STATUS REPORT OF CYCLONE

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ABSTRACT

Although the main effort of the cyclotron group during the last years was devoted to the production of radioactive ion beams, several other major developments have been undertaken. The experimental hall has been rearranged to accomodate a large neutron multidetector (DEMON) for the study of nuclear reaction mechanisms with heavy ions. A new beam transport line has been designed and built to bring the heavy ion beams to this experiment. To improve the possibilities for time-of-flight experiments, a beam chopper has been constructed. The neutrontherapy unit has been equipped with an in-house built multileaf variable collimator.

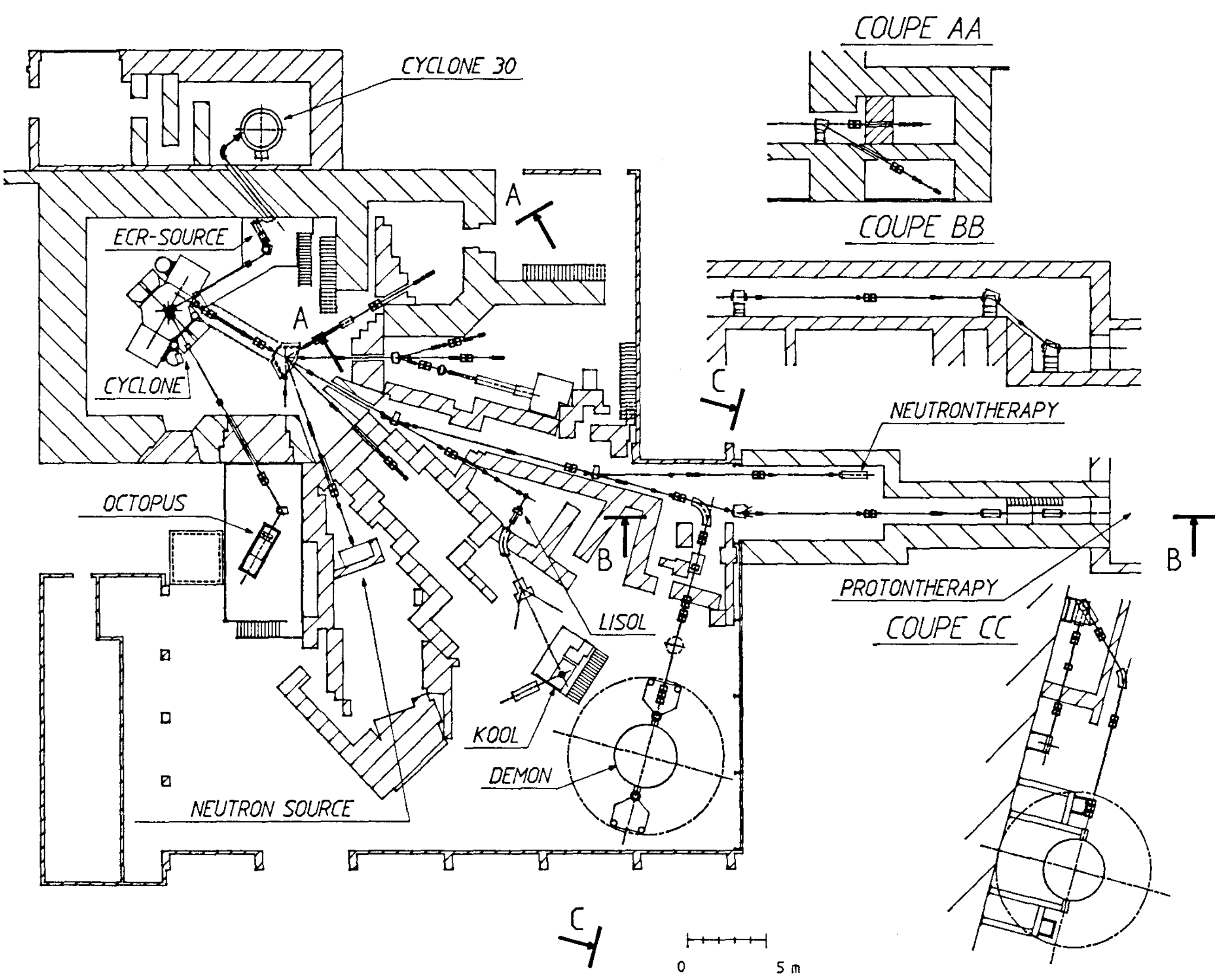

Figure 1. Layout of the Louvain-la-Neuve facility.

