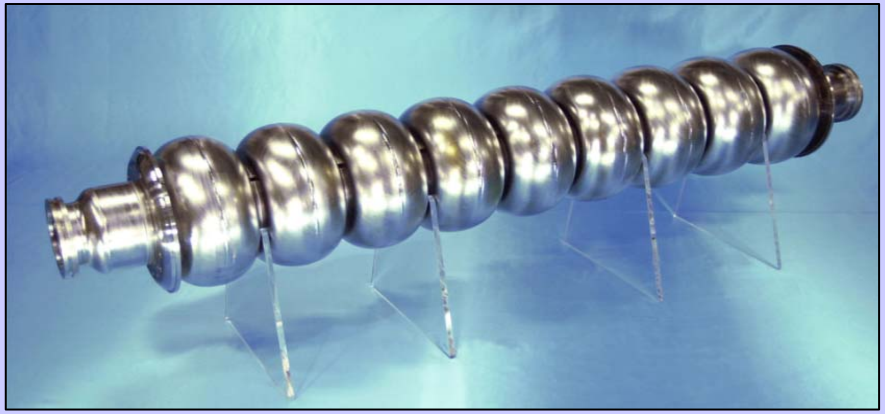
The Global Design Effort for an International Linear Collider



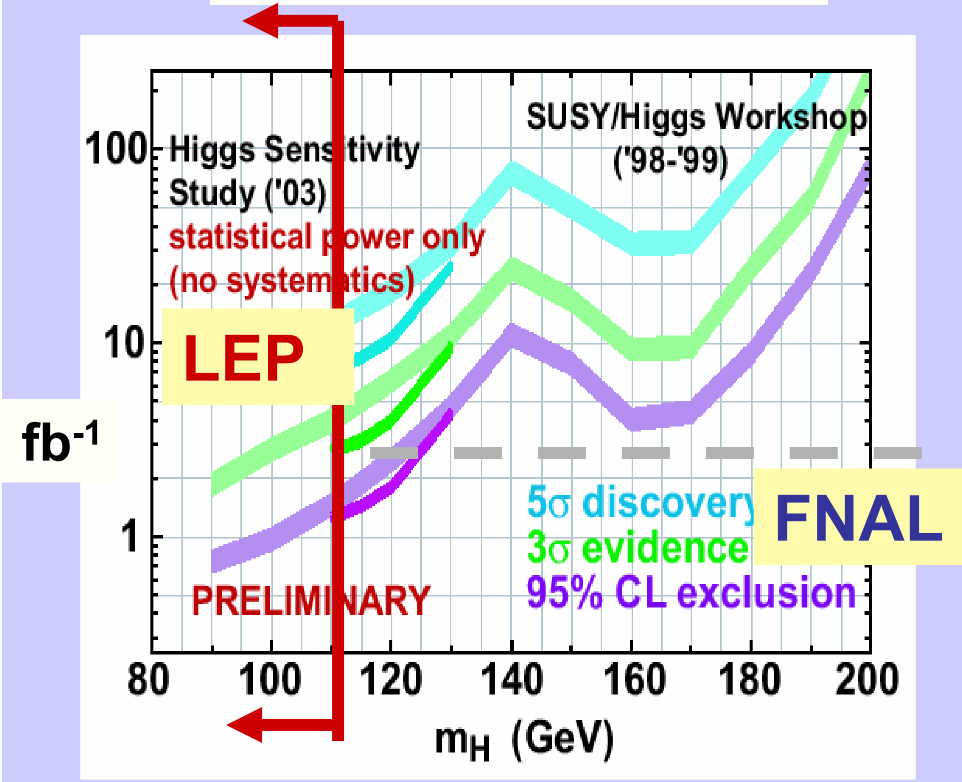
Barry Barish
CALTECH
Pasadena, CA
26-June-06

Accelerators at the Energy Frontier

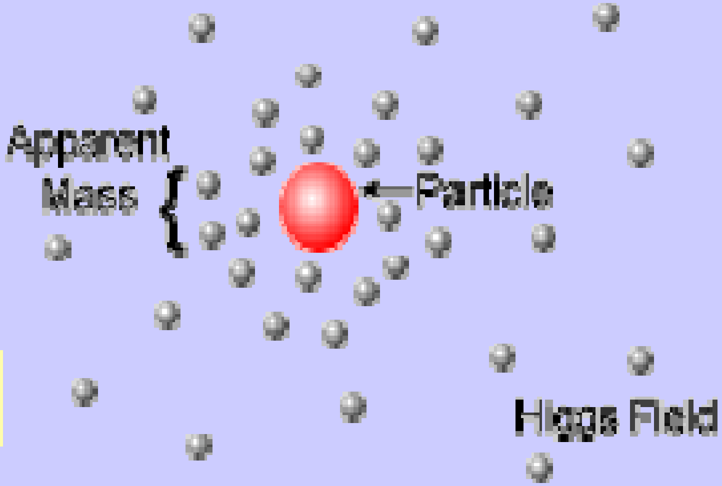
Large Hadron Collider
CERN – Geneva Switzerland

LHC and the Energy Frontier
Source of Particle Mass

Discover the Higgs

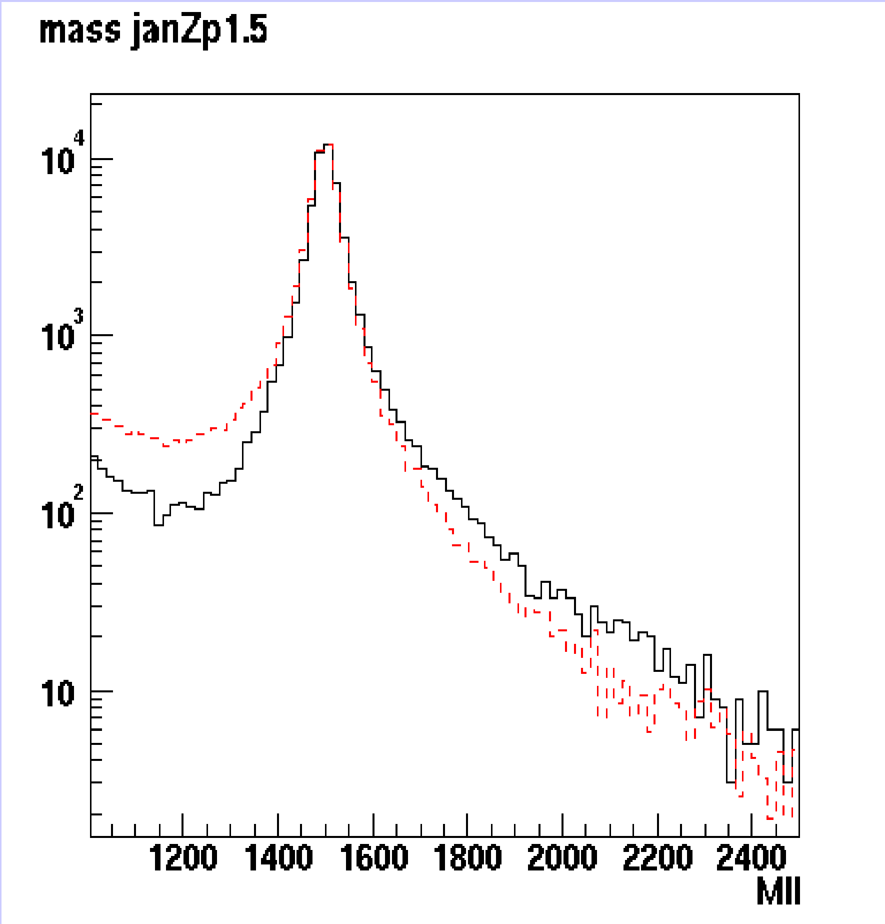


The Higgs Field



or variants or ???

LHC and the Energy Frontier
A New Force in Nature

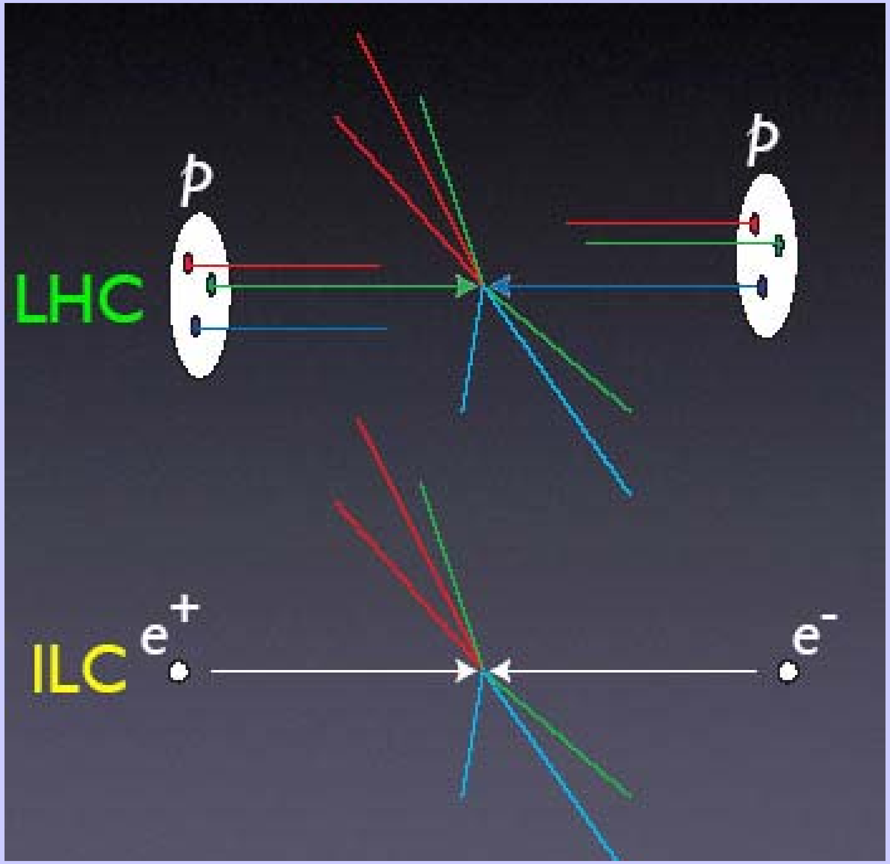


Discover a new heavy particle, Z'

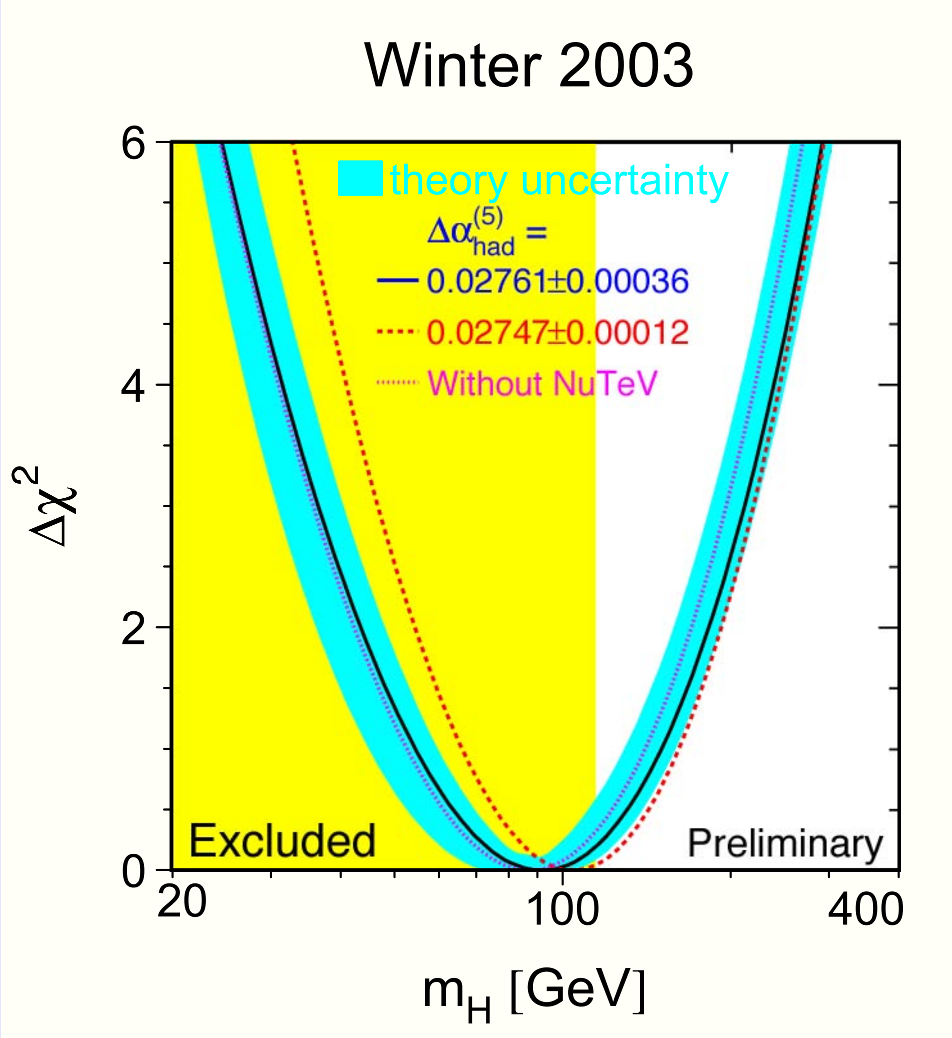
Can show by measuring the couplings with the ILC how it relates to other particles and forces

Why e^+e^- Collisions ?

