CERN, 16-18 October 2007

Program Advisory Committee

- M. Besançon
- G. Blair
- M. Calvetti
- S. Chattopadhyay
- T. Ekelof
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- H.H. Braun (Chair)
- R. Corsini
- J-P. Delahaye
- J. Ellis
- S. Escaffre
- G. Geschonke
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- W.D. Schlatter
- D. Schulte
- W. Wuensch

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

CLIC Workshop 07

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

Welcome

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
- Spain: CIEMAT-IFIC-UPC
- Sweden: Uppsala Univ.
- 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

CLIC07 workshop (Chairman: H.Braun)

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Outline

- **Linear Colliders in the HEP world-wide landscape**
- **The Compact Linear Collider (CLIC) concept**
- **Design and new parameters recently adopted**
- **Main challenges and strategy 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 15 years 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 support for R&D addressing by 2010 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.*

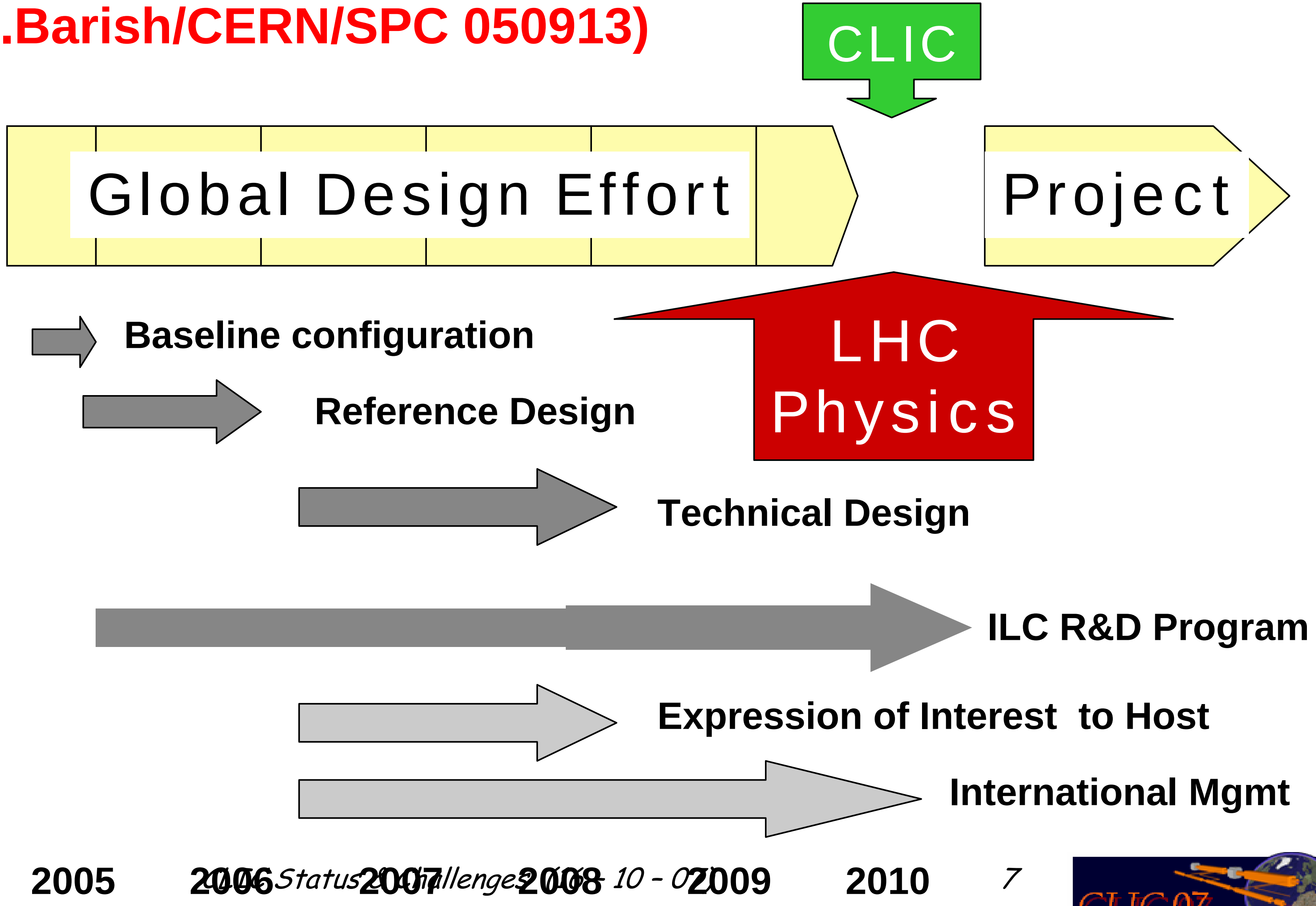
7. A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; *Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest.*

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.*

The ILC Plan and Schedule

(B.Barish/CERN/SPC 050913)



CLIC

Global Design Effort

Project

LHC Physics

Baseline configuration

Reference Design

Technical Design

ILC R&D Program

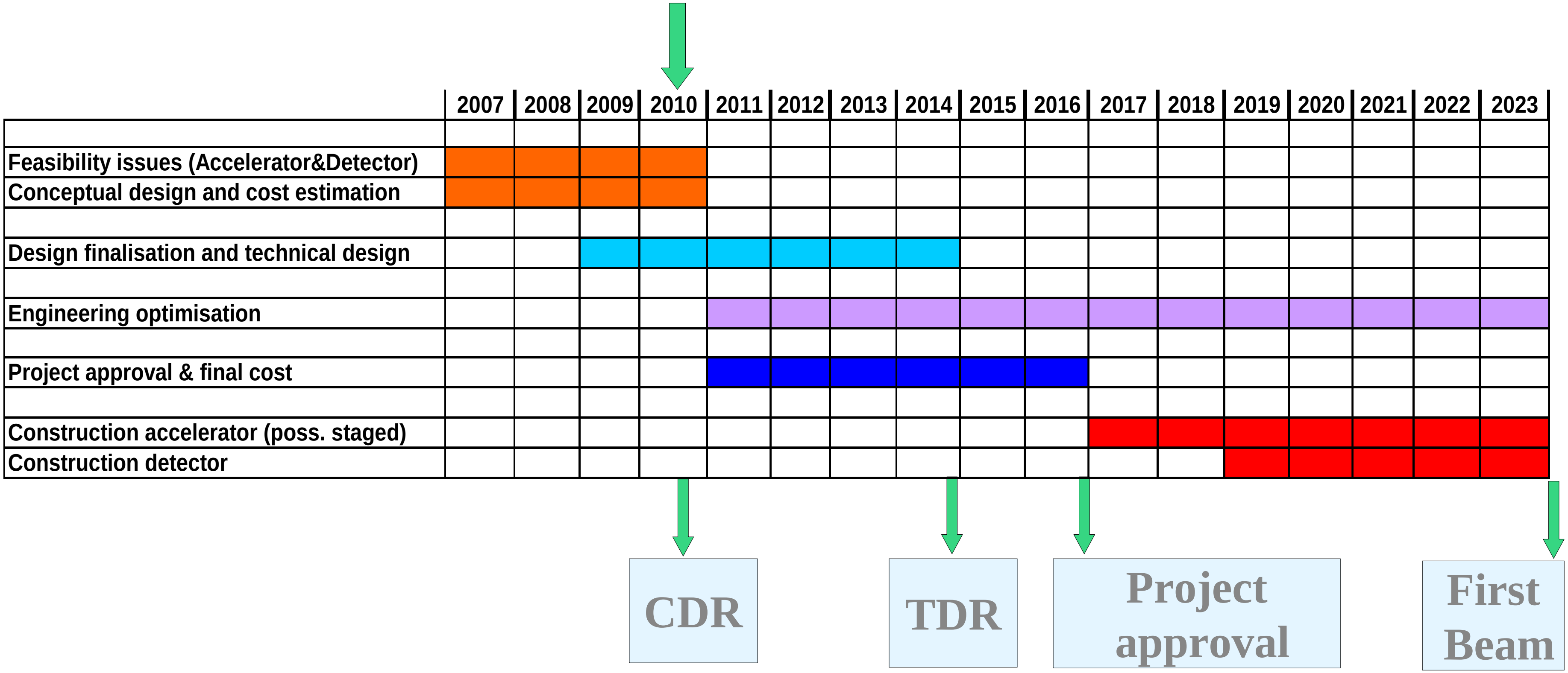
Expression of Interest to Host

International Mgmt

2005 **2006** **2007** **2008** **2009** **2010**

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



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Feasibility issues (Accelerator&Detector)	🟧	🟧	🟧	🟧													
Conceptual design and cost estimation	🟧	🟧	🟧	🟧													
Design finalisation and technical design			🟦	🟦	🟦	🟦	🟦	🟦									
Engineering optimisation					🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
Project approval & final cost					🟦	🟦	🟦	🟦	🟦	🟦							
Construction accelerator (poss. staged)											🟥	🟥	🟥	🟥	🟥	🟥	🟥
Construction detector													🟥	🟥	🟥	🟥	🟥

CDR

TDR

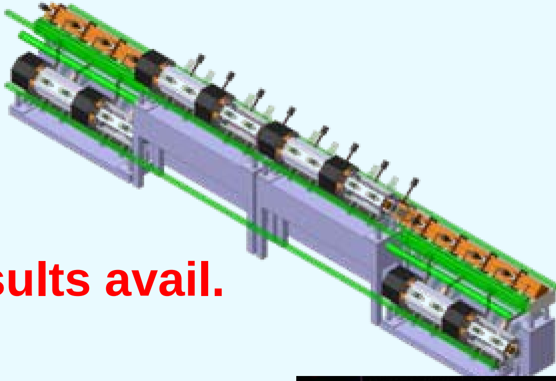
Project approval

First Beam

THE COMPACT LINEAR COLLIDER (CLIC) STUDY

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

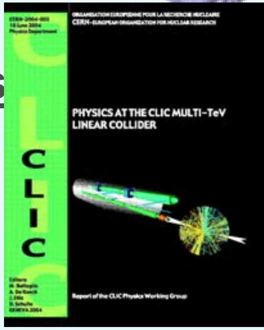
Site independent feasibility study aiming at the development of a realistic technology to extend e-/e+ linear colliders into the Multi-TeV energy range:



- ✓ 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



PHYSICS AT THE CLIC MULTI-TeV LINEAR COLLIDER

CLIC

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 major activities and milestones

- Demonstrate feasibility of CLIC technology
- Design of a linear Collider based on CLIC technology

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

  CERN 2000-008 (3 TeV) - CERN 2003-007 (500 GeV)
- 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

J.Ellis **(Physics case)**	**D.Schulte** **(Integ.&Backgrounds)**	**A de Roeck** **(Exp issues & Det.)**	**H.Videau** **ILC detectors**

- Conceptual Design Report to be published in 2010

CLIC/CTF3 Multi-Lateral Collaboration of Volunteer Institutes Organized as a Physics Detector Collaboration

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

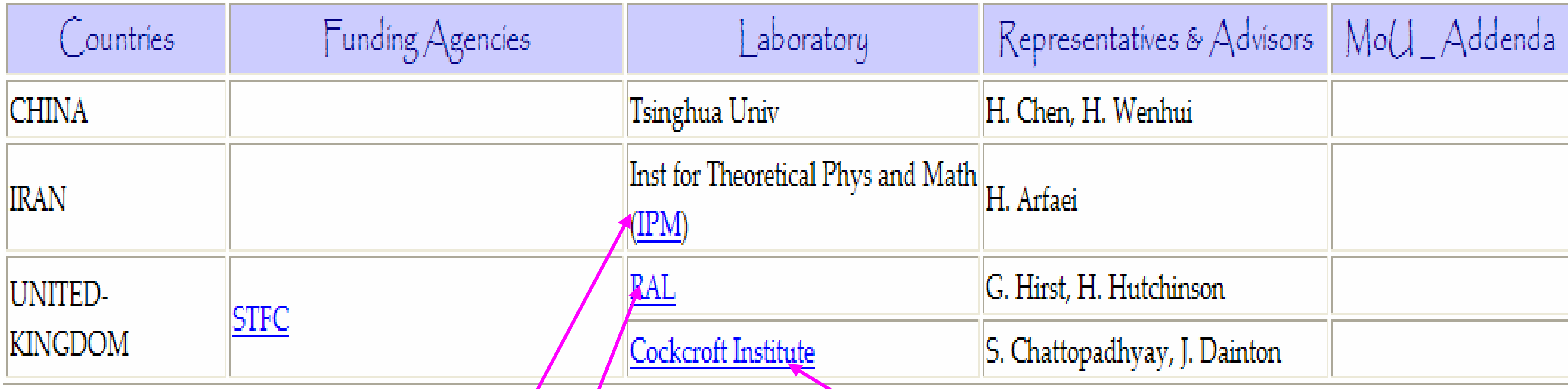
Collab. Board: Chairperson: M.Calvetti/INFN; Spokesperson: G.Geschonke/CERN

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:



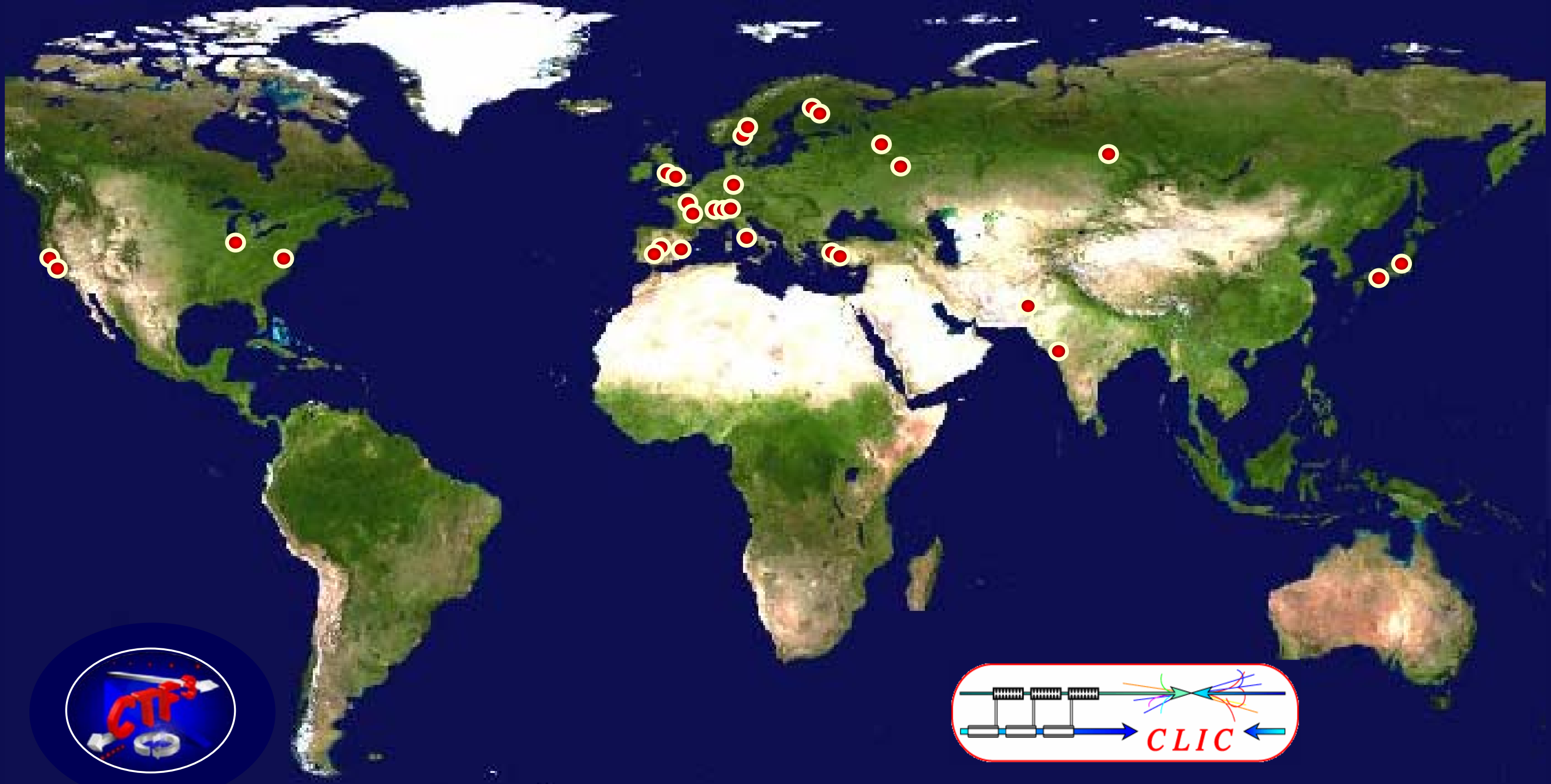
Countries	Funding Agencies	Laboratory	Representatives & Advisors	MoU_Addenda
CHINA		Tsinghua Univ	H. Chen, H. Wenhui	
IRAN		Inst for Theoretical Phys and Math (IPM)	H. Arfaei	
UNITED-KINGDOM	STFC	RAL	G. Hirst, H. Hutchinson	
		Cockcroft Institute	S. Chattopadhyay, J. Dainton	

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)

Linear Collider major parameters and challenges

- **Energy reach**

$$E_{cm} = 2\,F_{fill}\,L_{linac}\,G_{RF}$$

High accelerating gradient

- **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

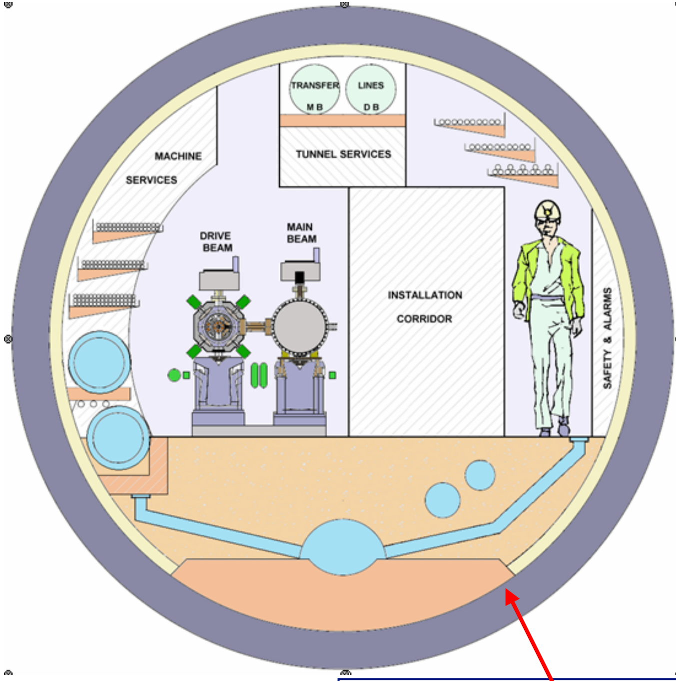
- **High Beam Power** (several MWatts)
- **Wall-plug to beam transfer efficiency** as high as possible (several %)
- **Generation & preservation of beam emittances** at I.P. as small as possible (few nmrad)
- **Beam focusing to very small dimentions at IP** (few nm)
- **Beamstrahlung energy spread** increasing with c.m. colliding energies

