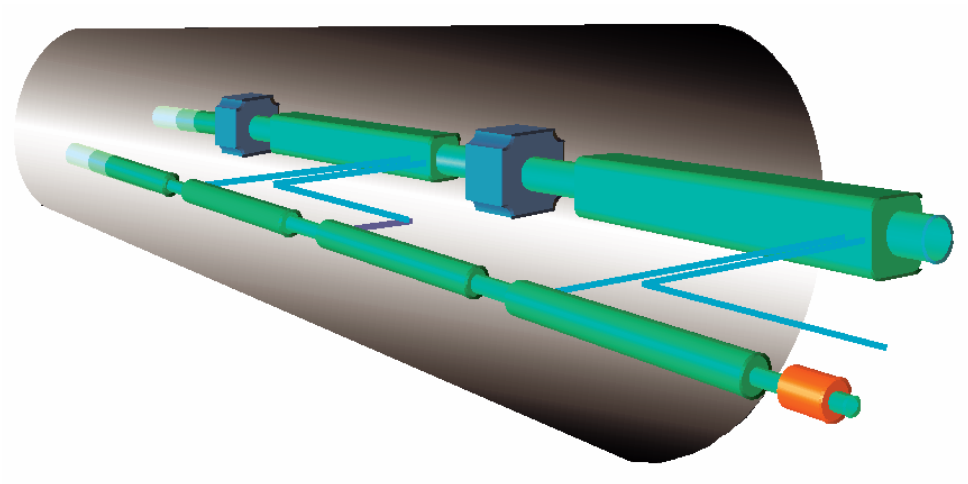
THE COMPACT LINEAR COLLIDER (CLIC) STUDY



J.P.Delahaye for

The Compact LInear Collider Study Team

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

OUTLINE

- CLIC in the HEP world-wide landscape
- The Compact Linear Collider (CLIC) concept
- Design and new parameters recently adopted
- Main challenges
- What has been achieved so far
- What remains to be demonstrated
- The facilities to address the key issues
- Plans and schedule
- Conclusion

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 up to at least 400 GeV/c

- **2003:** ILC-Technical Review Committee to assess the technical status of the various designs of Linear Colliders

- **2004:** International Technology Recommendation Panel selecting the Super-Conducting technology for an International Linear Collider (ILC) Linear Collider in the TeV energy range

- **2004:** CERN council support for R&D addressing the feasibility of the CLIC technology to possibly extend Linear Colliders into the Multi-TeV energy range.

CLIC @ SPC & Council

- CERN Scientific Policy Committee (SPC): March 2004
  - The SPC supports the many good arguments on the rich physics potential of CLIC. The range of possibilities would be clarified by the results of LHC

- Council's summary of conclusions: CERN/2554
  - In line with the conclusion of the SPC, the Council expressed strong support for accelerating the R&D on CLIC
  - Recommendation of a world-wide multi-lateral collaboration of volunteer institutes for tests of feasibility of the CLIC concept for Multi-TeV Linear Collider to arrive before 2010 at a firm conclusion on its possible use

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.*

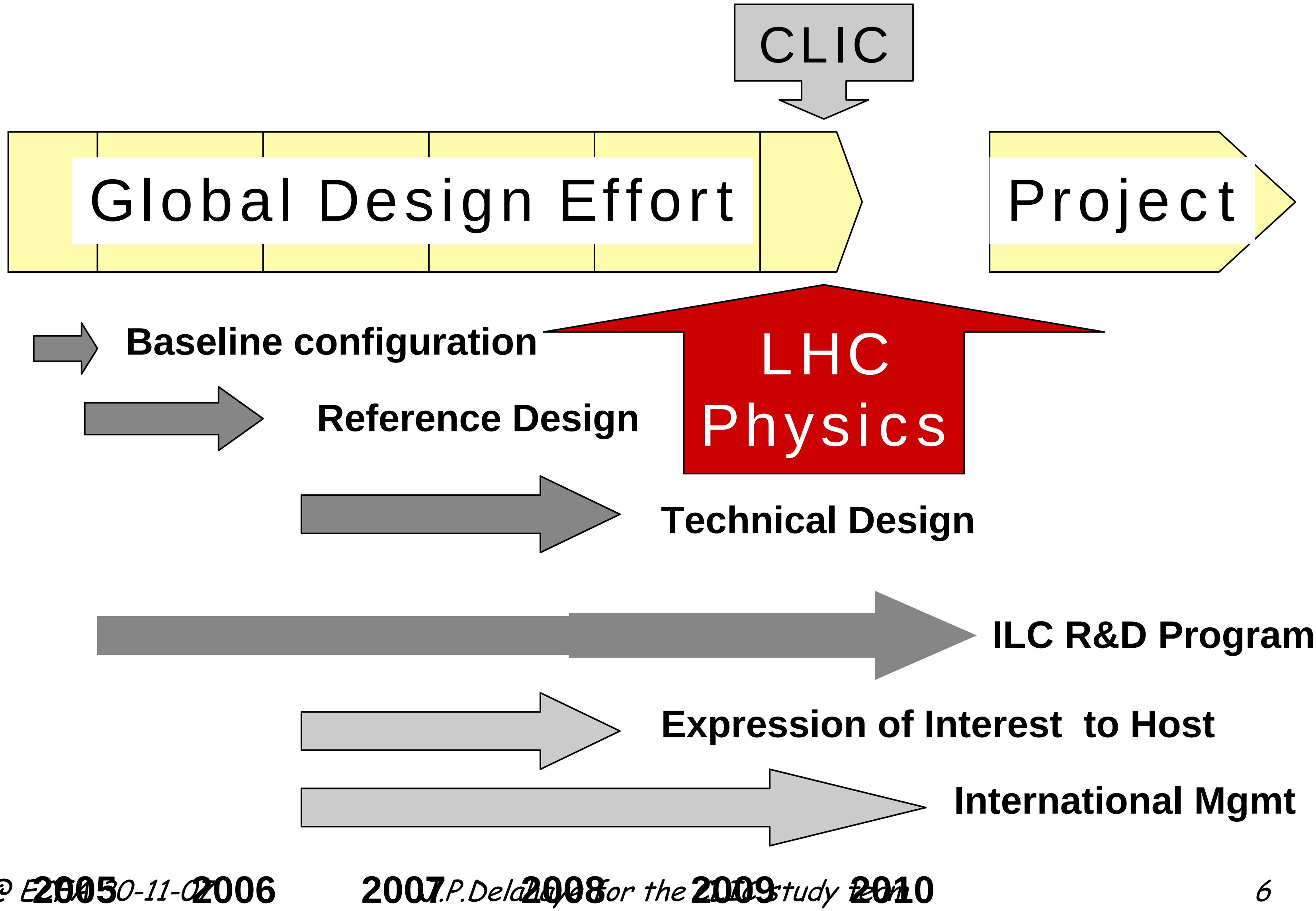
7. A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; *Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest.*

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.*

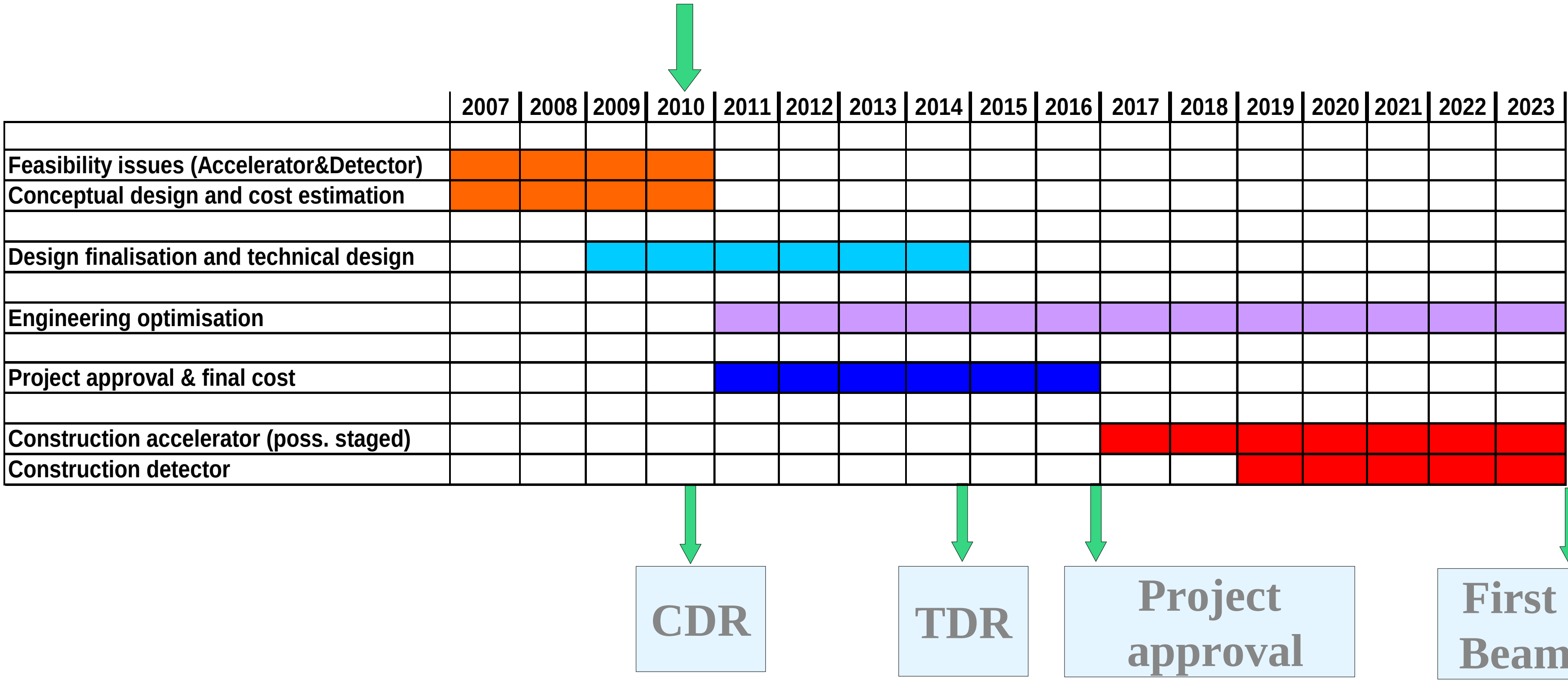
The ILC Plan and Schedule

(B.Barish/CERN/SPC 050913)

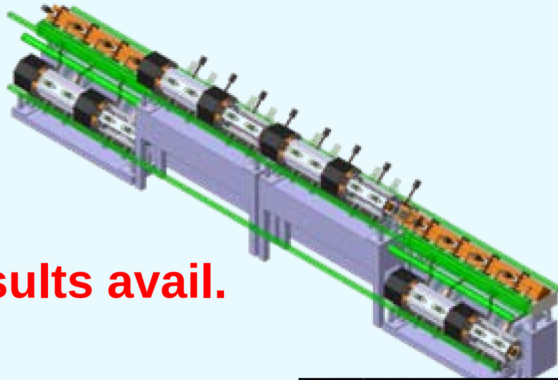


Tentative long-term CLIC scenario
Shortest, Technically Limited, Success Oriented Schedule (SOS)

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

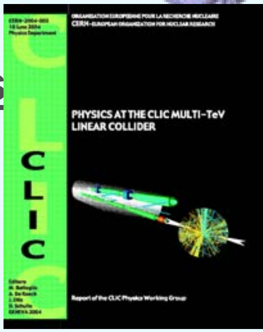


Site independent feasibility study aiming at the development of a realistic technology to extend e-/e+ linear colliders into the Multi-TeV energy range:



- ✓ 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:

Demonstrate all key feasibility issues and document in a Conceptual Design Report by 2010 and possibly Technical Design Report by 2014

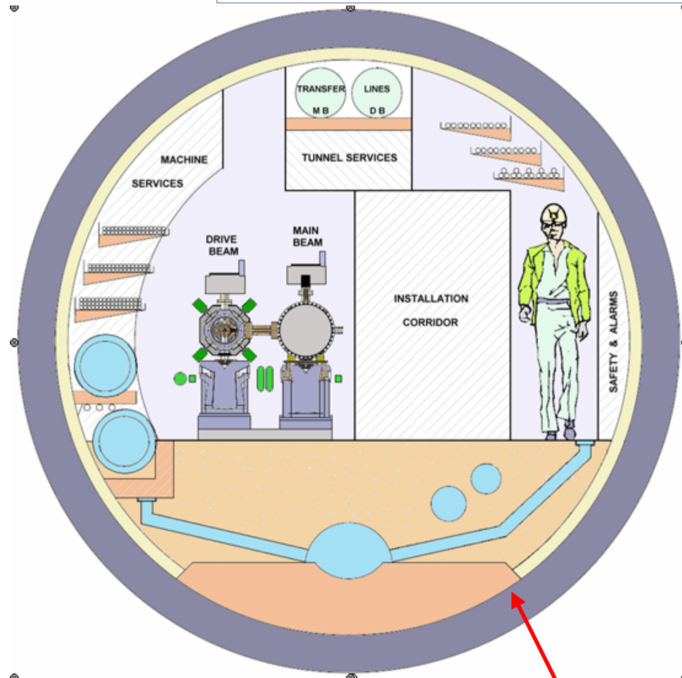
CLIC Advisory CommitteE (ACE):

L.Evans/CERN, M.Huening/DESY, A.Mosnier/CEA, P.Raimondi/INFN, V.Shiltsev/FNAL, T.Shintake/RIKEN, T.Raubenheimer/SLAC (Chairman), N.Toge/KEK

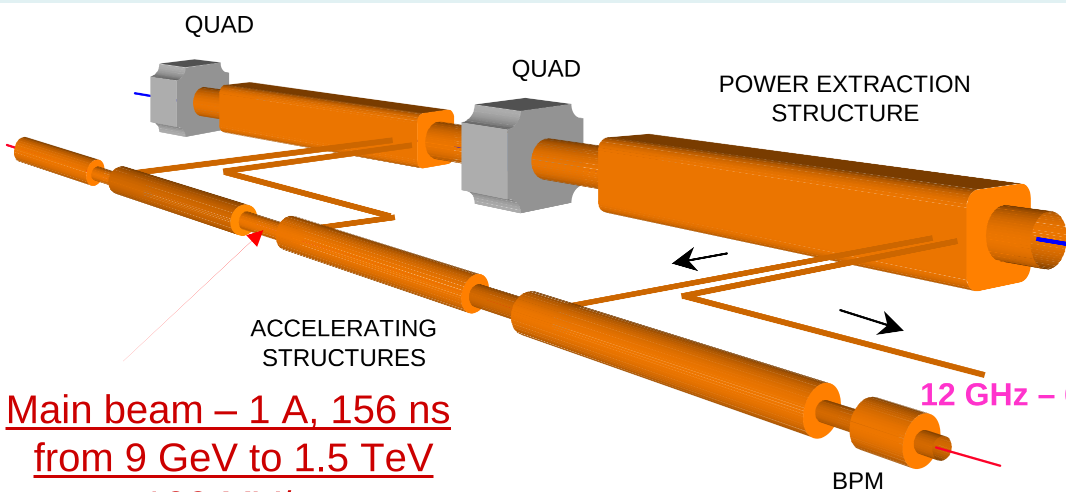
CLIC – basic features

- **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 TUNNEL CROSS-SECTION

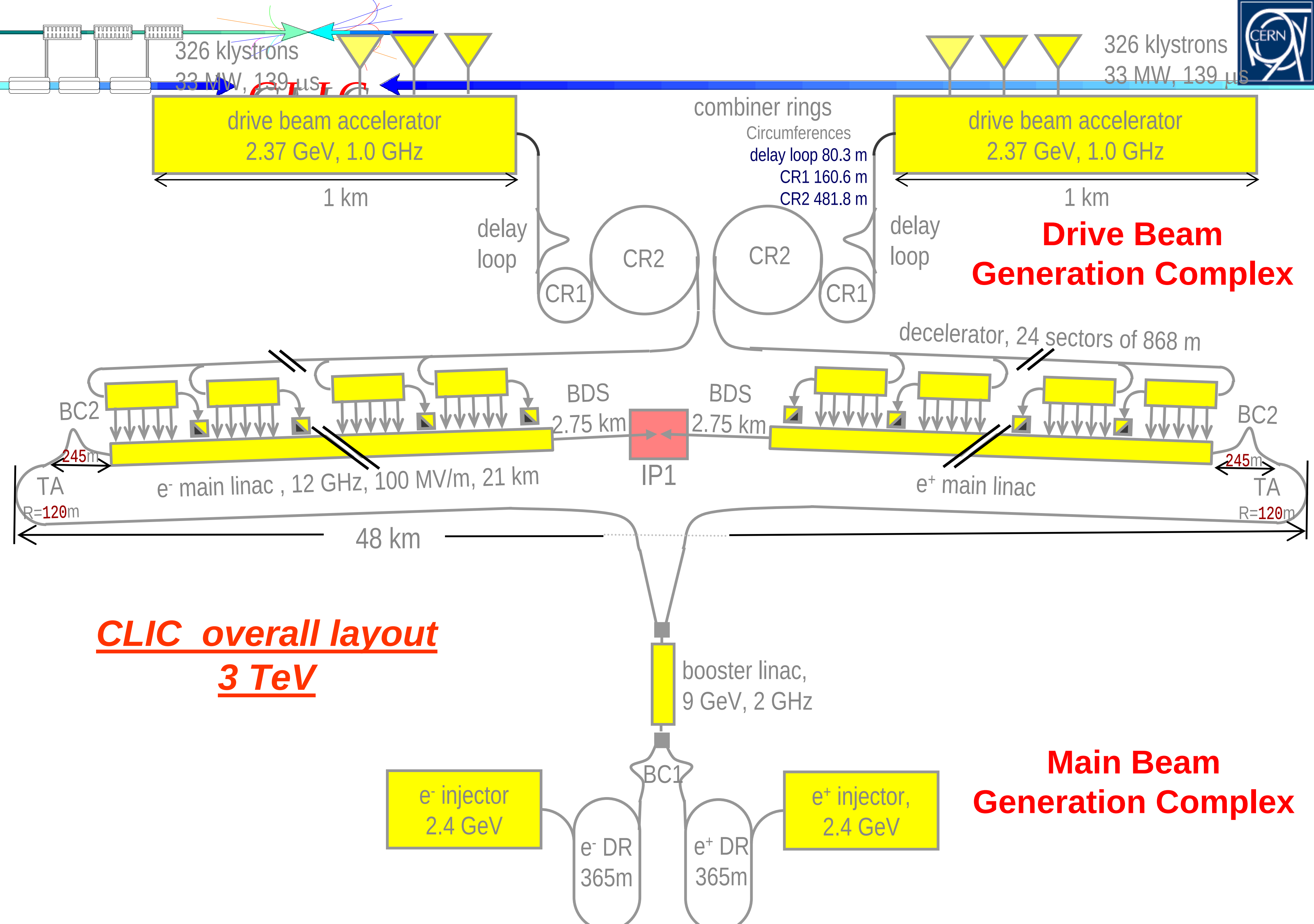


4.5 m diameter



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

Main beam – 1 A, 156 ns
from 9 GeV to 1.5 TeV
100 MV/m



CLIC overall layout 3 TeV

Strategy to address key issues

- **Key issues common to all Linear Collider studies independently of the chosen technology in close collaboration with the International Linear Collider (ILC) study:**
  - On Accelerator Test Facility (ATF1&ATF2@KEK)
  - With European Laboratories in the frame of the Coordinated Accelerator Research in Europe (CARE) and of a "Design Study" (EUROTeV) funded by EU Framework Programmes (FP6 presently and FP7 Integrated Activity in the future)

