Update on CLIC design
and
Results from the CLIC Test Facility CTF3

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for the CLIC team

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High Energy Physics after LHC

In 1999 ICFA issued a statement on Linear Colliders, ... that there would be compelling and unique scientific opportunities at a linear electron-positron collider in the TeV energy range. Such a facility is a necessary complement to the LHC hadron collider now under construction at CERN.

⇩

Two options: ILC - CLIC

Collaboration on common issues

⇦

The European strategy for particle physics

Unanimously approved by the CERN Council at the special Session held in Lisbon on 14 July 2006

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.*

CERN/2685

CLIC base-line

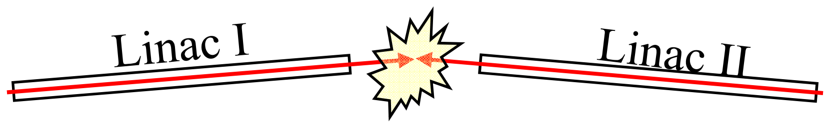
Electron-Positron Collider

- Centre-of-mass-energy: 3 TeV
- Luminosity in peak: $>2*10^{34}$

⟺

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

Storage Ring not possible, energy loss $\Delta E \sim E^4$
➔ two linacs, experiment at centre



- total energy gain in one pass: **high acceleration gradient**
- beam can only be used once: **small beam dimensions at crossing point**

Boundary conditions: site length
Power consumption, cost

CLIC acceleration system

CLIC = Compact Linear Collider

(length < 50 km)

CLIC parameters:

Accelerating gradient: 100 MV/m

RF frequency: 12 GHz

64 MW RF power / accelerating structure

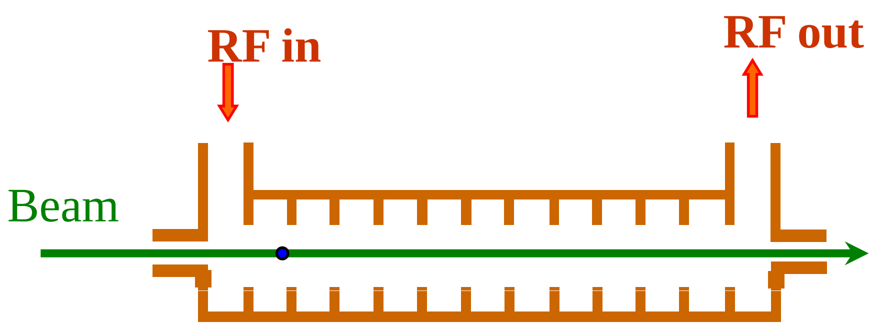
of 0.233m active length

➔ **275 MW/m**

total active length for 1.5 TeV: **16'500 m**

Pulse length 240 ns, 50 Hz

Acceleration in travelling wave structures:



Efficient RF power production !!!!!

The CLIC Two Beam Scheme

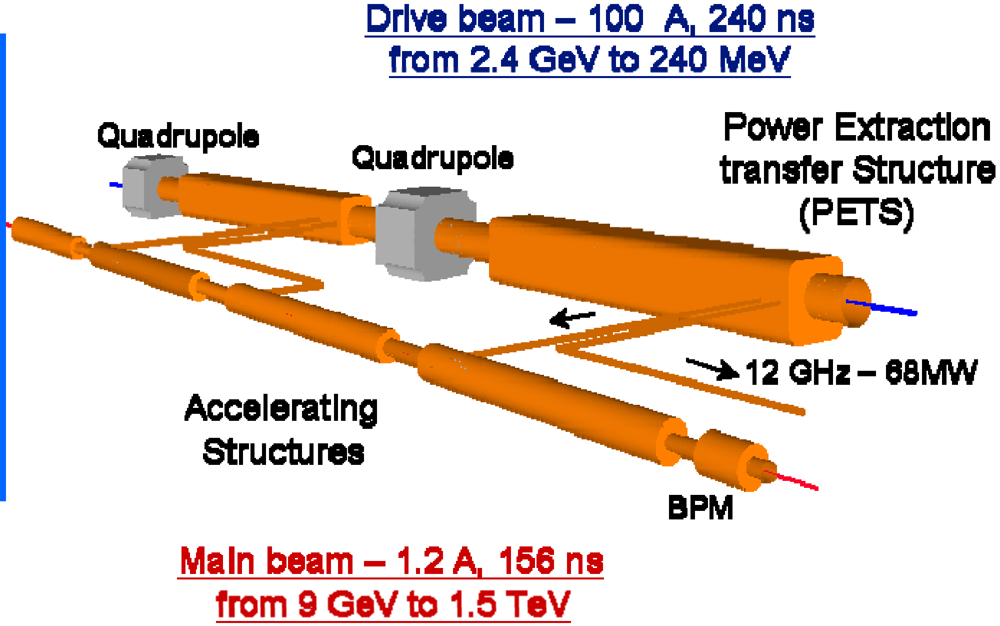
Individual RF power sources ?

➔ Not for the 1.5 TeV linacs

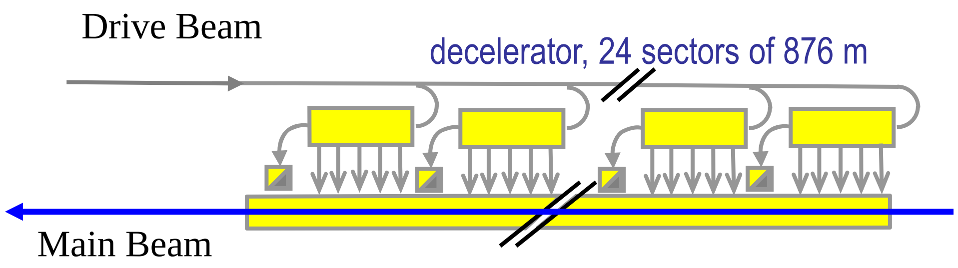
Two Beam Scheme:

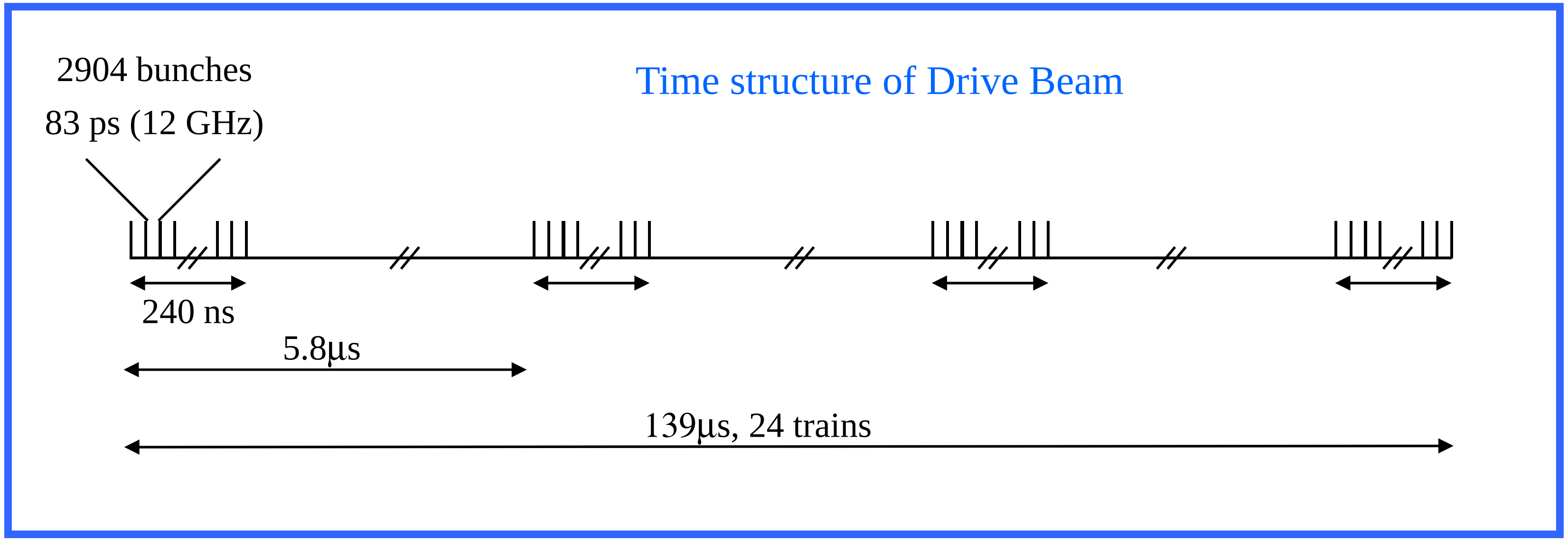
Drive Beam supplies RF power

- 12 GHz bunch structure
- low energy (2.4 GeV - 240 MeV)
- high current (100A)



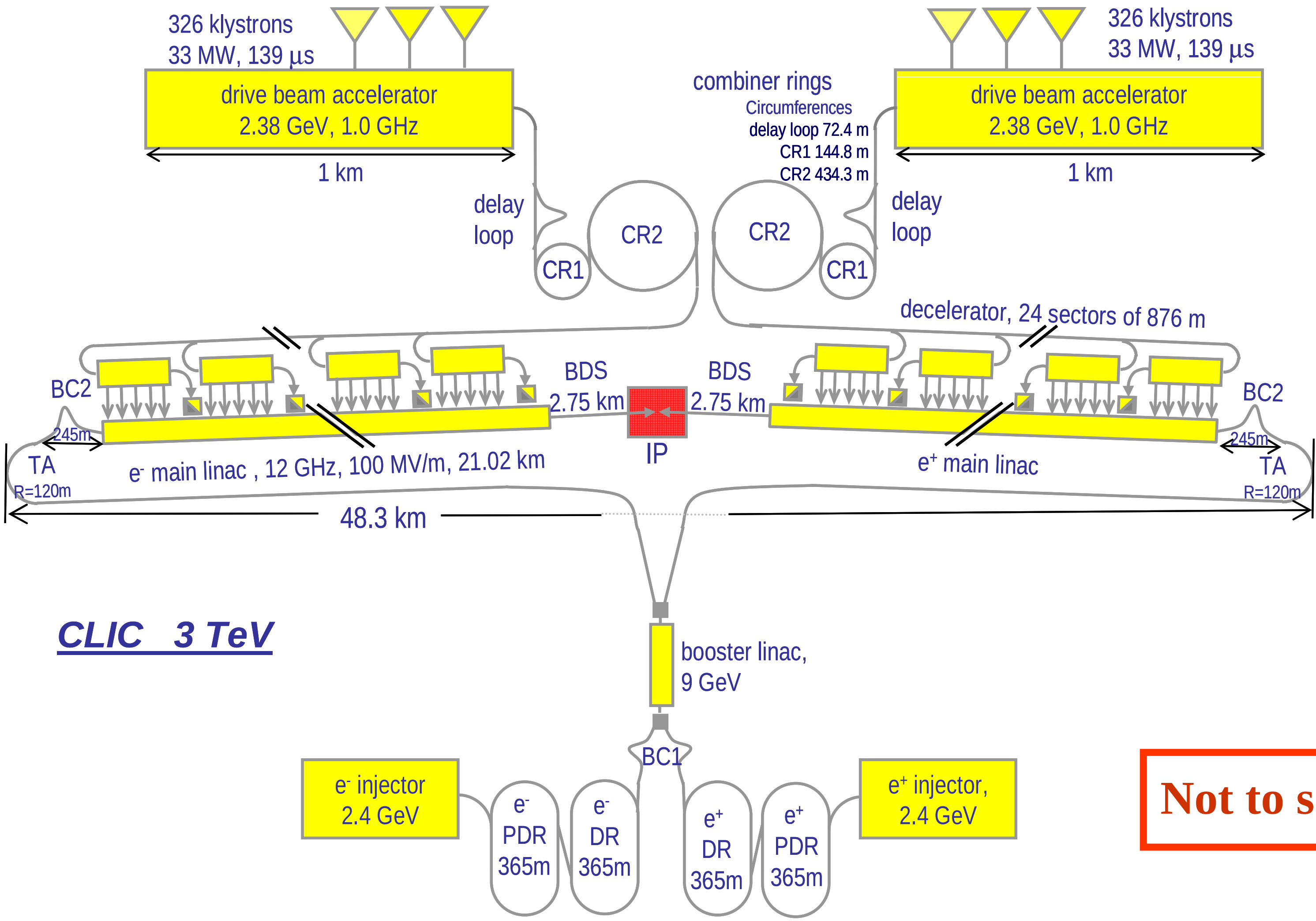
The CLIC Two Beam scheme





Bunch charge: 8.4 nC, Current in train: 100 A

The full CLIC scheme



CLIC 3 TeV

Not to scale!

Why 100 MV/m and 12 GHz ?

Optimisation: (A.Grudiev et al.)

