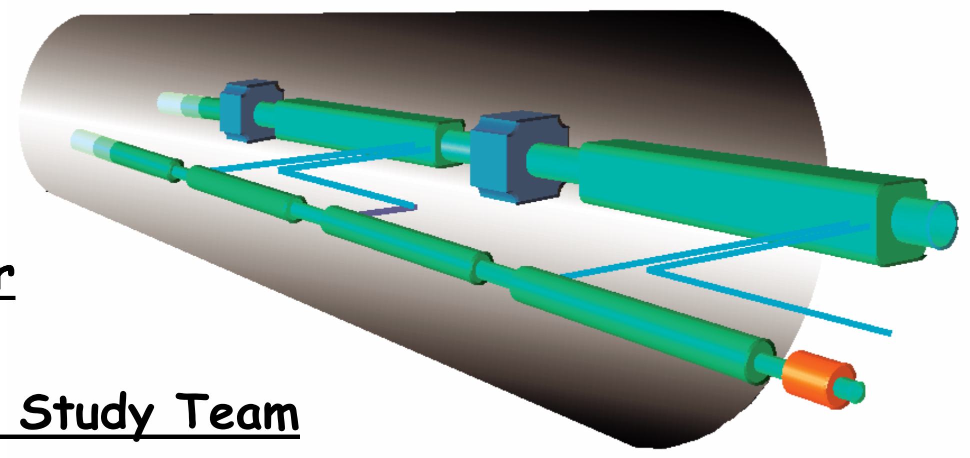
THE COMPACT LINEAR COLLIDER (CLIC) STUDY



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

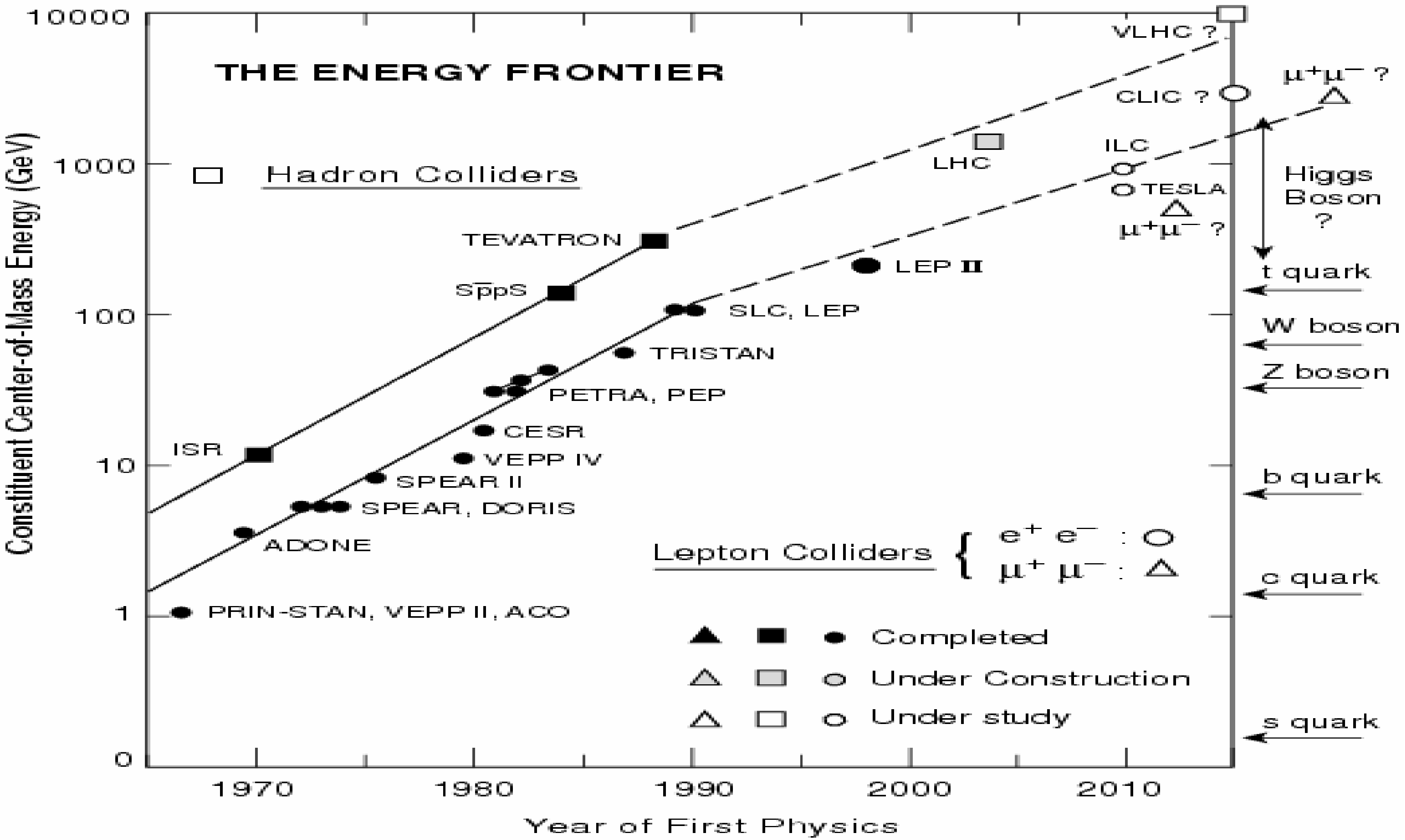
Outline

- Linear Colliders: The world landscape
- The CLIC scheme
- Main challenges of novel technology
- What has been achieved so far
- What remains to be demonstrated
- CTF3, the facility to address the key issues
- Plans and schedule
- Possible facilities at low energy
- Conclusion

World wide CLIC collaboration

- Ankhara University (Turkey): CTF3 beam studies & operation
- BERLIN Technical University (Germany): Structure simulations GdfidL
- BINP (Russia): CTF3 magnets development & construction
- CIEMAT (Spain): CTF3 kickers, septa, correctors & power supplies
- CERN (Switzerland): Study coord., Structures devel., CTF3 const.&com.
- DAPNIA (France): CTF3 probe beam generation, acceleration & meas.
- Finnish Industry (Finland): Sponsorship of a mechanical engineer
- INFN / LNF (Italy): CTF3 delay loop, transfer lines & RF deflectors
- JINR & IAP (Russia): Surface heating tests of 30 GHz structures
- KEK (Japan): Low emittance beams in ATF
- LAL (France): Electron guns and pre-buncher cavities for CTF3
- LAPP/ESIA (France): Stabilization studies
- LLBL/LBL (USA): Laser-wire studies
- North Western University (Illinois): Beam loss studies & CTF3 equipment
- RAL (England): Lasers for CTF3 and CLIC photo-injectors
- SLAC (USA): High Gradient Structure design&tests, CTF3 drive beam inj.
- UPPSALA University (Sweden): Beam monitoring systems for CTF3

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



Beam power radiation in storage ring

$$P_{Beam} = P_{Losses} + P_{Synchrotron\ Radiation}$$

$$P_{Synchrotron\ Radiation} = U_{SR}\, I_{beam}$$

with $U_{SR} = 4\pi/3\, r_e\, m_e\, c^2\, (\beta\gamma)^4 / \rho$: voltage by turn

$= 88.5\ \text{kV} \times E\ [\text{GeV}]^4 / \rho[\text{m}]$

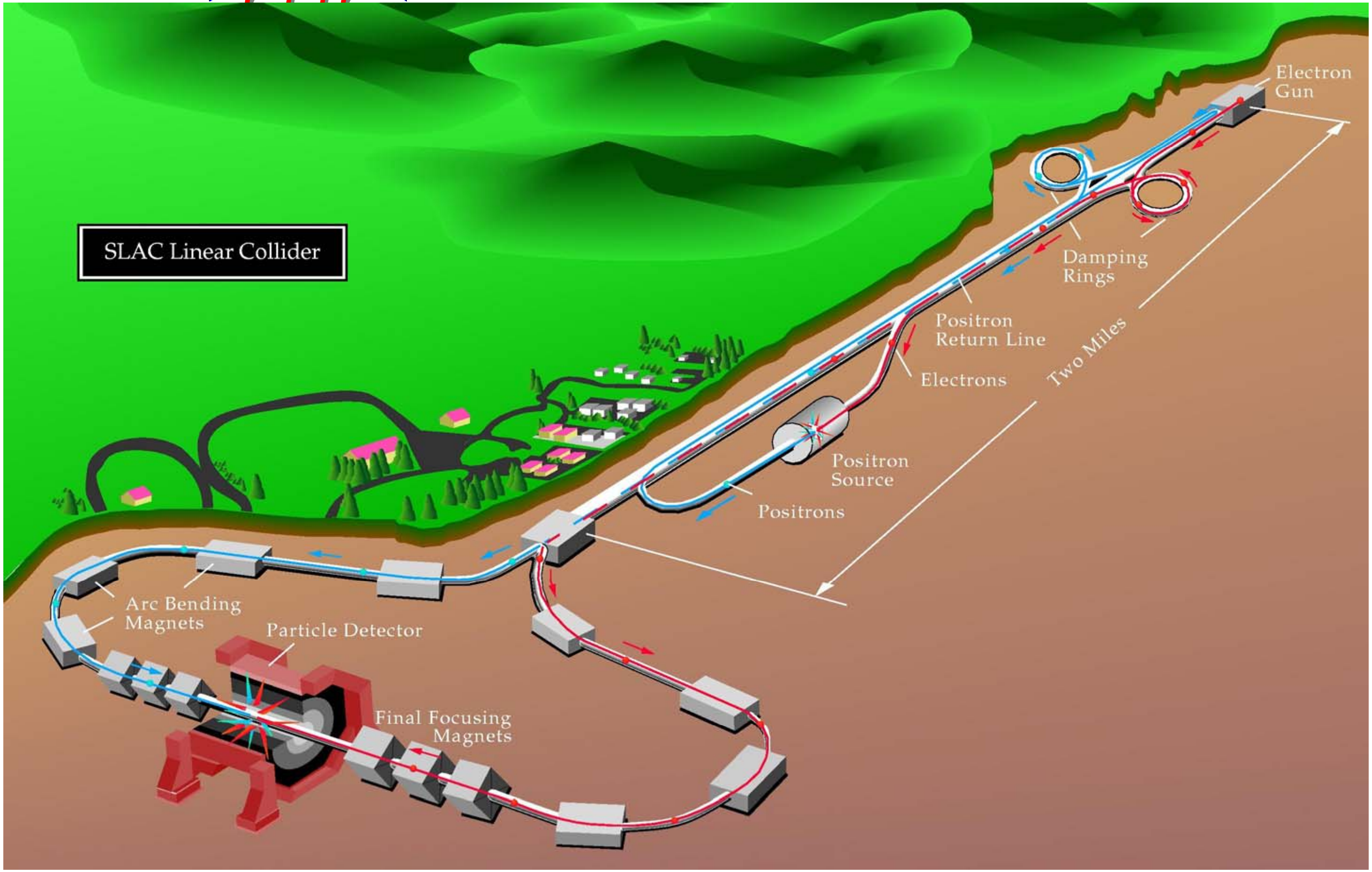
e.g. LEP: $\rho = 3096$ m, $I_{beam} = 2 \times 3$ mA, $L \approx 10^{31} \text{cm}^{-2}\text{s}^{-1}$

$\sqrt{s}$ [GeV]	100	200	500
U_{SR} [GV]	0.18	2.9	113
P_{SR} [MW]	1.1	17	664
P_{Losses} [MW]	16 Cu	~~190 Cu~~ 0.3 SC	11 SC

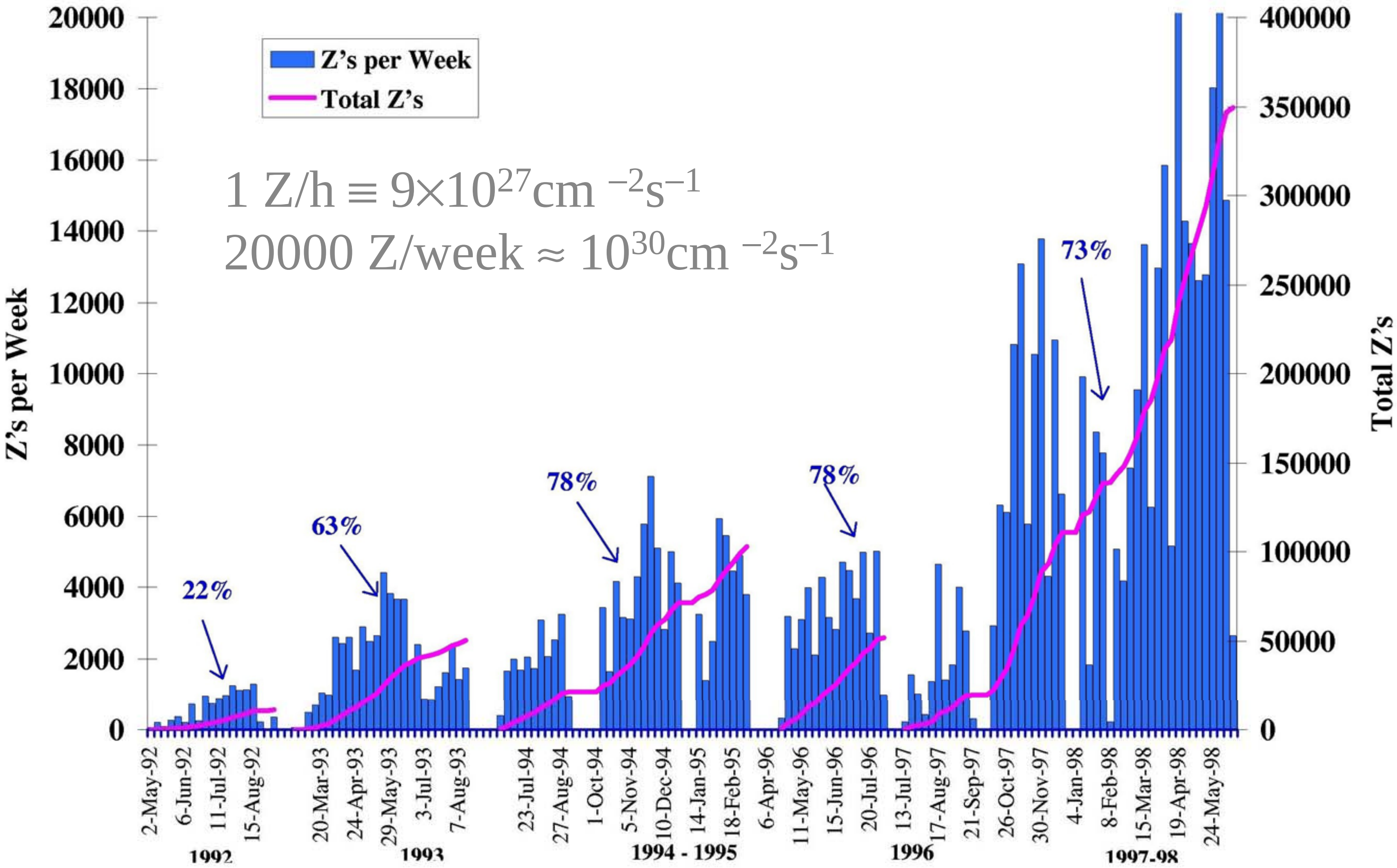
For comparison
Linear Collider
$L \approx 10^{34} \text{cm}^{-2}\text{s}^{-1}$
with
$P_{Beam} = 24$ MW

⇒ **Circular collider is too power consuming at high energy**

The LC's father: SLC @ SLAC



Luminosity in SLD (1992-1998)



CLIC

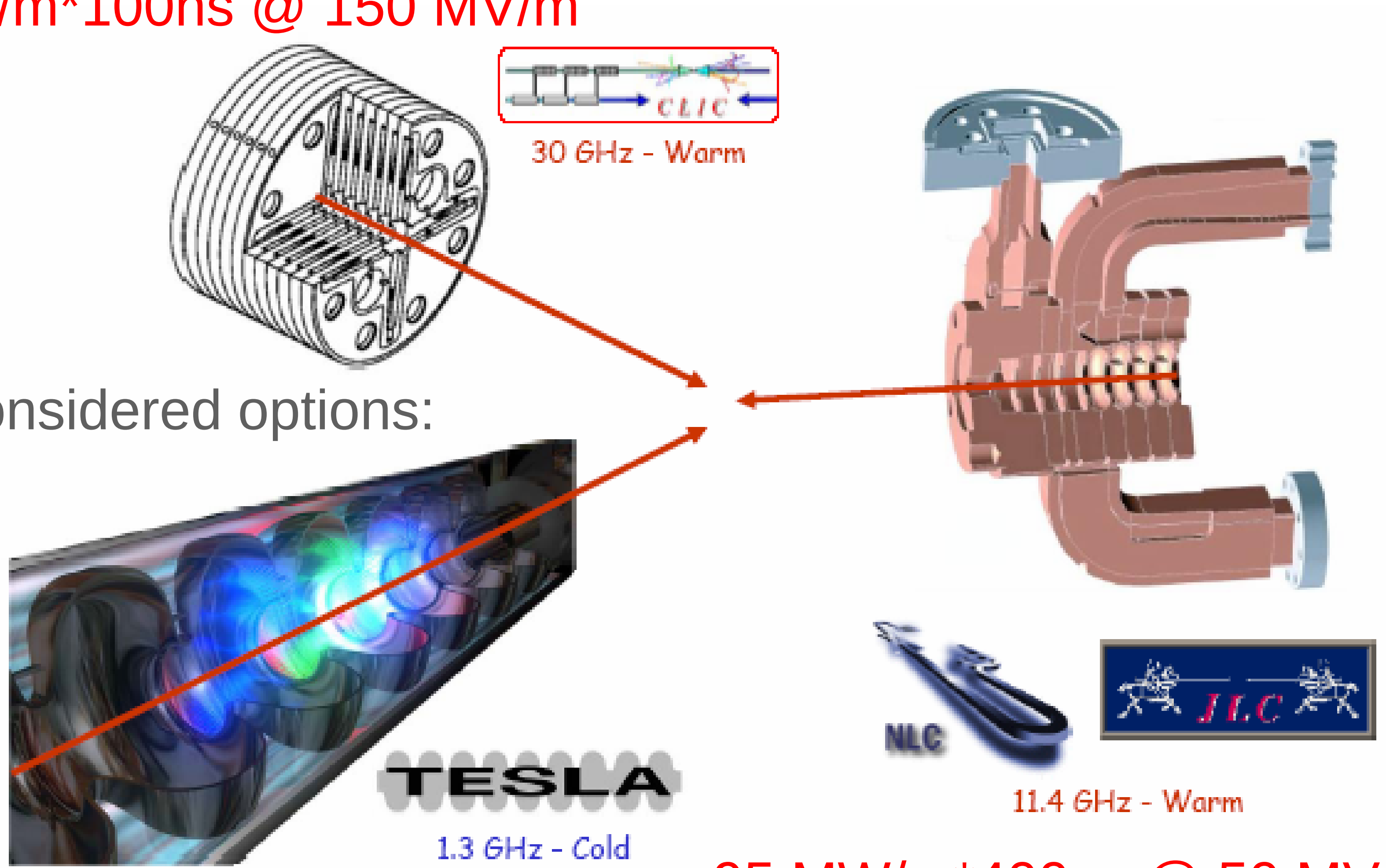
Broad range exploration of technologies (1988 - 2005)

500 GeV	TESLA	SBLC	JLC-S	JLC-C	JLC-X	NLC	VLEPP	CLIC
Techno.	Super Conduct	Norm Cond.	Norm. Cond.	Norm. Cond.	Norm. Cond.	Norm. Cond.	Norm. Cond.	Two Beams
f [GHz]	1.3	3.0	2.8	5.7	11.4	11.4	14.0	30.0
$L \times 10^{33}$ [$cm^{-2}s^{-1}$]	6	4	4	9	5	7	9	1-5
P_{beam} [MW]	16.5	7.3	1.3	4.3	3.2	4.2	2.4	~1-4
P_{AC} [MW]	164	139	118	209	114	103	57	100
$\gamma\varepsilon_y$ [$\times 10^{-8}$m]	100	50	4.8	4.8	4.8	5	7.5	15
σ_y^* [nm]	64	28	3	3	3	3.2	4	7.4

Internal Technology Review Panel (2001-2003)

350 MW/m*100ns @ 150 MV/m

The 3 considered options:



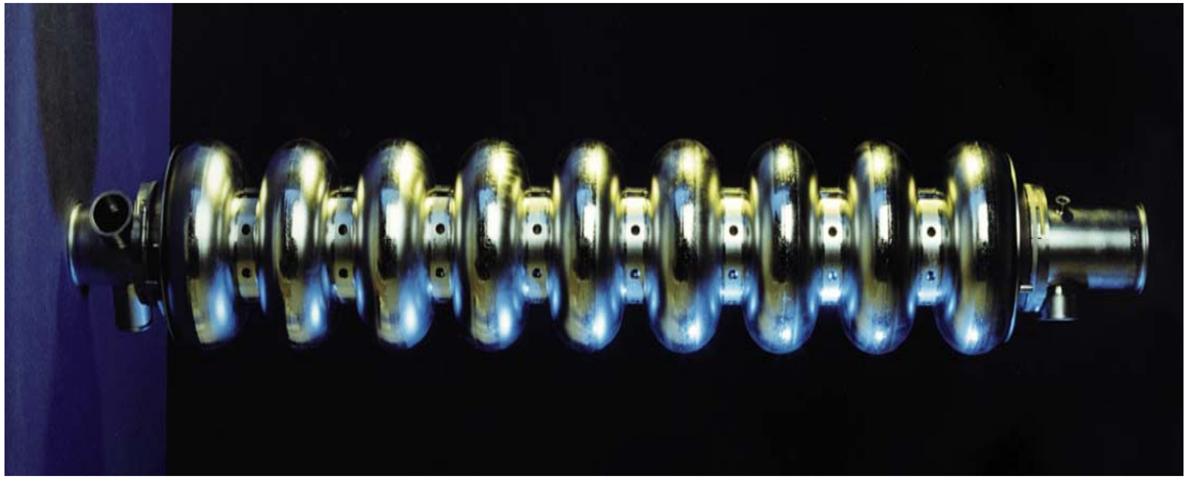
350 kW/m*1.3ms @ 35 MV/m

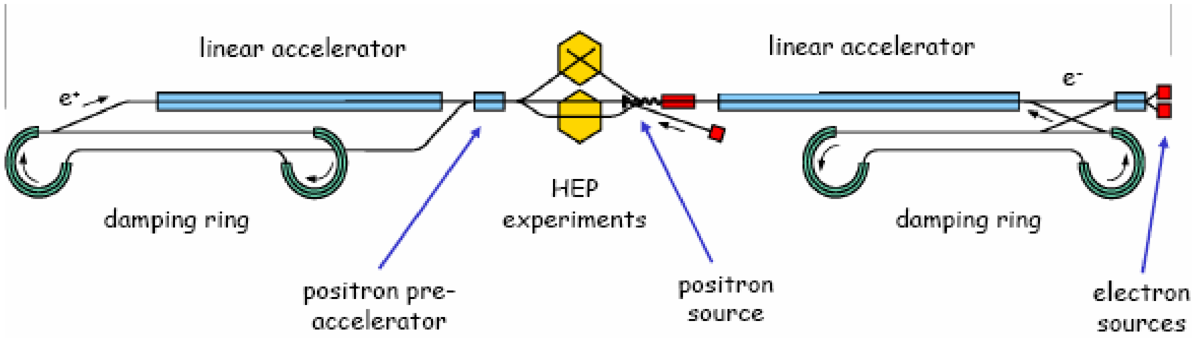
95 MW/m*400ns @ 50 MV/m

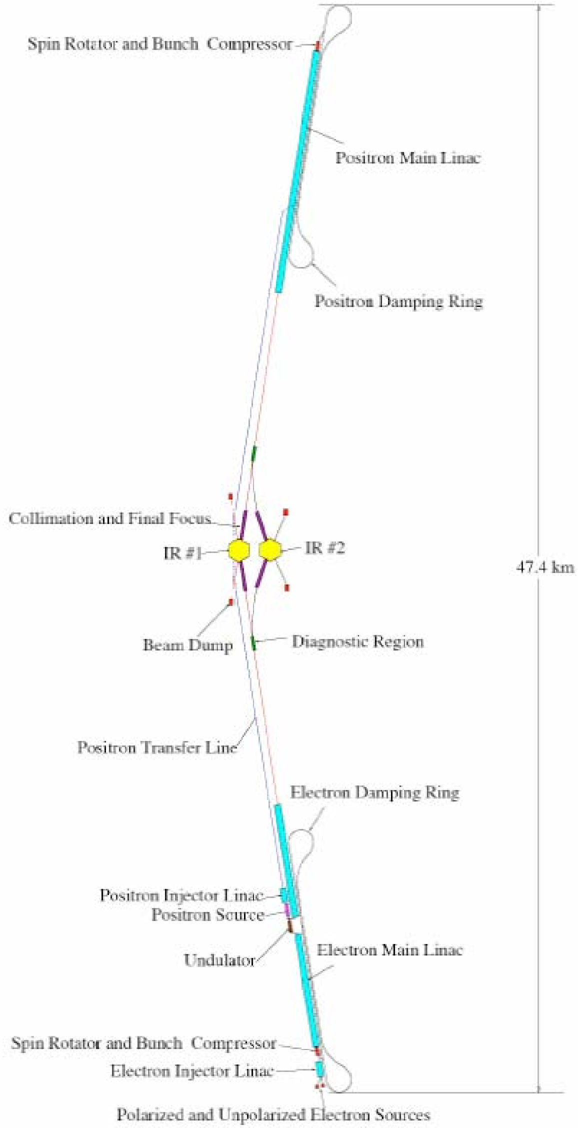
World consensus about a Linear Collider as the next HEP facility after LHC

- **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.