- **Key issues specific to CLIC technology:**
  - Focus of the CLIC study
  - All R1 (feasibility) and R2 (design finalisation) key issues addressed in test facilities: CTF1,2,3@CERN

Close CLIC & ILC Collaboration

- CLIC study members participating to ILC GDE
  - Major partners in specific studies and ILC Reference Design Report
  - ILC@CERN Site Specific Cost Study (CERN = European sample site)
- Key ILC experts in CLIC Advisory Committee
- Fruitful collaboration on R&D of generic Linear Colliders (CLIC&ILC) key issues
  - Participation in EUROTeV design study & CARE project
  - R&D on Beam diagnostics, Beam Delivery System (BDS), Beam dynamics
  - Tests with beam in CTF3 Test facility
  - Common participation to R&D on generation of Low Emittances generation @ ATF1/KEK and Strong Beam Focusing to nanometers sizes @ATF2/KEK
- Future common study of subjects with strong synergy between CLIC & ILC
  - FP7 EU supported in Coordinated Accelerator R&D (CARD) with a CLIC/ILC work package (NC Linacs)
  - Launching common CLIC/ILC studies with ILC Project Managers (Feb08 @ CERN) following constructive visit of B.Barish (Nov 07):
    - Civil engineering & conventional facilities
    - Beam delivery System and Machine –Detector Interface
    - Detectors
    - Cost & Schedule

CLIC/CTF3 Multi-Lateral Collaboration of Volunteer Institutes

CLIC

Organized as a Physics Detector Collaboration

19 members represent. 24 institutes involving 16 funding agencies from 13 countries

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

MoU with addenda describing specific contribution (& resources)

Countries	Funding Agencies	Laboratory	Representatives & Advisorsy	MoU _ Addenda
CERN	CERN	CERN	J-P. Delahaye, G. Geschonke	Link to pdf
FINLAND		Helsinki Inst of Phys (HIP)	D.O. Riska, K. Österberg	Link to pdf
FRANCE	CEA/DSM-Saclay	DAPNIA	G. Fioni, J. Zinn-Justin	Link to pdf
	CNRS/IN2P3	LAL, LURE	G. Wormser	Link to pdf
		LAPP	Y. Kariotakis	
INDIA*	Indian DAE	RRCAT, Indore	V. Sahni, P. Shrivastava	Link to pdf Add. T1 pdf Add. M2 pdf
ITALY	INFN	LNF	M. Calvetti, A. Ghigo	Link to pdf
PAKISTAN		National Centre for Physics (NCP)	H. Hoorani, S. Ahmad	Link to pdf
RUSSIA		Budker Inst (BINP)	A. Skrinski	Link to pdf - Draft Amendt pdf
		IAP	A.G. Litvak	Link to pdf
	Dubna	JINR	V. Samoilov	Link to pdf
SPAIN	Ministry of Education & Science (MEC)	CIEMAT, UPC, IFIC	J. Fuster, L. Garcia-Tabares	Link to pdf
SWEDEN	Swedish Research Council	Uppsala Univ and Svedberg Lab (TSL)	T. Ekelof, V. Ziemann	Link to pdf
	Wallenberg Foundation			Link to pdf
SWITZERLAND		Paul Scherrer Inst (PSI)	L. Rivkin, T. Garvey	Link to pdf
TURKEY		Ankara Univ & Gazi Univ	A.K. Ciftçi	Link to pdf
UNITED-KINGDOM	STFC	J. Adams Institute for Accelerator Science	G. Blair, K. Peach	Link to pdf
USA	DOE	Northwestern Univ Illinois (NWU)	M. Velasco	Link to pdf
		SLAC	R. Ruth, S. Tantawi	Link to pdf
		Jefferson Laboratory (JLAB)	A. Hutton	Link to pdf

CLIC/CTF3 collaboration observers

Discussion with possible future collaboration partners:

Countries	Funding Agencies	Laboratory	Representatives & Advisors	MoU _Addenda
CHINA		Tsinghua Univ	H. Chen, H. Wenhui	
IRAN		Inst for Theoretical Phys and Math (IPM)	H. Arfaei	
UNITED-KINGDOM	STFC	RAL	G. Hirst, H. Hutchinson	
		Cockcroft Institute	S. Chattopadhyay, J. Dainton	

Visiting Scientist: MoU being finalized

MoU being finalized

Present collaboration with RAL on Laser development for PHIN in EU FP6 CARE

World-wide CLIC&CTF3 Collaboration

Ankara University (Turkey)
Berlin Tech. Univ. (Germany)
BINP (Russia)
CERN
CIEMAT (Spain)
DAPNIA/Saclay (France)
RRCAT-Indore (India)

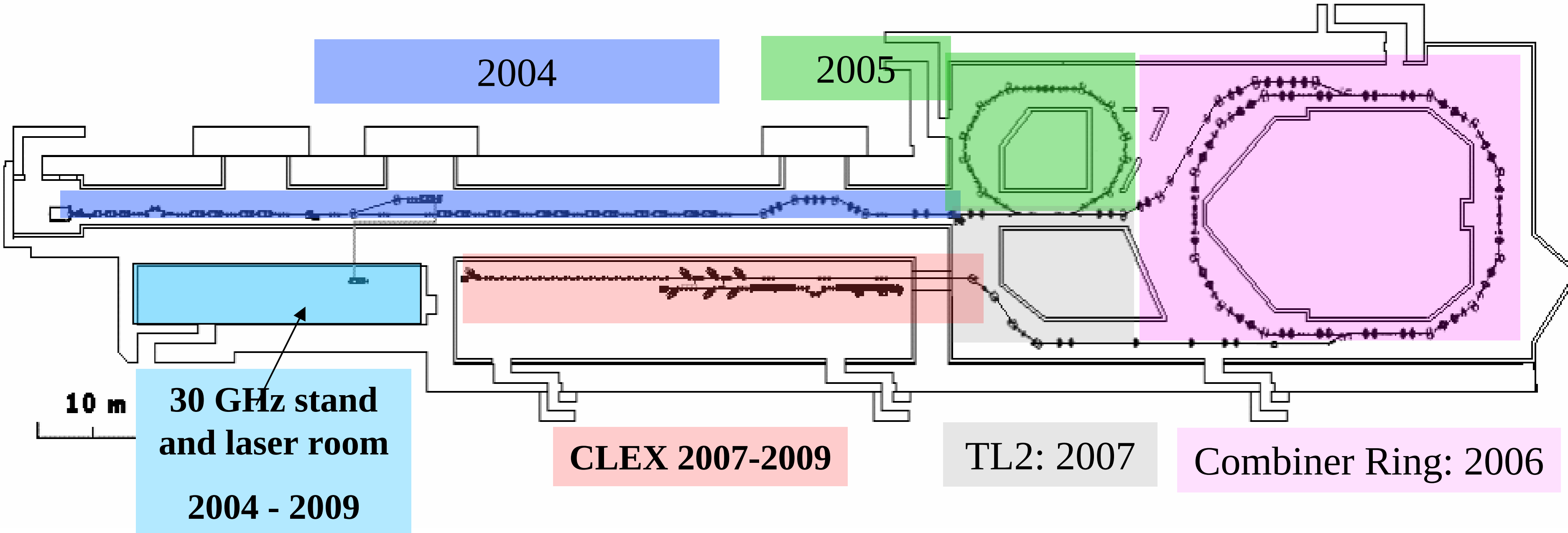
Finnish Industry (Finland)
Gazi Universities (Turkey)
Helsinki Institute of Physics (Finland)
IAP (Russia)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)
J. Addams Institute (UK)

JASRI (Japan)
Jefferson Lab (USA)
JINR (Russia)
KEK (Japan)
LAL/Orsay (France)
LAPP/ESIA (France)
LLBL/LBL (USA)

NCP (Pakistan)
PSI (Switzerland)
North-West. Univ. Illinois (USA)
Polytech. University of Catalonia (Spain)
RAL (UK)
SLAC (USA)
Svedberg Laboratory (Sweden)
Uppsala University (Sweden)

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

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



Key issues

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

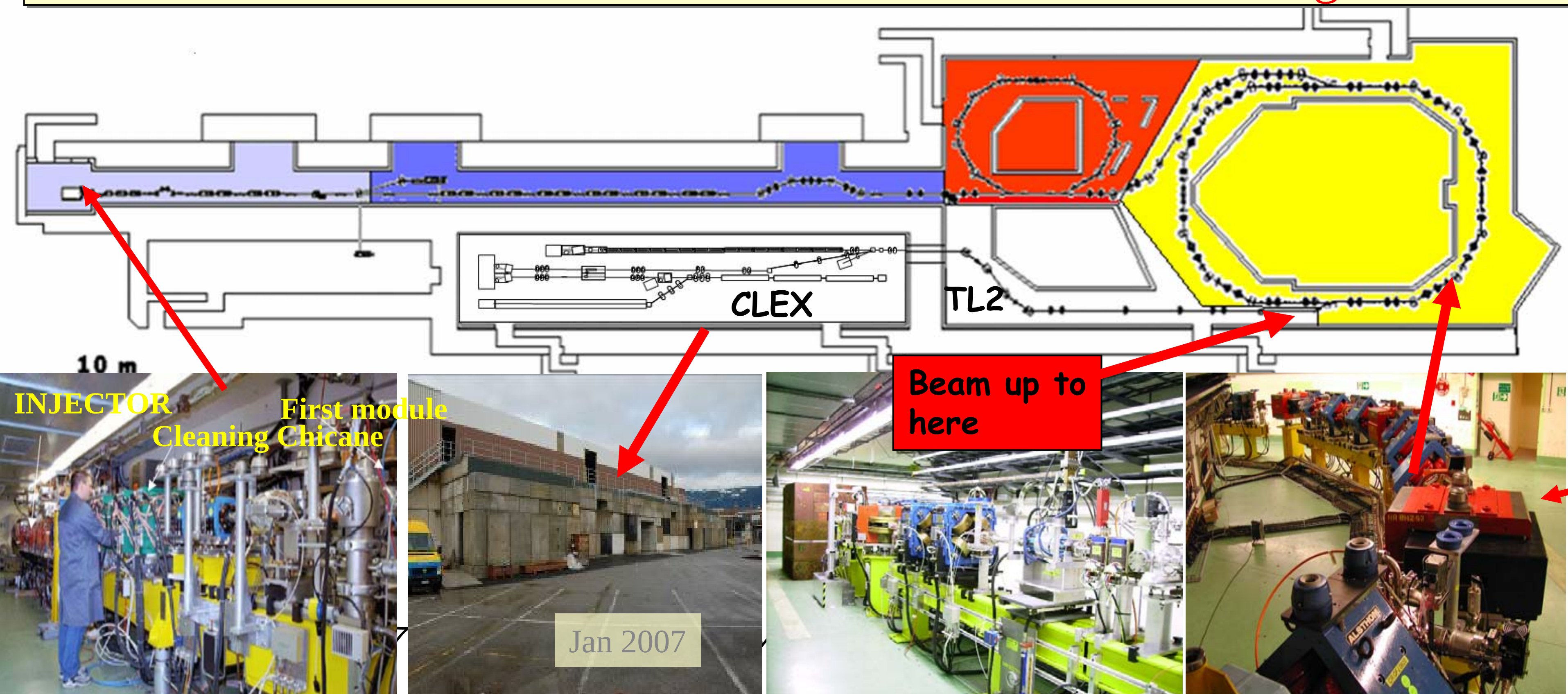
2007- 2008: Drive beam generation scheme (R1.2)

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)

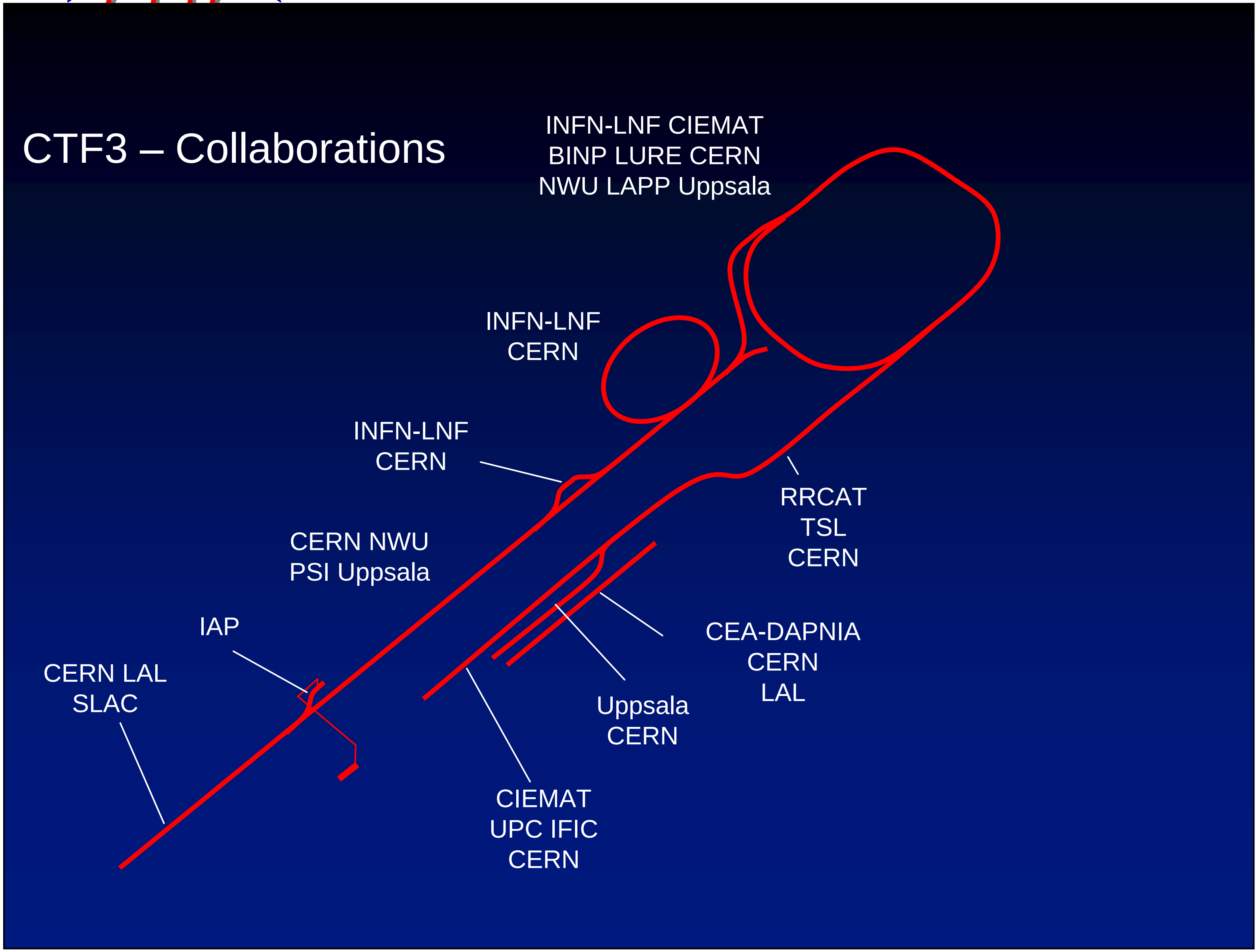
CTF3 Continuous 0peration (10months/year)

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

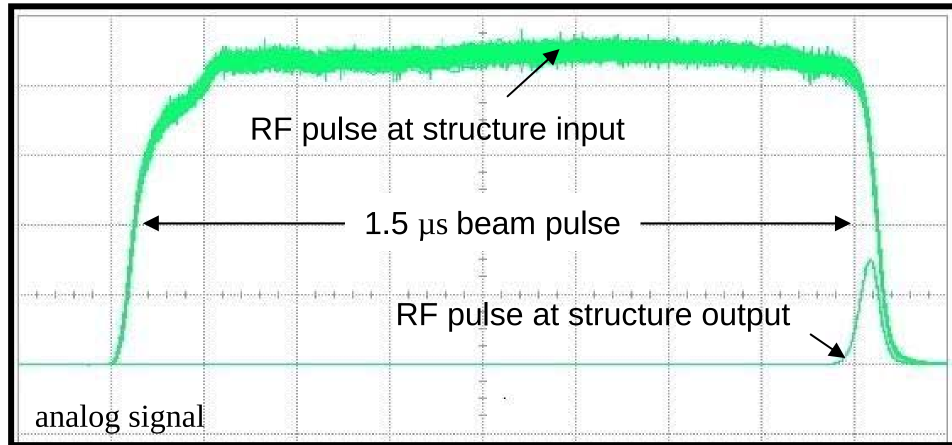


Work Package repartition

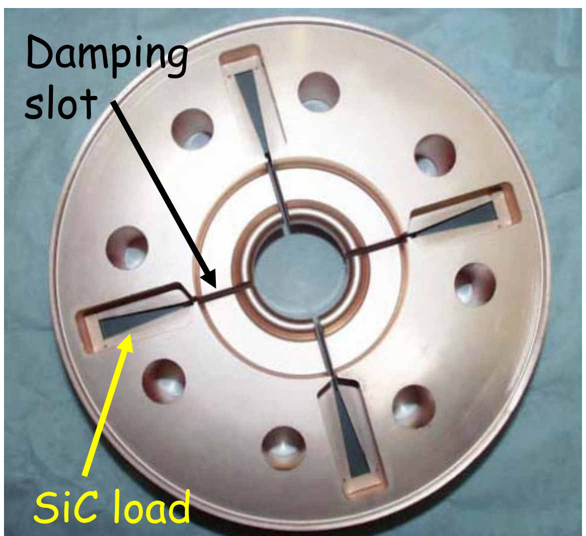


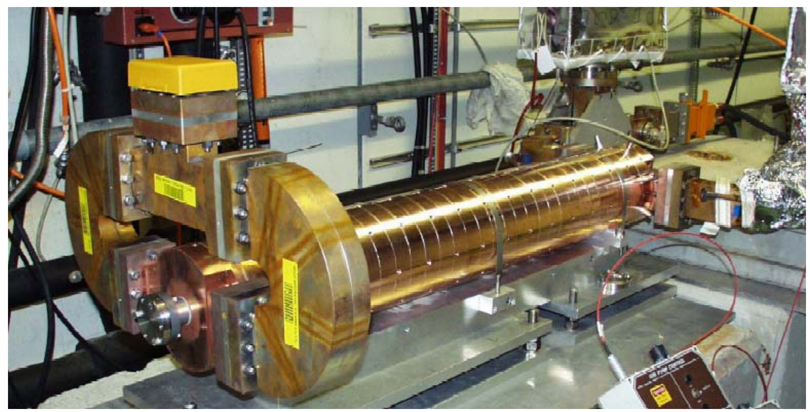
Drive beam generation with full beam-loading acceleration in CTF3 linac