Structure limits:

- RF breakdown – scaling
- RF pulse heating

Beam dynamics:

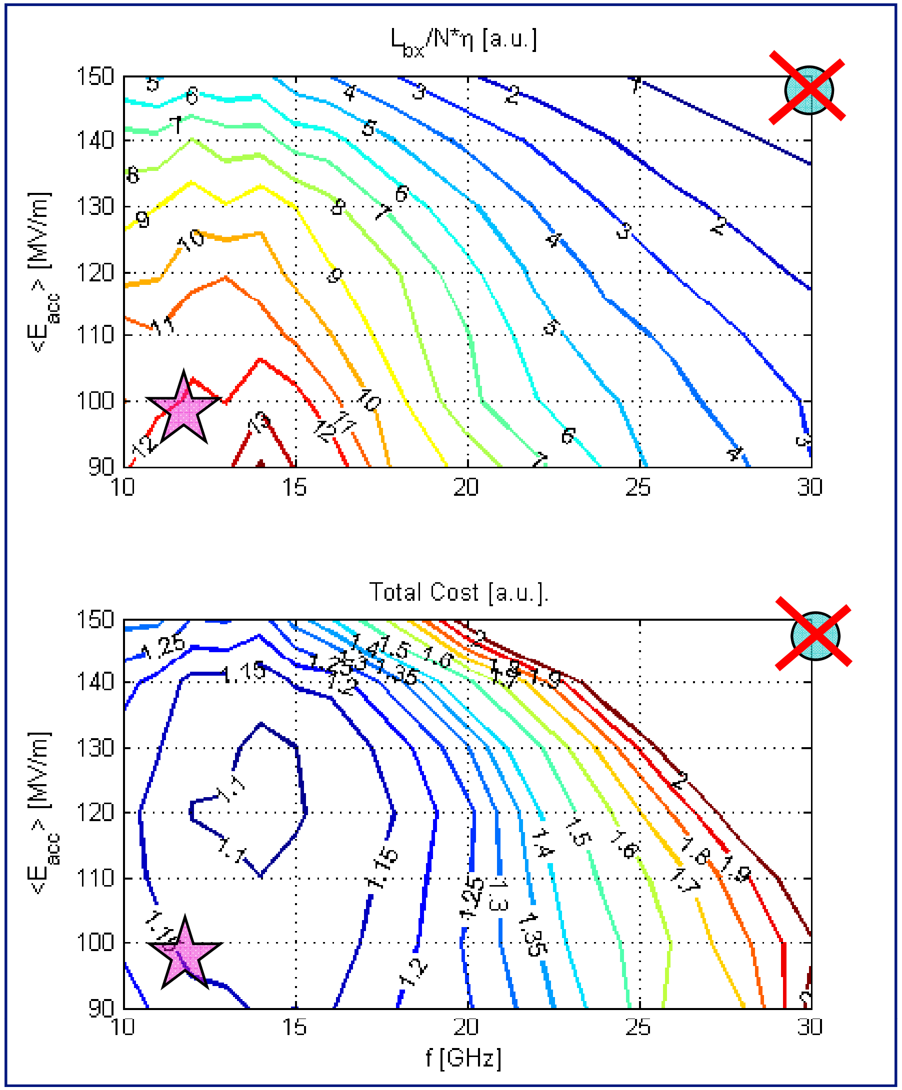
- emittance preservation – wake fields
- Luminosity, bunch population, bunch spacing
- efficiency – total power

Figure of merit:

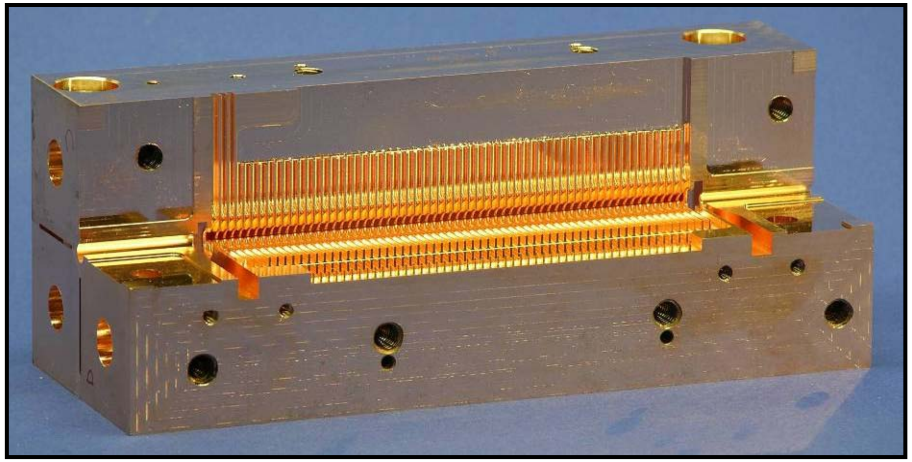
- Luminosity per linac input power

take into account cost model

after > 60 * 10⁶ structures:
100 MV/m 12 GHz chosen,
previously 150 MV/m, 30 GHz



Accelerating structures

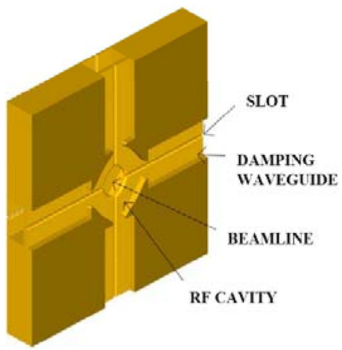


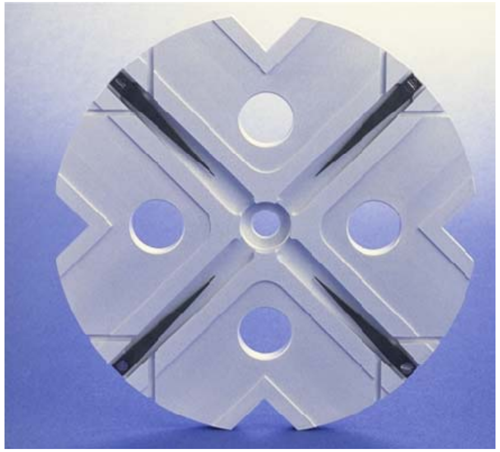
Objective:

- Withstand of 100 MV/m without damage
- breakdown rate < 10^{-7}
- Strong damping of HOMs

Technologies:

Brazed disks - milled quadrants



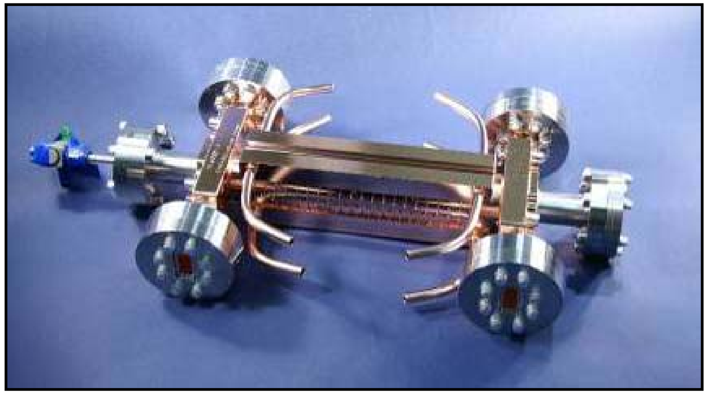


(W. Wünsch)

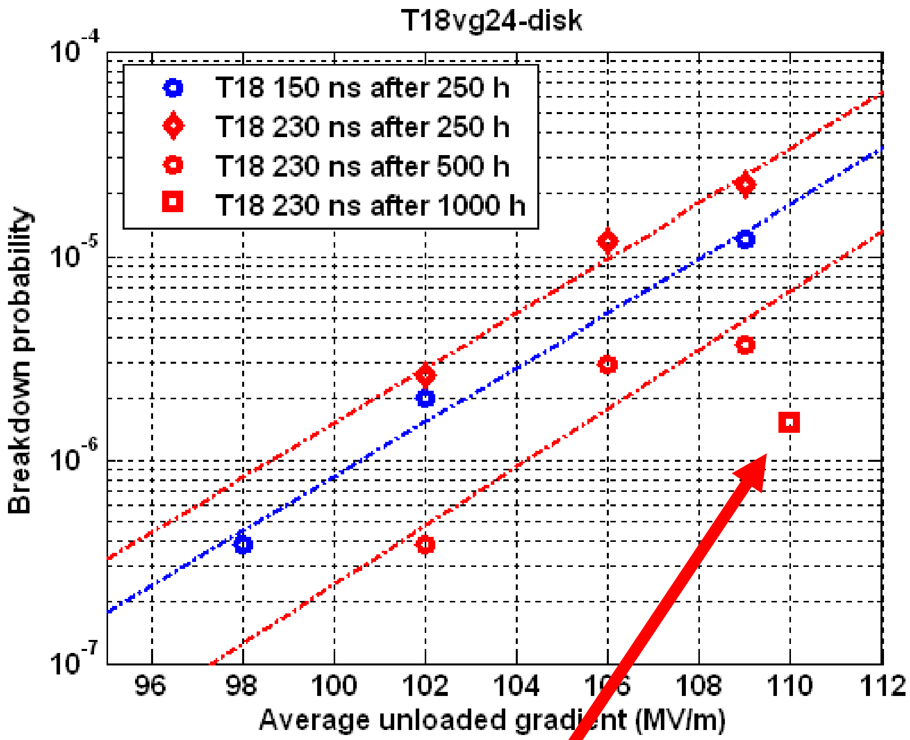
Collaboration: CERN, KEK, SLAC

Best result so far

High Power test of T18_VG2.4_disk [2]



- Designed at CERN,
- Machined by KEK,
- Brazed and tested at SLAC



Latest data

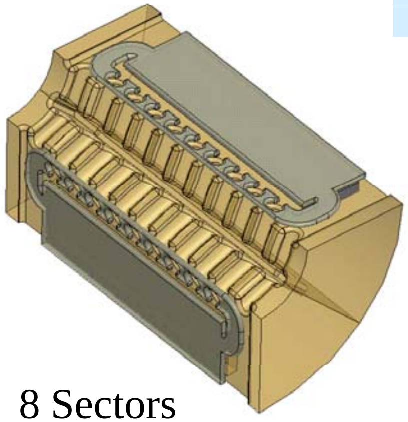
Design: 100 MV/M loaded

BR: 10^{-7}

Proof-of-principle !

(so far without damping)

PETS



8 Sectors

damped

on-off possibility

Special development for CLIC

- Travelling wave structures
- Small R/Q : 2.2 kΩ/m
  (accelerating structure: 15-18 kΩ/m)
- 100 A beam current

136 MW RF @ 240 ns per PETS
(2 accelerating structures)
0.21 m active length
total number : 35’703 per linac

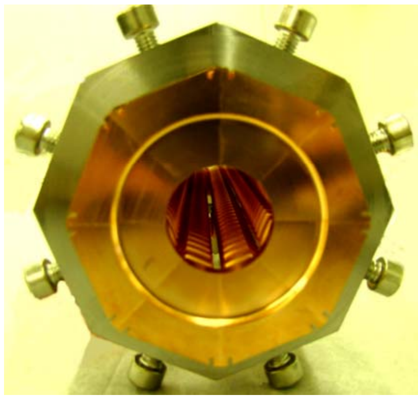
ref: Igor Syratchev

Status:

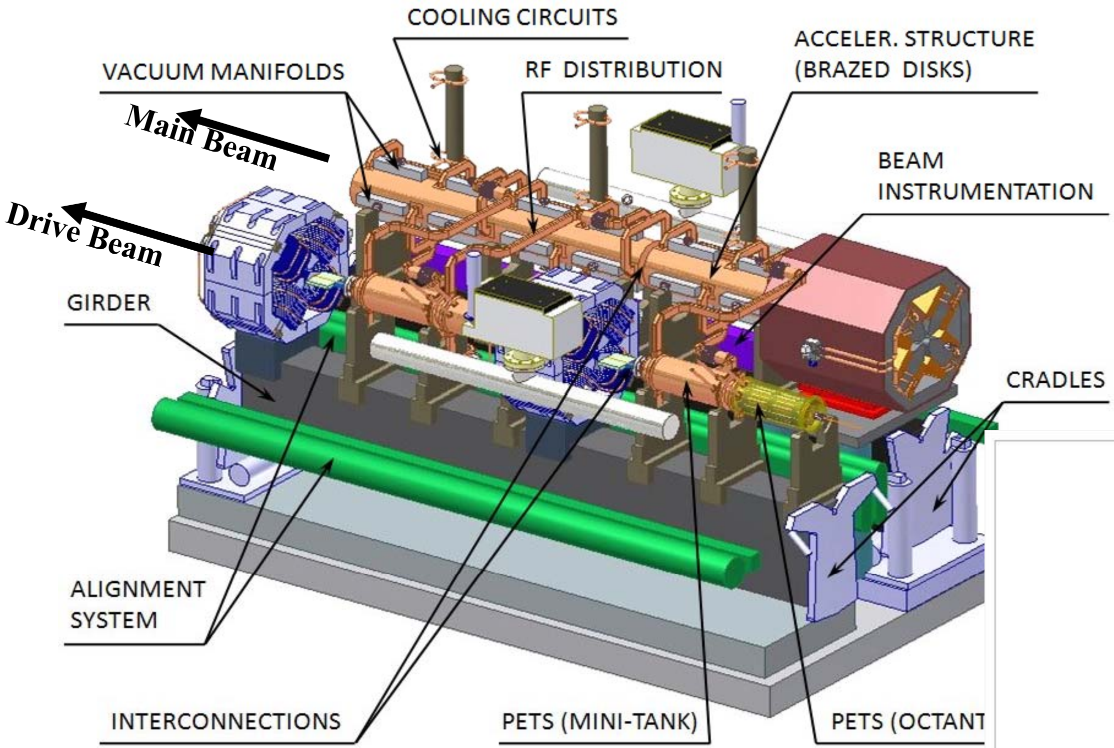
Advanced design,

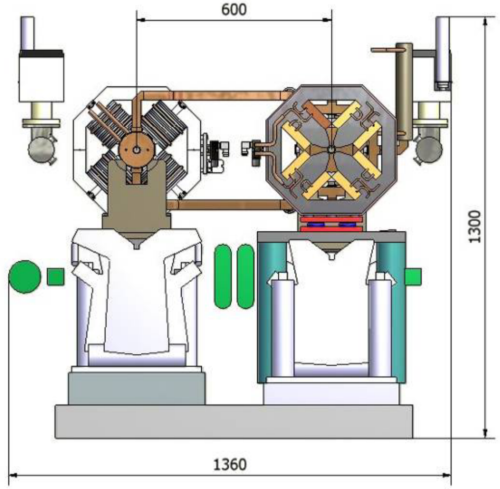
RF power testing at SLAC planned July 08

