Pre-Alignment in the context of the CLIC study

Welcome

CLIC scheme

R&D to address feasibility

Collaborations

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

World consensus about a Linear Collider as the next HEP facility after LHC?

- **2001: ICFA recommendation of a world-wide collaboration to construct a high luminosity e+/e- Linear Collider with an energy range of 400 GeV/c upgradeable to at least 1 TeV**
- **2003: ILC-Technical Review Committee to assess the technical status of the 15 years of R&D on various technologies and designs of Linear Colliders**
- **2004: International Technology Recommendation Panel selected the Super-Conducting RF technology developed by the TESLA Collaboration for an International Linear Collider (ILC) in the TeV energy range**
- **2004: CERN council strong support for R&D addressing the feasibility of the CLIC technology to possibly extend Linear Colliders into the Multi-TeV energy range.**

CERN Council Strategy Group (Lisbon July 2006)

The European strategy for particle physics

Particle physics stands on the threshold of a new and exciting era of discovery. The next generation of experiments will explore new domains and probe the deep structure of space-time. They will measure the properties of the elementary constituents of matter and their interactions with unprecedented accuracy, and they will uncover new phenomena such as the Higgs boson or new forms of matter. Long-standing puzzles such as the origin of mass, the matter-antimatter asymmetry of the Universe and the mysterious dark matter and energy that permeate the cosmos will soon benefit from the insights that new measurements will bring. Together, the results will have a profound impact on the way we see our Universe; European particle physics should thoroughly exploit its current exciting and diverse research programme. It should position itself to stand ready to address the challenges that will emerge from exploration of the new frontier, and it should participate fully in an increasingly global adventure.

General issues

1. European particle physics is founded on strong national institutes, universities and laboratories and the CERN Organization; *Europe should maintain and strengthen its central position in particle physics.*

2. Increased globalization, concentration and scale of particle physics make a well coordinated strategy in Europe paramount; *this strategy will be defined and updated by CERN Council as outlined below.*

Scientific activities

3. The LHC will be the energy frontier machine for the foreseeable future, maintaining European leadership in the field; *the highest priority is to fully exploit the physics potential of the LHC, resources for completion of the initial programme have to be secured such that machine and experiments can operate optimally at their design performance.* A subsequent major luminosity upgrade (SLHC), motivated by physics results and operation experience, will be enabled by focussed R&D; *to this end, R&D for machine and detectors has to be vigorously pursued now and centrally organized towards a luminosity upgrade by around 2015.*

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.*

6. Studies of the scientific case for future neutrino facilities and the R&D into associated technologies are required to be in a position to define the optimal neutrino programme based on the information available in around 2012; *Council will play an active role in promoting a coordinated European participation in a global neutrino programme.*

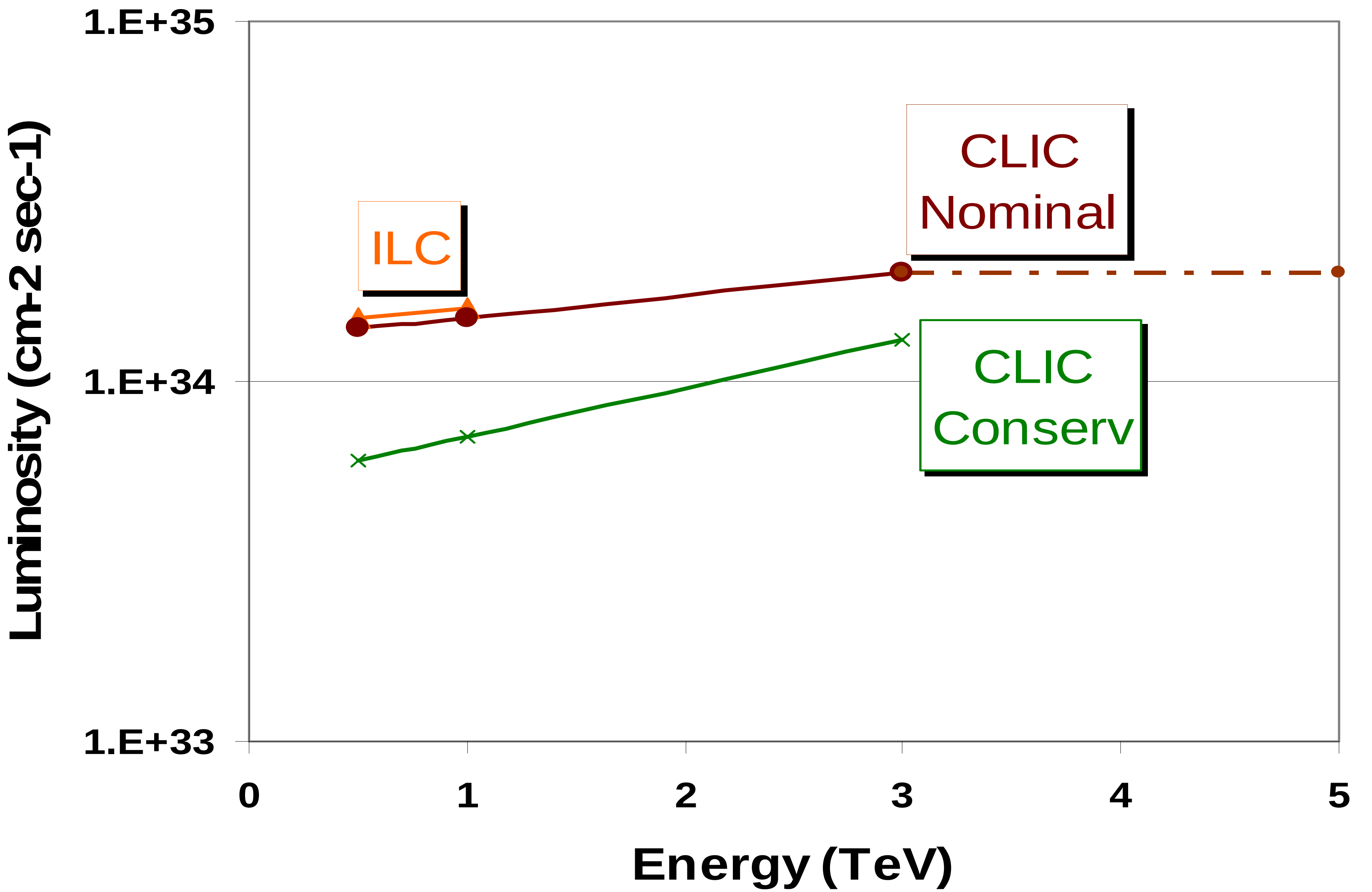
7. A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; *Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest.*

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.*

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.*

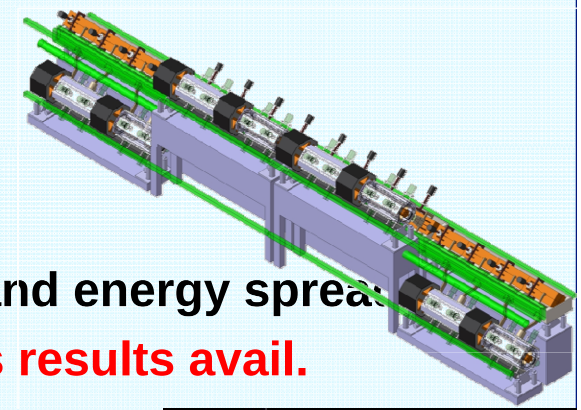
CLIC Parameters and upgrade scenario

http://cdsweb.cern.ch/record/1132079/files/CERN-OPEN-2008-021.pdf



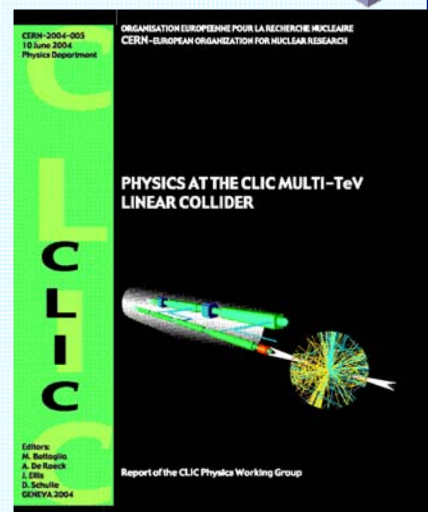
THE COMPACT LINEAR COLLIDER (CLIC) STUDY

Aim: develop technology to extend e-/e+ linear colliders into the Multi-TeV energy range:



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

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



Physics motivation:

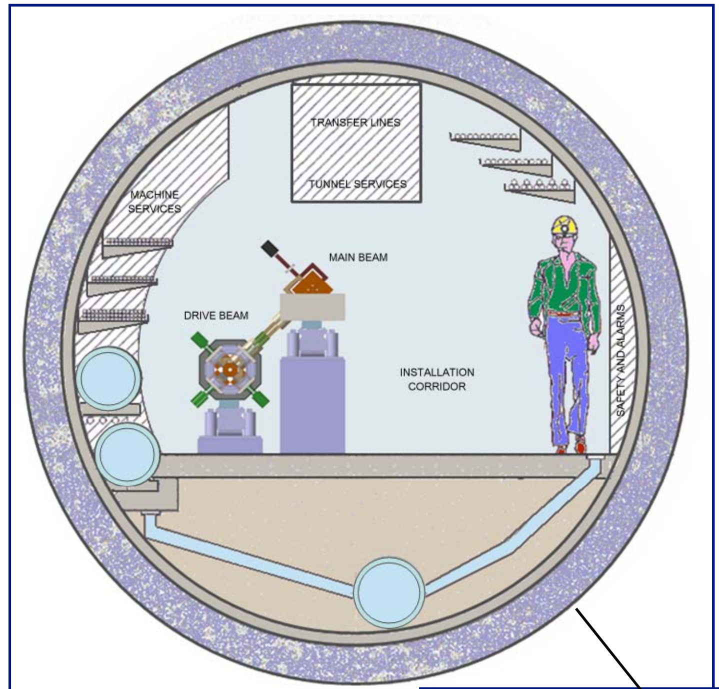
http://clicphysics.web.cern.ch/CLICphysics/

