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MECHANICAL MODIFICATIONS OF THE MEDIAN PLANE FOR THE SUPERCONDUCTING CYCLOTRON UPGRADE

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Abstract

The Superconducting Cyclotron (CS) is a three sectors, compact accelerator with a wide operating diagram, capable of accelerating heavy ions with q/A from 0.1 to 0.5 up to energies from 2 to 100 MeV/u. Recently a significant upgrade has been proposed to increase the light ion beam intensity by means of extraction by stripping. For the implementation of the new extraction mode, many relevant modifications are needed in the median plane. The biggest upgrade action is the replacement of the present superconducting magnet with a new one, compatible with the beam trajectory and envelope in the extraction by stripping. The extraction by stripping mode implies the installation of two stripper systems, one in a hill and the other in a valley, that allow to extract all the ions requested by the users. Finally, since the present electrostatic extraction mode will be maintained, several relevant mechanical issues have to be faced when switching from one extraction mode to the other one, the location of one electrostatic deflector being the same as the stripper system. The focus of this paper will be the presentation of the different mechanical features involved in the upgrade.

INTRODUCTION

The Superconducting Cyclotron (CS) is an accelerator which was designed for low intensity beams, whose main limitations to extract high beam power are the two electrostatic deflectors. The goal of the upgrade is to make extraction by stripping possible, interchanging the stripper with one of the two electrostatic deflectors, to achieve high power beams for the set of beams of interest and, at the same time, to maintain the versatility of the CS [1]. To reach our aim, it is necessary to design a stripper device, to be implemented when the Electrostatic deflector is not used and removed. To achieve fast extraction trajectories when we use the extraction by stripping, compatible with simulation studies, it is necessary to design a new extraction channel that overlaps geometrically with the tubes of the electrostatic deflectors movements, increasing the complications of the two setup functioning. These features cause the definition of a new median plane and the redesign of some components of the CS.

MEDIAN PLANE REDEFINITION

To satisfy all the extraction by stripping equipment, the median plane of the CS will be modified (Fig. 1).

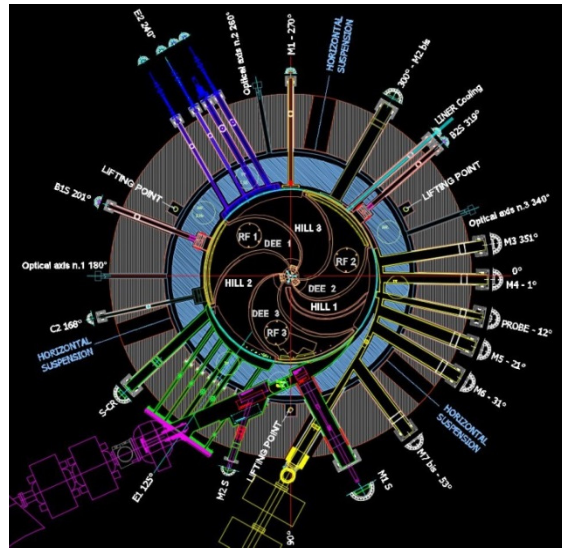

Figure 1: The new median plane.

Due to the new extraction channel, it has been necessary to optimise the position of the three lifting points and of the three horizontal suspensions of the vacuum chamber [2]. The design of the new extraction channel must allow the arrangement of two new magnetic channels, M1S and M2S, in addition to those already existing in the cyclotron, to locally reduce the magnetic field and focus the beam in the radial direction. These new magnetic channels have interferences with the electrostatic extraction mode. The M1S shaft collides with the actual extraction channel and so to solve that, the shaft has a suitable gap to permit the beam trajectory of the electrostatic extraction mode. The M2S channel has an interference with one of the electrostatic deflector handlings; therefore, we designed the new extraction channel to make the M2S channel and the electrostatic deflector setting compatible. The M1S and M2S are made of three iron bars, that need of a housing to contain them and a shaft, connected with the housing, that allows to modulate their position, for our selected ions. For the two magnetic channels, the geometrical dimensions and the resultant forces of the iron bars are different.

