High precision phase monitoring

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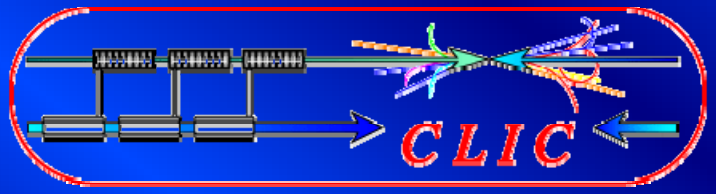

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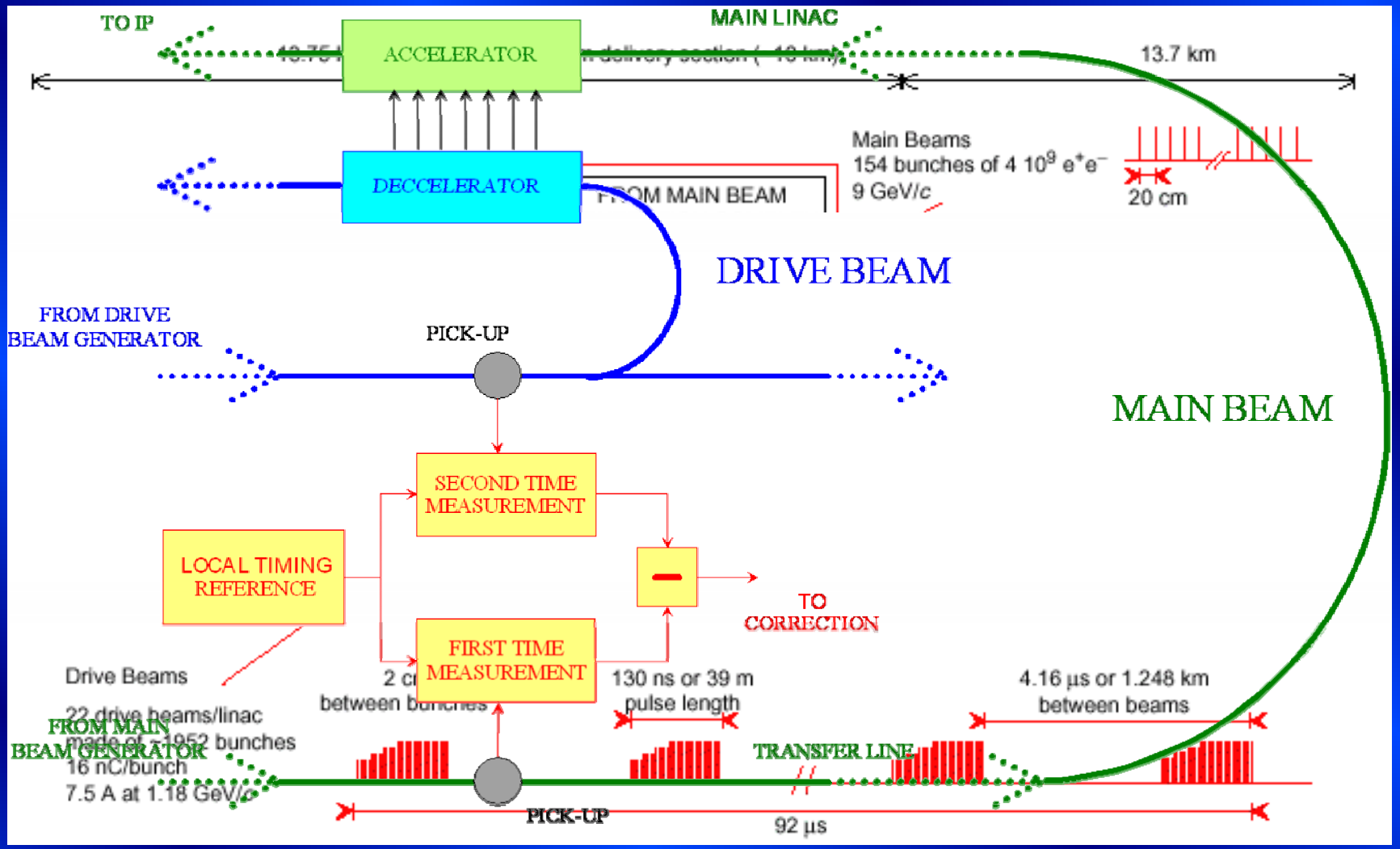
Phase errors

- Beam dynamics studies show that a phase error between the main beam and the accelerating RF of more than 0.1° will yield an unacceptable luminocity reduction
- A large quantity of phase jitter sources in the power production chain ensures that this limit will be well exceeded
- A need for phase error correction has been identified

Phase detection scheme in CLIC

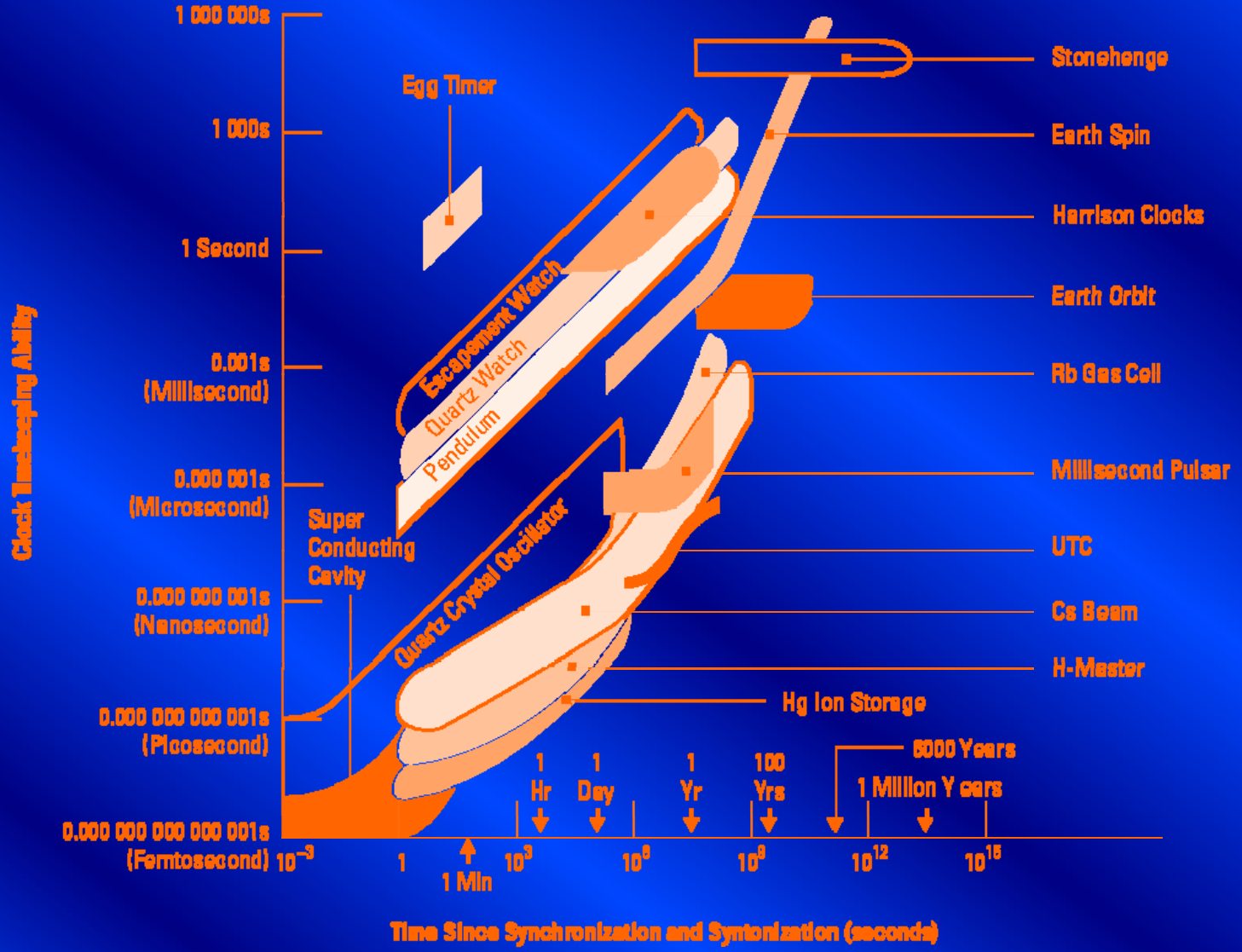
CLIC layout



Keeping time

- The local nature of the phase measurement obliterates the need for a global high-precision phase reference
- Due to the time difference of the passing of the two beams (92μs) the local oscillator must be stable to around 5fs for this duration

