CYKLOTRON FOR MEDICAL AND PHYSICAL USES IN SLOVAK REPUBLIC

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1. Introduction

In Slovakia there were several efforts to built Laboratory with nuclear equipment, for instance 30 years ago there was idea to built cyclotron for production of radionuclides used in nuclear medicine, in 80 -ties cyclotron for radiotherapy and about 10 years ago reactor for nuclear physics purposes. Now we are facing the situation with the strong need for Cyclotron Laboratory. There are at least three reasons for building such a complex. Two of them are connected with health care of Slovak population and the third one is concerning the science and technical research in field of nuclear physics.

Recently in Slovak Republic is evident trend of sharp increasing of cancer and cardiovascular diseases and they are the leading causes of deaths among the Slovak population. Nowadays for cancer treatment in Slovakia are available only conventional sources of radiotherapy, which are very often ineffective or inappropriate for treatment of some kind of tumors or because of their close localization near for life important organs. In these cases the only one solution is to involve the hadron therapy using proton and neutron therapeutic beam produced by the charged particle accelerators.

The best chance for successful treatment of the patient is early diagnose of tumor.
This can be reach by using the positron emission tomography (PET). To compare with nuclear magnetic resonance diagnostics or computer tomography, this method is able to diagnose the early stage tumor even two year earlier. PET is using the ability to detect very precise the positron emitters distributed in human bodies with special coincidence camera. When the special carriers with the affinity to the selected organs or type of cells are labeled by radionuclide emitting positrons, one can follow the biokinetics and accumulation of carrier in different parts of body.

In this way is possible to detect not only the tumors in their very early stage but also the cardiovascular, nervous system and brain diseases. The half-life time of positron emitters is short (tens of minutes). This is very favorable because of low radiation burden to the patient, but on the other site this imply the need for building the cyclotron in the close vicinity of PET diagnostic center.

Slovak Republic is country with three nuclear power plants, but there is no nuclear research center for education of nuclear physic specialists. Nowadays in Slovakia is shortage of high quality experimental equipment and in connection with this the high specialized Slovak scientists are involved to the international scientific research center like CERN, Darmstadt , with no possibility to built the own scientific-technical base. The logical result of this situation is the decreasing quality of education of nuclear physic students.

The Cyclotron Laboratory is being built with the goal to create the modern center with the wide possibilities for medical purposes, for industry and science and the educational reasons. The similar projects are elaborated also in Czech Republic (230 MeV proton accelerator for therapy), in Poland (60 MeV cyclotron for eye proton therapy and fast neutron therapy), in Austria (Austron-Med complex of accelerators for hadron therapy) and there are some activities for building such multipurpose complexes for medicine, science and research in Hungary.

II. Proposal for CYLAB

Cyclotron Laboratory is supposed to be the modern multipurpose complex for main activities in the field of radiotherapy and nuclear medicine, science, techniques, applied research and education, *as one can see on Fig.1.*

PET cyclotron is small cyclotron with the accelerated proton energy up to 18 MeV for production of radionuclides for nuclear medicine for positron emission tomography (PET).

The Basic Cyclotron with the 72 MeV proton energy will produce other radionuclides used in nuclear medicine, mainly the ^{123}I.

The 72 MeV protons are appropriate for some special kinds of hadron therapy, like proton therapy of eye tumors (PT), fast neutron therapy (FNT) and one of the most promising methods for treating the special kind of tumors – boron neutron capture therapy (BNCT).

The Basic Cyclotron will also produce the light and heavy ion beams up to Xe what will offer the wide possibilities in the applied research by solving different scientific and technical problems.

Together with using the CYLAB for medical, scientific and technical purposes, there will be running the educational program not only for students in physics but in medicine, techniques and mathematics as well.

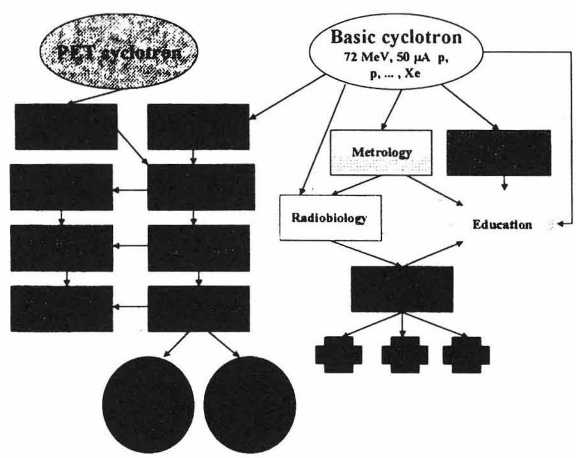


Fig. 1.

III. The construction of CYLAB

Cyclotron Laboratory (CYLAB) will build in the area of Slovak Institute of Metrology (SIM), which is now just being finished. The building site has a square shape with the area about 3500 m^2 .

The area of SIM is localized beyond the dense occupied parts of the city with the very good access to the highways to Czech Republic (145 km from Brno), to Austria (60 km from Vienna) and to Hungary (200 km from Budapest).

The actual construction of building will be performed by Slovak site. That is the reason why in the next we concentrate our attention to the CYLAB building project. The most complicated problem is to divide the areas (cyclotrons, radiotherapeutic rooms, rooms with the radionuclides production) with the intensive gamma and neutron radiation. The shielding will satisfied the ICRP 60 limits (1).

