Status of the International Linear Collider

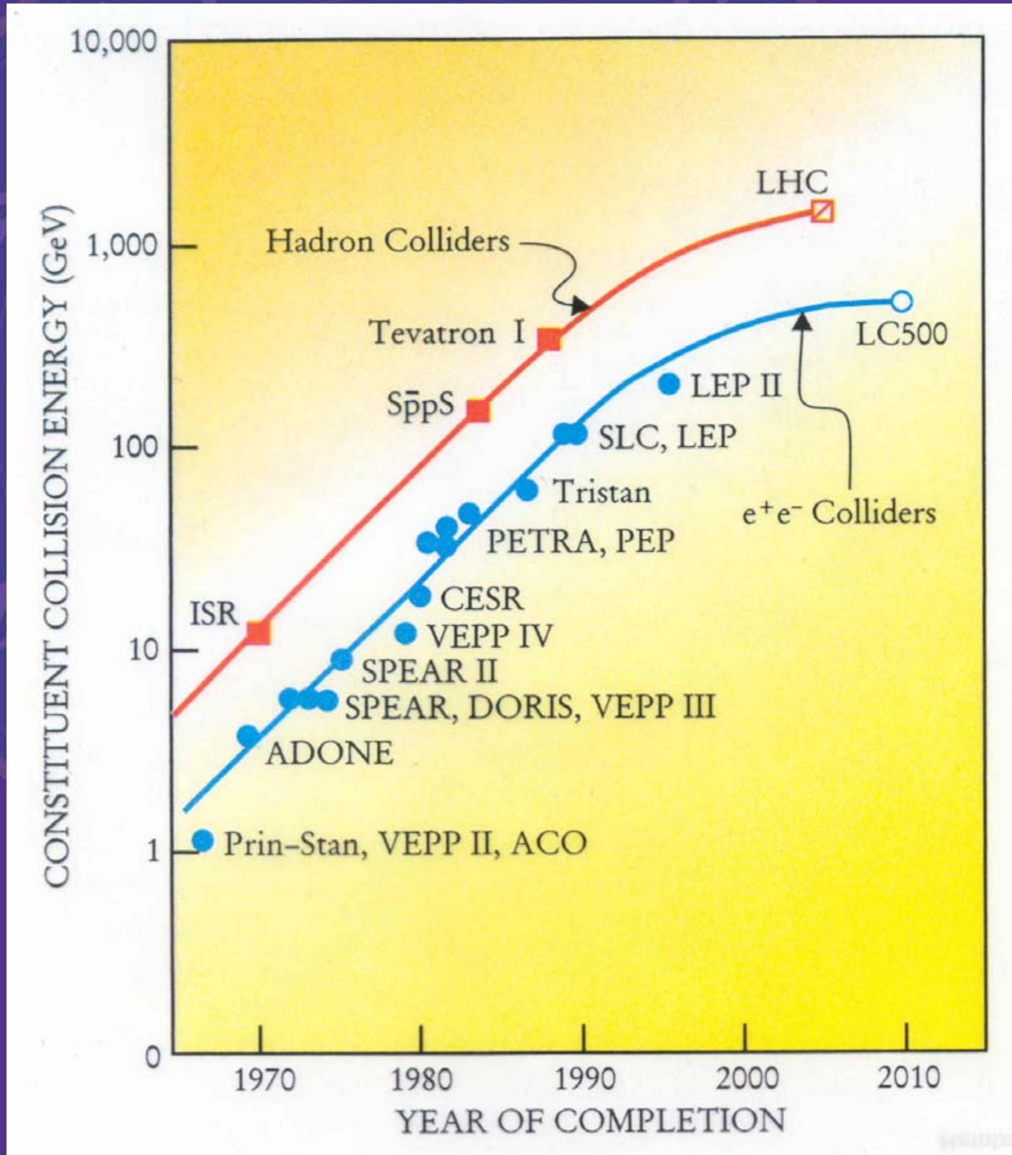
Brian Foster

Oxford

Physics @ LHC
Cracow
8/7/06

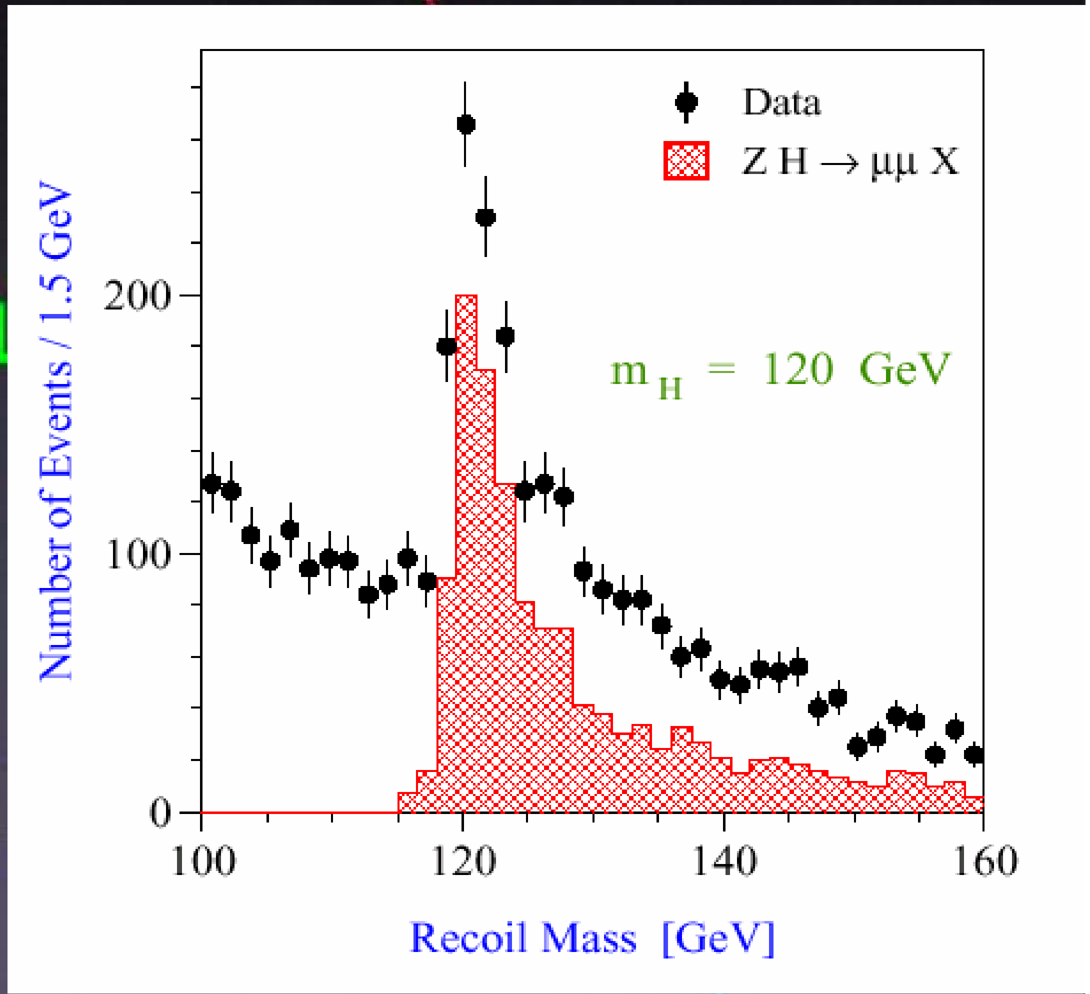
- Why/what, and whence comes, the ILC?
- The Global Design Effort and its structures
- Current status of the design, some examples, elements & BCD status
- The experiments
- Summary & outlook

Why/what is ILC?



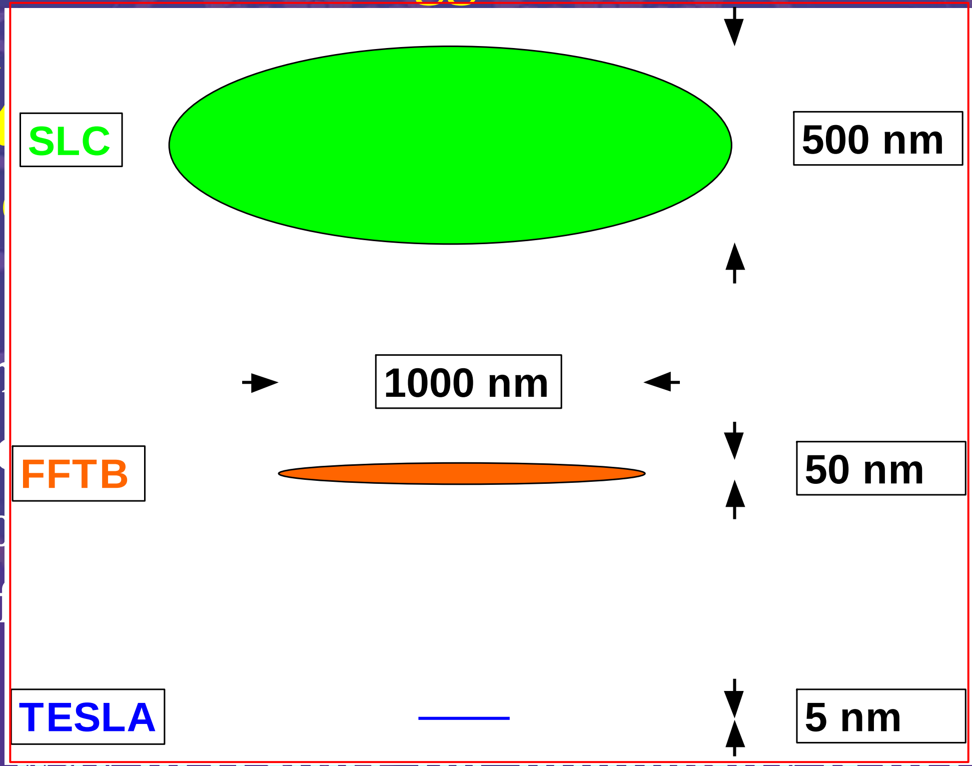
Why e^+e^-?

- Simple particles
- Well defined:
  energy
  angular mom.
- E can be scanned precisely
- Particles produced ~ democratically
- Final states generally fully reconstructable



Why/what is ILC?

- Because radiated synchrotron-radiation power goes like m^{-5}, circular e^+e^- colliders bigger than LEP are uneconomical. We didn … y machines (cf Tevat … osed. Now we …



- The ILC … synchrotron radiation … lar orbit. The challeng … ines, the beams pass thro … , giving many chances f … through … ed.
- The only … crush the beams to a tiny volume so that one pass gives all the particles the same chance to interact that many passes gives less dense bunches.

Status of the ILC

- TESLA was the catalyst that in the last four years has moved the ILC forwards very rapidly.
- There will only be one machine like this in the world – so it is essential that world-wide agreement be obtained. This has been in place for ~3 years.
- ECFA report (&, apparently, CERN Council Strategy report) :

  "..the realisation, in as timely a fashion as possible, of a world-wide collaboration to construct a high-luminosity e^+e^- linear collider with an energy range up to at least 400 GeV as the next accelerator project in particle physics; decisions concerning the chosen technology and the construction site for such a machine should be made soon"
- HEPAP report (& recent EPP2010 report):

  "We recommend that the highest priority of the U.S. program be a high-energy, high-luminosity, electron-positron linear collider, wherever it is built in the world…. We recommend that the United States prepare to bid to host the linear collider, in a facility that is international from the inception."
- ACFA:

  "ACFA urges the Japanese Government to arrange a preparatory budget for KEK to pursue an engineering design of the collider, to study site and civil engineering, as well as to investigate the process for the globalization."

Status of the ILC

- In January 2004 the Science Ministers of the OECD met in Paris and, following the detailed work of a GSF Consultative Group on particle physics that produced a road Map, agreed a statement on the Linear Collider: Ministers

  "acknowledged the importance of ensuring access to large-scale research infrastructure and the importance of the long-term vitality of high-energy physics. They noted the worldwide consensus of the scientific community, which has chosen an electron-positron linear collider as the next accelerator-based facility to complement and expand on the discoveries that are likely to emerge from the Large Hadron Collider currently being built at CERN. They agreed that the planning and implementation of such a large, multi-year project should be carried out on a global basis, and should involve consultations among not just scientists, but also representatives of science funding agencies from interested countries. Accordingly, Ministers endorsed the statement prepared by the OECD Global Science Forum Consultative Group on High-Energy Physics (see Appendix)."

