Beam Phase Stability at CTF3

Outline

- CLIC acceleration scheme
- CTF3
- Phase Measurement & Analysis
- Conclusions
- Future Plans

Compact Linear Collider

- Two beam acceleration scheme
- Accelerating energy needed is provided by “drive” beam
  - Low energy
  - High intensity
  - 24 trains of 2600 short bunches
    - 83 ps interval between bunches corresponding to a 12GHz structure
    - Total length of train 240ns

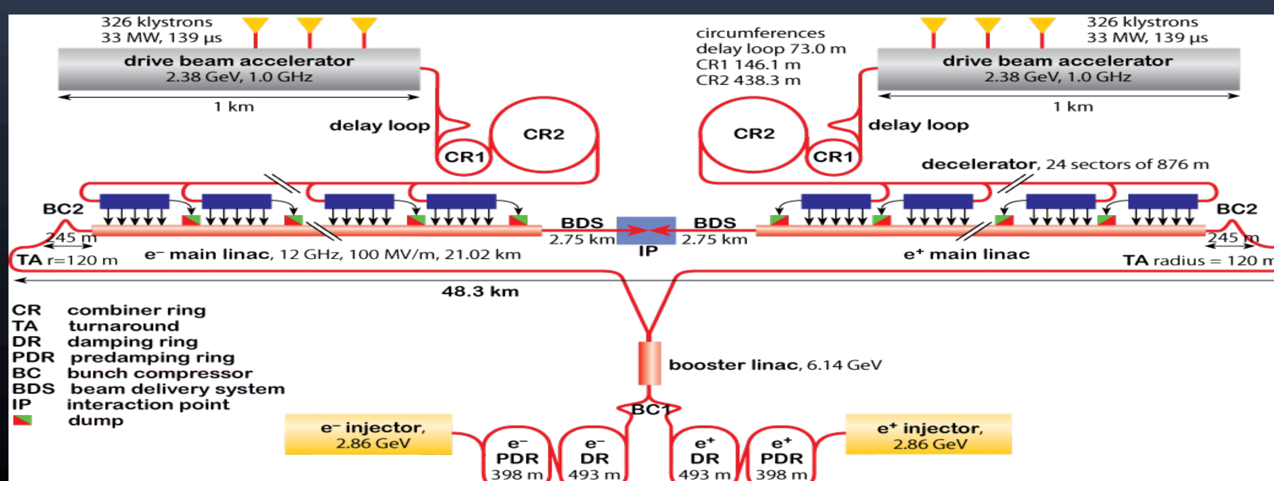
CLIC
Acceleration

Drive beam looses energy passing through "Power Extraction and Transfer Structures"

- Energy used to excite 12GHz RF power in a sequence of RF structures
- Acceleration of beam with a high gradient (~100MV/m) up to 1.5TeV

CLIC
Acceleration

- Proper acceleration mechanism needs very accurate synchronization of main and drive beams
  - Tolerance: 0.1degree at 12GHz (~20 fs)
- This precision will be achieved, if needed, with the help of feedback systems at “each drive beam turn-around”



CLIC
Acceleration

- At these locations measurement of the phase of the drive beam relative to the phase of the main beam
- Corrections applied by changing the beam path length
- Basic ingredient: capability of measuring very precisely the phases of the drive beam and of the main beam

Need to demonstrate the feasibility:
Work carried on at CTF3

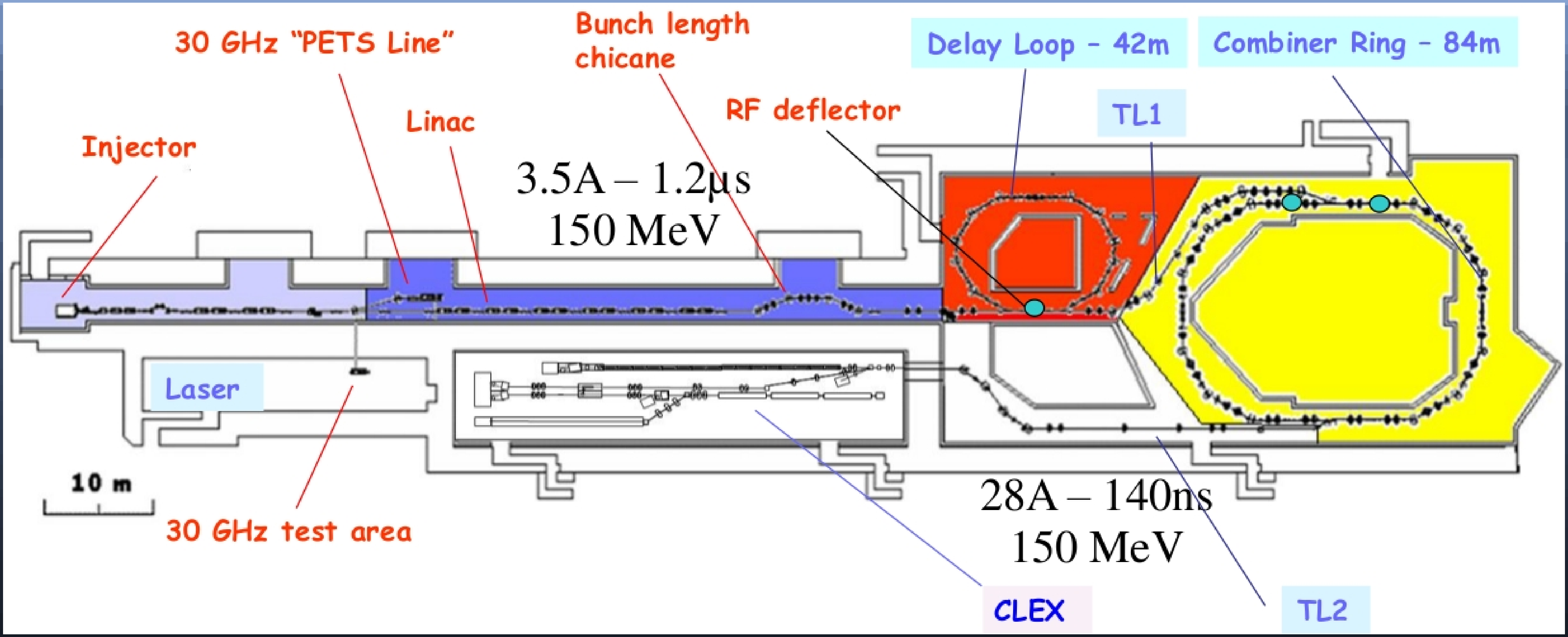
CLIC Test Facility

- International collaboration which aims at demonstrating the feasibility of the CLIC scheme
- Provides the 12 GHz RF power needed to test the main beam accelerating structures at the nominal gradient and pulse length (100 MV/m)