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

Present goal:

Demonstrate all key feasibility issues and document in a Conceptual Design Report by 2010 and possibly Technical Design Report by 2015

CLIC – basic features

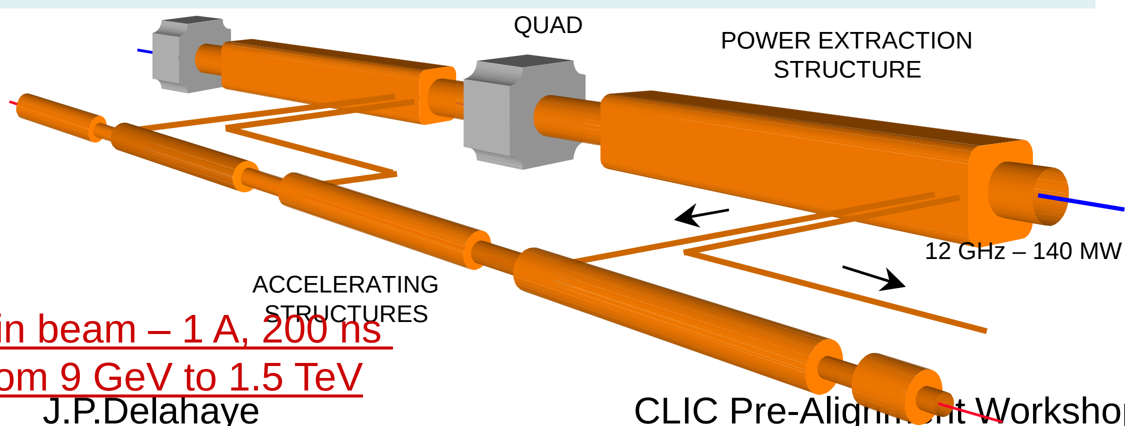


CLIC TUNNEL CROSS-SECTION

4.5 m diameter

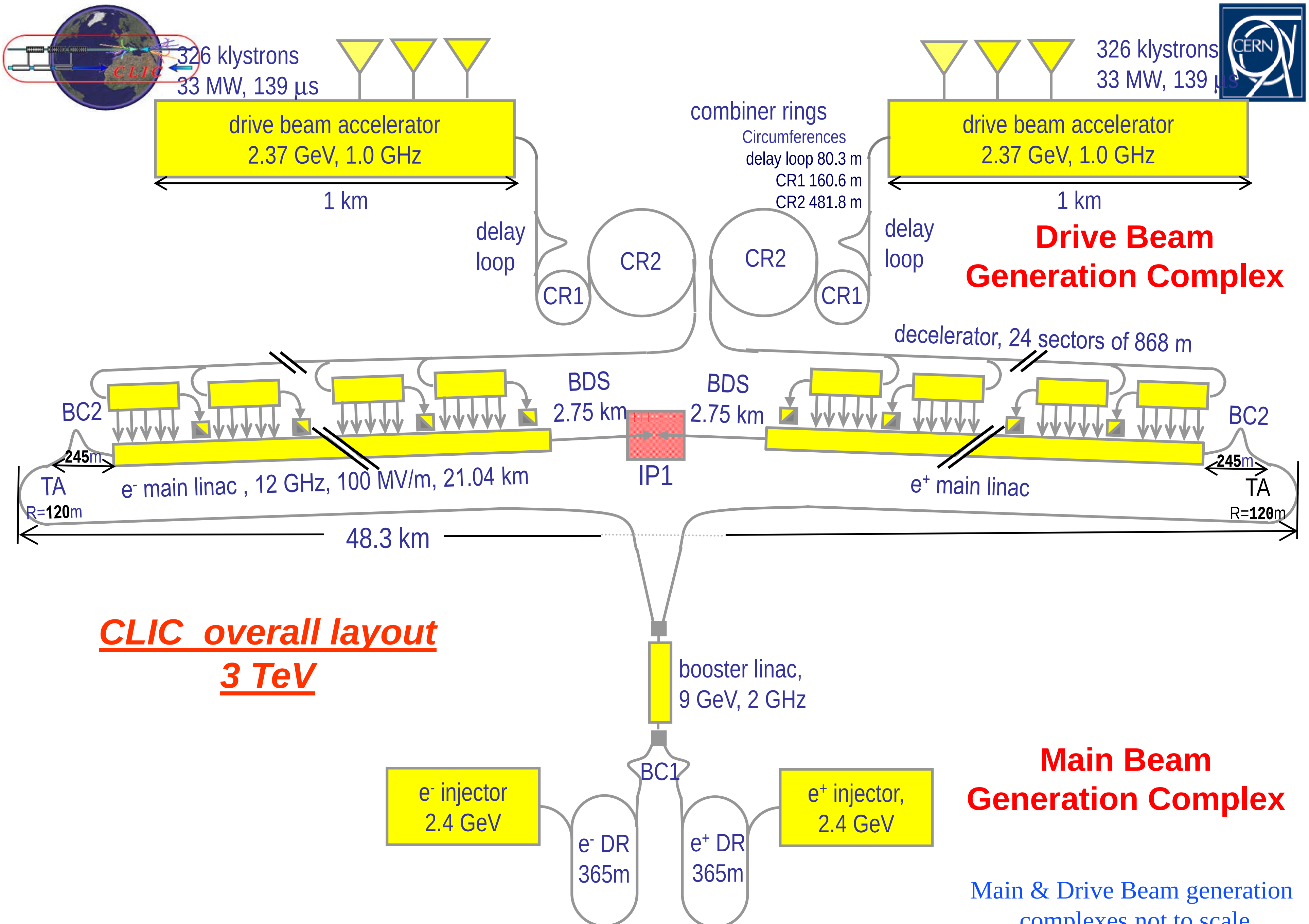
- **High acceleration gradient: > 100 MV/m**
  - **"Compact" collider – total length < 50 km at 3 TeV**
  - **Normal conducting acceleration structures at high frequency**

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



Drive beam - 95 A, 300 ns from 2.4 GeV to 240 MeV

Main beam – 1 A, 200 ns from 9 GeV to 1.5 TeV



CLIC overall layout
3 TeV

Luminosity in Linear Colliders

energy loss by beamstrahlung

wall-plug to beam efficiency

wall-plug power

$$L = \frac{k_b N_b^2 f_{rep}}{4\pi U_{cm} \sigma_x^* \sigma_y^*} \propto \frac{\delta_B^{1/2} \times \eta_{beam}^{AC} \times P_{AC}}{U_{cm} \, {\varepsilon_{ny}^*}^{1/2}}$$

center-of-mass energy

Vertical emittance

- Vertical beam emittance **at I.P. as small as possible**
- Wall-plug to beam efficiency **as high as possible**
- Beamstrahlung energy spread **increasing with c.m. colliding energies**

Getting the Luminosity ($>2*10^{34} cm^{-2}s^{-1}$ at 3 TeV)

Beam size at Interaction Point (rms) :

$$\sigma_x = 40 \text{ nm}, \sigma_y = 1 \text{ nm}$$

Issues:

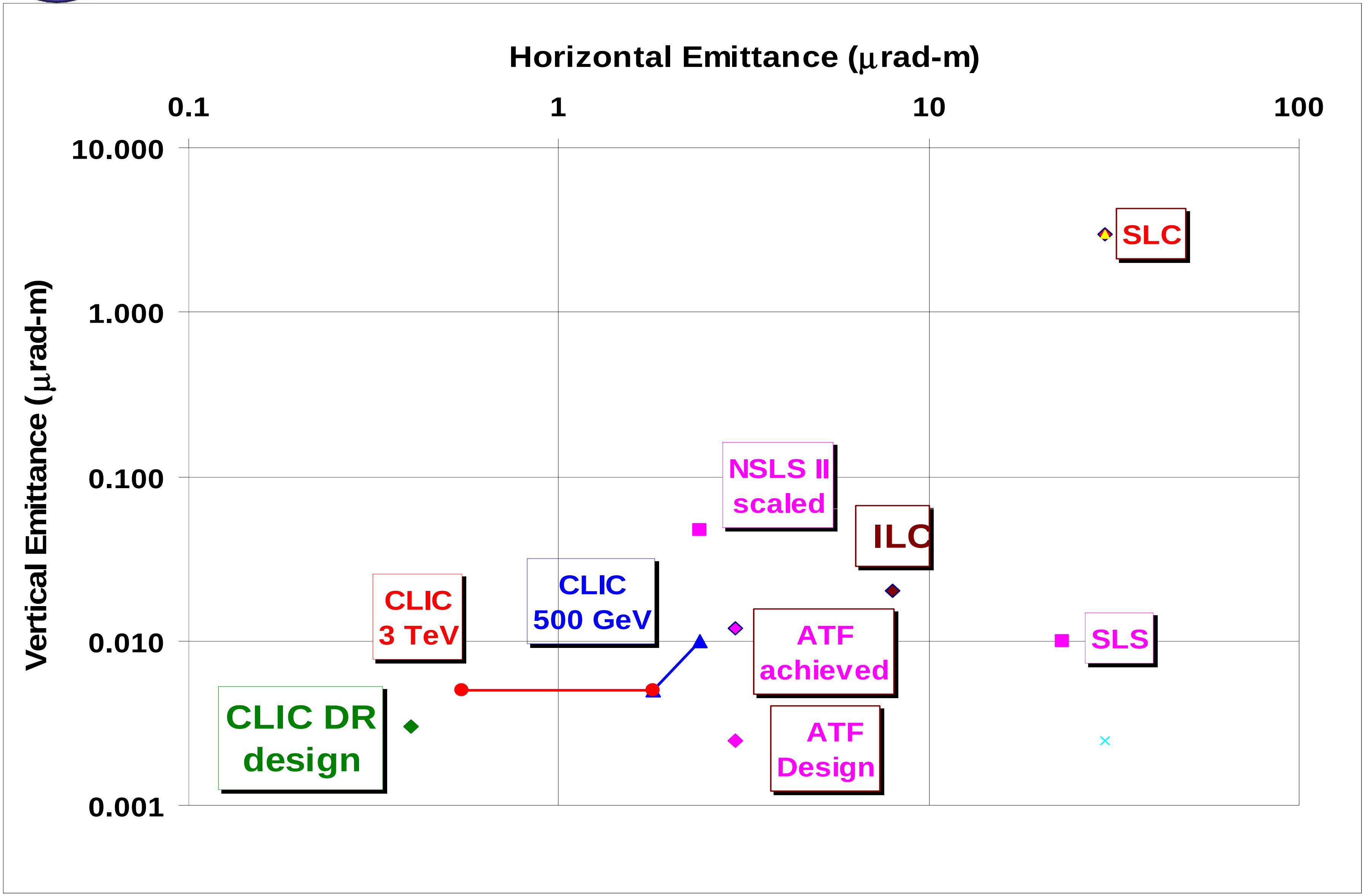
- generating small emittance beams
- emittance preservation
- alignment and vibration control
- final focus (Beam Delivery System)