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

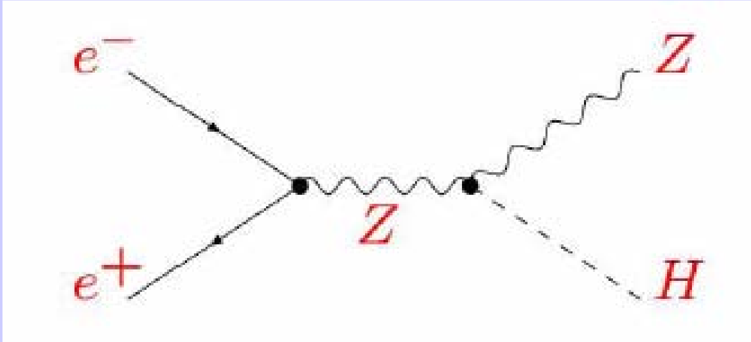


Electroweak Precision Measurements

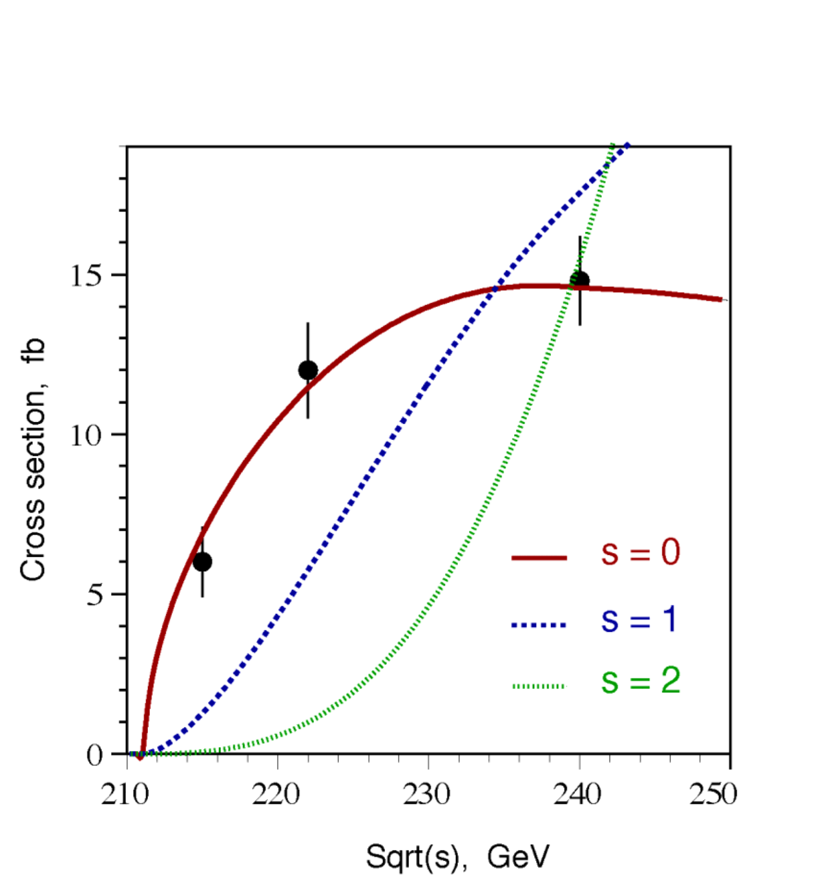


What causes mass??

The mechanism – Higgs or alternative appears around the corner



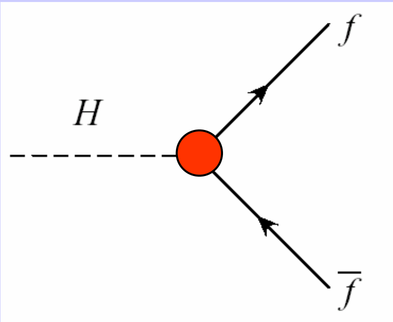
How do you know you have discovered the Higgs ?

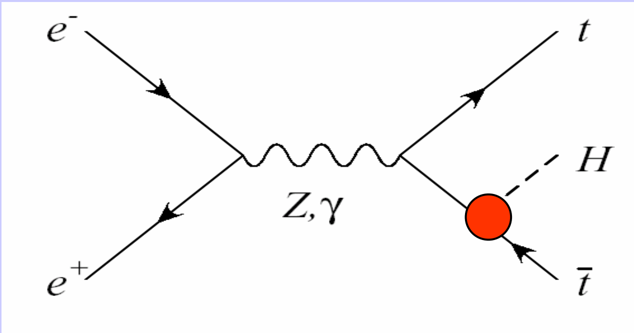


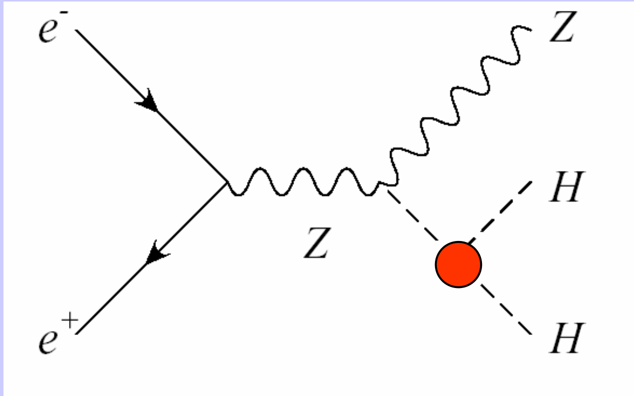
Measure the quantum numbers. The Higgs must have spin zero !

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

The ILC measures coupling strength of the Higgs with other particles





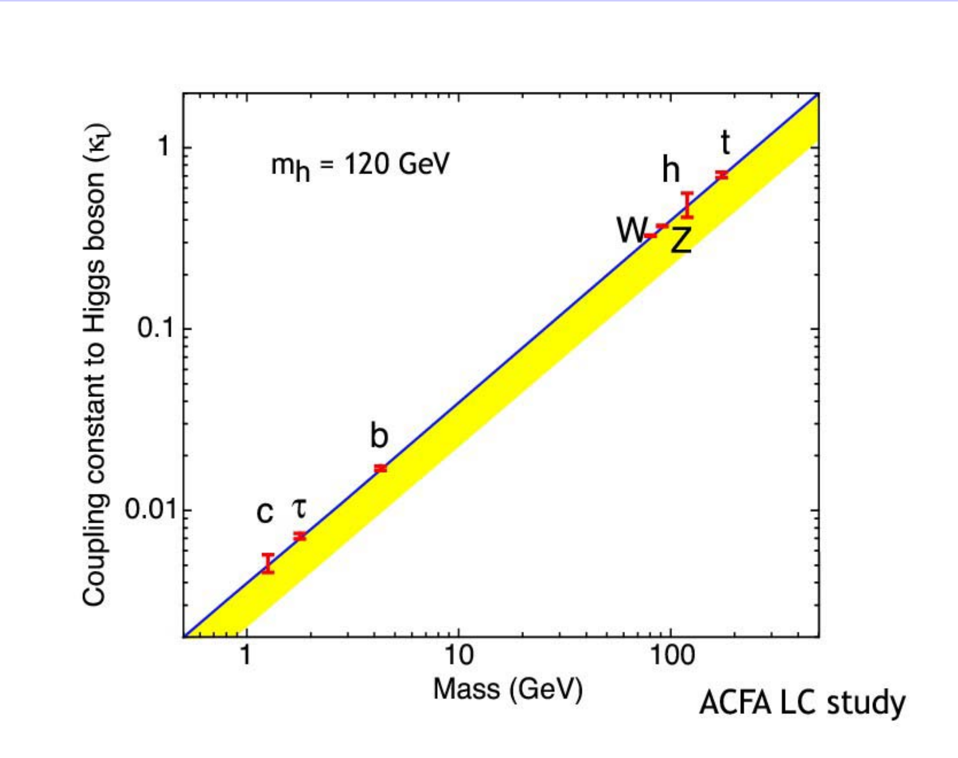


Higgs Coupling-mass relation

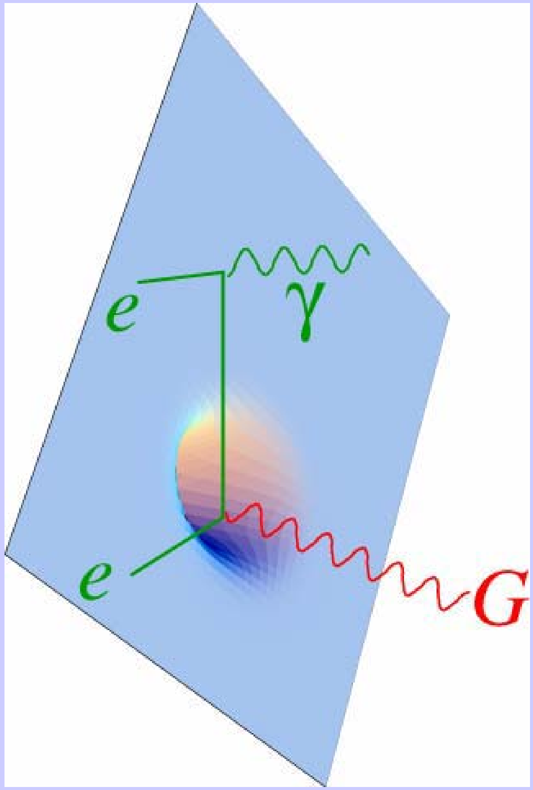
$$m_i = v \times \kappa_i$$

What can we learn from the Higgs?

