ESS FUNNEL DEVICE INVESTIGATION ACCELERATOR

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Abstract

The funneling system allows to reach the required ESS beam intensity of 107 mA in peak per micro pulse and in case of one frequency after funneling to fill each separatrix in accelerator, which results in the lower intensity in each bunch. We have developed the resonant method of funnelling [1]. It is based on the multi-gap deflector. The new idea differs from another ones [2] by the possibility to organize the π-mode standing wave deviation system. The method has the higher efficiency. Three different cavities with 352 MHz for the funneling have been investigated experimentally. The field distribution, the tuning and the cooling system have been tested and compared with the numerical results. The beam dynamics has been calculated numerically in the real field for the energy 5 MeV and 25 MeV. For both options the emittance growth does not exceed 5% and 10% in case of bunch frequency 350 MHz and 175 MHz correspondently.

1 BASIC PRINCIPLE

The basic principle of funneling is the merging of two identically bunched beams into a single beam with double intensity. The new idea is based the H-type cavity. We have analysed, designed and compared two types of different H-cavities with the quadrupole TE211 mode and

the dipole TE111 mode [1,3]. They both can provide the effective resonant merging of beams. Figure 1 shows schematically the cavities cross-section with E and B field indication. The TE111 (see fig.2) is much simpler from the cooling system design point of view.
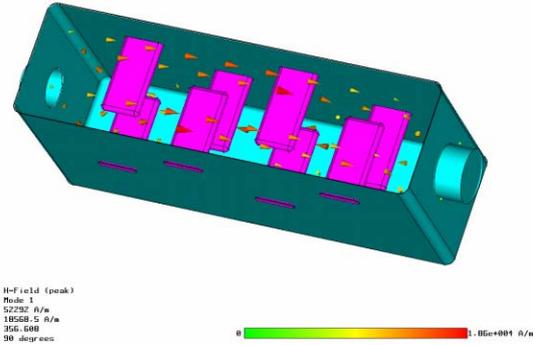
Figure 2: Rectangular TE101 structure

The electric field in the gap between plates is transverse to the beam direction and it is designed to merge two beams shifted in time relatively each of other for 180^0 (see fig.3).
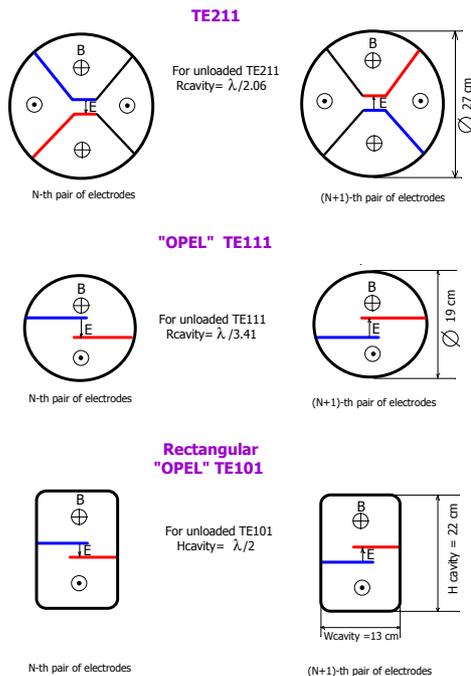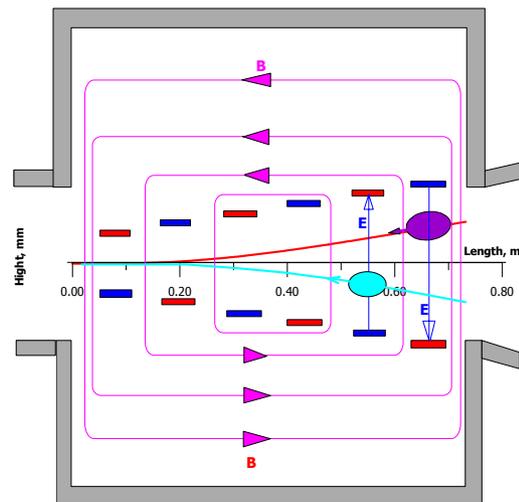
Figure 3: Resonance merging of two beams

The bunches must be phased to get the maximum kick in the opposite directions for two beams. Let us suppose the distribution of the transverse field in the gap is described by $E_y = E(x, y, z)\cos[\omega t(z) + \varphi]$, where Z is the longitudinal direction of beam, Y is the plane, where we

