CTF3 – Status and Plans

Frank Tecker – BE-OP

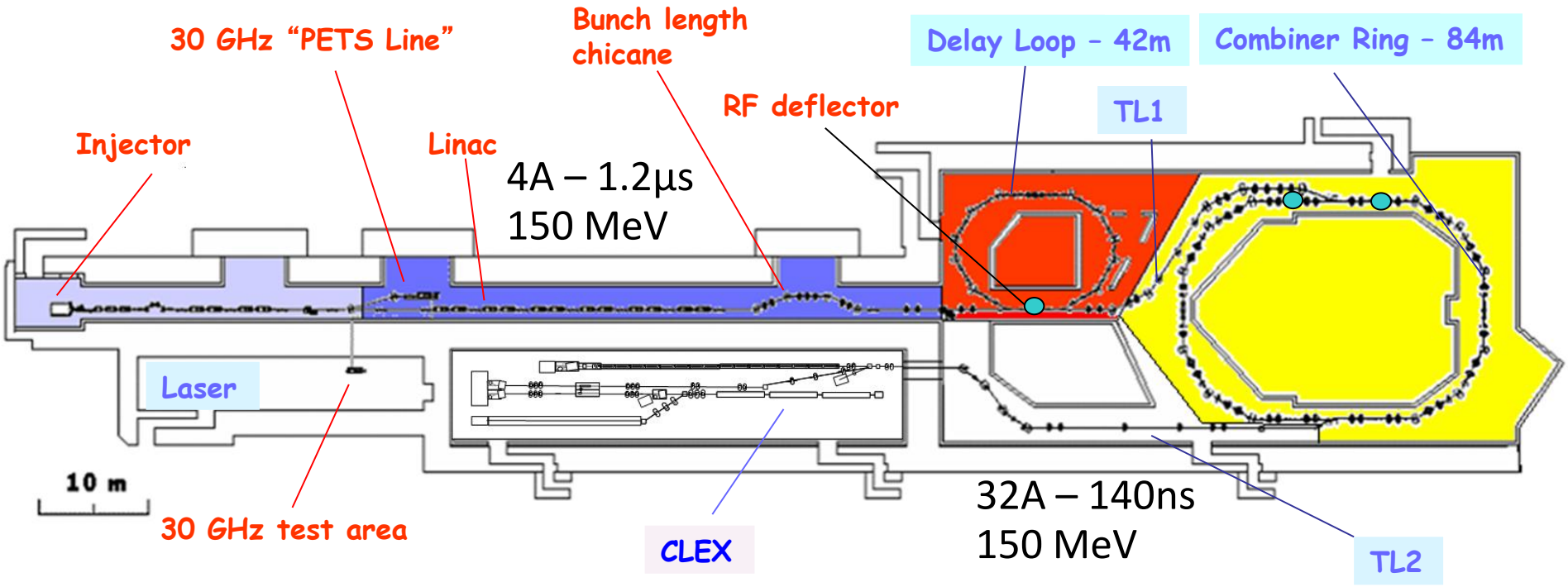
for the CTF3 team*

* Many thanks for all the material, esp. to R.Corsini

- Highlights from 2011
- CLIC Feasibility Demonstration
- Plans for 2012
- Running in 2013

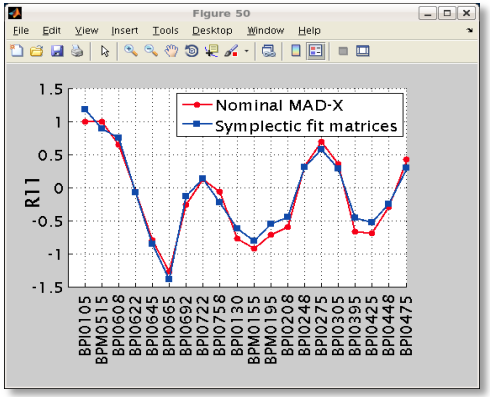
CTF 3

- demonstrate remaining CLIC feasibility issues, in particular:
  - Drive Beam generation (fully loaded acceleration, bunch frequency multiplication)
  - CLIC accelerating structures
  - CLIC power production structures (PETS)



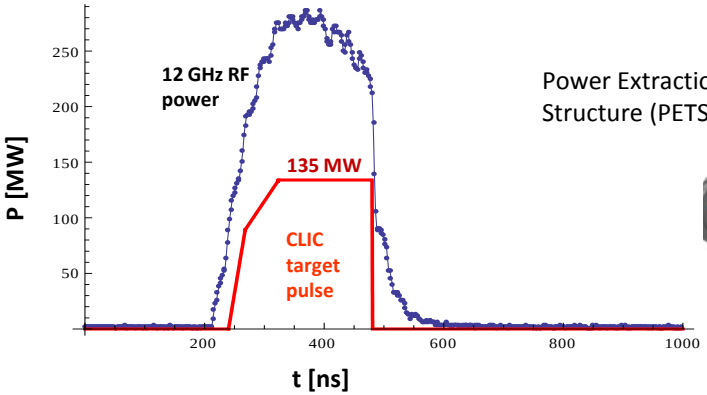
CTF3 Highlights - 2011

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

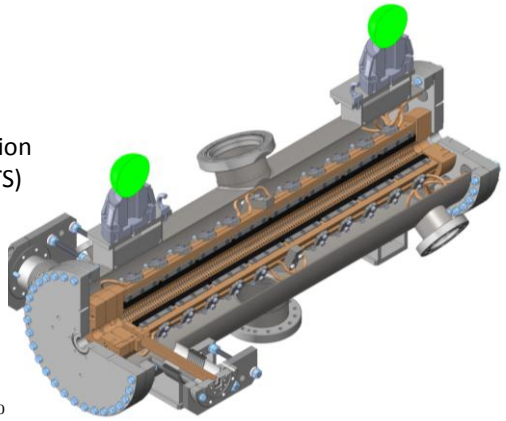


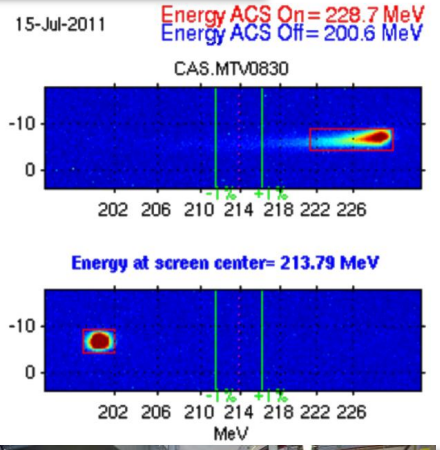
Optics model checks in Combiner Ring

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



Power Extraction Structure (PETS)





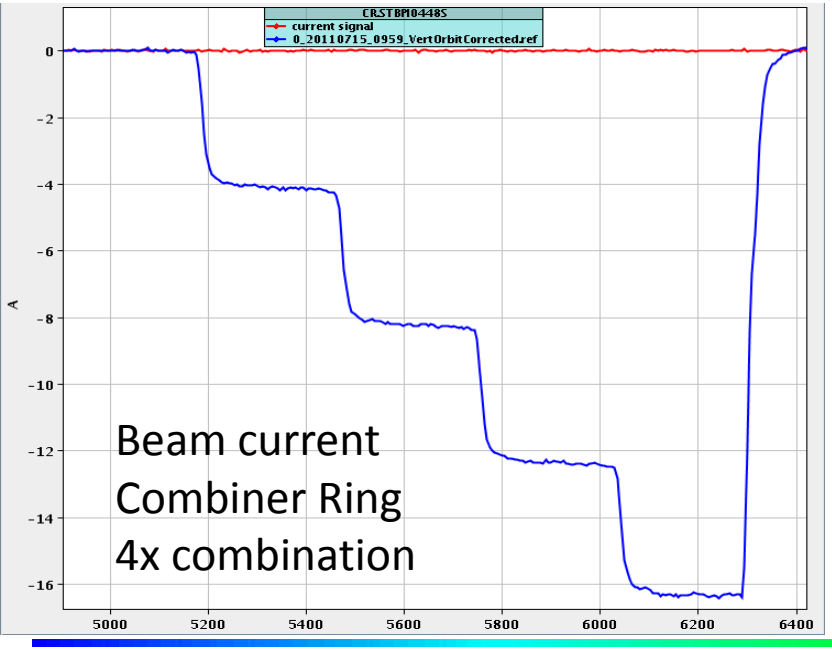
Two-beam acceleration in TBTS

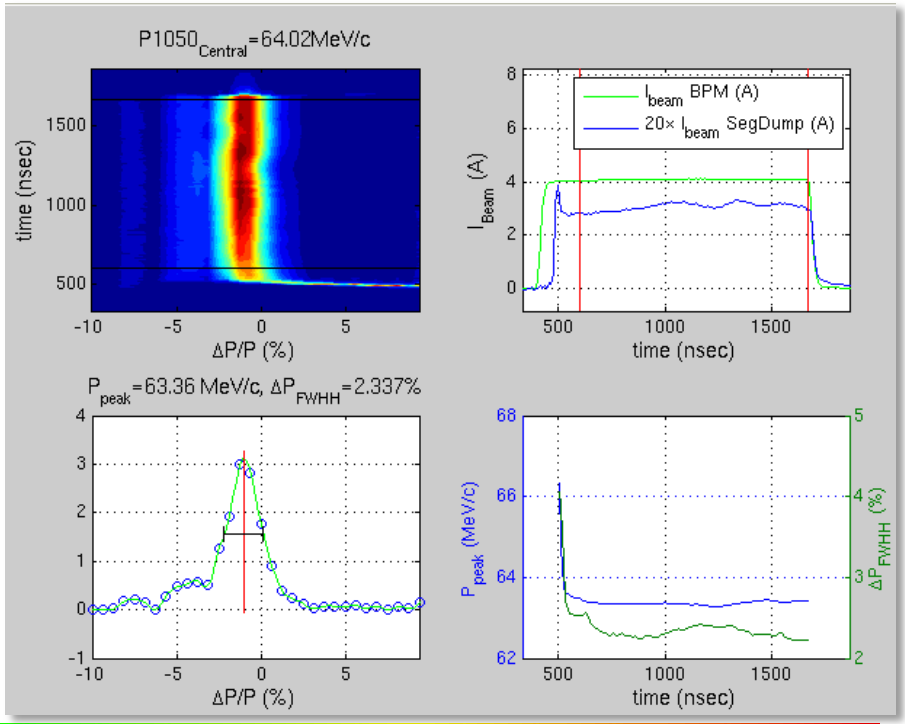
- Measured gradient in two-beam acceleration test 145 MV/m (CLIC nominal gradient of 100 MV/m)
- Nine PETS tanks installed in the Test Beam Line (TBL), 20 A decelerated by ~ 25%, matching well with expectations
- First successful test of PETS with on-off mechanism
- First measurements of break-down kicks in TBTS

