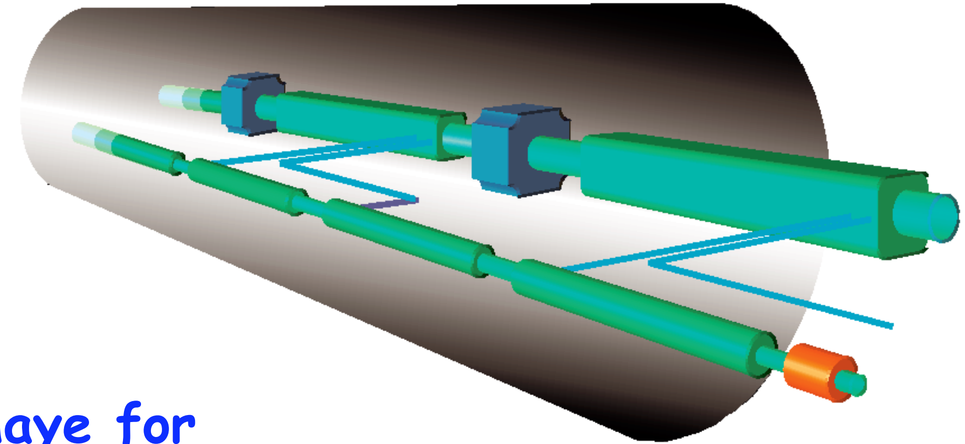
THE COMPACT LINEAR COLLIDER (CLIC) STUDY



J.P.Delahaye for

The Compact LInear Collider Study Team

&

The CLIC/CTF3 Collaboration

http://clic-study.web.cern.ch/CLIC-Study/

High Energy Physics after LHC
a world-wide consensus

In 1999 ICFA issued that there would be compelling and unique scientific opportunities at a linear electron-positron collider in the TeV energy range. Such a facility is a necessary complement to the LHC hadron collider now under construction at CERN.

Two options:

- **ILC based on SC technology in the TeV energy range**
- **CLIC based on novel Two Beam scheme in the Multi-TeV energy range**
- **Collaboration on common issues**

The European strategy *for particle physics*

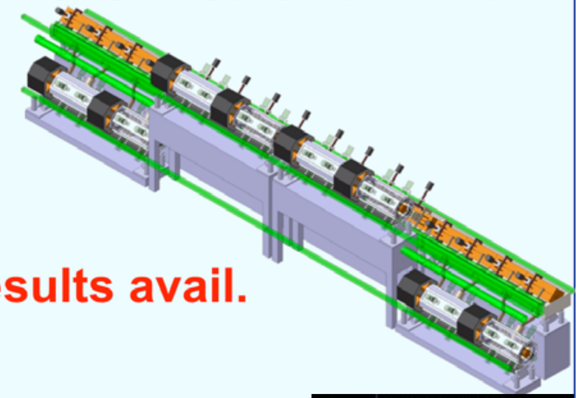
Unanimously approved by the CERN Council at the special Session held in Lisbon on 14 July 2006

4. In order to be in the position to push the energy and luminosity frontier even further it is vital to strengthen the advanced accelerator R&D programme; *a coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility.*

5. It is fundamental to complement the results of the LHC with measurements at a linear collider. In the energy range of 0.5 to 1 TeV, the ILC, based on superconducting technology, will provide a unique scientific opportunity at the precision frontier; *there should be a strong well-coordinated European activity, including CERN, through the Global Design Effort, for its design and technical preparation towards the construction decision, to be ready for a new assessment by Council around 2010.*

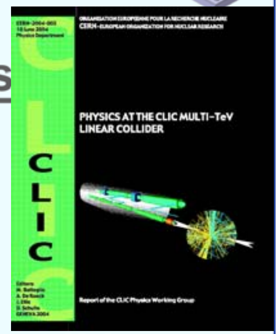
CERN/2685

Site independent feasibility study aiming at the development of a realistic technology to extend e-/e+ linear colliders into the Multi -TeV energy range:



- ✓ E_{CM} energy range complementary to LHC
  - => E_{CM} = 0.5- 3 TeV
- ✓ L > few 10^{34} cm^{-2} with acceptable background
  - E_{CM} and L to be reviewed when LHC physics results avail.
- ✓ Affordable cost and power consumption

Physics motivation: http://clicphysics.web.cern.ch/CLICphysics



"Physics at the CLIC Multi-TeV Linear Collider:
by the CLIC Physics Working Group:CERN 2004-5

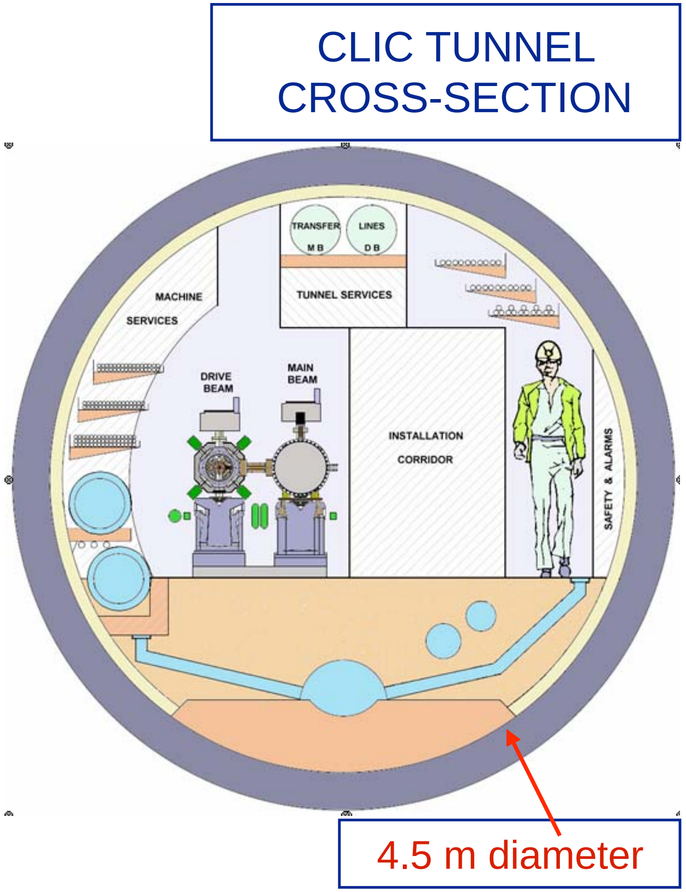
Present goal:

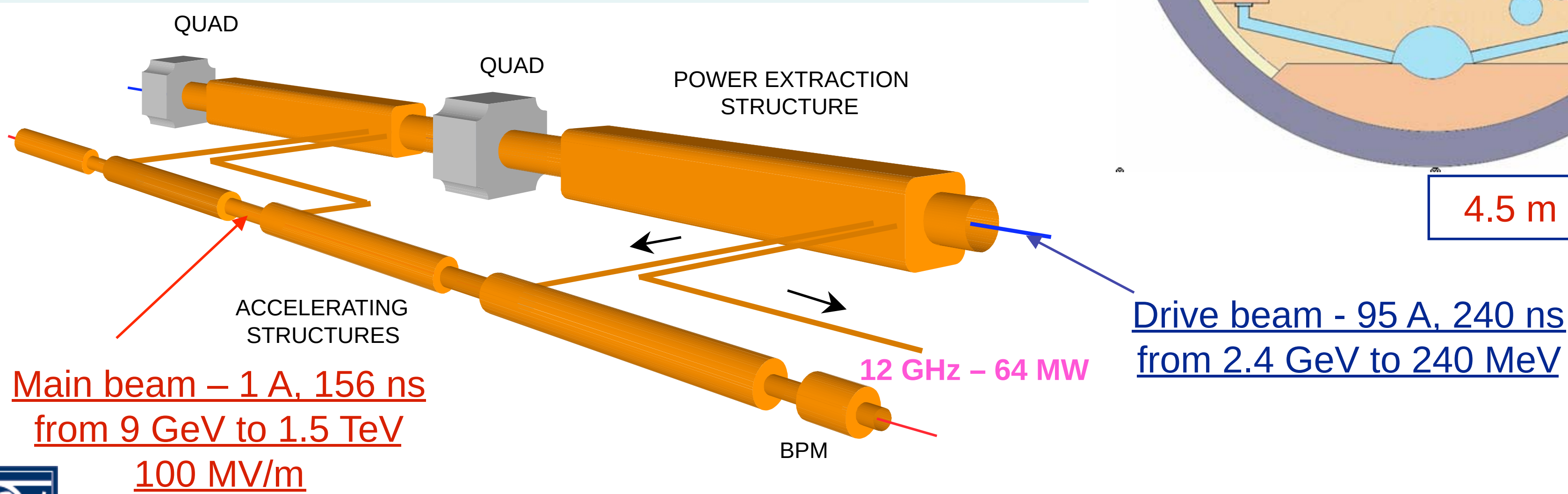
Design of a Linear Collider based on CLIC technology and address all key feasibility issues described in a Conceptual Design Report including Cost estimation by 2010

