CLIC Feasibility Study in CTF3

Andrea Ghigo for the CLIC Collaboration

EPAC06 Edinburgh June 28th, 2006

CLIC

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.

"J.P.Delahaye"

Physics Motivation

- Several theories beyond the Standard Model, that foresees supersymmetry, extra dimensions or new strong interactions, predict new dynamics at the TeV scale.

- Supersimmetry with relative sparticle production as well as heavy mass Higgs bosons can be studied raising the energy up to 5 TeV.

Basic Features of CLIC

- **High acceleration gradient (150 MV/m)**
  - **“Compact” collider - overall length < 40 km**
  - **Normal conducting accelerating structures**
  - **High acceleration frequency (30 GHz)**
- **Two-Beam Acceleration Scheme**
  - **Capable to reach high frequency**
  - **Cost-effective & efficient (~ 10% overall)**
  - **Simple tunnel, no active elements**
- **Central injector complex**
  - **“Modular” design, can be built in stages**

World wide CLIC/CTF3 Collaboration

CLIC

Ankara University (Turkey):	CTF3 beam studies & operation
Berlin Tech. University (Germany):	Structure simulations GdfidL
BINP (Russia):	CTF3 magnets development & construction
CERN:	Study coordination, structures devel., CTF3 construction/commissioning
CIEMAT (Spain):	CTF3 septa and kickers, correctors, power extraction structures
DAPNIA/Saclay (France):	CTF3 probe beam injector
Finnish Industry (Finland):	Sponsorship of mechanical engineer
INFN / LNF (Italy):	CTF3 delay loop, transfer lines & RF deflectors, ring vacuum chambers
JINR & IAP (Russia):	Surface heating tests of 30 GHz structures
KEK (Japan):	Low emittance beams in ATF
LAL/Orsay (France):	Electron guns and pre-buncher cavities for CTF3
LAPP/ESIA (France):	Stabilization studies, CTF3 beam position monitors
LLBL/LBL (USA):	Laser-wire studies
North-West. Univ. Illinois (USA):	Beam loss studies & CTF3 equipment
RAL (England):	Lasers for CTF3 and CLIC photo-injectors
SLAC (USA):	High Gradient Structure testing, structure design, CTF3 injector design
Uppsala University (Sweden):	Beam monitoring systems for CTF3

CLIC Main Parameters at 3 TeV

Center of mass energy	E_{cm}	3000	GeV
Main Linac RF Frequency	f_{RF}	30	GHz
Luminosity	L	6.5	10^{34} cm^{-2} s^{-1}
Luminosity (in 1% of energy)	$L_{99\%}$	3.3	10^{34} cm^{-2} s^{-1}
Linac repetition rate	f_{rep}	150	Hz
No. of particles / bunch	N_b	2.56	10^9
No. of bunches / pulse	k_b	220	
Bunch separation	Δt_b	0.267 (8 periods)	ns
Bunch train length	τ_{train}	58.4	ns
Beam power / beam	P_b	20.4	MW
Unloaded / loaded gradient	$G_{unl/l}$	172 / 150	MV/m
Overall two linac length	l_{linac}	28	km
Total beam delivery length	l_{BD}	2 x 2.6	km
Proposed site length	l_{tot}	33.2	km
Total site AC power	P_{tot}	418	MW
Wall plug (RF) to main beam power efficiency	η_{tot}	12.5	%

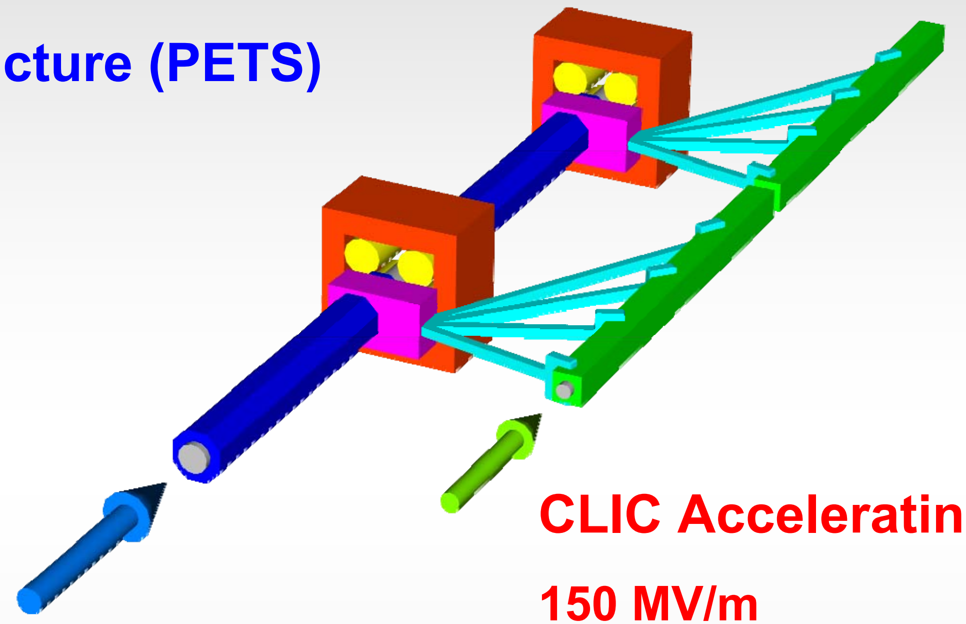
Two Beam Accelerator

Power Extraction Structure (PETS)

642 MW output Power
94 % transfer efficiency

Drive beam:

2.37 – 0.237 GeV
181 A
70 ns



CLIC Accelerating Structure

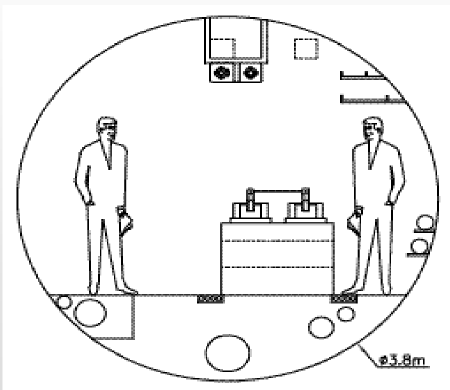
150 MV/m
70 ns pulse length
150 MW input Power

Main Beam:

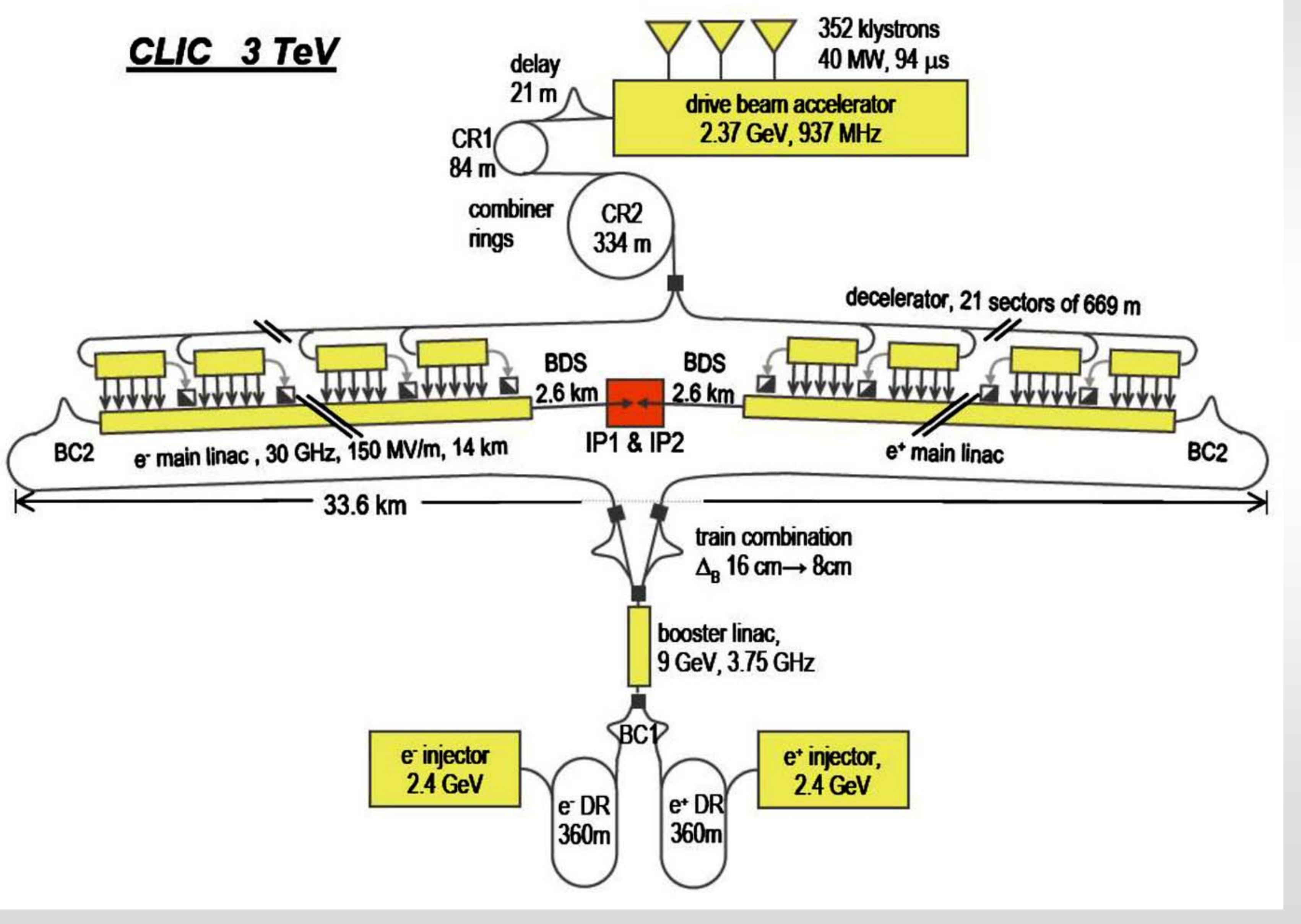
9-1500 GeV
1.5 A
60 ns

CLIC TUNNEL CROSS-SECTION

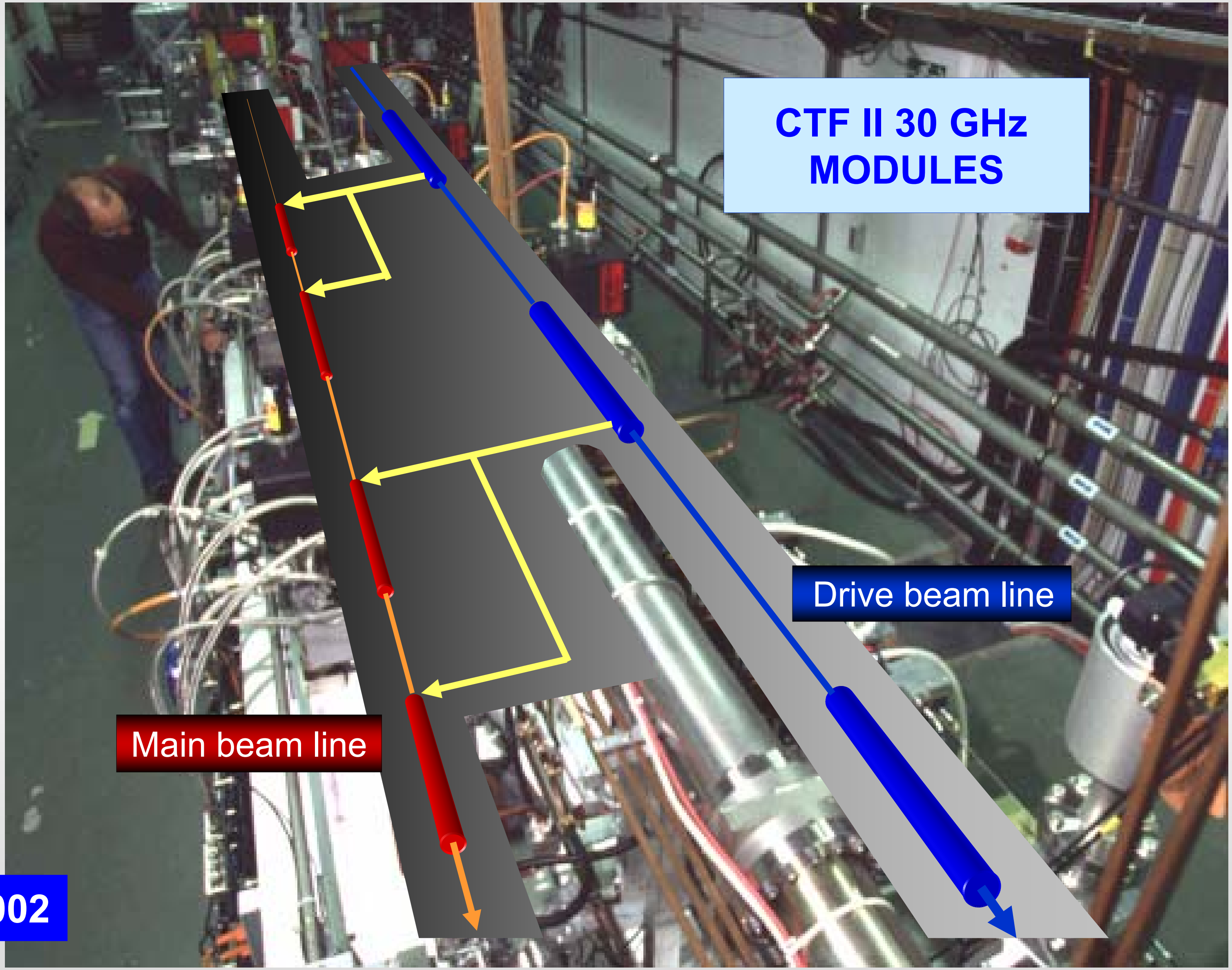
3.8 m diameter



CLIC 3 TeV Layout

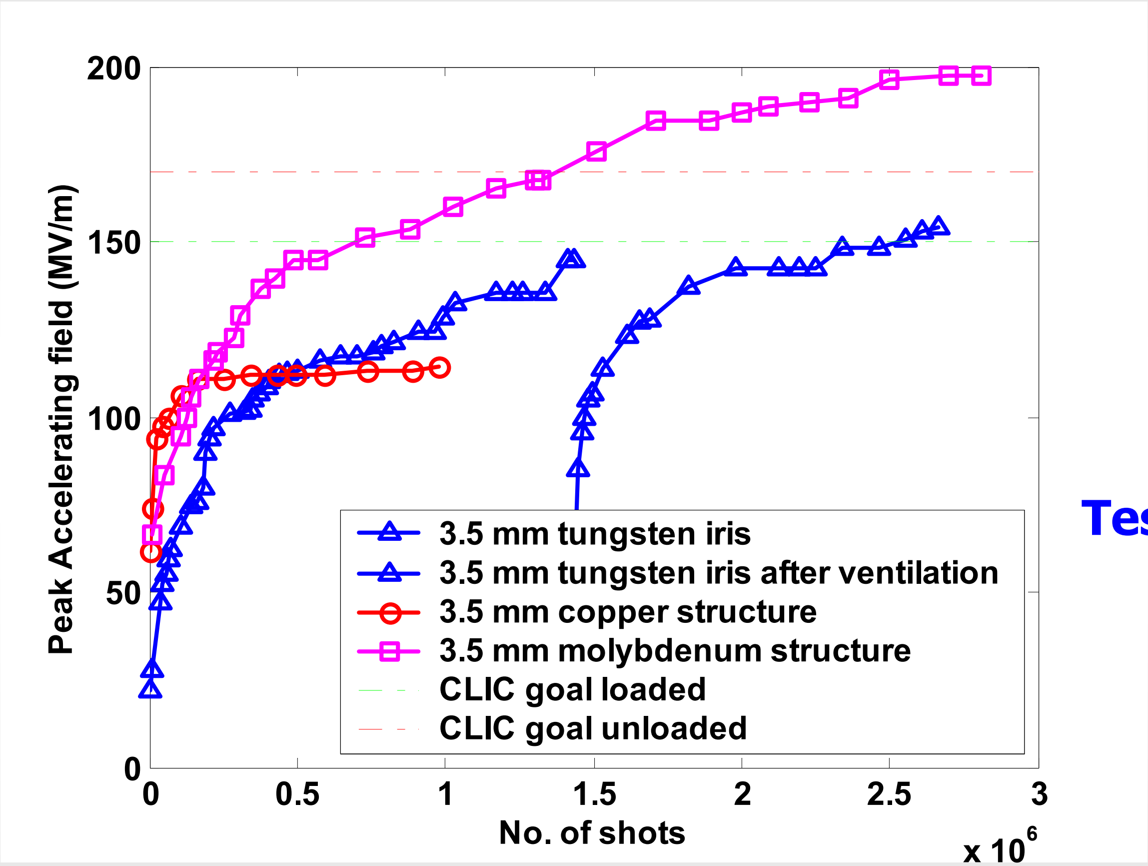


CLIC Test Facility CTF II

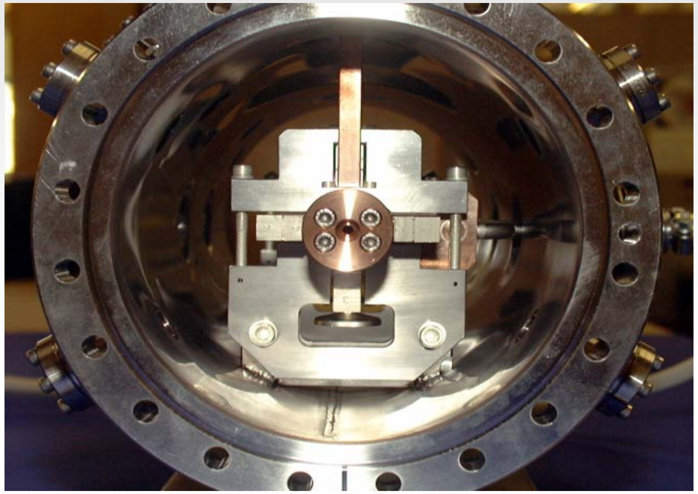


1996-2002

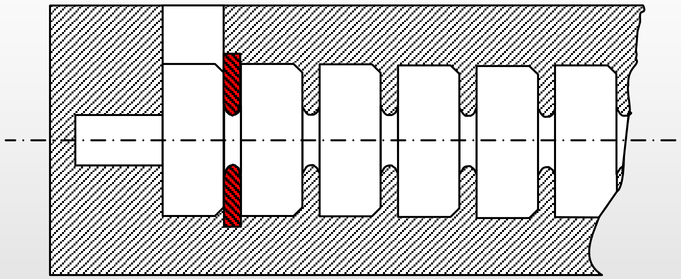
Accelerating Structure Tests in CTF II



Short RF pulses (16 ns)

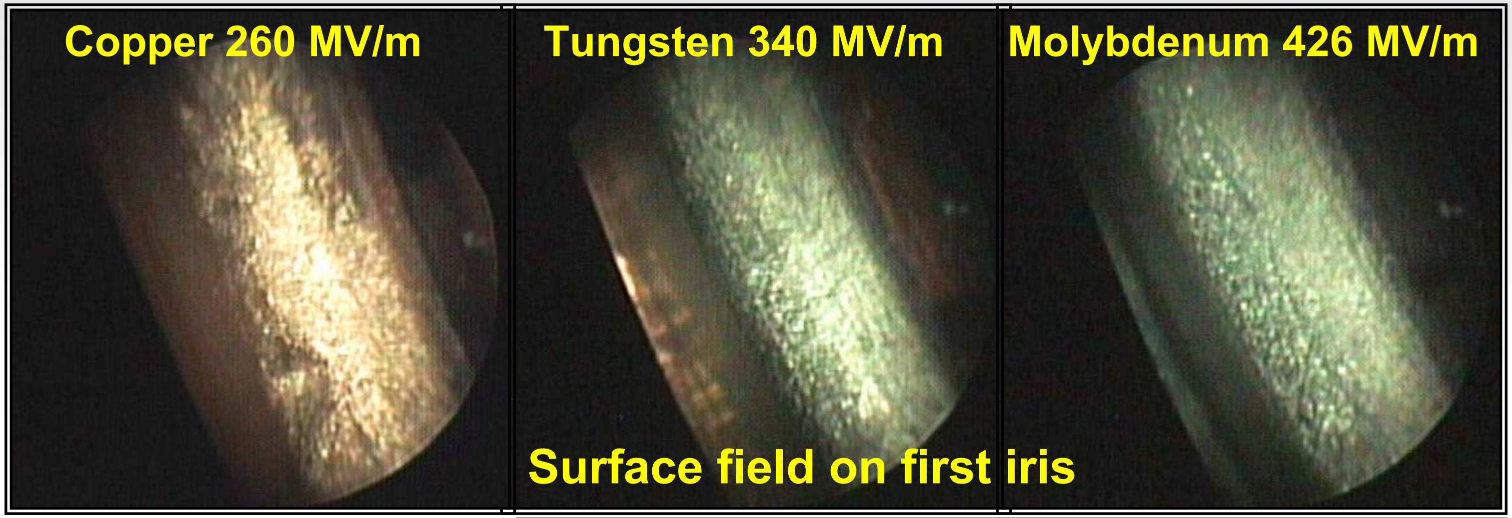


Test structure in external vacuum with clamped coupler cell



Copper iris replaced by Tungsten iris

Accelerating Structure Tests in CTF II



177 MV/m average

⇒228 MV/m peak

acceleration gradient

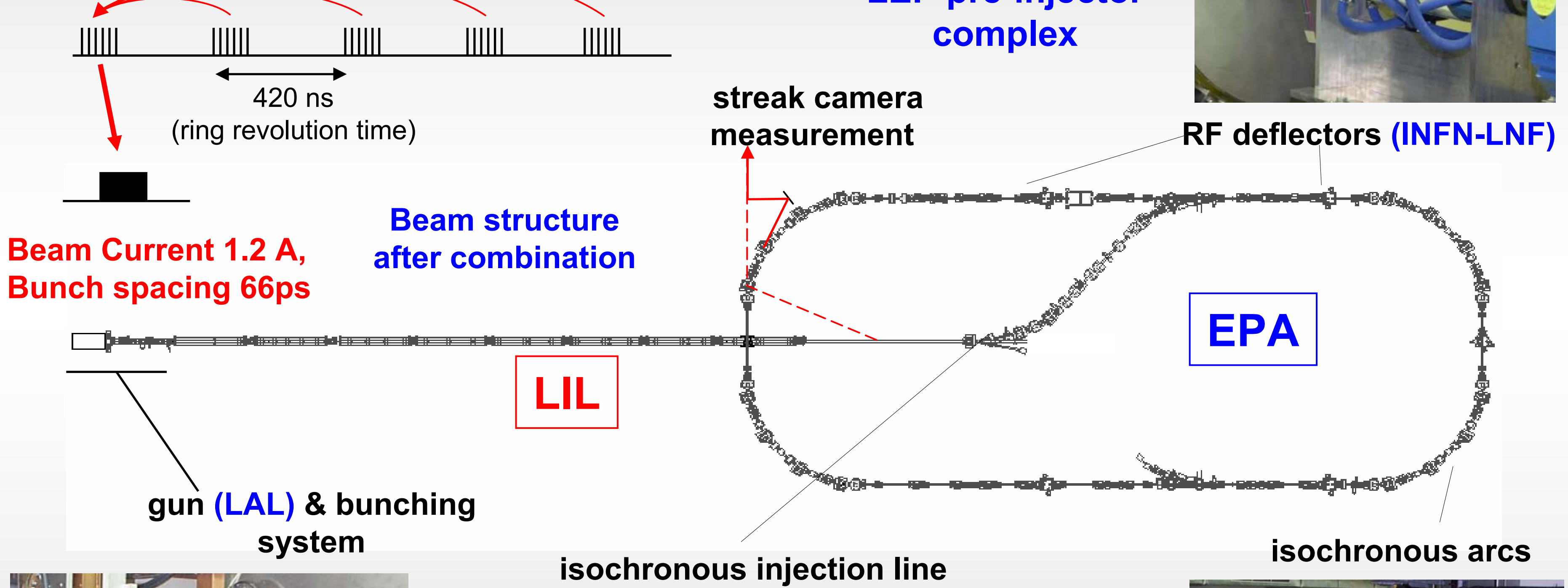
at 30 GHz with 8 ns RF pulses

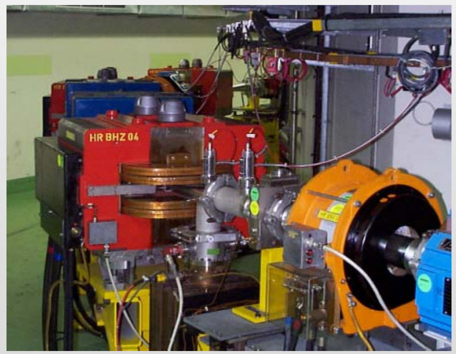
CTF3 Preliminary Phase

CLIC

2001-2002

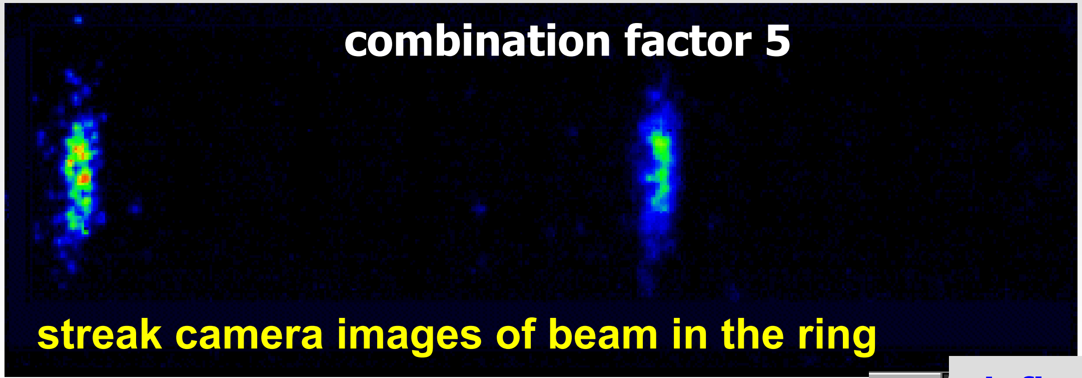
Modifications to the LEP pre-injector complex