Figure 1: 352.2 MHz funnelling structures

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merge the beams, X is the perpendicular direction and φ is RF phase. Below we will follow to this designation under MAFIA results discussion. From the motion equation the angle and the coordinate of particles are changed as

$$\Delta\left(\frac{dy}{dz}\right) = \frac{e}{m_0 \gamma c^2 \beta^2} \int_{-L/2}^{L/2} E_y(x,y,z)\cos[\omega t(z)+\varphi]dz$$

,

$$\Delta y = \frac{e}{m_0 \gamma c^2 \beta^2} \int_{-L/2}^{L/2} \Delta\left(\frac{dy}{dz}\right)dz$$

where L is the effective length of the beam interaction with RF field, λ is the wave length, $c\beta$ is the velocity of particle in Z direction, m and γ are the mass and Lorenz factor.

2 TRACKING RESULTS

In RF deflector the particle deviation depends on RF phase. Due to this fact the effective emittance of whole bunch increases. The beam dynamics with space charge has been calculated numerically in the real field from MAFIA for the energy 5 MeV and 25 MeV. Figures 4 and 5 show the phase portraits on the entrance and exit of funnel device for energy 5 MeV and 25 MeV correspondently.
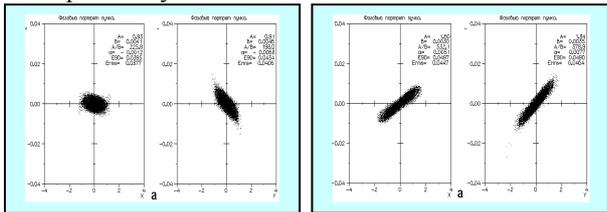
Figure 4: The phase portraits of beam in horizontal and vertical planes on the entrance and exit of funnelling at energy 5 MeV.
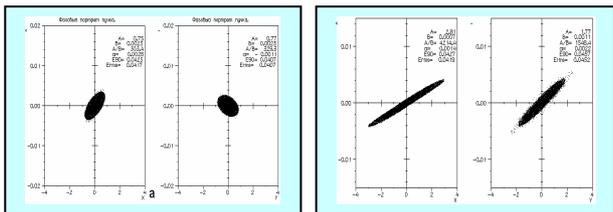
Figure 5: The phase portraits of beam in horizontal and vertical planes on the entrance and exit of funnelling at energy 25 MeV.

In both cases we have calculated the tracking in the funnelling device together with the transport channel and RFQ. Therefore the initial parameters of beam are different for 5 and 25 MeV options. However, for 5 MeV due to lower energy all elements (quadrupoles, bunchers)

of transport channel have to be smaller. Therefore, we suggest using the special transport RFQ with the constant period of vane modulation (see fig.6).
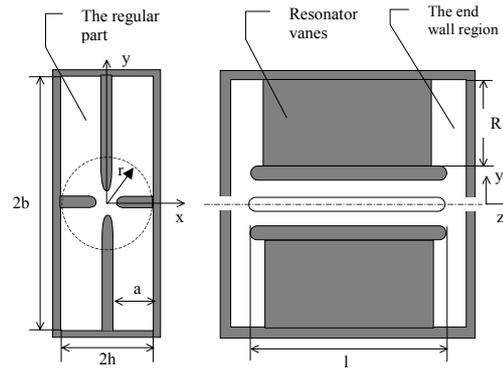
Figure 6: Transport channel for 5 MeV beam

For both options 5 and 25 MeV the emittance growth does not exceed 10%.

3 EXPERIMENTAL RF TEST

Three types of resonators were chosen for laboratory prototypes: coaxial, 2H resonator and H resonator (see figures 7-9).

Figure 7: Coaxial funnelling cavity
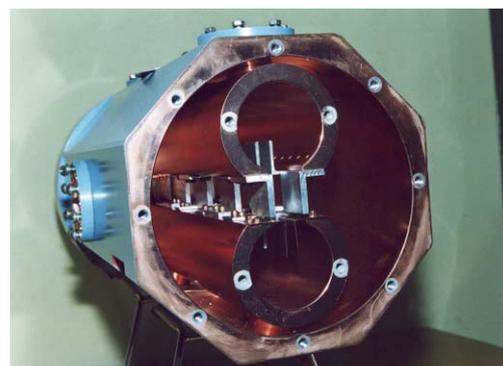
Figure 8: 2H funnelling cavity

