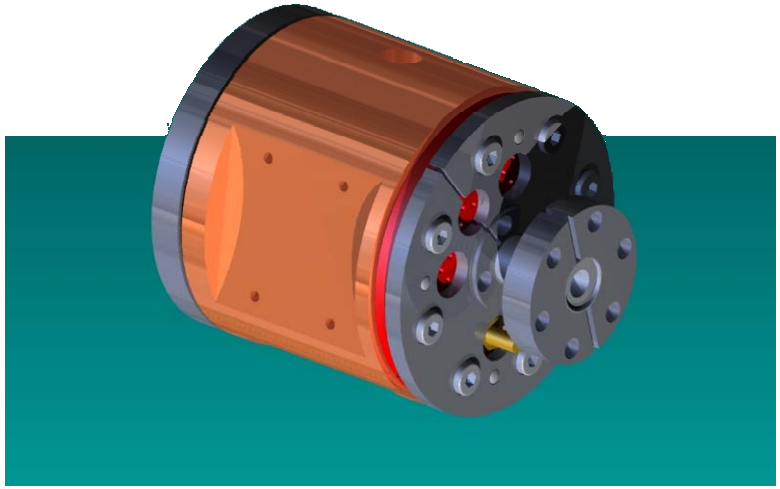
Status of the Precision Beam Position Monitor (PBPM) for EUROTeV



L. Soby, I. Podadera Aliseda
AB-BI-IP

Goal

Measurement of the beam position and current in the main linac (attached to the quadrupoles) of the next generation colliders (ILC and CLIC) with the specifications:

- **R**esolution:100 nm.
- **A**perture: 4-6 mm.
- **A**bsolute precision: 10 μm.
- **R**ise time: 15 ns.

Important parameter for the beam-based alignment

PBPM-specifications

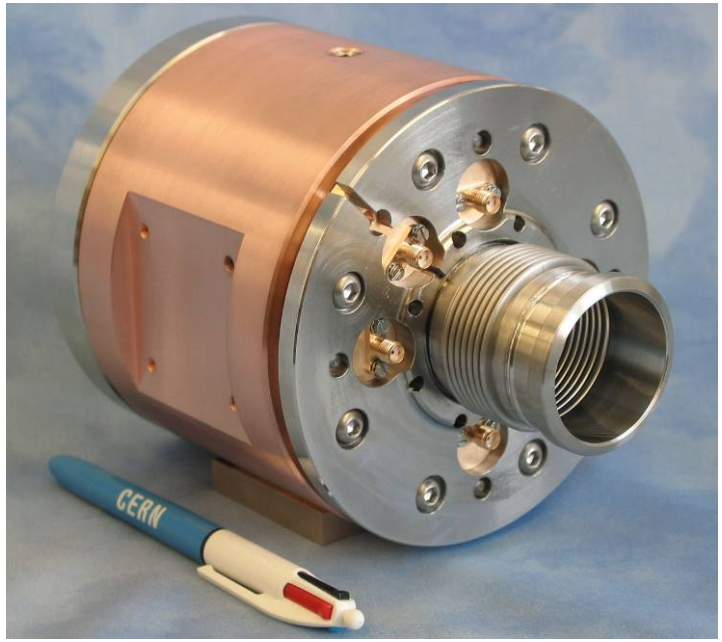
EUROTeV	Aperture	4mm
	Resolution	100nm
	Absolute precision	10µm
	Rise time	<15ns
Extended specifications	Dynamic range	±1.5mm (15 bits)
	Linearity error	< 1% (±1.5mm)
	24H stability	1µm
	Droop	< 5%
	Low frequency cutoff	100kHz *(3.6% droop, CLIC 58ns pulse)*
	High frequency cutoff	30MHz
	CMRR	>90dB
	Bake out temperature	150ºC
	Vacuum	10^{-9} Torr
	Operating temperature	~20°C

The design

From...

IPU at Clic Test Facility 3 (CTF3, CERN)

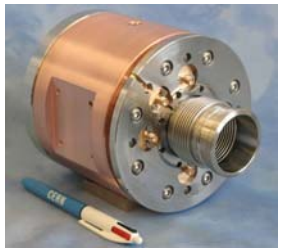
M. Gasior, *An Inductive Pick-Up for Beam Position and Current Measurements*, CERN-AB-2003-053-BDI



40 mm aperture

To...

PBPM



6 (4) mm aperture

Inductive pick-up: basic scheme

The electron beam induces an image current in the surrounding vacuum pipe...

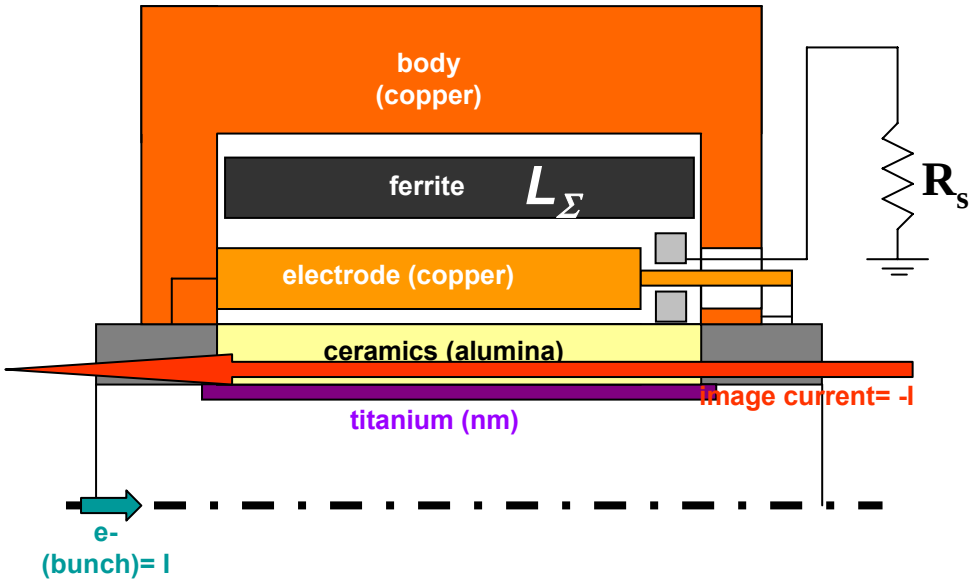
... the beam position (image current distribution) is picked outside the vacuum by the signal combination transformed by current transformers from strip electrodes (inductances L_Δ). The transformers are loaded in the secondary by a resistor R_s

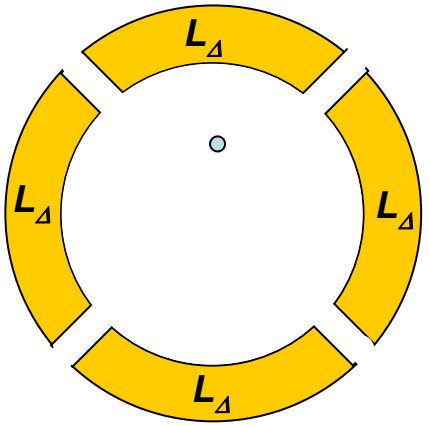
... the beam pipe is disrupted by a ceramics insertion in alumina which maintains the vacuum inside...

... a body shields the pick-up from environment perturbances...

... the low frequency cutoff is decreased by the addition of a ferrite external to the electrodes...

... the longitudinal impedance at high frequencies and the wakefields are limited by a titanium resistive coating in the internal face of the ceramics. Big enough to avoid signal losses at low frequencies and low enough for the impedance budget of the accelerator.



