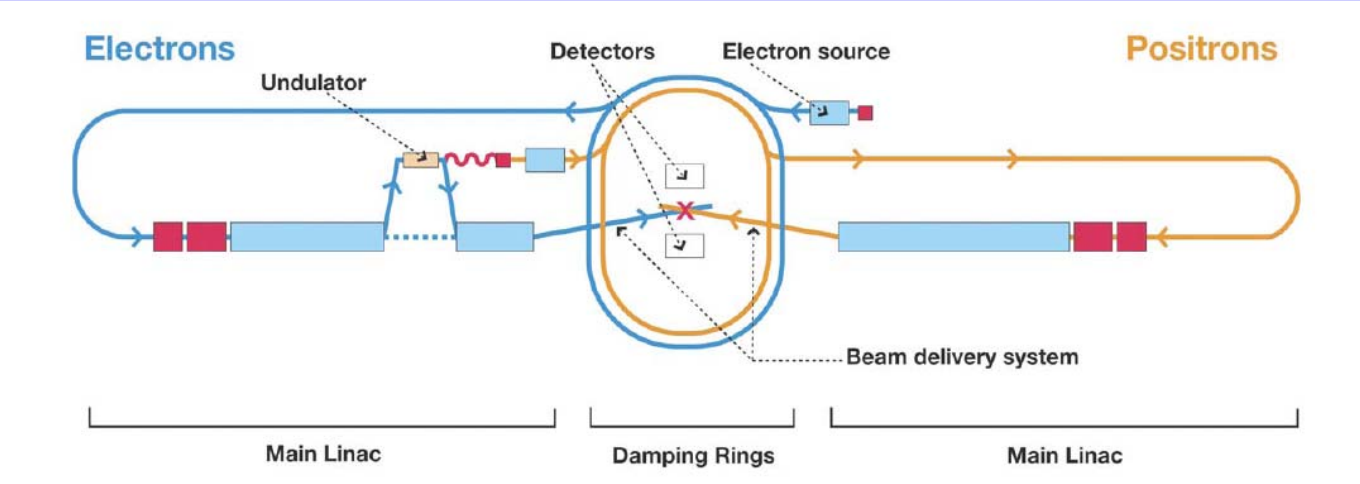
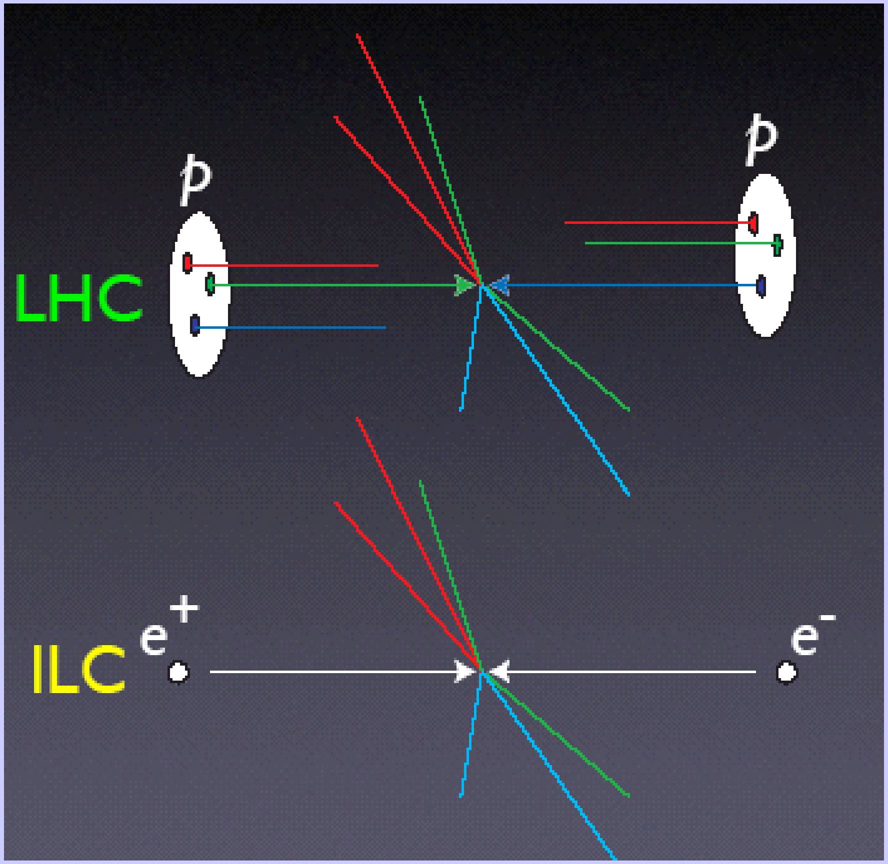
International Linear Collider



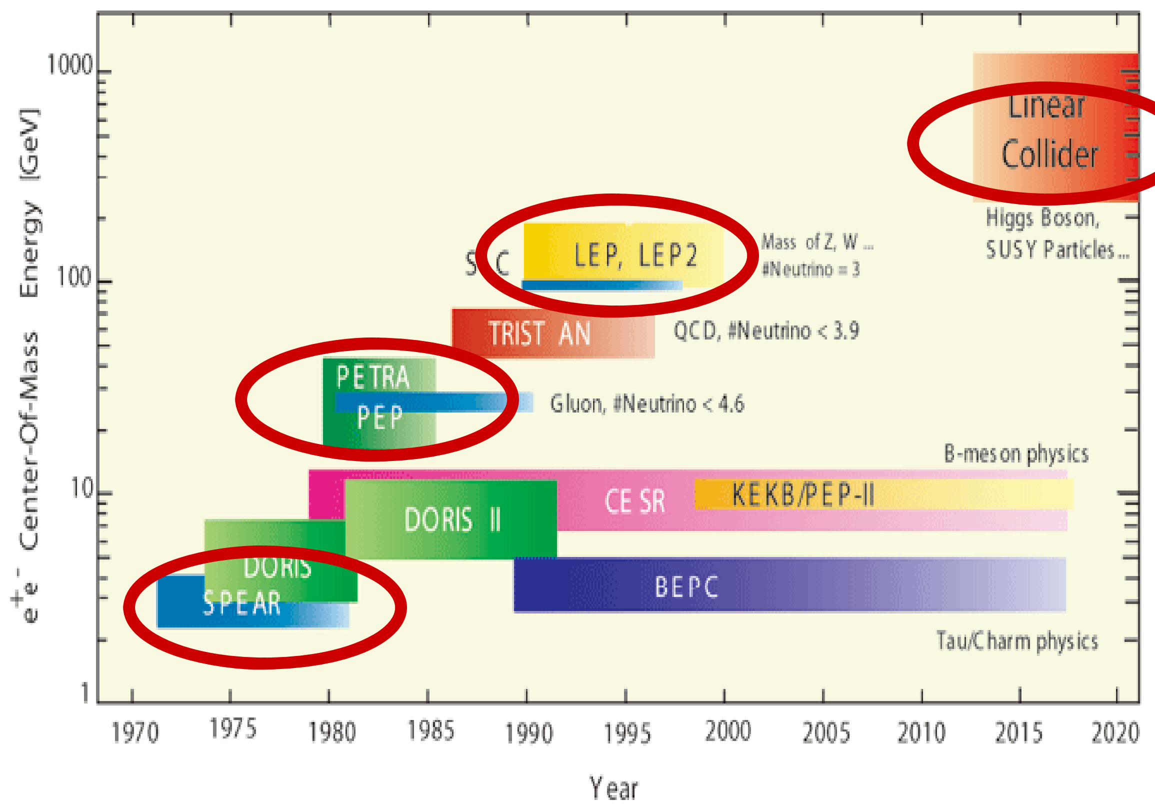
Barry Barish
Caltech
15-Feb-08

Why e^+e^- Collisions ?

