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Methods for Bunch Shape Monitor phase resolution improvement

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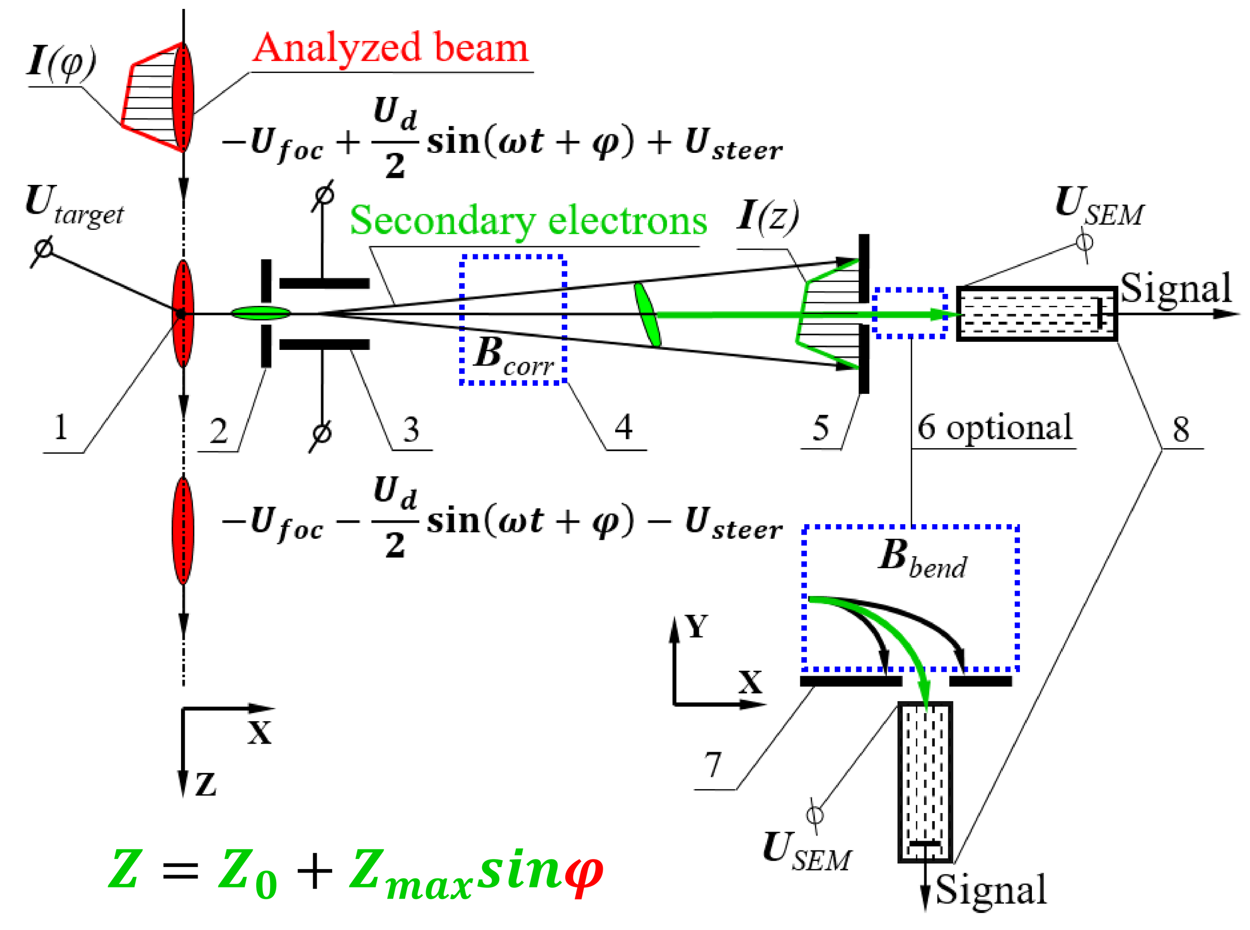
Abstract

Bunch shape monitors, based on secondary electrons emission, are widely used for measurements of longitudinal bunch profiles during a linac commissioning and initial optimization of beam dynamics. A typical phase resolution of these devices is about Δφ=1°. However it becomes insufficient for new modern linacs, which require at least twice better resolution. Some developed methods for a phase resolution improvement are discussed.