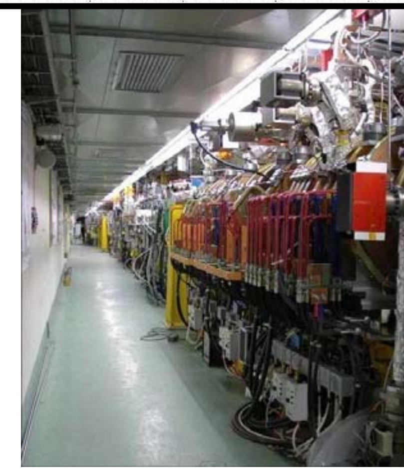
- Measured RF-to-beam efficiency 95.3%
- Theory 96% (~ 4 % ohmic losses)

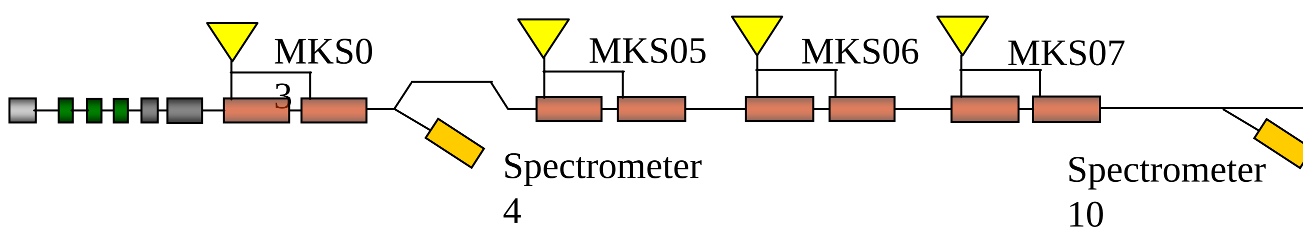


Dipole modes suppressed by slotted iris damping (first dipole's Q factor < 20) and HOM frequency detuning

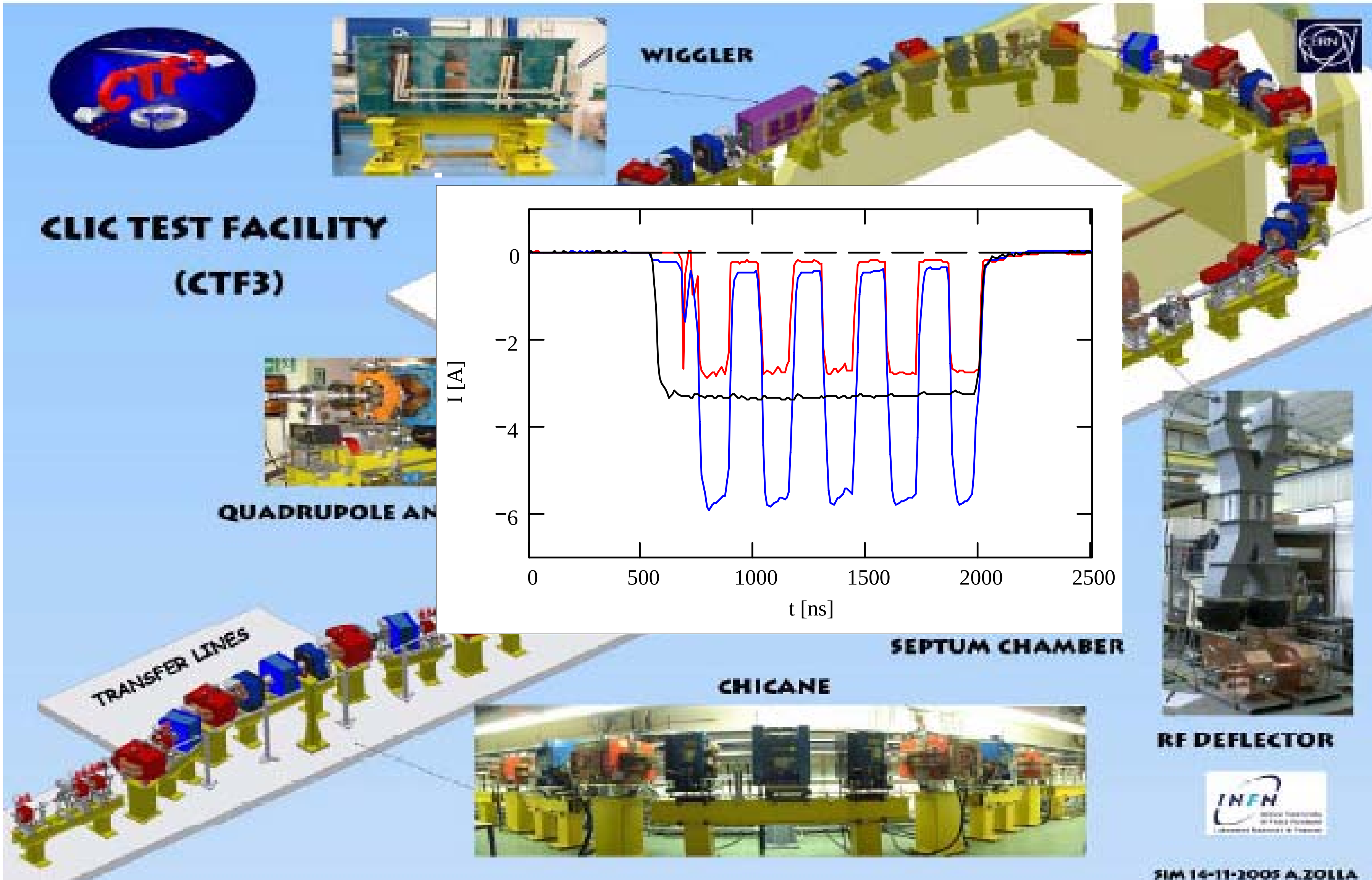






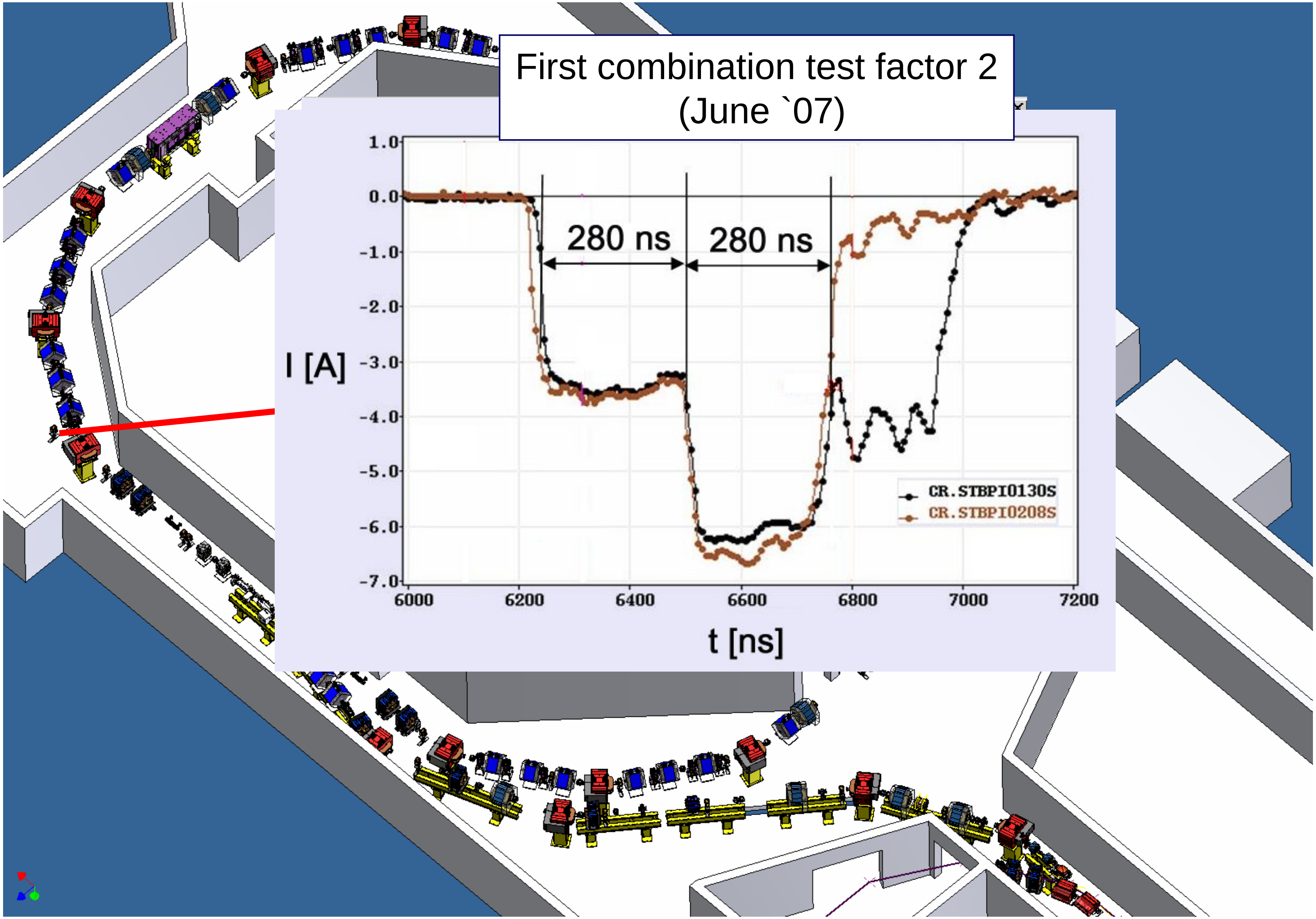


Beam intensity and RF frequency multiplication in CTF3 Delay Loop



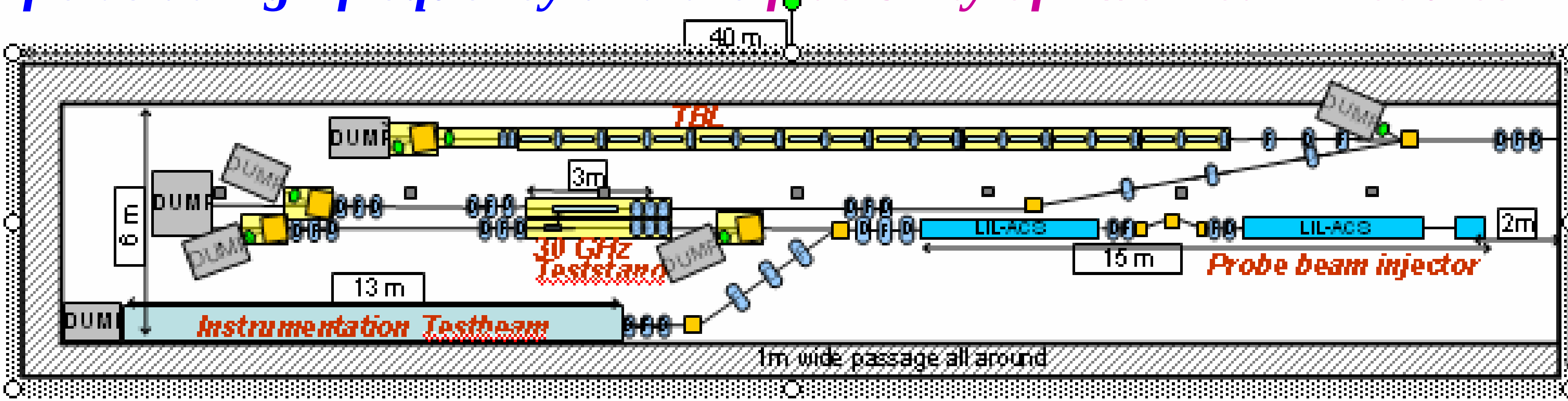
Beam commissioning of the Combiner ring

CLIC



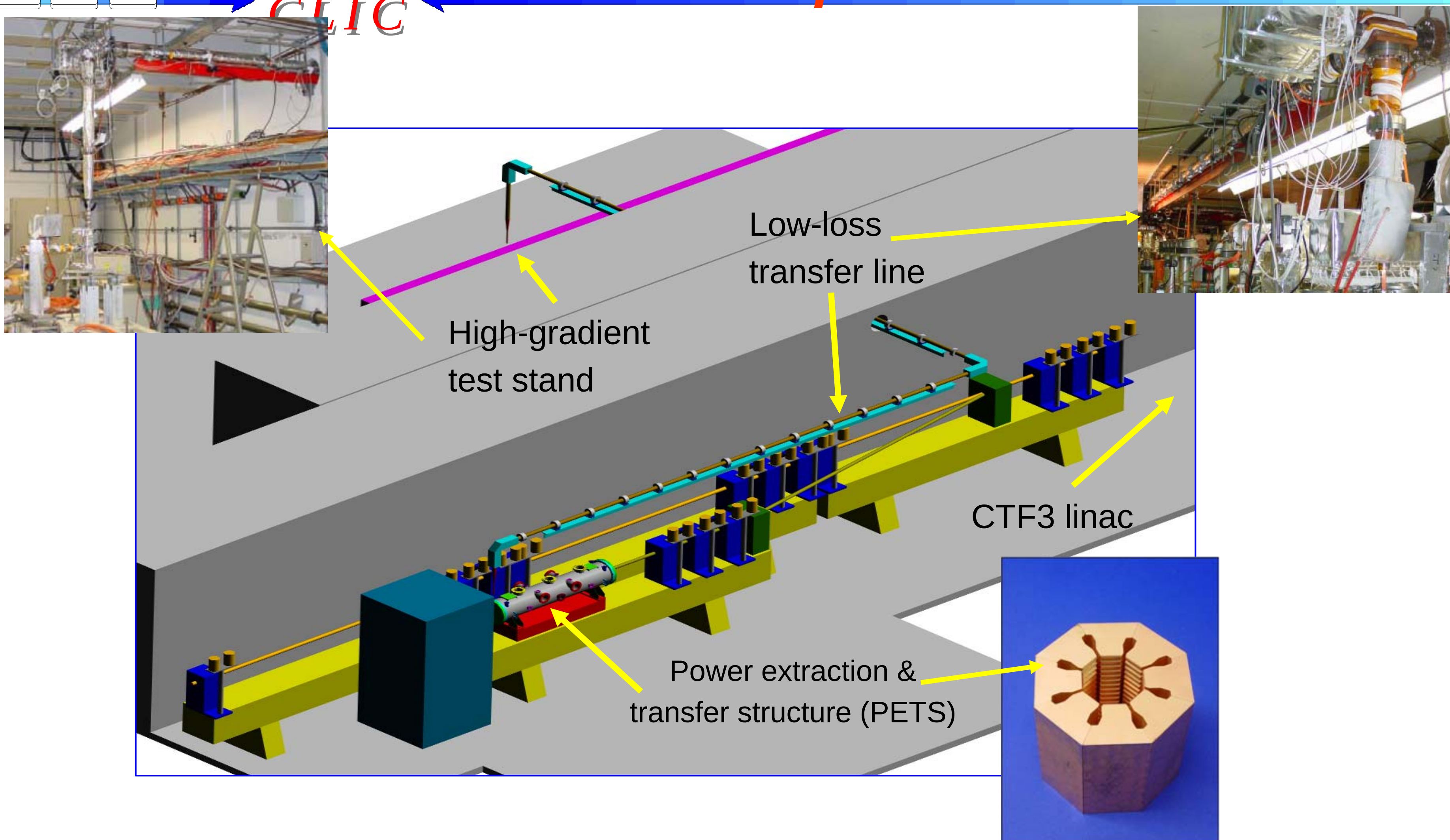
CLIC Experimental Area (CLEX)

- Test beam line (TBL) to study RF power production (2.5 TW at 12 GHz) and drive beam decelerator dynamics, stability & losses
- Two Beam Test Stand to study probe beam acceleration with high fields at high frequency and the feasibility of Two Beam modules



Construction on schedule
Equipment installation from May 2007,
Beam foreseen from March 2008

RF Power production in CTF3



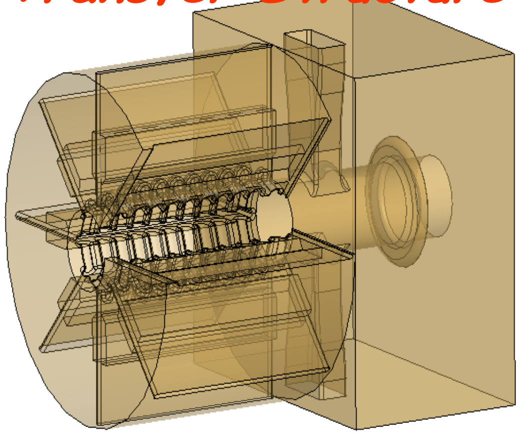
- Produced power at 30 GHz up to about 100 MW – long pulses (up to 300 ns) available for the first time
- Structure tests started in 2005 - 8 structures tested until now

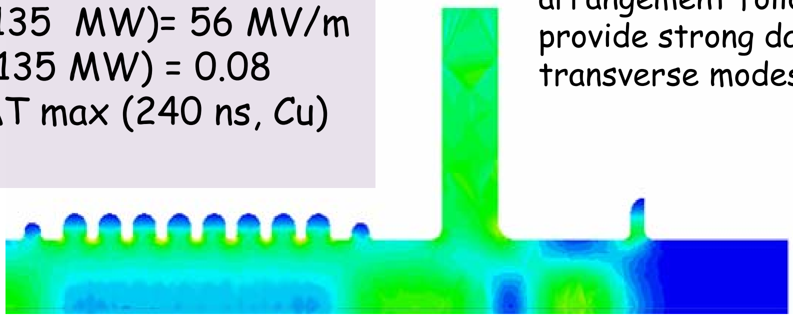
CLIC Power Extraction and Transfer Structure (PETS)

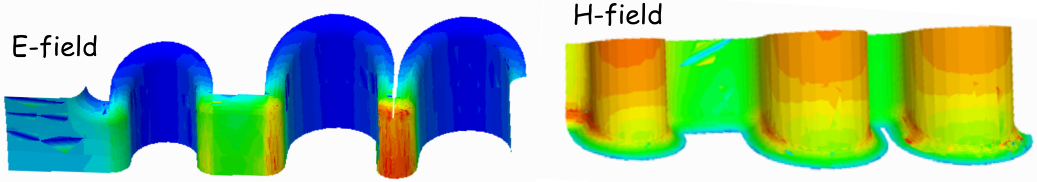
PETS parameters:

- Aperture = 23 mm
- Period = 6.253 mm (90⁰/cell)
- Iris thickness = 2 mm
- R/Q = 2258 Ω
- V group= 0.453
- Q = 7200
- P/C = 13.4
- E surf. (135 MW)= 56 MV/m
- H surf. (135 MW) = 0.08 MA/m (ΔT max (240 ns, Cu) = 1.8 C⁰)

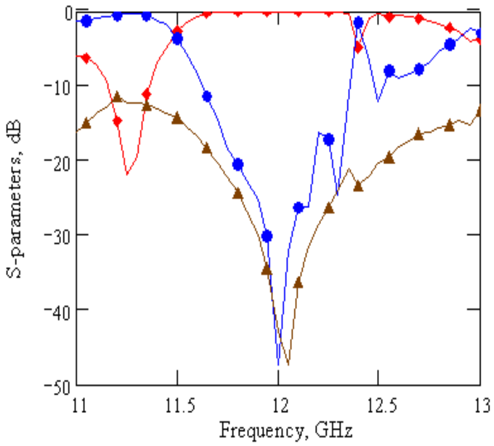
In its final configuration, PETS comprises eight octants separated by the damping slots. Each of the slots is equipped with HOM damping loads. This arrangement follows the need to provide strong damping of the transverse modes.



