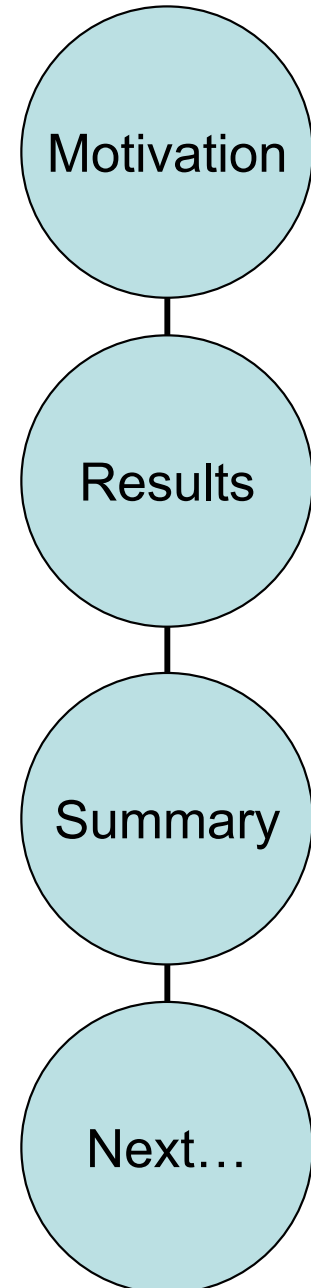
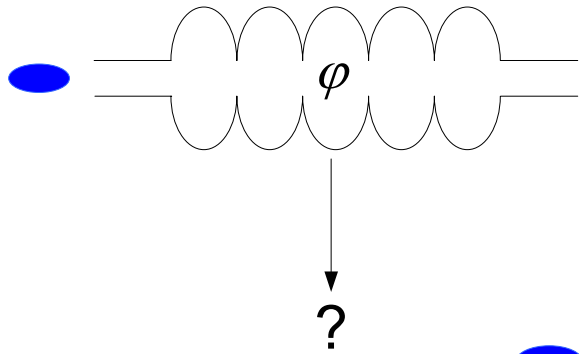


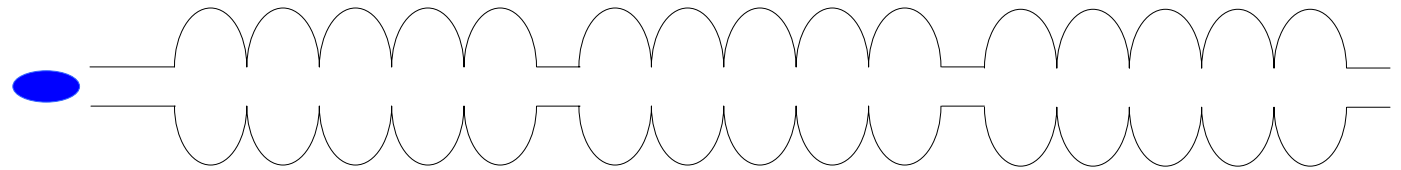
## Beam phase measurement with single bunch



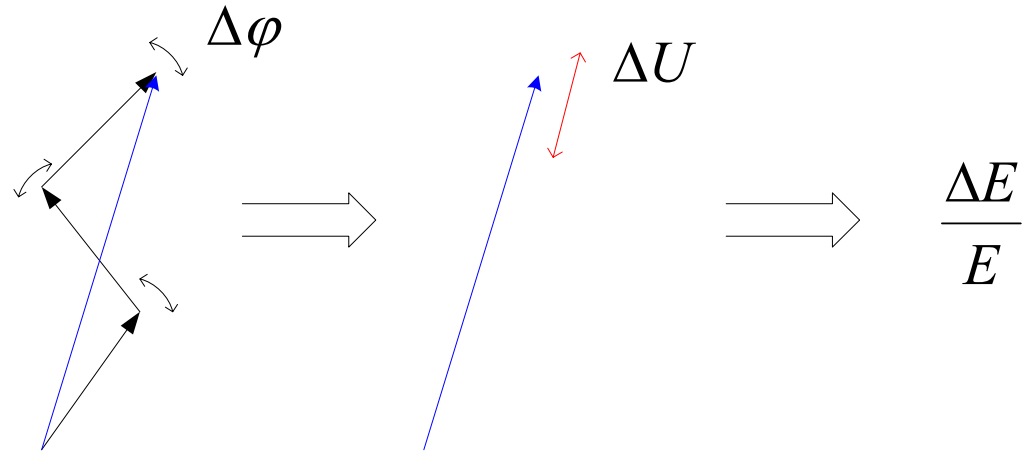
# For what we need beam phase?



