PERFORMANCE OF IBA NEW CONICAL SHAPED NIOBIUM [^{18}O] WATER TARGETS

F. Devillet*[a], J.-M. Geets[a], M. Ghyoot[a], E. Kral[a], B. Nactergal[a], R. Mooij[b], M.Vosjan[b]

[a]*IBA RadioPharma Solutions, Louvain-la-Neuve, Belgium*
[b]*BV Cyclotron VU, Vrije Universiteit, Amsterdam, The Netherlands*

Introduction

In order to address the increasing demand for Fluorine-18 and the rising cost per mL of ^{18}O enriched water, IBA developed improvements to their $^{18}F^-$ production systems.

For this new design we started from scratch, with the main objectives of reducing the required enriched water volume and improving the cooling of the insert. A better cooling allows increasing the target current and thus the produced activity. Finally, we aimed to reduce the number of parts and improve the design of auxiliary components.

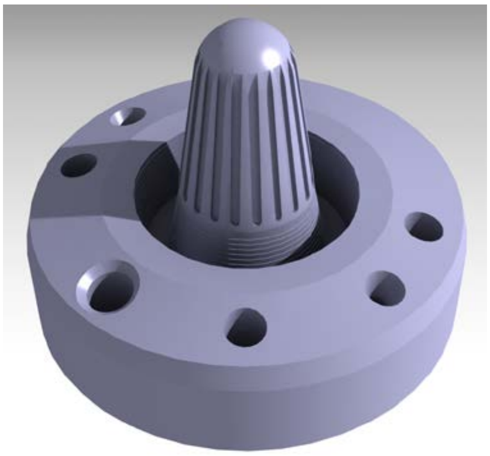

FIGURE 1: new conical shaped Niobium insert

Material and Methods

Six Niobium conical inserts with different target chamber volumes were machined and tested. Only 4 of these were selected to create the new range of IBA $^{18}F^-$ targets shown in Table 1.

Official name	*Insert chamber volume (mL)*
Nirta Conical 5	2.4
Nirta Conical 8	3.7
Nirta Conical 12	5.0
Nirta Conical 16	7.0

TABLE 1: IBA new $^{18}F^-$ target range

The new Niobium target inserts have a complex shape with drilled channels on the outside of the chamber (Figure 1) and a deep channel next to the beam strike area (Figure 2, green circle) to ensure efficient cooling.

The ^{18}O water inlet lines are now directly inserted in the Niobium body (Figure 2, blue circle) to improve $^{18}F^-$ quality (no more contact with small o-rings as it was the case with the old cylindrical design (Figure 3, red circle)). In operation, a 35µm Havar® target foil is used, reducing cooling needs and power loss in the foil.

Another benefit of this conical shape is that it sends the [^{18}O]-water back to the beam strike area, and when emptying the target at the end of the shot, the water flows naturally to the transfer line making the remaining activity inside the target as low as possible.

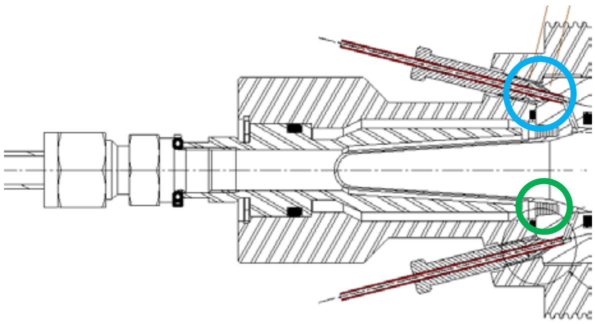

FIGURE 2: new conical design

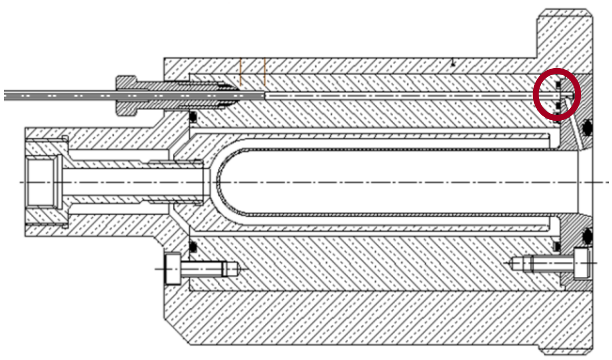

FIGURE 3: old cylindrical design

Maintenance has been simplified by using less pieces and o-rings. Disassembling and assembling are now much easier. As target foil is better cooled and because orings have been changed to Kalrez® to better resist heat, maintenance interval is expected

* Fabienne.devillet@iba-group.com

to be longer. Moreover, load and unload target tubings were changed to stainless steel in order to withstand higher pressure and temperature. Apart from the niobium insert and the water diffuser that are different for each target of the range, all other parts are common. A handle has been added to make the target manipulation easier (Figure 4).