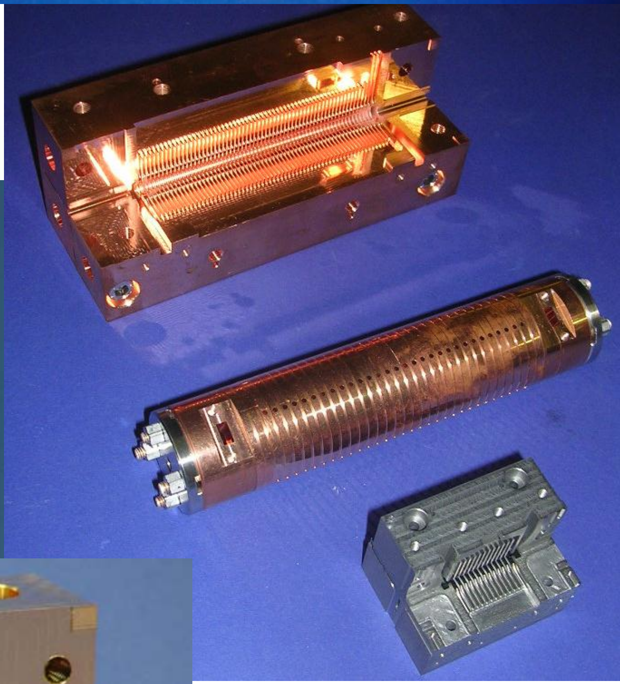


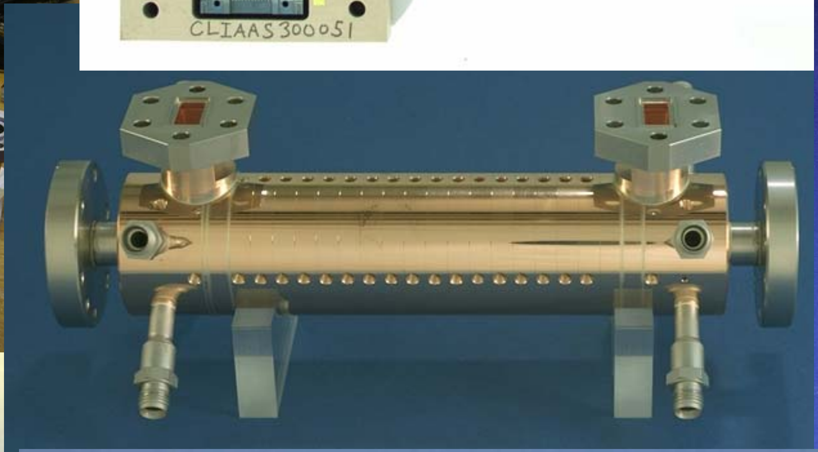


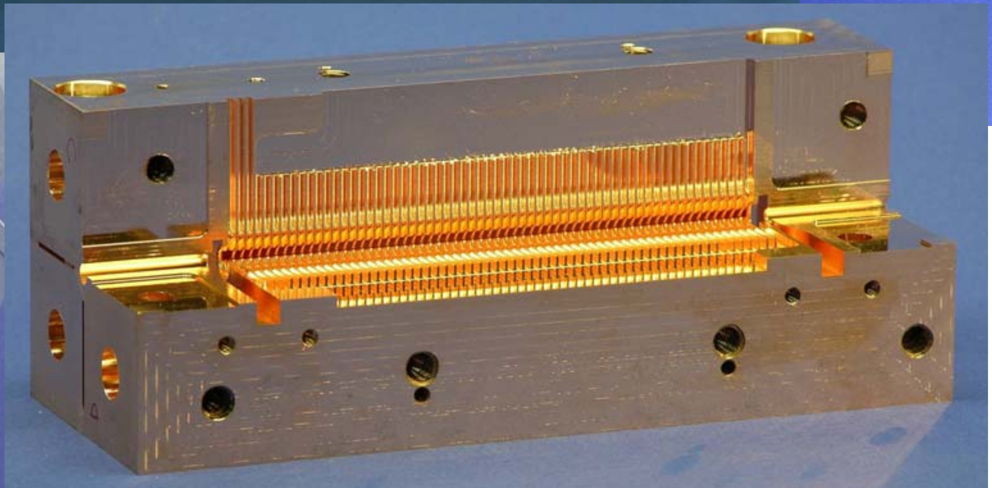
To reduce the surface field concentration in the presence of the damping slot, the special profiling of the iris was adopted.



I. Syratchev

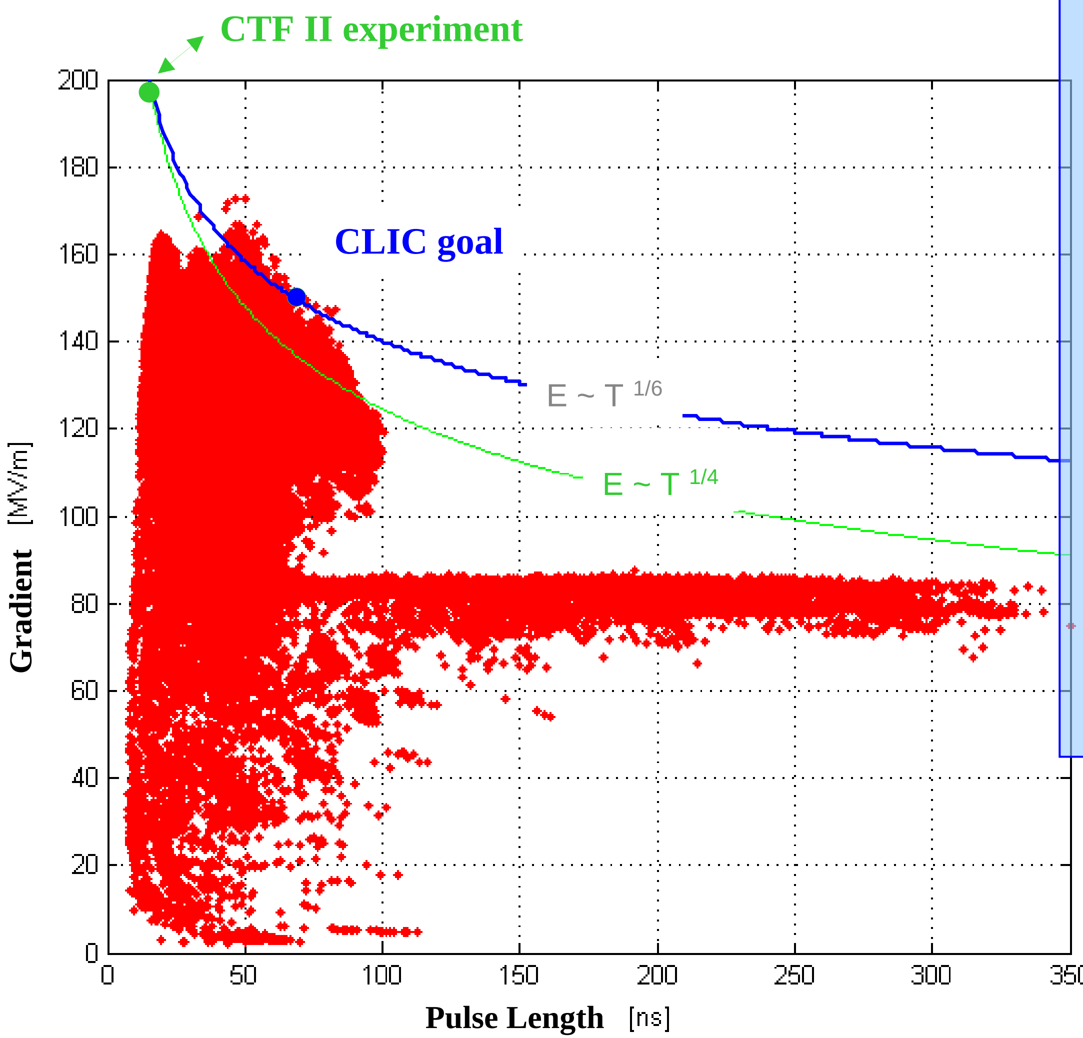






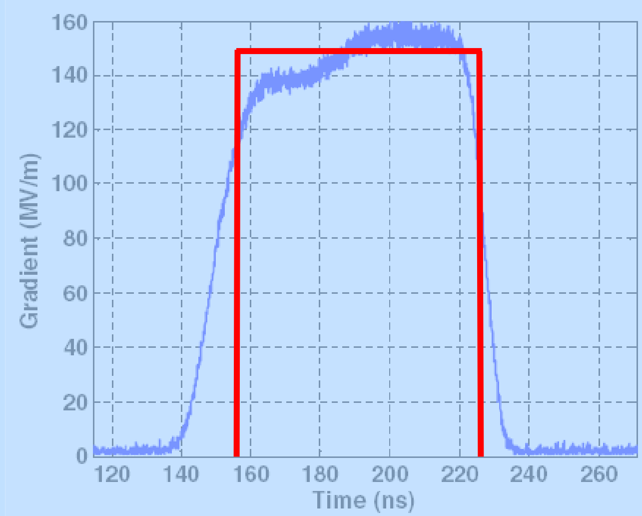
Testing Accelerating Structures

CTF3 High-Power test results @ 30 GHz



Reached nominal CLIC values :

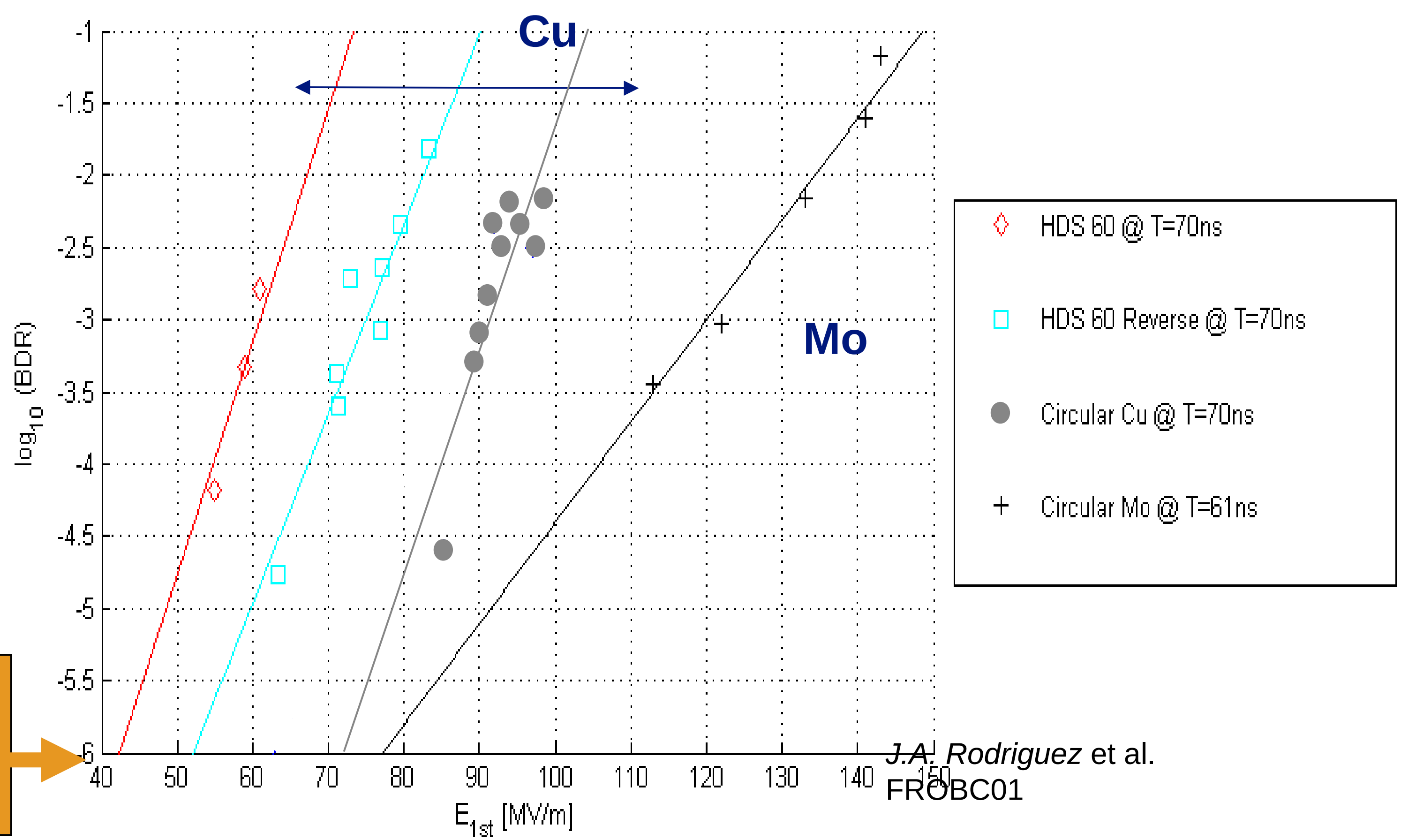
150 MV/m - 70 ns



Breakdown Rate not compatible with LC operation

CTF3 High-Power tests
various materials results @ 30 GHz

- Acceptable Breakdown Rate in linear collider operation not higher than 10-6
- Reduction of accelerating field by about 30 MV/m for low BR with Cu



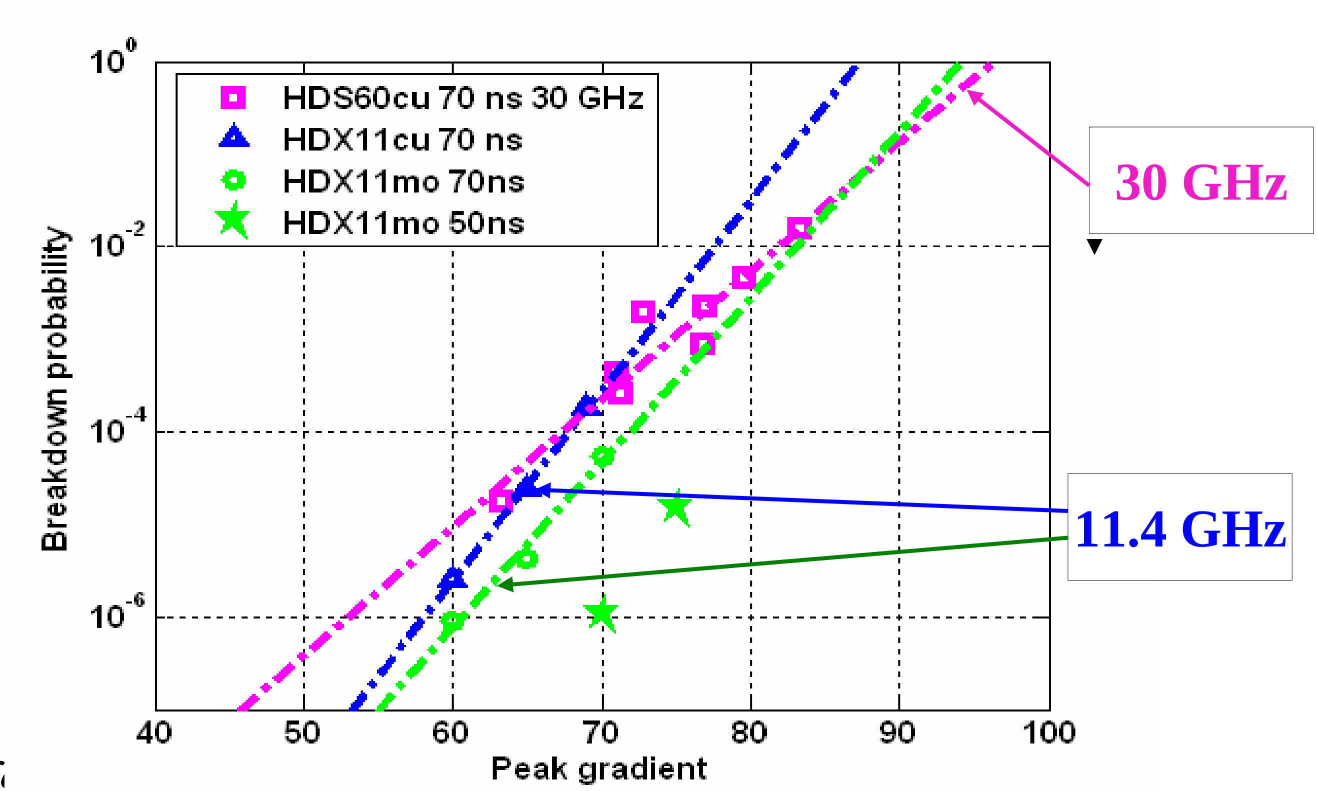
CLIC operational goal

J.A. Rodriguez et al.
FROBC01

CTF3 - SLAC High-Power test results @ 30 & 11.4 GHz

- Structures with scaled geometries at different frequencies have same performance

