PROTON THERAPY AT THE INSTITUT CURIE – CPO: OPERATION OF AN IBA C235 CYCLOTRON LOOKING FORWARD SCANNING TECHNIQUES

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Abstract

Since 1991, more than 6100 patients (mainly eye and head&neck tumours) were treated at the Institut Curie – Centre de Protonthèrapie d'Orsay (IC – CPO) using Single Scattering and Double Scattering (DS) proton beam delivery technique. After 19 years of activity, a 200 MeV synchrocyclotron has been shut down and replaced by a 230 MeV C235 IBA proton cyclotron. This delivers beam to two passive fixed treatment rooms and to one universal nozzle equipped gantry (DS, Uniform Scanning – US, Pencil Beam Scanning – PBS). In the past two years of operation more than 95.5% of the scheduled patients (near 500/year) were treated without being postponed. According to IBA recommendations, we have realized preventive maintenance and we have improved some diagnostic tools allowing us to reduce the number of downtime events from 499 in 2011 to 351 in 2012 [1]. In order to enhance cancer treatment capabilities we are now involved in the transition towards scanning particle therapy, requiring even more accurate quality assurance protocols. We describe here the main cyclotron issues looking forward the scanning technique, the main goal being the progress of our reliability performances.

ACCELERATOR OPERATION

More than 900 patients have been treated with the IBA C235 cyclotron from its commissioning in July 2010 until now (see Fig. 1). During the 51 weeks per year scheduled for the therapy, the day average activity is near 12 hours, so that the accelerator operation is in an almost two-shift mode. During the week night the machine is idle and over the week-end all is shut down. An on call system is activated every time the clinical activity ends.

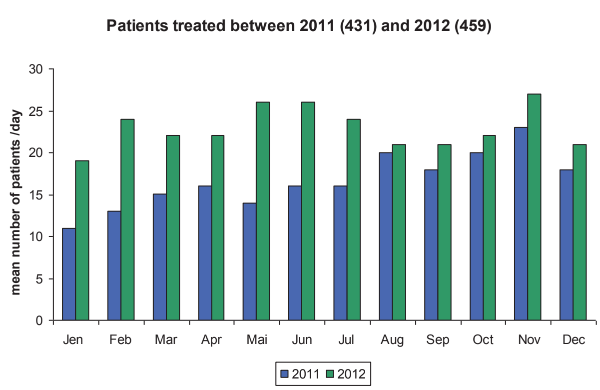

Figure 1: Patients treated (average per day) with the C235.

The beam delivery technique used to distribute the dose over the tumour volume is the passive spreading. This choice was motivated by the previous treatment experience of the centre coupled to the need to ensure a clinical break as short as possible between the shutdown of the existing synchrocyclotron and the start up of the new cyclotron. Actually we were able to start again the treatments a month after the shutdown.

Thanks to the change in the machine we have increase our uptime from 92% in 2009 to 95.9% in 2012. This is still improving as we are probably in the "early life failures period" of the equipment according to the Weibull model [2]. In order to reduce the number of possible issues, we perform regular maintenance interventions together with the local IBA team (3 engineers). The main guidelines in the servicing of the accelerators and ancillaries are discussed in the paper.

MAINTENANCE

We have from two to four hours per week for regular servicing as changing the ion source, servicing some power supplies units or fixing some beam line or treatment room issues. If this is not possible during this scheduled week time, we have also dedicated Saturdays or 1.5 days each 3 months. But the main maintenance is once a year when we open the cyclotron and the activity is off during one week.

In order to define priorities in the maintenance planning, IBA has a list of 256 procedures where the periodicity is well defined. Additional checks on the cyclotron operation are monthly performed by the IC – CPO team. Here we find some examples:

- Cyclotron efficiency (around 45%) via radial track (see Fig.2)
- Main Coil pancakes resistance
- Cooling (Main Coil and general)
- Water resistivity
- Vacuum
- Extraction system (deflector leakage current)
- Radio Frequency system (amplifiers efficiency and lifetime)

Nevertheless, even if we try to anticipate, we have experienced some critical failures affecting the clinical activity. We describe now a few preventive and curative interventions that we have made.