Test Beam Line (TBL) in CTF3

2011 Improvements

- Gun pulse current flattening
- All RF phase sags made the same, including TWTs and MKS02
- Allowed for very quick setup of the factor 4 recombination in CR
- CTF3 Monitor: watches all signals stability, complete references, …
- Feedbacks
- Increased recombined beam stability
- The recombination is now much less vulnerable to drifts and jitters
- 14A in CLEX, 13A routinely





Drive Beam Generation – Factor 8

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:

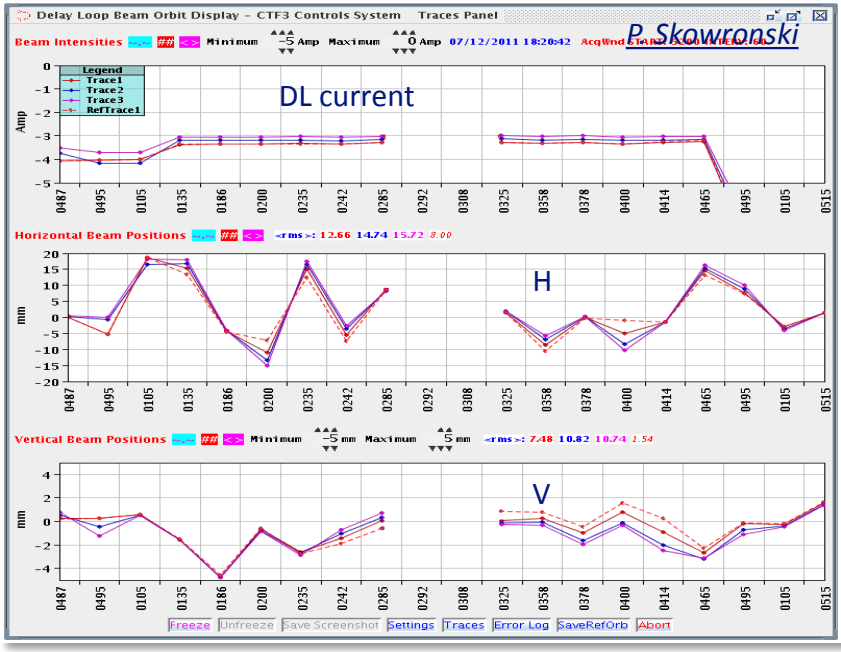
- Bad pulse shape (phase switches?)

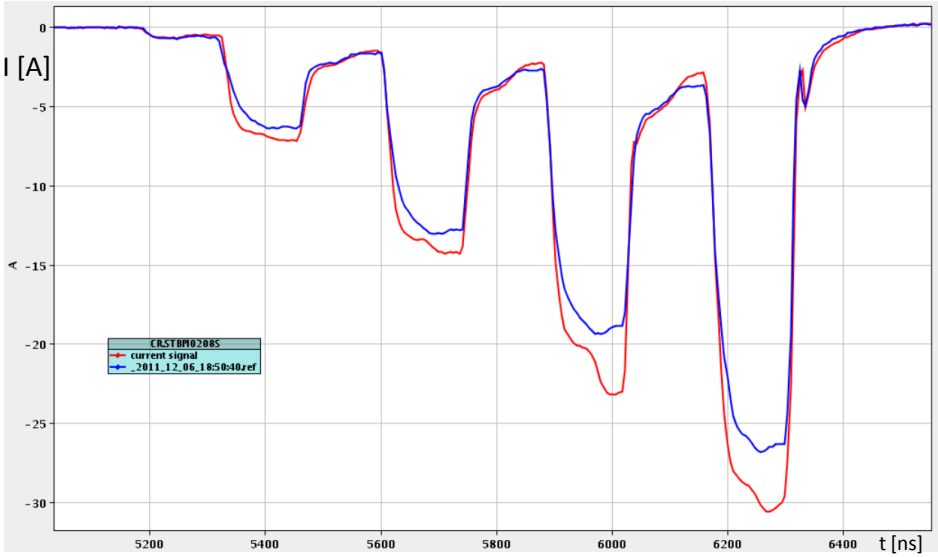
- Still limited acceptance -> stability was improved, but it is still not good enough

- DL quads measured and realigned

Future work:

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

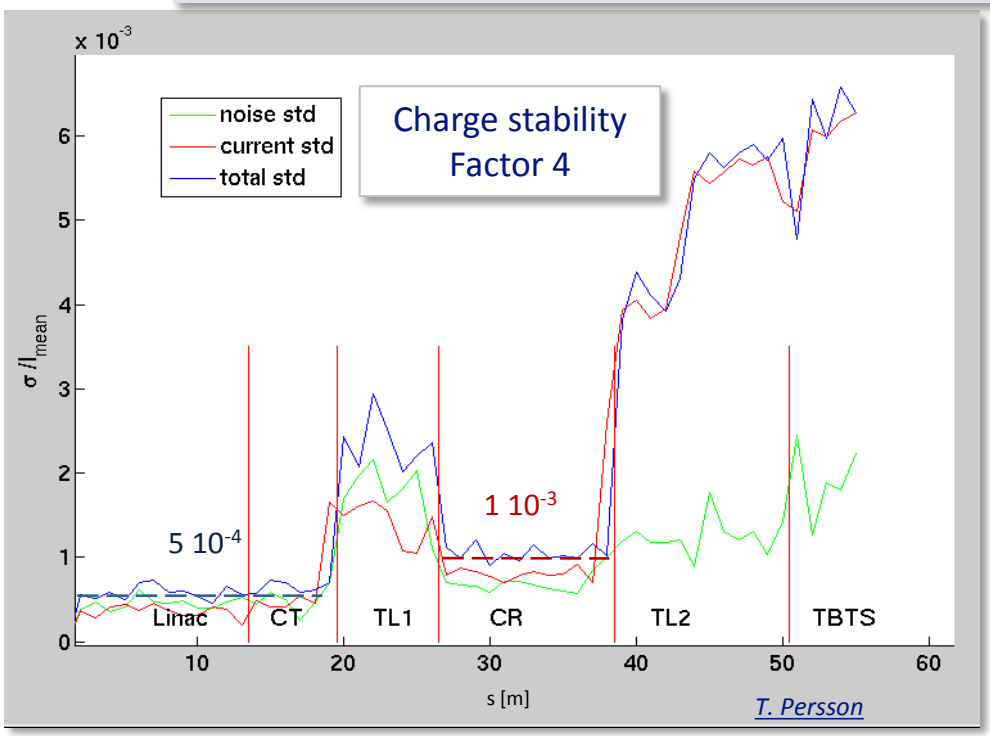




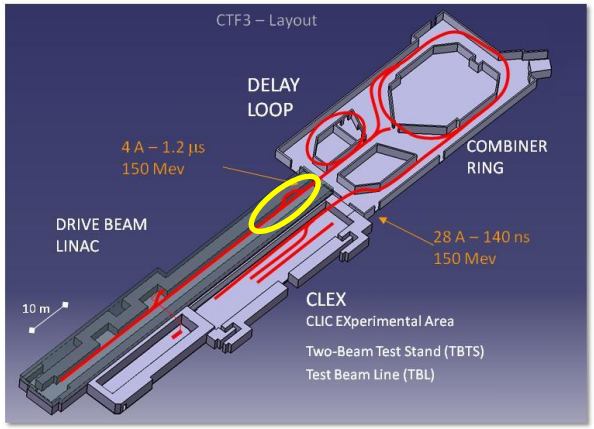
CTF3 Stability - Feedbacks

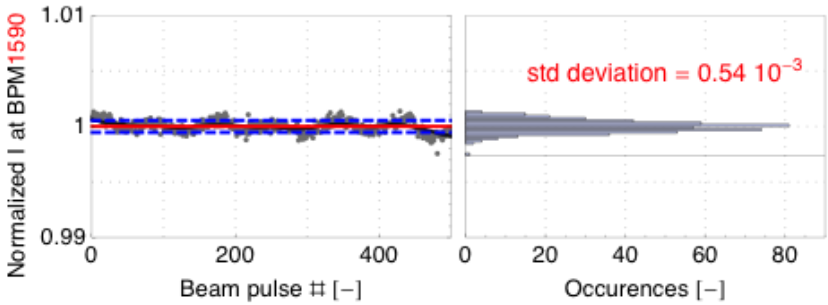
Repeatibility and long term current stability improved

