TUP44

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SOLEIL II BEAM POSITION MONITORS: DESIGN, SIMULATIONS AND BUTTON PROTOTYPING

M. El Ajjouri, N. Hubert, A. Gamelin, P. Alves, Z. Fan
Synchrotron SOLEIL, Saint-Aubin, France

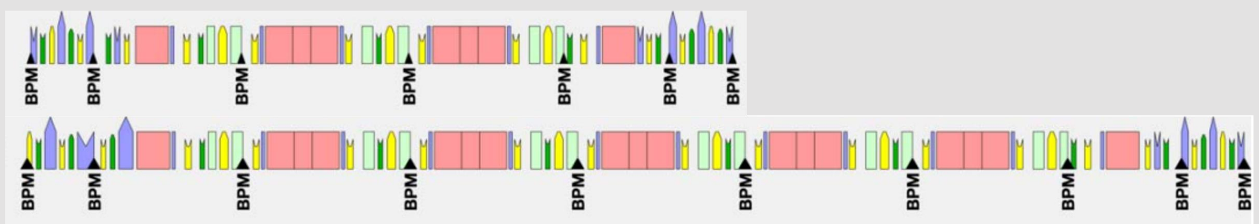
SOLEIL II is the low emittance upgrade project for Synchrotron SOLEIL, targeting an emittance of ~80 pm.rad. The new lattice includes 180 Beam Position Monitors (BPM). Due to the different constraints on the magnet yokes, beam stay clear and synchrotron radiation, 3 different types of BPM will be installed on the storage ring with inner diameter distributed between 16 and 24 mm. Electromagnetic and thermal simulations have been conducted to validate the designs.
Manufacturing the feedthroughs is a challenge due to the conical shape of the button and the small (200 µm) thickness of the gap with the BPM body. Prototypes of the button have been made by two different manufacturers, and possibilities for improvement identified. These prototypes will test in the current machine to validate the simulation results.

SOLEIL II

80 pm.rad upgrade project of SOLEIL light source.
Hybrid 7BA/4BA lattice.
ID sources points kept at the same location.

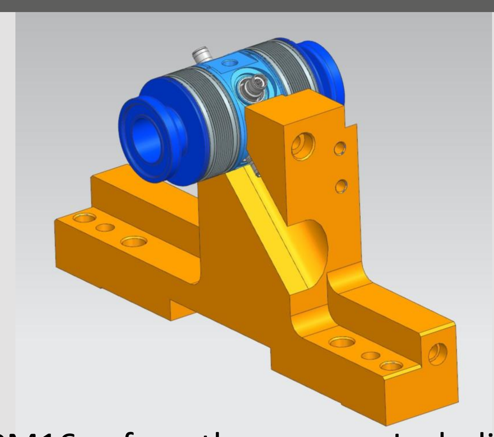
Important dates:
Dec. 2023: Project and founding approval.
2025: Beginning of construction phase.
Oct. 2028-end 2029: Shutdown.
2030: 29 beamlines operating.

BPM MECHANICAL INTEGRATION

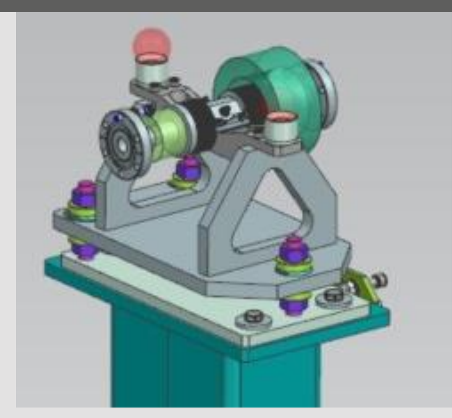


SOLEIL II storage ring will be equipped with 180 BPMs: 7 per 4BA section, 10 per 7BA section and 4 additional BPMs in the two long straight sections.

3 Types of BPM	Φ BPM	Φ Button	Number	Location
BPM16-6	16 mm	6 mm	128	Arcs
BPM20-7	20 mm	7 mm	40	Standard Straight Sections
BPM24-7	24 mm	7 mm	12	Long Straight Sections

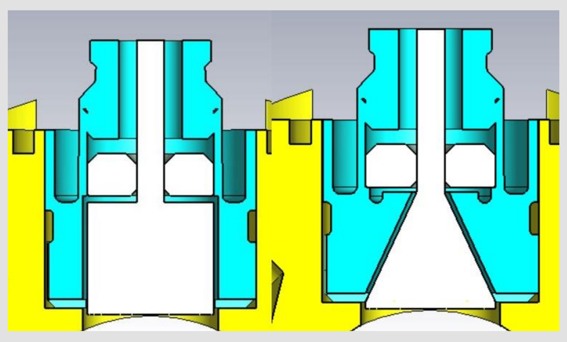


BPM16: for the arcs. Including bellows and flanges the BPM length is only 74.2 mm. Foreseen stand is water-cooled copper (on girder).

