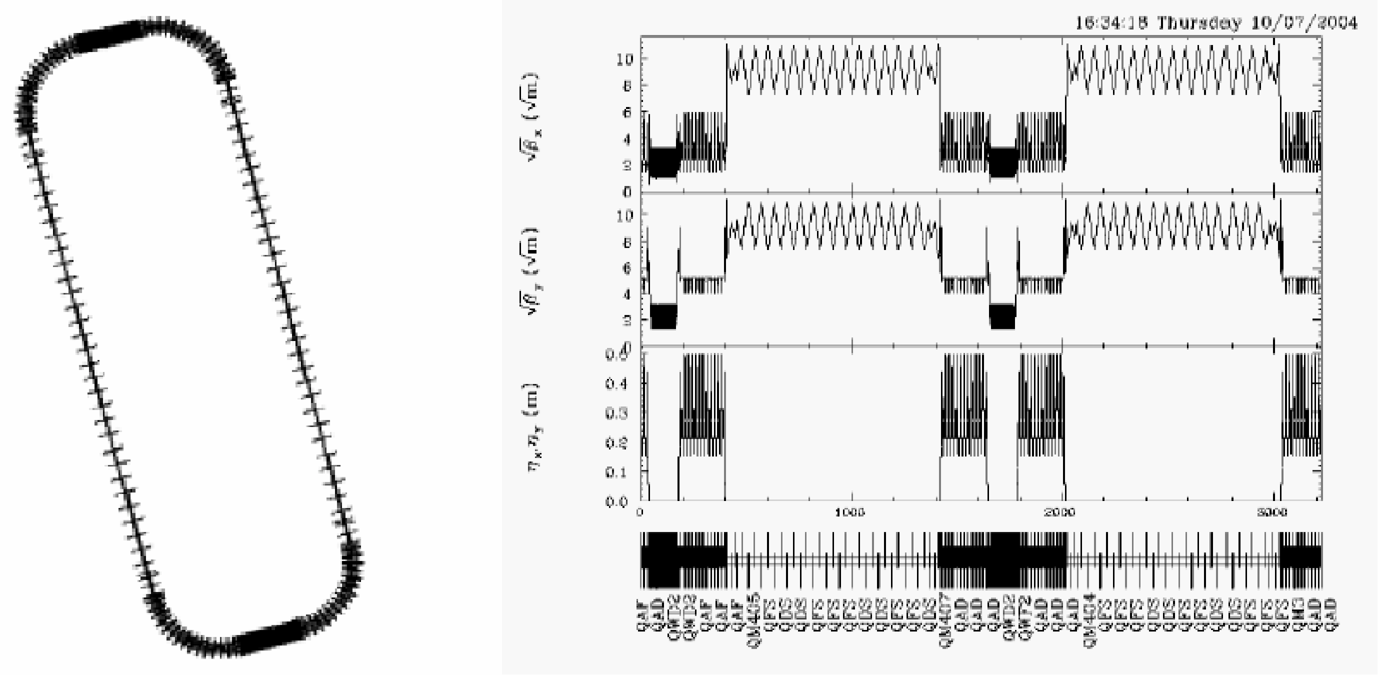
Weaknesses:

- Higher average current makes electron-cloud and ion effects more difficult.

DR Design Approaches: Example # 3

The KEK 3 km Lattice

5 GeV, 3.2 km lattice (racetrack design).



Lattice layout and optical functions in KEK 3 km damping ring.

