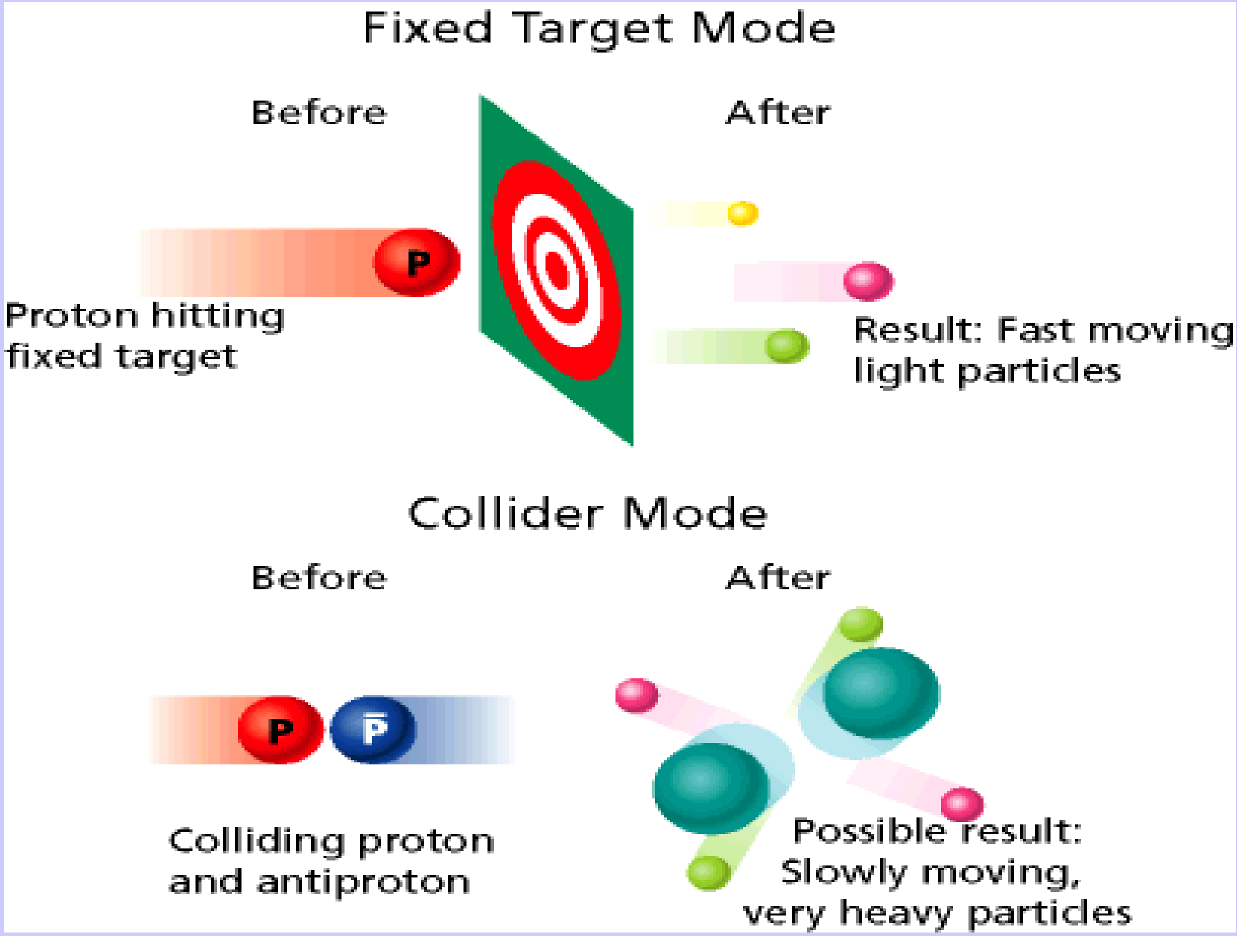
Introduction to the ILC

Lecture I-2

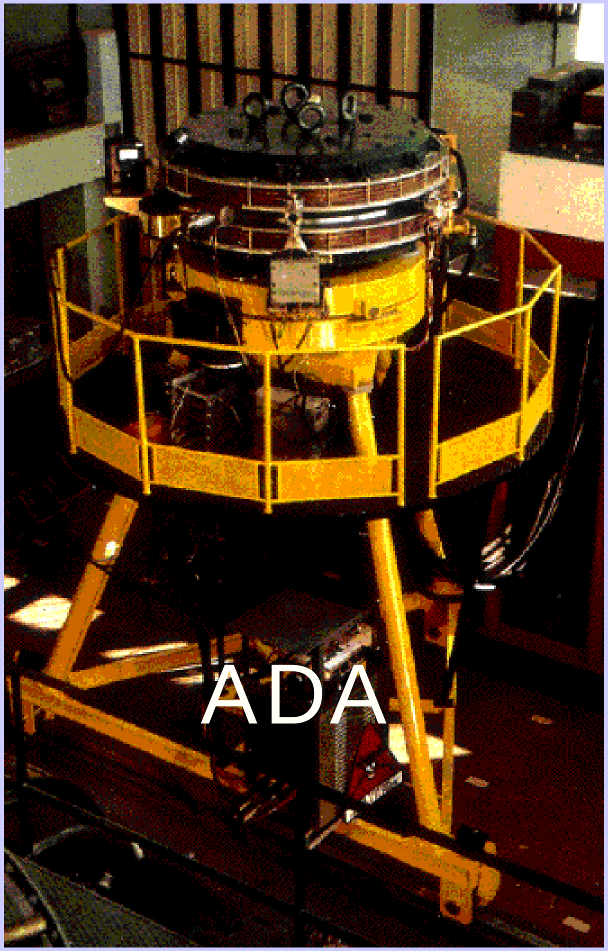


Barry Barish

Caltech / GDE

11-Nov-11

Electron-Positron Colliders

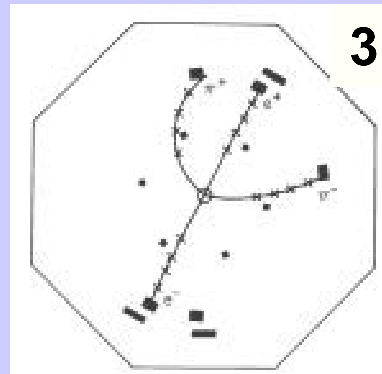


Bruno Touschek built the first successful electron-positron collider at Frascati, Italy (1960)

Eventually, went up to 3 GeV

But, not quite high enough energy ….

SPEAR at SLAC

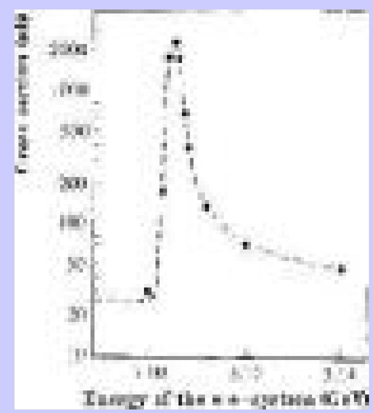


3.1 GeV

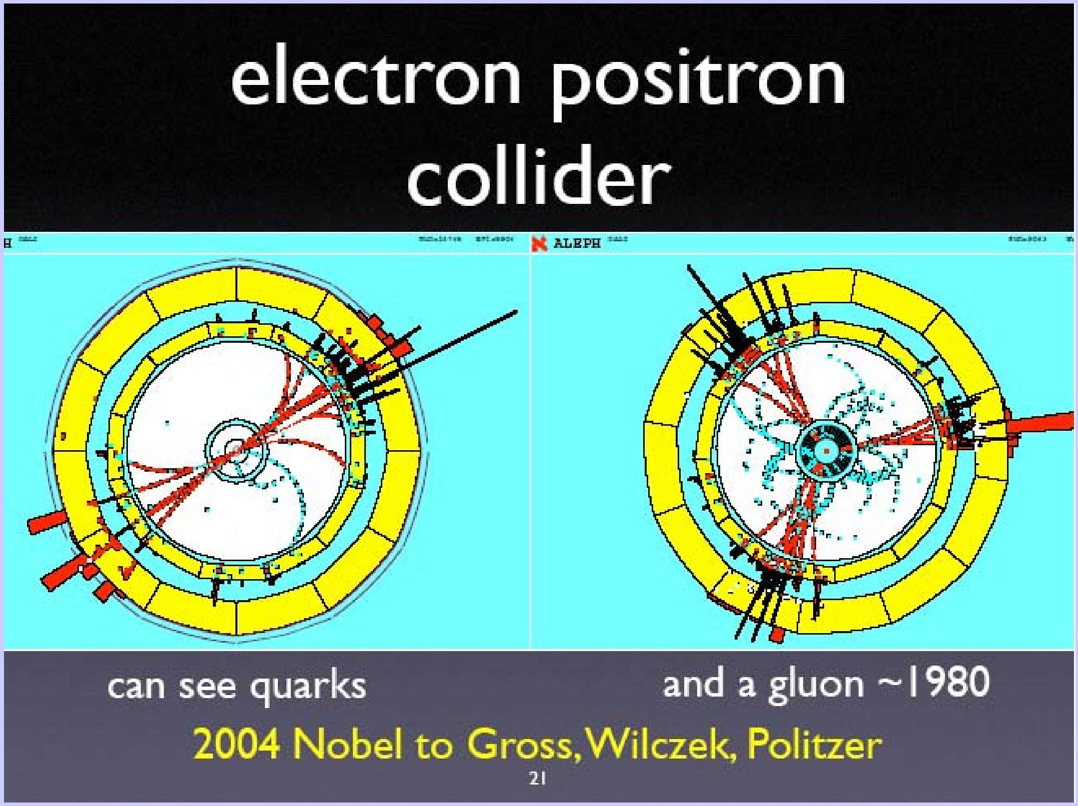
Burt Richter
Nobel Prize

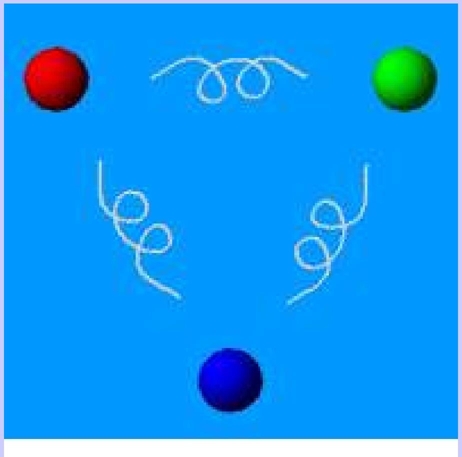
and

Discovery
Of
Charm
Particles



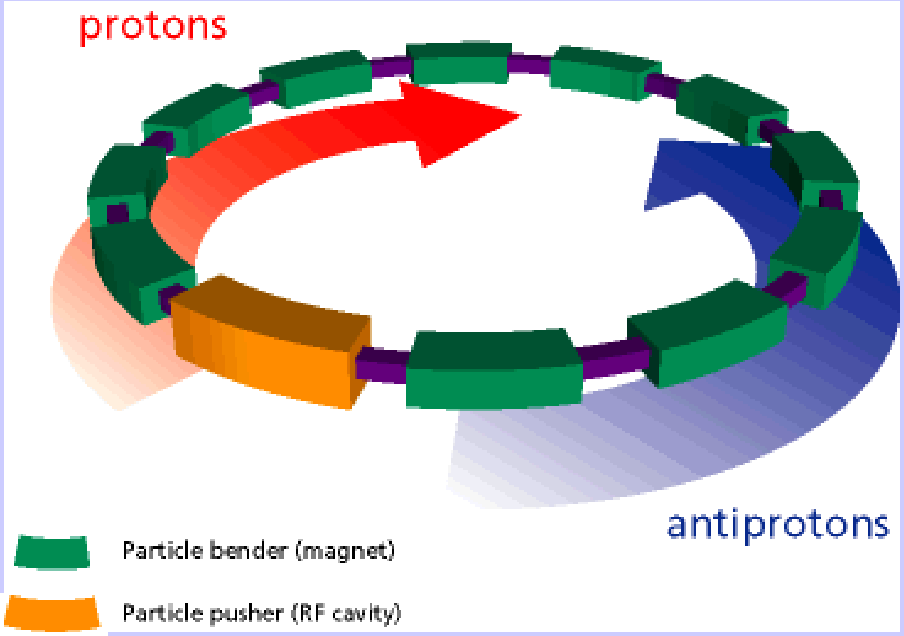
The rich history for e^+e^- continued as higher energies were achieved …





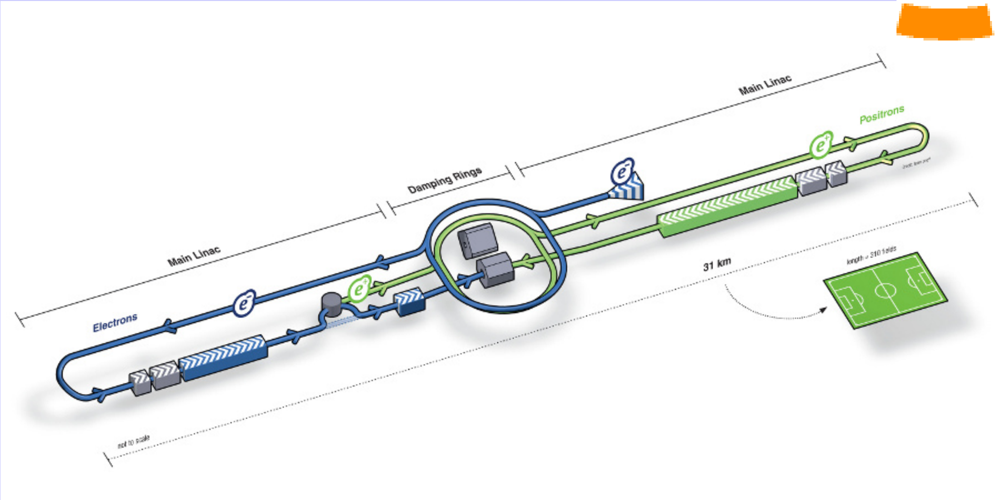
DESY PETRA Collider

Particle Colliders



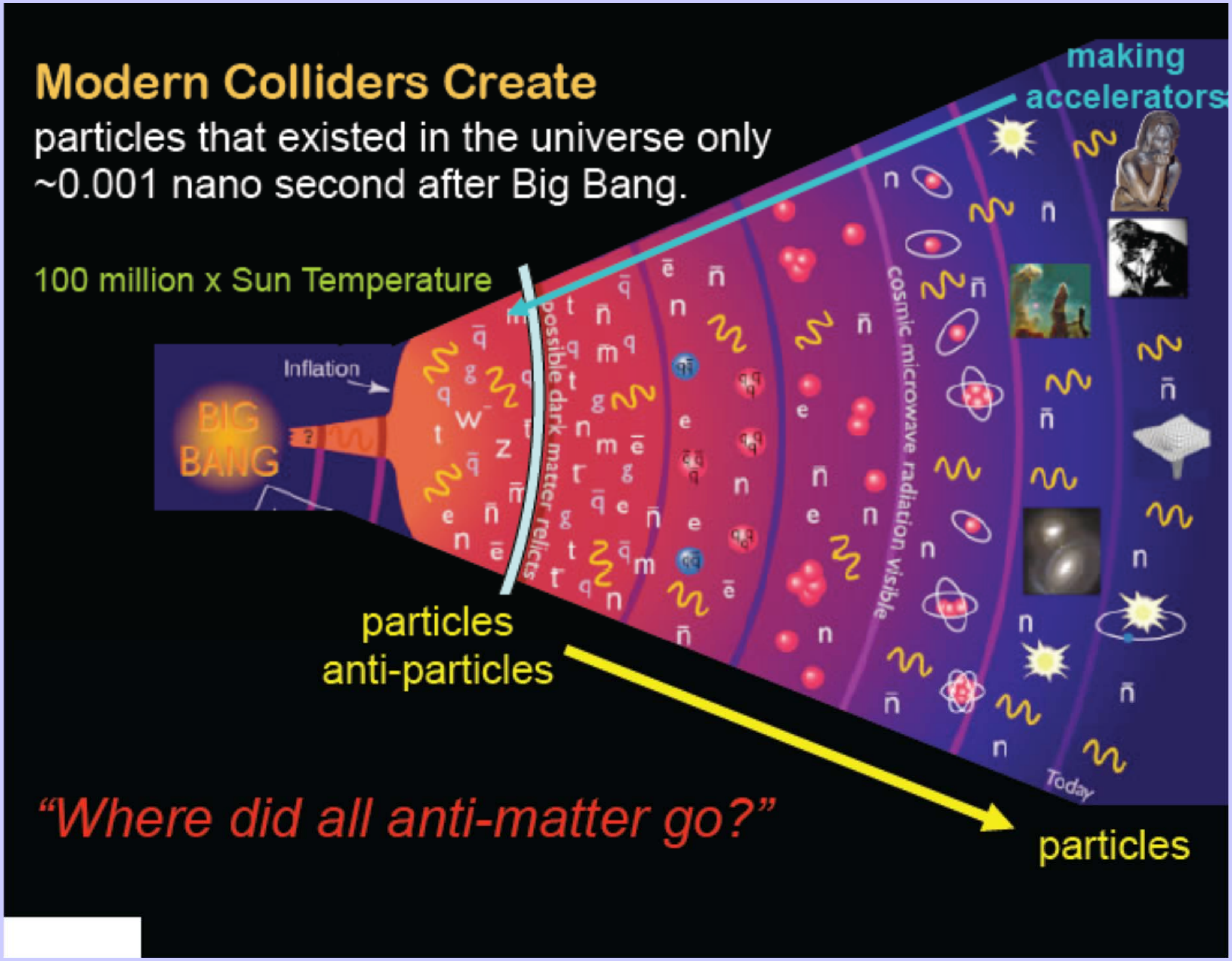
Hadron colliders:

Higher energies, but energy of collision of point-like constitutents have large variance.

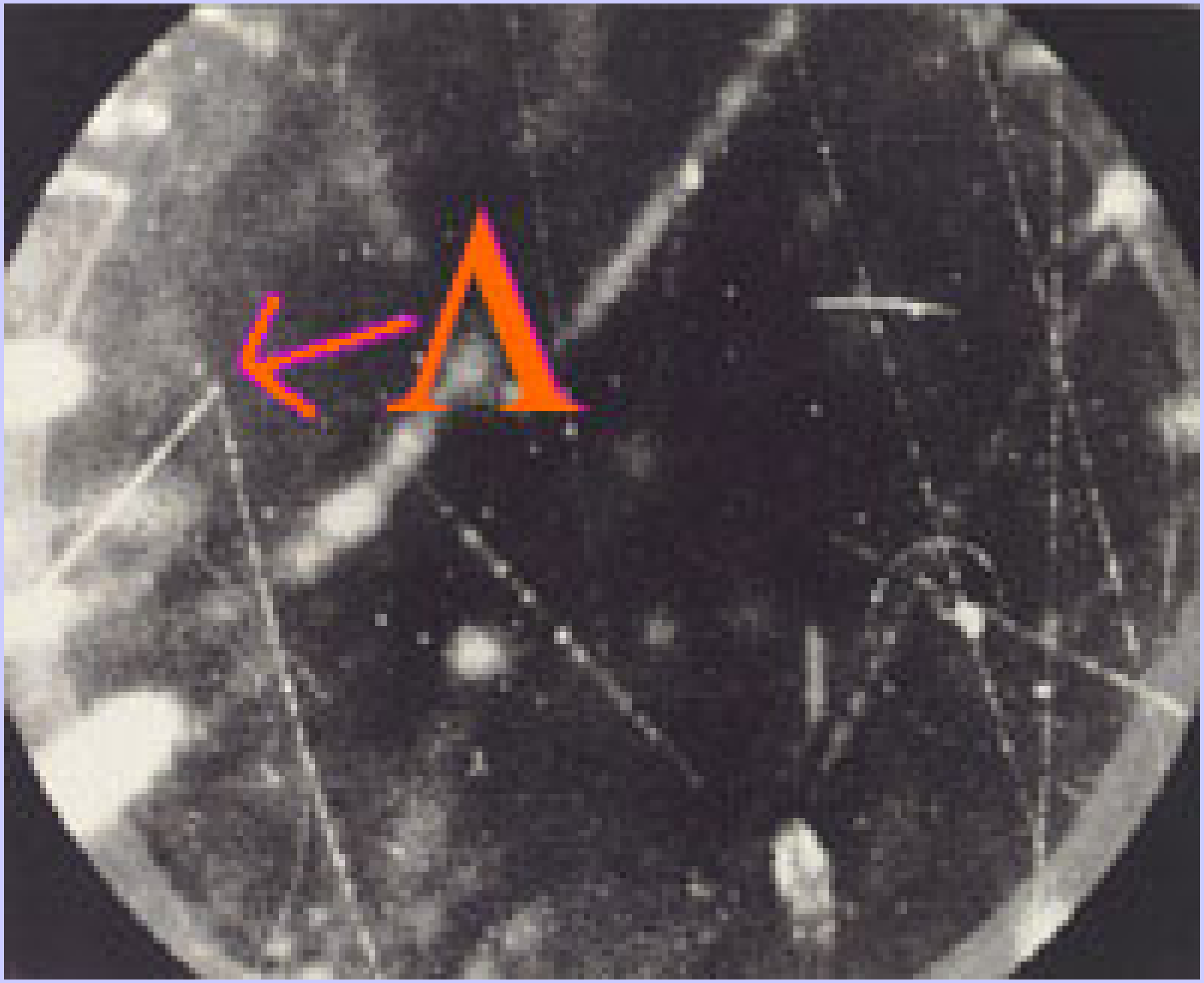


Lepton (ep) colliders:

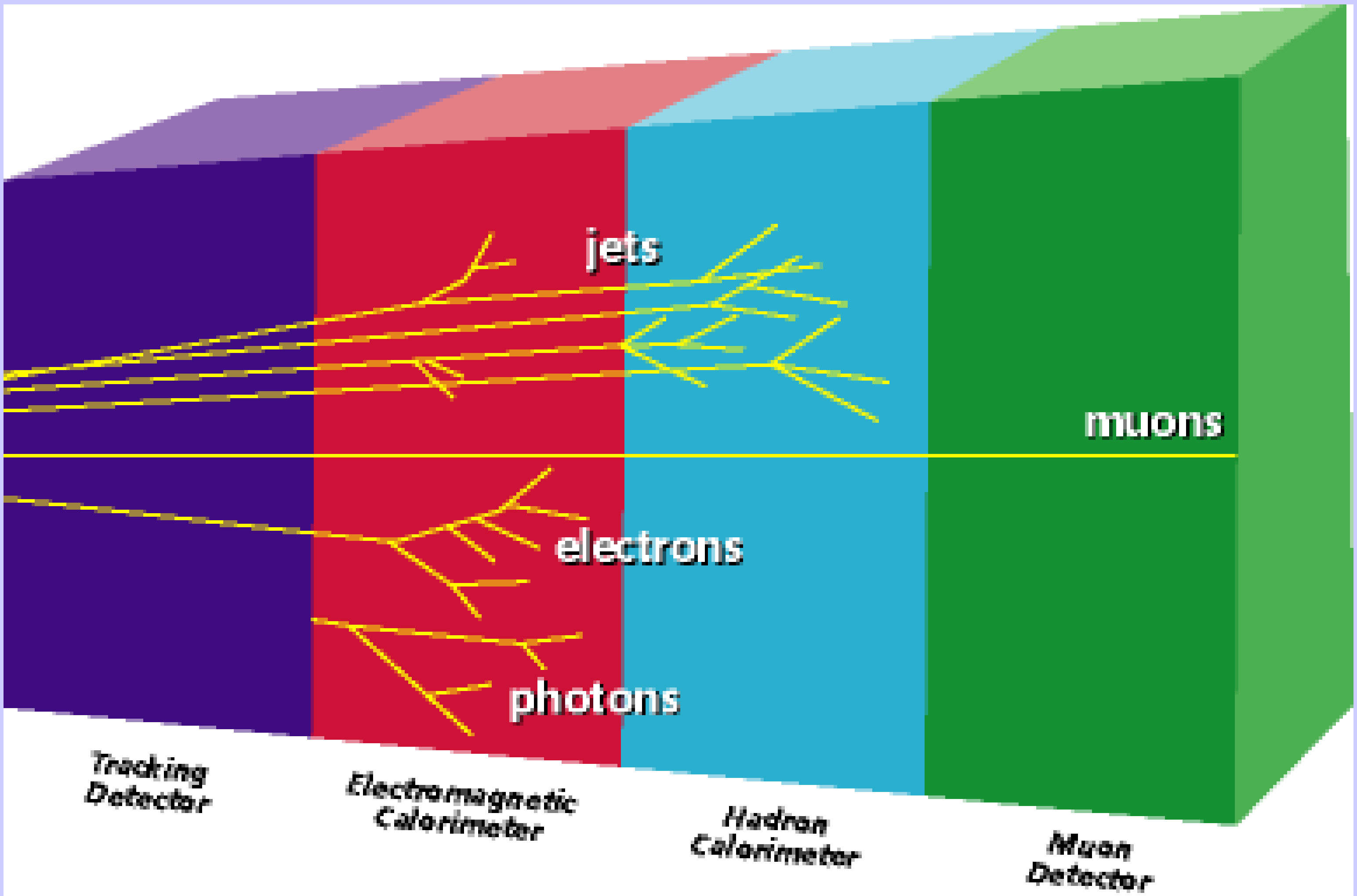
Lower energies, but well-known, controllable E_{CM} of collisions, much cleaner final states.


Modern Colliders Create
particles that existed in the universe only
~0.001 nano second after Big Bang.
100 million x Sun Temperature
making
accelerators
Inflation
BIG
BANG
possible dark matter relicts
cosmic microwave radiation visible
particles
anti-particles
"Where did all anti-matter go?"
particles
Today

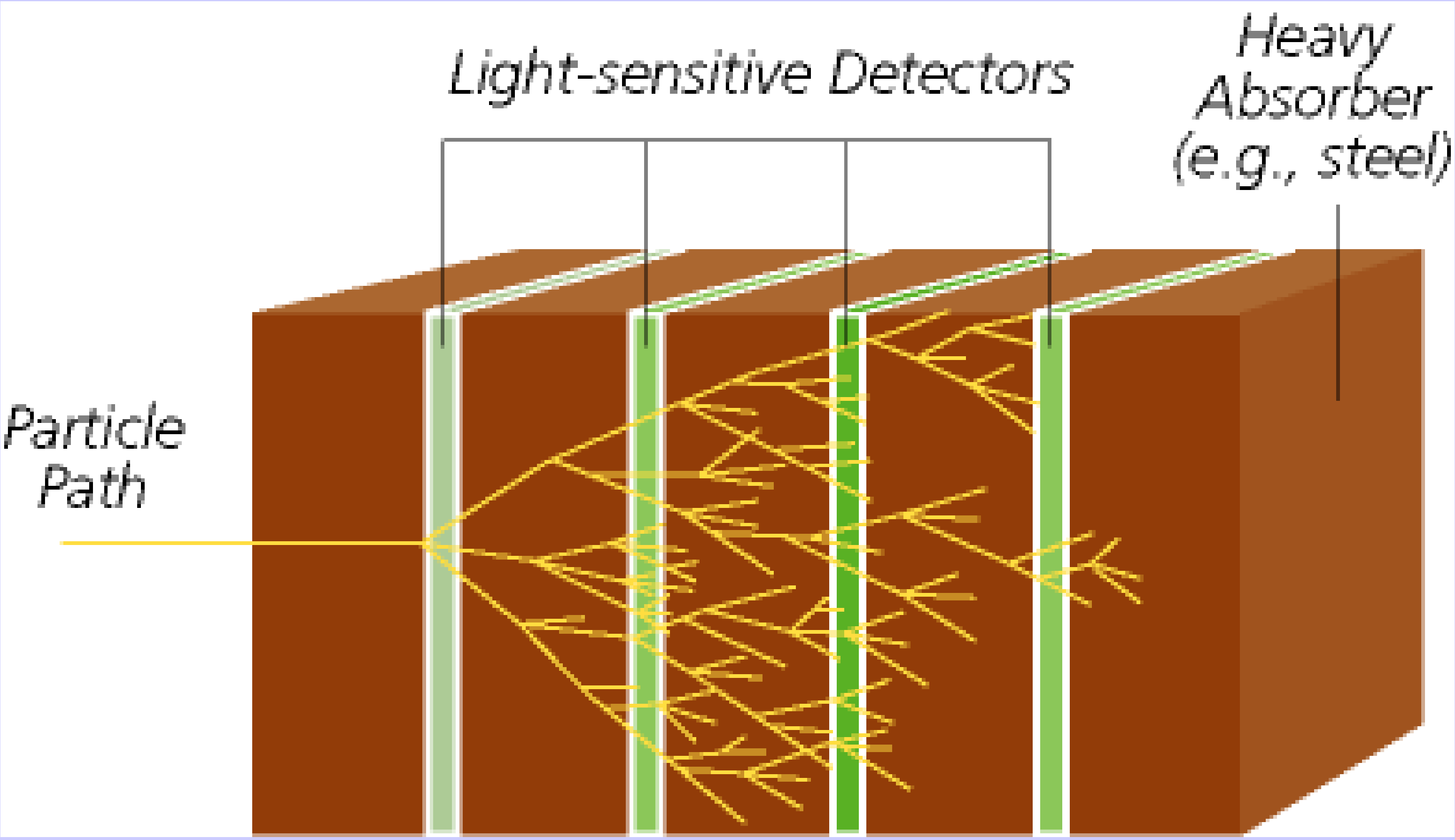
Tracking and Particle Identification
Bubble Chamber



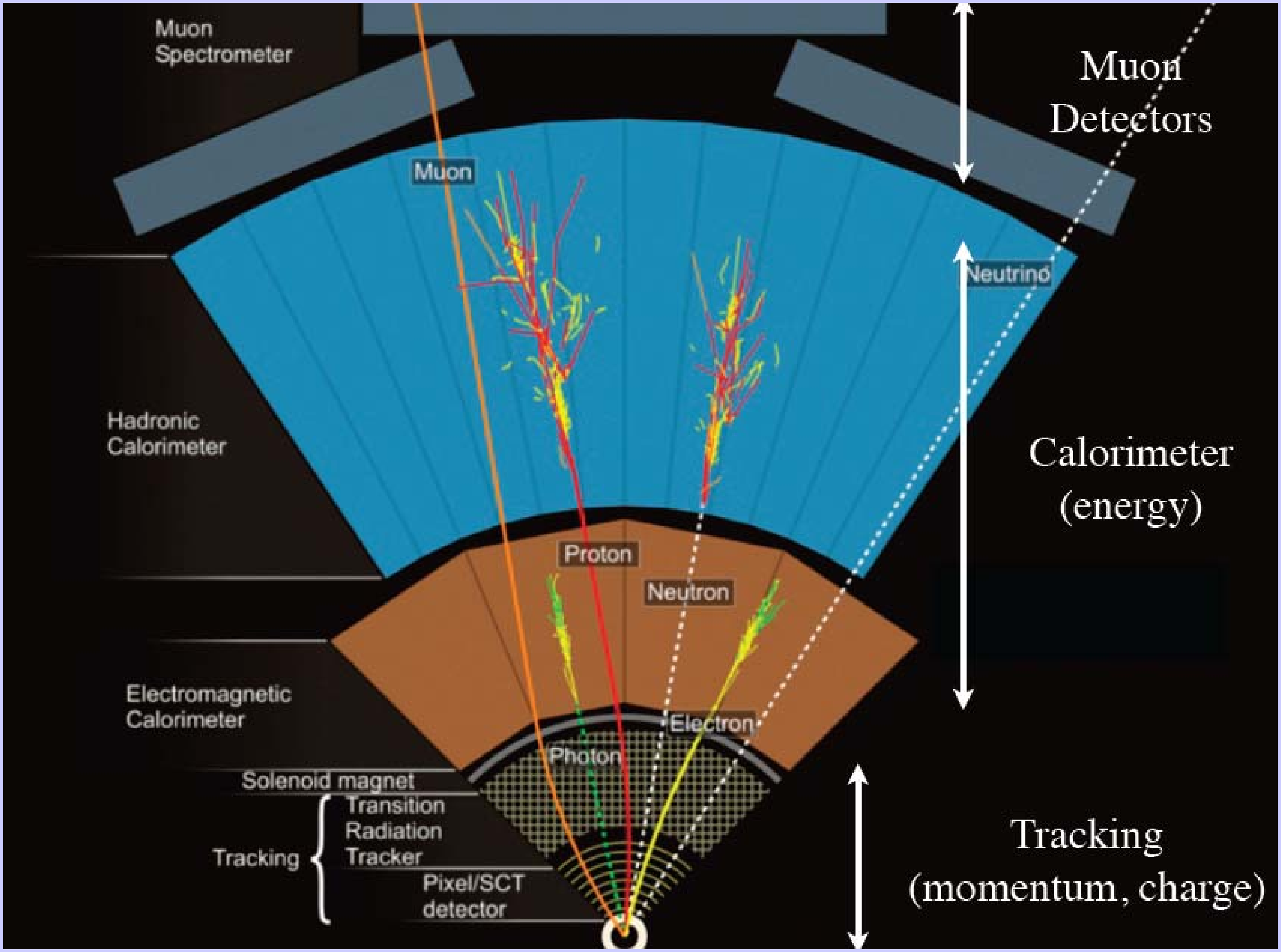
Particle Identification
Collider Detector



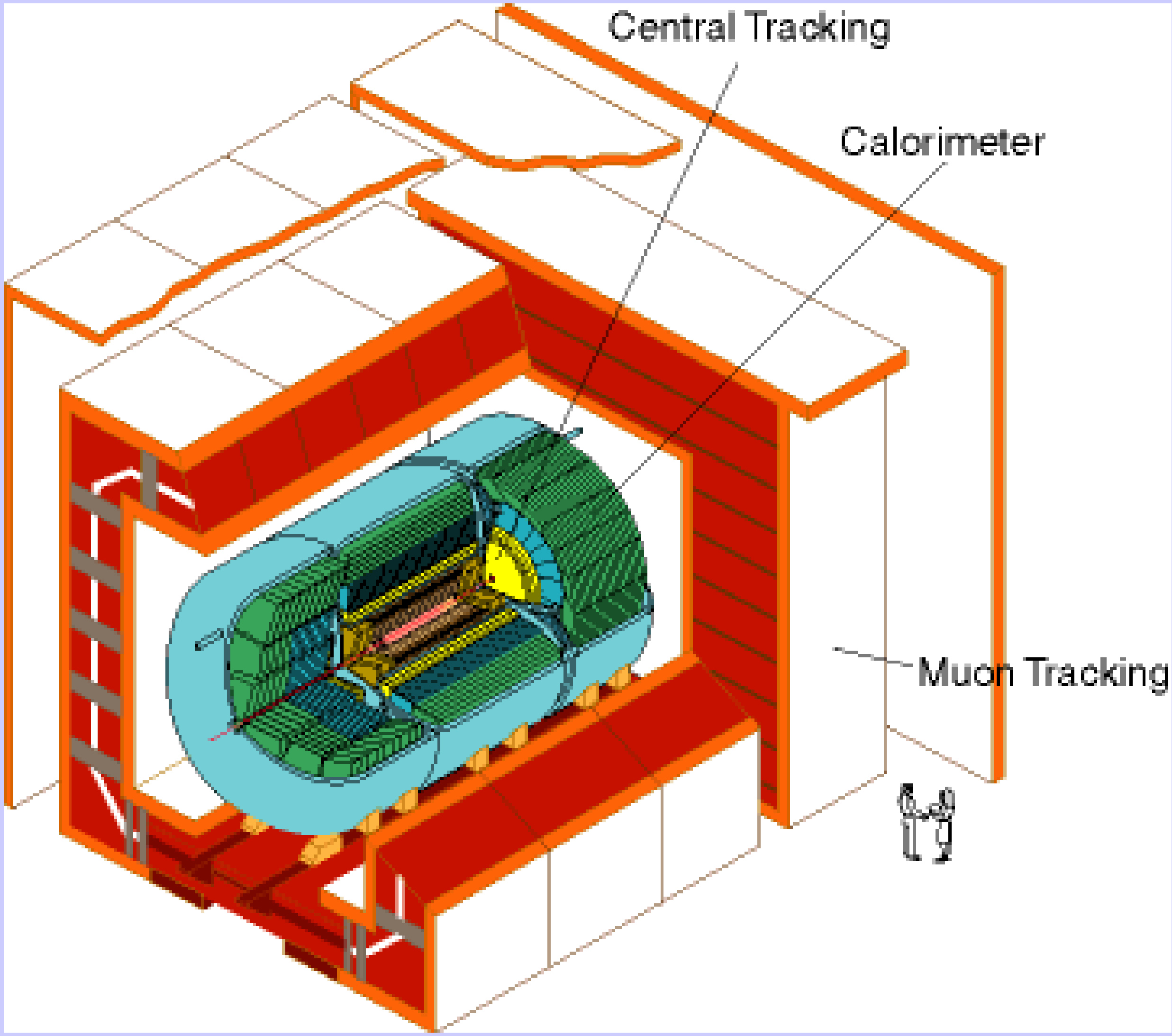
Particle Energy
Collider Detector



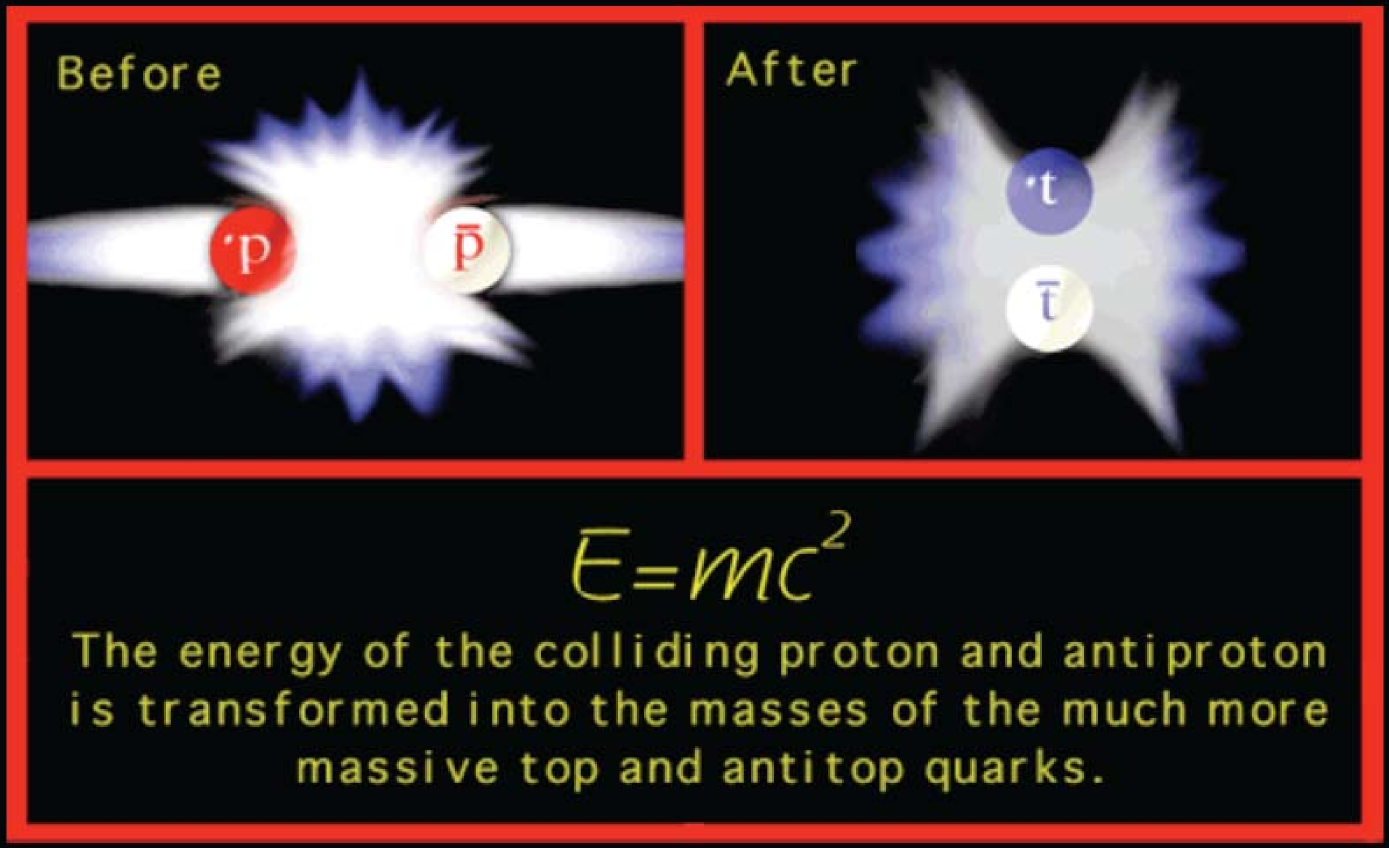
Collider Detector Subsystems

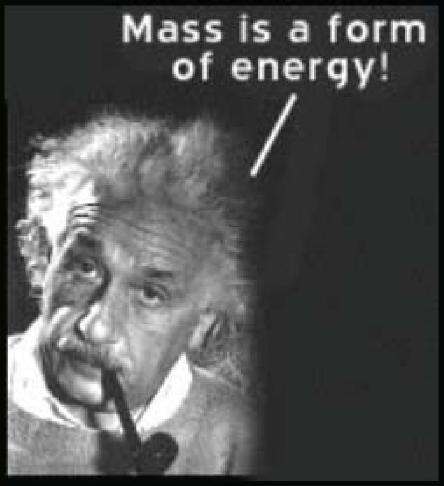


Collider Detectors

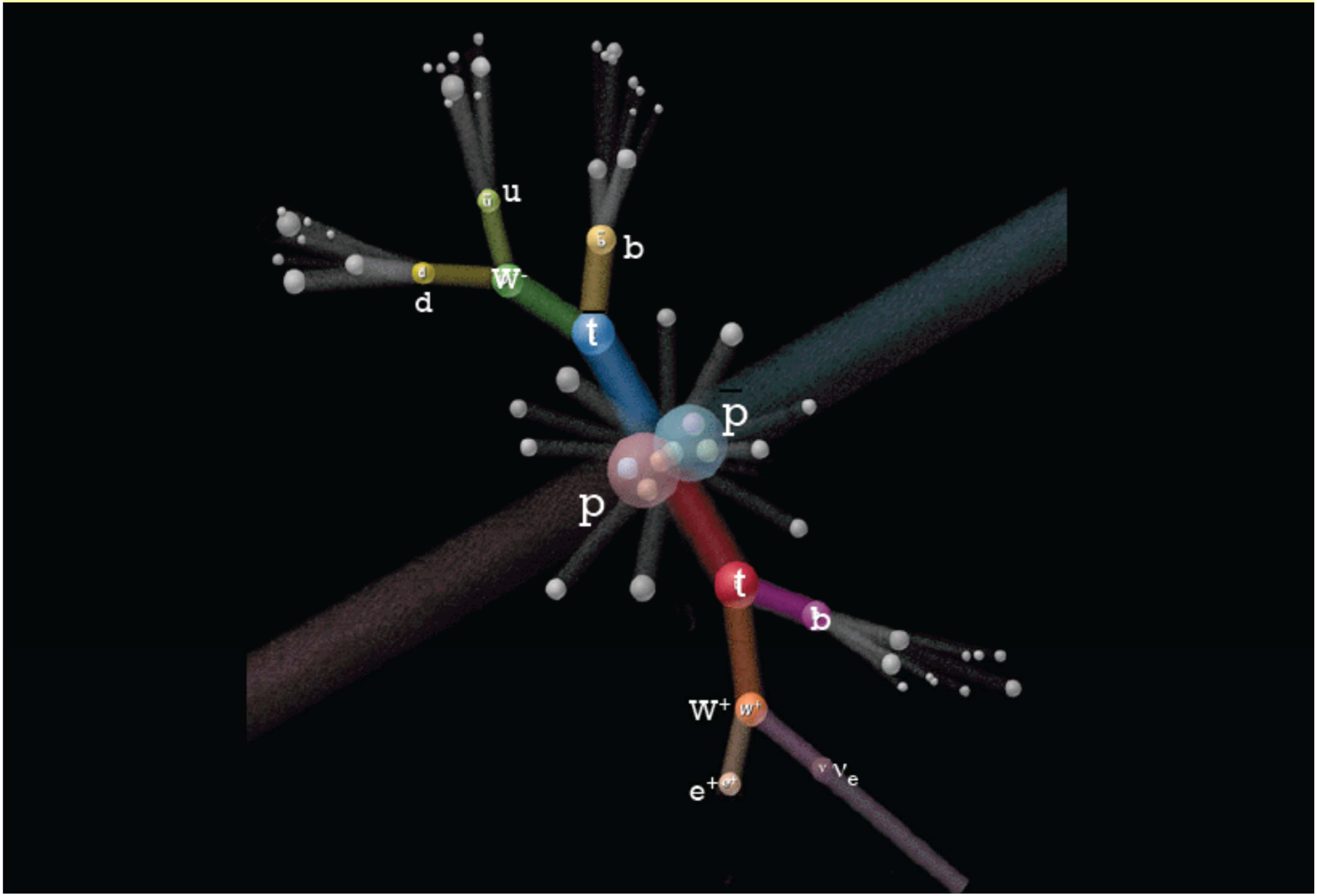


Discovery of the top quark

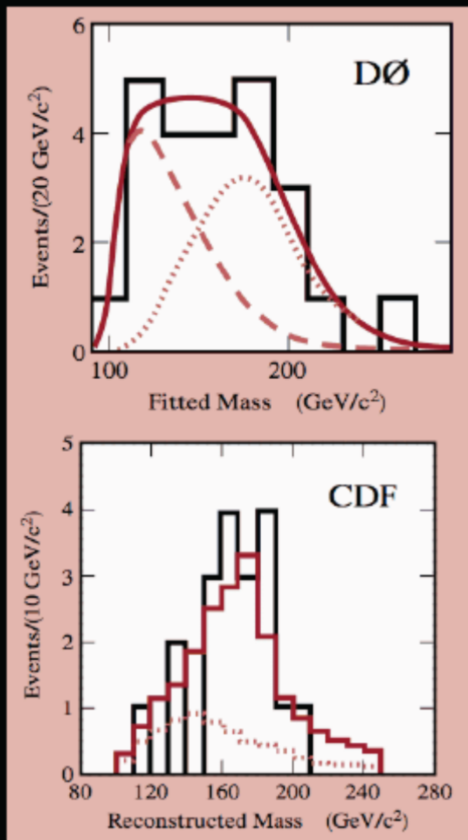




Complicated Signature - Top Quark

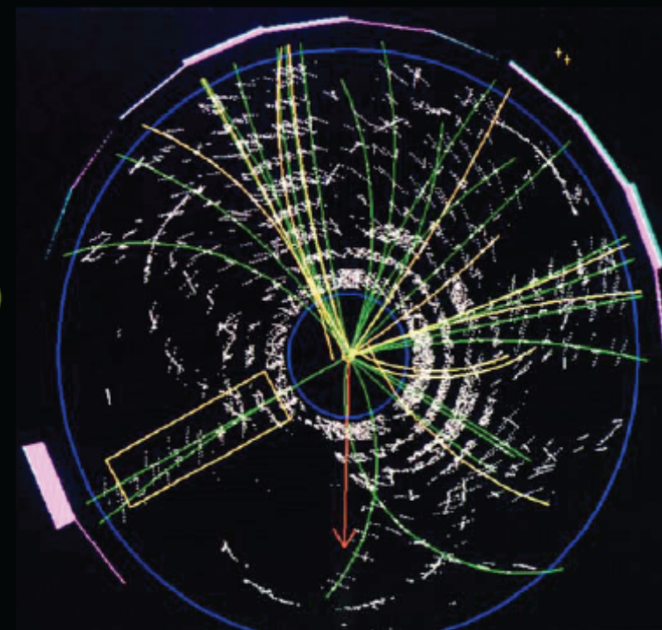


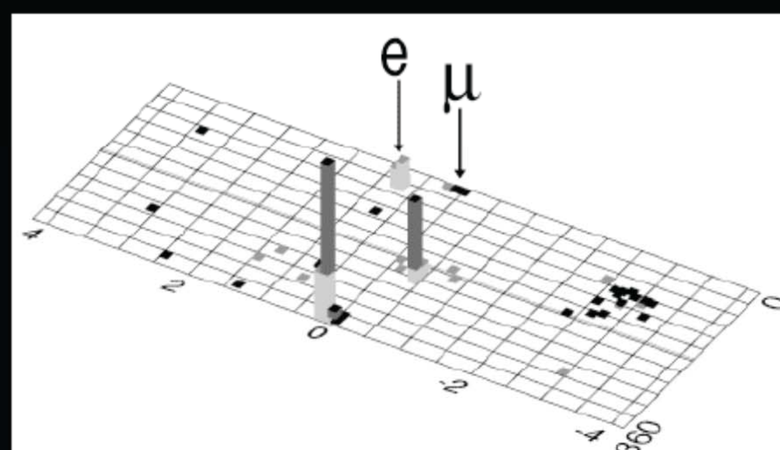
Discovery of the Top Quark

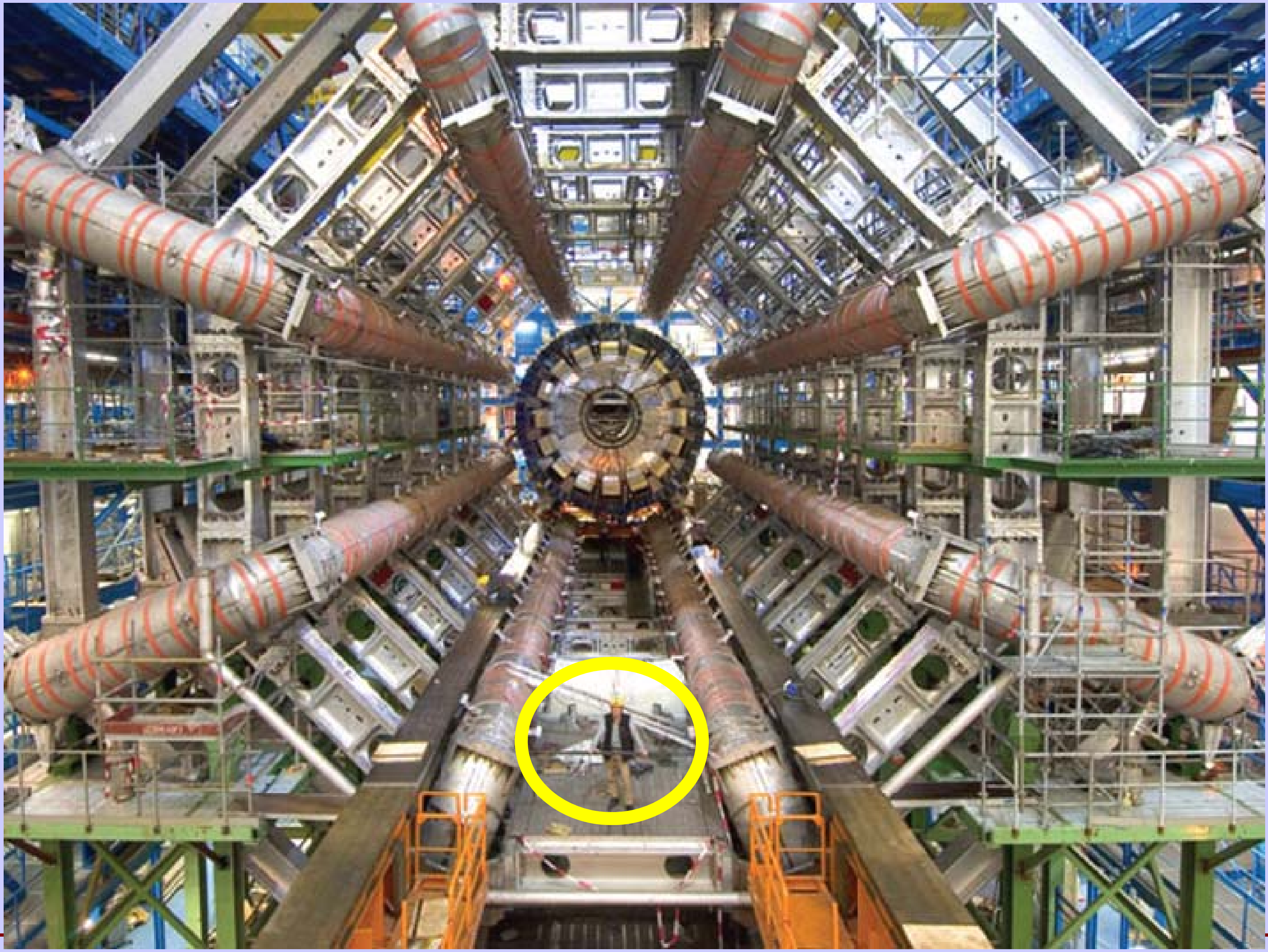


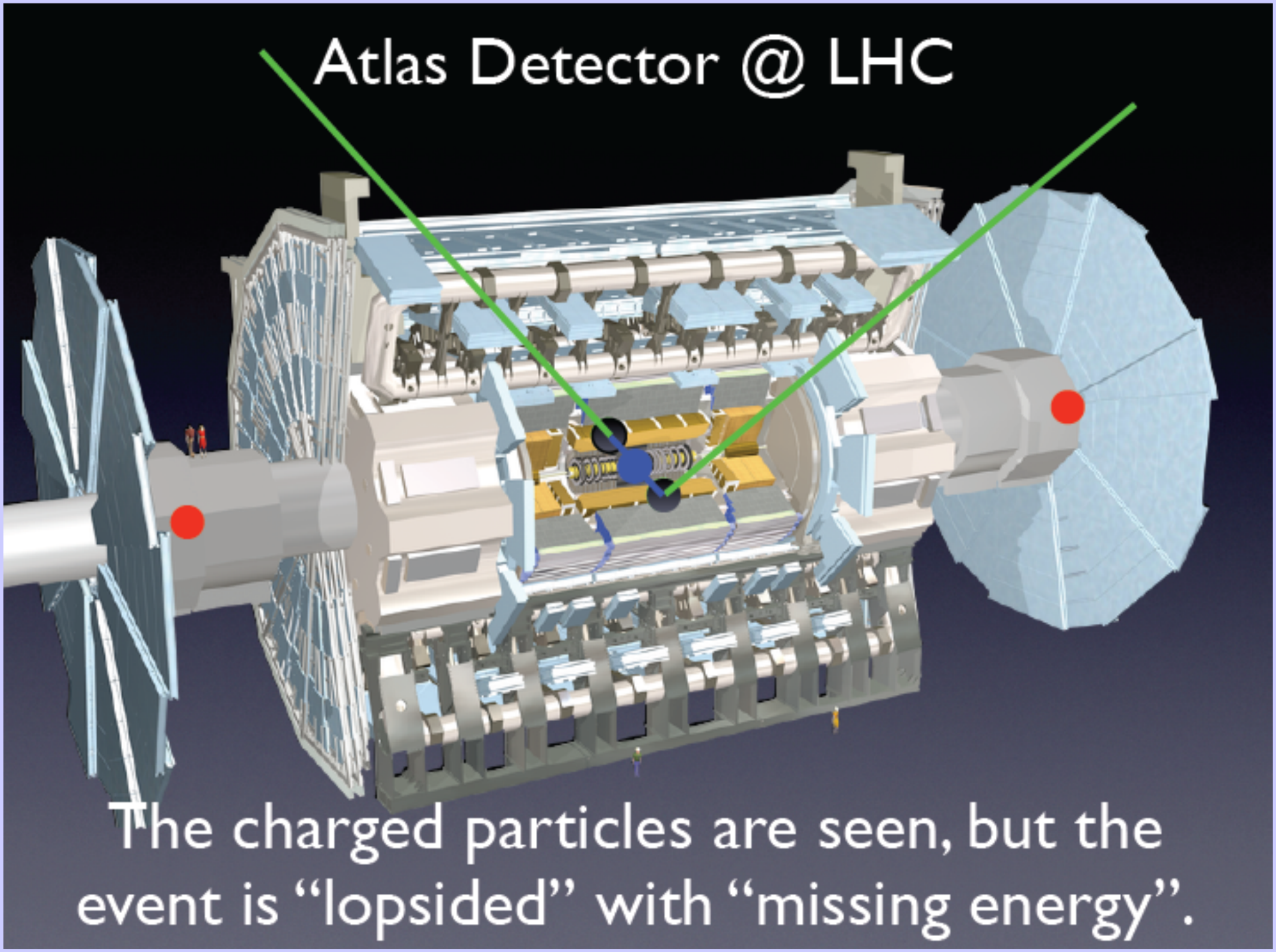
1994 - 1995

175 GeV !

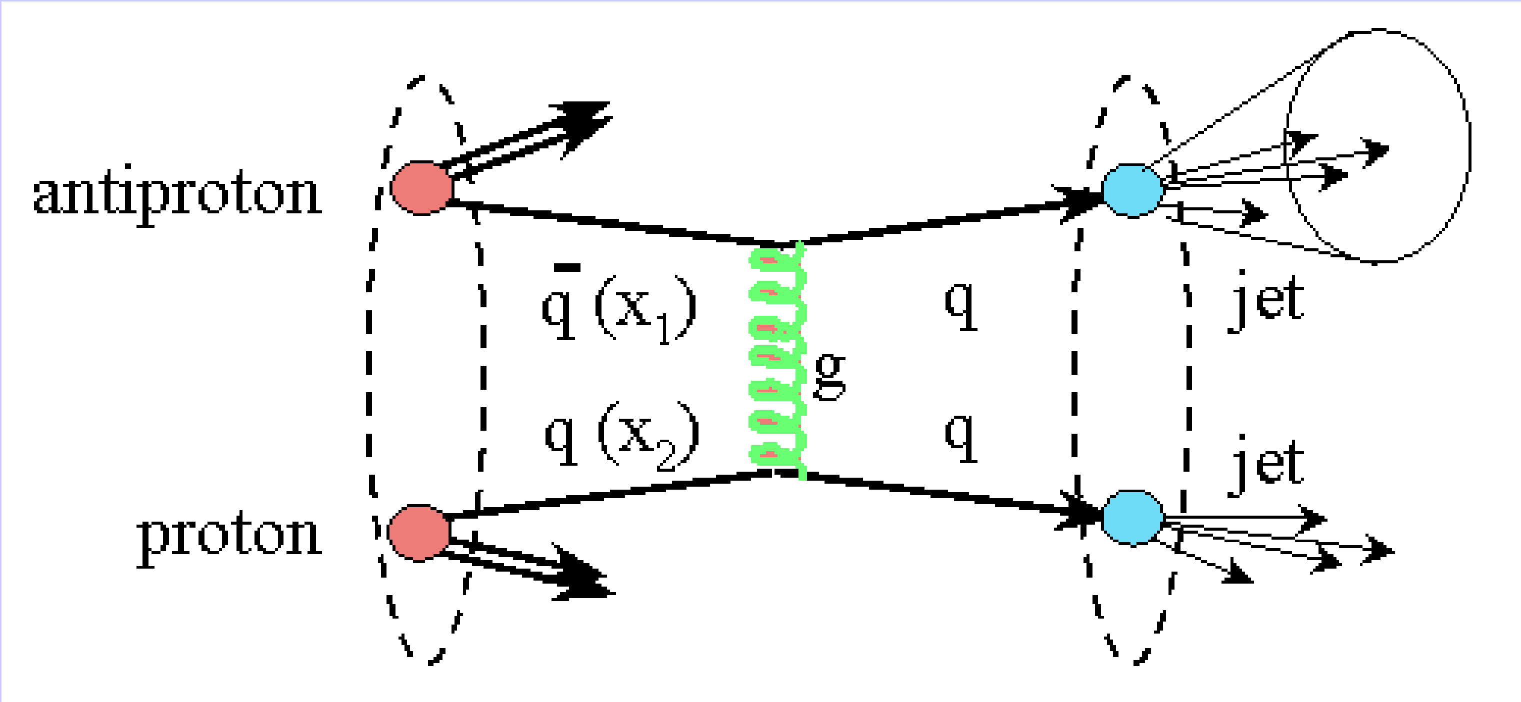







Atlas Detector @ LHC
The charged particles are seen, but the event is “lopsided” with “missing energy”.

