

THE DKFZ CYCLOTRON - STATUS REPORT

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We report here on the recent status and applications of the DKFZ biomedical cyclotron facility.

1 Introduction

Since 1971, the Institute of Nuclear Medicine, today Dept. of Radiology, DKFZ Heidelberg, then under the Direction of Prof. K. E. Scheer has operated the first compact cyclotron in Germany exclusively dedicated to biomedical research. After 19 years of successful operation, in 1991, the old K22 AEG Compact Cyclotron was replaced by a Scanditronix K32 negative ion cyclotron, model MC32NI. The plan to purchase a 30 MeV compact cyclotron had been accepted by an international review committee in 1988.

The growing demand for radionuclides and the increasing failure rate of the old machine requested a more powerful and more reliable system. The MC32NI was the first negative ion cyclotron to accelerate both negative hydrogen and deuterium ions. The capability to deliver also deuterons was recommended by the 2<sup>nd</sup> International Targetry Workshop in Heidelberg in 1987 in view of the production of <sup>18</sup>F-F<sub>2</sub> via <sup>20</sup>Ne(d,α) and <sup>15</sup>O from <sup>14</sup>N(d,n). The advantages of negative ion acceleration - quite new in those days for small machines - are the easy extraction of high beam currents with practically 100% efficiency and the consequent reduction of the radiation burden to the personnel.

The higher energies (32 MeV p, 16 MeV d) were needed for the production of heavier nuclides than the light positron emitters used in Positron Emission Tomography (PET) and the production of fast neutrons with acceptable dose rate and depth dose.

2 The accelerator facility

2.1 The cyclotron

The accelerator was designed by Scanditronix AB, Uppsala, Sweden and built in 1989/1991. Installation in Heidelberg started in April 1991; the first beam was extracted in June 1991. The design data of the MC32NI are given in Table 1.

2.2 The periphery

The beamline system could be taken over from the former cyclotron facility, because the magnets were generously overdimensioned by the manufacturer AEG in relation to K=22. It was extended and is continuously adapted due to the demand of the current biomedical applications as shown in Figure 1.

Table 1 : Design characteristics of the Scanditronix negative ion cyclotron MC32NI.

particles/energies	protons / 16 - 32 MeV deuterons / 8.5 - 16 MeV
extracted ion currents	≥ 60 μA
extraction efficiency	≅ 100 %
magnet pole faces	K=32, conventional H - shape 135 cm Ø, 10 - 18 cm gap, 3 spiral hill sectors
field strength	1.59 T average
accelerating system	2 Dees, 90° each
accelerating voltage	24 MHz, 30 kV master oscillator
ion source	dual PIG type, 2kV/ 2 A max.
vacuum	≅ 2x 10 <sup>-7</sup> mbar
gross weight	53 tons
total power consumption	185 kVA

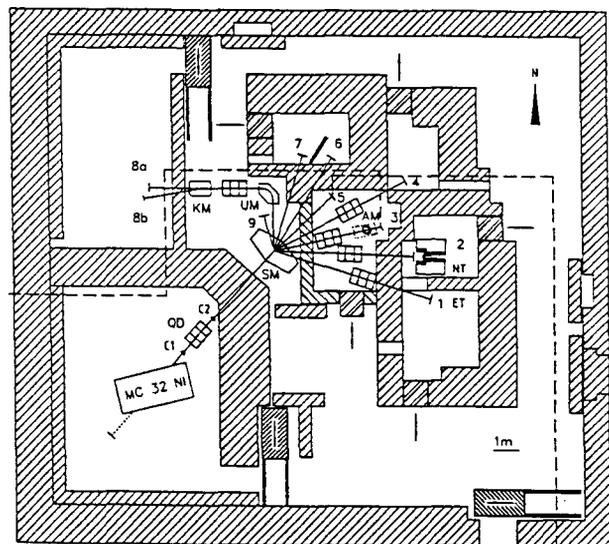


Figure 1 : Plan view of the Heidelberg cyclotron laboratory. The dimensions are approx. 18 by 20 m<sup>2</sup>. The cyclotron system together with a TRIGA research reactor is housed in a shielded annex directly adjacent to the medical department.

The periphery consists of a basic beam-line feeding a switching magnet (SM in Fig.1) with 9 exit ports eight of which are occupied by 4 long lines with additional focusing quadrupoles and 4 short ones without. One port is still free.