CTF3
Layout

- Drive Beam Injector
  - Thermionic gun: generates 1.6μs long drive beam pulse
  - Bunching System:
    Provides bunches
    - Spaced by 20cm
    - Charge of 2.3nC (average current 3.5A)
  - 3GHz fully-loaded traveling wave structures, bringing the beam energy up to 20MeV
- Drive Beam Accelerator
  - Sixteen 3GHz fully-loaded traveling wave structures
  - Final Energy 120MeV
- Delay Loop – Combiner Ring
  - electron pulse compression and bunch frequency multiplication
  - Drive Beam pulse: 140ns long, current ~30A
- Two Beam Test Area
  - Individual bunches are compressed in length to about 1mm rms
  - Transported in this area to produce 12GHz RF power

CTF3
Layout



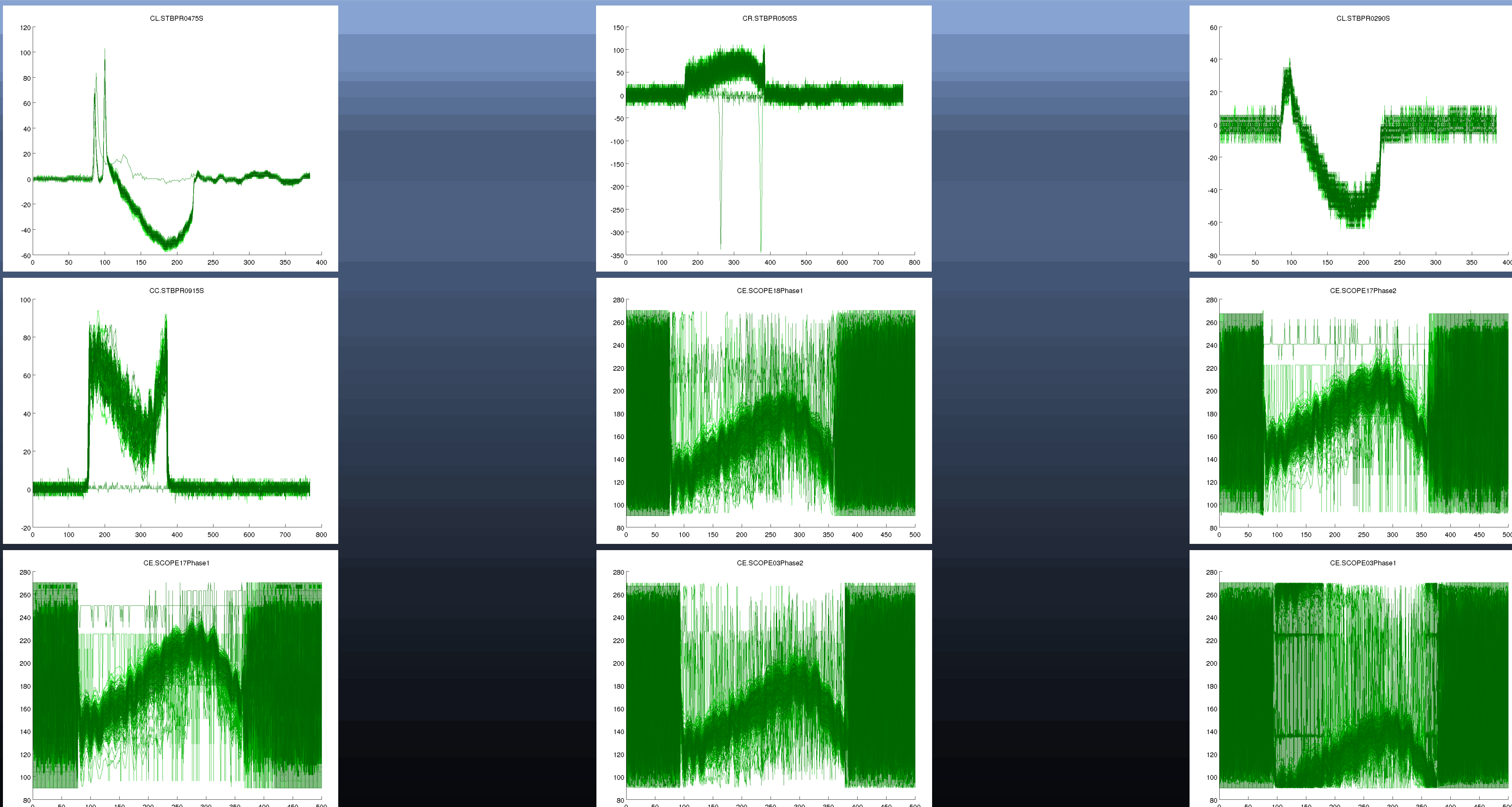
30 GHz "PETS Line"
Bunch length chicane
Delay Loop – 42m
Combiner Ring – 84m
RF deflector
TL1
Linac
Injector
3.5A – 1.2μs
150 MeV
Laser
10 m
30 GHz test area
28A – 140ns
150 MeV
CLEX
TL2

Beam Stability & Phase Measurement

- Two beam stability time scales
  - Pulse to Pulse
  - Stability over many Pulses
- Measurement done using:
  - BPRs (Button Pick-Ups)
    - Linac (x2) (CL)
    - Combiner Ring (CR)
    - Transfer Line to CLEX (CC)
  - PETS output
    - Test Beam Line (several output signals) (CE)
- The first goal is to determine if phase instabilities in different cavities are correlated or not