CLIC – basic features

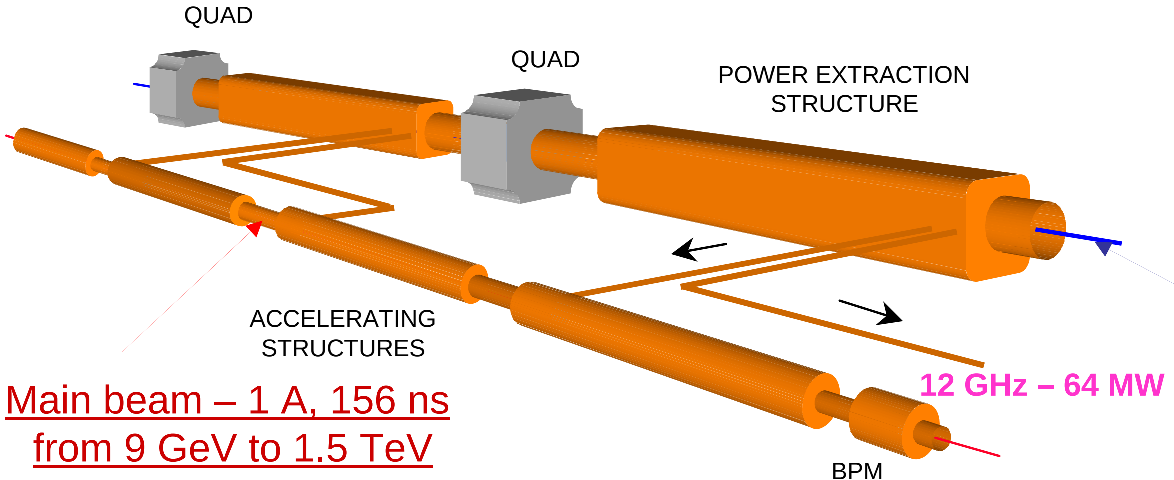
- **High acceleration gradient: > 100 MV/m**
- "Compact" collider – total length < 50 km at 3 TeV
- Normal conducting acceleration structures at high frequency

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

CLIC TUNNEL
CROSS-SECTION



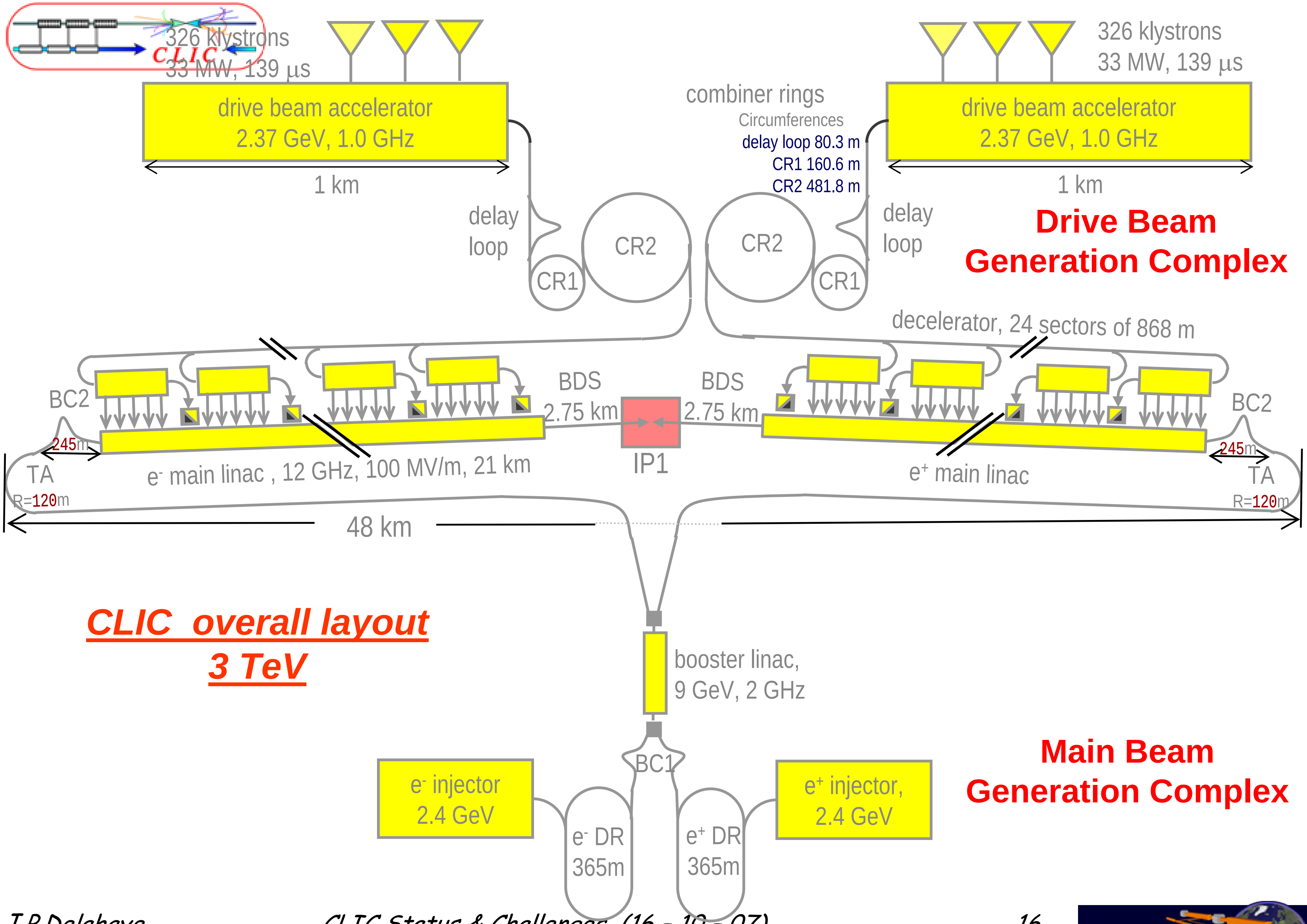
4.5 m diameter



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

E.Jensen

R.Corsini

The CLIC technology-related key issues as pointed out by ILC-TRC 2003

Covered by CTF3

R1: Feasibility

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

R2: Design finalization

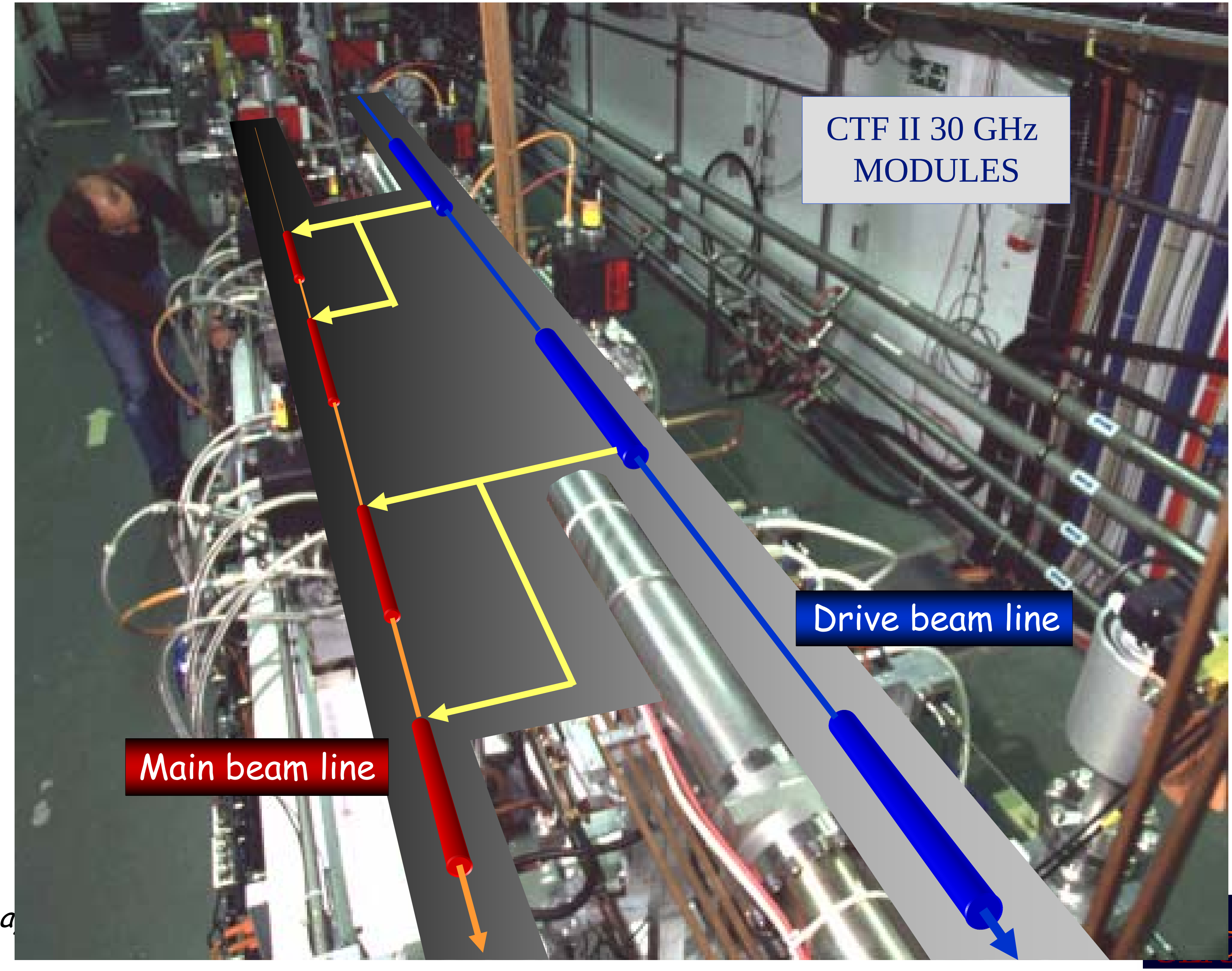
- R2.1: Developments of structures with hard-breaking materials (W, Mo…)
- R2.2: Validation of stability and losses of DB decelerator; Design of machine protection system
- R2.3: Test of relevant linac sub-unit with beam
- R2.4: Validation of drive beam 40 MW, 1 GHz Multi-Beam Klystron with long RF pulse *
- 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

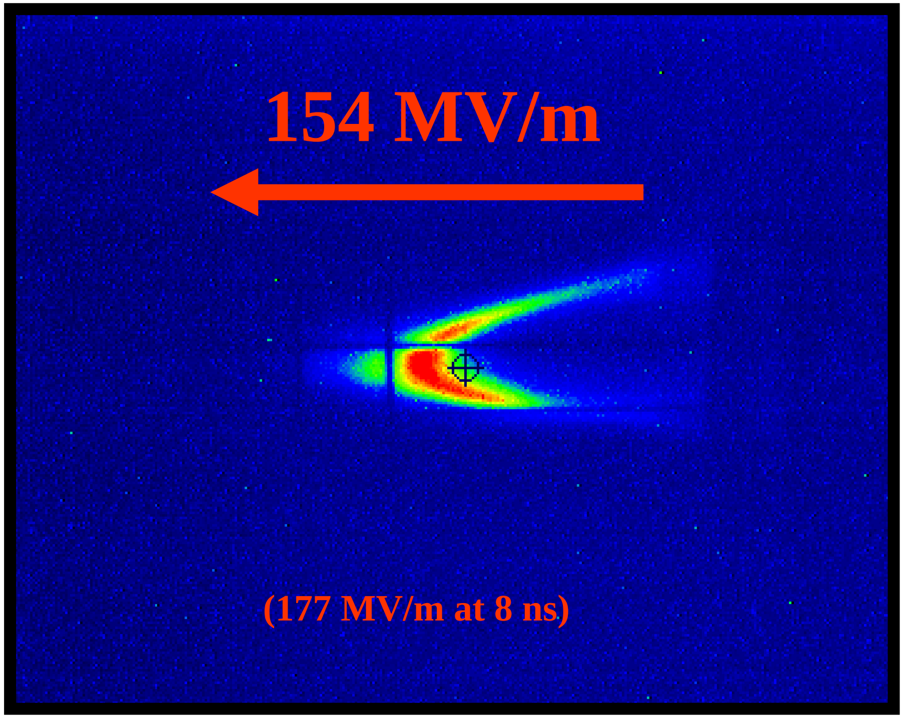
* *Feasibility study done – need development by industry.*
N.B.: Drive beam acc. structure parameters can be adapted to other klystron power levels

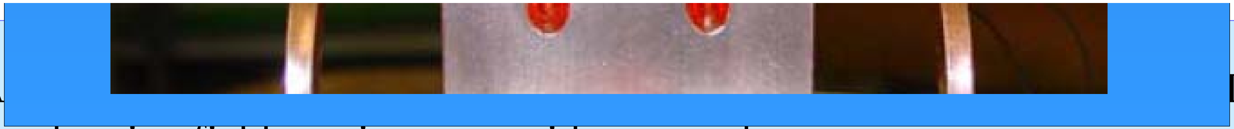
Principle of Two Beam scheme in CTFII

Dismantled in 2002, after having achieved its goals



High-gradient tests in CTF II



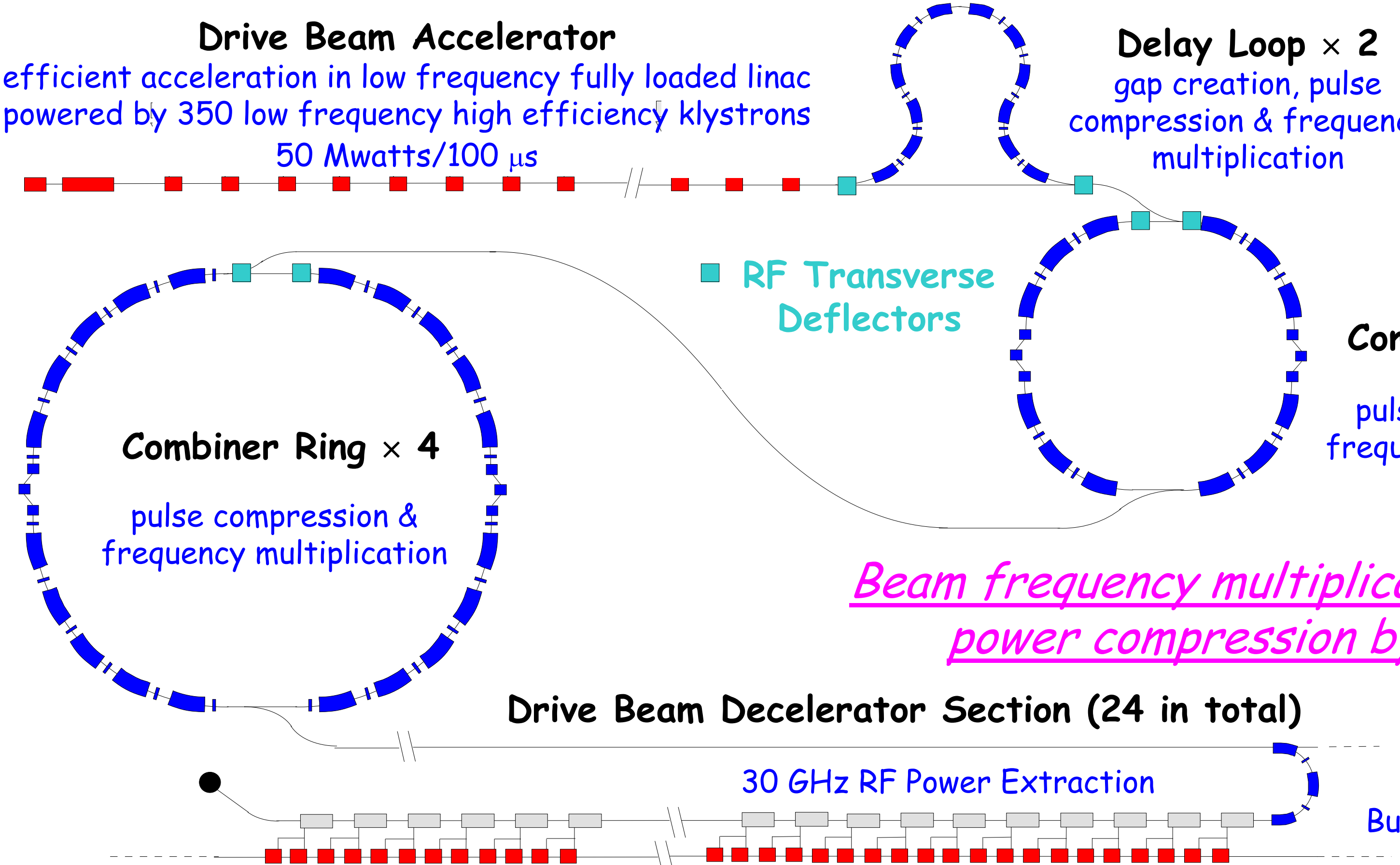


A [illegible] LIC accelerating field requirements without any damage

190 MV/m accelerating gradient in first cell - tested with beam ! (but only **16 ns pulse length**)

R.Corsini

The CLIC RF Power Source



Drive Beam Accelerator

efficient acceleration in low frequency fully loaded linac
powered by 350 low frequency high efficiency klystrons
50 Mwatts/100 μs

Delay Loop × 2

gap creation, pulse
compression & frequency
multiplication

🟦 RF Transverse Deflectors

Combiner Ring × 3

pulse compression &
frequency multiplication

Combiner Ring × 4

pulse compression &
frequency multiplication

Beam frequency multiplication and
power compression by 24

Drive Beam Decelerator Section (24 in total)

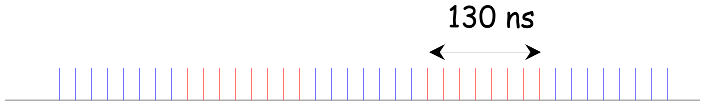
30 GHz RF Power Extraction

Return Arc

Bunch Compression

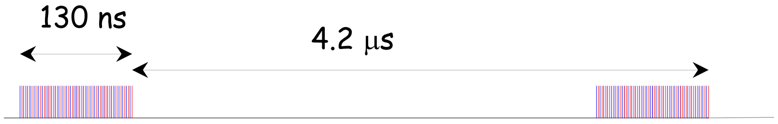
70 GeV/c energy gain – 800 m long

Drive beam time structure - initial



100 μs train length - 32 × 22 sub-pulses – **4.6 A**
2 GeV - 64 cm between bunches

