Physics Motivation and Status of the ILC

Eckhard Elsen

DESY

Hamburg

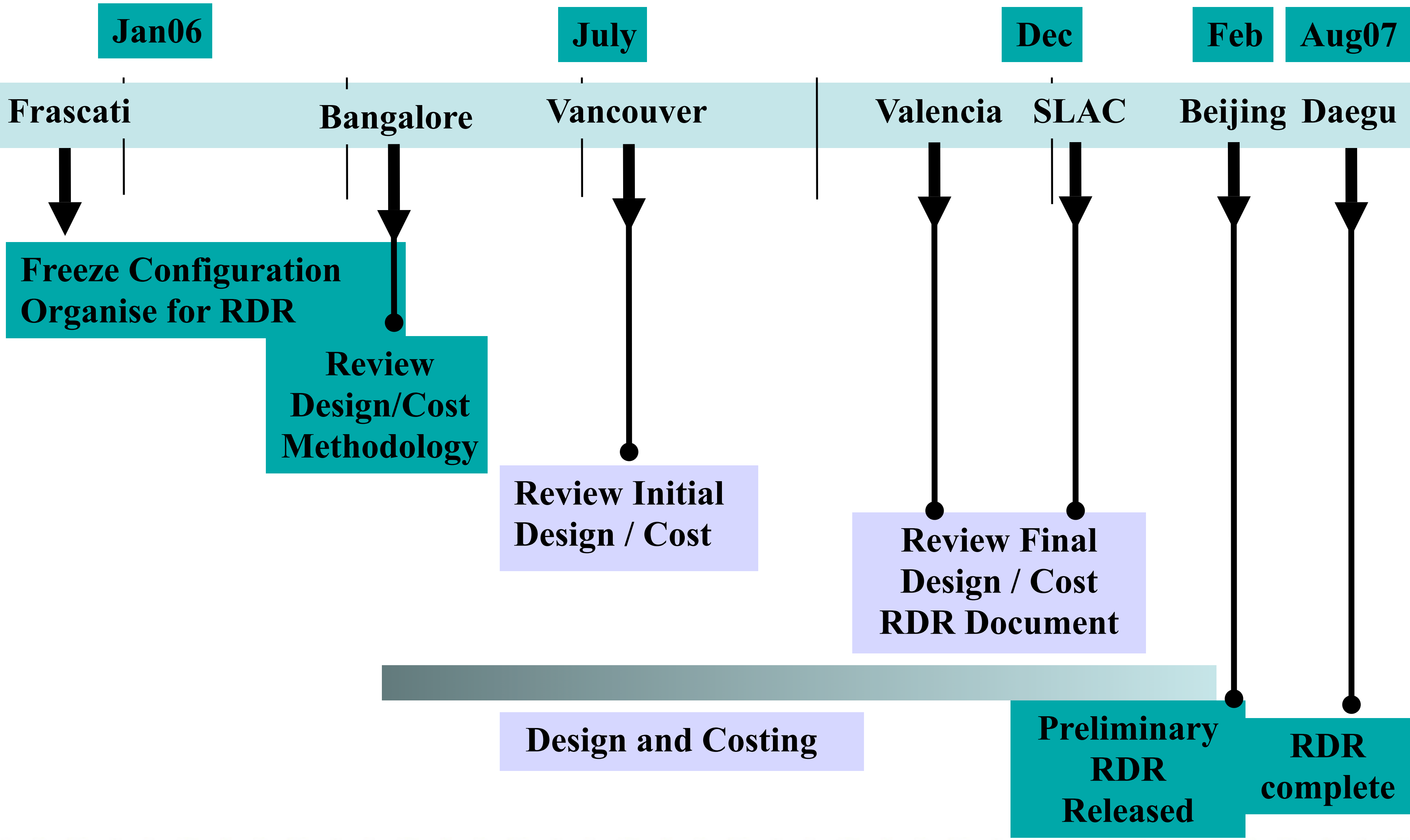
International Linear Collider

- Introduction to the International Linear Collider (ILC)
- ILC Physics Motivation
- ILC accelerator
  - **component choice**
  - **cost**
  - **engineering phase**
- ILC Status
  - **Timelines**

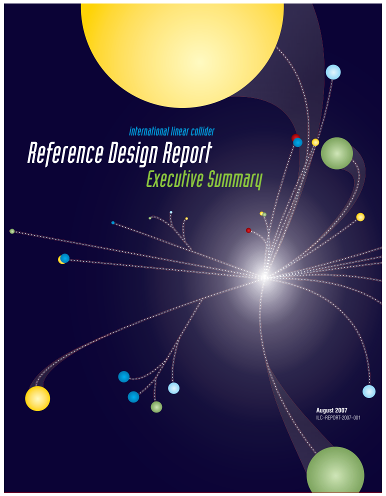
Brief History of e^+e^- LC

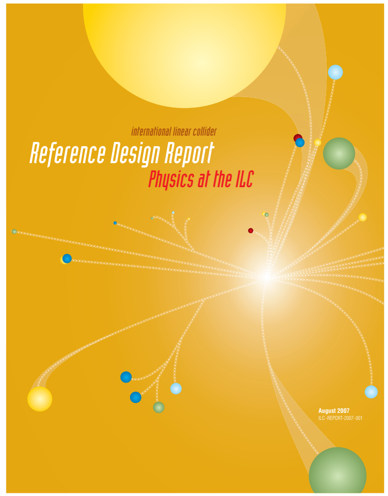
- SLC proved the viability of the linear collider concept
- over the past >15 years consensus emerged that the next big project of physics (after the completion of the LHC) should be a linear e^+e^- collider
- TESLA proposal in 2001 introduced a 500 GeV machine in SC technology; NLC and JLC were developed in parallel
- In 2004 the technology decision was taken in favour of SC technology and the Global Design Effort (GDE) was launched for the "ILC"
- In 2007 the Reference Design Report RDR was issued

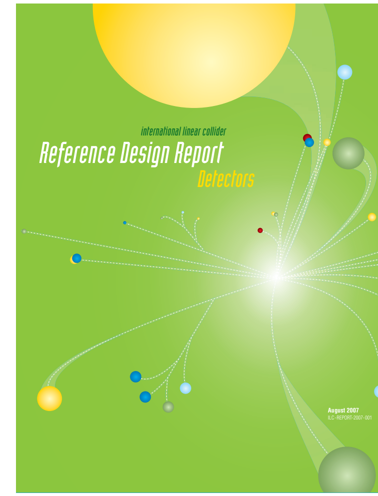
Towards the RDR



ILC Reference Design Report







~700 Contributors from 84 Institutes

available from http://www.linearcollider.org

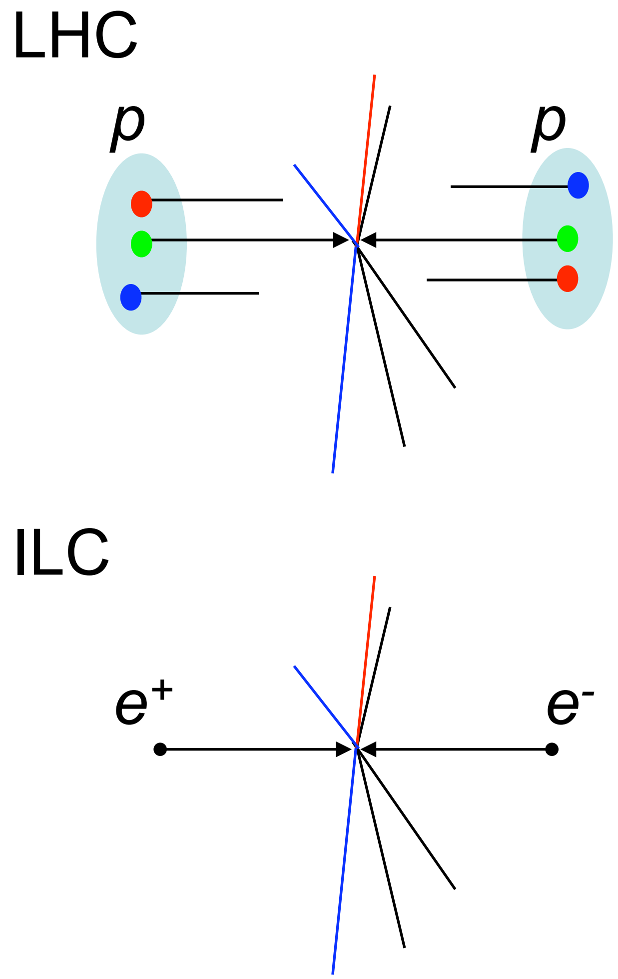
The RDR is not a full engineering design - it is conceptual; some aspects require R&D. It forms reliable basis for detailed engineering design & costing.

ILC Parameters (specified)

- E_{cm} adjustable from 200 – 500 GeV
- Luminosity $\int L dt$ = 500 fb^{-1} in 4 years
  (corresponds to 2×10^{34} $cm^{-2}s^{-1}$ with a start-up profile)
- Ability to scan between 200 and 500 GeV
- Energy stability and precision below 0.1%
- Electron polarisation of at least 80%
- The machine must be upgradeable to 1 TeV!

e^+e^- versus pp

- LHC
  - **discovery machine**
- ILC
  - **elementary particles**
  - **well-defined energy, angular momentum**
  - **produces particles democratically**
  - **captures nearly the full information**



LHC vs ILC

	LHC	ILC
total energy	14 TeV	0.5-1 TeV
usable energy	a fraction	full
beam	composite	point-like
signal rate	high	low
background	very high	low
analysis	specific modes	nearly all modes
reconstruction	loose along beam	full event
status	soon to start	design to be completed

Physics case of the ILC

- Discover the secrets of the Terascale
- shed light on dark matter
- reveal the ultimate unified theory

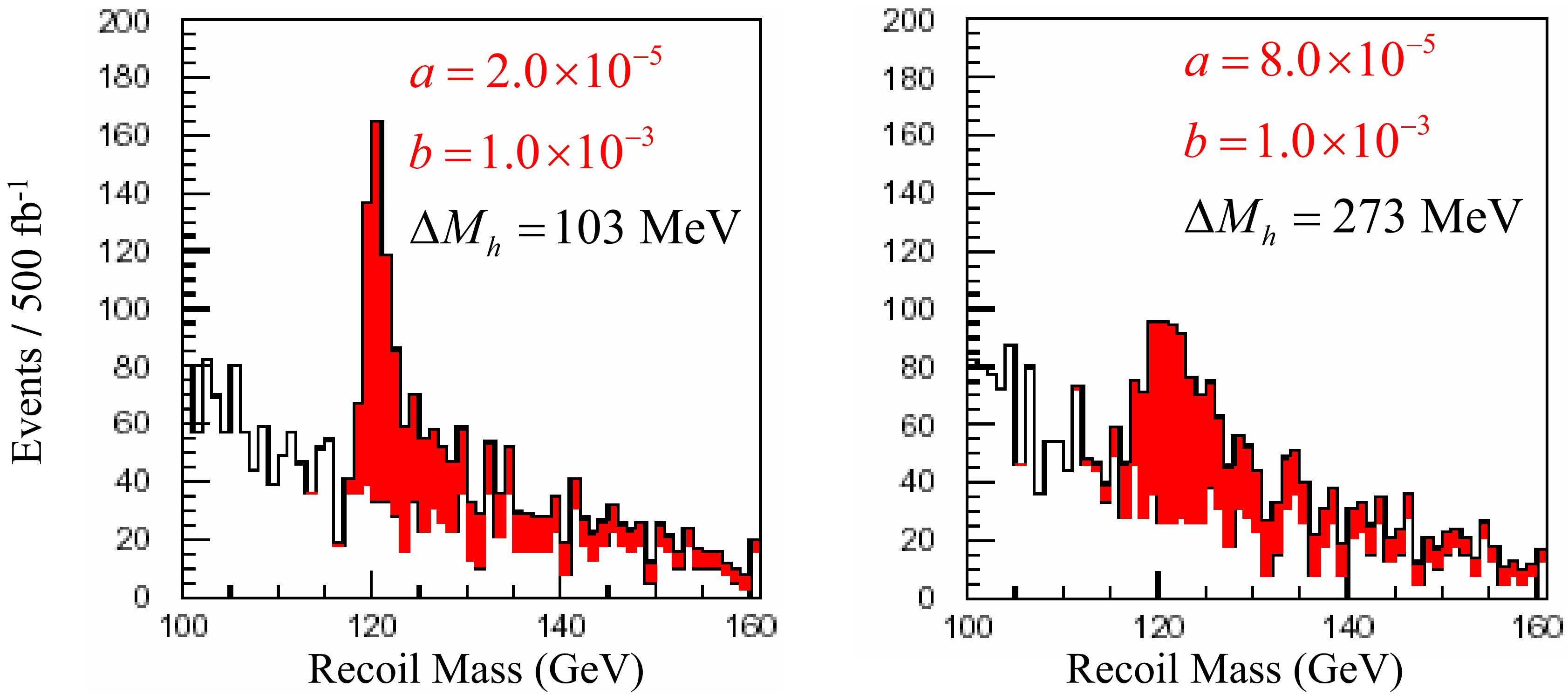
these goals are to be accomplished in concert with a diversified worldwide program of accelerator and non-accelerator experiments, including LHC, neutrinos, astrophysics, etc.