Most Common Events
hadron colliders

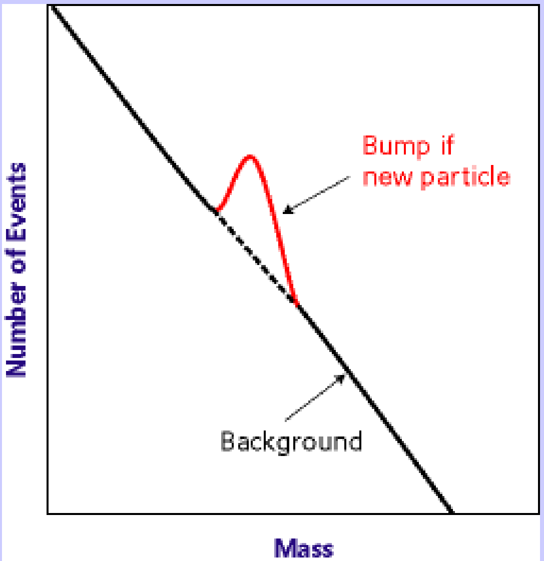


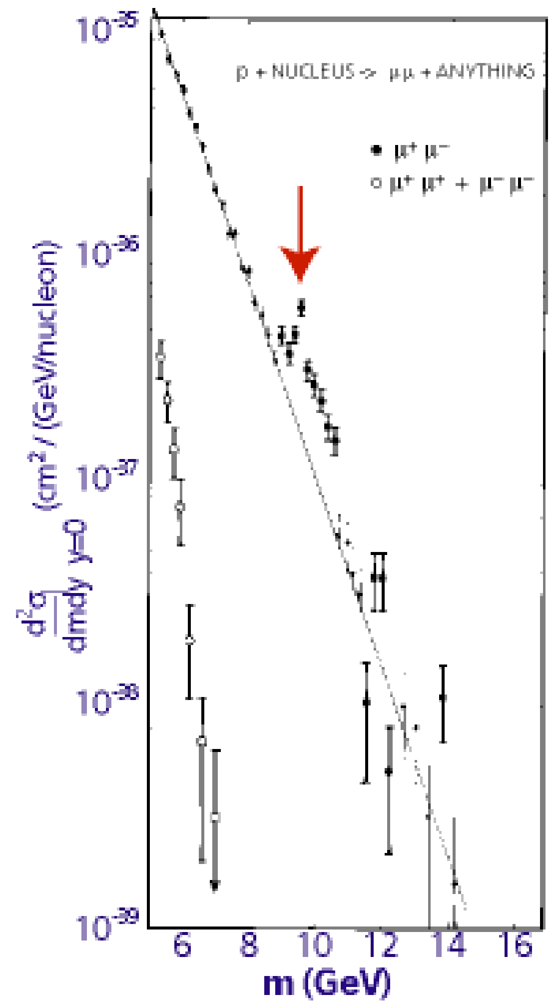
Production of two jets (narrow showers of high-energy particles)

Hadron Colliders

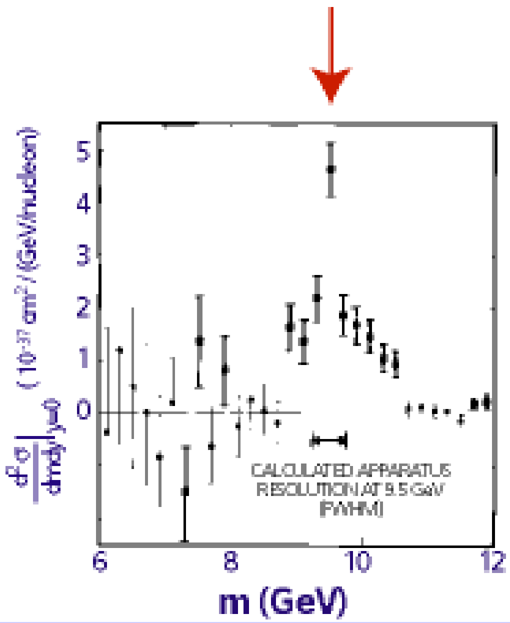
Searching for needles in haystacks

Bump-hunting



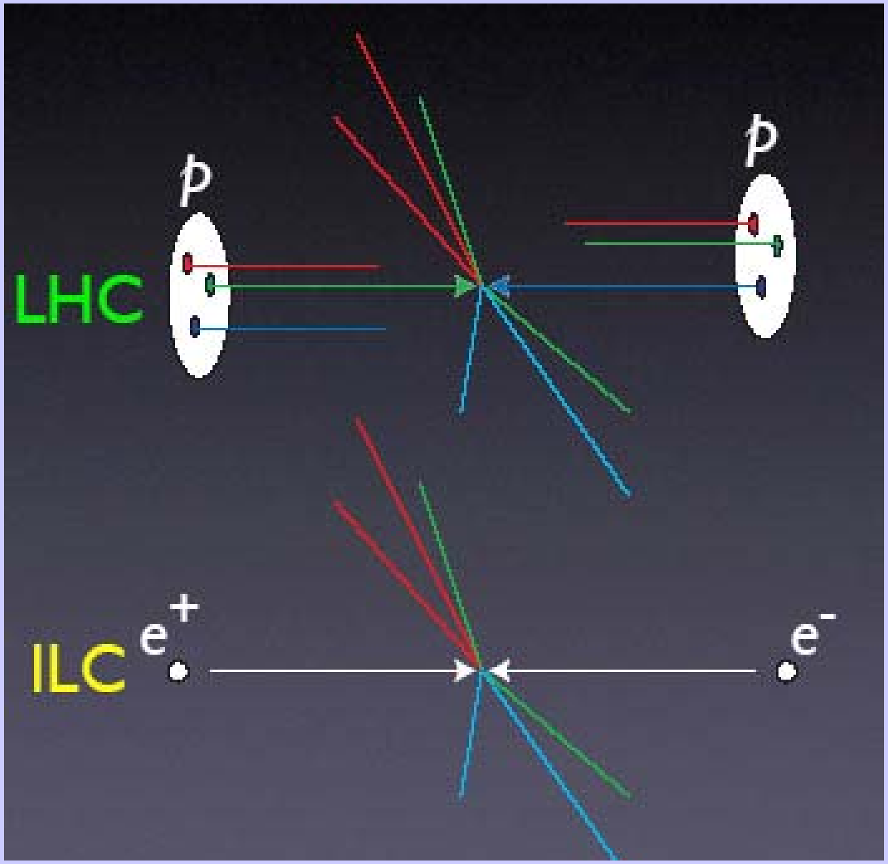


Results published in Physical Review Letters August 1, 1977



Advantages of e^+e^- Collisions ?

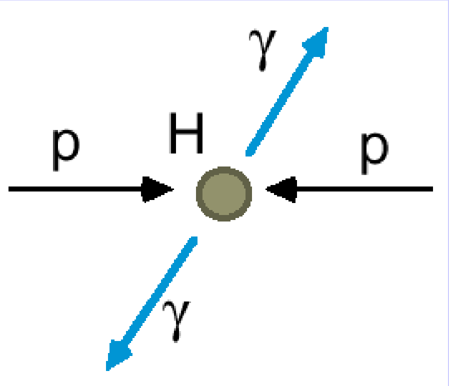
- elementary particles
- well-defined
  - energy,
  - angular momentum
- uses full COM energy
- produces particles democratically
- can mostly fully reconstruct events

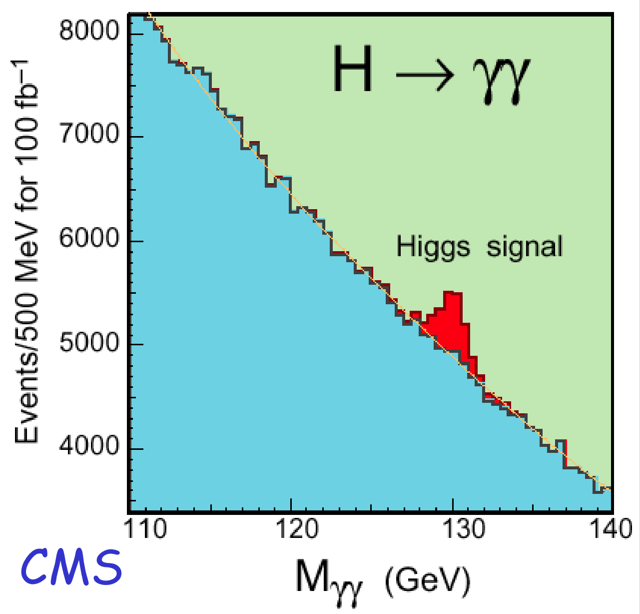


LHC: Low mass Higgs: $H \to \gamma\gamma$

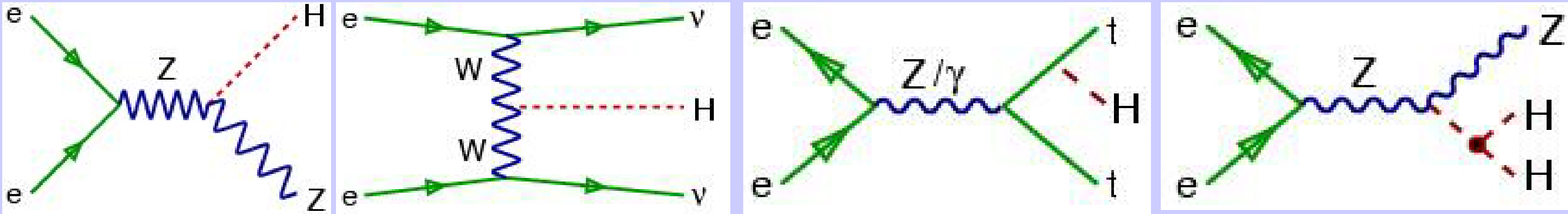
$M_H < 150$ GeV/c^2

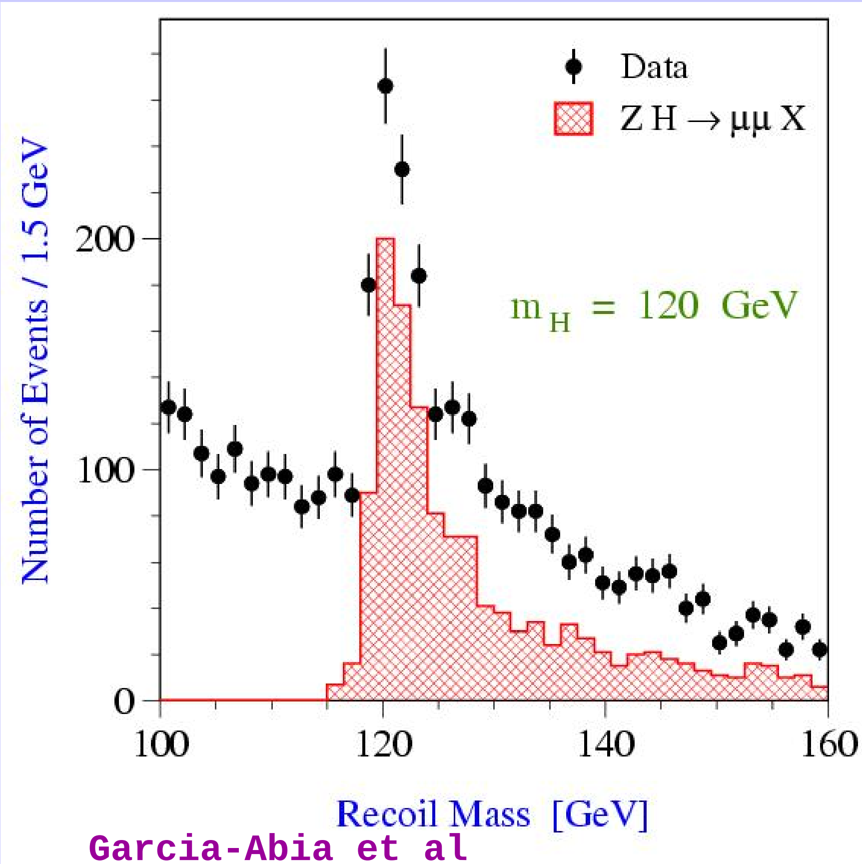
- **Rare decay channel: BR ~ 10^{-3}**
- **Requires excellent electromagnetic calorimeter performance**
  - **acceptance, energy and angle resolution,**
  - **γ/jet and γ/π^0 separation**
  - **Motivation for LAr/$PbWO_4$ calorimeters for CMS**
- **Resolution at 100 GeV: $\sigma \approx 1$ GeV**
- **Background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





Precision Higgs physics

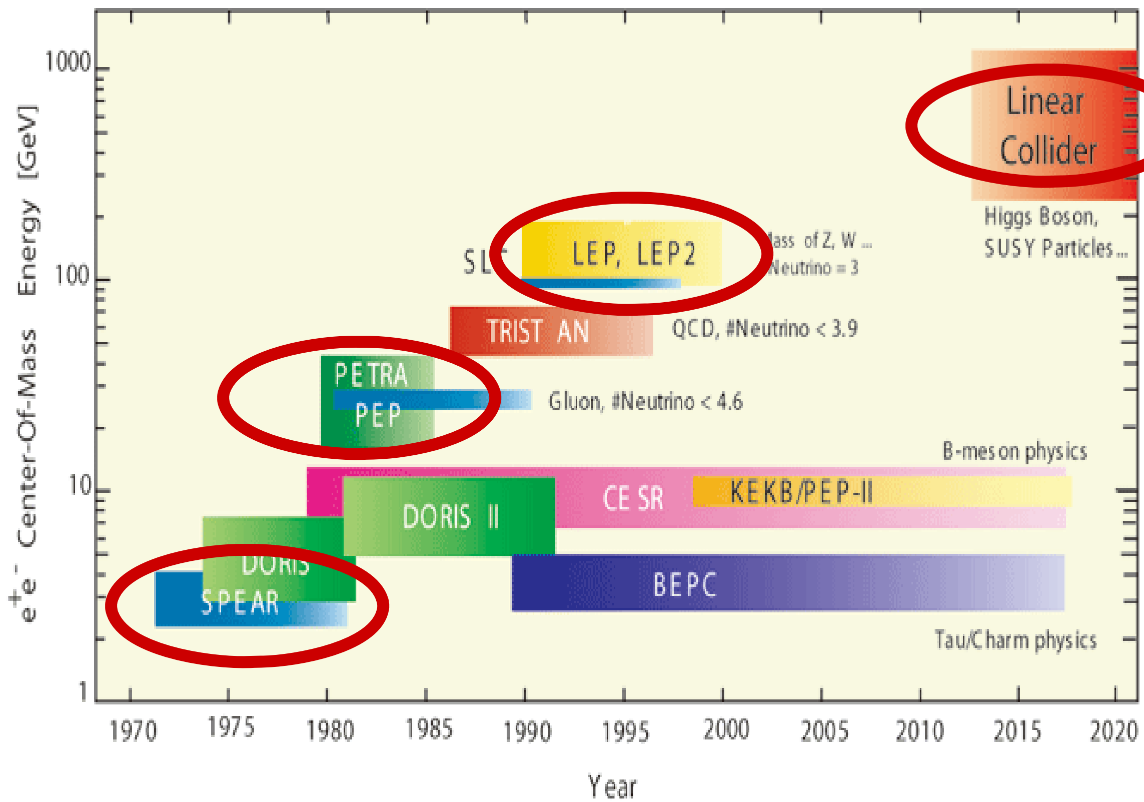




- **Model-independent Studies**
  - **mass**
  - **absolute branching ratios**
  - **total width**
  - **spin**
  - **top Yukawa coupling**
  - **self coupling**
- **Precision Measurements**

Three Generations of e^+e^- Colliders

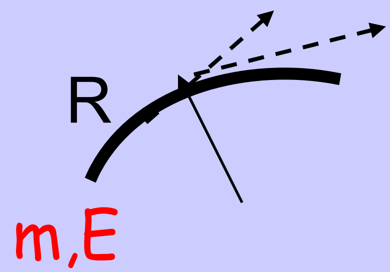
The Energy Frontier



Fourth Generation?

Circular or Linear Collider?

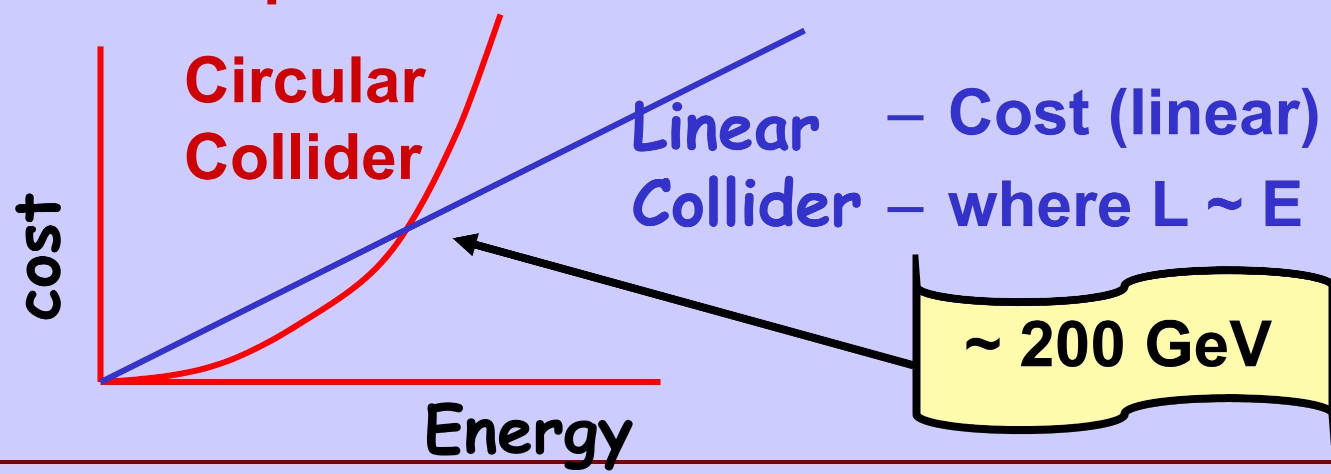
- **Circular Machine**



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 $\sim c E^2$

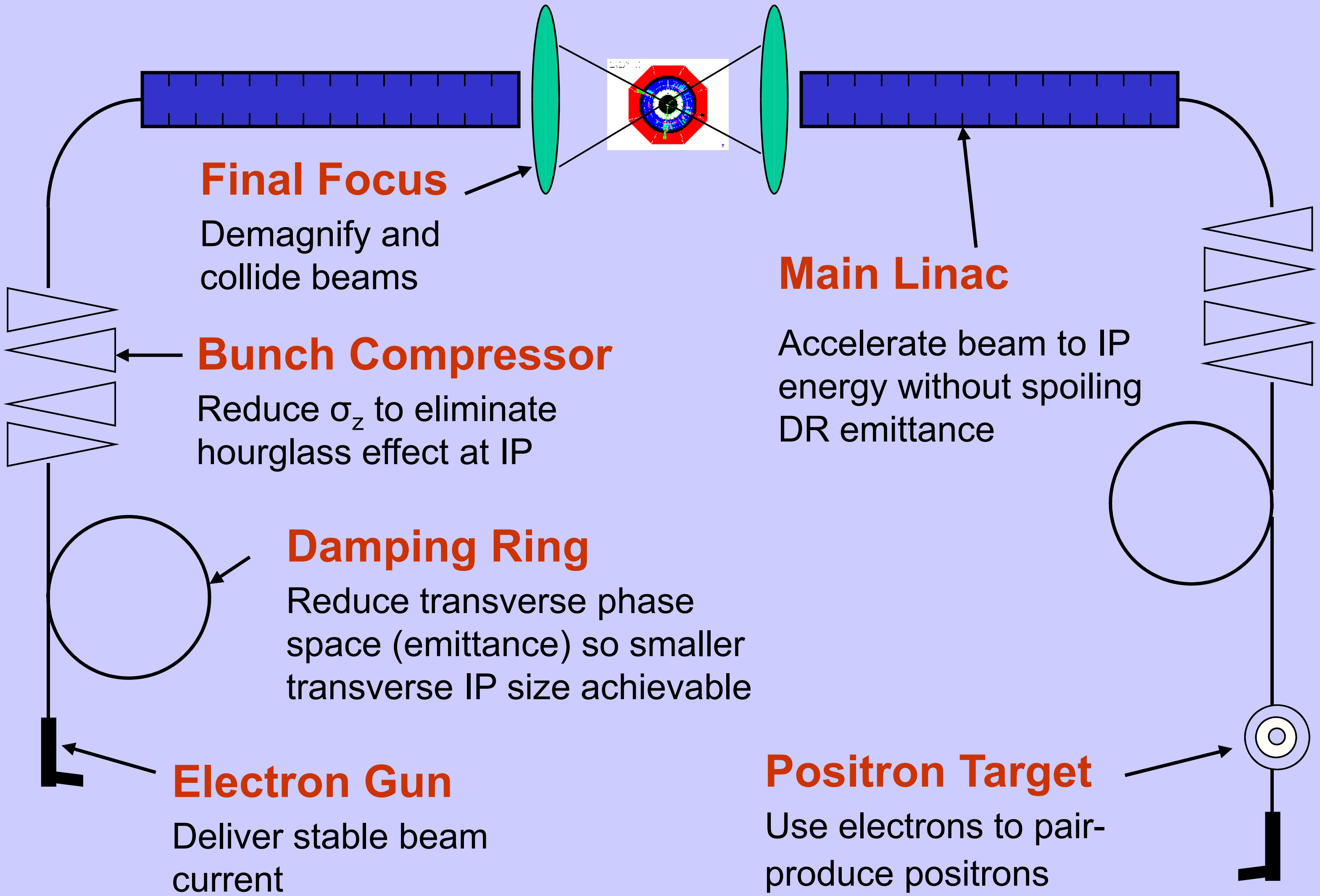


- Cost (linear) $\sim a' L$
- where $L \sim E$

A TeV Scale e^+e^- Accelerator?

- **Two parallel developments over the 1990s (the science & the technology)**
  - **Two alternate designs -- "warm" and "cold" had come to the stage where the "show stoppers" had been eliminated and the concepts were well understood.**
  - **A major step toward a new international machine required uniting behind one technology, and then make a unified global design based on the recommended technology.**

Linear Collider Conceptual Scheme



ILC Subsystems

- **Electron source**

  To produce electrons, light from a titanium-sapphire laser hit a target and knock out electrons. The laser emits 2-ns "flashes," each creating billions of electrons. An electric field "sucks" each bunch of particles into a 250-meter-long linear accelerator that speeds up the particles to 5 GeV.

- **Positron source**

  To produce positron, electron beam go through an undulator. Then, photons, produced in an undulator, hit a titanium alloy target to generate positrons. A 5-GeV accelerator shoots the positrons to the first of two positron damping rings.

- **Damping Ring for electron beam**

  In the 6-kilometer-long damping ring, the electron bunches traverse a wiggler leading to a more uniform, compact spatial distribution of particles. Each bunch spends roughly 0.2 sec in the ring, making about 10,000 turns before being kicked out. Exiting the damping ring, the bunches are about 6 mm long and thinner than a human hair.

- **Damping Ring for positron beam**

  To minimize the "electron cloud effects," positron bunches are injected alternately into either one of two identical positron damping rings with 6-kilometer circumference.

- **Main Linac**

  Two main linear accelerators, one for electrons and one for positrons, accelerate bunches of particlesup to 250 GeV with 8000 superconducting cavities nestled within cryomodules. The modules use liquid helium to cool the cavities to - 2° K. Two 12-km-long tunnel segments, about 100 meters below ground, house the two accelerators. An adjacent tunnel provides space for support instrumentation, allowing for the maintenance of equipment while the accelerator is running. Superconducting RF system accelerate electrons and positrons up to 250 GeV.

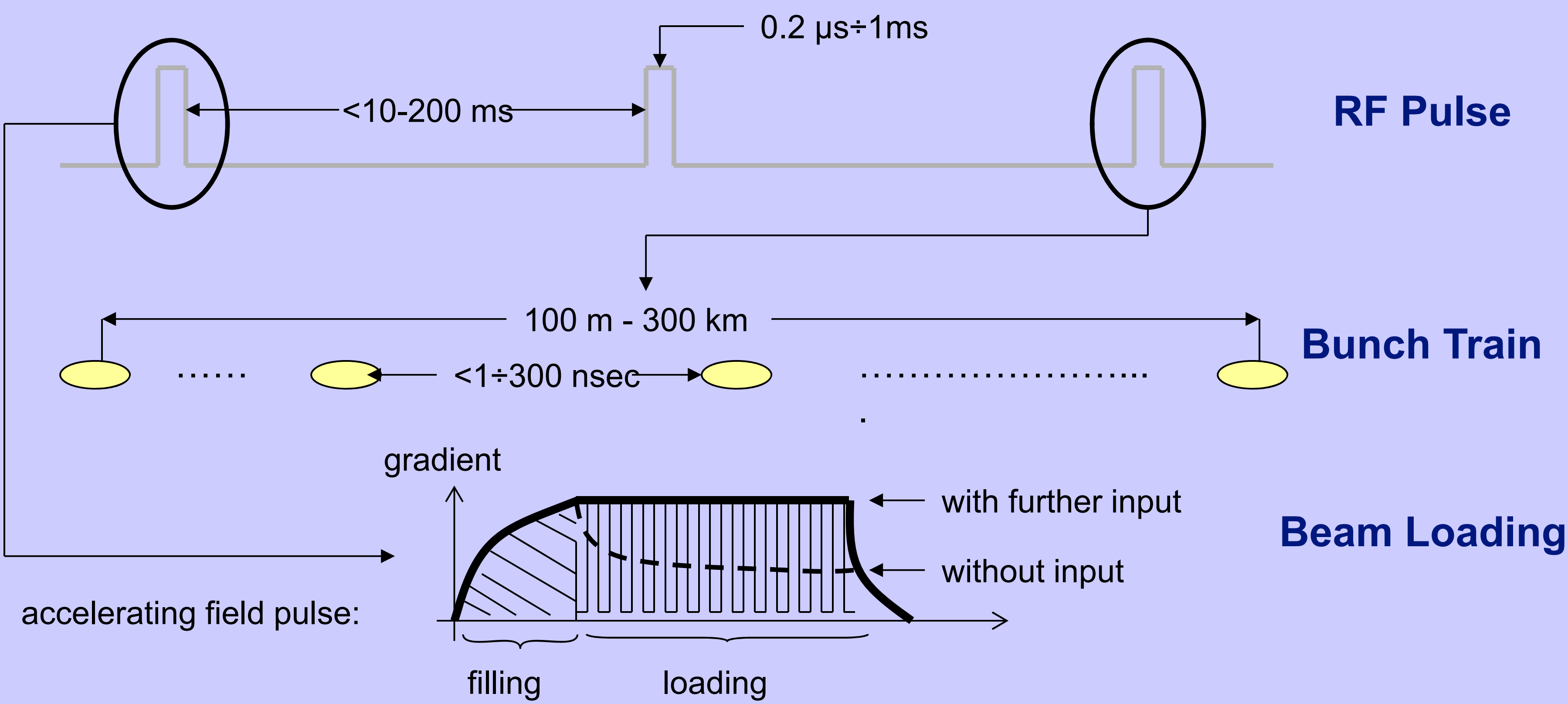
- **Beam Delivery System**

  Traveling toward each other, electron and positron bunches collide at 500 GeV. The baseline configuration of the ILC provides for two collision points, offering space for two detectors.

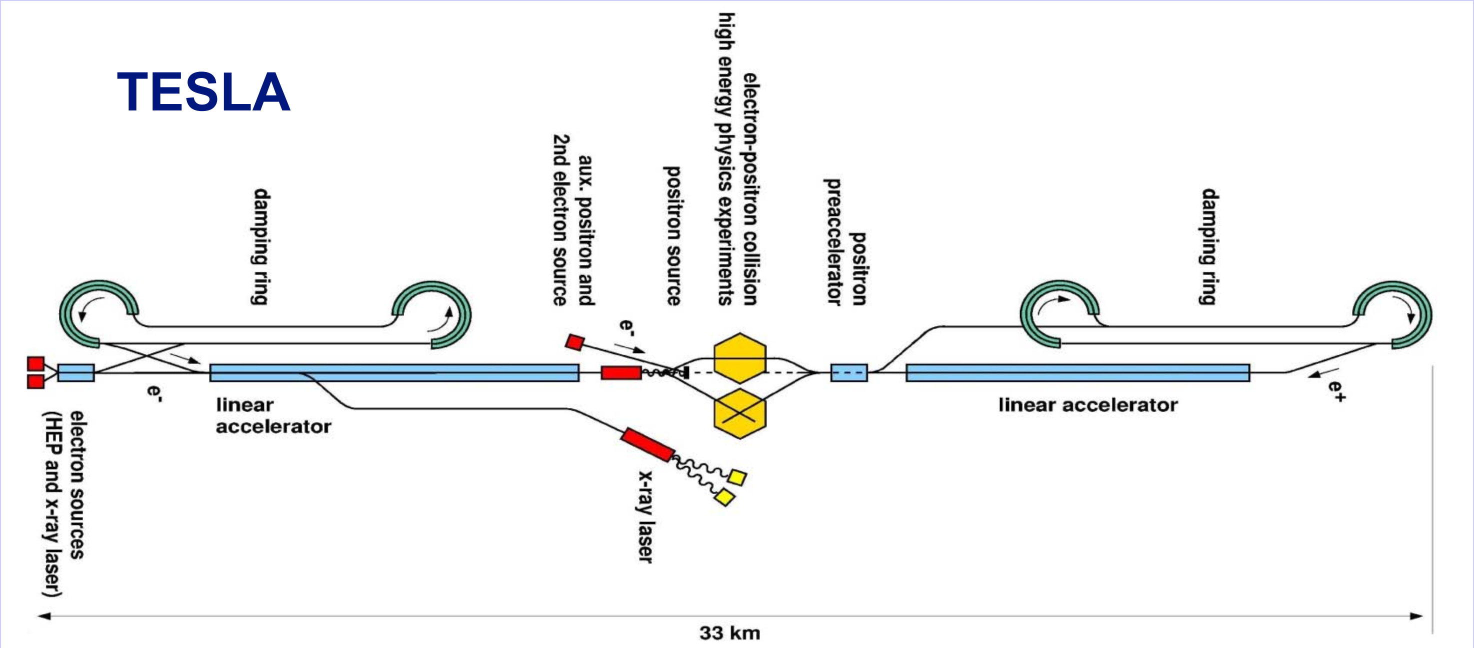
Linear Colliders are pulsed

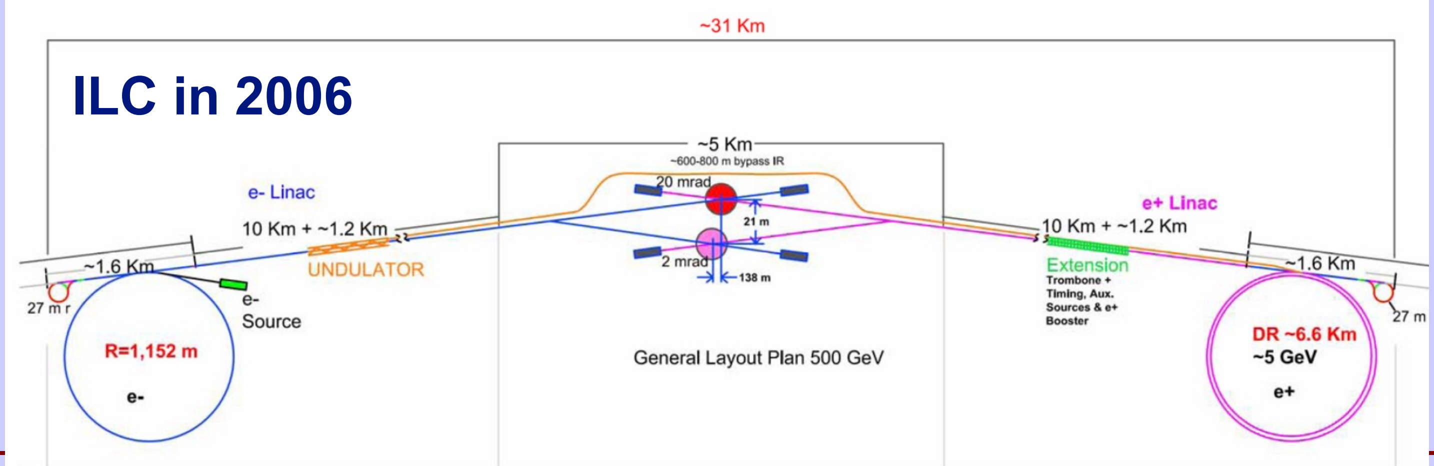
All LCs are pulsed machines to improve efficiency. As a result:

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

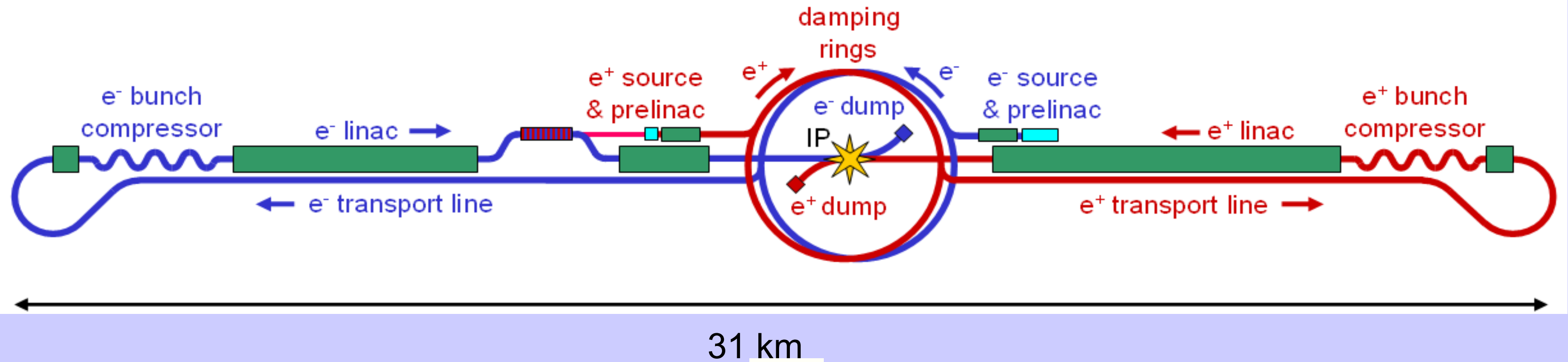


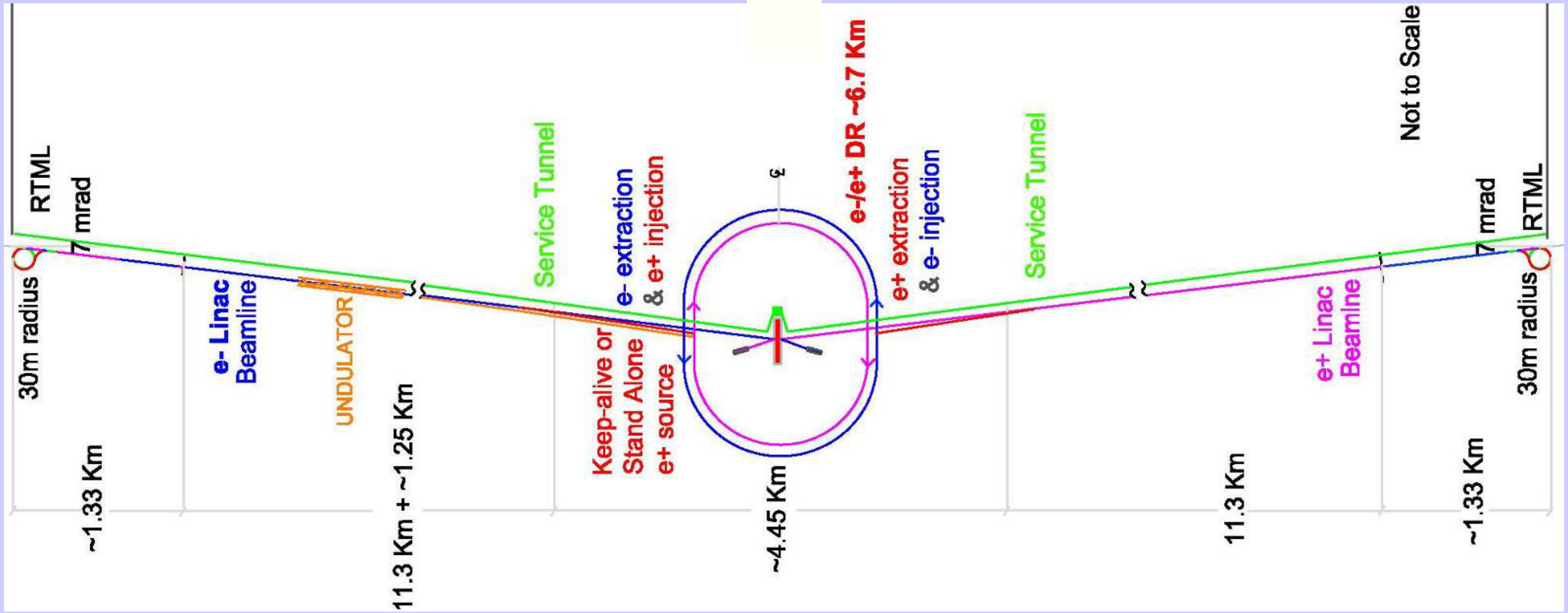
ILC Design Evolution



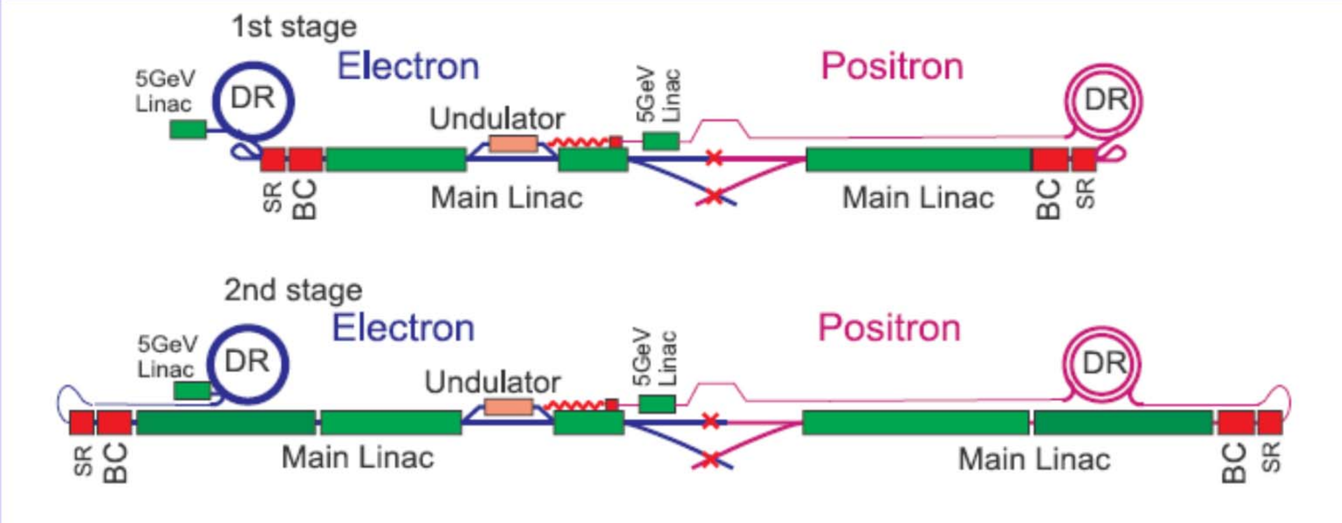


The ILC Reference Design





ILC Baseline Configuration

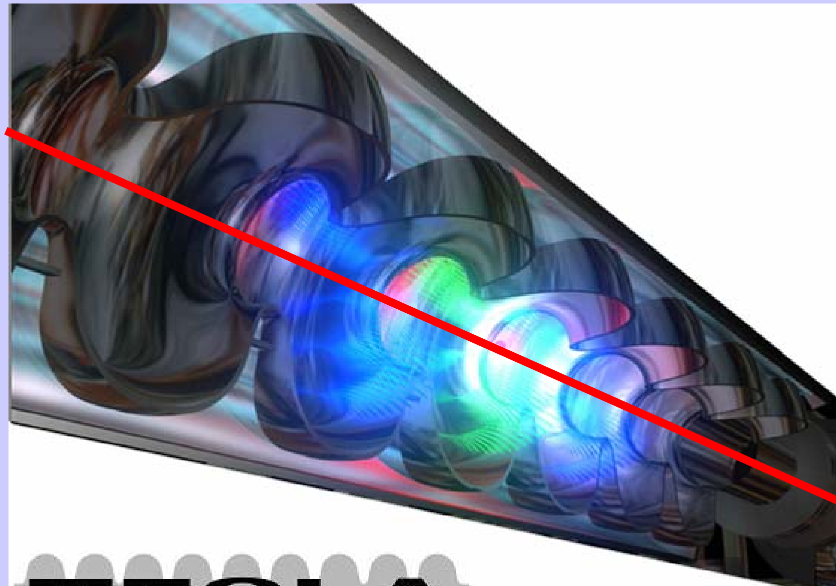


		min		nominal		max	
Bunch charge	N	1	-	2	-	2	$\times 10^{10}$
Number of bunches	n_b	1330	-	2820	-	**5640**	
Linac bunch interval	t_b	**154**	-	308	-	461	ns
Bunch length	σ_z	**150**	-	300	-	500	μm
Vert.emit.	$\gamma\epsilon_y^*$	**0.03**	-	0.04	-	0.08	mm·mrad
IP beta (500GeV)	β_x^*	**10**	-	21	-	21	mm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

A TeV Scale e^+e^- Accelerator?

- **Two parallel developments over the 1990s (the science & the technology)**
  - **Two alternate designs -- "warm" and "cold" had come to the stage where the "show stoppers" had been eliminated and the concepts were well understood.**
  - **A major step toward a new international machine required uniting behind one technology, and then make a unified global design based on the recommended technology.**

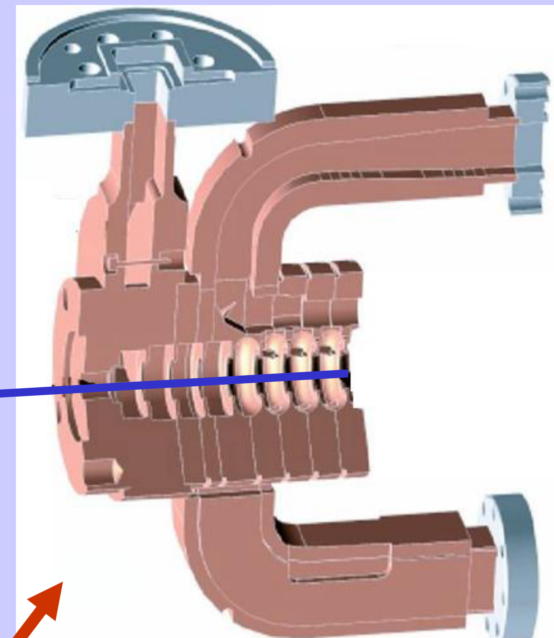
Linear Collier: Competing Technologies



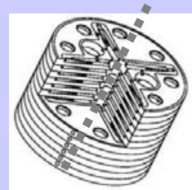
1.3 GHz - Cold

Evolution from: CEBAF & LEPII
+ TRISTAN, HERA, etc.

Evolution from: SLAC & SLC



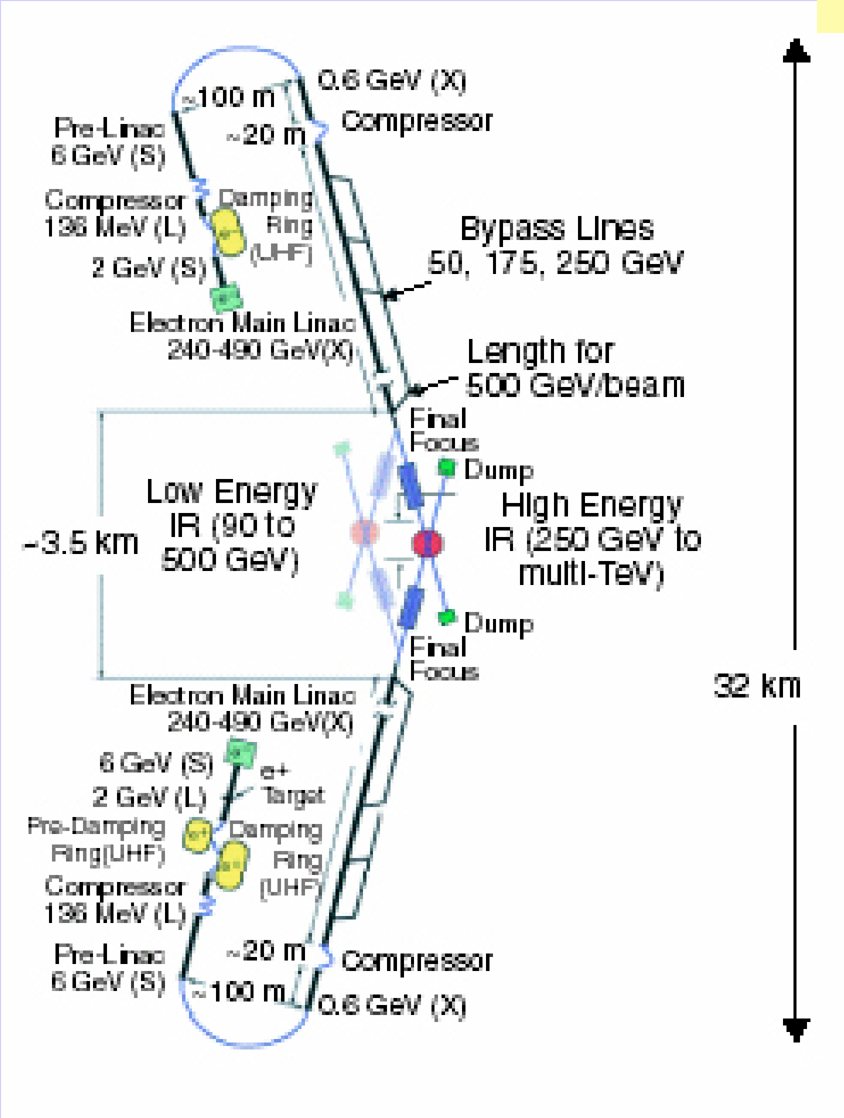
11.4 GHz - Warm



12 GHz - Warm

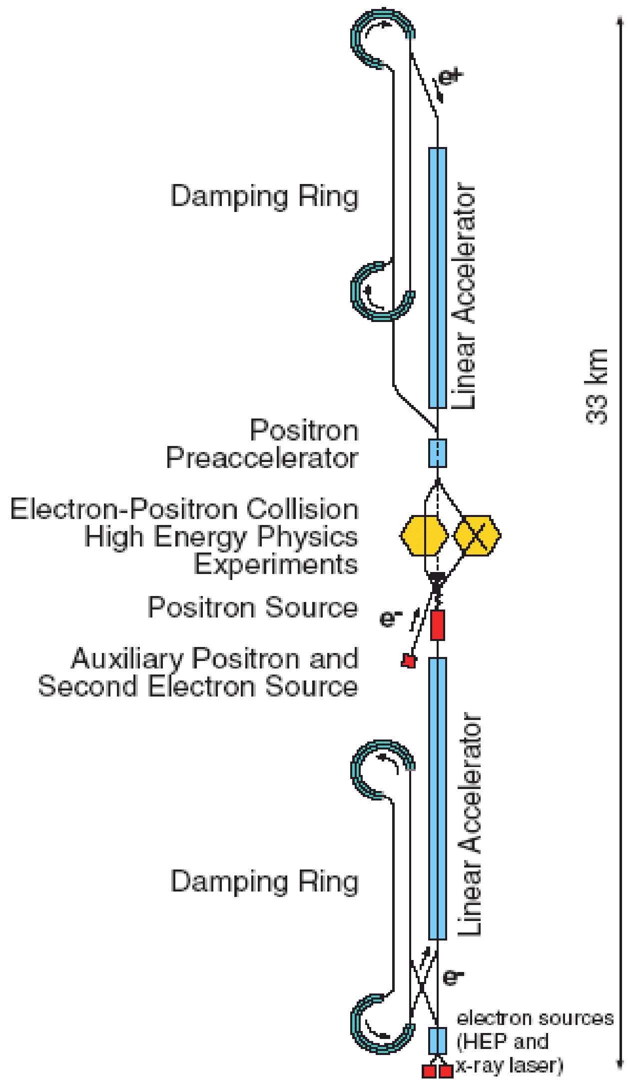
GLC

GLC/NLC Concept



The JLC-X and NLC essentially a unified single design with common parameters

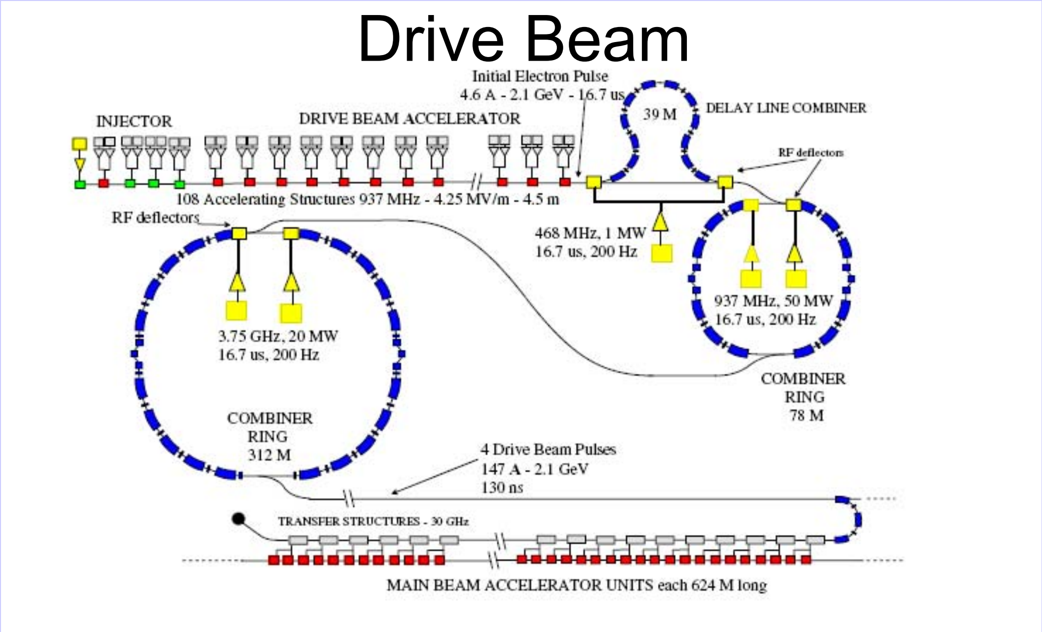
The main linacs based on 11.4 GHz, room temperature copper technology.

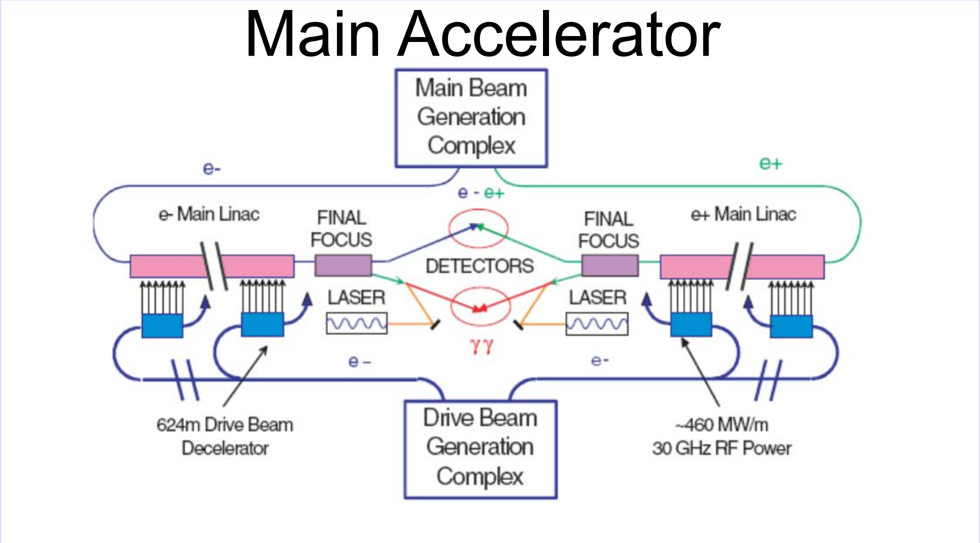


TESLA Concept

- **The main linacs based on 1.3 GHz superconducting technology operating at 2 K.**
- **The cryoplant, is of a size comparable to that of the LHC, consisting of seven subsystems strung along the machines every 5 km.**

CLIC Concept





The main linac rf power is produced by decelerating a high-current (150 A) low-energy (2.1 GeV) drive beam

Nominal accelerating gradient of 150 MV/m

GOAL

Proof of concept ~2010

Technical Review Committee

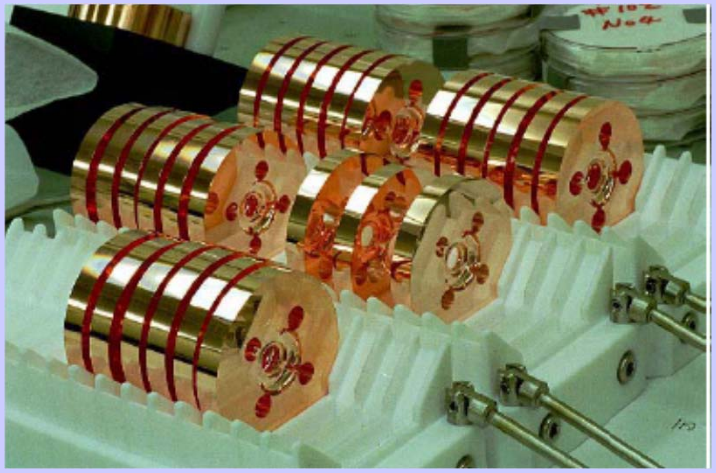
In Feb. 2001, ICFA charged a Technology Review Committee, chaired by Greg Loew of SLAC to review the critical R&D readiness issues.

The TRC report in 2003 gave a series of R&D issues for L-band (superconducting rf TESLA), X-band (NLC and GLC), C-band and CLIC. The most important were the R1's: those issues needing resolution for design feasibility.

