Measurements on phase stability at CTF3

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IWLC 2010

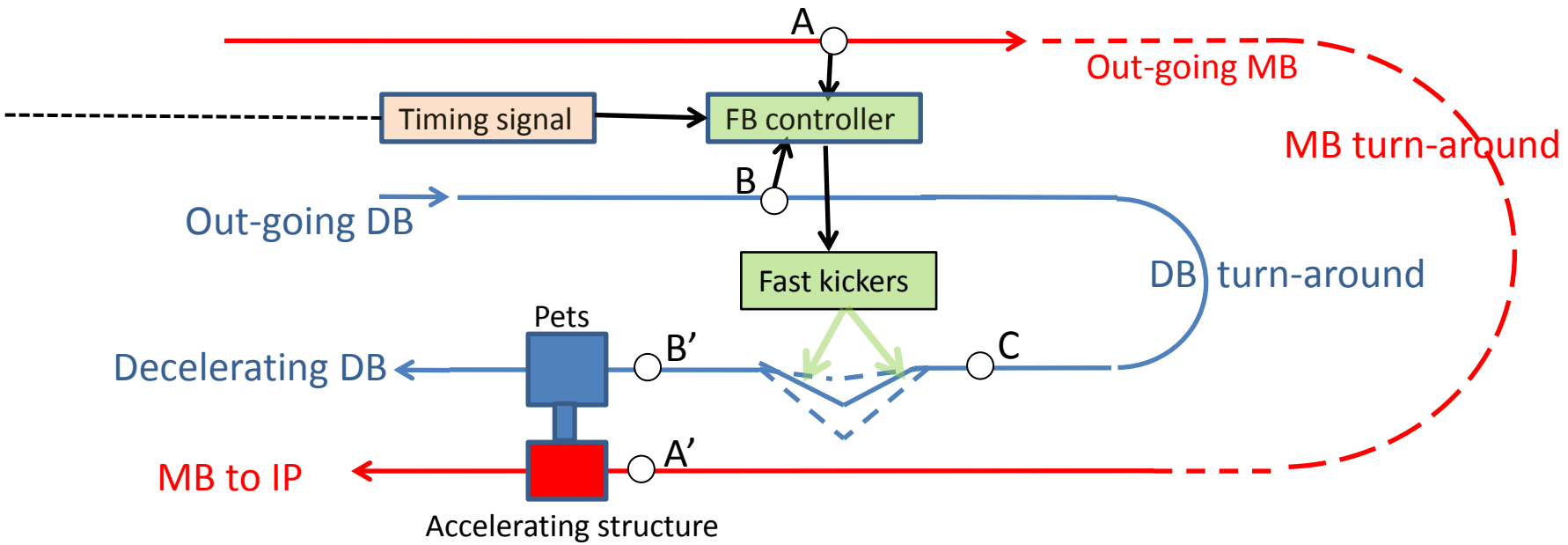
Outline of this presentation

- Why are we interested in the phase stability
- The test-stand (CTF3), and what do we would like to do there
- Some (very few) measurements

WHY : The famous MB <-> DB phase feed-forward in the tunnel (for more details, see Daniel Schulte's talk)

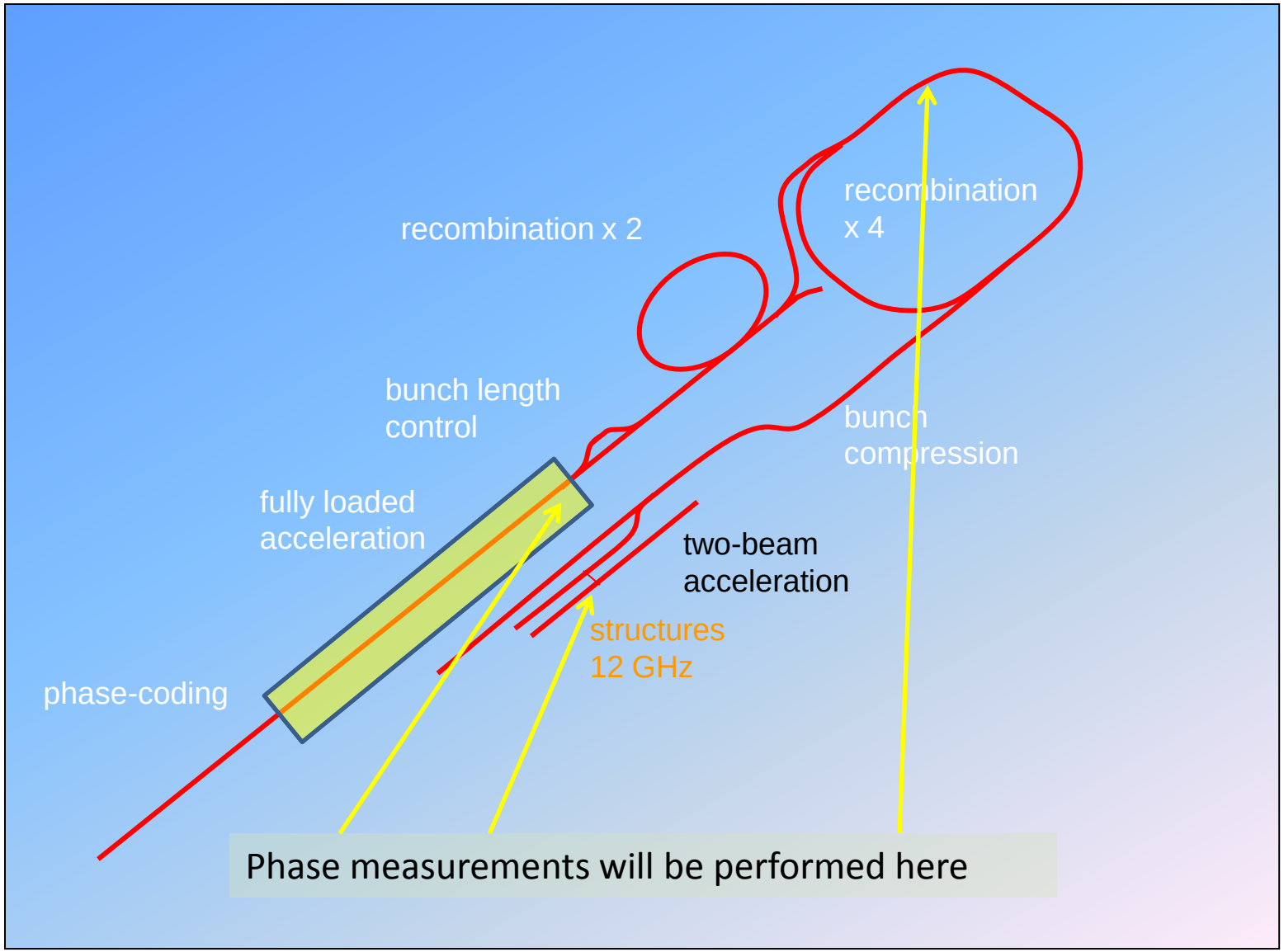
-Using a (local) **femto-timing system**, measure delay $\Delta\emptyset_{real}$ (at A,B) between the two outgoing beams

- Compare with $\Delta\emptyset_{ref}$, and use fast kickers to adjust the path length of the drive beam



Basic issues:
- Stability of local timing
- Precision of the « phase » measurement
- Intra-pulse corrections

CTF3 as a test-stand



Some main reasons to perform measurements at CTF3:

- Learning how to measure, and discovering the different problems
- Getting a first idea on how much the phase is (un)stable
- Analyse correlations between the different observables

Not treated here:
Different stages of the planned activity at CTF3

- Measure stability of RF phases and powers in the LINAC
- Measure signal induced by the beam in the last RF structure
- Measure beam current (with wall current monitors)
- Measure beam phase using BPRs (possibly enhancing sensitivity)
- Measure beam structure (intra-pulse spacing)
- Measure current, phase, position in combined ring
- Measure in TBTS (PETS and Accelerating structure, phase and power, BPMs, beam current and position).
- Study the stability of these quantities, and their correlations
- ....
- Use the Beam Phase Monitors (to come) to measure the beam phase with higher precision
- Implement a feedback system between the combined ring and the transfer line towards TBTS.

