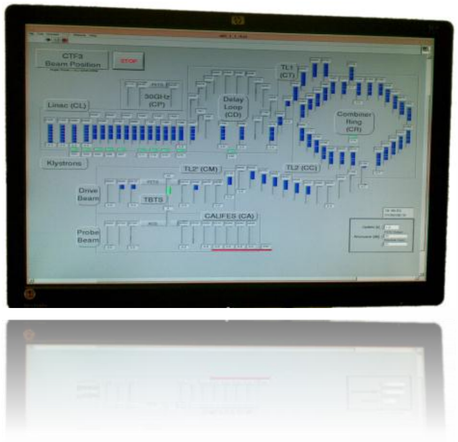


CTF3 results, status and plans in next phase

R. Corsini for the CTF3 Team

Talk Outline:

1. Status of CLIC feasibility benchmarks in CTF3 and 2011 Highlights
2. Update on 2012 run, last results and schedule
3. Plans for 2013 and beyond

CLIC Feasibility Benchmarks

System	Item	Feasibility Issue	Unit	Nominal	Achieved	How	Feasibility	Comments
Two Beam Acceleration	Drive beam generation	Fully loaded accel effic	%	97	95	CTF3	✓	Novel scheme fully demonstrated in CTF3 in spite of lower current since beam dynamics more sensitive than nominal due to lower energy (250MeV/2Gev)
		Freq&Current multipl	-	2*3*4	2*4	CTF3	✓	
		Combined beam current (12 GHz)	A	4.5*24=100	3.5*8=28	CTF3	✓	
		Combined pulse length (12 GHz)	nsec	240	140	CTF3	✓	
		Intensity stability	1.E-03	0.75	< 0.6	CTF3	✓	End of DBA. To be demonstrated for combined beam in 2011
		Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design
	Beam Driven RF power generation	PETS RF Power	MW	130	>130	TBTS/SLAC	✓	BD rate at nominal power and pulse lenght, measured on Klystron driven PETS. Beam driven tests under way in CTF3
		PETS Pulse length	ns	170	>170	TBTS/SLAC	✓	
		PETS Breakdown rate	/m	< 1·10-7	≤ 2.4 10-7	TBTS/SLAC	✓	
		PETS ON/OFF	-	@ 50Hz	-	CTF3/TBTS	2011 ✓	Prototype under fabrication for tests with beam
		Drive beam to RF efficiency	%	90%	-	CTF3/TBL	2012 ✓	TBL with 8 (16) PETS in 2011(12) for 30(50%) efficiency. Benchmark beam simulation for safe extrapolation of high efficiency at high drive beam energy(2GeV).
		RF pulse shape control	%	< 0.1%	-	CTF3/TBTS	2011-2012	
	Accelerating Structures (CAS)	Structure Acc field	MV/m	100	100	CTF3 Test Stand, SLAC, KEK	✓	Nominal performances of 3 structures without damping. [illegible] RF [illegible]
		Structure Flat Top Pulse length	ns	170	170		✓	
		Structure Breakdown rate	/m MV/m.ns	< 3·10-7	5·10-5(D)		2011 ✓	
		Rf to beam transfer efficiency	%	27	15		20[illegible] ✓	
	Two Beam Acceleration	Power producton and probe beam acceleration in Two beam module	MV/m - ns	100 - 170	106 - 170	TBTS	2011 ✓	Power production in Two Beam Test Stand (TBTS); Probe beam acceleration by Two Beam Test Stand(TBTS)
		Drive to main beam timing stability	psec	0.05	-	CTF3	2012	
		Main to main beam timing stability	psec	0.07	-	XFEL?	2012	
Ultra low beam emittance & sizes	Ultra low Emittances	Emittance generation H/V	nm	500/5	3000/12	ATF, NSLS/SLS + simulation	✓	Damping Ring design nom perf. Relax emitt achieved ATF
		Emittance preservation: Blow-up	nm	160/15	160/15		2011-12	Simulation + alignment/stability
	Alignment	Main Linac components	microns	15	10 (princ.)	Alignement & Mod.Test Bench	2011	Principle demonstrated in CTF2, to be adapted to long distances and integrated in Two Beam Module in 2010
		Final-Doublet	microns	2 to 8			2011	
	Vertical stabilisation	Quad Main Linac	nm>1 Hz	1.5	0.13 (principle)	Stabilisation Test Bench	2011-12	Adaptation to quad prototype and detector environment in 2010. Integrated in Two Beam Module with beam till 2012.
		Final Doublet (assuming feedbacks)	nm>4 Hz	0.2				
Operation and Machine Protection System (MPS)		72MW@2.4GeV main beam power of 13MW@1.5TeV				CTF3 simulations	2011	Report integrating LHC experience under preparation

Nextef – RF test stand KEK

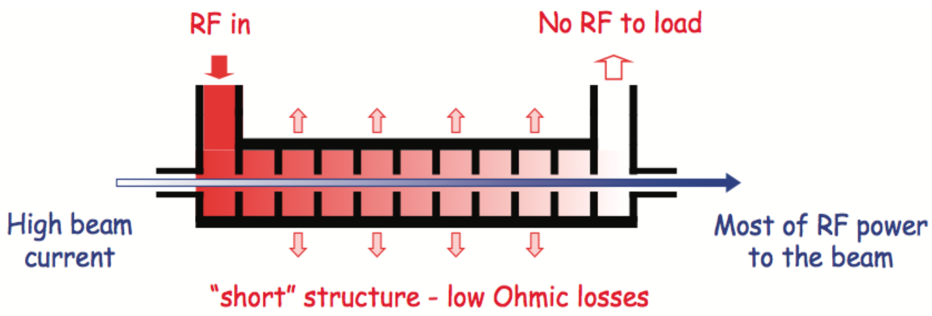
CTF3

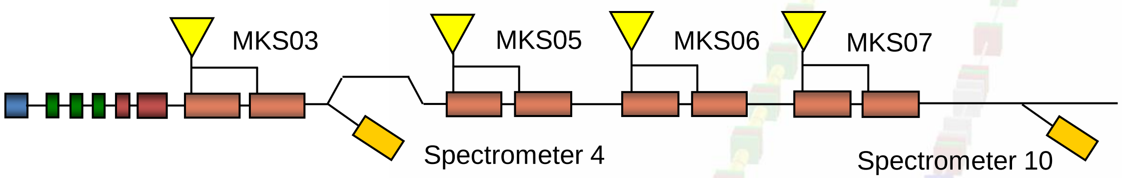
RF Test Stands
SLAC – KEK -CERN

Technical system tests and simulations

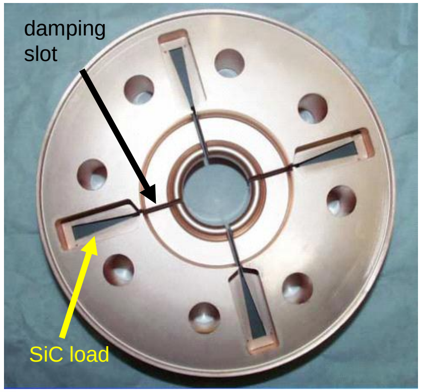
Achievements – Drive Beam Generation

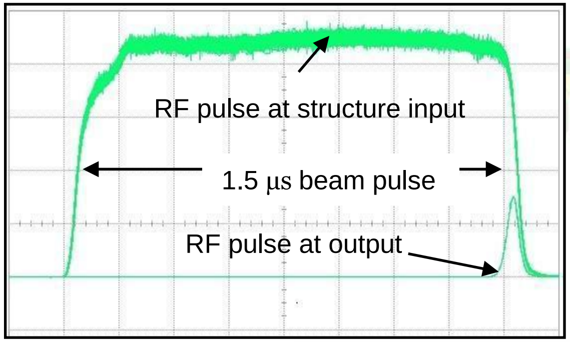
Item	Feasibility Issue	Unit	Nominal	Achieved	How	Feasibility	Comments
Drive beam generation	Fully loaded accel effic	%	97	95	CTF3	✓	Novel scheme fully demonstrated in CTF3 in spite of lower current since beam dynamics more sensitive than nominal due to lower energy (250MeV/2Gev)
	Freq&Current multipl	-	2*3*4	2*4	CTF3	✓	
	Combined beam current (12 GHz)	A	4.5*24=100	3.5*8=28	CTF3	✓	
	Combined pulse length (12 GHz)	nsec	240	140	CTF3	✓	
	Intensity stability	1.E-03	0.75	< 0.6	CTF3	✓	End of DBA. To be demonstrated for combined beam in 2011
	Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design





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





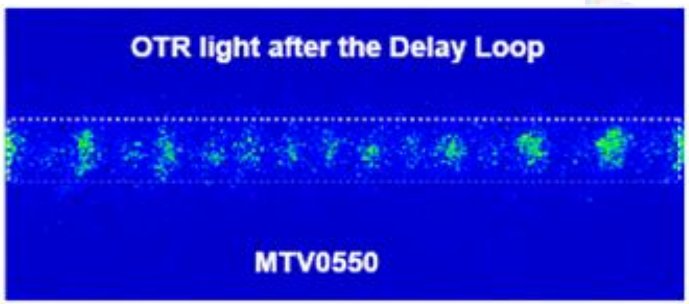
High current, full-loaded linac operation

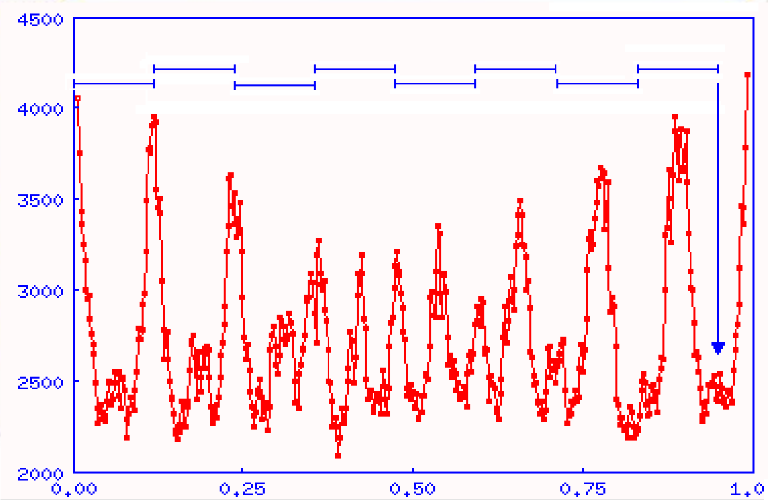
- 95 % RF to beam efficiency measured
- No instabilities

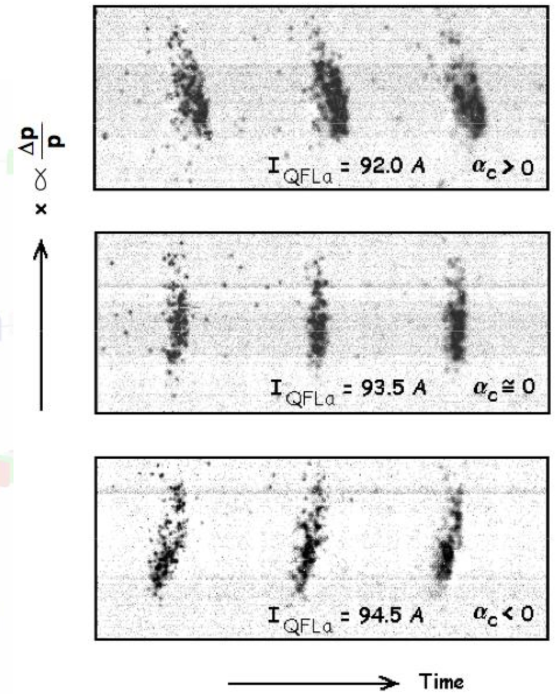
Achievements – Drive Beam Generation

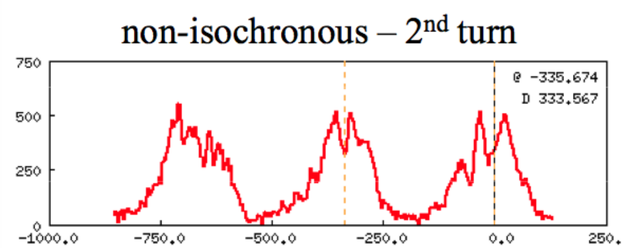
Beam recombination

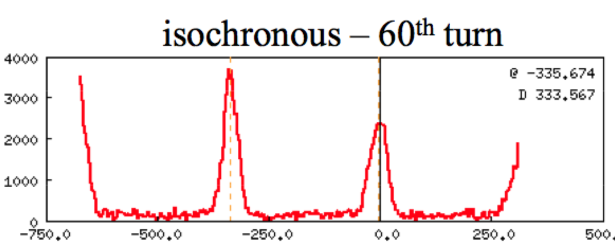
- Fast bunch phase switch in SHB system
- Operation of isochronous rings and beam lines



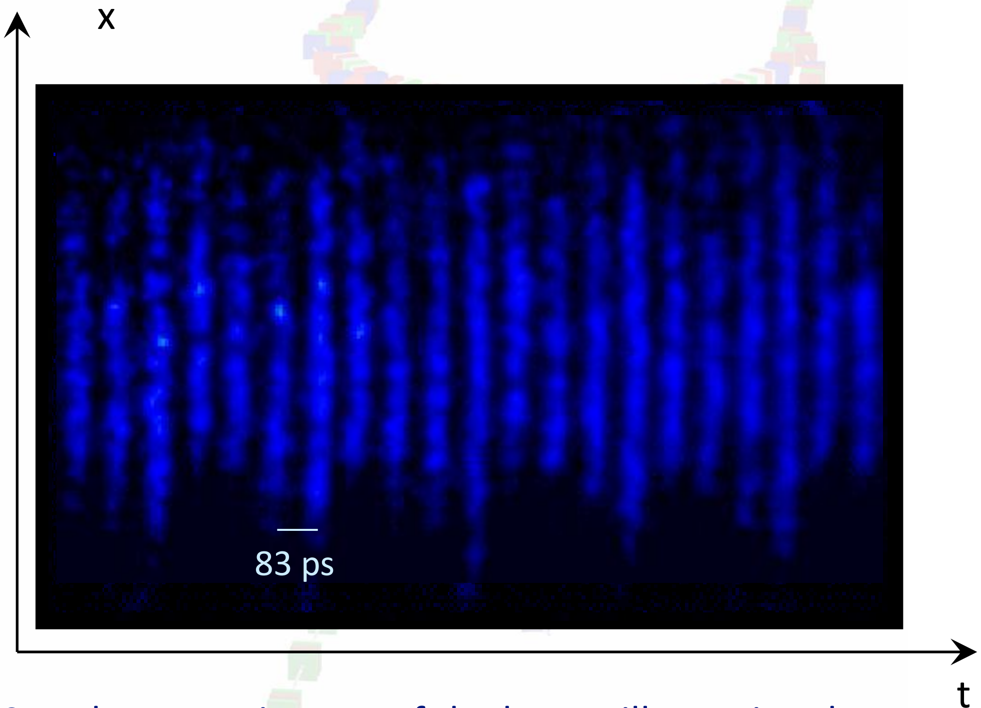








Achievements – Drive Beam Generation

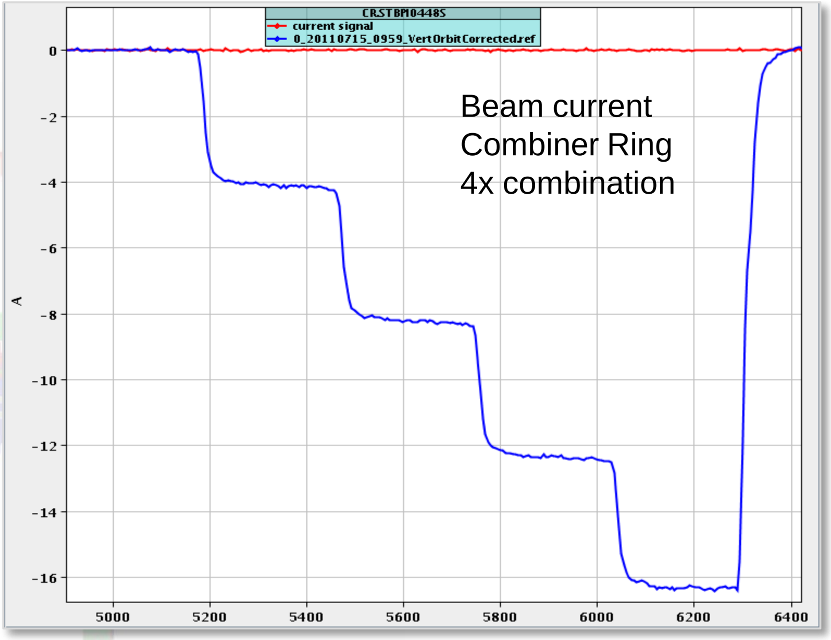


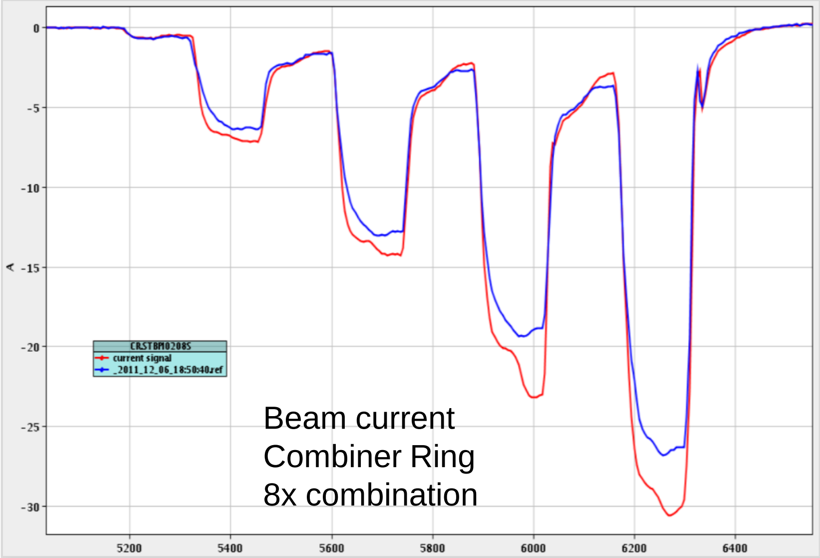
Streak camera images of the beam, illustrating the bunch combination process in the ring

Achievements – Drive Beam Generation

Beam recombination

- Factor 4 - OK
- Factor 8
  - basic principle demonstrated
  - need improvement (pulse shape, stability, losses, emittance)





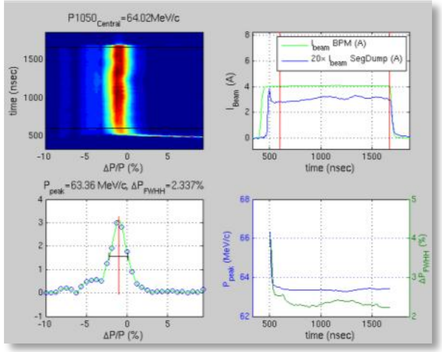
Beam recombination - Emittance

Best results in CLEX
for factor 4: ε_H= 250 um ε_V= 140 um
for factor 8: ε_H= 640 um ε_V= 170 um

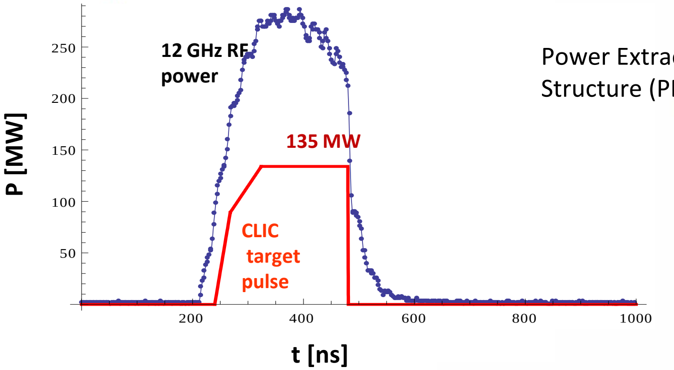
Different turns are ~ ok, no unknown effects
Emittance increase due to non perfect orbit

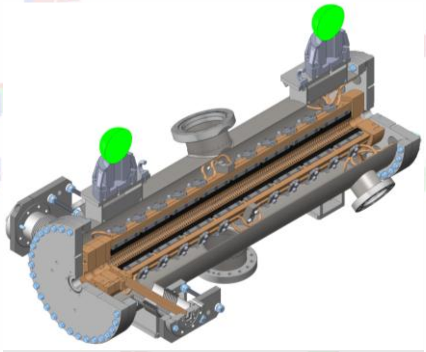
CTF3 highlights - 2011

- Many improvements on optics, hardware, feed-backs, beam stability, reproducibility…



- PETS operation to power levels (about 250 MW) well above CLIC goal, at nominal CLIC pulse length.

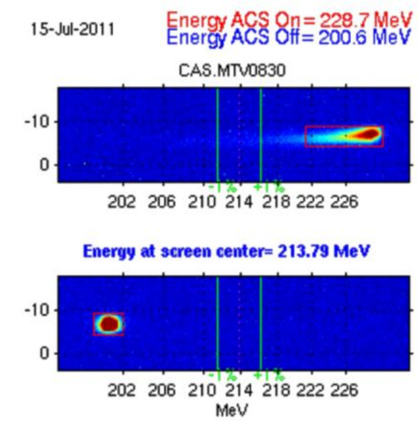




Power Extraction Structure (PETS)

- First successful test of PETS with on-off mechanism

Two-beam acceleration in TBTS



- Measured gradient in two-beam acceleration test 145 MV/m (CLIC nominal gradient of 100 MV/m)

- Nine PETS tanks installed in the Test Beam Line (TBL), 21 A decelerated by ~ 26%, matching well with expectations

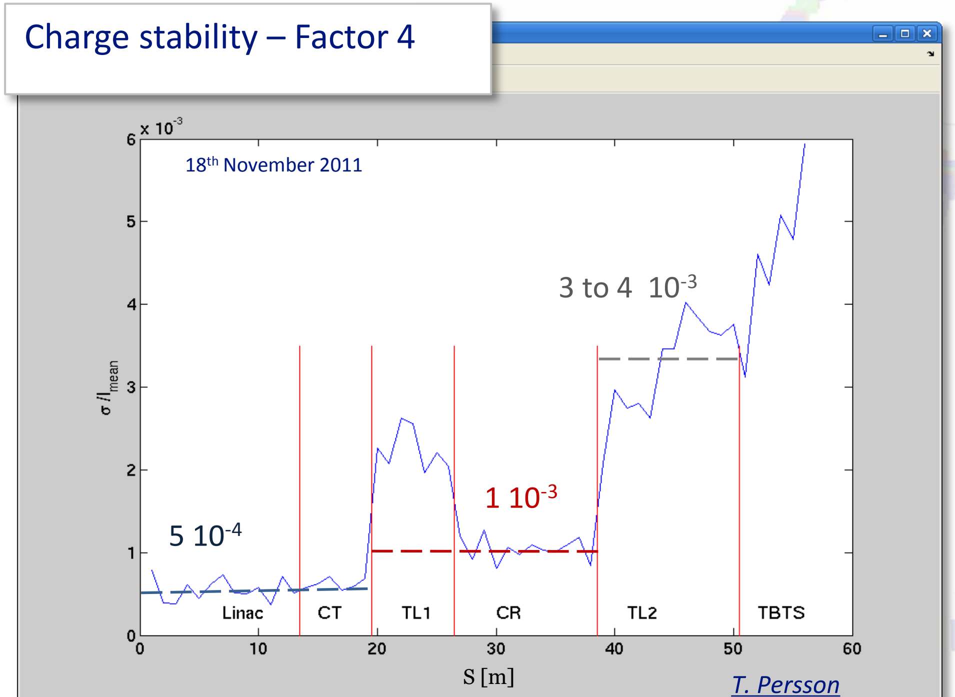
Test Beam Line (TBL) in CTF3

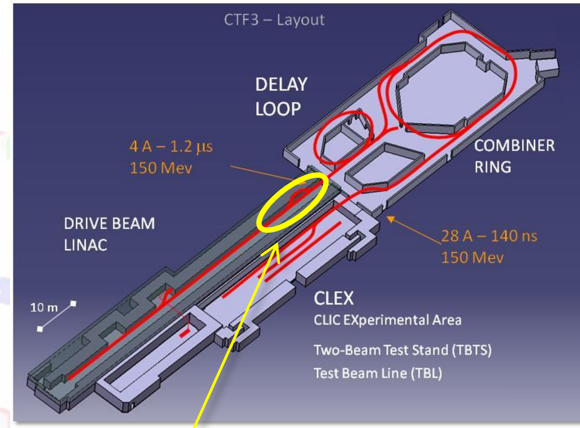
CTF3 Stability

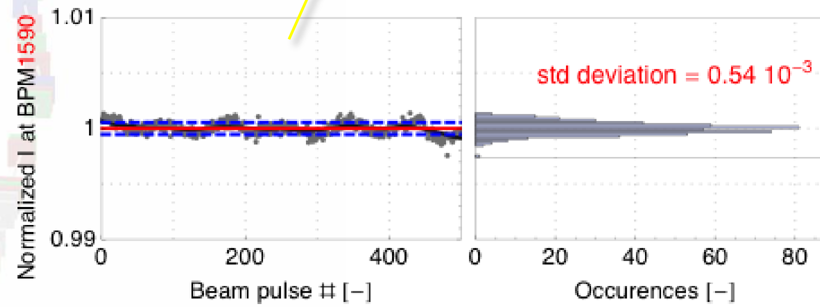
Repeatability and long term current stability improved

Pulse charge stability measured at end of the linac better than CLIC requirements

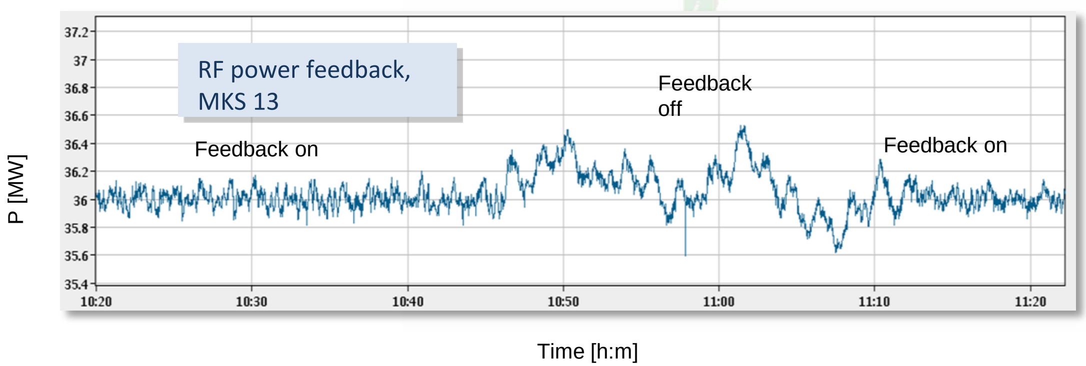
Charge stability – Factor 4







G. Sterbini



Several feed-back loops operational, for temperature, RF phase and power and gun current.

