THE ORLEANS NEUTRONTHERAPY FACILITY

BRETEAU N.*, SABATIER R.*, BAJARD J.C.** and GUEULETTE J.***
* Centre Hospitalier Regional d'ORLEANS (FRANCE)
** C.N.R.S. (FRANCE) *** Université Catholique de LOUVAIN LA NEUVE (BELGIQUE)

The first Cyclotron adapted for Neutrontherapy were using the Deuteron/Beryllium reaction.

Now, the Cyclotron recently installed or planned therapy, are using the Proton/Beryllium reaction for economical reasons. It is the case at the NEUTRONTHERAPY UNIT in Orleans Hospital in France, were the fast Neutrons produced by the isochronous Cyclotron of CNRS (CGR Mev 680 Type) are obtained with 34 Mev Protons on a Beryllium target with an additional polythene filter.

Since the 18th of september 1980, we dispose of a vertical downward neutron beam, produce by interaction of a 34 Mev proton beam, and a thick target with 40 μA current.

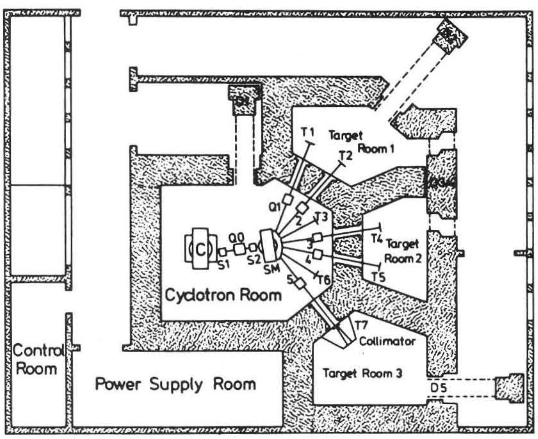


Fig.1 : Facility layout

We have 4 Lines of beam at our disposal : Line 1 is used to produce short lived radioisotopes, Line 2 is mainly used for activation experiments, Line 3 is used to produce I^{123}, at last, Line 4 is intended for Neutrontherapy. The treatment room (CGR Mev) (fig 2) based in the underground, under the beam carring room has an approximate size of 4 x 4 m and 2.5 m height. It is isolated from outside by 2 m of vibrated concrete and the inway lock-chamber allows of a chicane to avoid staff's irradiation.

The main collimator (F 3) is fixed, and made of 3 sorts of material : from up side to down side, we find: Steel, pure Iron, Baryta and boran concrete for the distal part, which is shaped like a hexagonal walls pyramid. The secondary collimator, or Inserts, are movable and define the irradiation field. They are made, for the upperside part of an epoxy resin charged with granular steel and for the downside part, of the same resin charged with borax. The use of these two types of materials has been recommended by J.P. MEULDERS.

The Insert is actually made of 2 nesting parts : the main insert used for all small fields. The secondary Insert specific of the wished field. The whole secondary insert is movable along its vertical axis.

