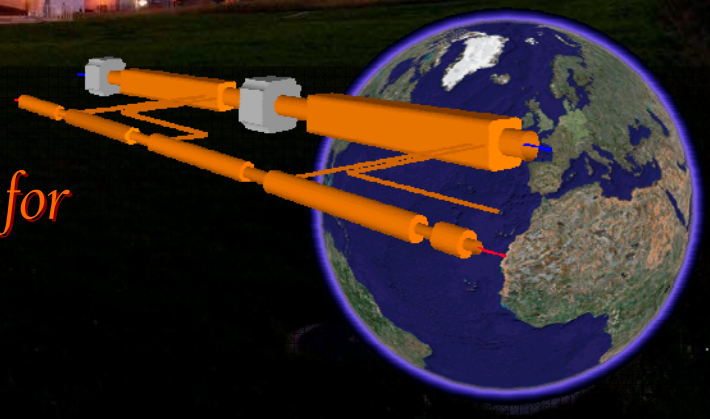
Talk outline

- The work plan – issues, organization & timescale
- Recent R&D results
  - High-gradient structures
  - CTF3
- Other R&D activities
  - Beam physics
  - Technical issues
- Conclusion



X-band high-gradient and CLIC R&D for future colliders

R. Corsini – CERN
for the CLIC/CTF3 Collaboration

Aim of the CLIC study:

develop technology for e-/e+ linear collider with the requirements:

- ✓ E_{CM} should cover range from ILC to LHC maximum reach and beyond ⇒ **E_{CM} = 0.5-3 TeV**,
- ✓ L > few **10^{34} cm^{-2}** with acceptable background and energy spread
- ✓ Design compatible with maximum length ~ **50 km**
- ✓ Affordable
- ✓ Total power consumption < **500 MW**

Physics motivation:

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

Present goal:

Demonstrate all key feasibility issues and document in a CDR by 2010

The CTF3 – CLIC world wide collaboration

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

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

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

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

CLIC/CTF3 Collaboration

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm

- 27 institutes involving 17 funding agencies from 15 countries
- Organized as a HEP Detector Collaboration
- Started as CTF3, recently extended to CLIC R&D in view of CDR and beyond

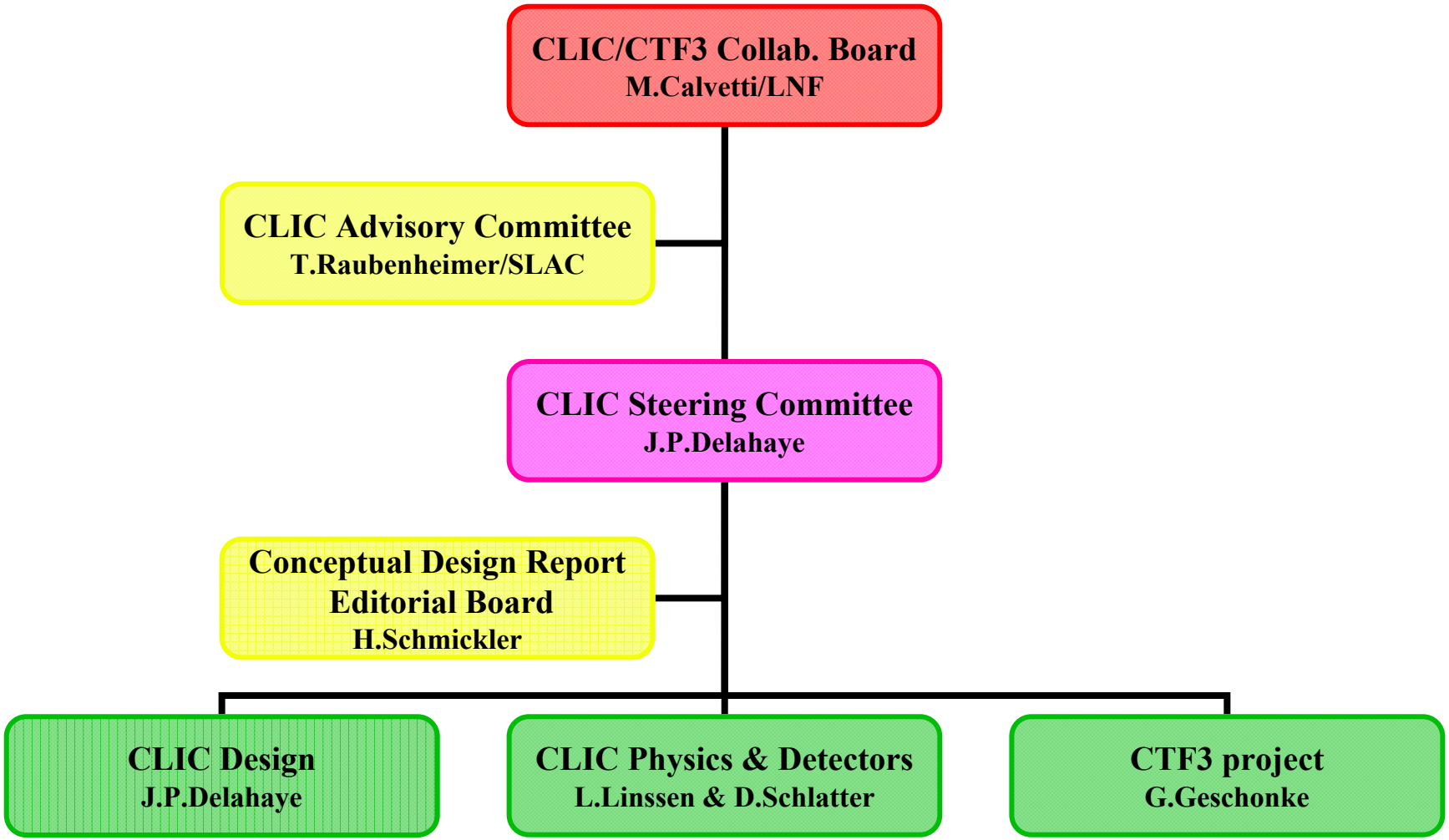
CLIC / ILC Collaboration

http://clic-study.web.cern.ch/CLICStudy/CLIC_ILC_Collab_Mtg/Index.htm

- Focusing on subjects with strong synergy between CLIC & ILC
- Making the best use of the available resources
- Identifying and understanding the differences due to technology and energy (technical, cost….)
- Preparing together the future evaluation of the two technologies by the Linear Collider Community made up of CLIC & ILC experts

CLIC organizational chart

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm



Work Plan until 2010:

- Demonstrate feasibility of CLIC technology (R&D on critical feasibility issues)
- Design of a linear Collider based on CLIC technology
  http://clic-study.web.cern.ch/CLIC-Study/Design.htm
- Estimation of its cost (capital investment & operation)
- CLIC Physics study and detector development
  http://clic-meeting.web.cern.ch/clic-meeting/CLIC_Phy_Study_Website/default.html

Conceptual Design Report to be published in 2010 including:

- Physics, Accelerator and Detectors
- Results of feasibility study
- Preliminary performance and cost estimation

R&D Issues classified in three categories:

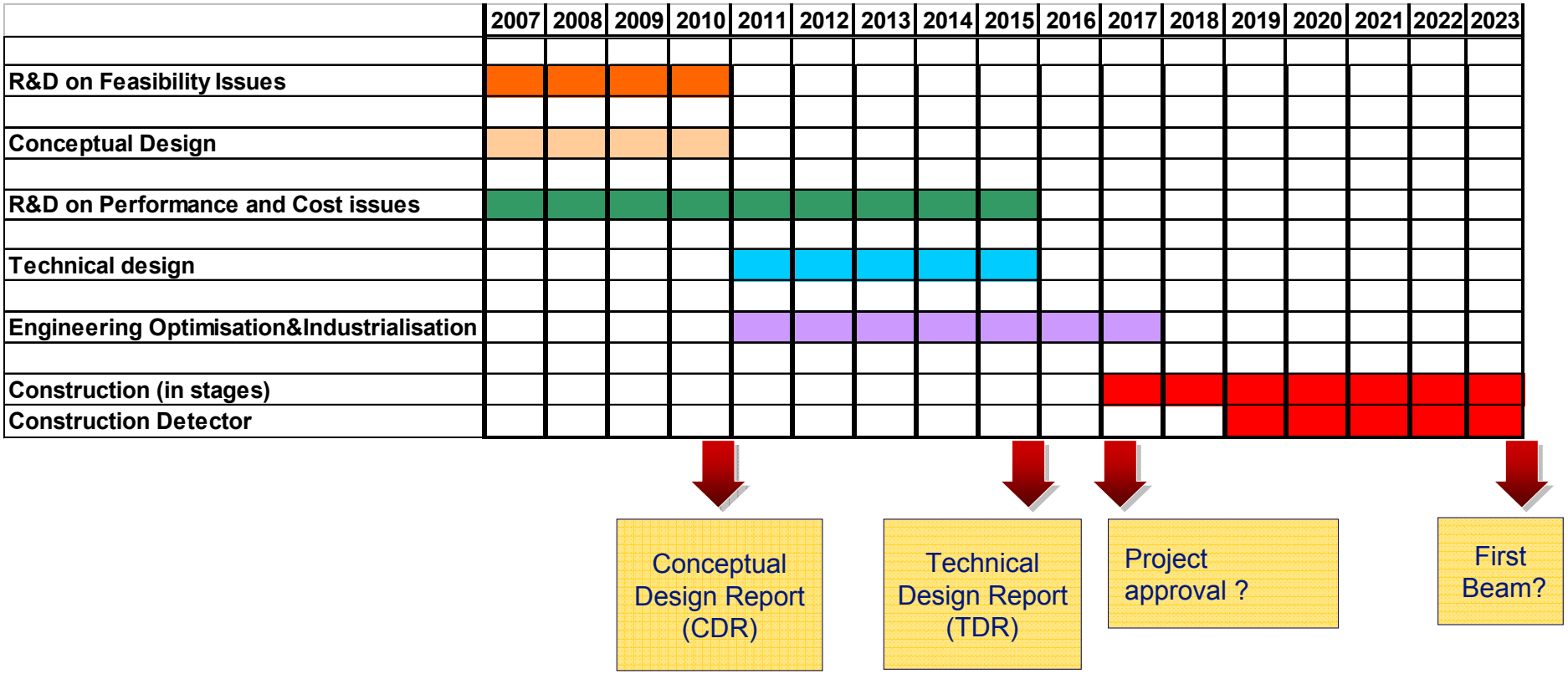
- critical for feasibility → fully addressed by specific R&D to be completed before 2010; results in CDR
- critical for performance
- critical for cost

→ being addressed now by specific R&D to be completed before 2015; first assessments in CDR; results in Technical Design Report (TDR) with consolidated performance & cost

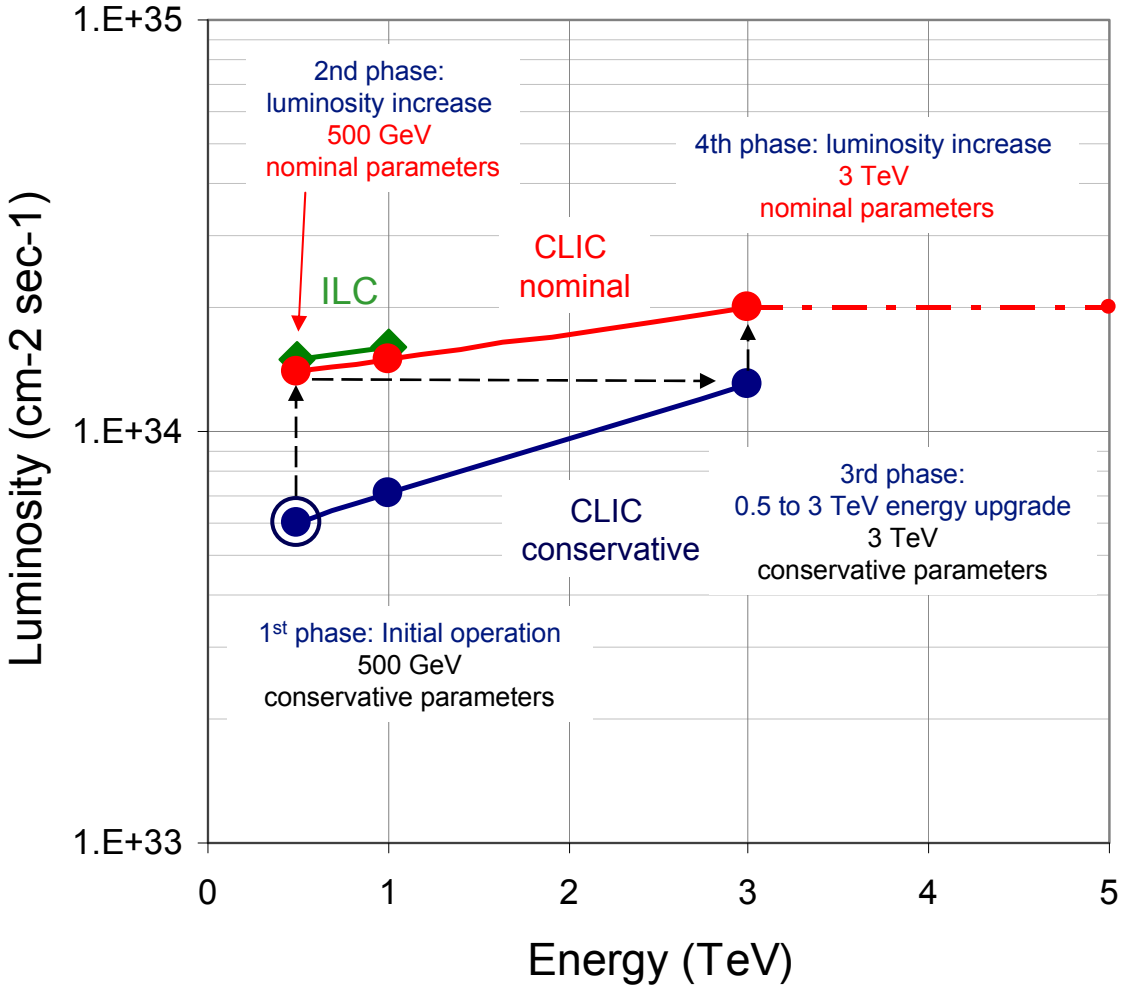
Tentative long-term CLIC scenario

Shortest, Success Oriented, Technically Limited Schedule

Technology evaluation and Physics assessment based on LHC results
for a possible decision on Linear Collider with staged construction starting with the lowest energy required by Physics



CLIC Parameters and upgrade scenario



CLIC Parameter Table

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

Center-of-mass energy	CLIC 500 GeV		CLIC 3 TeV	
Beam parameters	Conservative	Nominal	Conservative	Nominal
Accelerating structure	*502*		*G*	
Total (Peak 1%) luminosity	$0.9\ (0.6)\cdot10^{34}$	$2.3\ (1.4)\cdot10^{34}$	$2.7\ (1.3)\cdot10^{34}$	$5.9\ (2.0)\cdot10^{34}$
Repetition rate (Hz)	50			
Loaded accel. gradient MV/m	80		100	
Main linac RF frequency GHz	12			
Bunch charge10^9	6.8		3.72	
Bunch separation (ns)	0.5			
Beam pulse duration (ns)	177		156	
Beam power/beam MWatts	4.9		14	
Hor./vert. norm. emitt ($10^{-6}/10^{-9}$)	3/40	2.4/25	2.4/20	0.66/20
Hor/Vert FF focusing β^* (mm)	10/0.4	8 / 0.1		4 / 0.1
Hor./vert. IP beam size (nm)	248 / 5.7	202 / 2.3	83 / 1.1	40 / 1
Hadronic events/crossing at IP	0.07	0.19	0.75	2.7
Coherent pairs at IP	10	100	$5.\ 10^7$	$3.8\ 10^8$
BDS length (km)	1.87		2.75	
Total site length km	13.0		48.3	
Wall plug to beam transfert eff	7.5 %		6.8%	
Total power consumption MW	129.4		415	

What matters in a linear collider ?

Energy reach

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

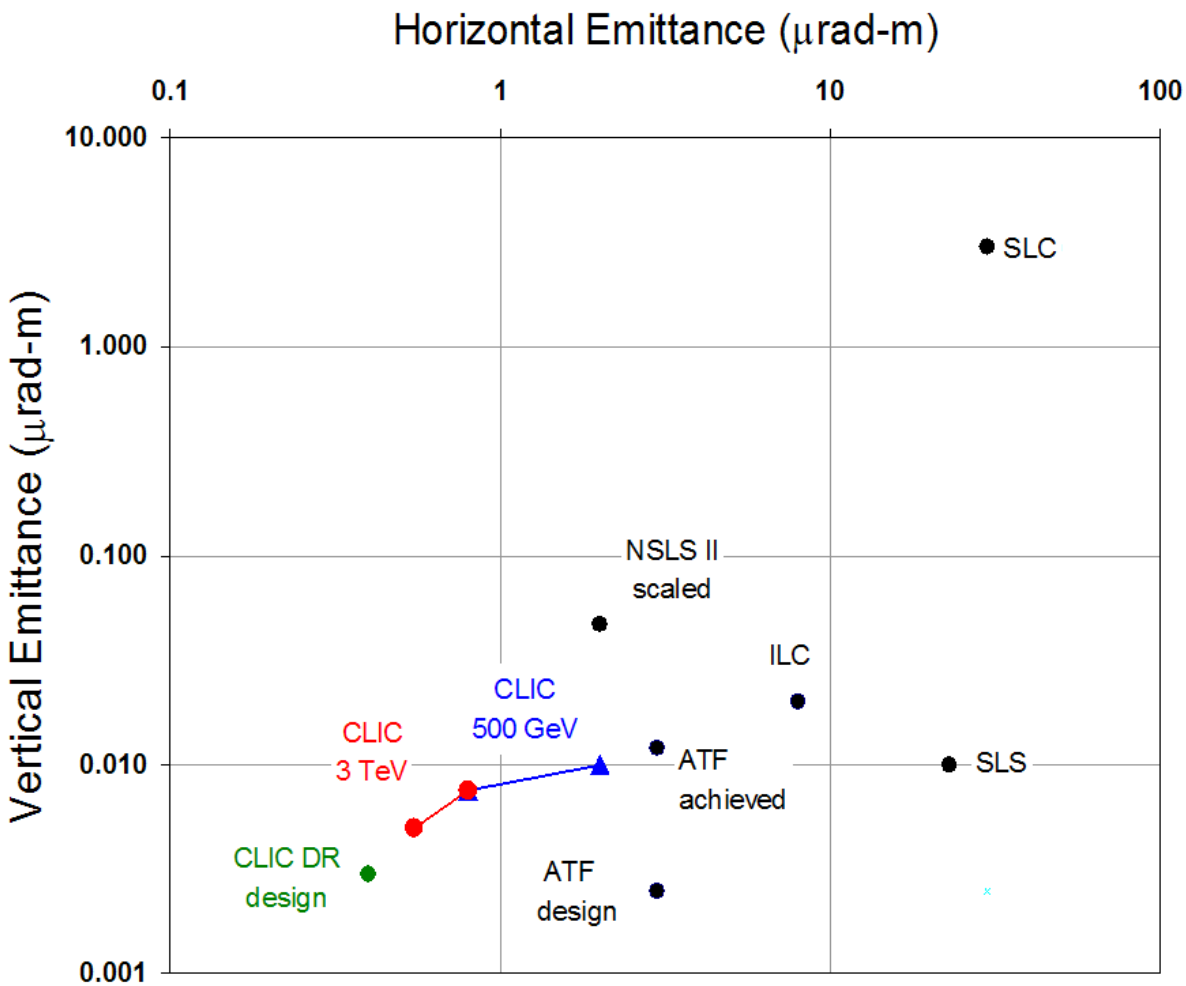
- High gradient

Luminosity

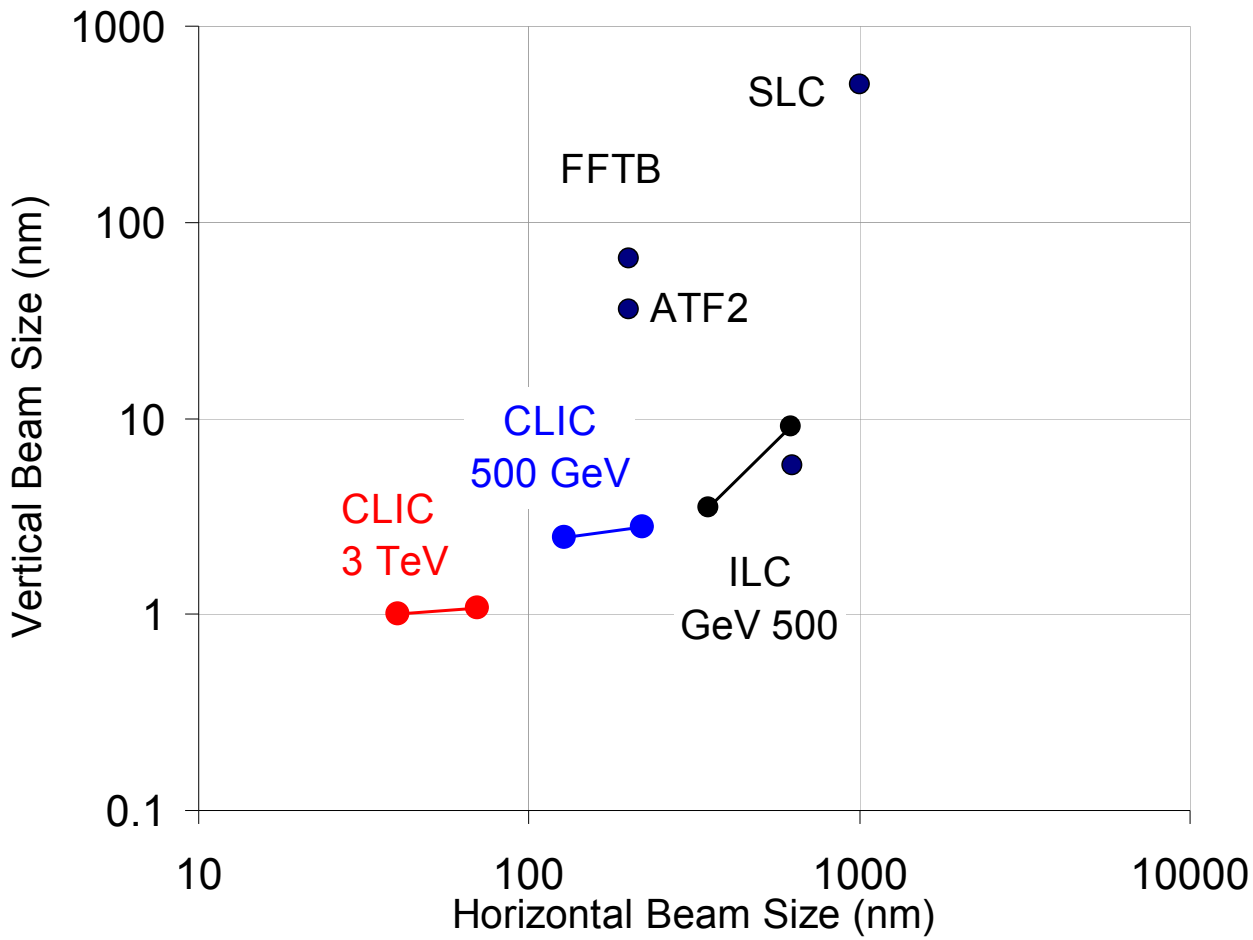
$$L = \frac{n_b N^2 f_{rep}}{4\pi\sigma_x^* \sigma_y^*} \times H_D \propto \frac{\eta_{beam}^{AC} P_{AC}}{\varepsilon_y^{1/2}} \frac{\delta_{BS}^{1/2}}{E_{cm}}$$

