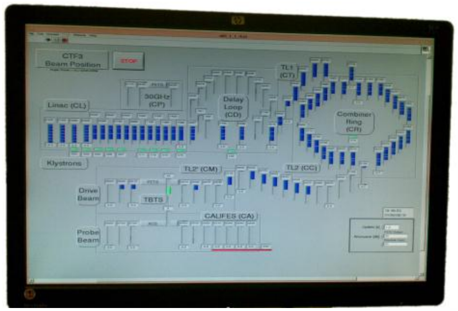


CTF3 Experimental program for 2012

R. Corsini for the CTF3 Team

CLIC Feasibility Benchmarks

CTF3

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. RF Nextef – RF test stand KEK
		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 ✓	
	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

RF Test Stands

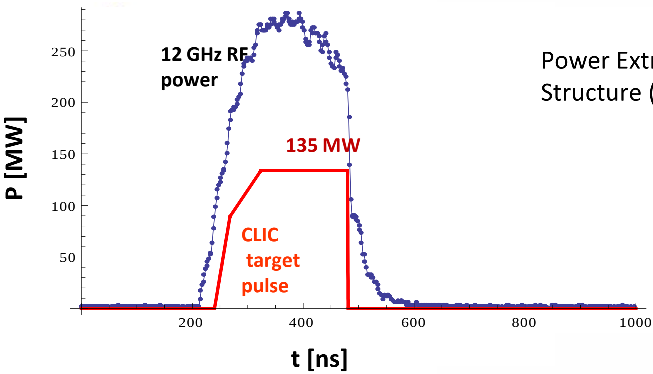
SLAC – KEK -CERN

Technical system tests and simulations

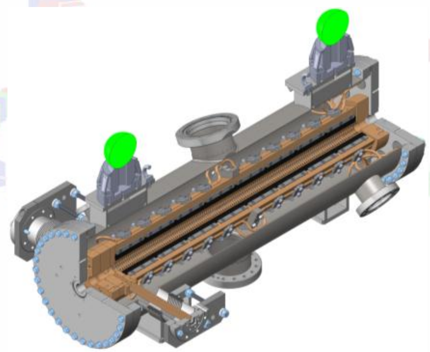
CTF3 highlights - 2011

- 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.



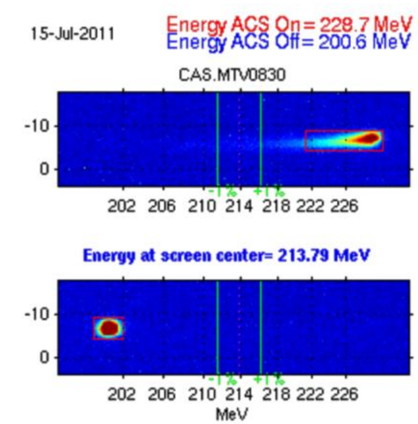
Power Extraction Structure (PETS)



- First successful test of PETS with on-off mechanism

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

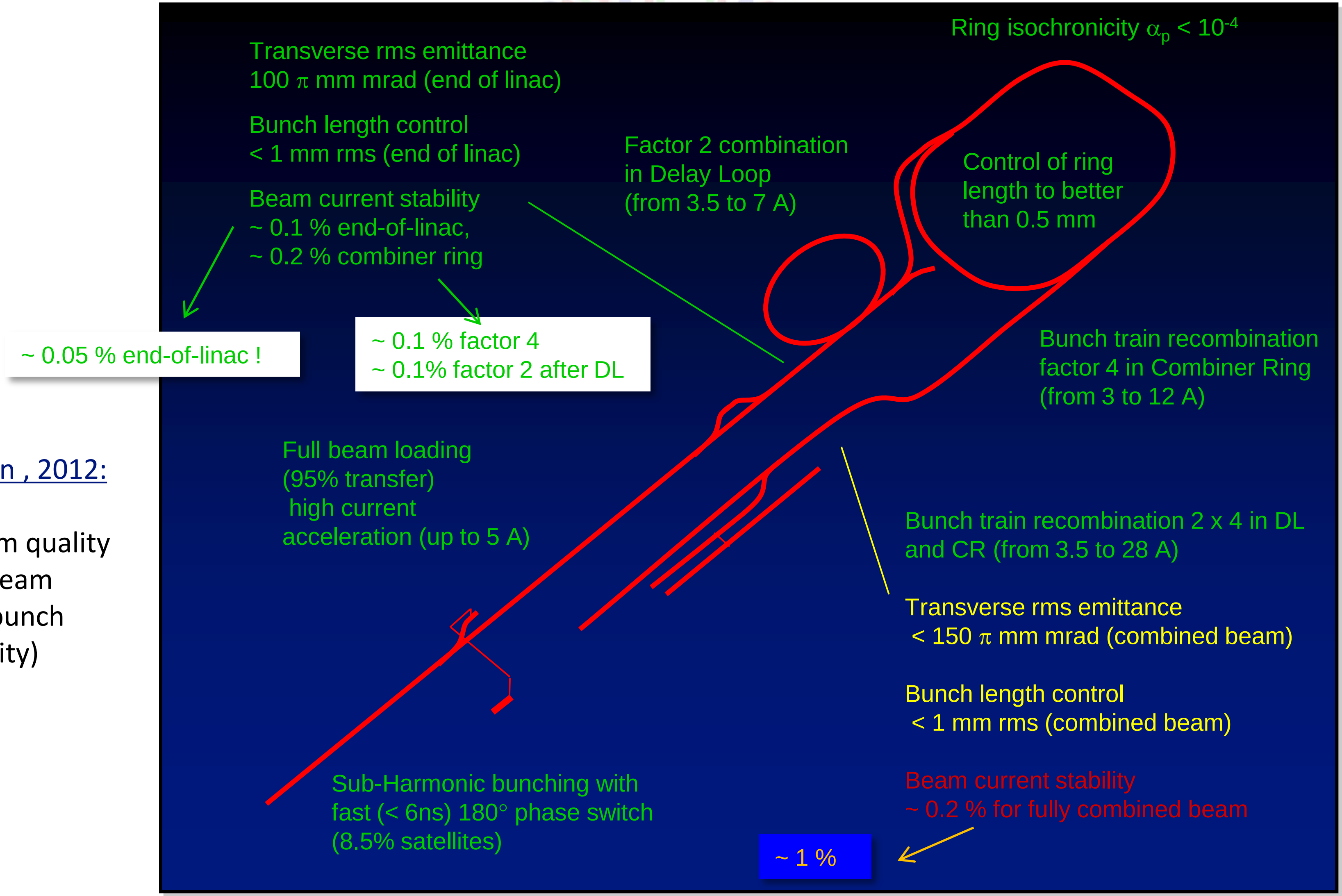
Two-beam acceleration in TBTS



- Nine PETS tanks installed in the Test Beam Line (TBL), 20 A decelerated by ~ 25%, matching well with expectations

Test Beam Line (TBL) in CTF3

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



DB generation , 2012:

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

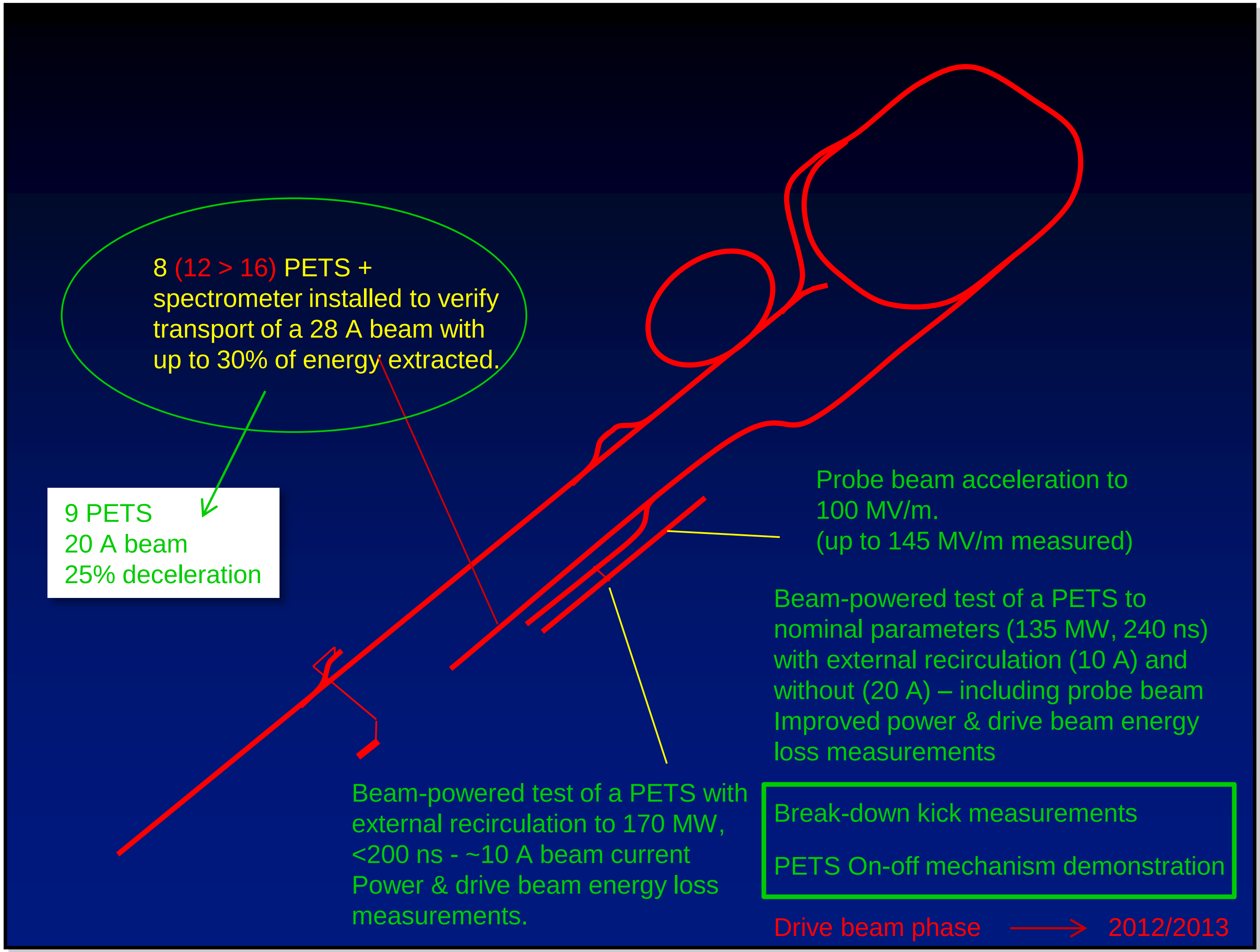
CTF3 Achievements – What is still missing for feasibility – TBL / TBTS

TBTS, 2012:

- Continue studies with two new structures
- Wakefield monitors

TBL:

- 12 PETS start 2012
- 16 PETS in 2013 (TBL+)



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.

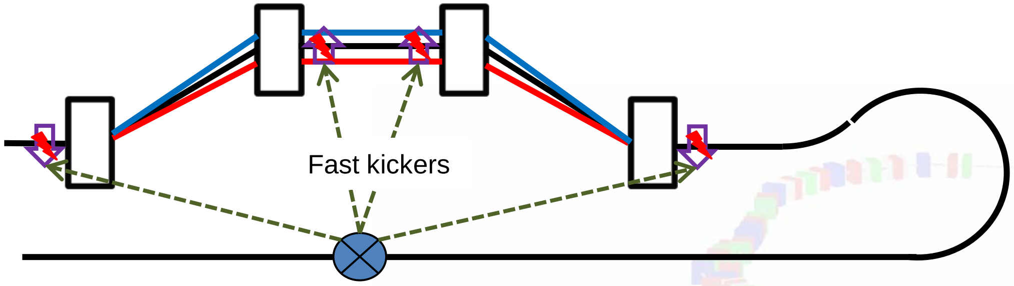
N.B.: CTF3 being limited in rep rate, some RF studies are better carried out in the stand-alone test stand (need common analysis – AND superposition of BD rate regimes).

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

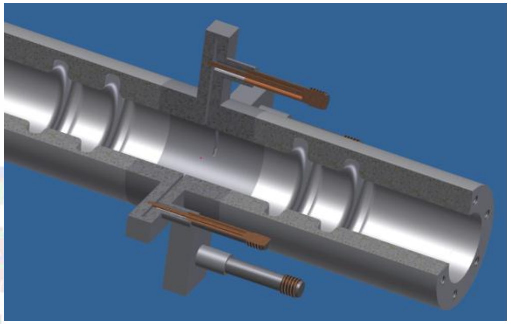
TBL

- 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)

Drive Beam feed-forward and feedback (CTF3-002)



CLIC drive beam phase feed-forward concept

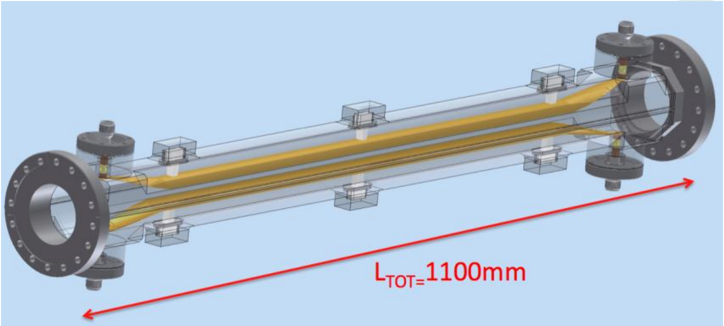

Phase monitor

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

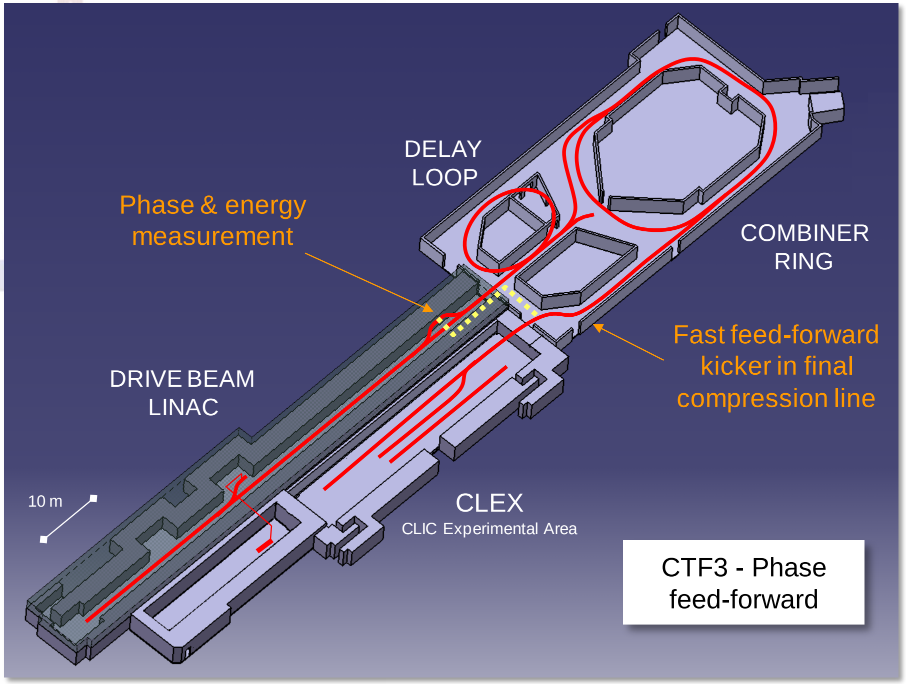
- Measure phase and energy jitter, identify sources, devise & implement cures, extrapolate to CLIC
- Phase monitor tests in 2012
- First feedback/feed-forward tests in 2013
- Show principle of CLIC fast feed-forward

Close link to collaborating partners (INFN, Oxford…)

P. Skowronski,
P. Burrows, A.Ghigo



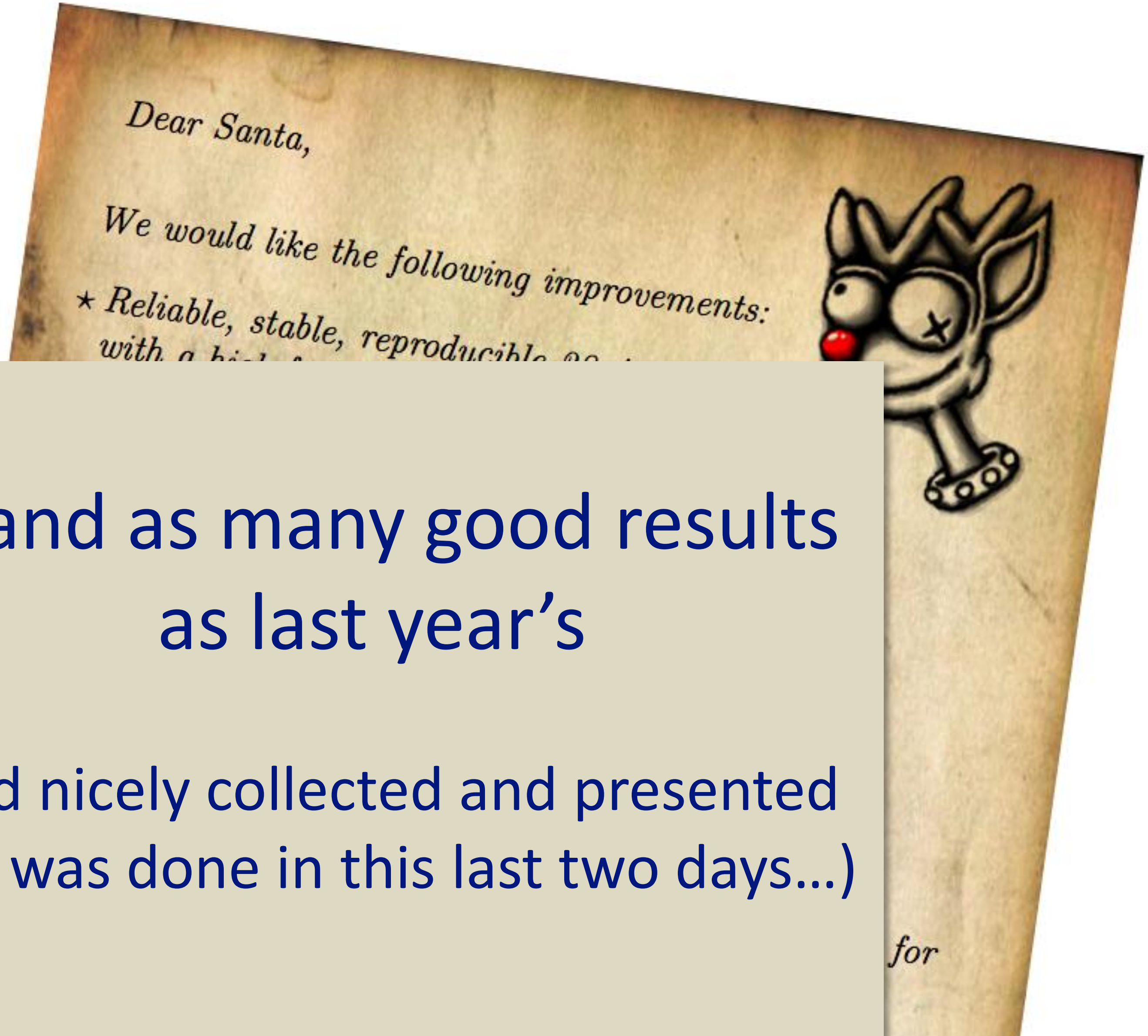
Stripline kicker



Other activities

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

Wishlist



... and as many good results as last year's

(and nicely collected and presented as it was done in this last two days...)

