Critical review of CTF3 performance

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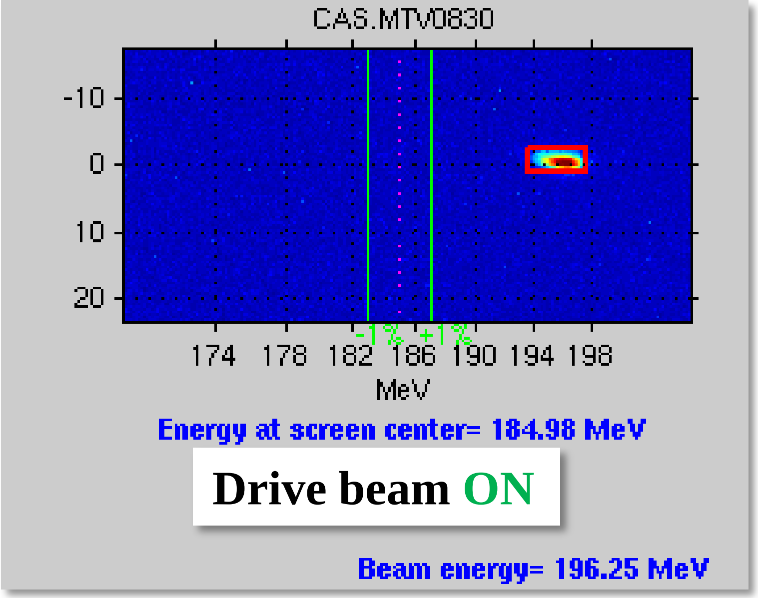
for the CTF3 Team

- Introduction
- Beam phase
- Improved operation mode
- Feasibility items
- Conclusion



Conclusion

Impressive progress in short time!

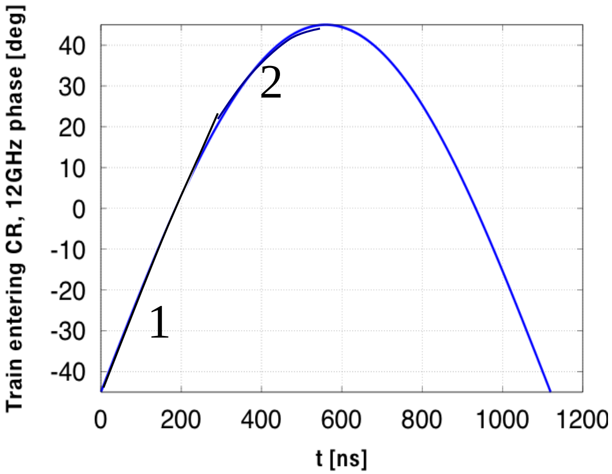
- Important progress despite the fire
- operation with full Drive Beam generation consolidated
- stability issues addressed and stability improved
  - CLIC current stability needs reached
  - CLIC klystron stability demonstrated
- Beam Driven RF power generation as expected
  - up to 200 MW generated in PETS structure (CLIC 135 MW nom.)
  - bunch phase crucial
  - still optimizing the combined beam
- First two-beam acceleration with 55 MV/m
- Many other points well covered
- many more detailed presentations on Wednesday and Thursday in WG6 (Drive beam complex and CTF3)

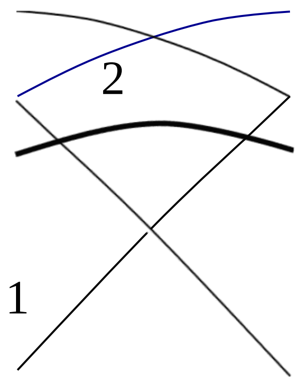
- Many Thanks to everyone who made this possible!!!

Phase variation along the pulse

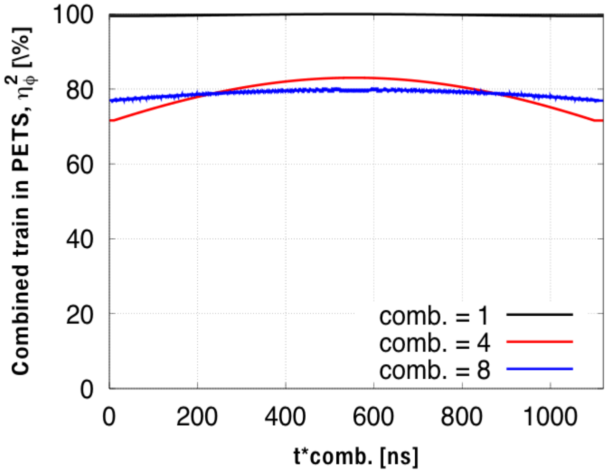
- Combined pulse generated by 'chopping' and 'superimposing' the long bunch train => bunch phase of individual bunches kept (for ideal combination)

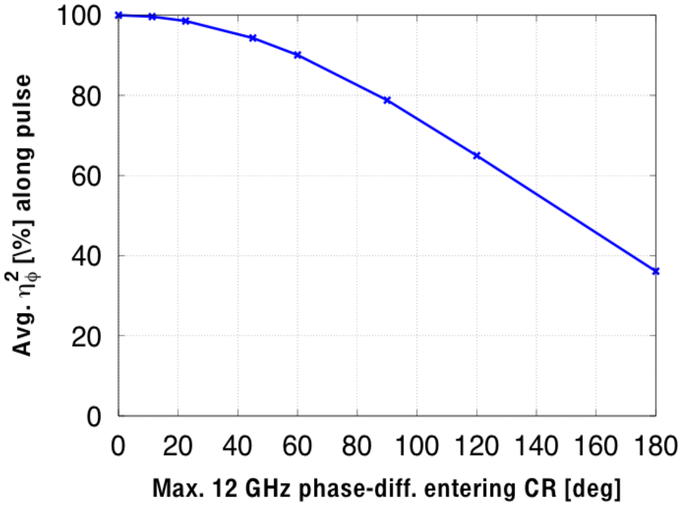
- phase variation leads to power reduction in combined beam