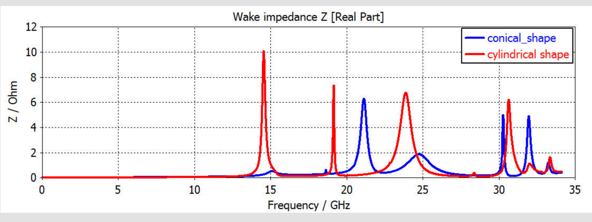


BPM20 : in the standard straight section. The block includes two bellows and a dedicated small thickness section to host a fast corrector. Stand will be in Invar fixed to the ground.

BUTTON DESIGN AND BPM EM SIMULATION

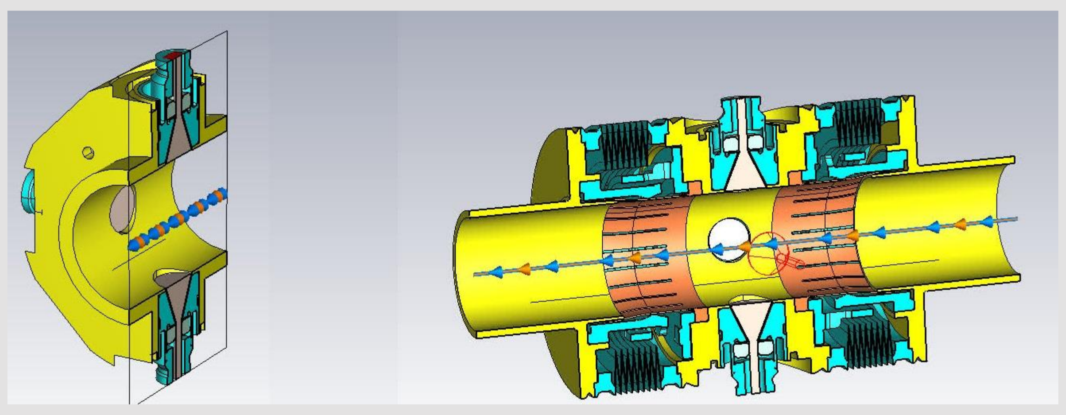


Cylindrical (left) and conical (right) shapes.

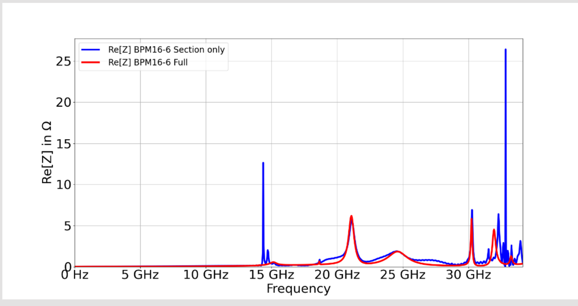


The real part of longitudinal impedance for the straight (red) and conical (blue) button shapes.

Conical shape shows much better impedance: -> design choice for SOLEIL II.



BPM16 section alone (left), and the full BPM16 structure with the two bellows.



Real part of long. impedance: full BPM structure with bellows (blue) and BPM section only (red).

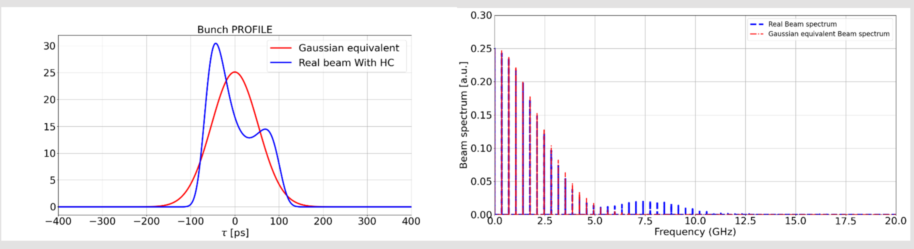
The presence of bellows upstream and downstream of the BPM introduces a peak at 14 GHz with a notable amplitude of 11Ω and another peak at 33 GHz with an amplitude of 30Ω, though these are not expected to significantly impact dissipated power. 21 GHz resonance is related to the trapped mode around the button.