- Acceleration efficiency
- Generation of small emittance — damping rings
- Conservation of small emittance — wake-fields, alignment, stability
- Extremely small beam spot at Interaction Point — beam delivery system, stability

The small emittance challenge



The small beam size challenge



The CLIC way to a multi-TeV linear collider - Basic features

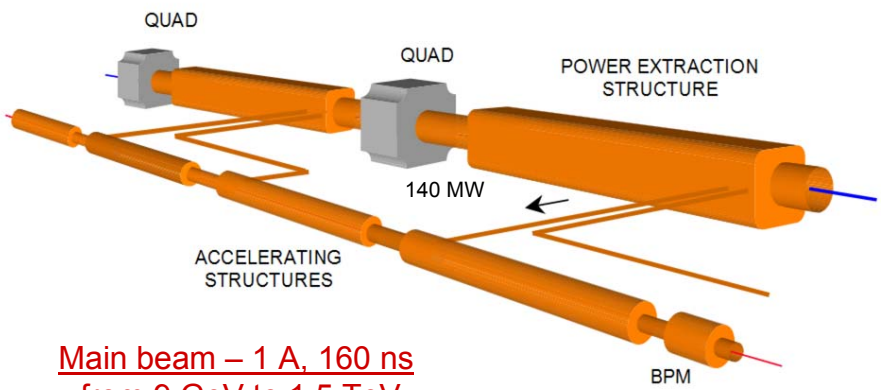
- High acceleration gradient (100 MV/m)

  - ✓ "Compact" collider - overall length @ 3 TeV < 50 km
  - ✓ Normal conducting accelerating structures
  - ✓ High acceleration frequency (12 GHz)

- Two-Beam Acceleration Scheme

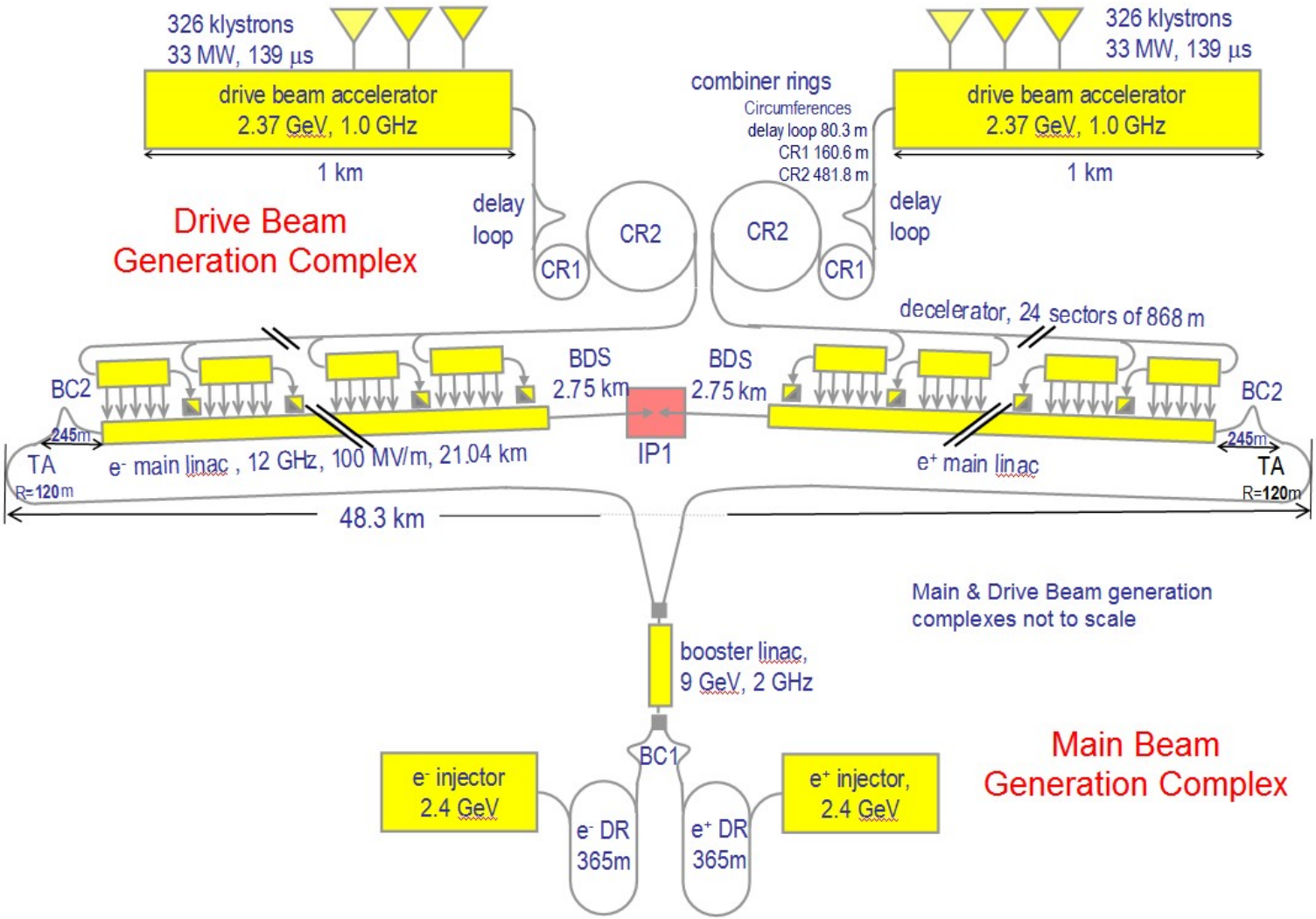
  - ✓ Cost effective, reliable, efficient
  - ✓ Simple tunnel, no active elements
  - ✓ Modular, easy energy upgrade in stages

Drive beam - 100 A, 240 ns
from 2.4 GeV to 240 MeV



Main beam – 1 A, 160 ns
from 9 GeV to 1.5 TeV

CLIC Layout 3 TeV



CLIC Layout 500 GeV

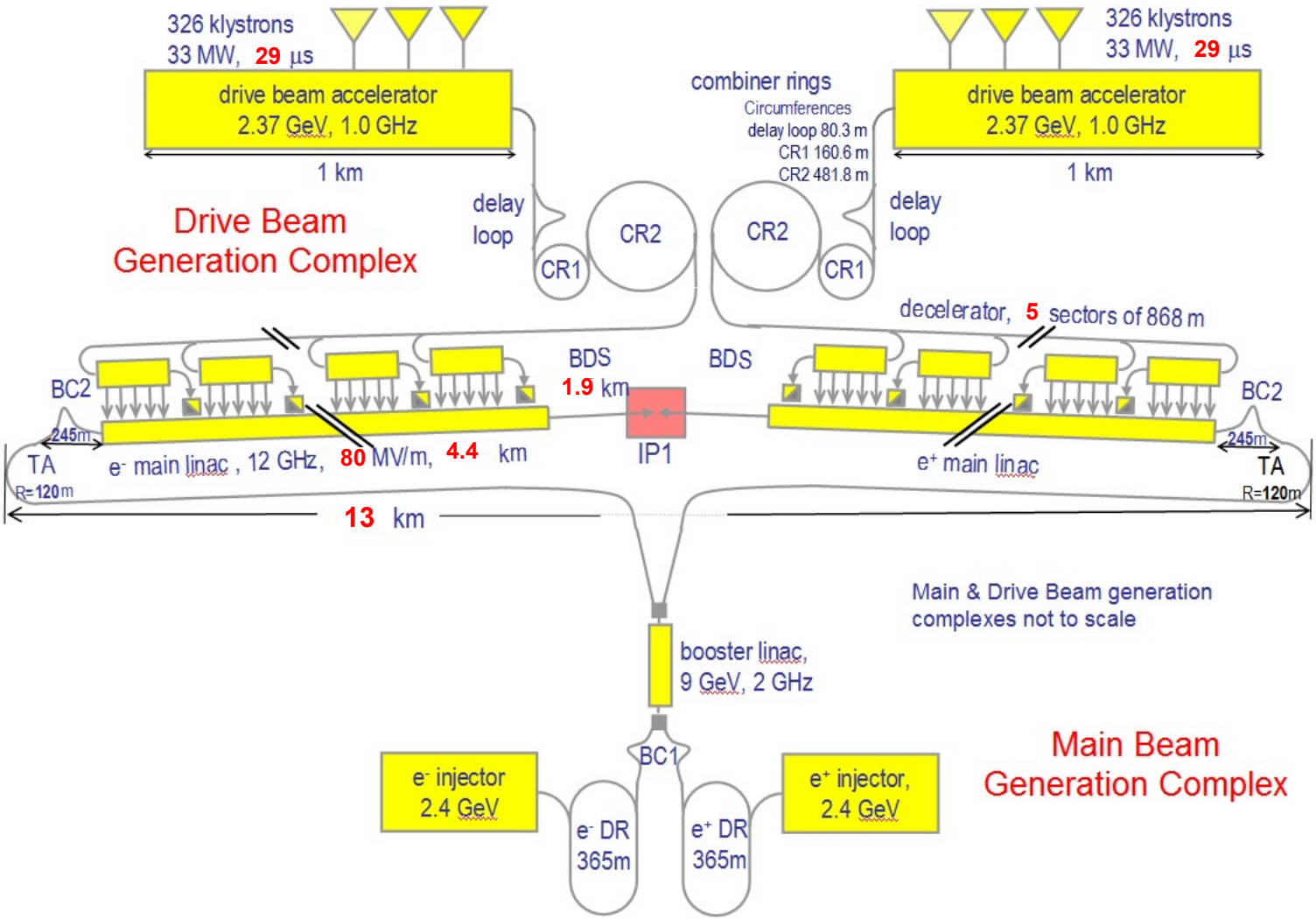


Table of CLIC feasibility issues

SYSTEMS (level n)		Critical parameters	Feasibility issue	Performance issue	Cost issue
Structures	**Main beam acceleration structures** Demonstrate nominal CLIC structures with damping features at the design gradient, with design pulse length and breakdown rate .	RF power facilities (SLAC, KEK, CERN, SACLAY… + CTF3)			
	Decelerator structures Demonstrate nominal PETS with damping features at design power, with design pulse length, breakdown rate on/off capability				
Drive Beam	**Validation of drive Beam** - production - phase stability , potential feedbacks - MPS appropriate for beam power	CTF3			
Two Beam	**Test of a relevant linac sub-unit with both beams**				
Beam Physics	**Preservation of low emittances (main linac + RTML)**	Absolute blow-up Hor: 160nradm Vert: 15 nradm	X	X	
Stabilization	**Main Linac and BDS Stabilization**	Main Linac : 1 nm vert (>1 Hz) BDS: 0.15…1 nm vert (>4 Hz) depending on implementation of final doublet girder	X	X	X
Operation and reliability	**Commissioning strategy** **Staging of commissioning and construction** **MTBF, MTTR** **Machine protection**	Handling of drive beam power of 72 MW	X	X	X

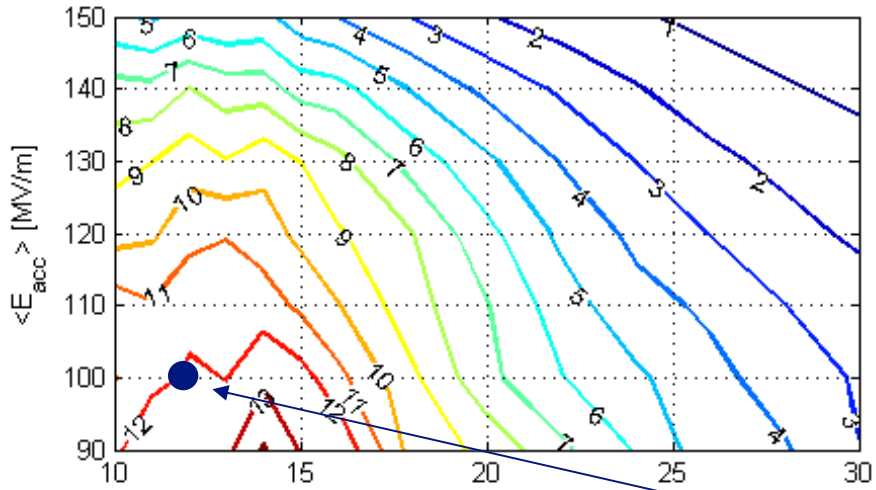
CLIC accelerating structure optimization

- Takes into account RF break-down limitations for peak surface field, power and pulse length
- Input from beam dynamics & beam-beam effects at collision
- Based on parametric total cost model

- Find structure parameters (aperture, length, group velocity) with optimum cost
- Calculate cost and performance (Luminosity/power)

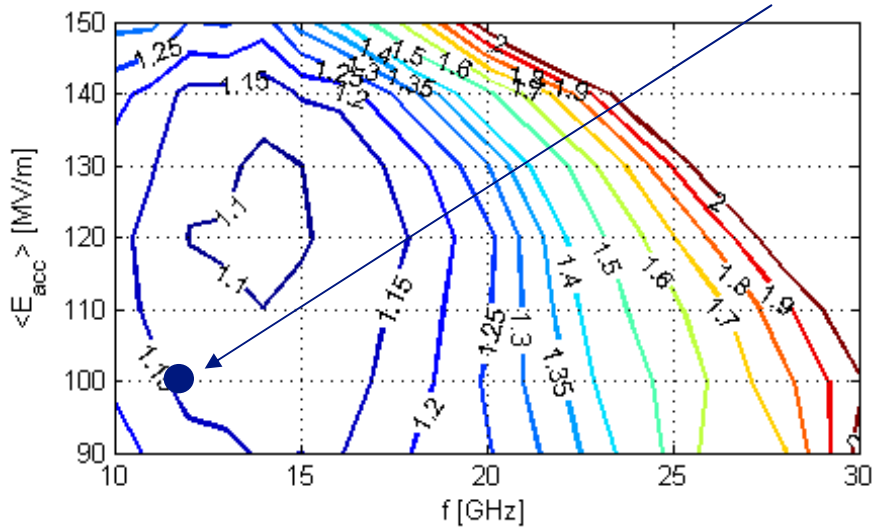
- Final choice of parameter is a compromise between cost, performance and other practical considerations

Luminosity / power



CLIC parameters

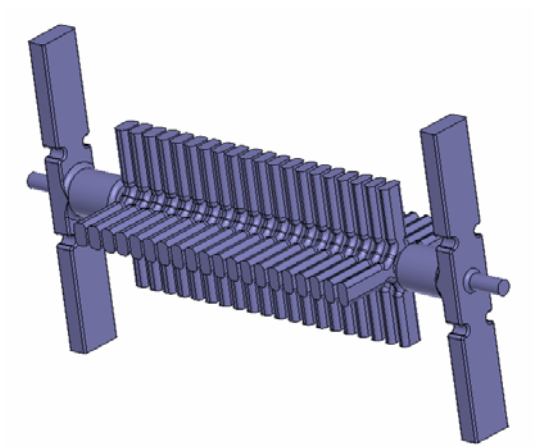
Total cost (a.u.)

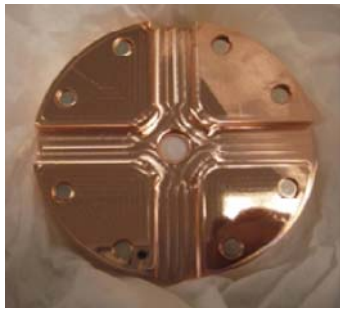


A. Grudiev et al.
EPAC '06

CLIC accelerating structure requirements

- Loaded average accelerating gradient ≥ 100 MV/m
- Breakdown rate at nominal gradient ≤ 2 10^{-7} per meter @ 3 TeV c.m. (1% luminosity loss)
- RF to beam efficiency in the 20 – 30% range @ 3 TeV
- Long range wake at 2nd bunch crossing $W_{t,2} \leq 0.27\ 10^{-6}$ V/pC/mm/m · E_{acc} / N





Structure	CLIC G
Frequency: f [GHz]	12
Average iris radius/wavelength: $\langle a \rangle/\lambda$	0.11
Input/Output iris radii: $a_{1,2}$ [mm]	3.15, 2.35
Input/Output iris thickness: $d_{1,2}$ [mm]	1.67, 1.00
Group velocity: $v_g^{(1,2)}/c$ [%]	1.66, 0.83
N. of reg. cells, str. length: N_c, l [mm]	24, 229
Bunch separation: N_s [rf cycles]	6
Luminosity per bunch X-ing: $L_{b\times}$ [m^{-2}]	1.22×10^{34}
Bunch population: N	3.72×10^{9}
Number of bunches in a train: N_b	312
Filling time, rise time: τ_f, τ_r [ns]	62.9, 22.4
Pulse length: τ_p [ns]	240.8
Input power: P_{in} [MW]	63.8
$P_{in}/Ct^P{}_p{}^{1/3}$[MW/mm $ns^{1/3}$]	18
Max. surface field: E_{surf}^{max} [MV/m]	245
Max. temperature rise: ΔT^{max} [K]	53
Efficiency: η [%]	27.7
Figure of merit: $\eta L_{b\times}/N$ [a.u.]	9.1

X-band high-gradient R&D - activities

- Structure construction (high precision machining, tolerances, material studies...)
- Power Extraction & Transfer Structures (PETS) development
- Development of high-power RF components
- Breakdown theory and simulation
- Basic physics experimental studies
  - Single-cell and short constant impedance structures
  - Waveguide breakdown experiments
  - Pulsed-power heating experiments
- Full Accelerator Structure Testing

pulsed-power heating testing (SLAC)

single-cell cavities (SLAC)

X-band high-gradient R&D - collaborating Institutes

CERN: Structure design & fabrication, high-power testing.

SLAC: High-power testing, pulsed-surface-heating testing, test structure fabrication.

KEK: Test structure fabrication and high-precision machining. High-power testing starting.

Cockcroft Institute: Structure and beam dynamics simulations planned.

PSI: Interest in structure design, breakdown theory and high-power testing.

Helsinki Institute of Physics: Precision mechanical engineering. Breakdown simulation.

Uppsala University: Two-beam test stand beam-lines, instrumentation and experiments. Breakdown experiments.

CIEMAT: Test-PETS and RF components.

Gycom/Nizhniy Novgorod: High-power RF components.

Pakistan: Two-beam test stand hardware.

Dubna: Pulsed surface heating experiment.

DAPNIA, SACLAY: Superconducting-level cleaning. Planned test accelerating structure fabrication, wakefield monitor, high-power testing.

US High-gradient collaboration: Many common subjects.