<= Combined phase seems to vary little

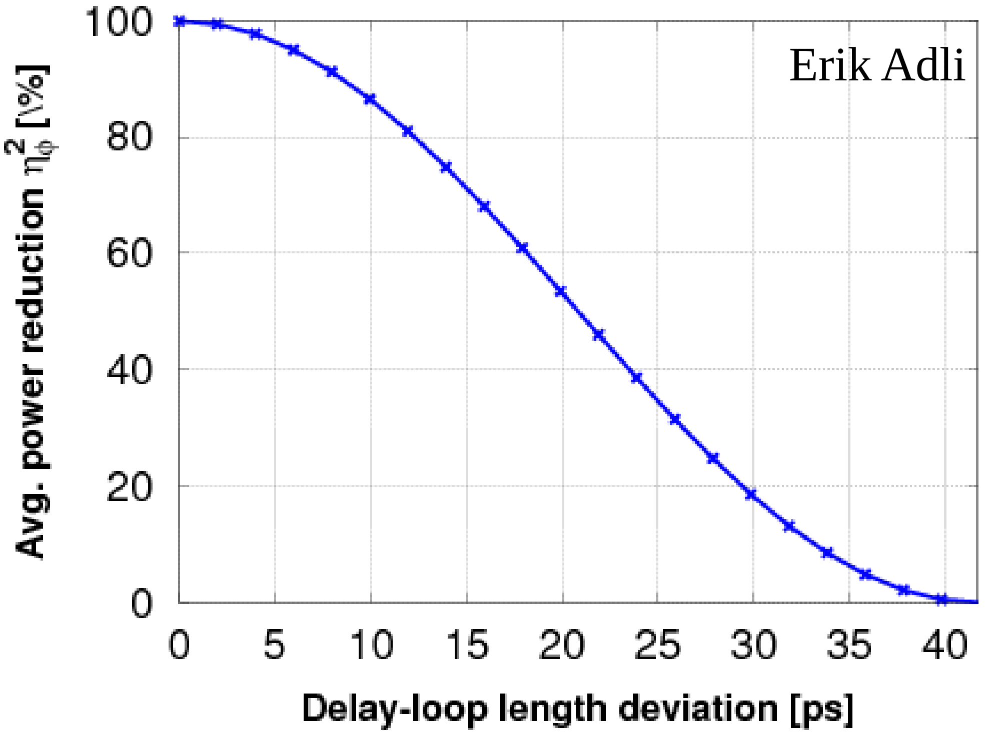




Erik Adli

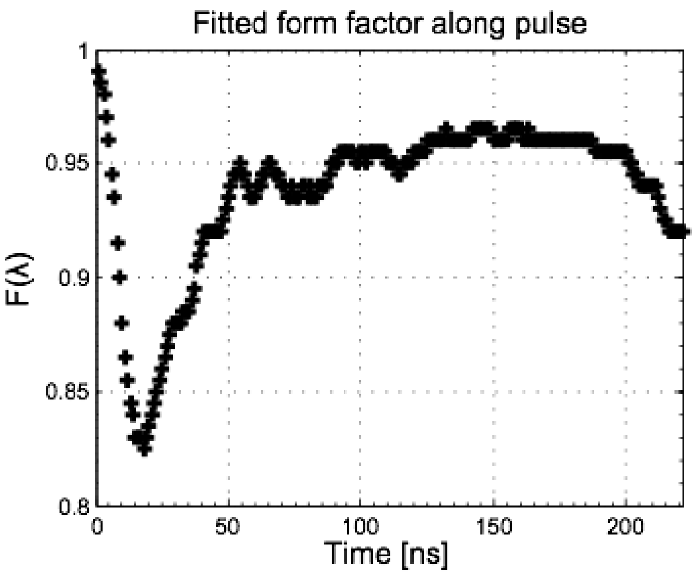
Phase variation from combination

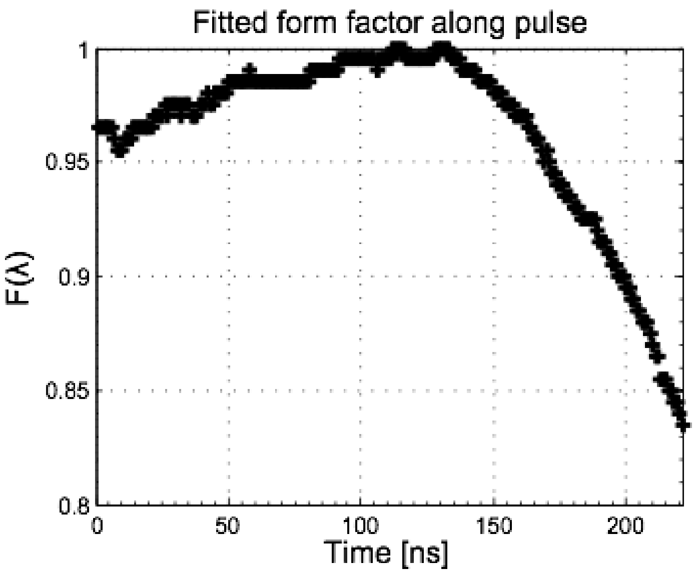
- Combination can be worsened by DL + CR path length error
- Example DL length error:



- we know the effects and we know how to correct

Form factor variation

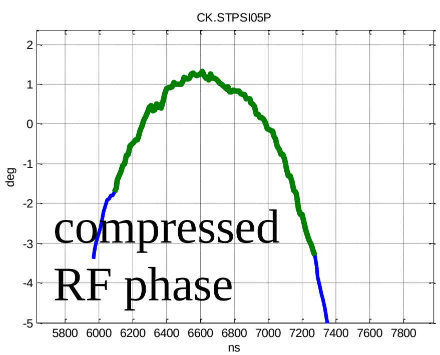


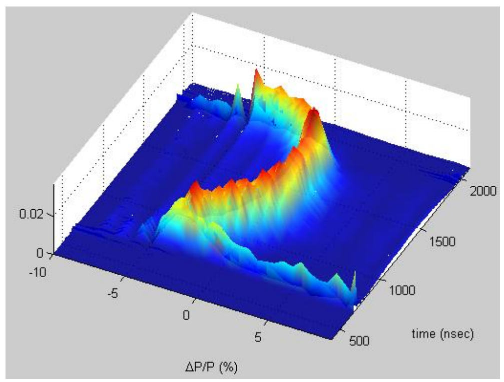


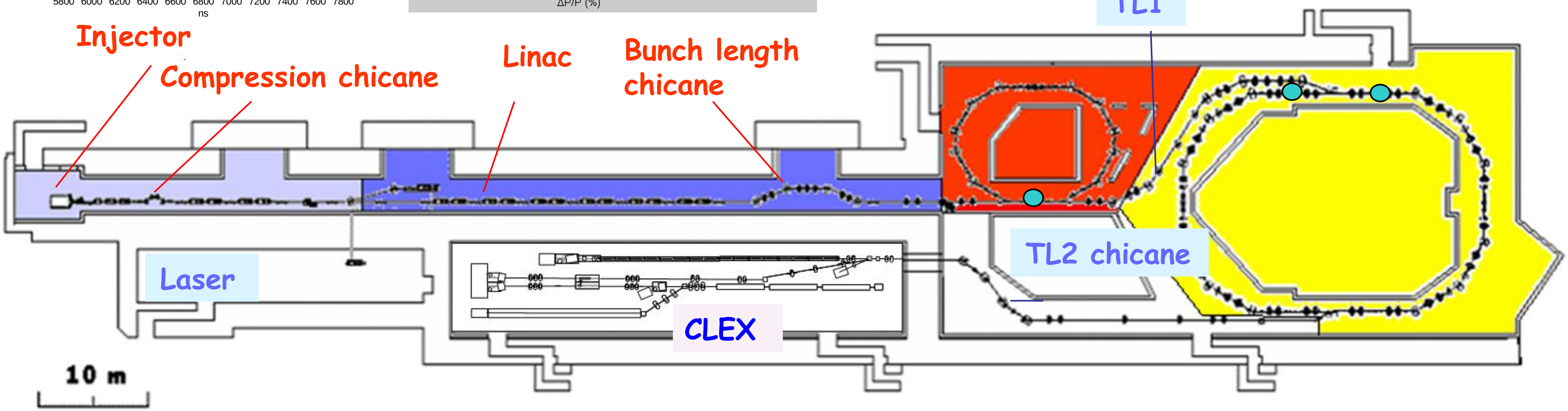
- we observe a form factor variation along the pulse – here factor 4 beam (TBL – from R.Lillestøl)
- bunch phase / bunch length variation
- in addition: factor 8 combination gives lower form factor than factor 4 => additional complication of DL length (we know how to change)

Beam phase evolution

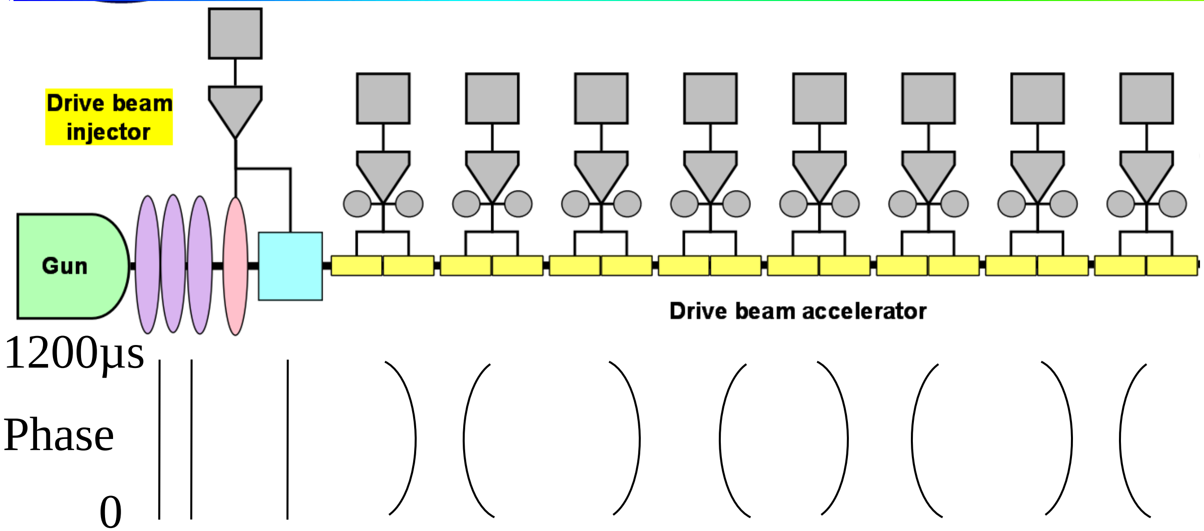
- flat phase MKS02/phase sag MKS03 due to pulse compression
- => energy, bunch length and beam phase variation after chicane
- => have to optimize machine for full train