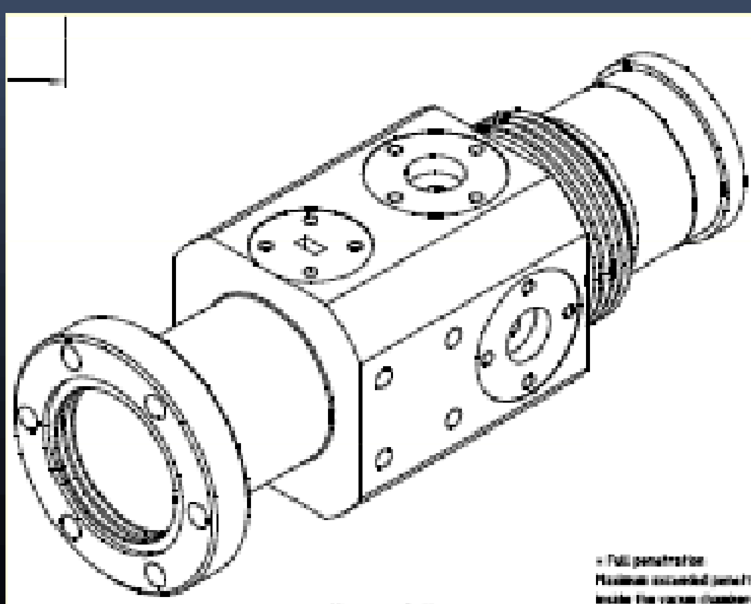
Phase Measurement

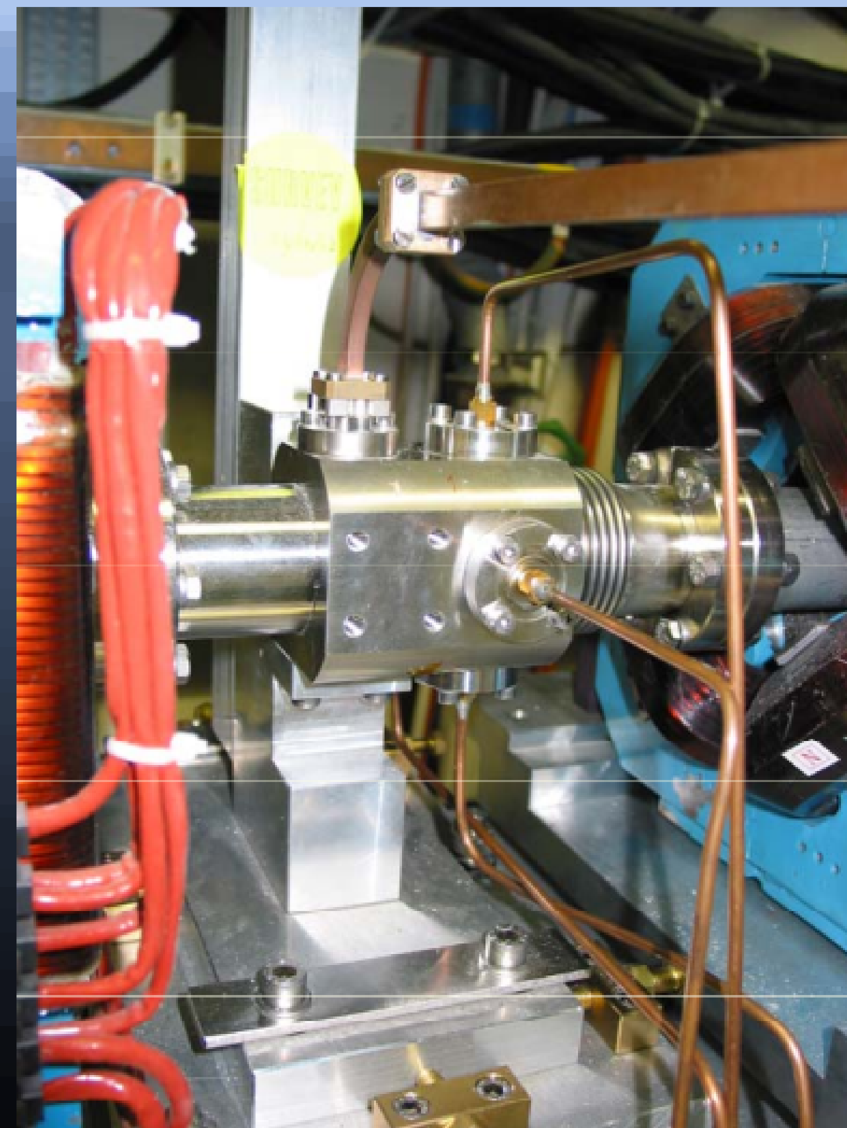
Data from 9 Devices



Phase Measurement

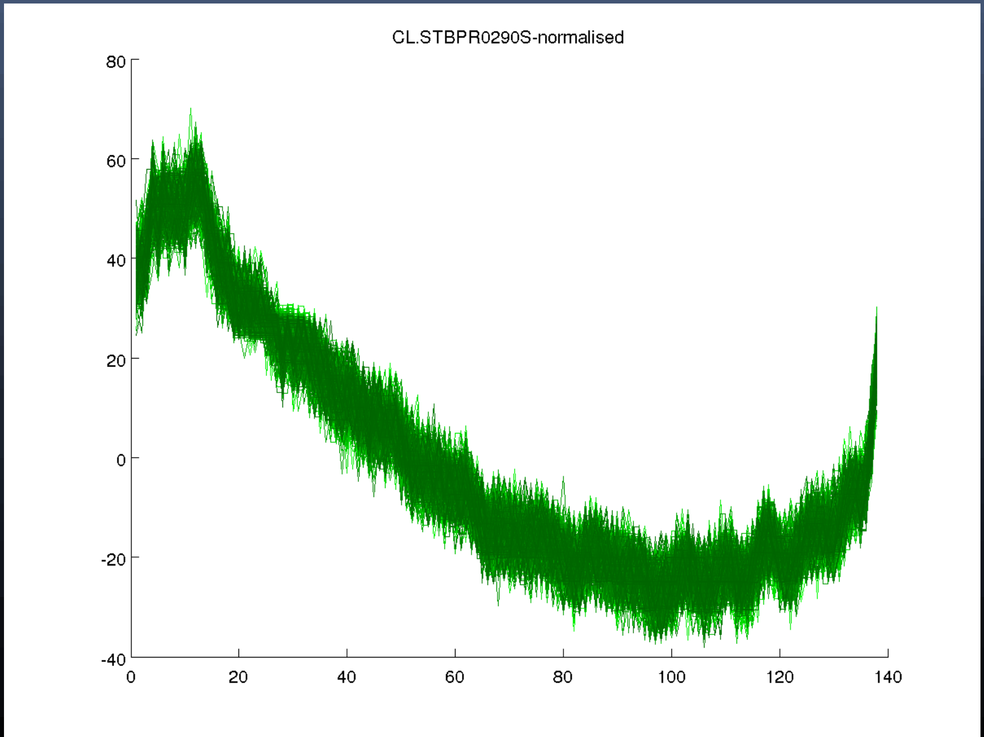
- BPRs
  - Button Pick-ups
  - 3GHz Frequency
  - Current output → Convert to degrees