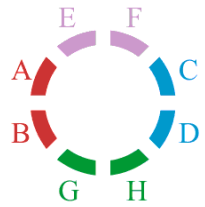


Inductive pick-up: basic scheme

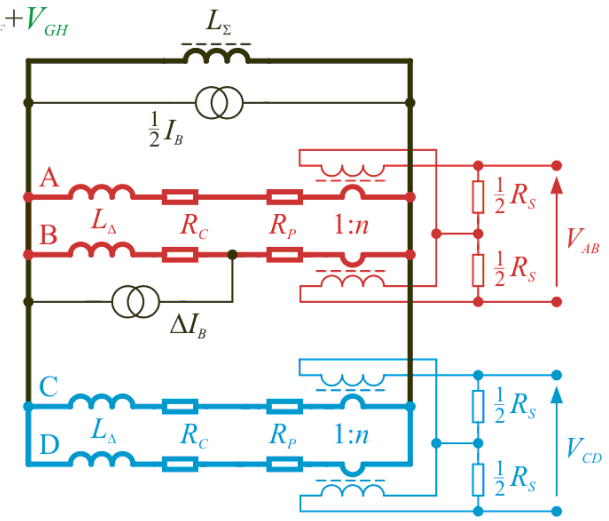
$V_\Sigma = V_{AB} + V_{CD} + V_{EF} + V_{GH}$

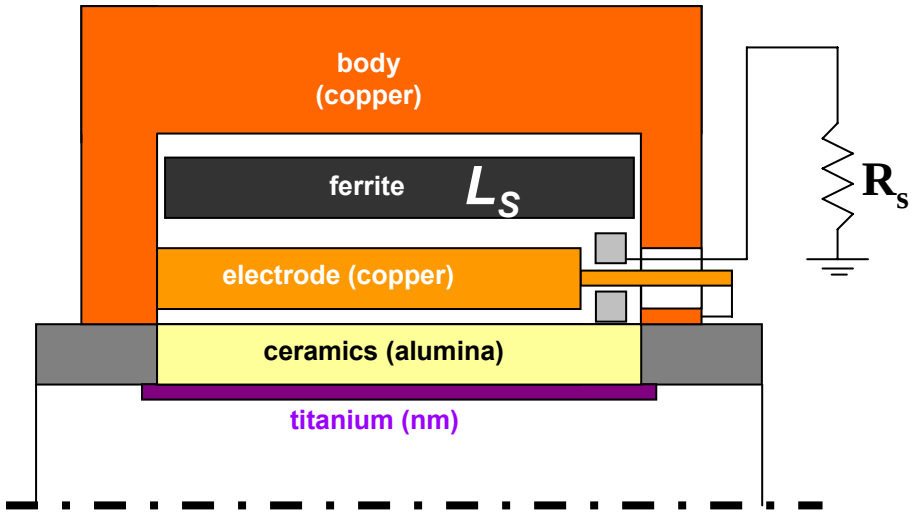
$V_{\Delta H} = V_{AB} - V_{CD}$

$V_{\Delta V} = V_{EF} - V_{GH}$



M. Gasior (IPU)





Coupling impedance

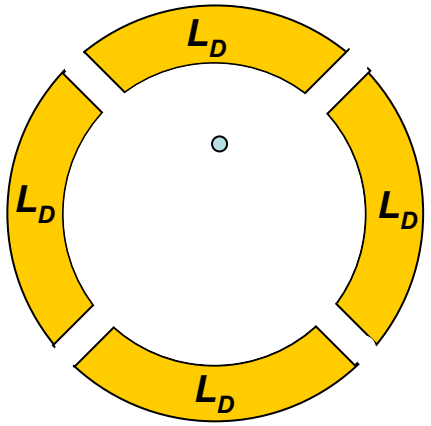
$$V_\Sigma = \frac{R_s}{n} I_B$$

Low cutoff (difference signal)

$$f_{L_\Delta} = \frac{R_s / n^2}{2\pi L_\Delta}$$

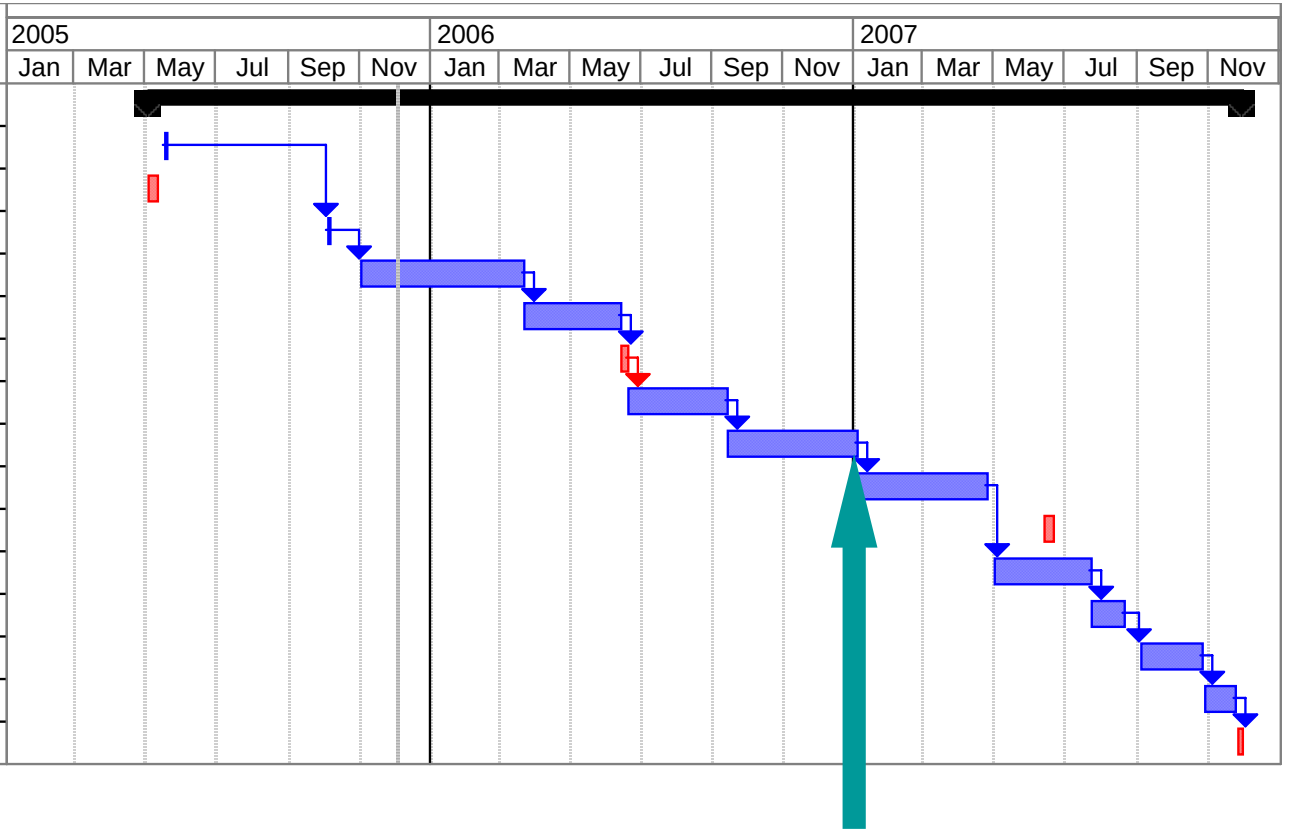
Low cutoff (sum signal)