R1 issues pretty much satisfied by mid-2004

ILC – Underlying Technology

- **Room temperature copper structures**



OR

- **Superconducting RF cavities**

ICFA/ILCSC
Evaluation of the Technologies

INTERNATIONAL LINEAR COLLIDER

TECHNICAL REVIEW COMMITTEE

SECOND REPORT

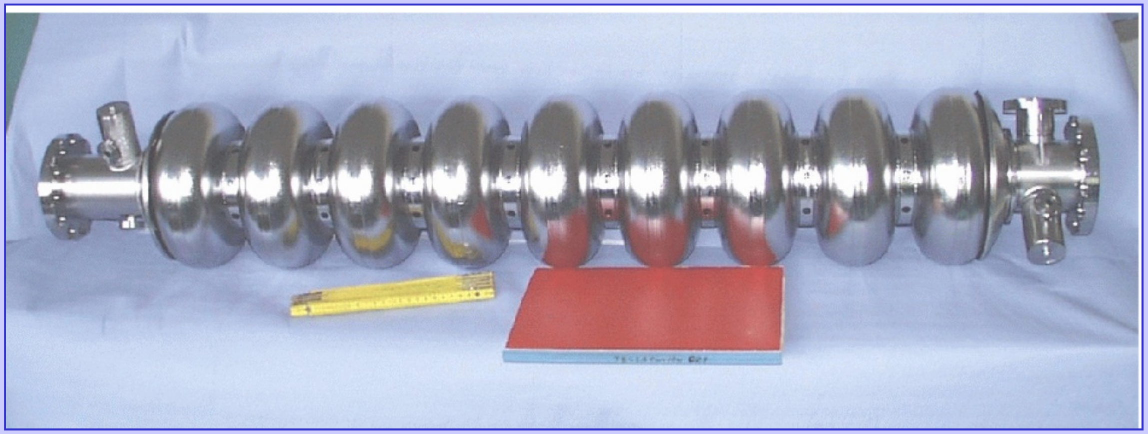
2003

The Report Validated the Readiness of L-band and X-band Concepts

ITRP in Korea

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

Superconducting RF Technology



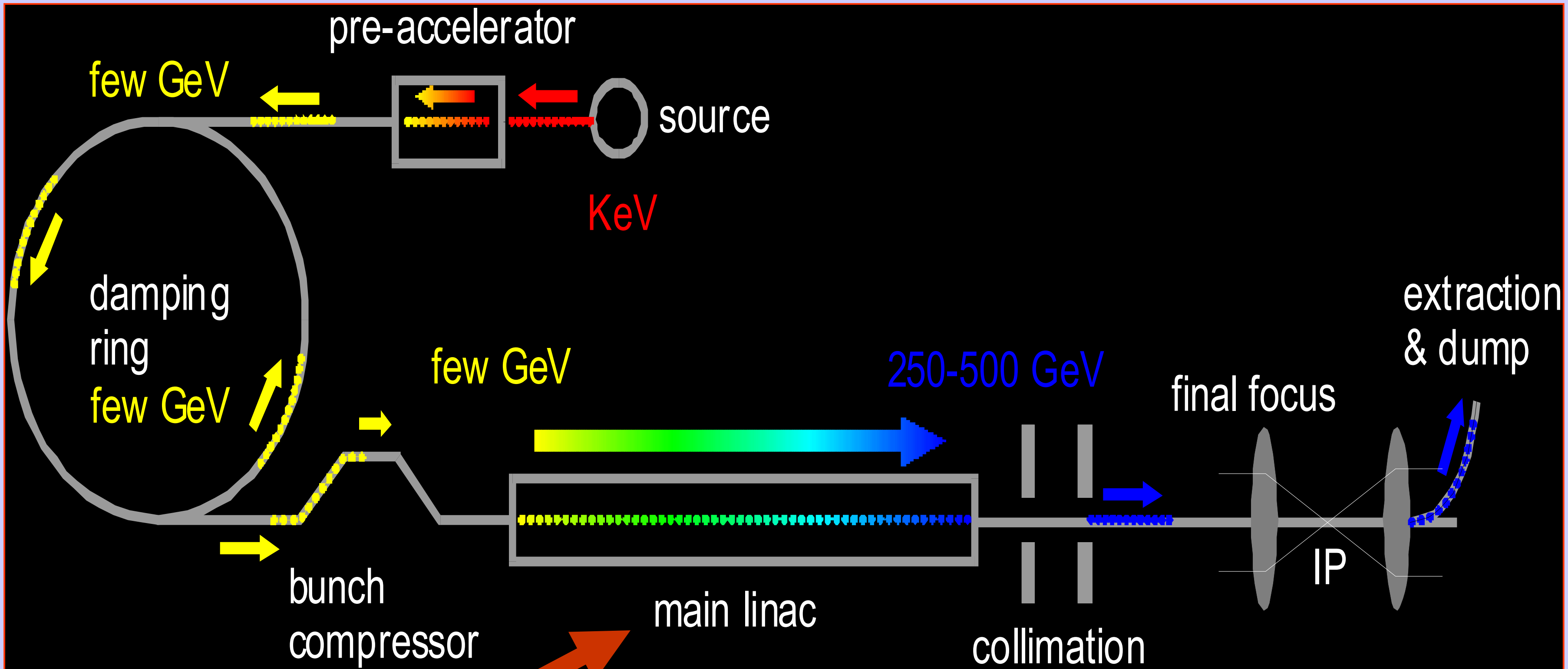
- **Forward looking technology for the next generation of particle accelerators: particle physics; nuclear physics; materials; medicine**
- **The ILC R&D is leading the way Superconducting RF technology**
  - high gradients; low noise; precision optics

SCRF Technology Recommendation

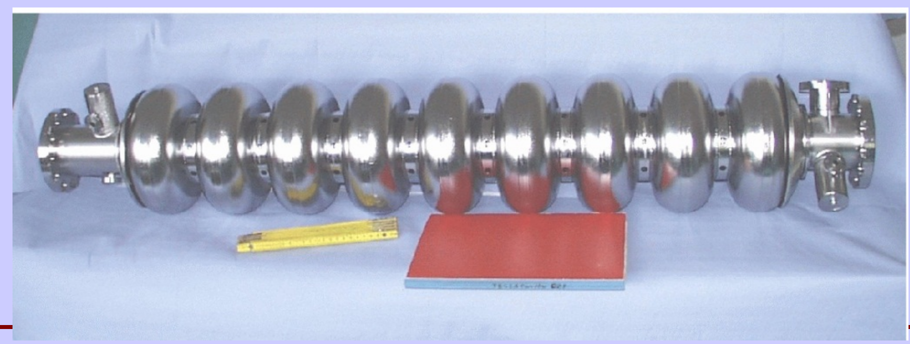
- The recommendation of ITRP was presented to ILCSC & ICFA on August 19, 2004 in a joint meeting in Beijing.

- ICFA unanimously endorsed the ITRP's recommendation on August 20, 2004

Designing a Linear Collider



Superconducting RF Main Linac



The Community Self-Organized

Nov 13-15, 2004

~ 220 participants from 3 regions, most of them accelerator experts

15

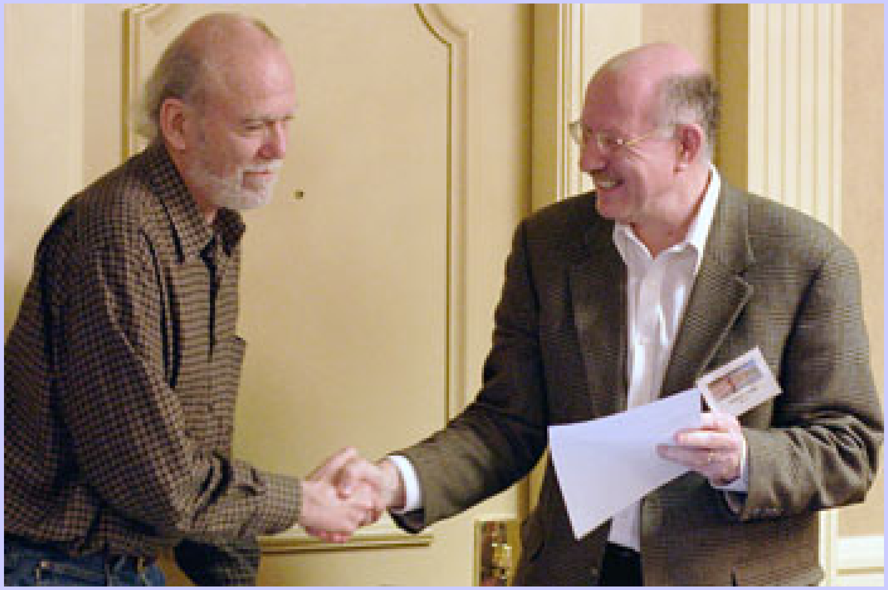
Self Organization following Technology Decision

- 1st ILC workshop at KEK November 2004
- ILCSC forms 5 technical WG + 1 communications and outreach WG
  - WG1 Parameters & General Layout
  - WG2 Main Linac
  - WG3 Injectors
  - WG4 Beam Delivery & MDI
  - WG5 High gradient SCRF
  - WG6 Communications

Global Design Effort (GDE)

- February 2005, at TRIUMF, ILCSC and ICFA endorsed the search committee choice for GDE Director

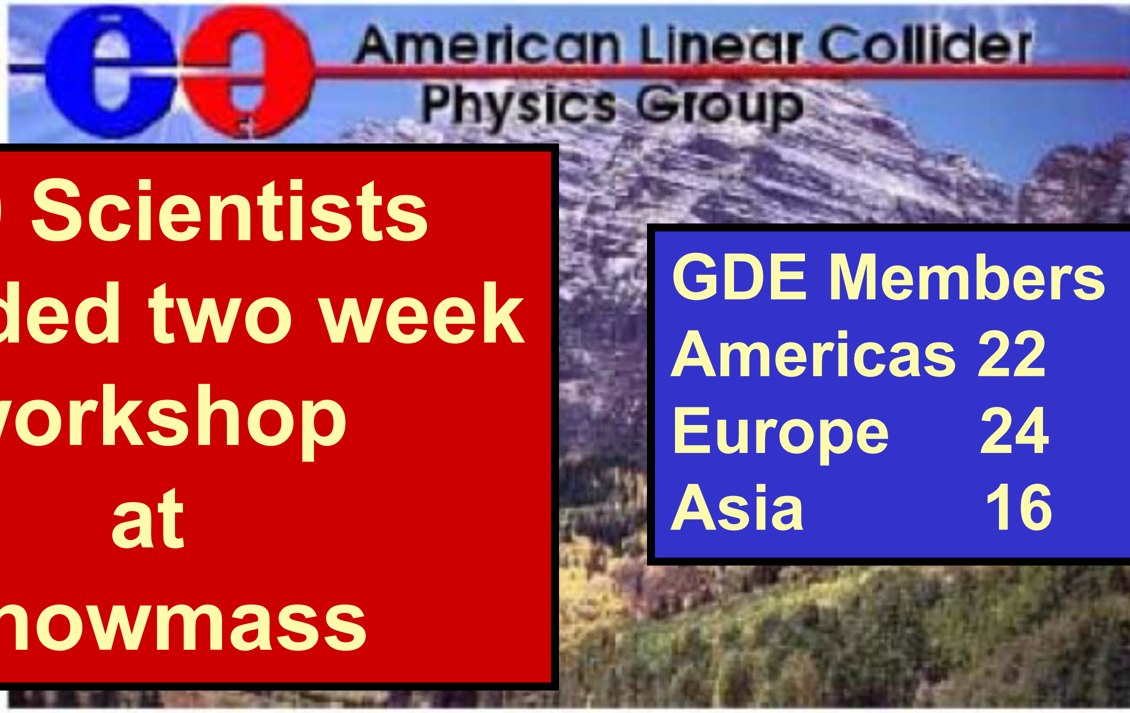
- On March 18, 2005, I officially accepted the position at the opening of LCWS 05 meeting at Stanford



Global Design Effort

– **The Mission of the GDE**
  - **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 Begins at Snowmass



670 Scientists attended two week workshop at Snowmass

GDE Members

Americas	22
Europe	24
Asia	16

2005 International Linear Collider Physics and Detector Workshop and Second ILC Accelerator Workshop

Snowmass, Colorado, August 14-27, 2005

Enter the GDE - Snowmass

Birth of the GDE and Preparation for Snowmass

- WG1 Parms & layout
- WG2 Linac
- WG3 Injectors
- WG4 Beam Delivery
- WG5 High Grad. SCRF
- WG6 Communications

- WG1 LET beam dynamics
- WG2 Main Linac
- WG3a Sources
- WG3b Damping Rings
- WG4 Beam Delivery
- WG5 SCRF Cavity Package
- WG6 Communications
- GG1 Parameters & Layout
- GG2 Instrumentation
- GG3 Operations & Reliability
- GG4 Cost Engineering
- GG5 Conventional Facilities
- GG6 Physics Options

Introduction of **G**lobal **G**roups
transition workshop → project

GDE Organization for Snowmass

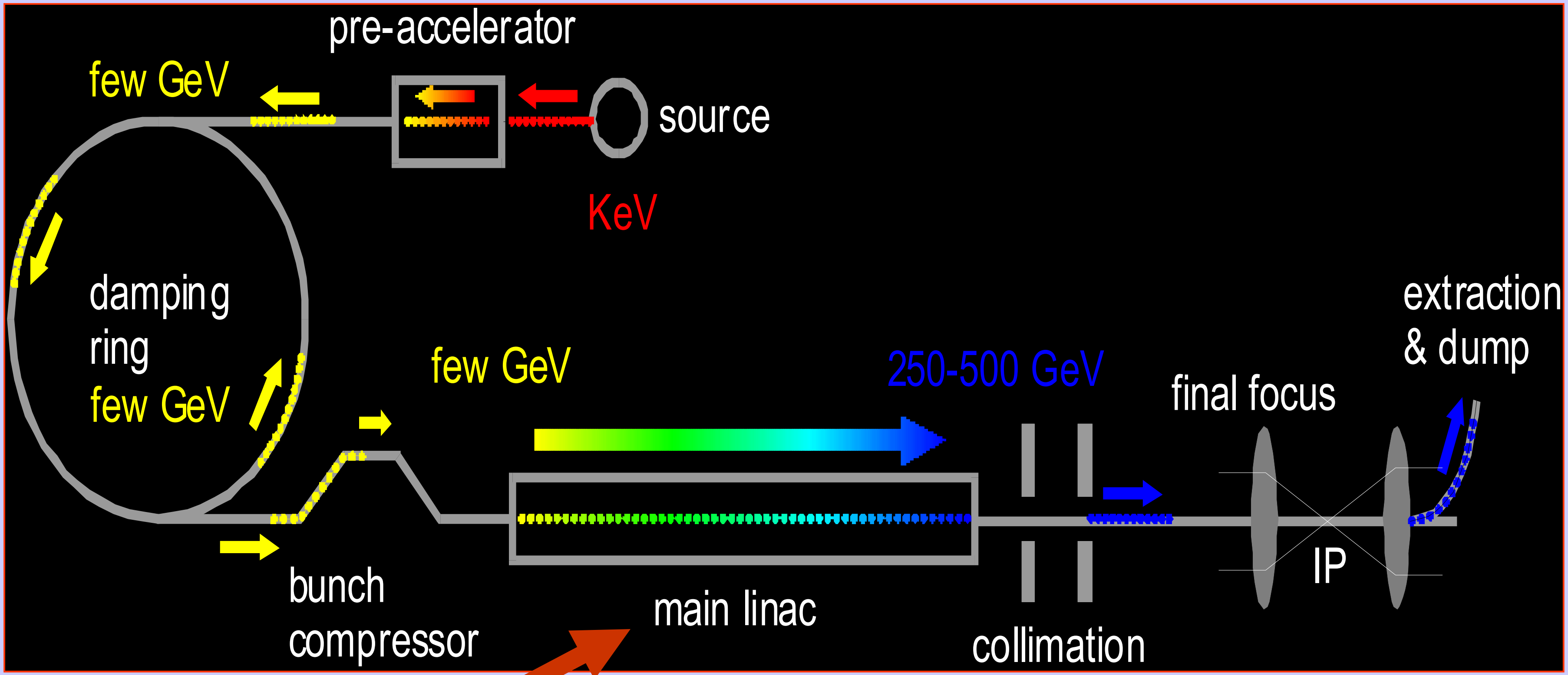
Technical sub-system Working Groups

Provide input

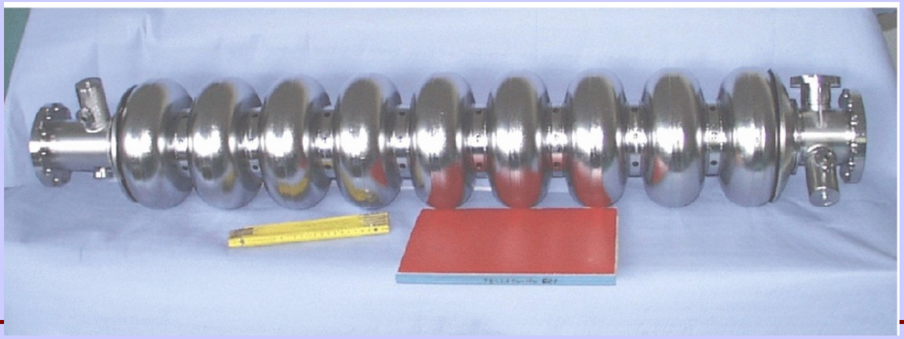
Global Group

	WG5 Cavity	WG4 BDS	WG3b DR	WG3a Sources	WG2 Main Linac	WG1 LET bdyn.
GG1 Parameters						
GG2 Instrumentation						
GG3 Operations & Reliability						
GG4 Cost & Engineering						
GG5 Conventional Facilities						
GG6 Physics Options						

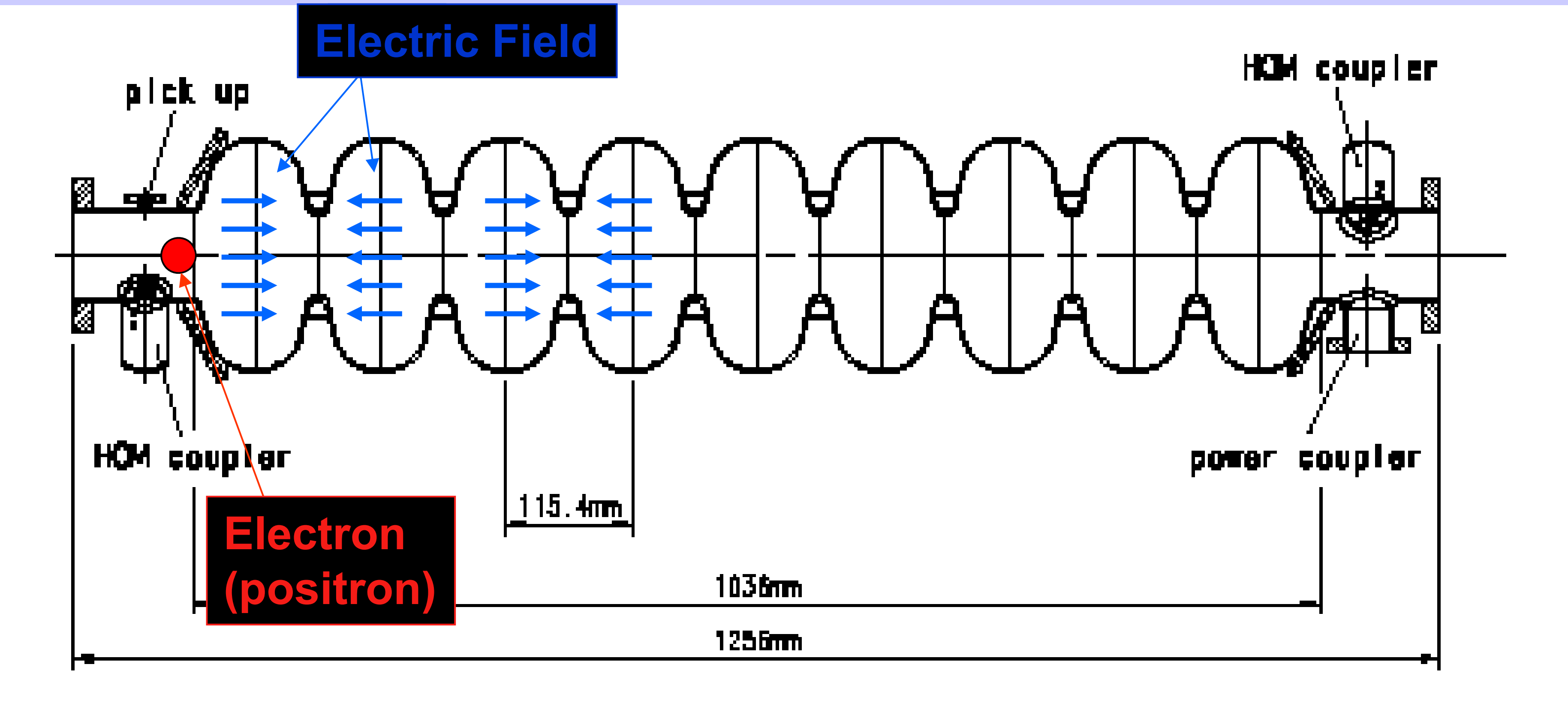
Designing a Linear Collider



Superconducting RF Main Linac



Technical Challenges: High Grad SCRF

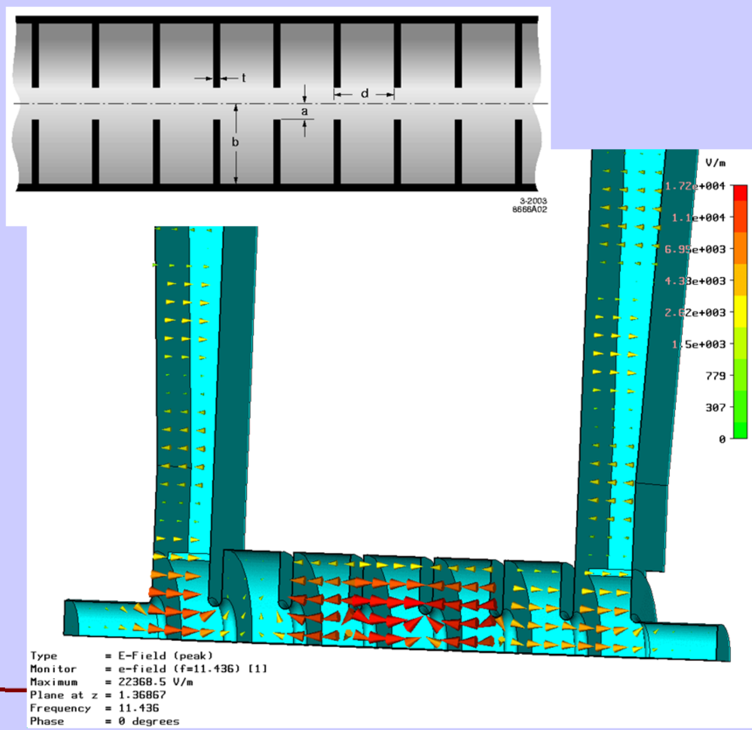


Real Accelerating Structures: Cavities

Imposing boundary condition in the longitudinal direction, z, we have for each mode (for example the TM_{01}) two waves: rightward-propagating (+z) wave and a leftward-propagating wave The combination can give a wave with phase velocity $v_{ph} \leq c$

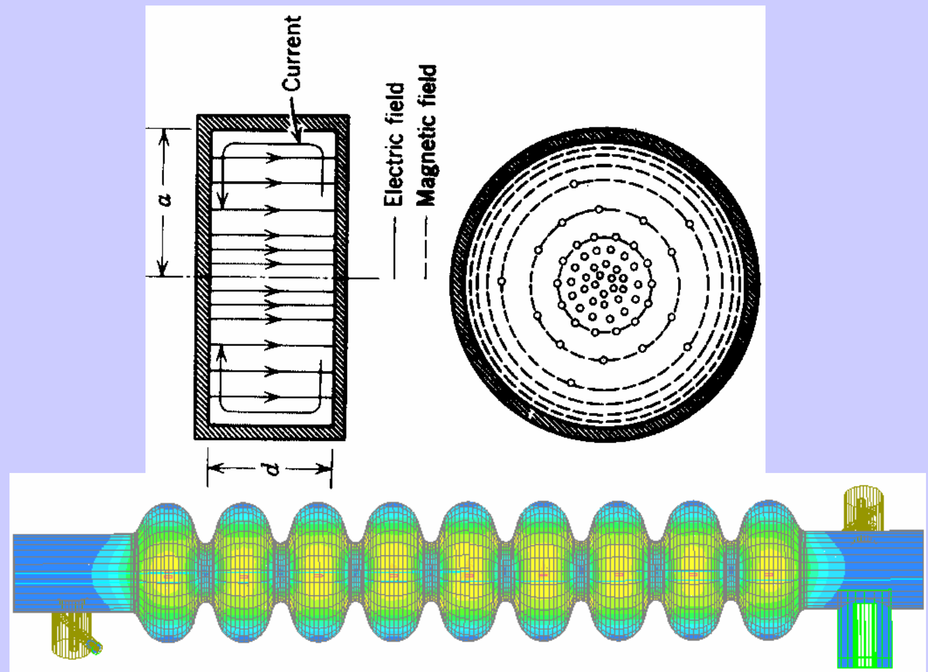
Traveling wave structure

$V_{ph} \approx c$ and $Vg < c$



Standing wave structure

$V_{ph} = 0$ and $Vg = 0$



π mode

Example of 9-cell cavity performance.

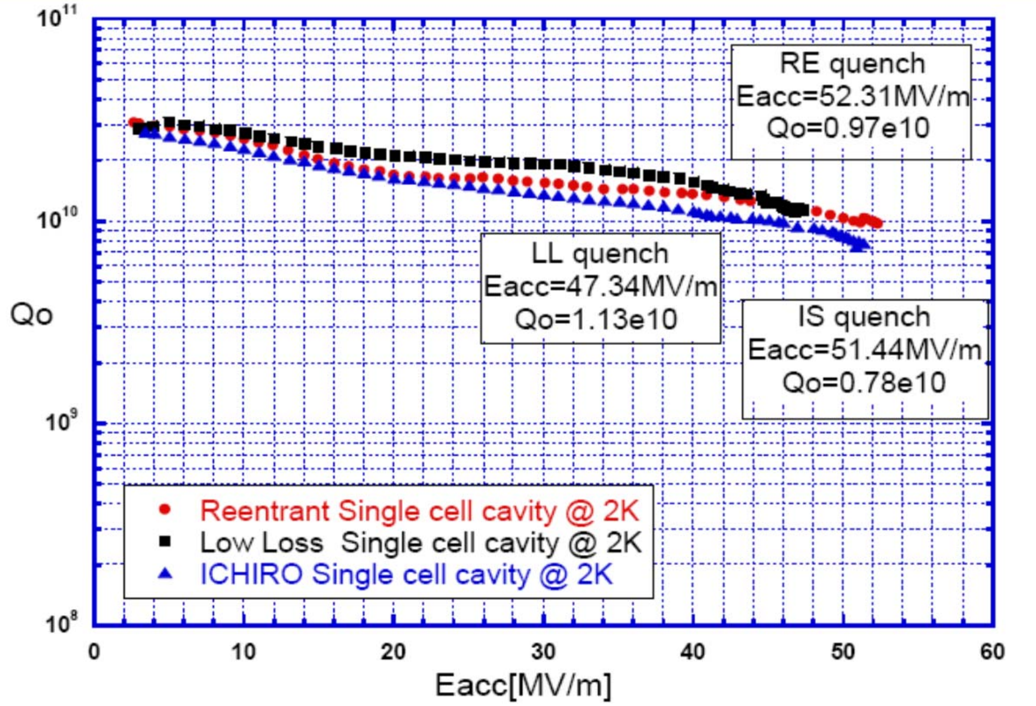
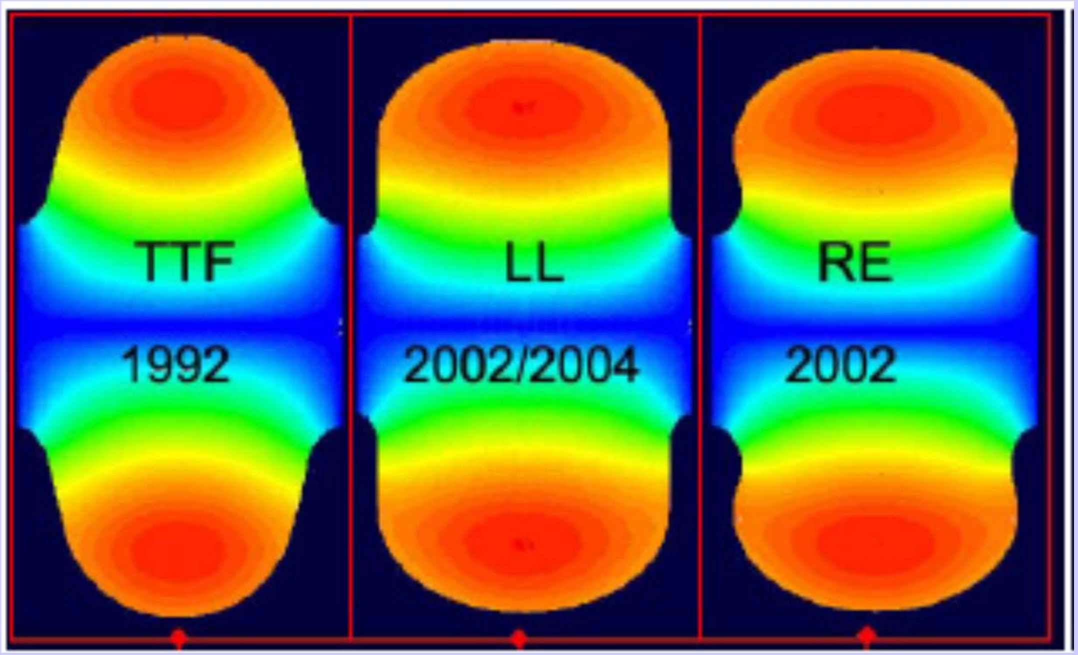


Figure 3: The results of high gradient measurements.

- Enormous R&D efforts have been made world wide to establish SCRF acceleration technology.

- We need more than 10,000 units of this kind of cavity assembled in the cryomodule.

Cavity Shape Optimization



	TESLA	LL	RE
Aperture, mm	70	60	70
k_c,%	1.9	1.52	2.38
K_e = E/Eacc	1.98	2.36	2.39
k_m, mT/(MeV/m)	4.15	3.61	3.78
(r/Q), Ω	113.8	133.7	120.6
G, Ohm	271	284	280

Luminosity & Beam Size

$$L = \frac{n_b N^2 f_{rep}}{2\pi\sigma_x\sigma_y} H_D$$

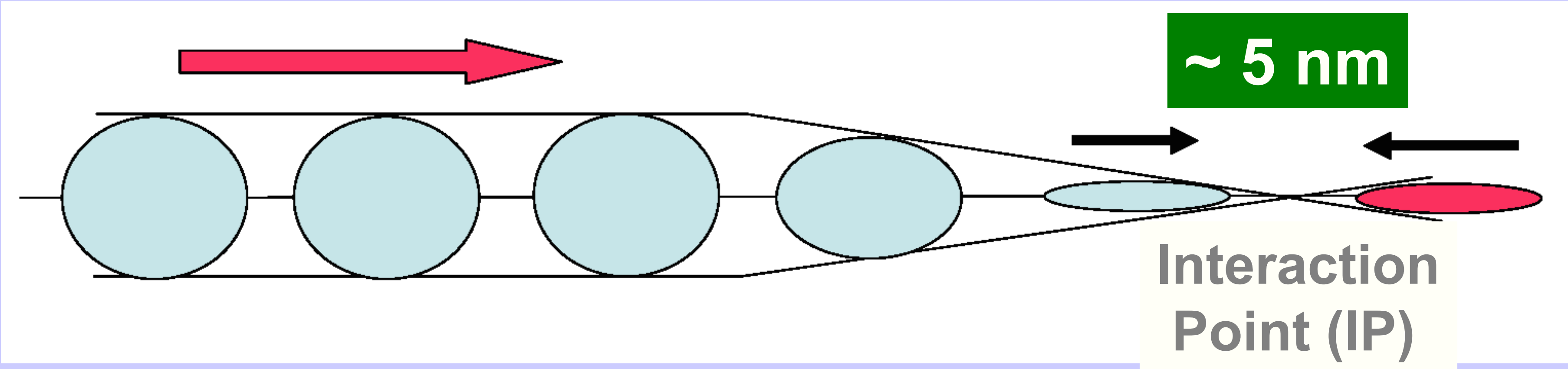
- f_{rep} * n_b tends to be low in a linear collider

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

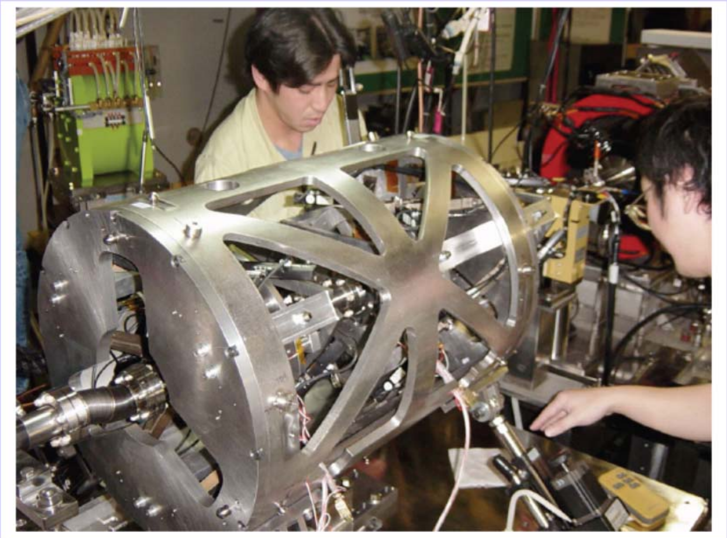
- Achieve luminosity with spot size and bunch charge

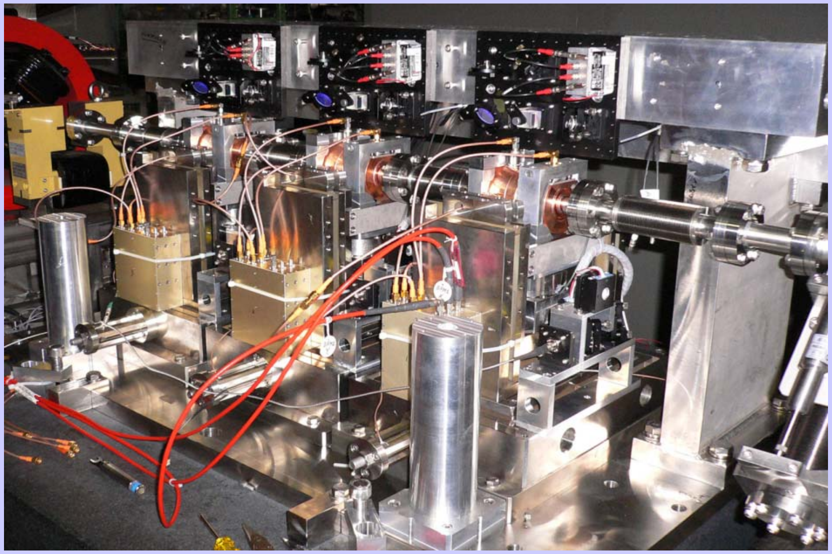
Achieving High Luminosity

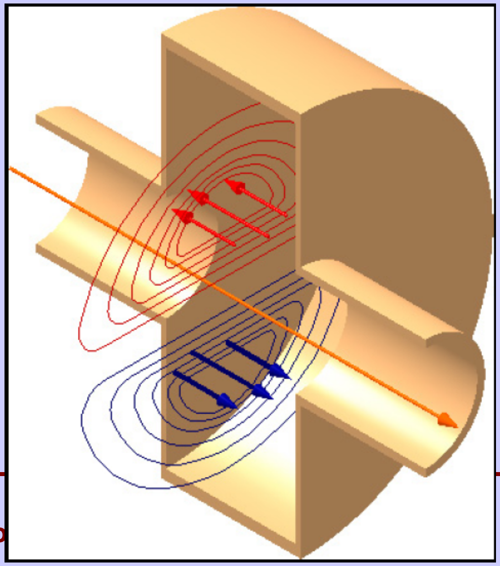
- Low emittance machine optics
- Contain emittance growth
- Squeeze the beam as small as possible

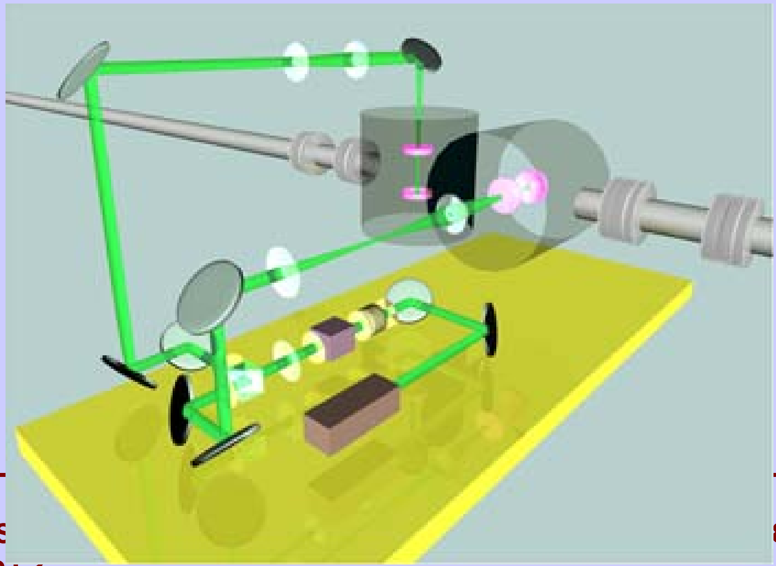


Making Very Small Emittance
(Beam Sizes at Collision)

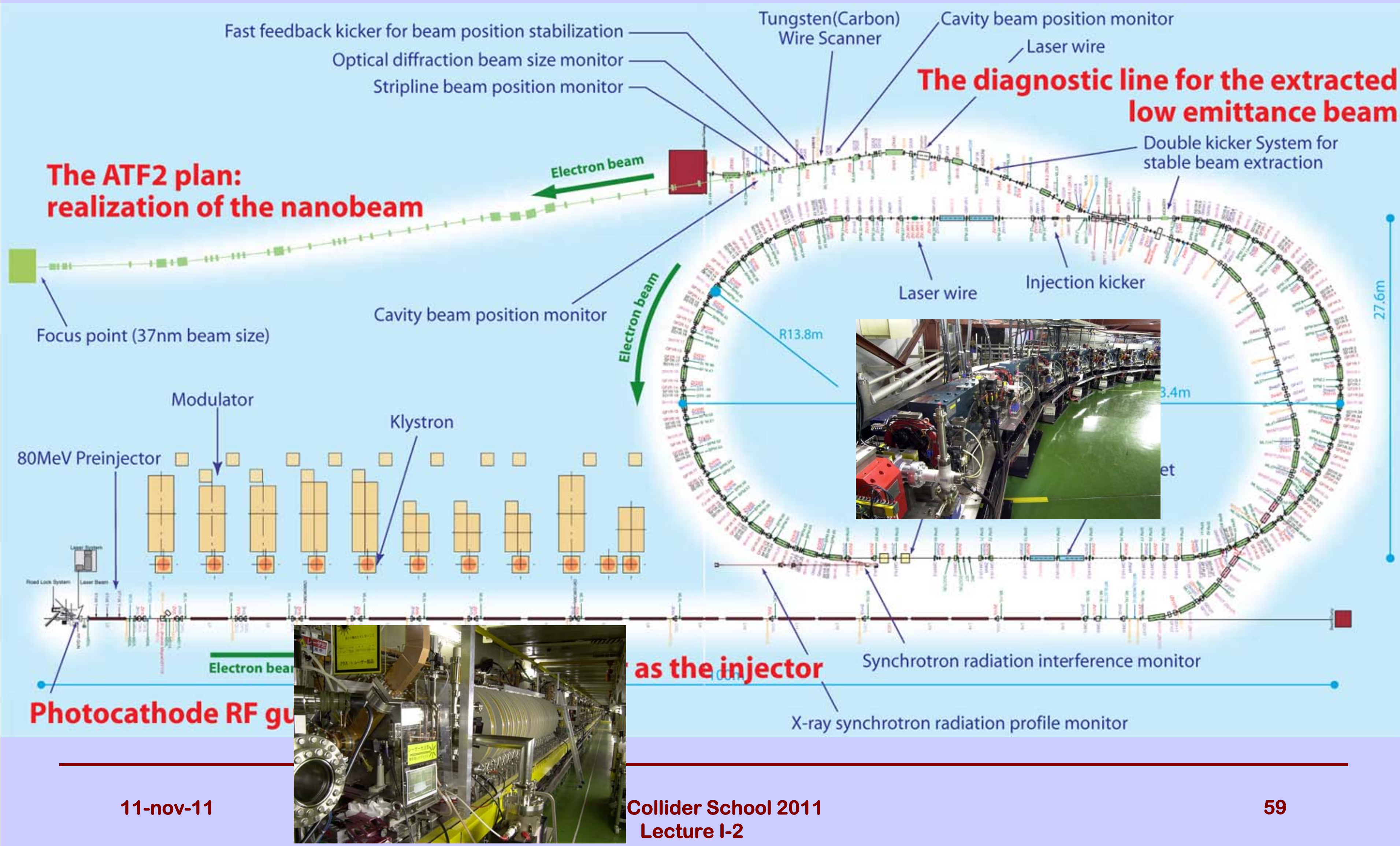




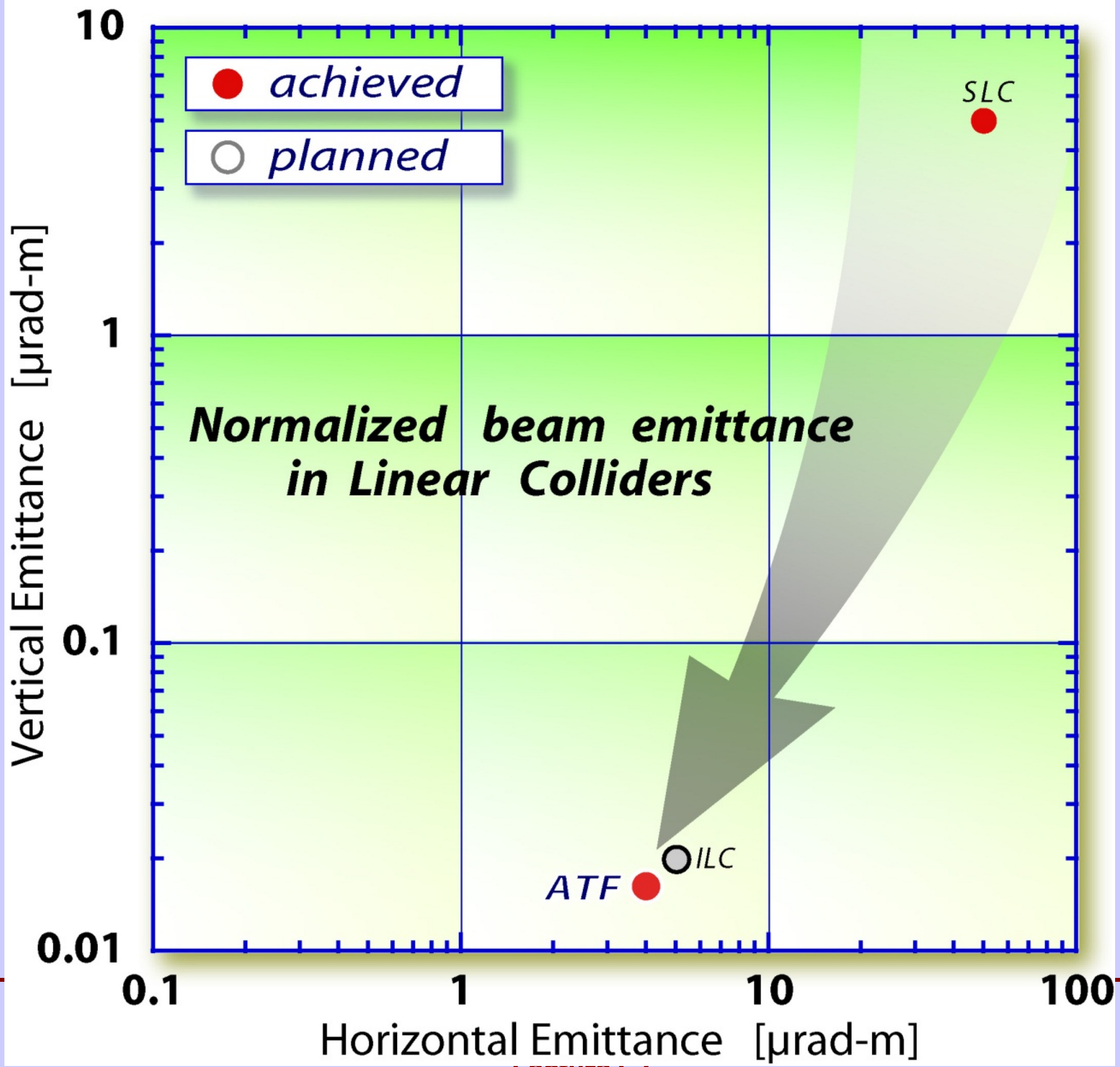




ATF
Accelerator Test Facility

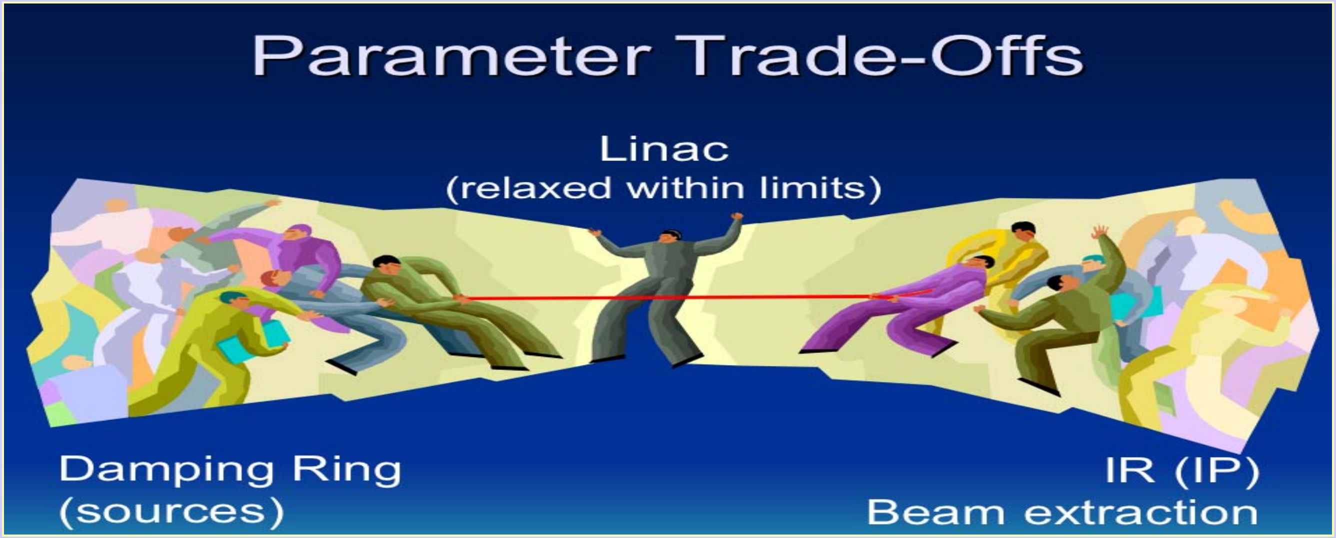


It seems that we have technology in hand
to squeeze beam down to the required size.



Parametric Approach

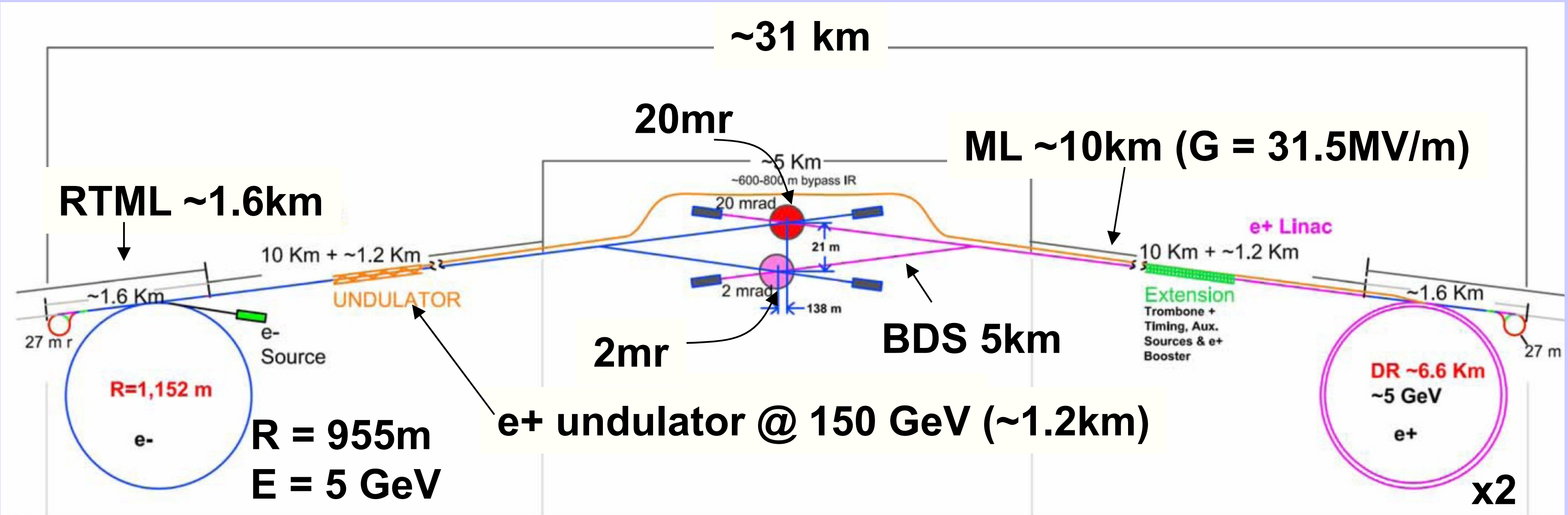
- **A working space - optimize machine for cost/performance**



		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 Baseline Machine (500GeV)

January 2006



not to scale

From Baseline to a RDR

2006

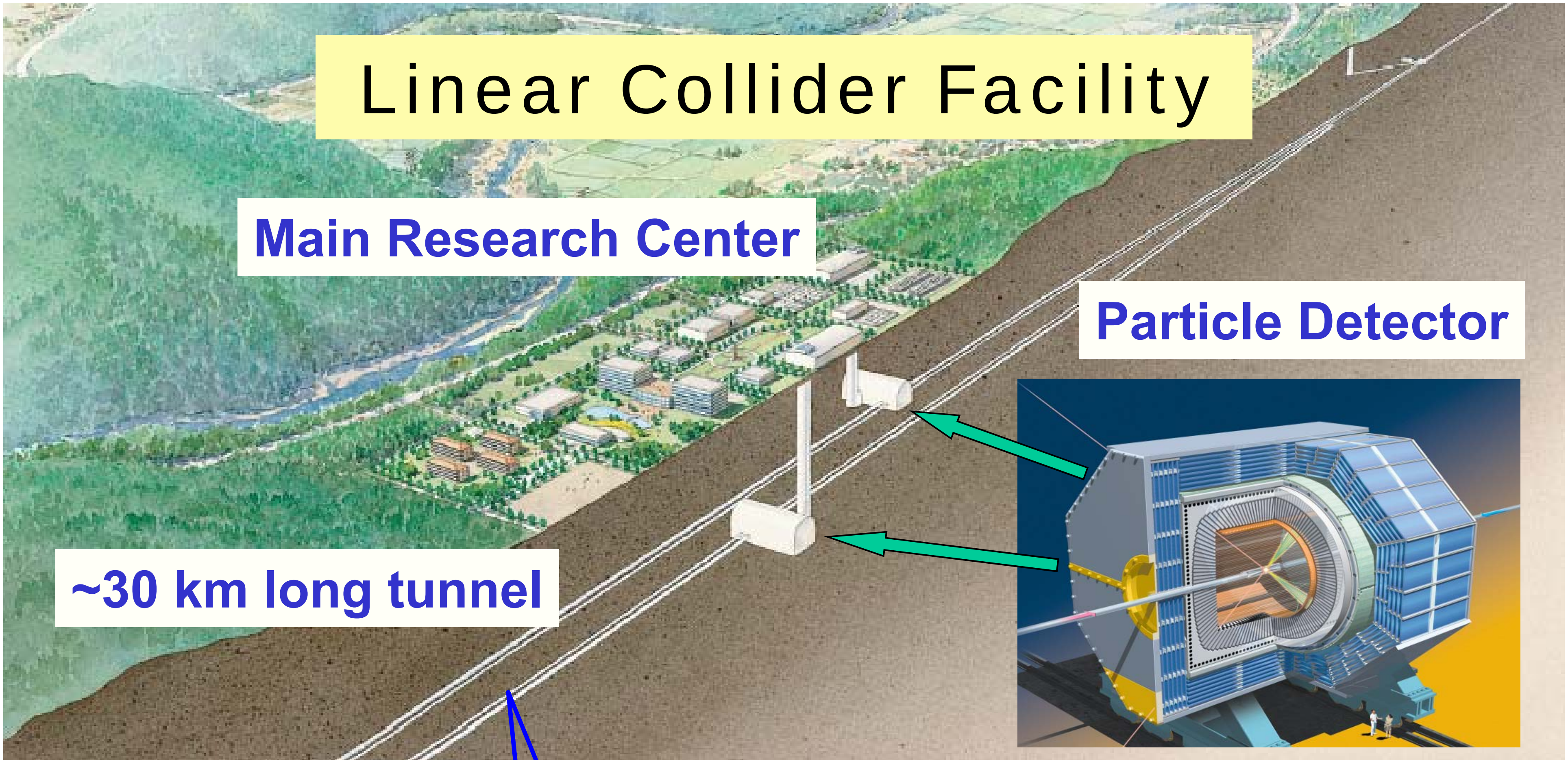
Jan | July | Dec

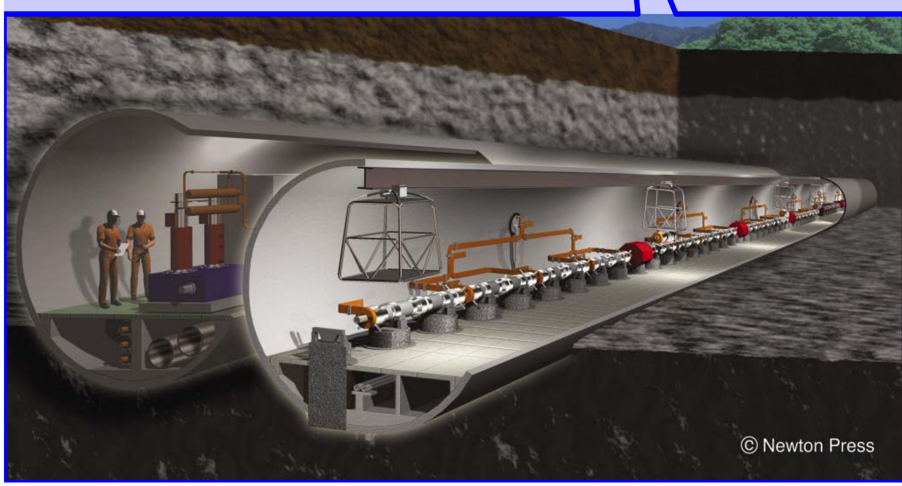
Frascati | Bangalore | Vancouver | Valencia

- **Frascati:** Freeze Configuration, Organize for RDR
- **Bangalore:** Review Design/Cost Methodology
- **Vancouver:** Review Initial Design / Cost
- **Valencia:** Review Final Design / Cost, RDR Document
- **Dec:** Preliminary RDR Released