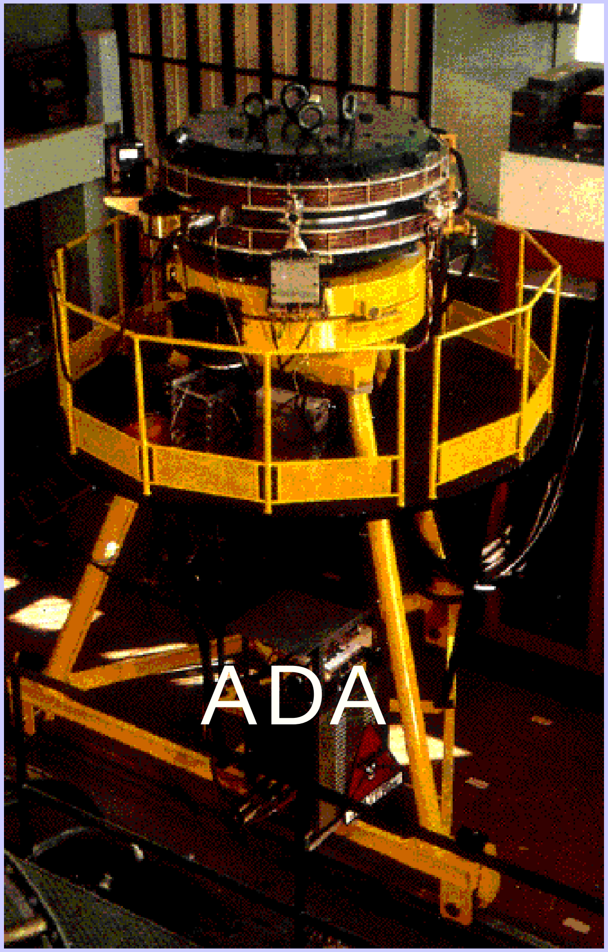
- elementary particles
- well-defined
  - energy,
  - angular momentum
- uses full COM energy
- produces particles democratically
- can mostly fully reconstruct events



Electron Positron Colliders
The Energy Frontier



Electron-Positron Colliders

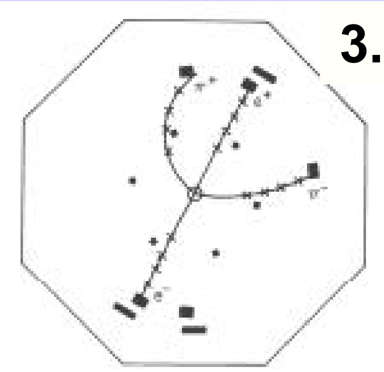


Bruno Touschek built the first successful electron-positron collider at Frascati, Italy (1960)

Eventually, went up to almost 3 GeV

A revolution in particle physics ....