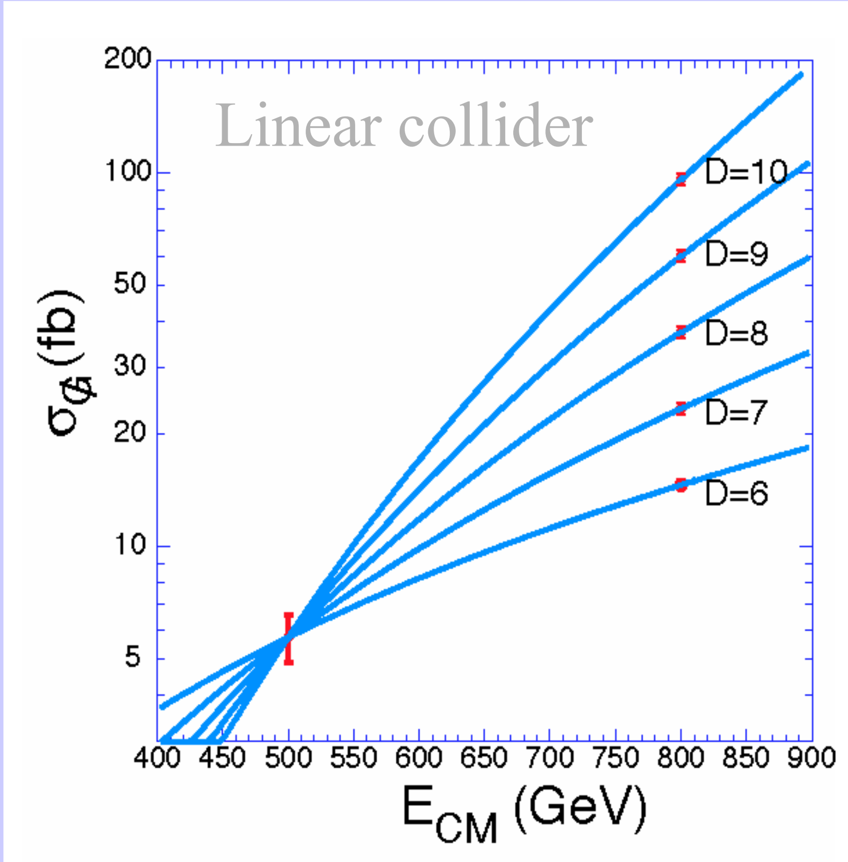
Precision measurements of Higgs coupling can reveal extra dimensions in nature



- Straight blue line gives the standard model predictions.
- Range of predictions in models with extra dimensions -- yellow band, (at most 30% below the Standard Model
- The red error bars indicate the level of precision attainable at the ILC for each particle



Direct production from extra dimensions ?



New space-time dimensions can be mapped by studying the emission of gravitons into the extra dimensions, together with a photon or jets emitted into the normal dimensions.

Is there a New Symmetry in Nature?

Super-symmetry

Bosons ⟷ **Fermions**

Integer Spin: 0, 1,..

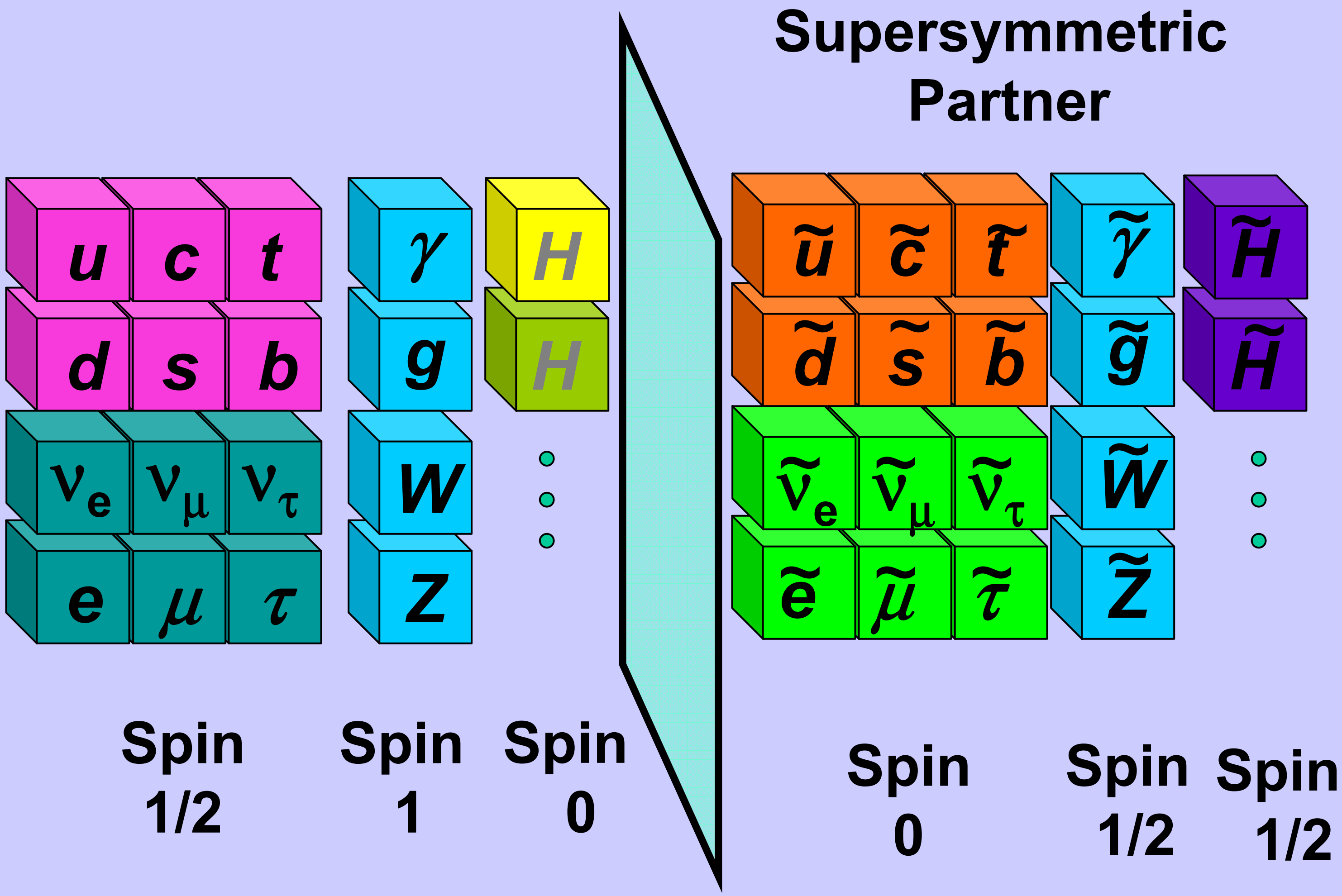
Half integer Spin: 1/2, 3/2,..

The virtues of Super-symmetry:

- **Unification of Forces**
- **The Hierarchy Problem**
- **Candidate for the Dark Matter**

  …

Supersymmetry



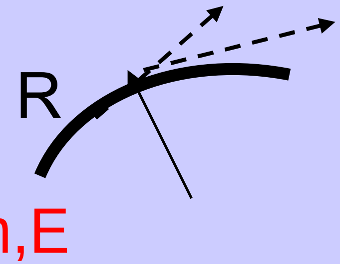
Parameters for the ILC

- 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

Circular or Linear Collider?

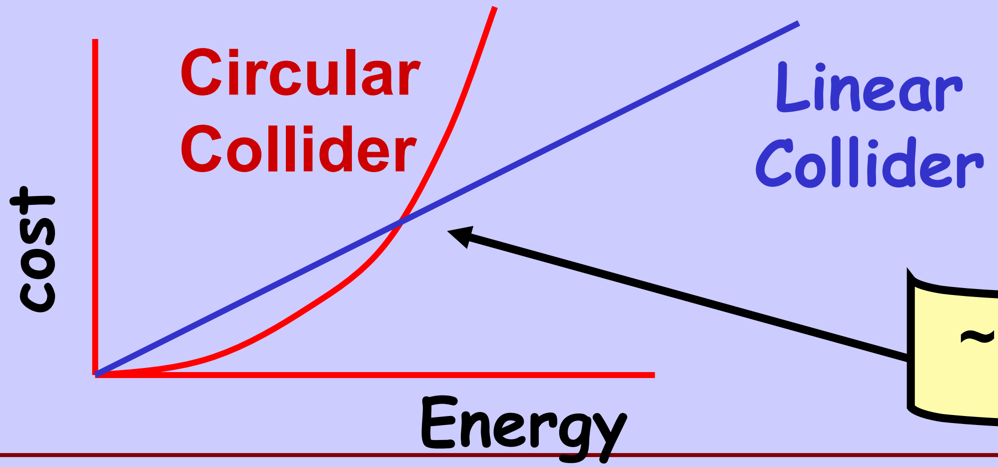
- **Circular Machine**



Synchrotron Radiation

  - $\Delta E \sim (E^4/m^4 R)$
  - Cost $\sim a R + b \Delta E$

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



Cost (linear) $\sim a' L$
where $L \sim E$

~ 200 GeV

Luminosity & Beam Size

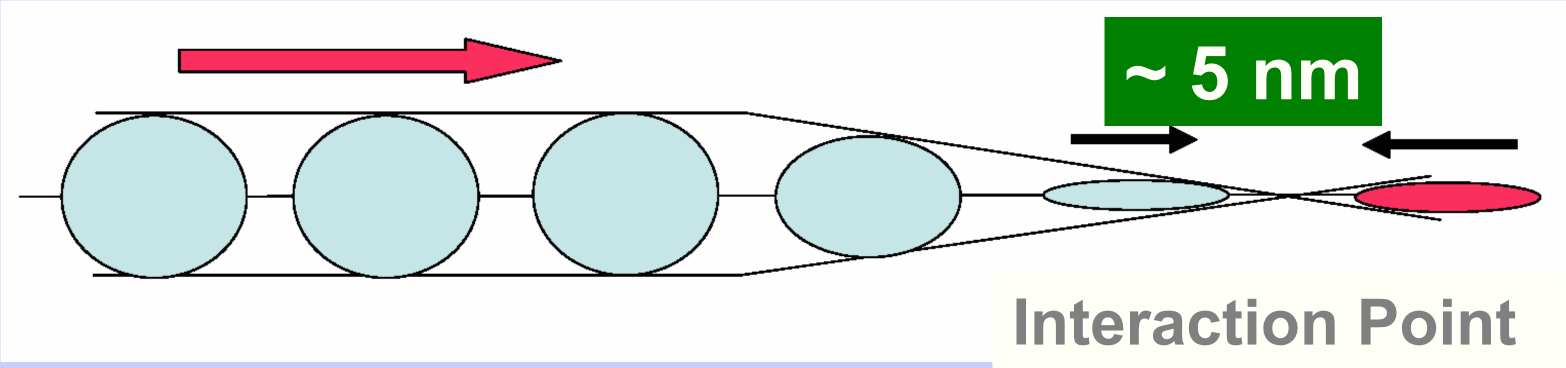
$$L = \frac{n_b N^2 f_{rep}}{2\pi \Sigma_x \Sigma_y} H_D$$

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

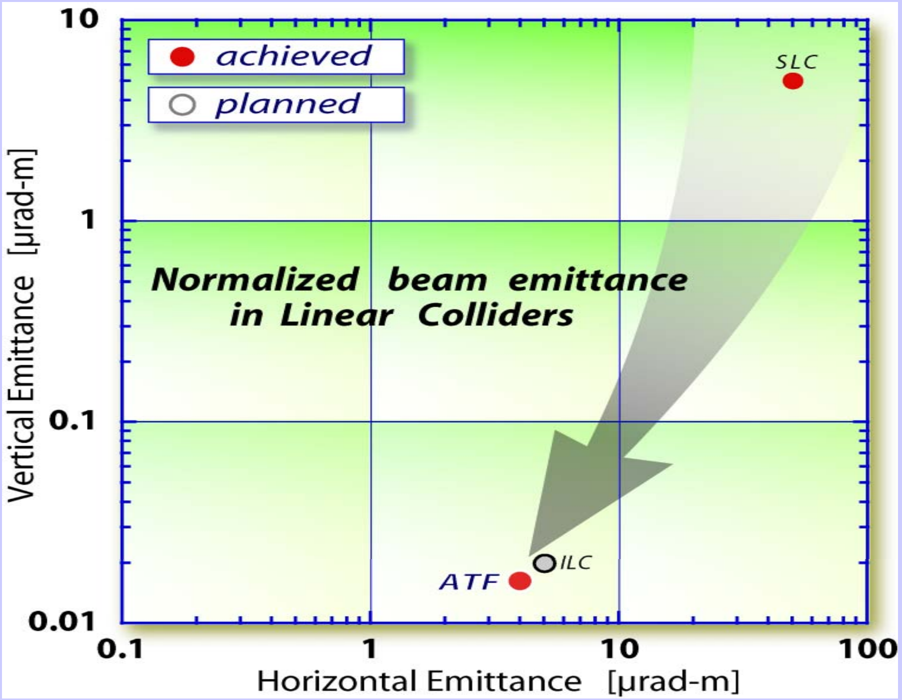
	L	f_{rep} [Hz]	n_b	N [10^{10}]	σ_x [μm]	σy [μm]
ILC	2×10^{34}	5	3000	2	0.5	0.005
SLC	2×10^{30}	120	1	4	1.5	0.5
LEP2	5×10^{31}	10,000	8	30	240	4
PEP-II	1×10^{34}	140,000	1700	6	155	4

