Beam phase measurement with single bunch
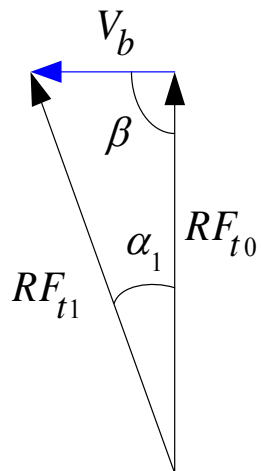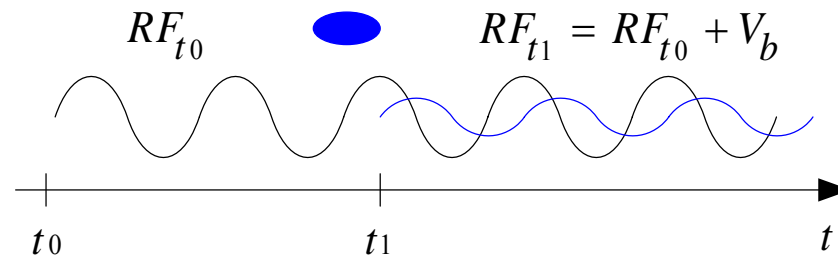
low level radio frequency

FLASH seminar

15.04.2008

HELMHOLTZ
| GEMEINSCHAFT

Goals
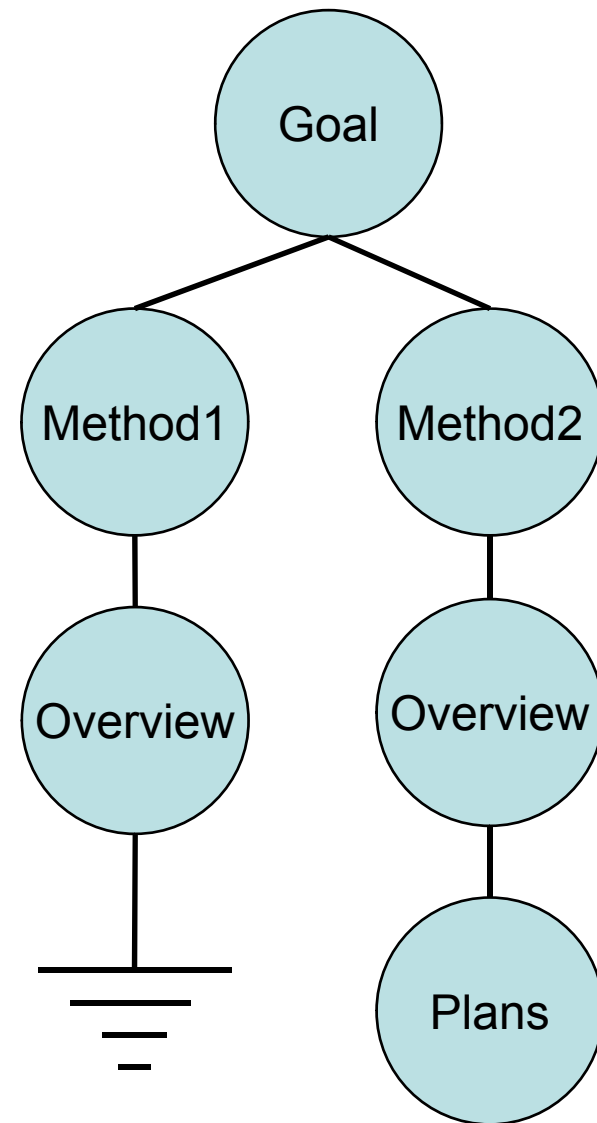
- Setup linac cavities beam phase with low charge

- Beam phase monitoring

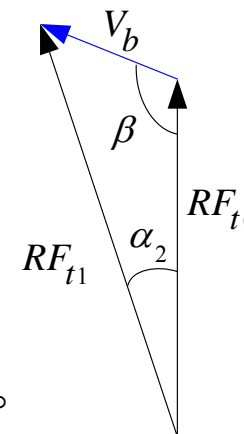- Vector sum calibration with low charge

Direct measurement

Conditions: $q_b = 1\,nC$ $RF_{t0} = 21 \cdot 10^3\,kV$ $V_b \approx 4\,kV$ $V_b = 2 \cdot \omega_{1/2} \cdot q_b \cdot R_L$

$$\beta = 90°$$

$$\alpha 1 \approx 0.01112629°$$
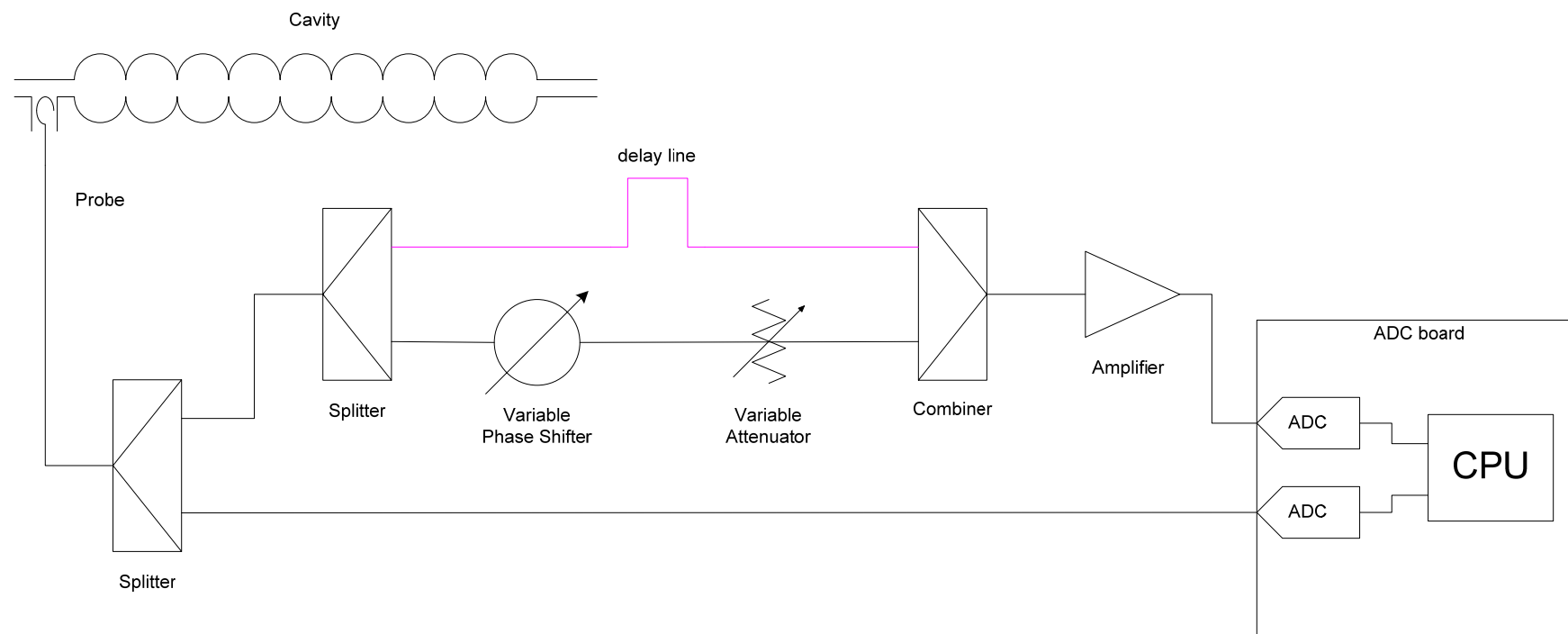
$$RF_{t1} \approx 21.00000039 \cdot 10^3\,kV$$

$$\beta = 90.5°$$

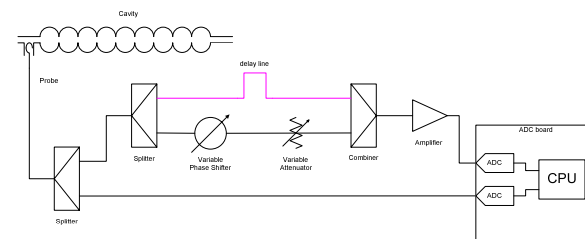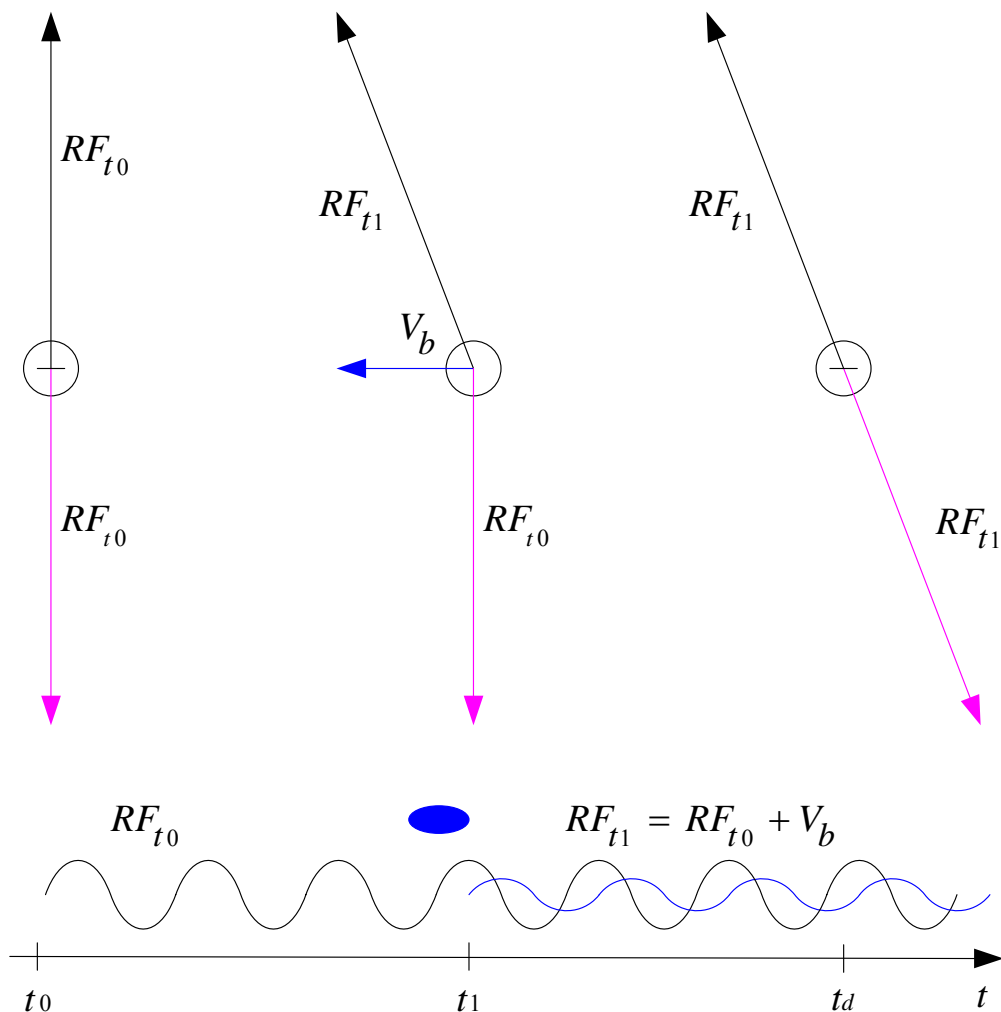$$\alpha 2 \approx 0.01112585°$$

