Phase stability of the CTF3 beam

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Outline

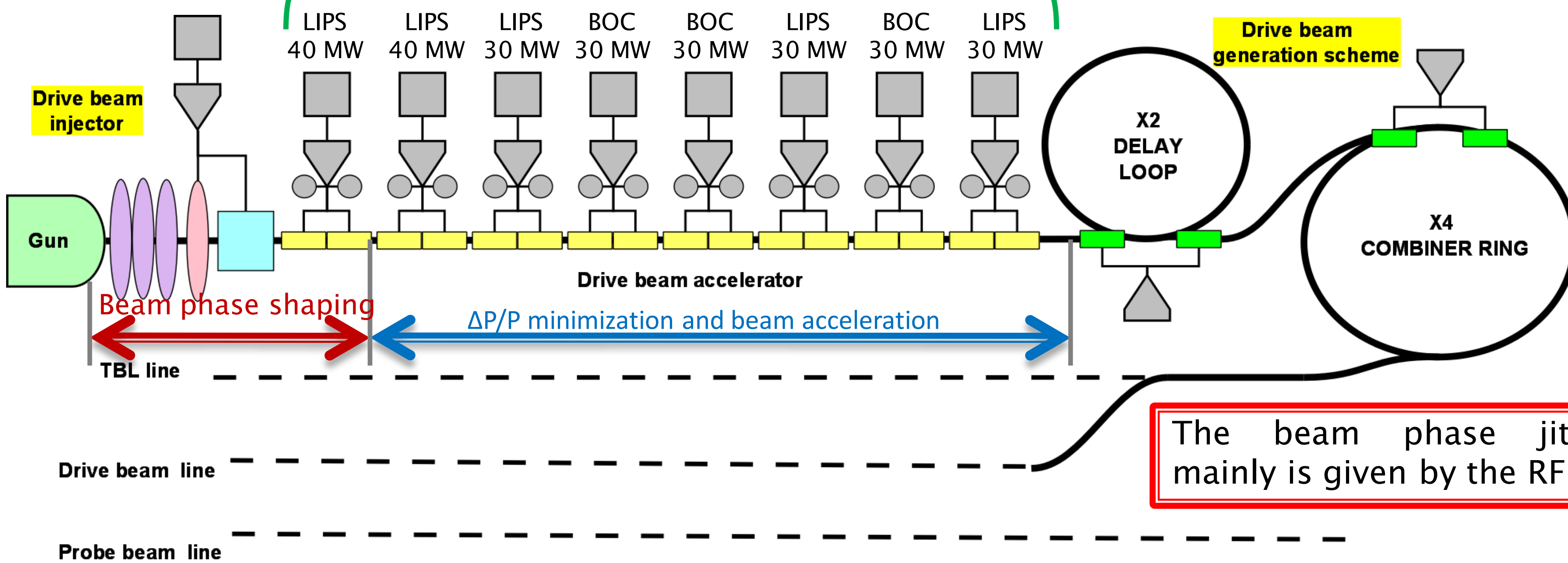
- CTF3 drive beam layout
- Short-term RF stability
- Improvements in the long-term RF stability
- Beam phase measurements
- On-going activities related to the beam phase stability
- Conclusions

CTF3 Linac layout

Beam current: 3.5 A
Beam frequency: 1.5 GHz

5 LIPS-type and 3 BOC-type RF pulse compressors are installed

The beam current and the current of magnet power supplies are very stable in CTF3.



The beam phase jitter mainly is given by the RF.

CTF Linac

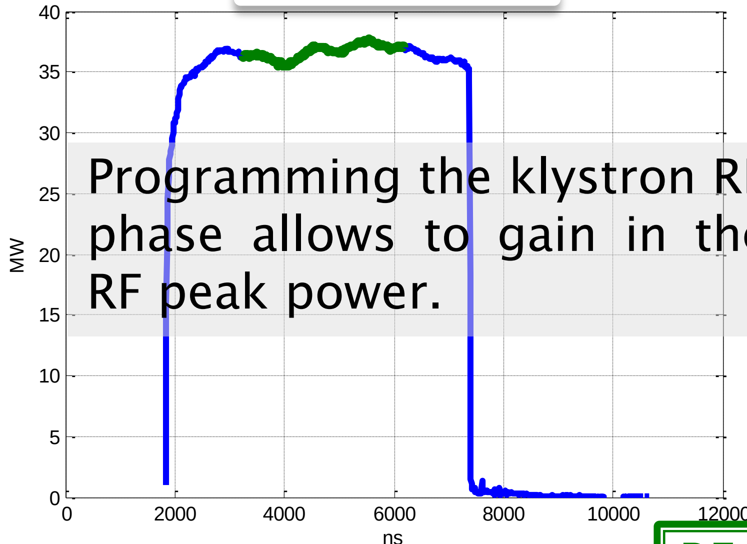
RF to beam:	~440 MW
Pulse length:	1.6 μs
Accelerating gradient :	7 MV/m
Klystron frequency:	3 GHz

* F. Tecker

[1] G. McMonagle, CLIC-Note- 694

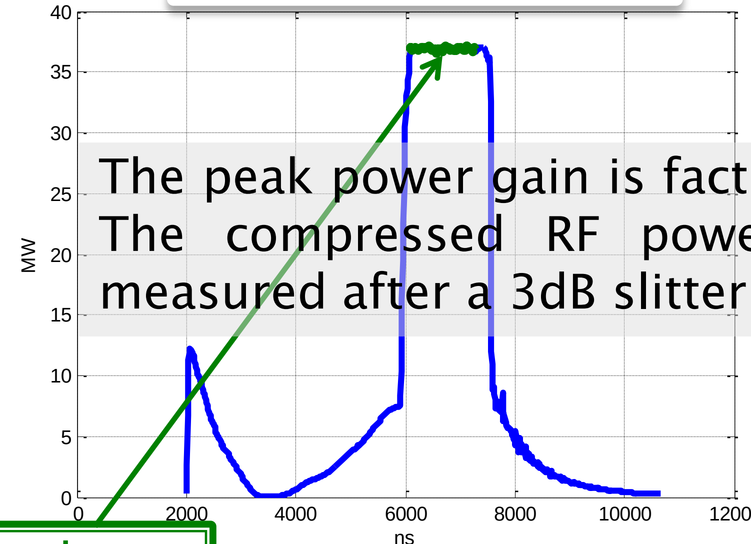
RF pulse compression

Klystron power



Programming the klystron RF phase allows to gain in the RF peak power.