a)
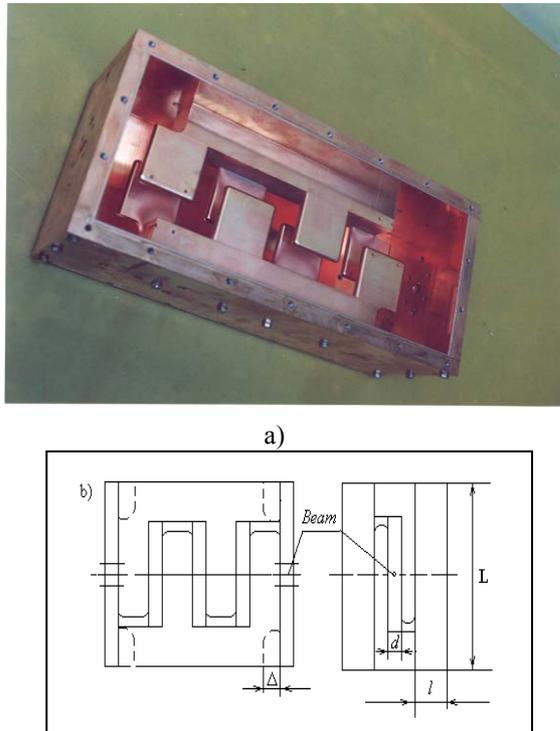
Figure 9: H funnelling cavity

The study of this prototypes allows to obtain more accurate resonator sizes and to research capabilities of tuning elements. Prototypes of coaxial, 2H and H resonators have been made for this purpose. They were made from aluminum alloy (copper plating of resonators is performed in the final stage). Initial sizes of these resonators were larger than calculated values. It was made to have a small reserve for the tuning using successive approximations.

The coaxial resonator is well known type. We insert two pairs of deflected plates, which are shortened capacities. To decrease losses in this resonator, the diameter of its inner conductor with inserted cooling system should be as small as possible. The deflector length determines the inner diameter of the outer coaxial conductor. However, the optimum number of plates in the coaxial cavity is two, what is not enough.

The 2H cavity is well investigated for RFQ. But in case of big capacity it has the problem with cooling system.

Finally we made a choice for the H cavity. Here we solved two problems: to get sizes in agreement with the operating frequency and to study the tuning ability of the required field distribution. The longitudinal distribution of the $E_\perp$ component was investigated by bead-perturbation technique with help of HP equipment. The thin metal disk with perpendicular direction to deflected plates was used as a perturbation body. The tuning of the operating frequency was performed by changing of chamber sizes l

and L. Frequency 354.6 MHz is achieved at $\frac{l}{L} = 0.3$.

Decreasing l or L by 1 mm the frequency increases by

≈ 1.1 MHz. As it was found out in order to get the symmetric distribution of the field with <20% dropping to the ends, we need to change Δ-depth. Figure 10 shows calculated normalized RF losses, capacity and Q-factor of the resonator at 352 MHz depending on a ratio l/L.
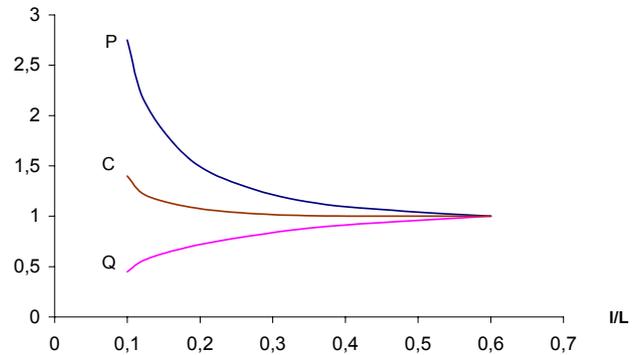
Figure 10: RF losses, Capacity, Q-factor vs l/L

We can see from this plot, the parameters of the resonator become abruptly worse at $\frac{l}{L} < 0.25$. The upper limit of l/L value is restricted by requirements, which imposes the cooling system of the deflector. The calculations of thermal deformations and the cooling system of the copper electrode have been fulfilled. The structure of the water-cooling system for the electrode has been proposed using results of these calculations. This structure is assumed to be consisting of system of 40 1.5×10 mm parallel channels located in the base and cooling water flowing through the hollow plate. factor.

4 CONCLUSION

We have developed the resonance funnelling method based on H mode cavity. We have done design and experimental RF testing of three types of cavities. TE101 mode cavity is the most appropriate for ESS purposes.

5 REFERENCES

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