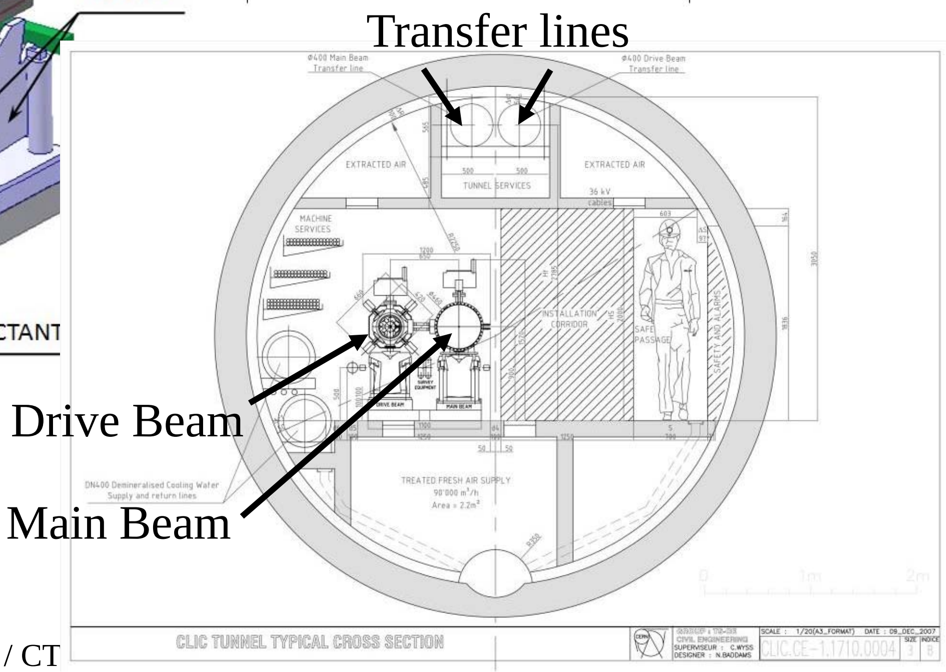
with beam in CTF3 in autumn 2008



CLIC Accelerating Module







ref: Germana Riddone

Getting the Luminosity (>$2*10^{34}cm^{-2}s^{-1}$)

Beam size at Interaction Point (rms) : σ_x = 40 nm, σ_y = 1 nm

Total site AC power: 322 MW

Issues:

- generating small emittance beams (EUROTeV)
- emittance preservation (EUROTeV)
- alignment and vibration control (EUROTeV)
- final focus (EUROTeV, see Rogelio)

jitter tolerances

	Final Focus quadrupoles	Main beam quadrupoles
Vertical	~0.2 nm > 4 Hz	~1 nm > 1 Hz
Horizontal	2 nm > 4 Hz	5 nm > 1 Hz

work ongoing,

Proof-of-principle:

quadrupole stabilized to < 0.5 nm in vertical plane

Staility of 0.15nm achieved in quiet place (Annecy)

Drive Beam Issues

Generation and efficient acceleration (CTF3)

fully loaded operation

Beam manipulation (CTF3)

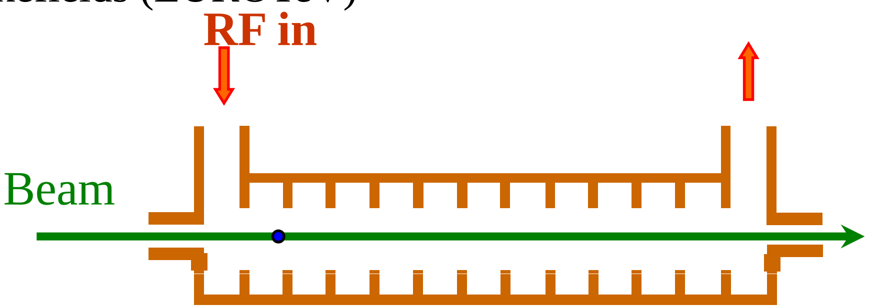
delay loop and combiner rings

Beam transport

fast beam-ion instability, resistive wall wakefields (EUROTeV)

Deceleration (EUROTeV, see Erik)

Phase stability (timing reference, see Jonathan)



CLIC Test Facility CTF3

Provide answers for CLIC specific issues

➔ Write CDR in 2010

Two main missions:

Prove CLIC RF power source scheme:

- bunch manipulations, beam stability,
- Drive Beam generation
- 12 GHz extraction

Demonstration of “relevant” linac sub-unit:

- acceleration of test beam

Provide RF power for validation of CLIC components:

accelerating structures,

RF distribution,

PETS (Power extraction and Transfer Structure)

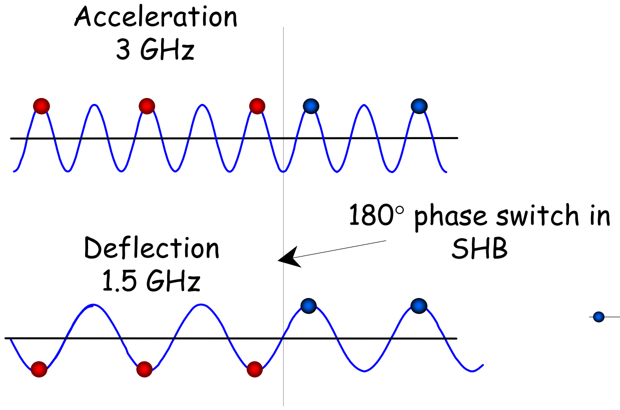
Drive Beam generation in CTF3

Principle: A long high intensity bunch train (1.4 μs) is accelerated with 3 GHz

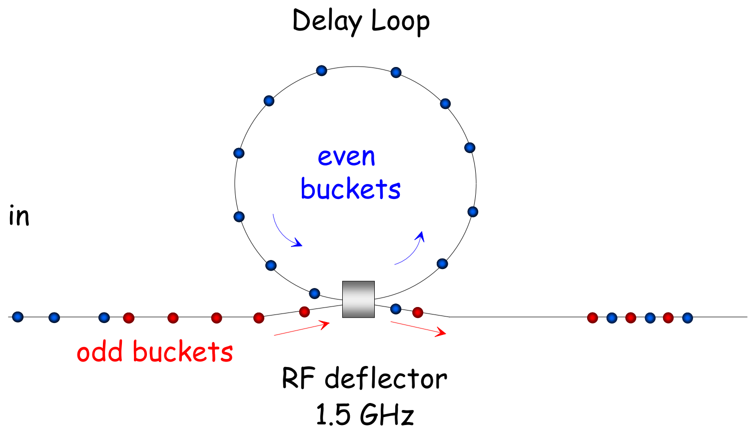
Bunch manipulations increase bunch repetition frequency

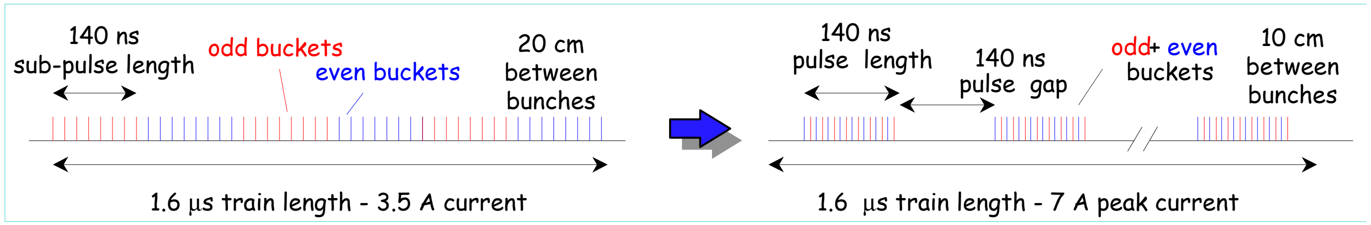
and increase peak current

“Phase-coding” of bunches



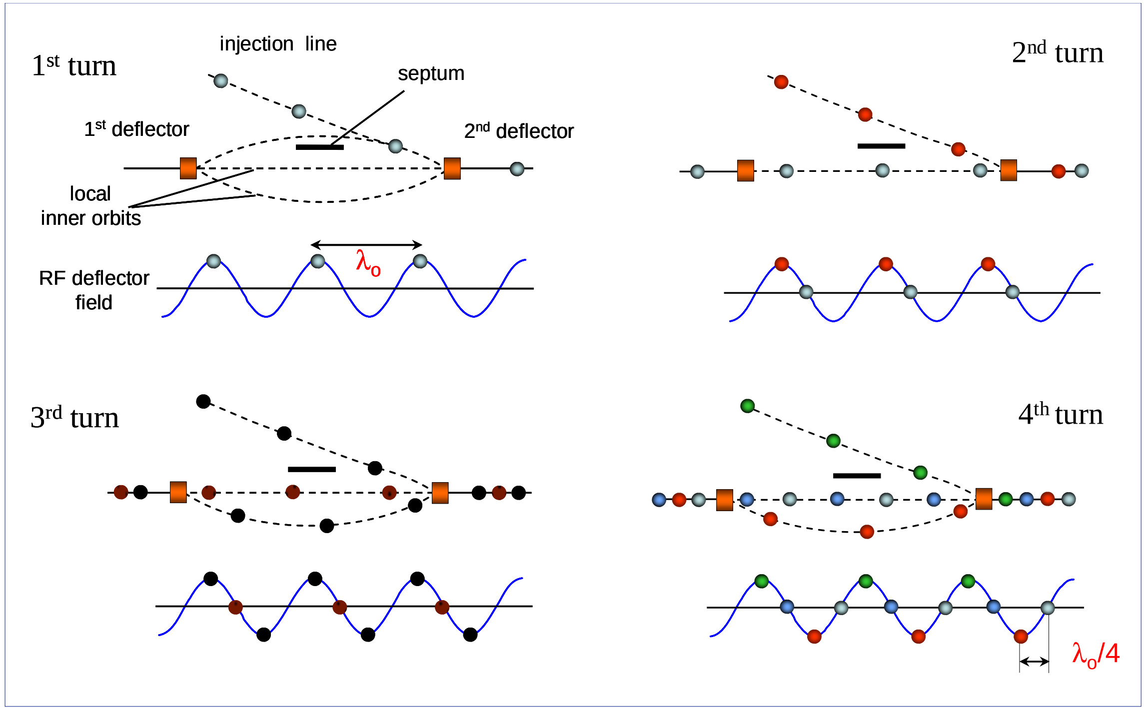
bunch interleaving with **Delay Loop**

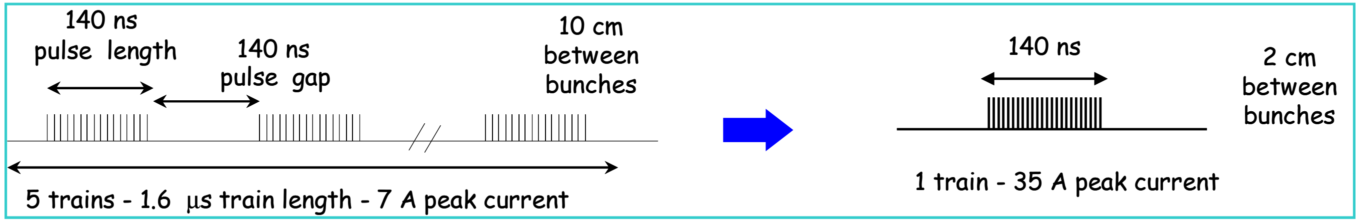




Drive Beam generation

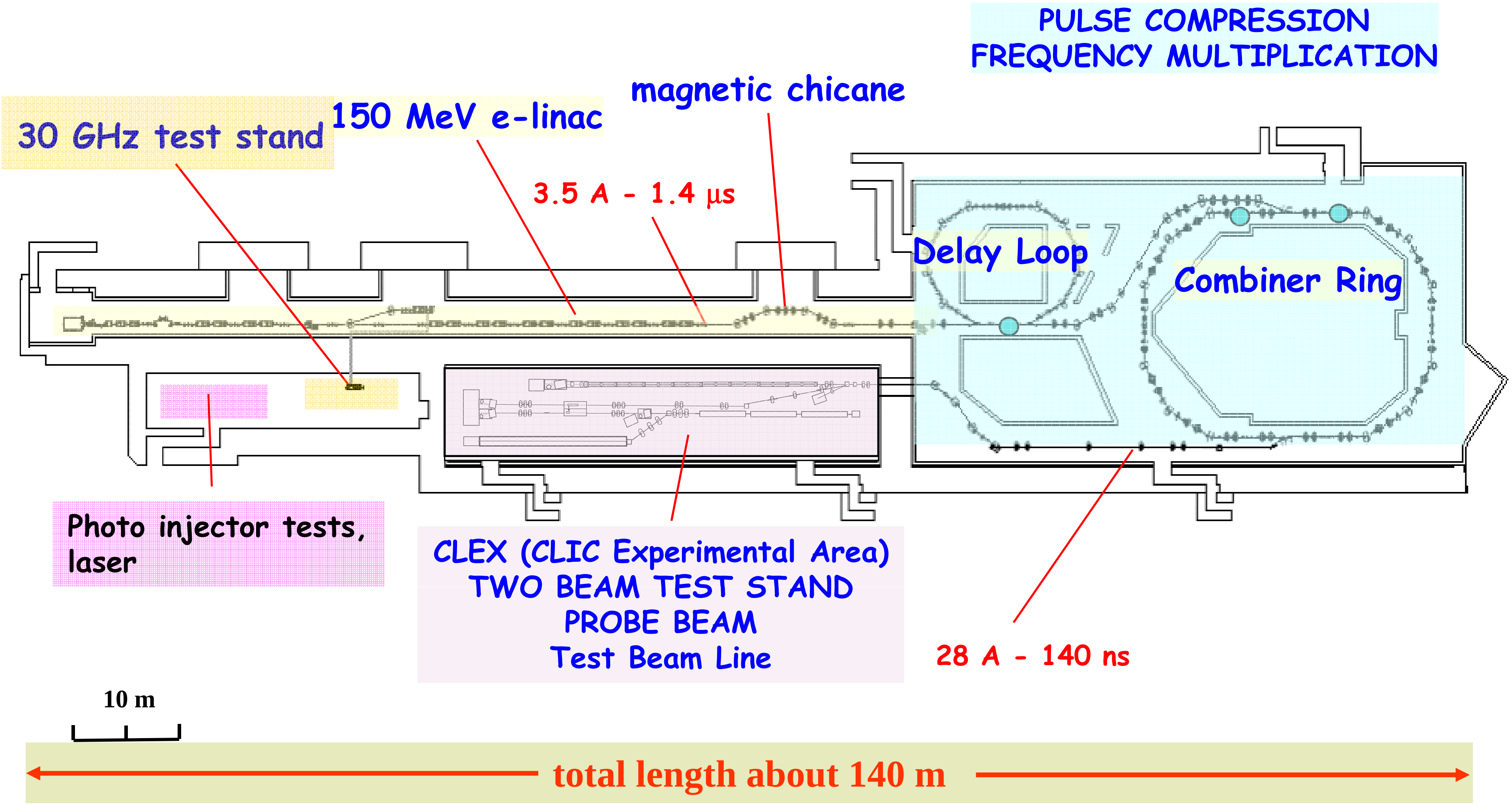
successive injection of 4 bunch trains into **Combiner Ring**