Status of the ILC

- In August 2004, group of "Wise Men", chaired by B. Barish, chose the "cold", superconducting, RF technology over the competing "warm" X-band RF.
- Despite the fact that both US and Asian research had been in warm technology, both regions accepted the decision and united behind cold technology; now, transition is complete.
- ICFA moved ahead quickly to appoint a Global Design Effort (GDE) to transform the technology decision into a full Technical Design Report, capable of being presented to world governments for a decision to construct.
- B. Barish appointed as GDE director, with three regional directors: M. Nozaki
BF (Europe), ~~F. Takasaki~~ (Asia), G. Dugan (Americas)

GDE Mission

- GDE mission:
- **Produce a design for the ILC that includes a detailed design concept, performance assessments, reliable international costing, an industrialization plan , siting analysis, as well as detector concepts and scope.**
- Coordinate worldwide prioritized proposal driven R & D efforts (to demonstrate and improve the performance, reduce the costs, attain the required reliability, etc.)

GDE – Staffing

EU

US

Snowmass
49 GDE members

Present
GDE Membership

Americas	22
Europe	24
Asia	18

About 30 FTEs

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

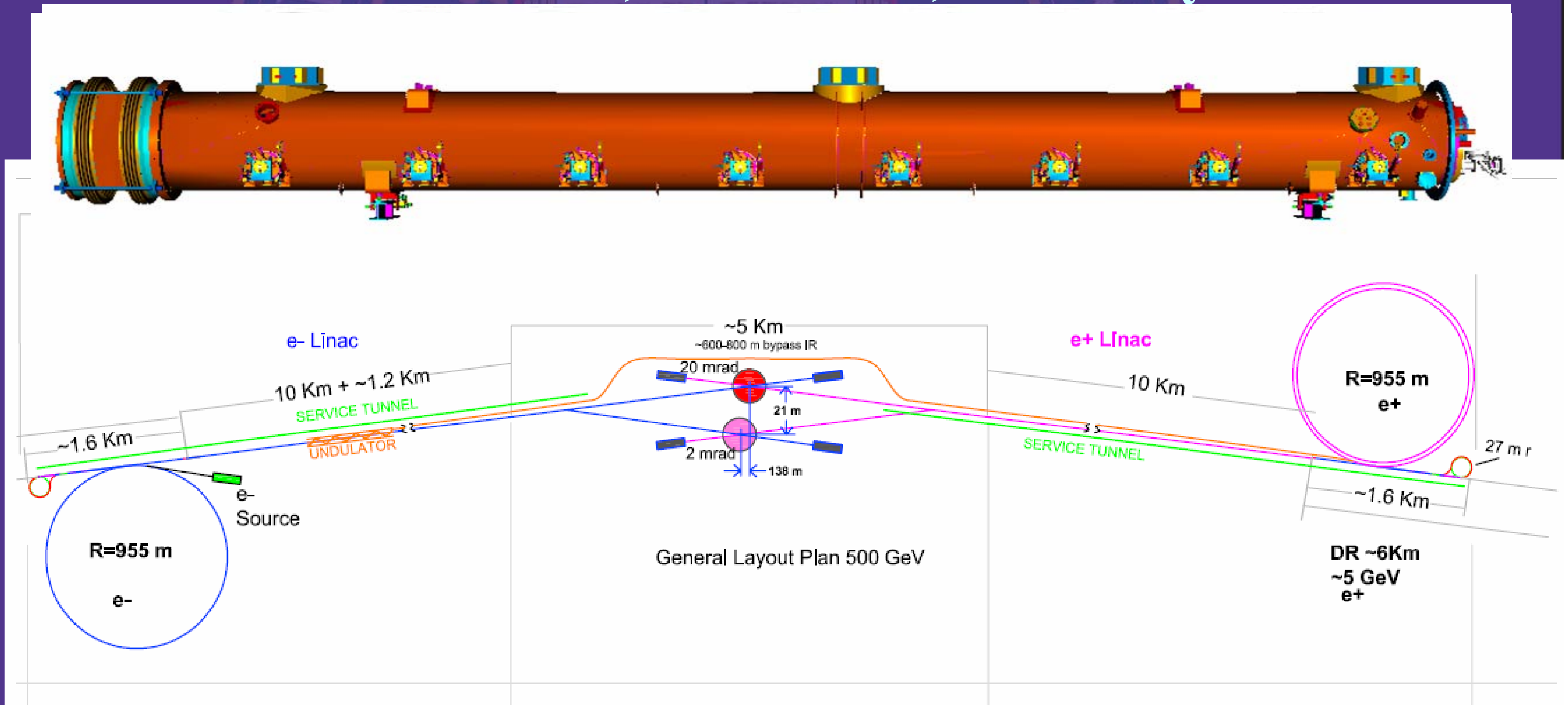
ILC Parameters

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

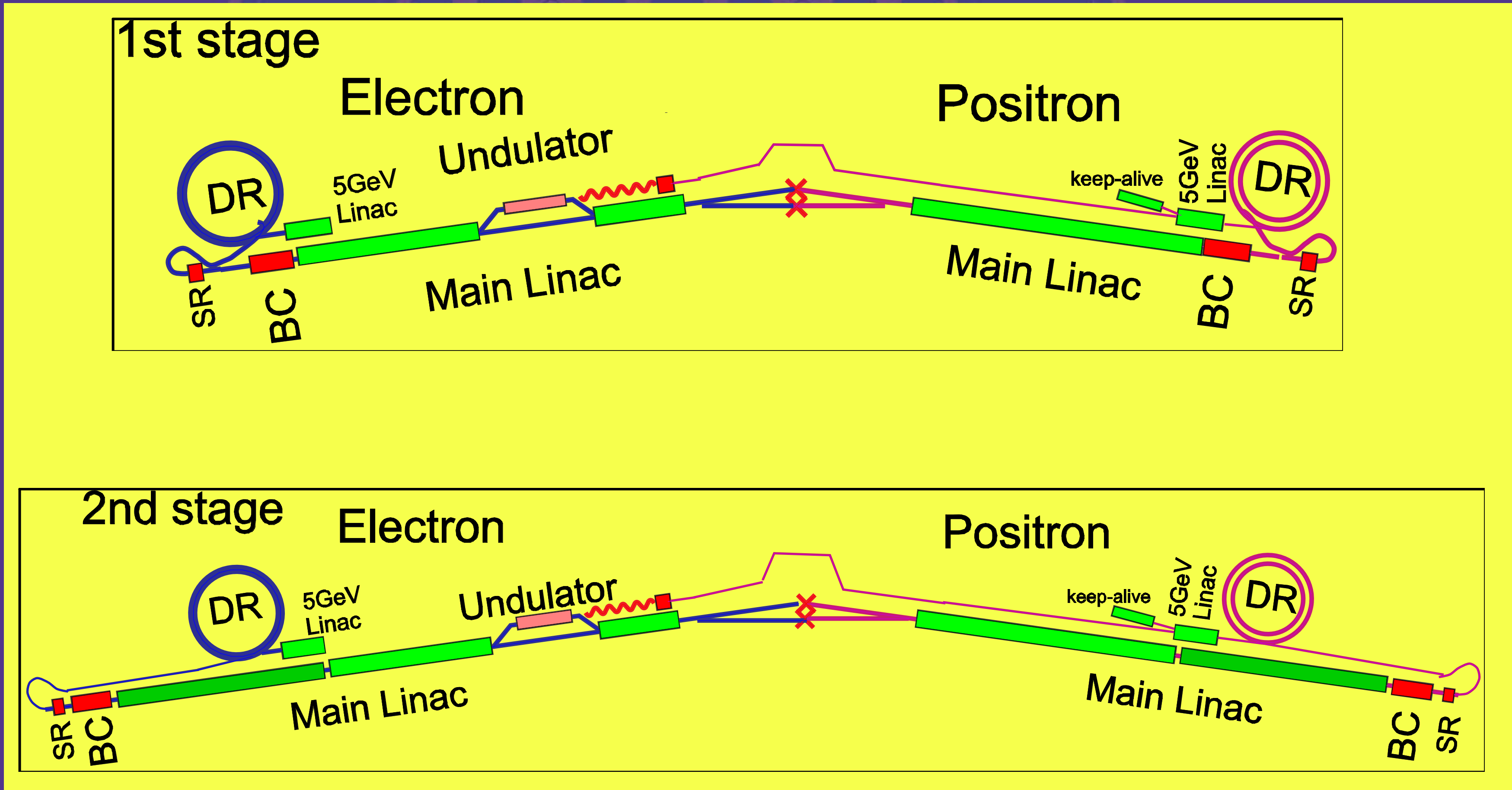
- The machine must be upgradeable to 1 TeV

BCD overview

- Baseline Design completed in December 2005 overseen by Executive: Directors + T. Raubenheimer, N. Walker, K. Yokoya.



Energy Upgrade

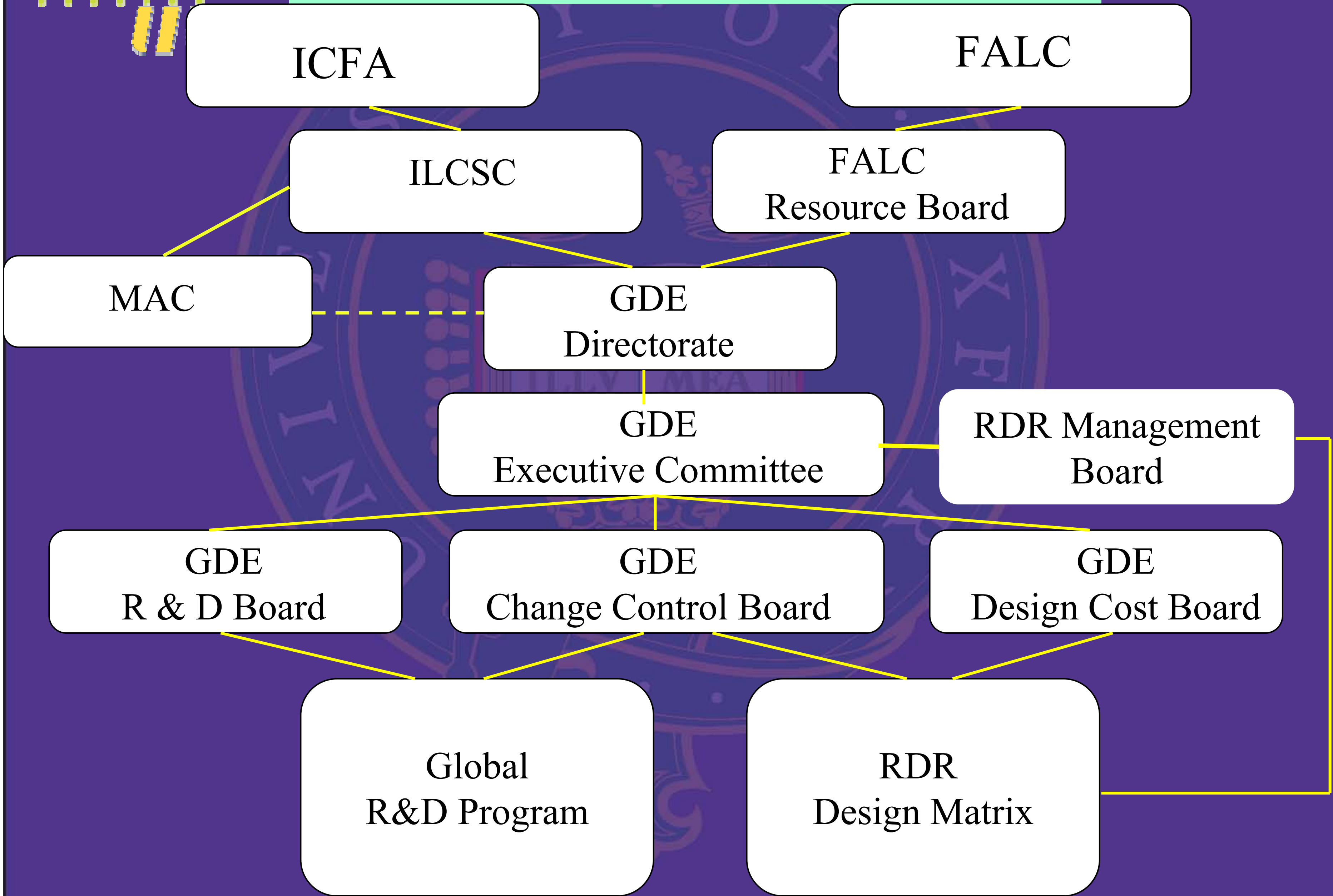


From BCD to RDR

- BCD is complete. In the next phase, RDR is taking forward the BCD, refining the design and in particular gathering industrialisation data in order to form the basis for reliable cost estimate.