Commission (accelerator start-up)



Vector sum calibration  
quality RF field regulation



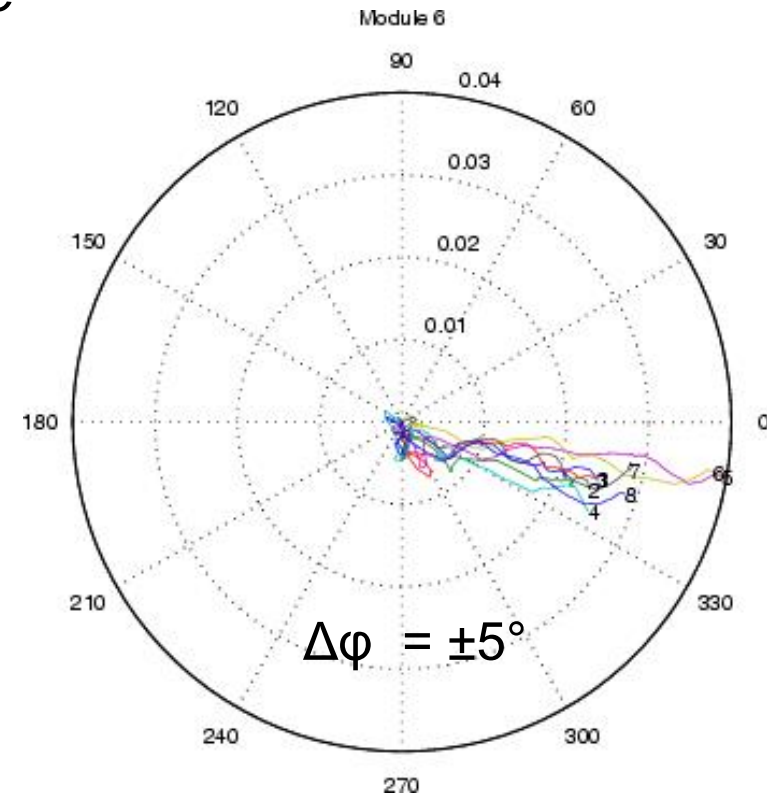
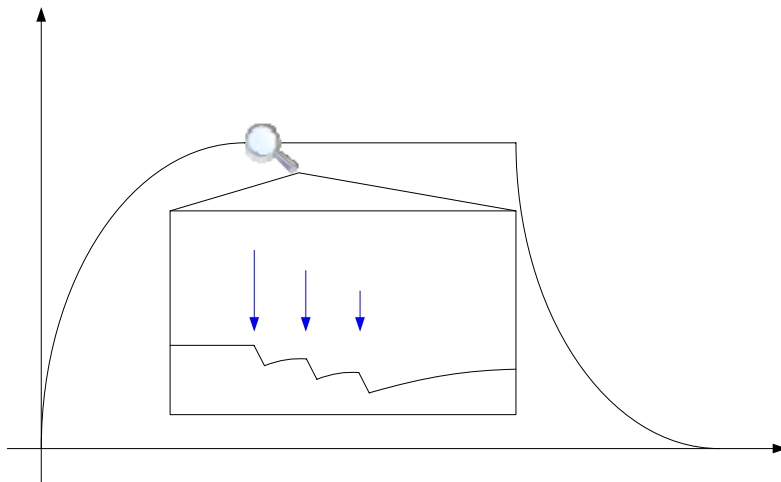
Diagnostic purposes

$$\Delta\varphi = \pm 0.5^\circ \text{ for } 8 \text{ cavities} \rightarrow \frac{\Delta E}{E} \approx 10^{-4}$$

(Alexander Brandt PhD. Theses)

High beam charge measurement:

- 30 bunches
  - ~3nC for each
- Not the user-mode conditions*



Special setup for that measurement

Charge limits resolution of this method

There is a risk to destroy equipment installed in tunnel

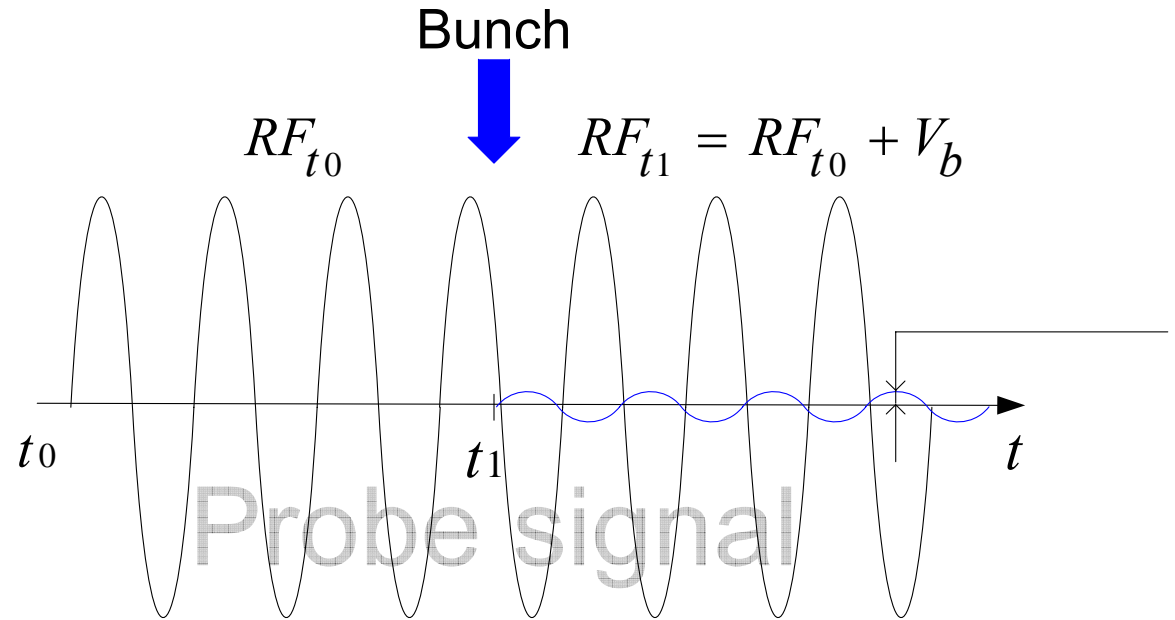
Develop a new more sensitive method

- accuracy  $\pm 1$  deg. or better
- reasonable bunch charge (1nC or less)