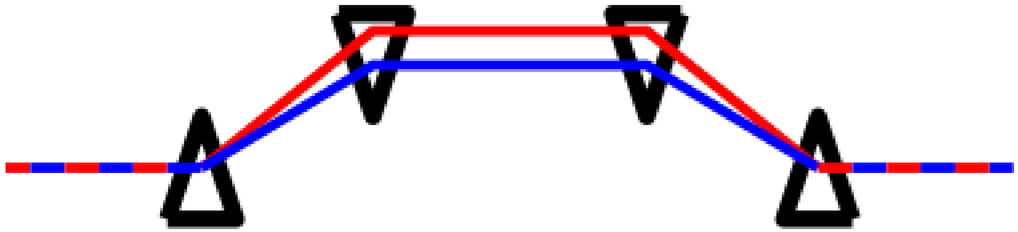
RF phase (presently)

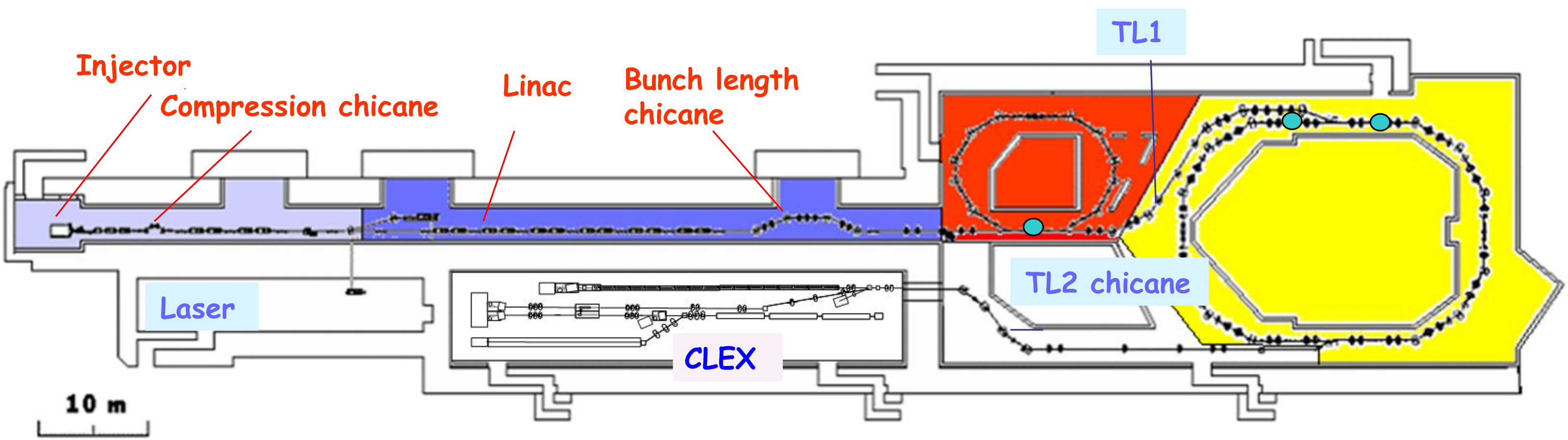


- flat phase along pulse for SHBs and pre-/buncher
- alternating phase sag for accelerating structures
- gives sufficiently low ΔE/E if well optimized
- still: bunch length variation + bunch phase variation

Phase evolution II

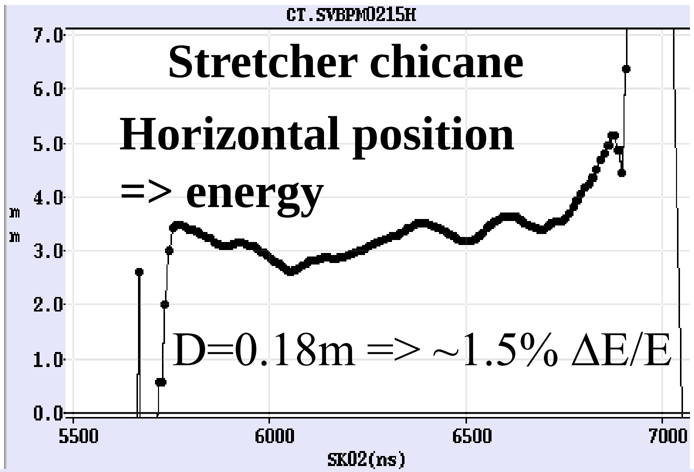
- Bunch length chicane has R_{56}=0.45 m at the moment
- 1% ΔE/E => 16.2 deg @ 3GHz phase => 65 deg @ 12 GHz
- => reduce R_{56} (but strong quads, more difficult)