Some of this programme is outlined in the Additional Material

Activity during 2010

- Only a very few “parasitic measurements” performed
  -Based on existing systems (BPMs, BPRs, PETS)
  -Performed in the shadow of CTF3 normal operation
  - (in particular, we could not measure the beam induced signal in the last LINAC rf structure, which would give an indication on how stably and reproducibly the LINAC accelerates the CTF3 drive beam)

- Some needed improvements have been identified

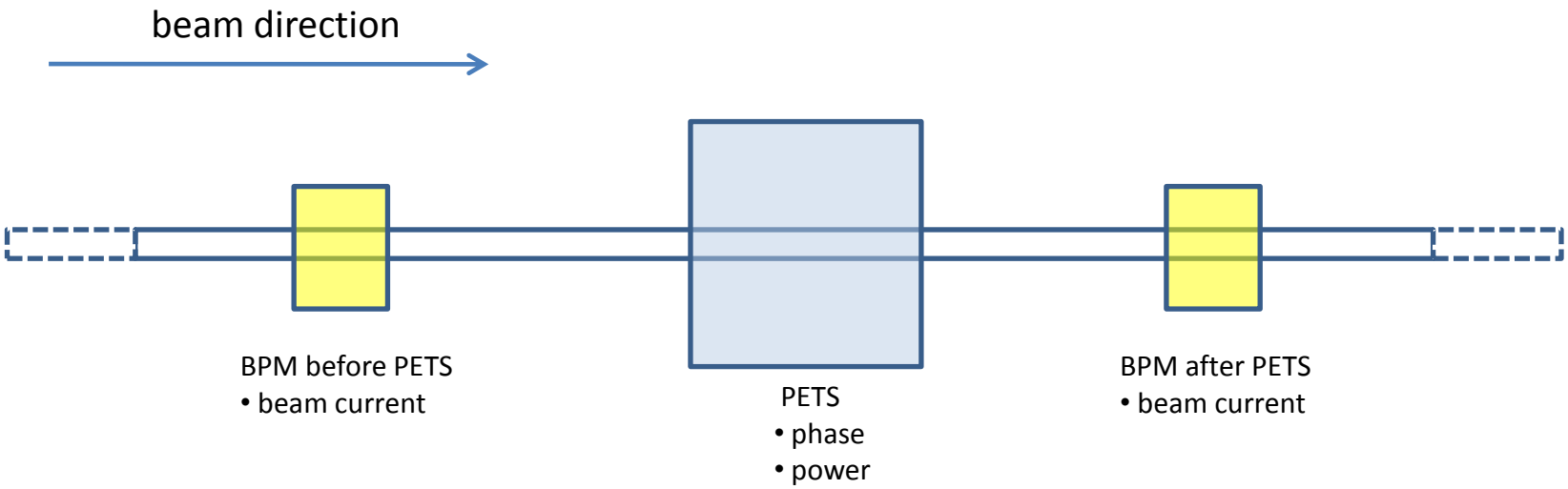
Improvements required (also for new acquisition system)

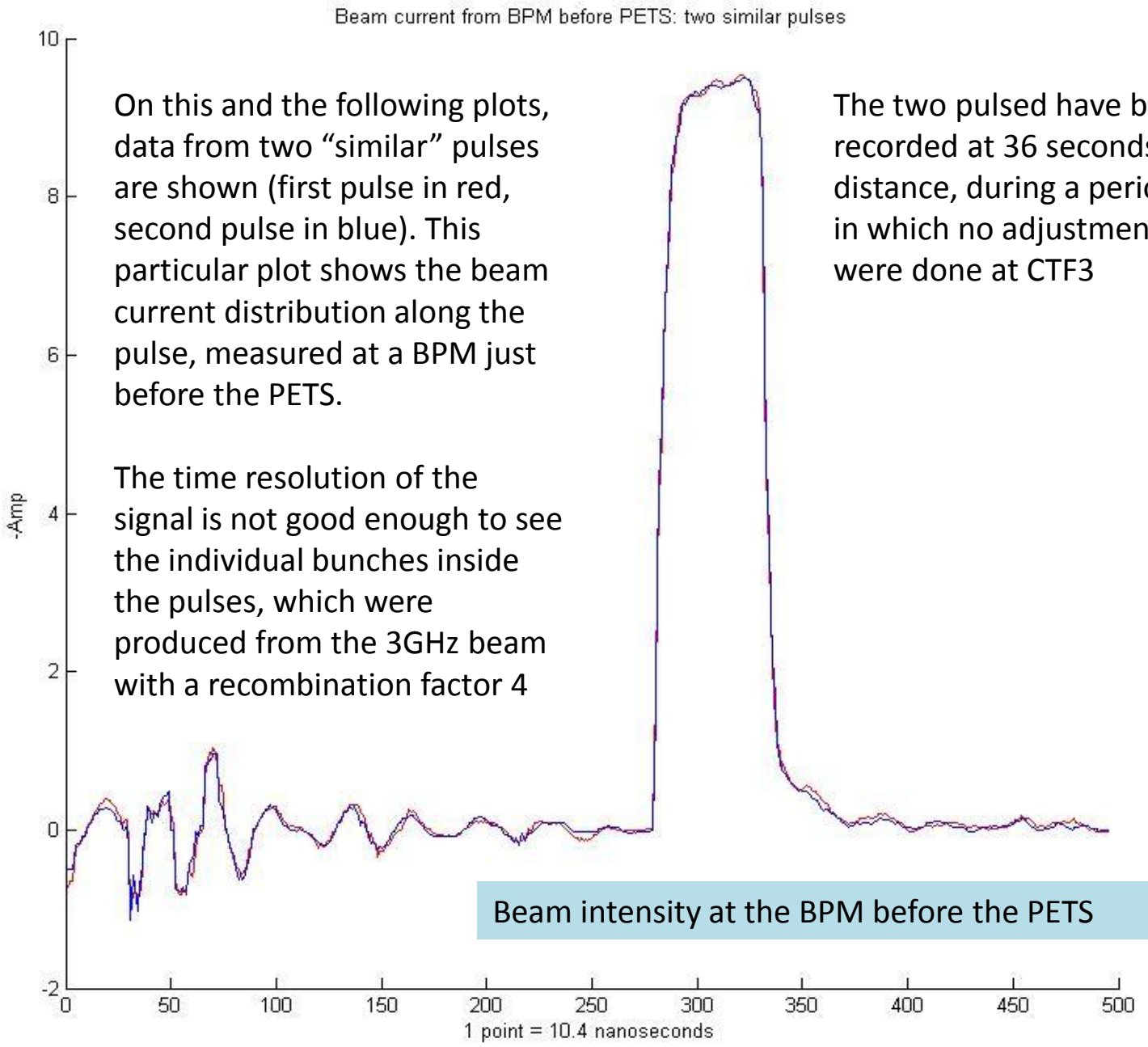
- Acquisition system: being able to easily specify
  - A set of input signals
  - A number of consecutive pulses over which the signals should be acquired (it does not have to be very large)
  - A place where the data should go

- Timing system: a centralized (and precise) timing system for the entire CTF3 complex, so that
  - The acquisition of all data will be controlled by the same timing system
  - We will not need to worry about the jitter between different timing systems when we analyze the data

The measurements at TBTS

(Thank you Alexey !)