- The beam-beam tune shift limit is much looser in a linear collider than a storage rings → achieve luminosity with spot size and bunch charge
  - Small spots mean small emittances and small betas: $\sigma_x = \text{sqrt}(\beta_x \varepsilon_x)$

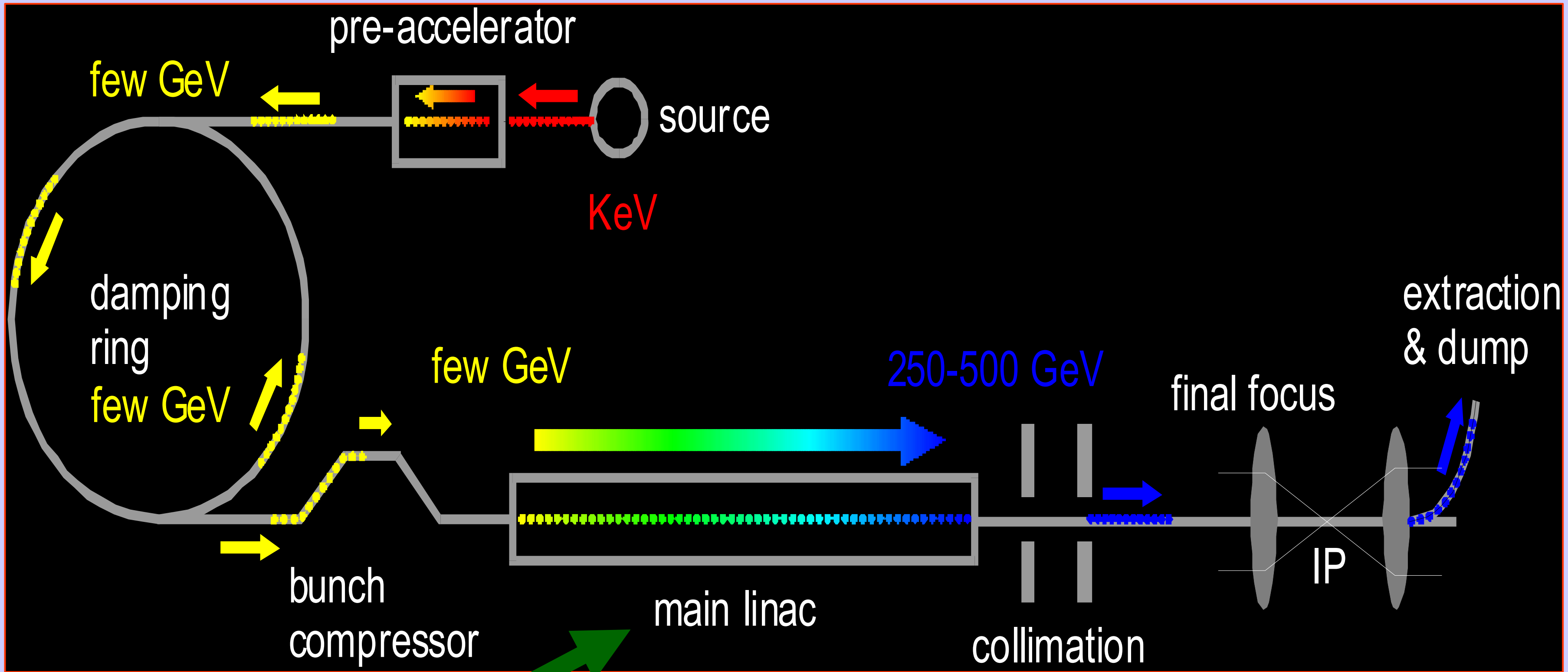
Achieving High Luminosity



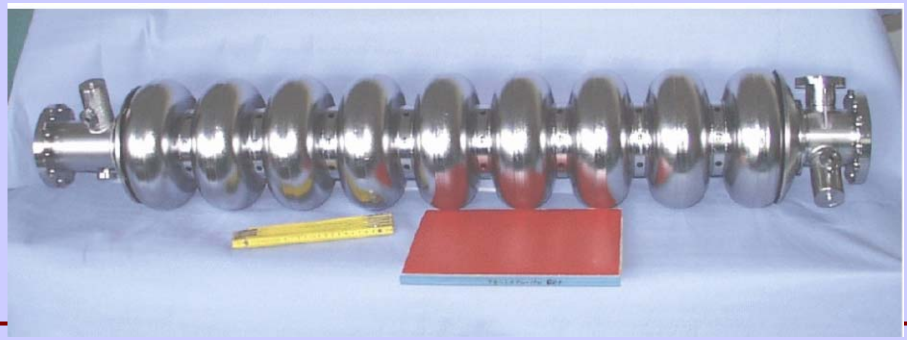
- Low emittance machine optics
- Contain emittance growth
- Maximally squeeze the beam



