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Linac 2018

GANIL laboratoire commun CEA/DSM — CNRS/IN2P3 spiral2

Subject

First results of the of the beam loading effects in the first rebuncher of MEBT Line of Spiral2 project.

In the cyclotron machine at Ganil the effects of the beam are quite small because of the low intensity of the beam. In Spiral2 ,as in others accelerators, the beam produces an important effect in the voltage and the phase of the cavity. So the system has to know the importance of the perturbations and must to take into account the behavior of the cavity with the beam to conduct the beam in good conditions to the experimental areas.
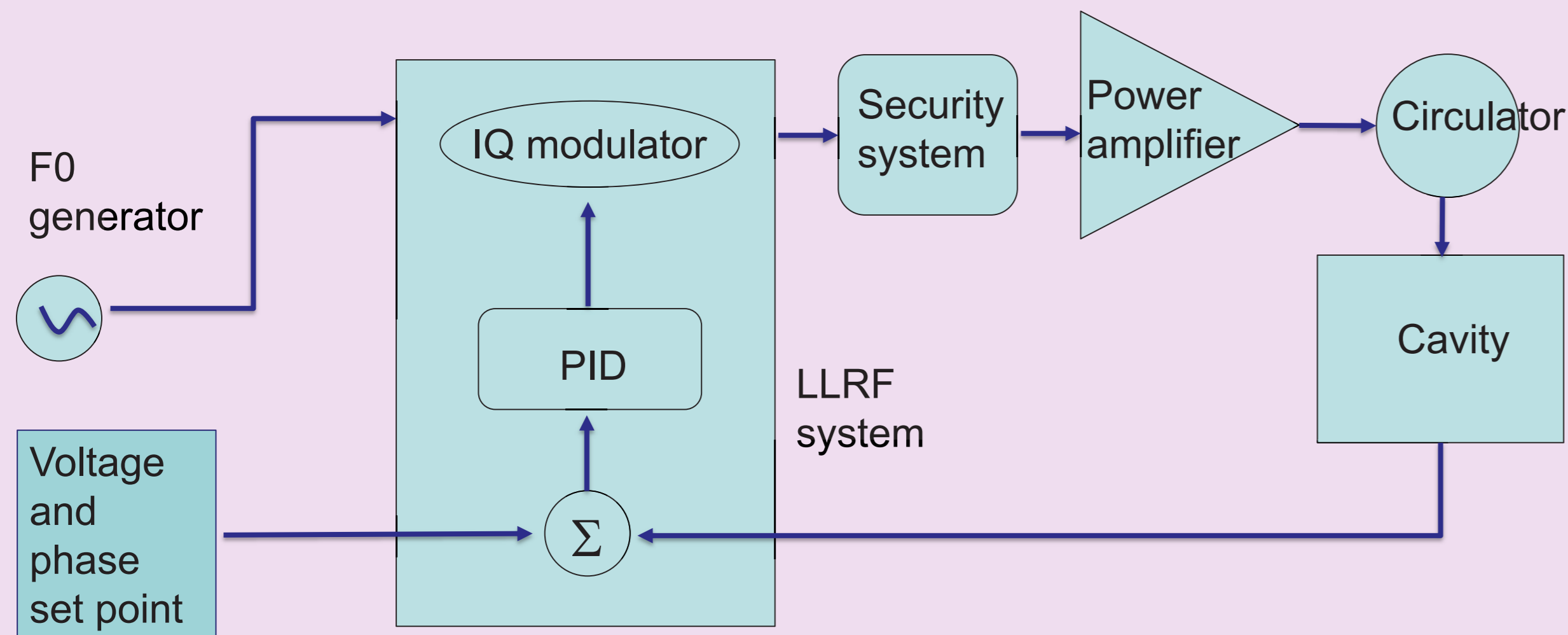
Rebuncher
RFQ Output
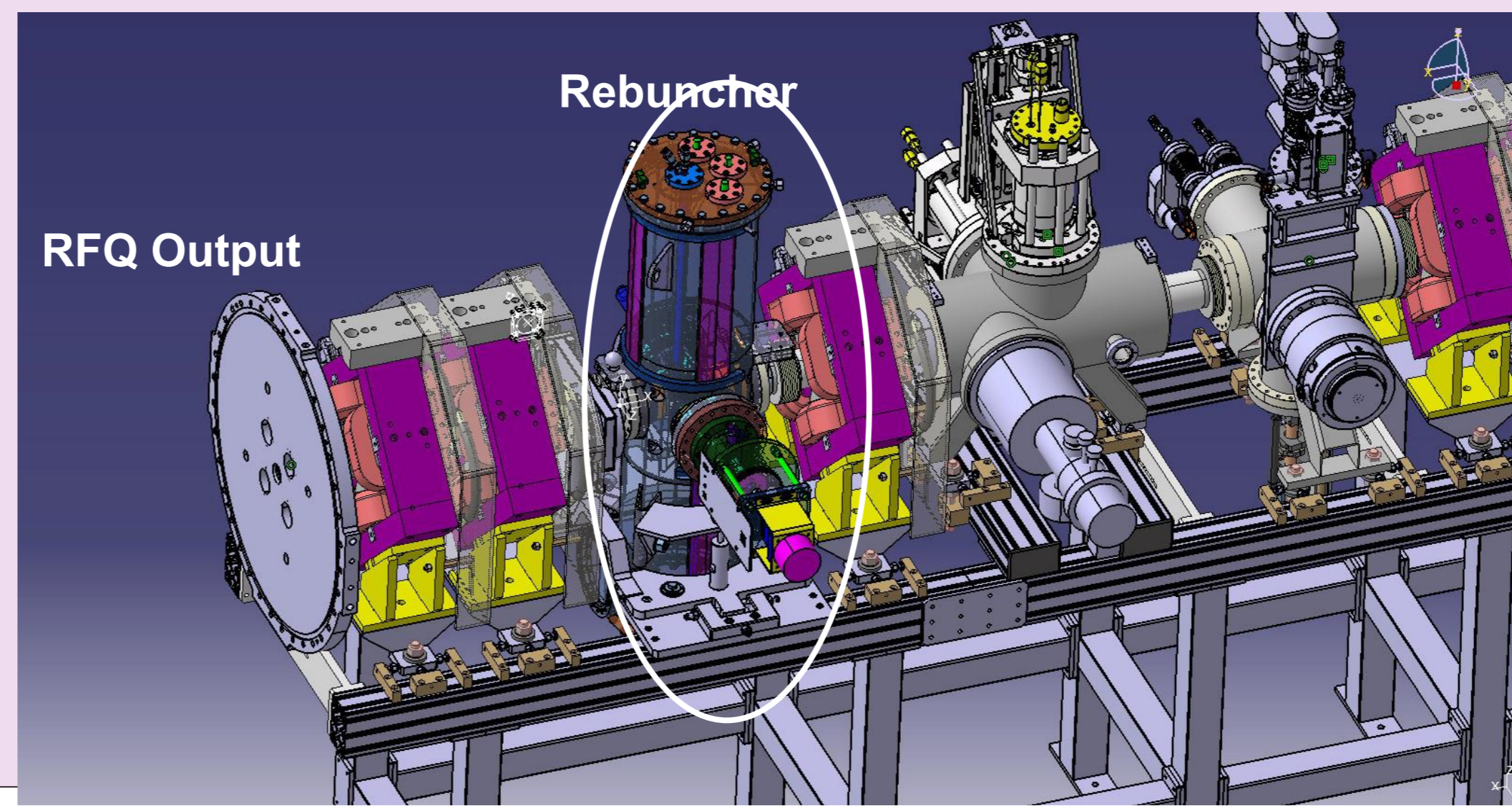
The MEBT Line
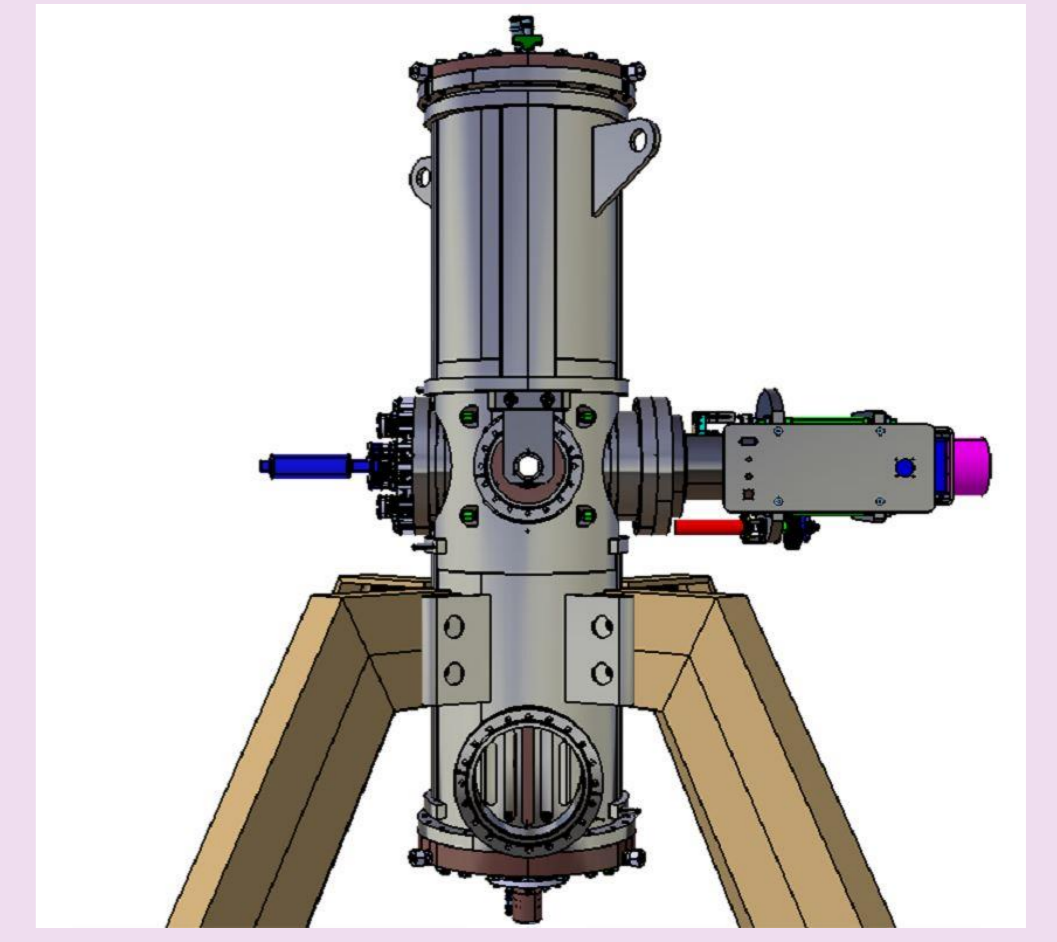
Rebuncher parameters