  Scaling introduced in a parametric model (taking into account RF structure & beam dynamics constraint), used to study optimum cost & efficiency



CLIC overall optimisation model

Accelerating structure limitations:

rf breakdown and pulsed surface heating (rf) constraints:

Beam dynamics constraints:

Beam quality preservation during acceleration in main linac with high wake fields environment: **(conditions similar to NLC)**

Beam focusing in Beam Delivery System and collison in detector in high beamstrahlung regime

Deduce CLIC parameters and performance: > 200 millions structures

Optimising

Performance or figure of merit
Luminosity per linac input power:

$$\int L dt / \int P dt \sim L_{b\times} / N \eta$$

Cost estimation of the overall complex at 3 TeV (invest. & exploit. 10 years)

Cost estimation and cost model

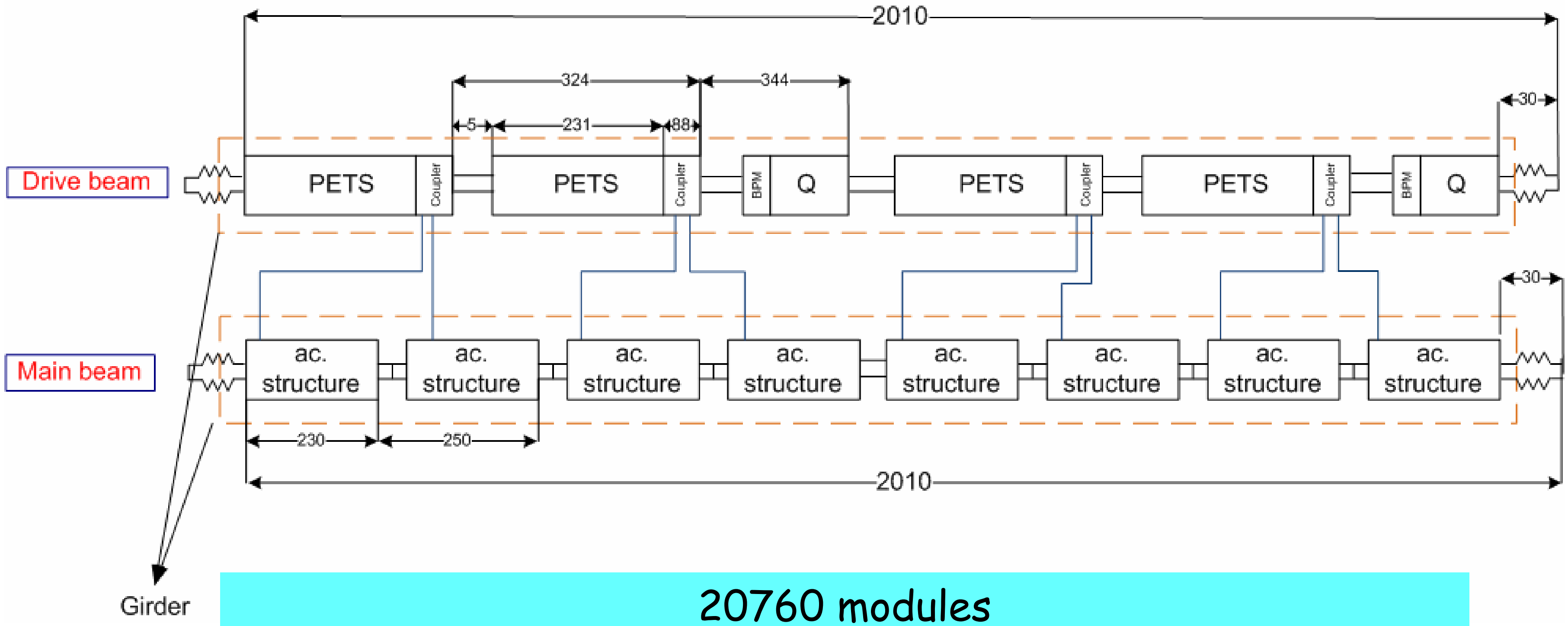
CLIC

Work in progress aiming for reliable cost estimate by 2010

- Presently still large imprecision

- Define cost drivers for Cost Conscious Design guiding
- Cost estimation in parallel with the ILC cost estimate for better comparison of the two technologies,
  - in collaboration with ILC experts,
  - by the same persons,
  - using the same tools,
  - on the same site as for the ILC@CERN
- Parametric model to estimate the influence on cost of the variation parameters
  - Design guiding
  - Cost scaling with colliding beam energy

Two Beam Module

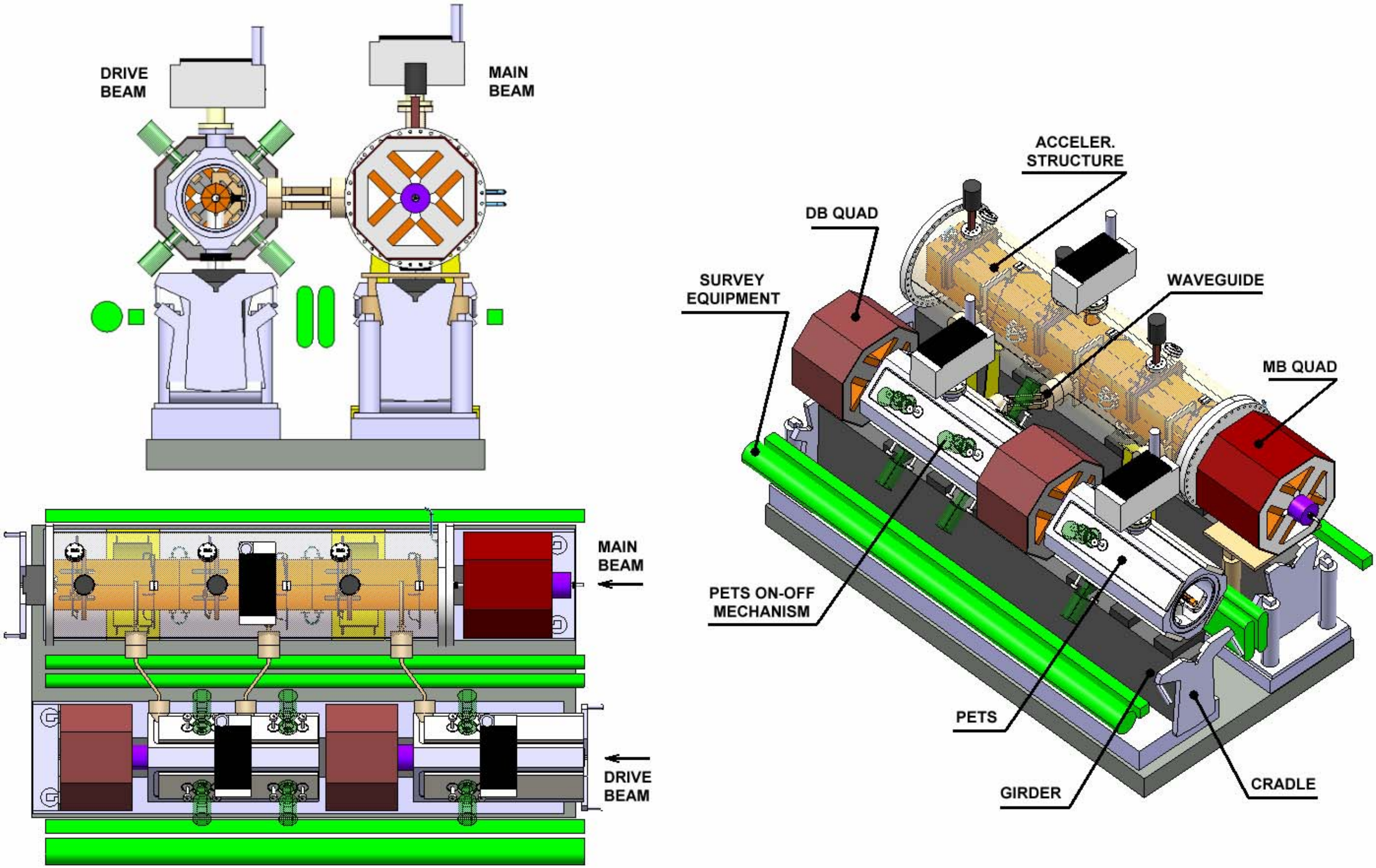


20760 modules

71460 power production structures PETS (drive beam)

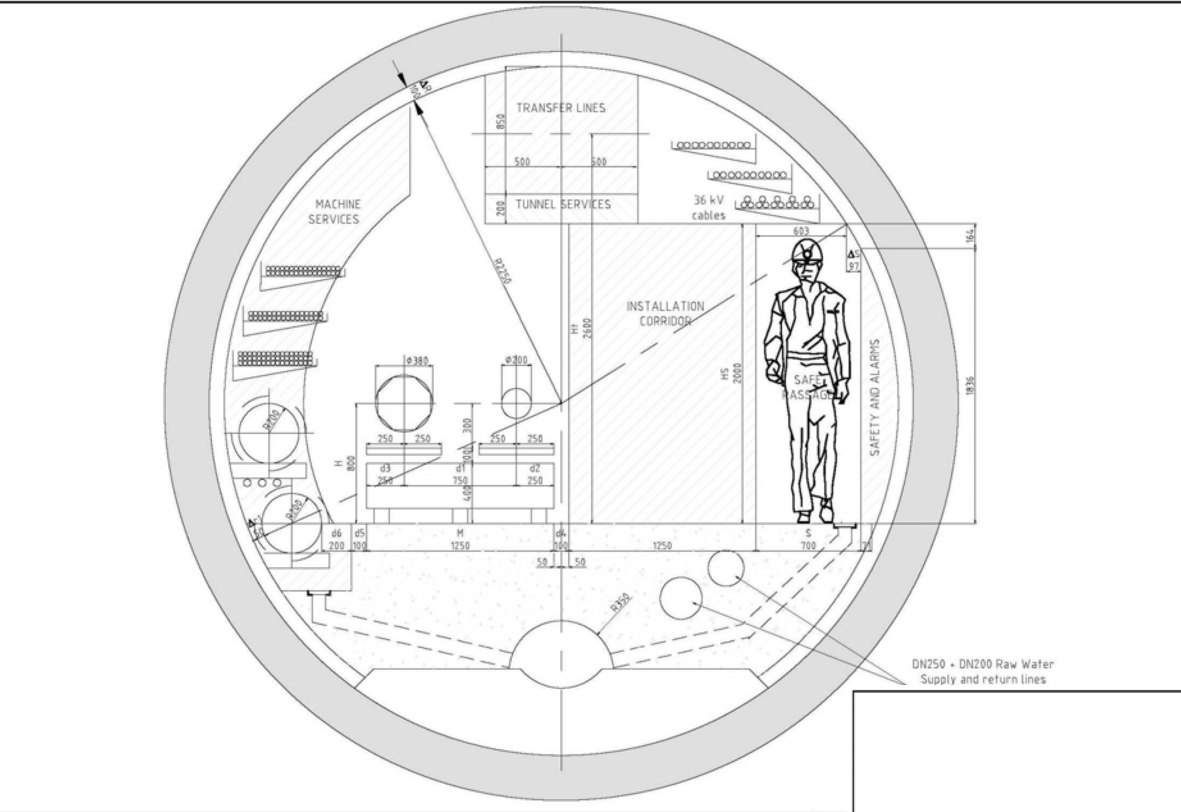
143010 accelerating structures (main beam)

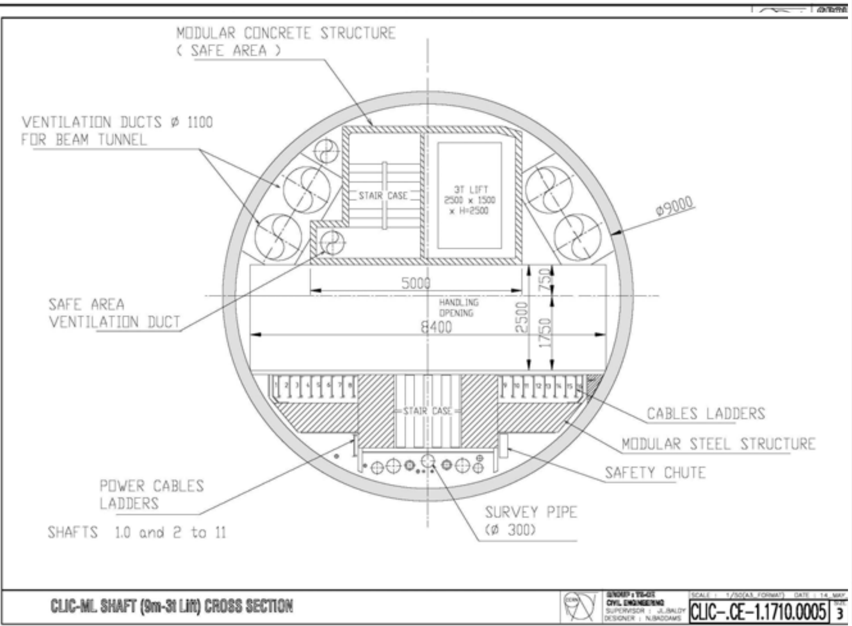
CLIC Standard Two Beam Module

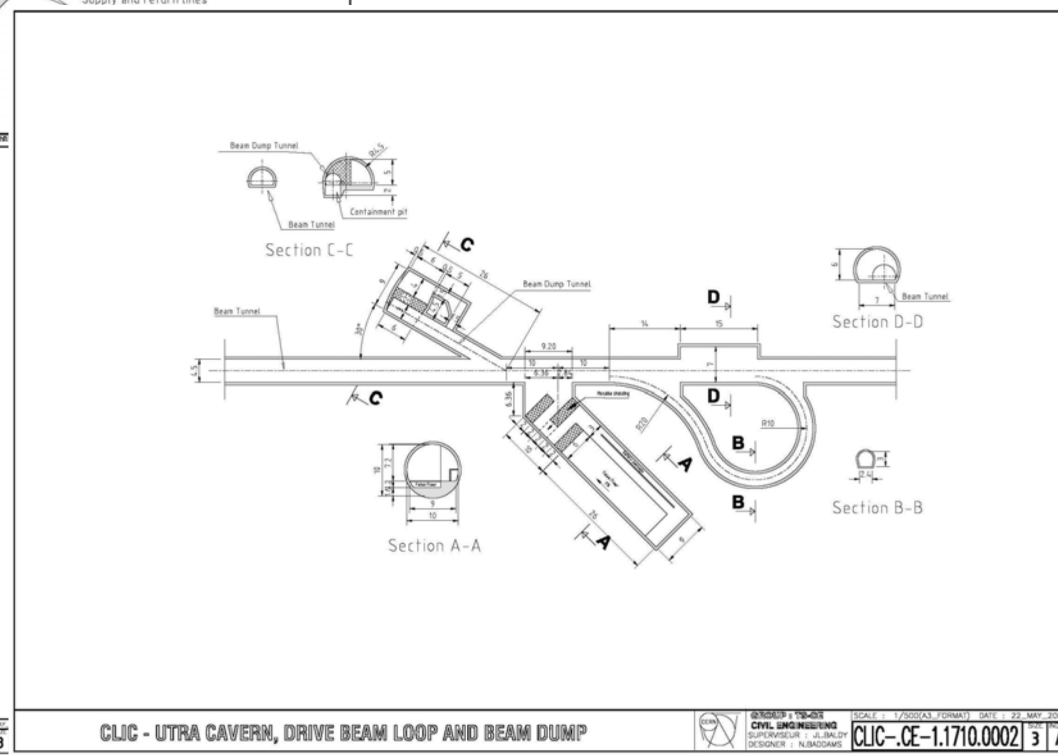


Single CLIC tunnel

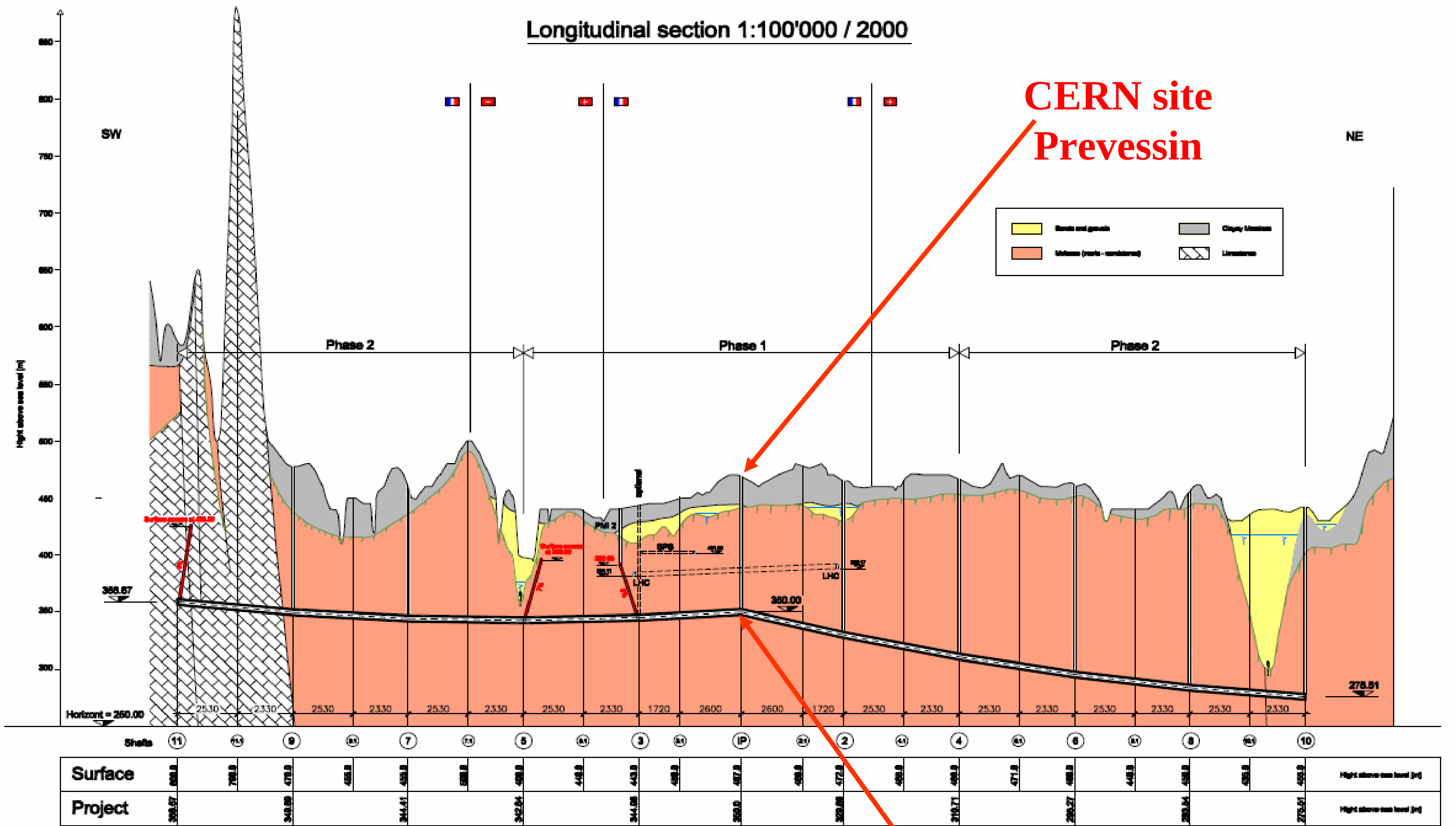
with alcoves for drive beam return loops and dumps







