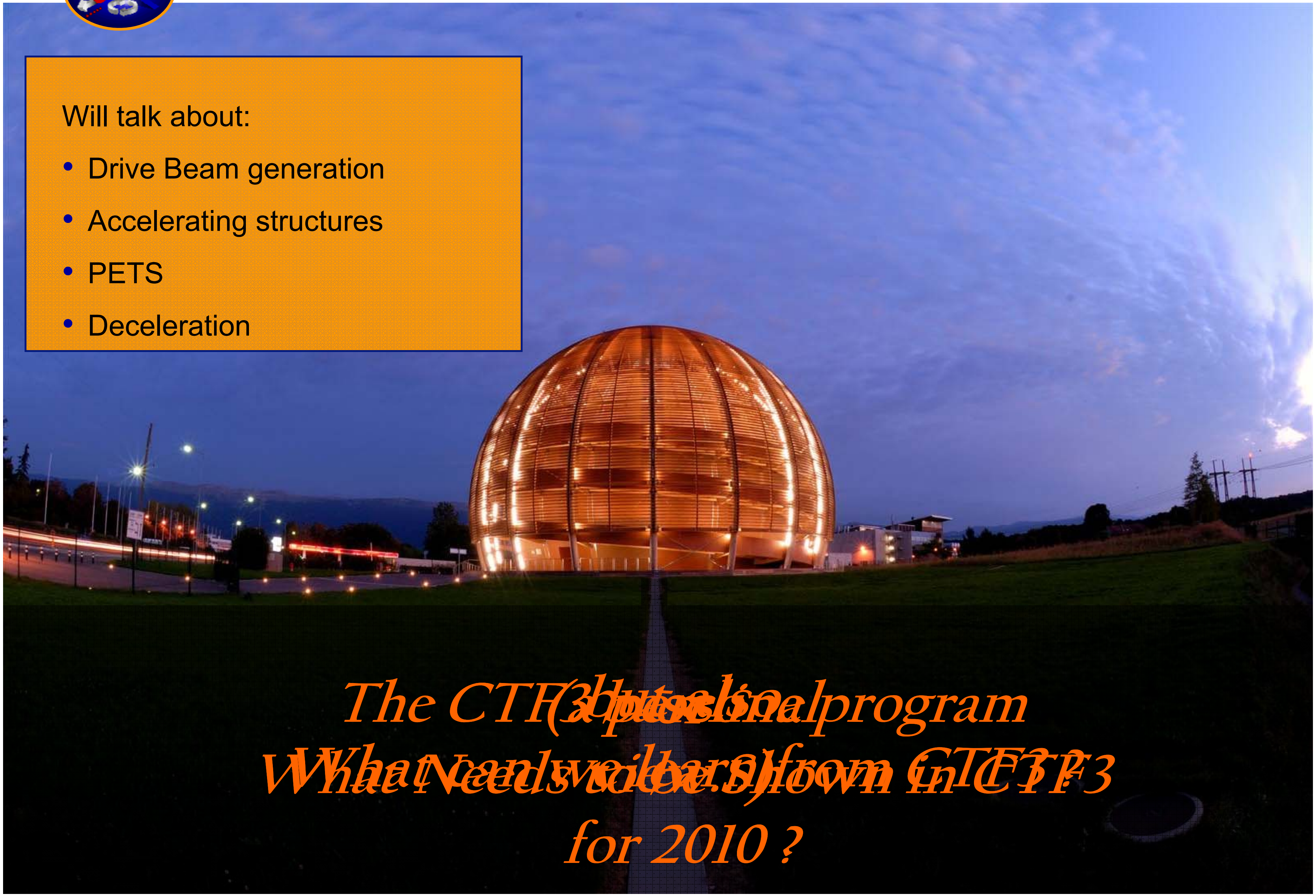
CTF3 Collaboration Meeting 2008

R. Corsini - CERN



Will talk about:

- Drive Beam generation
- Accelerating structures
- PETS
- Deceleration

The CTF3 experimental program

What can we learn from CTF3?

What Needs to be Shown in CTF3 for 2010 ?

Motivation and goals of CTF3 collaboration

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 RF power to **test the CLIC accelerating structures and components**

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

Covered by CTF3

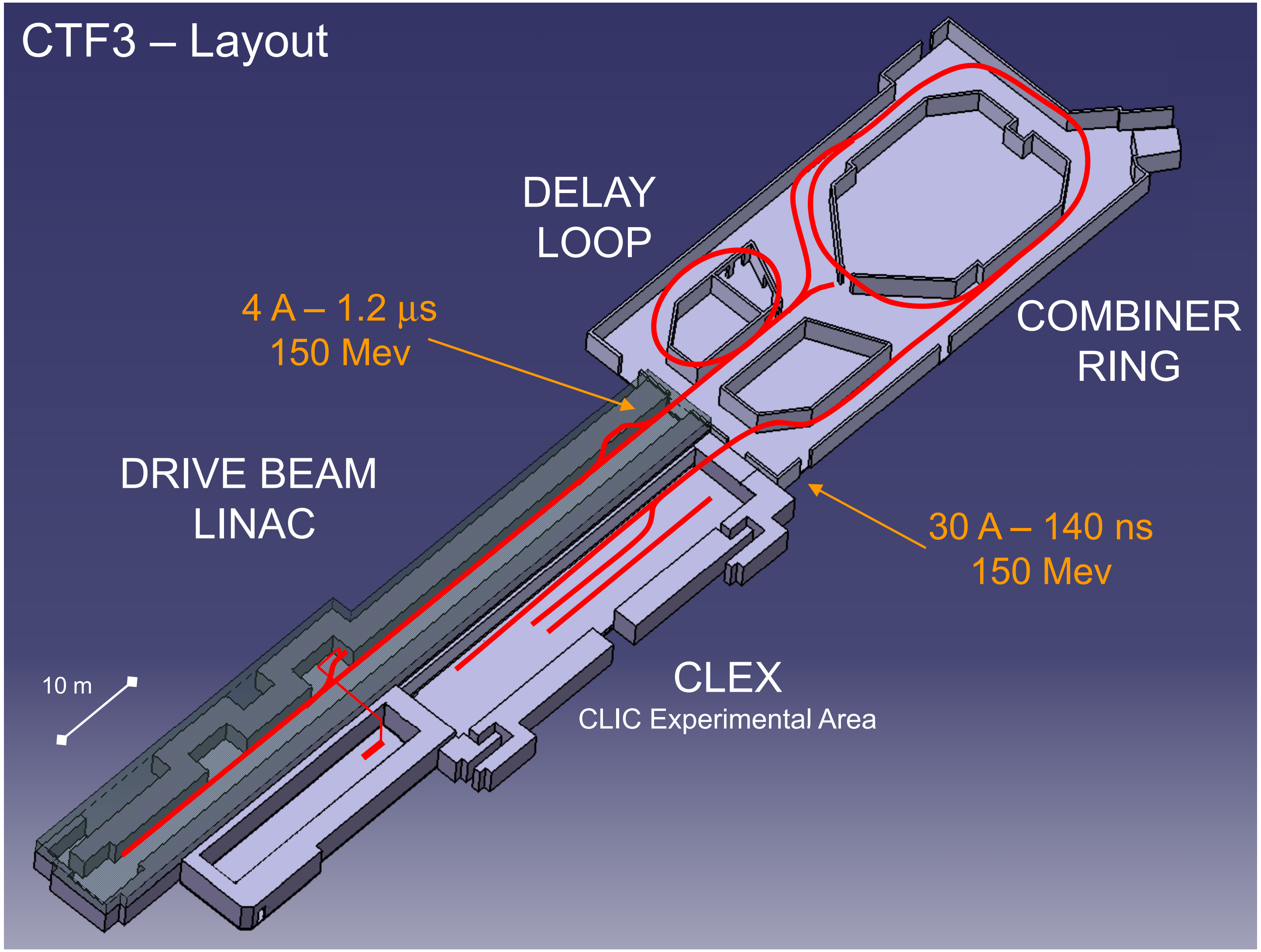
R1: Feasibility

- 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.