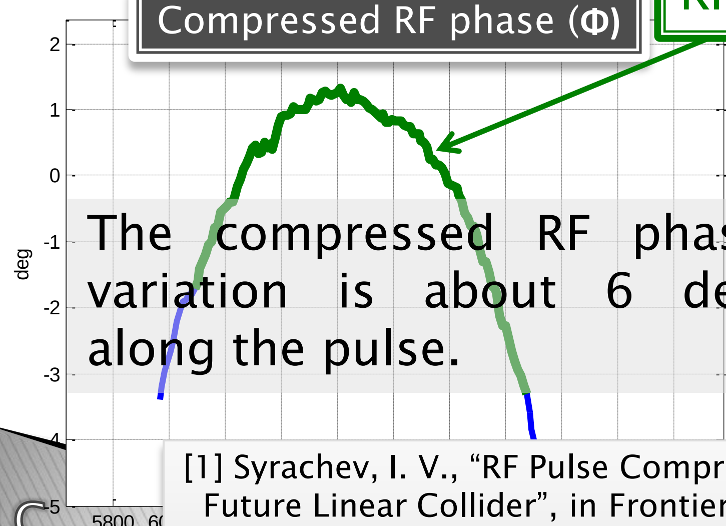
Compressed RF power (P)



The peak power gain is factor 2. The compressed RF power is measured after a 3dB slitter.

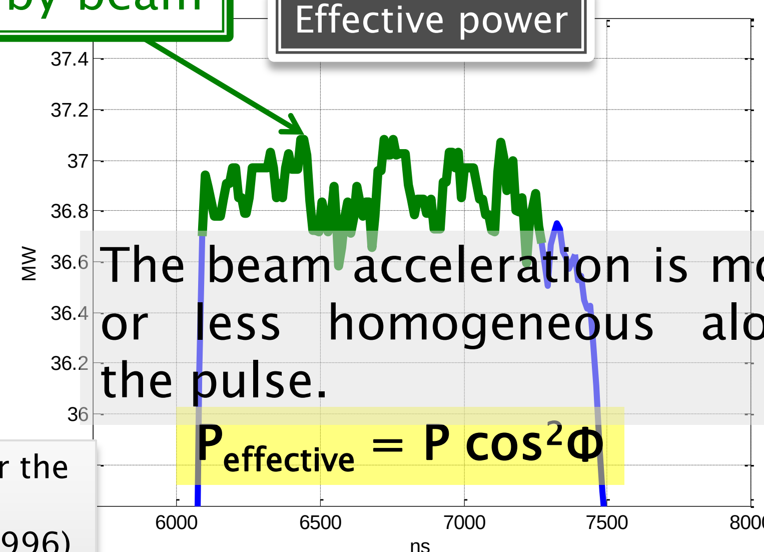
RF seen by beam

Compressed RF phase (Φ)



The compressed RF phase variation is about 6 deg along the pulse.

Effective power



The beam acceleration is more or less homogeneous along the pulse.

$$P_{effective} = P \cos^2\Phi$$

[1] Syrachev, I. V., "RF Pulse Compression for the Future Linear Collider", in Frontiers of Accelerator Technology, pages 716-741 (1996)

Static RF variation

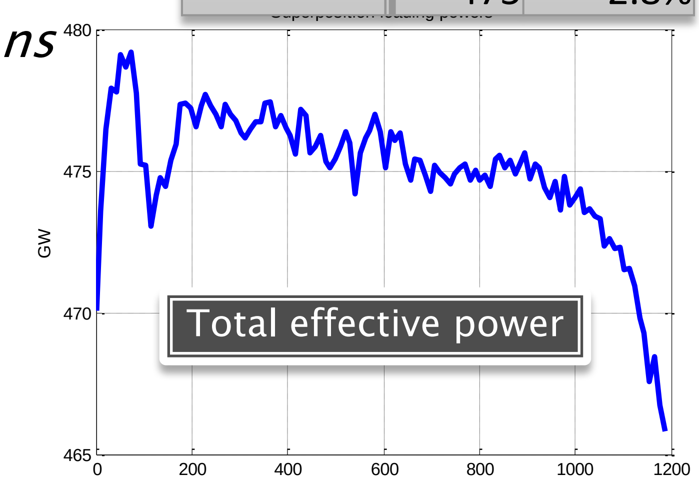
Klystron RF		
Klystron	A	ΔA/A
	MW	*%*
MKS02	34.2	1.5%
MKS03	35.5	3.4%
MKS05	36.7	6.2%
MKS06	33.2	7.6%
MKS07	22.8	2.9%
MKS11	28.5	4.0%
MKS12	30.3	4.5%
MKS13*	29.1	5.6%
MKS15	30.9	4.1%

Compressed RF after 3dB splitter			
Klystron	ΔP	A	ΔA/A
	deg	*MW*	*%*
MKS03	11.8	33.9	2.2%
MKS05	4.6	36.9	1.3%
MKS06	10.3	34.2	1.5%
MKS07	9.9	22.4	3.8%
MKS11	9.9	28.4	6.4%
MKS12	11.4	28.8	11.4%
MKS13*	8.3	28.5	2.7%
MKS15	7.3	25.0	1.4%

Effective power		
Klystron	A	ΔA/A
	MW	*%*
MKS03	33.8	1.7%
MKS05	36.9	1.4%
MKS06	34.1	2.4%
MKS07	22.4	5.0%
MKS11	27.8	9.0%
MKS12	28.7	9.0%
MKS13*	28.5	2.8%
MKS15	24.9	1.6%
Total	475	2.8%

The beam length = 1200 ns

Most of RF compressors reduce the static relative power variation. The static phase variation is about 5-10 deg. The total effective RF power production along the pulse is about 2.8%.