1. INTRODUCTION

After 20 years of operation, CYCLONE still delivers beams, of a greater variety than ever, to a multidisciplinary users community. This is illustrated e.g. by the beam time allocation in 1991, given in Table 1.

		HOURS	%
PHYSICS using		2843	52.9
light ions	1206 h		
heavy ions	1093 h		
radioactive ions	544 h		
ISOTOPE PRODUCTION		320	6.0
PROTON- AND NEUTRONTHERAPY		767	14.3
TECHNOLOGICAL APPLICATIONS		220	4.1
MAINTENANCE AND BEAM DEVELOPMENT		1223	22.7

Table 1 : Beam time distribution in 1991.

During the last years, a large effort was devoted to improve and extend the acceleration of radioactive ion beams mainly for nuclear astrophysics experiments.[1)] In the following paragraphs other developments for the nuclear physics and medical users of the cyclotron are described. Figure 1 shows an actual layout of the facility at Louvain-la-Neuve.

2. BEAM TRANSPORT TO "DEMON"

The beam transport between the cyclotron exit and the target in the centre of DEMON, a large neutron multidetector, can be followed on Fig.1. Note that the centre of the sphere is situated 5 metres above ground, far from large volumes of solid material, to avoid rebounding neutrons. Part of the beam transport uses existing lines. One of the requirements for the design of the new section was that existing lines would not (or very little) have to be modified and that, as much as possible, existing beam line elements, recuperated from the former installation, would be used. The final choice uses a doubly focusing 90° bending magnet which can be tilted up around its incoming axis to an angle of 45 degrees. When the beam reaches the height of 5 metres, it is bent back in the horizontal plane by a 45°

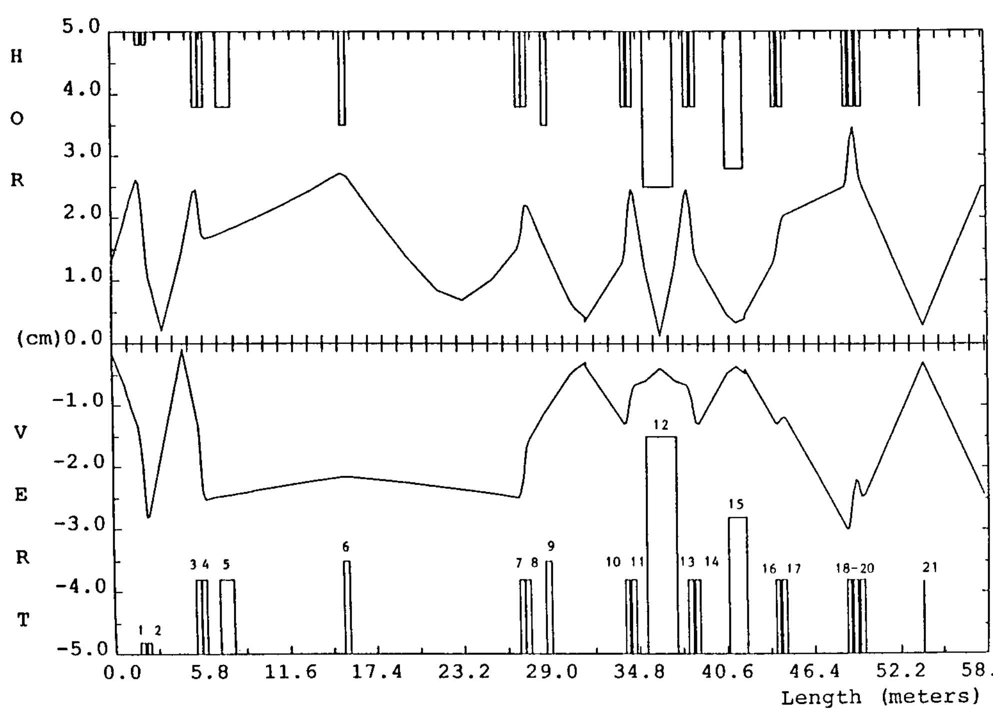

Figure 2. Beam envelopes along the transport line between the cyclotron and DEMON.
1, 3, 8, 11, 13, 17, 19 : horizontally focusing quadrupoles ;
2, 4, 10, 14, 16, 18, 20 : vertically focusing quadrupoles ;
6, 12, 15 : bending magnets ; 21 : target.