$$RF_{t1} \approx 21.00003598 \cdot 10^3\,kV$$

$$\Delta\alpha = \alpha 1 - \alpha 2 \approx 4.43 \cdot 10^{-7°}$$

$$\Delta RF_{t1} \approx 35.59V$$

Transient Detection System
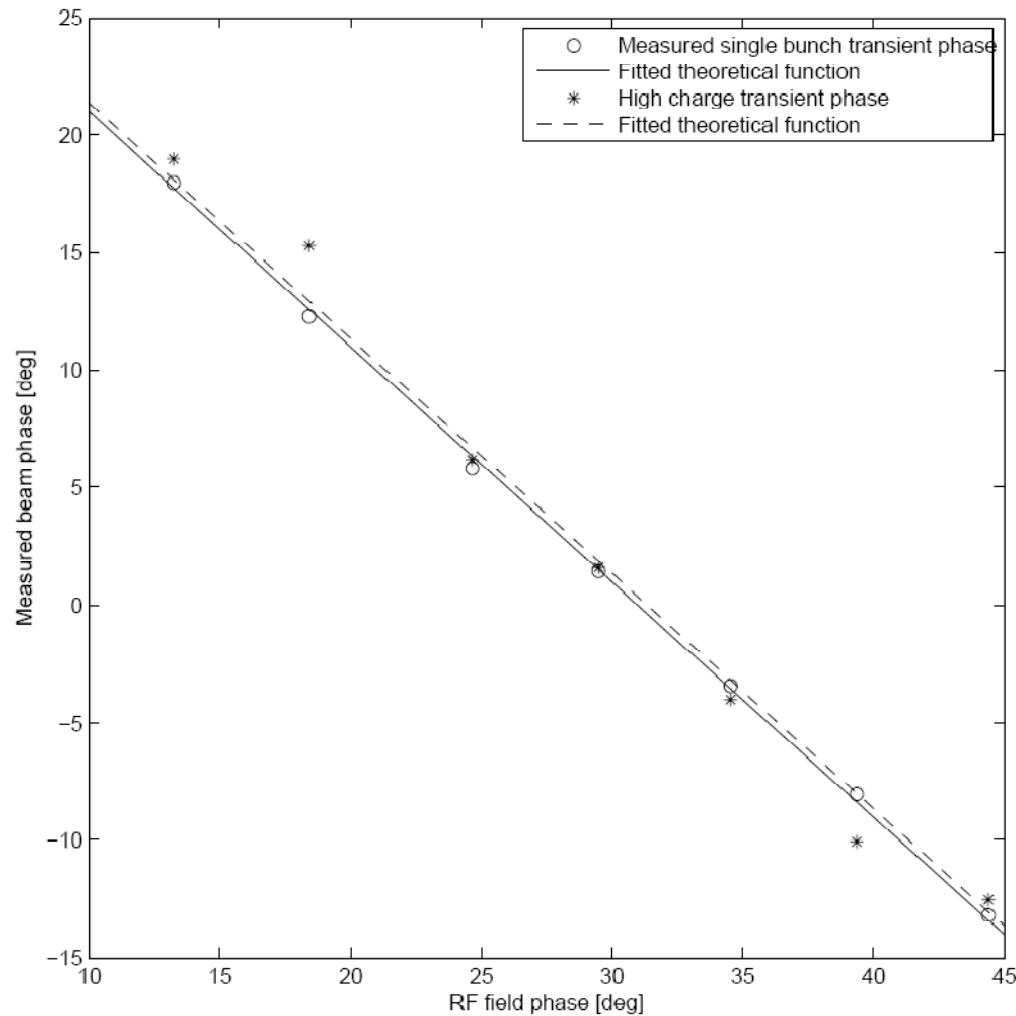
Cavity

Probe

delay line

Splitter

Variable
Phase Shifter

Variable
Attenuator

Combiner

Amplifier

ADC board

ADC

ADC

CPU

Splitter

Idea of Transient Detection System

RF_{t0}

RF_{t1}

RF_{t1}

V_b

RF_{t0}

RF_{t0}

RF_{t1}

RF_{t0}

$RF_{t1} = RF_{t0} + V_b$

t_0 t_1 t_d t

Measured phase comparison ACC1 cavity 3
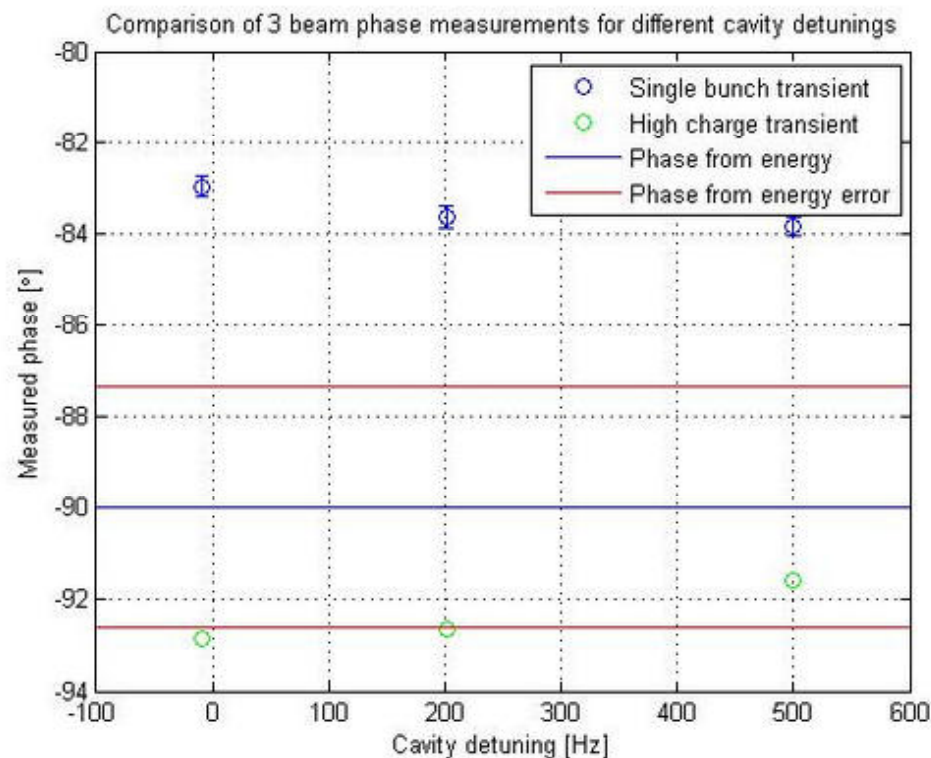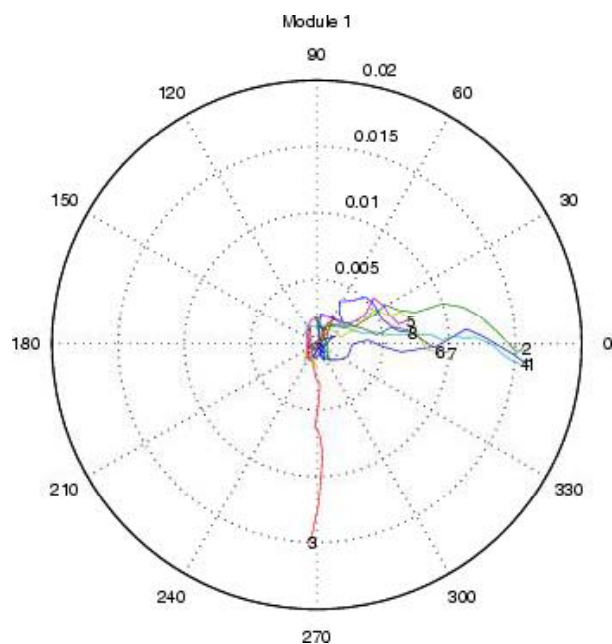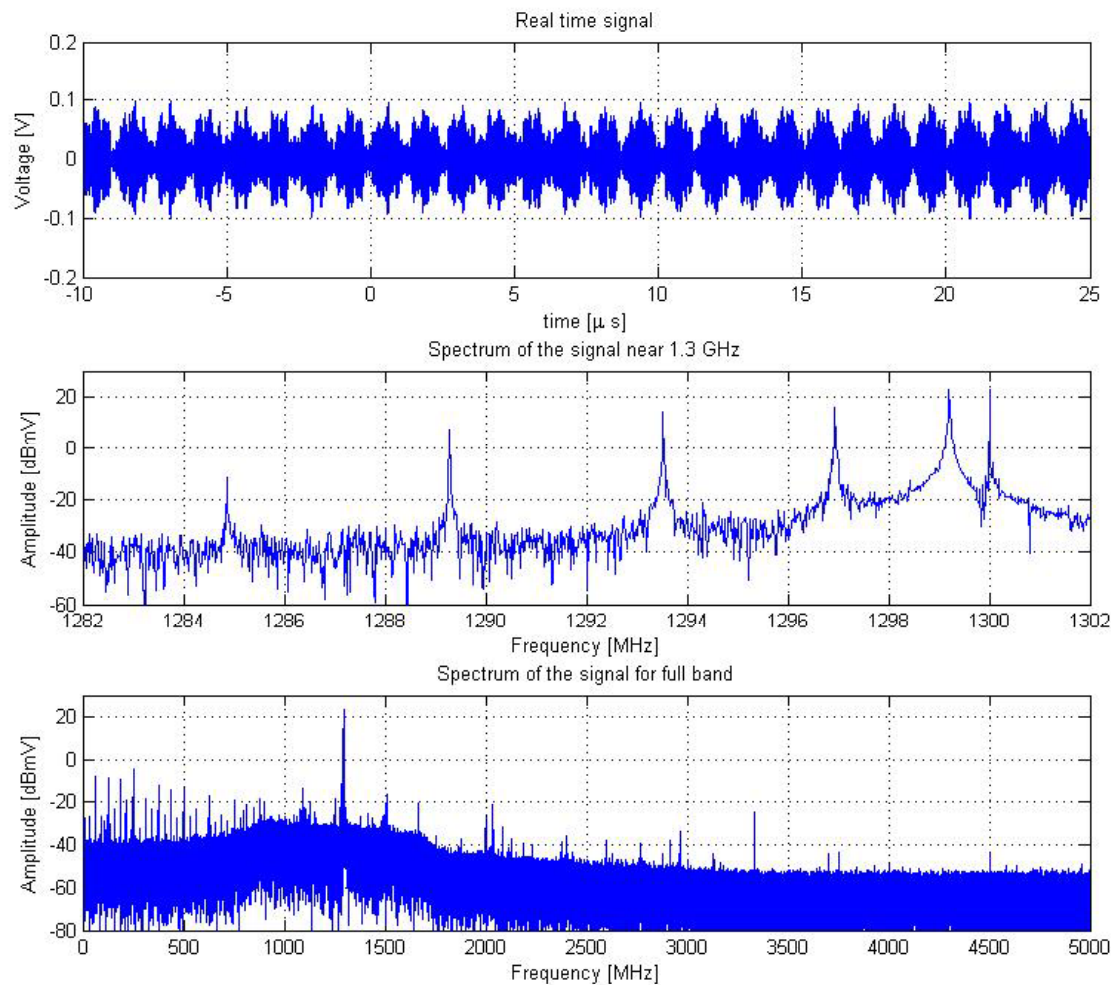

