SHIELDING DESIGN ON THE ″TESLA″ ACCELERATOR INSTALLATION IN THE INSTITUTE OF NUCLEAR SCIENCES ″VINCA″

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1.ABSTRACT

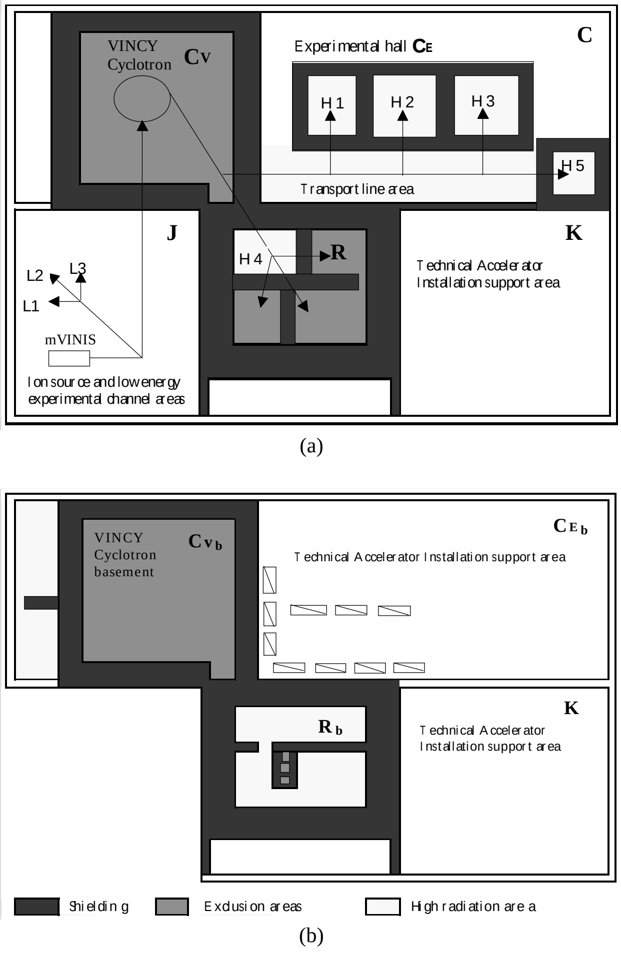
The TESLA Accelerator Installation is planned to be an ion accelerator facility consisting of an isochronous cyclotron - the VINCY Cyclotron, a heavy ion source - the mVINIS, a D^- and H^- ion source - the pVINIS, three low energy experimental channels, and five high energy experimental channels. The VINCY Cyclotron will be able to deliver approximately 1 μA of 36 MeV per nucleon O^{8+} ions, approximately 100 nA of 23 MeV per nucleon Ar^{16+} ions, and approximately 700 nA of 7 MeV per nucleon Xe^{28+} ions. It will be able to deliver also heavy ions of lower energies - above approximately 3 MeV per nucleon. This machine will be able to give approximately 20 μA of 73 MeV deuterons, and approximately 2 μA of 66 MeV protons. Shielding design of such multipurpose accelerator installation requires a number of nuclear data input including the energy and angular distribution of the neutron - gamma source term, the neutron attenuation lengths, dose equivalent attenuation characteristics. Substantial lack of these data, especially for protons and deuterons in the mentioned energy range caused some problems in the shielding calculations. Shielding design for this specific installation will be presented in this paper.

2. RADIATION SHIELDING

On the basis of worldwide experience in the cyclotron and target areas shielding we have decided that practically all shielding should be built from ordinary concrete with a density of 2.4 t m^{-3}. Some shielding walls will be built as monoliths, and others from concrete blocks with removing possibilities. Schematic layouts of the TESLA Accelerator Installation with shielding walls and indicated radiation areas are presented in Fig. 1.

2.1. Shielding calculations

The design of a practical shielding arrangement for medium energy accelerators are generally a rather complex task for which no simple hand-book formula is adequate [1,2]. At best the calculation for the shielding of a medium, as well as high energy accelerator involves many simplifying assumptions to make the problem tractable. Nevertheless the magnitude of the cost at stake and the engineering problems of support and handling forbid the casual use of large margins of safety, and require an attempt at precision compatible with the knowledge of the basic factors of production and propagation of radiation [1,3].



(a)

(b)

Fig. 1. Schematic layouts of the TESLA Accelerator Installation: (a) - on the ground level, (b) - on the basement level

The first goal of all efficient accelerator shielding designs is to attenuate the high radiation intensities produced by the accelerator and its associated equipment to levels that are acceptable outside the shielding, at minimum cost and without compromising the utility of the particle accelerator for its designed purposes. The first and most important and most complicated step is to determine of radiation sources, i.e. the space, time, particle and energy distribution of radiation fields [4]. It is, therefore the most complicated step in solving radiation protection and shielding problems on the TESLA Accelerator Installation as well, especially due to the substantial lack of information about interaction cross sections for the most important accelerated particles, from the radiation protection point of view - protons and deuterons, and produced neutrons, in the energy range of interest [5,6].