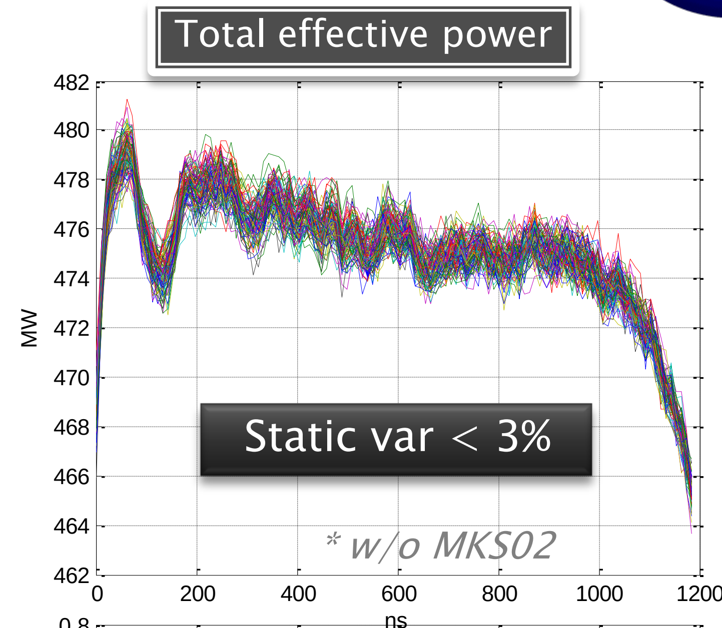


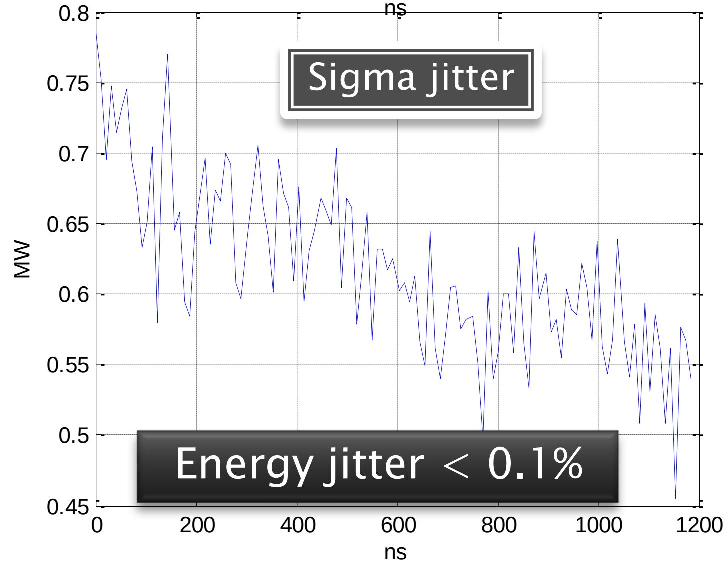
A. Dubrovskiy

** MKS13 is out of order in 2010*

RF short-term variation

Klystron	Kly. σ	Kly. σ	ACS σ	Eff. σ
	MW	deg	deg	MW
MKS02	0.12	0.19		0.12
MKS03	0.112	0.07	0.07	0.100
MKS05	0.115	0.16	0.074	0.089
MKS06	0.222	0.28	0.441	0.157
MKS07	0.080	0.41	0.083	0.187
MKS11	0.109	0.39	0.064	0.232
MKS12	0.154	0.28	0.069	0.154
MKS13*	0.119	0.24	0.195	0.117
MKS15	0.080	0.19	0.215	0.066
Total				σ = 0.79 μ = 475