Thanks for your attention

TBL beyond 2012 (CTF3-003)

R. Corsini,
CTF3 working meeting
February 10, 2012

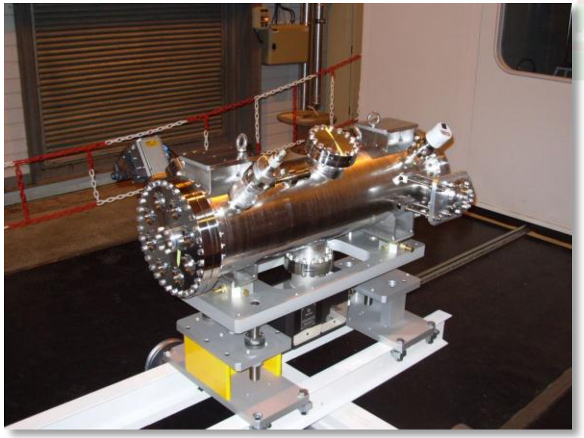
Upgrade TBL to a test facility relevant for CLIC TDR work

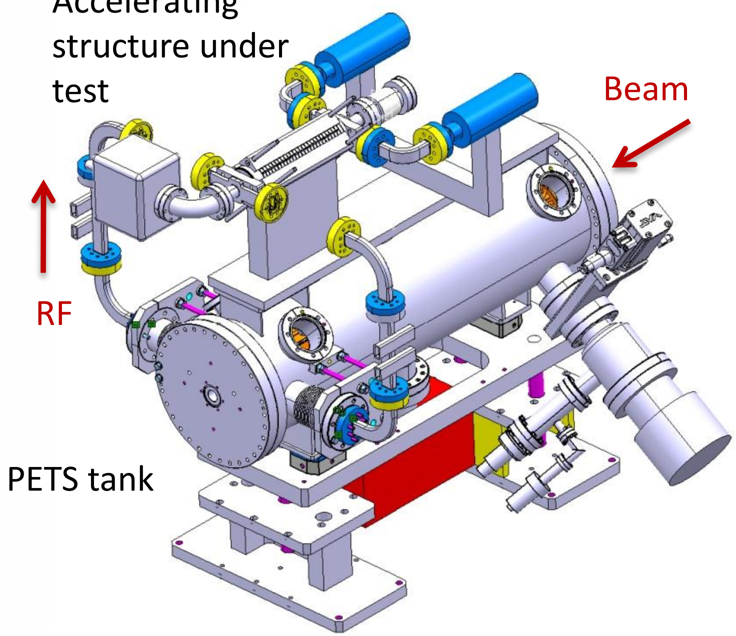
- 12 GHz power production for structure conditioning
- Working experience with a real decelerator
- Beam dynamics studies, pulse shaping, feedbacks, etc

Timeline:

- Last batch of four PETS installed in late 2012 will be adapted to high-power testing
- One (or two slots) tested at beginning of 2013
- Gradual increase of slots to 4-8 slots and rep rate to 25-50 Hz

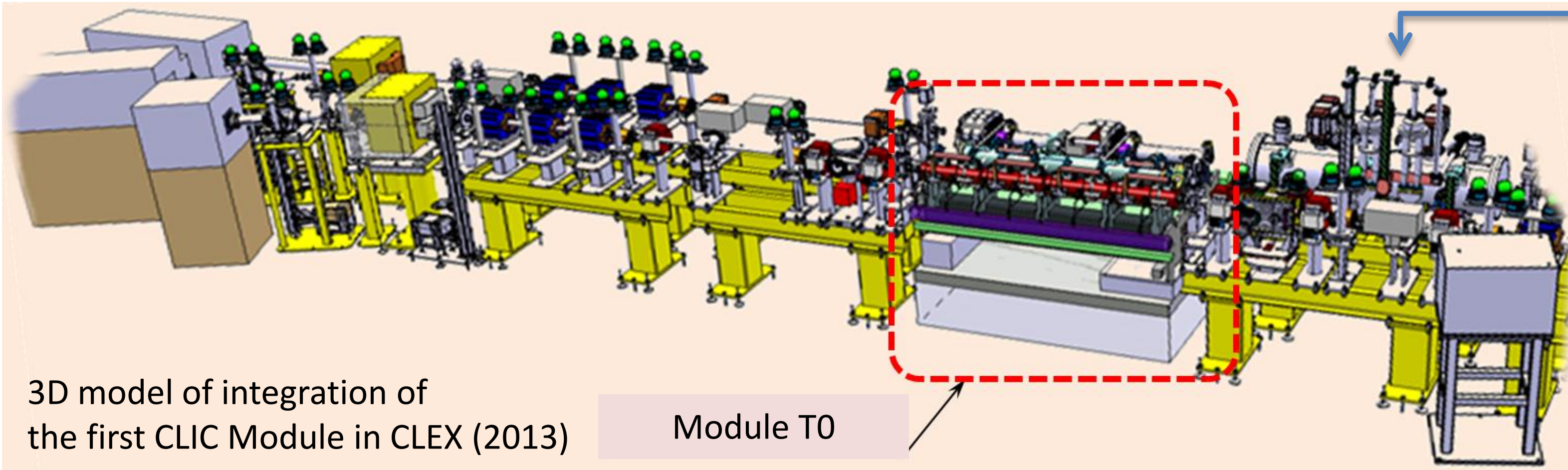
S. Doebert





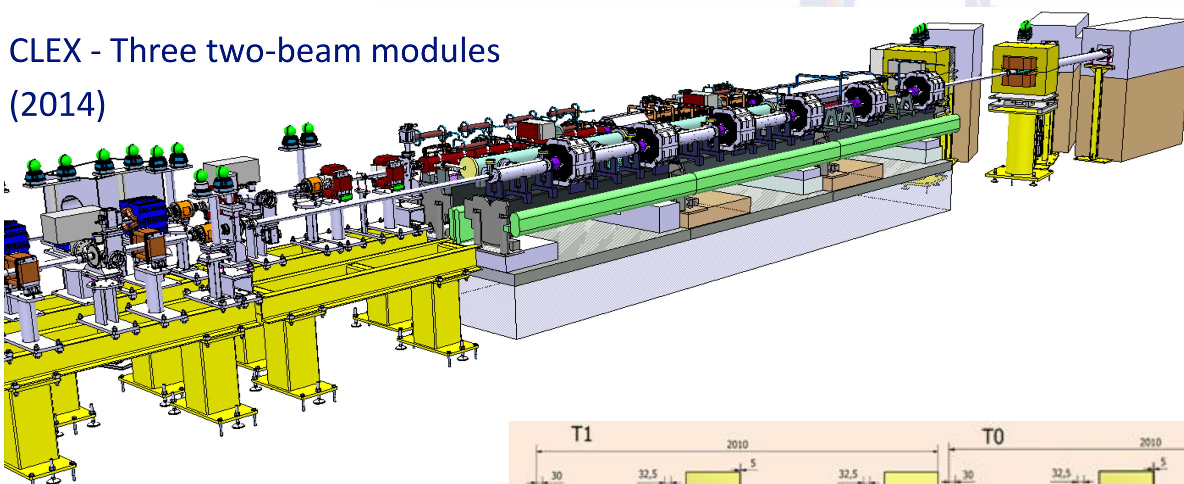
Two Beam Modules in CLEX (CTF3-004)

R. Corsini,
CTF3 working meeting
February 10, 2012



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

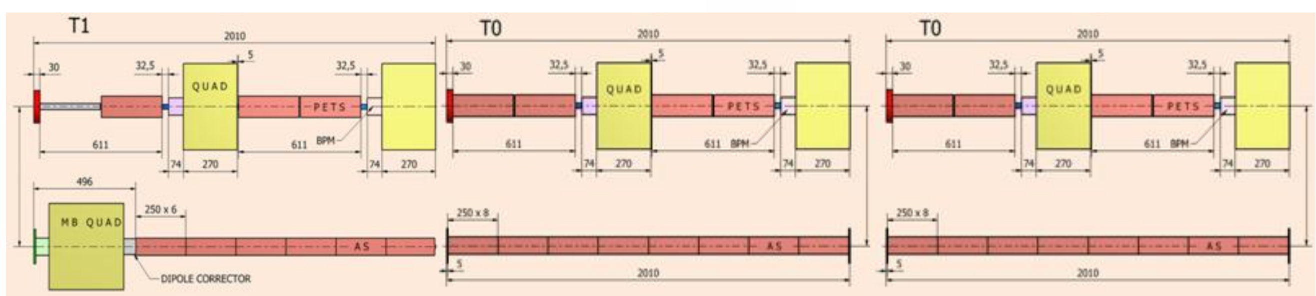
CLEX - Three two-beam modules
(2014)



TBTS PETS tank

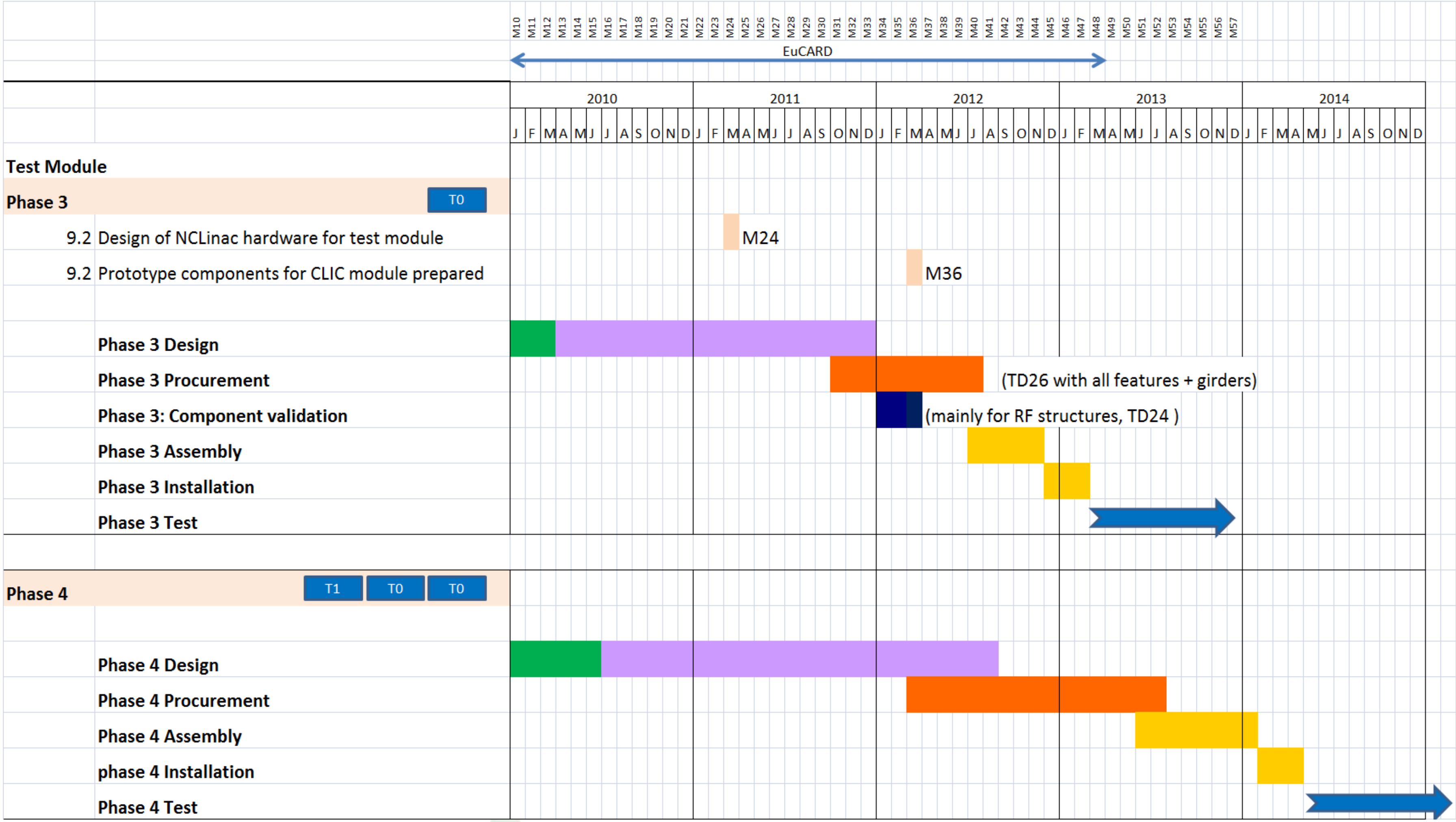
Drive beam

Probe beam



Schematic layout of CLIC Modules in CLEX

G. Riddone


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

Achievements – Drive Beam Generation

R. Corsini,
CTF3 working meeting
February 10, 2012

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	✓	
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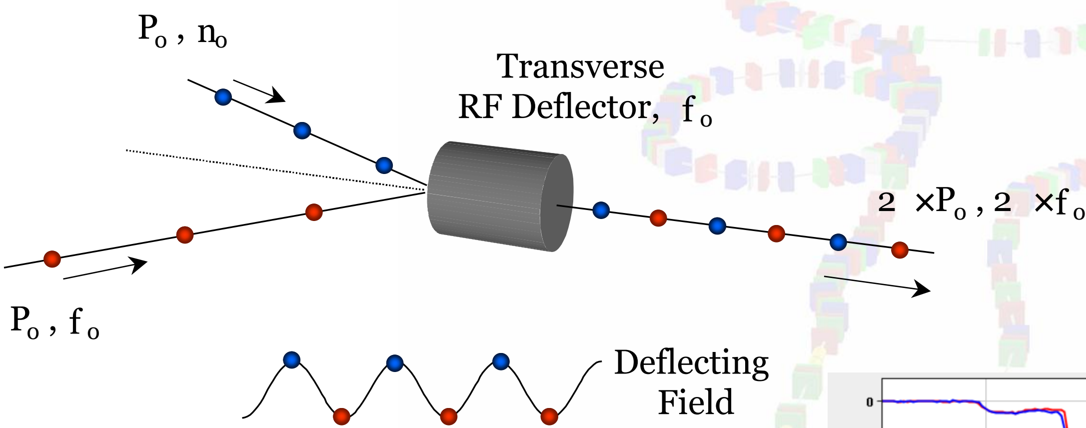
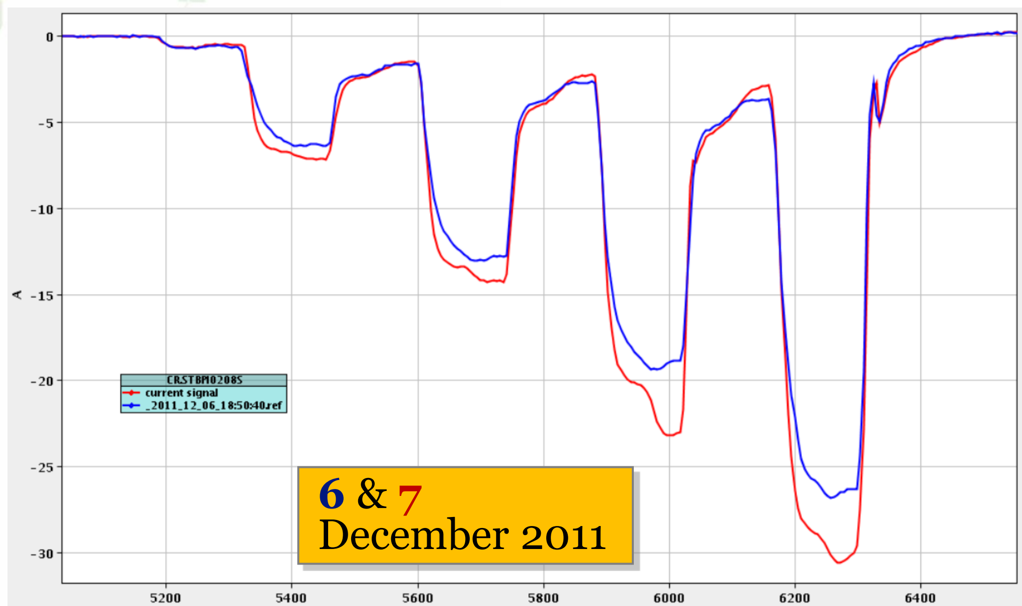
	Intensity stability	1.E-03	0.75	< 0.6	CTF3	✓	End of DBA. To be demonstrated for combined beam in 2011
	Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design



