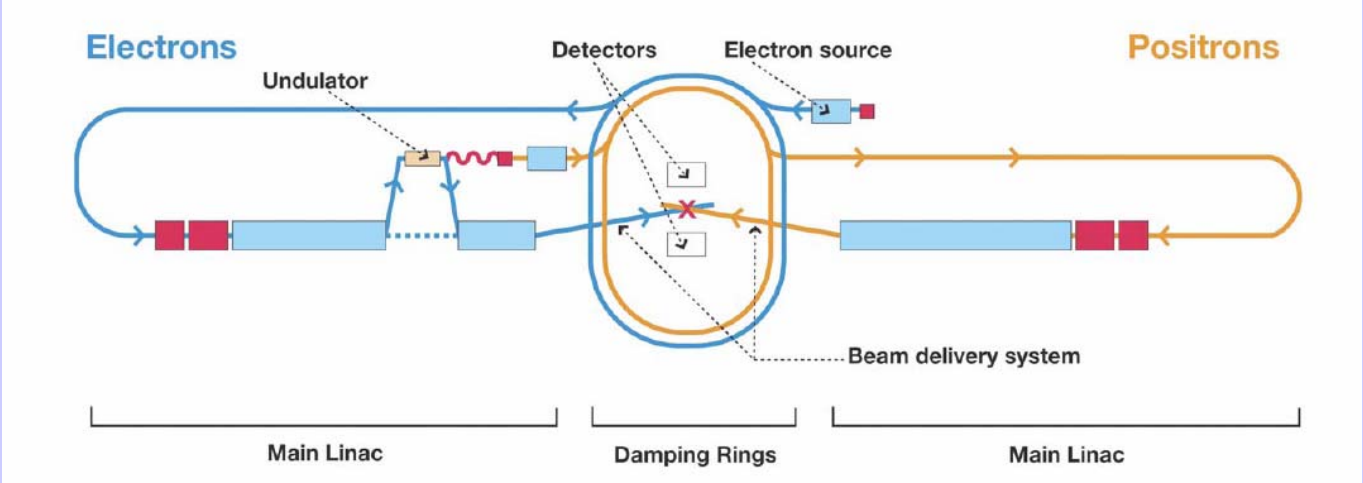
April Meeting

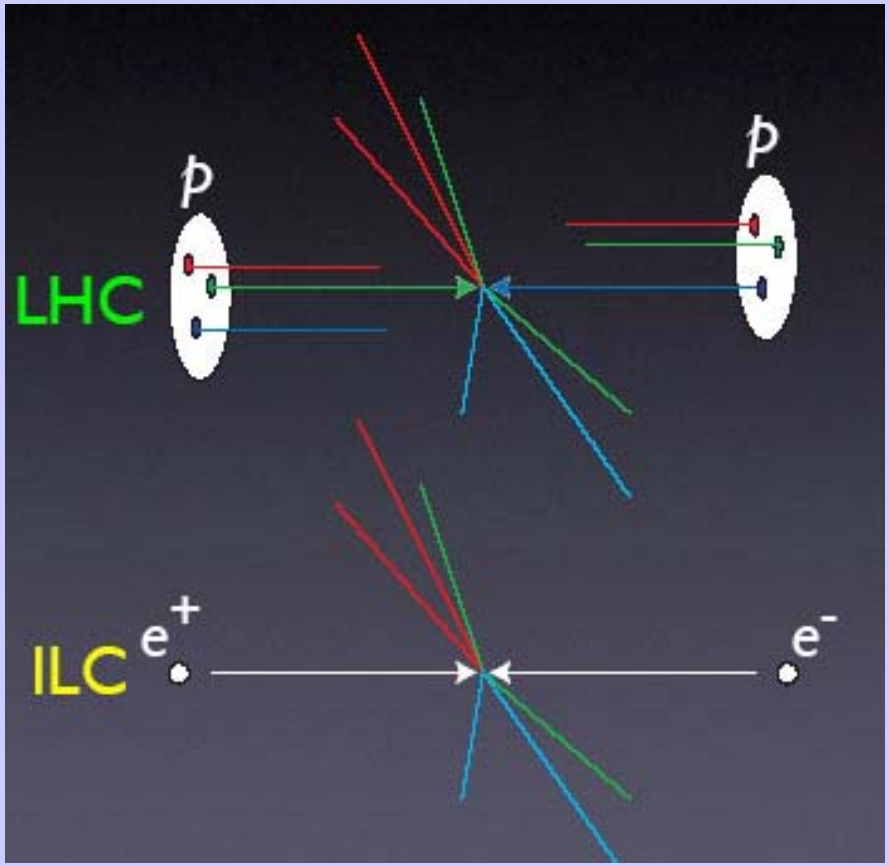
# International Linear Collider



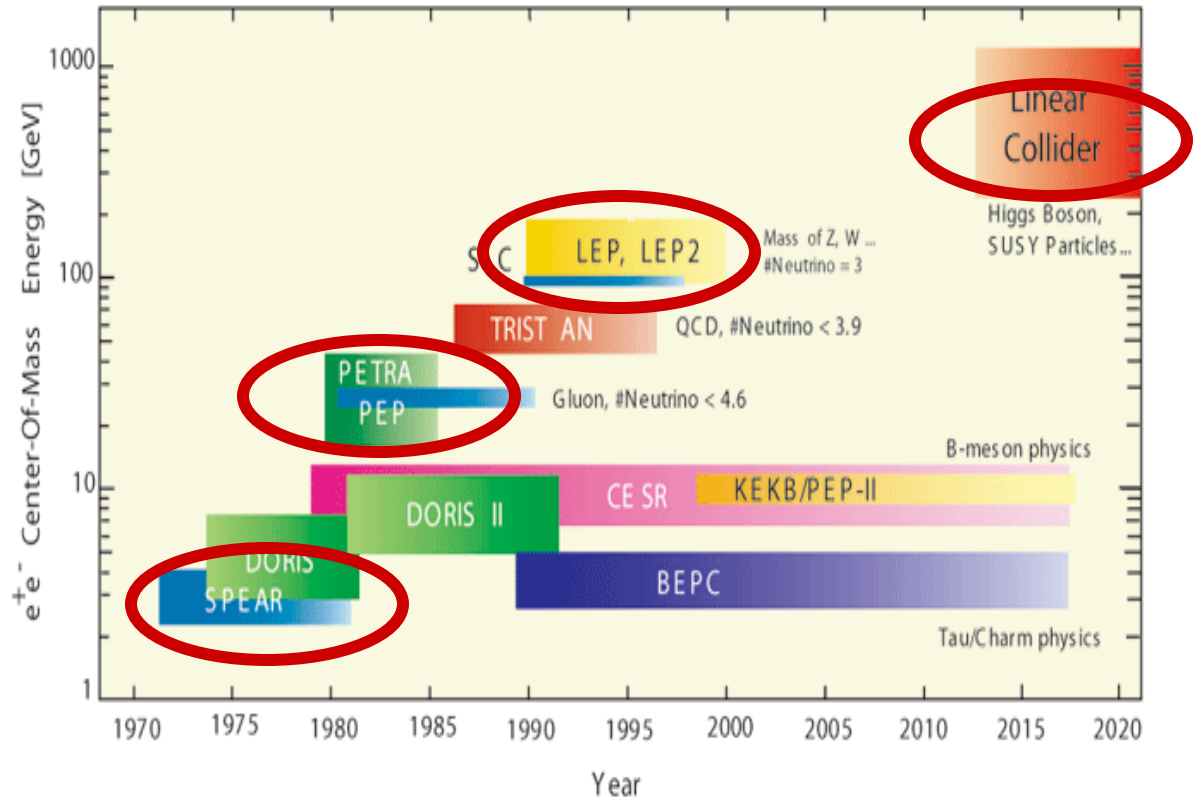

*Barry Barish*
GDE / Caltech
14-April-07

# Why $e^+e^-$ Collisions ?

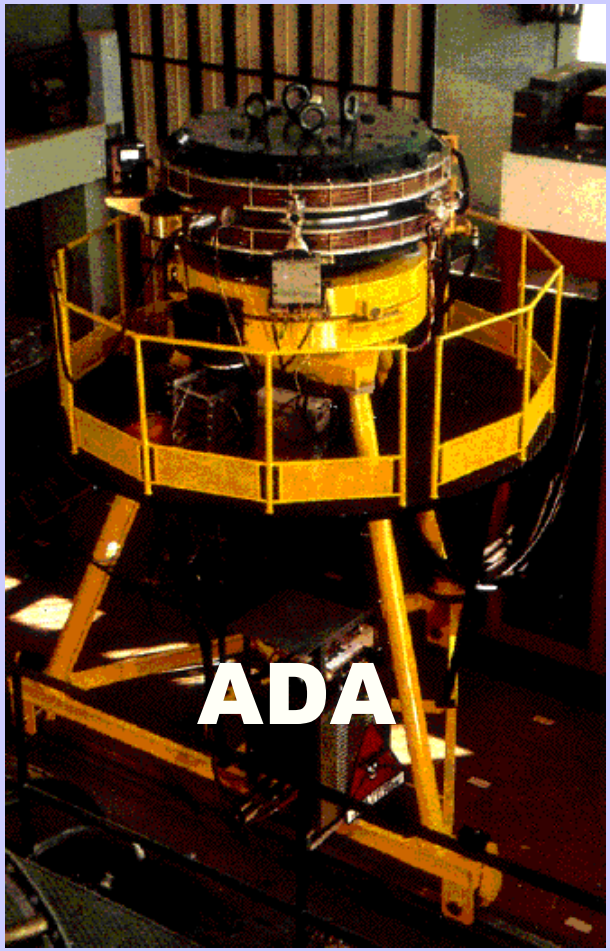
- elementary particles
- well-defined
  - energy,
  - angular momentum
- uses full COM energy
- produces particles democratically
- can mostly fully reconstruct events



# Electron Positron Colliders
# The Energy Frontier



# Electron-Positron Colliders

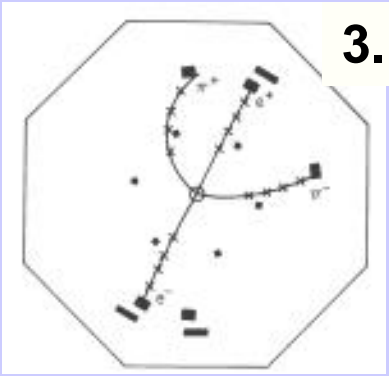