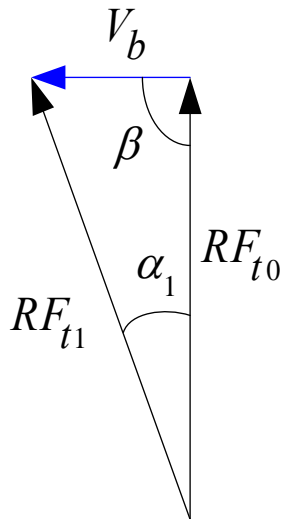
Condition:

$$RF_{t_0} = 21 \cdot 10^3 \text{ kV}$$

$$V_b = 4 \text{ kV} \rightarrow q_b \approx 1 \text{ nC}$$



1



$$\beta = 90^\circ$$

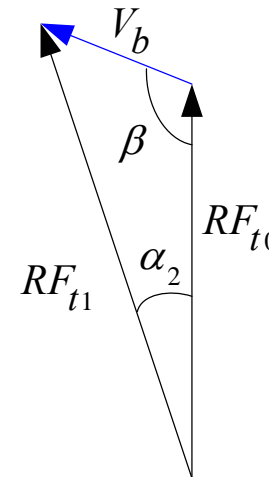
$$\alpha_1 \approx 0.01112629^\circ$$

$$RF_{t_1} \approx 21.00000039 \cdot 10^3 \text{ kV}$$

$$\Delta\alpha = \alpha_1 - \alpha_2 \approx 4.43 \cdot 10^{-7}$$

$$\Delta RF_{t_1} \approx 35.59 \text{ V} \sim 18 \text{ bit} \Leftarrow \text{Challenge!}$$