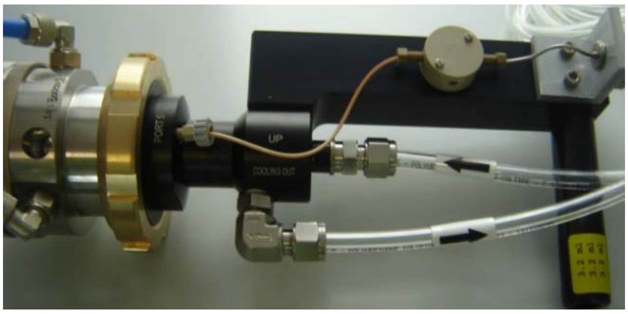

FIGURE 4: new Conical target: how it looks like

All tests were performed using IBA Cyclone® 18 cyclotron. The targets were filled with different volumes of enriched ^{18}O water (enrichment >92%) and irradiated with 18 MeV protons on target with beam currents up to 145 µA for 30 to 150 minutes, while the internal pressure rise of the target was recorded. For each target, a pressure-current curve was plotted (Figure 5). These curves are used in IBA Zephiros dynamic pressure control system to regulate the beam current in function of the target pressure in automatic mode [2].

An optimum balance between target water fill volume, pressure and current has been determined, which maximises available activity after two hours, in each case.

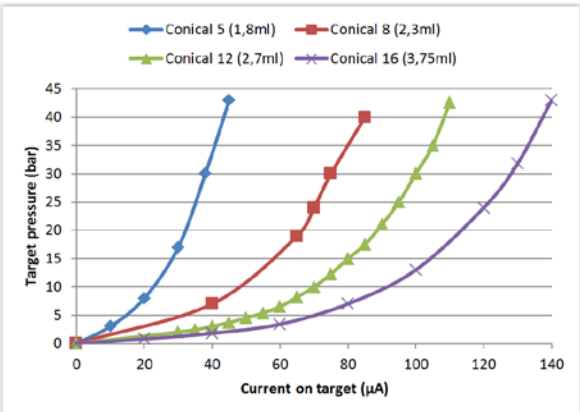

FIGURE 5: target pressure for given filling volumes

Results and Conclusion

Even though the new target body is made of Niobium and a Havar® window (35 µm) is used, the radionuclidic impurities were determined in the ^{18}F-solution (Figure 6 and Table 2).

Hundreds of FDG syntheses on various synthesizers confirmed the effectiveness of the new design by showing equivalent and consistent production yields (Figure 7).

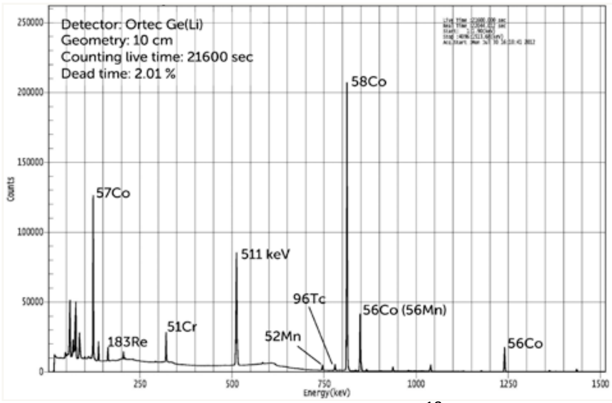

FIGURE 6: radionuclidic impurities in $^{18}F^-$ solution (Conical 8)

Amount in kBq @ EOB				
Radionuclidic impurities	MEX-AMS-001	MEX-AMS-002	MEX-AMS-003	MEX-AMS-005
Cr-51	5	6	11	13
Mn-52	23	3	14	2
Co-56	7	8	18	7
Co-57	3	3	7	3
Ni-57	32	4	7	ND
Co-58	34	36	80	34
Tc-96	1	1	1	3
Re-183	ND	ND	ND	1
F-18	258 GBq	264 GBq	314 GBq	276 GBq

TABLE 2: radionuclidic impurities (beam time 2h, current 65 µA)

