EuroGammaS

European Consortium for the delivery of a Gamma Beam System to ELI-NP

LIBERA Workshop 2016

ELI-NP Gamma Beam Source Diagnostics

Giovanni Franzini

Contributions:
S. Bini, F. Cioeta, A. Mostacci, D. Pellegrini, A. Stella, S. Tocci

Topics

- **Diagnostics overview**
- **Charge measurements**
  - Integrating Current Transformer
  - Digitizer
  - Other methods for Charge measurements
- **Beam Position measurements**
  - Stripline Beam Position Monitor
  - Readout electronics
  - Cavity Beam Position Monitor
- **Beam Screens**
  - Imaging system

giovanni.franzini@lnf.infn.it

Linac diagnostics

Electrical

Electrical Signal + Signal Processing

Non destructive

Beam Position (BPM)

- Strip Line BPM (#29)
- Cavity BPM (#4)

Beam Charge (ICT)

Train Beam Charge (with BPM)

Beam Loss (BLM)

Luminosity monitor

Optical Footprint of the electron beam

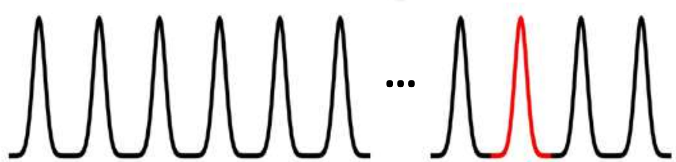
Image of the footprint

Centroid, RMS spot size

- → Envelope Scan
- + Corrector → Gun exit energy
- + Quadrupoles → Twiss Parameters (Quad Scan)
- + Dipole → Energy, Energy Spread
- + RF Deflector → Bunch Length

Energy Spread + Bunch Length → Longitudinal Phase Space

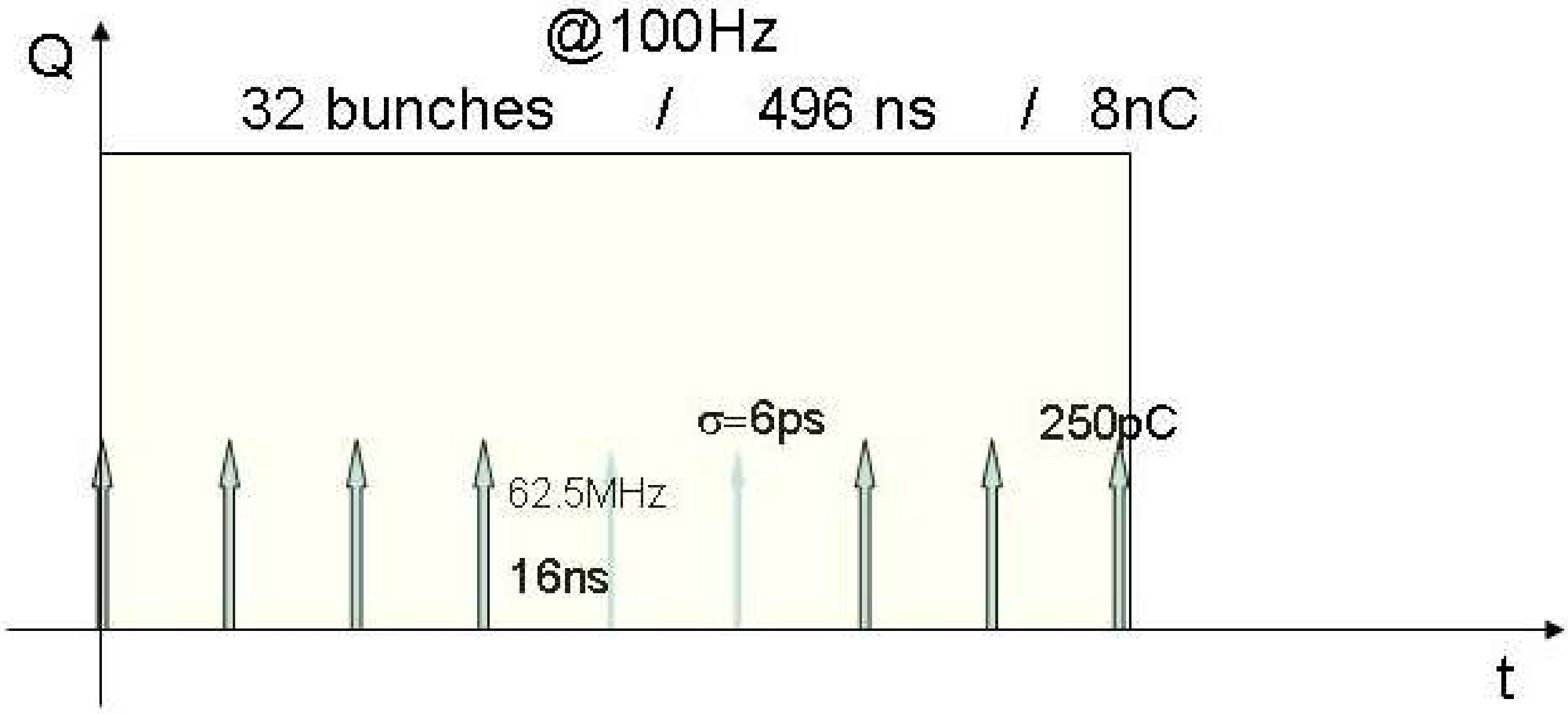
+ Gated Camera



32 bunches

giovanni.franzini@lnf.infn.it

Main parameter of the train



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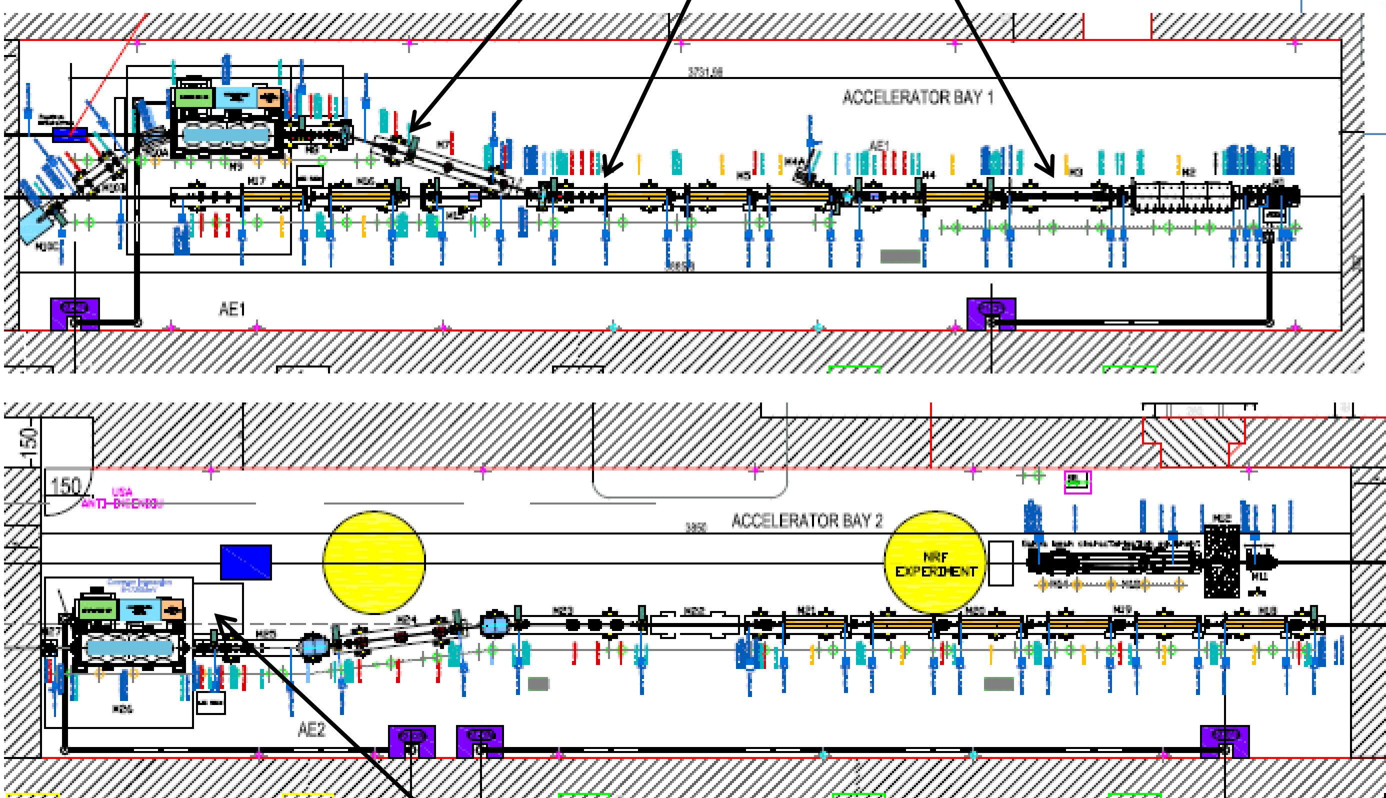
Beam Charge

