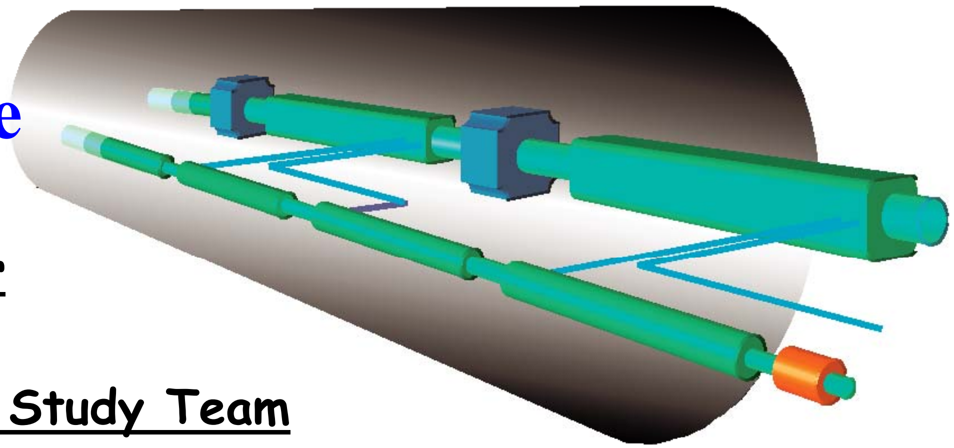
THE COMPACT LINEAR COLLIDER (CLIC) STUDY

Introduction to the CLIC Advisory Committee



J.P.Delahaye for

The Compact LInear Collider Study Team

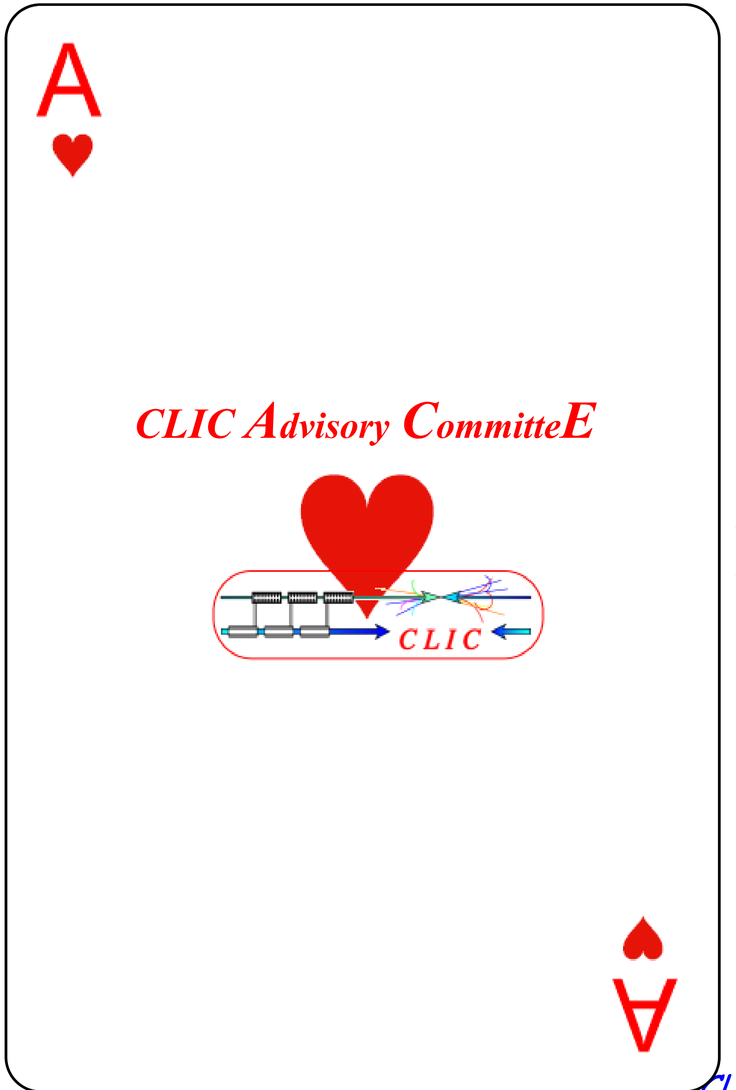
The CLIC study is a site independent feasibility study aiming at the development of a realistic technology at an affordable cost for an e± Linear Collider in the post-LHC era for Physics in the multi-TeV center of mass colliding beam energy range.

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

CERN 2000-008, CERN 2003-007, CERN 2004-005

Outline

- Welcome and organisation
- Mandate
- Introduction to the CLIC study and to the specific presentations
- Challenges and key issues
- CLIC feasibility demonstration
- Rational of new parameters
- Perspectives: Plans and schedule
- M&P Resources
- Conclusion



Name?

CLIC Advisory CommitteE : CLIC-ACE

CLIC Machine Advisory Committee: CLIC MAC

CLIC Study Advisory Committee : CLIC SAC

CLIC Advisory Committee: (CLIC) CLAC

Members?

http://clic-meeting.web.cern.ch/clic-meeting/2007/CLIC_ACE/index.htm

Advice and recommendations welcome on possible additional members (missing expertise…)

Any **organisational or administrative issues**: Sonia

- **Mandate** (Link)

A CLIC Study Advisory Committee is being set up with the following mandate:

- Assess the scope of the CLIC study and the technical choices for optimum performance and cost.
- Assess the work programme aiming at a demonstration of the main CLIC feasibility issues and the preparation of a Conceptual Design Report by 2010.
- Identify technical difficulties or risks of the study.
- Check the compatibility of the available resources with the work programme.
- Monitor the progress.

Organisation

The SAC acts as an advisory committee reporting to the CERN DG and the CTF3 Collaboration Board.

It meets at least once a year and provides a written report including recommendations at the latest two weeks after the meeting.

Members are nominated for three years.

The Ancester!

CLIC Note 19

Status Report

from

CLIC Advisory Panel
(March, 1986)

1. Introduction

At its meeting in February 1985, the CERN Council asked Professor C. Rubbia to chair a Long Range Planning Committee (LRPC) with the following membership : G. Brianti, P. Darriulat, G. Ekspong, C. Rubbia, J. Sacton, A. Salam, S. van der Meer, S.C. Ting and G-A. Voss.

At its first meeting on 5th June, 1985, the LRPC decided to create three advisory panels. The first one would be a continuation of the Committee on a Large Hadron Collider (LHC) chaired by G. Brianti. The second one should explore new ideas for e^+e^- colliders in the TeV range. K. Johnsen was asked to chair this panel. The third one would deal with topics of physics potential, instrumentation and related parameters. J. Mulvey was asked to chair this panel.

The present Status Report is from the second advisory panel, which subsequently got the following membership : U. Amaldi, K. Johnsen (chairman), J.D. Lawson, B.W. Montague, W. Schnell, S. van der Meer, W. Willis.

It was certainly realised that the subject for this Advisory Panel would have a wide range of very difficult aspects. Even the simplest system we could envisage would mean tremendous extrapolations from present-day accelerators. The Panel has so far mainly concentrated its effort on a possible CERN Linear Collider (CLIC) with a centre-of-mass energy of about 2 TeV and with a luminosity in the range of 10^{33}–10^{34} cm^{-2}s^{-1}, but always with an open mind towards the consequences for conclusions or parameters if it would be desirable to depart from these main requirements.

Specific to this meeting

- **Specific Mandate (Link)**

  The first CLIC-ACE meeting is mainly devoted to an introduction of the committee members to the present status and future plans of the CLIC study, via an extensive overview of the various aspects of the CLIC study, especially the CLIC design and plans to address the major key issues, demonstrate the feasibility of the CLIC technology and prepare a conceptual design report by 2010.

  - An analysis and specific recommendations by the committee concerning the following (non-exhaustive list of) subjects, would be greatly appreciated:
  - CLIC scheme and (new parameters).
  - major key-issues to be addressed before the CLIC technology can be considered feasible.
  - work programme to address the various key issues.
  - adequation of (Material & man-power) resources (including external collaborations) to the work programme.

Specific to this meeting

- Agenda:

http://indico.cern.ch/conferenceDisplay.py?confId=15452

- This room reserved for the Committee up to Friday 2pm
- Coffee breaks here (for Committee and Speakers…)
- Lunches in CERN Main Cafeteria (tickets provided to Committee)
- Dinner to-night in Glass Box (Main Cafeteria): (Committee and Speakers)
- Report by chairman to CTF3 collaboration Board on June 22 pm and possibly to the SPC in September?

Documentation

- **ACE site:** http://clic-meeting.web.cern.ch/clic-meeting/2007/CLIC_ACE/index.htm
  - Improvements suggestions welcome (useful doc? Public?)

- **General documentation about the CLIC study:**
  http://clic-study.web.cern.ch/CLIC-Study/

- **CLIC scheme description:**
- http://preprints.cern.ch/yellowrep/2000/2000-008/p1.pdf

- **CLIC Physics**
  http://clicphysics.web.cern.ch/CLICphysics/

- **CLIC Test Facility: CTF3**
  http://ctf3.home.cern.ch/ctf3/CTFindex.htm

- **CLIC technological challenges**
  - http://indico.cern.ch/conferenceDisplay.py?confId=a057972

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 down-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)

CLIC

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.*

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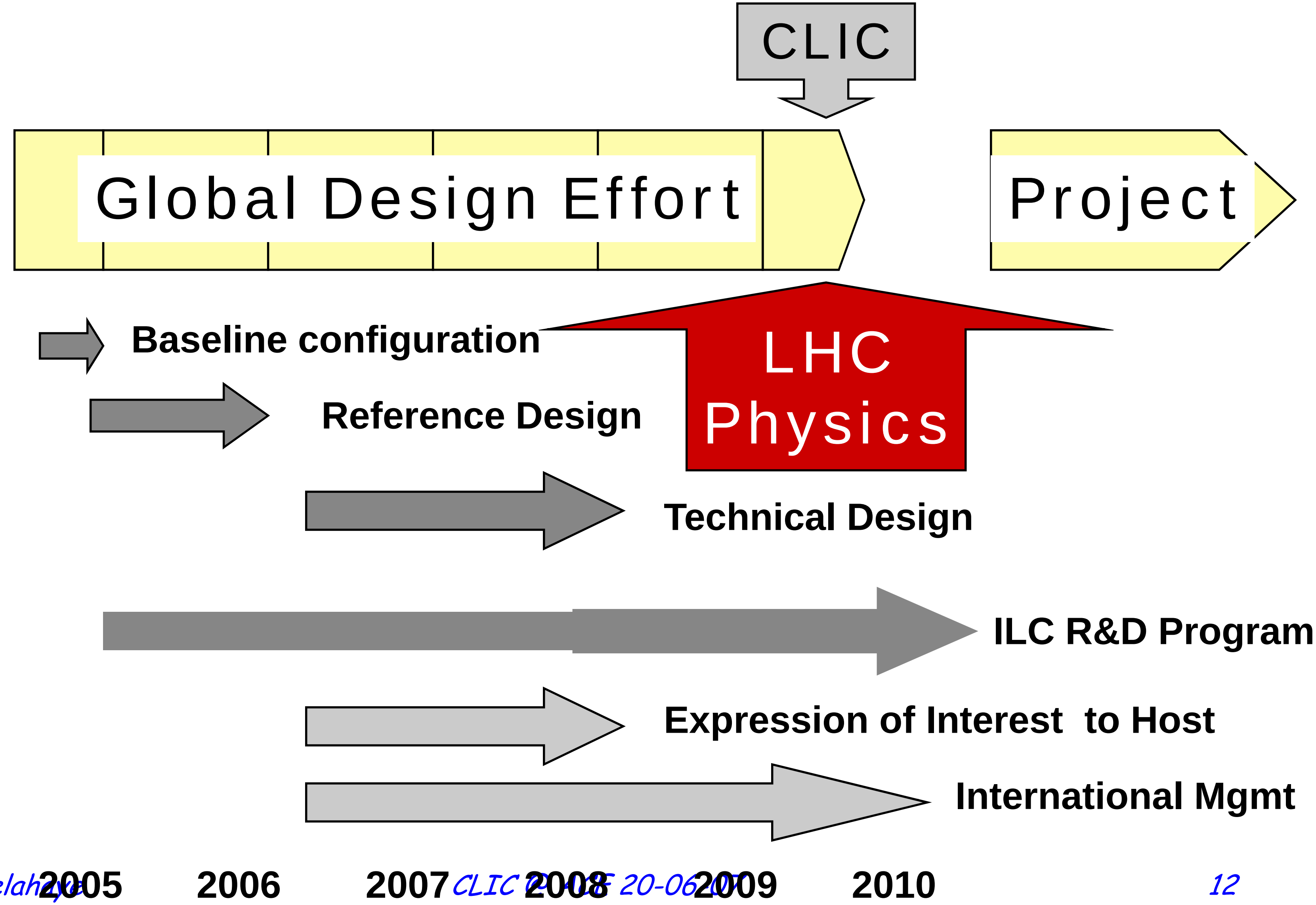
The ILC Plan and Schedule