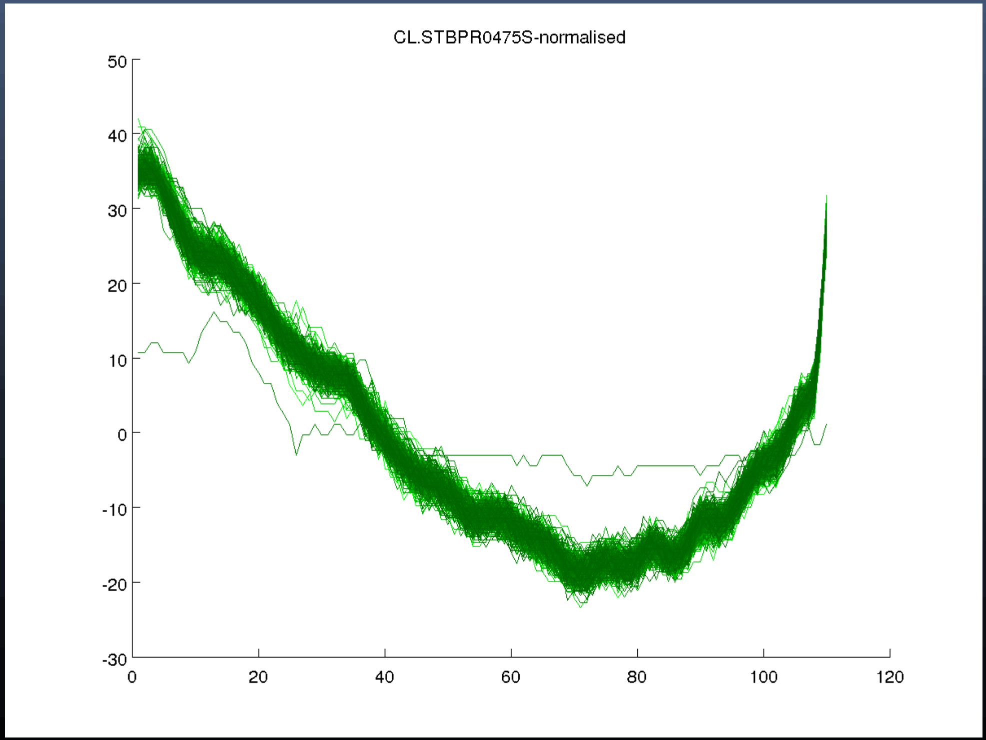




Phase Measurement

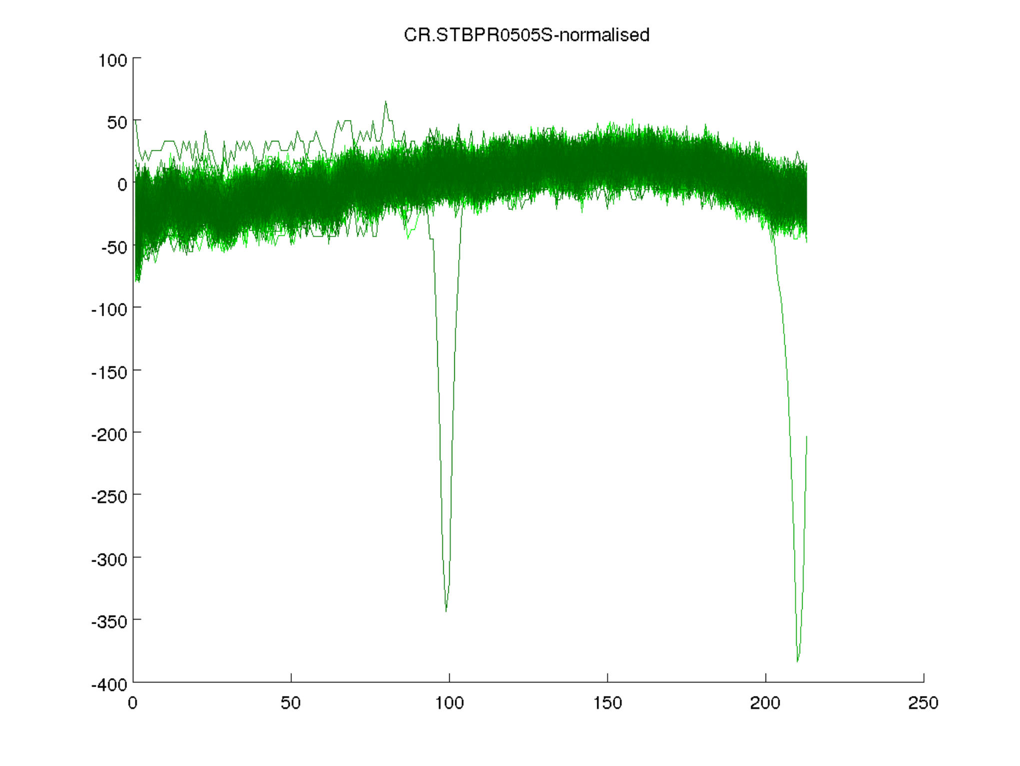
- Linac
  - RF Compression-> Phase sag ->Phase variation along the pulse (not present in CLIC)
  - Small oscillations: static, possible causes:
    - Beam current from the gun (more probable cause, can be corrected by modification of the gun current)
    - Oscillations of the Klystron RF Pulse

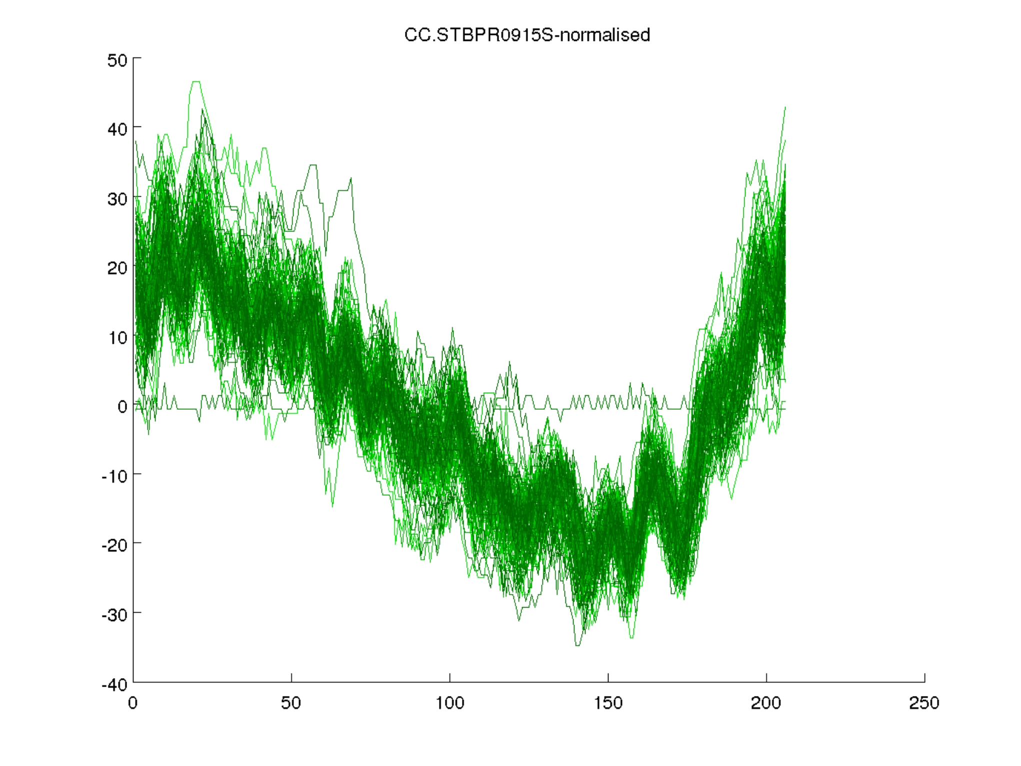




Phase Measurement

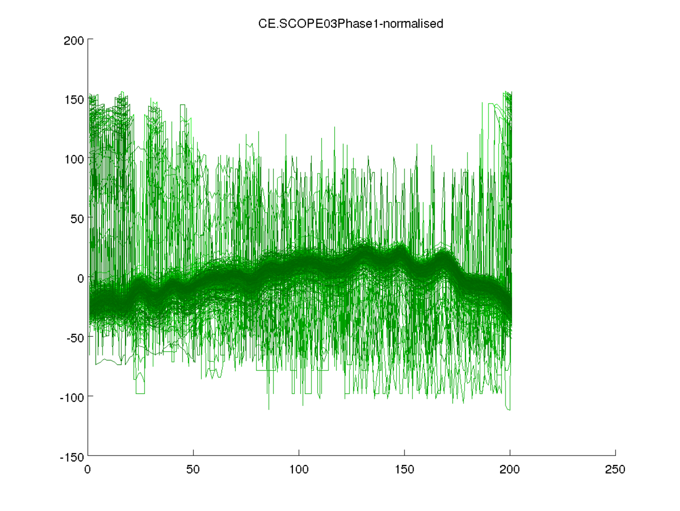
- Combiner Ring and Transfer Line to CLEX