**Bruno Touschek built the first successful electron-positron collider at Frascati, Italy (1960)**

**Eventually, went up to 3 GeV**

# But, not quite high enough energy ....

SPEAR at SLAC

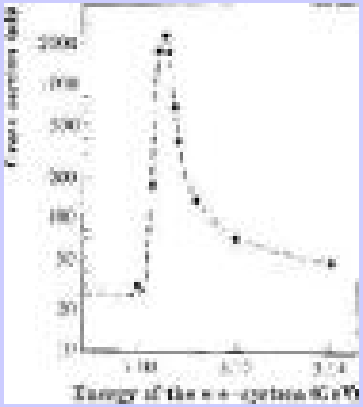


3.1 GeV

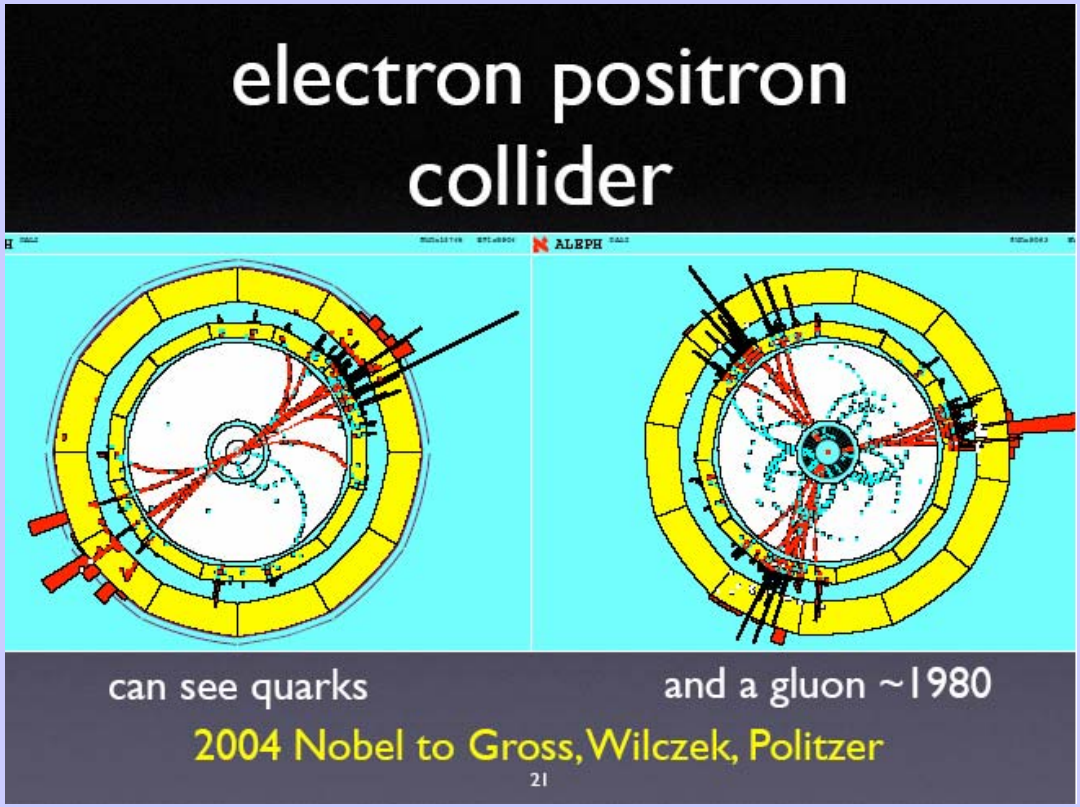
Burt Richter
Nobel Prize

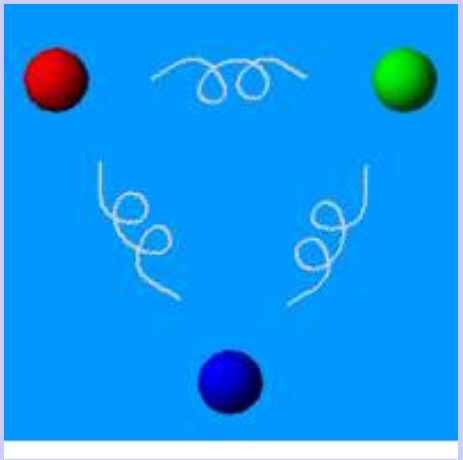
and

Discovery
Of
Charm
Particles



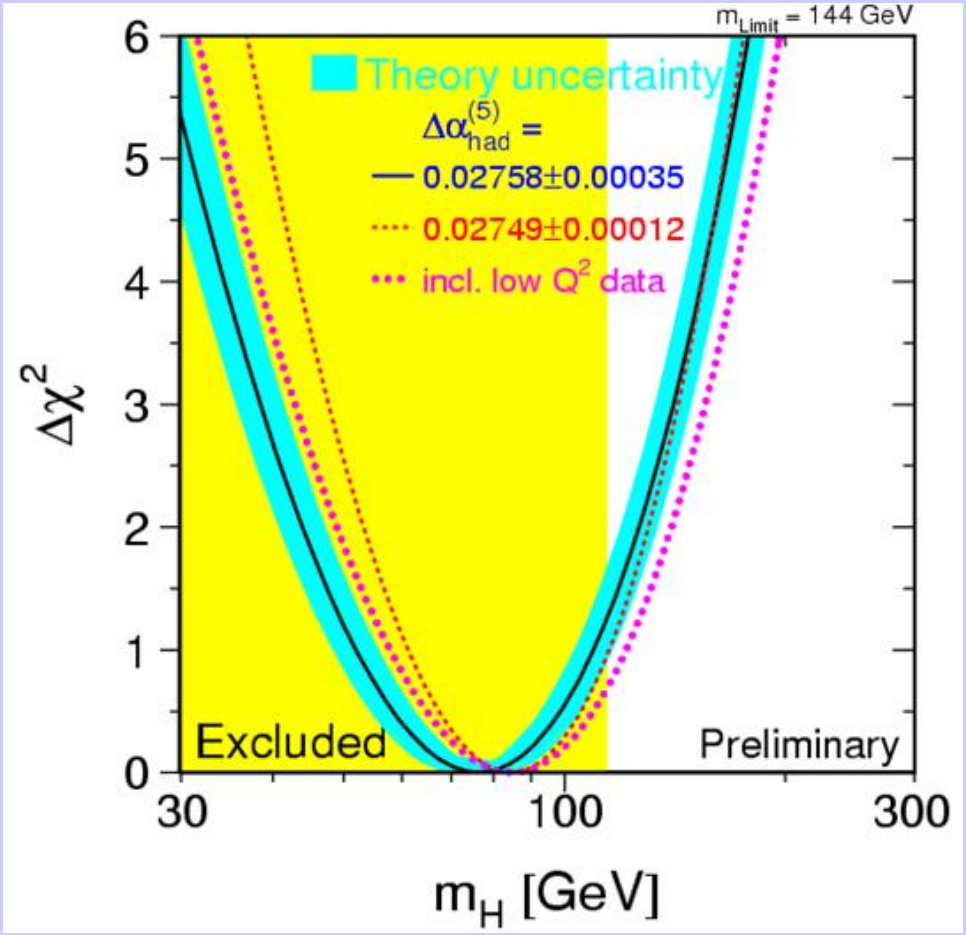
# The rich history for $e^+e^-$ continued as higher energies were achieved …



