ESS Warm linac meeting – July 6th 2011
Laboratori Nazionali del Sud (INFN), via S. Sofia 62, Catania

1.6.4 MEBT: basic considerations, achievements and criticalities

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1.Basic considerations:
a MEBT matches RFQ output into the DTL input, both transversely and longitudinally. The beam must be re-bunched to maintain the required longitudinal parameters

1.Basic considerations:

4 quads and 1|2 *buncher* would be sufficient.

if **Chopper**, 2 matchings are required: RFQ to chopper, chopper to DTL.

if **Diagnostics**, require some space.

2.Achievements

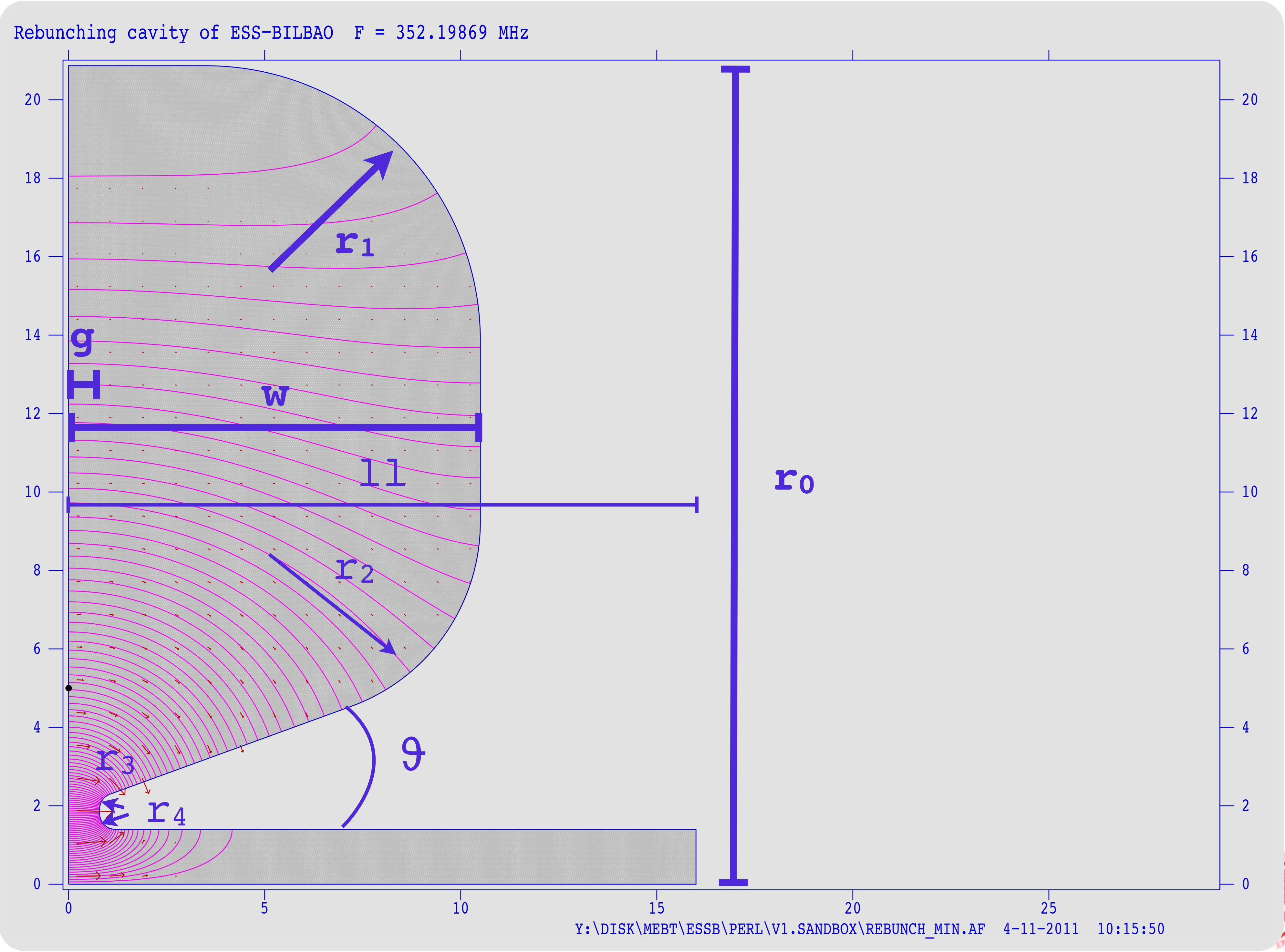
Buncher EM design
Tuner considerations
Coupler design
Quad design
LLRF definition
Optics/Layout preliminary definition

2a.Buncher EM design:

Starting from model *buncher_01*, a multivariable non-linear constrained optimization process has started.

The algorithm uses Matlab© for optimization functions and SUPERFISH/COMSOL© as eigenvalue solver.

The number of parameters (of the 2D buncher geometrical definition) to be optimized varies from 4 to 6. Optimization problem aims at maximizing ZTT with non-linear constrains f=352.2 MHz kilpatric≤1.4.

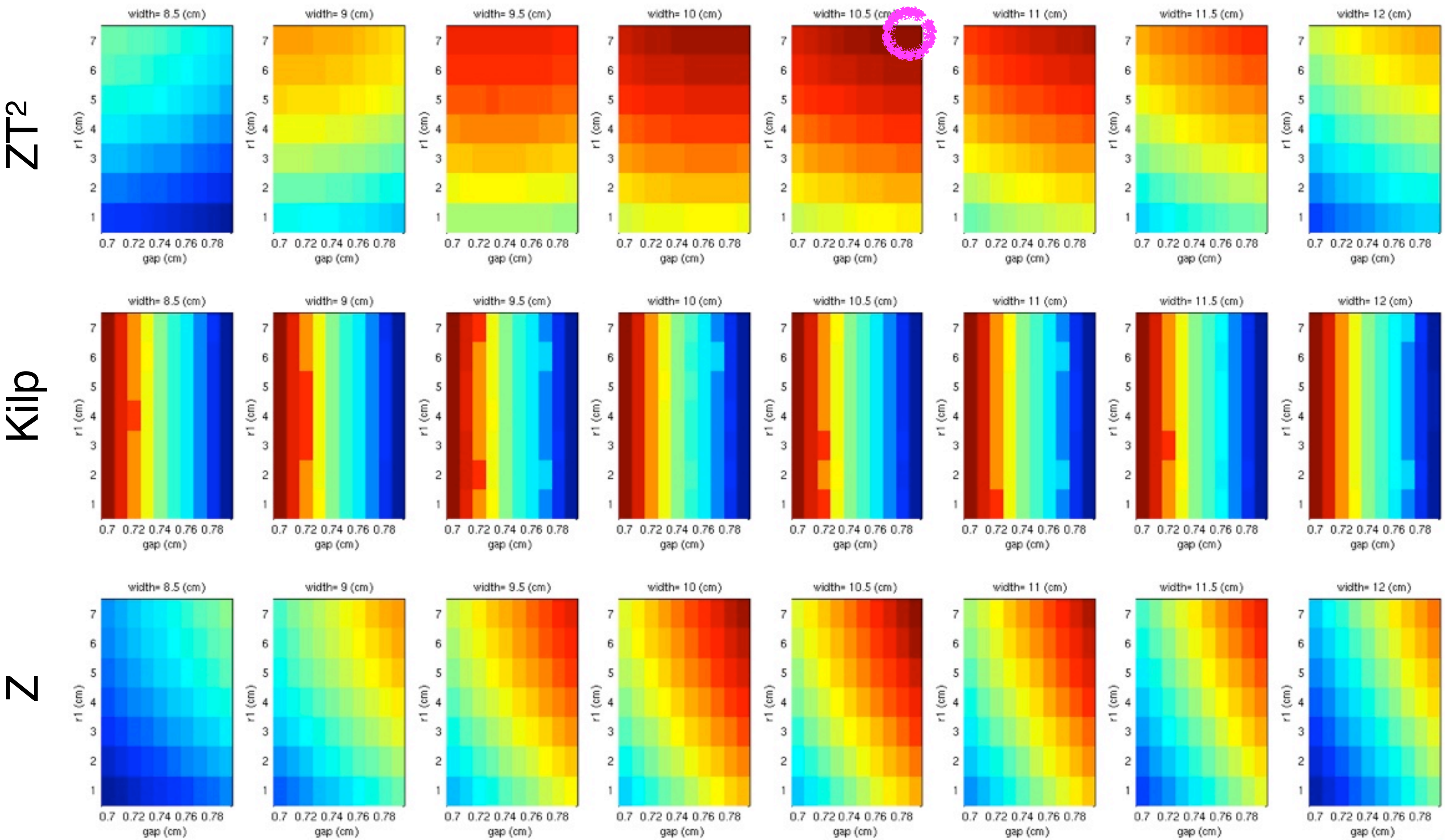


Rebunching cavity of ESS-BILBAO F = 352.19869 MHz
r1
g
w
l1
r0
r2
ϑ
r3
r4
0
5
10
15
20
25
2
4
6
8
10
12
14
16
18
20
Y:\DISK\MEBT\ESSB\PERL\V1.SANDBOX\REBUNCH_MIN.AF 4-11-2011 10:15:50

2a.Buncher EM design:

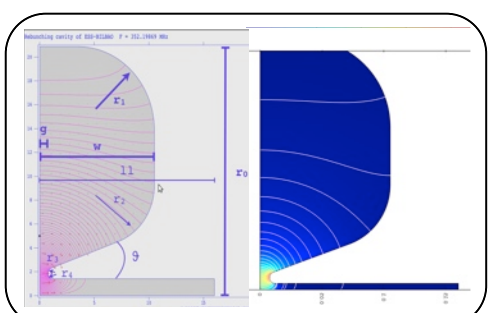
$7.4470 \leq ZT^2 \leq 8.3440$ [MΩ/m]
$1.3738 \leq$ Kilpatrick ≤ 1.4613
$20.7170 \leq Z \leq 24.0430$ [MΩ/m]

~140hrs.