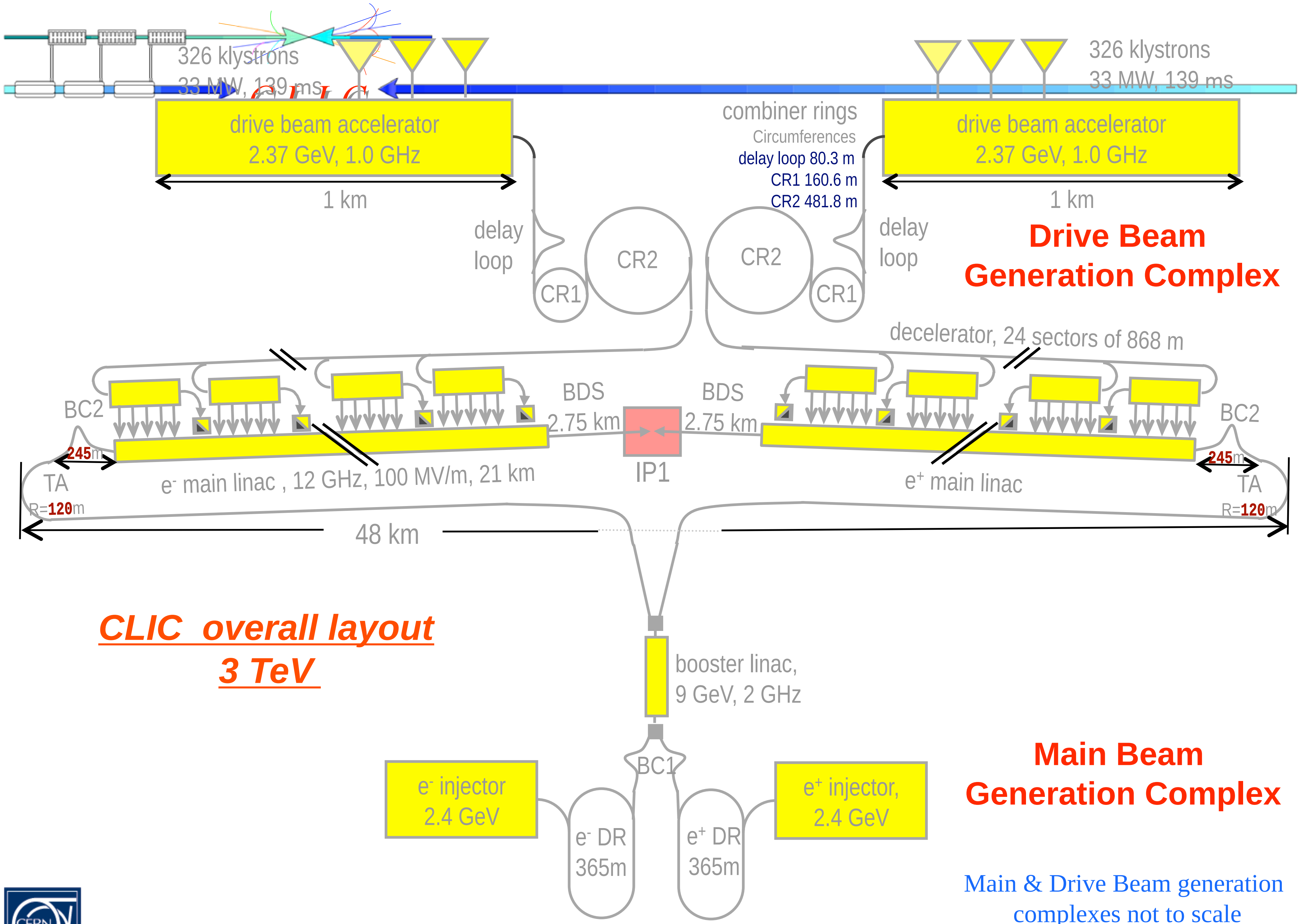
CLIC – basic features

- **High acceleration gradient: > 100 MV/m**
- "Compact" collider – total length < 50 km at 3 TeV
- Normal conducting acceleration structures at high frequency

- **Novel Two-Beam Acceleration Scheme**
  - Cost effective, reliable, efficient
  - Simple tunnel, no active elements
  - Modular, easy energy upgrade in stages







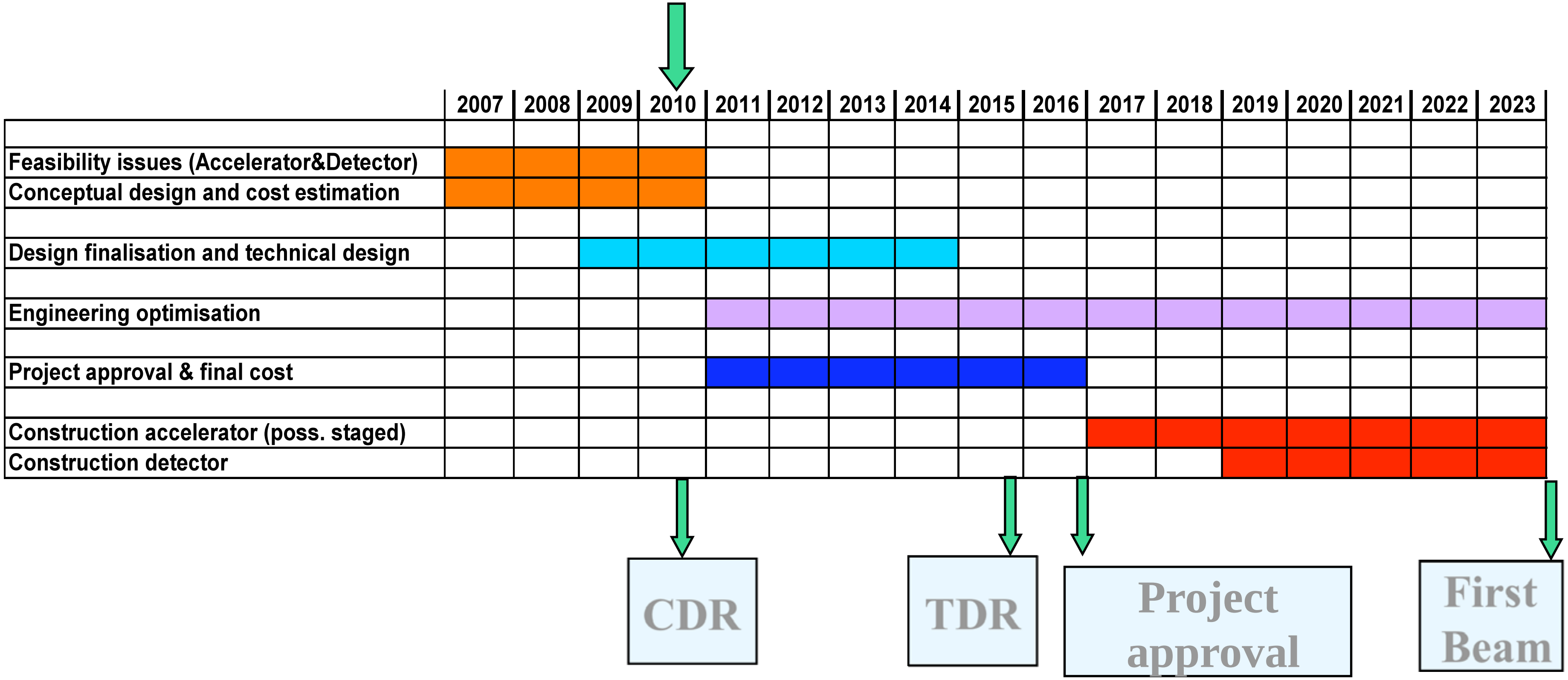
CLIC overall layout 3 TeV

Main & Drive Beam generation complexes not to scale

Tentative long-term CLIC scenario

Shortest, Success Oriented, Technically Limited Schedule

Technology evaluation and Physics assessment based on LHC results for a possible decision on Linear Collider funding with staged construction starting with the lowest energy required by Physics



CLIC/CTF3 Multi-Lateral Collaboration of Volunteer Institutes

27 institutes involving 17 funding agencies from 15 countries

Organized as a Physics Detector Collaboration

Collab. Board: Chair: M.Calvetti/INFN; Spokesperson: G.Geschonke/CERN

MoU with addenda describing specific contribution (& resources)

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm

***Members** (full responsibility of work packages and providing corresponding resources):*

- *CERN members with additional voluntary contributions:*

CERN, Finland (HIP), France (IRFU, LAL, LAPP, LURE), Italy (LNF), Norway (Oslo U.), Spain (CIEMAT, UPC, IFIC), Sweden (Uppsala), Switzerland (PSI), UK (Cockcroft, JAI, RHUL)

- *CERN non members with voluntary contributions:*

India (RRCAT), Pakistan (NCP), Russia (BINP, IAP, JINR), Turkey (Ankara U., Gazi U.), Ukraine (IAP), USA (NWU, SLAC, JLAB)

***MoU under discussion:** China (Tsinghua Univ.), Iran (IPM),*

World-wide CLIC / CTF3 collaboration

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm

24 members representing 27 institutes involving 17 funding agencies of 15 countries