giovanni.franzini@lnf.infn.it

Charge measurements

3 ICTs:– M8 – M6 – Gun

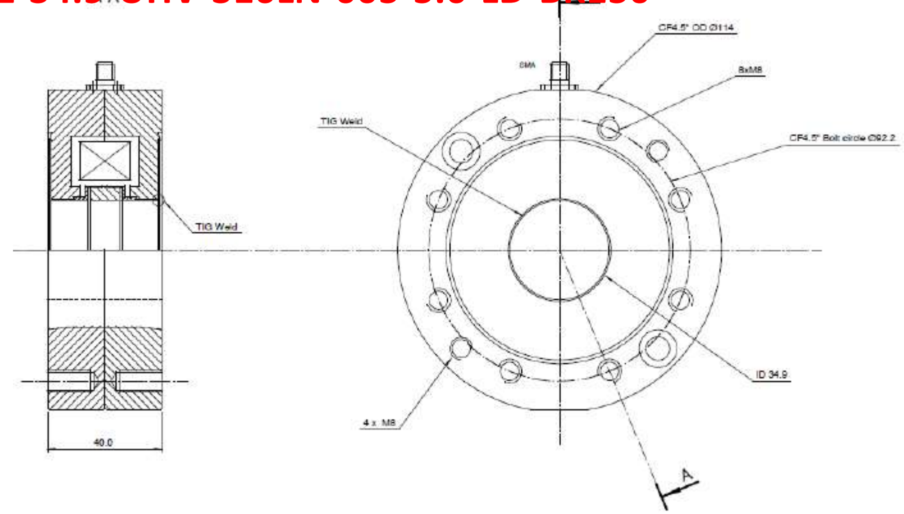


1 ICT @ M25

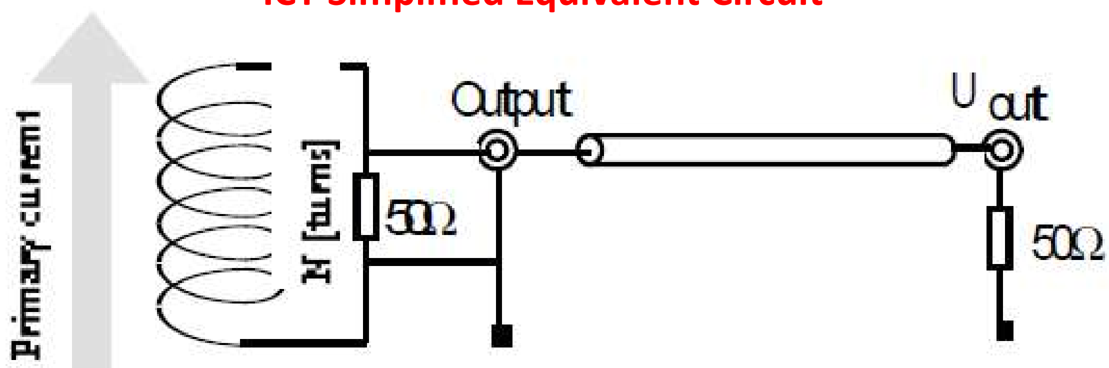
giovanni.franzini@lnf.infn.it

Integrating Current Transformer (ICT)

Model: BERGOZ ICT-CF4''1/2-34.9-UHV-316LN-005-5.0-LD-BK150



ICT Simplified Equivalent Circuit



$$I_{sec} \cong \frac{1}{5} \cdot I_{beam} \quad \rightarrow \quad V_{out} \cong \frac{I_{sec}}{2} \cdot 50[\Omega] \cong 5 \cdot I_{beam} \quad \rightarrow \quad \boxed{\int V_{out} \cdot dt \cong 5 \cdot Q_{beam}}$$

giovanni.franzini@lnf.infn.it

ICT characterization

BERGOZ ICT Transformer -- ICT-CF4''1/2-34.9-UHV-316LN-005-5.0-LD-BK150 --Passive Model				
Operating Temperature	< 150°C			
Operating Temperature with calibration coil	< 100°C			
Turns Ratio	5 : 1			
Sensitivity	5	V s / C	MEASURED	**5.04 V s / C**
Peak Voltage / Q_{beam}	~ 2	V / nC	MEASURED	**1,5 V/nC**
Upper cutoff frequency (typ)	150	MHz	MEASURED	**180 MHz**
Lower cutoff frequency	< 13	KHz	MEASURED	**4.5 kHz**
Signal Drop	3.59	% / us	MEASURED	**3,57 %/µs**
Pulse length (typ)	5	ns	MEASURED	**5,6 ns (full length)**

giovanni.franzini@lnf.infn.it

Agilent Digitizer

Digitizer Specification Agilent M9210A		
Resolution	10 bit	
Sampling rate (single ch./dual ch.)	4 Gs/s 2 Gs/s	~20 samples x pulse ~10 samples x pulse
Analog Bandwidth	1.4 GHz	
Memory	Up to 256 MS / channel	
Input Range	Programmable up to 5Vpp	

Next Steps:

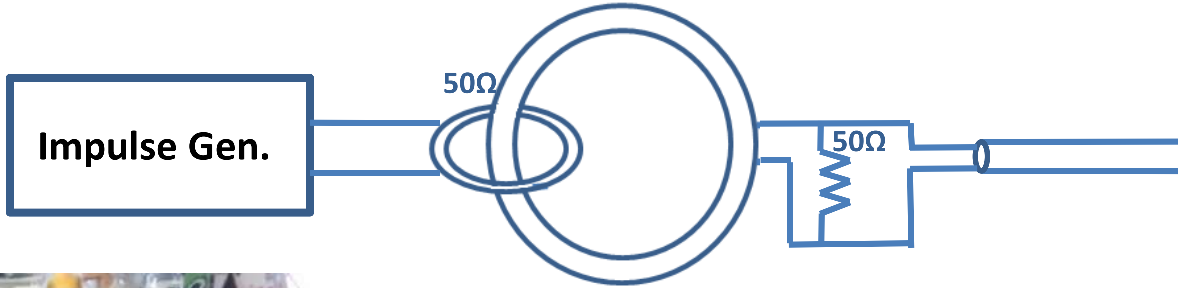
Multi-bunch measurements.

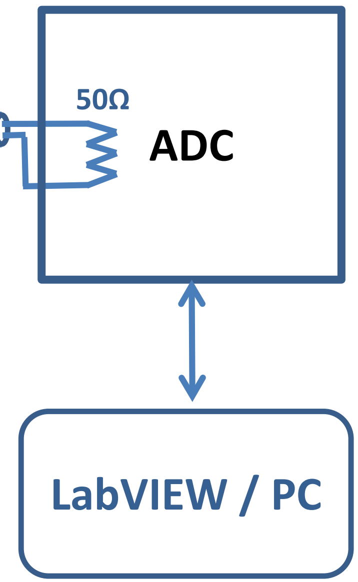
Impact analysis and measurements of the electrical noise and non linearity introduced by the digitizer.

Estimation/measurements of the precision and the resolution of the whole system.

giovanni.franzini@lnf.infn.it

Test bench for ICTs





Stanford RS DG535

Bergoz ICT (ELI)
Passive Model
Input/Output Ratio: 5:1
Output Pulse dur.: ~5ns

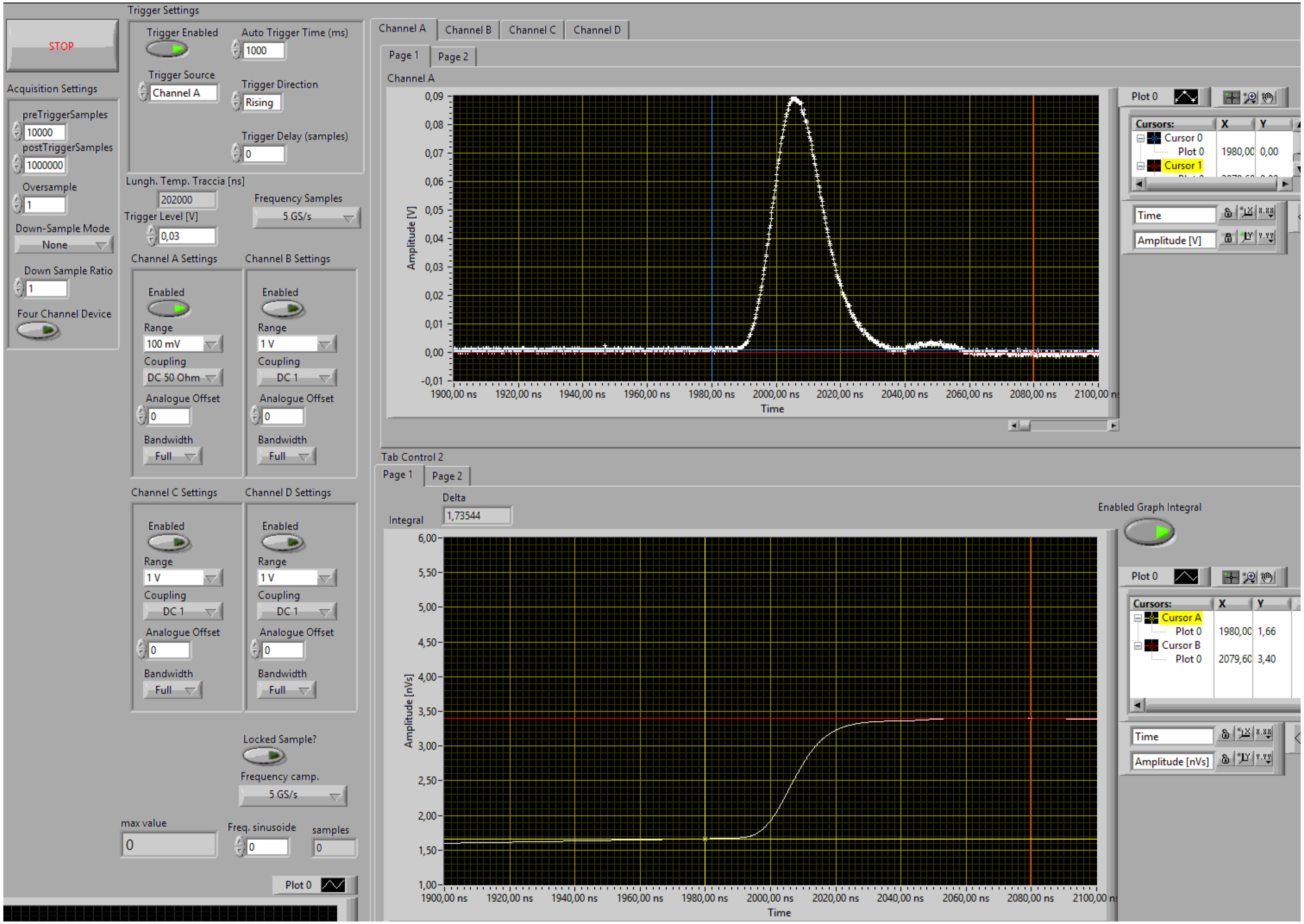
PicoScope 6404D
BW: 500MHz
Res.: 8 bits at 5 GS/s

Features are "comparable" with the Agilent M9210A

giovanni.franzini@lnf.infn.it

Test bench front panel

We programmed a LabVIEW VI in order to perform multiple test on ICT output (Time Domain and frequency domain measurements, signal integral,…)