Beam recombination

- Factor 8 recombination by RF deflector injection



Achievements – Drive Beam Generation

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Drive beam generation	Freq&Current multipl	-	2*3*4	2*4	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)
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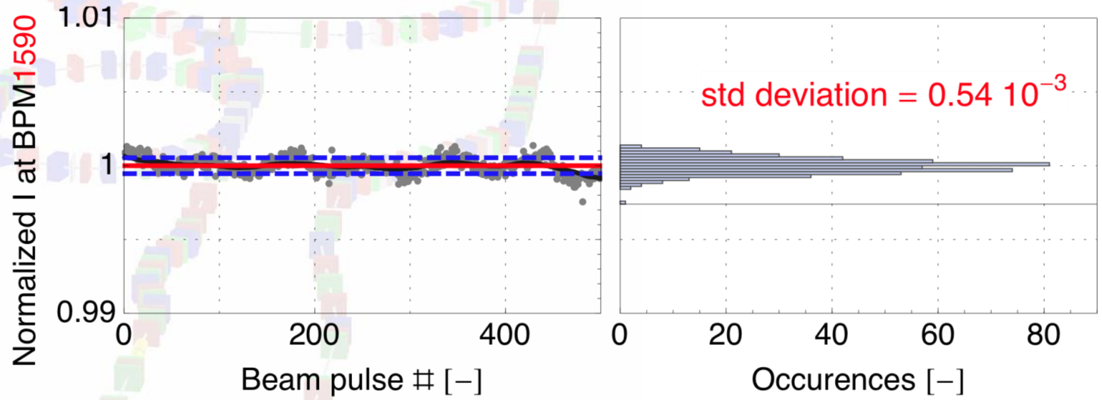
Drive beam generation	Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design

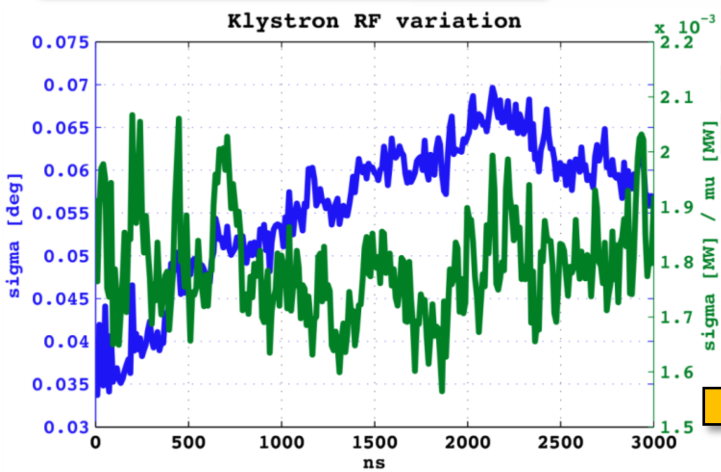
Pulse charge measured at end of the linac

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



- 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

	Tolerance	Measured
Beam current	0.75%	0.54%
RF Power	0.2%	0.16% - 0.21%
RF Phase	0.05°	0.035° - 0.07°

End 2011 – Mid 2012

G. Sterbini, A. Dubrovsky

Problems:

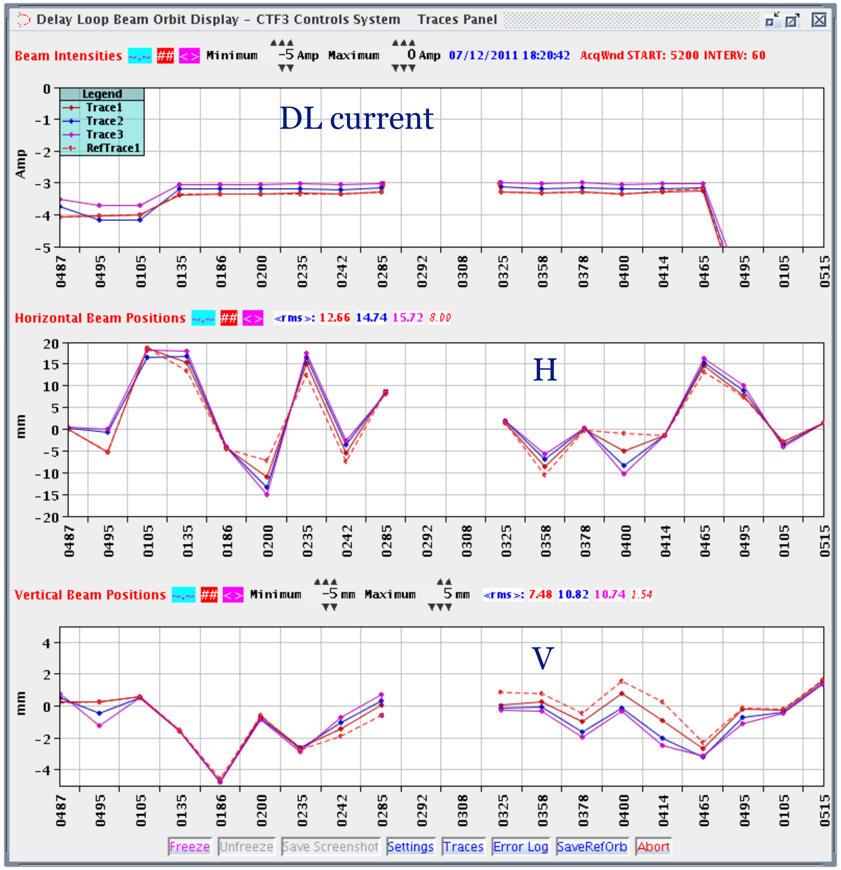
- TWT availability – still working with 2 SHB only – plus day-to-day power fluctuations
- Mainly working with 3 GHz beam for most of the year
- Difficult DL set-up after last stop – suspect misaligned quadrupole (+ radiation alarm problem)

Eventually able to get good recombination (current record

- Bad pulse shape (phase switches?)
- Still limited acceptance -> stability was improved, but i

Future work:

- Measure and realign DL quad(s)
- Work on phase switches, gun current compensation, ba

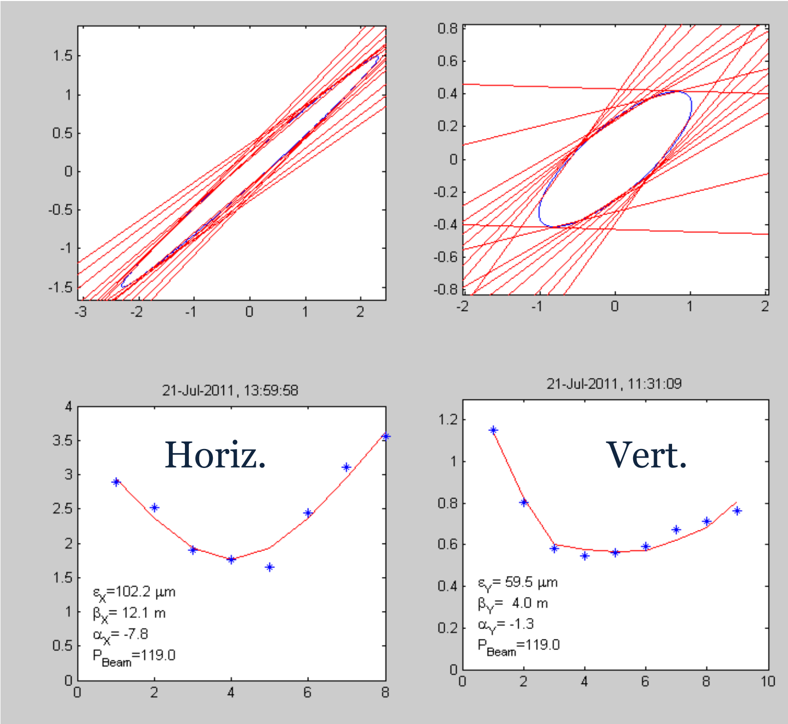


P. Skowronski

R. Corsini,
CTF3 working meeting
February 10, 2012

Achievements – Drive Beam Generation

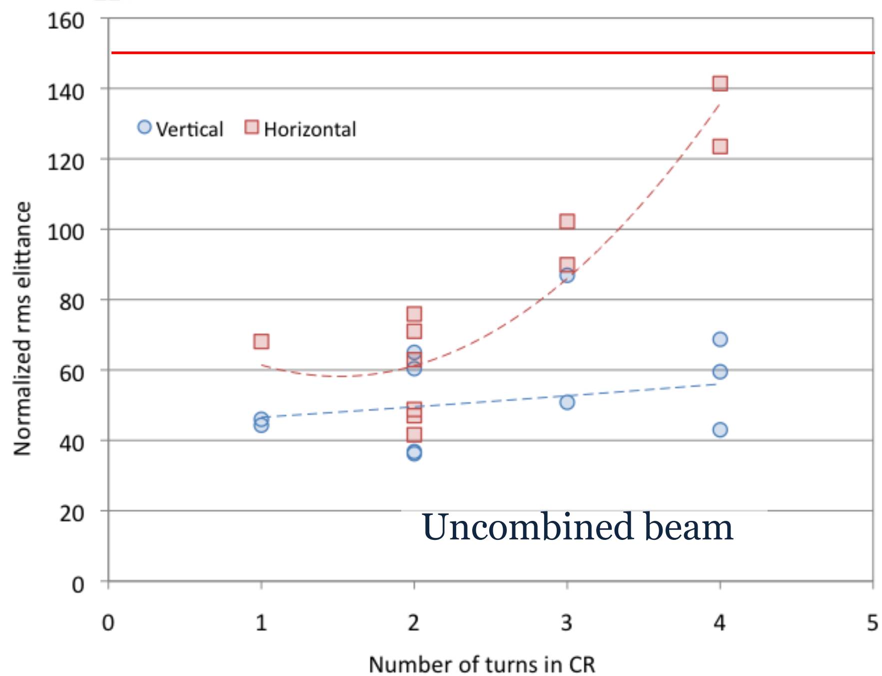
Measurements in TL2 - uncombined



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



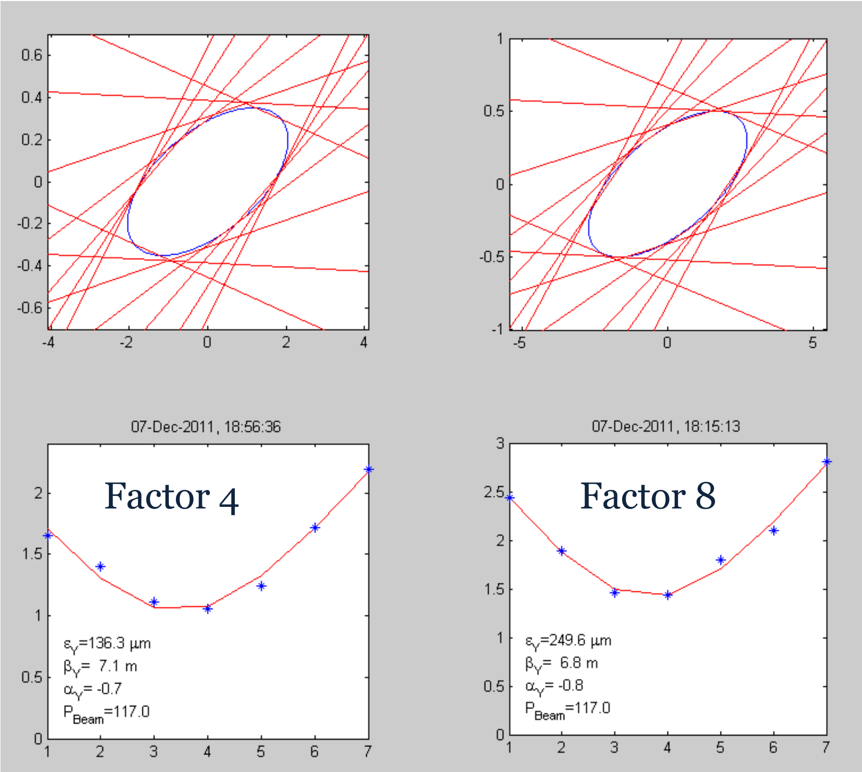
- Improve measurements
- Correct dispersion (linear, nonlinear)
- Correct multi-turn orbit
- Control beta-beating

End 2011 ?