F. Tecker, P. Skowronski, T. Persson

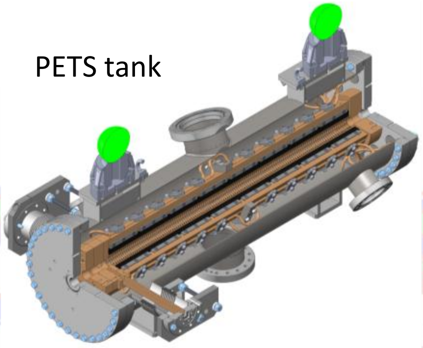
CTF3 Test Beam Line (TBL)

Nine PETS tanks installed and commissioned in 2011
(13 PETS installed in 2012)

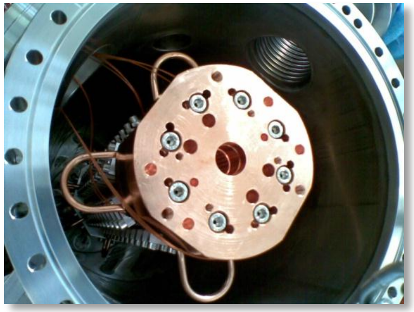
Full beam transport to end-of-line spectrometer, stable beam

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

PETS tank

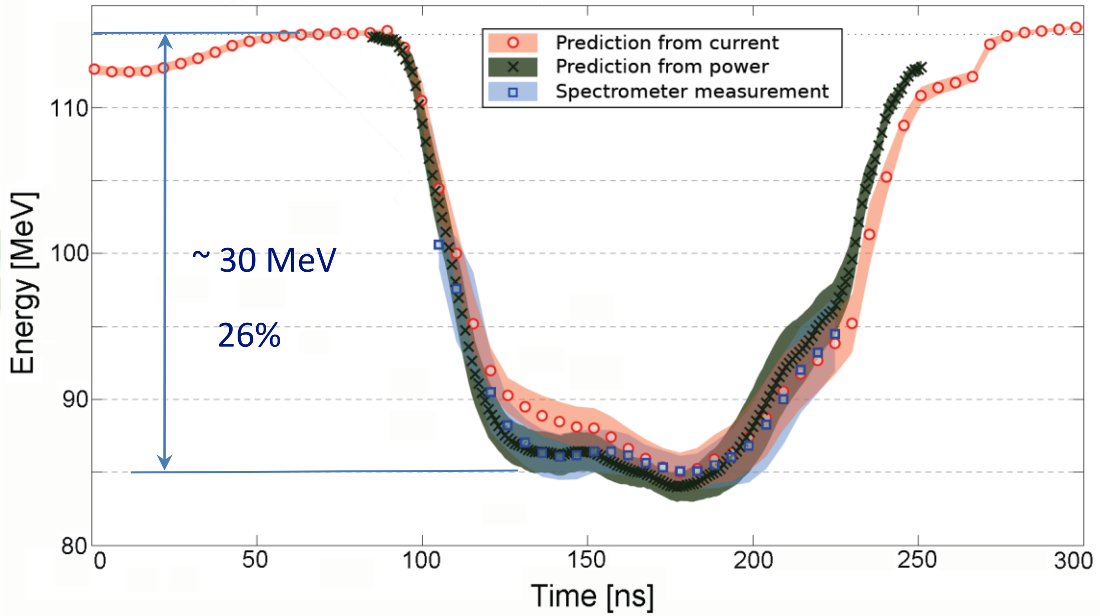


PETS tank during installation



TBL line in CLEX

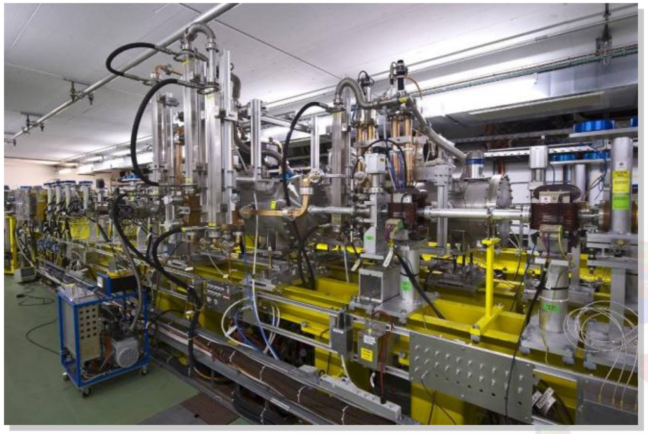
Beam deceleration,
measured in spectrometer and compared with expectations

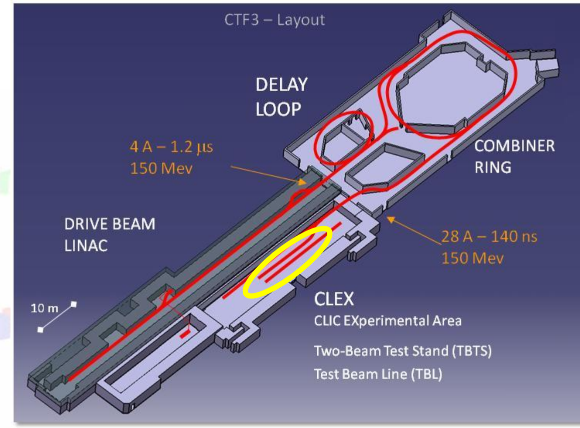


S. Doebert, R. Lillenstol

More than half a GW of 12 GHz power!

CTF3 Two-Beam Test Stand (TBTS) – power production

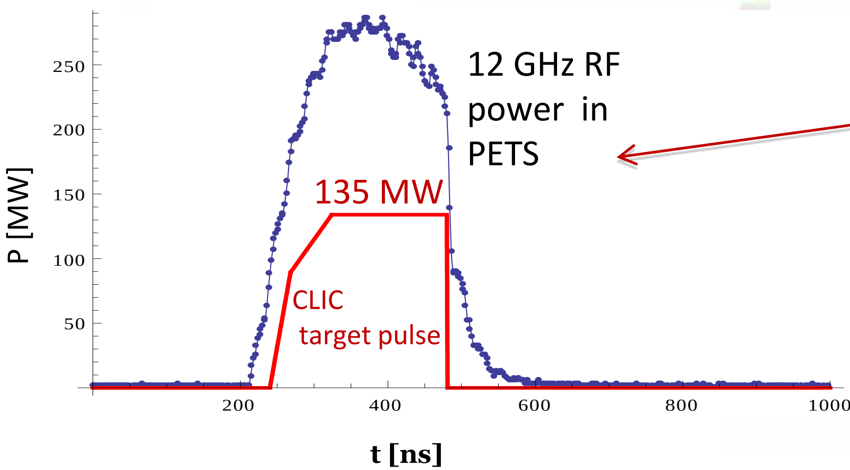


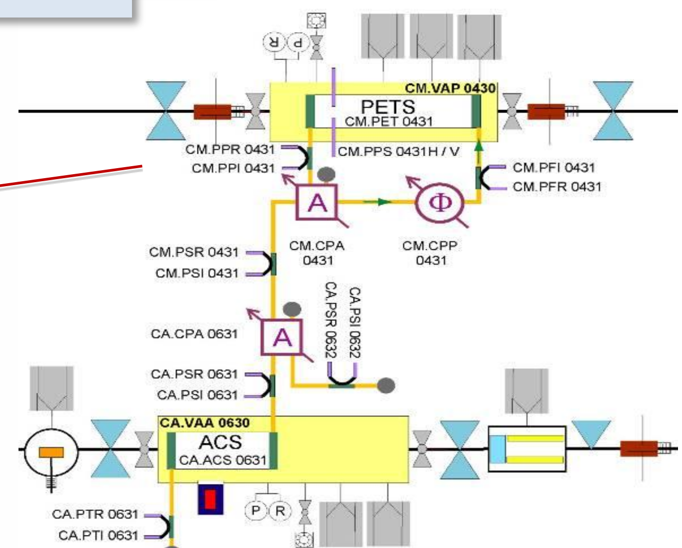


PETS operated routinely above **200 MW** peak RF power

providing reliably pulses ~ 100 MW peak to accelerating structure.

About twice the power needed to demonstrate 100 MV/m acceleration in a two-beam experiment with TD24 structure.





R. Ruber,
I. Syratchev

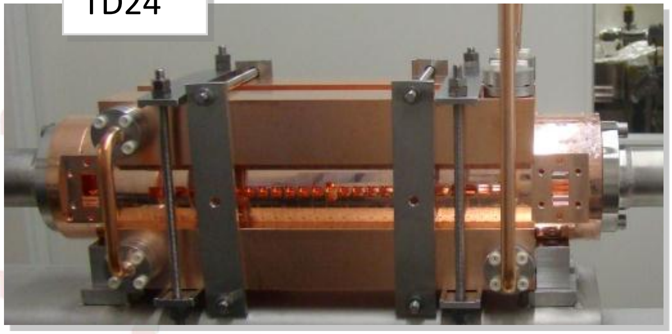
TBTS – Two-beam acceleration

Two-Beam Acceleration demonstration in TBTS

Up to 145 MV/m measured gradient

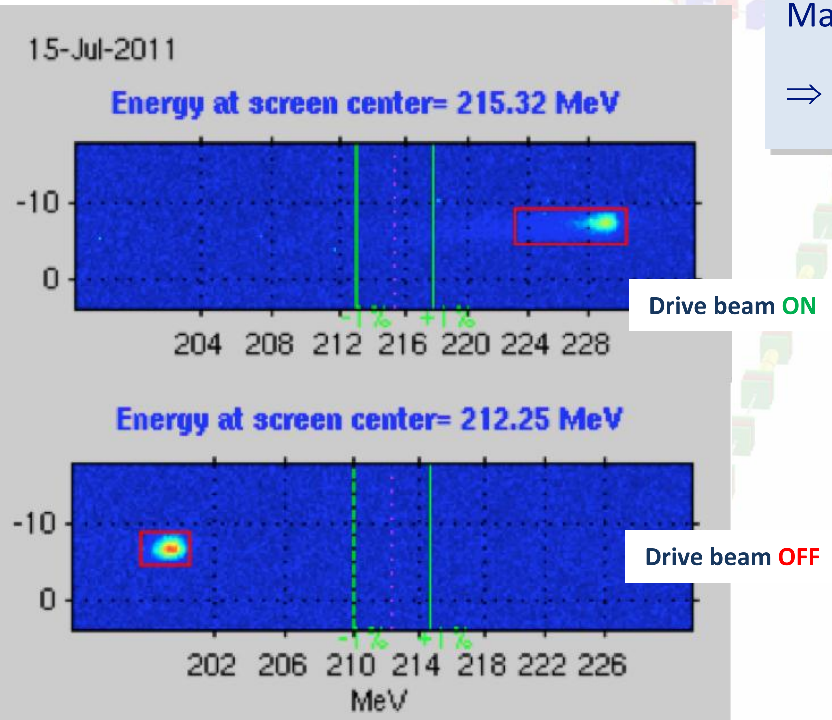
Good agreement with expectations (power vs. gradient)

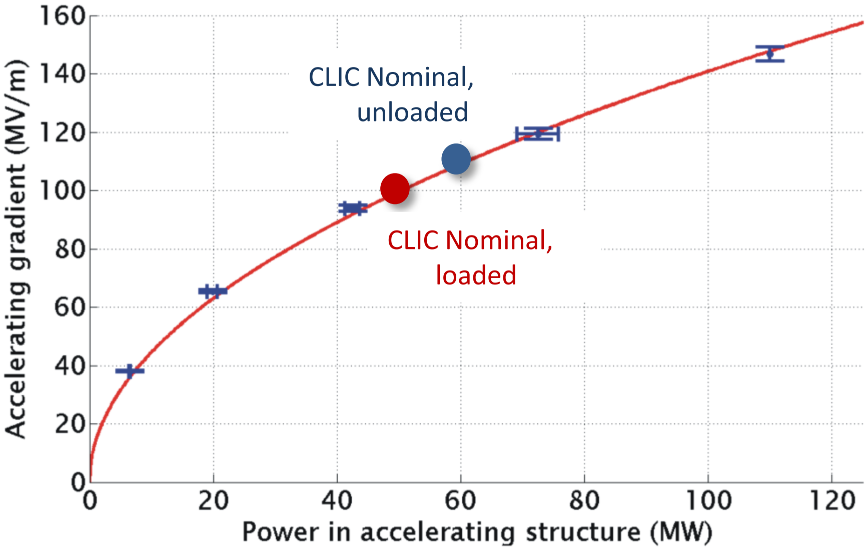
TD24



Maximum stable probe beam acceleration measured: 31 MeV

⇒ Corresponding to a gradient of **145 MV/m**



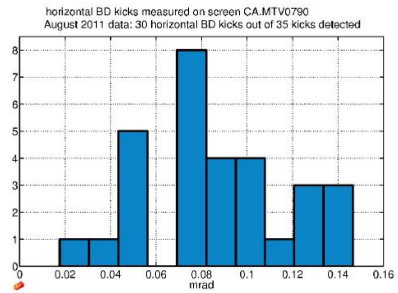


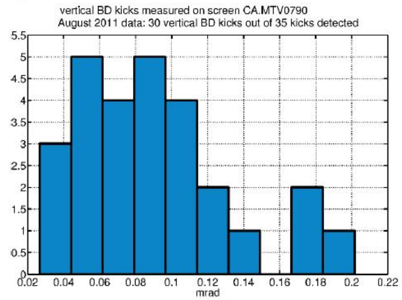
W. Farabolini, J. Barranco

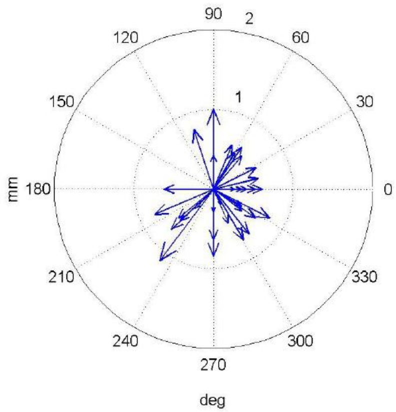
- kicks on horizontal and vertical planes between 0.02 and 0.2 mrad;
- kicks corresponding to a transverse momentum between 10 and 40 keV/c (measurements at NLCTA within 30 keV/c, Dolgashev et al., LINAC 2004);

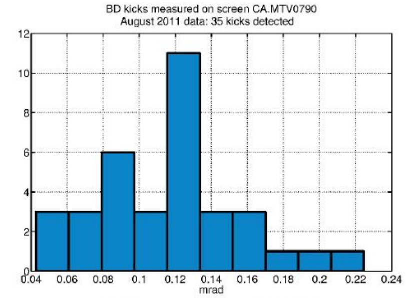
Break-down kicks
&
Break-down physics/statistics

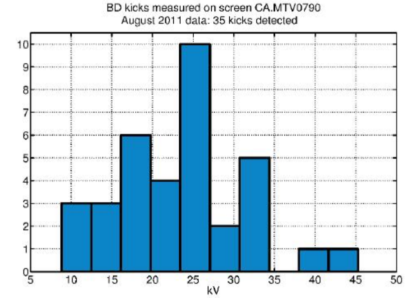
W. Farabolini, A. Palaia

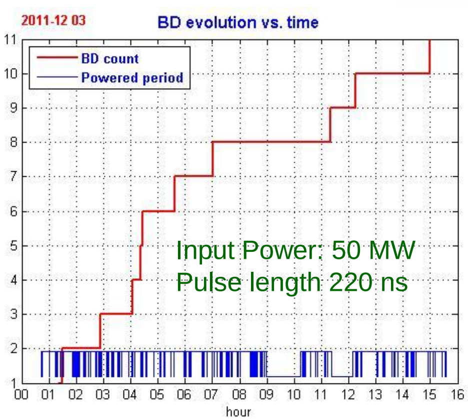


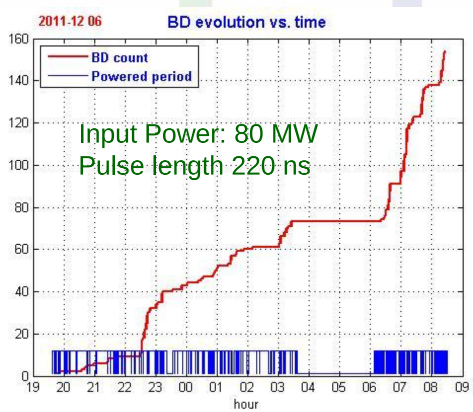


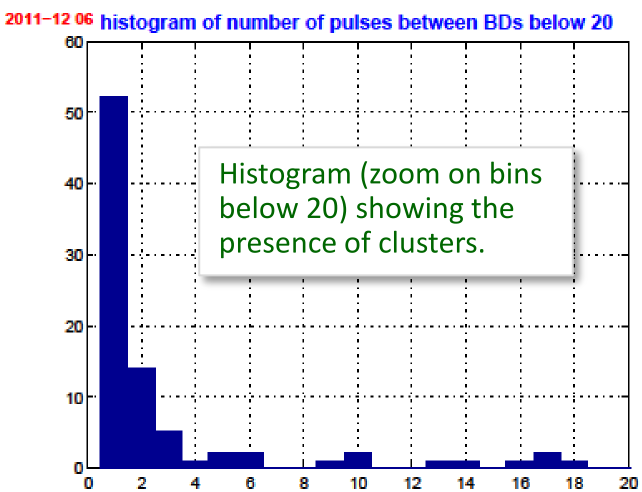




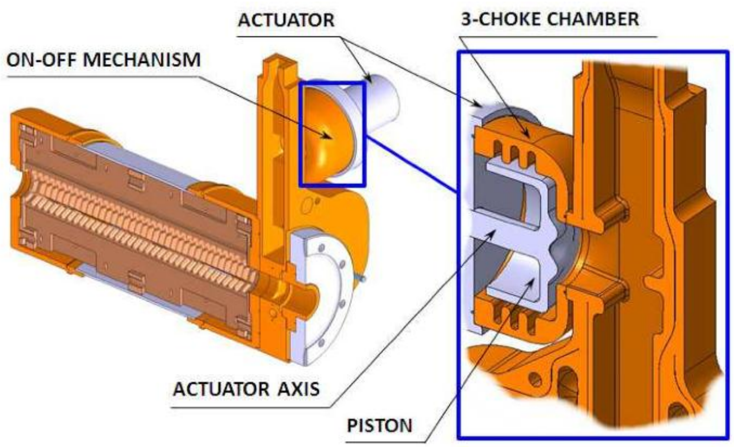




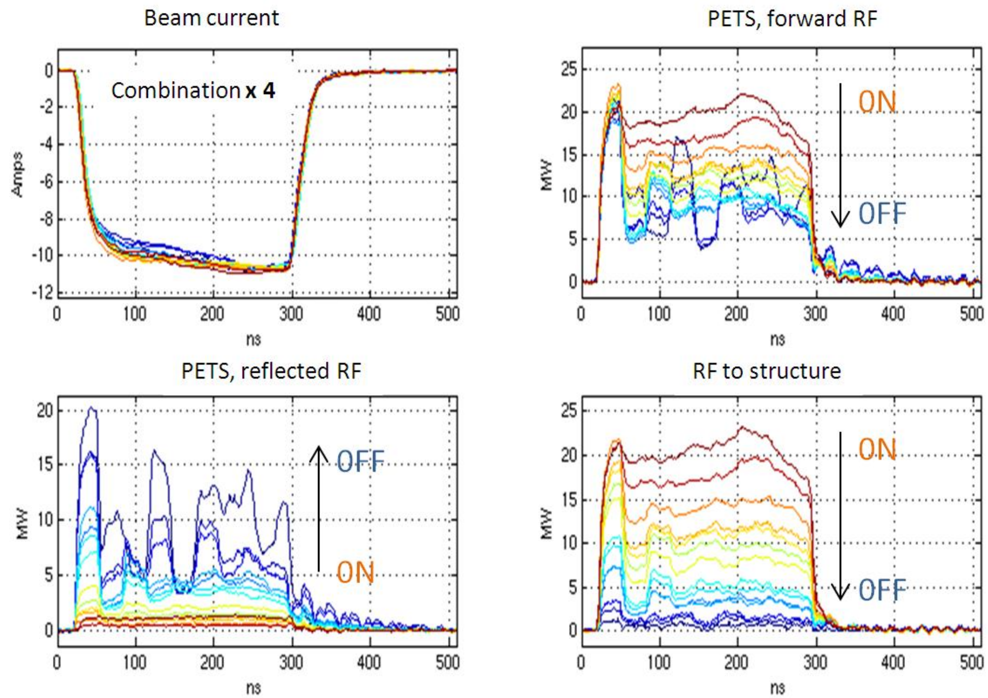




TBTS – PETS On-off mechanism

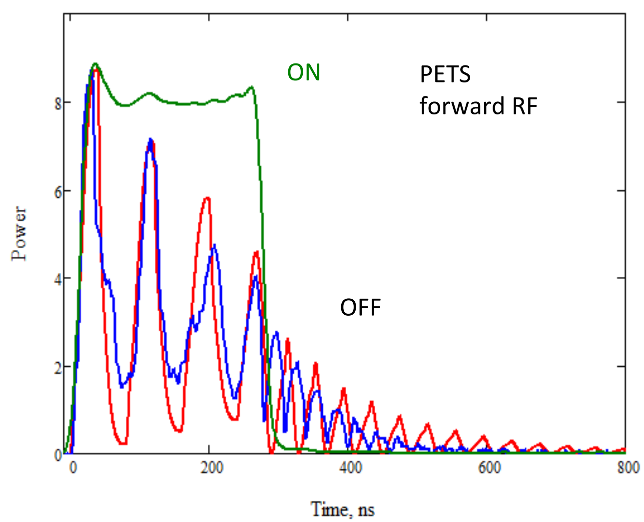


I. Syratchev,
A. Dubrowski

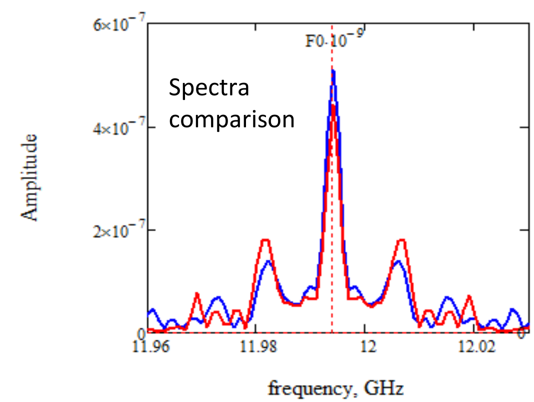


Demonstration of PETS of-off mechanism

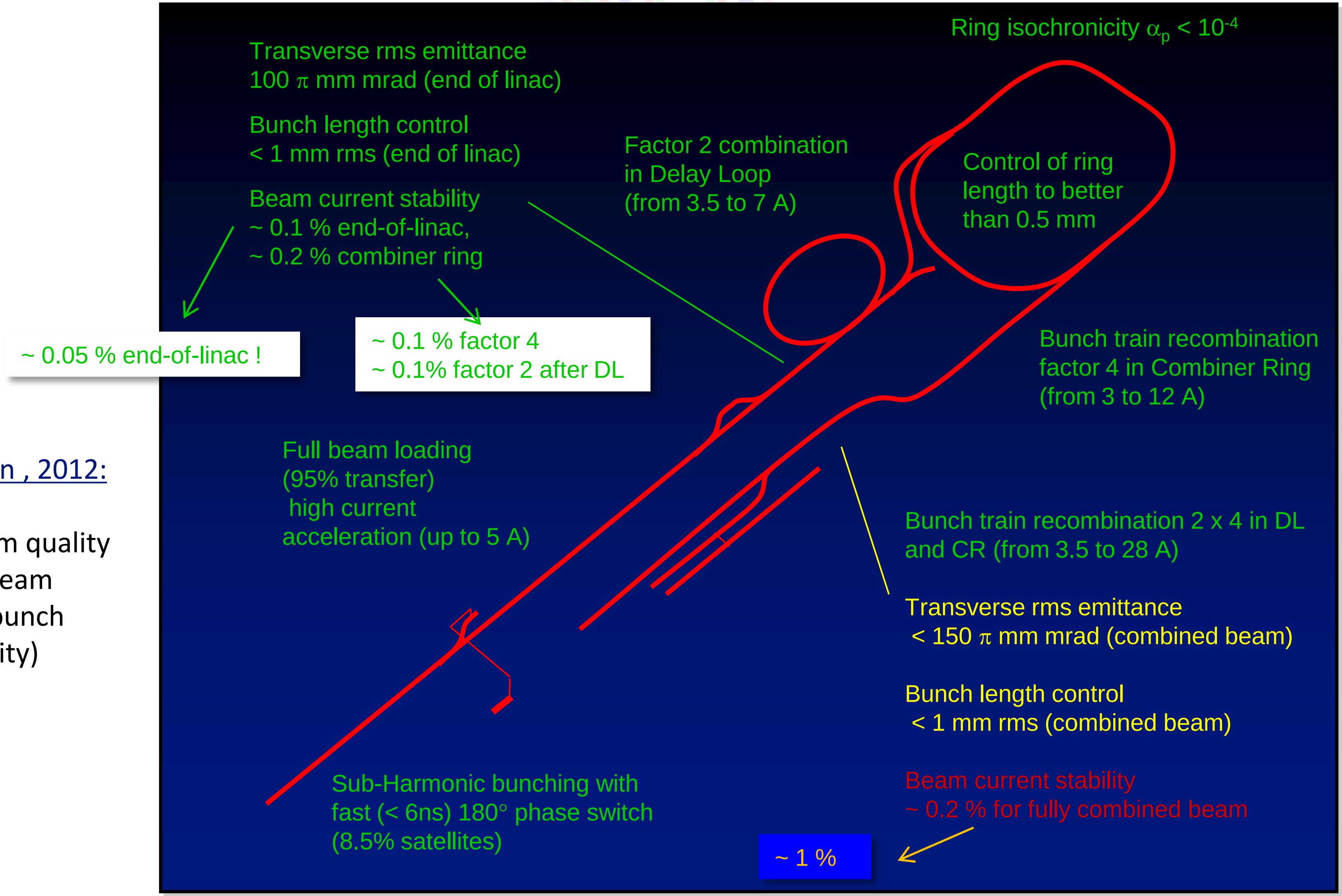
- Considered a feasibility issue
- Ability to:
  - Switch off power from individual PETS to accelerating structure in case of breakdown
  - Reduce substantially power in PETS, to cope with PETS breakdowns
- PETS on-off principle fully tested
- Conditioned at high power (135 MW - nominal) by recirculation



Simulation vs. experiment



CTF3 Achievements – What is still missing for feasibility studies – Drive Beam Generation



DB generation , 2012:

Improve beam quality for factor 8 beam (emittance, bunch length, stability)

CTF3 Achievements – What is still missing for feasibility studies – CLEX

TBTS, 2012:

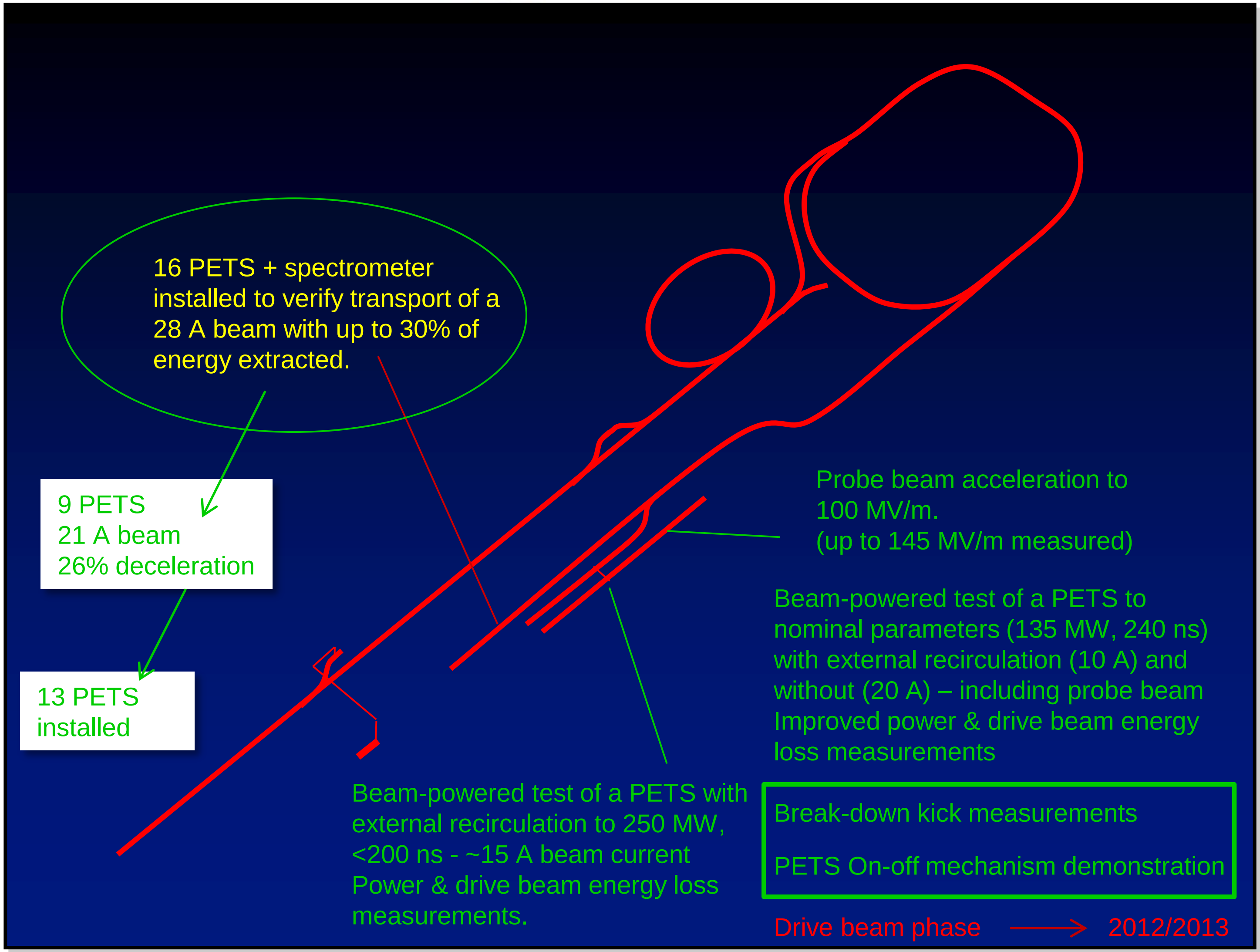
- Continue studies with two new structures
- Wakefield monitors

TBL:

- 13 PETS start 2012
- 16 PETS end 2012 ?