J.Lykken, Vancouver 06

Discover the secrets of the Terascale

- Mass generation: either a “simple” Higgs, a complicated “Higgs sector”, or a “something else”.
  - **Precision detectors at a 500 GeV ILC are the ideal instruments to discover what is happening in the first two cases, and will be indispensable in all cases.**
- Formation of the Terascale: supersymmetry, extra dimensions, new forces, ...
  - **At the ILC, observing new particles, and new interactions of known particles, will reveal the secrets of this larger universe.**

Higgs Recoil mass

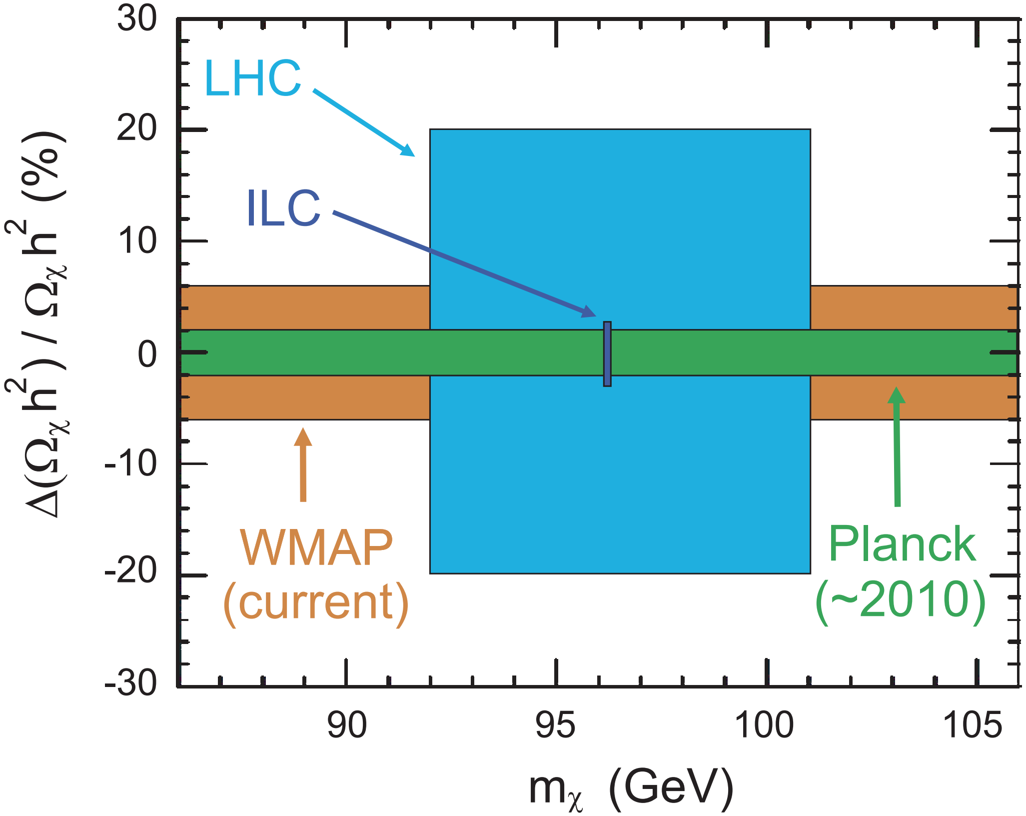


Tracker resolution matters

shed light on dark matter

- More than 80% of the matter in the universe is cold dark matter. Probably it consists of more than one stable component. Probably at least one is a thermal “WIMP” relic.
- To discover the identity of such dark matter, we must know how it interacted with itself and other exotics after the Big Bang.
  - **ILC can produce such particles and the other most relevant exotics.**
  - **ILC measurements will have the precision to identify the fingerprints of dark matter.**

Relic Density vs neutralino mass

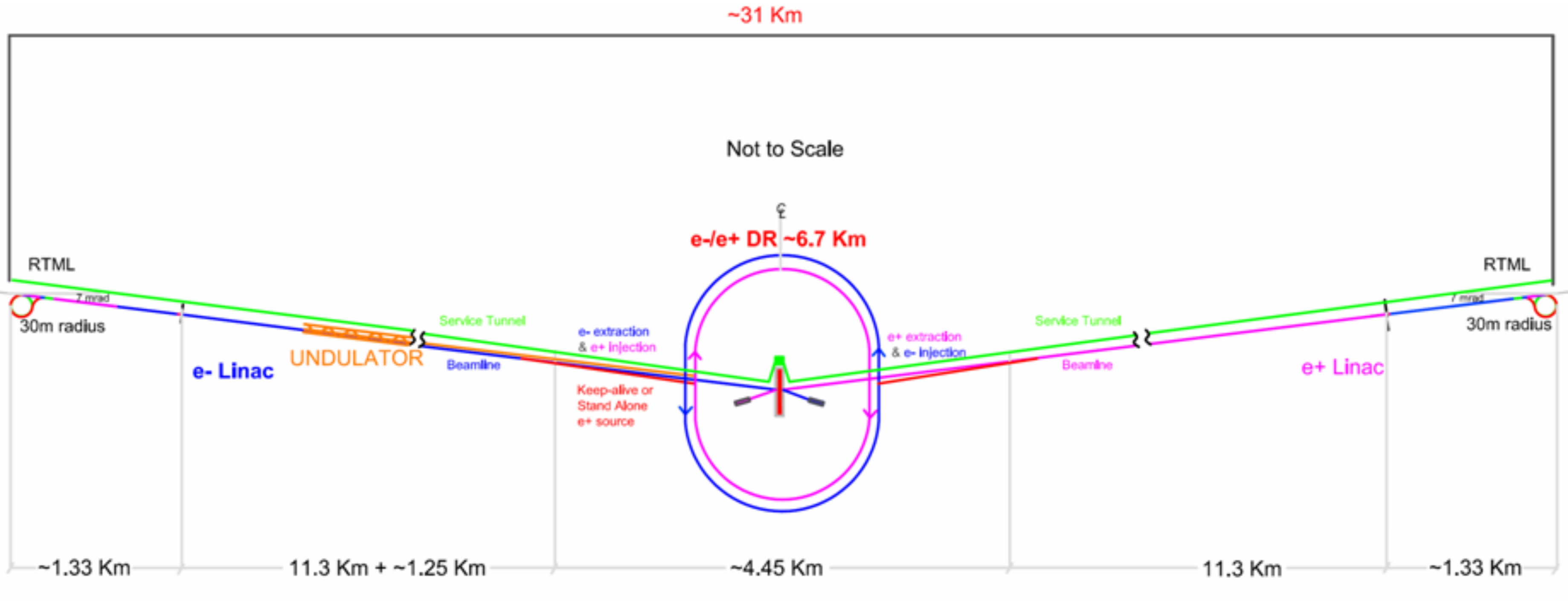


reveal the ultimate unified theory

- Discoveries at the ILC, the LHC and elsewhere will give us a more fundamental understanding of the laws of nature and of the origin of the universe. How far can we go?
  - **With supersymmetry, precision measurements at the Terascale become a telescope to the energies of ultimate unification.**
  - **ILC measurements could reveal unification of forces, unification of matter, signals of extra dimensions, and other telltale clues of superstrings.**

Overall Layout of the ILC

1st Stage: 500 GeV



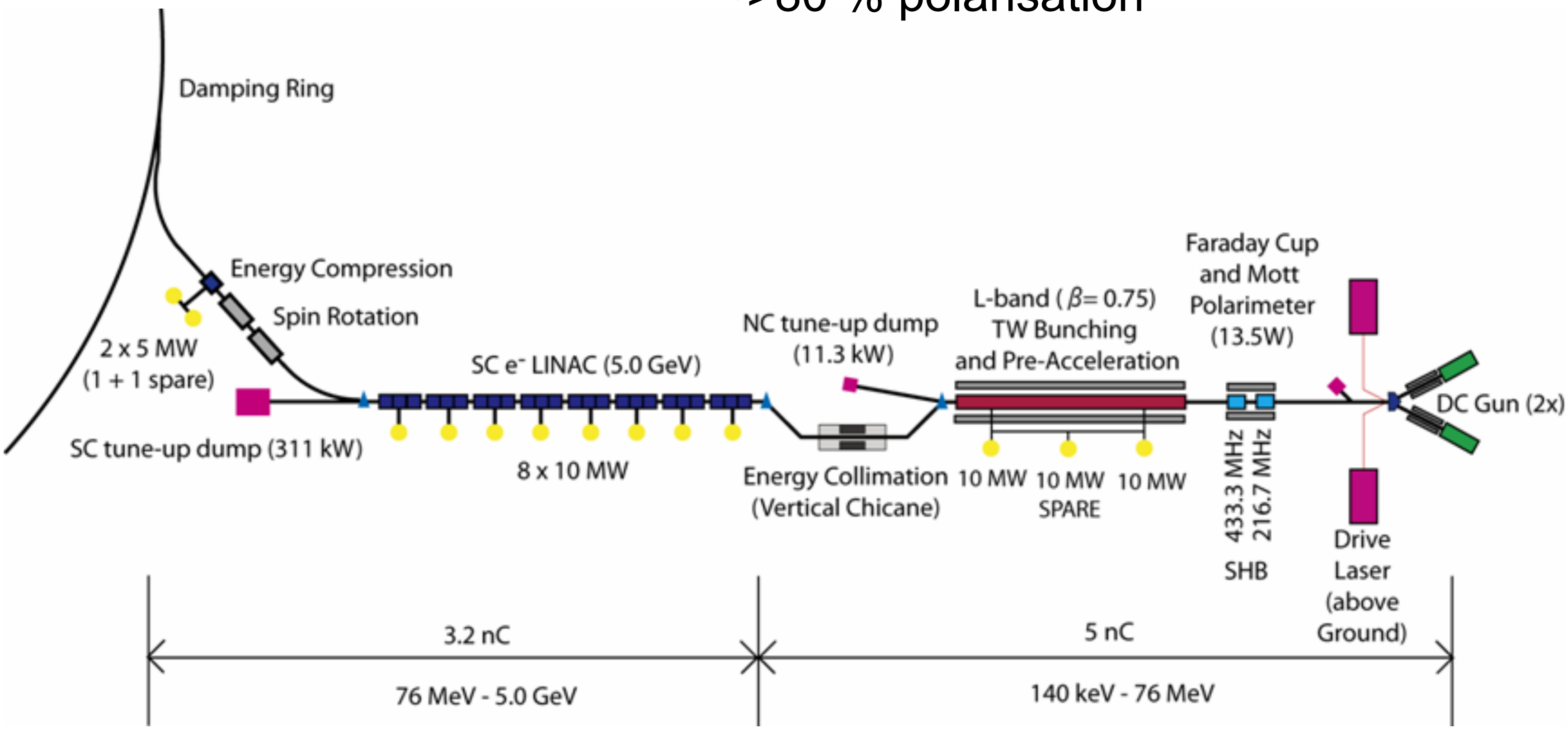
Schematic Layout of the 500 GeV Machine

Basic Parameters

Max. Centre-of-mass energy	500	GeV
Peak Luminosity	~2×10^{34}	$cm^{-2}s^{-1}$
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

Electron Source System

- ~2600 bunches, ~1 ms, 2×10^{10} at DR
- >80 % polarisation

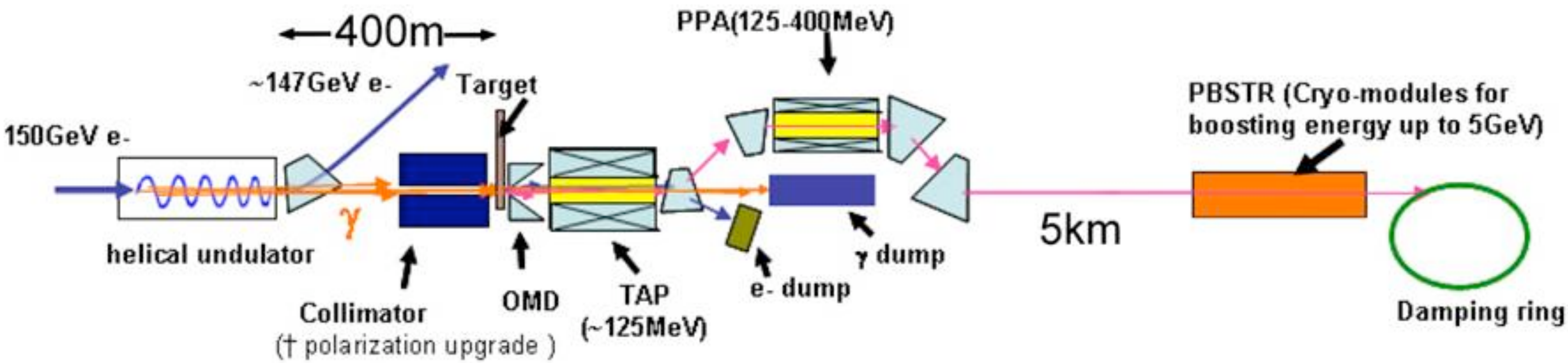


Positron Source

- 3 possible positron generation schemes have been proposed
  - A) **Standard method: a few GeV electron on target**
  - B) **Undulator scheme: use photons from >100 GeV electron through undulator**
  - C) **Compton scheme: use photons from a few GeV electron through laser-Compton scattering**
- Scheme B) has been selected as the baseline
  - **C) is immature**
  - **Cost saving by A) is not significant. Physics descoping (no positron polarisation)**