Condition:

- RF phase setps 5°
- Bunch charge 1 nC

Measured phase comparison ACC1 cavity 3

Probe spectrum

Condition:

- Klystron on
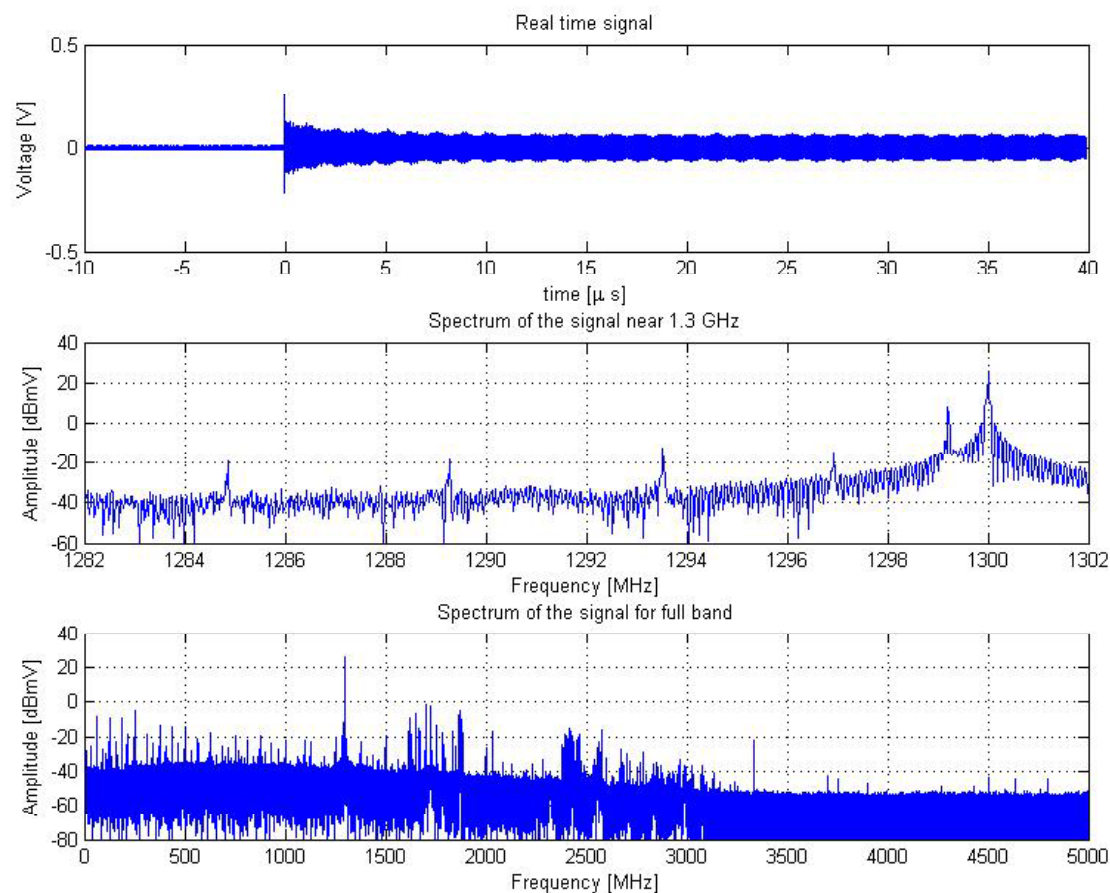- No bunch

Probe spectrum
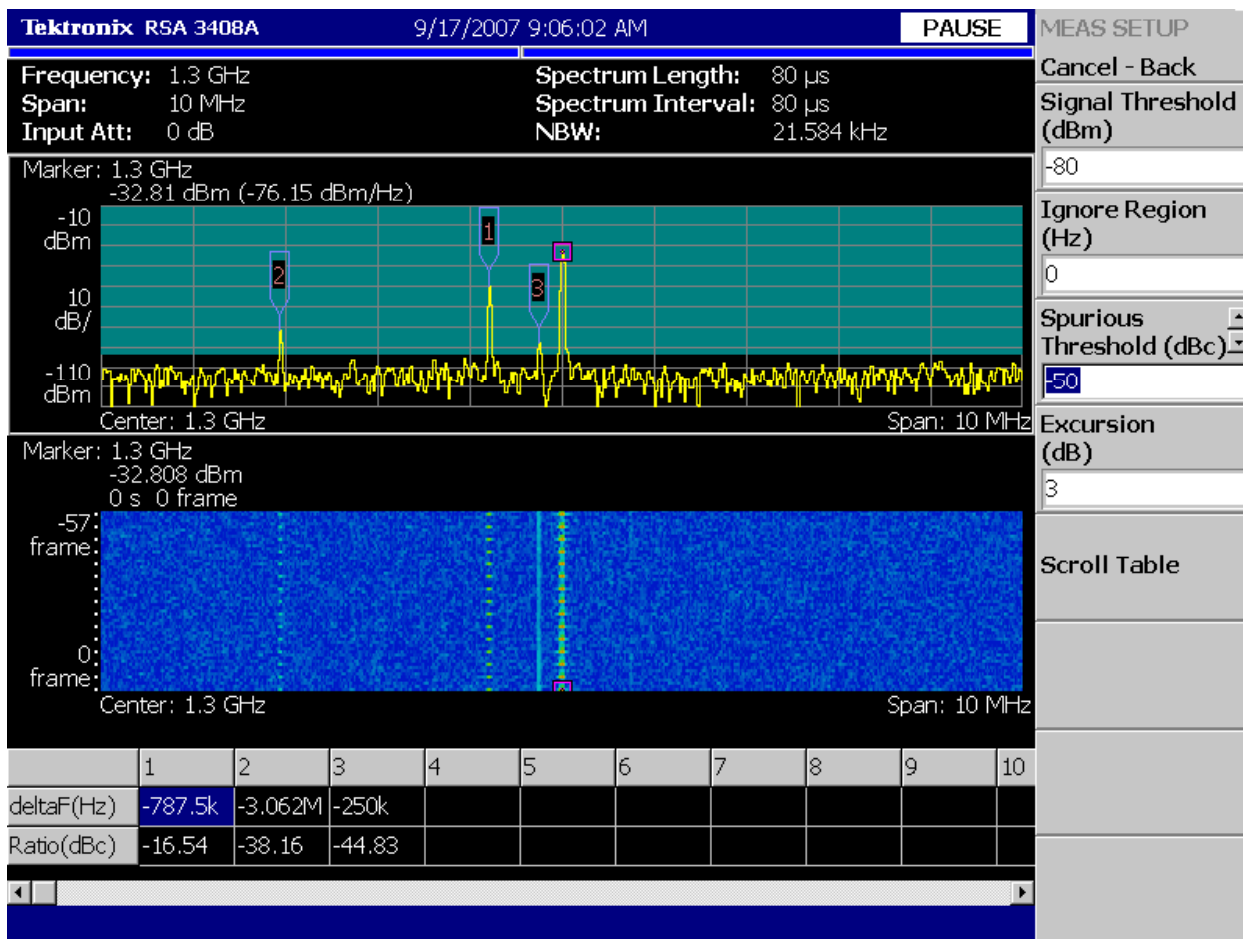

Condition:

- Klystron off
- Bunch 2 nC
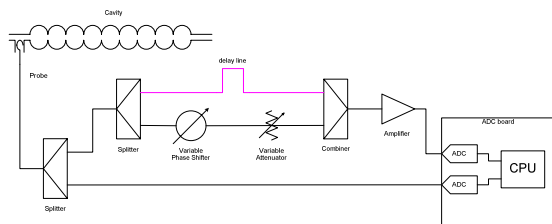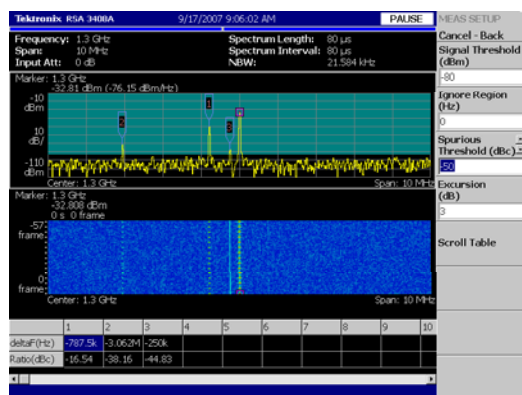
RF bunch spectrum

Condition:

- ACC1/C8
- Kly3 off
- Modulator off
- Bunch ~3.2nC
- Gun pulse 120us

Main difficulties

Manual adjustment of the transient
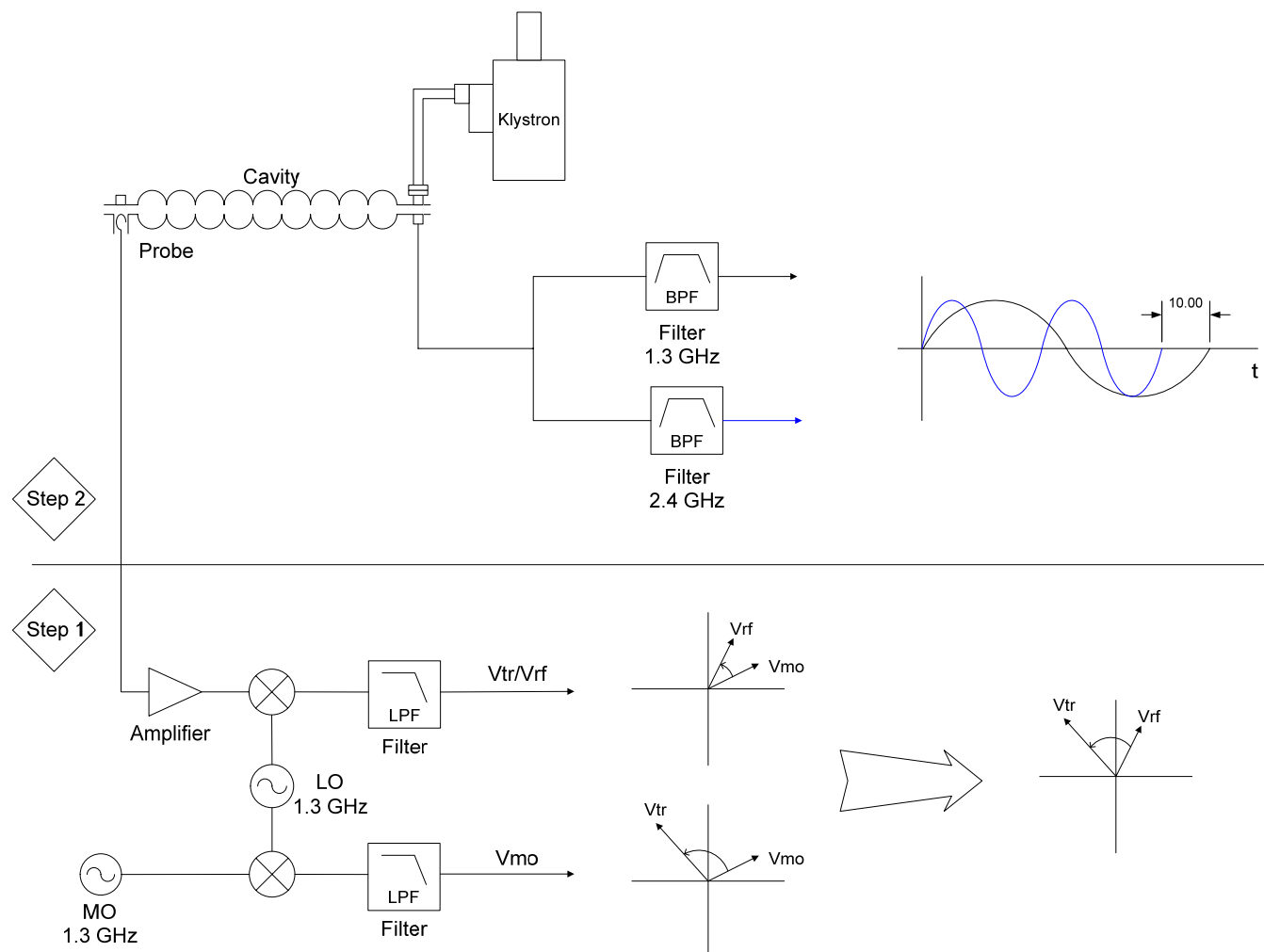
detection system

Other modes of a cavity (8/9 π, …)

€   ~40.000

Measurement has offset of ~7°

- which impossible to calibrate

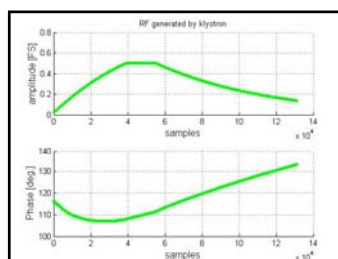- changes as function of time (time variant)
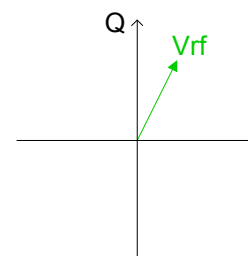
Beam phase monitor

Operation

Start-up

1. Measurement conditions :
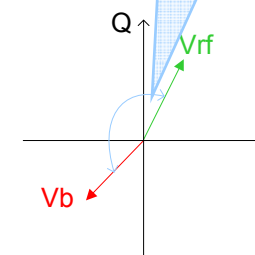
RF   - on
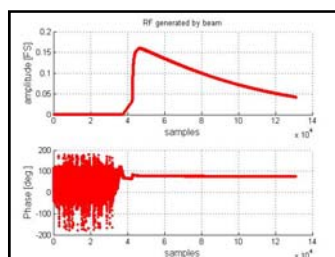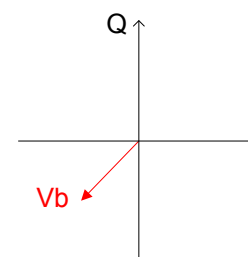Beam   - off
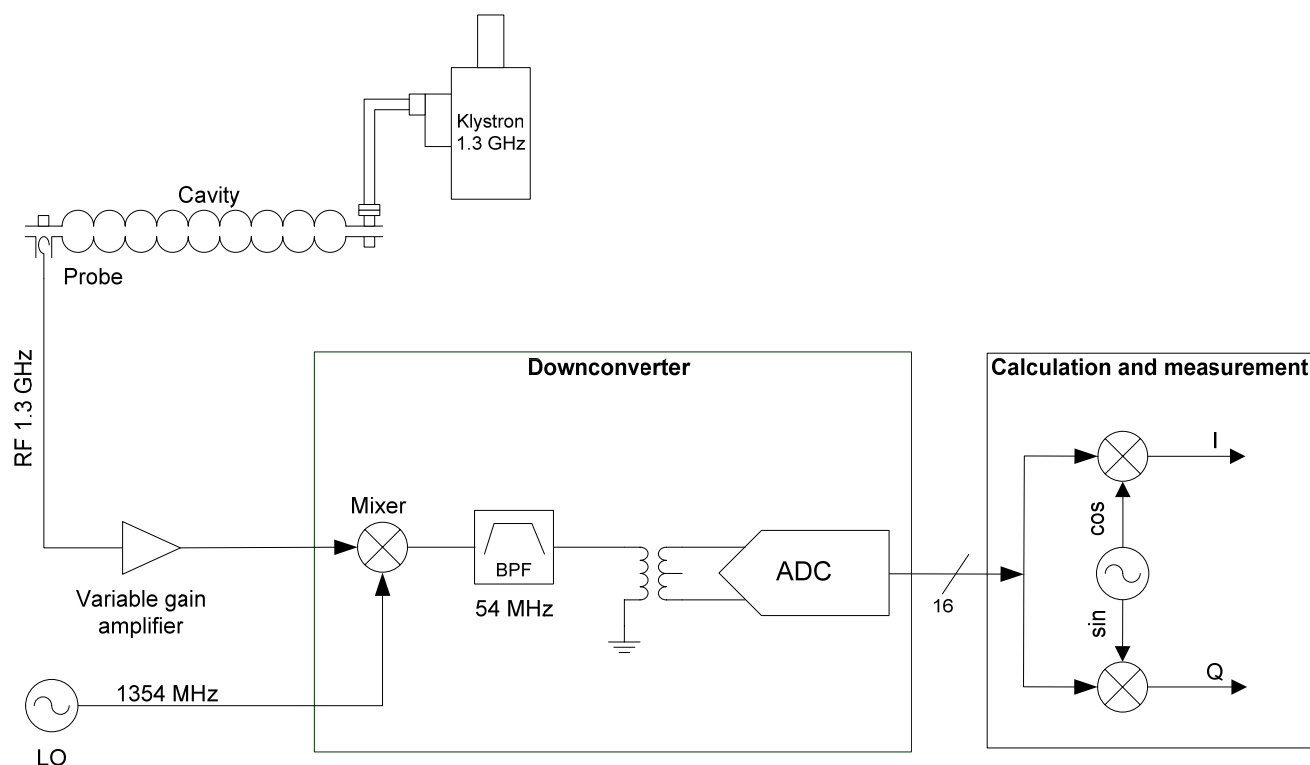