2a.Buncher EM design:

Figure of merit	SUPERFISH	COMSOL 2D	COMSOL 3D
Frequency [MHz]	352.19	352.19	352.19
Q	26415	26410	26440
Z [MΩ/m]	24.043	24.033	24.063
ZT^2 [MΩ/m]	8.344	8.366	8.377
TTF	0.5809	0.5900	0.5900
Es,max [MV/m]	25.35	25.92	29.176
Power loss [W] (½ Cu cav)	4794	4781	4775



Fields normalized to

E_0T = 0.5 MV/m

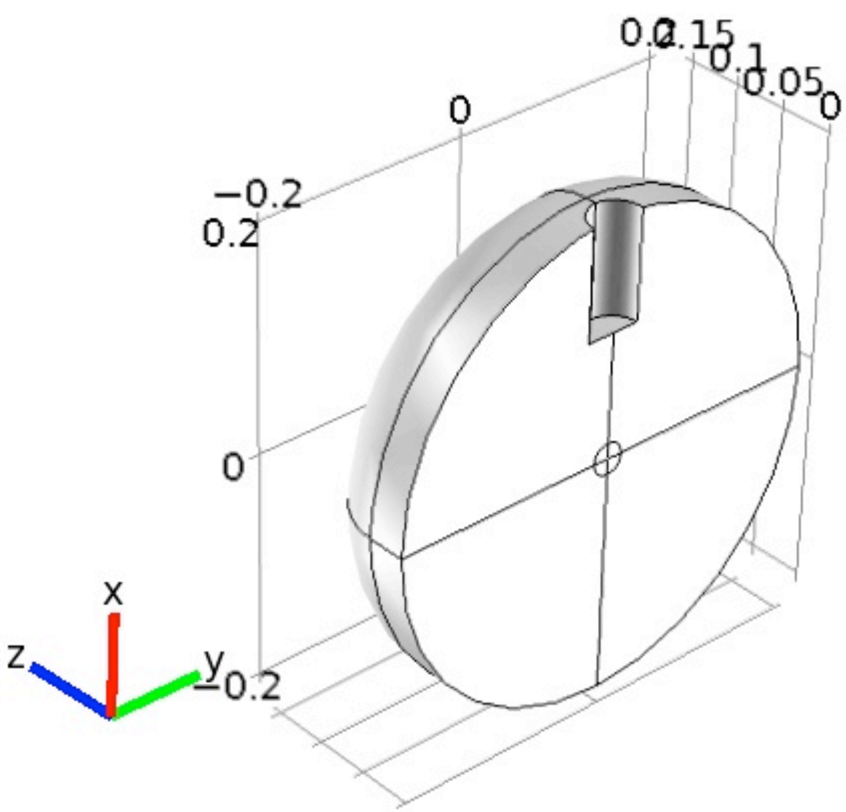
Kilpatrick: 1.37488

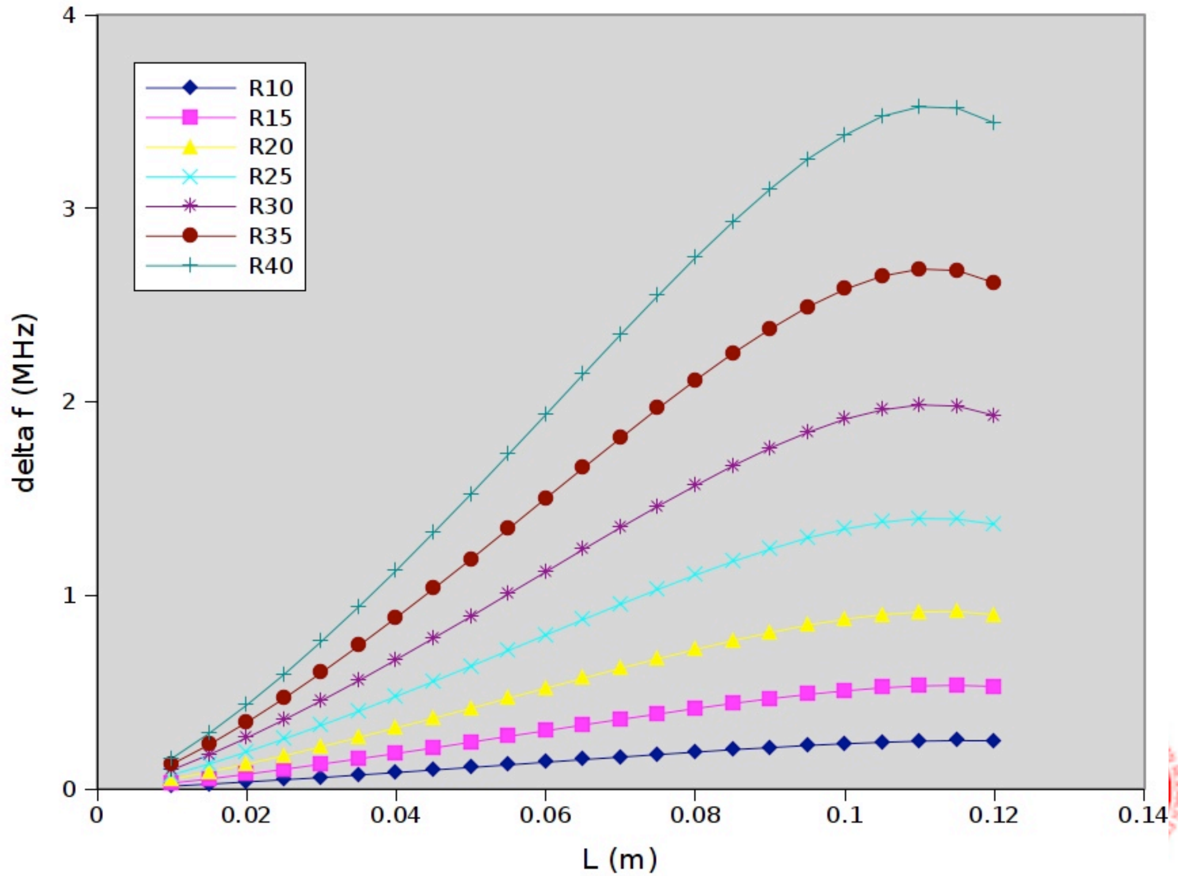
½ Cavity length: 160.00mm

2b.Buncher tuner design:

Different plunger tuner configurations are being considered. EM simulations use model *buncher_01* as test-bench for design, operating at nominal power.

The estimated power loss in the plunger is also computed to define cooling conditions.

