DEVELOPMENT OF THE CYCLONE® KIUBE: A COMPACT, HIGH PERFORMANCE AND SELF-SHIELDED CYCLOTRON FOR RADIOISOTOPE PRODUCTION

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Abstract

About 15 months ago, at IBA, we have launched the design, construction, tests and industrialization of an innovative isochronous cyclotron for PET isotope production (patent applications pending). The design has been optimized for cost effectiveness, compactness, ease of maintenance, activation reduction and high performances, with a particular emphasis on its application on market. Multiple target stations can be placed around the vacuum chamber. An innovative extraction method (patent applications pending) has been designed which allows to obtain the same extracted beam sizes and properties on the target window independent of the target position.

INTRODUCTION

This isochronous cyclotron for PET radioisotope production produces fixed energy 18MeV proton beam and is called the **Cyclone® KIUBE**, Figure 1.

Today, three versions are available producing 100μA, 150μA and 180μA on target and the option with self-shielding is also available.

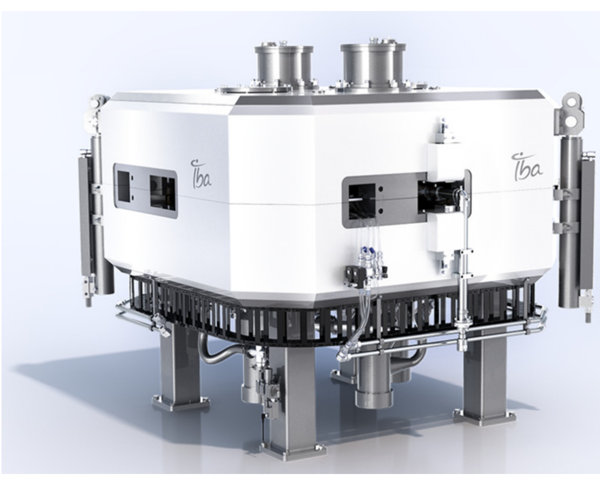

Figure 1: CYCLONE® KIUBE.

DESIGN

General Layout

The Cyclone® KIUBE, Figure 2, is a new concept starting from scratch. All the subsystems have been redesigned and optimized for high power beam production and reduced maintenance. During the study phase, all the teams have been largely challenged to meet requirements and systematic tools as TRIZ methods have been used.

First of all, the magnet system [1] has been designed to reduce the machine footprint, to make the access to all the sub-components easier and simplify the self-shielding concept. The median plan height has been modified to ensure an easy access to all the cyclotron components for maintenance.

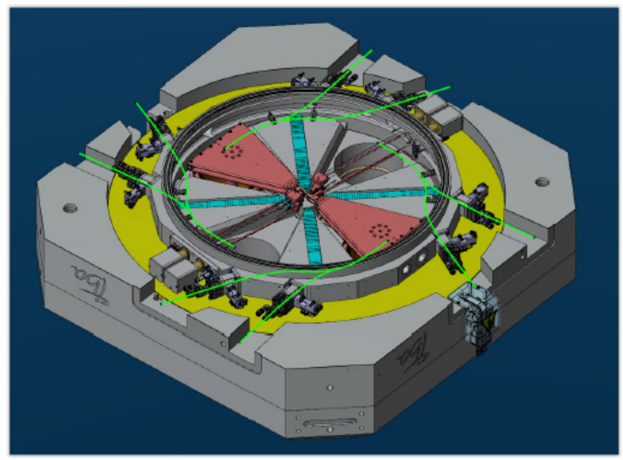

Figure 2: Magnet and extraction general overview.

The pole shape has been optimized [2] to ensure the same beam quality (shape and intensity) on the 8 targets surrounding the machine. The Figure 3 presents the top view of the pole with two gradient corrector cuts.

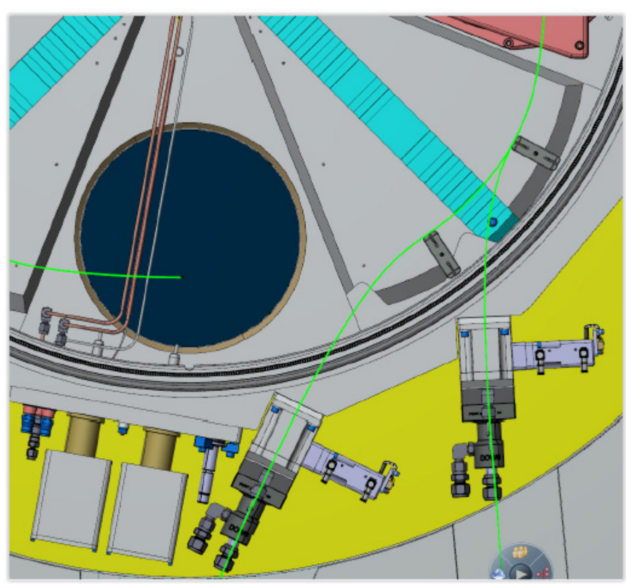

Figure 3: Two extraction systems per pole.

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Vacuum System

The vacuum system has been optimized for beam transmission and quick production restart after maintenance. The base vacuum is typically around 3.0E-7 mbar with RF on (40 kV dee voltage at 40.65 MHz). The evolution of the vacuum chamber pressure, from atmospheric pressure without cyclotron venting, is presented in Figure 4.