Ankara University (Turkey)
Berlin Tech. Univ. (Germany)
BINP (Russia)
CERN
CIEMAT (Spain)
Finnish Industry (Finland)
Gazi Universities (Turkey)

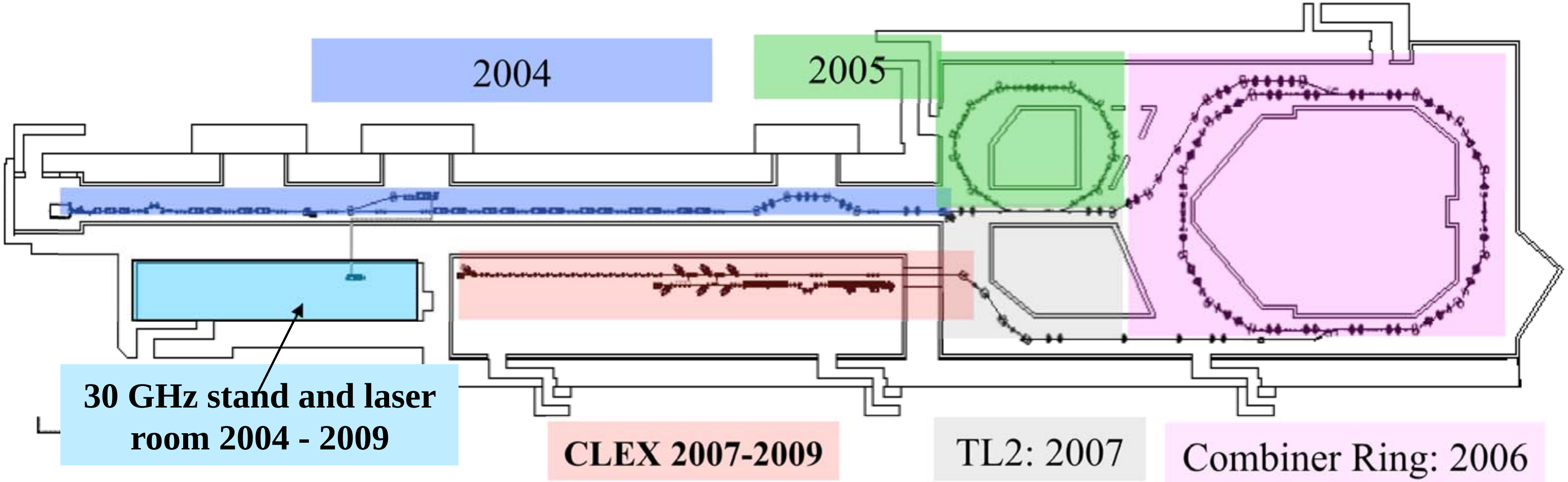
IRFU/Saclay (France)
Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)

JASRI (Japan)
JINR (Russia)
JLAB (USA)
KEK (Japan)
LAL/Orsay (France)
LAPP/ESIA (France)
LLBL/LBL (USA)
NCP (Pakistan)
North-West. Univ. Illinois (USA)

Oslo University
PSI (Switzerland),
Polytech. University of Catalonia (Spain)
RAL (England)
RRCAT-Indore (India)
Royal Holloway, Univ. London, (UK)
SLAC (USA)
Svedberg Laboratory (Sweden)
Uppsala University (Sweden)

All major CLIC technology key issues addressed in CLIC Test Facility (CTF3)

First Accelerator R&D recognized as Physics Experiment (Grey Book)



total length about 140 m

Key issues

From 2005: Accelerating structures Development& Tests (R2.1)

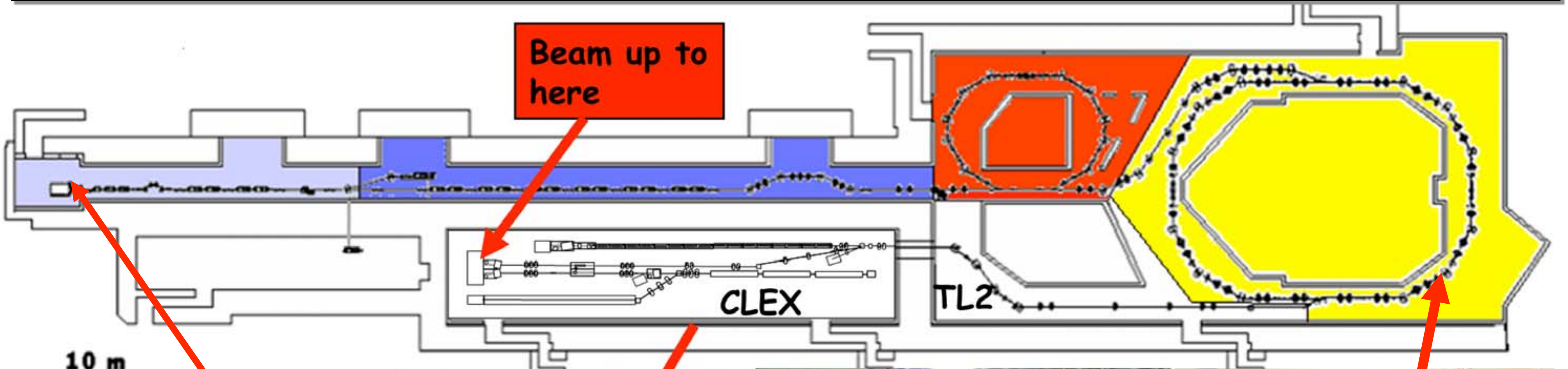
2007- 2008: Drive beam generation scheme (R1.2)

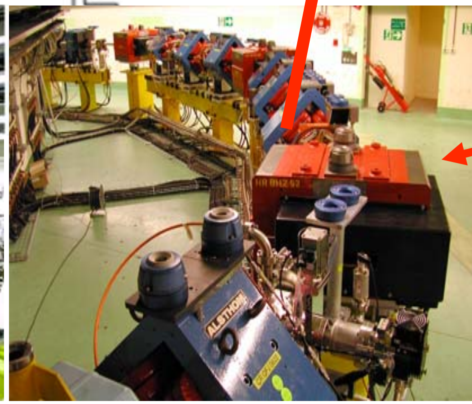
2008- 2009: Damped accelerating structure with nominal parameters (R1.1)
ON/OFF Power Extraction Structure (R1.3)
Drive beam stability bench marking (R2.2)
CLIC sub-unit (R2.3)

