The Cold Re-entrant BPM

Snowmass – ILC Workshop
August 15-27 2005

Introduction

- A re-entrant beam position monitor (BPM) is developed in CEA/Saclay in the framework of CARE/SRF/WP11.

- The task of the CEA is the design, fabrication and full test of high resolutions re-entrant BPM in collaboration with DESY.

- S.Chel, G.Congretel, M.Jablonka, M.Luong, C.Magne and C.Simon have a participation in this project.

Introduction

- ***Aim:***

  - BPM is a device to detect beam position in accelerators, it is used for the beam-based alignment and feedback systems which are essential for the operation of the future colliders and free electron lasers.

  - The re-entrant BPM is composed of a RF cavity with four feedthroughs, an analogue electronics and a digital electronics to calibrate the system and interface to the control-command.

  - It has to have a good resolution (~ 1 µm), good time resolution (~ 10 ns) and a wideband response.

  - It has to operate at cryogenic and room temperature.

BPM Parameters

- Some definitions:

  - ***Resolution***:

    It's the minimum position difference than can be resolved. It's the rms value.

    This parameter is particularly important in colliding machines, where luminosity depends on how accurately beams can be aligned.

  - ***Time resolution***:

    It's the BPM's speed of signal detection.

  - ***Accuracy***:

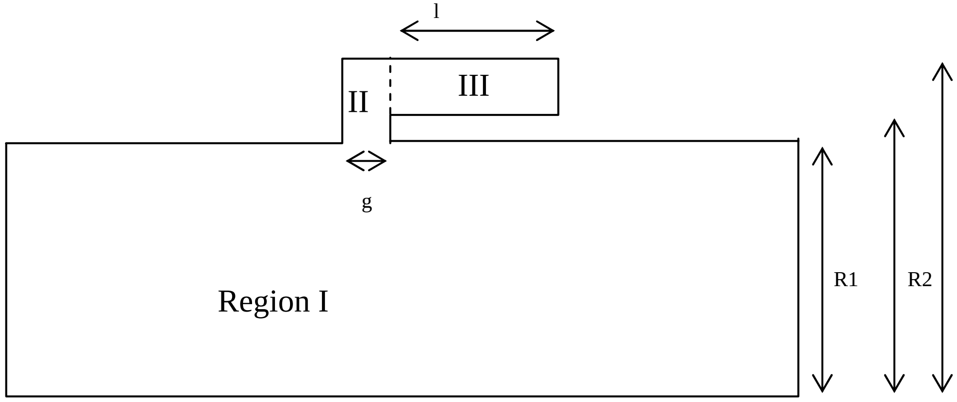
    It's the ability to determine the absolute beam position.

    This parameter is limited by mechanical tolerances and alignment, the magnetic field distribution and the electronic errors.

Re-entrant cavity

- A re-entrant coaxial cavity is arranged around the beam tube and forms a coaxial line which is short circuited at the downstream end.

- This cavity consists of three distinct regions: I.beam tube, II.gap, III. Coaxial cylinder [concept of R. Bossart]