Drive Beam phase

- Phase monitor tests
- System test in 2013



Status of 2012 run

Problems in 2011 – Actions:

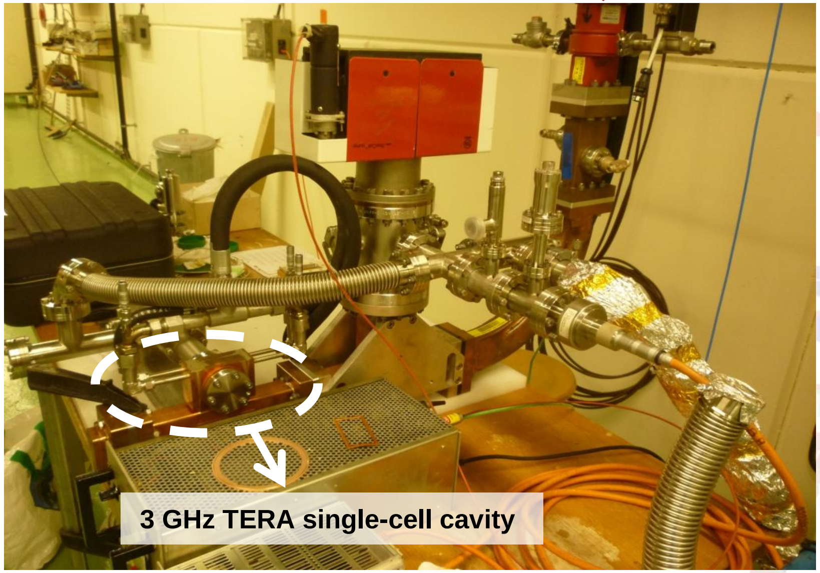
- TWT availability: still working with 2 SHB only – plus day-to-day power fluctuations, mainly working with 3 GHz beam for most of the year – One TWT back from repair, one to be sent soon, should have 3 available in Autumn
- Difficult DL set-up after last stop – suspect misaligned quadrupole (+ radiation alarm problem) – Measure and realign DL quad(s) & BPMs
- Unbalanced RF injection bump in CR – Modify RF network

Start of operation in 2012:

- Early operation (February-March) for TERA RF tests, PHIN – all goals met
- Beam in CTF3 linac in March, CLEX closed in April
- Problem with Modulator-klystron availability, reliability: it was the main cause of delays this year (slow start-up, had to replace a few tubes, frequent trips in some). Mixture of old equipment, bad luck and lack of manpower, should try to correct at least this last one.
- Lots of time spent on injector optimization (beam up to girder 10, half-linac), very good beam but not enough beam-time to keep the schedule – about 1 month delay.

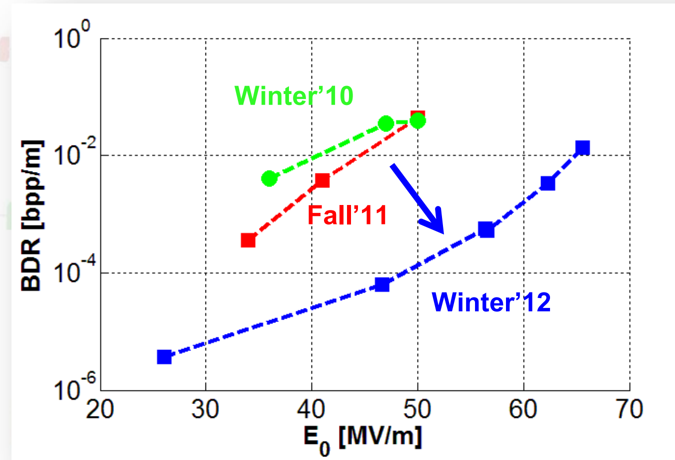
TERA high-power tests

from klystron 14

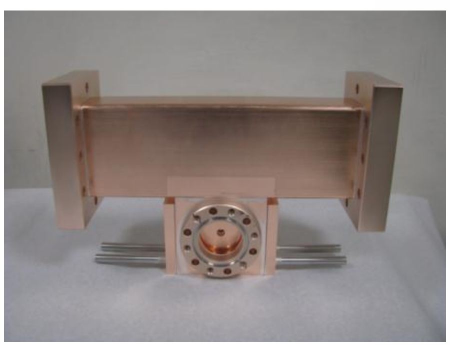


Total RF pulses: 10^7 / Total breakdowns: 10^5

-Great BDR improvement



S. Verdu-Andres
& TERA group

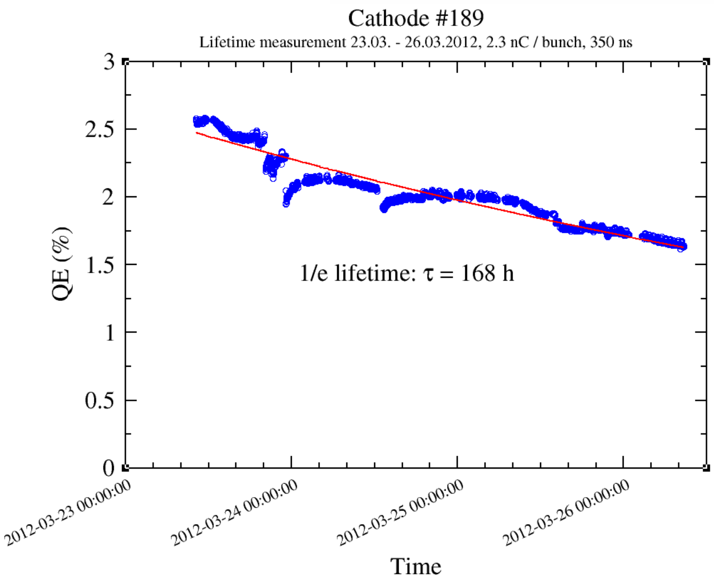


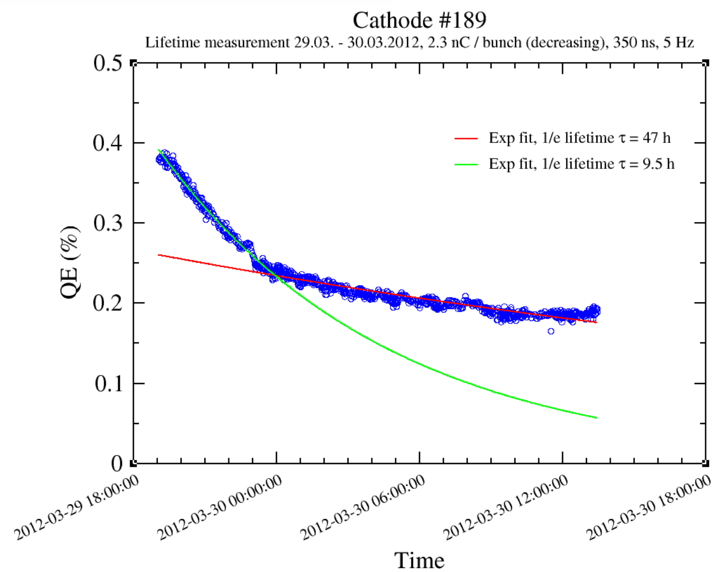
Preliminary
BDR evaluation

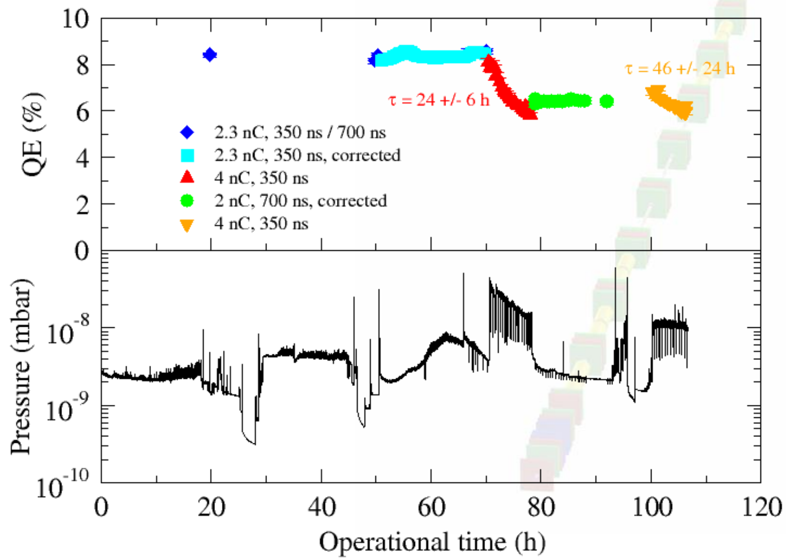
P_{in}	E_S	$E_0^{test\ cell}$	$E_0^{linac\ cell}$	T_{pulse}	$T_{flat\text{-}top}$	f_{rep}	$t_{measure}$	$\#_{FC}$	BDR_{FC}	$\#_{RE}$	BDR_{RE}
[kW]	[MV/m]	[MV/m]	[MV/m]	[µs]	[µs]	[Hz]	[s]	[--]	[bpp/m]	[--]	[bpp/m]
770	365	56		3.5	2.2	50	26104			19	$8\cdot10^{-4}$
980	415	64		3.5	2.2	50	7661			40	5.5·10-3
900	400	60		3.5	2.2	50	4755			11	2.4·10-3
770	365	56		3.5	2.2	50	10402			11	$1.1\cdot10^{-3}$
160	**168**	26	**37**	3.5	**2.2**	50	367417	33	$1\cdot10^{-4}$	0	**$<3\cdot10^{-6}$**
~500	~290	44		3.5	2.2	50	73333			4 -- 6	$6\text{—}9\cdot10^{-5}$
~900	~400	61		3.5	2.2	50	3615			6	$1.8\cdot10^{-3}$
~900	~400	61		2.8	1.5	50	27924			14	$5.3\cdot10^{-4}$
~900	~400	61		2.3	~1.2	50	50938			8	$1.7\cdot10^{-4}$
~700	~350			3.5	2.2	50	18052			3	$1.8\cdot10^{-4}$

PHIN run in March

March 2012: Lifetime studies of Cs_3Sb cathodes with green light, about 2 weeks







September 2011

- Correlation between lifetime and vacuum.
- In high e-9 mbar/ low e-8 mbar < 50h lifetime was measured.
- When vacuum is kept at low e-9 mbar lifetime is within specification.

C. Hessler, E. Chevallay, M. Csatari, S. Doebert, V. Fedosseev

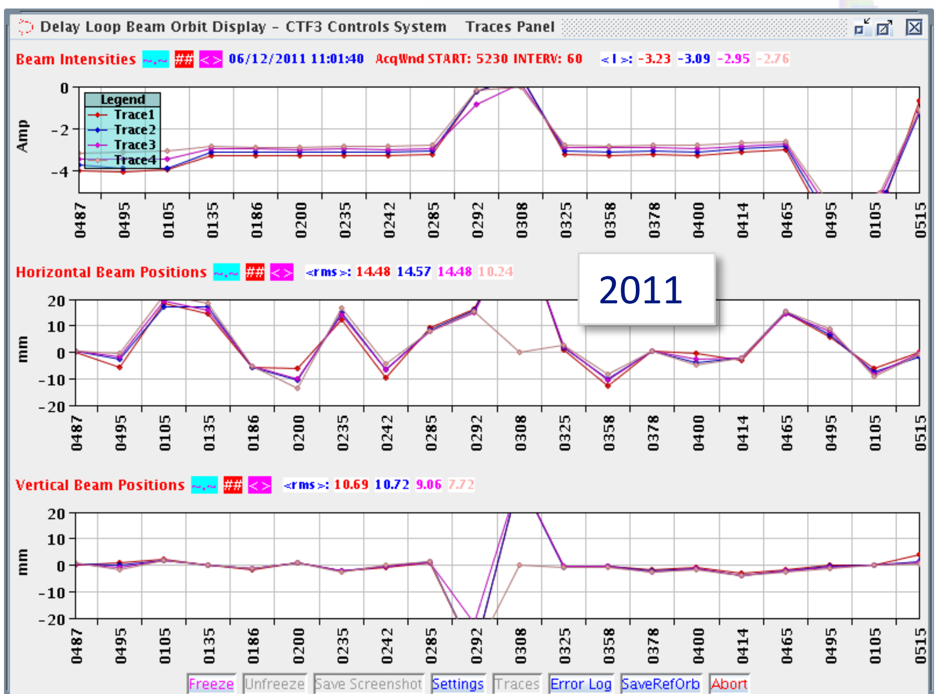
R. Corsini, CLIC Collaboration
Working Meeting, 9 May 2012

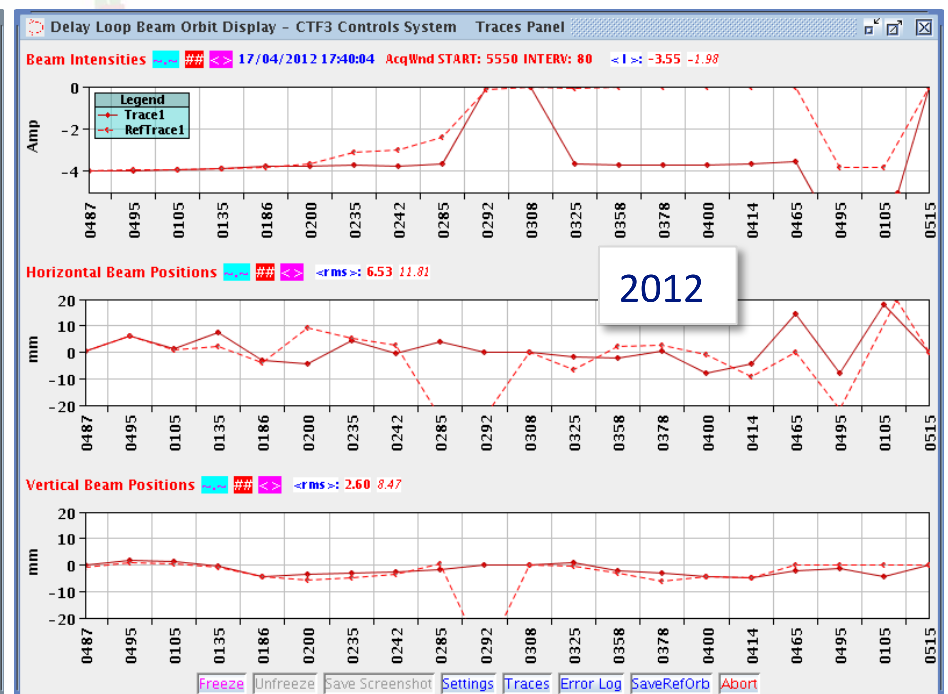
Delay Loop:

Measure and realign DL quad(s)

➔ Done. Two quads around DL injection region were found to be misaligned by 800 um in vertical and were realigned. Several BPMs were also misaligned (mainly in H) by up to a few mm with respect to the known positions supposedly in the database. When entering the new values, we discovered that (database corruption?) the calibration values were all at zero. ⇨ Database corrected.

➔ Together with the improved setting of the linac, this resulted in a fast DL loop set-up to full transmission, ½ day (it took 2-3 weeks last year) – with better orbit and more acceptance.

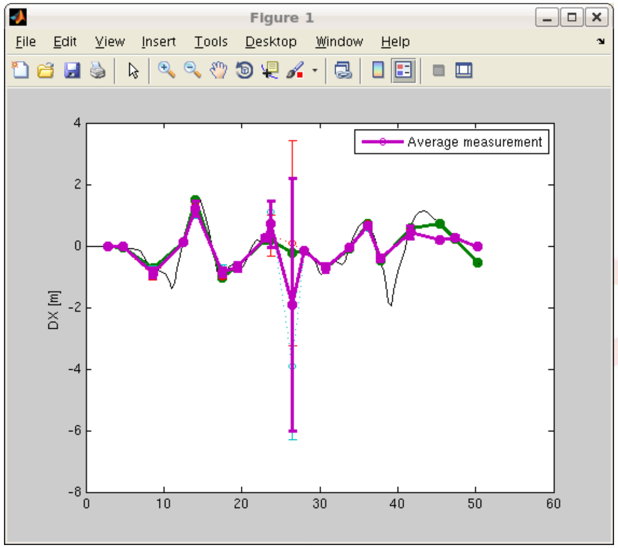


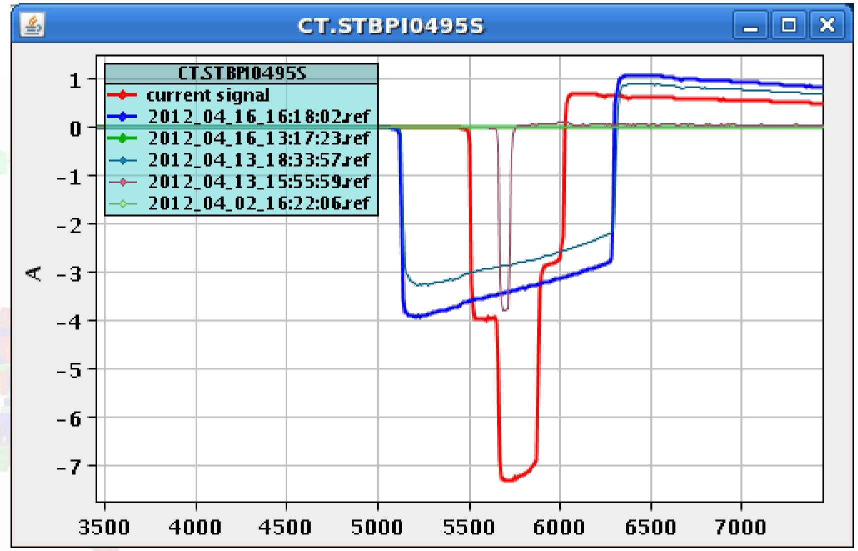


Status of 2012 run

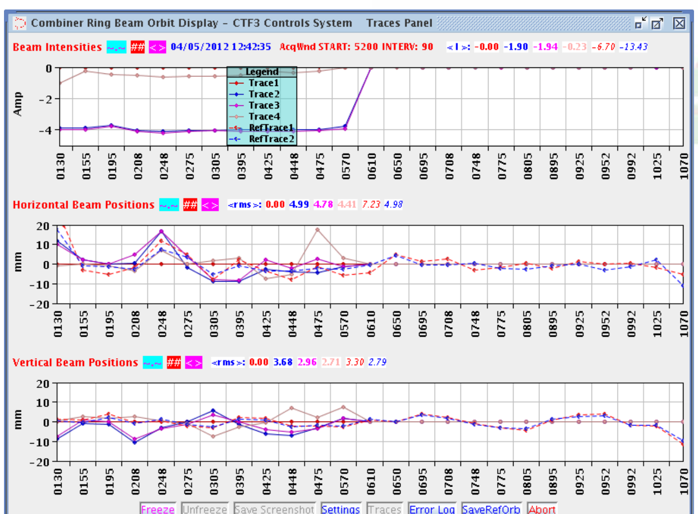
R. Corsini, CLIC Collaboration
Working Meeting, 9 May 2012

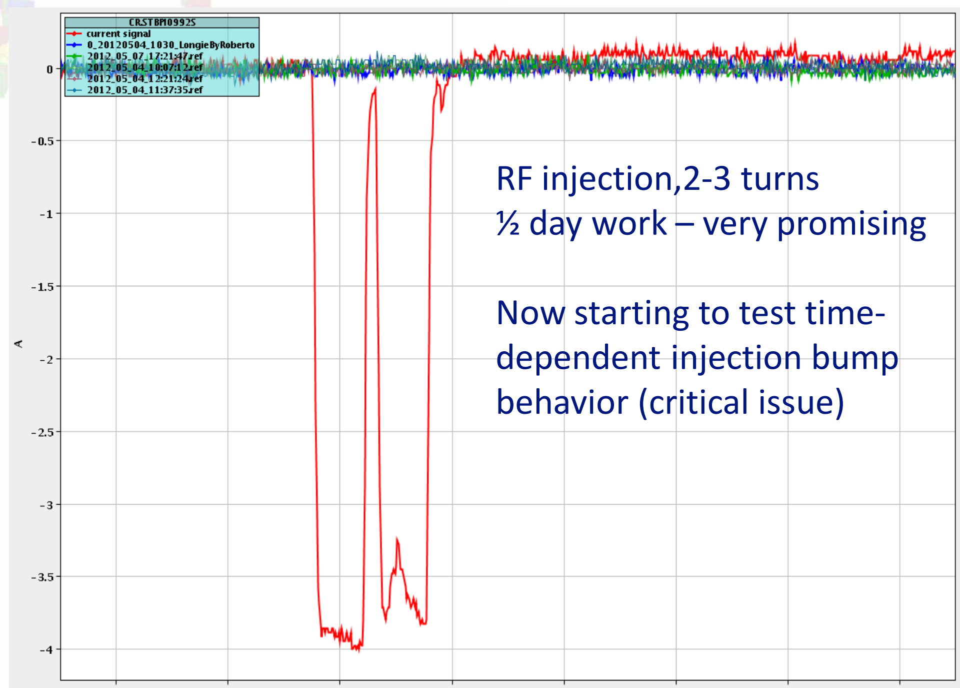
Delay Loop dispersion & transport…





Beam through CR…





RF injection,2-3 turns
½ day work – very promising

Now starting to test time-dependent injection bump behavior (critical issue)

Program

- TERA run for medical accelerator test
- PHIN photoinjector tests

- Improve beam quality: emittance, beam current (losses), bunch length, reproducibility, long & medium term stability, current & phase jitter – especially for factor 8
  - It's a goal in itself, but will also ease all other experimental goals

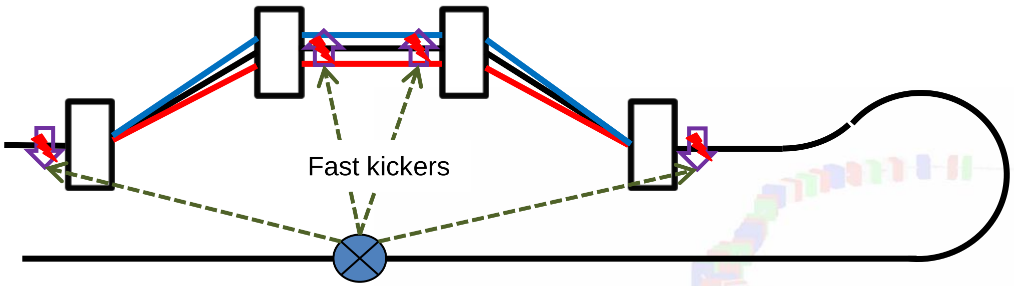
  - Improve existing feedbacks, develop & deploy new ones
  - increase beam repetition rate
  - Correct/cross-calibrate BPMs, improve DB phase diagnostics (BPRs, phase monitors)

- TBTS
  - PETS on/off:
    - Measure break-down rates in different conditions (recirculation high-power, nominal on and off)
  - New accelerating structures with wake-field monitors INSTALLED IN SUMMER
  - BD measurements & BD kicks measurements, wake-field monitor tests
  - RF pulse shaping tests

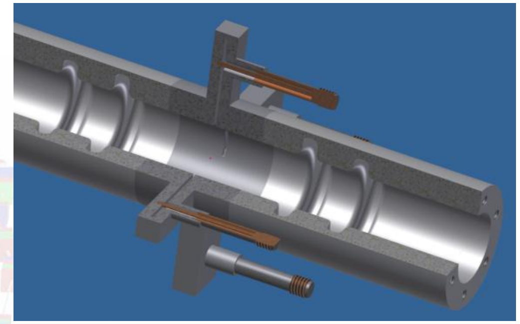
- TBL
  - RF power production: 12 to 13 PETS tanks, from 20 A towards 30 A
  - further improve precision of current, energy, bunch length & RF power measurements
  - Reach more than 1/3 deceleration

- Drive beam phase monitor tests, DB phase stability studies

Drive Beam feed-forward & feedback (WP CTF3-002)



CLIC drive beam phase feed-forward concept



Phase monitor

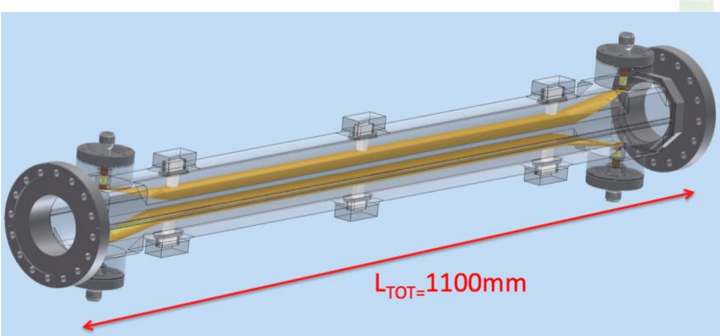
Not a single experiment – more a series of related studies:

- Measure phase and energy jitter, identify sources, devise & implement cures, extrapolate to CLIC
- Phase monitor tests – installation summer 2012
- First system tests in summer 2013

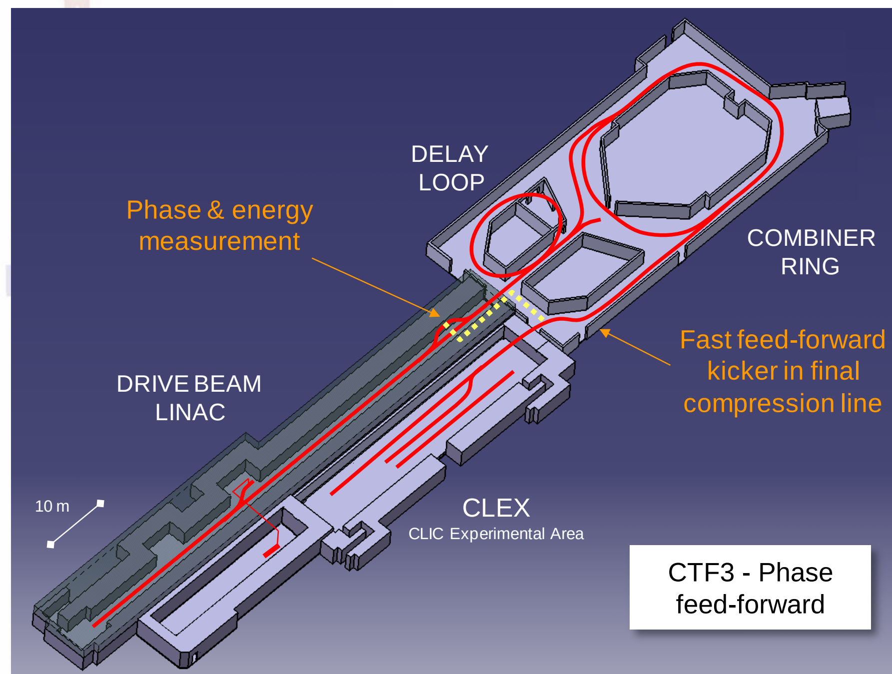
- Show principle of CLIC fast feed-forward