SPEAR at SLAC

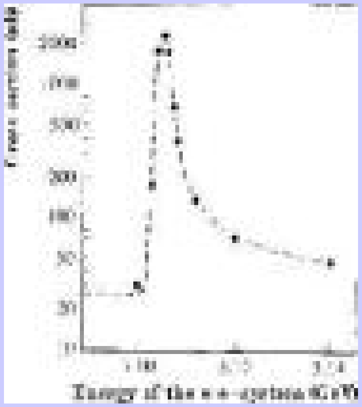


3.1 GeV

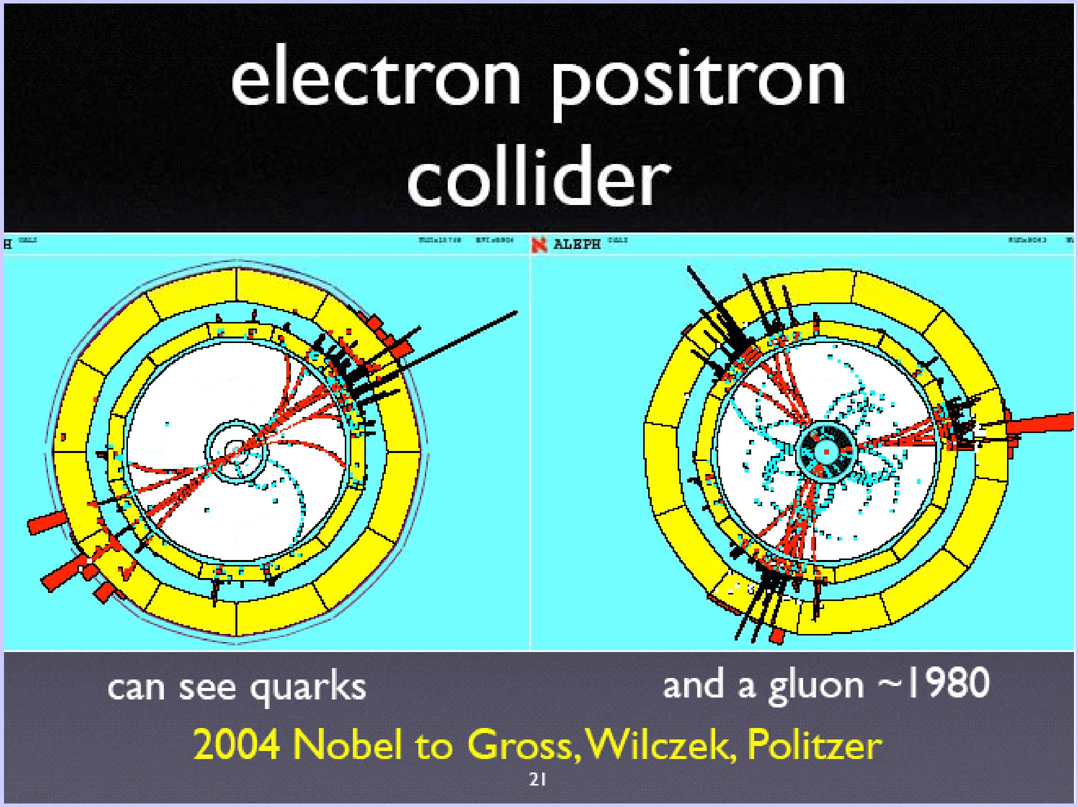
Burt Richter
Nobel Prize

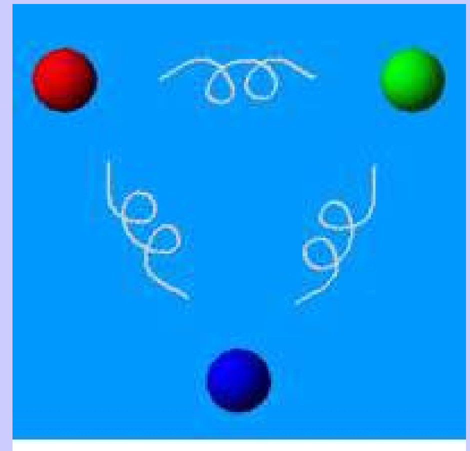
and

Discovery
Of
Charm
Particles



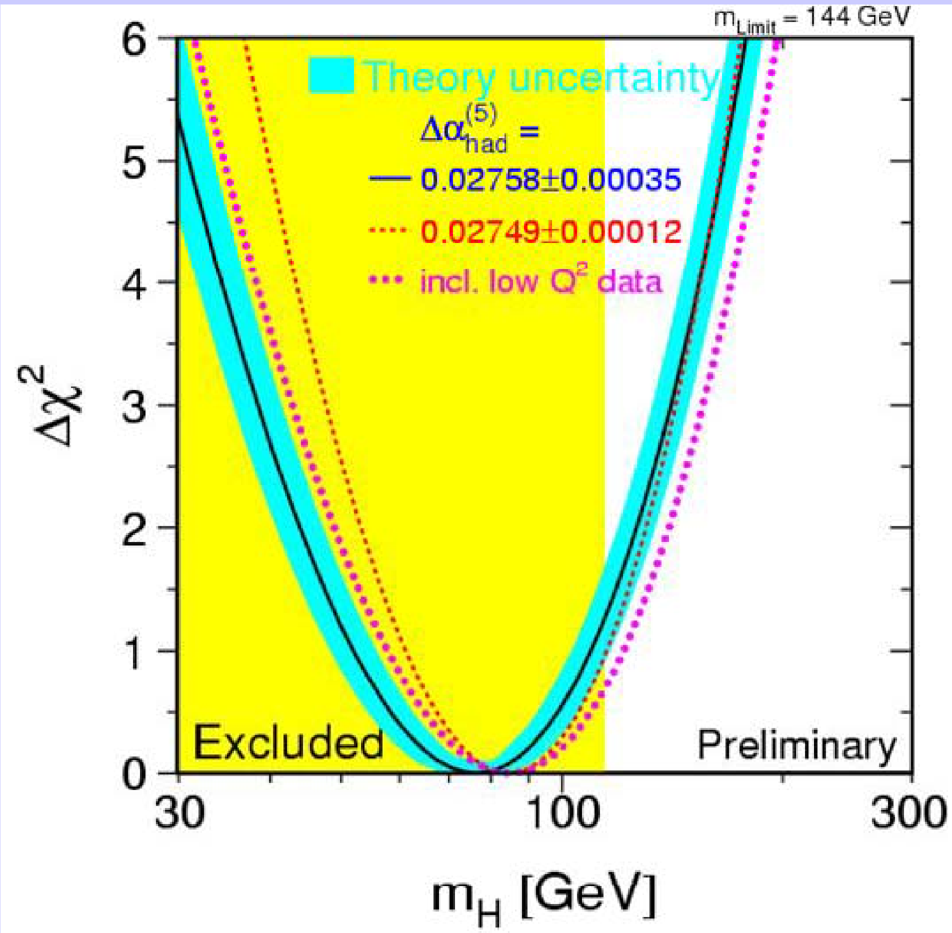
The rich history for e^+e^- continued as higher energies were achieved …





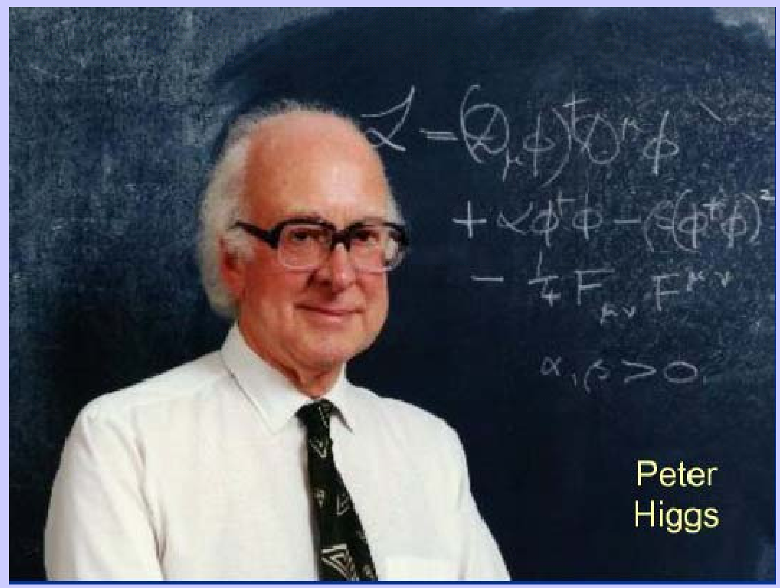
DESY PETRA Collider

Precision measurements at CERN/LEP and SLAC/SLC establish Standard Model and set the stage for next generation ..



What causes mass??

The mechanism – Higgs or alternative appears around the corner



Exploring the Terascale
the tools

- **The LHC**
  - It will lead the way and has large reach
  - Quark-quark, quark-gluon and gluon-gluon collisions at 0.5 - 5 TeV
  - Broadband initial state
- **The ILC**
  - A second view with high precision
  - Electron-positron collisions with fixed energies, adjustable between 0.1 and 1.0 TeV
  - Well defined initial state
- **Together, these are our tools for the terascale**

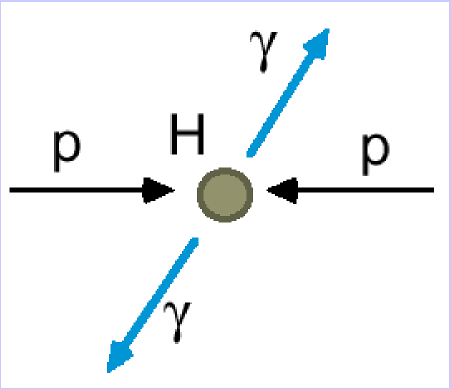
LHC: Low mass Higgs: $\mathbf{H \rightarrow \gamma\gamma}$
M_H < 150 GeV/c^2

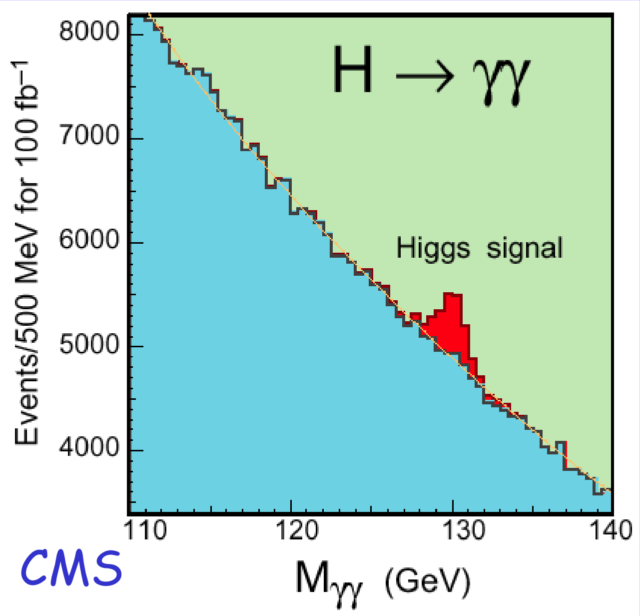
- **Rare decay channel: BR~10^{-3}**

- **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**

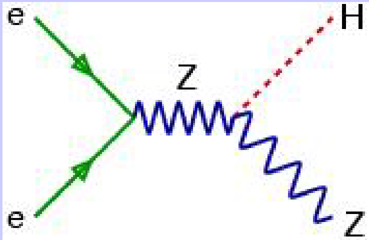
- **Resolution at 100 GeV: $\sigma \approx$ 1 GeV**