magnet. Underneath this line, another experimental set-up is installed which can be connected to the rest of the beam transport system by lowering the 90° magnet to its horizontal position when DEMON is not used. Other goals set for the design of these new lines were: a) minimise dispersion at the target location. b) keep the spot size on target within a 6 mm diameter. c) assure 100 % transmission. d) minimize the cost of the 90° magnet (small gap, optics rather unsensitive to small deviations from nominal values of its characteristics). The beam envelopes for a monoenergetic beam obtained with the TRANSPORT code are shown in Fig. 2. Table 2 shows the effect of energy dispersion on the beam characteristics at the target.

Beam characteristics	$\frac{\Delta E}{E} = 0$	$\frac{\Delta E}{E} = 0.3\ \%$
x/2	0,289 cm	0,290 cm
θ/2	6,191 mrad	6,261 mrad
y/2	0,296 cm	0,296 cm
ϕ/2	6,052 mrad	6,480 mrad
l/2	0,820 cm	0,821 cm

Table 2 : Spot size on target in DEMON with 0 and 0.3 % energy dispersion.

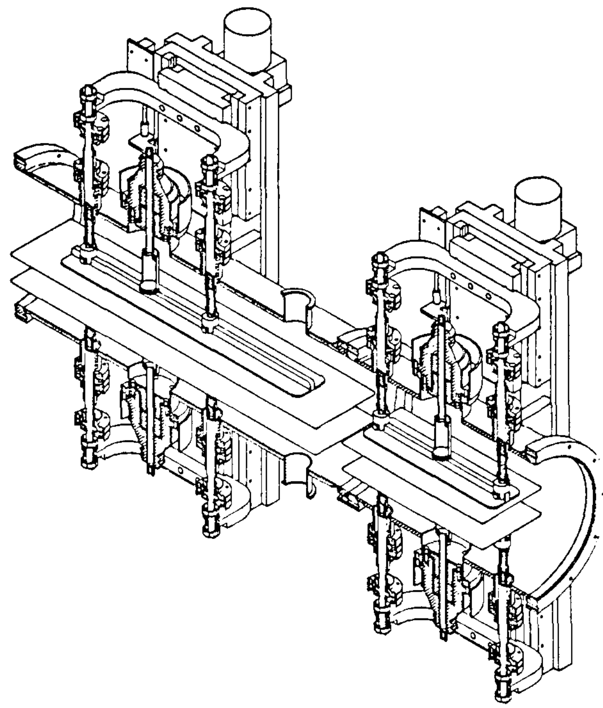

Fig. 3. View of the beam chopper.

3. EXTERNAL BEAM CHOPPER

Several experiments using time-of-flight methods request longer times between beam pulses than the cyclotron normally provides. Since single turn extraction is not practicable with CYCLONE,[2)] it was decided to build an external chopper to be placed in the main beamline between the cyclotron and the switching magnet. The beam chopper consists of two pairs of electrodes of respectively 60 cm and 28 cm length. The gap between electrodes is adjustable but nominally set to 35 mm. The first set is tuned around 1 MHz at a variable subharmonic of the cyclotron frequency. The second one works at the third harmonic. This way, the time between pulses is fixed in the range of 500 ± 50 ns. Peak voltage on the electrodes is 30 kV. Figure 3 shows a view of the electrode system and Fig.4 shows the block diagram.