<u>*P. Skowronski,*</u>
<u>*P. Burrows, A.Ghigo*</u>

Close link to collaborating partners (INFN, Oxford…)

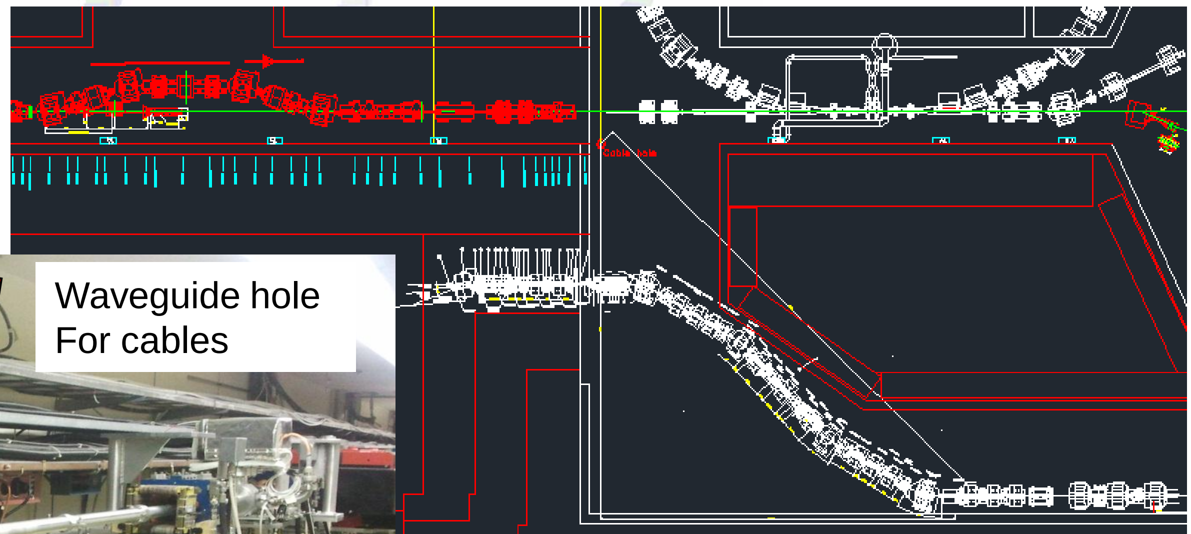


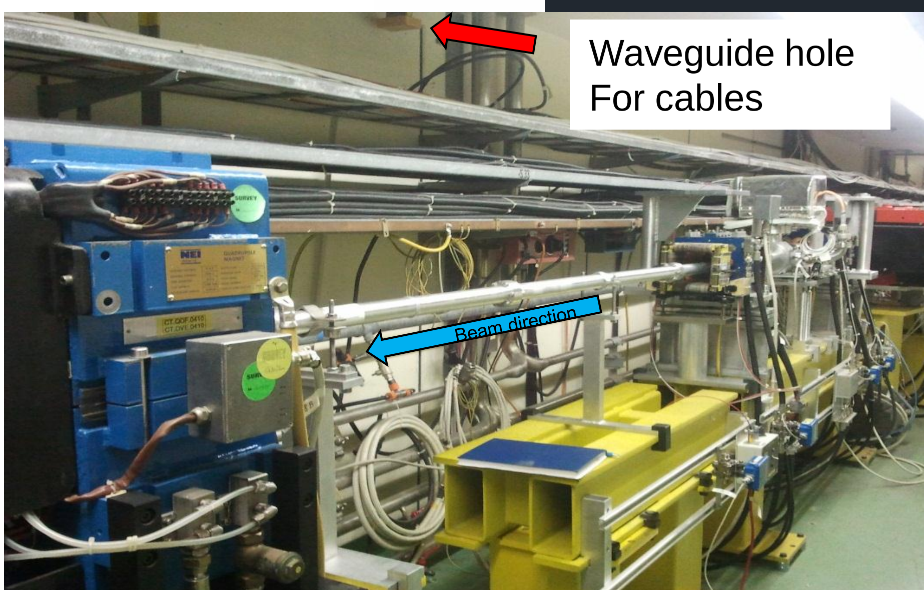
Stripline kicker



Drive Beam feed-forward & feedback (WP CTF3-002)

- The location of all the components was determined. The electronics will be installed next to MKS15. Total cable length from the monitor to the most distant kicker will be below 30m
- The 1st phase monitor should arrive at CERN any day
- Technical (re)design of the line modifications is progressing
- Need to fabricate the connecting vacuum chamber components (bellows, replacement chambers)
- 2 additional correctors will be installed to assure sufficient steering capabilities
- Installation in the tunnel should take place within a few weeks



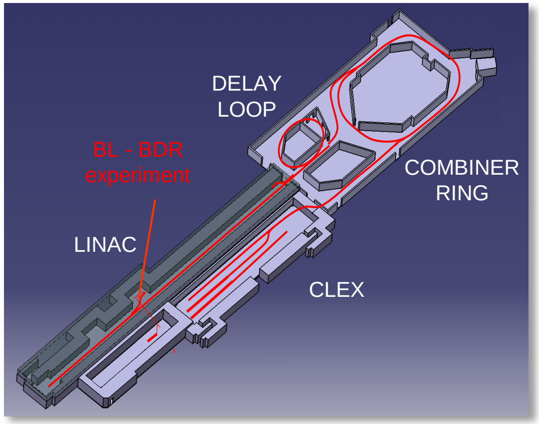


P. Skowronski

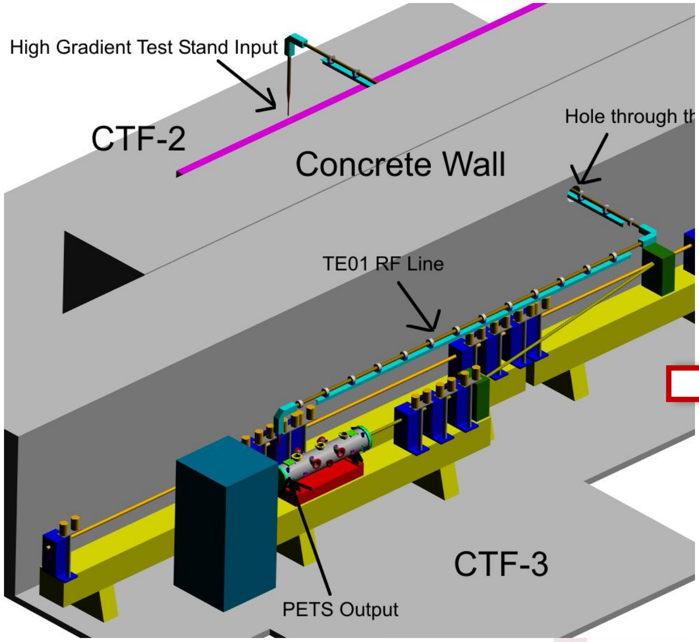
Beam-Loading experiment in CTF3 dog-leg (in WP CTF3-001)

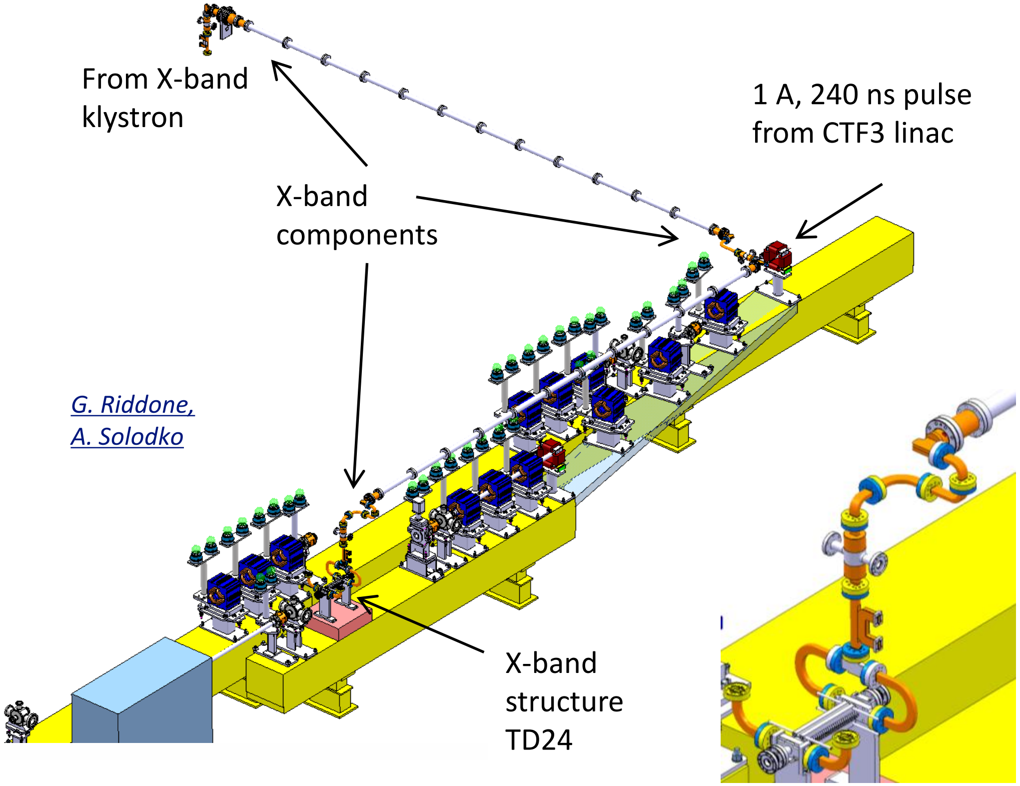
Beam loading reduces field locally in the structure
⇨ is it the break-down rate lower (or higher)?

- CLEX probe beam has only limited current/pulse length, CLEX Drive beam has limited rep rate
  ⇨ use CTF3 drive beam and klystron driven X-band structure
- Reactivate the old '30 GHz PETS' line, lower DB current, can reach 50 Hz
- Measure BDR with/without beam to get a direct comparison



Present schedule: Install in winter shutdown 2012-2013
Run experiment in 2013





G. Riddone, A. Solodko

TBL beyond 2012 (CTF3-003)

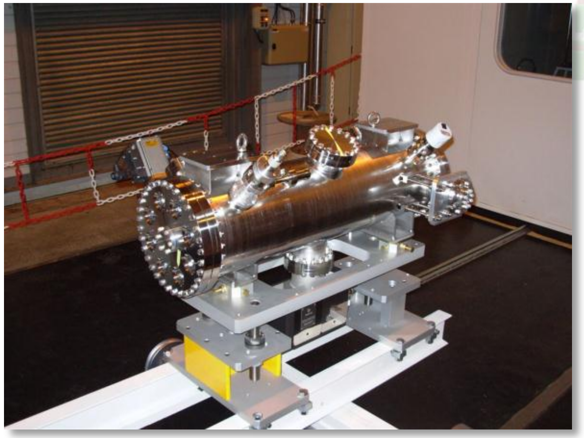
Upgrade TBL to a test facility relevant for CLIC TDR work

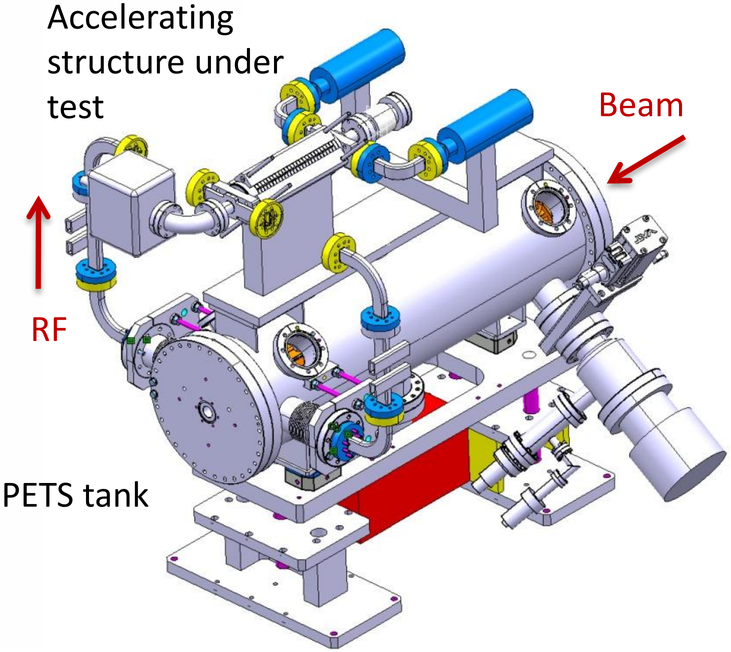
- 12 GHz power production for structure conditioning
- Working experience with a real decelerator
- Beam dynamics studies, pulse shaping, feedbacks, etc

S. Doebert

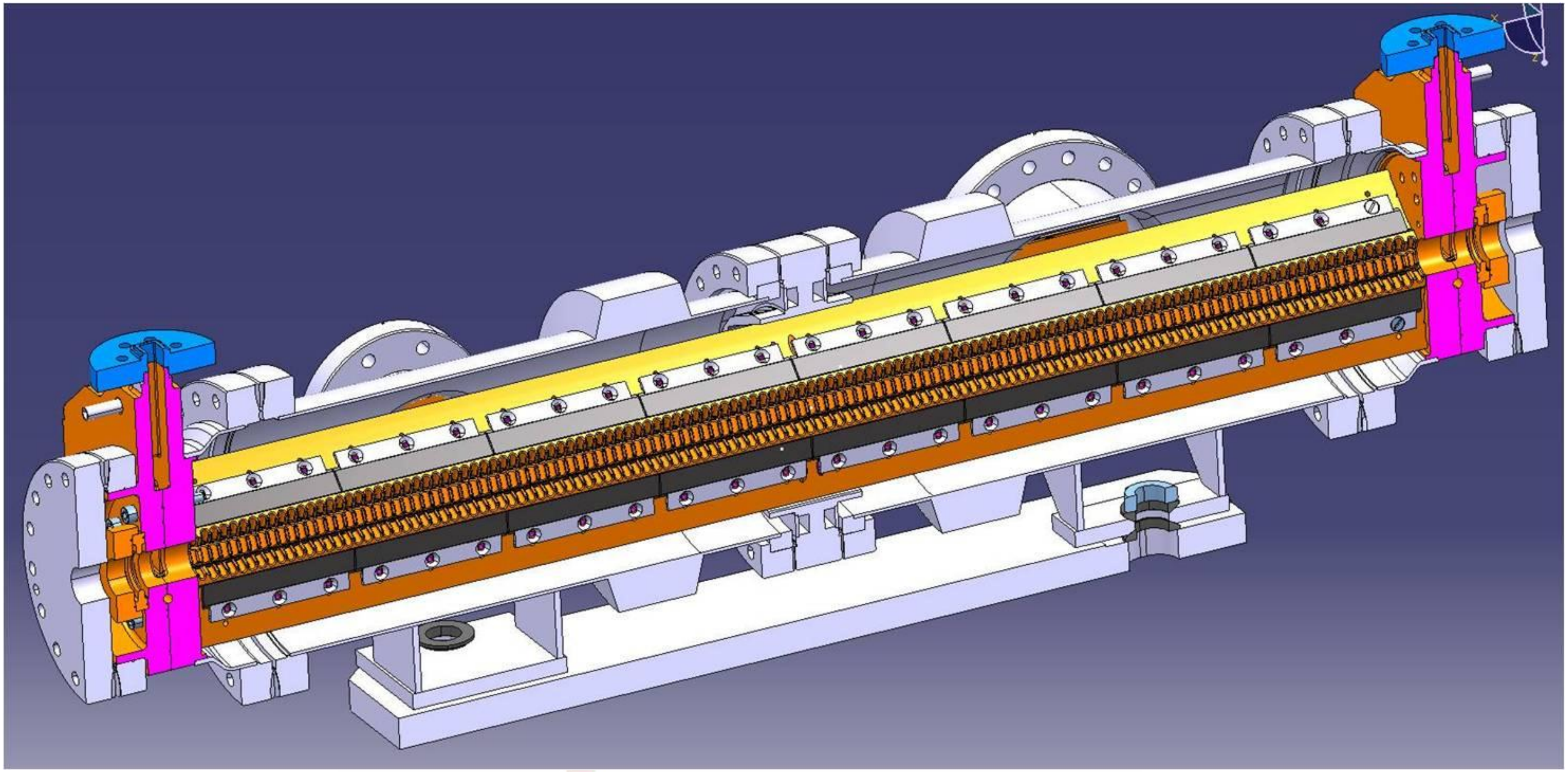
Timeline:

- Last batch of PETS will be adapted to high-power testing (using internal recirculation)
- One (or two slots) tested at beginning of 2013
- Gradual increase of slots to 4-8 slots and rep rate to 25-50 Hz





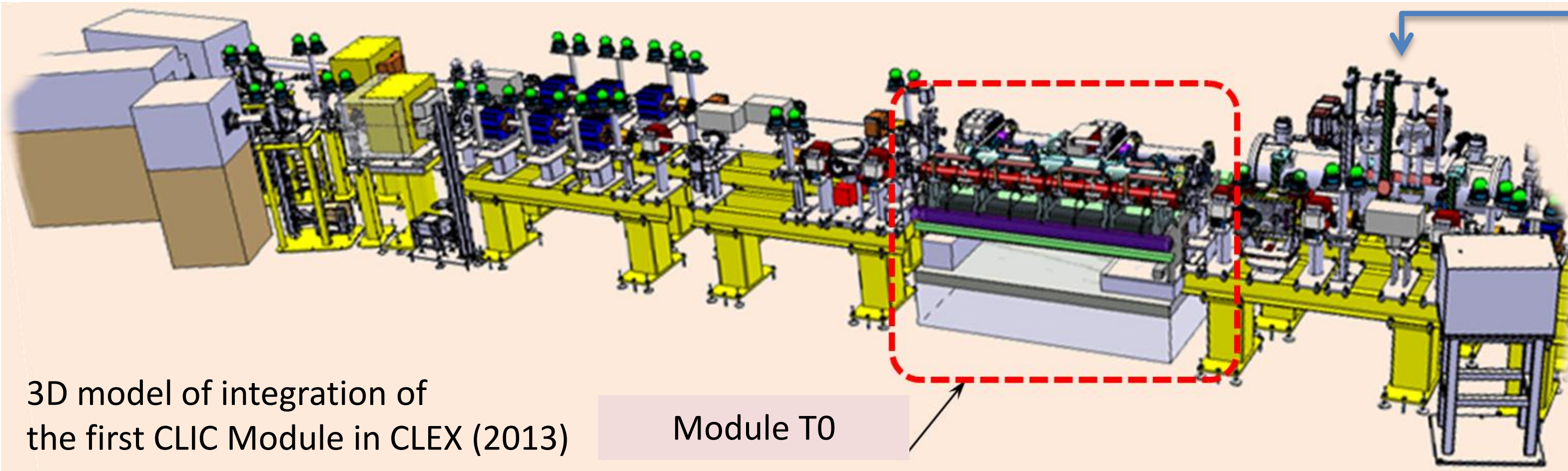
TBL beyond 2012 (CTF3-003)



Status:
modified PETS with input coupler and mini-tank designed

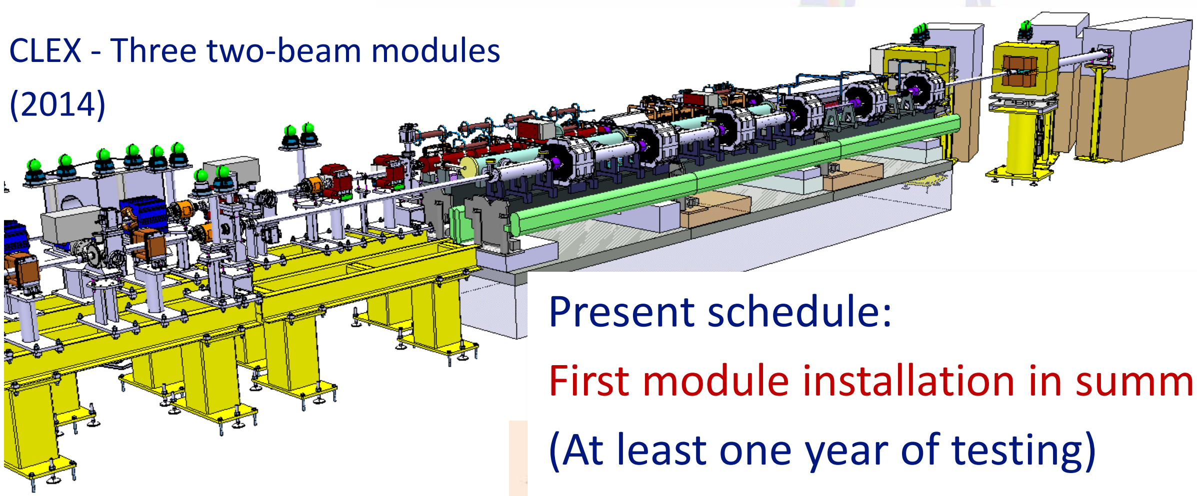
Next steps: fabrication drawings for PETS, complete integration study for accelerating structure
Missing resources in mechanical engineering

Two Beam Modules in CLEX (CTF3-004)



3D model of integration of the first CLIC Module in CLEX (2013)

CLEX - Three two-beam modules (2014)



TBTS PETS tank

Present schedule:

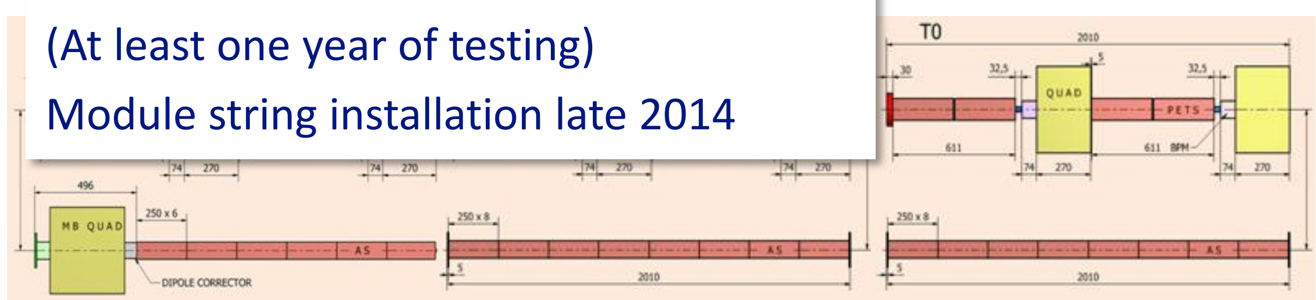
First module installation in summer 2013

(At least one year of testing)

Module string installation late 2014

Drive beam

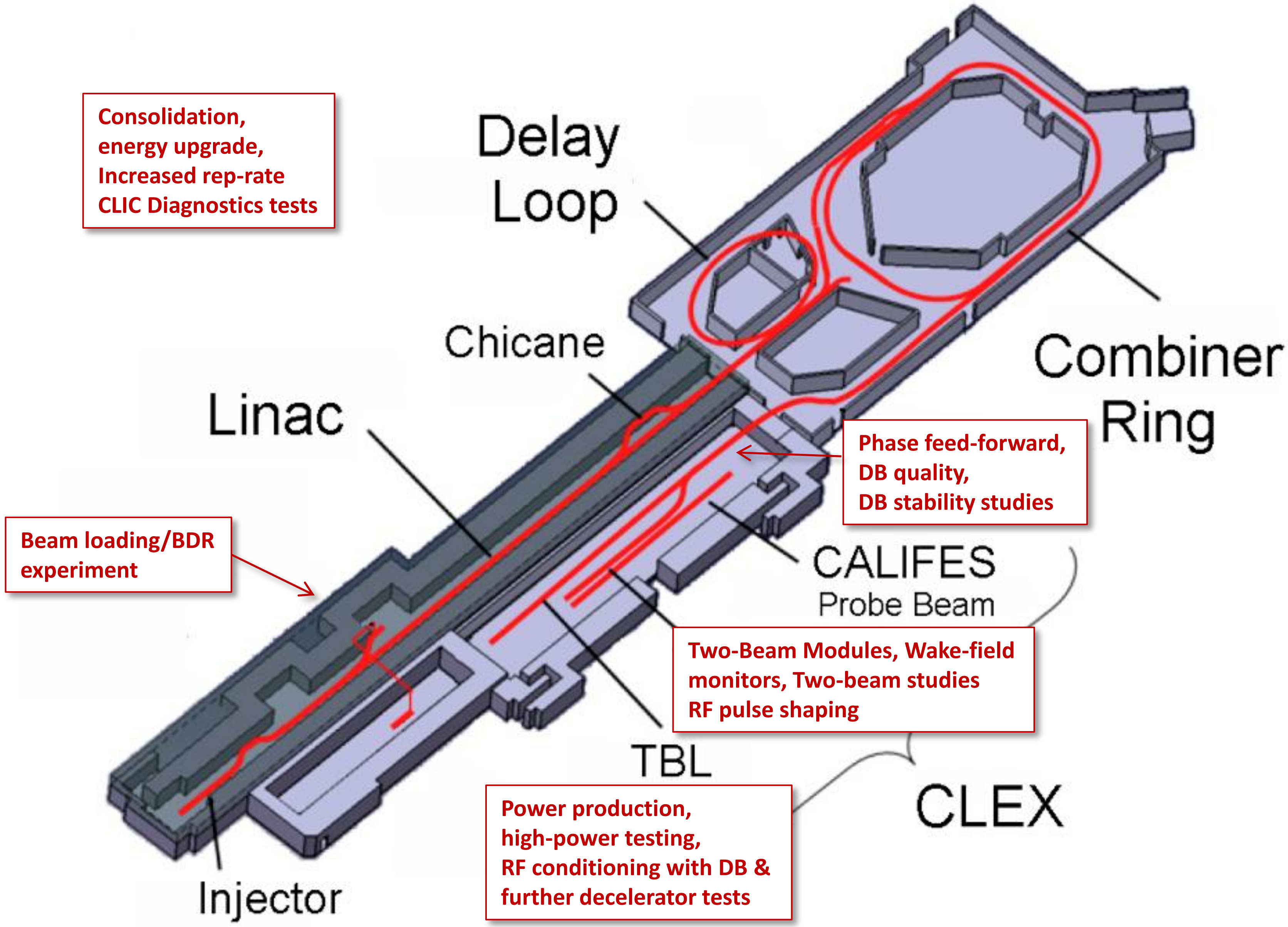
Probe beam



Schematic layout of CLIC Modules in CLEX

G. Riddone

CTF3 program in 2012-2017



Thanks for your attention

Drive beam quality

- To improve: beam current (losses), emittance, bunch length, reproducibility, long & medium term stability, current & phase jitter – especially for factor 8

- It's a goal in itself, but will also ease all other experimental goals.