Positron Source

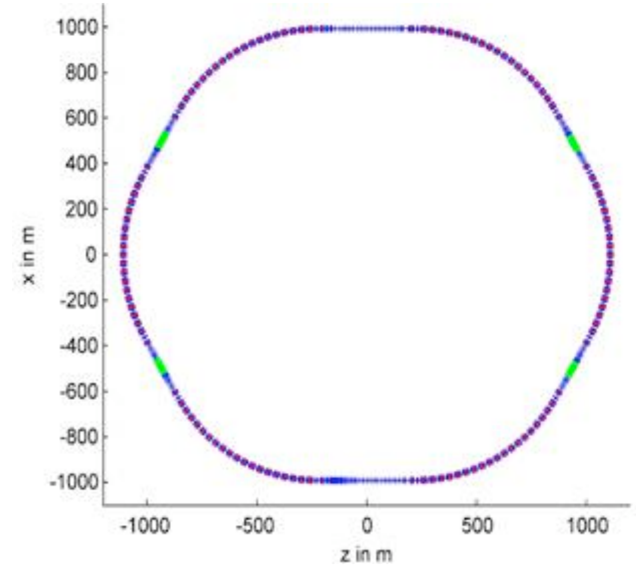
- Undulator scheme - Baseline
  - **Electron beam at 150 GeV**



  - **Undulator**
    - Helical, superconducting
    - length 147 m (longer for polarised e^+)
    - $K = 0.92$, $\lambda = 1.15$ cm, ($B = 0.86$ T)
  - **Separate source for commissioning forseen**
    - 10 % intensity
    - Share 5 GeV linac

Damping Ring Issues

- Injection/extraction kickers
- Instabilities
  - **Electron-cloud, Fast Ion, …**
- Dynamic aperture
- Tuning for low emittance

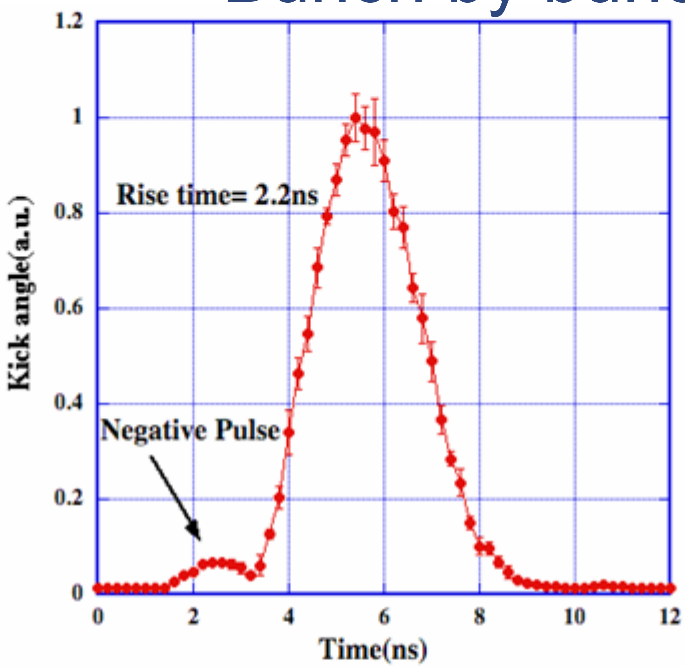


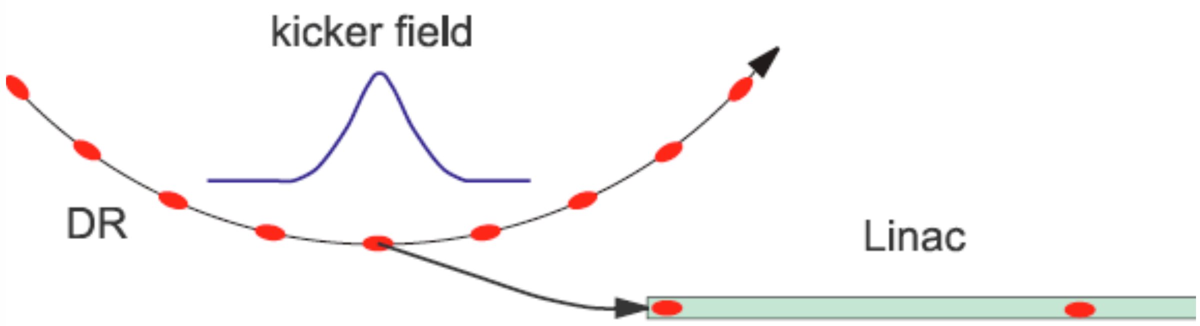
Electron-cloud topic remains a high priority research issue for ILC damping ring

- Machines available for tests
  - KEK-ATF
  - CesrTA (special NSF programme)

Kicker System

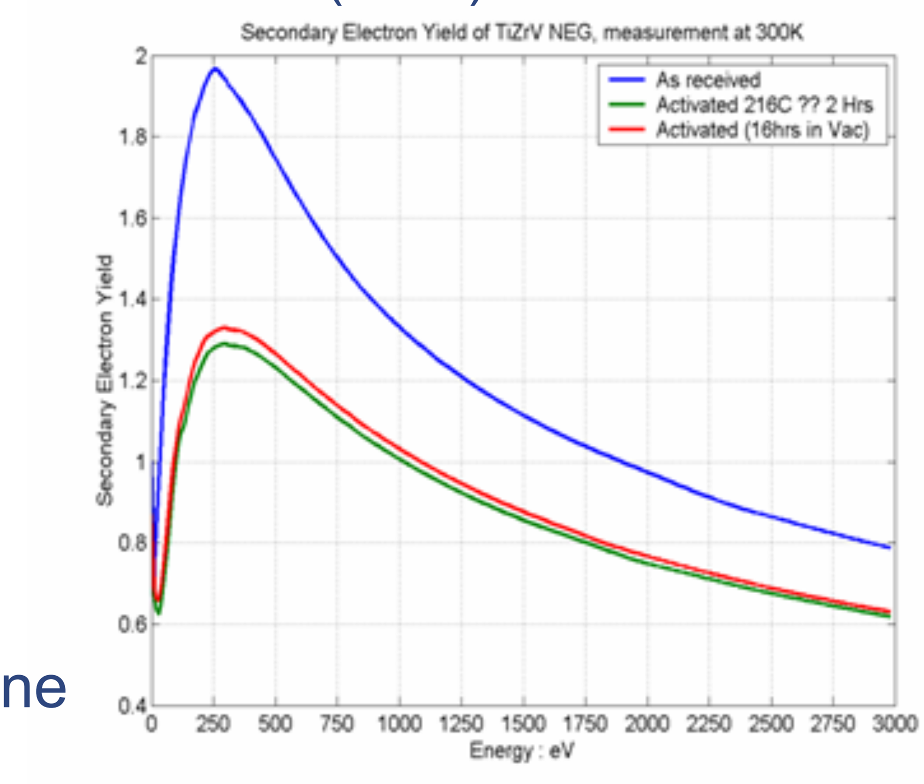
- Number of bunches ~3000 (6000 desirable)
- 300 ns interval in linac; total length for 1 ms train → 300 km
- Store compactly in DR (6 km circumference → ~6 ns bunch to bunch)
- Bunch by bunch extraction in 300 ns intervals





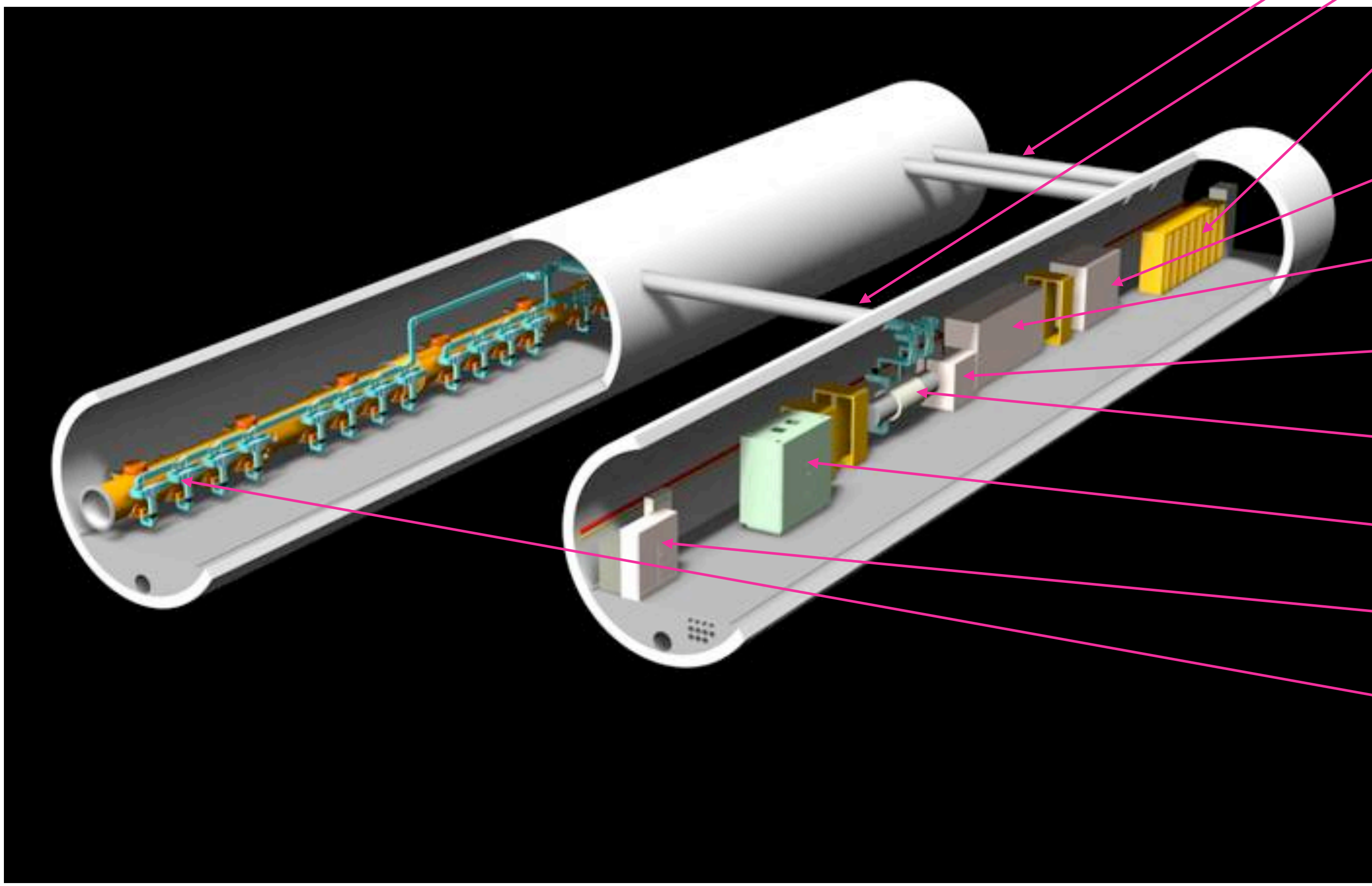
Electron Cloud

- Secondary electrons attracted by positron beam cause an instability
- Maximum of Secondary Electron Yield (SEY) should be < 1.1
- Possible cures
  - **Coating with NEG**
  - **Solenoids in free field region**
  - **Grooves on chamber wall**
  - **Clearing electrode**
- Confident enough to baseline single e^+ damping ring