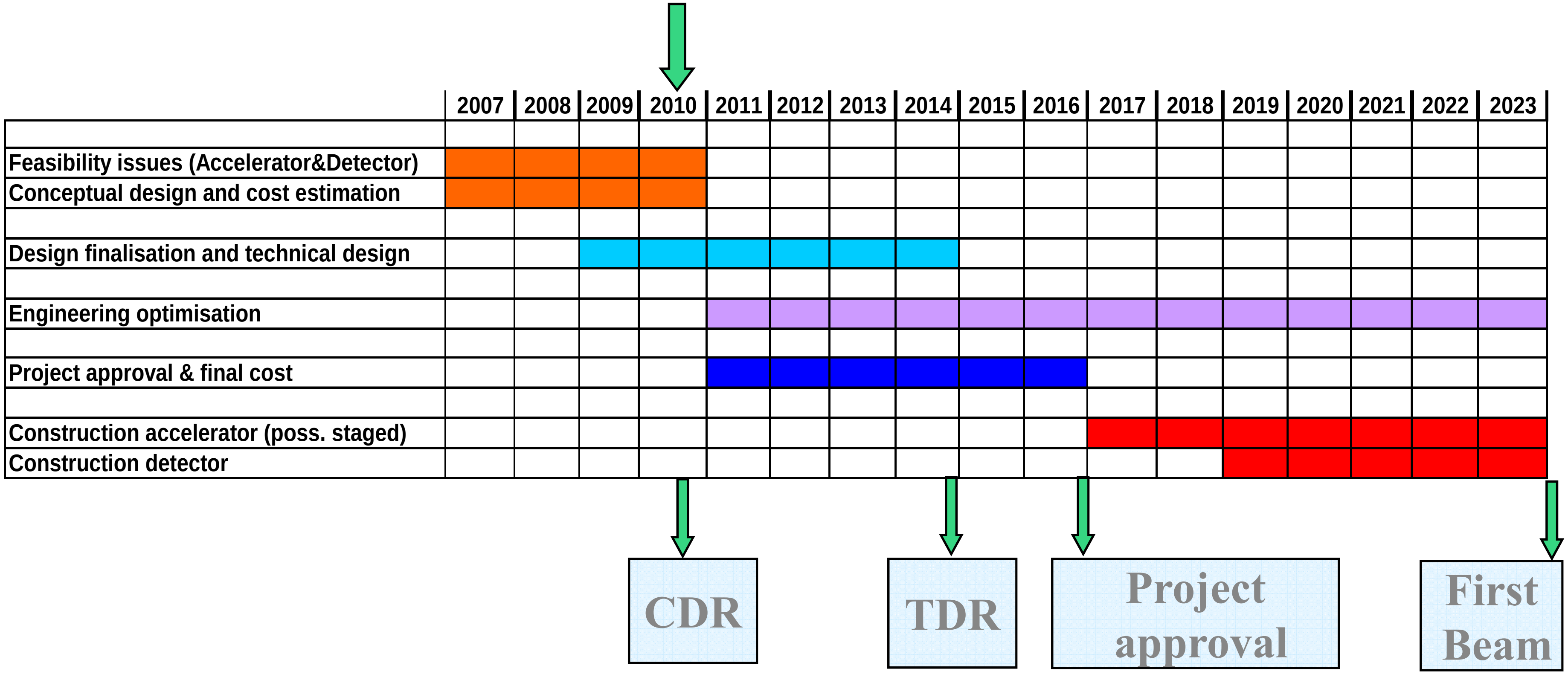
(B.Barish/CERN/SPC 050913)



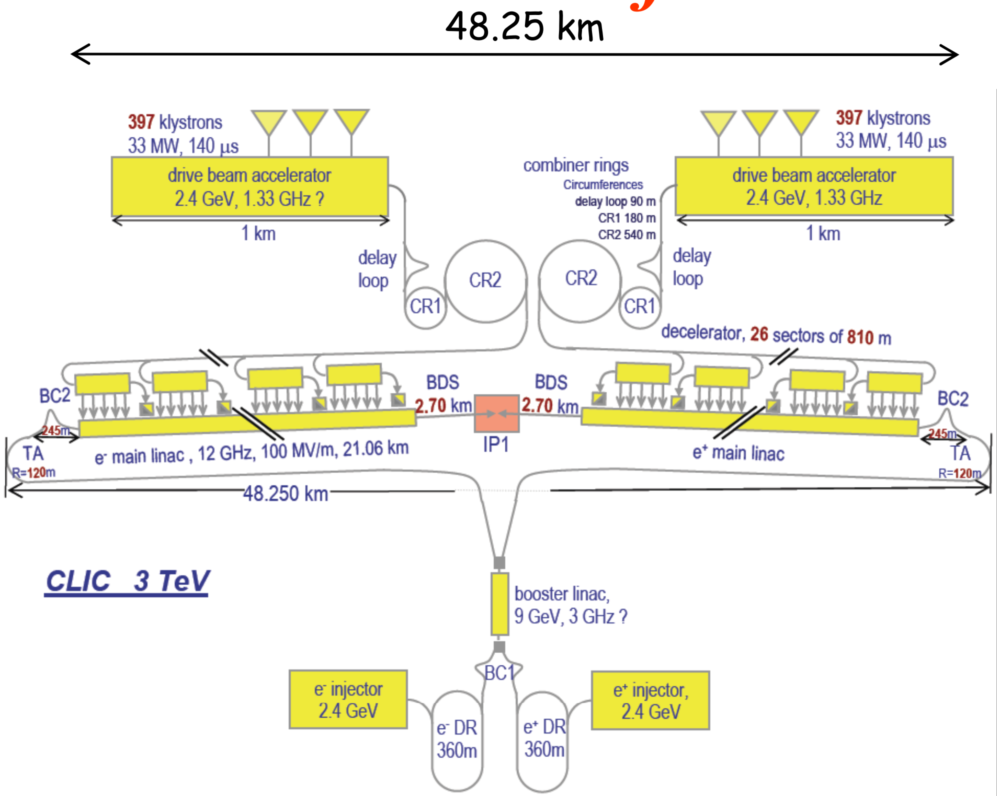
Tentative long-term CLIC scenario

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 technology for Multi-TeV Linear Colliders



Overall layout
Colliding energy of 3 TeV

H.Braun: Wed pm

- High acceleration gradient (100 MV/m)

W.Wuensch: Wed am

- "Compact" collider-overall length≈48 km
  - Normal conducting accelerating structures
  - High acceleration frequency (12 GHz)

- Two-Beam Acceleration Scheme

R.Corsini: Wed pm

  - RF power generation at high frequency
  - Cost-effective & efficient (~ 10% overall)
  - Simple tunnel, no active elements
  - "modular" design, can be built in stages
  - Easily expendable in energy

Long Term Plan (2006-2015)

- **Work program and resources**

http://clic-meeting.web.cern.ch/clic-meeting/2007/CLIC_ACE/201006_CLIC_LTP_2006_15.pdf

Abstract

This report summarizes the Long Term Plan (work and necessary M&P resources) concerning the CLIC study in the period 2006 to 2015. The plan during the first part of the period from 2006 to 2010 is well defined and focuses on the demonstration of the feasibility of the CLIC technology. The plan during the second part of the period from 2010 to 2015 strongly depends on the results of the CLIC feasibility study, the LHC physics results and world-wide decisions on Linear Colliders.

- **Specific program 2007 to 2010**

- Design, optimization of a Linear Collider based on the CLIC technology and estimation of its cost:

H,Braun & R.Corsini: Wed pm

- Demonstrate feasibility of the CLIC technology:

W.Wuensch, A.Grudiev, S.Doebert (Wed am), H.Braun, R.Corsini, G.Geschonke, D.Schulte (Thursday am&pm)

- CLIC Physics study and detector development:
  - A.deRoeck:Thu pm

- Preparation of a Conceptual Design Report to be published in 2010

Key issues (TRC)

1 Tables

Table 6.1 - CLIC Key issues

Category	Related	Nbr	Key issue	addressed	Date
Feasibility	Specific CLIC technology	R.1.1	Test of damped accelerating structure at design gradient and pulse length	CTF3: Power test stand STRUCTURES JRA (FP7)	2005-2010
		R.1.2	Validation of the drive beam generation scheme with a fully loaded linac	CTF3: Source, Linac, delay loop, combiner ring, bunch comp.	2007
		R.1.3	Design and test of a power-extraction structure, with damping and ON/OFF capability	CTF3- CLEX-TBL	2008-2009
Design finalization & machine reliability		R.2.1	Validation of beam stability and losses in the drive beam decelerator, design of a machine protection system	CTF3-CLEX-TBL EURODRIVE JRA (FP7)	2008-2010
		R.2.2	Test of a relevant linac sub-unit with beam	CTF3 – CLEX: Two beam test stand	2008-2010
		R.2.3	Precise synchronization drive beam /main beam for beam energy stability (not TRC identified)	EUROTEV WP5 LED JRA (FP7)	2007 2010
	Multi-TeV operation	R2.4	Multi-beam klystron performances	MBK proto by ILC HEMBA JRA (FP7)	08-12
		R2.5	Coherent radiation effects in CLIC bunch compressors	EUROTEV	
		R.2.5	Design of 3TeV extraction line after collision at IP	EUROTEV Des. St. LED JRA (FP7)	2007 09-12
		R2.6	Long term beam position stability, especially final quad. at nm level for collisions at IP (TRC classified as R3)	LED JRA (FP7)	09-12
Components fabrication cost optimiz. industrialization	Specific technology	R.3.1	Design of the low level RF system		
		R.3.2	Impacts of drive beam operation on main linac reliability, stability and operation		
		R.3.3	Muon and synchrotron radiation induced background tolerable?		
	Multi-TeV operation	R.3.4	Beam beam backgrounds by coherently electron/positron pairs		
		R.3.5	Efficient modulator		

Additional key issues

- Review of CLIC challenges and key issues:
  - R.Corsini (Thursday am)

- Program to address CLIC key issues including list of issues not or (not enough) adressed
  - H.Braun (Thursday pm)

- Specific HW developments:
  - Structures R&D and limitations: W.Wuensch (Wed am)
  - Structures design and optimisation: A.Grudiev (Wed am)
  - Structure tests and performances: S.Doebert (Wed am)

Strategy to address key issues

CLIC

- Key issues common to all Linear Collider studies independently of the chosen technology in close collaboration with:
  - International Linear Collider (ILC) study
  - The Accelerator Test Facility (ATF@KEK)
  - European Laboratories in the frame of the Coordinated Accelerator Research in Europe (CARE) and of a "Design Study" (EUROTeV) funded by EU Framework Programme (FP6)
- Key issues specific to CLIC technology:
  - Focus of the CLIC study
  - All R1 (feasibility) and R2 (design finalisation) key issues addressed in test facilities: CTF@CERN
- Key issues specific to the high collliding beam energy
  - Small beam emittances and dimensions
  - Large beam power (Efficiency)
  - Physics conditions
  - Cost

Luminosity

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

:ey issues: general to all Specifi

CLIC PHYSICS STUDY GROUP

CLIC

(Convener: A.De Roeck: Thursday pm)

From April 2000 - in response to a growing interest in the physics potential of a multi-TeV e+e- collider - a CLIC Physics Study Group has been set-up in order to:

1) Identify and investigate key processes that can help to optimize the machine design:

   luminosity spectrum,
   accelerator induced background,
   beam-beam background

2) Explore the physics program for CLIC and define a concept of the detector

3) Make a comparative assessment of the CLIC physics potential

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

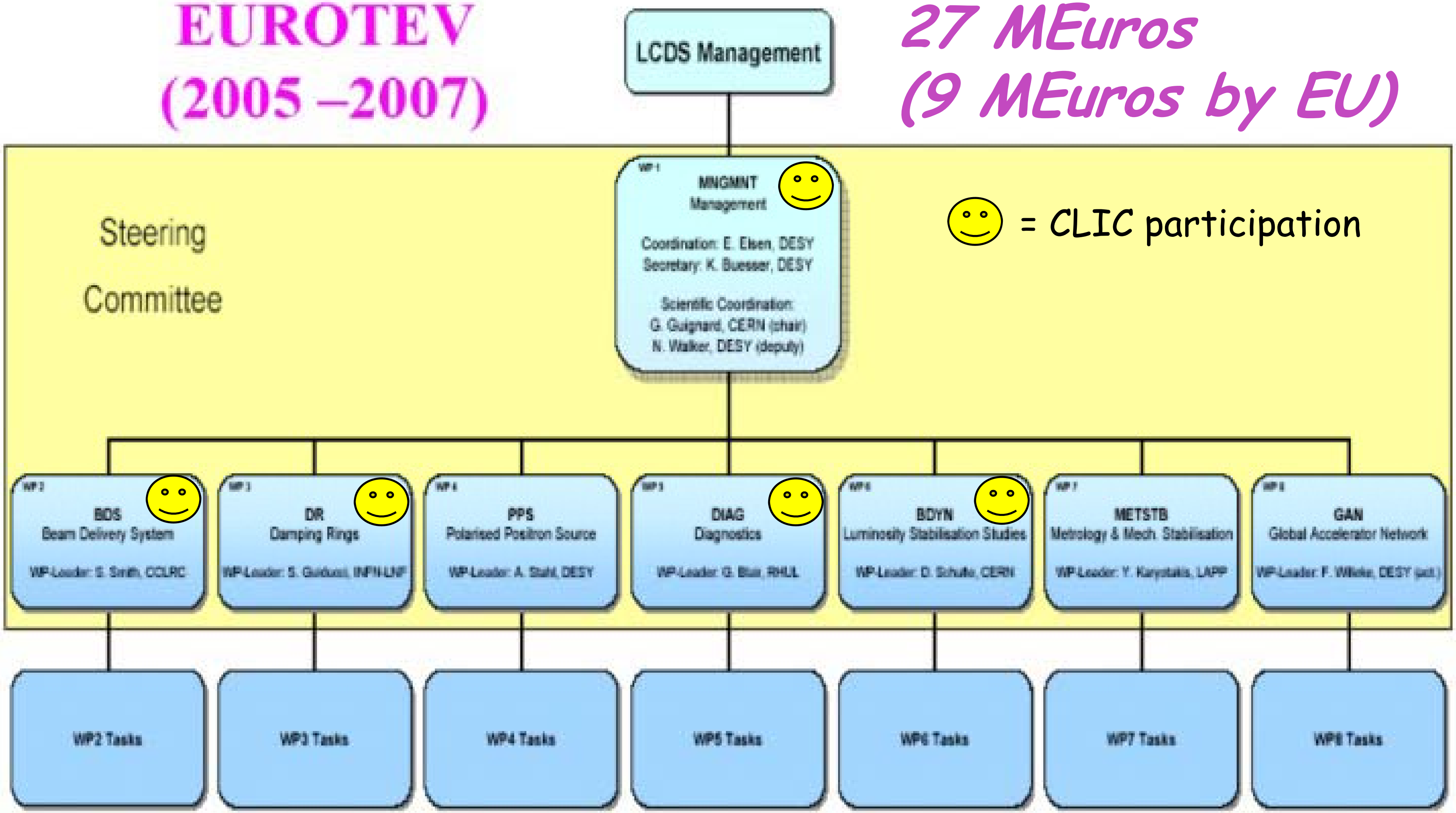
Report summarizing the physics potentials of a facility operating at a centre-of-mass energy from 1 to 5 TeV with luminosities in the order of 10^{35} cm^{-1} sec^{-2}.
"Physics at the CLIC Multi-TeV Linear Collider": CERN-2004-005

