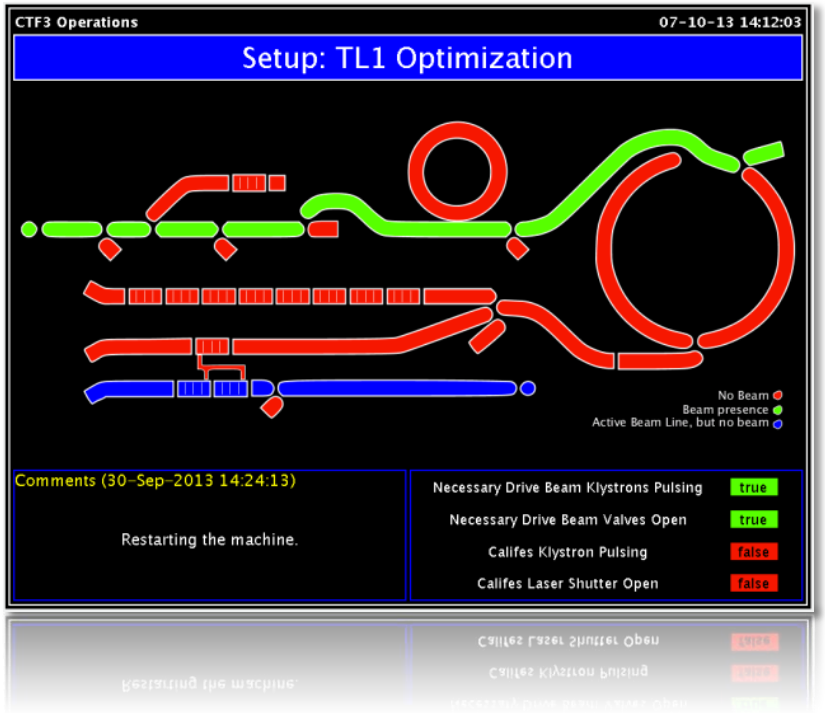
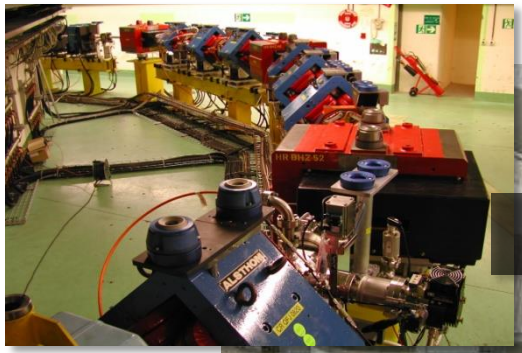
CTF3 results and outlook

Frank Tecker (CERN)
on behalf of the CTF3 team

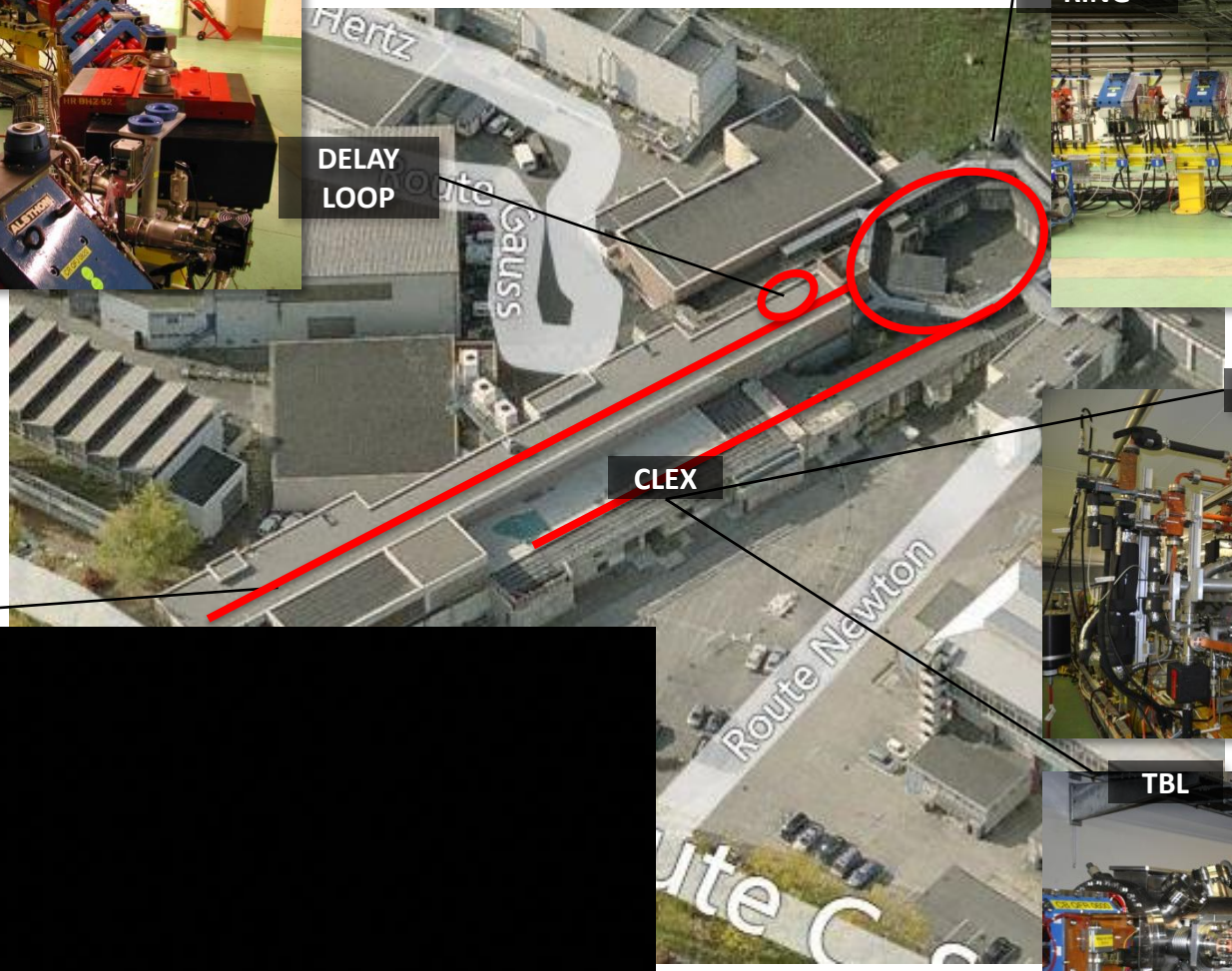


- Past results: completion of feasibility studies
- Future program 2013-2016
  - Objectives and schedule 2013 - 2014
  - Outlook on the following years

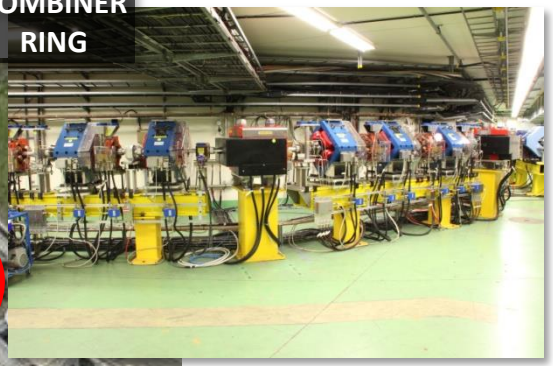
CLIC Test Facility (CTF3)