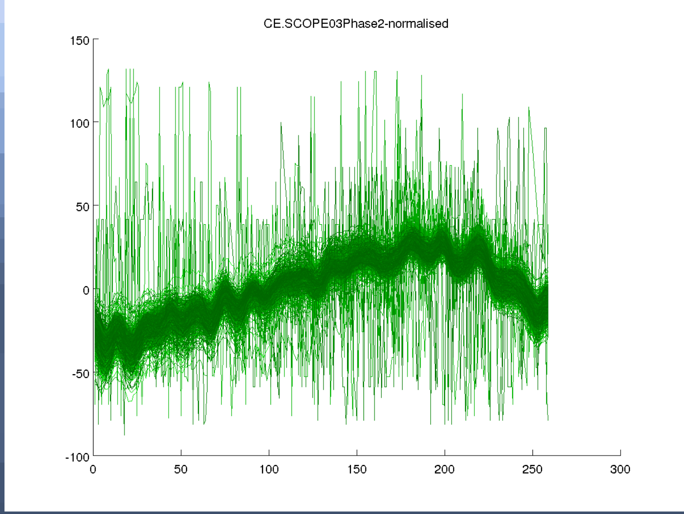


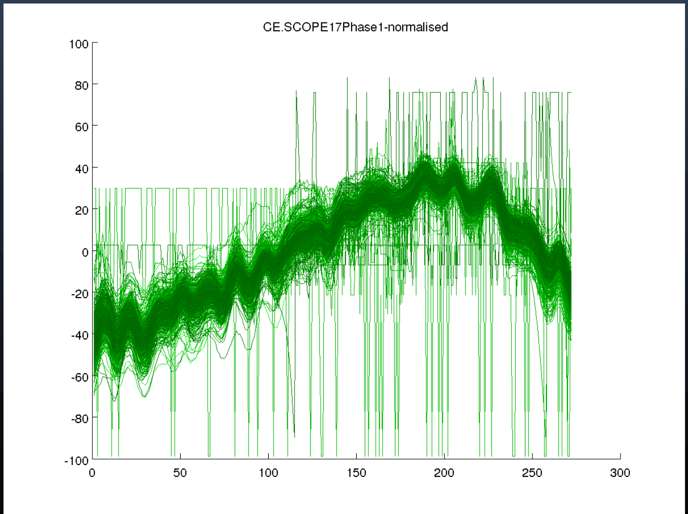


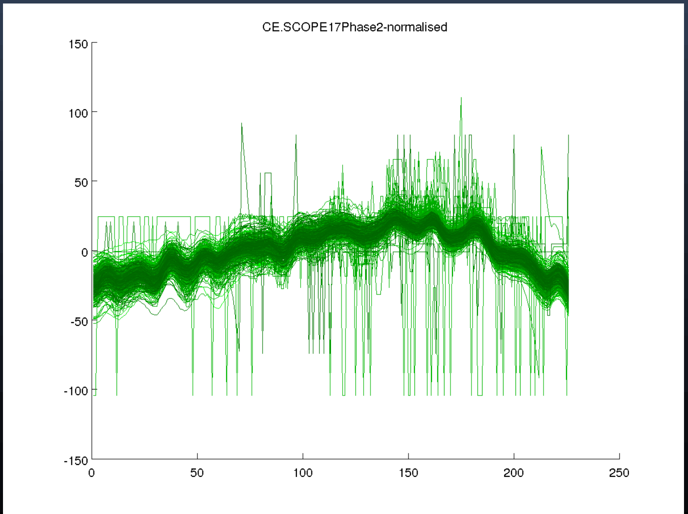
Phase Measurement

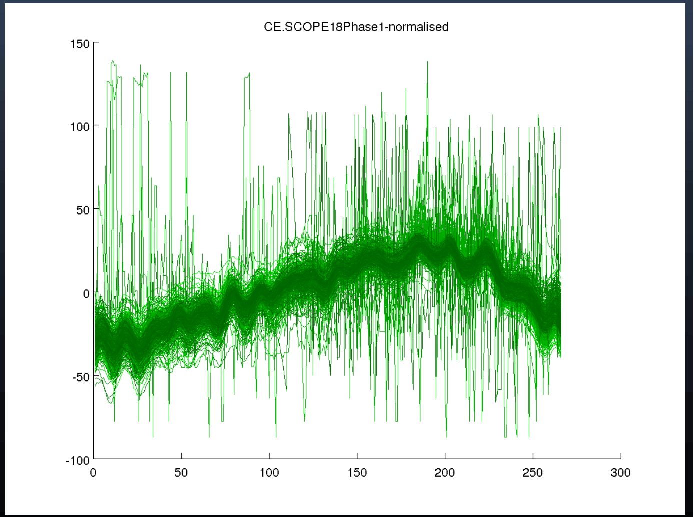
- TBL PETS
  - Direct RF Signal
  - 12GHz
    Signal frequency