Luminosity&Backgrounds: (D.Schulte Thursday pm)

Study of generic key issues common to ILC and CLIC

EUROTEV (2005 –2007)

27 MEuros (9 MEuros by EU)



CLIC Specific Key Issues

CLIC

(as pointed out by ILC-TRC 2003)

Covered by CTF3

R1: Feasibility

- R1.1: Test of damped accelerating structure at design gradient and pulse length
- R1.2: Validation of drive beam generation scheme with fully loaded linac operation
- R1.3: Design and test of damped ON/OFF power extraction structure

R2: Design finalisation

- R2.1: Developments of structures with hard-breaking materials (W, Mo…)
- R2.2: Validation of stability and losses of drive beam decelerator; Design of machine protection system
- R2.3: Test of relevant linac sub-unit with beam

Industrial development

- R2.4: Validation of drive beam 40 MW, 937 MHz Multi-Beam Klystron with long RF pulse

- R2.5: Effects of coherent synchrotron radiation in bunch compressors
- R2.6: Design of an extraction line for 3 TeV c.m.

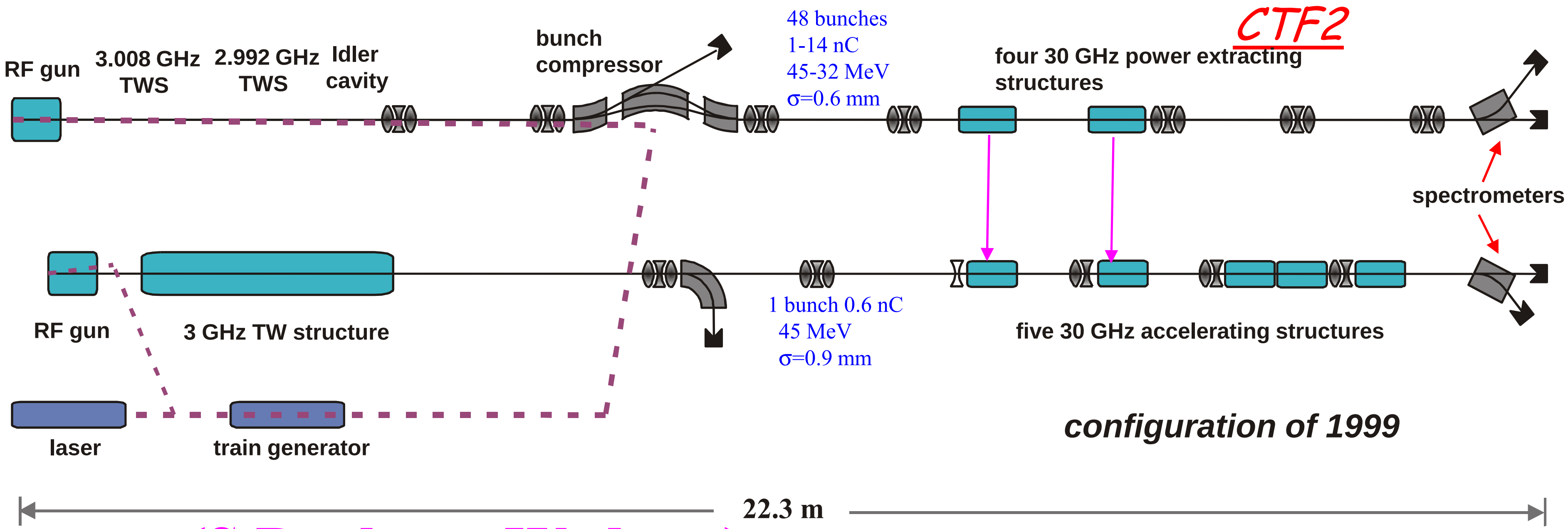
Covered by EUROTeV

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

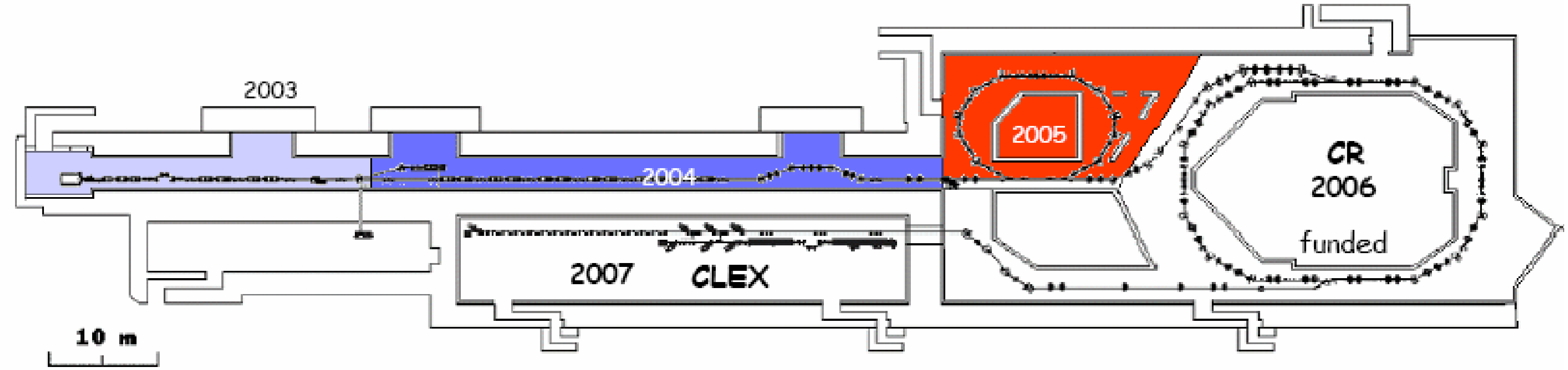
All-but-one of 30 GHz two-beam modules removed in 2000 to create a high-gradient test stand.



(S.Doebert: Wed am)

CTF3 project & schedule

G.Geschonke: Thursday am



SCHEDULE WITH EXTRA RESOURCES	2004	2005	2006	2007	2008	2009
Drive Beam Accelerator	■					
30 GHz power test stand in Drive Beam accelerator	■	■				
30 GHz power testing (4 months per year)		■	■	■	■	■
R1.1 feasibility test of CLIC structure				■		
Delay Loop	■	■				
Combiner Ring	■	■	■			
R1.2 feasibility test of Drive beam generation				■		
CLIC Experimental Area (CLEX)		■	■			
R1.3 feasibility test PETS				■		
Probe Beam			■	■		
R2.2 feasibility test representative CLIC linac section					■	
Test beam line		■	■	■	■	
R2.1 Beam stability bench mark tests					■	■

CTF3 Review (Octobre 2001)

B. Aune (Saclay), H. Henke (T. U. Berlin), R. Siemann (SLAC)

http://ctf3.home.cern.ch/ctf3/CTFindex.htm

Major Findings and Recommendations

- **The CTF3 concept is sound**, and it takes advantage of existing buildings and hardware to realize substantial savings. The project is staged intelligently with three stages that explore the various CTF3 goals with increasing demands on performance.
- **The project is technically demanding**, but there are no insurmountable problems. Resources and schedule look possible but tight. We believe that, because of the technical demands, several years of commissioning and operation will be required after the completion of the installation.
- **CLIC is critically dependent on developing the processes, materials, techniques**, etc. that firmly establish the feasibility of the high acceleration gradient. The RF power from CTF3 will be available for testing major CLIC components, but high power RF experiments need at least one fully dedicated and continuously available test stand. Either a dedicated power source or new collaborations devoted to understanding gradient limits are necessary soon for a timely and systematic exploration of the many issues that must be resolved.

CTF3 budget

		Status March 04		Status Nov 05	
		Budget	Manpower	Budget	Manpower
		MCHF	p-y	MCHF	p-y
TOTAL TO COMPLETION		95.4	393.3	101.1	395.8
CERN	Existing Equipments	40.0		40.0	
	Contrib. 2000-2003	16.0	100.0	16.0	100.0
	Pledged 2004-2009	17.4	150.0	14.9	125.0
	Contingency	0.0	0.0	5.5	25.0
COLLAB	Contrib. 2000-2003	4.8	48.3	4.8	48.3
	Pledged 2004-2009	0.0	0.0	9.4	59.0
Missing		17.2	95.0	10.5	38.5

CTF3 multi-lateral Collaboration
16 members

22 institutes involving 15 funding agencies from 10 countries

MoU with addenda describing specific contribution

Countries	Funding Agencies	Laboratory
CERN	CERN	CERN
FINLAND		Helsinki Inst of Phys (HIP)
FRANCE	CEA/DSM-Saclay	DAPNIA
	CNRS/IN2P3	LAL - LURE
		LAPP
INDIA*	Indian DAE	RRCAT, Indore
ITALY	INFN	LNF
RUSSIA		Budker Inst (BINP)
		IAP
	Dubna	JINR
SPAIN	Ministry of Education & Science (MEC)	CIEMAT, UPC, IFIC
SWEDEN	Swedish Research Council	Uppsala Univ and Svedberg Lab (TSL)
	Wallenberg Foundation	
SWITZERLAND		Paul Scherrer Inst (PSI)
TURKEY		Ankara Univ Group 1 & 2
USA	DOE	Northwestern Univ Illinois (NWU)
		SLAC

* India participating through a special agreement with CERN for the development of novel accelerator technologies

CTF3 collaboration observers

Discussion with possible future collaboration partners:

Countries	Funding Agencies	Laboratory
IRAN		Inst for Theoretical Phys and Math (IPM)
PAKISTAN		National Centre for Physics (NCP)
UNITED-KINGDOM	PPARC	RAL
		J. Adams Institute for Accelerator Science
		Cockroft Institute
UNITED-STATES	DOE	Jefferson Laboratory (JLAB)

Existing and fruitful collaboration with RAL on Laser development for PHIN in EU FP6 CARE

CLIC World wide collaboration

WORLD WIDE CLIC COLLABORATION

Ankara University (Turkey)
Berlin Tech. Univ. (Germany)
BINP (Russia)
CERN
CIEMAT (Spain)
DAPNIA/Saclay (France)
Department of Atomic Energy (India)
Finnish Industry (Finland)
Helsinki Institute of Physics (Finland)
IAP (Russia)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)
JASRI (Japan)
JINR (Russia)
KEK (Japan)
LAL/Orsay (France)
LAPP/ESIA (France)
LLBL/LBL (USA)
North-West. Univ. Illinois (USA)
Polytech. University of Catalonia (Spain)
RAL (England)
SLAC (USA)
Svedberg Laboratory (Sweden)
Uppsala University (Sweden)

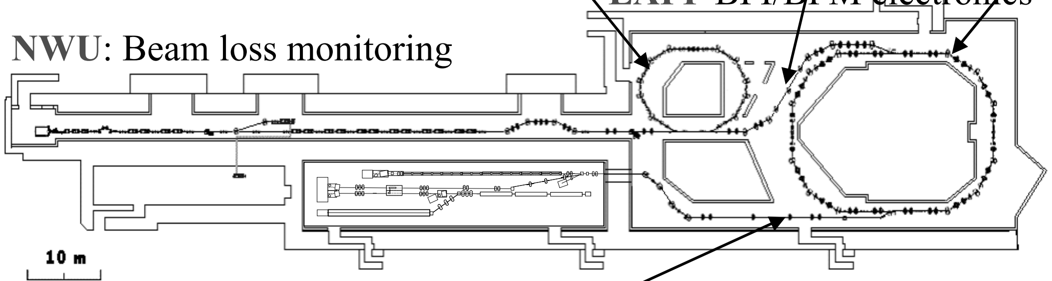
Work packages

INFN Overall responsibility, optics, vac chambers, BPI, RF deflector, installation, commissioning
CERN magnets, BPM, infrastructure, installation

INFN vac chambers, BPI, installation, optics, operation
CIEMAT correctors,
BINP quadrupoles
LURE quadrupoles
CERN magnets, BPM, infrastructure, installation
NWU RF bunch length monitor
LAPP BPI/BPM electronics

INFN vac chambers, BPI, wiggler, installation, optics, RF deflectors
CIEMAT correctors, septa, kicker + pulser
BINP quadrupoles, sextupoles
LURE quadrupoles
CERN Infrastructure, RF power, installation, magnets, Beam diagnostics, vacuum
Uppsala Bunch phase monitor
LAPP BPI/BPM electronics

NWU: Beam loss monitoring

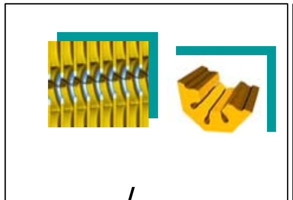


PSI additional modulator

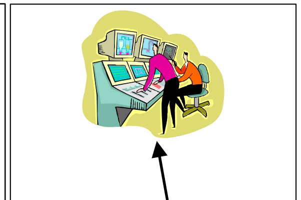
IAP

RRCAT optics, 5 bending magnets, Al vacuum chambers
TSL magnets
CERN Infrastructure, vacuum , magnets, installation