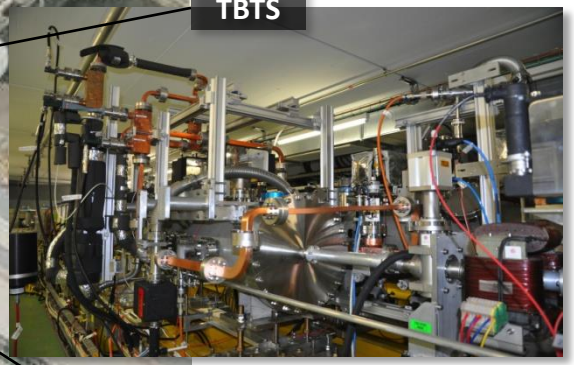
DELAY LOOP



COMBINER RING

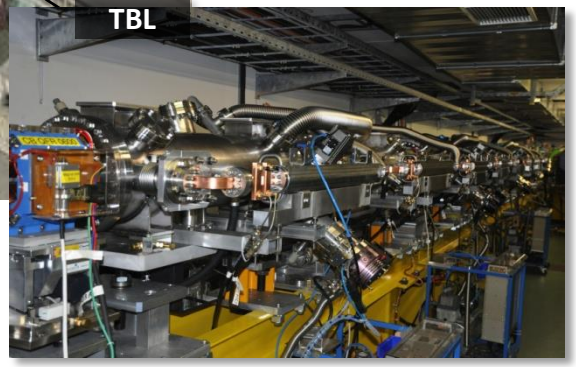


TBTS



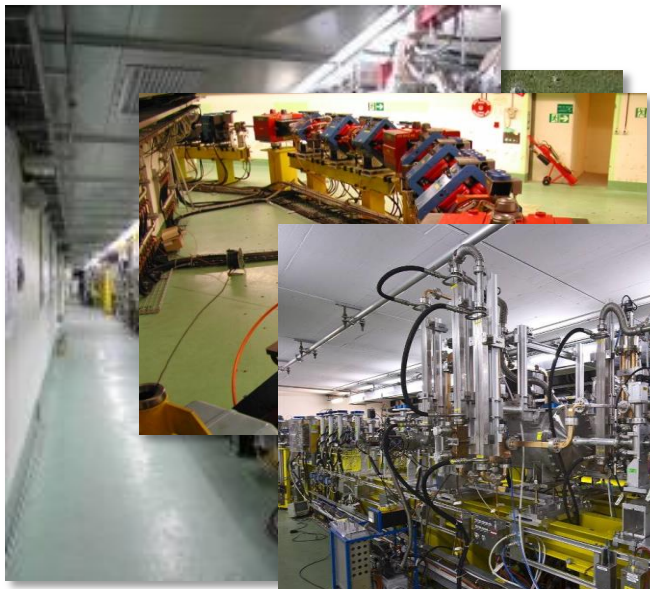
CLEX

TBL



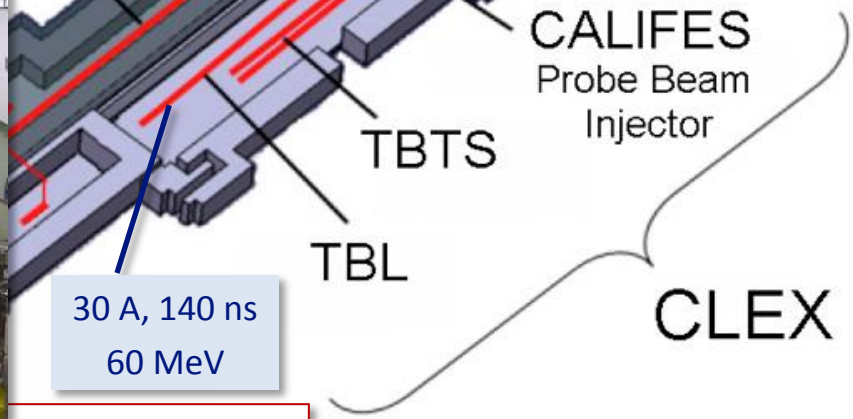
DRIVE BEAM LINAC

CLIC Test Facility – CTF3



Operation of isochronous lines and rings

and current multiplication by RF deflectors



30 A, 140 ns
60 MeV

unch phase coding

12 GHz power generation by drive beam deceleration

High-gradient two-beam acceleration

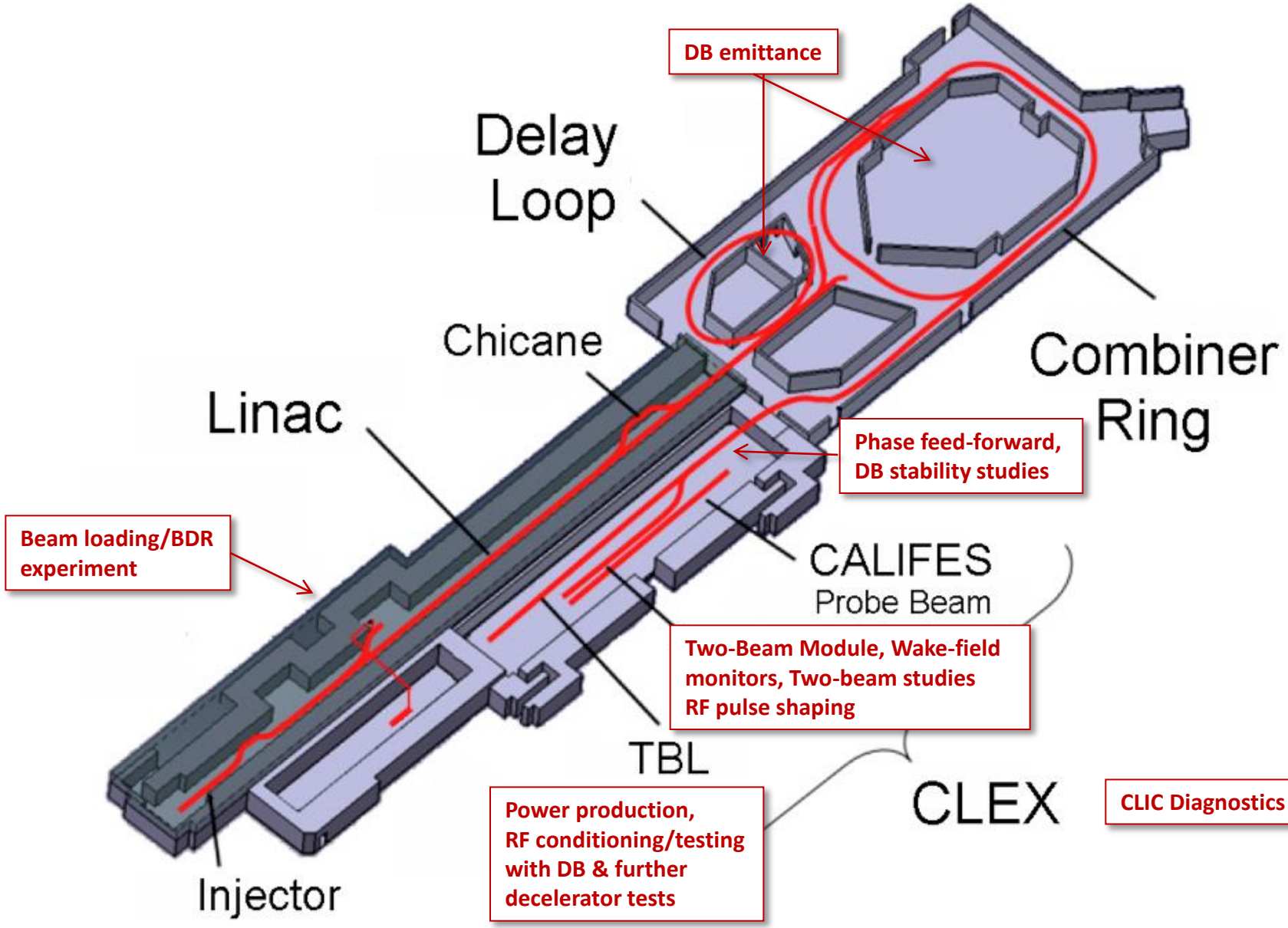
CTF3 Main Achievements

- Drive Beam generation
  - Full beam loading linac operation – stable acceleration of high current beam (4A)
  - Phase coding by fast-switched sub-harmonic bunching system
  - Isochronicity tuning of rings and lines – bunch length control
  - Proof of current amplification/pulse compression (factor 2 x 4, 28 A) by recombination with RF deflectors (need still some work on emittance)

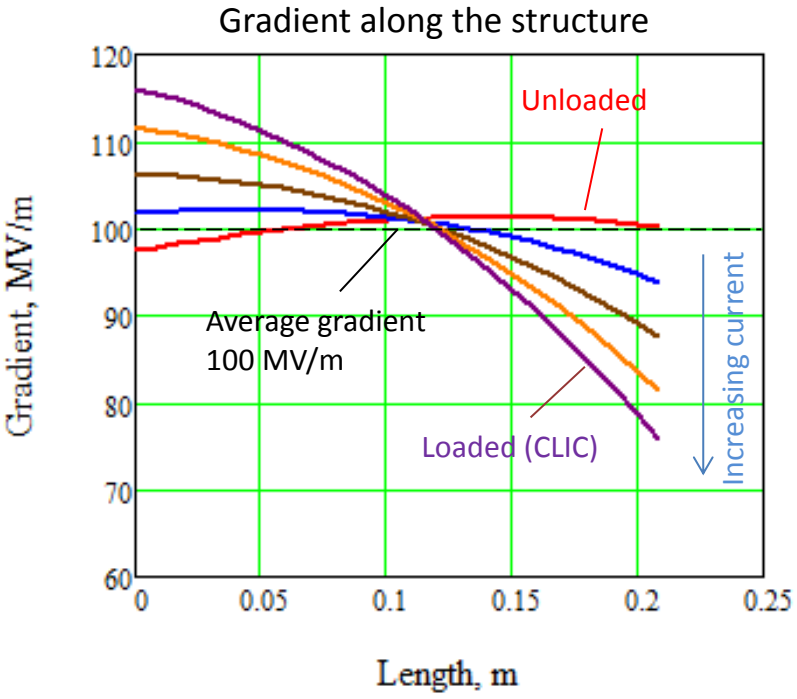
- Two Beam Test Stand
  - Power extraction from drive beam, 2 x CLIC nominal power
  - Two-Beam acceleration in CLIC structure 1.5 x CLIC nominal gradient
  - PETS ON/OFF mechanism demonstrated (not yet full power)

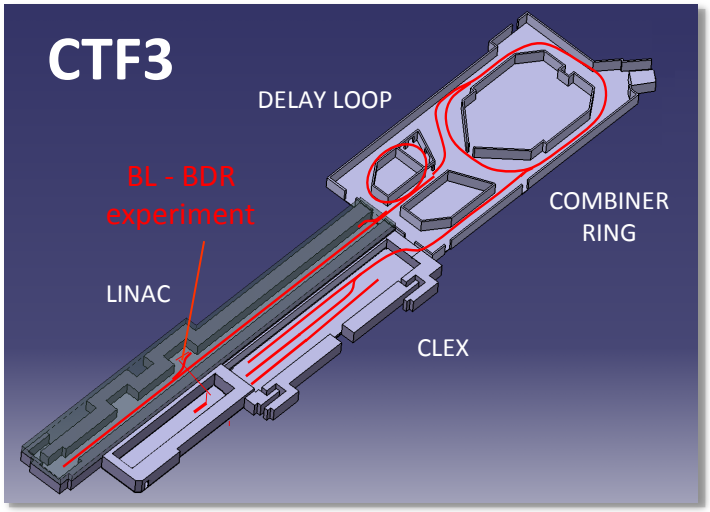
- TBL
  - Drive beam stable deceleration to about 35% of initial energy.
  - Production of 12 GHz RF power of the order of 1 GW in a string of deceleration structures

CTF3 program in 2013-2016



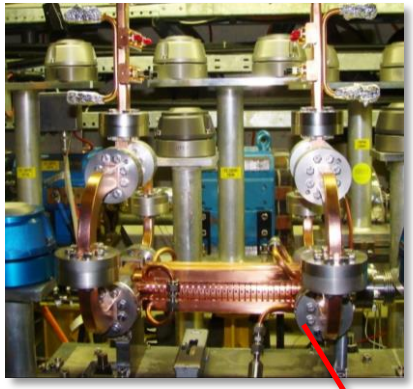
Experiment on the effect of Beam-Loading on BD rate