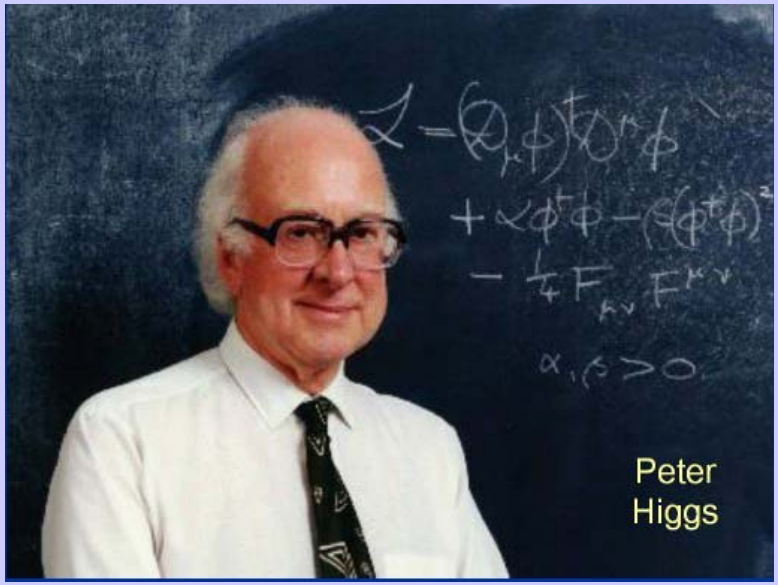
**DESY PETRA Collider**

# Precision Measurements at LEP




## What causes mass??

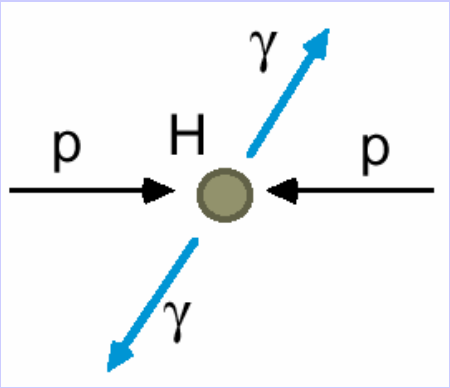
**The mechanism – Higgs or alternative appears around the corner**

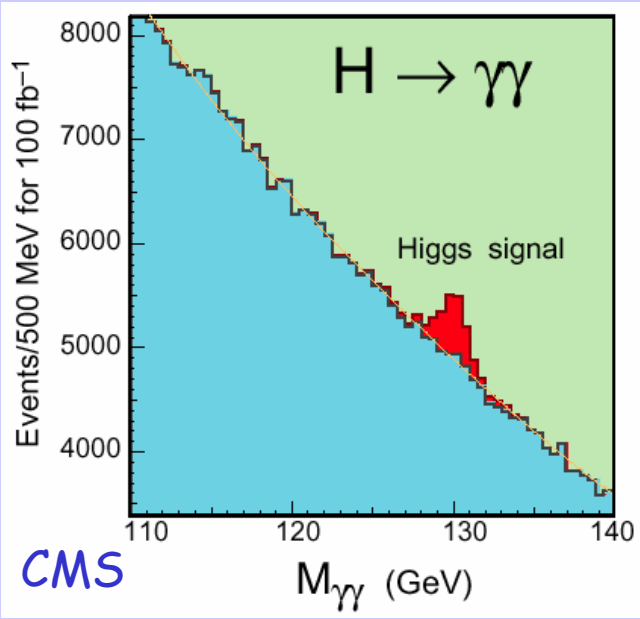


# LHC: Low mass Higgs: H → γγ

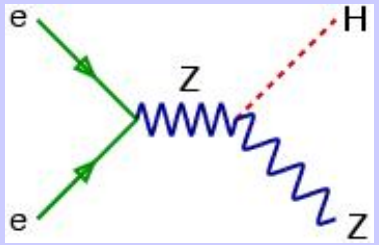
## $M_H < 150\ GeV/c^2$

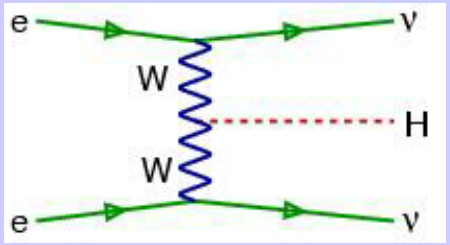
- **Rare decay channel: BR~$10^{-3}$**
- **Requires excellent electromagnetic calorimeter performance**
  - acceptance, energy and angle resolution,
  - g/jet and g/$p^0$ separation
  - Motivation for LAr/$PbWO_4$ calorimeters for CMS
- **Resolution at 100 GeV: $\sigma \approx 1$ GeV**
- **Background large: S/B ≈ 1:20, but can estimate from non signal areas**