calculation

Beam phase

+ =

2. Measurement conditions :
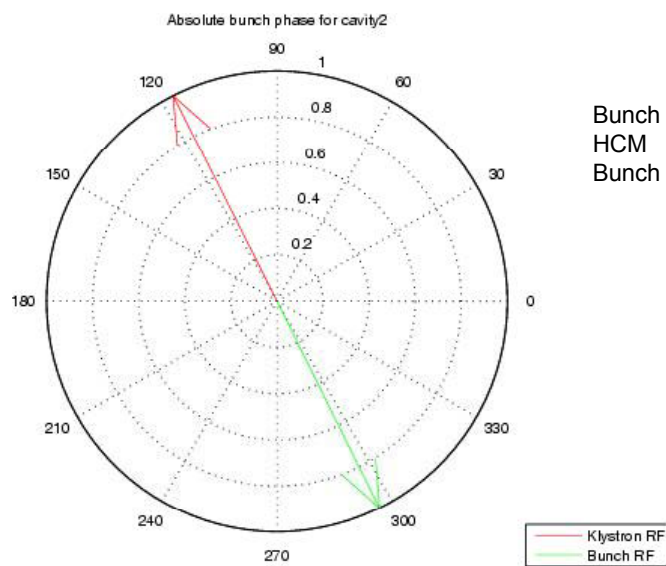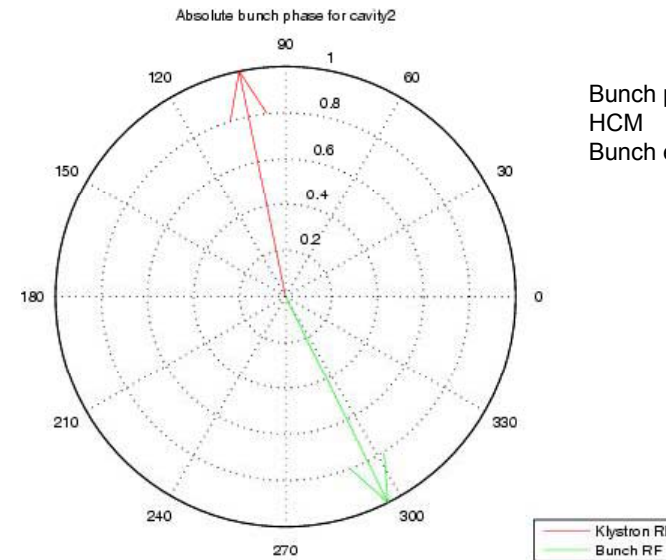
RF   - off
Beam   - on

calculation

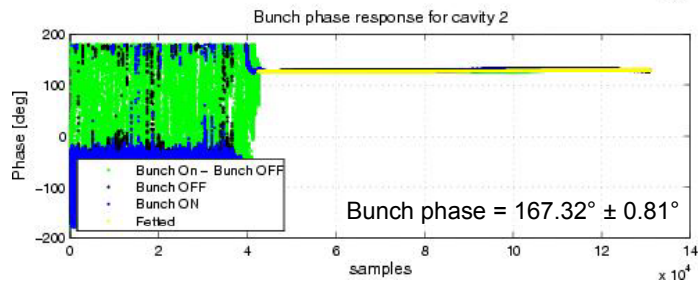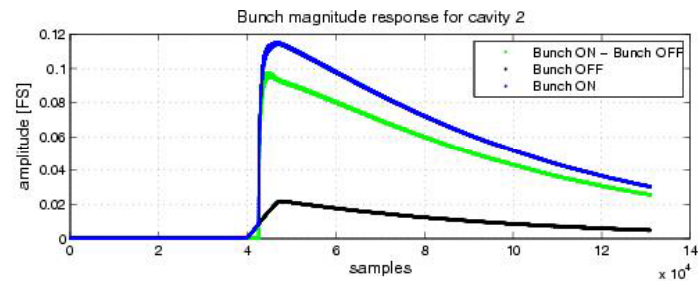Klystron 1.3 GHz

Cavity

Probe

RF 1.3 GHz

Downconverter

Calculation and measurement

Variable gain amplifier

Mixer

BPF
54 MHz

ADC

16

I

cos

sin

Q

1354 MHz

LO

Hardware and software :

- ▪ variable gain amplifier: -100 dB to +48 dB
- ▪ new downconverter, IF 54MHz
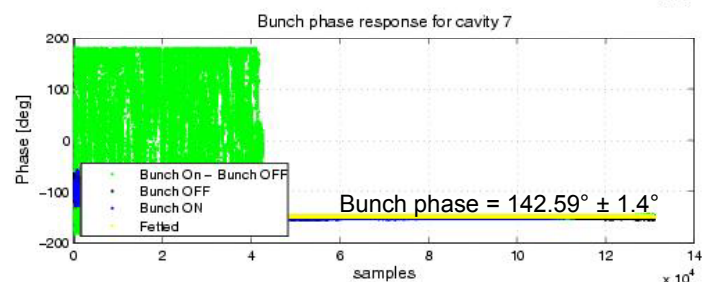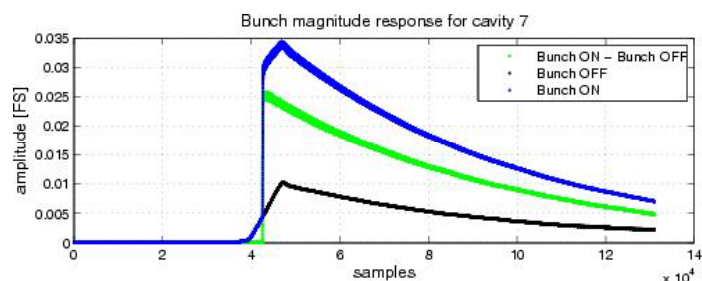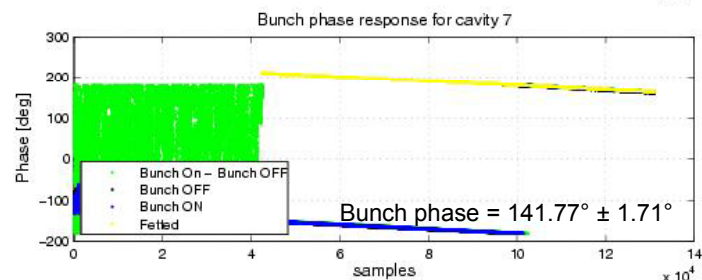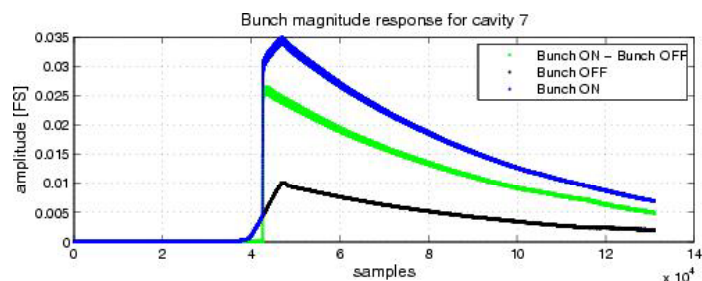- ▪ Advanced-Carrier-Board (ACB2.0), based on FPGA
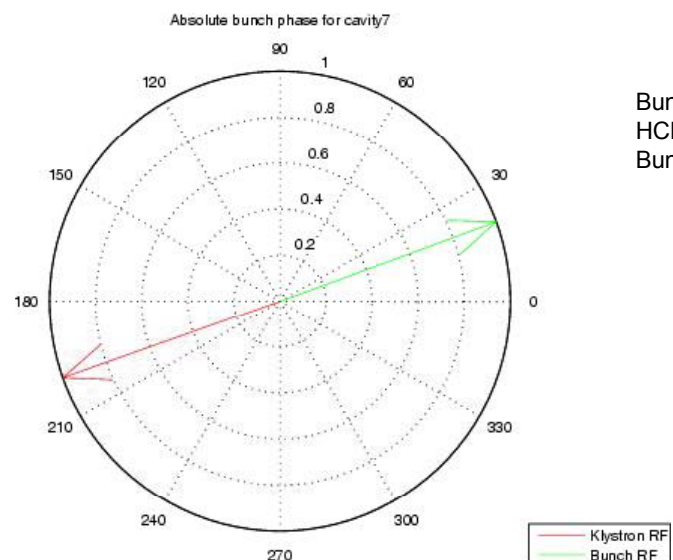- ▪ MatLab for I/Q calculation
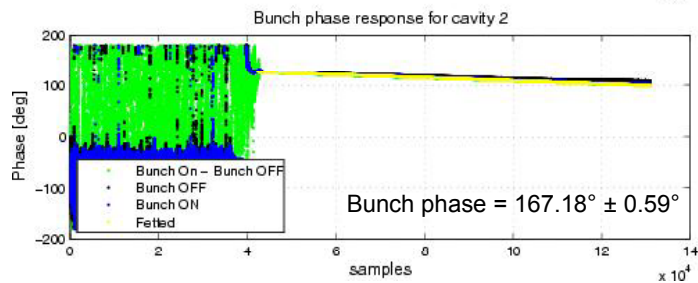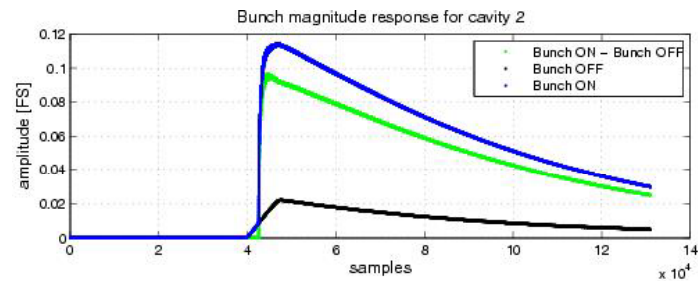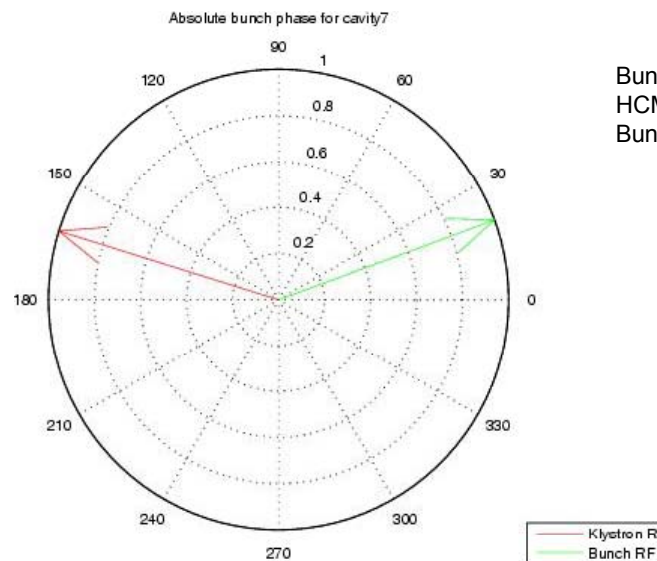
Bunch phase = 165.20° ± 0.63°
HCM   =   7.72° ± 2.32°
Bunch energy = 120.6 MeV