Contributions of this workshop

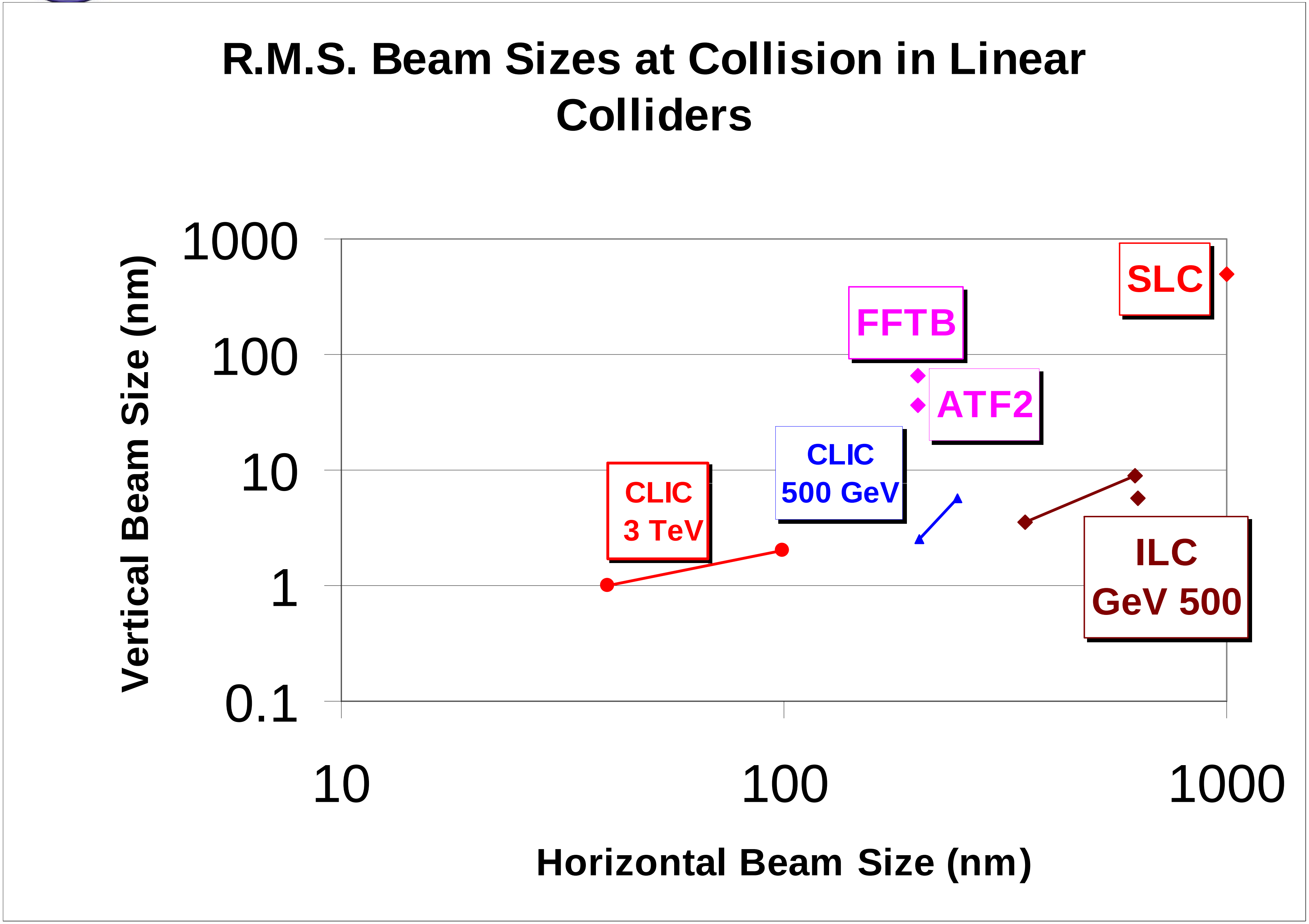
CLIC 3 TeV main parameters

Center-of-mass energy	CLIC conserv.	CLIC Nominal
Total (Peak 1%) luminosity	$1.5(0.73)10^{34}$	$5.9(2.0)\cdot 10^{34}$
Repetition rate (Hz)	50	
Loaded accel. gradient MV/m	100	
Main linac RF frequency GHz	12 (NC)	
Bunch charge10^9	3.72	
Bunch separation ns	0.5	
Beam pulse duration (ns)	156	
Beam power/linac (MWatts)	14	
Hor./vert. norm. emitt ($10^{-6}/10^{-9}$)	3 / 40	2.4 / 25
Hor/Vert FF focusing (mm)	10/0.4	8/0.1
Hor./vert. IP beam size (nm)	83 / 2.0	40 / 1.0
Soft Hadronic event at IP	0.57	2.7
Coherent pairs/crossing at IP	$5\ 10^7$	$3.8\ 10^8$
BDS length (km)	2.75	
Total site length (km)	48.3	
Wall plug to beam transfer eff.	6.8%	
Total power consumption (MW)	415	

Beam emittances at Damping Rings



Beam sizes at Collisions



Beam emittance preservation
Beam Dynamics, alignment and stability

Emittance blow-up from Damping Ring to BDS limited:
- in Horizontal to 30% from 500 nrad
- in Vertical to 300% from 5 nrad

Pre-alignment precision: 15 microns
Beam based alignement: 5-10 microns
Stability requirements (> 4 Hz)

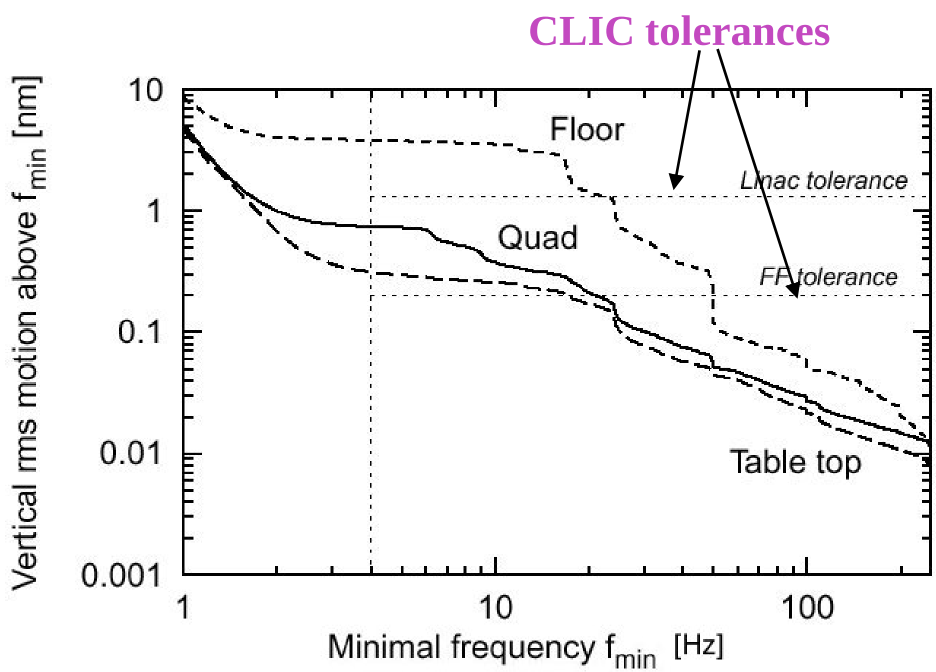
Magnet	Horiz.	Vert.
Linac (2600 quads)	14nm	1.3 nm
Final Focus (2quads)	4 nm	.15 to1 nm

Need active damping of vibrations

Achieved stability on CERN vibration test stand

Test made in noisy environment, active damping reduced vibrations by a factor about 20, to rms residual amplitudes of:

Vert. 0.9 ± 0.1 nm
1.3 ± 0.2 nm with cooling water
Horiz. 0.4 ± 0.1 nm



CLIC feasibility issues

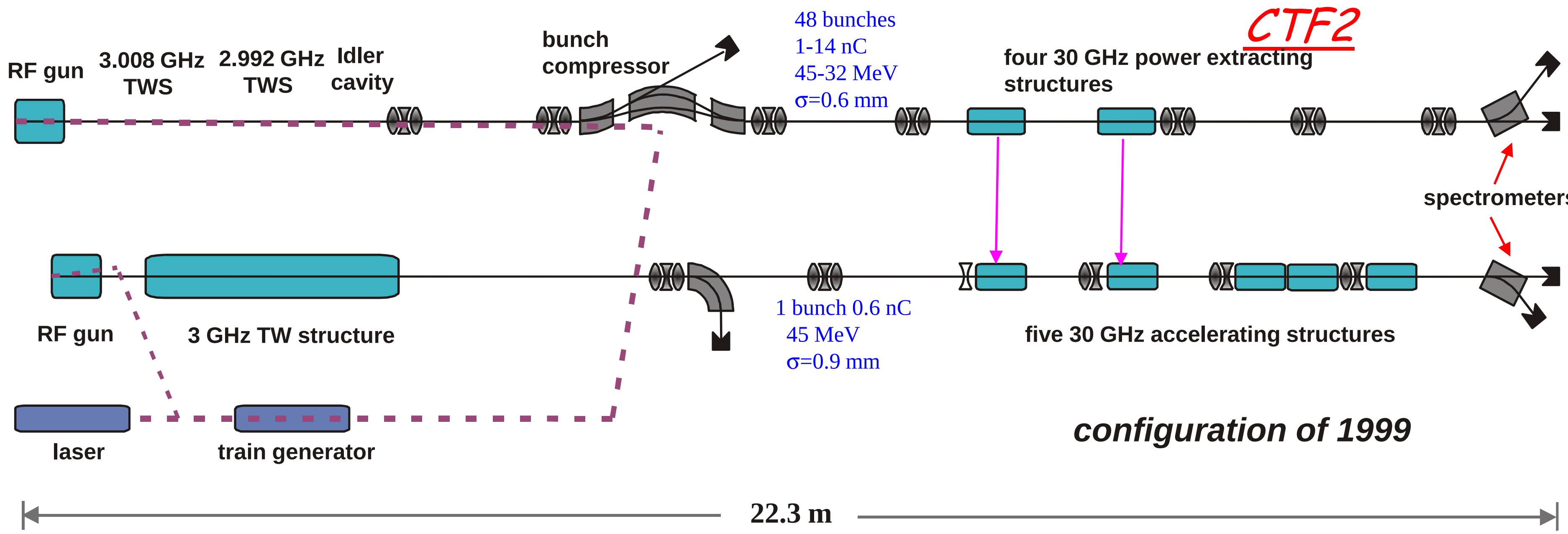
	SYSTEMS (level n)	Critical parameters	Feasibility issue	Performance issue	Cost issue
Structures	<u>Main beam acceleration structures</u> Demonstrate nominal CLIC structures with damping features at the design gradient, with design pulse length and breakdown rate .	100 MV/m 240 ns 3·10-7 BR/(pulse*m)	X	X	X
	<u>Decelerator structures</u> Demonstrate nominal PETS with damping features at design power, with design pulse length, breakdown rate on/off capability	136 MW 240 ns	X		X
Drive Beam	<u>Validation of drive Beam</u> - production - phase stability , potential feedbacks - MPS appropriate for beam power	0.2 degrees phase stability at 12 GHz	X	X	
Two Beam	Test of a relevant linac sub-unit with both beams	NA	X		
Beam Physics	- Preservation of low emittances (main linac + RTML)	Absolute blow-up Hor: 160nradm Vert: 15 nradm	X	X	
Stabilization	Main Linac and BDS Stabilization	Main Linac : 1 nm vert (>1 Hz) BDS: 0.15…1 nm vert (>4 Hz) depending on implementation of final doublet girder	X	X	X
Operation and reliability	Commissioning strategy Staging of commissioning and construction MTBF, MTTR Machine protection	Handling of drive beam power of 72 MW	X	X	X

CLIC Test Facility (CTF2) 1996-2002

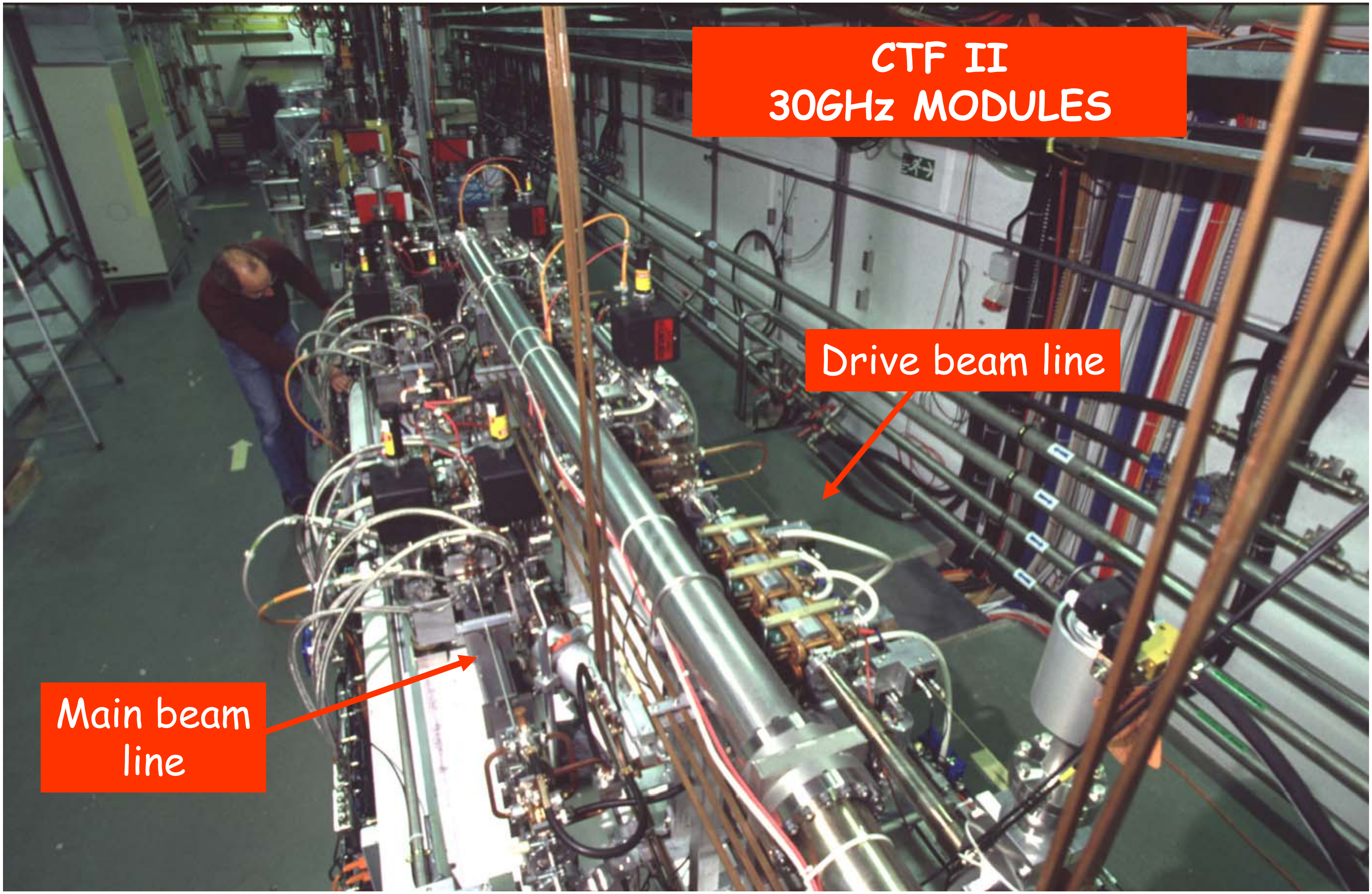
CTF2 goals :

- to demonstrate feasibility of CLIC two-beam acceleration scheme
- to study generation of short, intense e-bunches using laser-illuminated PCs in RF guns
- to demonstrate operability of μ-precision active-alignment system in accelerator environment
- to provide a test bed to develop and test accelerator diagnostic equipment
- to provide high power 30 GHz RF power source for high gradient testing ~90 MW 16 ns pulses

All-but-one of 30 GHz two-beam modules removed in 2000 to create a high-gradient test stand.