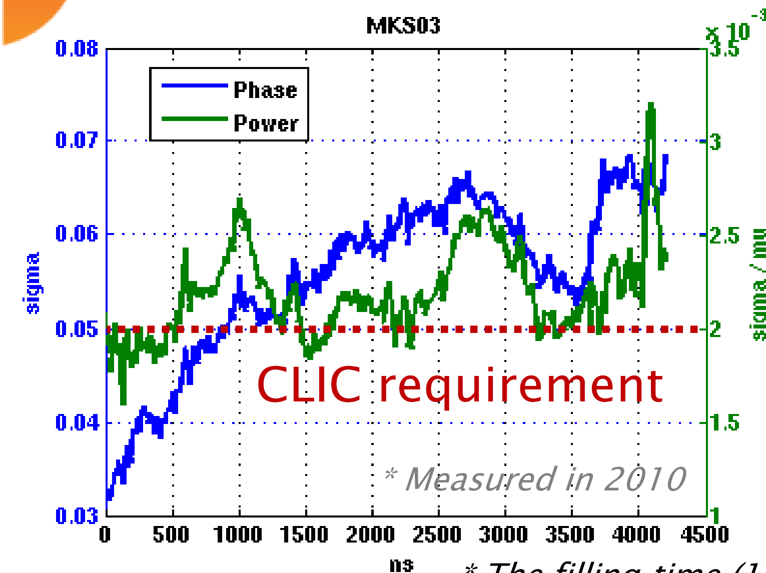


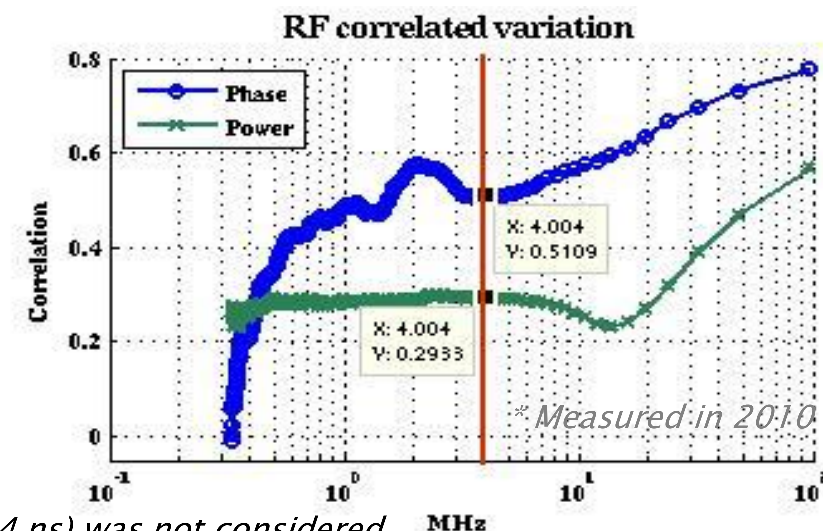
Most of RF compressors reduce the phase noise. The noise of the total effective power becomes smaller to the end of the pulse. The total effective RF power production is smooth and stable; the static variation is about 3% (it can be reduced); and the maximum jitter along the pulse is <0.2%.

** MKS13 is out of order in 2010*

A. Dubrovskiy

MKS03 RF stability



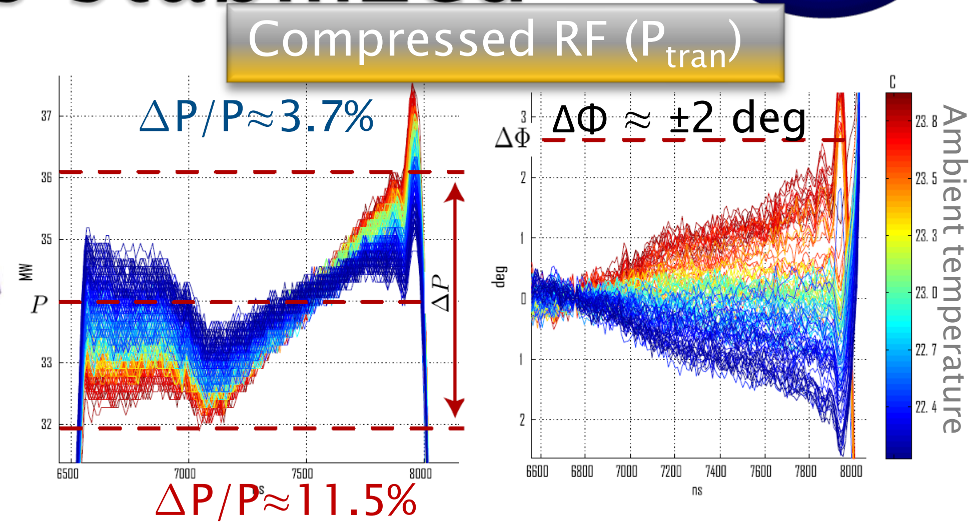


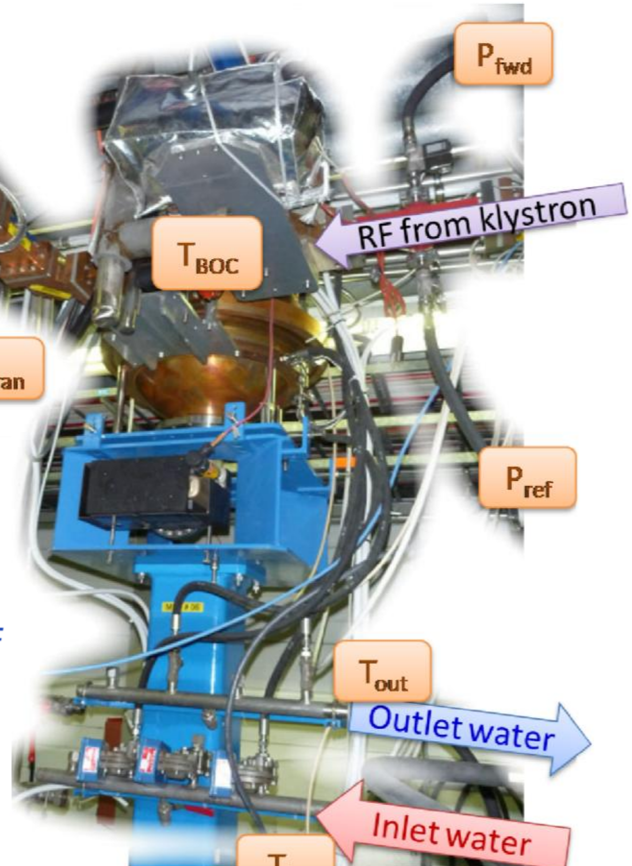
* The filling time (100.4 ns) was not considered

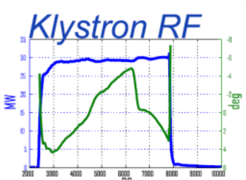
- The pulse-to-pulse phase stability for a fixed 10 ns time slice is 0.07 deg. The CLIC requirement is 0.05 deg.
- The pulse-to-pulse power stability is 0.3%. The CLIC requirement is 0.2%.
- The power and the phase variation is weakly correlated at 4 MHz.
- The phase variation is uncorrelated after a few μs.
- The correlation of the RF phase variation at high frequencies (20 – 100 MHz) and at ≈2 MHz is significant, which indicates the possibility to improve the klystron stability by using a fast phase feedback.