S. Kuroda and J. Urakawa (KEK)

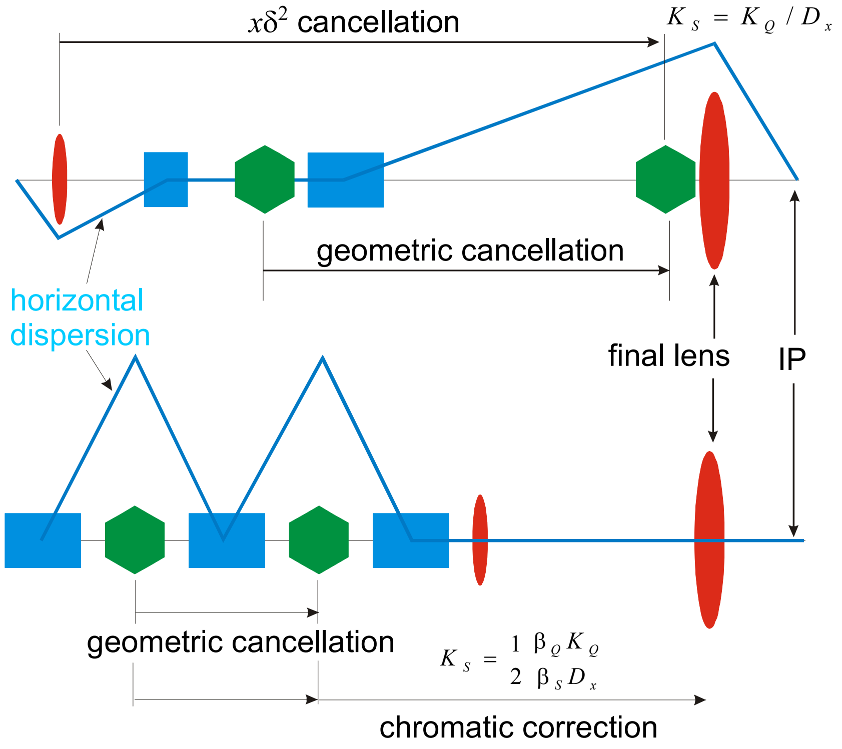
Beam Delivery System Functionality

- Focus and collide *nanobeams* at the interaction point (IP)
- Remove (collimate) the beam halo to reduce detector background
- Provide beam diagnostics for the upstream machine (linac)

Each one of these is a challenge!

Focusing and Colliding Nanobeams

- Correction of chromatic and geometric aberrations becomes principle design challenge
- A consequence: systems have extremely tight alignment (*vibration*) tolerances: stabilisation techniques a must!



Local correction
with *D*′ at IP
[*Raimondi*, 2000]

Non-local correction
(CCS)
[*Brown*, 1985]