Design and Costing

Linear Collider Facility





Two tunnels

- accelerator units
- other for services - RF power

Conventional Facilities

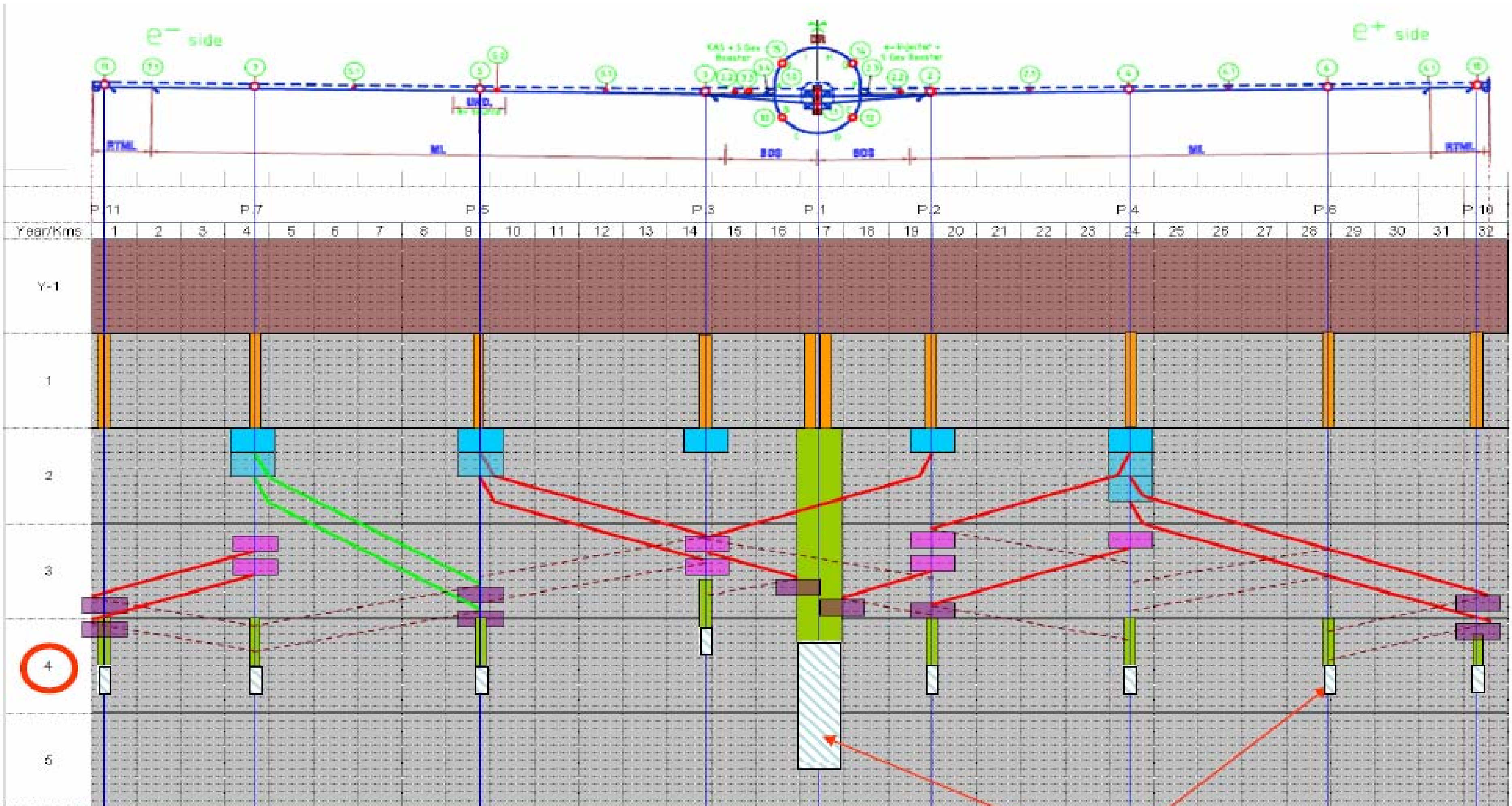
72.5 km tunnels ~ 100-150 meters underground

13 major shafts $\geq$ 9 meter diameter

443 K cu. m. underground excavation: caverns, alcoves, halls

92 surface "buildings", 52.7 K sq. meters = 567 K sq-ft

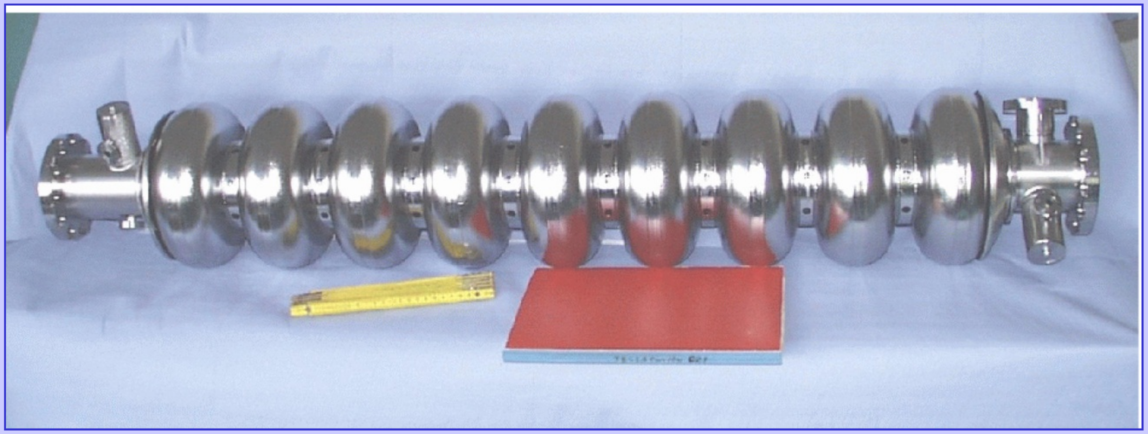
Civil Construction Timeline



- TBM $\varnothing_{finished}$=5m
- MS TBM $\varnothing$=5m
- Cavern finishing
- Shaft/cavern excavation
- TBM setup
- TBM transport
- TBM removal
- Finishing work

Install CFS services in Detector halls & Shaft base caverns

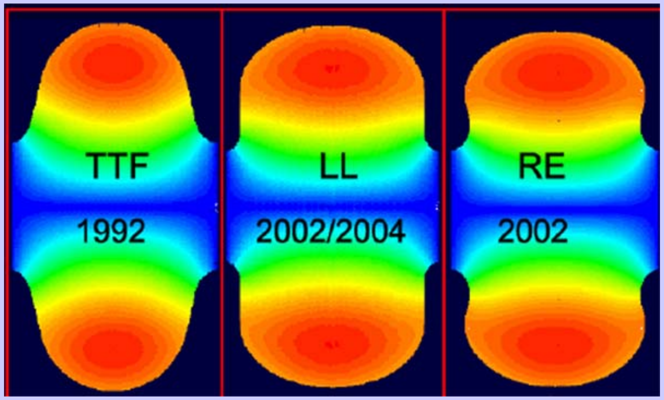
Superconducting RF Technology



- **Forward looking technology for the next generation of particle accelerators: particle physics; nuclear physics; materials; medicine**

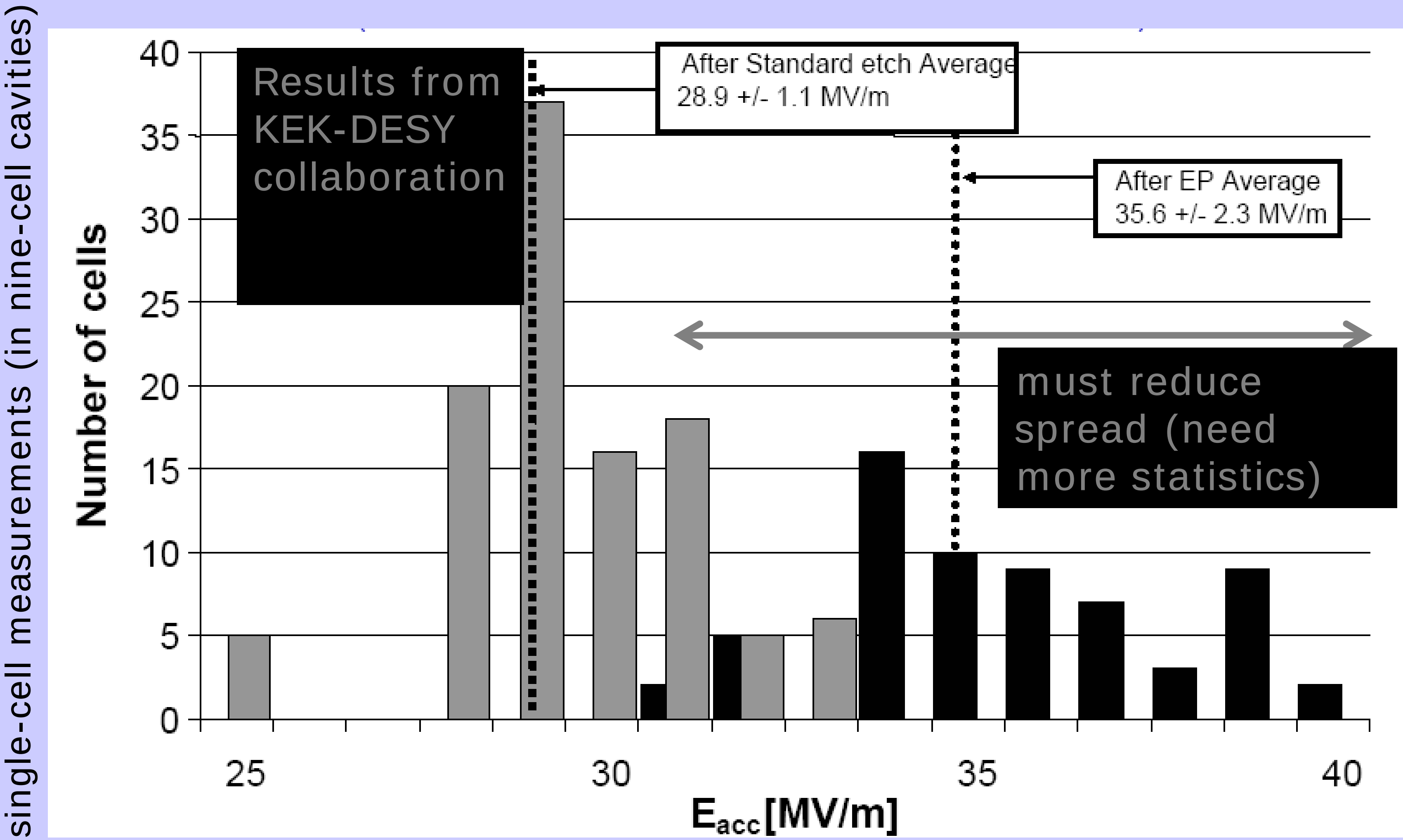
- **The ILC R&D is leading the way Superconducting RF technology**
  - **high gradients; low noise; precision optics**

Superconducting RF Cavities



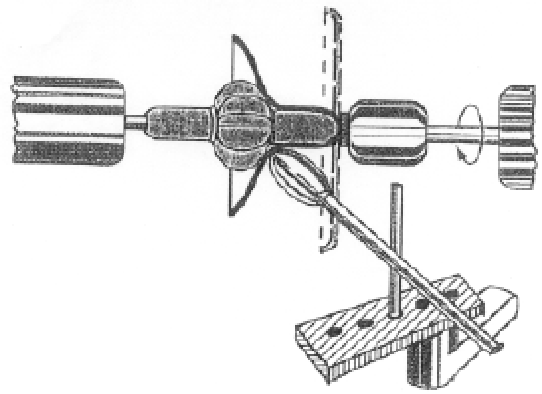
High Gradient Accelerator
35 MV/meter -- 40 km linear collider

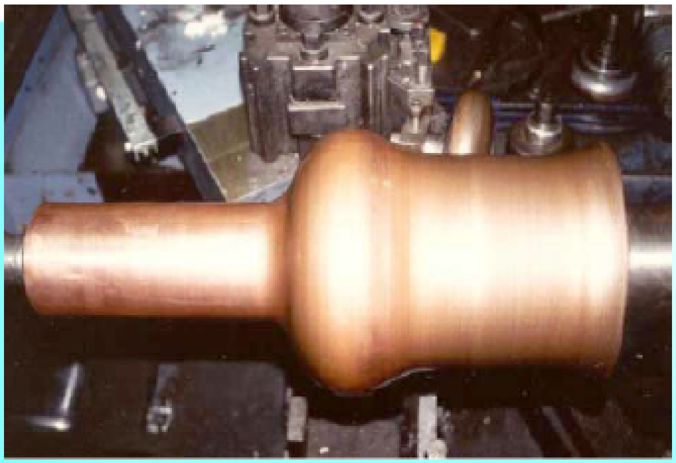
Gradient


single-cell measurements (in nine-cell cavities)
Number of cells
40
35
30
25
20
15
10
5
0
25
30
35
40
Eacc[MV/m]
Results from KEK-DESY collaboration
After Standard etch Average 28.9 +/- 1.1 MV/m
After EP Average 35.6 +/- 2.3 MV/m
must reduce spread (need more statistics)

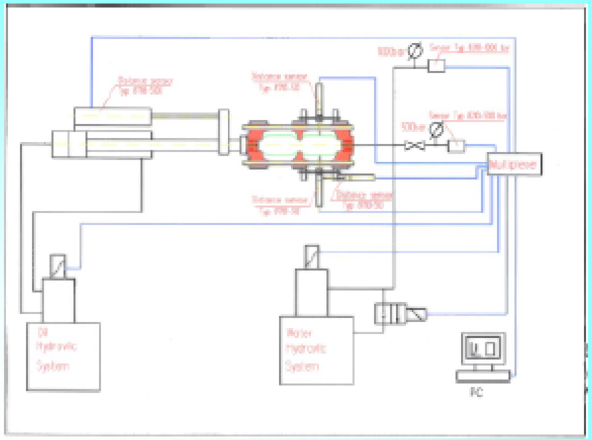
Improved Fabrication

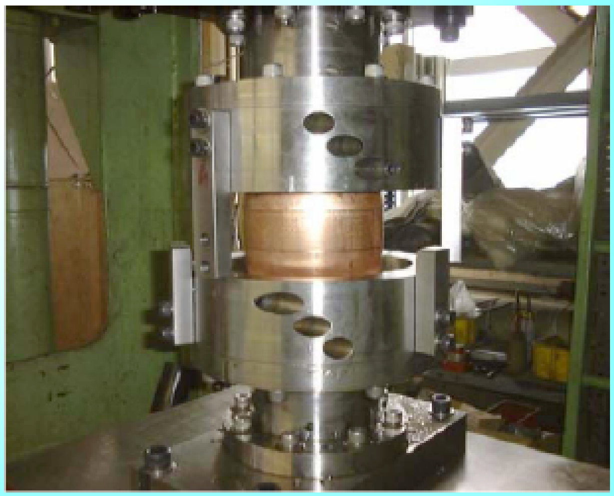
Spinning (V.Palmieri,INFN Legnaro)





Hydroforming, DESY, KEK



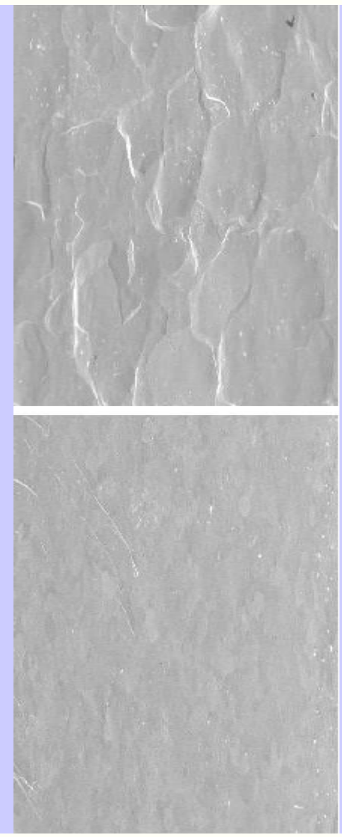


Improved Processing
Electropolishing

KEK / Nomura EP

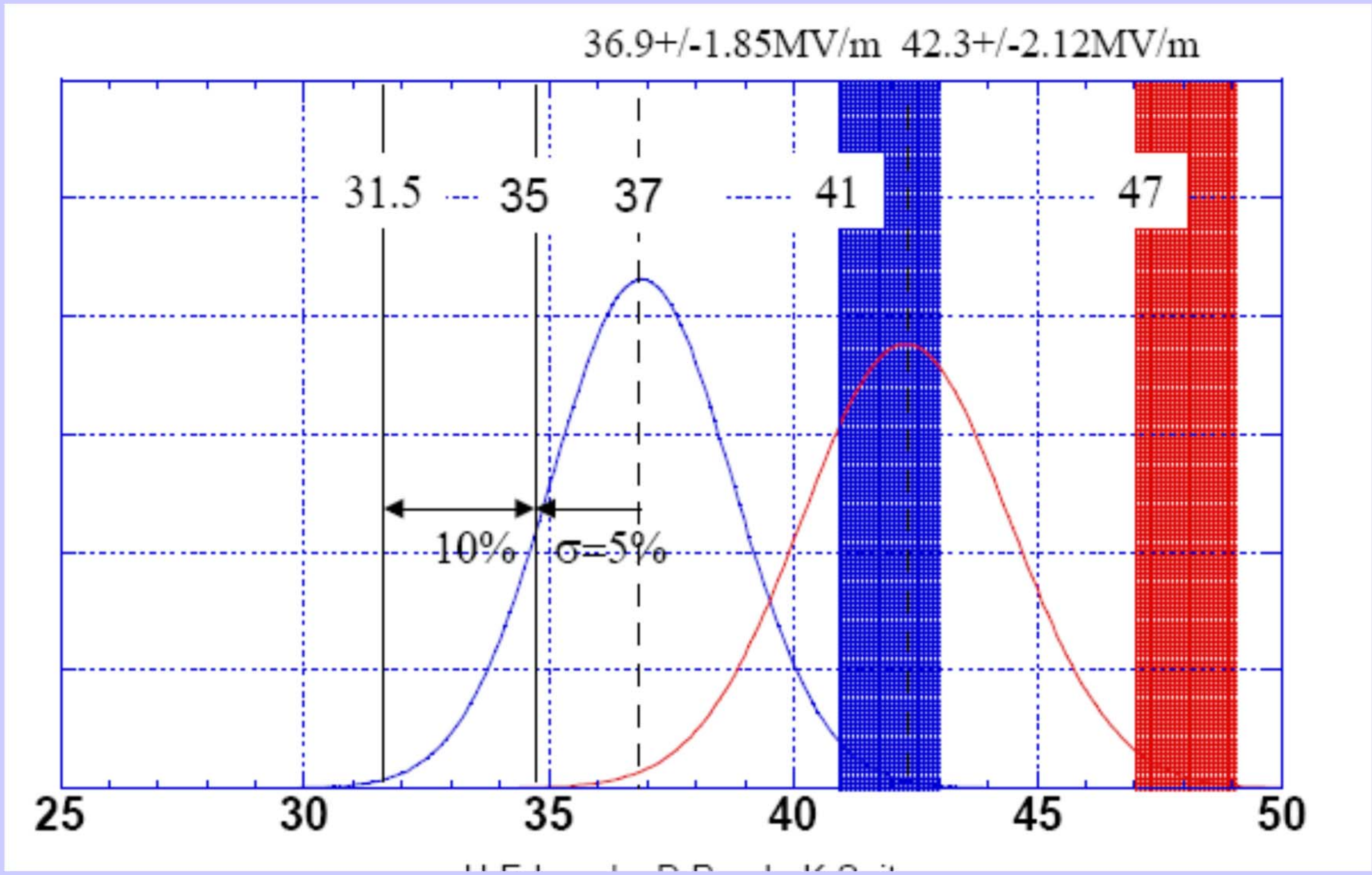
DESY EP

Chemical Polish



Electro Polish

Baseline Gradient



The ILC SCRF Cavity

Figure 1.2-1: A TESLA nine-cell 1.3 GHz superconducting niobium cavity.

- Achieve high gradient (35MV/m); develop multiple vendors; make cost effective, etc

- Focus is on high gradient; production yields; cryogenic losses; radiation; system performance

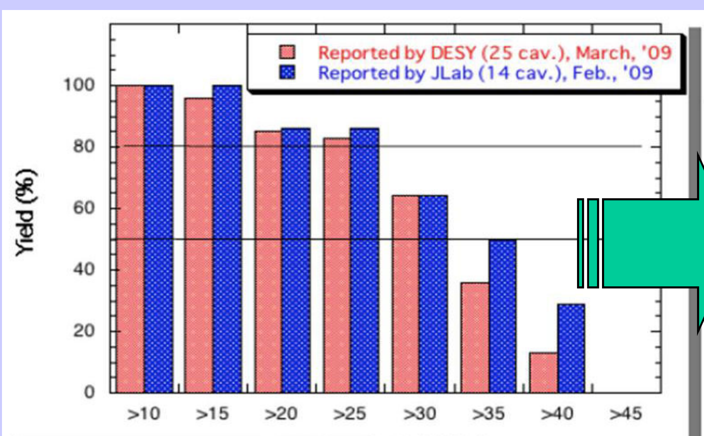
Yield Plot

- The gradients for DESY data were off by +2MV/m
- Not 08/09: large component of 2007, and very small component of 2009
- Not 1st or 2nd test: instead, last (DESY) or best (JLab)
- Included cavities fabricated by ACCEL, ZANON, AES, JLab-2, KEK-Ichiro

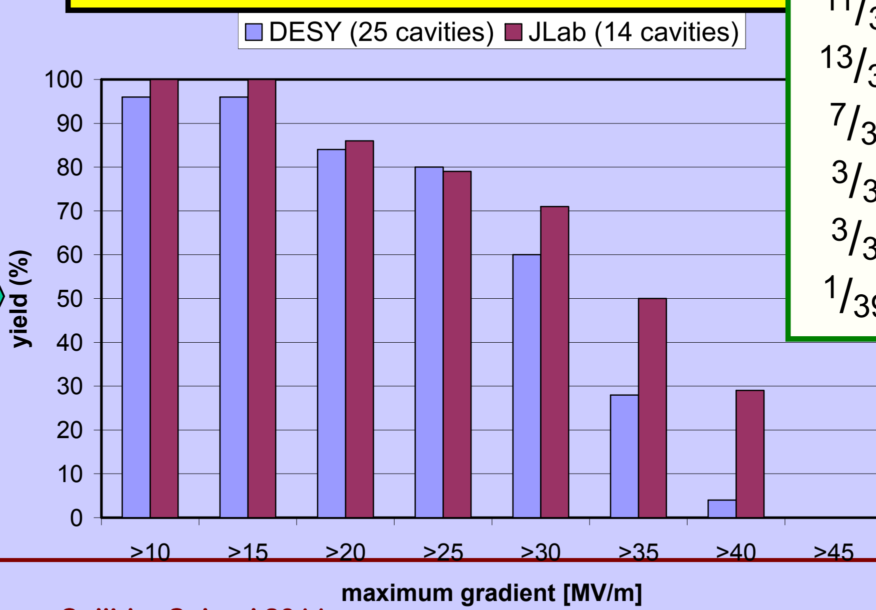
This is not the ideal data selection from which to infer a production yield

Old version,
shown at PAC, 2009

Revised version (corrected only for mistakes)
- same data shown



Current status:
50% yield at ~ 33 MV/m;
(80% >25MV/m)



11/39 1st test
13/39 2nd test
7/39 3rd test
3/39 4th test
3/39 5th test
1/39 8th test

Definition of ‘Yield’

- **Original S0 concept assumed:**
  - **Surface can be reset according to the EP process, and**
  - **Multiple processes may be integrated for statistics.**
- **Several years of experience shows**
  - **Repeat processing may cause degradation**
- **Processing and Test recipe has been updated**
  - **Complete the process and test only with the first cycle**
    - **no further processing if the results are acceptable**
- **Revision of the definition of ‘yield’ is required**
  - **Process (R&D) and Production definitions are different**
  - **A common means for collection and evaluation of the data is required**

Creation of a Global Database

Activity Plan in 2009:

- Mid-July: Initial report to FALC
- End July:
  - Determine whether DESY-DB is viable option (DONE→YES!)
- Aug. 19: (ILCSC)
  - Status to be reported
- Sept. 28 - Oct. 2, 2009: (ALCPG/GDE)
  - Dataset web-based
    - to be Supported by FNAL-TD or DESY
  - Explainable, and near-final plots, available, such as
    - Production (and process) yield with Qualified vendors and/or All vendors, and time evolution
- End Nov. 2009, with input from a broader group of colleagues, finalize:
  - DB tool, web I/F, standard plots, w/ longer-term improvement plan

Proposed Global Data Collection - 1

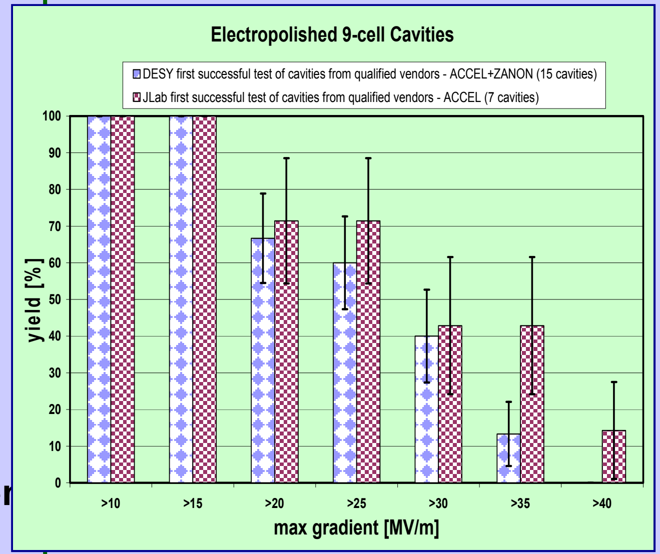
- **Proposition 1: all cavities fabricated and processed according to the following <u>rough steps</u>**
  - **Fine grain sheet material**
  - **Deep drawing & EBW**
  - **Initial field flatness tuning**
  - **Bulk EP for heavy removal**
  - **H_2 removal with vacuum furnace**
  - **Final tuning field flatness (and frequency)**
  - **Final EP for light removal**
  - **Post-EP cleaning**
  - **Clean room assembly**
  - **Low temperature bake-out**
  - **2K RF test**

Proposed Global Data Collection -2

- **Proposition 2: accept understood variations, and combine samples to maximize statistics, for example:**
  - **Fine grain niobium irrespective of vendor**
  - **EBW irrespective of prep design welding parameter**
  - **Cavities with or without helium tank**
  - **With or without pre-EP treatment (BCP, CBP…)**
  - **EP irrespective of parameters & protocols**
    - **Horizontal or (future) vertical EP**
    - **H_2SO_4/HF/H_2O ratio, pre-mixing or on-site mixing**
    - **Cell temp. control or return acid temp. control**
    - **With or without acid circulation after voltage shut off**
    - **Post-EP cleaning: Ethanol rinse or Ultrasonic cleaning or H_2O_2 rinsing**
  - **H2 out-gassing irrespective of temp. & time**
  - **HPR irrespective of nozzle style, HPR time**
  - **Clean Room assembly irrespective of practice variability**
- *Additional note: The variations of BCP/EP, fine-grain/large-grain are not considered as acceptable variation in this statistical evaluation.*

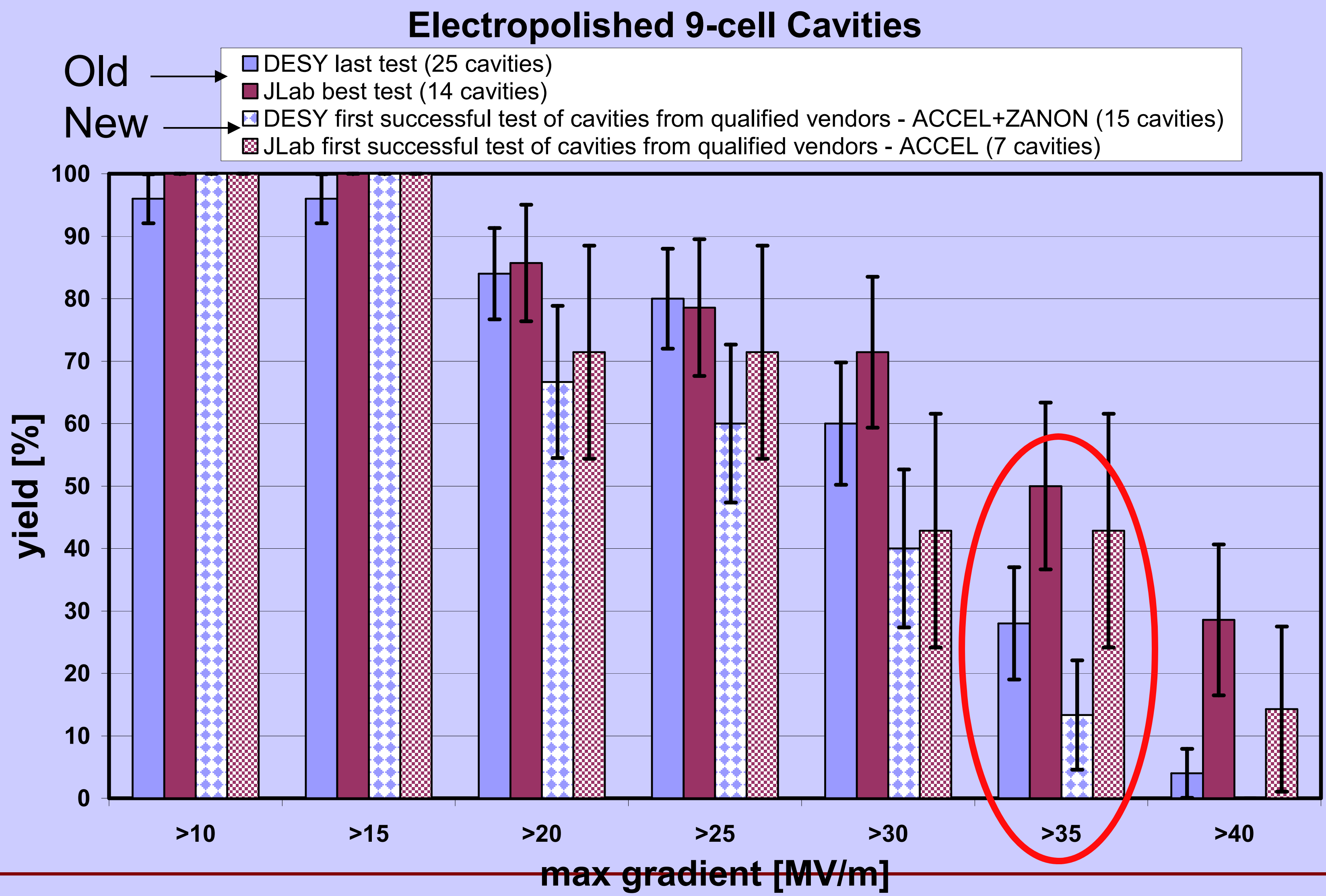
Example New Yield Plot

- **Vertical axis:** **fraction of cavities satisfying criteria where:**
  - **Denominator (logical and of the following):**
    - **Fabricated by <u>ACCEL or ZANON</u>**
    - **Delivered to labs within last 2-3 years**
    - **<u>Electro-polished</u>**
    - **Fine-grain material**
  - **Numerator (logical and of the following):**
    - **Denominator**
    - **Accepted by the lab after incoming inspection**
    - **1st successful vertical RF test,**
      - **excluding any test with system failure, has max gradien > (horizontal axis bin) MV/m;**
      - **ignore Q-disease and field emission (to be implemented in future)**
- **Horizontal axis:** **max gradient MV/m**
- **Exclude cavities which are work-in-progress, i.e., before rejection or 1st successful RF test**



Note: These are results from the vertical CW test at DESY and JLab

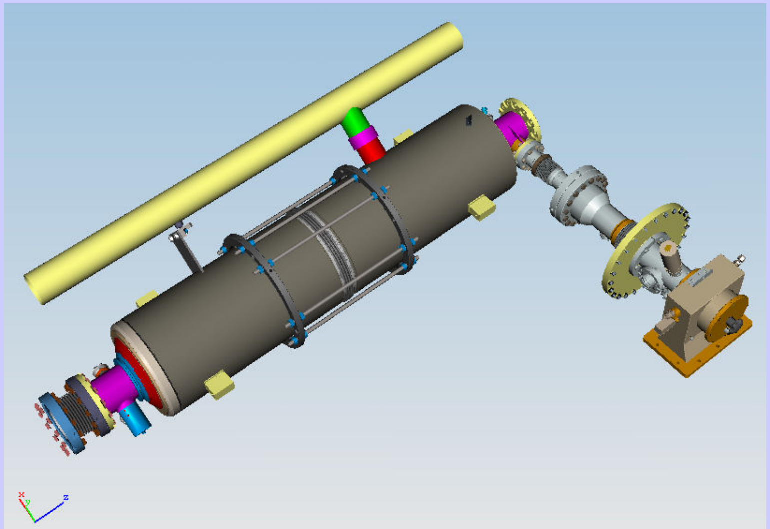
Comparison ‘Old’ vs ‘New’ Yield Plots

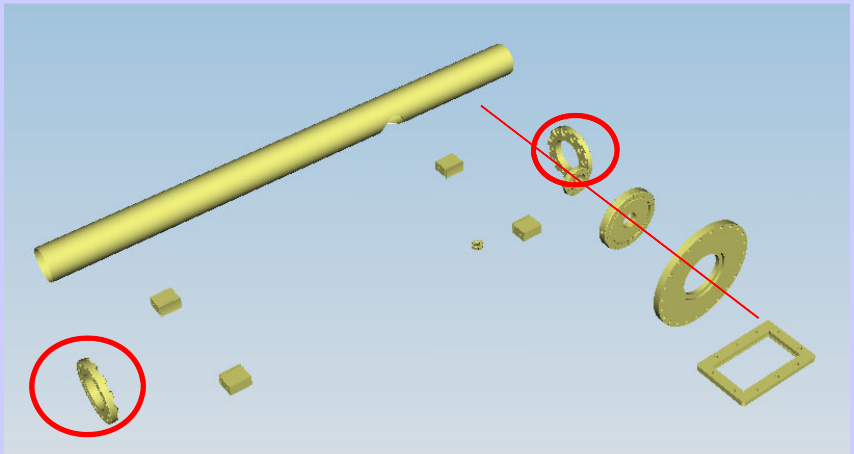


Preliminary Conclusions

- **The global database team has been formed to**
  - **Understand the cavity gradient status in a common-way, world wide**
- **The effort has started with**
  - **Checking of the 'old' yield plot presented in PAC, Vancouver**
  - **Revision of the yield plot with some correction:**
    - **The yield at 35 MV/m in a vertical test remains 50+/-13% for JLab results, and is corrected to 28+/-9% for DESY results**
  - **Agreement to use the DESY Database system for superconducting cavities**
- **A new 'production yield' is being defined with the 1st pass (and 2nd pass)**
  - **Introduced and under evaluation.**
    - **The yield at 35 MV/m in a vertical test remains 43+/-19% for JLab results, and is corrected to 13+/-9% for DESY results**

Plug Compatibility Concept

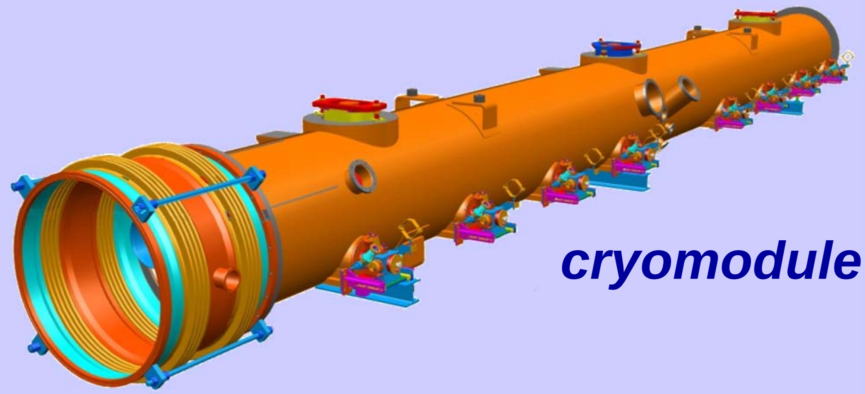




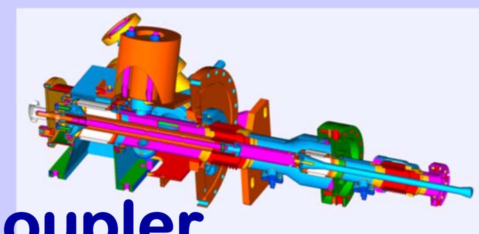
Helium Vessel Body		KEK-STF-BL	KEK-STF-LL	FNAL-T4CM	DESY-XFEL
Helium Jacket	Material	Ti	SUS	Ti	Ti
	Slot length, mm	1337	1337	1326.7	(1382:Type3)
	Distance between beam pipe flanges, m	1258.6	1254.5	1247.4	1283.4
	Distance between bellows flanges, mm	78.4	85.2	80.49 (cold)	
	Outer diameter, mm	242	236	240	240
Beam Pipe Flange	Material	NbTi	Ti	NbTi	NbTi
	Outer diameter, mm	130	140	140	140
	Inner diameter, mm	84	80	82.8	82.8
	Thickness, mm	14	17.5	17.5	17.5
	PCD, bolts	ϕ115, 16-ϕ9	ϕ120, 16-ϕ9	12, M8 SS studs	12, M8 SS studs
	Sealing	Helicoflex	M-O seal	Al Hex Seals	Hexagonal Al ring
	Distances between the connection				
	surface and input coupler axis	62, -1196.6	58.1, -1213.9	60.6, -1186.8	60.6, -1222.8

Superconducting RF Linac Technology

cavity

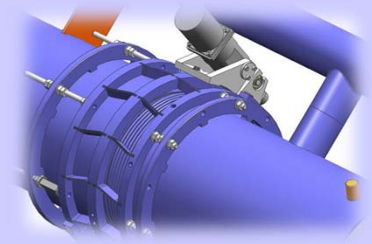


cryomodule



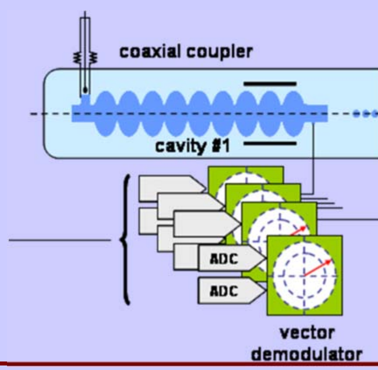
coupler

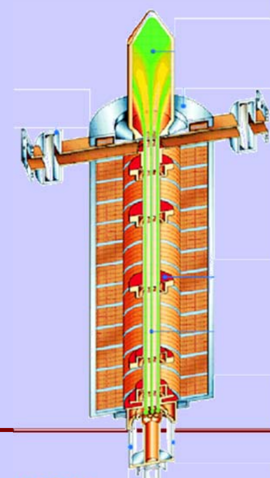
SCRF Linac Technology



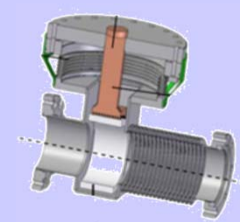
tuner

LLRF





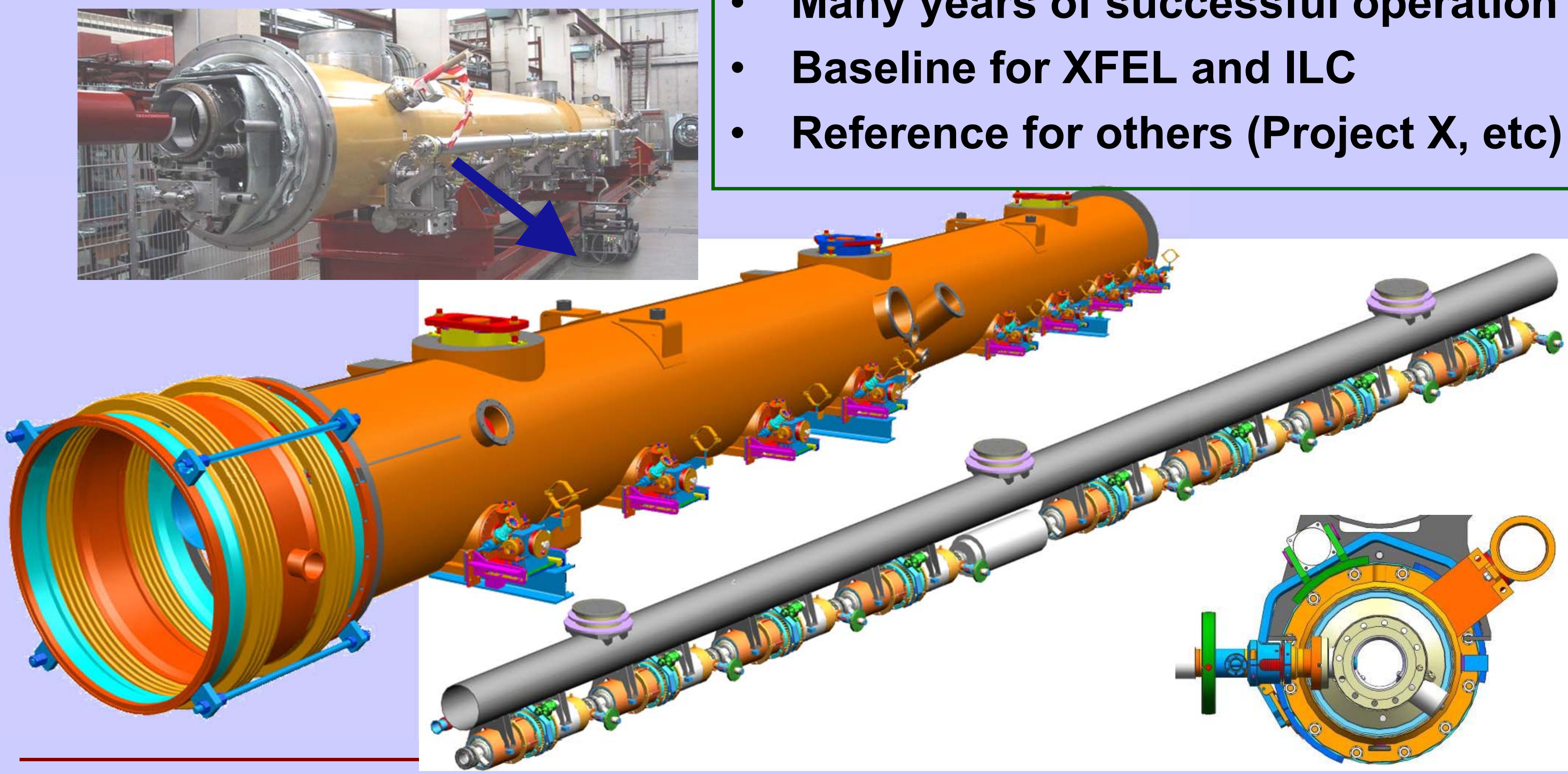
RF



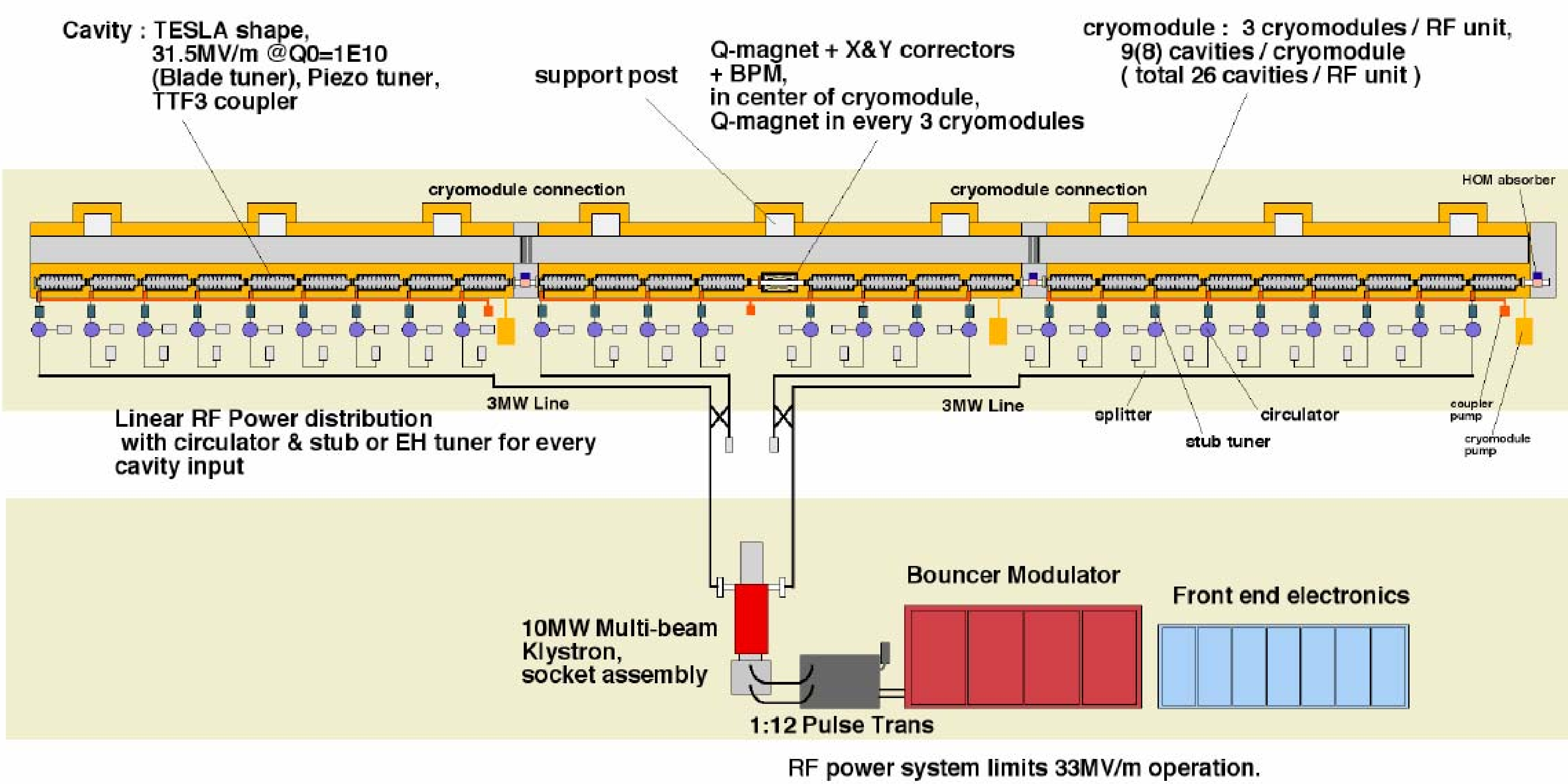
HOMs

ILC Reference Cryomodule

- Developed by INFN for TTF-TESLA
- **3rd generation of improvements**
- **Many years of successful operation**
- **Baseline for XFEL and ILC**
- **Reference for others (Project X, etc)**



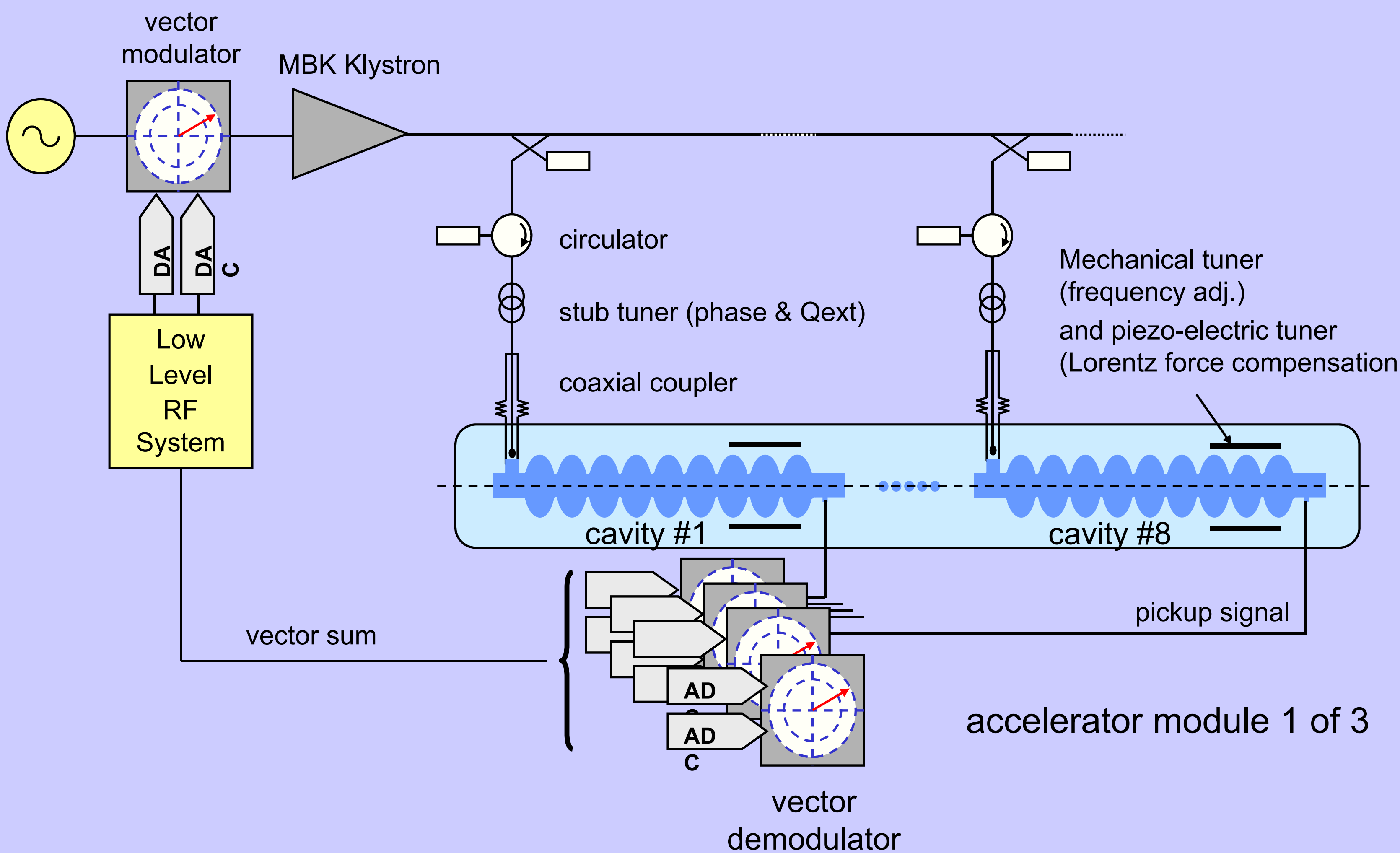
One ILC Linac RF Unit



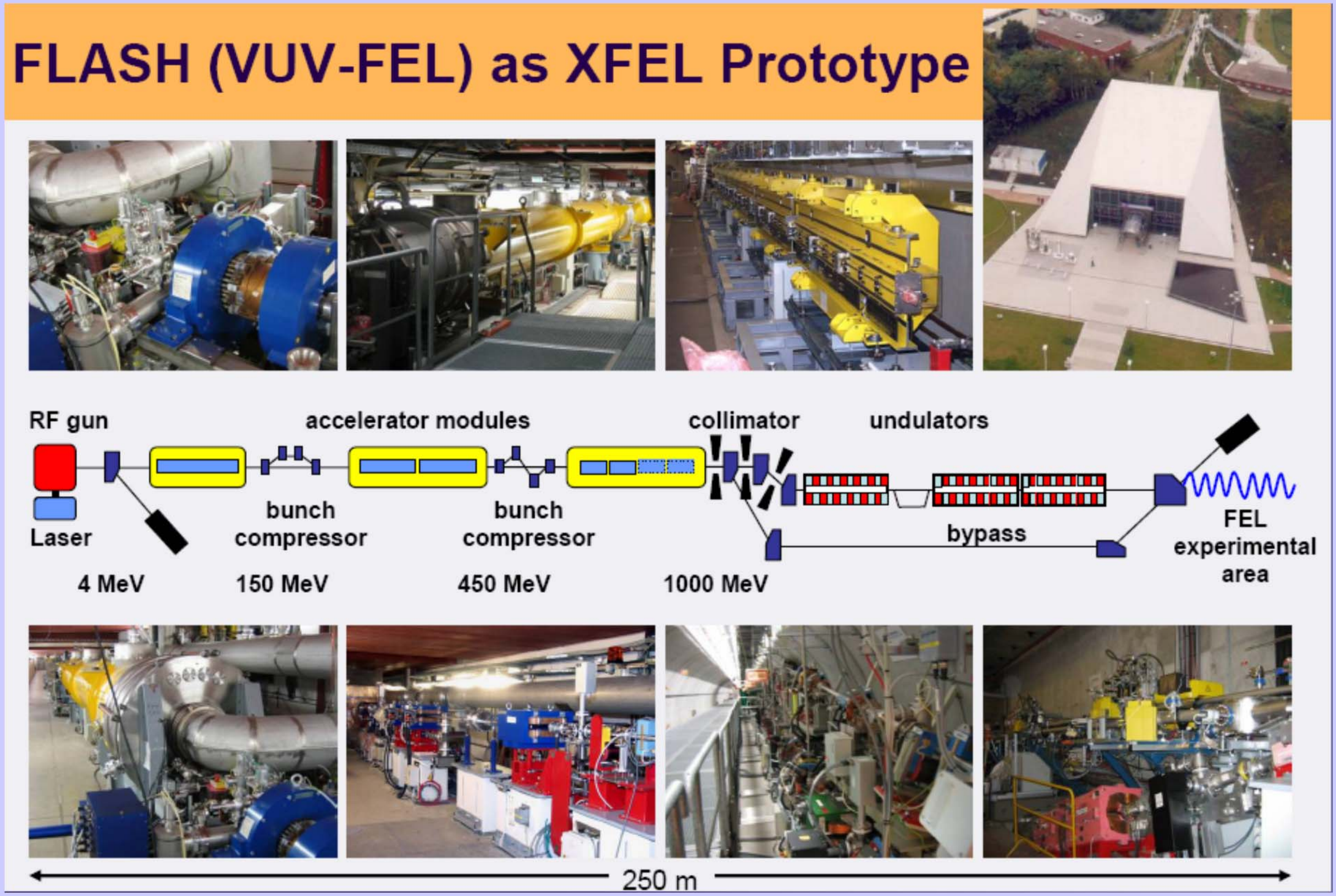
RDR configuration

Standard ILC RF Unit

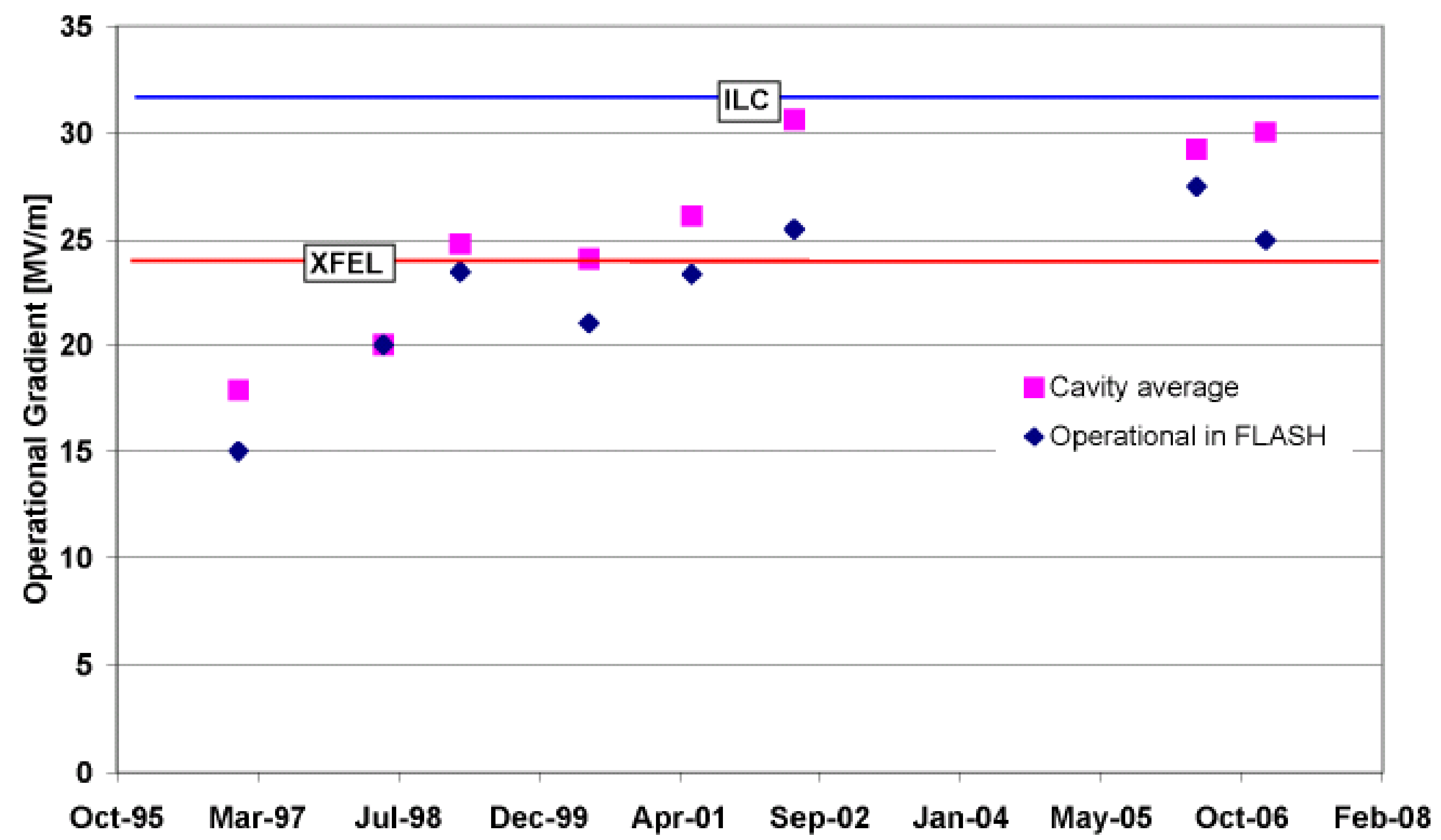
1 klystron for 3 accelerating modules, 9-8-9 nine-cell cavities each