Designing a Linear Collider



Superconducting RF Main Linac



Global Effort on Design / R&D for ILC

EU

Snowmass
49 GDE members

Present
GDE Membership
Americas 22
Europe 24
Asia 18

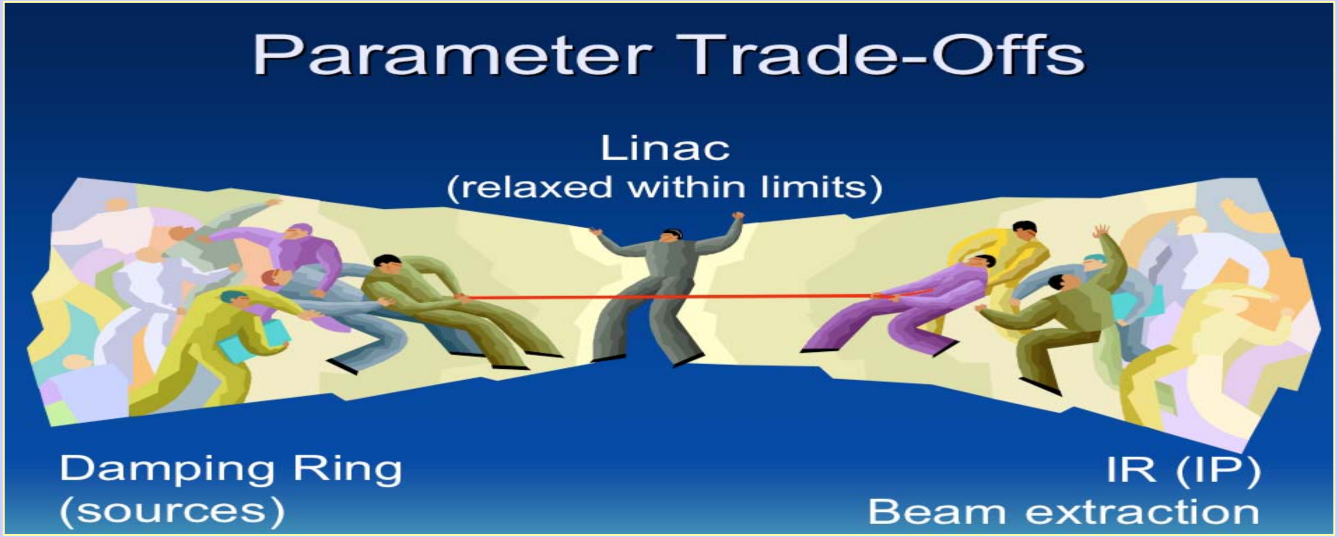
About 30 FTEs

US

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

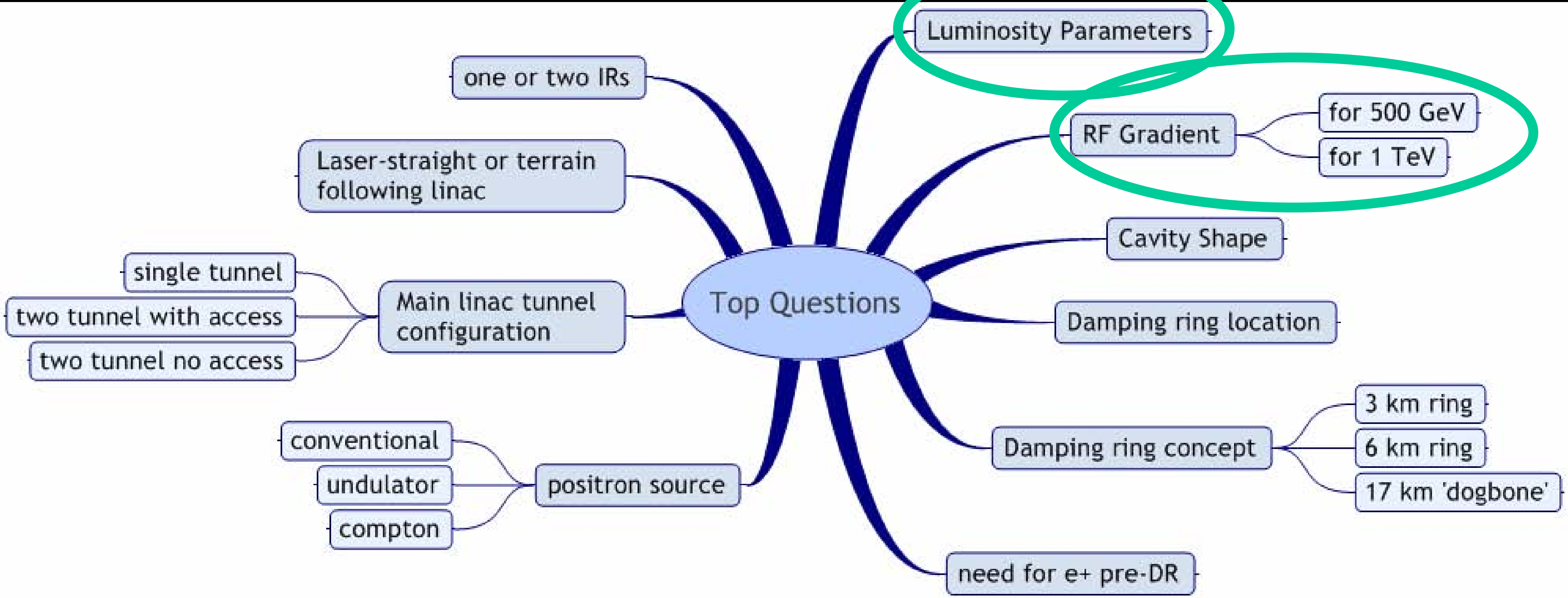
Parametric Approach

- **A working space - optimize machine for cost/performance**



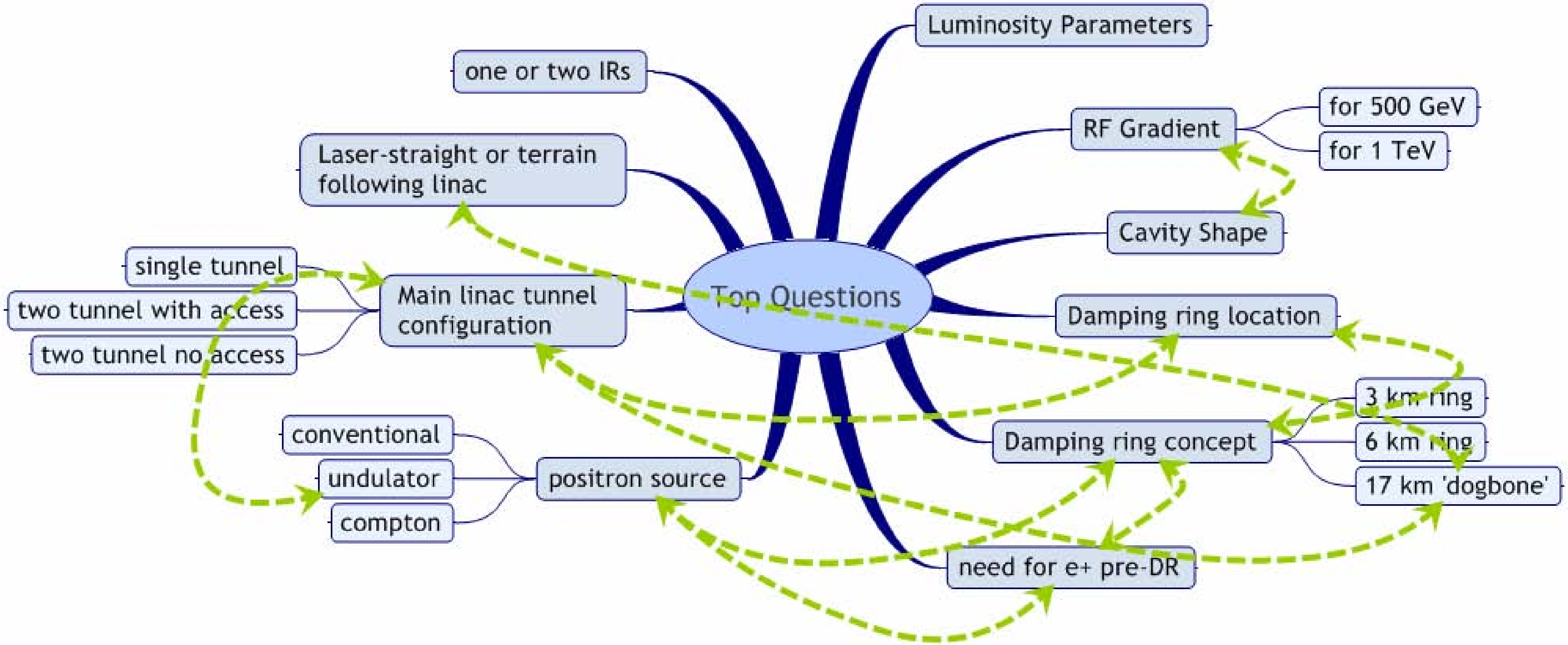
		min		nominal		max	
Bunch charge	N	1	-	2	-	2	$\times 10^{10}$
Number of bunches	n_b	1330	-	2820	-	**5640**	
Linac bunch interval	t_b	**154**	-	308	-	461	ns
Bunch length	σ_z	**150**	-	300	-	500	μm
Vert.emit.	$\gamma\epsilon_y^*$	**0.03**	-	0.04	-	0.08	mm·mrad
IP beta (500GeV)	β_x^*	**10**	-	21	-	21	mm
	β_y^*	**0.2**	-	0.4	-	0.4	mm
IP beta (1TeV)	β_x^*	**10**	-	30	-	30	mm
	β_y^*	**0.2**	-	0.3	-	0.6	mm

The Key Decisions



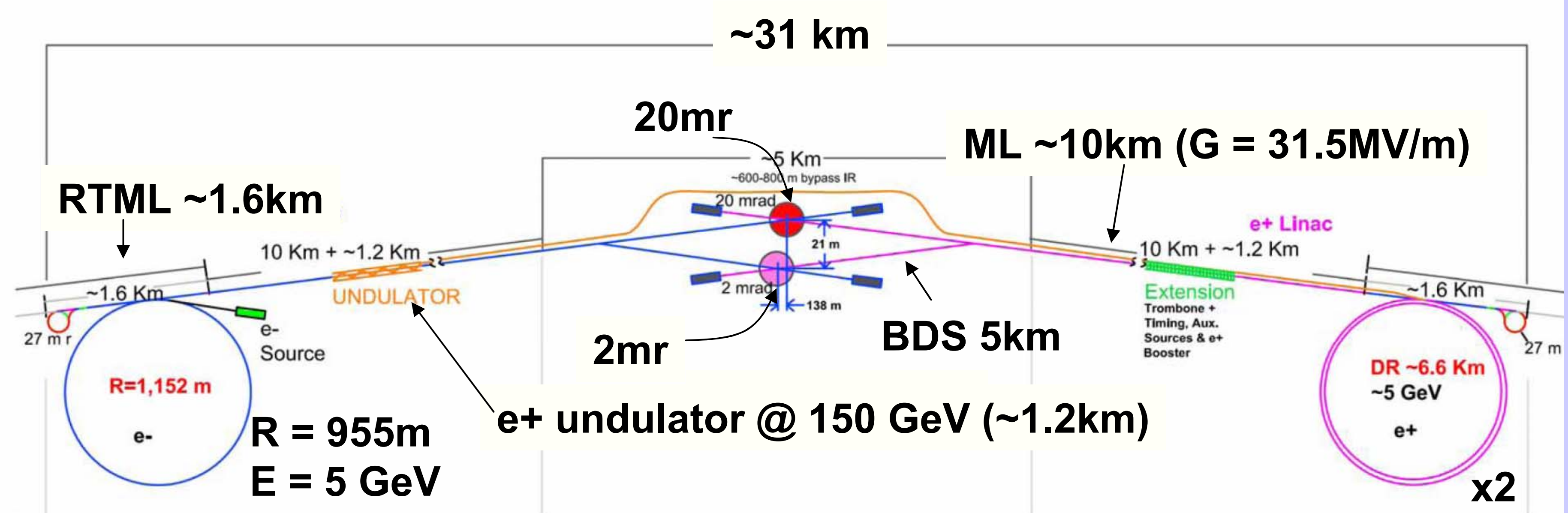
Critical choices: luminosity parameters & gradient

Making Choices – The Tradeoffs



Many decisions are interrelated and require input from several WG/GG groups

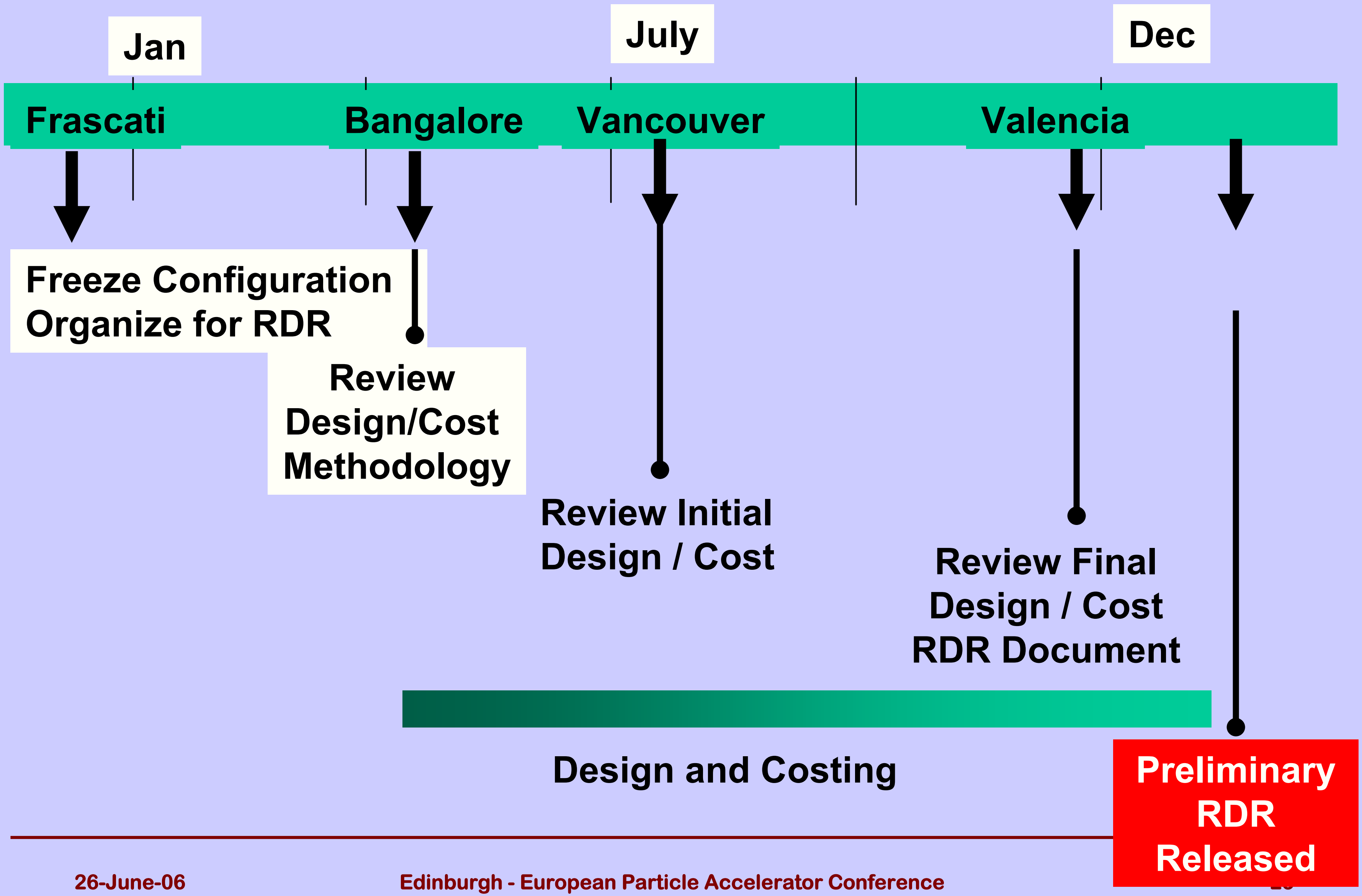
The Baseline Machine (500GeV)