Main Linac Layout

- 2 tunnels diameter 4.5 m



Penetrations:
Cable & Plumbing
Waveguide

LLRF, Controls,
Protection Racks

Charger

Main Modulator

HV Pulse Transformer

Horizontal Klystron

LCW Chiller

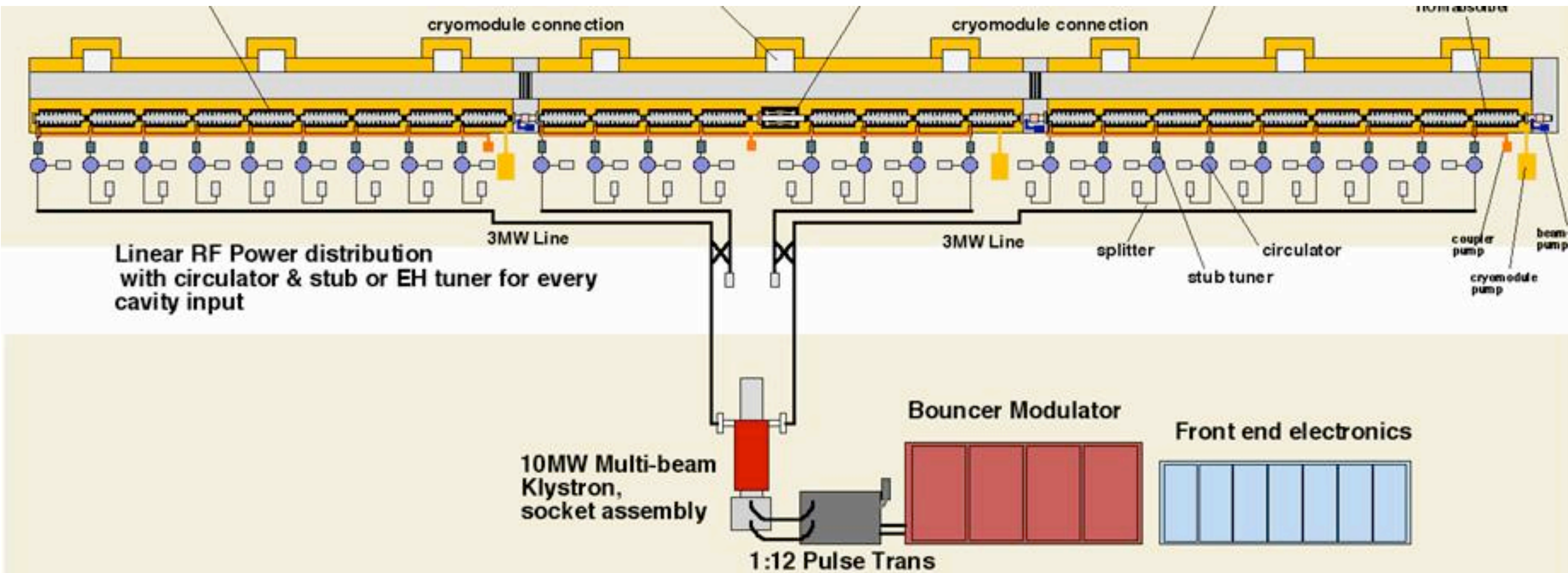
AC Switchgear

Waveguide
Distribution
System

Dwg: J. Liebfritz

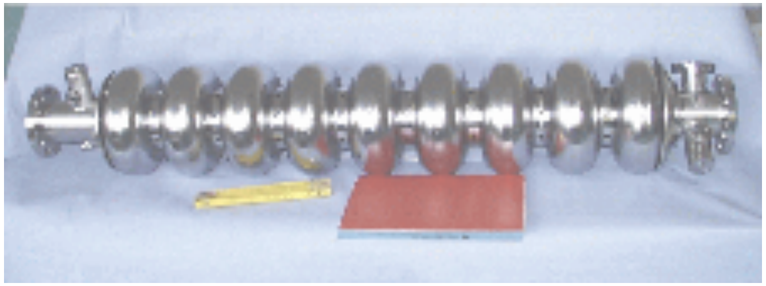
Main Linac RF Unit Overview

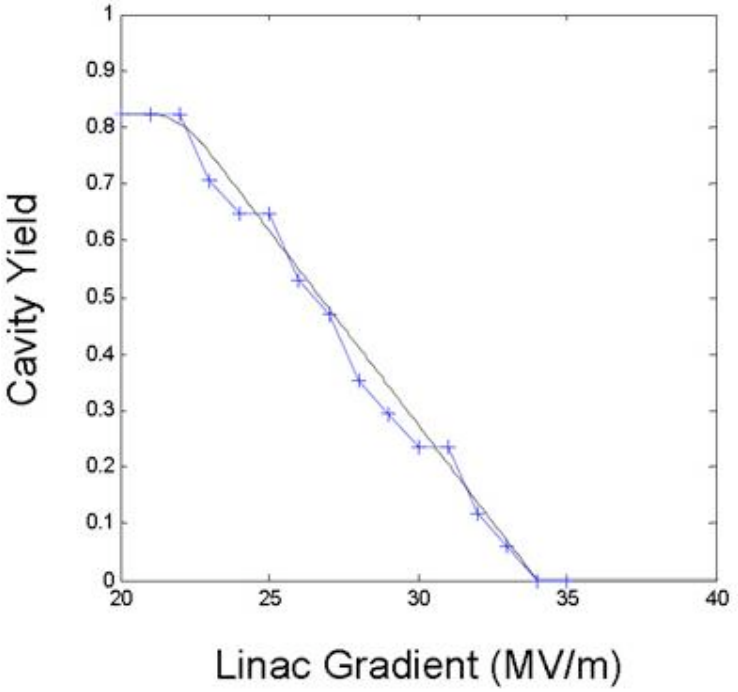
- Bouncer type modulator
- Multibeam klystron (10 MW, 1.6 ms)
- 3 Cryostats (9+8+9 = 26 cavities)
- 1 Quadrupole at the centre



Cavities

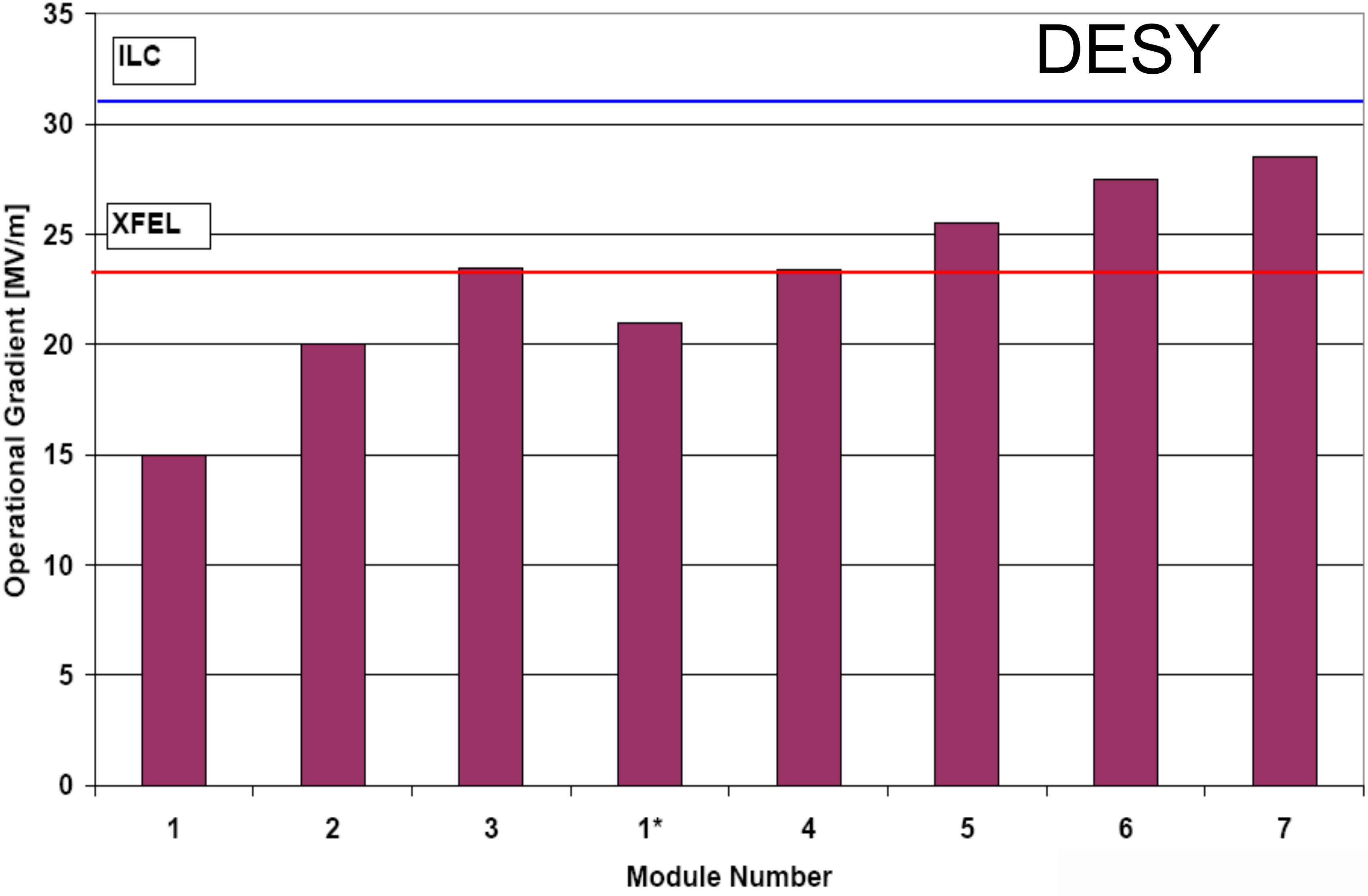
- Baseline: TESLA-type 1.3 GHz
  - Identical to XFEL cavities
    - beam-tubes shorter
- Accelerating gradient
  - Vertical test
    - >35 MV/m, $Q>0.8\times10^{10}$
  - Average gradient in cryomodule
    - 31.5 MV/m, $Q>1\times10^{10}$
- With the presently available technology
  - Average gradient lower than 31.5 MV/m
  - Spread of gradient large
  - If uniform distribution in 22<G<34 MV/m, average 28 MV/m: Cost increase ~7% w.r.t 31.5 MV/m





Dedicated effort to push gradient reproducibility under way (L.Lilje talk)

Module Test History

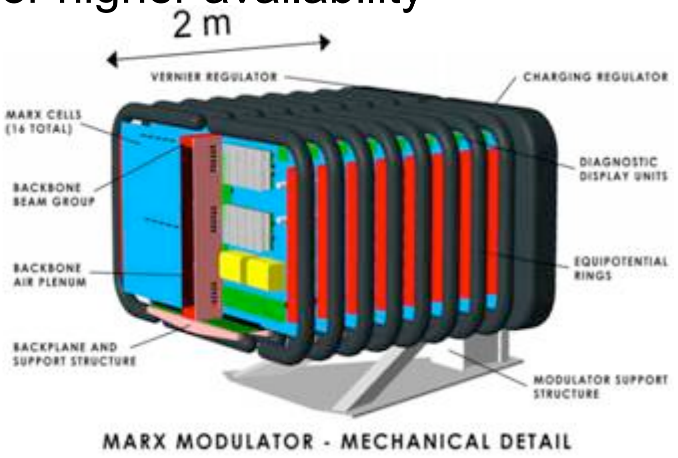


Module Tests at DESY

- High gradient modules have been assembled
  - **FLASH**
- Test in dedicated test stand possible e.g.
  - **Cavity performance**
  - **Thermal cycles**
  - **Heat loads**
  - **Coupler conditioning**
  - **Fast tuner performance**
  - **(LLRF tests)**
- Part of the ongoing preparatory work for XFEL

Modulator

- Baseline
  - **Bouncer-type modulator**
    - Design at FNAL
      - Has been working for >10 years at TTF at DESY
      - No major technical issues
      - XFEL choice
  - **Design improvements (within XFEL industrialisation)**
    - More cost-efficient design under way
    - Redundancy of internal components for higher availability
- Alternative:
  - **Marx Modulator**
    - Under development at SLAC
    - Smaller size
    - No step-up transformer
    - Potentially high cost saving



