Development of a beam position monitor for MYRRHA High Energy beams

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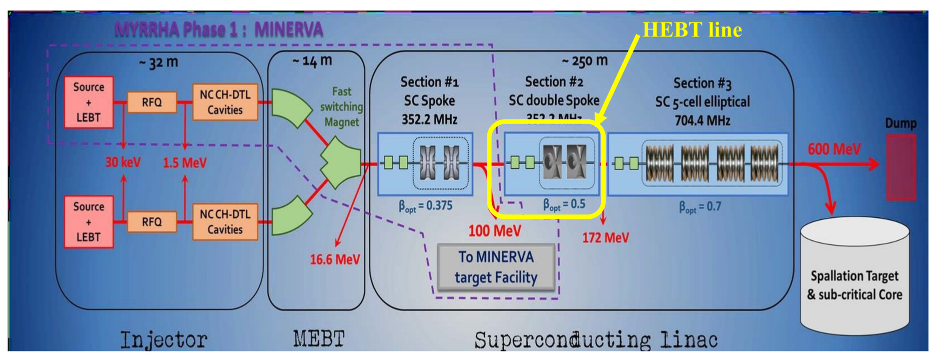
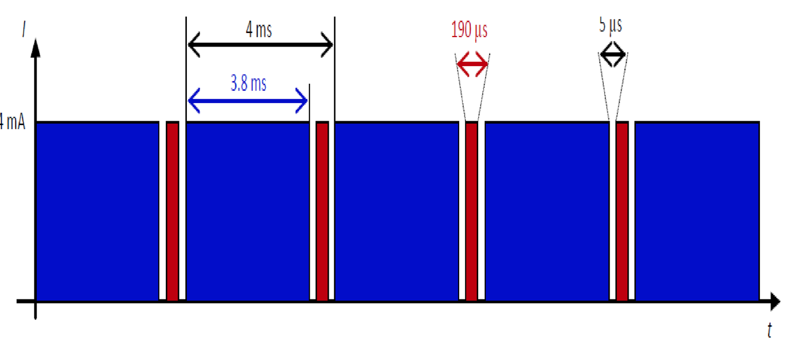
ABSTRACT

MYRRHA (Multi-Purpose Hybrid Research Reactor for High-Tech Applications) aims to demonstrate the feasibility of high-level nuclear waste transmutation at industrial scale. 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. MYRRHA is divided in three phases, the first phase, called MINERVA, includes several sections allowing beam acceleration up to 100 MeV. the second phase includes a High Energy Beam Transport (HEBT) line connects to two users' facility. A BPM prototype was realized for the HEBT line. 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 HEBT LINE & BPM SPECIFICATIONS



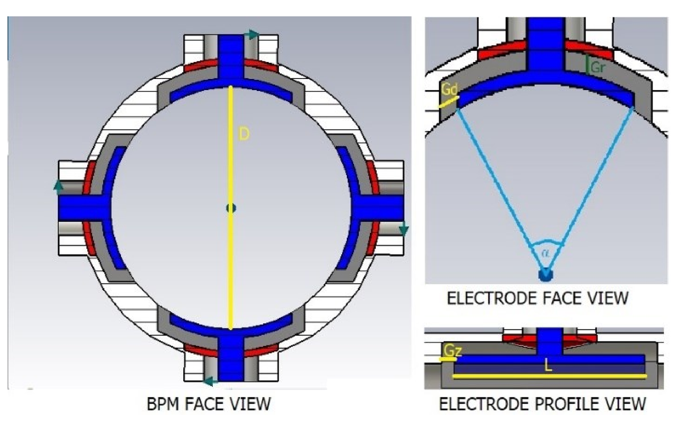
TIME STRUCTURE



Parameter	Range	Precision
Energy E	100MeV-200MeV	
Current I	0.1mA-4mA	
Duty cycle	2.10^{-4} to 0.125	
Bunch length @100MeV	5°; 80ps	
F_{acc}	176.1MHz	
Beam pipe diameter	80mm	
Measured Position on both axes	±5 mm	100µm
Measured Phase	360degrees	1degree
Measured Ellipticity	±5mm	Max(3.2mm²;20%)

BPM DESIGN AND SIMULATION

Experience with MYRTE and MINERVA BPMs [1,2] was of a great help. The relatively similar properties between the beams of MYRRHA and MYRTE led us naturally to match MINERVA BPM design to HEBT line. 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 HEBT line scope, the 2nd and upper harmonics of the beam image current are important. 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=56mm, α=60deg, Gr=Gz=Gd=6mm. 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)	29mV
	Position sensitivity	0.84dB/mm
	Ellipticity sensitivity	0.015dB/mm²
Section end	Output amplitude (centered beam)	22mV
	Position sensitivity	0.83dB/mm
	Ellipticity sensitivity	0.015dB/mm²