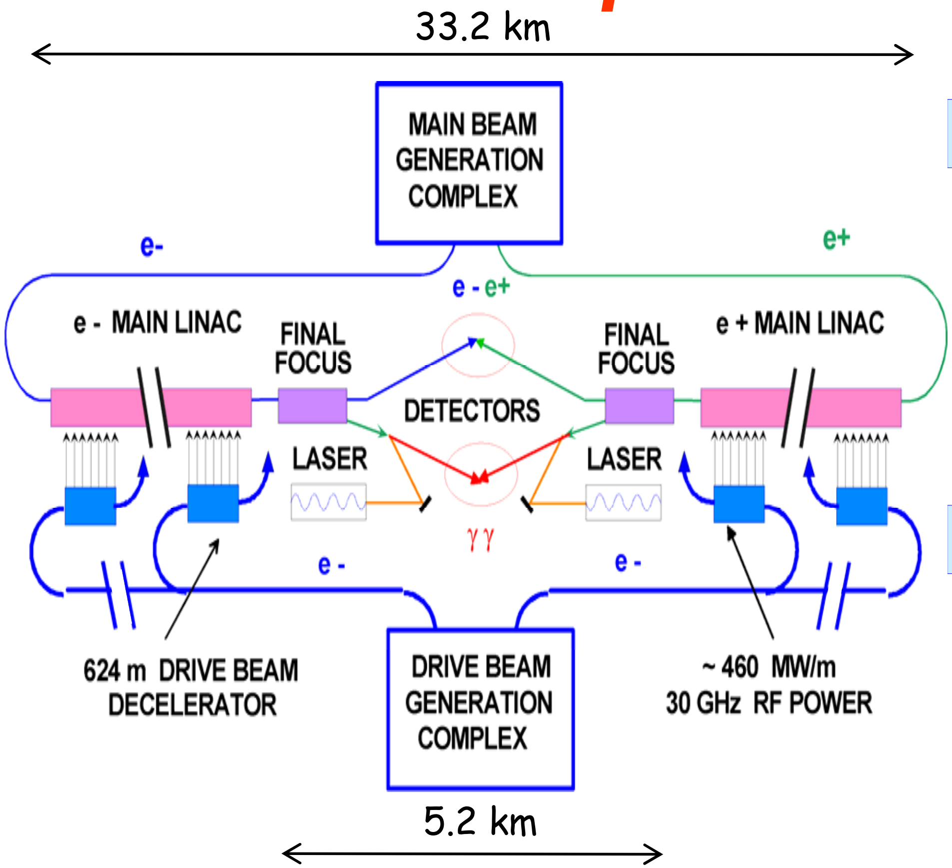
Super-conducting technology for TeV Linear Colliders (ILC)







CLIC technology for Multi-TeV Linear Colliders



Overall layout for a center of mass energy of 3 TeV/c

- High acceleration gradient (150 MV/m)

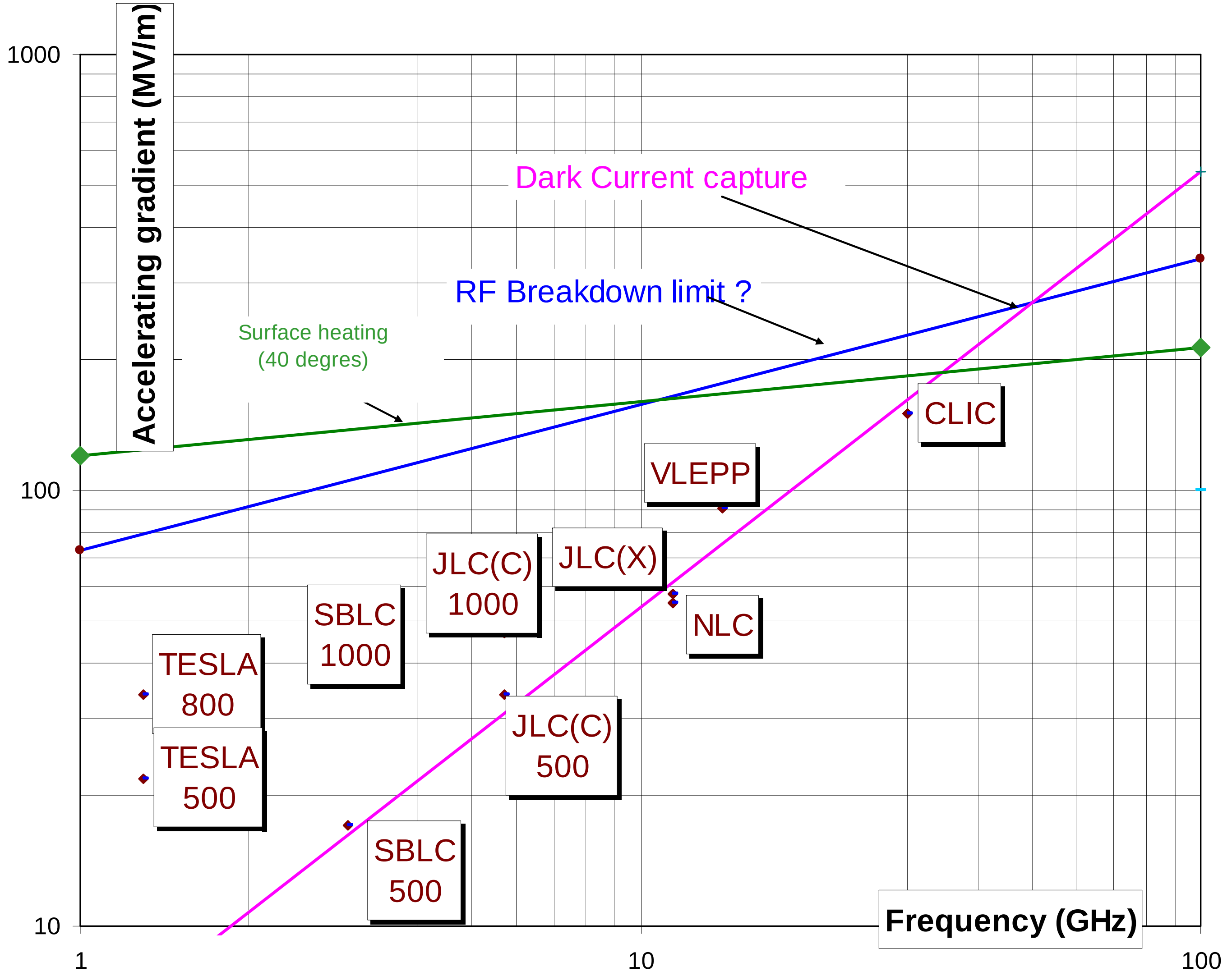
- "Compact" collider-overall length≈33 km
  - Normal conducting accelerating structures
  - High acceleration frequency (30 GHz)

- Two-Beam Acceleration Scheme

  - 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

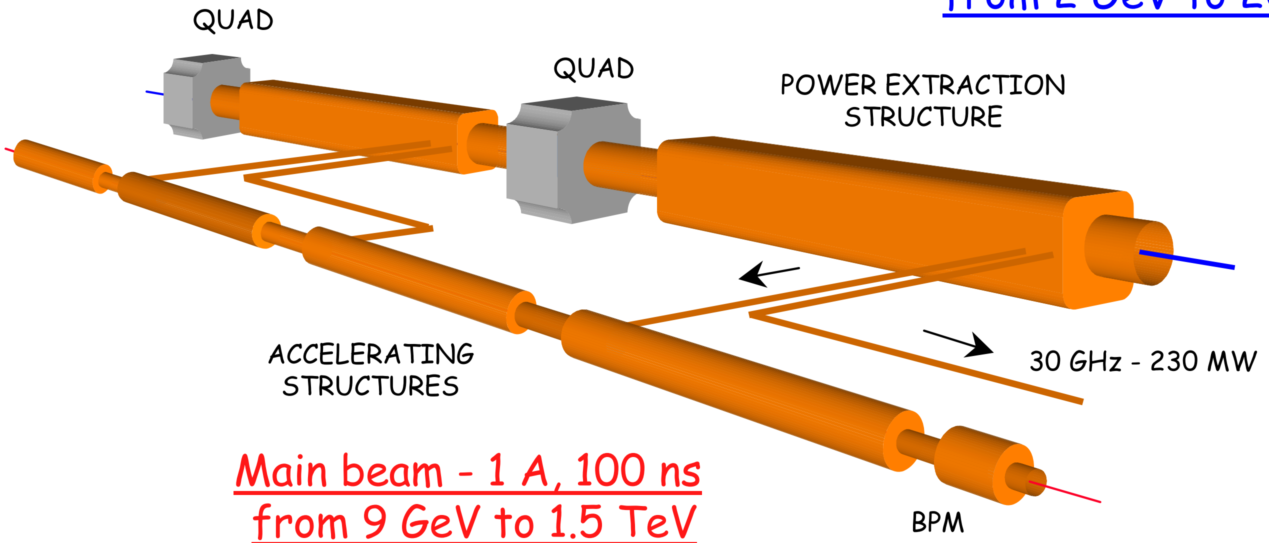
Accelerating Gradients

Loaded accelerating gradients in the TLC designs



CLIC Two-Beam scheme

Drive beam - 150 A, 130 ns
from 2 GeV to 200 MeV

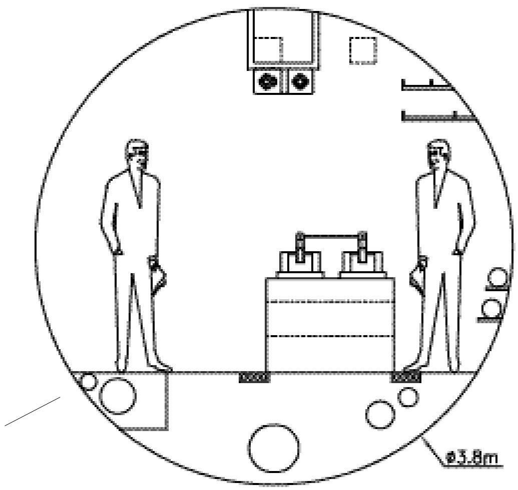


Main beam - 1 A, 100 ns
from 9 GeV to 1.5 TeV

CLIC MODULE

(6000 modules/linac at 3 TeV)

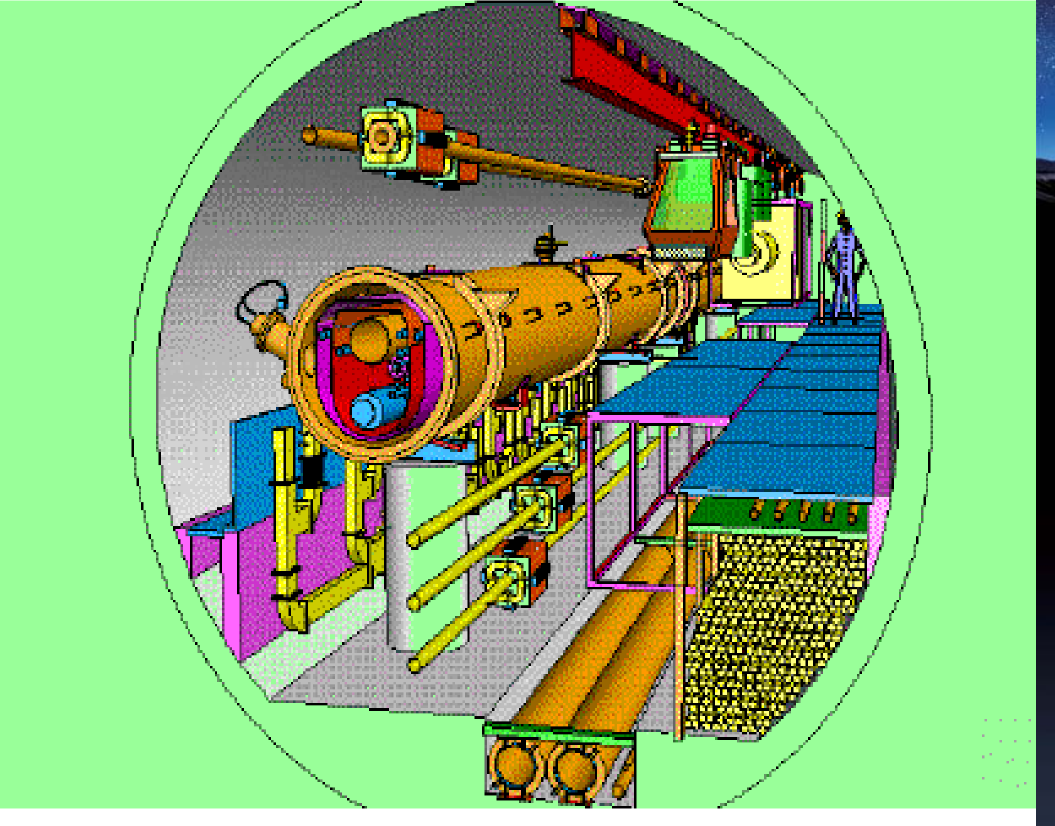
CLIC TUNNEL
CROSS-SECTION



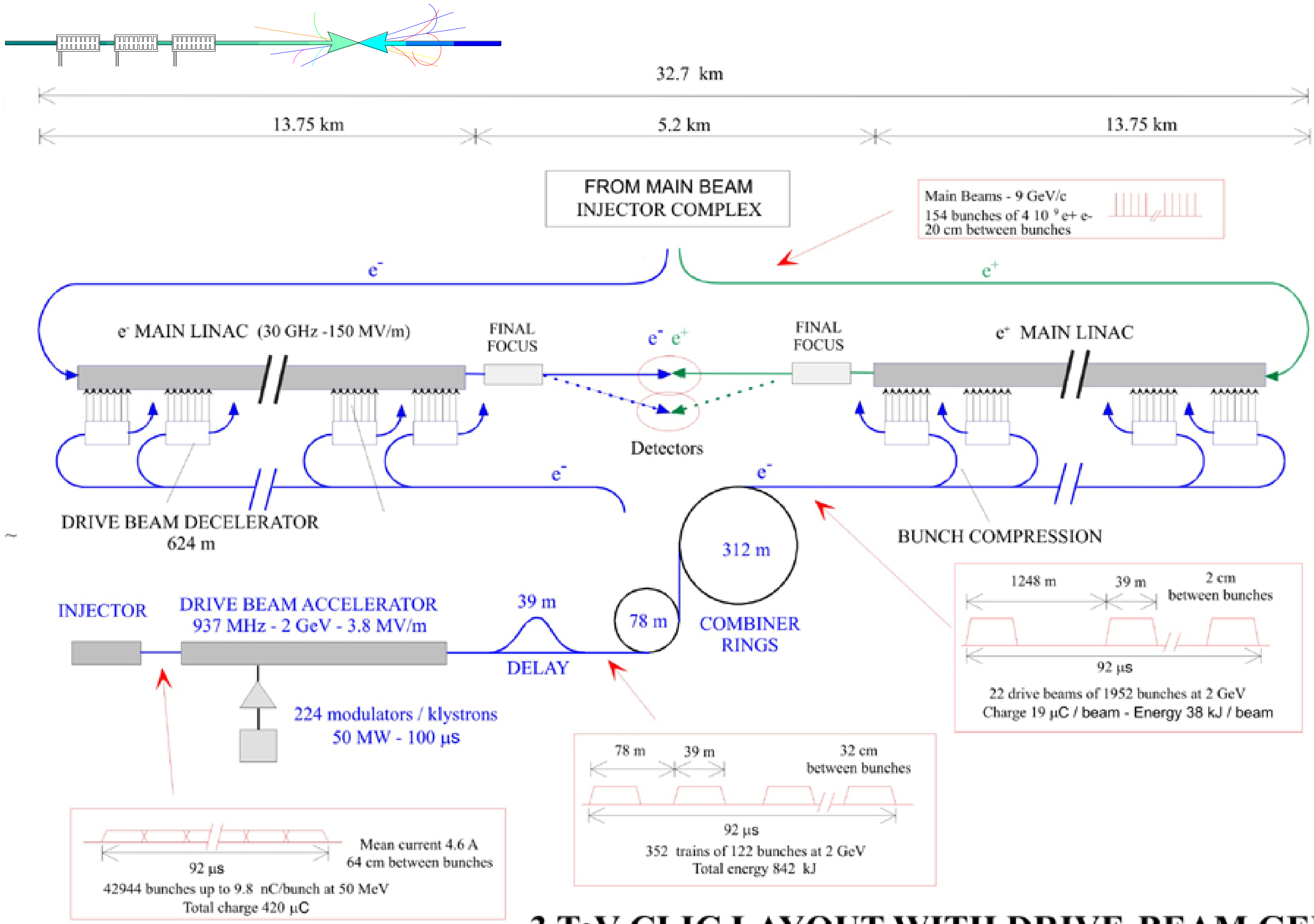
3.8 m diameter

TESLA & NLC TUNNELS

NLC TUNNEL
CROSS-SECTION



TESLA TUNNEL
CROSS-SECTION

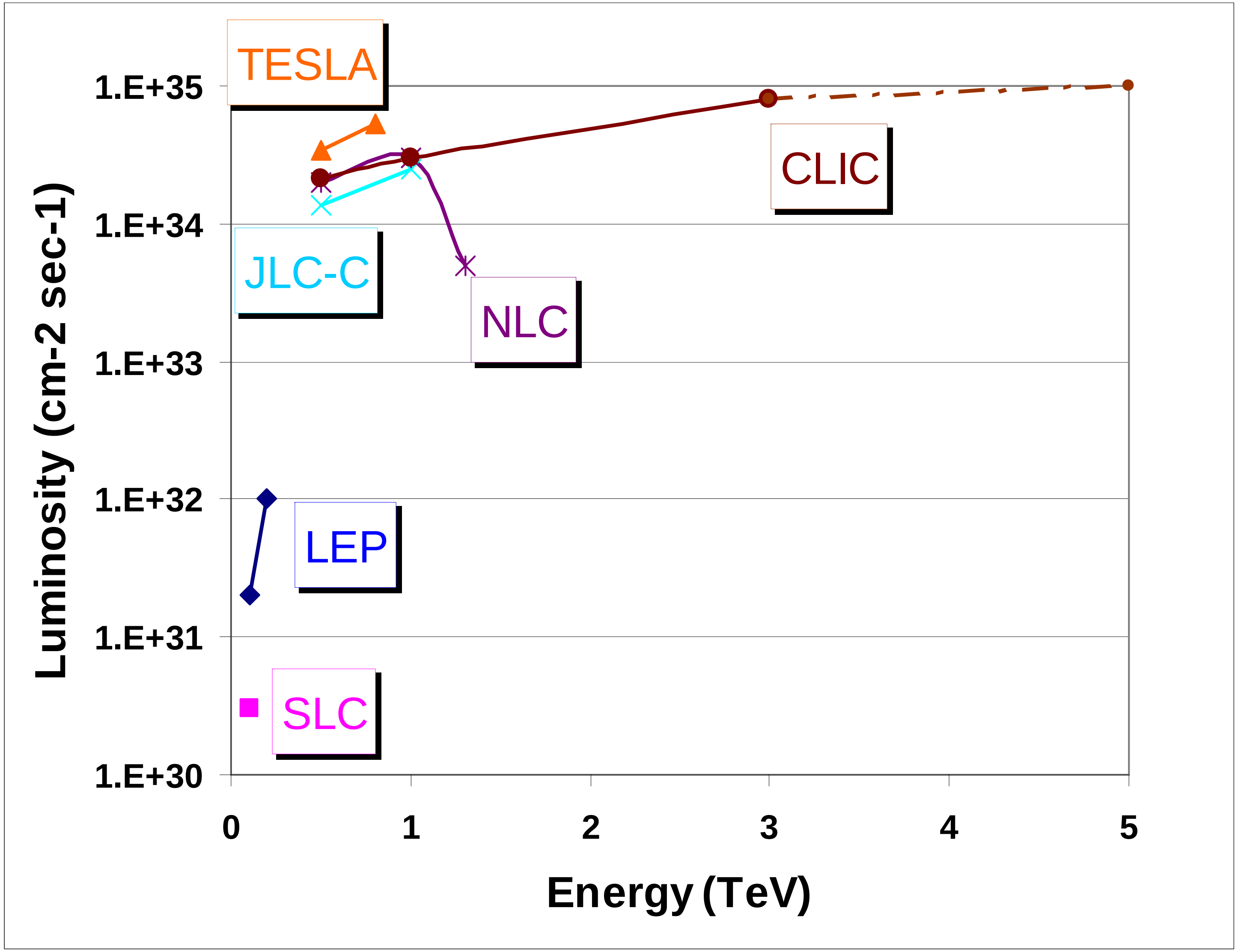


3 TeV CLIC LAYOUT WITH DRIVE-BEAM GENERATION

The CLIC main parameters

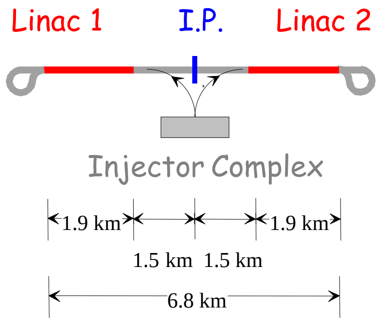
Center of mass Energy (TeV)	0.5 TeV	3 TeV
Luminosity (10^{34} $cm^{-1}s^{-1}$)	2.1	8.0
Mean energy loss (%)	4.4	21
Photons / electron	0.75	1.5
Coherent pairs per X	700	6.8 10^8
Rep. Rate (Hz)	200	100
10^9 $e^{\pm}$ / bunch	4	4
Bunches / pulse	154	154
Bunch spacing (cm)	20	20
H/V ε_n (10^{-8} rad.m)	200/1	68/1
Beam size (H/V) (nm)	202/1.2	60/0.7
Bunch length (µm)	35	35
Accelerating gradient (MV/m)	150	150
Overall length (km)	7.7	33.2
Power / section (MW)	230	230
RF to beam efficiency (%)	23.1	23.1
AC to beam efficiency (%)	9.3	9.3
Total AC power for RF (MW)	105	319
Total site AC power (MW)	175	410