PARAMETERS	Unity	Design
Beta Optimal	%	0.04
Diameter	mm	60
Flange to flange Distance	mm	280
design voltage (continuous)	kV	120
RF power for 120 kV	kW	5
design voltage (pulse)	kV	190
magnetic field surface peak (continuous)	A/m	5885
surface peak electric field (pulse)	Kp	1.1
RF power available (continuous, Amplifier output)	kW	10
Injection Loop Power Max	kW	15
Fine tuning range	MHz	+/-0.3
Power probe (@ 120 kV)	dBm	≤ 30
max temperature (@ 120 kV, cw)	°C	50
Alignment	mm	+/- 0.5

$Q_L = 3335$

$$\tau_{fill} = \frac{2.Q_L}{\omega_0} = 12\ \mu s$$

General Diagram of the RF system for one cavity

F0 generator

IQ modulator → Security system → Power amplifier → Circulator → Cavity

PID
LLRF system

Voltage and phase set point

Σ

Equivalent electronical circuit of the cavity with the beam

ampli 88.0525MHz
Rext Ccav Lcav Rcav Ib
GND
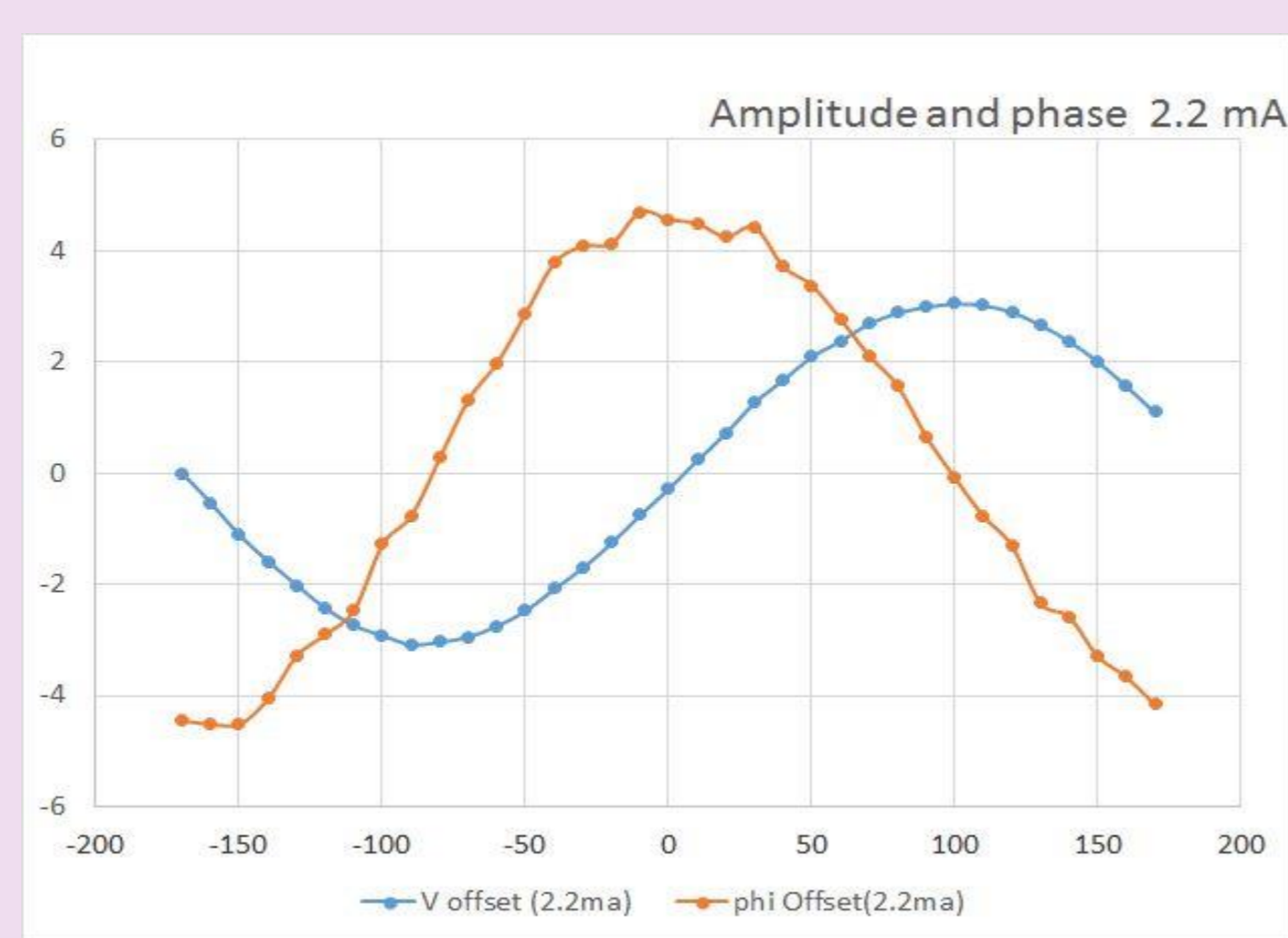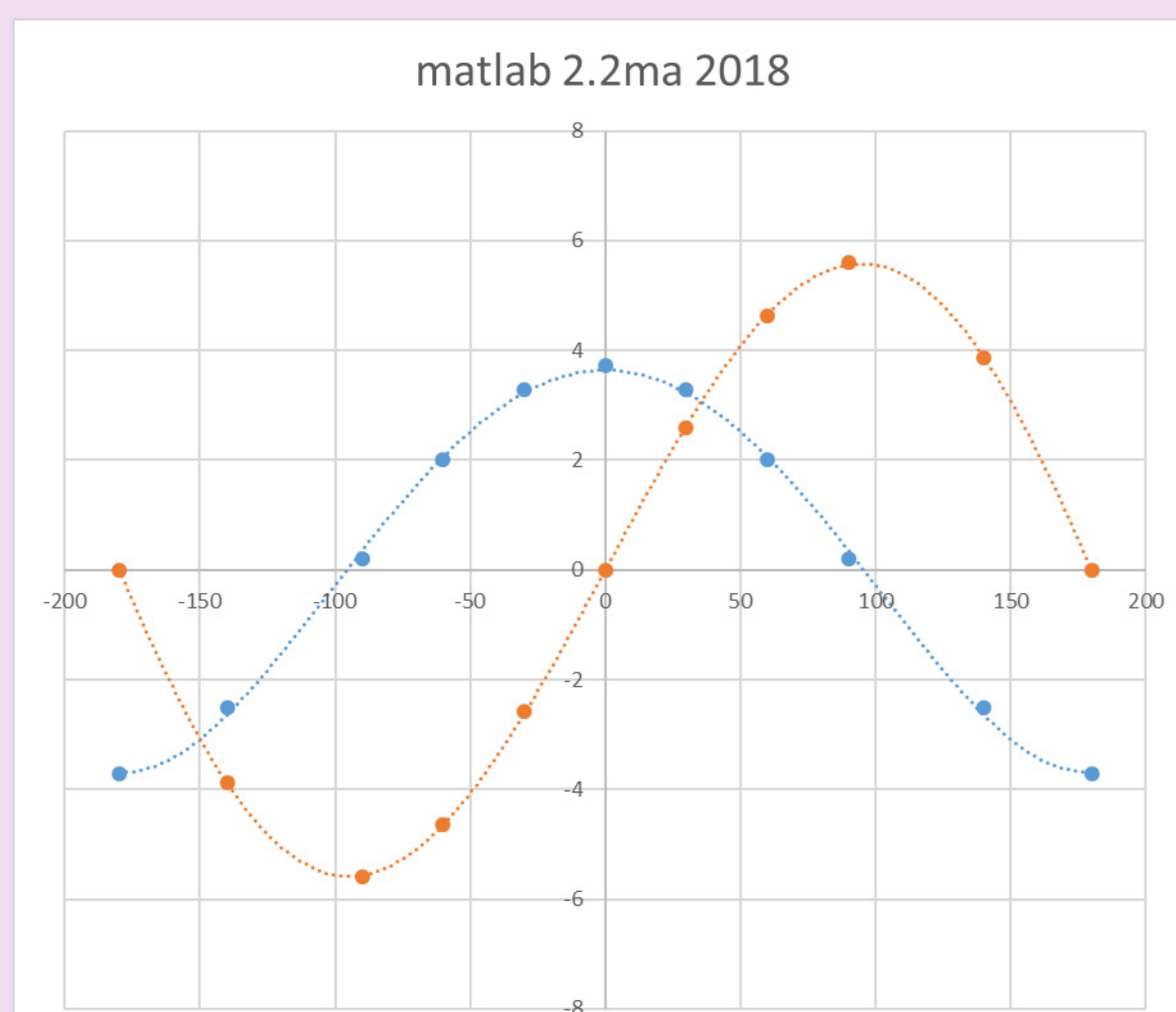
$$\frac{d^2V}{dt^2} + \frac{1}{R_L C}\frac{dV}{dt} + \frac{1}{LC}V(t) = \frac{1}{C}\frac{dI}{dt}$$

$$\frac{dV_{re}}{dt} = -\frac{\omega_0}{2Q_L}V_{re} + (\omega - \omega_0)V_{im} + R_L\frac{\omega_0}{2Q_L}I_{re}$$

$$\frac{dV_{im}}{dt} = -\frac{\omega_0}{2Q_L}V_{im} - (\omega - \omega_0)V_{re} + R_L\frac{\omega_0}{2Q_L}I_{im}$$

