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HIGH POWER CENTER REGION WITH INTERNAL ION SOURCE

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Abstract

Cyclotrons for medical isotope production require high beam current. Author proposes the design of central region with internal ion source at 6.6 kV potential placed in the center of cyclotron and delivering the beam to every RF cavity symmetrically, thus significantly increasing the beam current.

INTRODUCTION

The line of cyclotrons from 15 to 230 MeV, that uses same magnet field level and RF frequency 145 MHz and utilises many identical solutions within the line-up to make it cheaper to produce and run was described in IPAC 2022 [1]. The author has developed and presented here a variant of the similar line-up for the accelerating frequency 180 MHz [2].

Of course, high frequency of RF system can potentially lead to poor capture of particles in the first accelerating gap. In fact, if ion source would be placed in front of RF puller with such high frequency the capture would be equal to 0. But this problem can be solved if in the first accelerating gap particles will arrive with some energy, thus travel through first gap much quicker.

Particles start from the PIG source, which is placed under 6600 V and accelerate to the “ninja star” housing, see Fig. 5 (zero potential) and arrive to the first gap with 6.6 keV energy. Also, the advantage of such central region is that one ion source placed in the middle can deliver beam in each gap simultaneously, due to the symmetry of such central region. A similar center for three sectors cyclotron was described in [3], here the author presents a variant for four sectors structure and frequency 180 MHz at harmonic 8.

VIRTUAL PROTOTYPING

The idea of a new engineering methodology Virtual Prototyping is to replace physical mock-ups by an integrated software prototypes that include all functional simulations based on CAD/CAE/CAM techniques.

Usually when designing a cyclotron some systems are developing separately. An integrated platform which encapsulates these distributed components and provides an inter-communication mechanism is extremely useful, as it will contribute to the creation of a more optimal cyclotron.

We have combined the development of the individual cyclotron systems through a framework in MATLAB (Fig. 1).

The shapes of sectors and cavities of the magnet are selected directly in MATLAB, then sent to CAD (Solidworks) to create parametrized model of the cyclotron, and then individual systems are sent to CST studio to simulate in the corresponding modules. The calculation results of the electromagnetic fields from CST are imported into MATLAB, where they are analyzed using code CORD [4] and beam tracking codes. Careful calculations of the beam dynamics are performed for the central region and the exit zone. Based on the results of the analysis, changes are made to the structure of the cyclotron systems. The iterative procedure is repeated until an acceptable result is achieved, namely, successful injection, acceleration and beam extraction.

In a compact cyclotron, all systems compete with each other for space (Fig. 2). An integrated approach to design is necessary to ensure that the decision on the privileges of a particular system is made objectively, taking into account the interests of each system.

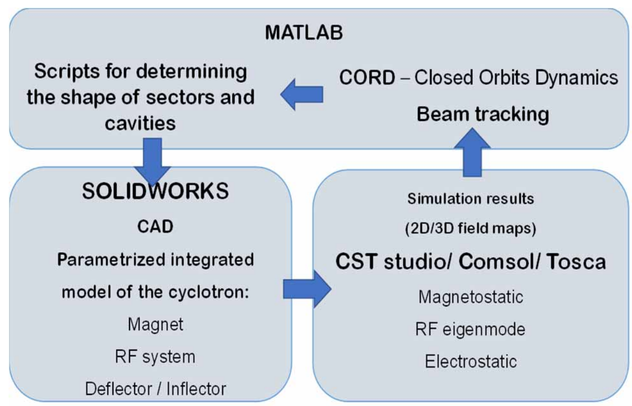

Figure 1: The framework of the cyclotron VP MATLAB integrated platform.

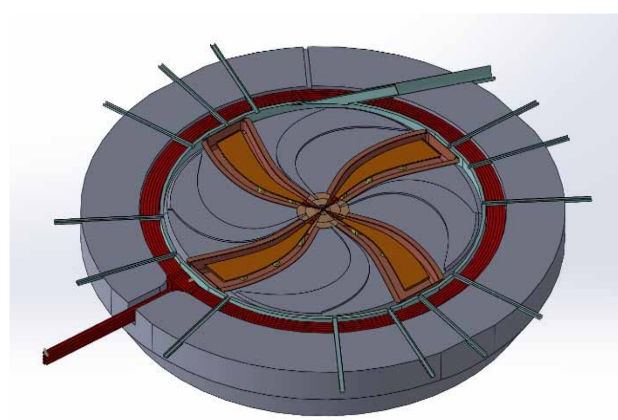

Figure 2: Parametrized model of the cyclotron.