Klystrons

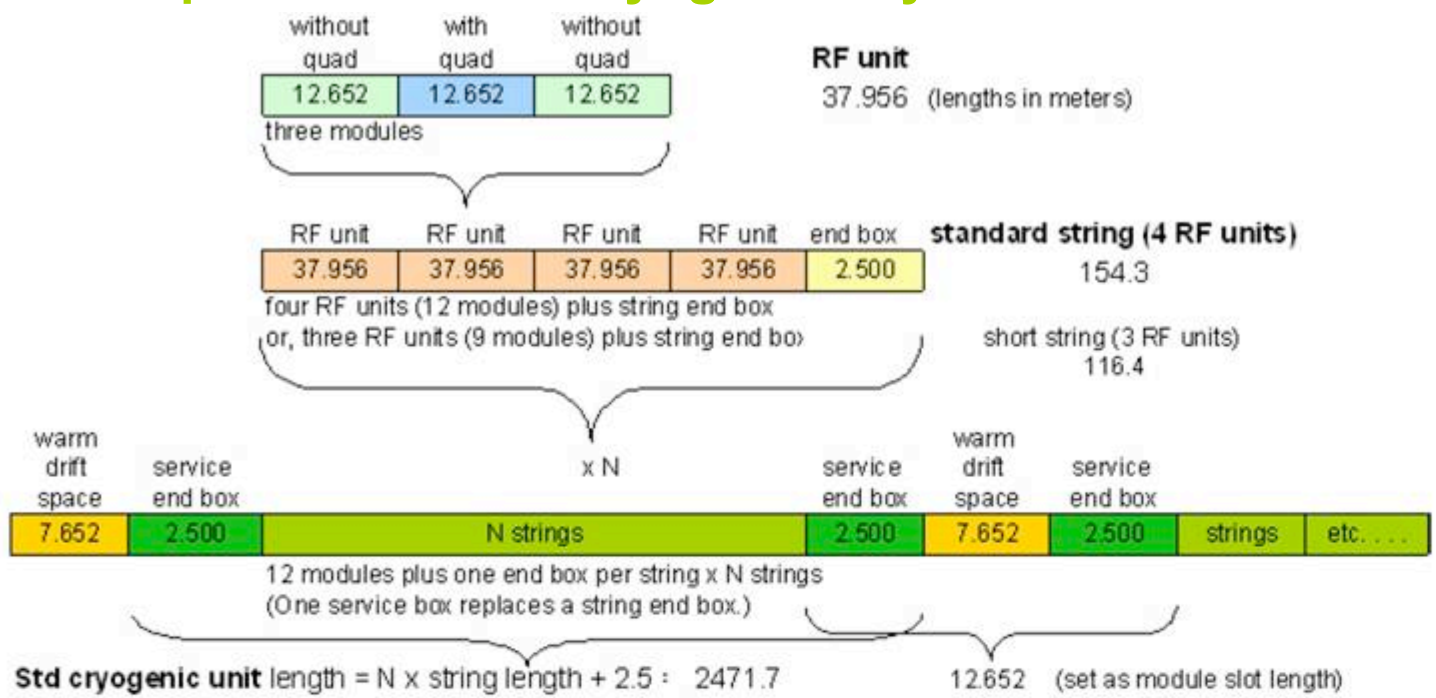
- Requirements:
  - **10 MW**
  - **1.6 ms**
  - **5 Hz**
  - **lifetime for full power >40000 hrs**
- Baseline solution: Multi-beam klystron
  - **Use multiple beams of low charge**
  - **Lower space-charge effects**
  - **Lower voltage (120 kV)**
  - **Higher efficiency (~65 %)**

Thales CPI Toshiba

- Prototypes from 3 manufacturers for the European XFEL (higher repetition rate: 10 Hz)
  - **Thales and Toshiba MBKs being successfully tested at DESY at full spec**
    - for > 1000 hrs
    - Several klystrons under varying operating conditions at FLASH, PITZ and test stand
- Horizontally mounted klystron needed for small tunnel diameter (first tests at Toshiba)
  - **XFEL develops this with industry**
- More lifetime testing going on (eventually also at SLAC)
  - **At DESY all tubes now in operation show no sign of degradation**

Cryogenics System

- 1 cryogenic plant covers 2.5km linac length.
  - **Installed power ~4.5MW**
- Total 10 plants
  - **installed power ~45MW**
  - **comparable to LHC cryogenics system**



Beam Delivery System (BDS)

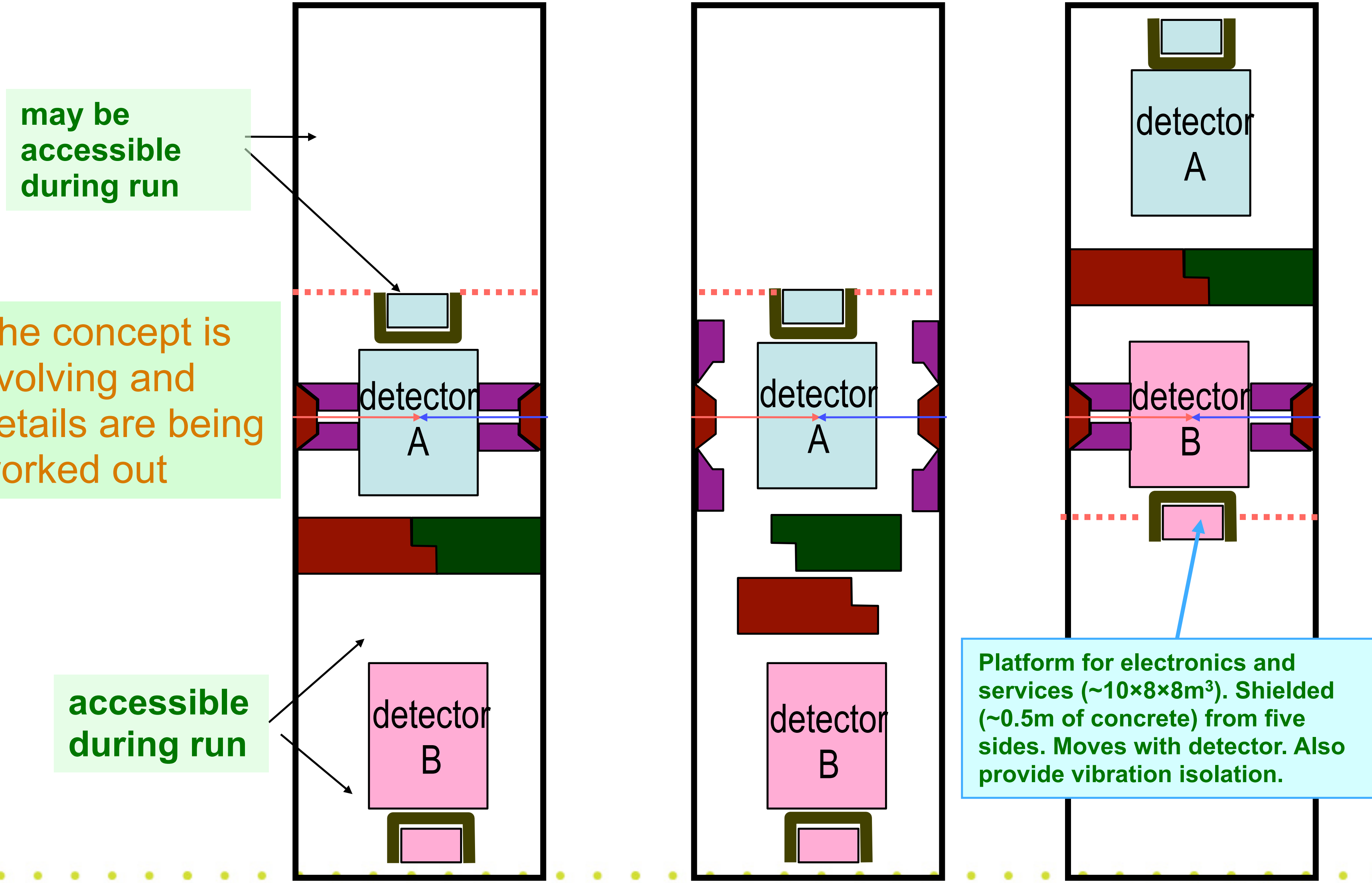
- From main linac exit to IP (Interaction Point) and to the beam dump
- Roles of BDS
  - Focus the beam to the desired spot size for collision
  - Remove beam-halo to minimise the background events
  - Protect the beam-line and detectors against mis-steered beam
  - Diagnostics of the linac beam
  - Safely dump the spent beams

Single IR with Push-Pull Detectors

- Large cost savings compared with 2 IR
  - **~200 M$ compared with 2 IR with crossing angles 14 + 14 mrad - much more if one IR has "small angle" crossing.**
- Push-pull detectors
  - **Task force from WWS and GDE formed**
  - **Conclusion is**
    - No show-stoppers
    - But need careful design and R&D works
    - 2IR should be left as an 'Alternative'