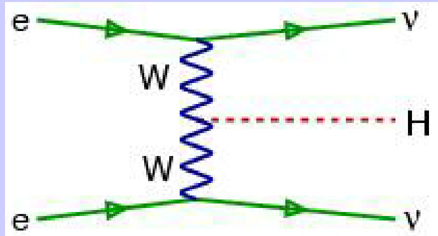
- **Background large: S/B $\approx$ 1:20, but can estimate from non signal areas**

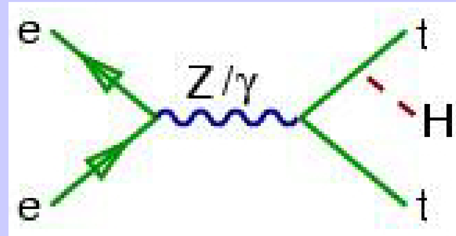


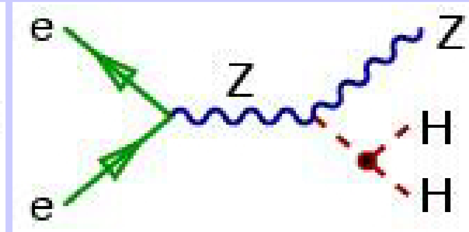


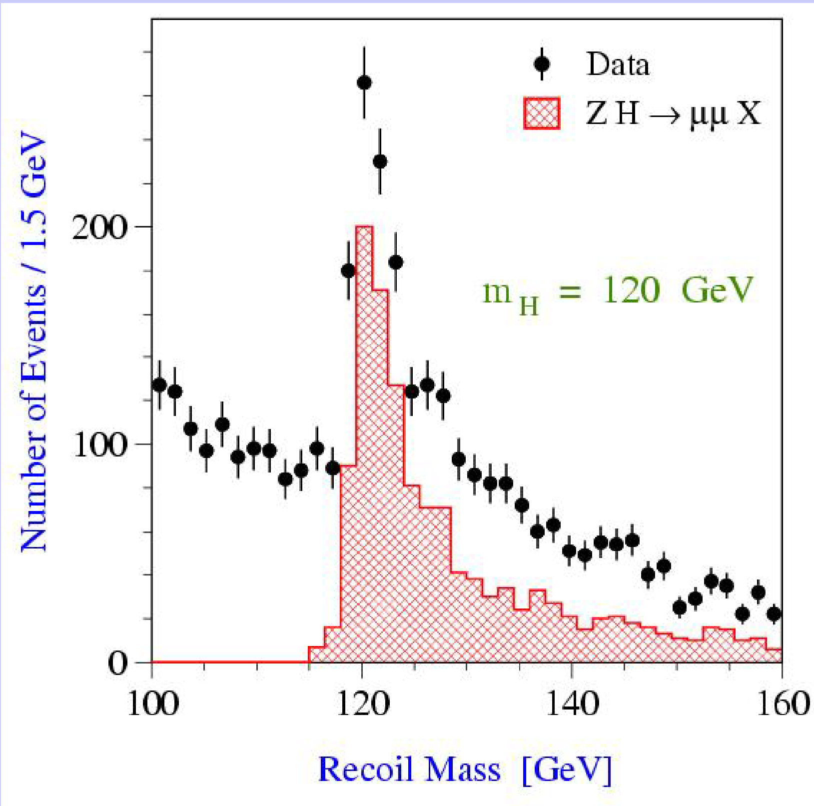
ILC: Precision Higgs physics







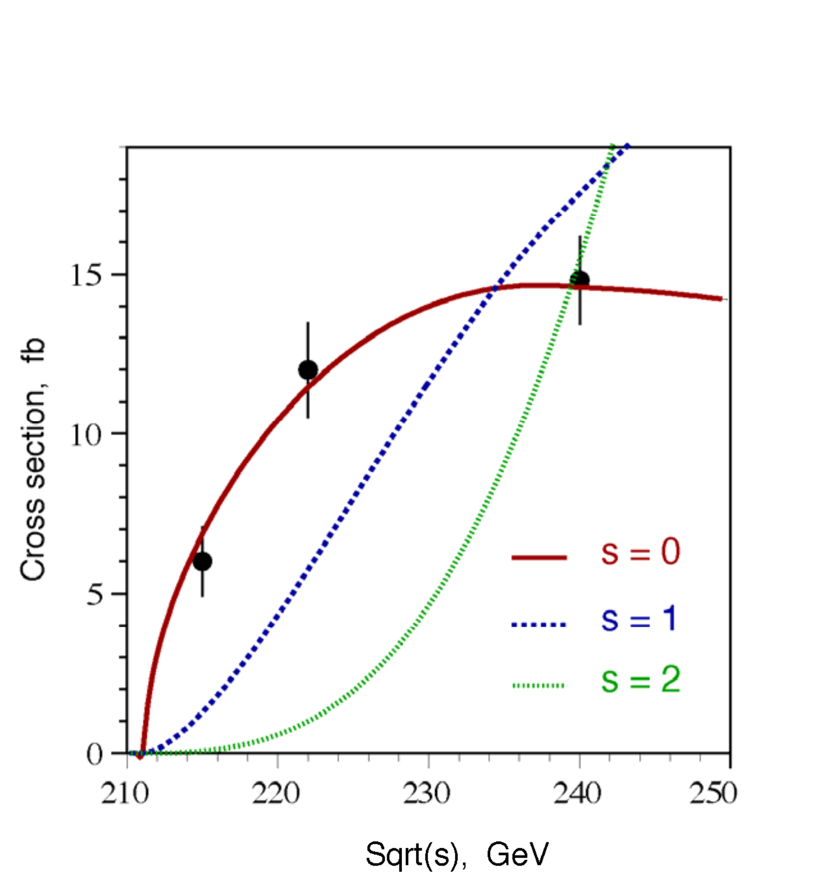




Garcia-Abia et al

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

How do you know you have discovered the Higgs ?