Performances of Lepton Colliders

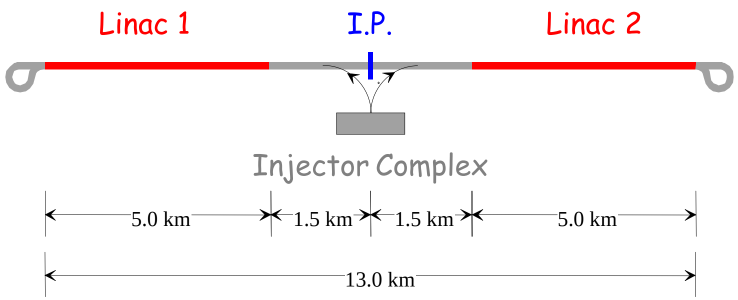


CLIC Layout at various energies

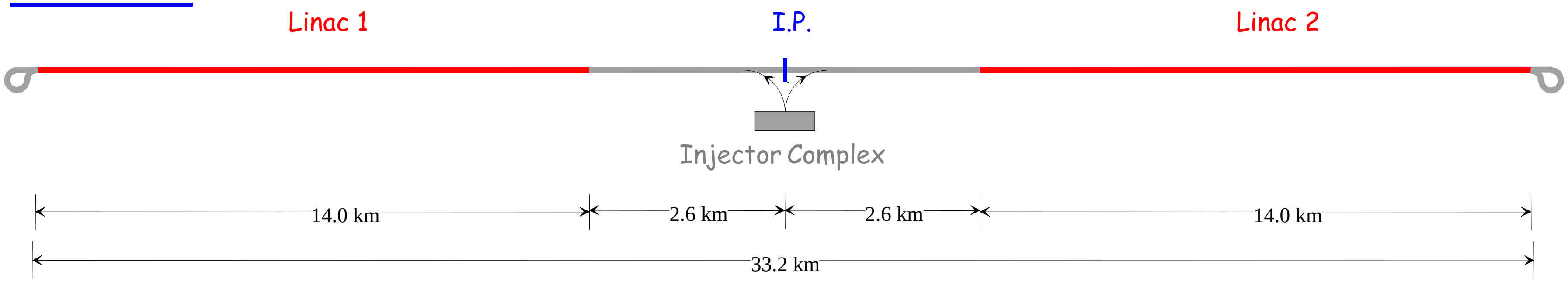
0.42 TeV Stage



1 TeV Stage



3 TeV Stage



Luminosity Scaling

Scaling laws for e+/e- Linear Colliders

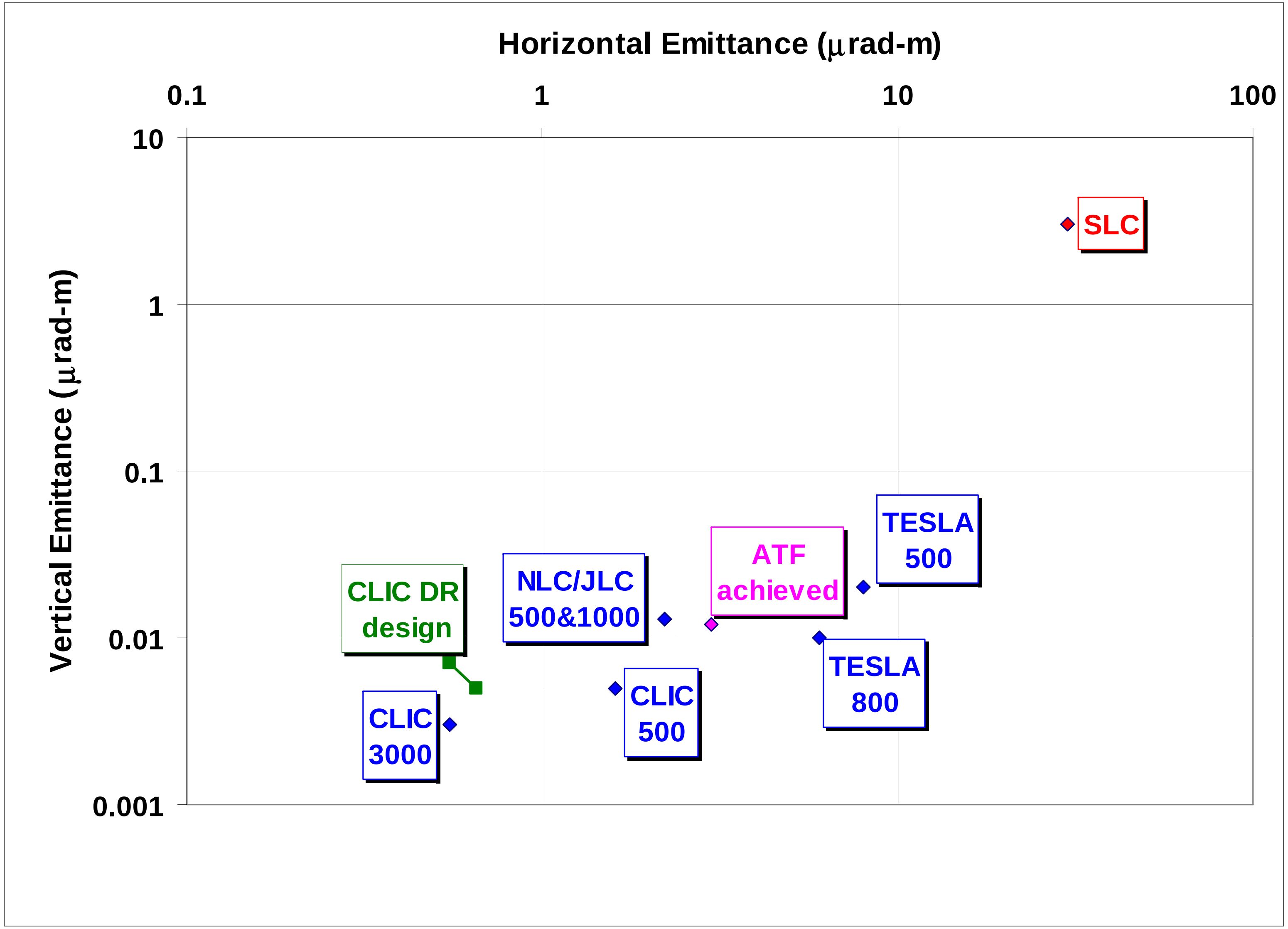
(J.P.Delahaye et al: NIM A421-1999-p 369-405)

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

- δ_B: energy loss by beamstrahlung
- η_{beam}^{AC}: wall-plug to beam efficiency
- P_{AC}: wall-plug power
- U_{cm}: center-of-mass energy
- ε_{ny}^*: Vertical emittance

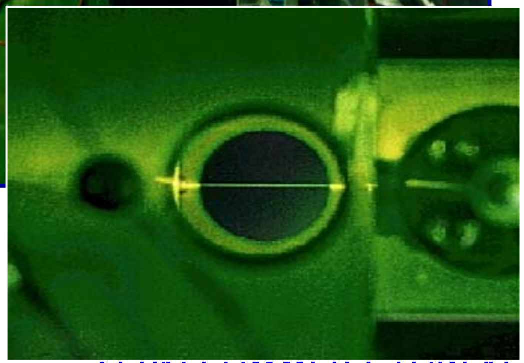
- **Vertical beam emittance** at I.P. as small as possible
- **Wall-plug to beam efficiency** as high as possible
- **Beamstrahlung energy spread** increasing with c.m. colliding energies

Beam emittances at Damping Rings

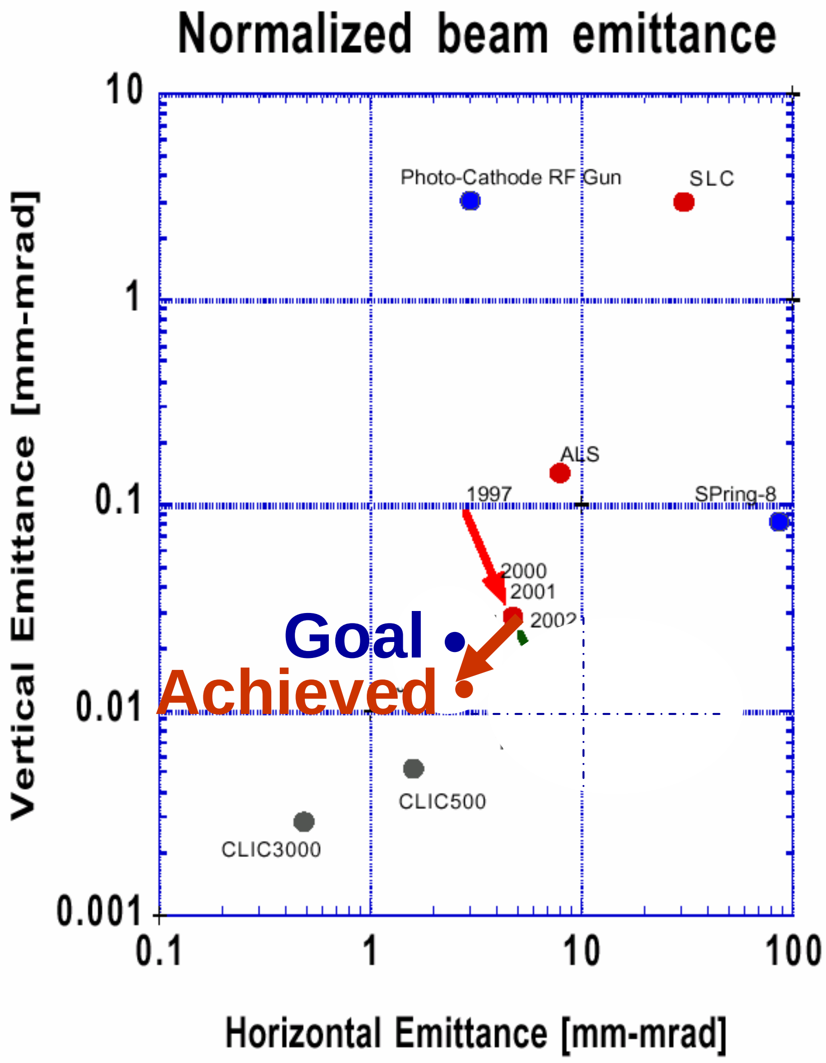


Ultra low beam emittances achieved at ATF Damping Ring (KEK)

SLAC and KEK physicists survey ring



"Laser Wire"



Required and achieved magnet stability

CLIC

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

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

Need active damping of vibrations

Achieved stability

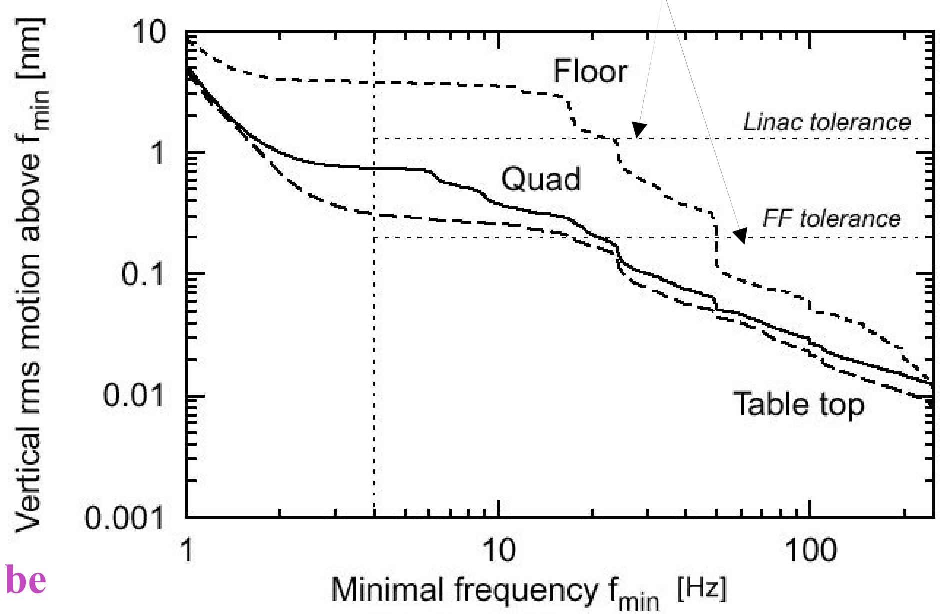
on CERN vibration test stand

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

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

Horiz. 0.4 ± 0.1 nm

CLIC tolerances

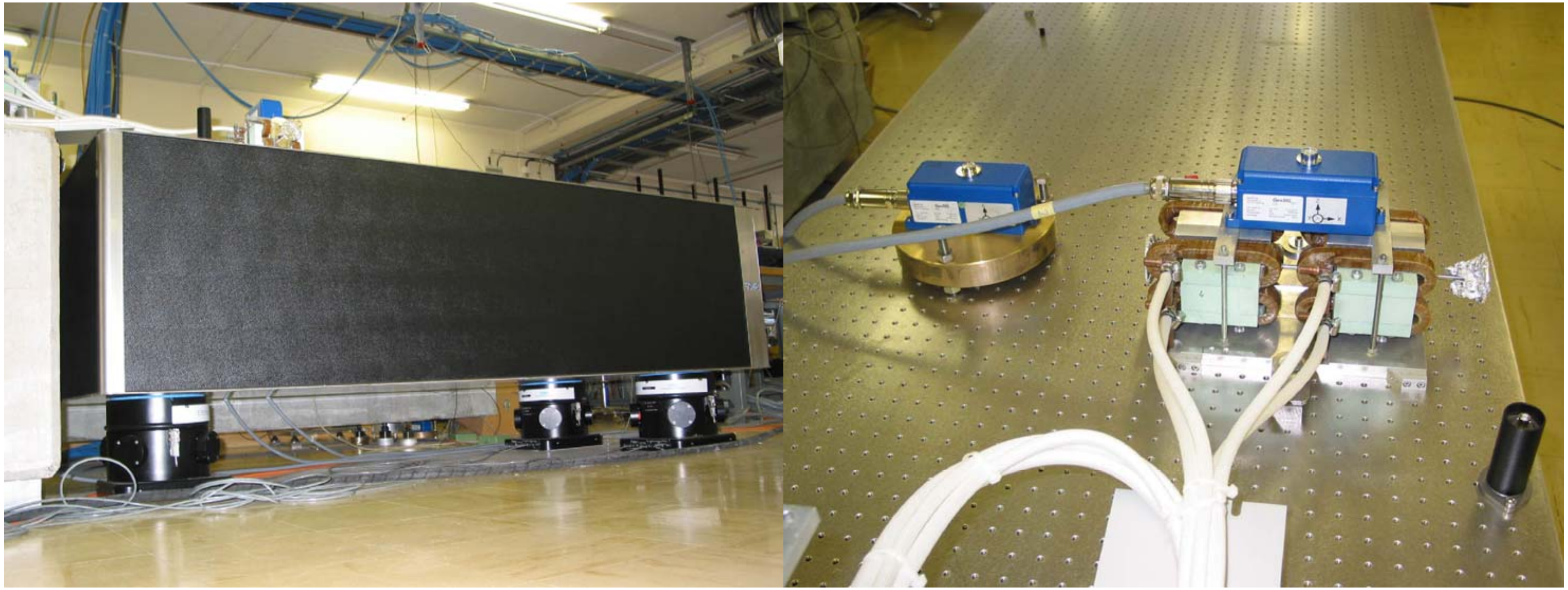


Big step towards believing that nanobeams can be made colliding on sites with CERN-like stability

Nanometer stabilisation

Latest stabilization technology applied to the accelerator field

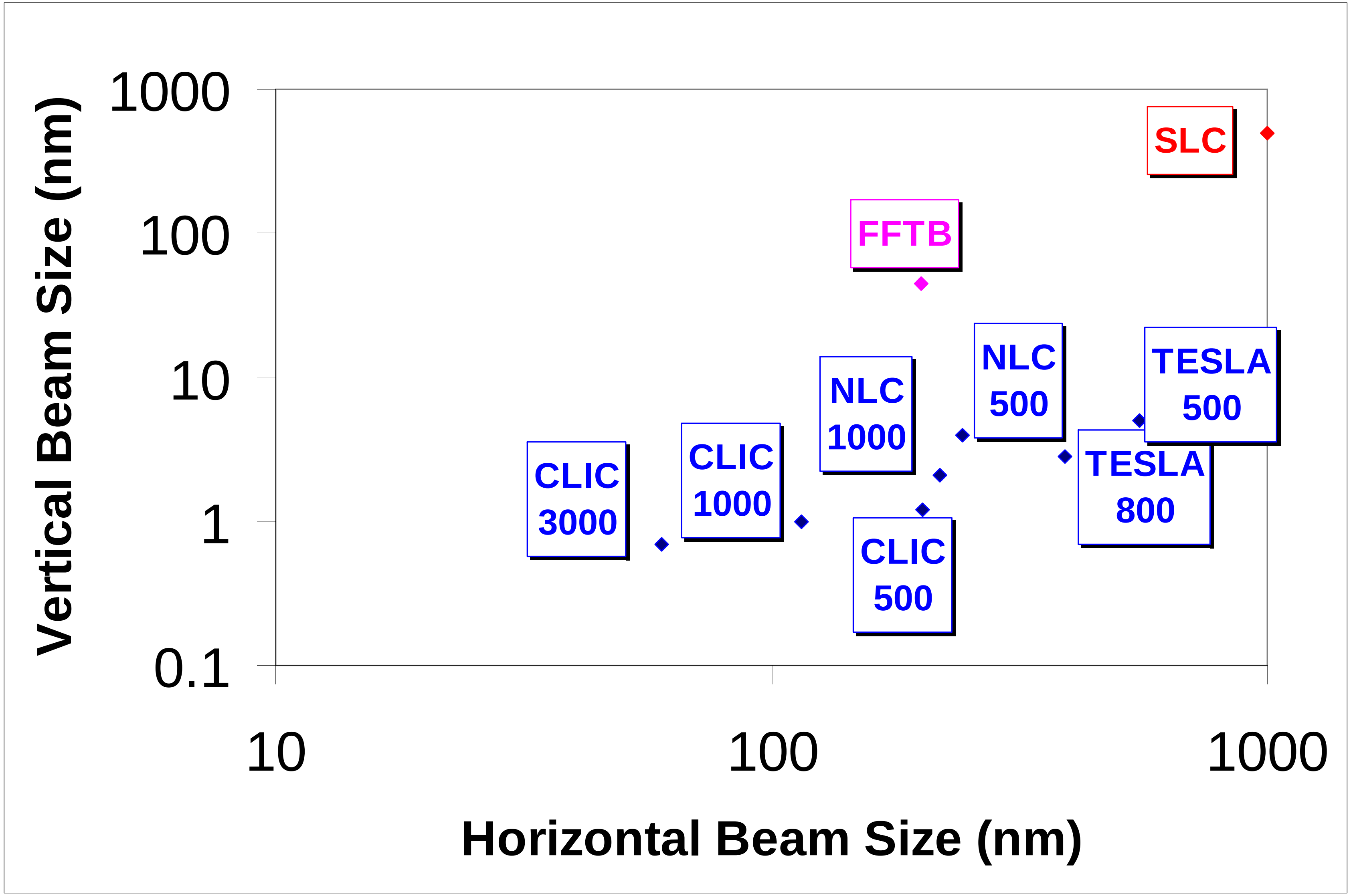
The most stable place on earth!!!



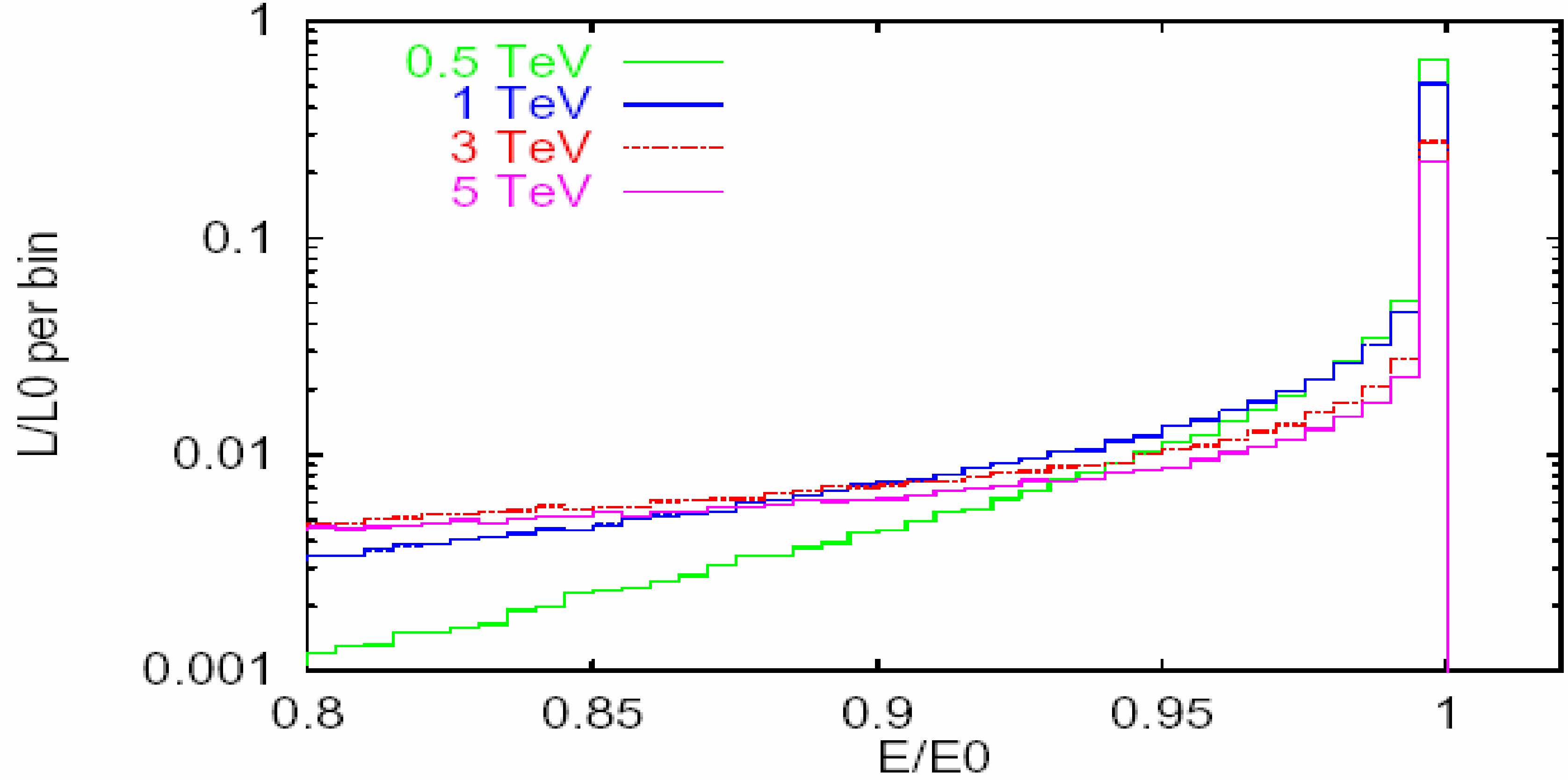
Stabilizing quadrupoles to the **0.5 nm** level!

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

Beam sizes at Collisions



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.