Longitudinal section of a laser straight Linear Collider on CERN site–



IP under CERN Prevessin site

Phase 1: 1 TEV extension 19.5 km

Phase 2: 3 TeV extension 48.5 km

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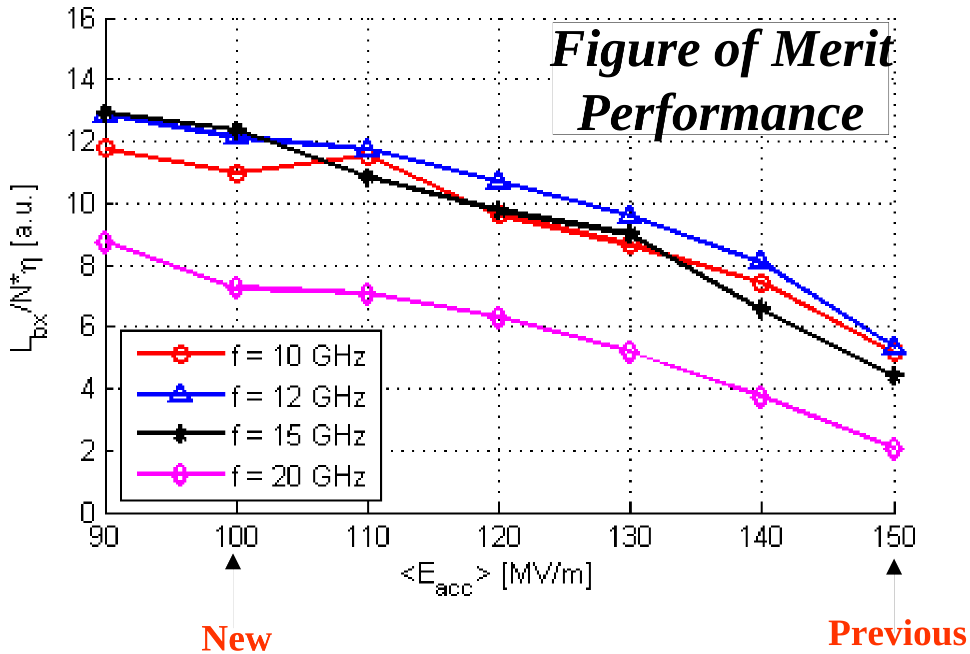
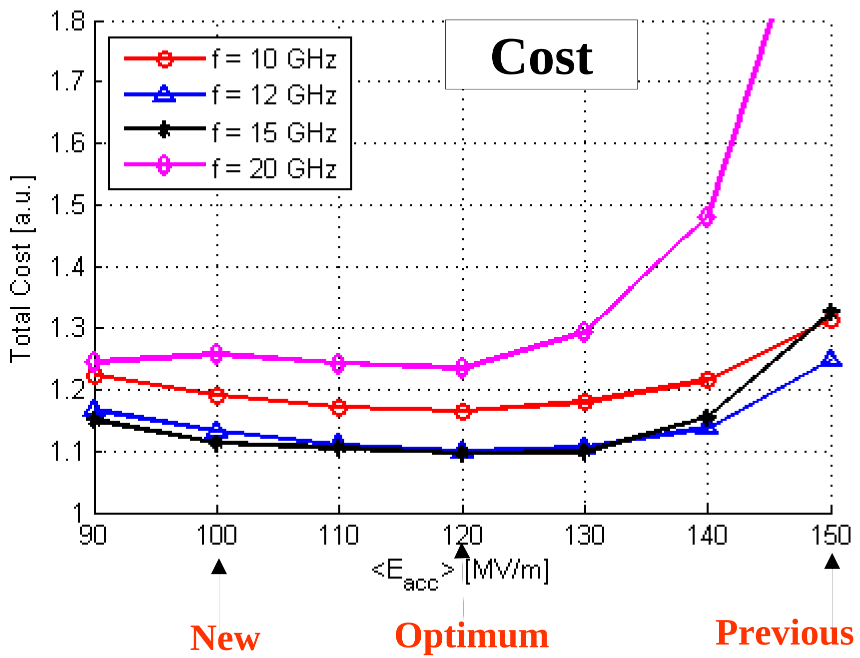
CLIC performances (FoM) and cost (relative) as a function of the accelerating gradient

E_{cms} = 3 TeV $L_{(1\%)} = 2.0\ 10^{34}\ cm^{-2}s^{-1}$



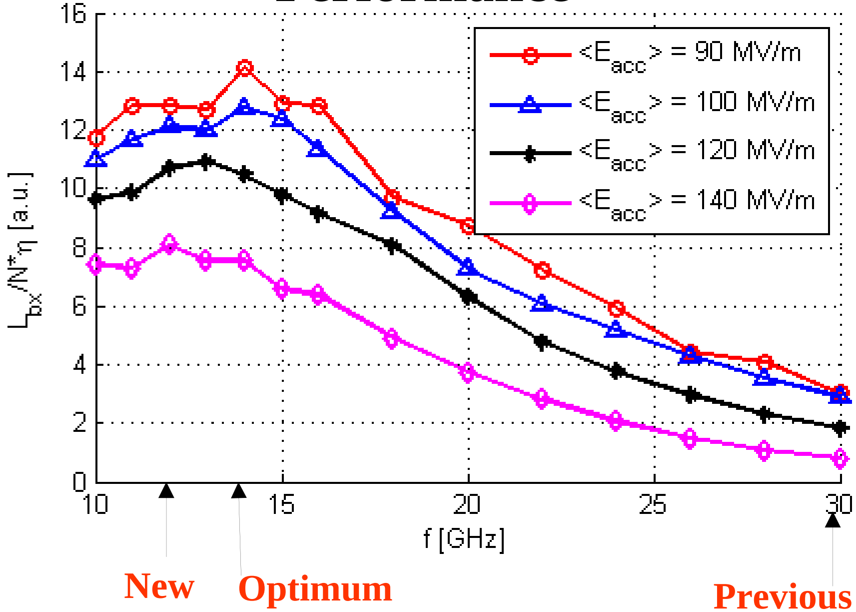


- **Performances increasing with lower accelerating gradient (mainly due to higher efficiency)**
- **Flat cost variation in 100 to 130 MV/m with a minimum around 120 MV/m**

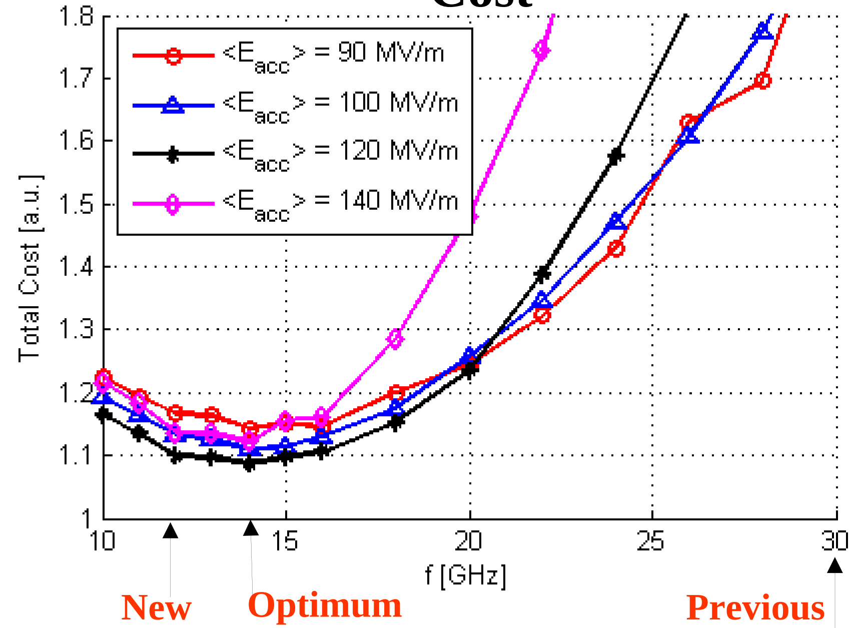
CLIC performances (FoM) and cost optimisation as function of RF frequency

E_{cms} = 3 TeV $L_{(1\%)}$ = 2.0 10^{34} $cm^{-2}s^{-1}$

Performance



Cost



- **Maximum Performance around 14 GHz**
- **Flat cost variation in 12 to 16 GHz frequency range with a minimum around 14 GHz**

The beauty of 12 GHz

- Close to maximum Performance and minimum Cost (14 GHz)
- Accelerating gradient of 100 MV/m already demonstrated at low breakdown rate with short pulse in non fully equipped structures
- Very close to the NLC and JLC frequency: 11.4 GHz
  - Building up on wide expertise and long-term R&D made during many years on warm structures, RF power sources, beam dynamics at SLAC and KEK
  - Take advantage of low(er than 30 GHz) frequency for easier fabrication (tolerances, vacuum), relaxed requirements (alignment, timing, etc…),
- RF power generation and frequency multiplication in CLIC TBA RF Power Source
  - Possibly drive beam linac at 1.3 GHz (with possible synergy with ILC MBK developments) and multiplication by 8 (2*4) instead 36
  - High gradients achievable with short RF pulse provided by TBA RF power source
  - Easy adaptation of CTF3 (multiplication factor by 8 instead of 10)
- Stand alone power sources available:
  - Makes the best use of developments and equipments at SLAC and KEK

Fruitful collaboration with US High Gradient Research

US collaborative effort of interested US institutes

Basic R&D on the understanding and tests of the fields limitations in warm accelerating structures

Initiated by "DOE interested in collaborating with CERN on long range accelerator and technology R&D of importance to the CLIC approach"

Laboratories (ANL, LBNL, NRL,SLAC), Universities (MIT, Maryland), Business associates,

Spokesperson: S.Tantawi/SLAC

Governance with CERN participation (E.Jensen)

SLAC MEMORANDUM

Date: March 29, 2007

To: Jean-Pierre Delahaye (jean-pierre.delahaye@cern.ch)

CC: Sami Tantawi, Ronald Ruth, Chris Pearson, Chris Adolphsen

From: Persis S. Drell

Re: CERN and CLIC Collaboration

With the recent change of the CLIC linac frequency to 12 GHz, we anticipate a growing collaboration between our two laboratories on high gradient research. Not only do we welcome this, but believe the resulting synergy is necessary for the future developments of accelerators and related technologies.

Our work on high gradient research is done under the auspices of the US High-Gradient Research Collaboration for future colliders. This effort at SLAC is managed by Sami Tantawi, who is also the spokesman for the national collaboration. Under this umbrella we are increasing our capabilities to serve users and collaborators. Collaborators can utilize the SLAC facilities in three ways:

1. Take advantage of the world-class design capabilities and manufacturing facilities to have accelerator structures, rf components, and rf sources (klystrons) designed and built. In particular, our extensive expertise for X-band systems will help ensure a successful design and implementation.

2. SLAC can provide reusable input power couplers and compatible flanges so you need only worry about the design of the accelerator structure "proper."

3. Finally, SLAC can offer high-power rf testing at 11.424 GHz.

For collaborative efforts, including pulsed heating research, manufacturing of accelerator structures, rf components, klystrons, modifying existing 11.424 GHz components to work at 12 GHz, and acquiring reusable couplers, please contact Sami directly. He will organize the work with others including Chris Pearson, the head of the klystron department, which is the prime manufacturing facility for these components.

For the time being, the NLCTA infrastructure is the best place for testing CERN-manufactured accelerator structures at 11.424 GHz. For this, as usual, please contact Chris Adolphsen directly, who will make the appropriate arrangements. On the timescale of summer 2007 we will have dedicated test stands in the Klystron Test Lab capable of 11.424 GHz testing. We anticipate these new test stands will offer faster turn around and

Collaboration with SLAC

Collaboration with KEK

CLIC

DRAFT Version 7
ICA-JP-???

Agreement on Collaborative Work

between

The European Organization for Nuclear Research
CERN CH-1211 Genève 23
Switzerland
(in the following called "CERN")

and

High Energy Accelerator Research Organization
1-1 Oho, Tsukuba-shi, Ibaraki-ken 305-0801
Japan
(in the following called "KEK")

2007

ia)

Appendix 2 to Agreement on Collaborative Work (V3)

Collaboration on
Fabrication and Tests of High- Gradient X-Band Accelerating Structures

1. Personnel of the Collaboration:

KEK: Yukihide Kamiya, Director of Accelerator Laboratory of KEK
Toshiyasu Higo, Accelerator Laboratory of KEK
Shigeki Fukuda, Accelerator Laboratory of KEK
CERN: Jean-Pierre Delahaye, Accelerators and Beams Department
Walter Wuensch, Accelerators and Beams Department

2. Time schedule:

From September, 2007 until December, 2010.

3. Scope of the Collaboration:

3.1 Test of high-field structures:
KEK utilizes the Nextef (X-band test facility) at KEK for this collaboration. CERN staff will visit KEK to help prepare the system to suit the Compact Linear Collider (CLIC) study. KEK expects to conduct a test of at least one CLIC structure in 2007. KEK will pursue the tests in a concerted manner with SLAC and CERN.

3.2 Fabrication of high-field test structures:
Test structures will be made by CERN, SLAC and KEK. The actual division of work will be decided by discussion among these three laboratories. KEK will focus in 2007 on the fabrication of "CLIC_vg1" structures composed of disks.

3.3 Fabrication of CLIC structures:
KEK starts studying the fabrication of a quadrant of a CLIC structure in 2007. If this is successful, KEK will make a high-power-ready CLIC structure in 2008.

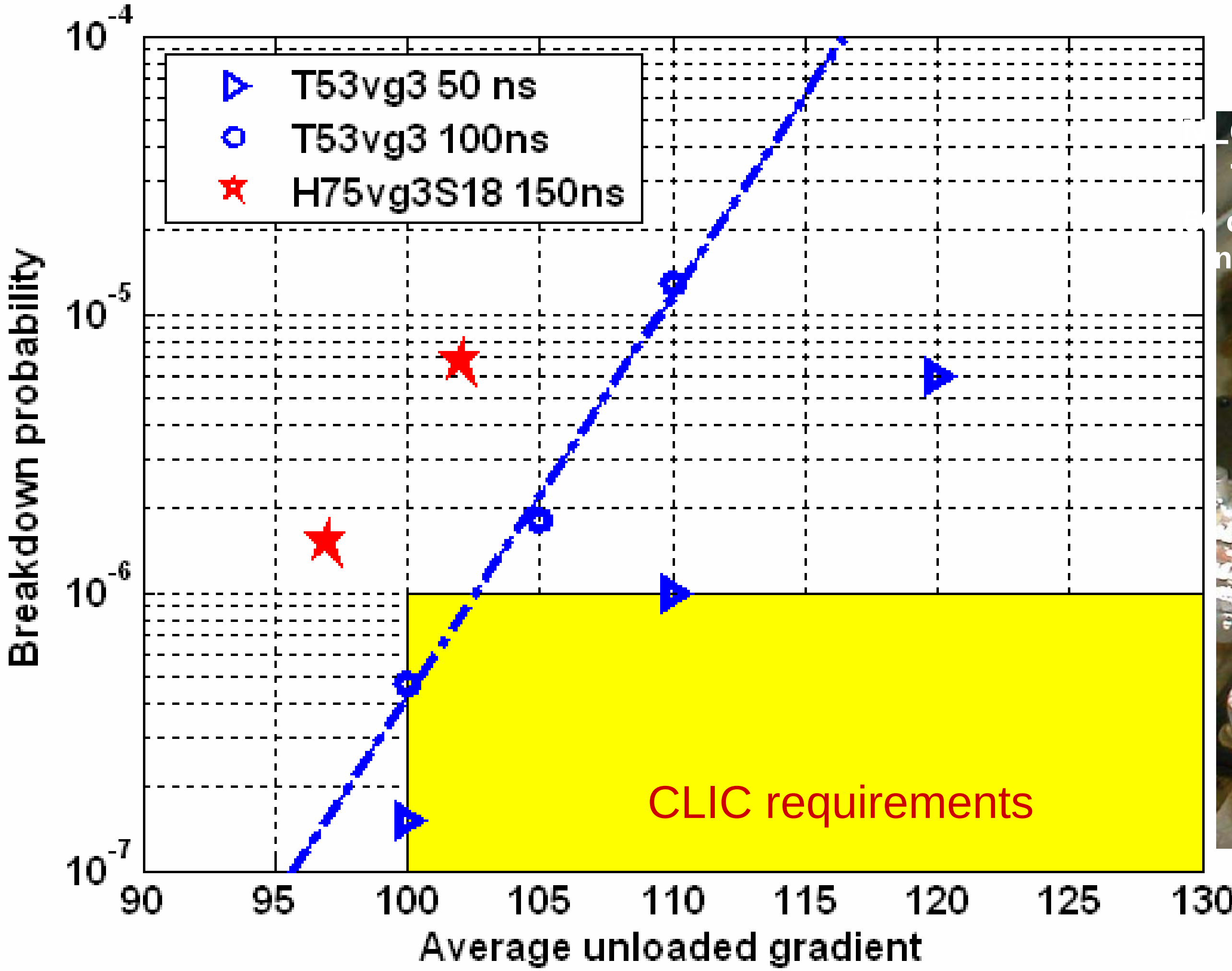
3.4 Future studies:
Further possible structure fabrications and tests will be defined by common agreement between CERN and KEK based on the outcomes of the initial tests.