Bunch Trains Combination

CLIC



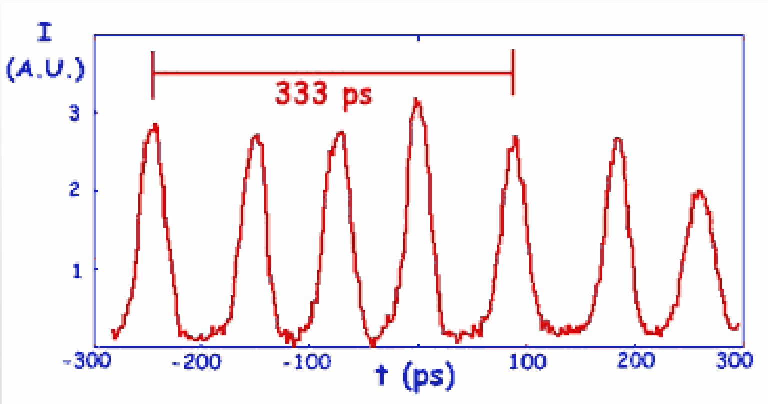
streak camera images of beam in the ring

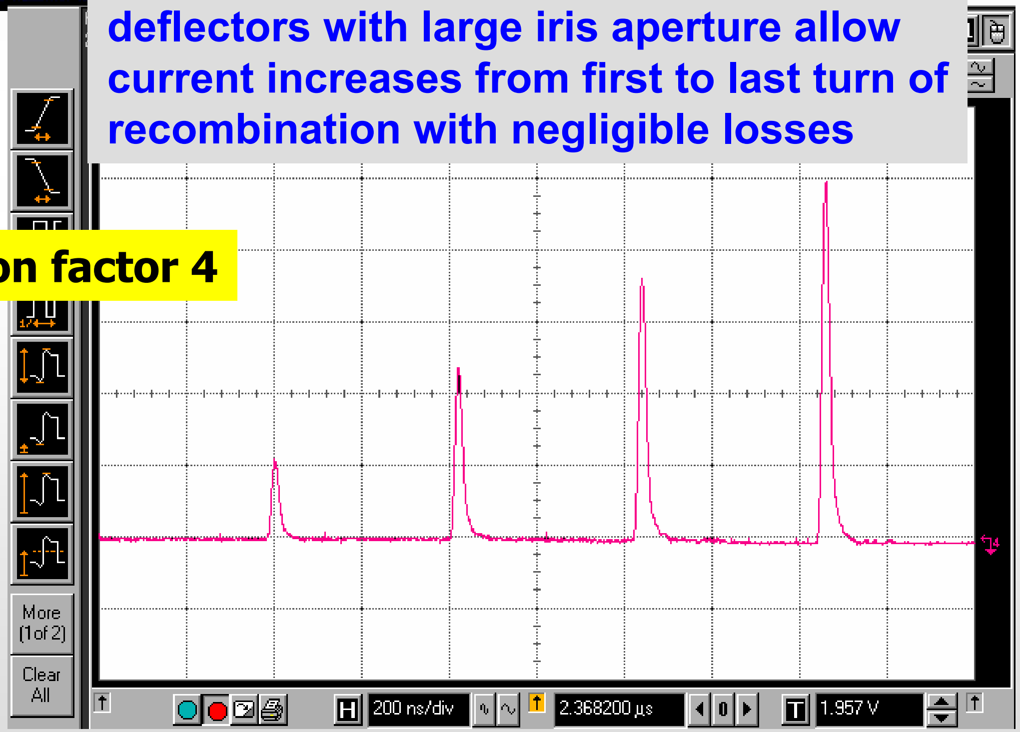
- First demonstration in June 2002
- Tested combination factors 4 & 5

deflectors with large iris aperture allow current increases from first to last turn of recombination with negligible losses

Charge: 1×10^{10} e- / train or 0.1 nC / bunch
Beam energy: 350 MeV
Bunch length (rms) ~ 8 ps

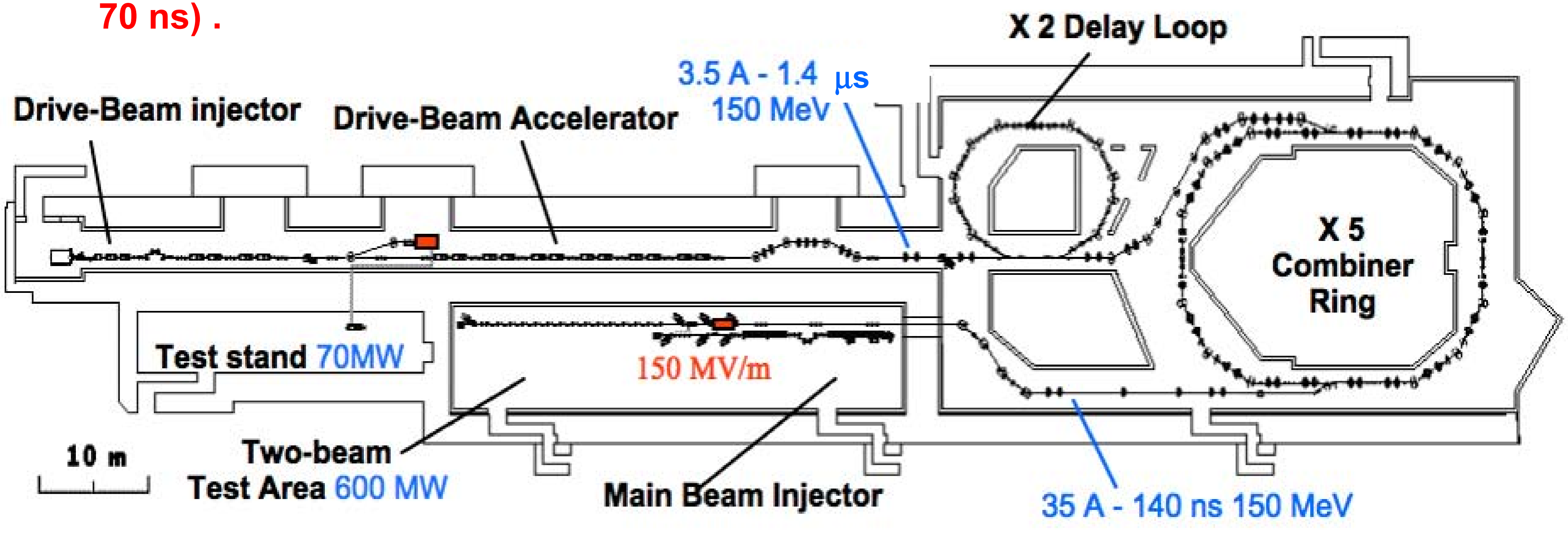
combination factor 4





CTF3 Motivation and Goals

- Build a small-scale version of the CLIC RF power source, in order to demonstrate:
  - full beam loading accelerator operation
  - electron beam pulse compression and frequency multiplication using RF deflectors
- Provide the 30 GHz RF power to test the CLIC accelerating structures and components at and beyond the nominal gradient and pulse length (150 MV/m for 70 ns) .



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

Covered by CTF3

R1: Feasibility

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

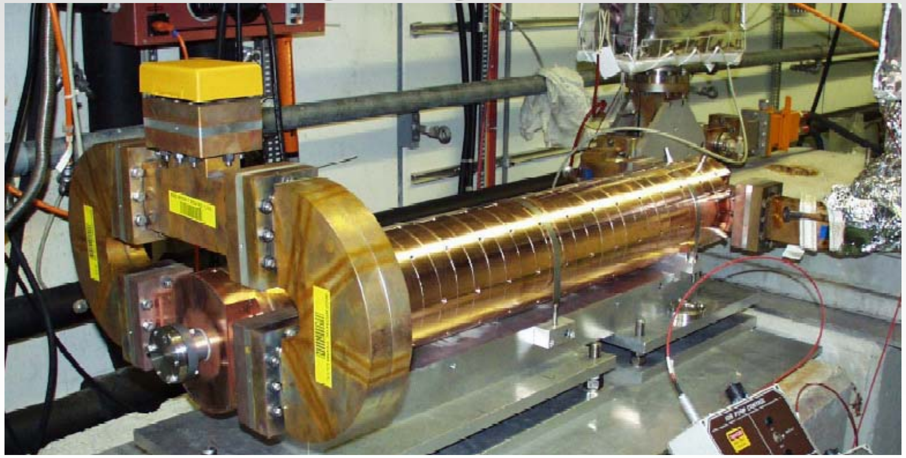
R2: Design finalization

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

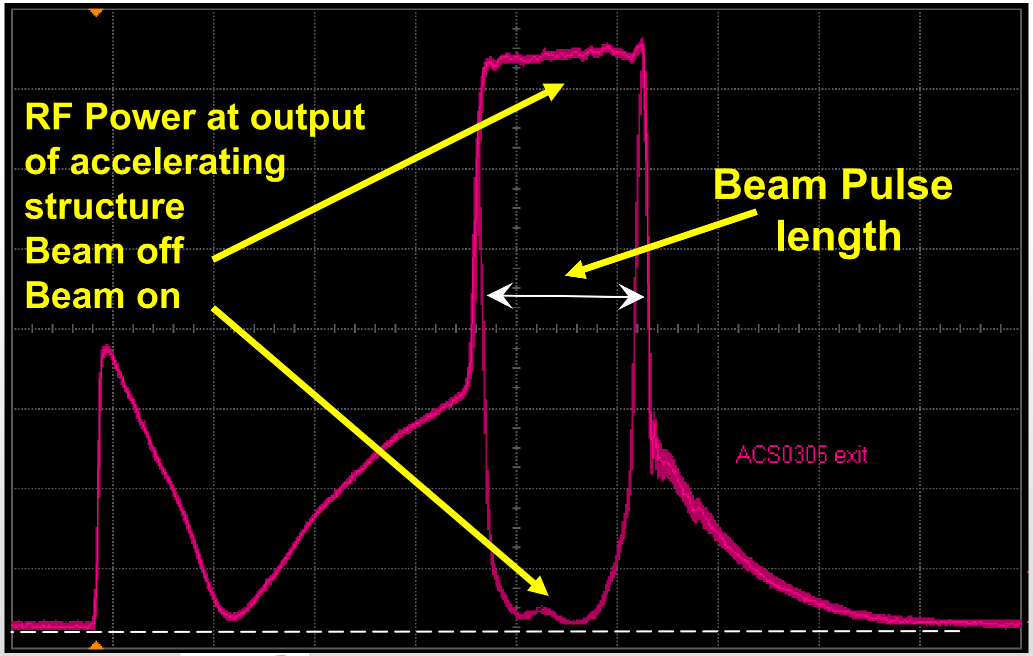
* Feasibility study done – need development by industry.
N.B.: Drive beam acc. structure parameters can be adapted to other klystron power levels

First “Full” Beam Loading operation in CTF3



2003

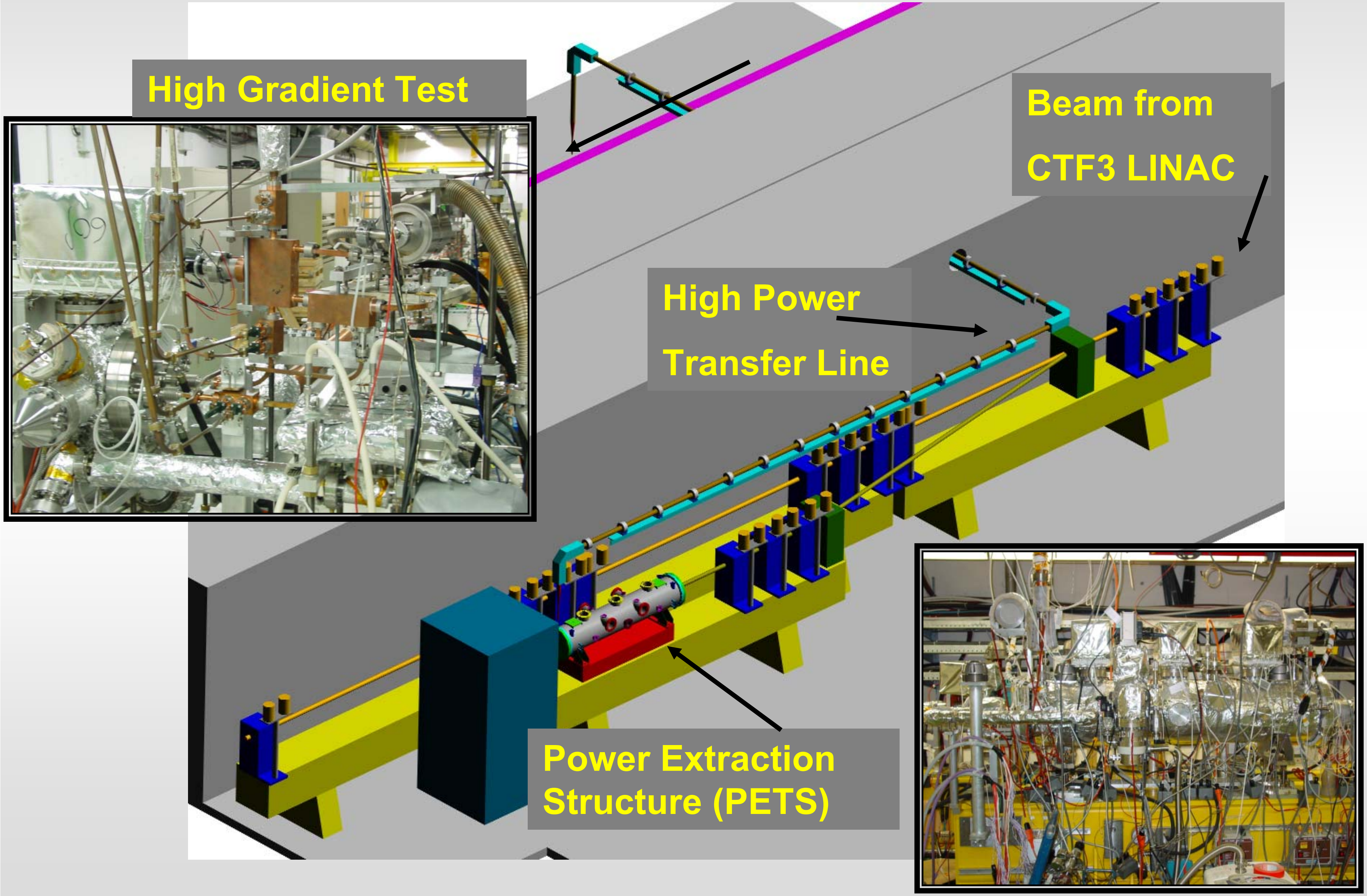
Dipole modes suppressed by slotted iris damping (first dipole’s Q factor < 20) and HOM frequency detuning