CLIC PHYSICS STUDY GROUP
(Convener: A.De Roeck)

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

The CLIC main challenges

COMMON TO MULTI-TEV LINEAR COLLIDERS

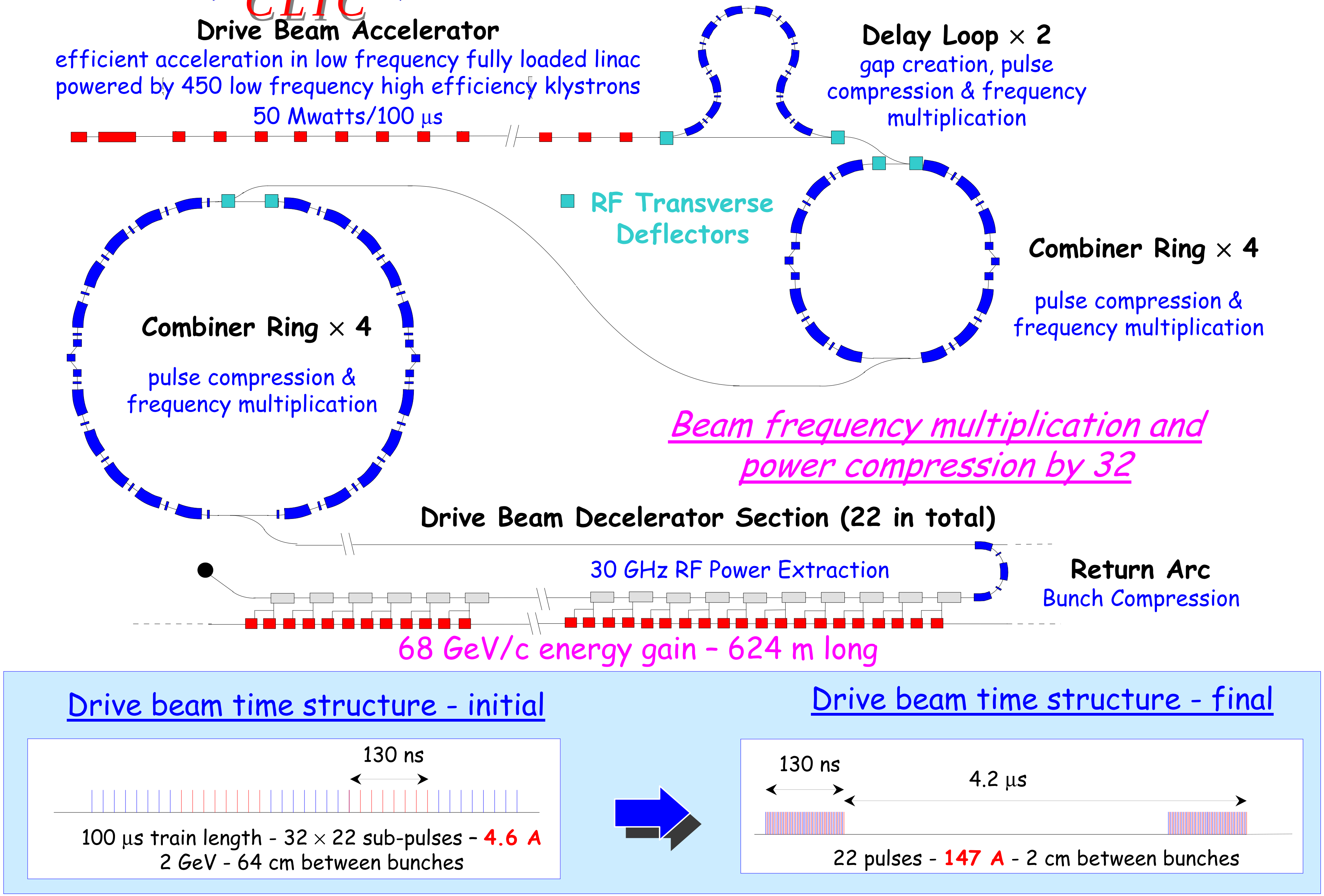
- Accelerating gradient *
- Generation and preservation of ultra-low emittance beams
- Beam Delivery & IP issues:
  - **nanometer size beams**
  - **Sub-nanometer component stabilisation** *
- Physics with colliding beams in high beamstrahlung regime

SPECIFIC TO THE CLIC TECHNOLOGY

- 30 GHz components with manageable wakefields*
- Efficient RF power production by Two Beam Acceleration *
- Operability at high power (beam losses) and linac environment* (RF switch)

* ⇒ addressed in Test Facilities

The CLIC RF Power Source



What does the RF power Source do?

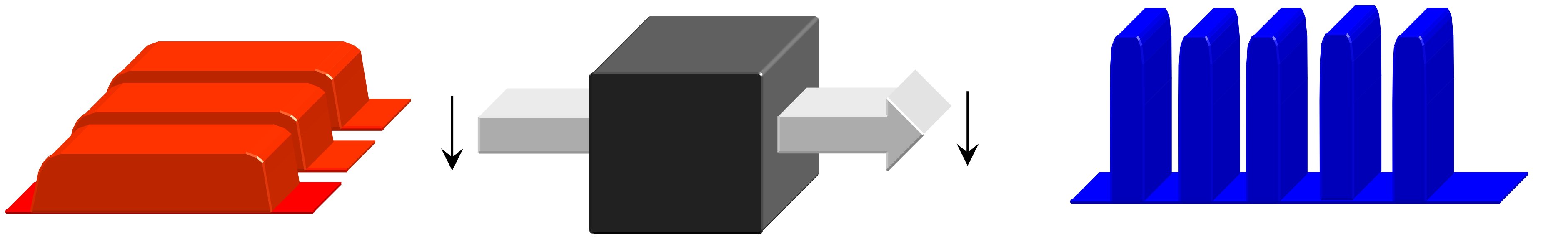
The CLIC RF power source can be described as a "black box", combining *very long RF pulses*, and transforming them in *many short pulses*, with *higher power* and with *higher frequency*

450 MBK Klystrons
Low frequency
High efficiency

Power stored in electron beam

Power extracted from beam in resonant structures

43000
Accelerating Structures
High Frequency – High field

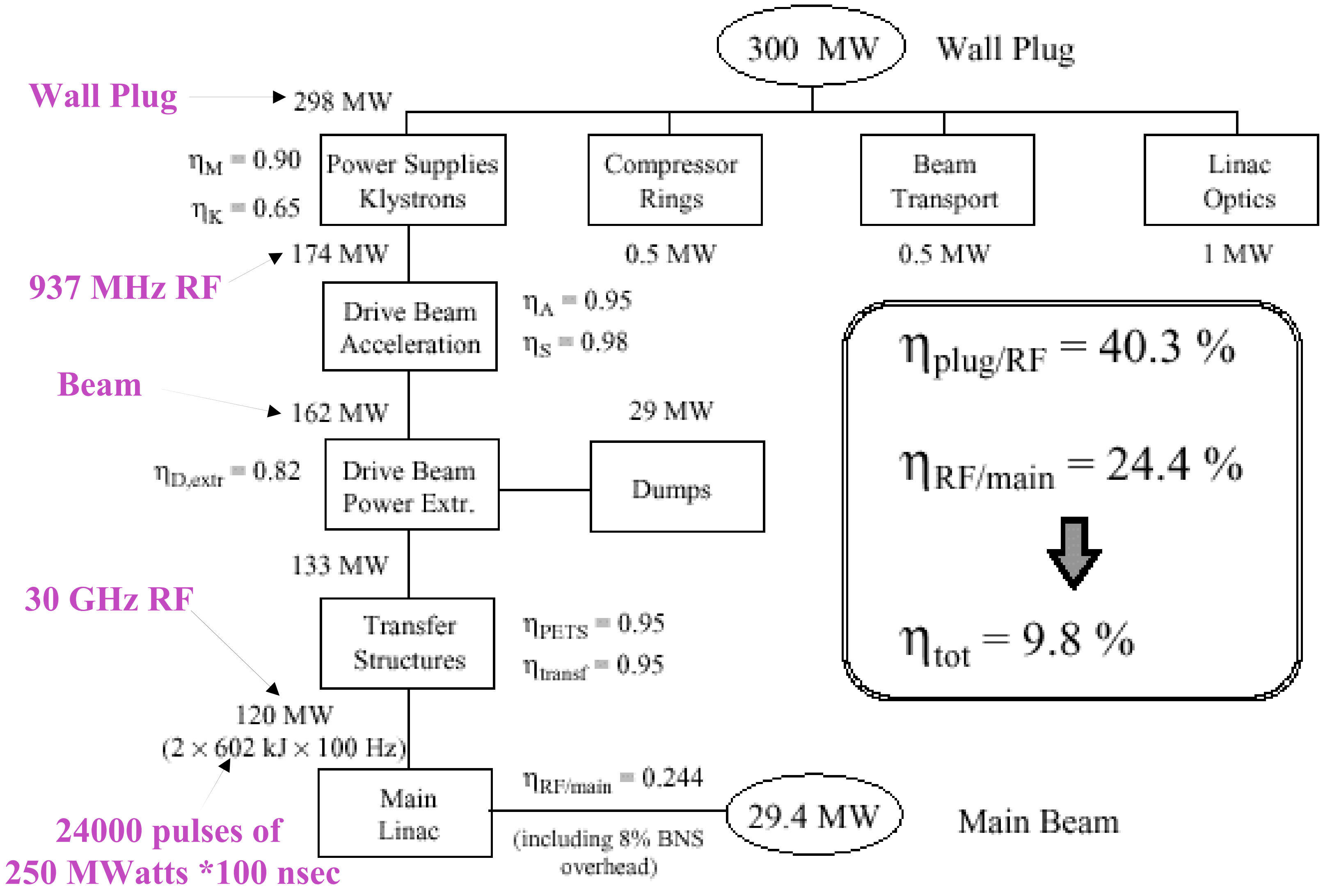


Long RF Pulses
P_0 , ν_0 , τ_0

Electron beam manipulation
Power compression
Frequency multiplication

Short RF Pulses
$P_A = P_0 \times N_1$
$\tau_A = \tau_0 / N_2$
$\nu_A = \nu_0 \times N_3$

Power flow from the grid to the beam



Improving the efficiency

CLIC

Wall Plug & 30 GHz RF power in CLIC

Wall plug: 300 MW

1 GHz Klystron: 65%
&
Modulator: 90%

30 GHz: 120 MW

New klystron development

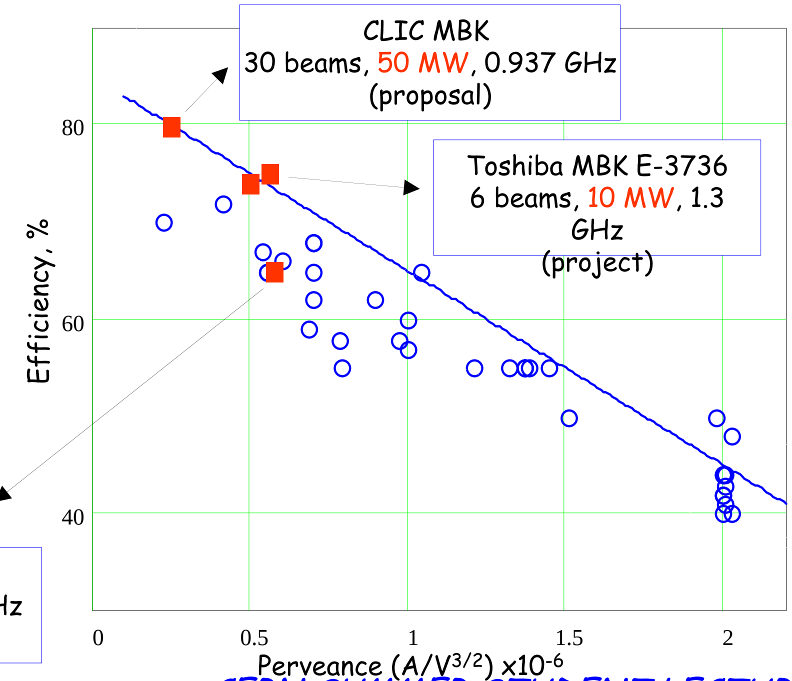
drive beam acceleration, manipulation & 30 GHZ RF power extraction

Wall plug: 230 MW

1 GHz Klystron: 80%
&
Modulator: 95%

30 GHz: 120 MW

Thales MBK TH1801
6 beams, 10 MW, 1.3 GHz
(measured)



Why Multi Beam?

- Low perveance ($A/V^{3/2}$) favor klystron efficiency.
- Multi Beam devices keep single beam perveance small to provide high efficiencies for high RF power output (tens of MW).

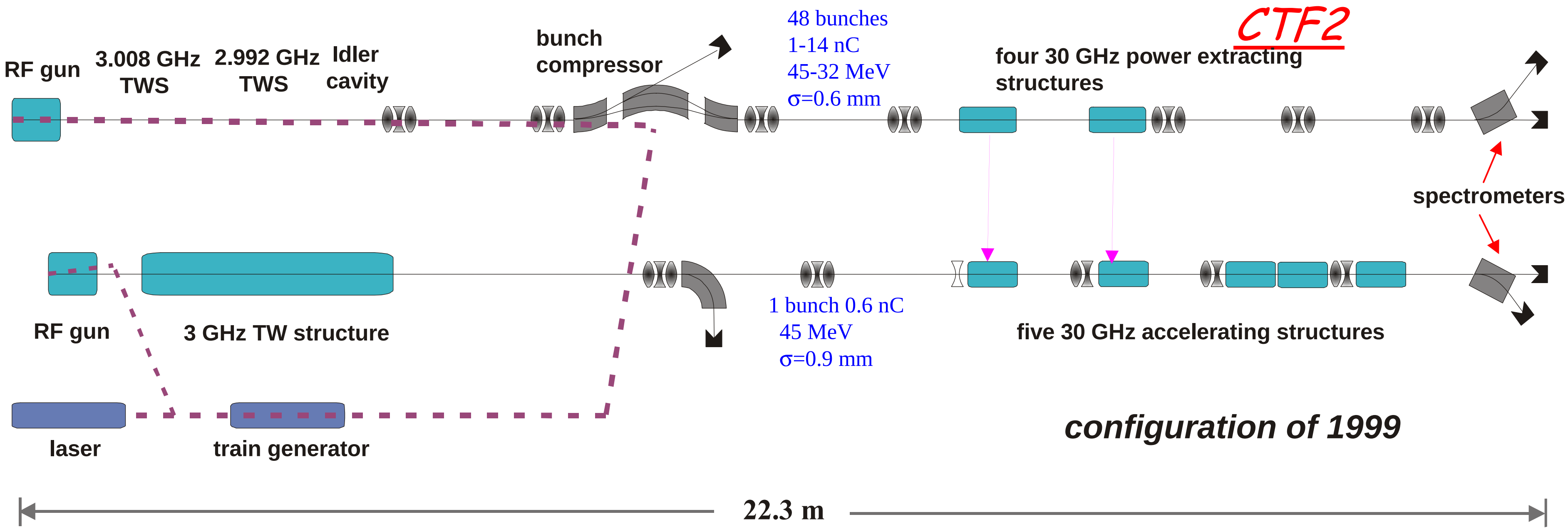
State-of-the-art klystron efficiencies vs. perveance for
single beam ○
multi-beam ■

CLIC Test Facility (CTF2) 1996-2002

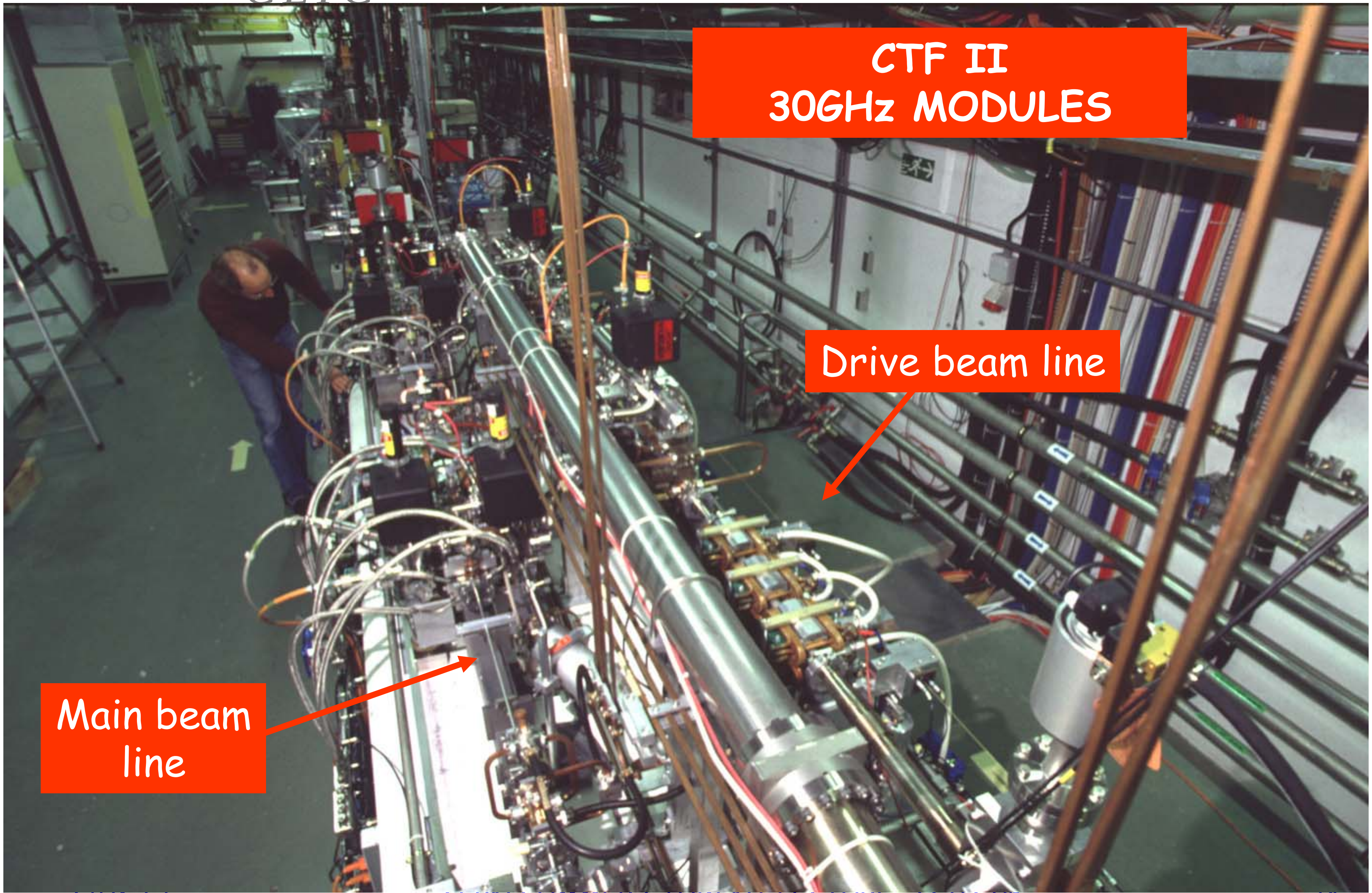
CTF2 goals :

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

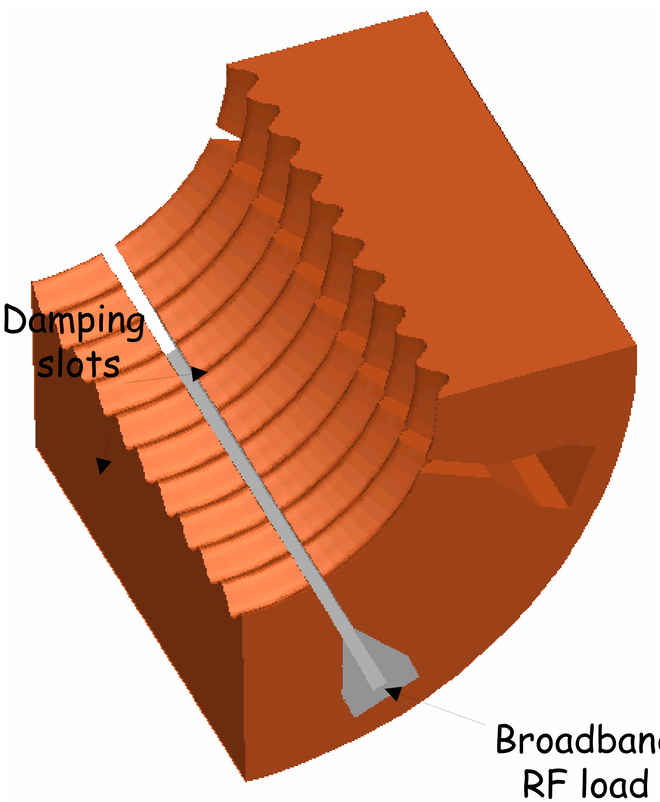
All-but-one of 30 GHz two-beam modules removed in 2000 to create a high-gradient test stand.



Two Beams set-up in CTF2



Power ExTraction Structure (PETS)



Quarter geometry of C-PETS

- Circularly-symmetric
- Large aperture (25 mm)
- Very shallow sinus-type corrugations
- Eight 1 mm-wide damping slots

Table 1. Parameters of the C-PETS.

Beam chamber diameter, mm	25
Synch. mode frequency, GHz	29.9855
Synch. mode β_g	0.85 c
Synch. mode R'/Q, Ω/m	244
Synch. mode Q-factor	12000
Peak transverse wakefield V/pC/m/mm	0.83
Transverse mode Q-factor (damped)	< 50

80 cm length of this structure produces about **560 MW** of 30 GHz RF power ⇒ enough to drive two CLIC accelerating structures

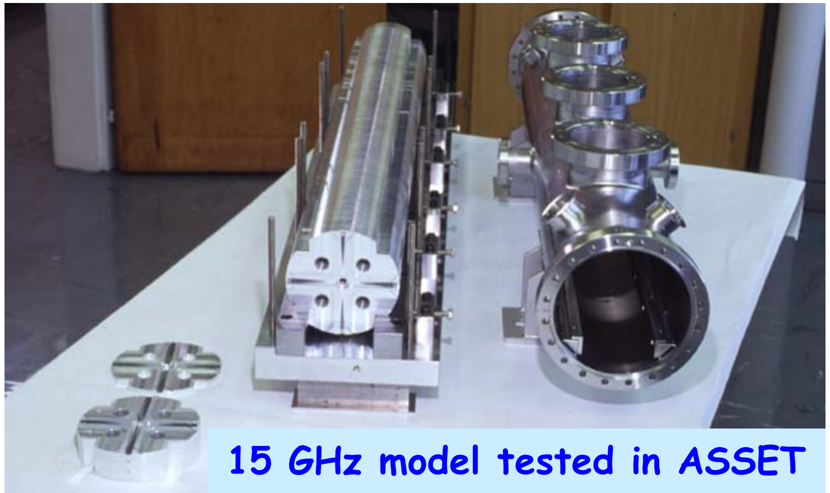
Accelerating structure developments

CLIC

CONTROL OF TRANSVERSE WAKEFIELDS

- short-range wakes ⇐ BNS damping
- long-range wakes ⇐ damping and detuning

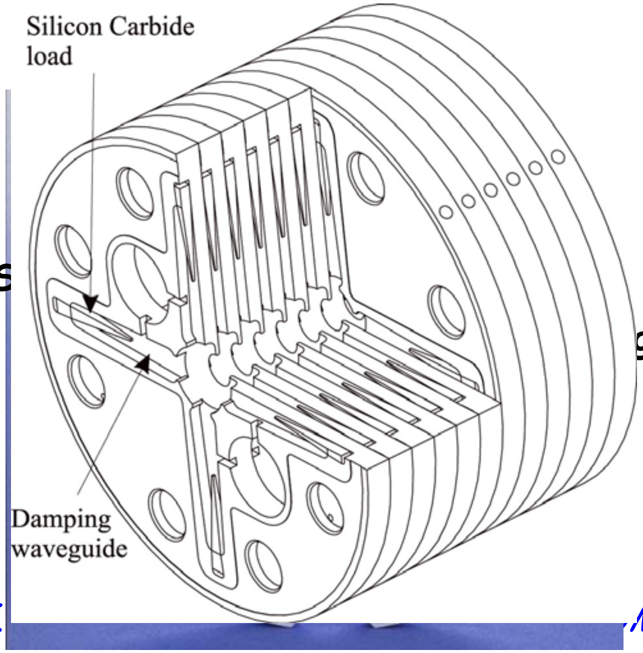
+ beam-based trajectory correction, ε bump



15 GHz model tested in ASSET

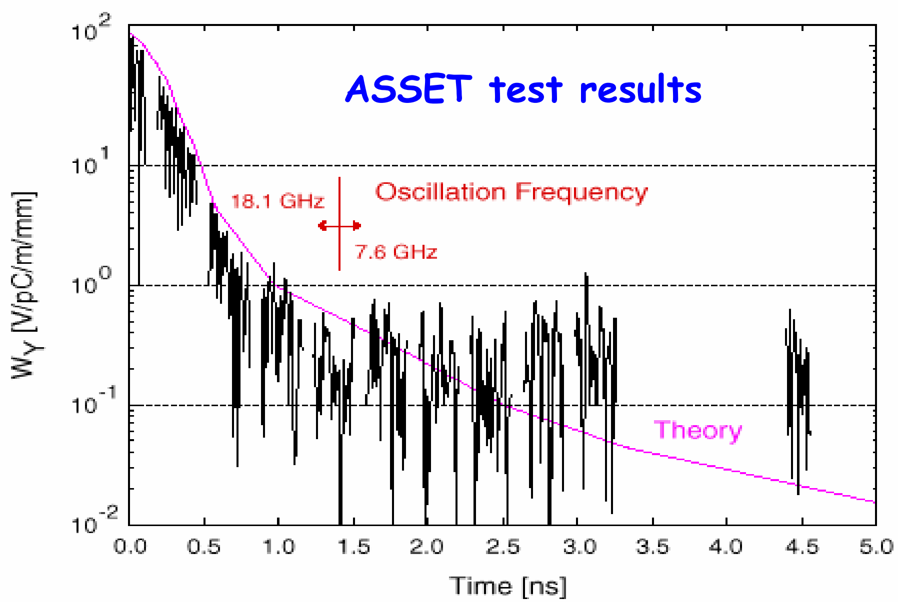
For wake suppression - work still focused on here.
Each cell is damped by 4 radial WGs terminated by waveguide-damped structures of type shown discrete SiC RF loads.