Time keeping devices



Low noise microwave source

- Jitter 10kHz to 50MHz from carrier:
  - Best commercial synthesizer 15fs
  - Best dielectric resonator 6fs
  - Sapphire loaded cavity oscillator 3fs
- For long term stability, locked to a reference:
  - Cesium standard
  - GPS-controlled quartz
  - CLIC master oscillator through reasonably stable distribution line

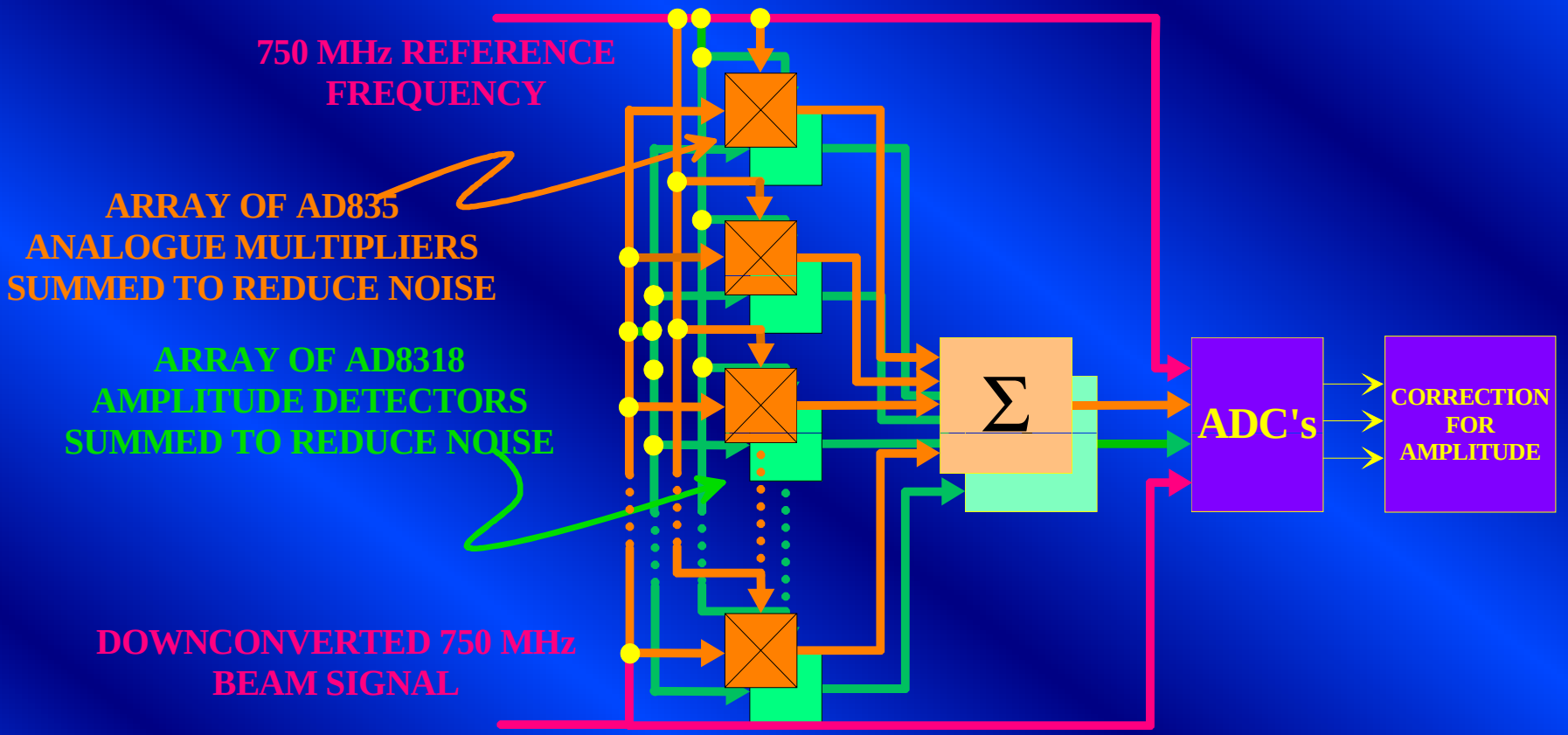
Phase detection

- Specifications
  - Single-shot
  - ± 50-100MHz bandwidth
  - 0.1 degree resolution
  - Limited linear range OK
  - Amplitude range 6dB?

Phase detection

- Mix down to some intermediate frequency and then
  - ADC
    - 2005 < 1 degree, 2007 < 0.25 degree
  - Analogue mixer
    - amplitude dependence very strong
    - (~ 0.1 degree for 1%)
  - Analogue multiplier
    - amplitude dependence
    - noisy (~ 0.2 degree RMS in 50 MHz)