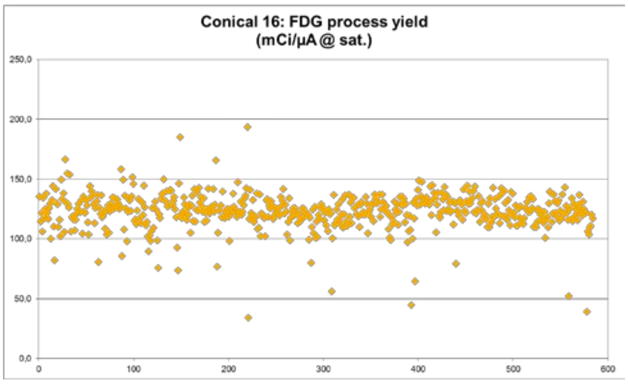

FIGURE 7: Production yield stability with Conical target.

Target window resistance to beam and pressure has been tested on Conical 16 with an enriched water filling volume of 4250 µl. The burst pressure was found to be above 50 bar for a target current above 150 µA (Figure 8).

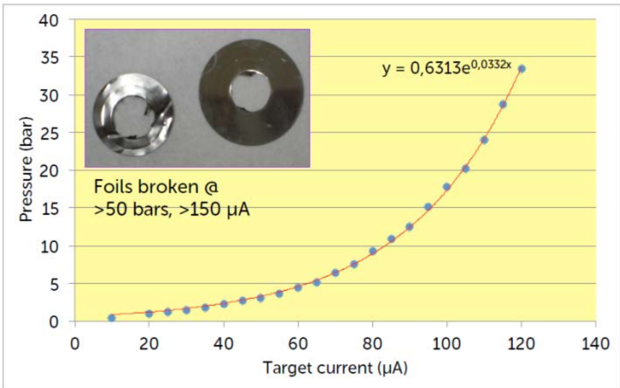

FIGURE 8: burst test (Conical 16, filling 4250µl)

The summary of the results can be found in Table 2 below.

In conclusion, with this new range of $^{18}F^-$ conical targets, we observe a switch in the performance compared to cylindrical ones with lower water consumption and higher activity output (as shown in Table 3).

The benefit of the new design becomes more evident as the volume of the insert increases. For Conical 12 versus 2XL target and Conical 16 versus 3XL target, with equivalent insert volume and enriched water filling, the beam current and then the output activities can be increased by 25%.

Increasing the current up to 145µA in Conical 16, the production reached 18Ci in 2 hours, single beam, with a target pressure under 43 bar.

Today, the use of these new targets for daily commercial production is increasing within the IBA Cyclone® installed base.

The new design with less o-rings and direct insertion of flow line into the niobium chamber has proven its effectiveness.

Table 3: Results summary

	Conical 5	**Conical 8**	**Conical 12**	**Conical 16**
Insert Volume	2.4 ml	3.4 ml	5 ml	7 ml
Filling Volume	1.8 ml	2.3 ml	2.8 ml	4.2 ml
Average current	45 µA	65 µA	100 µA	130 µA
Yield @ sat.	230 mCi/µA	230 mCi/µA	230 mCi/µA	230 mCi/µA
Activity output (2h)	5 Ci	8 Ci	12 Ci	16 Ci
Target pressure	40 bar	30 bar	30 bar	30 bar
$^{18}F^-$ concentration	2.8 Ci/ml	3.5 Ci/ml	4.3 Ci/ml	4.0 Ci/ml

Table 4: Performance comparison Nirta Cylindrical vs Nirta Conical

Nirta cylindrical	LV 1.8 ml 5 Ci	XL 2.5 ml 7 Ci	2XL 3 ml 9 Ci	3XL 4 ml 13 Ci
Nirta Conical	Conical 5 1.8 ml 5 Ci	Conical 8 2.3 ml 8 Ci	Conical 12 2.8 ml 12 Ci	Conical 16 4.0 ml 16 Ci

Figure 9: New conical design [3]: Niobium insert, target body, one piece water diffuser

Acknowledgment

The development of those new targets wouldn't have been possible without the close collaboration work between IBA R&D team and our test sites.

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References

[1] F.Schmitz et al, "Production of multi-curies fluoride using a Niobium target chamber at small PET cyclotrons", WTTC'09 proceedings , Turku, May 2002, p 12.

[2] J-M Geets et al., "Reliability enhancement and higher production on IBA PET cyclotron", EANM 2010, Vienna sept 2010, poster #9, session P13

[3] Belgian patent BE1019556A3 / International application WO2012055970 (A1)