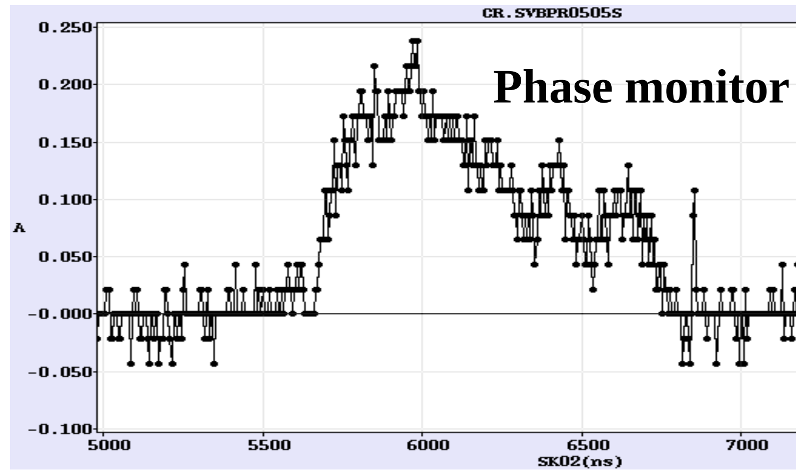


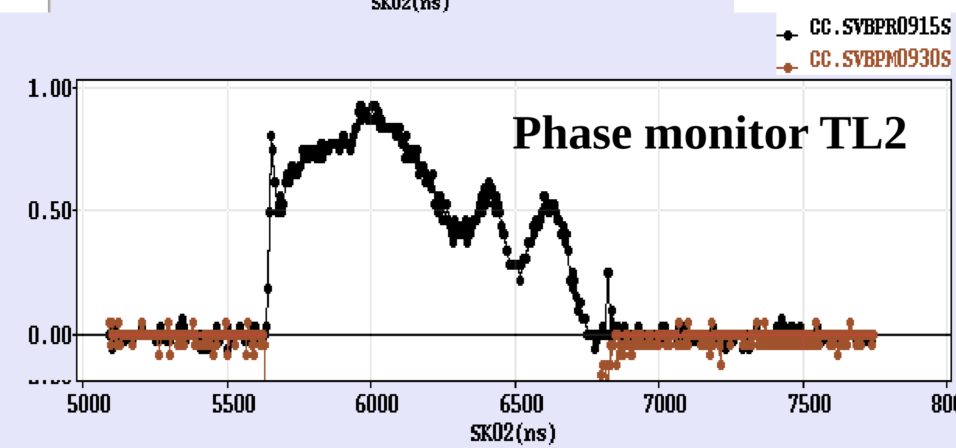


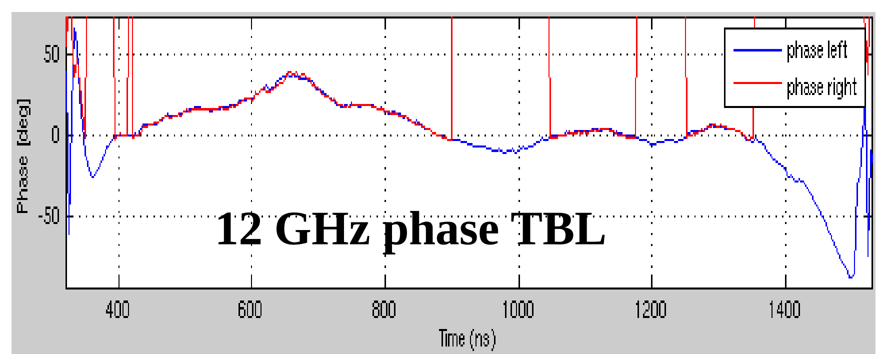
Energy/phase correlation

- Phase dominated by energy variation in stretcher chicane
- afterwards isochronous optics => phase stays constant