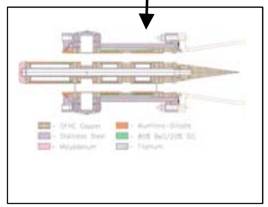
Structures



CTF3 Operation



30 GHz power source



HIP Helsinki
CERN
CIEMAT
SLAC structure testing

Ankara Universities,
INFN,
JINR Dubna automatic conditioning
RRCAT software
CERN

CTF3 objectives

Provide answers for CLIC specific issues by 2009
➔ Write CDR in 2010

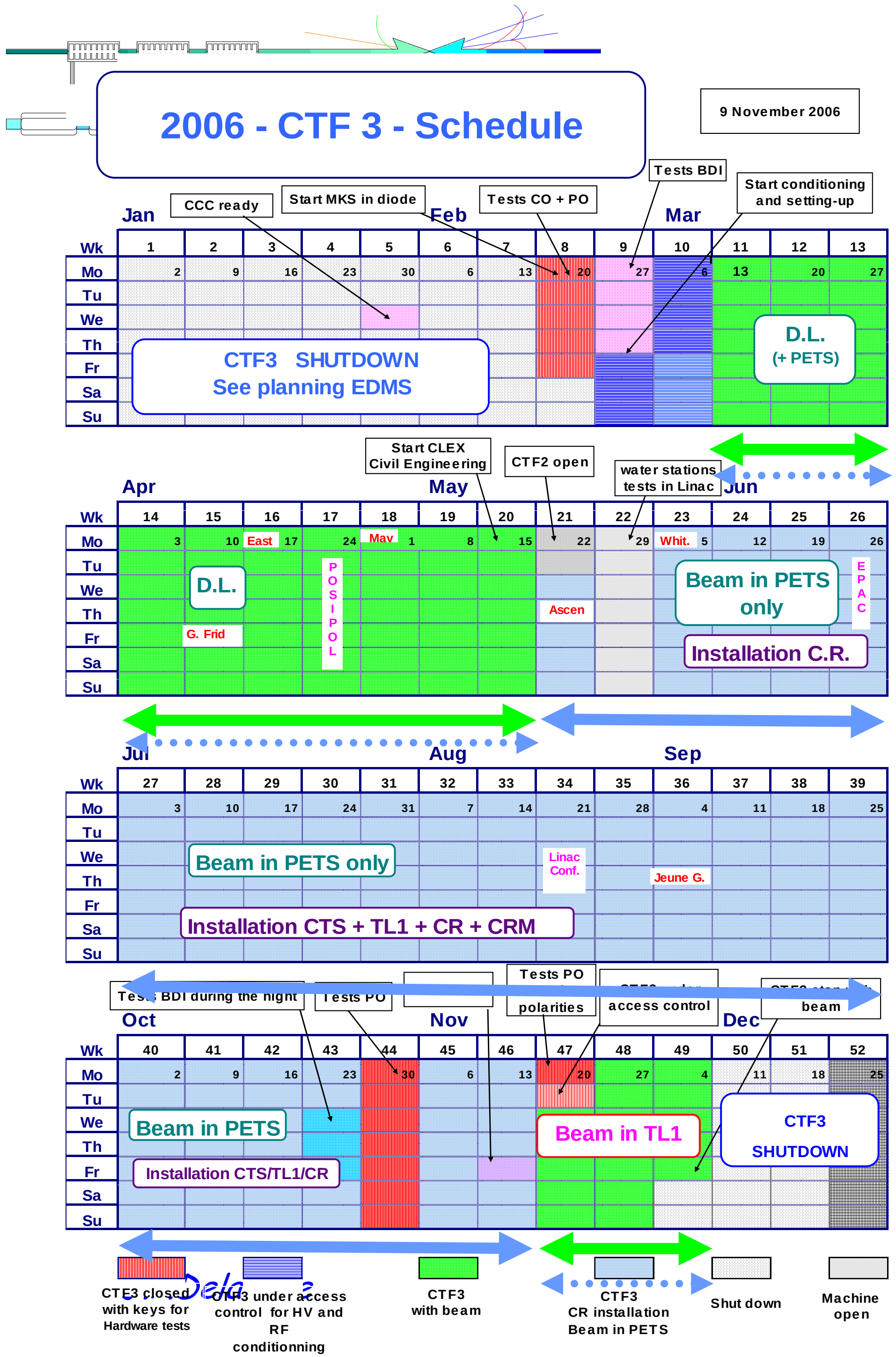
Two main missions:

Build a small-scale version of the CLIC RF power source, in order to demonstrate:
- full beam loading accelerator operation
- electron beam pulse compression & frequency multiplication using RF deflectors

Demonstration of "relevant" linac sub-unit of the Two Beam scheme:
- High frequency power production by drive beam and beam stability
- Test beam acceleration at high frequency

Provide High Frequency RF power for test and validation of CLIC components at nominal power and field (100 MV/m):
- Accelerating structures,
- RF distribution,
- PETS (Power extraction and Transfer Structure)

CTF3 Operation nearly all year !



F.Tecker: Thursday am

1. period:
DL commissioning,
Beam dynamics studies

operation for 30 GHz
at nights and weekends

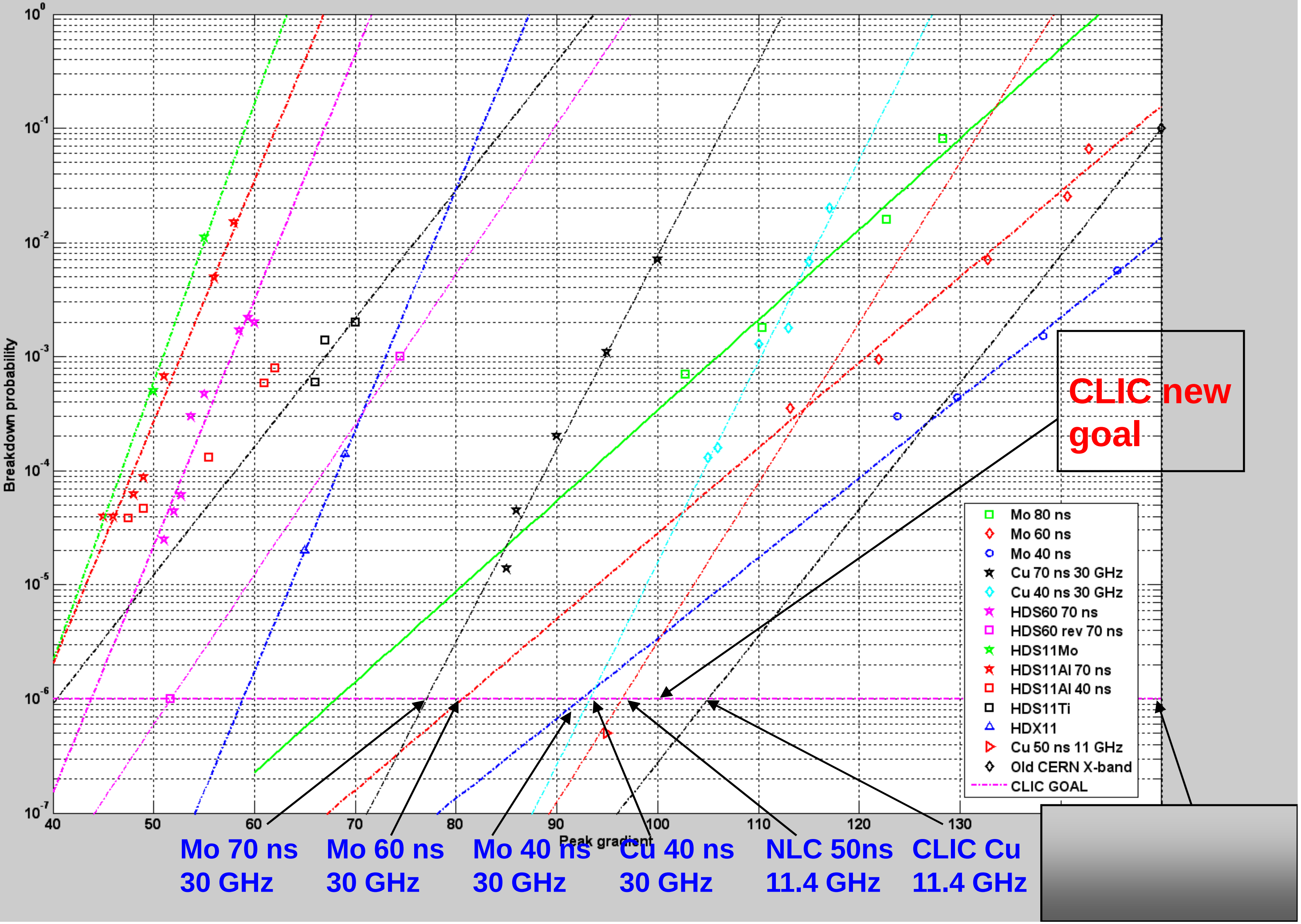
2. period:
operation for 30 GHz power production only,
installation of TL1 and CR

3. period:
Commissioning TL1 and CR injection,

operation for 30 GHz
at nights and weekends

Achieved Accelerating Gradient

S.Doebert: Wed am



CLIC overall optimisation model

(A.Grudiev: Wed am)

Accelerating structure limitations: (W.Wuensch: Wed am)

rf breakdown and pulsed surface heating (rf) constraints:

Beam dynamics constraints: (D.Schulte: Thursday am)

- 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:

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

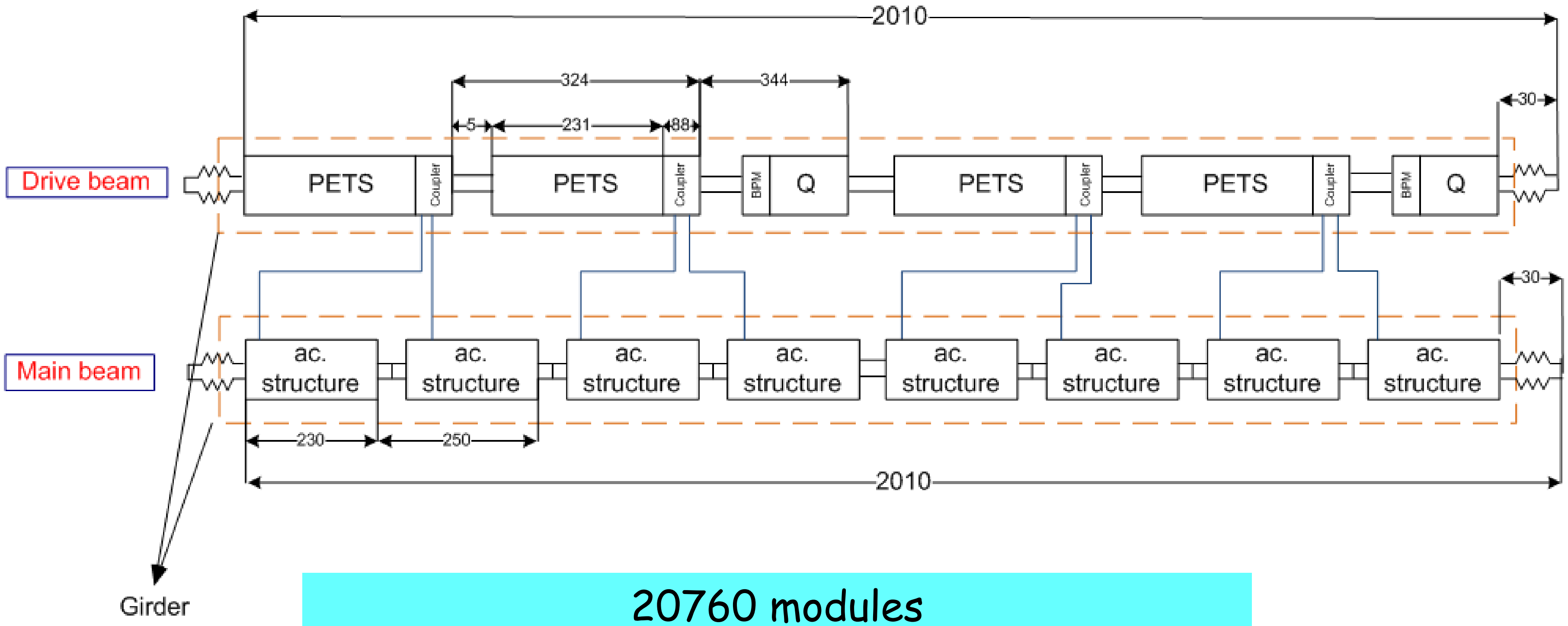
Cost estimation of the overall complex at 3 TeV (invest. & exploit. 10 years) and scaling with Energy

Cost estimation and cost model (H.Braun: Wed pm)

- Towards a Cost Conscious Design

- Work in progress aiming for reliable cost estimate by 2010
- Presently still large imprecision
- Define cost drivers for design guiding
- Cost estimation made in parallel with the ILC cost estimate, by the same persons, the same tools, the same location as for the ILC@CERN for easier comparison of the two technologies
- Parametric model to estimate the influence on cost of the variation parameters
- No absolute value, only arbitrary units