Excellent agreement obtained between theory and experiment – believe we can solve damping problem



S

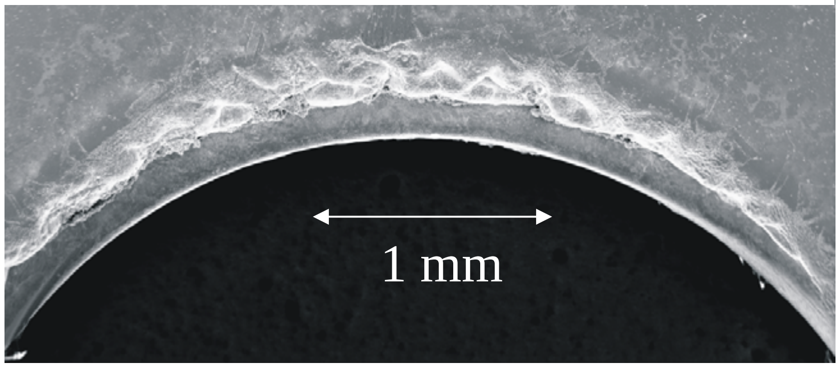
g WG



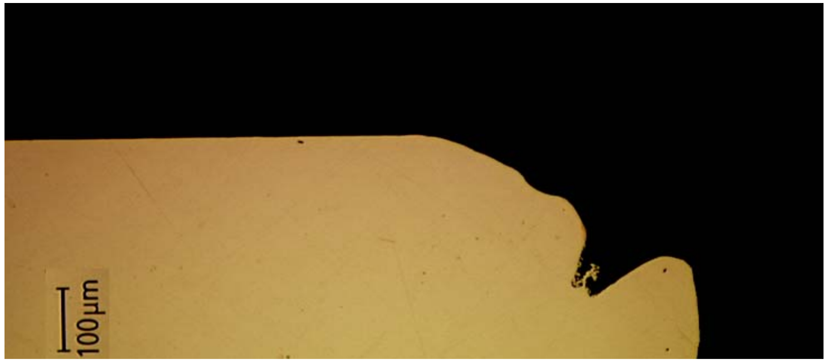
Structure breakdown and damages

High-power tests of copper accelerating structures indicates that for RF pulses **>10 ns**, the maximum surface field that can be obtained with copper is always around **300-400 MV/m.**

At these field levels structures with large apertures (or rather with large a/λ ratios) seem to suffer **severe surface damage.**



Microscopic image of damaged iris

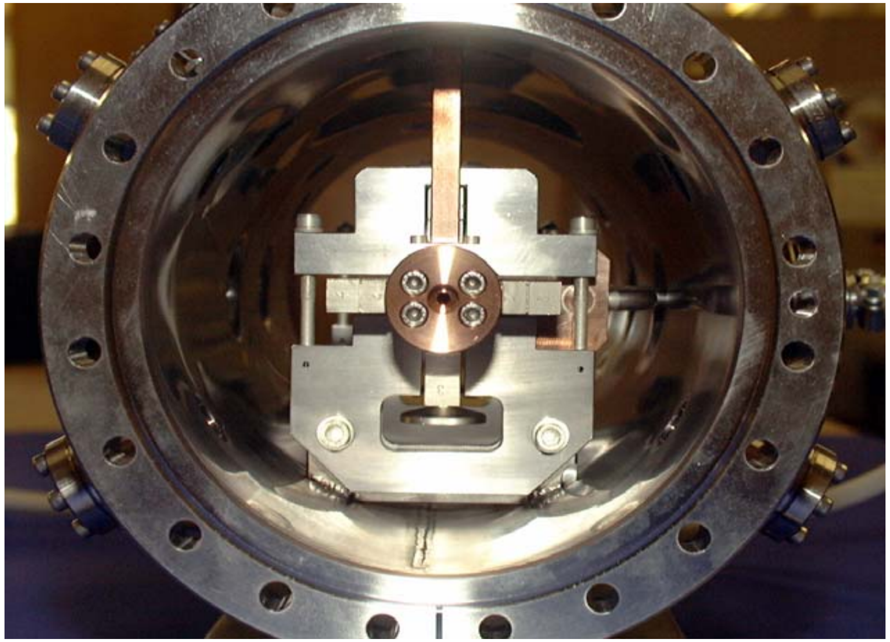


Damaged iris – longitudinal cut

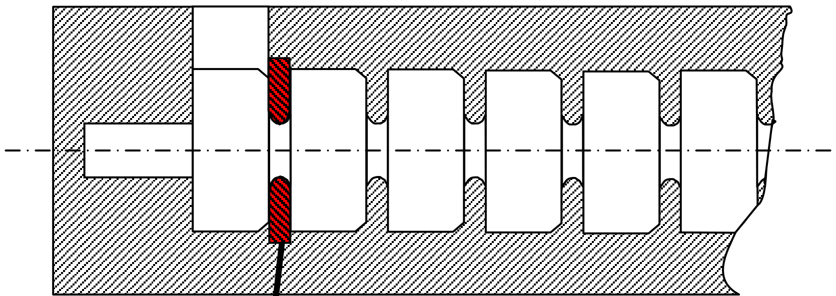
The CLIC study group is adopting a two-pronged approach to solving the breakdown problem

- **Modify the RF design** to obtain lower surface field to accelerating field ratio **(Es/Ea ~ 2)**
- Investigating **new materials** that are resistant to arcing - **tungsten** looks promising

Tests of tungsten iris in CTF2

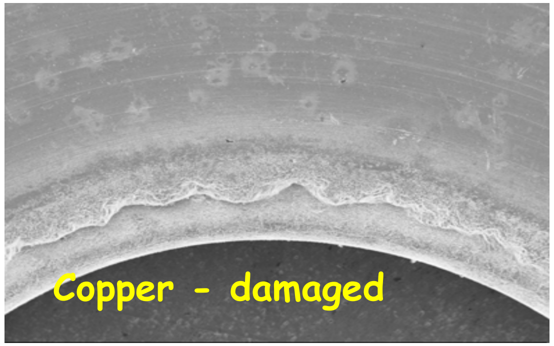


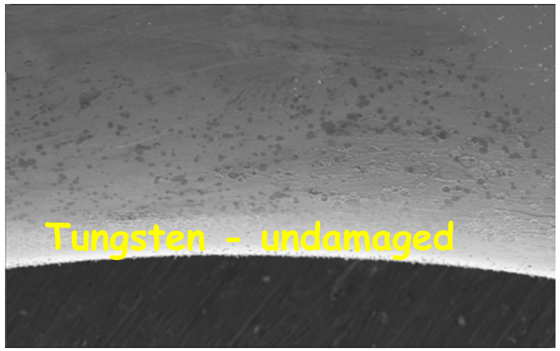
Test structure in external vacuum can, with clamped coupler cell



Copper iris replaced by Tungsten iris

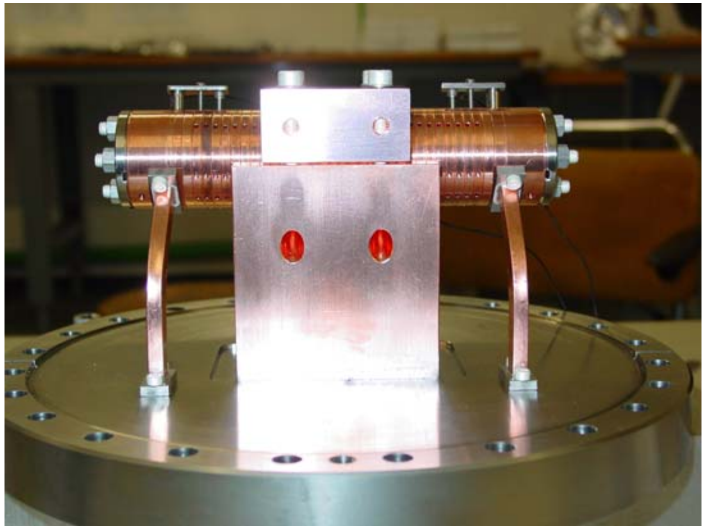
Irises after high-gradient testing to about the same field level



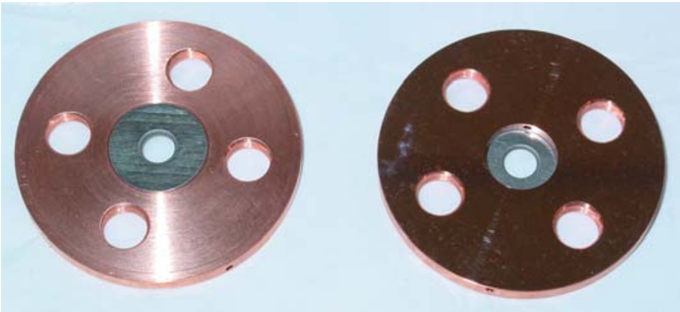


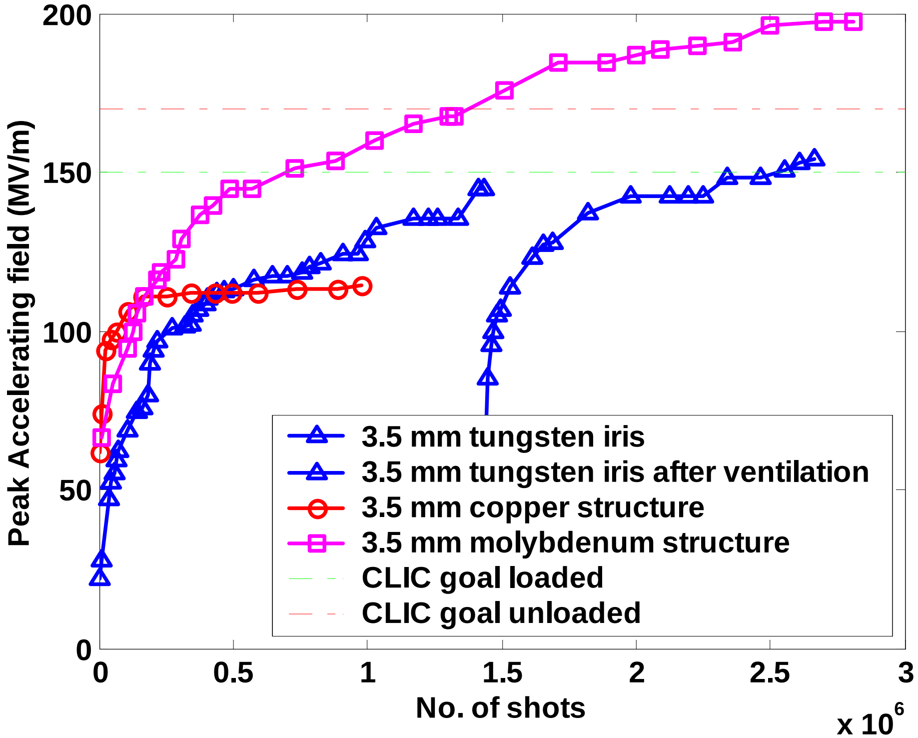
Achieved accelerating fields in CTF2

High gradient tests of new structures with molybdenum irises reached 190 MV/m peak accelerating gradient without any damage well above the nominal CLIC accelerating field of 150 MV/m but with RF pulse length of 16 ns only (nominal 100 ns)



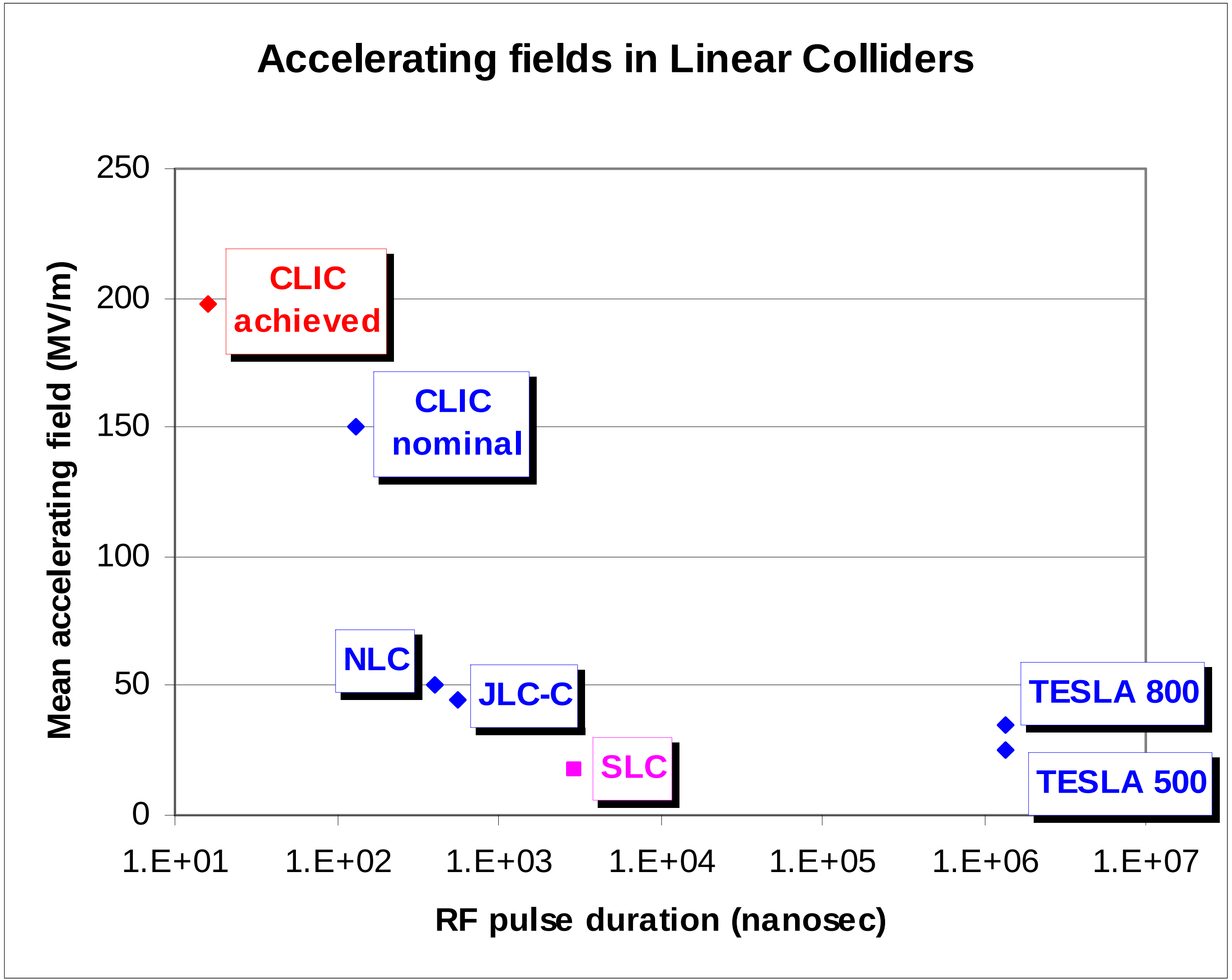
30 cell clamped tungsten-iris structure





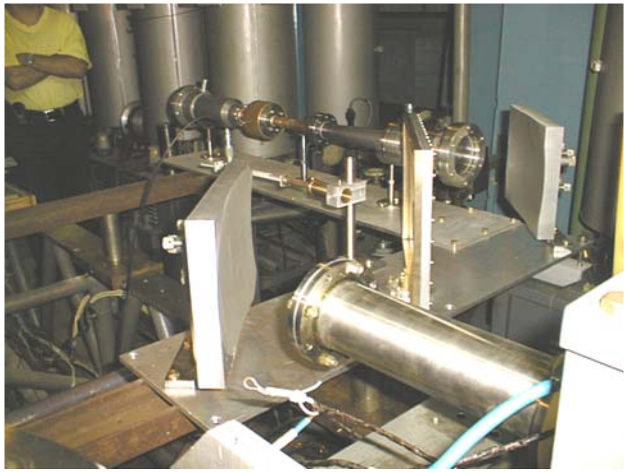
A world record !!!

Accelerating fields in Linear Colliders

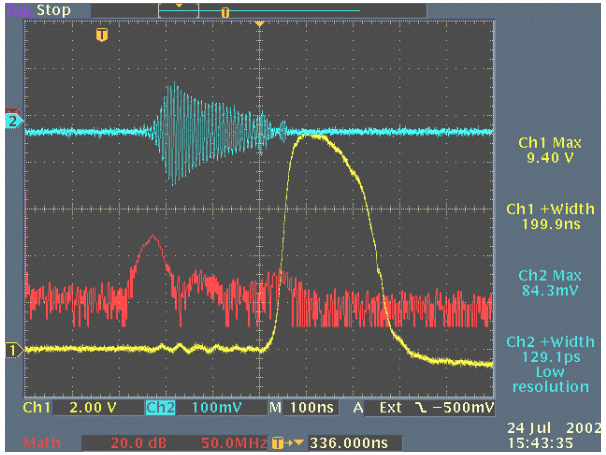


RF pulse heating experiment

The fatigue limit of cooper surface due to cyclic pulsed heating is being tested with an experimental setup based on 30 GHz FEM in Dubna, JINR.
RF accessories designed and manufactured in Nizny Novgorod, IAP.



General views of the experimental setup



30 GHz, 25 MW, 200 ns RF pulse

Test H_{012} cavity

International Technical Review Committee

Review of the various Linear Colliders studies requested by ICFA (February 2001)

ILC-TRC Report (2003)

- **Status of various studies (TESLA, JLC-C/X, NLC, CLIC)**
- **Ranking of R&D topics still to be made for each study**

  - ✓ **R1: R&D needed for feasibility demonstration**
  - ✓ **R2: R&D needed to finalize design choices**
  - ✓ **R3: R&D needed before starting production**
  - ✓ **R4: R&D desirable for technical/cost optimisation**

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

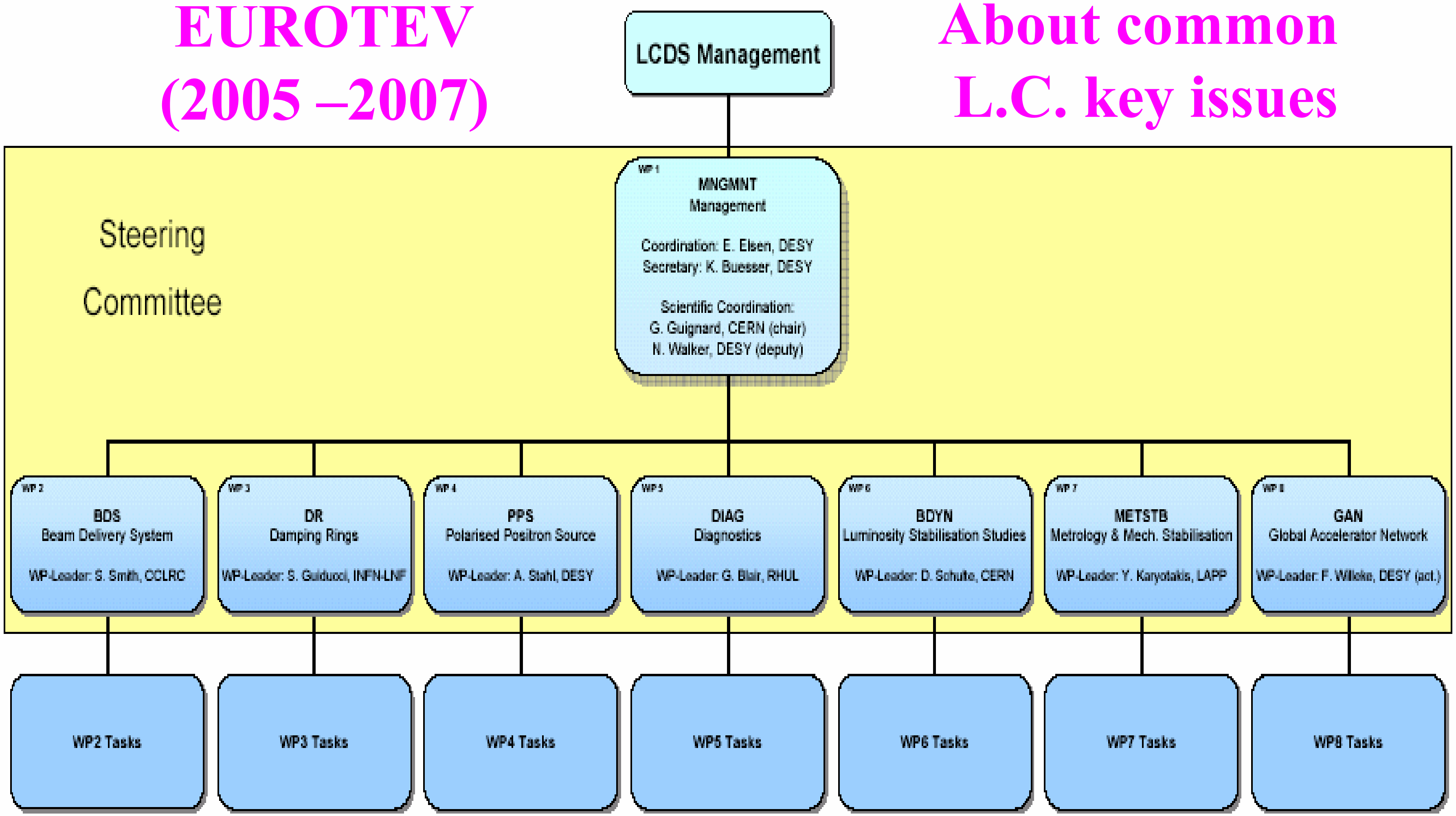
except the Multi-Beam Klystron (MBK) which does not require R&D but development by industry (feasibility study already done)

CLIC

EU supported (9MEuros) Linear Colliders Design Study

EUROTEV (2005 –2007)

About common L.C. key issues



CLIC

27 collaborating institutes

Institute	WP1: MNGMNT	WP2: BDS	WP3: DR	WP4: PPS	WP5: DIAG	WP6: ILPS	WP7: METSTB	WP8: GANMVL
CCLRC	X	C	X	X			X	
CEA		X						
CERN	C	X	X		X	C		
DESY	C		X	C	X	X	X	C
ELETTRA								X
FHG								X
GSI								X
INFN-LNF	X		C					X
INFN-Mi								X
INFN-Ro2								X
IPPP				X				
LAL					X	X		
LAPP	X						C	
PSI						X		
QMUL		X				X		
RHUL	X				C	X		
TEMF,TUD		X						
UBER				X				
UCAM					X			
UCL					X			
ULANC		X						
ULIV				X				
UMA		X				X		
UMH								X
UNIUD								X
UOXF.DL					X		X	
UU					X	X		