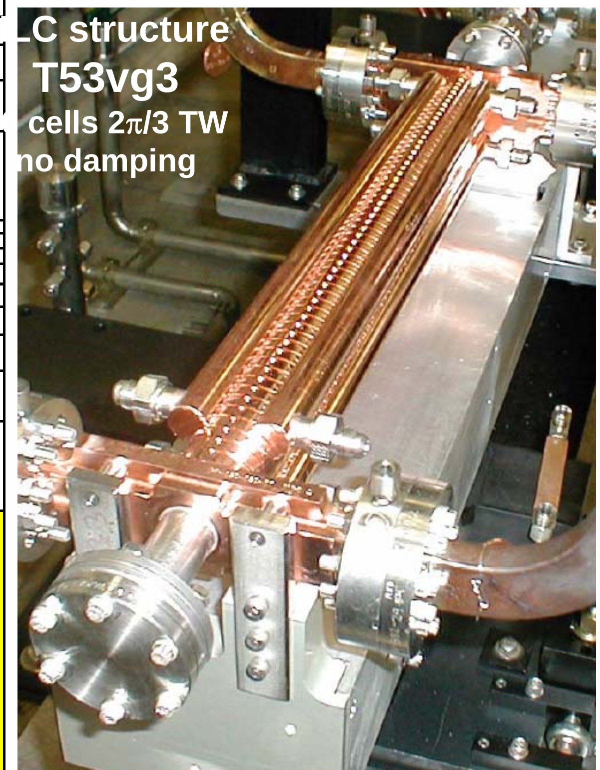
New CLIC Parameters (December 2006)

Main Linac RF frequency	30 GHz ⇒ 12 GHz
Accelerating field	150 MV/m ⇒ 100 MV/m
Overall length @ E_{CMS}= 3 TeV	33.6 km ⇒ 48.2 km

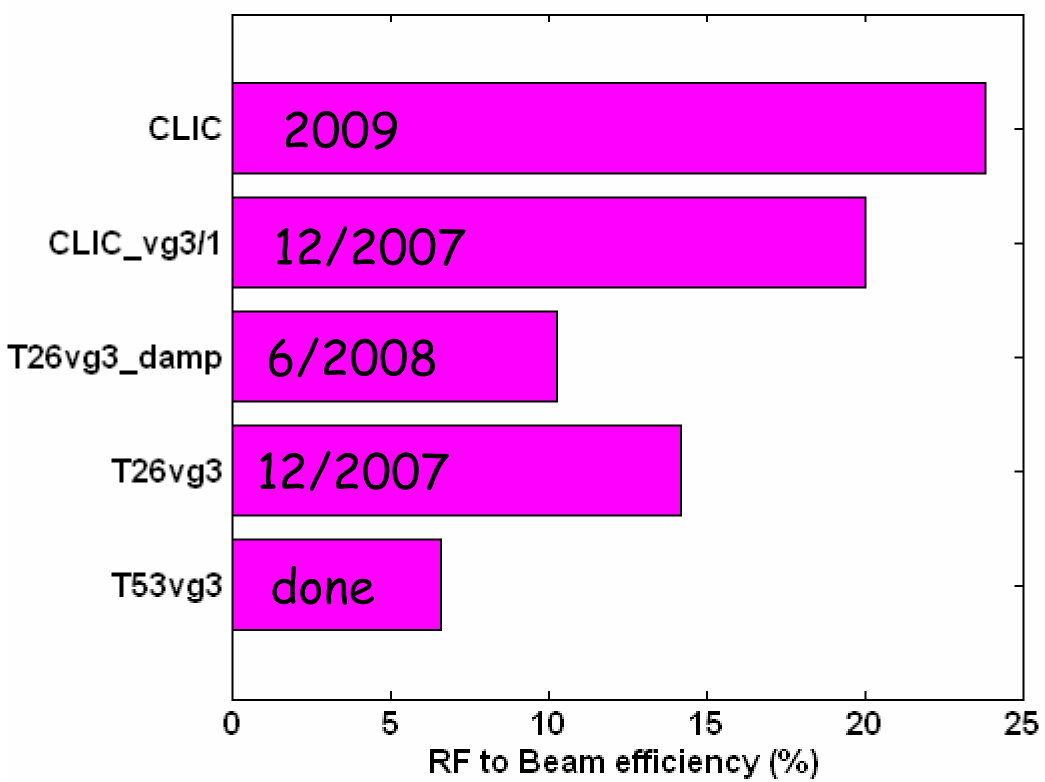
- **Substantial cost savings and performance improvements for 12 GHz / 100 MV/m indicated by parametric model (flat optimum in parameter range)**
- **Promising results already achieved with structures in test conditions close to LC requirements (low breakdown rate) but still to be demonstrated with long RF pulses and fully equipped structures with HOM damping.**
- **Realistic feasibility demonstration by 2010**

Recent High-Power test results @ SLAC (11.4 GHz)





RF to Beam Efficiency milestones



P = 65 MW; 297 ns ⇔ nb = 311

P = 70 MW; 295 ns ⇔ nb = 359

P = 111 MW; 102 ns ⇔ nb = 66

P = 102 MW; 113 ns ⇔ nb = 93

P = 134 MW; 104 ns ⇔ nb = 27

100 MV/m loaded, 10^{-6} break down rate, qb=$4*10^{9}$,
8 rf period bunch spacing, P*pl/C = 18 Wue

12 GHz Structure Tests Flow Chart

CLIC

2007

TD18_vg2.4_quad

T28_vg2.9

T18_vg2.4_disk

2008

CLICvg1
geometry OK

CLICvg1
geometry not OK

Quads OK
+Damp

Disks OK

TD18_vg2.4_disk

(T18_vg2.4_quad)

TD28_vg2.9

Damping
Not OK

2009

Input from break down R&D

CLIC prototype quads damped

?

CLIC prototype disks damped

CLIC prototype TD28 like

2010

Go towards more extreme structures

Current structure testing program

2008	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
CTF3/CERN 30 GHz		HDS11_vg2	C30_vg2.6 C30_vg8.2	C30_vg2_TM02
NLCTA/SLAC Station 1 11.4 GHz	→ TD18_vg2.4 _quad	C10vg2.9 [2x] C10vg1.5 [2x]	C10vg0.6 [2x]	C10vg2.4_ thick [2x]
NLCTA/SLAC Station 2 11.4 GHz	→ T28_vg2.9	T18_vg2.4_ disk	TD18_vg2.4	PETS 11.4 GHz
XTF/KEK 11.4 GHz	→ C10_vg1.5	T18_vg2.4_ disk [2]	TD18_vg2.4 _quad [2]	TD18_vg2.4 [2]
CLEX/CTF3 12GHz			PETS 12 GHz	T18_vg2.4_disk

Future Structure Testing Program

2007: Study Parameter Space at 30 GHz and testing of real structures at 11 GHz (focus on copper structures)

2008: Focus on two main geometries, develop damping, optimize structure

2009: CLIC prototype structure

2010: Longer term testing and better statistics

Possible number of tests

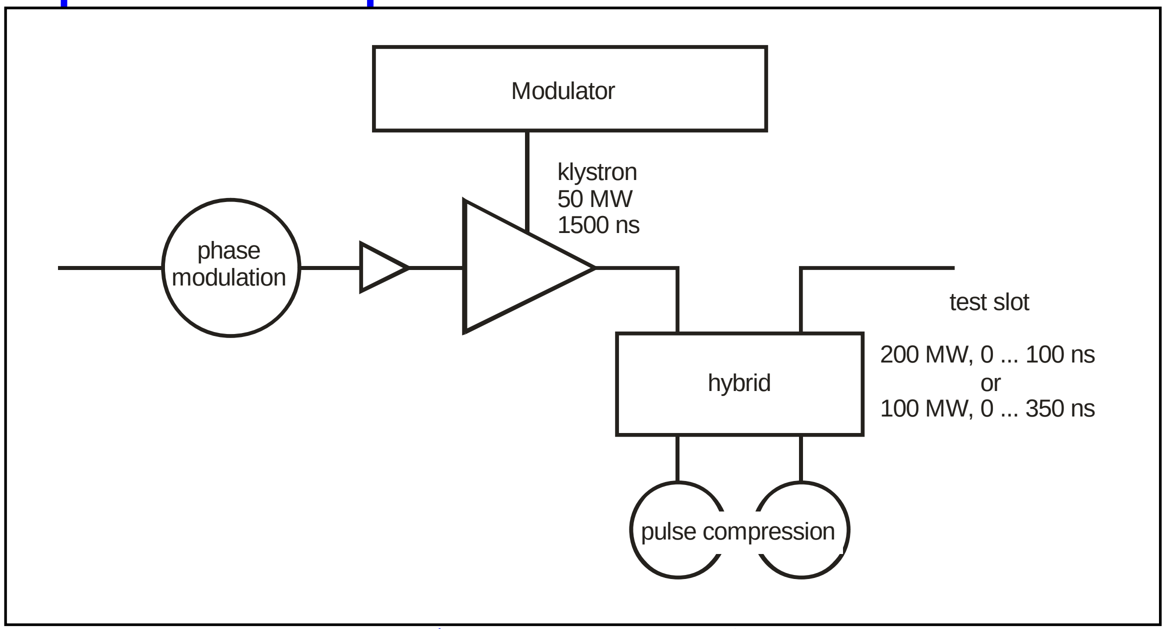
	2007	2008	2009	2010	sum
30 GHz@CERN	5	3	0	0	8
12 GHz@CERN	0	1	4	4	9
11.4 GHz @ SLAC & KEK	2	4	4	4	14
12GHzPowerTes Stand@CERN	0	0	8	11	19
sum	7	8	16	19	50

A 12 GHz stand alone power source @ CERN

Common interest with PSI, EPFL, INFN-Frascati & Trieste

Possible in kind contribution from Switzerland

In parallel with power tests in CLEX

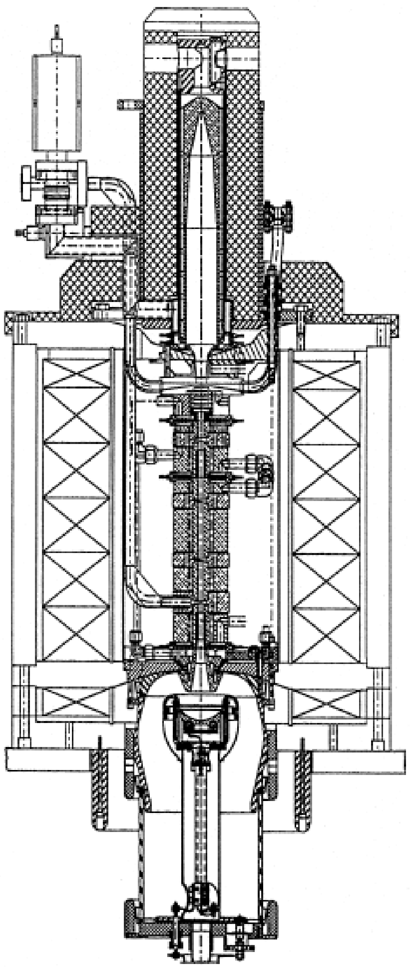


Independent 24/7 testing with fast turn around

Variable pulse length

High repetition rate

Easier to operate



Derived from NLC 11.4 GHz klystron

New CLIC main parameters

CLIC

Center-of-mass energy	3 TeV
Peak Luminosity	$7 \cdot 10^{34}$ cm^{-2} s^{-1}
Peak luminosity (in 1% of energy)	$2 \cdot 10^{34}$ cm^{-2} s^{-1}
Repetition rate	50 Hz
Loaded accelerating gradient	100 MV/m
Main linac RF frequency	12 GHz
Overall two-linac length	41.7 km
Bunch charge	$4 \cdot 10^{9}$
Beam pulse length	200 ns
Average current in pulse	1 A
Hor./vert. normalized emittance	660 / 20 nm rad
Hor./vert. IP beam size bef. pinch	53 / ~1 nm
Total site length	48.25 km
Total power consumption	390 MW

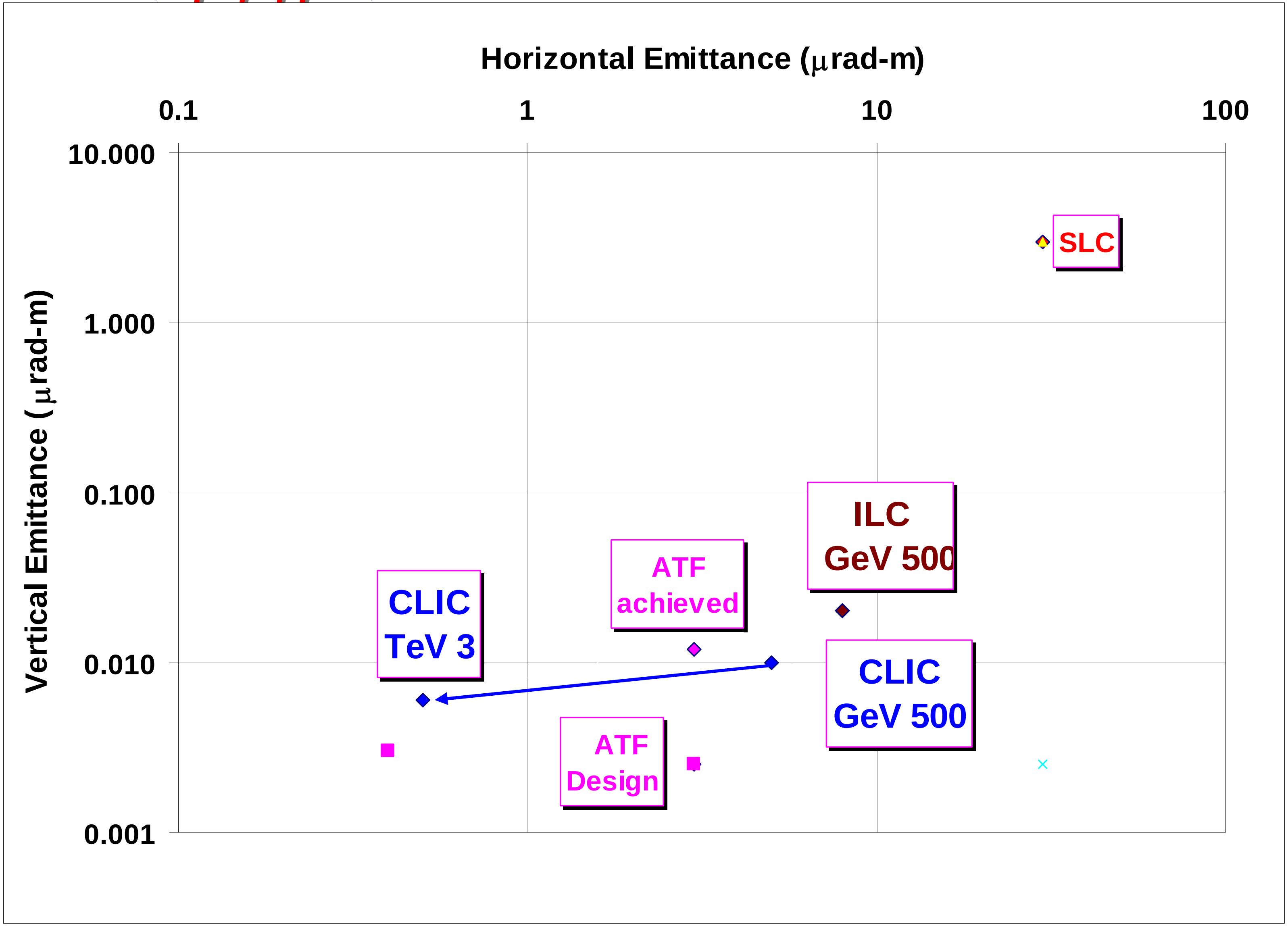
Provisional values

Main CLIC/ILC parameters @ various energies

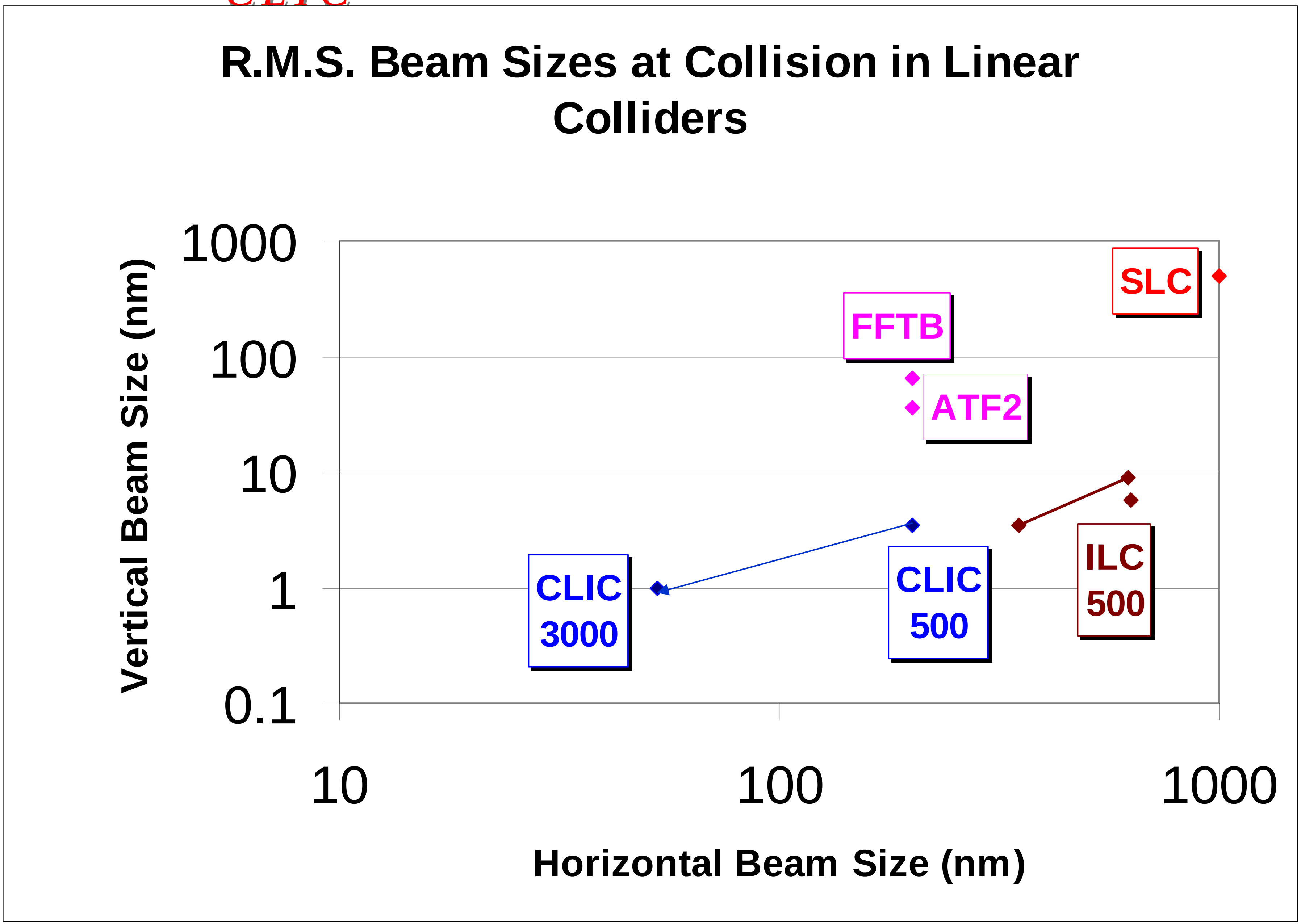
https://clic-meeting.web.cern.ch/clic-meeting/ComparisonTable_RC_12oct07.html