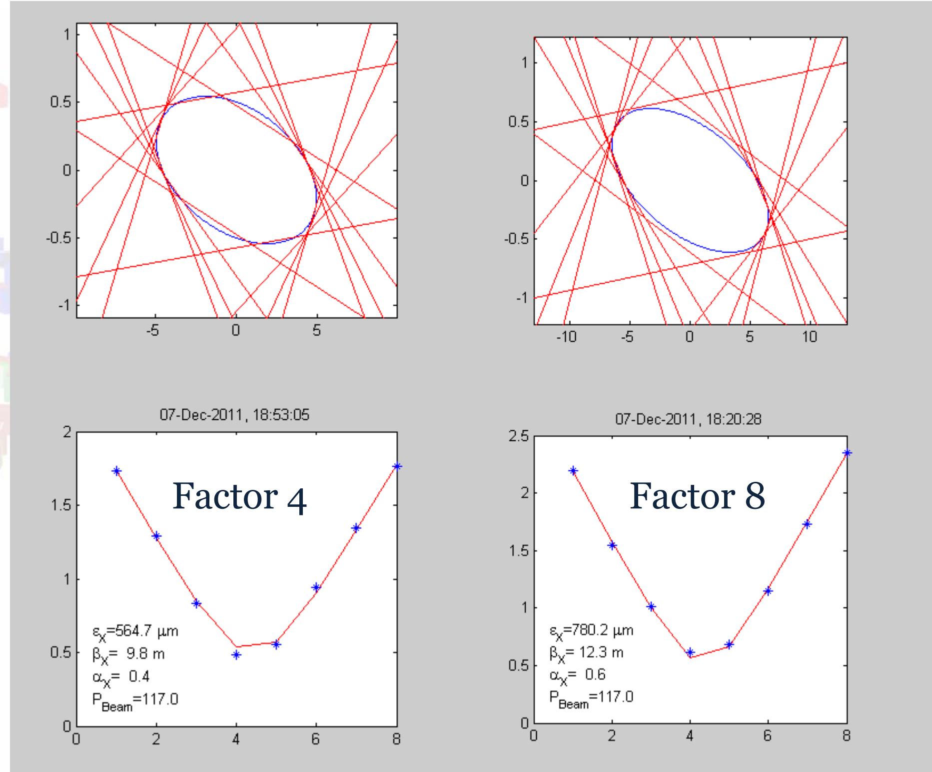
Achievements – Drive Beam Generation

R. Corsini,
CTF3 working meeting
February 10, 2012

Vertical



Horizontal



Emittance – last measurements in CLEX

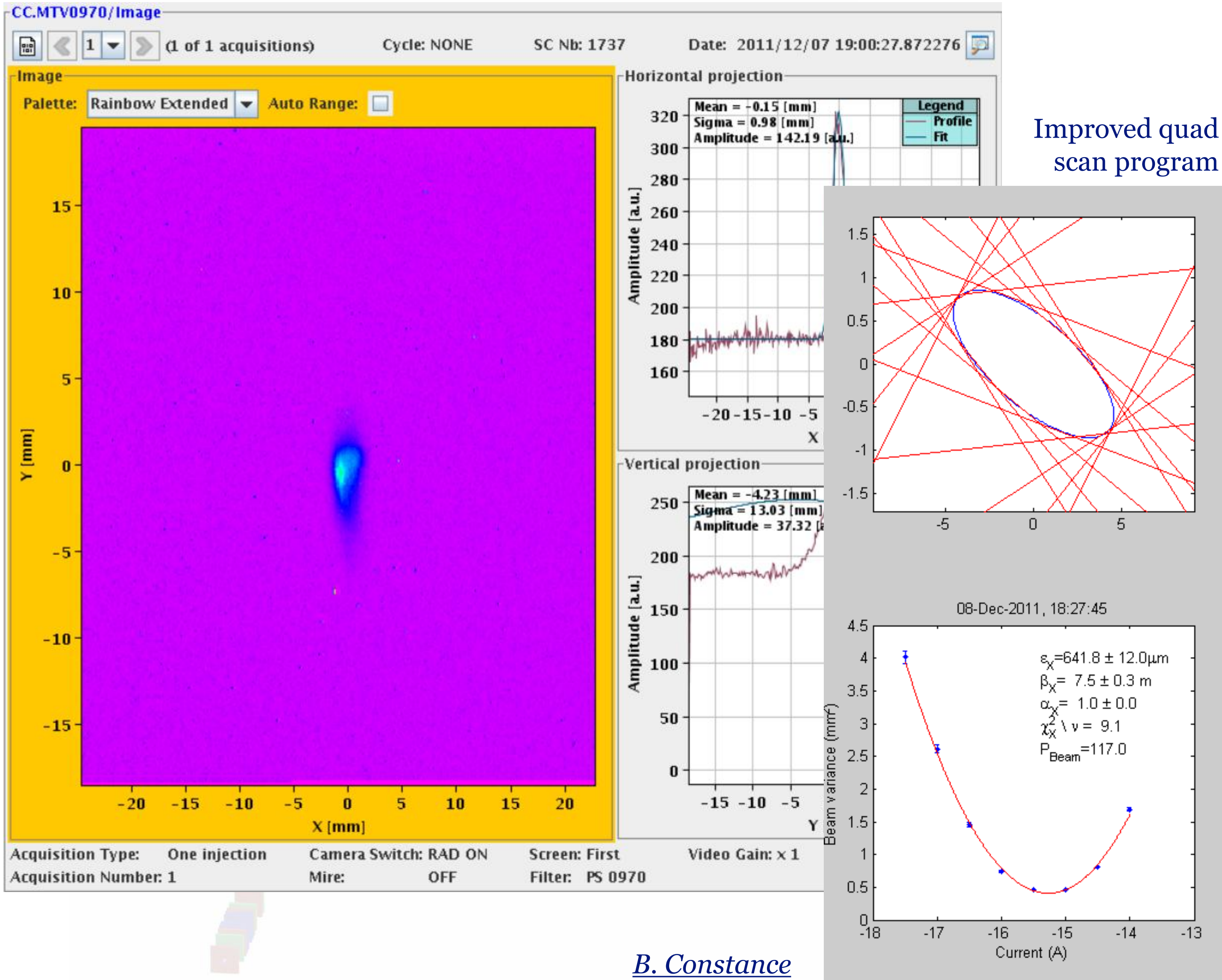
- No time for optimization
- Main issue: different trajectories for DL & bypass beams and ring orbit closure (differences of the order of 1 σ)
  - Vertical: main effect from DL, small effect from ring
  - Horizontal: ring closure is dominant
- Similar Twiss parameters for factor 4 and factor 8 combination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

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

Beam profile during emittance measurements

Factor 8

Improved quad scan program



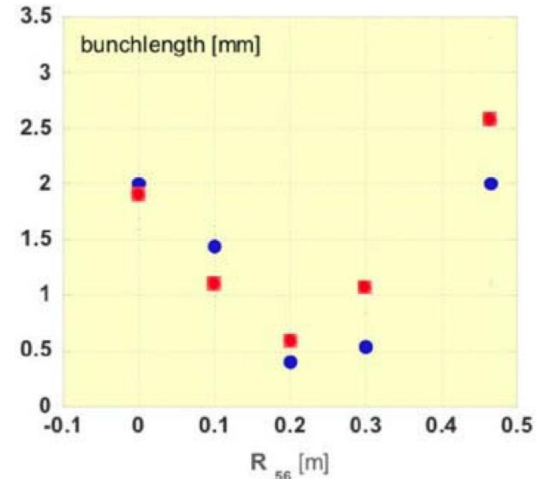
B. Constance

Beam recombination – Bunch lenght

nominal in CLEX 1 mm sigma

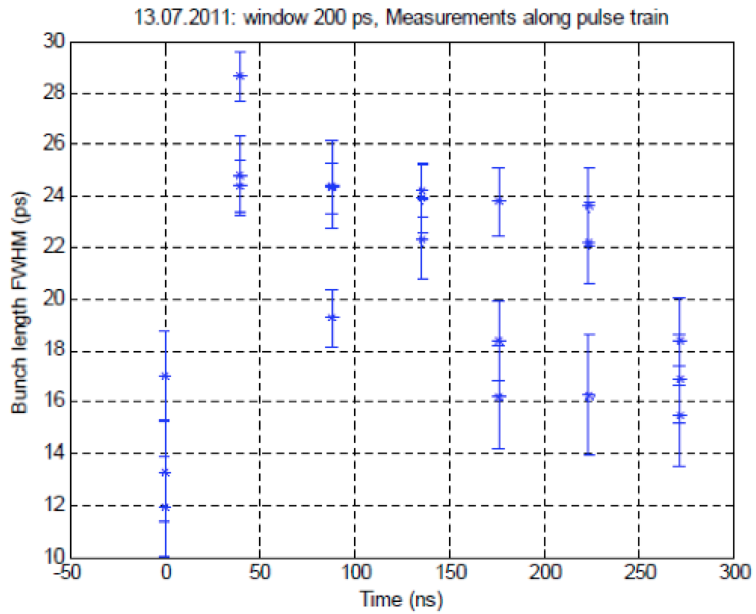
In the past, well below 1 mm sigma measured at the end of the linac (tuned chicane)

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



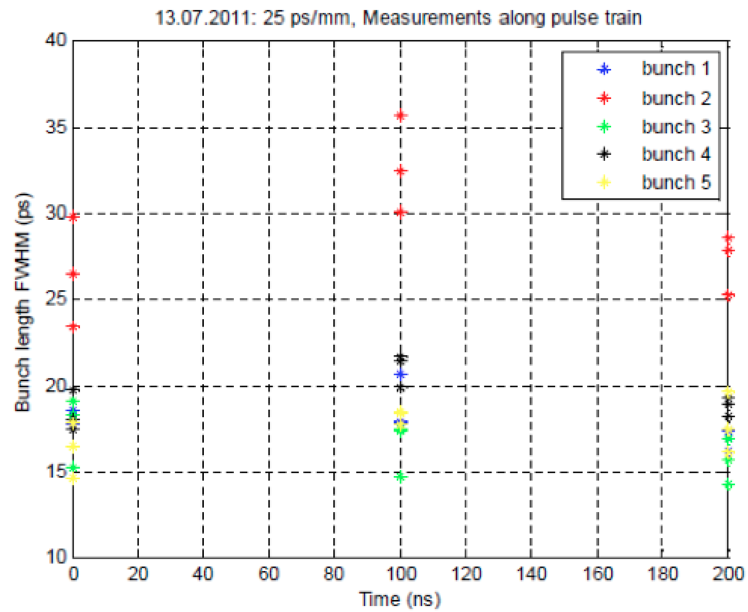
Combiner ring

turn 1, 3 data for each timing



CLEX

5 bunches per measurement, 3 data for each timing



Achievements – Drive Beam Generation

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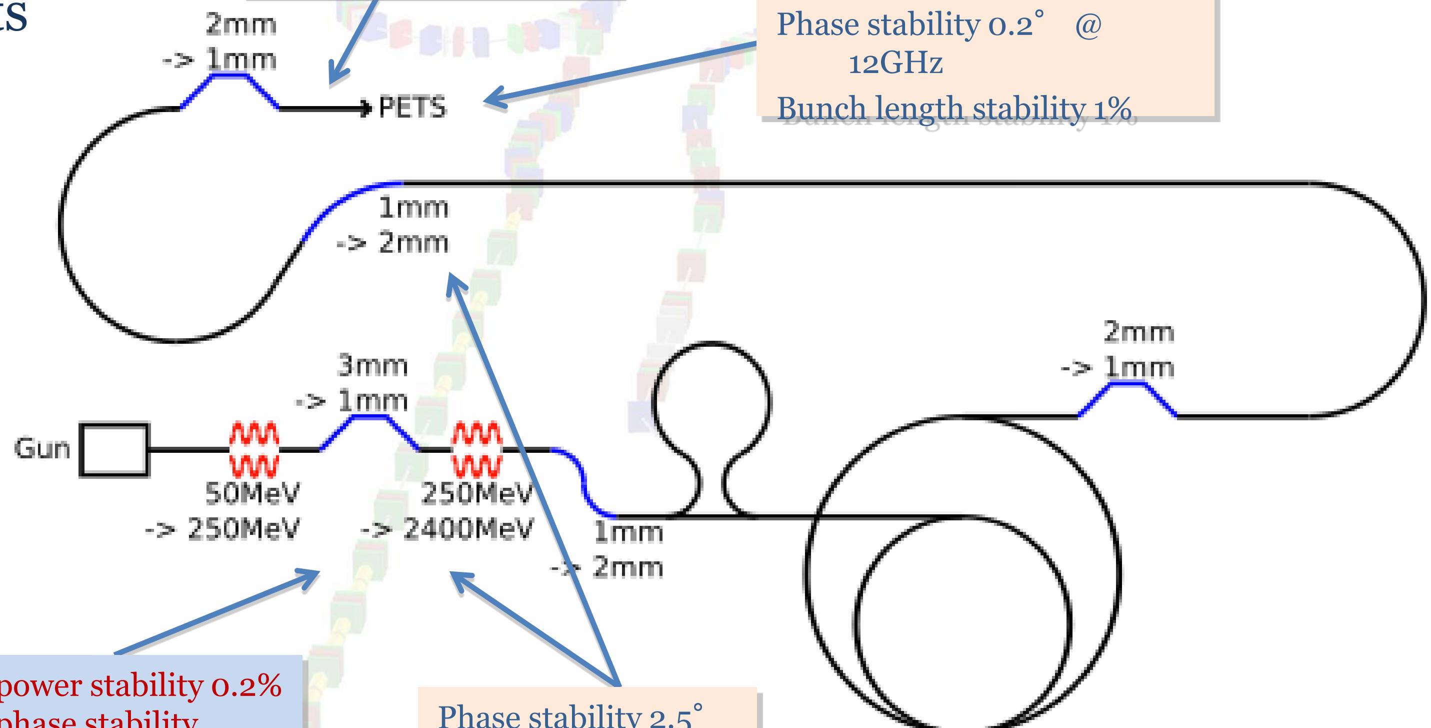
➡	Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design

CLIC Drive Beam requirements

Emittance $\varepsilon_{x,y} \leq 150\mu m$
Transverse jitter $\leq 0.3\sigma$

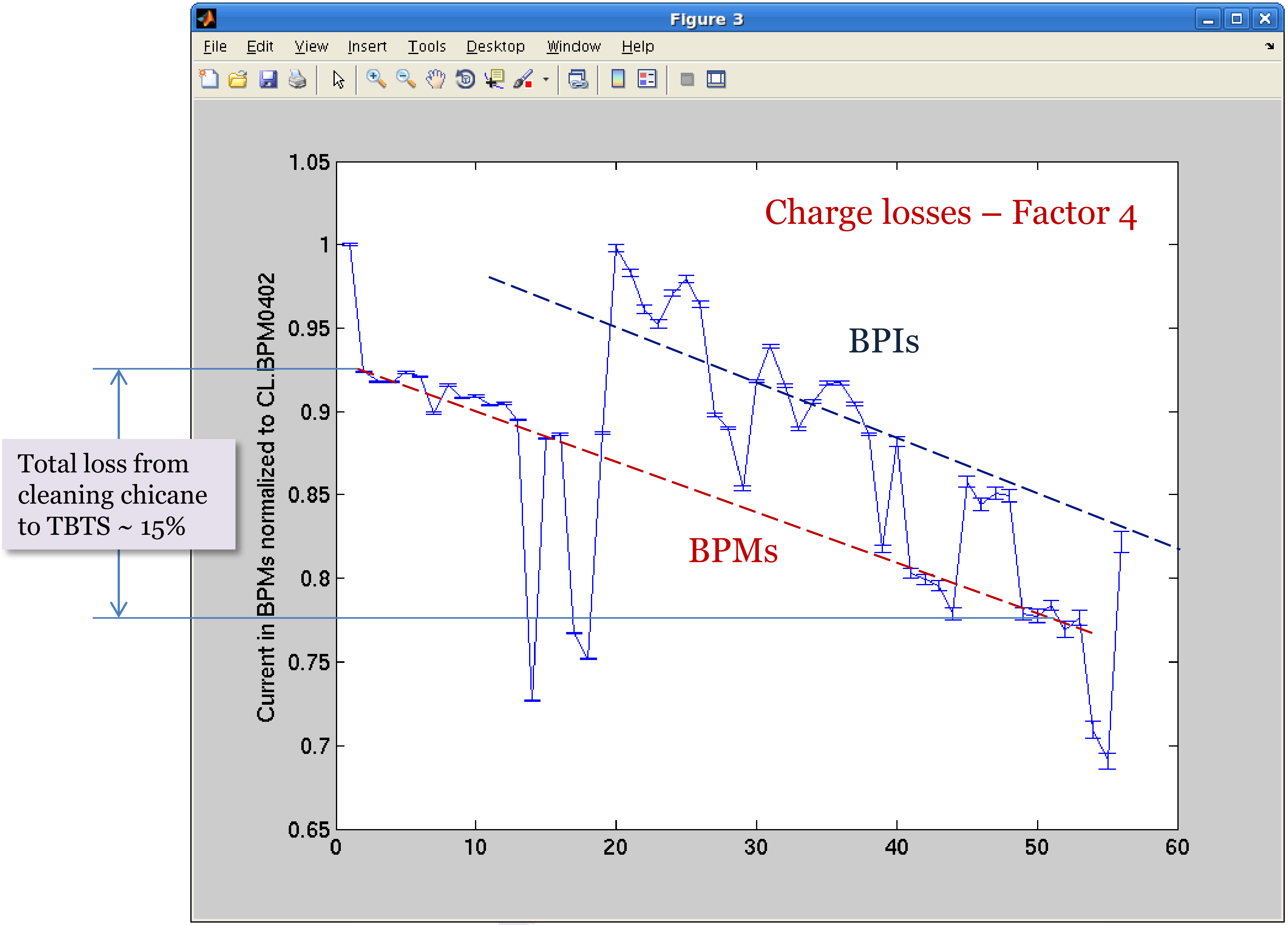
Current stability $0.75 \cdot 10^{-3}$
Phase stability 0.2° @ 12GHz
Bunch length stability 1%