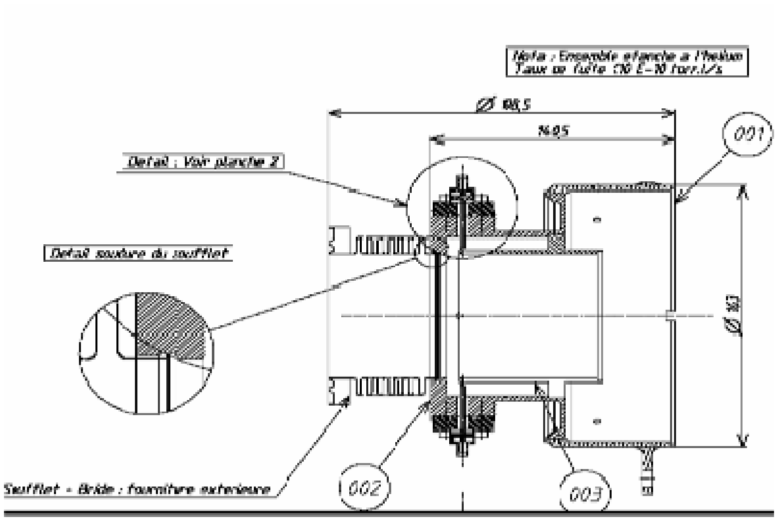


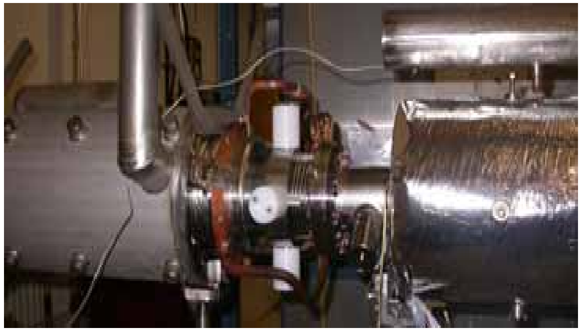
Length l	50mm
Gap g	8mm
r1	39mm
r2	41.5mm
r3	49.5mm

- It has a small size and a cylindrical symmetry which allows a high precision of the machining.

- The signal voltage of the monopole mode is proportional to beam intensity and does not depend on the beam position. And, the dipole mode voltage is proportional to the intensity and to the distance of the beam from the centre axis of the monitor.

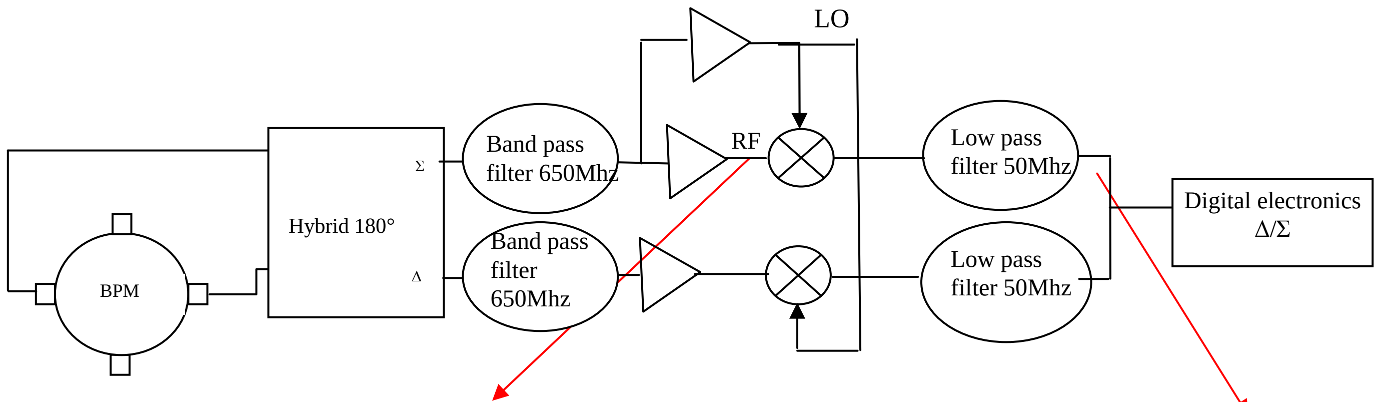
- An existing re-entrant BPM has already operated at 2K inside the capture cavity cryostat (ACC1) on the Tesla Test Facility 2 (TTF2).
- It is a resonant cavity with 4 feedthroughs to keep the symmetry.
- The fixing of the antenna tips to the inner diameter of the cavity over coupled the cavity.



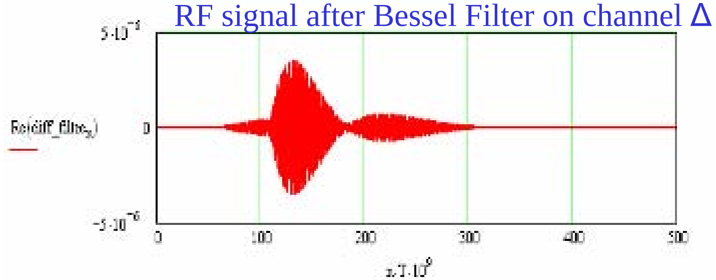


Design of the re-entrant BPM cavity in ACC1 on TTF2

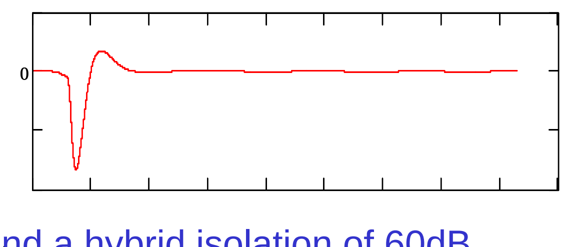
- Schematic of signal processing:



RF signal after Bessel Filter on channel Δ



IF signal after Lowpass Filter on channel Δ



Simulations done with a beam position of 10µm and a hybrid isolation of 60dB.