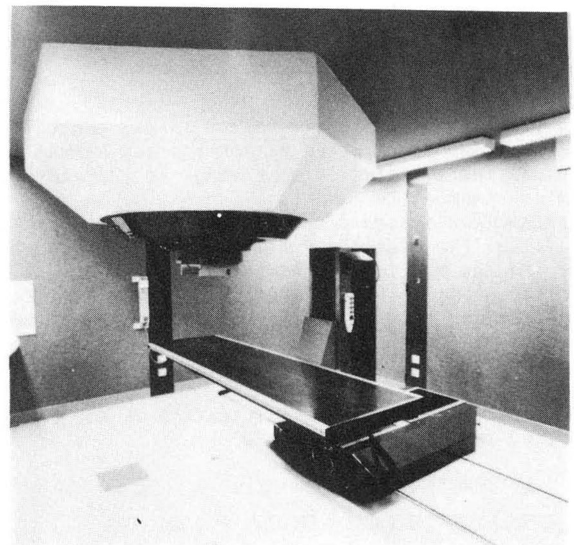


Fig. 2 : Treatment room

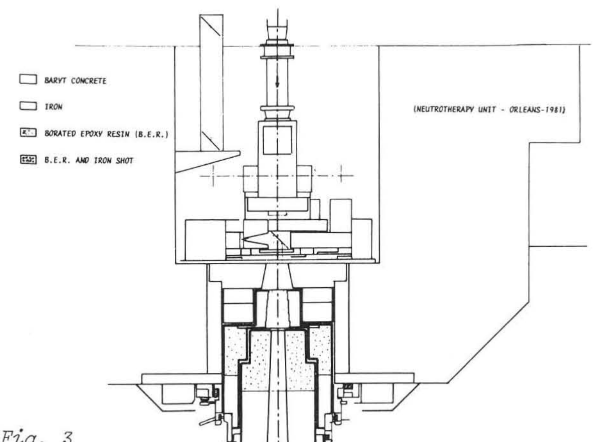


Fig. 3

The target (F 4) consists from upperside to downside of : A retractable alumina allowing the adjustement of the proton beam on the target before irradiation. 4 slits covered with tantalum and assigned to the control of the beam stability during the treatment. To ensure the draining off of the power by the beam (1.5 Kw), the target whose diameter is 50 mm consists from upperside to downside in : 3 mm Beryllium, a 0,5 mm thick strip of deionized water, 6mm Beryllium, a 2nd strip of water, a 3mm thick strip of copper which ensure the vacuum-tightness in the conducting tube. The remote controlled operated cylinder allows the interposition of various absorbants.

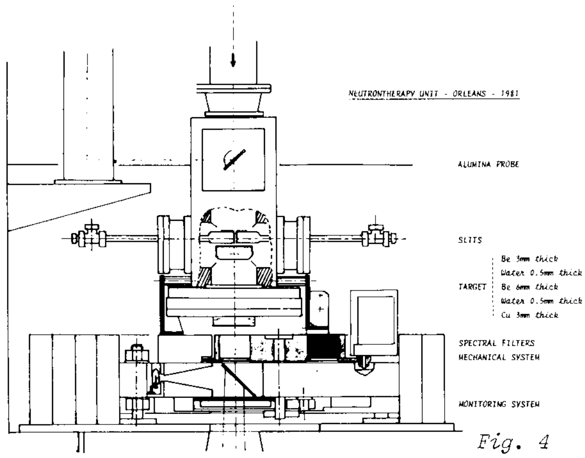


Fig. 4

in the beam. The luminous simulation system consists in an halogen lamp and a fixed mirror made of aluminized plexiglass. The irradiation monitorage is ensured by a ionization chamber
The collimation system inherent filtration therefore consists in: The plexiglass mirror, the target copper strips and the monitoring chambers.
Foresaw to be, as a routine, used by a manipulator the medical command desk is ran by a microprocessor and its concept is as close aspossible of the linac command desk.

The main physical characteristics of the beam are summarized in table I :

INTERACTION : 34 Mev P / Be
BERYLLIUM TARGET : THICK - 9 mm -
PROTON BEAM CURRENT : 40 μA
ADDITIONAL FILTER : POLYTHENE -50 mm-
COLLIMATION FOR FIELD SHAPING:
Fe + Polyester + Borax = 60 cm
S.S.D : 135 cm
WITH A 10 x 10 cm FIELD AT S.S.D 135 cm:
TISSUE KERMA IN AIR : 0.17 $Gy.min^{-1}$
GAMMA COMPONENT IN AIR : 6.5 %
DEPTH OF 50 % DOSE : 11.8 g cm^2
PHANTOM : shonka

The influence of the variation of the different parameters according to the filtration thickness has been studied: without any filtration, the dose rate is : 0.3 $Gy.min^{-1}$.

Before the treatment of the patients, we have compared the biological effects of our beam with those of the Deuteron fifty Mev neutron beam of Louvain La Neuve (Pr WAMBERSIE, BELGIUM).

We have compared the Relative Biological Effectiveness values of the two beams for early tolerance in mice after total body and abdominal irradiation in one and many fractions. The biological criterion is the L.D fifty (DL 50) at the five-sixth day after irradiation, the reference beam are the sixty Cobalt Gamma Rays.
The death scored at a given time after irradiation corresponds to a given survival level of intestinal stem cells.

On figure 5 , the curve on the right is the best theoretical cellular survival curve for the intestinal stem cells irradiated by Gamma, obtained from a series of experiences in fractionated irradiation up to twenty fractions. It is derived from measures of increasing of the LD 50 when keeping the overall time constant-each of the fraction of our irradiation in N fractions is split in two subfractions separated by three and half hours.