RF power stability 0.2%
RF phase stability 0.05°
Current stability 0.1%

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

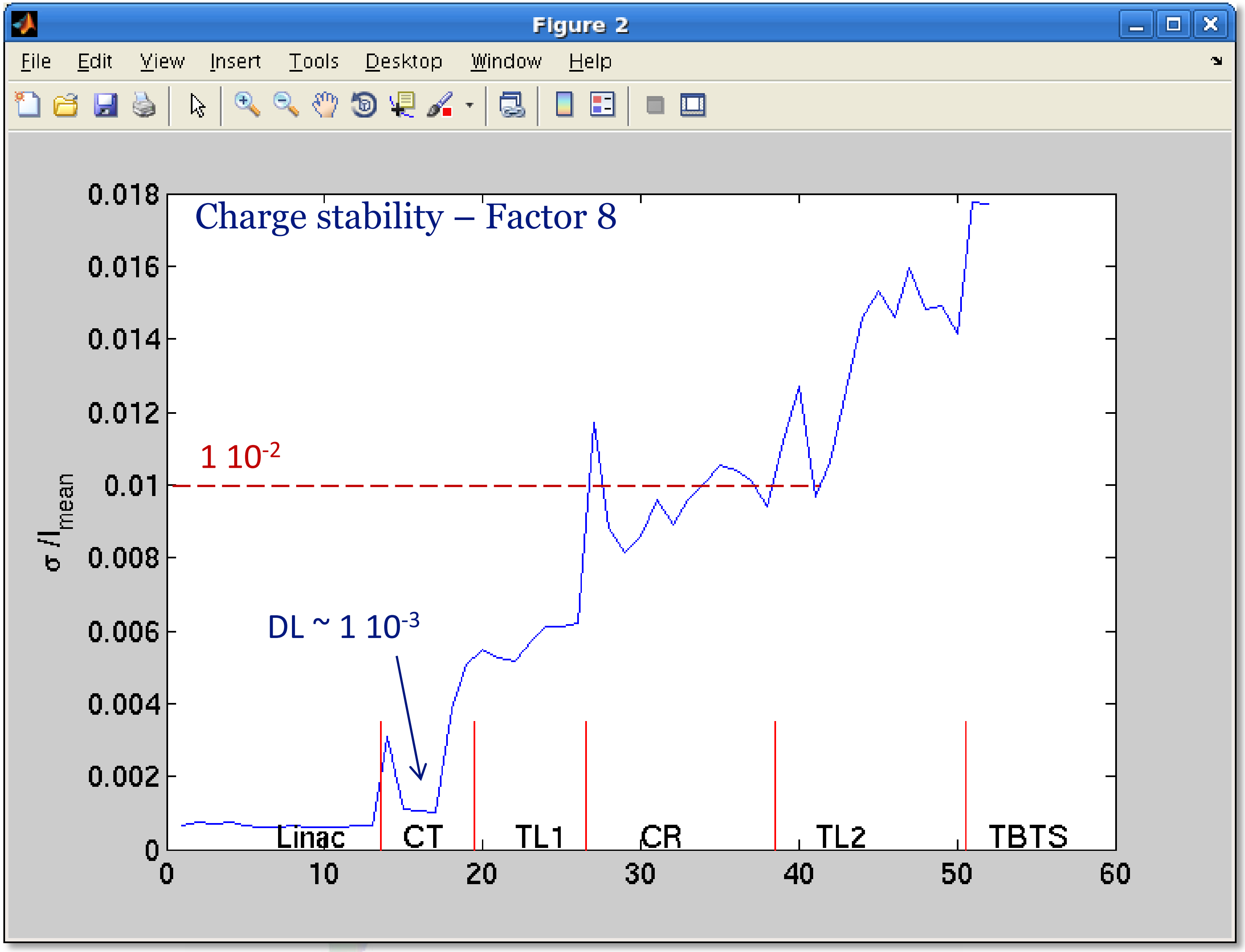
Achievements – Drive Beam Generation



18th November 2011

T. Persson

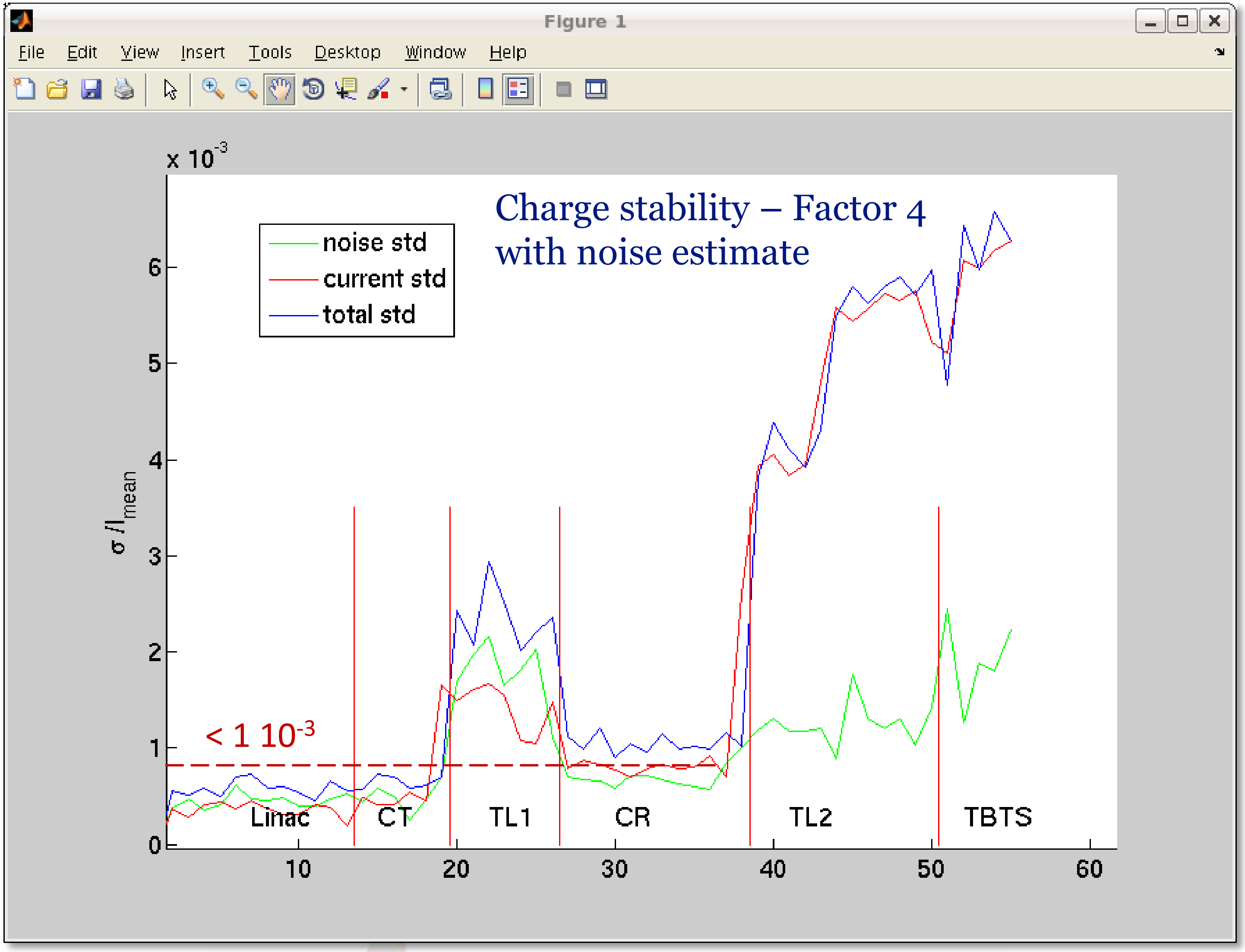
Achievements – Drive Beam Generation



T. Persson

6th December 2011

Achievements – Drive Beam Generation



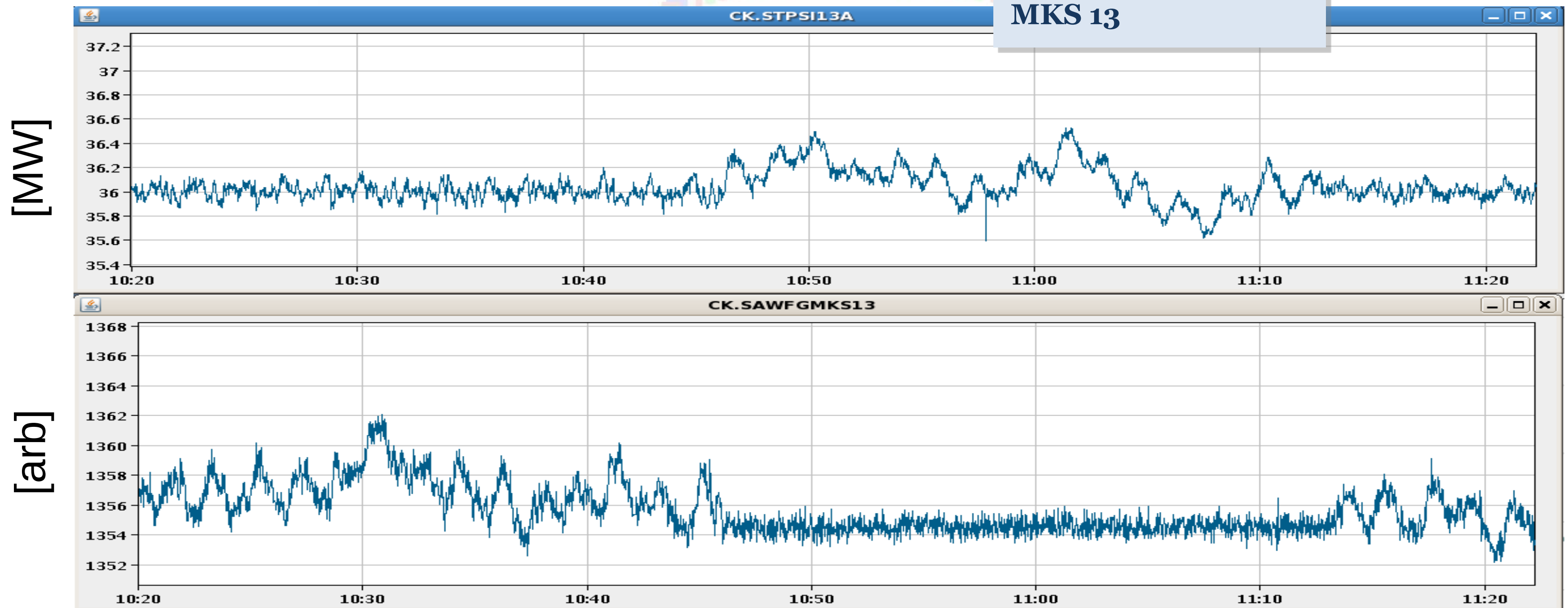
T. Persson

6th December 2011

R. Corsini,
CTF3 working meeting
February 10, 2012

Feed-backs, stability

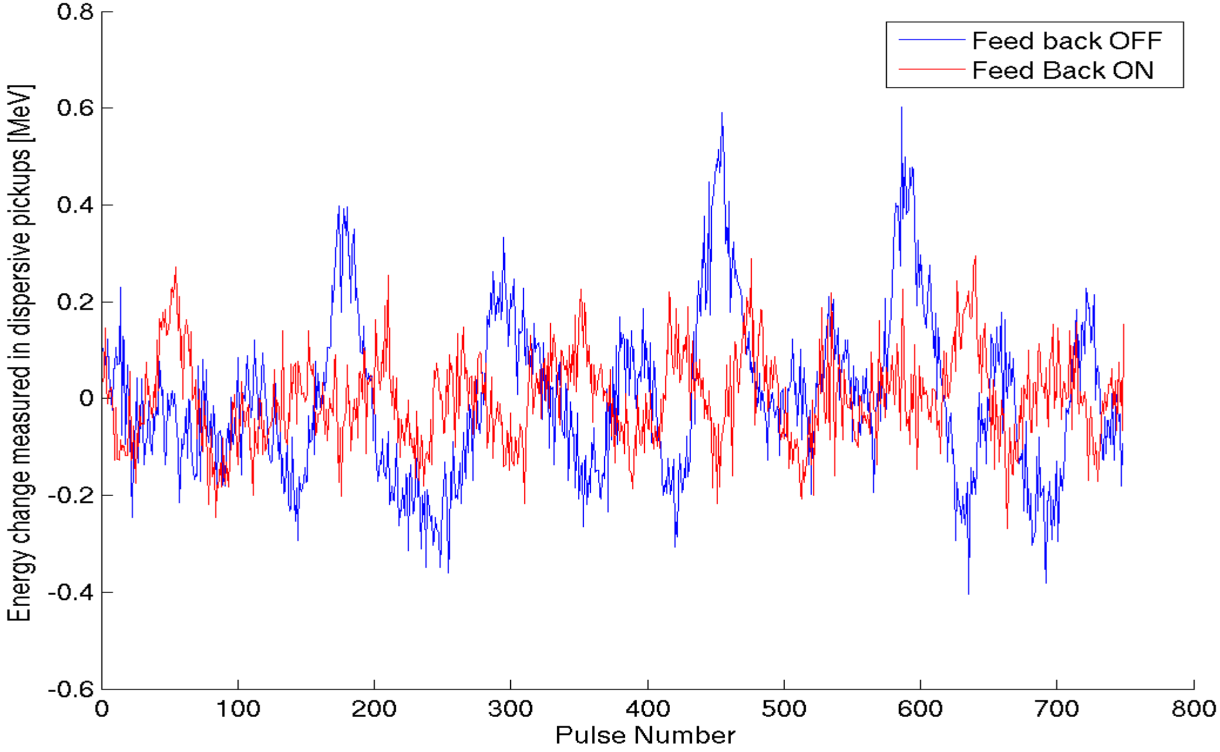
RF power feedback, MKS 13



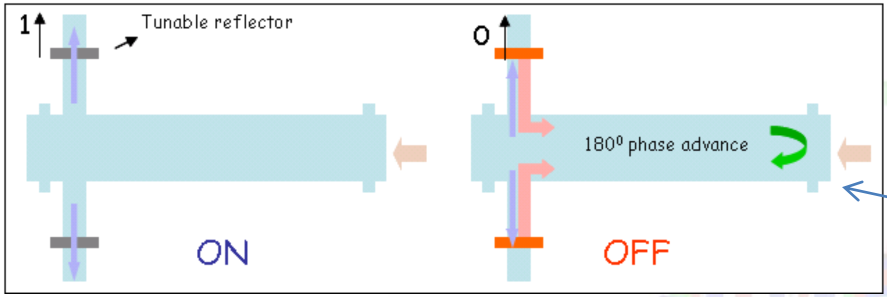
Tobias Persson,
Piotr Skowronski

Feed-backs, stability

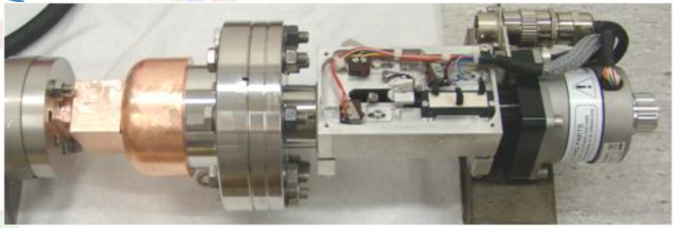
RF power feedback, effect on beam



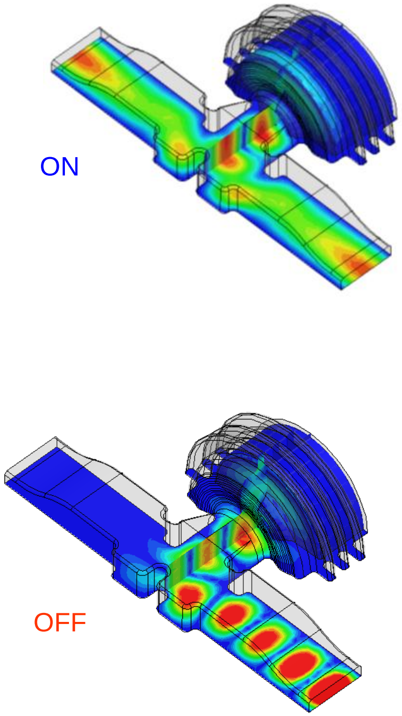
Tobias Persson, Piotr Skowronski

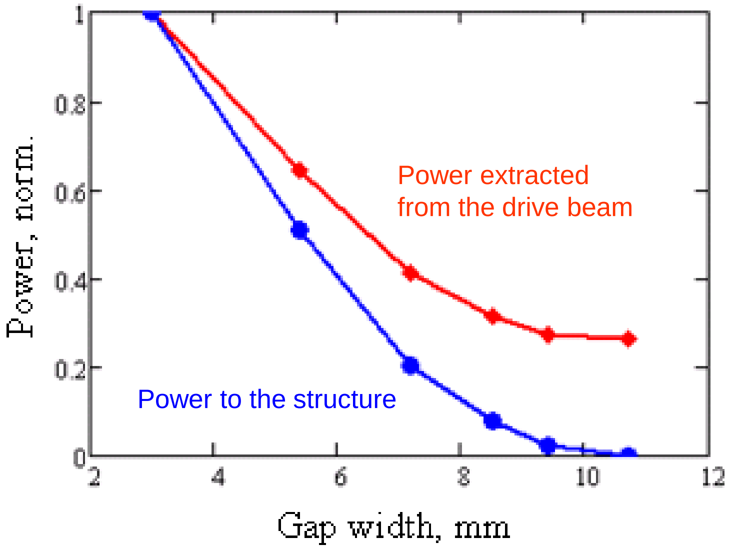


PETS On-Off concept



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

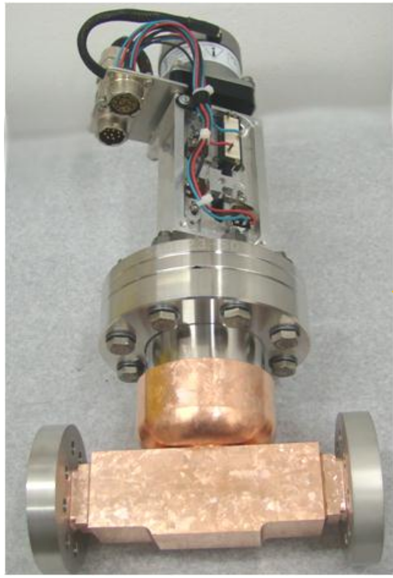




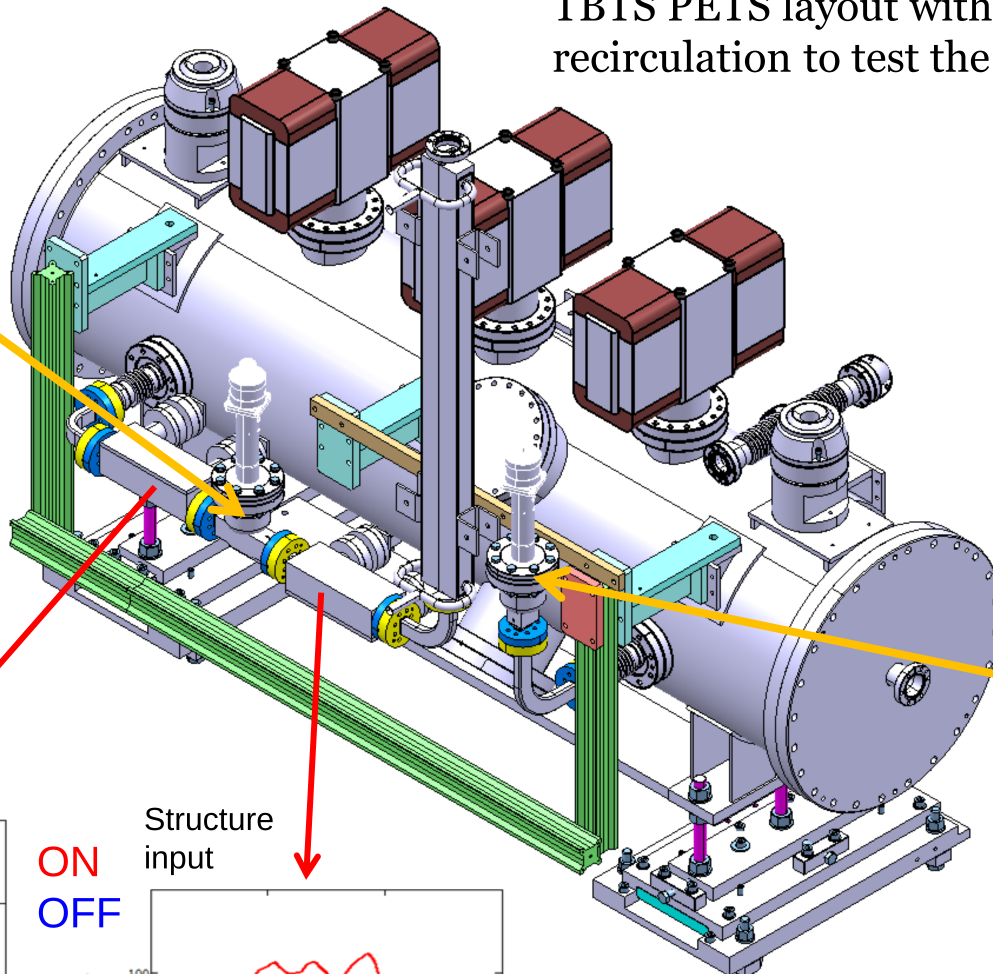
Igor Syratchev, Alexei Dubrowski

Achievements – Beam driven RF power generation

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

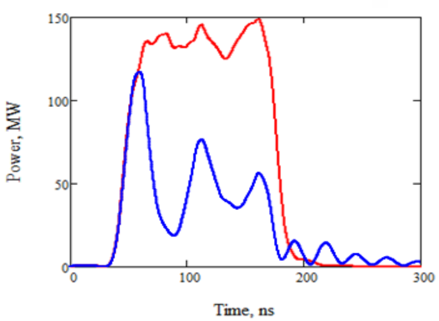


Variable reflector (to tune the recirculation coupling)