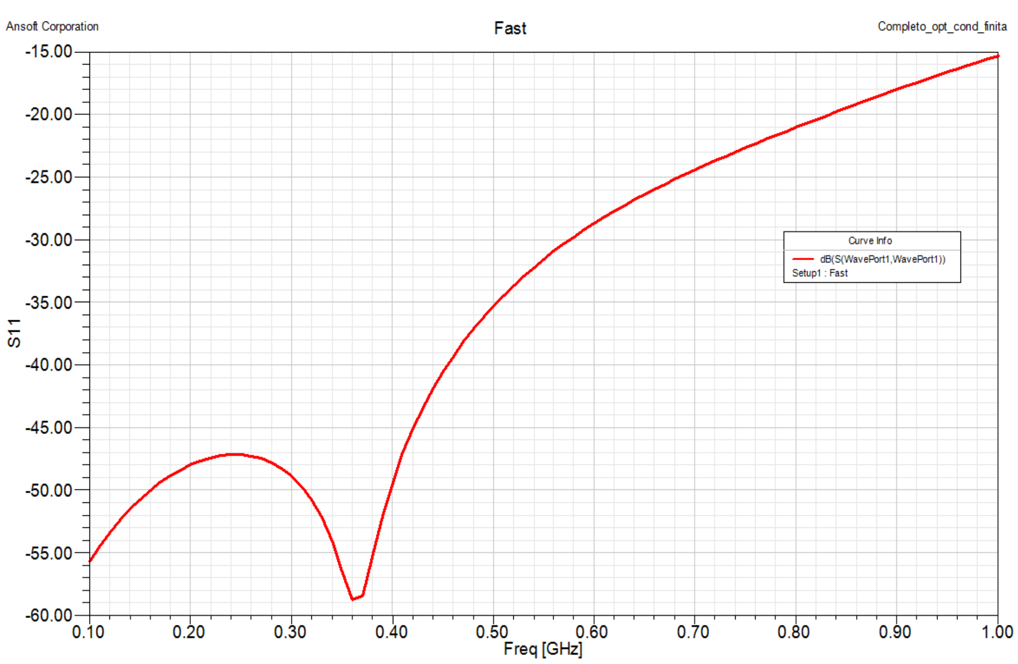


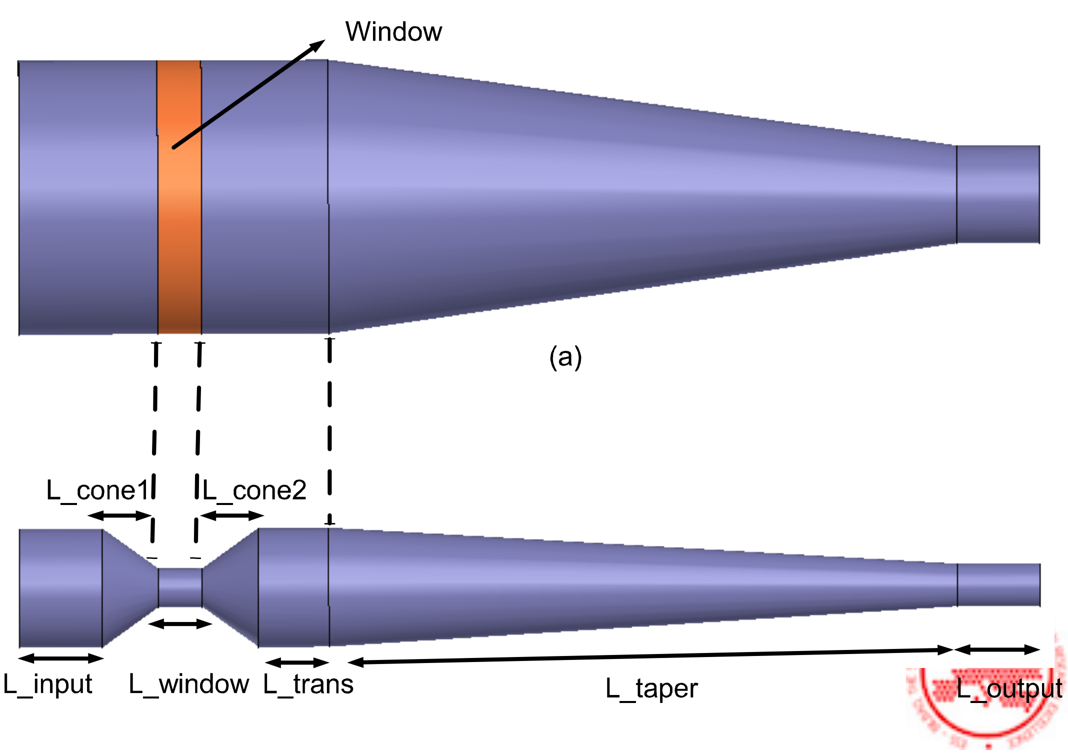


2b.Buncher coupler design

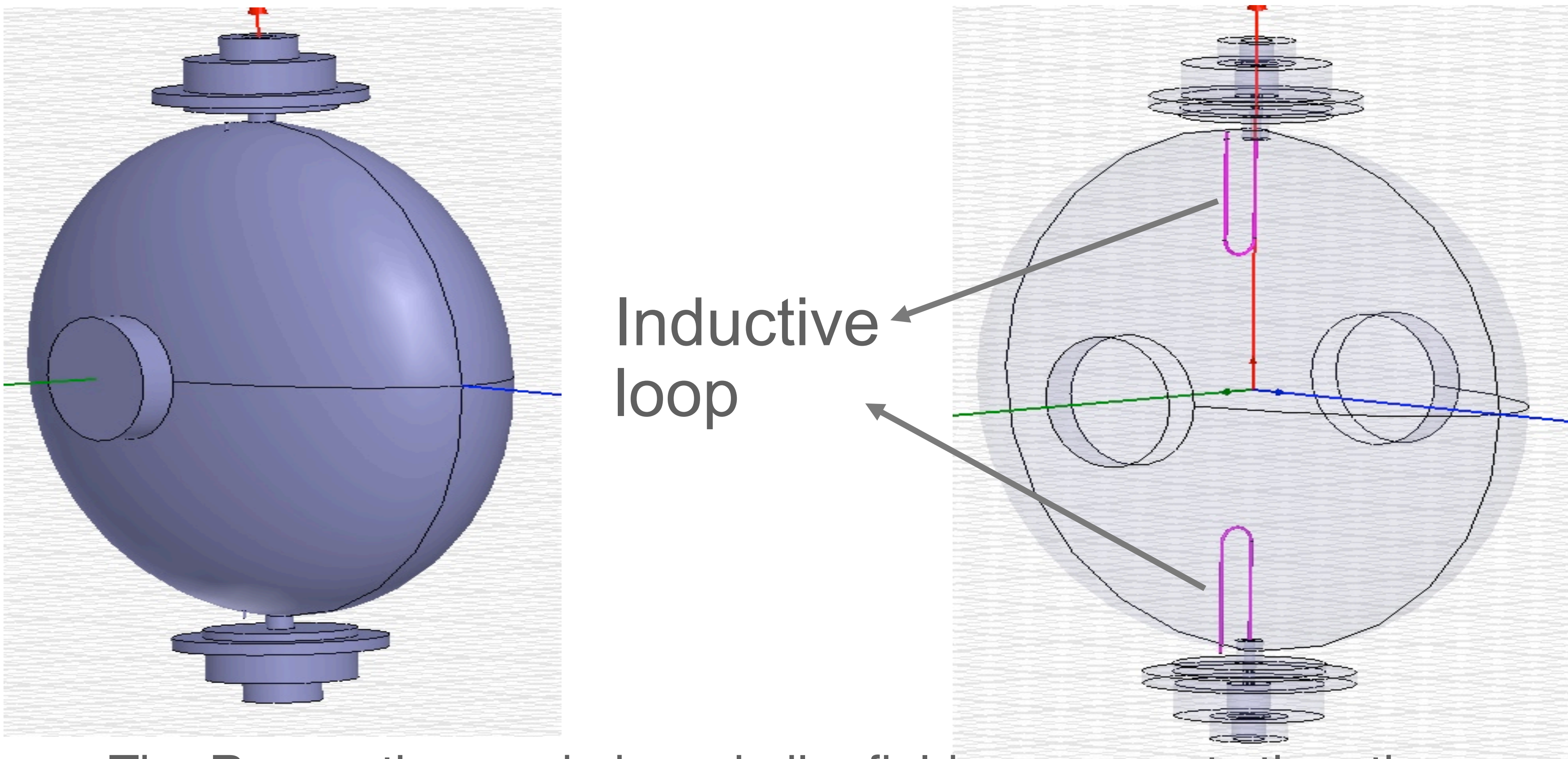
The **power coupler** for the buncher cavity is being designed using electromagnetic codes.

The optimum taper design to guarantee 50 Hz matching and ceramic window thickness are obtained from this study.





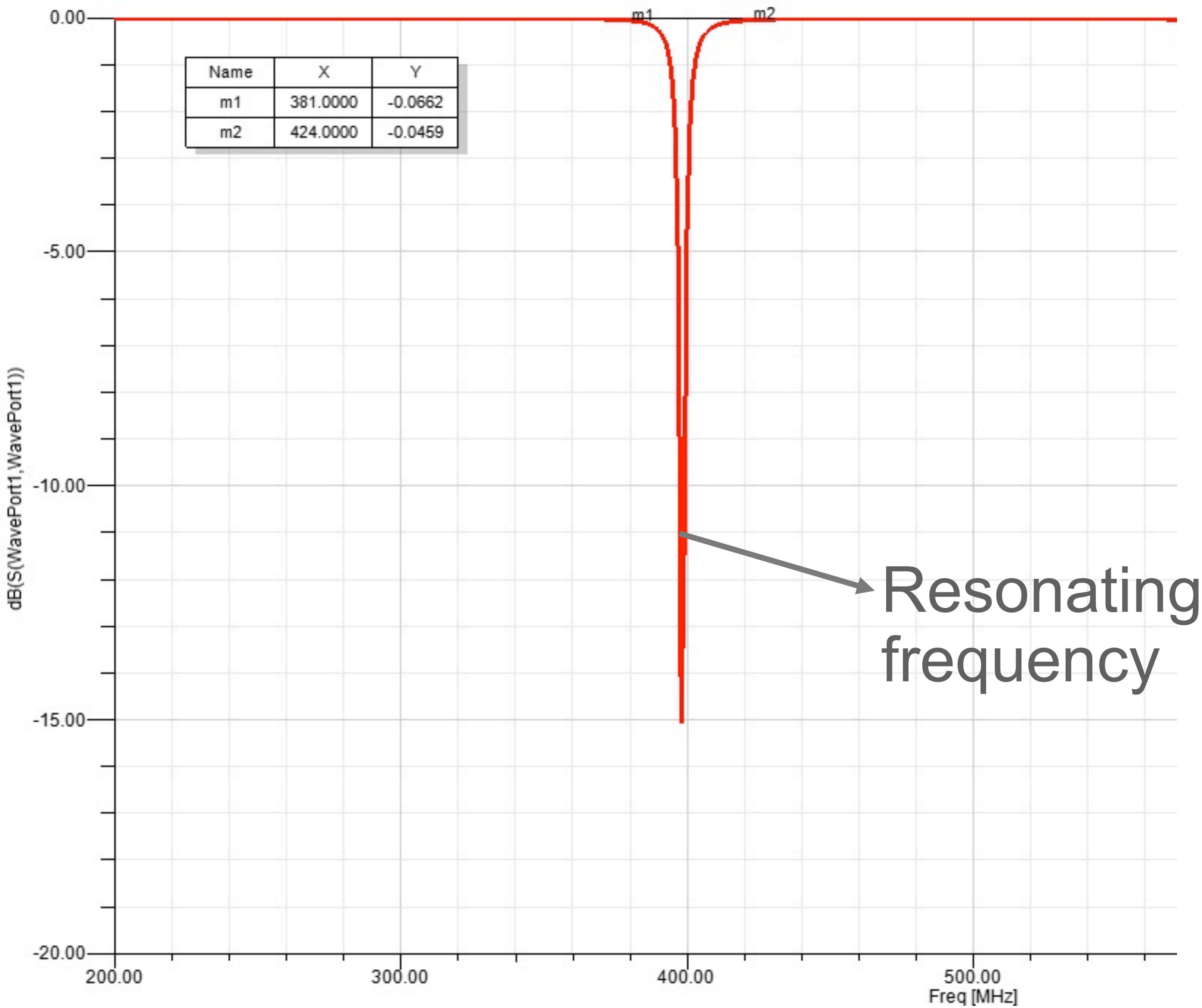
Elliptical Cavity with couplers



The Resonating mode has similar field components than the bunching cavity.

Two couplers have been inserted into an elliptical cavity to **check the inductive coupling** provided by the loops.