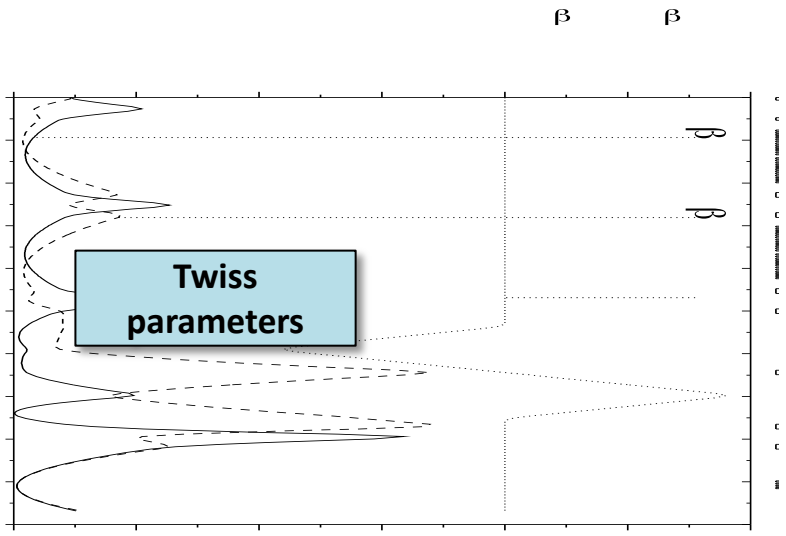


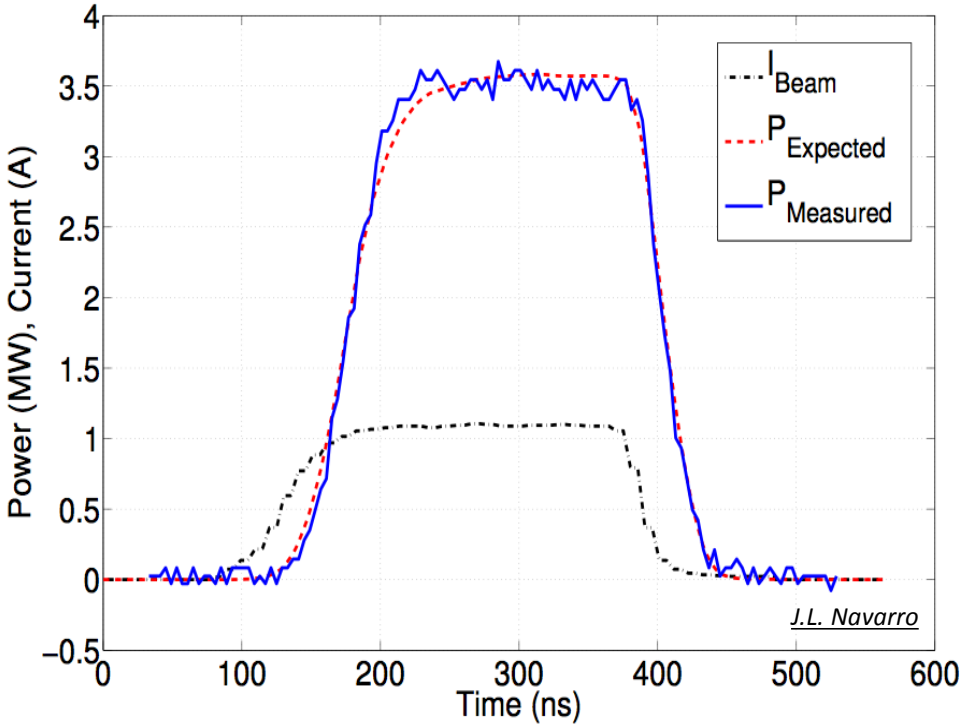
Beam loading changes the field distribution for the same average gradient
⇨ how is the break-down rate affected?

- Reactivated an old beam line (dogleg)
- 1 A DB current (like CLIC Main Beam)
- Measure BDR with/without beam for a direct comparison



Experiment on effect of Beam-Loading on BD rate





2013 1st run:

- Beam line optics commissioned with beam (1 A)
- first measurements of produced RF power
- calibration needs improvement

2013-2014 Goals

- recalibration of RF measurements - done
- Beam set-up, transport, RF signals check (klystron taken by structure testing)
- After winter shut-down: structure conditioning with klystron, break-down rate measurements

Drive Beam emittance

Goal: 150 µm for combined beam

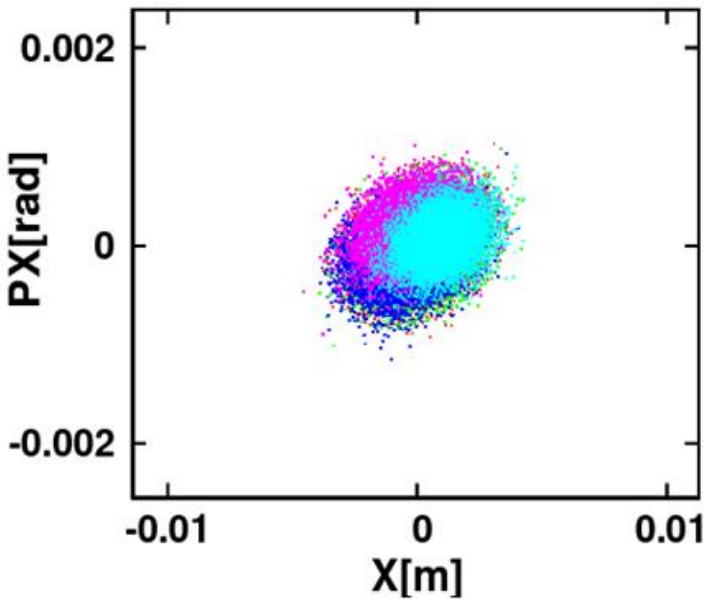
Best results in CLEX
for factor 4: ε_H= 170 µm ε_V= 120 µm
for factor 8: ε_H= 550 µm ε_V= 170 µm

Very short beam time:
Problem with SHB power sources availability

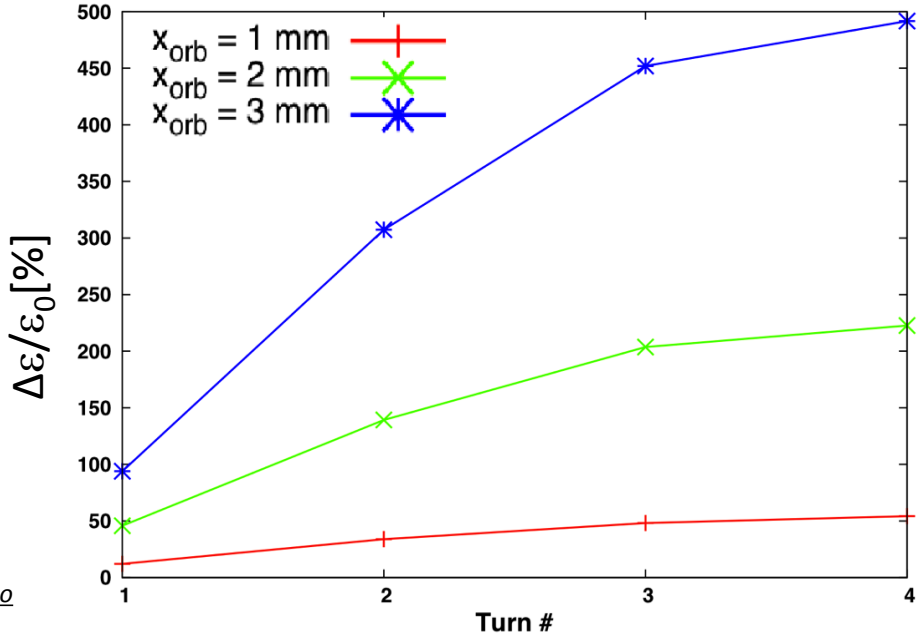
Emittance increase due to non perfect orbit

(high chromaticity leads to filamentation - Δp/p ≈ 1%, CR chromaticity ≈ -13/-9 per turn)