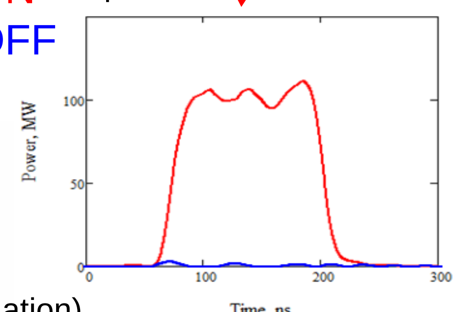
Movable RF short circuit (to tune the resonant length)

PETS output



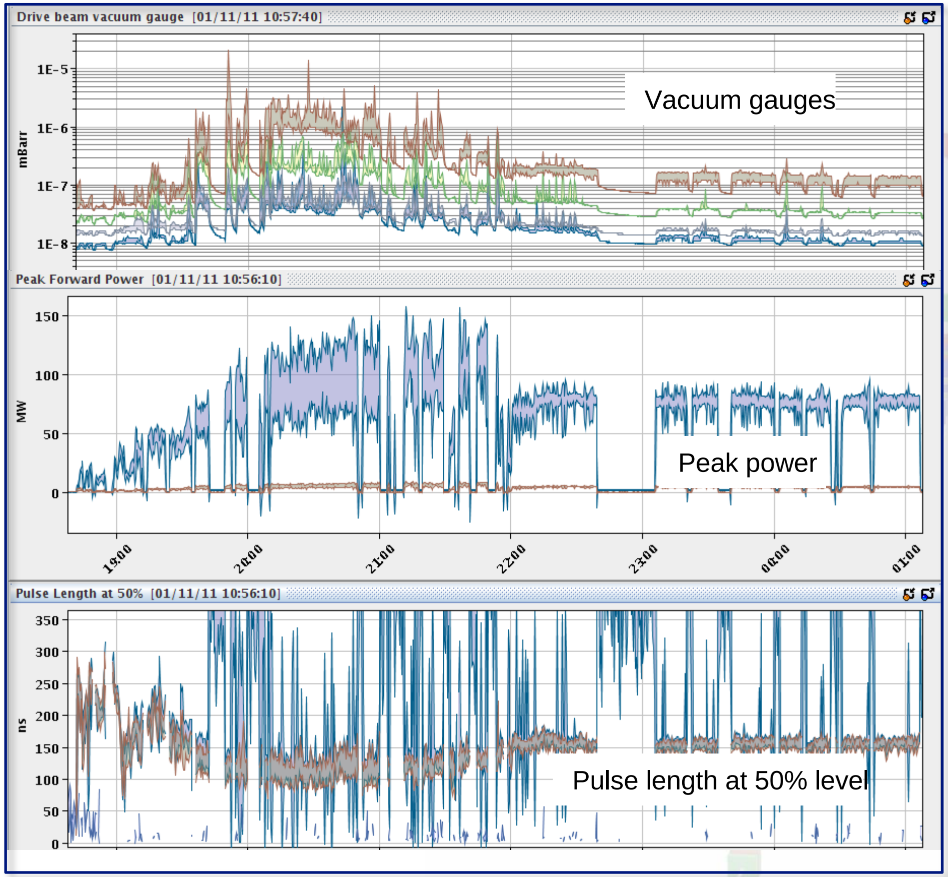
ON
OFF

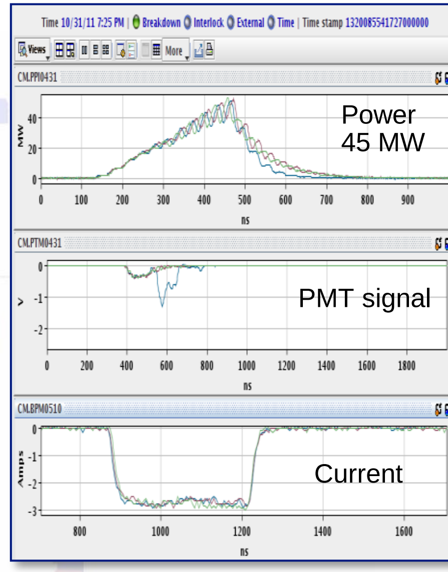
Structure input

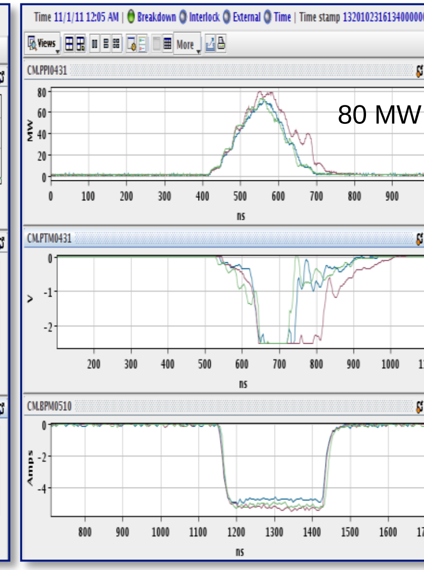


(as predicted by computer simulation)

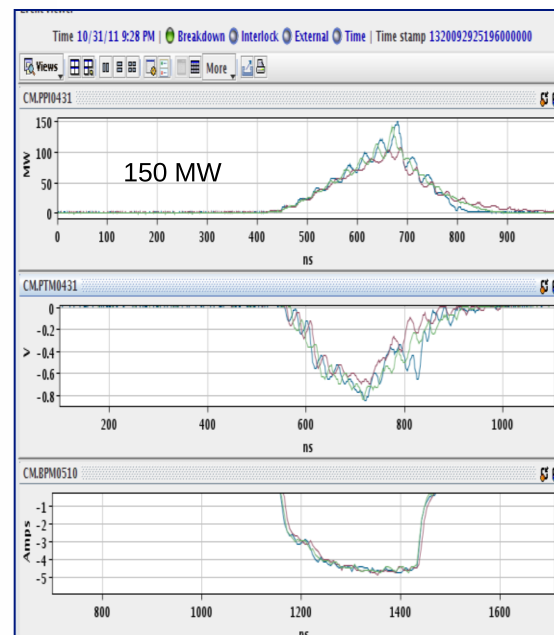
Igor Syratchev







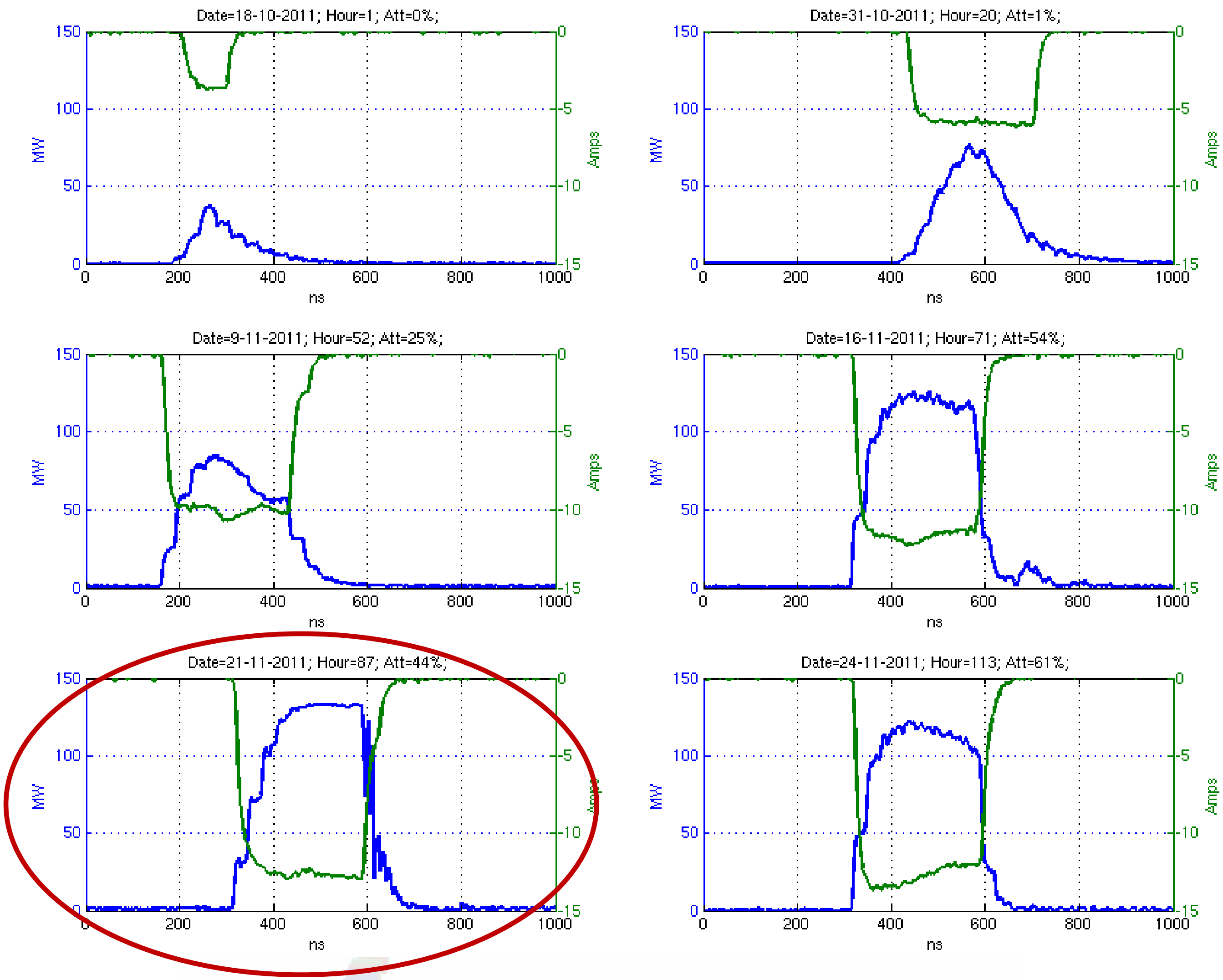
30 October
(logbook pictures)



PETS On-Off conditioning

Igor Syratchev,
Alexei Dubrowski

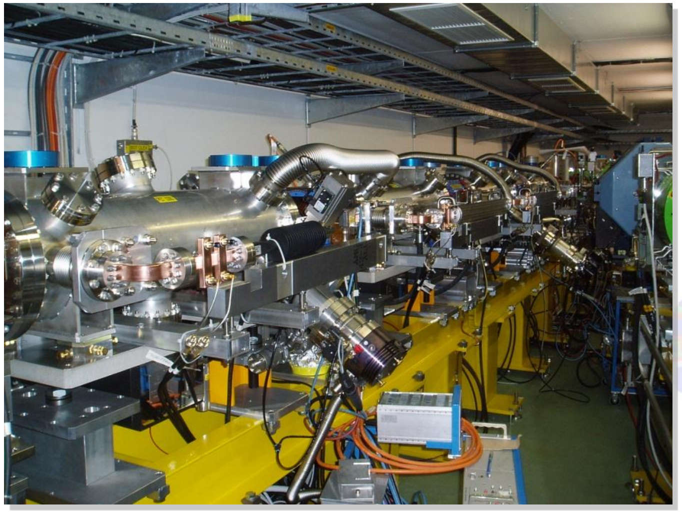
PETS On-Off operation – high current, high power



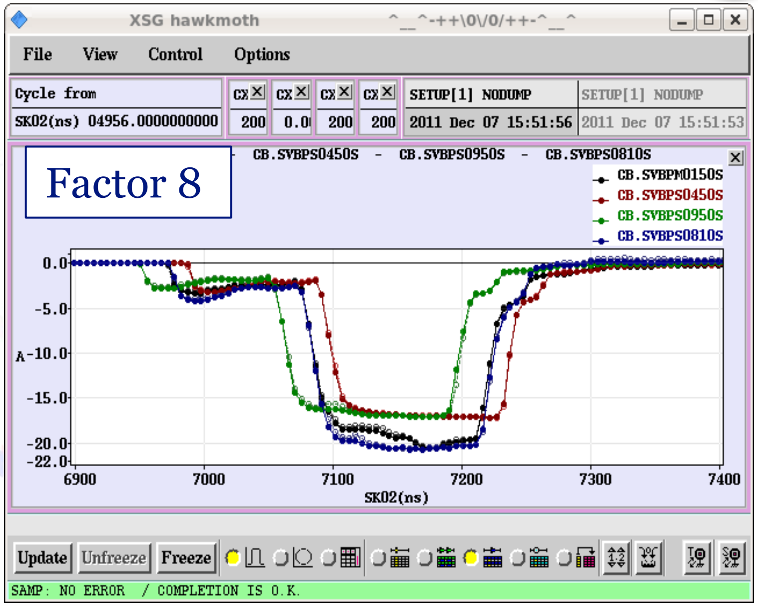
Igor Syratchev,
Alexei Dubrowski

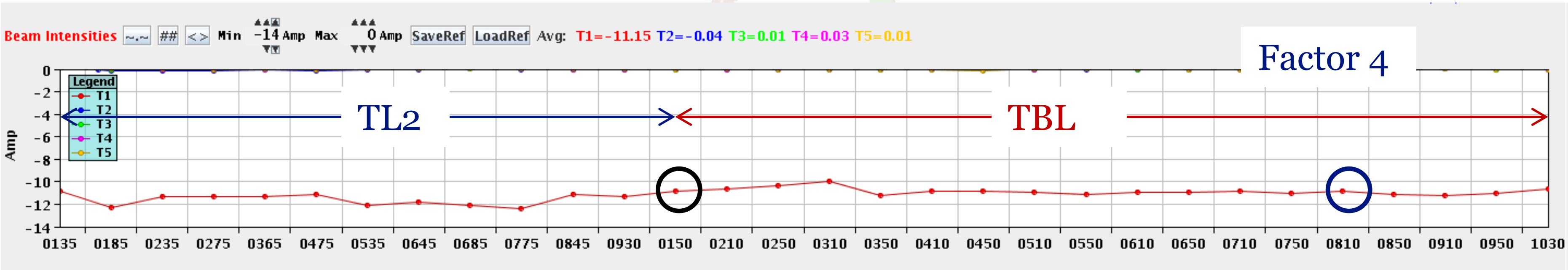
Achievements – Beam driven RF power generation