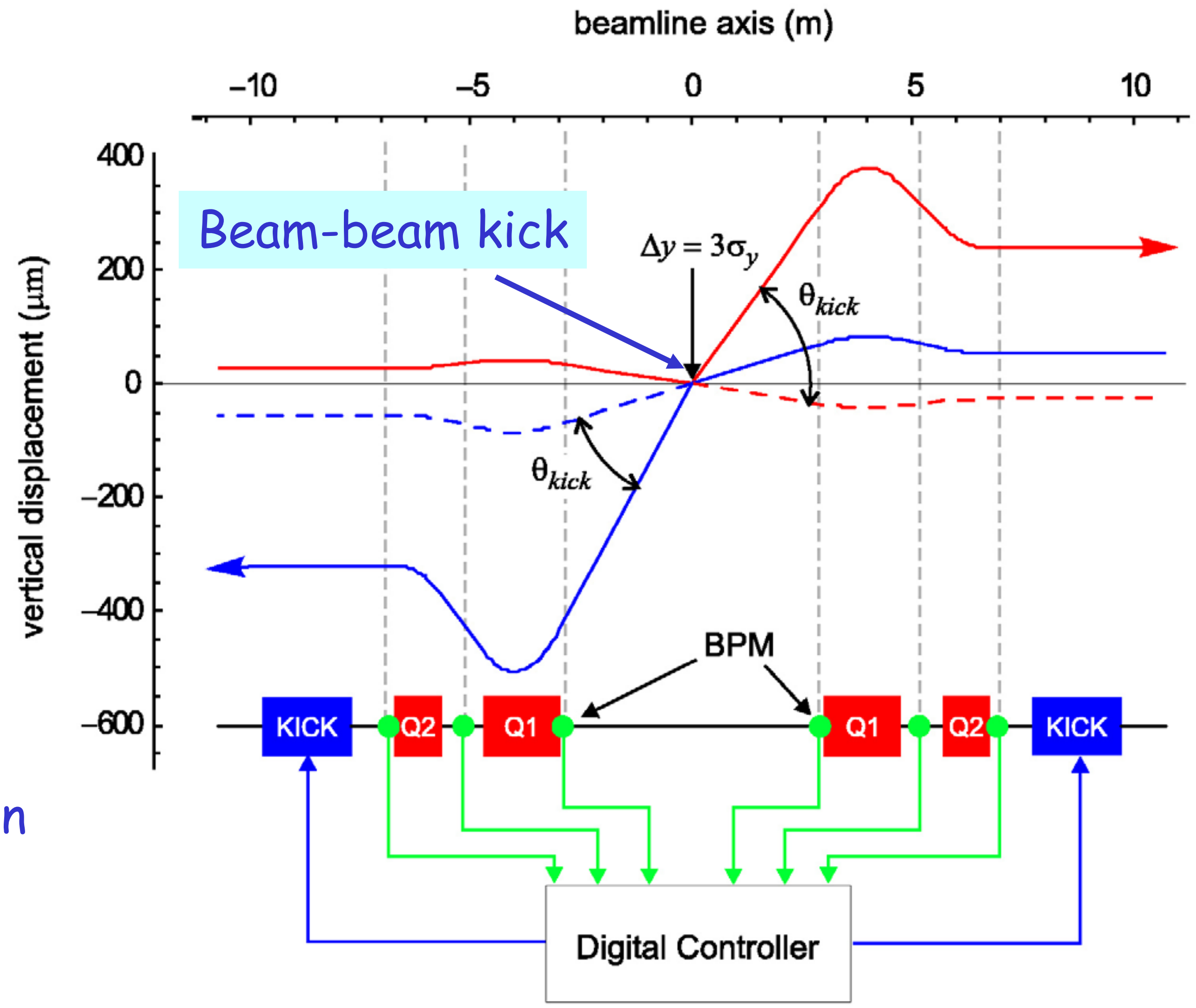
IP Fast (Orbit) Feedback

Long bunch train:

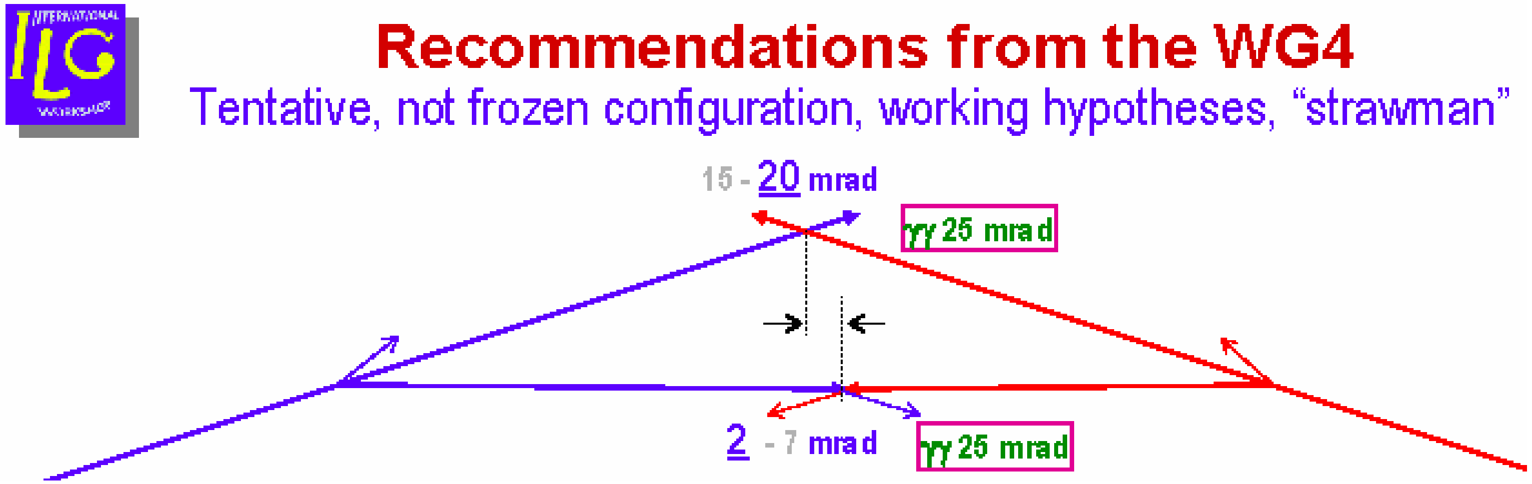
~ 3000 bunches

$t_b = 337$ ns

Multiple feedback systems will be mandatory to maintain the *nanobeams* in collision



