IBIC '20 International Beam Instrumentation Conference

SOLEIL SYNCHROTRON

BPM studies and prototype design for the SOLEIL Upgrade

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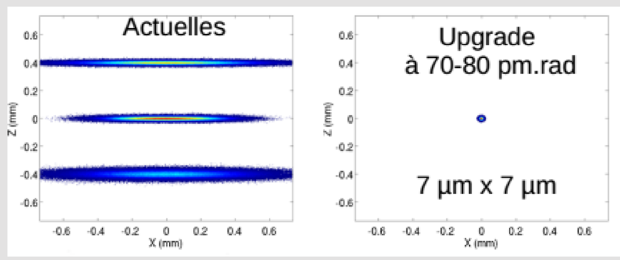
Synchrotron SOLEIL is preparing a machine upgrade with a reduction by more than a factor 10 the horizontal electron beam emittance (< 100 pm•rad). The future multibend achromat lattice will be composed of a large number of magnet elements. Quadrupole and sextupole strengths will impose a drastic reduction of the vacuum chamber dimensions and in particular its diameter that will be reduced to 10 mm. One of the challenges for the beam position monitors will be the mechanical integration of the 4 buttons and feedthroughs on such a small beam pipe.
In this context we have manufactured a first prototype with Component Off the Shelf 3 mm button diameter. To validate this mechanical integration, and we are starting the 3D electromagnetic simulations to study the impedance characteristics, the RF parameters, the heating and thermal issues.

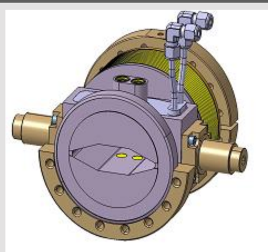
SOLEIL UPGRADE PARAMETERS

	SOLEIL	Upgrade
Emittance H (2,75GeV)	4 nm.rad	80 pm.rad
Circumference	354,1 m	353,7 m
Straght lengths	12/7/3,8 m	7,66/7,35/2,71 m
Natural Bunch Length	15,17 ps	9,18 ps
Energy loss per Turn	917 Mev	490Mev
RF Voltage	2,9MV	1.38MV
Vacuum chamber dimension	70mm*25mm	10mm
Number of BPM	120	180



Transverse dimension of the SOLEIL beam in straight section

SOLEIL BPM UPGRADE CHALLENGE

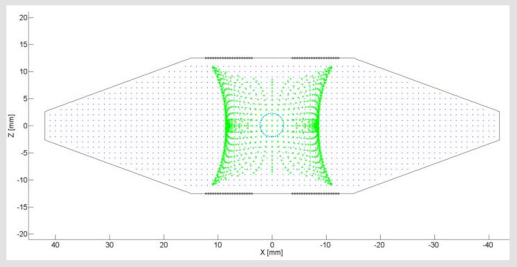


Actual BPM block design: 120 BPMs on the storage ring

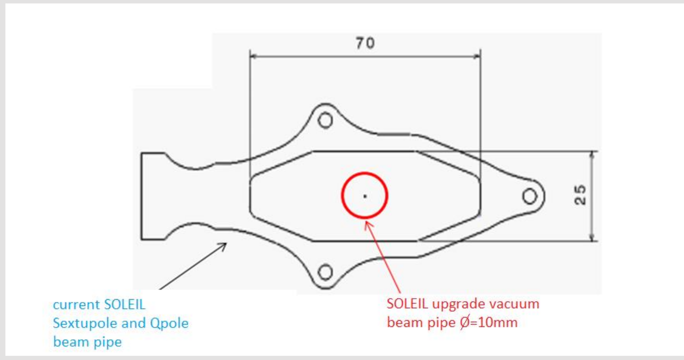
Very high gradient (~100 T/m) is required in the magnets.

-> **Drastic reduction of the vacuum chamber diameter**

SOLEIL Upgrade is considering a 10 mm diameter pipe.

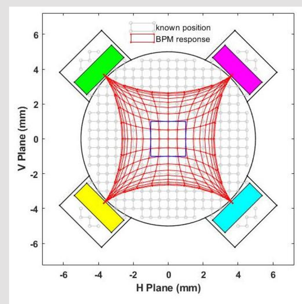


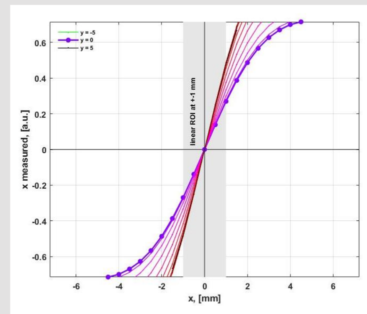
Response of BPM from each beam position: Linear region is limited to ±2mm around the BPM centre.