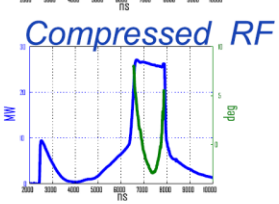
[1] D. Schulte et al., "Status of the CLIC Phase and Amplitude Stabilisation Concept", LINAC10 (2010)
[2] D. Schulte et al., CLIC-Note-598 (2004)

Compressed RF pulse Variation is stabilized









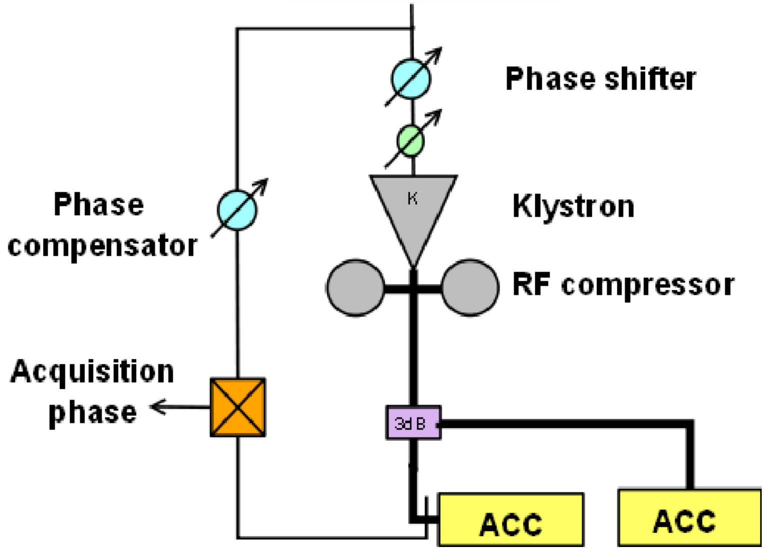
Compressed RF drift can be explained as a shift of the resonance frequency of the compressor cavity, which is sensitive to the cavity temperature.

The temperature stabilization system became operational in 2010.

[1] A.Dubrovskiy, F.Tecker, "RF Pulse Compression Stabilization at the CTF3 CLIC Test Facility", IPAC2010

Slow Phase Offset Variation is stabilized

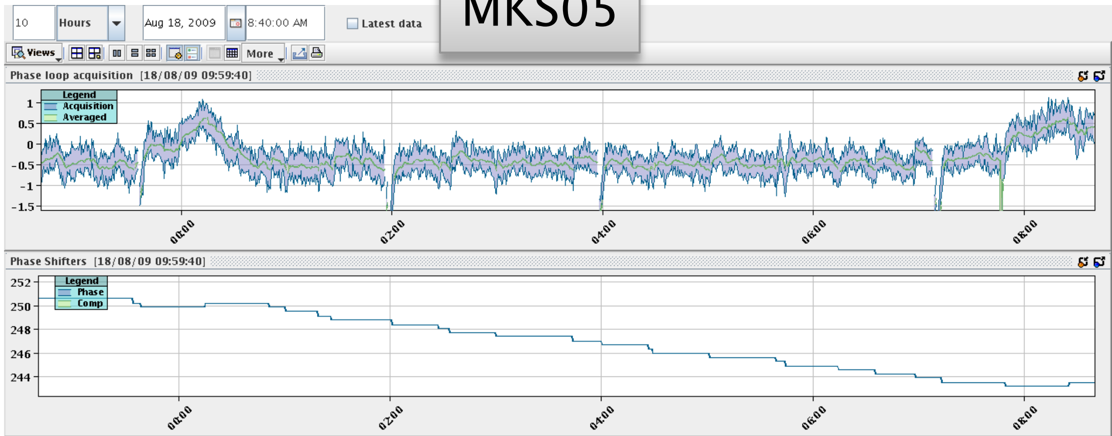
Phase loop



The phase loop was prepared in order to compensate slow RF phase variations at the input of accelerating structures

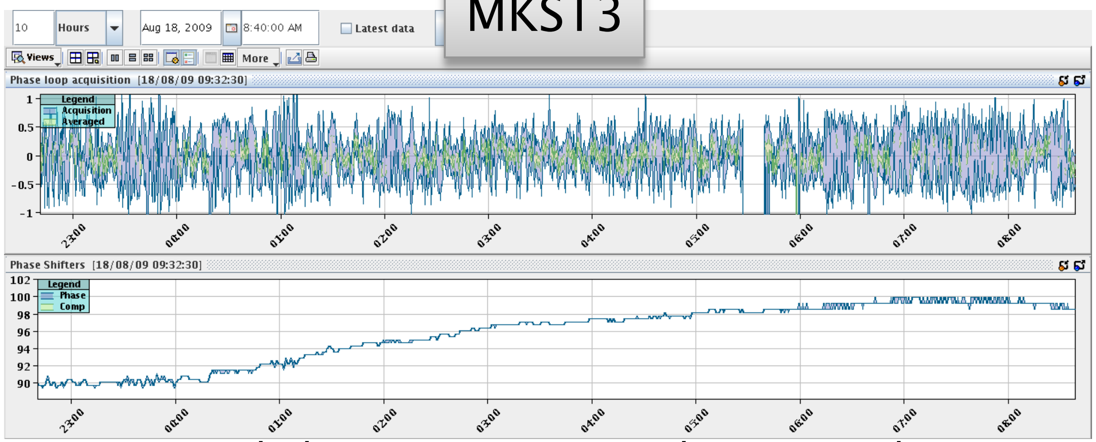
[1] A.Dubrovskiy, "RF phase & amplitude stability of the CTF klystrons", CLIC Beam Physics Meeting (2010)