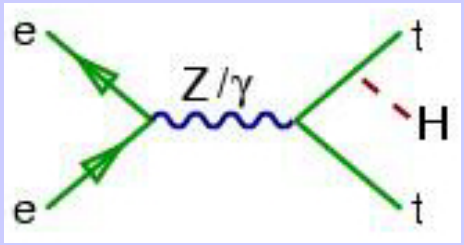


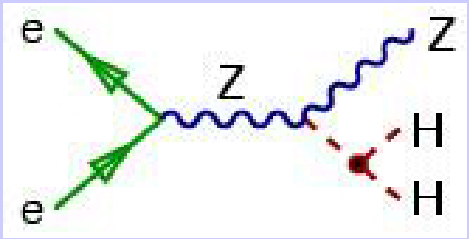



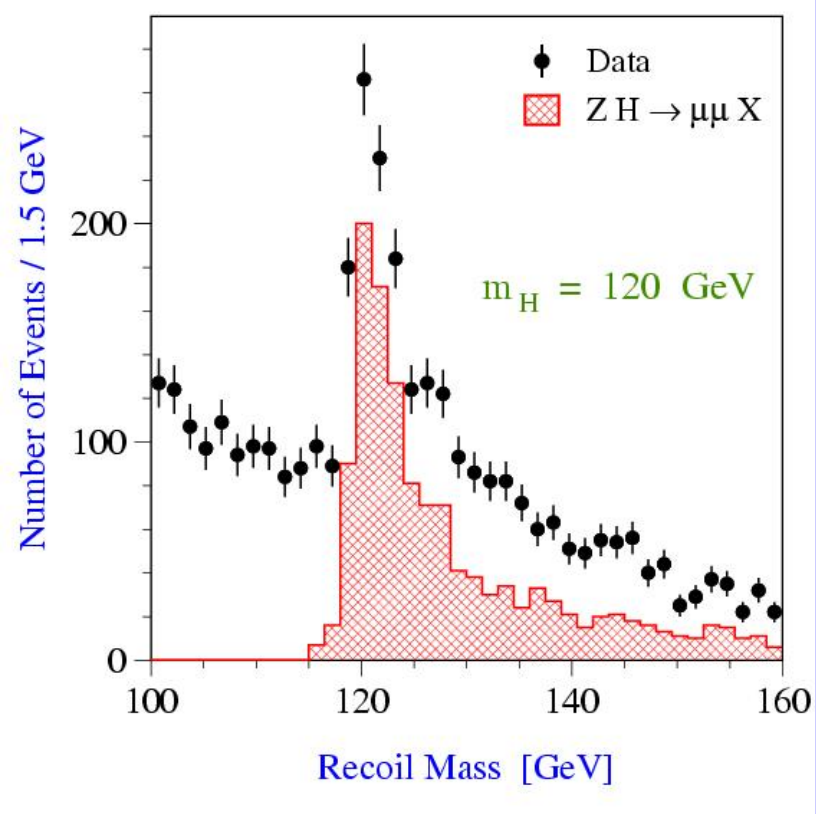
# ILC: Precision Higgs physics



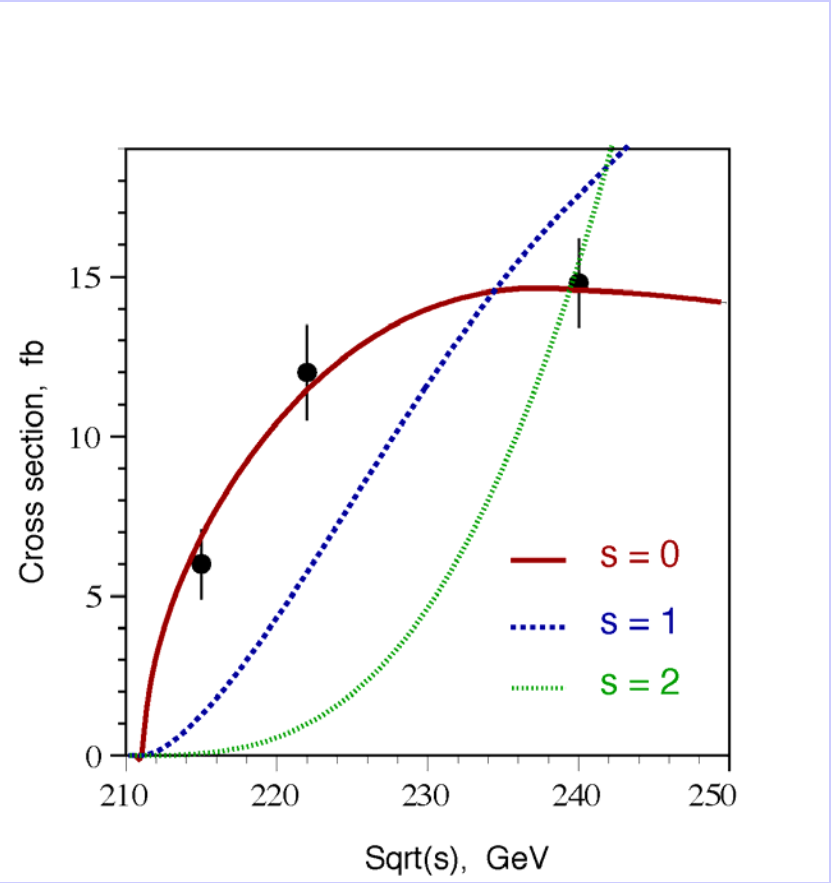




- **Model-independent Studies**
  - **mass**
  - **absolute branching ratios**
  - **total width**
  - **spin**
  - **top Yukawa coupling**
  - **self coupling**
- **Precision Measurements**

Garcia-Abia et al

# How do you know you have discovered the Higgs ?

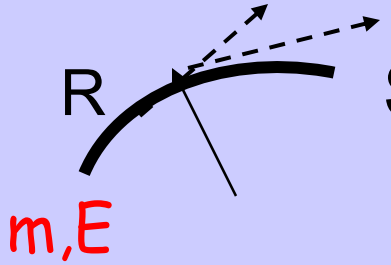



***Measure the quantum numbers. The Higgs must have spin zero !***

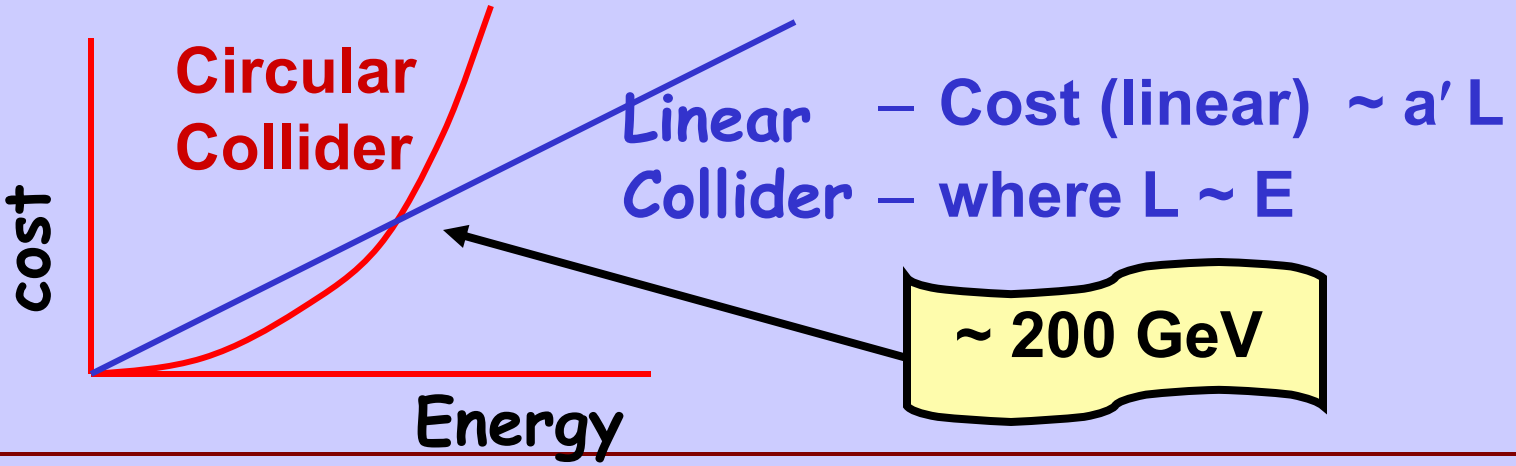
**The linear collider will measure the spin of any Higgs it can produce by measuring the energy dependence from threshold**

# Why Linear?

- **Circular Machine**
  - $\Delta E \sim (E^4 / m^4 R)$
  - Cost $\sim a R + b \Delta E$
    $\sim a R + b (E^4 / m^4 R)$
  - **Optimization :** $R \sim E^2 \Rightarrow$ Cost $\sim c E^2$