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

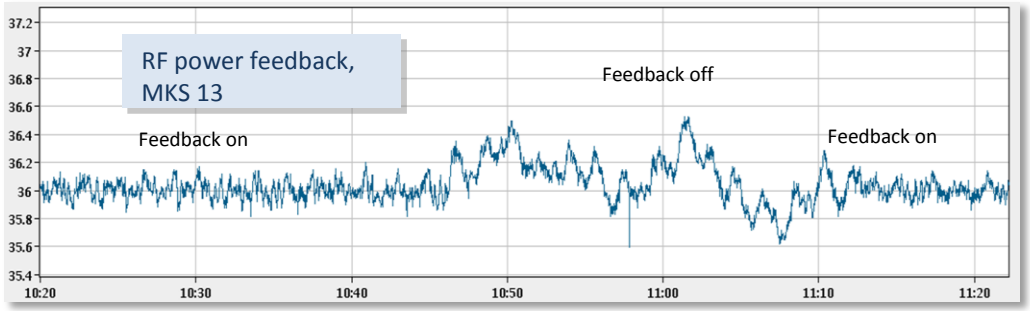


T. Persson





G. Sterbini

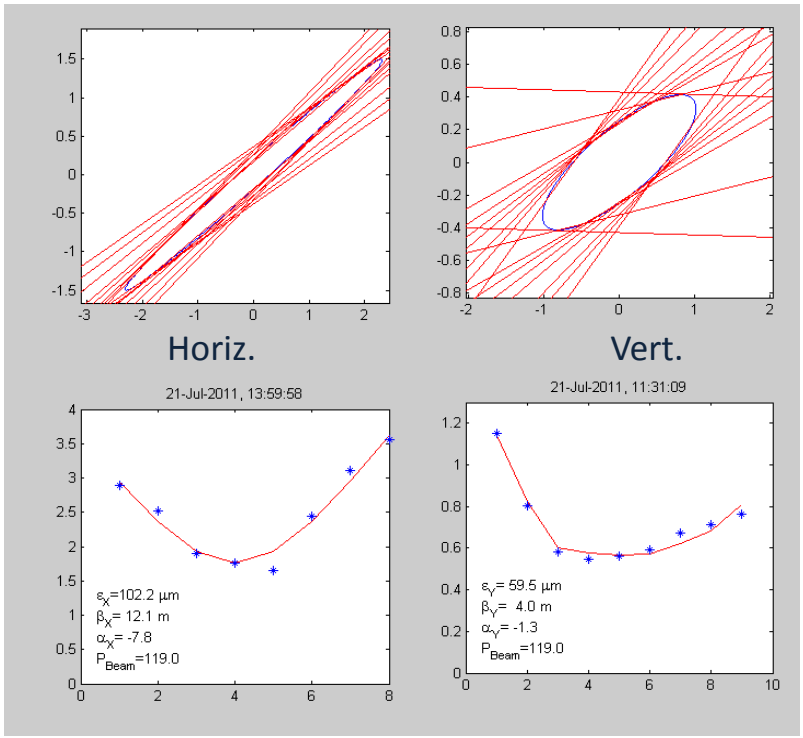


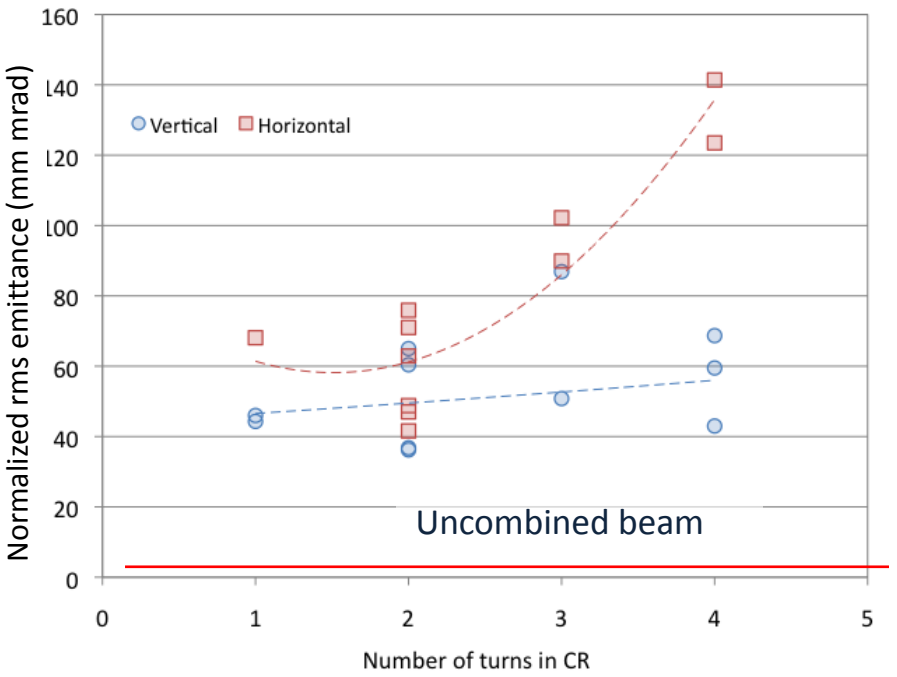
Several feed-back loops operational, for temperature, RF phase and power and gun current.

P. Skowronski, T. Persson

Drive Beam Generation - Emittance

Measurements in TL2 - uncombined





- Improve measurements
- Correct dispersion (linear, nonlinear)
- **Correct multi-turn orbit**
- Control RF deflector bump

2012

Beam recombination - Emittance

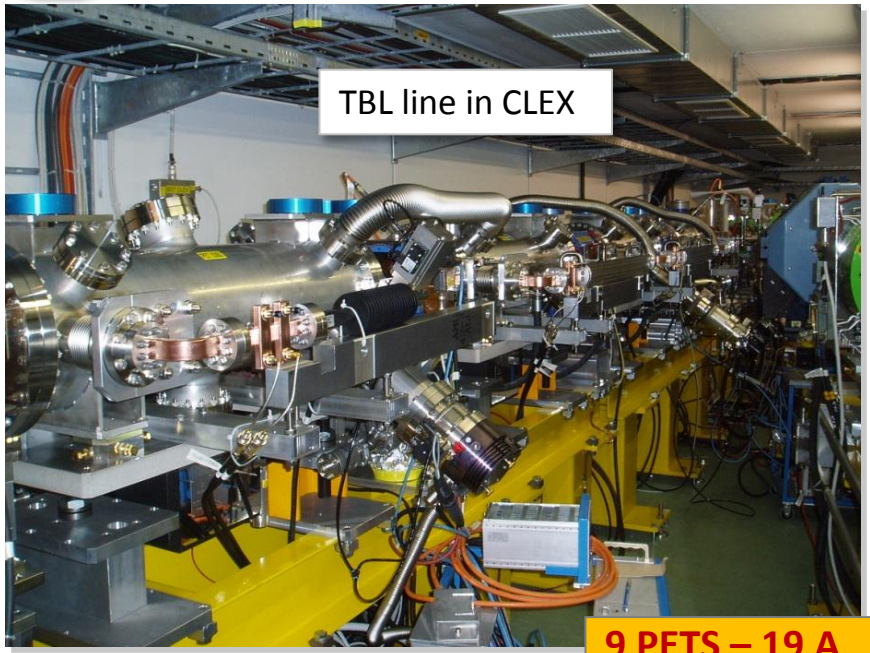
Best results in CLEX

for factor 4: ε_H= 250 um ε_V= 140 um

for factor 8: ε_H= 640 um ε_V= 170 um

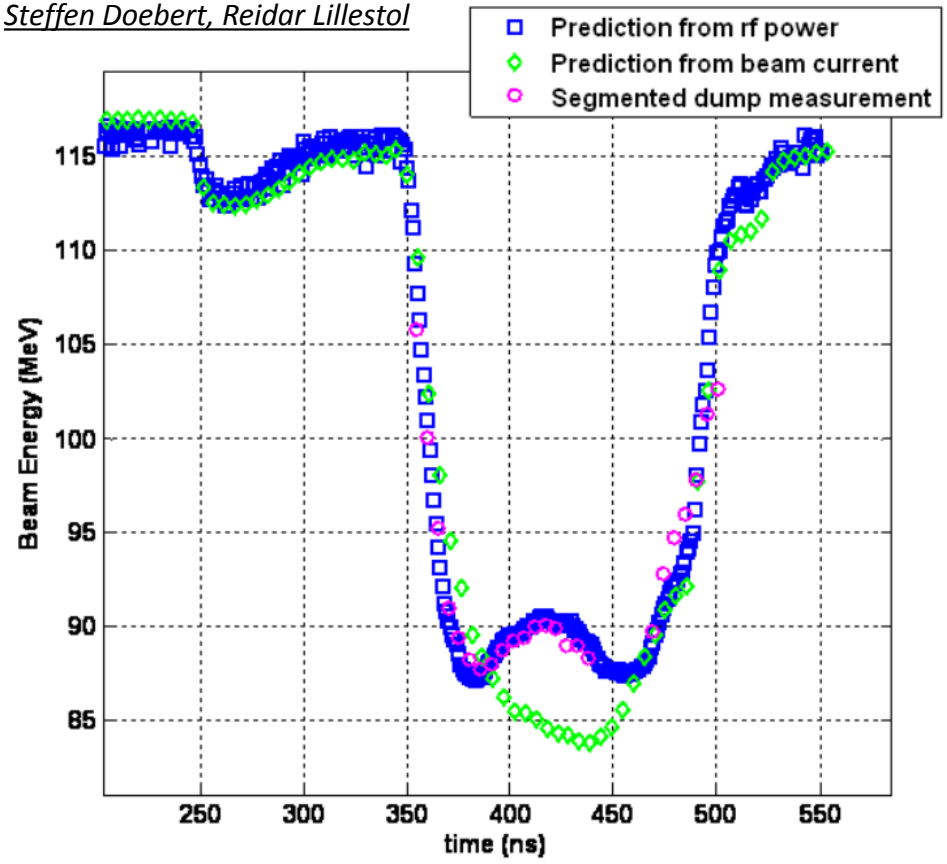
Different turns are ~ ok, no unknown effects
Emittance increase due to non perfect combination