The Existing FLASH at DESY



TTF-FLASH System Performance

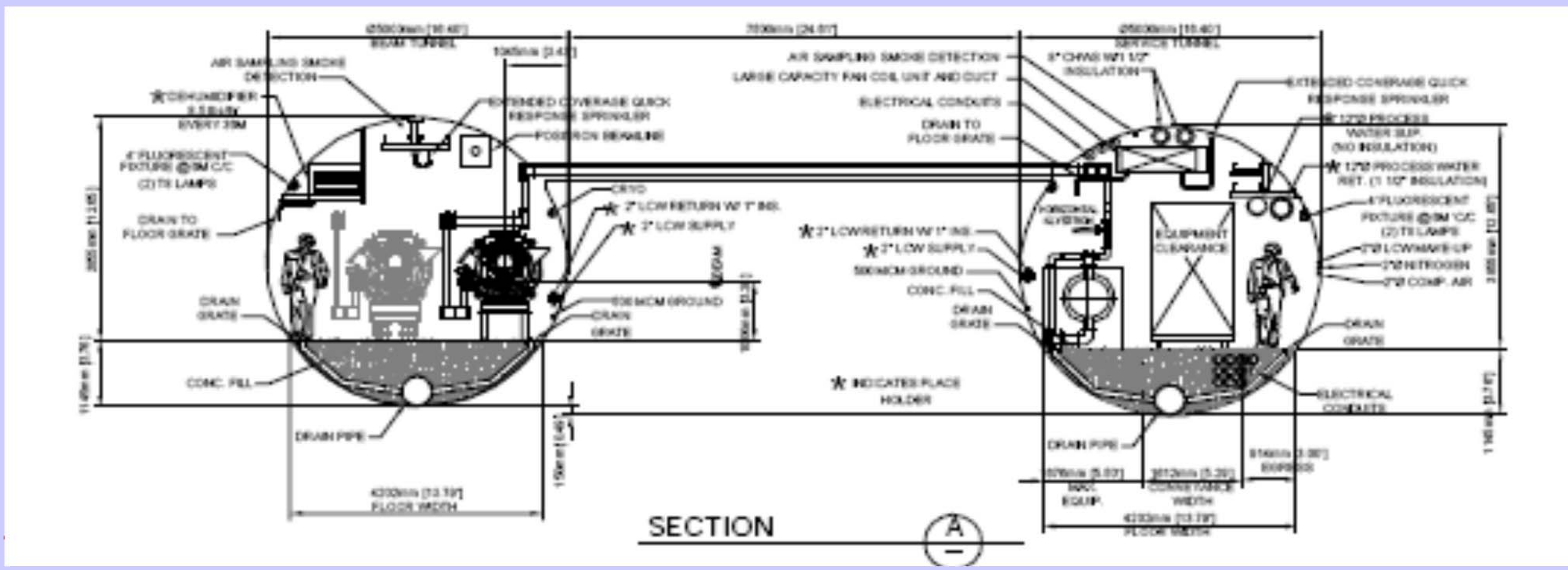


A more flexible RF Distribution System will allow higher operation gradient

Reference Design – Regional Differences

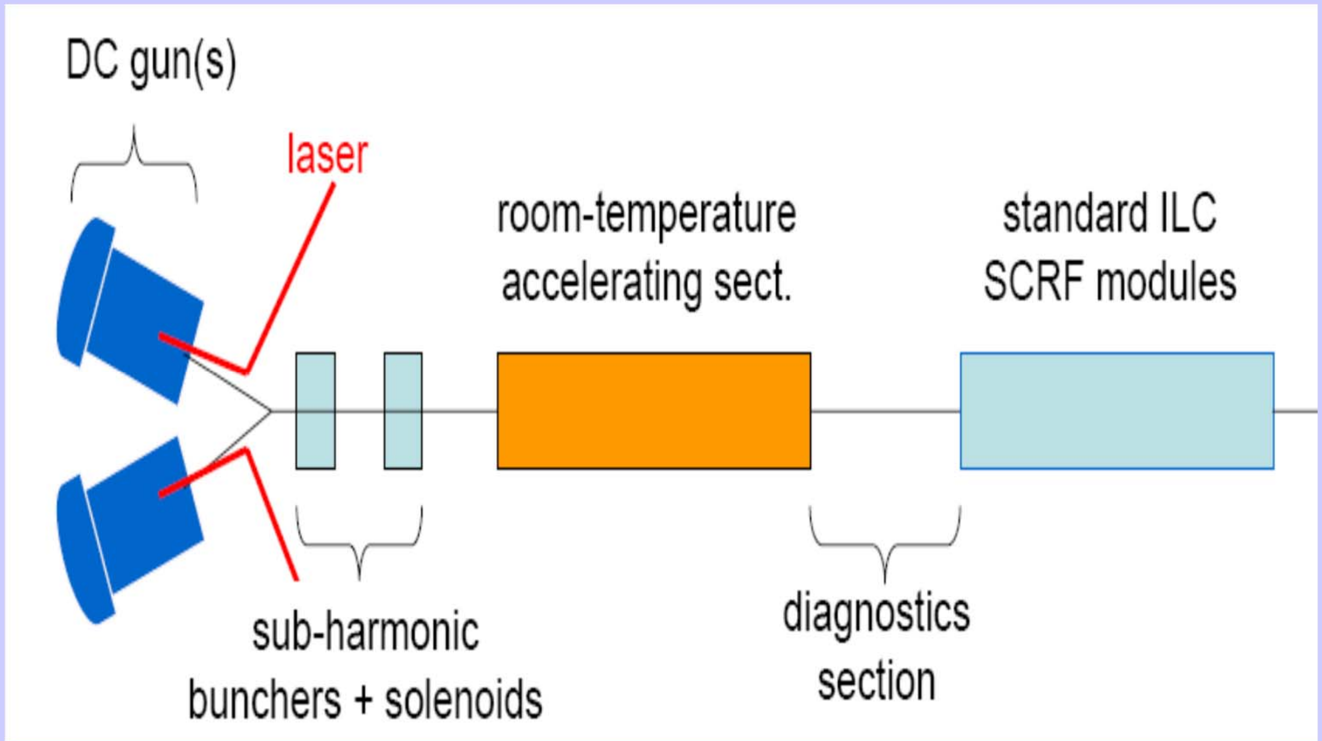
Tunnel Diameter

- **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**



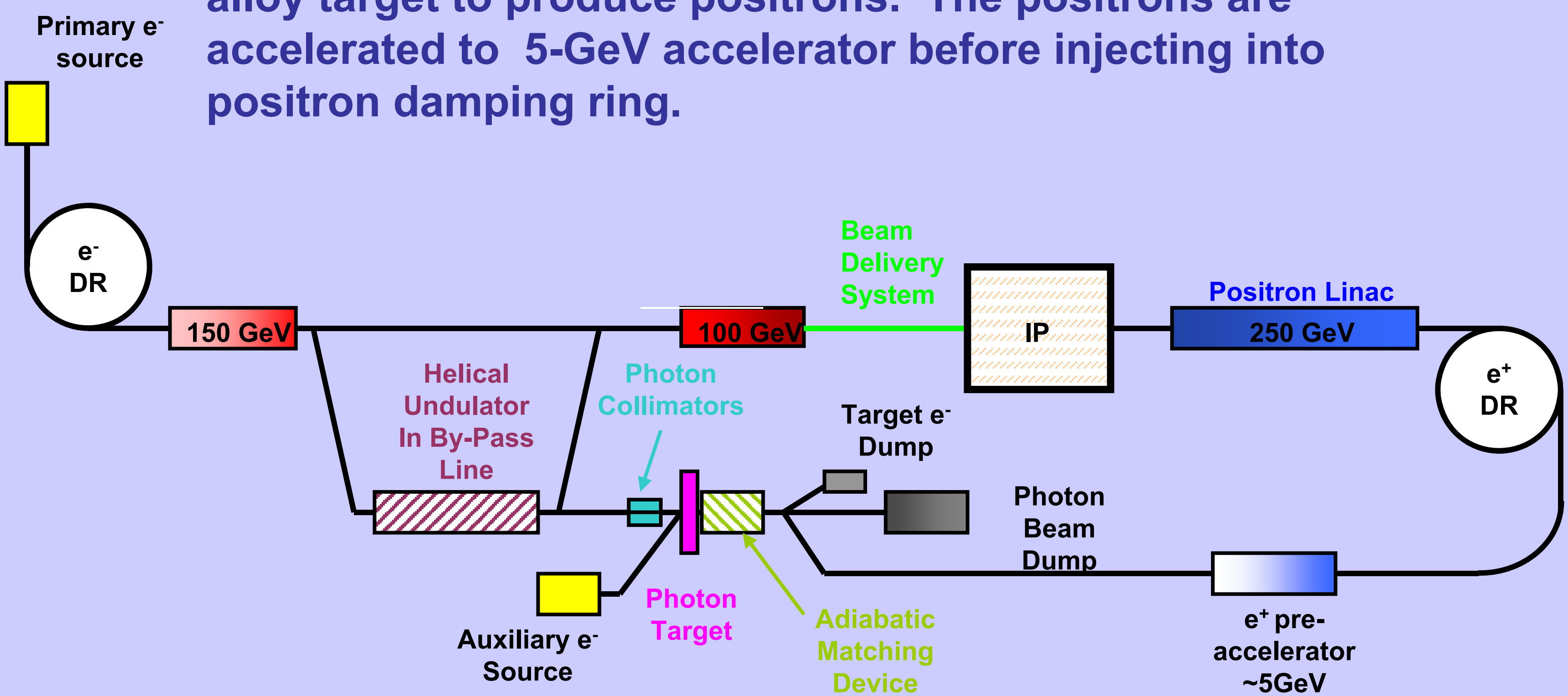
Baseline Features – Electron Source

- **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**

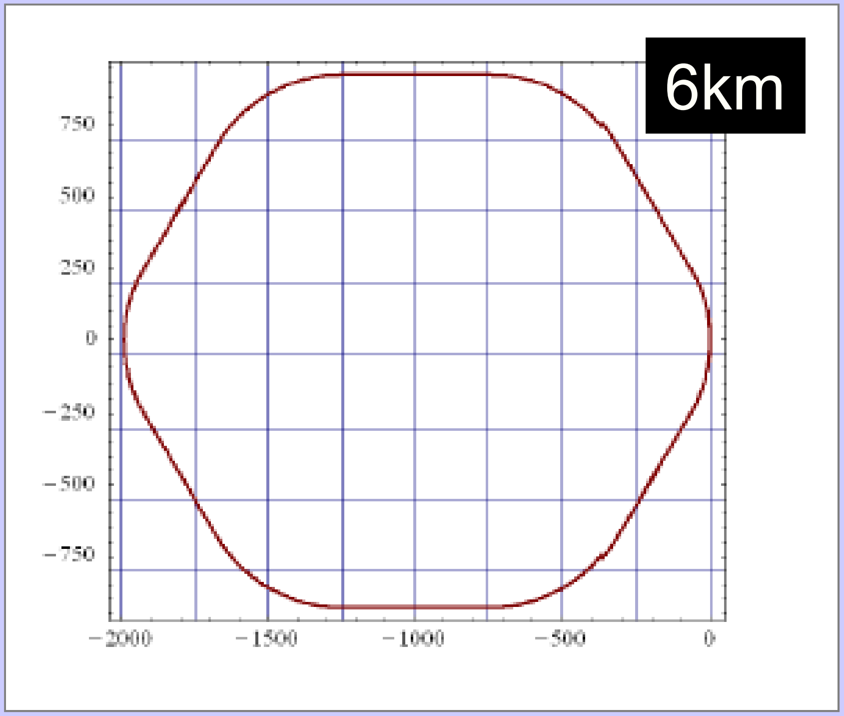


Baseline Features – Positron Source

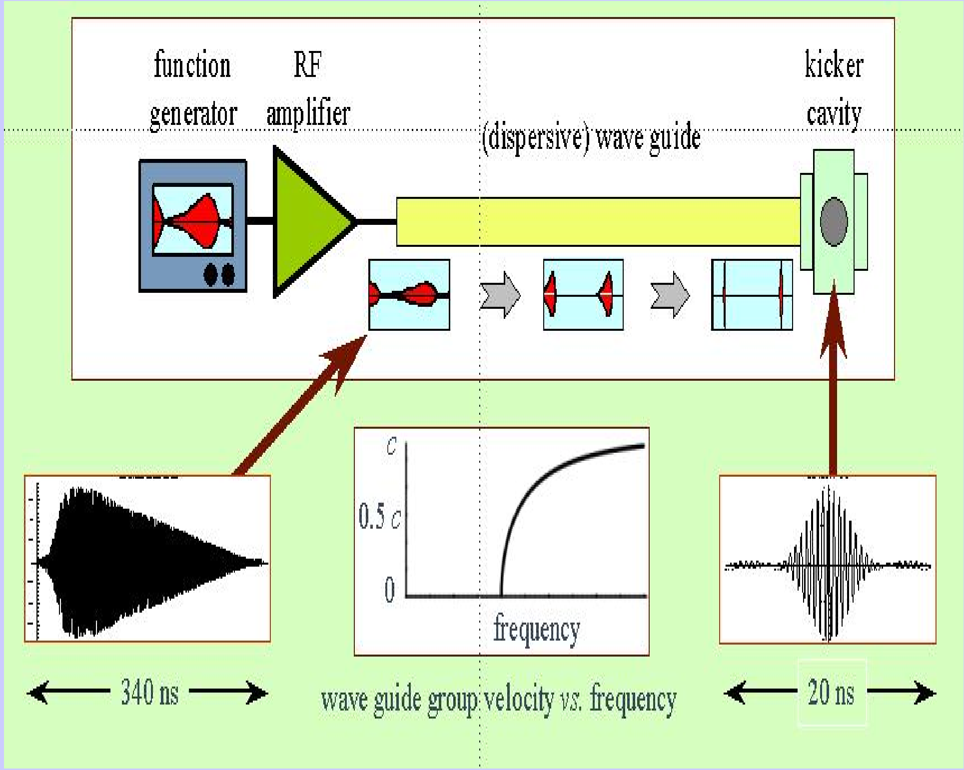
- **Positron Source – Helical Undulator with Polarized beams –** 150 Gev electron beam goes through a 200m undulator ing making photons that hit a 0.5 rl titanium alloy target to produce positrons. The positrons are accelerated to 5-GeV accelerator before injecting into positron damping ring.



6 Km Damping Ring

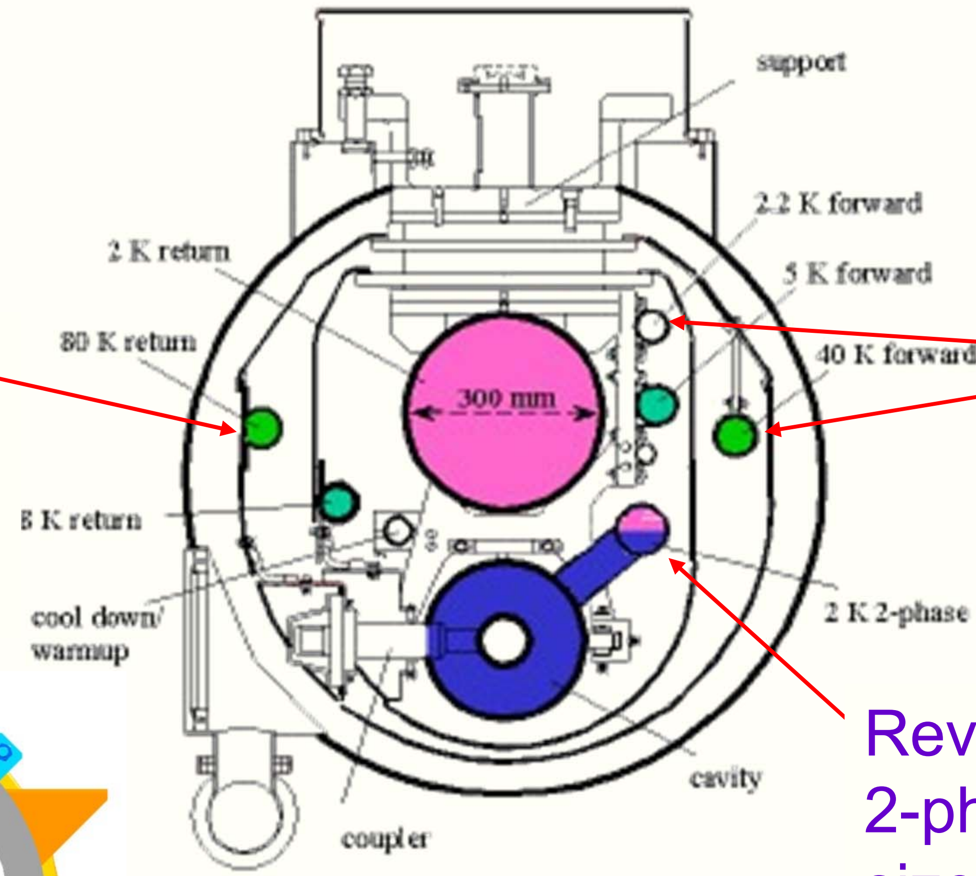


Requires Fast Kicker
5 nsec rise and 30 nsec fall time



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

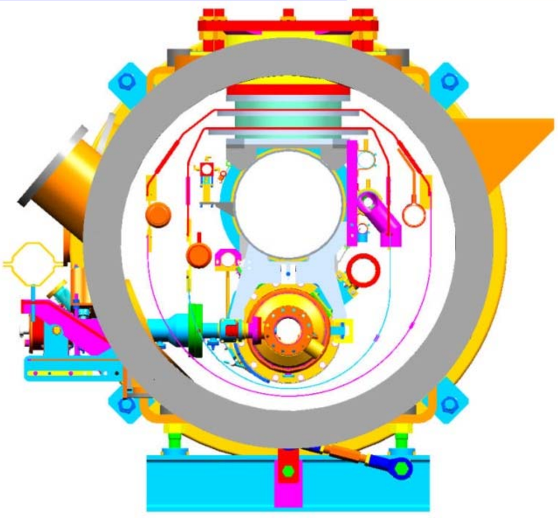
ILC Cryomodule



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:

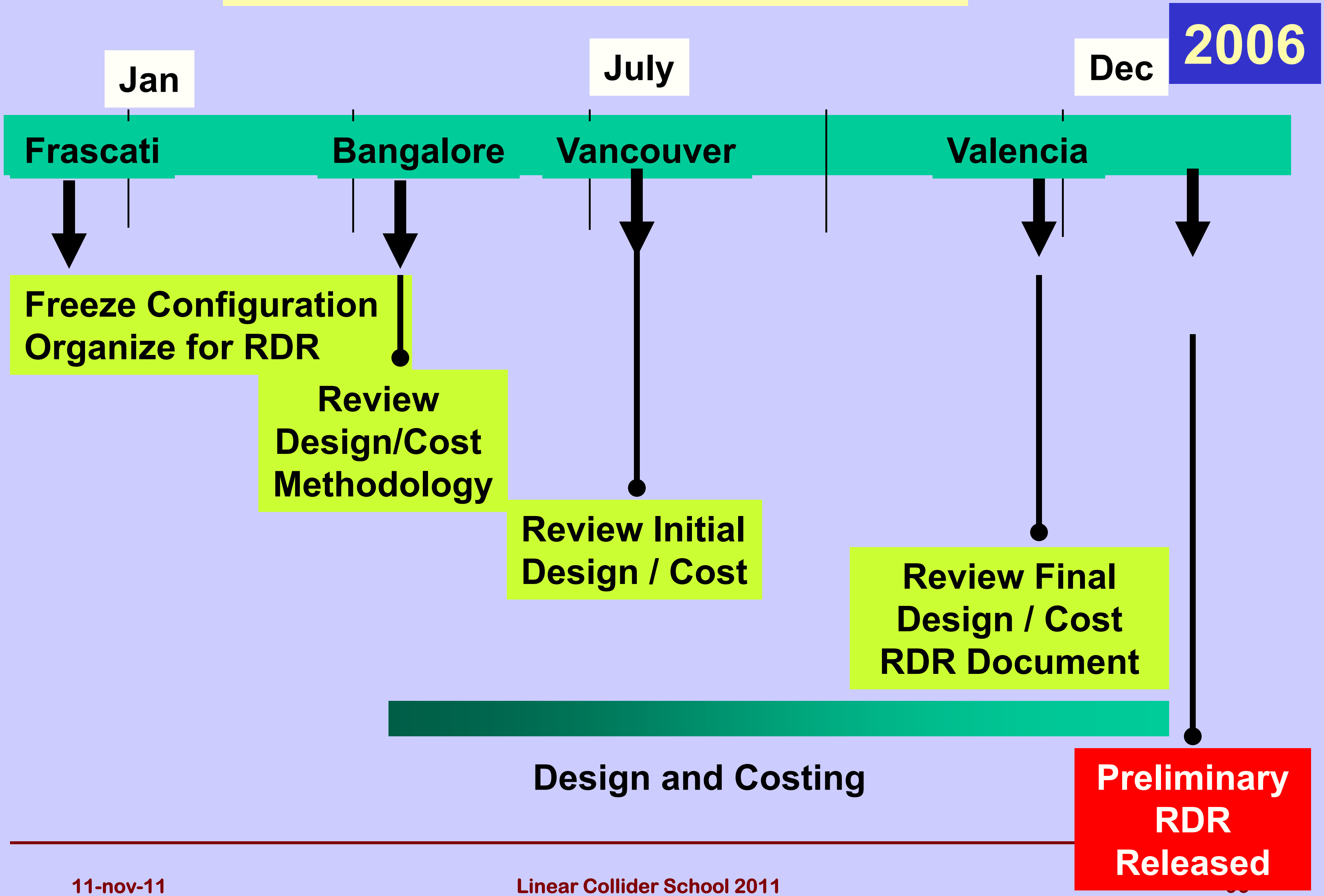
10MW MBK

1.5ms pulse

65% efficiency

BREAK

Baseline to a RDR



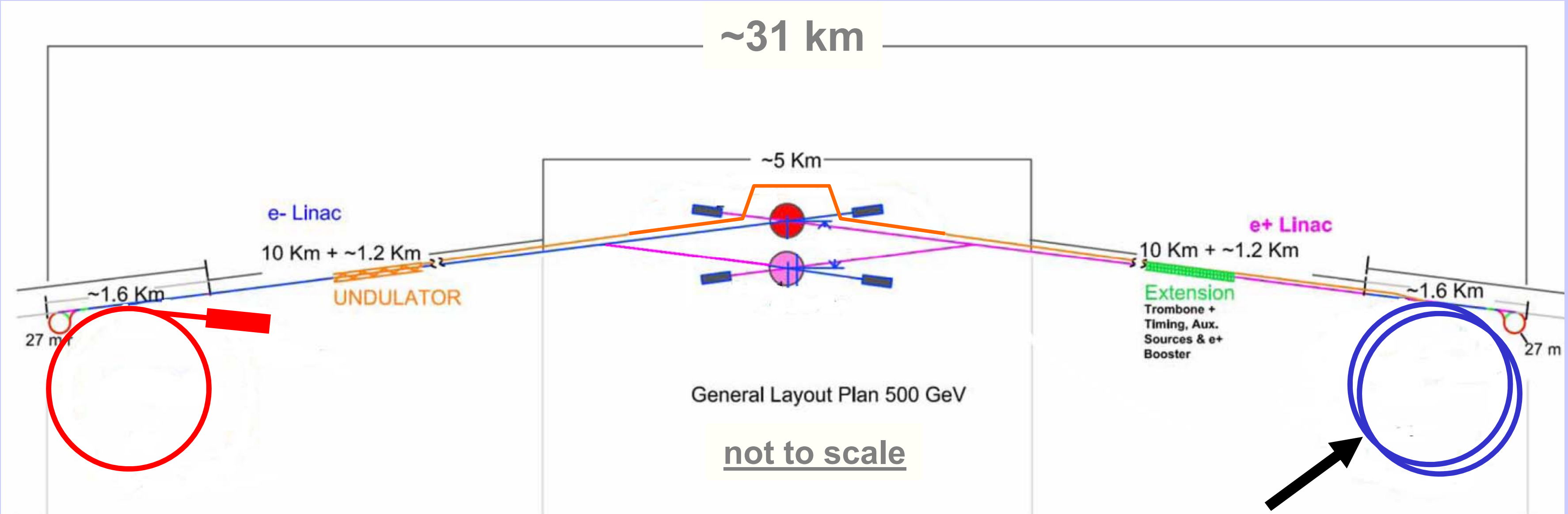
Cost-Driven Design Changes

Area		RDR MB	CCR	CCB	approx. Δ$
BDS	**2´14mr IRs**	**supported**	**14**	✓	**~170 M$**
	Single IR with push-pull detector	**supported**	**23**	✓	**~200 M$**
	Removal of 2nd muon wall	**supported**	**16**	✓	**~40 M$**
ML	**Removal of service tunnel**	rejected			**~150 M$**
	RF unit modifications (24 → 26 cav/klys)	**supported**	**20**	✗	**~50 M$**
	Reduced static cryo overhead	**supported**			**~150 M$**
	Removal linac RF overhead	**supported**			**~20 M$**
	Adoption of Marx modulator (alternate)	rejected			**~180 M$**
RTML	**Single-stage bunch compressor**	rejected			**~80 M$**
	Miscellaneous cost reduction modifications	**supported**	**19**	✓	**~150 M$**
Sources	**Conventional e+ source**	rejected			**<100M$**
	Single e+ target	**supported**	***in prep***		**~30 M$**
	e- source common pre-accelerator	**supported**	**22**	✓	**~50 M$**
DR	**Single e+ ring**	**supported**	**15**	✓	**~160 M$**
	Reduced RF in DR (6 → 9mm σ_z)	**supported**	***in prep***		**~40 M$**
	DR consolidated lattice (CFS)	**supported**	***in prep***		**~50 M$**
General	**Central injector complex**	**supported**	**18(19)**	✓	**~180 M$**

(CCR 20 and CCB ✗ apply jointly, via a brace, to the three supported ML items: RF unit modifications, Reduced static cryo overhead, Removal linac RF overhead.)

The Evolving Baseline

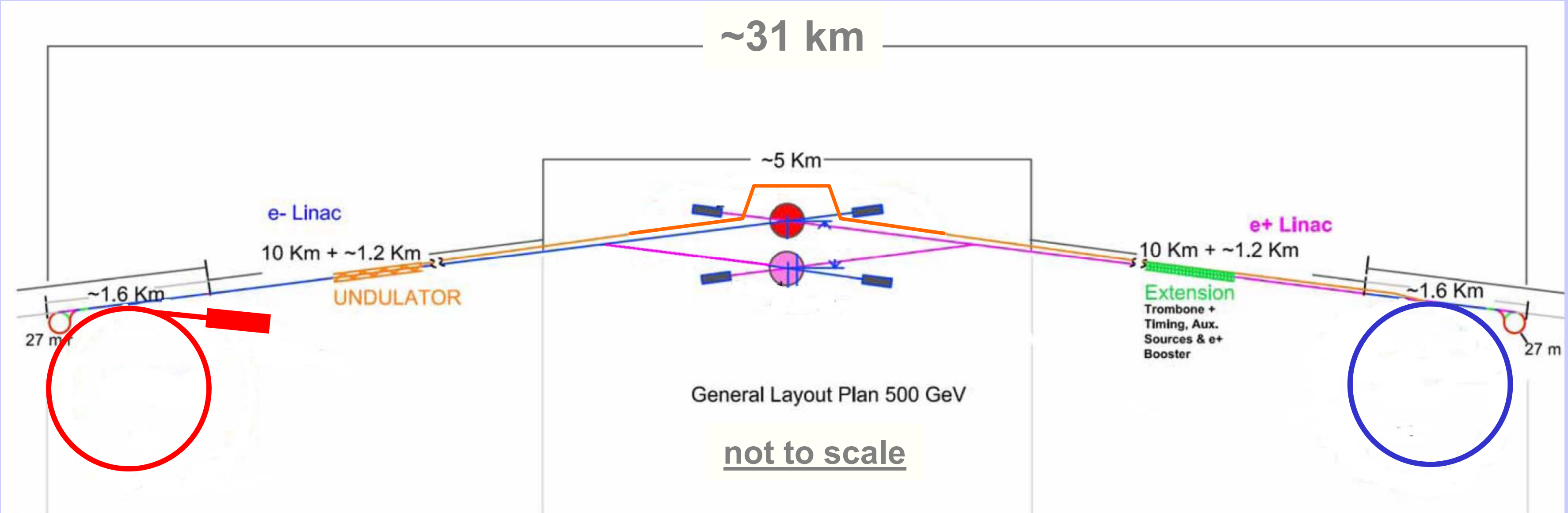
Baseline Configuration



Removal of second e+ ring

The Evolving Baseline

Baseline Configuration **Damping Ring**

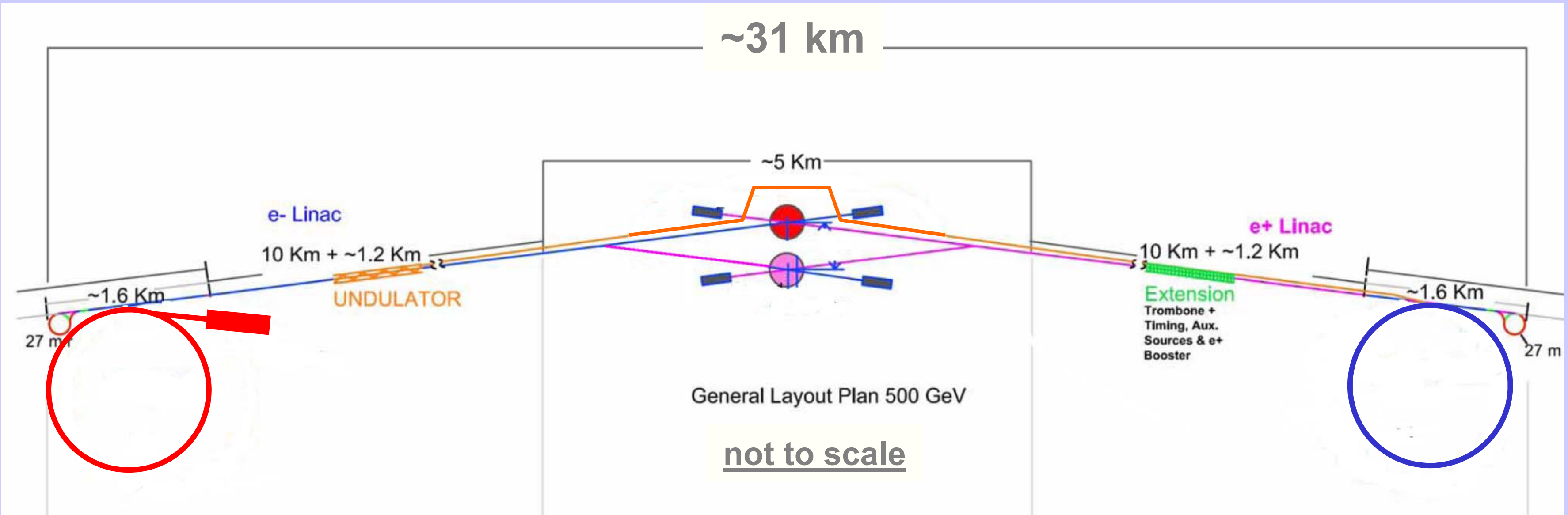


Removal of second e+ ring

simulations of effect of clearing electrodes on **Electron Cloud** instability suggests that a **single e+ ring** will be sufficient

The Evolving Baseline

Baseline Configuration

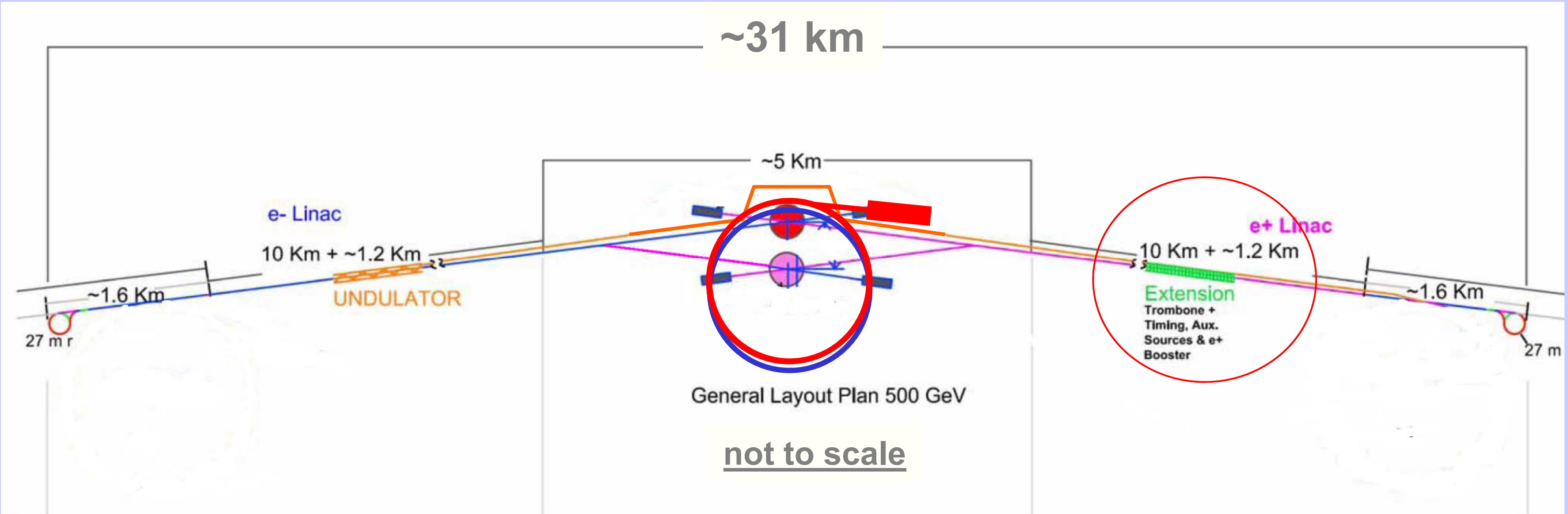


Centralised injectors

Place both e+ and e- ring in single centralized tunnel

The Evolving Baseline

Baseline Configuration



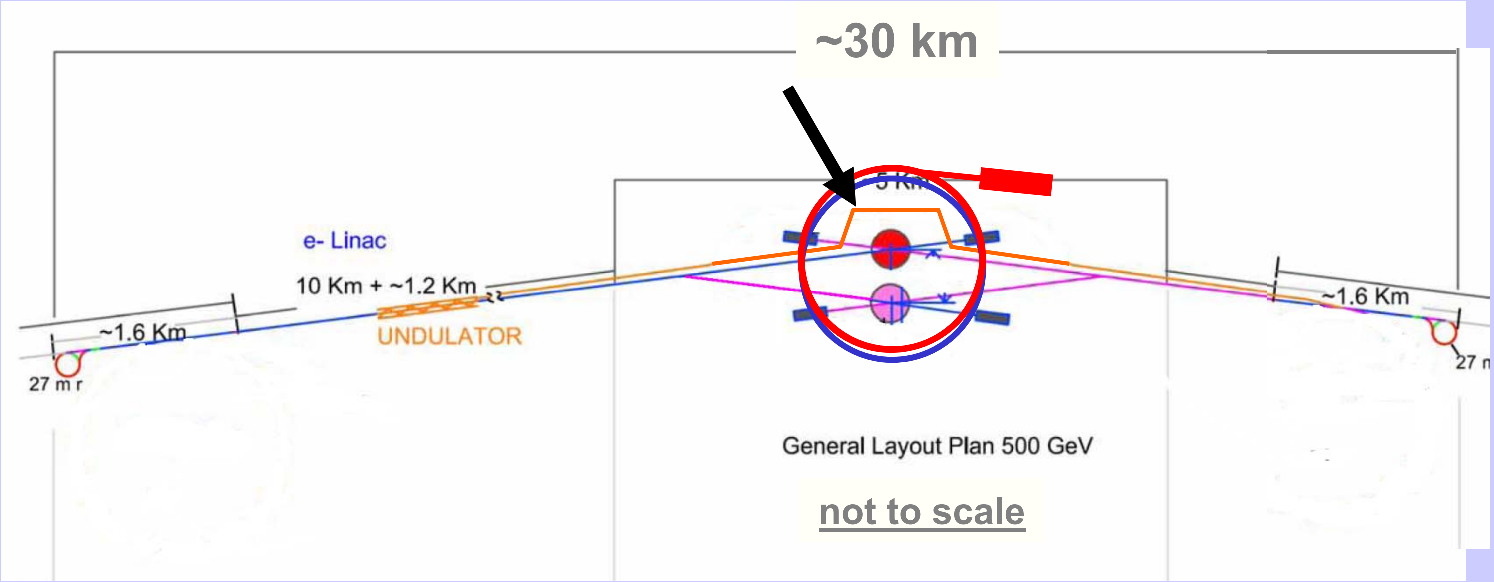
Centralised injectors

Place both e+ and e- ring in single centralized tunnel

Adjust timing (remove timing insert in e+ linac)

The Evolving Baseline

Baseline Configuration



Centralised injectors

Place both e+ and e- ring in single centralized tunnel

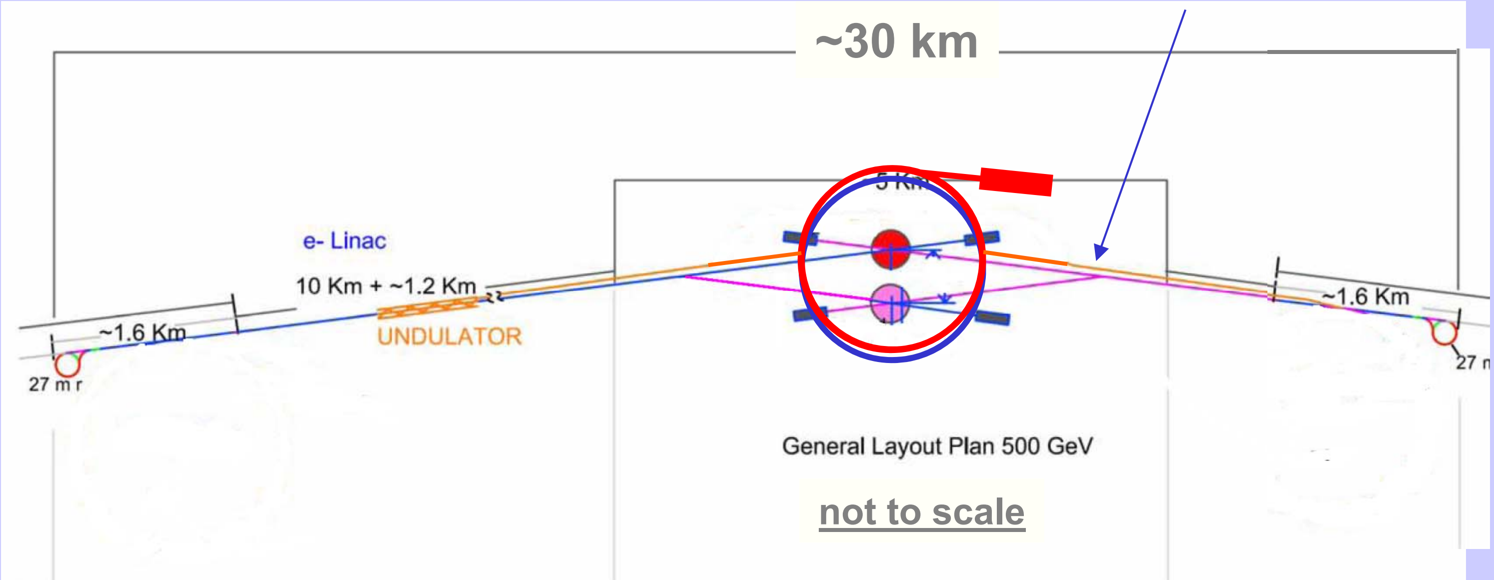
Adjust timing (remove timing insert in e+ linac)

Remove BDS e+ bypass

The Evolving Baseline

Baseline Configuration

Long 5GeV low-emittance transport lines now required



Centralised injectors

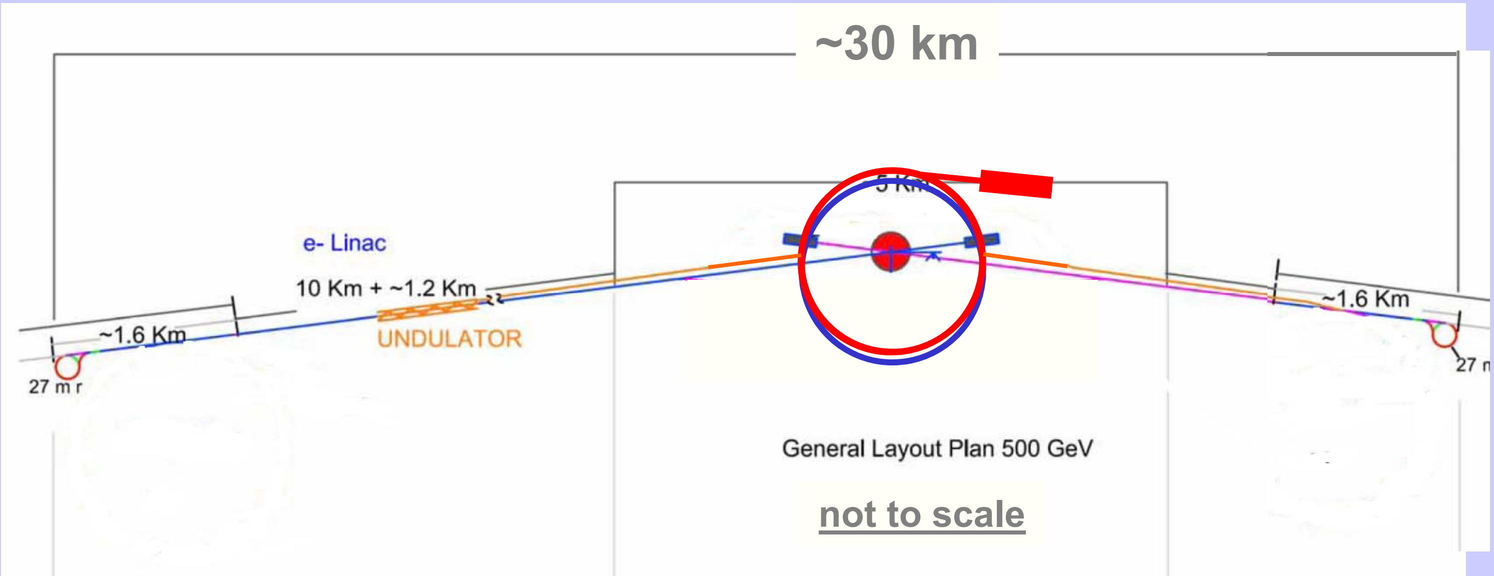
Place both e+ and e- ring in single centralized tunnel

Adjust timing (remove timing insert in e+ linac)

Remove BDS e+ bypass

The Evolving Baseline

Baseline Configuration

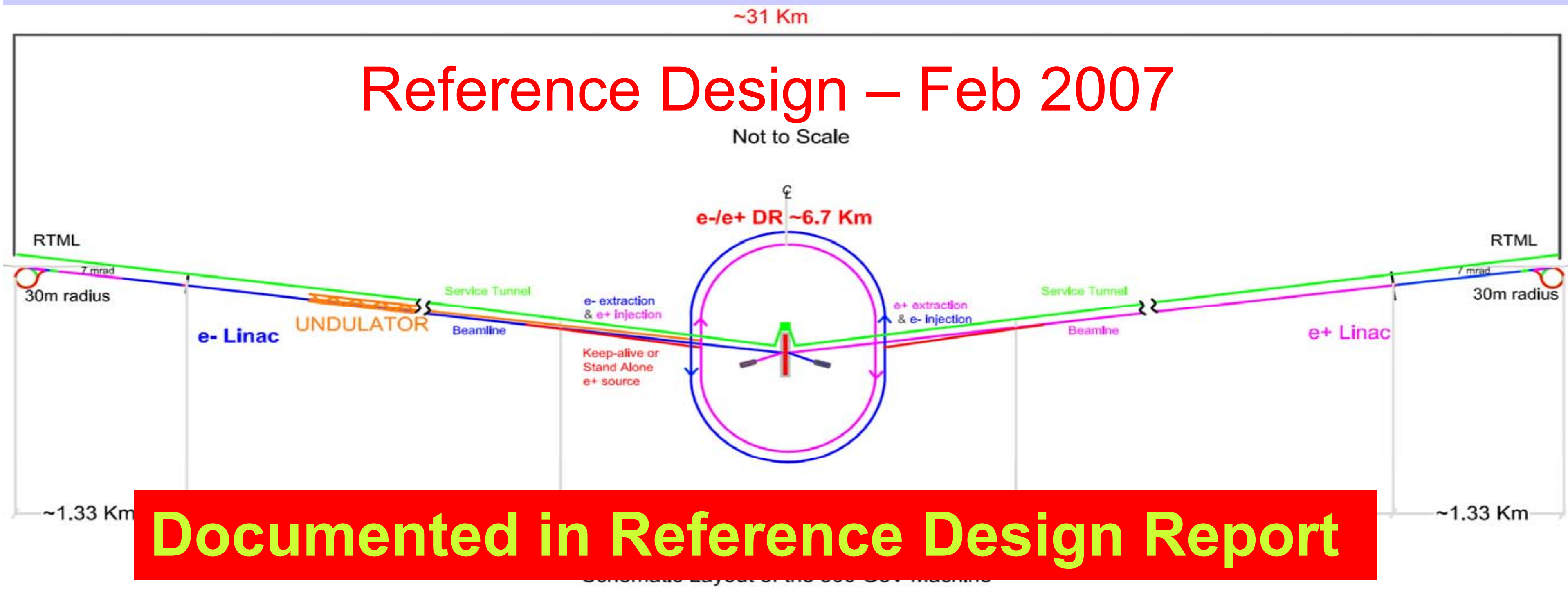


Single IR with Push-Pull Detector

Final RDR baseline

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

Parameters Report Revisited

- **The ILCSC Parameters Group has given updated selected clarification on accelerator requirements, based on achieving ILC science goals:**
  - **Removing safety margins in the energy reach is acceptable but should be recoverable without extra construction. The max luminosity is not needed at the top energy (500 GeV), however …..**
  - **The interaction region (IR) should allow for two experiments ….. the two experiments could share a common IR, provided that the detector changeover can be accomplished in approximately 1 week.**

RDR Design Parameters

Max. Center-of-mass energy	500	GeV
Peak 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 site power: ~ 230MW

Main Linacs
140 MW

Sub-Systems
90 MW

RF
100 MW

78%

65%

Cryogenics:
40 MW

Injectors

Damping rings

BDS

Auxiliaries

60%

Beam Power
22 MW

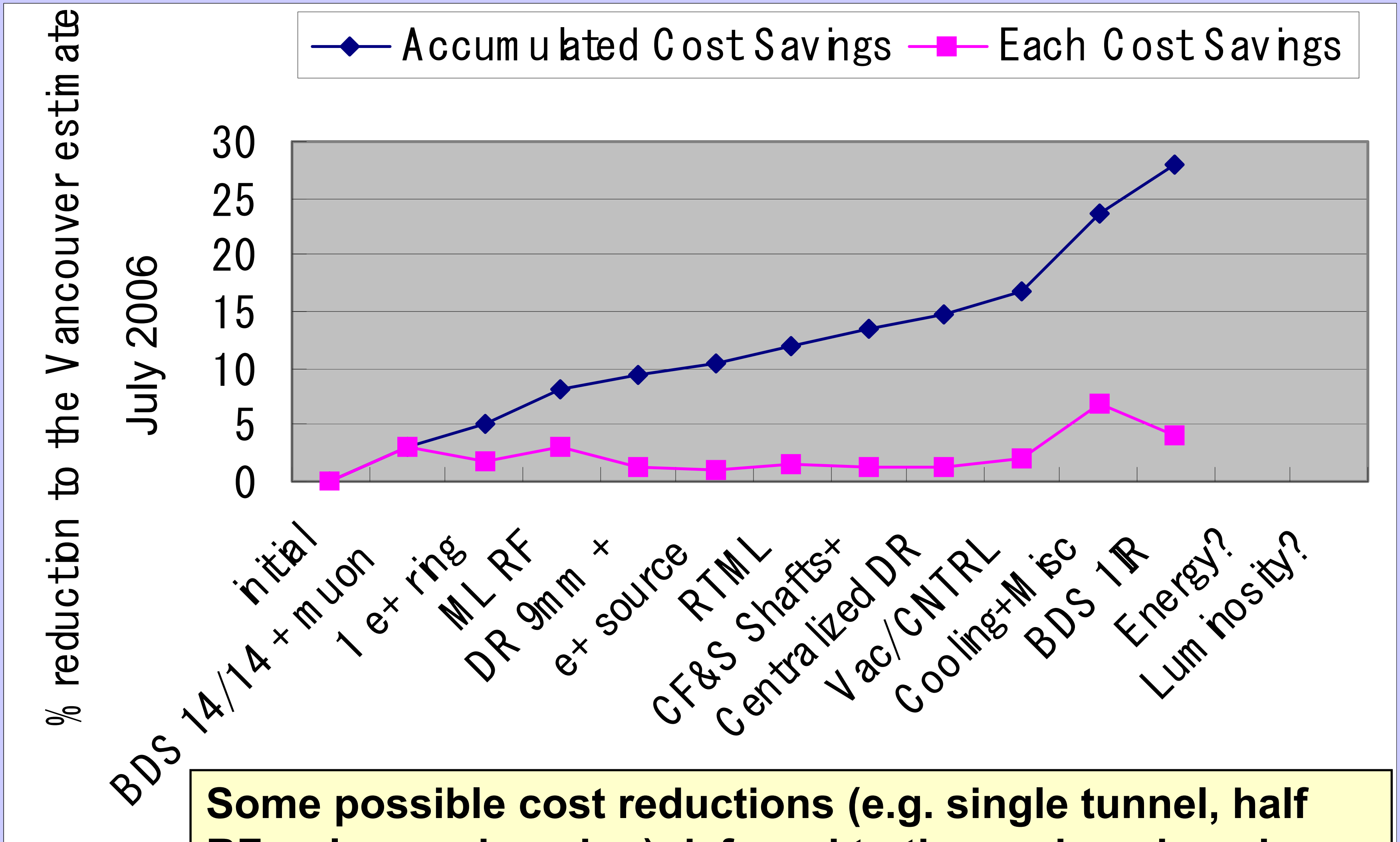
RDR Cost Estimating

- **“Value” Costing System: International costing for International Project**
  - **Provides basic agreed to “value” costs**
  - **Provides estimate of “explicit” labor (man-hr)]**

- **Based on a call for world-wide tender:**
  lowest reasonable price for required quality

- **Classes of items in cost estimate:**
  - **Site-Specific: separate estimate for each sample site**
  - **Conventional: global capability (single world est.)**
  - **High Tech: cavities, cryomodules (regional estimates)**

Evolving Design → Cost Reductions



Some possible cost reductions (e.g. single tunnel, half RF, value engineering) deferred to the engineering phase

RDR Design & "Value" Costs

The reference design was "frozen" as of 1-Dec-06 for the purpose of producing the RDR, including costs.

It is important to recognize this is a snapshot and the design will continue to evolve, due to results of the R&D, accelerator studies and value engineering

The value costs have already been reviewed three time

- 3 day "internal review" in Dec
- ILCSC MAC review in Jan
- International Cost Review (May)

Σ Value = 6.62 B ILC Units

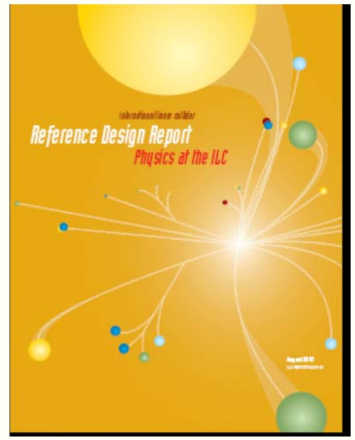
Summary
RDR "Value" Costs

Total Value Cost (FY07)
4.80 B ILC Units Shared
+
1.82 B Units Site Specific
+
14.1 K person-years
("explicit" labor = 24.0 M person-hrs @ 1,700 hrs/yr)
1 ILC Unit = $ 1 (2007)

RDR Complete

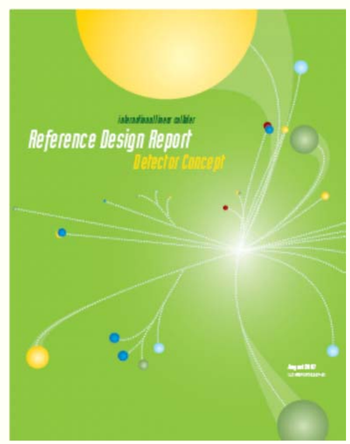
- Reference Design Report (4 volumes)

Executive Summary



Physics at the ILC

Accelerator



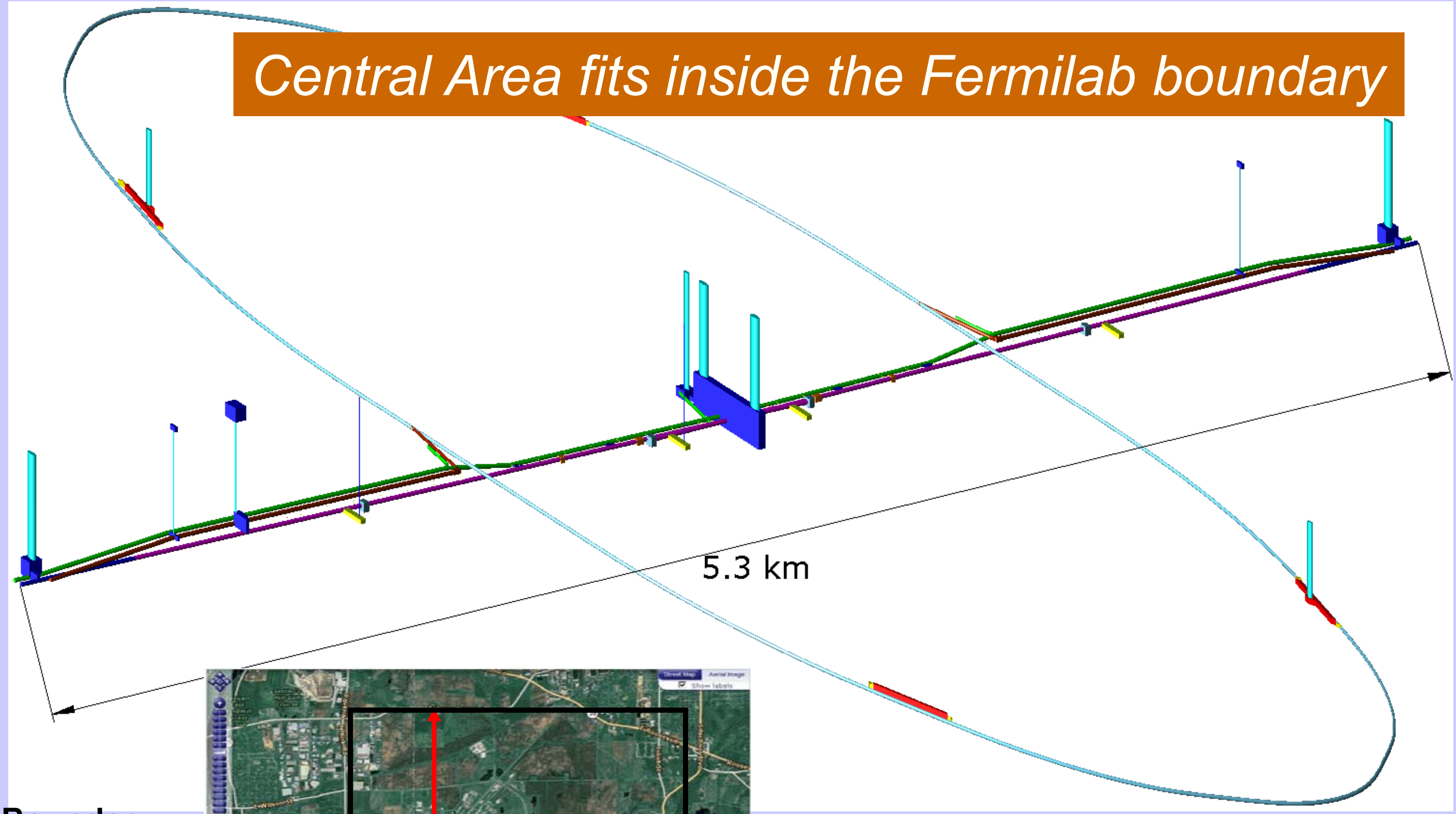
Detectors

RDR vs ICFA Parameters

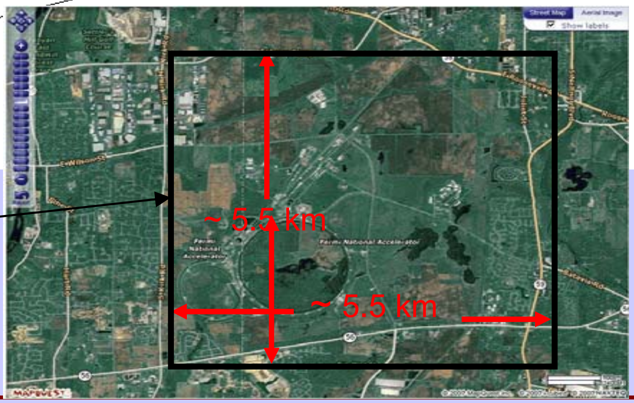
- E_{cm} adjustable from 200 – 500 GeV
- Luminosity → $\int L dt$ = 500 fb^{-1} in 4 years
- Ability to scan between 200 and 500 GeV
- Energy stability and precision below 0.1%
- Electron polarization of at least 80%

The RDR Design meets these “requirements,” including the recent update and clarifications of the reconvened ILCSC Parameters group!