Drive beam time structure - final

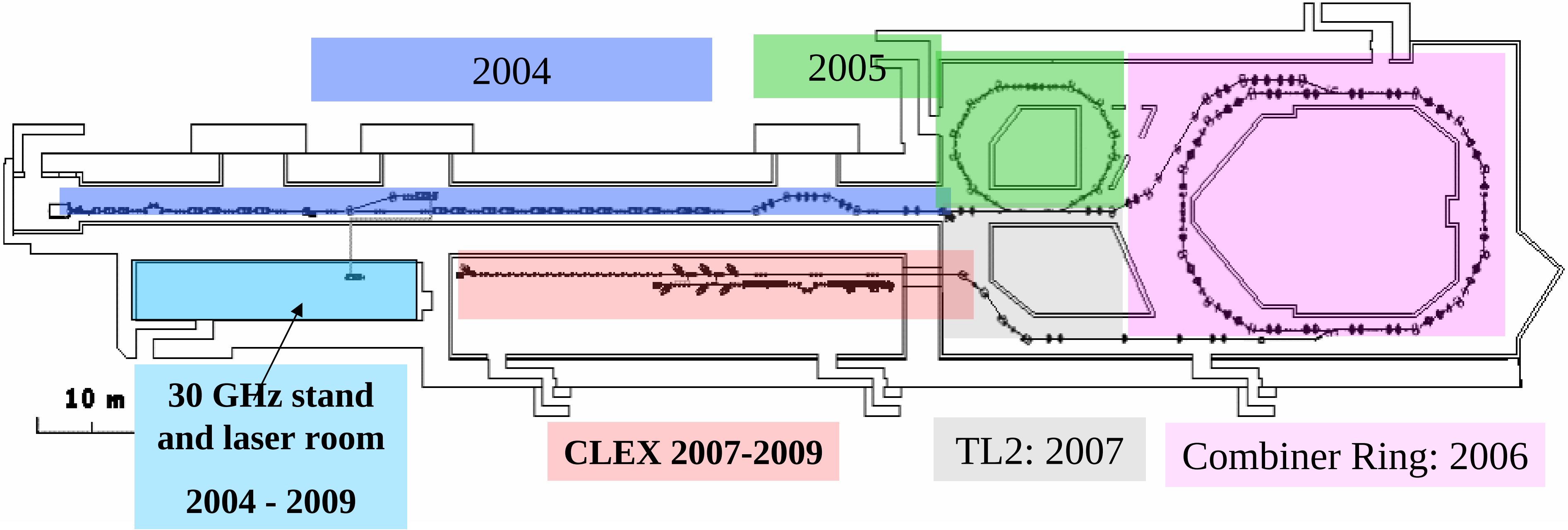


22 pulses - **147 A** - 2 cm between bunches

C.Biscari

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

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



2004

2005

10 m

30 GHz stand and laser room

2004 - 2009

CLEX 2007-2009

TL2: 2007

Combiner Ring: 2006

Key issues

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

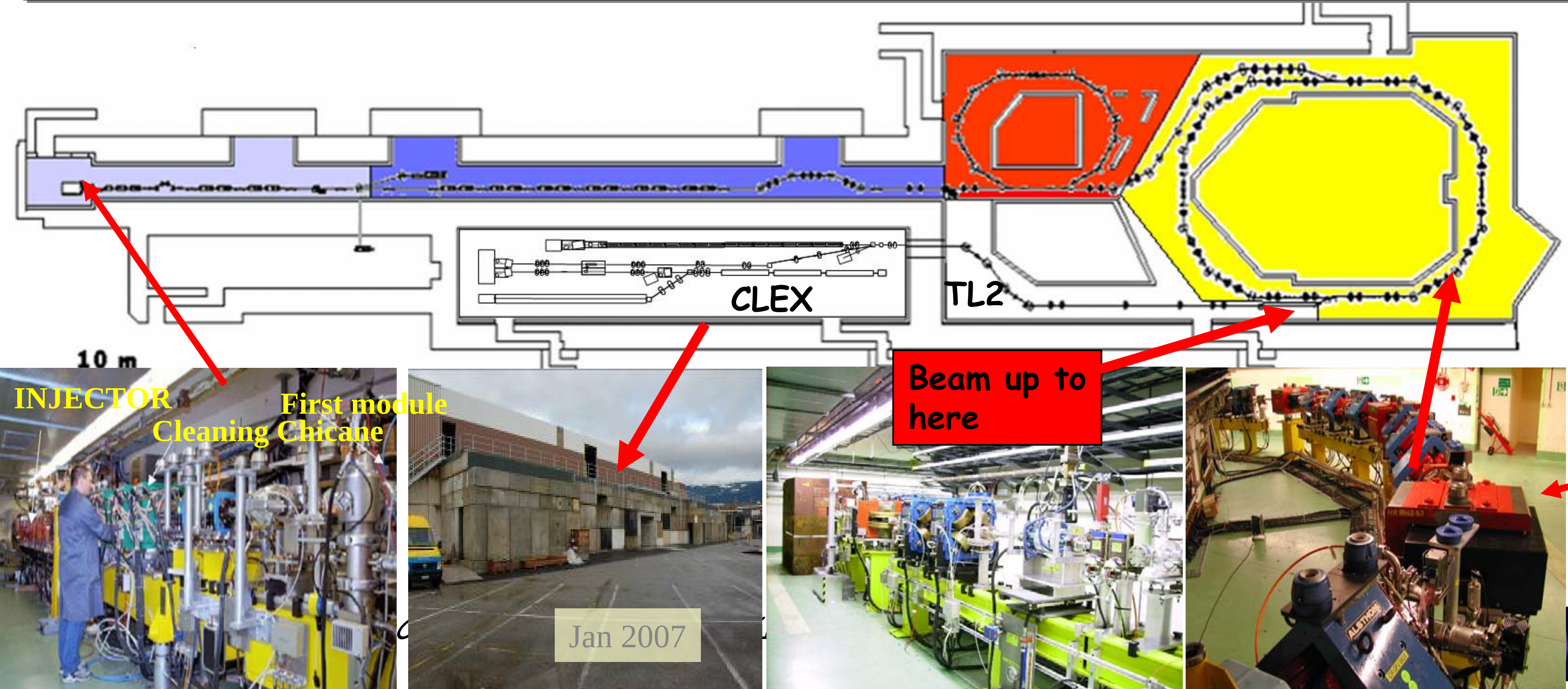
2007- 2008: Drive beam generation scheme (R1.2)

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)

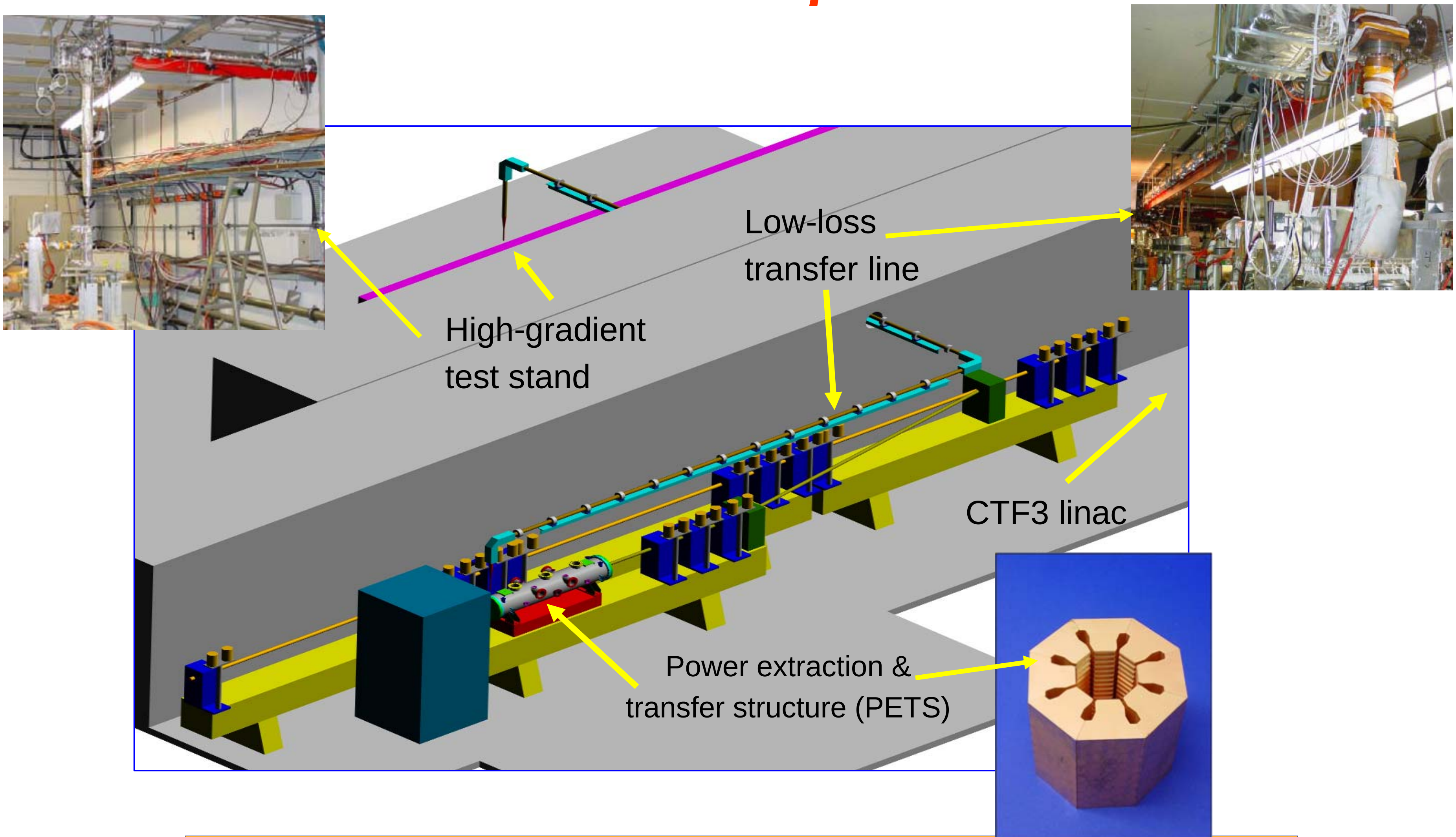
HW & Beam Commisioning and RF power production for structure tests

- 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



Beam up to here

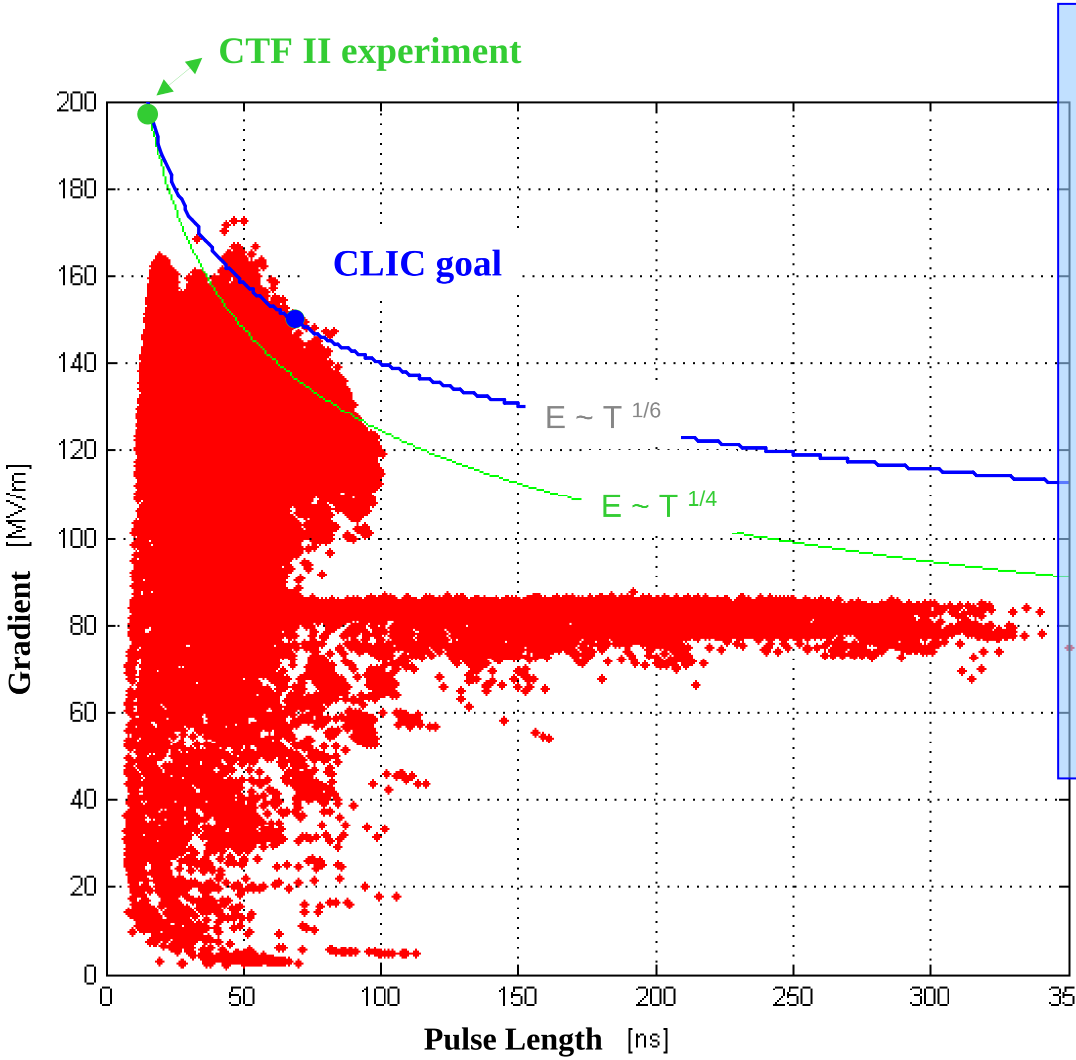
RF Power production in CTF3



- 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 - 10 structures tested until now

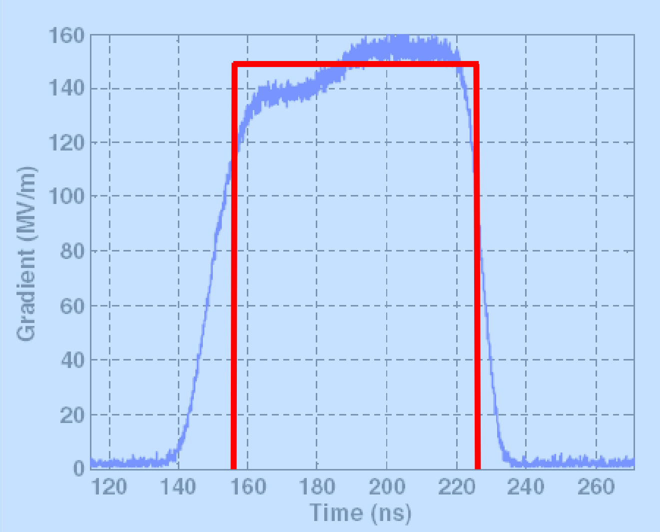
RF Structures
W.Wuensch

CTF3 High-Power test results @ 30 GHz



Reached nominal CLIC values :

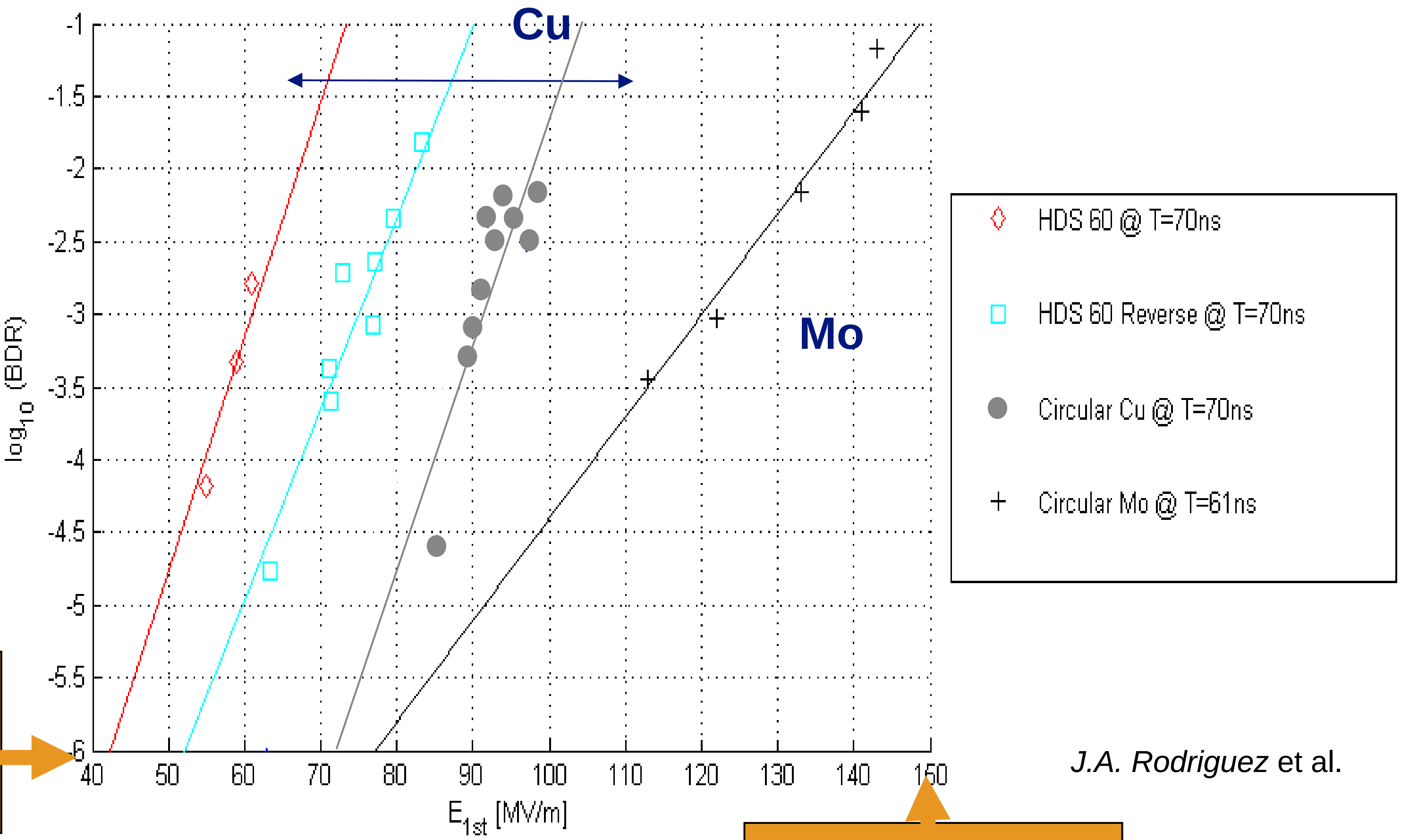
150 MV/m - 70 ns



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



J.A. Rodriguez et al.