shown in simulations



Emittance growth vs. turn nb.
for different injection orbit errors

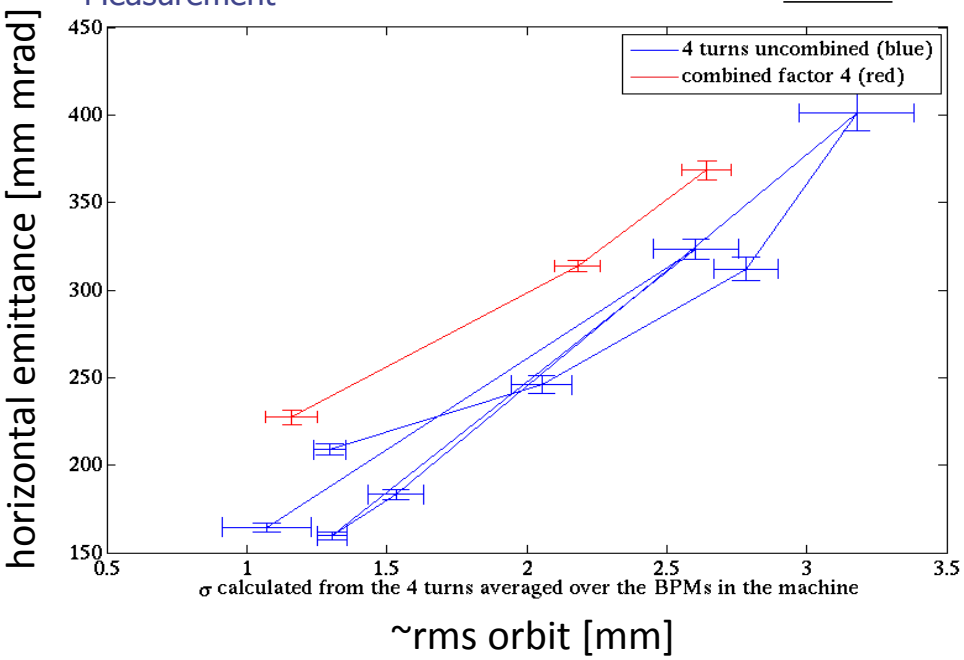


J. Barranco

Drive Beam emittance

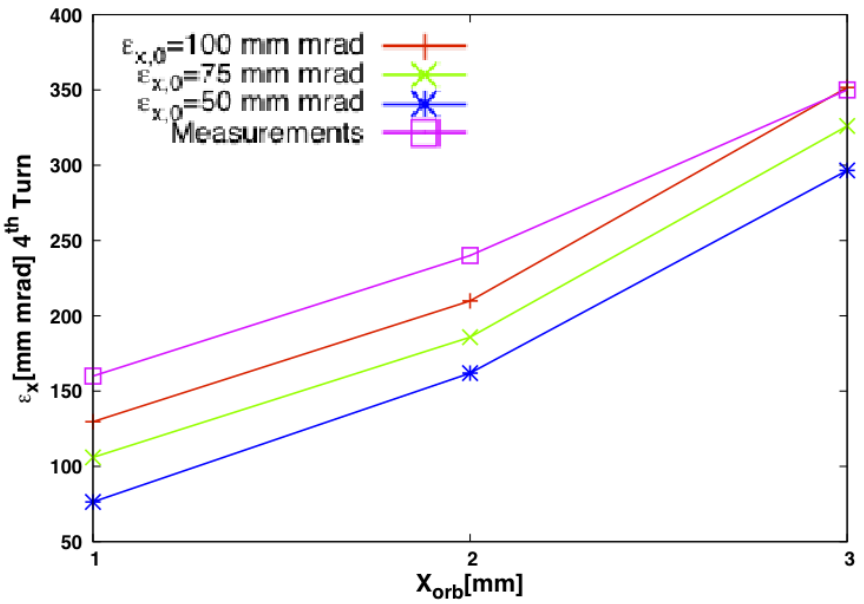
Measurement

T. Persson



Simulations

J. Barranco



verified in measurements

can be controlled by careful steering

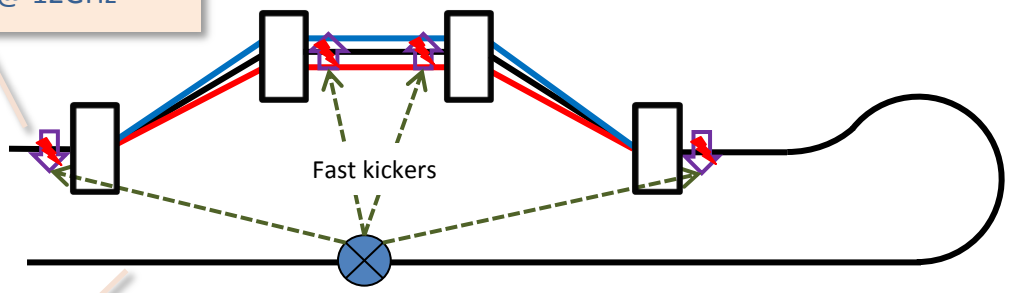
similar effect from transverse mismatch

2013-2014 Goals

- optimize recombination trajectory after DL (for factor 8) (as presented by Davide Gamba)
- automatic correction of Combiner Ring injection, orbit, and closure
- use sextupoles to reduce chromaticity
- reduce spurious dispersion

Drive Beam phase feed-forward experiment

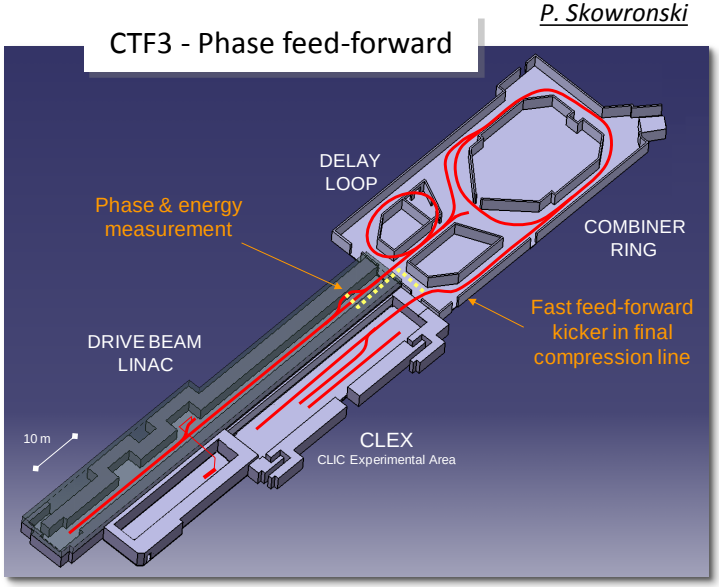
Phase stability
0.2° @ 12GHz



CLIC drive beam phase feed-forward concept

Phase stability 2.5° @ 12GHz
0.2° @ 1GHz

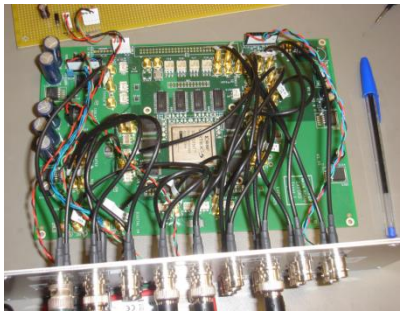
P. Skowronski



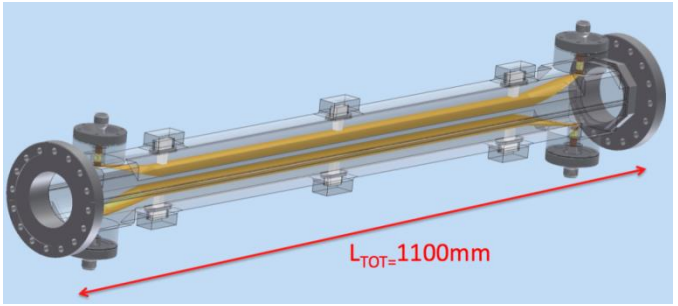
Series of related studies:

- Measure phase and energy jitter, identify sources, devise & implement cures, extrapolate to CLIC
- Show principle of CLIC fast feed-forward

FONT5 board (Oxford)



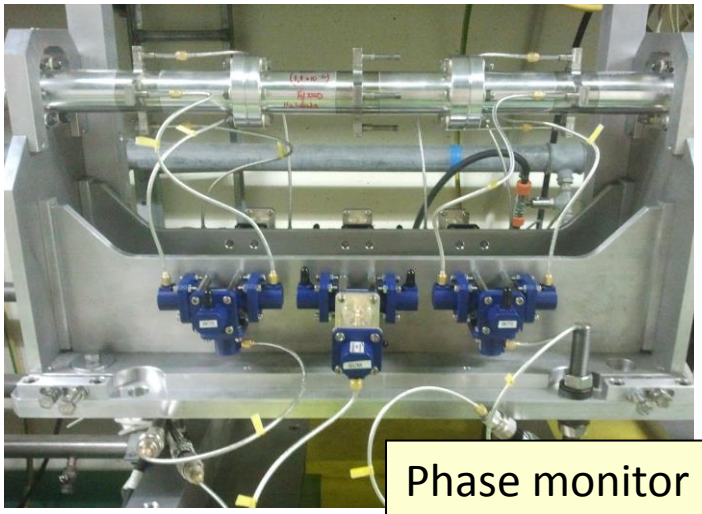
Stripline kicker (INFN-LNF)

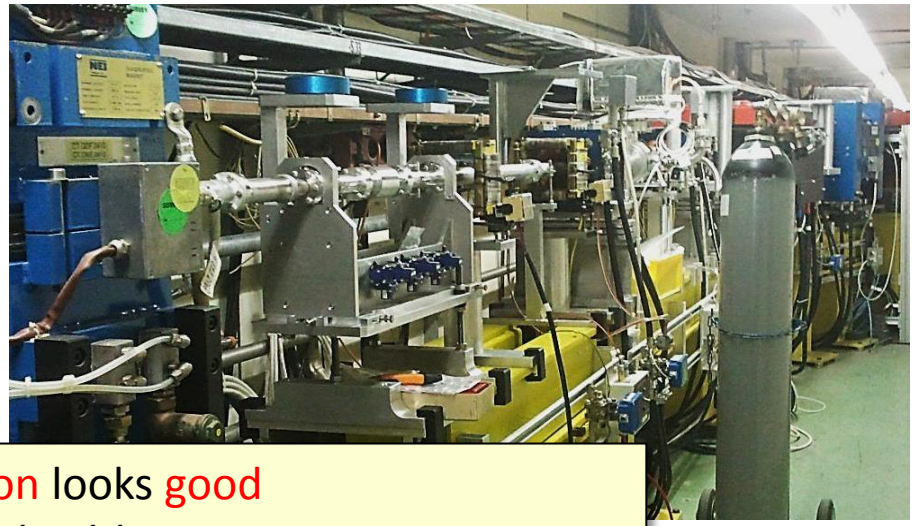


Close link to collaborating partners:

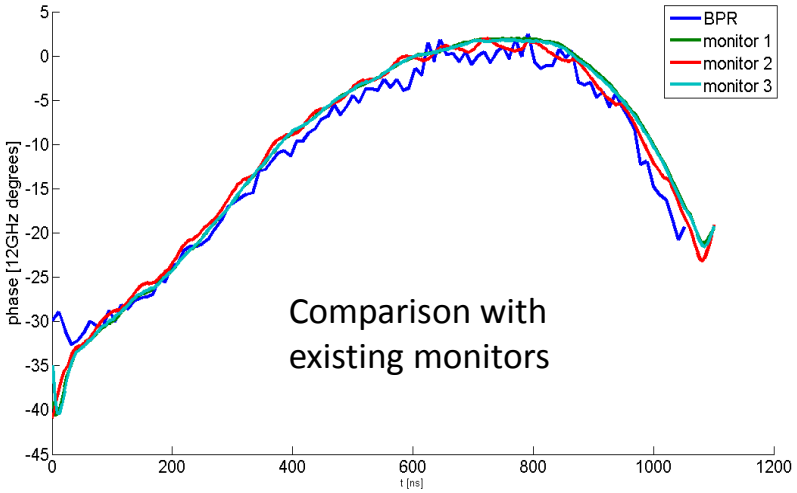
- *INFN-LNF: Phase monitors, stripline kickers*
- *Oxford University/JAI: feedback electronics, amplifiers*