High-power RF facilities

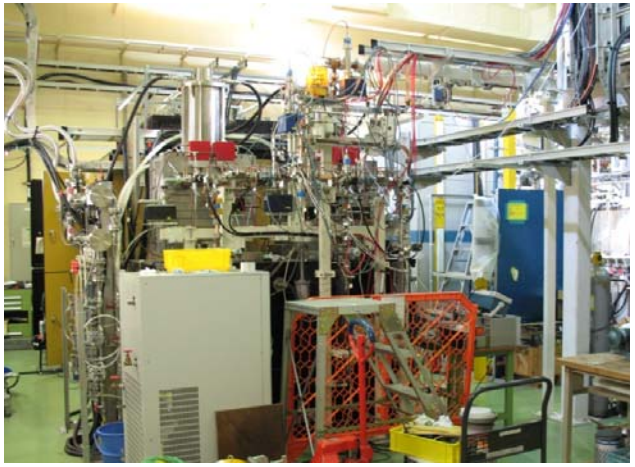
Testing of RF components:

Accelerating structures
PETS
RF components

SLAC NLCTA (3 RF stations)
Klystron Lab (4 RF stations)

Operational

11.4 GHz
Up to 300 MW @ 400ns



KEK Nextef
X-band Klystron Test Station

Operational

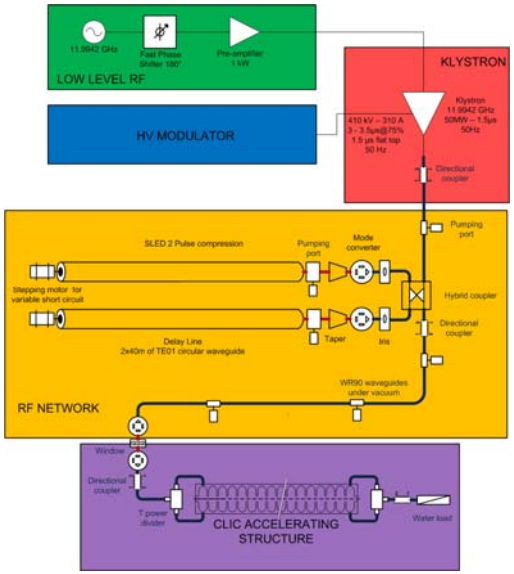
11.4 GHz
Up to 100 MW @ 400 ns

CERN 12 GHz Test Stand

(CEA-DAPNIA)

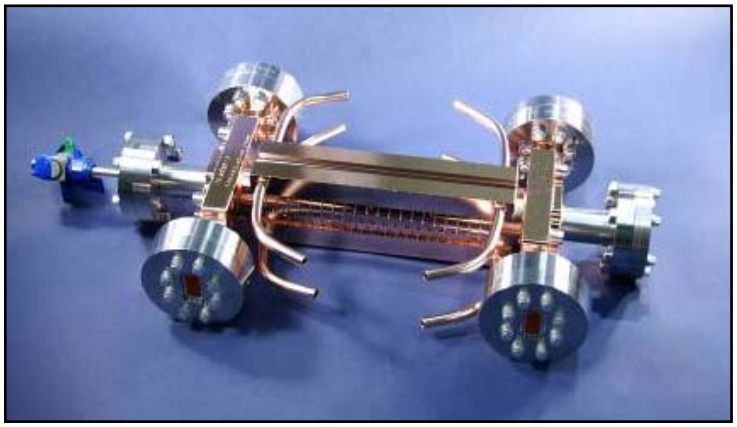
Under construction
start beginning 2010

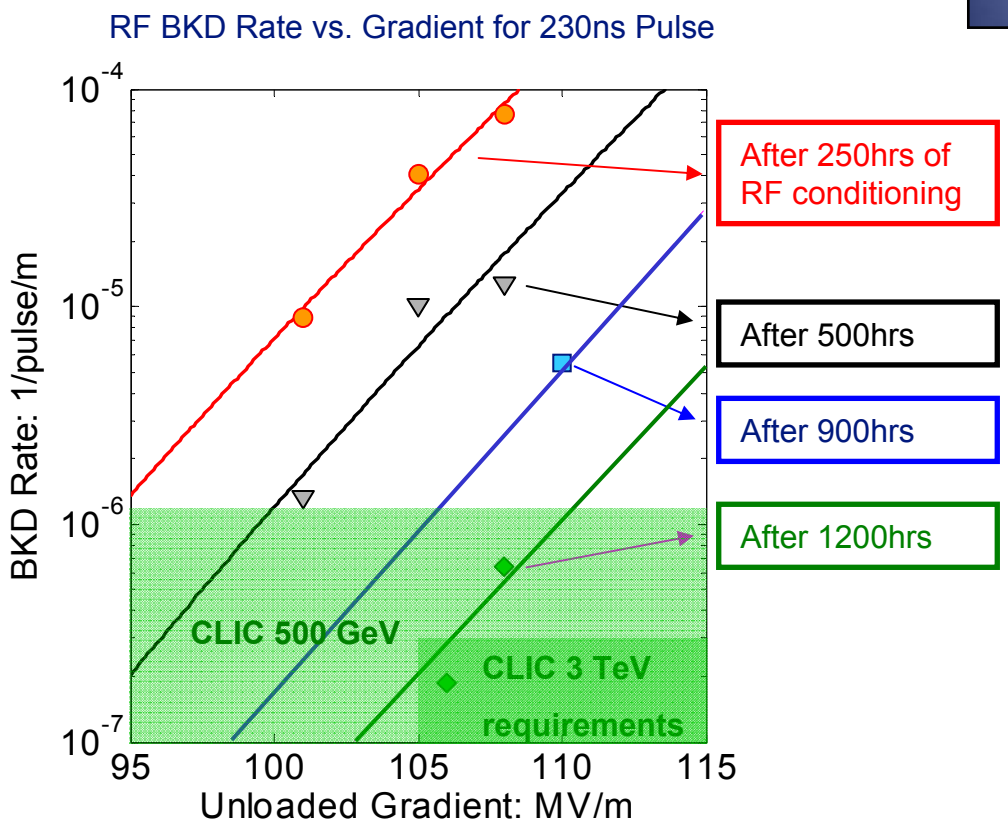
12 GHz
50 MW @ 1.5 μs

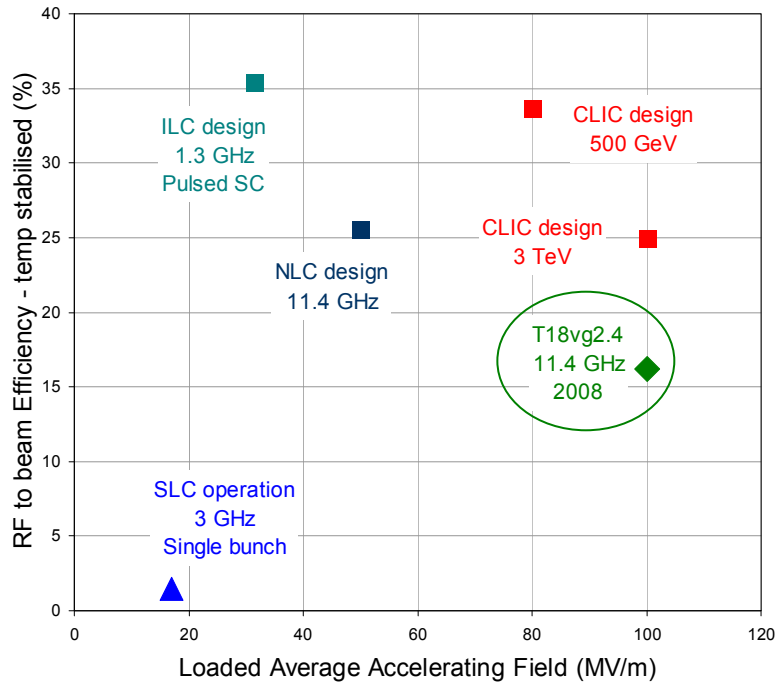


Structure T18_vg4.2

- designed by CERN
- built at KEK,
- assembled and bonded in SLAC
- tested at SLAC (NLCTA).