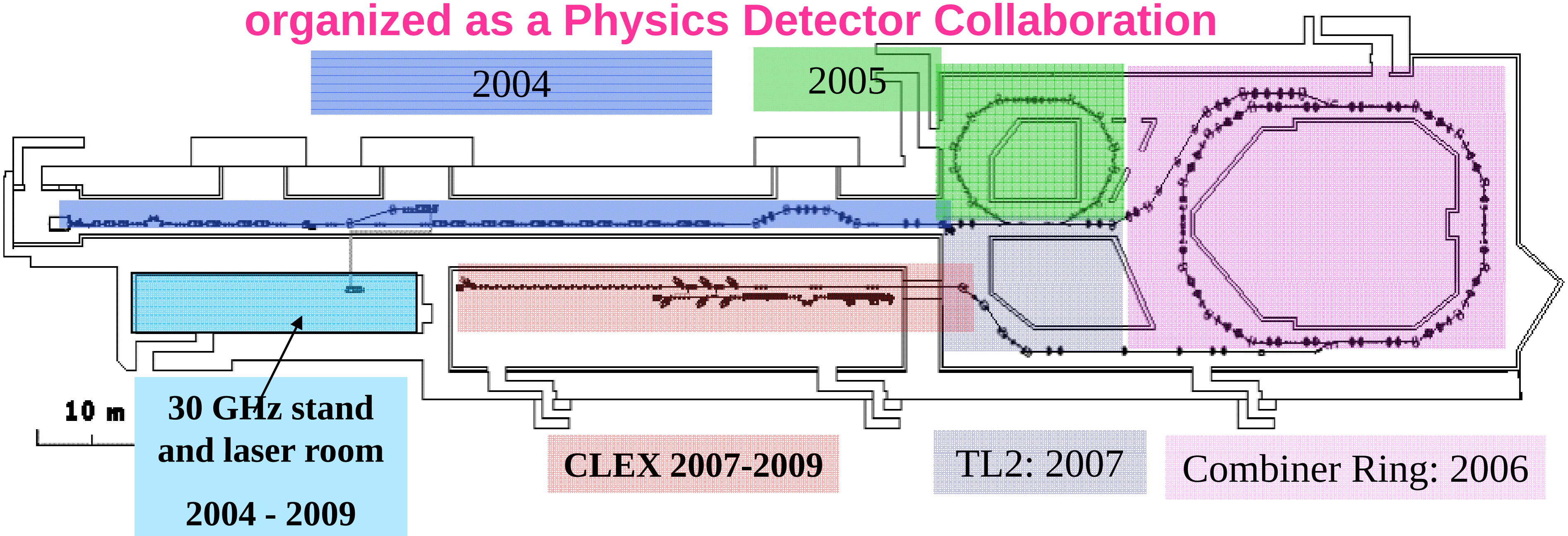


Two Beams set-up in CTF2



Addressing all major CLIC technology key issues in CLIC Test Facility (CTF3)

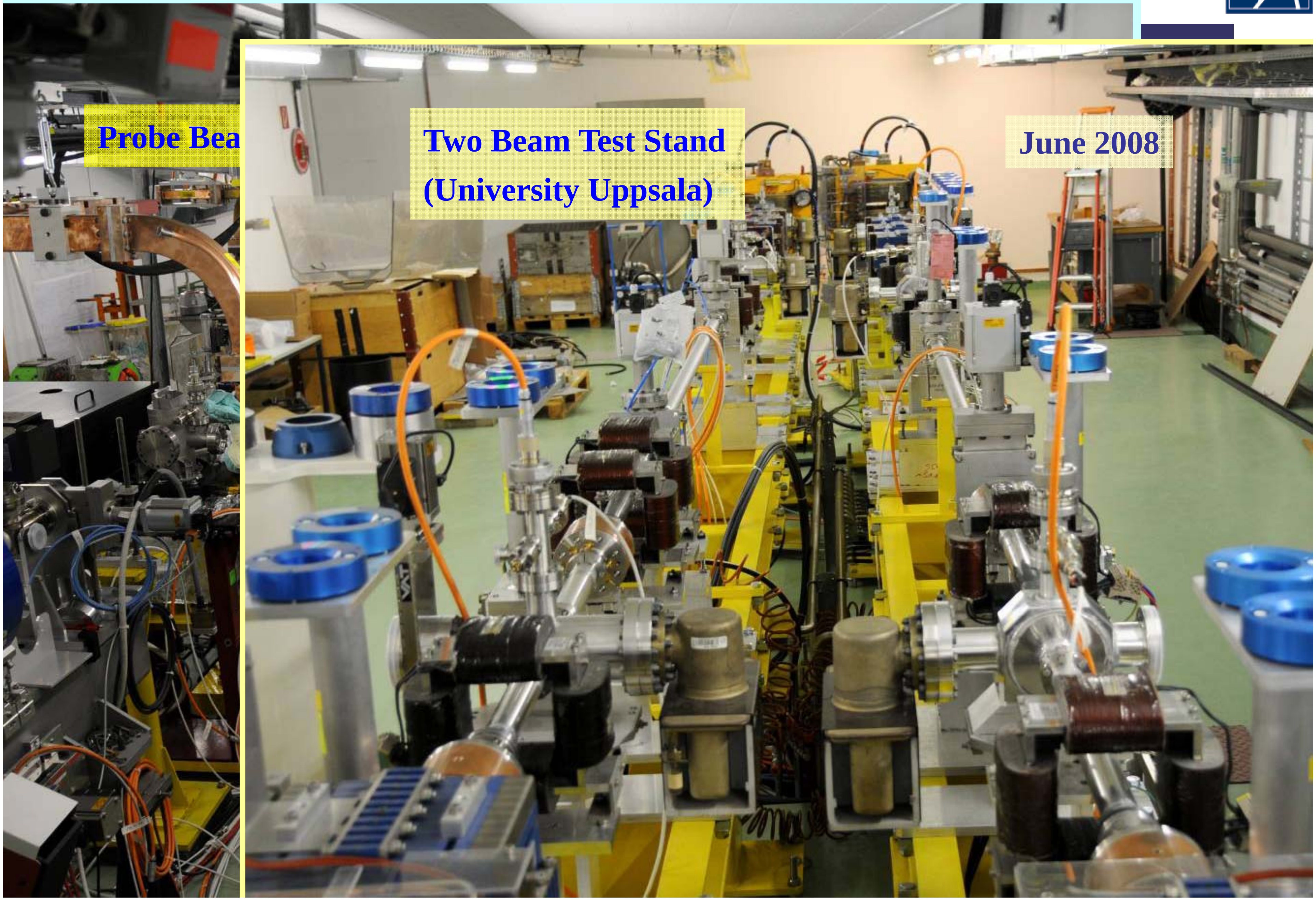
Multi-lateral Collaboration of 27 volunteer institutes organized as a Physics Detector Collaboration



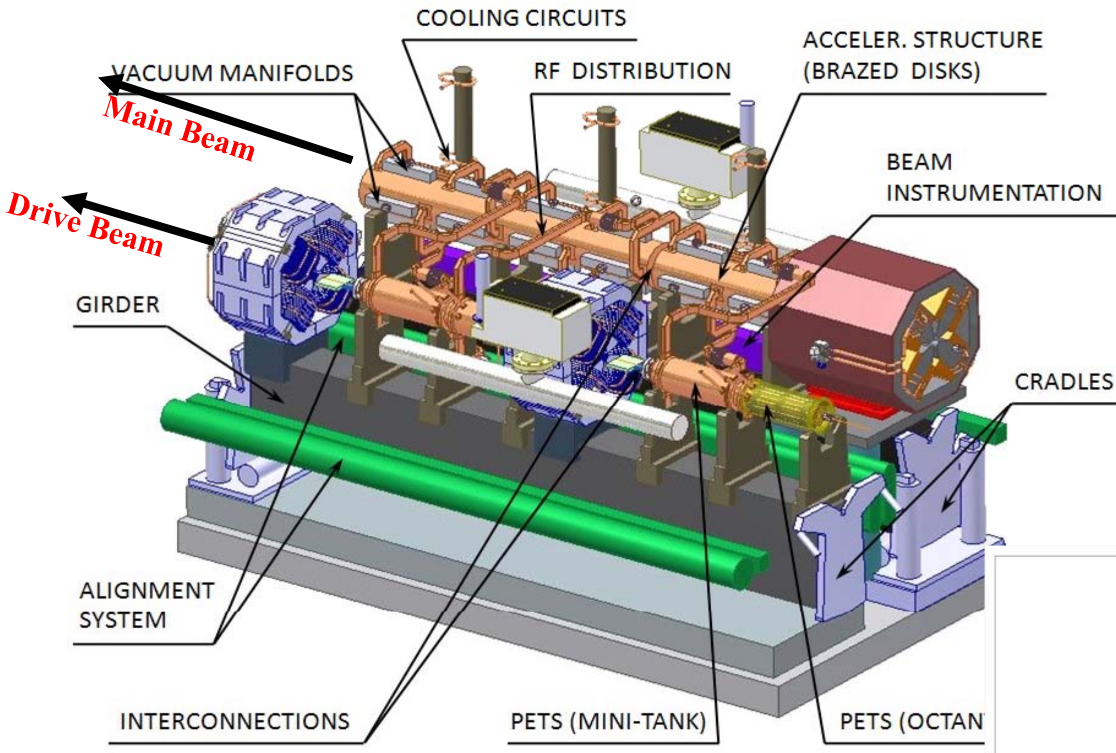
Key issues

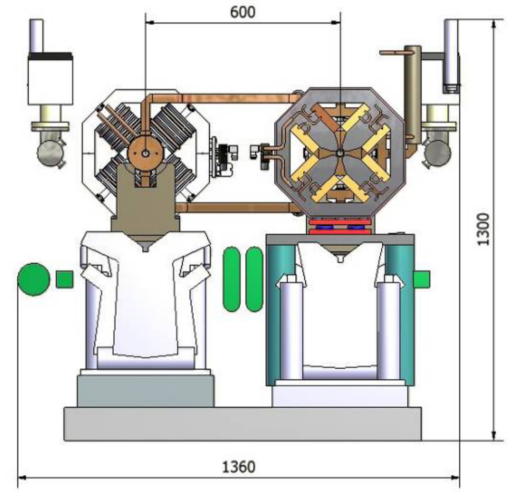
- ***From 2005: Accelerating structures (bi-metallic) Development& Tests (R2.1)***
- ***2007- 2008: Drive beam generation scheme (R1.2)***
- ***2008- 2009: Damped accelerating structure with nominal parameters (R1.1)***
  - ***ON/OFF Power Extraction Structure (R1.3)***
  - ***Drive beam stability bench marking (R2.2)***
  - ***CLIC sub-unit (R2.3)***