Preconstruction Plan for Fermilab



~ Boundary of Fermilab



Site Characterization of the Central Area can be done

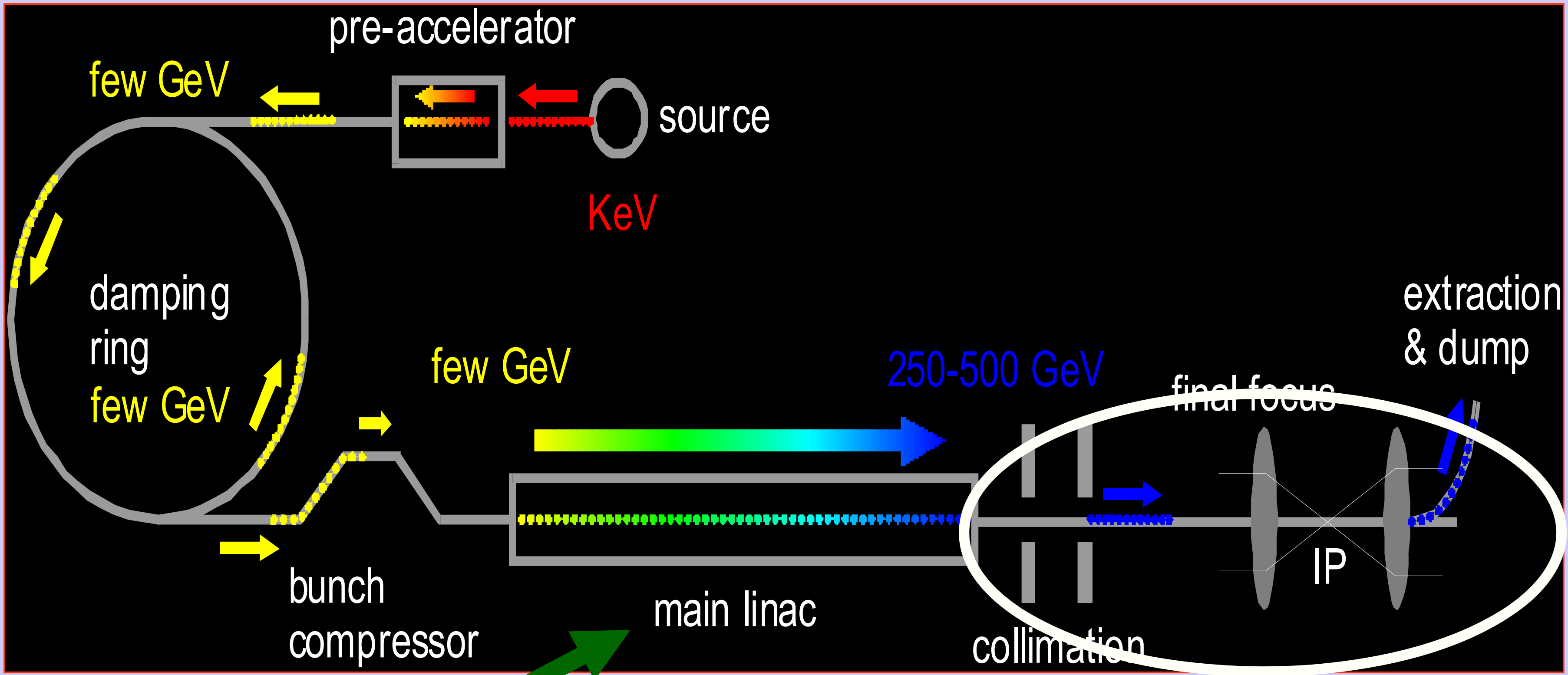
RDR Milestone Achieved

- **"Draft" Reference Design Report (RDR) was released and presented to ICFA as a ~300 page report at Beijing**
- **"Preliminary" International Value Costing presented**
- **This report and costing will serve as the foundation for the development of an Engineering Design Report that will define the ILC construction proposal. The reference design will guide:**
  - **The R&D program demonstrating the design or validating alternatives that improve performance or reduce risk**
  - **The Engineering Design Effort and especially the value engineering will be guided by the RDR.**

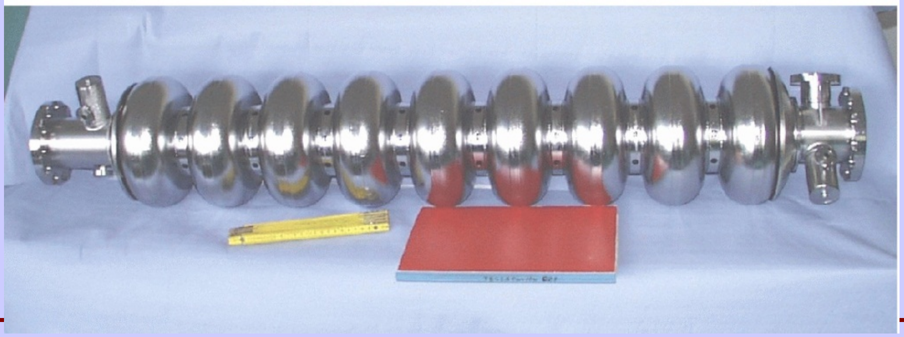
March 2005
I accepted
GDE job

Feb 2007
Reference Design
Presented to
ICFA/ILCSC

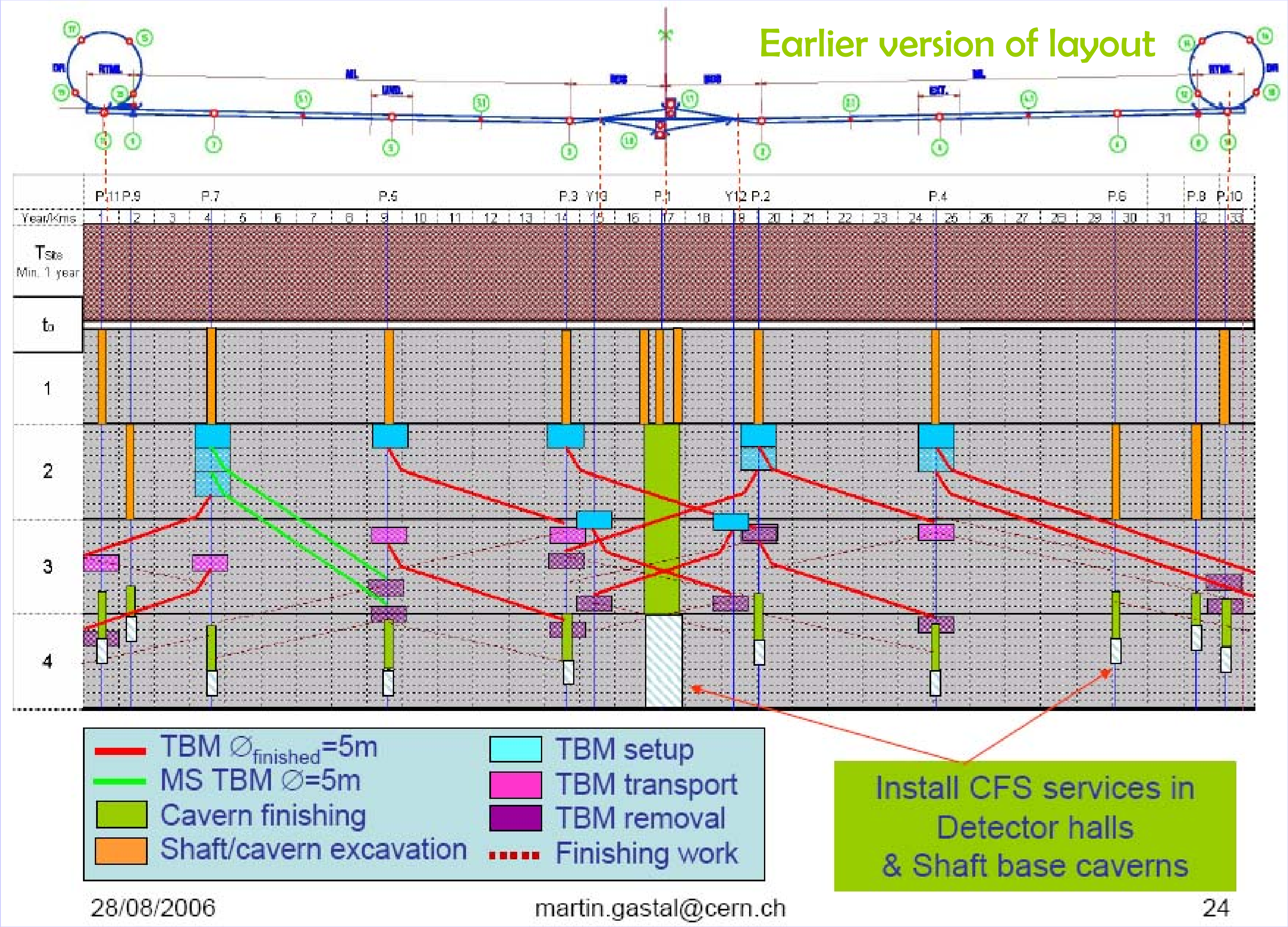
Designing a Linear Collider



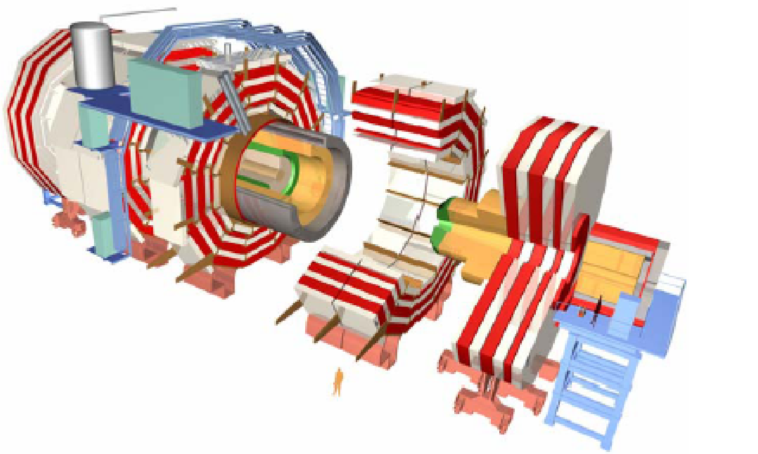
Superconducting RF Main Linac

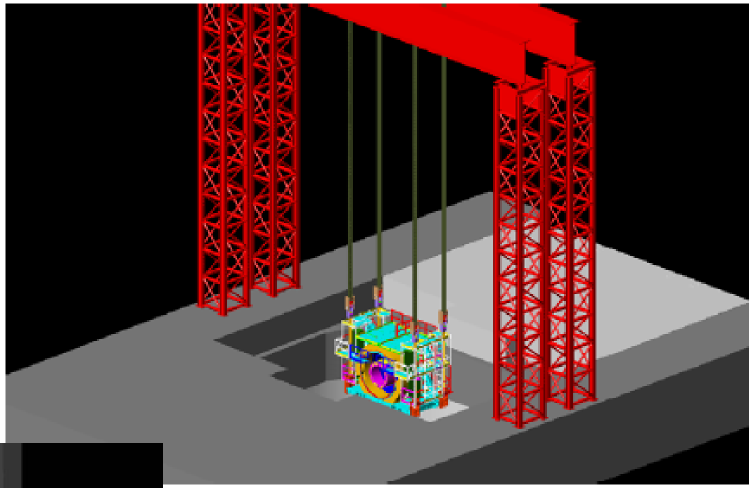


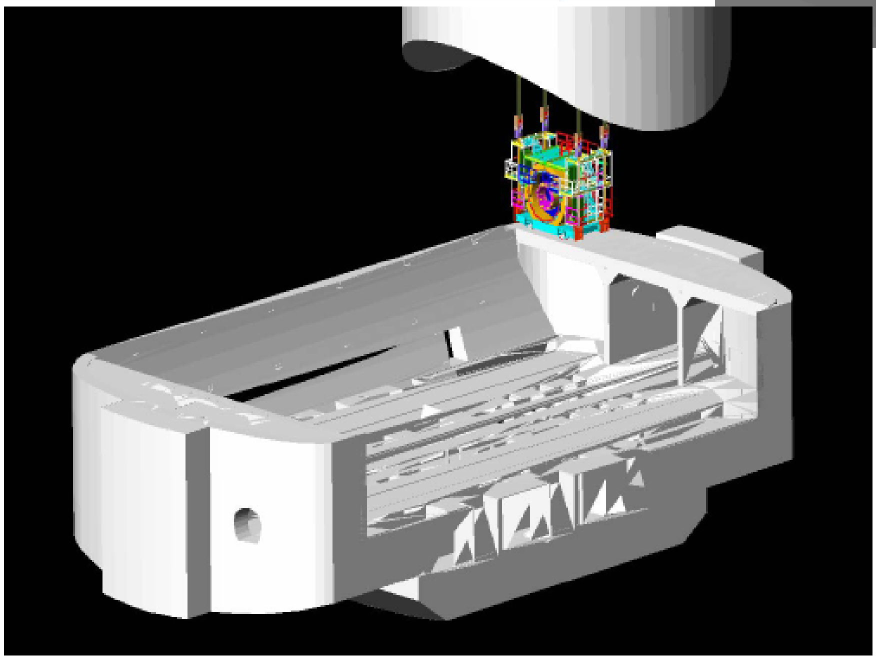
ILC Underground Construction Schedule



On-surface Detector Assembly
CMS approach



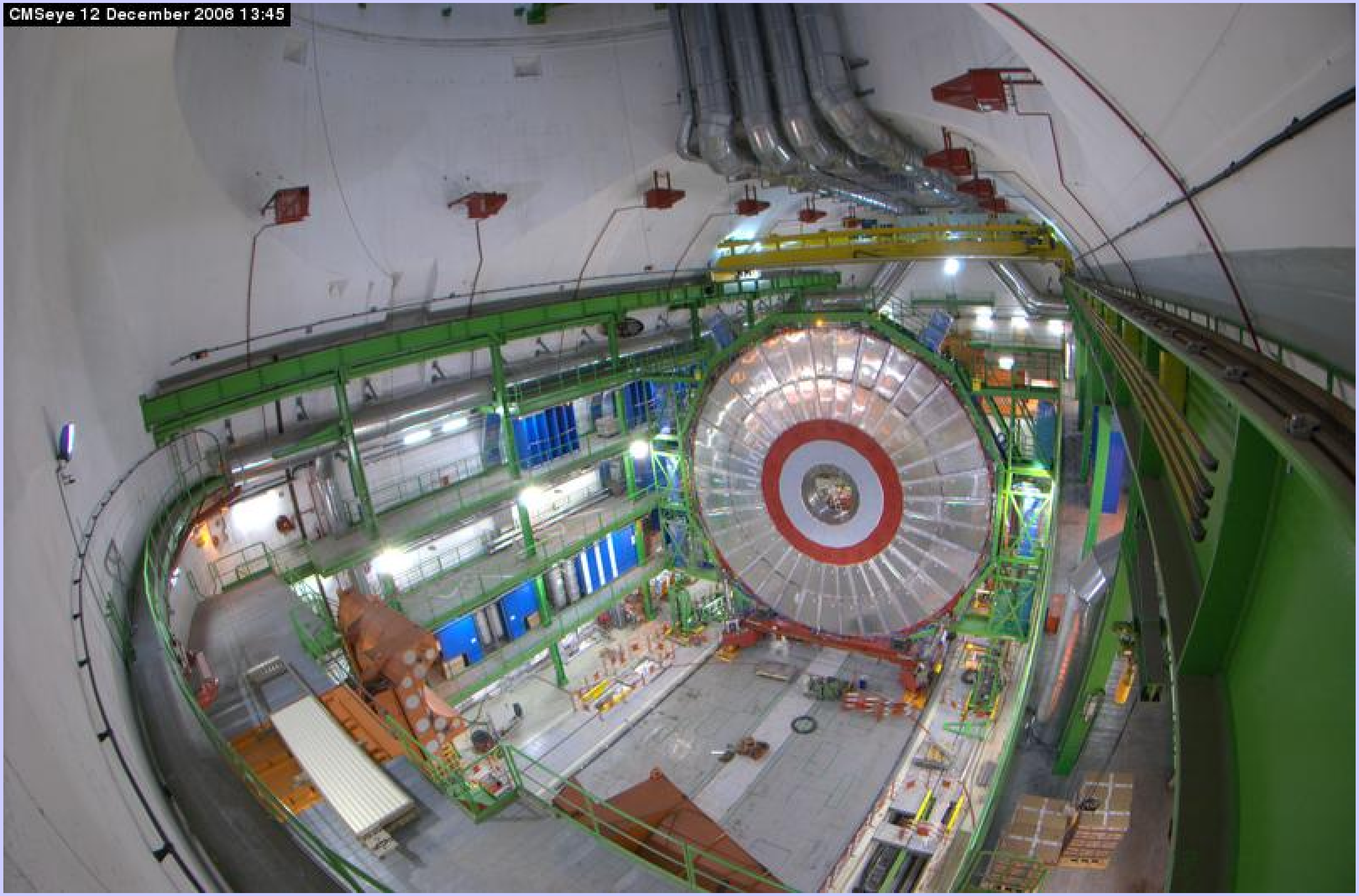




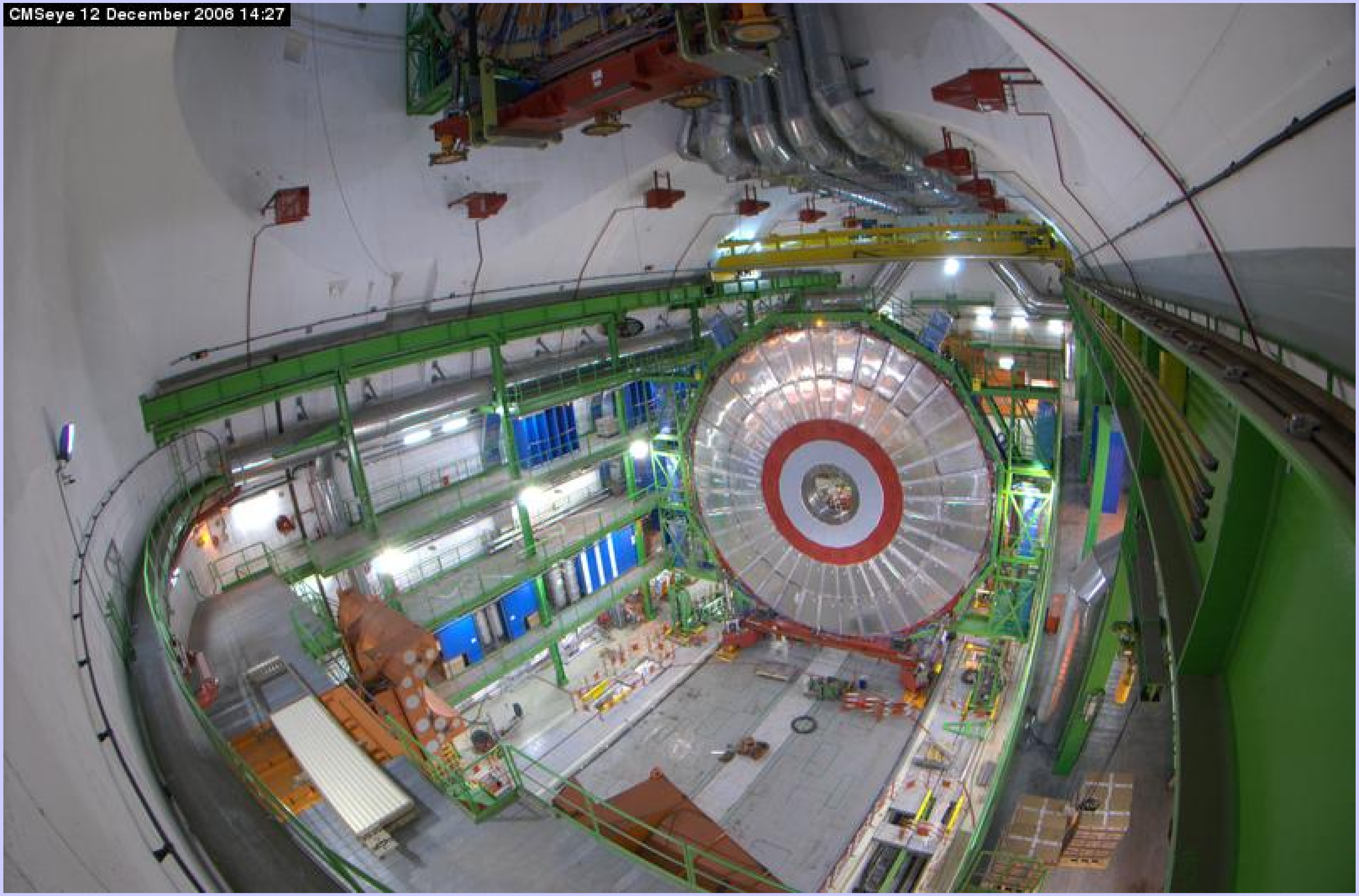
CMS assembly approach:

- **Assembled on the surface in parallel with underground work**
- **Allows pre-commissioning before lowering**
- **Lowering using dedicated heavy lifting equipment**
- **Potential for big time saving**
- **Reduces size of required underground hall**

CMS Assembly



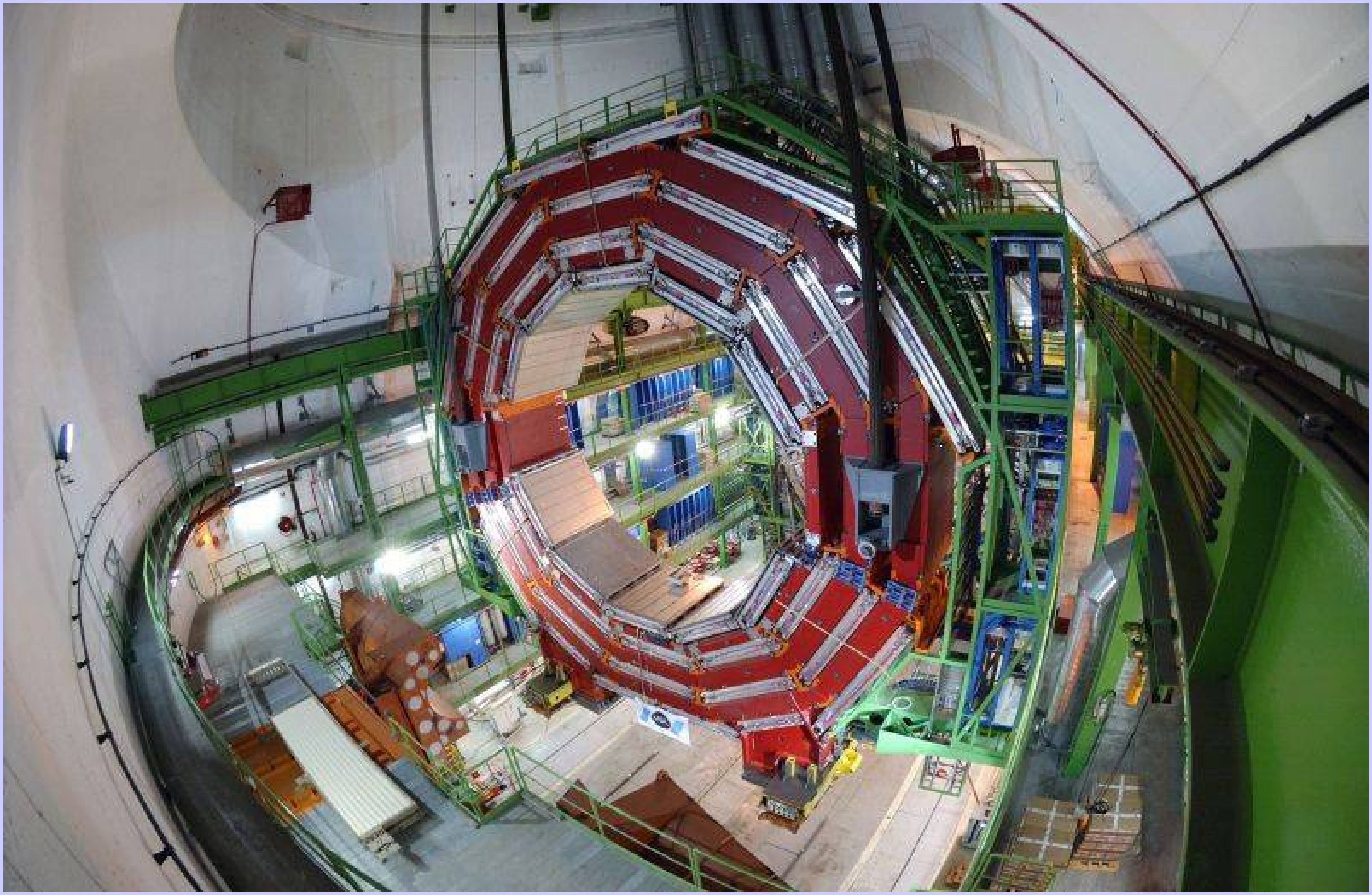
CMS Assembly



CMS Assembly

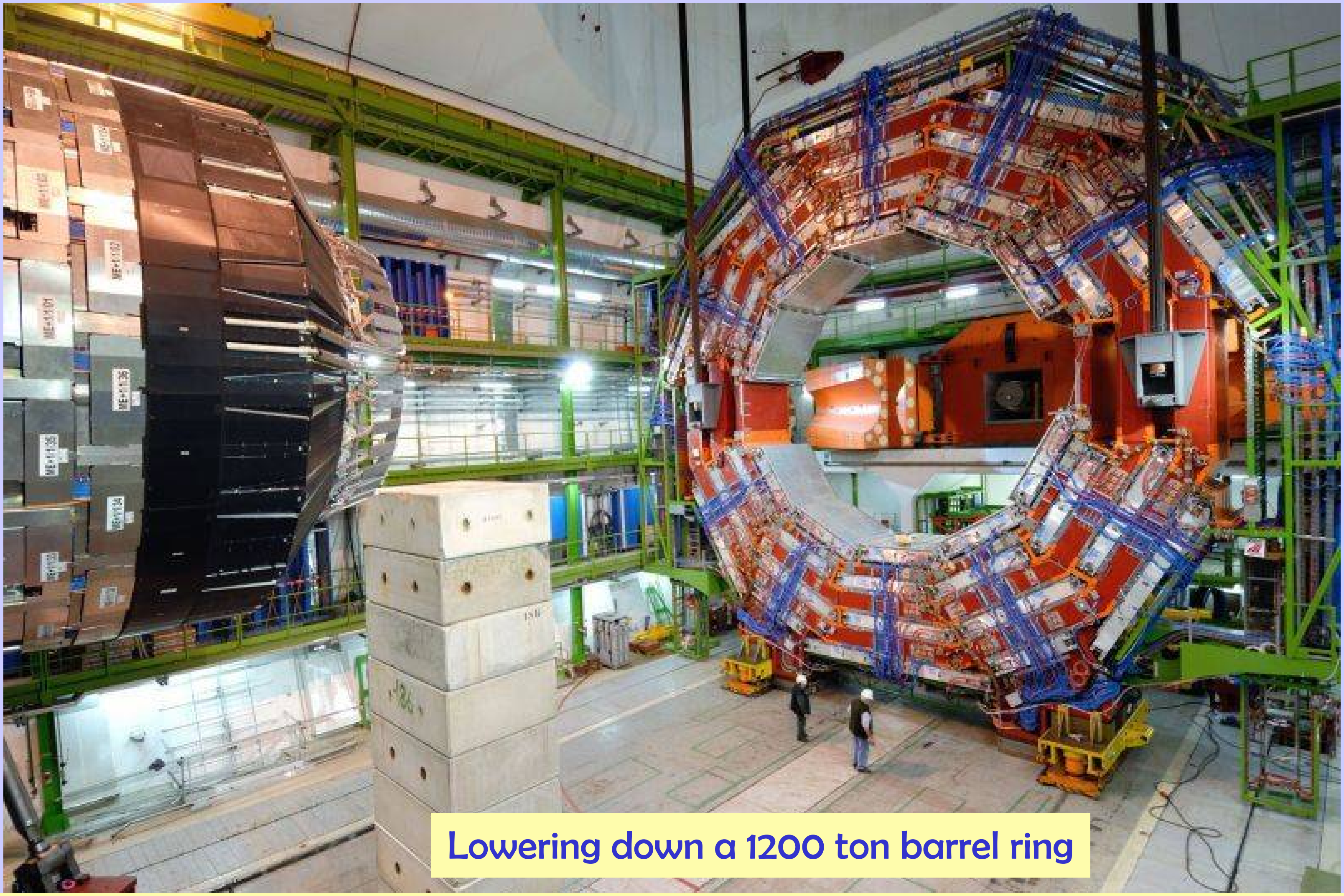
CMS Assembly

CMS Assembly



February 1. Lowering down a 1200 ton barrel ring. Photo and info courtesy Alain Herve

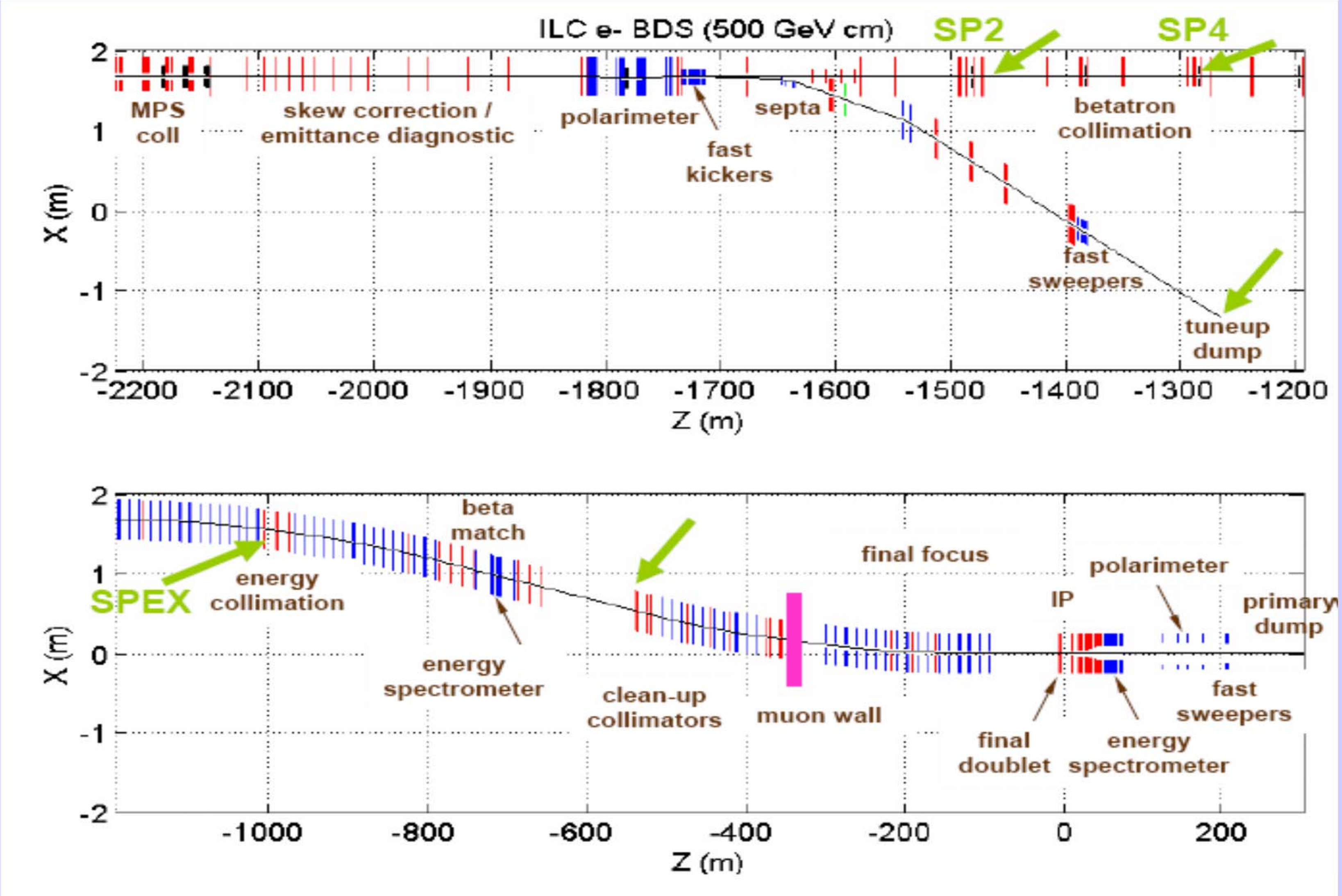
CMS Assembly



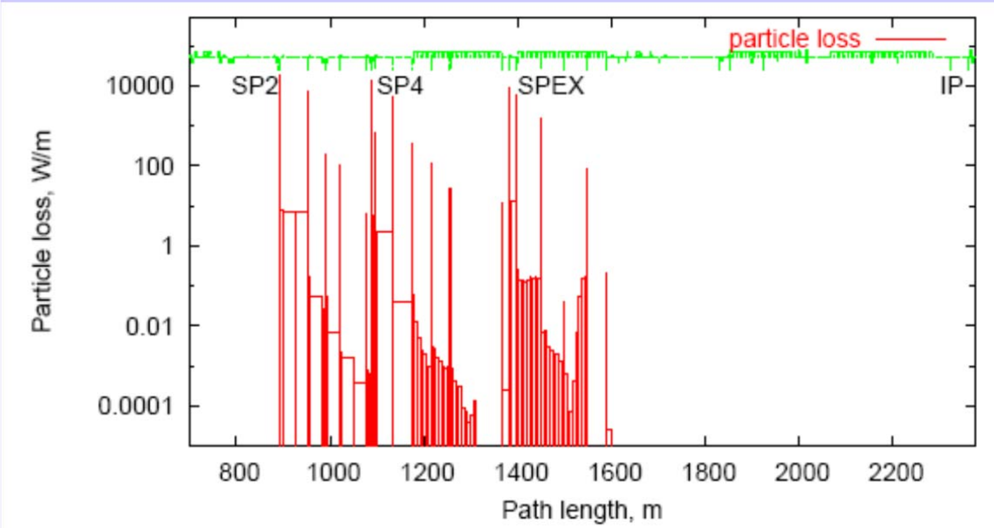
Lowering down a 1200 ton barrel ring

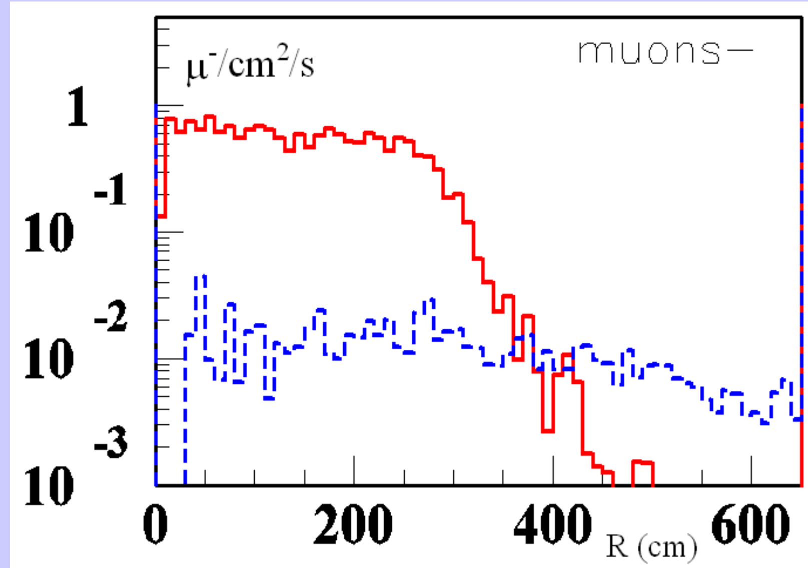
CMS is at half process. Next -- lowering 2kt central barrel by the end of February. **Alain Herve**

Possible Sources of Muons

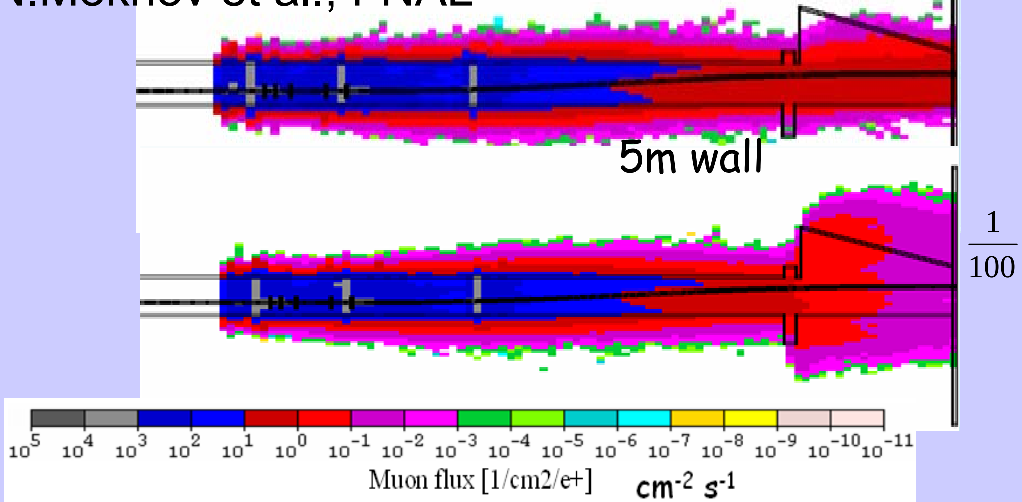


Muon Reduction





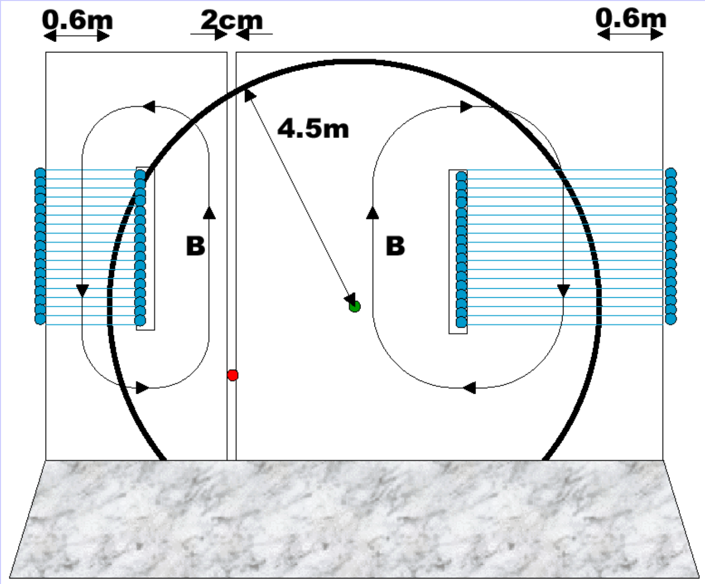
N.Mokhov et al., FNAL

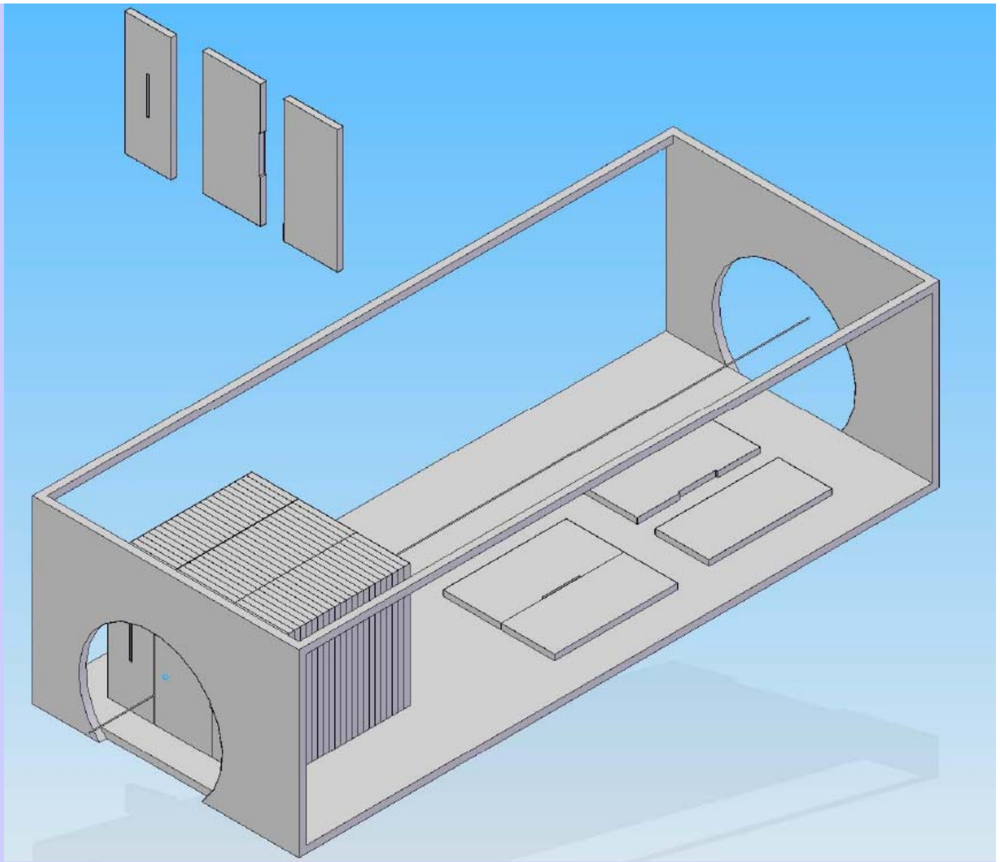


- **Muon flux in BDS & IR with and without 5m muon wall**
- **Allows reducing flux in TPC to a few m per ~100 bunches**

Muon walls

- **Purpose:**
  - **Personnel Protection: Limit dose rates in IR when beam sent to the tune-up beam dump**
  - **Physics: Reduce the muon background in the detectors**



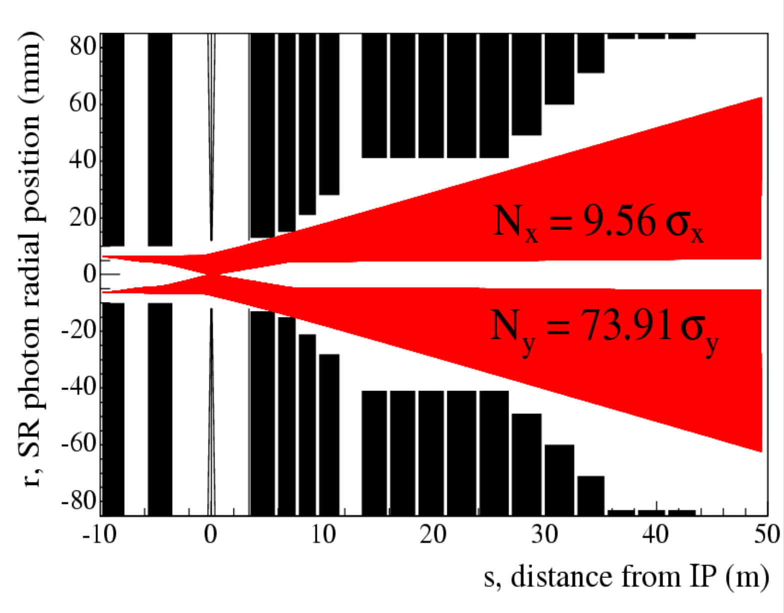


5m muon wall installed initially

If muon background measured too high, the 5m wall can be lengthened to 18m and additional 9m wall installed
(Local toroids could be used also)

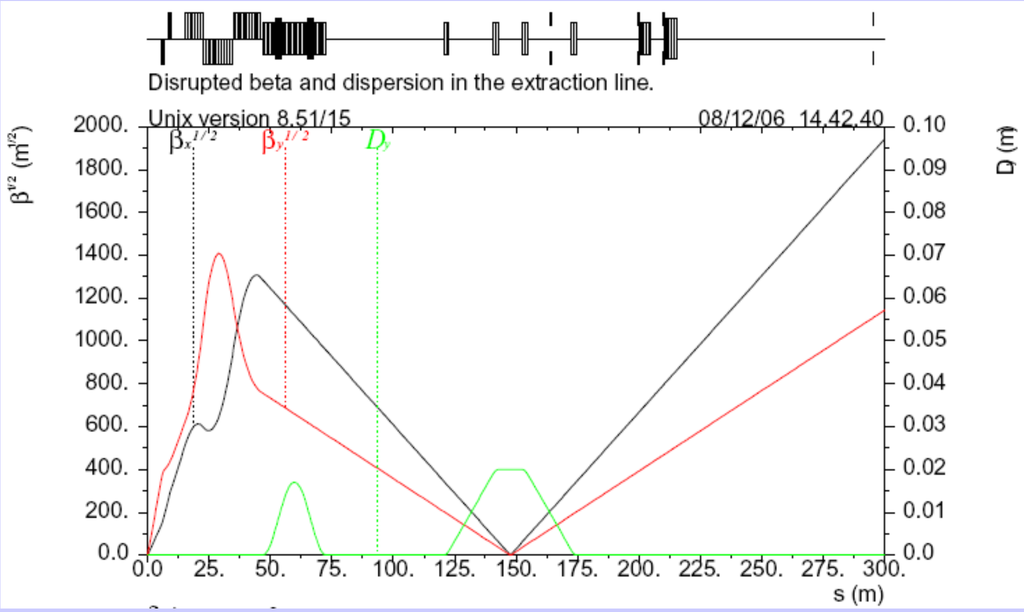
Beam Gas & Synchrotron Radiation in IR

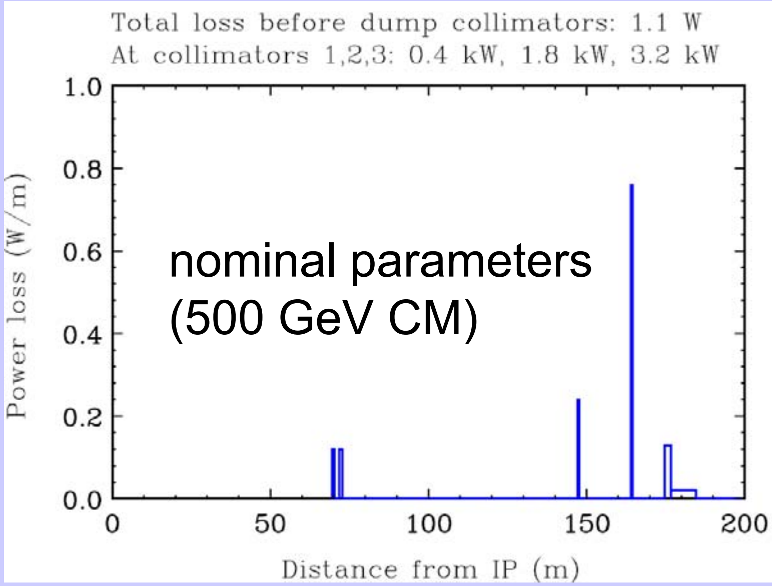
- **Beam gas**
  - is minimized by controlling the pressure near IP within 1nTorr level, 10nTorr in 200-800m from IP and ~50nTorr in the rest of the system
- **Synchrotron Radiation in IR**
  - due to upstream collimation is contained within a defined cone which is extracted away

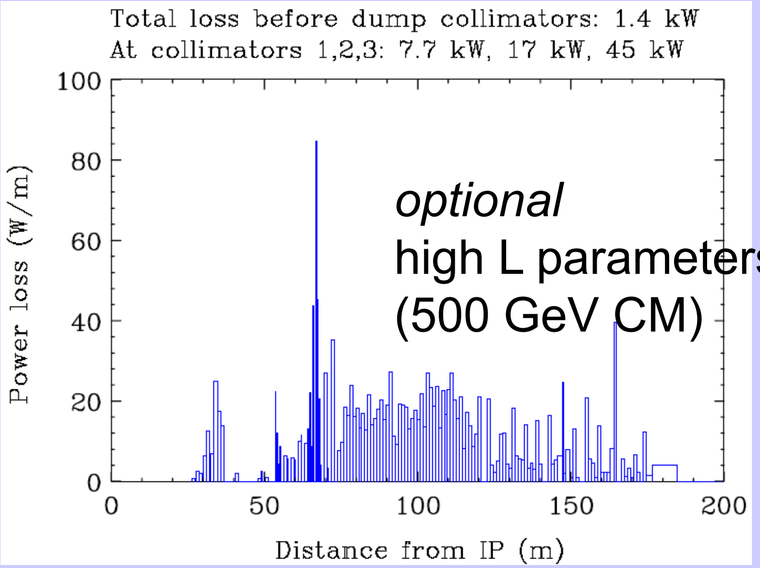


Example of SR rays from beam halo in IR apertures

Extraction Lines

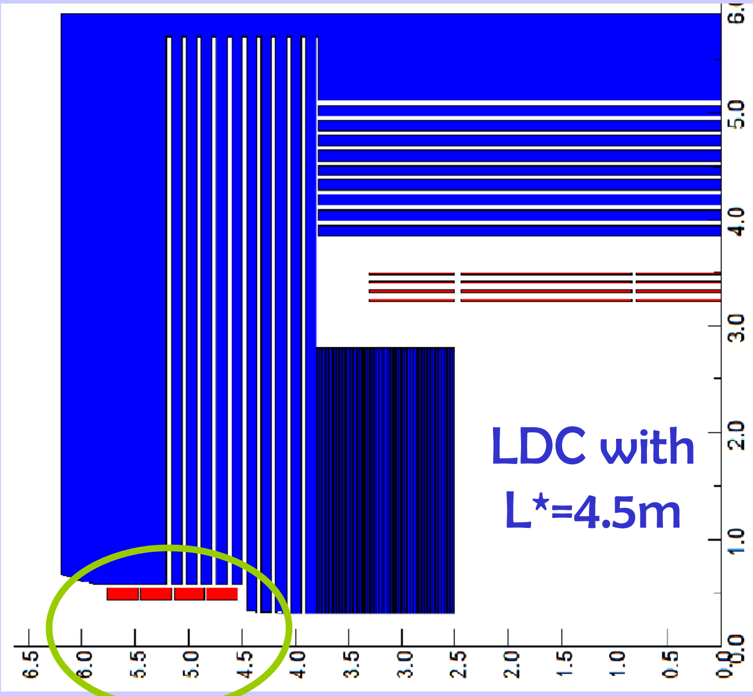


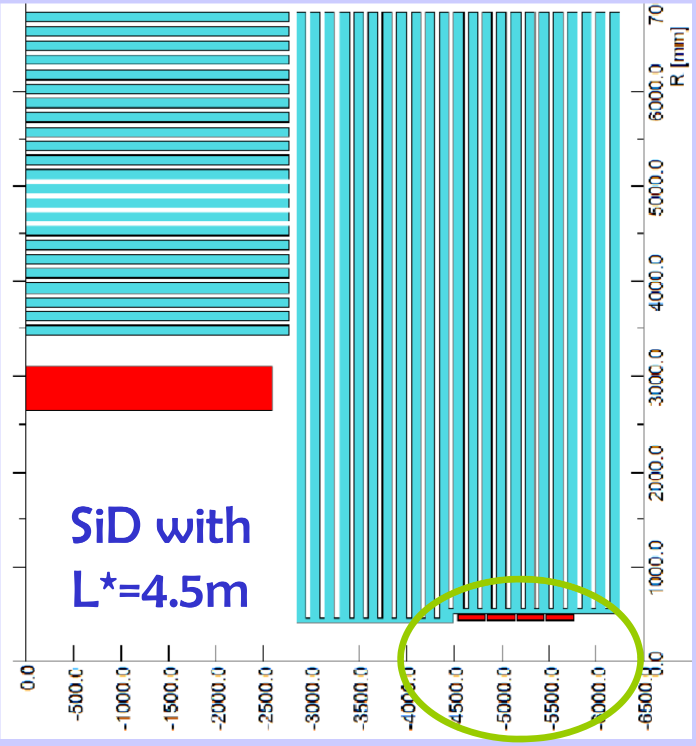




- Losses for the nominal case are negligible (~1W for 200m from IP)
- Even for High L parameters is within acceptable levels
- Small losses in extraction and separation from dump are important to keep the back-shine low

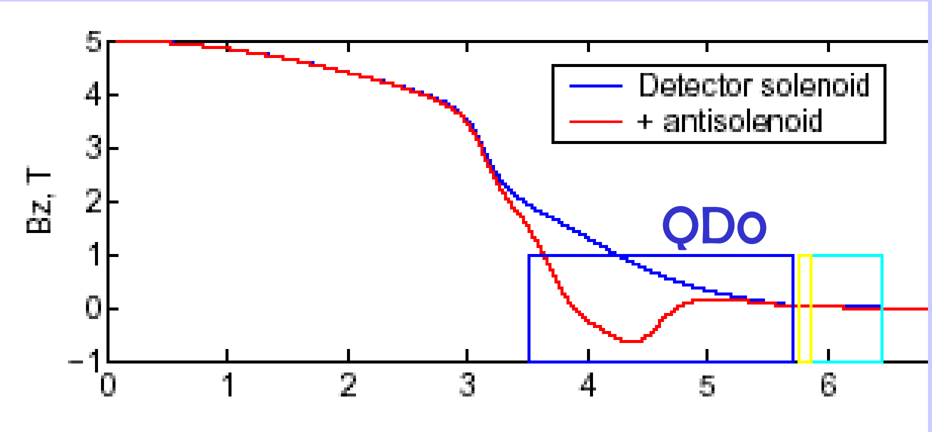
Antisolenoids





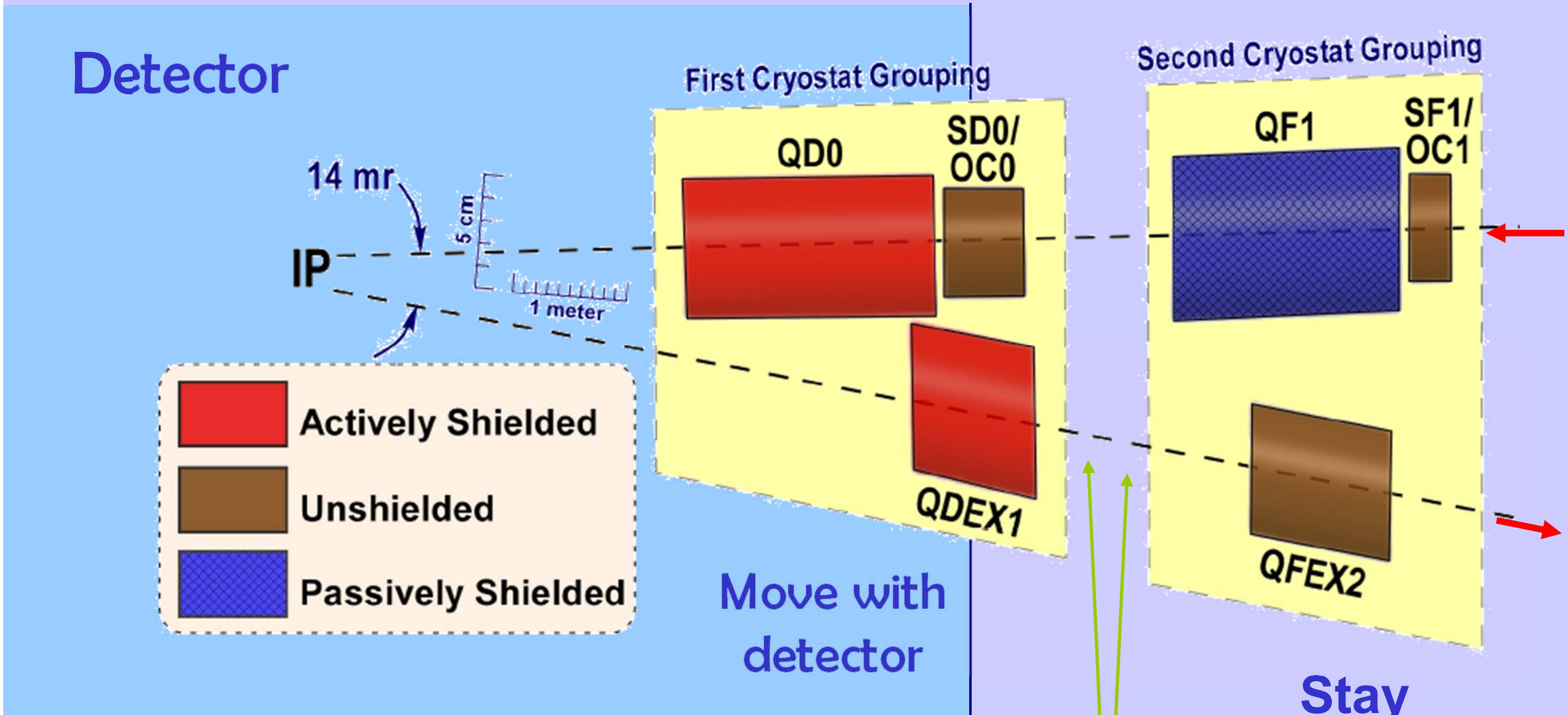
- Antisolenoids for local compensation of beam coupling
- Depend on all parameters (L*, field, sizes, etc) and is a delicate MDI issue