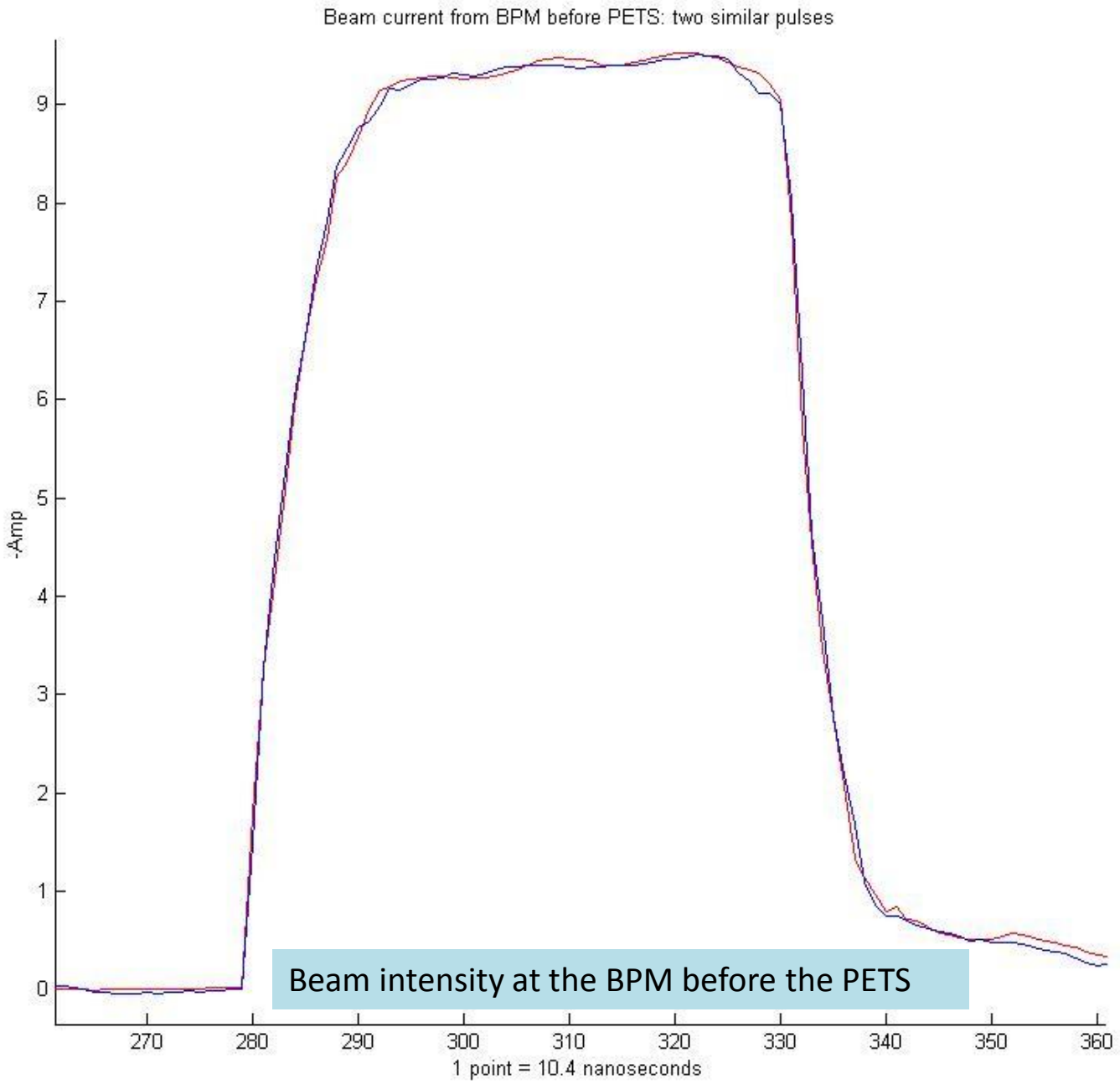


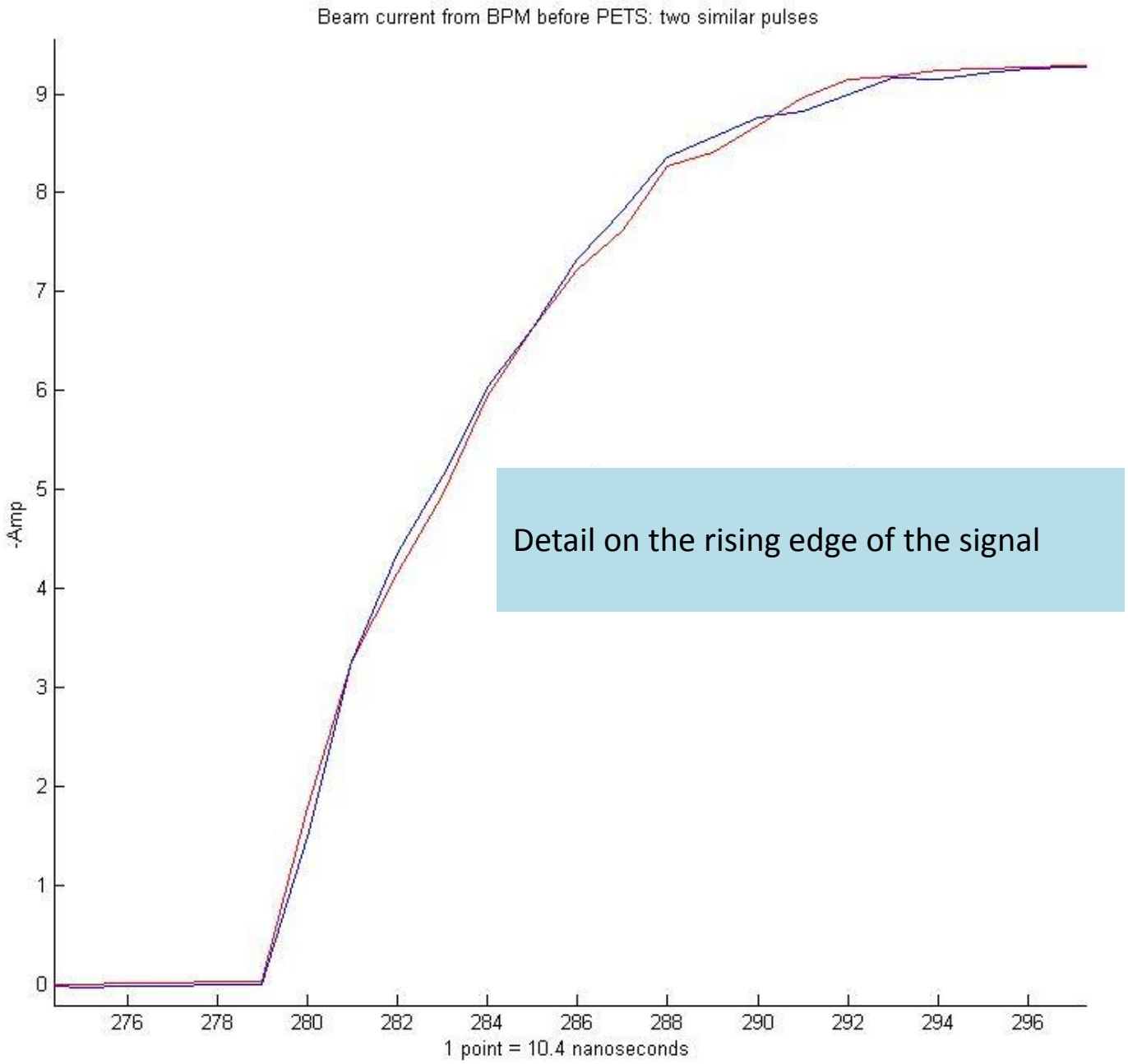
On this and the following plots, data from two "similar" pulses are shown (first pulse in red, second pulse in blue). This particular plot shows the beam current distribution along the pulse, measured at a BPM just before the PETS.

The time resolution of the signal is not good enough to see the individual bunches inside the pulses, which were produced from the 3GHz beam with a recombination factor 4

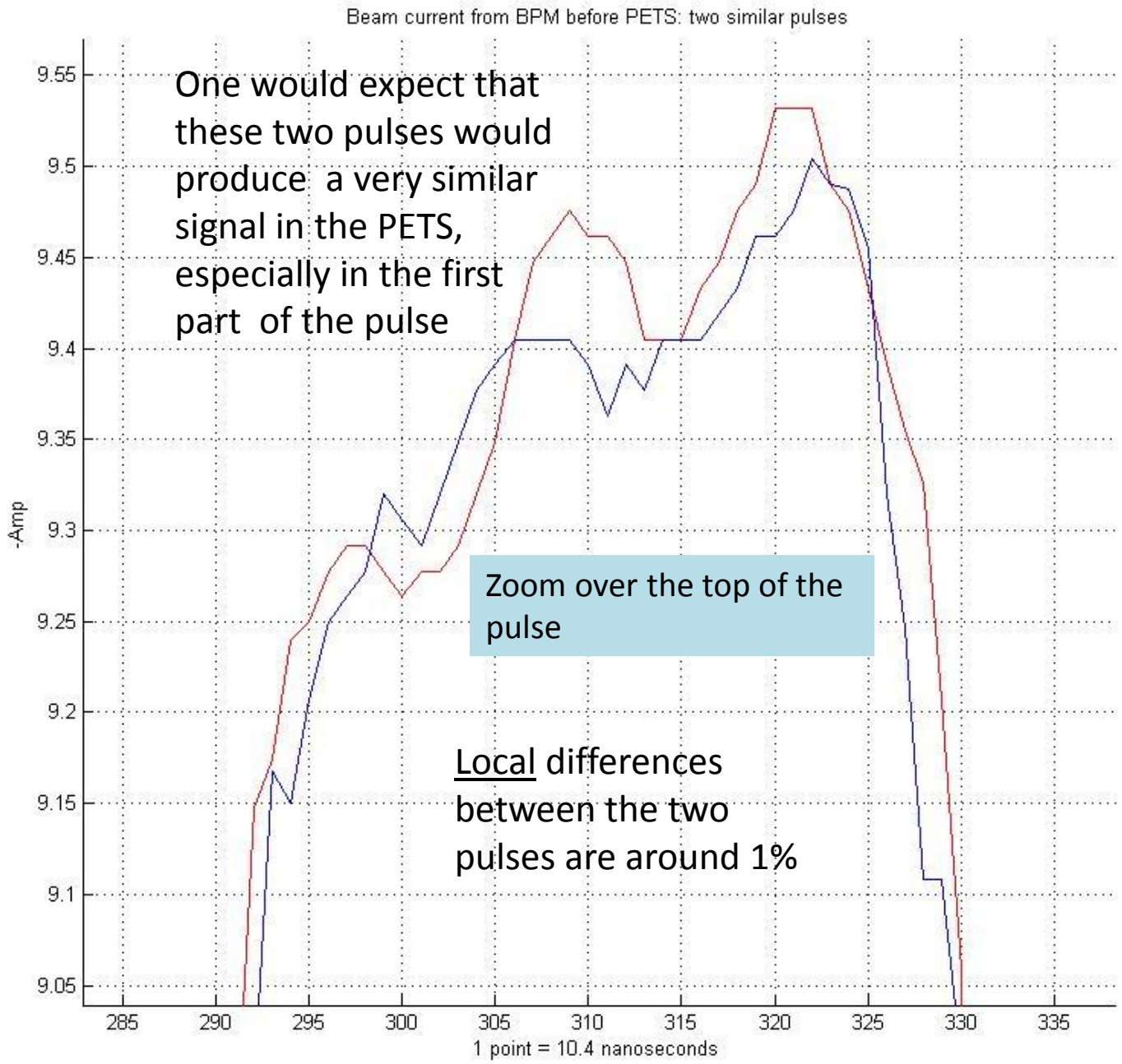
The two pulsed have been recorded at 36 seconds of distance, during a period in which no adjustments were done at CTF3