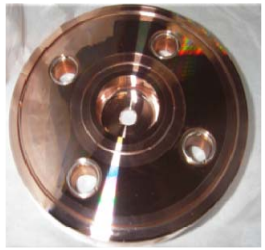




Next steps

T18
tested

105 MV/m, 230 ns,
$2x10^{-7}$/(mxpulse)



Today

Supporting tests:
Quadrant fabrication
CD10
Choke mode CD10

Add damping

TD18

early 2009

Move to design iris range

Move to design iris range and add damping

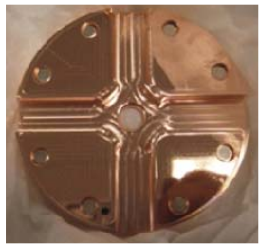
Move to design iris range

Supporting tests:
C10 series
T23

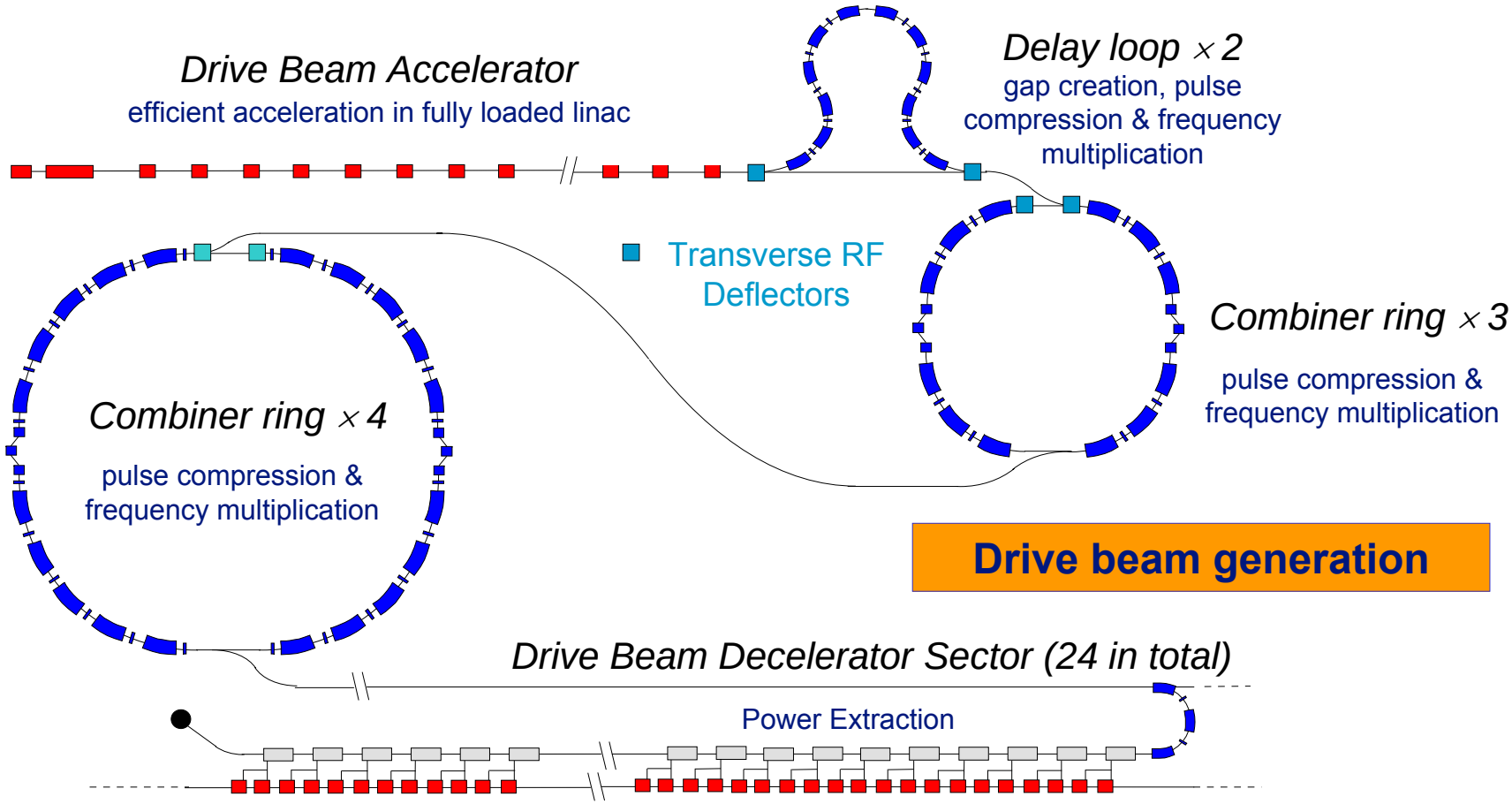
CLIC G
undamped

Add damping

CLIC G
with damping
full prototype

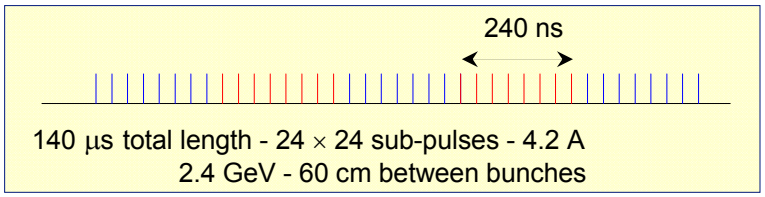


late 2009

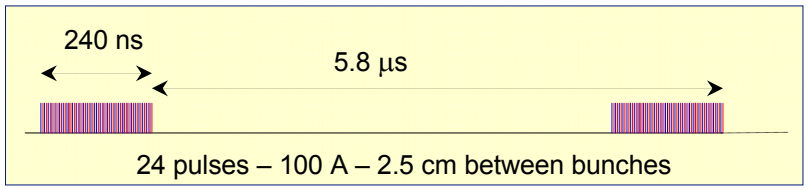


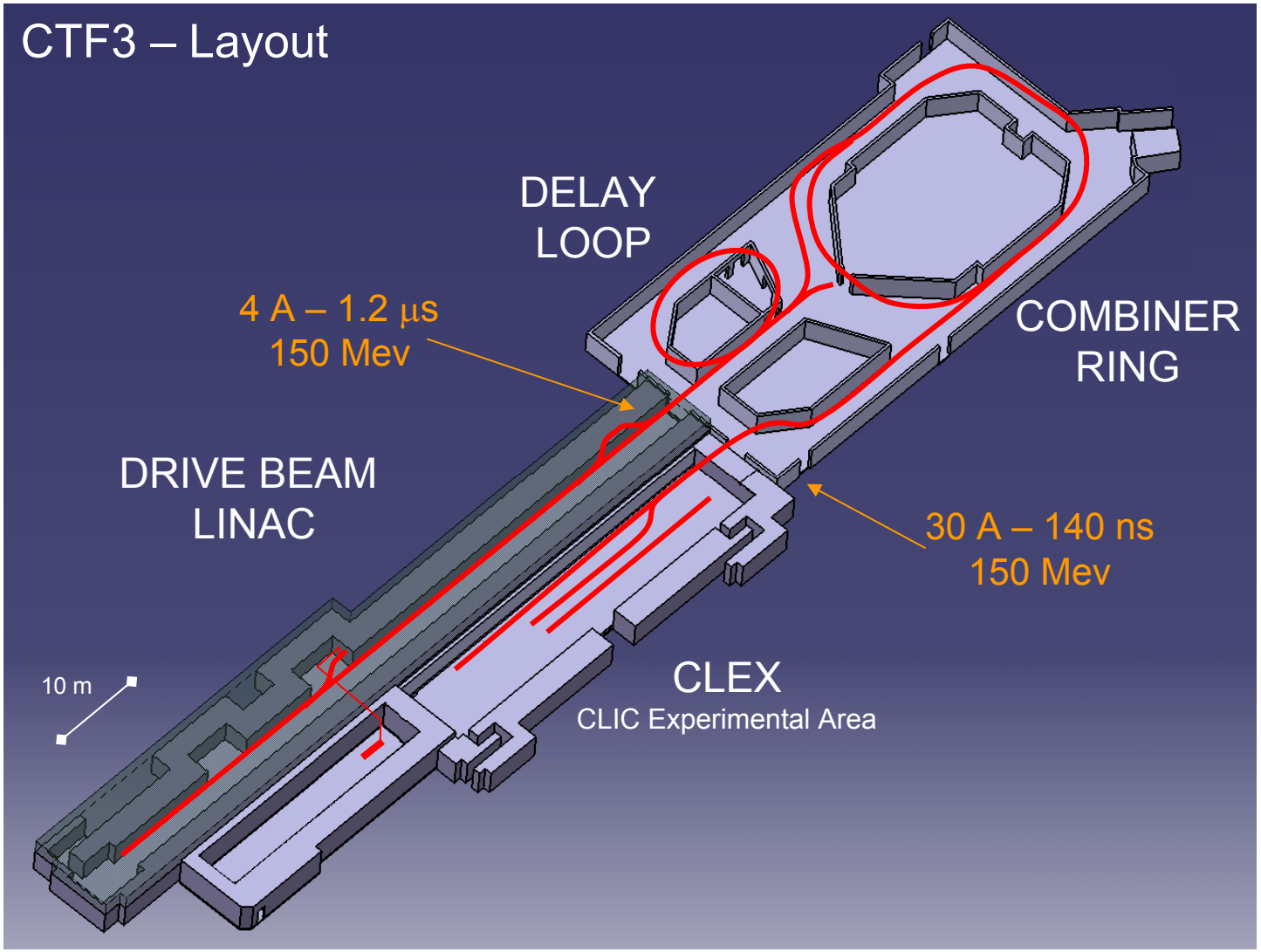
Drive beam generation

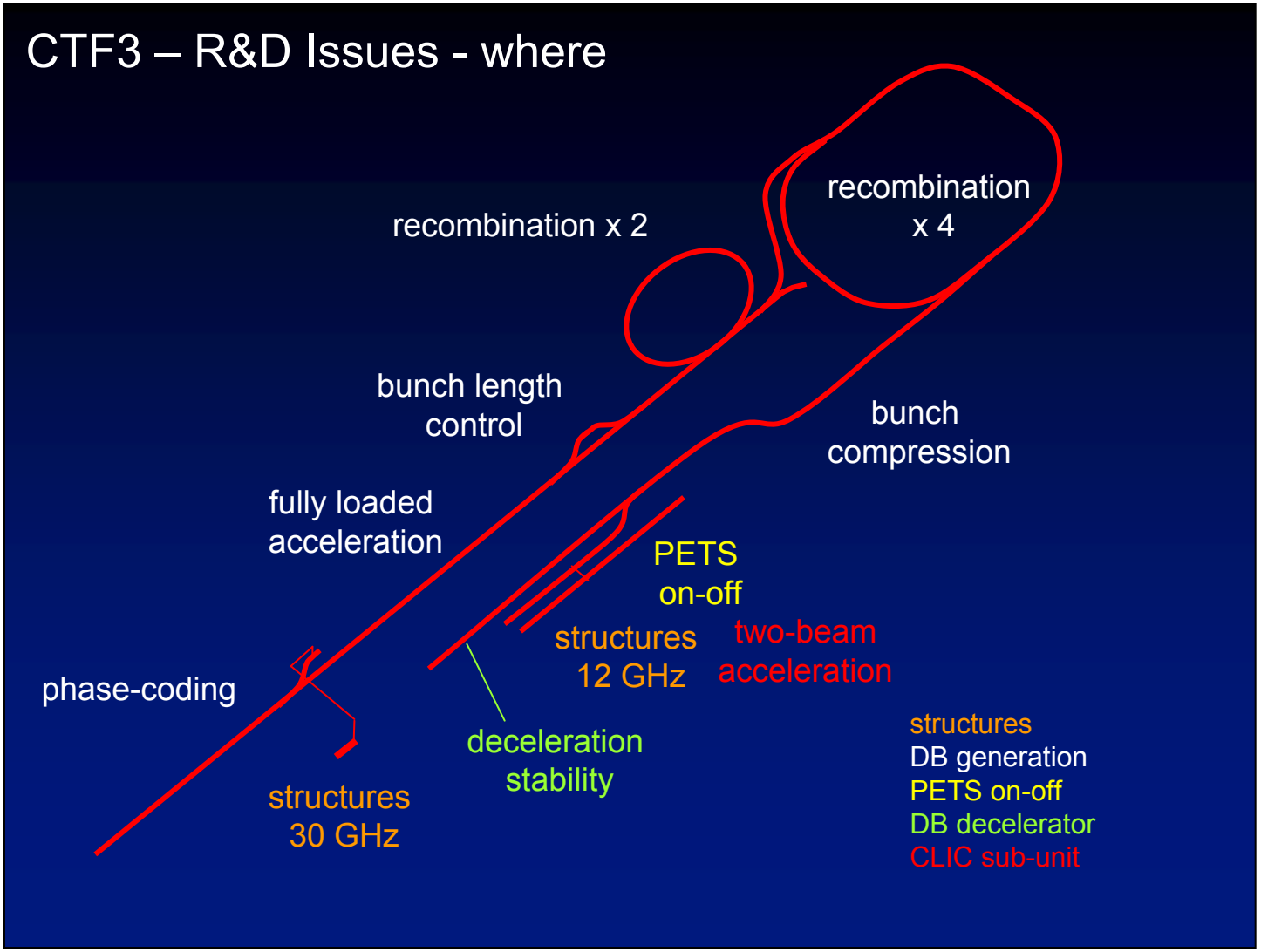
Drive beam time structure - initial

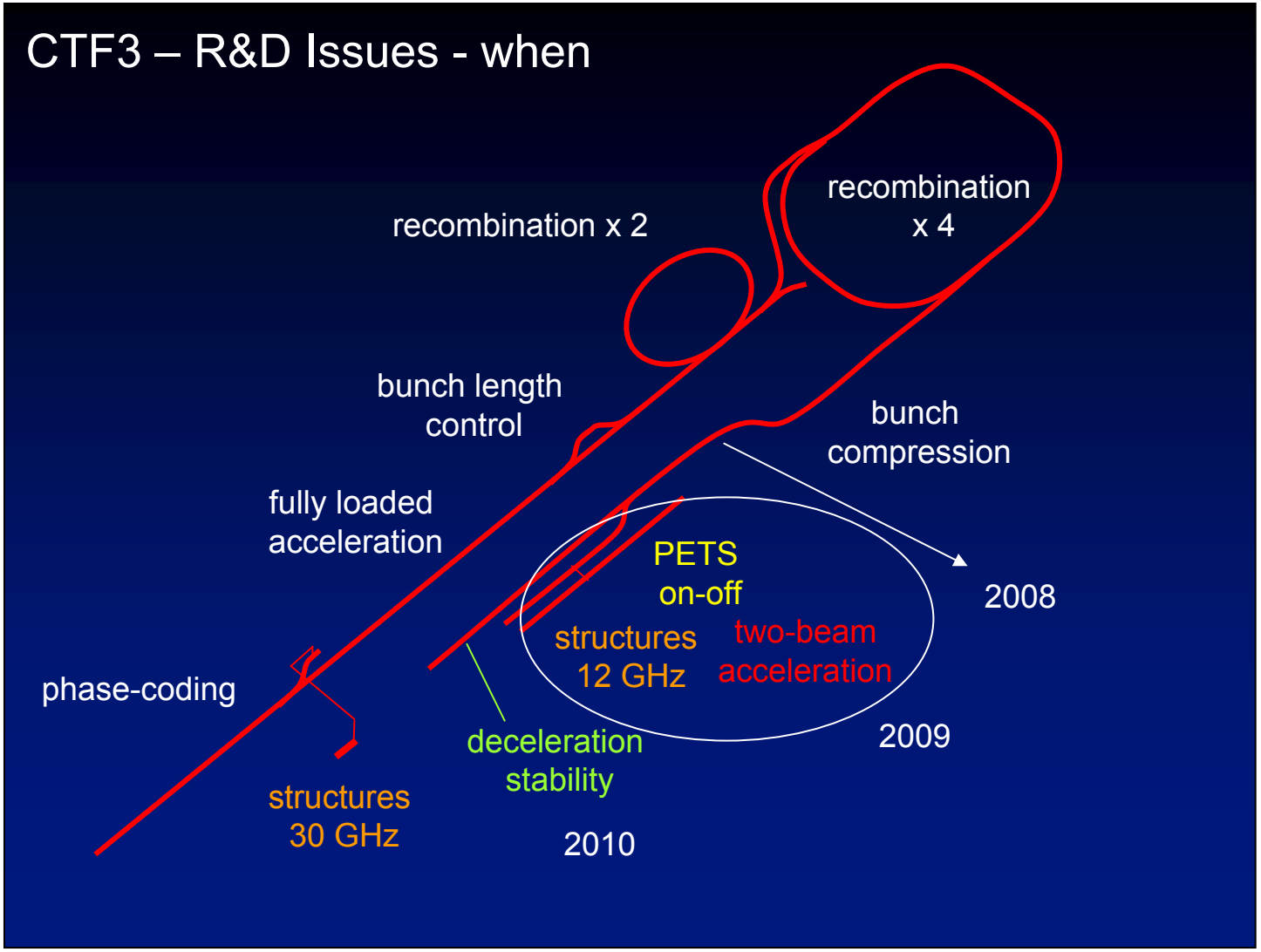


Drive beam time structure - final

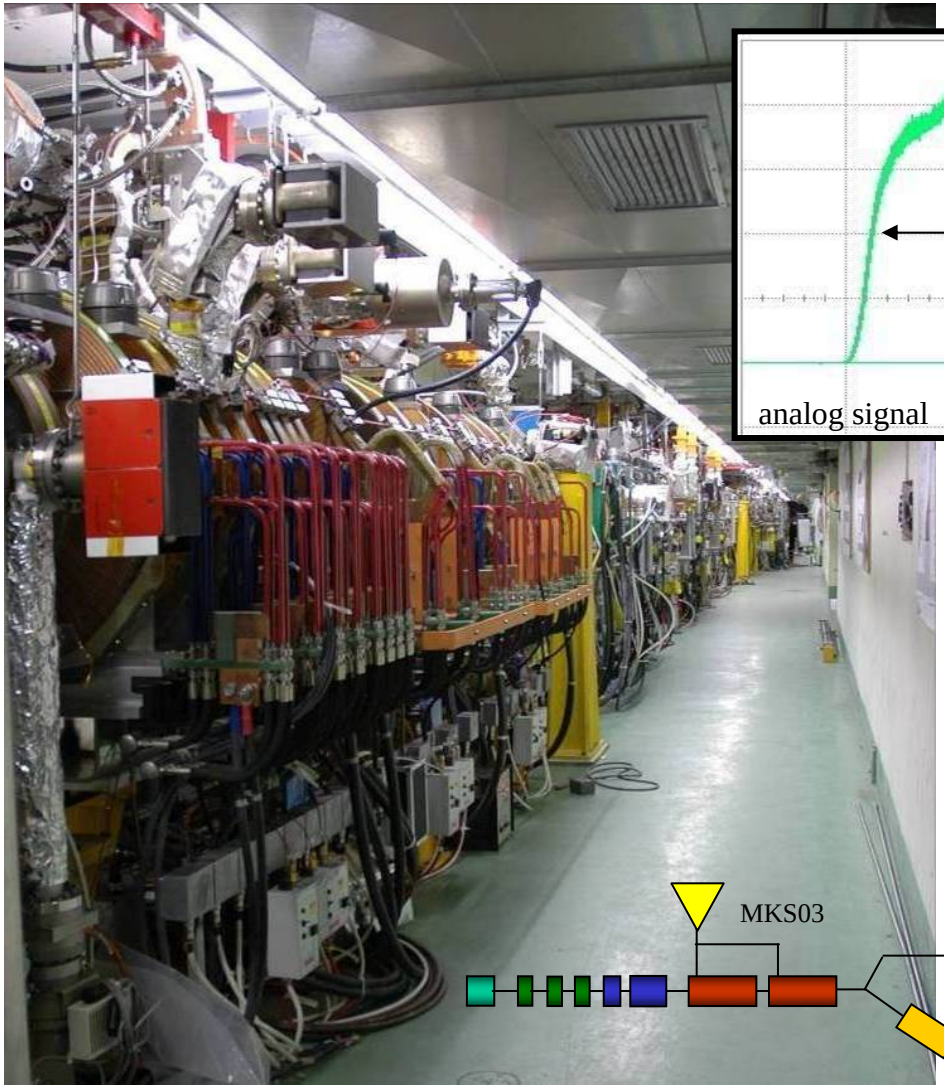


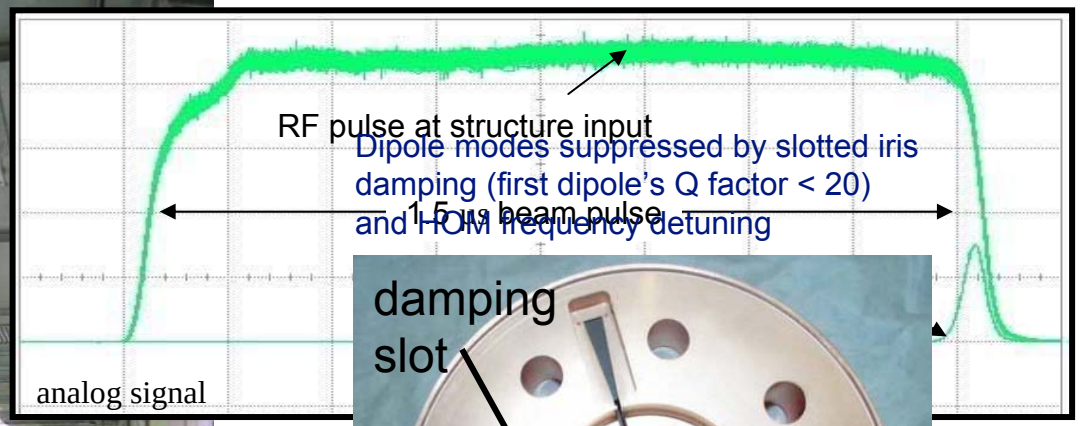

CTF3 – Layout
DELAY LOOP
4 A – 1.2 μs
150 Mev
COMBINER RING
DRIVE BEAM LINAC
30 A – 140 ns
150 Mev
10 m
CLEX
CLIC Experimental Area

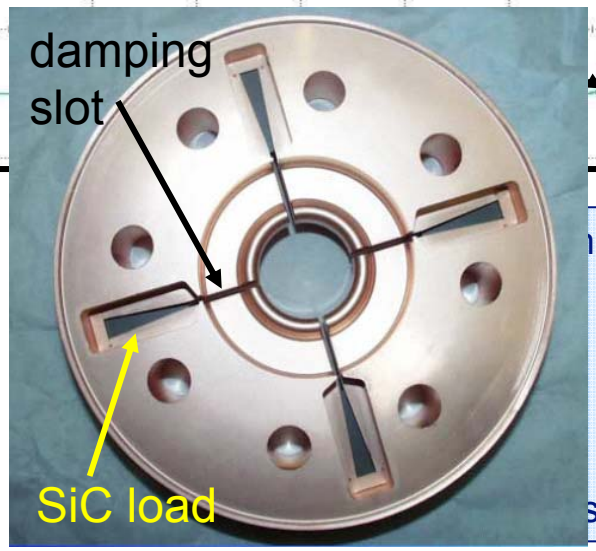

CTF3 – R&D Issues - where
recombination x 2
recombination x 4
bunch length control
bunch compression
fully loaded acceleration
PETS on-off
structures 12 GHz
two-beam acceleration
phase-coding
deceleration stability
structures 30 GHz
structures
DB generation
PETS on-off
DB decelerator
CLIC sub-unit


CTF3 – R&D Issues - when
recombination x 2
recombination x 4
bunch length control
bunch compression
fully loaded acceleration
PETS on-off
2008
structures 12 GHz
two-beam acceleration
phase-coding
2009
deceleration stability
structures 30 GHz
2010

Drive Beam linac – high current, full beam loading operation

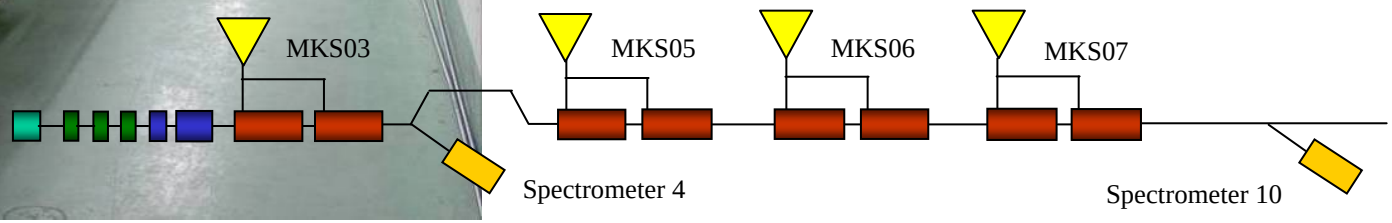






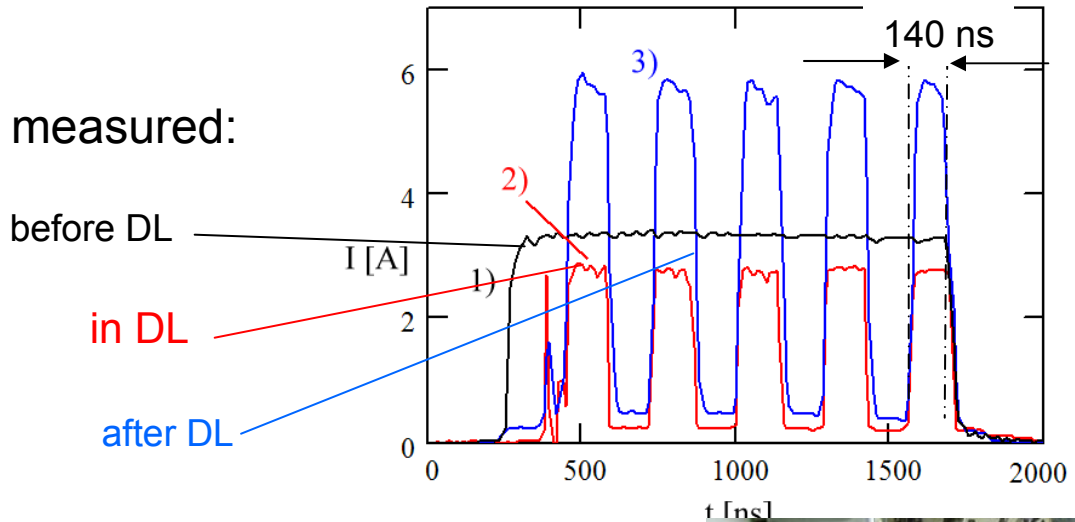
n efficiency

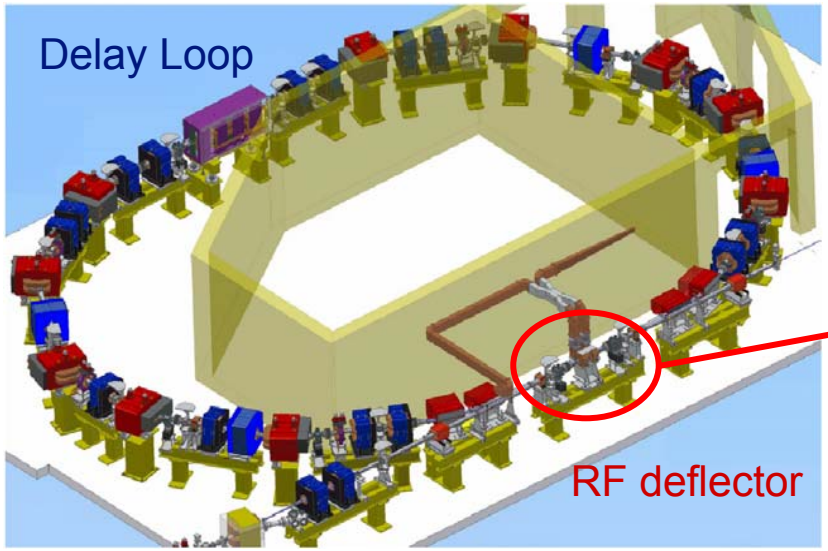
ses)

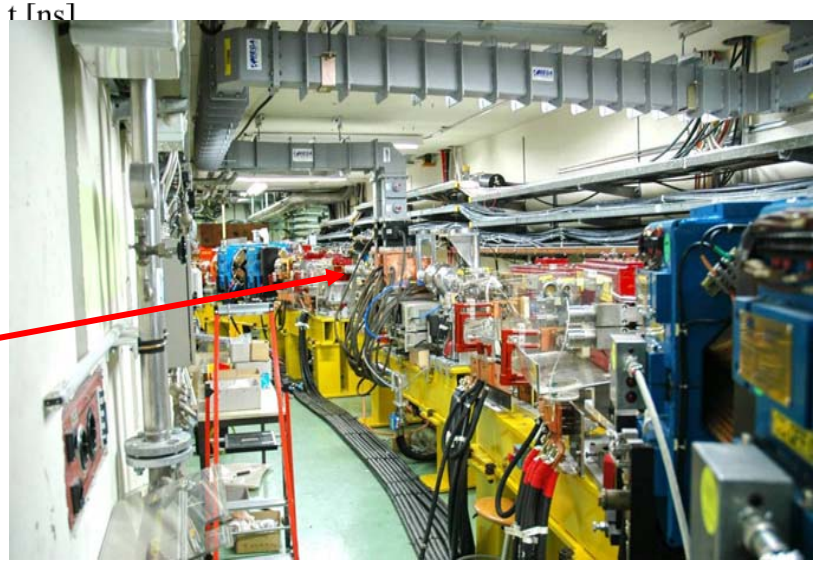


Delay Loop – beam current multiplication x 2, hole creation

Beam current measured:

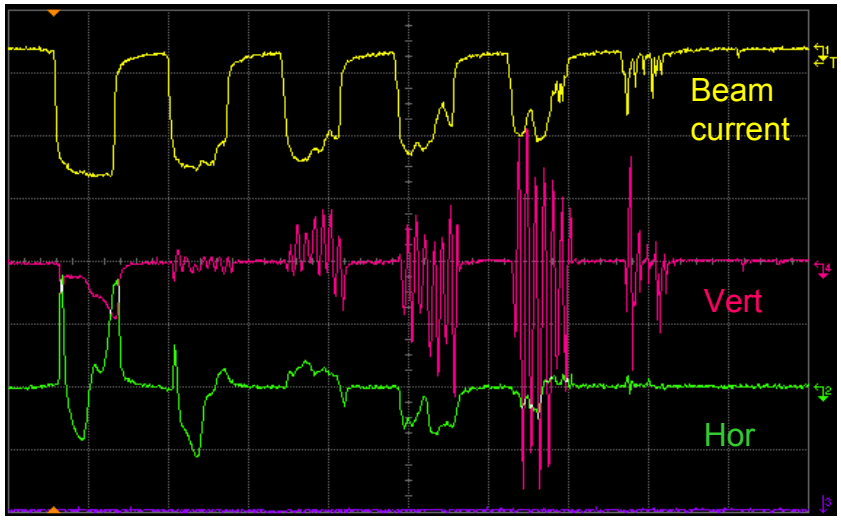


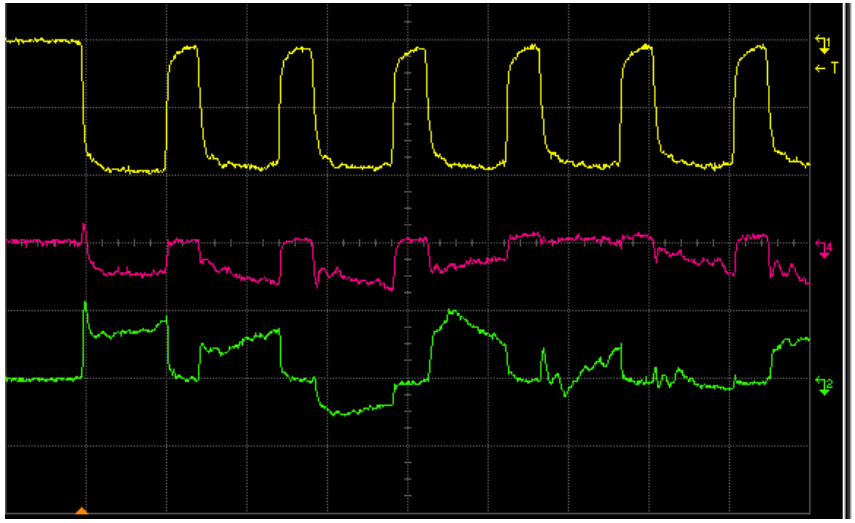


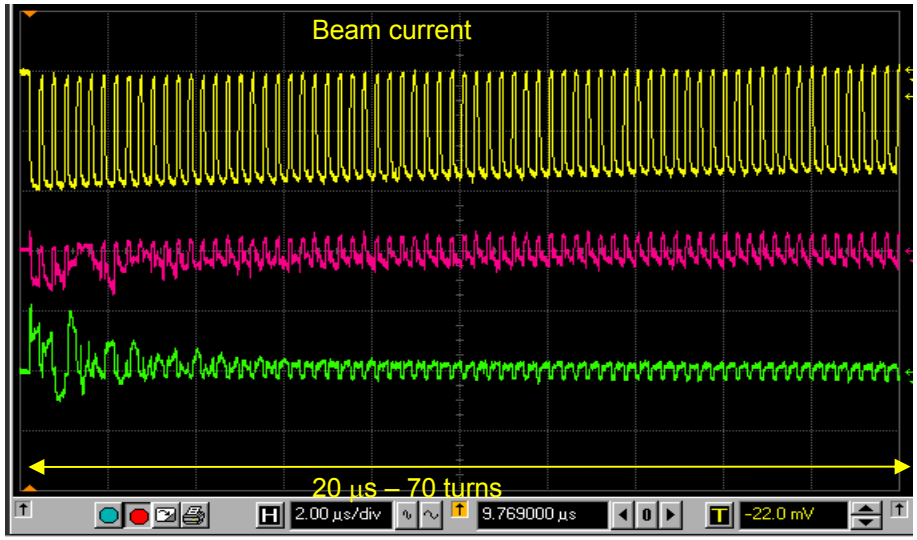


Fast vertical beam instability in CTF3 solved by new deflectors

with strong damping of the vertical deflecting mode and larger hor./vert. detuning



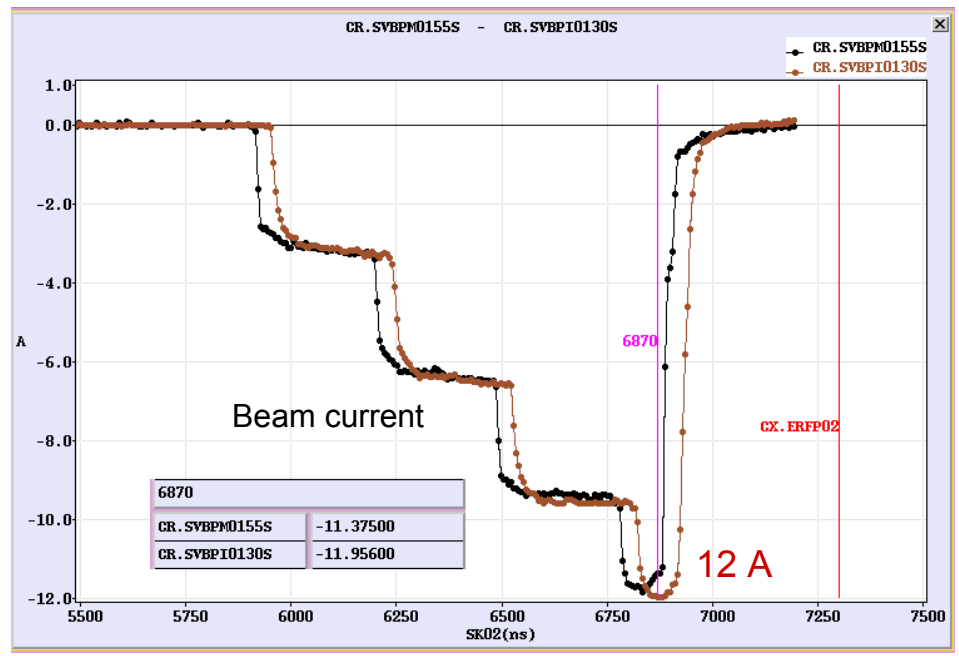




Without the losses from the fast vertical beam instability (plus improved optics control and tuning tools) it is now possible to circulate the 3 A beam with very small losses for hundreds of turns.