- New tools were necessary to go from BCD to RDR - 4 new boards: Change Control Board; Global R&D Board; Design & Cost Board and an RDR management board to oversee whole process.

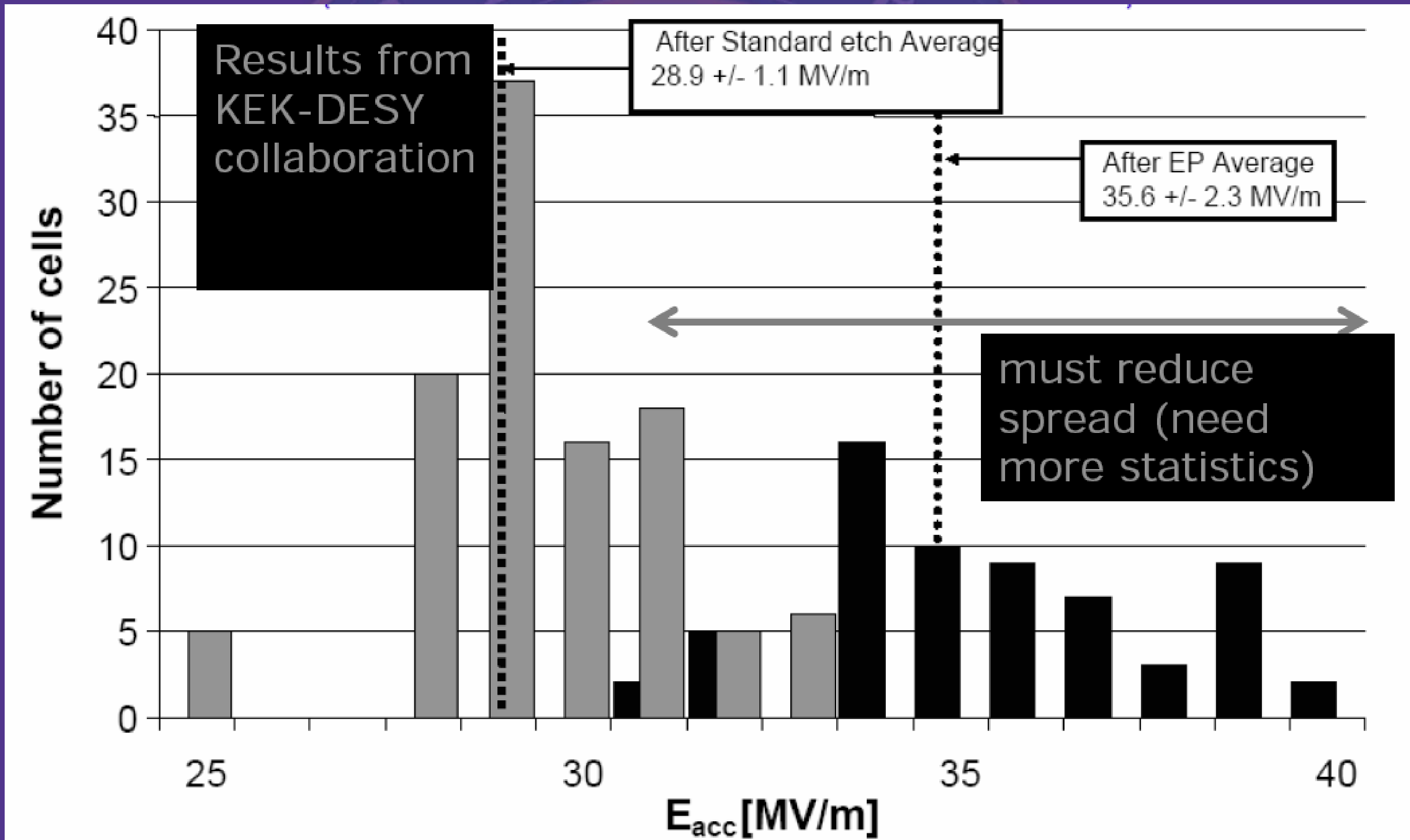
ILC Structure



MAC report

- The first meeting of the Machine Advisory Committee, which reports to ILCSC, took place last month in Fermilab.
- Generally they were very positive and impressed by the scale of the progress that has been made. They had concerns about the current accelerating gradient spec. and how R&D could be done to achieve it, about communications with the experimenters and also about the coordination of world-wide R&D.

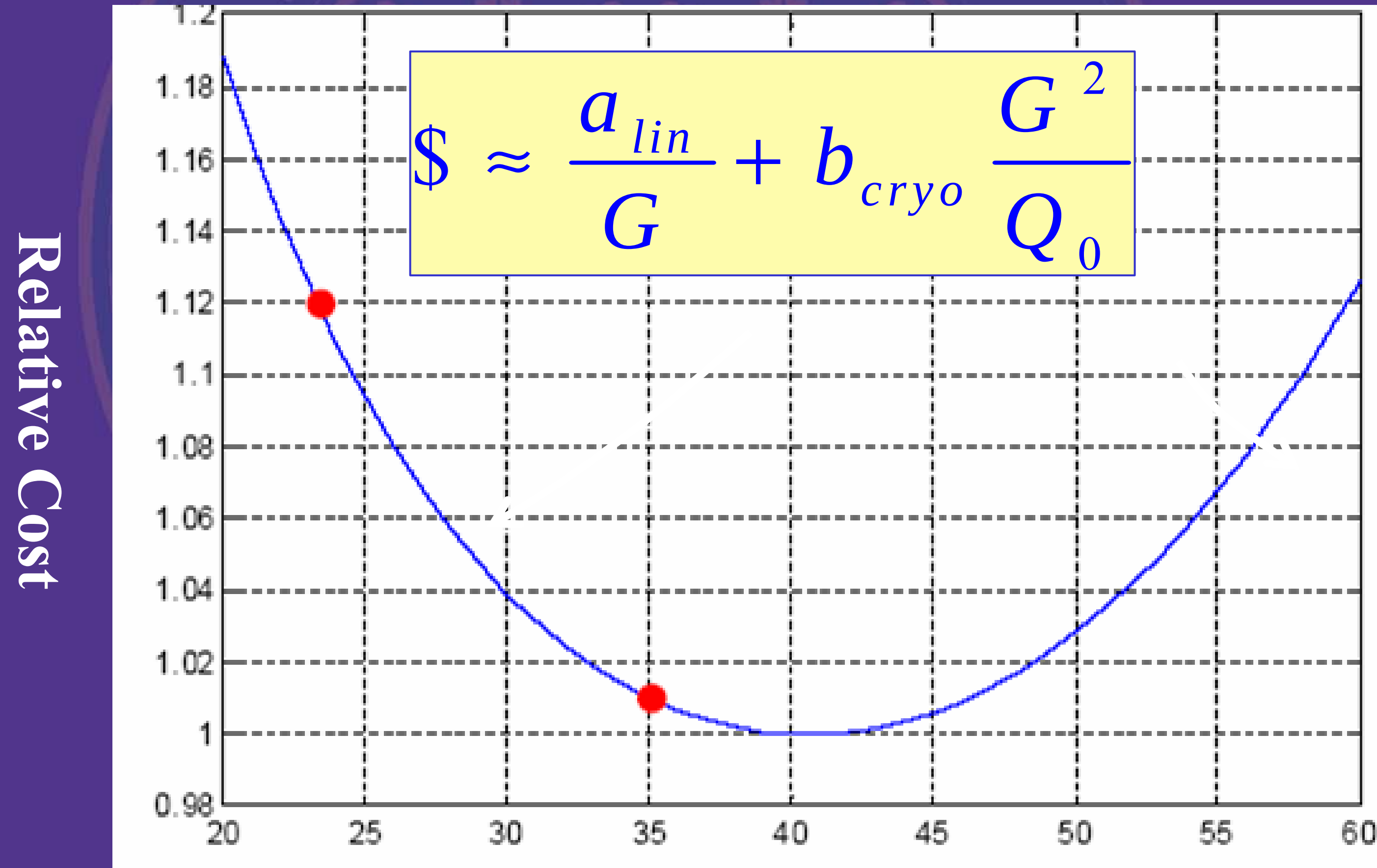
Cavity performance



- Somewhat inconsistent! GDE task force being set up.

RDR cavities

- What knobs do we have to turn?



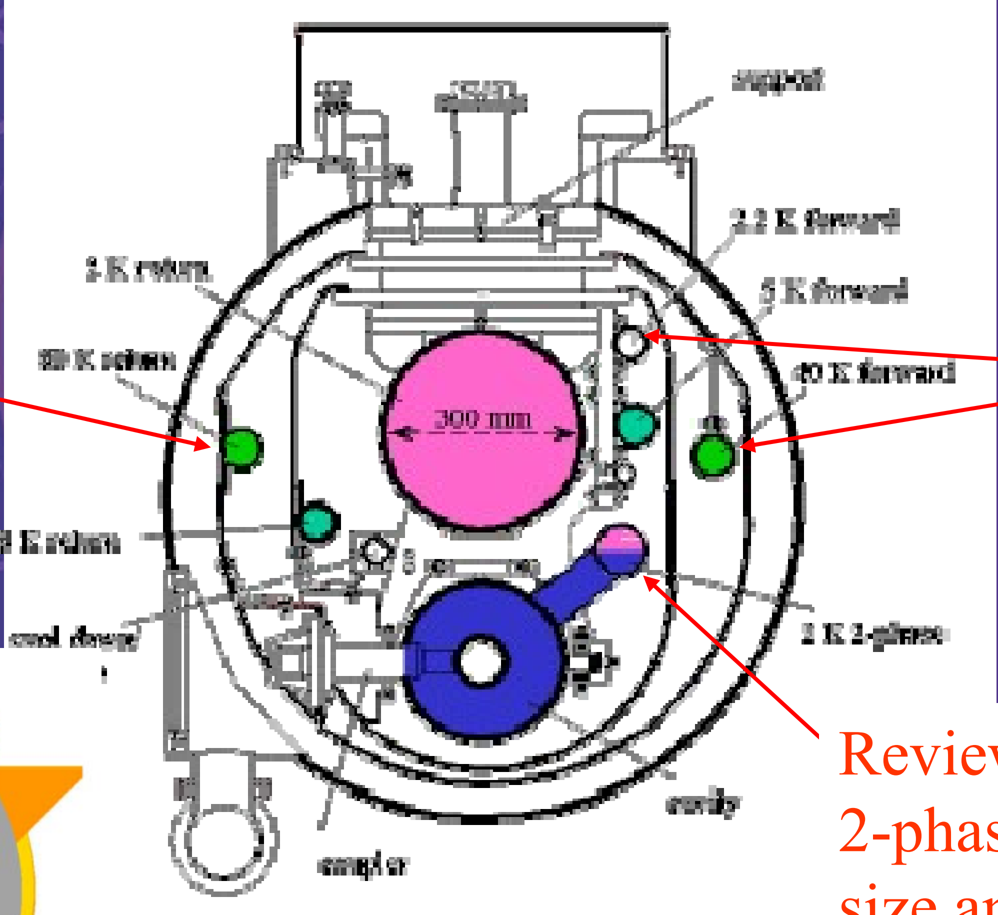
$$\$ \approx \frac{a_{lin}}{G} + b_{cryo} \frac{G^2}{Q_0}$$