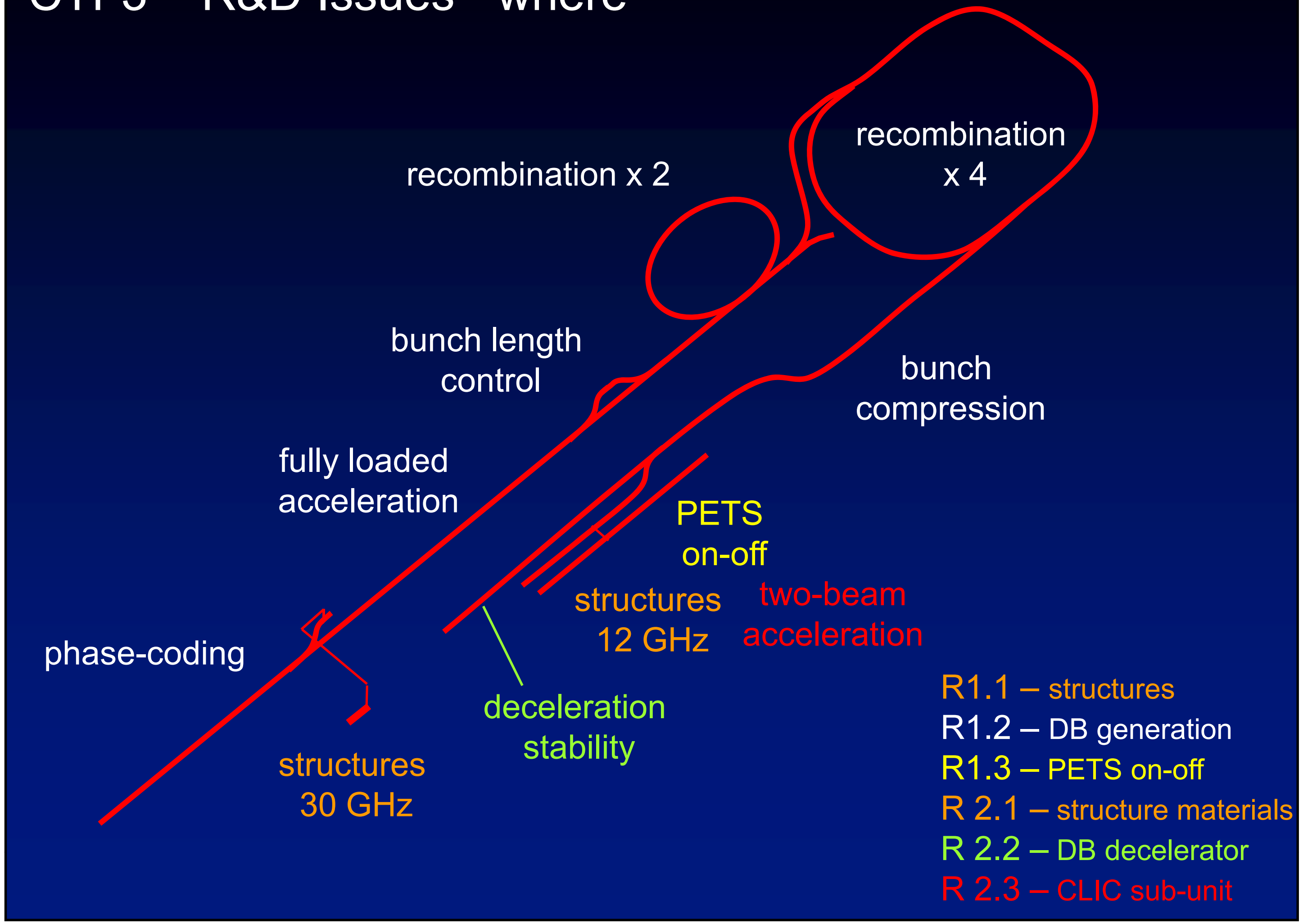
The CTF3 baseline program



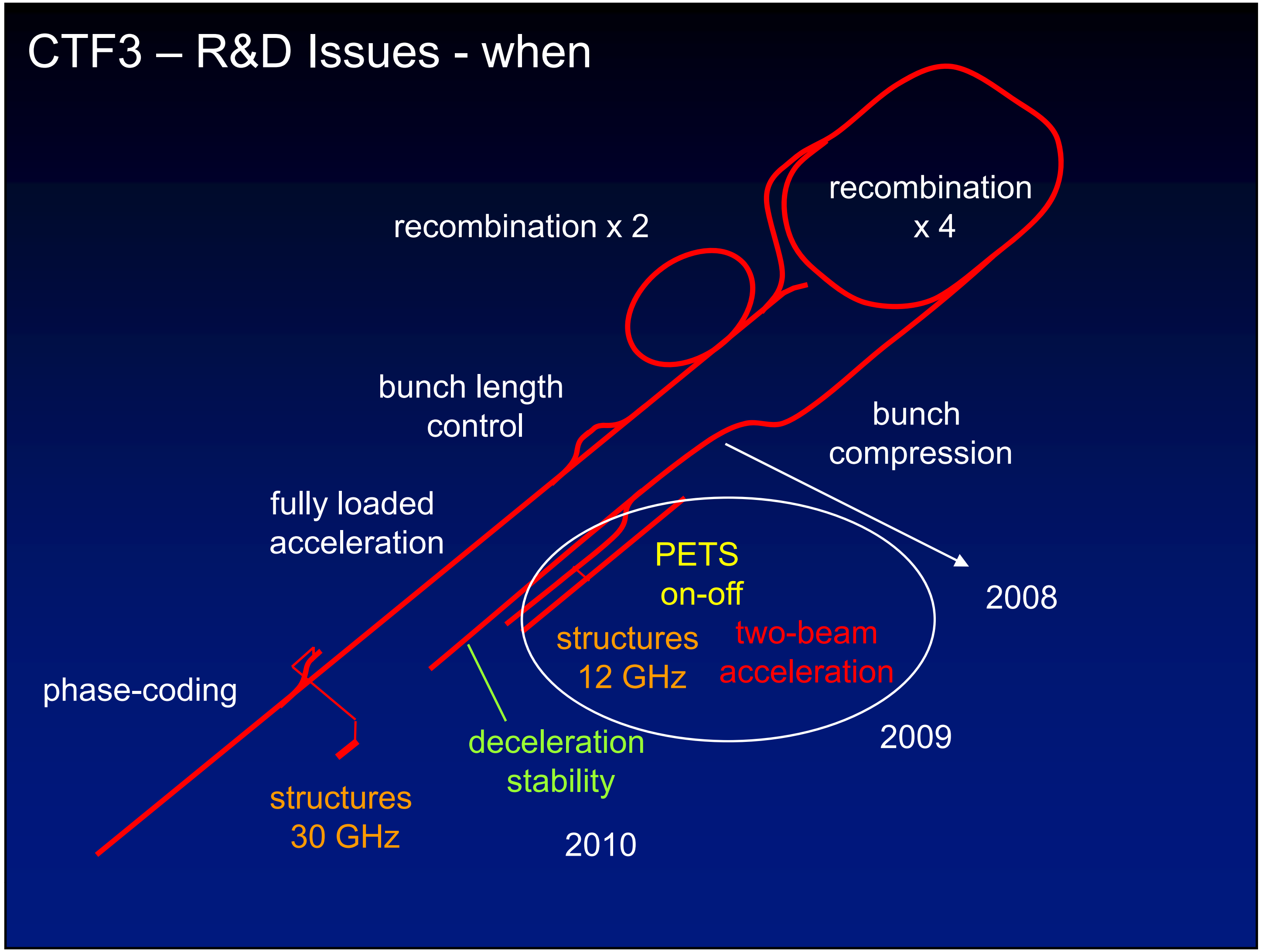
The CTF3 baseline program

R. Corsini, 23/01/08

CTF3 – R&D Issues - where



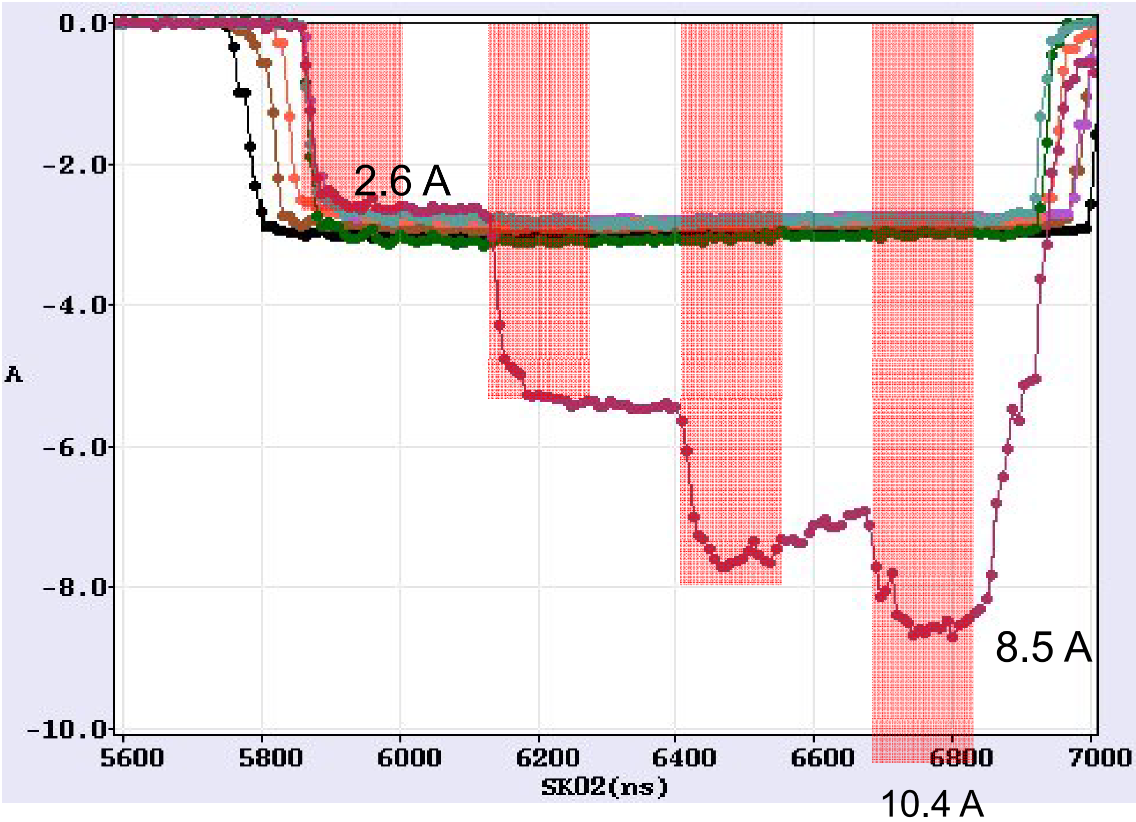
The CTF3 baseline program



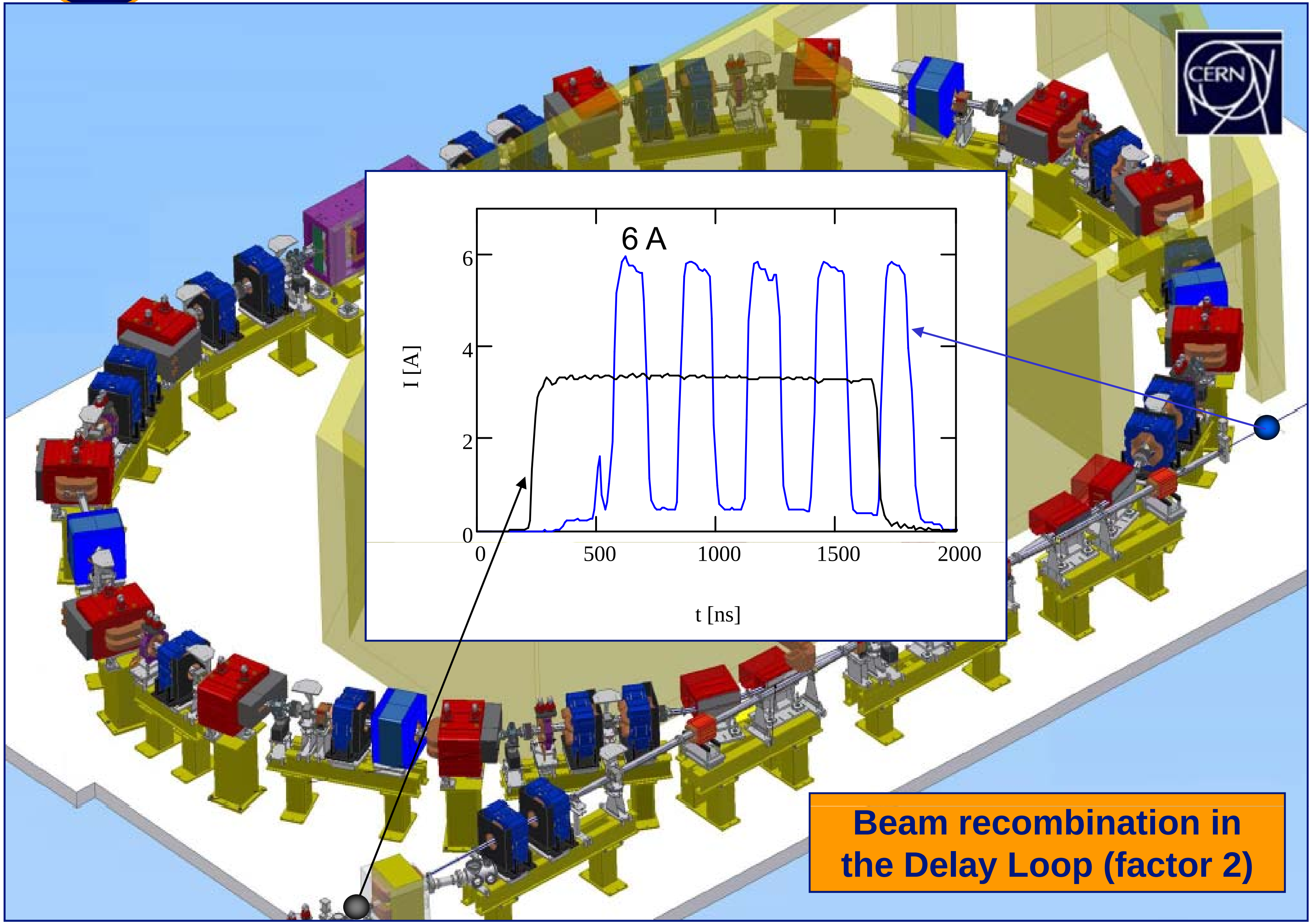
Drive beam generation

Achieved recombination:

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

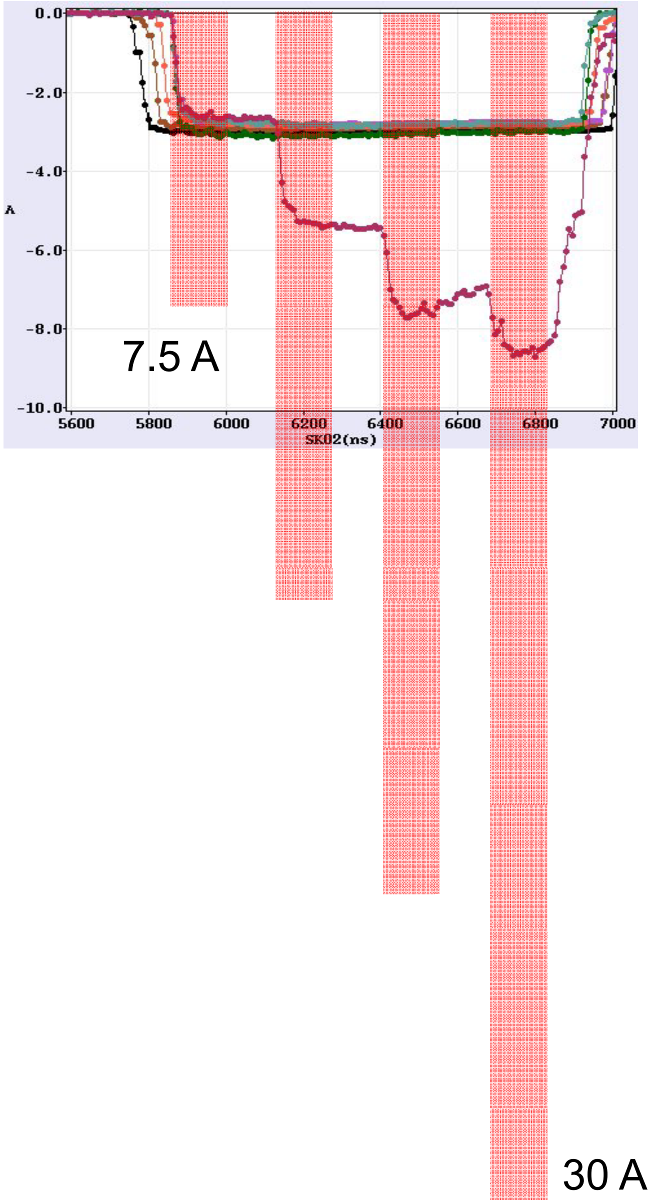


The CTF3 baseline program



Beam recombination in the Delay Loop (factor 2)

The CTF3 baseline program



current !

What is missing ?

But also…

What is missing ?

ISSUE	GOAL
• Emittance conservation	final ε_N < 150 π mm mrad
• Longitudinal beam dynamics	final bunch length < 1 mm rms
• Phase & current stability along the pulse	Flat-top in produced RF power < 1 % ?
• Pulse-to-pulse fluctuations	below 1 % ?
• Losses control	Overall losses (from girder 4) < 10 % ?
• Satellites	RF gun option, or scheme to eliminate satellites at low energy in CLIC
• Others…	

What has been shown already ?

Isochronicity…

ISOCHRONOUS OPTICS AND RELATED MEASUREMENTS IN EPA

R. Corsini, J.P. Potier, L. Rinolfi, T. Risselada, CERN, Geneva, Switzerland

CERN/PS 2000-033 (AE)
CLIC-Note 440

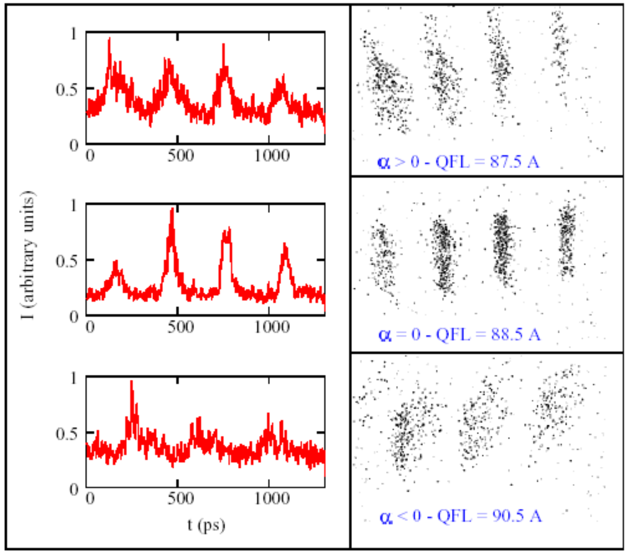


Figure 6: Streak camera images and time profiles for different settings of the QFL quadrupole family.