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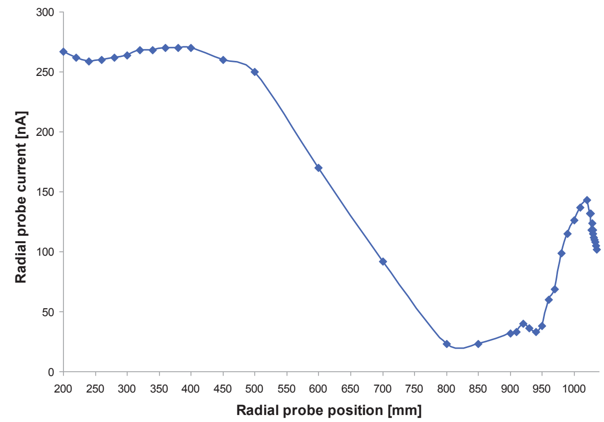

Figure 2: Radial track. Cyclotron transmission efficiency is defined as the ratio between the beam current at two radial probe positions, 1030 mm over 300 mm.

Preventive

In September 2012, after more than 20000 hours of operation, we have changed the Intermediate Power Amplifier (IMPA – 2 kW) and the Final Power Amplifier (FPA – 51 kW) tetrodes. Theses actions were performed by the IBA team, according to the principle that any non regular maintenance is on their duty. It took 2.5 days to complete the intervention, and it was planned during one of the 3 times 1.5 day maintenance dedicated break.

This operation allows us to avoid a potential failure and a consequent loss of reliability in our clinical activity.

The RF behaviour was unchanged with a FPA and IMPA efficiency of 50% and 36% respectively and a gain (dB) substantially constant over the last year (see Fig. 3).

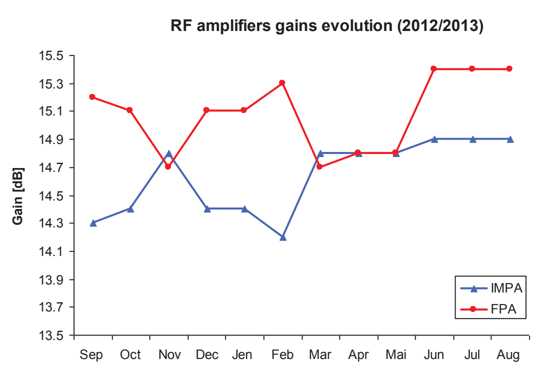

Figure 3: RF amplifiers gains evolution in one year. Their standard deviation is better than 0.3.

Taking advantage on the past experience with the synchrocyclotron and being more confident with the new cyclotron, the IC-CPO team developed some additional monitoring tools helping in the preventive maintenance. In particular we worked on new controls programs to check the Main Coil pancakes voltages and temperature and on the ion source filament lifetime monitoring (see Fig. 4). For the same ion source, the extracted beam current is varying from 0.9 to 11 mA without a clear dependence on the ion source aging.

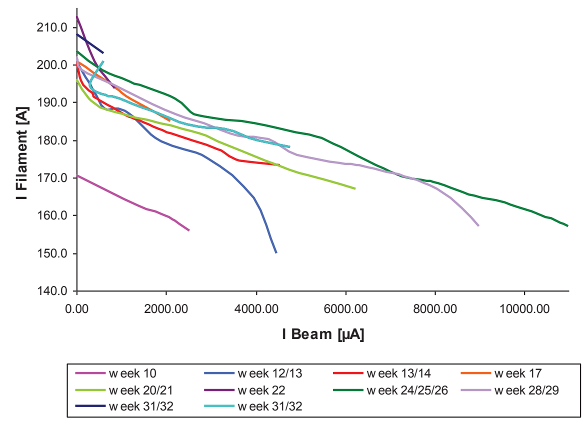

Figure 4: Ion source filament lifetime.

Curative

Among the main issues affecting the reliability of our cyclotron, the failures on the injection (ion source) and extraction system (deflector insulator and resistance) are presented in the next sections.

