

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

F. Devillet*, J.-M. Geets, M. Ghyoot, E. Kral, O. Michaux, B. Nactergal, V. Nuttens,
IBA RadioPharma Solutions, Louvain-la-Neuve, Belgium
J. Courtyn, IBA Molecular Europe, Paris, France

R. Mooij, L. Perk, BV Cyclotron VU, Vrije Universiteit, Amsterdam, The Netherlands

Abstract

Background: Because of an ever increasing demand for Fluoride-18 (^{18}F), efforts are made to increase the performance of the ^{18}F -target systems. Moreover, given the particularly high cost of ^{18}O enriched water, only a small volume of this target material, at the very most a few milliliters, is desired.

Procedure: Four conical shaped targets with different target chamber sizes (Conical 6 – 2.4 ml; Conical 8 – 3.4 ml; Conical 12 – 5 ml; Conical 16 – 7 ml) were tested using IBA Cyclone[®] 18 MeV cyclotrons. The insert volumes of the new Conical targets are identical to the cylindrical insert volumes: LV – Conical 6; XL – Conical 8; 2XL – Conical 12; 3XL – Conical 16. Fluoride-18 saturation activity yields and pressure curves were completed. Radionuclidic impurities were measured, even if the new target is using the same principle of Niobium body [1] with Havar[®] window.

NEW TARGET DESIGN

When designing this new conical shaped Niobium insert, the objectives were multiple:

- reduce the enriched water volume;
- improve the cooling of this insert;
- increase the produced activity;
- reduce and improve auxiliary parts.

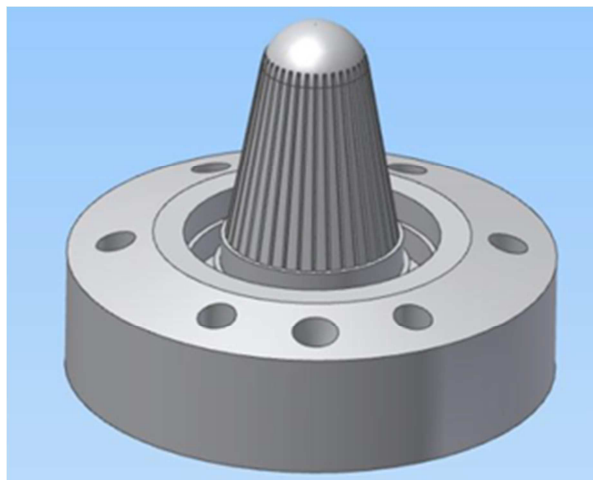


Figure 1: new conical shaped Niobium insert [3]

The cooling has been improved thanks to the drilled channels on the outside of the insert chamber. Another

deep channel has been foreseen to be able to cool the beam strike area next to the target window (Figure 3, green circle).

Maintenance has been simplified by using less pieces and o-rings. The insertion of the flow lines is now done directly inside the Niobium (Figure 3, blue circle). This solution improves the purity of the ^{18}F -Fluoride, because there is no contact between the product and small o-rings as it was the case with the old cylindrical design (Figure 2, red circle). The maintenance interval is expected to be longer.

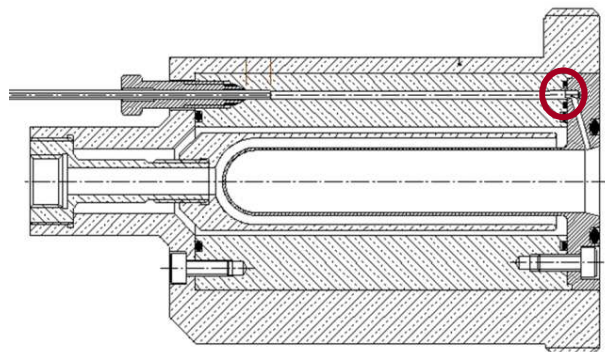


Figure 2: old cylindrical design

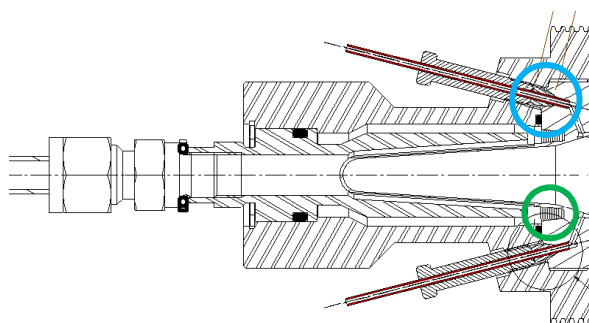


Figure 3: new conical design

Another benefit of this new design is the target weight. It is now much lighter and avoids the target misalignment with the beam that was at the origin of many target and synthesis yield problems. A handle has been added to make the target manipulation easier (Figure 4).

Compared to the cylindrical design, this conical shape allows sending 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.

* Fabienne.devillet@iba-group.com

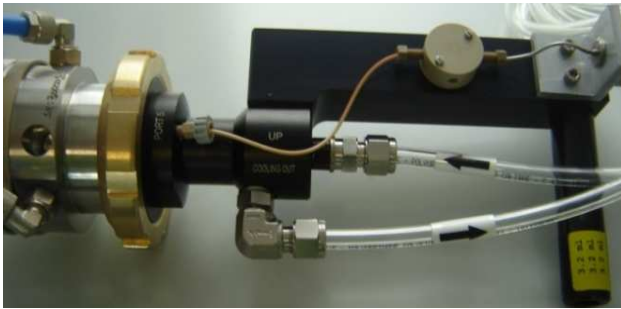


Figure 4: new conical target: how it looks like...