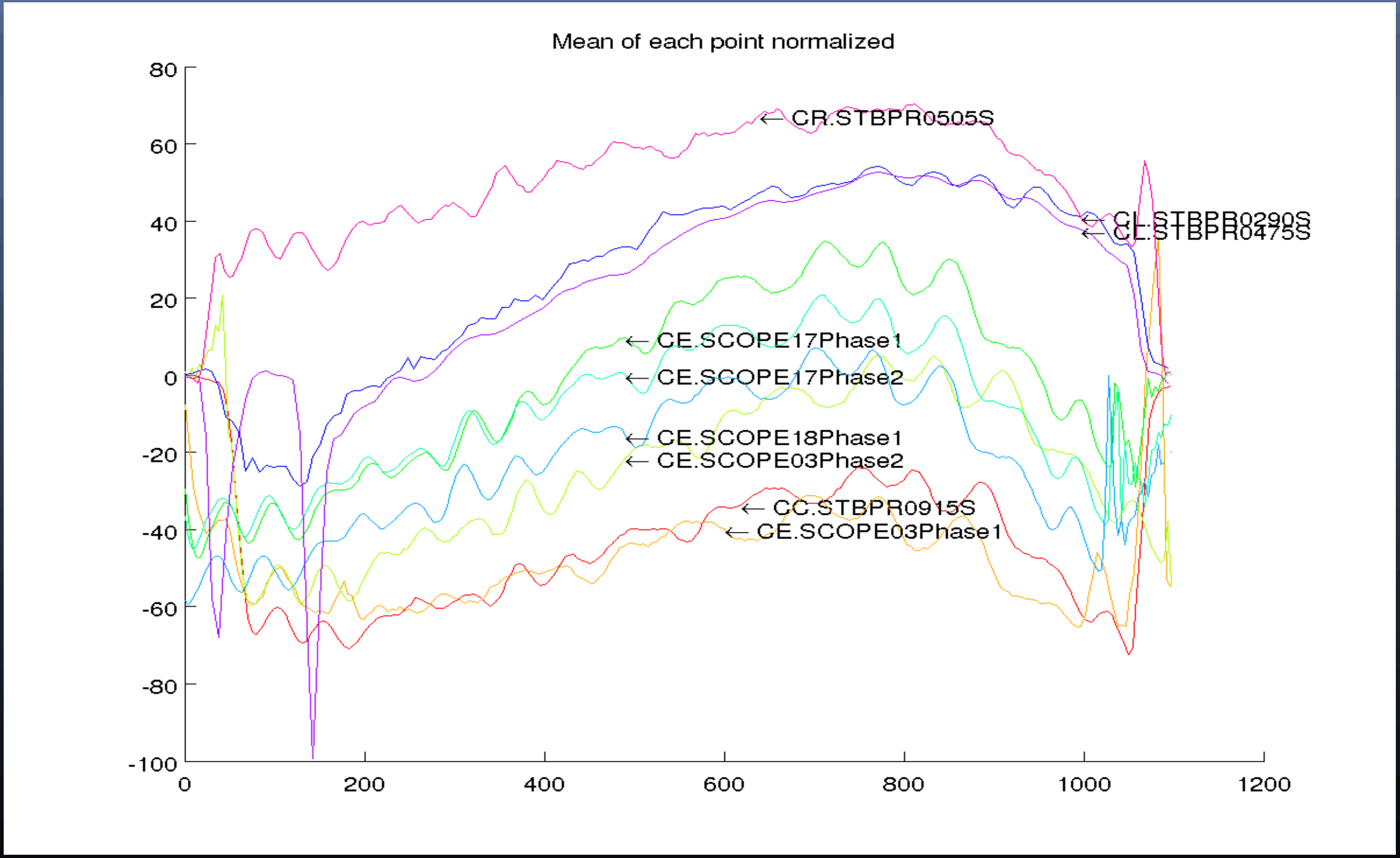




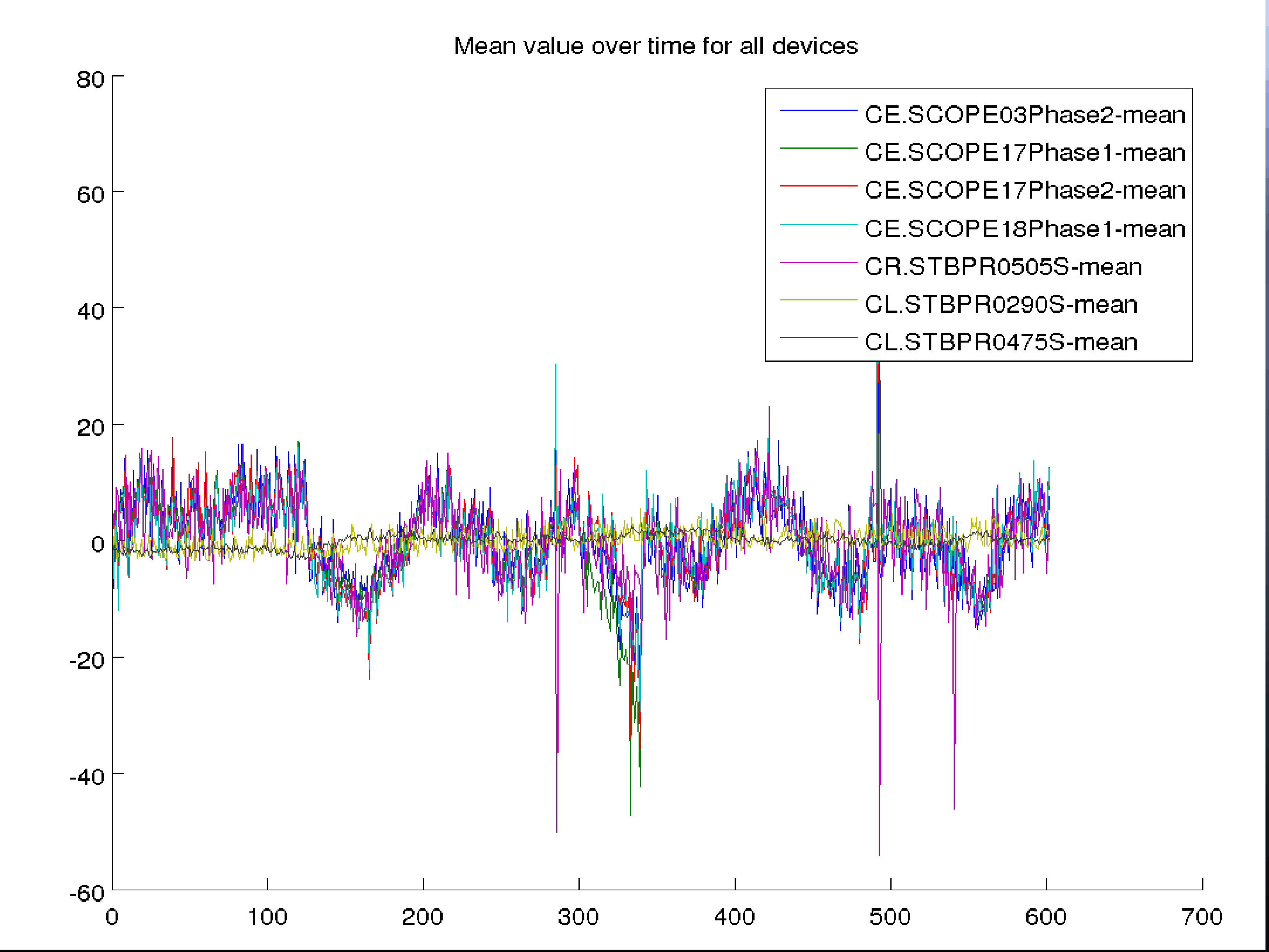


Phase Measurement

Phase variation seems to be consistent in all devices

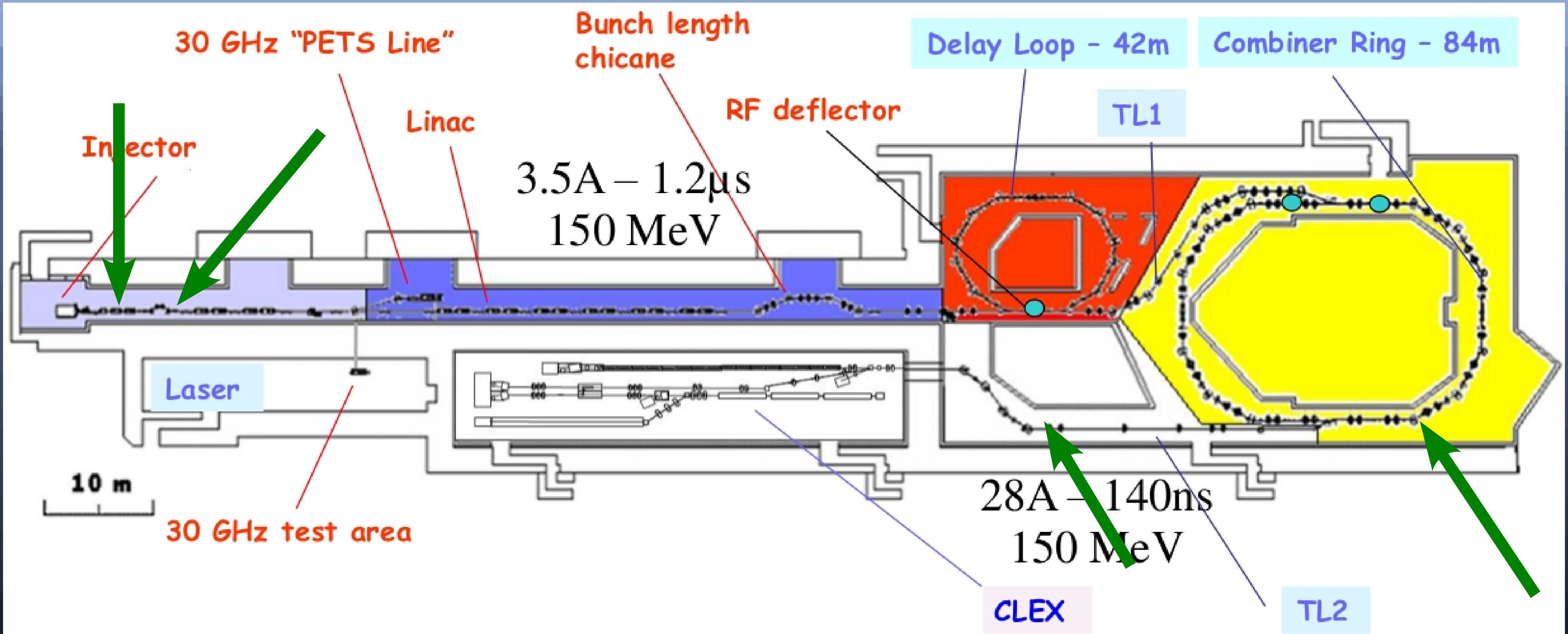