For both magnetic channels, the resultant forces are tilted in relation to the penetrations axis, we implemented mechanical simulations by means of Comsol Multiphysics, a FEM (Finite Element Method) software. To obtain acceptable stress and strain values for the two housings and shafts, we optimized the mechanical design and the choice of the materials. Moreover, for the extraction by stripping, two identical compensation bars, B1S and B2S

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are necessary, in order to compensate the imperfections of the new magnetic field. B1S and B2S are made up of one iron bar, contained in a housing, and a shaft, connected with the housing, allowing to adjust the position. Unlike the magnetic channels M1S and M2S, the bars resultant forces are radial, along the penetration axis.

CONSEQUENCES OF THE NEW SUPERCONDUCTING MAGNET

For the CS upgrade with the extraction by stripping, the focus was the design of a new superconducting magnet. A preliminary study, relating to the dynamics of the beam along the stripping trajectories and the following magnetic, structural, thermal analysis, including the consumption of helium and liquid nitrogen, confirm the feasibility of the new superconducting magnet. The whole replacement of the Cryostat, that will contain all the tubes, the actual ones and the new ones, causes the geometrical modification of the six iron sectors of the yoke. The changes with respect to the CS present configuration, turned to be so significant that the central ring of the yoke will be completely replaced.

LINERS

Due to the dimensions of the beam spot, it is mandatory to increase the vertical gap of the acceleration chamber, from the present 24 mm to 30 mm. This will cause the whole replacement of the lower Liner and upper Liner, because it is impossible to keep the present ones. The two liners were redesigned, simplifying them appropriately and considering the possibility of using more modern construction techniques.

STRIPPER DEVICES

To realise the extraction by stripping mode, the design of two stripper devices is necessary. The two stripper devices have to permit the extraction of all ions requested by the users. Some extraction points are located in one valley, others in one hill. The valley stripper device is made up of an automatic and sequential structure, that holds a revolving carousel (Fig. 2).

The carousel has to move sequentially, around a vertical axis A1, five stripper foils, that have to be hit by the ion beams.

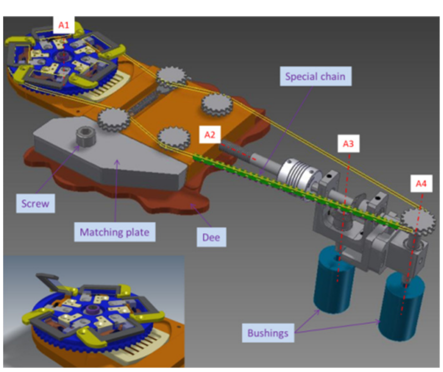

Figure 2: The valley stripper device.

The foils rotation is allowed by a special chain that transfers a shaft rotation (A4) to a gear, integral with the carousel. In the rest condition, all frames are lowered and one frame at a time, can be raised and lowered through a cam profile. The carousel can translate along an axis (A2), perpendicular to the axis A1. This translation movement is assured through two conical gear wheel, that transfer a shaft rotation (A3), to a screw integral with the carousel [3]. The device is arranged from the top to one of the three positions, in the DEE number three (Fig. 3).

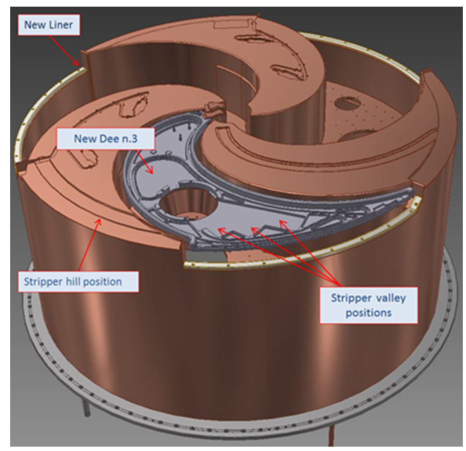

Figure 3: The stripper devices positions.

To allow the placement of the valley stripper device, it is necessary the redesign of several RF components [4, 5].