- First 3-4 months of operation: need systematic studies on relevant issues. A large part of them can be performed with a 3 GHz beam (but…)
  - Injector set-up: min energy spread & bunch length (need new measurements, like energy spread scan?), current flatness. Reference signals established. 1-2 weeks.
  - Linac: RF set-up, references. Transverse optics (girder 10, CT line, girder 5?). 1 week.
  - Chicane & CT line: Prepare a few optics with lower R56, optics checks (kick, dispersion), matching. Bunch length measurements. 2 weeks.
  - DL: Orbit & matching, new references (misalignment?). Bunch length measurements. 2 weeks.
  - CR: Closed orbit correction, orbit closure, ring length, isochronicity (bunch length measurements), matching, dispersion (no combination). Combination set-up (factor 4). 2-3 weeks.
  - TL2, CLEX: optics studies (matching, dispersion, emittance, bunch length measurements…). 1-2 weeks.
  - Set-up of 1.5 GHz beam, repeat all studies. Set-up of combination factor 8. 2-3 weeks.

Drive beam quality

- In parallel:
  - Improve existing feedbacks, develop & deploy new ones.
  - Correct/cross-calibrate BPMs, improve DB phase diagnostics (BPRs).
  - Improve/develop operation software.
  - Define, document and put in place operational procedures.
  - …

TBTS

- PETS on/off:
  - Basic demonstration done. Need some time to condition above nominal in recirculation mode (in the shadow of new structures conditioning…).
  - Measure break-down rates in different conditions (recirculation high-power, nominal on, nominal off).
- Structures:
  - Conditioning. Questions: how aggressive should we be? How much time can we dedicate to that? What rep rate will be available? When will CALIFES be available to check power calibrations?
  - In the shadow of conditioning: prepare tools for BD studies (analysis, flash-box signals…)
  - BD measurements (exploit flash-box) & BD kicks measurements, wake-field monitor tests.
  - RF pulse shaping tests.

N.B.: CTF3 being limited in rep rate, some RF studies are better carried out in the stand-alone test stand (need common analysis – AND superposition of BD rate regimes).

However, the added value of CTF3 is the possibility to study the whole system (e.g., PETS BDs induced by structure BDs, etc…)

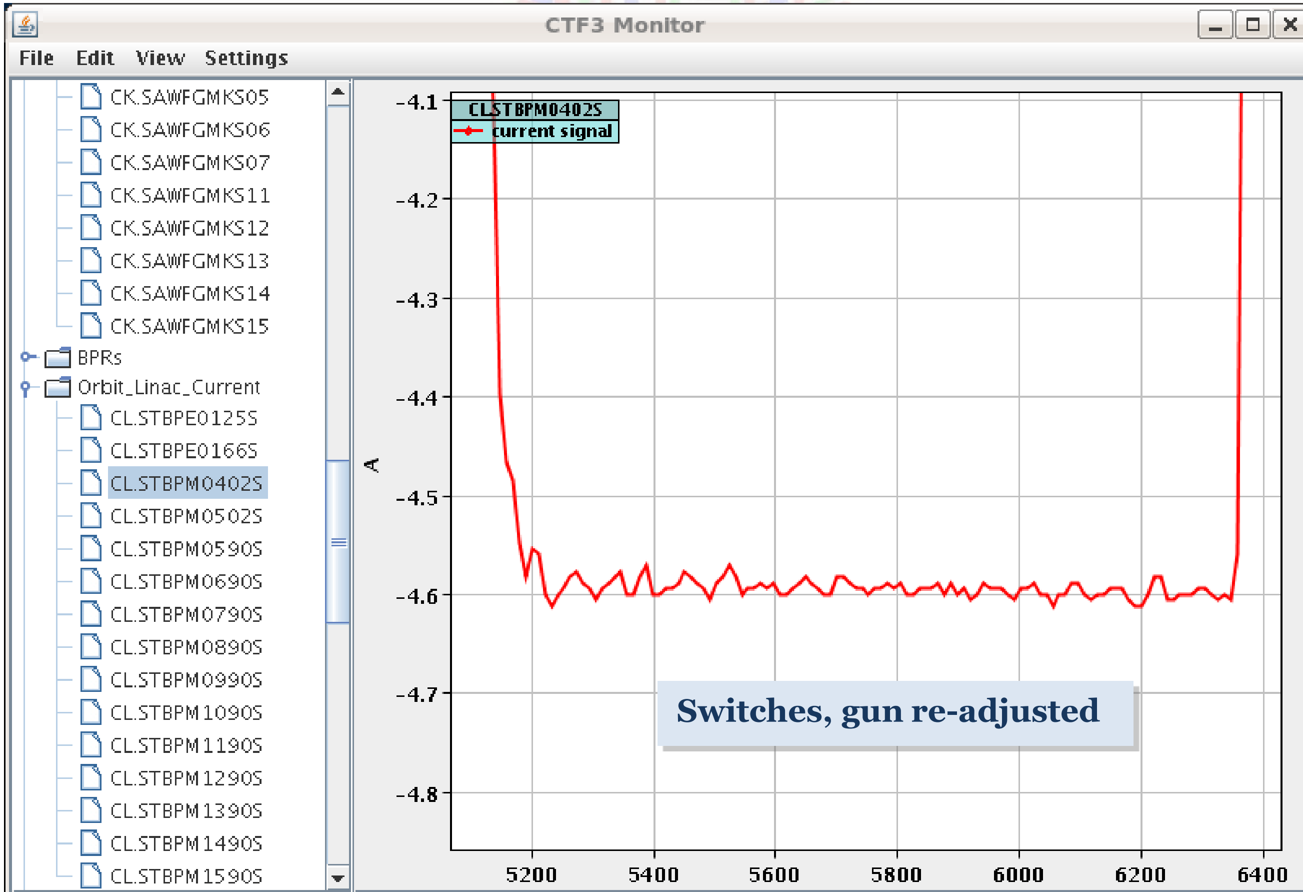
TBL

- RF power production: 12 to 13 PETS tanks, from 20 A to 30 A
  - Improve precision of current, energy, bunch length & RF power measurements further
  - Reach more than 1/3 deceleration
  - Drive beam phase stability monitoring
- Dispersion free steering, optics studies – also extend to high current/large deceleration
- Possibly, a new PETS prototype for TBL+ to be tested before the end of the year (input coupler, mini-tank, PETS On/Off)

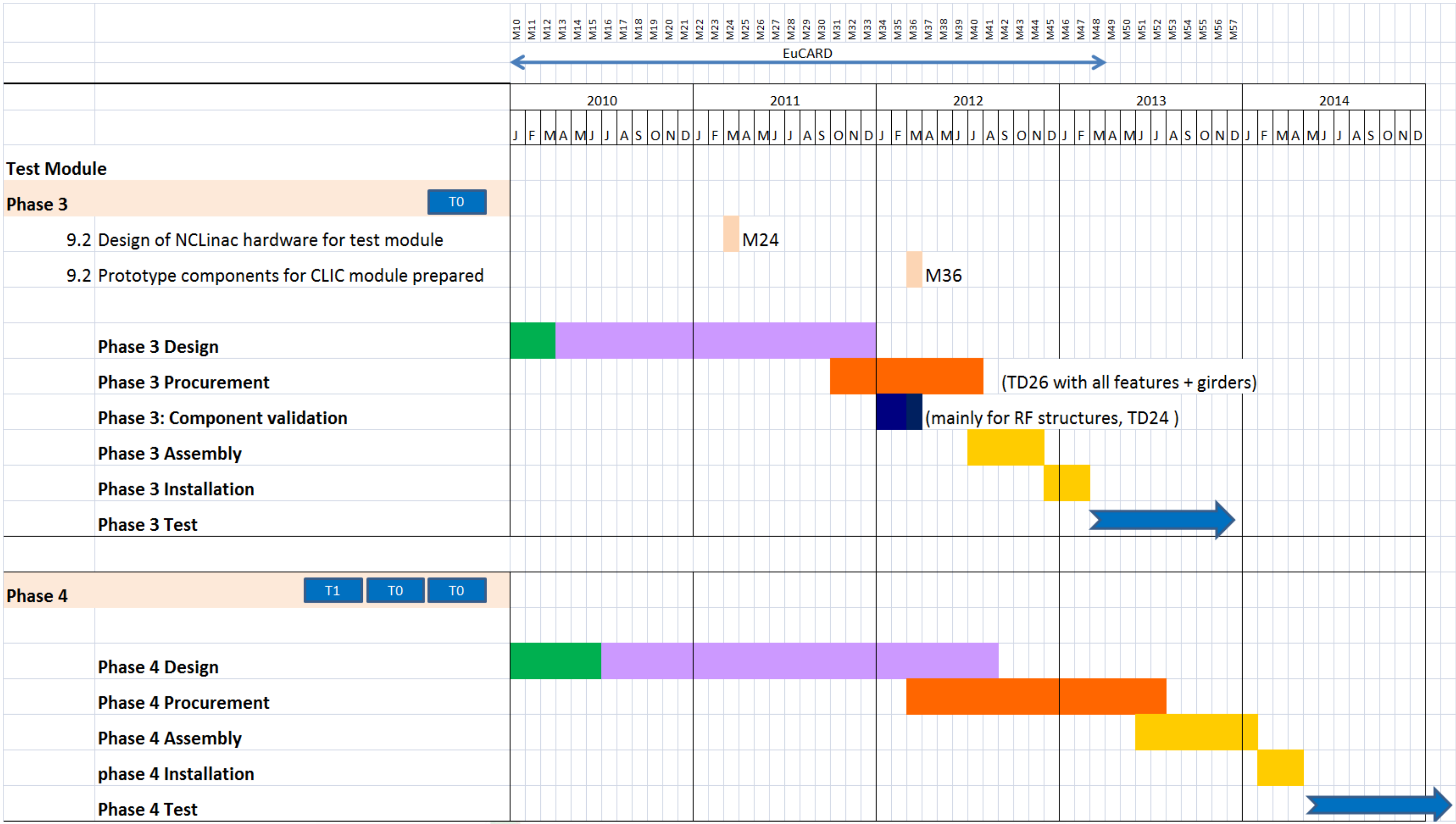
Other activities

- TERA
- PHIN (2 runs)
- BLM studies
- Other diagnostics development
- …

Compensation of phase switches



Alexandra Andersson, Frank Tecker, Piotr Skowronski


EuCARD
2010
2011
2012
2013
2014
Test Module
Phase 3
T0
9.2 Design of NCLinac hardware for test module
M24
9.2 Prototype components for CLIC module prepared
M36
Phase 3 Design
Phase 3 Procurement
(TD26 with all features + girders)
Phase 3: Component validation
(mainly for RF structures, TD24)
Phase 3 Assembly
Phase 3 Installation
Phase 3 Test
Phase 4
T1
T0
T0
Phase 4 Design
Phase 4 Procurement
Phase 4 Assembly
phase 4 Installation
Phase 4 Test

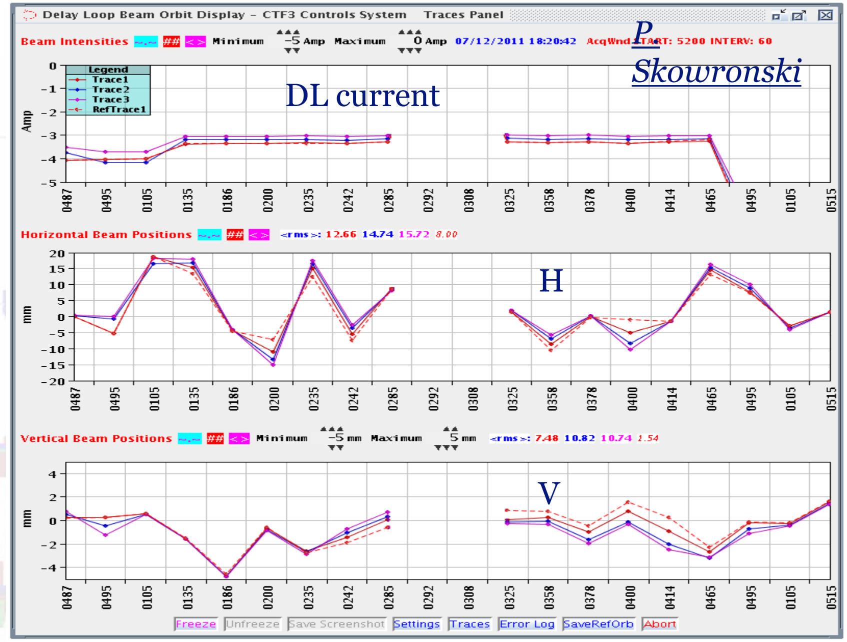
G. Riddone

Status of 2012 run

Problems:

- TWT availability – still working with 2 (out of 3) SHB only
  – plus day-to-day power fluctuations
  => Mainly working with 3 GHz beam for most of the year

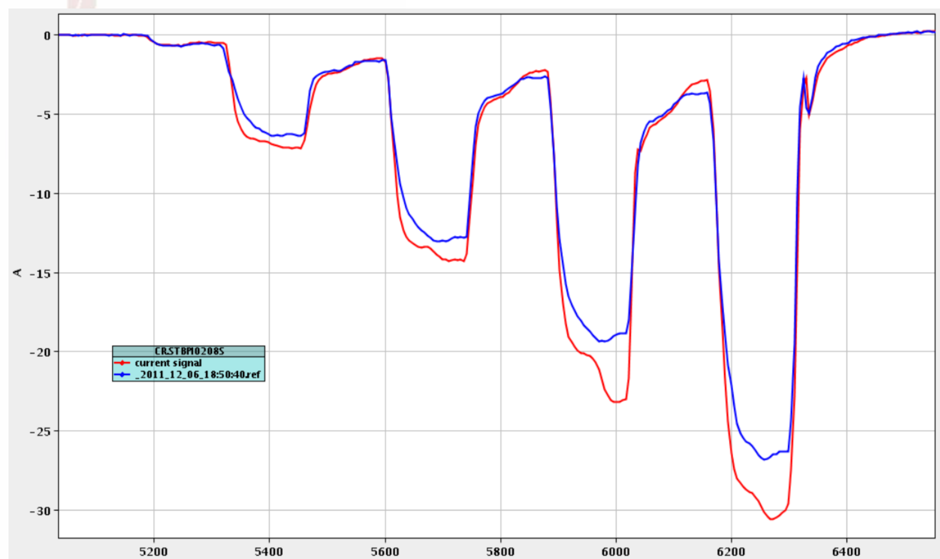
- Difficult DL set-up after last stop
  – suspect misaligned quadrupole (+ radiation alarm problem)



Eventually able to get good recombination (current record), but:

- Bad pulse shape (phase switches?)

- Still limited acceptance -> stability was improved,
  but it is still not good enough



- DL quads measured and realigned

Future work:

- Work on phase switches, gun current compensation,
  back to 3 TWTs, improve trajectories

- Phase monitor installation: summer 2012
  → get experience with phase monitor r/o
  → digitisation of signals
  → develop + test firmware
- Kicker installation: winter 2012/3
- Amplifier ready: winter 2012/3
  → test kickers: spring 2013
  → system tests: spring/summer 2013

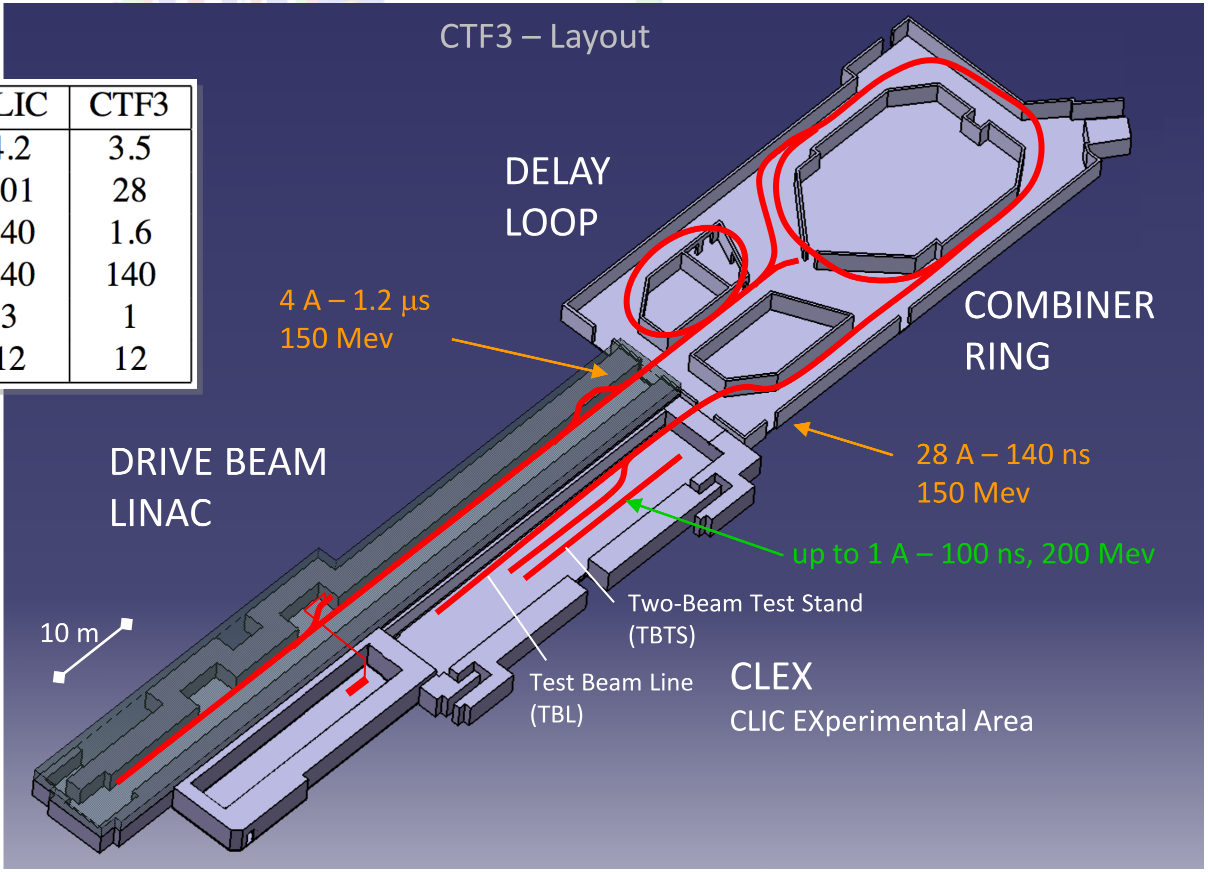
Introduction to CTF3

CTF3 is a scaled model of CLIC RF power source

It was built partly re-using existing infrastructure (LPI)

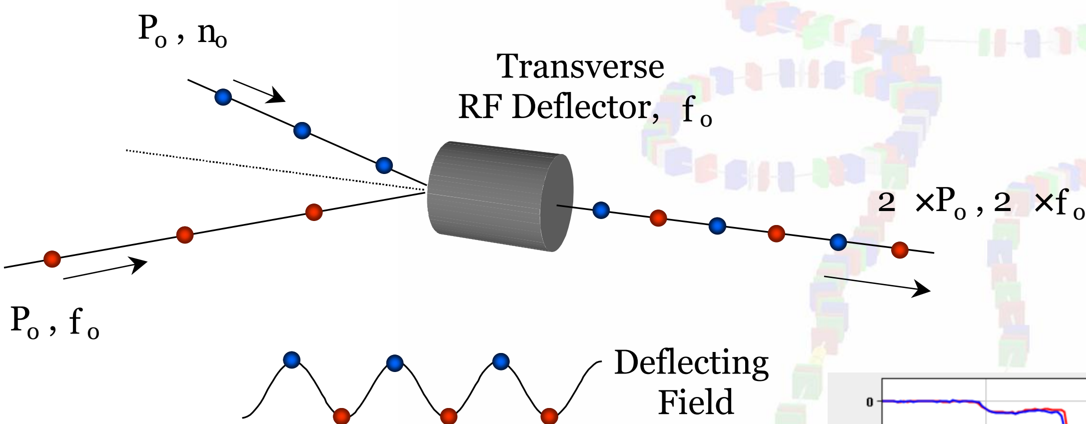
- Compromises on parameters in order to make it affordable
- In some cases issues are more difficult than in CLIC

parameter	unit	CLIC	CTF3
accelerated current	A	4.2	3.5
combined current	A	101	28
accelerated pulse length	μs	140	1.6
final pulse length	ns	240	140
acceleration frequency	GHz	3	1
final bunch frequency	GHz	12	12



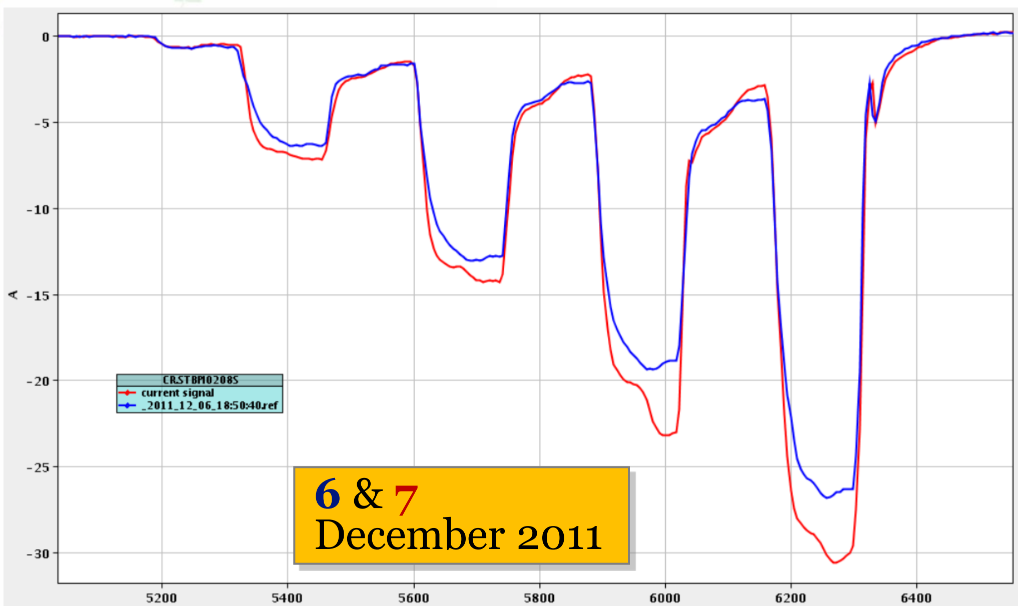
Achievements – Drive Beam Generation

Item	Feasibility Issue	Unit	Nominal	Achieved	How	Feasibility	Comments
Drive beam generation	Fully loaded accel effic	%	97	95	CTF3	✓	Novel scheme fully demonstrated in CTF3 in spite of lower current since beam dynamics more sensitive than nominal due to lower energy (250MeV/2Gev)
	Freq&Current multipl	-	2*3*4	2*4	CTF3	✓	
	Combined beam current (12 GHz)	A	4.5*24=100	3.5*8=28	CTF3	✓	
	Combined pulse length (12 GHz)	nsec	240	140	CTF3	✓	
	Intensity stability		1.E-03	0.75	< 0.6	CTF3	✓	End of DBA. To be demonstrated for combined beam in 2011
	Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design



Beam recombination

- Factor 8 recombination by RF deflector injection

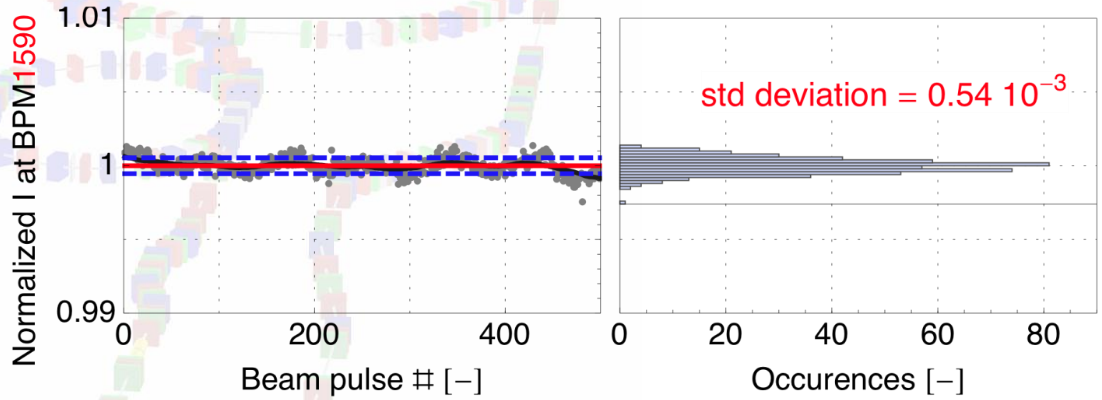


Achievements – Drive Beam Generation

Item	Feasibility Issue	Unit	Nominal	Achieved	How	Feasibility	Comments
Drive beam generation	Fully loaded accel effic	%	97	95	CTF3	✓	Novel scheme fully demonstrated in CTF3 in spite of lower current since beam dynamics more sensitive than nominal due to lower energy (250MeV/2Gev)
	Freq&Current multipl	-	2*3*4	2*4	CTF3	✓	
	Combined beam current (12 GHz)	A	4.5*24=100	3.5*8=28	CTF3	✓	
	Combined pulse length (12 GHz)	nsec	240	140	CTF3	✓	
➔	Intensity stability	1.E-03	0.75	< 0.6	CTF3	✓	End of DBA. To be demonstrated for combined beam in 2011
	Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design

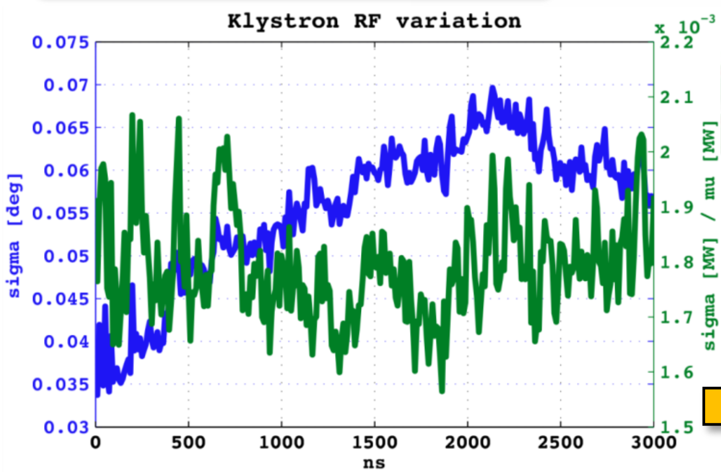
Pulse charge measured at end of the linac

After factor 8 combination
~ 1% jitter



"Good" CTF3 klystron

- pulse-to-pulse jitter
- 10 ns time slices along the RF pulse
- with respect to local phase reference



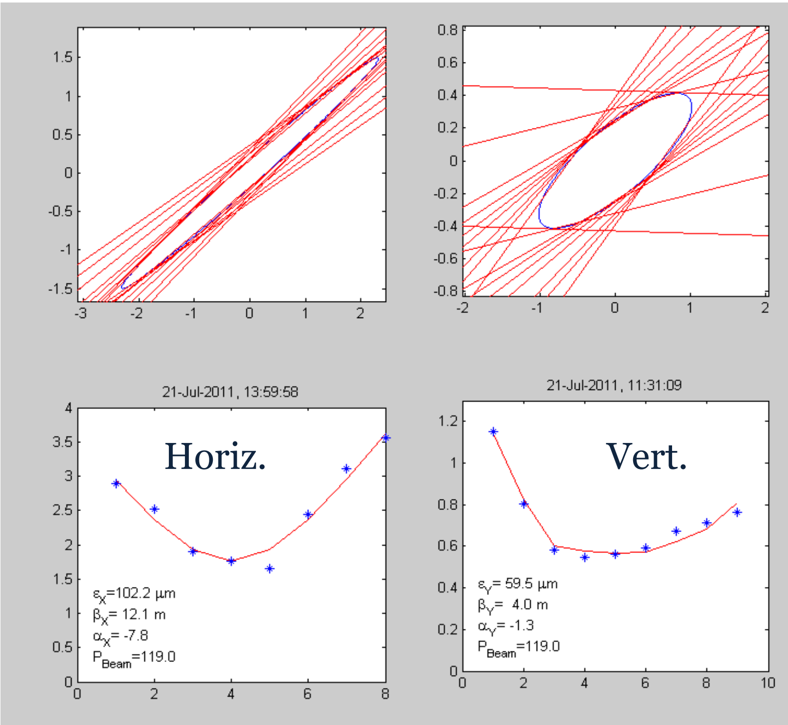
	Tolerance	Measured
Beam Current	0.075%	0.054%
RF Power	0.2%	0.16% - 0.21%
RF Phase	0.05°	0.035° - 0.07°