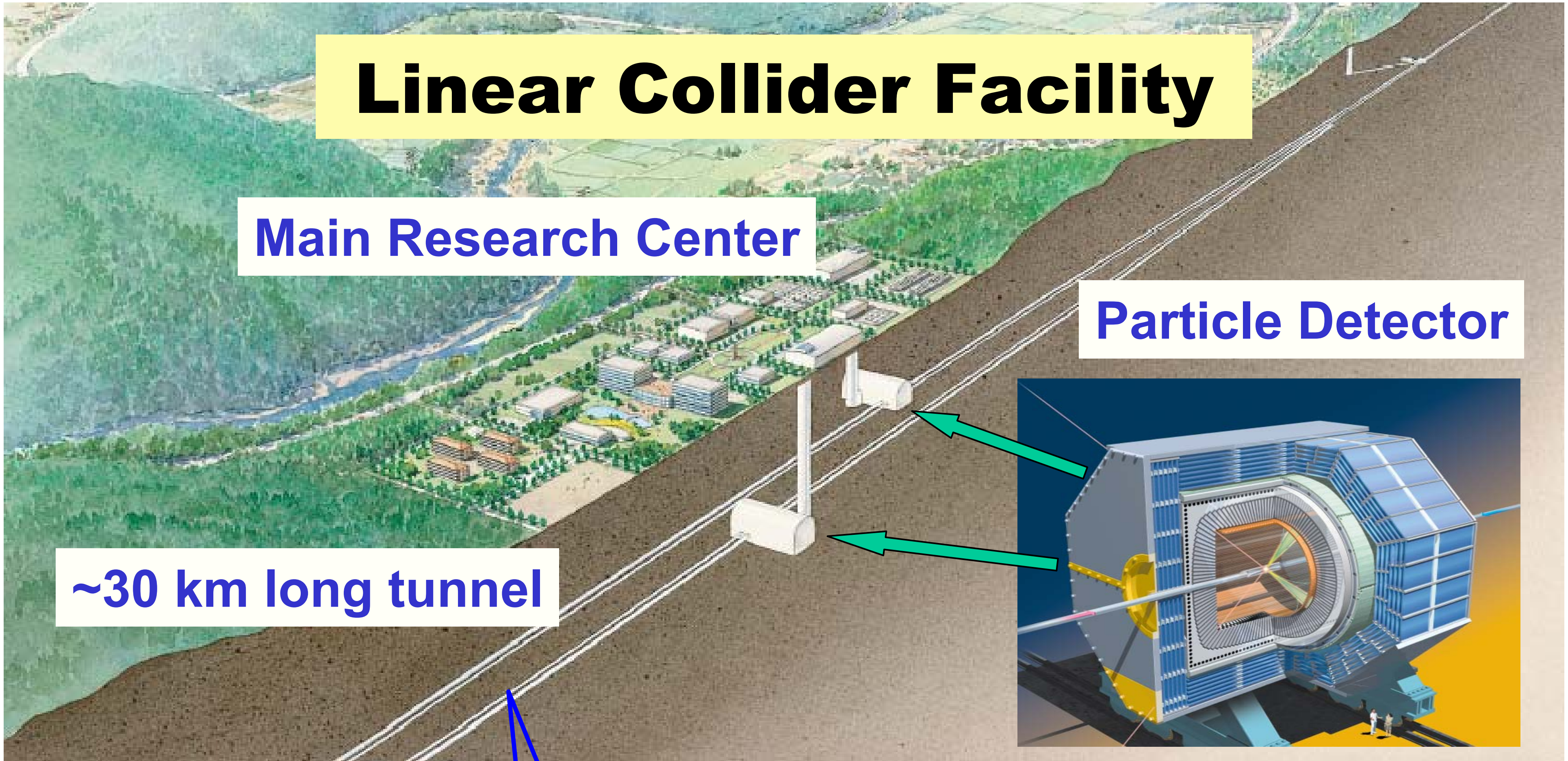
not to scale

From Baseline to a RDR

2006



Linear Collider Facility

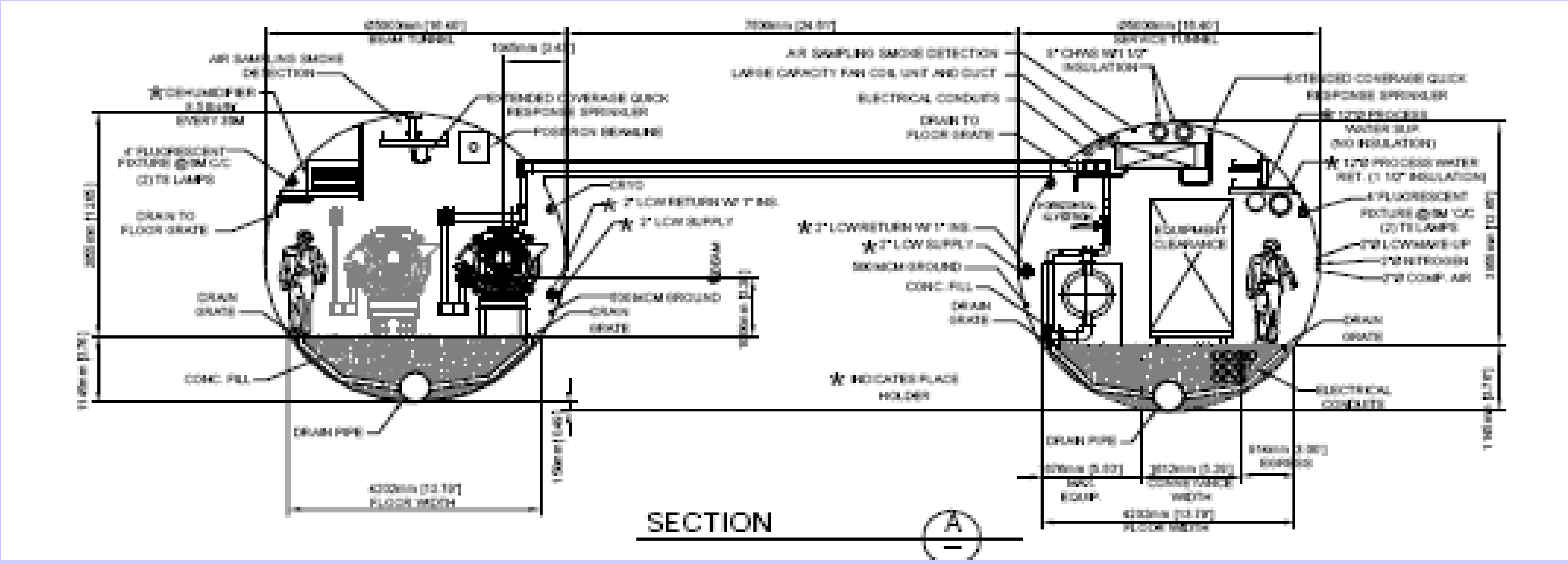


Two tunnels
- accelerator units
- other for services - RF power

Reference Design: Regional Specific

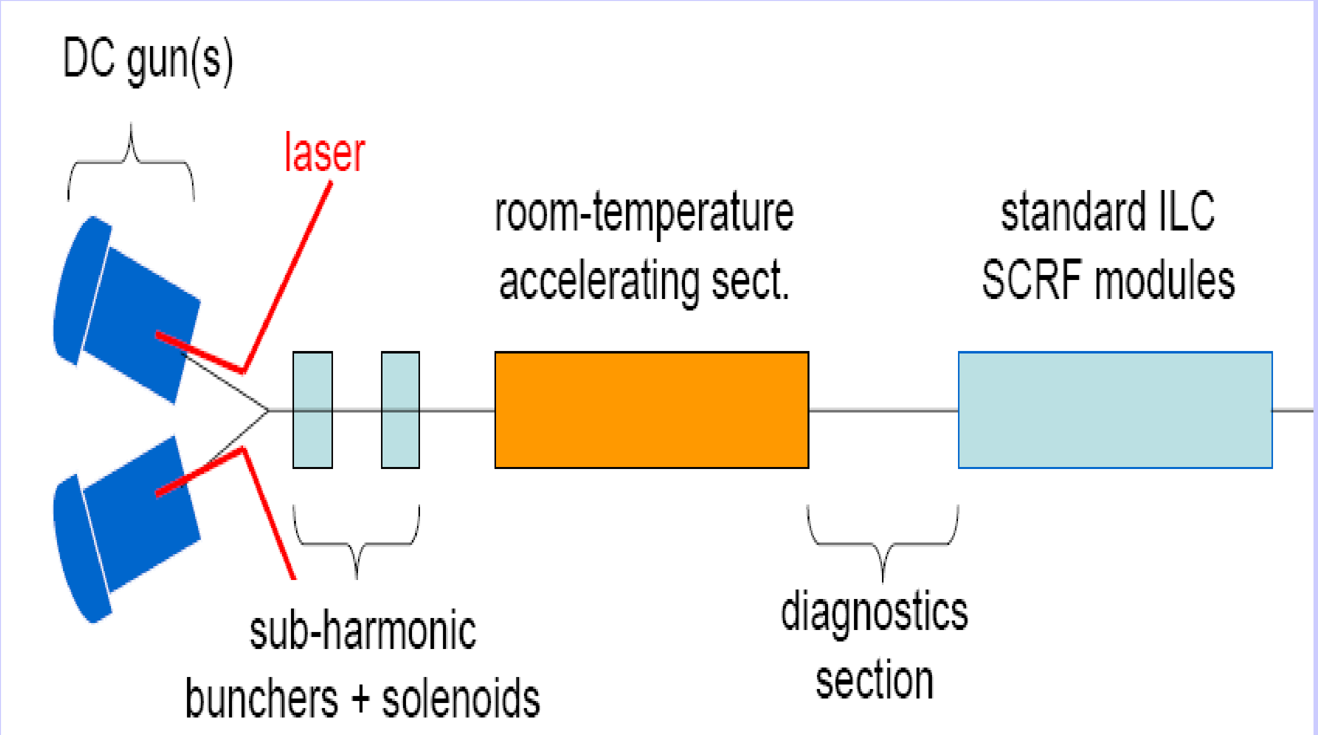
Tunnel Diameter

- Both tunnels are 5 meter diameter (Fixed)
- 5 meters in Asia & 7.5 meters elsewhere between tunnels (for structural reasons)
- 5 meters between tunnels required for shielding