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 finalisation

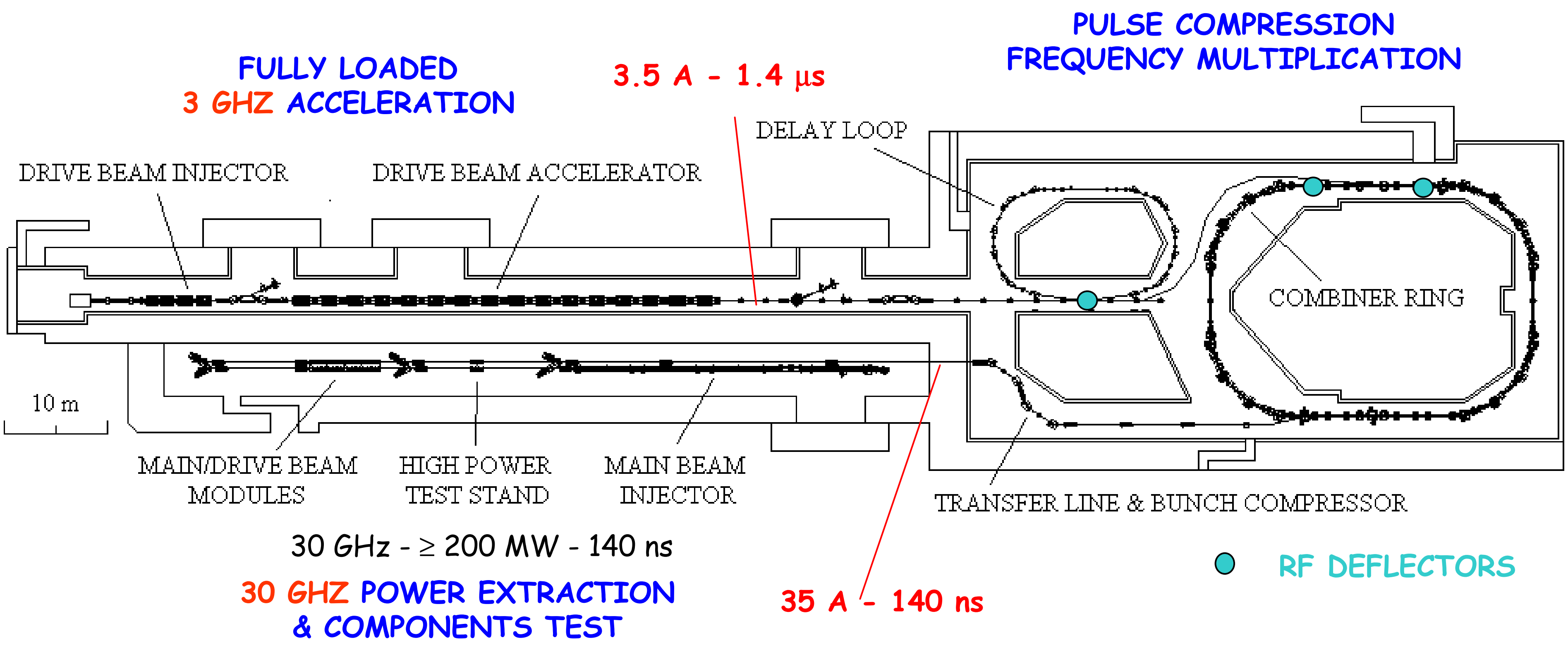
- R2.1: Developments of structures with hard-breaking materials (W, Mo…)
- R2.2: Validation of stability and losses of drive beam decelerator;
  Design of machine protection system
- R2.3: Test of relevant linac sub-unit with beam
- R2.4: Validation of drive beam 40 MW, 937 MHz Multi-Beam Klystron with long RF pulse
  Drive beam acc. struct. parameters can be adapted to other klystron power levels

- 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

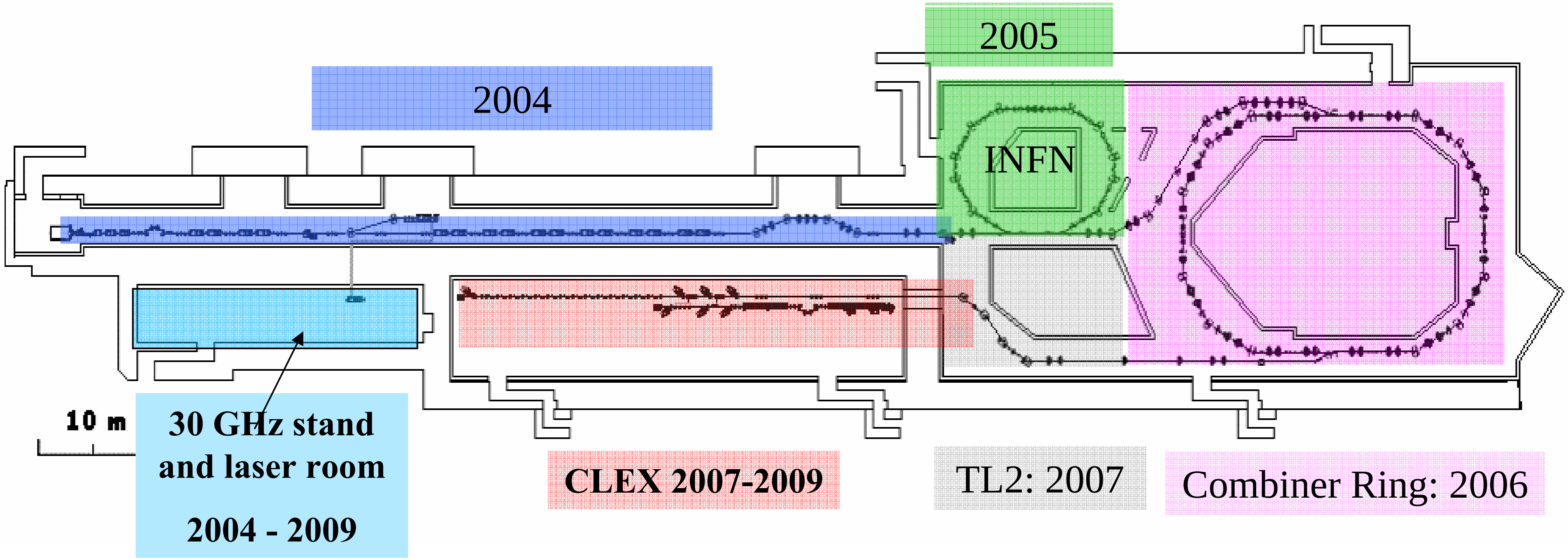
All R1 and R2 CLIC key issues addressed in CLIC Test Facility (CTF3)

Test of Drive Beam Generation, Acceleration & RF Multiplication by a factor 10
Two Beam RF power generation & component tests with nominal fields & pulse length



CLIC Test Facility (CTF3)

Collaboration CERN –INFN –LAL –NWU –RAL –SLAC -Uppsala

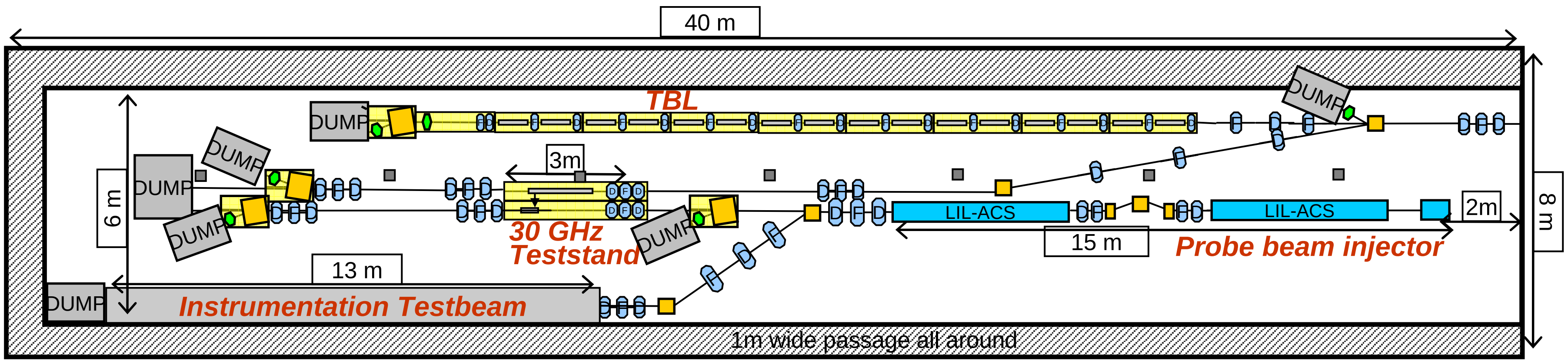


Key issues

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

CLIC experimental area (CLEX)

- Test beam line (TBL) to study RF power production (5 TW at 30 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

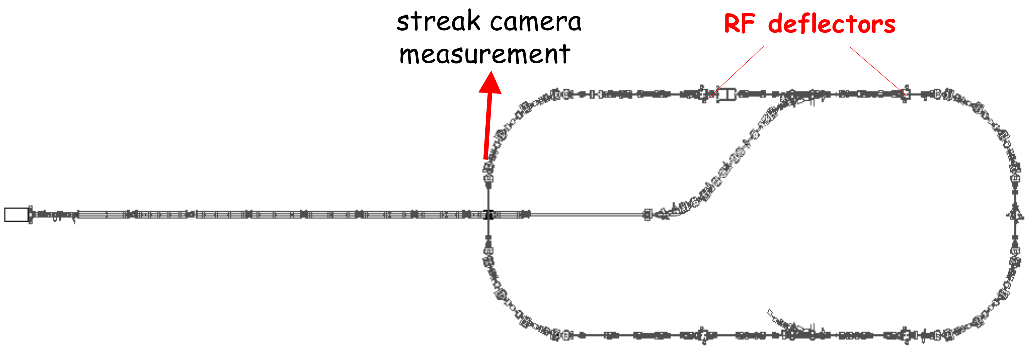


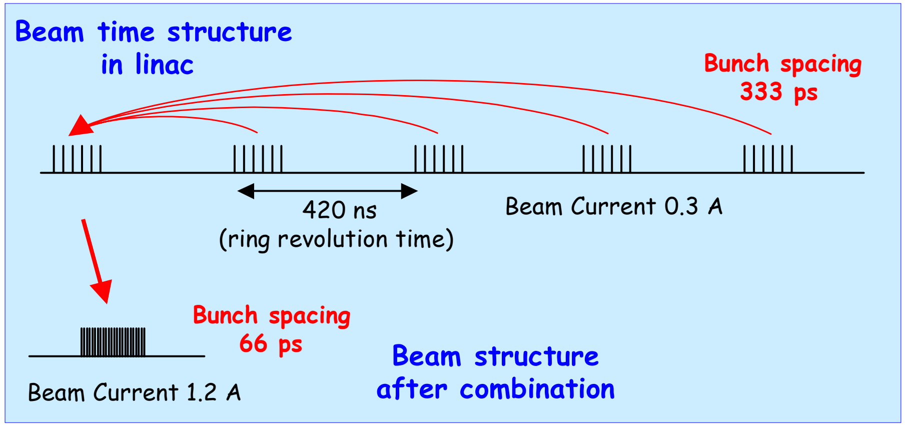
Layout for CLEX floor space

Beam power and frequency multiplication

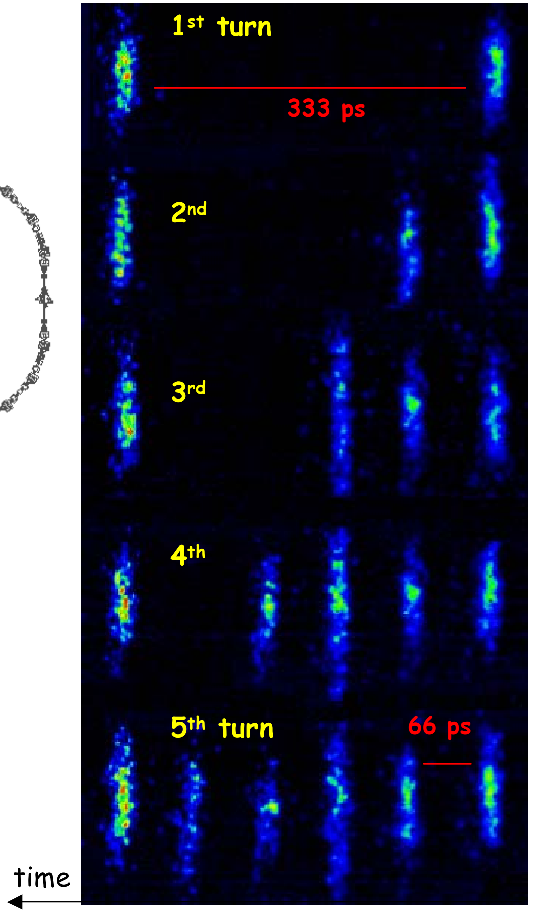
CTF3 - PRELIMINARY PHASE

low-charge demonstration of electron pulse combination and bunch frequency multiplication by up to factor 5



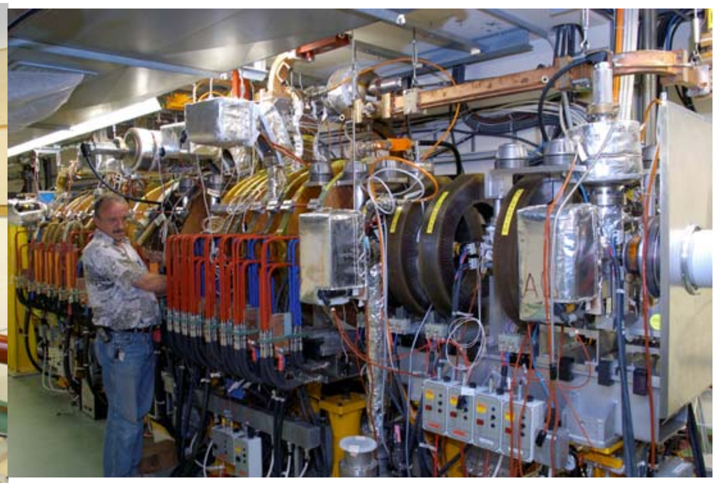


Streak camera image of beam time structure evolution



CTF3 Injector installation

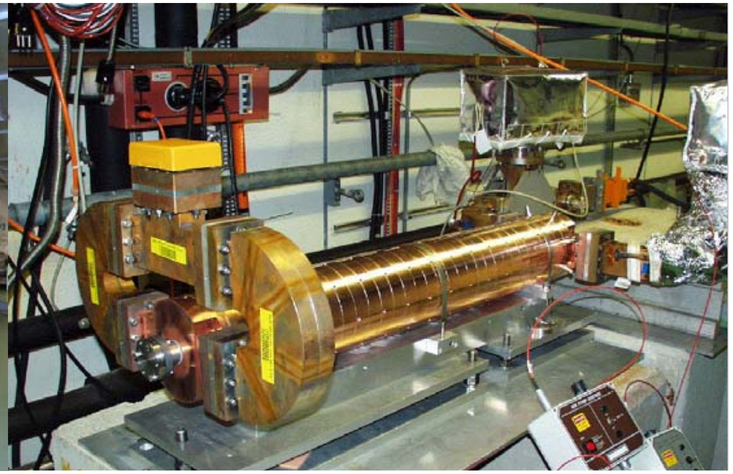
7A Thermionic Gun (LAL-SLAC)



Bunchers(LAL)&Solenoids(SLACstudy)

Novel RF power compression with Barrel Open Cavity (BOC)

Bunch length adjustment with magnetic chicane



Accelerating structure with full beam loading

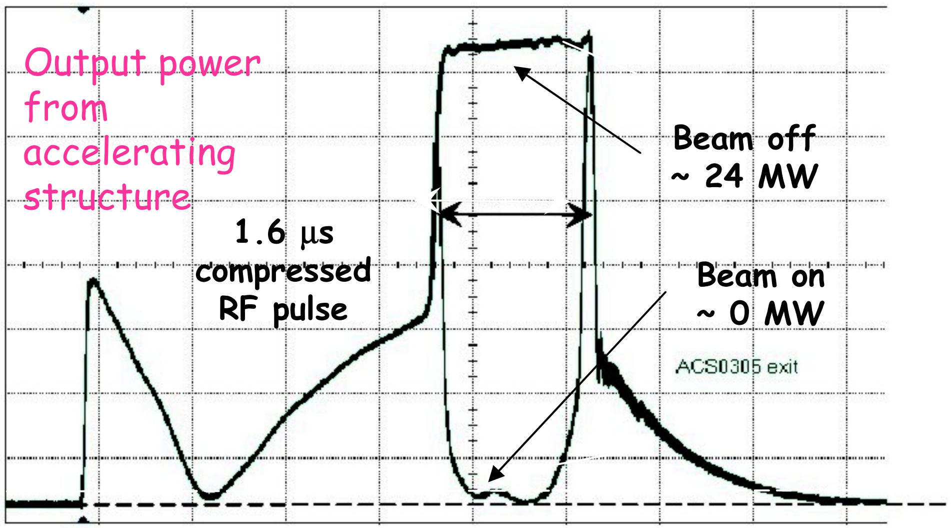
Injector commissioning 2003

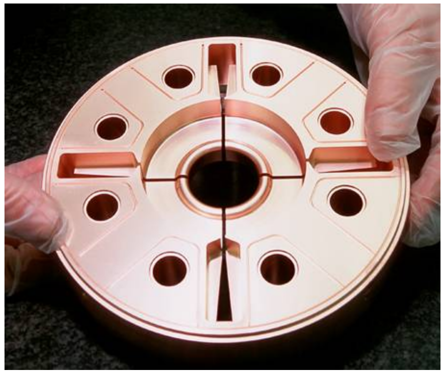
Nominal Beam parameters reached

	Nominal	Achieved
I	3.5 A	4.5 A
τ_p	1.5 μs	1.5 μs
E	20 MeV	20 MeV
$\varepsilon_{n,rms}$	100 π mm mrad	60-90 π mm mrad
$\tau_{bunch,rms}$	5 ps	< 6.5 ps

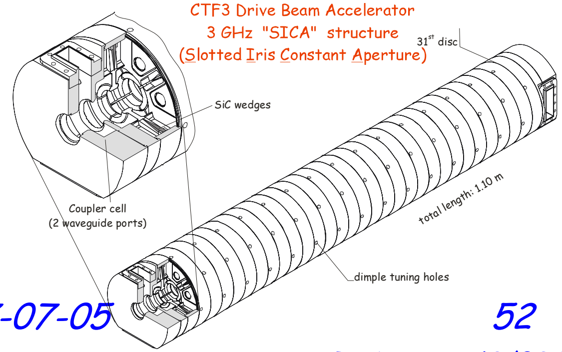
Full Beam Loading demonstrated:
>95 % efficiency ! More than with Superconducting systems (when including cryogenics)!
Beam stable !

First demonstration of full beam loading





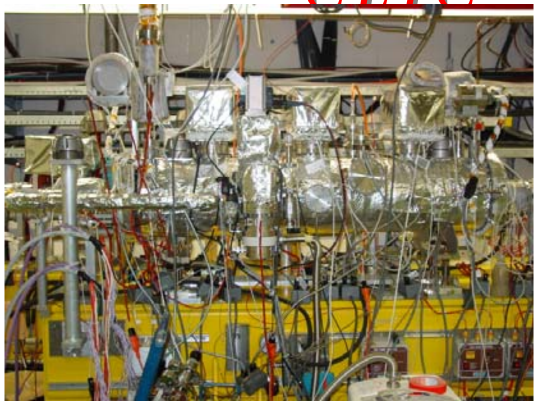
Damped DBA structure



R. Corsini – 18/08/2003

30 GHz power production in CTF3 for tests in CTF2

CLIC

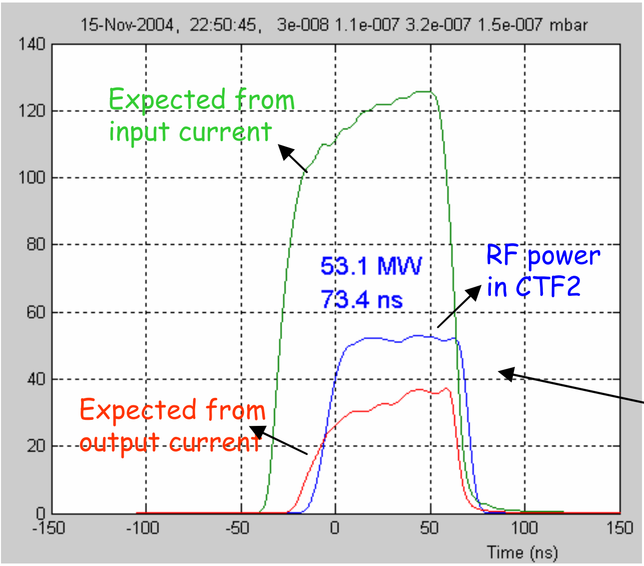


vacuum tanks containing Power Extraction Transfer Structure

power out – rectangular WR34 to circular (overmoded) H01

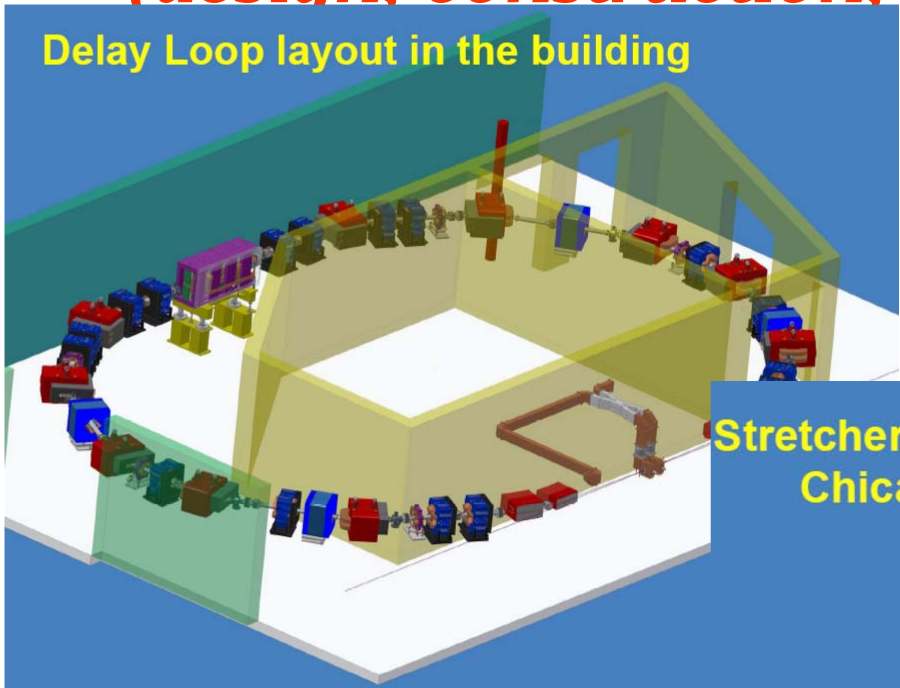
17m waveguide with 5 bends but low-loss (85% transmission) (Russian collaboration)

high power load



result !!