BPM expected results at Facc

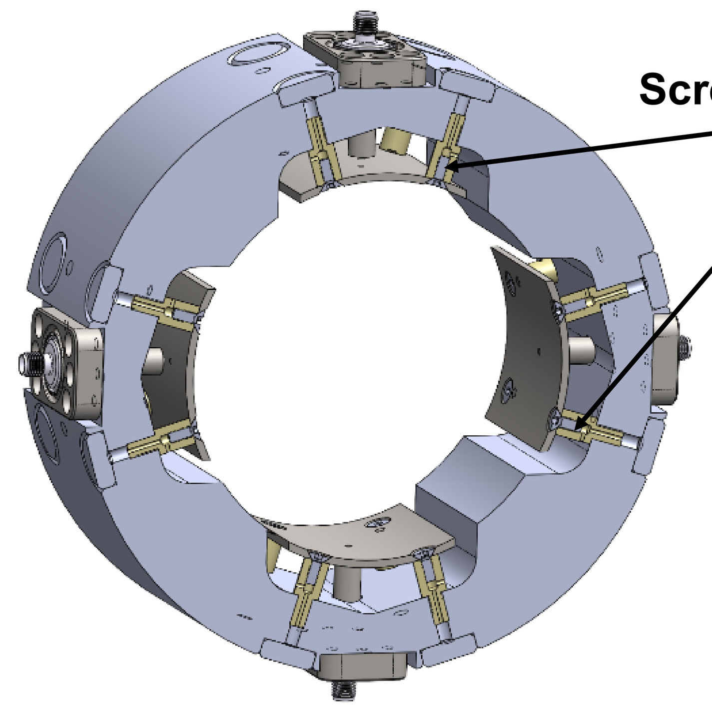
Energy	Parameter	Value
Section start	Output amplitude (Centered beam)	43mV
	Position sensitivity	0.85dB/mm
	Ellipticity sensitivity	0.015dB/mm²
Section end	Output amplitude (Centered beam)	35mV
	Position sensitivity	0.84dB/mm
	Ellipticity sensitivity	0015dB/mm²

BPM expected results at 2*Facc

With a beam intensity of 100µA, the level is 32dB 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 FABRICATION

The feedthrough pin is large , long and therefore fragile. Brazing it to a large electrode is subject to errors in electrodes positioning and concentricity over the 4 electrodes of the BPM. It would be even more difficult to repeat this operation properly over more than 100 electrodes.
In common agreement with NTG*, 4 spacers are screwed on each electrode corners as depicted .



BPM Electrode with screwed spacers for enhanced robustness and repeatability

BPM CHARACTERIZATION

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

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

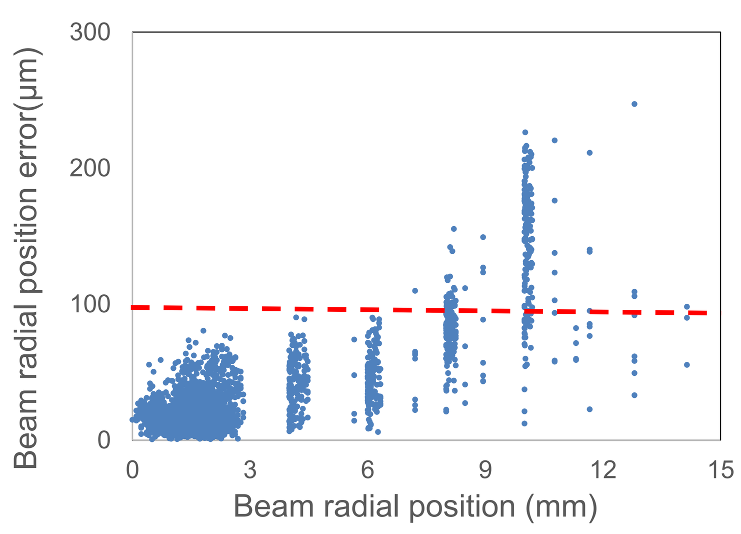
(X, Y) are the beam position coordinates. β the beam relative velocity.
f the electrodes output signal acquisition frequency.
(S_x , S_y) is the position sensitivity at β=1. (Δ_x , Δ_y) are the position offsets at β=1.
G(β,f) is a correction factor set by Shafer [3].
S_E is the ellipticity sensitivity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

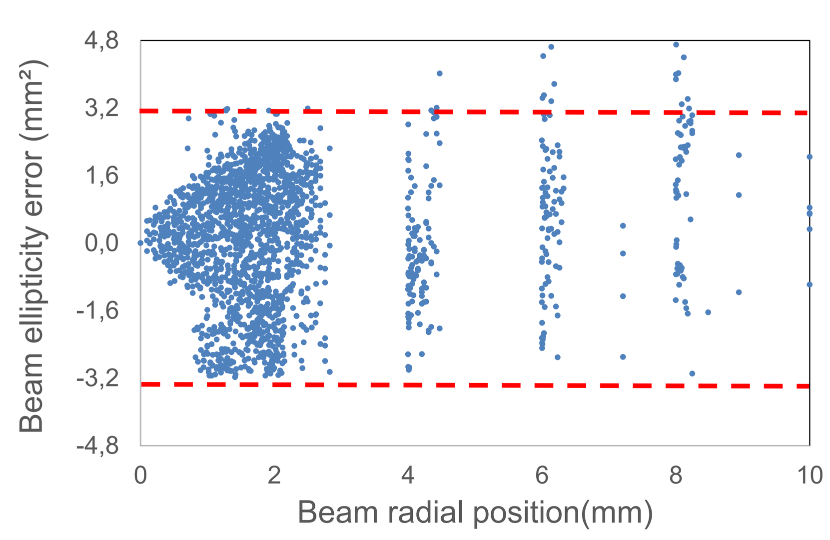
Frequency	(Δ_x , Δ_y)	S_x , S_y
Facc	(-271µm; -97µm)	0.78dB/mm
2*Facc	(-328µm; -193µm)	0.81dB/mm

BPM position parameters

Frequency	Δ_E	S_E
F_{acc}	0.065dB	0.015dB/mm²
$2F_{acc}$	0.088dB	0.015dB/mm²

BPM ellipticity parameters





CONCLUSION

MYRRHA HEBT 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.

REFERENCES

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[3] R.E. Shafer, "Beam position monitor sensitivity for low beta beams", in Proc. Int. Linac Conf, pp. 905-907.

[4] G.R. Lambertson, "Calibration of Position Electrodes using external measurements", LSAP Note-5, LBL, 1987.

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