Site length vs. Gradient for 1TeV

Subject to many uncertainties

C. A

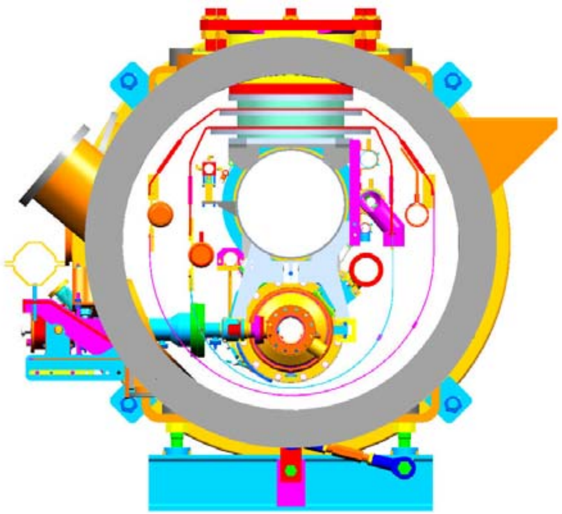
ILC Cryomodule



Increase diameter beyond X-FEL

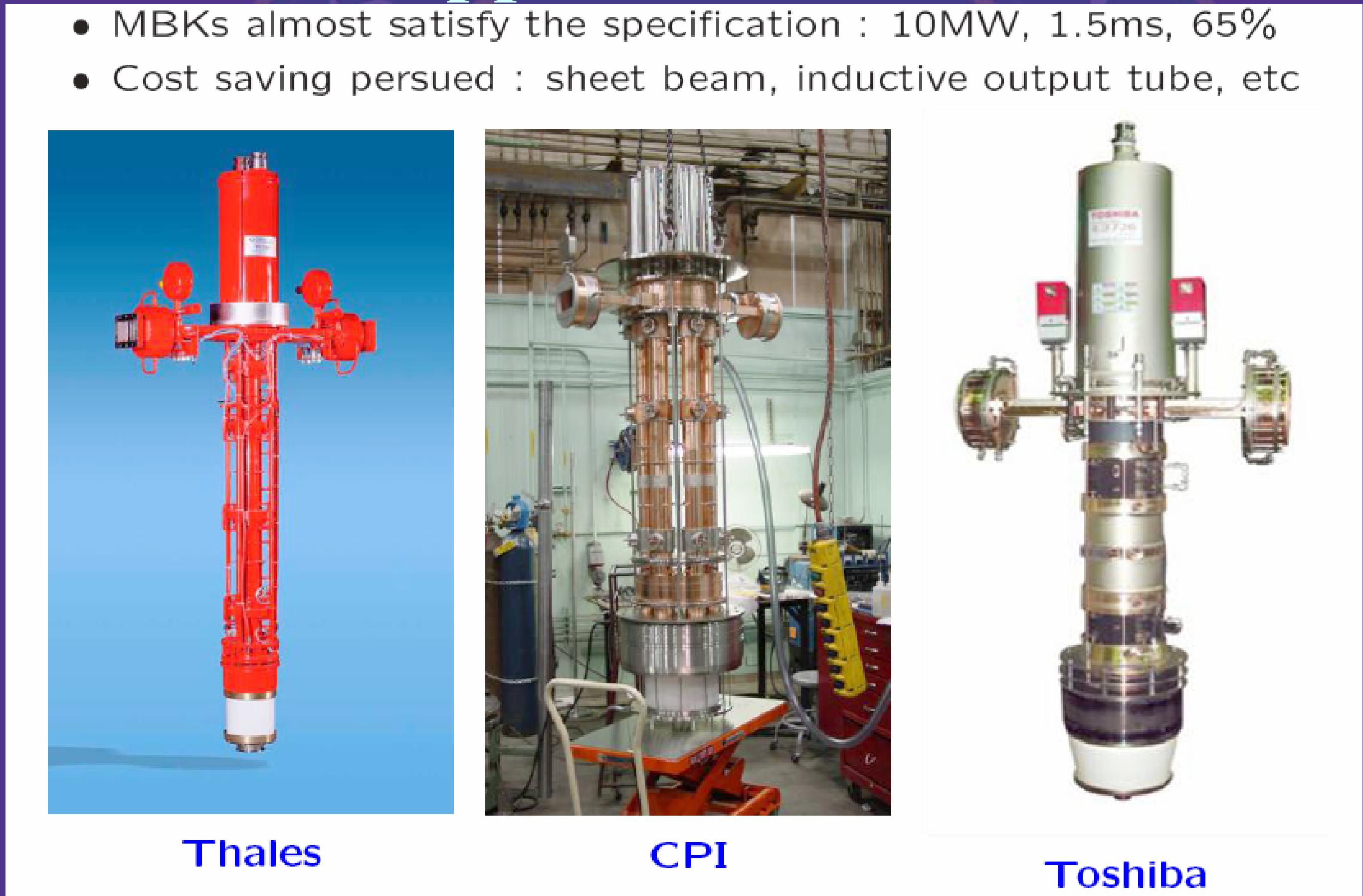
Increase diameter beyond X-FEL

Review 2-phase pipe size and effect of slope



Klystron Fabrication

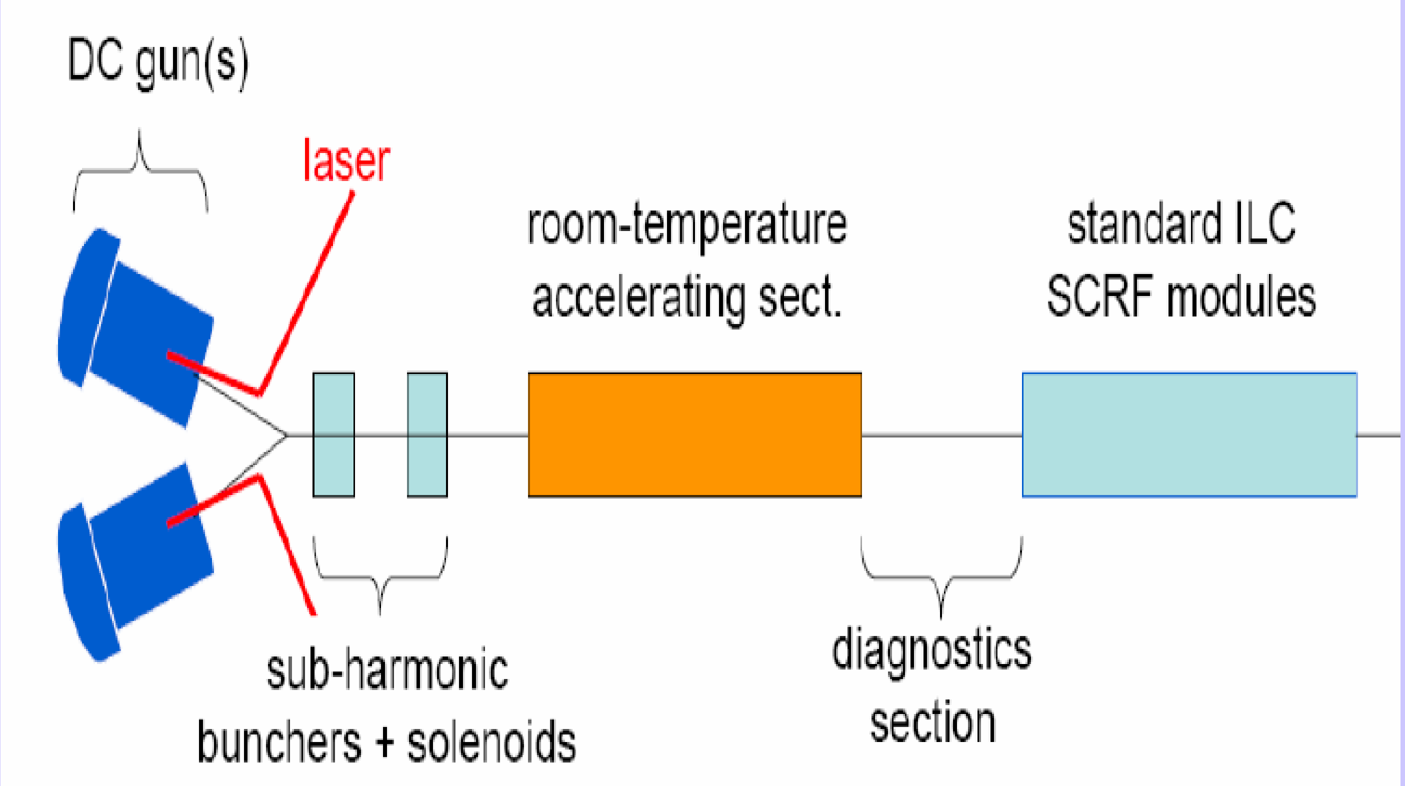
- Several suppliers for BCD:



- New Toshiba tube now at DESY and working well at 10 MW.

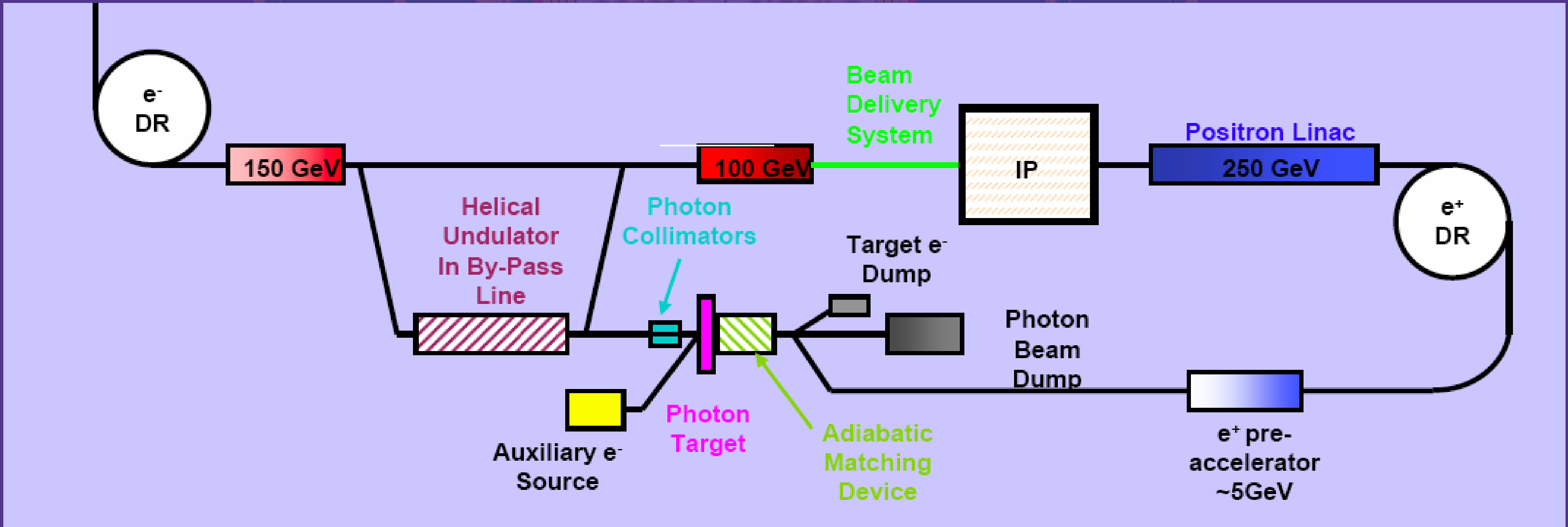
Electron source

- **Electron Source – Conventional Source using a DC** ----- **Titanium-sapphire laser emits 2-ns pulses that knock out electrons; electric field focuses each bunch into a 250-meter-long linear accelerator that accelerates up to 5 GeV**



Positron source

- 200 m long helical undulator producing polarised photon beams that hit 0.5 rl Ti target. Positrons accelerator to 5 GeV, damped and then accelerated to IP.



Damping Rings

- **Damping Ring for electron beam**
  - Synchrotron radiation damping times ~ 10 - 100 ms.
  - Linac RF pulse length is of the order of 1 ms.
  - Damping rings must store (and damp) an entire bunch train in the (~ 200 ms) interval between machine pulses.