Two Beam Module

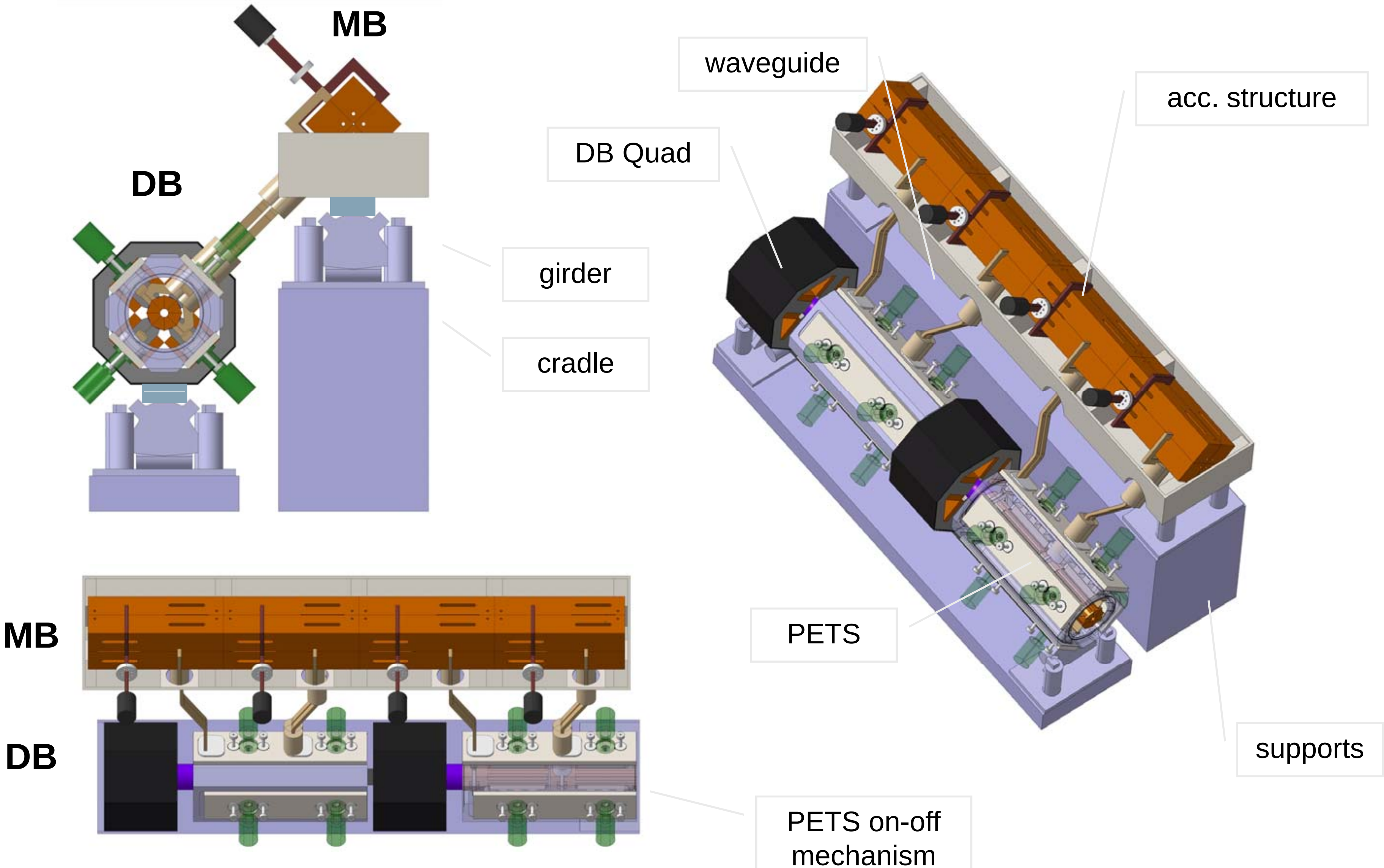


20760 modules

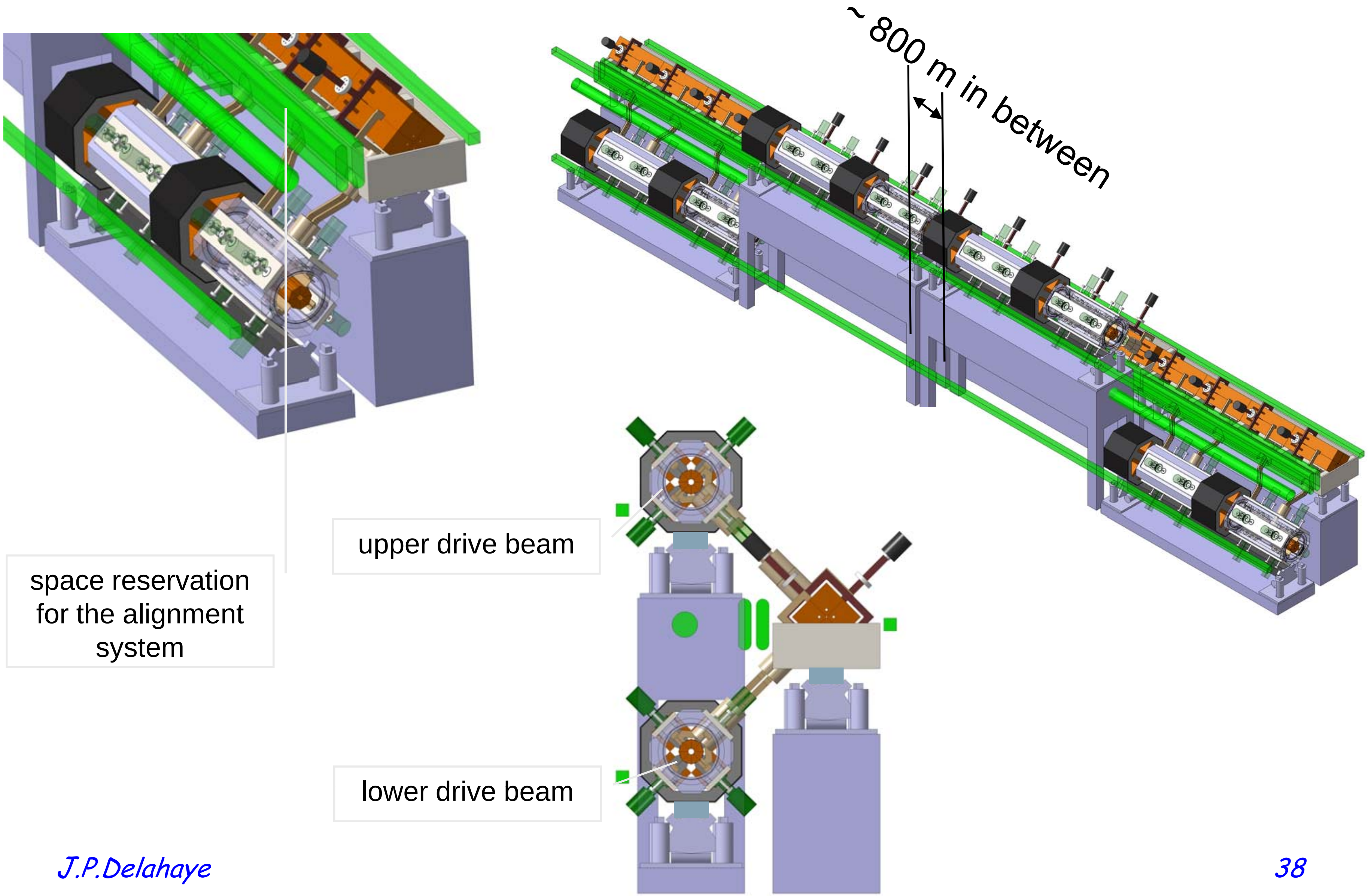
71460 PETS (drive beam)

143010 accelerating structures (main beam)