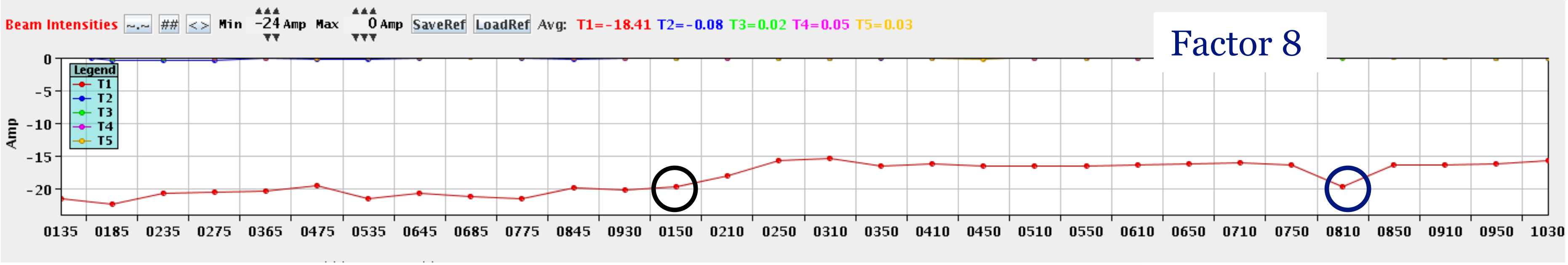
Steffen Doebert, Reidar Lillestol



High current transport in TBL



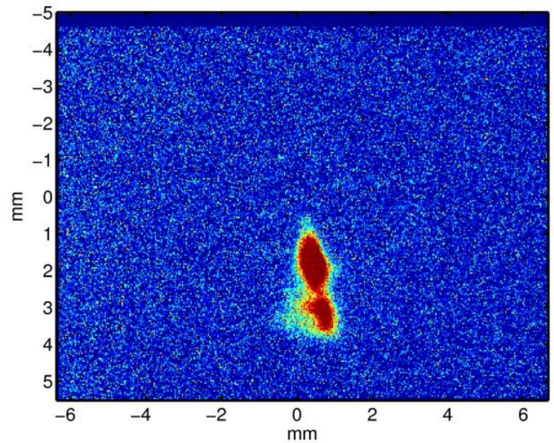


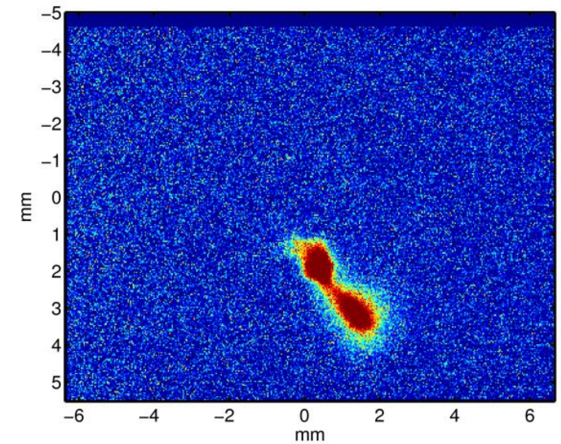


Achievements – Two-Beam Acceleration

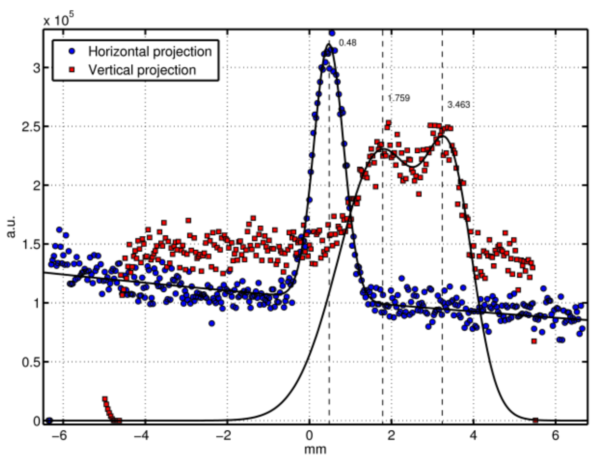
Break-down kicks

Andrea Palaia, Wilfrid Farabolini, Javier Barranco

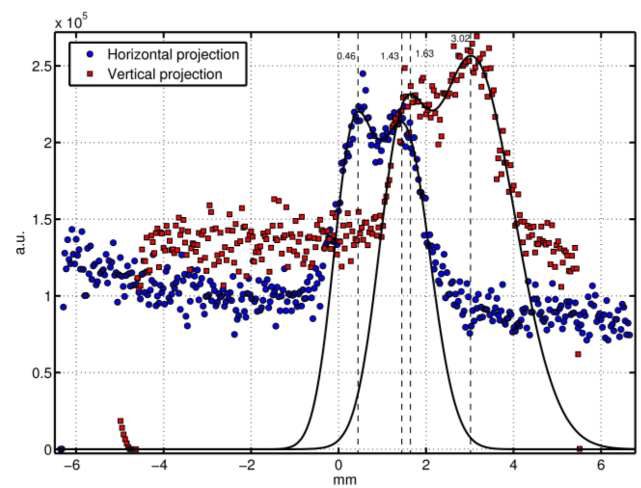




Measured on OTR screen CA.MTV0790 (~4.9 m from the accelerating structure).

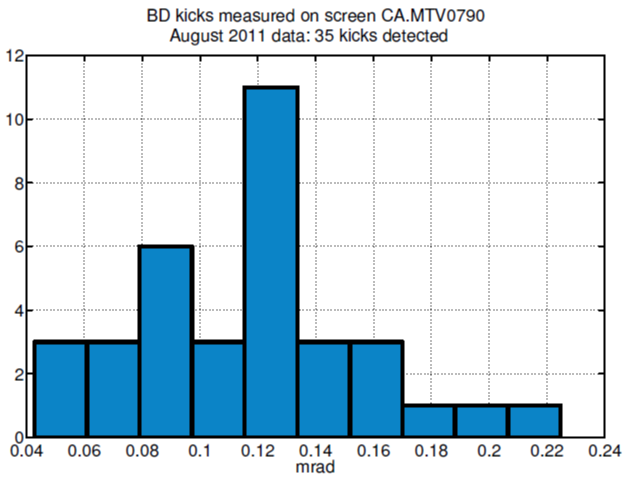


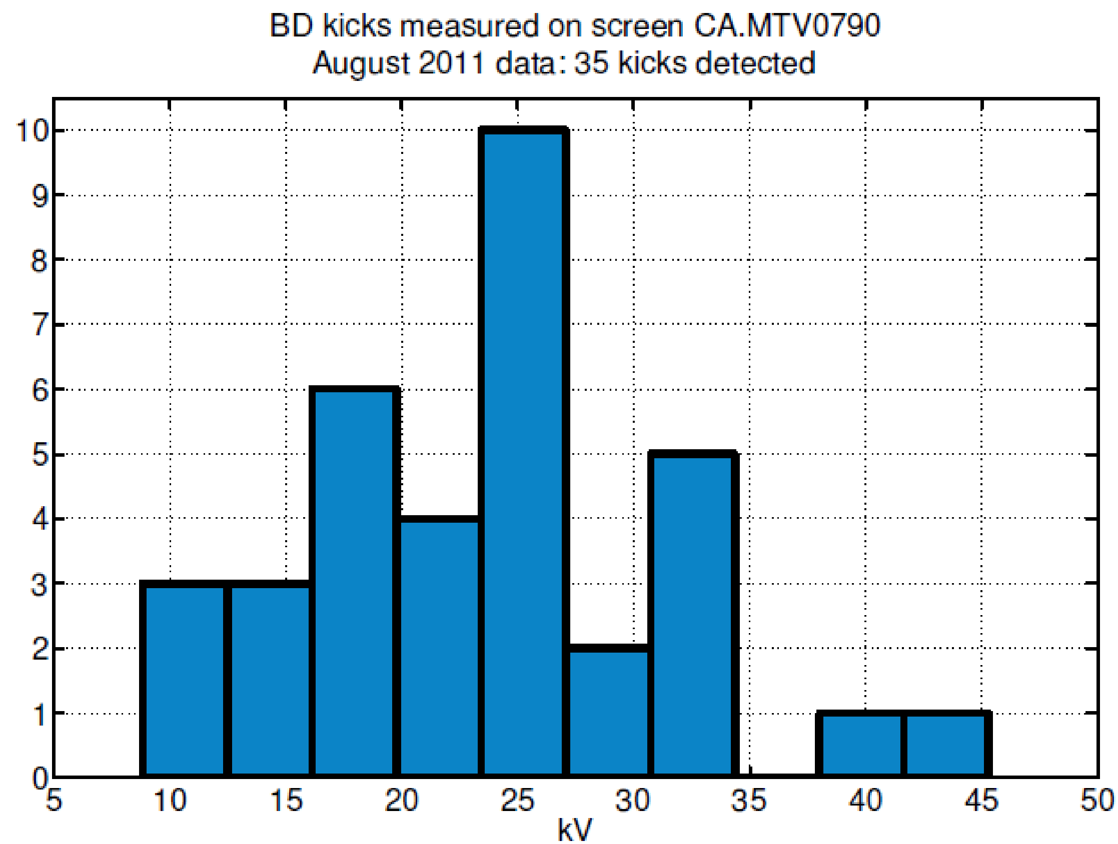
kick angle = 340 μrad



kick angle = 400 μrad

Break-down kicks, distribution





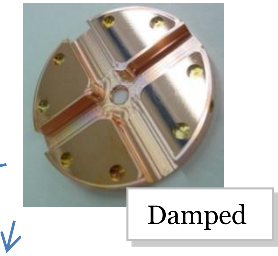
Andrea Palaia

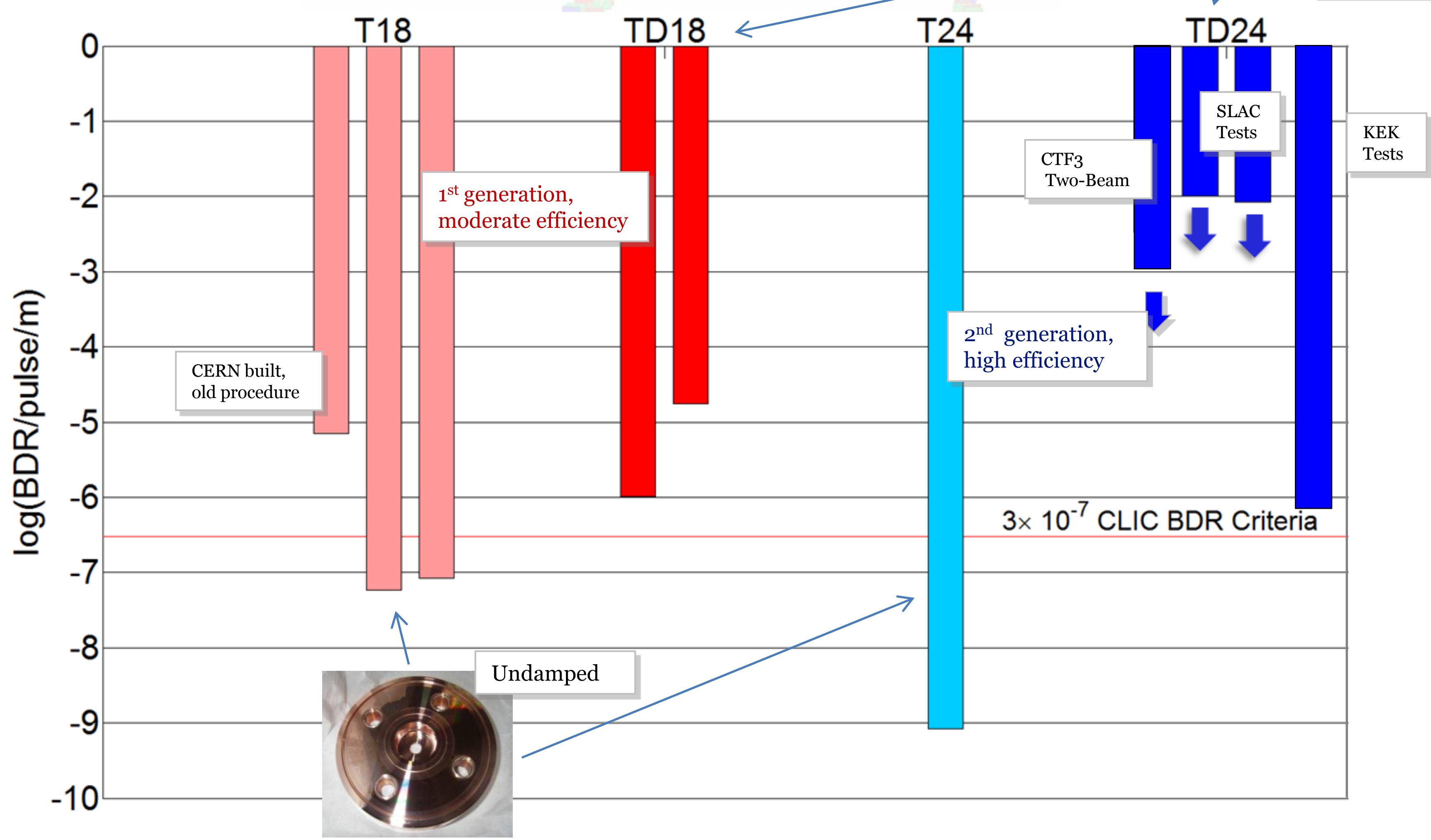
Accelerating Structure - Experimental results

R. Corsini,
CTF3 working meeting
February 10, 2012

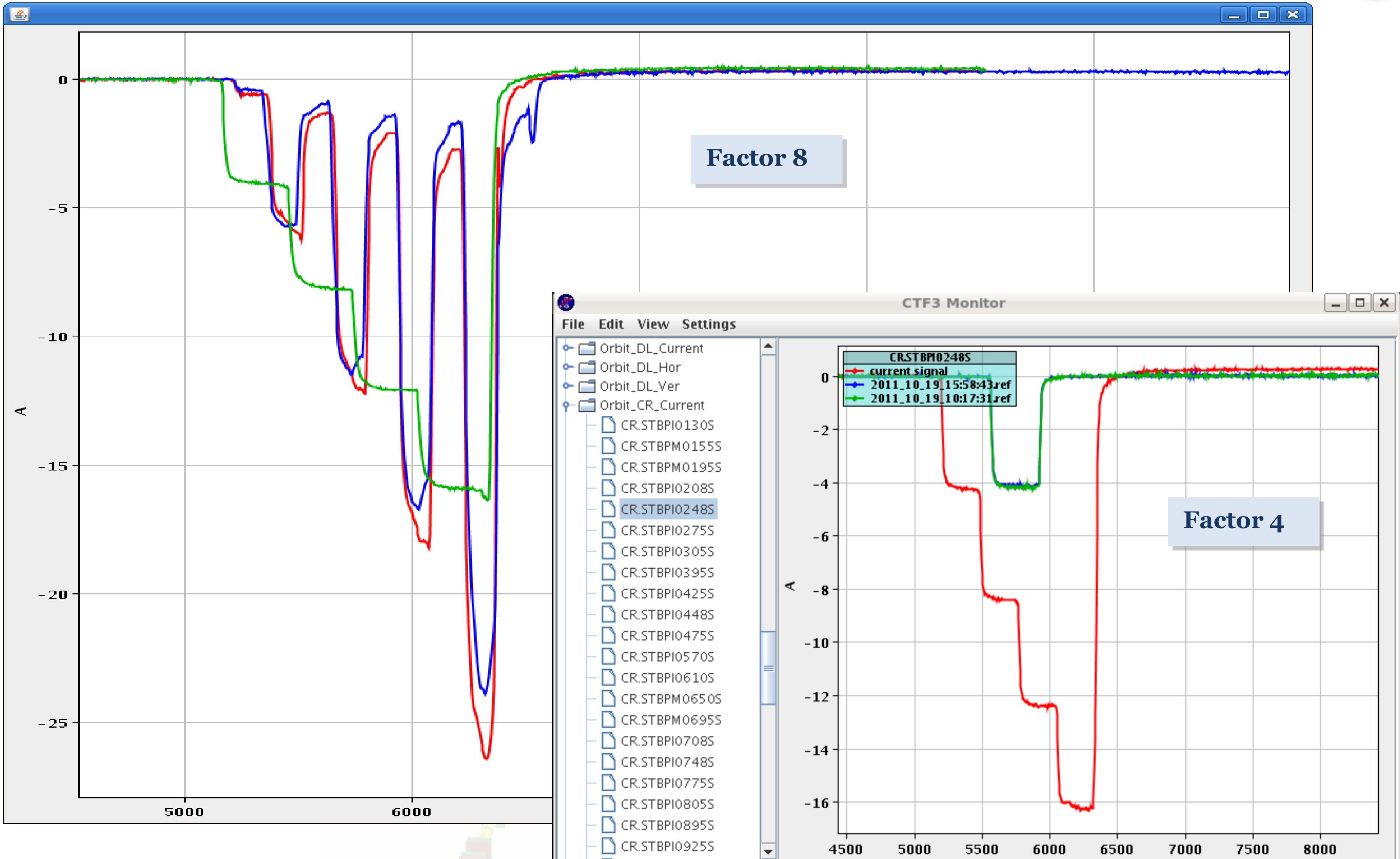
Breakdown rate at 100 MV/m (unloaded) accelerating gradient and scaled to 180 ns pulse length