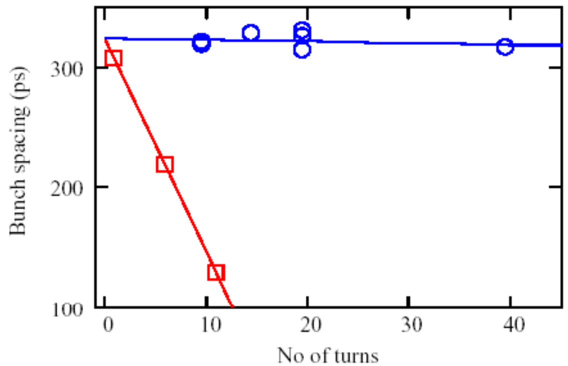
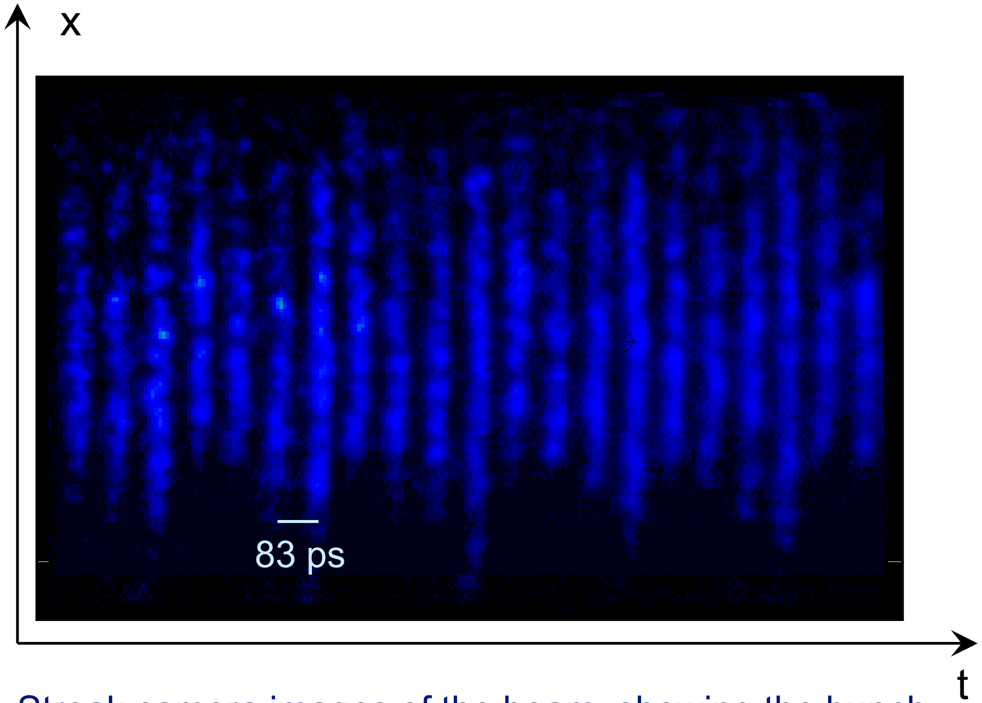


Figure 7: Bunch-to-bunch spacing as a function of the number of turns for the normal (squares) and the isochronous optics (circles).

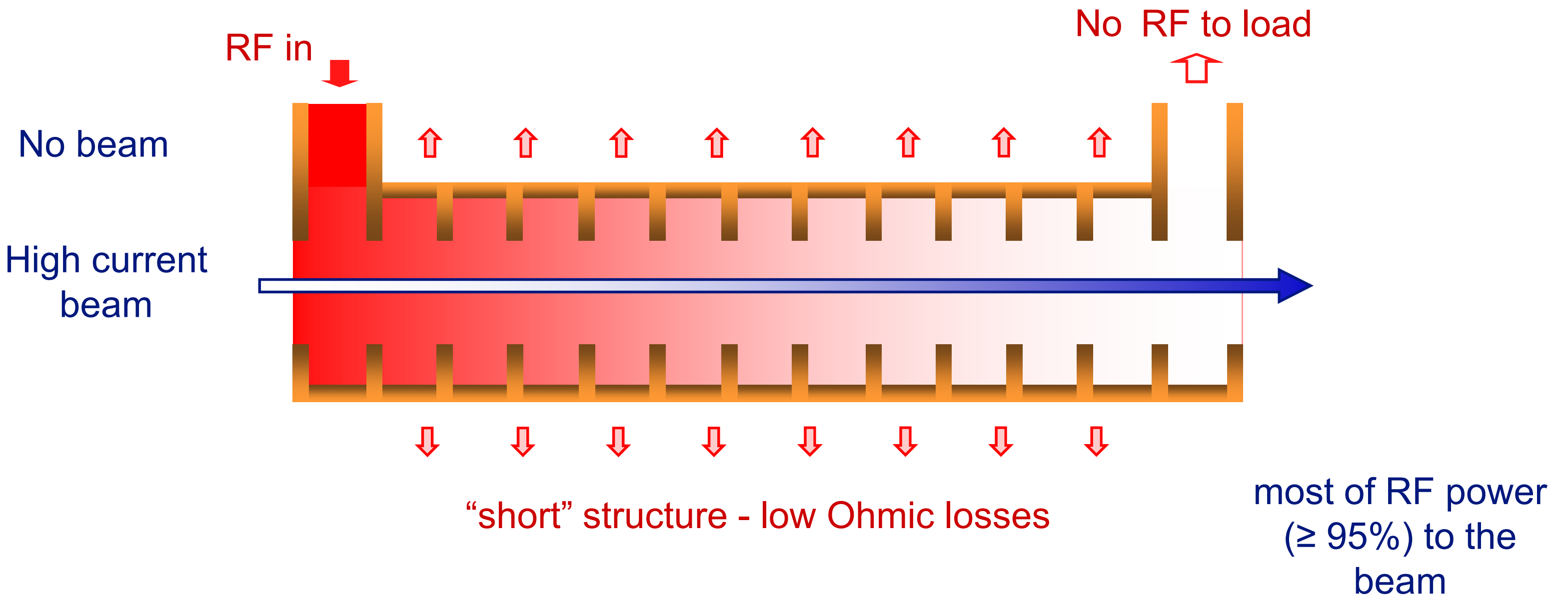
…Not 2nd order, but less important at 12 GHz, 1 mm σ_Z

Bunch combination at low charge (including phasing)

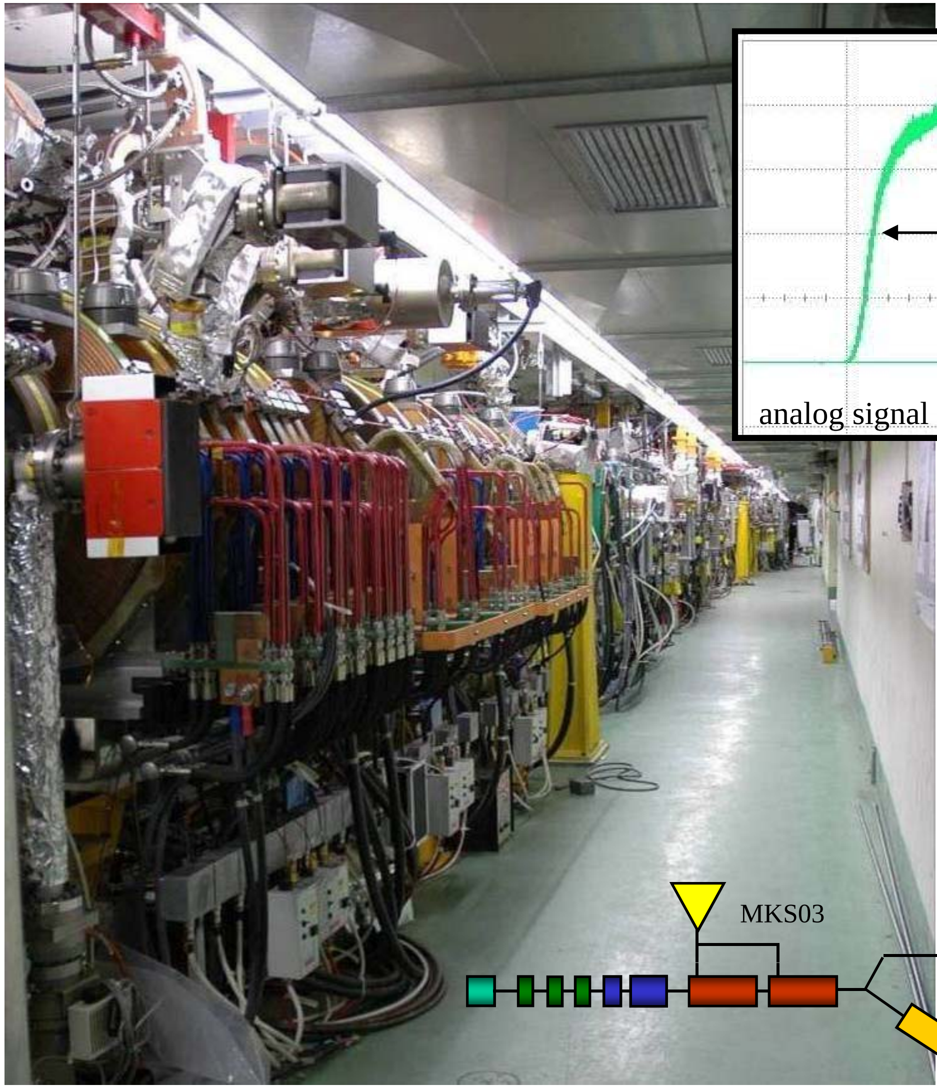


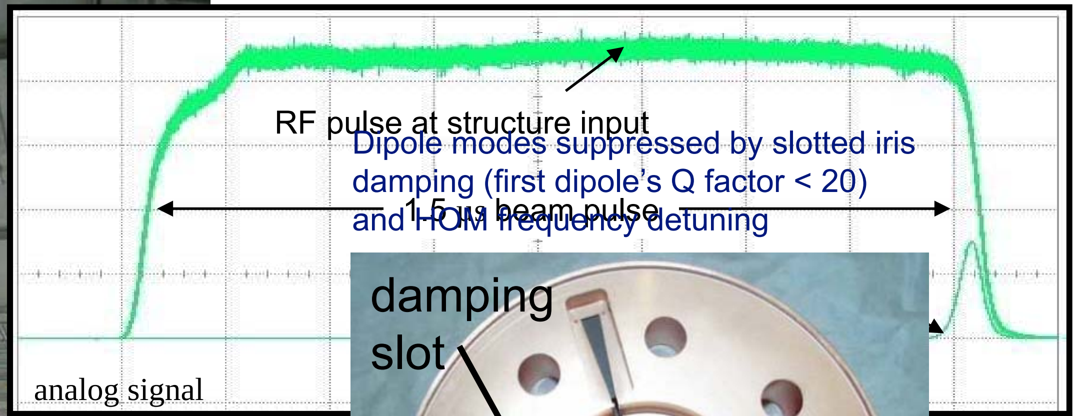
Streak camera images of the beam, showing the bunch combination process in the CTF3 preliminary phase

Full beam loading acceleration in TW sections



Full beam loading acceleration stability - efficiency

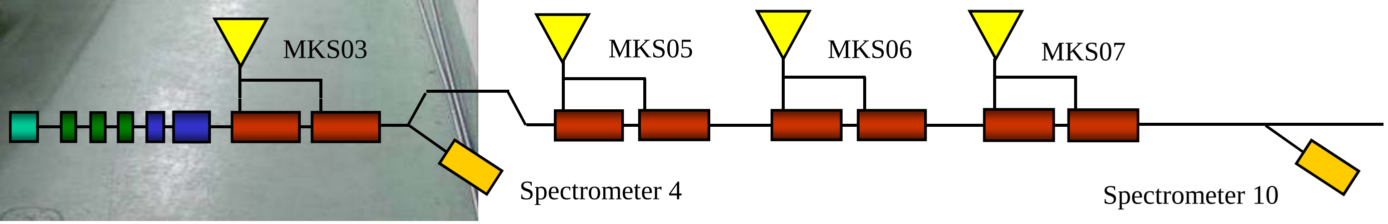




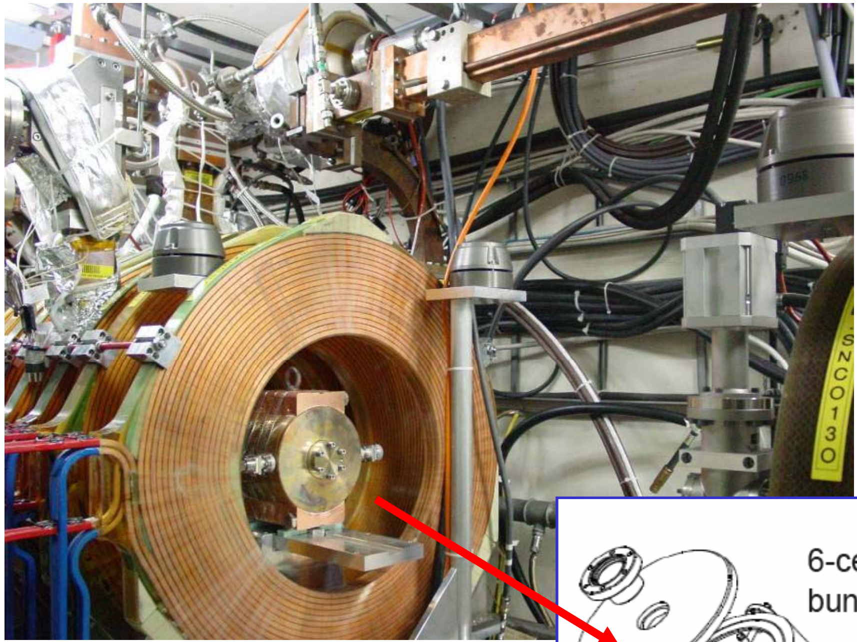
Dipole modes suppressed by slotted iris damping (first dipole's Q factor < 20) and HOM frequency detuning