CTF3 Continuous Operation (10months/year)

HW & Beam Commisioning and RF power production for structure tests

- Demonstrate Drive Beam generation
  (fully loaded acceleration, beam intensity and bunch frequency multiplication x8)
- Demonstrate RF Power Production and test Power Structures (PETS)
- Demonstrate Two Beam Acceleration and test Accelerating Structures





Major Components to Complete CTF3 by 2010

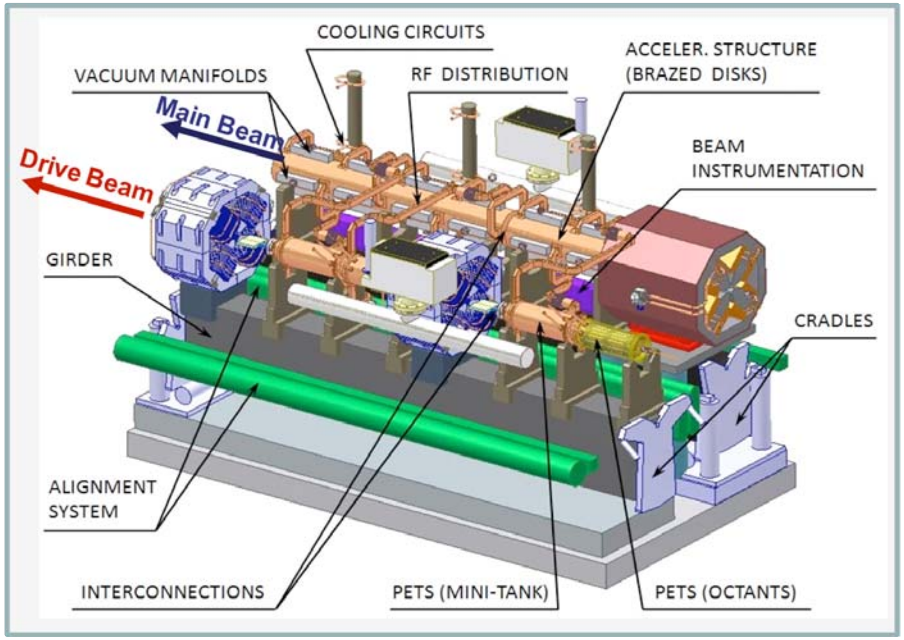
- The main installation is complete, a part from Test Beam Line (TBL) 15 cells:
  - vacuum components,
  - PETS structures and tanks, PETS vacuum tanks,
  - X-band waveguides, RF loads, waveguide directional couplers
  - Low level X-band detectors,
- High power RF components for CTF3
  - S-band klystrons repair / replacement (about 2-3 per year)
  - L-band replacement klystron
  - maintenance of modulators:
  - thyratrons (about 3/year)
  - S-band waveguides (bends, straights) in small quantities for replacements and modifications
  - directional couplers,
  - high power RF windows
  - Low power RF:
  - S-band components (amplifier modules, phase shifters, amplitude detectors)
- Stand-alone power test stand
  - klystron (SLAC) and modulator
  - RF pulse compressor
  - X-band waveguides and components
  - vacuum equipment,
- Instrumentation: for example network analyzer
- PHIN laser: instrumentation

CLIC Two Beam Modules Development and Tests

CLIC will need in its final configuration about 20000 two-beam modules, each 2.01 m long.

These modules comprise 12 GHz high power RF components, beam diagnostics, vacuum equipment, active alignment & stabilization equipment and magnets.
All this components have to be assembled with very high precision.

To adapt the module design for mass production and to validate the technology a number of prototypes have to be build with industry and tested in a test facility at CERN .



- *Micron tolerance 3D machining and assembly*
- *Compatibility with high-power operation*
- *Sub-micron 3D metrology*
- *Mass production and cost estimate*

Prototype development of CLIC modules	
Period for purchase and validation tests	2011-2015
Number	10
Approximate total cost	10 – 25 MCHF

Accelerating structures/PETS

High power test structure supply

Motivation: structure development program

- Schedule:
  - 2009-2010: 10 per year
  - 2011: 20
- Cost: 50-70 kCHF per unit
- Tolerance: about 5 mm
- UHV compatible materials: Cu OFE, copper alloys (CuZr, Glidcop,..)
- Manufacturing techniques: 3D milling, 3D turning
- Assembly method: vacuum brazing, hydrogen brazing, EB welding,..

Accelerating structures/PETS

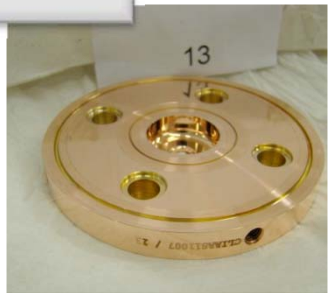
High precision and mass production technology development