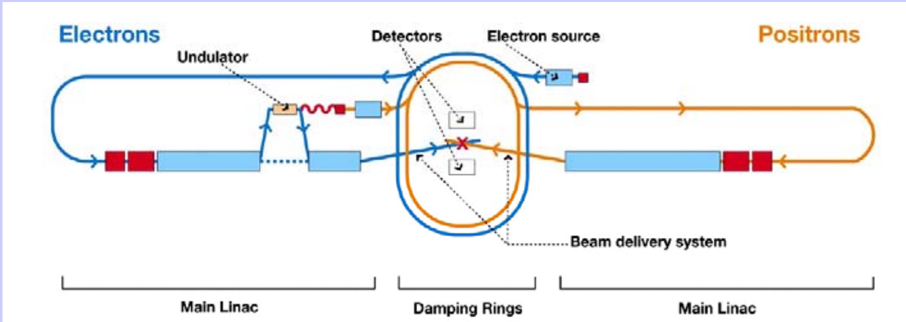


Measure the quantum numbers. The Higgs must have spin zero !

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

Possible TeV Scale Lepton Colliders

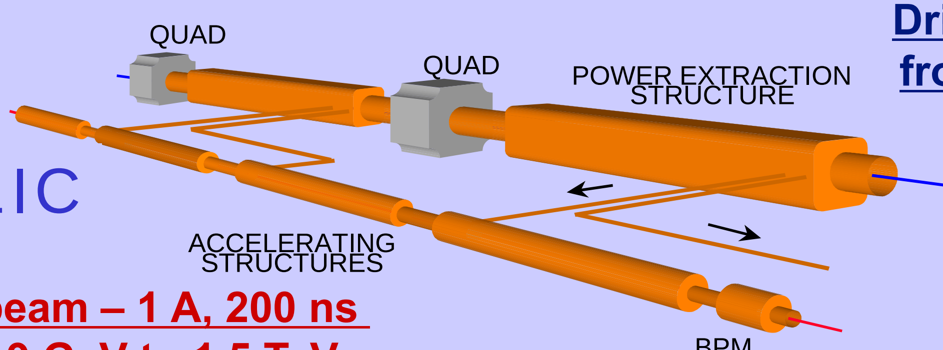
ILC



ILC < 1 TeV
Technically possible
~ 2019

Drive beam - 95 A, 300 ns
from 2.4 GeV to 240 MeV

CLIC

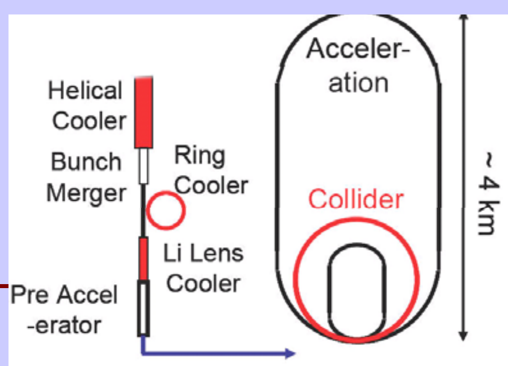


CLIC < 3 TeV
Feasibility?
ILC + 5-10 yrs

Main beam – 1 A, 200 ns
from 9 GeV to 1.5 TeV

Muon Collider

Much R&D Needed
- **Neutrino Factory R&D +**
- **bunch merging**
- **much more cooling**
- **etc**



Muon Collider
< 4 TeV
FEASIBILITY??
ILC + 15 yrs?

ILC Physics Goals

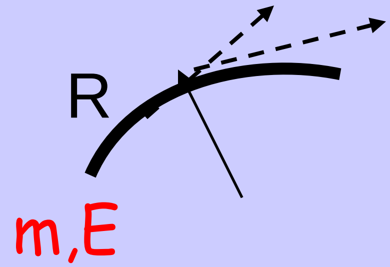
- E_{cm} adjustable from 200 – 500 GeV
- Luminosity → $\int L dt$ = 500 fb^{-1} in 4 years
- Ability to scan between 200 and 500 GeV
- Energy stability and precision below 0.1%
- Electron polarization of at least 80%

- The machine must be upgradeable to 1 TeV

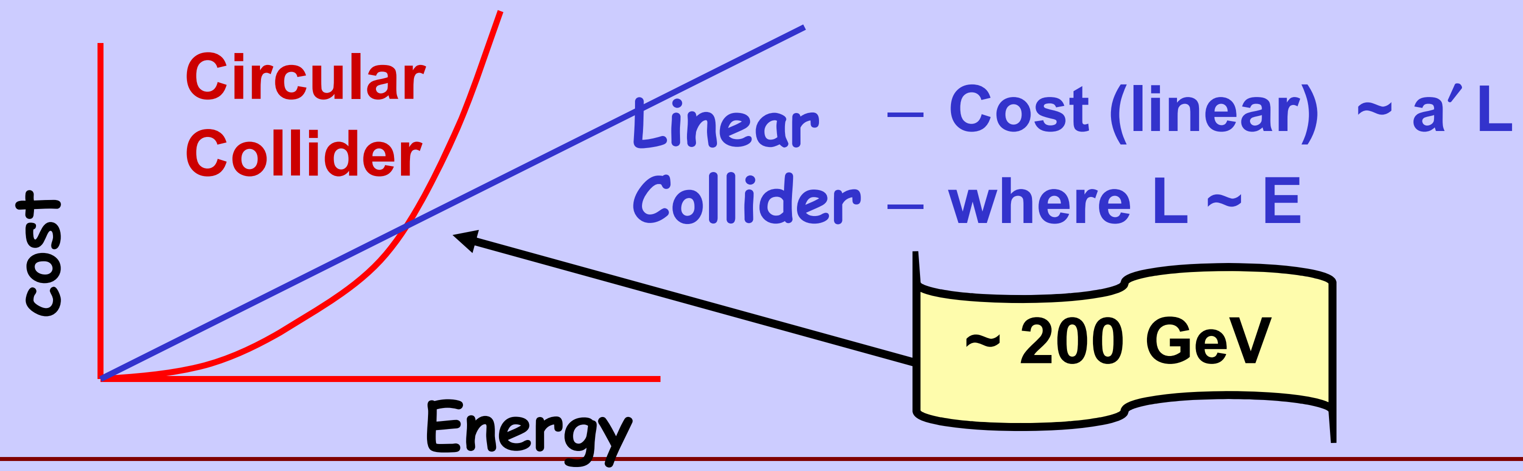
The Reference Design meets the goals of the ICFA- ILCSC parameters study

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 : $R \sim E^2 \Rightarrow \text{Cost} \sim c E^2$