Introduction

In Bunch Shape Monitor (BSM), developed in INR RAS, a transverse RF-scanning is used (Fig. 1).



$$Z = Z_0 + Z_{max} \sin\varphi$$

$$\Delta\varphi = \frac{\Delta Z}{Z_{max}} \approx \frac{2\sigma_Z}{Z_{max}}$$

Fig. 1: BSM scheme: 1 – tungsten wire target, 2 – inlet collimator, 3 – RF-deflector combined with electrostatic lens, 4 – correcting magnet, 5 – outlet collimator, 6 – optional bending magnet, 7 – registration collimator, 8 – secondary electron multiplier.

BSM resolution Δφ can be defined as a full width at a half maximum of a spread function for infinitely short bunches. Due to a finite phase resolution a fine bunch structure can be lost.

RF & static electric fields

The RF-deflector is combined with the electrostatic lens thus enabling simultaneous focusing and RF-scanning of the electrons. Typically, BSM deflectors are RF-cavities, based on parallel wire lines with capacitive plates. An electrical length of the deflectors is usually λ/4 or λ/2. To improve the uniformity of both deflecting and focusing fields in Y-direction, the new λ-type symmetric cavity is developed (Fig. 2).

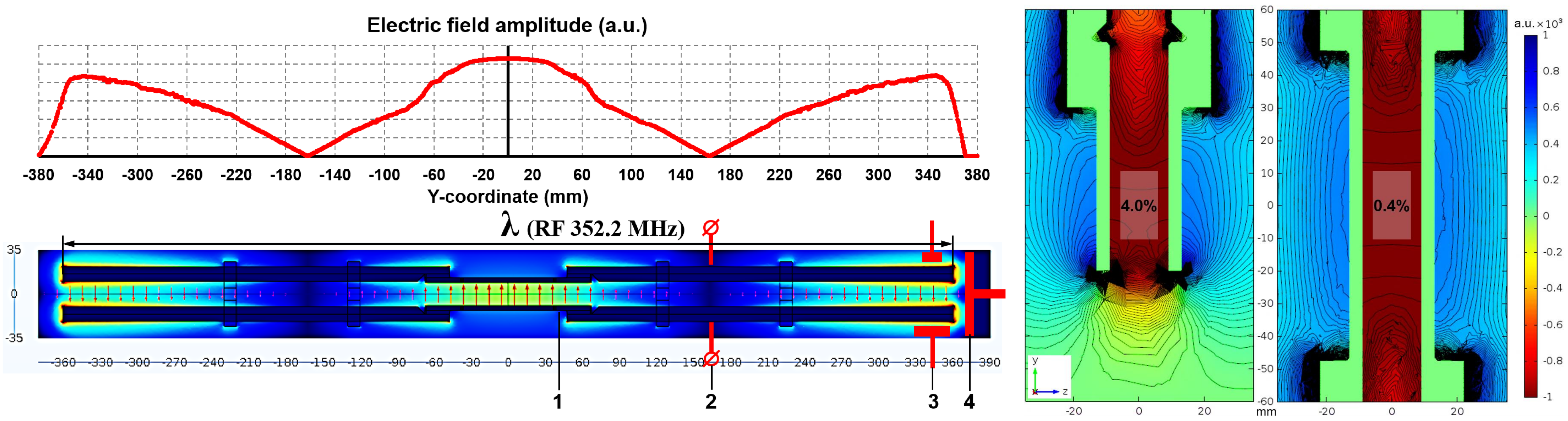


Fig. 2: λ-type deflector and E_Z-component of RF-field in YZ-plane of λ/2- and λ-type BSM deflectors.