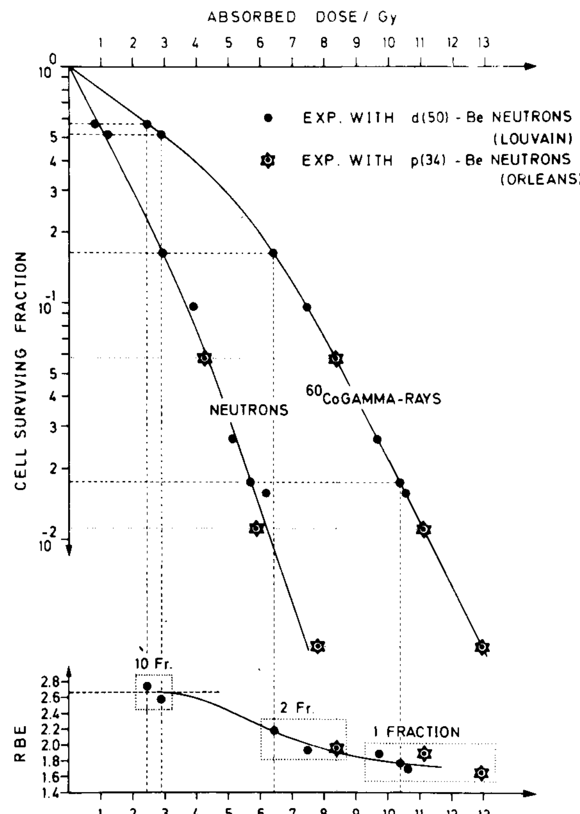


Fig. 5

The closed circles on this Gamma curve, correspond to the Gamma doses per fraction obtained with the RBE experiments of Fifty Mev neutrons, for irradiation in one, two and ten fractions.
Left of each of them, one has put the corresponding neutron point, wich allows to trace the best neutron cell survival curve. The down curve shows the variation of the RBE expected from the comparison between the two cell survival curves obtained in this way. As one can see, the star like points for experiments with Proton thirty four Mev neutrons of Orleans can be eventually mixed with those of Louvain La Neuve.

For total body irradiation in a single fraction, if one considers the dose survival curves at 30 days, taking as hundred percent the survival at the 7 th or the 8 th day, one observes an hematopoietic Relative biological Effectivness of one point four, one point five, really inferior to the intestinal R.B.E.

(Figures 6 and 7 have been realized in the professor WAMBERSIE's laboratory - Louvain La Neuve-).

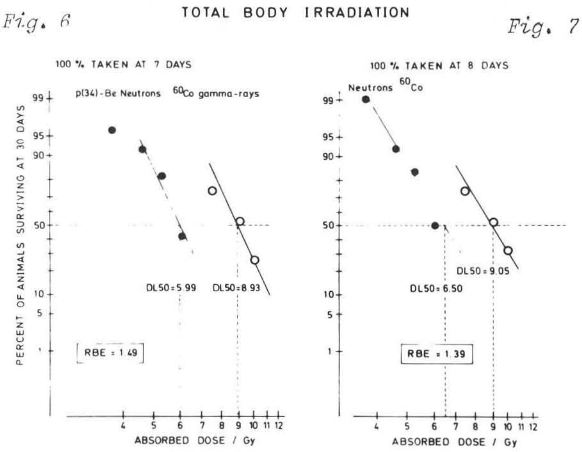


Fig. 6 Fig. 7

Radiations around the Neutrontherapy Unit

Measures of radiations are effectuated by means of a rem-counter model 2202d Studwick and an ionization chamber for neutron and gamma. The collimator is equipped with its insert of 15×15 cm. Figures 8 -9 show the results for the groundfloor and the basement respectively. Controlled area consists of basement and carrying beam room.

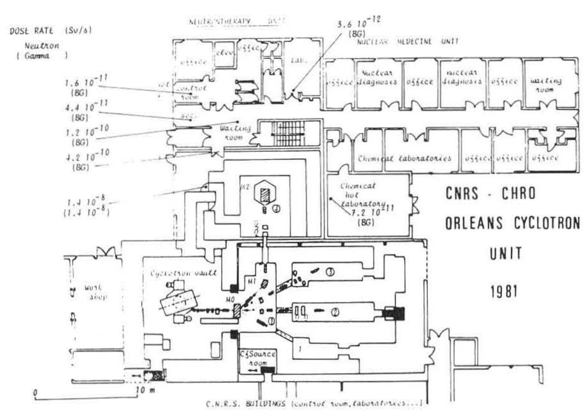
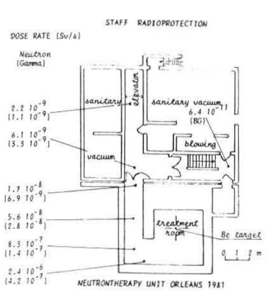


Fig. 8



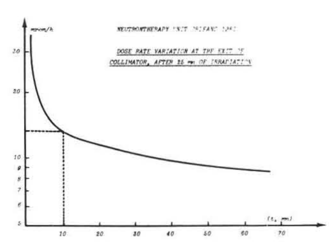


Fig. 9 Fig. 10

Residual activation of treatment room.