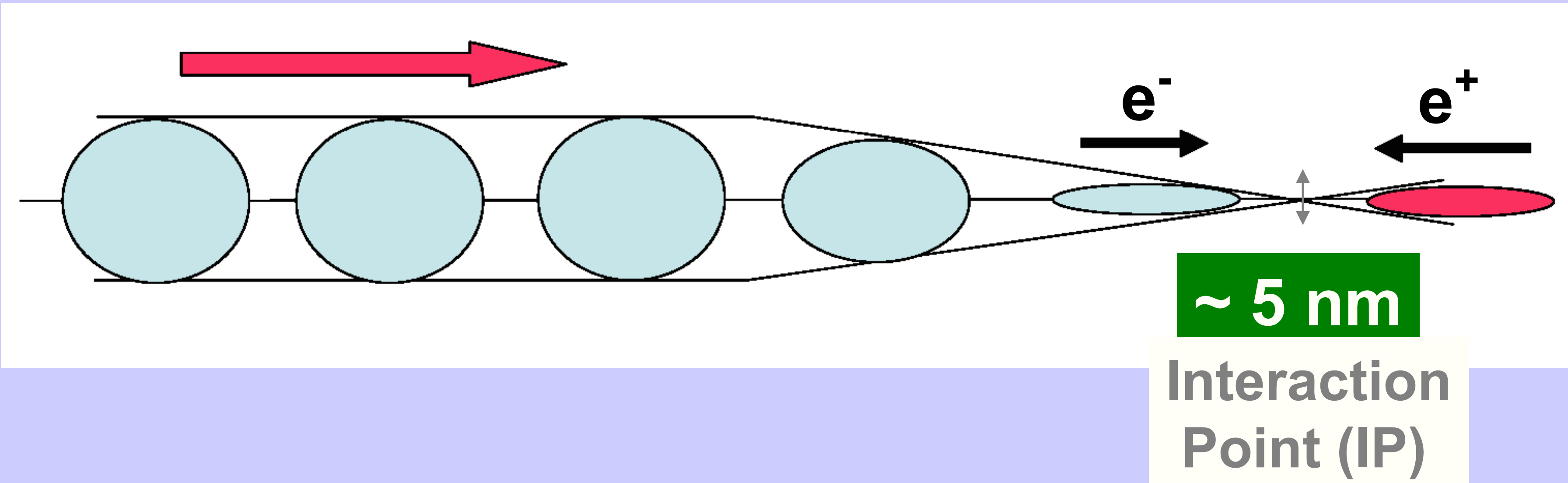


Synchrotron Radiation



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

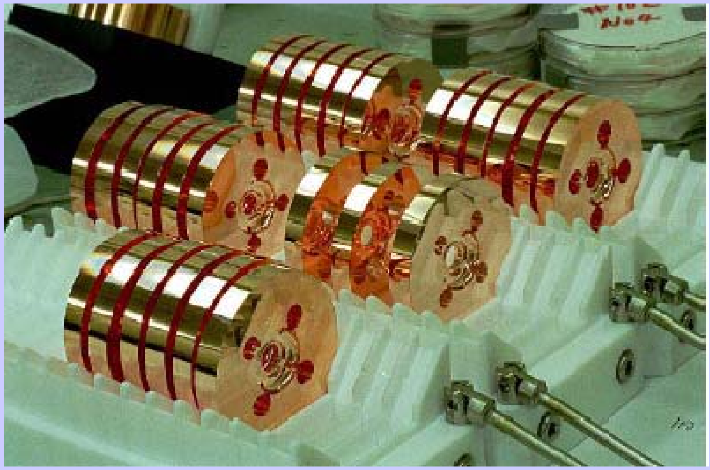
2002: ICFA commissioned the second ILC TRC Report, under Greg Loew as Chair

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**

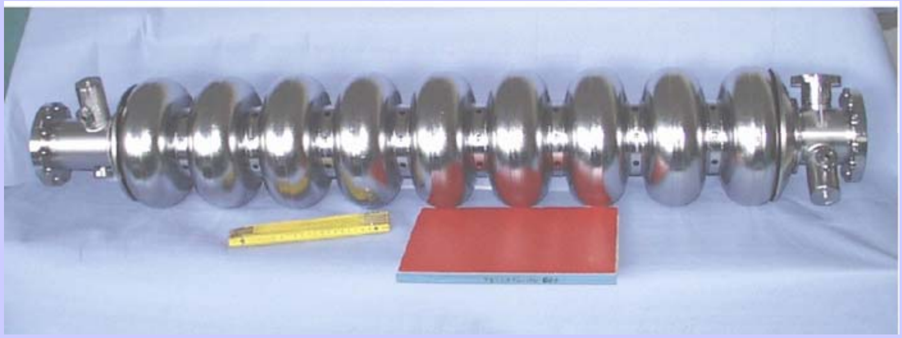
ILC – The Underlying Technology

- **Room temperature copper structures**
  (KEK & SLAC)



OR

- **Superconducting RF cavities**
  (DESY)



International Technology Review Panel

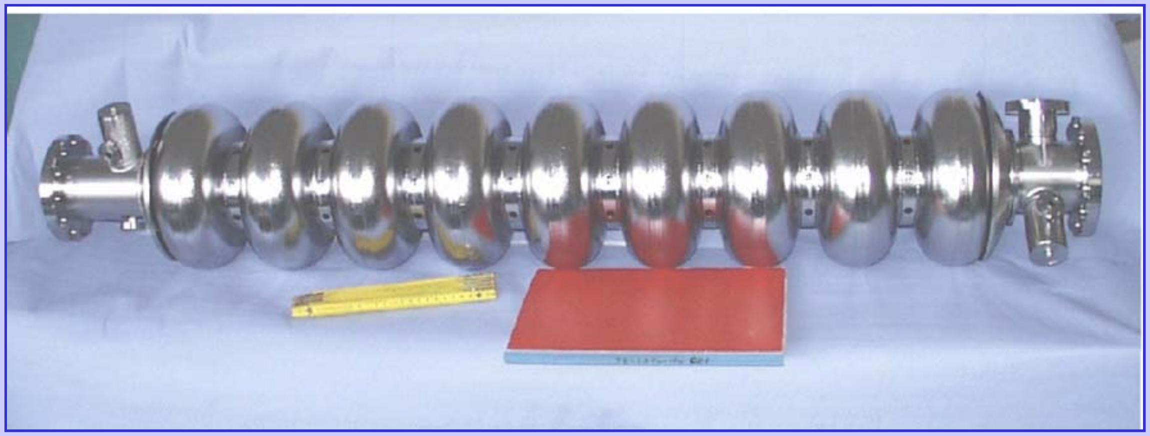
International Technology Recommendation Panel Meeting
August 11 ~ 13, 2004. Republic of Korea