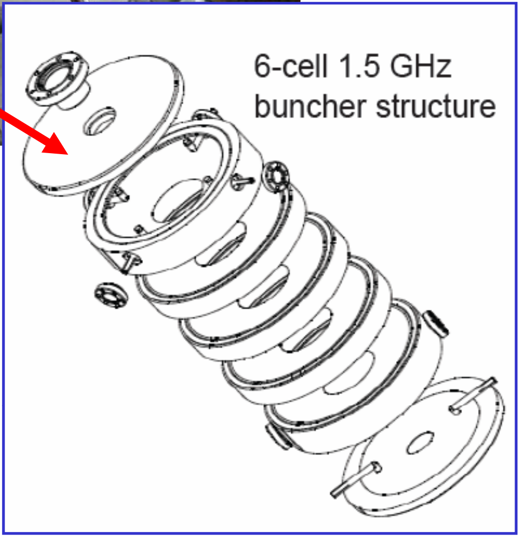
efficiency

ses)



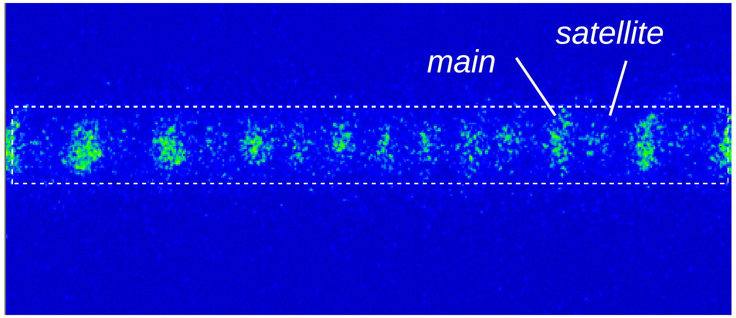
Fast phase switch from SHB system phase coding