MKS05



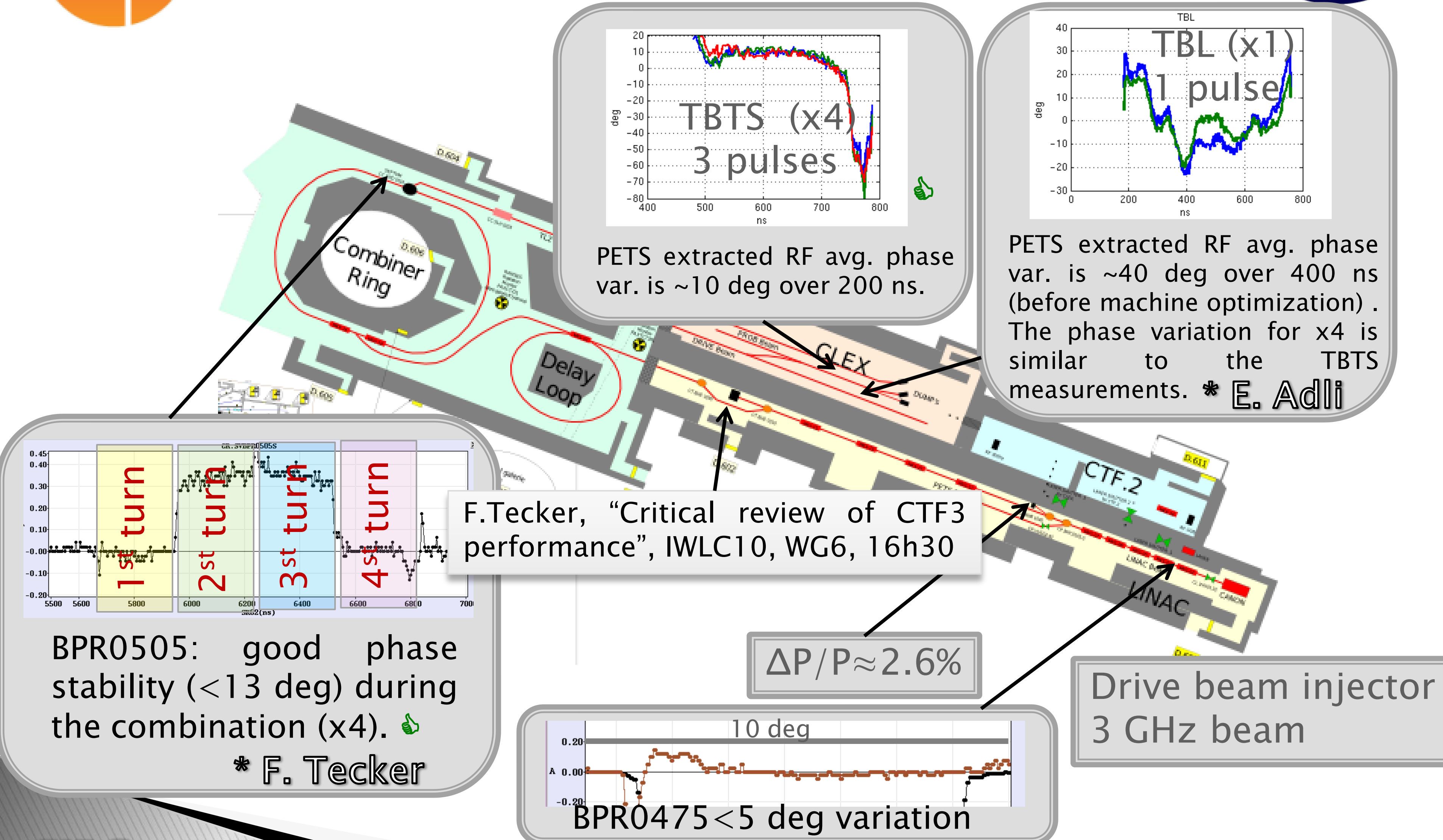
Compensated phase variation = 10 deg over 10 hours
Residual phase variation = 2.2 deg, σ ~ 0.7 deg

MKS13



Compensated phase variation = 10 deg over 10 hours
Residual phase variation = 2 deg, σ ~ 0.4 deg

Beam phase stability along the drive beam line



PETS extracted RF avg. phase var. is ~10 deg over 200 ns.

PETS extracted RF avg. phase var. is ~40 deg over 400 ns (before machine optimization) . The phase variation for x4 is similar to the TBTS measurements. * E. Adli

F.Tecker, “Critical review of CTF3 performance”, IWLC10, WG6, 16h30

BPR0505: good phase stability (<13 deg) during the combination (x4).