2D SIMULATION

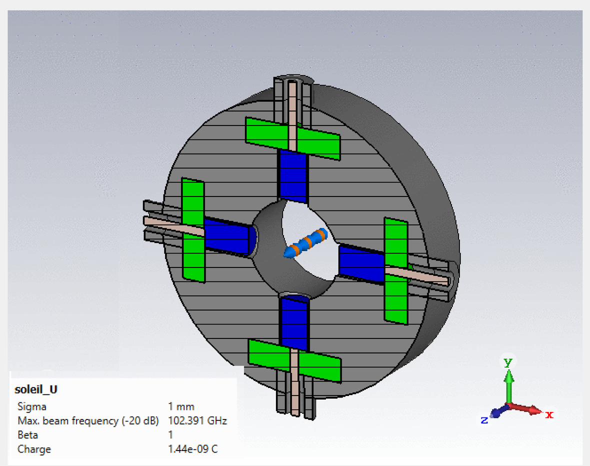
Model specification simulation:
RF pickups installed at 45 ° on the vacuum chamber.
Inner pipe diameter : 10 mm
Considered button diameter : 3 mm , 4 mm, curved 4 mm
Gap between button and housing: 200 µm





the linear region will be limited to ± 1mm around the BPM center .

LONGITUDINAL IMPEDANCE SIMULATION



3D simulations using CST Wakefield Solver [1] are in progress to optimise the longitudinal impedance of the BPM. Different parameters such as button diameter, housing diameter, size and type of insulator are simulated and compared to theoretical formulas to determine the contribution of each element.

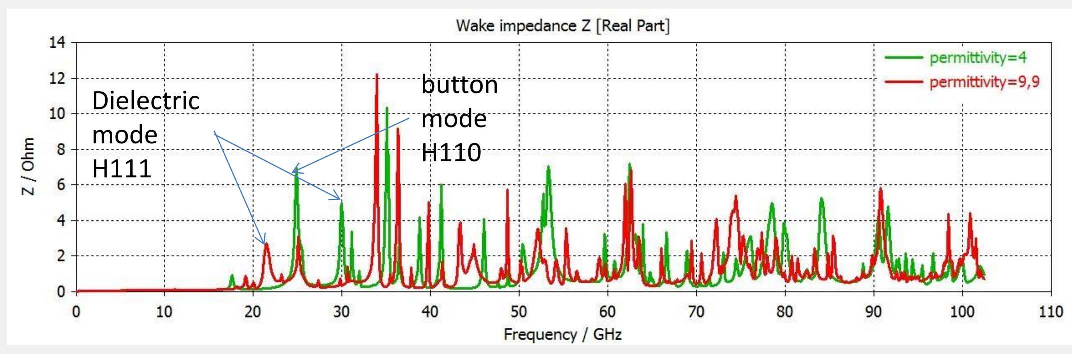
Frequency of the mode due to the dielectric vacuum Insulator

$$f^{Hm1p} = \frac{1}{\sqrt{\varepsilon_r}} \frac{c}{2\pi} \sqrt{\left(\frac{2*m}{r_p+rd}\right)^2 + \left(\frac{\pi*p}{t_i}\right)^2} \quad [2]$$

Frequency of the mode due to the button and housing

$$f^{Hm1} = \frac{c}{\pi} \frac{m}{(rb+rh)}$$

ε_r : Dielectric permittivity
t_i : Insulator thickness
m : Azimuthal index
p : Longitudinal modes number
r_p : pick-up radius in the insulator
r_b : button radius
r_h : housing radius



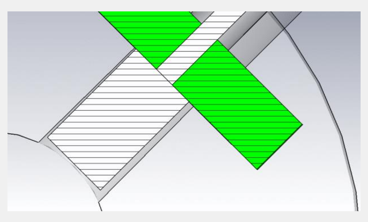
Real part of longitudinal impedance versus frequency, for two dielectric permittivity of the vacuum insulator: In red dielectric permittivity = 9,9. In green with dielectric permittivity = 4

For all the simulated cases, the longitudinal impedance remains below 20 Ω , First resonances are above 20 GHz. We continue the simulations to determine which design minimizes the contribution of impedance.

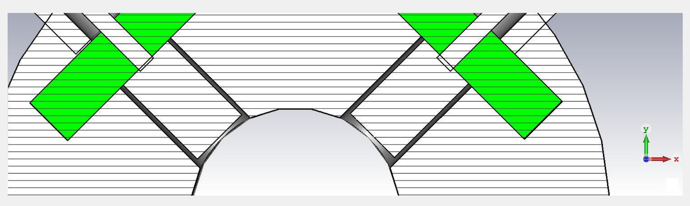
MECHANICAL TOLERANCE SIMULATION

S parameter simulation

The aim of these simulations is to determine the impact of a mechanical offset during the manufacturing of the BPM block. For this we simulate a concentricity error of one button in it housing, and a retreat error of one button.
We determine the resulting horizontal and vertical offset using the external measurement "Lambertson method" [2,3,4]. These results will allow us to determine adequate tolerances in the mechanical design of the BPM block.



The concentricity error of the button in its housing.