BEAM DYNAMICS SIMULATION

When calculating particle, an electromagnetic field was specified in the form of a field maps obtained as a result of model calculations (3D field maps). We used 3D field maps received in CST RF eigenmode solver for accelerating field (Fig. 3) and magnetostatics solver for magnet simulation (Fig. 4).

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The movement of particles begins from the PIG ion source that is placed under 6600 V, then particles are accelerating to a grounded "Ninja star" housing, and then by an accelerating system (see Figs. 6 and 7).

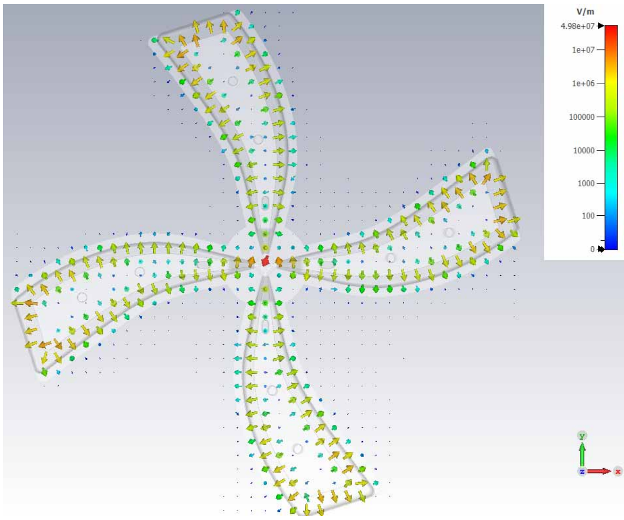

Figure 3: Electric field vector plot.

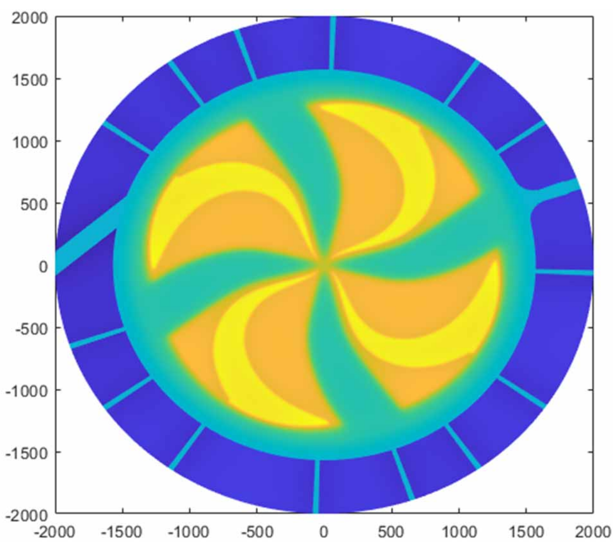

Figure 4: Magnetic field.

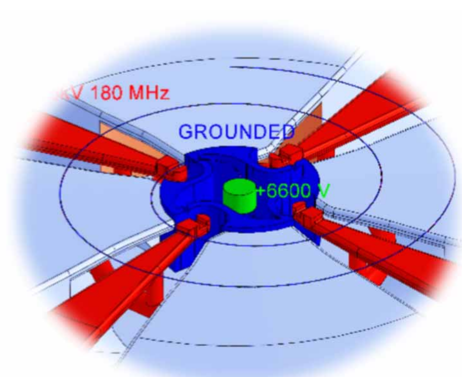

Figure 5: Center region view. Dark blue – "ninja star" housing, blue – anti-dees, red – dee tips, green- PIG ion source.