Elliptical Cavity with couplers

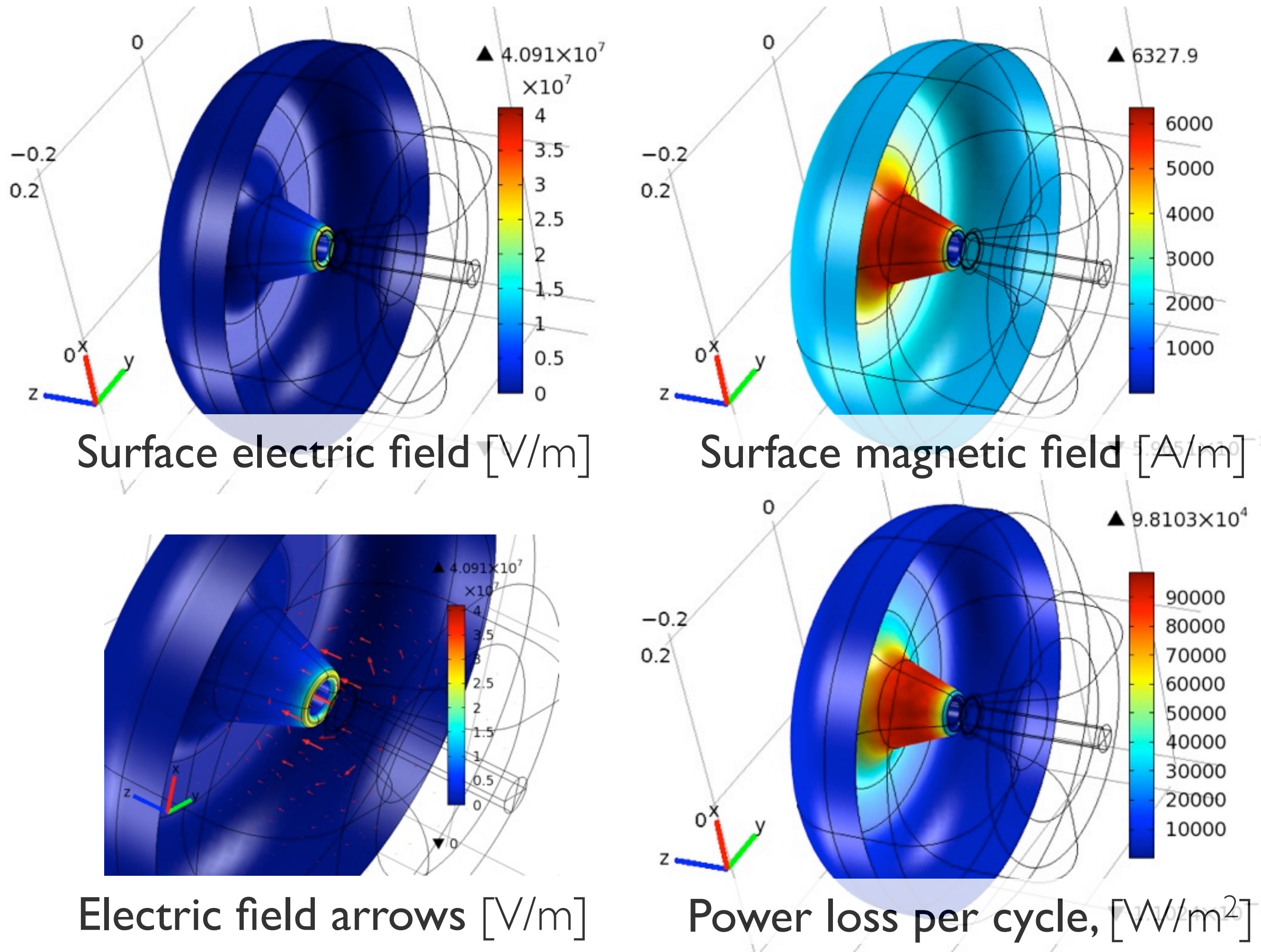


Name	X	Y
m1	381.0000	-0.0662
m2	424.0000	-0.0459

2c.Buncher cooling

Power loss obtained with model *buncher_01* provides heat source input for a heat transfer solver and the temperature field map in the copper volume is obtained for the operating conditions of the cavity. Cooling is being designed based on this information.

Fields normalized to E_0T=0.5 MV/m



Surface electric field [V/m]

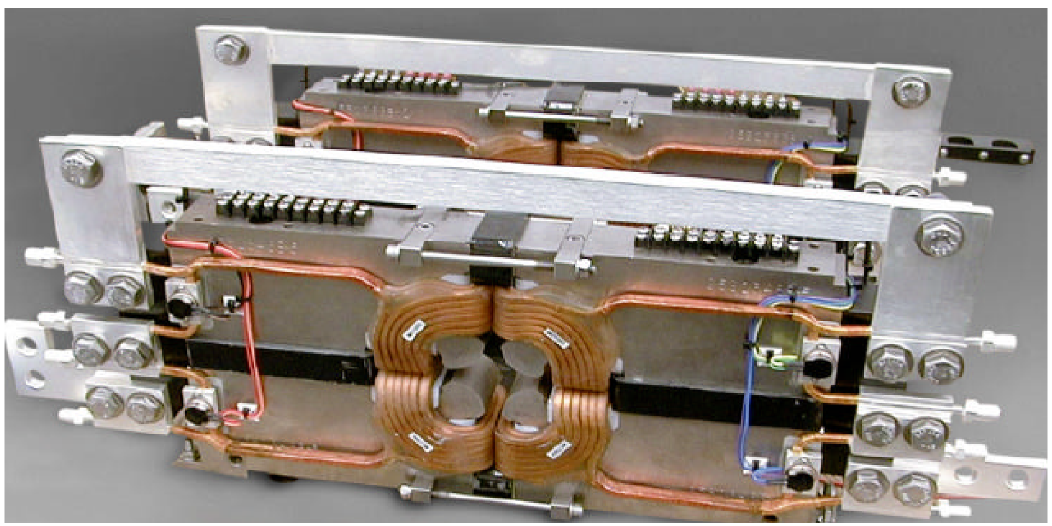
Surface magnetic field [A/m]

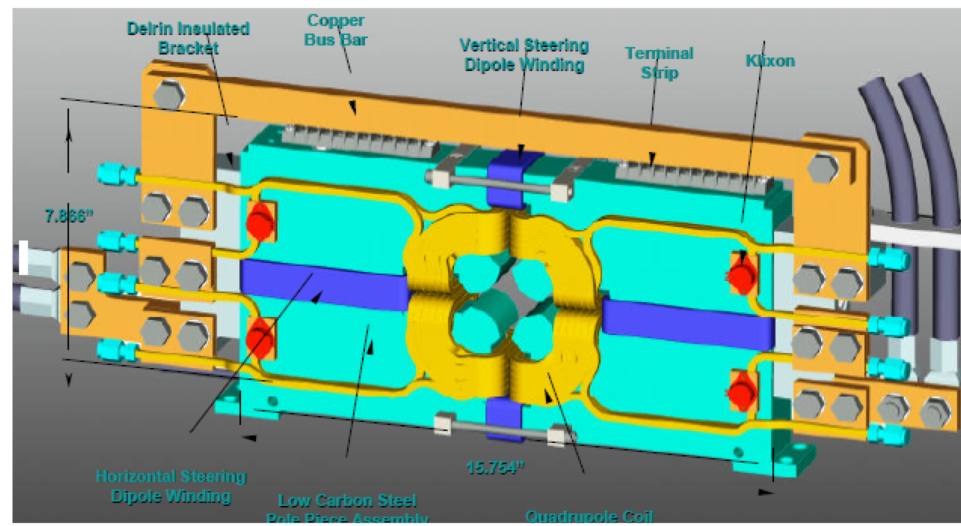
Electric field arrows [V/m]

Power loss per cycle, [W/m²]

2d.Quadrupoles for MEBT

A review of different focusing elements used in similar MEBTs worldwide is being done.





SNS **MEBT** Quadrupole

2d.Quadrupoles for MEBT

	Energy (MeV)	Length (m)	# Quadrupoles	Types
SNS	2.5	3.64	14	32 mm ø, 41 T/m, 61 mm l_{eff}, 45 mm iron 42 mm ø, 29 T/m, 66 mm l_{eff}, 45 mm iron
LINAC4	3	3.9	11	20 mm ø, 1.7 T/m, 255 mm l_{eff} 44 mm ø, 4.3 T/m, 155 mm l_{eff} 28 mm ø, 38 T/m, 56 mm l_{eff} 28 mm ø, 12 T/m, 82 mm l_{eff}
RAL FETS	3	3.2 to 4.6	11	28 mm ø, 9 to 33 T/m, 70 mm l_{eff}
J-PARC	3	3	8	From 13 to 37.5 T/m, 60 mm l_{eff}
CSNS	3	3	8	From 12 to 33 T/m, 60 mm l_{eff}

Summary of the **MEBT**s quadrupoles

2e.RF Interfaces for MEBT: LLRF

- Based on the IQ Demodulation (0-IF frequency)
  - RF frequency too high for direct sampling of the cavity fields and waveguide coupler signals
  - Narrow bandwidth
  - Easier implementation of the I and Q loops
  - Analog solution provides a wider bandwidth, short group delay, and cheaper than digital solution