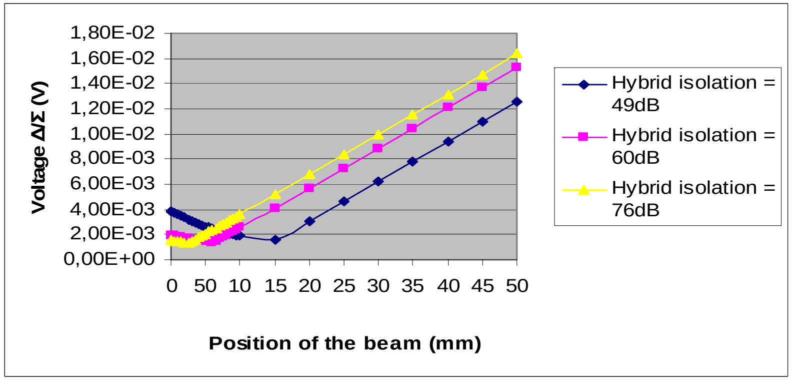
- The monopole signal is not efficiently rejected in spite of an isolation of 60db between the Δ and Σ channels of the hybrid coupler.

- Indeed, the coupling is very high → Q are low (Q=2 for the monopole mode and Q=4 for the dipolar mode). The monopole and dipole signals are spread out in spectrum.

BPM in ACC1 on TTF2

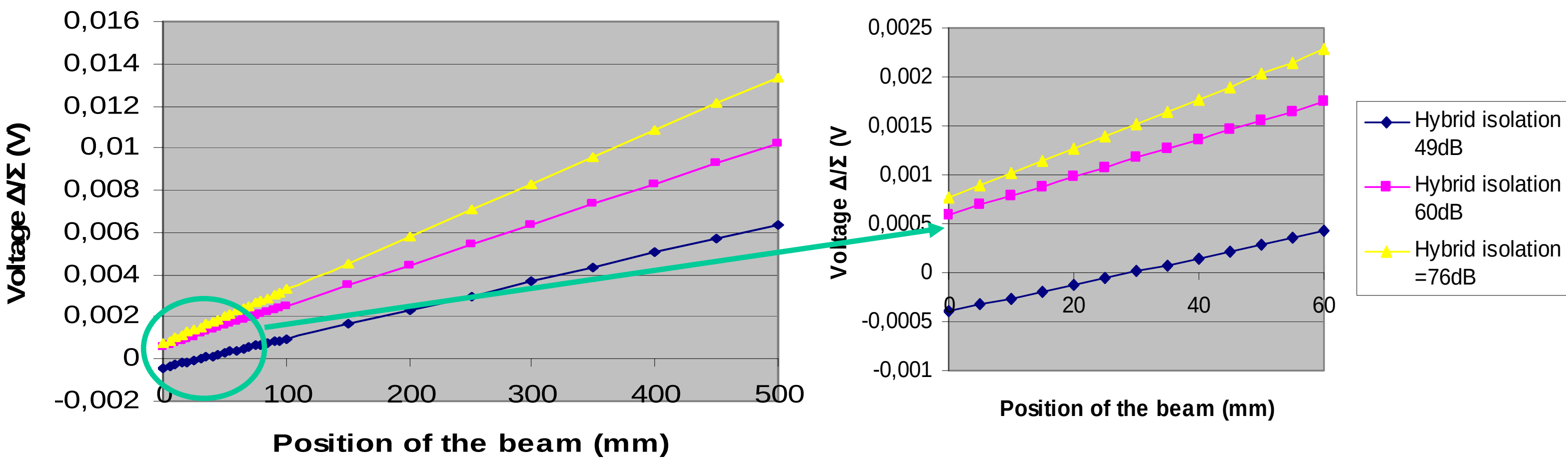
- A simulation of the cavity and the signal processing, with Mathcad, is realized.