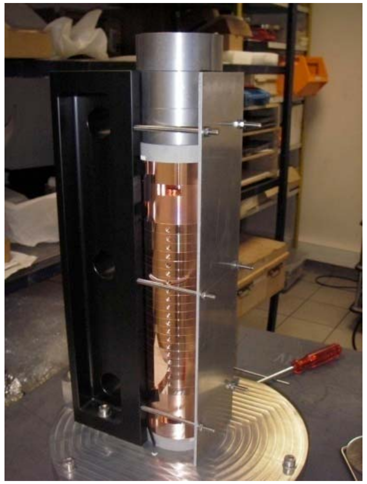
Motivation: series production for CLIC

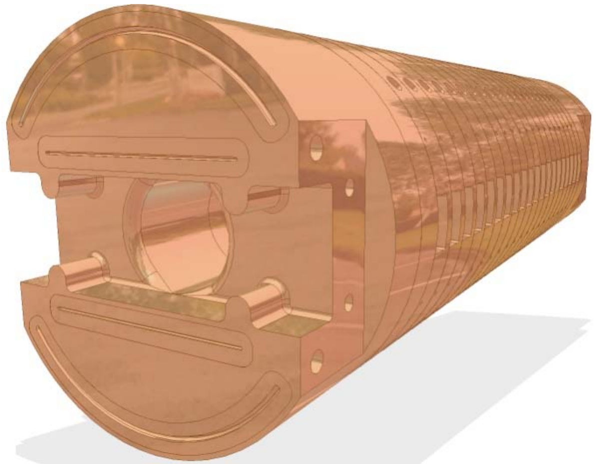
- Joint CERN/Industry machining development
  ➔ "shared-risk contract"
- 1 mm tolerance manufacturing
- Technology development (conventional and alternative, such ECM and molding)
- Mass production (about 140000 ac. structures for CLIC)
- Industrialization (fabrication over about 8 years)
- Cost estimate

Accelerating structures and Power Extraction Structures (PETS)

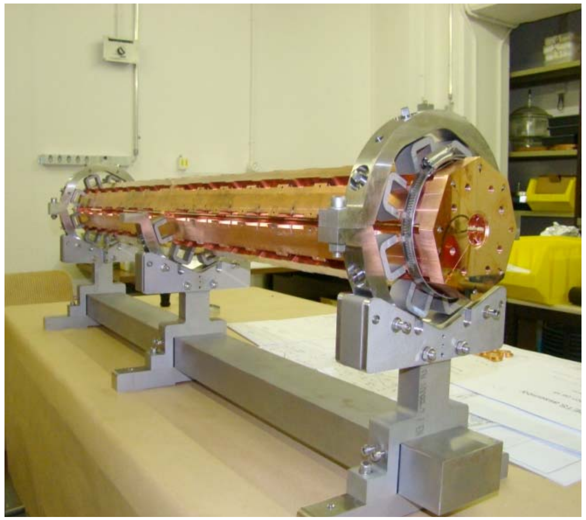
Accelerating structure
- disks
- assembly







PETS
- bars
- assembly



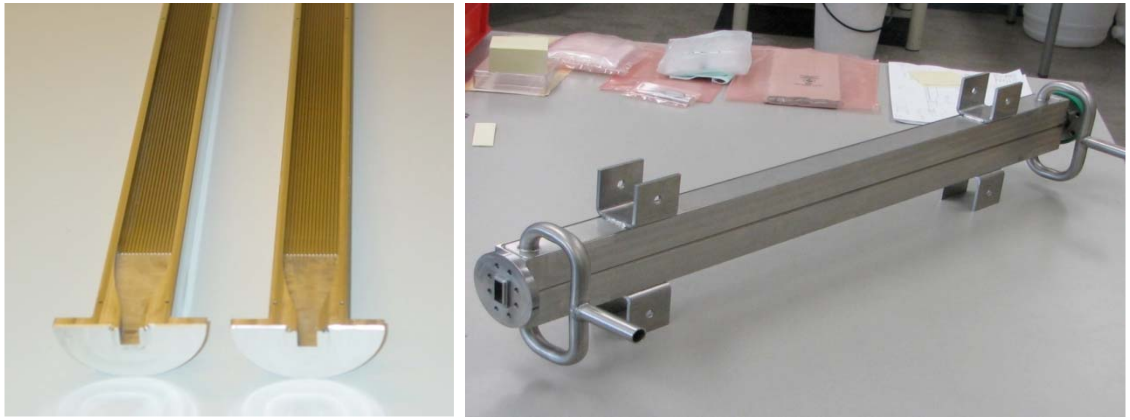
High Power RF components

Motivation: supply of components for high-power structure testing

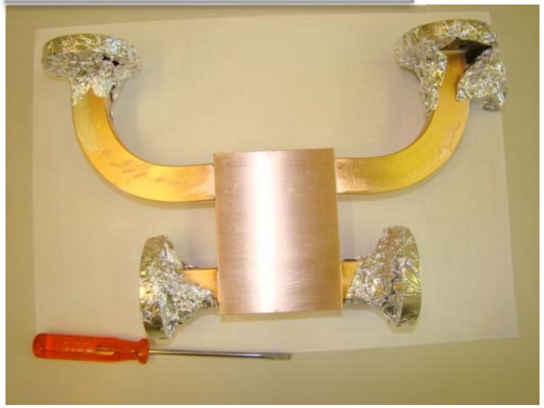
- Schedule 2009-2011:
  - Supply components for TBTS (10's) , X-band Klystron (CERN, Saclay) (10's), TBL (100's)
- Cost: depends on component (High power load ~ 10-15 kCHF, hybrid ~ 3-4 kCHF)
- UHV compatible materials: Cu OFE, Stainless steel
- Manufacturing Techniques: wire cutting, 3-5 axis 3D milling, conventional milling,..
- Assembly method: vacuum brazing, EB welding,..
- Metrology: conventional precision

High-power RF components

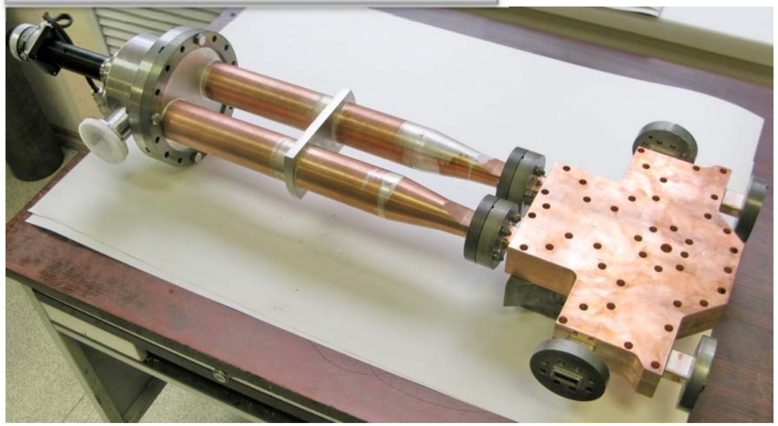
High-power loads (parts and assembly)