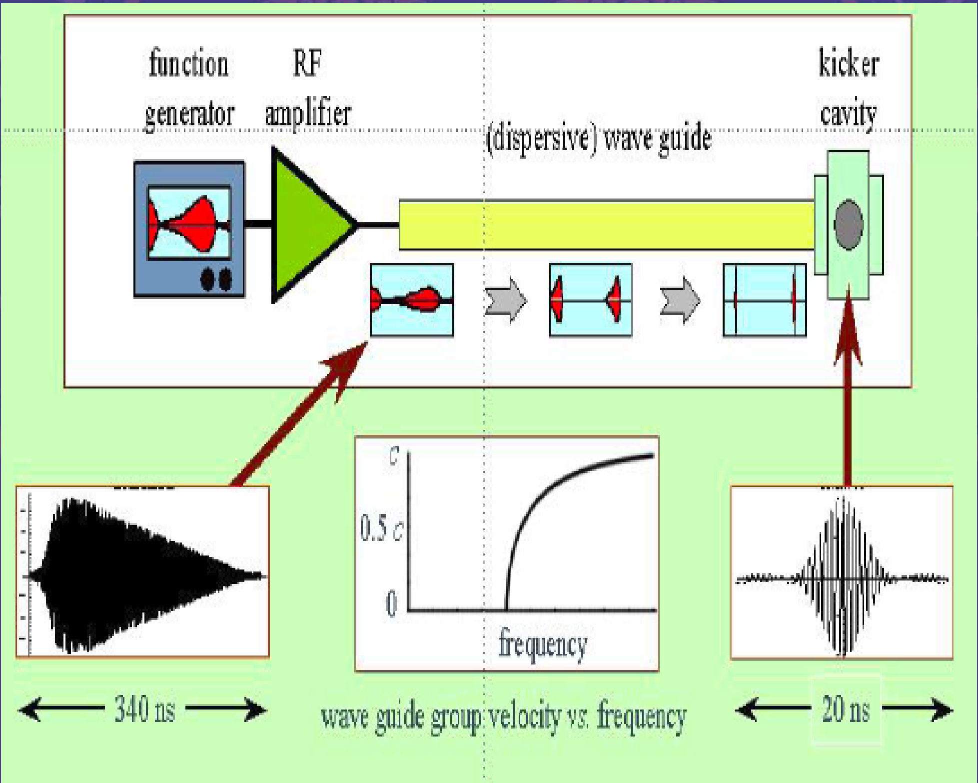
Particles per bunch	1×10^{10}
Particles per pulse	5.6×10^{13}
Number of bunches	5600
Average current in main linac	9.5 mA
Bunch separation in main linac	168 ns

- **Damping Ring for positron beam**

  In the present baseline, in order to minimize "electron cloud effects," positron bunches are injected alternately into either one of two identical positron damping rings with 6-kilometer circumference.

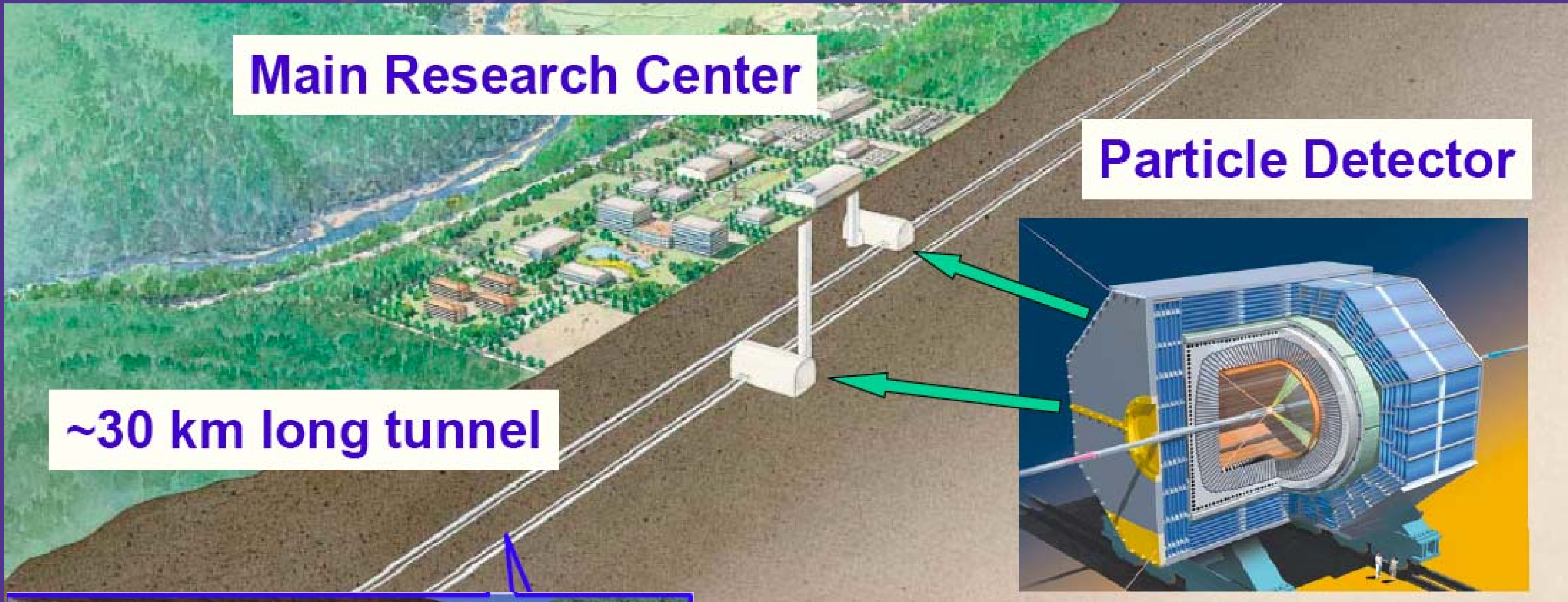
Damping Rings

- 6km ring is current baseline - requires kicker with 5 nsec rise time and 30 nsec fall.



- Most complex machine physics in ILC! But Ex/Ey 8/0.02 micron already achieved at ATF

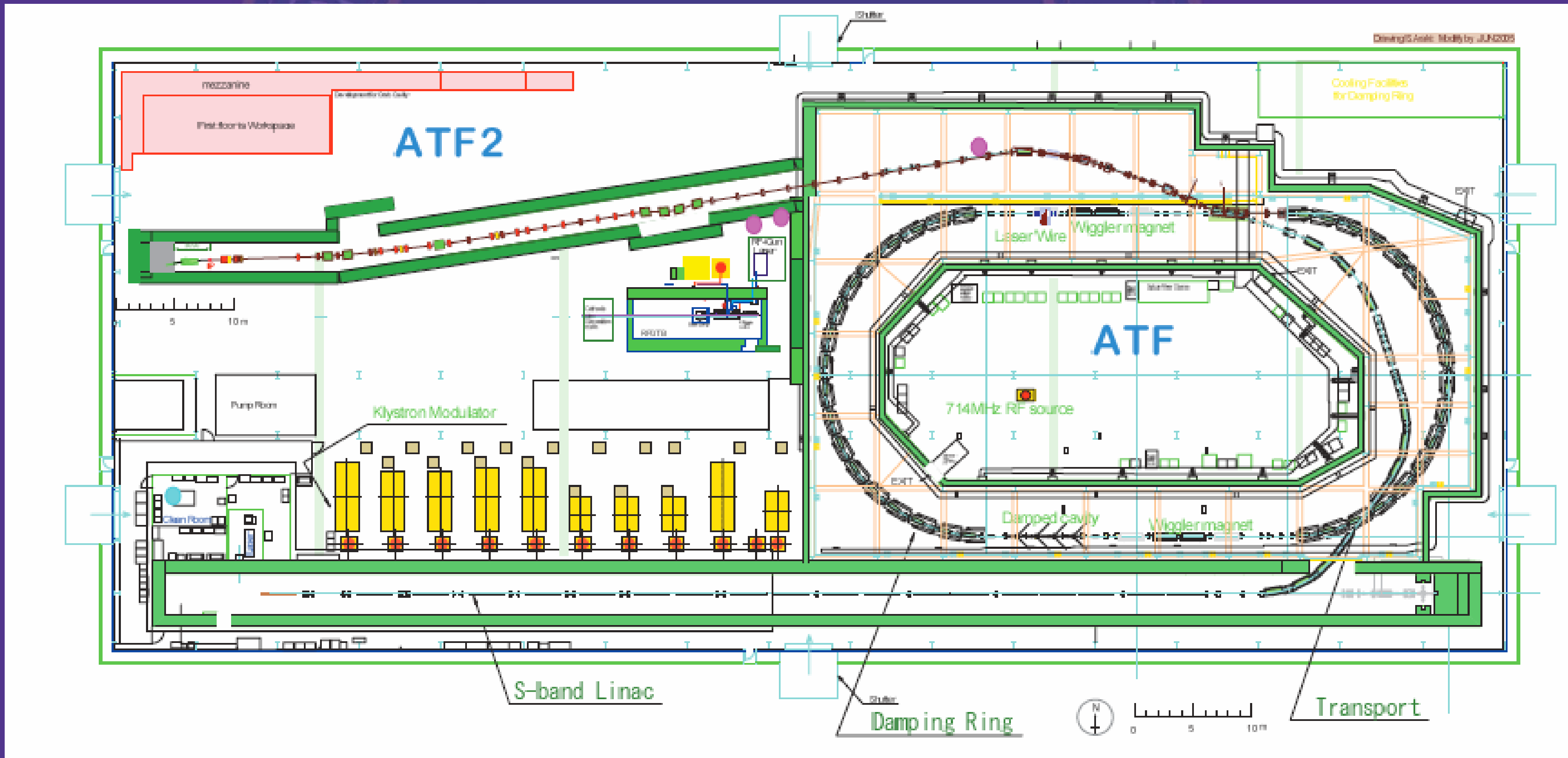
Civil Engineering



- Two tunnels - Accelerator Services & RF power

Test facilities

- ATF @ KEK has been a great success. Time for further improvement:

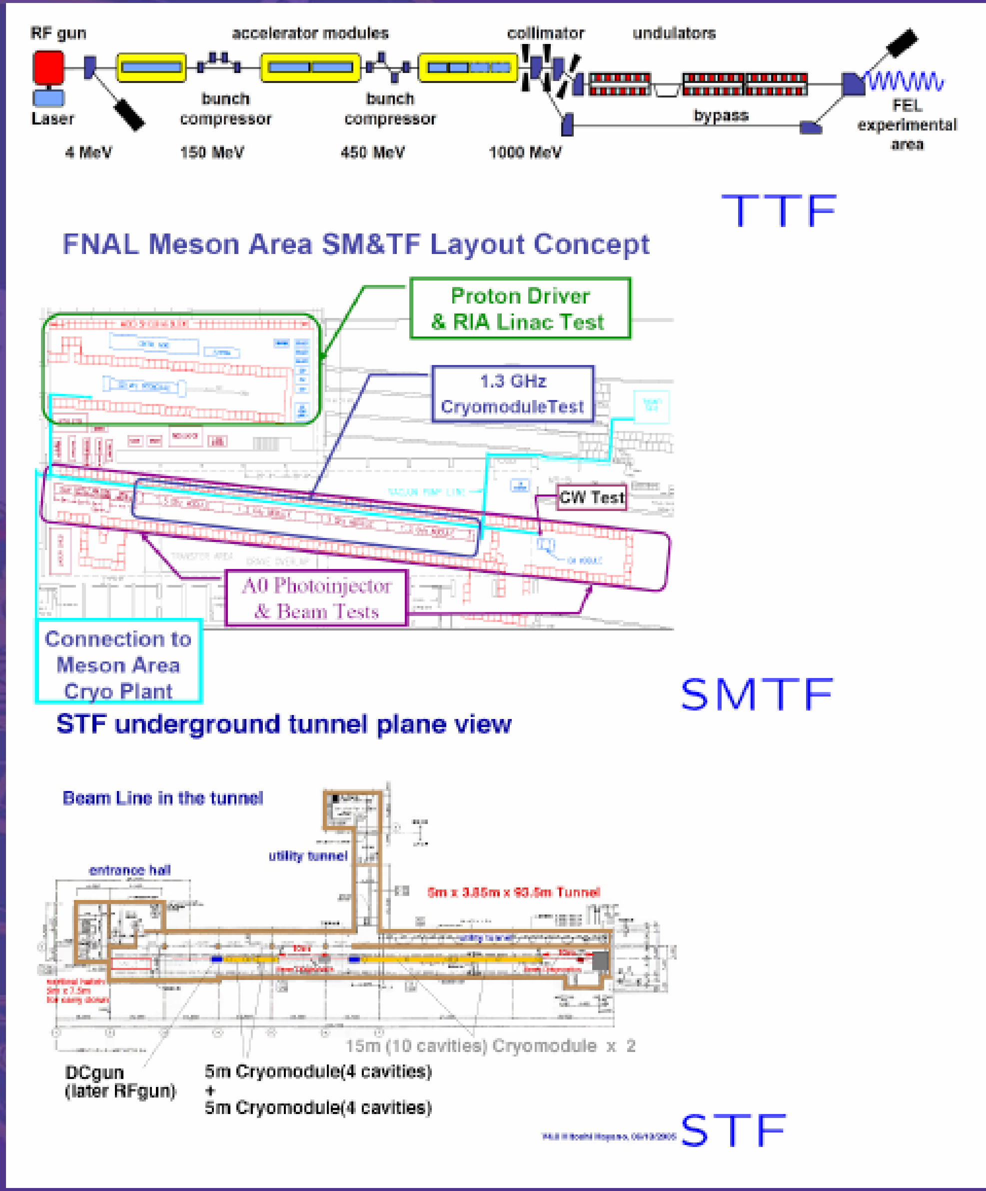


Test facilities

- Extend ATF to give FF prototype - squeeze down to 35 nm and stabilise to 2 nm.

