A New Powerful Compact Cyclotron

Samy Bertrand[1▲], Ilse Vaneycken[2], Tony Lahoutte[2], Peter Covens[2], Vicky Caveliers[2], Eric Kral[1], Jean-Michel Geets[1], Benoit Nactergal[1], Michel Ghyoot[1], Fabienne Devillet[1].
1. IBA, Louvain La Neuve, Belgium, 2. Universitair Ziekenhuis Brussel, Brussels, Belgium,

Objectives

^{18}F is one of the most used radionuclides [> 90%] in PET procedures and its demand will continue to raise. With the increasing number of fluorine-18 [^{18}F] procedures (annual growth of more than 10% foreseen), there is an urgent need for a more cost-effective and simple solutions allowing the production of much larger quantities of ^{18}F per batch.

Figure 1: Cyclone® KIUBE - Powerful cyclotron capable of producing 300µA

In order to respond to this increasing market for ^{18}F radionuclide, IBA proposes a new mid-energy cyclotron, a state-of-the-art industrial cyclotron with:

- Maximal reliability
- Minimal maintenance requirements
- Energy-efficient
- Cost-efficient
- Fully automated and yet flexible

This cyclotron is capable to produce up to 300 µA of proton beam at 18 MeV; i.e. 30 Ci of ^{18}F in 2 hours. A stable and circular beam optics is provided on the eight exit ports fixed around the horizontal median plane. High current proton beam can also be extracted to high power solid targets for ^{89}Zr, ^{99m}Tc & other non-standard isotopes.

Methods

A proton only optimized cyclotron (18 MeV energy) has been designed using the well-known internal ion source, negative ions H$^-$ acceleration and stripping extraction.

The major innovations [1] to reach the required target current with such conditions were:

- Construction design: smaller vacuum chamber volume and higher pumping capacity to allow better base vacuum; optimization of magnet design* [Fig 2]

Figure 2 : Redesigned Magnetic Circuit and Accelerating Plane

- Cyclotron core redesign: pole inserts to allow improved magnetic field symetry over the accelerating path and gradient correctors on extraction path to obtain a near circular beam spot on the targets [2].

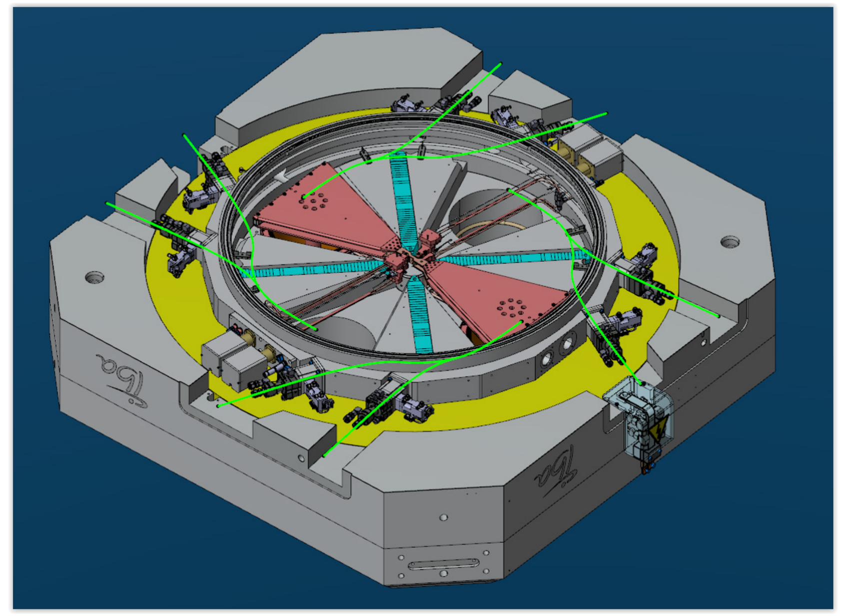

Figure 3: Upped half of the Cyclone® KIUBE

View on the upped half of the Cyclone® KIUBE [Fig 3]. In grey, the magnetic iron including the return yoke and the four poles are shown. The pole-inserts (in blue) are used to shim the isochronous field. In addition, the main coil (yellow), the accelerating structure (red) and the 8 target stations mounted on the vacuum chamber are illustrated in [Fig3]. The extracted orbits are shown in green.