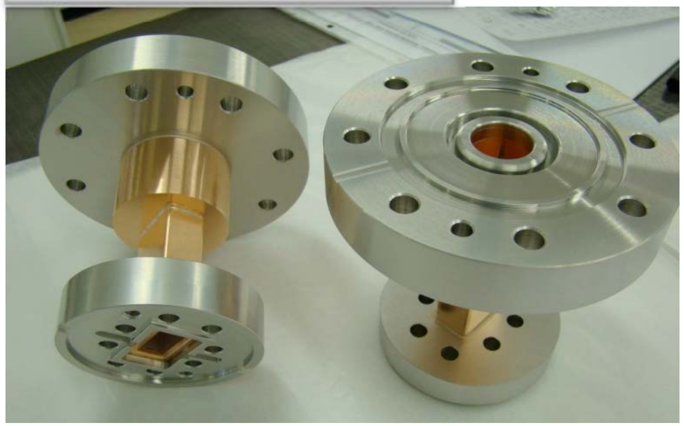
High-power hybrid



High-power attenuator



Choke mode flanges



RF power stations

CLIC will need in its final configuration about 700 RF power stations operating at 1 GHz.
The most promising RF source candidates are multi-beam klystrons driven by high voltage pulse modulators.
To validate the technology prototypes of these RF stations have to be developed and tested.

Prototype development of pulsed power RF sources	
Frequency	1 GHz
Pulse length	140 ms
Rep. rate	50 Hz
Peak power	40 MW
Period for purchase and validation tests	2011-2015
Number	2
Approximate total cost	10 – 20 MCHF

Major CLIC Components pending project approval (2016)

- Civil engineering:
  - 60 km of tunnels diameter 4.5 m, 150 m below ground
  - 24 shafts diameter 6 m, 150 m long
- 21000 Two Beam modules
  - 140000 accelerating structures 0.23m long, nanometer precision
  - 70000 power structures 0,75 m long, nanometer precision
  - 50000 Quadrupole Magnets and power supplies
  - 50000 Beam Position monitors & electronics
  - 100 kms of vacuum chambers
- Alignment
  - at micron level (nm vibration stabilisation) along 20 kms linacs
- Injectors
  - 15 GeV standard linac (2 GHz)
  - 700 Klystrons 1 GHz, 35 MWatts, 150 microsec
  - 700 Modulators (500 kJ, 10 kJoules)
- Physics
  - 2 Detectors similar to CMS/LHC

Conclusion

- CLIC study well on schedule to address major issues and demonstrate feasibility including cost to be published in a Conceptual Design Report by 2010
  - Completion and commissioning of test facility CTF3
  - Development and tests of high precision/ high power components assembled with very high precision in modules comprising 12 GHz high power RF components, beam diagnostics, vacuum equipment, active alignment & stabilization equipment and magnets.
- From 2011, Technical Design including adaptation to mass production, industrialization and cost optimization
  - Construction and tests of large number of prototypes
  - Strong collaboration with industry

Reserve slides

DG to CERN staff
Jan 08

Prospects for Scientific Activities over the Period 2012 - 2016

To be decided in 2010-2011 in light of first physics results from LHC, and designed and R&D results from the previous years. This programme could most probably comprise:

- An LHC luminosity increase requiring a new injector (SPL and PS).

  The total cost of the investment over 6 years (2011-2016: 1000-1200 MCHF + a staff of 200-300 per year. Total budget: ~200-250 MCHF per year.

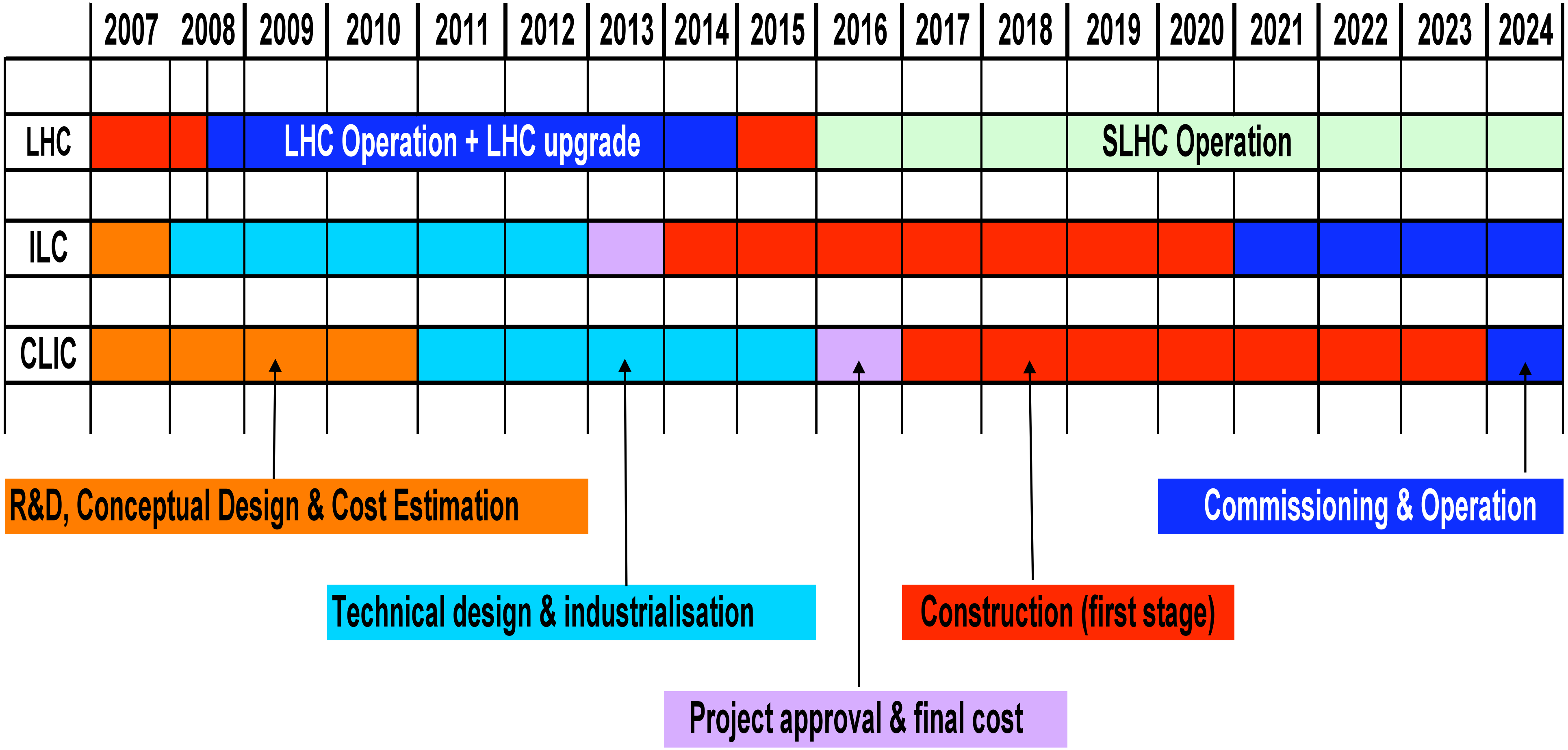
- Preparation of a Technical Design for the CLIC programme, for a possible construction decision in 2016 after the LHC upgrade (depending on the ILC future).
  Total CERN M + P contribution + ~250 MCHF + 1000-1200 FTE over 6 years.