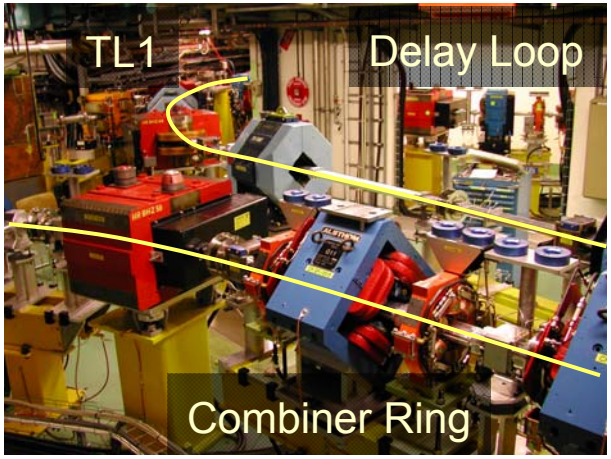
Bunch re-combination of a 3 A beam with factor four current increase had been demonstrated – 12 A reached.

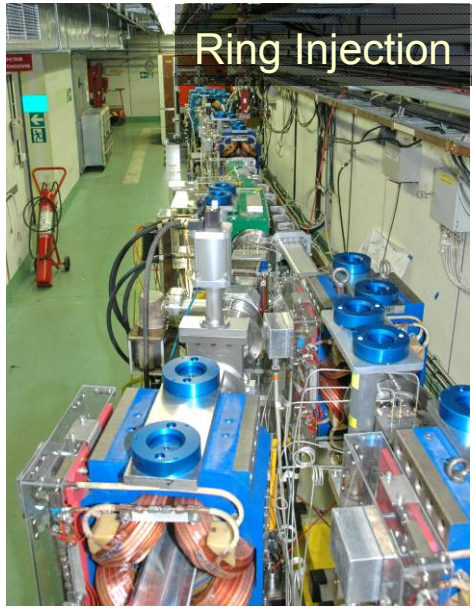
(DL still by-passed, and limited by RF pulse length)

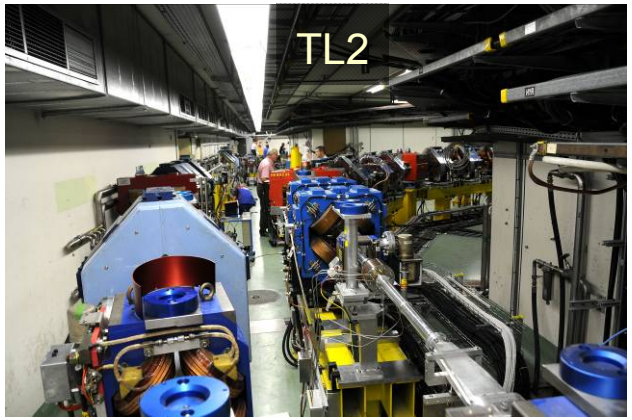


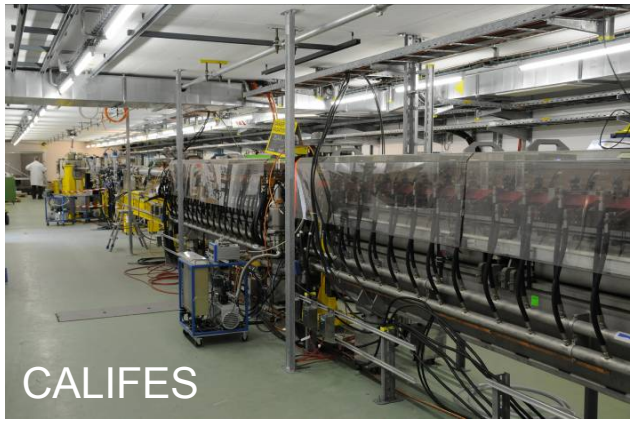
Most of the hardware has now been installed !

Ring Area

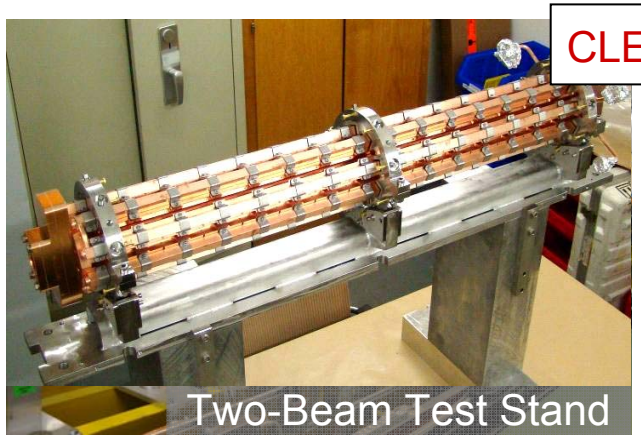


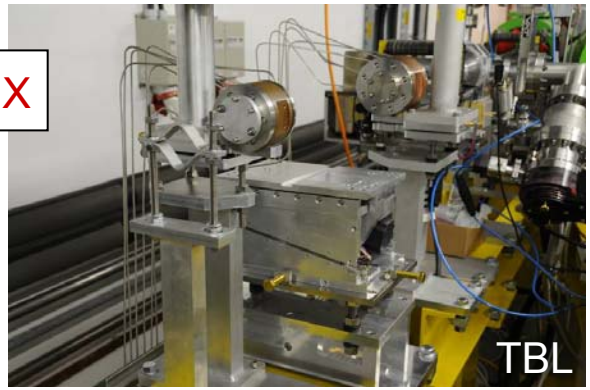


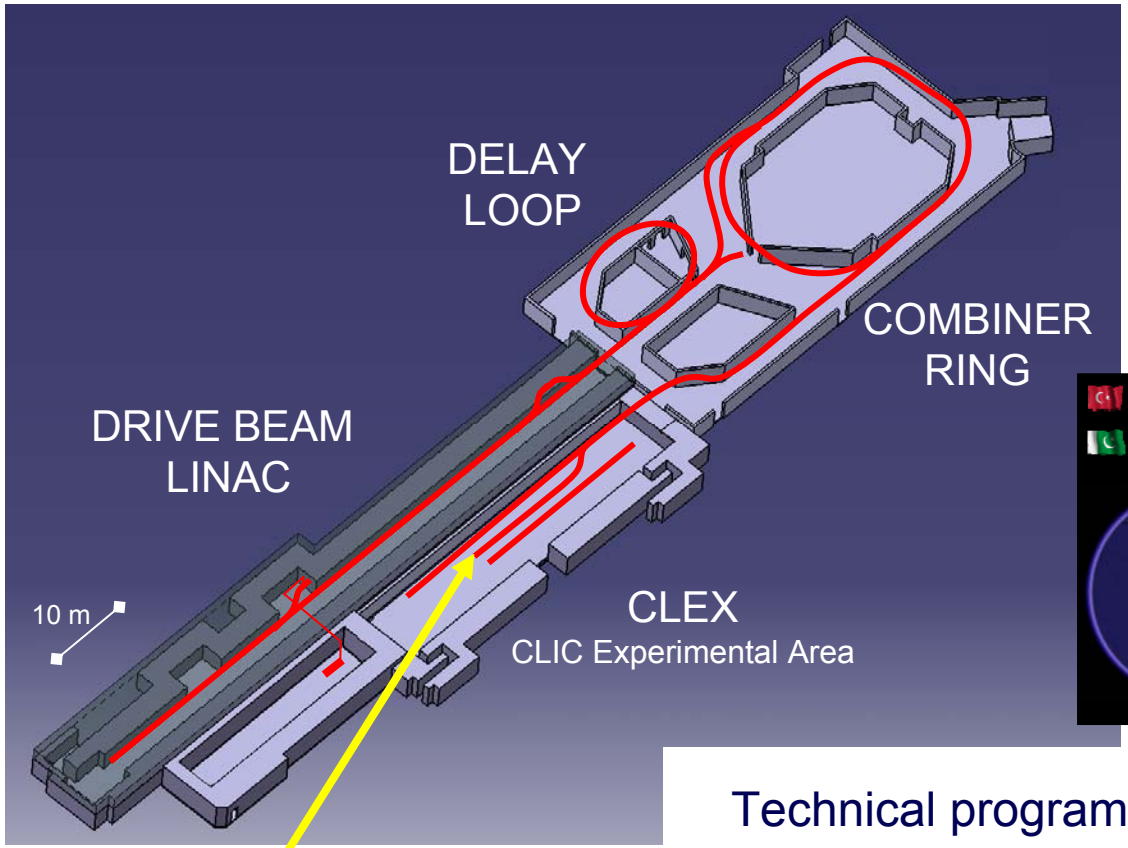




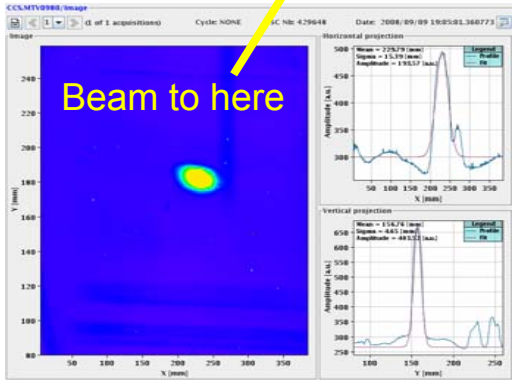
CLEX







Progress only possible through successful collaboration between 27 international institutes



Technical programme is on track

- CTF3 on schedule

  full beam loading

  bunch phase coding and Delay Loop operation

  First results on recombination on Combiner Ring

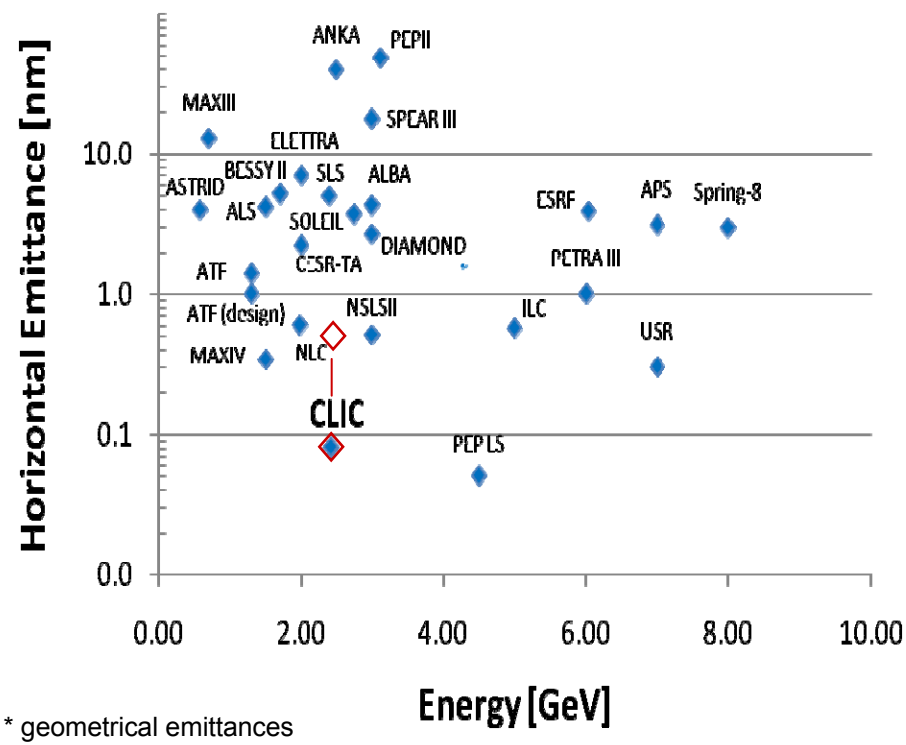
All machine components installed (apart from TBL)

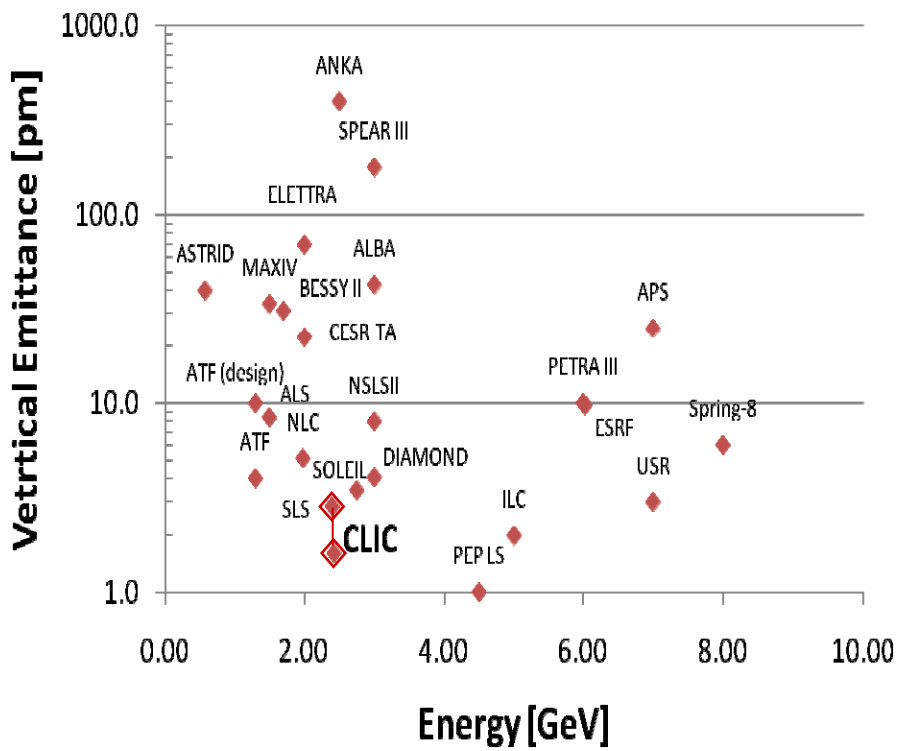
Matching critical issues & test facilities

	SYSTEMS (level n)	Critical parameters	Crucial design choice or fesibility	Performance issue	Cost issue	Relevant Facilities (also valid for ILC)
Structures	Main beam acceleration structures Demonstrate nominal CLIC structures with damping features at the design gradient, with design pulse length and breakdown rate .	100 MV/m 240 ns 3·10-7 BR/(pulse*m)	X	X	X	CTF2&3 (2005-2010) Test Stand (2009-2010) SLAC/NLCTA SLAC/ASTA KEK/NEXTEF
	Decelerator structures Demonstrate nominal PETS with damping features at design power, with design pulse length, breakdown rate on/off capability	136 MW 240 ns	X		X	CTF3 (2005-2010) CTF3/TBTS (2008-2010) CTF3/TBL (2009-2010) SLAC ASTA
Drive Beam	Validation of drive Beam - production - phase stability , potential feedbacks - MPS appropriate for beam power	0.2 degrees phase stability at 12 GHz	X	X		CTF3 (2005-2010) CTF3/TBL (2009-2010) X-FEL LCLS
Two Beam	Test of a relevant linac sub-unit with both beams	NA	X			CTF3/TBTS (2008-2010)
Beam physics	Ultra-low emittances - Generation of low-emittances (damping rings)	Hor:500 nradm Vert: 5 nradm		X		ATF (2008-10): 3000/12 CESRTA:Electron Cloud NSLSII: Hor 2000nradm SLS: Vert 10nm
	- Preservation of low emittances (main linac + RTML)	Absolute blow-up Hor: 160nradm Vert: 15 nradm	X	X		Beam simulations LCLS SCSS
	- Beam focusing to small dimensions (BDS)	Hor: 40 nm Vert: 1 nm		X		ATF2 (2006-2012) Hor: 200 nm Vert: 36 (20) nm

Small emittances from Damping Rings

- Present CLIC DR design for **3TeV** achieves goals for transverse emittances with a 20% - 30% margin (**380 nm** horizontal and **4.1 nm** vertical)
- Conservative DR output emittances (**2.4 μm** horizontal, **10 nm** vertical) for CLIC @ **500GeV** scaled from operational or approved light source projects (NSLSII, SLS)