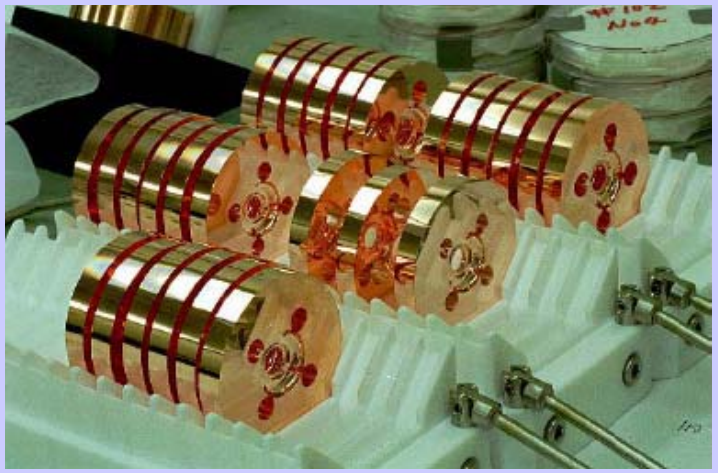

Synchrotron Radiation



# ILC – The Underlying Technology

- **Room temperature copper structures**

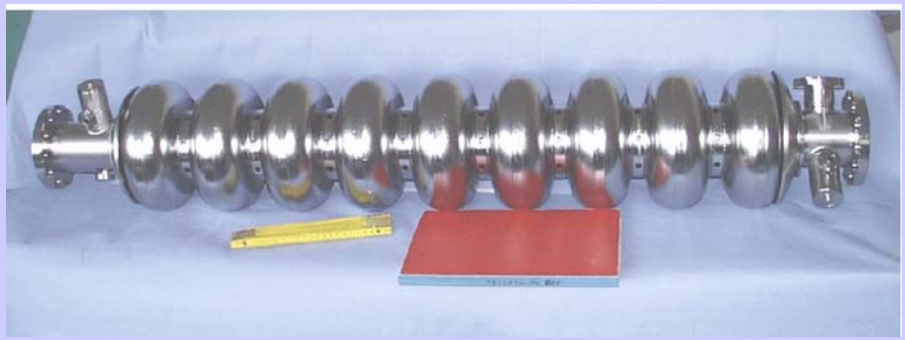
  **(KEK & SLAC)**



OR

- **Superconducting RF cavities**

  **(DESY)**



# Luminosity & Beam Size

$$L = \frac{n_b N^2 f_{rep}}{2\pi \Sigma_x \Sigma_y} H_D$$

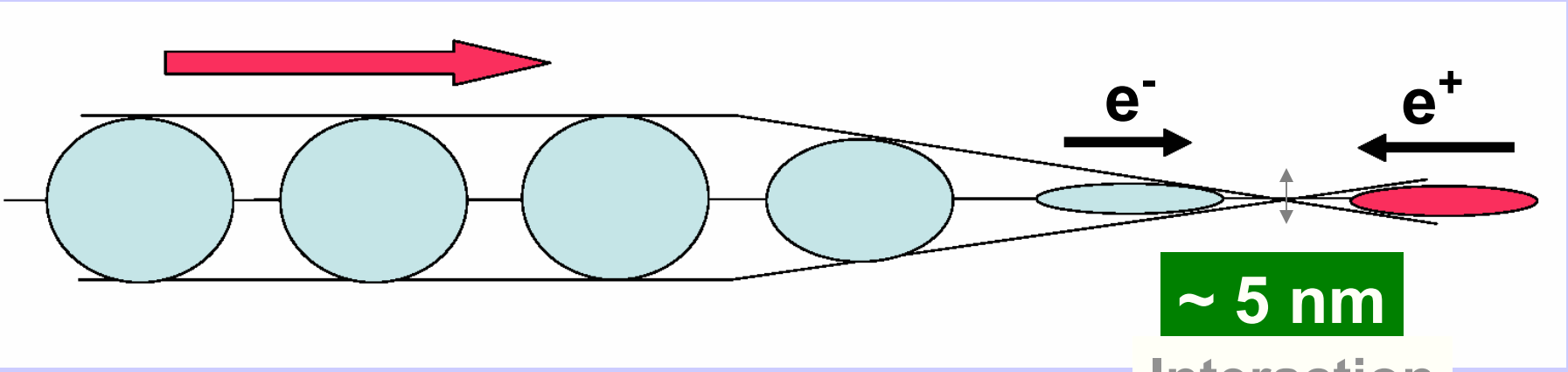
- $f_{rep} * n_b$ tends to be low in a linear collider

| | $L$ | $f_{rep}$ [Hz] | $n_b$ | N [$10^{10}$] | $\sigma_x$ [$\mu$m] | $\sigma$y [$\mu$m] |
|---|---|---|---|---|---|---|
| ILC | $2x10^{34}$ | 5 | 3000 | 2 | 0.5 | 0.005 |
| SLC | $2x10^{30}$ | 120 | 1 | 4 | 1.5 | 0.5 |
| LEP2 | $5x10^{31}$ | 10,000 | 8 | 30 | 240 | 4 |
| PEP-II | $1x10^{34}$ | 140,000 | 1700 | 6 | 155 | 4 |

- Achieve luminosity with spot size and bunch charge

# Achieving High Luminosity

- Low emittance machine optics
- Contain emittance growth
- Squeeze the beam as small as possible



# The Role of ICFA


**ICFA, the International Committee for Future Accelerators, was created to facilitate international collaboration in the construction and use of accelerators for high energy physics. It was created in 1976 by the International Union of Pure and Applied Physics.**

**Its purpose, as stated in 1985, are as follows:**

- **To promote international collaboration in all phases of the construction and exploitation of very high energy accelerators**
- **To organize regularly world-inclusive meetings for the exchange of information on future plans for regional facilities and for the formulation of advice on joint studies and uses**
- **To organize workshops for the study of problems related to super high-energy accelerator complexes and their international exploitation and to foster research and development of necessary technology**

# Global Planning
## *A Must for HEP*


- **Never before has a field of science attempted to globalize itself as extensively as HEP has done recently. It is a challenging task, but one that must be accomplished. *Indeed the long-term health of the field depends critically on truly global cooperation***

- **The necessity for global coordination was formalized by ICFA in its May 1993 ICFA Statement entitled "International Collaboration in the Construction of Future Large Accelerator Projects".**

- **ICFA's role was crucial for the ultimate realization of a *global* LHC and is crucial for launching the ILC**

# ICFA and the Linear Collider

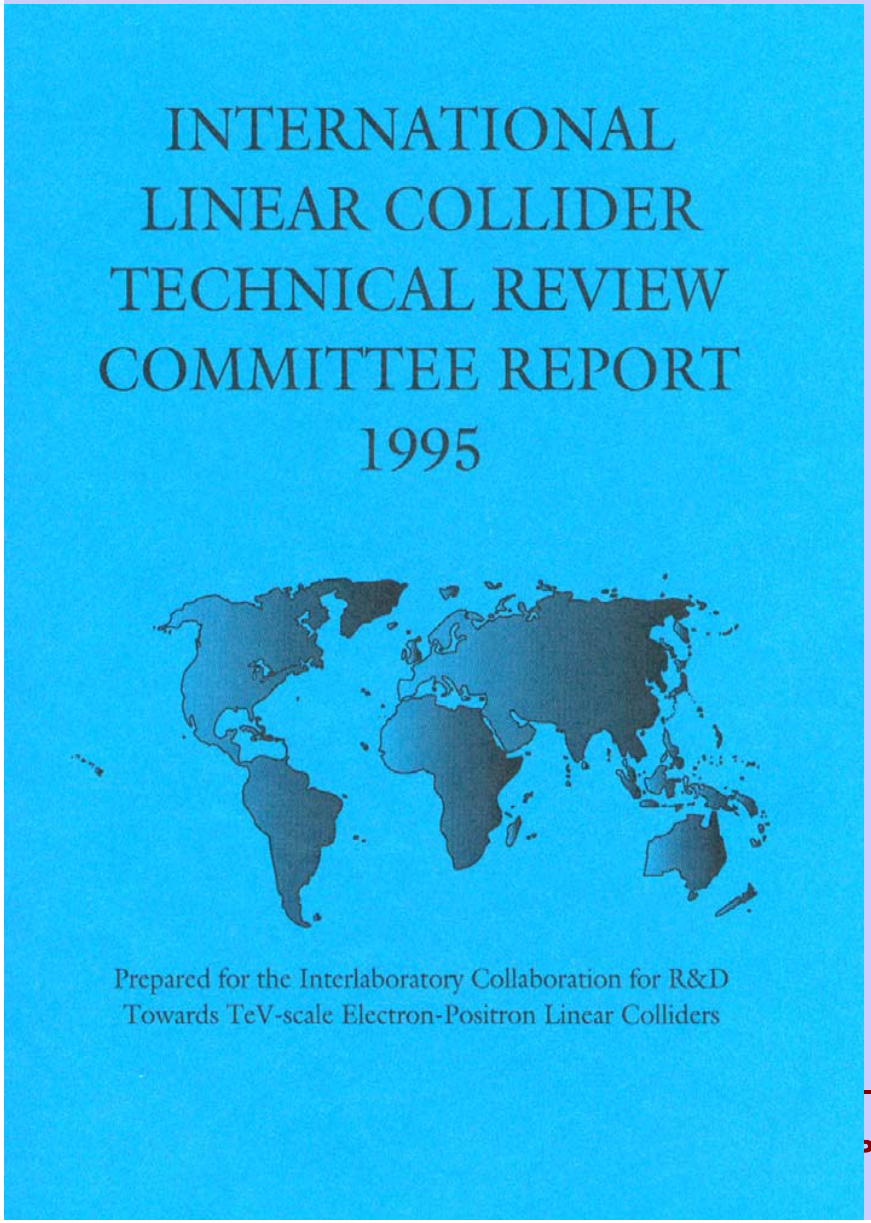

- **ICFA has been helping guide international cooperation on the Linear Collider since the mid 1990's. Major early steps:**