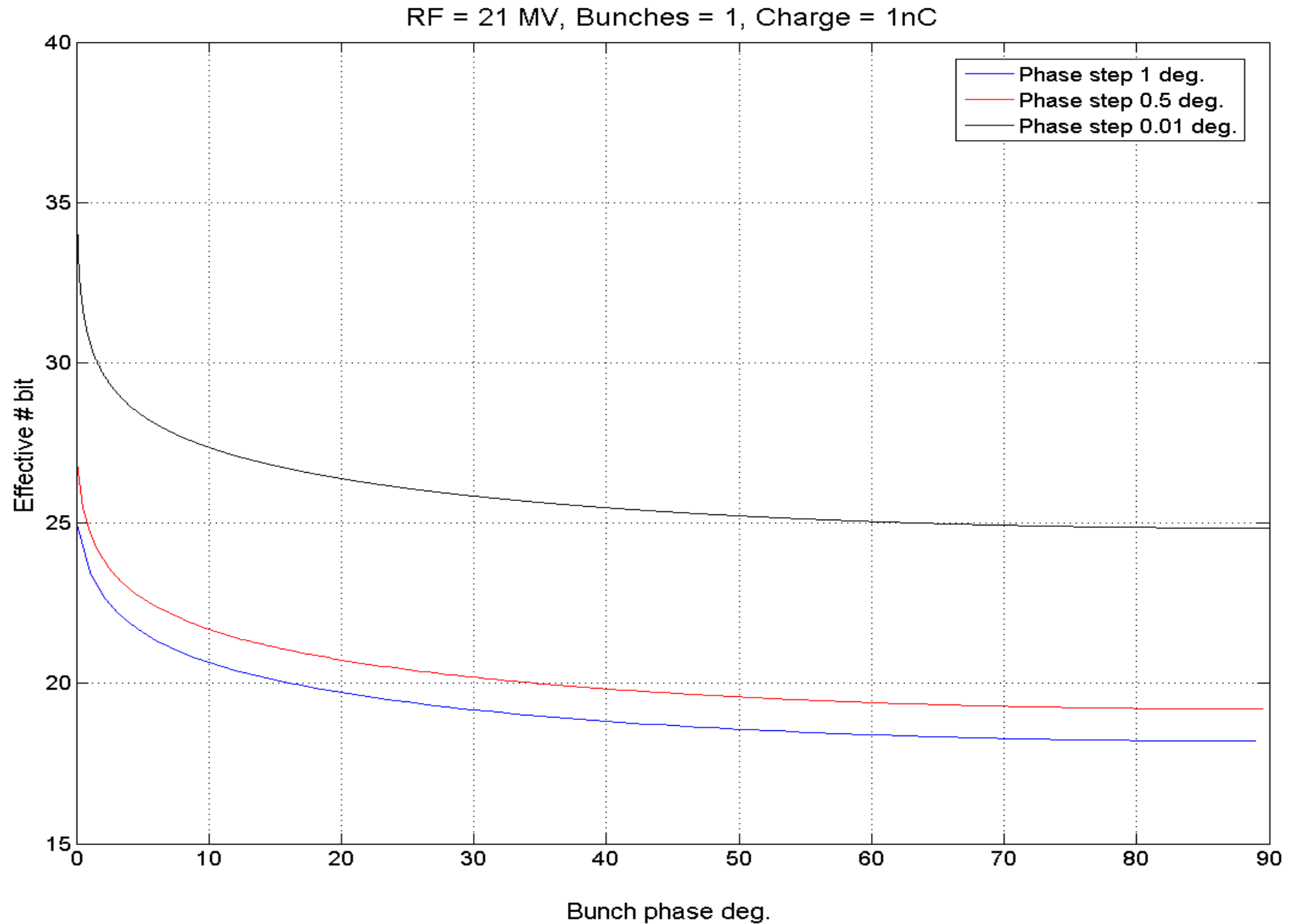
2

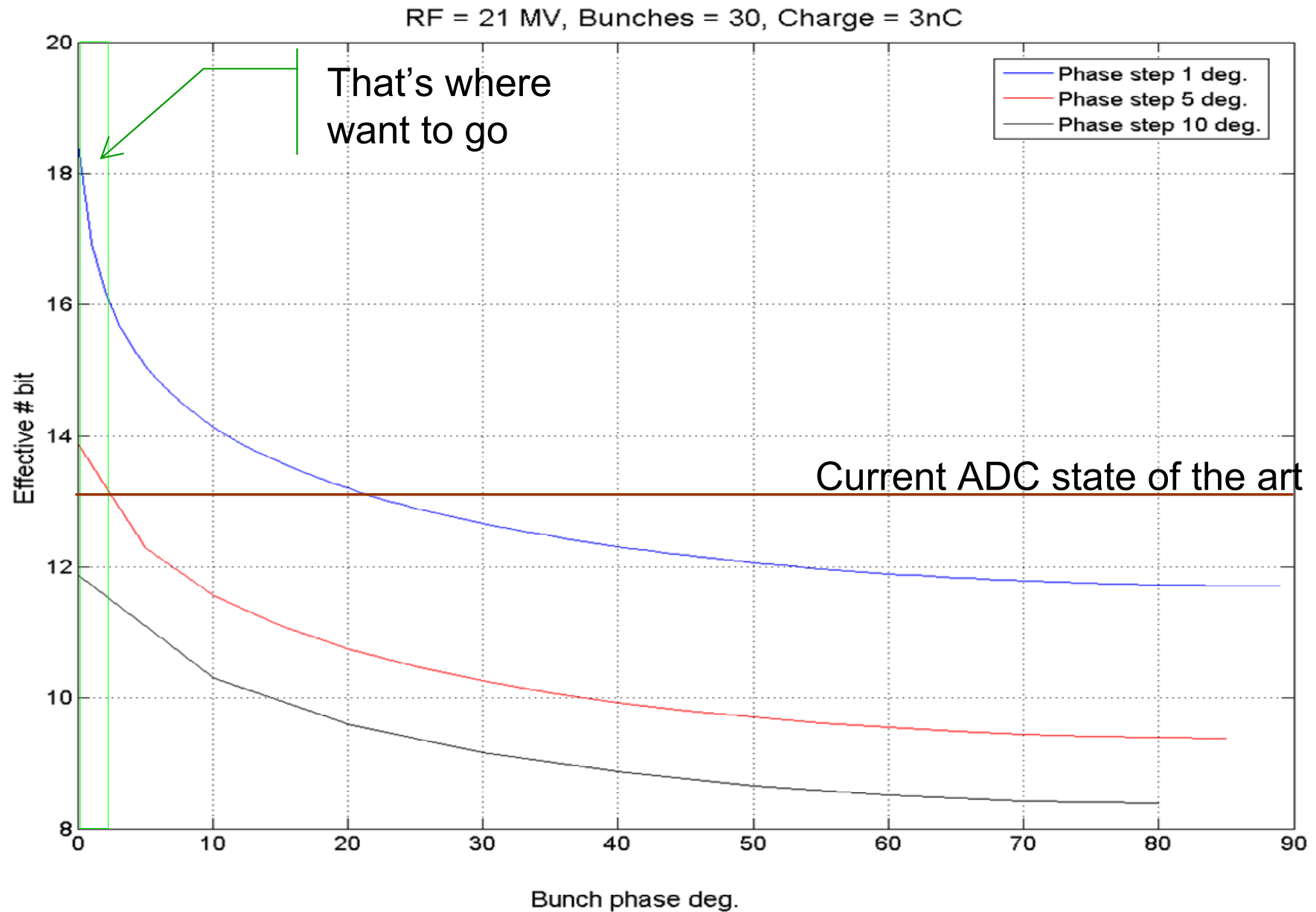


$$\beta = 90.5^\circ$$

$$\alpha_2 \approx 0.01112585^\circ$$

$$RF_{t_1} \approx 21.000003598 \cdot 10^3 \text{ kV}$$

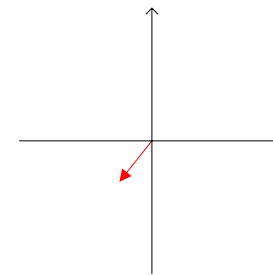
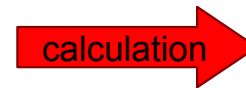