Progress in phase feed-forward experiment

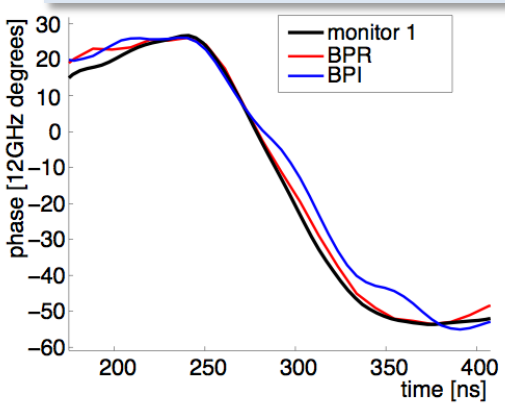


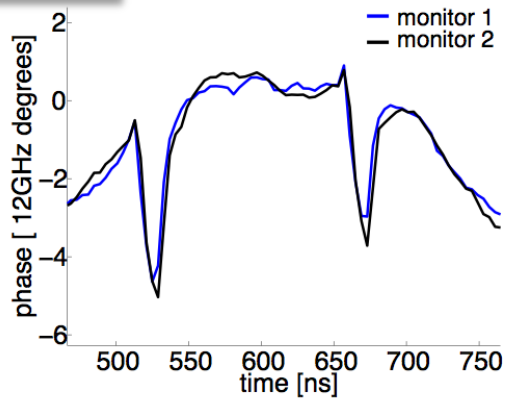


Phase monitor resolution looks good
Good indication on bandwidth
Around 0.05 degrees (12 GHz) per 1 mm vertical offset



Time Response of Phase Monitors



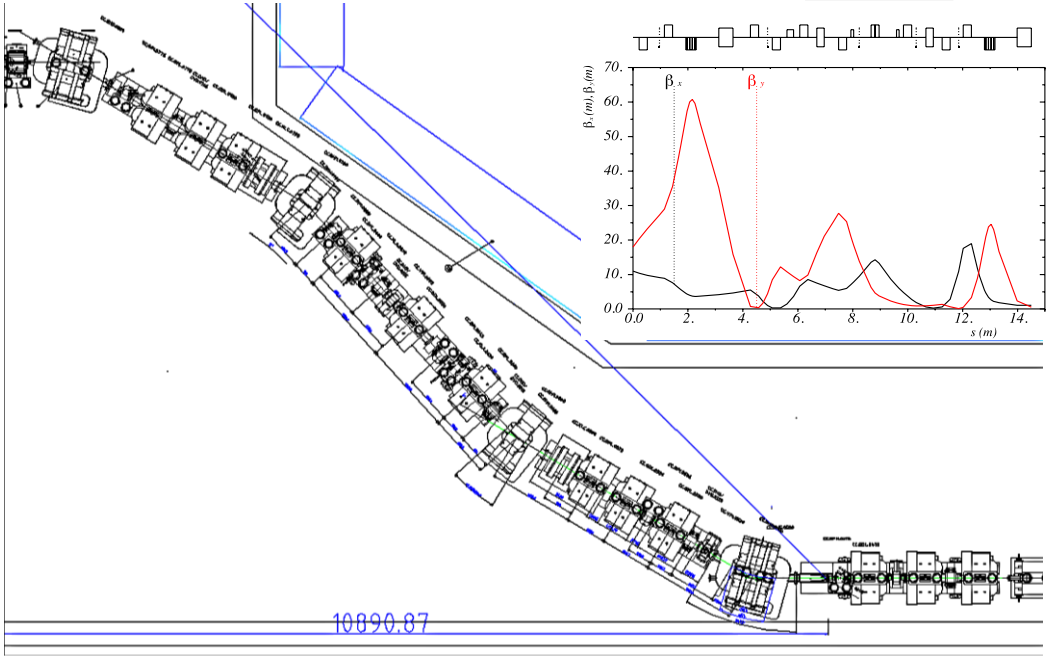


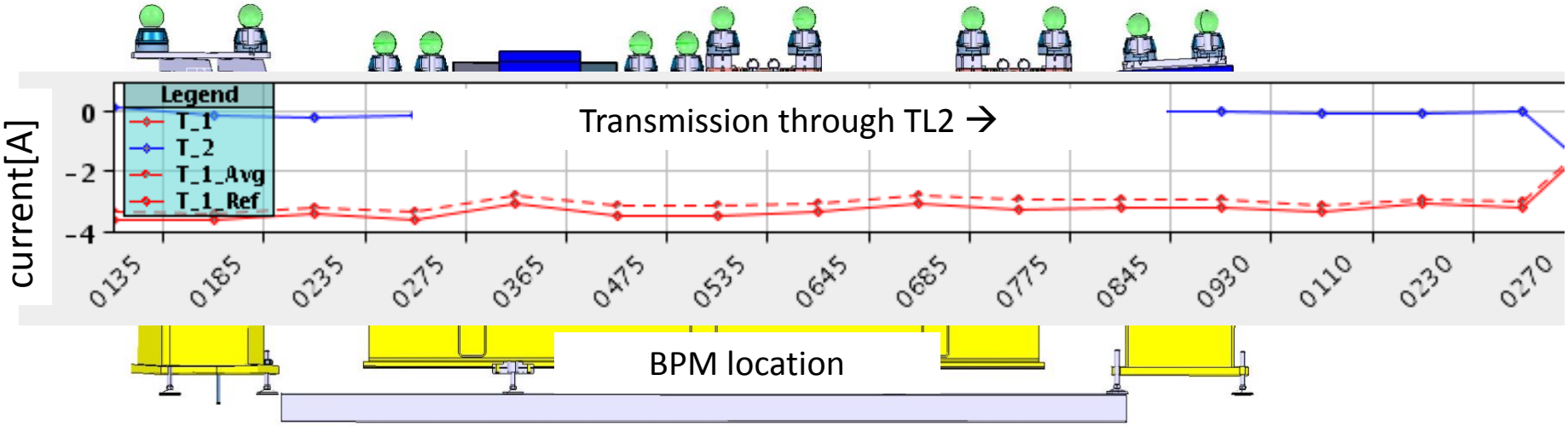
Progress in phase feed-forward experiment

- **2013 Summer shut-down:**
- modifications of TL2 beam-line
- installation of kickers
- vacuum leak in phase monitor

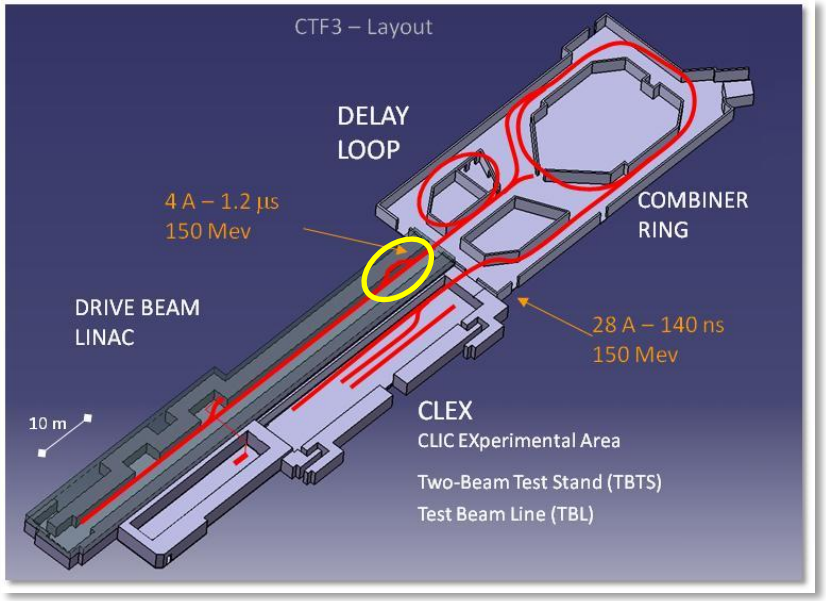
- **2013 2nd run in autumn:**
- commissioning of beam line (ongoing)
- amplifier installation
- first feed-forward tests soon