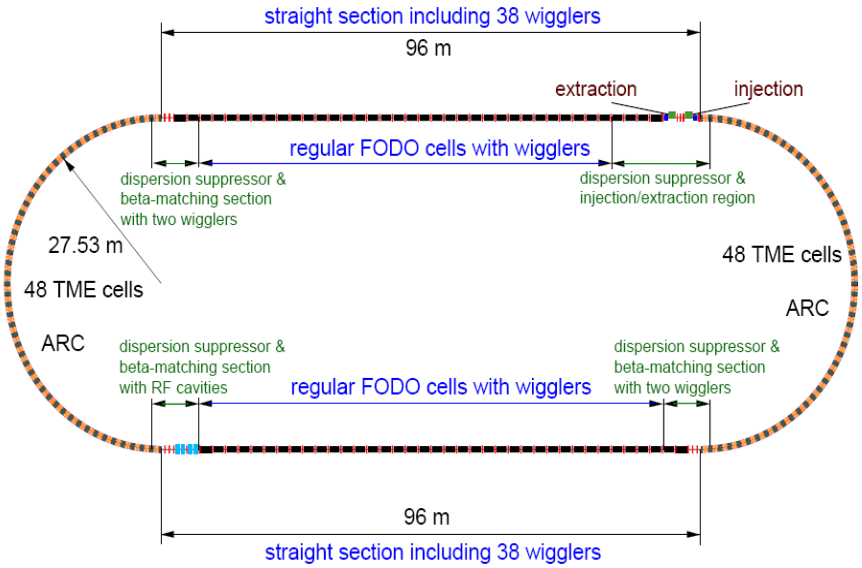


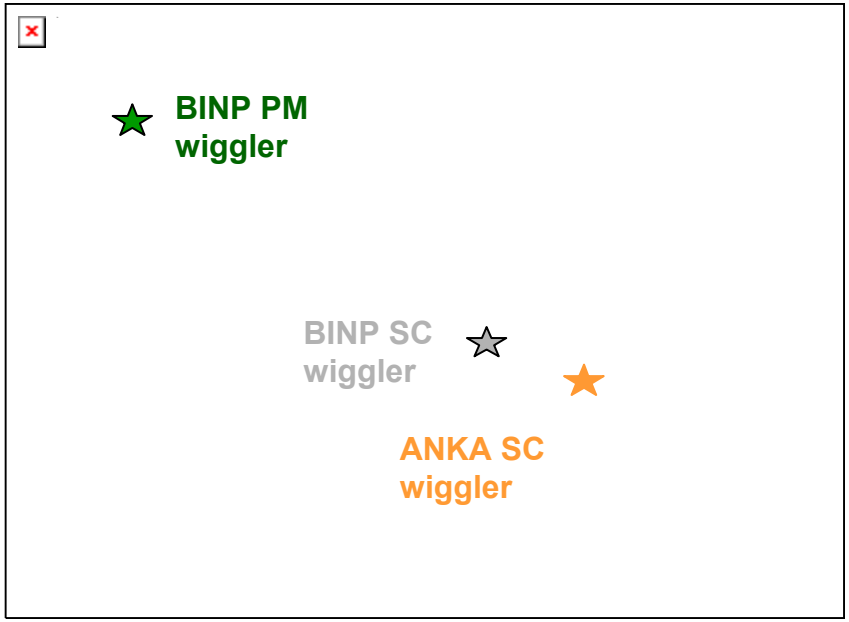


* geometrical emittances

Damping Rings

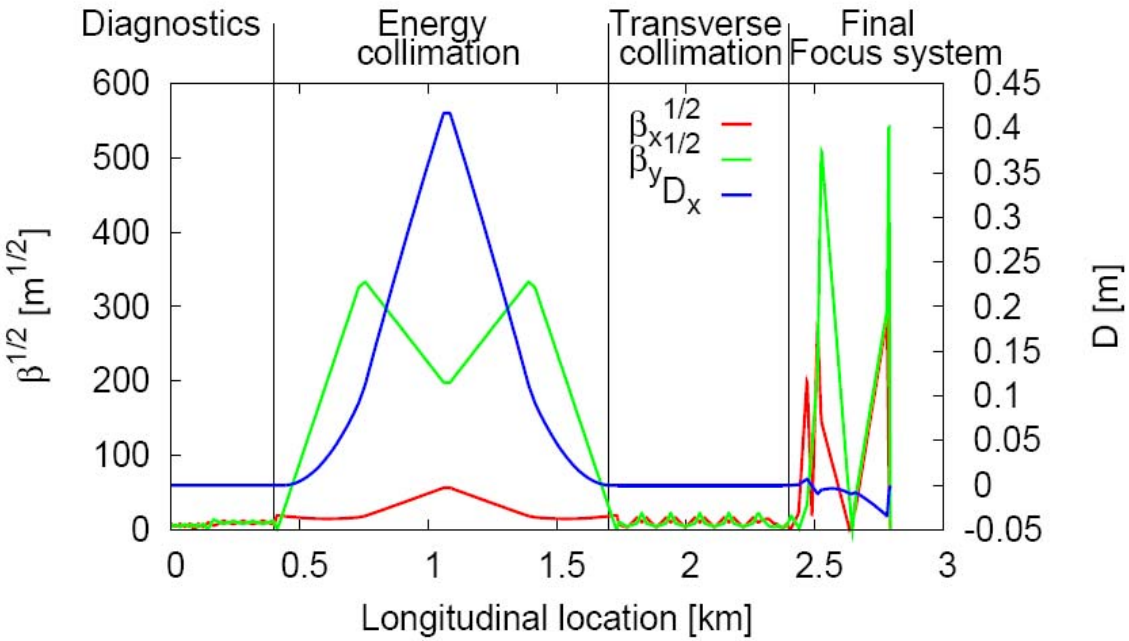
- CLIC damping ring design
  - Racetrack, 365 m long, E = 2.4 GeV
  - Arcs filled with TME cells
  - Straights filled with 2 m-long superconducting damping wigglers (2.5 T, 5 cm period)
  - Output emittance strongly dominated by IBS
- Work in progress
  - SC wiggler prototype to be built and tested at ANKA
  - IBS theory, numerical tools
  - Pre-damping rings optics design
  - Radiation absorption protection, vacuum chamber design and impedance budget
  - Design of HOM free high frequency RF cavities
  - Collective effects evaluation (electron cloud and fast ion instability)
  - Injection and extraction elements
  - Diagnostics and feedback
  - Route from 500GeV to 3TeV

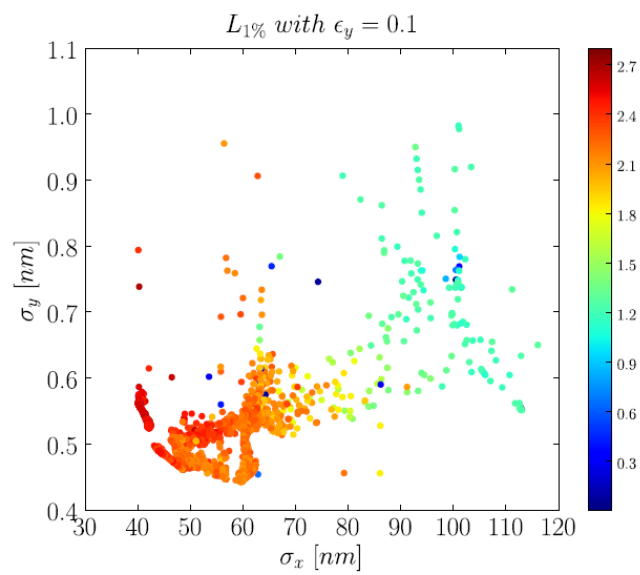




Beam Delivery System

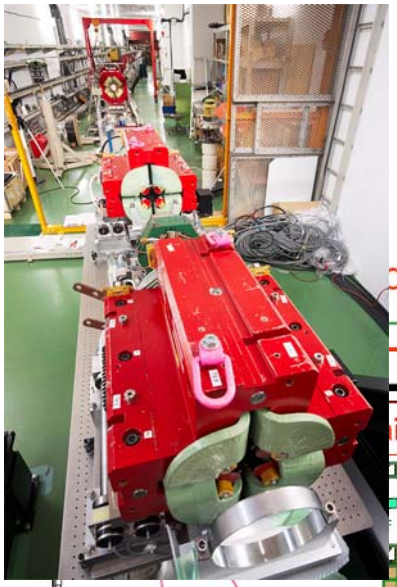
- Convergence to an optimized BDS design – meet requirements on paper
- Recent proposal for a larger *L** solution (relax final doublet alignment tolerances)
- The challenge remains to verify tuning in realistic simulations with dynamic effects
- Lots to learn from ATF2 experience
- ATF2 ultra-low betas proposal: demonstrate CLIC-like chromaticities

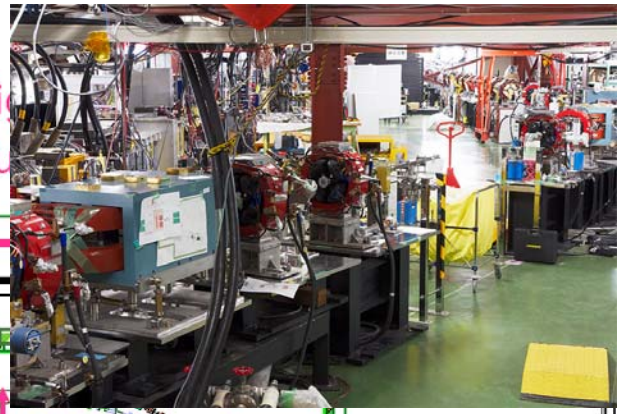


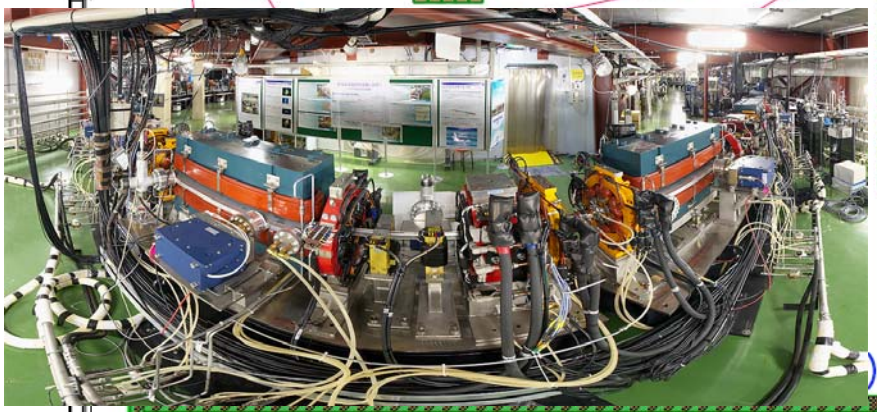


Peak Luminosity has been optimized by varying dispersion, betas, adding decapoles (CLIC-Note-735).

ATF & ATF 2



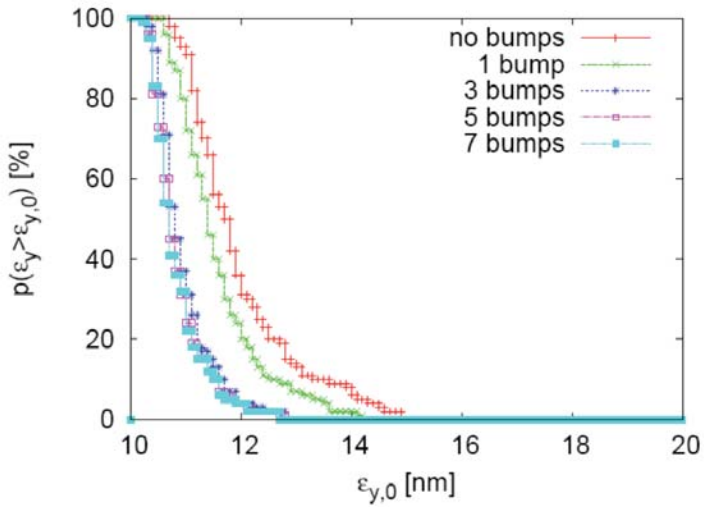




Project	Status	β_y^* [mm]	L* [m]	L*/β_y^*	ξ_y
FFTB	Design	0.1	0.4	4000	17000
FFTB	Measured	0.167	0.4	2400	10000
ATF2	Design	0.1	1.0	10000	19000
ATF2 pushed	Proposed	0.05	1.0	20000	38000
CLIC 500GeV	Design	0.2	4.3	21500	35000
CLIC 3TeV	Design	0.09	3.5	39000	63000
ILC	Design	0.4	3.5	8750	15000
ILC pushed	Design	0.2	3.5	17500	30000

Beam Emittance Conservation

- Emittance budget:
  - $\varepsilon_y \leq 5$ nm and $\varepsilon_x = 550$ nm after damping ring
  - $\Delta\varepsilon_y \leq 5$ nm in transport to main linac
  - $\Delta\varepsilon_y \leq 10$ nm in main linac
  - $\varepsilon_x = 660$ nm before the beam delivery system (growth mainly in RTML)
  - BDS budget: 20% spot size increase in the vertical plane
  - includes design, static and dynamic effects
  - requires 90% of the machines to perform better than the target
- Emittance budget is respected in simulations



- Tolerances are derived, iteration with experts of technical systems started
  - Alignment & stabilization
  - Magnets
  - Correctors
  - Instrumentation
- Feedback studies ongoing
- Benchmarking between codes and with beam tests

CLIC Technical Committee (CTC)
(created in spring 2008)

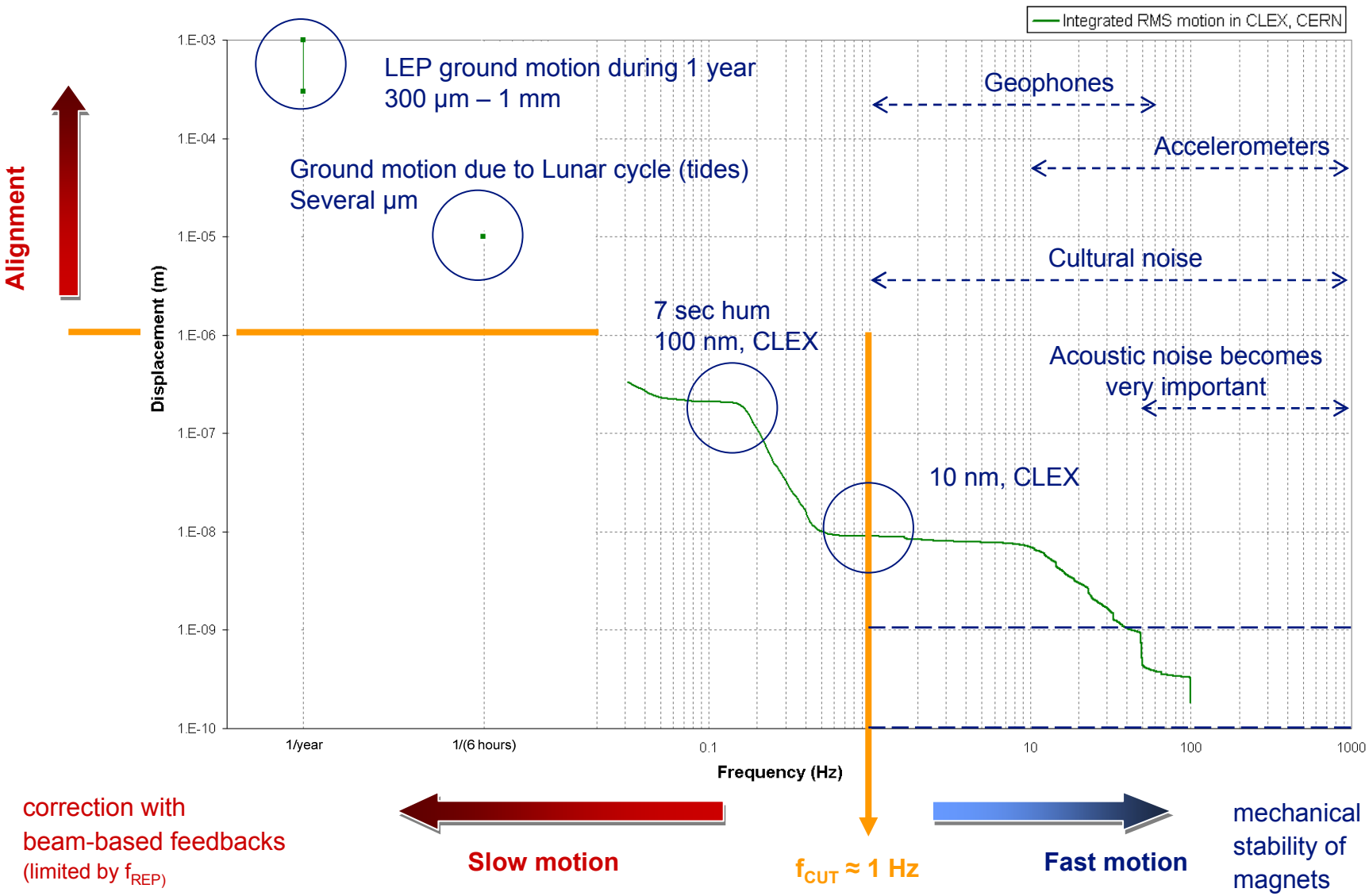
- General objective:

  Towards a Project Oriented and Cost Conscious CLIC Design in preparation for the Conceptual Design Report to be edited in 2010.

- Specific responsibility:

  - Set-up and keep updated an overall CLIC Work Breakdown Structure (nomenclature, components specs, documentation).
  - Review the ensemble of technical equipments in the present CLIC design in terms of:
    Components specifications, technical feasibility, fabrication and industrialization, integration (machine/tunnel), machine-detector interface, installation, schedule, cost.
  - Identify technical key issues requiring specific R&D or prototyping in view of the CDR, assess present R&D program and propose prioritized R&D.
  - Suggest possible improvements aiming at improving the performance to cost and risk ratio.
  - Elaborate for the CDR a baseline scenario and schedule, a CLIC baseline complex and possible options for improved performance and/or reduced cost.

Stabilization & Alignment



Stabilization

Vertical spot size at IP is ~ 1 nm *(size of water molecule)*

Stability requirements for a 1% loss in luminosity

Magnet	Ix	Iy
Linac (4000 quads, f > 1 Hz)	5 nm	1 nm
Final Focus (4 quads, f > 5 Hz)	5 nm	0.1 nm

Need active damping of vibrations

Stabilization

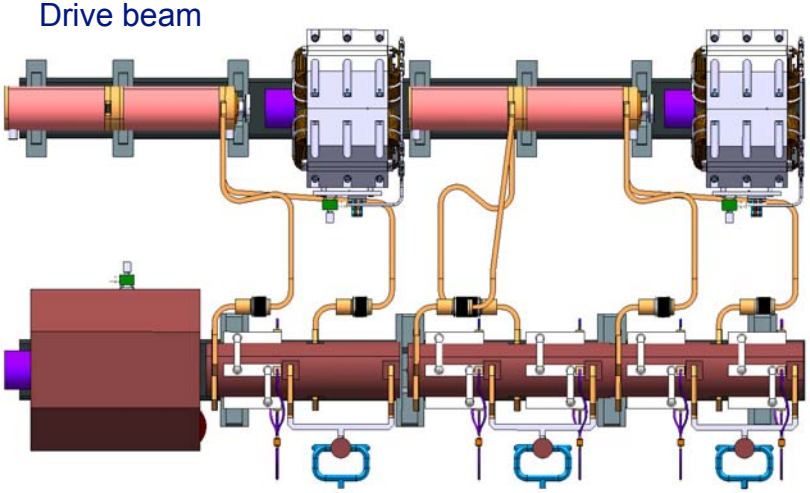
- Extensive work done between 2001 and 2003 concerning CLIC stabilization
- From 2004 to 2007:
  - Work continued only at LAPP-Annecy, France
  - At CERN beam dynamic studies, update of stabilization requirements
- Collaboration between several Institutes started in 2008:
  - http://clic-study.web.cern.ch/CLIC-Study/CLIC_Stabilisation/Index.htm
  - LaViSta (LAPP, Universite de Savoie-SYMME)
  - CERN (TS, AB)
  - JAI- Oxford University
  - CEA-DSM-IRFU-SIS
  - Information exchange with DESY, SLAC

MONALISA IRFU/SIS

Two-Beam module studies

- Module design and integration have to be studied for different configurations. Potential advantages and drawbacks are being evaluated for each configuration.
- Integration of the systems in terms of space reservation has been done for all the module types and detailed design started for the main systems, such vacuum, cooling, alignment, stabilisation …
- Important aspects of cost are raised and basic parameters provided for other areas of the study.
- Goal: build prototype → test with beam of a few modules in CTF3 from 2010

Drive beam

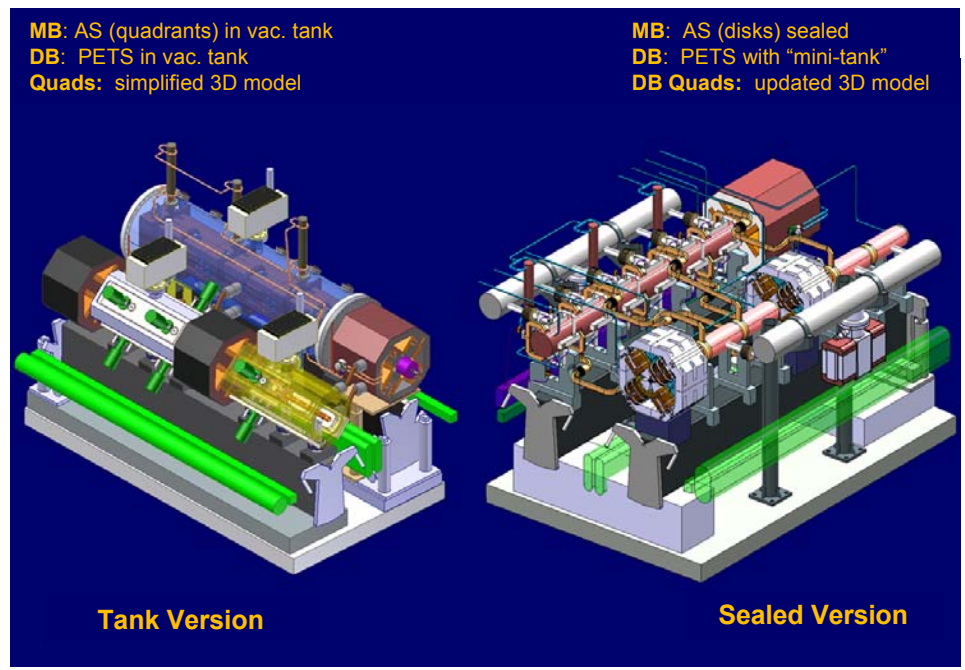


Main beam

20760 modules (2 m long)

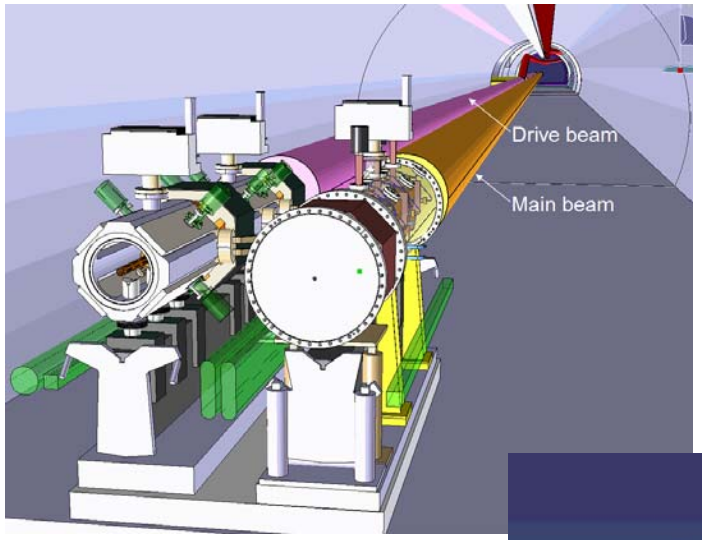
71460 power prod. structures PETS (drive beam)