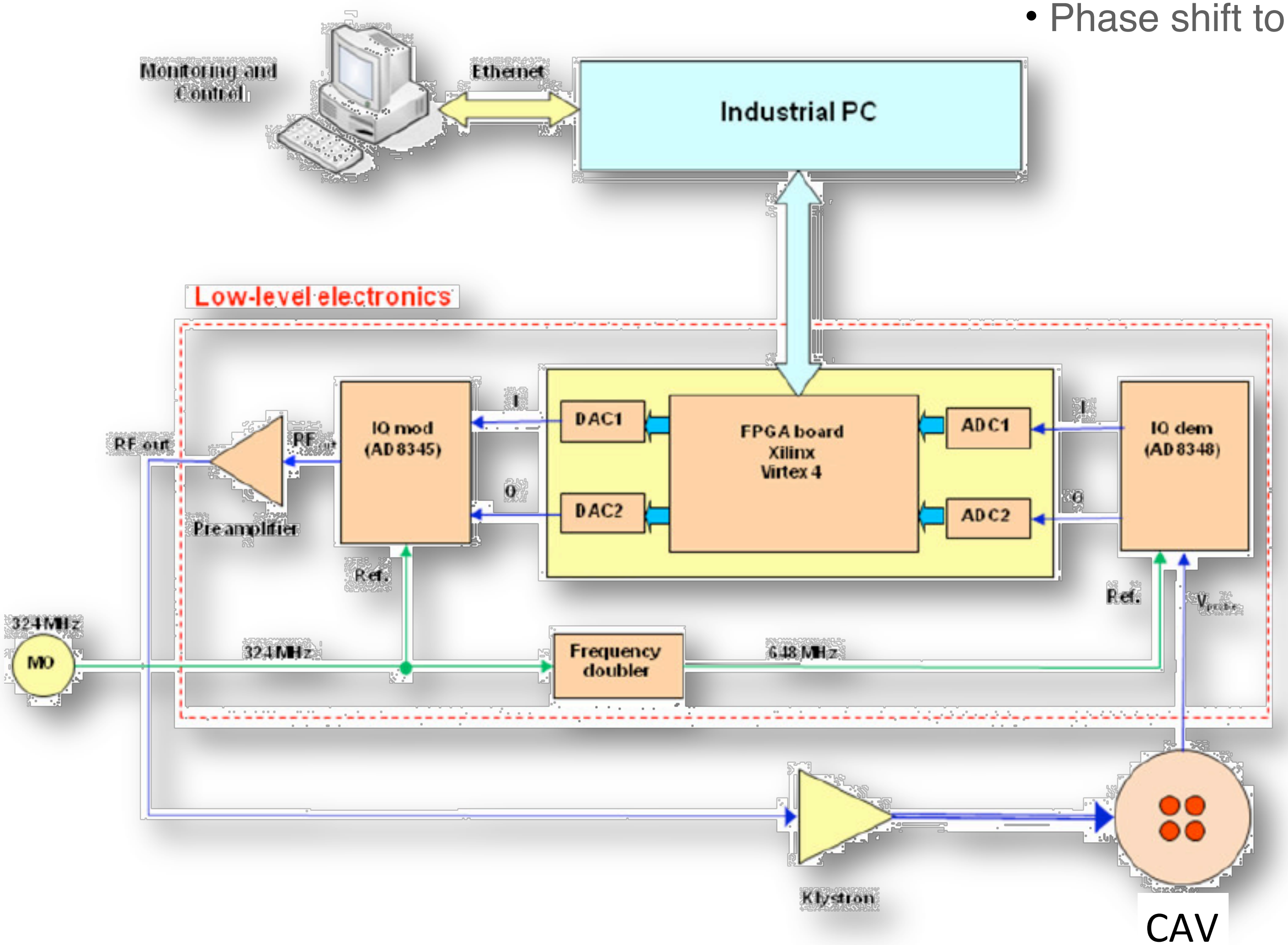
- LLRF composed of three different loops:
  - Amplitude loop
  - Phase loop
  - Tuning loop

- Klystron polar loop considered as a separate part of the LLRF

Block Description of the LLRF

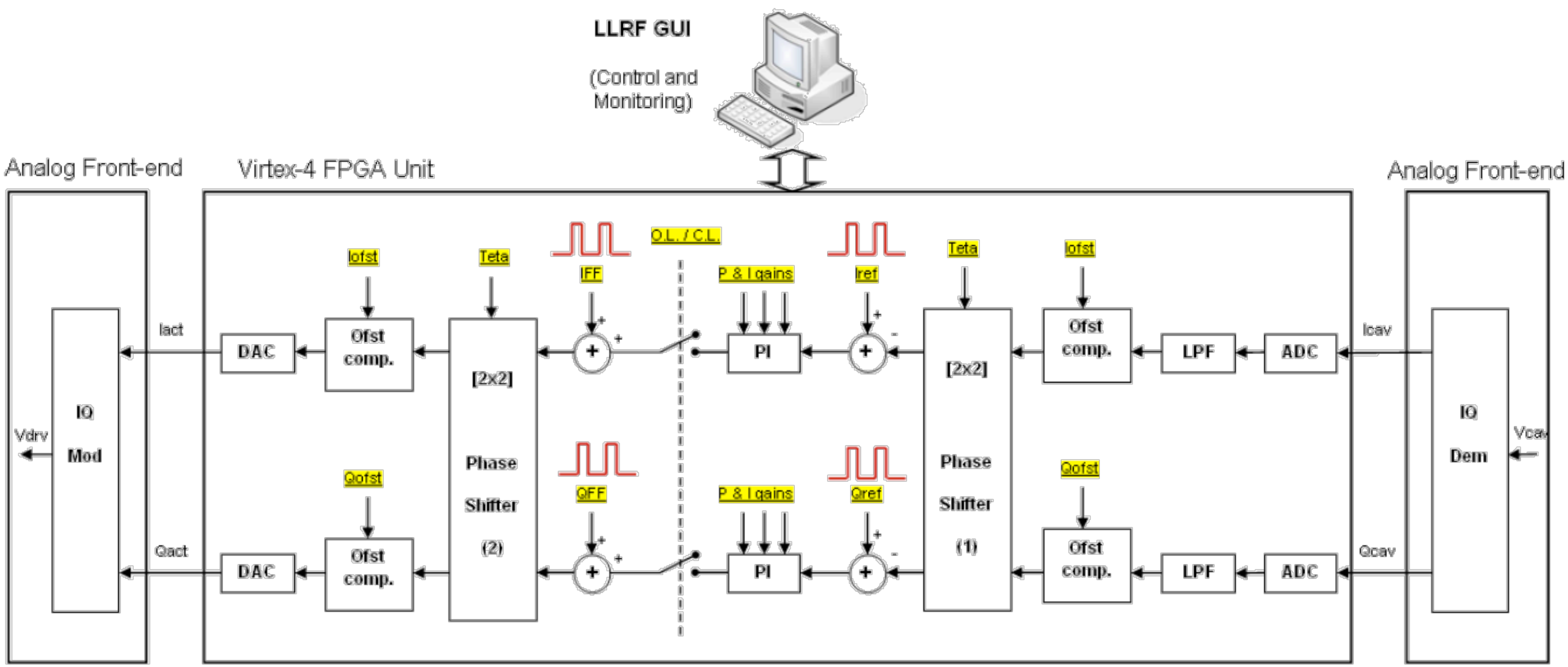
- Amplitude and phase loops

• RF signal demodulated to IQ components
• IQ comp. compared with reference levels
• PI regulation depending on the error signal
• Phase shift to compensate the loop delay