- New dual-stripper system for high beam current (2x 150 µA)
- New ion source system (Fig 4): the overall maintainability and beam performance stability were further improved thanks to an auto-positioning ion source system. The ion source is radially mounted on a bi-axial table, which movement regulation throughout bombardment can compensate thermal and mechanical effects. This further reduces the need for lengthy maintenance inside the cyclotron. The cyclotron is offered with the TWIN** [4] proton source system for higher reliability and extended operating period. This hence can guarantee 300 µA on target over a lifetime exceeding 800 h without human intervention in the machine.

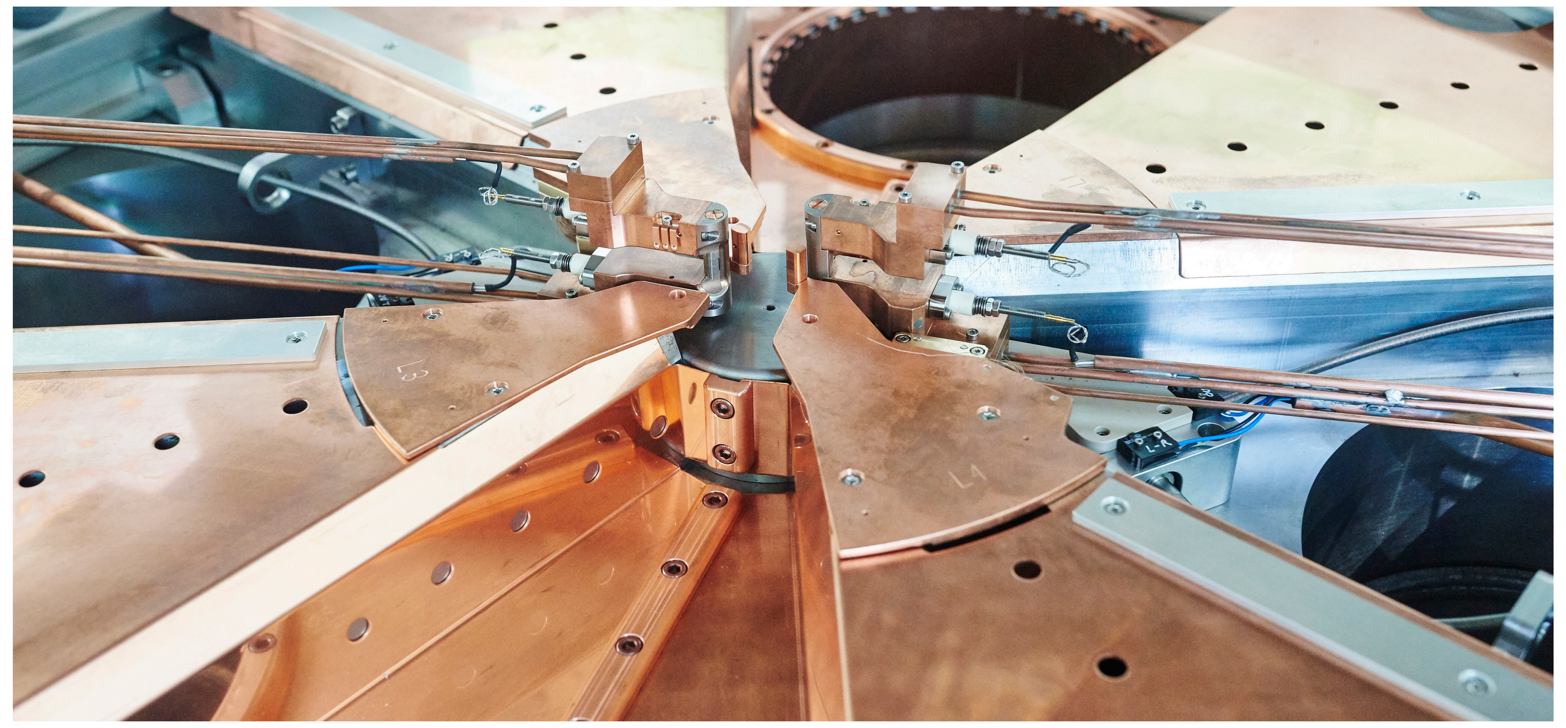

Figure 4 : Central Region and Ion Sources

Results

Some technical challenges were faced to be able to maintain 300 µA steadily over time while using an internal ion source. Indeed, raising the ion source output inherently increases the amount of polluting gas that could deteriorate the cyclotron transmission. The combination of the different technologies described previously resulted in a sustainable target current over 300 µA with large security margin and excellent stability over time.

Using IBA Nirta® Conical [3] Fluorine target [Fig 5] and dual bombardment, a production capacity of 30 Ci of ^{18}F was successfully demonstrated, which meets the original requirements. The cyclotron design is at least twice more energy-efficient than a standard mid-energy PET cyclotron.

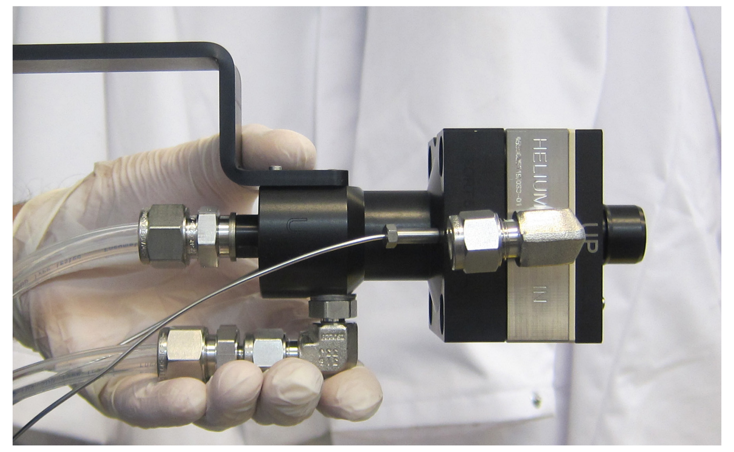