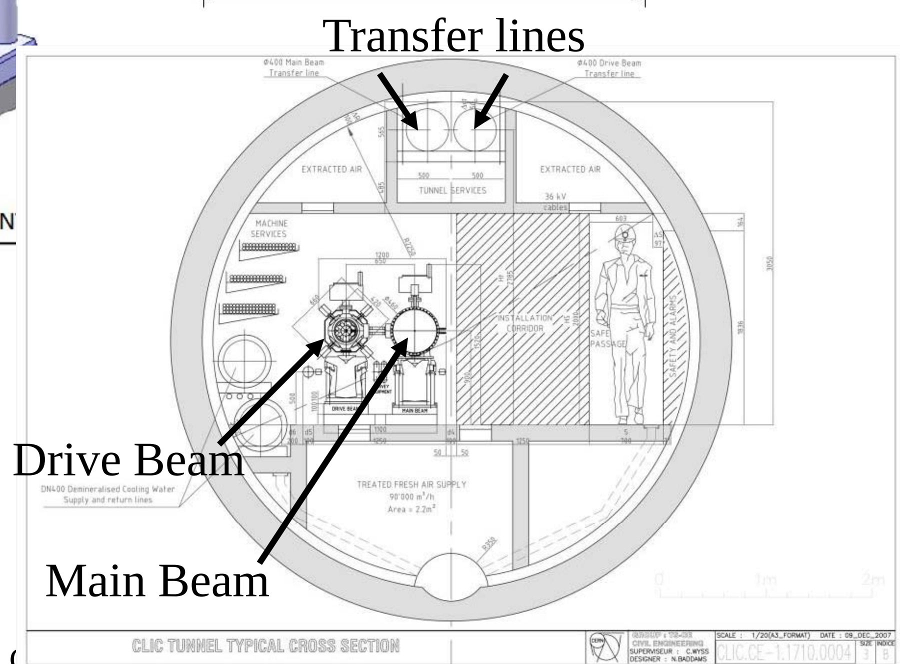
CLIC Experimental Area



CLIC Two Beam Module







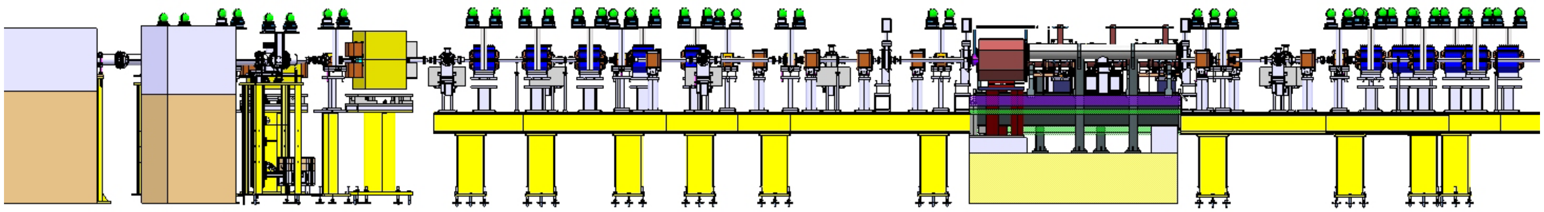
20760 modules (2 meters long)

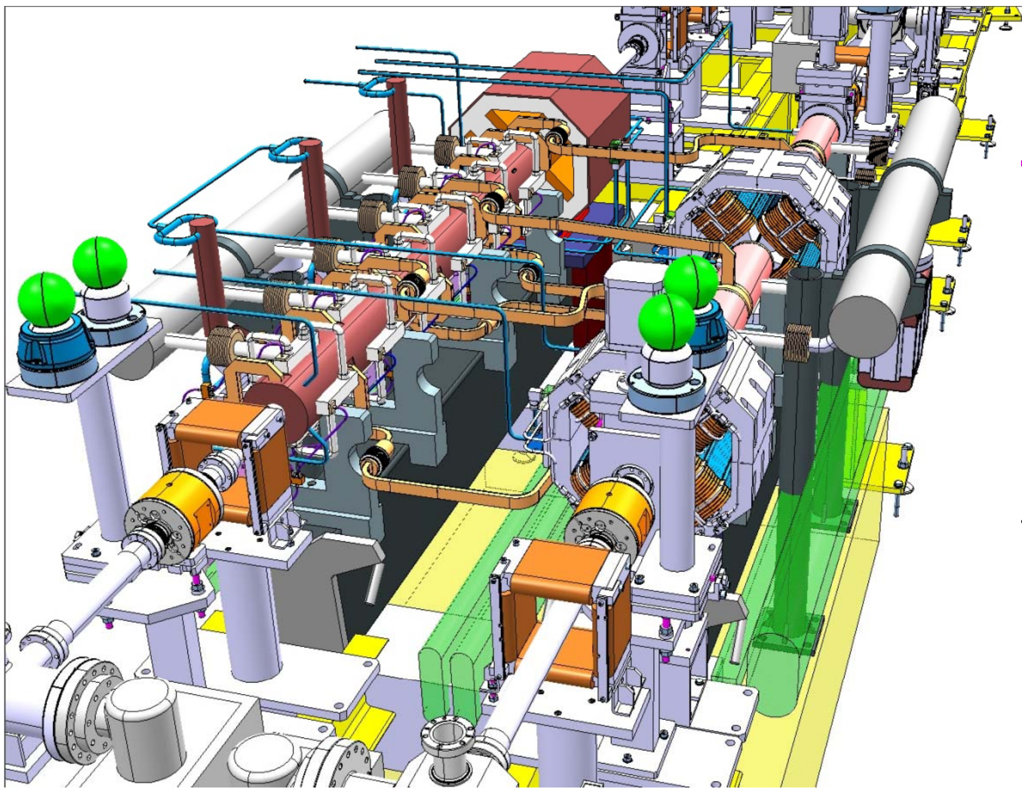
71460 power production structures PETS (drive beam)

143010 accelerating structures

(main beam)

Two Beam Module tests in CTF3/CLEX





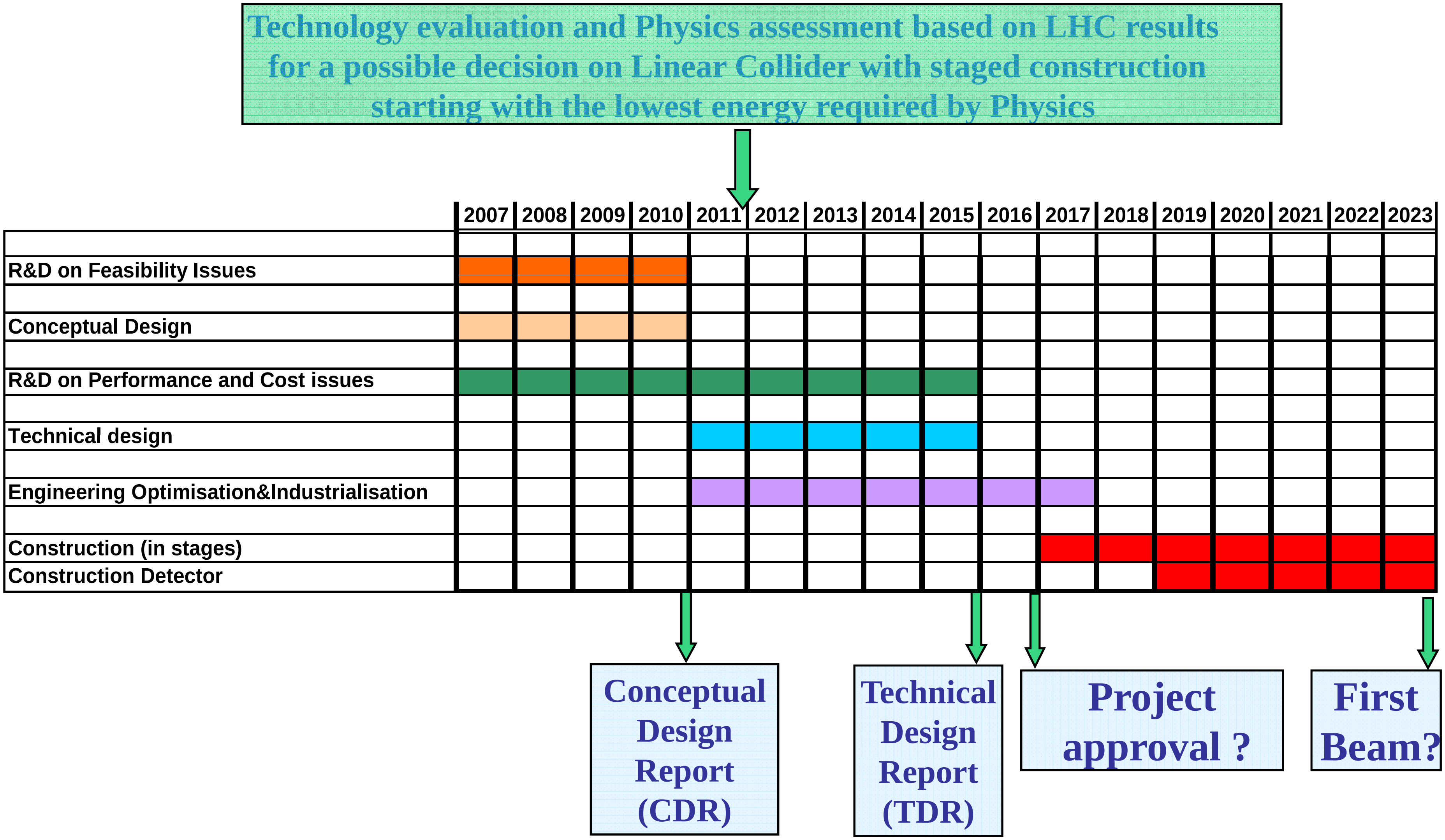
Two Beam Test Stand:

Design and integration of different sub-systems, i.e. to simultaneously satisfy requirements of highest possible gradient, power handling, tight mechanical tolerances and heavy HOM damping

20

Tentative long-term CLIC scenario

Shortest, Success Oriented, Technically Limited Schedule



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)
BINP (Russia)
CERN
CIEMAT (Spain)
Cockcroft Institute (UK)
Gazi Universities (Turkey)
IRFU/Saclay (France)

Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)
J.Adams Institute, (UK)

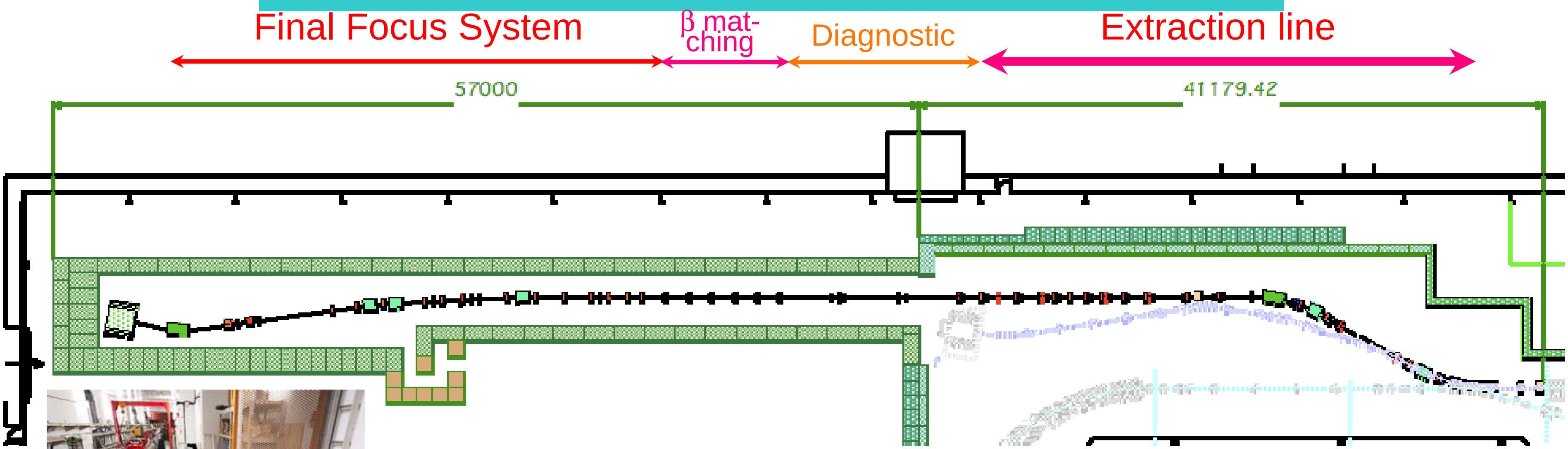
JINR (Russia)
JLAB (USA)
KEK (Japan)
LAL/Orsay (France)
LAPP/ESIA (France)
NCP (Pakistan)
North-West. Univ. Illinois (USA)

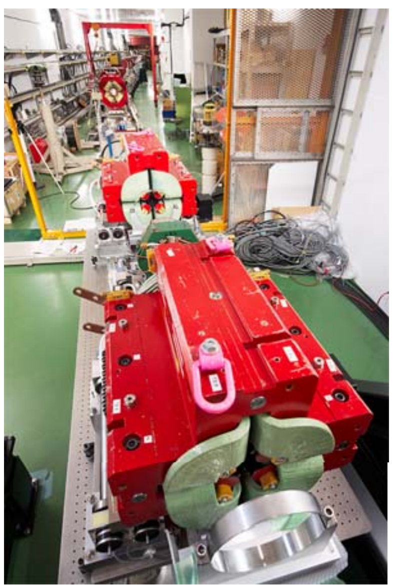
University of Oslo (Norway)
PSI (Switzerland),
Polytech. University of Catalonia (Spain)
RRCAT-Indore (India)
Royal Holloway, Univ. London, (UK)
SLAC (USA)
Uppsala University (Sweden)

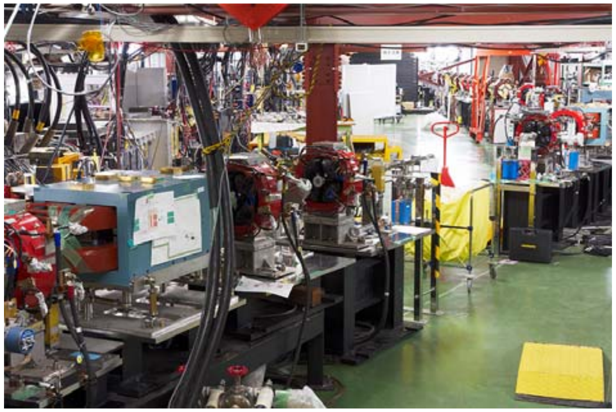
Fruitful collaboration with ILC on subjects with strong synergy

	CLIC	ILC
Physics & Detectors	L.Linssen, D.Schlatter	F.Richard, S.Yamada
Beam Delivery System (BDS) & Machine Detector Interface (MDI)	D.Schulte, R.Tomas Garcia E.Tsesmelis	B.Parker, A.Seriy
Civil Engineering & Conventional Facilities	C.Hauviller, J.Osborne.	J.Osborne, V.Kuchler
Positron Generation	L.Rinolfi	J.Clarke
Damping Rings	Y.Papaphilipou	M.Palmer
Beam Dynamics	D.Schulte	A.Latina, K.Kubo, N.Walker
Cost & Schedule	H.Braun (P.Lebrun), K.Foraz, G.Riddone	J.Carwardine, P.Garbincius, T.Shidara

Fruitful Collaboration with KEK ATF2







Conclusion

- Novel CLIC scheme with promising performances presently only possible technology to extend Linear Collider into the Multi-TeV colliding beam energy range
  - Complementary to ILC
- Ambitious work program well established and on schedule to address CLIC feasibility with preliminary performance and cost by 2010
  - Still a lot of work…
- Pre-Alignement with high precision of large number of components along the 20 kms of linacs one of the key issues to reach high luminosity
  - Target performance: 10 micron rage
  - Cost (large number of components)
  - Reliability
- Joining expertise and efforts (& resources) in a multi-lateral collaboration of volunteer laboratories key for success
  - Common issues to all linear collider: CLIC/ILC collaboration
- Welcome participation to CLIC Pre-Alignment R&D and contribution to:
  - Conceptual Design with feasibility demonstration by end 2010
  - Technical Design with industrialisation and cost optimisation by 2015
  - Join the CLIC/CTF3 collaboration strong of 27 Institutes/15 countries
- Great importance of CLIC Pre-Alignment Workshop:
  - Review present status of the art
  - Define necessary R&D to improve performances
  - Foster fruitful collaboration