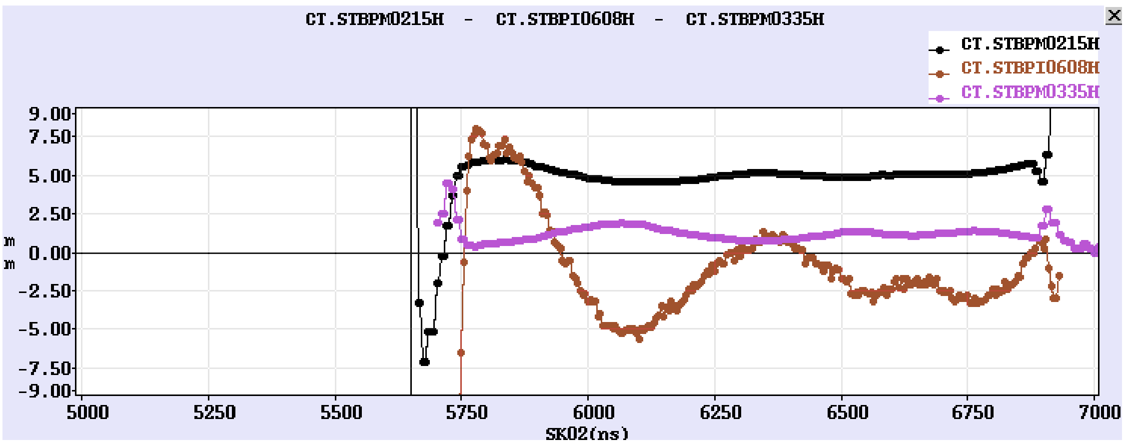


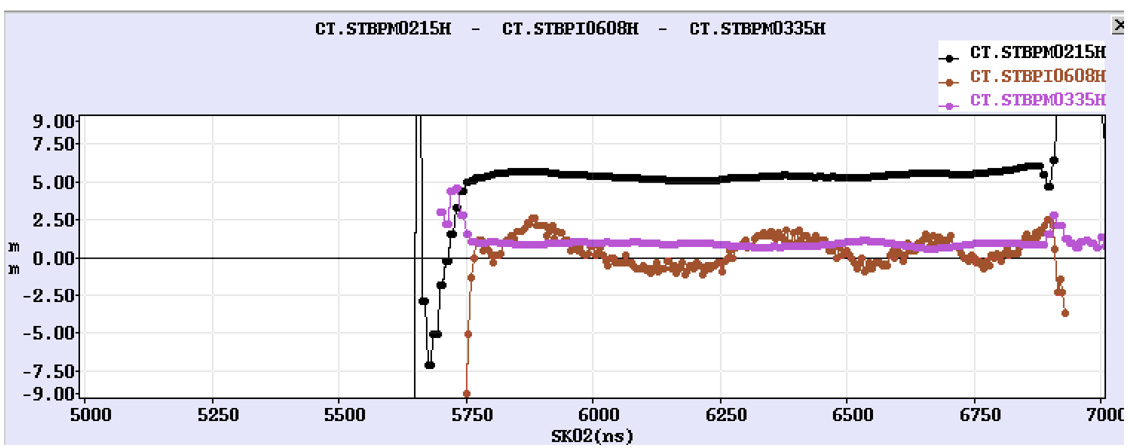


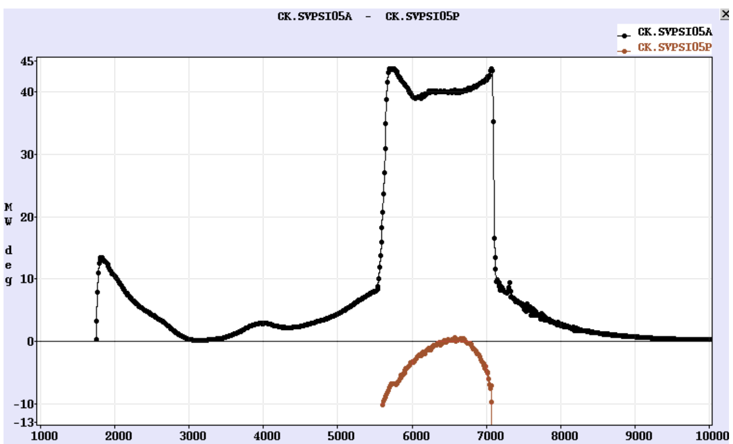


Energy variation minimized

- used RF pulse compression to minimize ΔE/E after the linac
- D_{0608}=0.61m => 13mm = ~2% to ~3mm = ~0.5% ΔE/E