- Improve and document current stability for combination factor 4
- Improve stability for combination factor 8 – at the per mil level
- Means: improve acceptance (dispersion, orbit, beta-beating)
- Reduce energy spread – bunch length

End 2011 – Mid 2012

G. Sterbini, A. Dubrovsky

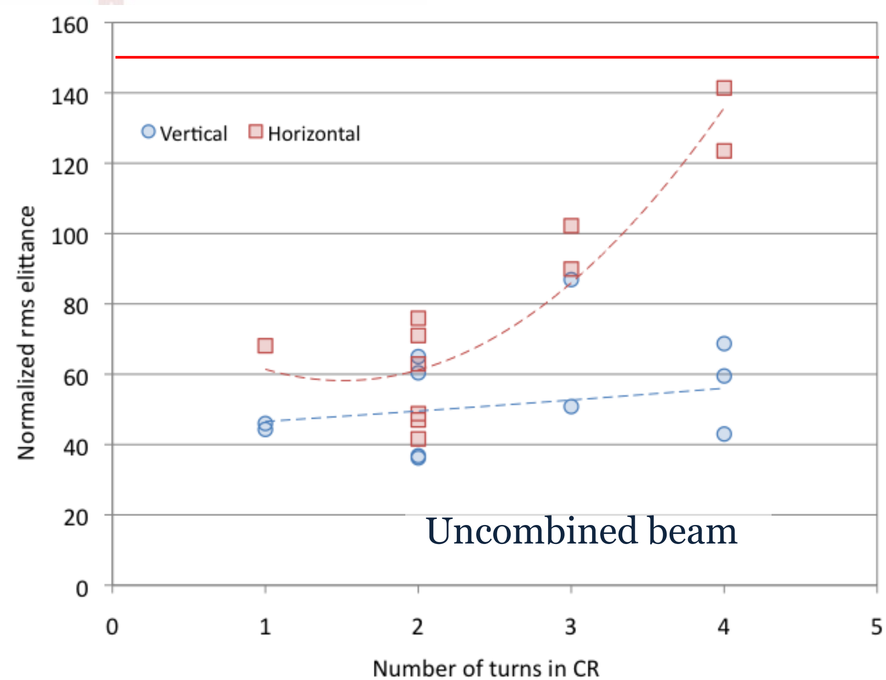
Measurements in TL2 - uncombined



Beam recombination - Emittance

Best results in CLEX
for factor 4: ε_H= 250 um ε_V= 140 um
for factor 8: ε_H= 640 um ε_V= 170 um

Different turns are ~ ok, no unknown effects
Emittance increase due to non perfect combination

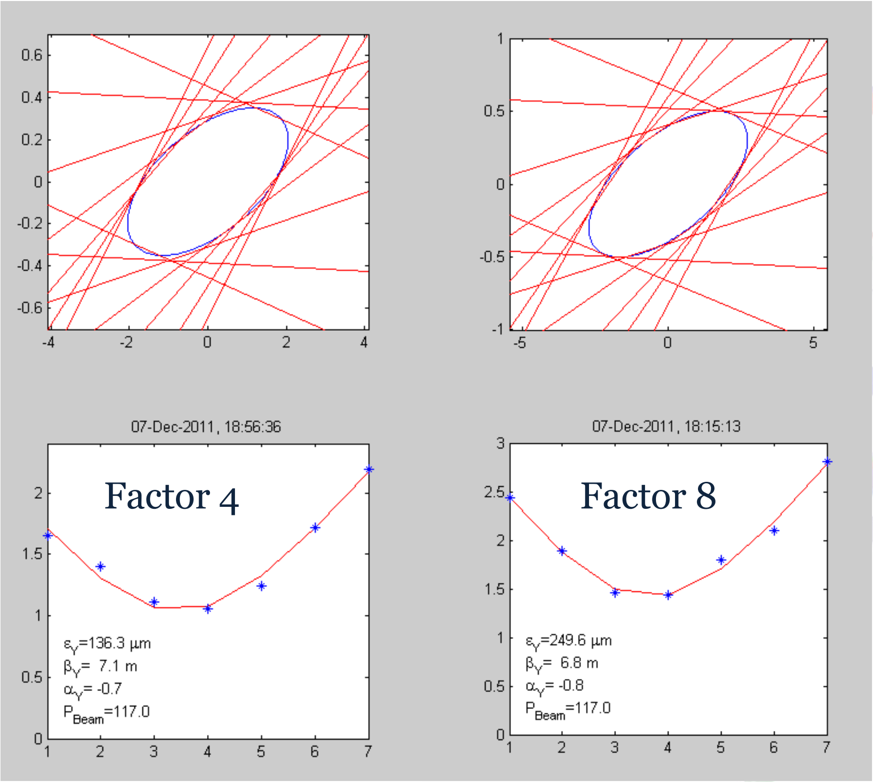


- Improve measurements
- Correct dispersion (linear, nonlinear)
- Correct multi-turn orbit
- Control beta-beating

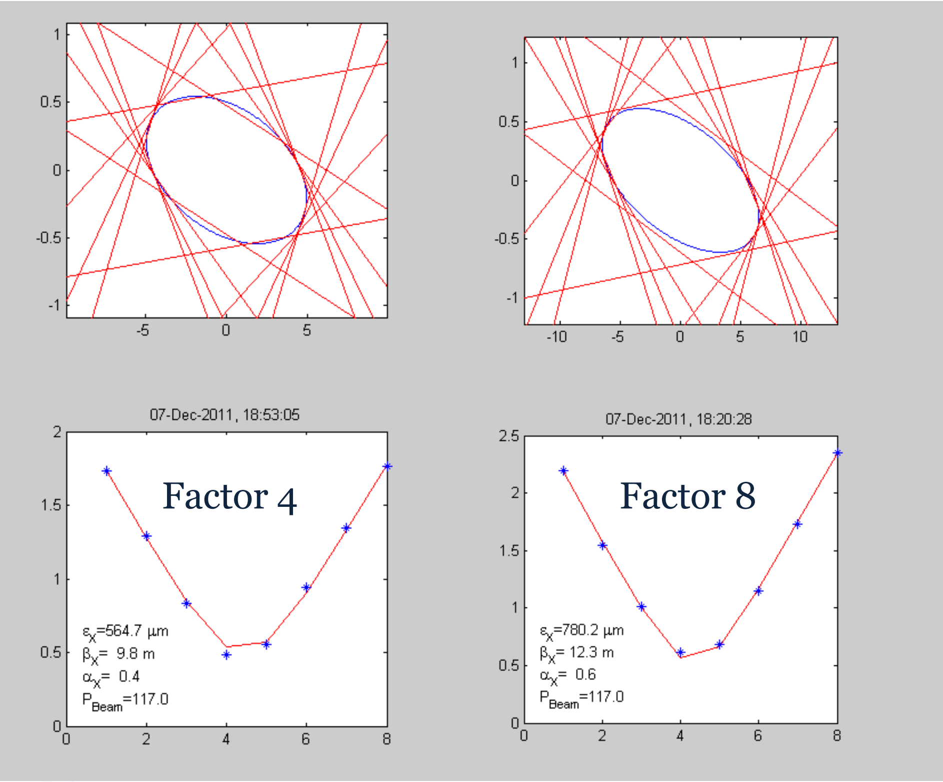
End 2011 ?

Achievements – Drive Beam Generation

Vertical



Horizontal



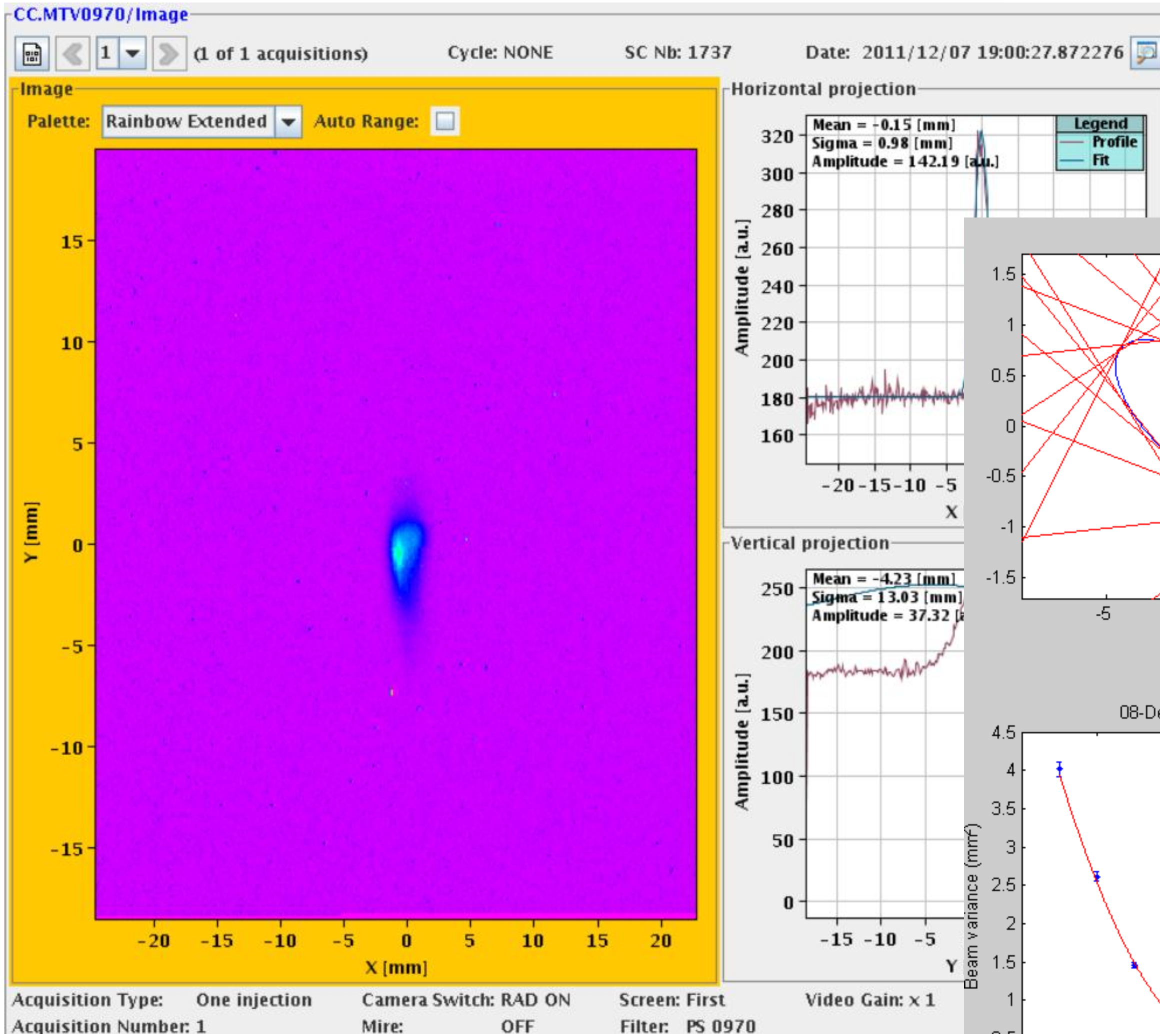
Emittance – last measurements in CLEX

- No time for optimization
- Main issue: different trajectories for DL & bypass beams and ring orbit closure (differences of the order of 1 σ)
    - Vertical: main effect from DL, small effect from ring
    - Horizontal: ring closure is dominant
- Similar Twiss parameters for factor 4 and factor 8 combination (small betatron mismatch)

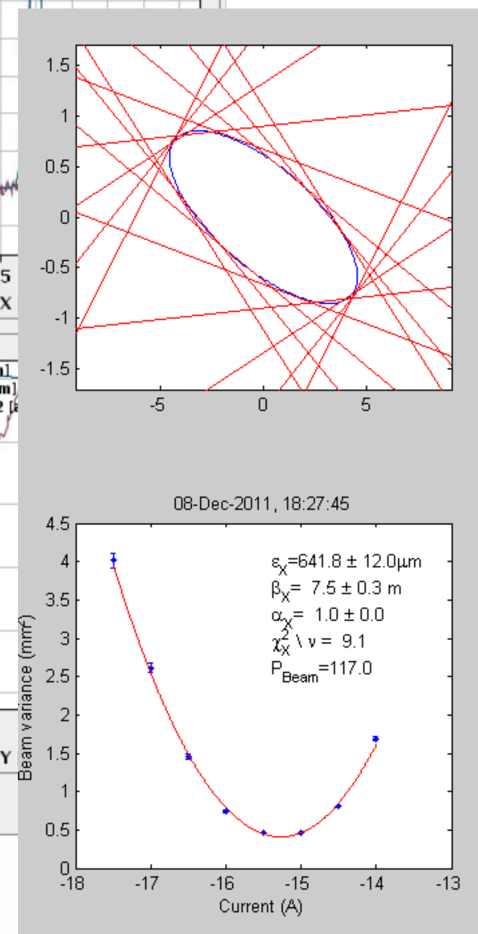
F. Tecker, P. Skowronski, S. Doebert, R. Lillestol

Beam profile during emittance measurements

Factor 8



Improved quad scan program



B. Constance

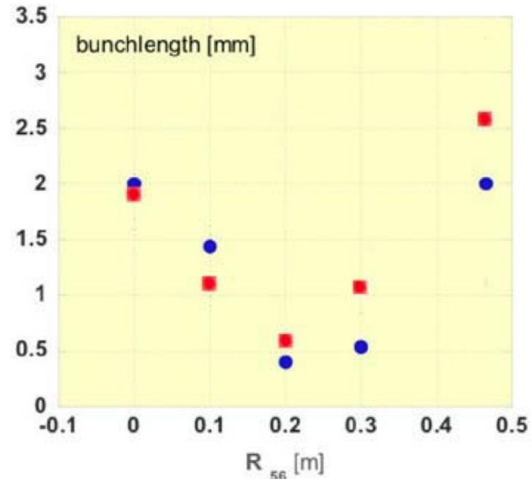
Achievements – Drive Beam Generation

Beam recombination – Bunch lenght

nominal in CLEX 1 mm sigma

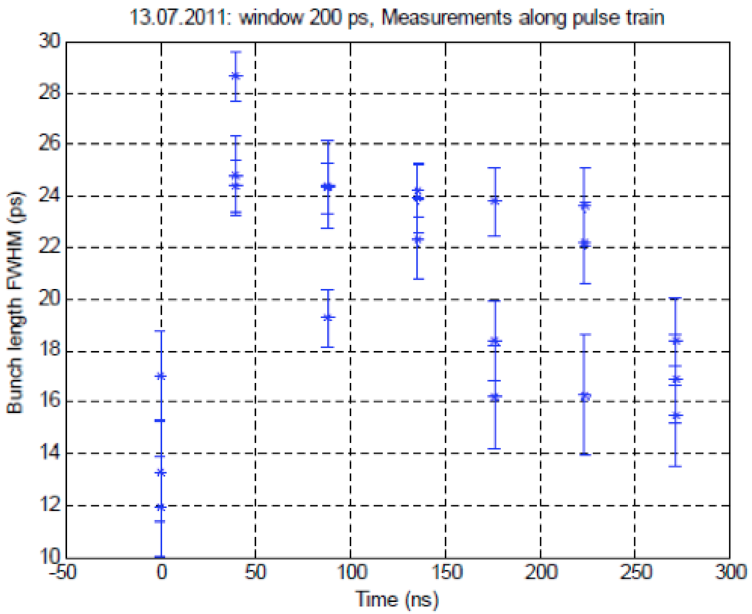
In the past, well below 1 mm sigma measured at the end of the linac (tuned chicane)

Recent results (preliminary): 1.5 to 4 mm sigma for CR and CLEX (natural chicane)



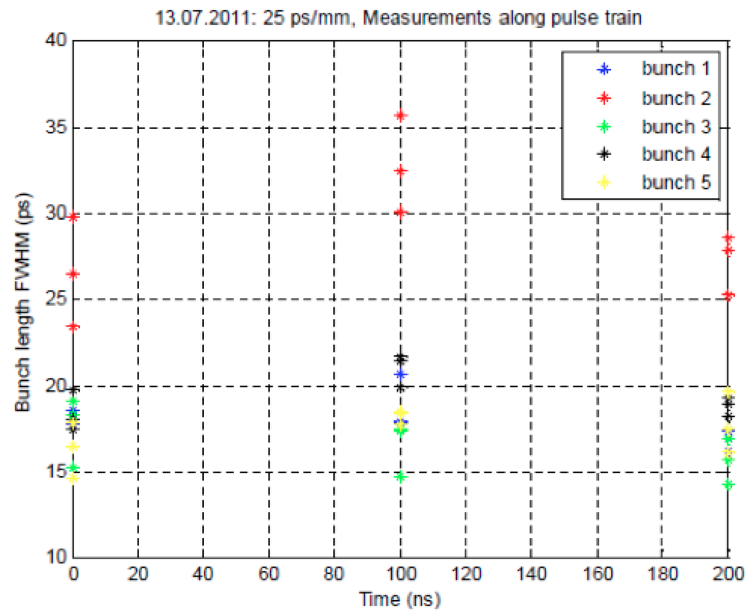
Combiner ring

turn 1, 3 data for each timing



CLEX

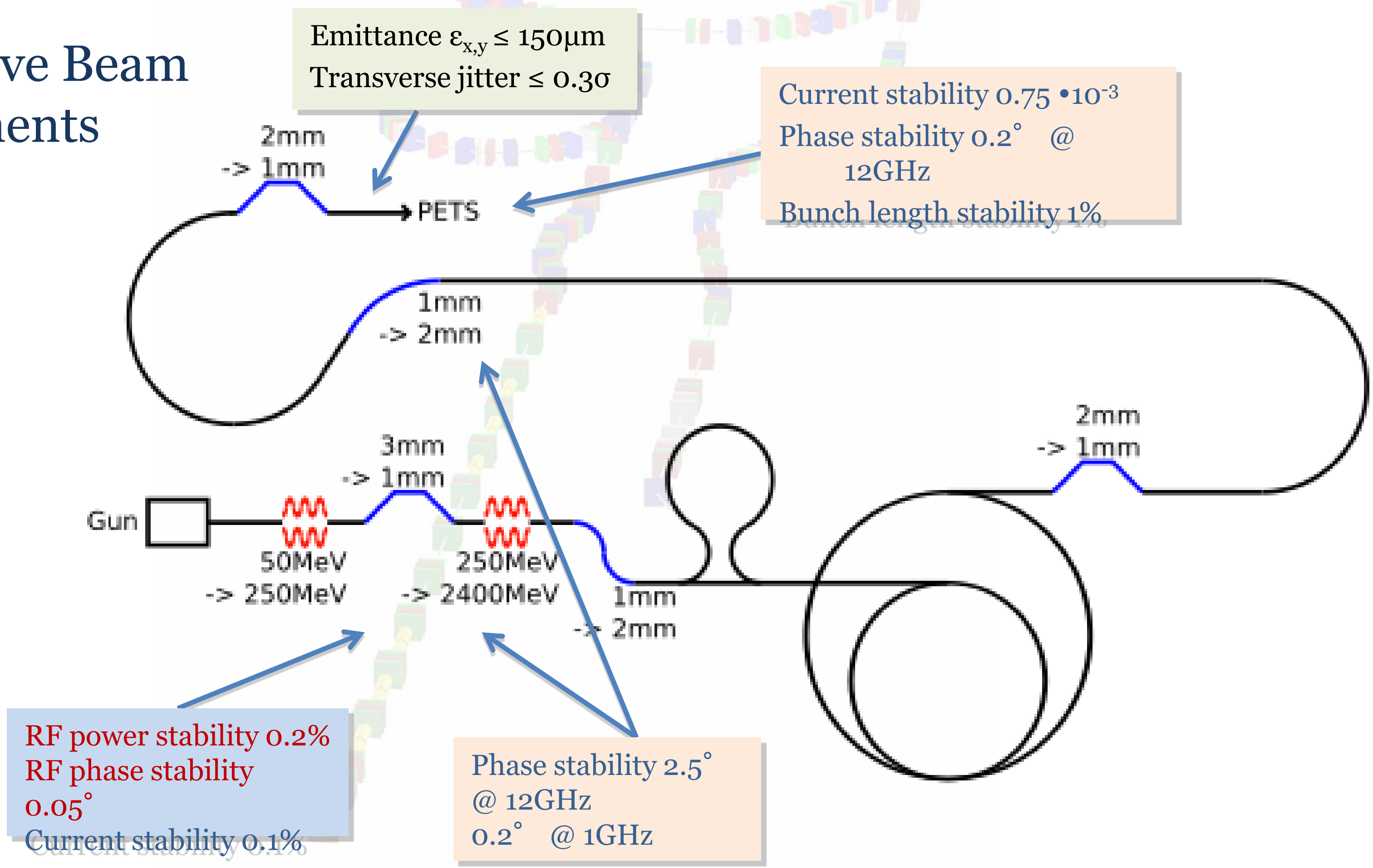
5 bunches per measurement, 3 data for each timing



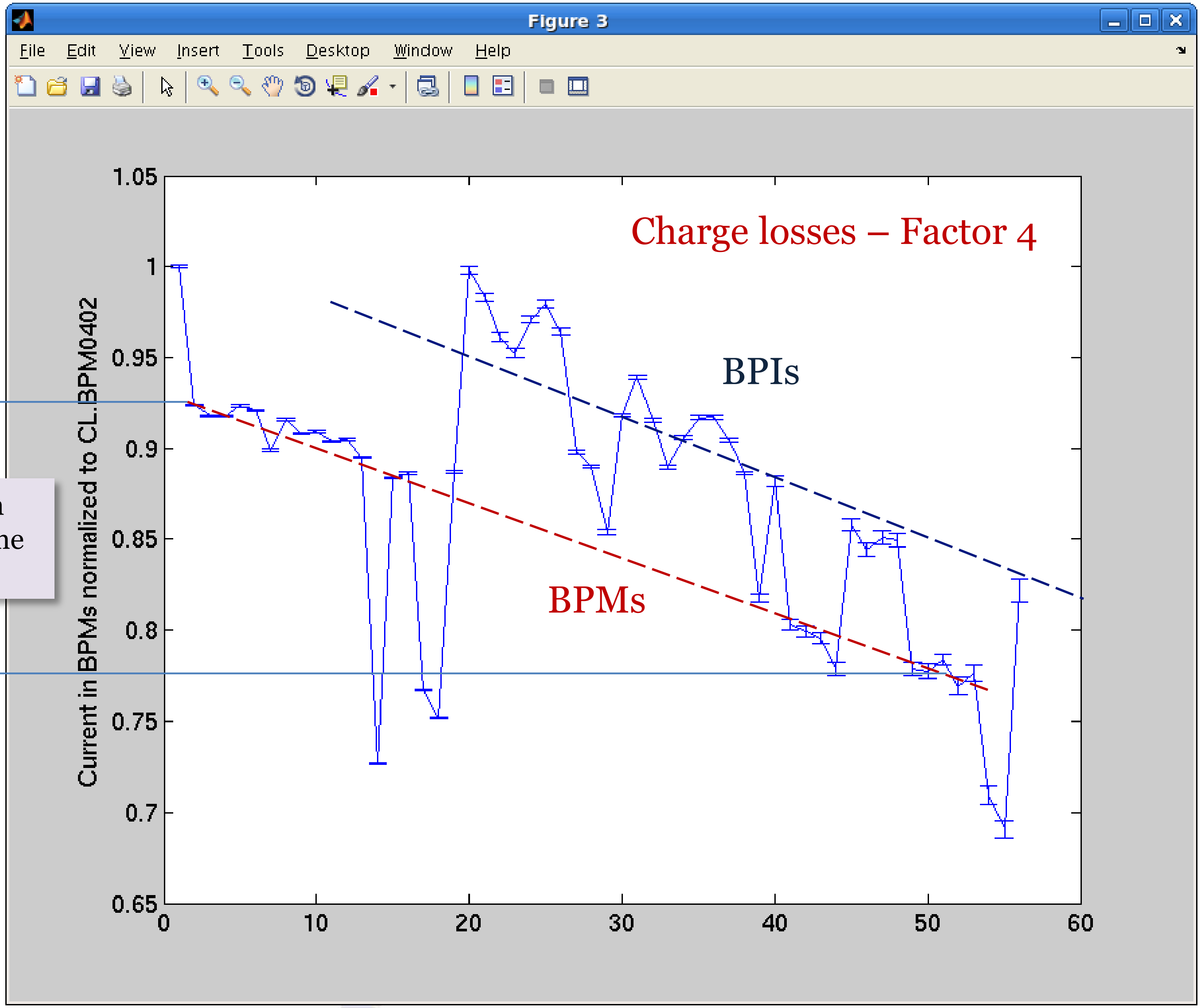
Achievements – Drive Beam Generation

Item	Feasibility Issue	Unit	Nominal	Achieved	How	Feasibility	Comments
Drive beam generation	Fully loaded accel effic	%	97	95	CTF3	✓	Novel scheme fully demonstrated in CTF3 in spite of lower current since beam dynamics more sensitive than nominal due to lower energy (250MeV/2Gev)
	Freq&Current multipl	-	2*3*4	2*4	CTF3	✓	
	Combined beam current (12 GHz)	A	4.5*24=100	3.5*8=28	CTF3	✓	
	Combined pulse length (12 GHz)	nsec	240	140	CTF3	✓	
	Intensity stability	1.E-03	0.75	< 0.6	CTF3	✓	End of DBA. To be demonstrated for combined beam in 2011
	Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design