Plots of the output voltage (in front of detection) vs position of the beam



We note a “blind” zone because the rejection of the monopole signal isn’t total. The LO signal has to be in phase with the “second “ bump to avoid the “blind “ zone.

Plots of the output voltage (after detection) vs position of the beam at the same sampling point in time



We note that the output voltage depends on the isolation of the hybrid coupler.

The best using for this system is to have a hybrid coupler isolation of -60dB.

New design of the BPM cavity

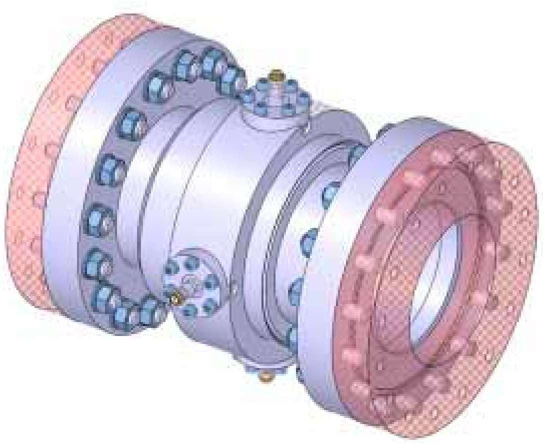
- Overall length 170mm

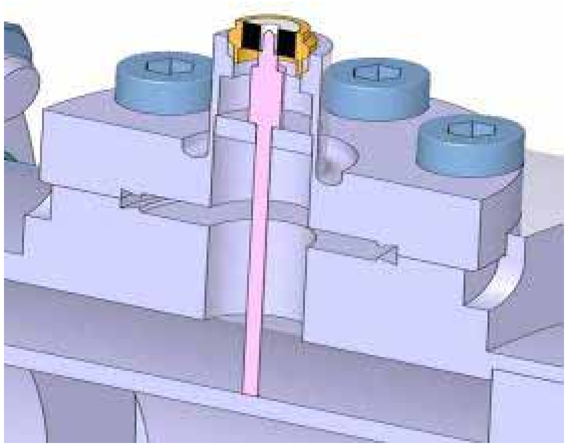
- Keep the basic design of the existing cavity.

- Twelve holes of diameter 5mm are drilled at the end of coaxial cylinder to clean the cavity

- Feedthroughs move from 31.5mm in the reentrant cavity
  - Q higher to have a signal longer in the time. The monopole and dipole signals should be to distinguish.

- New feedtroughs
  - Feedthroughs simpler and more robust. Indeed a critical point was the fragility of feedthroughs, 50% was rejected.

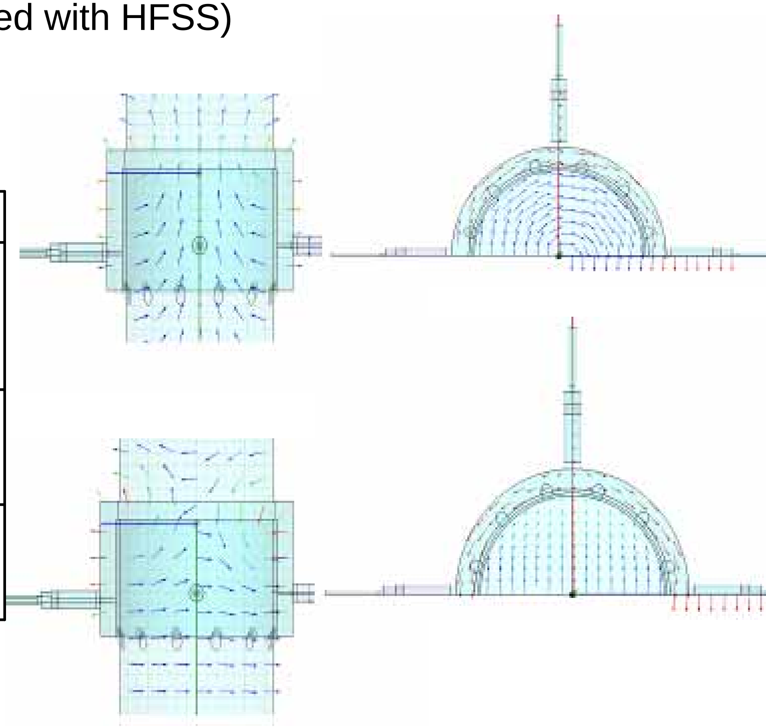




RF characteristics of the BPM

➢ Resonant modes with the new design (simulated with HFSS)