Multiplier phase detection scheme – summing devices for noise reduction



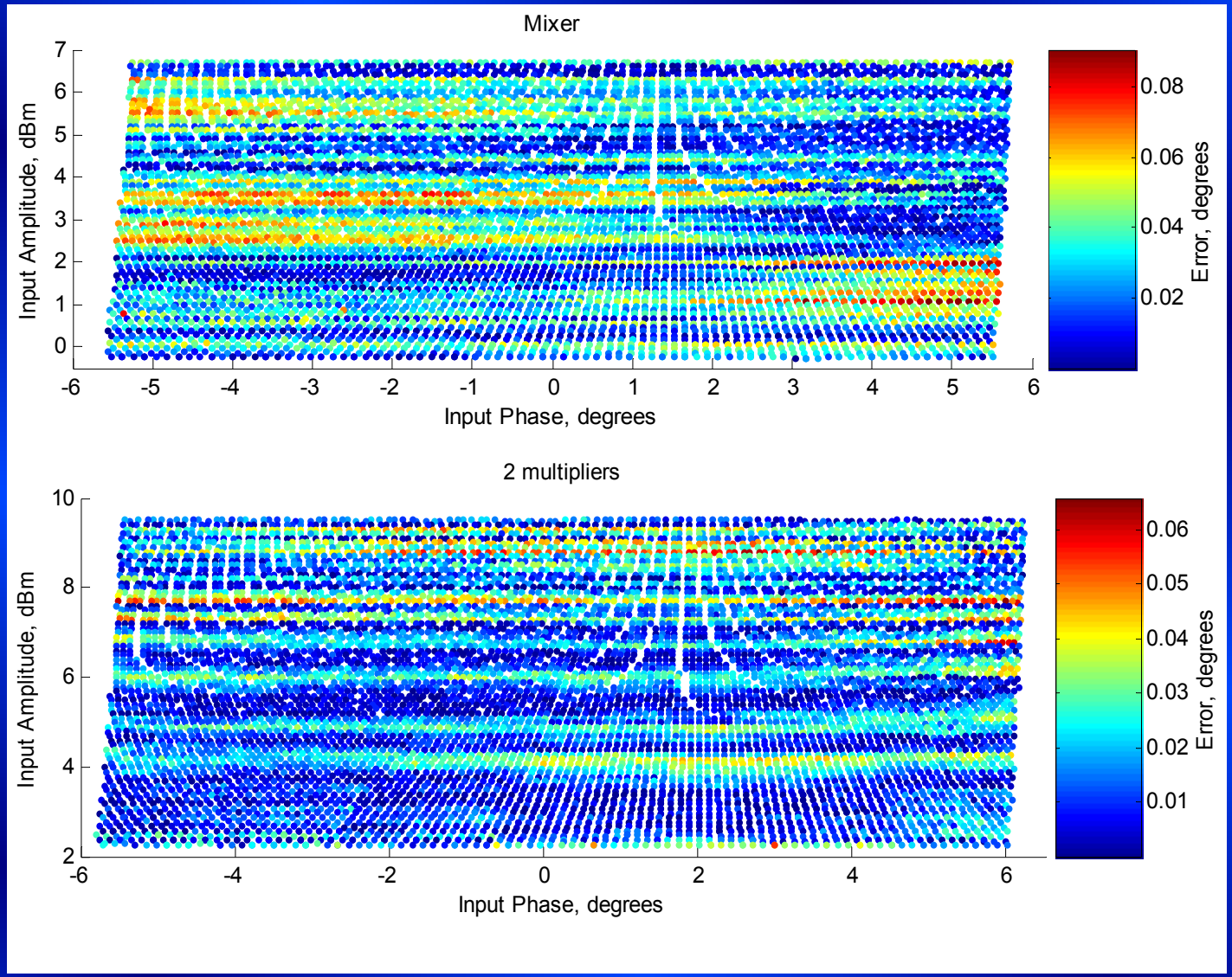
Intermediary Frequency selection

- Devices tested at 250MHz and 750MHz as these frequencies are readily available in CTF3
- Devices found to have good performance at both frequencies
- 750MHz selected as downconversion is more easily implemented with a higher frequency

IF tests

- Two phase detectors:
  - Analog multiplier Analog Devices AD835
  - Double balanced mixer Mini-Circuits ZFM-2000
- Amplitude detector:
  - Analog devices AD8318
- Measure phase detector output and amplitude detector output
- Fit to input phase using polynomial of 3rd order in and first order in

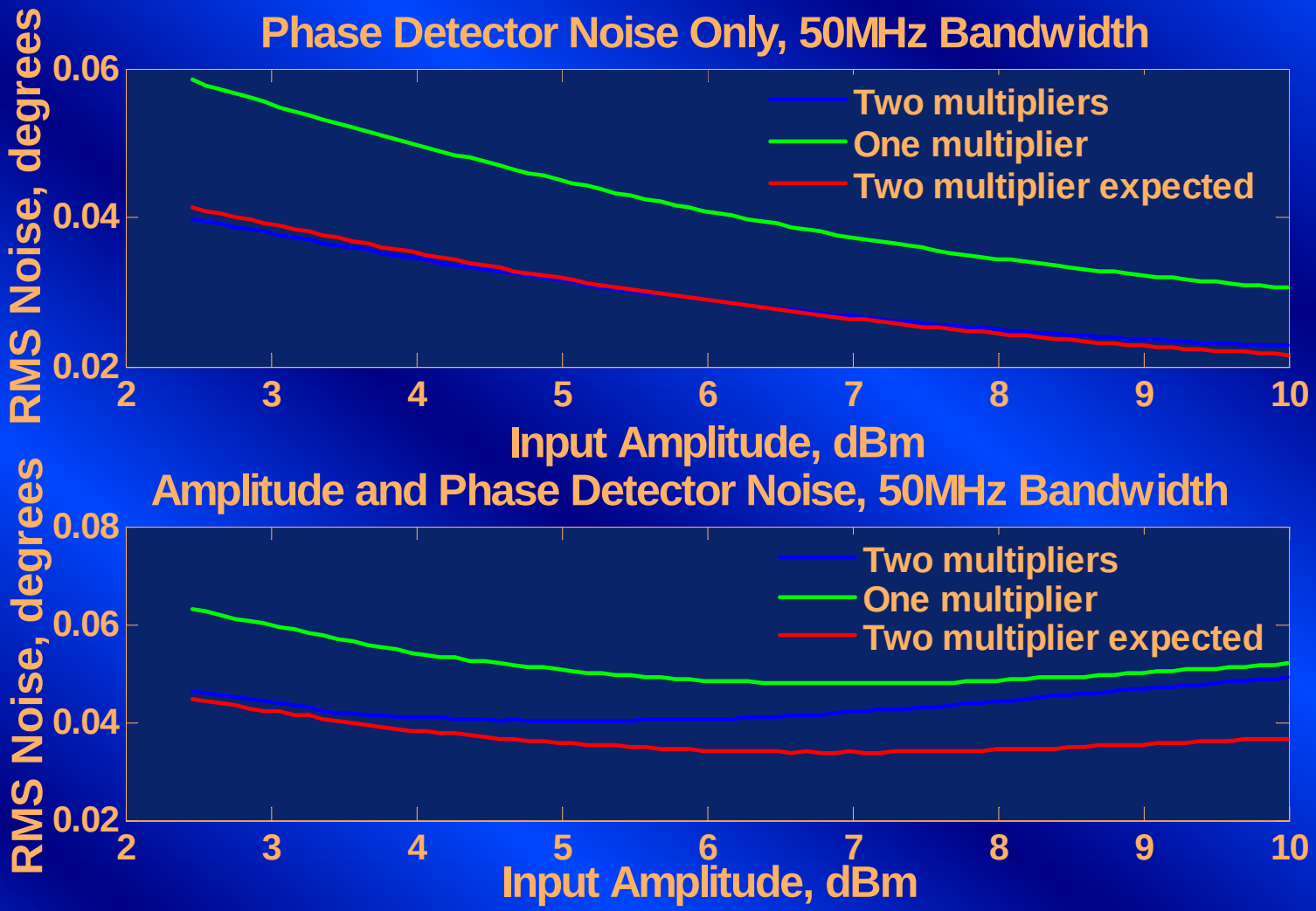
Errors, phase and amplitude fit, 750MHz



Noise

- Two sources of noise, amplitude and phase detectors
- 3rd degree amplitude correction yields more severe impact of amplitude noise at extremes of range.
- Averaging both amplitude and phase detectors necessary.
- Averaging 2 phase detectors yields the expected improvement