SOLEIL II main operational mode will be 500 mA distributed uniformly in the 416 bunches. Bunches will be lengthened up to about 50 ps rms using a harmonic RF cavities (HC). In case of a failure of this cavity the bunch length will be 15 ps rms. In this mode the current would be limited to 300 mA.

$$\Delta P = (f_0 e N_{beam})^2 \sum_{p=-\infty}^{p=+\infty} |\Lambda(p\omega_0)|^2 \, Re[Z_{||}(p\omega_0)]$$

Total power loss by taking into account the beam spectrum and the real part of the longitudinal impedance,

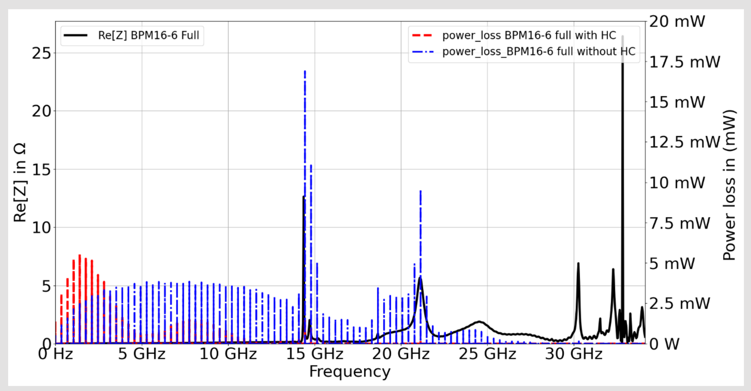
The simulations and calculations take in consideration the non-gaussian bunch deformation due to the HC.



Comparison of the bunch shape (left) and spectrum contents (right) for gaussian (red) vs real (blue) distributions.

BPM power loss calculated for the nominal operation mode with the HC and a degraded case with potential HC failure.

	With HC σ≈50ps rms	Without HC σ≈15ps rms
Power Loss (mW)	140	440

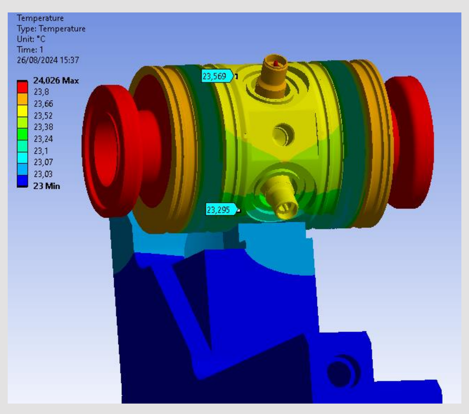


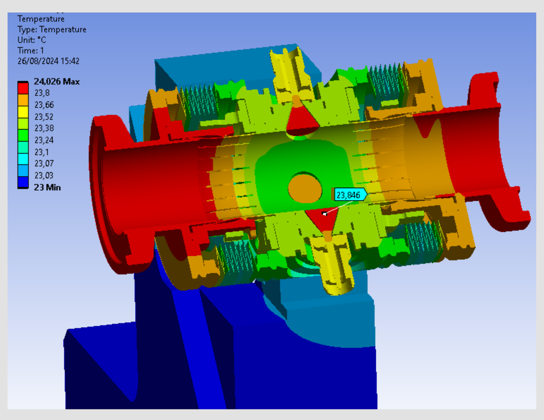
The spectral distribution of power dissipated in the BPM with (blue) and without (red) HC.

THERMAL SIMULATION AND HEAT DISSIPATION

Field Frequency (GHz)	Power loss (mW)	Power loss (mW)
RW	130	237
14.39	10	105
21.1	0	90
32.8	0	14

Power loss applied for different resonant frequencies. The nominal operation mode (blue) und and degraded case (red).

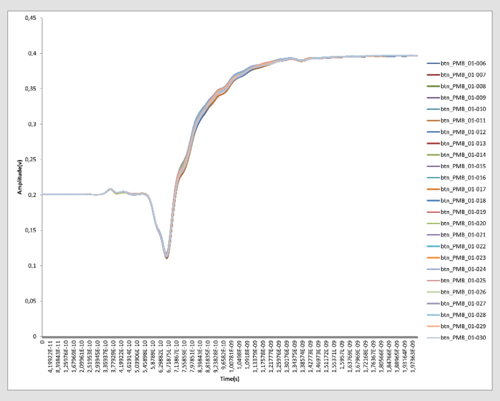




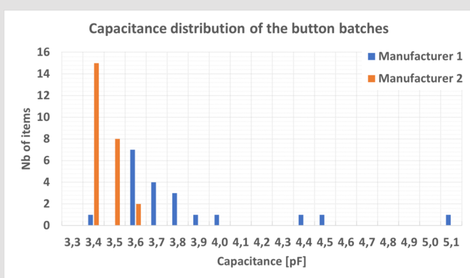
Resulting temperature increase of the BPM block in the arcs is only +1°C during operation in the worst-case scenario. The electrodes are at a temperature of 23.84°C, with a difference of 0.25°C observed between them. This variation is due to asymmetric contacts between the BPM and the support.