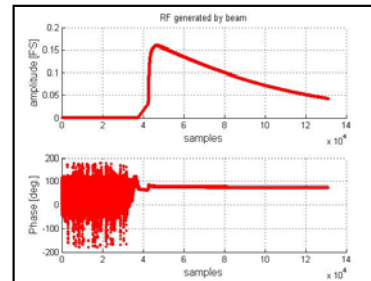




## Measurement in 2 steps

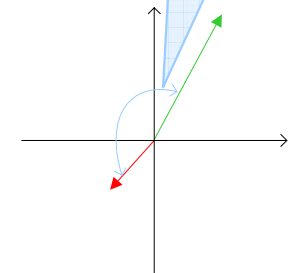
### 1. Conditions :

RF - off  
Beam - on



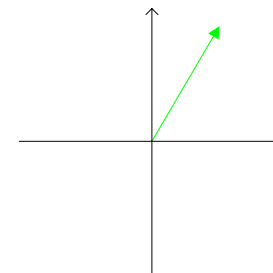
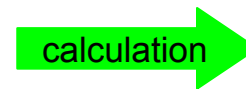
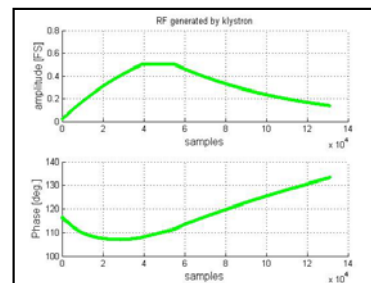
Beam phase