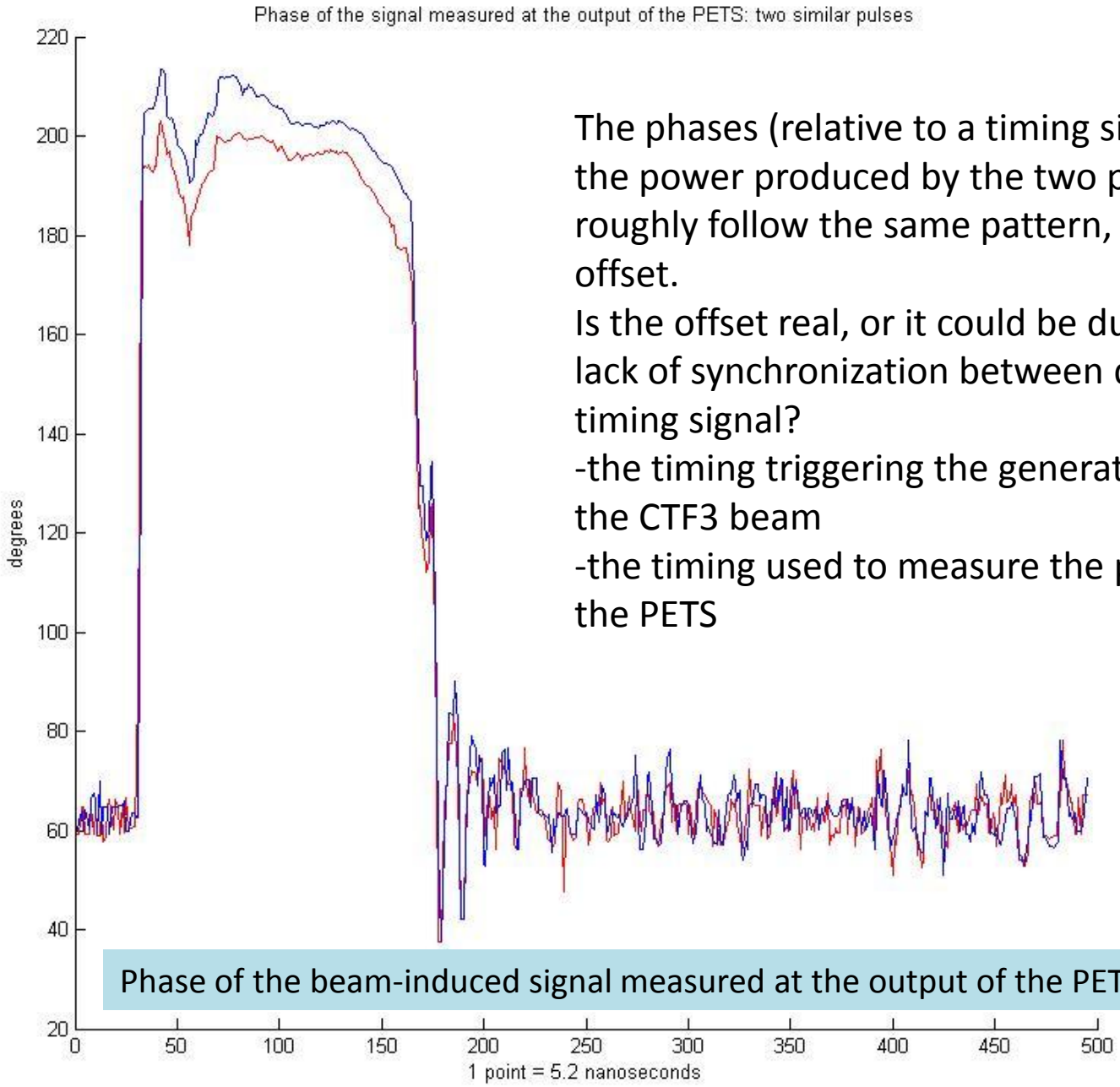
Beam intensity at the BPM before the PETS


Beam current from BPM before PETS: two similar pulses
-Amp
0
1
2
3
4
5
6
7
8
9
270
280
290
300
310
320
330
340
350
360
1 point = 10.4 nanoseconds
Beam intensity at the BPM before the PETS



Detail on the rising edge of the signal


Beam current from BPM before PETS: two similar pulses
One would expect that these two pulses would produce a very similar signal in the PETS, especially in the first part of the pulse
Zoom over the top of the pulse
Local differences between the two pulses are around 1%
-Amp
9.55
9.5
9.45
9.4
9.35
9.3
9.25
9.2
9.15
9.1
9.05
285
290
295
300
305
310
315
320
325
330
335
1 point = 10.4 nanoseconds



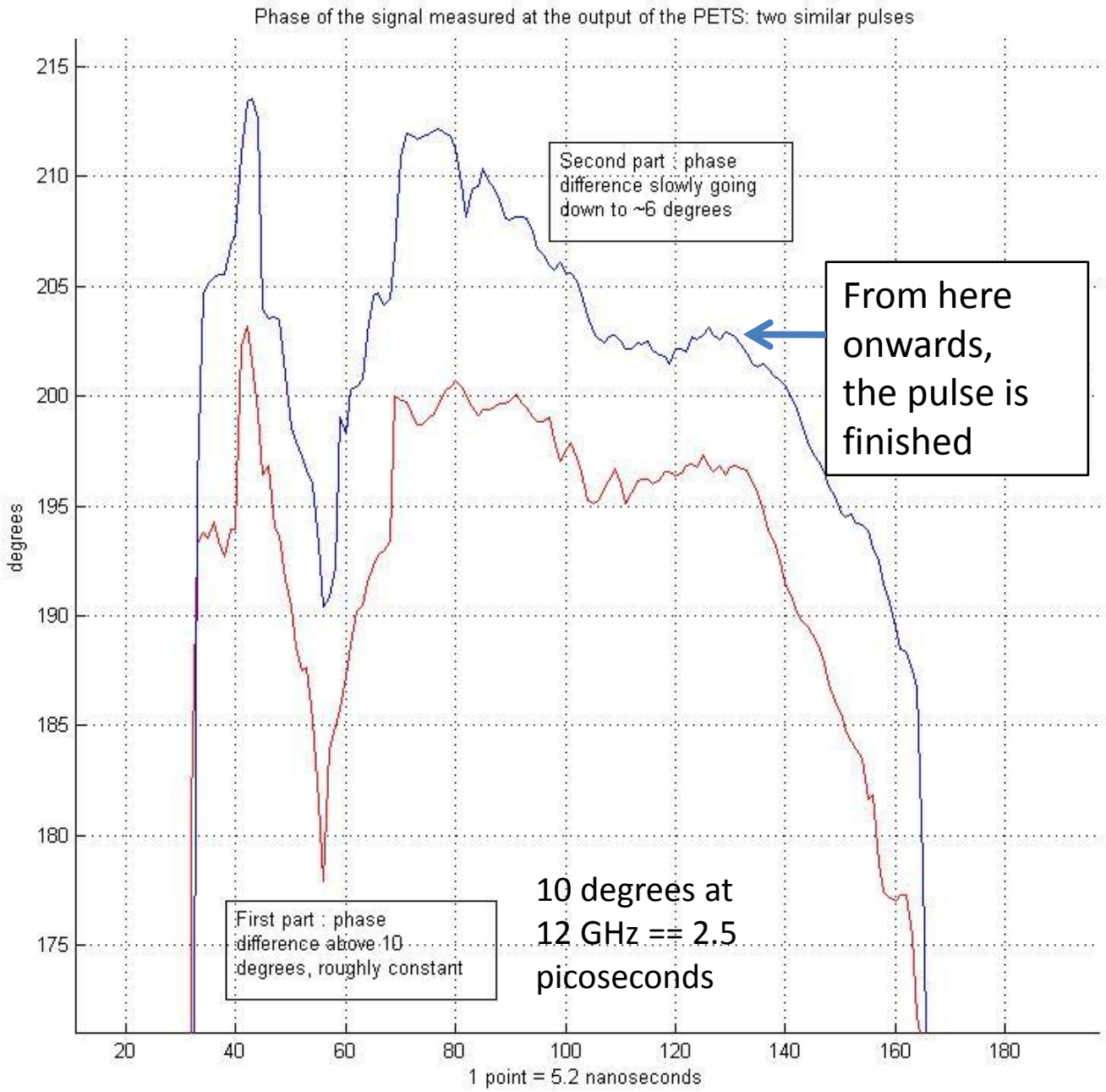
The phases (relative to a timing signal) of the power produced by the two pulses roughly follow the same pattern, with an offset.