PROTOTYPING

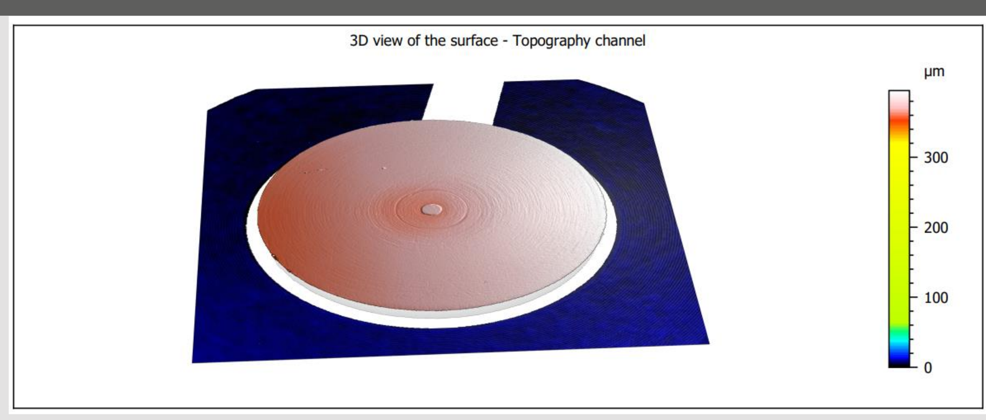
Based on initial SOLEIL II BPM design with 5 mm diameter conical buttons, two different commercial companies have been contacted to produced batches of 20 units.



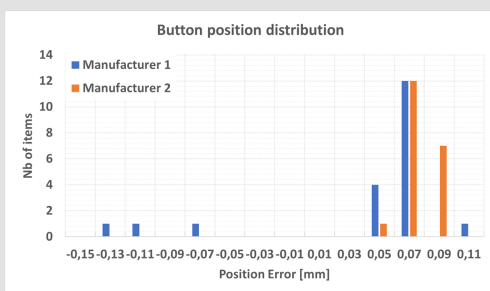
Capacitance of the feedthroughs has been measured with a linear regression of the button rising time response to a pulse using a Time Domain Reflectometer (TDR).



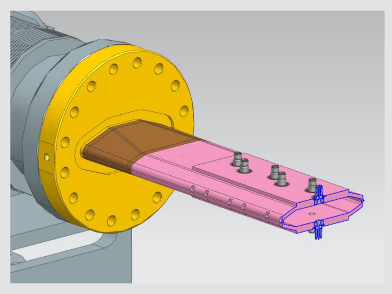
Capacitance measurements show a much better reproducibility for manufacturer 2 with a standard deviation in the values of 0.05pF RMS. This has been correlated with higher dispersion in button position error in its housing.



The metrology of the elements has been performed with microscope imaging and interferometry maps.

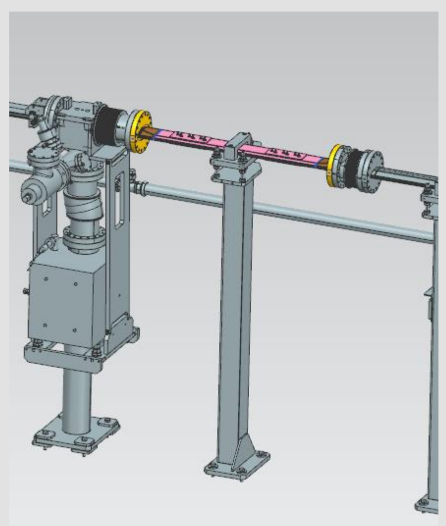


Both batches present an average error in the button position of ~70 µm which is too high. Discussions with the two manufacturers are ongoing to minimize this error.



Considering the elliptical shape of the SOLEIL chamber and to maintain the 8 mm distance from the beam center as specified in the SOLEIL II BPM pipe, the electrodes are arranged in a staggered configuration.

To validate the simulation results button designs, prototypes will be mounted on a dedicated chamber and installed on SOLEIL.



CONCLUSION

SOLEIL II BPM design must answer the challenge of miniaturization while minimizing the power loss to maintain an excellent stability. Conical buttons are a good choice to minimize the impedance of the BPM but makes the mechanical realization a little bit more complex. To validate the design, prototypes have been produced by two different manufacturers. Although mechanical errors and possible improvements have already been identified, final validation will be done on SOLEIL beam at the beginning of 2025 with the prototypes installed on a dedicated vacuum chamber.