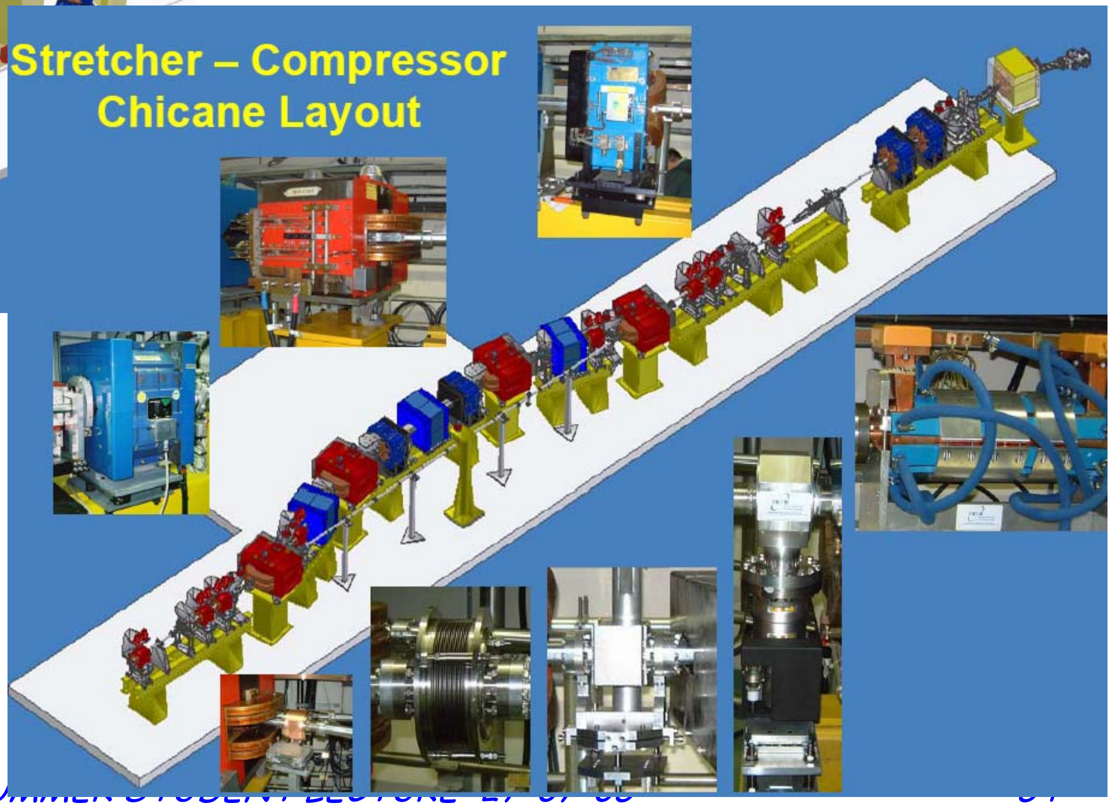
Bunch Compressor and Delay Loop (design, construction, resources by INFN-LNF)



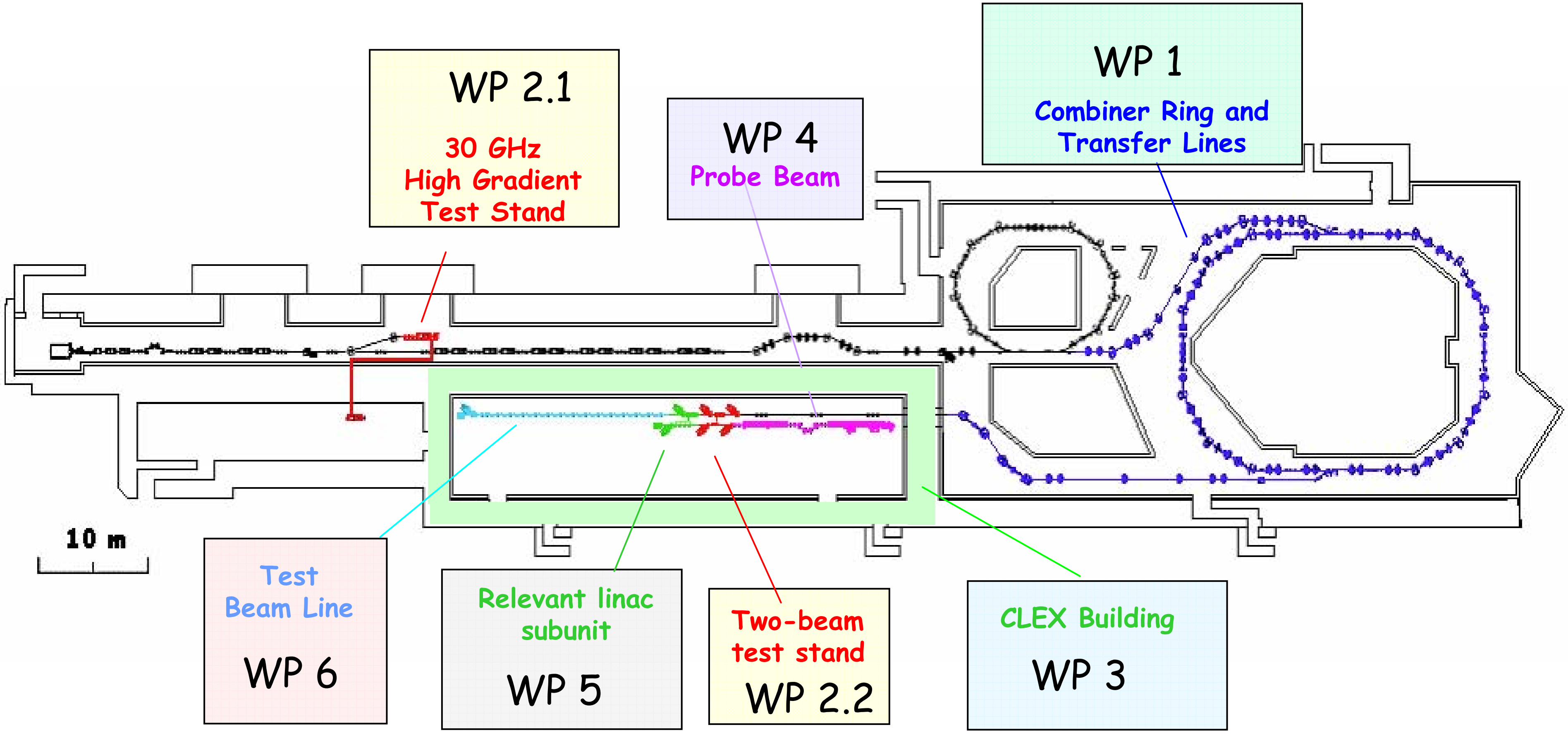
PAC05 Commissioning and First Measurements on the CTF3 Chicane

Andrea Ghigo, David Alesini, Gabriele Benedetti, Caterina Biscari, Michele Castellano, Alessandro Drago, Daniele Filippetto, Fabio Marcellini, Catia Milardi, Barbara Preger, Mario Serio, Francesco Sgamma, Angelo Stella, Mikhail Zobov (INFN/LNF)

Roberto Corsini, Thibaut Lefevre, Frank Tecker (CERN)



Work packages



Plea for collaboration

- World-wide Institutes have been invited to contribute to this programme by:
  - ✓ taking full responsibility for part, complete of one or several work-packages
  - ✓ providing voluntary contributions "a la carte" in cash, in kind and/or in man-power

- Multilateral collaboration network of volunteer institutes (from which CERN is one of them) participating jointly to the technical coordination and management of the project.

CTF3 collaboration meetings held at CERN on 19/05/04 and 28/01/05
MoU under discussion

CLIC

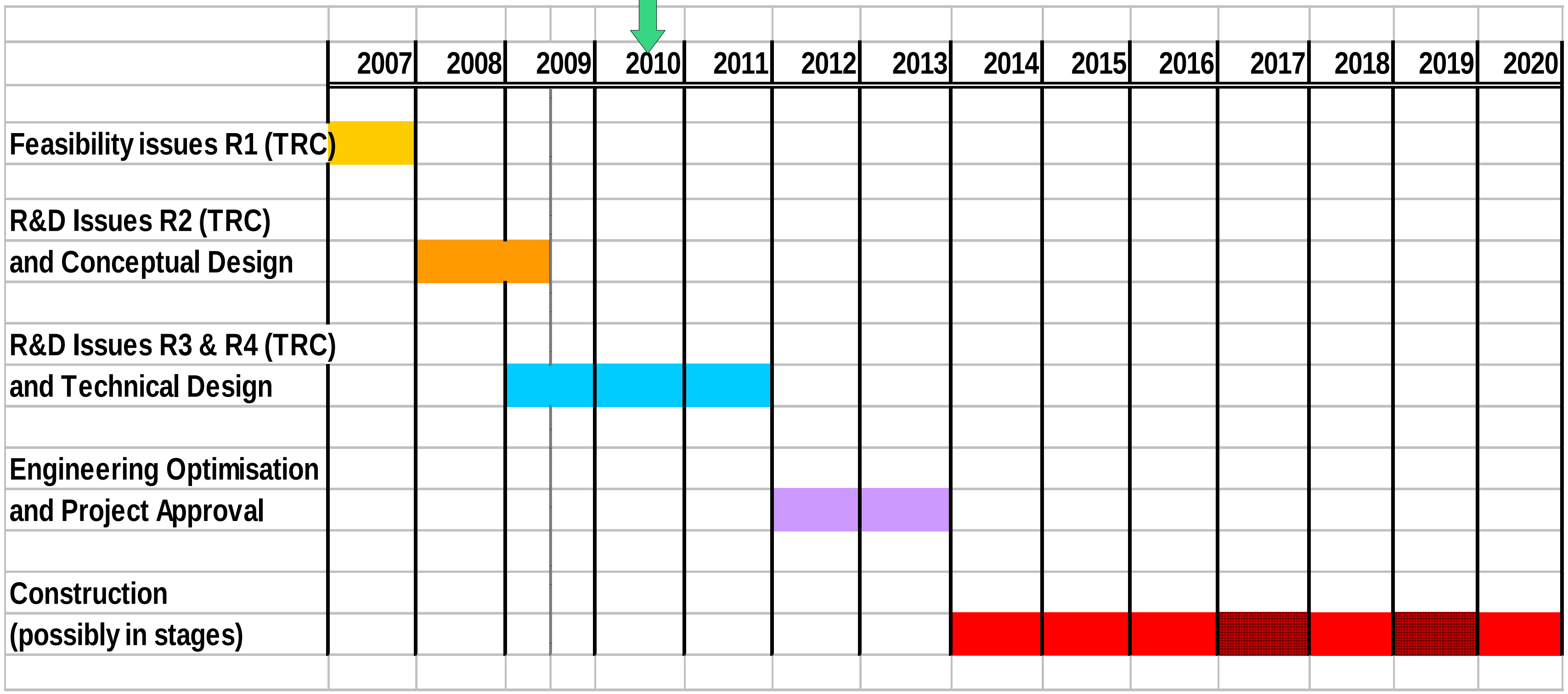
Schedule with extra resources

	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 representativeCLIC linac section					■	
Test beam line		■	■	■	■	
R2.1 Beam stability bench mark tests					■	■

CLIC

Tentative long-term CLIC scenario
Shortest and 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



CONCLUSION

- CLIC only possible scheme to extend Linear Collider energy into the Multi-TeV range
- CLIC technology not mature yet, requires challenging R&D
- A development:
  - ✓complementary to Super-Conducting technology recently down-selected by ITRP for a TeV Linear Collider
  - ✓necessary in order to extend energy range of LC in the future
- Very promising performances already demonstrated in CTF2
- Remaining key issues clearly identified (ILC-TRC)
- L.C. Key-issues independent of the technology studied by 2008 in a wide collaboration of European Institutes (Design Study submitted to EU FP6 funding)
- CLIC-related key-issues addressed in CTF3 (feasibility by 2007 and design finalisation by 2009) if extra resources can be found

CONCLUSION

- Provides the High Energy Physics community with the information about the feasibility of CLIC technology for Linear Collider in due time when Physics needs will be fully determined following LHC results
- Safety net to the Super-Conducting technology in case sub-TeV energy range is not considered attractive enough for Physics
- Possible construction in stages starting with low energy applications
- A lot still to be done before the CLIC technology can be made operational;
- Novel Ideas and Challenging work in world-wide collaborations needed
- YOU ARE ALL WELCOME to participate and make the CLIC scheme and technology a realistic tool in the best interest of Physics

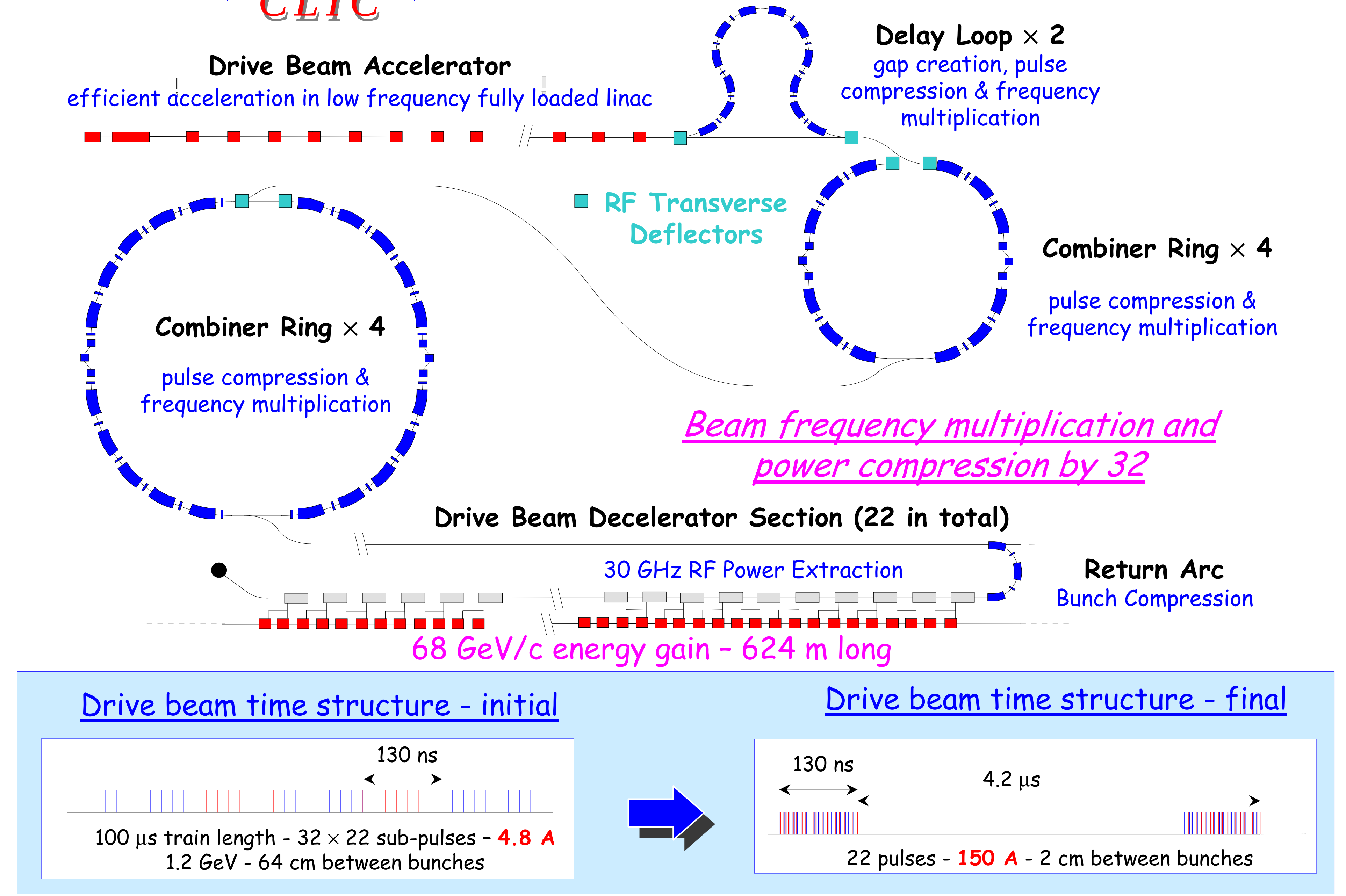
References

- Scaling laws for e+/e- Linear Colliders: NIM A421 (1999) p 369-405
- A 3 TeV e+/e- Linear Collider based on CLIC technology: CERN 2000-008
- CTF3 Design Report: CERN/PS 2002-008
- CLIC contribution to the Technical Review Committee on a 500 GeV e+/e- Linear Collider: CERN 2003-007
- Physics at the CLIC Multi-TeV Linear Collider: CERN 2004-005

Staged approach

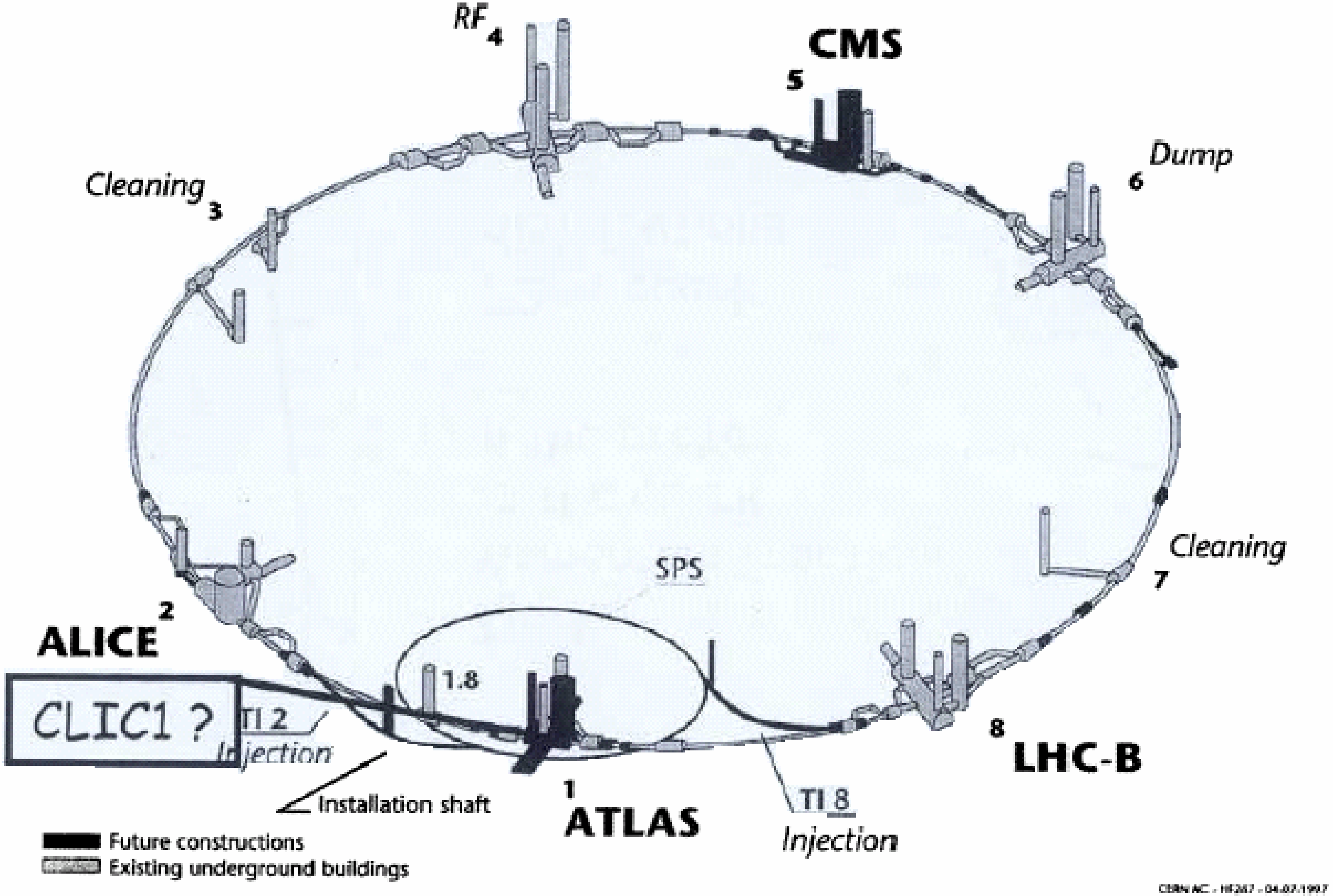
Possible low energy Physics facilities which could be built with CLIC technology on the way towards a Linear Collider

A single CLIC section: 68 GeV



LHC-CLIC1

(A de Roeck, D.Schulte, F.Zimmermann)



LHC Project Note 333

CLIC Note 589

08.01.2004

QCD Explorer Based on LHC and CLIC

D. Schulte, F. Zimmermann

Keywords: Linac-Ring Collider, Superbunches, Luminosity,
Beam-Beam Interaction, Disruption

7 Summary

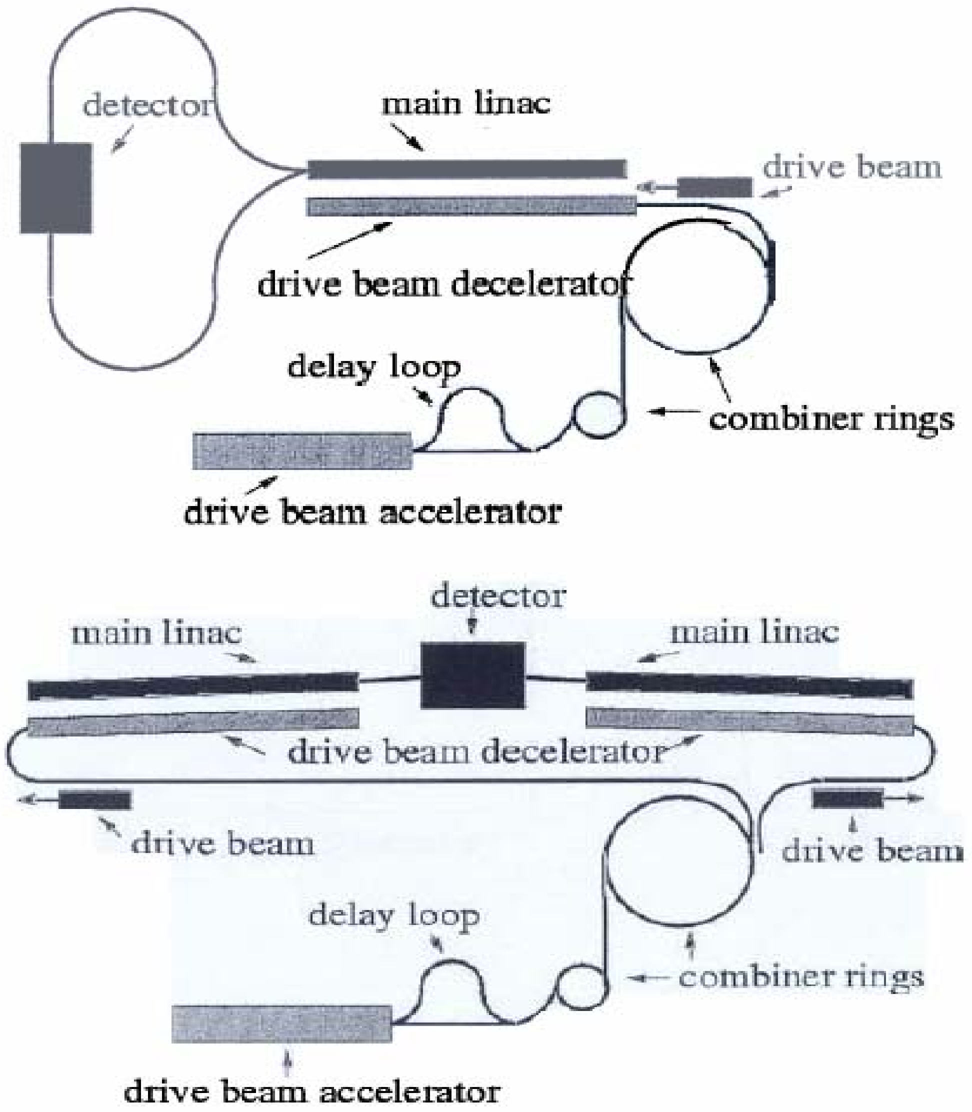
We have described a novel scheme for an ultimate QCD explorer based at CERN, where a portion of the 7-TeV LHC proton beam is repeatedly collided with 75-GeV electron bunch trains generated by a single CLIC drive-beam unit. This concept is attractive, since it exploits and fosters a large number of possible synergies between the LHC upgrade and the CLIC development in addition to its complementary physics-discovery potential. The estimated luminosity is in excess of 10^{31} $cm^{-2}s^{-1}$. If the nominal CLIC bunch spacing and train length were to be reduced in the future, the length and the total charge of the proton superbunch could be decreased as well for the same total luminosity.

Finally, the collider concept outlined in this note strongly encourages further research in wide-band rf technologies required to create and maintain intense proton superbunches in the LHC. We note that first machine experiments with suitable novel rf units are underway at the KEK PS [7].