B.Parker, BNL



Example of optimal field for local compensation of coupling (SiD, L*=3.5m)

Interaction Region Conceptual Design

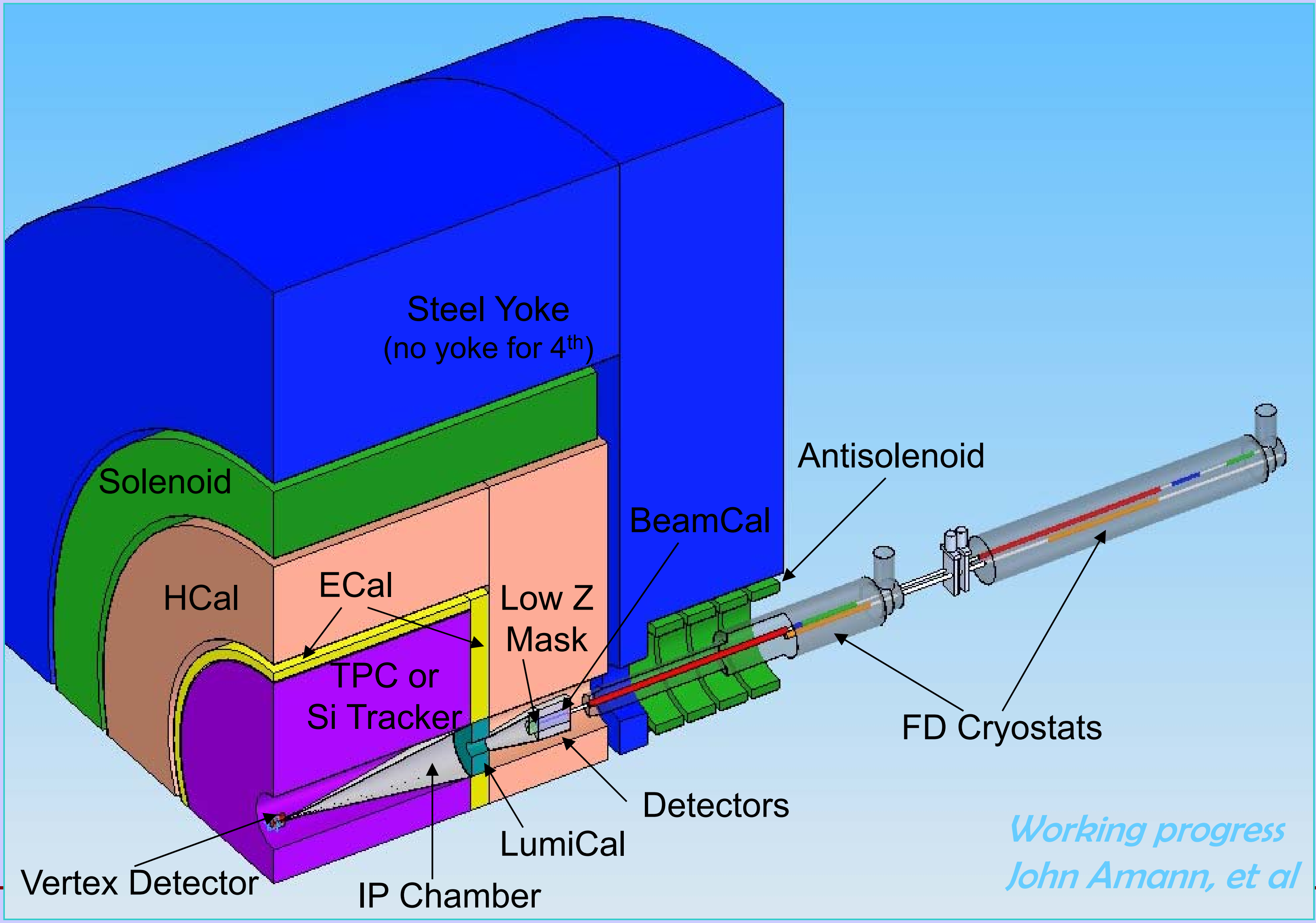


Stay fixed

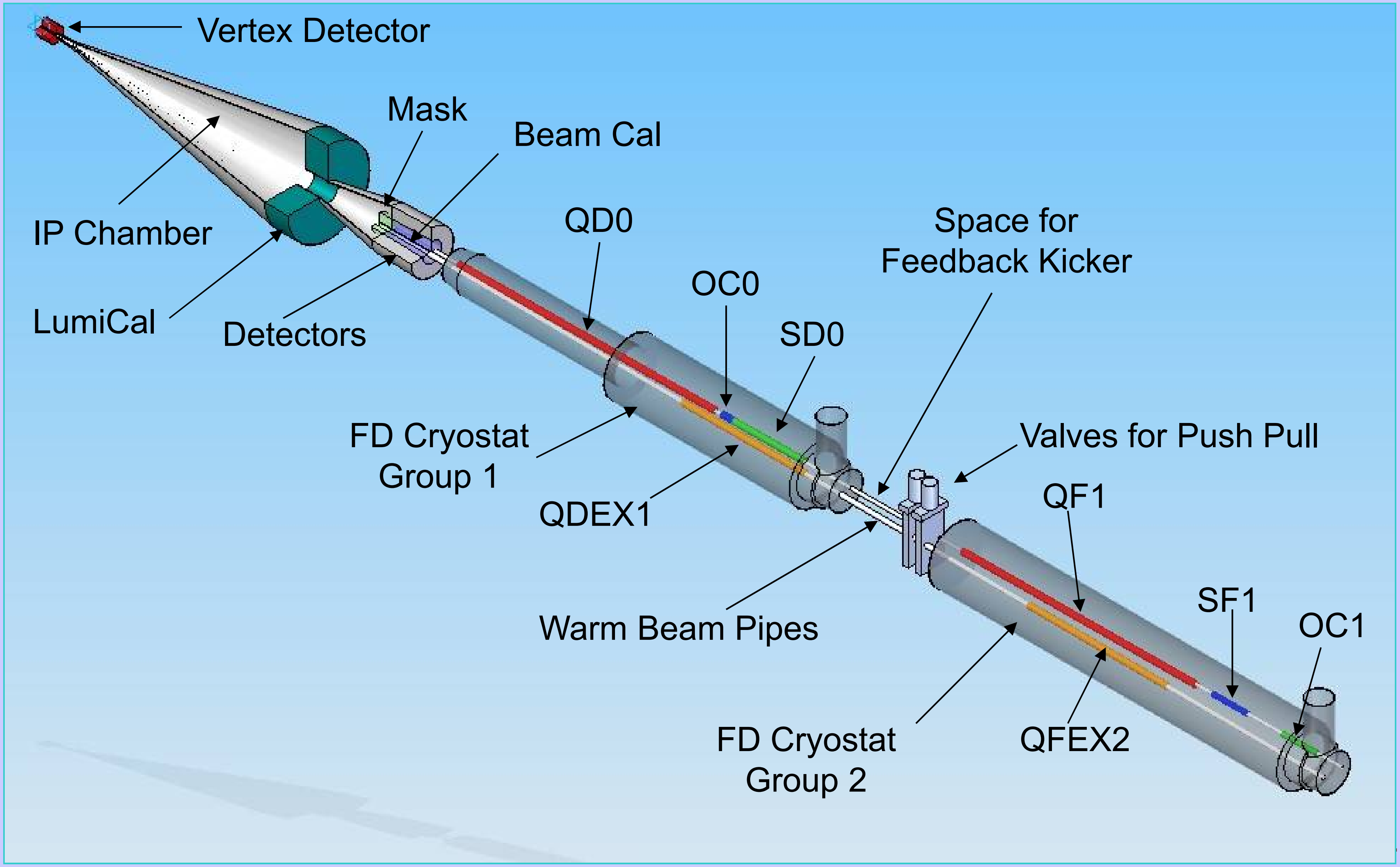
Warm space for vacuum valves for disconnect

B.Parker, et al, BNL

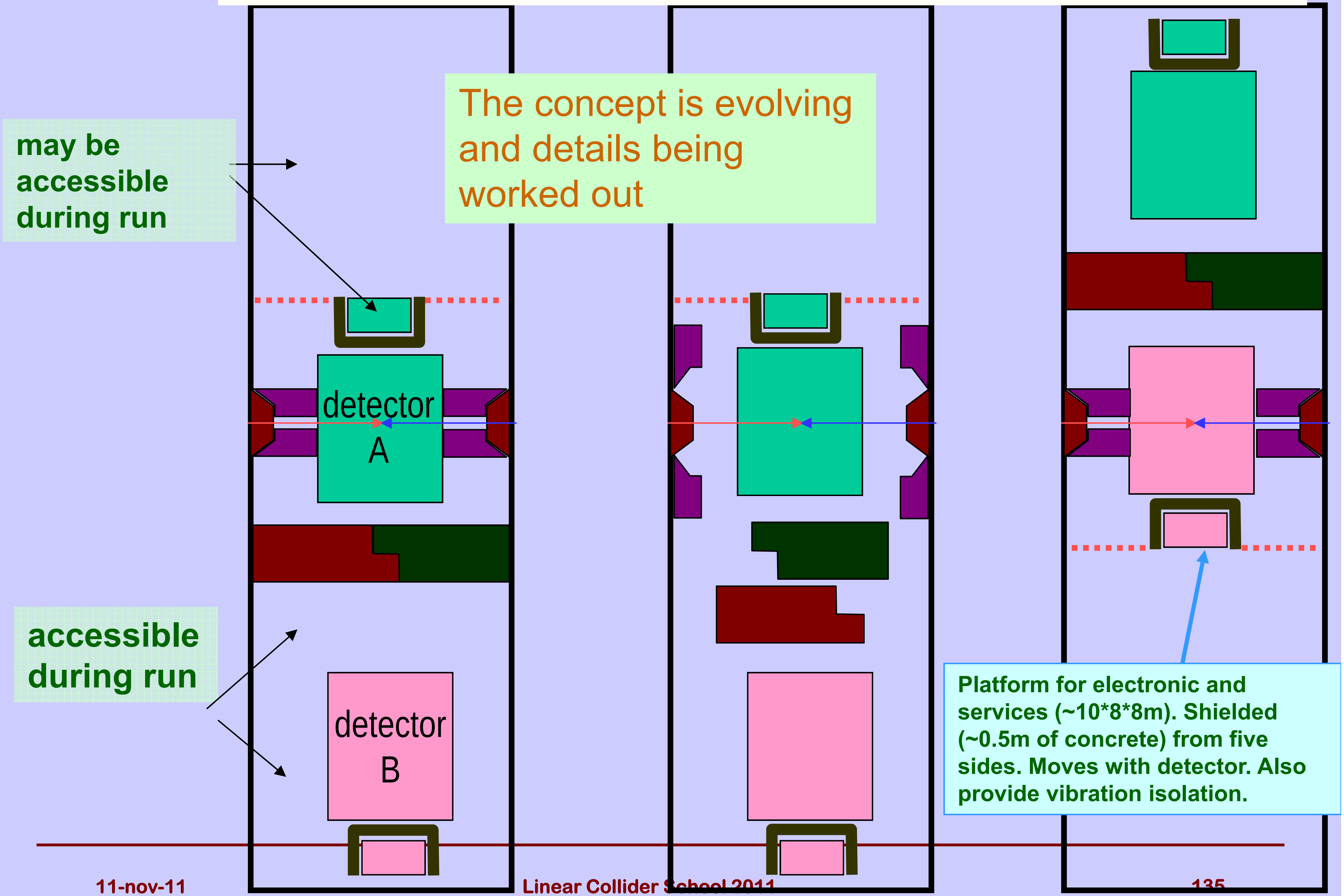
Generic Detector - IR Details



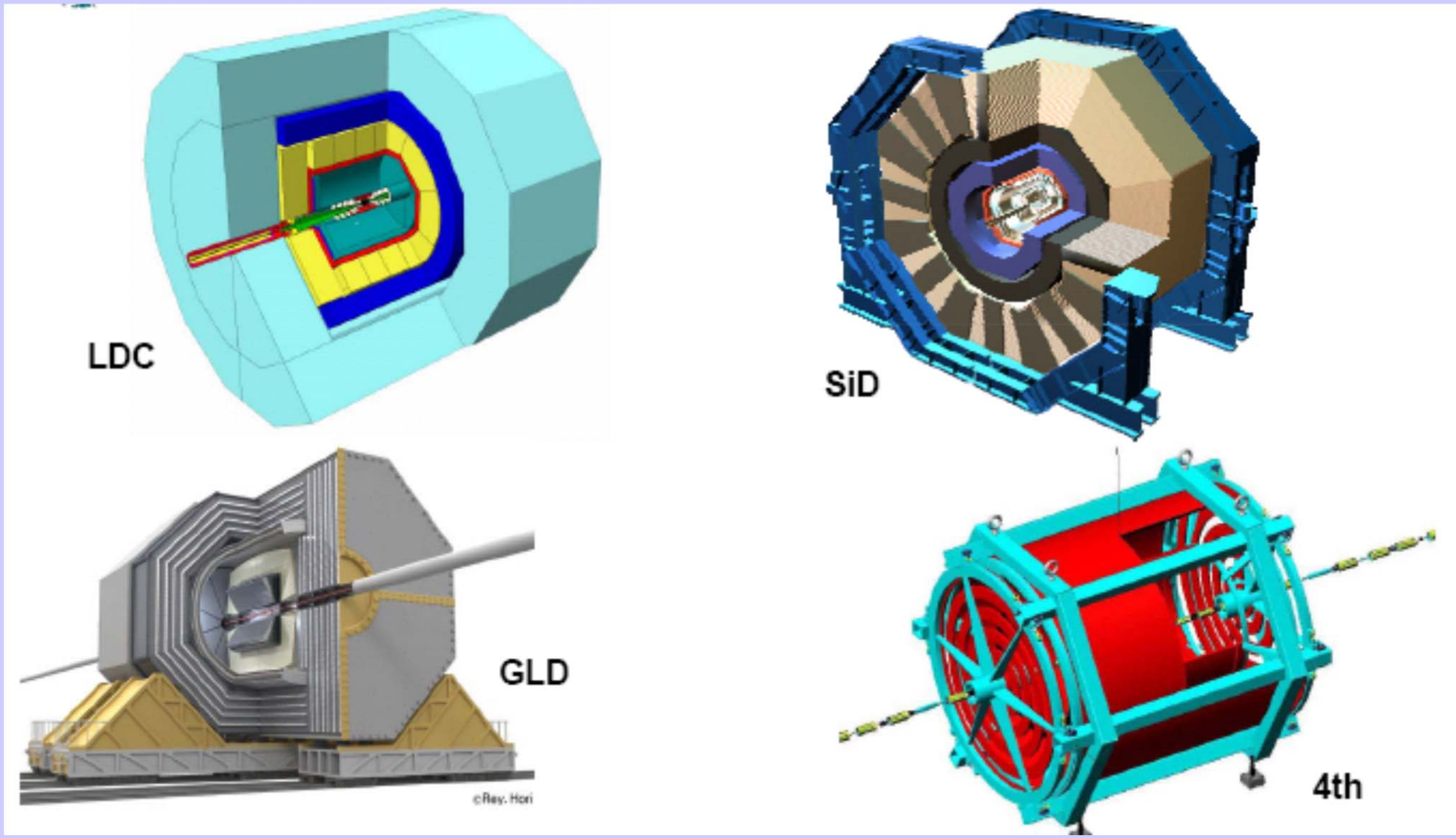
Generic IR layout



Concept of IR hall with two detectors



Detector Concepts



Detector Philosophies

- **Detector designing philosophy is somewhat different for the three main concepts.**
  - **The small detector does not use gaseous tracker, since the operation of silicon tracker might be more robust. Also, in principle, smaller detector is inexpensive.**
  - **The large detectors use TPC for the main tracker, because of large number of hit points along a track in the TPC → easier pattern recognition.**
  - **The separation of the charged particles and photons at the calorimeter inner surface is essential for the particle flow algorithm.**

- **The main differences of the three concepts are**

  (1) Use silicon detector alone or with TPC for the tracker

  (2) Use Si-W or Scintillator-W for ECAL

Detector Concepts

	Tracking	ECal Inner Radius	Solenoid	EM Cal	Hadron Cal	Other
SiD	silicon	1.27 m ↓	5 Tesla ↑	Si/W	Digital (RPC..)	Had cal inside coil
LCD	TPC gaseous	1.68 m ↓	4 Tesla ↑	Si/W	Digital or Analog	Had cal inside coil
GLD	TPC gaseous	2.1 m	3 Tesla	W/ Scin.	Pb/ Scin.	Had cal inside coil
4th	TPC gaseous			crystal	Compen-sating fiber	Double Solenoid (open mu)

Detector Performance Goals

- **ILC detector performance requirements and comparison to the LHC detectors:**
  - ○ Inner vertex layer ~ 3-6 times closer to IP
  - ○ Vertex pixel size ~ 30 times smaller
  - ○ Vertex detector layer ~ 30 times thinner

  Impact param resolution $\Delta d = 5\ [\mu m] \oplus 10\ [\mu m] / (p[GeV] \sin 3/2\theta)$

  - ○ Material in the tracker ~ 30 times less
  - ○ Track momentum resolution ~ 10 times better

  Momentum resolution $\Delta p / p^2 = 5 \times 10^{-5}\ [GeV^{-1}]$ central region

  $\Delta p / p^2 = 3 \times 10^{-5}\ [GeV^{-1}]$ forward region

  - ○ Granularity of EM calorimeter ~ 200 times better

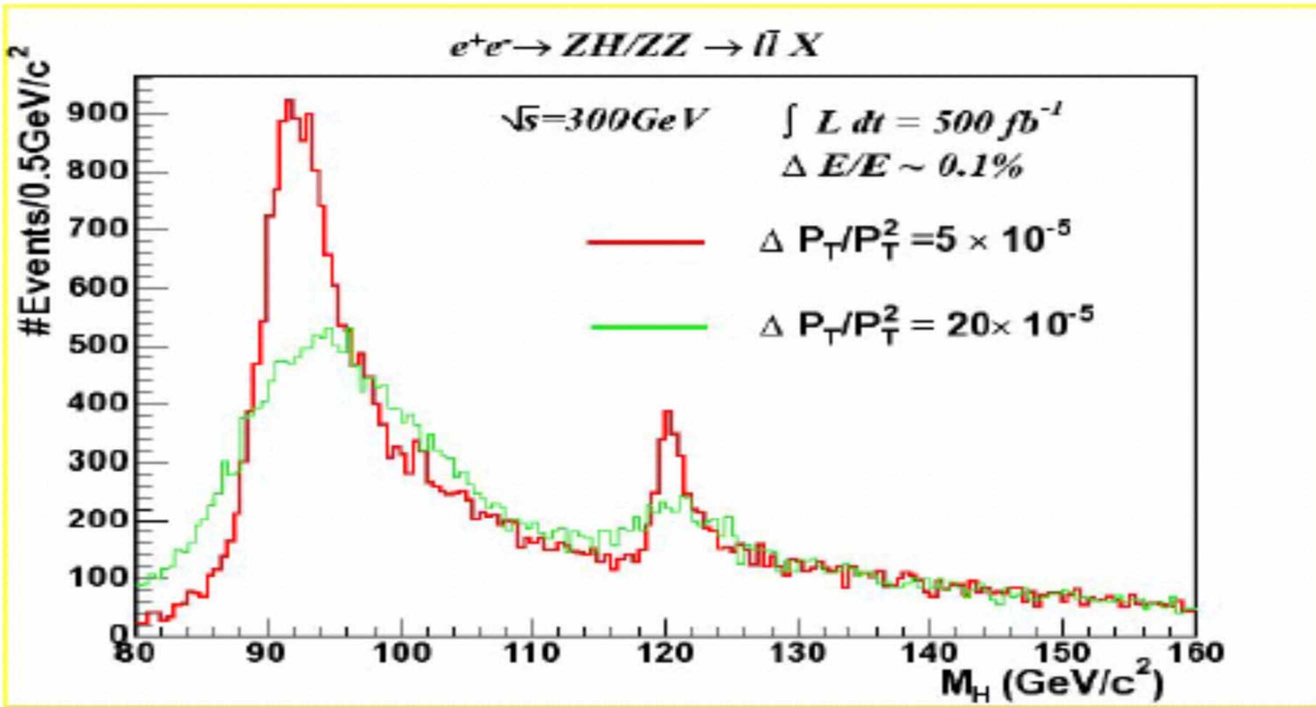
  Jet energy resolution $\Delta E_{jet} / E_{jet} = 0.3 / \sqrt{E_{jet}}$

  Forward Hermeticity down to θ = 5-10 [mrad]

Detector Performance Goals

e.g: The Higgs tagging mode

$e^+e^- \rightarrow ZH, \quad Z \rightarrow \ell^+\ell^-$



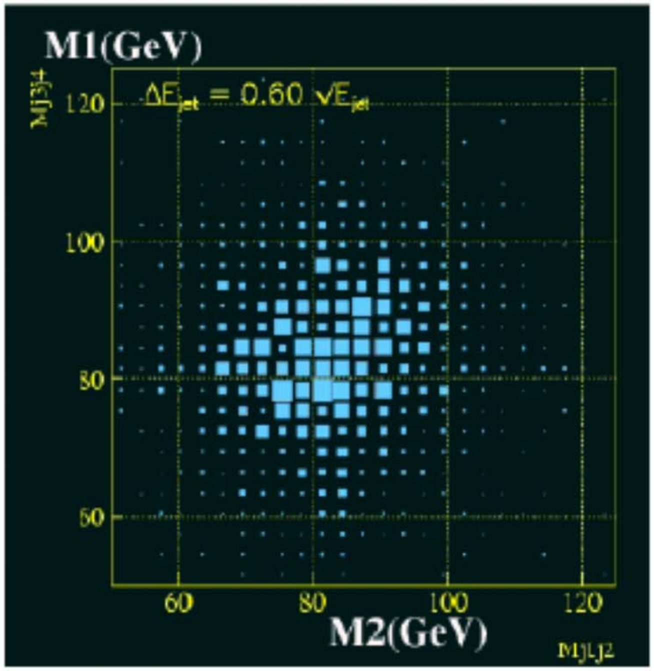
$\sigma_p/p^2 \sim 5 \times 10^{-5}$ is "necessary"

Detector Performance Goals

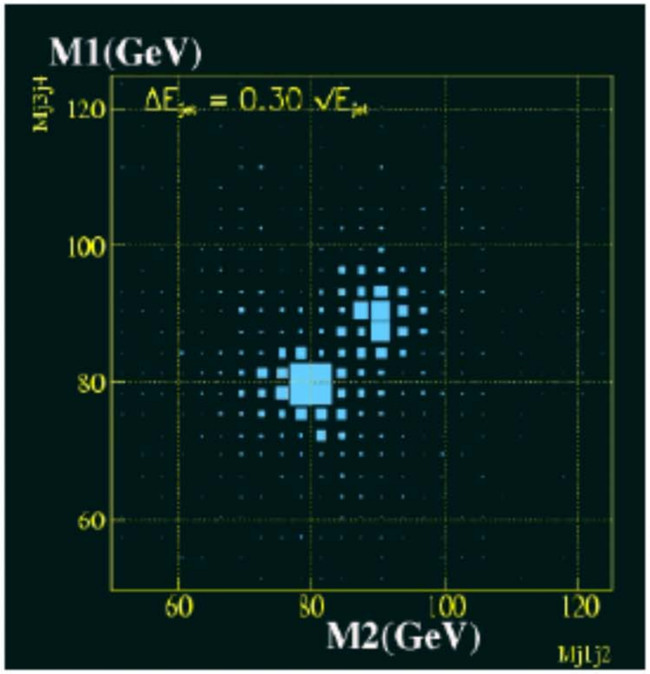
e.g: Separation of WW and ZZ

$$e^+e^- \to \nu\bar{\nu}W^+W^-, \nu\bar{\nu}ZZ\,, \quad W, Z \to 2\text{jets}$$

$$\frac{\sigma_E}{E} = \frac{0.6}{\sqrt{E}}$$



$$\frac{\sigma_E}{E} = \frac{0.3}{\sqrt{E}}$$



$\frac{\sigma_E}{E} \sim \frac{0.3}{\sqrt{E}}$ is 'needed'.

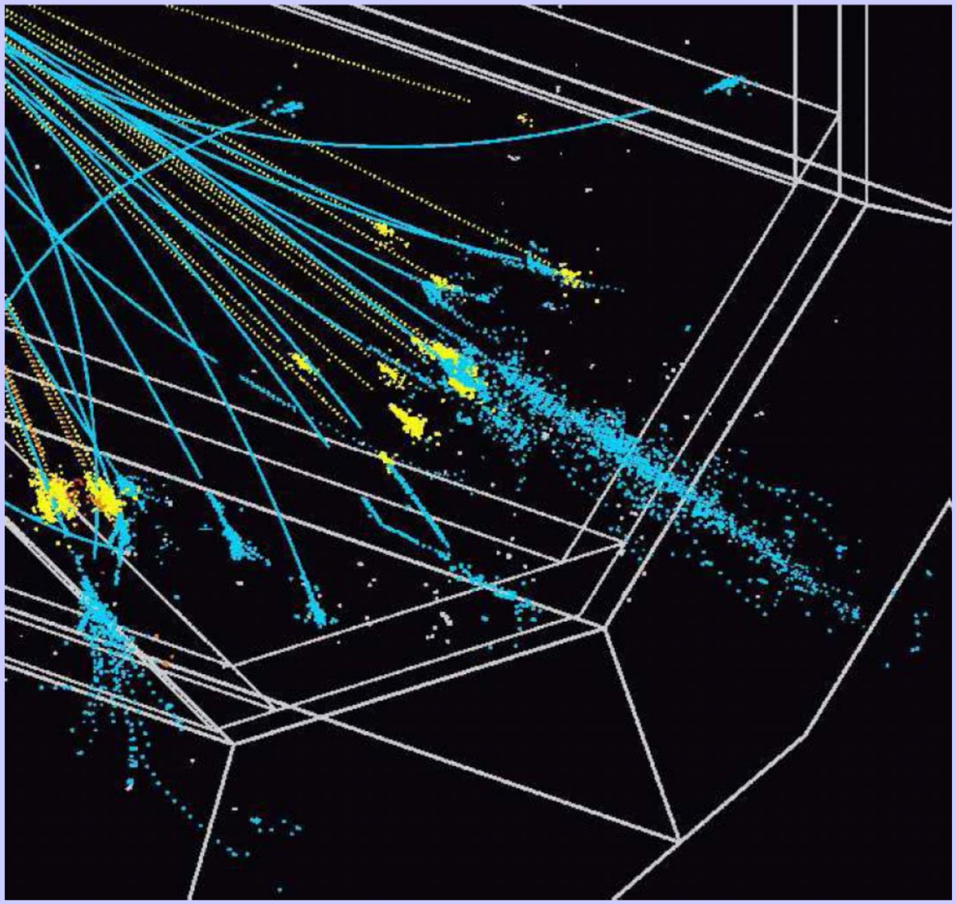
For jets !!!!

How to Achieve $\Delta E/E = 0.3/\sqrt{E}$

- **Must improve beyond sampling calorimeters**
- **Proposal → Use "energy / particle flow"**
  - EM calorimeter (EMCAL) used to measure photons and electrons
  - Track charged hadrons from tracker through EMCAL
  - Identify energy deposition in hadron calorimeter (HCAL) with charged hadrons & replace deposition with measured momentum
  - The remaining energy of neutral hadrons (K's, Lambda's) is measured by sampling calorimetry
- **Requires imaging calorimeter with very fine transverse segmentation and large dynamic range and EM resolution**

How to Achieve $\sigma_E/E = 0.3/\sqrt{E}$

- **Simulation studies are underway to determine transverse and longitudinal sampling and test algorithms.**
- **Beam tests are needed to demonstrate the technique and resolutions achieved**



Imaging calorimeter, where spatial resolution becomes as important as energy resolution.

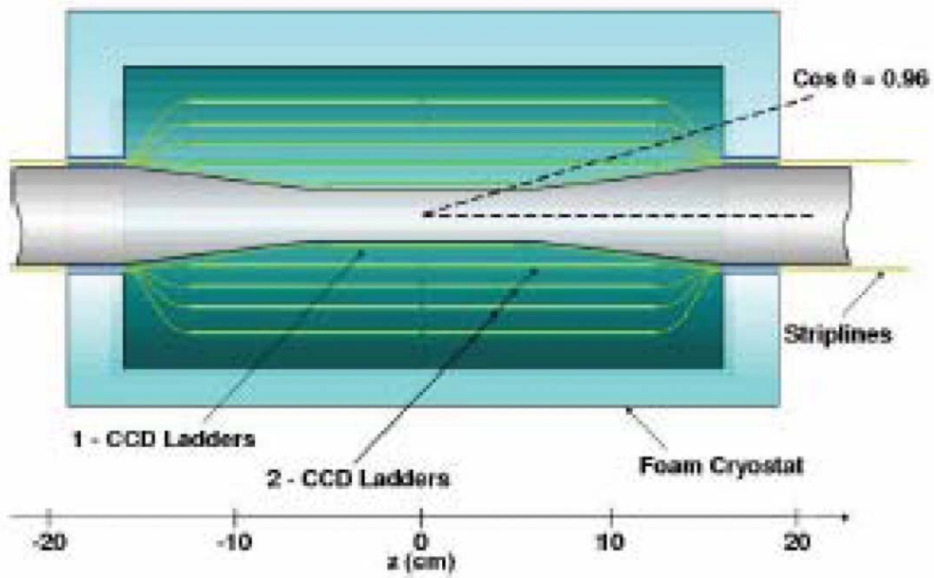
ILC Energy Flow Calorimetry

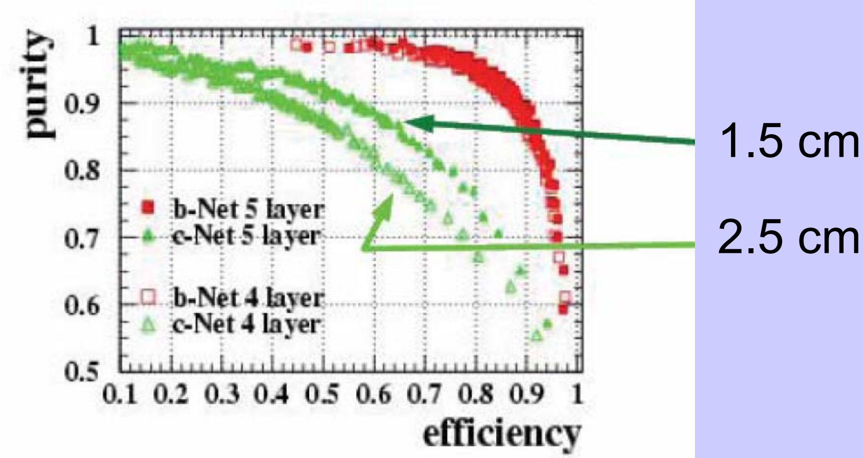
- **Jet energy measurement is by the Energy/particle flow algorithm**
- **Charged particle momentum is measured by tracker**
- **Photon energy is measured by ECAL**
- **Neutral hadron (K_L n) energy is measured by HCAL(+ECAL)**
- **Separate these particles in the calorimeters**

- $\sigma(E_{jet})^2 = \Sigma\Delta E_{ch}^2 + \Sigma\Delta E_{\gamma}^2 + \Sigma\Delta E_{neutral\ had}^2 + \Sigma\Delta_{confusion}^2$

- **Due to high particle density in the core of jet and large fluctuation of HCAL energy flow, jet energy resolution is dominated by $\Delta E_{neutral\ had}$ and $\Delta_{confusion}$**

Vertex Detectors





- Measurement of Higgs Boson coupling requires high purity and high efficiency b- and c-quark identification
- High occupancy due to soft e+e- pairs created by Beamstrahlung, therefore Si pixel detector
- The inner layers must be as thin close to the beam as possible

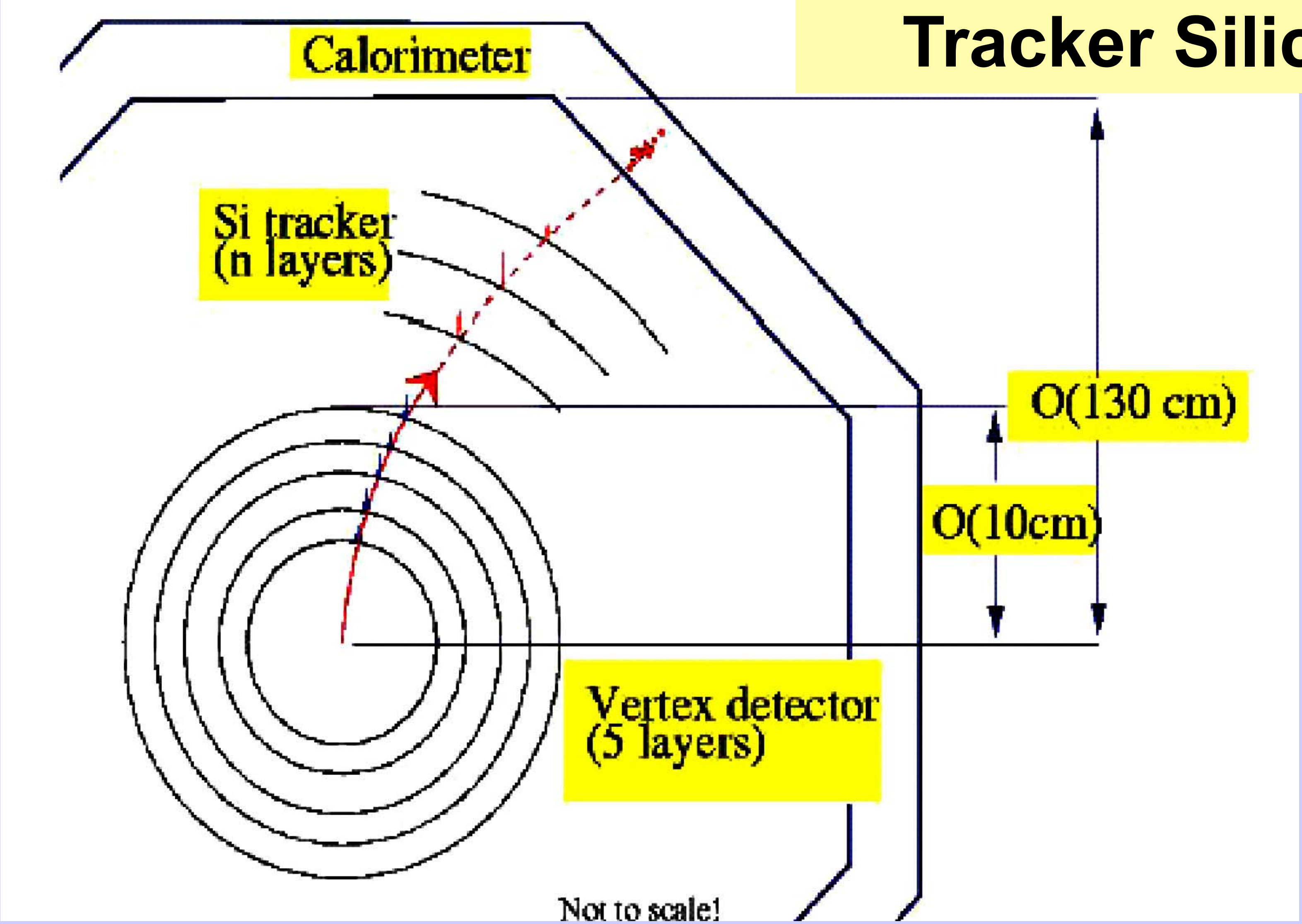
Tracking Considerations

- **Momentum resolution (hit position accuracy, calibration, alignment)**

$$\Delta p/p^2 \sim \sigma/R^2B\sqrt{N}$$

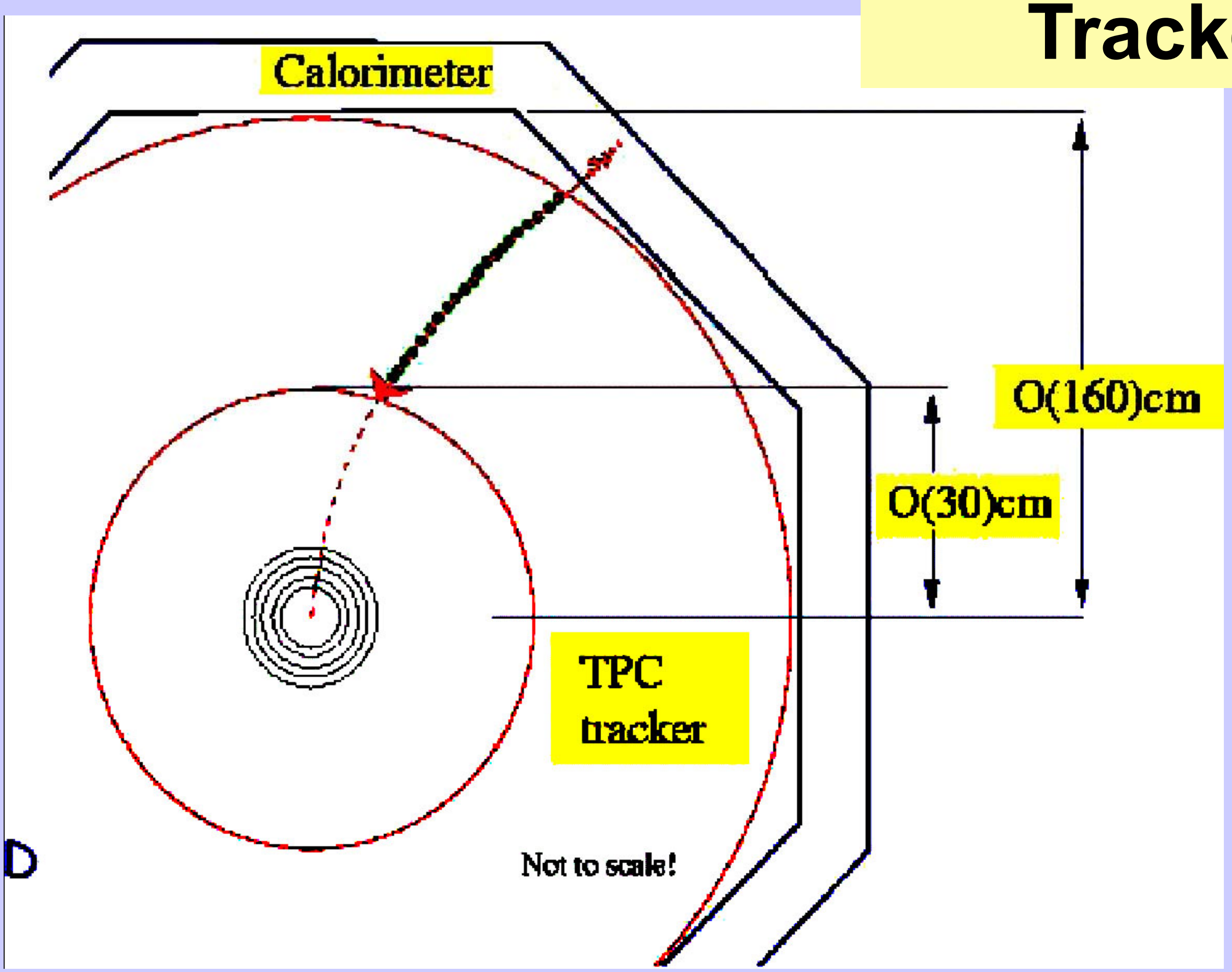
- **Pattern recognition efficiency ~ N**
- **Need robustness vs background**
- **Two approaches in the Detector Concepts**

Tracker Silicon



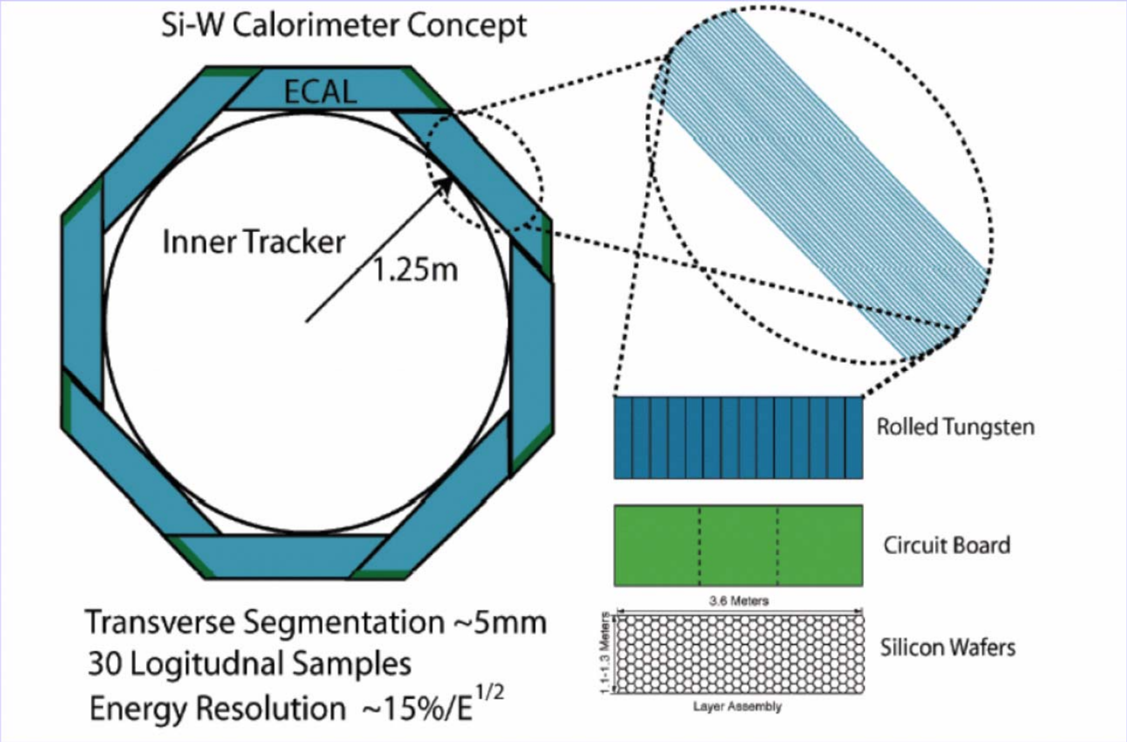
- **5 layers of pixel detectors and 5 layers of Si-strip**

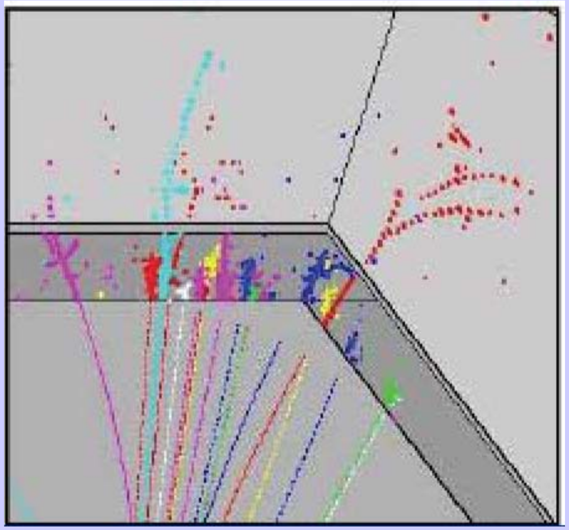
Tracker TPC



- $\mathcal{O}$(200pts) in TPC; 5 layers pixel vertex detectors; $\mathcal{O}$(2) Silicon tracking layers

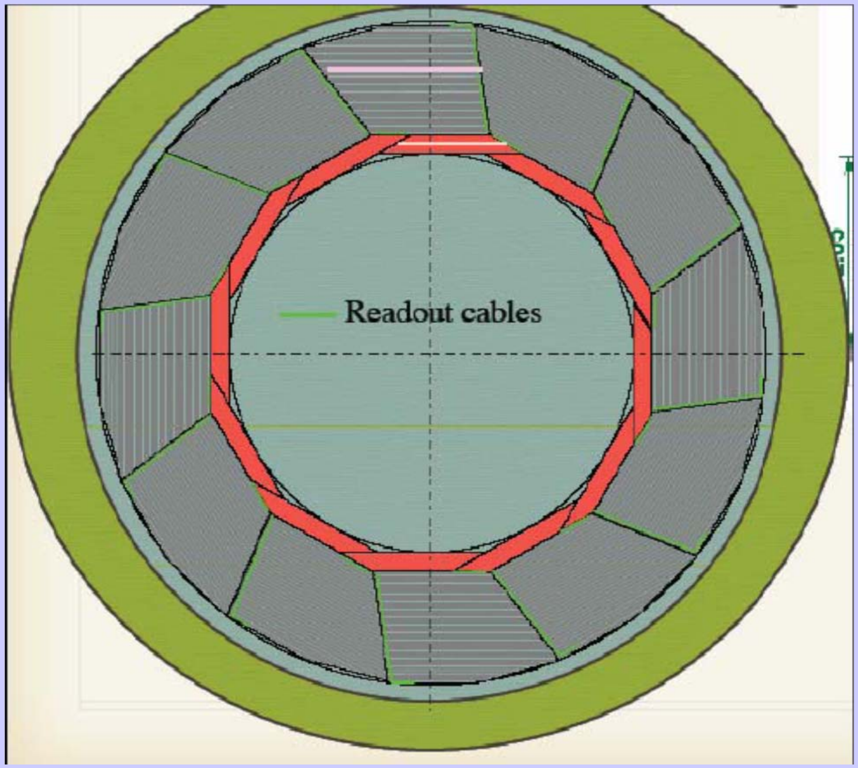
EM Calorimeter





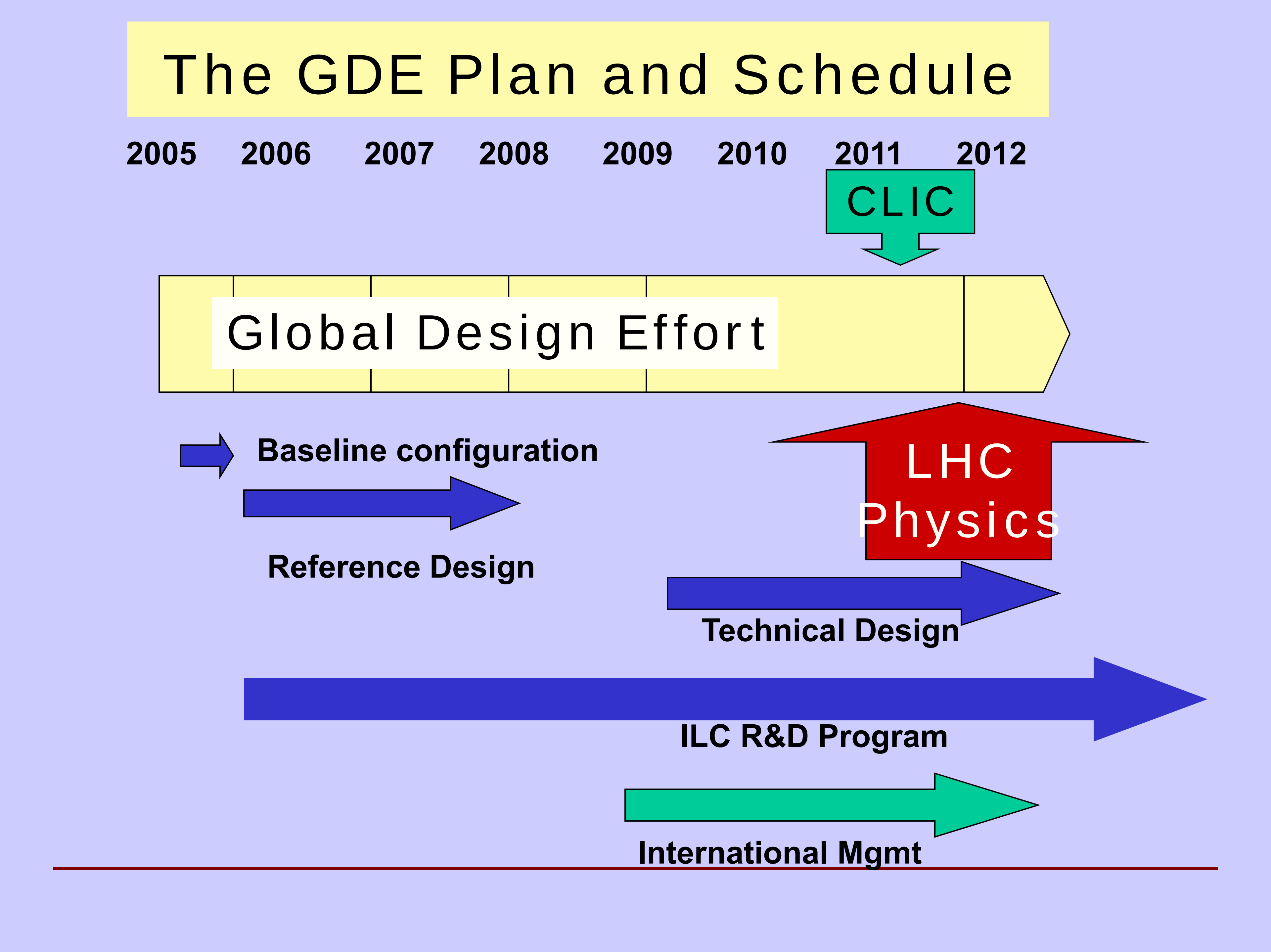
- **Electro-magnetic Calorimeter Tungsten is an ideal material**
  - **short radiation length 3.5mm**
  - **small Moliere radius 9mm**
  - **Si-sensor / Si-PMT**

Hadronic Calorimeter

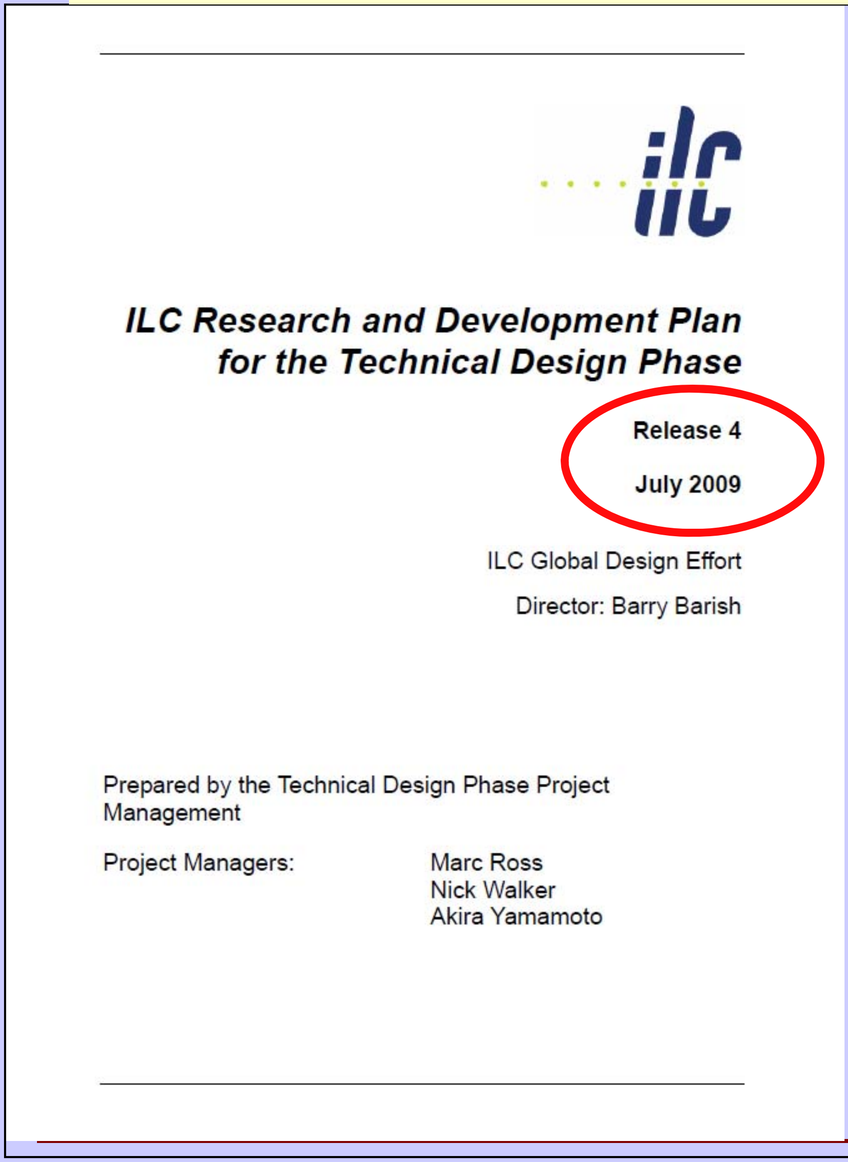


Hadron Calorimeter
Digital vs analog

- **Granularity, Hermeticity, Energy resolution, Thickness**


The GDE Plan and Schedule
2005
2006
2007
2008
2009
2010
2011
2012
CLIC
Global Design Effort
Baseline configuration
LHC Physics
Reference Design
Technical Design
ILC R&D Program
International Mgmt

What's Next? - Technical Design Phase


ILC Research and Development Plan for the Technical Design Phase

Release 4

July 2009

ILC Global Design Effort

Director: Barry Barish

Prepared by the Technical Design Phase Project Management

Project Managers: Marc Ross, Nick Walker, Akira Yamamoto

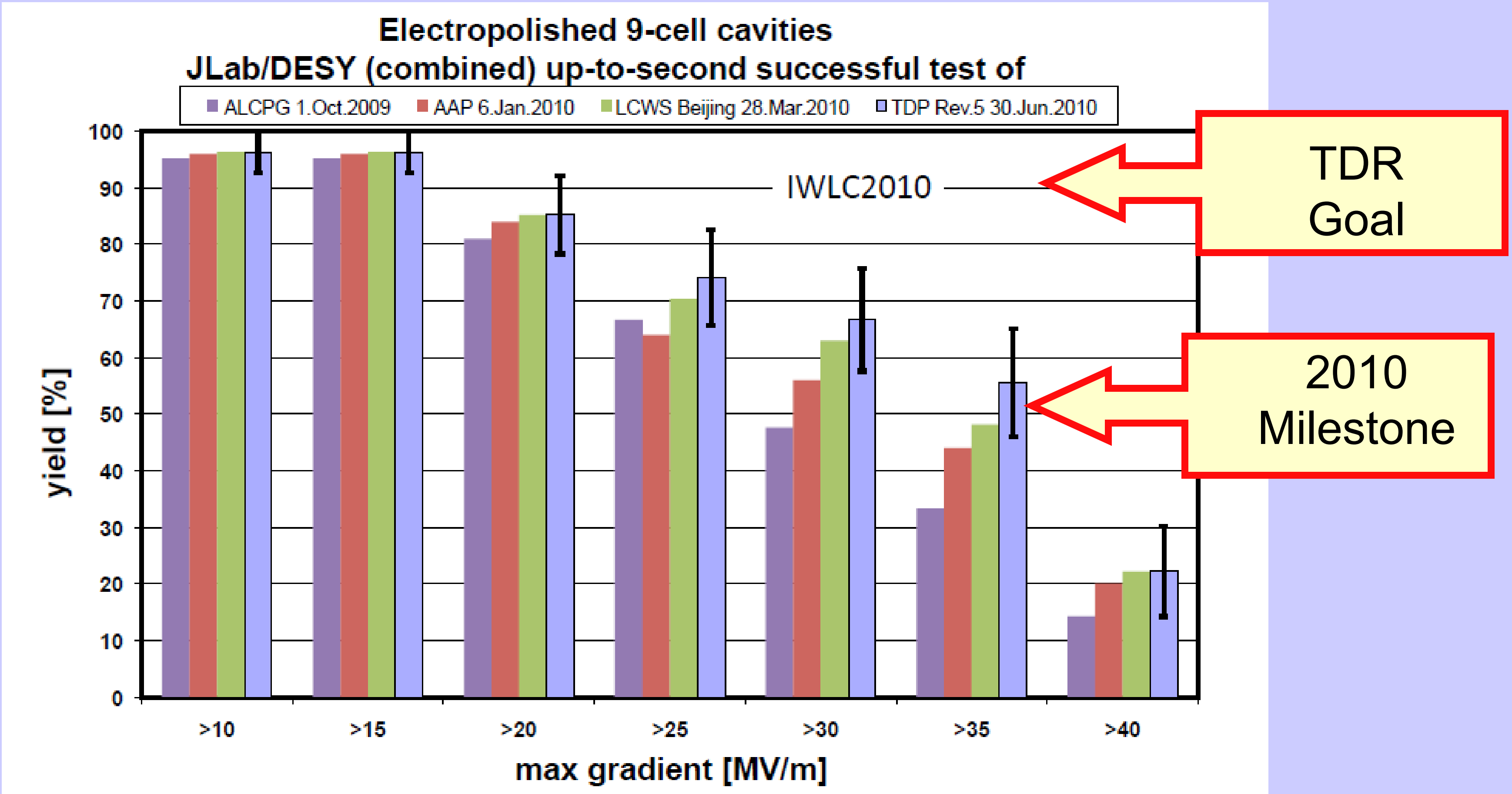
Major TDP Goals:

- ILC design evolved for cost / performance optimization
- Complete crucial demonstration and risk-mitigating R&D
- Updated VALUE estimate and schedule
- Project Implementation Plan

Global Plan for SRF R&D

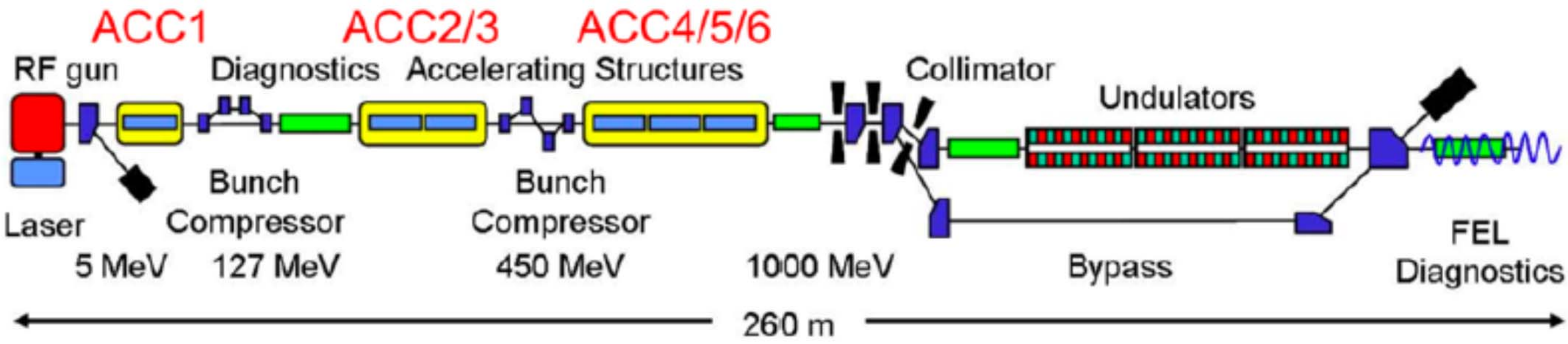
Year	07	2008	2009	2010	2011	2012
Phase	TDP-1				TDP-2	
Cavity Gradient in v. test to reach 35 MV/m	→ Yield 50%				→ Yield 90%	
Cavity-string to reach 31.5 MV/m, with one-cryomodule		Global effort for string assembly and test (DESY, FNAL, INFN, KEK)				
System Test with beam acceleration		FLASH (DESY) , NML (FNAL) STF2 (KEK, test start in 2013)				
Preparation for Industrialization			Production Technology R&D			

Cavity Gradient Milestone Achieved



TTF/FLASH 9mA Experiment

Full beam-loading long pulse operation → "S2"



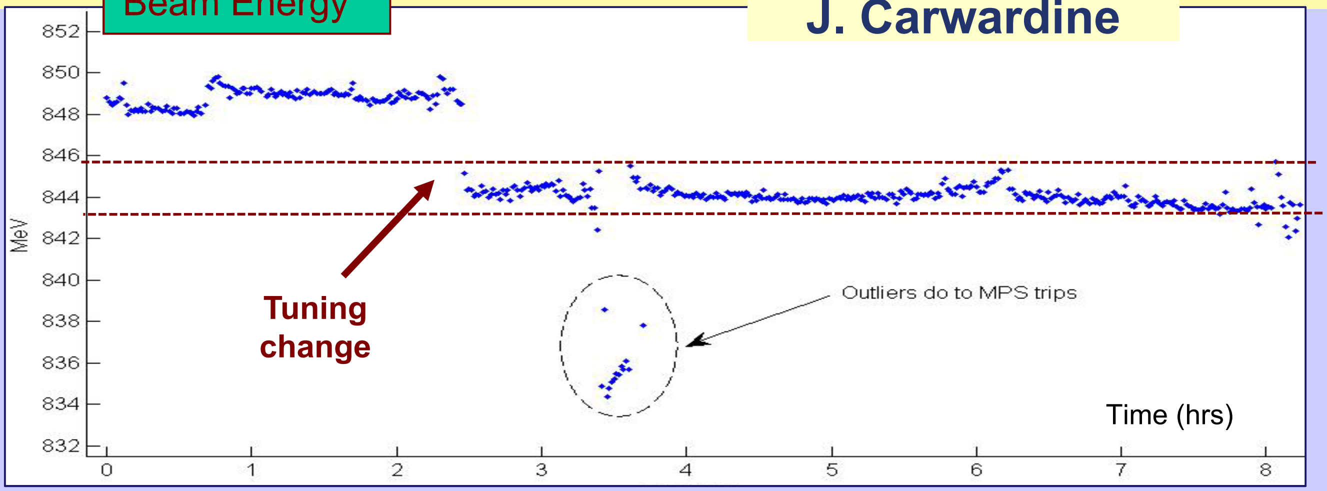
		XFEL	ILC	FLASH design	9mA studies
Bunch charge	nC	1	3.2	1	3
# bunches		3250	2625	7200*	2400
Pulse length	µs	650	970	800	800
Current	mA	5	9	9	9

- Stable 800 bunches, 3 nC at 1MHz (800 µs pulse) for over 15 hours (uninterrupted)
- Several hours ~1600 bunches, ~2.5 nC at 3MHz (530 µs pulse)
- >2200 bunches @ 3nC (3MHz) for short periods

Energy stability over 8hrs (3mA, 800us bunch trains)

J. Carwardine

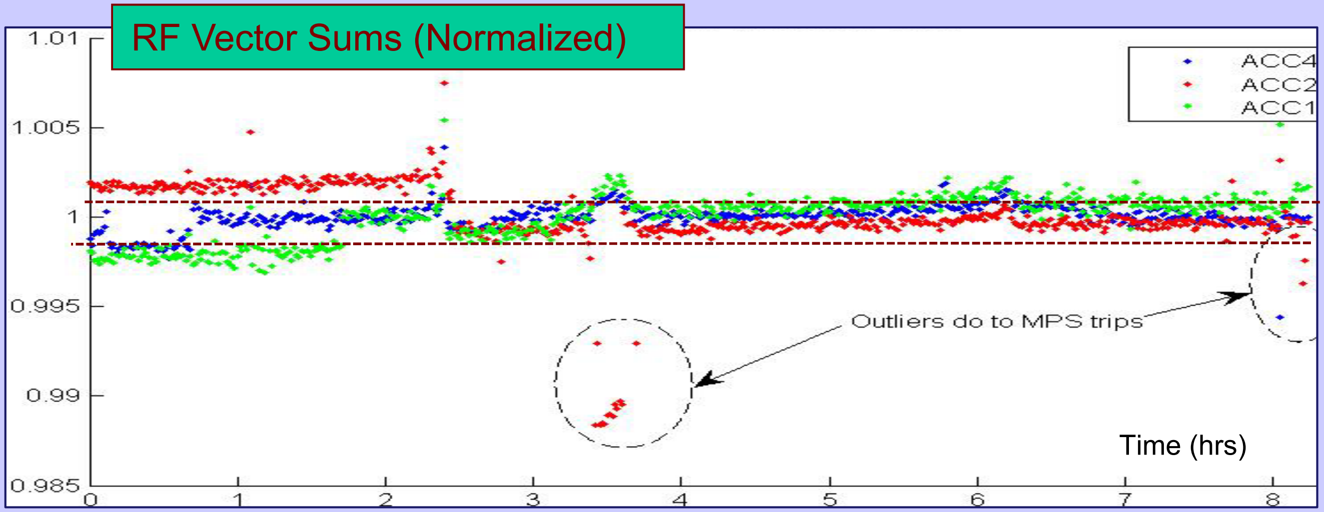
844 MeV



2MeV (0.25%)

(Spec: +/-0.1%)

Nominal

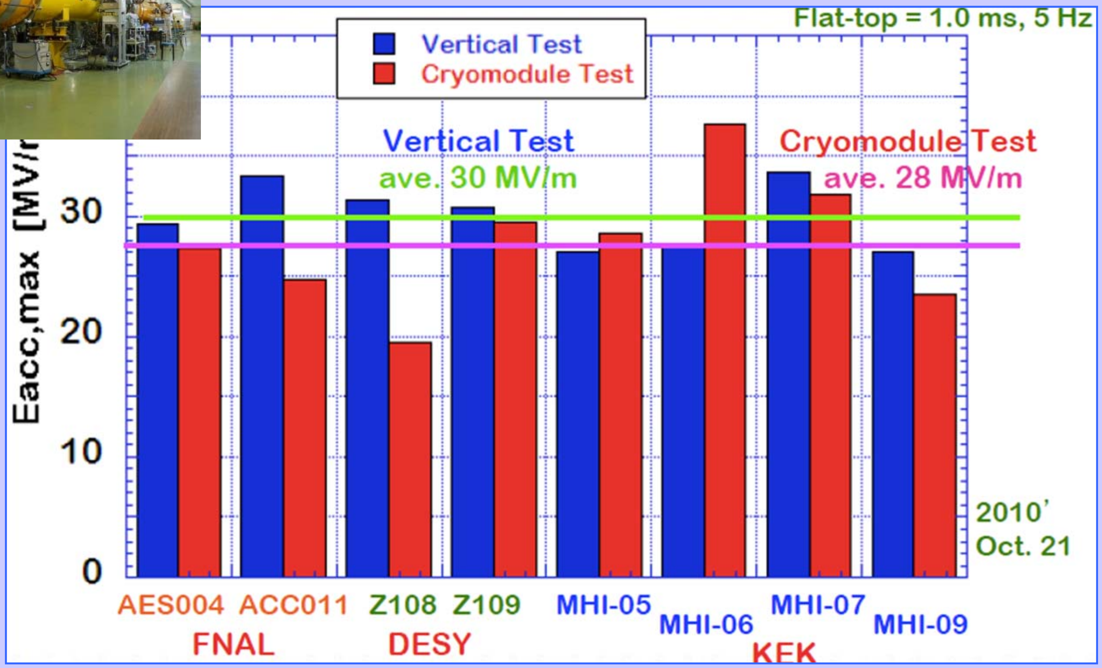


0.2%

8 hrs

S1-Global Cryomodule Test in Progress

DESY, FNAL, IHEP, INFN, KEK, SLAC Cooperation



<u>Vertical cavity test</u>

- CW low power test reached:

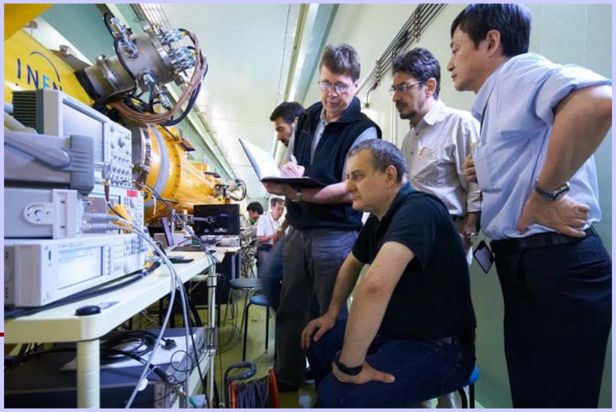
  < 30 MV/m >

<u>S1-Global cryomodule</u>

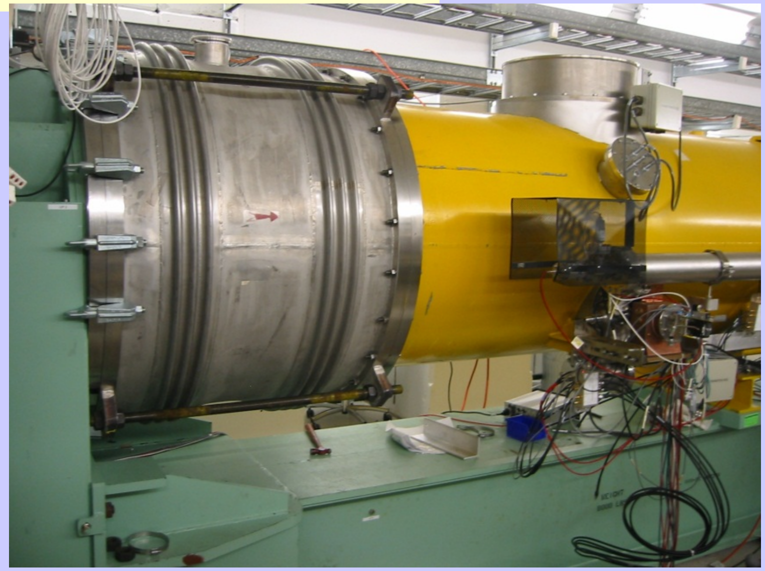
- 1ms, 5 Hz pulse Individual test reaching:

  < 28 MV/m >

{as of Oct. 22, 2010}



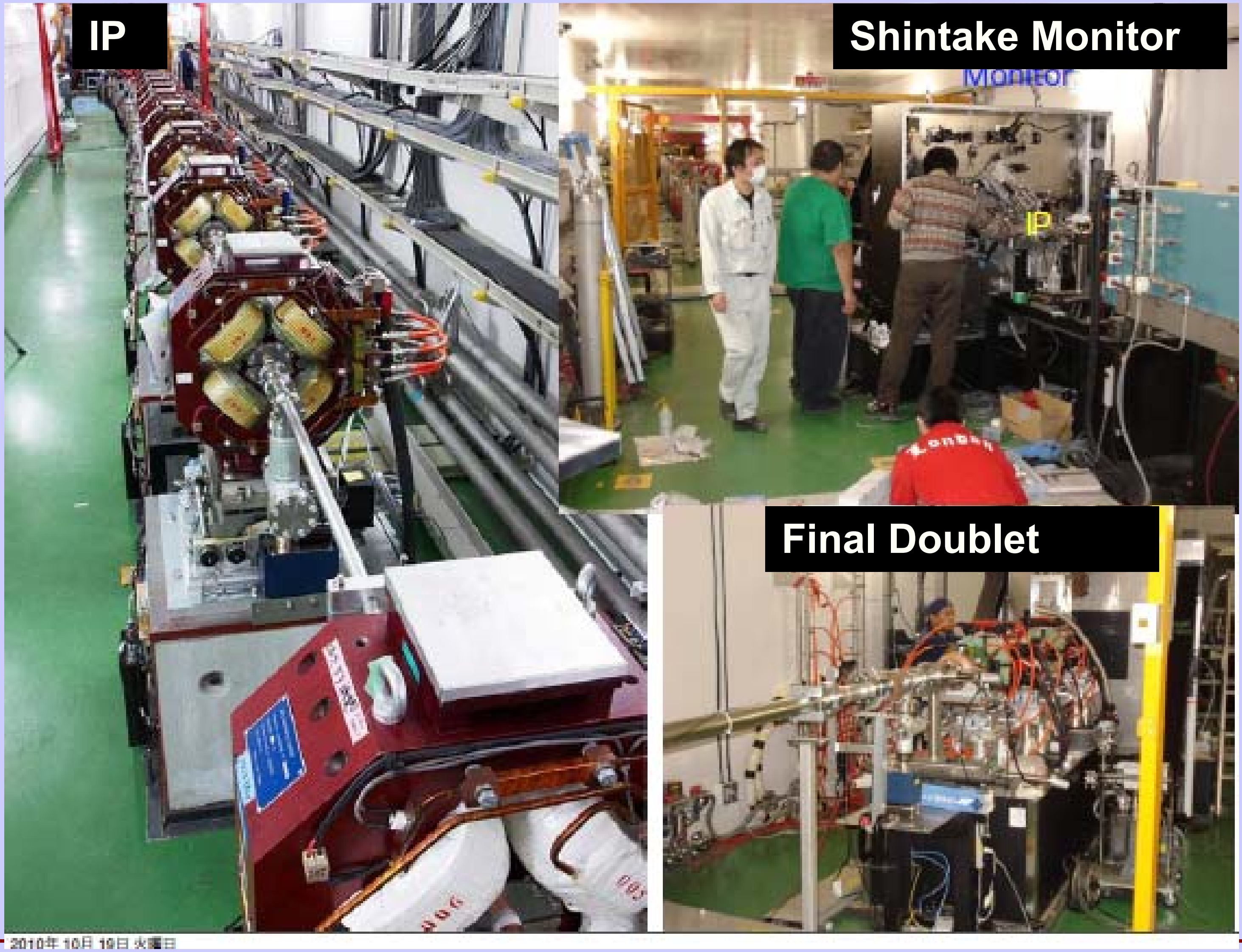
NML Cryomodule



NML CM1 cryomodule (Fermilab, DESY, INFN).

Closed and cool down is imminent.

ATF2 – Beam size/stability and kicker tests



ATF2 (KEK) Status/Plans

T. Tauchi

DR vertical emittance to < 2pm as the ILC-DR

BPM electronics was upgraded after IPAC10, June 2010.

Fast kicker studies next study in October, 2010

(1) Good performance for single bunch beam, i.e. angular jitter of about 4×10^{-4}

(2) Need improvements for multi-bunch beam
for the FID pulser, BPM system, stable generation and storage in DR

R&Ds for the 2nd goal of ATF2 and ILC-BDS

(1) FONT5 : good progress, i.e. very impressive results

(2) IPBPM : tested at the upstream, wakefield effects seen,
KNU electronics will be updated at KNU.

(3) LW : installed and tested in the last run in April, 2010

(4) Multi-OTR system was installed in May, 2010.

ATF2 < 100nm and 37nm by December, 2010, and March 2011, respectively

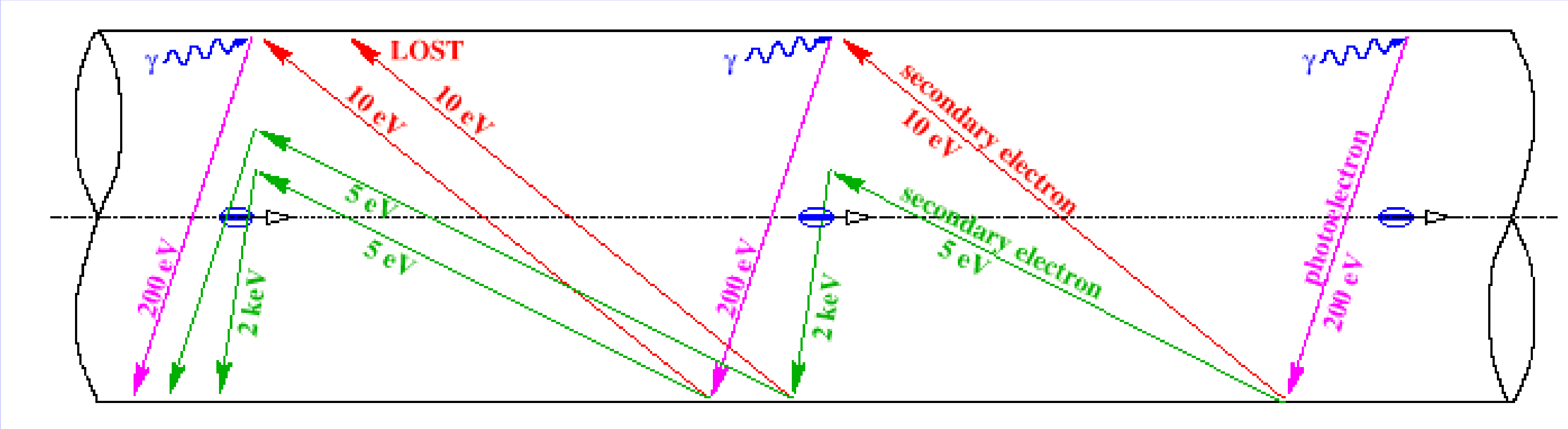
(1) All the instruments have been commissioned; i.e. BPMs, IPBSM etc.

(2) Beam tuning knobs have been developed and were also commissioned.

(3) The continuos run was successful to achieve 300nm beam size;
Improvements during this summer, e.g. FD alignment, Shintake monitor, BPMs

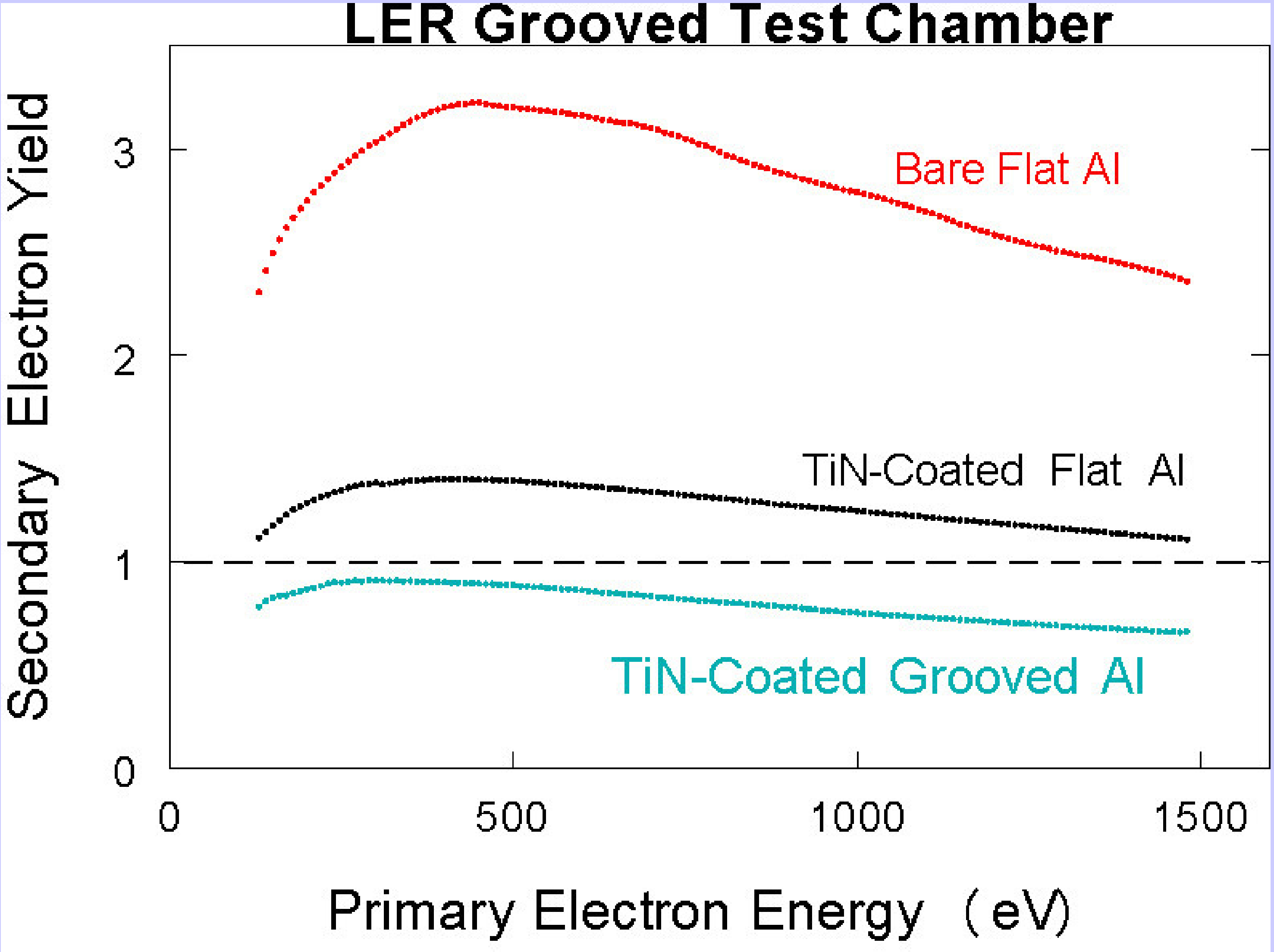
eCloud R&D

- Mitigating Electron Cloud

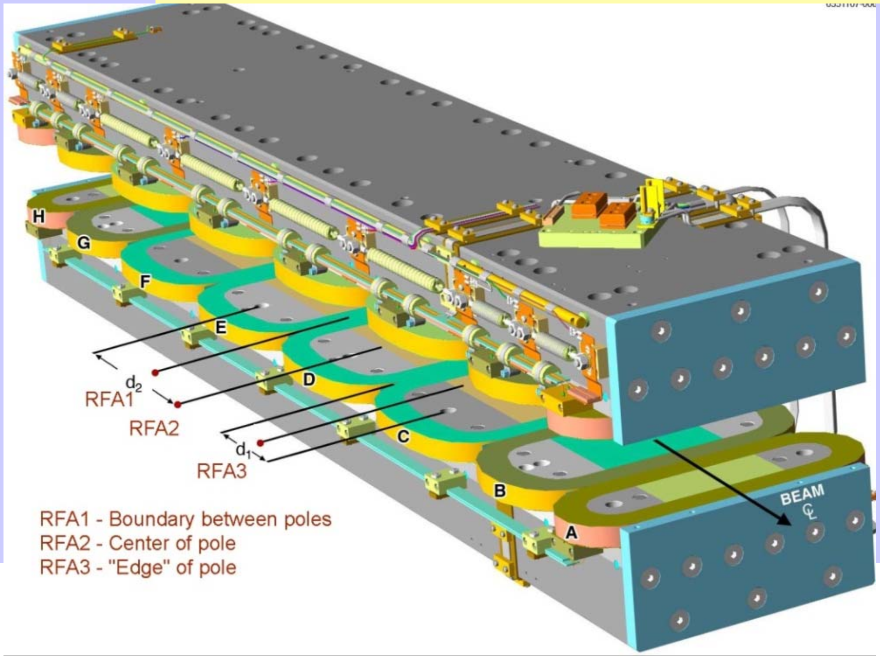


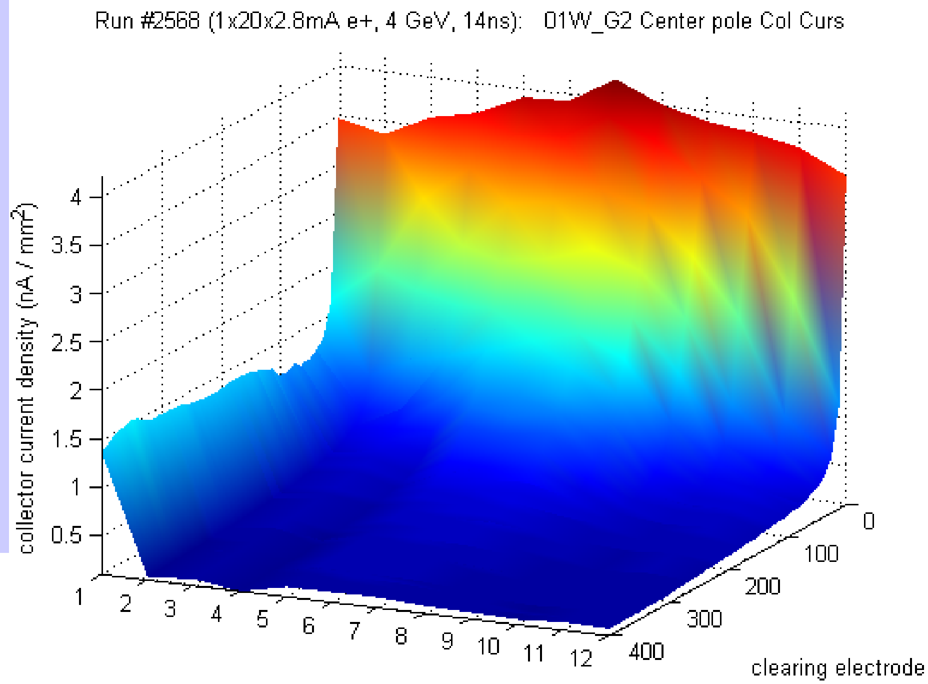
- Simulations – electrodes; coating and/or grooving vacuum pipe
- Demonstration at CESR critical tests

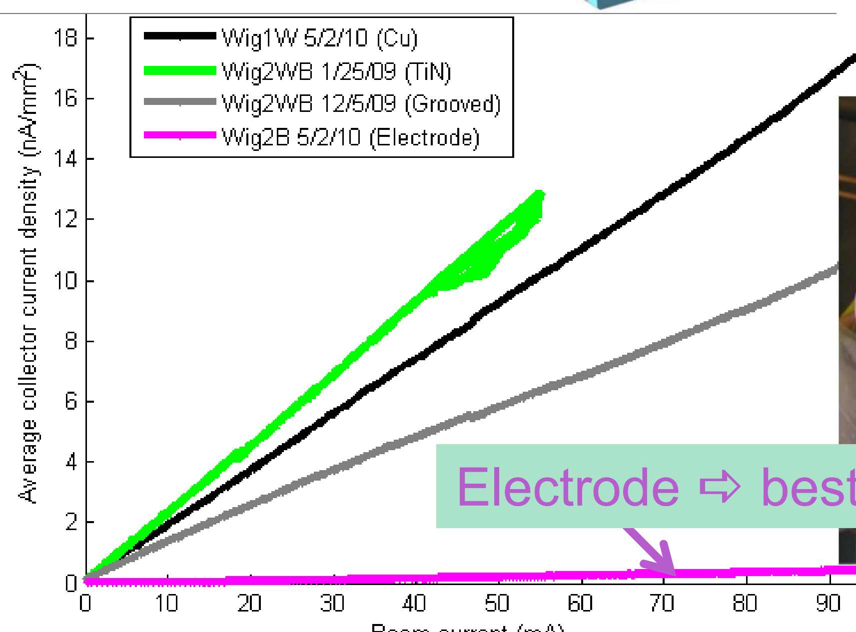
Mitigation - Simulation Studies



CesrTA – Wiggler Observations







CESRTA - eCloud

Mitigation performance:

- **Grooves are effective in dipole/wiggler fields, *but challenging to make when size is small***
- **Amorphous C, TiN and NEG show similar levels of EC suppression so each is a potential candidate for DR use**
  - **TiN and a-C have worse dP/dI than Al chambers at our present level of processing**
  - **In regions where TiN-coated chambers are struck by wiggler radiation (high intensity and high E_c), we observe significant concentrations of N in the vacuum system**
- **EC suppression with the clearing electrode in the wiggler is significantly better than other options**
  - **No heating issues have been observed with the wiggler design in either CESRTA or CHESS operating conditions**
- **Work is in progress to take RFA measurements in chambers with mitigations and convert these to the effective SEY of the chamber surfaces**
  - **Agreement between data and simulation looks very promising**
  - **Magnetic field region model requires full inclusion of RFA in simulation**
- **Trapping and build-up of the EC over multiple turns in quadrupole and wiggler chambers**
  - **Simulation and experimental evidence**
  - **Further evaluation of impact on the beam is required**

Design Update

Global Design and Decision Making

Why change from RDR design?

- Timescale of ILC demands we continually update the technologies and evolve the design to be prepared to build the most <u>forward looking</u> machine at the time of construction.

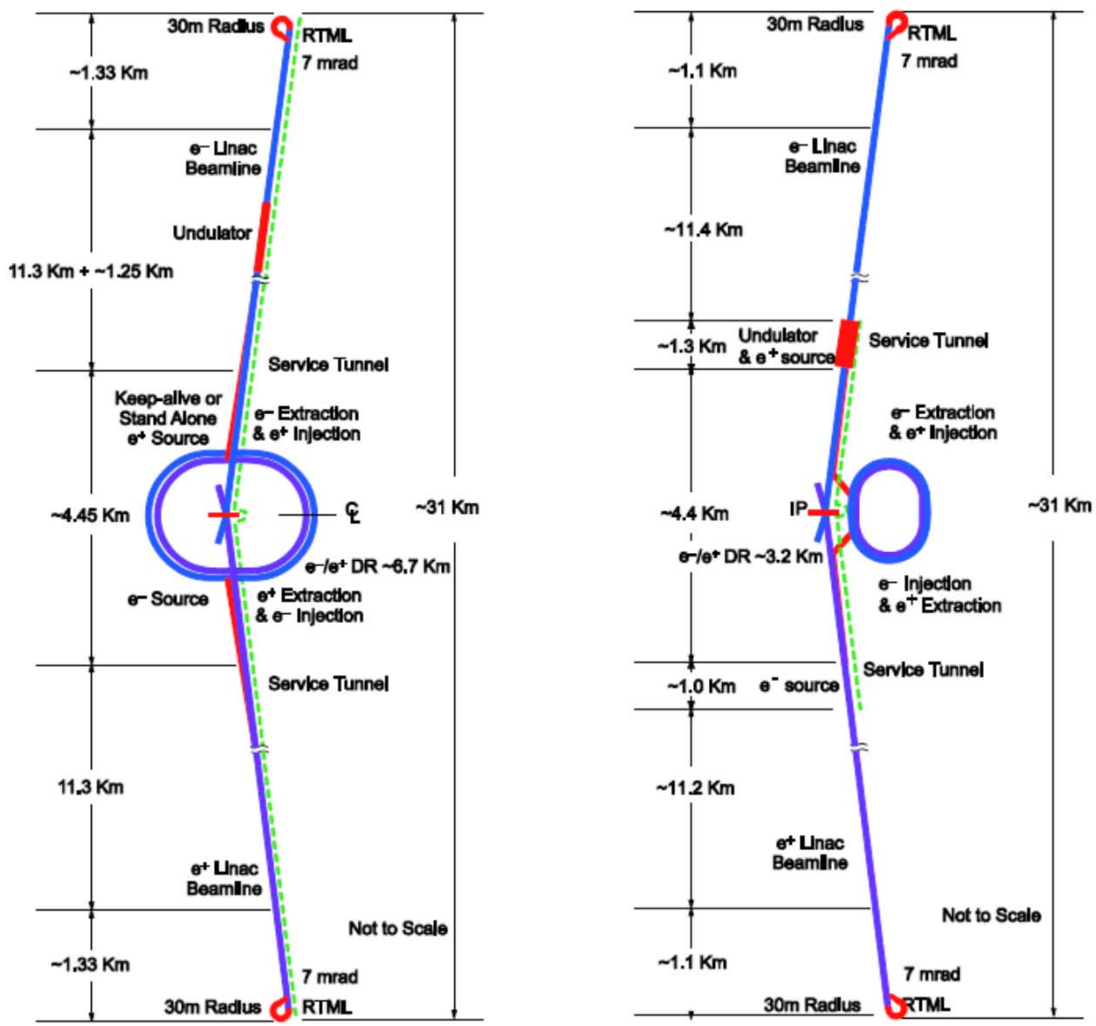
- Our next big milestone – the technical design (TDR) at end of 2012 should be as much as possible a <u>“construction project ready” design</u> with crucial R&D demonstrations complete and design optimised for performance to cost to risk.

- <u>Cost containment</u> vs RDR costs is a crucial element. (Must identify costs savings that will compensate cost growth)

Proposed Design changes for TDR

RDR

SB2009



- Single Tunnel for main linac
- Move positron source to end of linac ***
- Reduce number of bunches factor of two (lower power) **
- Reduce size of damping rings (3.2km)
- Integrate central region
- Single stage bunch compressor

Top Level Change Control Process

Issue Identification

- Planning
- Identify further studies
- Canvas input from stakeholders
- …

Baseline Assessment Workshops

- Face to face meetings
- Open to all stakeholders
- Plenary

Formal Director Approval

- Change evaluation panel
- Chaired by Director

keywords: open, transparent

TLCC Process

Baseline Assessment Workshops

- Face to face meetings
- Open to all stakeholders
- Plenary

Physics and detector input / representation mandatory

	When	Where	What
BAW 1	Sept. 7-10, 2010	KEK	1. Accelerating Gradient 2. Single Tunnel (HLRF)
BAW 2	Jan 18-21, 2011	SLAC	3. Reduced RF 4. e+ source location

TLCC Process

Baseline Assessment Workshops

- **Face to face meetings**
- **Open to all stakeholders**
- **Plenary**

- Open plenary meeting
- Two-days per theme
- Two themes per workshop
  - Two four-day workshops
- Participation (mandatory)
  - PM (chair)
  - ADI team / TAG leaders
    - **Agenda organised by relevant TAG leaders**
  - Physics & Detector Representatives
    - **Brau, Buesser, Markiewicz, Fujii & Thomson**
  - External experts
- Achieve primary TLCC goals
  - In an open discussion environment
- Prepare recommendation

Proposals Received

Proposal to adopt a single tunnel configuration for the ILC main linac

Submitted by ILC GDE Project Managers for consideration as a Baseline Change Request, 28 September, 2010.

Introduction

The proposal to adopt a single tunnel solution for the Main Linac technical systems remains essentially that outlined in the SB2009 report. The primary motivation was and remains a reduction in project cost due to the removal of the support tunnel for the Main Linac. (The service tunnel for the BDS remains.)The

BAW-1: ML Accelerator Gradient
Summary of Discussions and Proposal

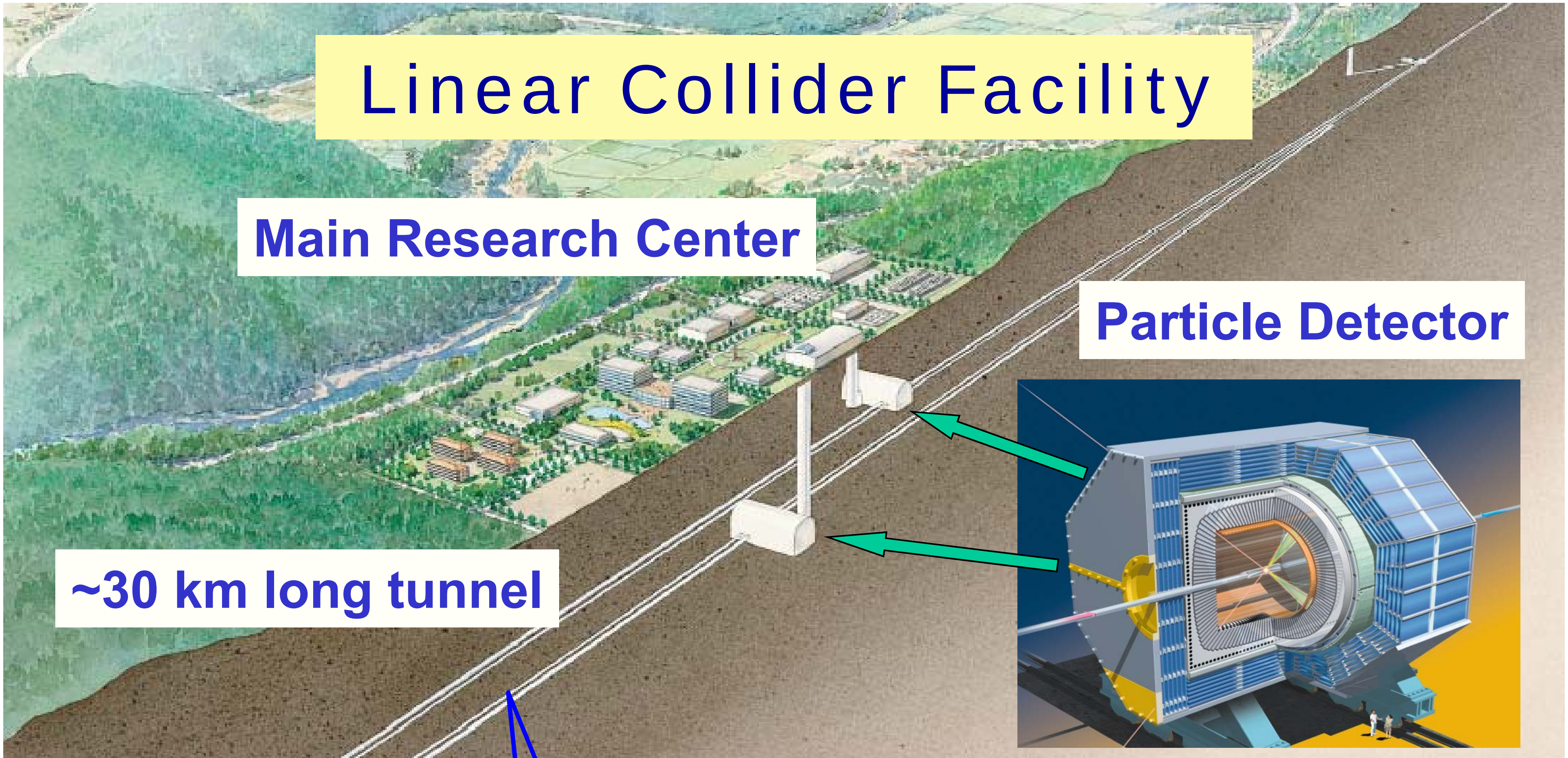
Proposal submitted by ILC GDE Project Managers for consideration as a Baseline Change Request, 28 September, 2010.

Summary

We discussed the optimum Main Linac (ML) operational field gradient based on the current status of the global R&D effort and the evaluation of achieving the milestone cavity performance of 35 MV/m, with $Q_0 \geq$ 8E9, and a second pass production yield of 56% in the middle of TDP.

As a result of the workshop discussions, we propose keeping our best effort to realize a ML accelerator operational gradient of $\geq$ 31.5 MV/m with $Q_0 \geq$ 1E10, on average, with a gradient spread of not larger than ±20%.

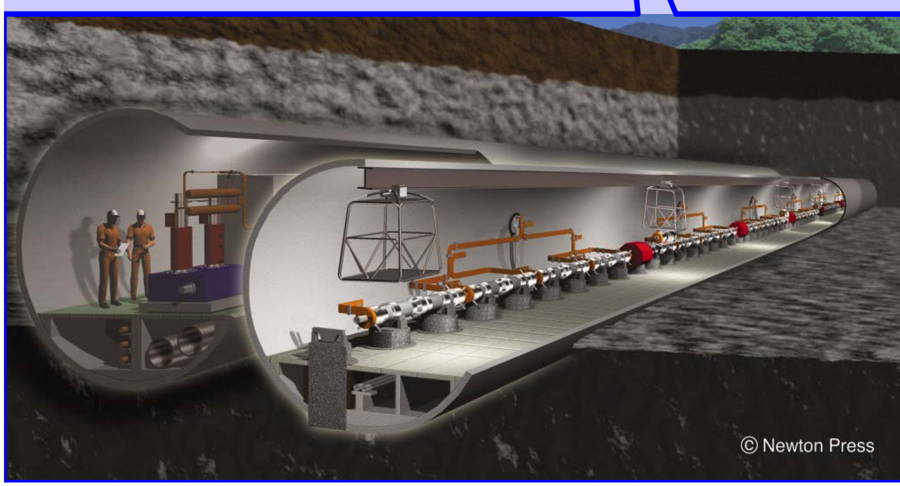
Linear Collider Facility



Main Research Center

Particle Detector

~30 km long tunnel



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

Conventional Facilities

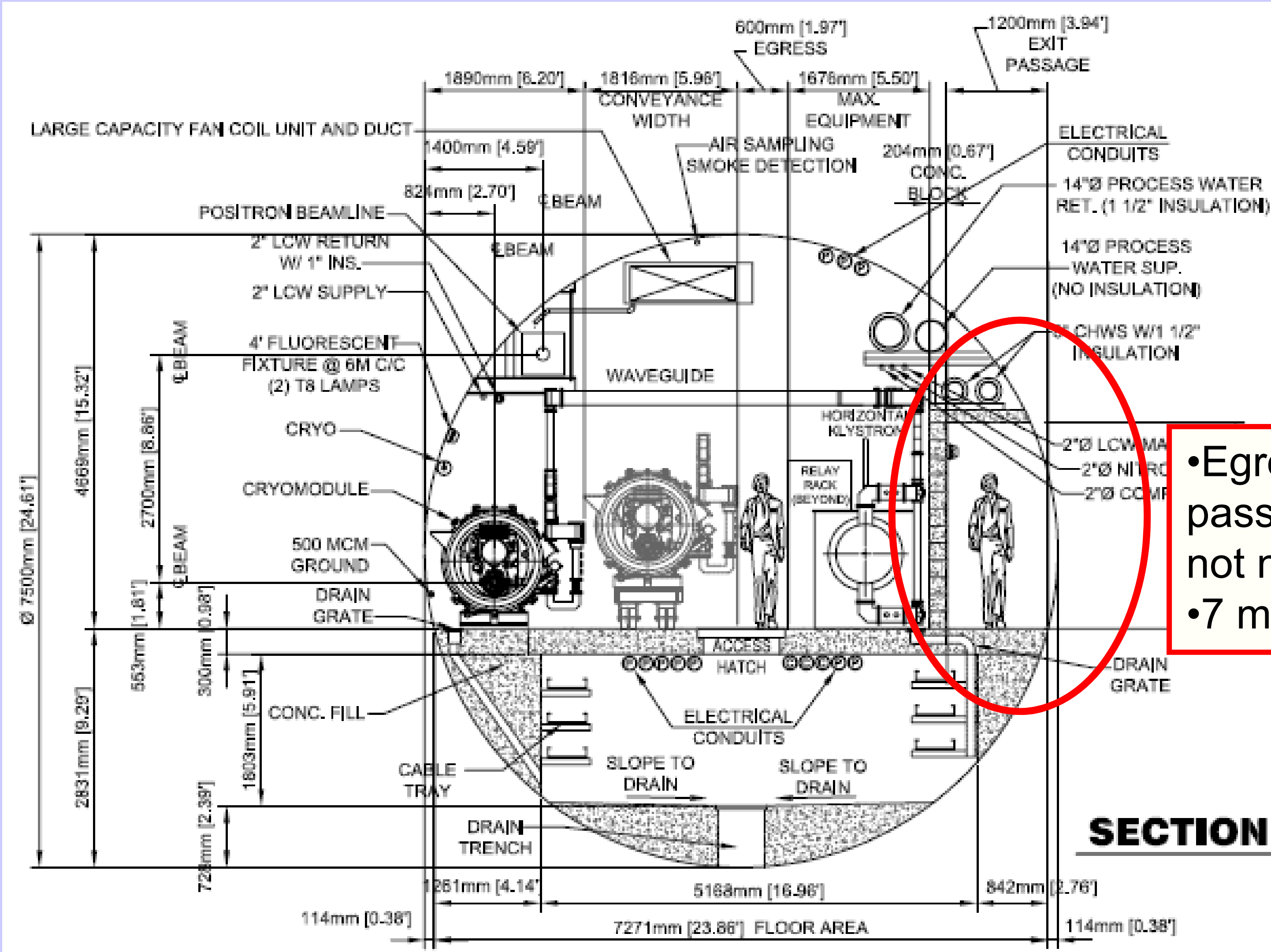
72.5 km tunnels ~ 100-150 meters underground

13 major shafts $\geq$ 9 meter diameter

443 K cu. m. underground excavation: caverns, alcoves, halls

92 surface "buildings", 52.7 K sq. meters = 567 K sq-ft

7.5 m Diameter Single Tunnel



- Egress passageway not needed;
- 7 m Ø ok

7.5 m Diameter Single Tunnel
High-Level RF Solution

- Critical technical challenge for one-tunnel option is the high level RF distribution.
- Two proposed solutions :
  - **Distributed RF Source (DRFS)**
    - Small 750kW klystrons/modulators in tunnel
    - One klystron per four cavities
    - ~1880 klystrons per linac
    - Challenge is cost and reliability
  - **Klystron Cluster Scheme (KCS)**
    - RDR-like 10 MW Klystrons/modulators on surface
    - Surface building & shafts every ~2 km
    - Challenge is novel high-powered RF components (needs R&D)

TLCC Process

Formal Director Approval

- **Change evaluation panel**
- **Chaired by Director**

- Final formal step (recommended by AAP)
- Change Evaluation Panel
  - **Chaired by director**
  - **Experts to evaluate impact on performance, cost, schedule, risk**
  - **F. Asiri, K. Buesser, J. Gao, P. Garbincius, T. Himel, K. Yokoya**
- Decision by Director
  - **Accepts – becomes baseline; guidance in decision memo**
  - **Rejects – sent back for further work with comments**

Plans through 2012

Technical Design Report (TDR)

Technical Design Report

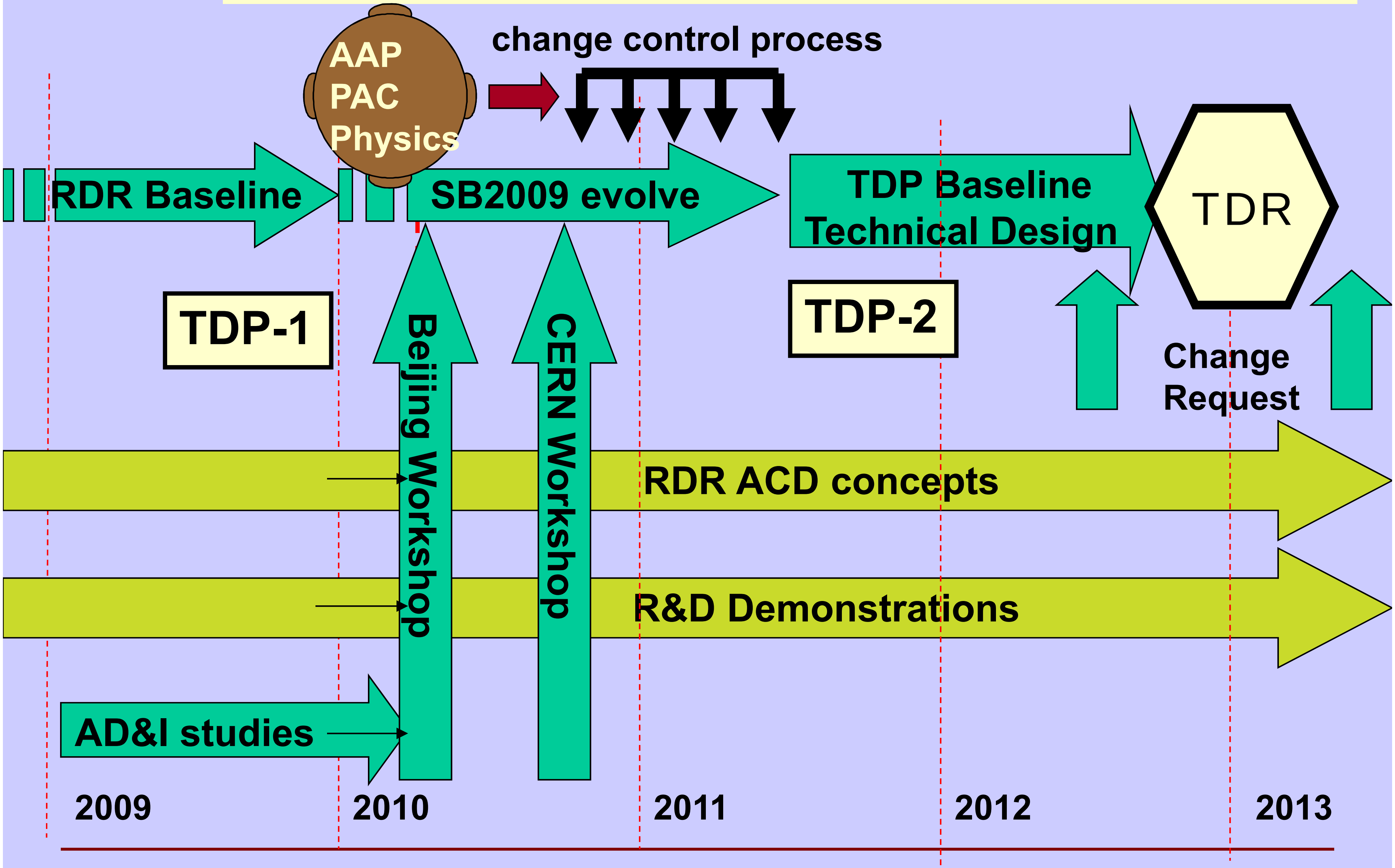
- **Goals**
  - Major R&D demonstrations completed; no outstanding issues of feasibility or large cost impact. (ILC R&D will continue after 2013+)
  - Baseline design will be documented, including a new costing (Cost containment is basic to plan)
  - Site specific issues will be selectively addressed
  - An accompanying Project Implementation Plan (PIP) is being developed (governance, siting, industrialization, management, host responsibilities, etc)

- **Detailed plan for TDR will be developed once baseline is established (e.g. ALCPG11 – Eugene)**

TD Phase 1

- **Timescale: Interim report mid 2010**
- **Major theme: High-priority risk-mitigating R&D**
  - Superconducting RF linac technology – technical demonstration of gradient, plug compatiblity and identifying potential cost reductions
  - Confirm mitigation of electron cloud effects
  - The re-baseline will take place after careful consideration and review of the results of the TD Phase 1 studies and the status of the critical R&D.

Technical Design Phase and Beyond



TD Phase 2

- **Timescale: Produce final reports mid-2012**
  - **Technical Design**
  - **Project Implementation**

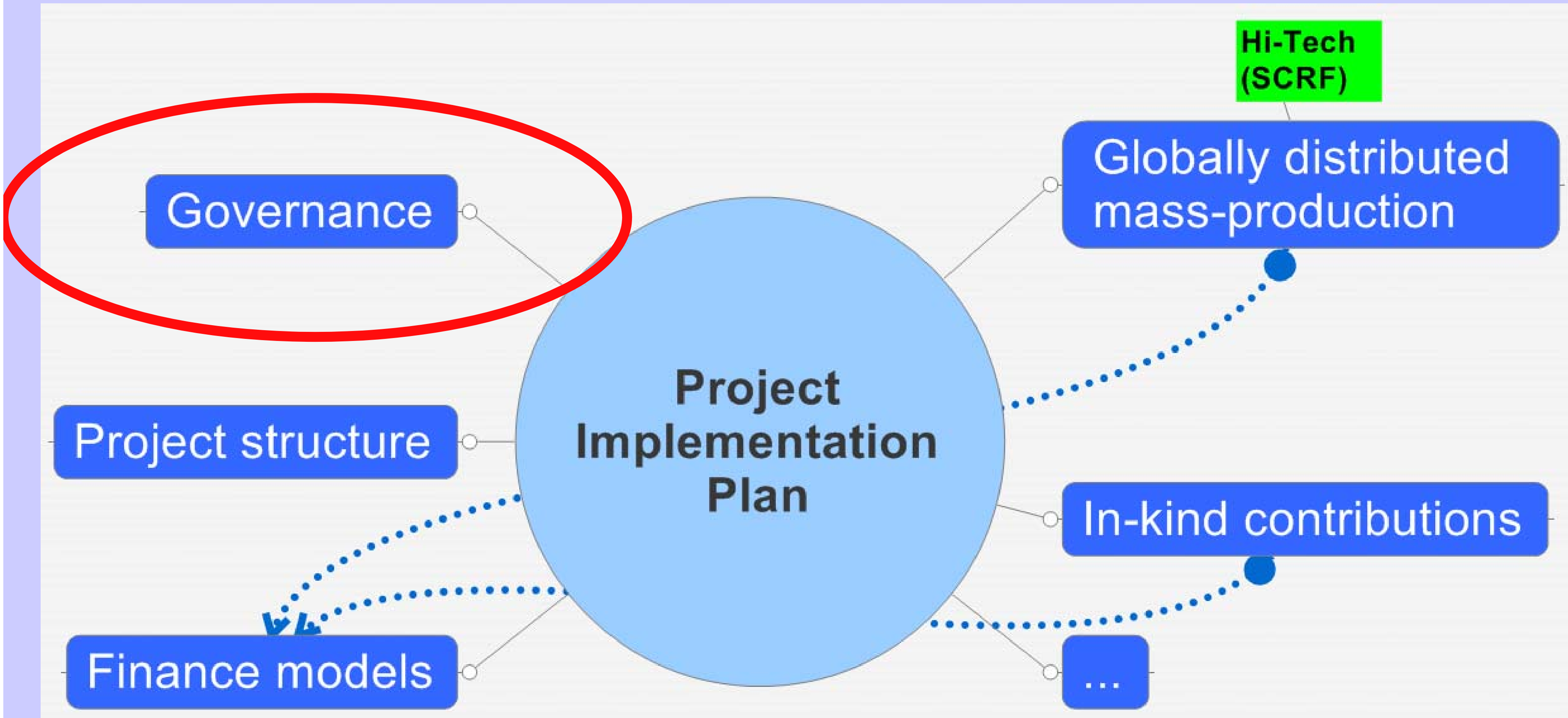
- First goal: **Technical Design**
  - **SCRF – S0 gradient and S1 Global Tests of one RF unit**
  - **Detailed technical design studies (minimum machine)**
  - **Updated VALUE estimate and schedule.**
  - **Remaining critical R&D and technology demonstration identified and planned**

- Second Goal: **Project Implementation Plan**
  - **Studies of governance; siting solicitation and site preparations; manufacturing; etc**

Essential Elements of TDP

- Optimize the design for cost / performance / risk
  - Top down approach to ‘minimum’ design; value engineering; risk mitigation
- Key Supporting R&D Program (priorities)
  - High Gradient R&D - globally coordinated program to demonstrate gradient for TDR by 2010 with 50%yield
  - Electron Cloud Mitigation – Electron Cloud tests at Cornell to establish mitigation and verify one damping ring is sufficient.
  - Final Beam Optics – Tests at ATF-2 at KEK
- GOAL – Bring us ready to propose a solid and defendable “construction project” to world’s governments by 2012 (linked to LHC results)

Project Implementation Plan



Final Remarks

- **ILC accelerator R&D progress and design evolution is on track for <u>Technical Design Report</u> at end of 2012. This will be accompanied a <u>Project Implementation Plan</u>**
- **The first joint CLIC/ILC workshop has been a big success! This is one more step toward bringing these two (competitive) efforts closer together.**
- **Let the science decide between them.**
- **Our joint goal is for having "one LC community" that jointly supporting a well-conceived global project (ILC or CLIC?), once the LHC opens up this new physics frontier and points the way.**