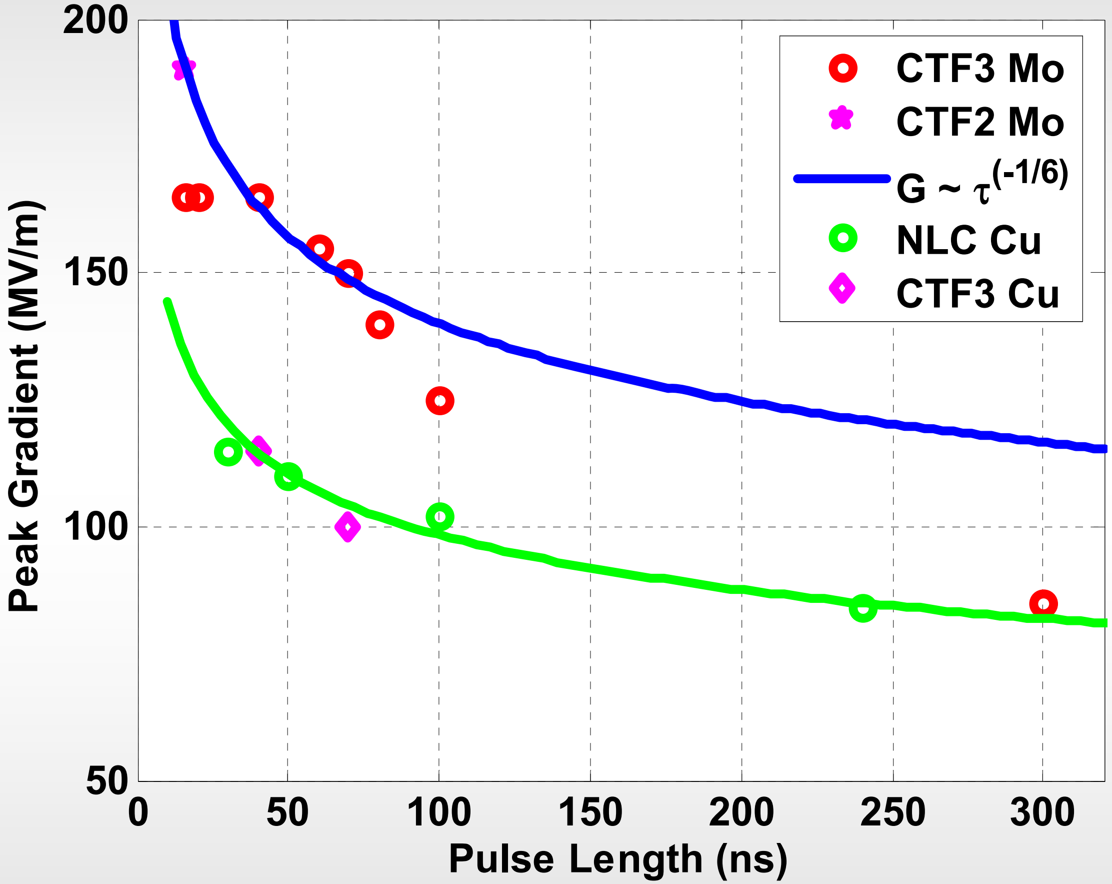
Beam current	4 A
Beam pulse length	1.5 μs
Power input/structure	35 MW
Ohmic losses (beam on)	1.6 MW
RF power to load (beam on)	0.4 MW

RF-to-beam efficiency ~ 94%

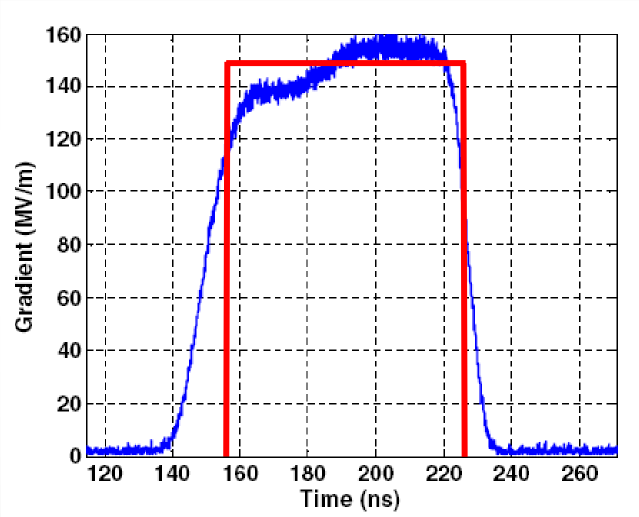
30 GHz Power Production in CTF3



Pulse Length Dependence

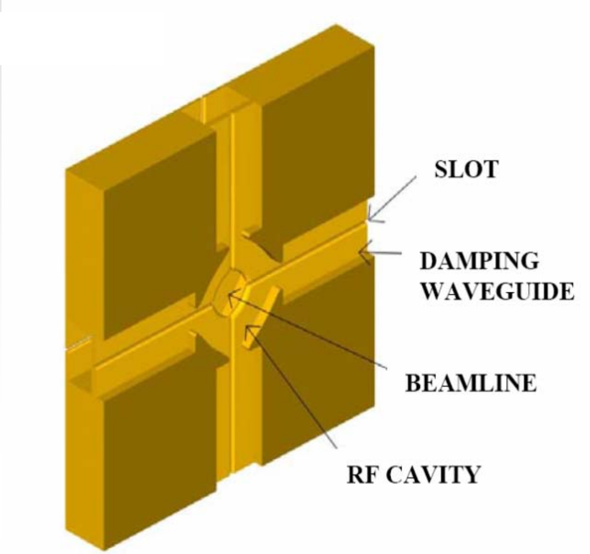


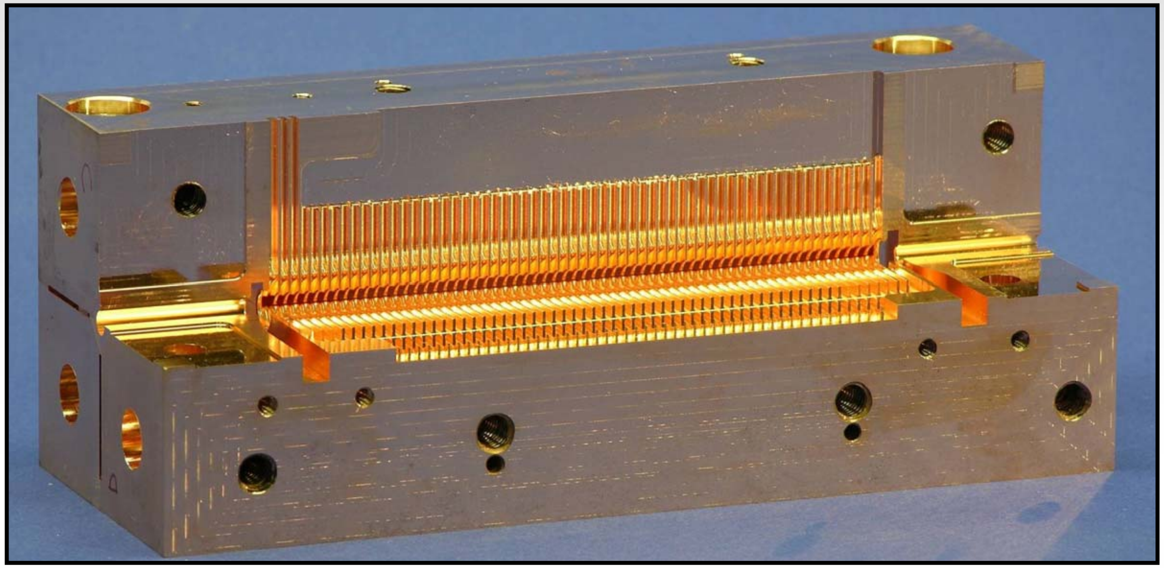
Reached nominal CLIC values:
150 MV/m 70 ns



Recent Results from CTF3

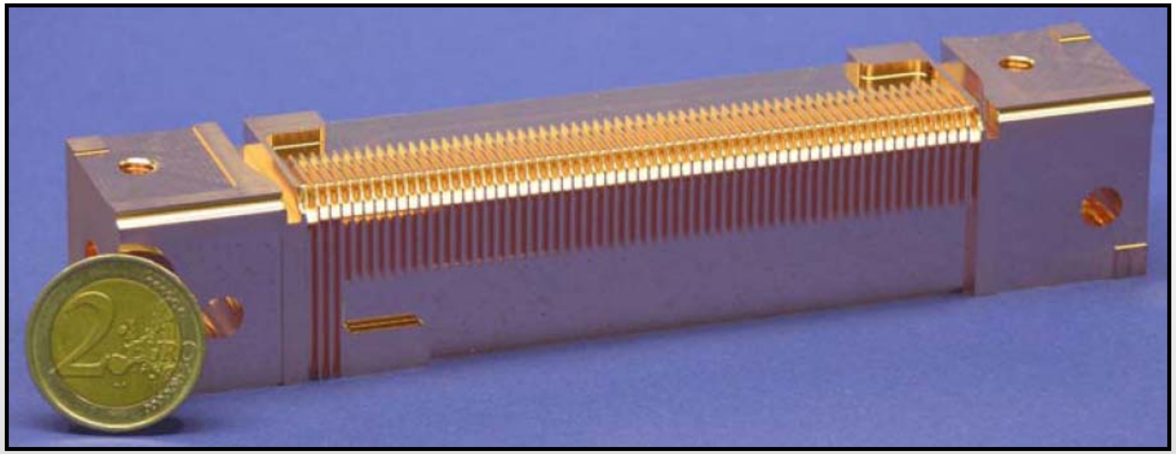
New Ideas from CLIC





30 GHz, 150 MV/m, 70 ns,
$< 10^{-6}$ trip probability

installed
for testing



30 GHz results so far

Power Production (642 MW, 70 ns):

280 MW (350 peak) for 16 ns (CTF II)

100 MW for 70 ns (CTF3)

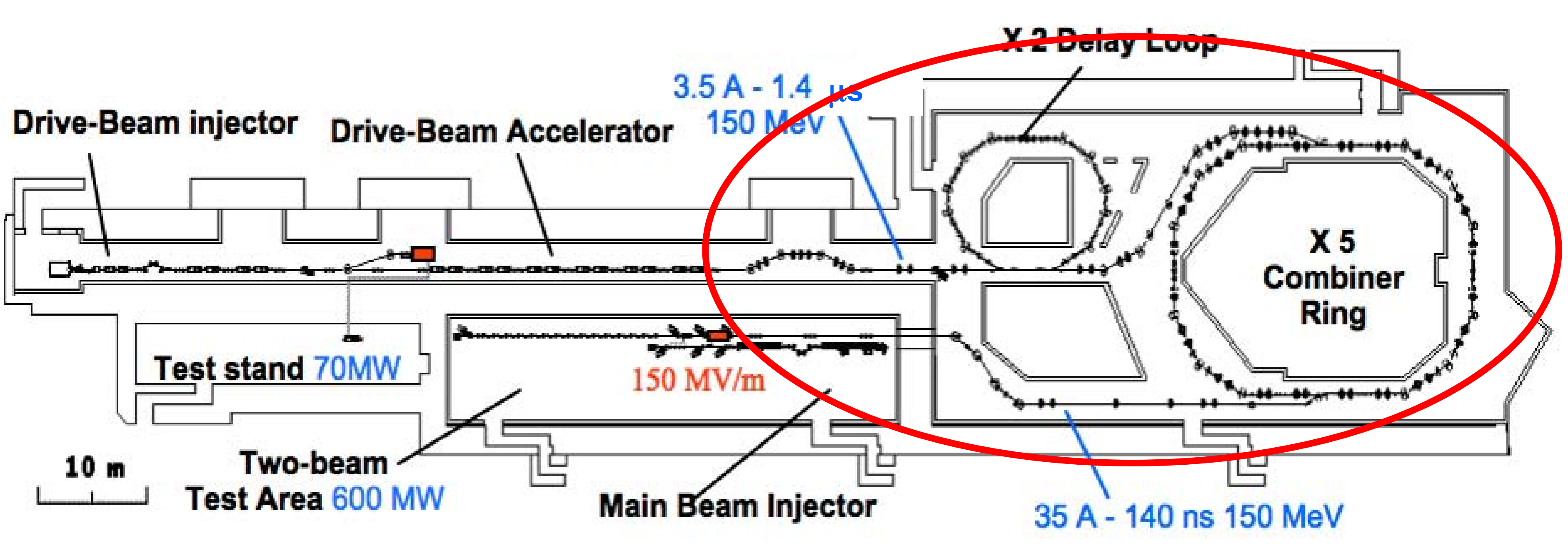
Accelerating structure (150 MV/m, 70 ns):