The two shafts, A3 and A4, are linked, by two bushings, to two shafts inside the RF cavity and there is a lateral matching plate that traps and leads the system. The device is disassembled through a little rotation of a screw and the matching plate is removed. This process allows a fast and safe disassembly in a radioactive zone and gives us the possibility of assembly a new device, outside the machine. If the magnetic simulations will allow to extract all the ions with the hill extraction, this device will not be necessary. Instead the hill stripper device is definitely mandatory. This device is made up of an arm hinged in a fixed point; the arm must rotate around this point, of a 4 degree.

A crank, that transforms a linear movement in a rotating one, converts the translational movement of a shaft, in the arm rotation. In the arm, there is a track with a chain, that moves some housings for the stripper foils, in a carousel system. A kinematic chain (gears, bearings and pulleys), transfers a rotation shaft to the chain [3]. Every housing is equipped with four foils and for every ion, only one foil will be hit (Fig. 4). The hill stripper device is arranged from the top to the liner surface, in the same area of the electrostatic deflector E1 (Fig. 3), because we must have all at the ground potential. The device is disassembled by disconnecting the rotation shaft, through the bushing and the translation shaft, through the screw, inside the lever. Then, it's possible to release definitively the arm, unscrewing the special screw, to

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achieve the assembly of a new device, outside the machine. The two shafts are moved from outside of the Cyclotron and their combined control, allows to reach all the hill extraction points for the ion beams of our interest.

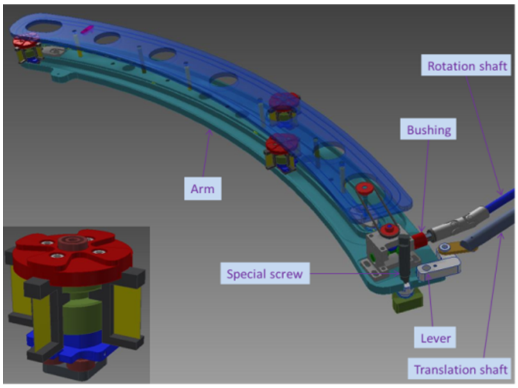

Figure 4: The hill stripper device.

MECHANICAL COMPATIBILITY OF THE TWO EXTRACTION MODES

In addition to the explained modifications inside the CS, the extraction by stripping requires a design of mechanical parts located outside, to make compatible the new extraction mode with the present electrostatic extraction mode (Fig. 5).

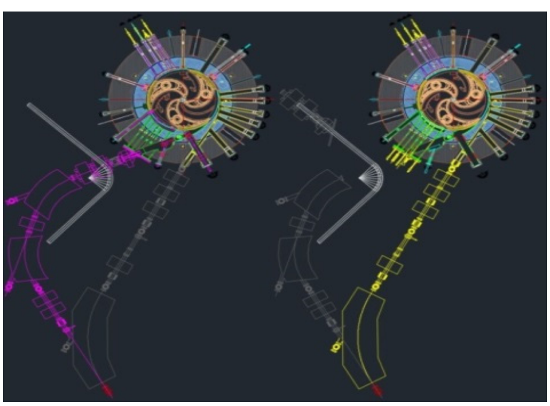

Figure 5: The two extraction settings.

When we work with the stripping setting (magenta in Fig. 5), the electrostatic deflector E1 assembly must be disassembled and removed. When we work with the deflector setting (yellow in Fig. 5), a whole section of beam line must be disassembled and translated (to assemble the electrostatic deflector E1 handlings), using a carriage over a track, that allows its translation movement.

So we have the possibility of move one of the two settings out of the operation area, while the other one is working. Anyway all choices regarding other devices (vacuum, cabling, control, etc.) will be subjected to a future revaluation.

CONCLUSION

To realise the CS upgrade, the extraction by stripping mode will be implemented. To satisfy the physical and mechanical requirements, we redesigned the median plane and we investigated on the feasibility of the new superconducting magnet construction. We designed two stripper devices to reach all extraction points for the ion beams of interest. Moreover, to make the two extraction modes compatible, a study was necessary to define the possible movements of the two settings and to obtain their simultaneous presence and alternative operation.

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