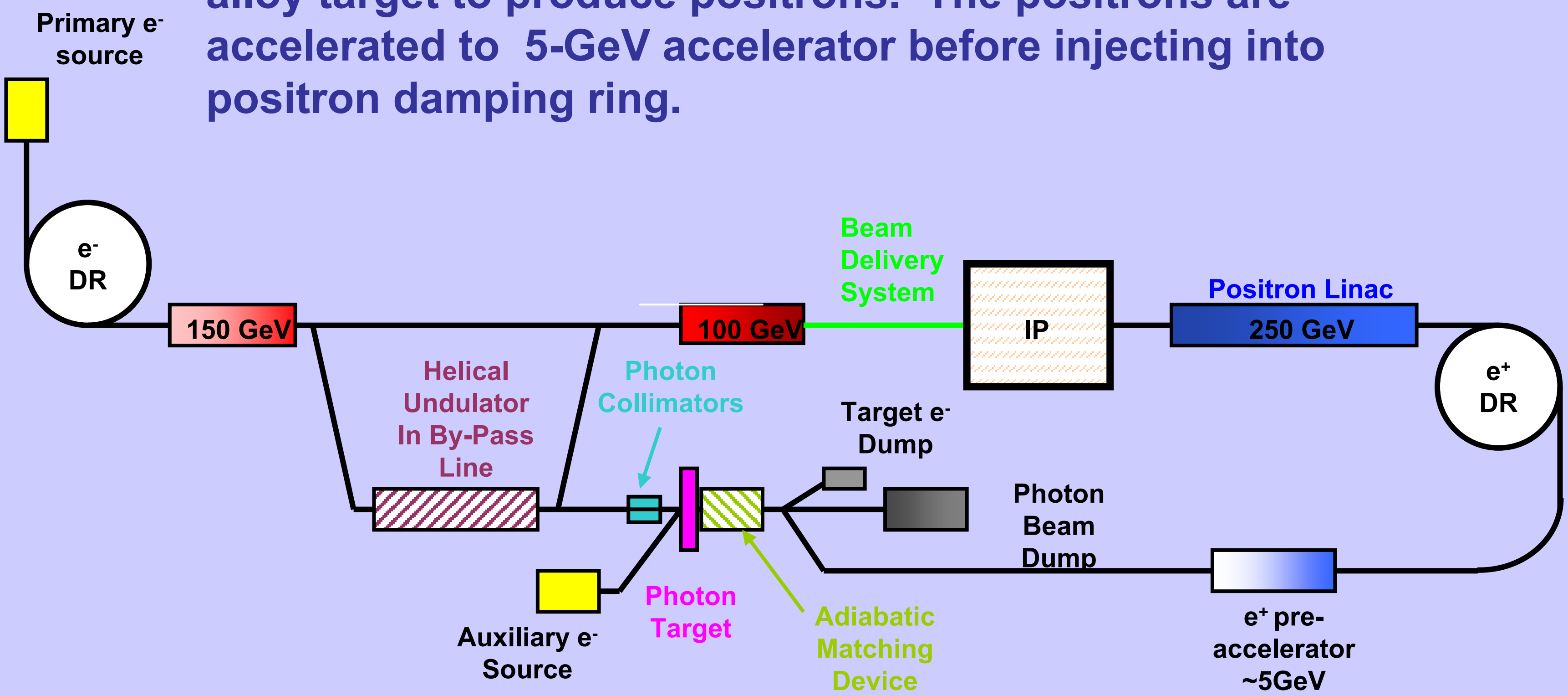
Baseline Features – Electron Source

- **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**

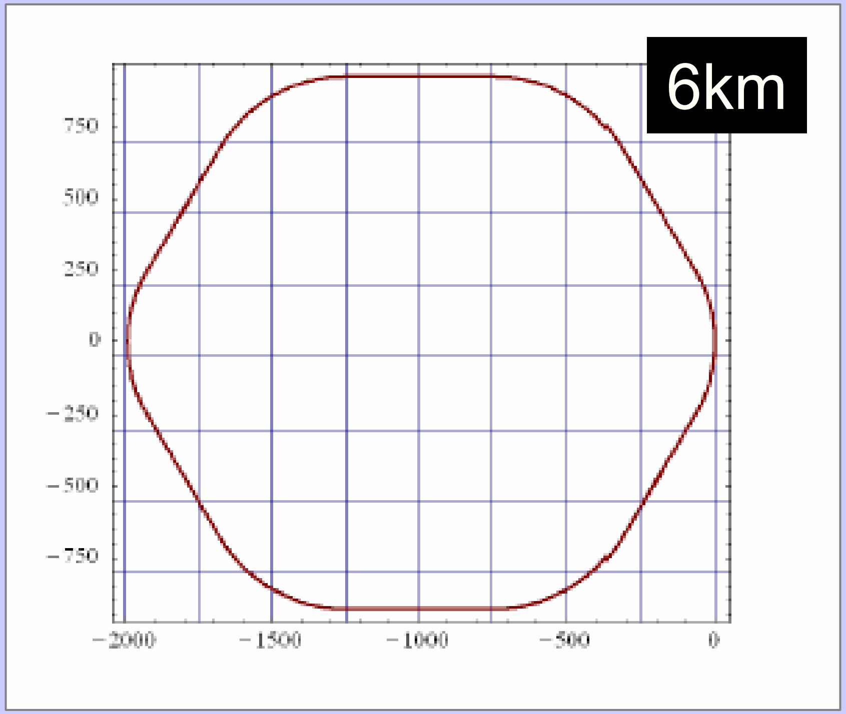


Baseline Features – Positron Source

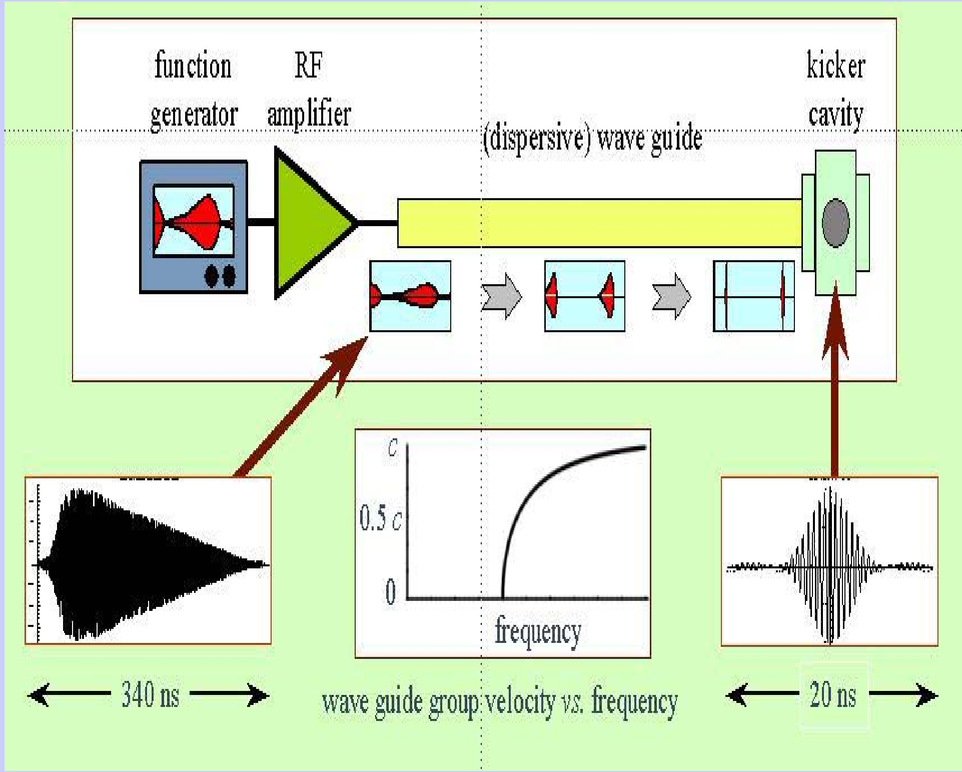
- **Positron Source – Helical Undulator with Polarized beams –** 150 Gev electron beam goes through a 200m undulator ing making photons that hit a 0.5 rl titanium alloy target to produce positrons. The positrons are accelerated to 5-GeV accelerator before injecting into positron damping ring.



6 Km Damping Ring



Requires Fast Kicker 5 nsec rise and 30 nsec fall time

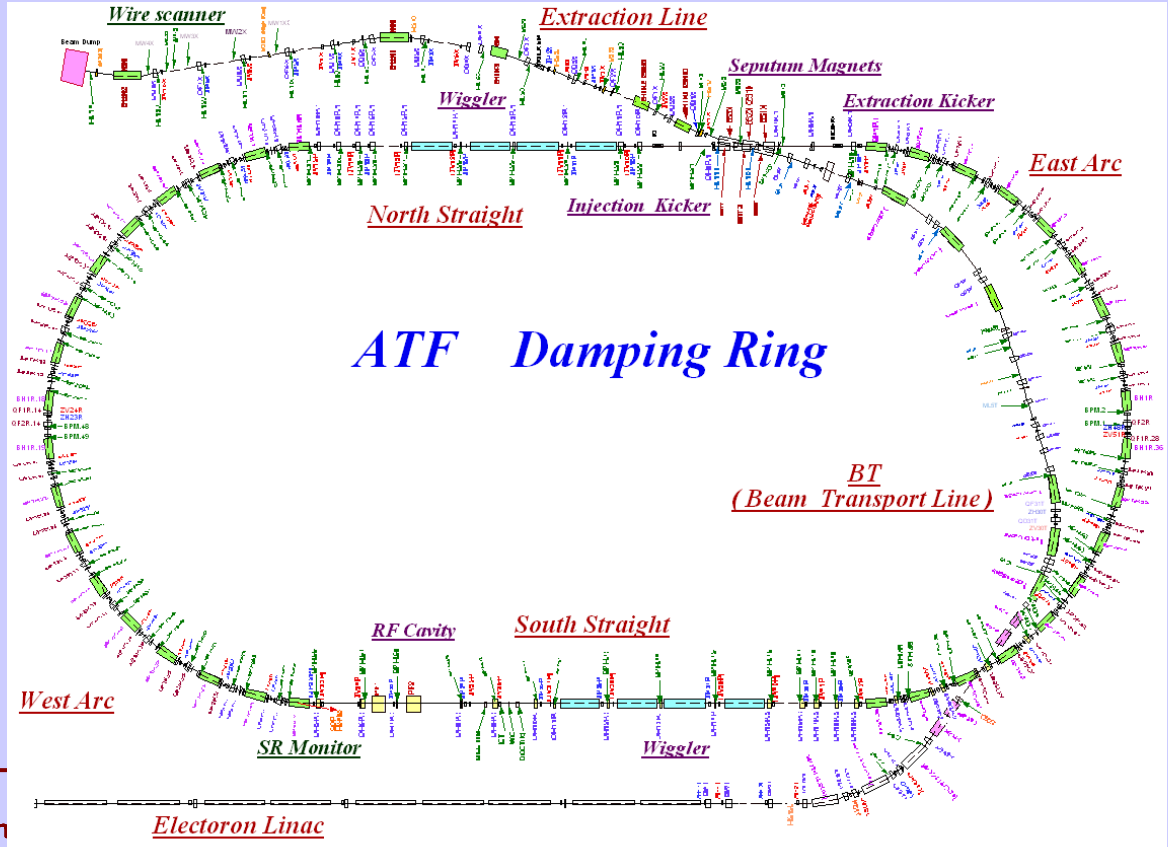


The damping rings have more accelerator physics than the rest of the collider

KEK ATF Damping Ring

- **Probably world's largest linear collider test facility**

1.3 GeV Damping Ring and S-band linac
Commissioning started in 1997



Emittances of
e_x/e_y = 8.0/.02 μm,
have been achieved

Damping Ring - Features

- 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
Train length in main linac	0.94 ms = 283 km

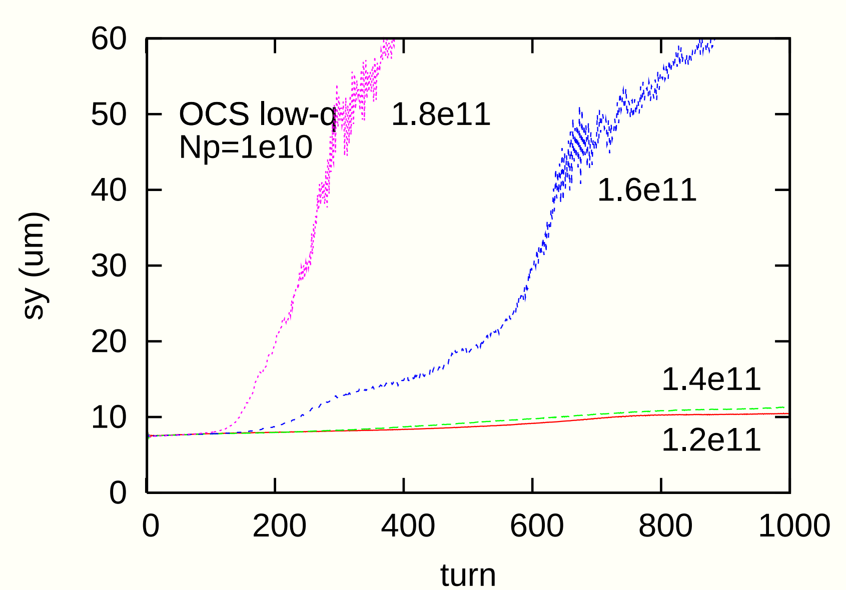
- Damping Ring for positron beam

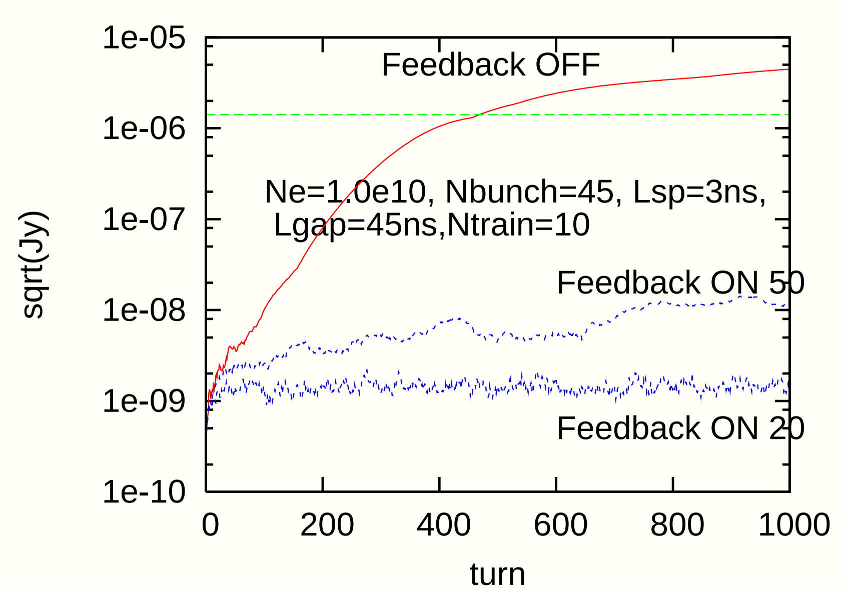
  In the present baseline, in order to minimize "electron cloud effects," positron bunches are injected alternately into either one of two identical positron damping rings with 6-kilometer circumference.

Damping Ring Design Issues

Electron Cloud

- Ecloud: Threshold of electron cloud, $1.4 \times 10^{11}\ m^{-3}$.
- Ion: Feedback system can suppress for 650 MHz (3ns spacing),
- Number of bunch in a train 45, and gap between trains 45ns.