Load and unload target tubings were changed to stainless steel in order to withstand higher pressure and temperature. During endurance tests, a PEEK tubing was melted by water steam (Figure 5).

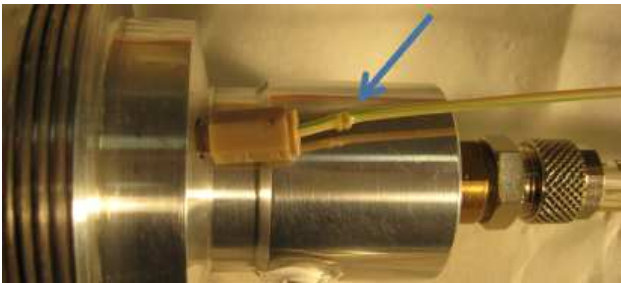


Figure 5: melted PEEK tubing

In operation, 35µm Havar® target window are used instead of 50µm, reducing the power loss in the window and cooling needs.

TESTS AND RESULTS

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.

Pressure curves

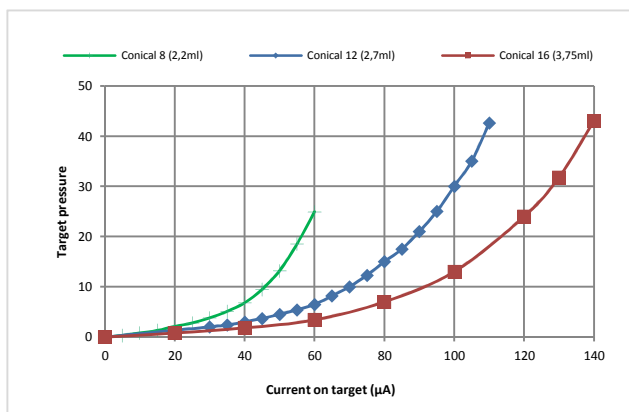


Figure 6: target pressure curves for given filling volumes

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].

Radionuclidic impurities

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. The results of the radionuclidic impurity tests can be found in Figure 7 and Table 1.

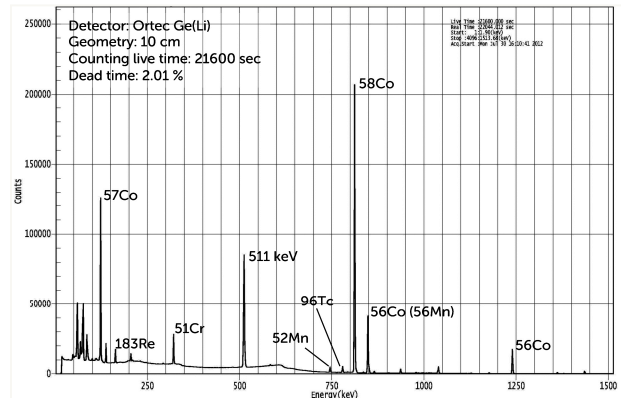


Figure 7: radionuclidic impurities in ^{18}F -solution (Conical 8)

Table 1: radionuclidic impurities (beam time 2h, current 65 µA)

Radionuclidic impurities	Amount in kBq @ EOB			
	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

Burst test

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).

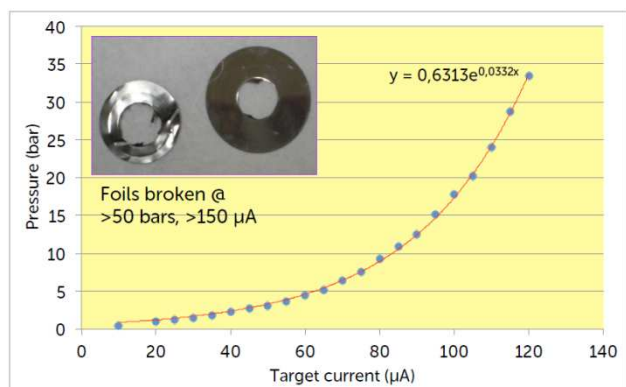


Figure 8: burst test (Conical 16, filling 4250µl)

Target optimization

The tests aimed to find an optimal filling volume, allowing:

- Minimal use of enriched water;
- Keeping good Fluoride-18 saturation activity yields;
- Maximizing activity output.

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

CONCLUSION

With this new range of 18F- 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 global activity output per ml enriched water has increased: from 2.8 Ci/ml to respectively 3 and 3.5 Ci/ml for the smallest targets (Conical 6 and Conical 8); and from 3 Ci/ml (111 GBq/ml) to over 4 Ci/ml (148 GBq/ml) for the biggest targets (Conical 12 and Conical 16.)

Conical 6 and Conical 8 inserts will be slightly redesigned to increase the insert volume to achieve the targeted output activities (respectively 6 Ci and 8 Ci).

Reliable operation in a production environment has been observed at beam currents up to 145 μ A using less 18 O enriched water as compared to the currently available IBA target systems without affecting the yield.

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

Table 2: Results summary

	Conical 6	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	2.7 ml	4.2 ml
Average current	45 μ A	65 μ A	100 μ A	130 μ A
Yield @ sat.	230 mCi/ μ A	224 mCi/ μ A	228 mCi/ μ A	235 mCi/ μ A
Activity output (2h)	5.5 Ci	7.7 Ci	12.1 Ci	16.2 Ci
Target pressure	40 bar	30 bar	30 bar	30 bar

Table 3: 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 6 1.8 ml 5.5 Ci	Conical 8 2.3 ml 7.7 Ci	Conical 12 2.7 ml 12 Ci	Conical 16 4.2 ml 16 Ci



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

ACKNOWLEDGMENT

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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 BE109556A3 / International application WO 2012/005970 A1