Parameter	Symbol	3 TeV	1 TeV	0.5 TeV	ILC	Unit
Center of mass energy	E_{cm}	3000	1000	500	500	GeV
Main Linac RF Frequency	f_{RF}	12	12	12	1.3	GHz
Luminosity	**L**	**5.9**	**2.25**	**2.24**	**2**	**10^{34} cm^{-2} s^{-1}**
Luminosity (in 1% of energy)	$L_{99\%}$	2	1.08	1.36		10^{34} cm^{-2} s^{-1}
Linac repetition rate	f_{rep}	50	50	100	5	Hz
No. of particles / bunch	N_b	3.72	3.72	3.72	20	10^9
No. of bunches / pulse	k_b	312	312	312	2670	
No. of drive beam sectors / linac	N_{unit}	24	8	4	-	-
Overall two linac length	l_{linac}	42	14	7	22	km
Proposed site length	l_{tot}	48	19.5	12	**31**	**km**
DB Pulse length (total train)	τ_t	139	46	23	-	μs
Beam power / beam	P_b	14	4.6	4.6	10.8	MW
Wall-plug power to beam efficiency	$\eta_{wp\text{-}rf}$	8.7	6.1	6.1	9.4	%
Total site AC power	P_{tot}	**322**	**~150**	**~150**	**230**	**MW**
Transverse horizontal emittance	$\gamma\varepsilon_x$	660	660	660	8000	nm rad
Transverse vertical emittance	$\gamma\varepsilon_y$	20	20	20	40	nm rad
Horizontal beam size at IP before pinch	β^*_x	40		142	640	mm
Vertical beam size at IP before pinch	β^*_y	1		2	5.7	mm

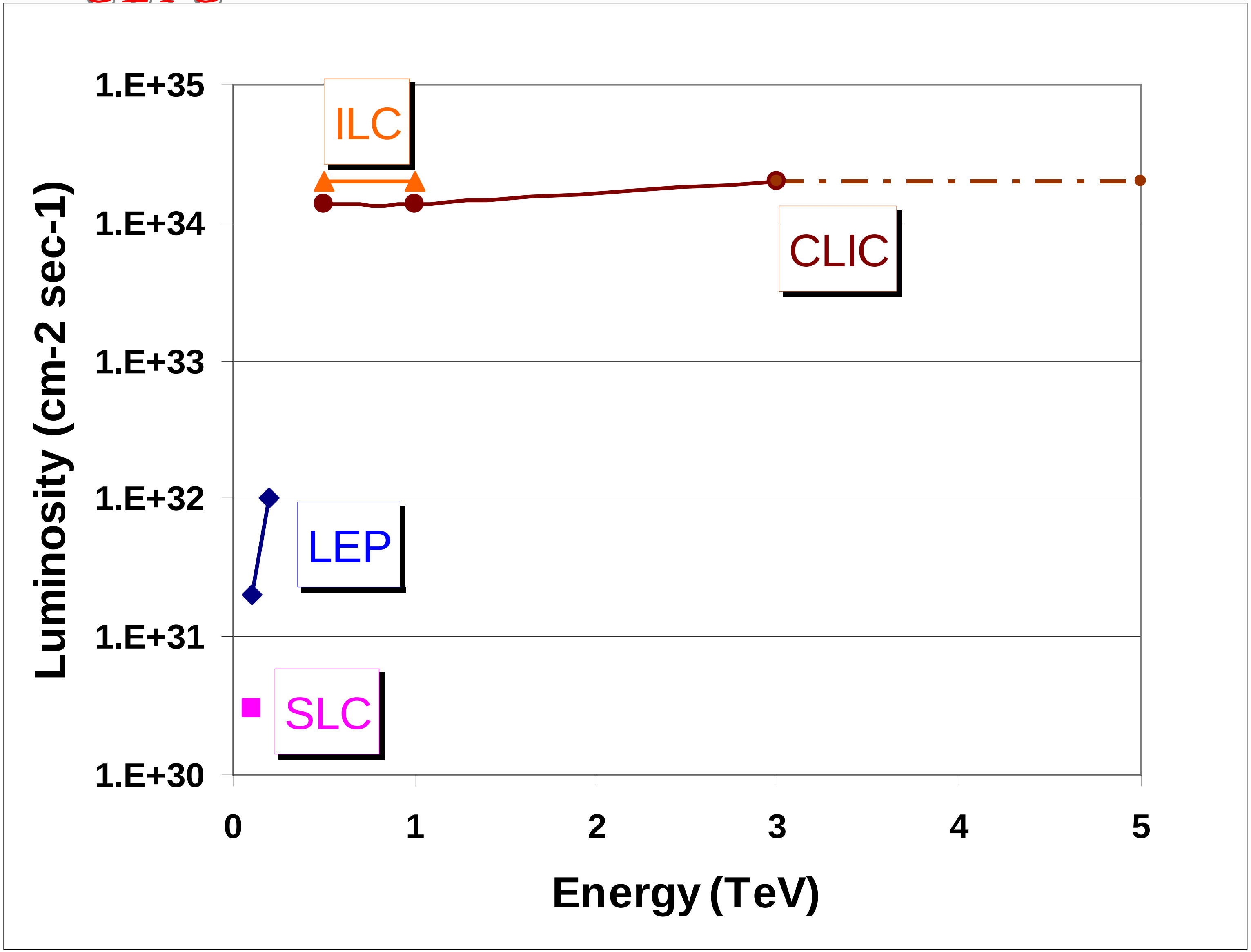
Beam emittances at Damping Rings



Beam sizes at Collisions

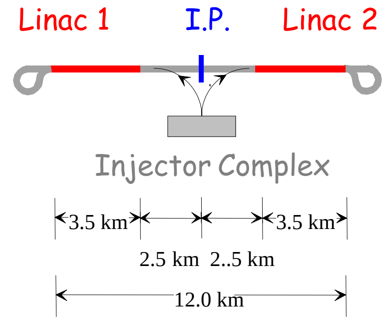


Performances of Lepton Colliders

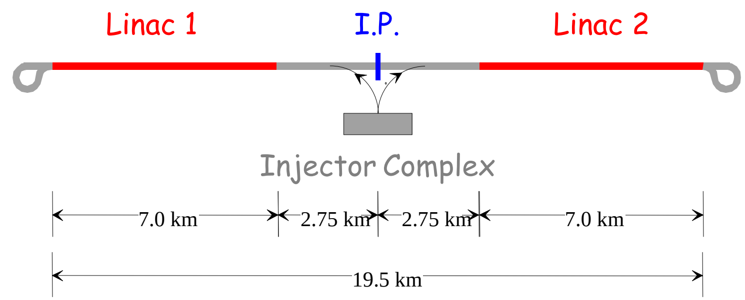


CLIC Layout at various energies

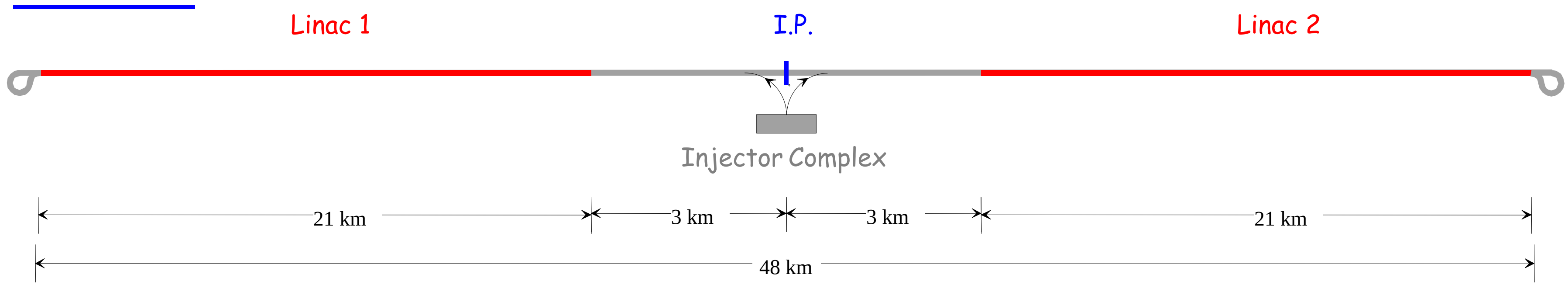
0.5 TeV Stage



1 TeV Stage



3 TeV Stage



Work program till 2010

- Work programme and resources (2007-2015)
  http://clic-meeting.web.cern.ch/clic-meeting/2007/CLIC_ACE/201006_CLIC_LTP_2006_15.pdf

- Demonstrate feasibility of CLIC technology in CTF3
- Design of a linear Collider based on CLIC technology
  http://clic-study.web.cern.ch/CLIC-Study/Design.htm
- Estimation of its cost in the CERN area and comparison with ILC
- CLIC Physics study and detector development:
  http://clic-meeting.web.cern.ch/clic-meeting/CLIC_Phy_Study_Website/default.html
- Preparation of a Conceptual Design Report to be published in 2010

CERN, 16-18 October 2007

CLIC'07 provides a forum to review all aspects related to the Accelerator, Detector and Particle Physics of a Multi-TeV Linear Collider based on the CLIC technology.

It is open to any interested Accelerator and Physics expert already part or not of the CLIC/CTF3 collaboration.

The workshop will address in particular:

- Present status and future plans of the CLIC study
- CLIC physics case and detector issues
- The Test Facility CTF3 used to address major CLIC technology issues
- The ongoing CLIC R&D, future plans (including FP7 proposals) and open issues
- The CLIC related collaborative efforts

Program Advisory Committee

- M. Besançon
- G. Blair
- M. Calvetti
- S. Chattopadhyay
- T. Ekelof
- A. Faus-Golfe
- L. Garcia
- T. Higo
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- Y. Karyotakis
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- S. Tantawi
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Local Organising Committee

- H.H. Braun (Chair)
- R. Corsini
- J-P. Delahaye
- J. Ellis
- S. Escaffre
- G. Geschonke
- A. de Roeck
- W.D. Schlatter
- D. Schulte
- W. Wuensch

CLIC Workshop 07

The CLIC workshop will be held at CERN in the Main Auditorium, Main building, 1st Floor

Welcome

CLIC

Participants: 200 (registered) from 49 Inst. of 19 countries

- China: Tsinghua University
- Finland: Helsinski Univ.- HIP
- France: CNRS/IN2P3/LAL-LAPP LPNHE-LPSC, THALES, CEA DAPNIA
- Germany: DESY-ANKA/FZK
- Greece: Athens NTU-IASA-PATRAS
- India: BARC-RRCAT
- Iran: IPM
- Italy: INFN/LNF-Napoly Fed.II
- Japan: KEK
- Norway: NTNU
- Pakistan: NCP
- Russia: IAP—BINP-JINR
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- Switzerland: CERN-ETHZ-IPP-PSI
- Turkey: Ankara U-Dumlupinar U TOBB Univ Eco&Tech
- UK: COCKROFT-J.ADAMS-Lancaster Univ-Oxford-RHUL
- Ukraine: IAP-NAS
- USA: LBNL-Northwestern U.-TJNAF-OHMEGA-Oklahoma Univ-SLAC

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  - **The Test Facility CTF3 used to address major CLIC technology issues**
  - **The ongoing CLIC R&D, future plans (including FP7 proposals) and open issues**
  - **The CLIC related collaborative efforts**

  - ***Agenda and slides (plenary and working groups)***
  http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=17870

CLIC07 Conclusion
(M.Calvetti/ CLIC Collab. Board chaiman)

CLIC technology the ONLY possible scheme to extend linear collider beam energy into Multi-TeV energy range

- Very promising results BUT CLIC technology not mature yet
- novel Ideas and Challenging R&D in world-wide collaboration

Nevertheless CLIC Conceptual Design with cost estimate by 2010

Your participation to the CLIC study during and after the workshop warmly welcome and appreciated

CTF3 technical meeting on 21-23/01/08

CLIC08 Workshop on 14-17/10/08

Conclusion

- New CLIC parameters close to optimum performance and cost taking into account structure limitations measured in Test Facilities

  Nominal structure parameters already achieved with acceptable break down rate (not fully equipped and efficiency still to be improved)

- Excellent collaboration with ILC community on common R&D key issues: EU-FP6: Eurotev Design Study   EU-FP7: Integrated Activity (NAS)

- Well defined program focused on specific key issues to demonstrate CLIC technology feasibility by 2010
  - Completion and commissioning of CTF3 test facility to demonstrate CLIC RF power production and Two-Beam-Acceleration schemes
  - Use of CTF3 as RF power source to test RF components

- Presently under schedule thanks to the efficient and motivated world-wide multi-lateral collaboration of volunteer institutes organised as Physics experiment: 24 institutes from 13 countries

- Heavily relies on SLAC and KEK for Structure Tests at 12 GHz

- Strongly committed (but still large effort necessary) to a Conceptual Design including reliable cost estimate by 2010

Plea

- Expression of Interest and support by ECFA for a Multi-TeV Linear Collider Study

- Performance Parameters in the Multi-TeV energy range defined by Physics Community

Spares

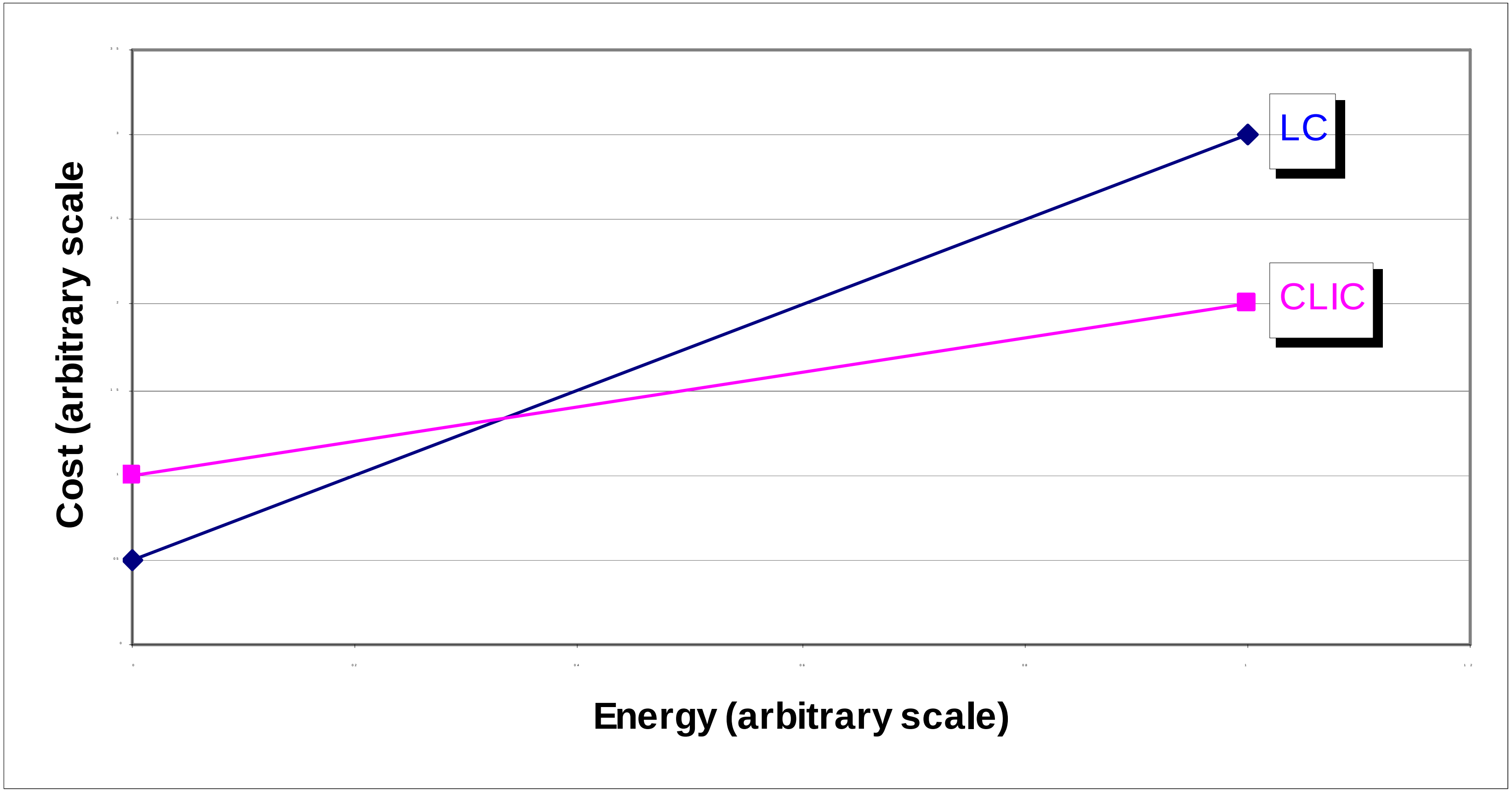
Parameters for the Linear Collider

September 30, 2003

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

- The machine must be upgradeable to 1 TeV

Relative cost of Linear Colliders



CERN participation to ILC

- **ILC- MoU: Support to GDE**
  - 4 members including deputy of the European GDE Director
- **Member of Funding Agencies for Large Colliders (FALC)**
  - CERN collecting European budget for common funds
- **Major partner in specific studies and ILC Reference Design Report (RDR):**
  - Civil eng.&CFS (Baldy), Cryogenics&Cryostats (Tavian), Beam dynamics (Schulte)
- **ILC@CERN Site Specific Cost Study**
  - CERN = European sample site
- **Providing ILC with CERN experience and tools developped for large projects**
  - LHC project management tools: INDICO for meetings & agendas
    CERN Documents Server (CDS) for general documentation
- **Fruitful collaboration with ILC community on R&D of generic Linear Colliders (ILC&CLIC) key issues**
  - Participation in EUROTeV design study & CARE project
  - R&D on Beam diagnostics, Beam Delivery System (BDS), Beam dynamics
  - Tests with beam in CTF3 Test facility
- **Participation to R&D on generation of:**
  - Low Emittances generation @ ATF1/KEK
  - Strong Beam Focusing to nanometers sizes @ATF2/KEK