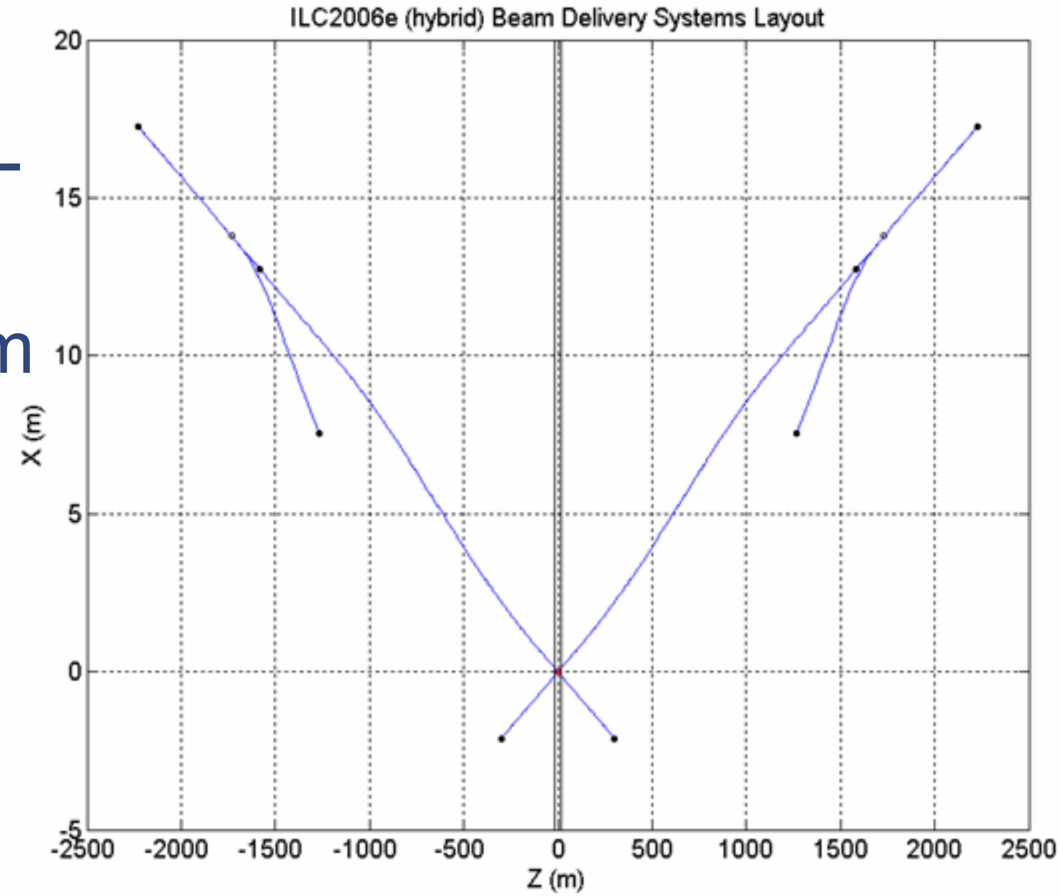
IR Hall for push-pull

The concept is evolving and details are being worked out

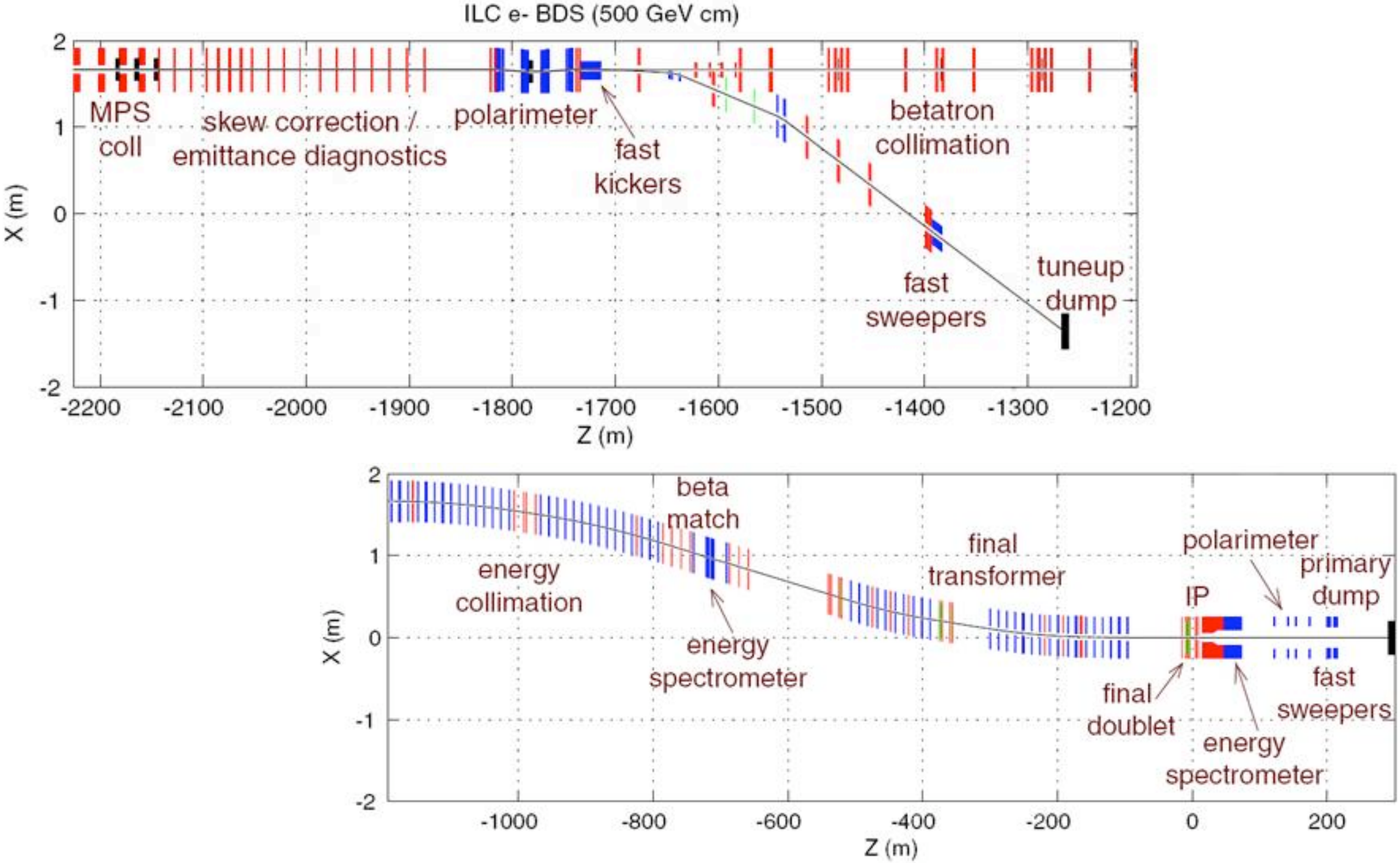


BDS (Beam Delivery System)

- Single IR and push-pull detector
- Total length 4.45 km
- 1 TeV upgrade by inserting components (no geometry change)

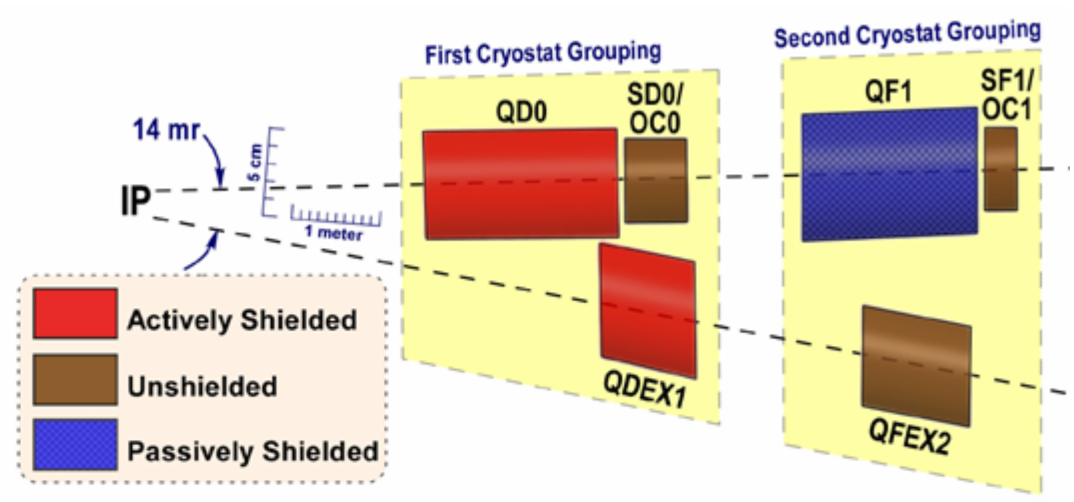


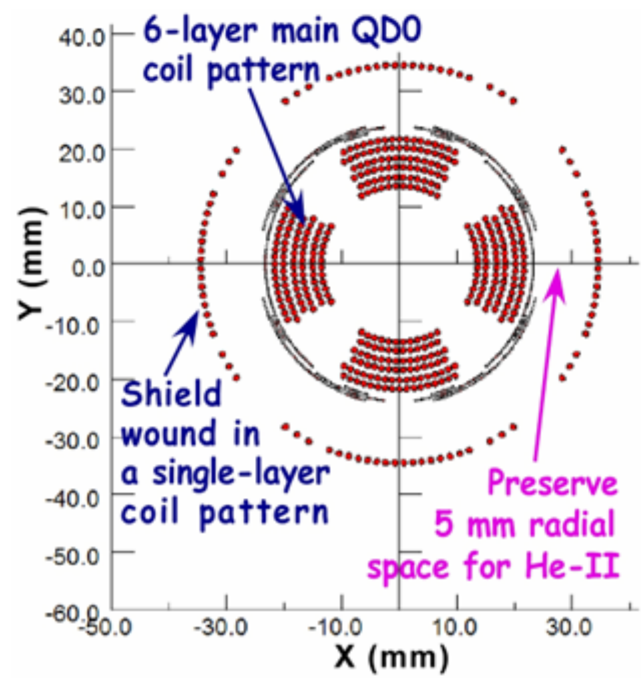
BDS Layout


ILC e- BDS (500 GeV cm)
MPS
coll
skew correction /
emittance diagnostics
polarimeter
fast
kickers
betatron
collimation
fast
sweepers
tuneup
dump
X (m)
Z (m)
energy
collimation
beta
match
energy
spectrometer
final
transformer
final
doublet
IP
polarimeter
primary
dump
fast
sweepers
energy
spectrometer

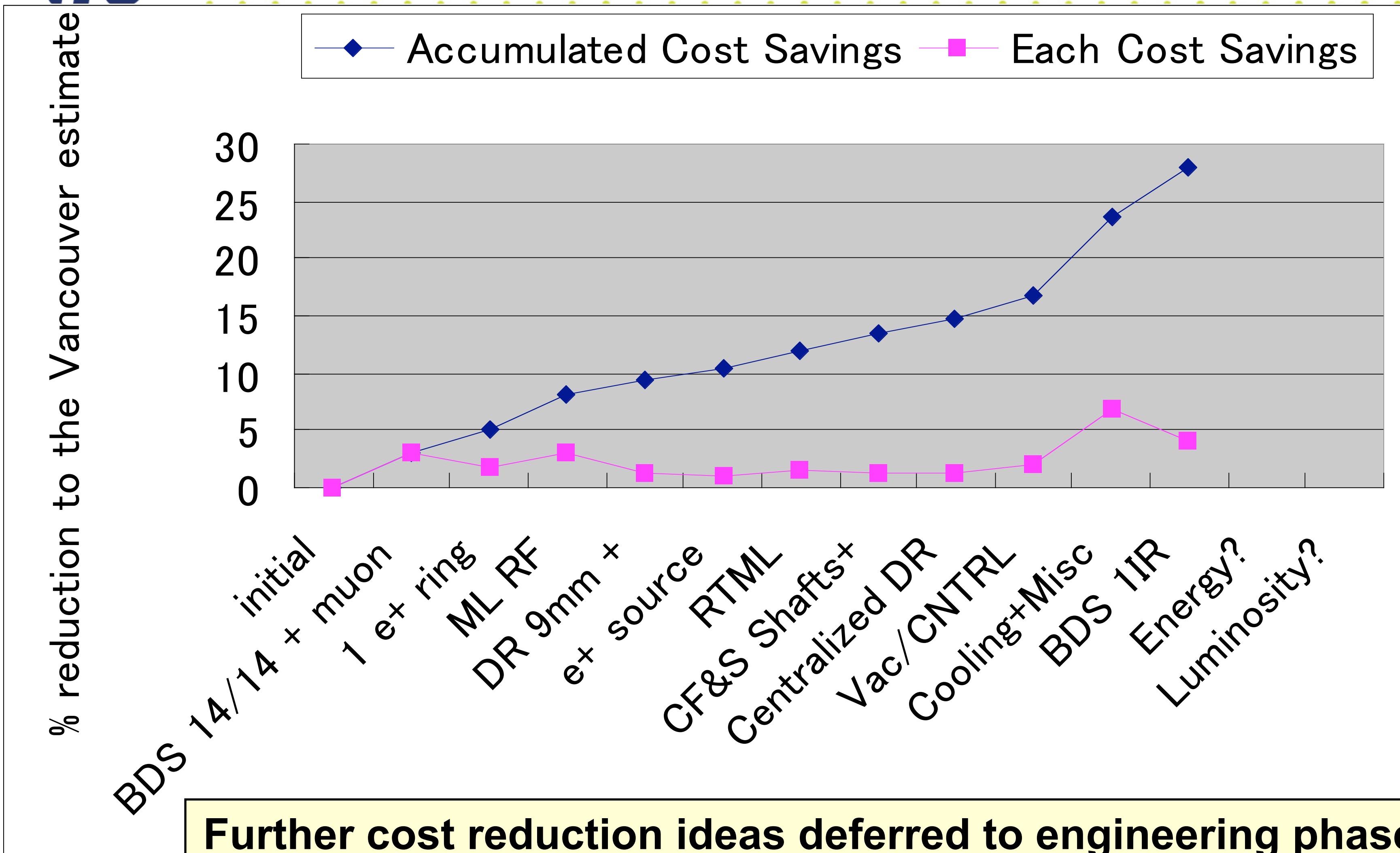
Interaction Region

- Crossing angle 14 mrad
- Final quadrupole magnets
  - **Superconducting (QD0 in detector magnetic field)**
  - **Out-going beam goes outside**





RDR Cost reduction



Further cost reduction ideas deferred to engineering phase

ILC COST

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" labour = 24.0 M person-hrs @ 1,700 hrs/yr)

1 ILC Unit = $ 1 (2007)

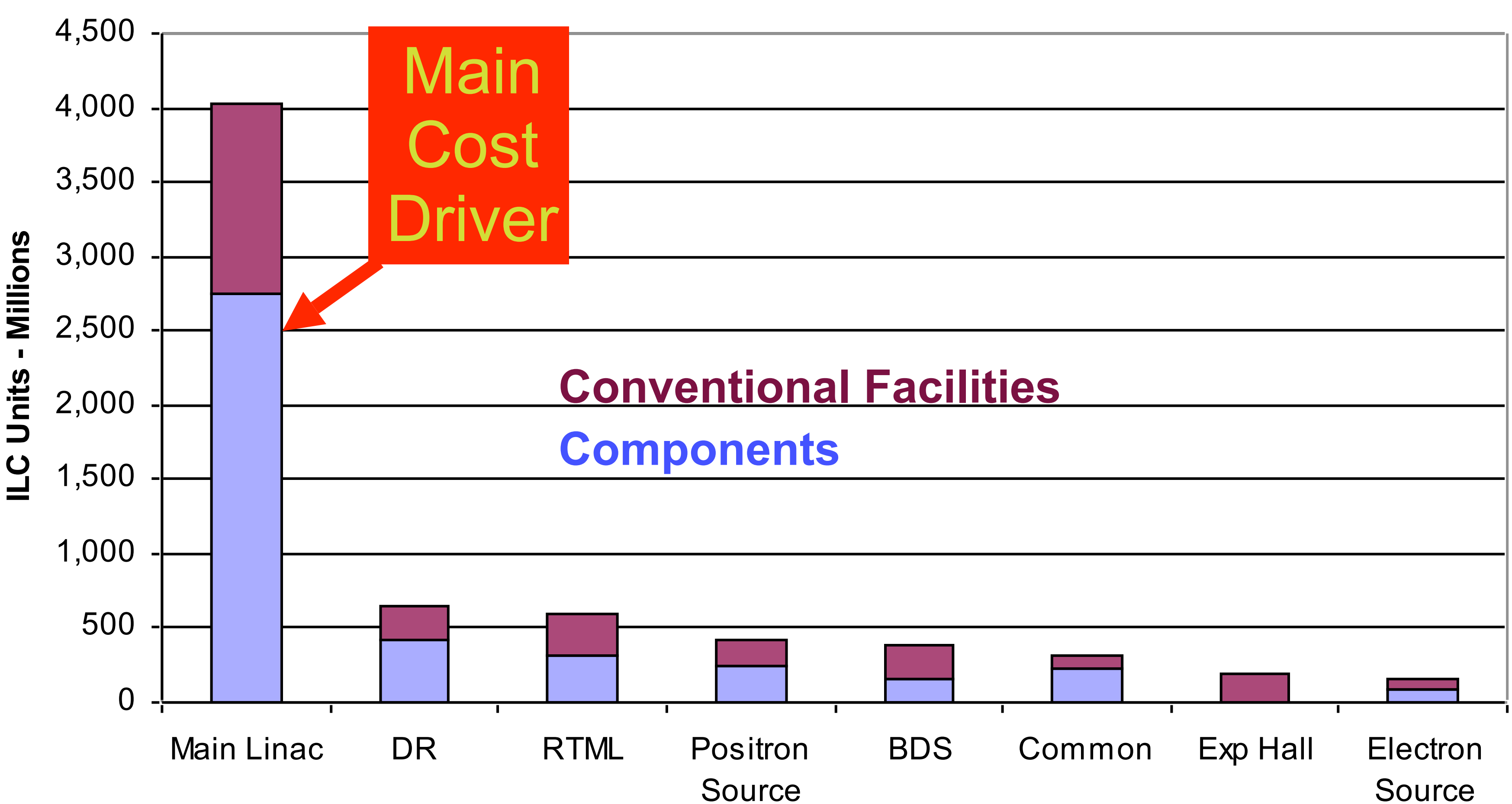
Σ Value = 6.62 B ILC Units

The reference design was "frozen" on 1-12-06 for RDR production, including costs.