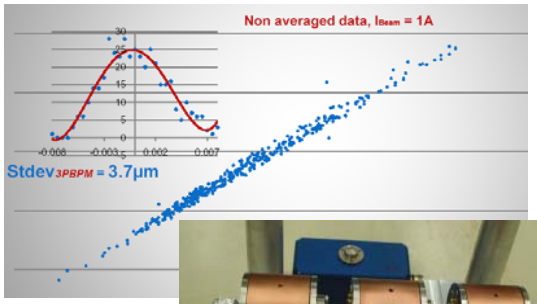
143010 accelerating structures (main beam)

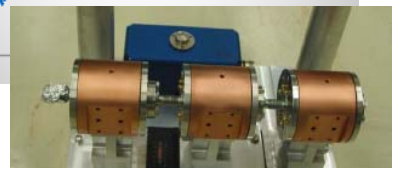


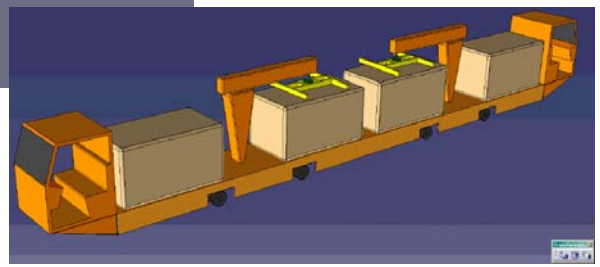
Other technical Issues presently under investigation

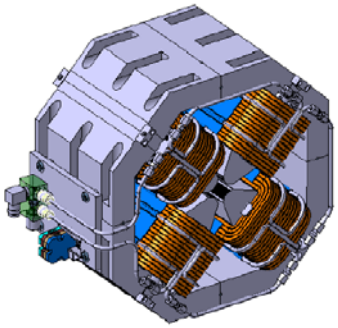
- Civil Engineering
- Magnets
- Diagnostics
- Alignment & survey
- Vacuum
- Cooling & Ventilation
- Transport & Installation
- Radiation & Safety
- Cost & Schedule

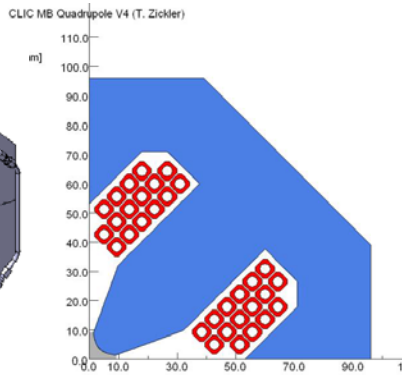


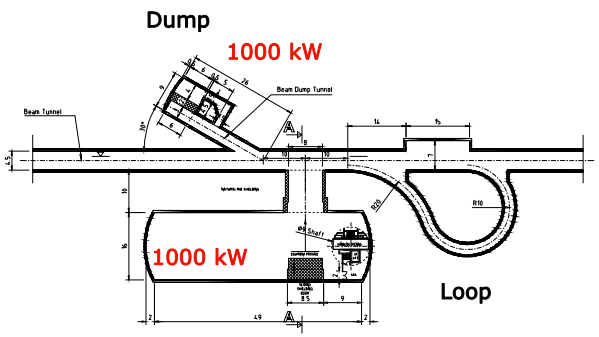










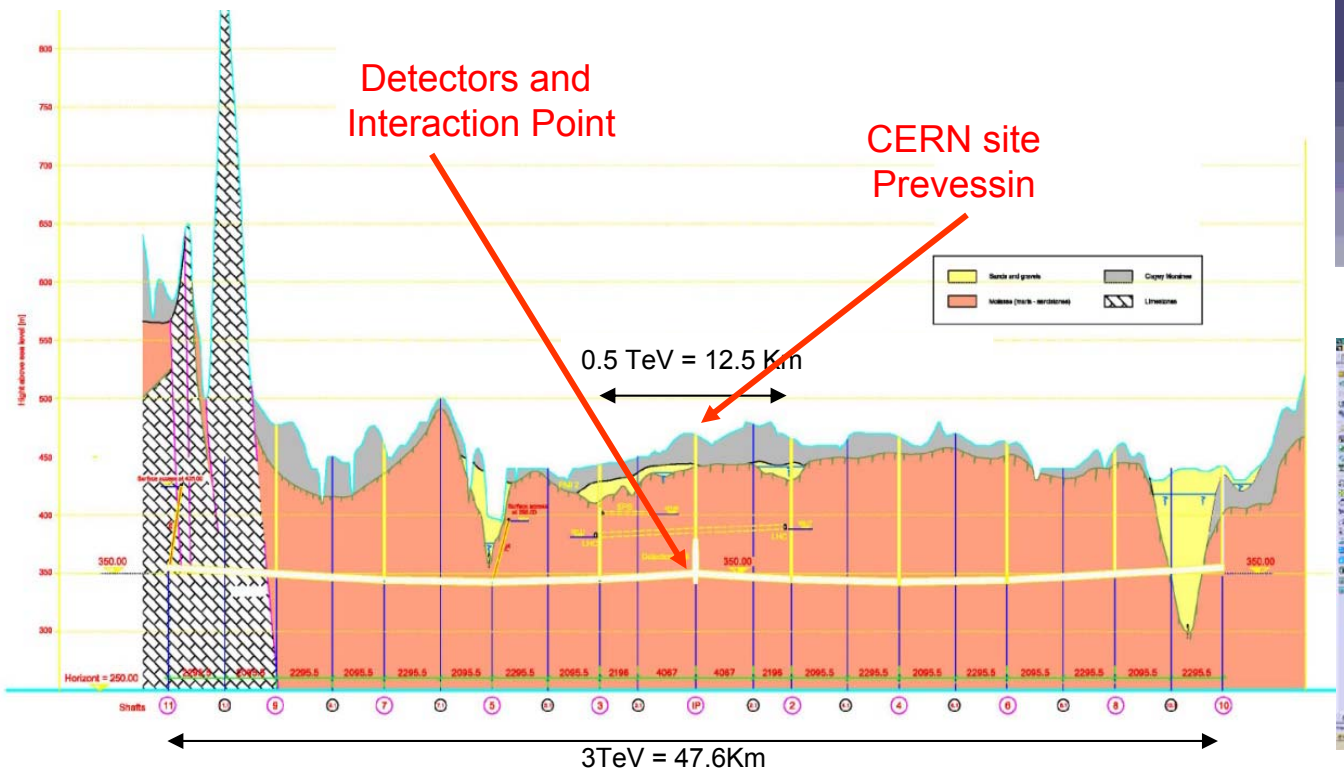


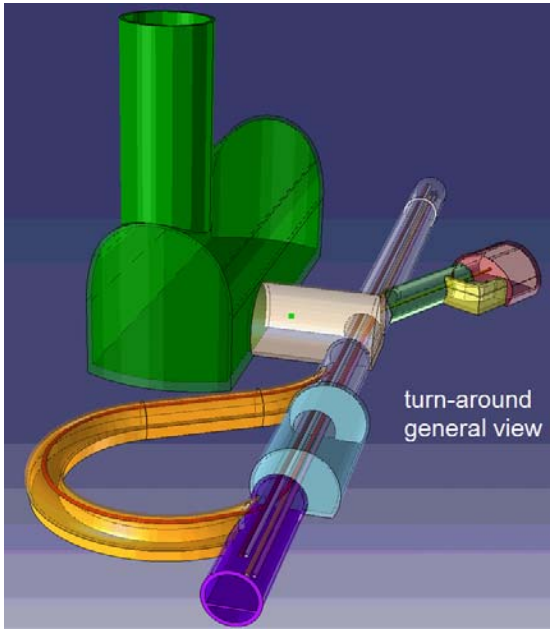
UTRC

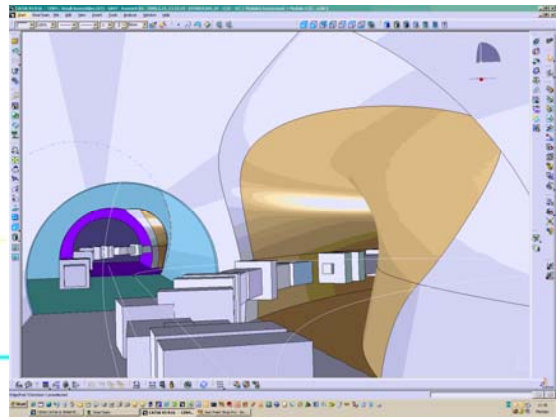
Civil Engineering

CERN sample site (in conjunction with ILC site studies)

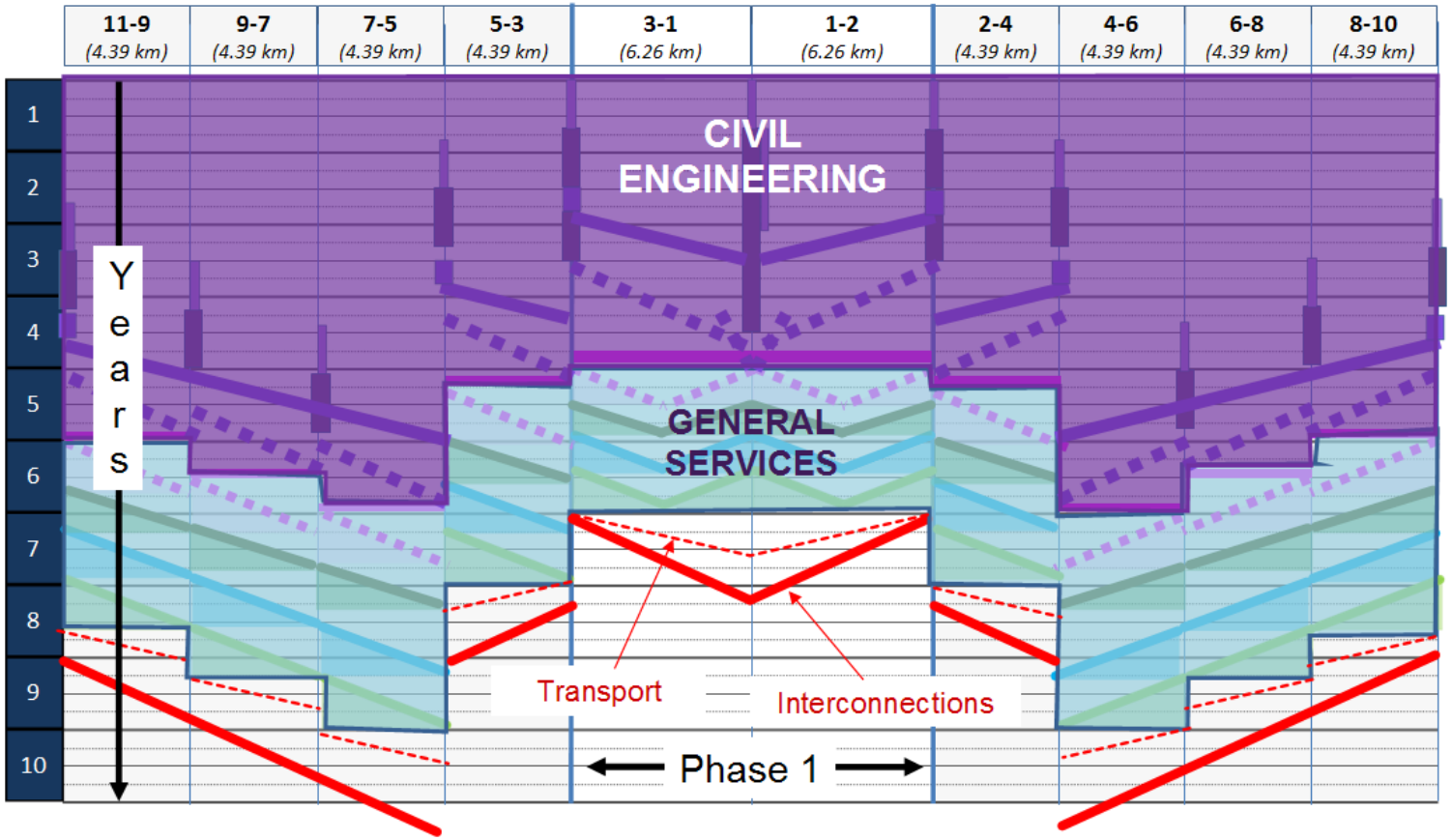
IP under CERN Prevessin site
Phase 1: 0.5 TeV extension 13 km
Phase 2: 3 TeV extension 48.5 km







Planning



Based on LHC experience
Consistent with 7 years construction for phase 1

CLIC08 Workshop

All of the R&D activities I have presented (and some I didn't have the time to) were reviewed & discussed recently in the 2nd CLIC Workshop (CERN, 14-17 October 2008)

http://project-clic08-workshop.web.cern.ch/project-clic08-workshop/

Participation actually larger than present CLIC/CTF3 collaboration:

215 (registered) participants from 57 Institutes of 18 countries

Next CLIC Workshop tentatively scheduled for October 13-16, 2009

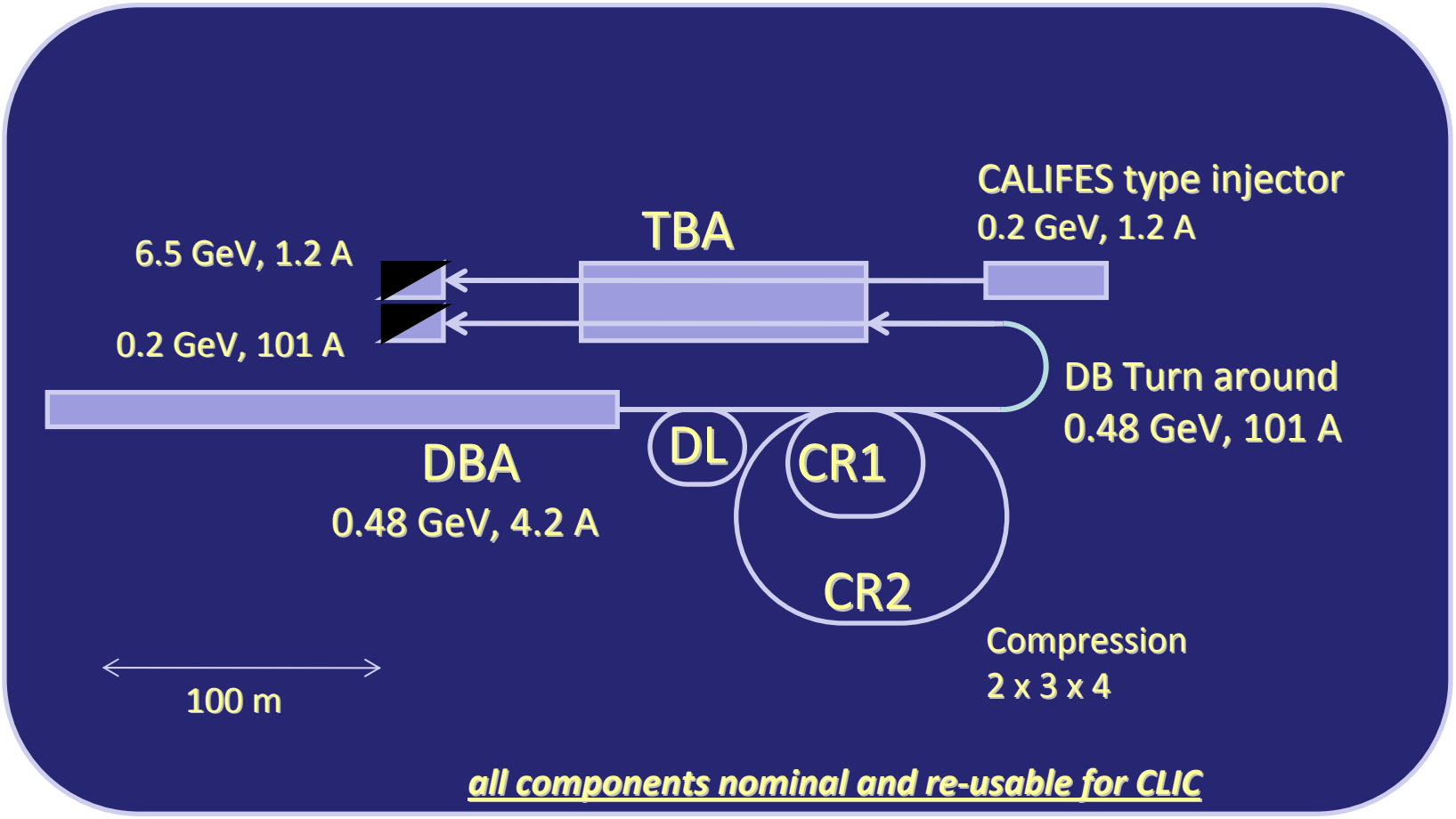
CONCLUSIONS

- CLIC design and R&D on all CLIC feasibility issues on schedule for completion of CDR by 2010 including:
  - Concept of accelerator and detector
  - Feasibility results
  - Preliminary performance and cost
- R&D on complementary issues (performance and cost) to be completed and reported in a TDR with consolidated performance and cost by 2015
  - Consolidate/extend CTF3 in the medium term (2010 – 2012)
  - Identify, plan and execute complementary CLIC R&D in other facilities world-wide (ATF, ATF2, Cesr-TA, light sources...)
  - Increase RF testing capabilities (New X-band sources, transform CTF3 in RF factory)
  - Start development-industrialization of components (DBA klystrons, structures, etc...) at nominal parameters
  - Reflection started on facility, possibly first step (re-usable) – toward CLIC on 2015 time scale
- CLIC/CTF3 multi-lateral collaboration strong of 27 institutes from 15 countries extremely efficient and fruitful
  - Importance of CLIC/ILC collaboration

A lot still to be done before the CLIC technology is mature enough to be considered for a future Linear Collider

…but also a lot of recent progress

Reserve



all components nominal and re-usable for CLIC

CERN DG's talk to Staff
3 October '08

Outlook for Scientific Activities over the Period 2012 - 2016

To be decided in 2010-2011 in light of first physics results from LHC, and designed and R&D results from the previous years. This programme could most probably comprise:

- An LHC luminosity increase requiring a new injector (SPL and PS).

  The total cost of the investment over 6 years (2011-2016: 1000-1200 MCHF + a staff of 200-300 per year. Total budget: ~200-250 MCHF per year.

- Preparation of a Technical Design for the CLIC programme, for a possible construction decision in 2016 after the LHC upgrade (depending on the ILC future).
  Total CERN M + P contribution + ~250 MCHF + 1000-1200 FTE over 6 years.

- Enhanced infrastructure consolidation: 30 MCHF + 40 FTEs from 2011.

NB: Over the period 2012-2016. Effective participation of CERN in another large progra cted resou l Design. This s proved or if a new, more ambitious level of activities and support is envisaged in the European framework.

N.B.: Expect additional significant contribution from outside CERN, up to the same level

The *CLIC Technology-related* key issues 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 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, 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.