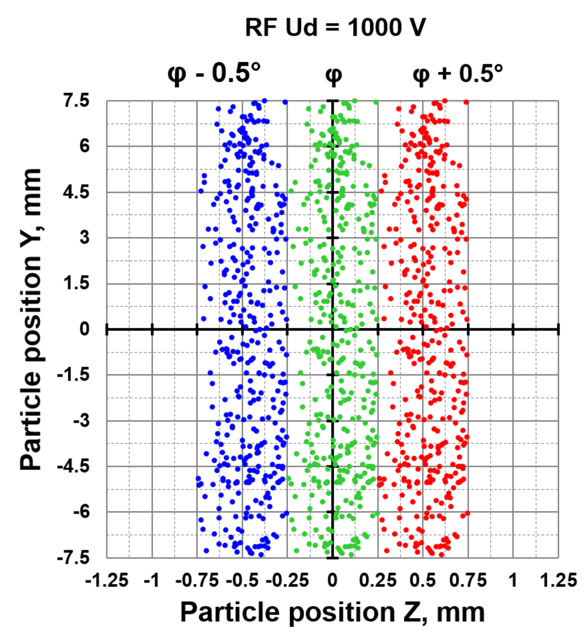


Fig. 3: E-beam at the outlet collimator.

Besides, the electrostatic lens with U_{foc} focuses the electron beam to completely fit into the outlet collimator (typically 0.5 mm width and 10 mm length). Fig. 3 shows the e-beams at the outlet collimator for three δ-function analyzed bunches with the interval of 0.5° for 352.2 MHz ($2\sigma_Z = 0.25$ mm $\rightarrow \Delta\varphi_0 = 0.21°$).

One more crucial component of the phase resolution is a time dispersion of secondary electron emission. We assume it to be uniformly distributed within the range of 0÷6 ps, so the double RMS dispersion is 3.46 ps, that corresponds to $\Delta\varphi_{SEE}$ = 0.44° for 352.2 MHz. The resulting phase resolution can be found as $\sqrt{(\Delta\varphi_0)^2 + (\Delta\varphi_{SEE})^2} = 0.48°$.

Magnetic fields

A correcting magnet (Fig. 4a) is implemented to compensate external fringe magnetostatic fields. The dipole field moves the electron beam along Y-axis. The quadrupole field enables to adjust the tilt of the beam image in YZ-plane (Fig. 4b) for the e-beam inclined initially at the entrance of the magnet.

Strong fringe static and alternating magnetic fields can be decreased by several configurations of magnetic shield. Fig. 5 shows the effect of the BSM shield on the fringe field of the quad located in the vicinity of BSM. Red line represents the component B_Y without and green one with the shield.