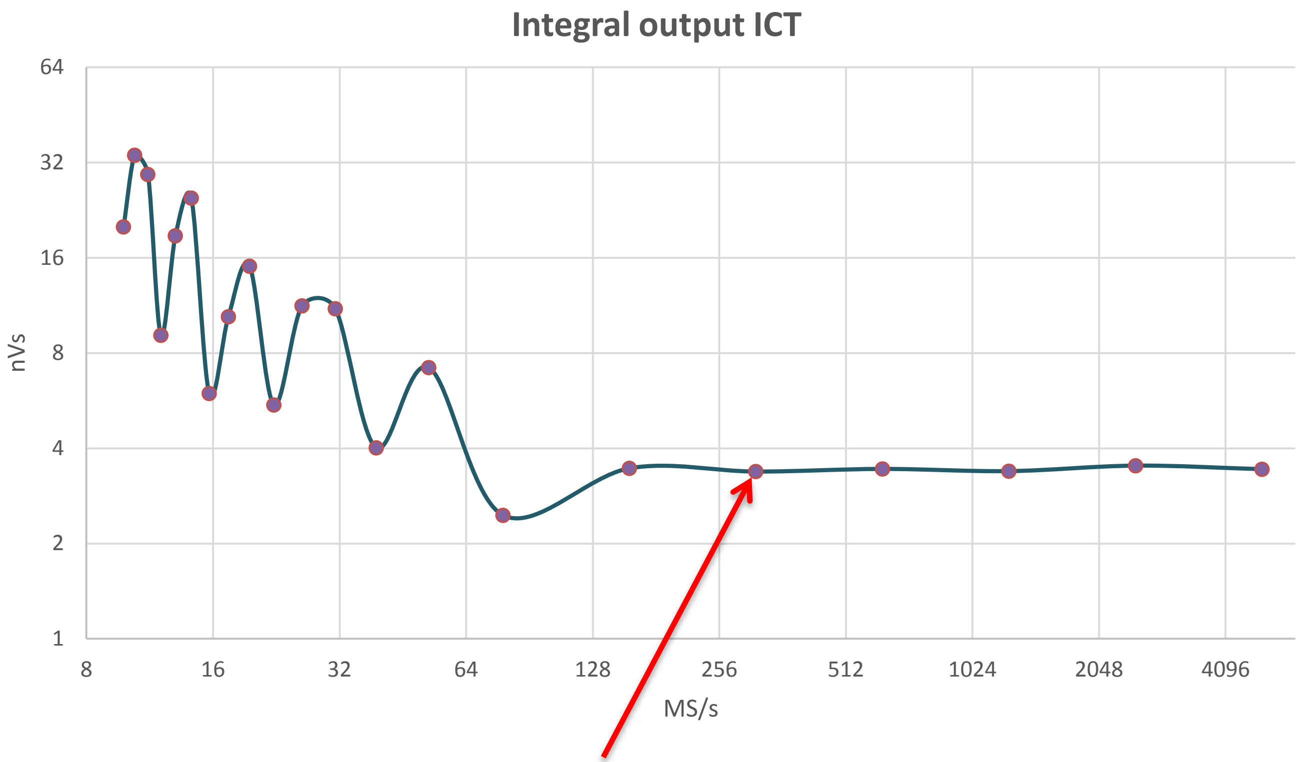


giovanni.franzini@lnf.infn.it

Q_{beam} / Q_{out} Measurements

Input signal: 3,84 V Impulse on 50,3 Ω, duration ~ 10ns

Δ_{in_ict} [nVs]	$Q_{in} = \Delta_{in\_ict}/50,3$ [nC]
34,83	0,6924



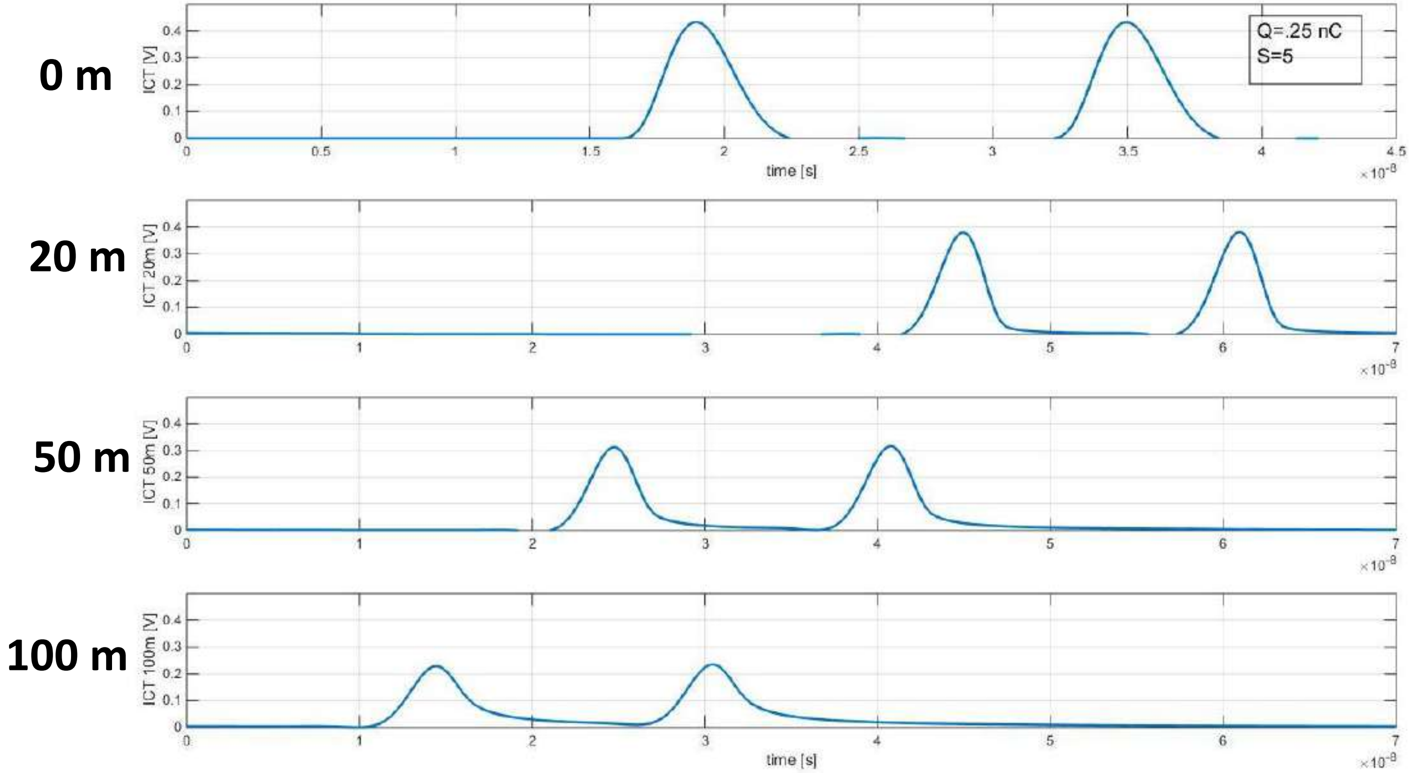
Q_{beam} / Q_{out} becomes stables at ~312 MS/s

Frequenza di Camp. [MS/s]	Δ_{out_ict} [nVs]
5000	3,4375
2500	3,5271
1250	3,3891
625	3,4435
312,5	3,3783
156,3	3,4583
78,3	2,4584
52,1	7,2000
39,1	4,0167
31,25	11,0417
26,04	11,2750
22,32	5,4833
19,53	15,0667
17,4	10,4250
15,67	5,9583
14,2	24,7042
13,02	18,8000
12,02	9,1000
11,2	29,4000
10,42	33,7500
9,8	20,0667

giovanni.franzini@lnf.infn.it

Long cable effects

Simulations with two pulses (T2 – T1 = 16 ns) for different cable lengths, connected to the ICT output

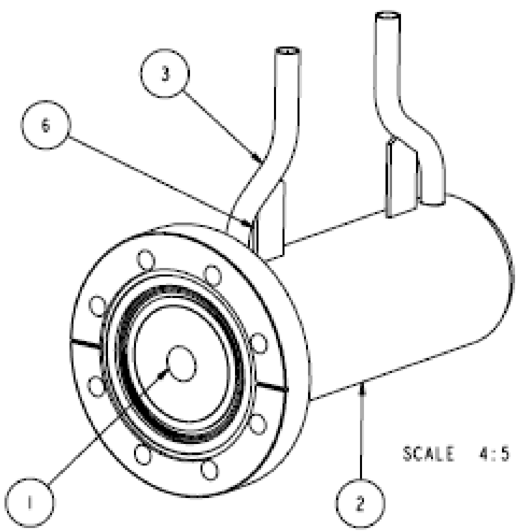


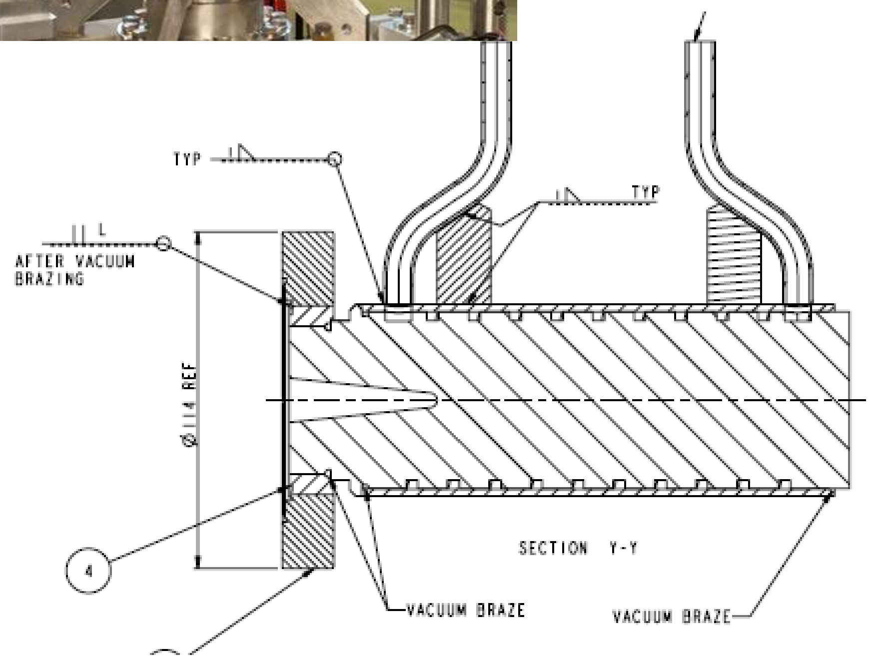
Long cable introduces attenuations and stretch the signals.
Measurements are on-going...

giovanni.franzini@lnf.infn.it

Other types of Charge measurements

Measurements of the Beam Charge by using the Stripline BPM.
Measurements of the Beam Charge on the dump @M4.