Figure 10 shows the activity of collimator after an irradiation. This activity is caused by radionuclides such as ^{15}O, ^{11}C, ^{56}Mn. Theses radionuclides are the result of activation of oxygen, carbon, iron incorporated in the collimator. Because of good protection accorded by this one, walls of treatment room are practically not activated.

Activation of air in treatment room.

Table II shows radionuclides present in air of treatment room. Radionuclides are identified and measured by GeLi gamma spectrometic analysis of small appropriate targets.

Characteristics of treatment room:

-Total volume : 53 m3

-Irradiated air volume under collimator (with its insert of 15×15 cm) : 0.080 m3

-Air turnover : 7 (in room volume by hour)

^{41}Ar is the only radionuclide to exceed the M.P.C.-40h at saturation. If including air turnover, air dilution and time irradiation, concentration of these radionuclides are well beneath the Maximum Permissible Concentration.

All measures are given for a 34 MeV proton beam at target intensity 40 μA.

AIR CONSTITUANTS	PRODUCT RADIONUCLIDE	HALF-LIFE	NUCLEAR REACTION	SPECIFIC ACTIVITY ** AT SATURATION (Bq/m^3)	MPC 40h (Bq/m^3)
Nitrogen	^{13}N	9.97mn	$^{14}N(n,2n)$	$2.3\ 10^5$	$4.8\ 10^6$
Oxygen	^{16}N	7.14s	$^{16}O(n,p)$	$7.4\ 10^6$ *	$8.1\ 10^7$
	^{15}O	2.05mn	$^{16}O(n,2n)$	$1.7\ 10^6$	$1.7.10^7$
Carbon	^{11}C	20mn	$^{12}C(n,2n)$	$3.8\ 10^2$	$2.6\ 10^6$
Argon	^{41}Ar	1.83h	$^{40}Ar(n,\gamma)$	$3.4\ 10^5$	$4.4\ 10^4$
	^{39}Cl	56.2mn	$^{40}Ar(n,p)$	$3.4\ 10^5$	$4.1\ 10^6$
	^{37}S	5.06mn	$^{40}Ar(n,\alpha)$	[illegible].0 10^4 *	-

* Estimated.
** Average concentration in the irradiated volume (under collimator).

Table II

Fig. 11 shows the dose measured outside the field in a polythene phantom.

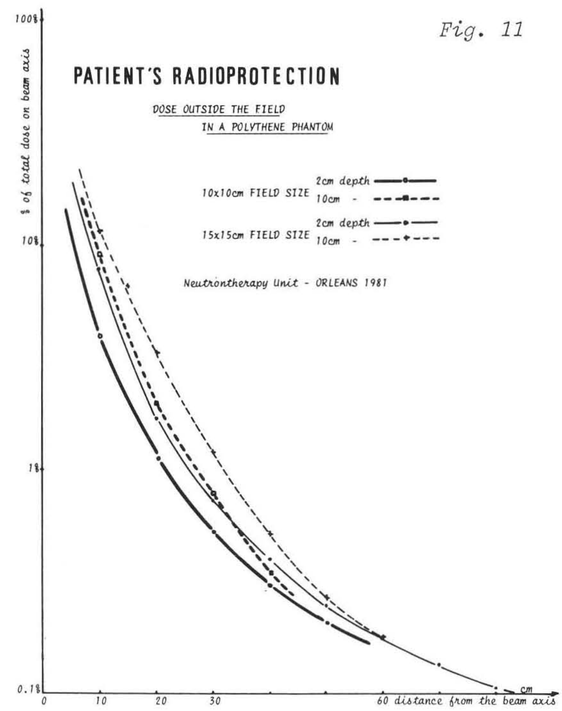


Fig. 11

The clinical study has begun since the 20th of January we have treated presently 30 patients in phase I study. We use the same protocol as Louvain La Neuve:
9 or 10 Gy equivalent Gamma in 5 fractions a week,
3 Neutron, 2 Photons.