To	15 min	30 min	45 min
Full open	1.9 E-5 mbar	3.6 E-6	< 2.4 E-6

Figure 4: Pumping speed with 4 pumps after 2h opening without N_2 venting.

Beam Production

The machine has been redesigned around the “twin proton” concept allowing a redundancy during beam production.

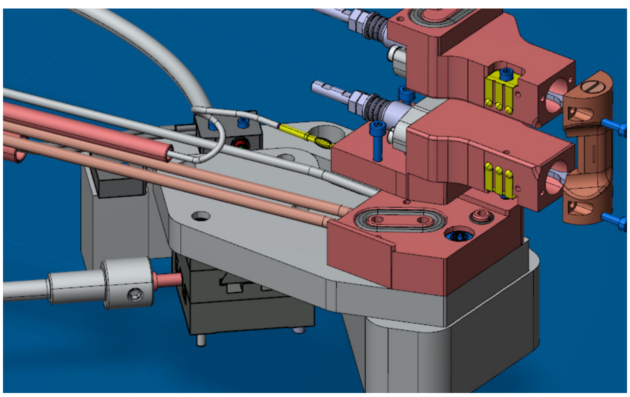

Figure 5: Ion source positioning system.

The two ions sources have been also equipped with a remote positioning system, Figure 5, ensuring the azimuthal and longitudinal automatic positioning. This positioning system allows the ion source to move remotely and be positioned without any machine opening. Continuously the ion source position could be optimized to maximize beam production.

The way to perform maintenance has been also optimized allowing the extraction of the source head easily (to maintain the ion source cathodes and chimney) out of the cyclotron. The Figure 6 presents the way to dismount the ion source.

Beam Transmission

Thanks to the several improvements, beam transmission, presented in Figure 7, and beam performance have been drastically improved comparing to the classical Cyclone® 18/9. This reduces beam losses and cyclotron activation during operation allowing easier and safer cyclotron maintenance.

For maintenance purpose, as well, the gate valves and the target have been designed to reduce the maintenance and to allow a quick disconnection of the target from the support. The special tools for handling and positioning have been developed to limit the personal exposure.

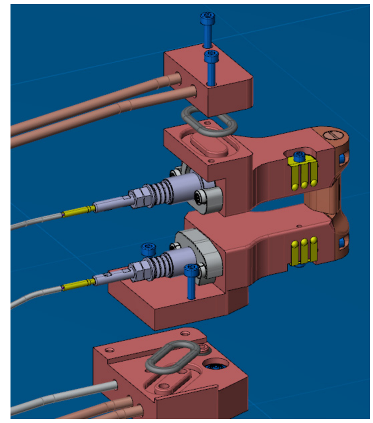

Figure 6: Ion source maintenance.

Porter valve H2 flow	Transmission 4 ODP	2 ODP
4 T – 150µA	81 %	
6 T – 180 µA	**> 77 %**	**63 %**

Figure 7: Beam transmission performance as a function of the number of ODP oil diffusion pumps.

Vault

Finally, thanks to the size reduction with respect to the classical Cyclone® 18/9, the vault height could be reduced from 3m to 2.5m. The top of the yoke is for Cyclone® KIUBE at the distance 1.6m vs 2.2m from the vault floor for Cyclone® 18/9.

For existing site or site with local constraints, IBA developed as well a self-shielding for the machine. The artistic view of the Cyclone® KIUBE self-shielding is presented in Figure 8.

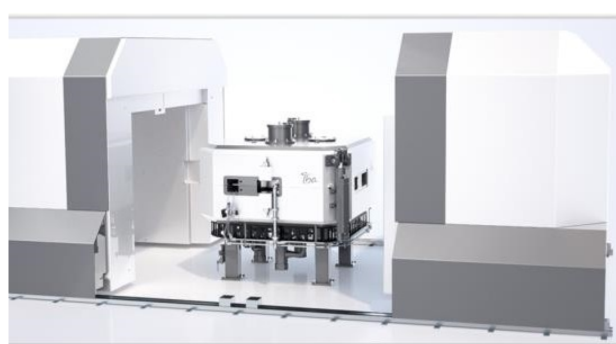

Figure 8: Cyclone® KIUBE and self-shielding.

Thanks to this option and the job performed by our Integralab team (integration of the quality control, hot cells, radio-chemistry,…), IBA can propose now the full radiopharmacy installation on a footprint smaller than 100m².

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CONCLUSIONS

The new Cyclone® KIUBE has been successfully designed, commissioned at the IBA factory and installed on our partner side. Cyclone® KIUBE outperforms the classical IBA Cyclone®18/9 in terms of beam intensity, size, weight, pumping speed, beam transmission, extraction efficiency and power consumption. The self-shielding option has been as well designed for 100µA and 150µA configurations.

REFERENCES

[1] S. Zaremba *et al.*, "Magnet Design of the New IBA Cyclotron for PET Radioisotope Production", presented at Cyclotrons'16, Zurich, Switzerland, paper TUP04, this conference.

[2] W. Kleeven *et al.*, "Extraction System Design for the New IBA Cyclotron for PET Radioisotope Production", presented at Cyclotrons'16, Zurich, Switzerland, paper TUP03, this conference.

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