- Enhanced infrastructure consolidation: 30 MCHF + 40 FTEs from 2011.

NB: Over the period 2012-2016. Effective participation of CERN in another large programme (ILC or a neutrino factory) will not be possible within the expected resources if positive decisions taken on LHC upgrade and CLIC Technical Design. This situation could totally change *if none of the above programmes is approved* or if a new, more ambitious level of activities and support is envisaged in the European framework.

Large Colliders Technically Driven Scenarii?

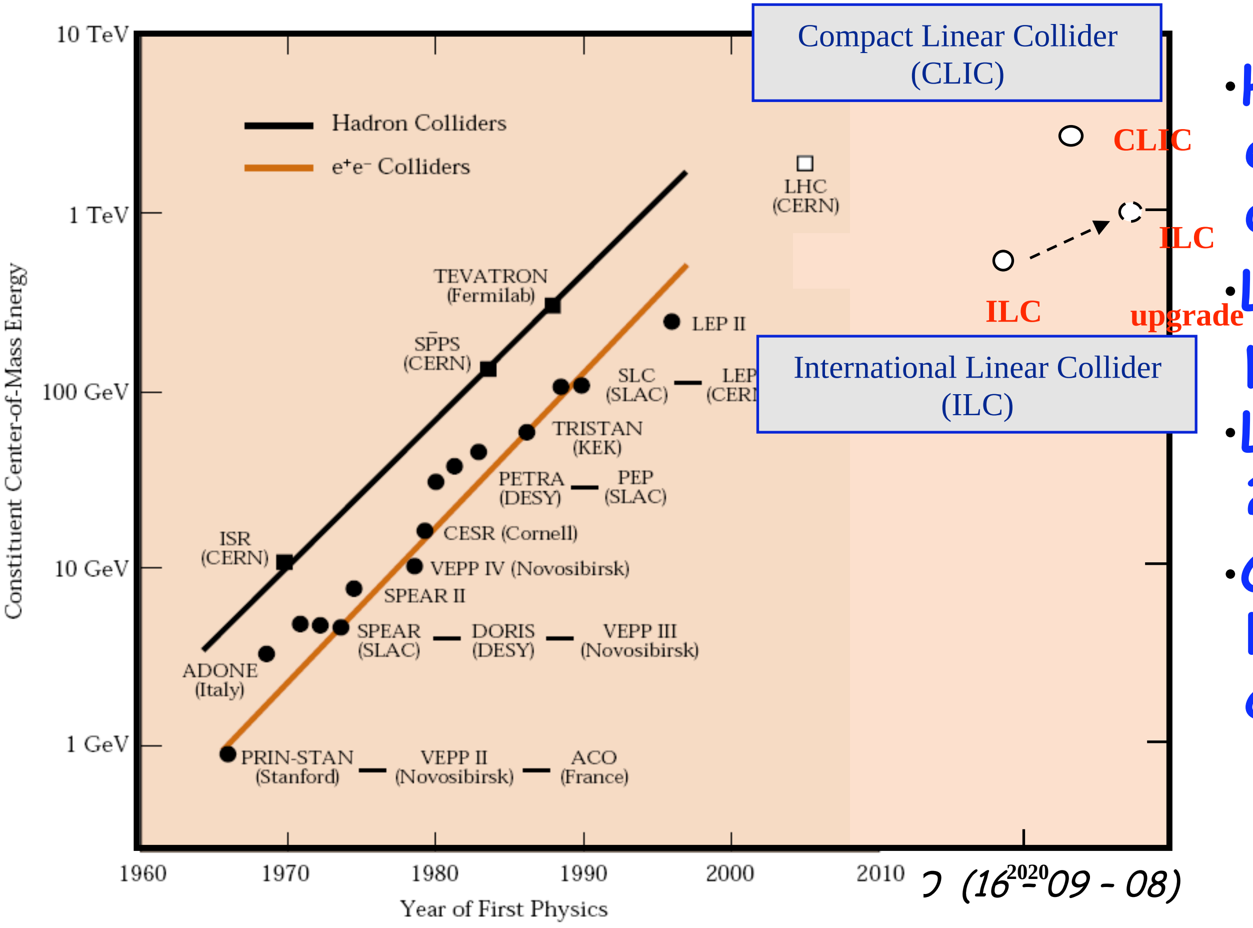
A look into the crystal ball !



Lepton and Hadron facilities complementary for discovery and physics of new particles

Particle accelerators with colliding beams a long standing success story in particles discoveries and precision measurements

Energy (<u>exponentially !</u>) increasing with time: a factor 10 every 8 years!



- Hadron Colliders at the energy frontier as discovery facilities
- Lepton Colliders for precision physics
- LHC coming online from 2008
- Consensus for a future lepton linear collider to complement LHC physics