$$f_{L_\Sigma} = \frac{R_s / n^2}{2\pi L_\Sigma}$$



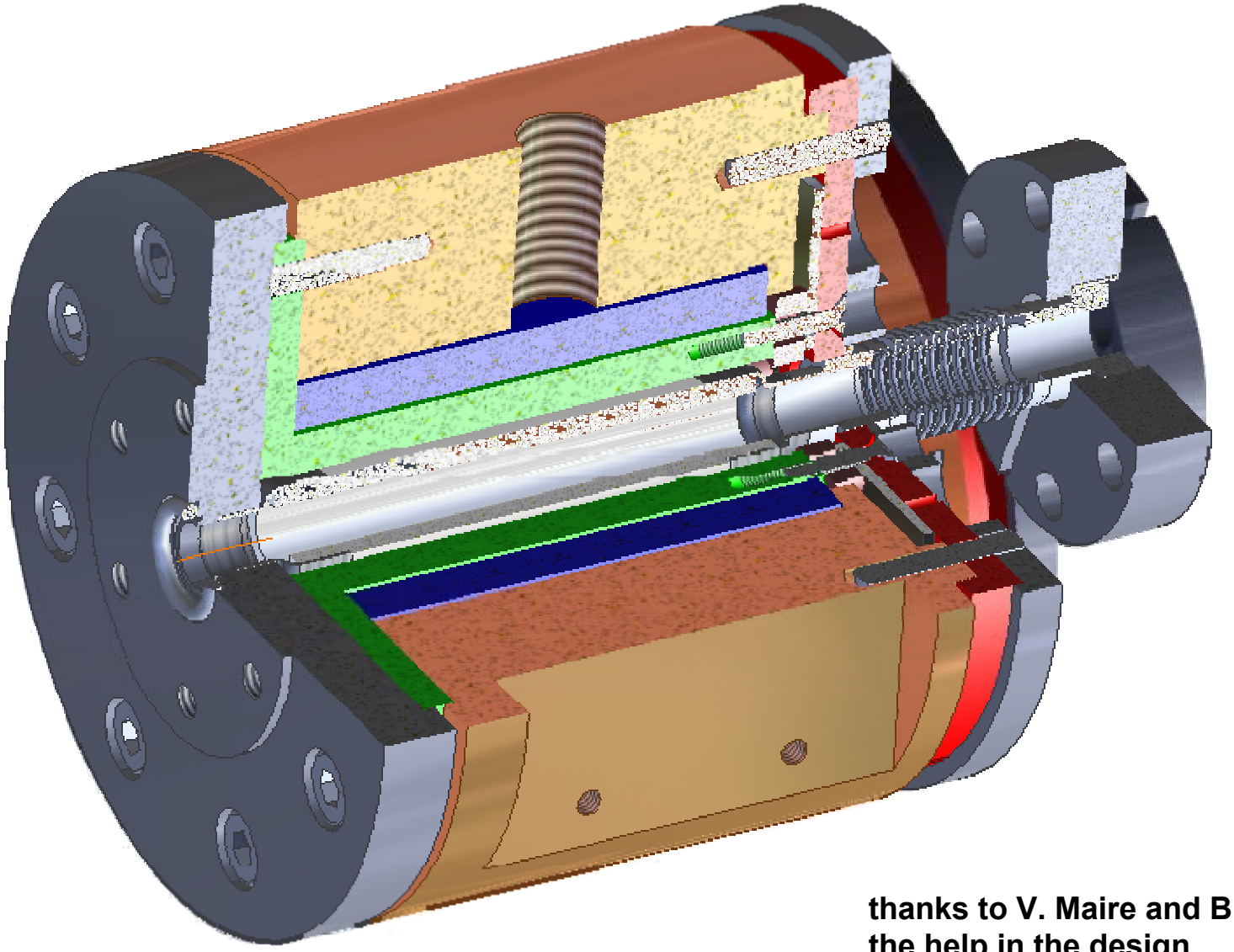
PBPM planning

ID	Task Name
1	**PBPM**
2	Publish fellow post
3	Present work plan for EUROTeV
4	Hire fellow
5	Design PBPM
6	Simulate PBPM
7	Present design for EUROTeV
8	Fabrication drawings
9	Fabrication of 1BPM
10	Tests on bench
11	Present Results for EUROTeV
12	Manufacture 3 PBPMs
13	Tests on bench
14	Tests in CTF3
15	Write report
16	Send report to EUROTeV



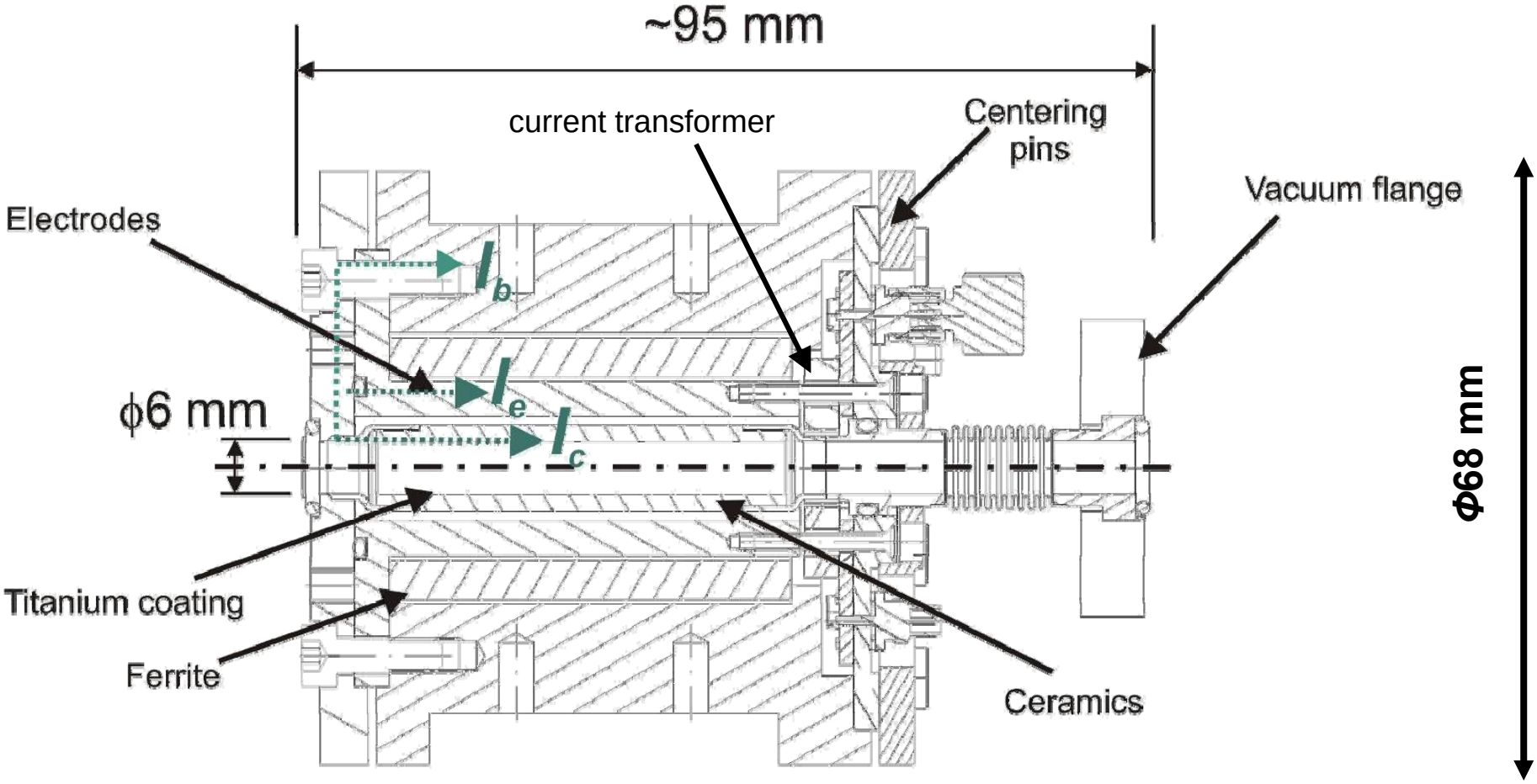
According to the schedule!