Phase Measurement



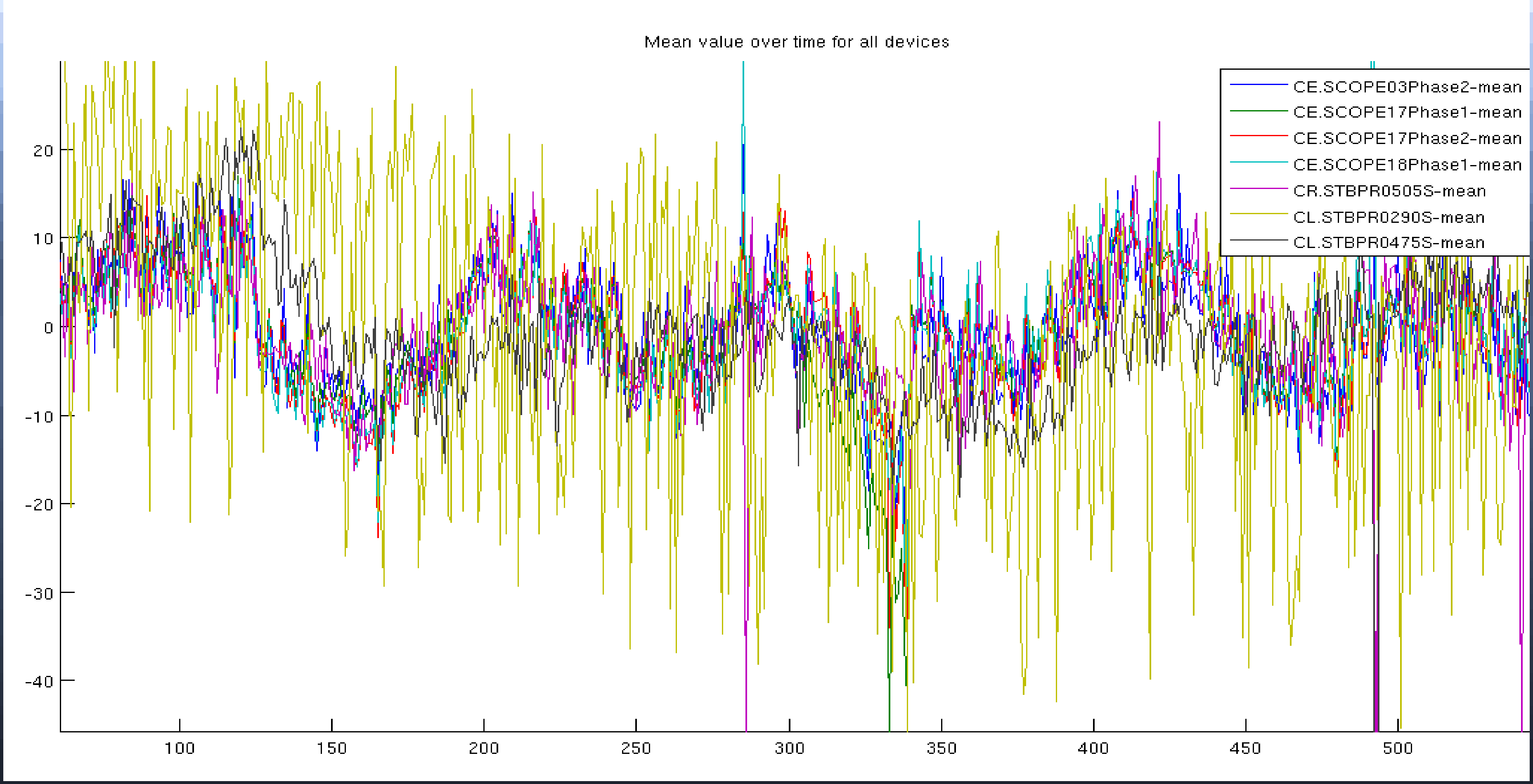
Phase Measurement

Position of the measuring devices



- Chicanes transform Energy variations to Phase variations
  - Phase jitter is amplified