BDS Strawman Model



Recommendations from the WG4

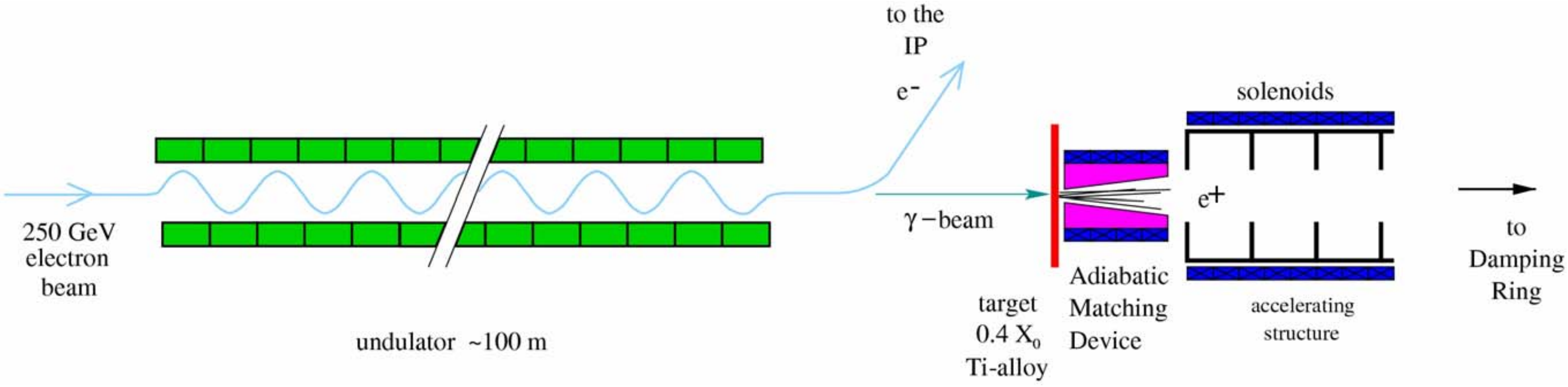
Tentative, not frozen configuration, working hypotheses, “strawman”

Discussion on angles between the Linacs was again hot:

- Multi-TeV upgradeability argument is favoured by many
- Small crossing angle is disfavoured by some

Positron Source

As in the TESLA TDR



- Photons (γ) produced in undulator by the high energy electron beam upstream of BDS and IR
- Option for polarised e+ with s.c. helical undulator
- Thin target converts γ to positrons
- High energy electrons (> 150 GeV) required for positron beam

Positron Source

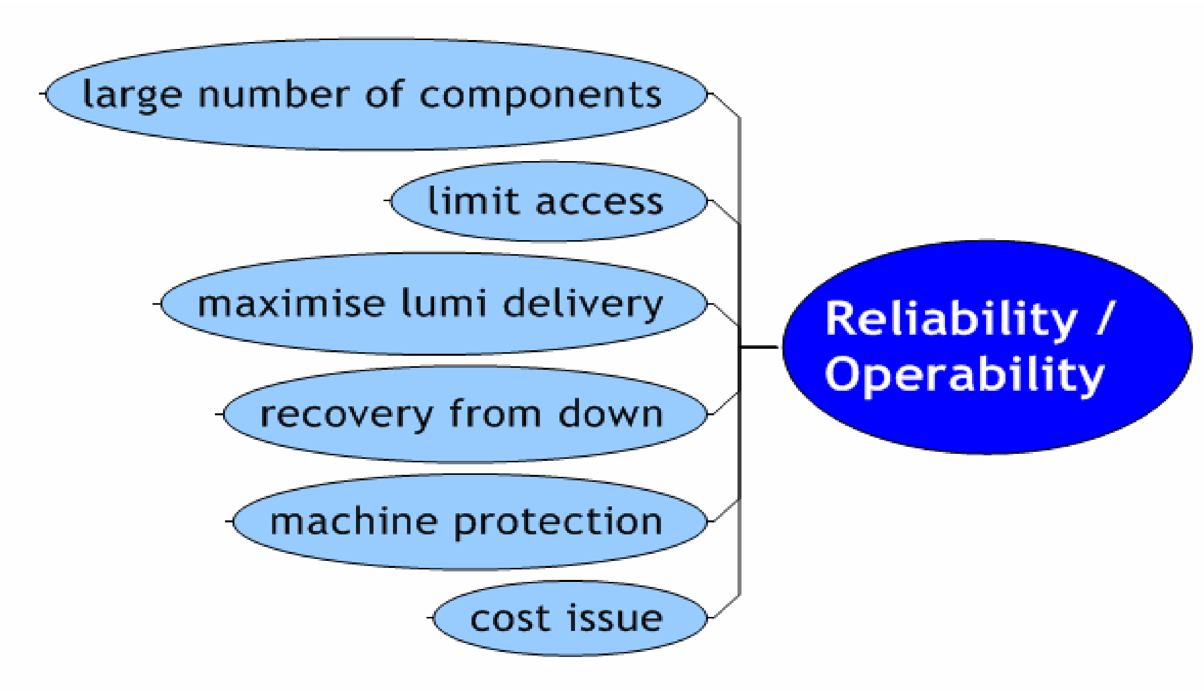
Advantages

- significantly reduced power deposition in thin target (~5 kW)
- smaller emittance beam produced
  - less multiple coulomb scattering
  - reduced acceptance requirements for DR
    - no pre-DR foreseen
- much cheaper / less complex than equivalent 'conventional source' for TESLA
- Naturally allows upgrade to polarised e^+ source