Final design



thanks to V. Maire and B. Favrat for the help in the design

Final design

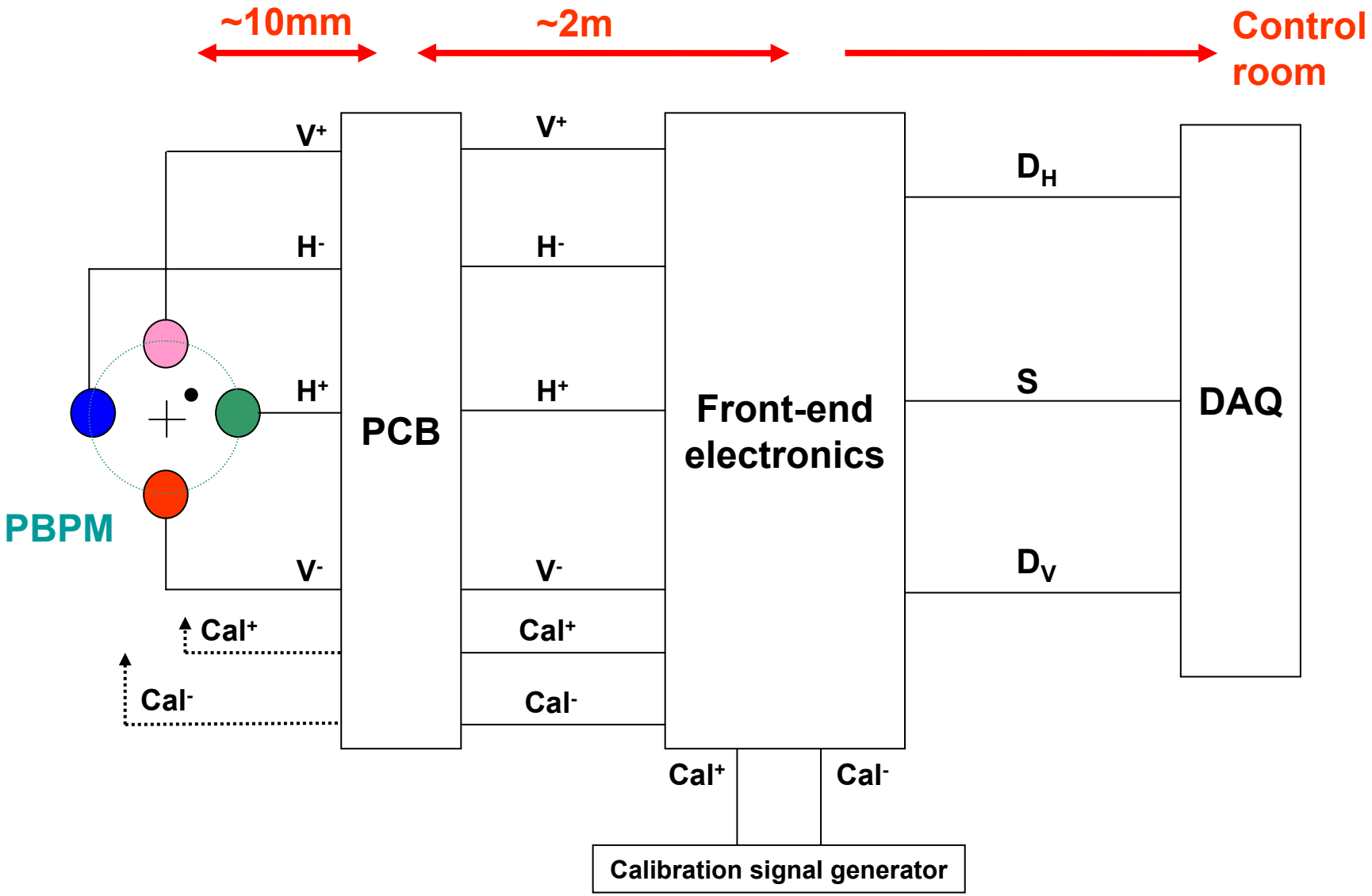


Mechanical challenges

- **Sputtering of the ceramics:**
  - Very small diameter.
  - Deposition thickness of the coating proportional to distance titanium wire-ceramics wall: uniformity problems.
- **Tight tolerances:**
  - Three reference planes in the body machined with at least 10 μm precision from the axis of the body. Very good precision of the mechanical center from the reference planes even without metrology.
  - The mechanical axis of the electrodes is coaxial in 5 μm with the axis of the body. The offset between the mechanical and “electrical” center is minimized.
  - Good coaxility coating-ceramics-electrodes to define a constant impedance along the coaxial line.
- **Vacuum flanges:**
  - Beam tests in different machines to take into account (CTF3, ATF-2).
  - Small flange in order to have small electrodes and pick-up. In addition it minimizes the cavity and resonances.
  - Solution: small **helicoflex seal (Ø7.7 x Ø10.9 mm) with screws adapted to standard CF-16**.

- **Use of SMC connectors instead of SMA.**

PBPM electronics

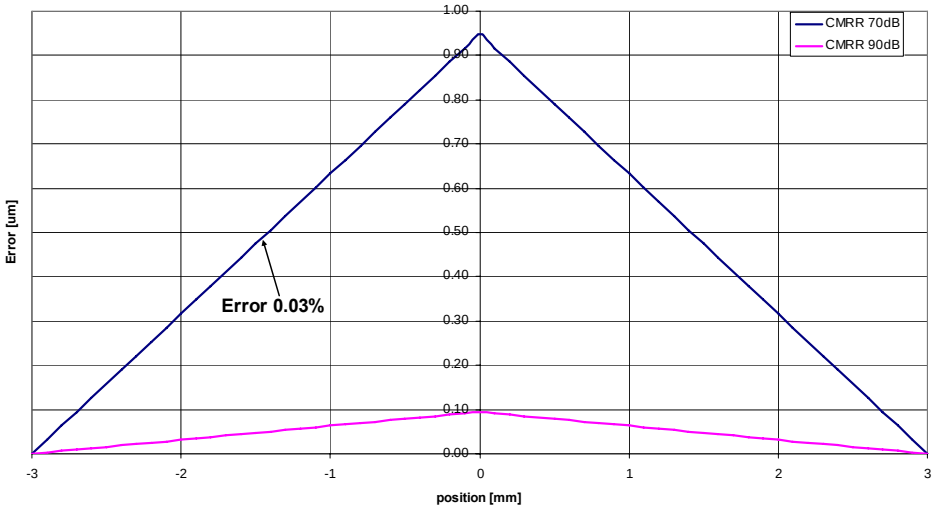


PBPM front-end electronics

- Test IPU electronics and Passive front-end hybrid *(radiation hard)* to generate Δ and Σ signals (BW=100kHz-30MHz).
- Difference must have CMRR >95 dB (100nm over 6mm) to minimize offset error.
- ILC version must include 10MHz Bessel filter to dilute 1ps bunch to ~60ns.
- Fast 200MS ADC, 12 or more bits (or oscilloscope).

CMRR error

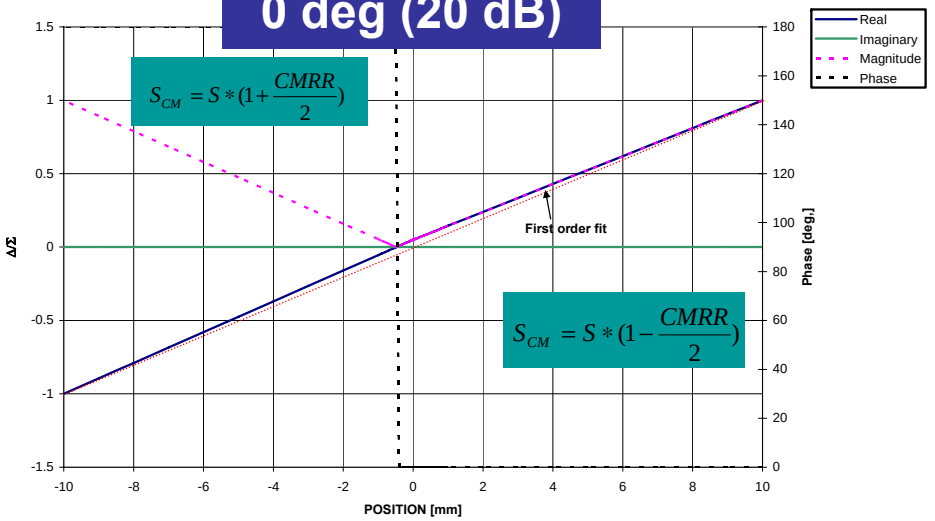
CMRR



0 deg (20 dB)