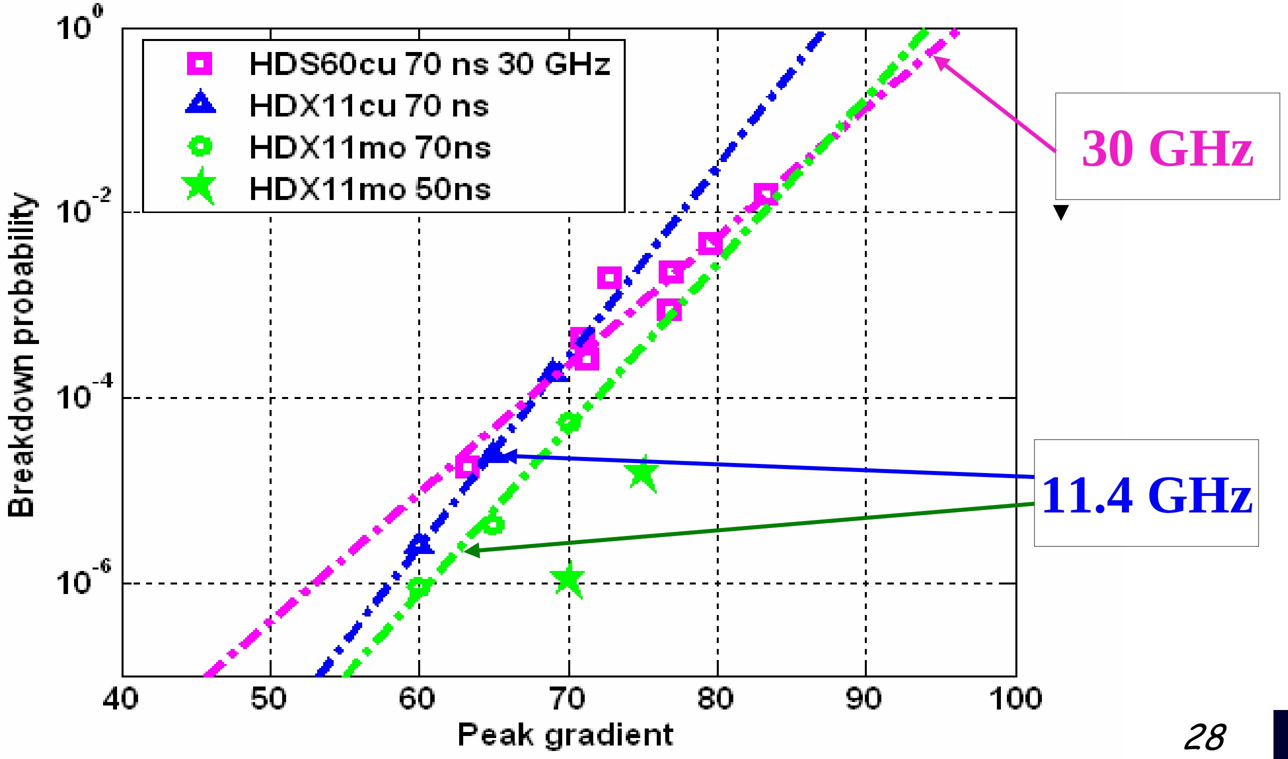
CLIC Breakdown Rate Operational Goal

150MV/m

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

W.Wuensch

Accelerating structure limitations:

rf breakdown and pulsed surface heating (rf) constraints:

Model derived from Experimental Data and based on Physics of RF power coupled to Field Emission

A.Grudiev
(Structure WG)

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 collision in detector in high beamstrahlung regime

D.Schulte

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

Work in progress aiming for reliable cost estimate by 2010

- Presently still large imprecision

- Define cost drivers for Cost Conscious Design guiding

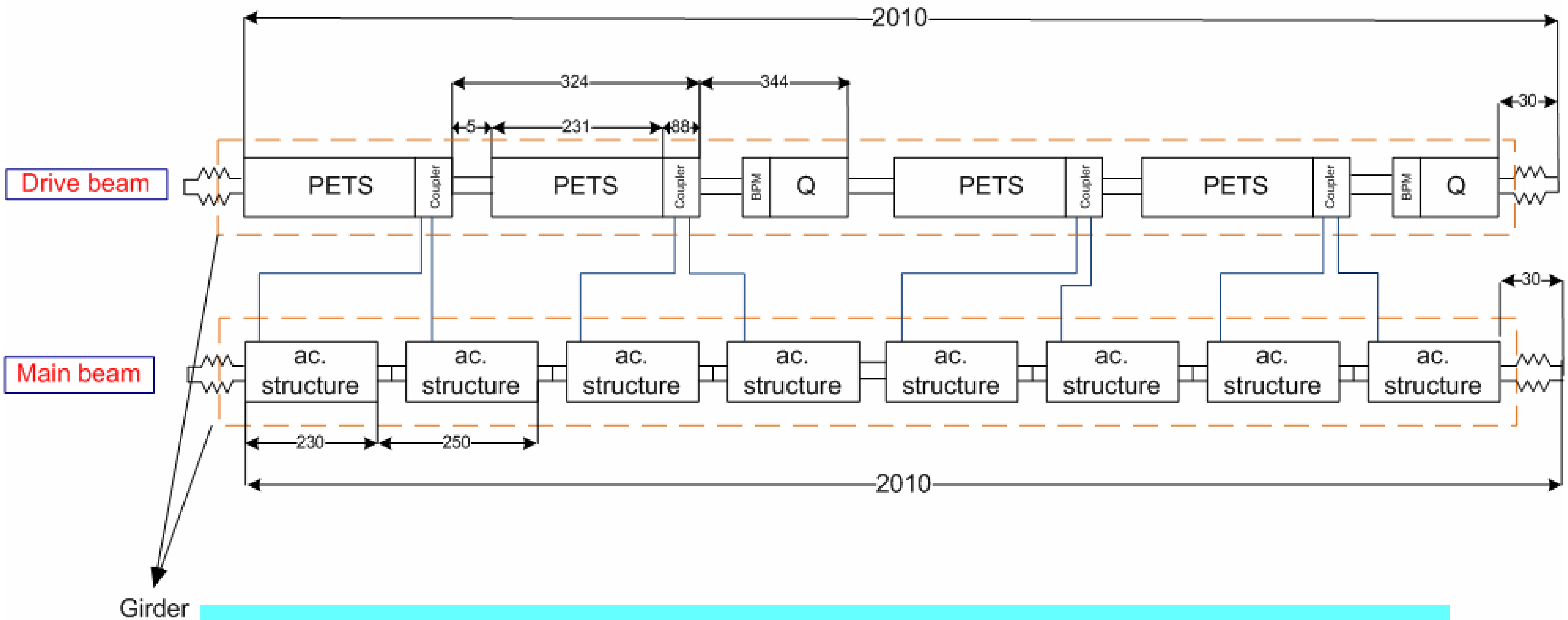
- Cost estimation made in parallel with the ILC cost estimate, by the same persons, using the same tools, on the same site as for the ILC@CERN for easy comparison of the two technologies

- Parametric model to estimate the influence on cost of the variation parameters

- Scaling of cost with colliding beam energy

Two Beam Module

Two Beam HW & Int. WG

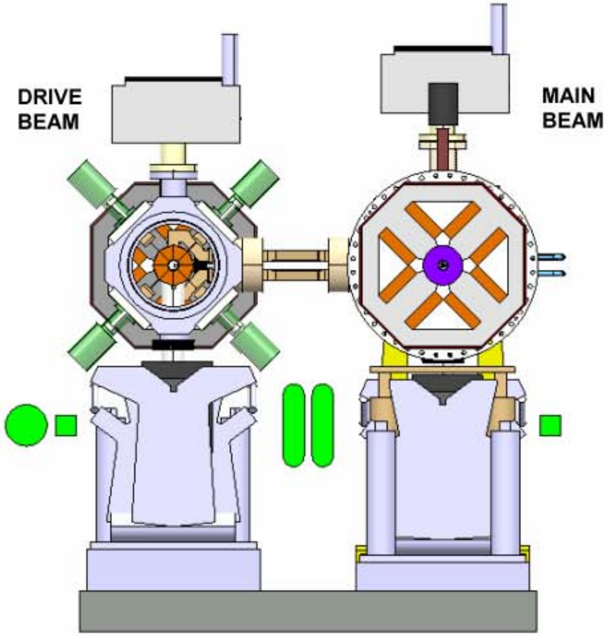


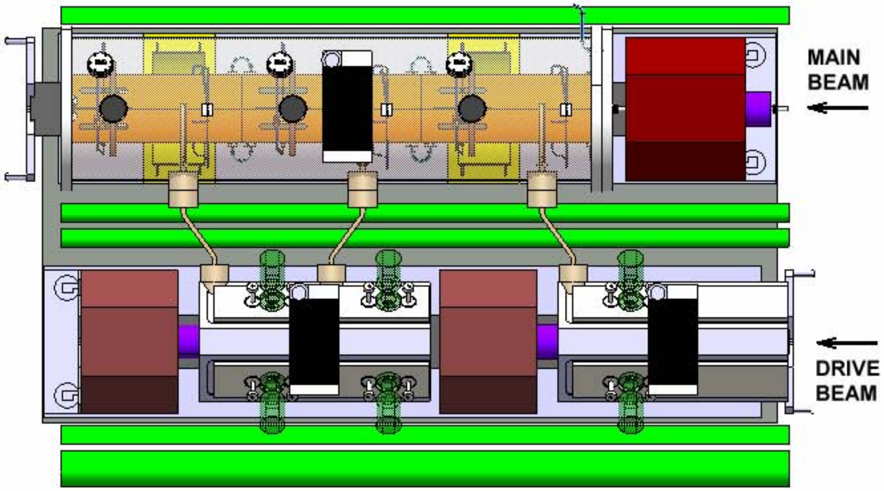
20760 modules

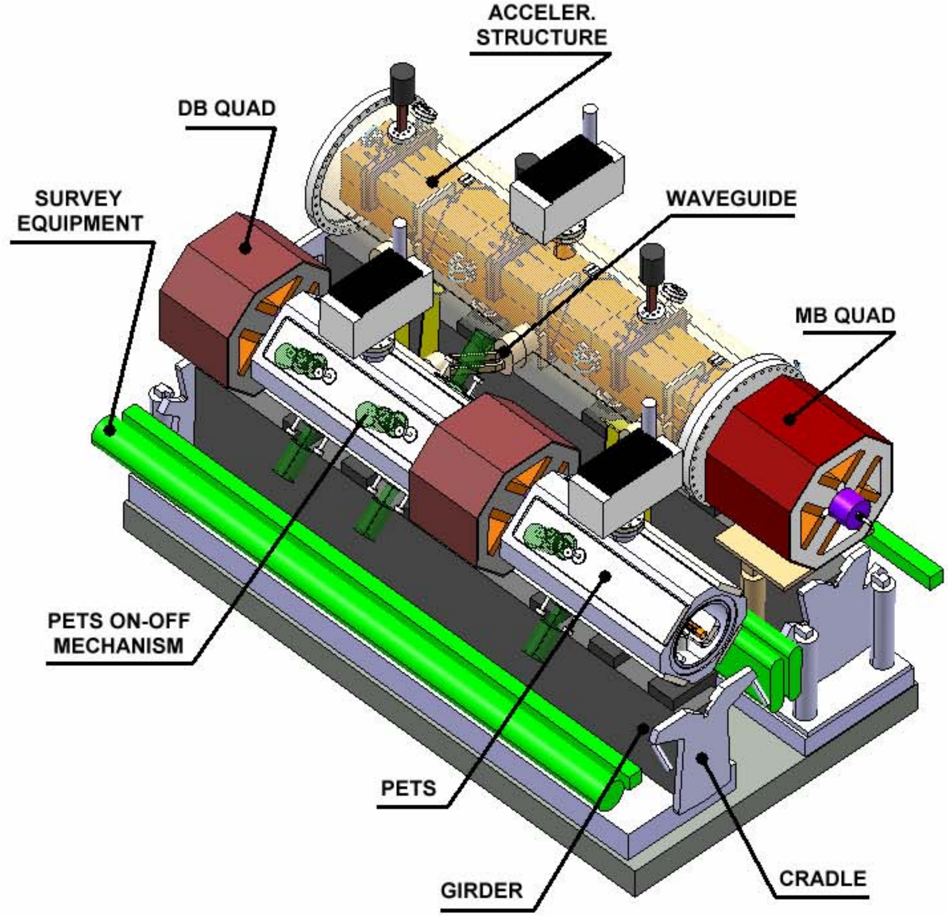
71460 power production structures PETS (drive beam)

143010 accelerating structures (main beam)