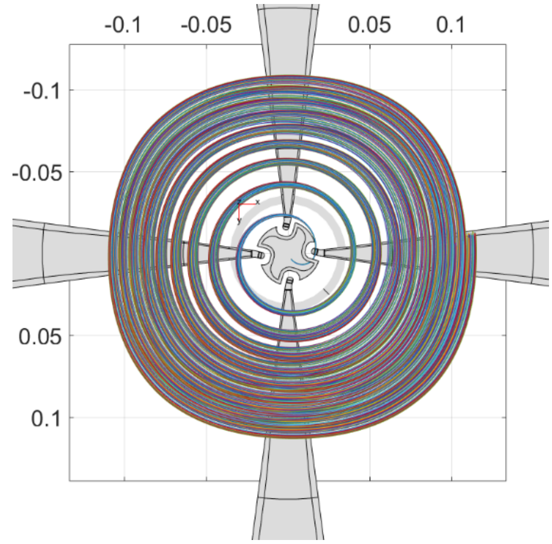

Figure 6: Beam trajectories from one gap.

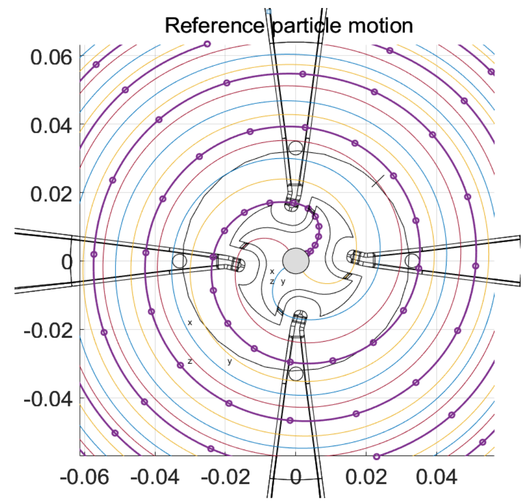

Figure 7: Four trajectories of reference particles are shown. Dots mark every 180 RF degrees.

Magnetic focusing caused by the decreasing field begins after a radius R = 35 mm (see Fig. 8). For a radius less than 35 mm (approximately one turn), an electric accelerating field provides vertical focusing of lagging particles (Fig. 9).

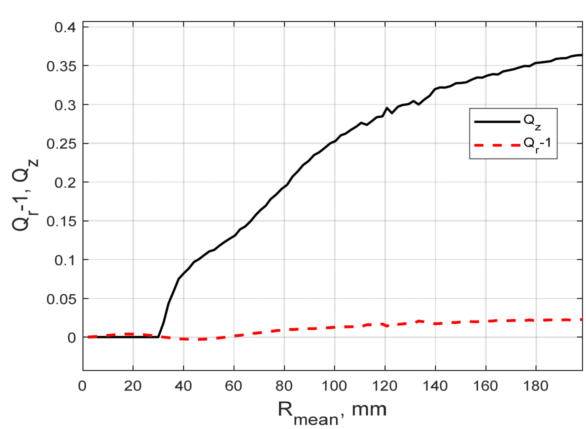

Figure 8: Betatron tunes in the center region.

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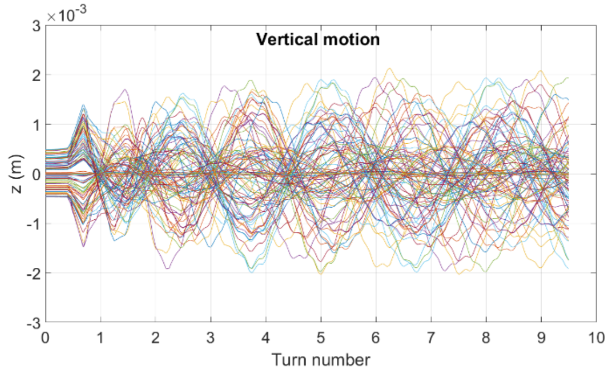

Figure 9: Vertical motion of the beam.

CONCLUSION

Advantages of the proposed scheme of central region:

- At least 4 times higher current, as 4 bunches captured at the same time
- Much higher capture in each 1st gap due to initial acceleration. In this case from 0 to 15 deg RF.
- Only protons arrive to the RF puller, less erosion of RF parts.
- Improved vacuum in the cyclotron, as ion source is separated from the rest of the chamber by "Ninja star" housing. Additional pump can be used to pump gas from ion source from the inside of the "Ninja star".

Of course, 8 harmonic acceleration is not an ideal option for truly high-power cyclotron, however such design of center region if used with 4th harmonic acceleration, especially with even higher voltage on the source can lead to 10 mA currents and higher.

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