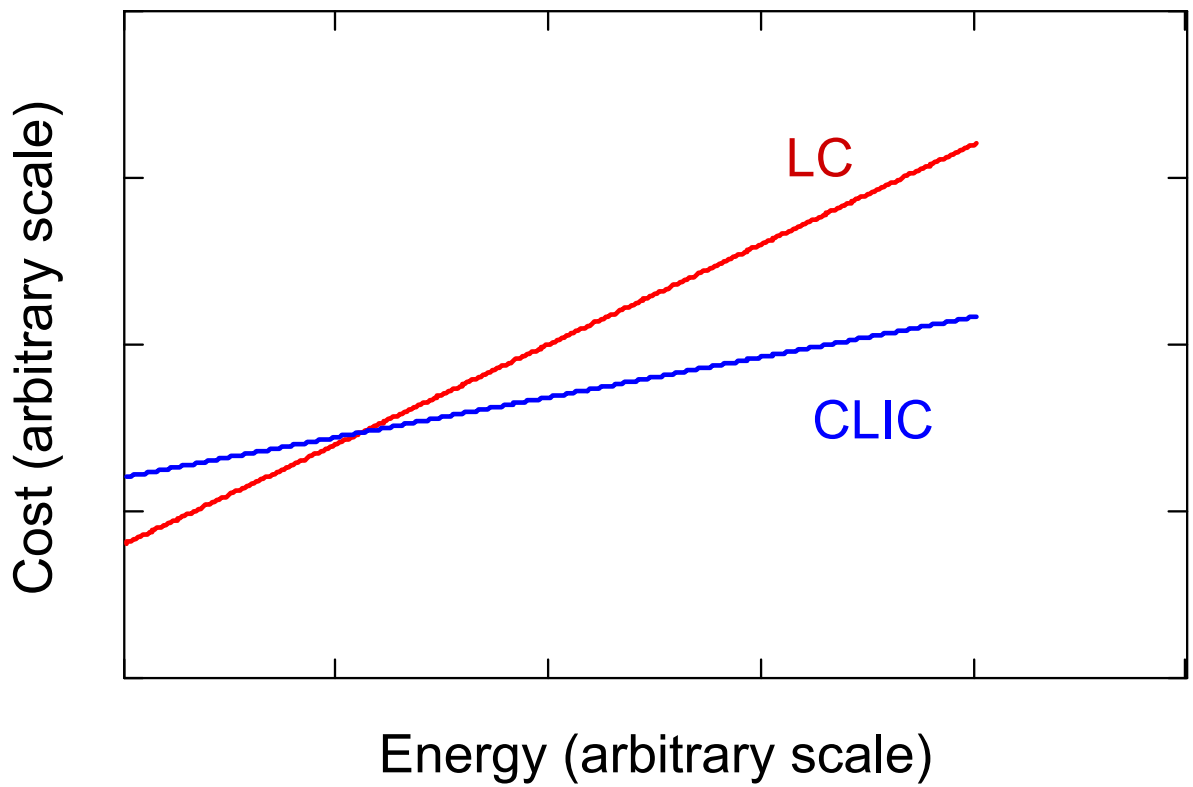
Covered by EUROTeV

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

500 GeV comparison Table

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

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

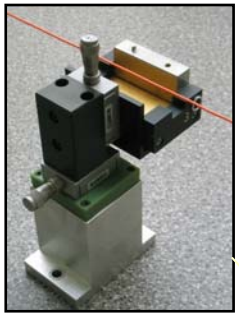

LC
CLIC
Cost (arbitrary scale)
Energy (arbitrary scale)

Alignment studies in CTF II

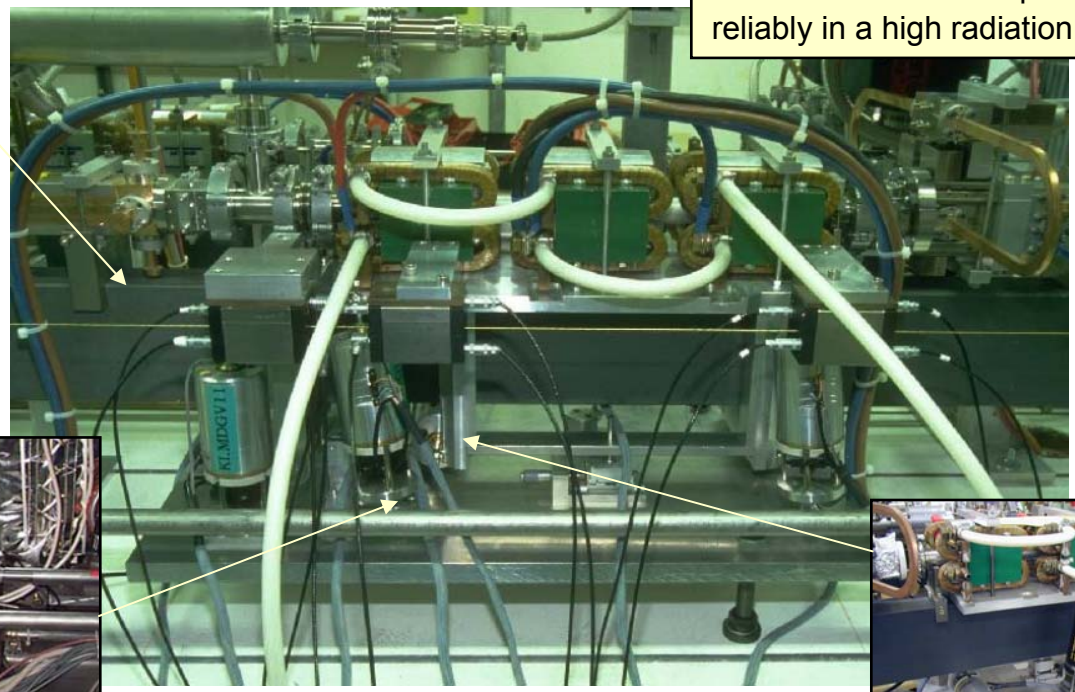
Tolerance of CLIC pre-alignment: ± 10 μm transverse position over 200 m
(enough to send a pilot beam, and start beam-based alignment)

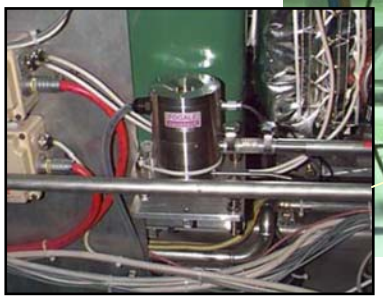
Full system Tested in CTF II:

In a closed loop, the elements were maintained w.r.t wire within a ± 5 μm window and operated reliably in a high radiation environment



WPS
Wire Positioning System





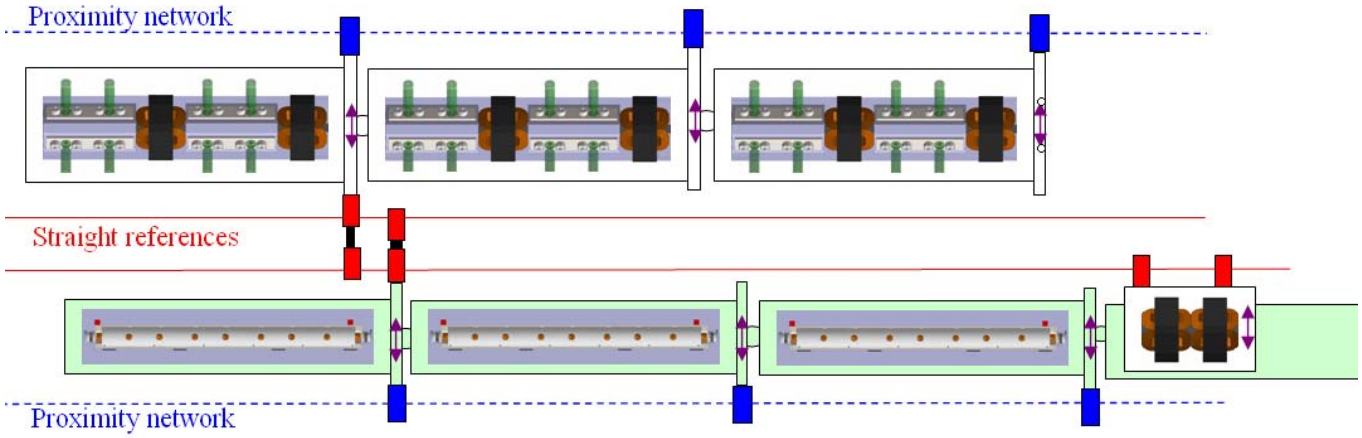
HLS
Hydrostatic Levelling System

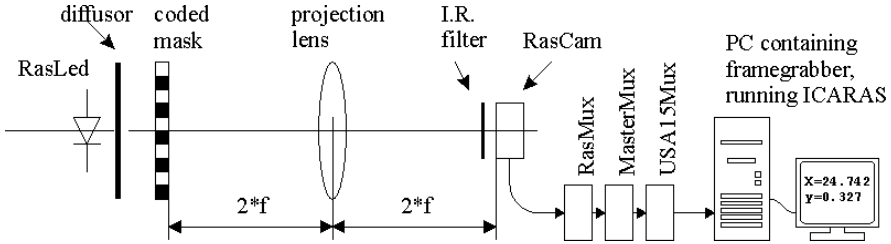
3 D active movers

Active pre-alignment

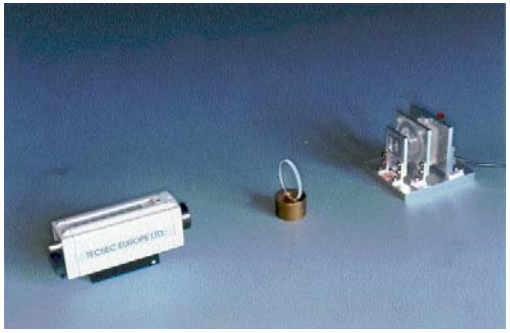
Some of the issues:

- Integration of active pre-alignment system in modules
- Mechanical tolerances of components on girder
- Tests on longer distances than CTF II
- Influence of gravity
- New methods (performance, cost)

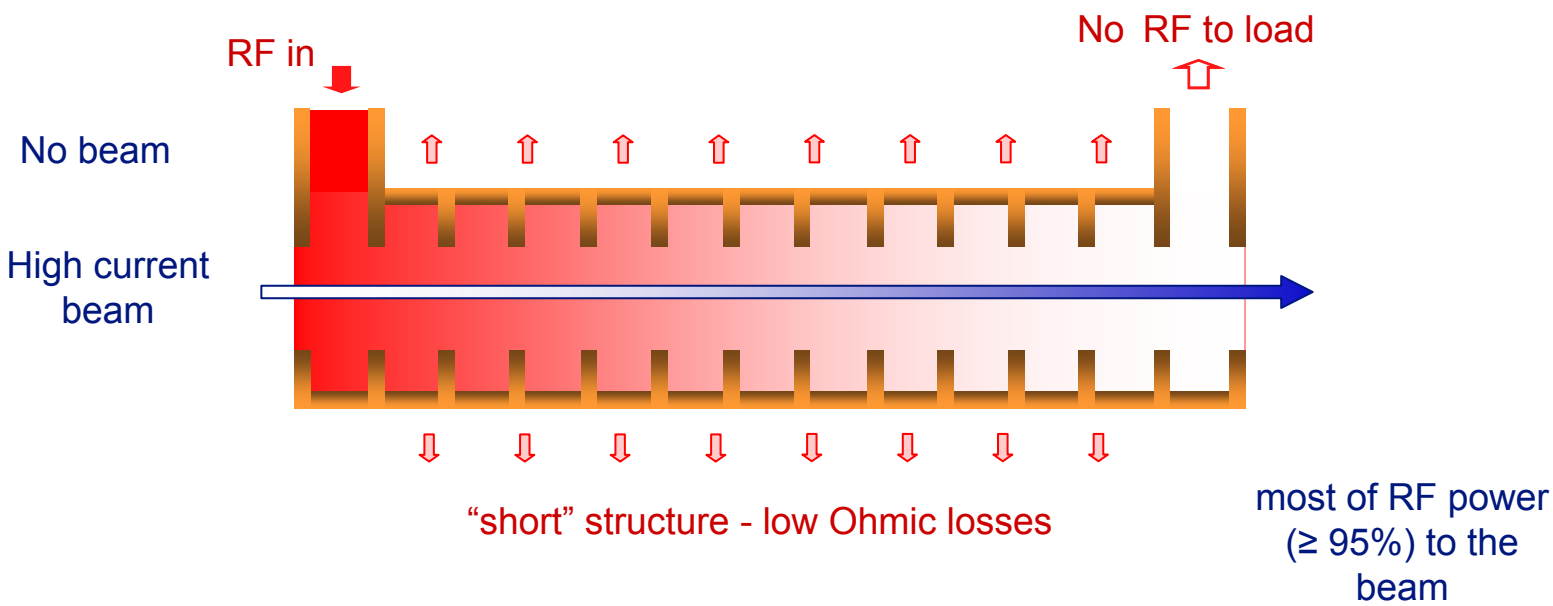




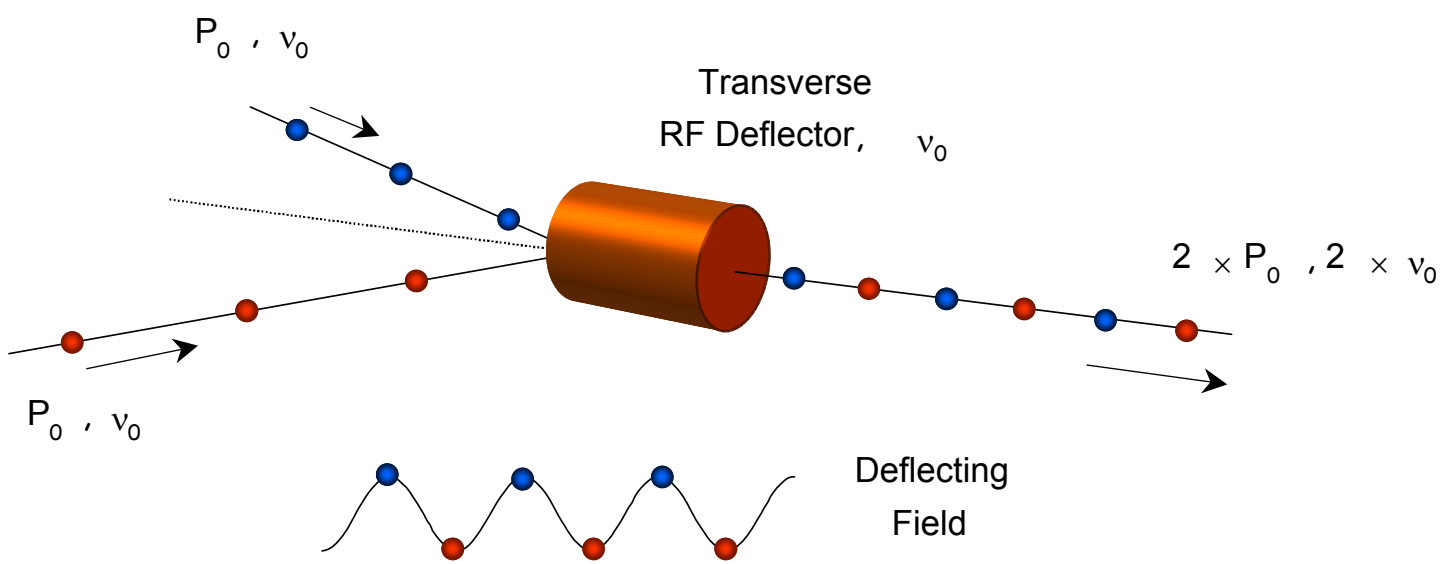
Red Alignment System from NIKHEF (RASNIK)



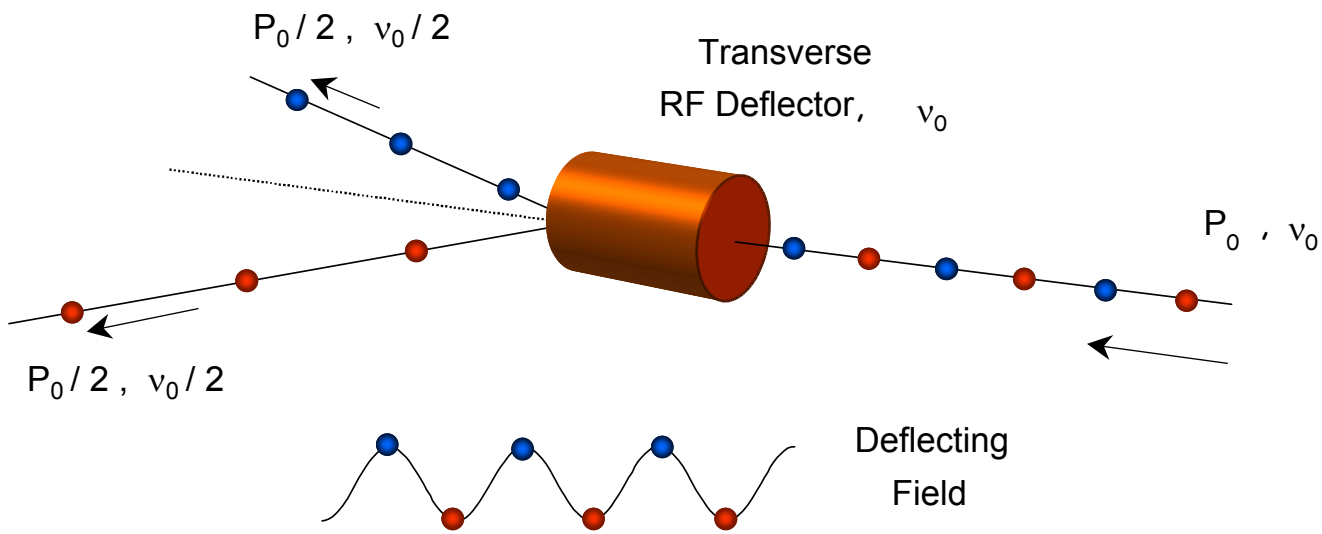
Full beam-loading acceleration in TW sections



Beam combination/separation by transverse RF deflectors

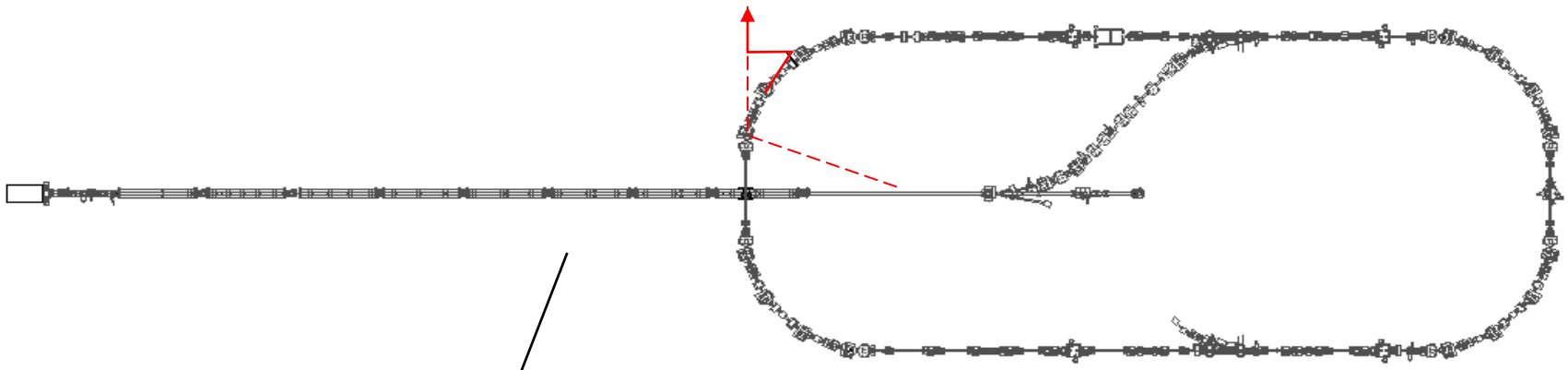


Beam combination/separation by transverse RF deflectors



CTF3 Preliminary Phase (2001-2002)

streak camera measurement



Beam structure in linac – 4 pulses

Beam structure after combination (factor 4)

6.6 ns

420 ns

Bunch spacing 333 ps

total length 1.3 ms - Peak Beam Current 0.3 A

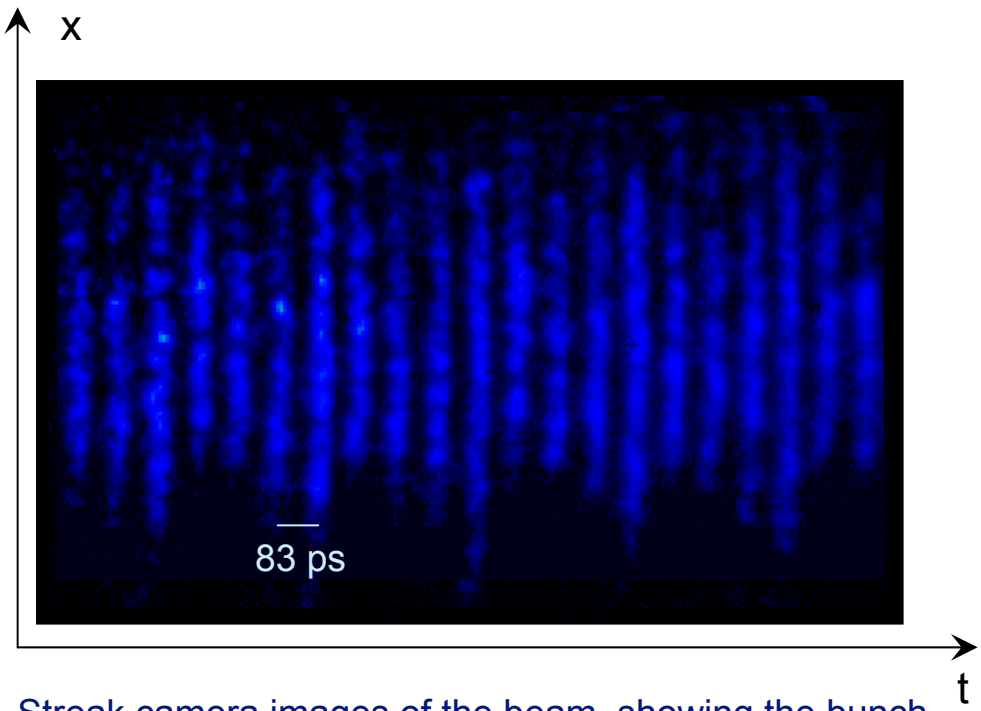
Bunch spacing 83 ps

Pulse Length 6.6 ns

Beam Peak Current 1.2 A

A first ring combination test was performed in 2002, *at low current and short pulse*, in the CERN Electron-Positron Accumulator (EPA), properly modified

Preliminary phase results



Streak camera images of the beam, showing the bunch combination process