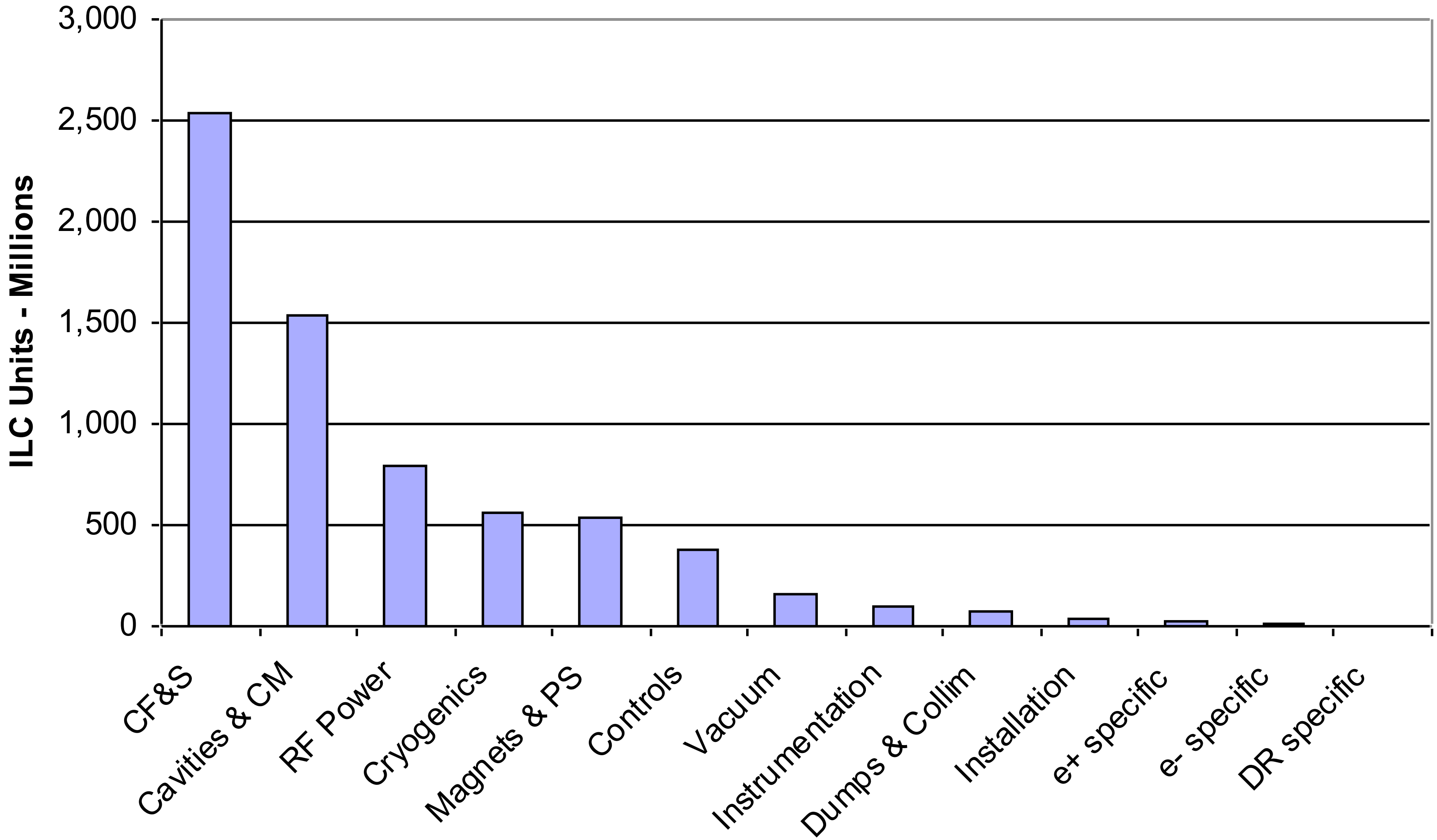
Important to realise this is a snapshot; design will continue to evolve, due to R&D, accelerator studies & value engineering.

The value costs have already been reviewed many times.

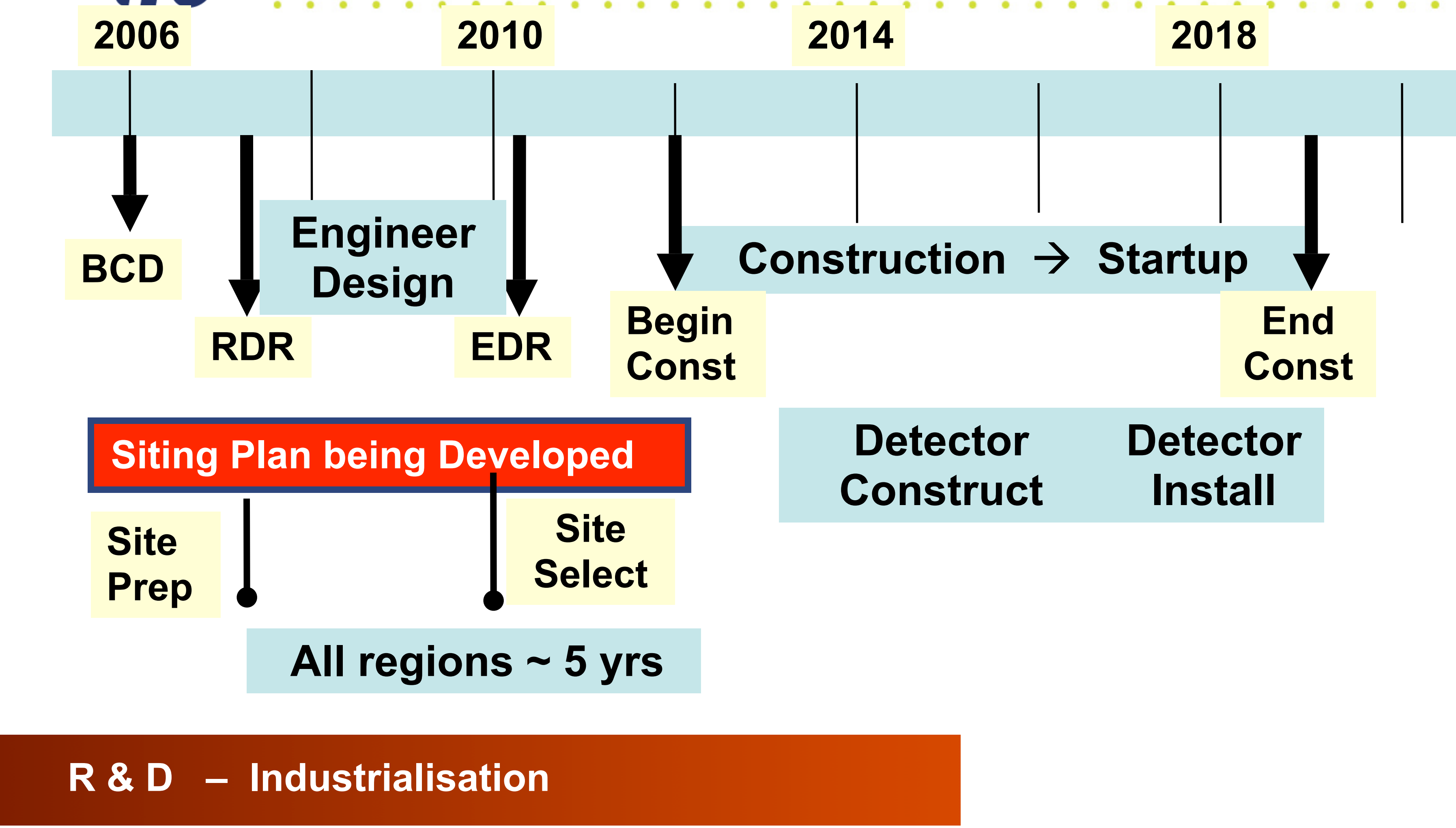
ILC Value – by Area Systems



ILC Value – by Technical Systems



Future - Technically Driven Timeline



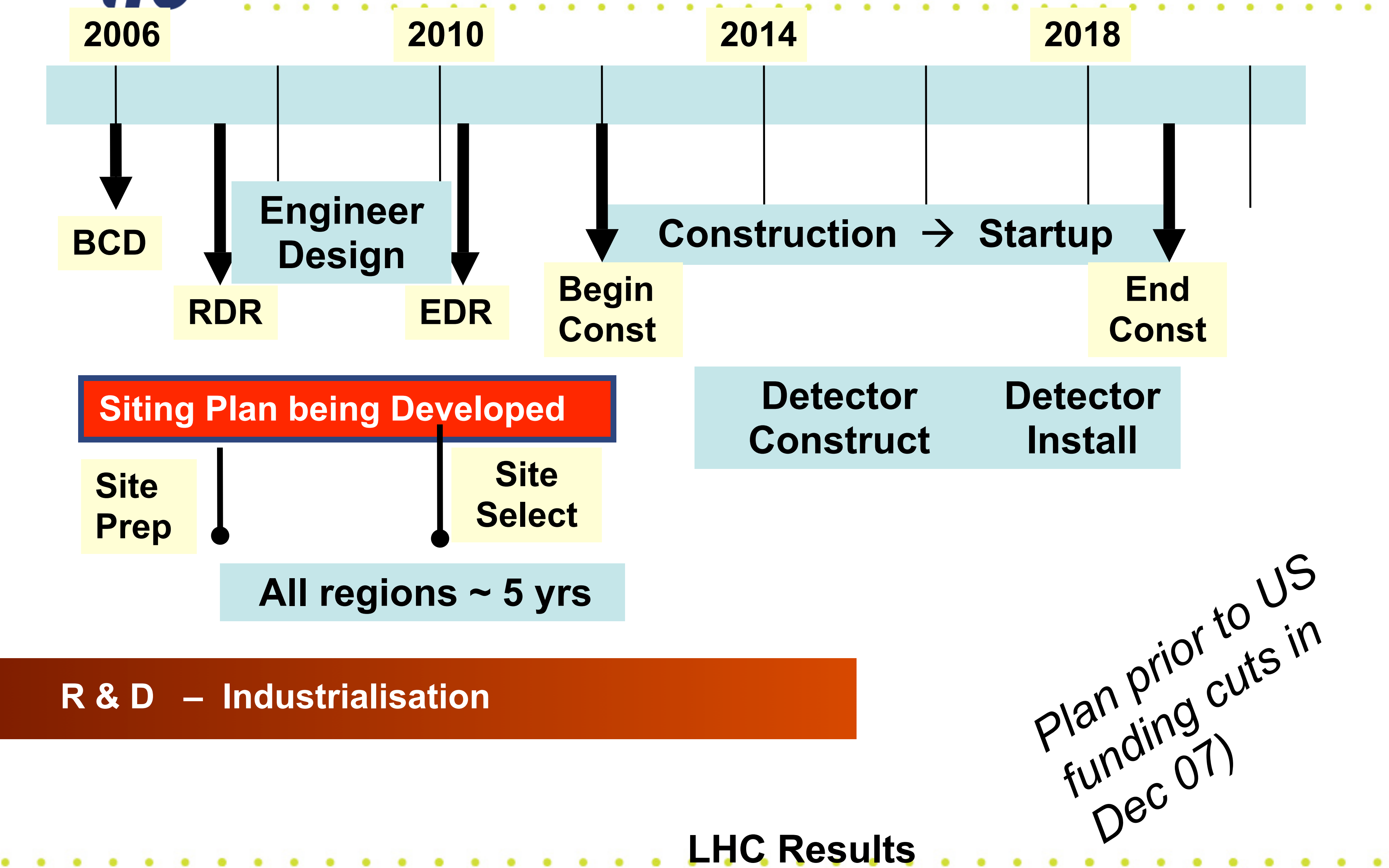
Black December 2007

- In a dispute between US president and legislative non-approved science projects are faced with drastic funding reductions
- Faced with a budget deficit the UK decide to stop ILC R&D (and other engagements)
- US R&D programme for the ILC comes to a halt; a short term US site for the ILC is not realistic
- Role of European and Japanese sites become more relevant; the CERN site creates a stronger "entanglement with the LHC"