150 MV/m (193 peak) for 16 ns (CTF II)

150 MV/m peak for ~ 60 ns (CTF3, Dec 2005)
(but the breakdown rate is too high, surface erosion)

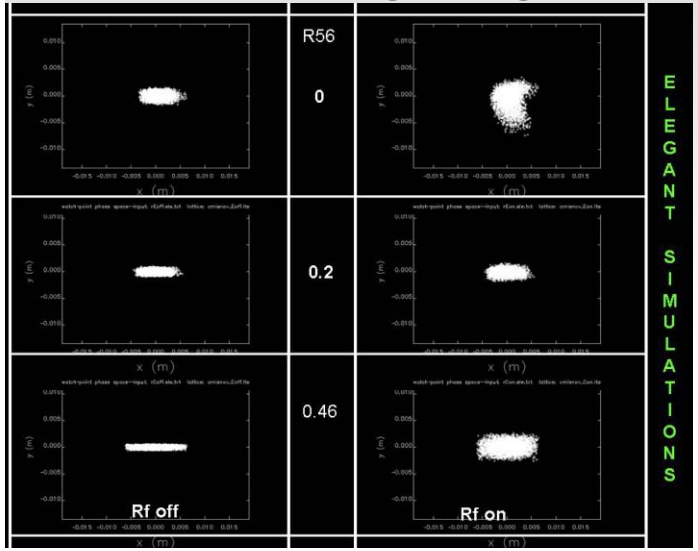
Two Beam acceleration demonstrated at low Power in CTFII

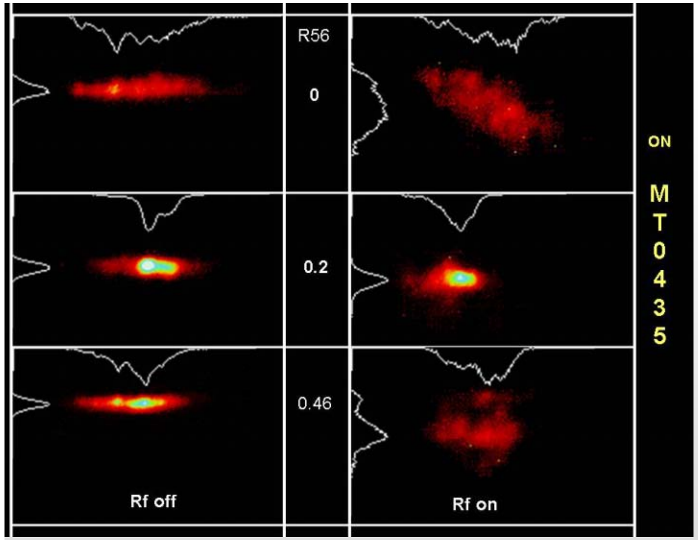
Beam recombination system

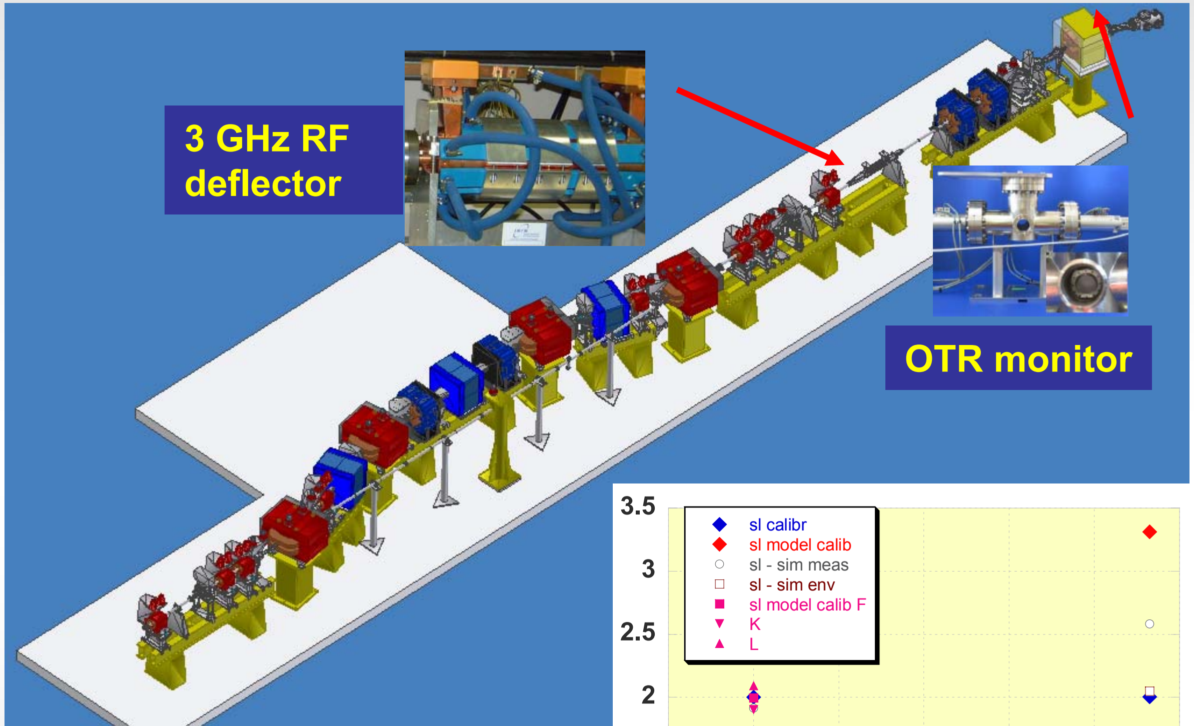


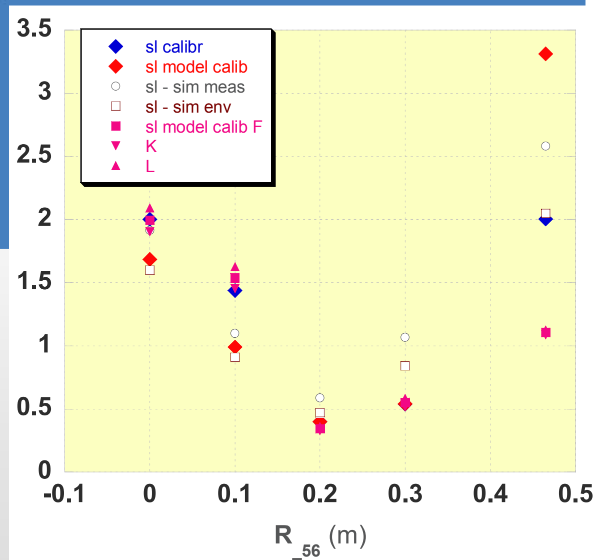
Magnetic chicane

Bunch length control







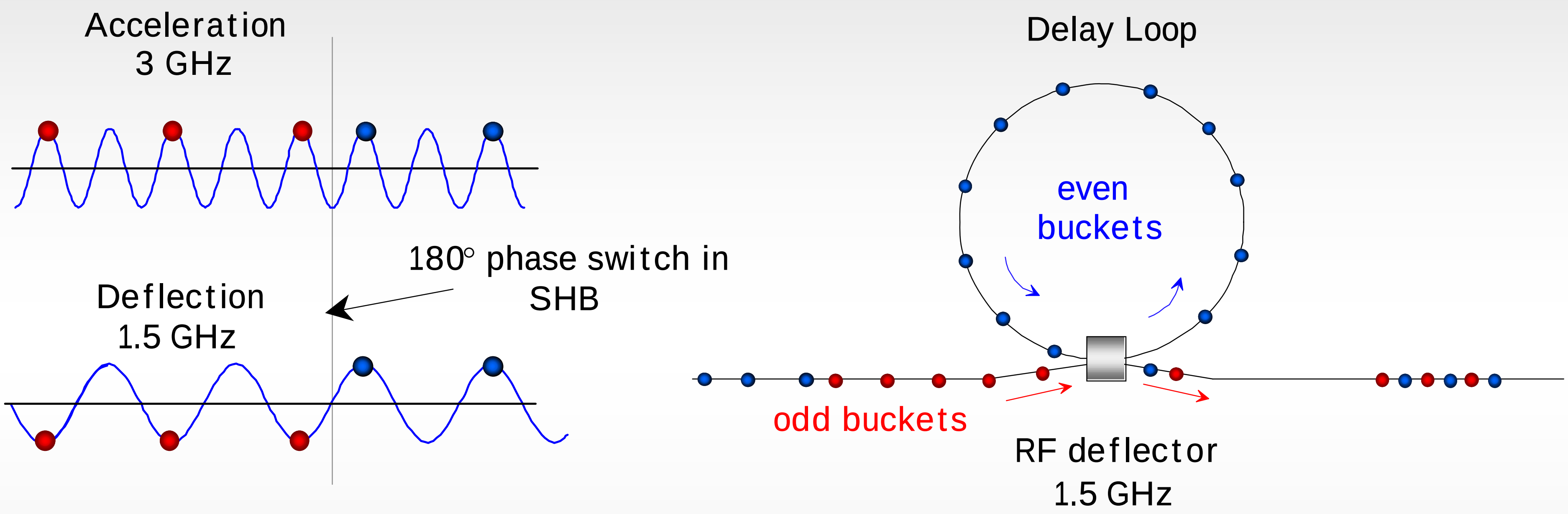


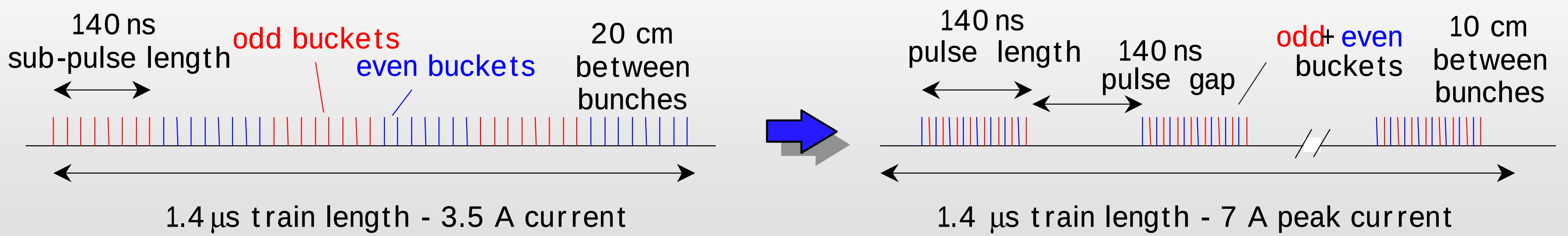
Bunch length pass from 1 to 10 mm changing R56 : ± 40 cm