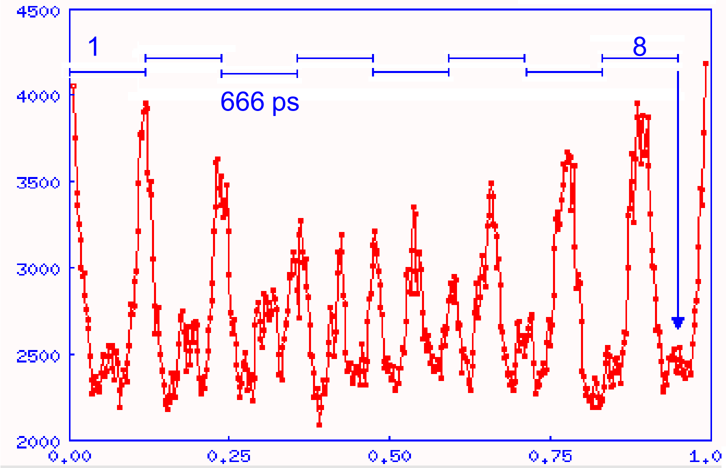




3 TW Sub-harmonic bunchers, each fed by a wide-band TWT

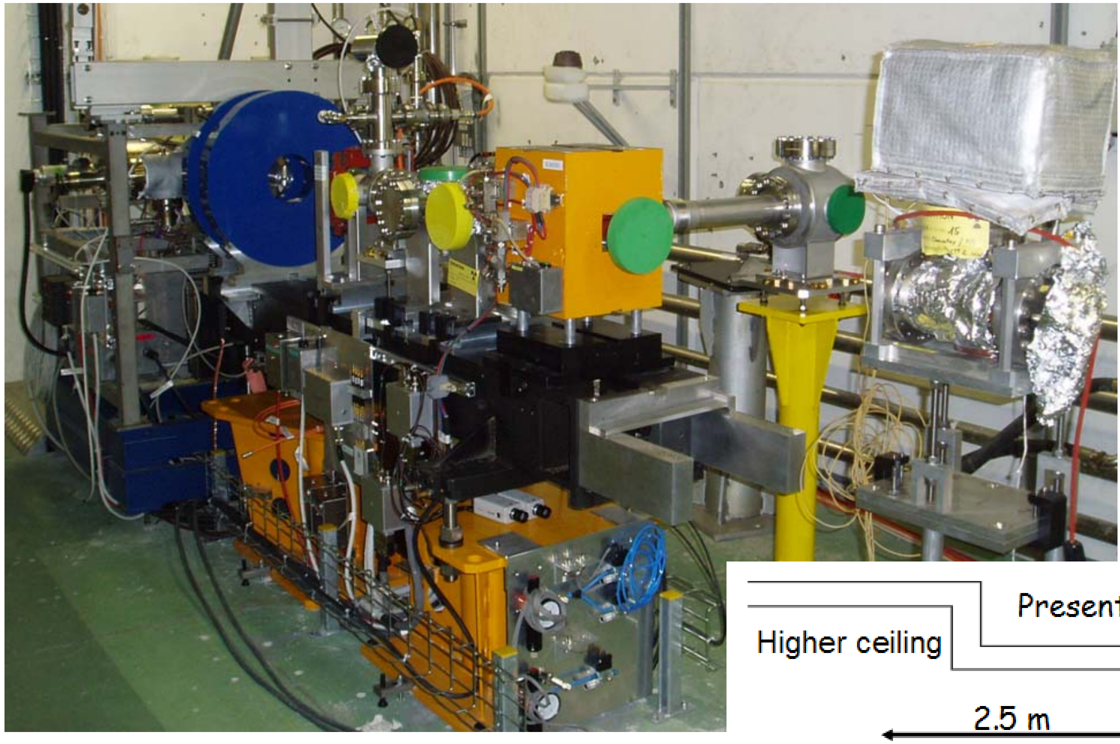
Streak camera image



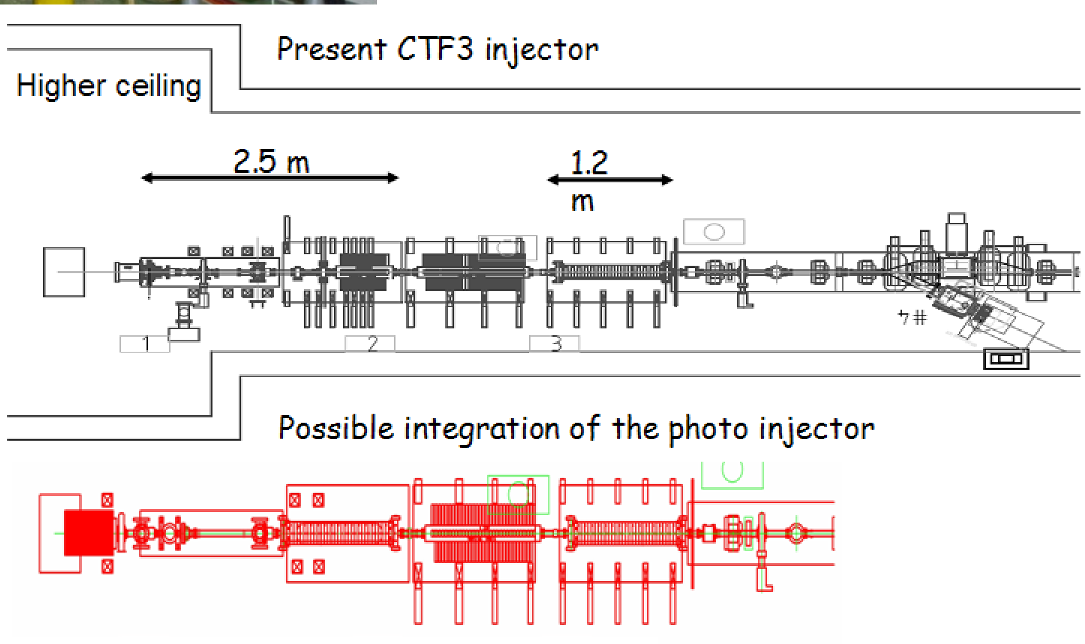


8.5 · 666 ps = 5.7 ns

The CTF3 baseline program

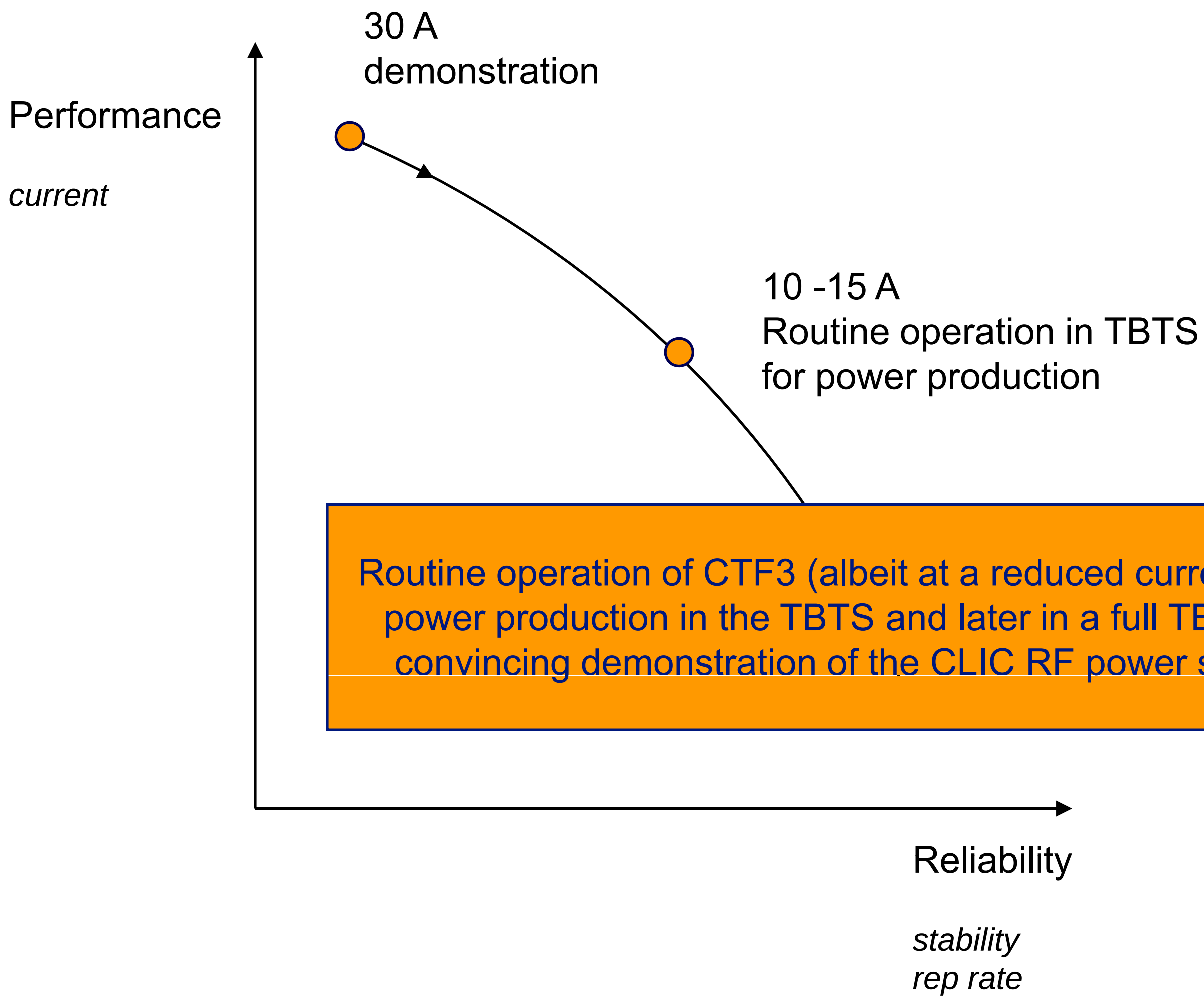


Satellite control, RF gun option



- Better emittance
- Shorter bunches
- No satellites
- Lower current

Performance vs reliability

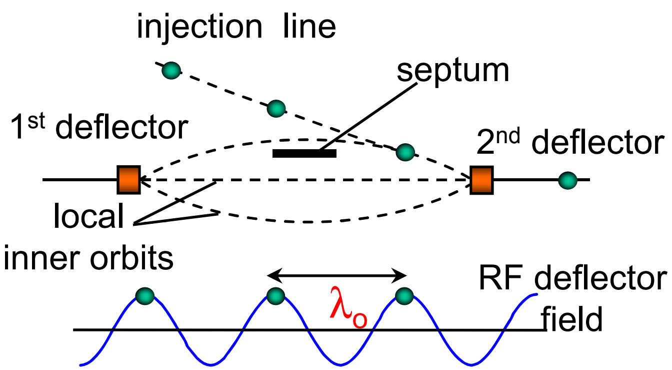


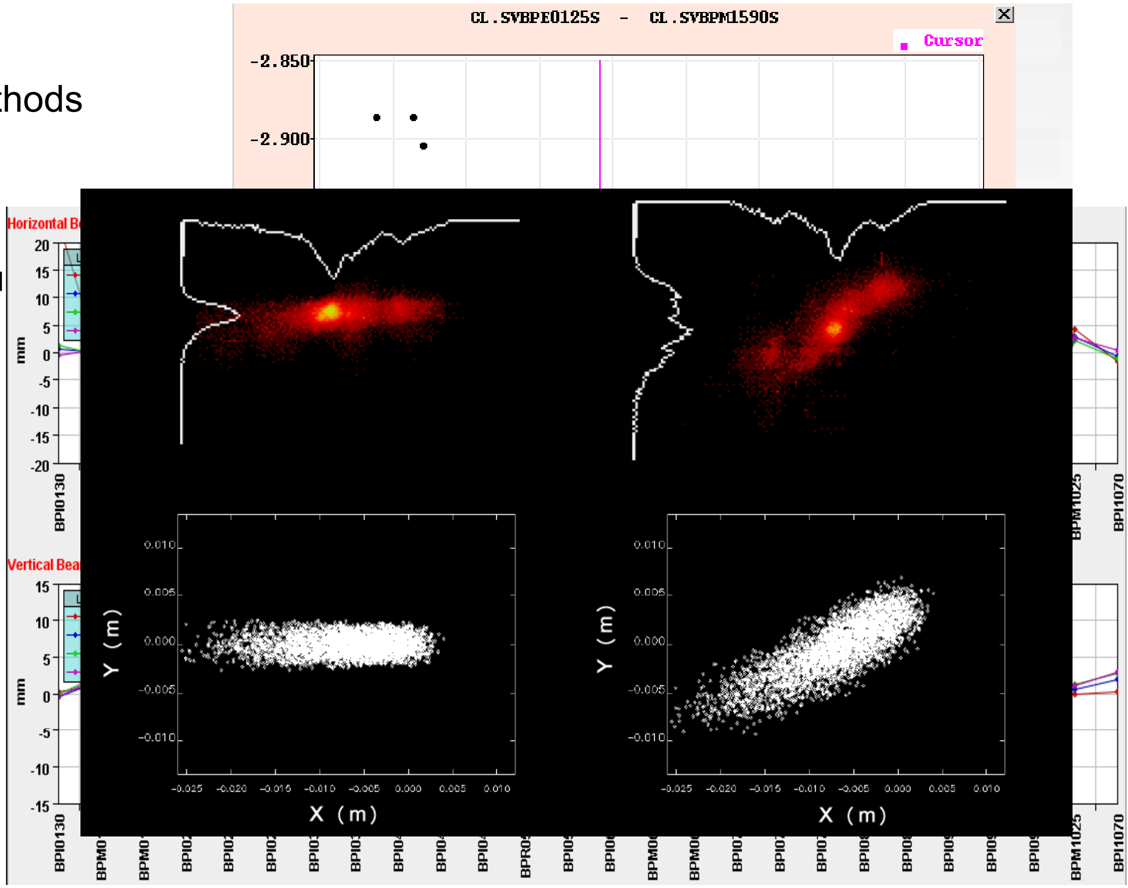
Routine operation of CTF3 (albeit at a reduced current), with 12 GHz power production in the TBTS and later in a full TBL will provide a convincing demonstration of the CLIC RF power source concept

Learning in CTF3: procedures, measurements etc..

CTF3 is a test facility, we assume its main goal is to provide a convincing demonstration of the CLIC technology, BUT possibly *even more important* is use it to

- Identify potential problems
- Develop measurement devices & methods
- Develop beam tuning procedures
- Test feedback & stabilization techniques
- Benchmark simulations



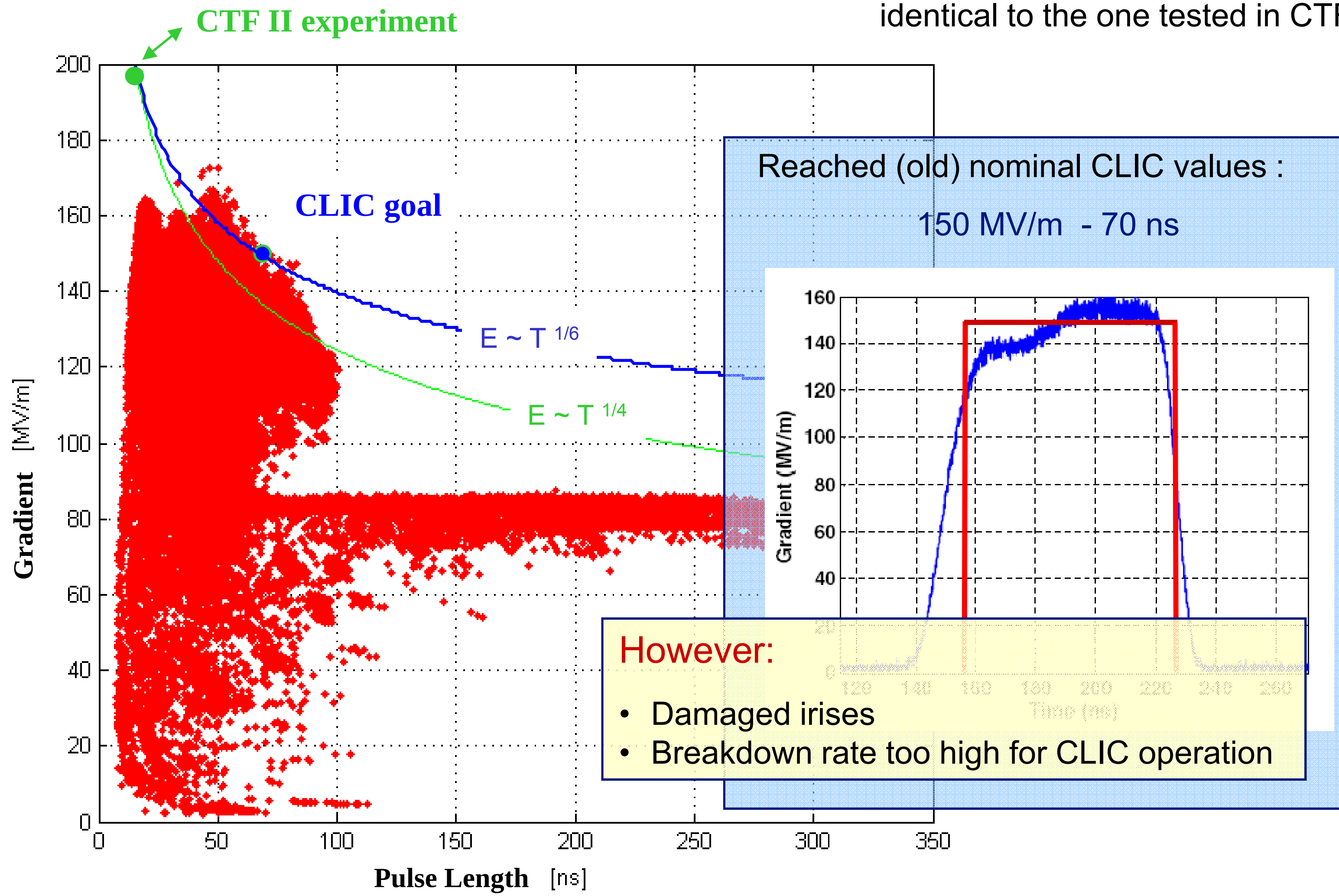


Accelerating structures R & D

- When CTF3 was designed & decided, it was the only possible high-power RF source for structure development at the CLIC frequency & pulse length.
- Since the frequency change from 30 GHz to 12 GHz, CTF3 is no more unique.
- However it should be noted that the change in frequency was mainly motivated by CTF3 results (combined with SLAC tests & previous experience).

CTF3 High-gradient test results – 30 GHz

Mo iris – clamped structure, identical to the one tested in CTF II



Reached (old) nominal CLIC values :

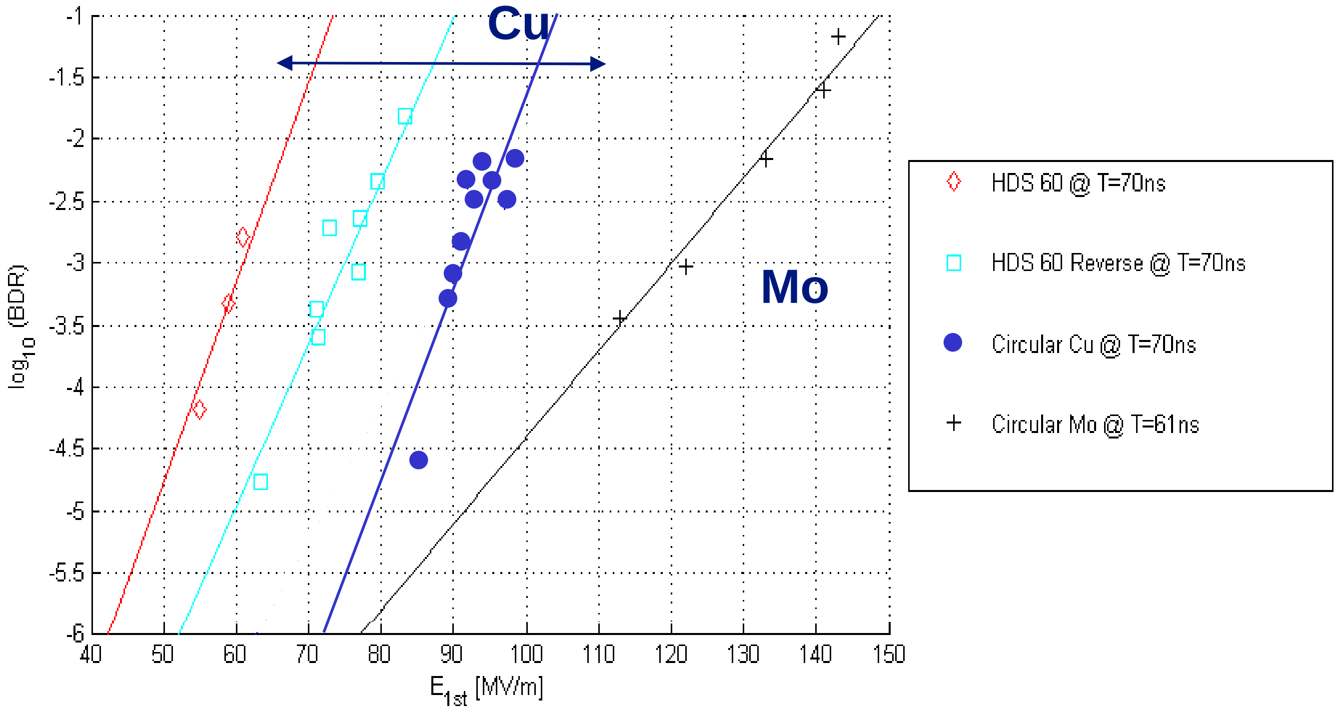
150 MV/m - 70 ns

However:

- Damaged irises
- Breakdown rate too high for CLIC operation

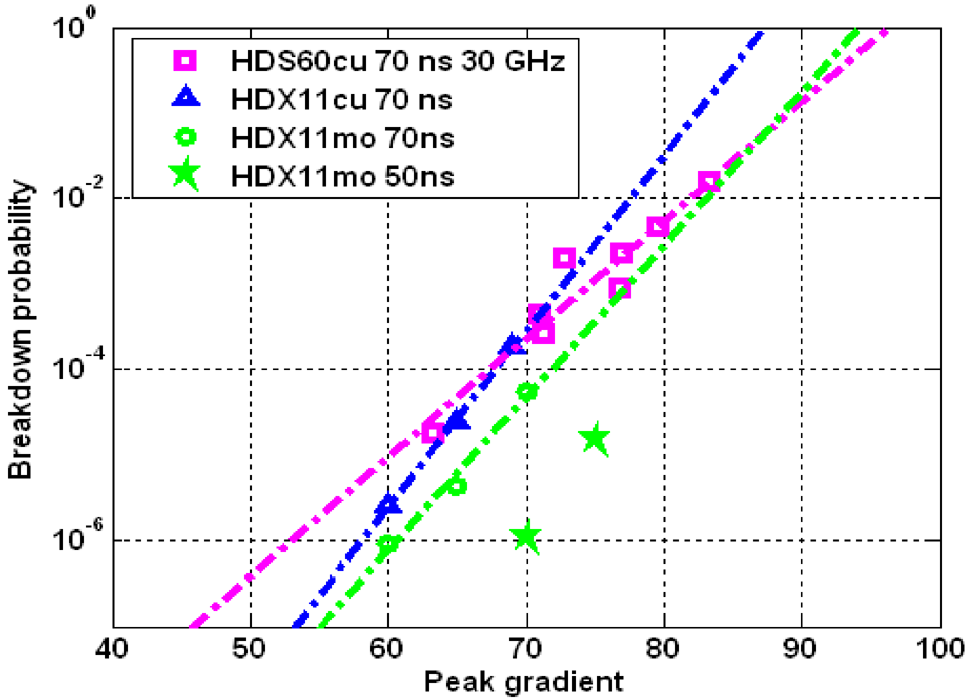
CTF3 High-gradient test results – 30 GHz

- Breakdown-rate slope for Mo (and W) in general less steep than Cu
- Mo slope & conditioning limit not consistent in different tests…



CTF3 + SLAC High-gradient test results – 30 & 11.4 GHz

- Structures with scaled geometries at different frequencies have same performance
- Scaling introduced in a parametric model (taking into account RF structure & beam dynamics constraint), used to study optimum cost & efficiency