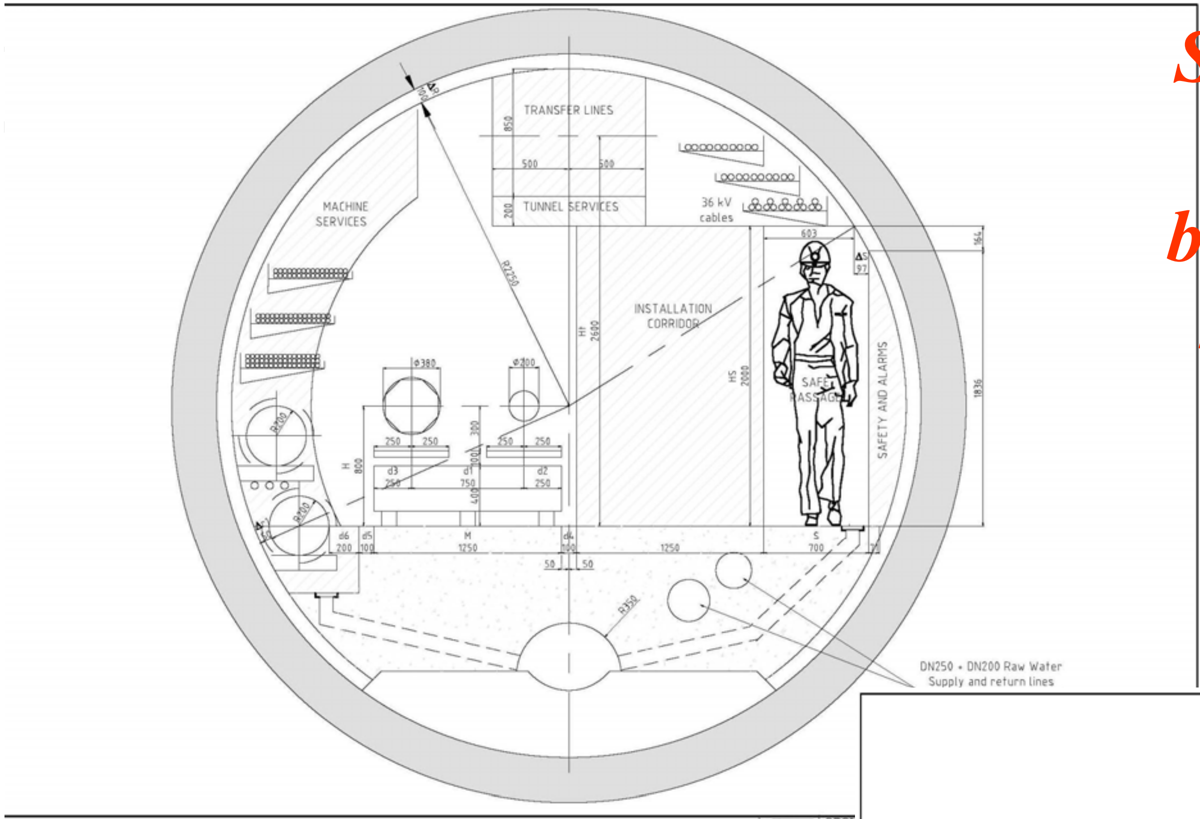
Standard module



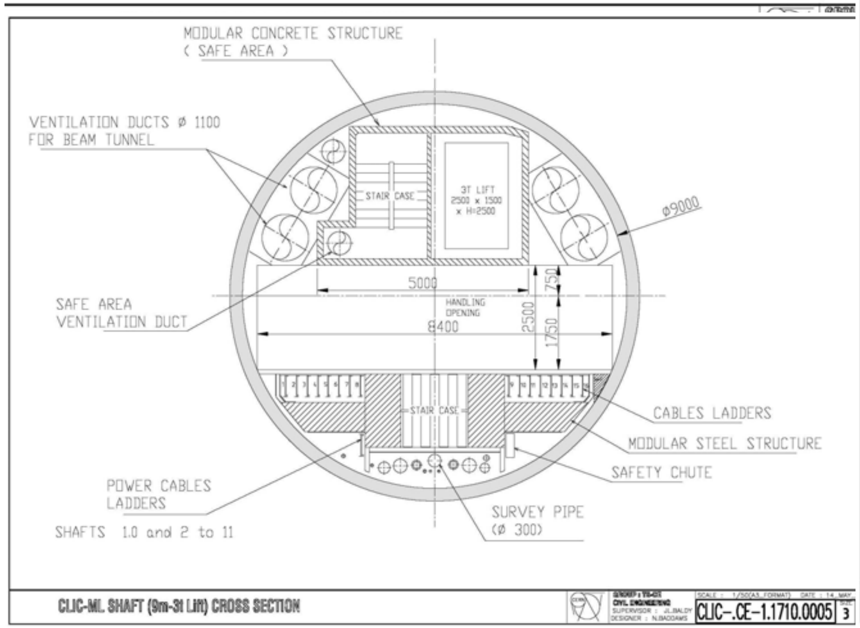
Standard module

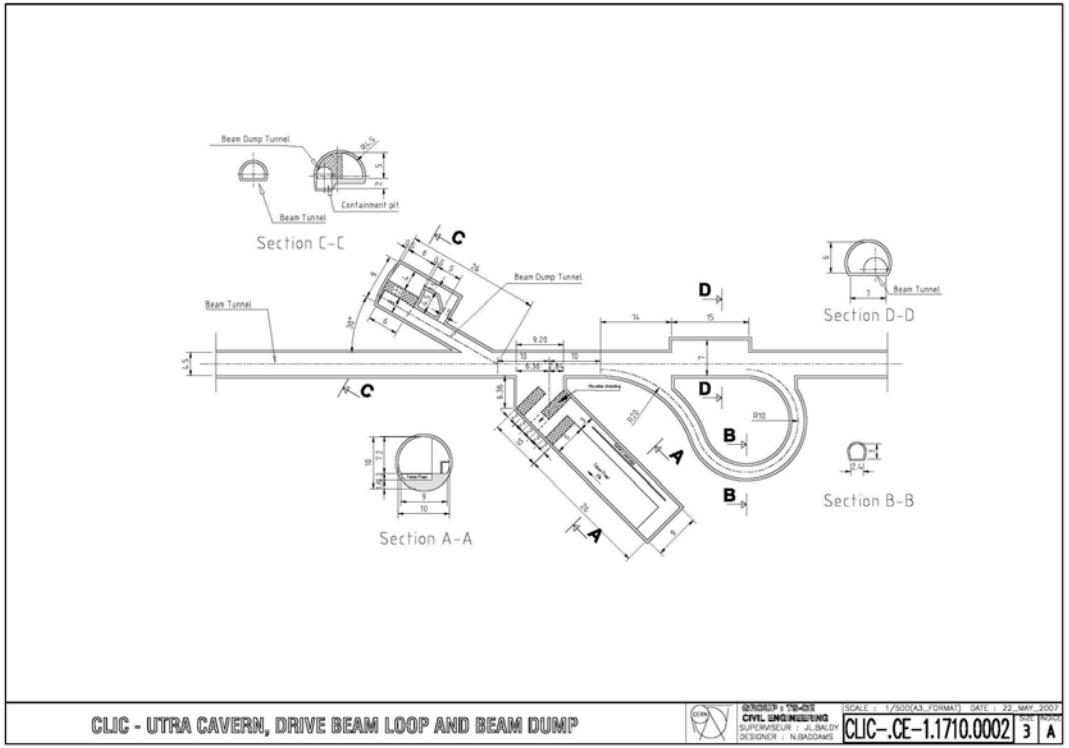


Single CLIC tunnel

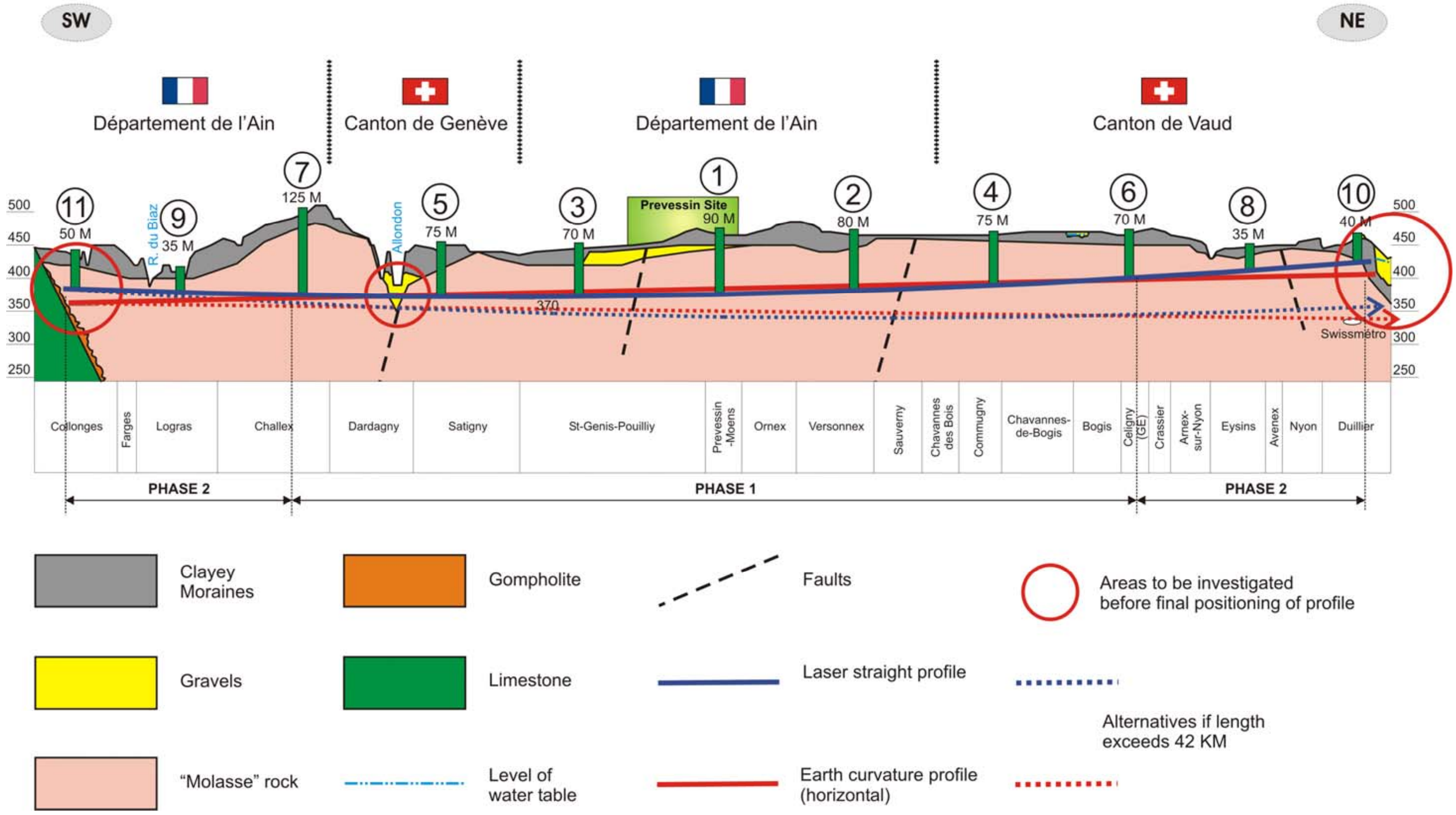


but alcoves for drive beam return loops and dumps





Longitudinal section of a Linear Collider on CERN site–

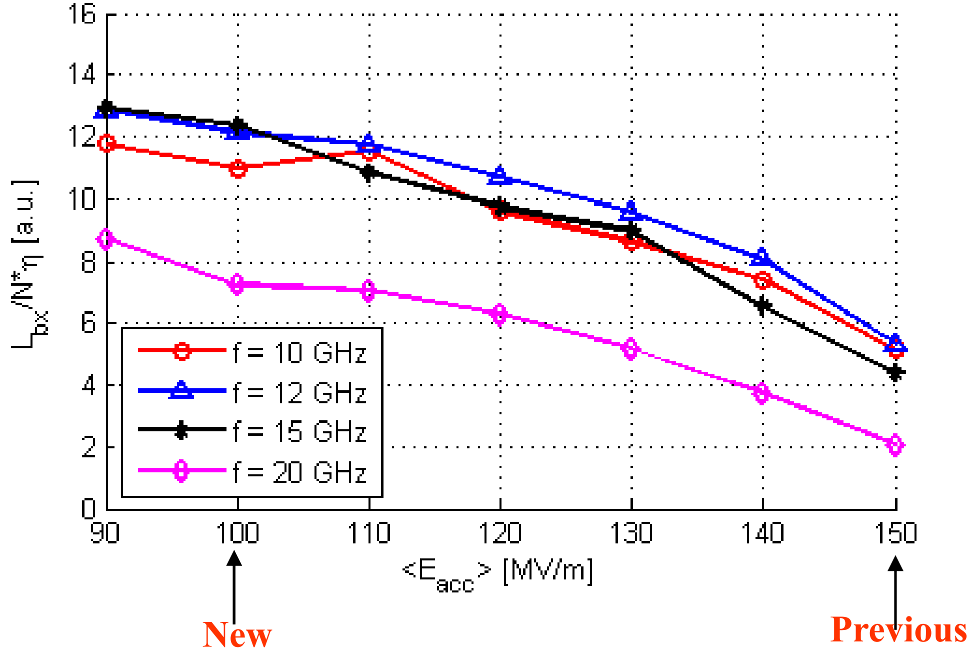


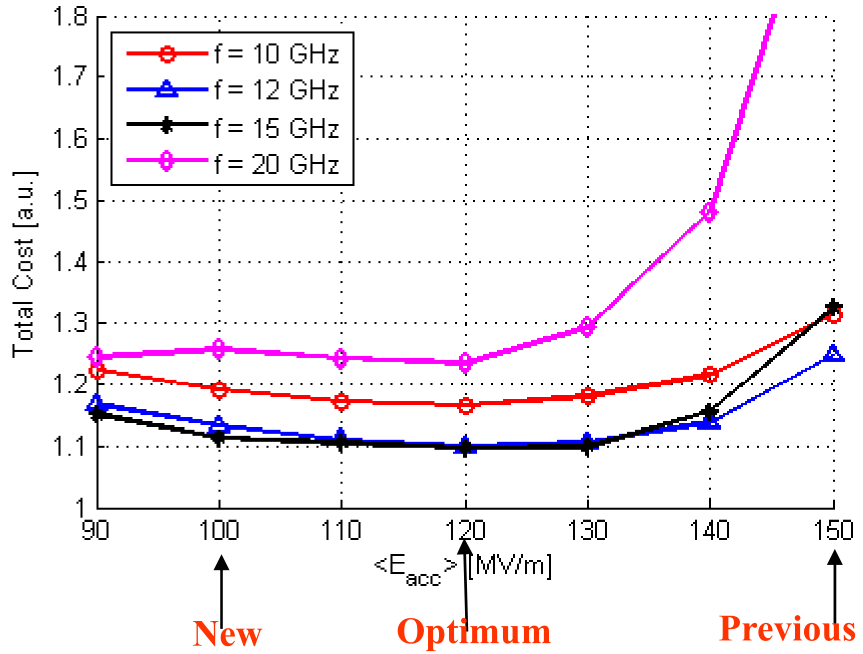
CLIC

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

A.Grudiev: Wed am

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



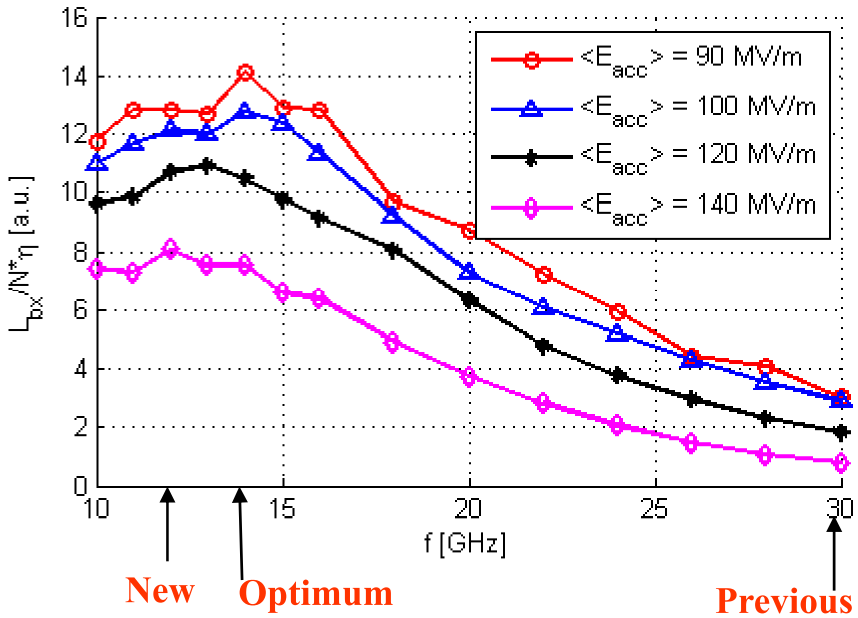


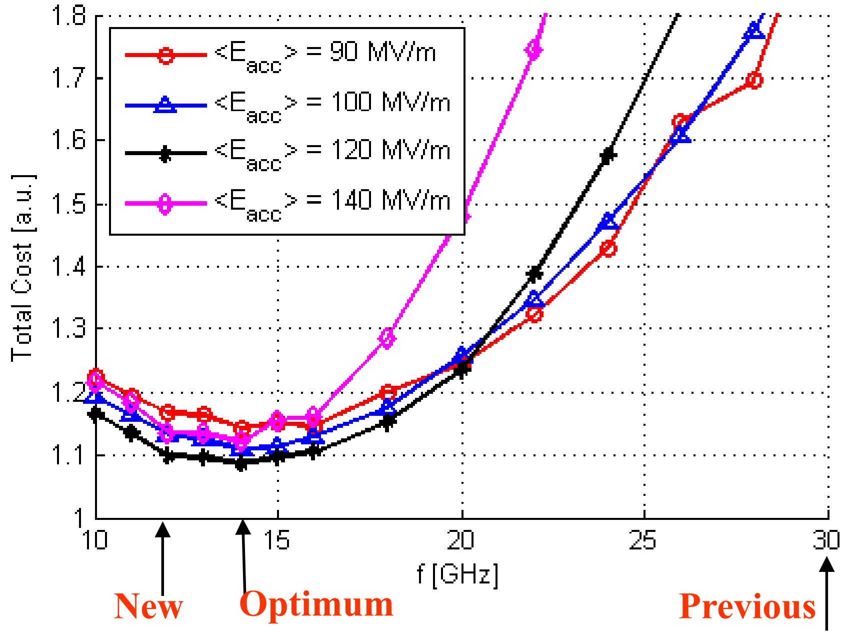
- **Performances increasing with lower accelerating gradient (mainly due to higher efficiency)**
- **Flat cost variation in 100 to 130 MV/m with a minimum around 120 MV/m**