CLIC Drive Beam requirements



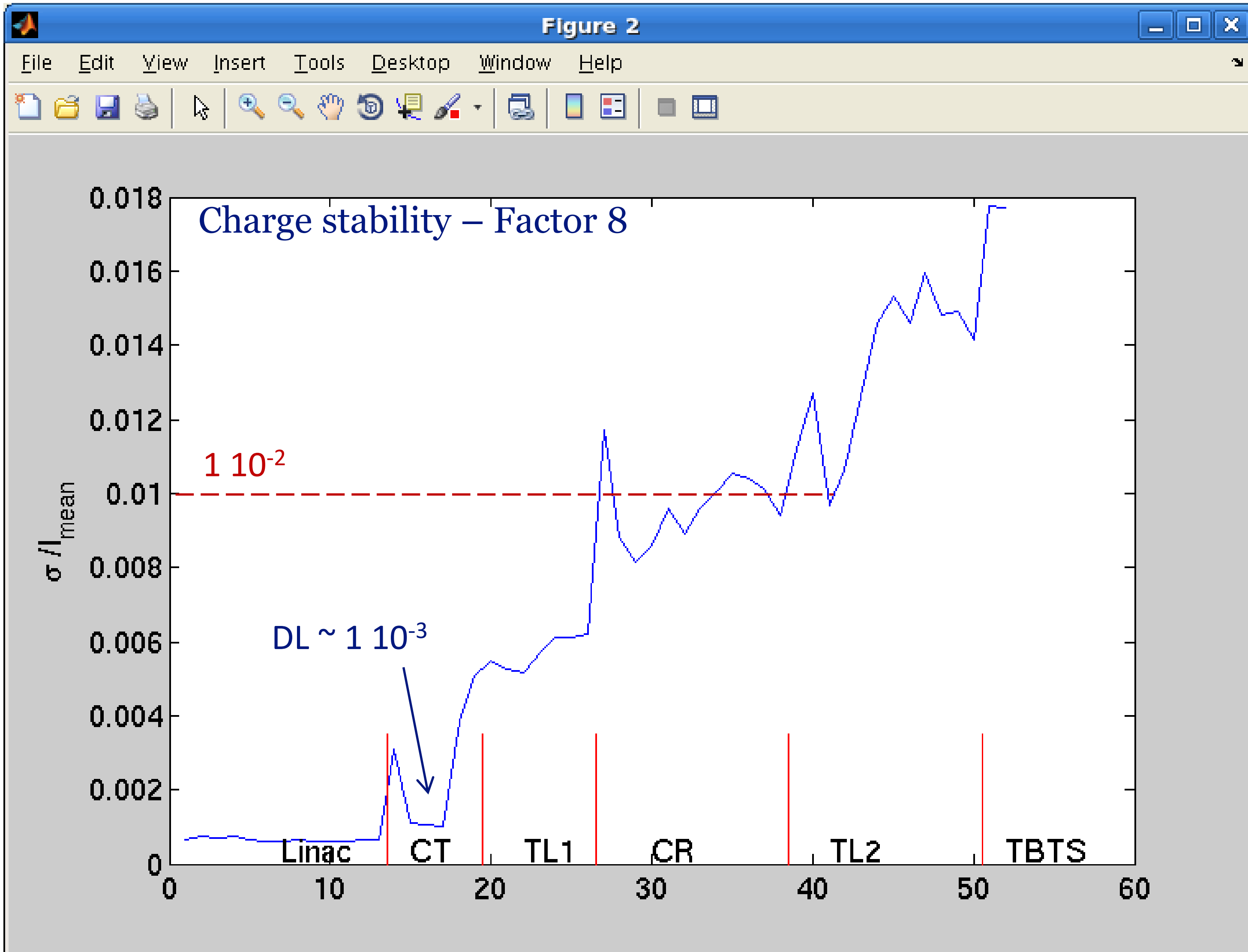
Achievements – Drive Beam Generation



Total loss from cleaning chicane to TBTS ~ 15%

18th November 2011

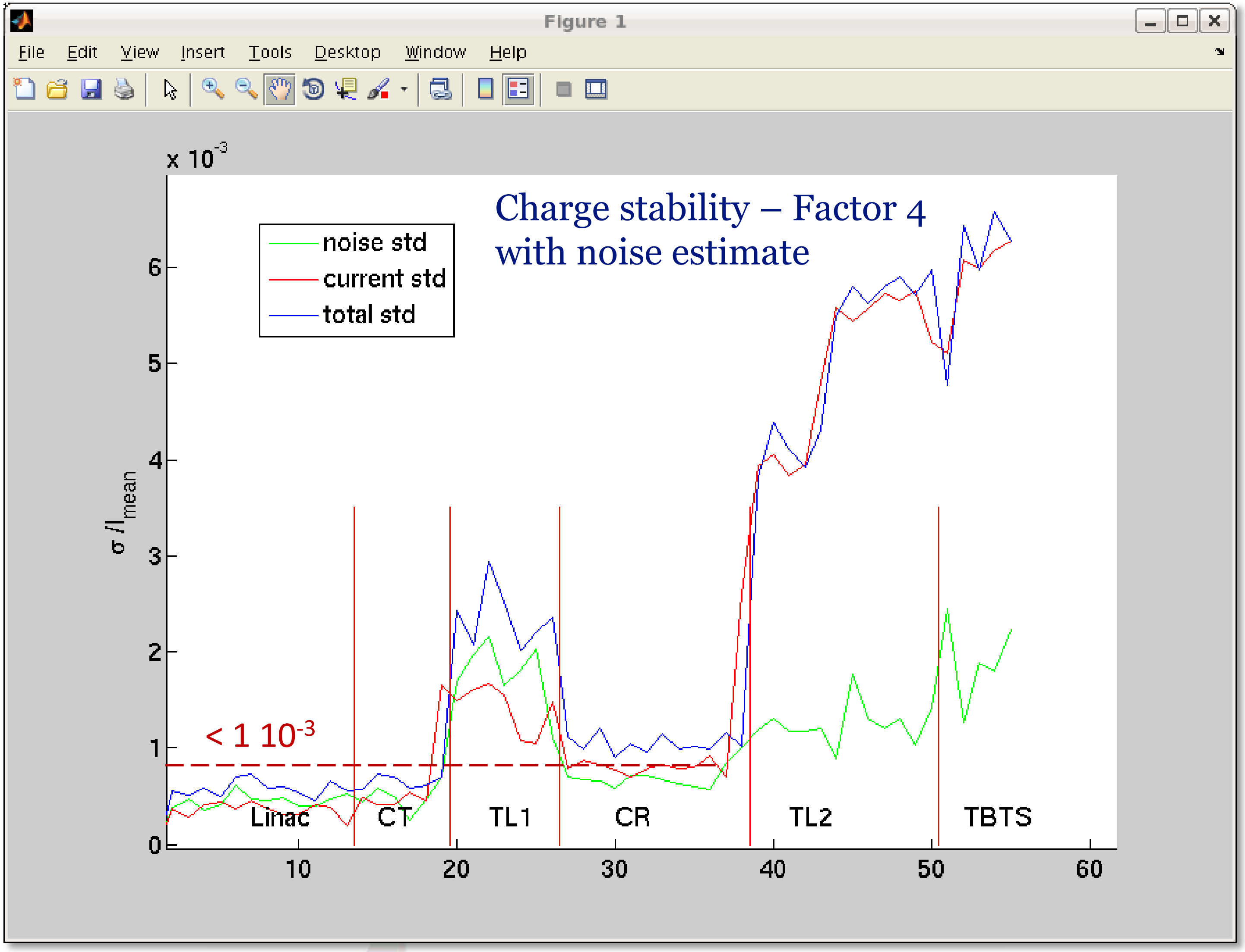
T. Persson



T. Persson

6th December 2011

Achievements – Drive Beam Generation

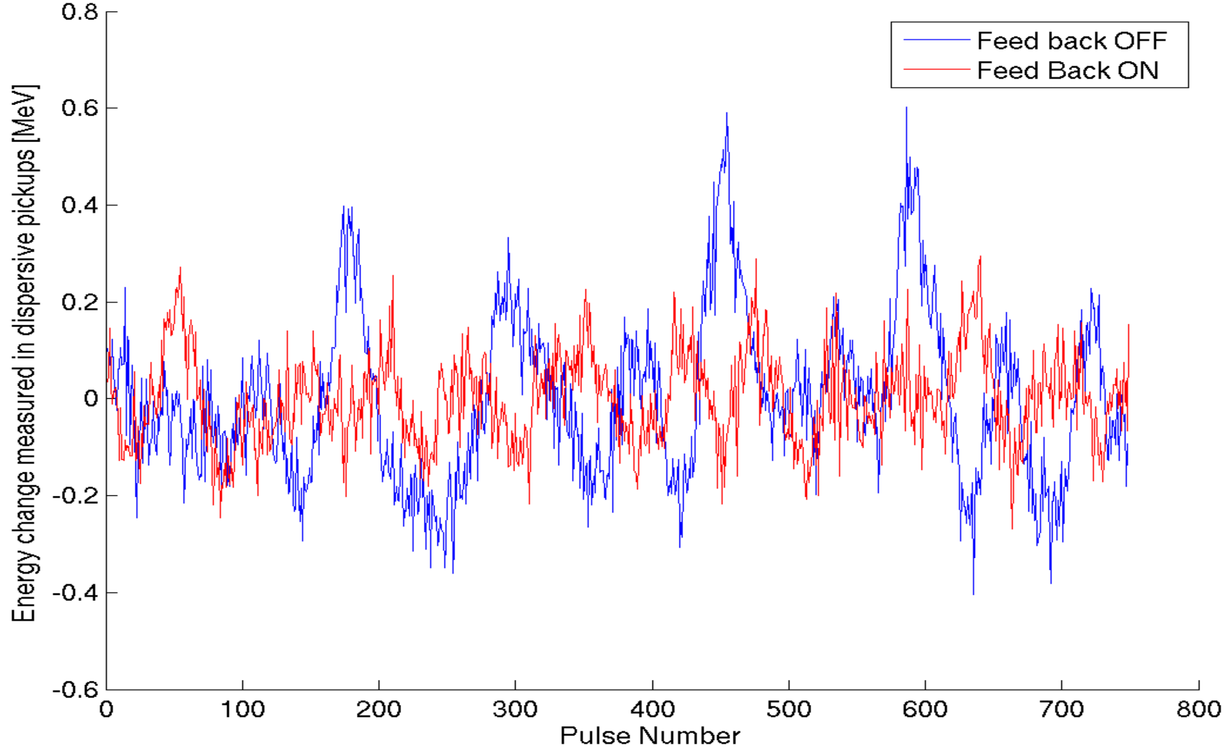


T. Persson

6th December 2011

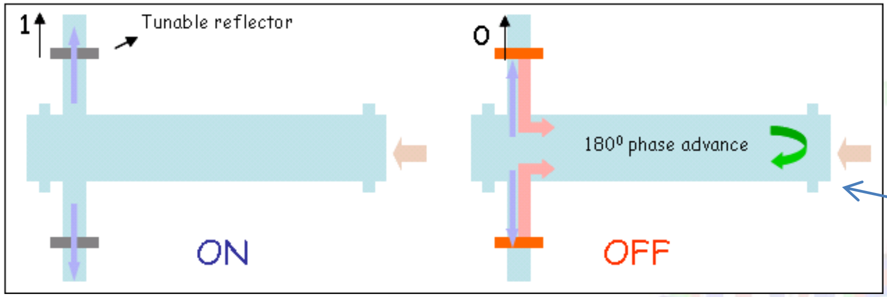
Feed-backs, stability

RF power feedback, effect on beam

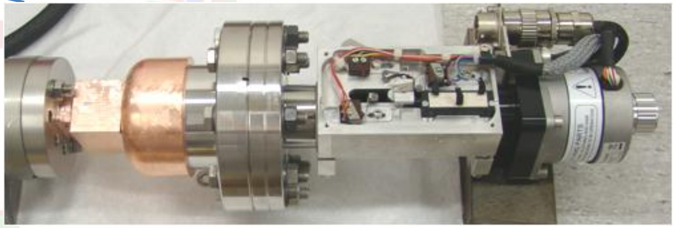


Tobias Persson, Piotr Skowronski

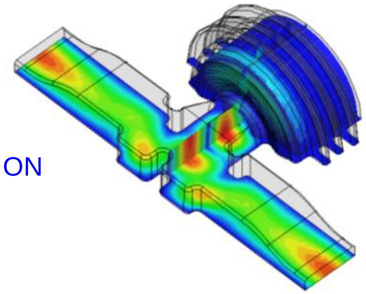
Achievements – Beam driven RF power generation

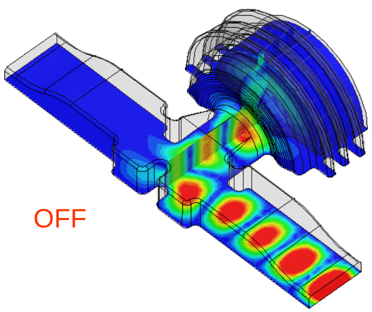


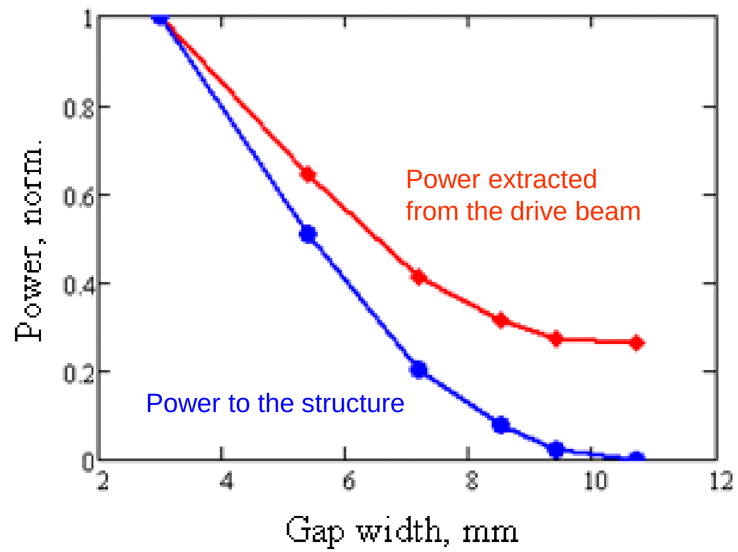
PETS On-Off concept



In CTF3 a movable short is added, to allow for recirculation mode



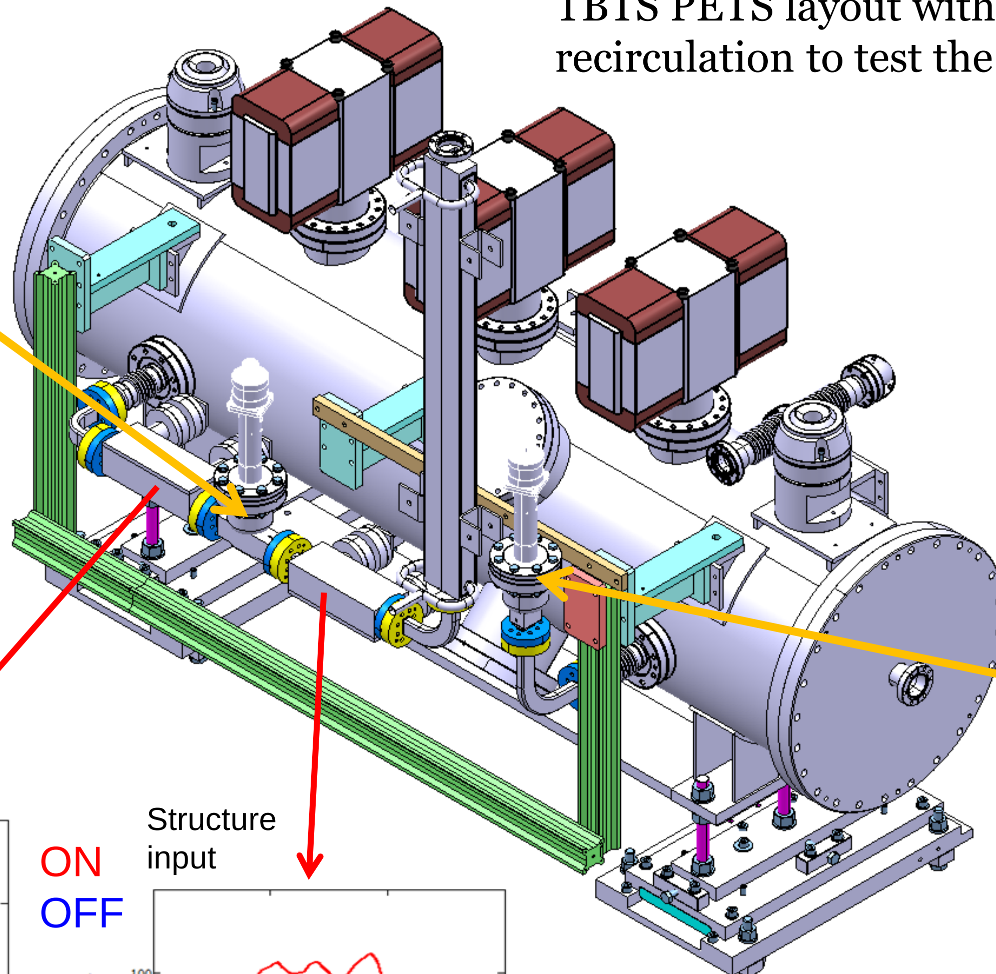




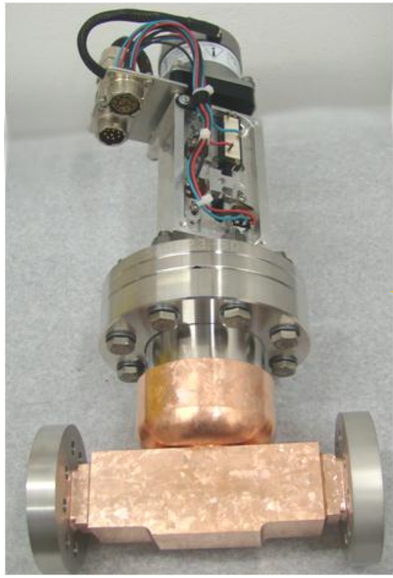
Igor Syratchev, Alexei Dubrowski

Achievements – Beam driven RF power generation

TBTS PETS layout with internal recirculation to test the ON/OFF concept

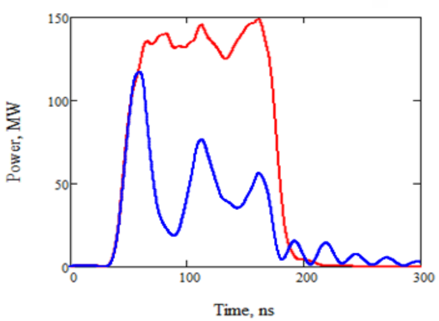


Variable reflector (to tune the recirculation coupling)



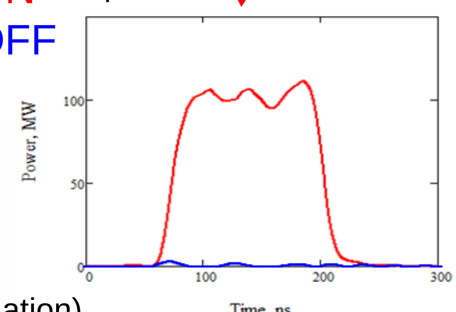
Movable RF short circuit (to tune the resonant length)

PETS output



ON
OFF

Structure input

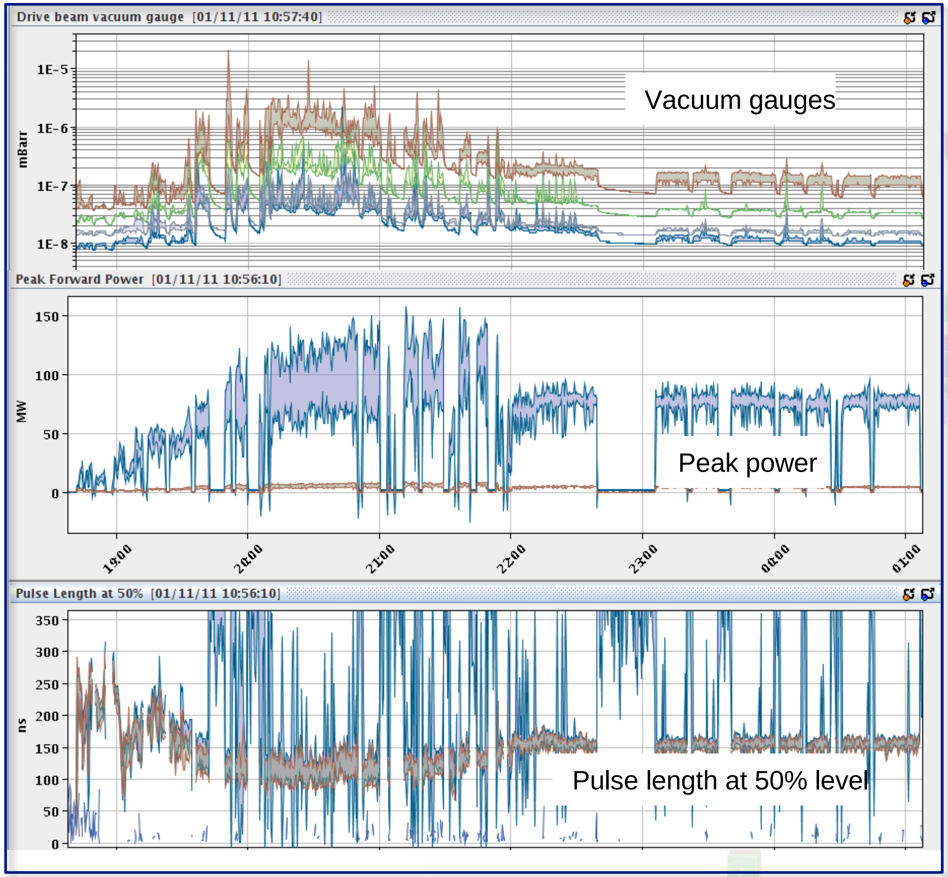


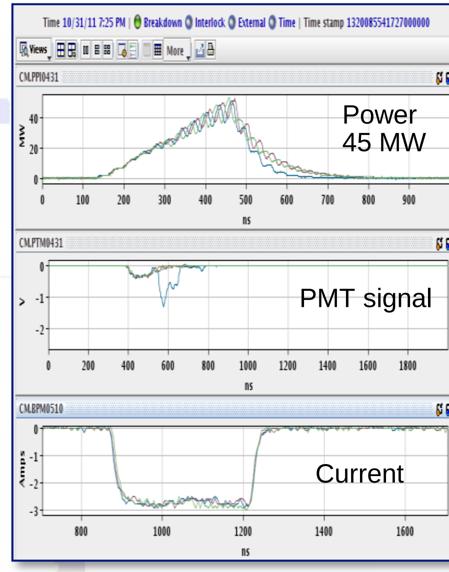
(as predicted by computer simulation)

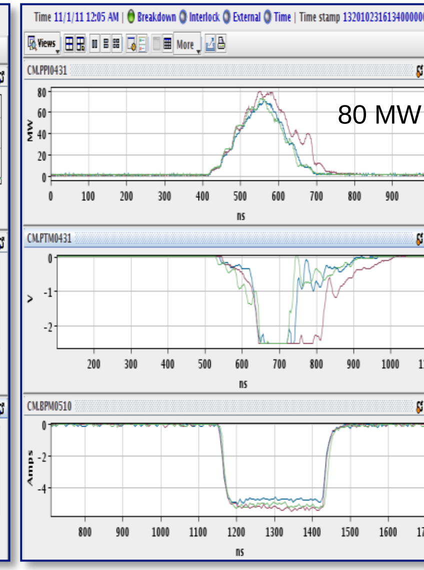
Igor Syratchev

CTF3 Achievements – Beam driven RF power generation

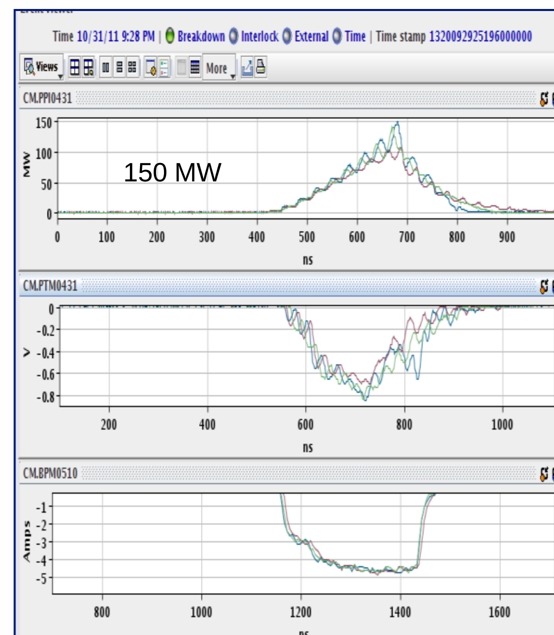
R. Corsini, CLIC Collaboration Working Meeting, 9 May 2012







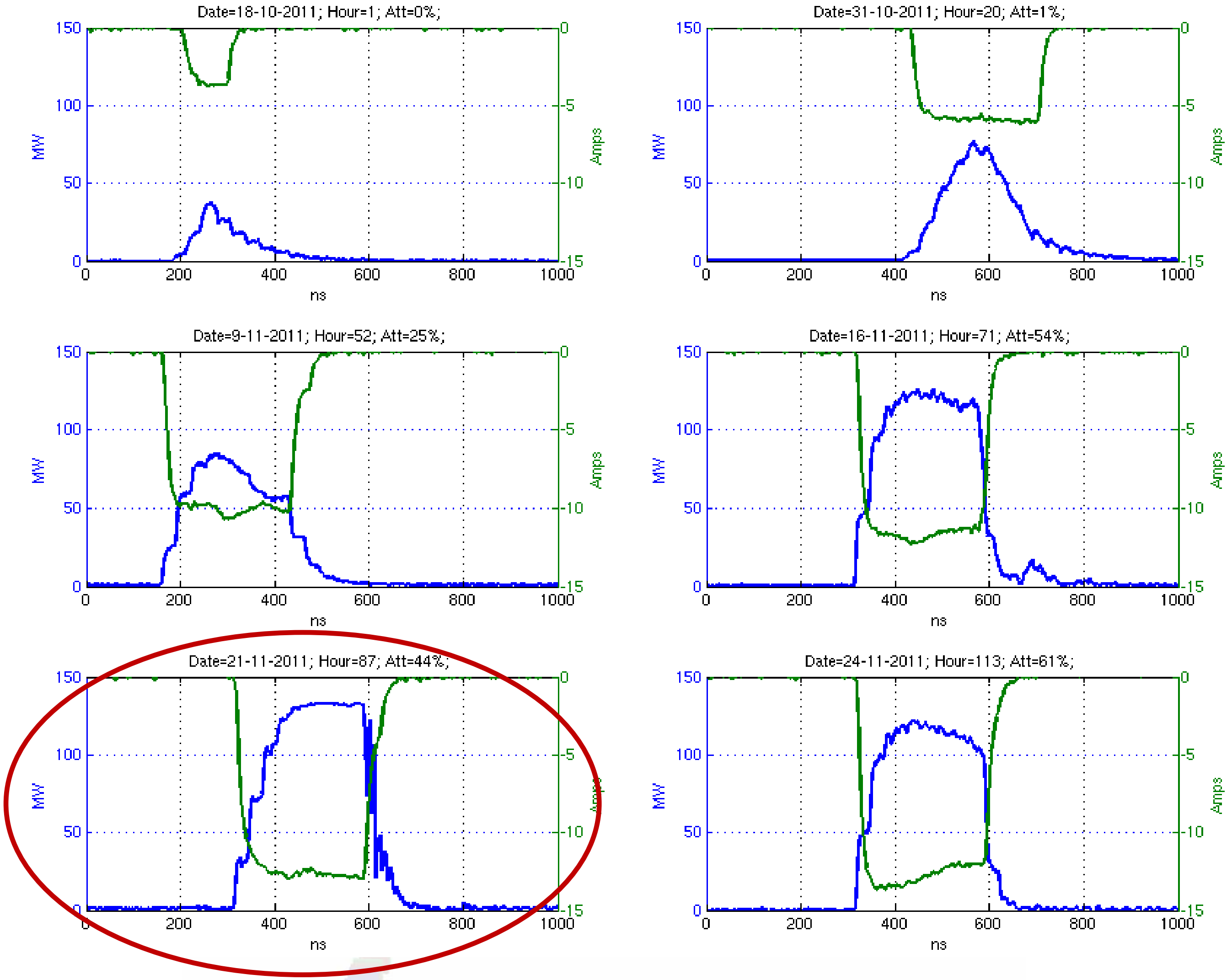
30 October
(logbook pictures)



PETS On-Off conditioning

Igor Syratchev,
Alexei Dubrowski

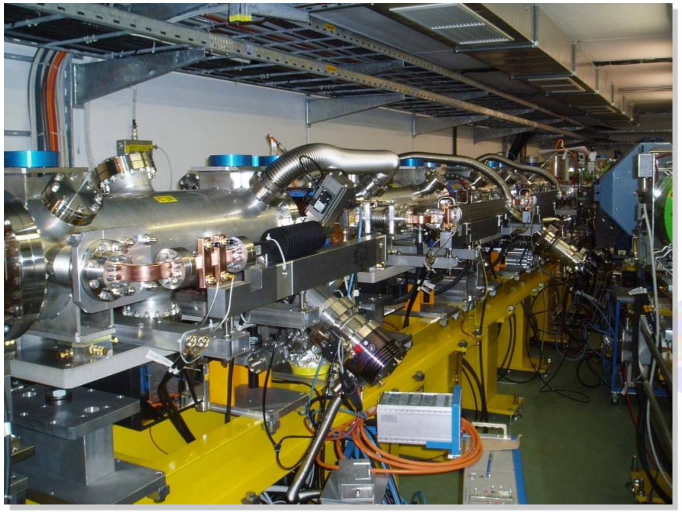
PETS On-Off operation – high current, high power