Bunch phase = 180.38° ± 0.63°
HCM   =   7.72° ± 2.32 °
Bunch energy = 120.6 MeV

Bunch phase = 142.51° ± 0.45°
HCM   = -22.57° ± 1.36°
Bunch energy = 120.6 MeV

Bunch phase = 141.77° ± 1.71°

Bunch phase = 178.87° ± 0.45°
HCM   = -22.57° ± 1.36 °
Bunch energy = 116.2 MeV

Bunch phase = 142.59° ± 1.4°

Measured phase comparison

	Cavity 1	Cavity 2	Cavity 3	Cavity 7
New:	183.57	165.2	164.48	142.51
HCM:	3.16	7.72	-1.33	-22.57

Bunch phase = 142.51° ± 0.45°
HCM   = -22.57° ± 1.36°
Bunch energy = 120.6 MeV

Bunch phase = 141.77° ± 1.71°

Bunch phase = 178.87° ± 0.45°
HCM   = -22.57° ± 1.36 °
Bunch energy = 116.2 MeV

Bunch phase = 142.59° ± 1.4°

Bunch magnitude response for cavity 1

Bunch phase response for cavity 1
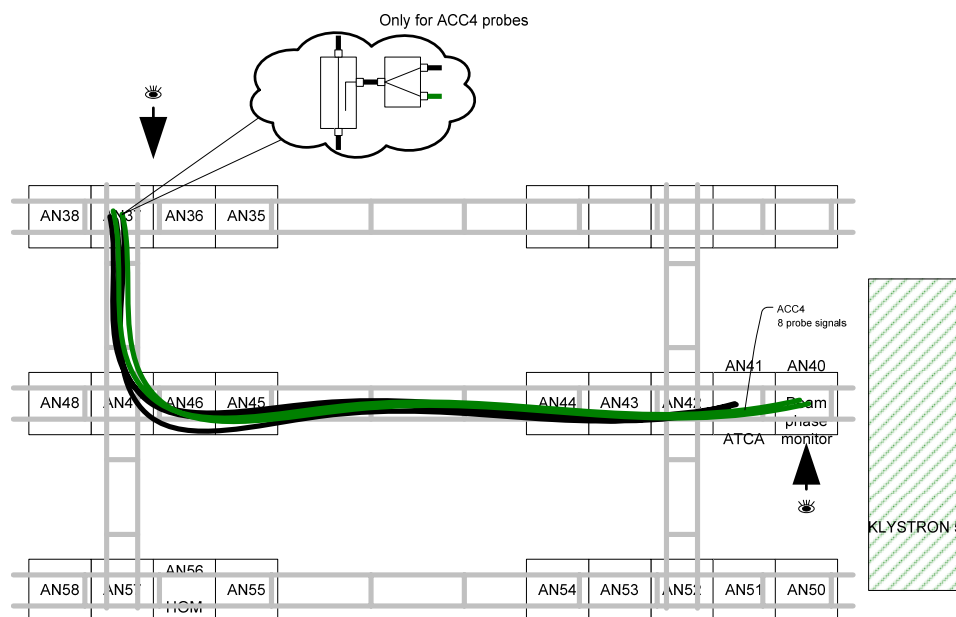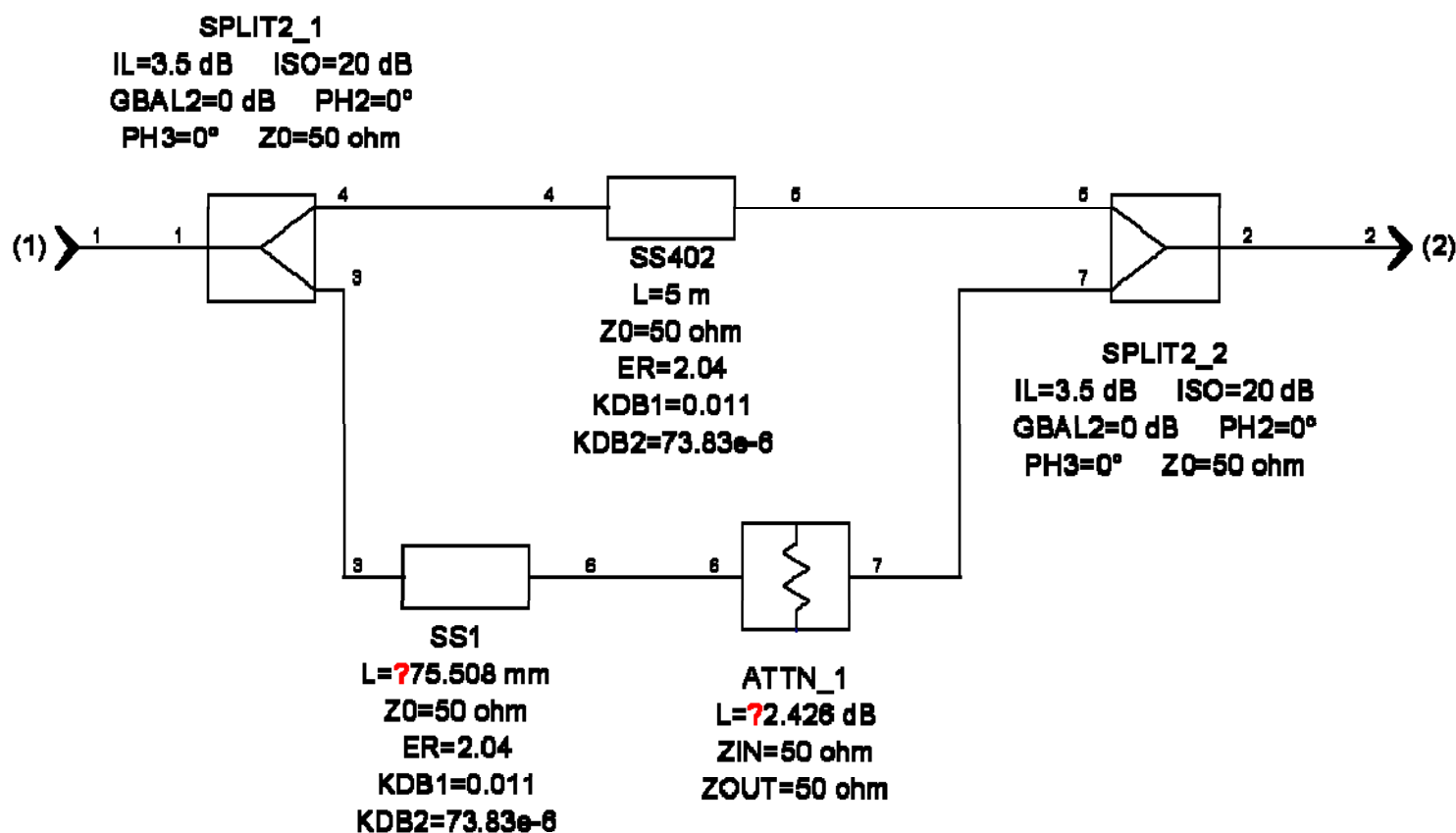
250 KHz
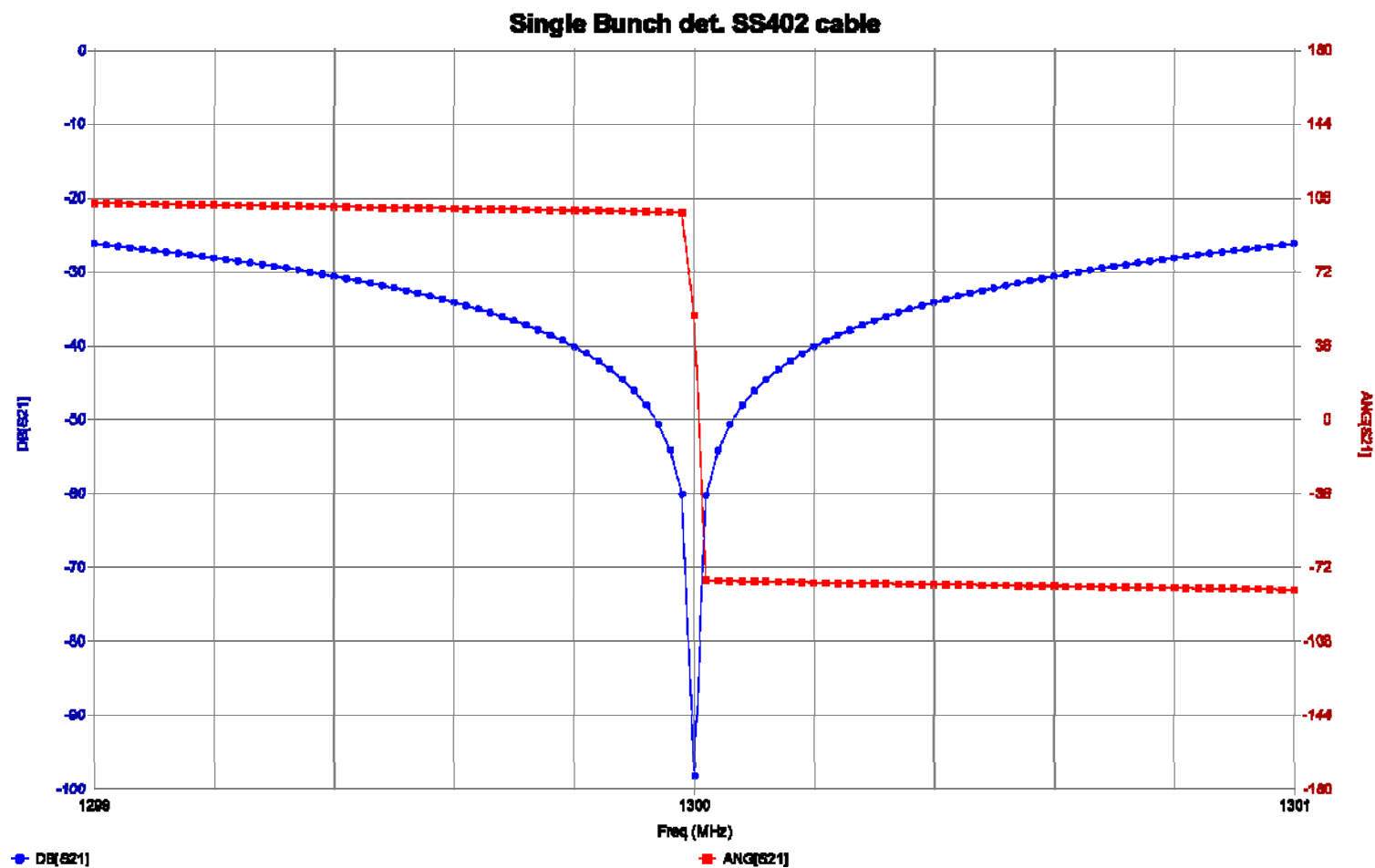
8/9π
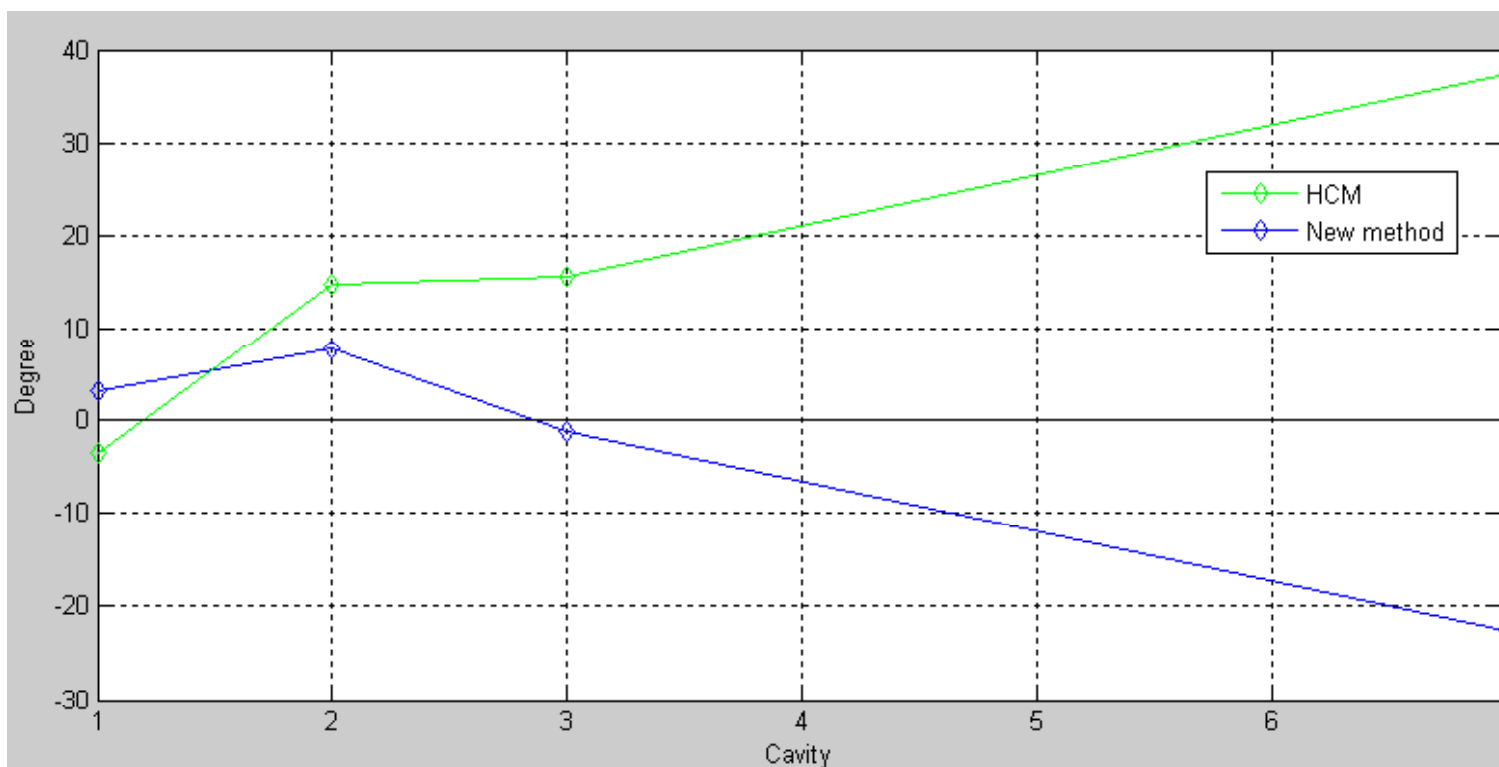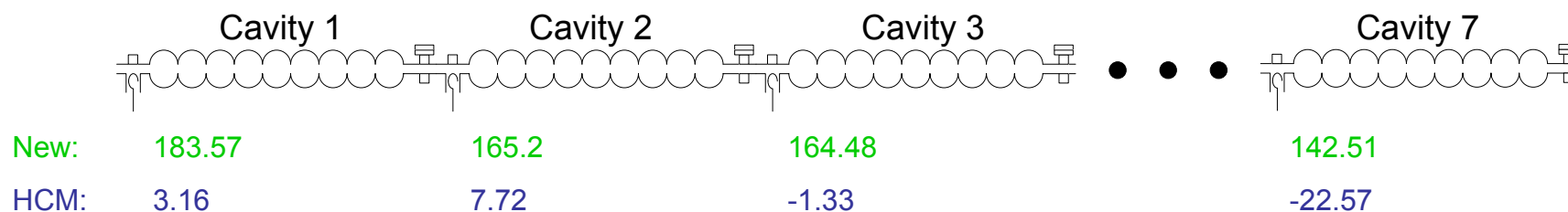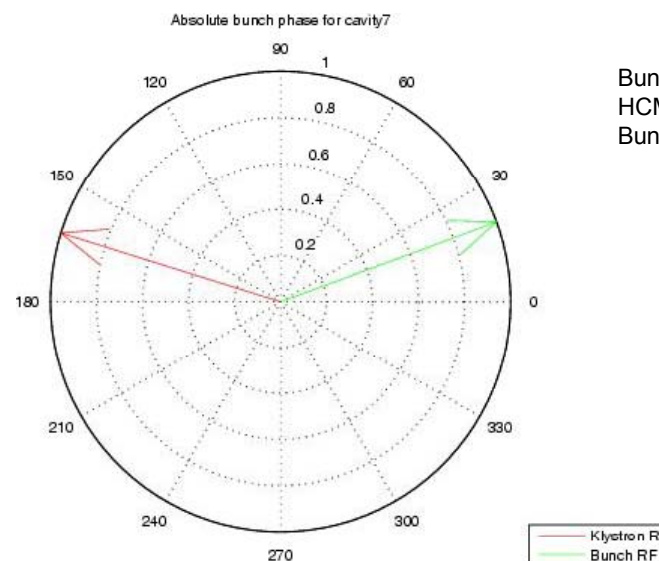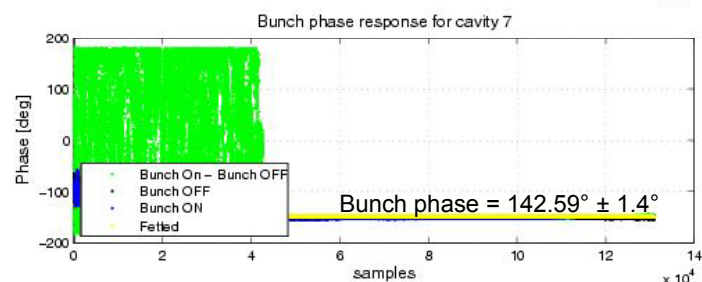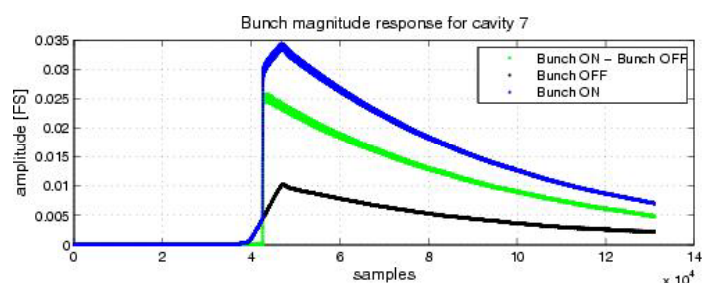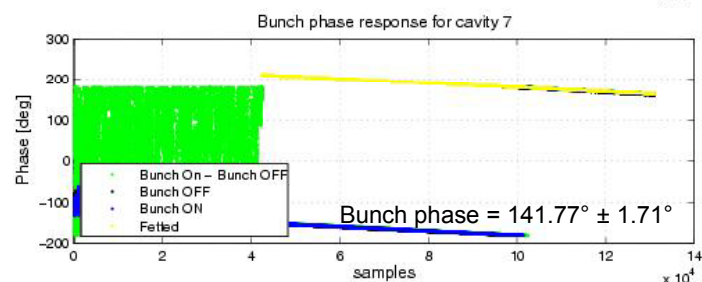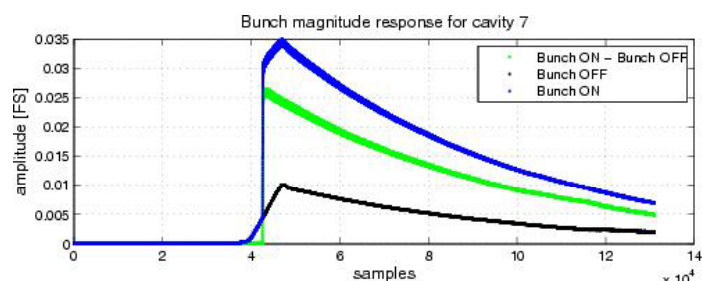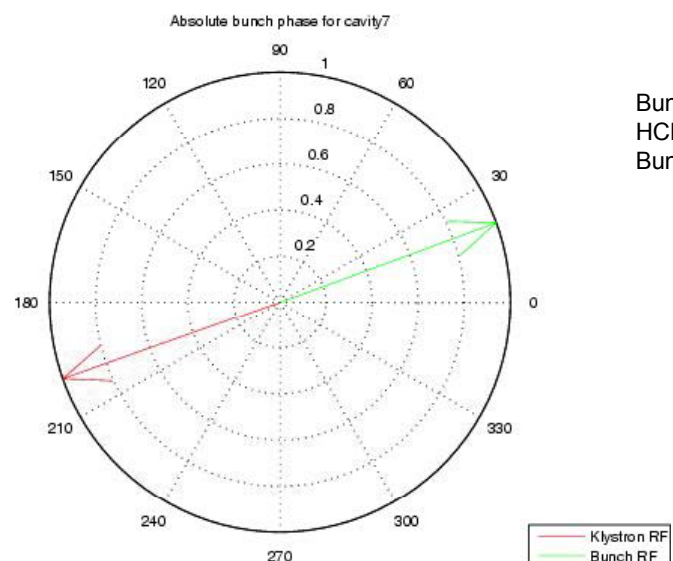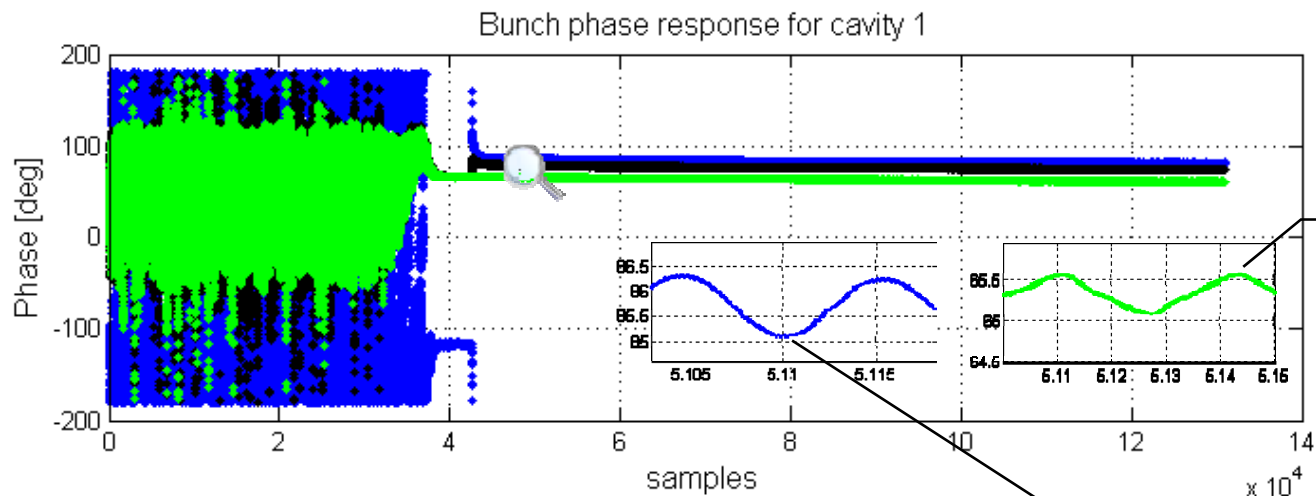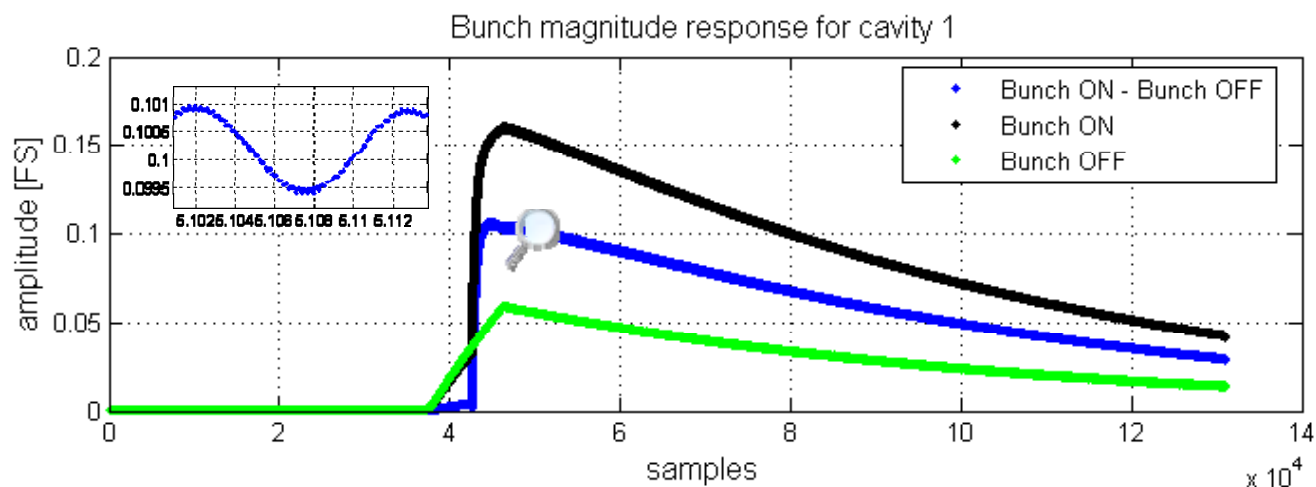
Measurement setup for ACC4
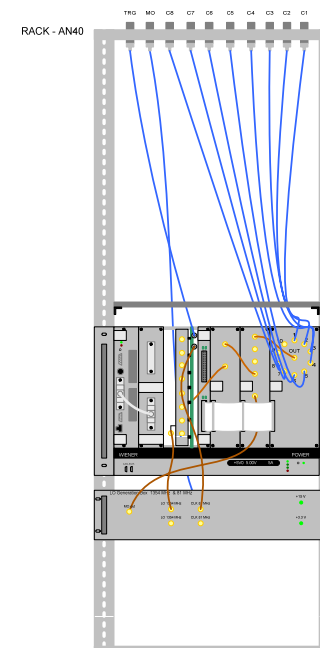
- Confirm the ACC1 results at ACC4