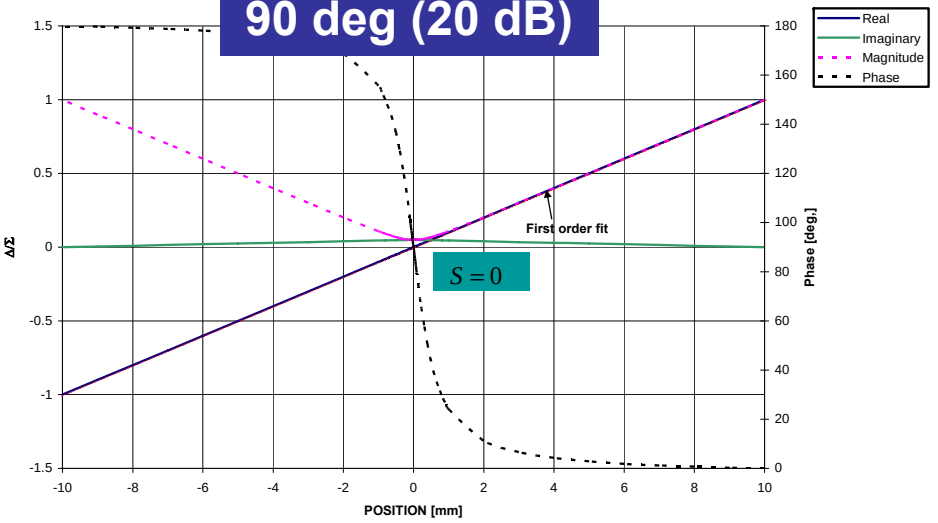
$$S_{CM} = S * (1 + \frac{CMRR}{2})$$

$$S_{CM} = S * (1 - \frac{CMRR}{2})$$



90 deg (20 dB)

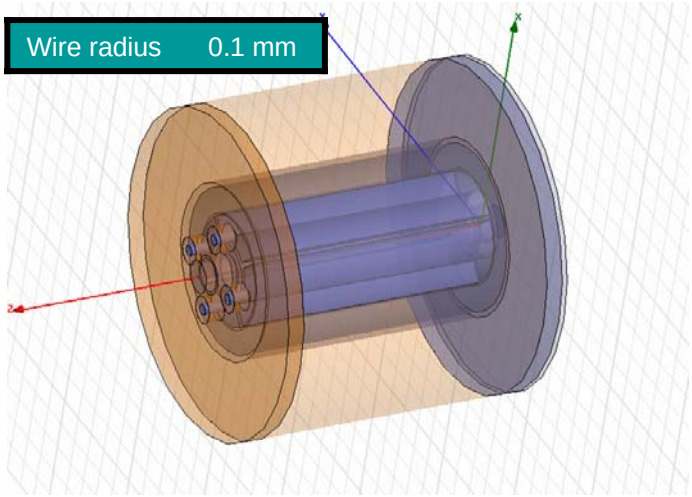
$$S = 0$$



Electromagnetics simulations: validation and optimization of the design

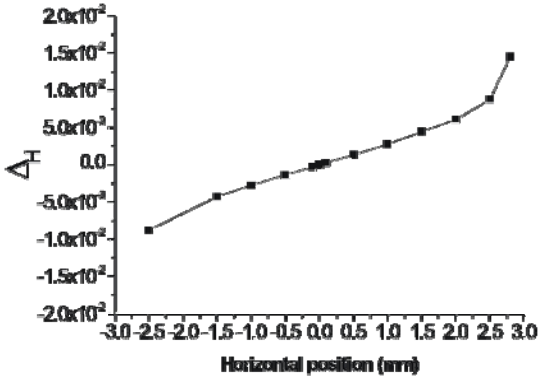
Beam position linearity

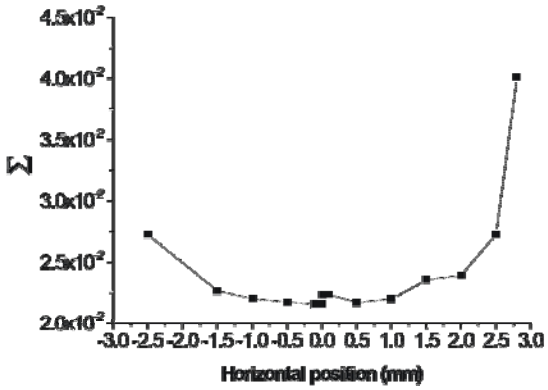
HFSS model

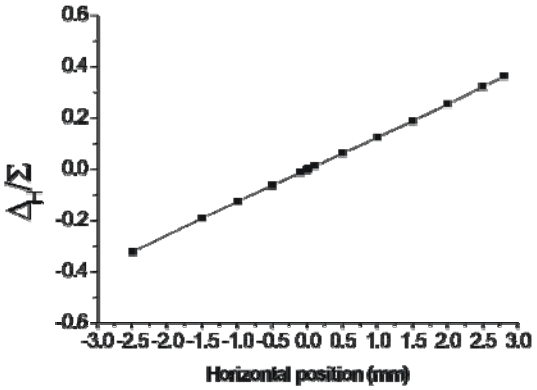


- Position evaluated at a single frequency 10 MHz
- Primary load resistance R_P of 100 mW for the 4 electrodes.
- Complex substraction and sum of the S-parameters.
- 50 W wire system gives less accurate results in terms of linearity.

Horizontal movement of a thin wire







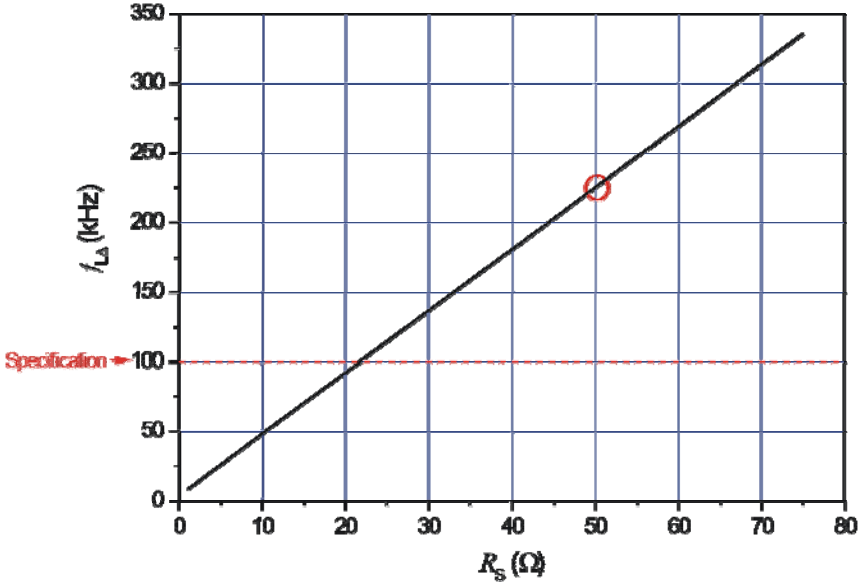
Sensitivity~0.128 (Δ/Σ) / mm

The accuracy of the simulation depends very much on the mesh (number of passes).