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**

Superconducting RF Technology

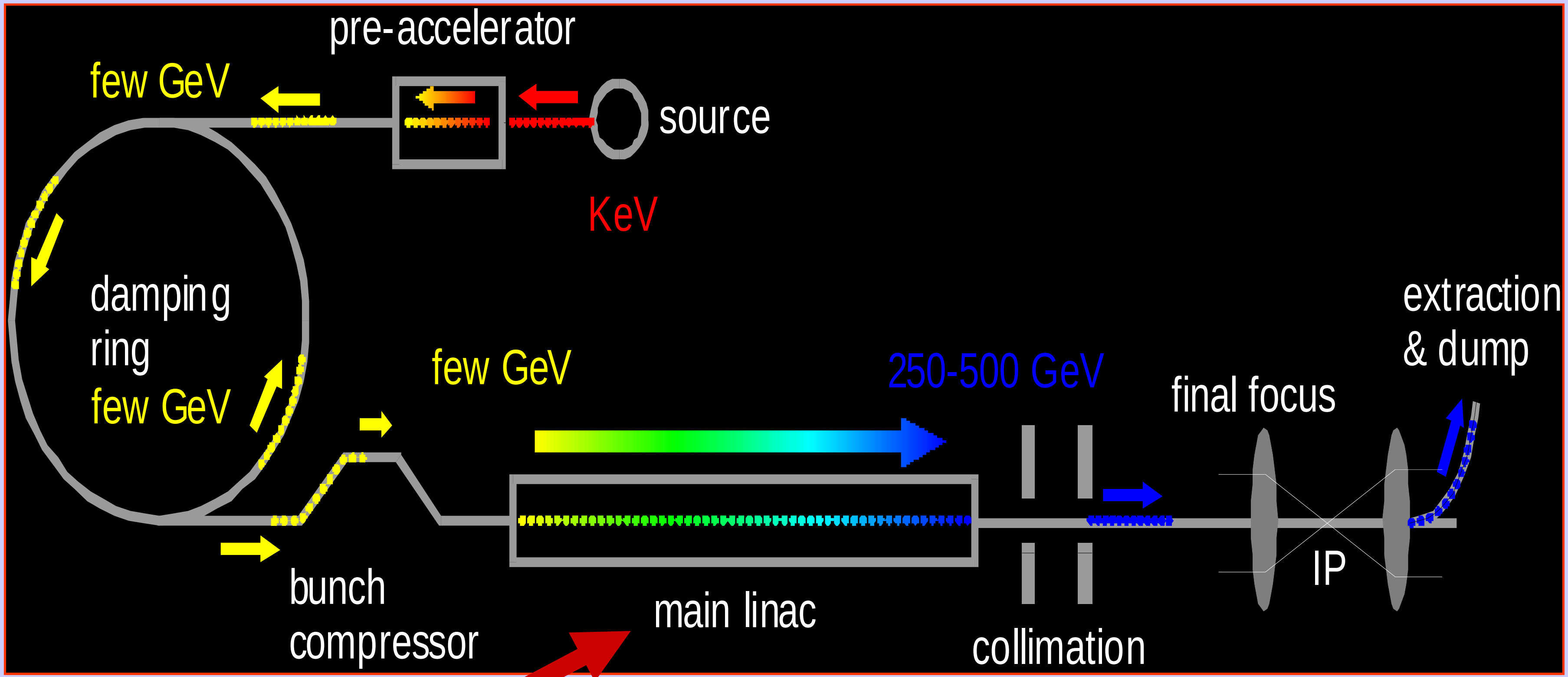


- **Forward looking technology for the next generation of particle accelerators: particle physics; nuclear physics; materials; medicine**
- **The ILC R&D is leading the way Superconducting RF technology**
  - **high gradients; low noise; precision optics**

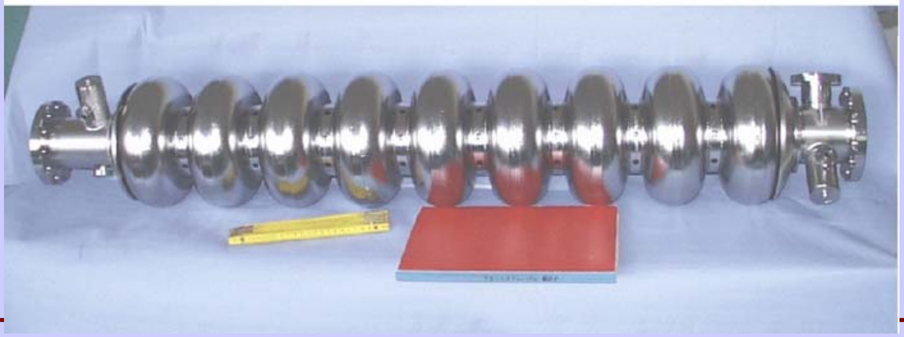
Global Effort on Design / R&D for ILC

<u>Joint</u> Design, Implementation, Operations, Management
Host Country Provides Conventional Facilities