Disadvantages

- Requires e-linac with ≥150 GeV
  - TDR solution to use main e-linac
  - coupling e- to e+ production raises questions of
    - operability
    - reliability
    - commissioning strategy
- Never been done before
  - although physics is well understood!
  - E166 experiment at SLAC

Reliability / Operability



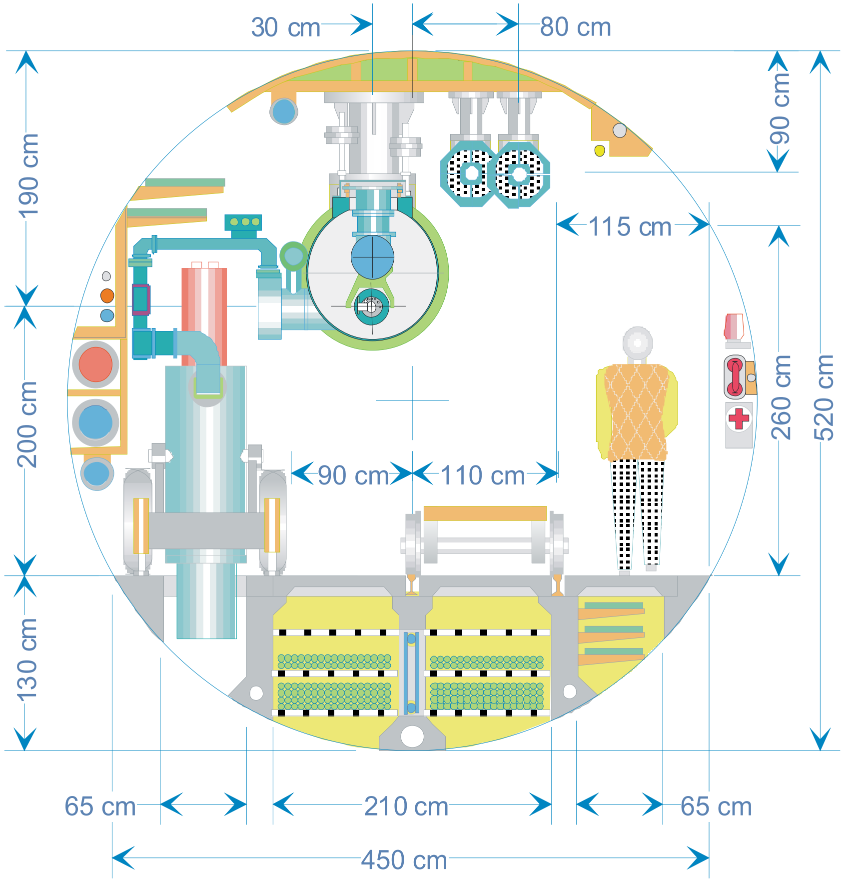
Reliability / Operability

- large number of components
- limit access
- maximise lumi delivery
- recovery from down
- machine protection
- cost issue