Matlab simulink Simulation

It is assumed than during the pulse the cavity with it large bandpass is allways very closed to the resonance frequency

- Operating Voltage : **Rebuncher 1: 120 kV**

Structure 3-gaps- Two stems quarter wave in opposition
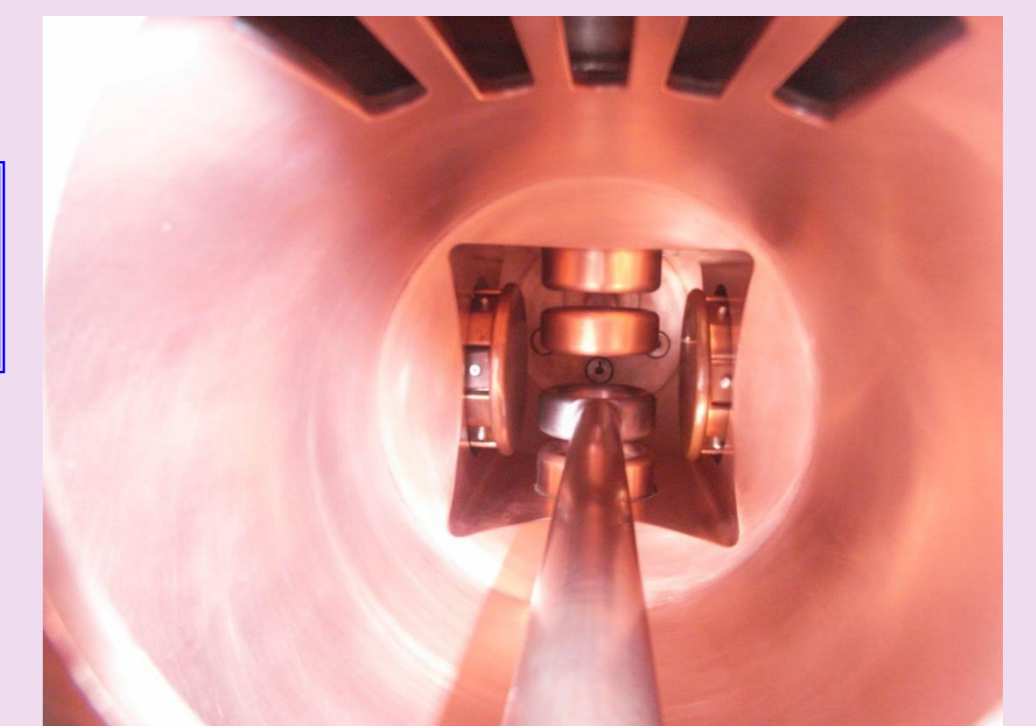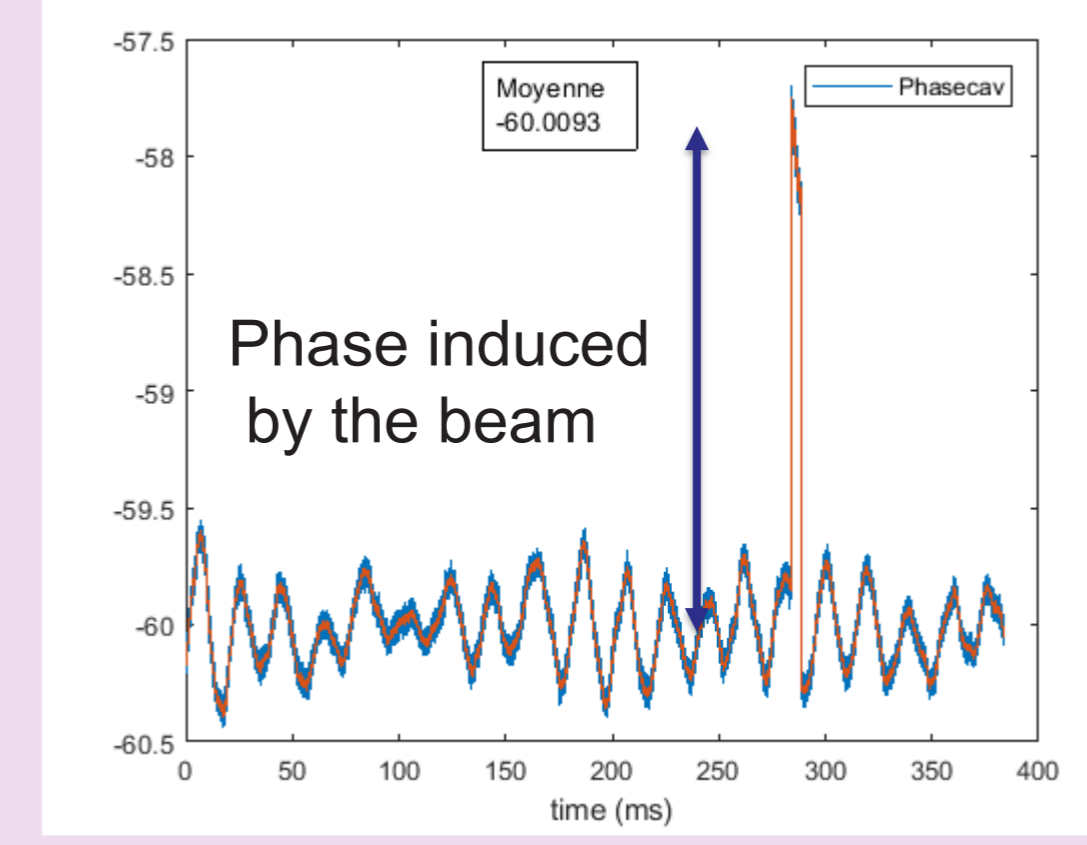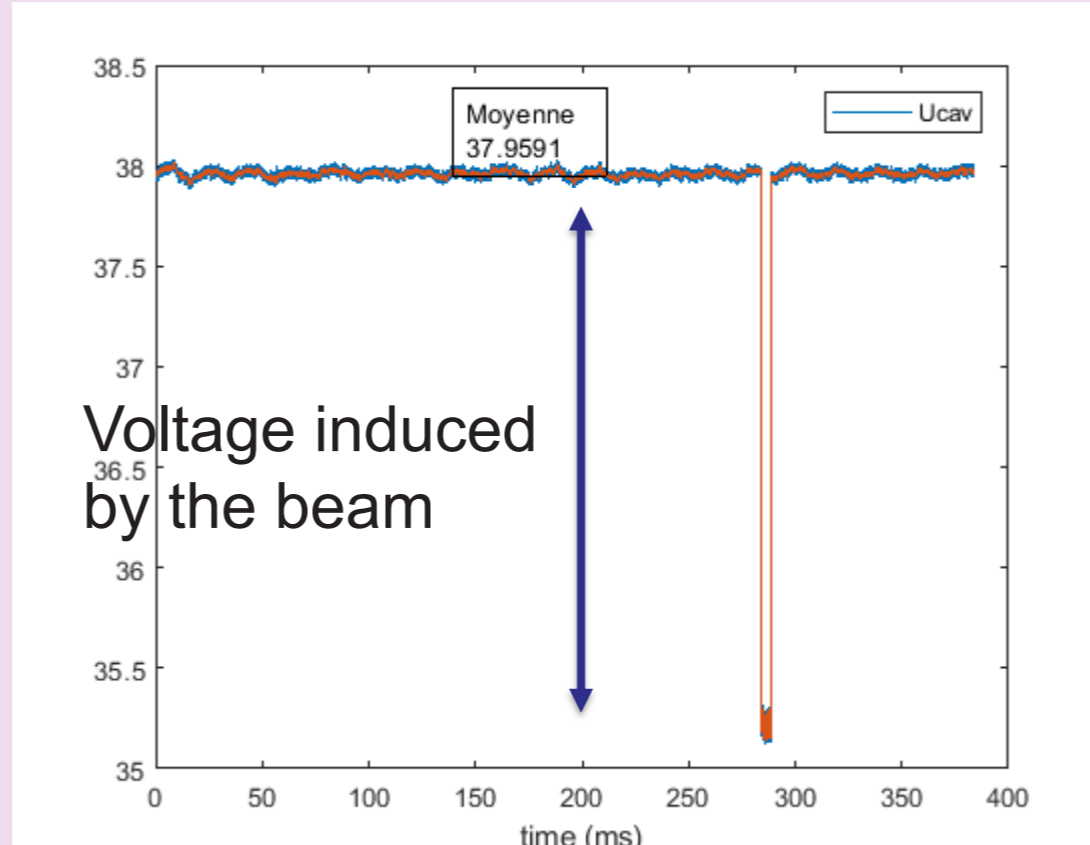Two capacitive panels- Inductive Coupler
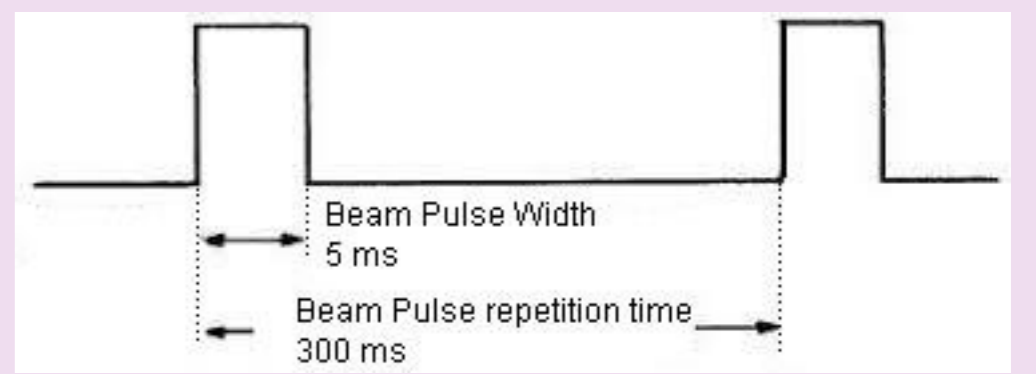
Tests conditions