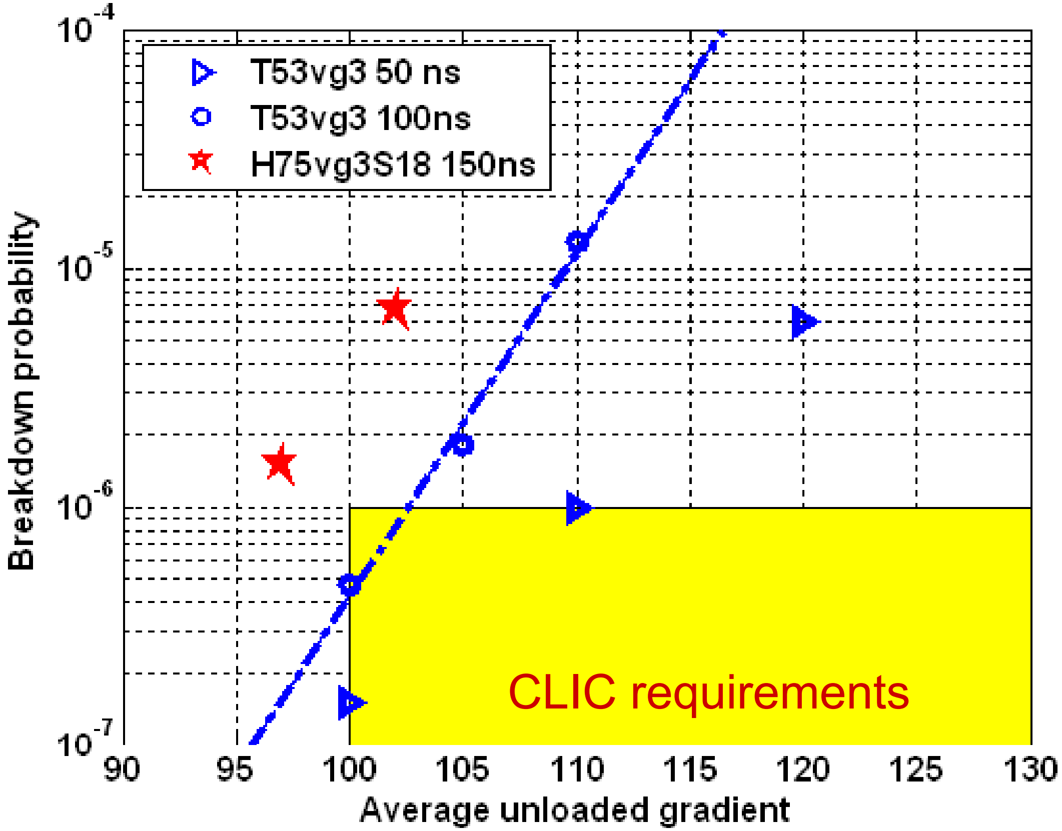
Accelerating structures R & D

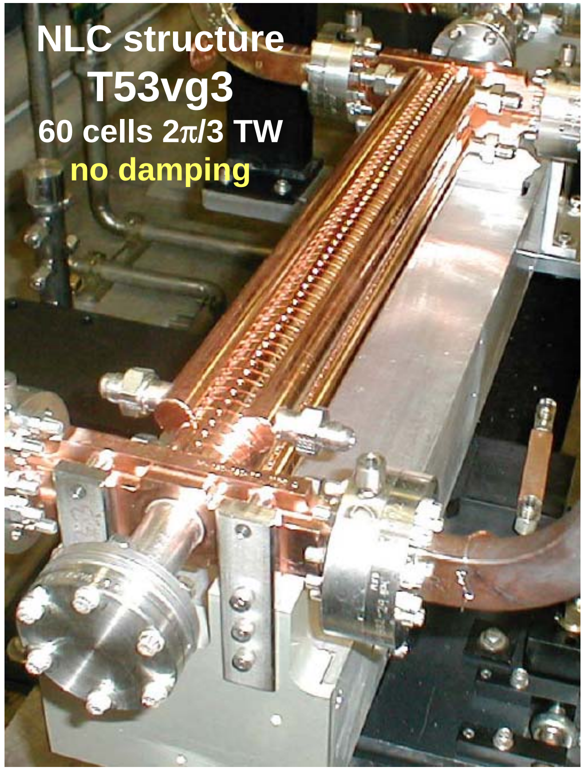
- When CTF3 was designed & decided, it was the only possible high-power RF source for structure development at the CLIC frequency & pulse length.
- Since the frequency change from 30 GHz to 12 GHz, CTF3 is no more unique.
- However it should be noted that the change in frequency was mainly motivated by CTF3 results (combined with SLAC tests & previous experience).
- Many structure tests (most of them ?) will be done at SLAC & KEK.
- The standalone power source @ 12 GHz will be however well integrated in the CTF3 environment, which is important in many respects (see later discussions).
- CTF3 will stay however the (only ?) place to test structures with beam (more about it later).

Structures R & D – what has to be shown ?

- Gradient 100 MV/m @ 10^{-6}-10^{-7} BDR, average, loaded
- Pulse length at present 240 ns – could evolve again before 2010
- Damping wake-field at the second bunch $W_{t,2} < 10$ V/pC/mm/m · 4×10^9 / N
  - Pulse length, damping and bunch charge (dependent from a/λ) determine efficiency
  - Present efficiency 28 % - what is the minimum acceptable ?
  - NB: fatigue resistance to RF pulse surface heating must be shown as well !

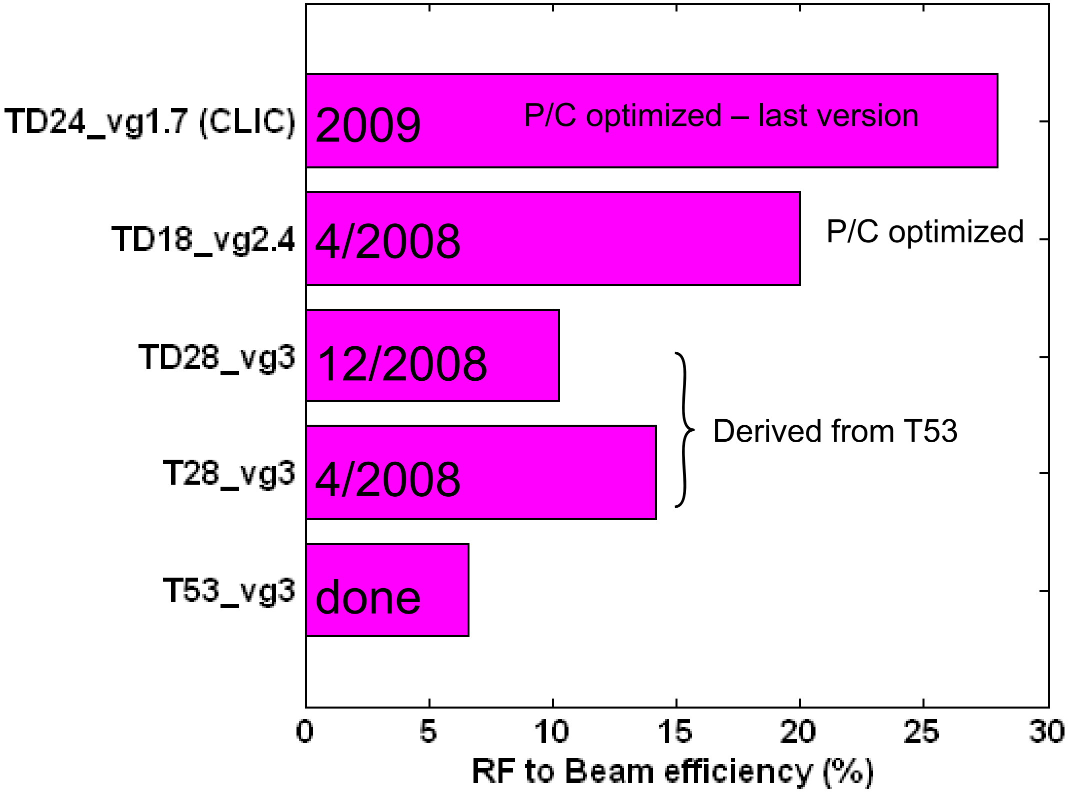
Recent SLAC High-gradient test results – 11.4 GHz





T53vg3 (shortened) would give ≥ 5% efficiency at 100 MV/m loaded, 10^{-6} BDR
but undamped !

Efficiency milestones in structure testing



P = 64 MW; 241 ns ⇔ nb = 312

P = 70 MW; 295 ns ⇔ nb = 359

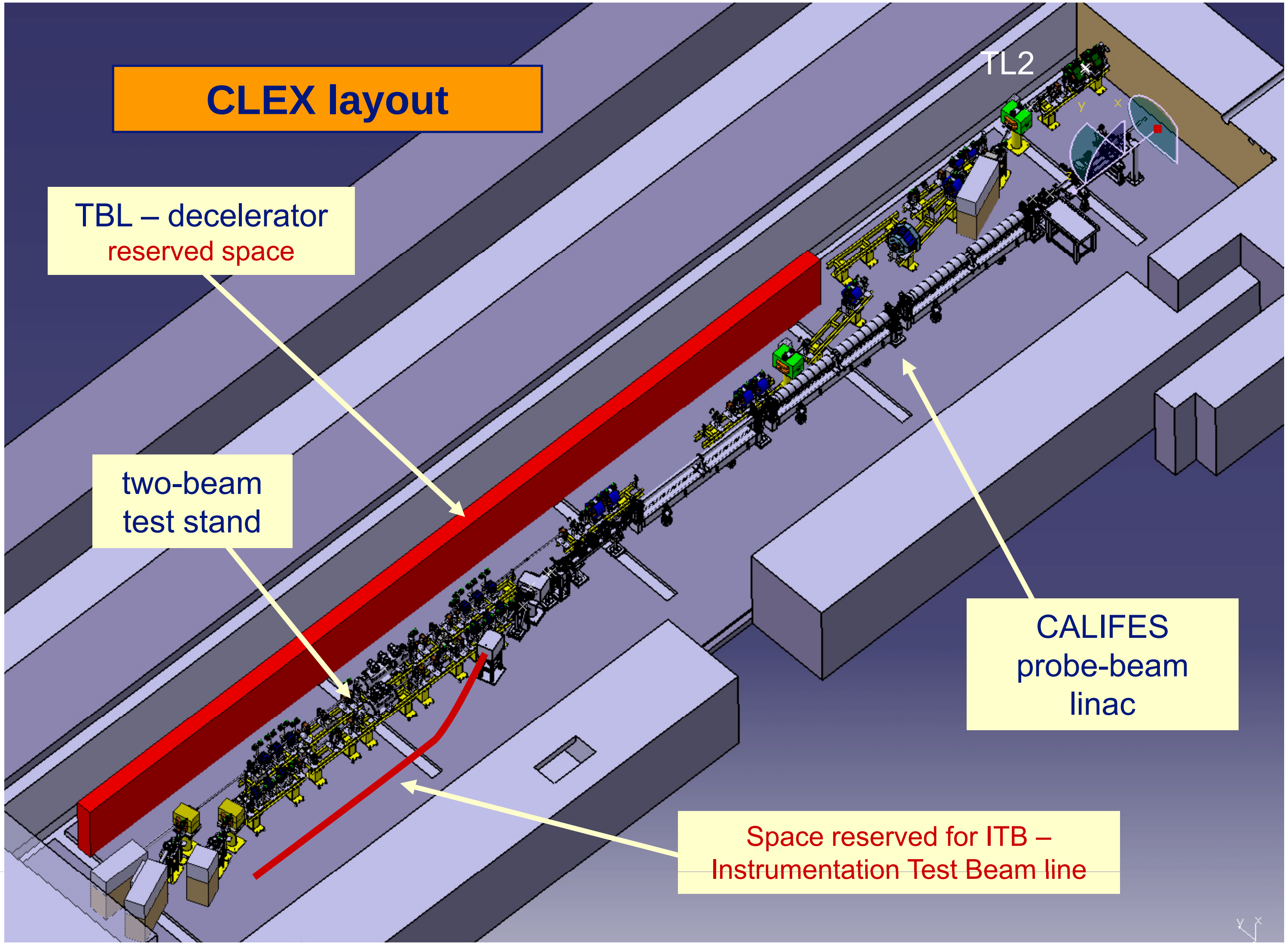
P = 111 MW; 102 ns ⇔ nb = 66

P = 102 MW; 113 ns ⇔ nb = 93

P = 134 MW; 104 ns ⇔ nb = 27

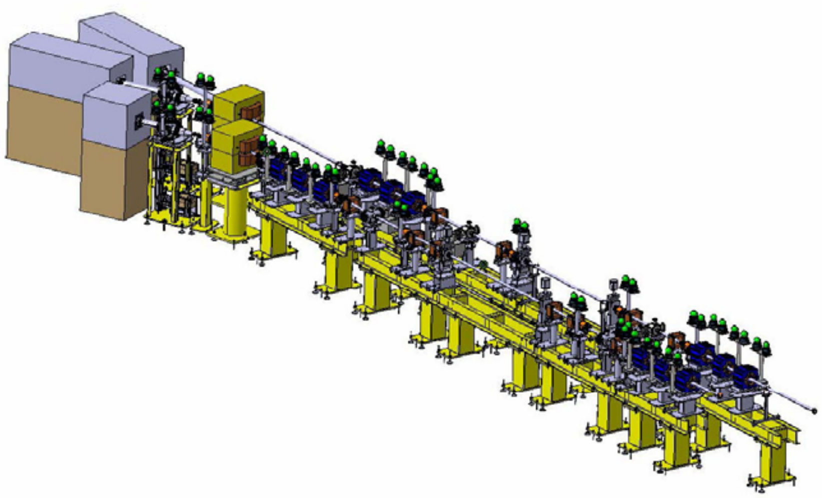
More details in presentations to the 2nd CLIC Advisory Committee (CLIC-ACE):
http://indico.cern.ch/conferenceDisplay.py?confId=24998