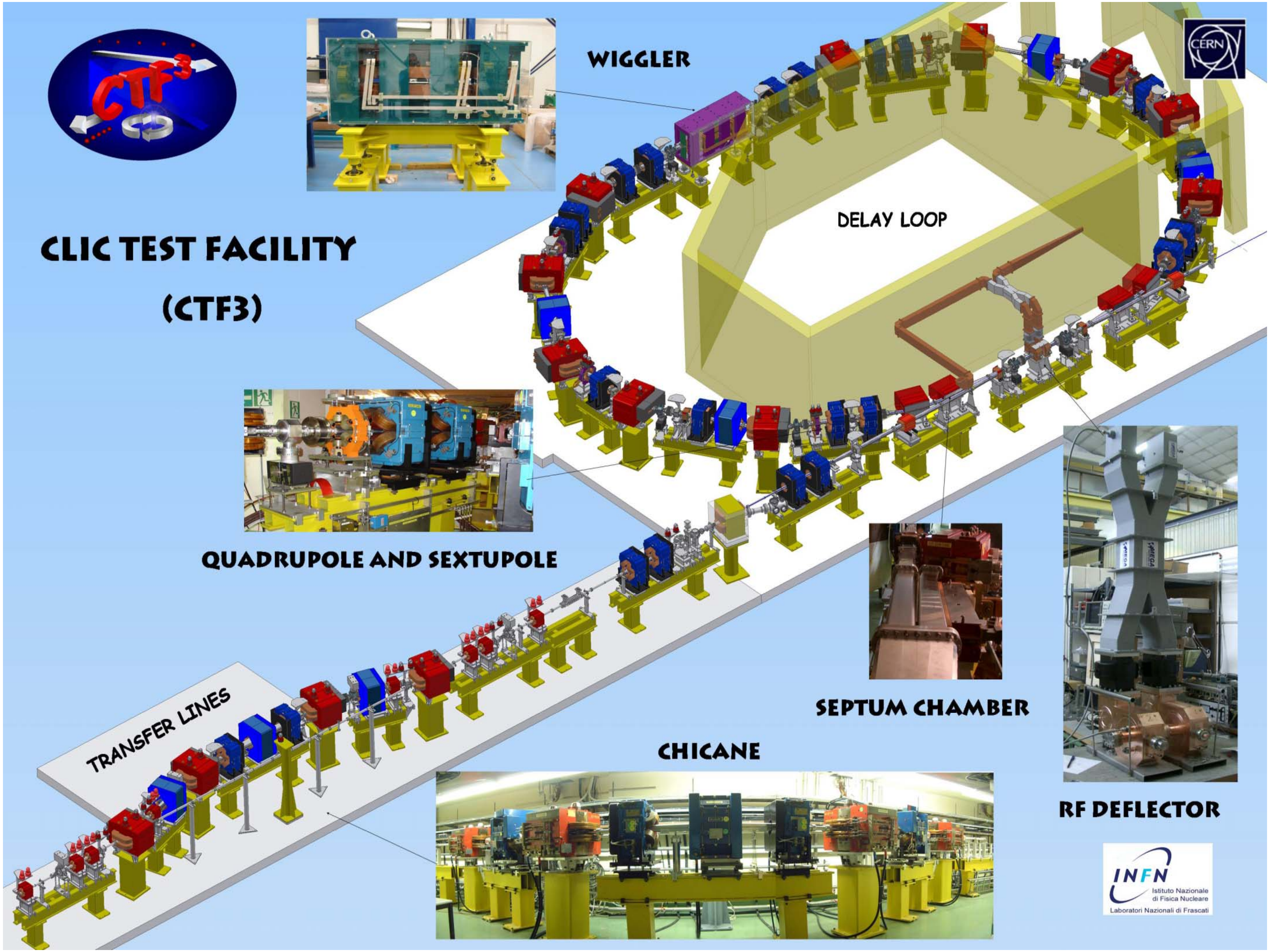
2004

Delay Loop

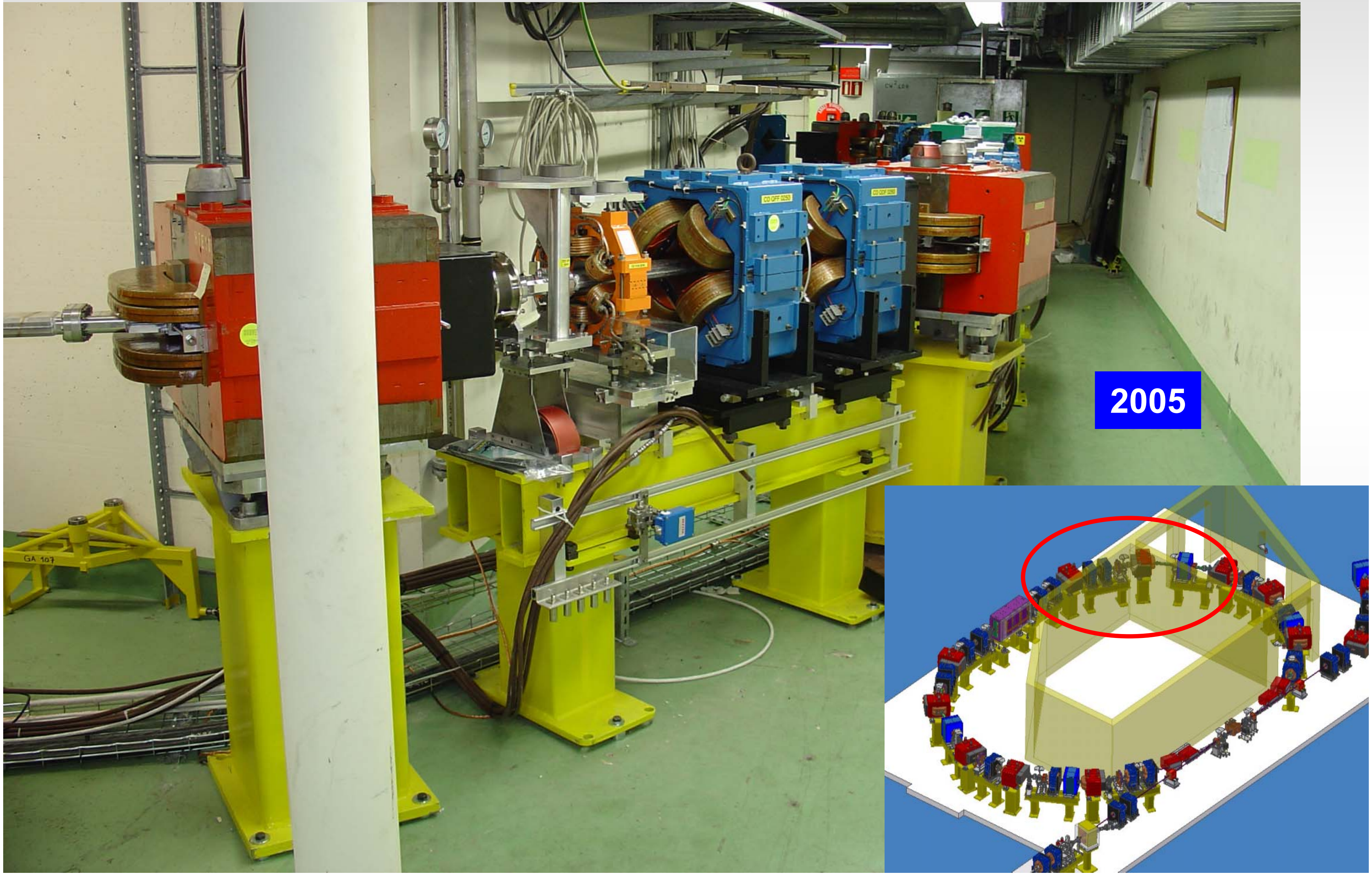
X2 Multiplication scheme



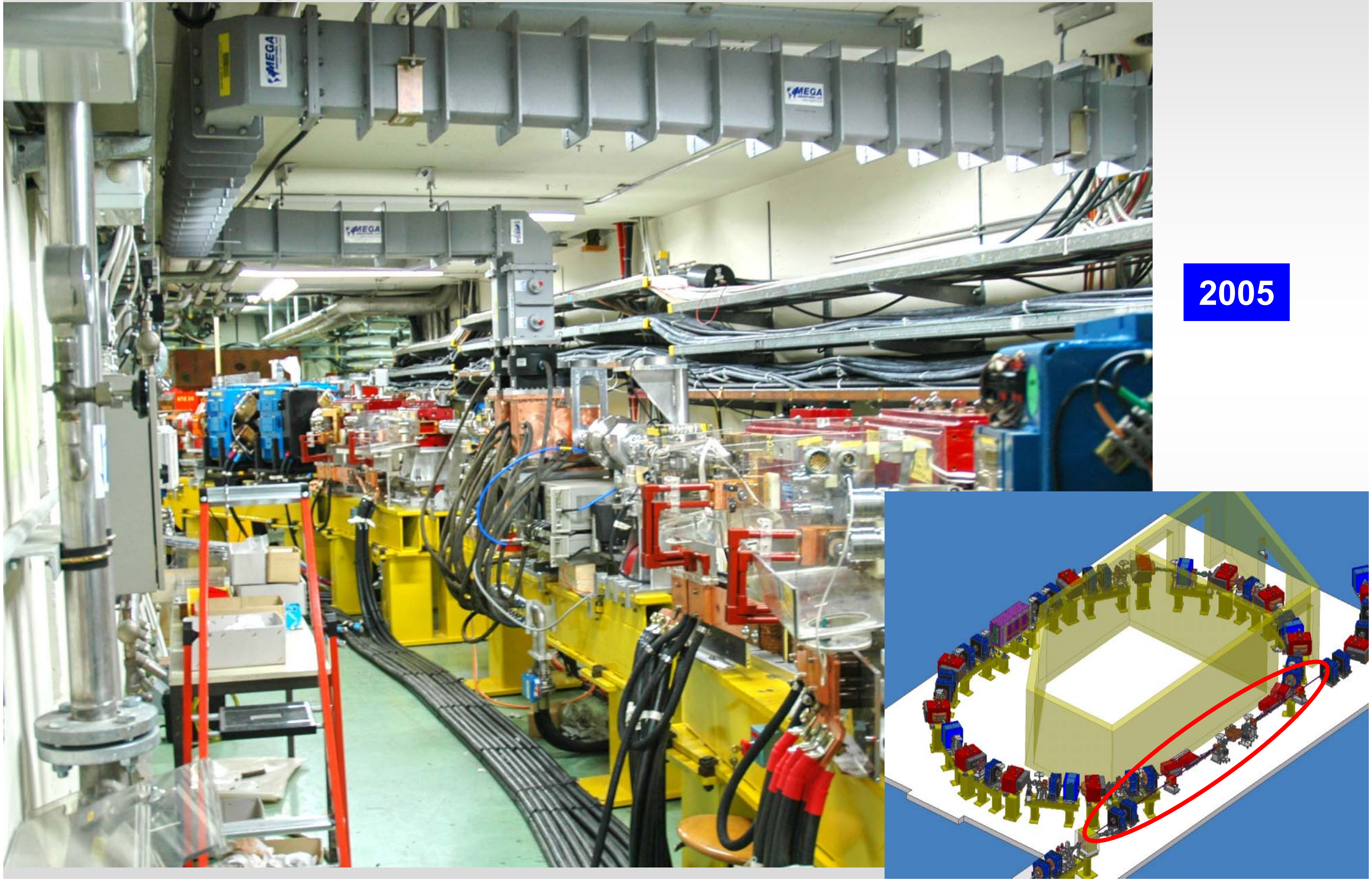



CTF3
WIGGLER
CERN
DELAY LOOP
CLIC TEST FACILITY
(CTF3)
QUADRUPOLE AND SEXTUPOLE
TRANSFER LINES
SEPTUM CHAMBER
CHICANE
RF DEFLECTOR
INFN
Istituto Nazionale
di Fisica Nucleare
Laboratori Nazionali di Frascati

