THPO009

NHa NORMANDY HADRONTHERAPY

Vacuum study of the C400 system for beam losses optimization

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INTRODUCTION

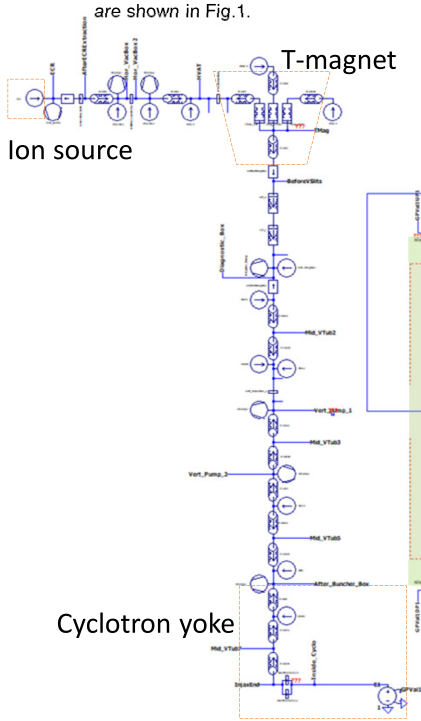
IBA and Nha are collaborating to develop a multiparticle cyclotron system dedicated to hadron therapy. C^{6+} and He^{2+} ions will be accelerated up to 400 MeV/n and H_2^+ up to 260 MeV/n. Vacuum management in the injection line and cyclotron are of prime importance to avoid large beam losses. This poster presents the numerical study based on an electrical equivalent model of the vacuum system which enables to predict the pressure level along the particle path considering the main driving parameters such as outgassing surfaces, O-ring permeation, pole finish and vacuum pump performance and locations.

VACUUM MODEL

➢ **LTSpice model** for a cyclotron vacuum system was already successfully applied on other IBA products [1,2], using the following electrical equivalence:

Electricity	Vacuum
Voltage / [V]	Pressure / [mbar]
Current source / [A]	Gas throughput / [mbar.L/s]
Resistance / [Ω]	1/Conductance / $[L/s]^{-1}$
Ideal diode	Vacuum pump

Such a model has been proven to be the perfect tool for rapid computation of vacuum levels, even in a complex system. Based on the simplified geometrical parameters of the system, one can compute the conductances, outgassing throughput of surfaces, outgassing and permeation throughput of o-rings.
The number, locations and speed of vacuum pumps, and surface finish can then be easily optimized in terms of cost versus benefit. Injection line and half-cyclotron LTSpice model are shown in Fig.1.



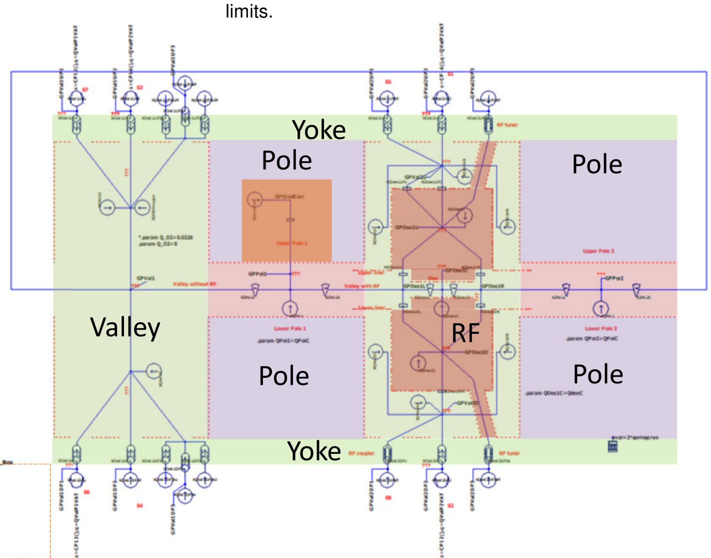


Figure 1: LTSpice model of the C400 injection line (left) and half cyclotron (right).

BEAM LOSSES OPTIMIZATION

In the injection line, beam losses are dominated by charge exchange cross-section of C^{6+} ions, whereas in the cyclotron, the pressure requirements are driven by the molecular break-up cross-section of H_2^+ ions [3].

➢ **Injection line**

In the injection line, the major contributions that are the water vapor outgassing surfaces and o-ring permeations and neutral support gas (CH_4 or C_2H_2) coming out from the extraction point of the ECR ion source were studied. Since the first few meters are largely dominated by the ECR neutral gas (Fig.2), it was concluded that a pumping as efficient as possible of this gas was the way to go to optimize the overall beam transmission (the cross section of C^{6+} charge exchange interaction between water vapor and the ECR gas are comparable). Therefore, two large turbo-pumps are foreseen to be located as close as possible to the extraction point and with a differential pumping system installed downstream.

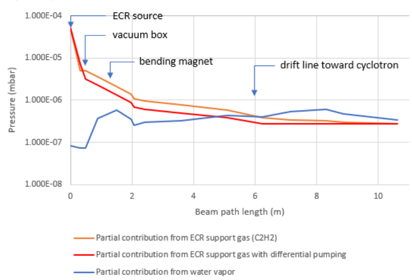


Figure 2: Pressure contributions of the ECR gas support and water vapor along the ion beam path in the injection line.

➢ **Cyclotron**

Literature has several references for the molecular hydrogen break-up cross section (Fig.3). Olson has proposed a fit of the experimental data [4] that is being used here as the nominal case for the present study. Berkner-Gryzinski and Berkner-Born [5] cross section fit are used as maximum and minimum uncertainty limits.

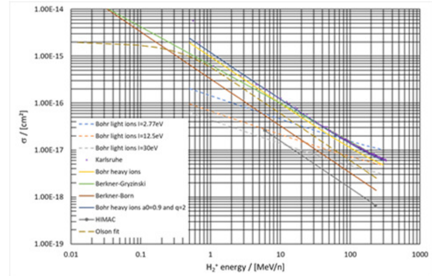


Figure 3: Molecular hydrogen break-up cross section from the literature as function of H_2^+ incident energy.

Outgassing of materials in vacuum depends not only on the material, but also on its surface state. In the case of an iron-dominated cyclotron, the surface of the poles therefore may play an important role. This is especially true for an accelerator dedicated to medical applications since the downtime following maintenance opening is one of its critical performance parameters. It was therefore studied whether pumping time could be significantly improved with the application of nickel-plating on the inner poles of the cyclotron. According to the simulation results (see Fig.4), only a limited gain on transmission could be saved after a given pumping time. Therefore, since this procedure would not impact significantly the clinical functioning of the system and because of the risk presented by the manufacturing process (manual application of the nickel was mandatory due to the very large yoke size), it was decided NOT to proceed with the nickel plating of the poles.

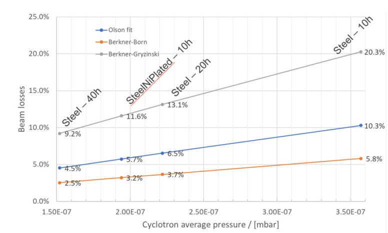


Figure 4: Beam loss versus cyclotron pressure after a given pumping time, with or without nickel plating. And according to different models.

CONCLUSIONS

Models for vacuum computation of the critical beam parts of the C400 system have been performed to help and orient various design steps. They confirmed that the pressure level was well under control to ensure a beam transmission matching the performance requirements. Those studies also permitted to optimize the vacuum, mechanical and manufacturing processes.

REFERENCES

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