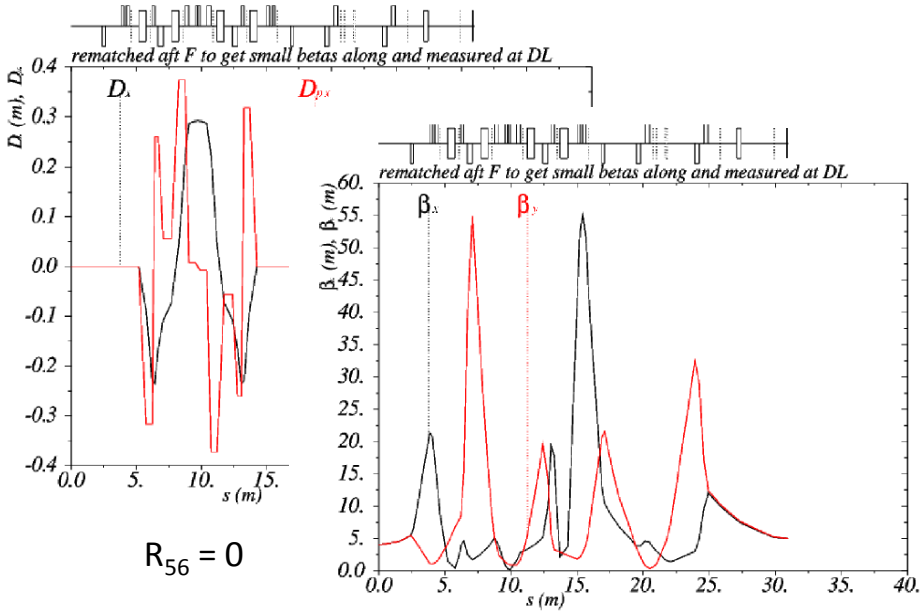
P. Skowronski





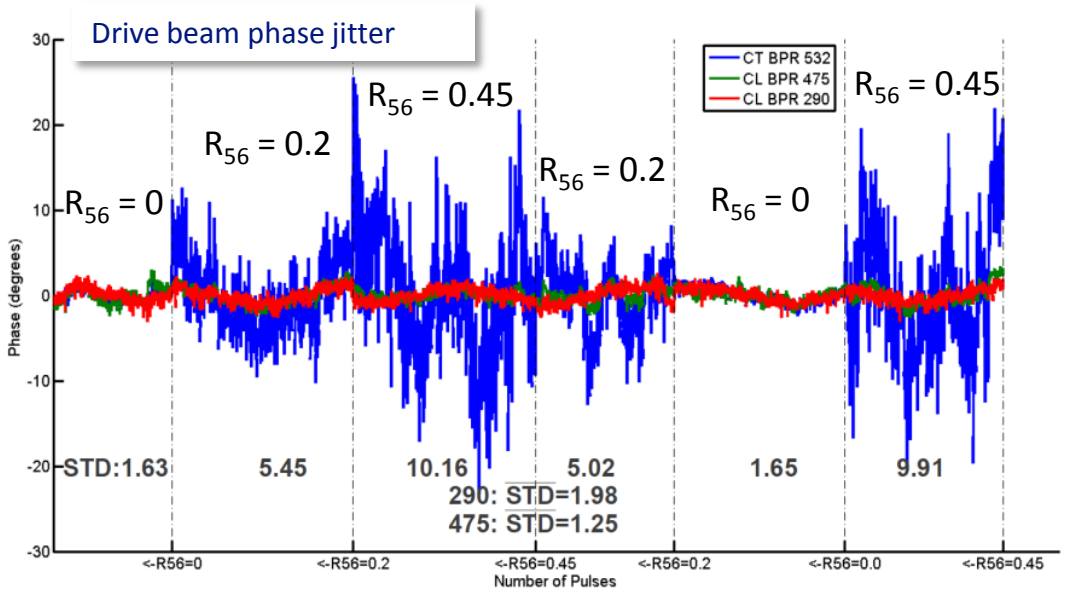
Drive Beam phase stability





$R_{56} = 0$

- New optices with low momentum compaction in the end-of-linac chicane commissioned (also spurious dispersion corrected)
- lower R_{56} optics
  => Energy fluctuations in the linac cause less phase fluctuations

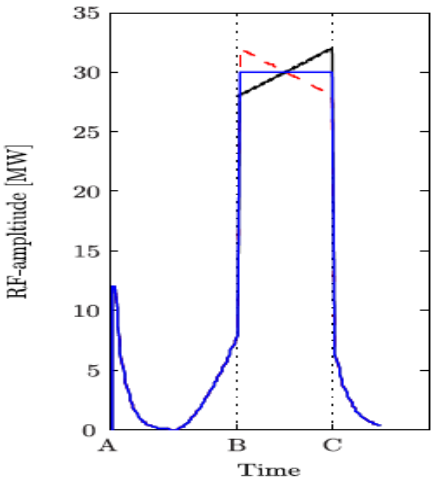


Feedbacks!!!

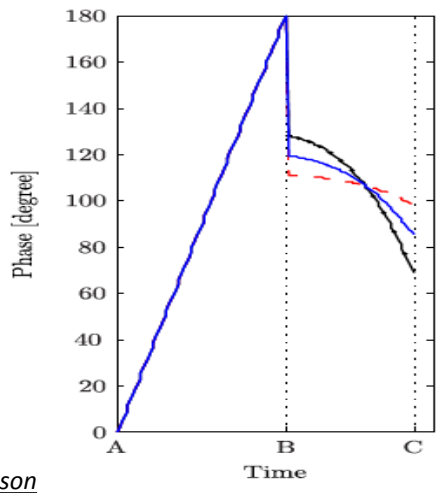
A "jungle" of feedbacks:

- RF compressor temperature
- RF pulse compression
- klystron phases
- beam current
- injector feedback (beam phase)
- beam loading
- beam energy

RF compression sensitive to temperature



Compensate by compression program

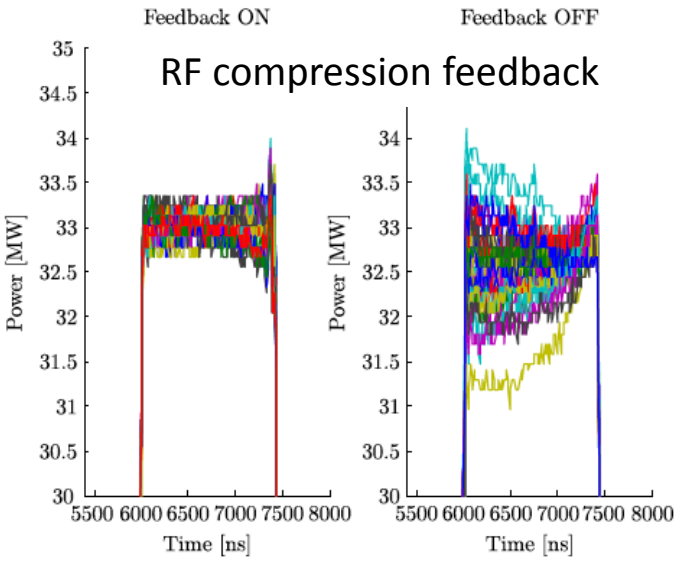


T. Persson

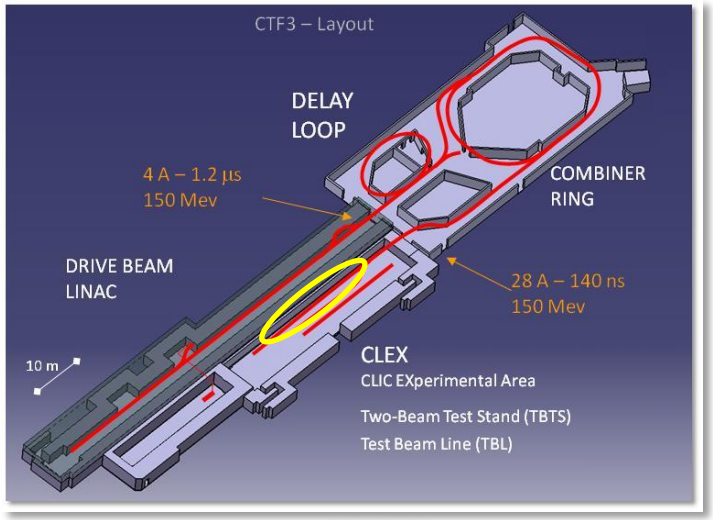
- make the machine operational and reproducible!!!

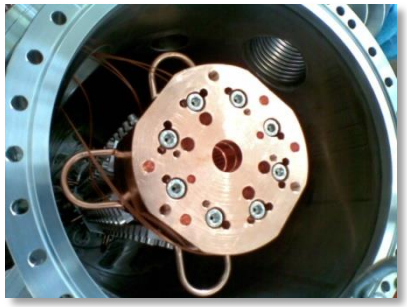
- see Tobias Persson's talk following…

RF compression feedback

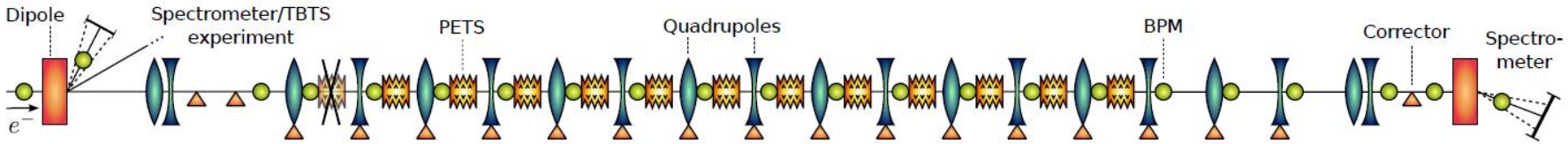


Test Beam Line - TBL





PETS tank during installation



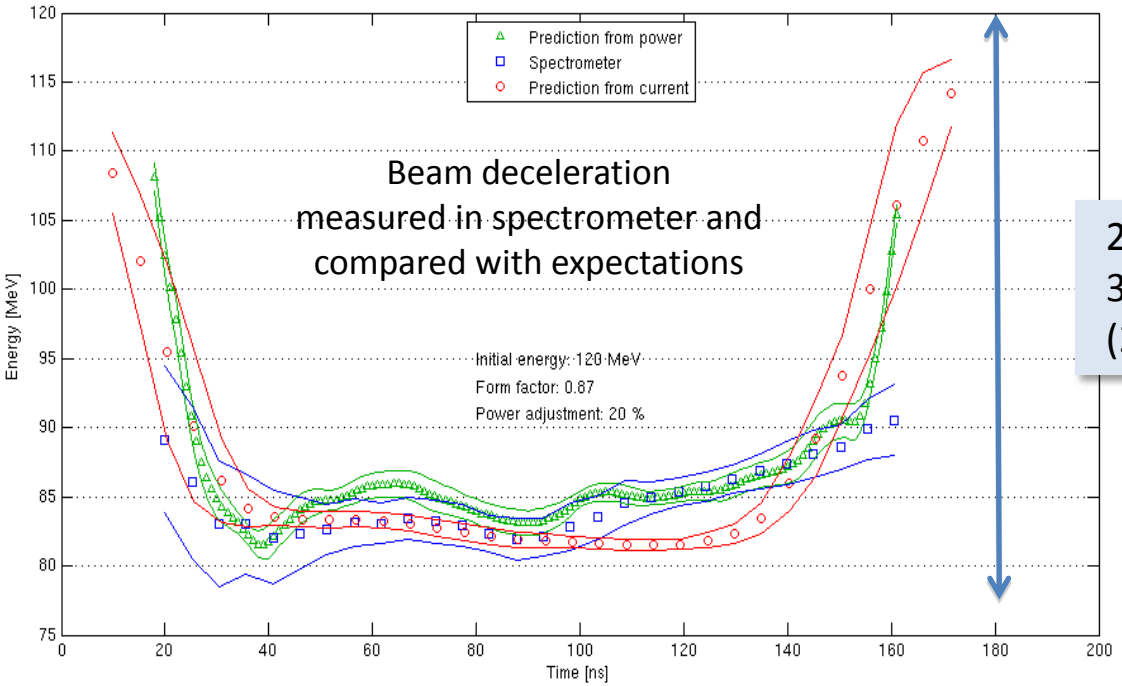
13 Power Extraction & Transfer Structures (PETS) installed and running in 2012

Full beam transport to end-of-line spectrometer, stable beam

Power produced (70 MW/PETS) fully consistent with drive beam current (21 A) and measured deceleration.