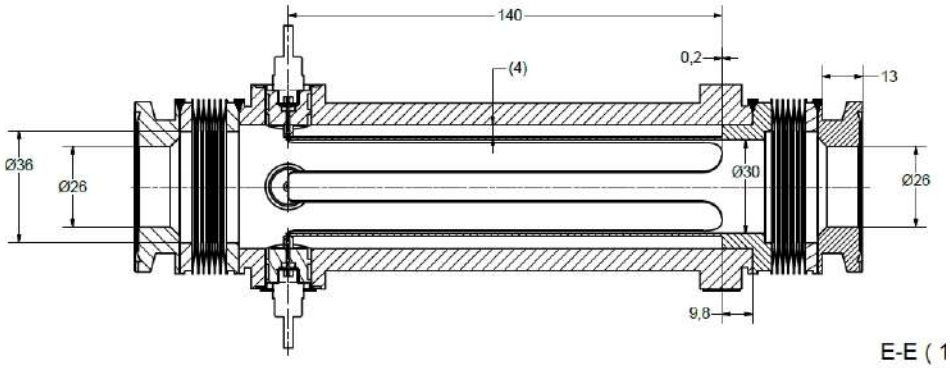


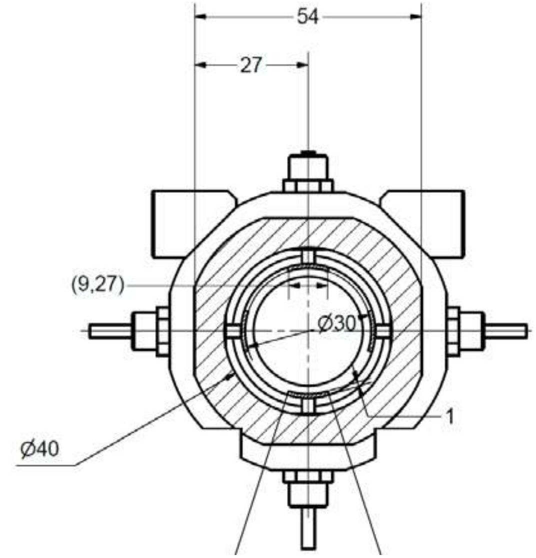
giovanni.franzini@lnf.infn.it

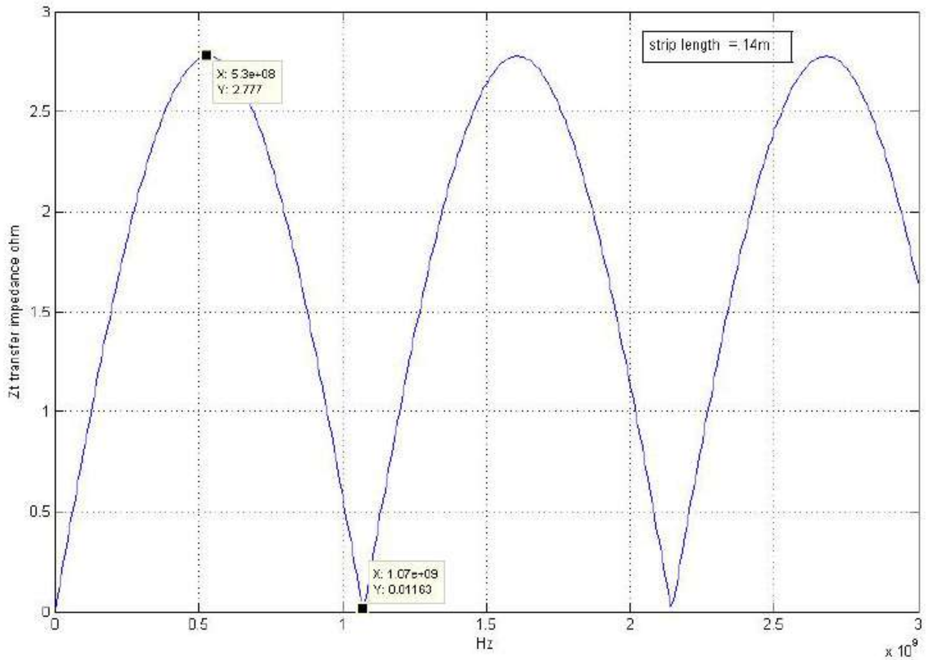
Beam Position Monitor

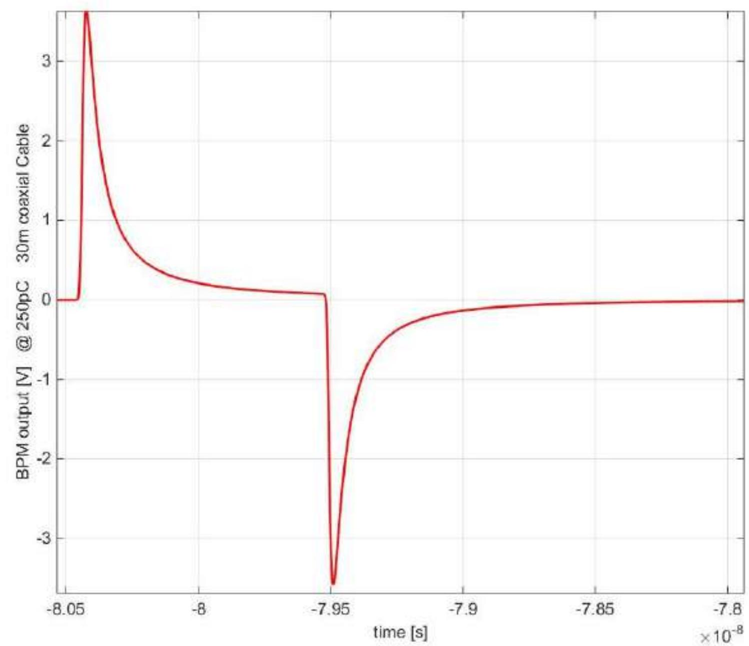
giovanni.franzini@lnf.infn.it

Stripline Beam Position Monitors



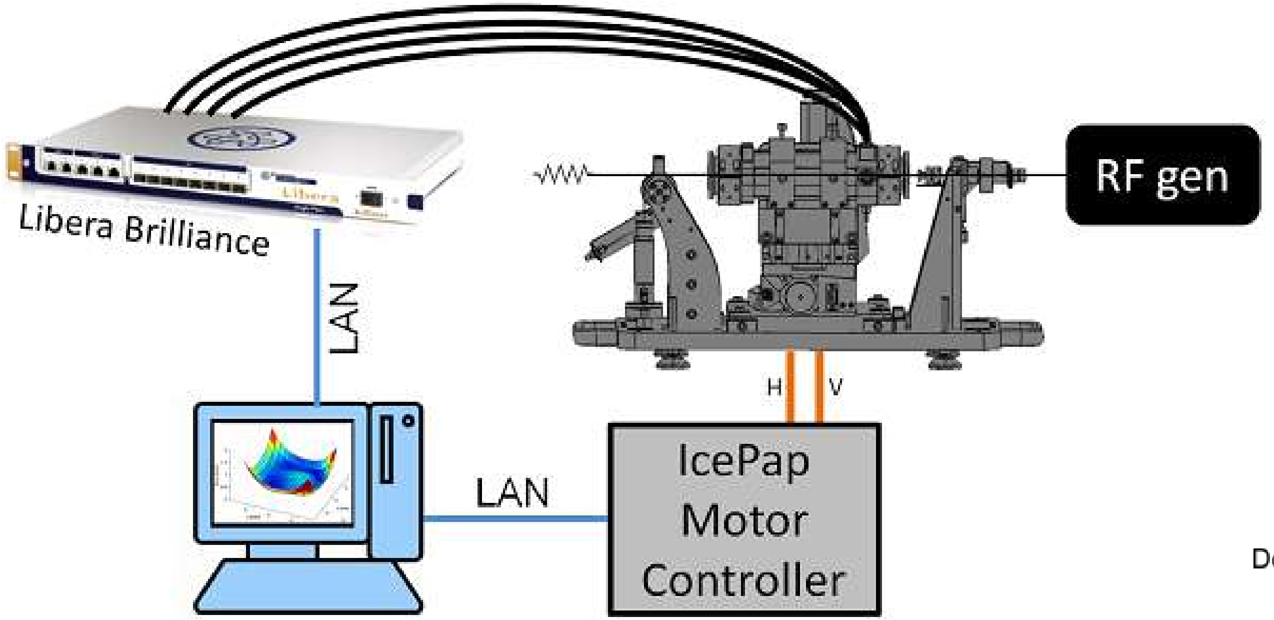






giovanni.franzini@lnf.infn.it

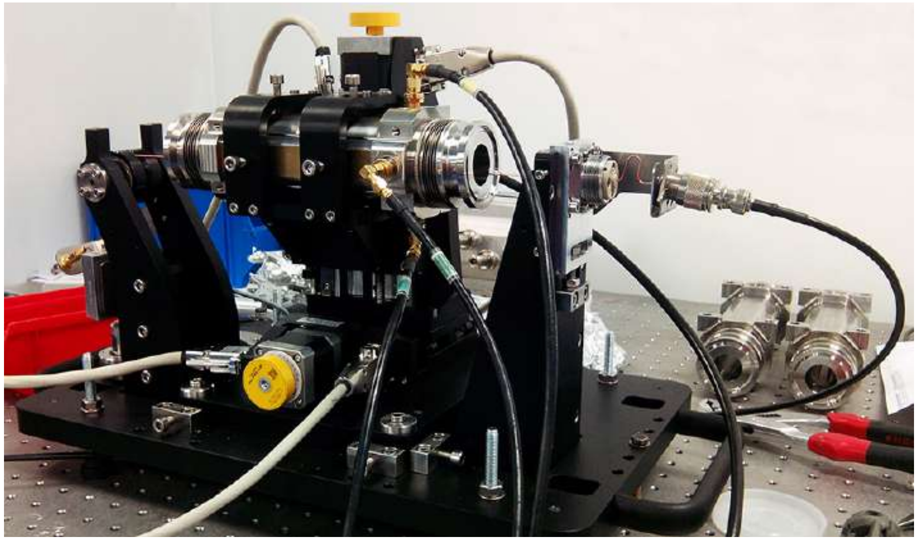
ALBA calibration bench

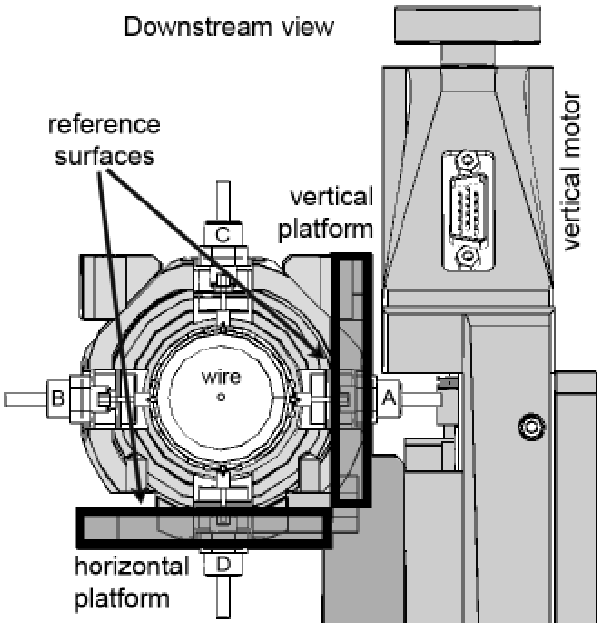


RF generator:

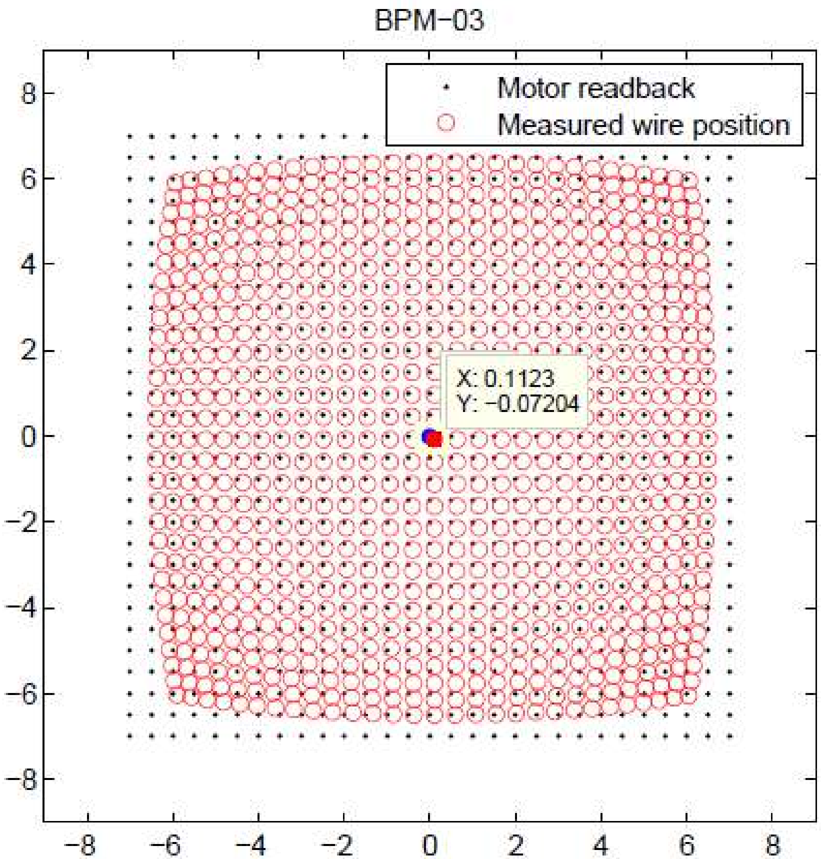
ampli = +0dBm

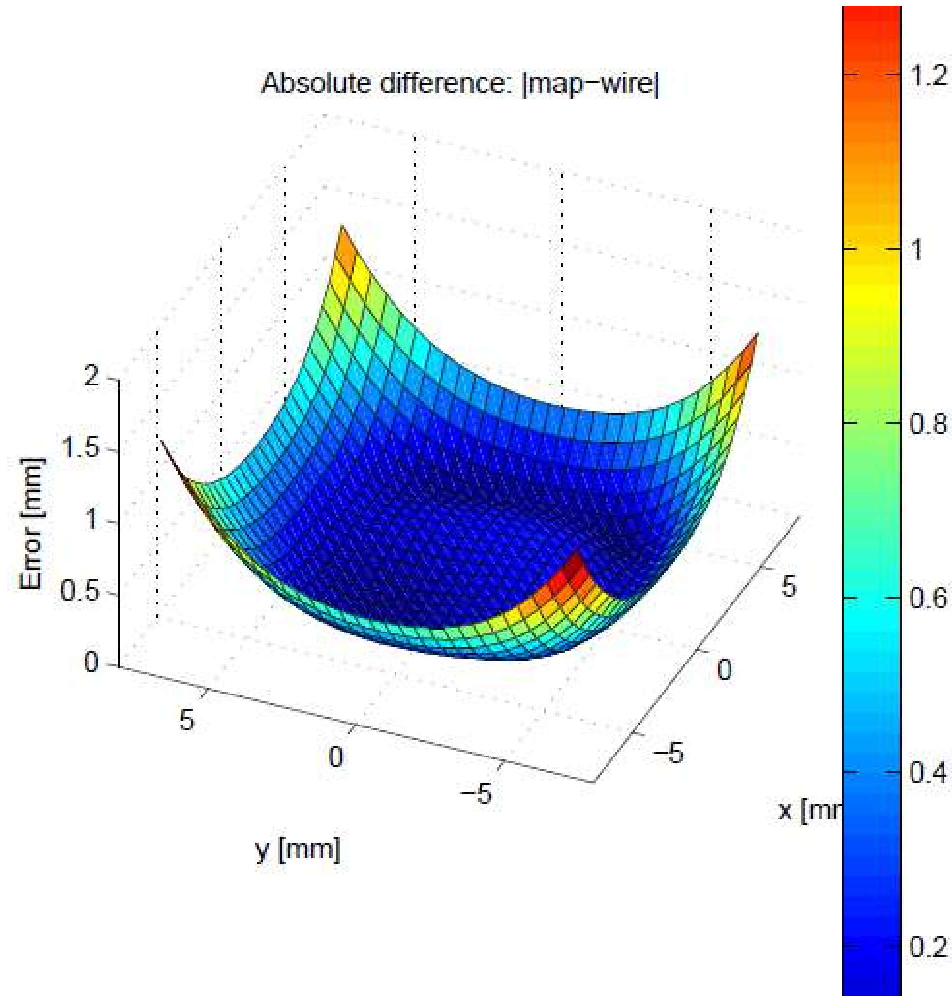
freq = 499.654MHz





Mechanical offset measurements ±0.5 mm



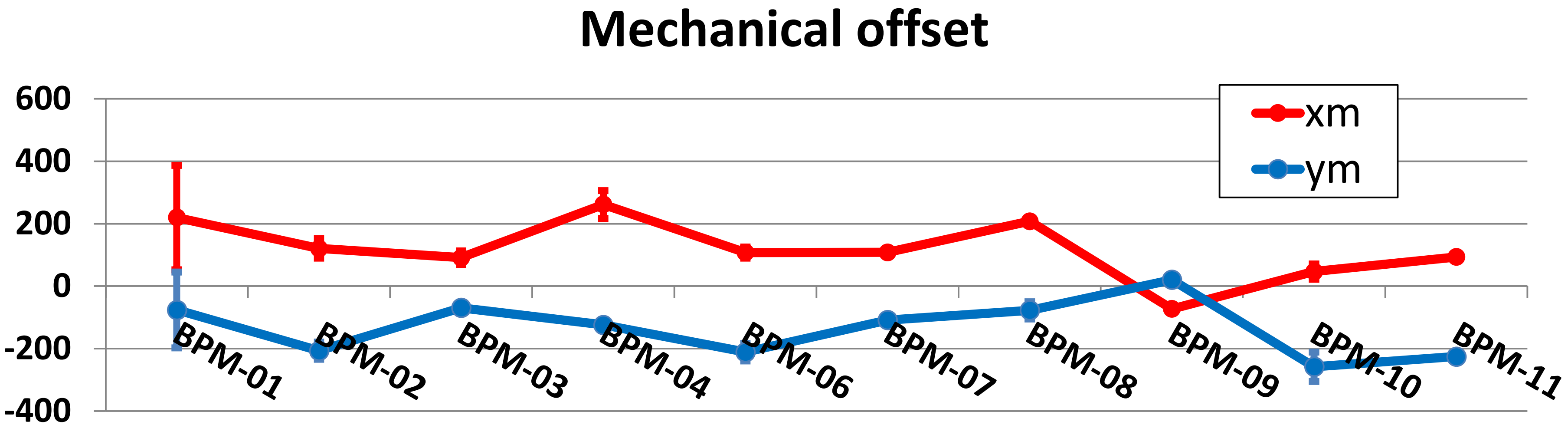


Main offset contributions:

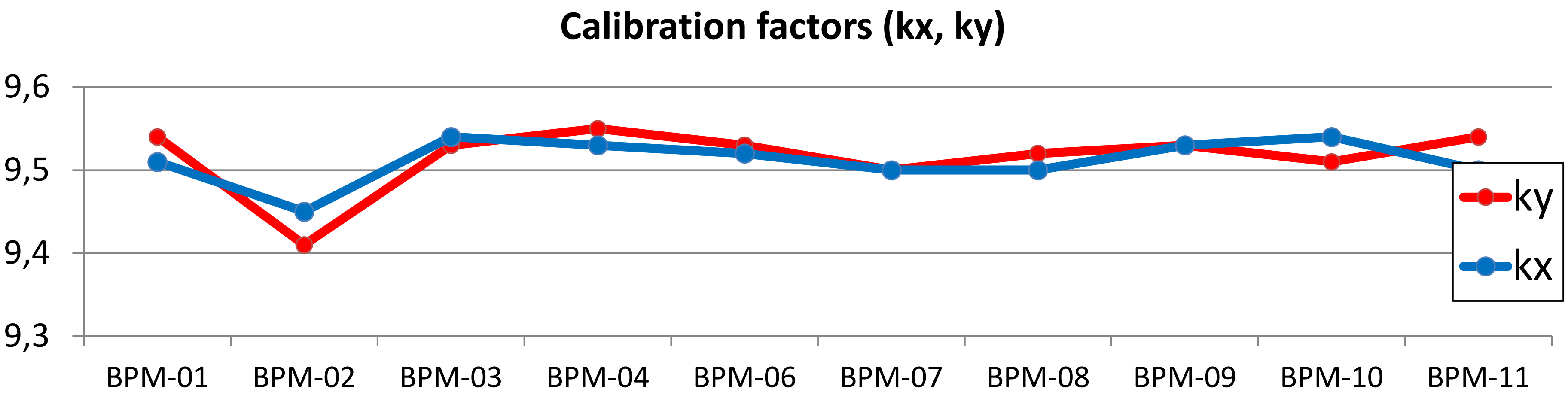
- **Geometrical Imperfections**
- **Different cable length**
- **Electrical offset (load mismatches)**
- **Electronic noise**