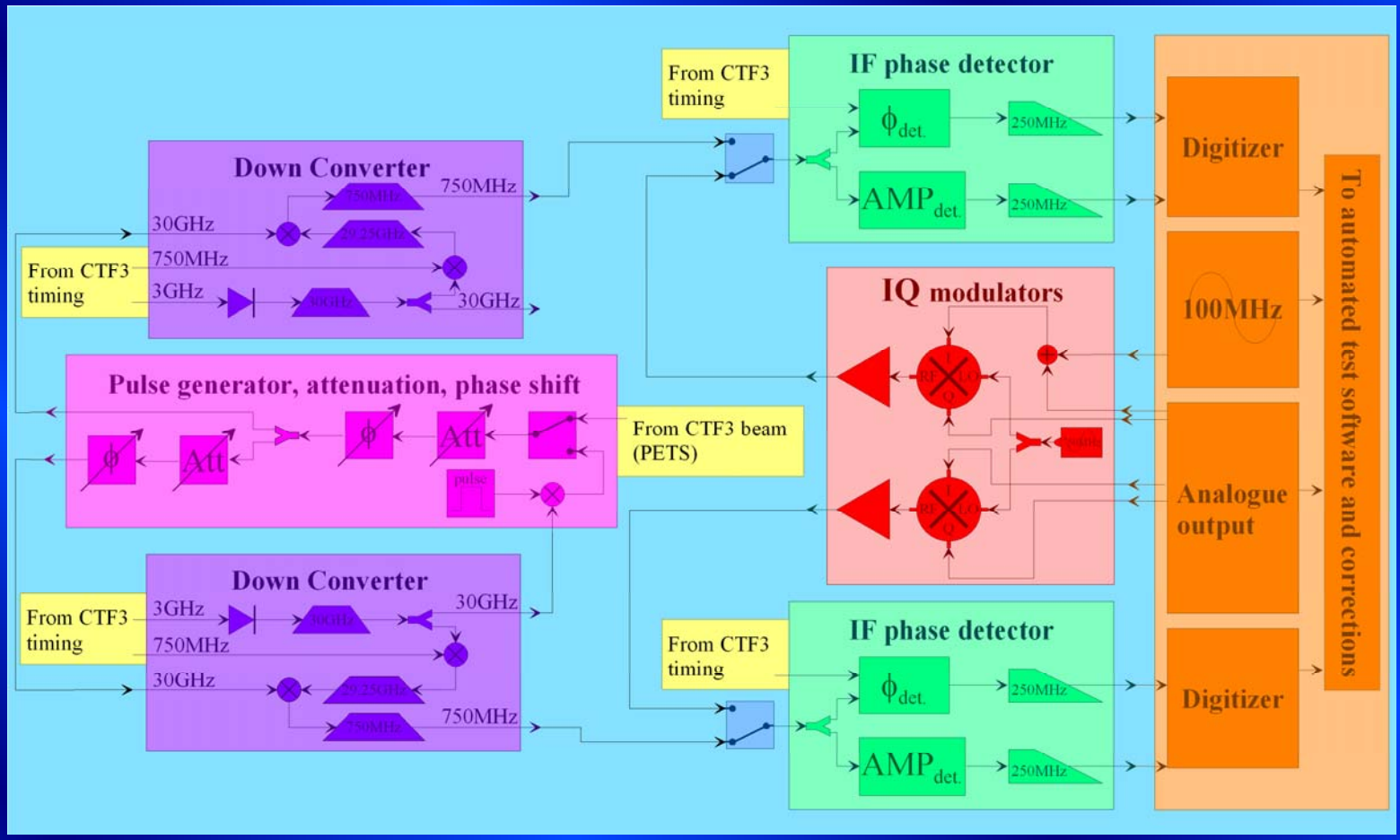
Noise plots


Phase Detector Noise Only, 50MHz Bandwidth
RMS Noise, degrees
0.06
0.04
0.02
2
3
4
5
6
7
8
9
10
Input Amplitude, dBm
Two multipliers
One multiplier
Two multiplier expected
Amplitude and Phase Detector Noise, 50MHz Bandwidth
RMS Noise, degrees
0.08
0.06
0.04
0.02
2
3
4
5
6
7
8
9
10
Input Amplitude, dBm
Two multipliers
One multiplier
Two multiplier expected

PCB

- More than two of both multipliers and amplitude detectors must be averaged for adequate noise reduction
- PCB has been designed 8 amplitude detectors, 8 multipliers in parallel.
- Need to use power splitters as input impedances are too low for direct parallelization

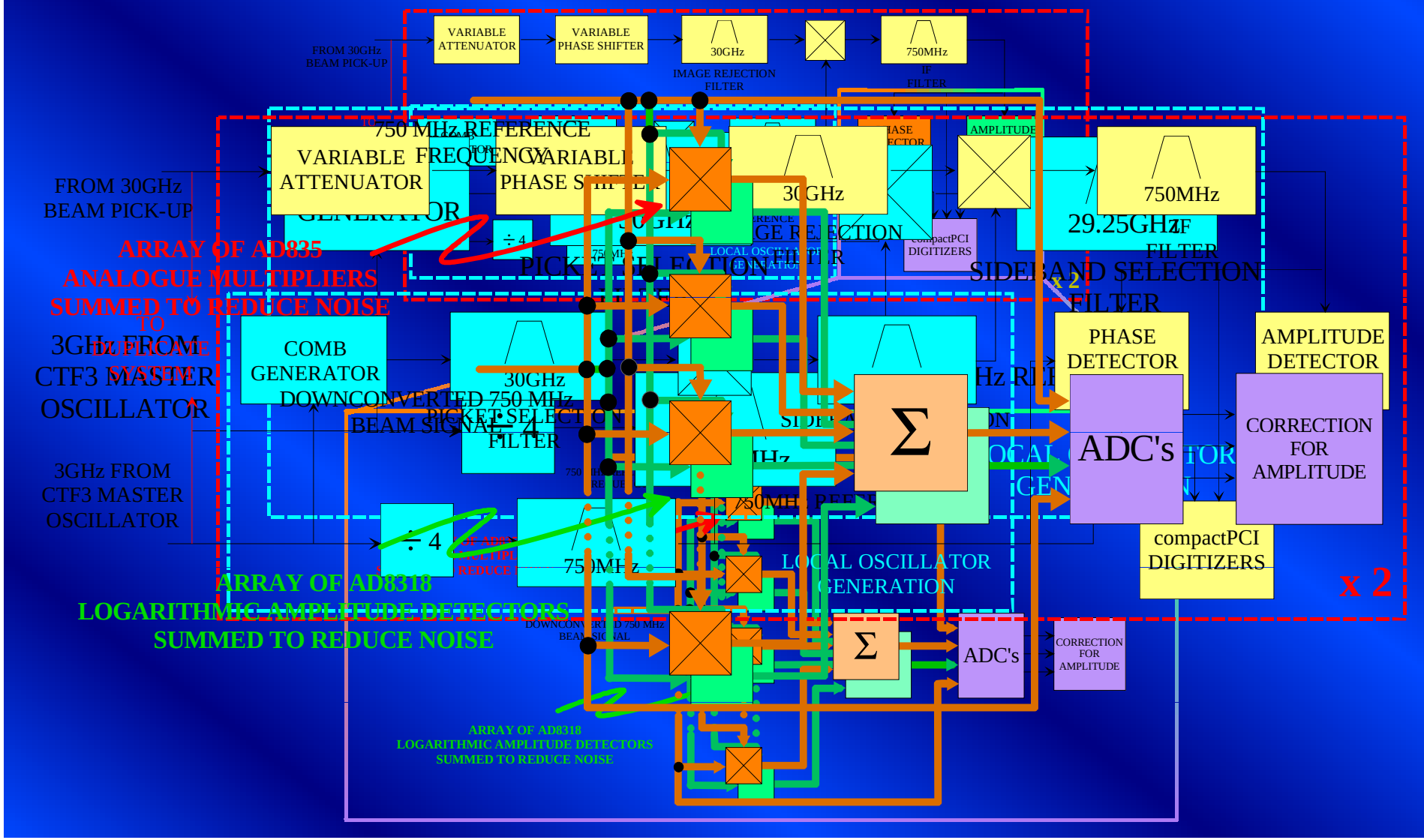
CTF3 installation



CTF test setup

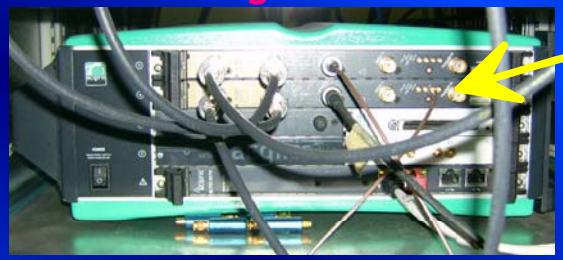
- 30GHz signal is mixed down to 750MHz
- CTF3 beam jitter greatly exceeds the required system accuracy
- Two system are built and compared with each other
- 30GHz reference is generated from CTF3 3GHz timing signal, which is common for both systems
- As the performance with standalone oscillator is not indicated to present a difficulty, the extreme price for such crystals prohibits their acquisition.