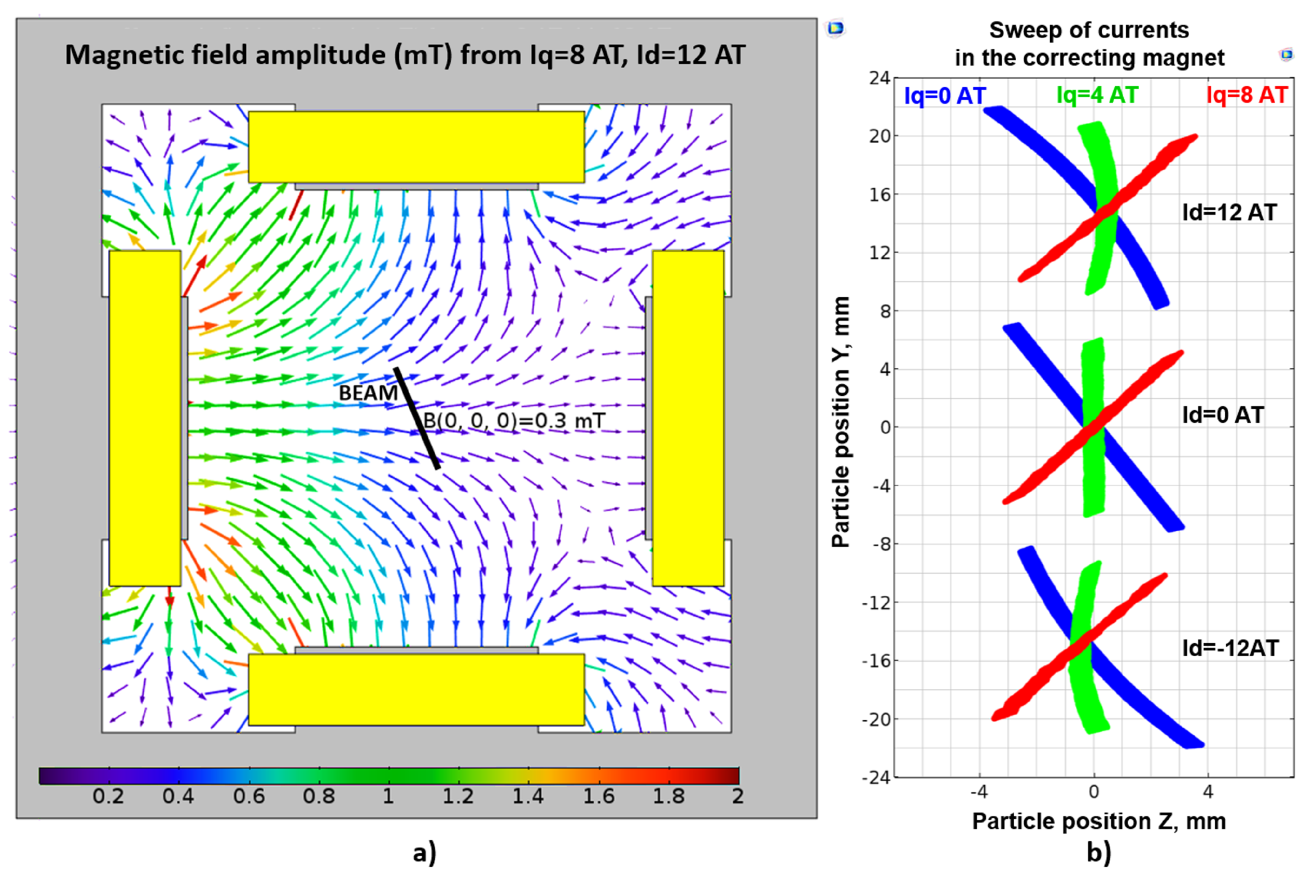


Fig. 4: Correcting magnet & e-beam corrections.