CTF3 building blocks

Infrastructure from LEP



CTF3 - CLIC

CTF3 is scaled down from CLIC:

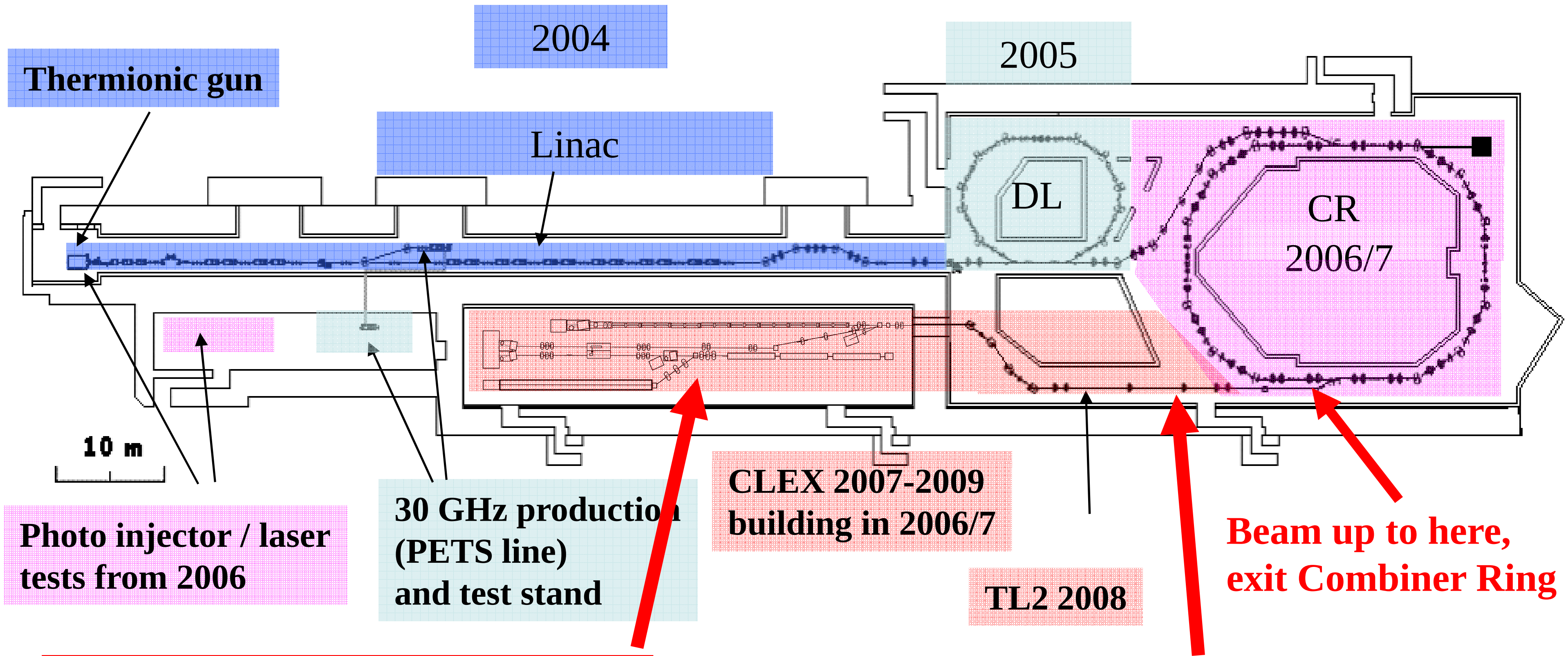
	CLIC	CTF3
Drive Beam energy	2.4 GeV	150 MeV
compression / frequency multiplication	24 (Delay Loop + 2 Combiner Rings)	8 (Delay Loop + 1 Combiner Ring)
Drive Beam current	4.2 A*24 ➔101 A	3.5 A*8➔ 28 A
RF Frequency	1 GHz	3 GHz
train length in linac	139 μs	1.5 μs
energy extraction	90 %	~ 50 %

CTF3 uses existing infrastructure from LEP injector:

Building, infrastructure,

3 GHz RF power plant,

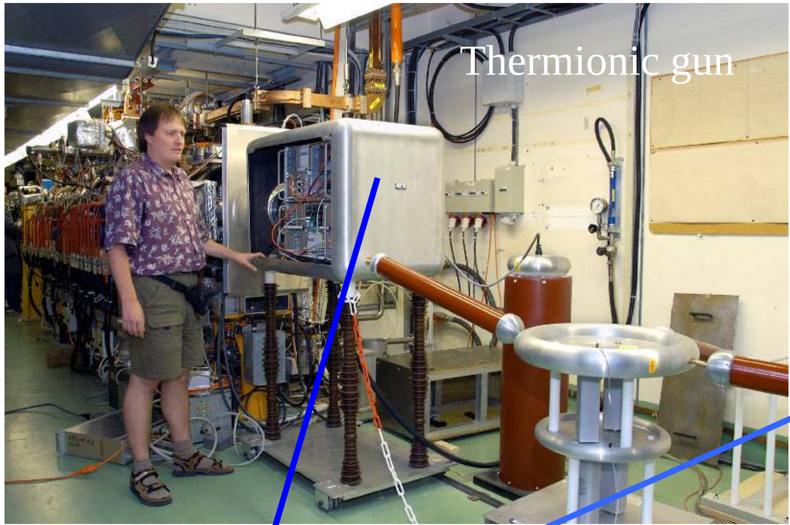
Present CTF3 status

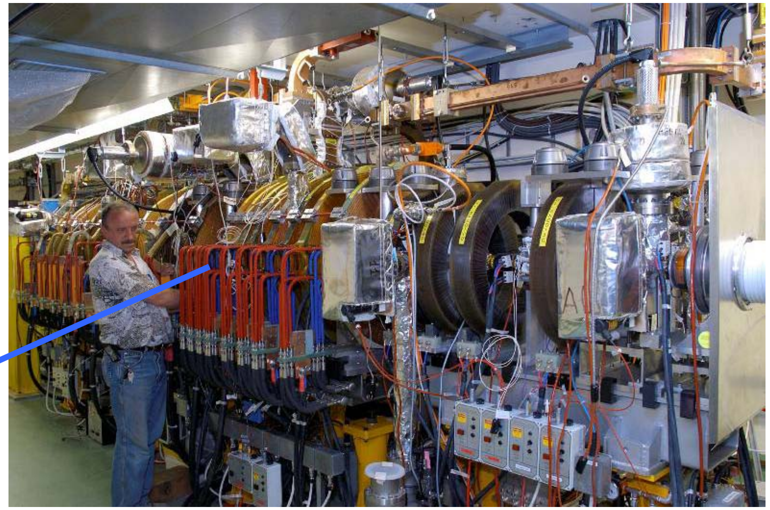


CLEX building:
Everything installed (except TBL)
Commissioning start June 2008

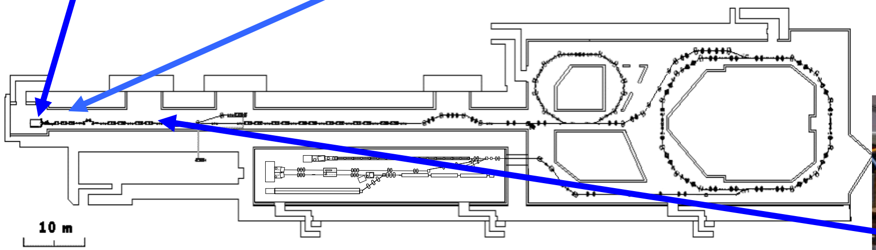
TL2 / TL2' installation ongoing, commissioning start in June 2008

CTF3 Installation





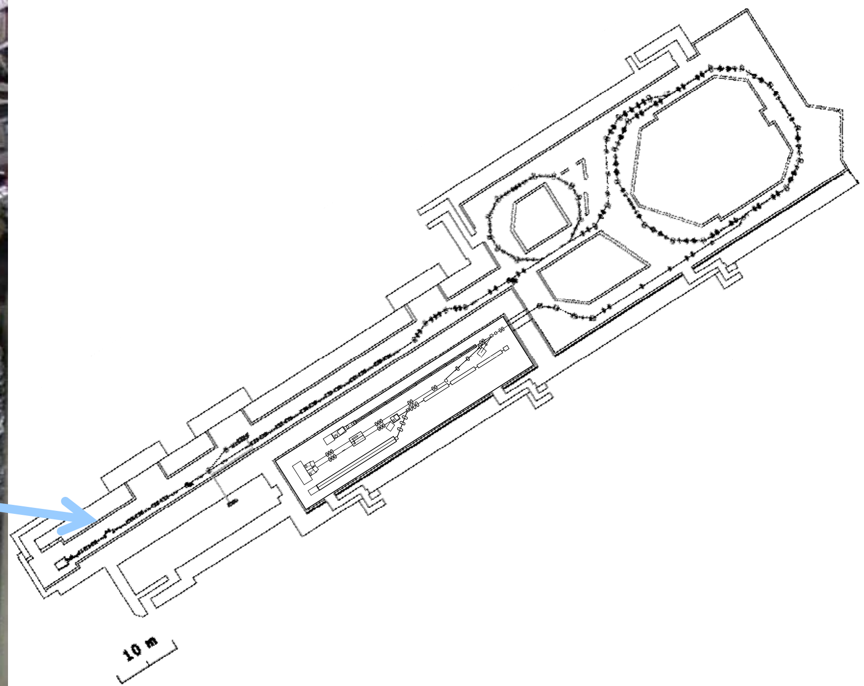
Injector solenoid



Thermionic gun
- 10 A max,
- after bunching
  - 3.5 A nominal, max. 7 A
- one sw and one tw buncher
- three 1.5 GHz bunchers

Magnetic chicane

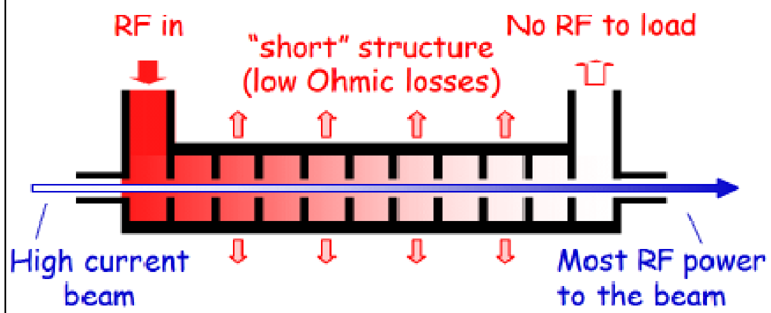
Injector and Linac



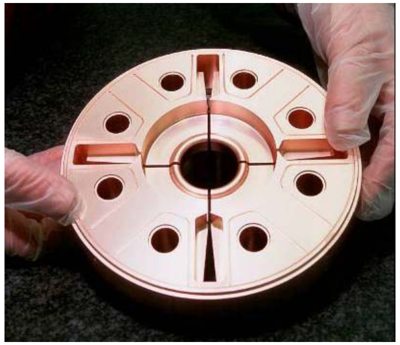
Full Beam loading

Proof of one of the major CLIC features:

Full Beam Loading

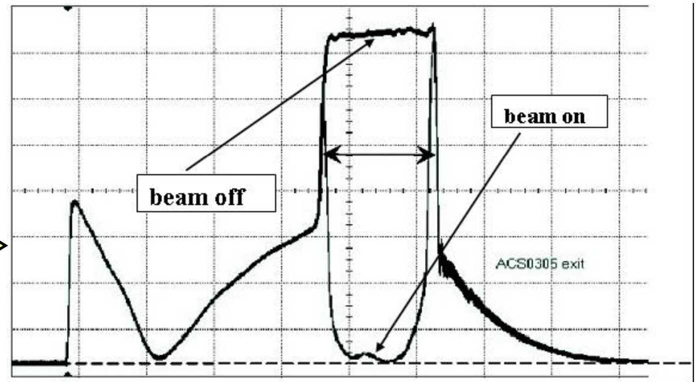


Drive Beam accelerating structure:



RF to beam transfer:

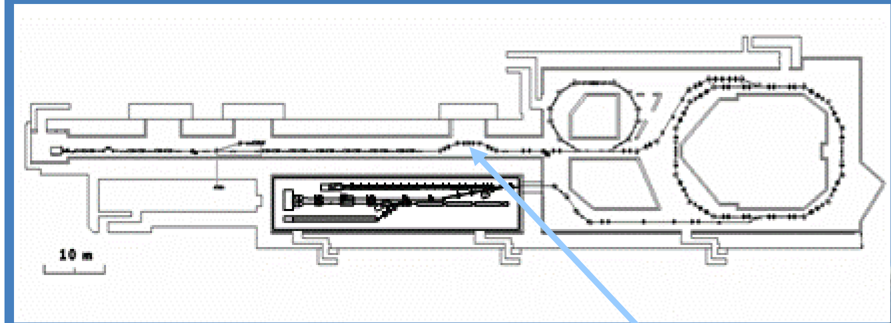
95.3 % measured



RF power at output of accelerating structure

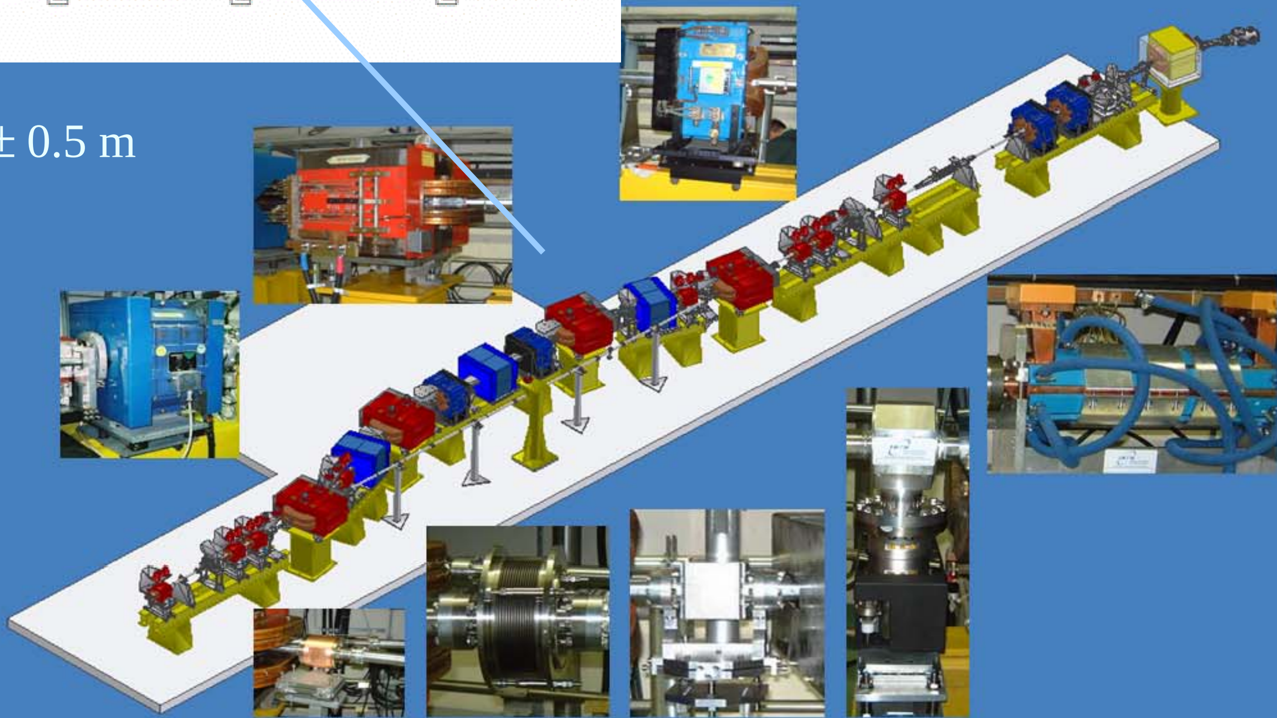
Linac routinely operated with full beam loading

Bunch Stretcher – Compressor Chicane

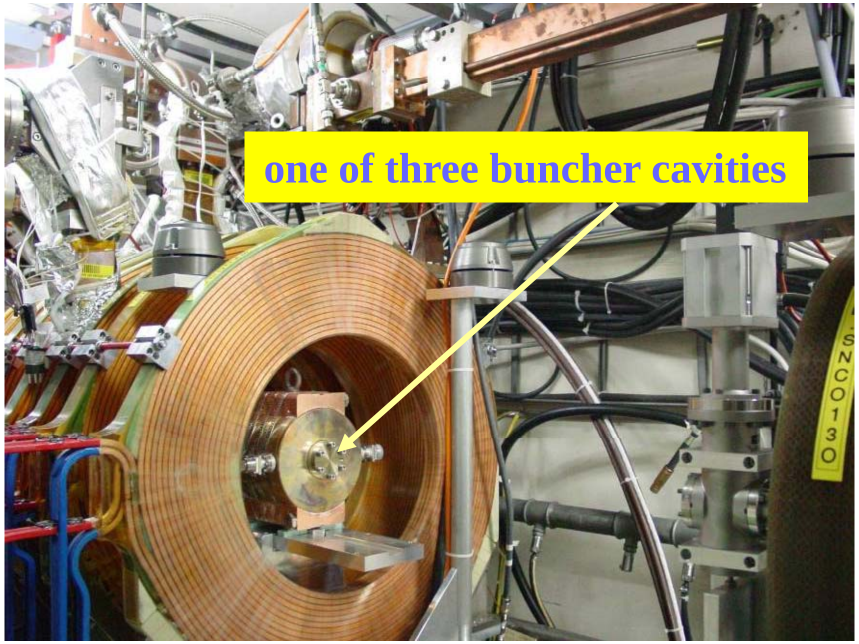


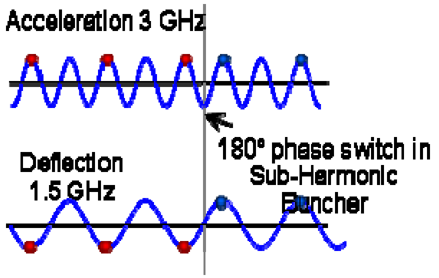
Built by INFN Frascati

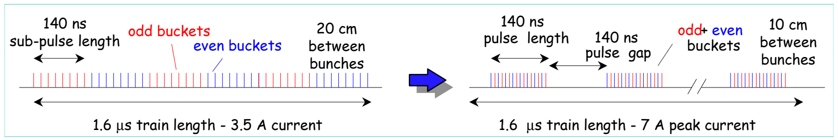
R_{56} between ± 0.5 m



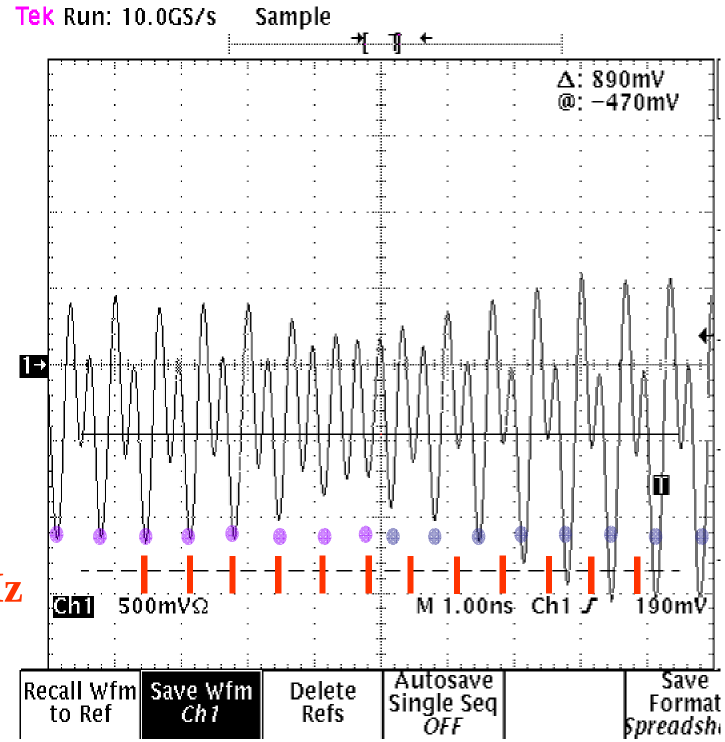
Sub-harmonic bunching / phase coding







1.5 GHz



Switching transient about 7 bunches

Delay Loop

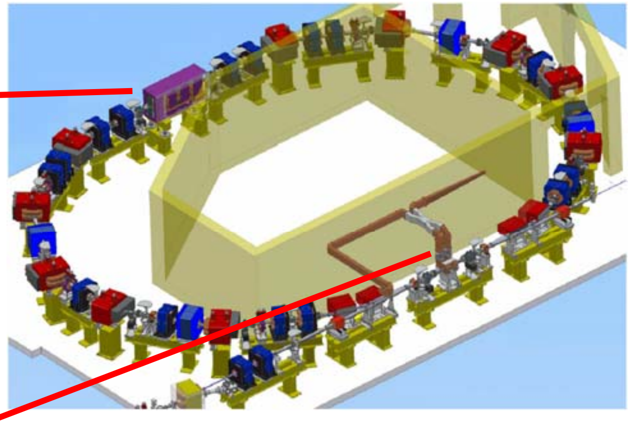
Designed and built by INFN Frascati

circumference 42 m (140 ns)

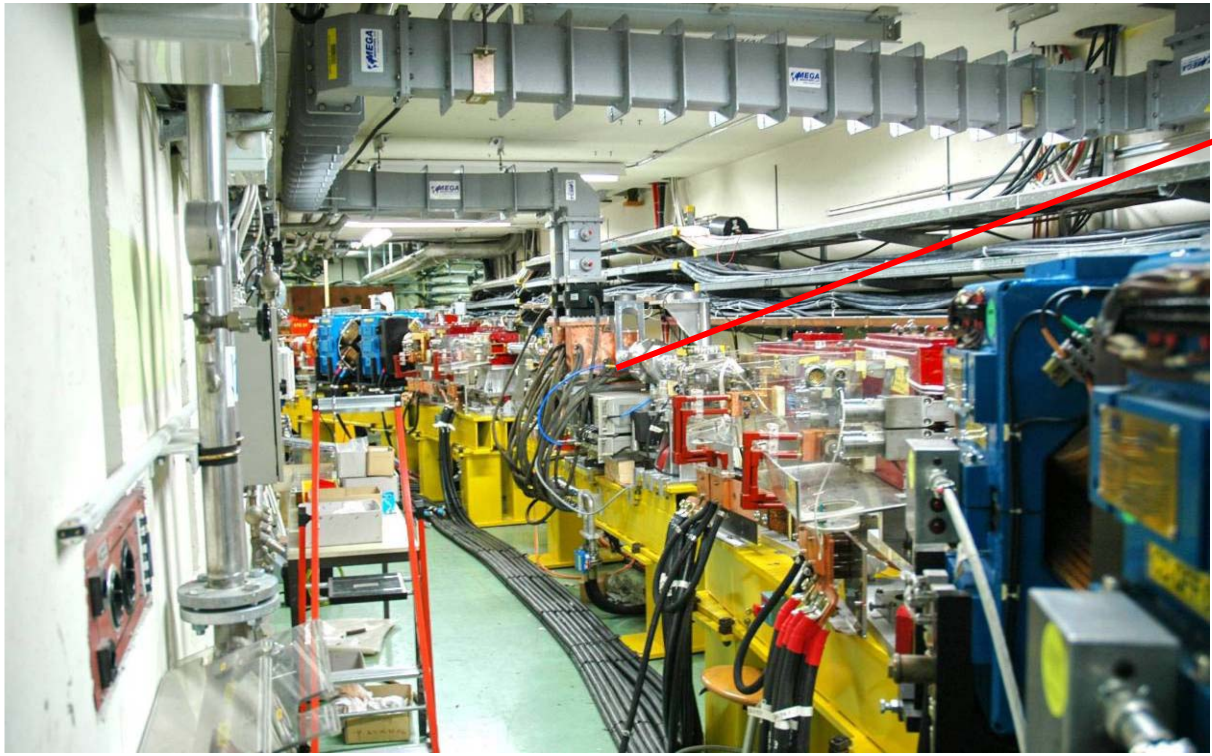
isochronous optics

wiggler to tune path length

(9 mm range)

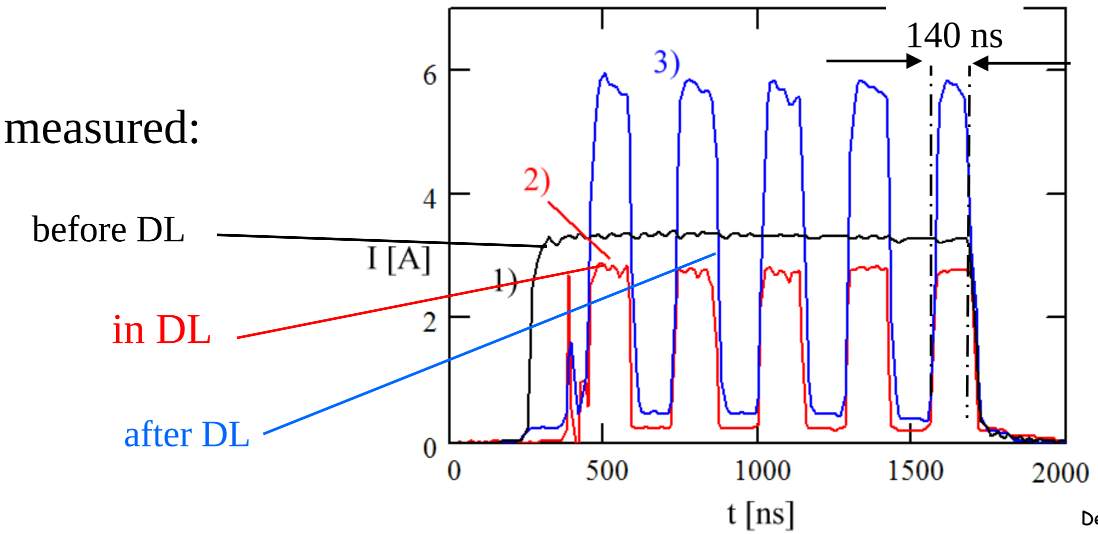


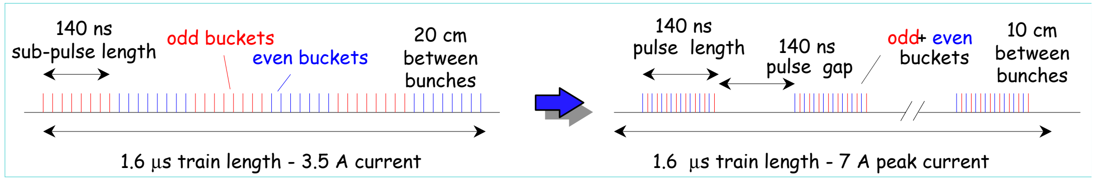
1.5 GHz RF deflector

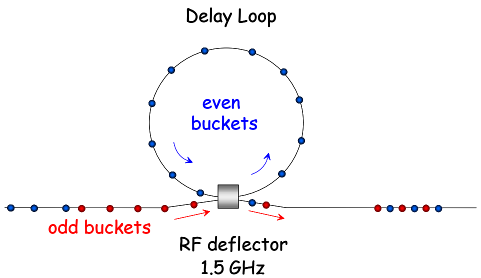


Bunch interleaving in Delay Loop

Beam current measured:

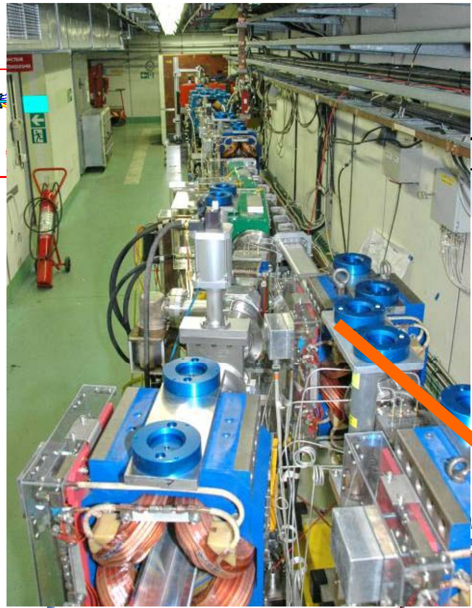


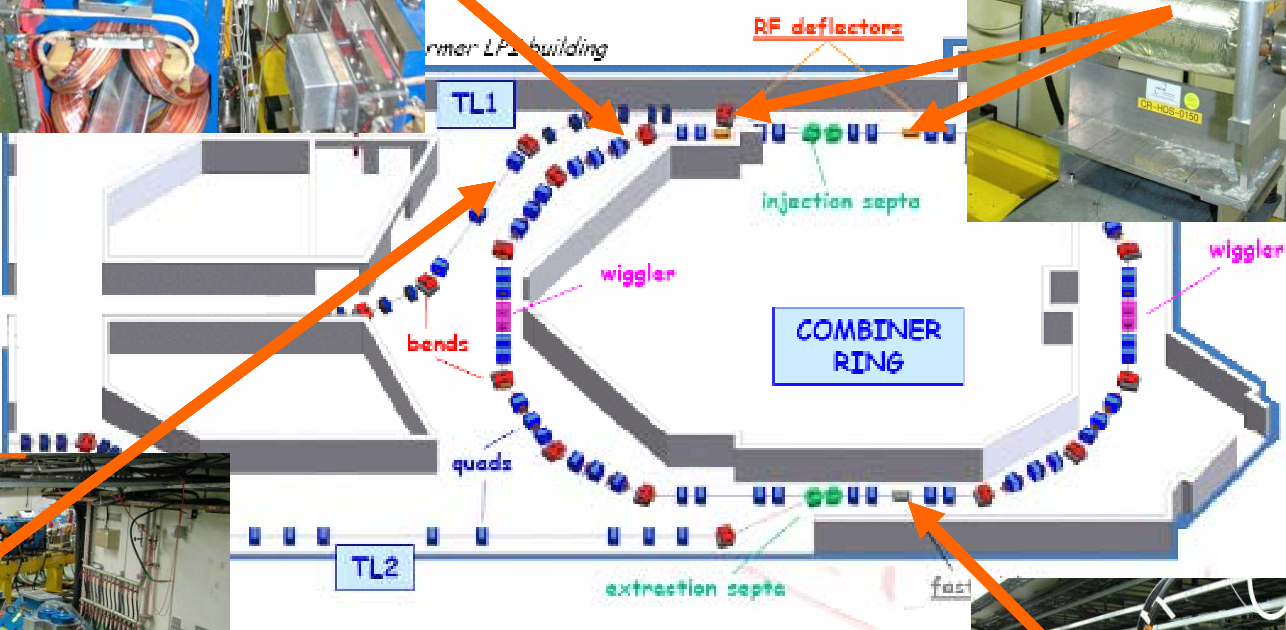


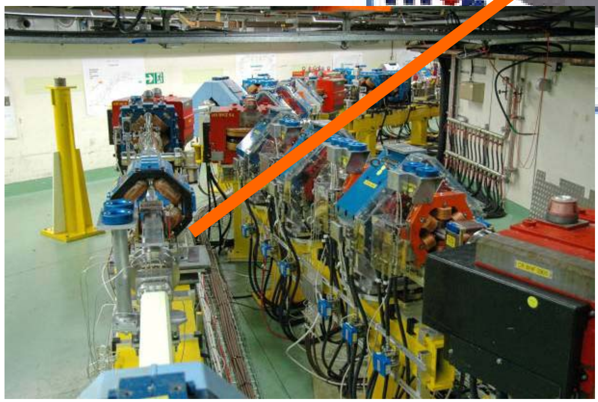


Successful demonstration of Delay Loop operation !

mbiner Ring



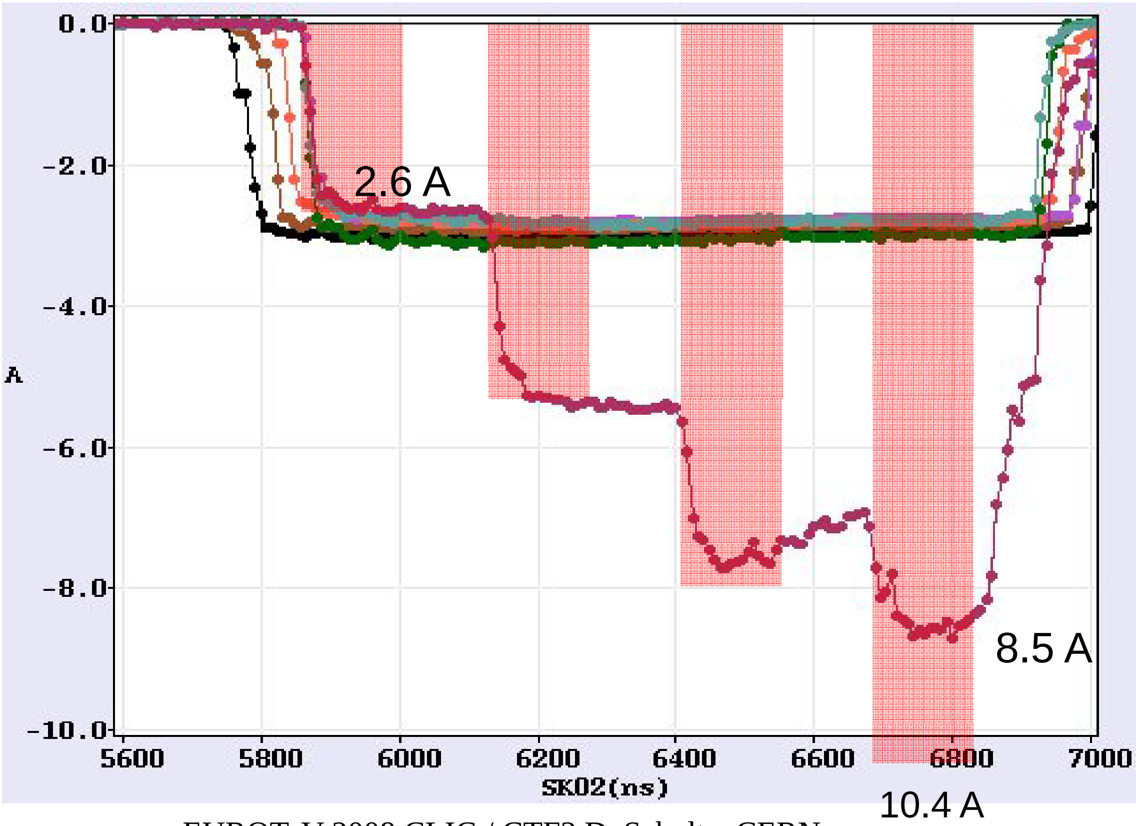

rmer LPI building
RF deflectors
TL1
injection septa
wiggler
wiggler
COMBINER RING
bends
quads
TL2
extraction septa
fast



Combiner Ring commissioning

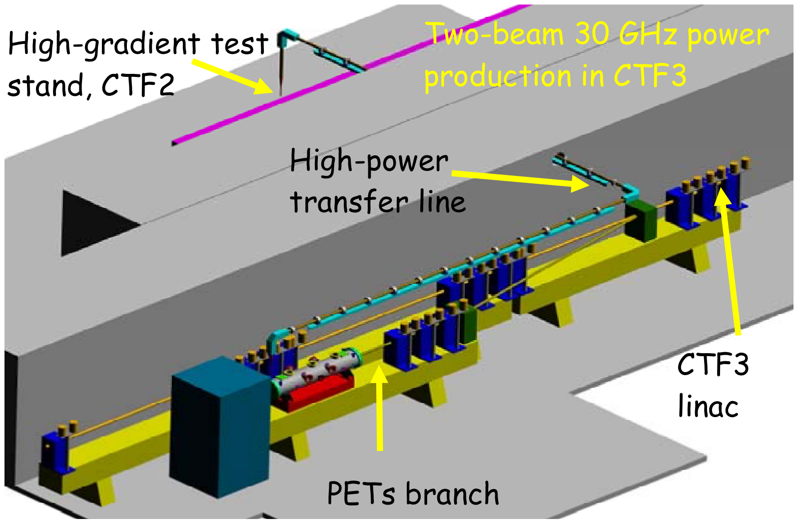
Achieved recombination:

- Linac current lower than nominal
- DL bypassed (no holes, missing factor 2)
- Losses during recombination (**instability**…)



Accelerating structure testing

Tests at 30 GHz still continuing

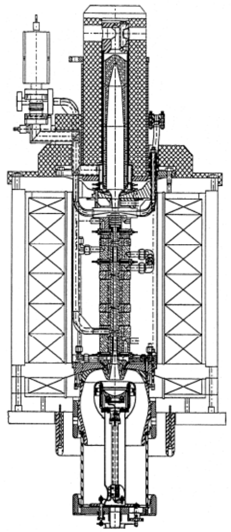


100 MW produced at 30 GHz,
Transmission via circular TE_{01} line (17 m) with 65 % efficiency

operation for 30 GHz now routine,
largely automatic.
24 hour operation

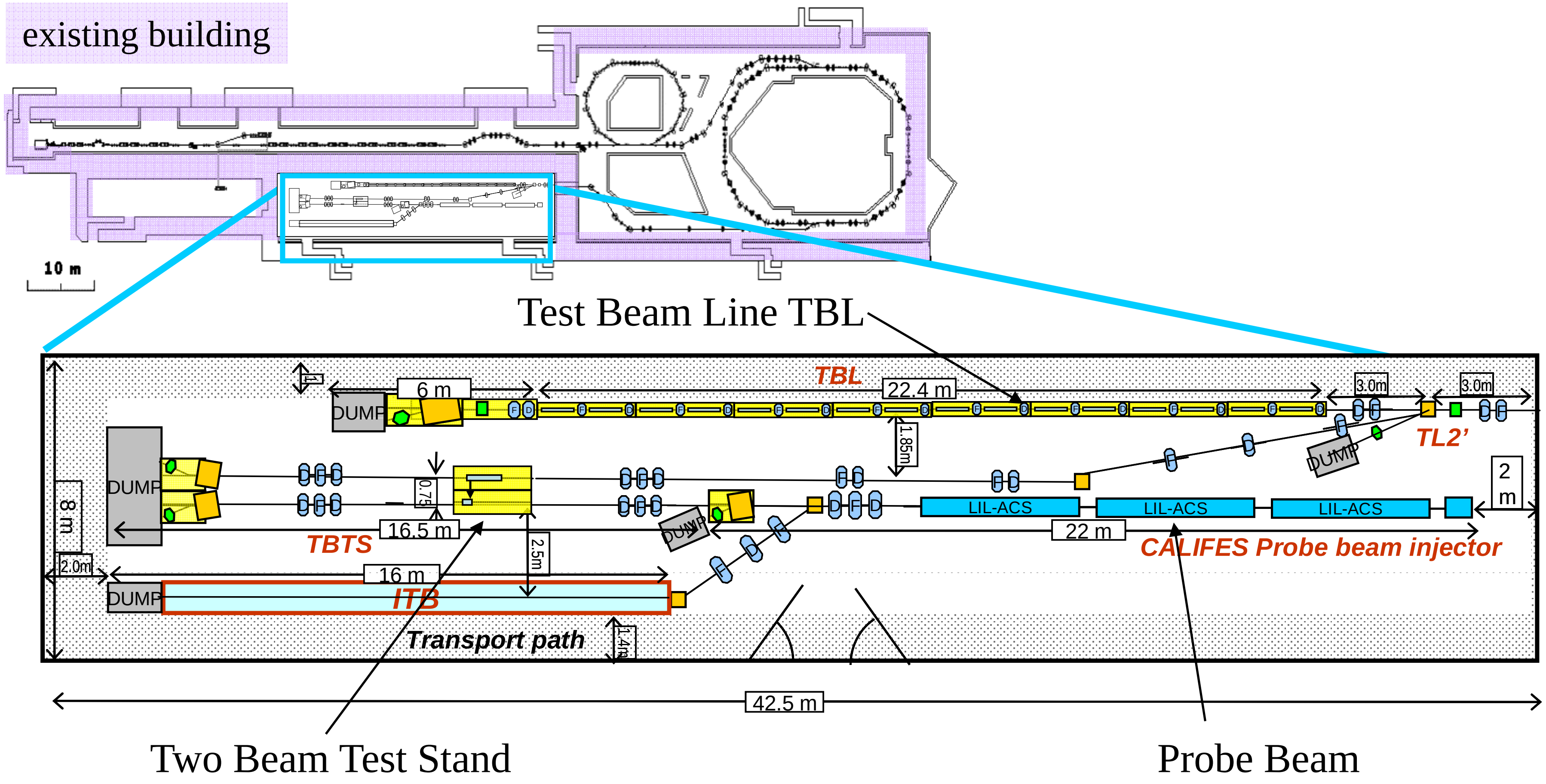
12 GHz work:
Collaboration with SLAC and KEK,
presently no test facility at CERN