IF Downconversion

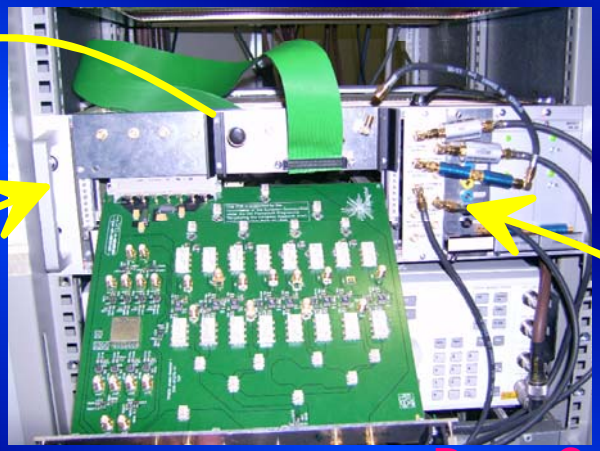


CTF3 installation

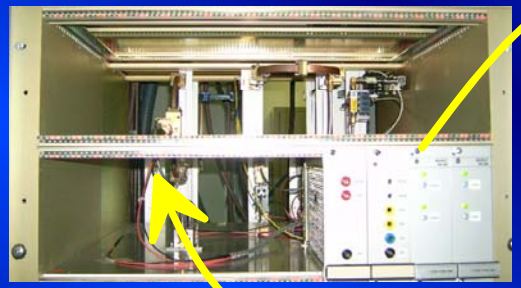
Digitiser



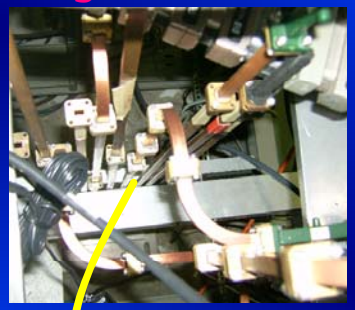
IF detectors



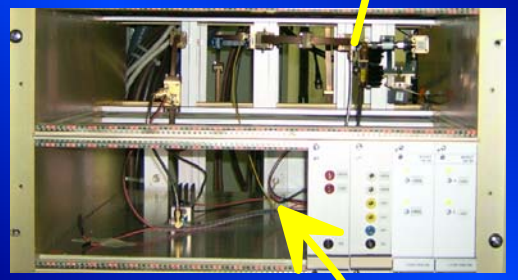
Down Converter



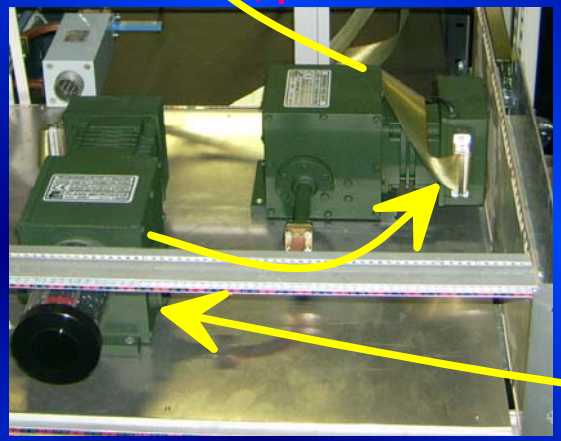
