BEAM POSITION MONITOR FOR MYRRHA 17-100MEV SECTION

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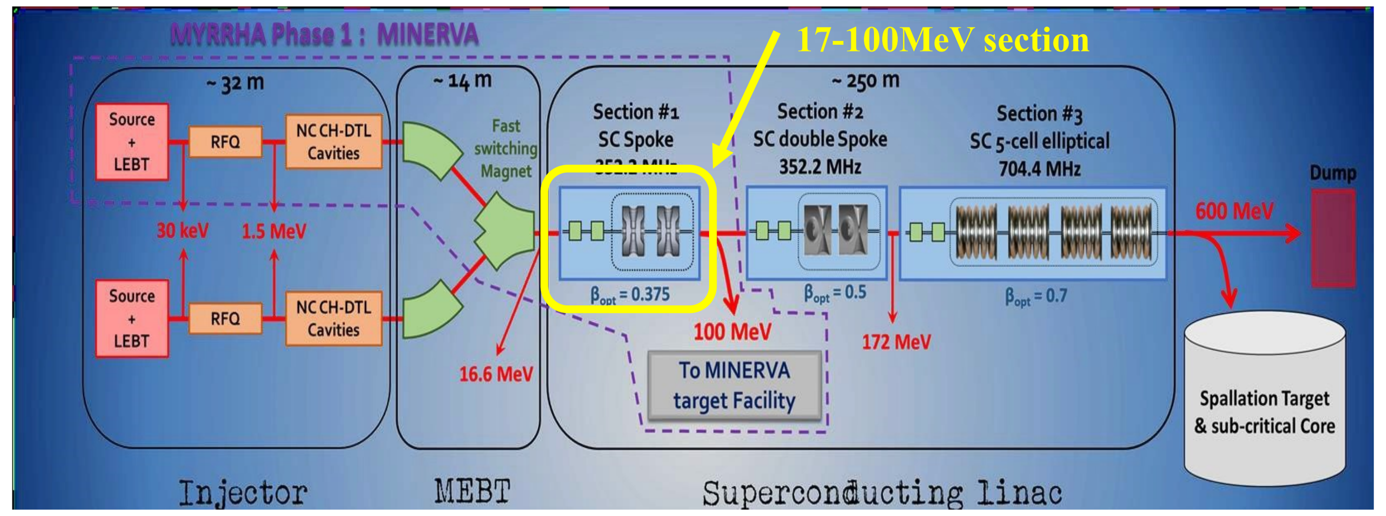
ABSTRACT

MYRRHA (Multi-Purpose Hybrid Research Reactor for High-Tech Applications) aims to demonstrate the feasibility of high-level nuclear waste transmutation at industrial scale. MYRRHA Facility aims to accelerate 4 mA proton beam up to 600 MeV. The accurate tuning of LINAC is essential for the operation of MYRRHA and requires measurement of the beam transverse position and shape, the phase of the beam with respect to the radiofrequency voltage with the help of Beam Position Monitor (BPM) system. MINERVA is the first phase of MYRRHA. It includes several sections allowing beam acceleration up to 100 MeV. A BPM prototype was realized for the single spoke section (17 MeV-100 MeV). This paper addresses the design, realization, and calibration of this BPMs and its associated electronics. The characterization of the beam shape is performed by means of a test bench allowing a position mapping with a resolution of 0.02 mm.

MYRRHA PROJECT

MYRRHA is a high power proton accelerator with strongly enhanced reliability performances. The first phase (MINERVA) aims at demonstrating the fault compensation strategy for the 600MeV linac on a 100MeV linac. MINERVA addresses the topics identified as priority ones to successfully design the MYRRHA accelerator and prepare for its construction. Among the topics, beam characterization would deliver data of fundamental importance in all beam dynamics simulation tools.



Beam Position Monitor (BPM) is a non-destructive beam diagnostic system, it measures beam position and beam ellipticity giving though an indication on the beam transverse shape. A BPM prototype is realized in order to contribute to the characterization of the beam along 17-100MeV section; Table 1 addresses beam properties and BPM specifications at this section.