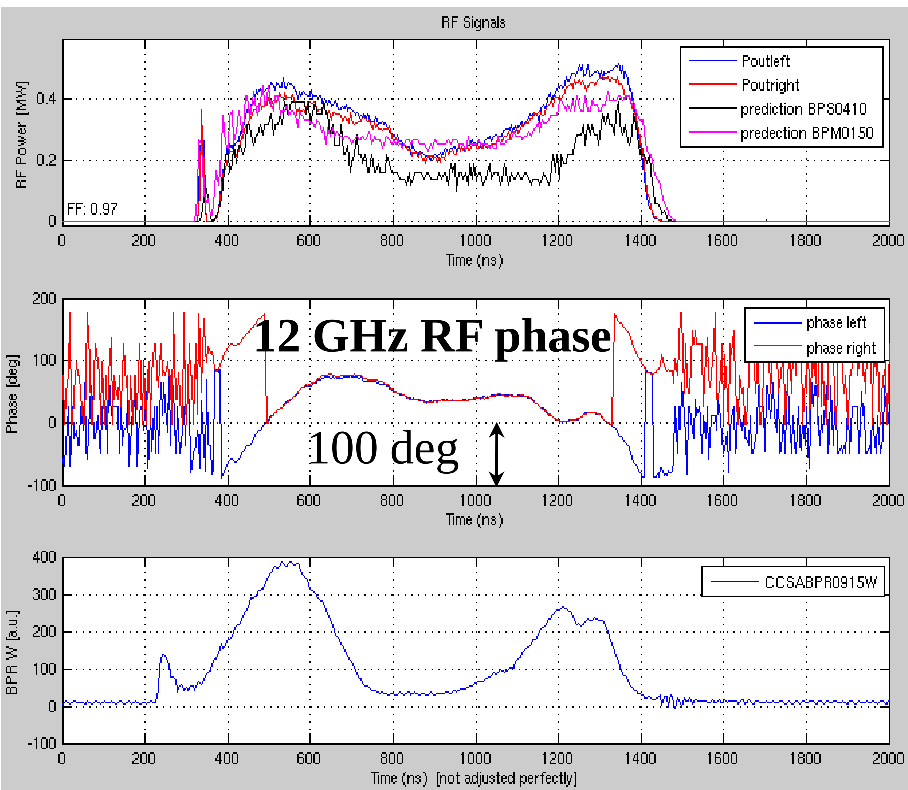


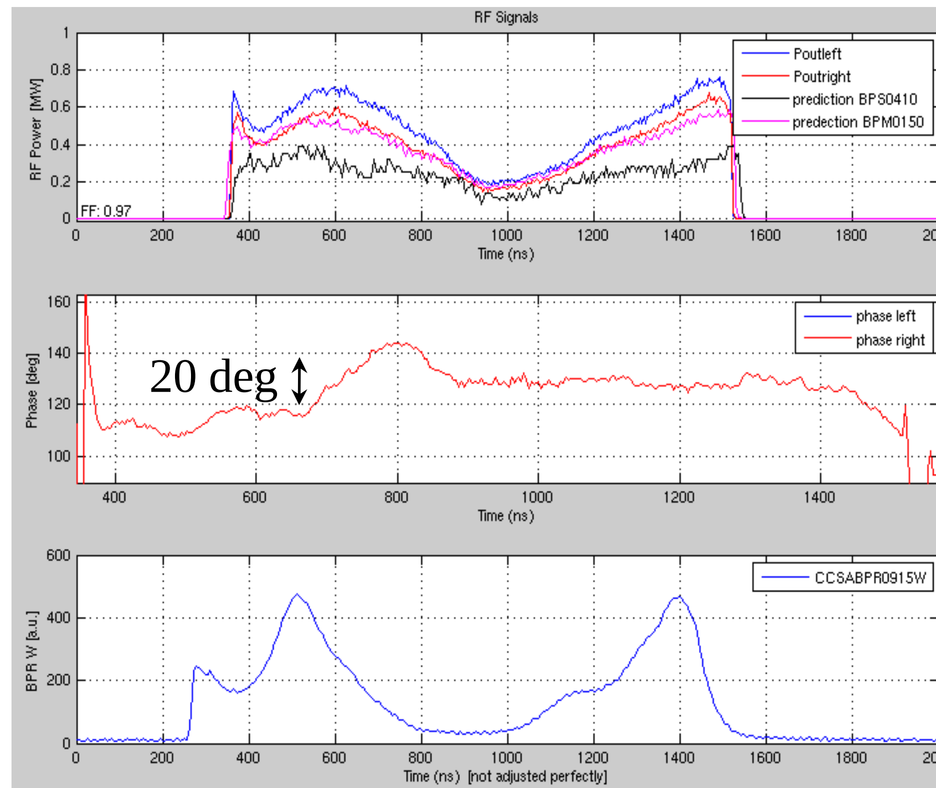




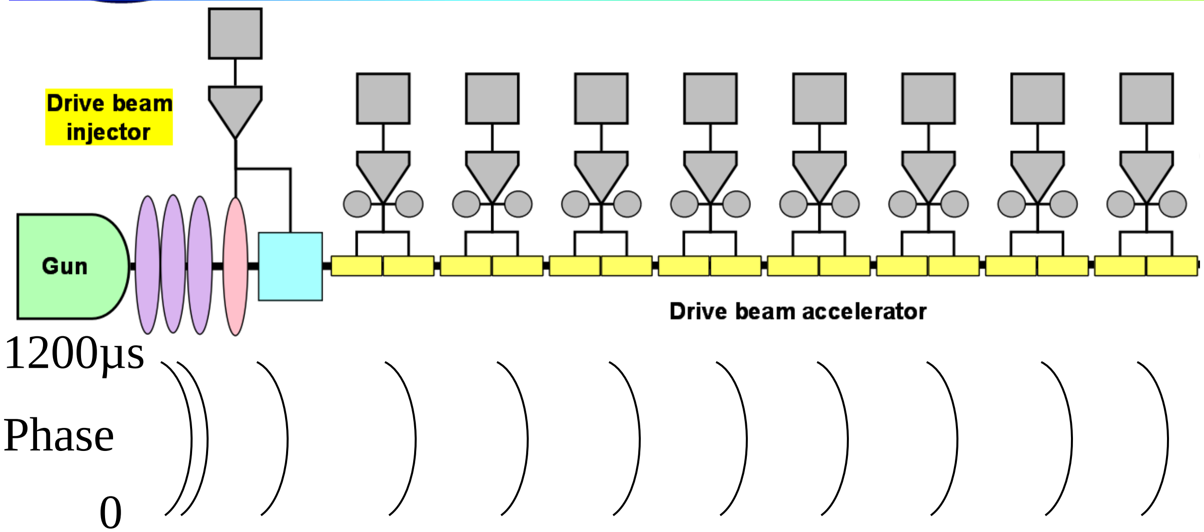
Phase optimization

- this energy optimisation results in a phase optimisation





RF phase proposal



- same sag for SHBs and pre-/buncher + accelerating structures
- ΔE/E = 0 along the pulse, no bunch length variation
- still: bunch phase variation – could be compensated in Frascati or TL2 chicane (slight energy shaping along the pulse)
- tuning all along the pulse identical
- much less sensitive to phase errors [cos(~few deg)]

DB generation – mid 2011

- Bunch train recombination
  - Consolidate results, routine operation, stability of fully combined beam
- Transverse rms emittance
  - Complete TL2, TL2', TBTS commissioning – full transport to CLEX
  - < 100 π mm mrad after ring, combined beam
  - < 150 π mm mrad in CLEX, combined beam
- Bunch length control to < 1 mm rms (combined beam)
  - Measurement campaign with different meas. systems (RF defl.& screen, fast streak-camera, RF monitors)
  - R_{56} tuning experiments in Frascati chicane and TL2
- Beam current stability: improve slow variations, obtain ~0.2 % for combined beam
  - Full measurement campaign (find correlations, jitter sources)
  - Gun pulse flatness, "slow" feedback
  - Improve overall klystron stability (at least up to best performing klystrons)
  - Slow RF feedback (temp. in pulse compressors)