TBL – Test Beam Line Decelerator



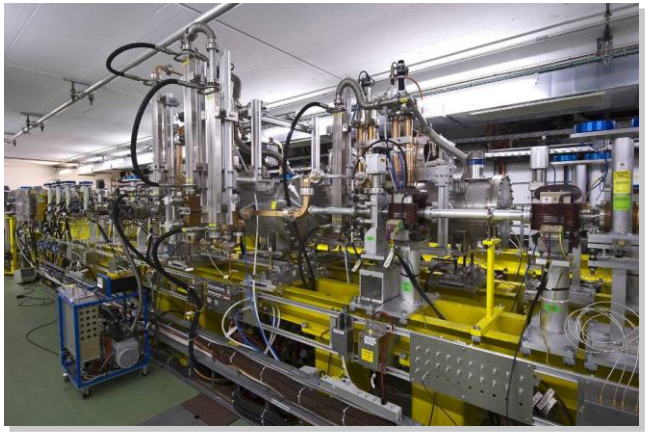
9 PETS – 19 A November 2011

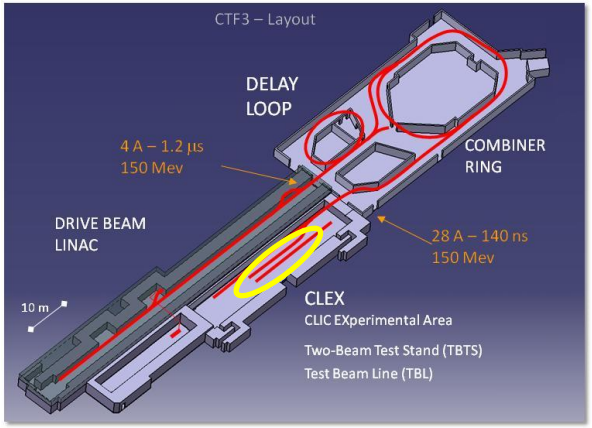
Steffen Doebert, Reidar Lillestol



- Drive beam has high current and gets high energy spread
- Stable transport in simulations verified experimentally with 9 PETS
- no losses in TBL, optics understood
- So far 19 A beam decelerated by ~25%, 0.5 GW power produced!
- Good agreement of power production, beam current and deceleration

Two-Beam Test Stand (TBTS) – power production

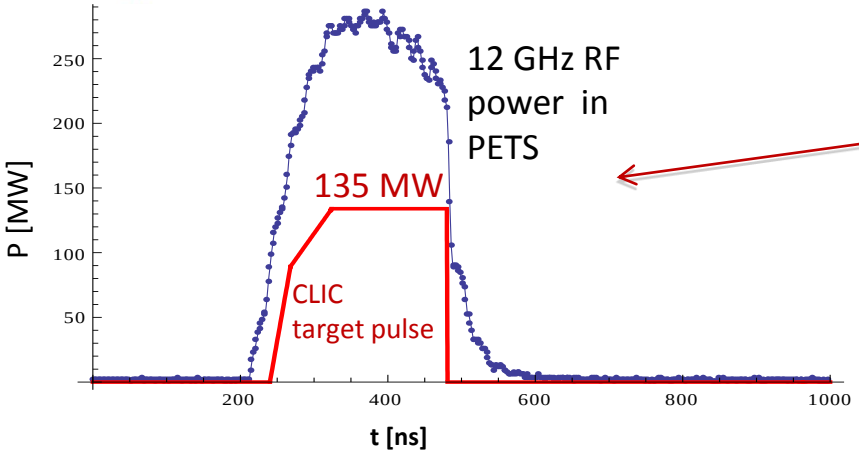


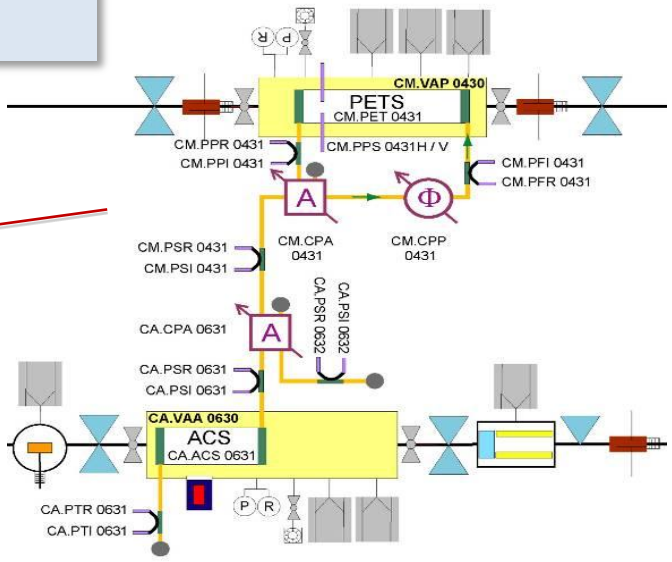


PETS operated routinely above **200 MW** peak RF power

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.

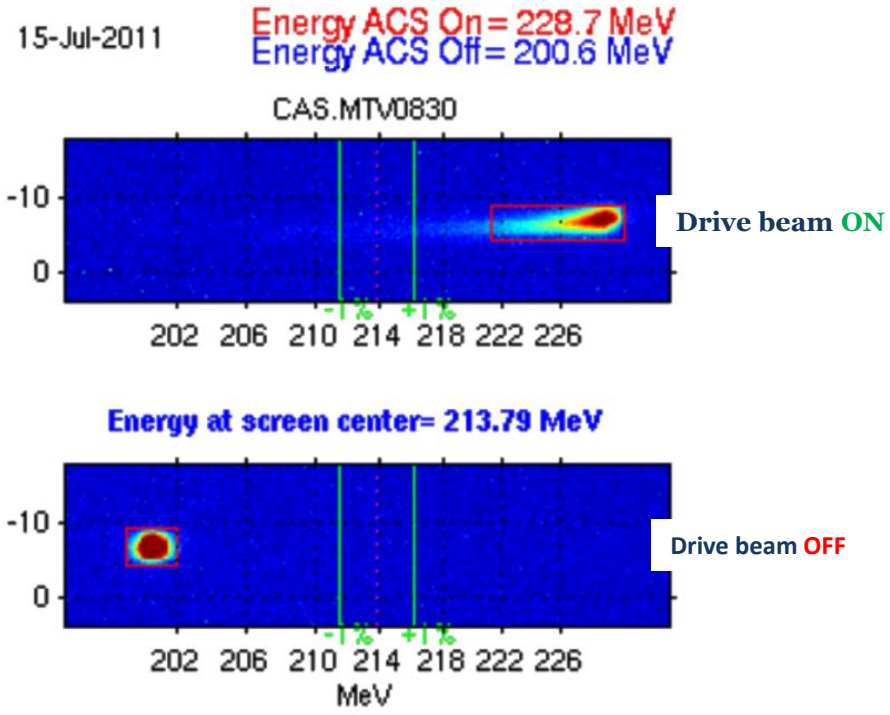


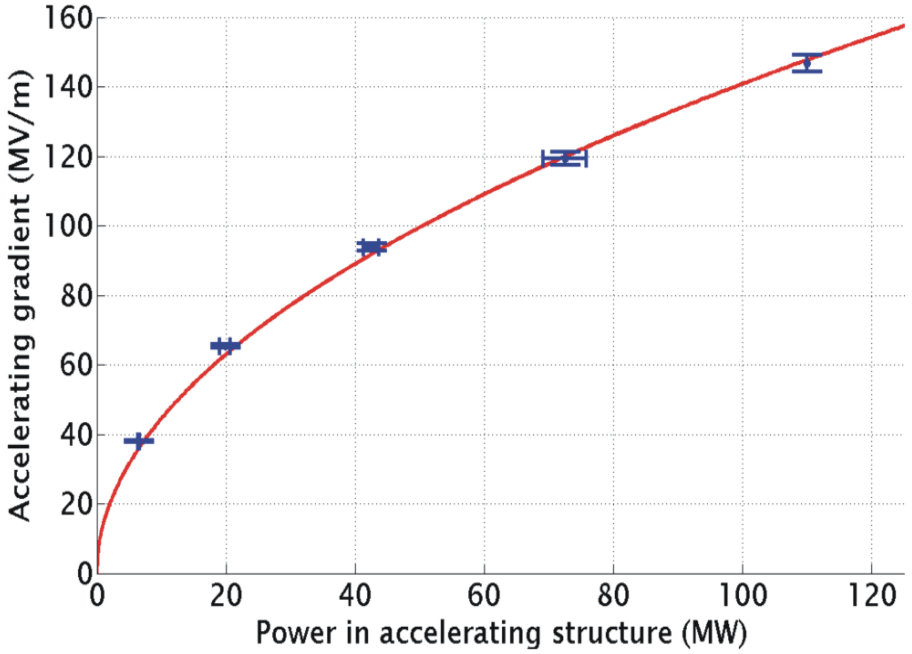


R. Ruber, I. Syratchev

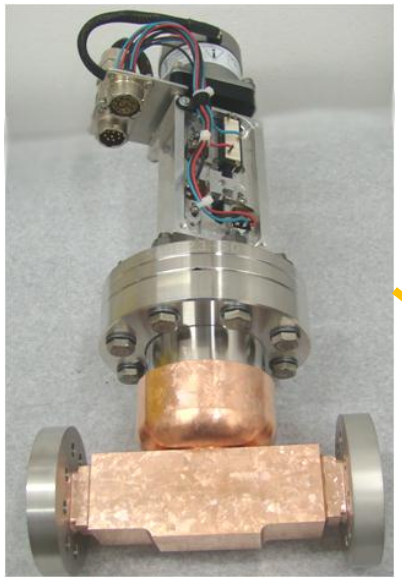
Achieved Two-Beam Acceleration

- Maximum probe beam acceleration measured: 31 MeV
  - Corresponding to a gradient of 145 MV/m