Stand-alone power source in preparation



Klystron with pulse compressor

CLEX (CLIC Experimental Area)



Construction during 2006/beg 2007
installation of equipment from
2007 - 2009

Beam in CLEX from June 2008 onwards

Probe Beam

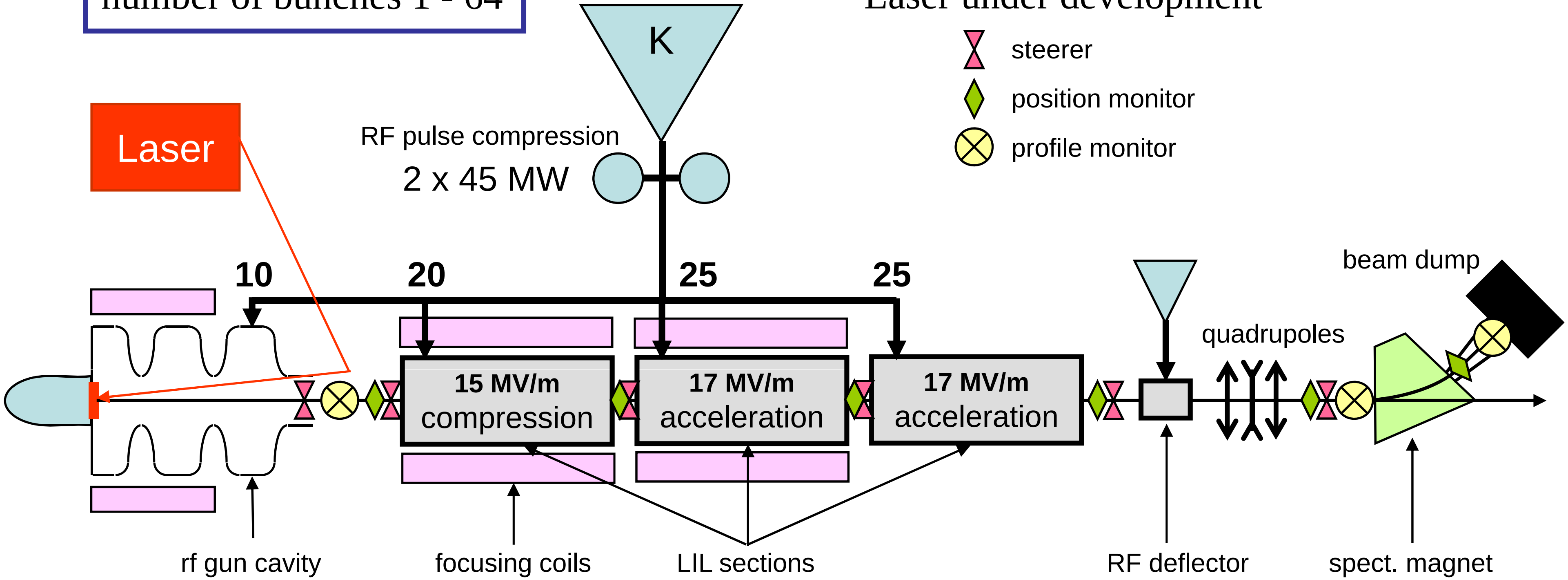
Responsibility of IRFU (DAPNIA), CEA, Saclay

200 MeV
bunch charge 0.5 nC
number of bunches 1 - 64

Status:

Installed, RF conditioning in June

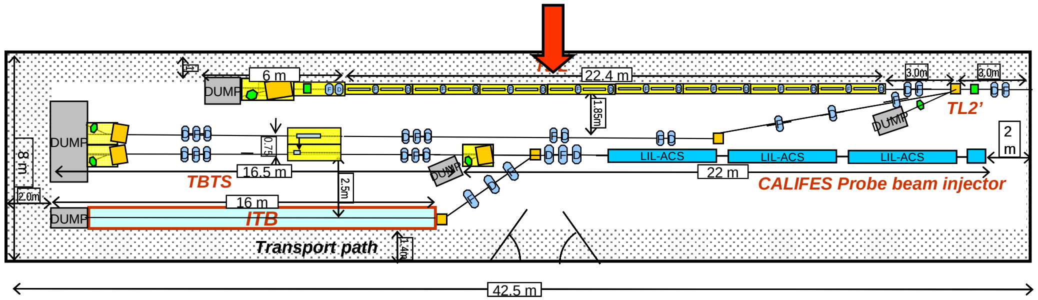
Laser under development



CALIFES

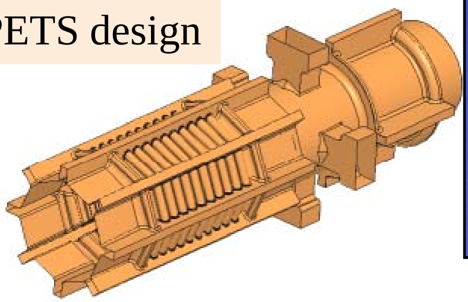
A. Mosnier, CEA Dapnia

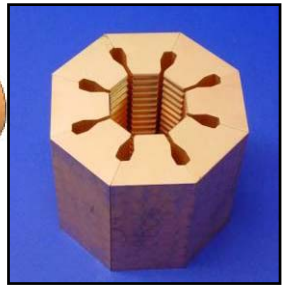
Test Beam Line TBL



- High energy-spread beam transport
  decelerate to 50 % beam energy
- Drive Beam stability
- Stability of RF power extraction
  total power in 16 PETS: 2.5 GW
- Alignment procedures

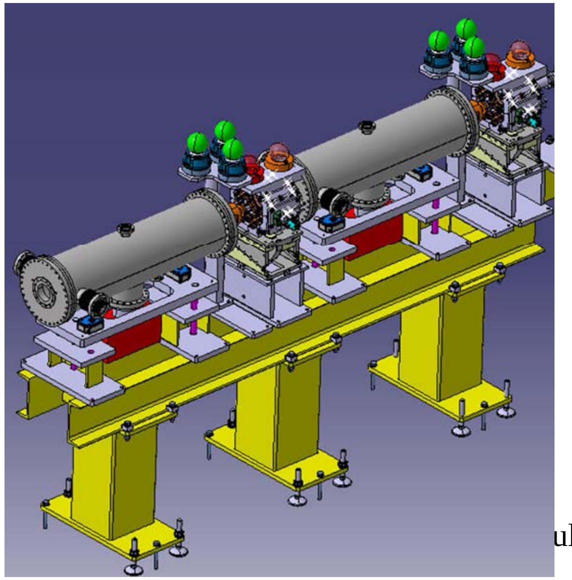
PETS design

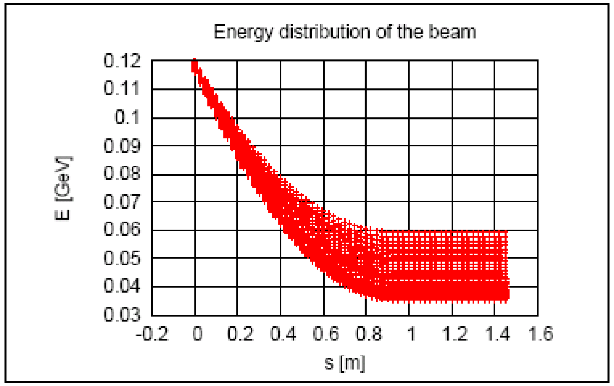




5 MV/m deceleration (35 A)

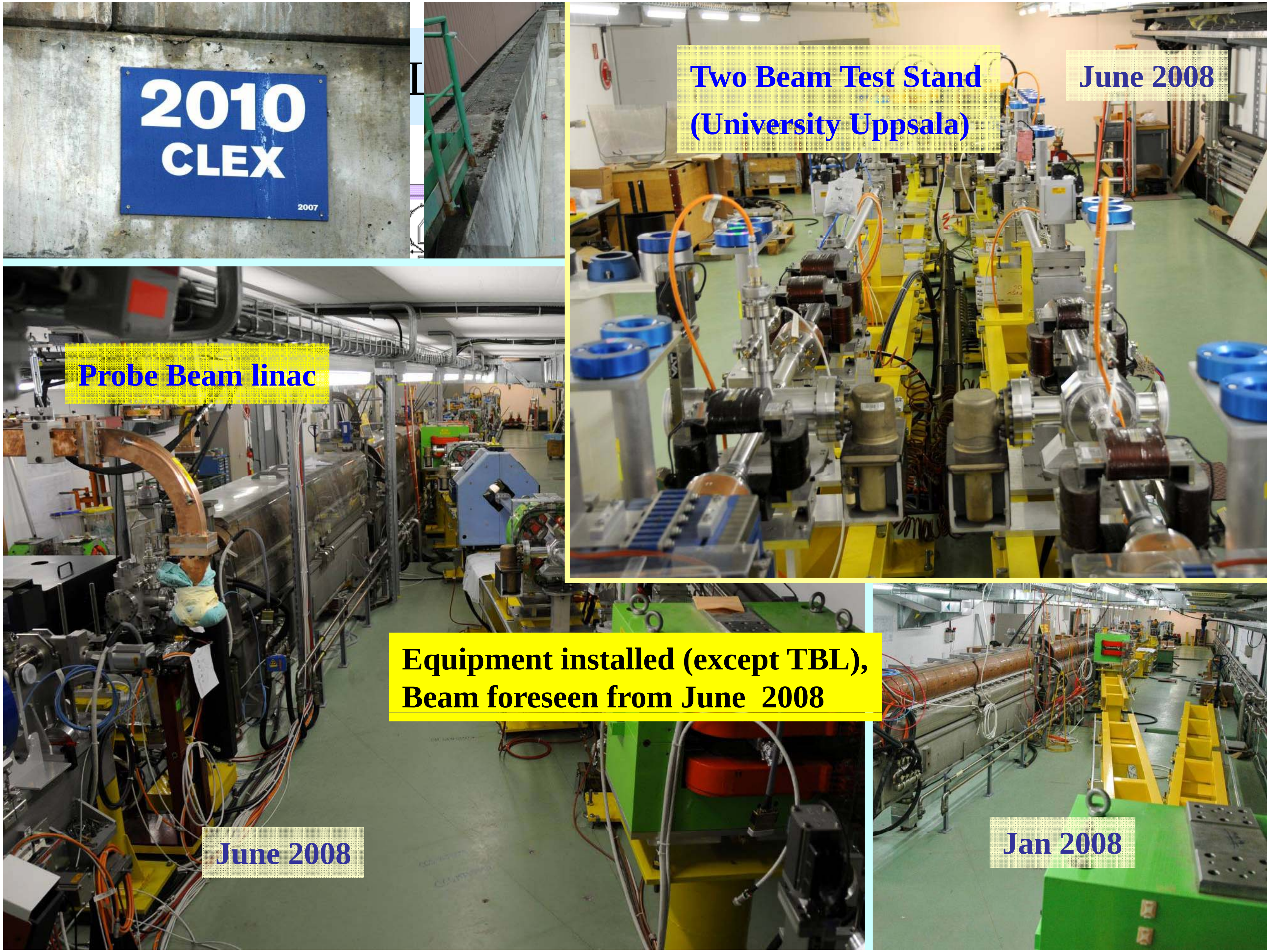
165 MV output Power



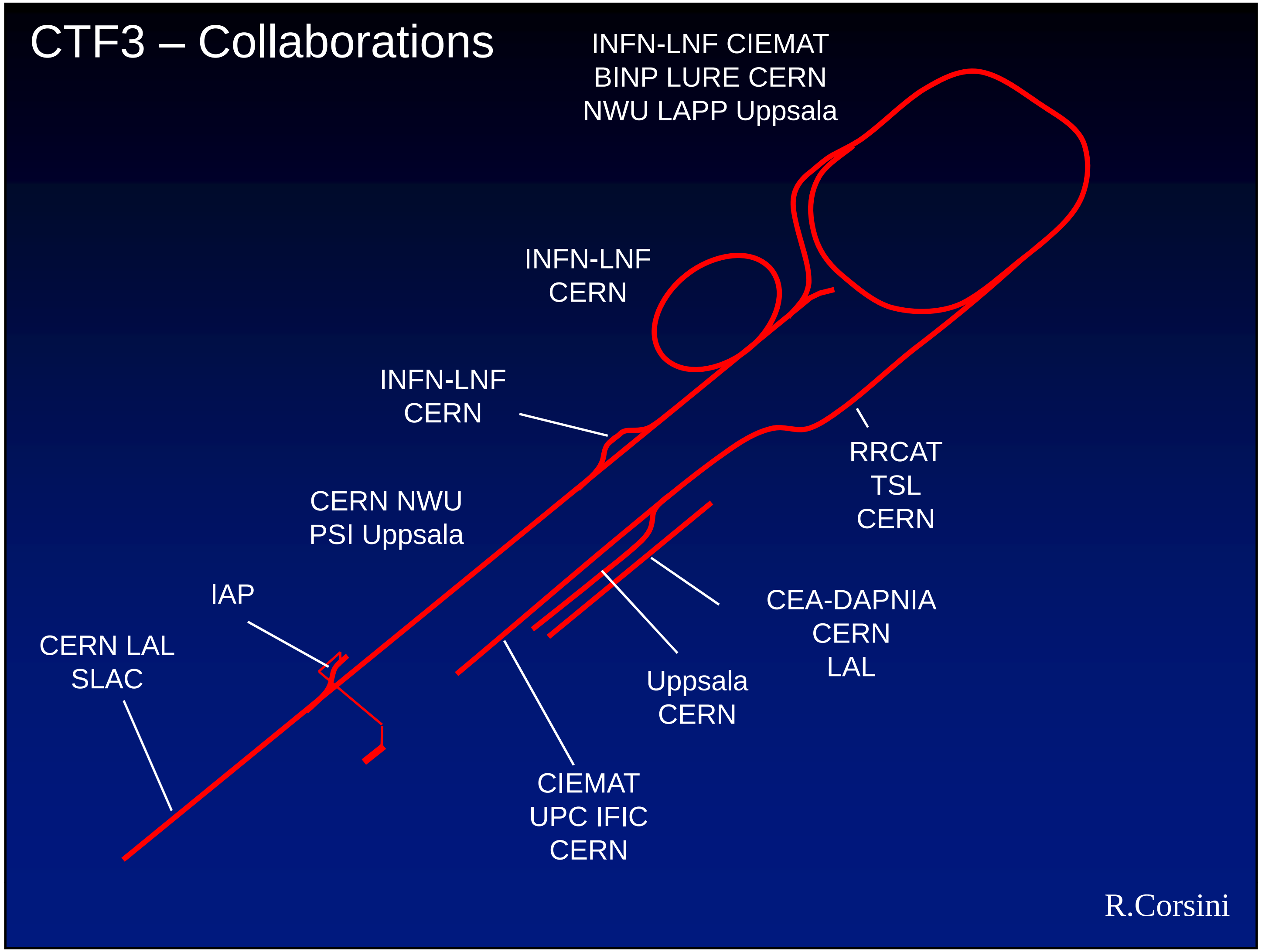


2 standard cells, 16 total

PETS development: CIEMAT
BPM: IFIC Valencia
and UPC Barcelona


2010
CLEX
2007
Two Beam Test Stand
(University Uppsala)
June 2008
Probe Beam linac
Equipment installed (except TBL),
Beam foreseen from June 2008
June 2008
Jan 2008