I beam=2.2mA to 5.1 mA

Beam pulse time = 5ms /300ms
Voltage = 38 kV

Inside view

Beam Pulse Width 5 ms
Beam Pulse repetition time 300 ms

Example of 38kV rebuncher and a phase offset betwwen RFQ and rebuncher of -60°
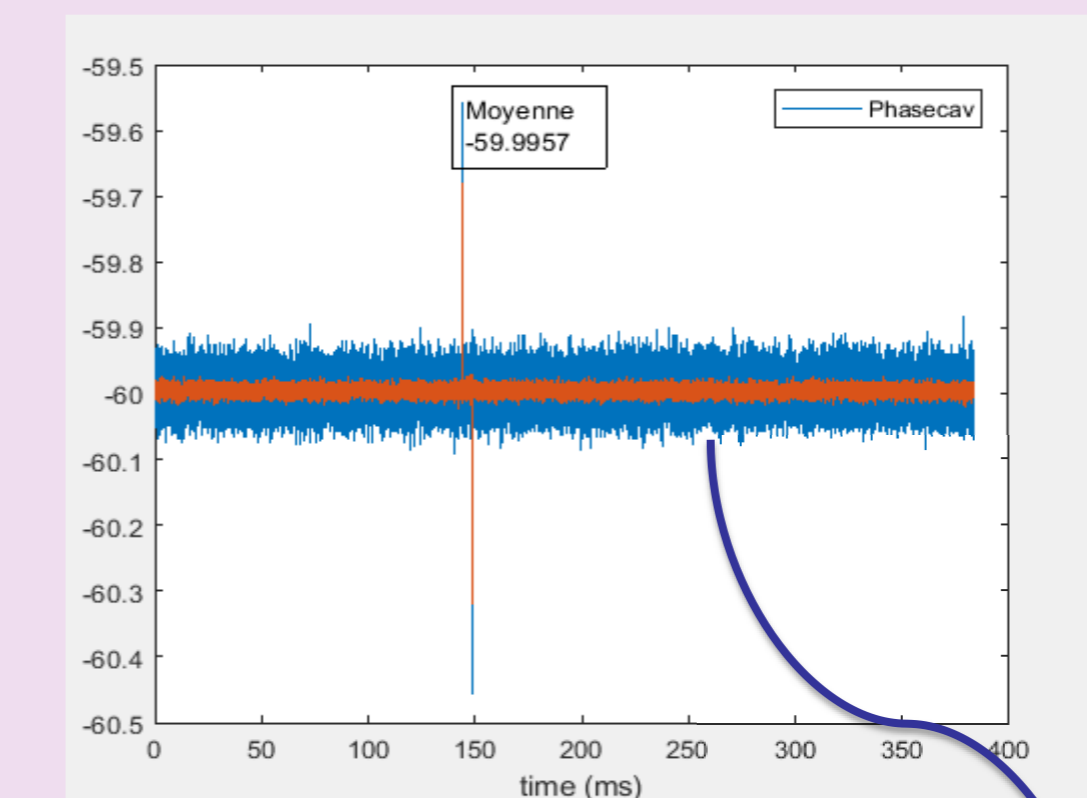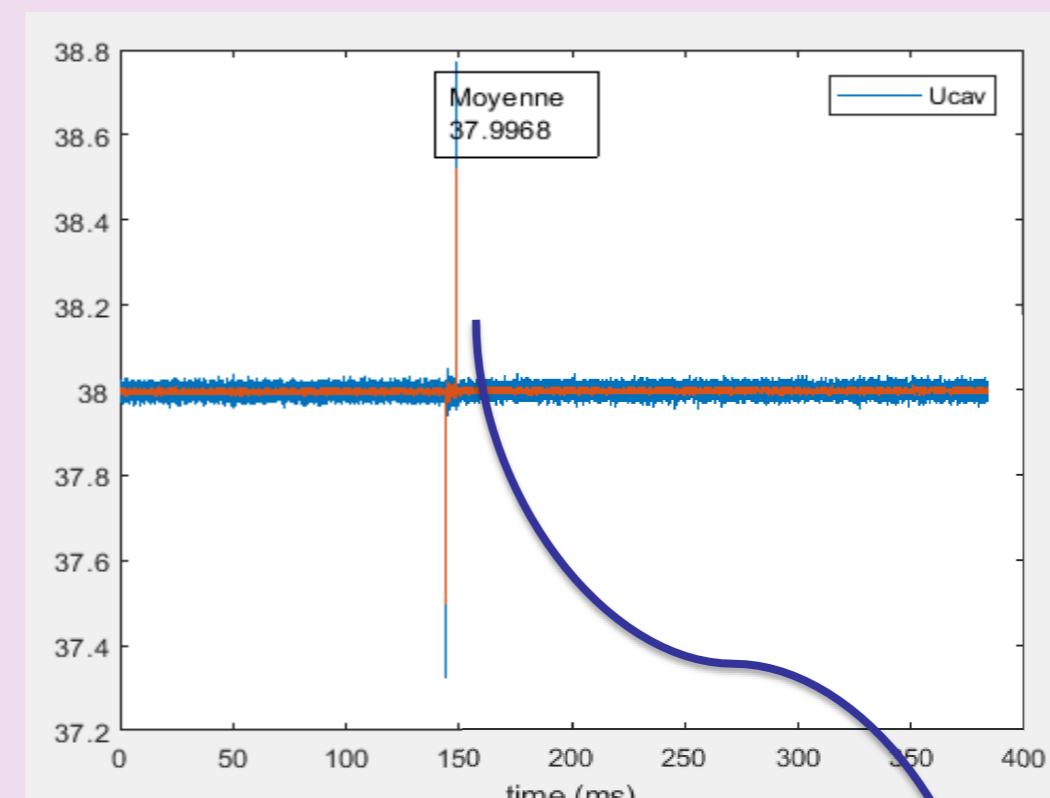
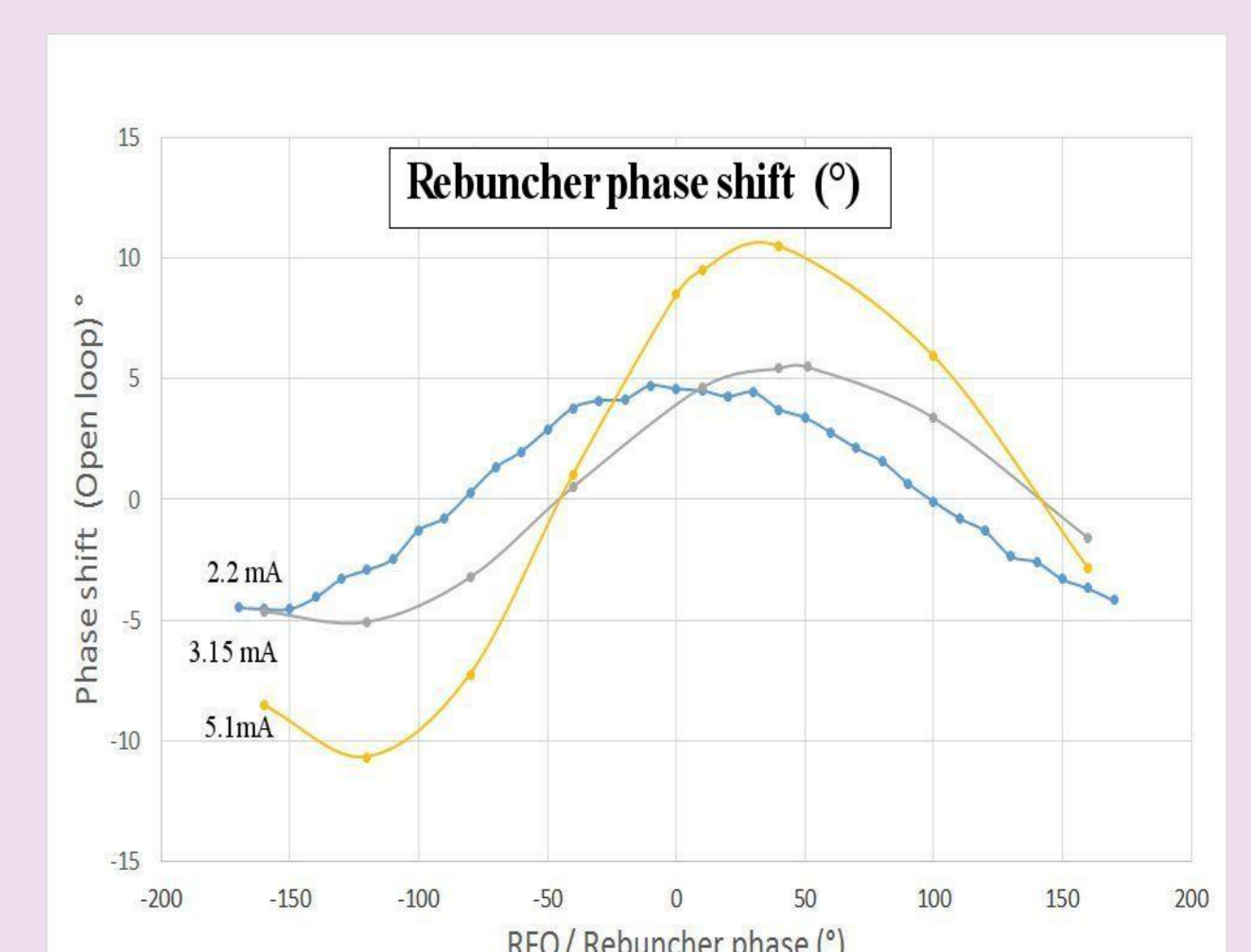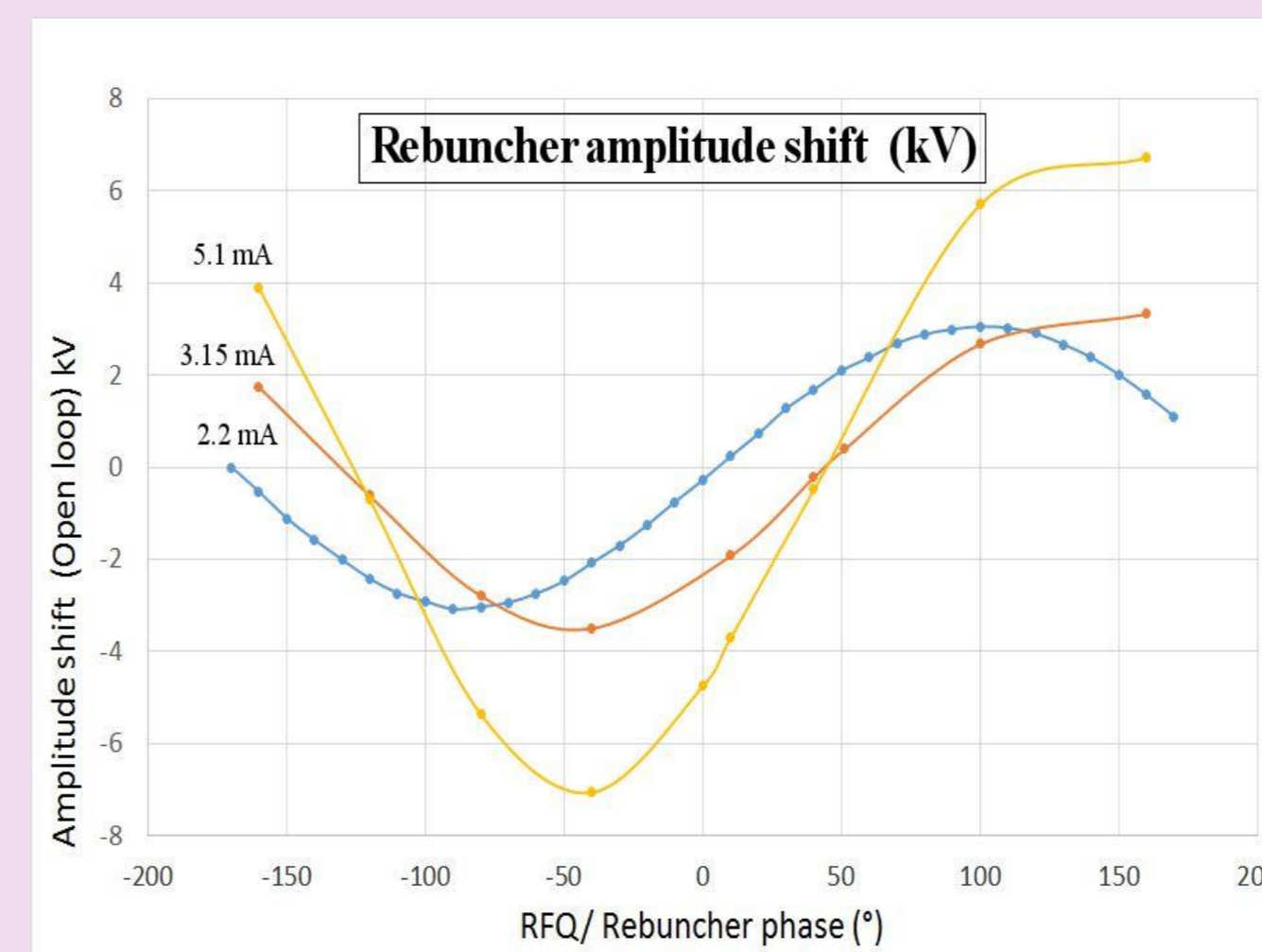- Open loop regulation