Waveguides from CTF3



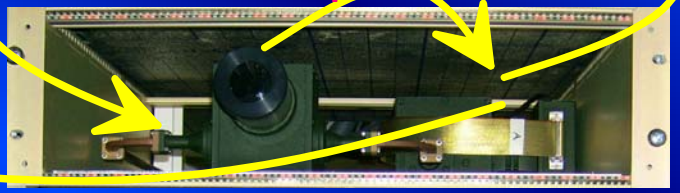
Down Converter



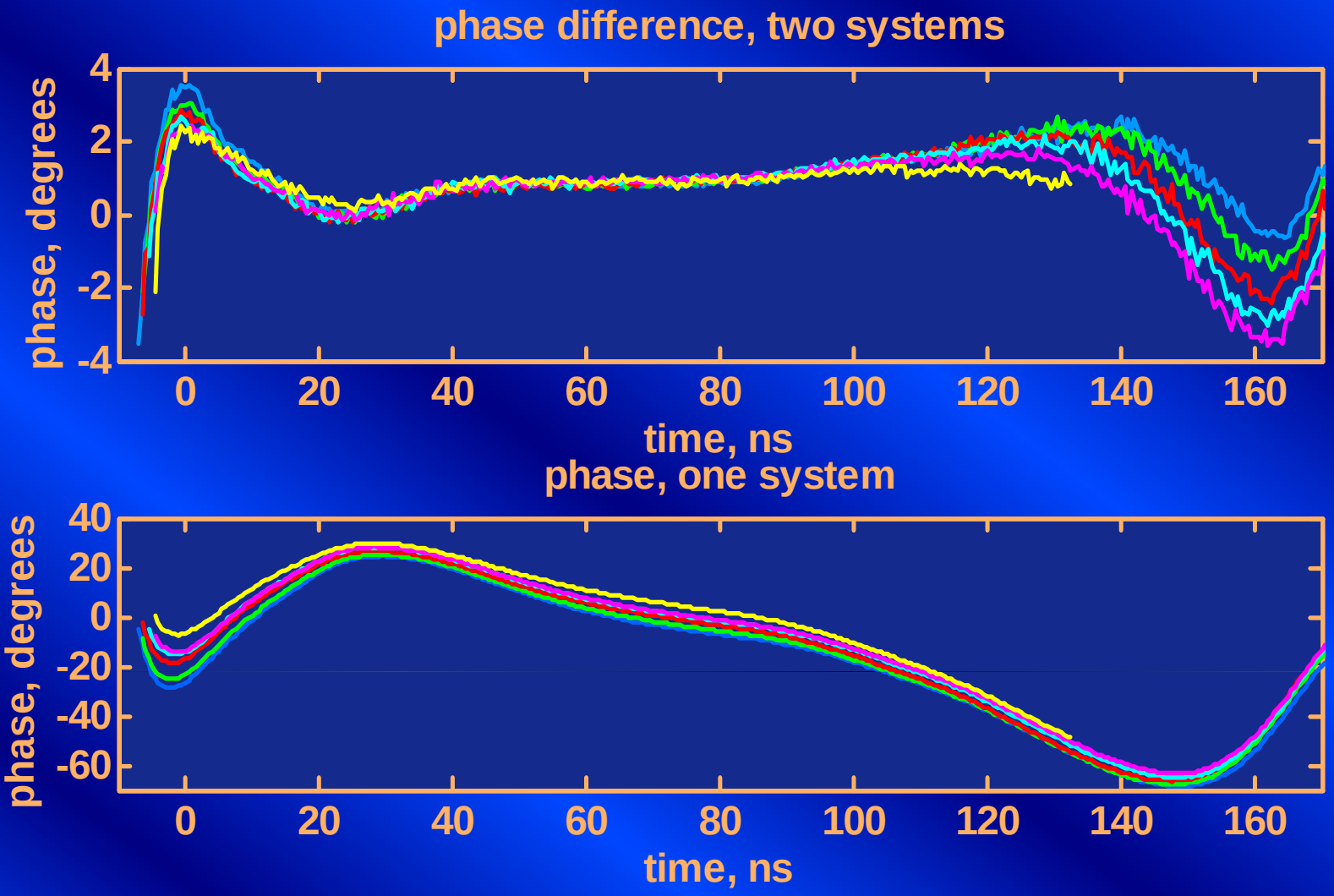
Attenuator, phase shifter



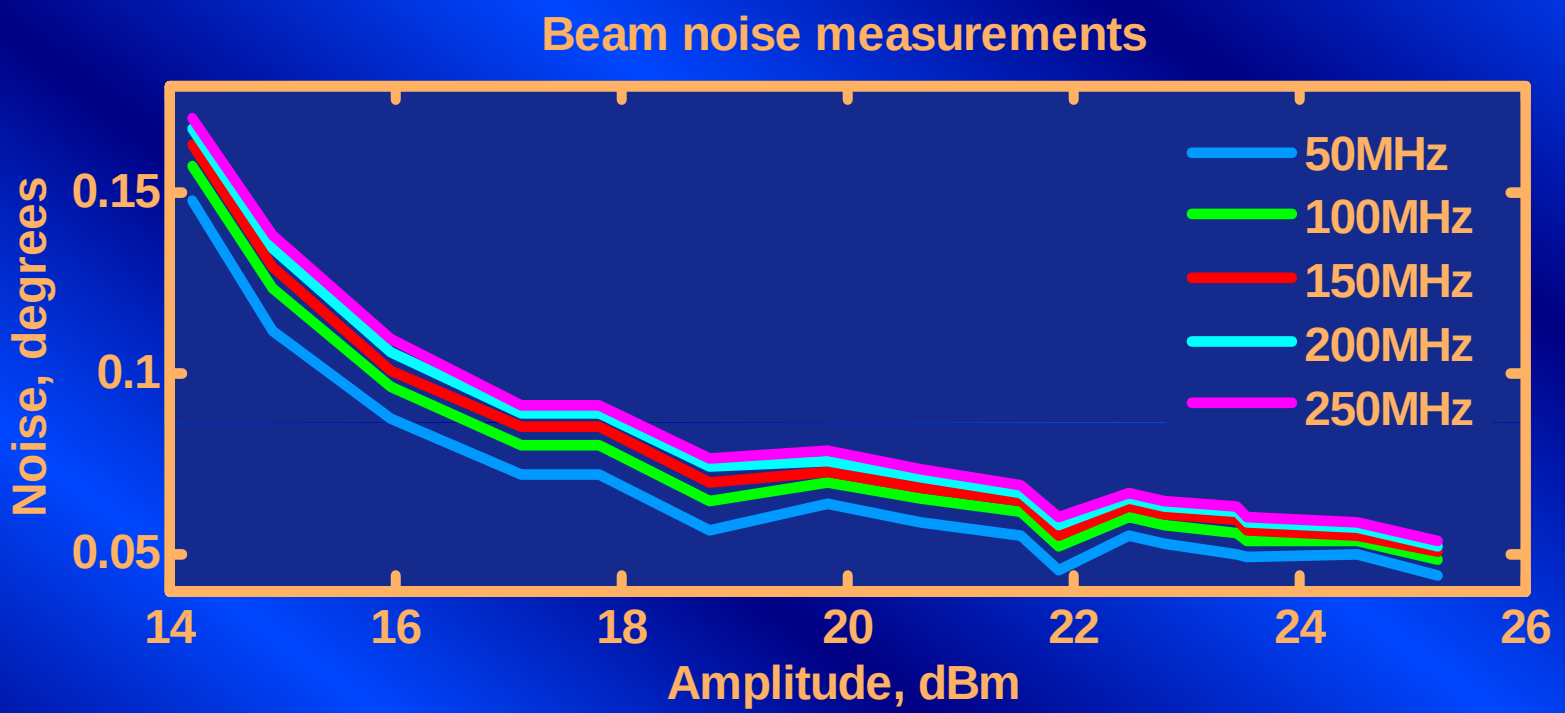
Attenuator, phase shifter



CTF results (1)



CTF3 results (2)