Delay Loop arc

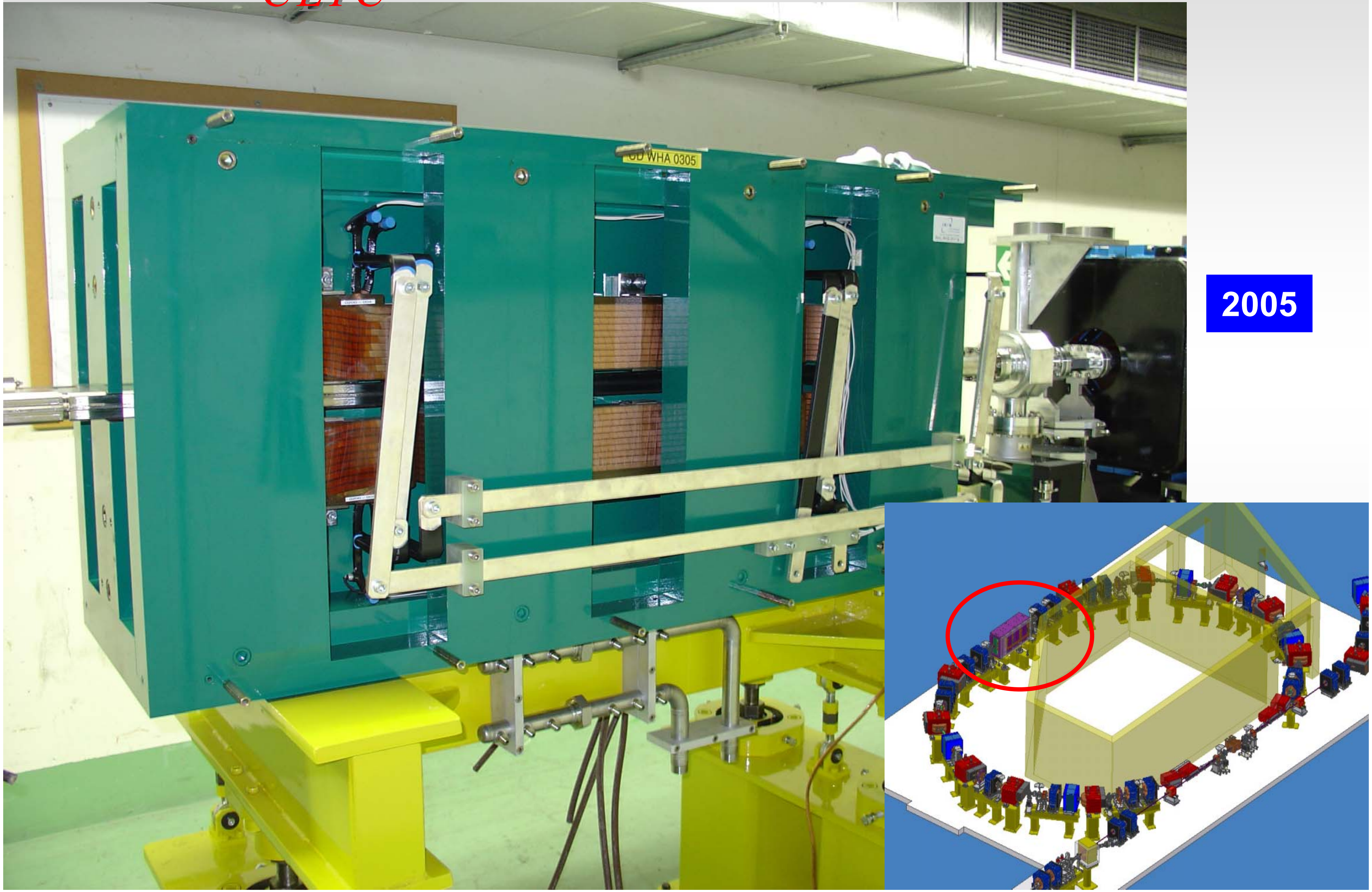


Delay Loop injection/extraction



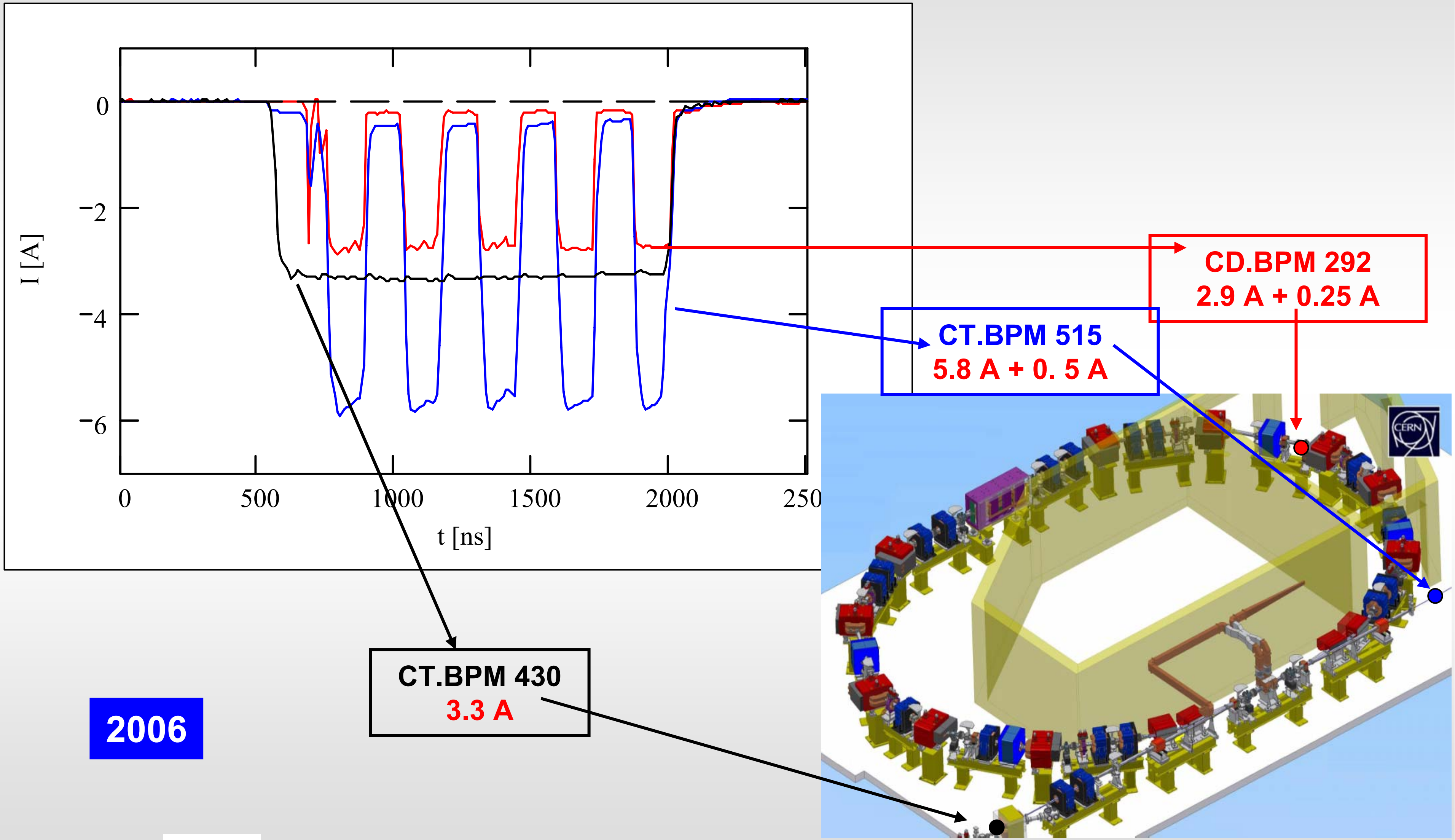
2005

Path length tuning wiggler



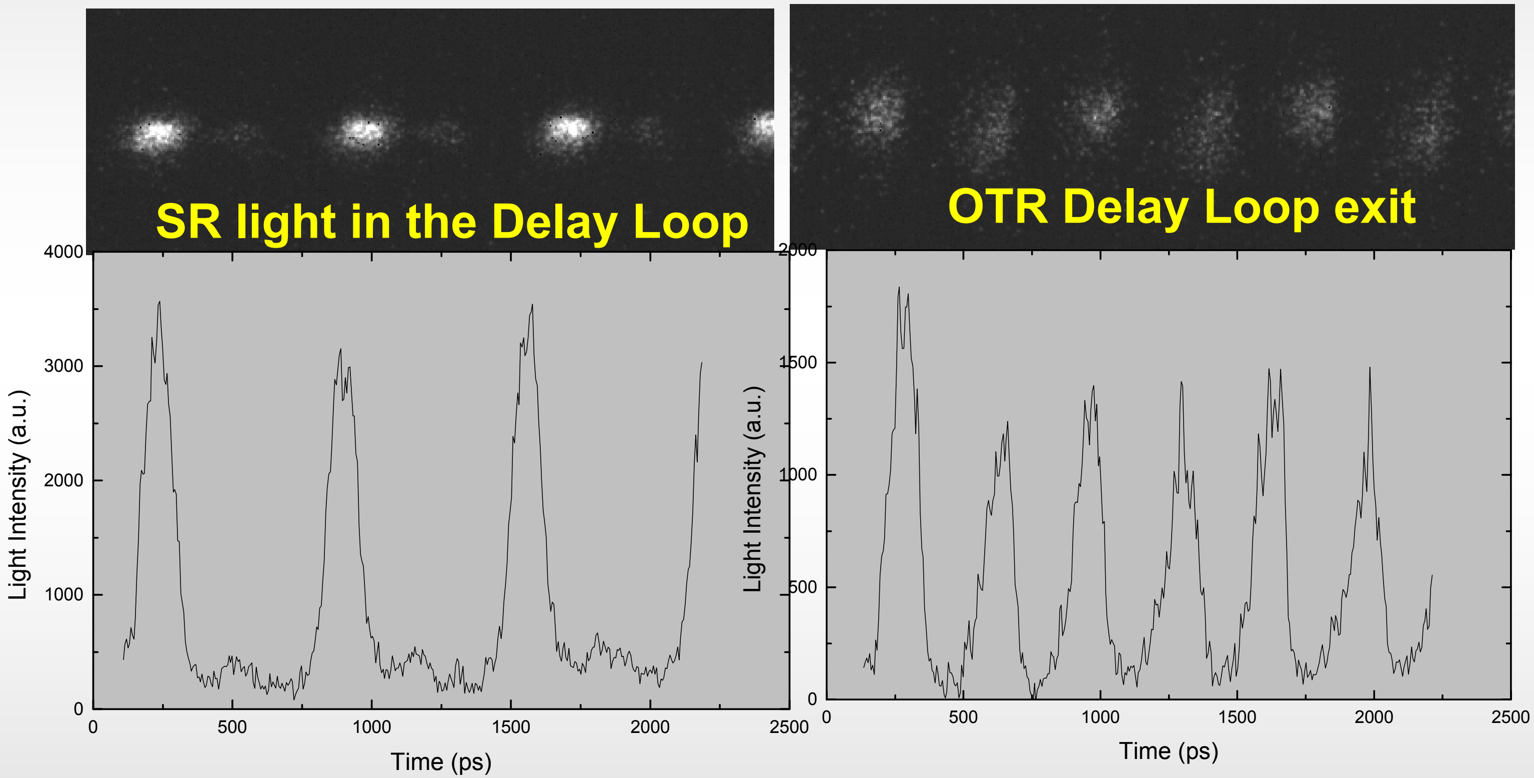
2005

Five pulse recombination



2006

RF combination : 11th May 2006



Stability studies

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

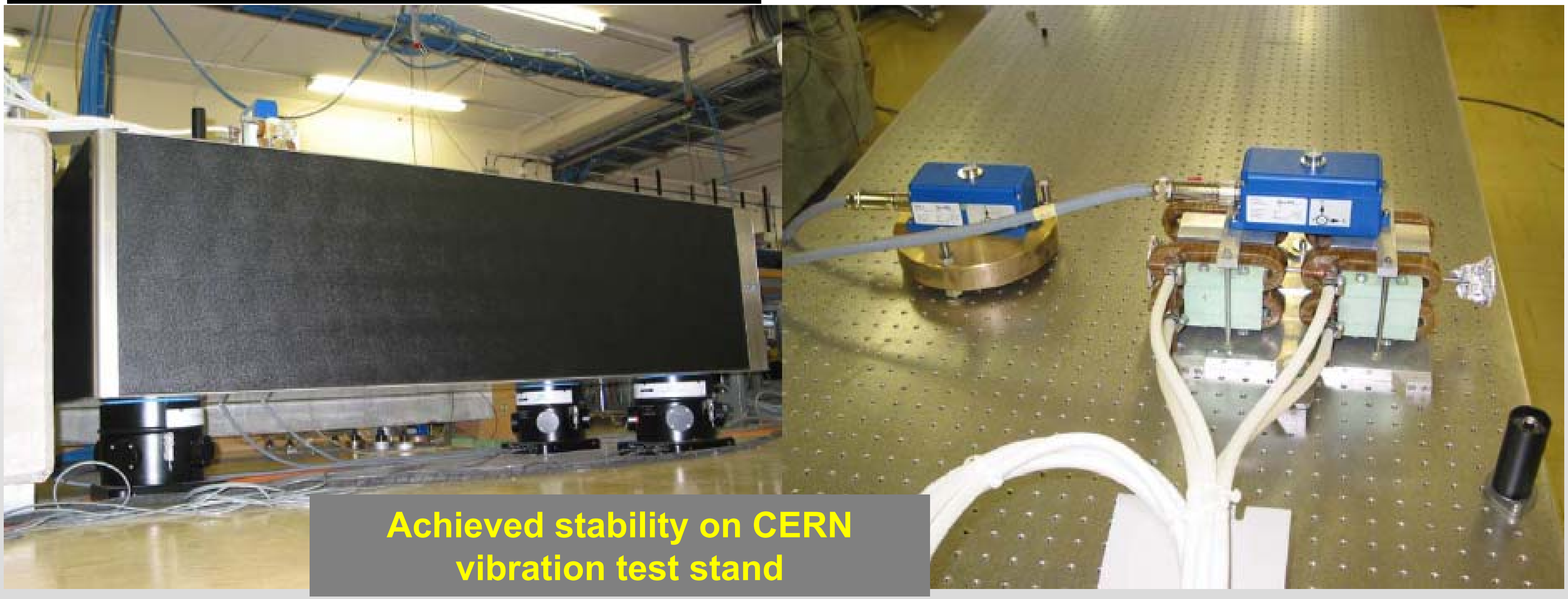
**Stability requirements (> 4 Hz)
for a 2% loss in luminosity**