A major issue for ILC – needs much more work

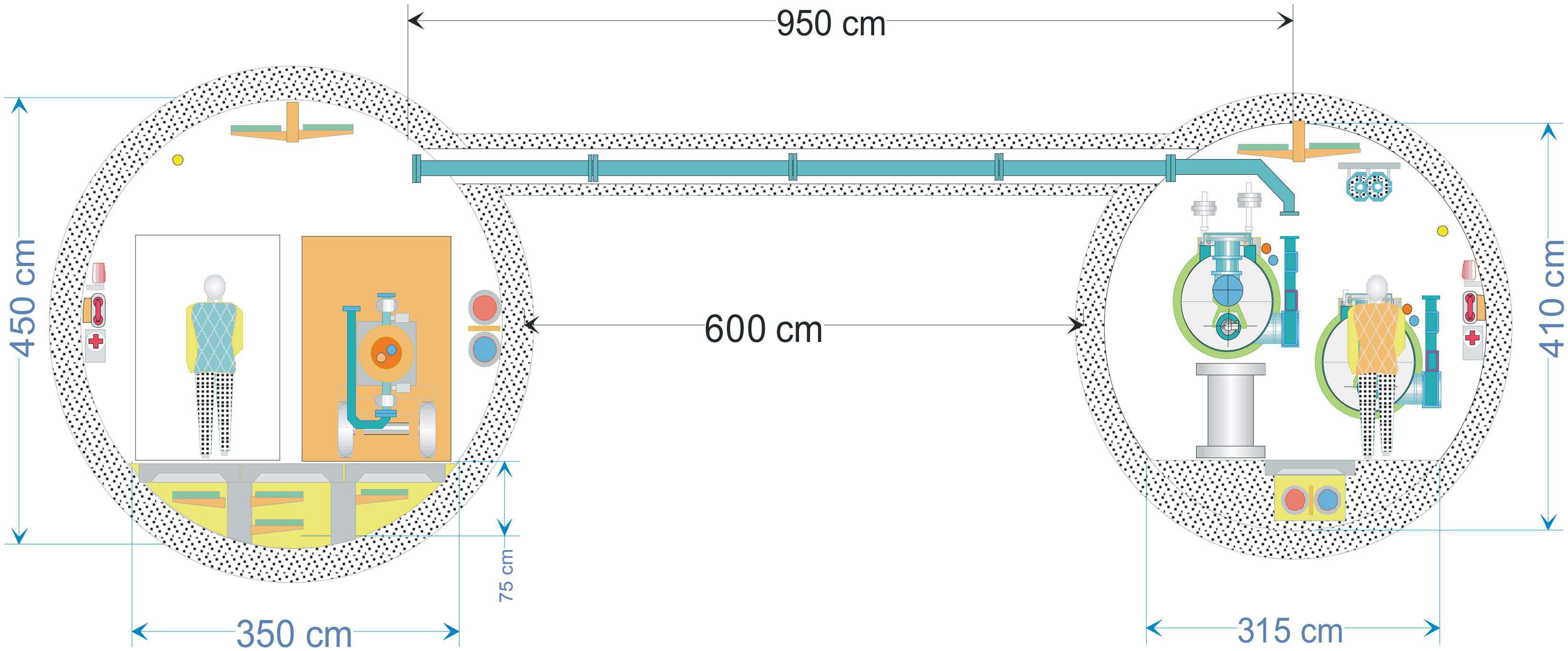
Current state-of-the-art is Tom Himel study for USCWO

LINAC tunnel housing



Single tunnel solution
a la TESLA TDR
(and for the XFEL)