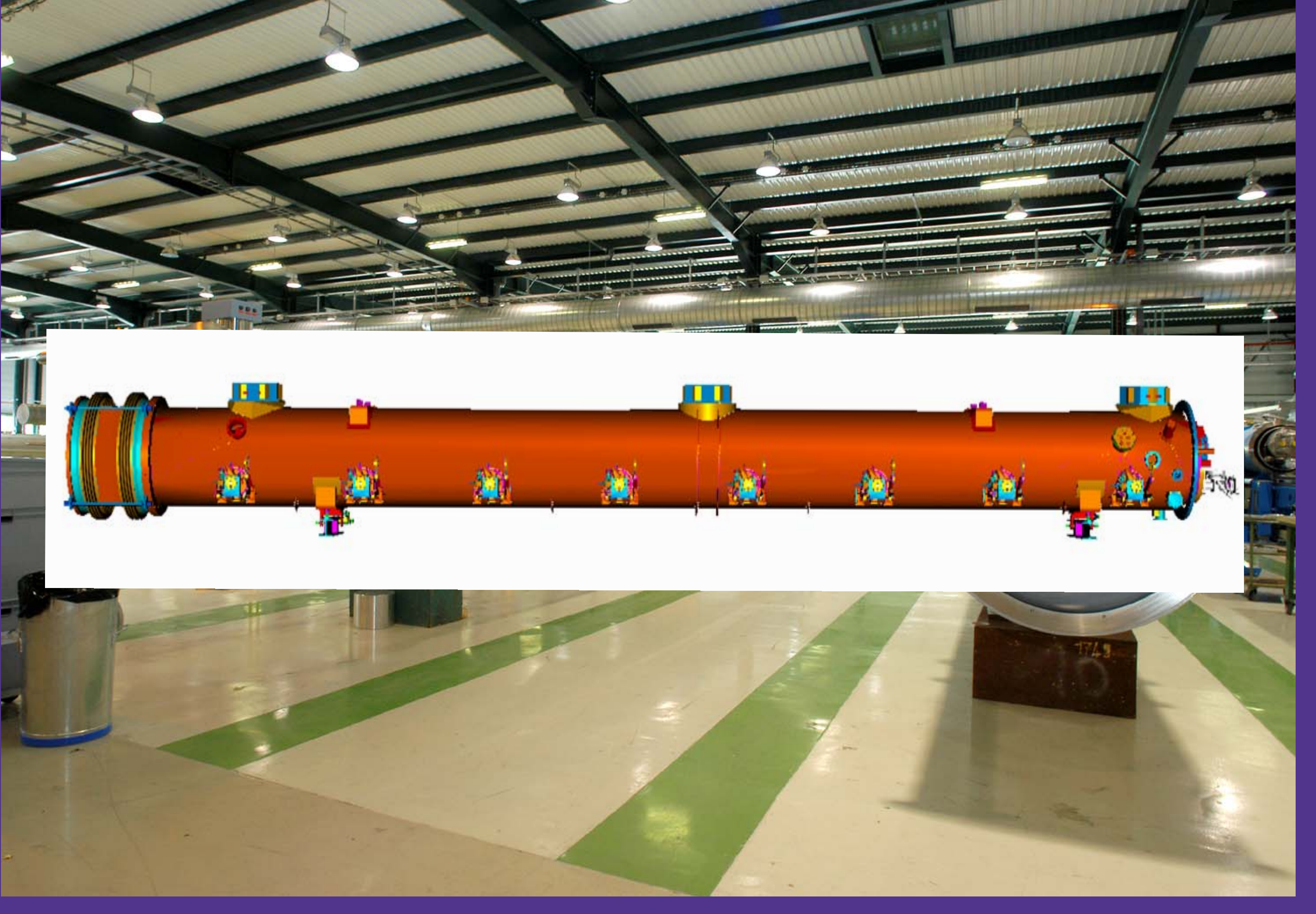
Test facilities

- TTF exists at DESY, SMTF (FNAL), STF (KEK):
- Stimulate SC industry in the regions - collaborate on SC technology



European SCF in FP7

- Need new large-scale test facility for SC cavity & module manufacture with industry.

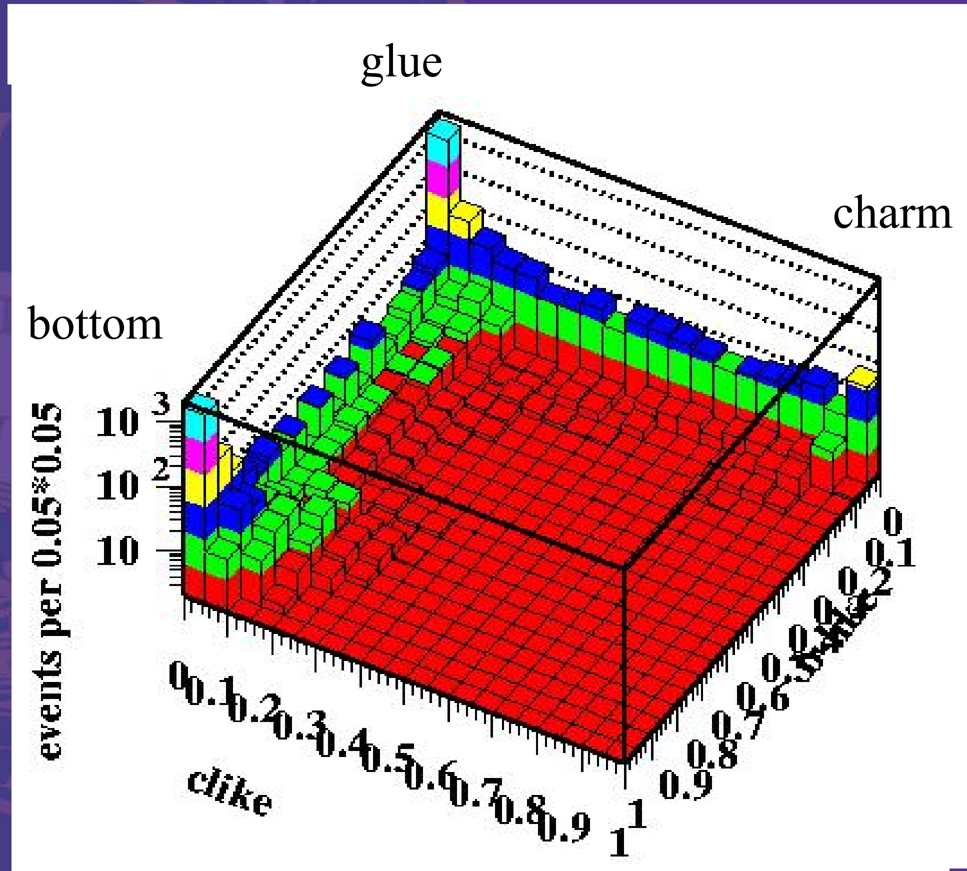


ILC Detectors

- The simplicity of the final state, the possibility of full reconstruction, with unprecedented HQ & L id via vertex tagging implies that ILC detectors must be state-of-the-art and beyond to utilise fully the potential of the ILC.
- The challenges are very different to those of the LHC detectors, but in some areas just as great. In particular the vertex detector and calorimeter need substantial R&D.
- Since Lumi shared at ILC, necessity for 2 detectors & 2 IRs must be carefully justified

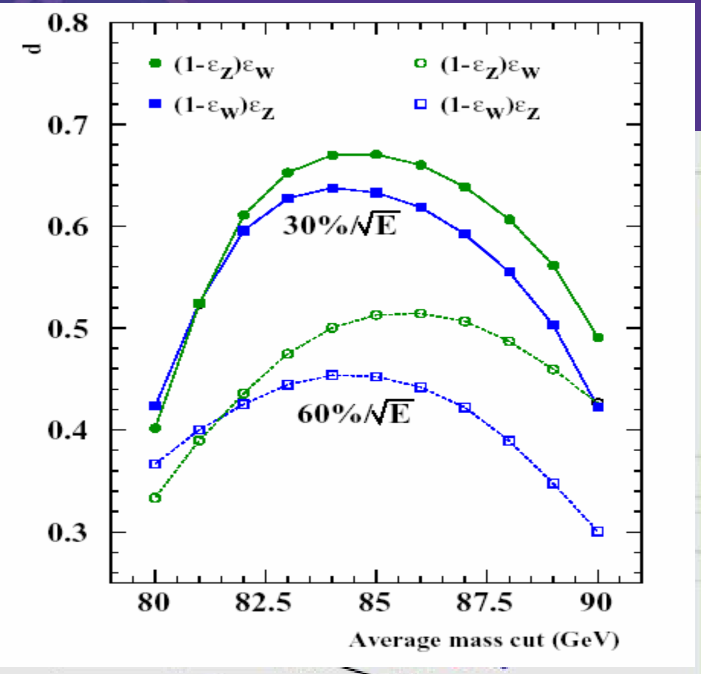
ILC Detectors

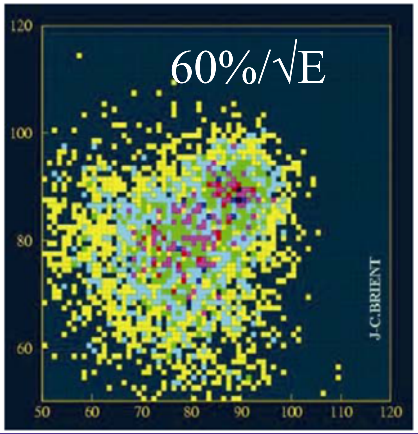
- An excellent VXD with CCD-like performance but much quicker readout

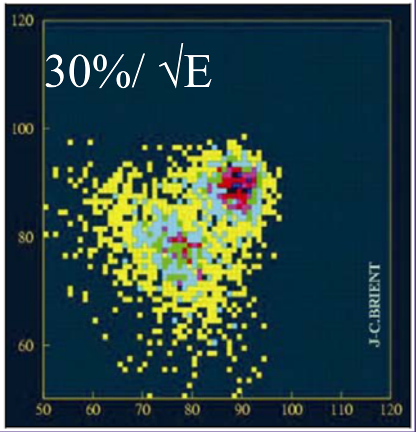


ILC Detectors

- Very high precision and granularity calorimetry
- The physics requires taupolarisation measurement
- High precision calorimetry can double effective lumi.