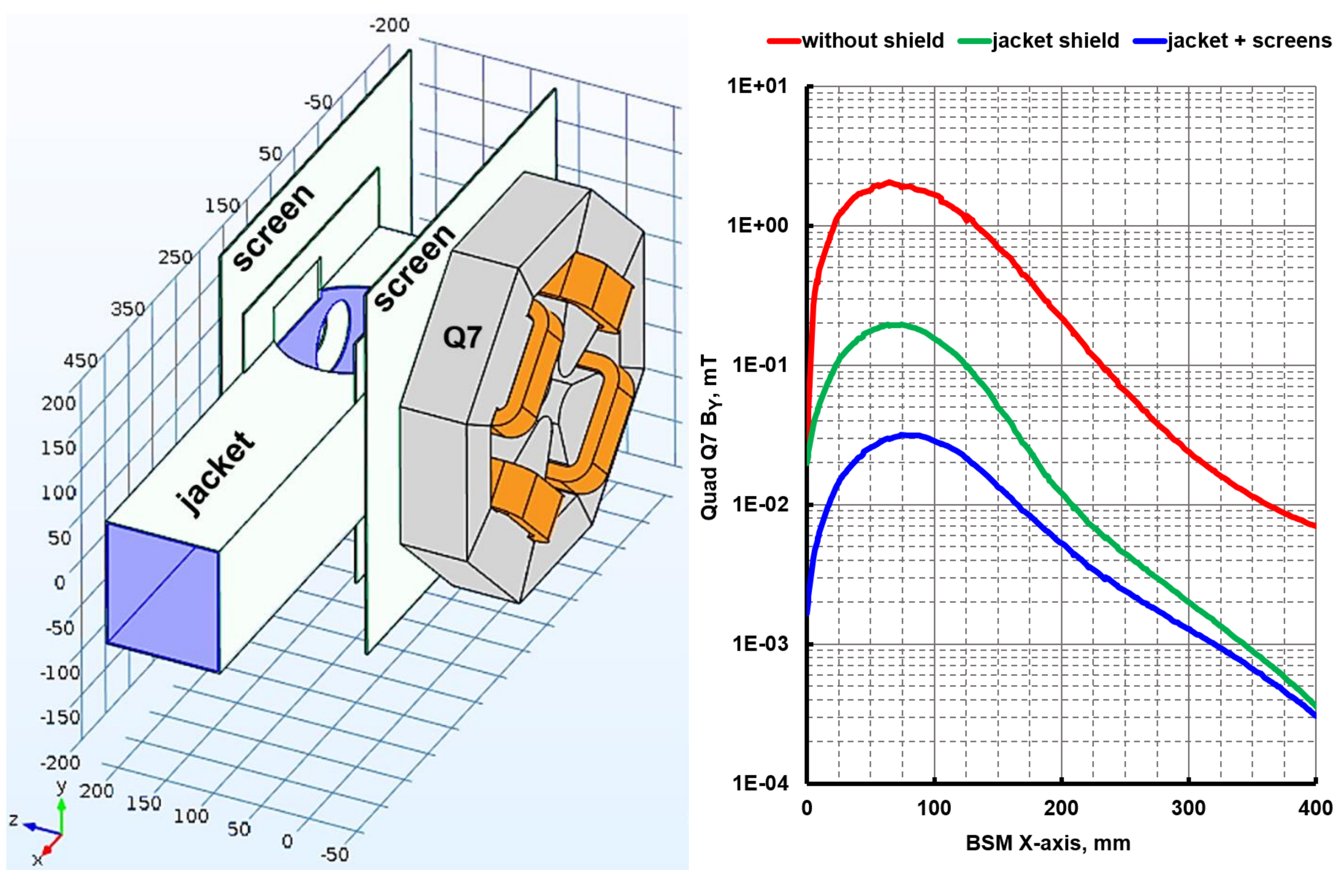


Fig. 5: Magnetic shield & quad field distribution.

Beam space charge

All estimations described above are done with the assumption of a zero-intensity analysed beam, while a beam space charge can strongly influence the secondary electrons trajectories.

As an example, the results of simulations for ESS proton linac at different beam currents are presented in Fig. 6.

The phase resolution is given as a function of a longitudinal coordinate along the bunch. The bunch head is at the left side in the figure.

Also the energy modulation of secondary electrons by the space charge can result in a phase reading error.

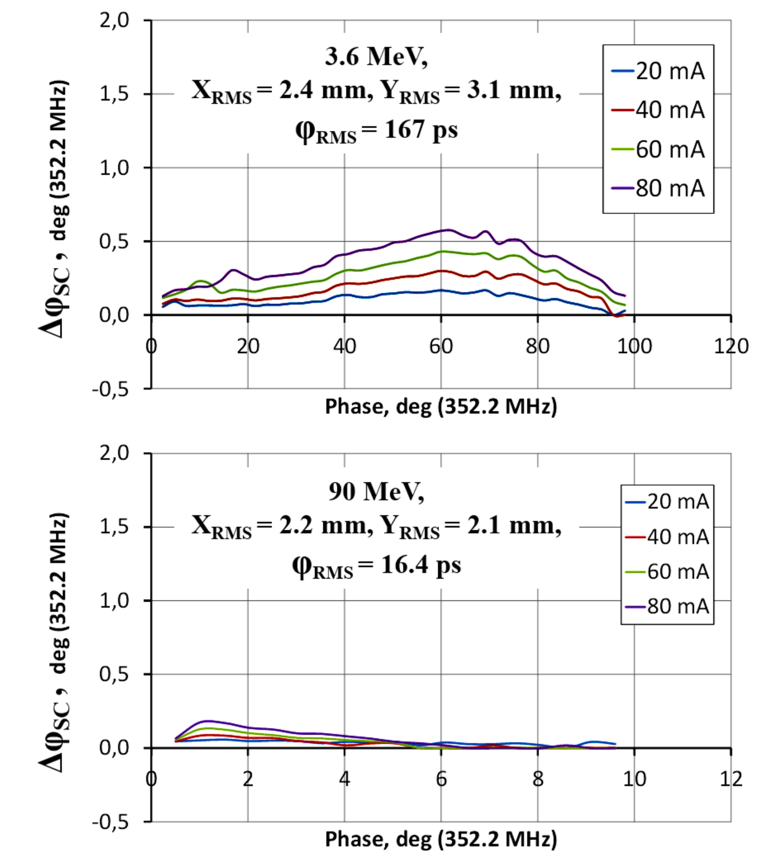


Fig. 6: Space charge effect.

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