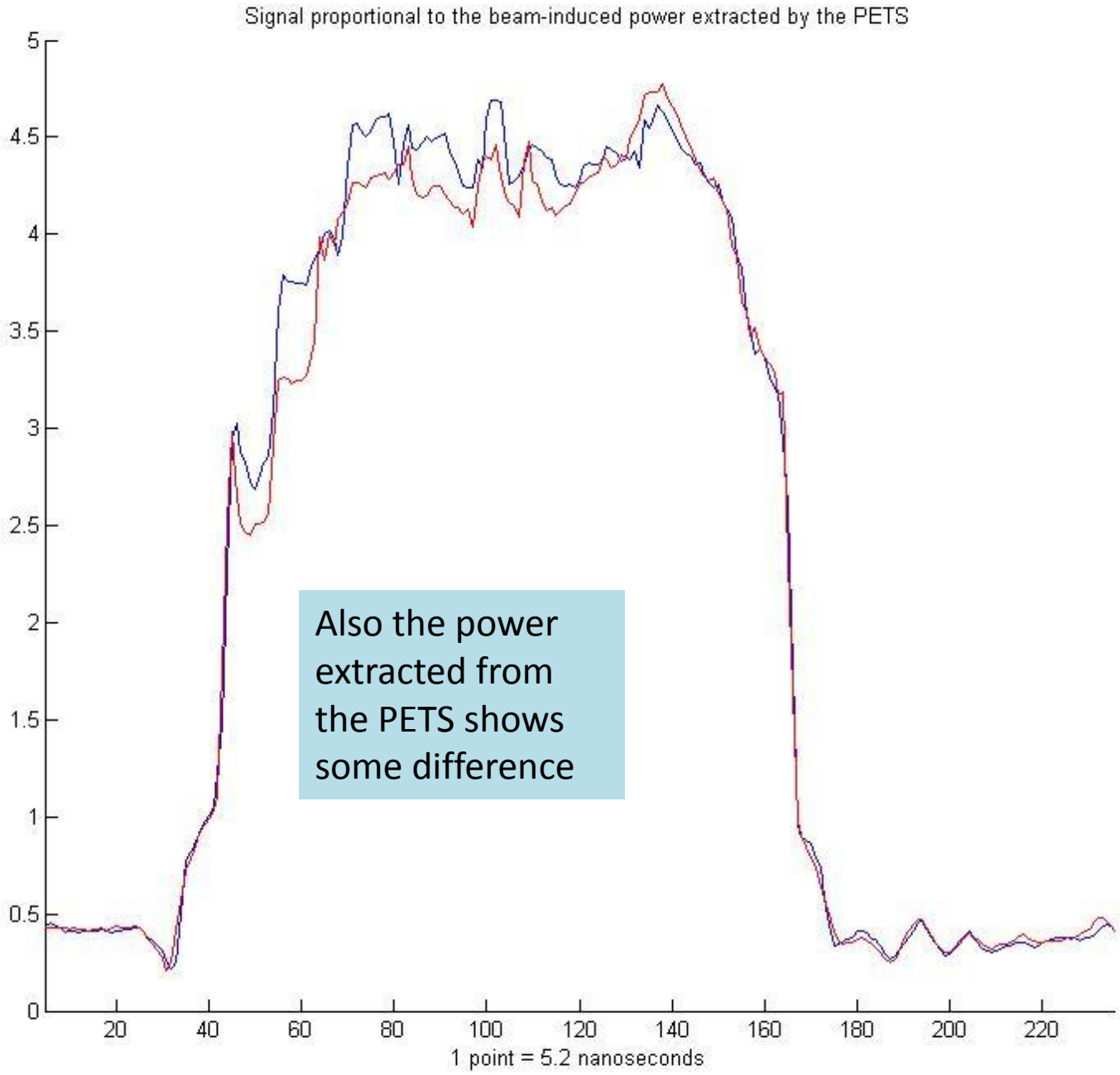
Is the offset real, or it could be due to lack of synchronization between different timing signal?

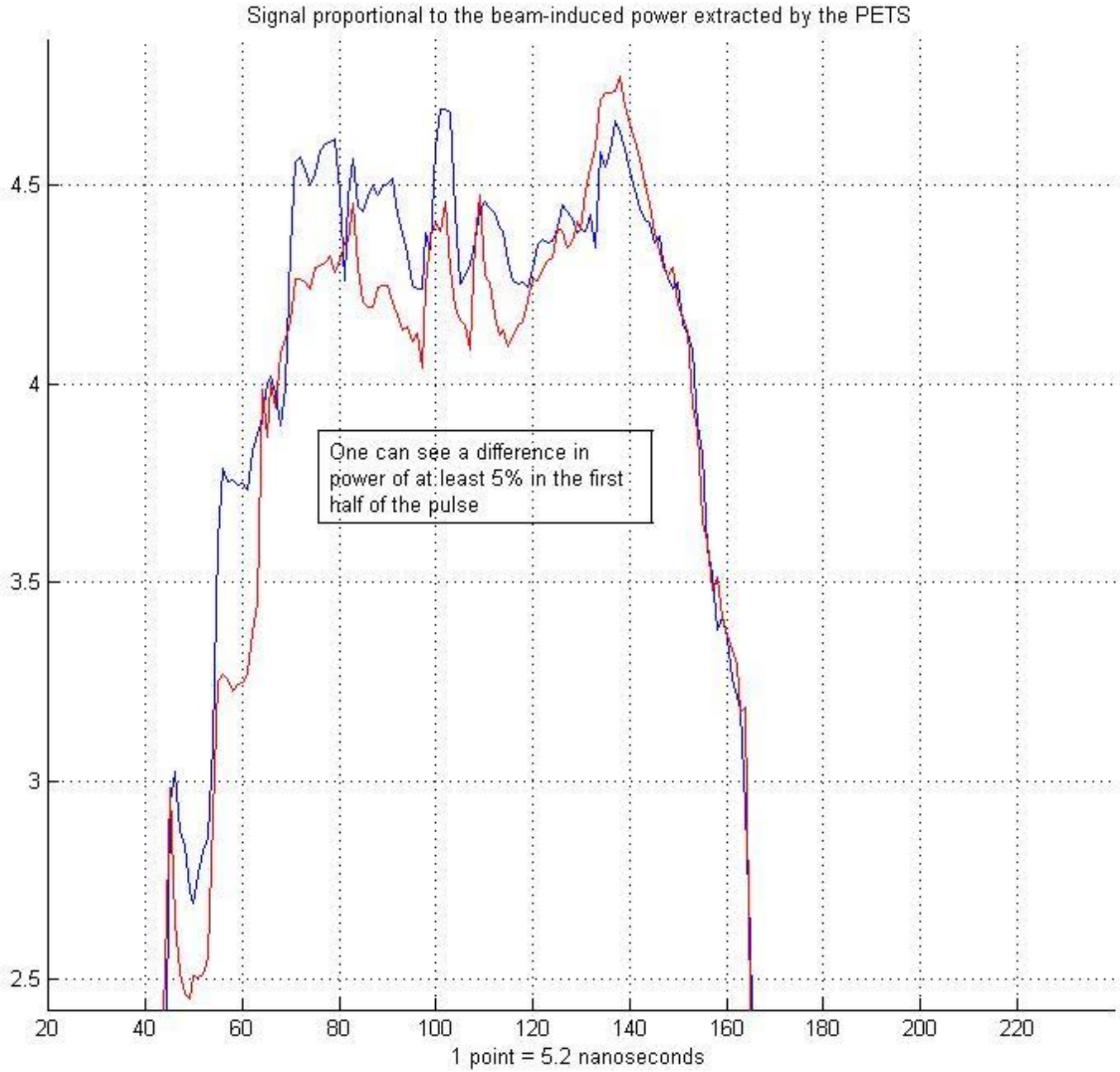
-the timing triggering the generation of the CTF3 beam