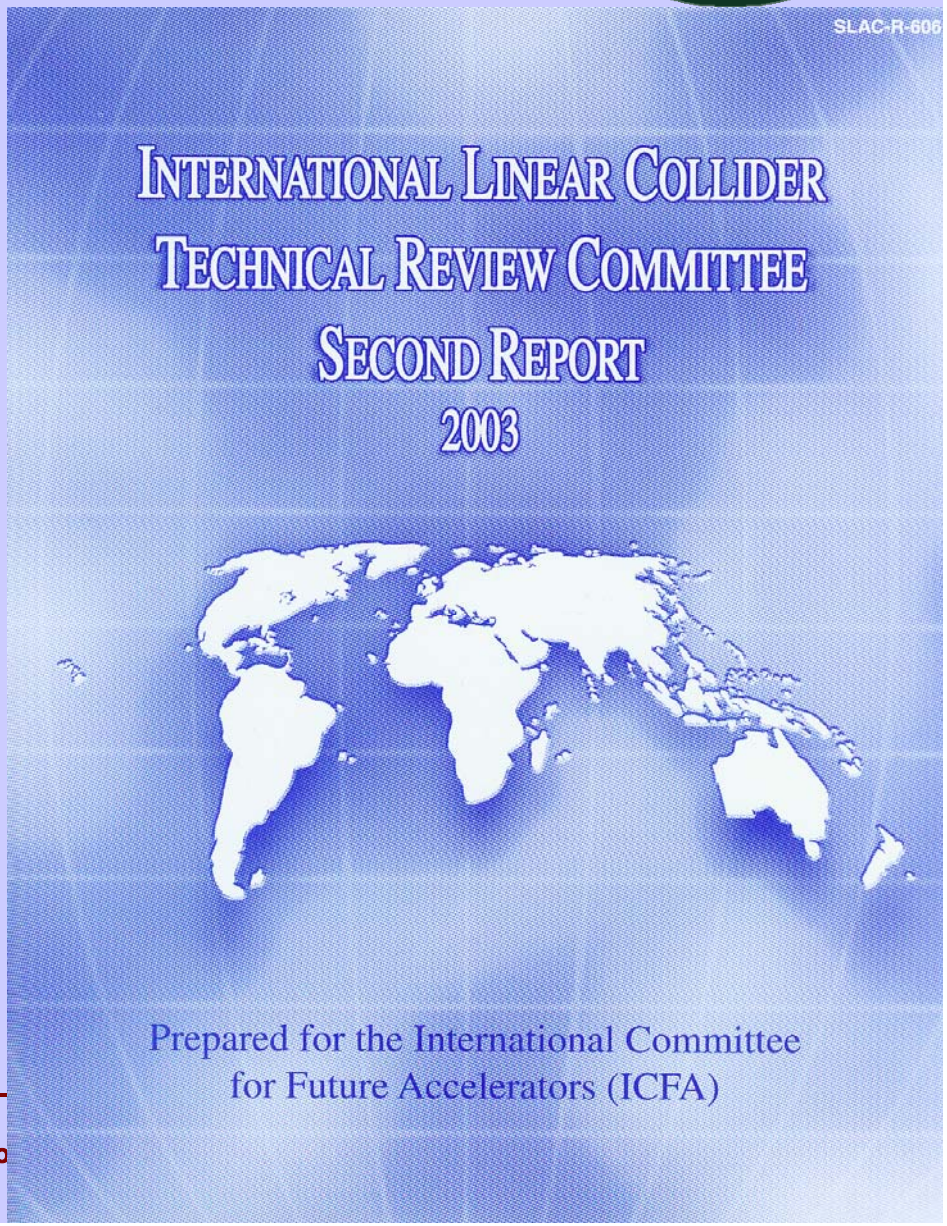
**1995: First ILC Technical Review Committee (TRC) Report, under Greg Loew as Chair**

**1999: ICFA Statement on Linear Collider**

**2002: ICFA commissioned the second ILC TRC Report, under Greg Loew as Chair**

# TRC Reports


INTERNATIONAL
LINEAR COLLIDER
TECHNICAL REVIEW
COMMITTEE REPORT
1995
Prepared for the Interlaboratory Collaboration for R&D
Towards TeV-scale Electron-Positron Linear Colliders

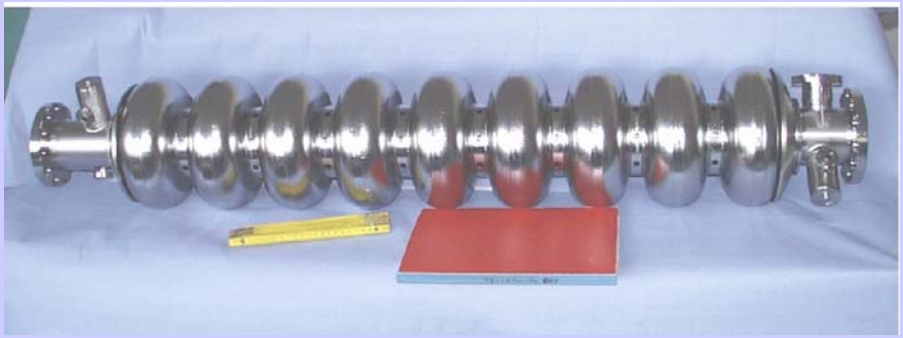

SLAC-R-606
INTERNATIONAL LINEAR COLLIDER
TECHNICAL REVIEW COMMITTEE
SECOND REPORT
2003
Prepared for the International Committee
for Future Accelerators (ICFA)

# International Technology Review Panel

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

# The ITRP Recommendation

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



  - **This recommendation is made with the understanding that we are recommending a technology, not a design. We expect the final design to be developed by a team drawn from the combined warm and cold linear collider communities, taking full advantage of the experience and expertise of both (from the Executive Summary).**

# SCRF Technology Recommendation

- The recommendation of ITRP was presented to ILCSC & ICFA on August 19, 2004 in a joint meeting in Beijing.
- ICFA unanimously endorsed the ITRP's recommendation on August 20, 2004

# 2002: Worldwide Concensus on Next Major HEP Facility

- **In 2002, future-looking planning exercises in Europe (ECFA), Asia (ACFA) and the US (HEPAP) resulted in a unanimous alignment of each regions highest priority goal, namely the support for the construction of a 500 GeV electron positron linear collider as a necessary physics companion for the LHC**
  - **ECFA, ACFA & HEPAP all endorsed this as an urgent need. All regions strongly urged that the project be fully international from the outset**

# Global Effort on Design / R&D for ILC


**Joint Design, Implementation, Operations, Management**
**Host Country Provides Conventional Facilities**

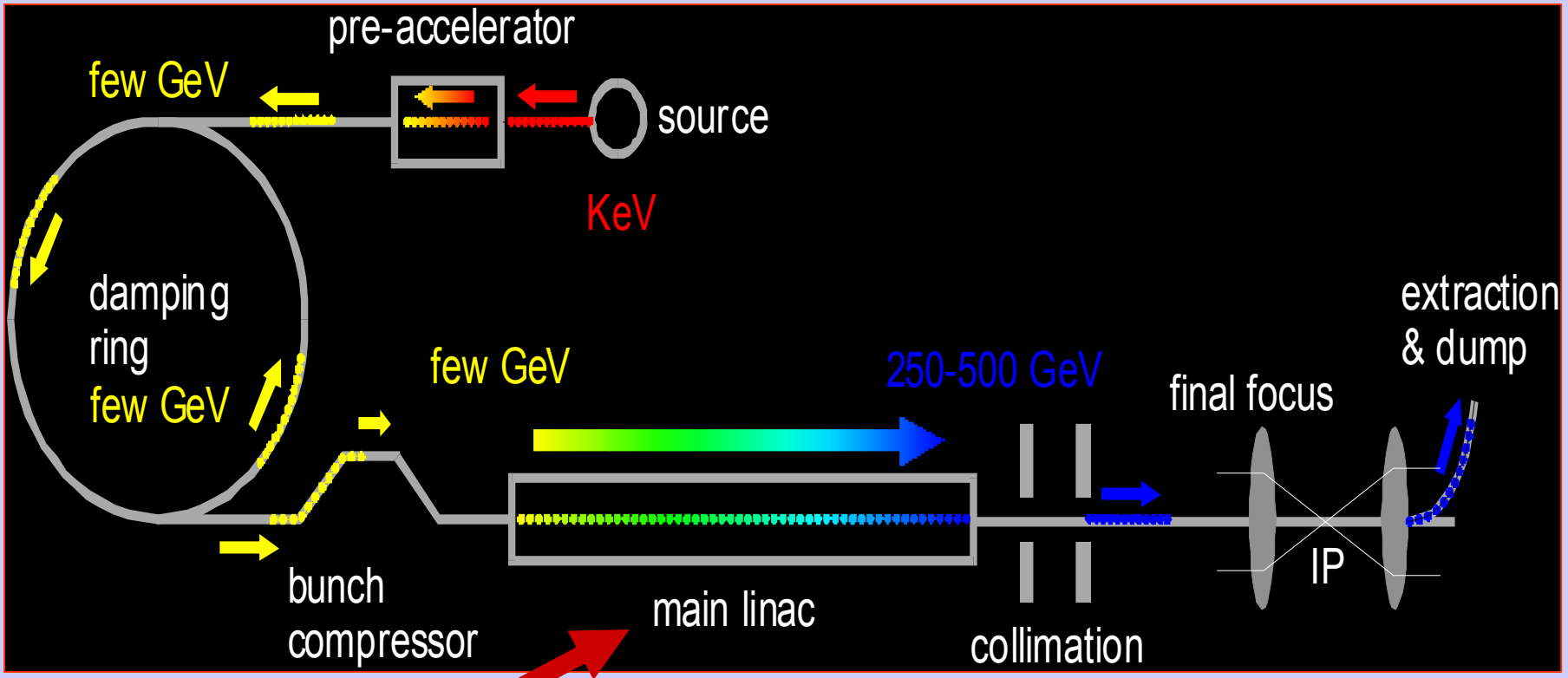
# ICFA (2002): ILC Organizational Structure