Low frequency cut-off

Electrical model

$f_{L\Delta}$



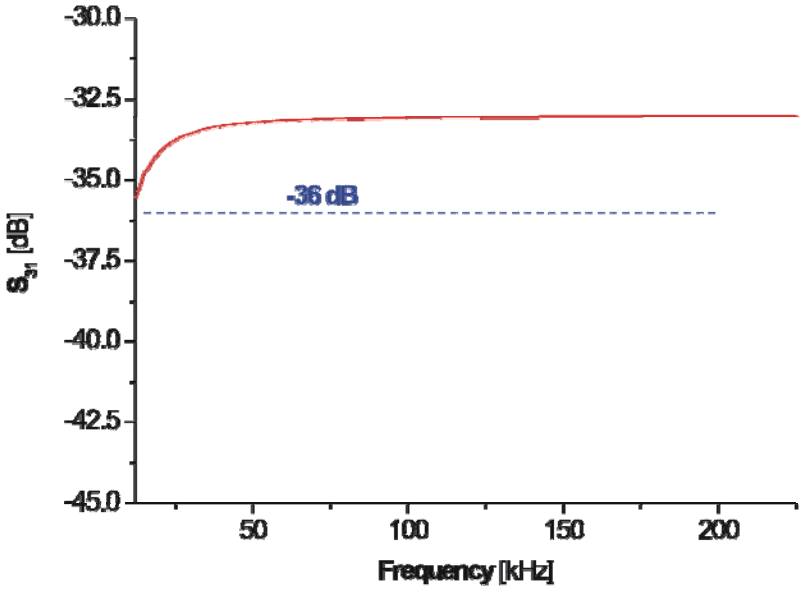
Transformer: 30 turns

L_Δ = 20 nH

f_Δ = 220 kHz

Microwave

$f_{L\Sigma}$



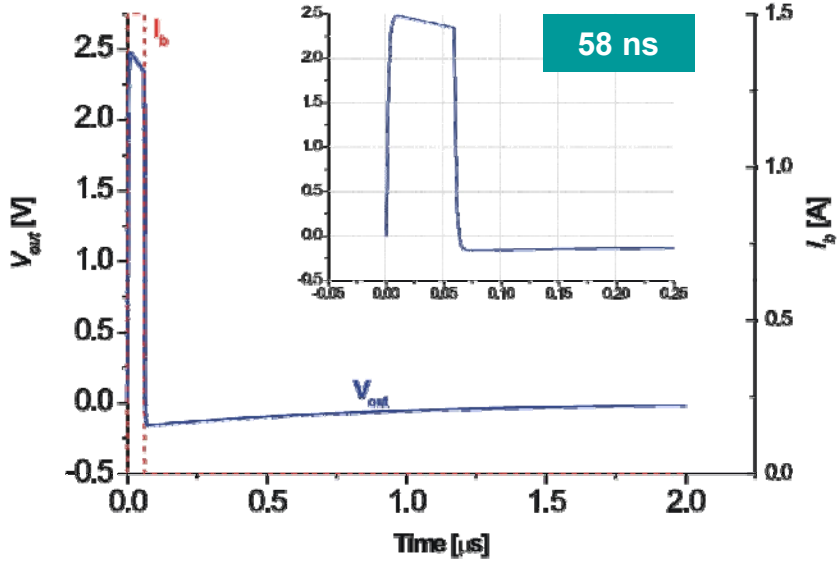
R_P = 100 mΩ

f_Σ ~ 10 kHz

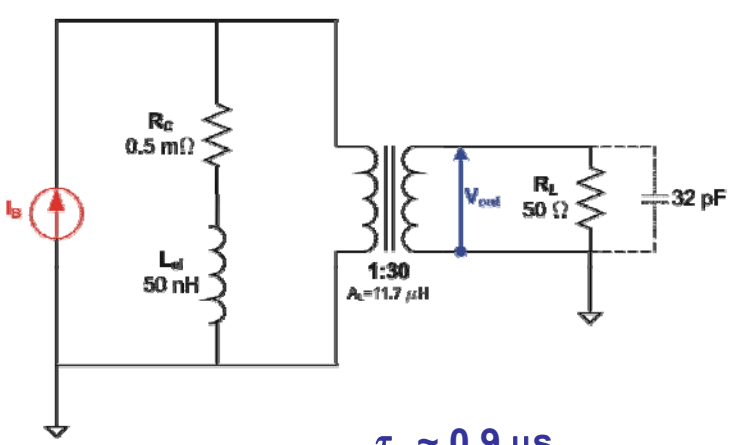
L_Σ ~ 1.5 μH

Time domain response

CLIC



Low frequency model



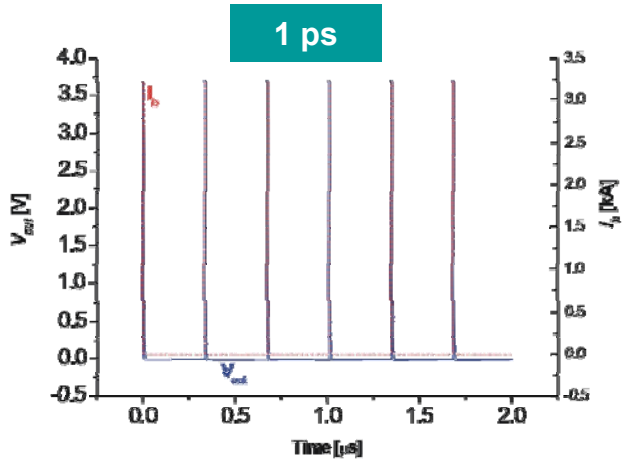
Bessel Filter (5th order)

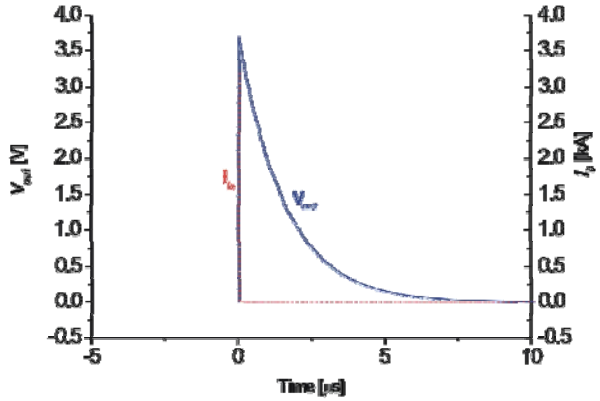
ILC

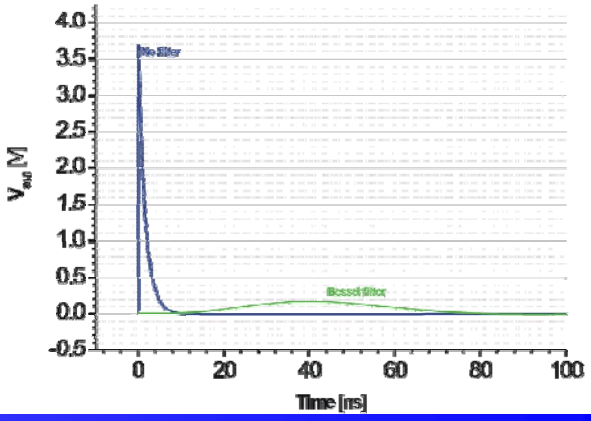
τ_Δ ~ 0.9 μs

Droop (Δ) ~ 5%

ILC

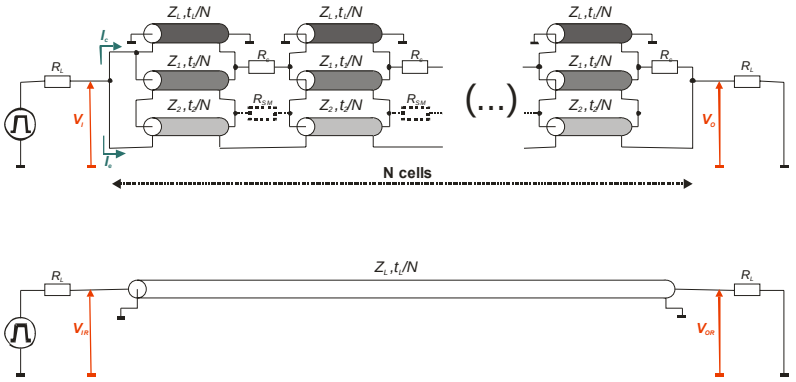






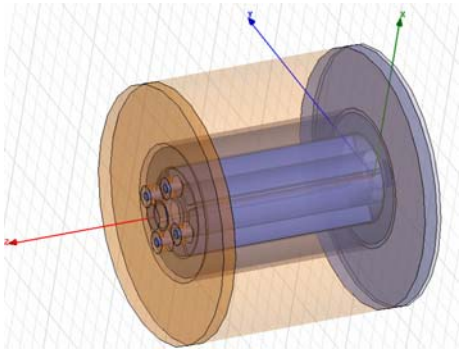
High frequency cut-off

PSPICE model



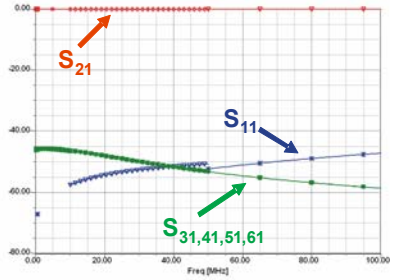
Developed from the model proposed by M. Gasior