ALBA contribution

Mechanical offset

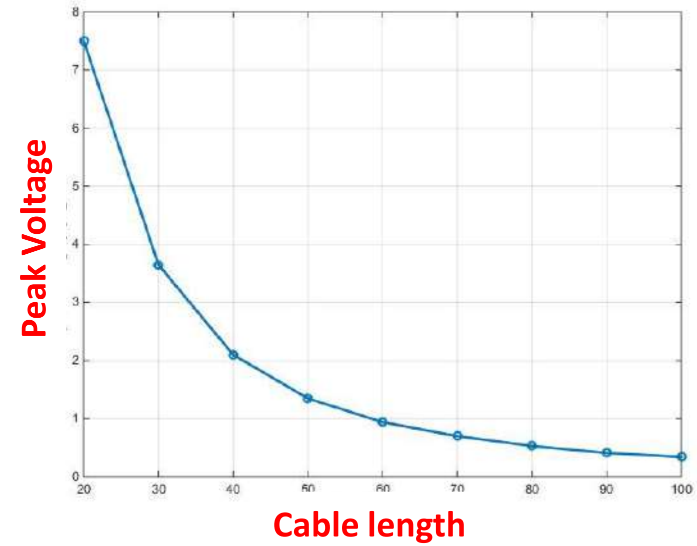


$$x_{beam} = k_x \cdot \frac{V_3 - V_1}{V_3 + V_1} - x_{offset} \qquad y_{beam} = k_y \cdot \frac{V_2 - V_4}{V_2 + V_4} - y_{offset}$$