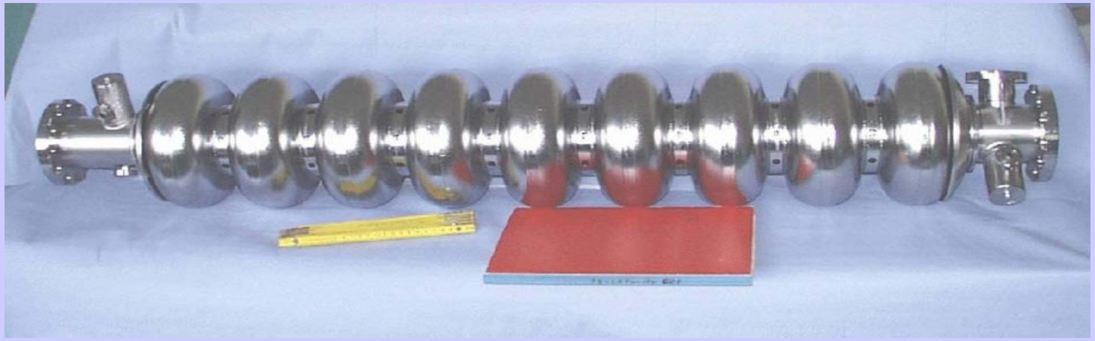


SRF Cavity Gradient

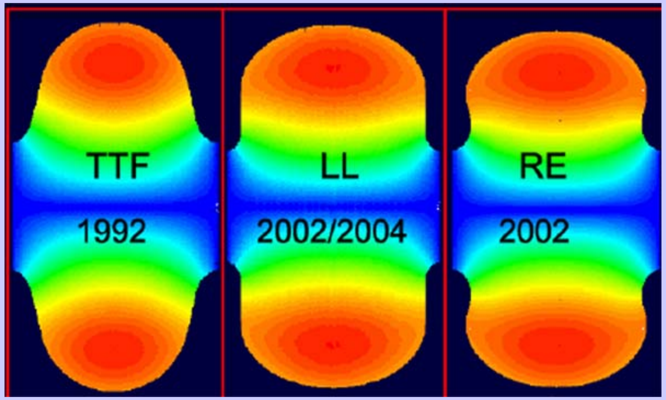
	Cavity type	Qualified gradient	Operational gradient	Length*	energy
		MV/m	MV/m	Km	GeV
initial	TESLA	35	31.5	10.6	250
upgrade	LL	40	36.0	+9.3	500

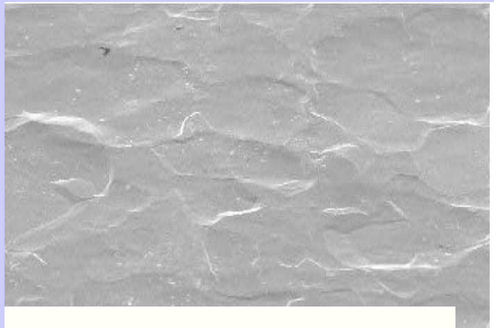
Total length of one 500 GeV linac ≈ 20km

* assuming 75% fill factor



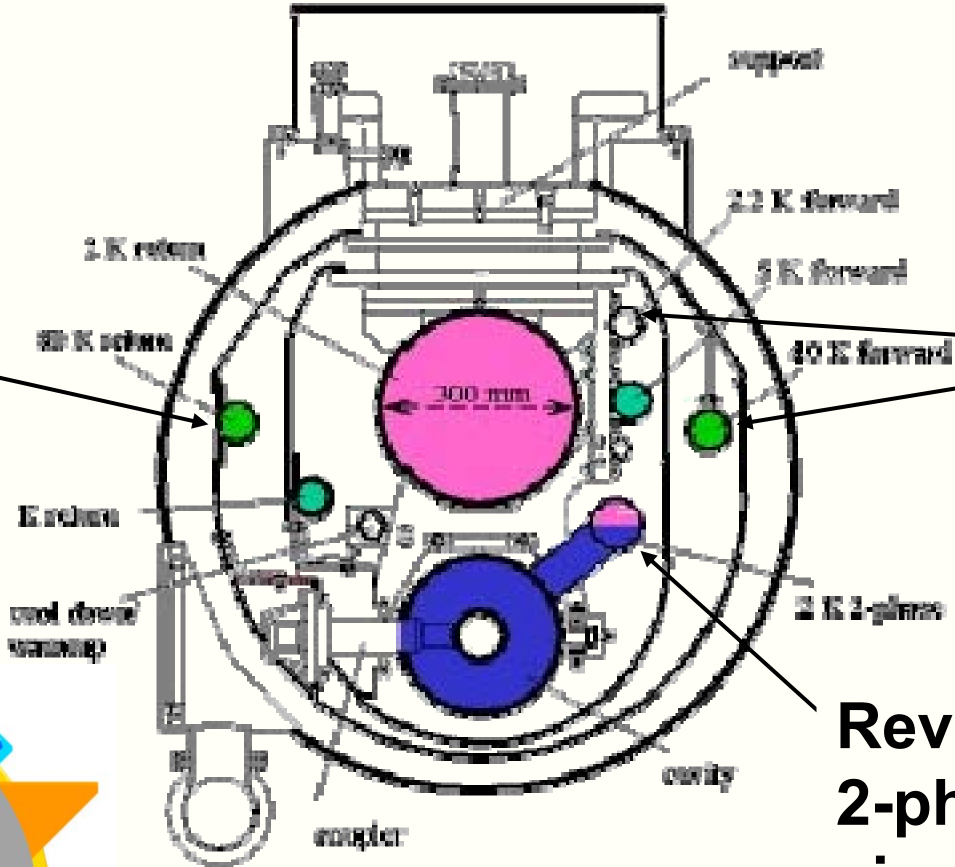
Superconducting RF Cavities




Chemical Polish


Electro Polish

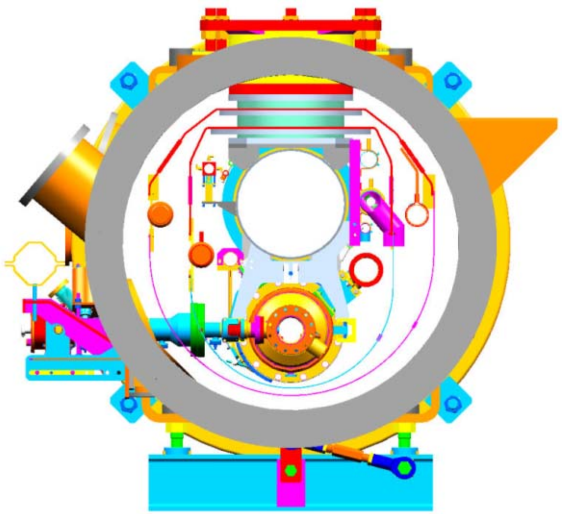
ILC Cryomodule



Increase diameter beyond X-FEL

Increase diameter beyond X-FEL

Review 2-phase pipe size and effect of slope



RF Power: Baseline Klystrons

Thales

CPI

Toshiba

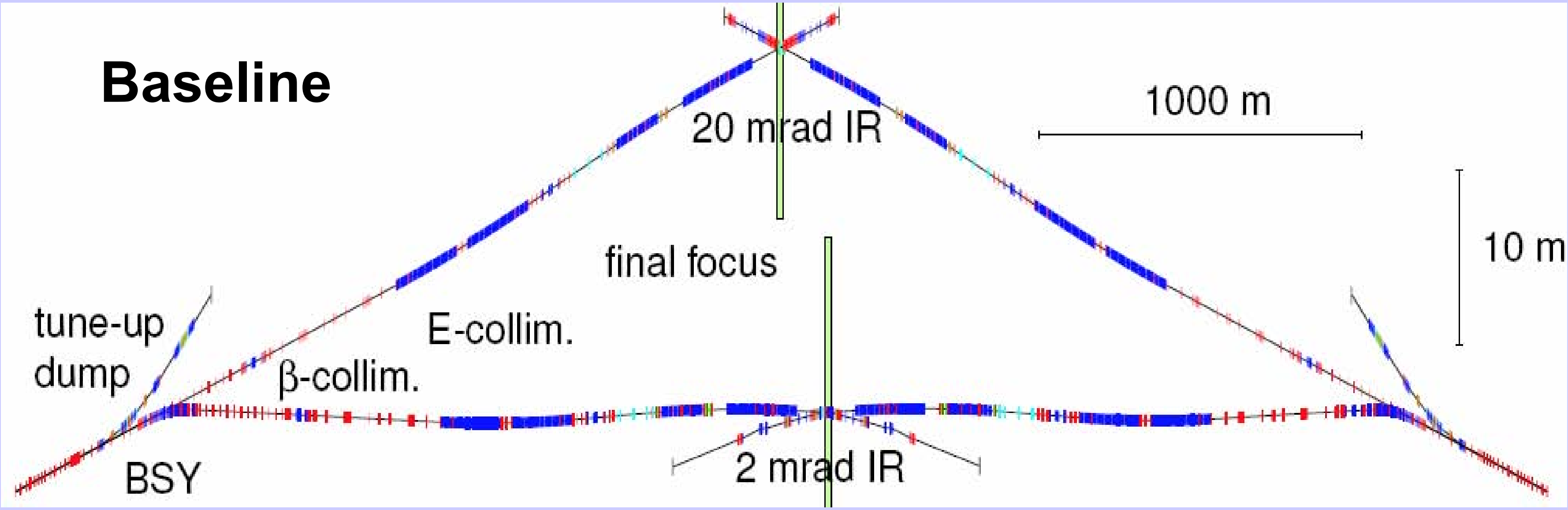
Specification:

10MW MBK

1.5ms pulse

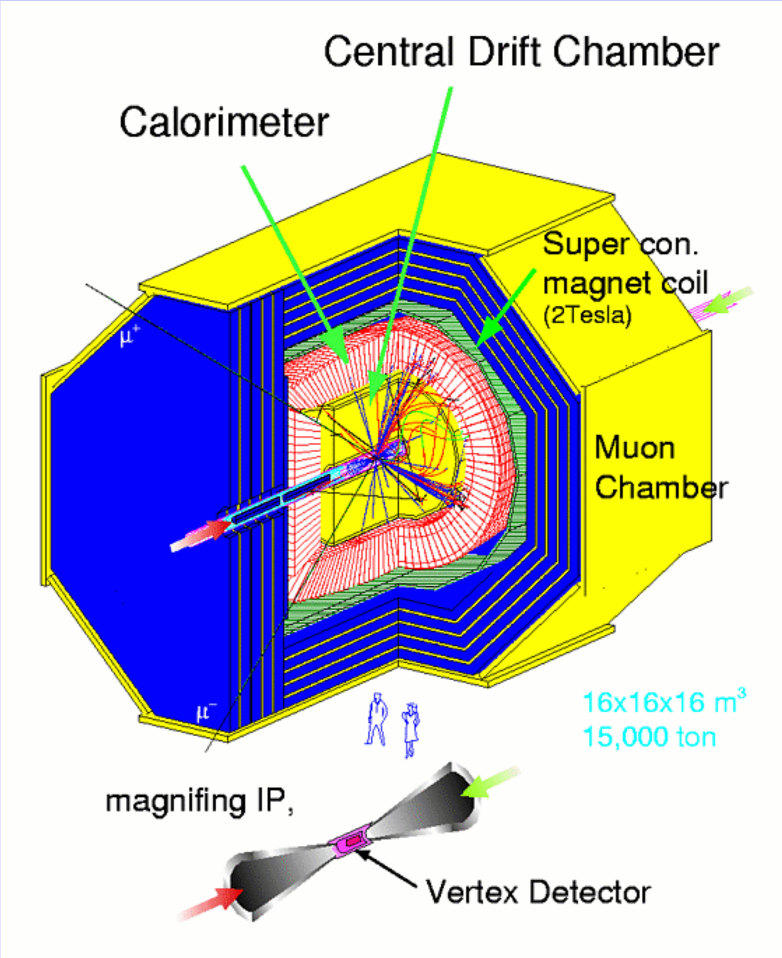
65% efficiency

Beam Delivery System



- **Requirements:**
  - **Focus beams down to very small spot sizes**
  - **Collect out-going disrupted beam and transport to the dump**
  - **Collimate the incoming beams to limit beam halo**
  - **Provide diagnostics and optimize the system and determine the luminosity spectrum for the detector**
  - **Switch between IPs**

Detectors for the ILC



- **Large Scale 4π detectors with solenoidal magnetic fields.**
- **In order to take full advantage of the ILC ability to reconstruct, need to improve resolutions, tracking, etc by factor of two or three**
- **New techniques in calorimetry, granularity of readout etc being developed**

Elements of the ILC R&D Program

- R&D in support of the baseline
  - Technical developments, demonstration experiments, industrialization, etc.
- R&D in support of alternatives to the baseline
  - Proposals for potential improvements to the baseline, resources required, time scale, etc.
  - Guidance from Change Control Board
- DETECTOR R&D program aimed at technical developments needed to reach combined design performance goals

Final Remarks

- **Design Status and Plans**
  - Baseline was determined and documented at end of 2005
  - Plan to complete reference design / cost by the end of 2006
  - Technical design by end of 2009
- **R & D Program**
  - Support baseline: demonstrations; optimize cost / perfomance; industrialization
  - Develop improvements to baseline – cavities; high power RF
- **Overall Strategy**
  - Be ready for an informed decision by 2010
  - Siting; International Management; LHC results; CLIC feasibility etc