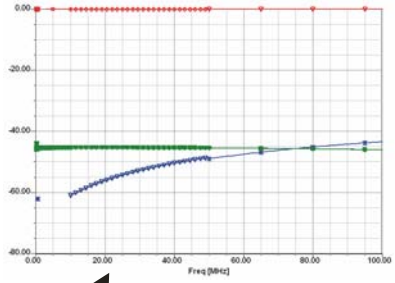
HFSS model

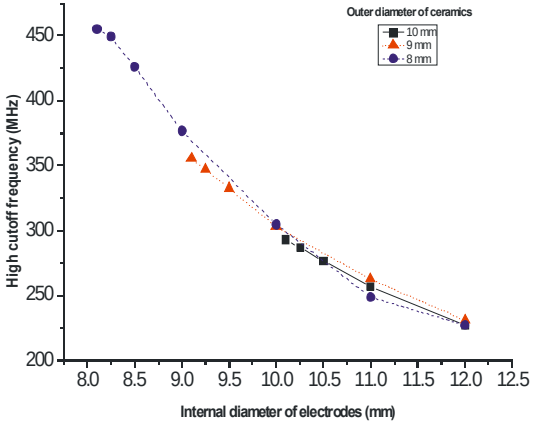


Titanium coating included

$$R_{sq} = R_{Ti}\frac{2\pi r_{i,ceramics}}{L_{ceramics}}$$

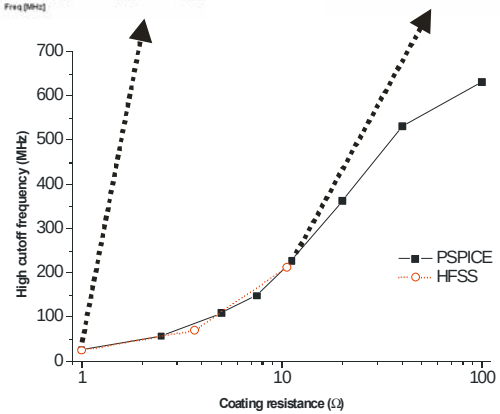


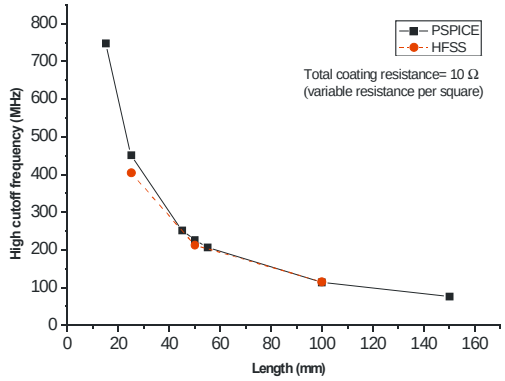




Optimization of:

- Internal diameter of the electrodes.
- Thickness ceramics.,
- Length ceramics-electrodes.
- Value of resistive coating.

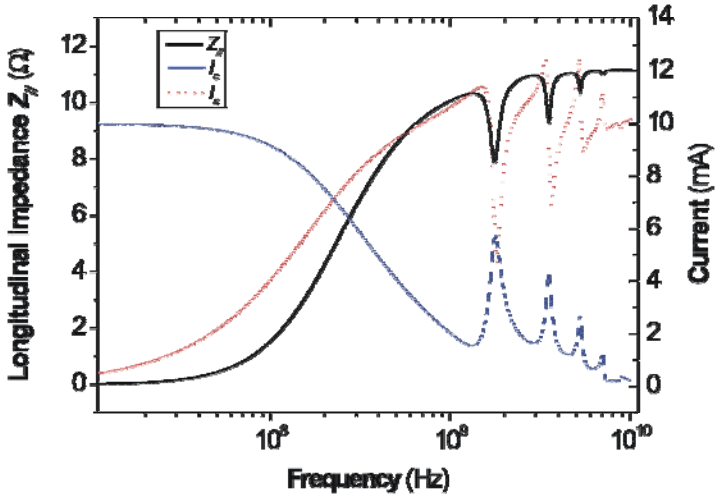




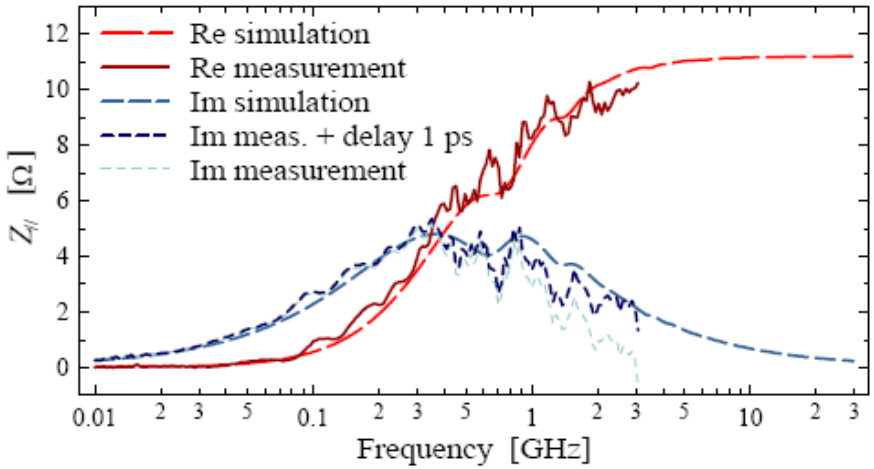
High frequency cut-off

Longitudinal impedance (PSPICE model)

PBPM



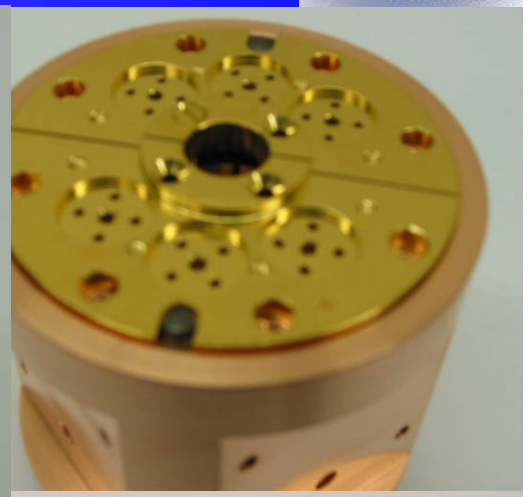
IPU-CTF3



M. GASIOR, *LIMITING HIGH FREQUENCY LONGITUDINAL IMPEDANCE OF AN INDUCTIVE PICK-UP BY A THIN METALLIC LAYER*, CERN-AB-2004-090 CLIC Note 609

The increase in line impedances in the PBPM with respect to the simulated IPU version provokes some small dumps in the longitudinal impedance of the PBPM.

Preliminary assembly



PBPM- deliverables

2005

EUROTeV report prepared and to be published

- **Report on bench tests:**
  - Design and build a mechanical stable test bench. **DONE!**
  - Develop front end electronics.
  - Measure PBPM prototype.

(middle 2007)

- **Report on beam tests:**
  - Build 3 PBPM's for beam tests at CTF3 or ATF-2 beam.