Figure 5 : ^{18}F Nirta® Conical Liquid Target

Conclusion

The cyclotron design is completed and the first units are already running in daily production. The complete design and first prototype validation were delivered in less than two years [1]. The UZ Brussel (Belgium) became today one of the State of the Art PET radioisotope production centres, achieving large batches of ^{18}F with a cost-efficient industrial cyclotron solution.

References

[1] E. Kral et al., "Development of a new IBA cyclotron for PET production", in Proc. 21th Int. Conf. Cycl. Appl., Zurich, Switzerland, Sep. 2016, paper, TUD03
[2] S. Zaremba, W. Kleeven, J. Van de Walle, V. Nuttens, S. Deneuter and M. Abs, "Magnet design of the new IBA cyclotron for PET radioisotope production" in Proc. 21th Int. Conf. Cycl. Appl., Zurich, Switzerland, Sep. 2016, paper, TUP04
[3] F. Devillet et al., "High power conical-shaped Niobium targets for reliable F-18 production and lower O-18 water consumption", Int. Workshop on Targetry and Target Chemistry, Prague, Czech Republic, Aug. 2014,
[4] JM. Geets, E. Kral, L. Meideros Romao and M. Abs, "Doubling the current on IBA PET cyclotrons, and other improvements", J Nucl Med. 2009; 50 (Supplement 2)
[5] MEDraysintell & Markets and Markets reports
[6] EP 0 222 786 B1, U.S. Patent 4 771 208

▲Contact: Samy.Bertrand@iba-group.com, IBA Booth #548

Poster 2106 - Presentation: Sunday, June 24, 4:00 PM Room 103C
SNMMI June 2018, Philadelphia, United States

*Cyclotron design covered by multiple patents: EP3244707, EP3244708, EP3244709, EP3244710.

**Under patent: EP20196073