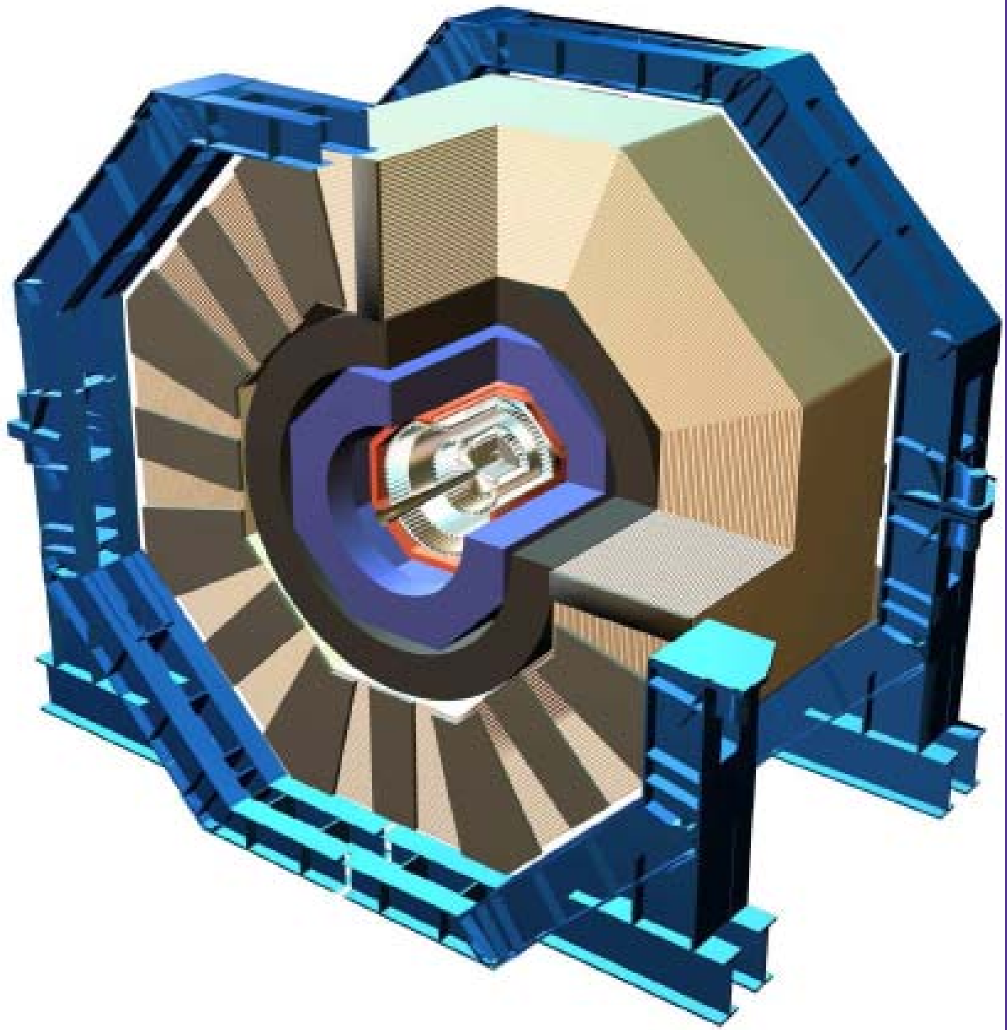




Detectors - SiD

Design philosophy

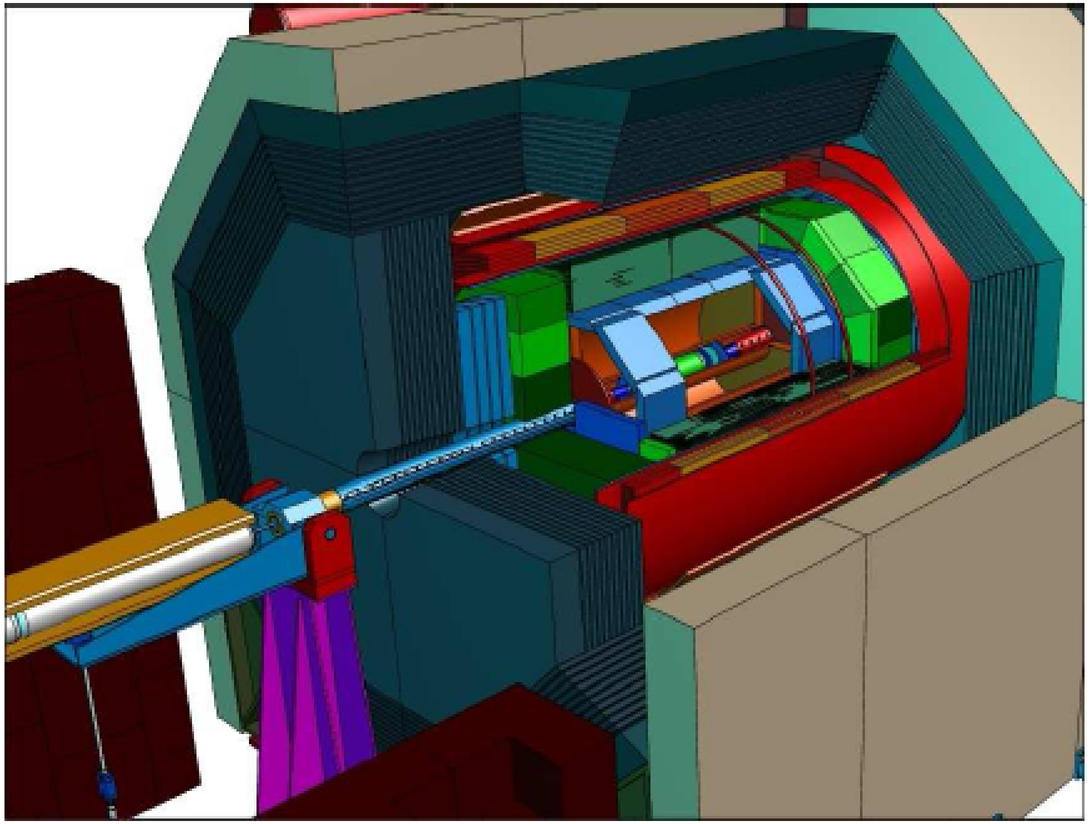
- Aim for SiW calorimeter with best possible resolution
- Keep radius small to make this affordable
- Compensate by high B-field (5 T) and very precise tracking (Si)
- Fast timing of Silicon to suppress background



Detectors - LDC

Design philosophy

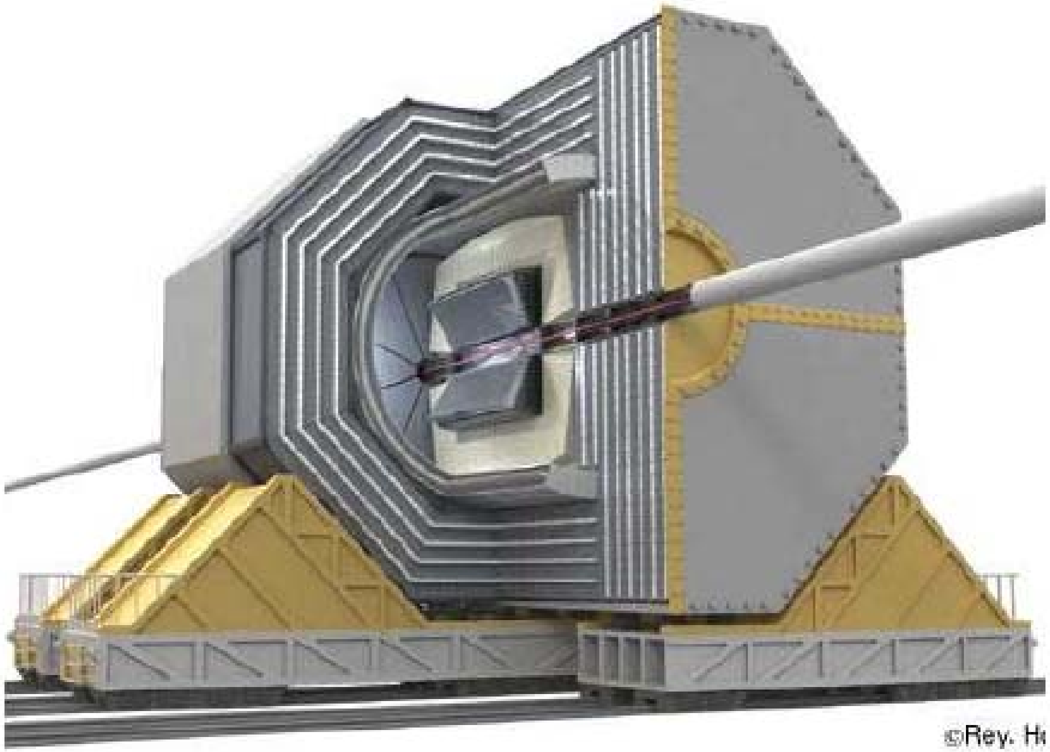
- Fine resolution calorimeter for particle flow
- Gaseous tracking for high tracking efficiency and redundancy
- Large enough radius and high enough B-field (B=4 T) to get required momentum resolution



Detectors - GLD

Design philosophy

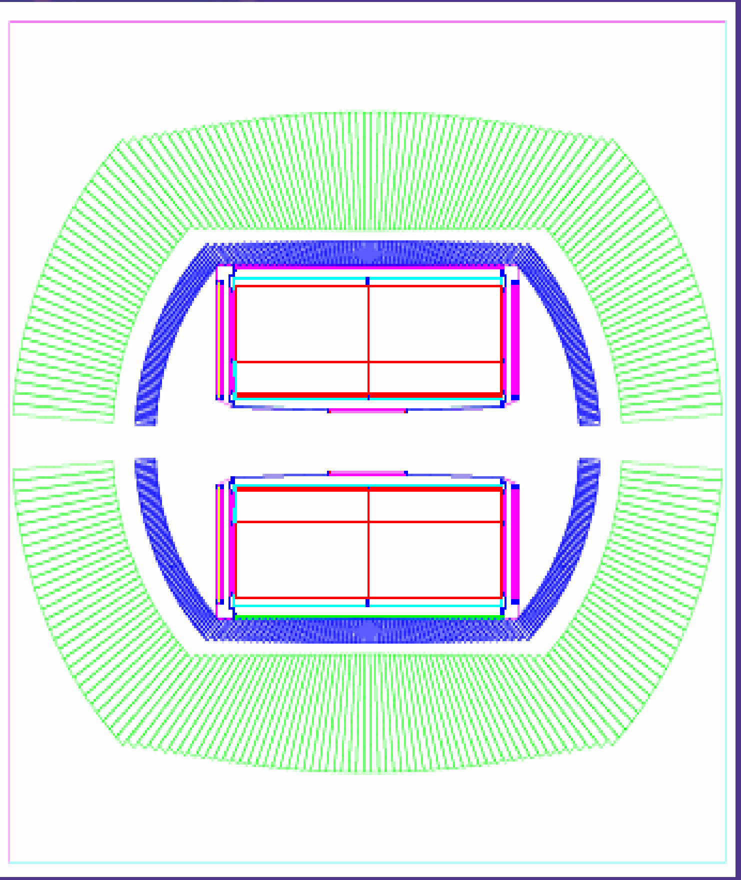
- Large radius for particle flow optimisation
- Gaseous tracking for high tracking efficiency and redundancy
- Fine grained Scintillator-tungsten calorimeter
- Moderate B-filed (3 T)