QCDE main parameters

	electrons	protons
energy	75 GeV	7 TeV
bunch population	4×10^{9}	6.5×10^{13}
Rms bunch length	35 μm	9 m
#bunches	154	1
effective pulse density	2×10^{10} m^{-1}	2×10^{12} m^{-1}
IP beta function	0.25 m	0.25 m
IP spot size	11 μm	11 μm
Interaction length	2 m	
Normalized emittance	73 μm	3.75 μm
Collision frequency	100 Hz	
luminosity	1.1×10^{31} cm^{-2} s^{-1}	
beam-beam tune shift	N/A	0.004

Z factory with 1*1 CLIC section



Possible layouts

1 module + arc

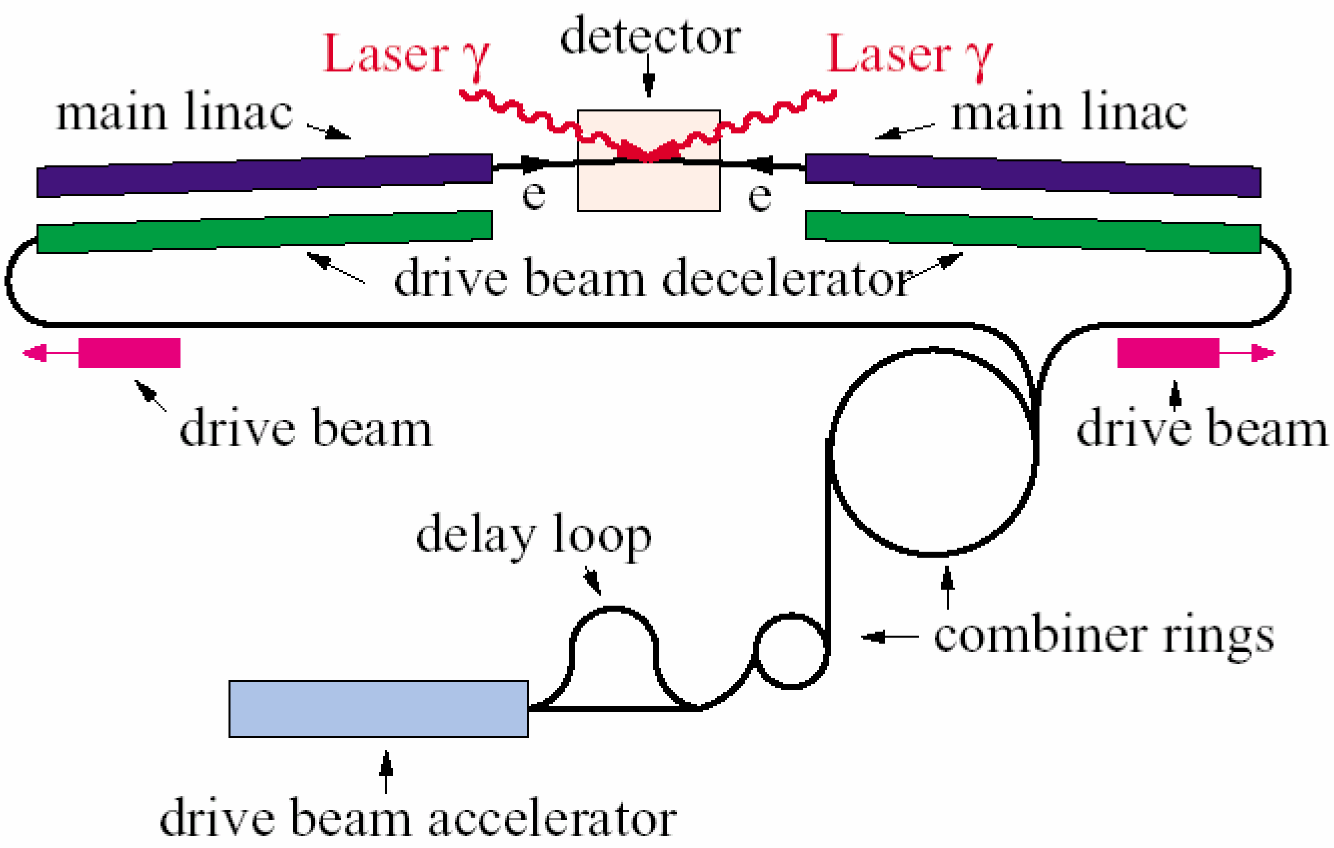
2 modules

Latter is presently preferred

Z to W factories

- Electron to positron collisions at 90 GeV (Z) up to 160 GeV (W) with two linacs made each by one CLIC section with an overall length of about 2 km
  - 9 GeV fom injector and 68 GeV by linac at nominal gradient
  - 36 GeV by linac for Z at reduced gradient of 80 MV/m
  - 71 GeV by linac for W at increased gradient of 157 MV/m (possibly two CLIC sections and an overall length of 3.5 km)
- Luminosity (L1%) of 8 10^{33} cm^{-2} s^{-1} at Z and 1.3 10^{34} cm^{-2} s^{-1} at W if accelerating structures can be powered at 200 Hz repetition rate (to be demonstrated)
- Complete injector complex of electrons and positrons required with possible polarisation of electrons but not of positrons
- Half of power source injector complex powering alternatively both linacs

CLIC HIGGS Experiment (CLICHÉ)



BNL-HET-01/32
CERN-PS-2001-062 (AE)
CERN-SL-2001-055 (AP)
CERN-TH-2001-235
CLIC-Note 500
HEP-PH/0111056
NUHEP-EXP/01-050
UCRL-JC-145692
Nov. 16, 2001

Higgs Physics with a $\gamma\gamma$ Collider Based on CLIC 1

D. Asner[1], H. Burkhardt[2], A. De Roeck[2], J. Ellis[2], J. Gronberg[1], S. Heinemeyer[3], M. Schmitt[4], D. Schulte[2], M. Velasco[4] and F. Zimmermann[2]

[1] Lawrence Livermore National Laboratory, Livermore, California 94550, USA
[2] CERN, CH-1211 Geneva 23, Switzerland
[3] Brookhaven National Laboratory, Upton, New York, USA
[4] Northwestern University, Evanston, Illinois 60201, USA

Abstract

We present the machine parameters and physics capabilities of the CLIC Higgs Experiment (CLICHE), a low-energy $\gamma\gamma$ collider based on CLIC 1, the demonstration project for the higher-energy two-beam accelerator CLIC. CLICHE is conceived as a factory capable of producing around 20,000 light Higgs bosons per year. We discuss the requirements for the CLIC 1 beams and a laser backscattering system capable of producing a $\gamma\gamma$ total (peak) luminosity of 2.0 (0.36) $\times 10^{34}$ cm^{-2}s^{-1} with $E_{CM}(\gamma\gamma) \sim 115$ GeV. We show how CLICHE could be used to measure accurately the mass, $\bar{b}b$, WW and $\gamma\gamma$ decays of a light Higgs boson. We illustrate how these measurements may distinguish between the Standard Model Higgs boson and those in supersymmetric and more general two-Higgs-doublet models, complementing the measurements to be made with other accelerators. We also comment on other prospects in $\gamma\gamma$ and $e^-\gamma$ physics with CLICHE.

Tentative CLICHÉ parameters

variable	symbol	value
total power consumption for RF	P	150 MW
beam energy	E	75 GeV
beam polarization	P_e	0.80
bunch population	N	4×10^9
number of bunches per train	n_b	154
number of trains per rf pulse	n_t	11
repetition rate	f_{rep}	100 Hz
rms bunch length	σ_z	30 μm
crossing angle	θ_c	$\geq$ 20 mrad
normalised horizontal emittance	ϵ_x	1.4 μm
normalised vertical emittance	ϵ_y	0.05 μm
nominal horizontal beta function at the IP	β_x^*	2 mm
nominal vertical beta function at the IP	β_y^*	20 μm
e^-e^- geometric luminosity	$\mathcal{L}$	0.9–4.8 $\times 10^{34}$ cm^{-2}s^{-1}

- E-/E- geometric luminosity of 9 10^{33} cm^{-2} s^{-1} envisageable if accelerating structures shown to be able to handle 200 Hz repetition rate

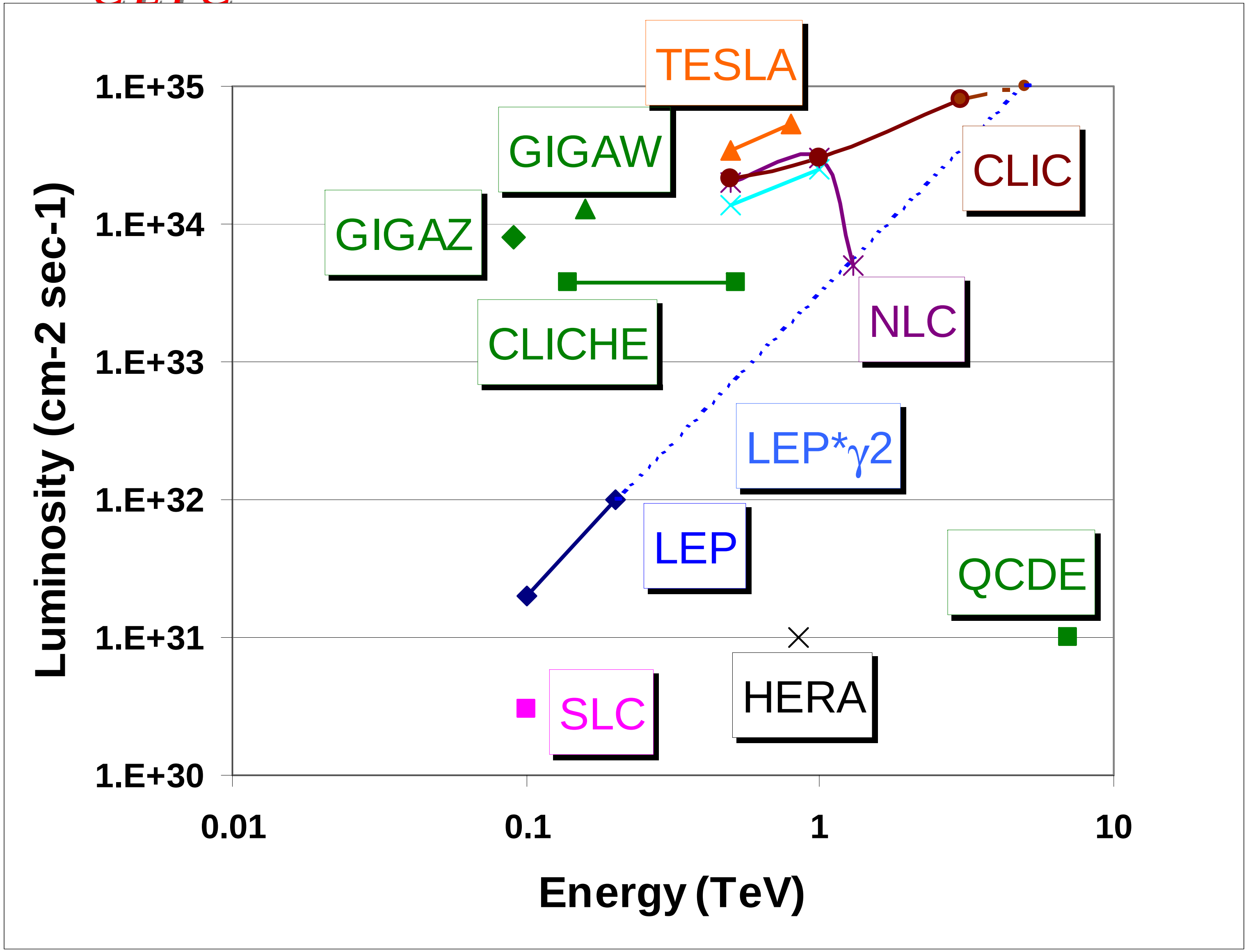
Challenging Laser parameters

variable	symbol	value
Laser beam parameters		
Wavelength	λ_L	0.351 μm
Photon energy	$\hbar\omega_L$	3.53 eV = 5.65×10^{-19} J
Number of laser pulses per second	N_L	169400 s^{-1}
Laser peak power	W_L	2.96×10^{22} W/m^2
Laser peak photon density		5.24×10^{40} photons/m^2/s
Photon beam		
Number of photons per electron bunch	N_γ	9.6×10^{9}
$\gamma\gamma$ luminosity	$\mathcal{L}_{\gamma\gamma}$	2.0×10^{34} cm^{-2}s^{-1}
$\gamma\gamma$ luminosity for $E_{\gamma\gamma}\geq 0.6E_{CM}$	$\mathcal{L}^{peak}_{\gamma\gamma}$	3.6×10^{33} cm^{-2}s^{-1}

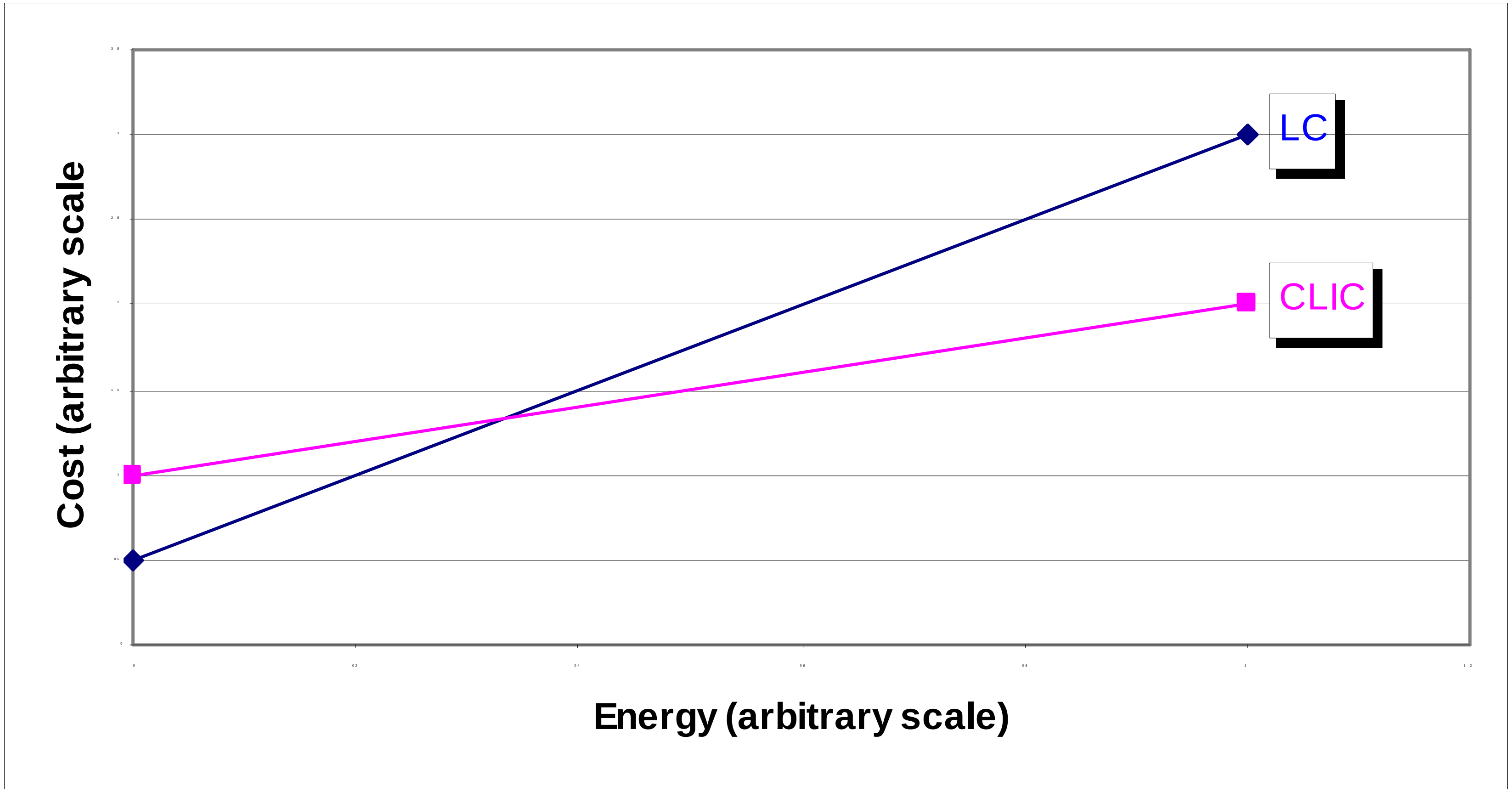
Parameters above assume unrealistic 11*100 e- beam repetition rate and 154*1100=169400 laser pulses /sec

$\gamma\gamma$ luminosity of 3.8 10^{33} cm^{-2} s^{-1} (6.8 10^{32} cm^{-2} s^{-1} for E $\gamma\gamma$ > 0.6 Ecm) envisageable if accelerating structures shown to be able to handle 200 Hz repetition rate and laser with 30000 pulse/sec developed

Performances of CLIC based facilities

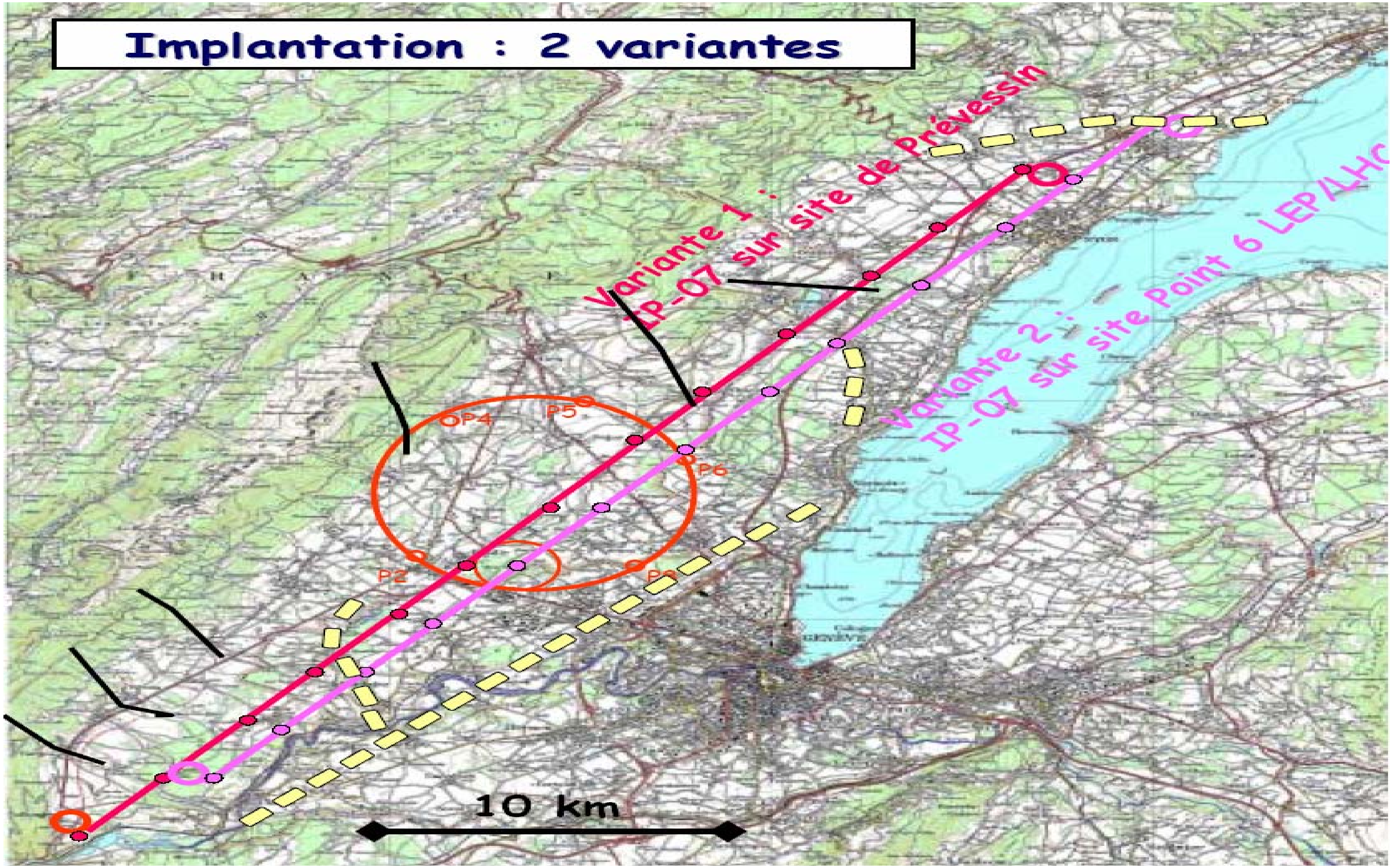


Relative cost of Linear Colliders



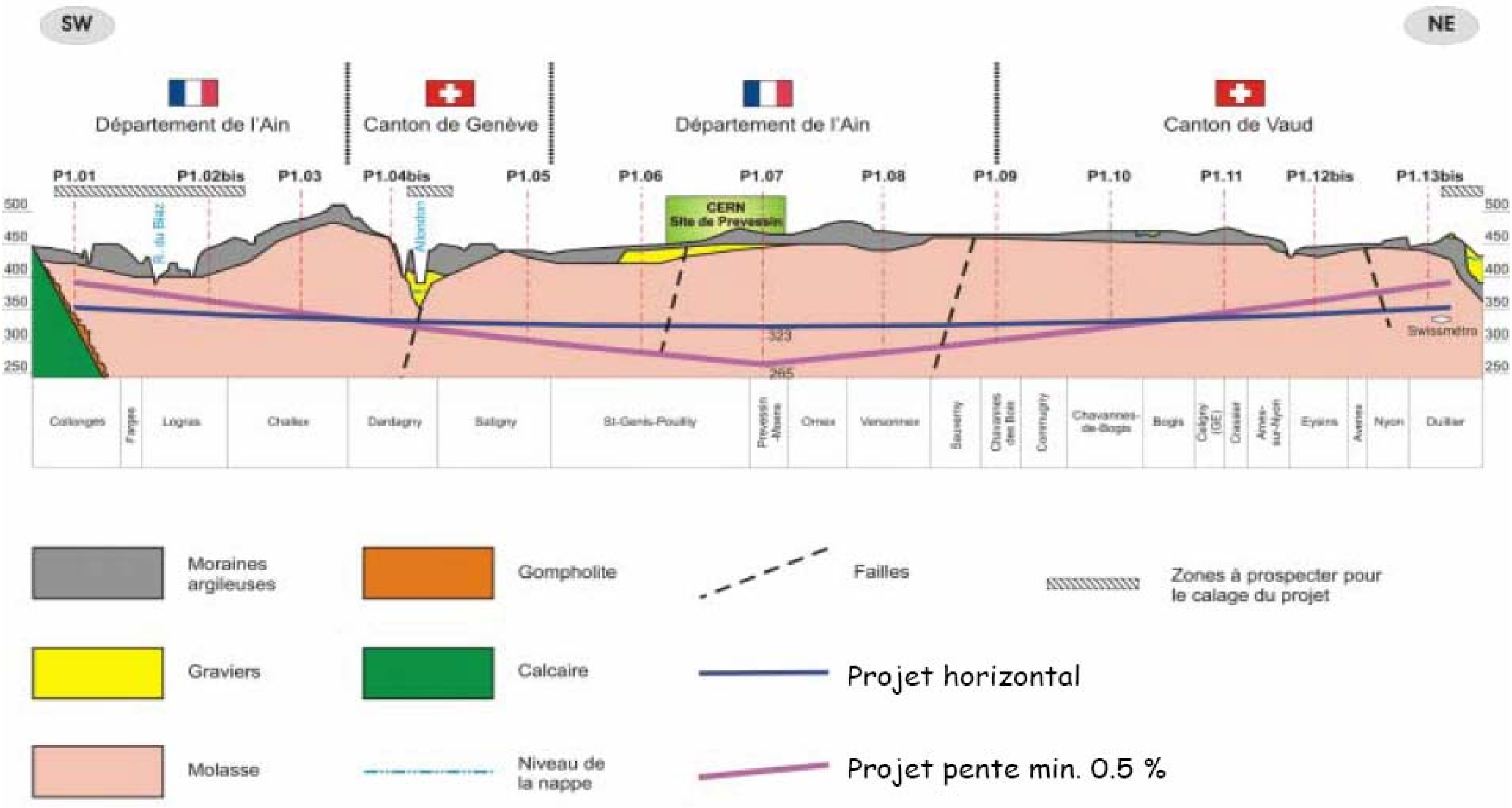
Possible Site for a Linear Collider @ CERN

CLIC



Possible Site for a Linear Collider @ CERN

CLIC



PROJET CLIC - Variante 1