+ =

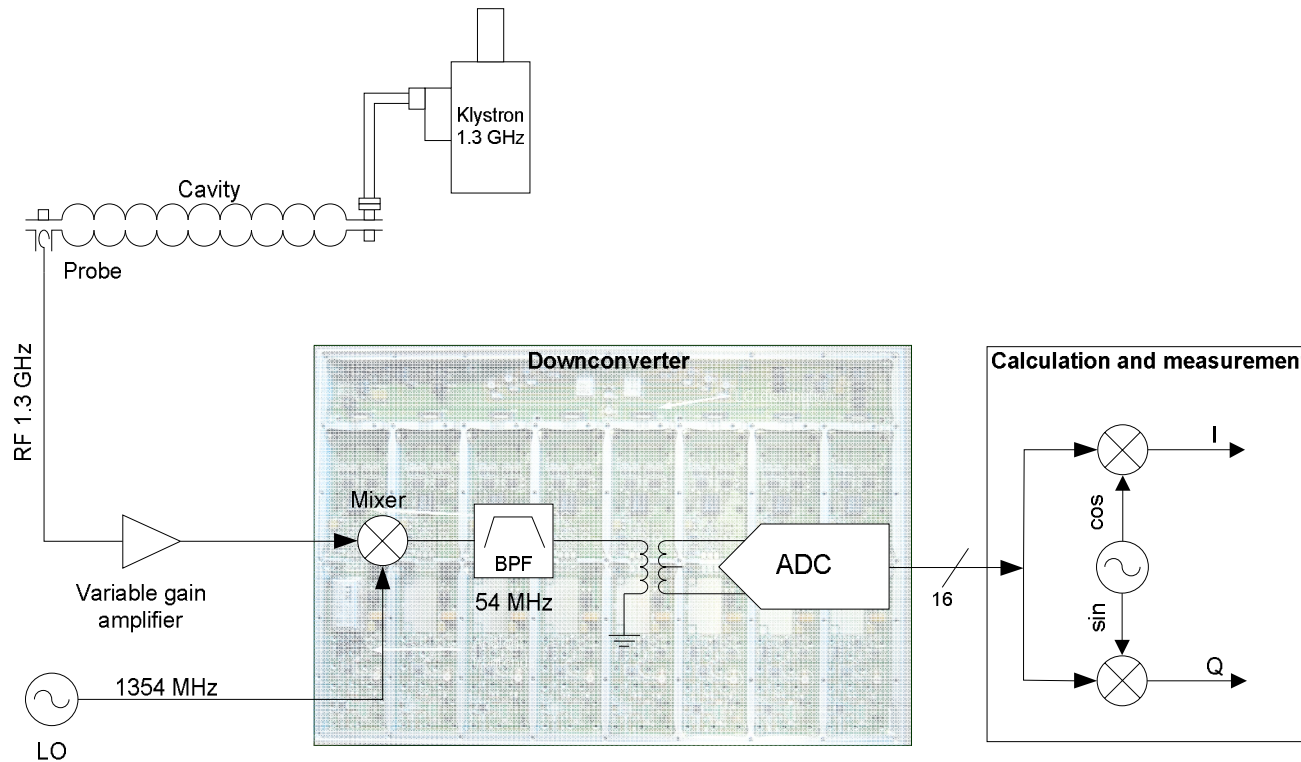


### 2. Conditions :

RF - on  
Beam - off



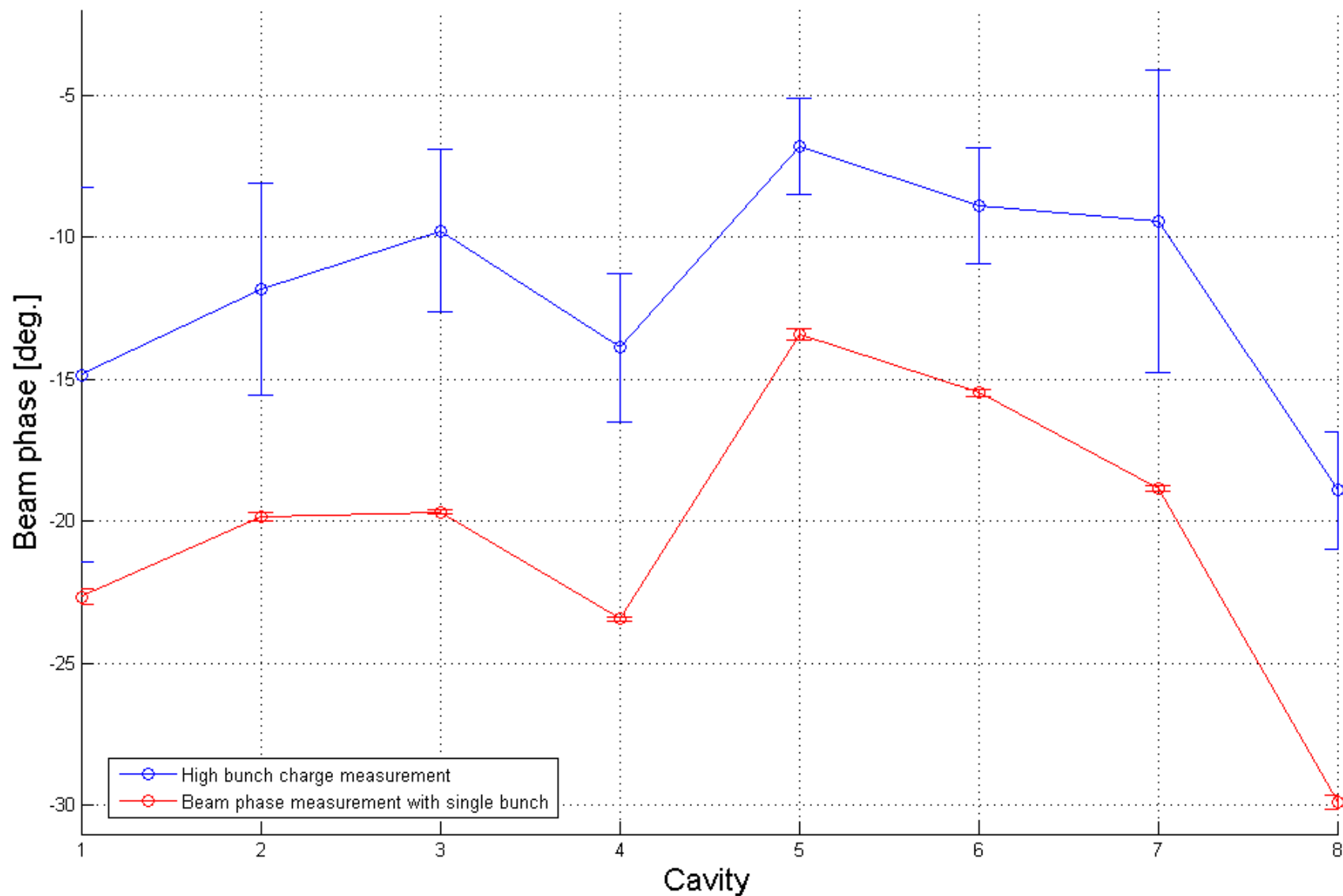




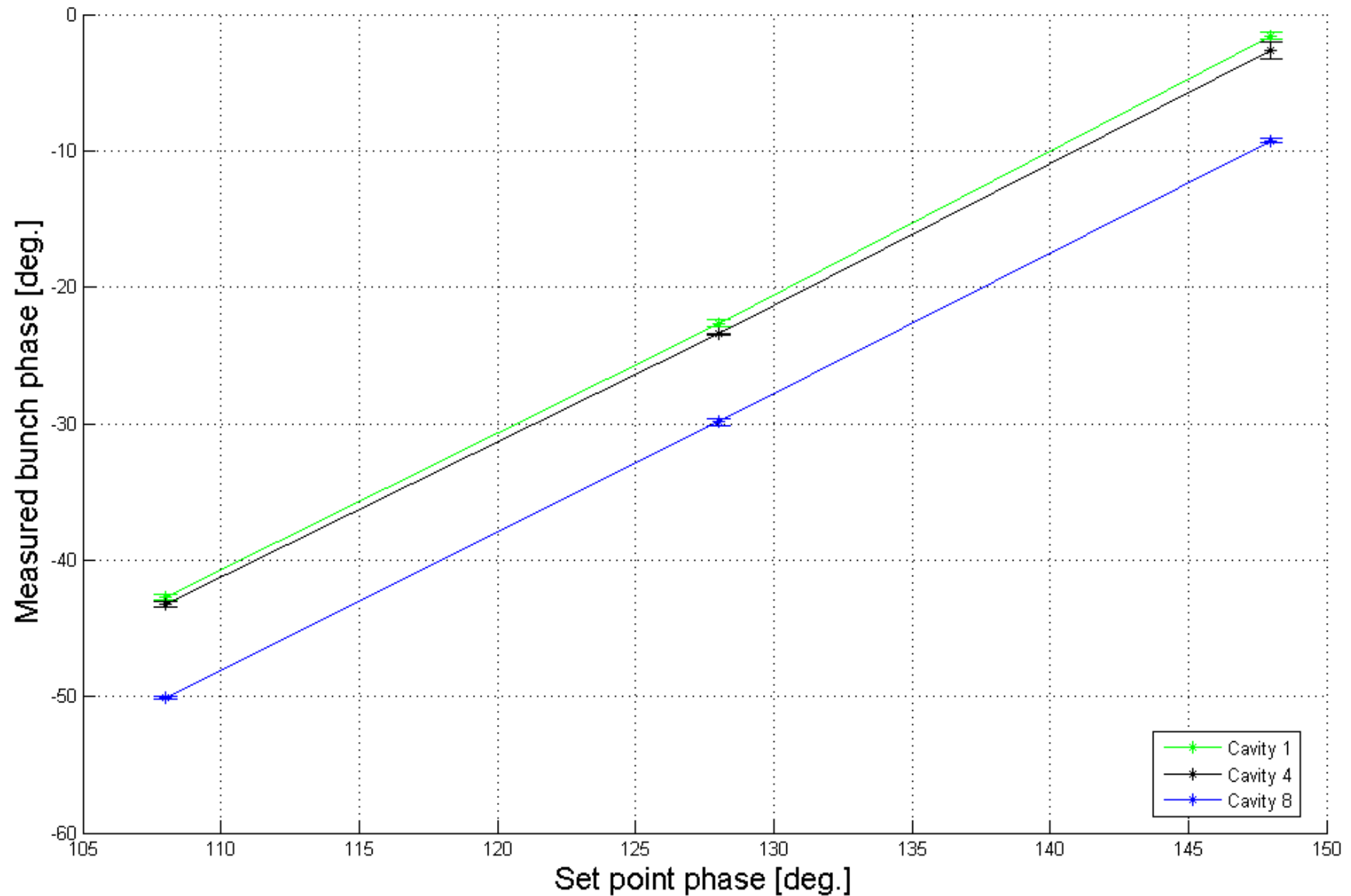
## Hardware and software :

- variable gain amplifier: -70 dB to +47 dB