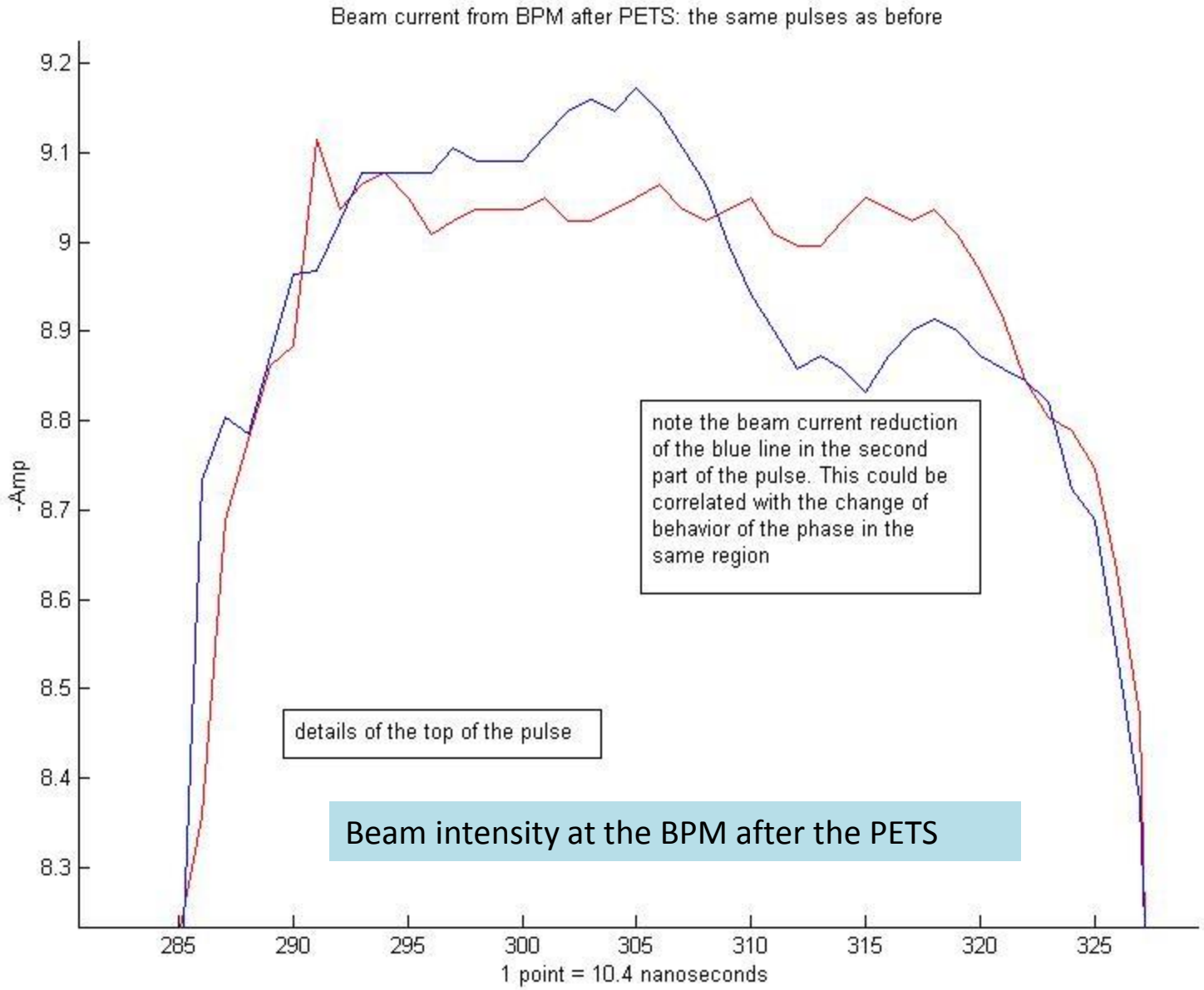
-the timing used to measure the phase at the PETS

Phase of the beam-induced signal measured at the output of the PETS


Phase of the signal measured at the output of the PETS: two similar pulses
Second part : phase difference slowly going down to ~6 degrees
From here onwards, the pulse is finished
First part : phase difference above 10 degrees, roughly constant
10 degrees at 12 GHz == 2.5 picoseconds
degrees
1 point = 5.2 nanoseconds
215
210
205
200
195
190
185
180
175
20
40
60
80
100
120
140
160
180


Signal proportional to the beam-induced power extracted by the PETS
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
20
40
60
80
100
120
140
160
180
200
220
1 point = 5.2 nanoseconds
Also the power extracted from the PETS shows some difference


Signal proportional to the beam-induced power extracted by the PETS
One can see a difference in power of at least 5% in the first half of the pulse
4.5
4
3.5
3
2.5
20
40
60
80
100
120
140
160
180
200
220
1 point = 5.2 nanoseconds


Beam current from BPM after PETS: the same pulses as before
-Amp
9.2
9.1
9
8.9
8.8
8.7
8.6
8.5
8.4
8.3
285
290
295
300
305
310
315
320
325
1 point = 10.4 nanoseconds
note the beam current reduction of the blue line in the second part of the pulse. This could be correlated with the change of behavior of the phase in the same region
details of the top of the pulse
Beam intensity at the BPM after the PETS

Other measurements

• We also performed some phase measurements using the CTF3 BPRs (see Alexey Dubrovskiy' talk)

• In their current settings, the resolution of the BPRs is not really good enough to perform precision pulse-to-pulse phase measurements.

Conclusions

• The measurements we could perform until now this year were not “very structured”

• This was due to a number of circumstances
  -dedicated machine time was more difficult to obtain (fire delay)
  -the acquisition system is (in my view) not adequate

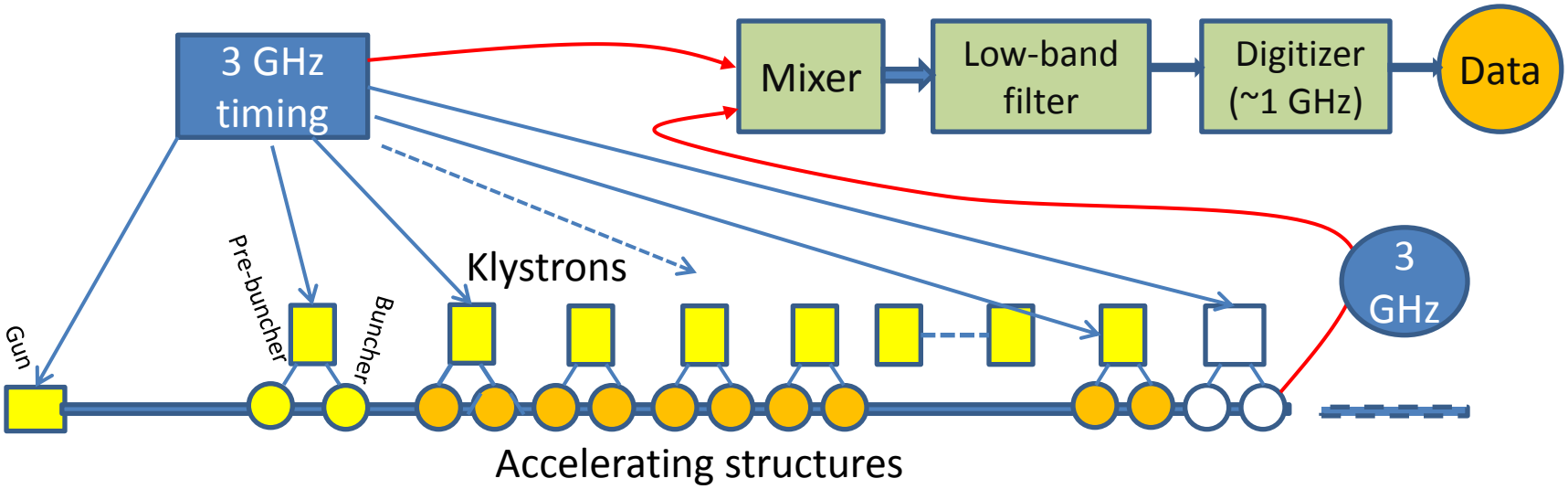
• Nevertheless, in the few measurements we manage to collect, some interesting effects are visible