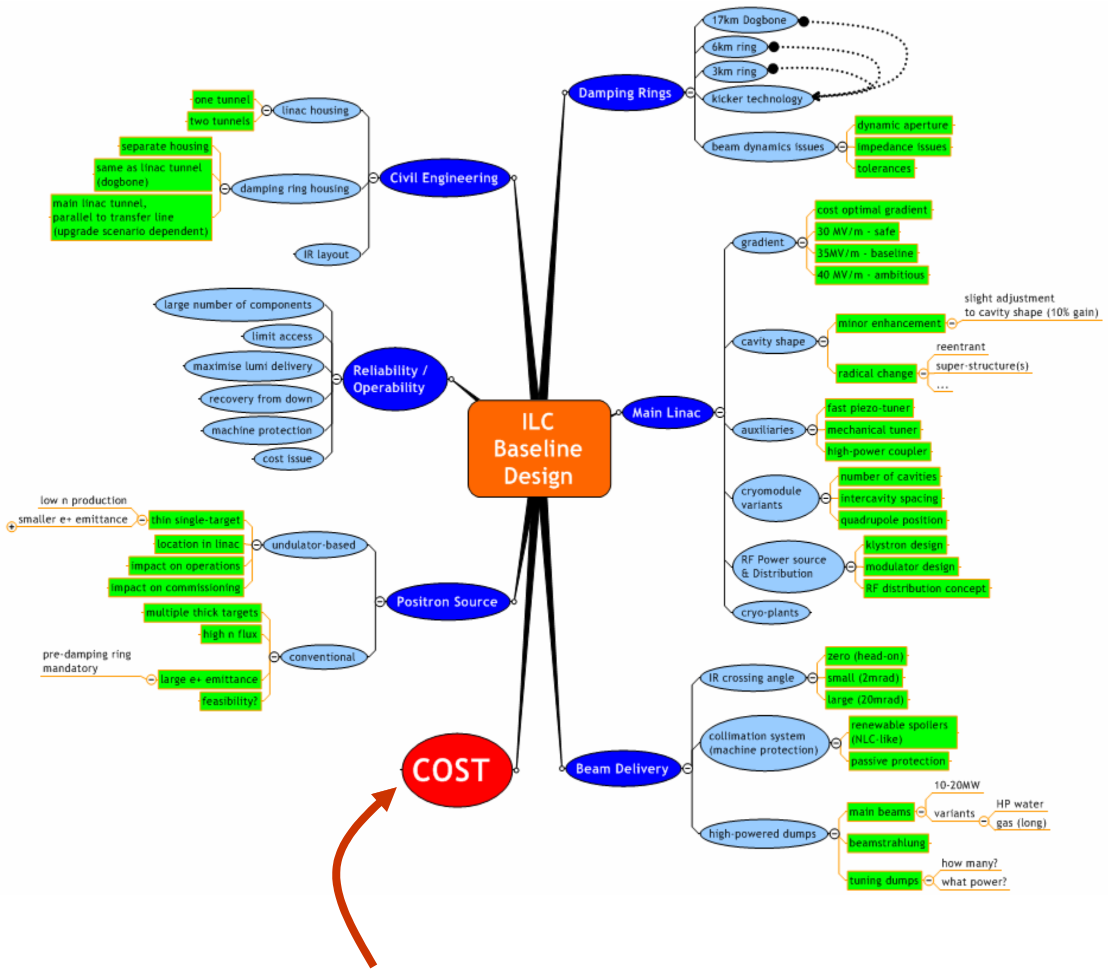
LINAC tunnel housing



Two-tunnel (possible) option

klystrons/modulators(?)/LLRF/PS is Service Tunnel to allow access during operation (availability arguments).

Much To Do?



don't forget this one!!!

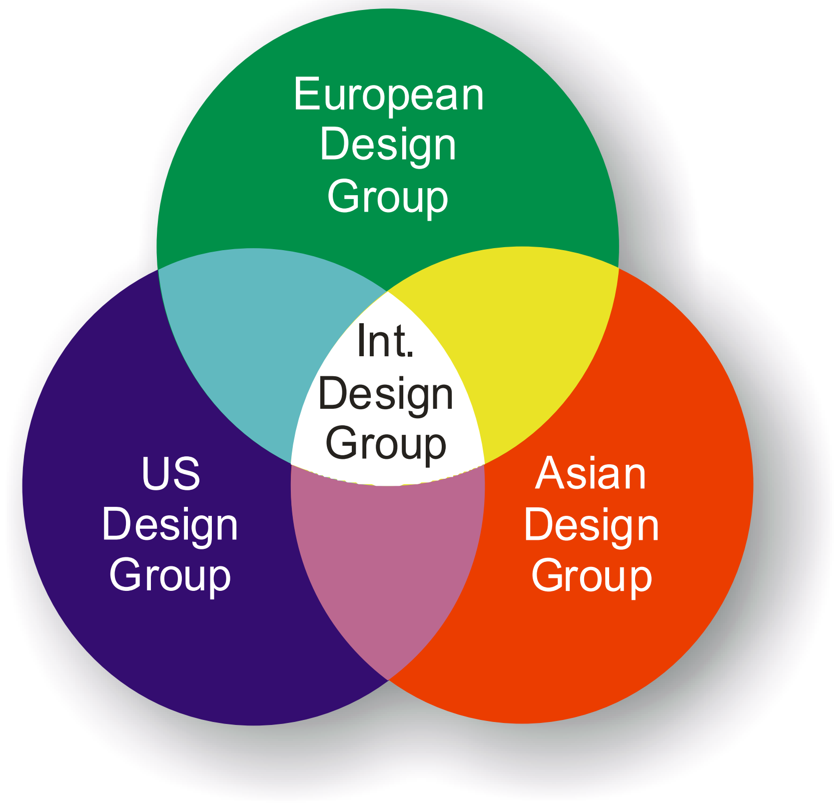
It would seem we still have a great deal to do.

However, we can make decisions towards a baseline design relatively quickly (→ CDR)

Critical R&D:

- industrialisation
- cost reduction
- 'value engineering'