The calculations of the wall thickness was performed by 2 different methods (according a type and energy of radiation). These calculations were often doubled, to be sure about right results, because the thickness of walls are sometime about 3.5 m and every mistake in shielding calculation would be very expensive one. For more flexibility we decided to use the modular shielding system consisting from removable concrete blocks.

IV. The calculation of the wall thickness and maze of the irradiation room for BNCT

The protection of the BNCT irradiation room is very pretentious, because there is a very little information about the shielding. In the center of BNCT room there is a gantry (2) which is able to move the therapy epithermal neutron beam to the patient. The gantry for BNCT is shown on Fig.2.

In the center of gantry is localized the neutron source with the emission of $5x10^{13}$neutrons. The source of neutrons is based on the spallation process in which 72 MeV protons impact on a heavy target from tungsten, with the proton beam intensity about 50 μA. System of reflectors concentrated neutrons to moderator site, which is just in front of patient.

On Fig.3 are spectrum of the neutron energy penetrating from the gantry surface in different directions. The shielding of BNCT rooms were calculated for the most " pessimistic" situation – front patient side, when the neutron energy spectrum is the less convenient. The thickness of shielding was calculated for annual irradiation

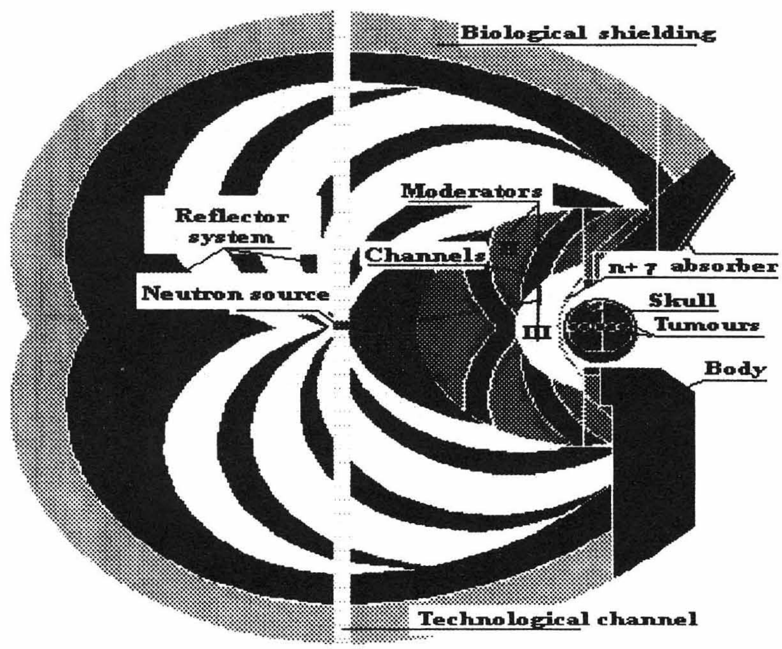
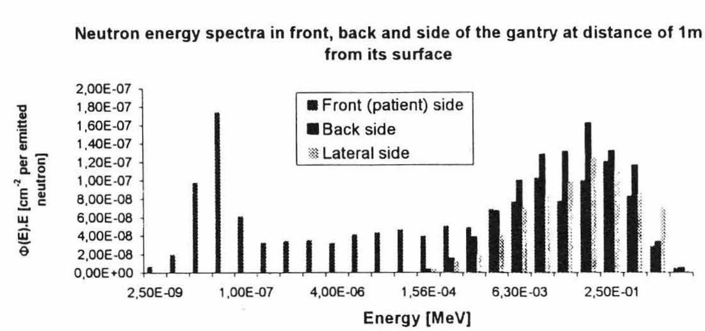


Fig. 2. Gantry for BNCT patient.



time about 250 hours and the occupational limit was determine to be 2 mSv per year what represents 1/10 of occupational annual limit according the ICRP 60 (1).

Table 1 presents some results of calculations of the maze with the walls 2 m thick from ordinary concrete. Dose equivalent attenuation behind the door is about factor 1000 for neutrons and about factor 20 – 30 for gamma rays. The main component of the dose equivalent behind the shielding is from gamma radiation. The dose equivalent around the BNCT room is lower than 2 mSv, except the site behind the door, what should be indicated.

DOSE CHARACTERISTICS IN VICINITY OF ROOM FOR BNCT

Locality		1	2	3	4	5
Void door	n	2830	42.4	-	-	-
Maze 250 cm	p	314	2.9	-	-	-
Void door	n	2130	26.6	-	-	-
Maze 350 cm	p	242	2.93	-	-	-
Void door	n	1560	24.6	-	-	-
Maze 450 cm	p	174	3.13	-	-	-
Door PE/Pb 25/5 cm	n	1.4	0.0245	-	-	-
Maze 350 cm	p	11.34	0.16	-	-	-
Door PE/Pb 25/5 cm	n	0.62	0.012	6.8e-6	2.76e-6	12.8e-6
Maze 450 cm	p	5.76	0.049	0.005	0.012	0.008

Door PE/Pb 25/5 cm -- 25 cm boronated polyethylene (3 % B-10) lined with 5 cm of lead

n -- neutron equivalent dose rate [mSv/year] (250 working hours per year)

p -- photon equivalent dose rate [mSv/year] (250 working hours per year)

Localities -- 1 in front of the door, 2 in front 525 cm from 1, 3 on the left side, 4 on the right side, 5 on the top

V. Conclusion

In Bratislava there is a quite elaborated project of the construction of Cyclotron Laboratory for purposes of medicine and physics. Slovak government by the end of this year will make the final decision about the definitive size of this project, which is supposed to be finished in 2003.

Literature

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