The CTF3 baseline program



The Two-Beam Test Stand

- drive and probe beam parallel along ~ 10 m
- unique test possibilities
  - PETS
  - accelerating structures
  - direct measurement of gradient
  - two-beam operation
  - beam loading energy spread compensation
  - breakdown rate with beam
  - RF breakdown transverse kick



PETS test program overview

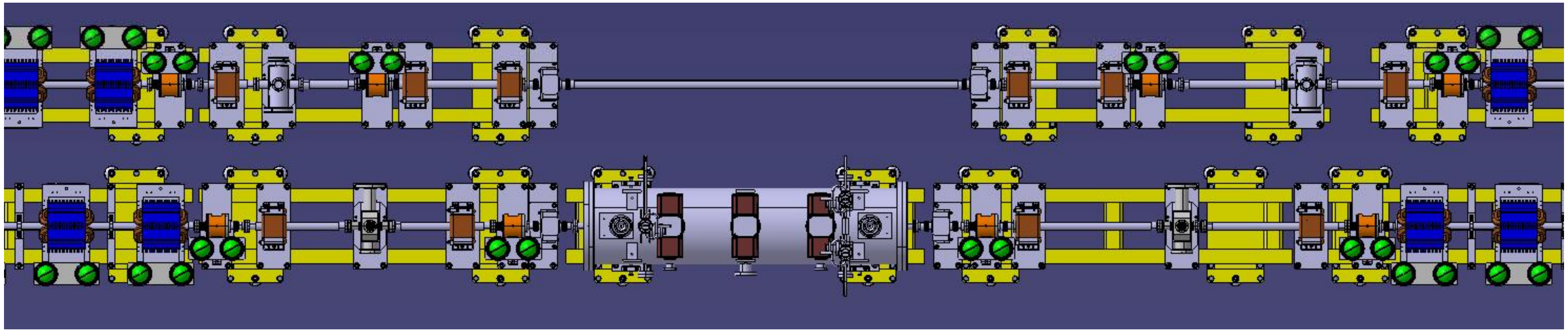
I. Syratchev

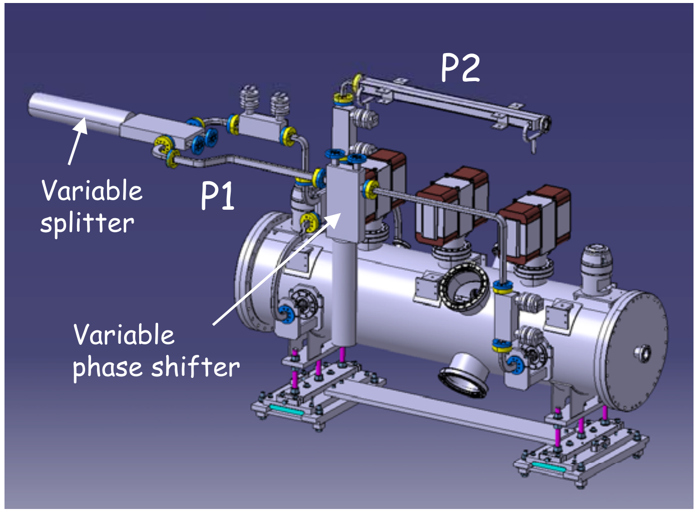
	Test areas		
	X-band klystron test stand at SLAC	Two beam test stand CLEX, CERN	TBL CLEX, CERN
PETS target is to generate reliably 136 MW x 240 ns RF pulses	Access to the high power and full pulse length: 240 ns x 300 MW. High rep. rate. RF source driven.	Access to the high power (~ 200 MW) Pulse length limited to 140 ns, for maximum beam current. Low rep. rate. Beam driven.	
Objectives: The ultimate PETS high RF power performance	●	●	
Objectives: RF power generation from the drive beam		●	●
Objectives: Demonstration of the ON/OFF capability		●	
Objectives: Study/benchmarking of the beam dynamic in decelerator		●	●
Objectives: Testing of the special RF components	●	●	
PETS design specifics	Scaled (12->11.424) CLIC PETS. Active length **0.23 m** Two couplers.	CLIC PETS. Active length **1.0m**. Two couplers	CLIC PETS. Active length **0.8 m**. One coupler
Origin and availability	CERN, spring 2008.	CERN, summer 2008.	CIEMAT, autumn 2008.

I. Syratchev

Integration layout for the phase I – PETS power production tests.

Two beam test stand





PETS with recirculation

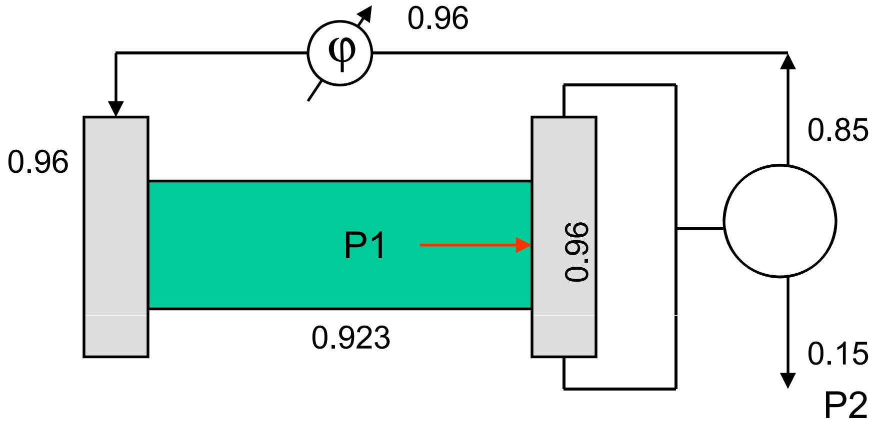
CLEX 2BTS:
Drive beam: 12GHz, 140ns, 30 A (max)
CLIC PETS, active length 1.0 m,
135 MW will be produced with 20.8 A beam.
Access to 270 MW (30 A)

Number of tests:

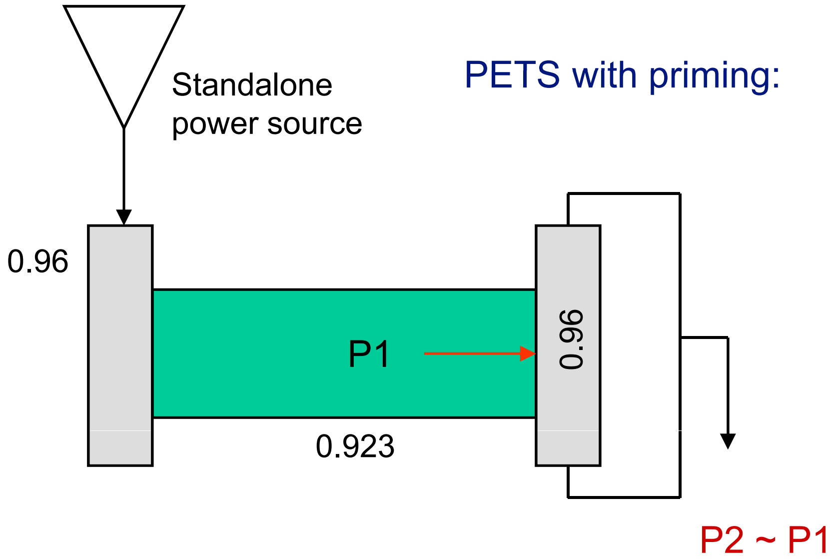
#1. PETS/ no damping material
#2. PETS/ with damping material
#3. PETS with recirculation (access to full pulse length)
#3b. PETS with priming (access to full pulse length)
#4. On/Off demonstration (slow)

PETS recirculation & priming

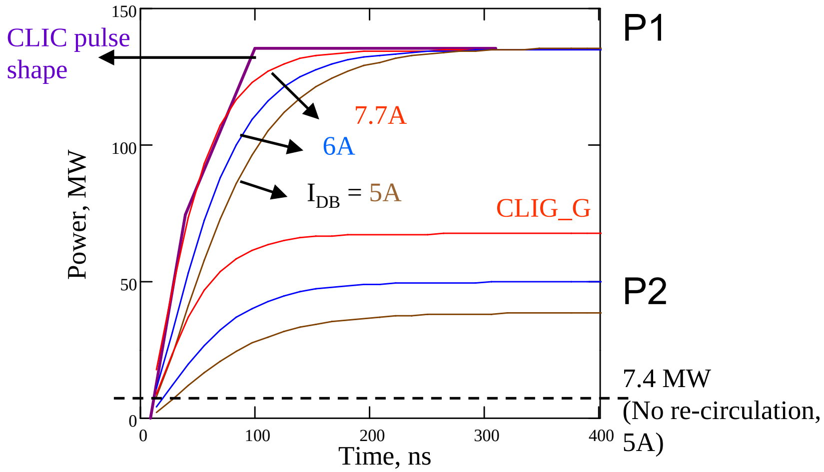
PETS with recirculation schematic:



PETS with priming:



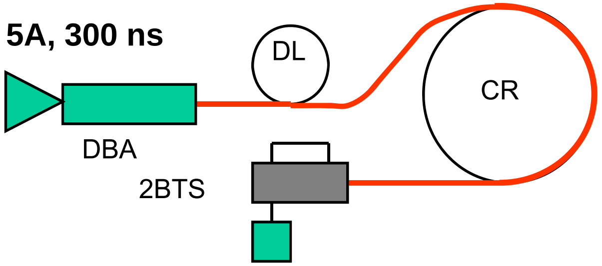
RF pulse shapes

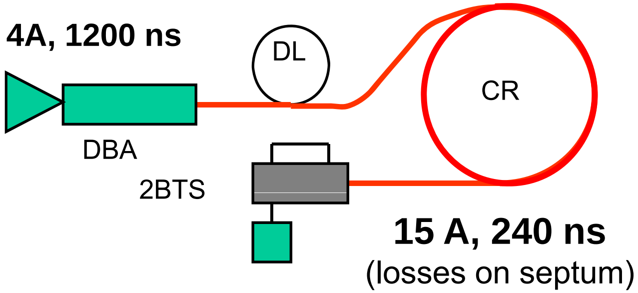


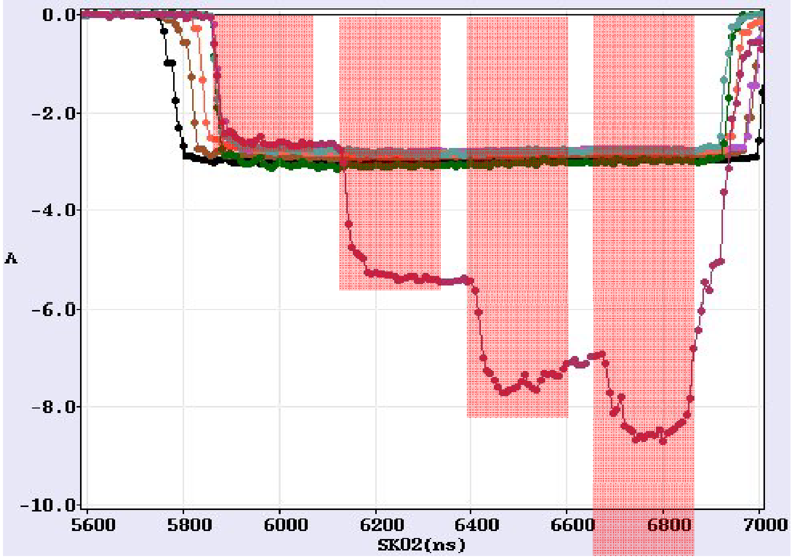
RF input power needed for 135 MW nominal output

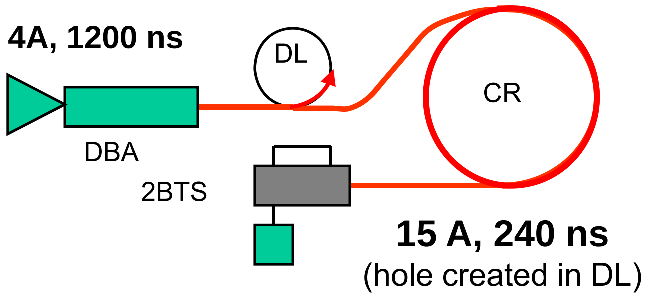
DB current	Pin
5 A	80 MW
10 A	40 MW
15 A	12 MW