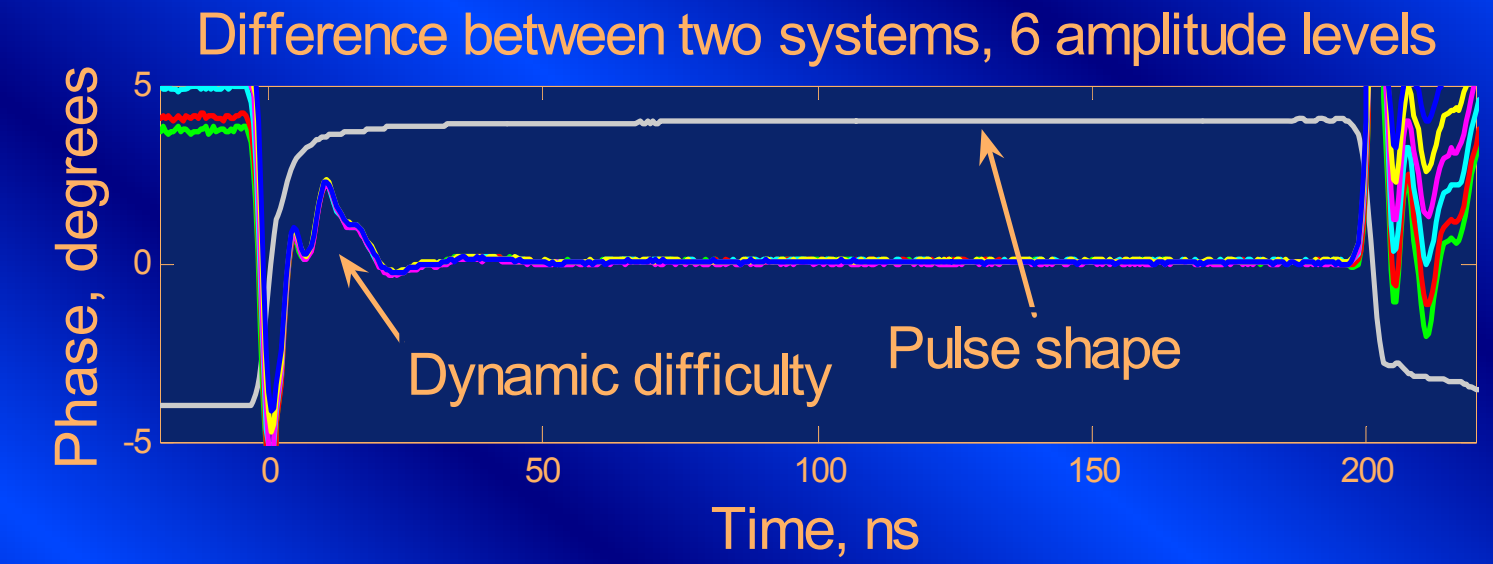


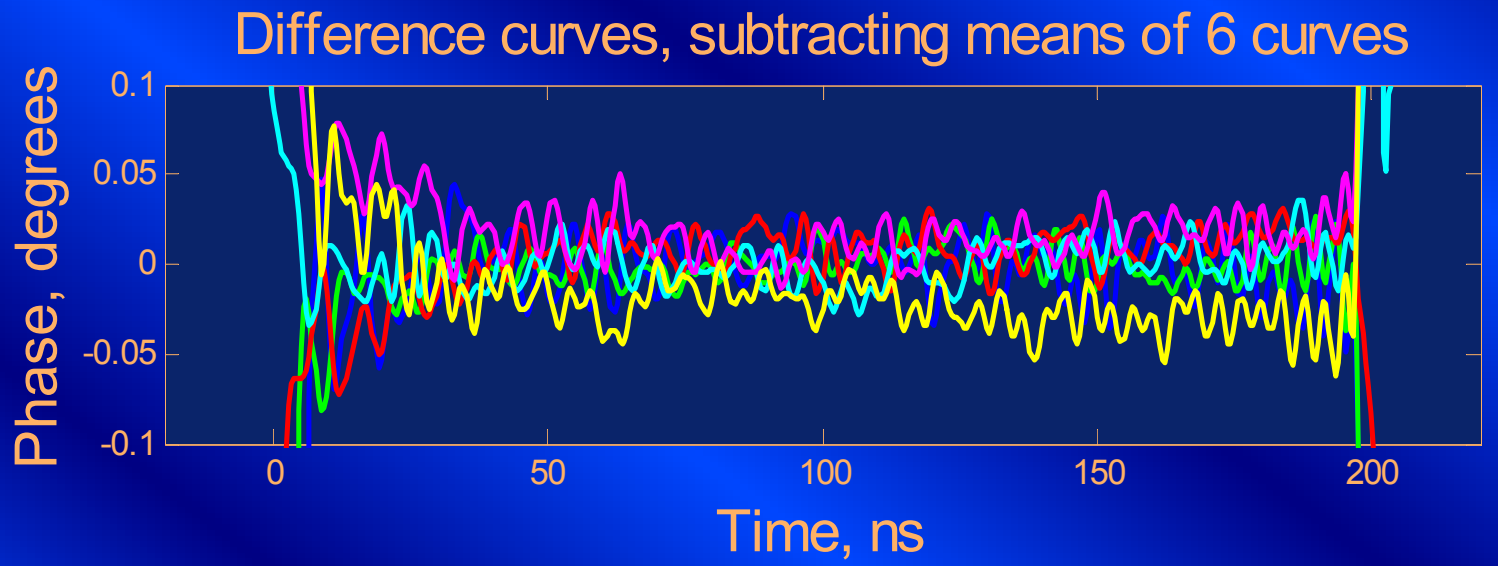
- This is the noise for one system
- Noise measurements look promising from 250MHz and 50MHz

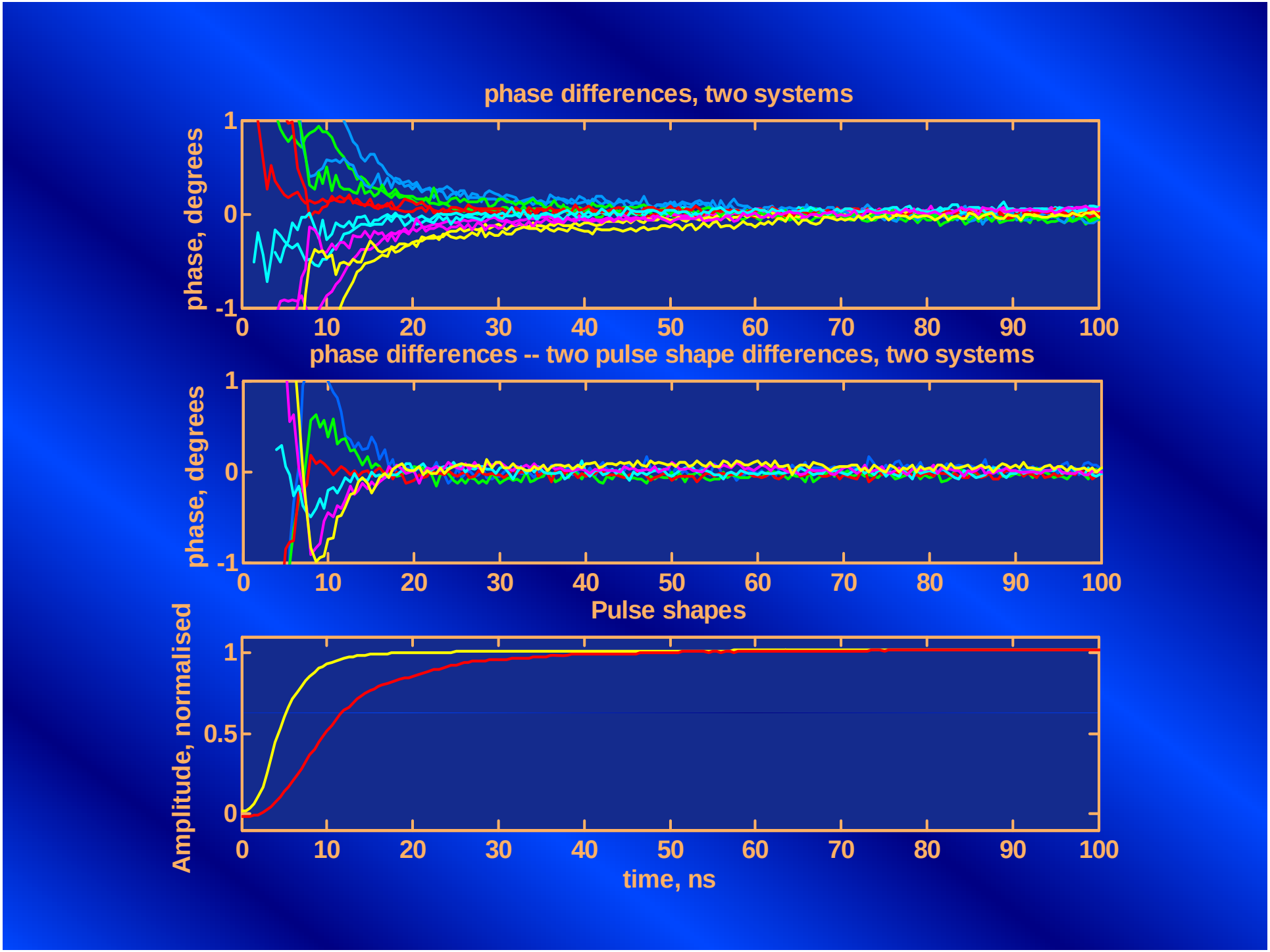
‘Static’ Calibration

- Due to the amplitude dependence of the phase detector, a ‘static’ calibration must be performed to interpret results over a range of amplitudes
- This ‘static’ calibration is done with 100ns RF pulses over a range of amplitudes, using average values over a 30ns interval towards the end of the pulses
- It cannot be done in a non-pulsed system, due to discrepancies most likely due to device heating.
- The duty cylcle of the calibration pulses must be sufficiently low to not alter the average device too much