- RF leakage from Gun eliminated

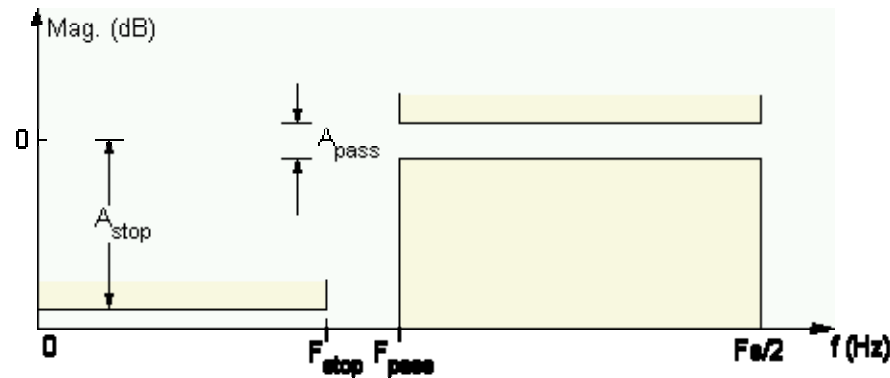- Bunch energy at ACC4 (450MeV) to compare with at ACC1 (5MeV)

Comb filter schematic

Comb filter magnitude and phase response

Single Bunch det. SS402 cable

$$\Delta F = Fpass - Fstop = 787 \cdot 10^3\, Hz$$

$$\Delta Fnorm = \frac{\Delta F}{Fs}$$

$$Nfilter = \frac{K}{\Delta Fnorm} = \frac{K \cdot Fs}{\Delta F} \quad where$$

$K = 3.3$ for Hamming window

$K = 3.1$ for Hann window

Delay line $\qquad\qquad dl = 20 \cdot 10^{-9}\, s$

Sampling frequency $\quad Fs = 10 \cdot 10^9\, Hz$

Number of points $\qquad Np = dl \cdot Fs = 200$

$$Nfilter\_hann = \frac{3.1 \cdot 10^{10}}{787 \cdot 10^3} = 39390$$