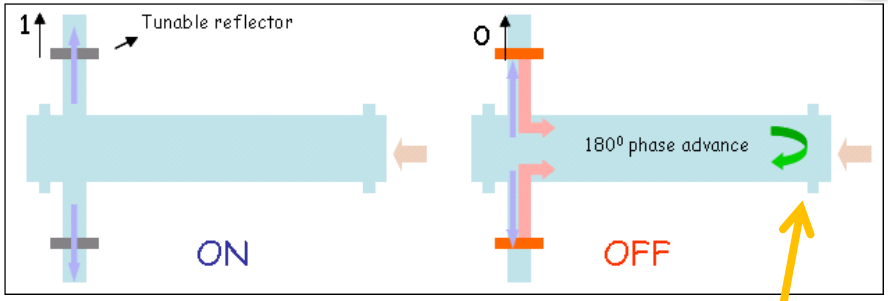


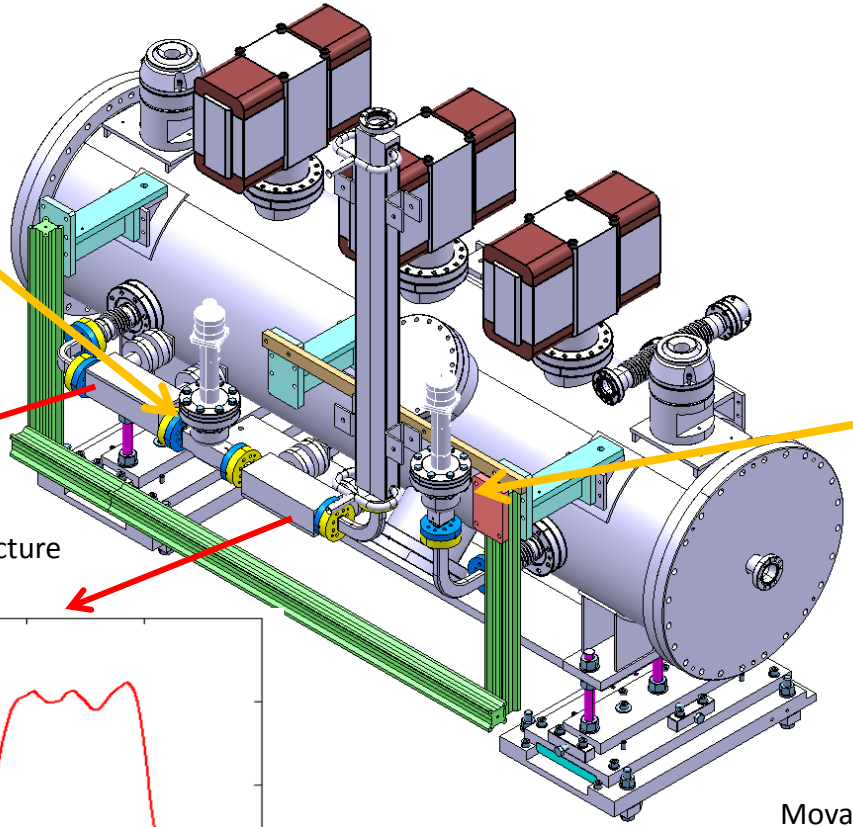
PETS ON/OFF mechanism in TBTS



Variable reflector (to tune the recirculation coupling)

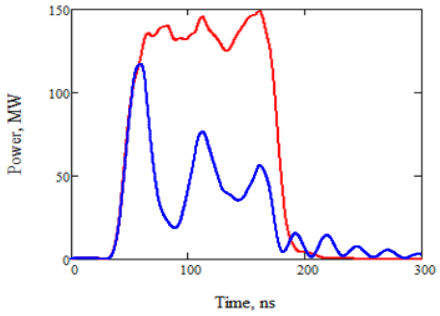
TBTS PETS layout with internal recirculation to test the ON/OFF concept





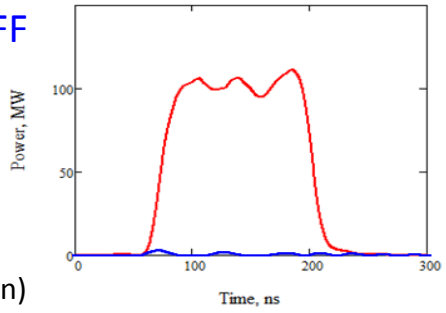
Movable RF short circuit (to tune the resonant length)

PETS output



ON
OFF

To Structure input

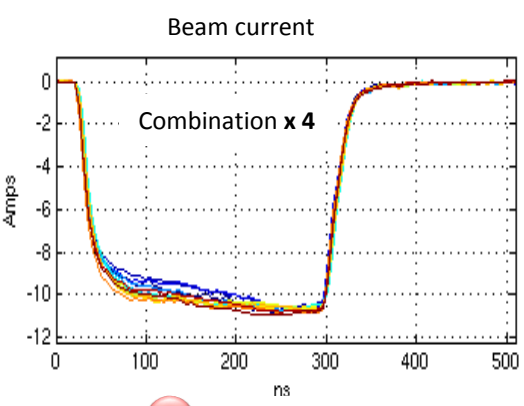


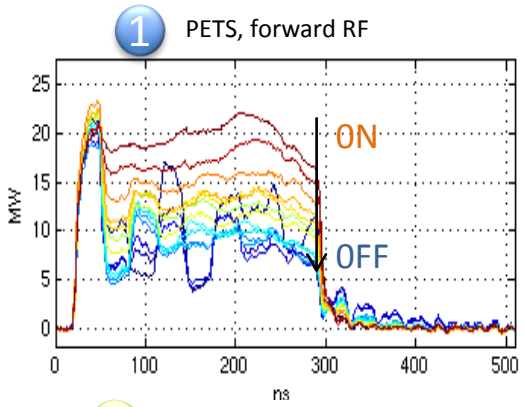
(as predicted by computer simulation)