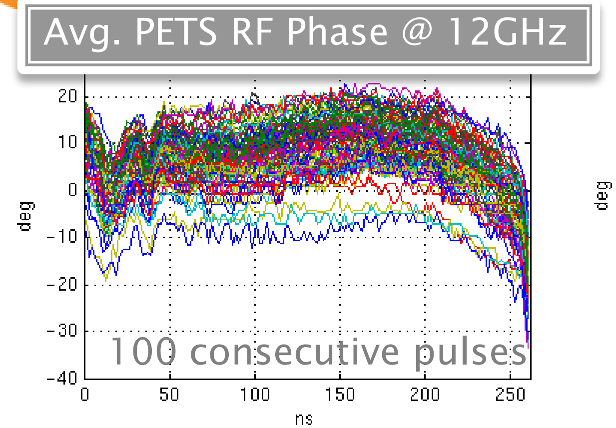
* F. Tecker

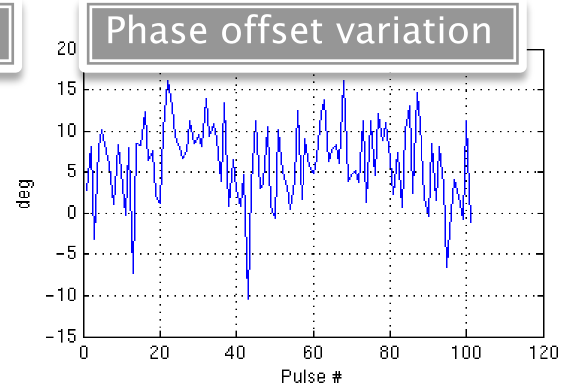
ΔP/P≈2.6%

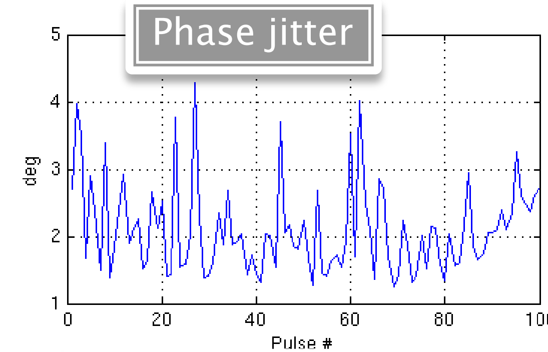
BPR0475<5 deg variation

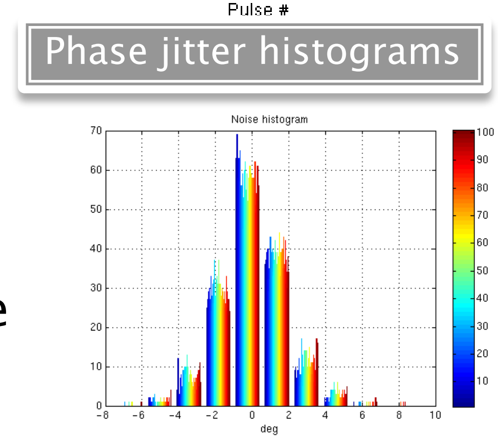
Drive beam injector
3 GHz beam

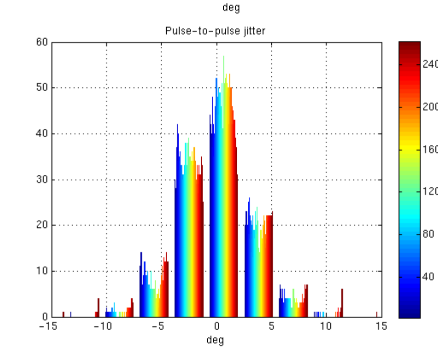
TBTS Drive Beam phase stability







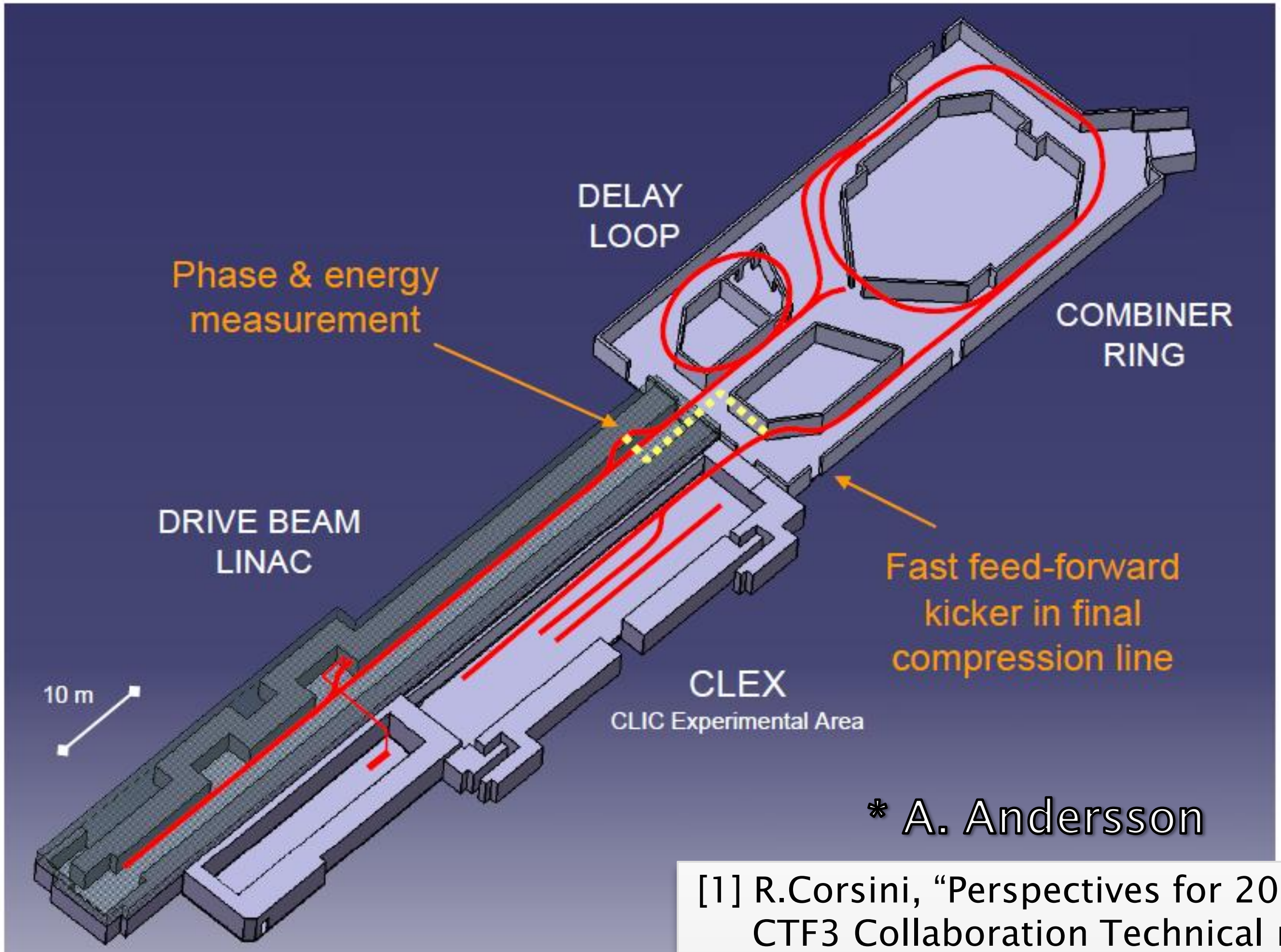




- The phase jitter along the pulse is < 4 deg.
- The phase offset pulse-to-pulse jitter is about 20 deg.
- The phase jitters along the pulse and pulse-to-pulse do not correlate with the beam and the jitters look to be a measurement noise.

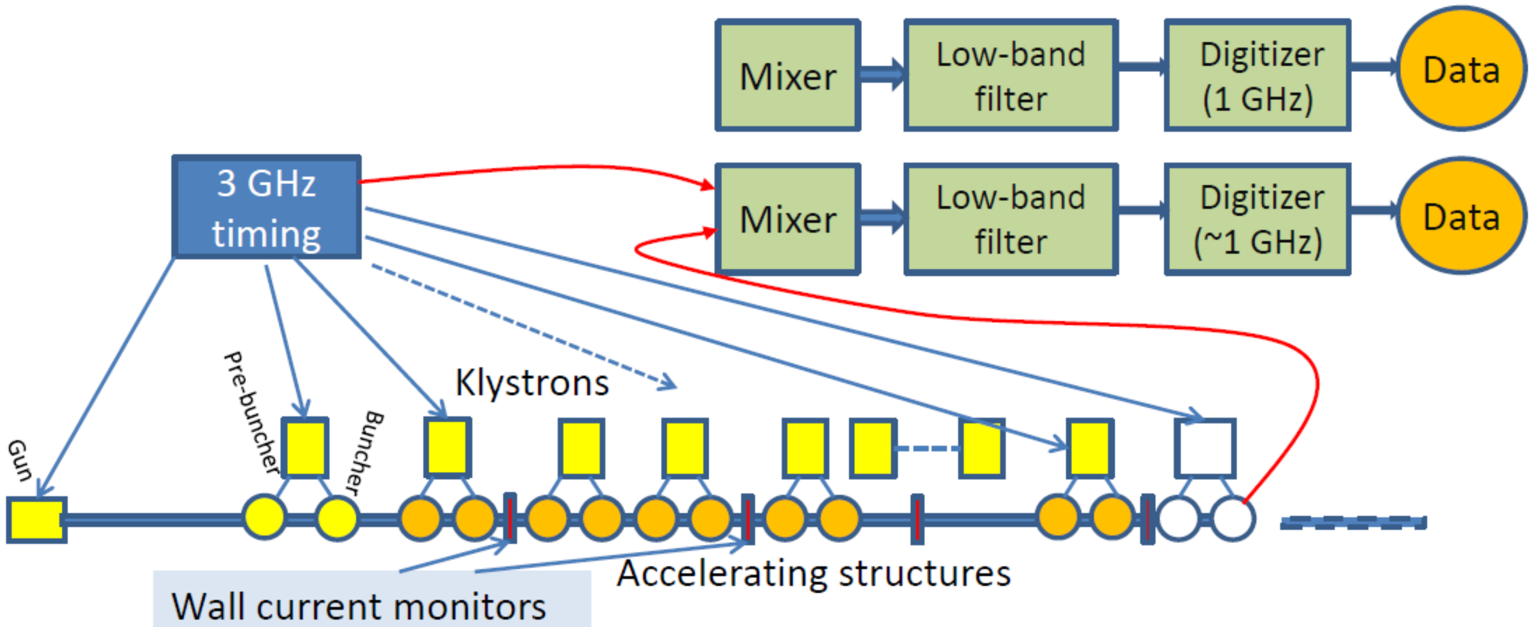
Conclusion: the measured beam phase jitter is mainly a measurement noise and the phase measurement must be improved.

Phase measurement and feed-forward stabilization



[1] R.Corsini, “Perspectives for 2010 and beyond”, CTF3 Collaboration Technical meeting (2010)
[2] J.Sladenand, A.Andersson, EPAC 2006, PAC 2007, CLIC-Note-734

Accurate phase measurement along the pulse and pulse-to-pulse jitter



* G. Morpurgo

[1] G. Morpurgo, “R&D program for RT phase feedbacks”, 5th CLIC-ACE (2010)

Conclusions

- ✓ CTF3 short-term RF stability allows to produce the drive beam with a small phase jitter.
- ✓ RF stability of the klystron MKS03 is very close to the CLIC requirements.
- ✓ The long-term beam phase stability has been significantly improved last year by the RF stabilization systems, low-level and high-level RF updates.
- ✓ In spite of non-square RF waves the beam was combined with a small phase variation along the pulse due to RF optimizations and optics improvements. This result has been confirmed by phase measurements in TBL and TBTS.
- ✓ More studies on the beam phase stability after the combiner ring are required.
- ✓ More precise beam phase measurements are need.