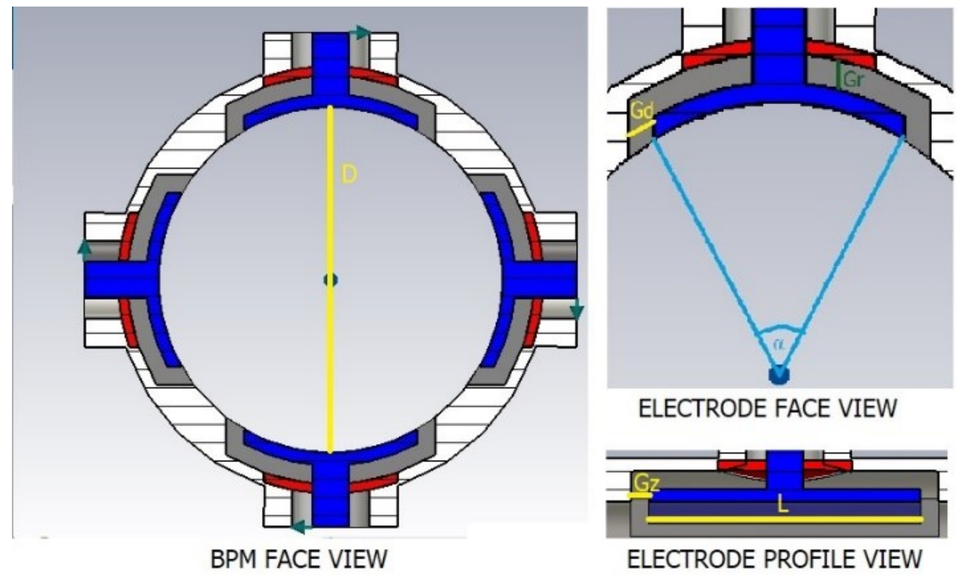
Parameter	Range	Precision
Energy E	17MeV-100MeV	
Current I	0.1mA-4mA	
Duty cycle	2.10^{-4} to 0.125	
Bunch length @17MeV	15°; 230ps	
Bunch length @100MeV	5°; 80ps	
F_{acc}	176.1MHz	
Beam pipe	28mm	
Measured Position	±5 mm	100µm
Measured Ellipticity	±5 mm	Max(1.6mm²;20%)

BPM DESIGN AND SIMULATION

SPIRAL2 BPMs [1] experience was helpful. The relatively similar properties between the beams of MYRRHA and SPIRAL2 led us naturally to match the design of SPIRAL2 BPMs to MYRRHA and also improve this design. The BPM probe is considered as a capacitance that is charged by the beam and discharged through a resistance connected to ground. The probe has a high-pass-filter characteristic with cutoff frequency $F_c=1/2\pi RC$. BPM operates at low frequencies ($F_{acc} < F_c$).

In the MYRRHA scope (beam energies between 17 and 100MeV/u), the 2nd and upper harmonics of the beam image current are important. Consequently, Readout electronics process BPM signals at Facc and 2*Facc tones.

Simulations measures the effect of BPM design parameters sketched below. We aim to obtain the strongest signal tones at Facc and 2Facc while ensuring BPM mechanical stability and fabrication repeatability. The optimization on the parameters mentioned above led to the following result: L=45mm, α=45deg, Gr=Gz=Gd=4mm. The optimization results, for a beam current equal to 4mA, are sketched in the tables below.



BPM DESIGN PARAMETERS

Energy	Parameter	Value
Section start	Output amplitude (centered beam)	24mV
	Position sensitivity	1.25dB/mm
	Ellipticity sensitivity	0.19dB/mm²
Section end	Output amplitude (centered beam)	11mV
	Position sensitivity	1.22dB/mm
	Ellipticity sensitivity	0.11dB/mm²

BPM expected results at Facc

Energy	Parameter	Value
Section start	Output amplitude (Centered beam)	27mV
	Position sensitivity	1.38dB/mm
	Ellipticity sensitivity	0.13dB/mm²
Section end	Output amplitude (Centered beam)	16mV
	Position sensitivity	1.24dB/mm
	Ellipticity sensitivity	0.11dB/mm²

BPM expected results at 2*Facc

With a beam intensity of 100µA, the level is 34dB lower; the cables bringing the BPM signals to electronics rack (about 30m long) would bring an extra 3dB lost. The signals strengths at the electronics inputs are close -60dBm

BPM CHARACTERIZATION

Beam position and ellipticity measurement formulas

$$\left(\frac{R}{L}\right)_{dB} = \left(1 + G(\beta,f)\right)S_x(f) * \left(X - \Delta_x(f)\right)$$

$$\left(\frac{T}{B}\right)_{dB} = \left(1 + G(\beta,f)\right)S_y(f) * \left(Y - \Delta_y(f)\right)$$

$$\left(\frac{R*L}{T*B}\right)_{dB} = \left(1 + G_E(\beta,f)\right) * S_E(f) * (X^2 - Y^2) - \Delta_E(f)$$