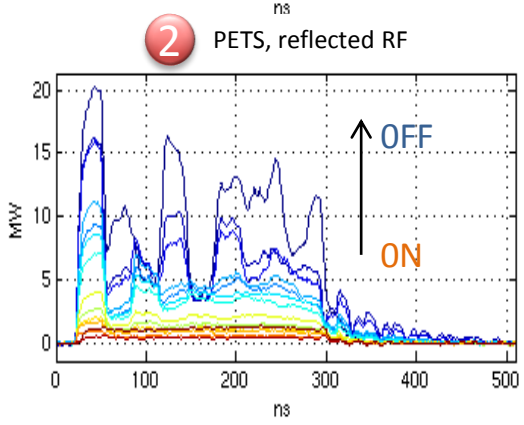
Igor Syratchev

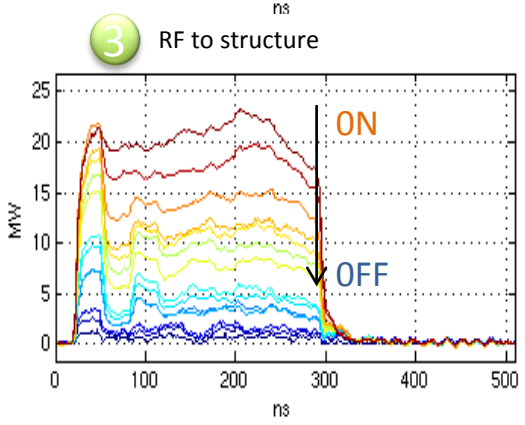
PETS On-Off mechanism - results

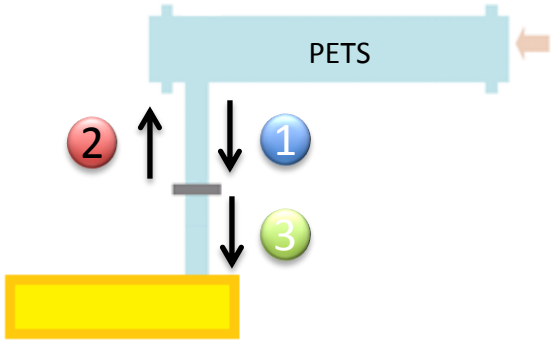
Signal evolution during On-Off

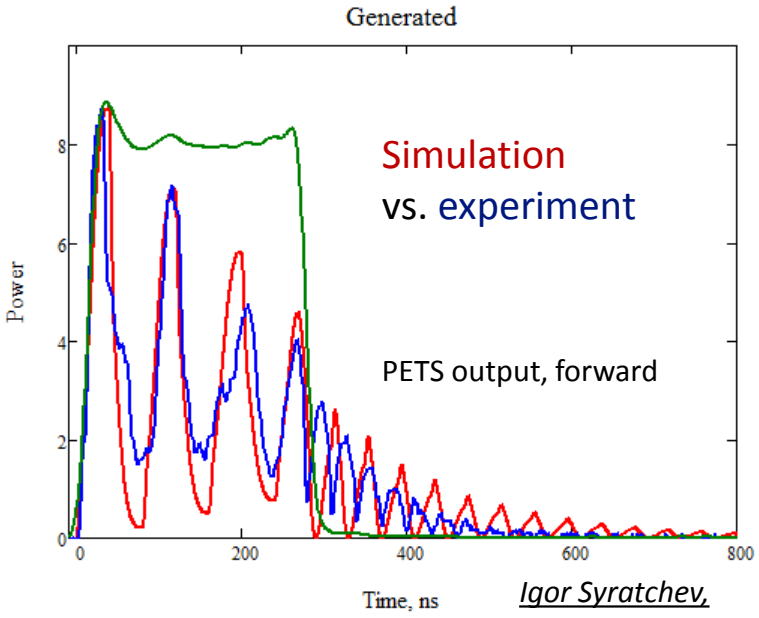










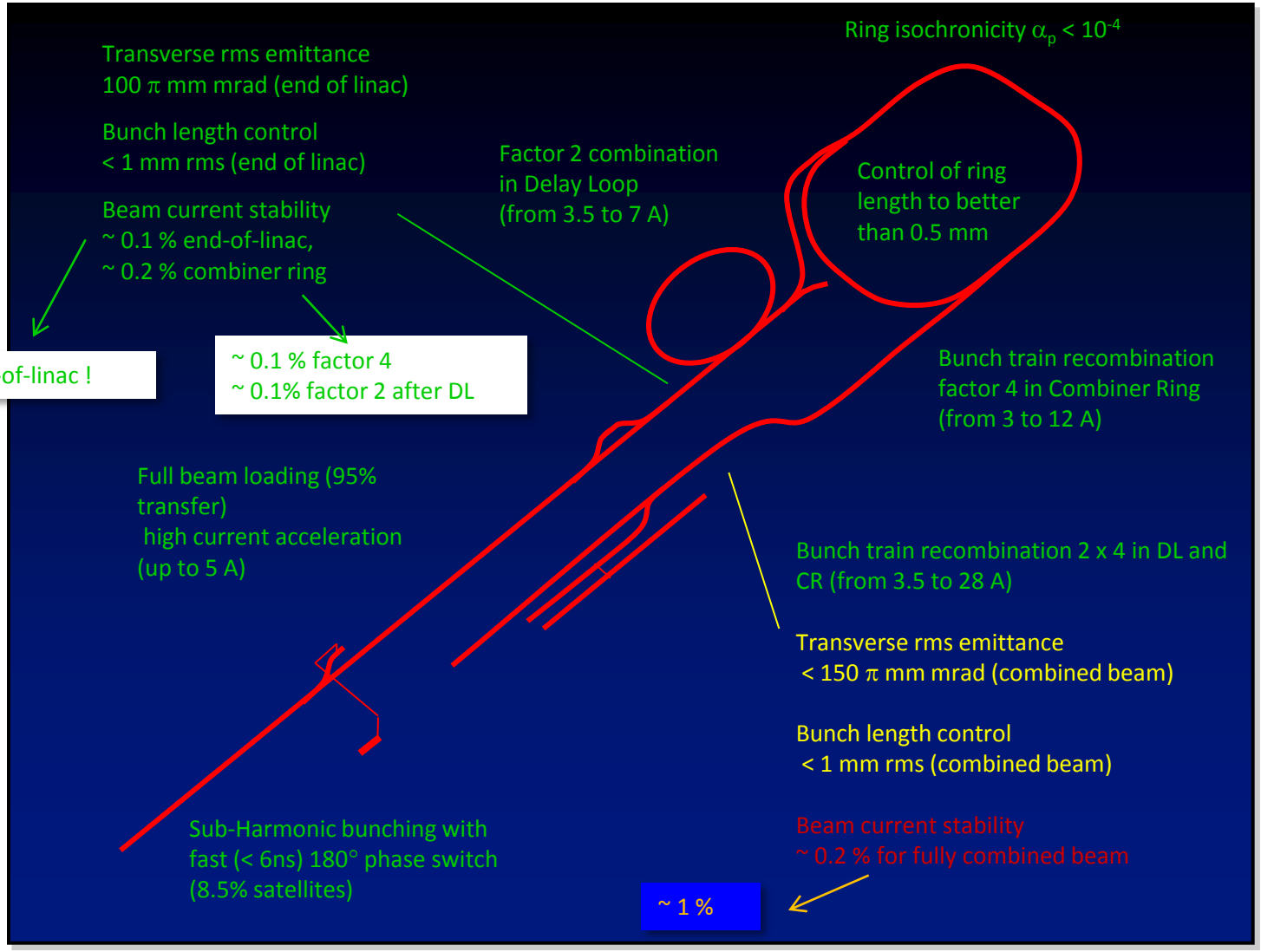


Igor Syratchev, Alexey Dubrovskiy

- PETS on-off principle fully tested
- Conditioned at high power (135 MW - nominal) by recirculation

CTF3 Achievements – Drive Beam

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 – Two-Beam issues

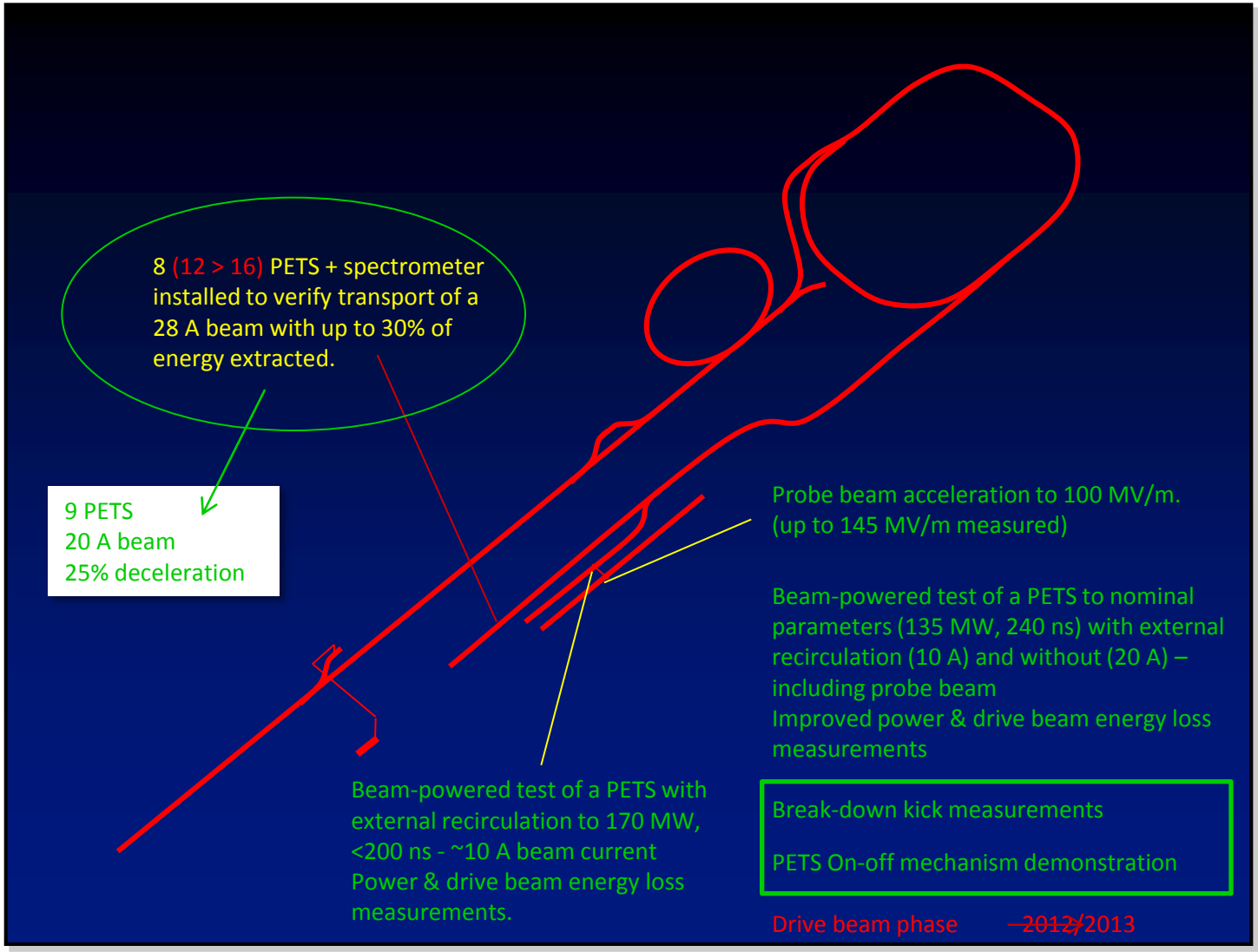
CTF3 Achievements – What is still missing for feasibility – TBL / TBTS

TBTS, 2012:

- Continue studies with two new structures
- Wakefield monitors

TBL:

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



CLIC Feasibility Benchmarks

CTF3 in green colour

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. 1 structure equipped with damping features under RF conditionning to reduce breakdown rate.
		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		2011	
	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	Emitttance 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

Main goals for 2012

- 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)