- new downconverter, IF 54MHz, Input power +17dBm, 16bit ADC
- Advanced-Carrier-Board (ACB2.0), based on FPGA
- MatLab for I/Q calculation

## Measured phase comparison



# Bunch phase for different set point



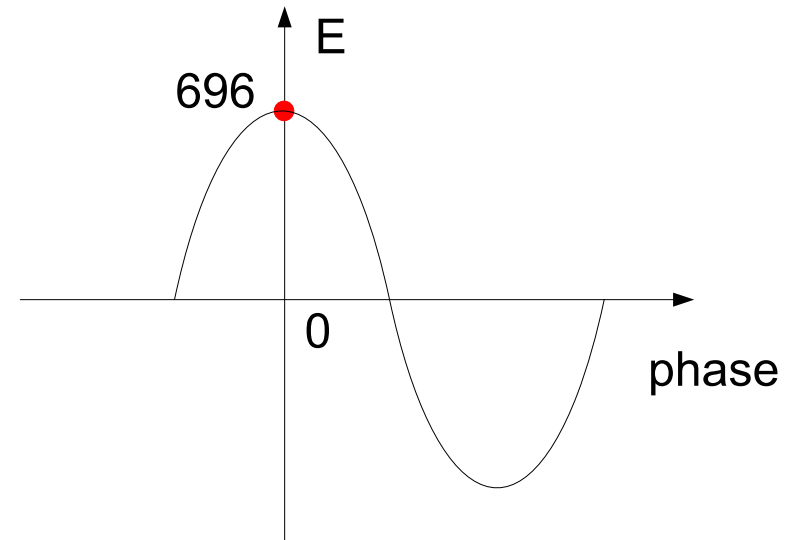
## Which of two measurements is telling the truth?