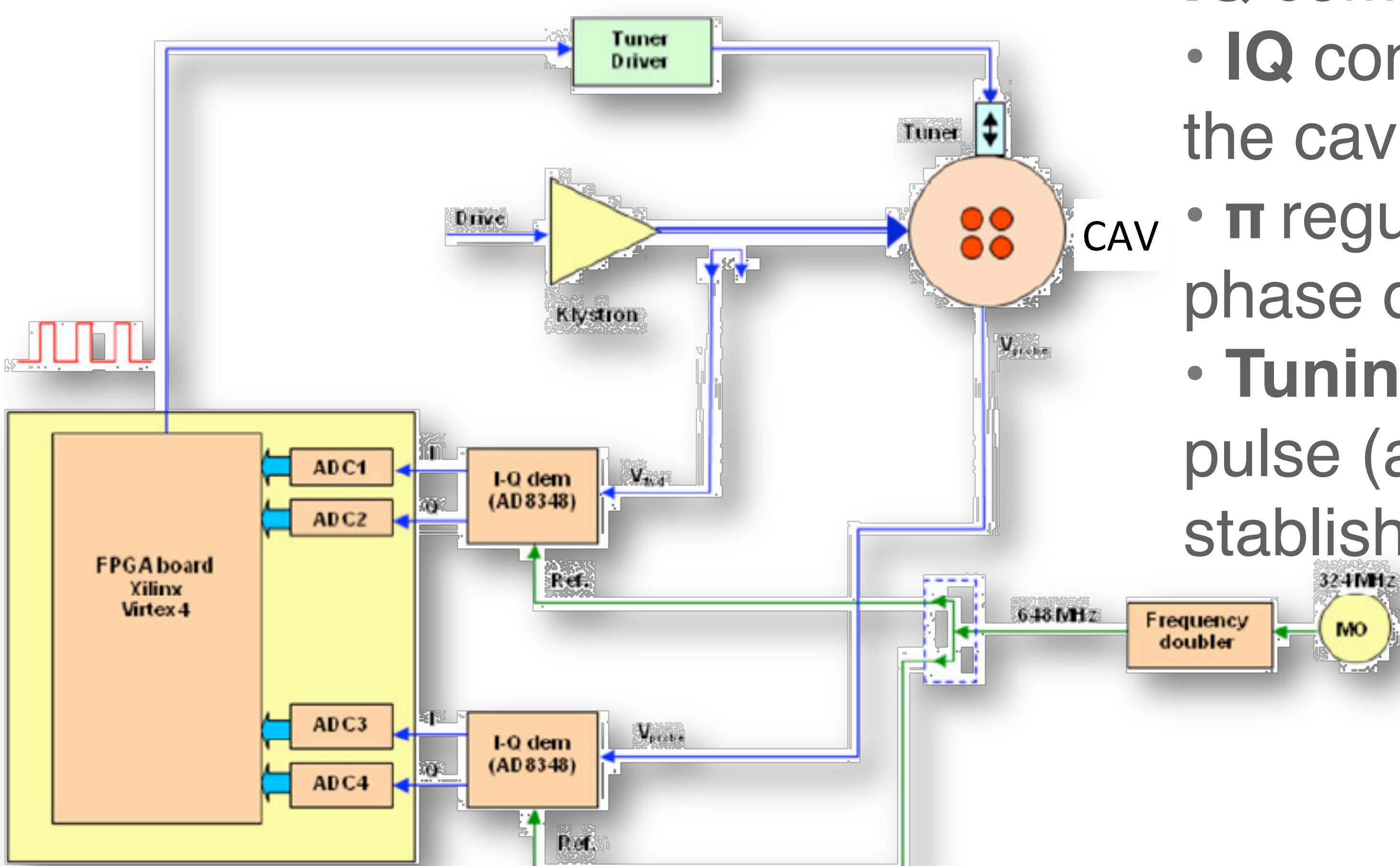
Block Description of the LLRF

- FPGA program for the amplitude and phase loops



Block Description of the LLRF

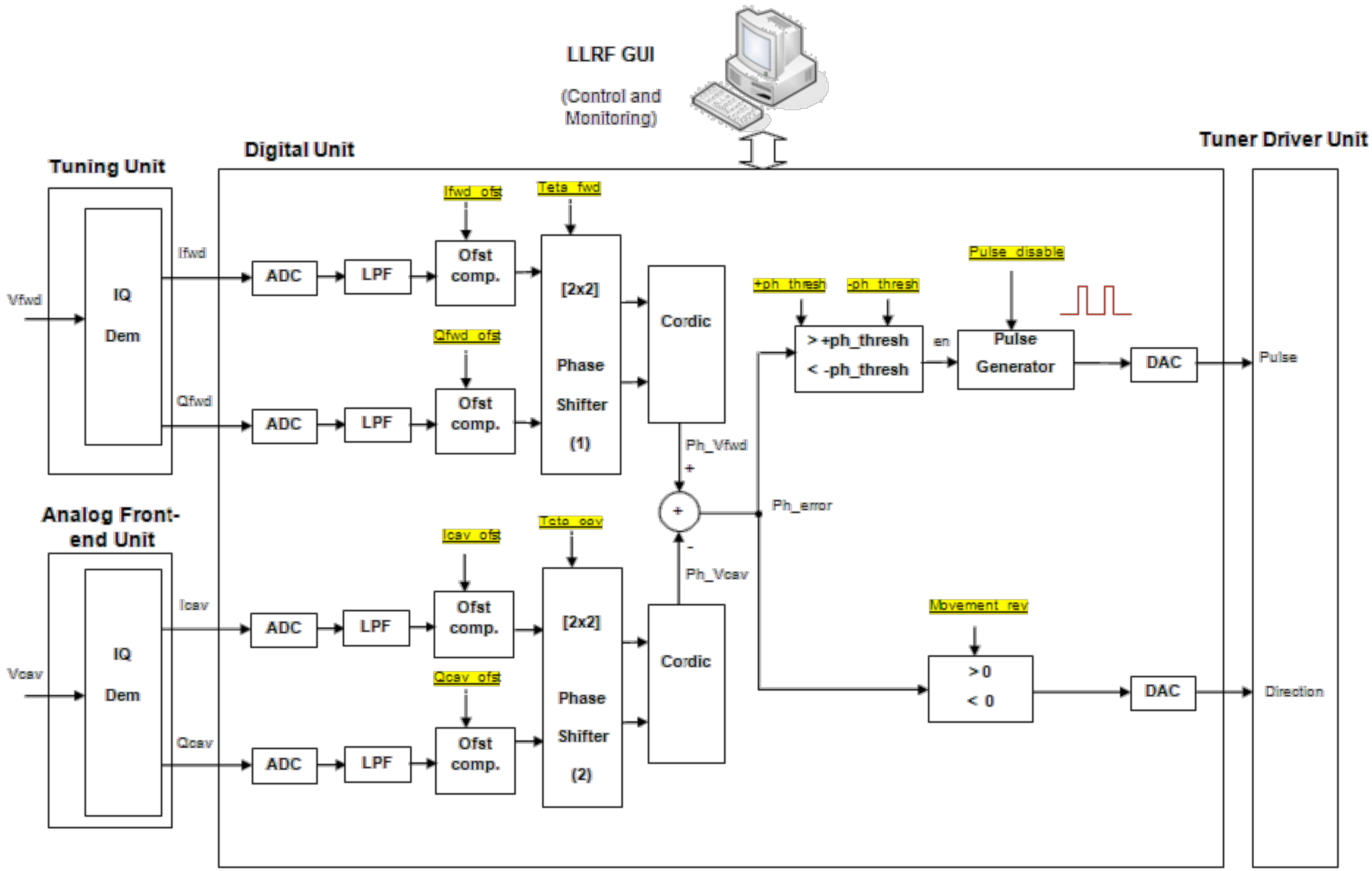
- Tuner Loop



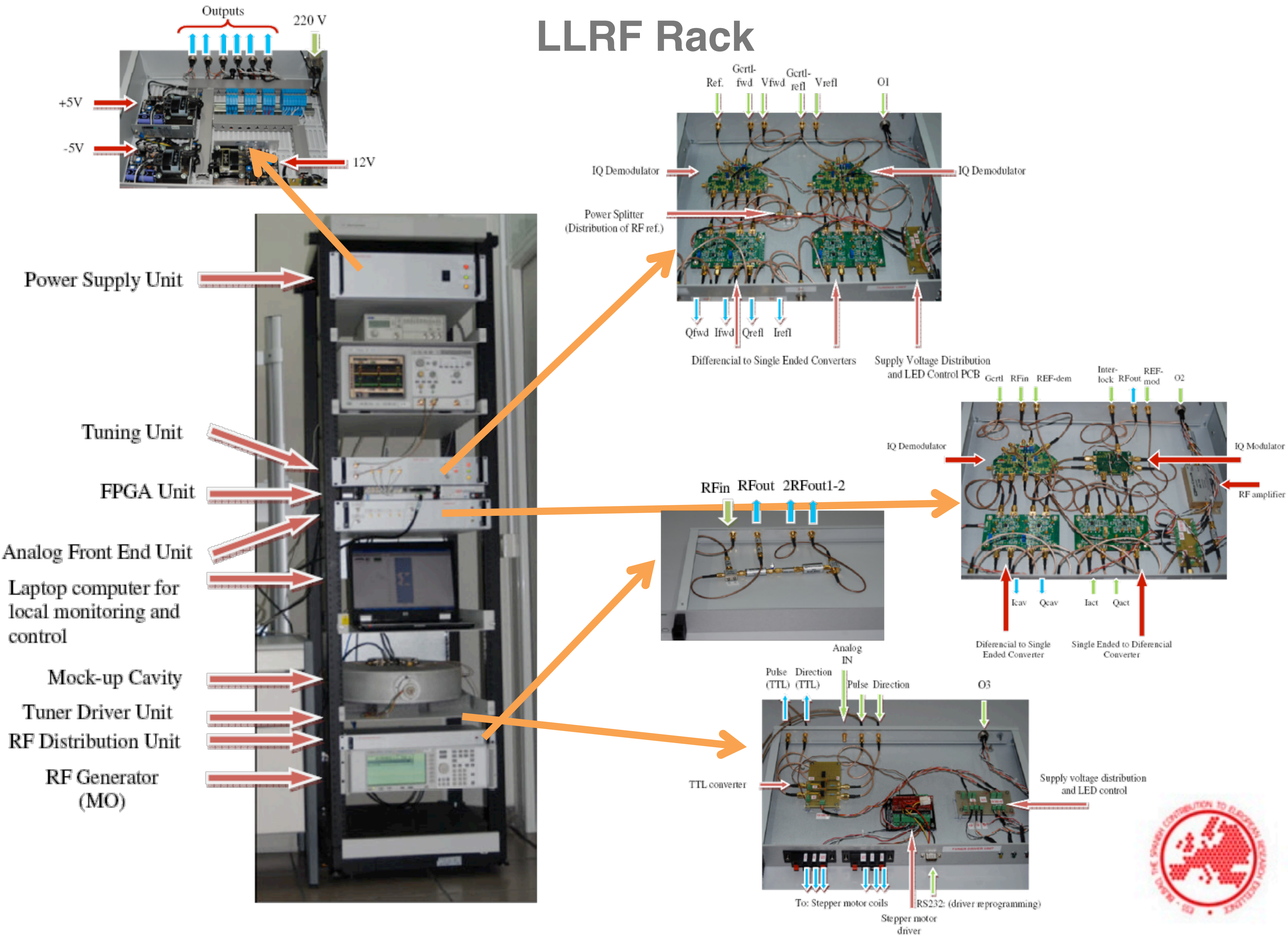
- RF signal demodulated to **IQ** components
- **IQ** comp. after and before the cavity
- **π** regulation to keep the phase difference
- **Tuning** done during RF pulse (after phase is stablished)