Static Calibration, results



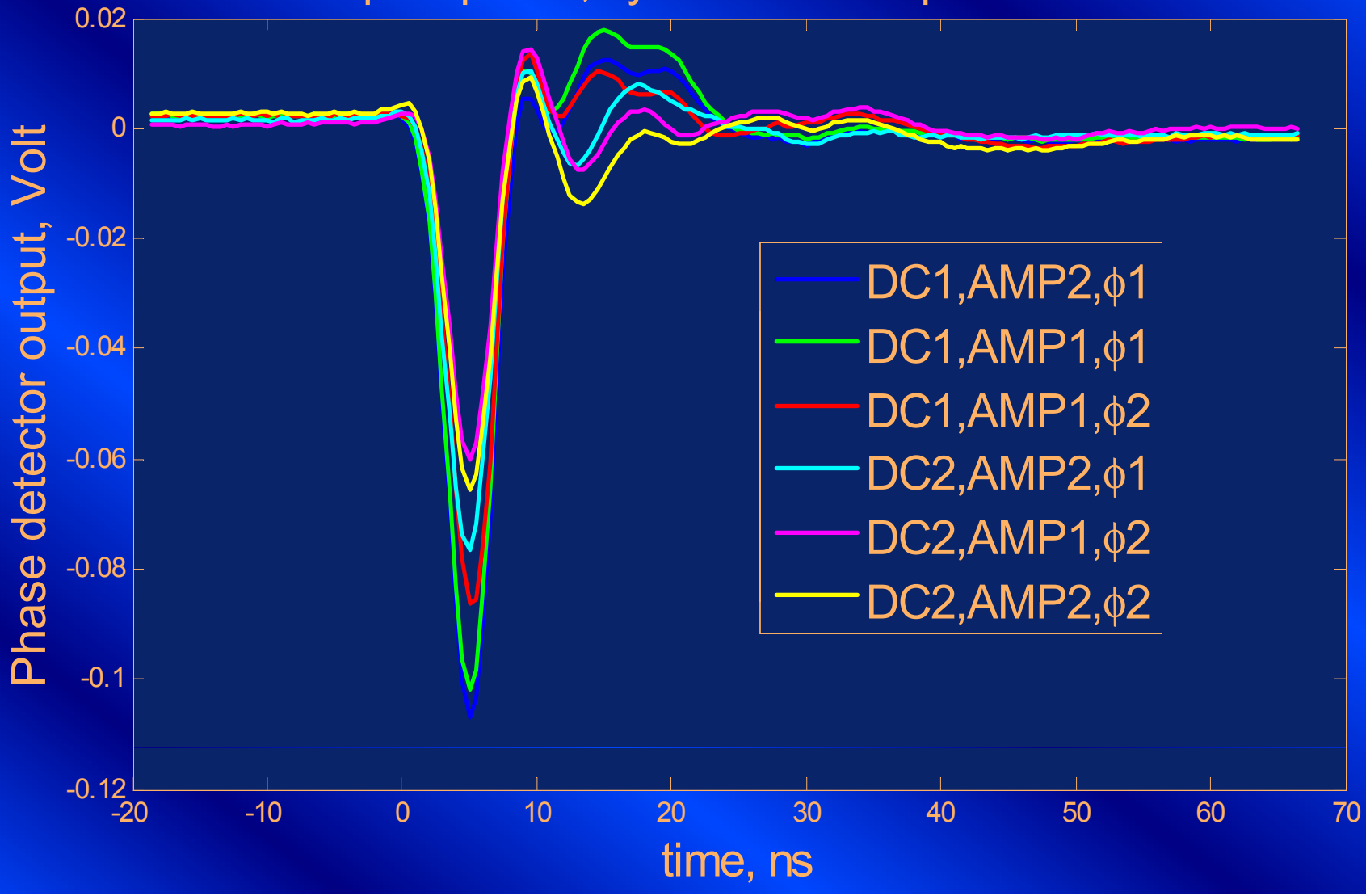



phase differences, two systems
phase, degrees
1
0
-1
0
10
20
30
40
50
60
70
80
90
100
phase differences -- two pulse shape differences, two systems
phase, degrees
1
0
-1
0
10
20
30
40
50
60
70
80
90
100
Pulse shapes
Amplitude, normalised
1
0.5
0
0
10
20
30
40
50
60
70
80
90
100
time, ns

Dynamic Calibration

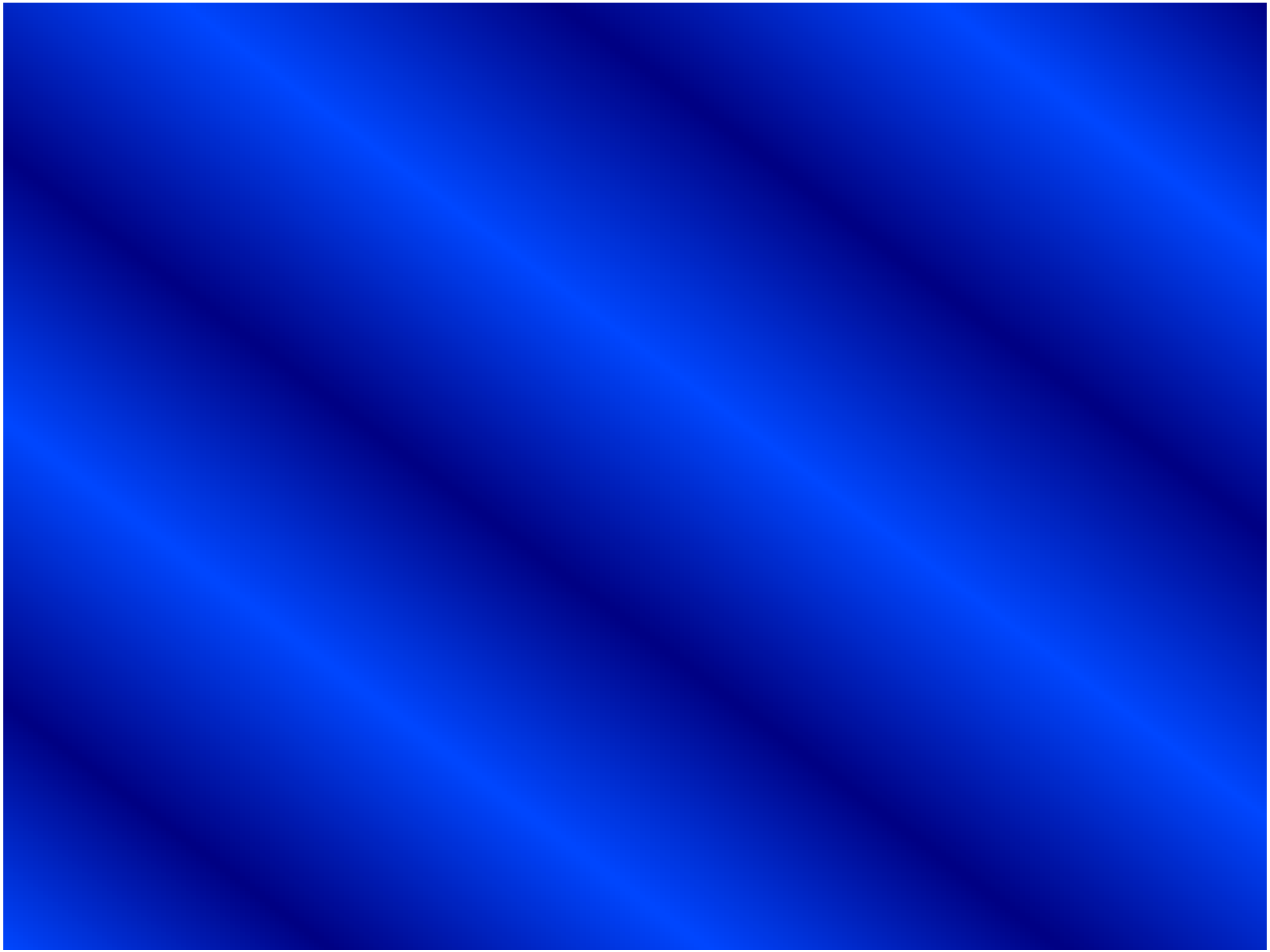
- There is a difference between the two systems with a pulse input
- It will be necessary to characterize and correct this imperfection
- First (naïve) attempts to numerically compute a correction based on pulse shape have yielded a small improvement.
- Further study necessary

Step response, localization of dynamic error



Dynamic modeling

- The main source of the problem is in the down converter (probably the mixer)
- Further work to localize the problem will be undertaken
- We are hoping that this error might be possible to model in an ad hoc manner with a simulation program



Phase detection scheme in CLIC