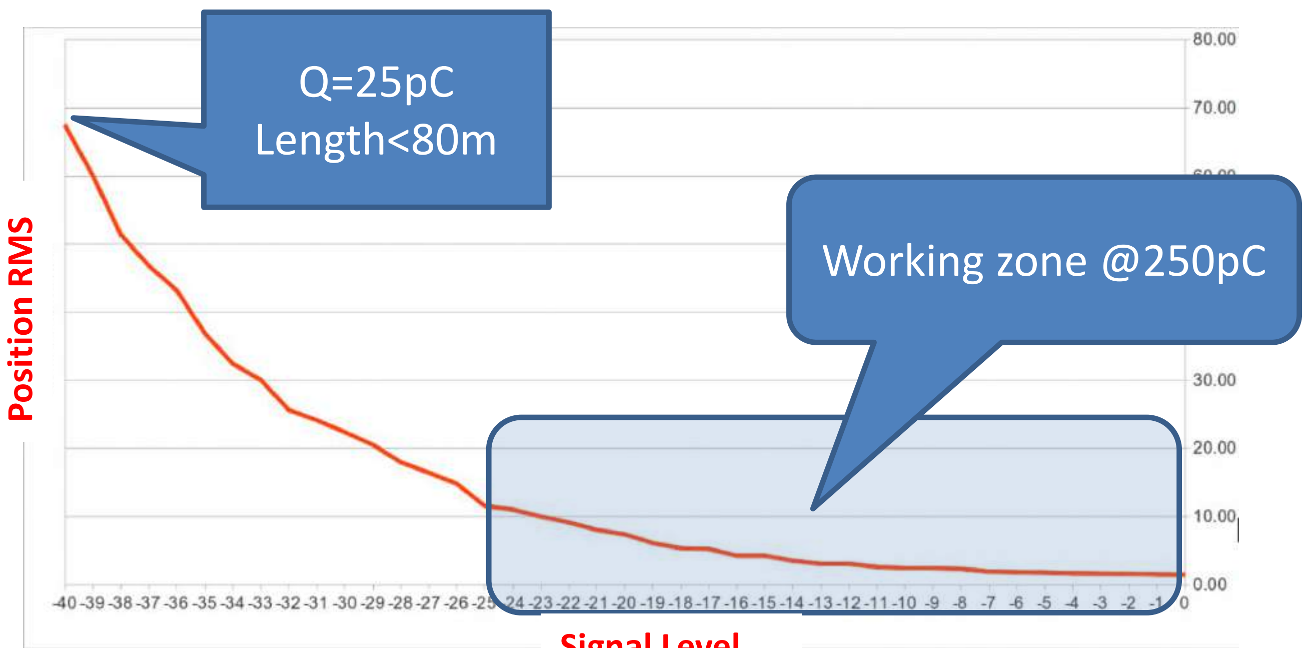


Acquisition System

Libera Single Pass E



Limiting factor for resolution is detector noise

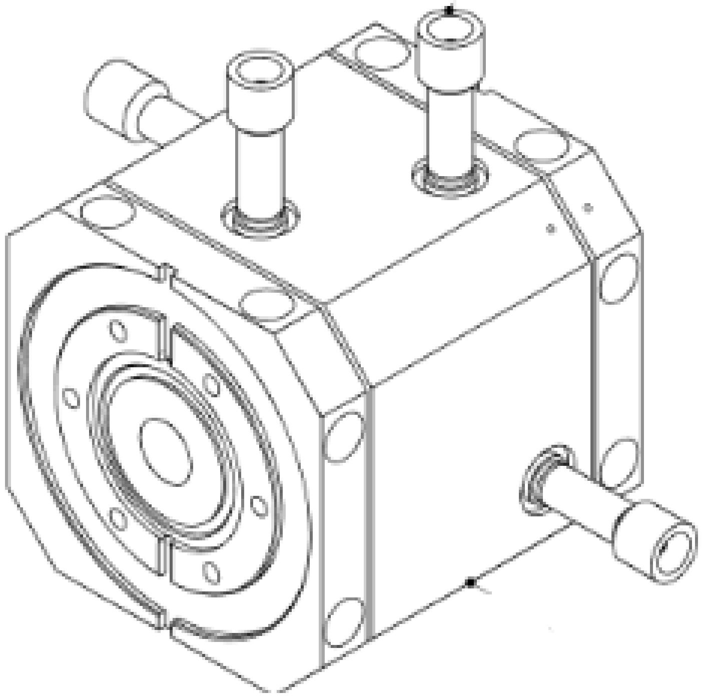


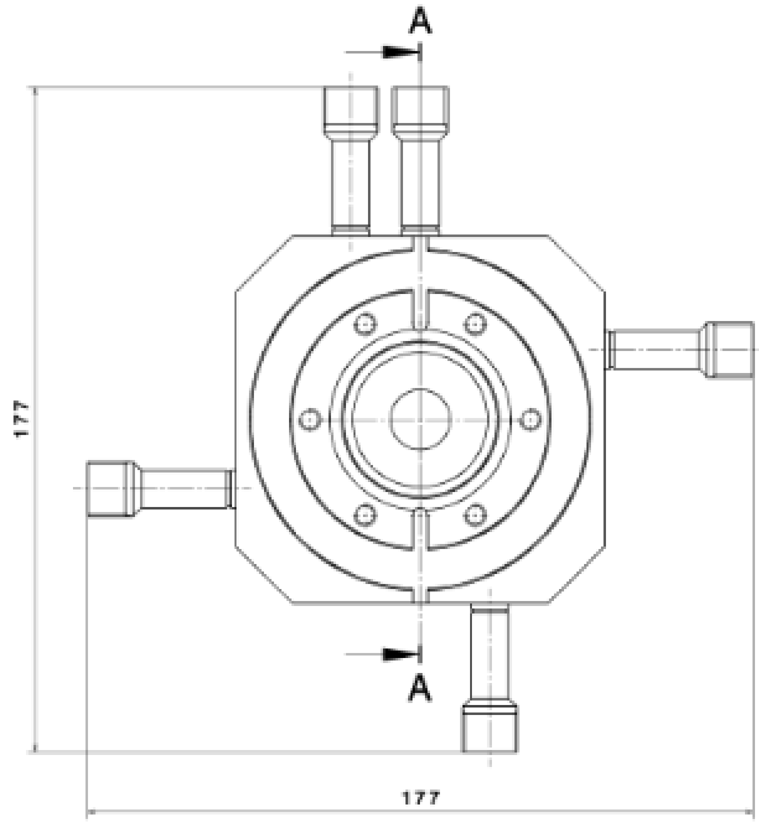
giovanni.franzini@lnf.infn.it

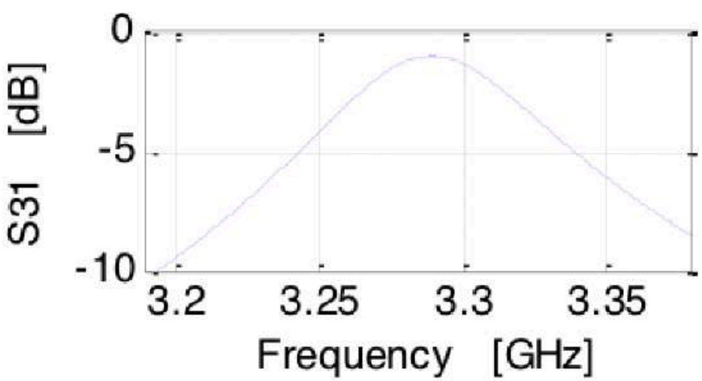
Cavity BPM

giovanni.franzini@lnf.infn.it

Cavity Beam Position Monitor





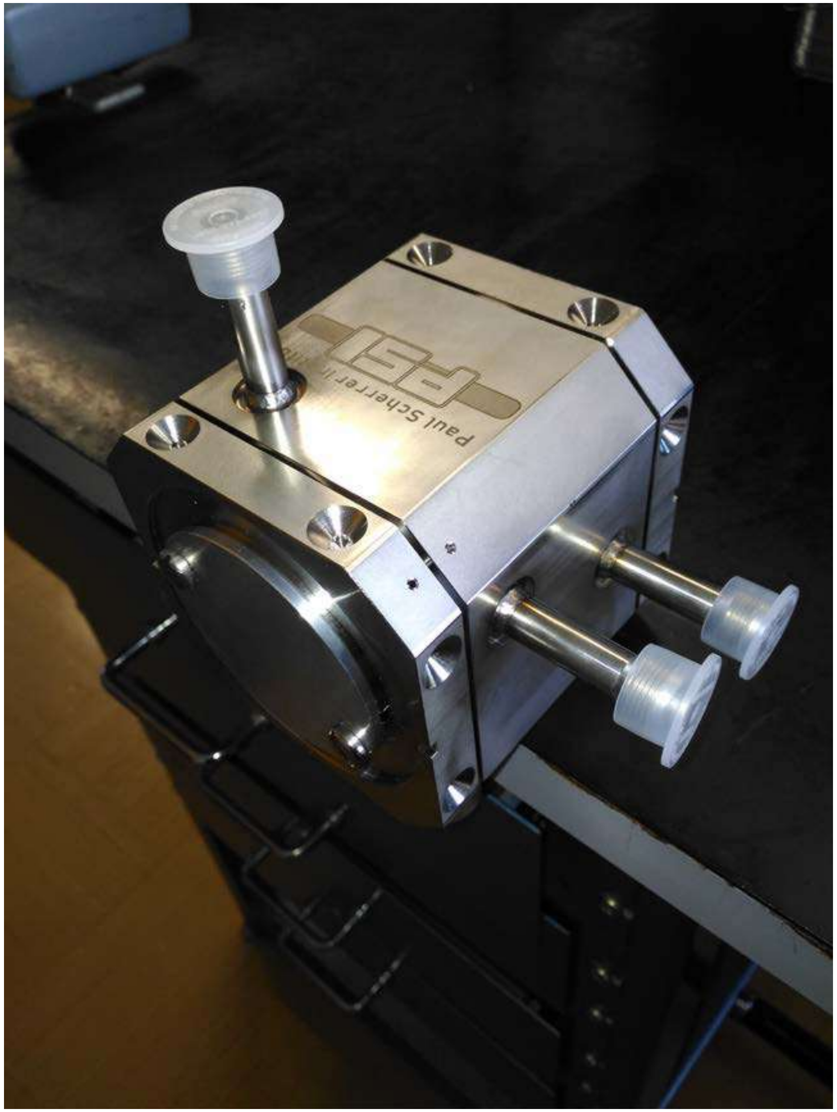


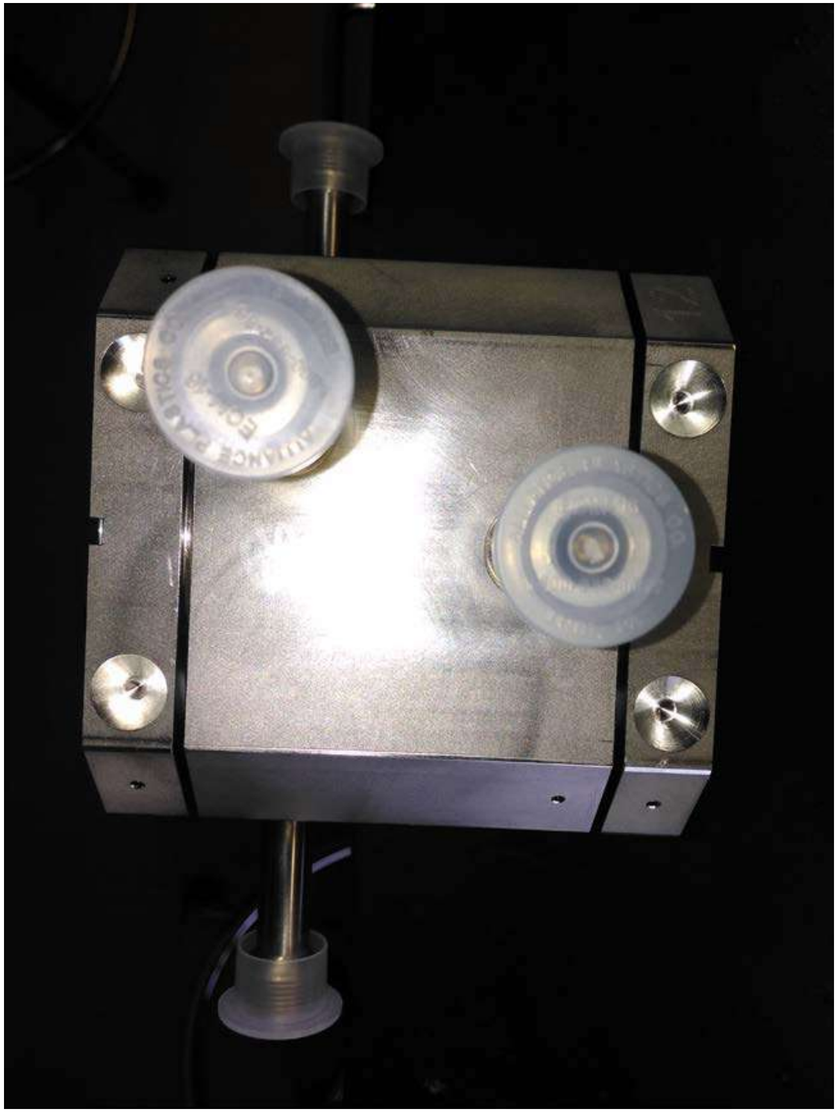
f_0=3.2886GHz

Q=42.4

giovanni.franzini@lnf.infn.it

Cavity Beam Position Monitor #2



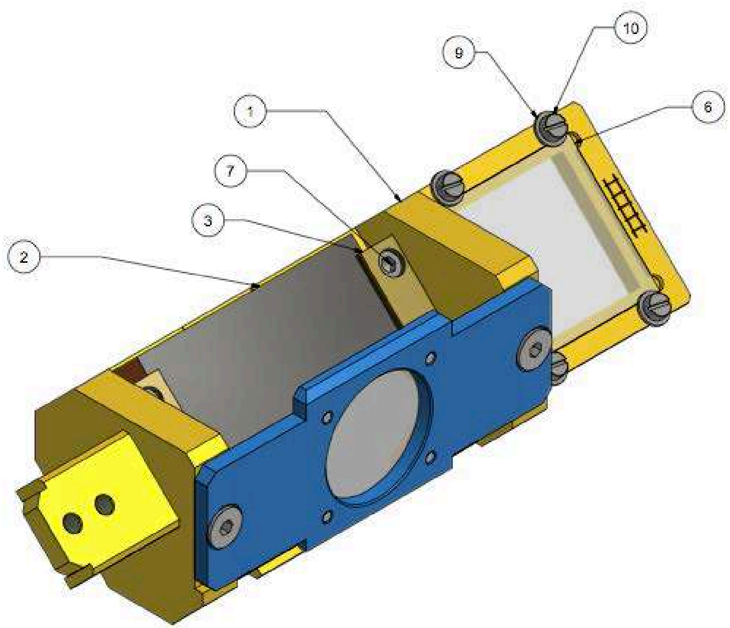


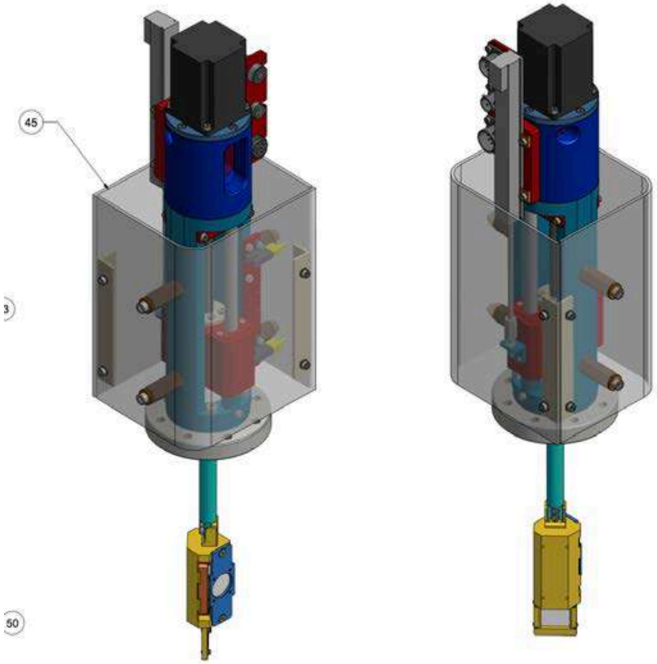
giovanni.franzini@lnf.infn.it

Beam Screens

giovanni.franzini@lnf.infn.it

Beam Screen





Yag: single bunch measurement
Si OTR: full train measurement
Si OTR (with Gated camera): measurements on every single bunch of a train