The Global Design Effort GDE



European Design Group

Int. Design Group

US Design Group

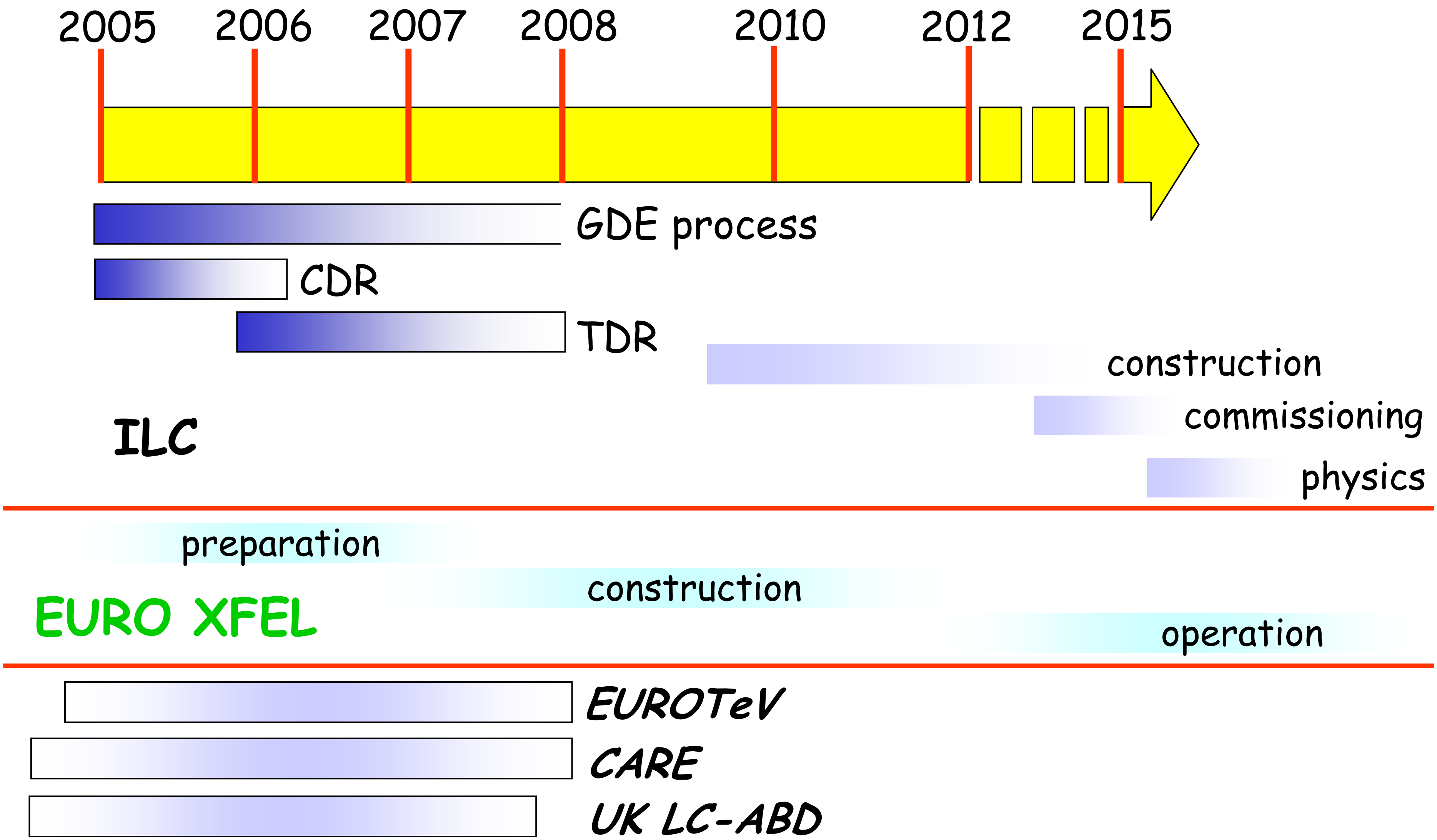
Asian Design Group

- 3 Regional Design Teams
- Central Group with Director

- **Goal:**

  Produce an internal full costed ILC Technical Design Report by 2008

Project Timelines



2005 2006 2007 2008 2010 2012 2015

GDE process

CDR

TDR

construction

commissioning

physics

ILC

preparation

construction

operation

EURO XFEL

EUROTeV

CARE

UK LC-ABD

European Funding for ILC R&D

Structured and integrated European area in the field of accelerator research and related R&D.

3 Networking Activities and 4 Joint Research Activities.

European Design Study

(27 institutions, including CERN and DESY)

With top marks (score: 4.8/5), EU funding: ~9 M€

Kick-off meeting 1.11.2004

Summary

- The ILC is ambitious project which pushed the envelope in every subsystem:
  - Main SCRF linac — cost driver
  - sources
  - damping rings
  - beam delivery

  } ***ILC*** performance bottleneck

- Still many accelerator physics issues to deal with, but **reliability** and **cost issues** are probably the **greater challenge**
- Probably in excess of 3000 man-years already invested in design work.

Comments

- Still in 'recoil' from Aug. 20th Technology decision
  - the ILC world is still ringing
- Must make moves quickly to 'suppress the rapid increase in entropy'
  - need the GDE (and its director!). Possibly this month
  - formal structure required to contain and focus enthusiasm
- Should aim for baseline design by Snowmass Workshop in August
  - tough decisions to be made in next six months by WGs
  - baseline design to be used for CDR (early 2006)
- We must learn to be 'One Lab'
  - perhaps more challenging than the machine itself ☺

Final Message

- ILC is a great opportunity for HEP
- Physics expectations are great
- The interest for the cold technology is enormous
- As in the past, HEP will have a leading role in technology development for scientific and human applications