	New BPM			
	F (Ghz)	**Q**	**R/Q at 5mm of the center of cavity**	**R/Q at 10mm of the center of cavity**
Monopole Mode similar to TM010 mode	1.25	24	13	13
Dipole Mode similar to TM110 mode	1.72	51.4	0.25	1.11

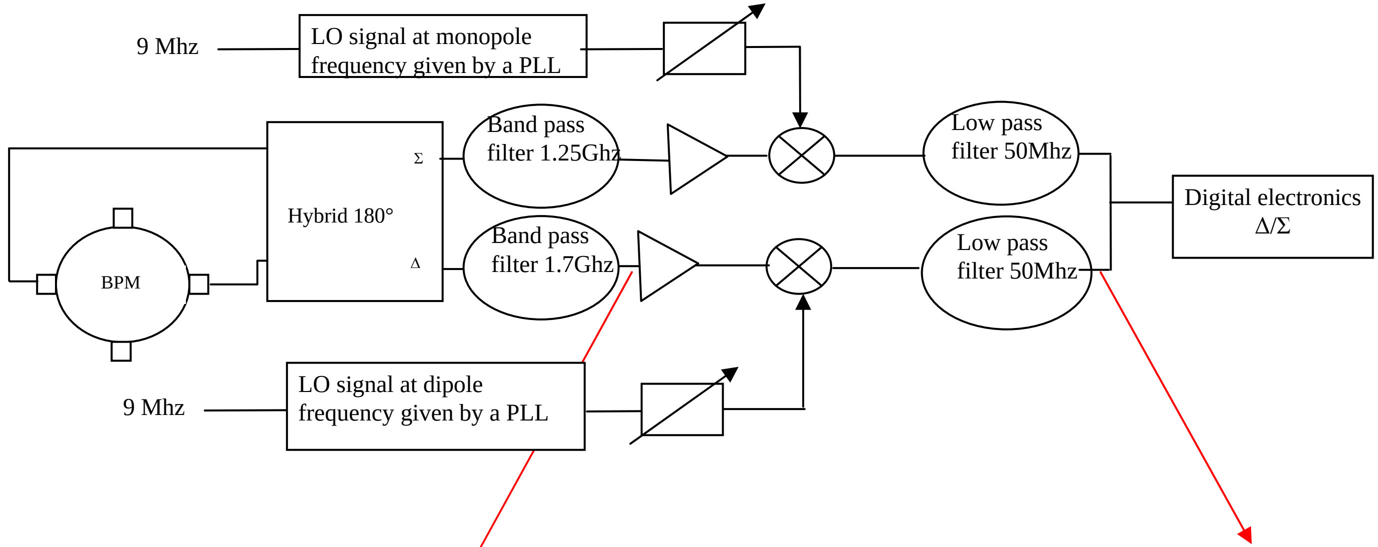


➢ Q is determined by HFSS with matched feedthroughs.

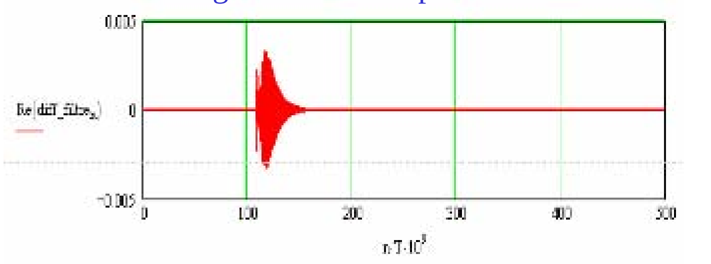
➢ The choice of resonant mode frequencies was determined according to the 180° junction hybrid available on the market.

➢ All modes of the cavity which have an eigen frequency higher than the beam pipe TE11 mode cut off frequency (2.25 GHz) are damped, so their contribution is negligible and the linearity of measurement are ensured.