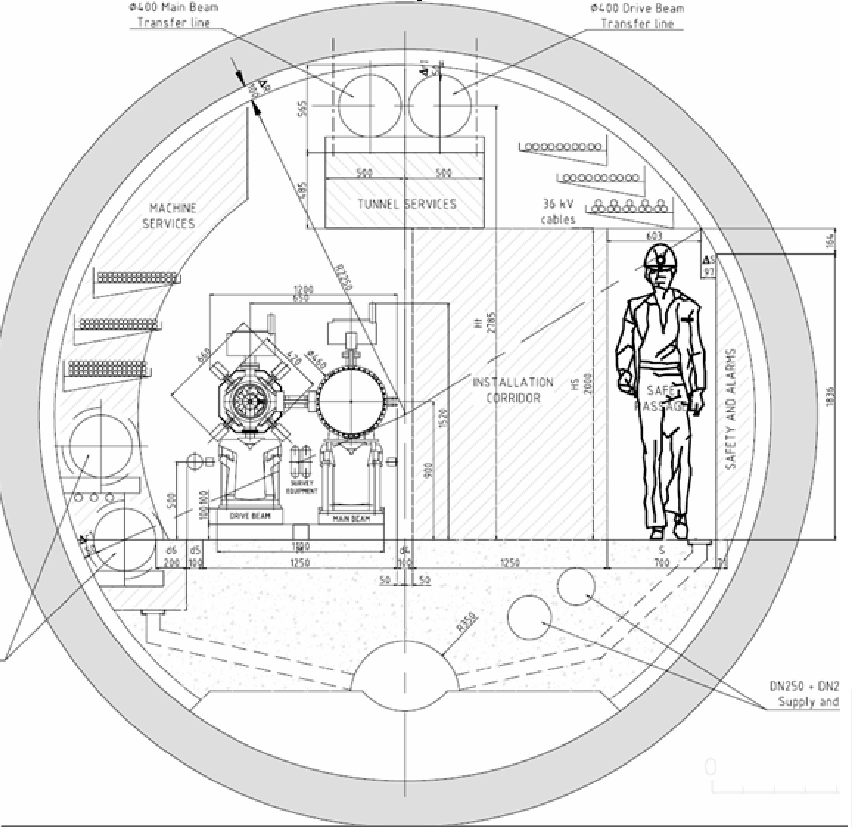
CLIC Standard Two Beam Module

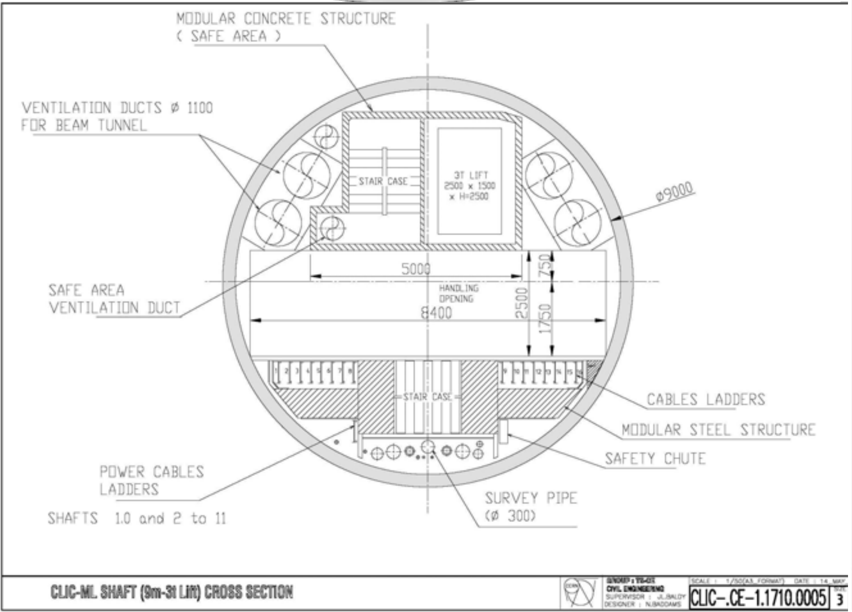


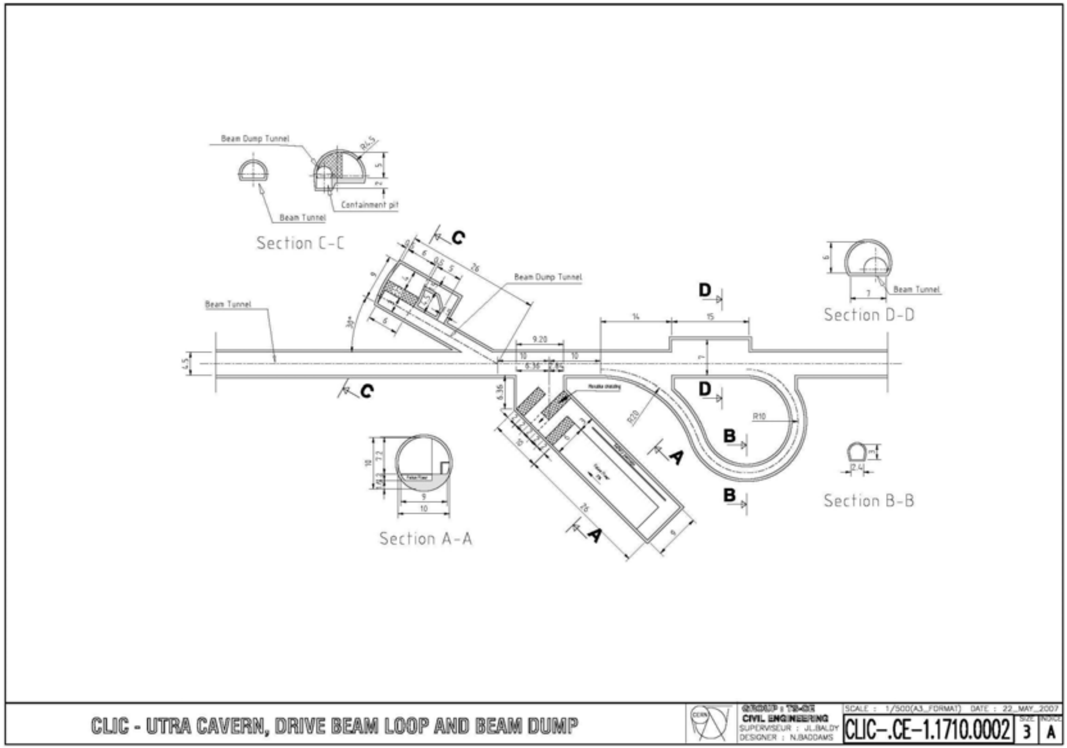




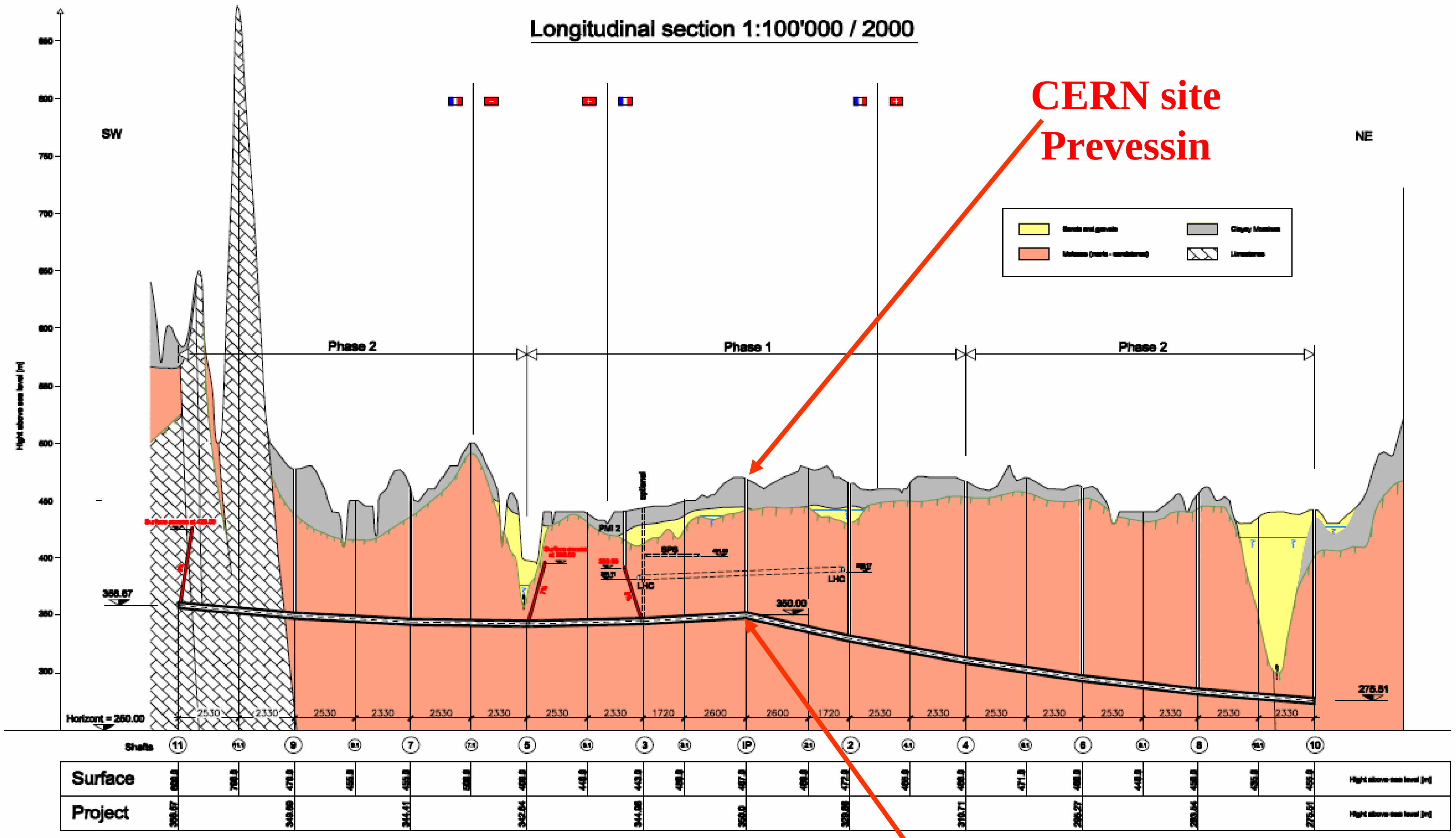
Single CLIC tunnel with alcoves for drive beam return loops and dumps







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



CERN site Prevessin

Detectors and Interaction Point

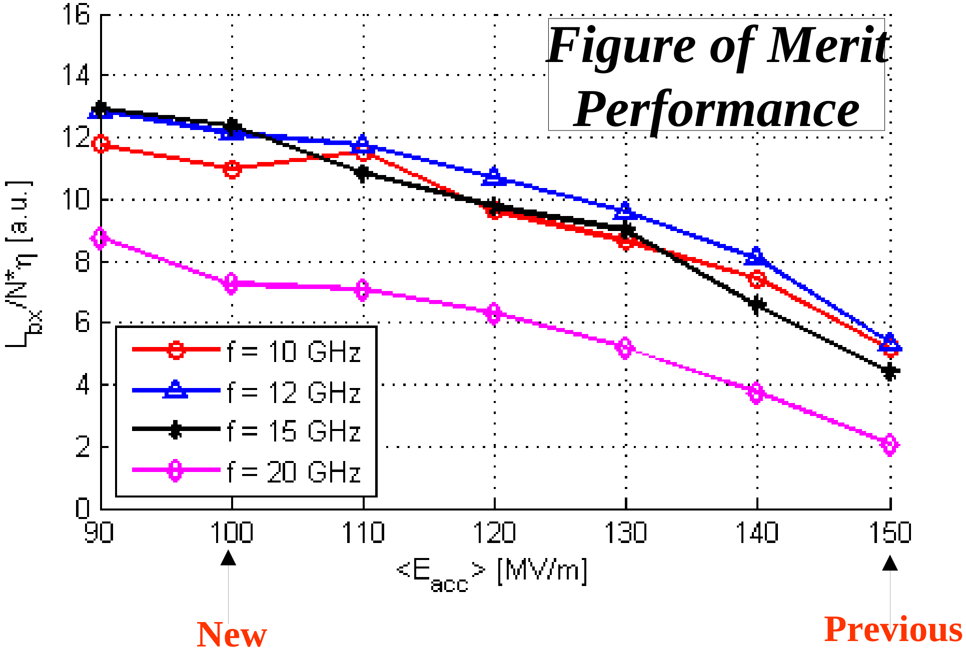
IP under CERN Prevessin site
Phase 1: 1 TEV extension 19.5 km
Phase 2: 3 TeV extension 48.5 km

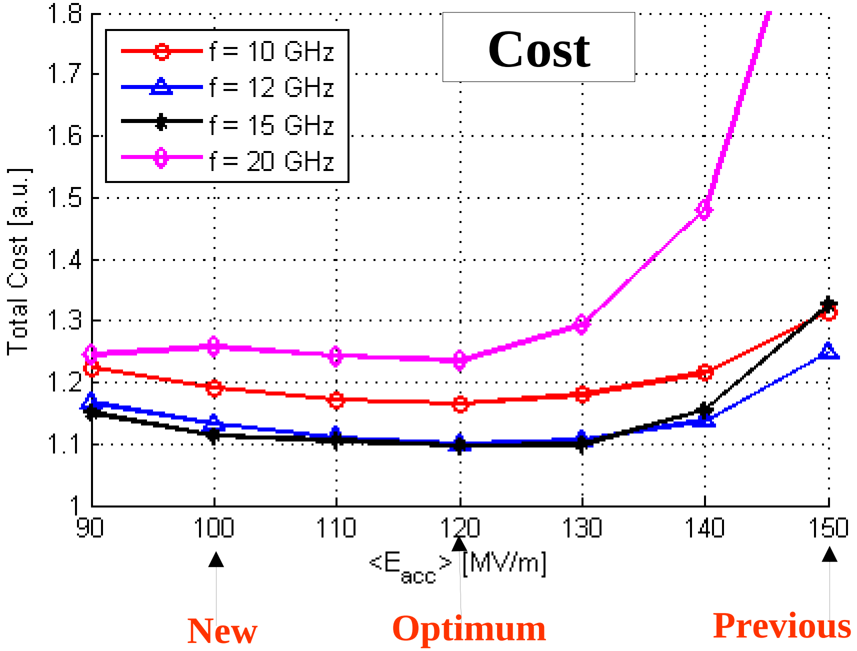
CLIC
Longitudinal section
1:100'000 / 2000

W:\Abrdata\G017 CLIC\ACAD\Längenprofil_01.dwg

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

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

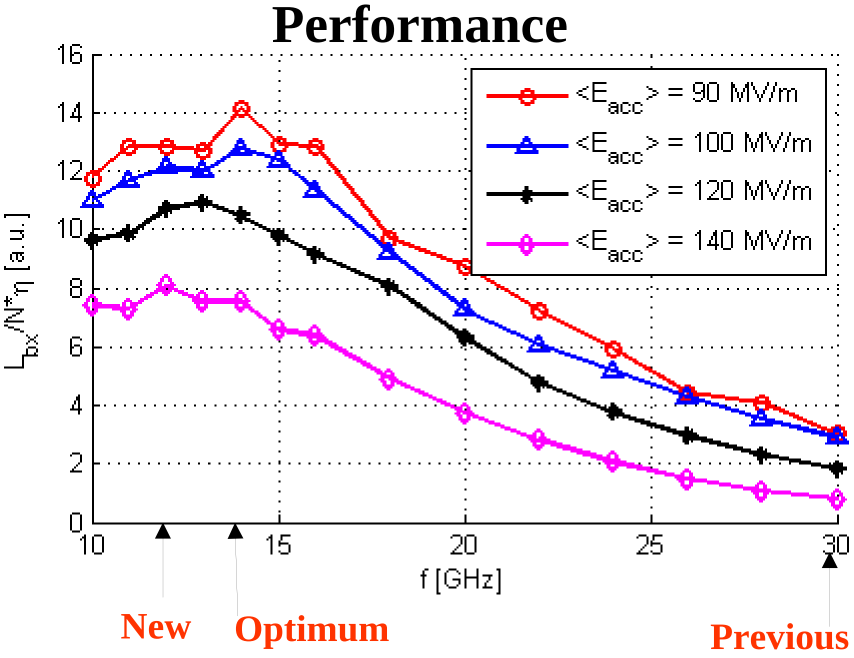


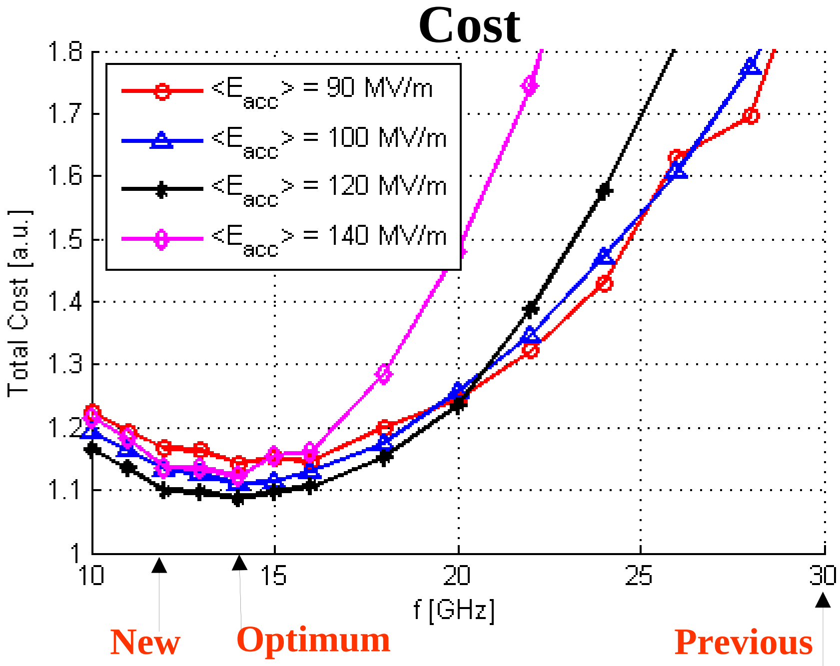


- **Performances increasing with lower accelerating gradient (mainly due to higher efficiency)**
- **Flat cost variation in 100 to 130 MV/m with a minimum around 120 MV/m**

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

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





- **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)
- 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…),
- Stand alone power sources available:
  - Makes the best use of developments and equipments at SLAC and KEK
- RF power generation and frequency multiplication in CLIC TBA RF Power Source
  - Drive beam linac at 1.0 GHz (with possible synergy with ILC MBK developments) and multiplication by 12 (3*4)
  - High gradients achievable with short RF pulse provided by TBA RF power source
  - Easy adaptation of CTF3 (multiplication factor by 8 instead of 10)
- Accelerating gradient of 100 MV/m already demonstrated at low breakdown rate with short pulse in non fully equipped structures

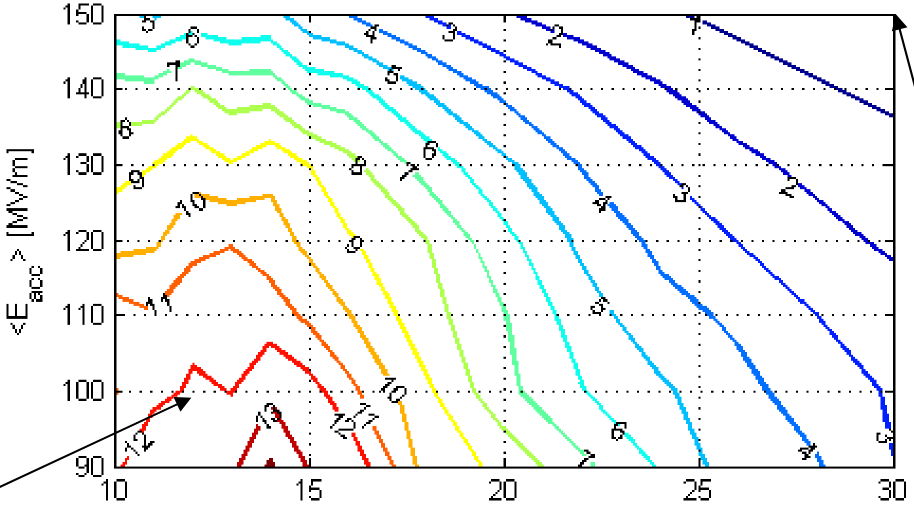
CLIC Performance and Cost optimization

CLIC
New parameters

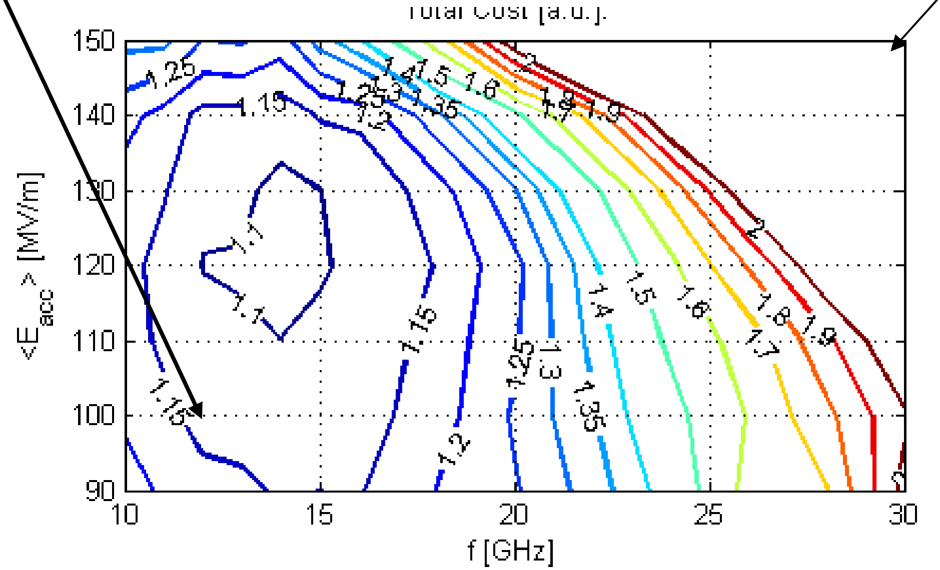
Accelerating field
= 100 MV/m

RF frequency
= 12 GHz

Luminosity / power



Total cost (a.u.)