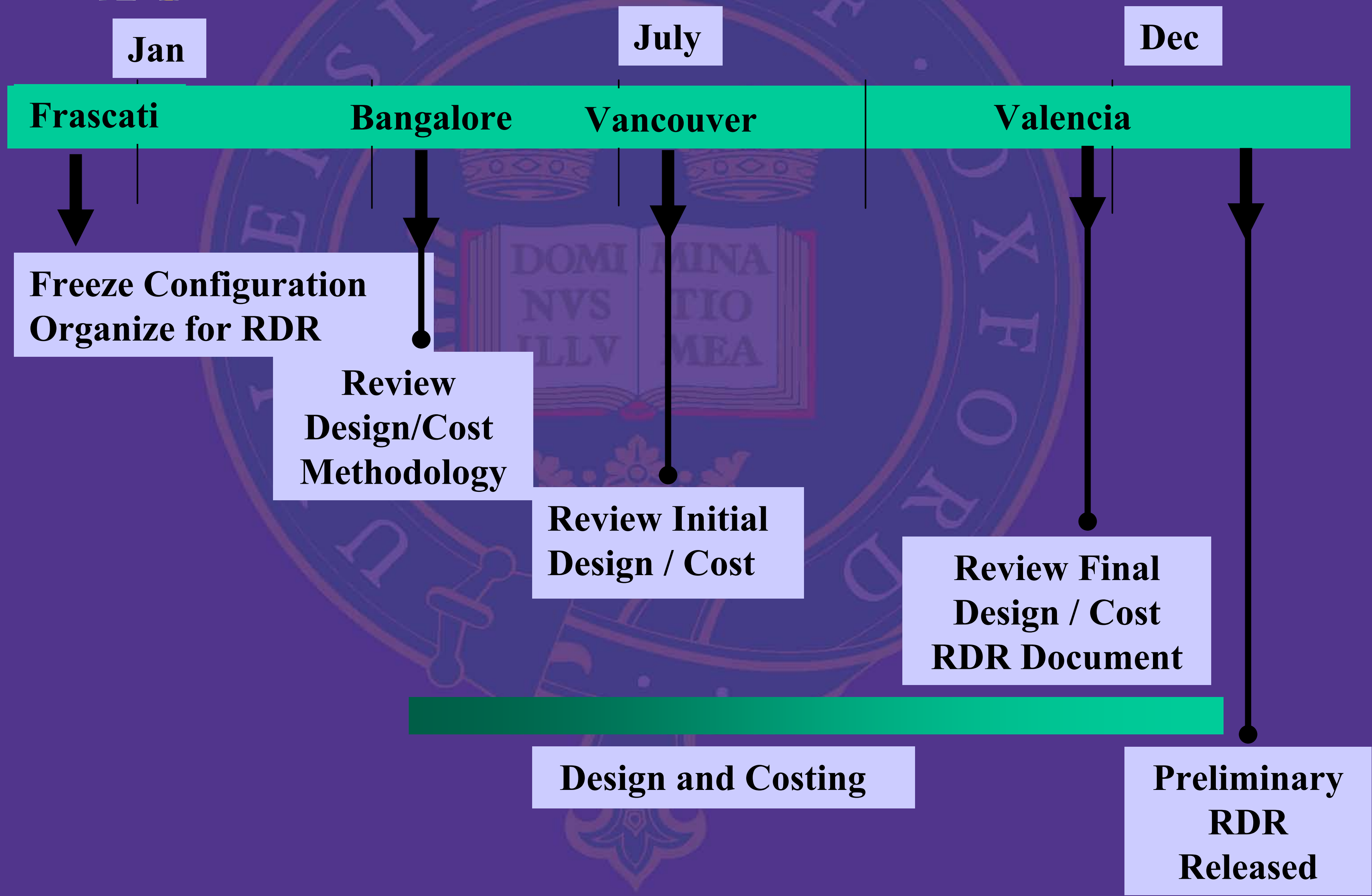
Detectors - 4th concept

Design philosophy:

- Pixel Vertex (PX) 5-micron pixels
- TPC (like GLD or LDC)
  with silicon strips on outer radius
- Crystal dual-readout ECAL
- Triple-readout fiber HCAL:
  scintillation/Cerenkov/neutron (new)
- Muon dual-solenoid geometry (new),
  with ATLAS drift tubes.

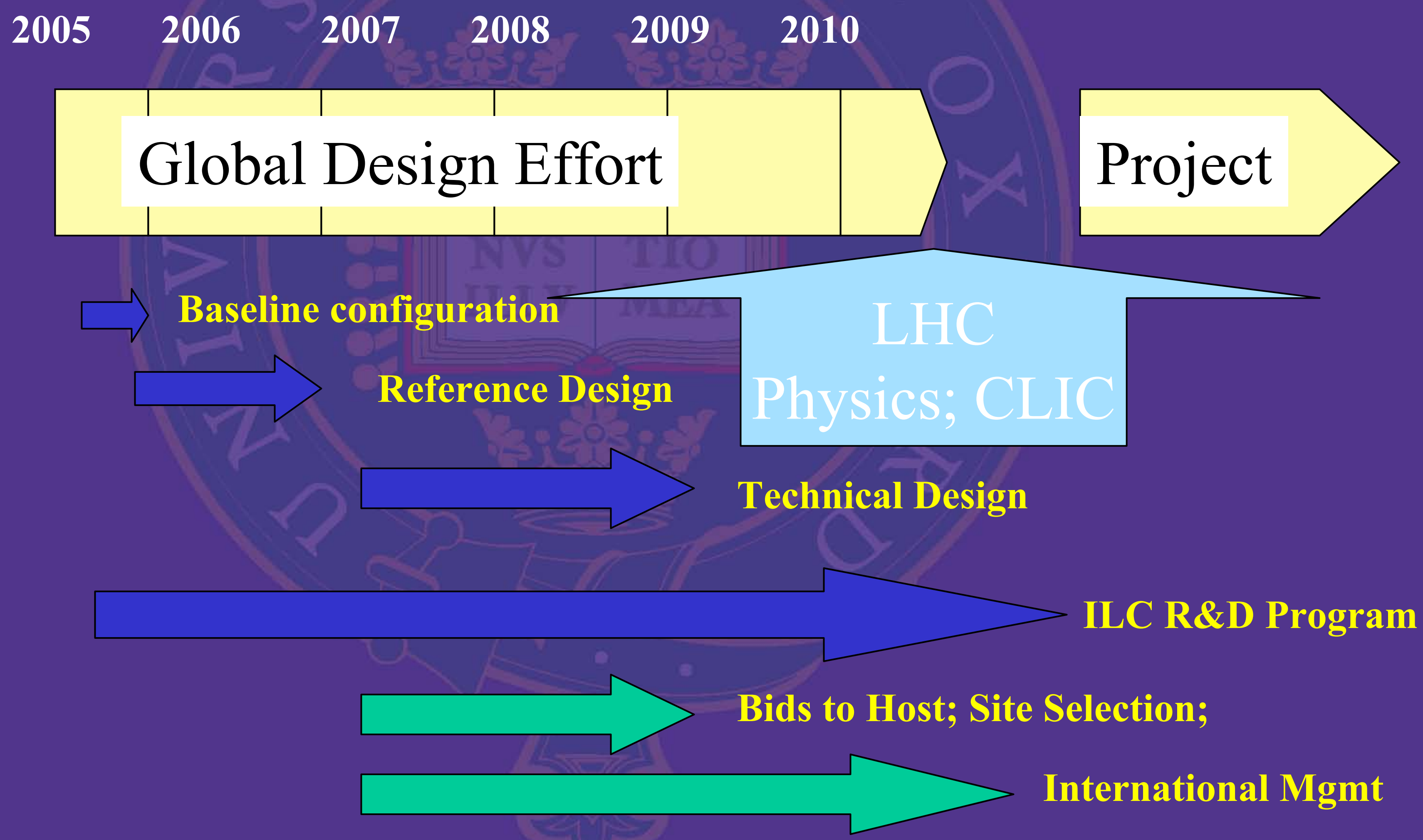


Next steps



Jan
July
Dec
Frascati
Bangalore
Vancouver
Valencia
Freeze Configuration
Organize for RDR
Review
Design/Cost
Methodology
Review Initial
Design / Cost
Review Final
Design / Cost
RDR Document
Design and Costing
Preliminary
RDR
Released

GDE Timeline

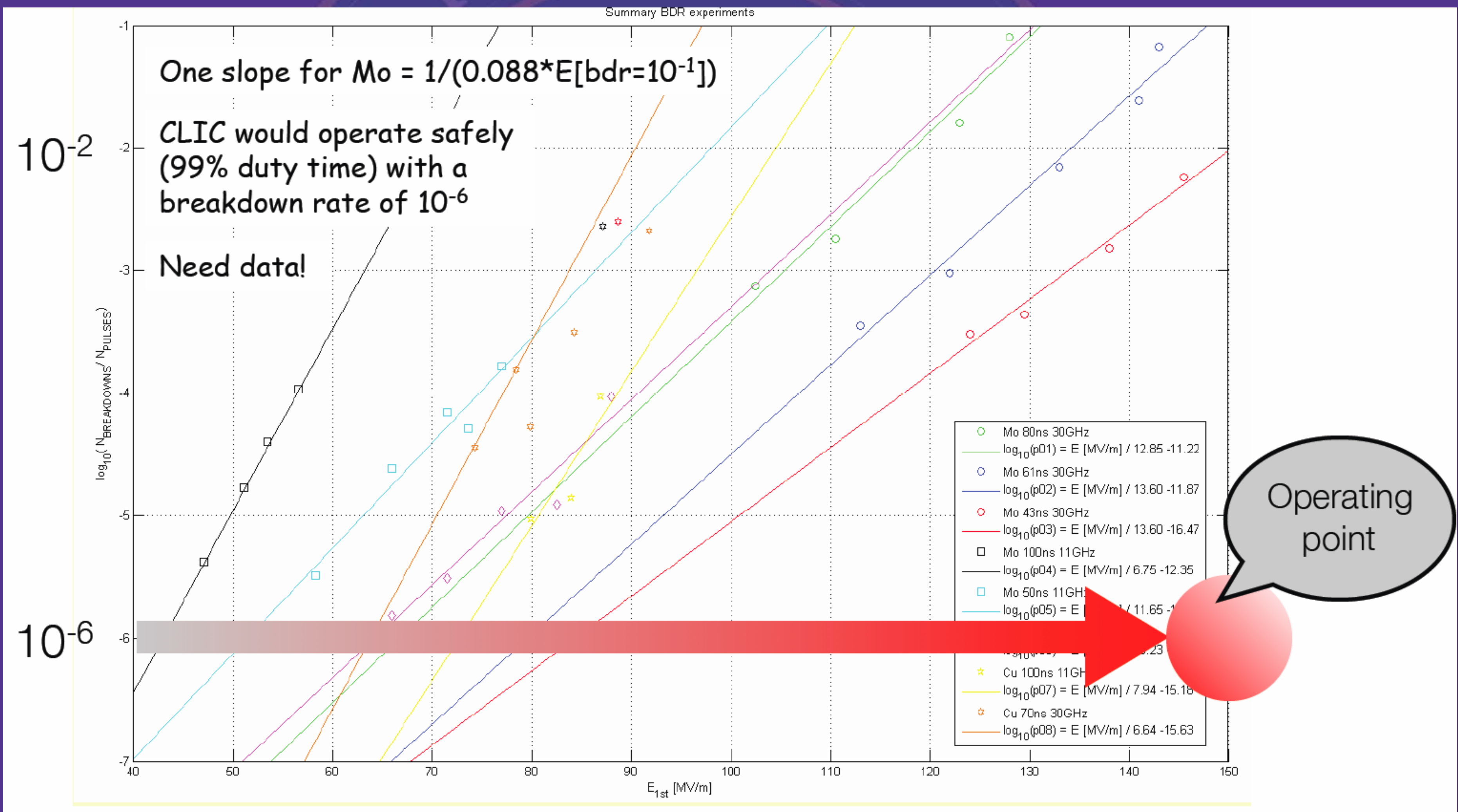


Summary

- The GDE is evolving - new structures and new tools are being developed as required. We are keeping to schedule.
- A first look at the project costing will be carried out at Vancouver. The emphasis until now has been on assuring functionality - it is likely to shift to reducing cost.
- As we approach 2010, political developments must be carefully followed. A decision to construct the ILC will not be easy & it will not be cheap. It is the right next major step for particle physics.

Backup slides

CLIC Status



Summary BDR experiments
One slope for Mo = 1/(0.088*E[bdr=10^-1])
CLIC would operate safely (99% duty time) with a breakdown rate of 10^-6
Need data!
10^-2
10^-6
log10(N_BREAKDOWNS/ N_PULSES)
E_1st [MV/m]
-1
-2
-3
-4
-5
-6
-7
40
50
60
70
80
90
100
110
120
130
140
150
Mo 80ns 30GHz
log10(p01) = E [MV/m] / 12.85 -11.22
Mo 61ns 30GHz
log10(p02) = E [MV/m] / 13.60 -11.87
Mo 43ns 30GHz
log10(p03) = E [MV/m] / 13.60 -16.47
Mo 100ns 11GHz
log10(p04) = E [MV/m] / 6.75 -12.35
Mo 50ns 11GH
Cu 100ns 11GH
log10(p07) = E [MV/m] / 7.94 -15.18
Cu 70ns 30GHz
log10(p08) = E [MV/m] / 6.64 -15.63
Operating point