Measurements scaled according to ➡ $p \propto G^{30}\tau^{5}$

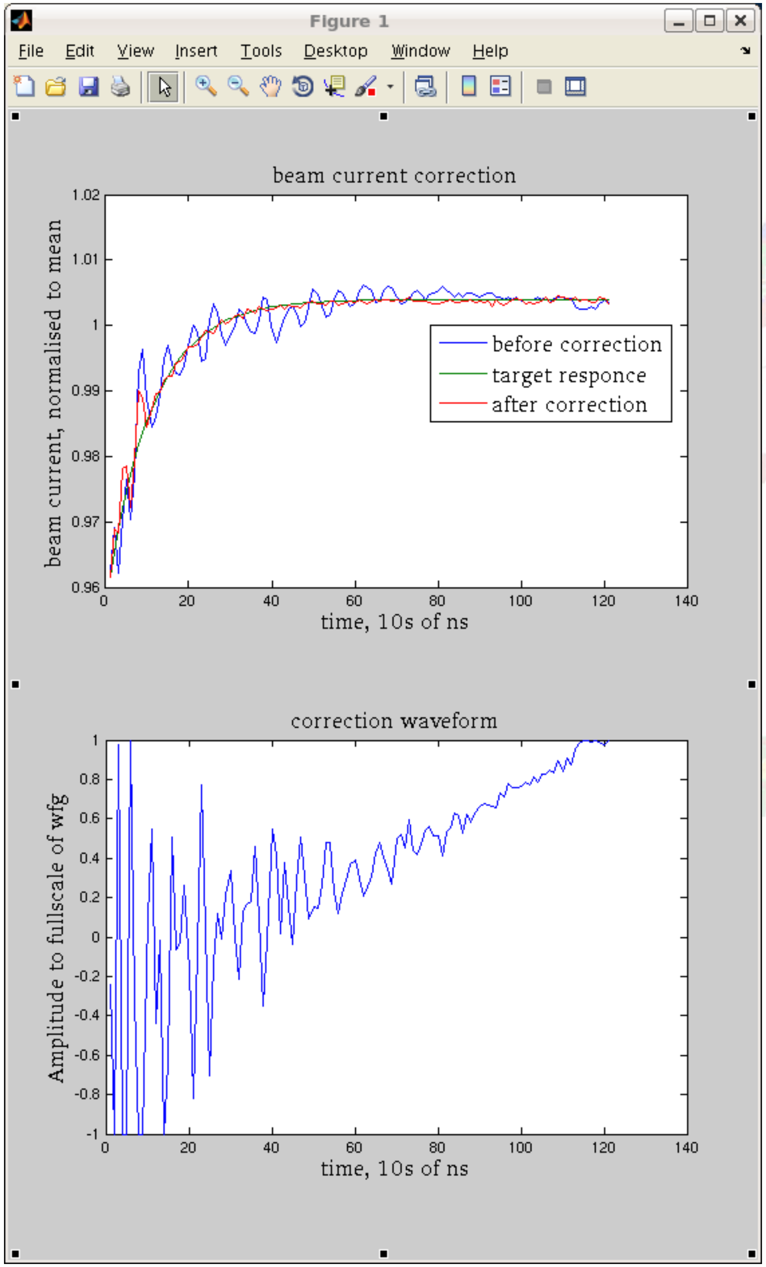




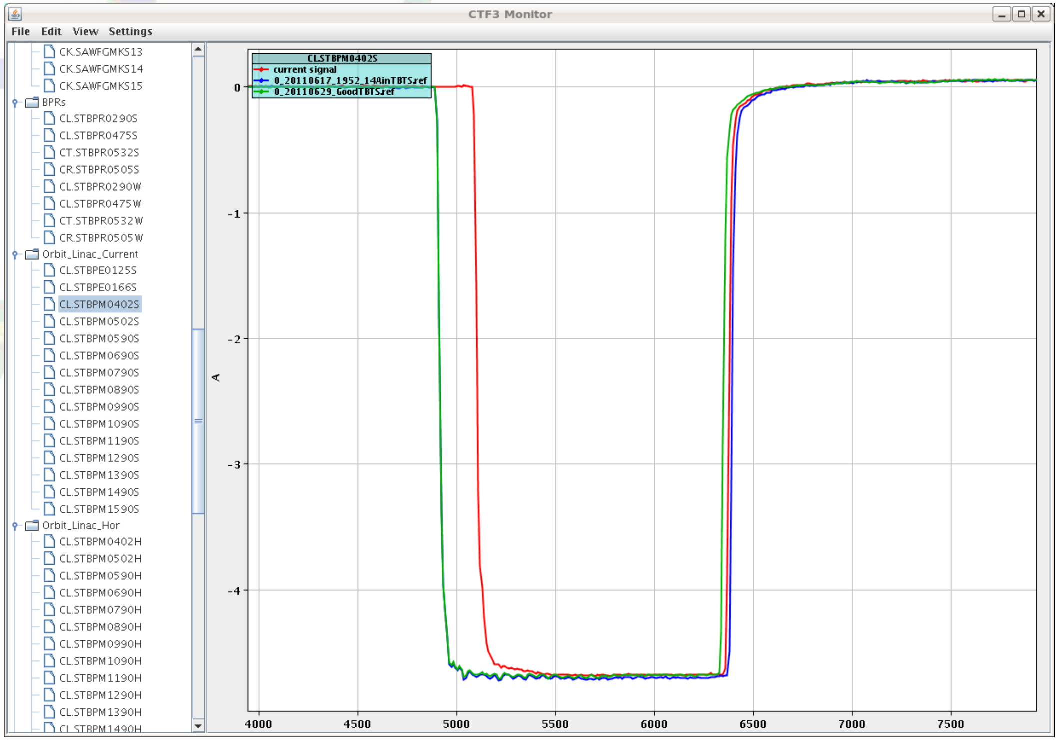
Beam Recombination



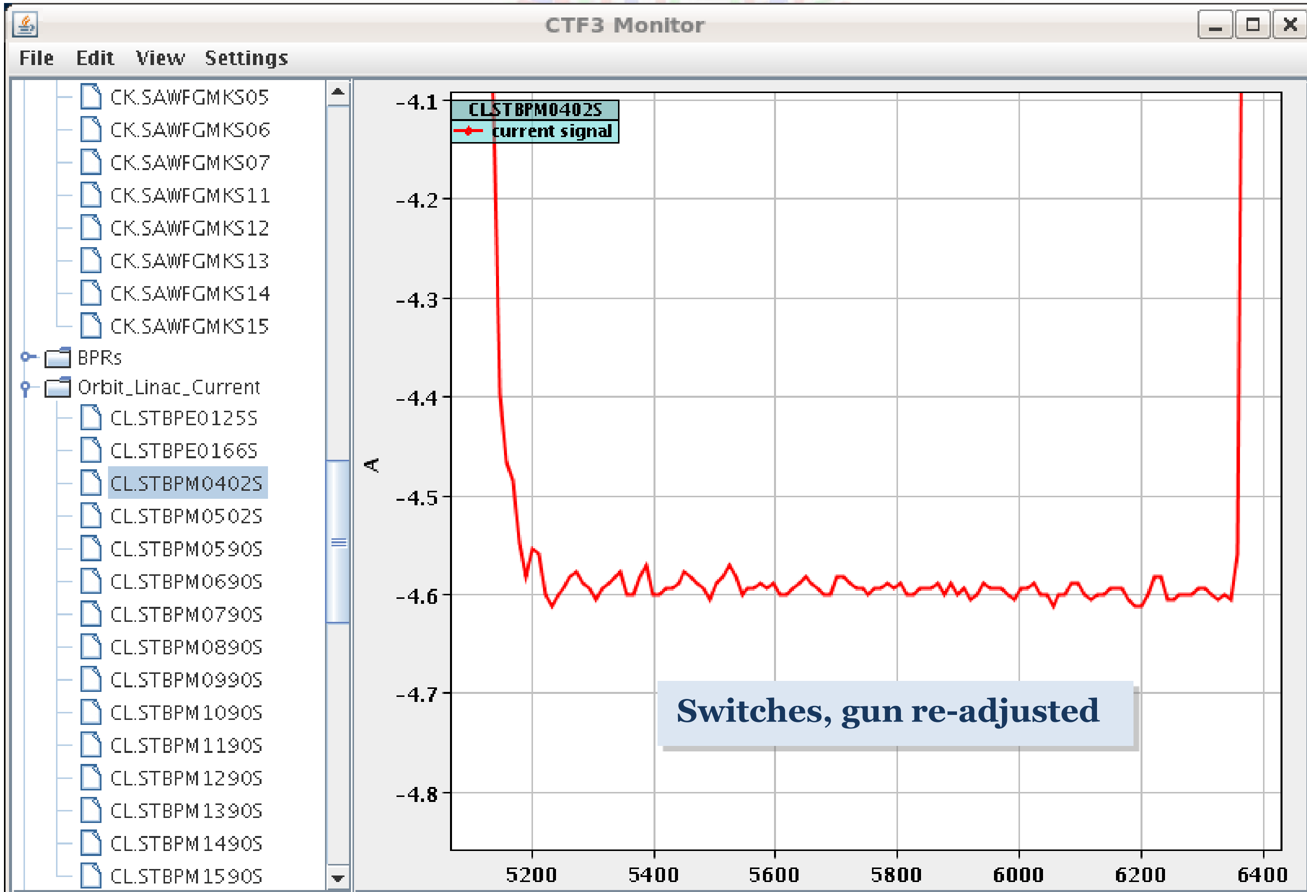
Gun current Correction



Alexandra Andersson



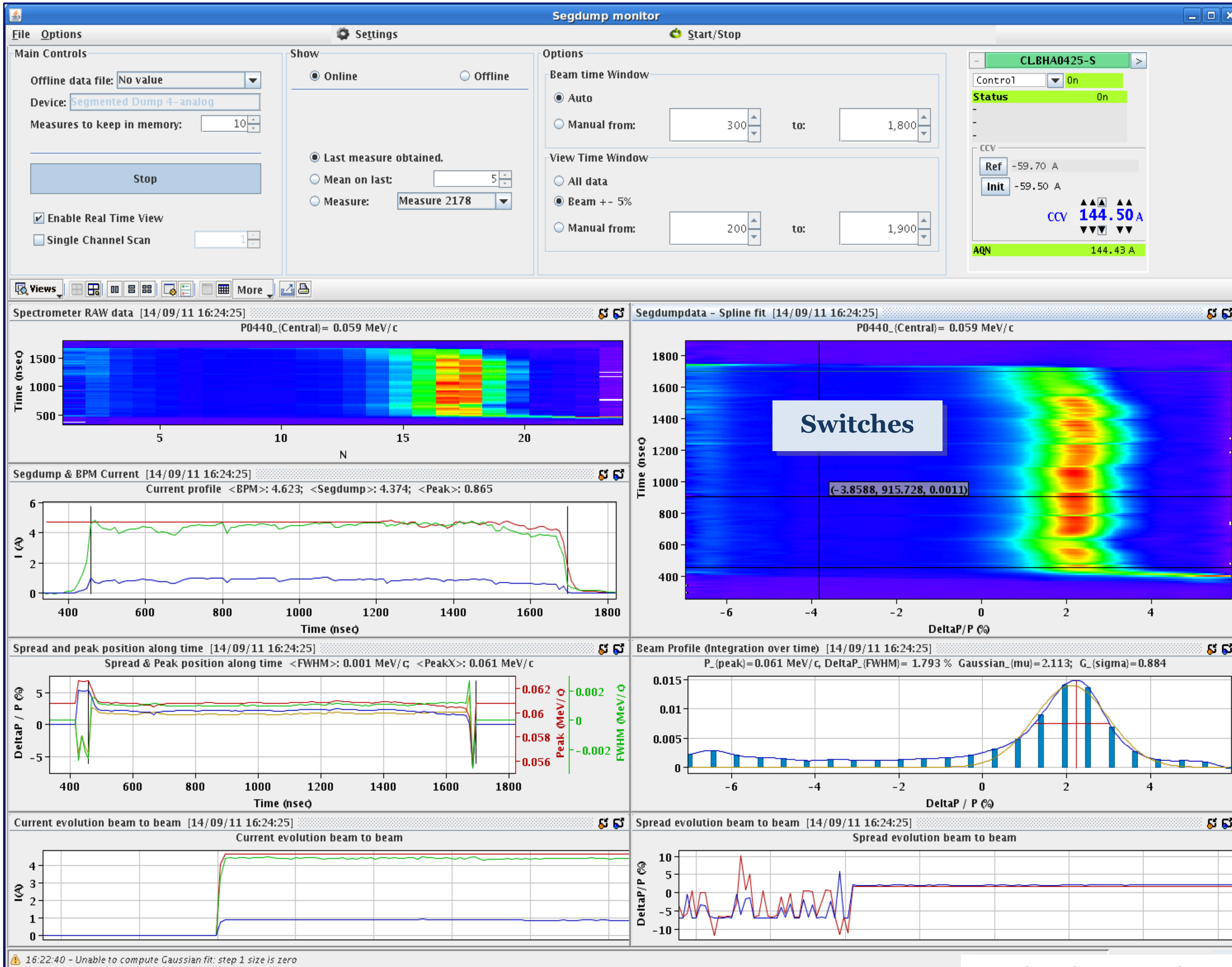
Compensation of phase switches



<u>*Alexandra Andersson, Frank Tecker, Piotr Skowronski*</u>

Compensation of phase switches

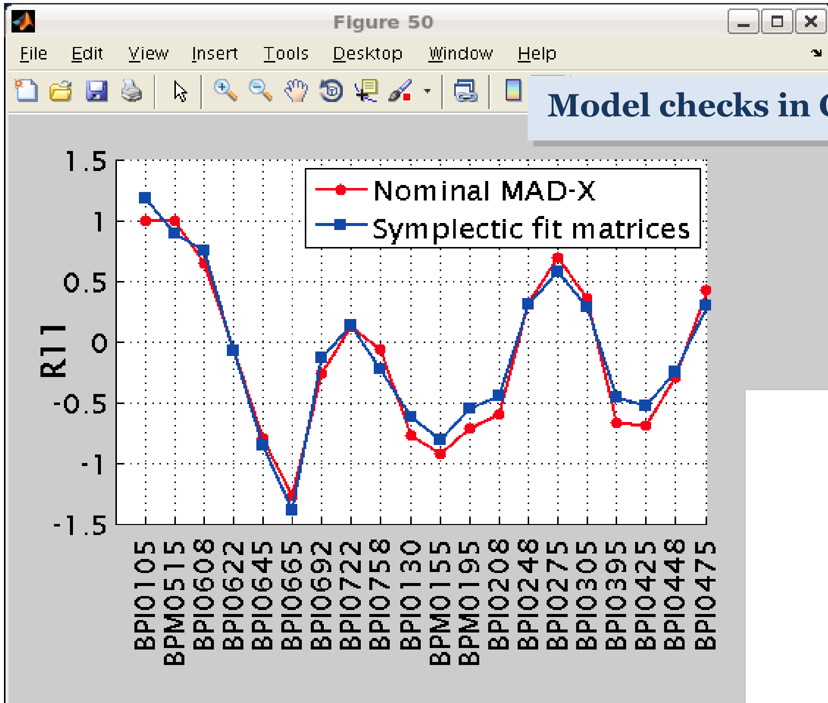
R. Corsini,
CTF3 working meeting
February 10, 2012



Frank Tecker, Piotr Skowronski

Optics studies, orbit correction

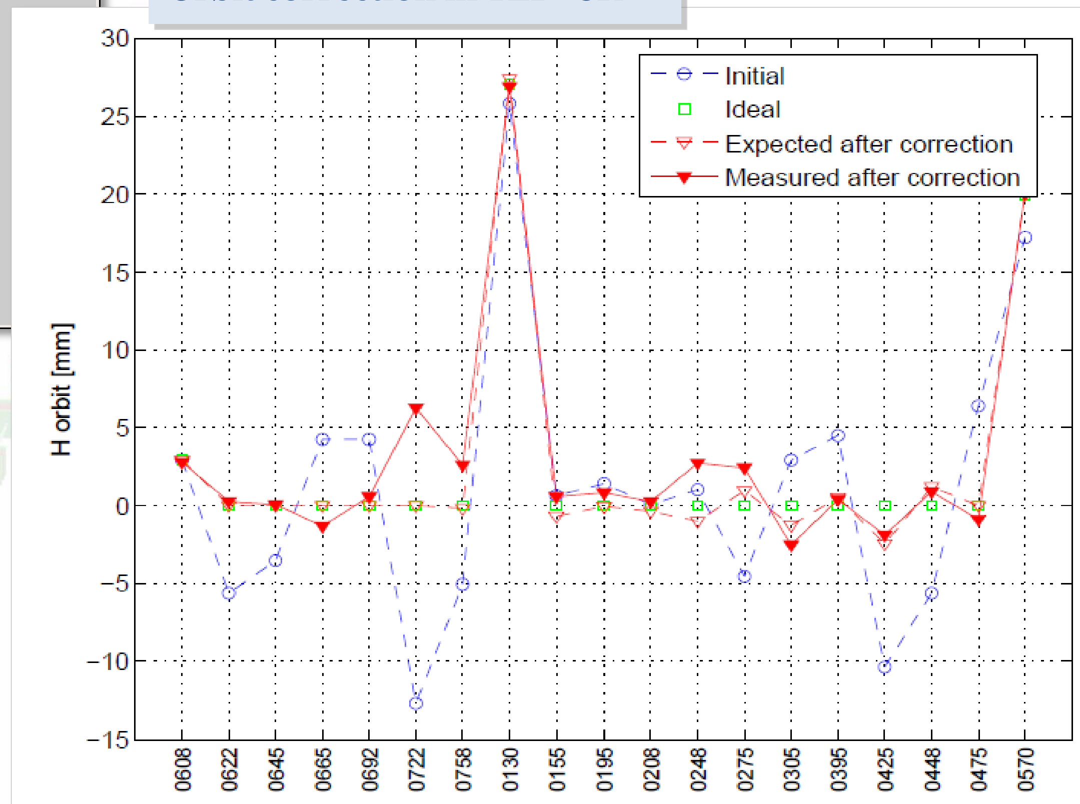
Model checks in CR



Ben Constance

Orbit correction in TL1 - CR

Guido Sterbini, Ben Constance



R. Corsini,
CTF3 working meeting
February 10, 2012

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