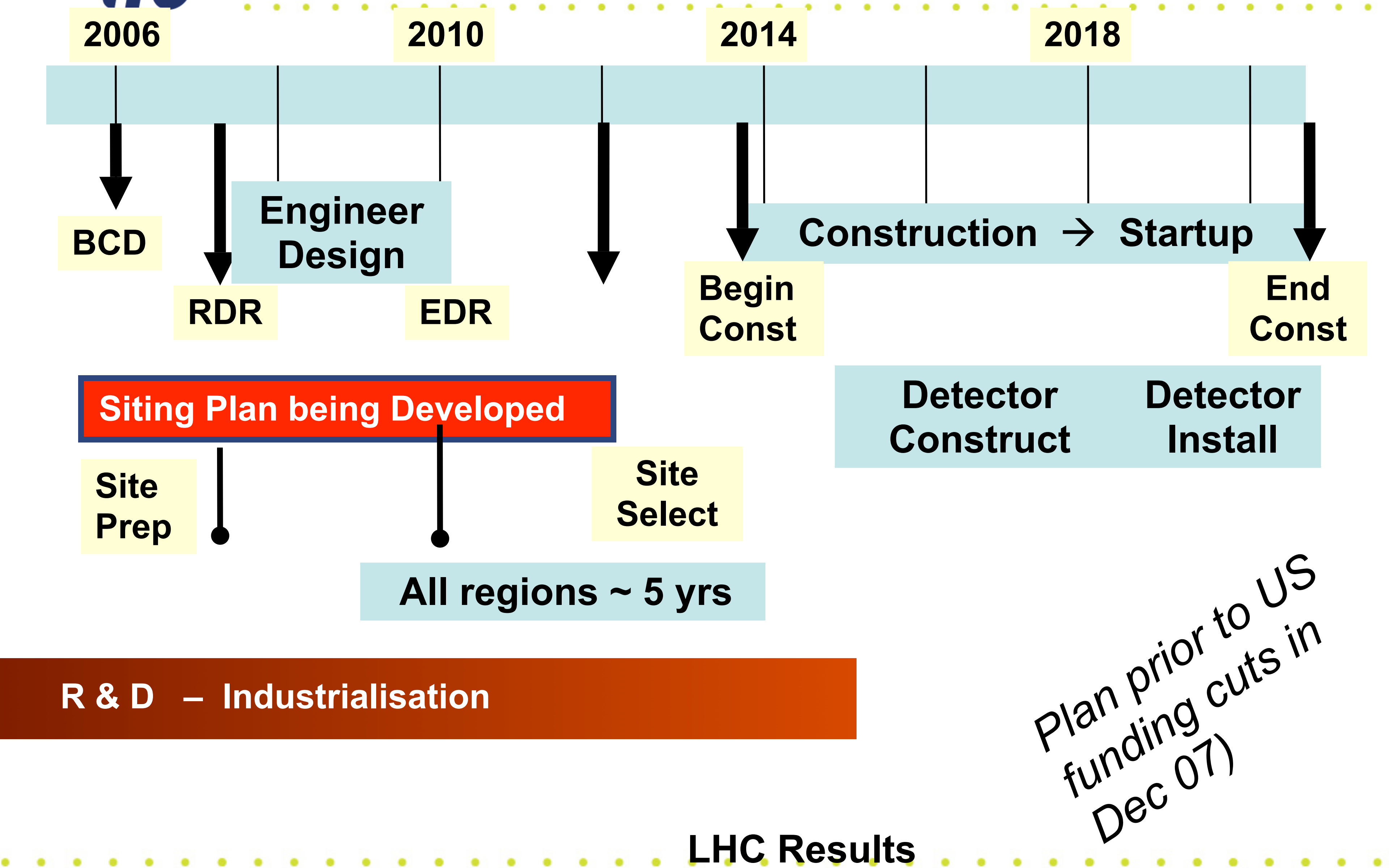
Consequences

- A decision on a Linear Collider will have to await the successful start-up of LHC
- ILC is ready for (European style) approval to date
  - **Technical Design Phase I (2008-2010) cost/performance optimisation**
    - High-gradient programme
    - Damping ring studies
    - Conventional facilities cost reduction
  - **Technical Design Phase II (2010-2012)**
    - engineering level design

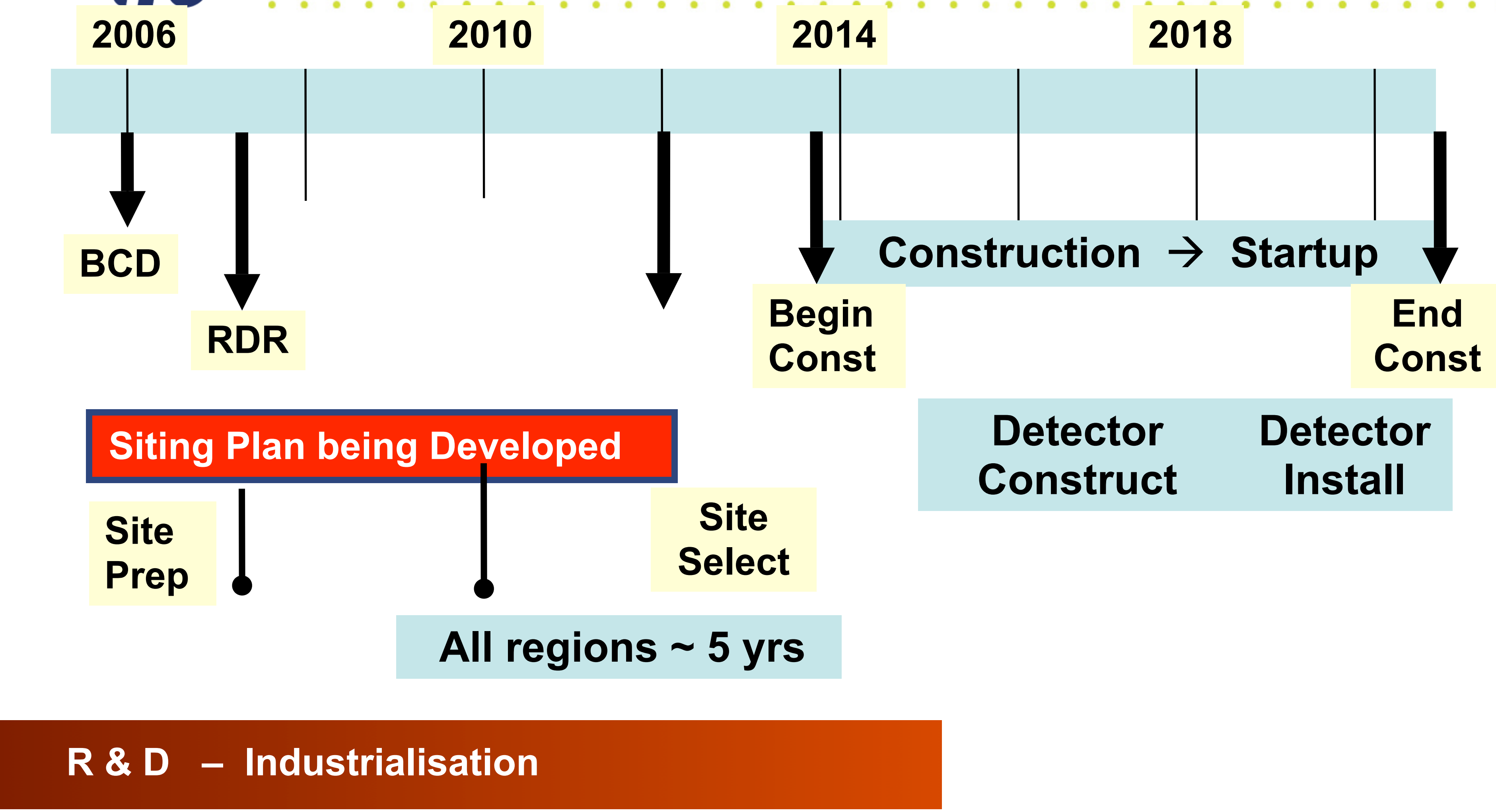
Future - Technically Driven Timeline



Future - Technically Driven Timeline

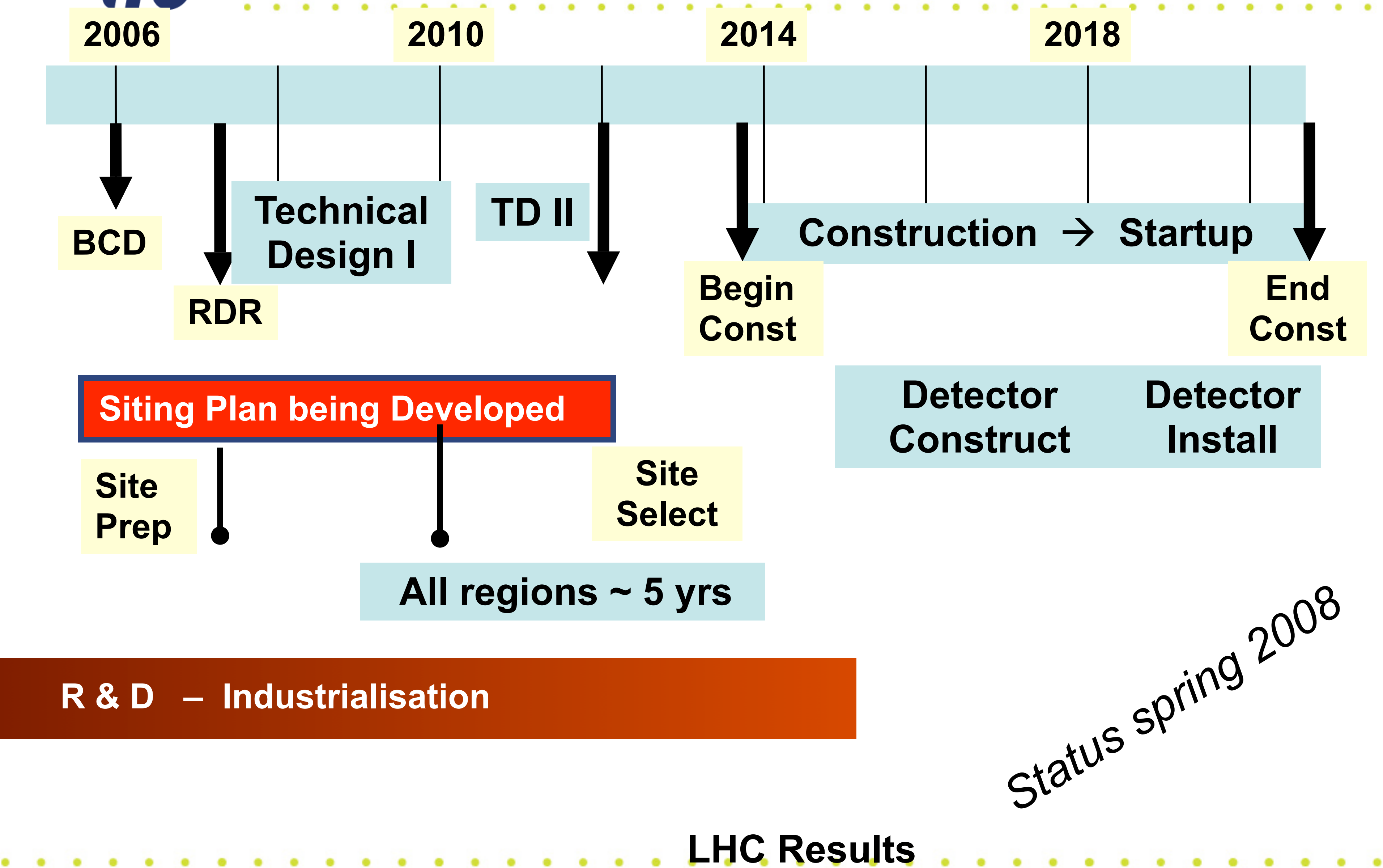


Future - Technically Driven Timeline



LHC Results

Future - Technically Driven Timeline



Summary and Outlook

- Reference Design Report published in August 2007
  - **truly international design**
  - **machine is well understood**
    - and ready for old-style approval
  - **remaining R&D and optimisations over the next few years**
    - Technical Design Phase I till 2010
    - Technical Design Phase II till 2012
- Job of the GDE is two-fold
  - **produce the blueprint for ILC construction containing (and hopefully reducing) cost so that governments have to act**
  - **mount political and scientific campaign to convince them and the general public that the ILC is a good investment.**
- In parallel, WWS optimising the selection process for two detectors
  - **Have to present the full impact to the politicians**
- It is now also clear that the success of this effort is tightly coupled to the success of LHC