Retreat error 200 µm instead of 100 µm

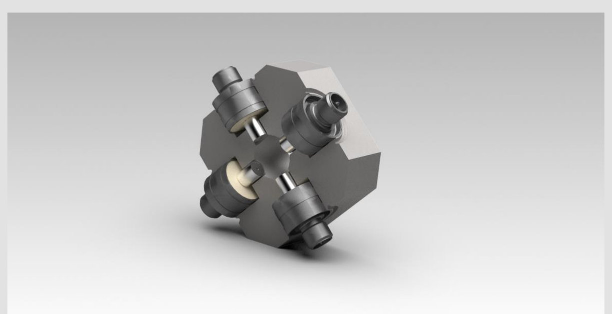
S parameter matrix for the concentricity case

	Withdrawal error 200 µm instead 100µm.	The concentricity error of the button in its housing .
offset X	-0,140	-0,020
offset Y	-0,137	-0,011

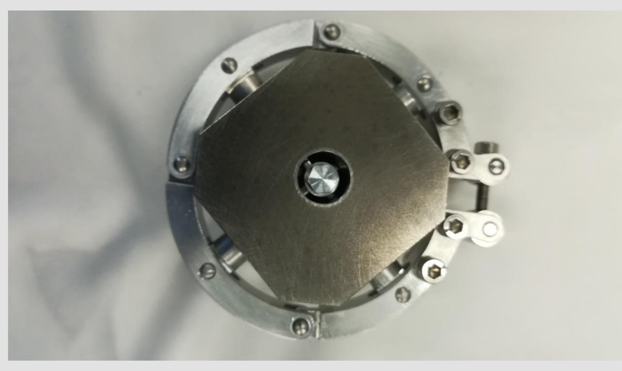
100 µm error on the retreat of an electrode induces a position offset error of 140 µm. The decentering of a button induces very little variation (<20 µm). The combination of both errors induces a position error of 150 µm.

MECHANICAL DESIGN OF A PROTOTYPE

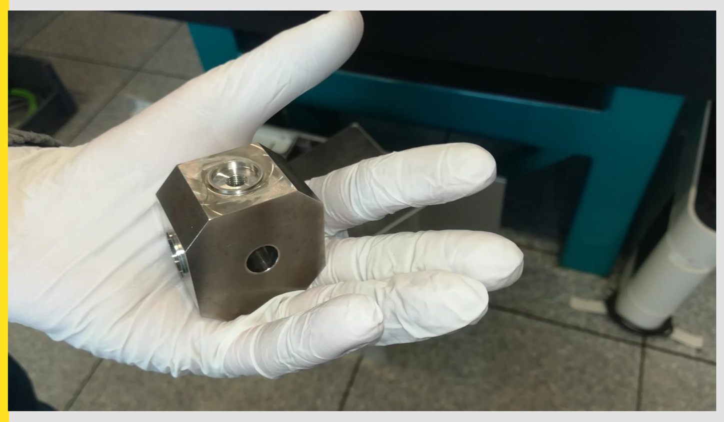
We have realised a first prototype with Component Off the Shelf 3 mm button diameter, to validate this mechanical integration



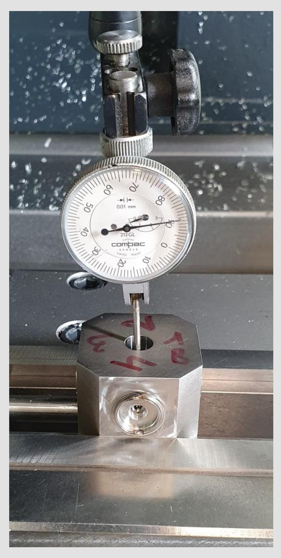
3D view of the inside of the BPM blocks



BPM block with the electrode positioning system before welding



BPM after electrode welding



BPM block on the mechanical metrology bench

Conclusion:

Future BPM for the SOLEIL upgrade are under design. The main challenge is the drastic reduction of the vacuum chamber circumference. Accurate electromagnetic simulations are ongoing to minimise impedance. Deposited power should also be estimated to decide whether to have a water cooling circuit around the body of the BPM. A study of mechanical stability of the BPM will allow us to choose either to integrate BPM blocks in the vacuum chambers or to install them independently between bellows.

REFERENCES:
[1] https://www.3ds.com/fr/produits-et-services/simulia/produits/cst-studio-suite/
[2] H. O. C. Duarte L. Sanfelici, S. R. Marques "**DESIGN AND IMPEDANCE OPTIMIZATION OF THE SIRIUS BPM BUTTON.**" IBIC2013, Oxford, UK
[3] W. Cheng, B. Bacha, O. Singh "**BEAM POSITION MONITOR CALIBRATION NSLS-II.**" BIW2012, Newport News, VA USA
[4] Y. Chung , G. Decker "**Offset Calibration of the Beam Position Monitor Using External Means*.**" BIW1991, Newport News. 1991.