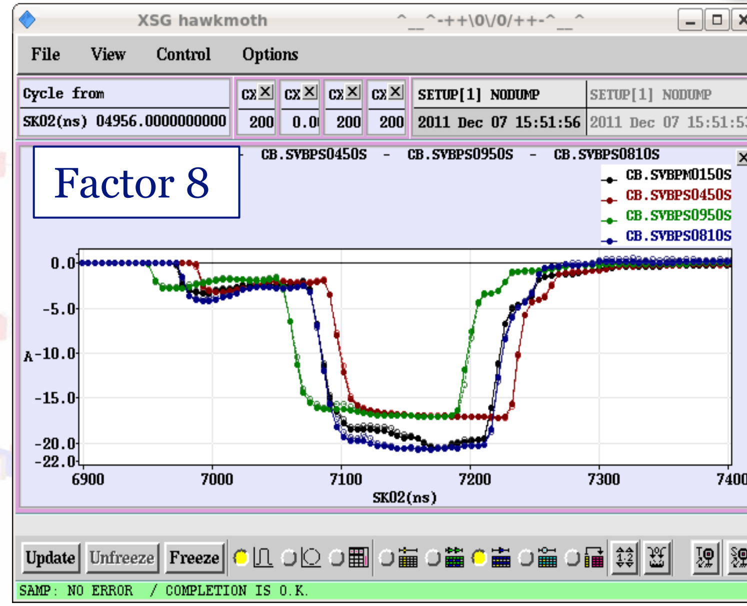
Igor Syratchev,
Alexei Dubrowski

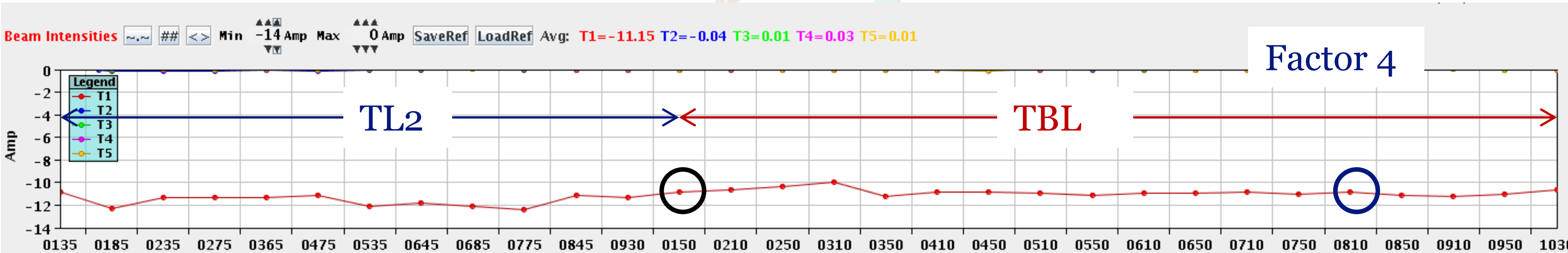
Achievements – Beam driven RF power generation

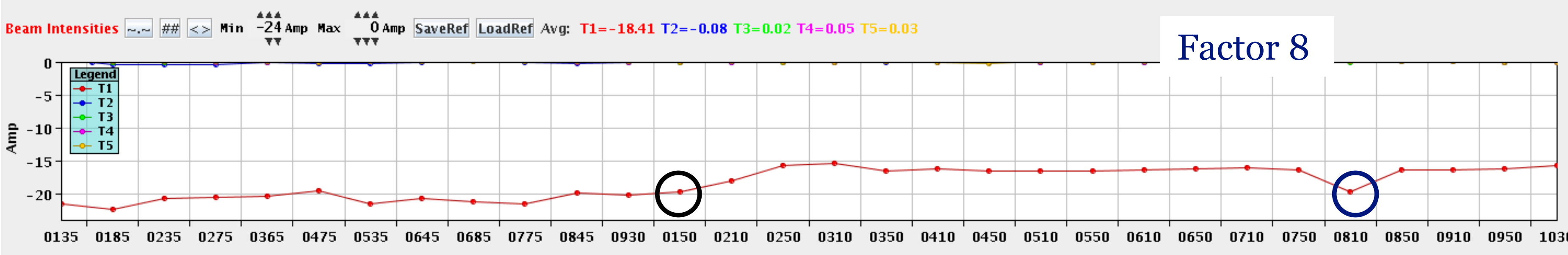
Steffen Doebert, Reidar Lillestol



High current transport in TBL

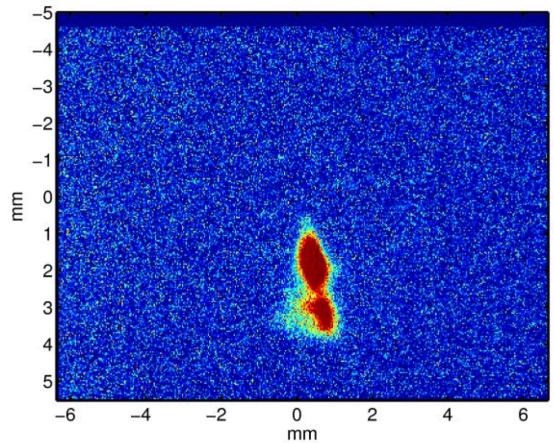


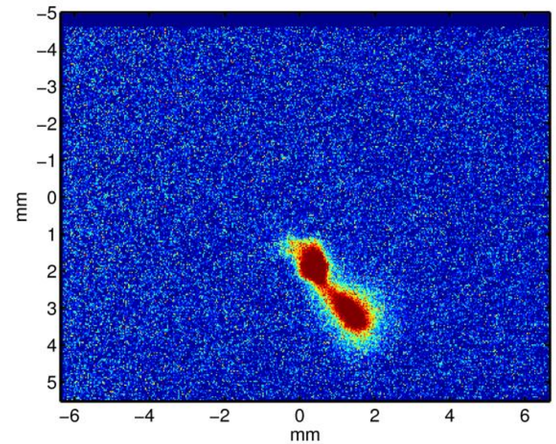




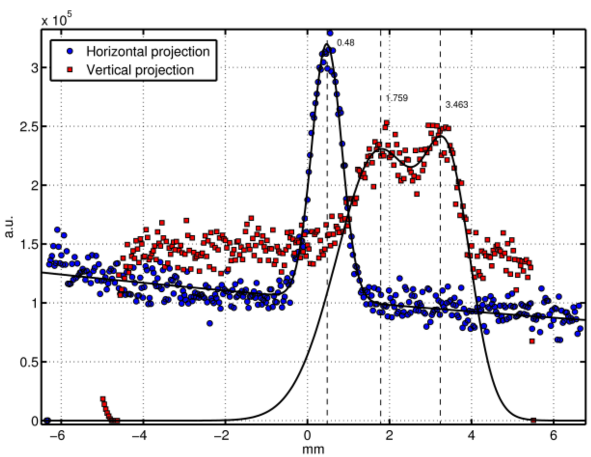
Break-down kicks

Andrea Palaia, Wilfrid Farabolini, Javier Barranco

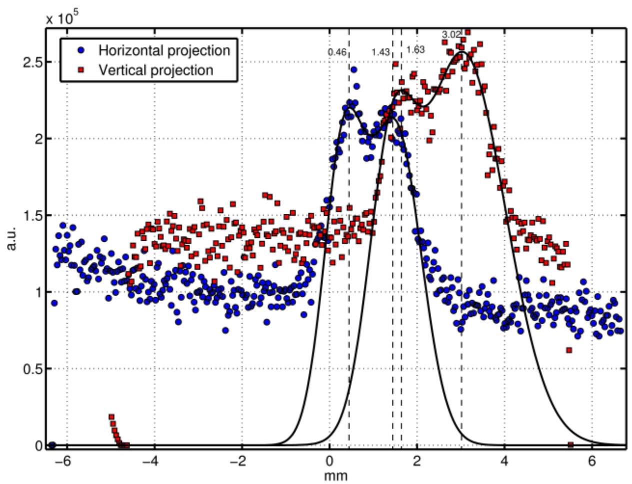




Measured on OTR screen CA.MTV0790 (~4.9 m from the accelerating structure).

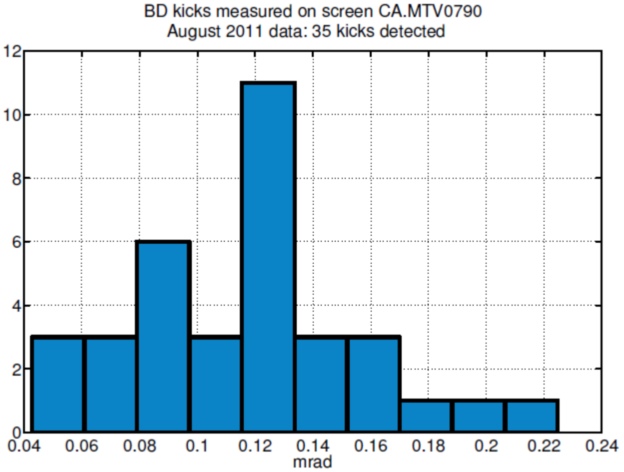


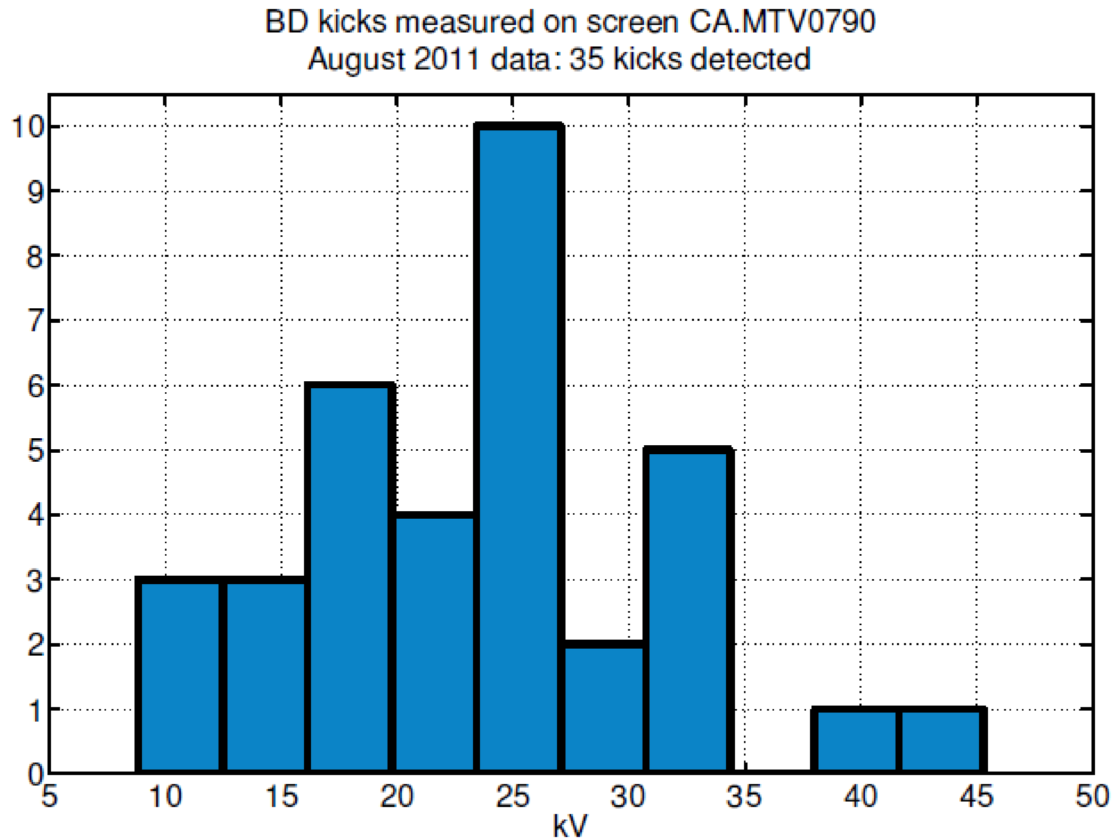
kick angle = 340 μrad



kick angle = 400 μrad

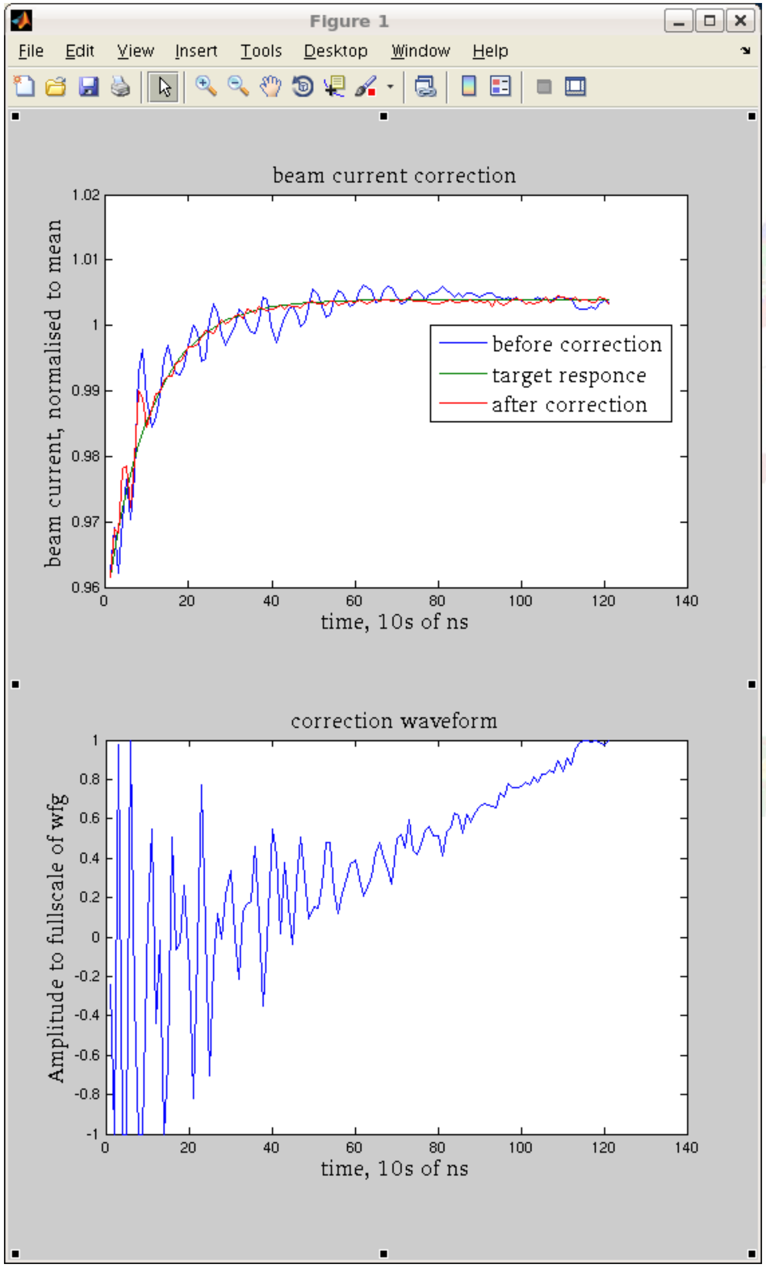
Break-down kicks, distribution



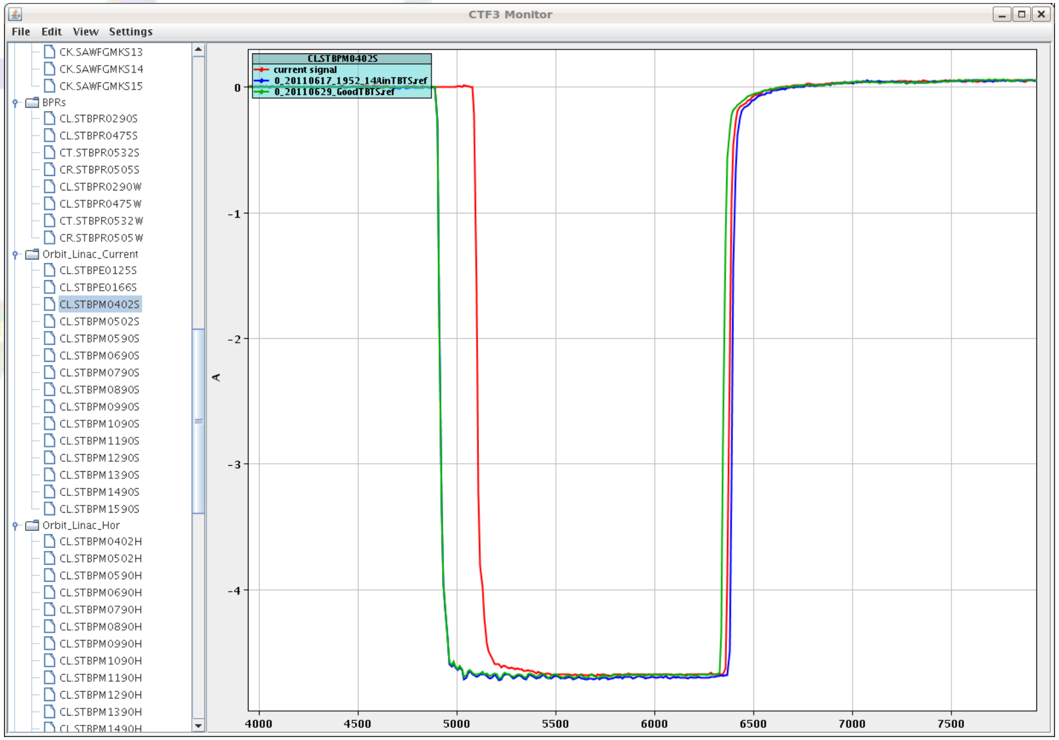


Andrea Palaia

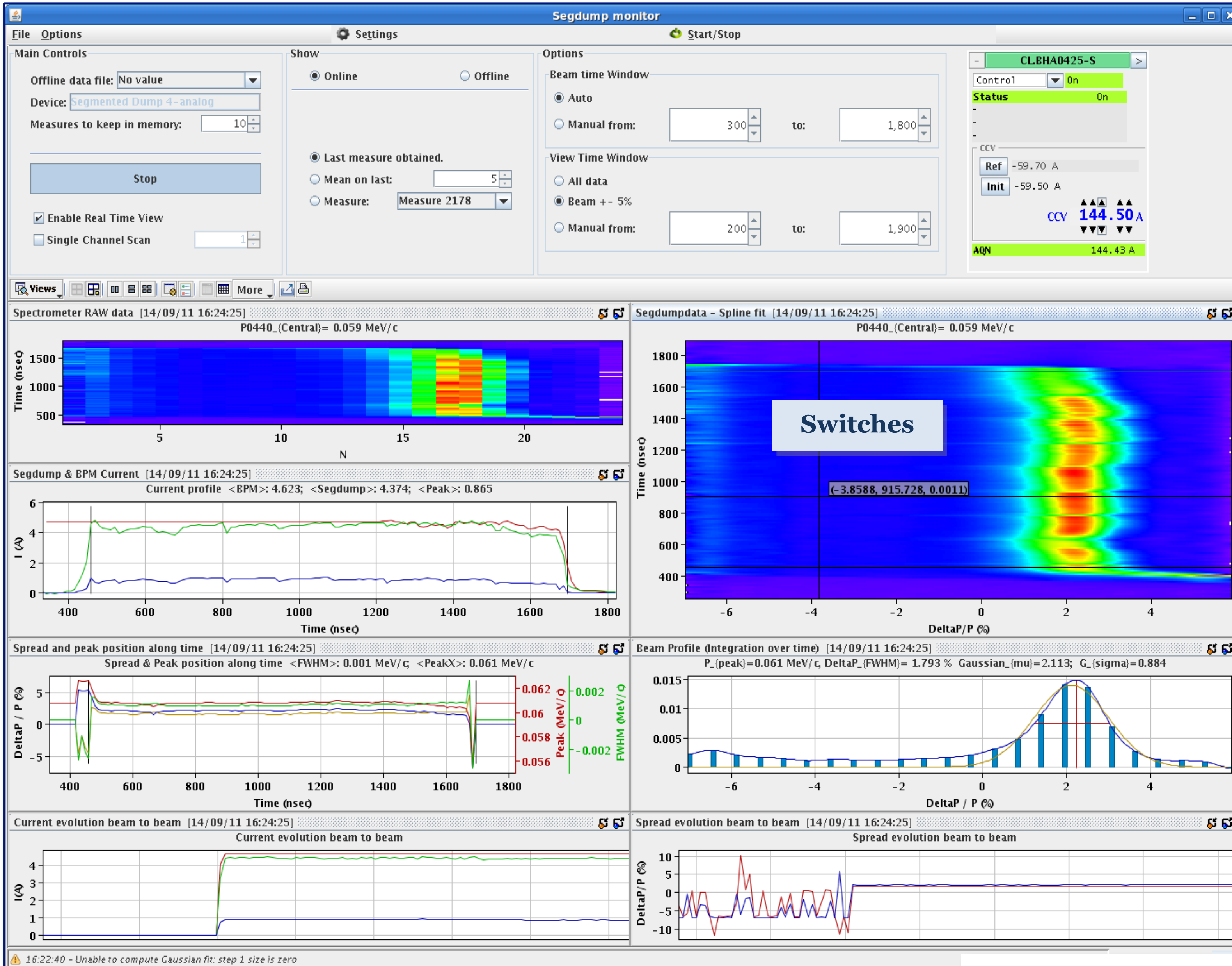
Gun current Correction



Alexandra Andersson



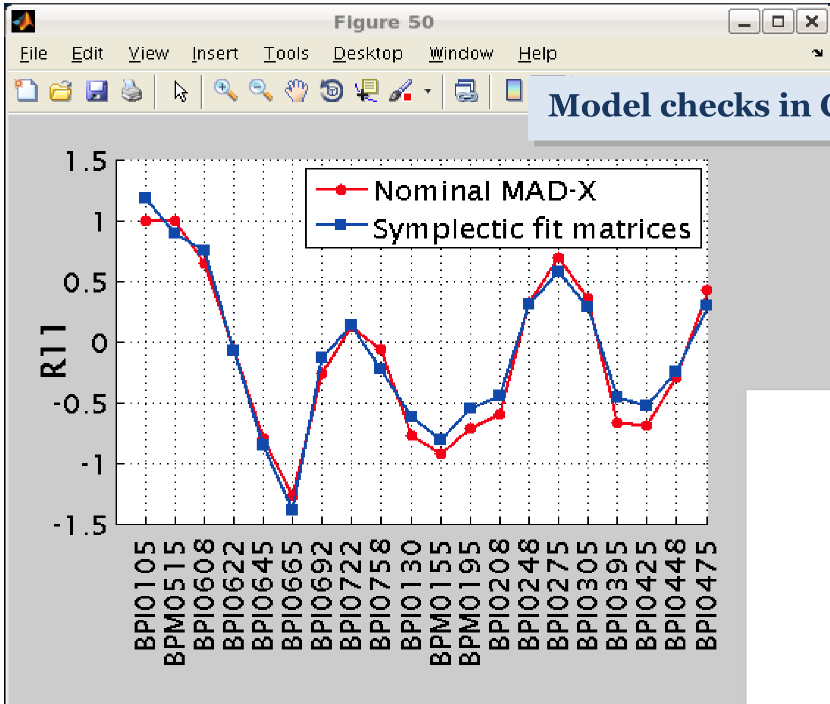
Compensation of phase switches



Frank Tecker, Piotr Skowronski

Optics studies, orbit correction

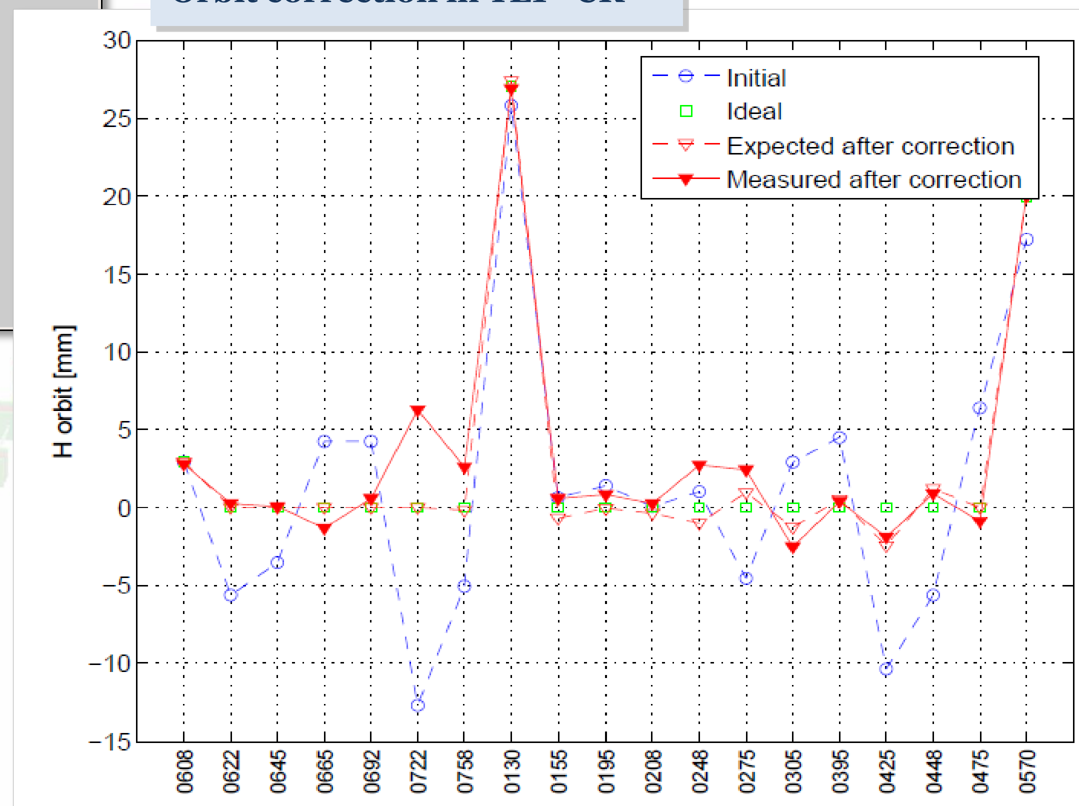
Model checks in CR



Ben Constance

Orbit correction in TL1 - CR

Guido Sterbini, Ben Constance



What do we learn in CTF3, relevant for the CLIC RF power source ?

A non-exhaustive list ☺ easier ☹ more difficult

System	quantity/issue	CTF3	CLIC
Injector/linac	bunch charge	2-3 nC	7.7 nC
	current	3.5 - 4.5 A	4.2 A
	pulse length	1.4 μs	140 μs
	phase coding	same	
	frequency	3 GHz	1 GHz
	transverse stability	about the same - CTF3 ``too stable´´	
Delay loop/ring	final current	30 A	110 A
	beam energy	150 MeV	2.4 GeV
	combination	2 - 4	2 - 3, 4
	CSR, wakes	worse in CTF3 (lower energy)	
	Deflector instability	about the same	
Power production (PETS)	Aperture	23 mm	23 mm
	Length	≈ 1 m	23 cm
	Power	> 135 MW	135 MW
	Pulse length	140 ns (240 with recirculation)	240 ns
Decelerator	Fractional loss	50-60 %	90%
	Final energy	70 MeV	240 MeV
	wakes, stability	somehow ``masked´´ in CTF3	
	beam envelope	much larger in CTF3	

In general, most of unwanted effects are equivalent or worse in CTF3 because of the low energy, however in CLIC the beam power is much larger (heating, activation, machine protection)

Needed tolerances on the final drive beam parameters (phase, current, energy stability...) are more stringent in CLIC – some could be demonstrated in CTF3 as well