CTF3 Collaboration

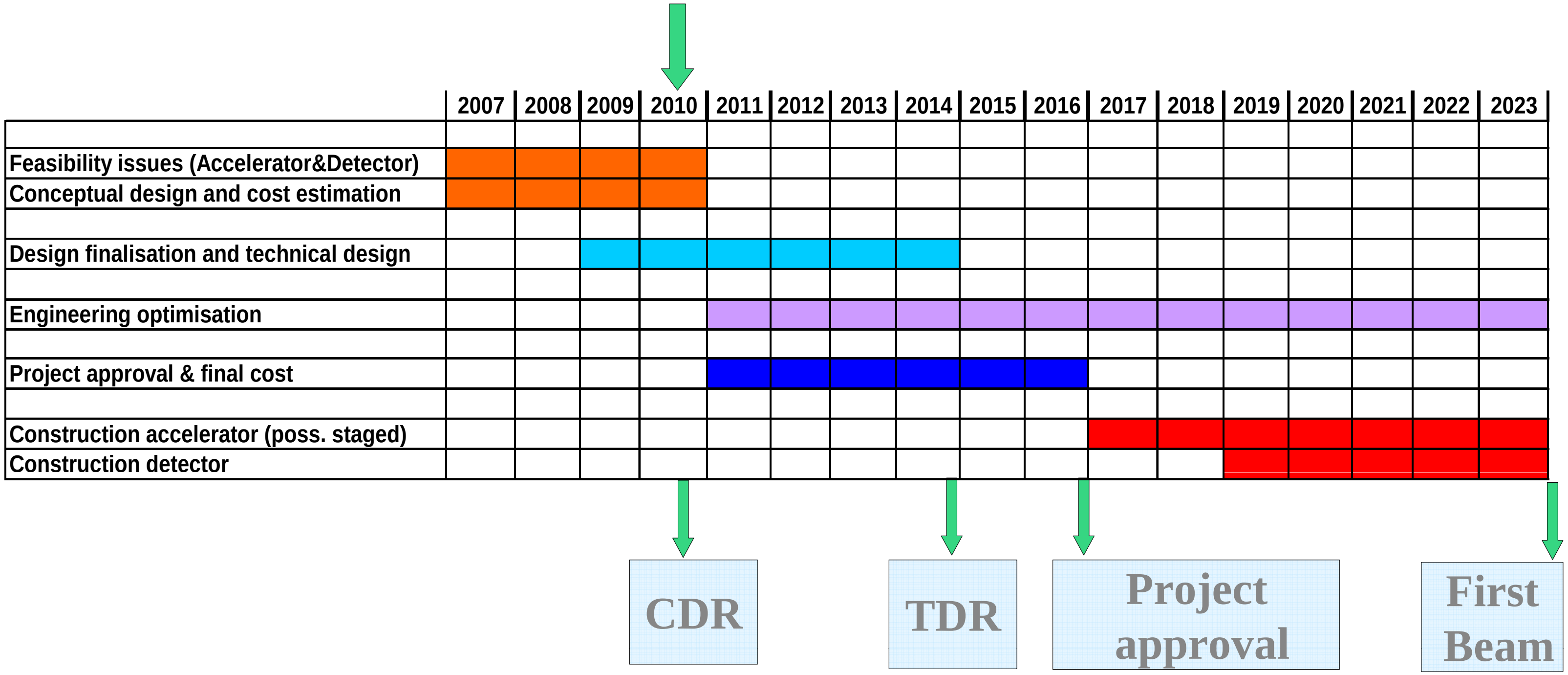


Conclusion

Tentative long-term CLIC scenario

Shortest, Success Oriented, Technically Limited Schedule (Jean-Pierre Delahaye)

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 II

Well advanced programme

Consistent parameter set

Technical programme is on track

- **Accelerating structure progressing**, Proof-of-principle
- **CTF3 on schedule**

  full beam loading

  bunch phase coding and Delay Loop operation

  First results on recombination on Combiner Ring

Progress is only possible because we have a very prosperous collaboration between 24 international institutes

CLIC / CTF3 collaboration

24 collaborating institutes

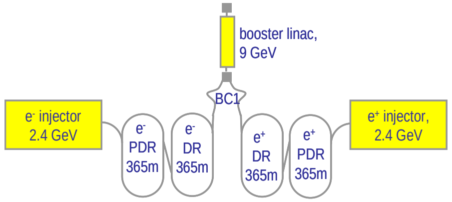
Ankara University (Turkey)
Berlin Tech. Univ. (Germany)
BINP (Russia)
CERN
CIEMAT (Spain)
Finnish Industry (Finland)
Gazi Universities (Turkey)

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)

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

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

Emittance



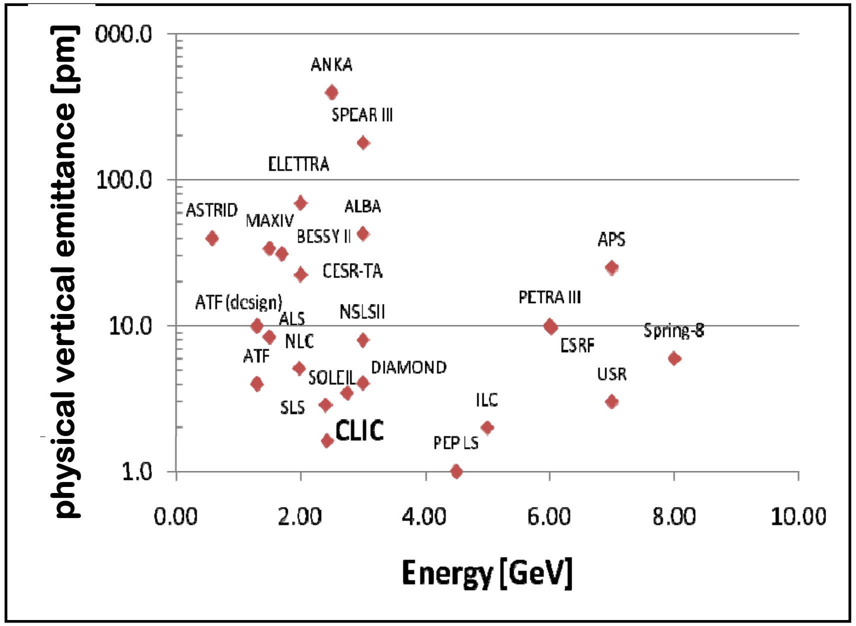
CLIC has two damping rings each for e$^+$ and e$^-$

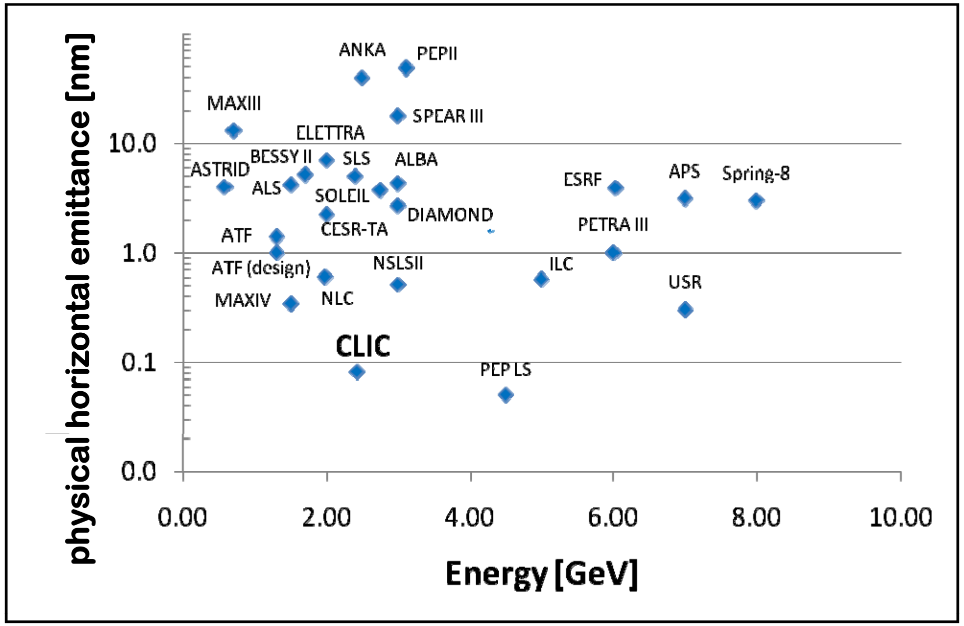
output DR: $\gamma\varepsilon_x$=381 / $\gamma\varepsilon_y$= 4.1 nm rad

for 4.1*10^9 particles at 2.4 GeV

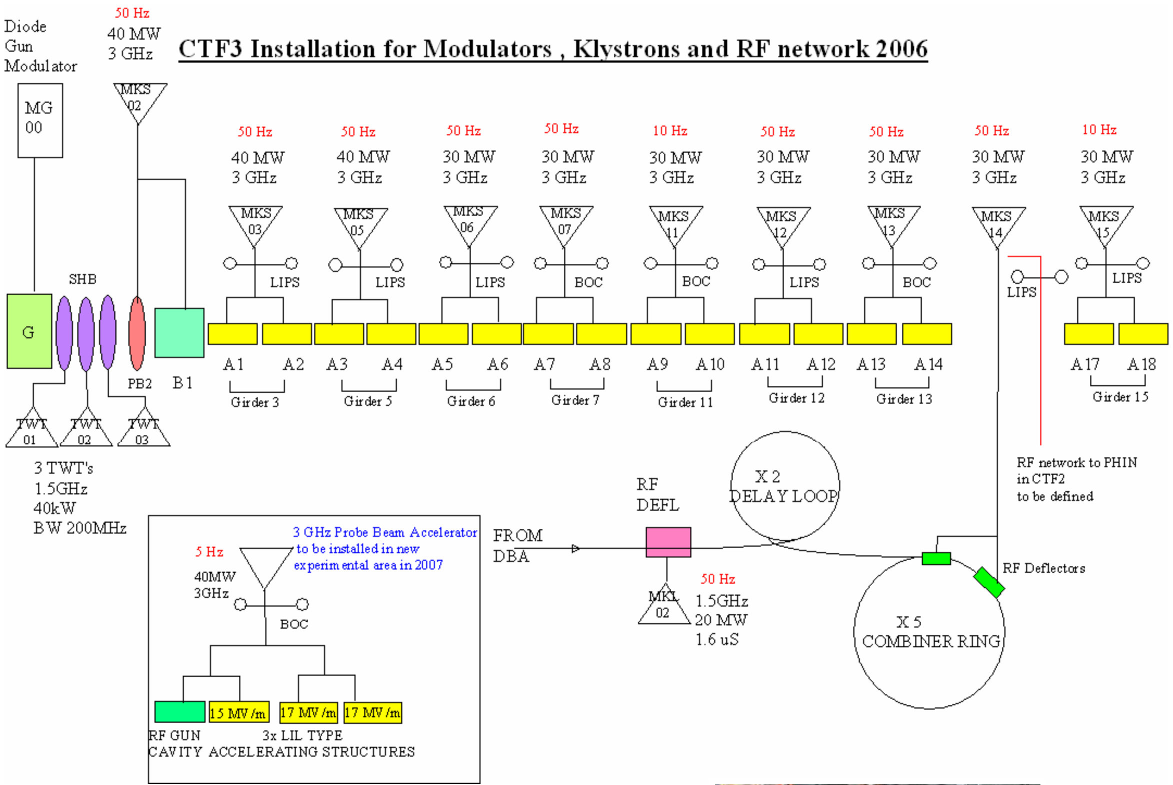
DR design exists

Wigglers being developed, superconducting and normal conducting versions considered





RF power plant



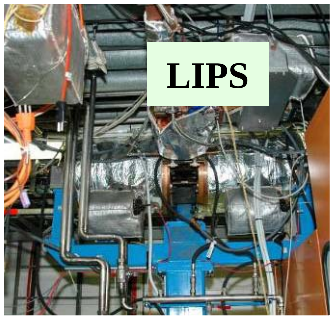
10 s-band klystrons 3 GHz
35 – 45 MW, 5.5 μs

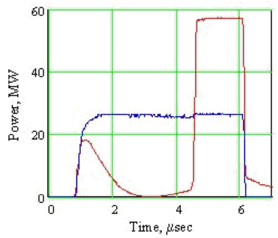
9 with pulse compressors:
factor 1.9 – 2 (1.6 μs)

3 L-band travelling wave tubes
40 kW, 3 μs
1.5 GHz BW >200 MHz

1 L-band klystron
22 MW, 5.5 μs

RF Pulse compression





phase error: 6 deg
amplitude: ±1%