Injection System

Beam production elements represents near 30% of the total issues of the equipment. Ion source is the main component to be affected. In particular a problem in its movement mechanism (see Fig. 5) caused a downtime of 2 days (20% of the delayed treatment sessions) in 2011 and a failure in the arc power supply 1 day of breakdown in 2012 (5% of the total delayed treatment sessions). The presence of sudden short circuit in the ion source chimney represents a regular issue. The corresponding downtime is about 30 minutes which is the time needed to the ion source changing. Among others specific ion source failures, the source RF contact ring wear is one of the most common.

Figure 5: Damage on the guidance system of the ion source (left) and stripe on the shaft (right).

Extraction System

Deflector dysfunction was the main responsible of cyclotron downtime in 2010 and 2012. In particular in 2012 it has represented the 80% of the delayed session depending on cyclotron issues (30% of the total delayed treatment sessions). We experienced in two occasions wear on the main insulator (see Fig. 6) and once on its resistance. We were able to detect this problem trough the deflector leakage current increase. Since the last failure in June 2012, a dedicated control on this parameter allows us to have a direct alarm if the problem is repeating.

Figure 6: Damage on deflector insulator.

CONCLUSIONS AND DISCUSSIONS

We just move into our first three years of operation of the C235 IBA proton cyclotron. Thanks to the cooperation with the local IBA team and with the experience of our technical team we are now able to have a good understanding of the regular issues of the equipment. Enhancing the diagnostic tools will represent a major improvement in the knowledge of the IBA system, which is still a sensitive item. We are now involved in the installation process of the PBS delivery technique [3] (see Fig. 7).

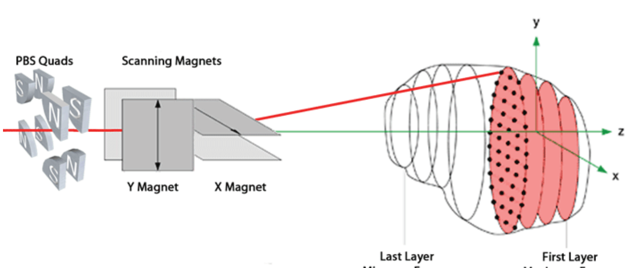

Figure 7: PBS delivery scheme.

This is considered as the most accurate dose delivery method, but it is still a non established technology. From the accelerator point of view performing an accurate treatment (accuracy on the delivered dose in the order of 1%), a very stable and reproducible beam intensity is needed (few percent accuracy within a millisecond) [4]. In addition we need to distribute 2 Gy in a volume of one liter (10x10x10 cm^3) in less than 2 minutes. This is close to 10000 spots per liter, so that the cyclotron has to deliver near 100spots/second. It is possible that variations in the beam intensity or in the alignment of the beam at the cyclotron exit could represent new possible issues in the definition of the spot position in the target. This can be related to the link between the yoke temperature and its magnetic field (isochronisms). A specific tuning of the main coil could help to reduce the risk of drift in the beam position. Furthermore a beam intensity of near 300 nA, which is a quite high value compared to the average beam current required for a DS delivery mode treatment, could represent others possible issues (i.e. beam current regulation system failures or increasing the number of ion source changes).

Being aware of the advantages that the pencil beam scanning can have on the cancer treatment, will allow us to continue to develop our knowledge of the system trying to ensure the highest possible accelerator reliability.

ACKNOWLEDGEMENTS

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REFERENCES

[1] S. Meyroneinc et al., “Some reliability issues of two accelerators for protontherapy”. Poster ARW 2013, Melbourne, Australia.
[2] B. Dodson (2006). “The Weibull analysis handbook”.
[3] B. Marchand, D. Prieels, et al. (2000). “IBA proton pencil beam scanning: an innovative solution for cancer treatment”. Proceedings of European Particle Accelerator Conference (EPAC), Vienne, Autriche.
[4] J.M. Schippers, D. Meer, E. Pedroni (2010). “Fast Scanning techniques for cancer therapy with hadrons – a domain of cyclotrons”. Proceedings of CYCLOTRONS 2010, Lanzhou, China.

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