Block Description of the LLRF

- FPGA program for the tuning loop



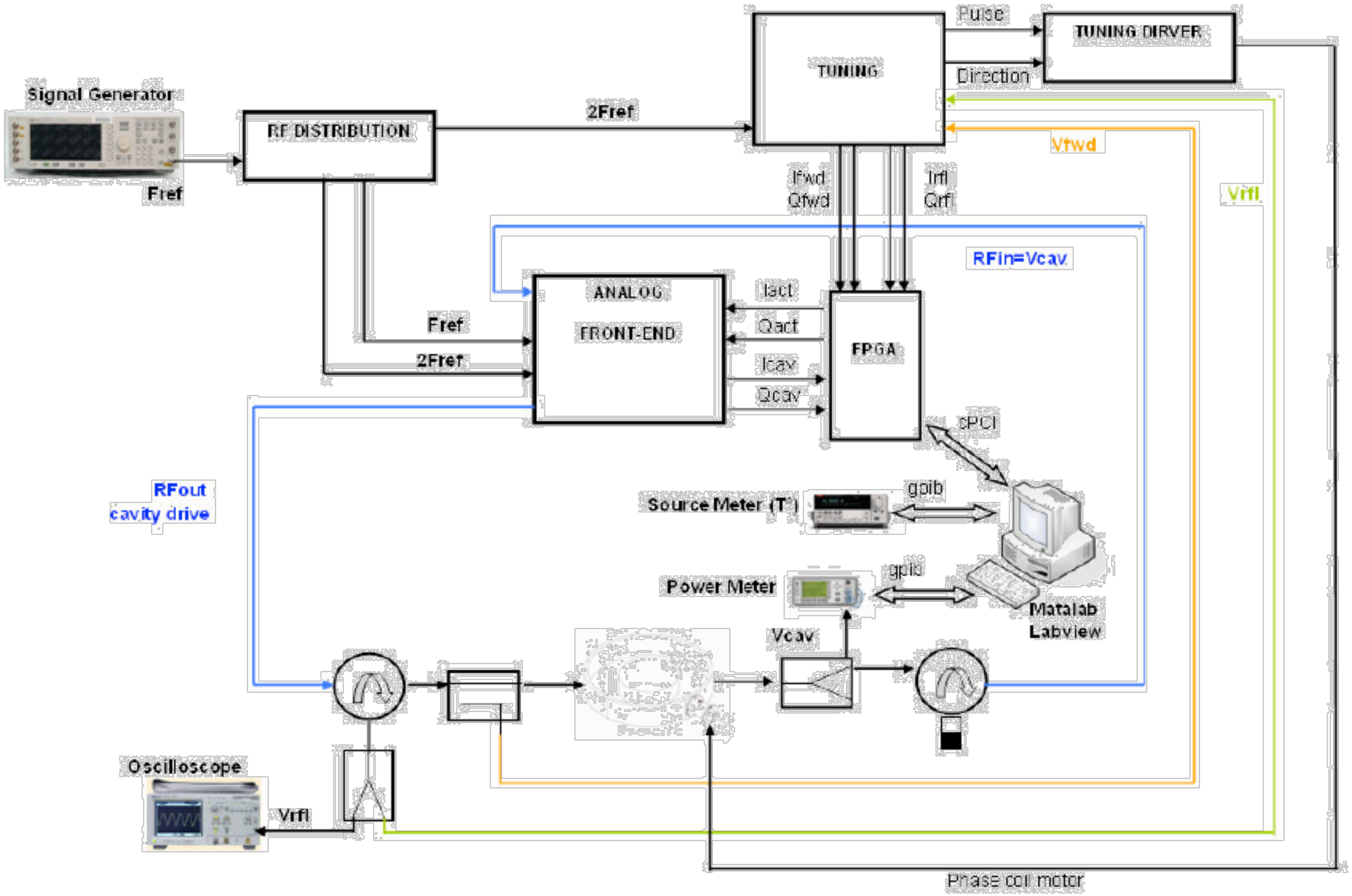
LLRF Rack



Outputs
220 V
+5V
-5V
12V
Power Supply Unit
Tuning Unit
FPGA Unit
Analog Front End Unit
Laptop computer for local monitoring and control
Mock-up Cavity
Tuner Driver Unit
RF Distribution Unit
RF Generator (MO)
Ref.
Gcrtl-fwd
Vfwd
Gcrtl-refl
Vrefl
O1
IQ Demodulator
IQ Demodulator
Power Splitter (Distribution of RF ref.)
Qfwd
Ifwd
Qrefl
Irefl
Differencial to Single Ended Converters
Supply Voltage Distribution and LED Control PCB
Gcrtl
RFin
REF-dem
Inter-lock
RFout
REF-mod
O2
IQ Demodulator
IQ Modulator
RF amplifier
Icav
Qcav
Iact
Qact
Diferencial to Single Ended Converter
Single Ended to Diferencial Converter
RFin
RFout
2RFout1-2
Analog IN
Pulse (TTL)
Direction (TTL)
Pulse
Direction
O3
TTL converter
Supply voltage distribution and LED control
To: Stepper motor coils
RS232: (driver reprogramming)
Stepper motor driver

LLRF measurements

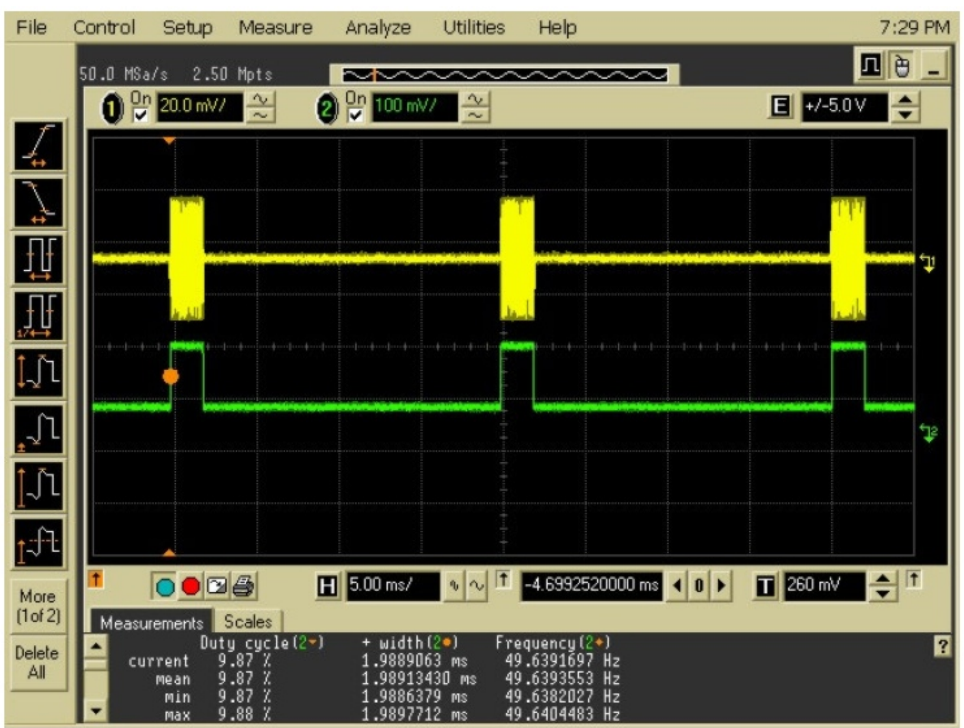
- Test Set-up

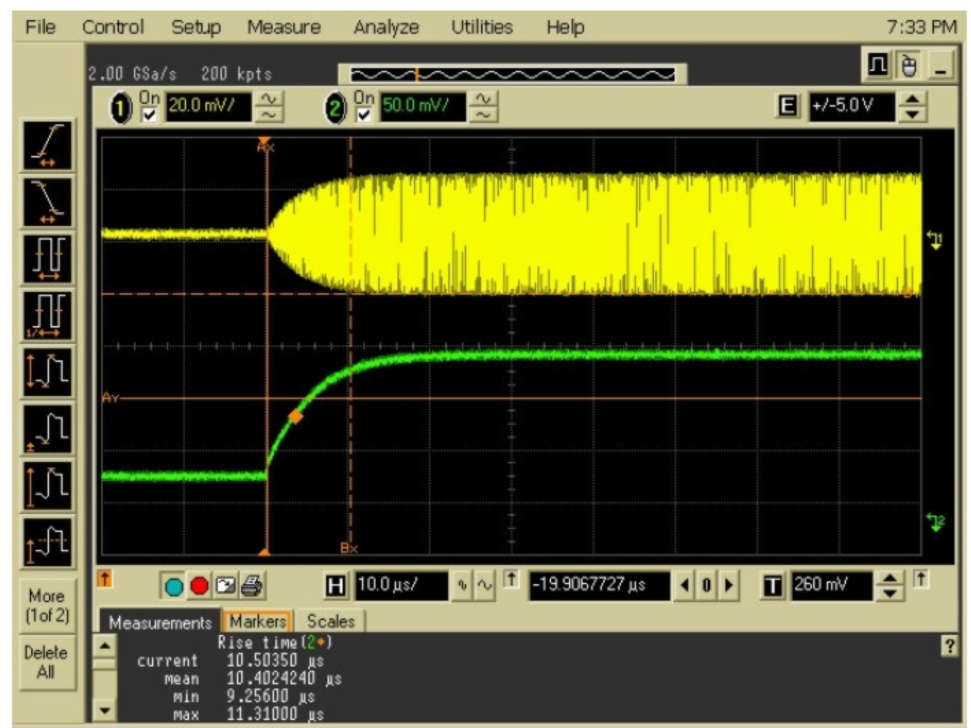


LLRF measurements

- Transient fields into the cavity and I_{fwd} component

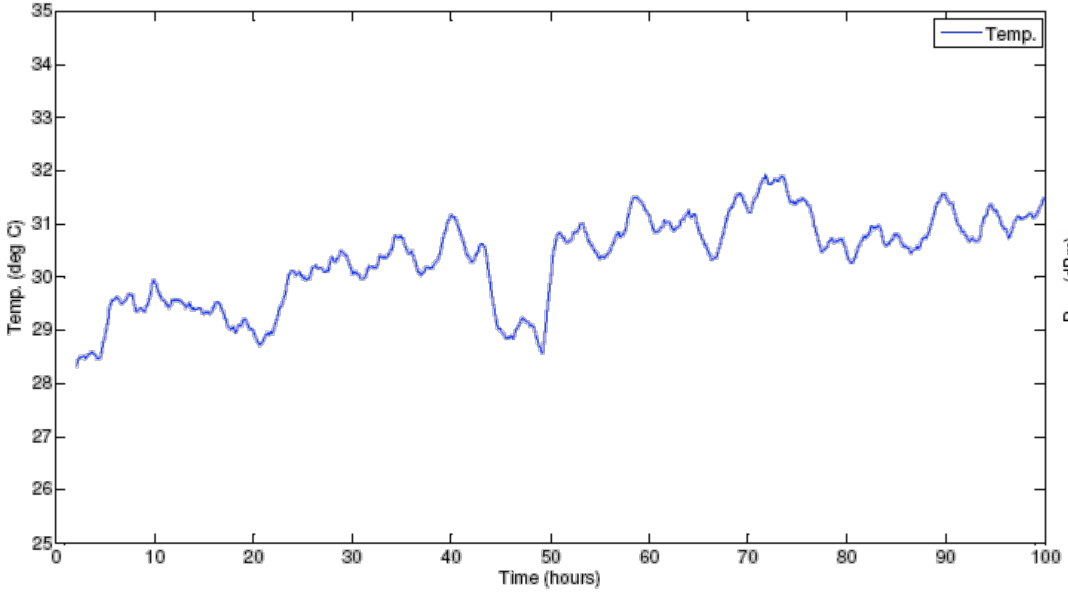
Parameter	Specification	Measured
Pulse Frequency	50 Hz	49.64 Hz
Pulse Width	250 – 2000 µs	1988 µs
Duty Cycle	1.25 – 10%	9.88 %
Settling Time	< 100 µs	2 – 10 µs