Designing a Linear Collider

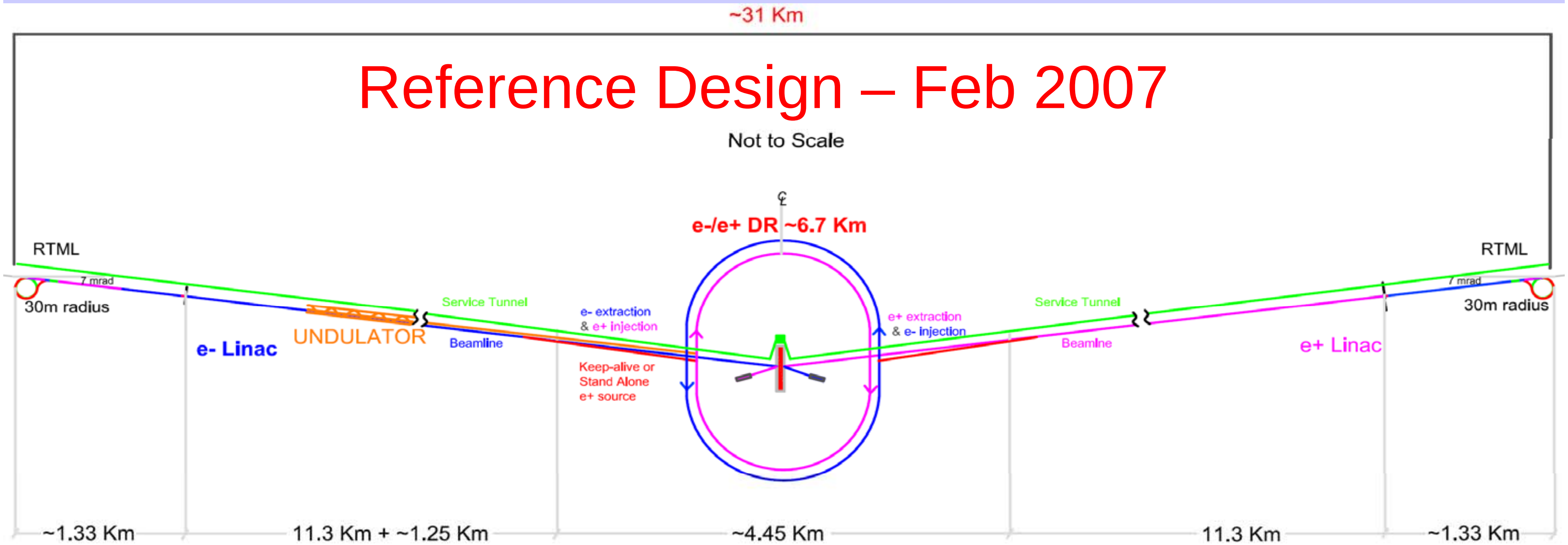


Superconducting RF Main Linac



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

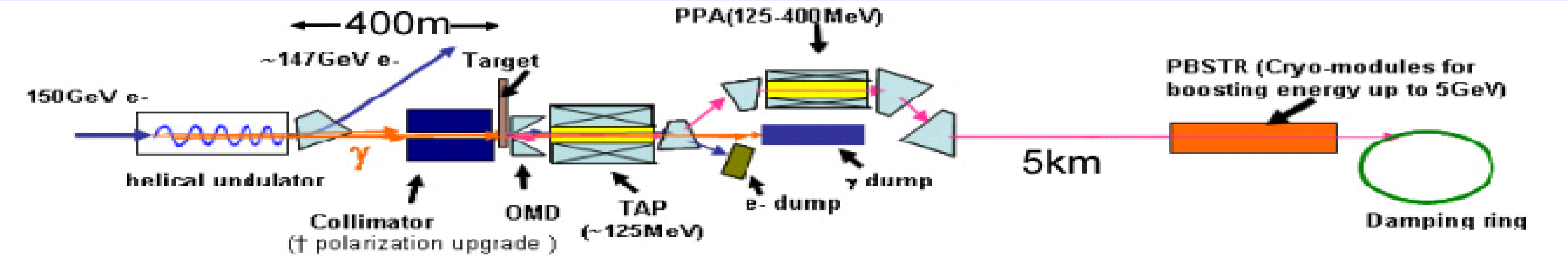


Documented in Reference Design Report

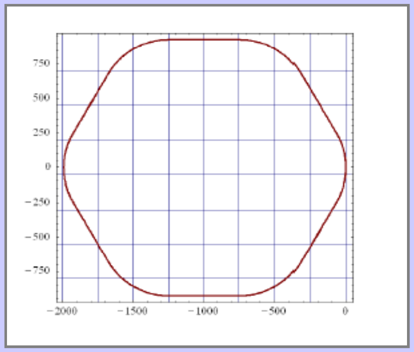
ILC Reference Design

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 Reference Design and Plan

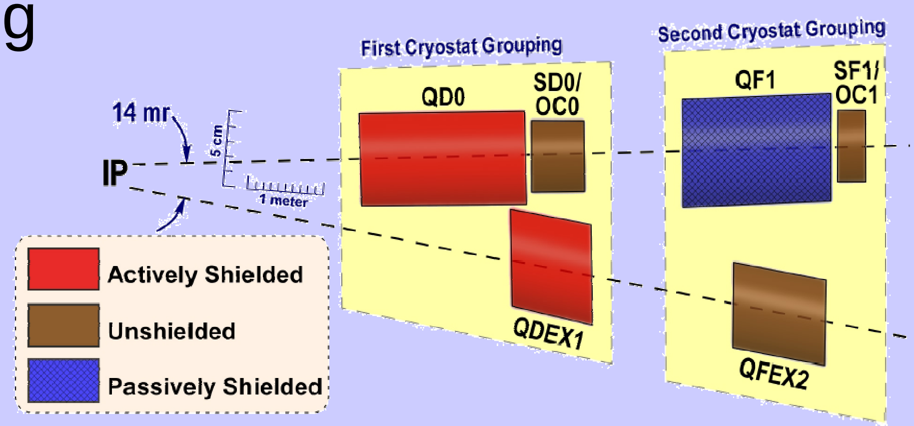


Making Positrons



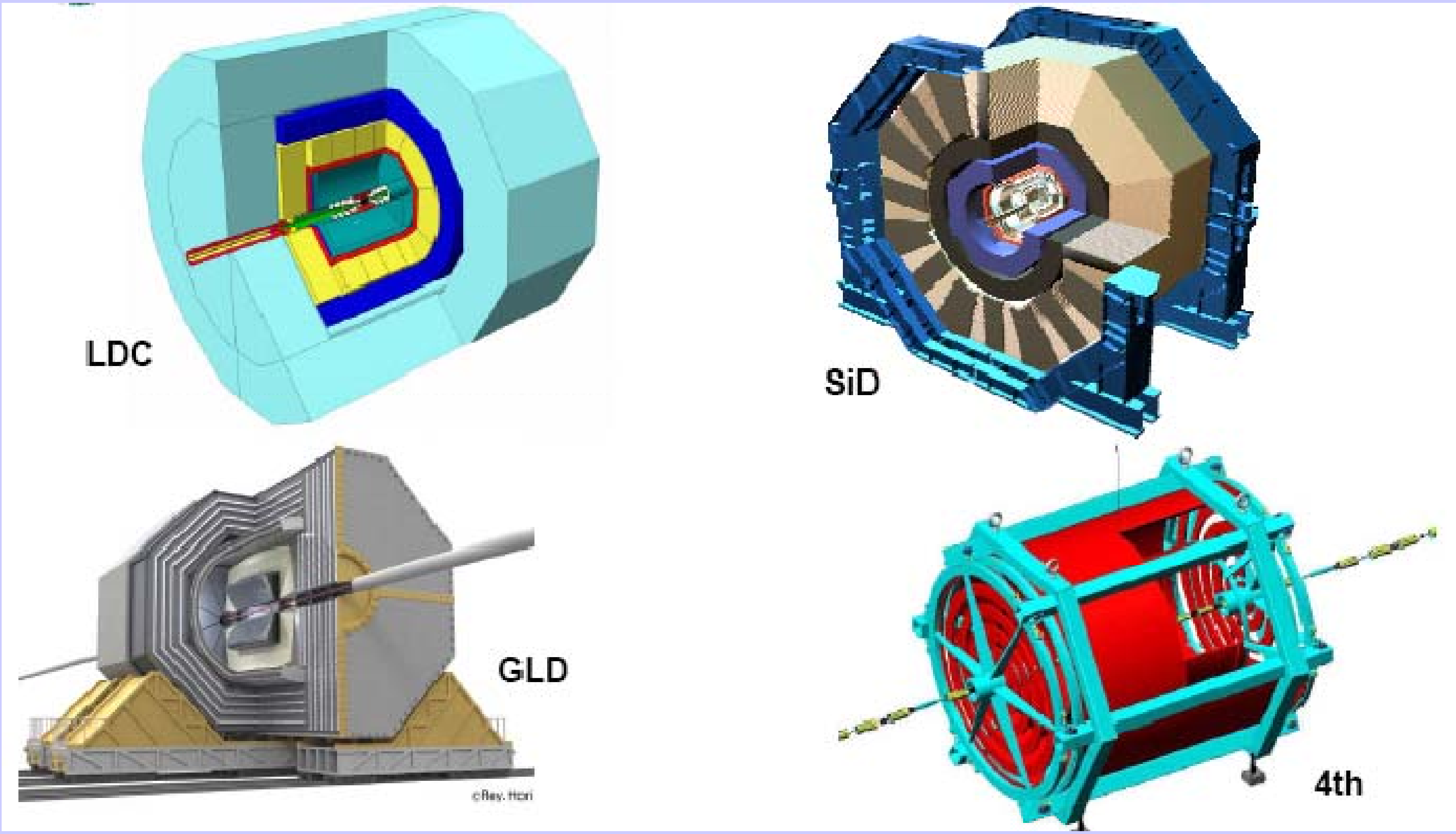
6km Damping Ring

10MW Klystrons



Beam Delivery and Interaction Point

Detector Concepts Report



Final Comments

- The energy frontier continues to be the primary tool to explore the central issues in particle physics
- The LHC at CERN will soon open the 1 TeV energy scale and we anticipate exciting new discoveries
- A companion lepton collider appears will be the logical next step, but such a machine has technical challenges and needs significant R&D and design now
- LHC results will inform the final design and even whether a higher energy options is needed, If so, this may also be possible, but on a longer time scale.