Most ports of the lines carry target exchanging devices so that a total of 15 targets can be mounted. Critical targets, i. e. those for routine  $^{18}\text{F}$  and  $^{18}\text{F}\text{-F}_2$  production have been duplicated for emergency, i. e. in case of foil rupture the second target can overtake immediately.

The beam-lines have the following functions :

# 1 : changer with five target ports for experiments on target development and yield optimization ;

# 2 : thick and thin (for 32 MeV protons) Beryllium targets for fast neutron production via  $\text{Be}(p,n)$  or  $\text{Be}(d,n)$  at various energies.

# 3 : High pressure gas target for  $^{14}\text{N}(d,n)^{15}\text{O}$ . Here we intend to install a dipole magnet to bend the beam downward by  $90^\circ$ . This work is scheduled for the end of this year.

# 4 : 2 identical Neon gas targets for  $^{20}\text{Ne}(d,\alpha)^{18}\text{F}\text{-F}_2$ .

# 5 : Nitrogen gas target (30 bar) for  $^{14}\text{N}(p,\alpha)^{11}\text{C}$ .

# 6 : Krypton82 target for  $^{82}\text{Kr}(p,2n)^{81}\text{Rb} \rightarrow ^{81\text{m}}\text{Kr}$ . This Rb-Kr-generator is delivered to the near-by Dept. of Nuclear Medicine of the University of Heidelberg once or twice a week. In addition, this line carries a  $^{78}\text{Kr}$  gas target for  $^{78}\text{Kr}(p,\alpha)^{75}\text{Br}$ , a short-lived positron emitter.

# 7 : two identical  $^{18}\text{OH}_2$  water targets (volume  $\cong 1$  ml) for  $^{18}\text{O}(p,n)^{18}\text{F}$ .

# 8 : Deuteron beam into free air for the activation of metallic samples for wear measurements, accidentally used by the Research Center Karlsruhe.

# 9 : foreseen for two identical water targets for  $^{16}\text{O}(p,\alpha)^{13}\text{N}$ .

From the  $^{11}\text{C}$ -,  $^{15}\text{O}$ -, and  $^{18}\text{F}\text{-F}_2$  targets the radioactive gas mixtures are transferred by steel pipe-lines directly to the labelling processors in the hot laboratories.

The radiochemical targets and exchanging devices have been designed by F. Helus, F. Oberdorfer and their colleagues [1], the fast neutron facility by G. Wolber et al. [2]. Nearly all electrical, electronical and mechanical work on the construction and control of the periphery, i. e. of targets, target exchangers and of the fast neutron facility was done by our own workshops.

### 3 Applications

80% of the beam time is dedicated to radionuclide production, primarily of short-lived positron emitters for the oncological PET Project; about 15% for dosimetric and radiobiological experiments with fast or moderated neutrons. The high energy allows also to produce high Z nuclides from which  $^{81}\text{Rb}$  is the most important one at present. The aqueous  $^{81}\text{Rb}$  solution is automatically flushed to a portable  $^{81}\text{Rb}\text{-}^{81\text{m}}\text{Kr}$  generator for regular clinical use in lung function tests (see above).

The fast neutron beam facility (targets plus collimator) has been built to provide for the needs of the radiobiological research program after shut-down of the fast neutron d-T generator operated for fast neutron radiotherapy.

As far as the intramural program allows external groups are invited to make use of the facilities.

### 4 Future plans

As mentioned above, a vertical beam line will be built with horizontal targets in the basement below the cyclotron lab (at the end of beam-line # 3, see Fig. 1) to enable the irradiation of meltable samples with high current load.

Work is under way to assign optical or accoustical signals to all critical operation conditions and to integrate them into a safety system using the existing PLC (SIMATIC).

In case the demand for  $^{15}\text{O}$  rises considerably, we plan to install a second beam extractor for which an optional exit has been provided by the design. There we will mount 2 targets for « on-line » production of  $^{15}\text{O}$  via  $^{16}\text{O}(p,pn)$  or  $^{14}\text{N}(d,n)$  depending on which particle is in current use.

Increasing demand for radionuclides is expected from the closer cooperation envisaged with the new Head of the Dept. of Nuclear Medicine of the University and by the proposed regional PET Center.

### 5 Conclusions

The operation of the cyclotron has turned out to be smooth, reliable ( $\cong 95\%$ ) and comfortable. The beam is on target during 1300 h out of about 2600 h of annual operating time.

The progress of computer control has - in comparison to pure manual operation - introduced some additional probability of failures. This minor drawback is, however, over-compensated by the reduction in time for the many switches between particles and energies requested by the versatile program.

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### References

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