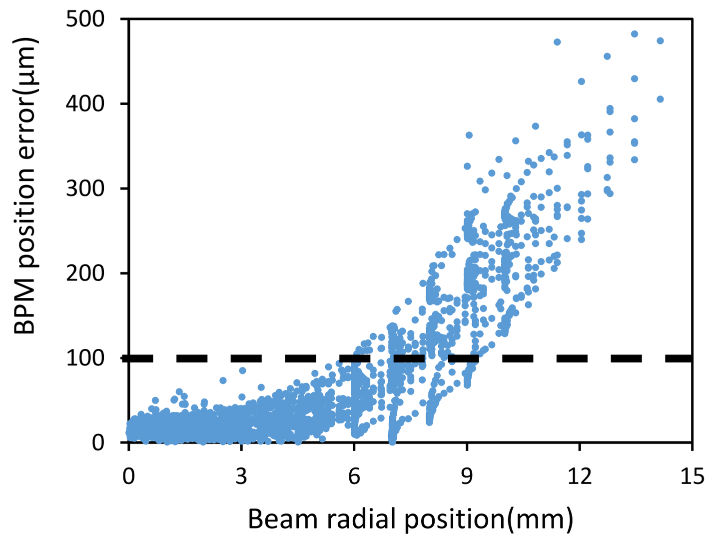
(X, Y) are the beam position coordinates.
β the beam relative velocity.
f the electrodes output signal acquisition frequency.
(S_x, S_y) is the position sensitivity at β=1.
(Δ_x, Δ_y) are the position offsets at β=1.
G(β,f) is a correction factor set by Shafer [3].
S_E is the ellipticity sensitivity at β=1.
Δ_E is the ellipticity offset at β=1.
$G_E(\beta,f)$ is a correction factor mentioned in [4]

Frequency	(Δ_x, Δ_y)	S_x, S_y
Facc	(76µm; -162µm)	1.19dB/mm
2*Facc	(71µm; 98µm)	1.2dB/mm

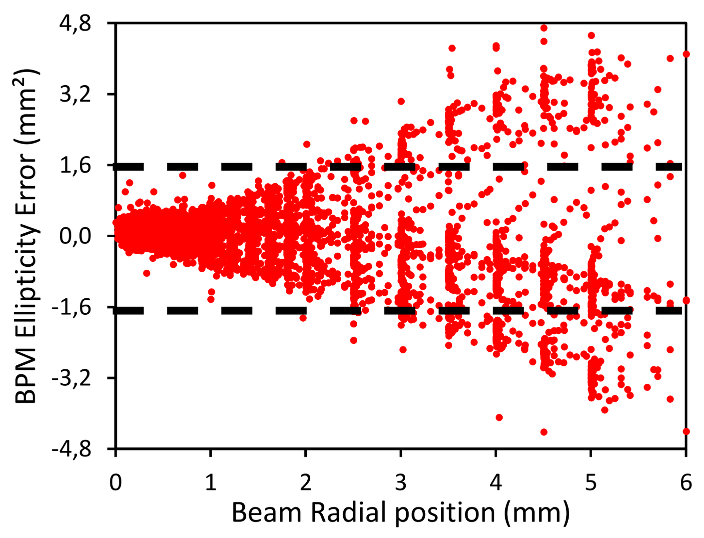
BPM position parameters

Frequency	Δ_E	S_E
F_{acc}	0.2dB	0.033dB/mm²
$2F_{acc}$	0.1dB	0.033dB/mm²

BPM ellipticity parameters



BPM position error at Facc



BPM ellipticity error at Facc

The error in position is within 100µm for radial position up to 6mm, which is within the specifications
The error in ellipticity is within 1.6mm² for radial position up to 2mm, it does not satisfy specifications.

BPM FABRICATION

Feedthrough pin was reinforced with a molybdenum spacer around it assuring a better positioning and concentricity of the electrodes.
MYRTE BPM [2] realization steps were repeated for the prototype BPM

BPM Feedthrough and bloc photos

The following issues were noticed during this realization:

- The external diameter of feedthroughs is higher than requested. However, it doesn't affect the BPM operation as they all suffer from the same default.
- BPM reference faces are used to align the BPM inside the LINAC. Controls had shown a deviation over these faces higher than the precision requested. Therefore, the offset between the BPM and the beam pipe revolution axe is increased. However, this offset could be measured with precision and taken into account in BPM operation.

CONCLUSION

MYRRHA 17-100MeV section BPM prototype is presented in this paper. The mechanical fabrication is offering stable and reproducible BPM. BPM Characterization shows that beam position measurement is satisfied within specifications. Beam ellipticity is measured properly for a limited range of beam positions, a better mapping of ellipticity sensitivity is needed to match specifications on that point.

REFERENCES

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CONTACT

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