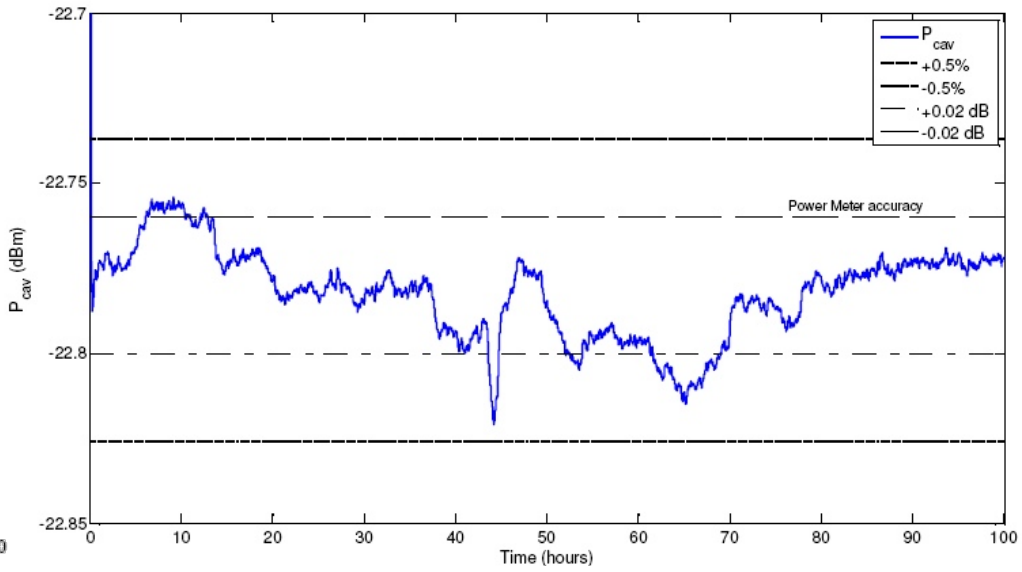




LLRF measurements

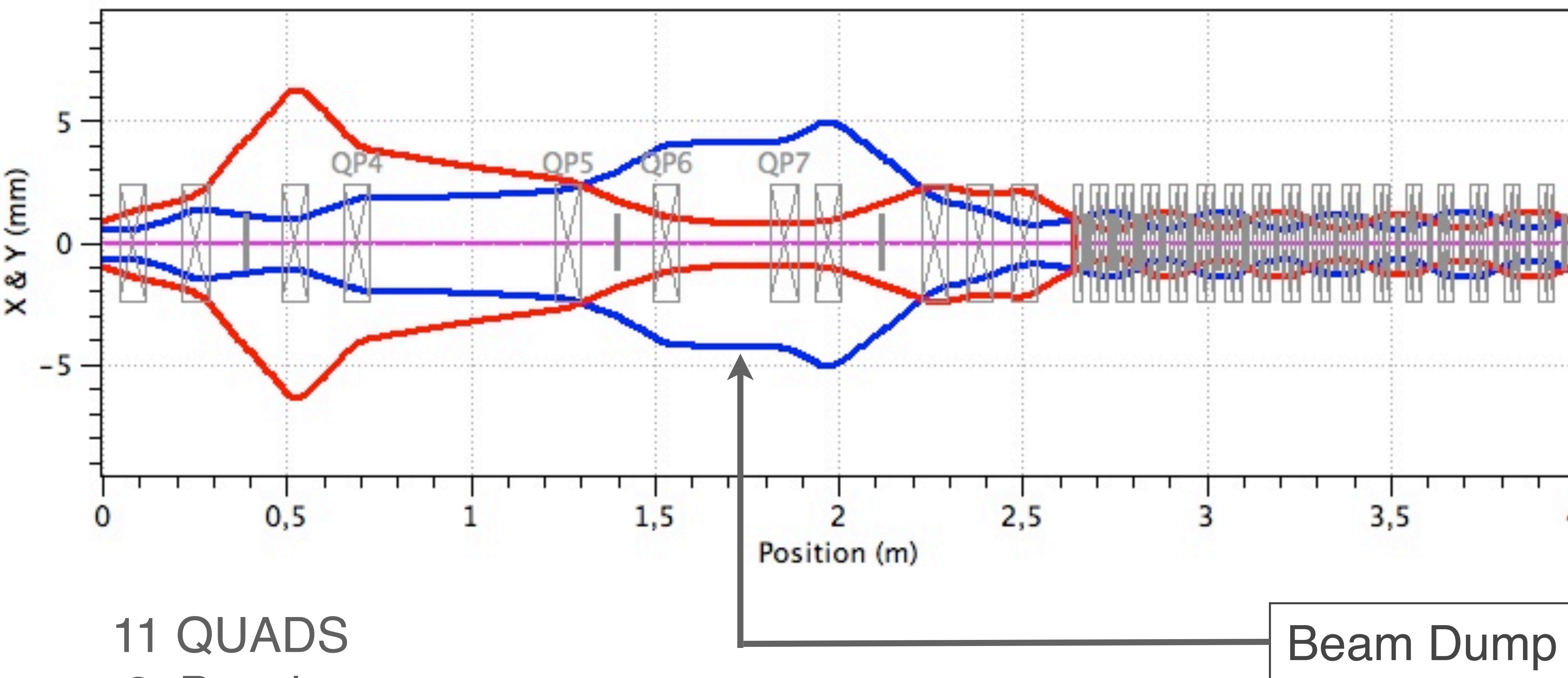
- Temperature Room & Cavity field stability





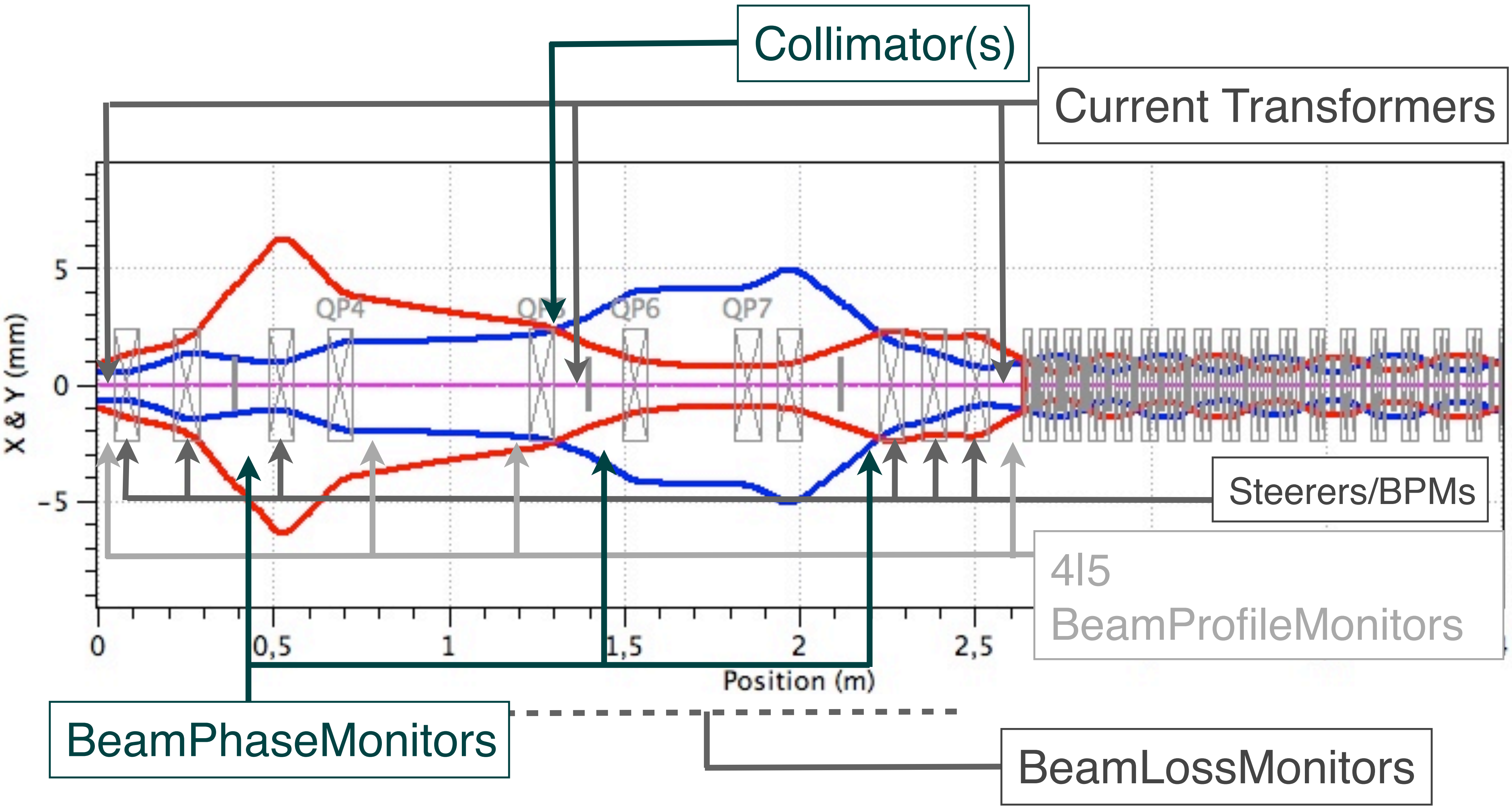
2f.Optics

Aperture ø**20** mm
Gradients **8-23** T/m
Effective length **70** mm



11 QUADS
3 Bunchers
1 Fast Chopper
1 Beam Dump

2g.Diagnostic Elements



measure:

emittance/Courant-Snyder parameters

beam distribution

3.criticalities

DTL input data missing

Emittance budget missing

Aperture definition missing

Fast/Slow Chopper undefined