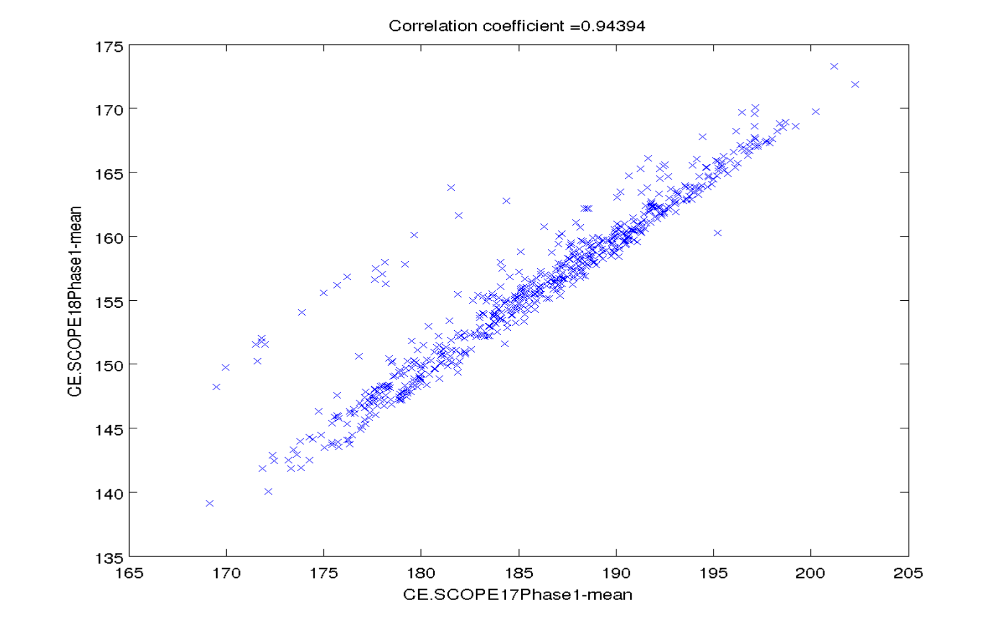
Phase Measurement

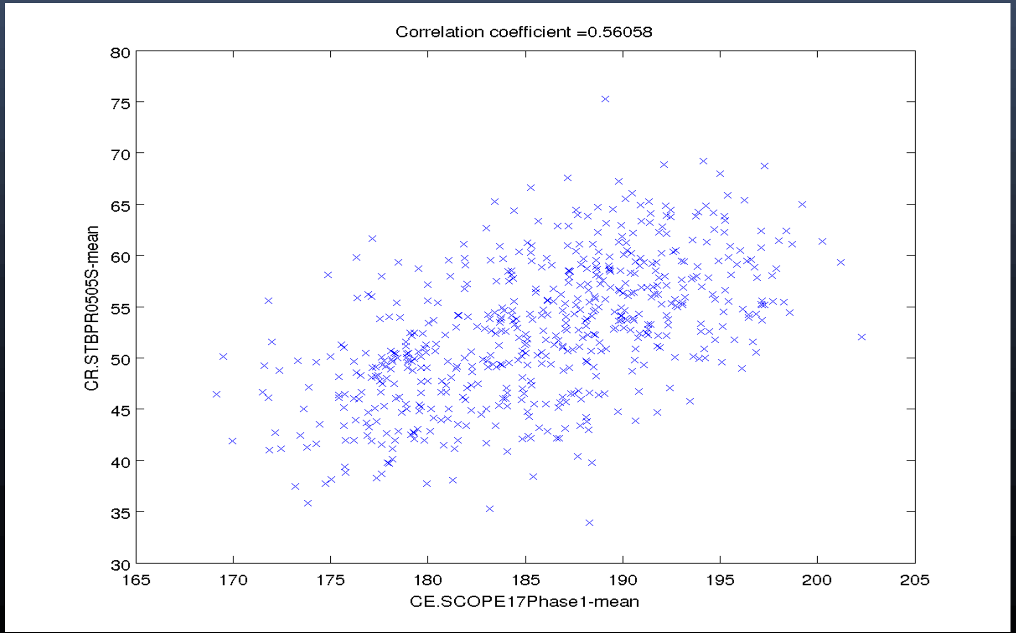


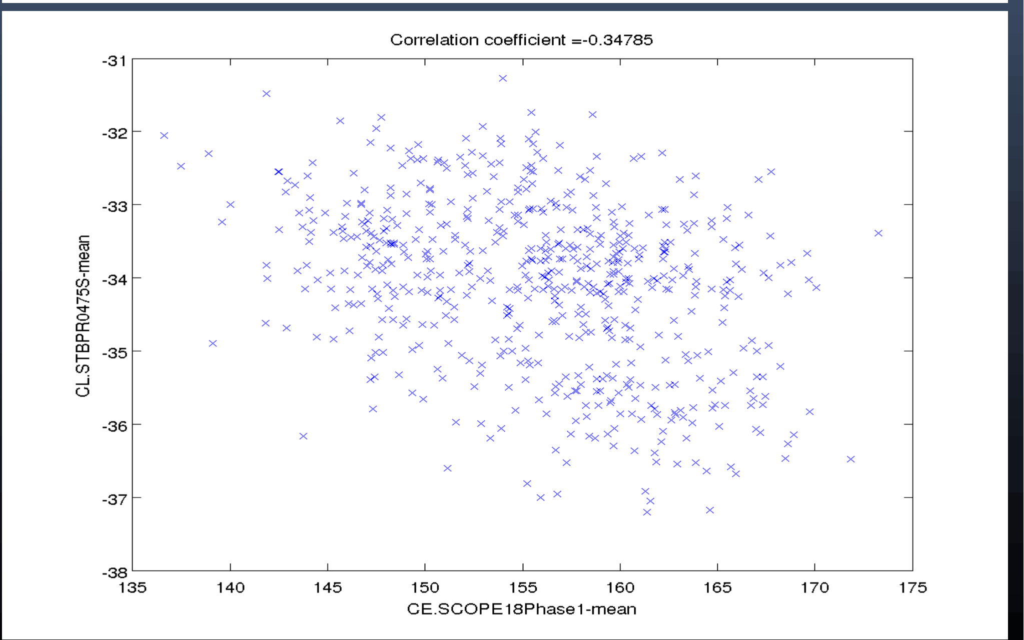
- Arbitrary calibration factor to show the correlation between results from all devices
  - BPR 290 (positioned after the first Klystron-buncher) seems to be very noisy → further investigation needed
  - BPR 475 (positioned after the small chicane after the 2 klystrons) in accordance with the results from PETS
    - obvious shift caused by timing issues (to be addressed by post-processing the data or by changes on acquisition system)
- Variation over time (slow drift) will be reduced by new temperature feedback system on the Klystrons

Phase Measurement

- Correlation Plots
  - PETS correlate very good
  - BPR505 in Combiner Ring does not correlate well
  - BPR475 after small chicane → even worse correlation
- Possible causes
  - Timing issue
  - Phase drift of the Klystrons (Temperature feedback might improve it vastly)
  - Reference Phase stability







Conclusions

- The static phase variation is more or less preserved from the injector to CLEX (is not growing) and it is 40-60 degrees at 12GHz
- Phase Variation is still very large (needs to be investigated further)

Future Plans

- Analysis of the noise of the electronics
- Measurement of the reference phase noise
- New sets of measurements including the temperature feedback system
- Cross correlate with other devices (BPMs etc)
- Installation of the new Drive Beam phase monitor produced by INFN-Frascati in collaboration with CERN