RF structures – mid 2011

- PETS TBTS
  - Initial configuration with variable power splitter & phase shifter
  - Fast fall-back solution: recirculation with no active elements (maximum power to accelerating structure)
  - Goal: nominal power / pulse length inside PETS with recirculation (135 MW, 250 ns total pulse length, 170 ns flat-top)
  - Breakdown rate measurements (at high BD rate - extrapolation to lower rates)
  - Operation w/out recirculation – may have different breakdown rate…
  - Test of new PETS on-off scheme (components and concept)
- Acc. structure in TBTS
  - TD24, initial conditioning in the shadow of PETS operation
  - Goal: nominal power / pulse length delivered to structure (65 MW, 250 ns total pulse length, 170 ns flat-top)

Two beam issues – mid 2011

- TBTS
  - Two-Beam test – 100 MV/m, consistency between power & beam energy gain
  - Drive beam, deceleration, power produced
  - Probe beam, power delivered to accelerating structure, energy gain
  - Beam Loading compensation experiment - by varying fast phase switches – check control of RF pulse shape with probe beam acceleration
  - Measurement of breakdown kicks
  - Measurement of effect of beam loading on breakdown rate
- TBL
  - Measurement of deceleration / produced power
  - Goal: deceleration by 30% (need 8 PETS installed)
    Measurement of energy spectrum
  - Optics, steering algorithm studies

Other issues – mid 2011

- CALIFES
  - Fully reach nominal parameters (total charge)
  - Bunch length measurements (RF defl. & screen)
- PHIN
  - 2010: complete measurement program
  - 2011: test of phase coding with beam
- Other
  - First measurements of phase stability (PETS output, RF pickups…)
  - Operation at 5 Hz (or more)
  - Control of beam losses
  - Coherent Diffraction Radiation (RHUL collaboration)
  - …

Conclusion

- we understand how to improve power production
- primary goal: two-beam acceleration 100 MV/m
  (including RF power signals consistency and deceleration)
- complete the list of feasibility issues as much as possible
- new setup with increased current when MKS13 is available (2011)
- still a lot of work ahead…

Spares

CTF3 2010 outlook

Roberto's comments Feb 2010:

Drive Beam Generation

- Bunch train recombination 2 x 4 in DL and CR (from 3.5 to 28 A)
- Transverse rms emittance < 150 π mm mrad (combined beam)
- Bunch length control to < 1 mm rms (combined beam)
- Beam current stability ~ 0.1 % for combined beam

Will be OK, possibly somewhat reduced performance…

Drive Beam Power Production & Two Beam Acceleration

- 20.8 A beam-powered test of a single PETS (without recirculation) in the TBTS
  - **135 MW** (with 28 A potentially available in CLEX, the peak power can reach 240 MW)
  - 140 ns total pulse length
  - A measured breakdown rate in the range of 10-4 or lower
  - Operation of a few hundred hours at 1 Hz
- 7.4(10) A beam-powered test of a single PETS with ext. recirculation in TBTS
  - **135 (81) MW** circulating power or **65 (65) MW** available for accelerating testing
  - 250 ns total pulse length, 100 (170) ns flattish-top
  - A measured breakdown rate in the range of 10-4 or lower
  - Operation of a few hundred hours at 5 Hz
  - On/off/adjust will be demonstrated using the external reflection/recirculation system mounted on one of the PETS in TBL.

Overall reasonable goals, but difficult to have a few hundred hours, and 5 Hz

- TBTS
  - Improved measurements of power and energy loss.
  - Breakdown transverse kick measurements.
  - Probe Beam energy gain and beam loading tests.
- TBL
  - The current schedule is to have **8 PETS** installed as well as a spectrometer dump for energy spectrum studies, toward the summer 2010. This will allow to verify transport of a beam with up to **30%** of the energy extracted.

TBTS studies and especially TBL results can happen only quite late in 2010…

Item list

- current stability combined beam
- TBL deceleration
- <100 MV/m acceleration
- emittance combined beam
- isochronicity DL + CR
- laser stability (PHIN)
- loss management, higher rep rate
- phase: linac, R56, path length DL + CR
- bunch compression TL2
- RF power calibrations
- gun current along pulse

DB scheme - status

- quite close to all requirements already at the end of 2009

Parameter	Unit	CLIC nominal	Present state	Objective mid 2011	Objective 2013
I initial	A	4.2	5		
I final	A	100	28	30	
Q_b	nC	8.4	4 (2.3 nom.)		
Emittance, norm rms	π mm mrad	≤ 150	≤ 100 (end of linac) ≤ 150 (y, comb. beam)	≤ 150 (comb. beam)	
Bunch length	mm	≤ 1	≤ 1 (comb. beam)		
E	MeV	2400	120		150
T_{pulse} initial	μs	140	1.4		
T_{pulse} final	ns	240	140 (240)	140 (240)	140 (240)
Beam Load. Eff.	%	97	95		
Deceleration	%	90	-	30	50 or more
Phase stability @ 12 GHz	degrees	0.2	-	0.5 ?	0.2
Intensity stability		7.5$10^{-4}$ to few 10^{-5}	2 10^{-3} (comb.4)	2 10^{-3} (comb.8)	≤ 1 10^{-3} (comb.8)