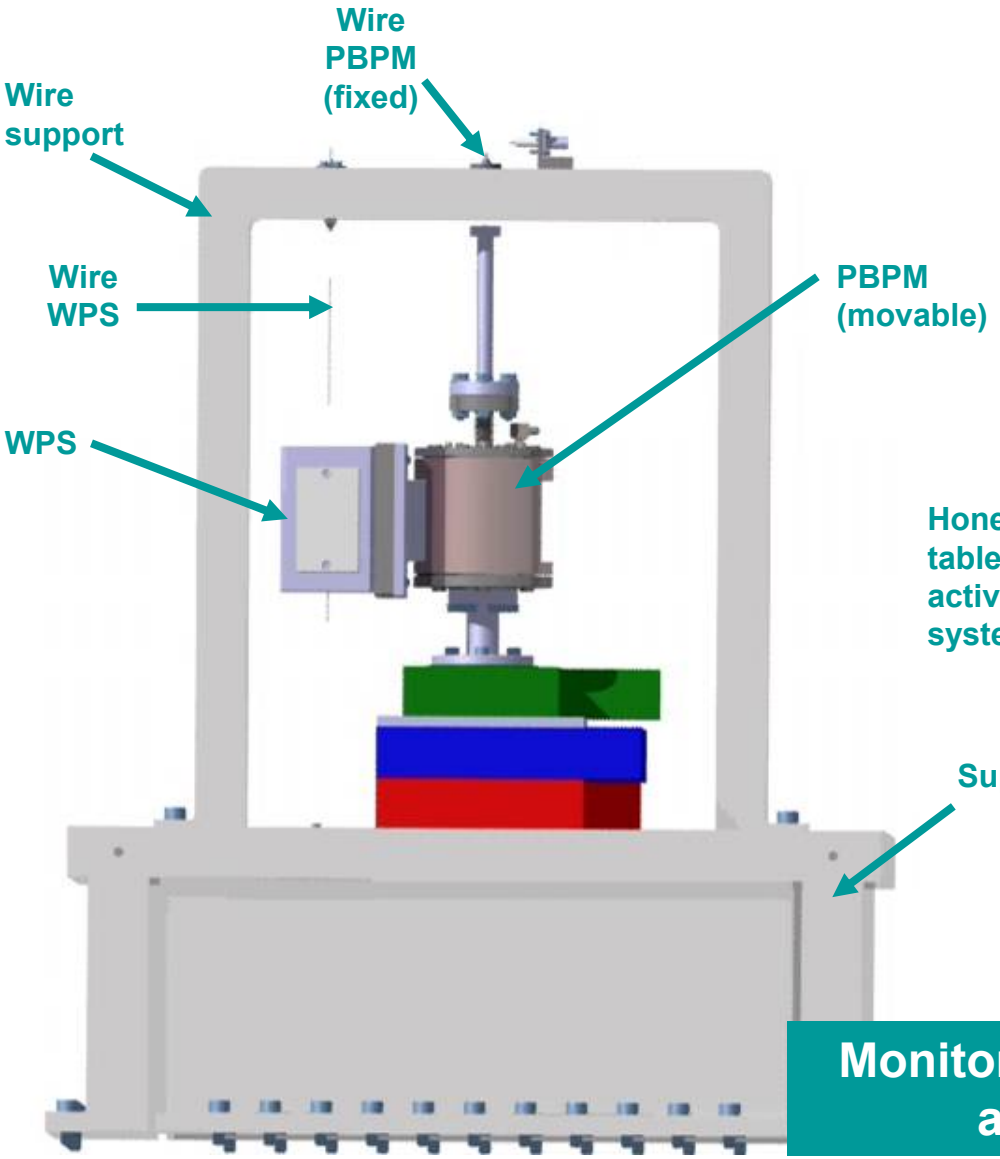
(end 2007)

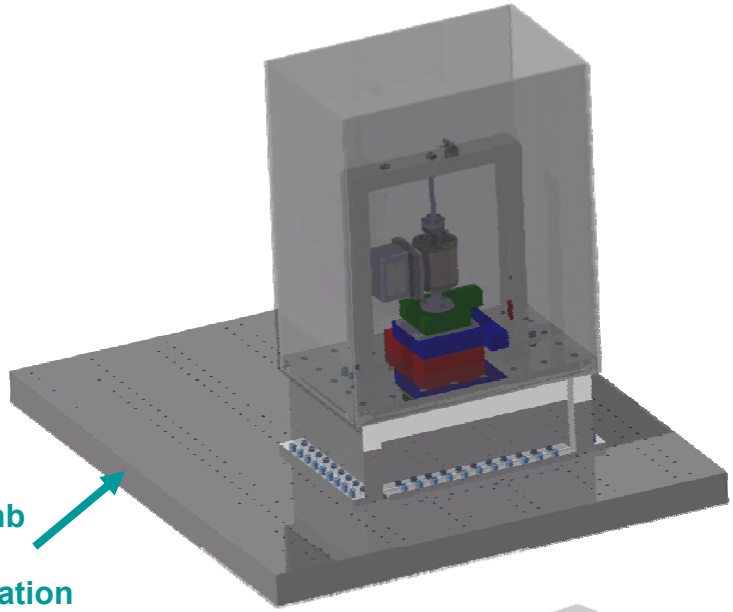
2007

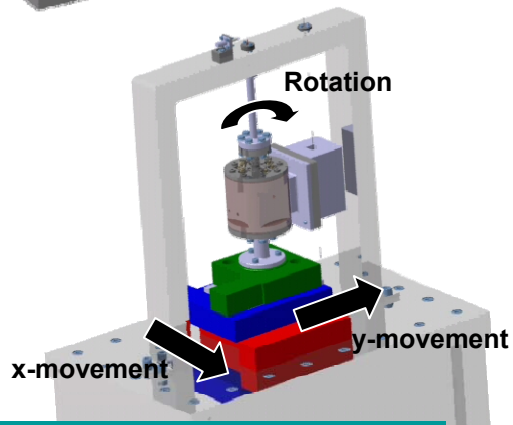
Test bench measurements

- **Resolution with CLIC and ILC type beams *(1.5A / 0.1A, 60ns pulse)*. Use of a network analyzer to obtain the information of the real and imaginary part *(sinusoidal signals)*.**
- **Sensitivity and Linearity (in both planes and in diagonal).**
- **Electrical offset (with respect to the mechanical center).**
- **Position stability with respect to temperature fluctuations 15-25°C.**
- **24 hours stability.**
- **Long term stability.**
- **Longitudinal impedance (50 W setup).**

Final design



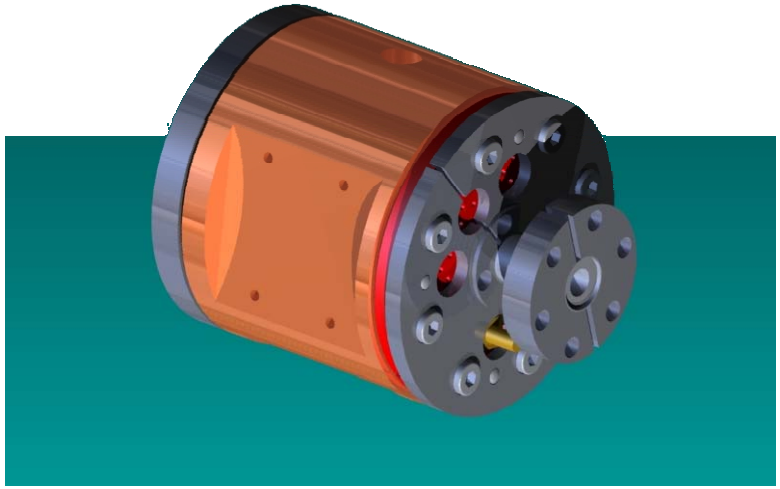




Monitoring of temperature (thermistor) and vibrations (geophone)

Acknowledgments

Many thanks to all the people that help in this project!



R. Boudot, M. Gasior, F. Guillot-Vignot, V. Maire, B. Favrat, H. Mainaud-Durand, H. Neupert, S. Calatroni, T. Tardy, L. Leggiero, P. Frichot, T. Kroyer, F. Caspers, J. Belleman, S. Redaelli, J-M. Wickham, P. Odier...