Condition:

- Set point phase 128 deg.
- All cavity at ACC6 was tuned to ~on-crest
- New method was used as indicator the beam phase

Energy measurement results:

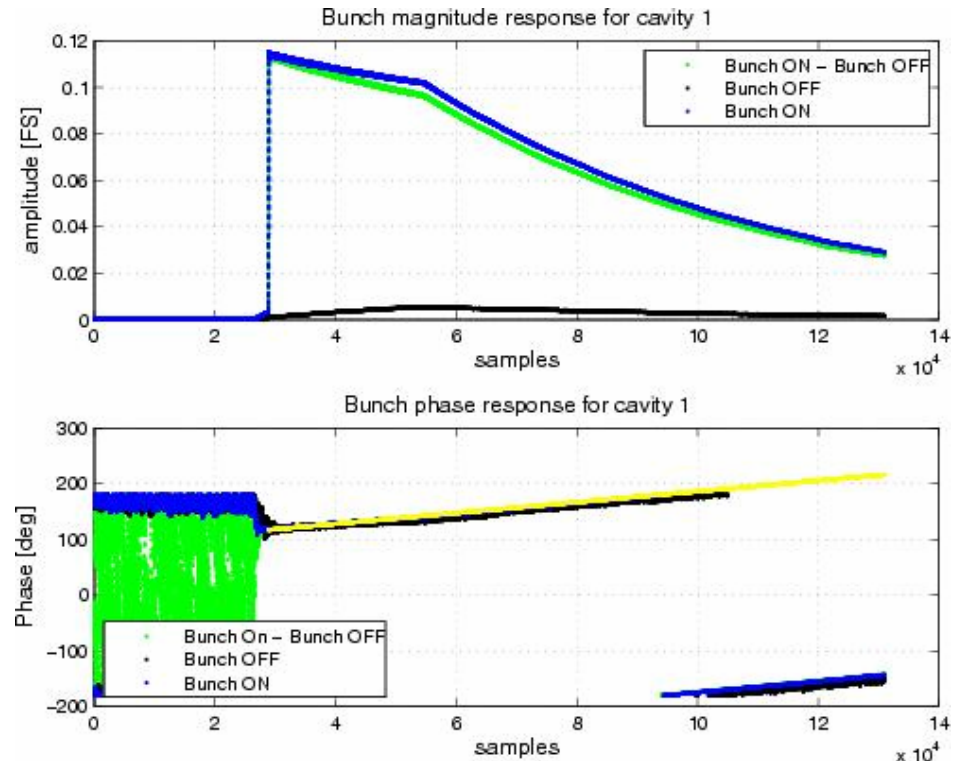
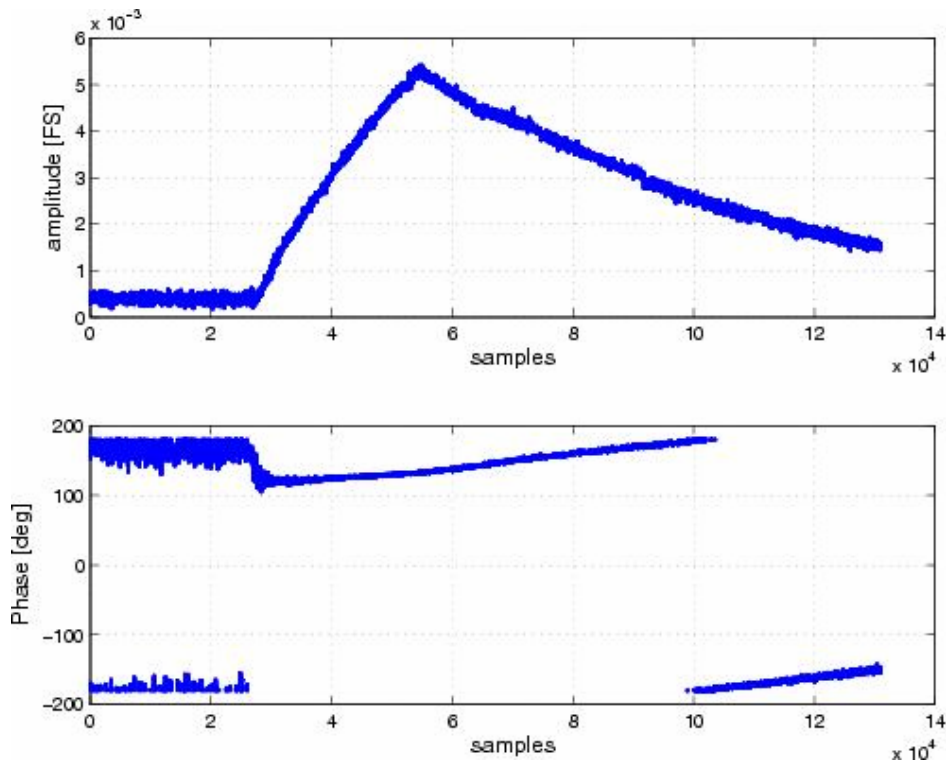
Before	$\sim 695 \pm 0.5 \text{ MeV}$
After	$\sim 696 \pm 0.5 \text{ MeV}$
Back	$\sim 695 \pm 0.5 \text{ MeV}$



## Where the phase offset come from...

RF - off  
Bunch - off

RF - off  
Bunch - ~3nC



Discover a new method for bunch phase measurement

- Commission (accelerator start-up)
  - single bunch 1-2 nC
  - reduce risk of breaking equipment installed in tunnel
- Vector sum calibration
  - more precise beam phase measurement ( better 0.5 deg)
  - expected better RF field regulation

Open point:

Source for difference (offset) compared to high bunch charge measurement

Surprise:

Possibility to also use dark current!

## MSK

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