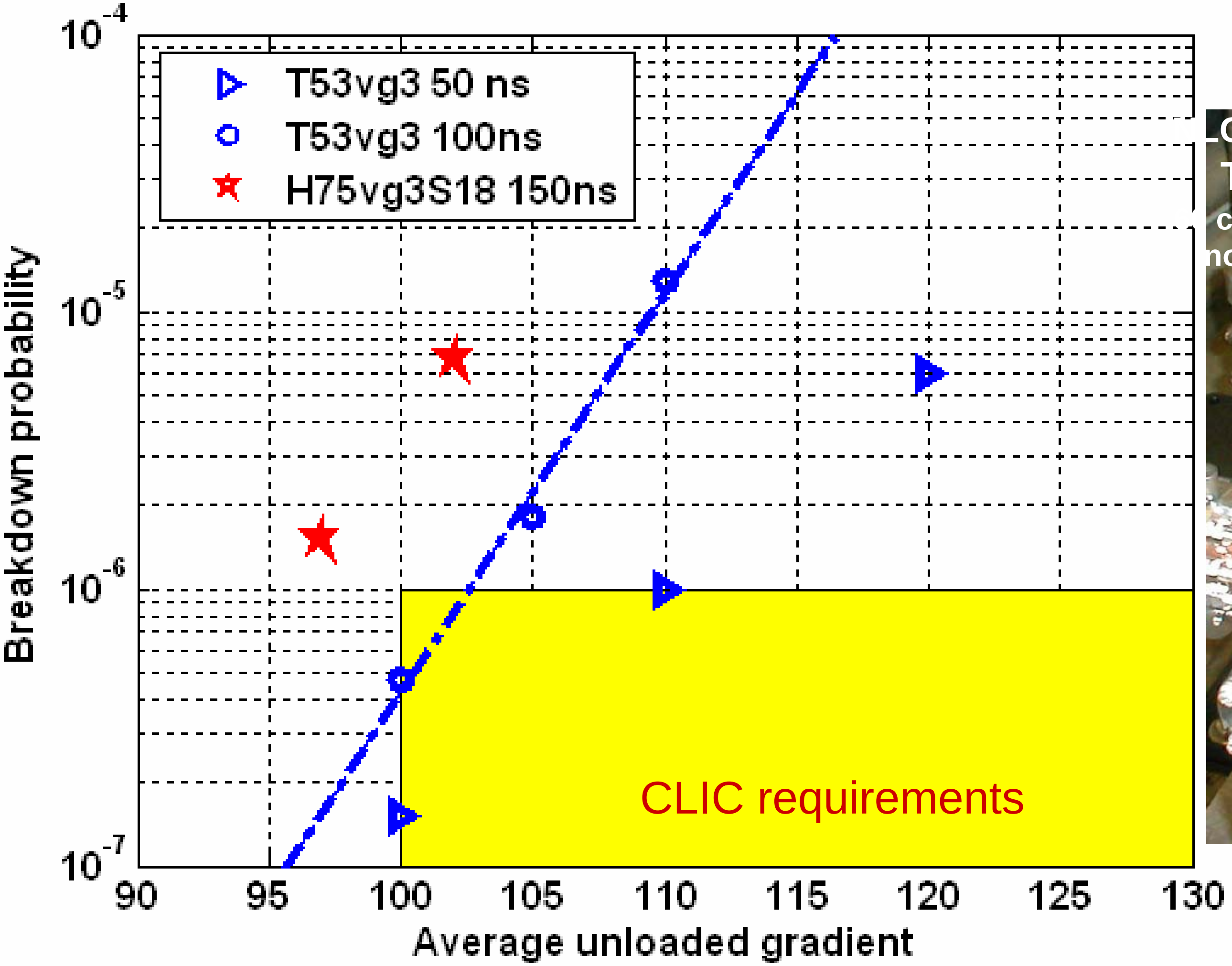
CLIC
Old Parameters

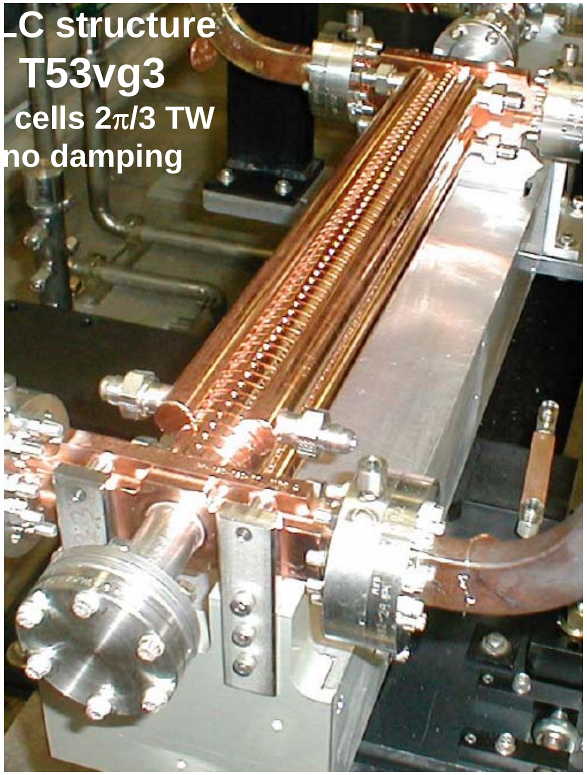
Accelerating field
= 150 MV/m

RF frequency
= 30 GHz

A. Grudiev et al.
EPAC'06

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



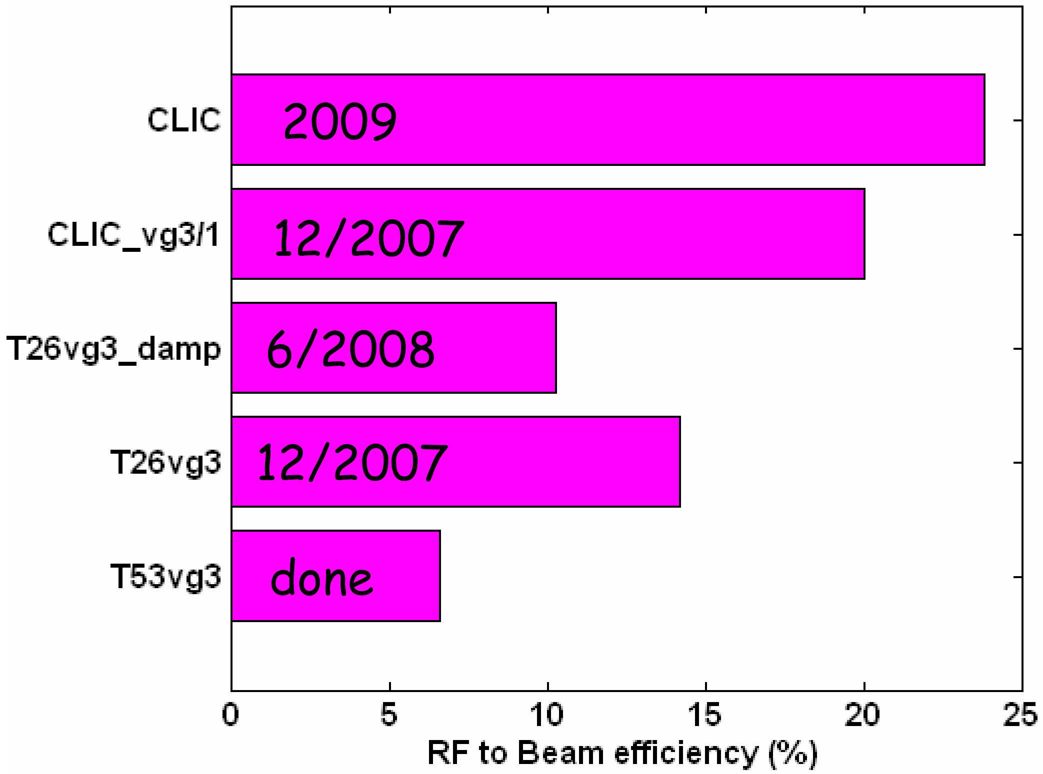

LC structure

T53vg3

cells 2π/3 TW

no damping

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

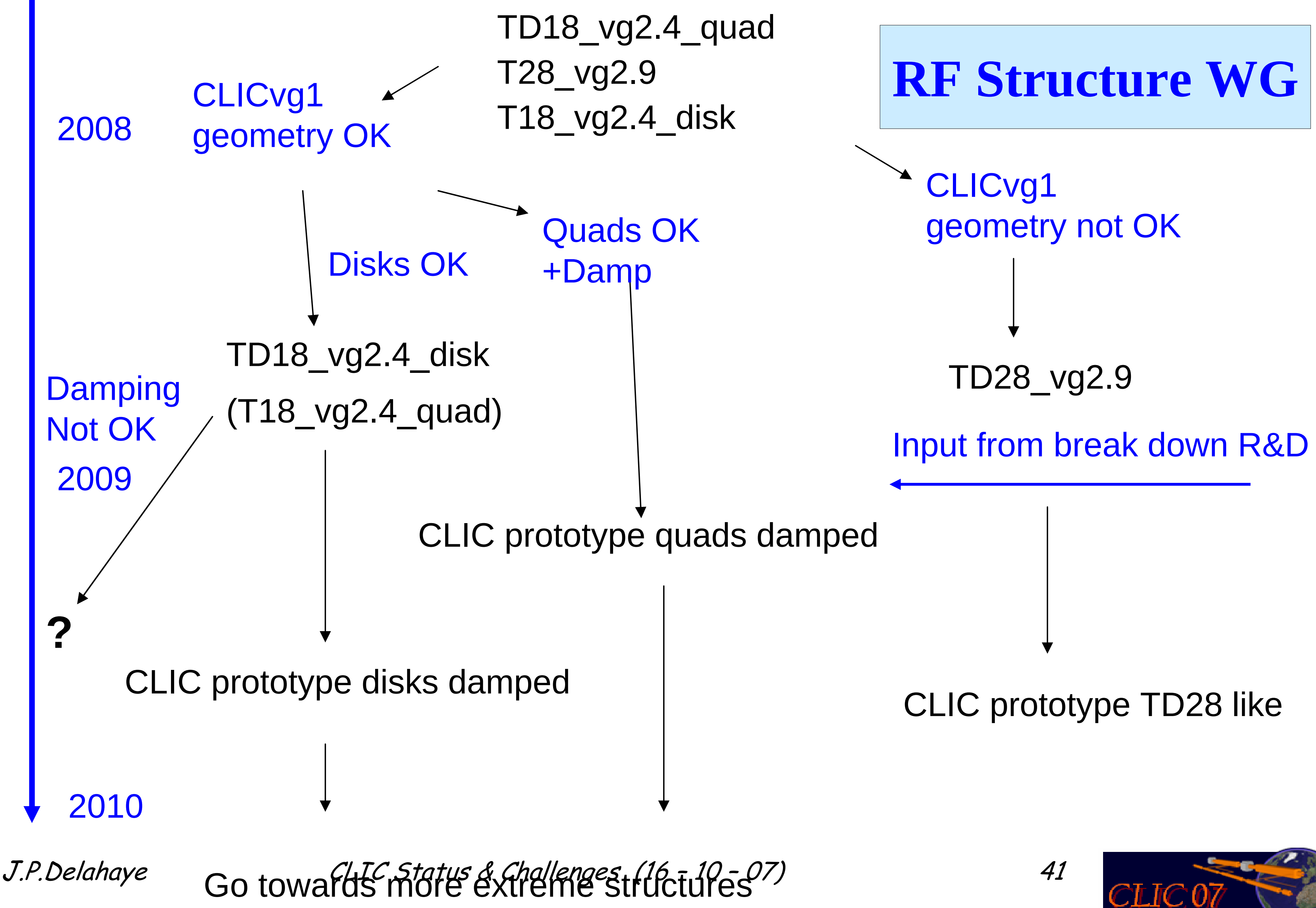
P = 102 MW; 113 ns ⇔ nb = 93

P = 134 MW; 104 ns ⇔ nb = 27

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

12 GHz Structure Tests Flow Chart

RF Structure WG



2007

TD18_vg2.4_quad
T28_vg2.9
T18_vg2.4_disk

2008

CLICvg1
geometry OK

CLICvg1
geometry not OK

Disks OK

Quads OK
+Damp

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

Structure testing program

RF Structure WG

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

S.Tantawi

New CLIC main parameters

http://clic-meeting.web.cern.ch/clic-meeting/clictable2007.html

CLIC 06 parameters: http://cdsweb.cern.ch/record/950185

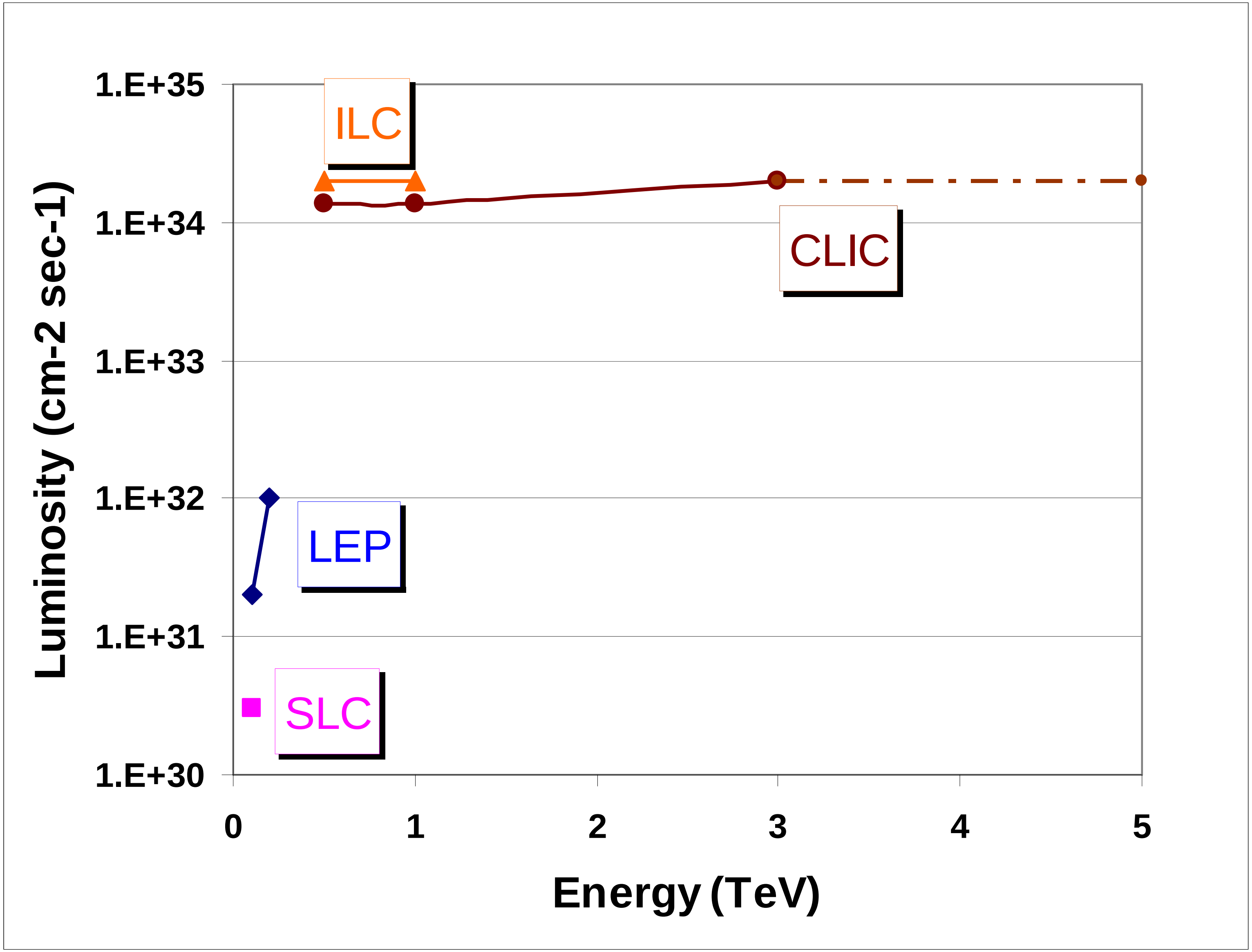
Center-of-mass energy	3 TeV
Peak Luminosity	$7 \cdot 10^{34}$ cm^{-2} s^{-1}
Peak luminosity (in 1% of energy)	$2 \cdot 10^{34}$ cm^{-2} s^{-1}
Repetition rate	50 Hz
Loaded accelerating gradient	100 MV/m
Main linac RF frequency	12 GHz
Overall two-linac length	42 km
Bunch charge	$3.72 \cdot 10^{9}$
Bunch separation	0.5 ns
Beam pulse duration	156 ns
Beam power/beam	14 MWatts
Hor./vert. normalized emittance	660 / 20 nm rad
Hor./vert. IP beam size bef. pinch	40 / ~1 nm
Total site length	48 km
Total power consumption	322 MW

Main CLIC/ILC parameters @ various energies

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

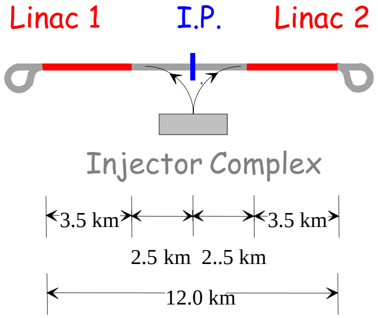
Parameter	Symbol	3 TeV	1 TeV	0.5 TeV	ILC	Unit
Center of mass energy	E_{cm}	3000	1000	500	500	GeV
Main Linac RF Frequency	f_{RF}	12	12	12	1.3	GHz
Luminosity	**L**	**5.9**	**2.25**	**2.24**	**2**	**$10^{34}\ cm^{-2}\ s^{-1}$**
Luminosity (in 1% of energy)	$L_{99\%}$	2	1.08	1.36		$10^{34}\ cm^{-2}\ s^{-1}$
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	η_{wp-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