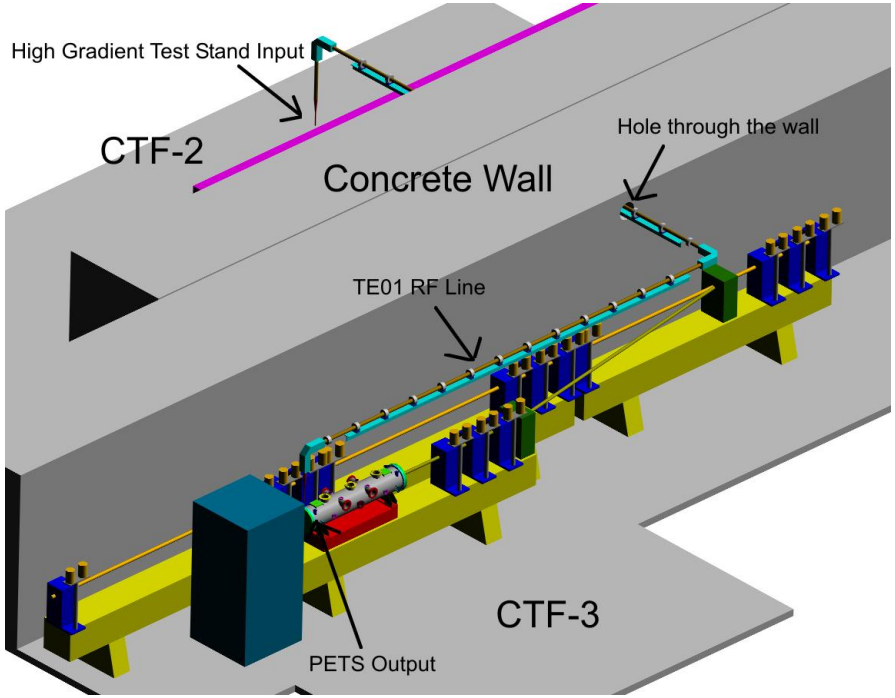
- TBTS
  - PETS on/off:
    - Measure break-down rates in different conditions (recirculation high-power, nominal on and off)
  - New accelerating structure with wakefield monitors
  - BD measurements & BD kicks measurements, wake-field monitor tests
  - RF pulse shaping tests

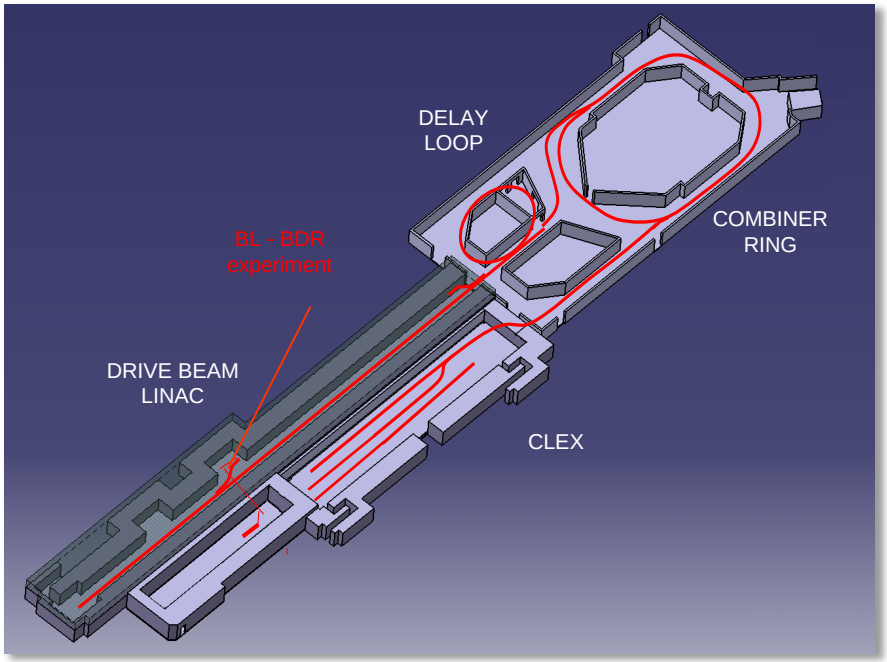
- TBL
  - RF power production: 12 to 13 PETS tanks, from 20 A to 30 A
  - further improve precision of current, energy, bunch length & RF power measurements
  - Reach more than 1/3 deceleration
  - Drive beam phase stability monitoring

- TERA run for medical accelerator test
- PHIN photoinjector tests

2012/13 - BDR with beam loading

- Beam loading reduces field => BDR lower?
- CLEX probe beam has only low current
- => use CTF3 drive beam and klystron driven X-band structure
- reactivate the old '30 GHz PETS' line

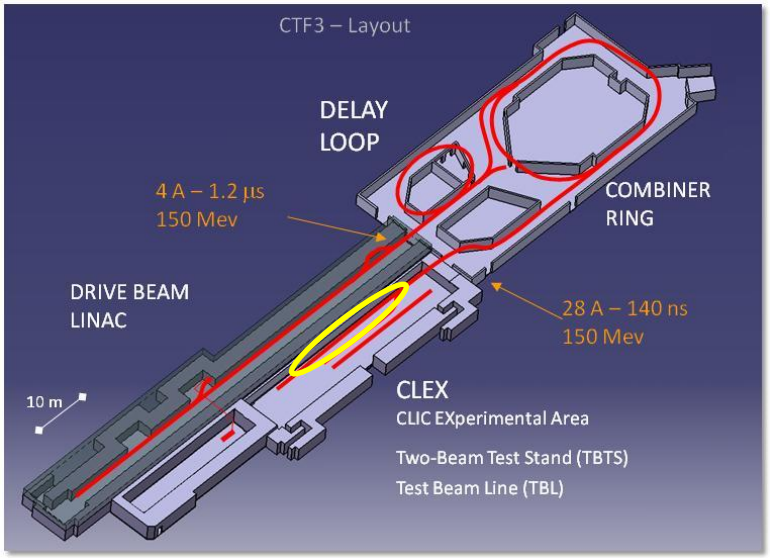


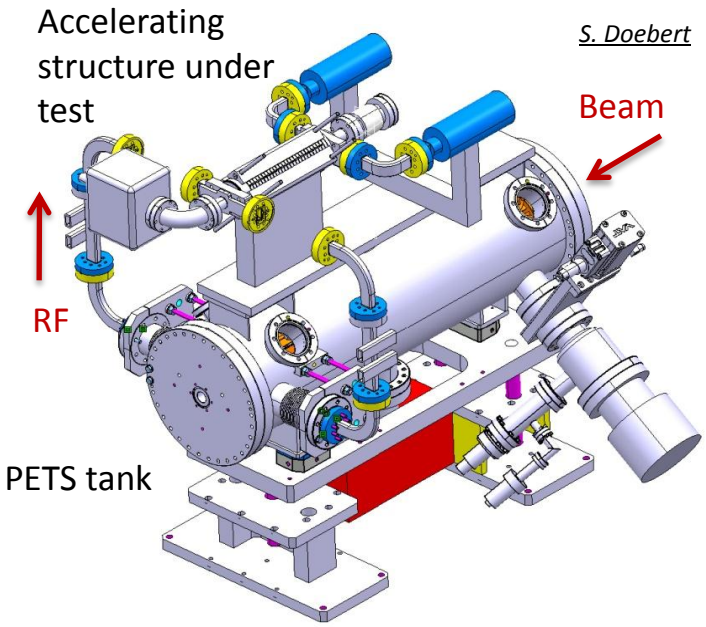


CTF3 plans for 2013+ - TBL+

- 12 PETS installed start 2012
- Improve Drive Beam quality for combination 8 in 2012 (emittance, bunch length, stability)
- Study deceleration, power production, and beam stability
- 16 PETS installed late 2012

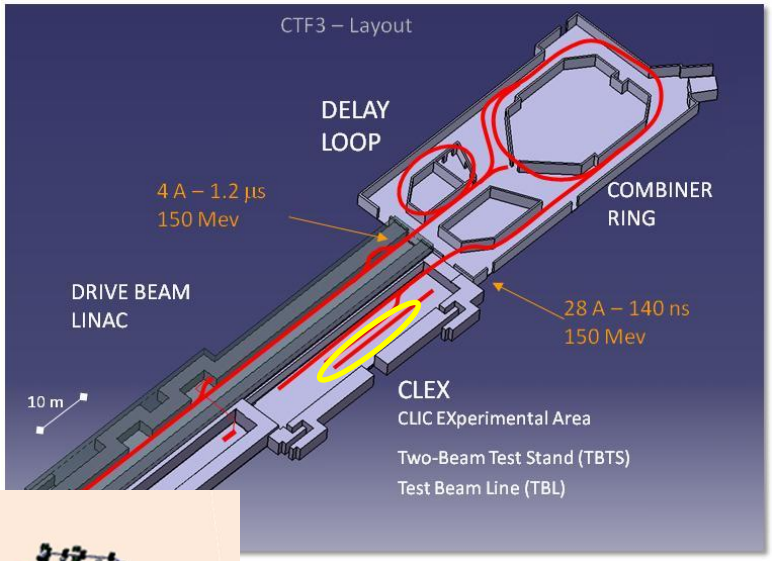
- Upgrade TBL to a test facility relevant for CLIC TDR work
  - **12 GHz power production for structure conditioning and component testing**
  - Working experience with a real decelerator
  - Beam dynamics studies, pulse shaping, feedbacks, etc.
- Timeline:
  - Last batch of four PETS installed in late 2012 will be adapted to high-power testing
  - One (or two) slots tested at beginning of 2013
  - Gradual increase to 4-8 slots and higher rep rate