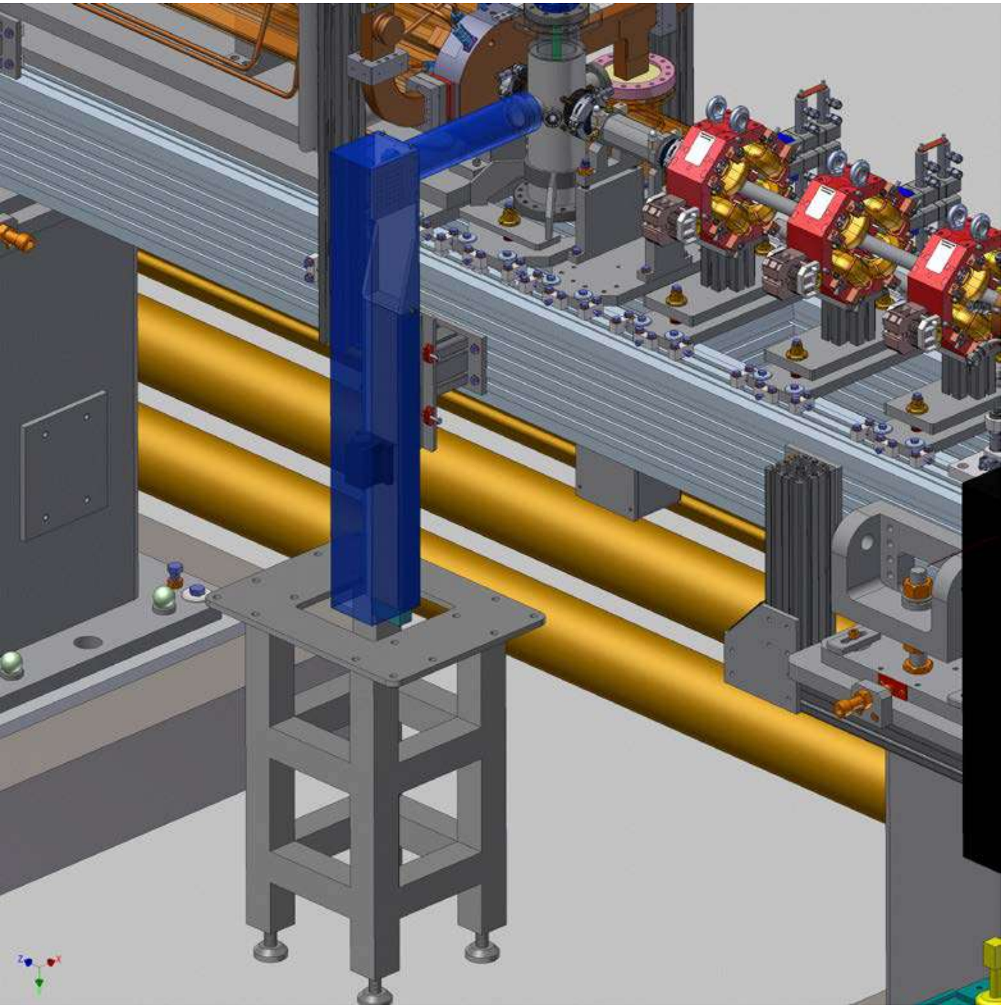
Damage studies for multi munch Operation (on going)

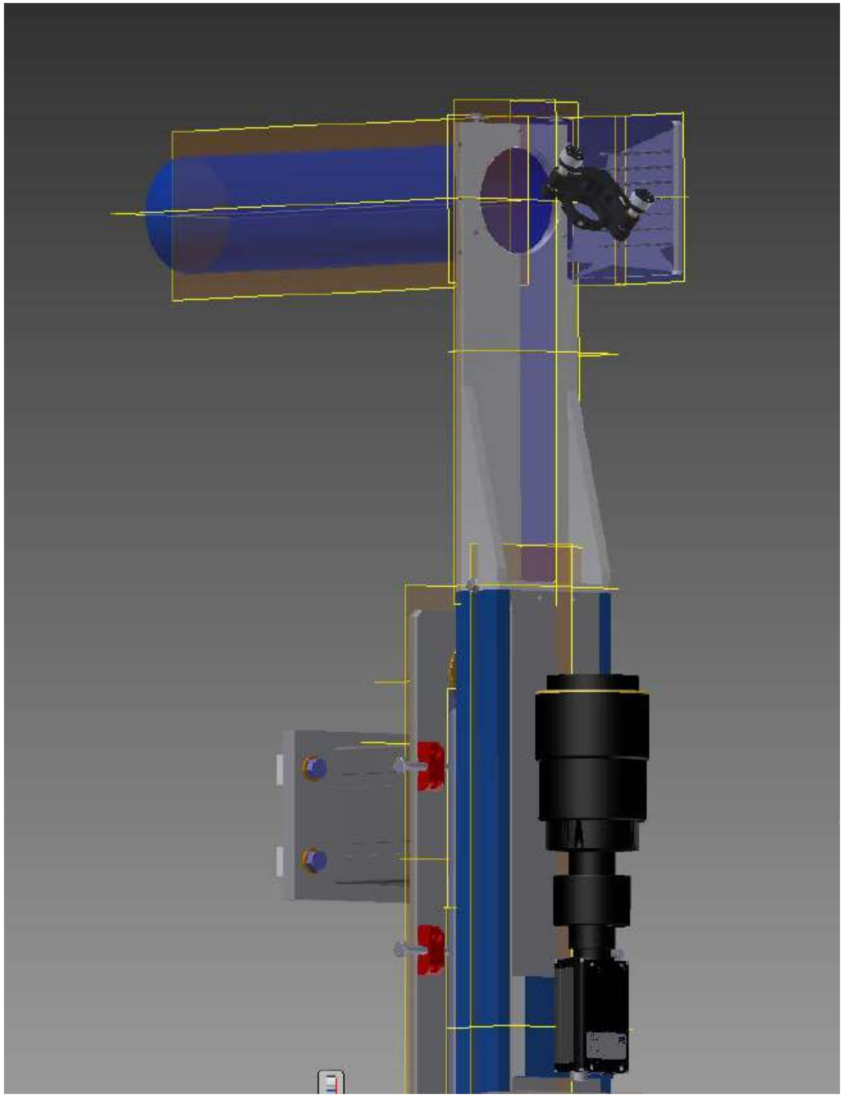
Screen Specifications OTR
Bulk Si, 40mm x 40mm x 0.380mm
One side Al coated 50nm

Screen Specifications YAG
YAG:Ce screen, both size polished
One side Al coated 60nm
Dimension: dia. 25.4 x 0.1 mm

giovanni.franzini@lnf.infn.it

Optical line





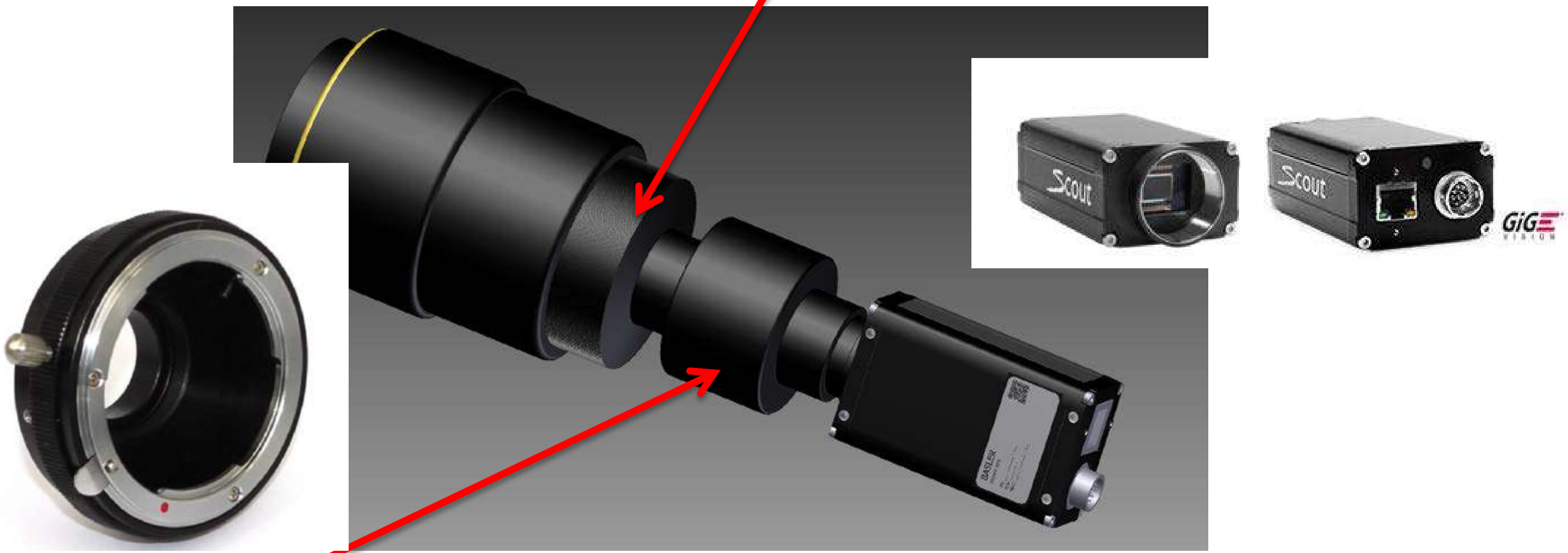
giovanni.franzini@lnf.infn.it

Imaging system

Camera lens

Magnification better than 1:3
Target distance 0.6-1 m

Teleconverter
Factor 2



Diaphragm aperture control for Nikon G lens – C mount

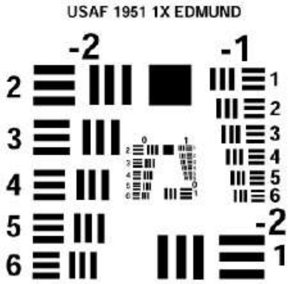
Coma Firm

CCD Camera

Model	Basler Scout scA640-70gm
Pixel size	7.4um x 7.4um
Resolution	659 px x 494 px
Pixel bit depth	12 bits

giovanni.franzini@lnf.infn.it

Camera lens test-bench @ SPARC_LAB



$$x = 2^{Group+(Element-1)/6}$$

The resolution is 1/x;

The sizes of each horizontal line are 2,5/x for the length and 1/(2x) for the width and viceversa for the vertical lines.

Distance [cm]	Resolution [μm]	M	Field of View [cm]
45	25	1	0.47 x 0.35
50	25	1.26	0.61 x 0.46
60	44	**2.01**	0.98 x 0.74
70	50	2.48	1.21 x 0.91
75	56	2.91	1.42 x 1.06
80	63	3.25	1.58 x 1.19
90	79	**3.88**	1.89 x 1.42
95	79	4.12	1.96 x 1.47
115	111	5.54	2.7 x 2.03
130	125	**6.37**	3.11 x 2.33

180mm lens

Distance [cm]	Resolution [μm]	M	Field of View [cm]
65	31	**1**	0.49 x 0.37
80	35	1.56	0.76 x 0.57
90	39	**1.88**	0.92 x 0.69
100	50	2.17	1.06 x 0.79
110	56	2.41	1.18 x 0.88
120	63	2.82	1.38 x 1.03
130	70	**3.13**	1.53 x 1.14
195	111	5.04	2.57 x 1.93

180mm lens with teleconverter (2x)

giovanni.franzini@lnf.infn.it

Thank you for your attention

giovanni.franzini@lnf.infn.it