# The Role of Governments

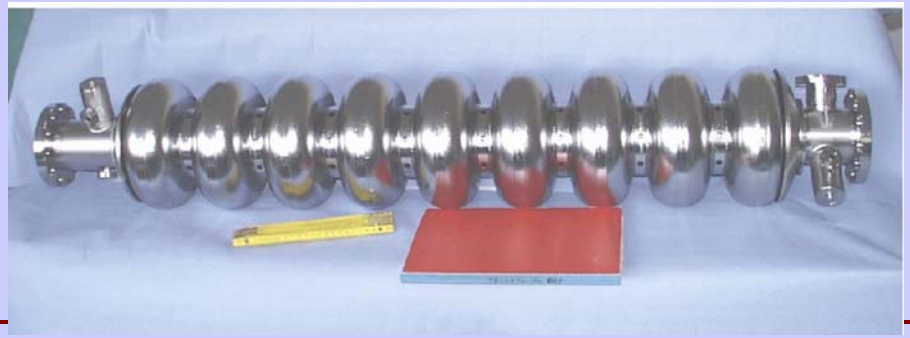
- Governments are the key – they will make the decisions that lead to the establishment of an ILC project

- The scientific community, through ICFA, are maintaining close contact with the key government agencies
  - The main forum is the Funding Agencies for Large Colliders (FALC), which meets about twice a year. Major strategy steps (like ITRP, GDE etc) are discussed with FALC to ensure acceptance by the governments of ICFA's actions

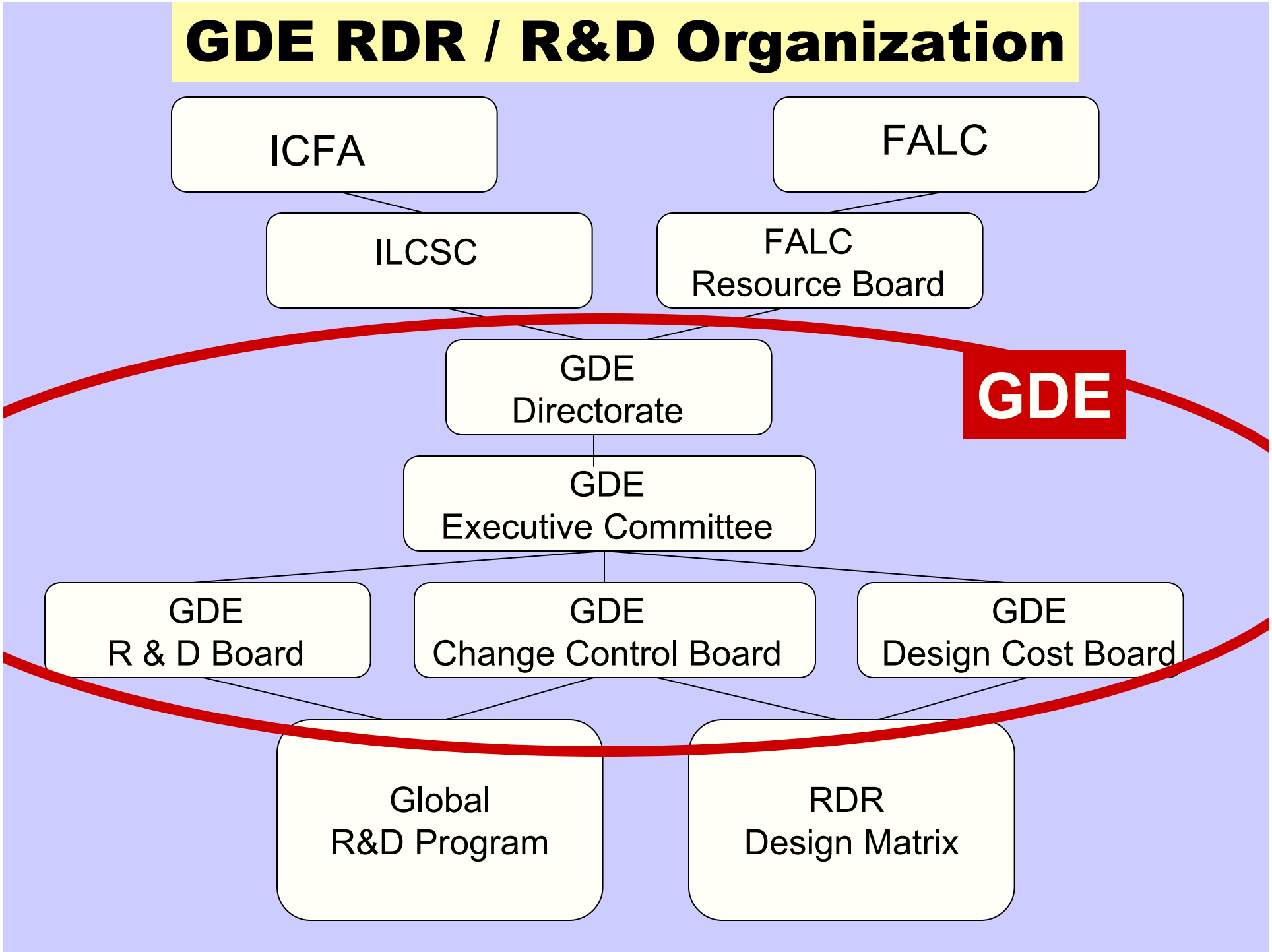
# Designing a Linear Collider




**Superconducting RF Main Linac**

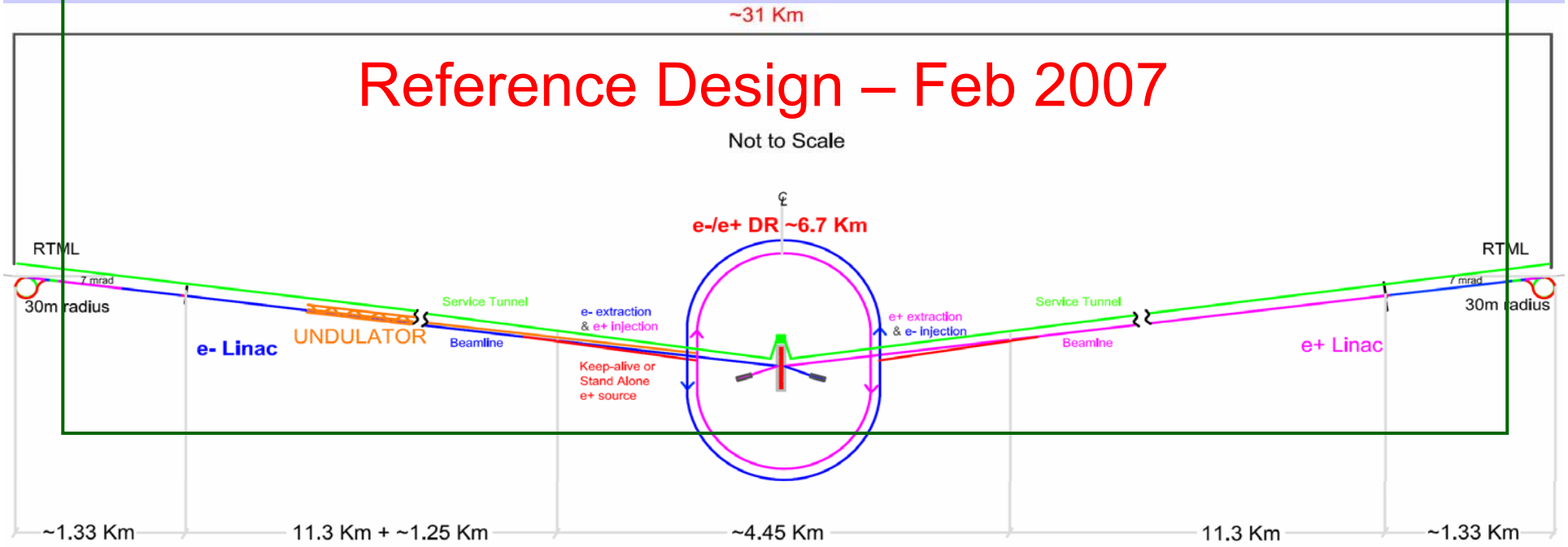


# GDE RDR / R&D Organization



# ILC Reference Design

- 11km SC linacs operating at 31.5 MV/m for 500 GeV
- Centralized injector
  - Circular damping rings for electrons and positrons
  - Undulator-based positron source
- Single IR with 14 mrad crossing angle
- Dual tunnel configuration for safety and availability