Performances of Lepton Colliders



CLIC Layout at various energies

0.5 TeV Stage



Linac 1 I.P. Linac 2

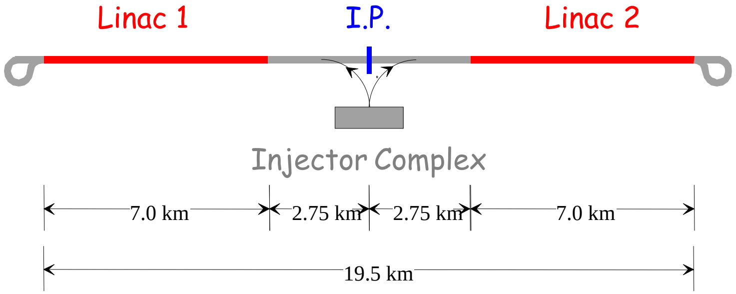
Injector Complex

3.5 km 3.5 km

2.5 km 2..5 km

12.0 km

1 TeV Stage



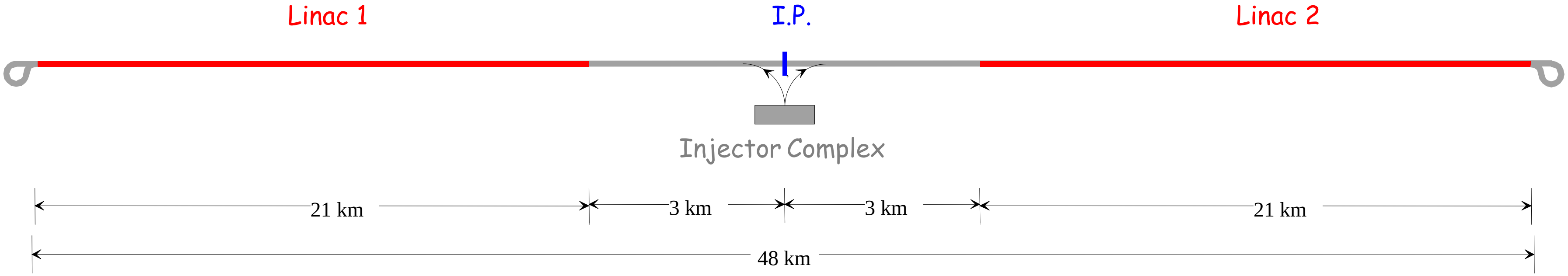
Linac 1 I.P. Linac 2

Injector Complex

7.0 km 2.75 km 2.75 km 7.0 km

19.5 km

3 TeV Stage



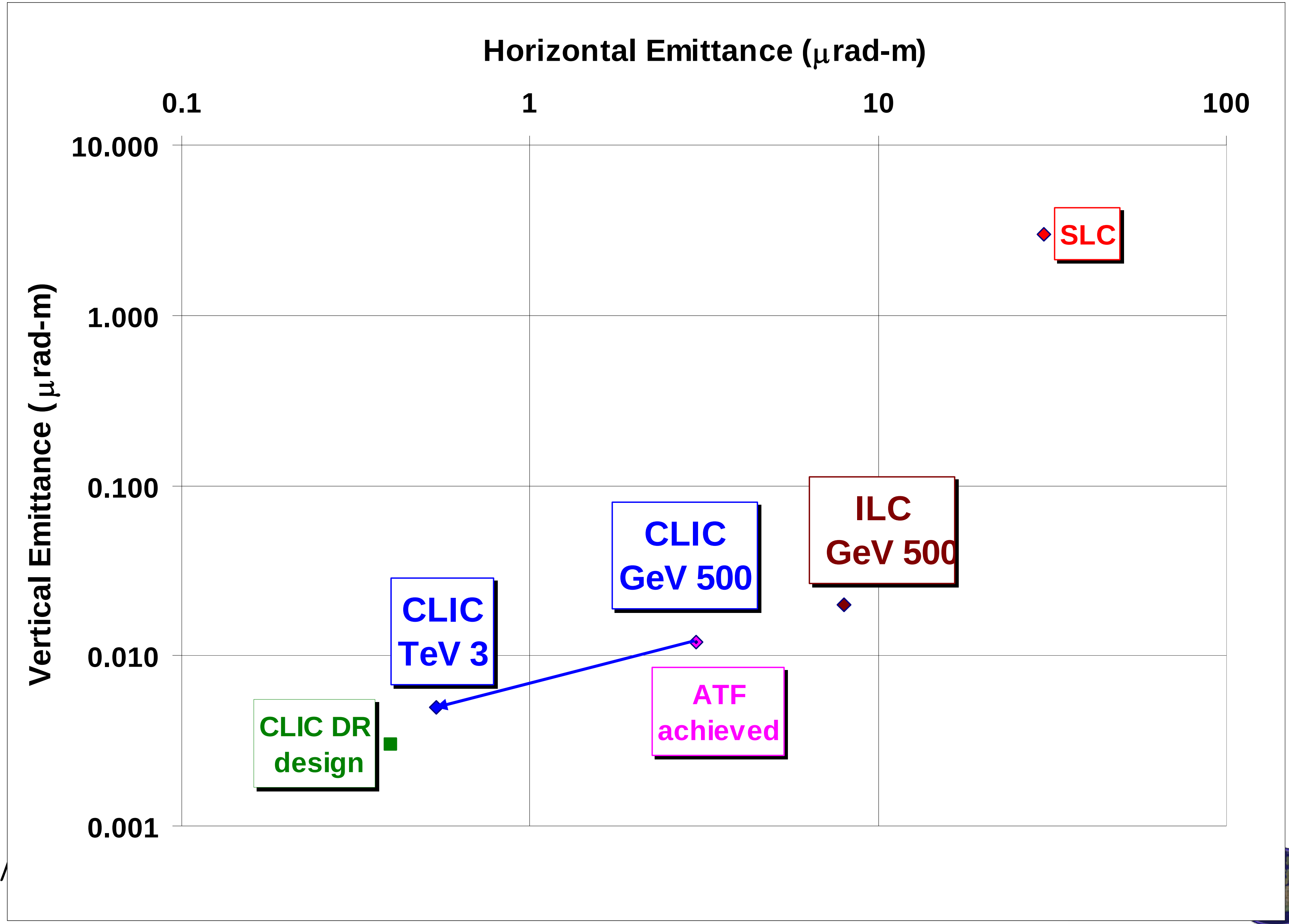
Linac 1 I.P. Linac 2

Injector Complex

21 km 3 km 3 km 21 km

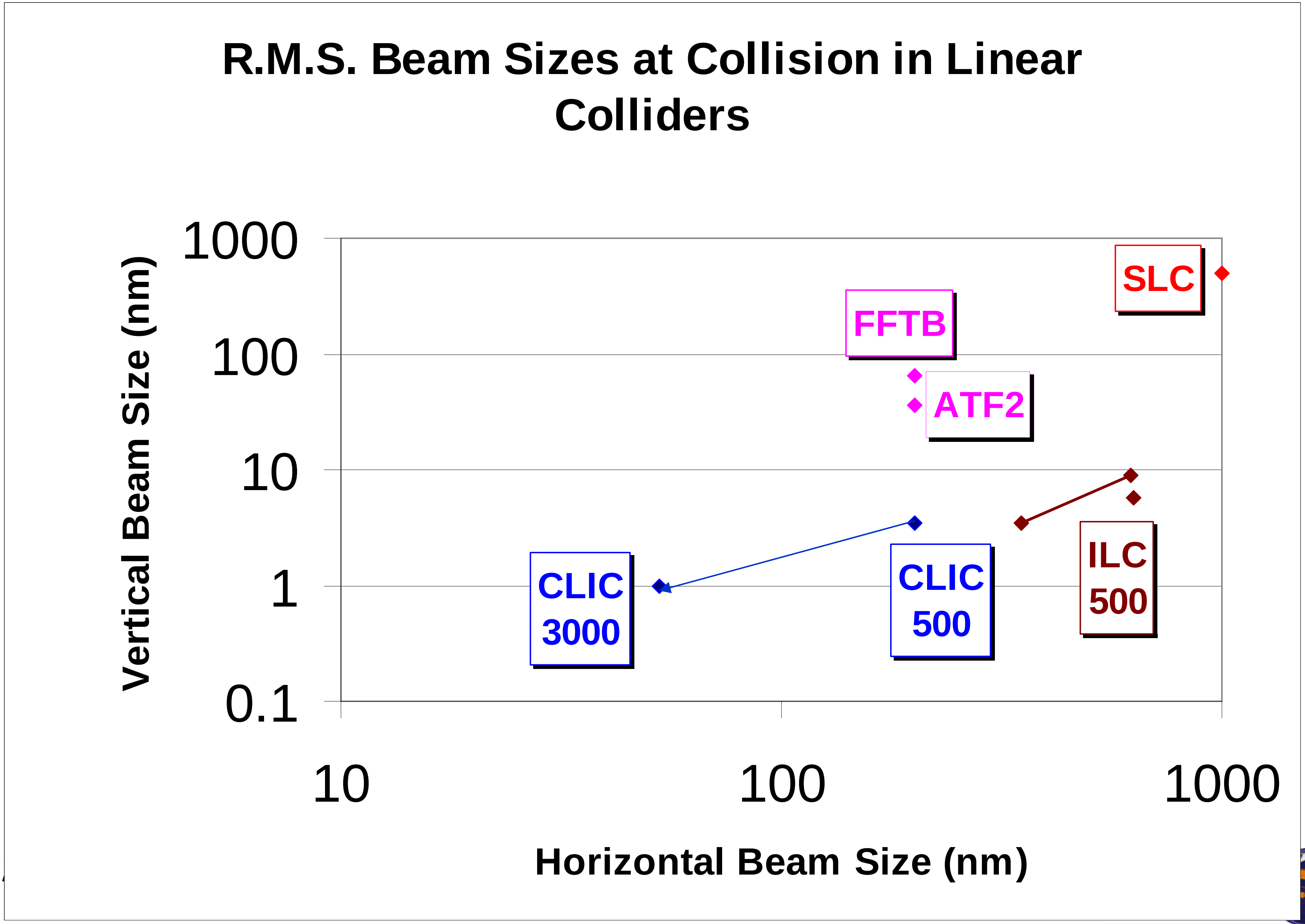
48 km

Beam emittances at Damping Rings

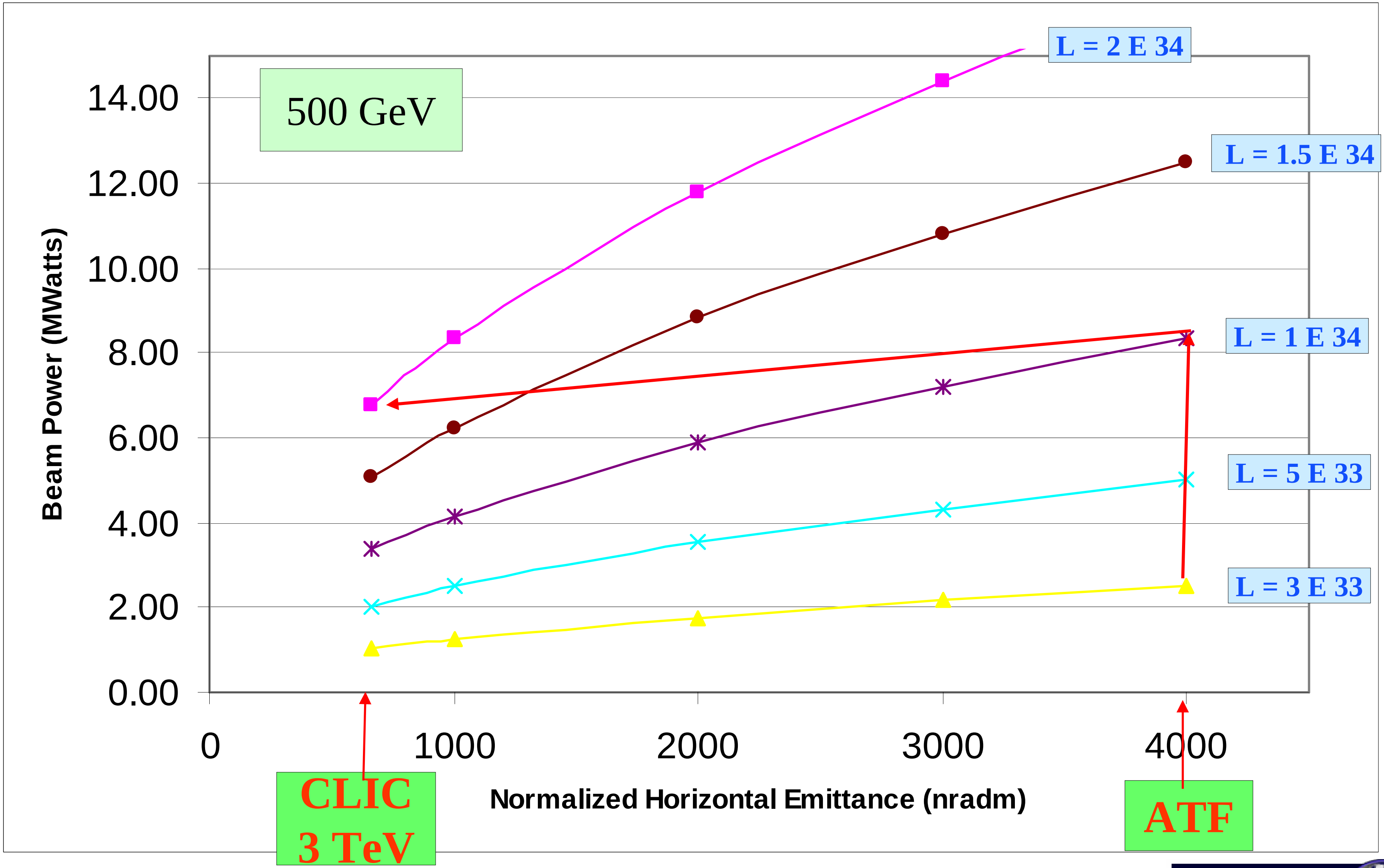


J.P.Del

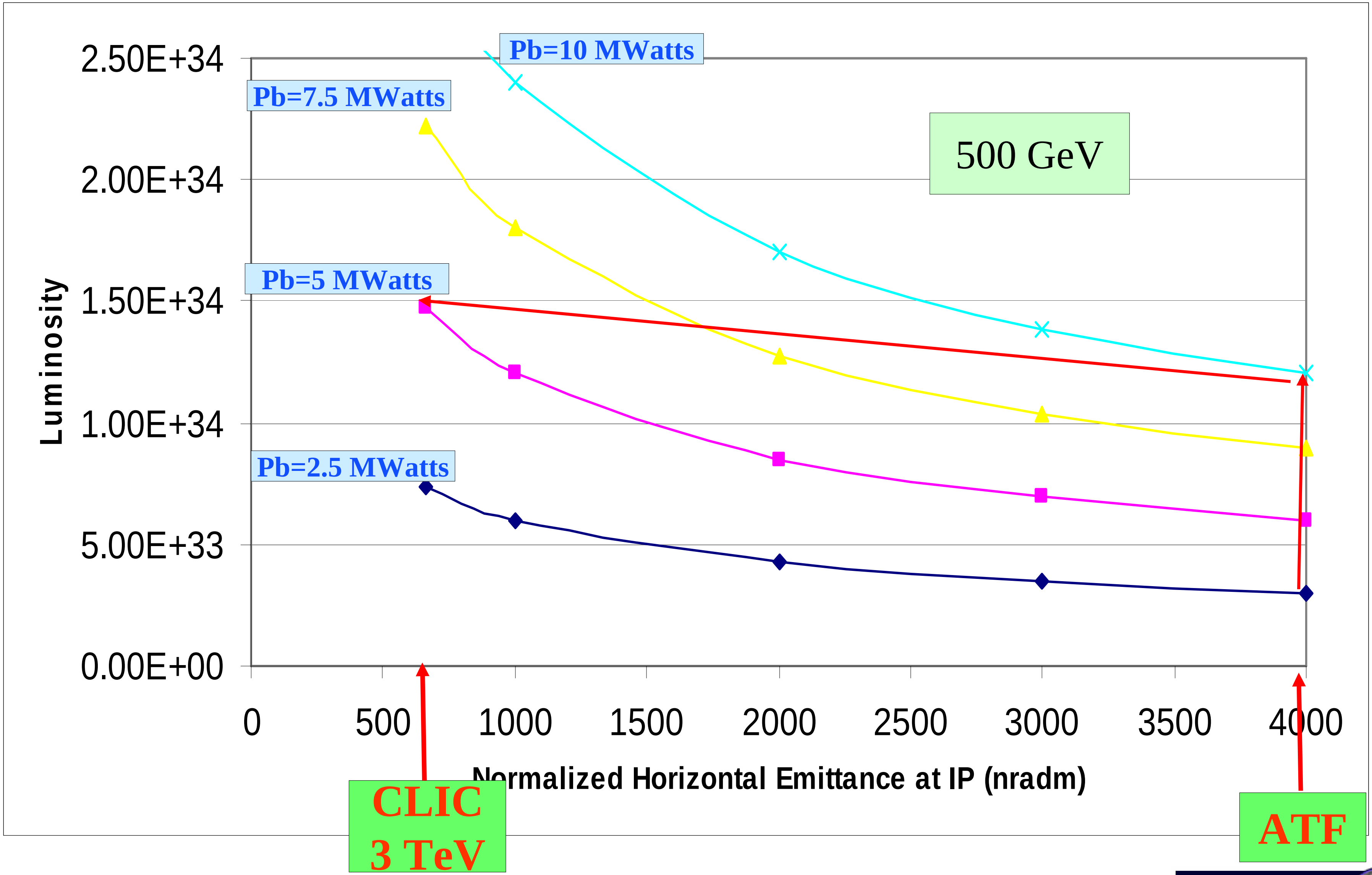
Beam sizes at Collisions



Luminosity & parameters range



Luminosity and Parameters range



CONCLUSION

- World-wide Consensus for a Lepton Linear Collider as the next HEP facility to complement LHC at the energy frontier
- CLIC technology only possible scheme to extend linear collider beam energy into Multi-TeV energy range
  - CLIC complementary to ILC in the TeV energy range
- Very promising results but CLIC technology not mature yet, requires challenging R&D on key issues clearly identified:
  - Common key issues addressed in close collaboration with ILC
  - CLIC-related key issues addressed in CLIC Test Facility (CTF3)
- A lot still to be done before the CLIC technology can be made operational and fully optimised based on novel Ideas and Challenging R&D in world-wide collaboration.
- All interested experts and laboratories invited to participate to Linear Collider Design based on CLIC technology and R&D on its Feasibility in the frame of an extended CLIC/CTF3 multi-lateral collaboration
- CLIC Conceptual Design with cost estimate by 2010 in due time, when physics needs will be fully determined following LHC results

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

Organisation & Objectives of the workshop

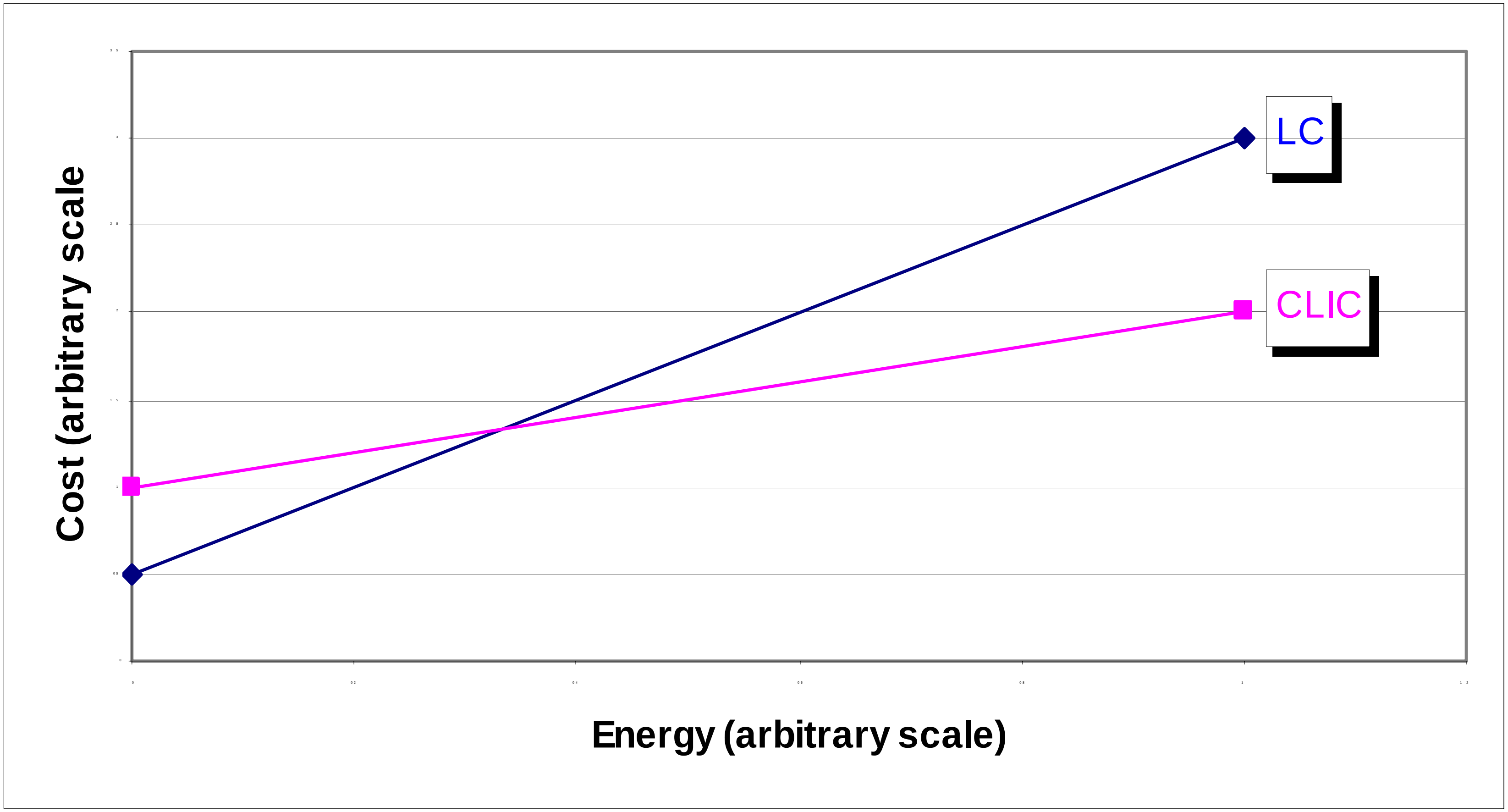
http://indico.cern.ch/conferenceDisplay.py?confId=17870

- Status of the study and Plans for the future in plenary sessions on Accelerator (16/10) and Physics & Detector (17/10 am)
- 6 Working Groups (presentation on 16/10 at 4pm) with // sessions (17/10pm + 18/10am)
  - Injector & Damping Rings: S.Guiducci/INFN & L.Rinolfi/CERN
  - Main & Drive Beam Dynamics: C.Biscari/INFN & D.Schulte/CERN
  - Instrumentation: G.Blair/RHUL & T.Lefevre/CERN
  - RF Structures & Sources: C.Adolphsen/SLAC & W.Wuensch/CERN
  - Two beam HW & Integration: R.Ruber/Uppsala & G.Riddone/CERN
  - Physics& Detectors: R.Settles/MPI & M.Hauschild/CERN
- Summary of Working Groups (18/10pm):
  - Critical review of the present status of the various systems and the plans to demonstrate their feasibility by 2010
  - Constructive proposals for improvements and new ideas welcome
  - Repartition and organisation of work after the workshop