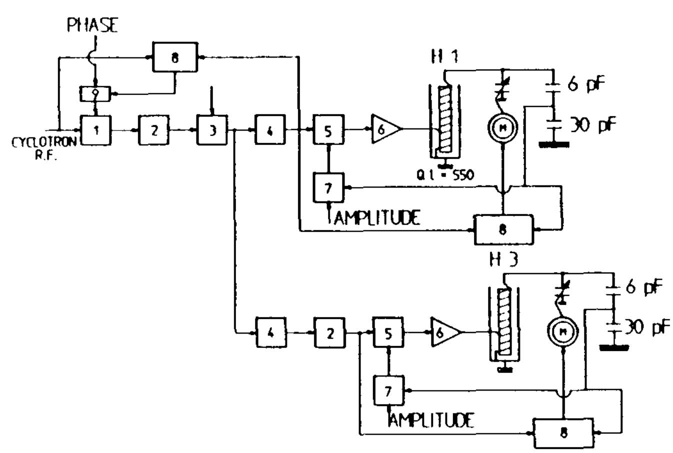

Fig. 4. Block diagramme of the chopper electronics : 1 : phase modulator; 2 : delay line ; 3 : programmable frequency divider ; 4: filter ; 5 : amplitude modulator ; 6 : power amplifier ; 7 : amplitude regulation ; 8 : phase discriminator.

4. MULTILEAF VARIABLE COLLIMATOR FOR NEUTRONTHERAPY

For more than ten years, a fixed collimator with variable inserts of various sizes has been used to define the irradiated field at the level of the patient. In order to be able to generate in all cases an optimally defined neutron field, a multileaf collimator, of SCANDITRONIX design was constructed and put into operation in 1992. The main part consists of two sets (left and right) of 22 leaves of 92 centimeters long. Each leaf can be positioned independently. A maximum field of 30*30 cm at the patient can be obtained. The leaves, made of soft iron with borated polyester disks imbedded, have been optimized to minimize the neutron leakage flux. Figure 5 shows a section through the new collimator.

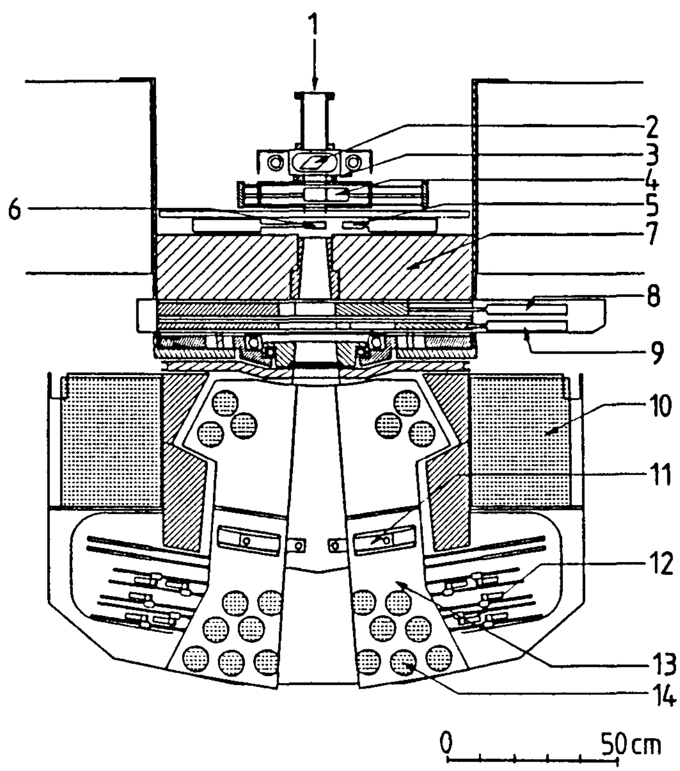

Figure 5. Section view of the multileaf neutron collimator.
1 : 65 MeV Protons (15 µA) ; 2 : Alumina ; 3 : Collimator ; 4 : Beryllium target ; 5 : Filter ; 6 : Light source ; 7 : Iron-precollimator ; 8 : Transmission chamber ; 9 : Filter ; 10 : Borated paraffin ; 11 : Slide ; 12 : Motor + potentiometer ; 13 : Iron leaf ; 14 : Borated polyester.

5. REFERENCES

1) Ryckewaert, G., Loiselet, M. and Postiau, N., "Radioactive ion beam production using the Louvain-la-Neuve cyclotrons : present status and future developments," Proceedings of this Conference.
2) Yokota,W., et al., "Design of beam chopping system for JAERI AVF cyclotron," Proceedings 12th Int. Conf. on Cyclotrons and their Applications (World Scientific, Singapore,1991) pp. 388-391.