**Documented in Reference Design Report**

# ILC Reference Design

| | | |
|---|---|---|
| Max. Center-of-mass energy | 500 | GeV |
| Peek Luminosity | ~$2x10^{34}$ | $1/cm^2s$ |
| Beam Current | 9.0 | mA |
| Repetition rate | 5 | Hz |
| Average accelerating gradient | 31.5 | MV/m |
| Beam pulse length | 0.95 | ms |
| Total Site Length | 31 | km |
| Total AC Power Consumption | ~230 | MW |

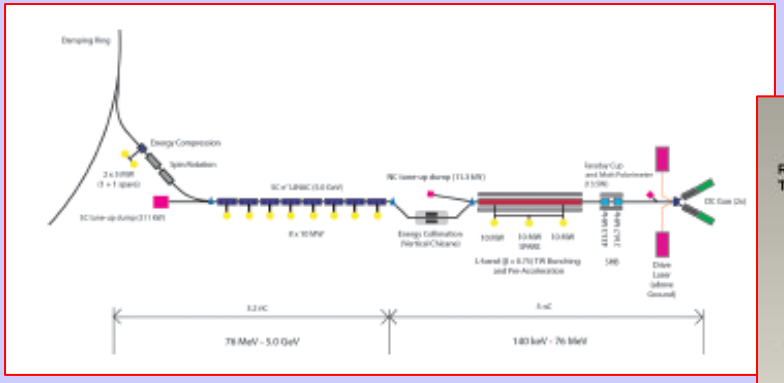
# ILC Physics Goals

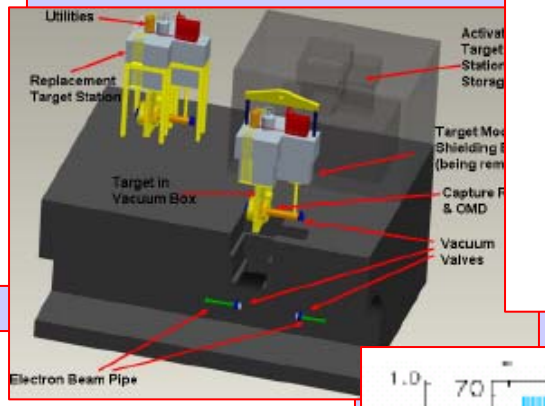
- $E_{cm}$ adjustable from 200 – 500 GeV
- Luminosity → $\int L dt$ = 500 $fb^{-1}$ in 4 years
- Ability to scan between 200 and 500 GeV
- Energy stability and precision below 0.1%
- Electron polarization of at least 80%

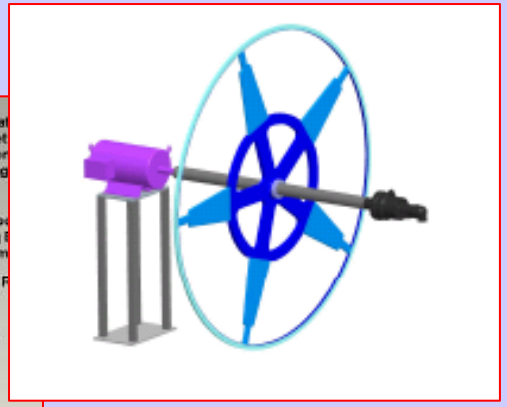
- The machine must be upgradeable to 1 TeV

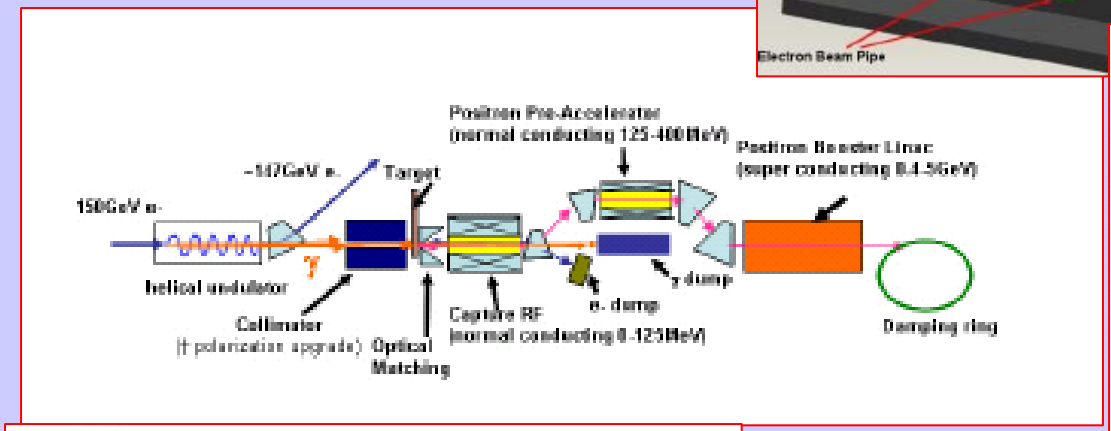
**The Reference Design meets the goals of the ICFA- ILCSC parameters study**

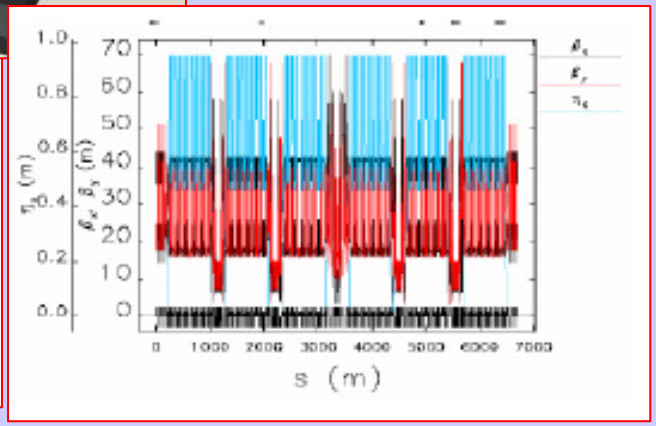
# Next Step – Engineering Design

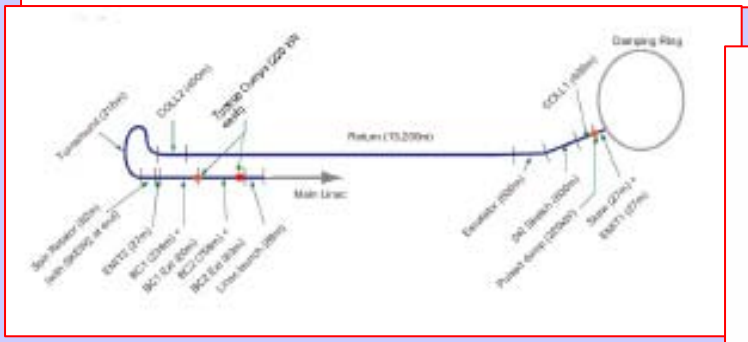






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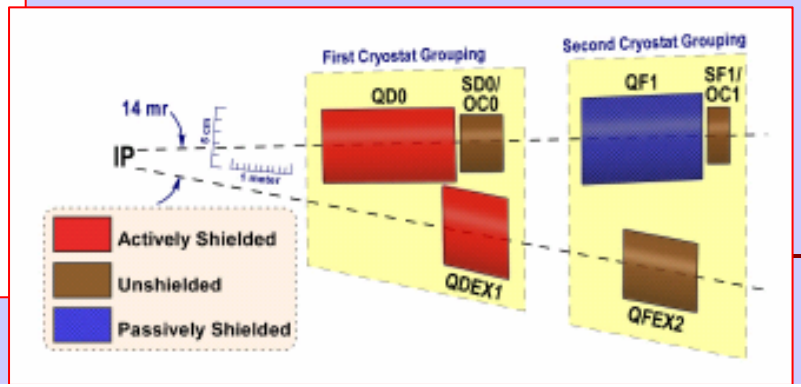


**+ Main Linac**

# R&D Task Forces

**S0**
**High-Gradient Cavities**

**S1**
**High-Gradient Cryomodule**

**S2**
**Test Linac**

**S3**
**Damping Ring**

**S4**
**Beam Delivery**

S5…Sn

To address priority R&D items, RDB has convened several 'task forces'.

These programs are being developed with milestones needed for –

- engineering proposal
- construction start
- fabrication & commissioning

# The GDE Plan and Schedule