• We should aim at more regular data taking, and for this we need
  -a better acquisition system
  -a global and precise timing system
  -possibly signals with finer time resolution

Thank you

Additional material from previous presentations

CTF3 as a test stand



FIRST MEASUREMENT

Phase stability measurement:

- Mix 3GHz from timing and 3GHz signal induced by the beam in the last accelerating structure (whose Klystron will be switched off)
- Filter out high frequencies, digitize (one point every 1 ns), average over 10 points
- Look at Ø(t), the phase of the Beam Induced signal, relative to the (0) phase of the timing system

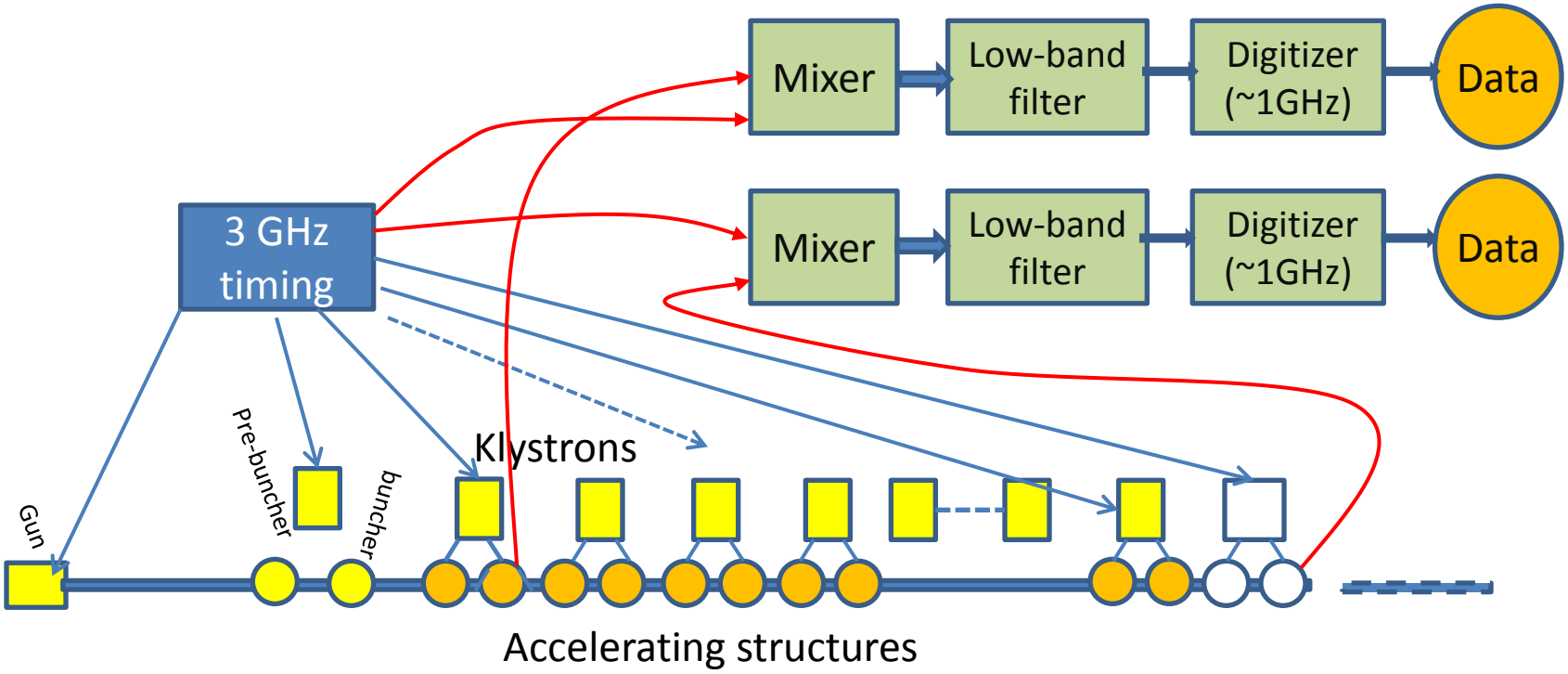
GOAL OF THE MEASUREMENT

- Look at stability along the pulse
- Look at reproducibility pulse after pulse

Notes

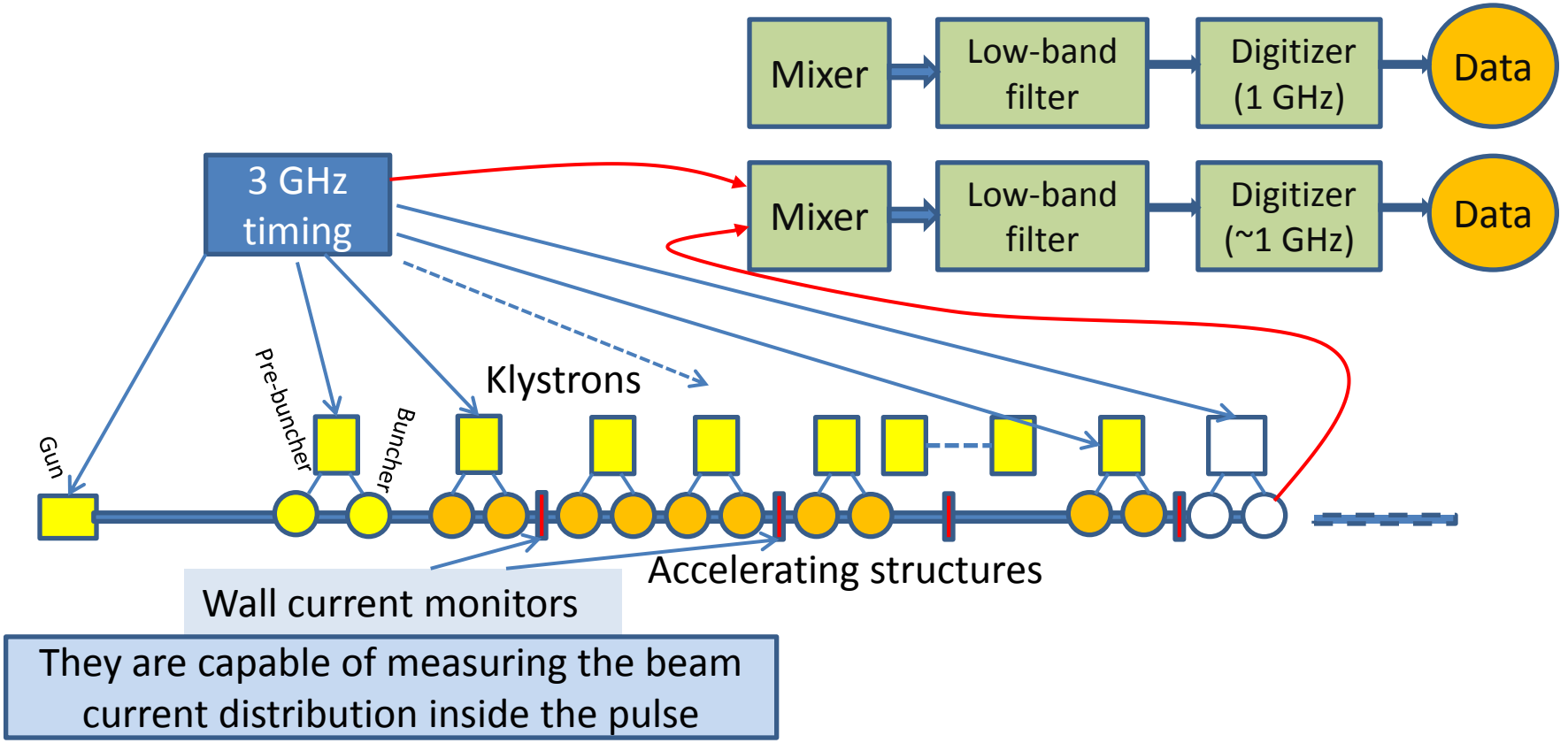
- The CTF3 Drive Beam is preceded by a “header”, made of ~100 bunches. This header is used to bring the RF structures to a stable regime, so that all the bunches of the Drive Beam are accelerated as uniformly as possible. The header (or what is left of it) is then dumped after the Linac .

In our case, the header will induce some signal in our “monitor” RF cavity. We should discard this signal, which will come at the beginning of our acquisition window.