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

A.Grudiev: Wed am

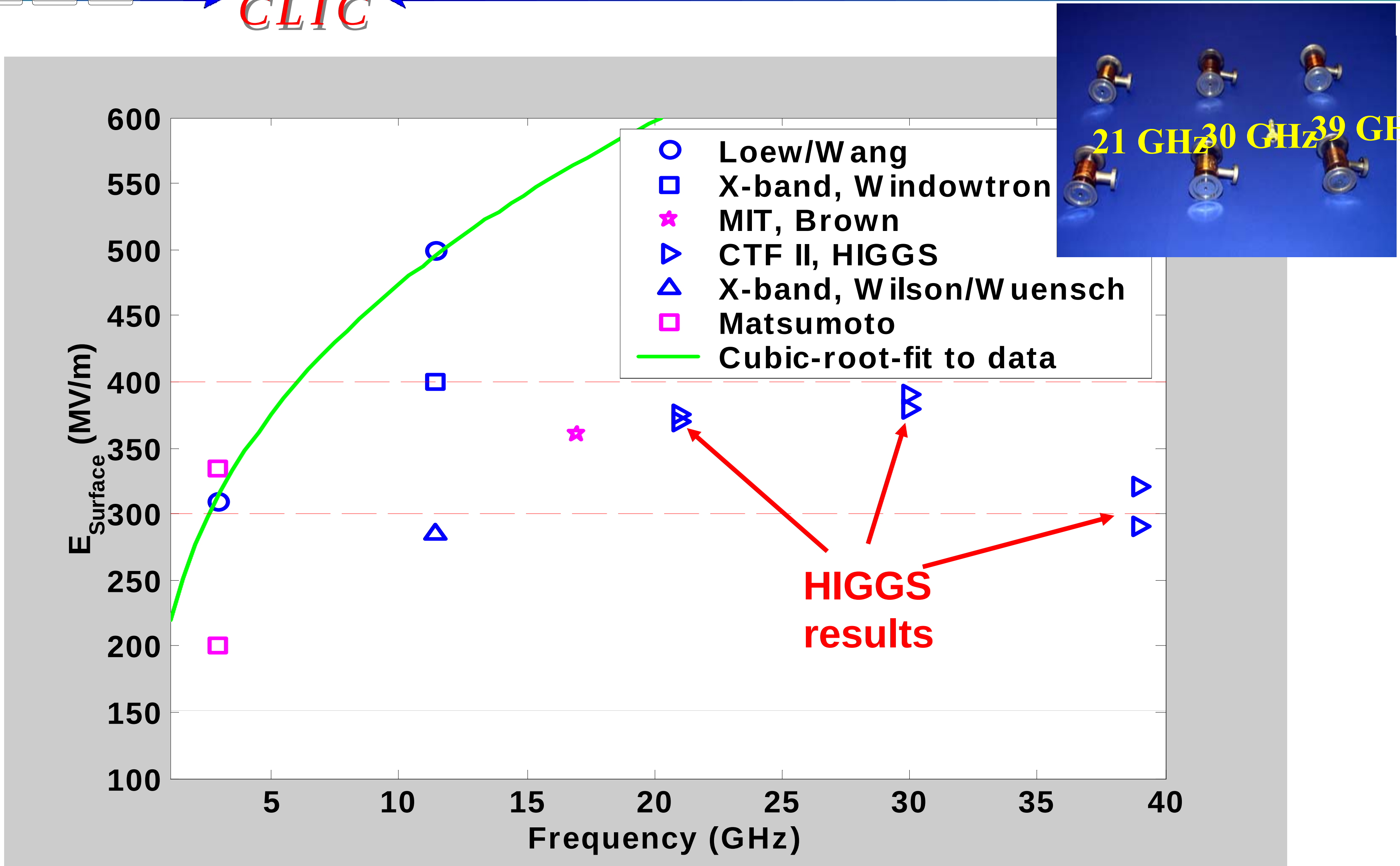
E_{cms} = 3 TeV $L_{(1\%)}$ = 2.0 10^{34} $cm^{-2}s^{-1}$



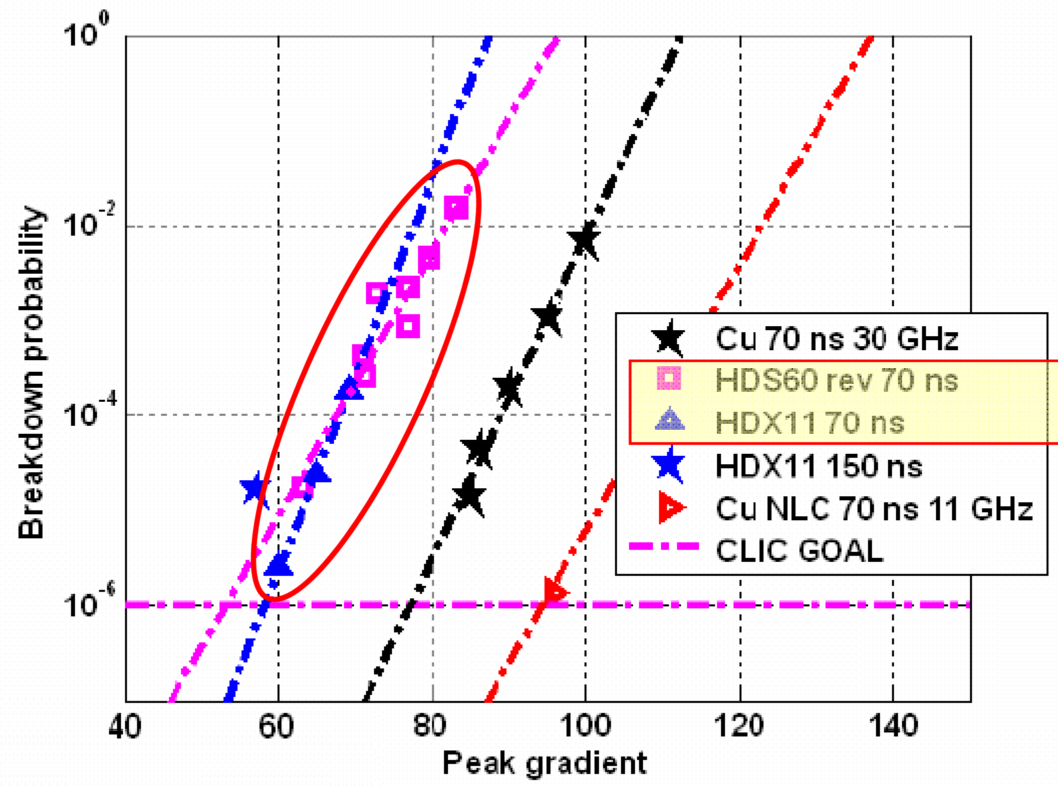


- **Maximum Performance around 14 GHz**
- **Flat cost variation in 10 to 16 GHz frequency range with a minimum around 14 GHz**

FIELD LIMITS ON COPPER SURFACES



Frequency scaling of power constraint



Experimental data at X-band and 30 GHz

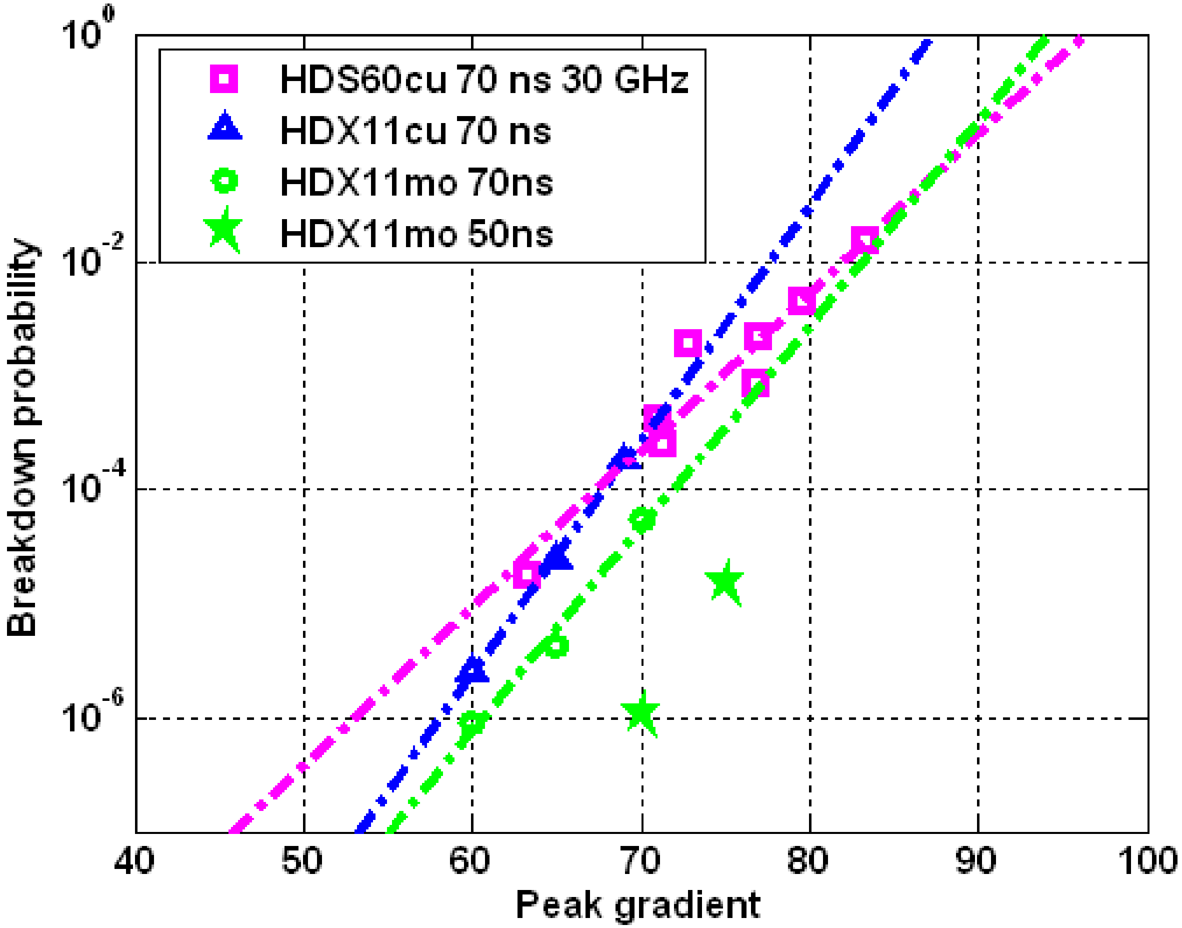
Scaled structures

Scaled structures show the same gradient at X-band and at 30 GHz:

$$E_a t_p^{1/6} = const$$

$$P/C \cdot t_p^{1/3} \cdot f = const$$

Hybrid damped structures (HDX) at x-band
Frequency scaling



Scaled structures show very similar performance

HDS-type structures show consistently limited performance

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
  - Profit from low(er than 30 GHz) frequency for easier fabrication (tolerances, vacuum), relaxed requirements (alignment, timing, etc…),
- RF power generation and frequency multiplication with single stage beam combination in CLIC TBA RF Powers 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)

CLIC

New CLIC Parameters (December 2006)

(H.Braun: Wed pm)

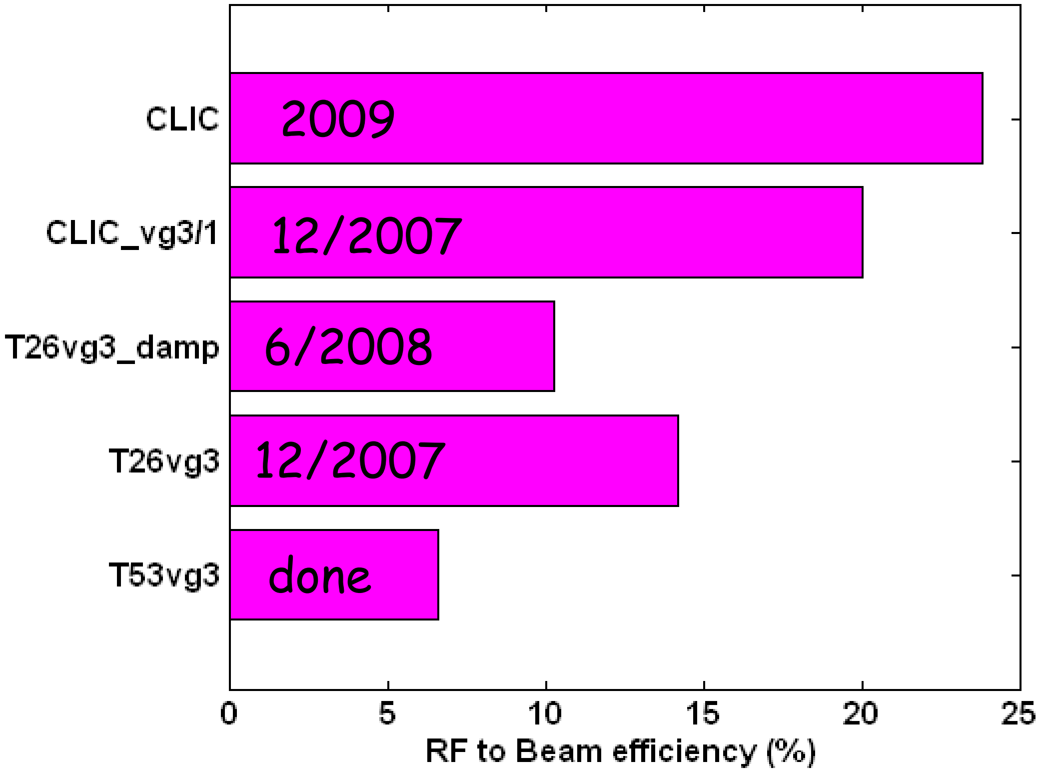
Main Linac RF frequency	**30 GHz ⇒ 12 GHz**
Accelerating field	**150 MV/m ⇒ 100 MV/m**
Overall length @ E_{CMS}= 3 TeV	**33.6 km ⇒ 48.2 km**

- **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.**
- **No strong frequency dependence of achieved accelerating gradients in copper structures for RF > 12 GHz**
- **Realistic feasibility demonstration by 2010**
- **Review in 2010 on optimum gradient and frequency based on experiments**

		Optimum from model	Derived from model	Derived from NLC
		CLIC	CLIC_vg1	T26vg3 damped
Frequency: f [GHz]		12	12	11.424
Average iris radius/wavelength: $<a>/\lambda$		0.12	0.128	0.134
Input/Output iris radii: $a_{1,2}$ [mm]		3.87,2.13	3.87, 2.53	3.89, 3.17
Input/Output iris thickness: $d_{1,2}$ [mm]		2.66, 0.83	2.66, 1.25	1.66
Group velocity: $v_g^{(1,2)}/c$ [%]		2.39, 0.65	2.4, 0.95	2.86, 1.42
N. of cells, structure length: N_c, l [mm]		24, 229	18, 179	30, 265
Bunch separation: N_s [rf cycles]		8	8	8
Number of bunches in a train: N_b		311	359	66
Pulse length, rise time: τ_p		297	295	102
Input power: P_{in} [MW]		65	70	111
Max. surface field: E_{surf}^{max} [MV/m]		298	283	216
Max. temperature rise: ΔT^{max} [K]		56	58	25
Efficiency: η [%]		23.8	20	10.3
Bunch population: N		4.0×10^9	4.0×10^9	4.0×10^9

Efficiency milestones

(S.Doebert: wed am)



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

Future 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

Number of tests (optimistic)

	2007	2008	2009	2010	sum
30 GHz	5	3	0	0	8
12 GHz	0	1	4	4	9
11.4 GHz	2	4	4	4	14
Stand alone at CERN	0	0	8	8	16
sum	7	8	16	16	47

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

- Dear Dr. Jean-Pierre Delahaye

- The KEK X-band group has strong interest to collaborate with CERN as well. The group is small, but active. And as you know, KEK holds an X-band test facility and some klystrons even after the "cool and super" decision of ILC technology. I think your proposal is a great opportunity to the KEK X-band group and our Accelerator Laboratory.