Spares

CLIC Web Site and Doc

- **Web site reflecting the CLIC organisation**

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

- **Technical documentation on EDMS:**

https://edms.cern.ch/nav/CERN-0000060014

- **Weekly CLIC meeting (Friday am, open):**

http://clic-meeting.web.cern.ch/clic-meeting/

- **Annual CLIC workshop (12-16/10/09):**

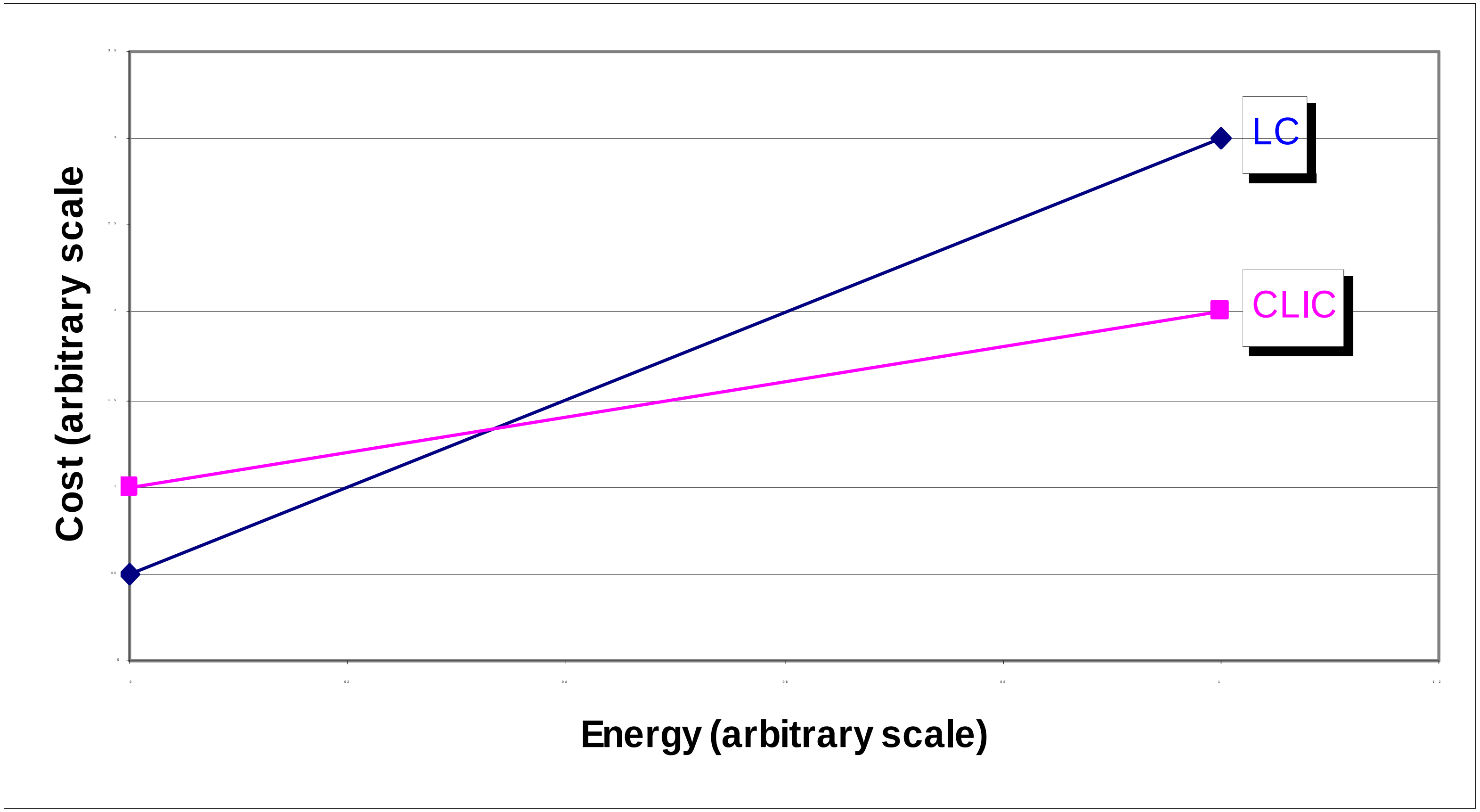
http://indico.cern.ch/conferenceDisplay.py?confId=45580

LC 500 GeV Main parameters

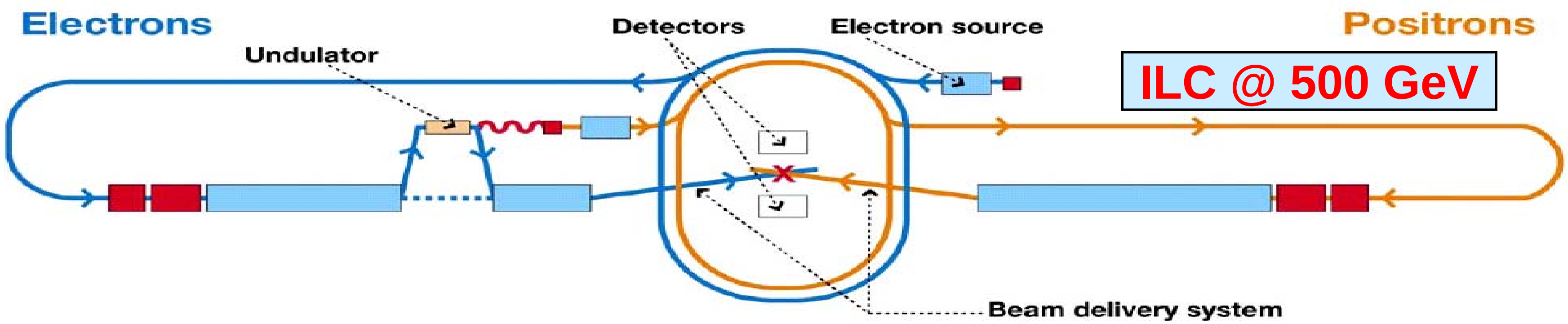
http://clic-meeting.web.cern.ch/clic-meeting/ComparisonTable.html

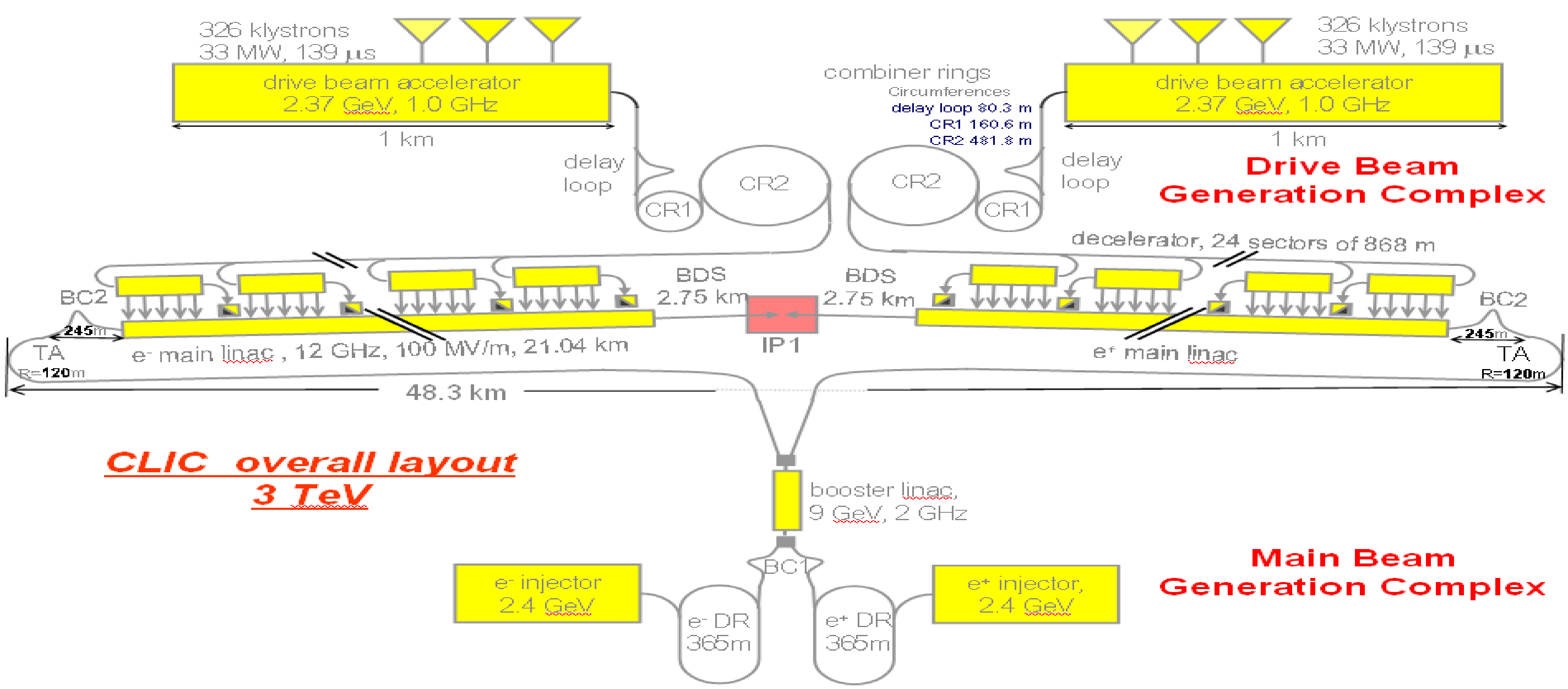
Center-of-mass energy	NLC 500 GeV	ILC 500 GeV	CLIC 500 G Conservativ	CLIC 500 G Nominal
Total (Peak 1%) luminosity	$2.0(1.3)\cdot10^{34}$	$2.0(1.5)\cdot10^{34}$	$0.9(0.6)\cdot10^{34}$	$2.3(1.4)\cdot10^{34}$
Repetition rate (Hz)	120	5	50	
Loaded accel. gradient MV/m	50	33.5	80	
Main linac RF frequency GHz	11.4	1.3 (SC)	12	
Bunch charge10^{9}	7.5	20	6.8	
Bunch separation ns	1.4	176	0.5	
Beam pulse duration (ns)	400	1000	177	
Beam power/linac (MWatts)	6.9	10.2	4.9	
Hor./vert. norm. emitt ($10^{-6}/10^{-9}$)	3.6/40	10/40	3 / 40	2.4 / 25
Hor/Vert FF focusing (mm)	8/0.11	20/0.4	10/0.4	8/0.1
Hor./vert. IP beam size (nm)	243/3	640/5.7	248 / 5.7	202/ 2.3
Soft Hadronic event at IP	0.10	0.12	0.07	0.19
Coherent pairs/crossing at IP	10?	10?	10	100
BDS length (km)	3.5 (1 TeV)	2.23 (1 TeV)	1.87	
Total site length (km)	18	31	13.0	
Wall plug to beam transfer eff.	7.1%	9.4%	7.5%	
Total power consumption MW	195	216	129.4	

Relative cost of Linear Colliders



CLIC and ILC layouts





CLIC major activities and milestones up to 2010

- **Demonstrate feasibility of CLIC technology**
  - **Address all feasibility issues**
- **Design of a linear Collider based on CLIC technology**

  http://clic-study.web.cern.ch/CLIC-Study/Design.htm
- **Estimation of its cost (capital investment & operation)**
- **CLIC Physics study and detector development:**

  http://clic-meeting.web.cern.ch/clic-meeting/CLIC_Phy_Study_Website/default.html
- **Conceptual Design Report to be published in 2010 including**
  - **Physics, Accelerator and Detectors**
  - **R&D on critical issues and results of feasibility study,**
  - **Preliminary performance and cost estimation**