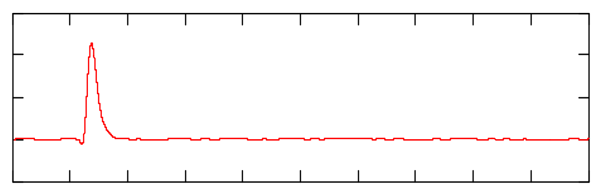
RF electronics for the new BPM



RF signal after Band pass Filter



IF signal after Lowpass Filter on channel Δ



- ➢ On the Δ channel, the monopole signal is rejected and on the Σ channel the dipolar signal is rejected. This system uses 3 rejections: the 180° hybrid coupler, the pass band filter and the mixer.
- ➢ The noise is limited by the band pass filters.

RF electronics for the new BPM

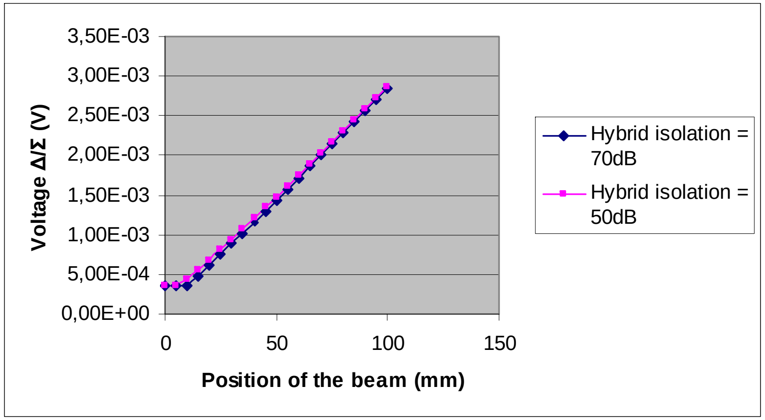
- To perform the synchronous detection, the signal must be amplified.

- The 9 MHz reference signal, from the control system, combined with some PLLs generates the LO signals at the monopole and dipole mode frequencies for the mixer.

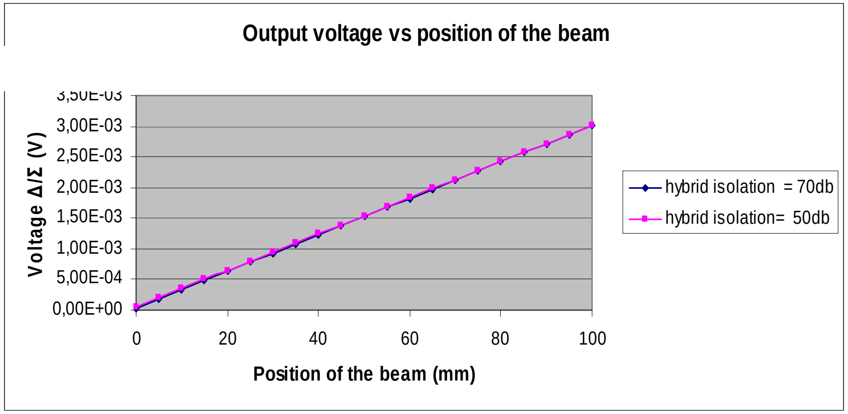
- Phase shifters, controlled by the digital electronics adjust the LO signals which have to be in phase with the signals coming from the hybrid.

- The digital electronics makes the sampling, the calibration of the system, the control-command interface and the normalization Δ/Σ.

Plots of the output voltage (in front of detection) vs position of the beam



Plots of the output voltage (after detection) vs position of the beam at the same sampling point



A “blind” zone is around 10µm because the rejection of the monopole signal isn’t total on the Δ channel.

The output voltage is less depending on the isolation between the Σ and Δ channels than the first system.

Conclusion

- **Now, the cleaning of the cavity, with the holes, is ok. Tests in DESY were made**

- **The re-entrant BPM works at cryogenic and room temperature**

- **If we take into account only the thermal noise, the resolution is <1µm.**

- **Good time resolution. The damping time for the re-entrant cavity is 9.5 ns.**

- **The next prototype will be used for warm tests with beam on TTF2 and to validate the fabrication process.**

- **Tests on the new system at the beginning of 2006 at DESY.**