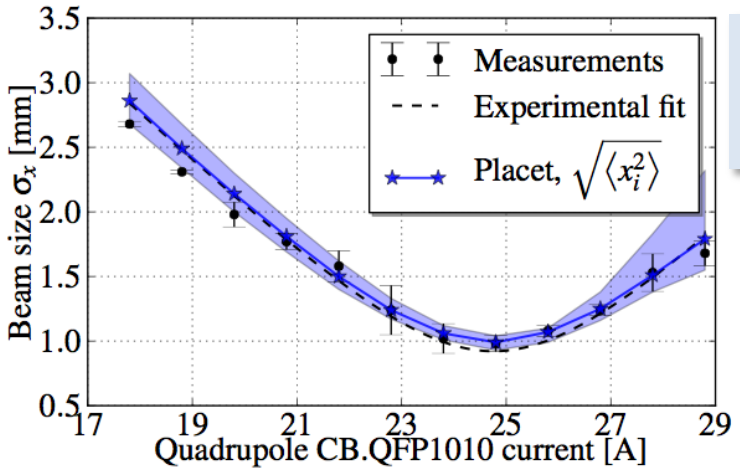
More than half a GW of 12 GHz power!

Test Beam Line - TBL



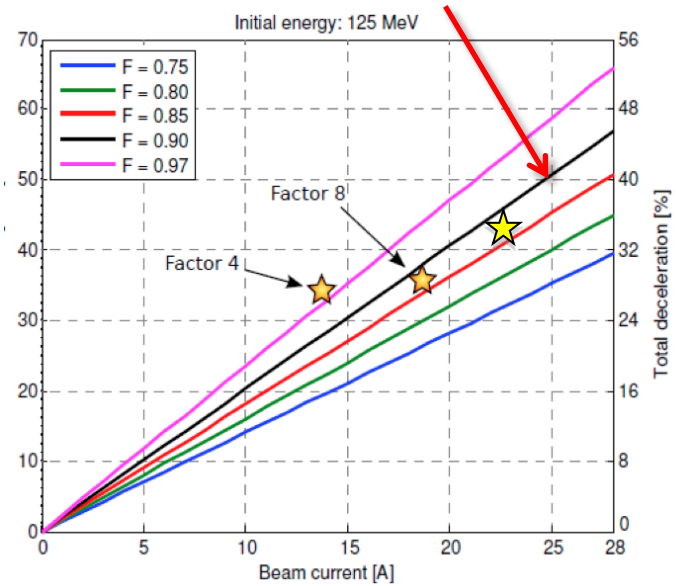
R. Lillenstol,
S. Doebert

2013 1st run:
35% deceleration
(22 A beam)



Quad scan
Downstream
end of TBL

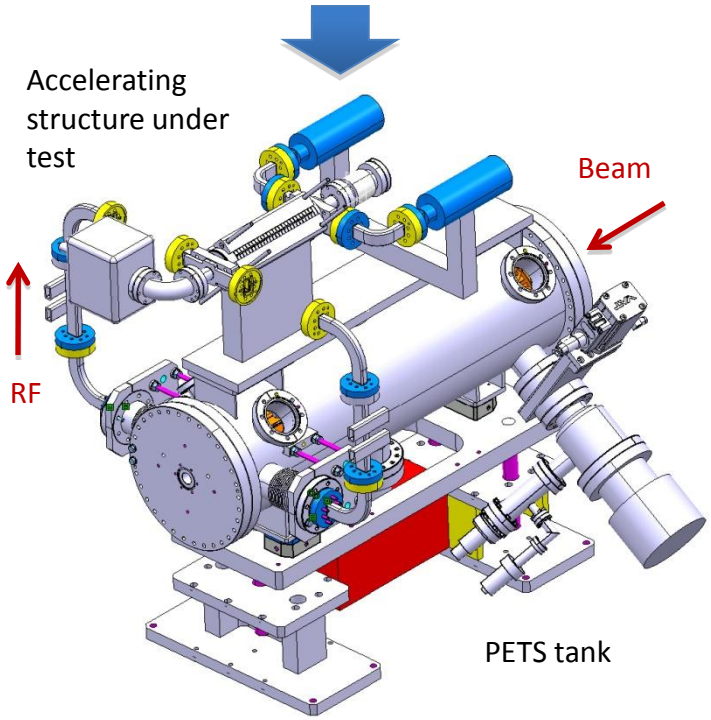
2013 Goal

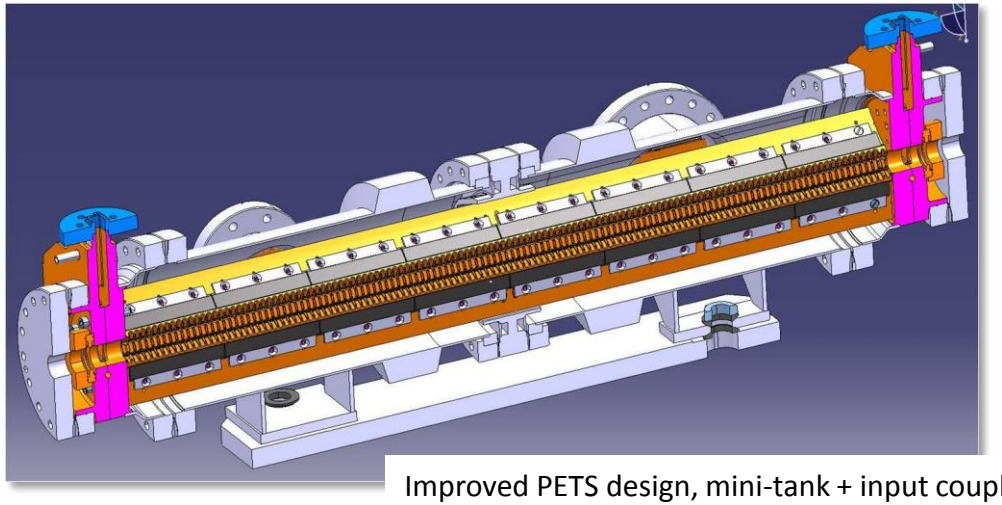


Evolution of TBL

Upgrade TBL to a test facility relevant for future CLIC program

- 12 GHz power production for structure conditioning
  - Working experience with a real decelerator
  - Beam dynamics studies, pulse shaping, feedbacks, etc
- Last batch of PETS will be adapted to high-power testing (using internal recirculation)
  - components for 2 structures being manufactured



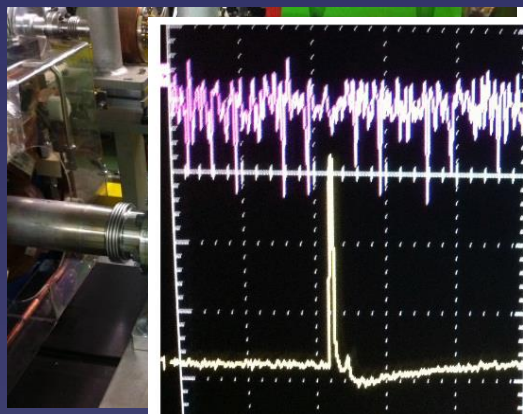


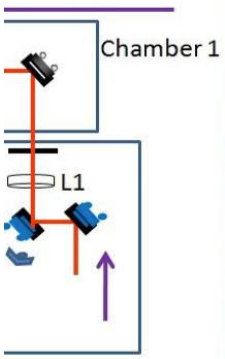
Improved PETS design, mini-tank + input coupler

CTF3 as diagnostics test bed

Electro-optic bunch profile monitor in CALIFES

(CERN-Dundee University)

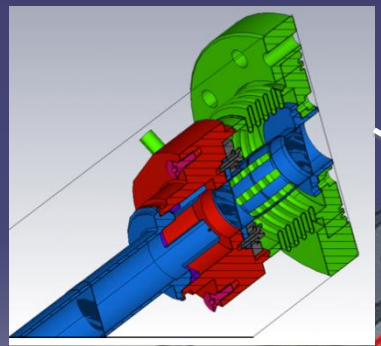


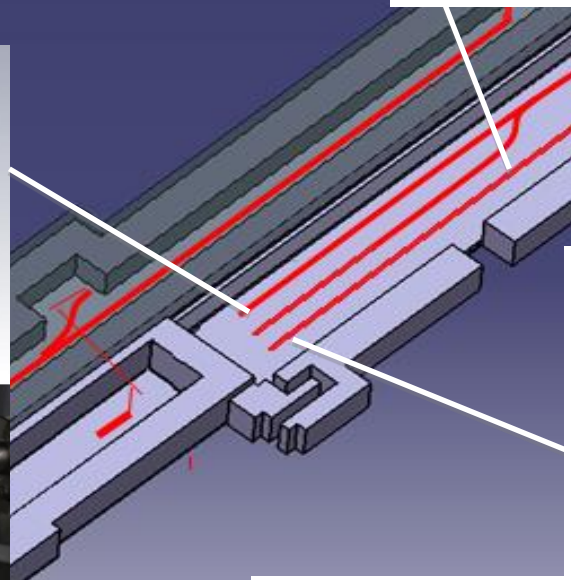


R. Pan, T. Lefebre

Stripline Drive Beam BPM in TBL

(CERN-LAPP)