Voltage induced by the beam

Phase induced by the beam

In open loop, for this tuning point :
The beam change the voltage : -2.7kV
The phase : +2°

- Closed loop regulation

voltage
Pulse timing zoom

phase
Pulse timing zoom
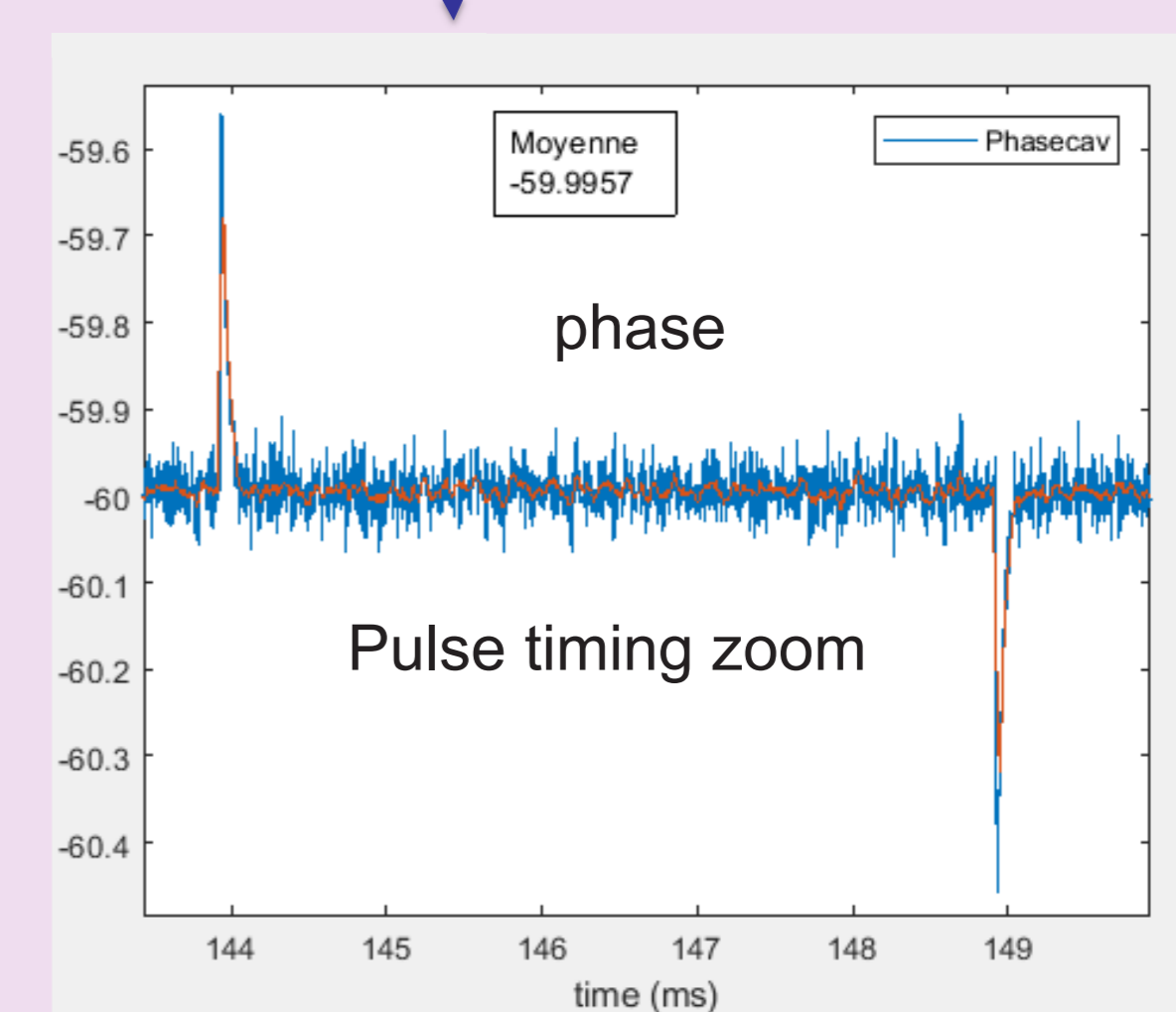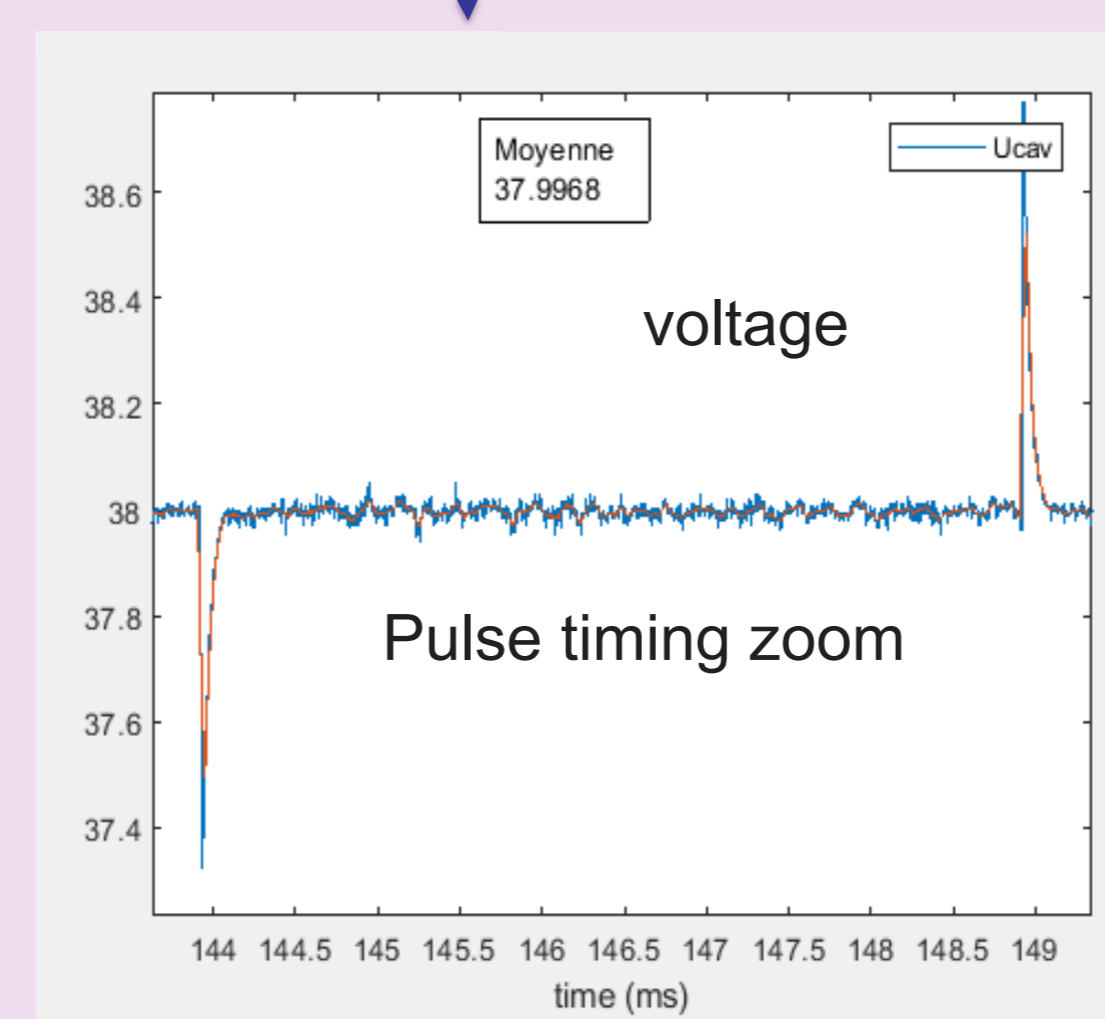
In closed loop, for this tuning point :
The IQ regulation (with the choosed constants of (PID system) brings back to the set point in 100 µs

Measurements of the amplitude and phase in open loop with the tuning of the phase between RFQ and rebuncher (for many currents of the beam)

Measurements and Simulations of the amplitude and phase offsets created by the beam in open loop with the tuning of the phase between RFQ and rebuncher

matlab 2.2ma 2018

Amplitude and phase 2.2 mA
V offset (2.2ma) phi Offset(2.2ma)

Rebuncher amplitude shift (kV)
5.1 mA
3.15 mA
2.2 mA
Amplitude shift (Open loop) kV
RFQ/ Rebuncher phase (°)

Rebuncher phase shift (°)
2.2 mA
3.15 mA
5.1mA
Phase shift (Open loop) °
RFQ/ Rebuncher phase (°)

Conclusion:
We have measured the influence of the beam in the voltage rebuncher regulation. Values are in accordance to the simulated ones. The next steps are to optimize the regulation and to improve the RF system to keep the beam 'on'.