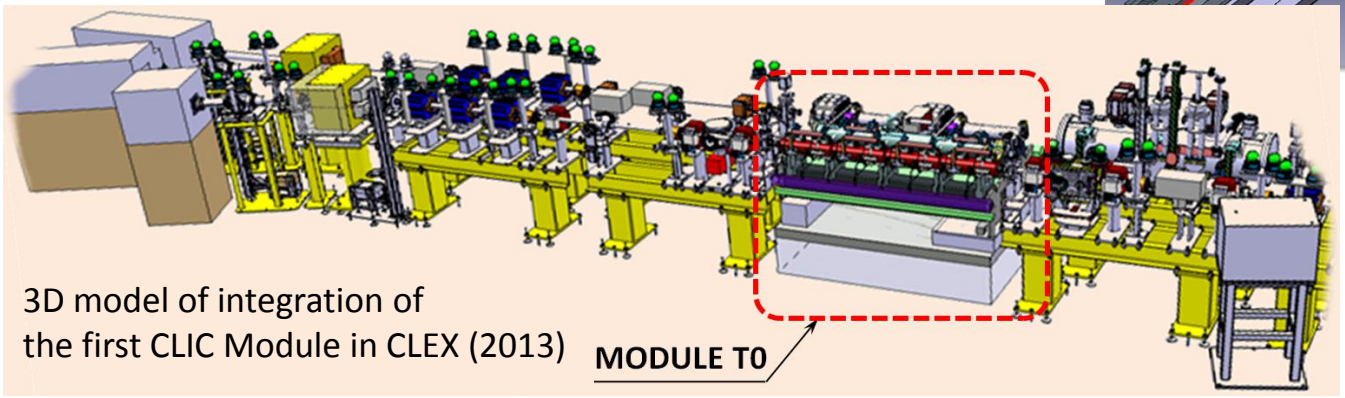




CTF3 plans 2013+ - Two-beam modules

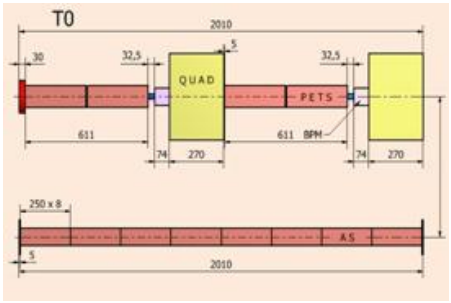
- Tests of a series of full-fledged Two-Beam Accelerator modules with beam
- Tests of RF, beam instrumentation, cooling, alignment, etc. in real accelerator environment
- First module in CLEX TBTS in 2013
- Three modules types foreseen for 2014





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

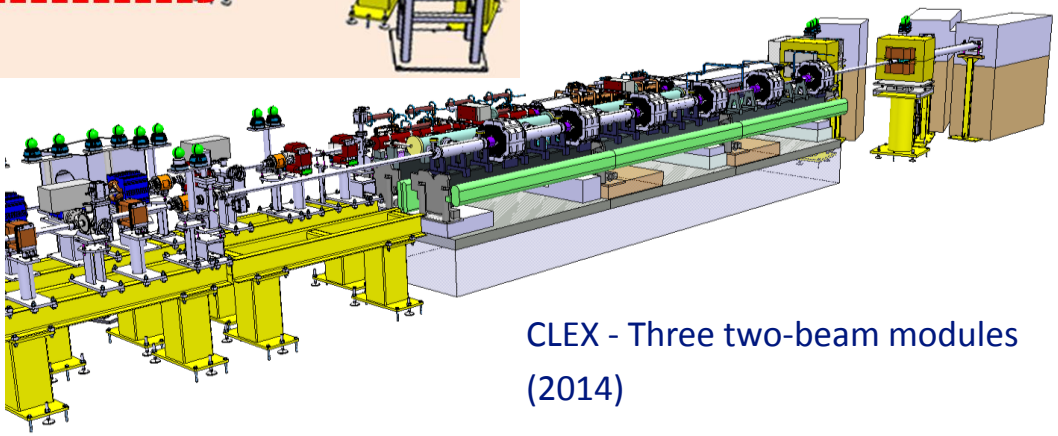
G. Riddone



Drive beam

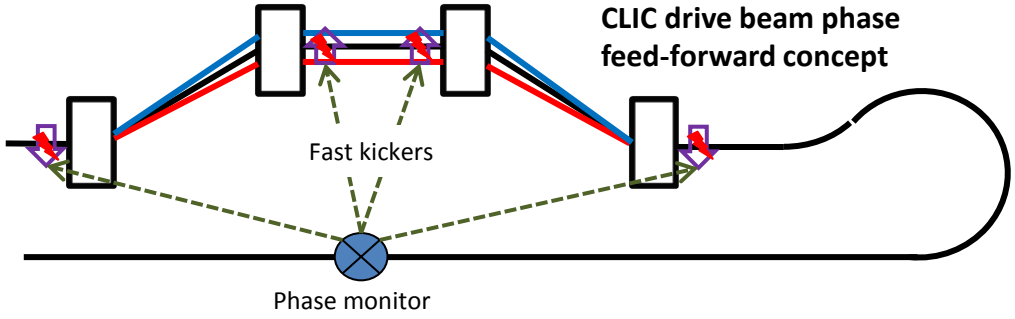
Probe beam

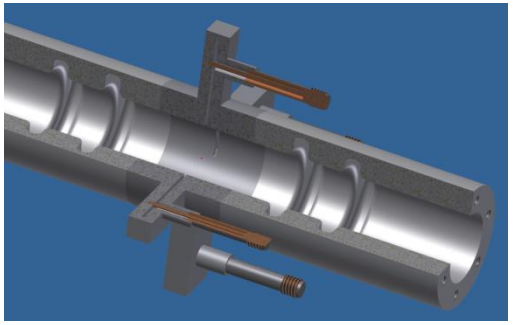
Schematic layout of T0 module



CLEX - Three two-beam modules (2014)

Drive Beam feed-forward and feedback

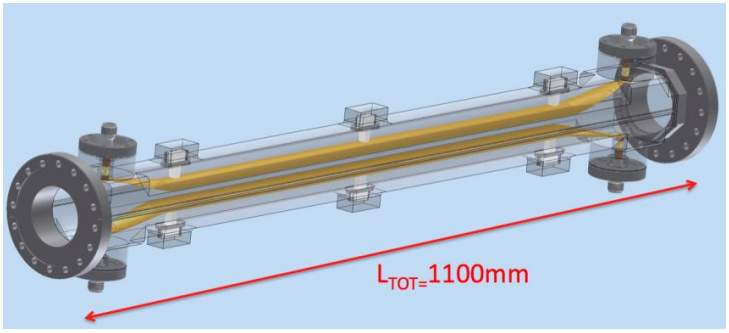




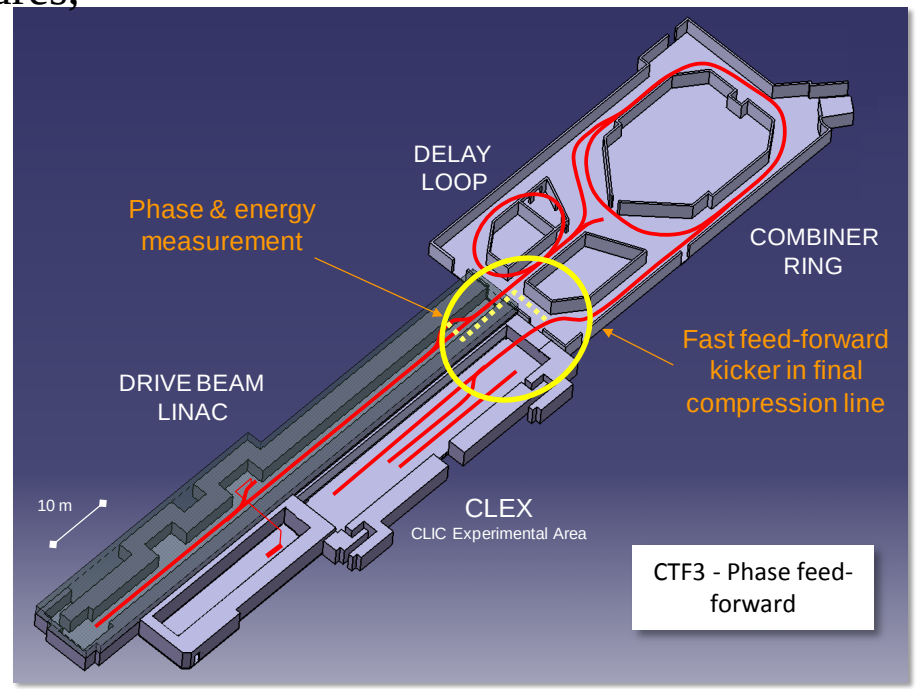
Phase monitor

- Show principle of CLIC fast feed-forward
- Series of related studies at CTF3 to 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
- Close link to collaborating partners (INFN, Oxford…)

P. Skowronski,
P. Burrows, A.Ghigo



Stripline kicker



2013 - CTF3 operation wish list

- Beginning March: water, electrical systems, CO, etc. for HW tests
- Beginning April: start with beam
- Mid December: Beam stop

- During operation CTF3 normally uses the resources of:
  - Piquet Control
  - First line PO
    - Both not absolutely essential for CTF3 operation (at expense of efficiency)
      Best effort service from specialist has been done for limited time in the past
  - RP controls
  - Access control
    - Discussion started how this can be done
  - CCC for night and weekend supervision
    - Can be dropped
  - Occasionally EN/CV for water stations and some vacuum support

Summary

- Very good progress in 2011 through many improvements
  - >250 MW produced in PETS
  - up to 145 MV/m acceleration
  - 19A beam decelerated by ~25%, >0.5 TW RF power produced
  - PETS ON/OFF mechanism verified
- Main goals in 2012
  - improve beam quality in particular for factor 8 combination
  - deceleration studies with 12/13 PETS in TBL
  - Breakdown rate measurements for PETS ON/OFF
  - Accelerating structure test with wakefield monitors in TBTS
  - continue breakdown kick and breakdown rate studies
- Further planning
  - increase beam energy and repetition rate
  - measure breakdown rate with beam loading
  - study CLIC two-beam modules
  - upgrade TBL to an RF testing facility
  - implement a phase feed-forward for the drive beam