- Two items you suggested in the following are fine.
  - high power test of structures using the available X-band facilities at KEK,
  - design and fabrication of structures by KEK experts.

  I think that both are feasible and the other items would also be possible.

- Anyway, please discuss with Prof. Higo and define the detailed subjects of collaboration. T. Higo will be a contact person for the CERN-KEK collaboration on X-band. Prof. Shigeki Fukuda is now a leader of X-band group at KEK, and his e-mail address is shigeki.fukuda@kek.jp.

- I hope that the discussion with our Director General is successful and fruitful. I am looking forward to hearing good news from you.

- With best wishes,

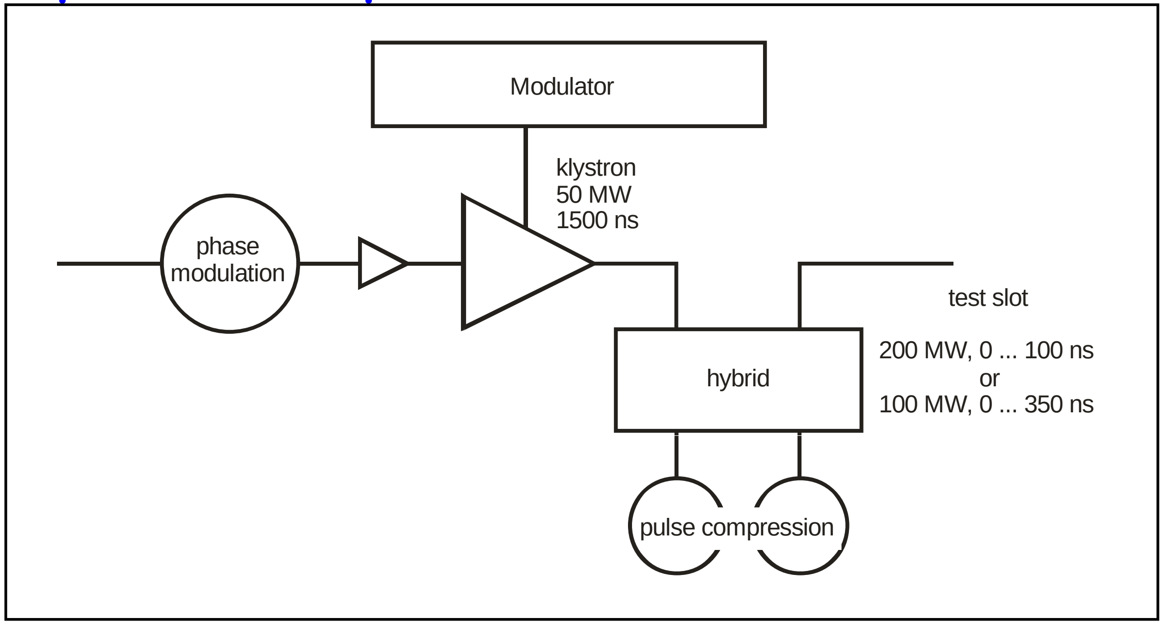
Yukihide Kamiya
ACCL, KEK

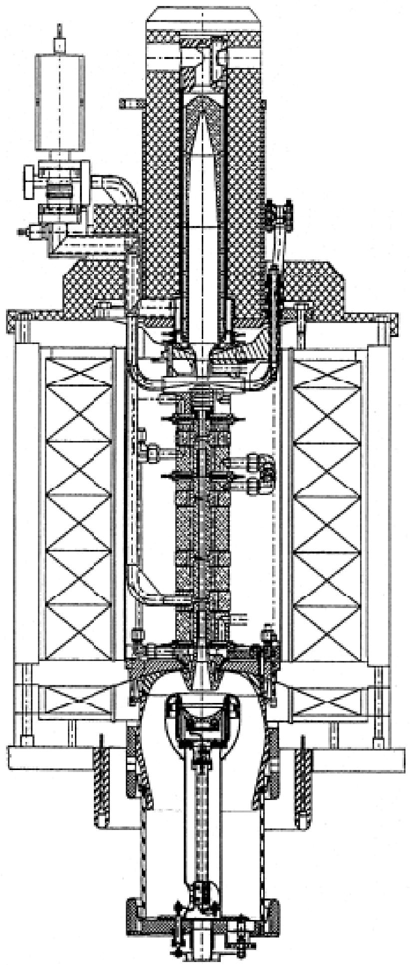
A 12 GHz stand alone power source @ CER

12 GHz power source: common interest with PSI, INFN-Frascati & Trieste

Possible in kind contribution from Switzerland (discussed today at FC)

In parallel with power tests in CLEX





Derived from NLC 11.4 GHz klystron

- Independent 24/7 testing with fast turn around
- Variable pulse length
- High repetition rate
- Easier to operate

CLIC main parameters
(H.Braun: Wed pm)

- At nominal energies of 3 TeV:
  http://clic-meeting.web.cern.ch/clic-meeting/clictable2007.html

- At lower energies and comparison with ILC
  http://clic-meeting.web.cern.ch/clic-meeting/ComparisonTable.html

- Consistent set of parameters resulting from a first iteration based on the accelerating structure defined by optimisation procedure (performance and cost)

- Second iteration necessary based on a best suited structure based on updated beam dynamics constraints

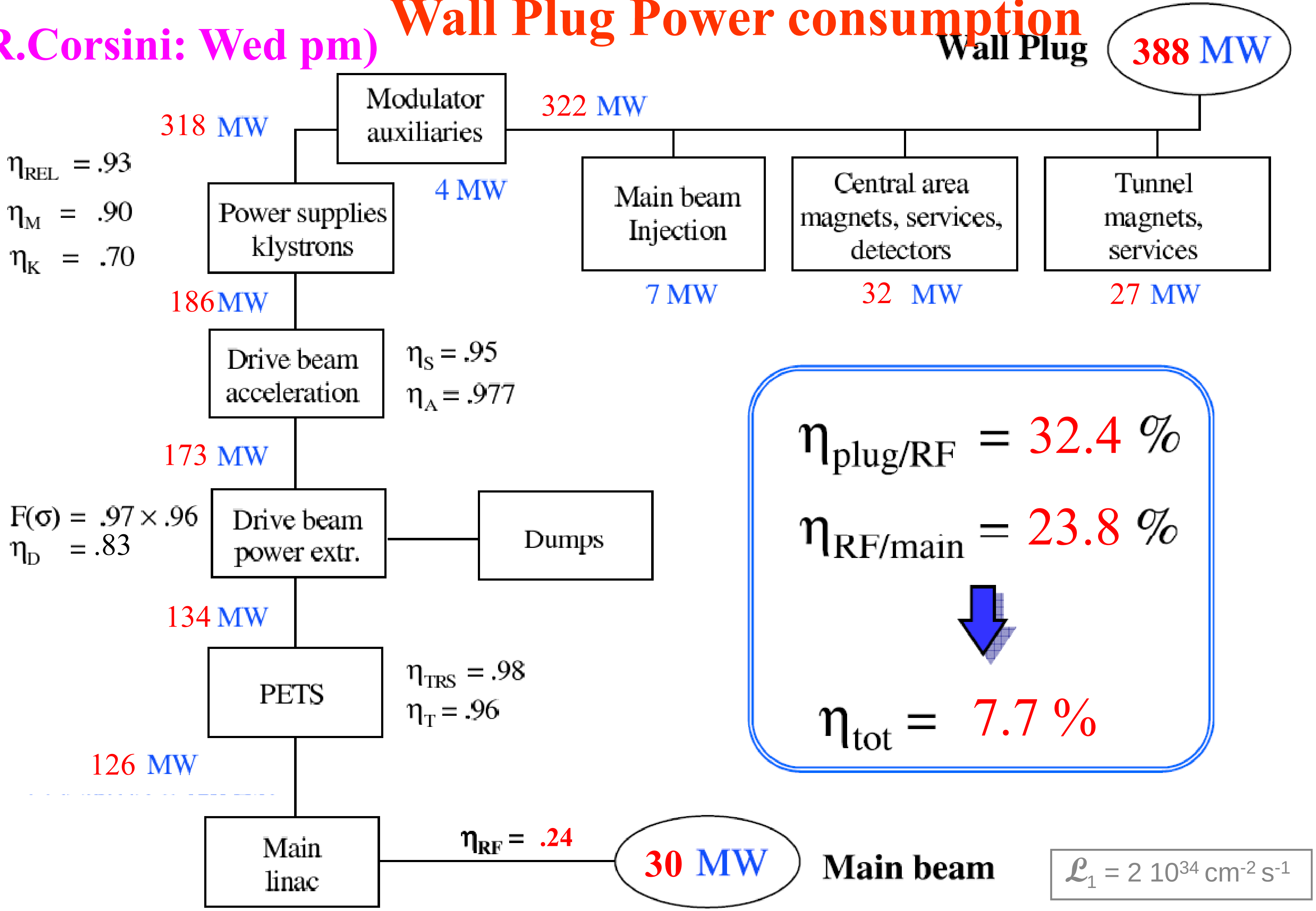
Main CLIC/ILC parameters: First iteration

(H.Braun: Wed pm)

	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**	**7**	**2.7**	**2.1**	**2**	**10^{34} cm^{-2} s^{-1}**
Luminosity (in 1% of energy)	$L_{99\%}$	2	1.5	1.4		10^{34} cm^{-2} s^{-1}
Linac repetition rate	f_{rep}	50	75	100	5	Hz
No. of particles / bunch	N_b	4.0	4.0	4.0	20	10^9
No. of bunches / pulse	k_b	311	311	311	2670	
No. of drive beam sectors / linac	N_{unit}	26	9	5	-	-
Overall two linac length	l_{linac}	41.7	14.4	8.0	22	km
Proposed site length	**l_{tot}**	**48.25**	**20.55**	**14.15**	**31**	**km**
DB Pulse length (total train)	τ_t	139	48	27	-	µs
Beam power / beam	P_b	15	5	5	10.8	MW
Total site AC power	**P_{tot}**	**388**	**~250**	**158**	**230**	**MW**
Nominal horizontal IP beta function	β^*_x	4	20	15	20	mm
Nominal vertical IP beta function	β^*_y	0.09	0.1	0.1	0.4	mm
Horizontal IP beam size before pinch	σ^*_x	53		142	640	nm
Vertical IP beam size before pinch	σ^*_y	1		2	5.7	nm
Beamstrahlung energy loss	δ_B	31	11	7	2.4	%

CLIC Power Flow and Wall Plug Power consumption

(R.Corsini: Wed pm)



CERN overall resources

		2008	2009	2010	Total
Material budget (kCHF)	Present MTP	3485	3485	3485	10455
	Additional LTP (CLIC-PLO/06-17 and White Paper)	4000	4000	4000	12000
	12 GHz power test stand and structure tests	1050	1850	600	3500
	Total additional (to present MTP plans) resources	5050	5850	4600	15500
	Total needed resources (to be included in future MTP)	8535	9335	8085	25955
Man-Power (FTE)	Present MTP	30.5	28	26.5	85
	Additional LTP (CLIC-PLO/06-17 and White Paper)	20	20	20	60
	12 GHz power test stand and structure tests	3	3	3	9
	Total additional (to present MTP plans) resources	23	23	23	69
	Total needed resources (to be included in future MTP)	53.5	51	49.5	154

Conclusion

- CLIC team fully committed to optimise a Multi-TeV Linear Collider based on CLIC technology and demonstrate its feasibility reported in a Conceptual Design Report by 2010

- First iteration completed of a consistent set of new parameters based on optimum structure following a performance and cost model and adapted to new gradient and RF frequency
  - Further iteration needed after revisiting optimum structure

- Major issues well identified and R&D program to address them well defined mainly in the CTF3 facility
  - Other key issues (stability, phasing) to be addressed in the frame of EU FP7

Conclusion

- **CTF3 installation and commissioning on schedule thanks to fruitful collaboration of 22 volunteer institutes**
  - Promising performances
  - Buth heavy coordination due to (too) small work packages
  - Heavy to operate (10months/year as RF power source for tests of structure tests
- **Structures with accelerating gradient of 100 MV/m at low breakdown rates already) demonstrated but at low efficiency and not fully equipped**
  - 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
  - Takes advantage of the RF High Power facilities available at X band at SLAC and KEK
- **Path for full demonstrated well defined but schedule very tight**
  - Strongly relies on tests at SLAC and KEK
  - 12 Ghz RF test stand @ CERN mandatory