Longer DB pulses in CTF3

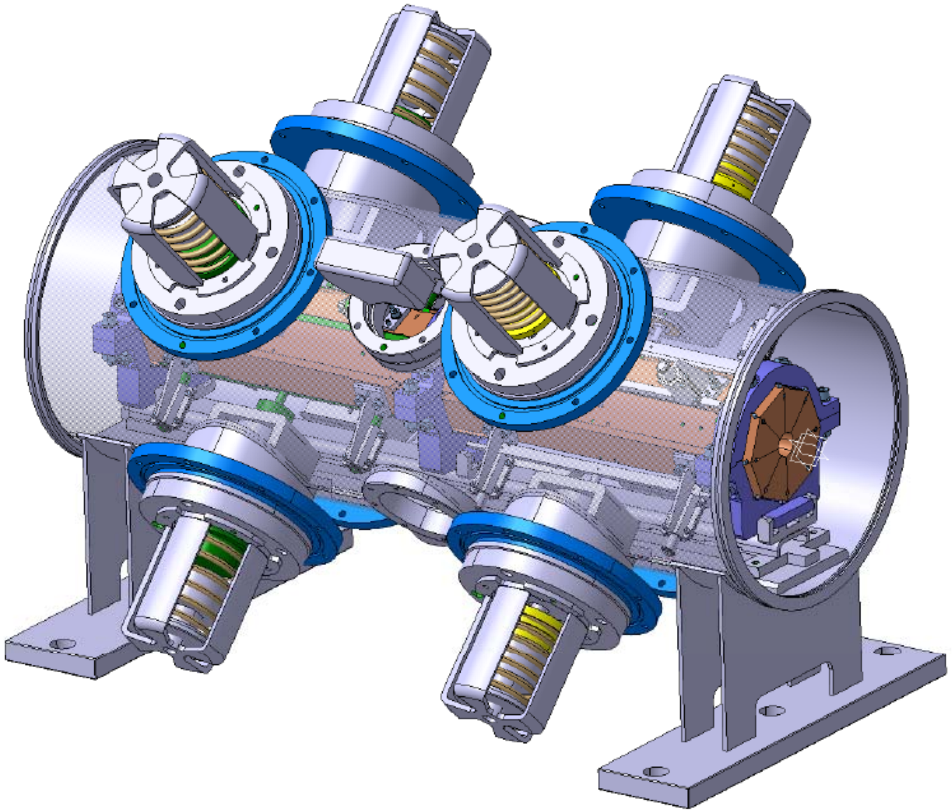








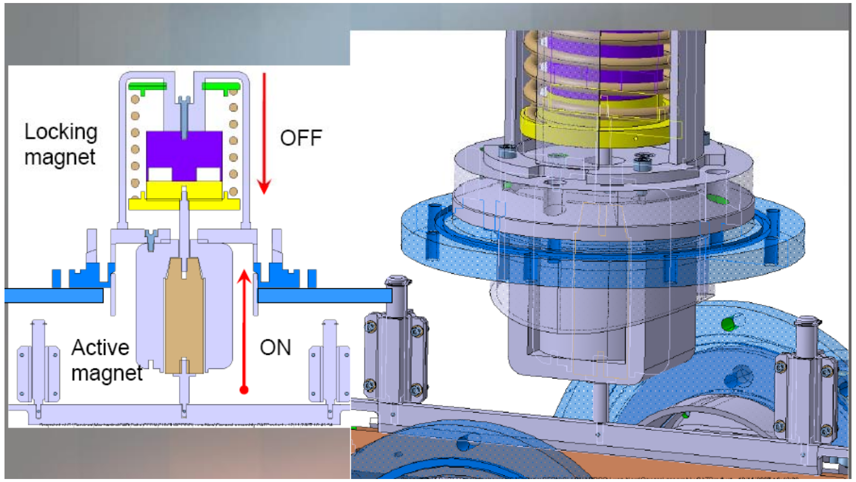
The electromagnet version developed in TS, CERN



Petsonov

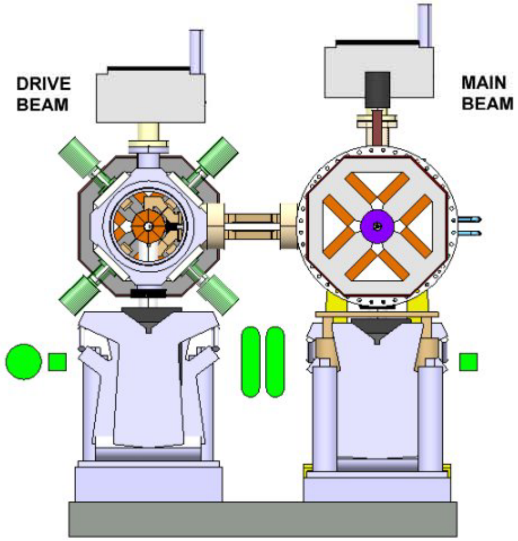
Fast ON/OFF mechanical prototype study

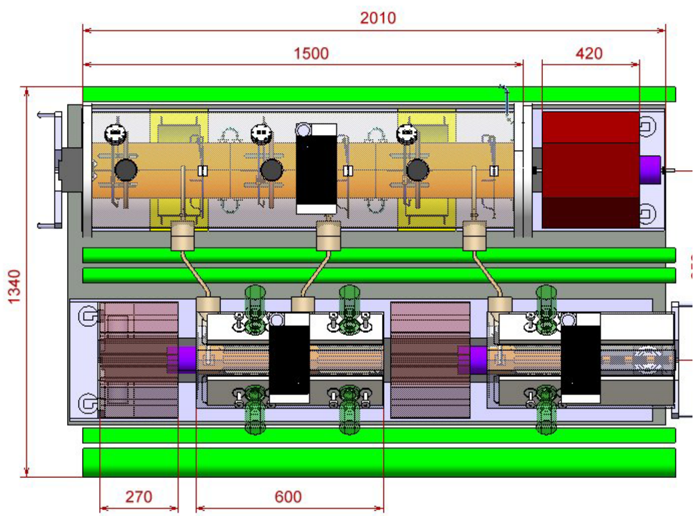
The objective is to demonstrate the fast – 20 ms and accurate movement (OFF) of the detuning wedges in a vacuum environment.

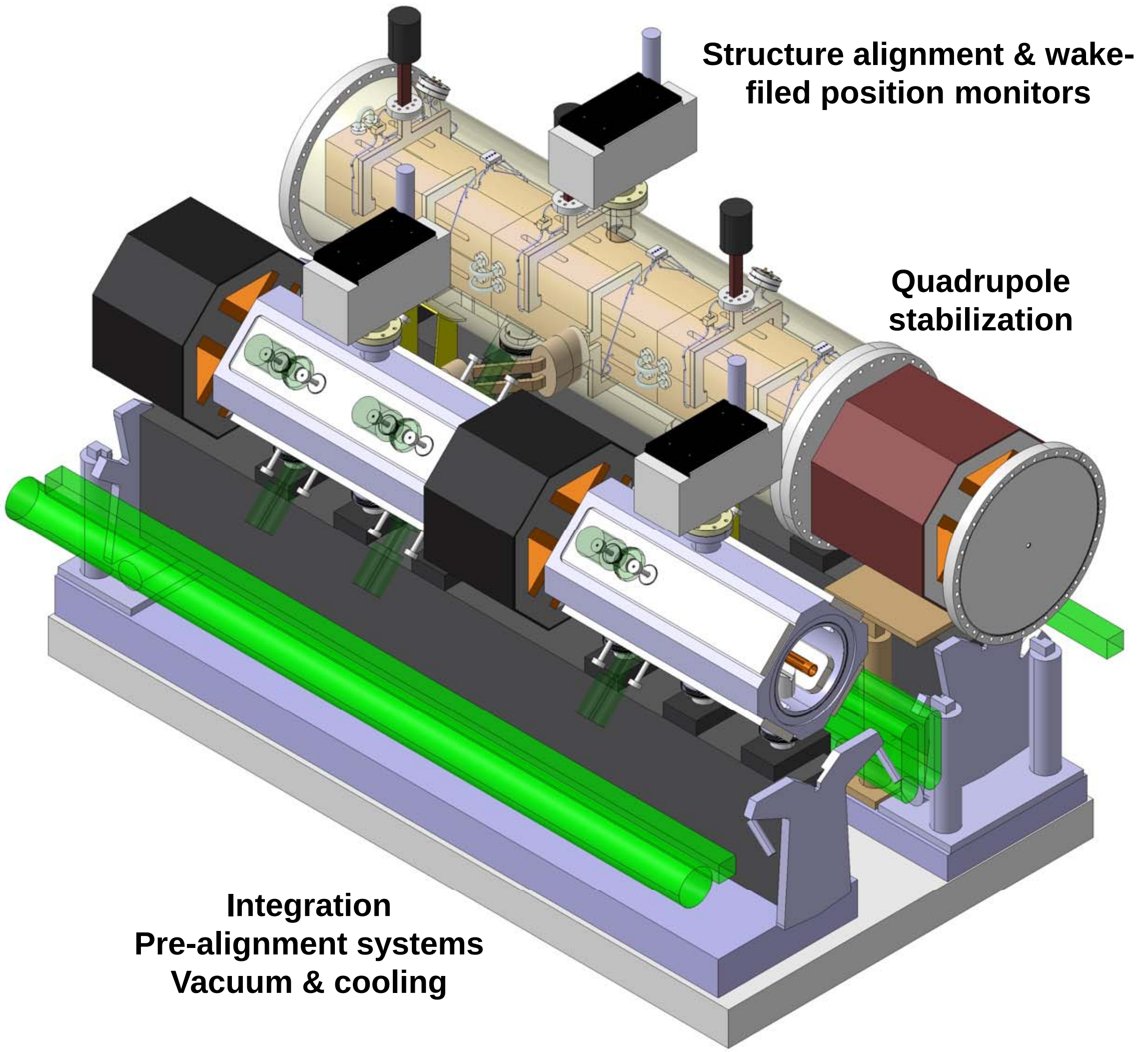


The CLIC Module

Straightforward continuation of the CTF3 baseline program

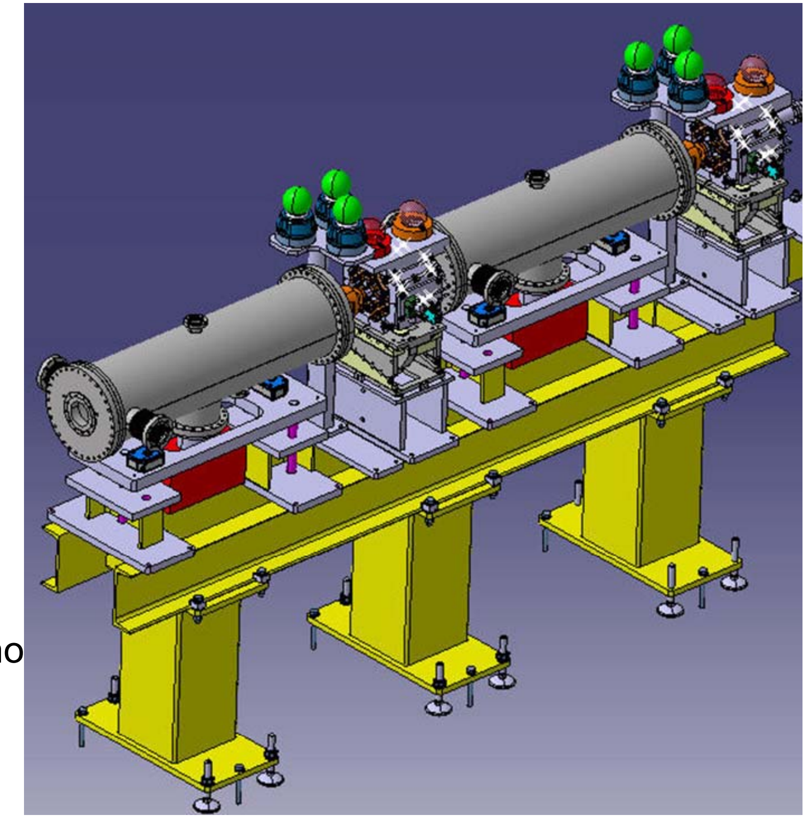


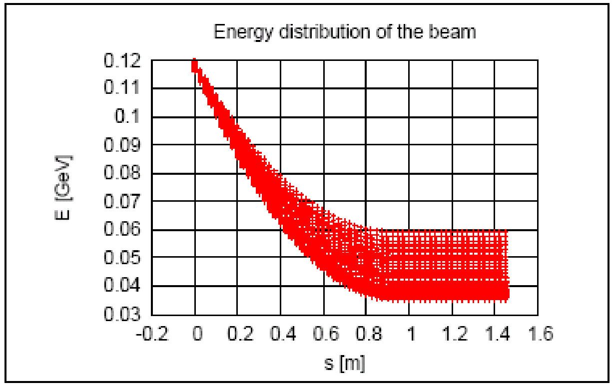


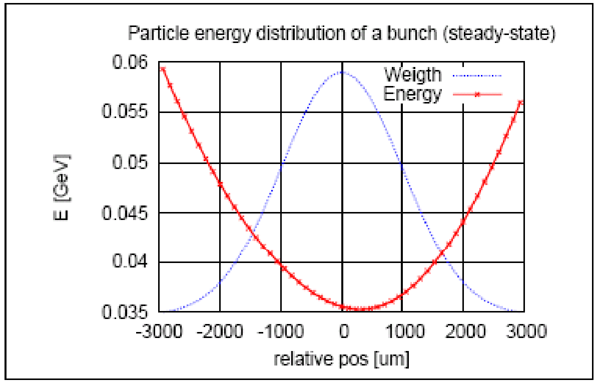


TBL goals

- 'Realistic' show case of a CLIC decelerator
- High energy spread beam transport, low losses
  (Bench mark simulations)
- RF Power Production, Stability
  (End Energy <50%, 2.4 GW of RF power)
- Alignment (Test procedures for BBA)
  100 microns alignment for PETS, test of CLIC alignment equipment
- Drive Beam Stability, Wake fields (no
  direct measurement of the wake fields)
- Industrialization of complicated RF components







CONCLUSIONS

- A full, challenging and complete experimental program, which can keep all of us busy until 2010 and beyond
- A lot to learn and study – invaluable towards the completion of a CLIC design report first and a technical report later
- A lot of tests are relevant to determine the feasibility of the CLIC technology, however:

I don't know which one represents CTF3 better, but definitely the test facility is not exactly like CLIC …


… and we will need a real quantum leap
in order to reach the CLIC scale
NCC-1701