MEASURE PHASES FROM ALL CAVITIES

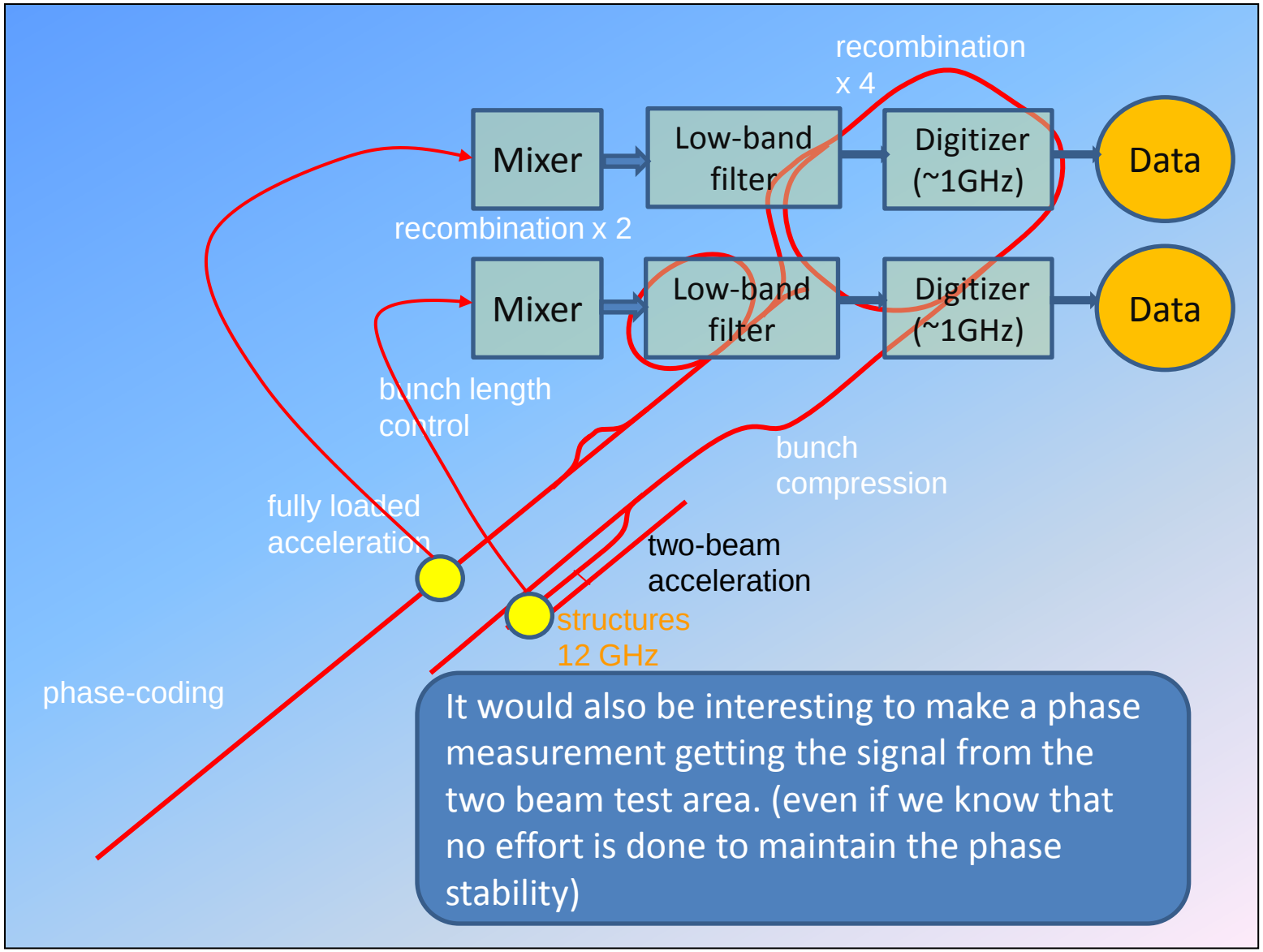
• The goal of this measurement is to determine if phase instabilities in different cavities are correlated or not. This is important to predict the way the error will accumulate in the CLIC Drive Beam Linac. The tolerance for correlated errors is a factor 4 tighter than the tolerance for uncorrelated ones



INCLUDE BEAM CURRENT DATA FROM WALL CURRENT MONITORS
MONITOR ALSO THE TEMPERATURE

- The goal is to study correlation between the phase measurements and the beam current, both inside a pulse, and pulse after pulse
- Also the temperature can have an effect which should be analyzed

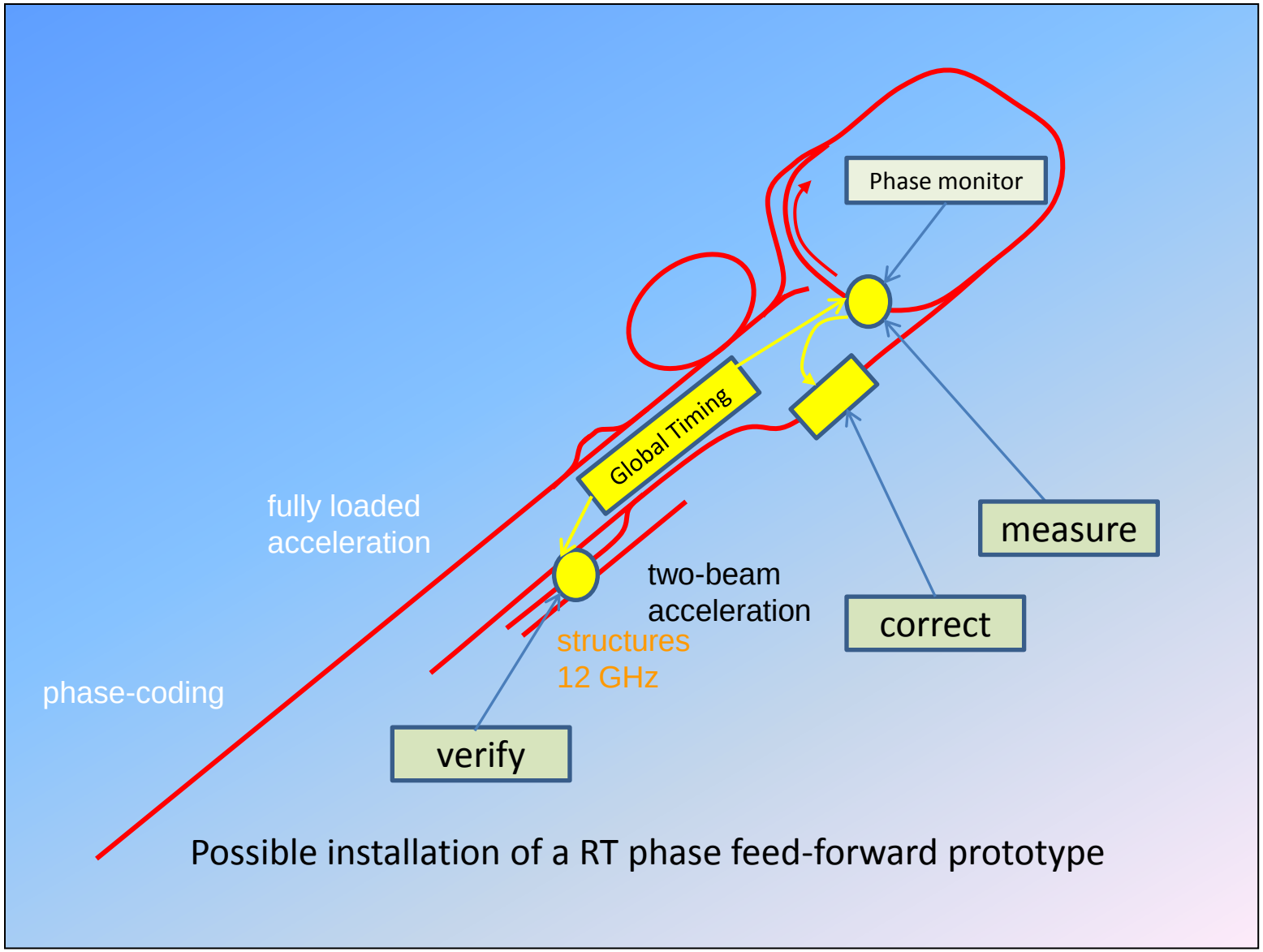
Future development: measure phase at the two beam test stand



Other measurements (beyond 2010)

- Phase feedback prototype
  - It would be nice to use the Combined Ring and the Extraction Line as a Test Stand to implement a Phase / Beam Arrival Time feedback
- Timing distribution
  - The CTF3 complex should also be used to gain experience with a “femto-second” timing system like the one needed for CLIC

CTF3 as a test-stand for phase feed-forward



Possible installation of a RT phase feed-forward prototype