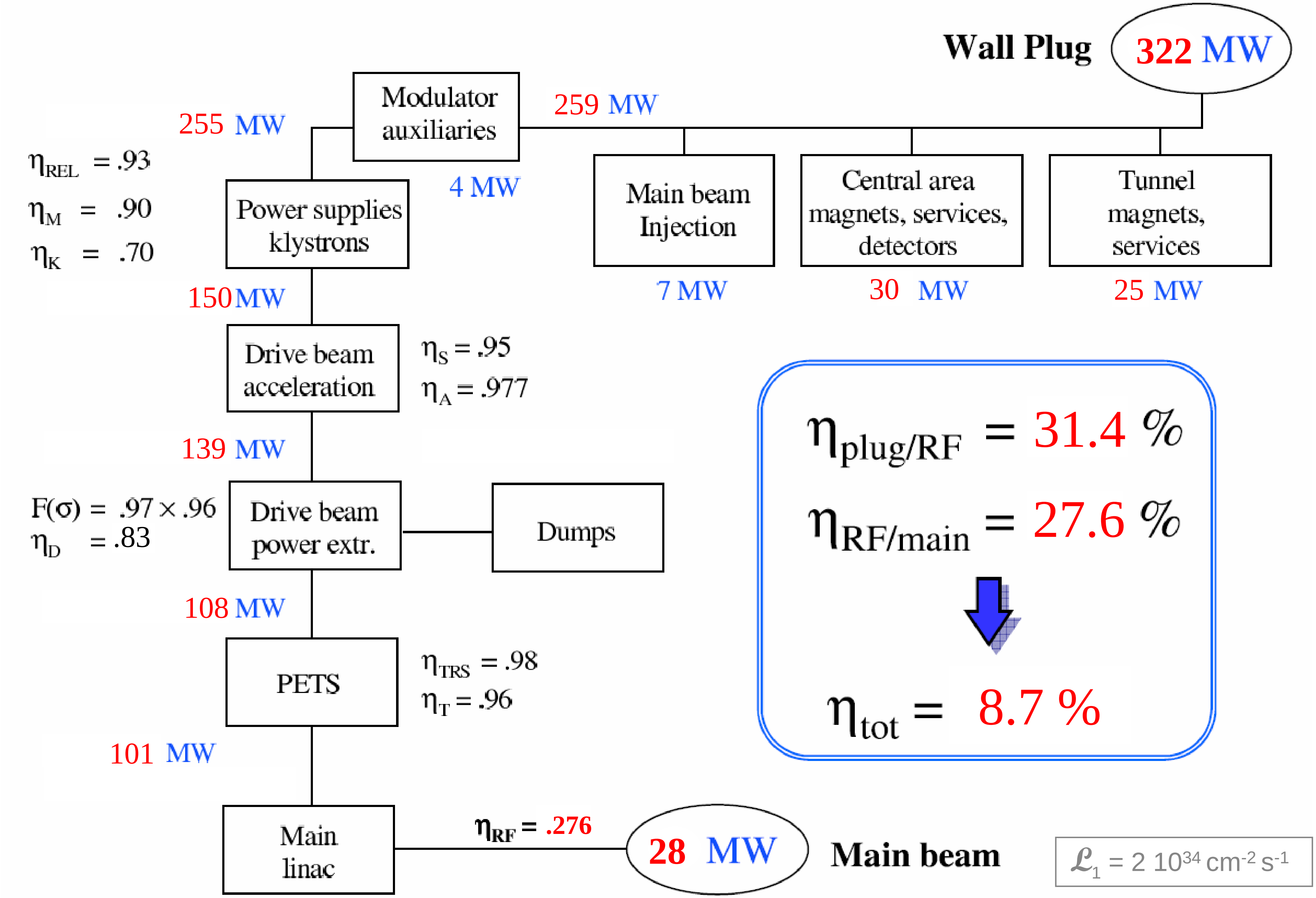
Review of the progress in CLIC08 workshop (date TBD)

Spares

Relative cost of Linear Colliders



Wall Plug to Beam Power Flow



Wall Plug 322 MW

259 MW

Modulator auxiliaries

255 MW

4 MW

Main beam Injection

7 MW

Central area magnets, services, detectors

30 MW

Tunnel magnets, services

25 MW

$\eta_{REL} = .93$

$\eta_M = .90$

$\eta_K = .70$

Power supplies klystrons

150 MW

Drive beam acceleration

$\eta_S = .95$

$\eta_A = .977$

139 MW

$F(\sigma) = .97 \times .96$

$\eta_D = .83$

Drive beam power extr.

Dumps

108 MW

PETS

$\eta_{TRS} = .98$

$\eta_T = .96$

101 MW

Main linac

$\eta_{RF} = .276$

28 MW **Main beam**

$\eta_{plug/RF} = 31.4\ \%$

$\eta_{RF/main} = 27.6\ \%$

$\eta_{tot} = 8.7\ \%$

$\mathcal{L}_1 = 2\ 10^{34}\ \text{cm}^{-2}\ \text{s}^{-1}$

Required and achieved magnet stability

Stability requirements (> 4 Hz) for a 2% loss in luminosity

Need active damping of vibrations

Magnet	Ix	Iy
Linac (2600 quads)	14 nm	1.3 nm
Final Focus (2quads)	4 nm	0.2 nm

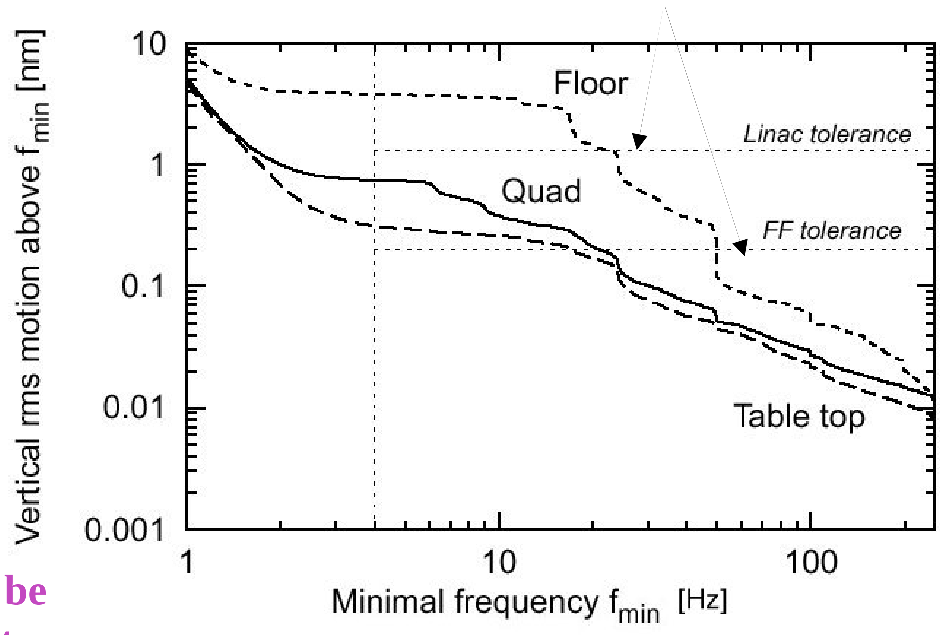
Achieved stability

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



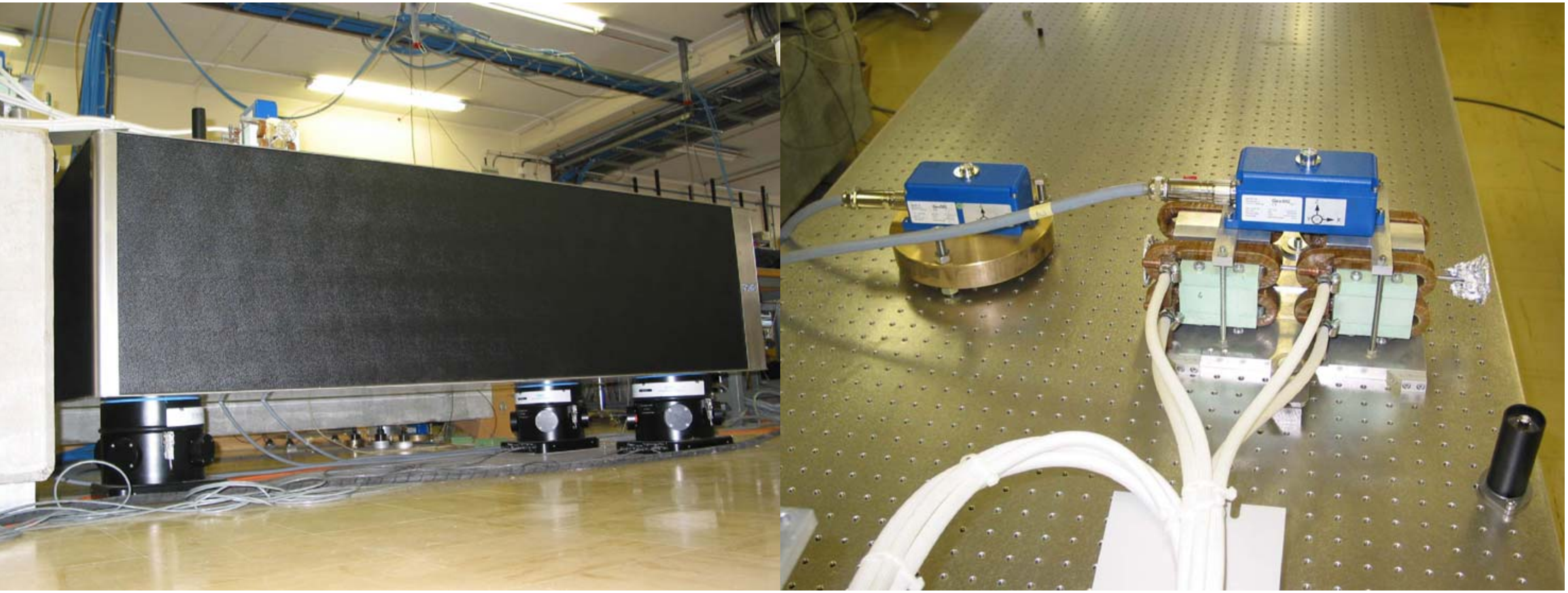
CLIC tolerances

Big step towards believing that nanobeams can be made colliding on sites with CERN-like stability

Nanometer stabilisation

Latest stabilization technology applied to the accelerator field

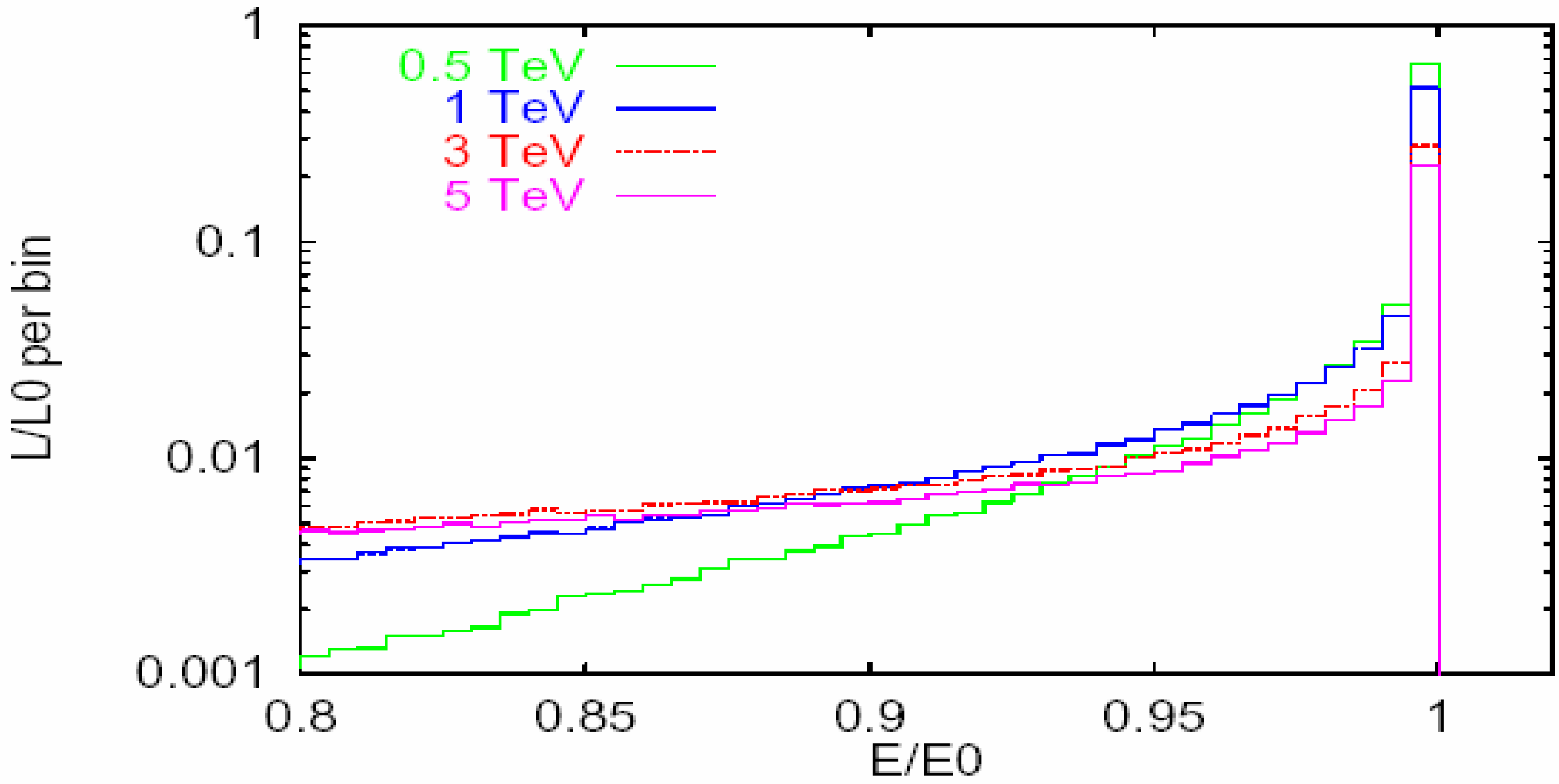
The most stable place on earth!!!



Stabilizing quadrupoles to the **0.5 nm** level!

(up to 10 times better than supporting ground, above 4 Hz)

Luminosity Spectrum

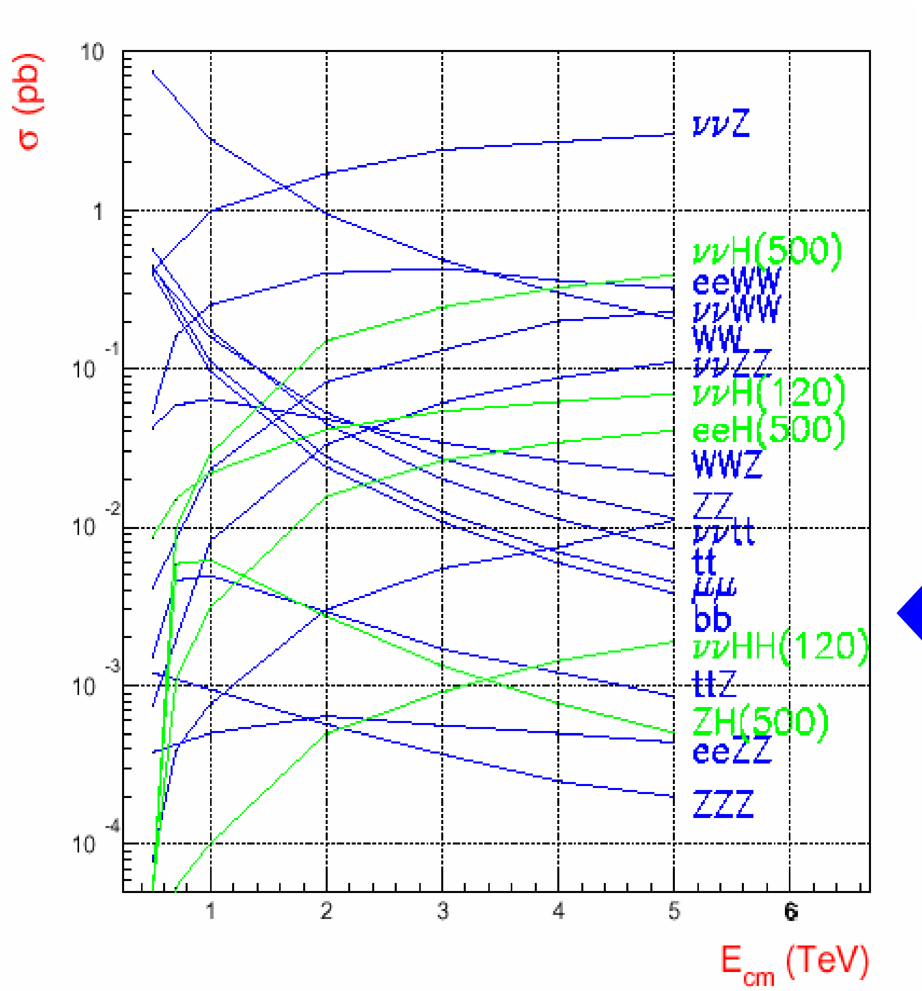


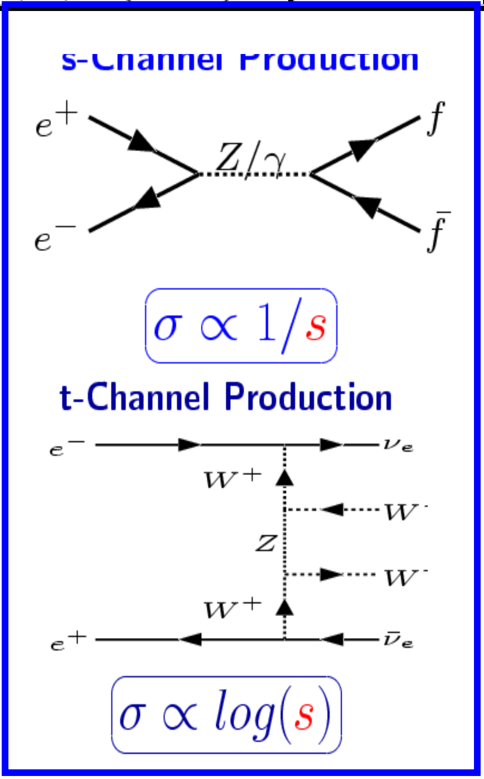
Energy (TeV)	0.5	1	3	5
L in 1% E_{cm}	71%	56%	30%	25%
L in 5% E_{cm}	87%	71%	42%	34%

Momentum spread after collision increases with colliding beam energy. Substantial luminosity from particles within small momentum spread.

Cross Sections at CLIC colliding beam energy range

Event Rates/Year (1000 fb^{-1})	3 TeV 10^3 events	5 TeV 10^3 events
$e^+e^- \to t\bar{t}$	20	7.3
$e^+e^- \to b\bar{b}$	11	3.8
$e^+e^- \to ZZ$	27	11
$e^+e^- \to WW$	490	205
$e^+e^- \to hZ/h\nu\nu$ (120 GeV)	1.4/530	0.5/690
$e^+e^- \to H^+H^-$(1 TeV)	1.5	0.95
$e^+e^- \to \tilde{\mu}^+\tilde{\mu}^-$ (1 TeV)	1.3	1.0





$\sigma \propto 1/s$

$\sigma \propto log(s)$