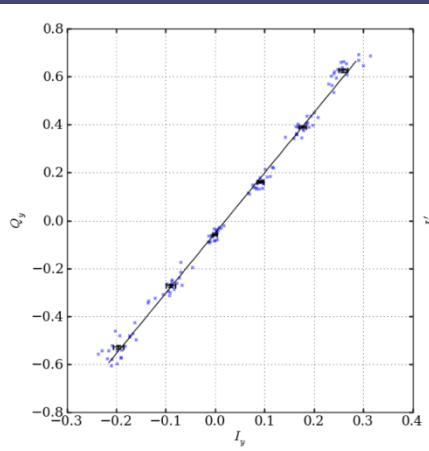


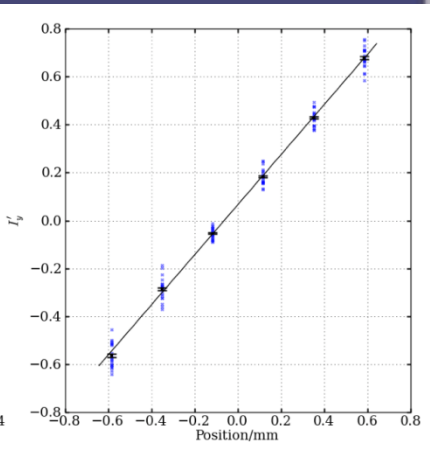
F. Cullinan, J. Towner, W. Farabolini, M. Wendt…

2013 Goals

Cavity Main Beam BPM in CALIFES/TBTS

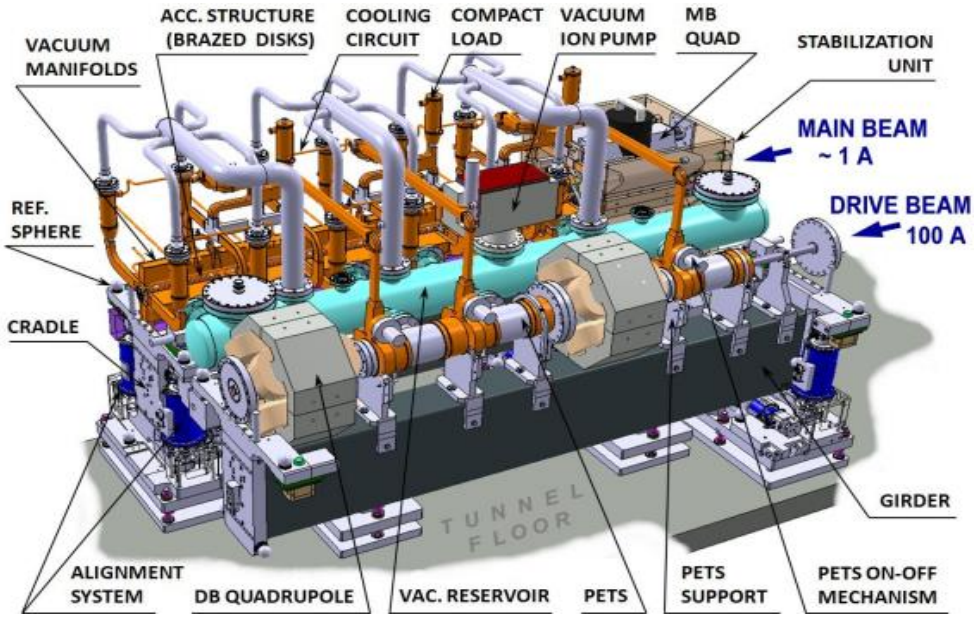
(CERN-JAI at Royal Holloway)

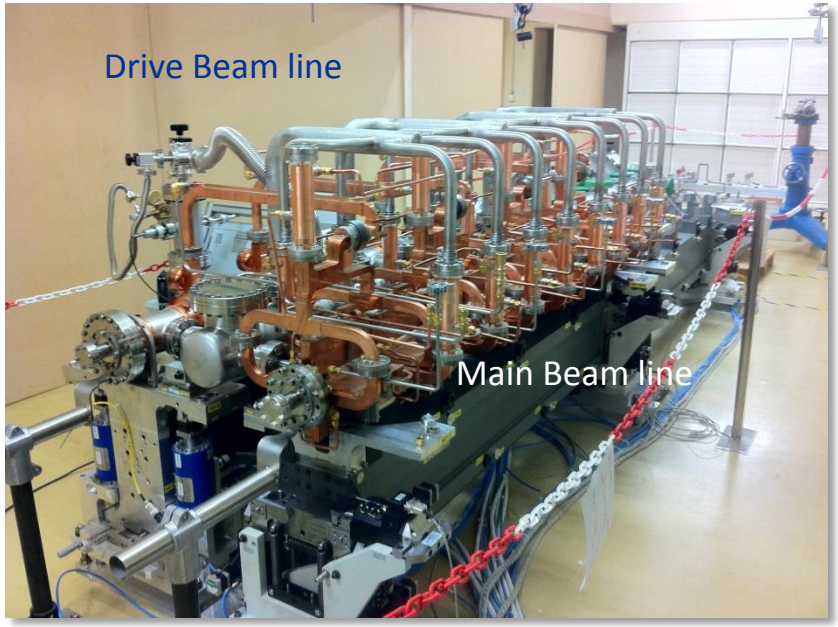




Two-Beam Modules

- From TBTS to CLIC Module studies:
  - End of TBTS program: WF monitors, beam kicks, multi-poles…
  - Module program:
    - Basic RF behaviour (system conditioning, breakdown cross talks…).
    - Basic two-beam acceleration (energy gain, set-up with beam and phasing…).
    - Active alignment and stabilization, in presence of radiation and EM noise.
    - Alignment and fiducialization - WF monitors vs BPMs.
    - Phase drifts studies (thermal effects, losses…)





Milestones 2013-2014

CTF3 Drive Beam generation & operation	★ $\varepsilon_H = \varepsilon_V \cong$ 150 µm for factor 8 ★ Charge stability $\sigma_Q \approx 10^{-3}$ for factor 8 ★ Beam diagnostics experiments (DB and MB BPMs, EO bunch length monitor)
Beam Loading experiment	★ 1st phase: commissioning with beam ★ Start 2nd phase, RF conditioning and BDR measurements (from 2014)
TBTS	★ Full conditioning and break-down rate measurements of TD24 structures - characterization of WF monitor, with high power in fundamental mode ★ Prove power production with correct pulse shape for beam loading compensation of probe beam ★ Prepare for installation and commissioning of first module (mid 2014)
TBL	★ Deceleration beyond 40% ★ TBL+ , two new PETS with ON/OFF mechanism constructed and installed (from mid 2014).
DB Phase Feed-Forward	★ Full characterization of monitors ★ Summer shut-down: installation of kickers/amplifiers ★ Autumn: first feed-forward tests

CTF3 program in 2013-2016

- What can we still learn on drive beam generation in CTF3:
  - Emittance, bunch length control for combination factor 8 (2013-2014).
  - Stability: Current/Energy, RF (amplitude and phase) and impact on drive beam, D.B. Phase stability (including feed-forward).
  - Phase stability including timing reference.
  - Control of beam losses.
  - Orbit feed-forward.

- Power production issues:
  - Stability and control of RF amplitude and phase (RF profile for main beam loading compensation, in TBTS and TBL).
  - Phase/amplitude drifts along TBL (temperature, diff. losses…).
  - Further tests on PETS on-off (switch off at full power).
  - Further tests on beam deceleration and DFS in TBL.
  - Demonstration of routine operation for power production (TBL+)

CTF3 program in 2013-2016

- From TBTS to CLIC Module studies:
  - End of TBTS program: WF monitors, beam kicks, multi-poles…
  - Module program:
    - Basic RF behaviour (system conditioning, breakdown cross talks…).
    - Basic two-beam acceleration (energy gain, set-up with beam and phasing…).
    - Active alignment and stabilization, in presence of radiation and EM noise.
    - Alignment and fiducialization - WF monitors vs BPMs.
    - Phase drifts studies (thermal effects, losses…)
- Beam-loading experiment in dog-leg
  - Influence of beam-loading on RF Breakdown rate
- Diagnostics prototype tests:
  - Drive Beam stripline BPMs
  - Main Beam BPMs
  - EO bunch length monitor
  - Beam Loss Monitors
  - …

CTF3 experimental program 2013-2016

Preliminary

	2013				2014				2015				2016			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Phase feed-forward & stability studies	Initial studies, commissioning of phase monitors		Installation	Feed-forward commissioning		Installation work in CLEX	Complete commissioning & 1st run	shut down	2nd run including fs timing?				shut down	3nd run improved system transverse feed-forward?		
Beam Loading / BDR experiment	Beam line commissioning		Installation	beam tests, X-box not available		1st run	X-box not available	shut down	2nd run (Alternating with normal operation)			X-box not available	shut down	3rd run ? (Alternating with normal operation)		
Two-Beam Module	TBTS		shut down	TBTS program completion WF monitors, tests on RF shaping		Installation of TBM	TBM commissioning	shut down	Complete commissioning & 1st run				shut down	2nd run module upgraded ?		
TBL decelerator	Deceleration to 35%		shut down	Deceleration to 40% 1st tests on RF shaping		Installation of new tank 1	Deceleration to 50% RF shaping experiment	Installation of new tank 2	RF conditioning & testing with drive beam				shut down	RF conditioning & testing with drive beam		
Diagnostics tests	Commissioning of EO bunch profile monitor DB BPM, MB BMP		Installation, consolidation	Testing of EO bunch profile monitor, DB BPM, MB BMP		Installation	Available beam time	shut down	Available beam time				shut down	Available beam time		

Now

- still an exciting interesting program ahead!!!

Long term perspectives for CTF3

Definitely want to stop CTF3 at some point (now end 2016!)

Gradual evolution towards DB front-end delayed =>

- No local (CERN) real testing capability (diagnostics and components) beyond 2016
- no way to test new generation modules with beam (budget constraints)

Potential use of CTF3 beyond present plan:

- Generic test facility (reduced to CALIFES?) for diagnostics/components
- Refurbished as lepton injection chain at CERN (SPS damping ring tests, plasma wake-field experiments in AWAKE, …)
- Extend dog-leg tests? Dog-leg for X-band testing?

It may be wise to keep open the possibility to re-start CTF3 after 2016 if needed. However, may want to re-use CTF3 buildings and equipment (Front-End, 3 GHz testing…)

For sure we need to develop a plan on CTF3 phasing out.