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

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

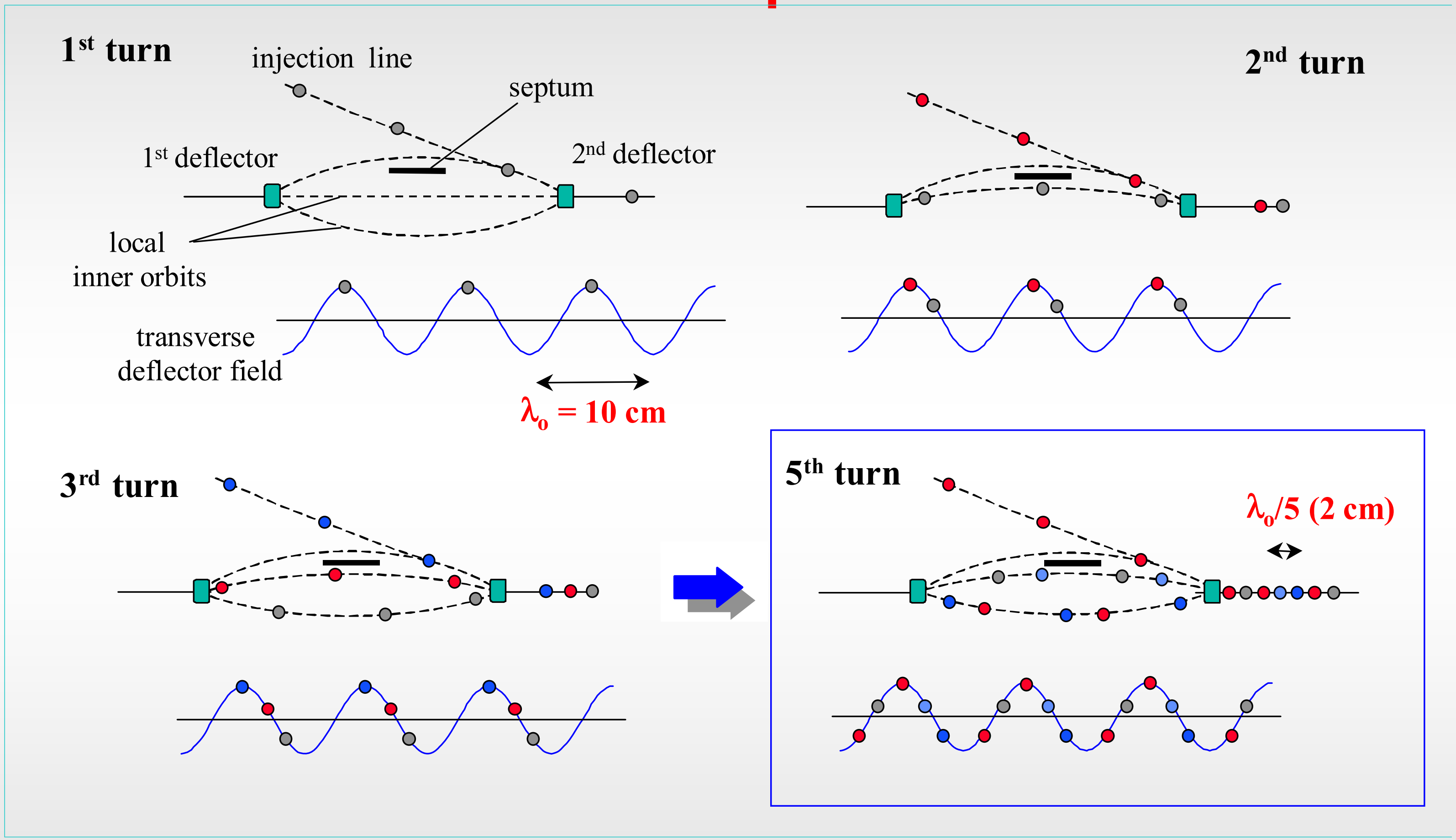
Horiz. 0.4 ± 0.1 nm

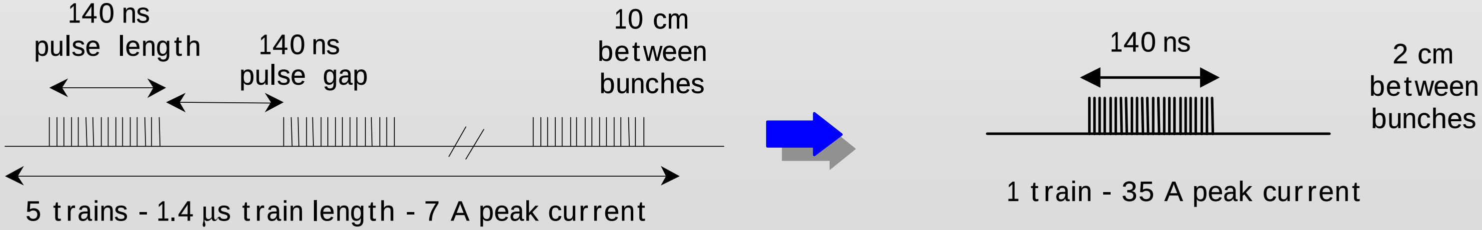


Achieved stability on CERN vibration test stand

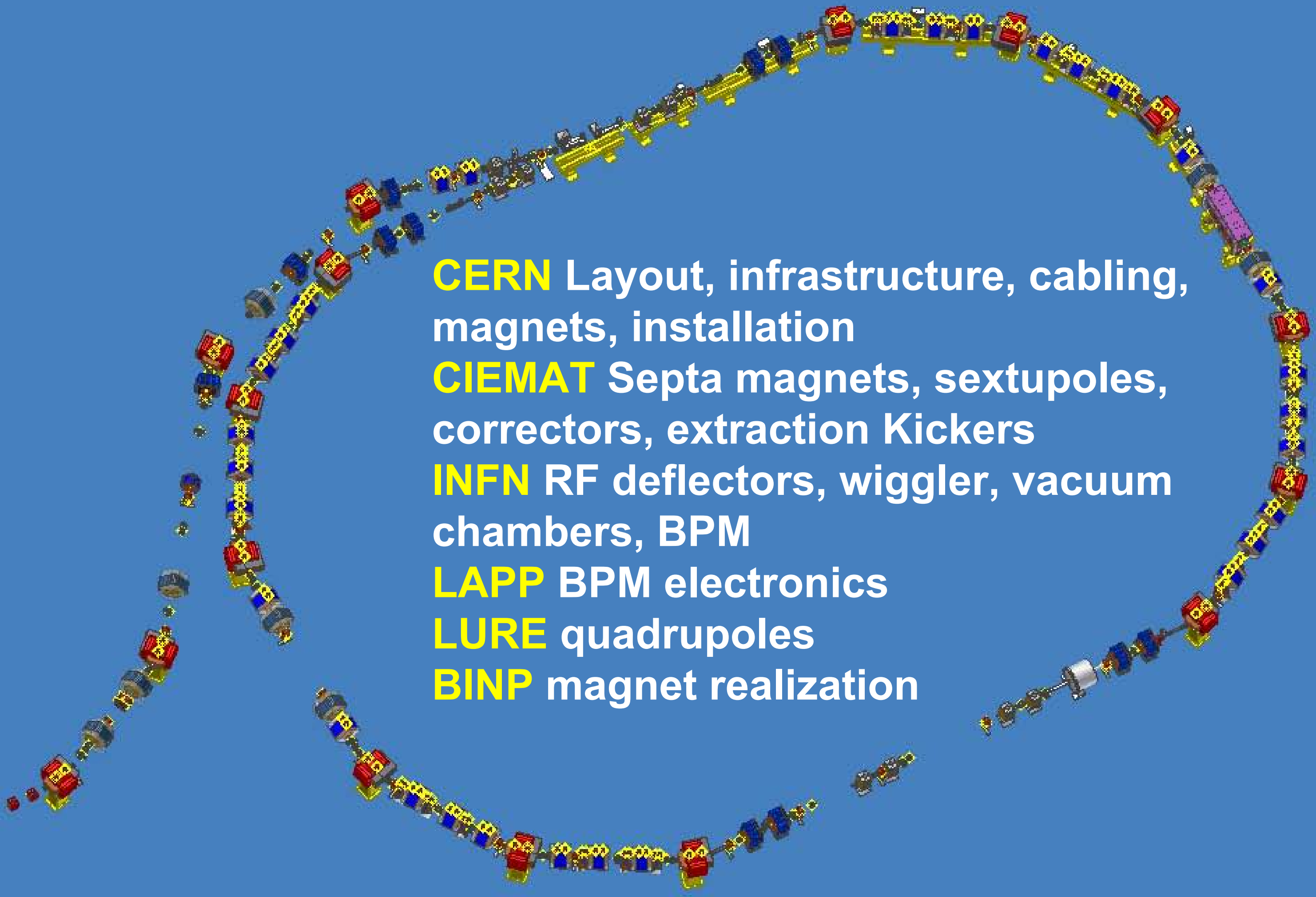
Combiner Ring

X5 Multiplication scheme





Combiner Ring



CERN Layout, infrastructure, cabling, magnets, installation
CIEMAT Septa magnets, sextupoles, correctors, extraction Kickers
INFN RF deflectors, wiggler, vacuum chambers, BPM
LAPP BPM electronics
LURE quadrupoles
BINP magnet realization

CLIC Experimental Area

The Photo-Injector drive beam

e^- source for CTF3

CERN

Photocathodes

+

Timing

RF power

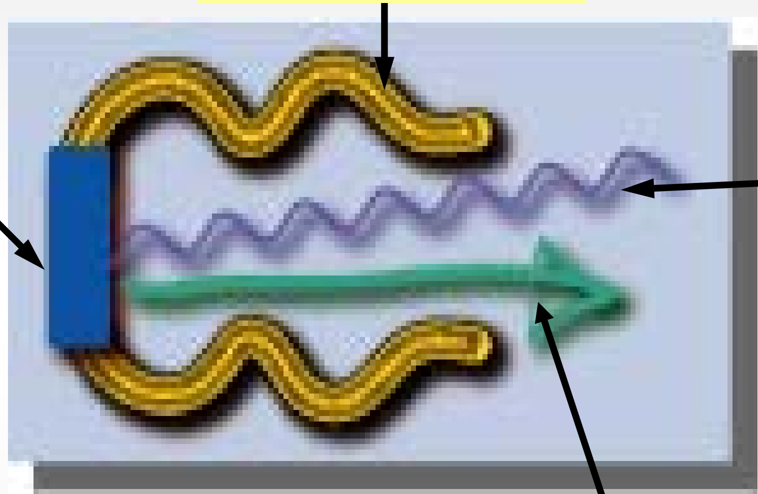
Laser beam transport

Installation

Monitoring …

LAL (F)

3 GHz RF gun



RAL (GB)

High power

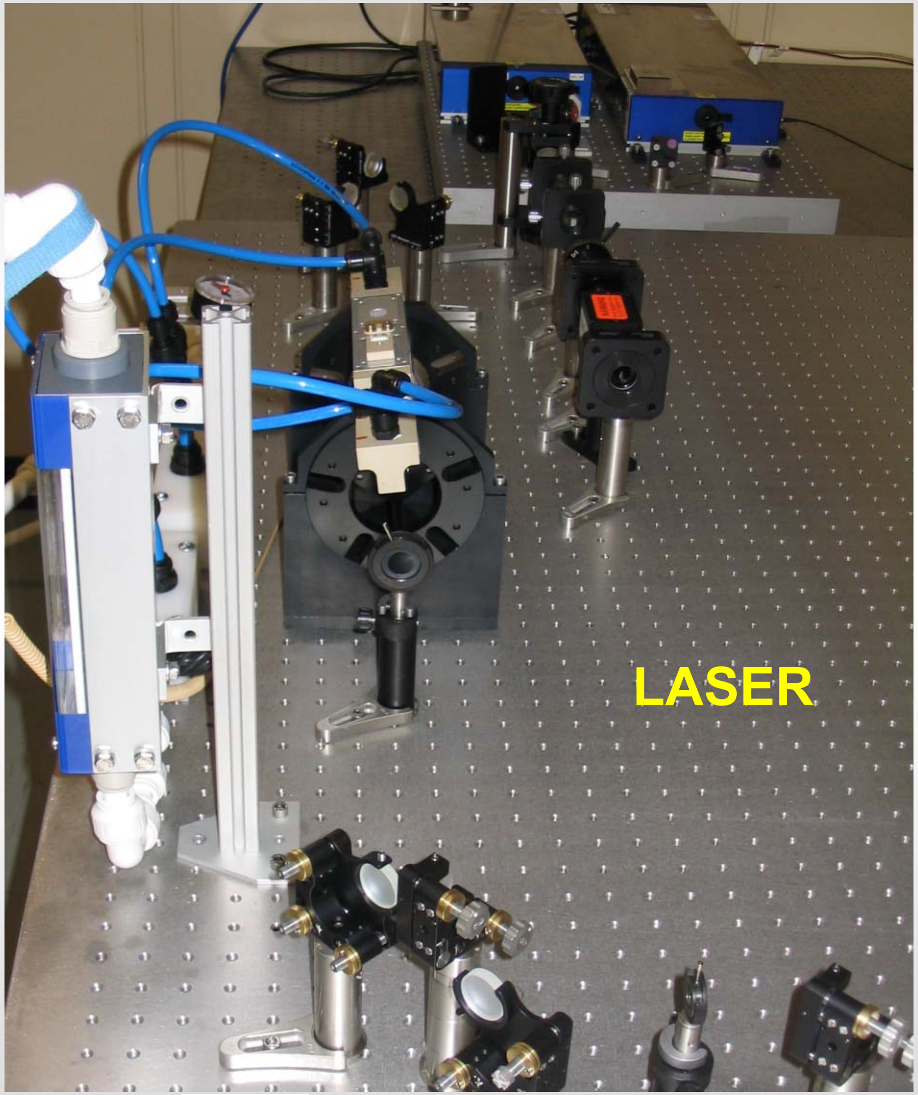
Laser

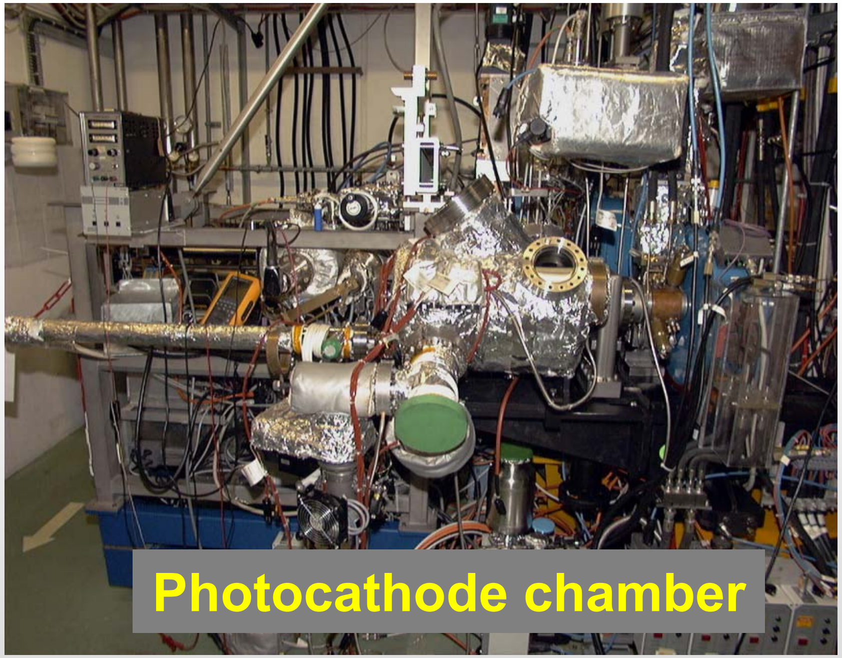
2332 e^- pulses distant from 667 ps ; s = 4 ps ; Q_{pulse} = 2.33 nC

2004 - 2006 : construction and installation of the photo-injector included in the European program CARE (FP6)

E.U. funding: 90 % of the request » 2 MCHF

Photoinjector components





CLIC

CLIC Study Group presents more than 30 posters and talks at this conference

Thanks to EPAC06 Committee for inviting me to talk about this exciting project.

Thanks to all CLIC study group colleagues for all the information that I reported in this talk.

Thanks to all of you for the attention