In order to calculate necessary shielding wall thickness we have used a simple exponential attenuation function for predicting the neutron ambient equivalent dose behind the shields:

$$H\cdot R^2 = \int B(E)\cdot \frac{d^2Y}{d\Omega\cdot dE}\cdot h(E)\cdot e^{-x/\lambda(E)}dE, \qquad (1)$$

where $B(E)$ - the buildup factor and $\lambda(E)$ - neutron equivalent dose attenuation length, $h(E)$ - neutron fluence to equivalent dose conversion factor, and $d^2Y/d\Omega dE$ double differential distribution of produced neutrons by accelerated ions.

2.2. Cyclotron vault

According to the planned characteristics of accelerated ion beams, their energy, intensities, mass and charge of ions, we have concluded that the biggest problem for cyclotron shielding will be with deuteron acceleration. Sides of the vacuum chamber will be the source of secondary neutrons due to the interactions of deuterons lost from acceleration, with average energy about 30 MeV/nucleon. It was assumed that the number of deuterons lost from acceleration, J, would be about 10^{13}, and that the emitted neutron spectrum would be with average energy in the range from 5 to 20 MeV. On the basis of these assumptions from the exponential attenuation function for the ambient equivalent dose rate [7], $\dot{H}$, out of the shield walls

$$\dot{H} = J\cdot f\cdot \frac{Y\cdot B\cdot h}{4\pi\cdot R^2}\, e^{-x/\lambda} \qquad (2)$$

where: Y - neutron yields per one deuteron lost from acceleration, B - buildup factor, λ - ambient equivalent dose attenuation length, h - neutron fluence to equivalent dose conversion factor for neutrons penetrated through shielding wall, x - shielding wall thickness, and R - distance from neutron source to the point of interest, using iterative method, we have calculated cyclotron shielding vault wall thickness on the cyclotron and the basement level, as well as the cyclotron vault roof thickness.

There were many reasons to make some compromises in order to get optimal cyclotron vault design. Some details of cyclotron vault design, with accepted wall thickness in the range from 1.8 to 2 m, are presented in Figures 2 and 3

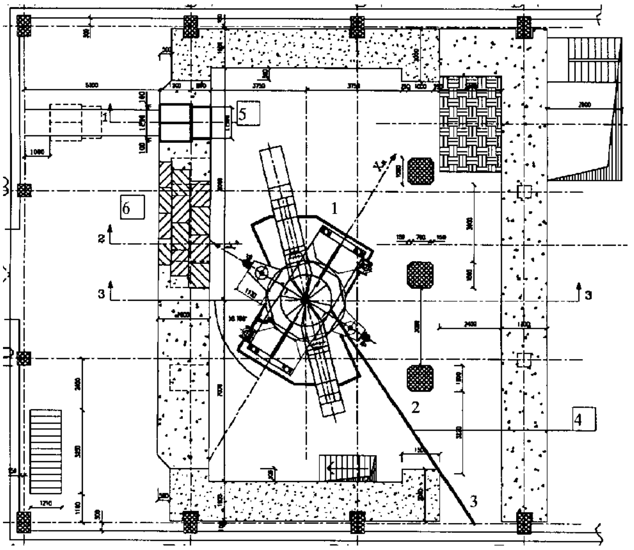


Fig. 2. Layout of the cyclotron vault on the ground level. 1 - Cyclotron VINCY; 2 -The main transport line; 3 - Transport line to the radioisotope production (channel H4); 4 -Transport line to channels H1, H2, H3 and H5; 5 - Shielded door; 6 - Removable part of the shielding wall

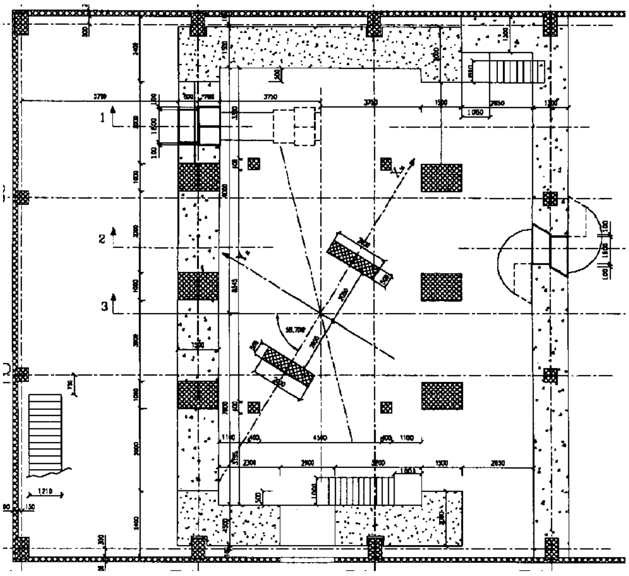


Fig. 3. Layout of the cyclotron vault on the basement level

Shielding walls were designed so that total (neutron + γ) ambient equivalent dose rate outside the shields has to be less than 10 μSv/h in the areas occupied by professionally exposed workers, and less than 0.1 μSv/h in the areas that can be occupied by non-radiation workers and members of the public [8].

2.3. Radioisotope production vault

The radioisotope production vault, **R**, is planned to be built as a separate building located between halls **C**, **J** and **K** (Fig. 1.). It is the best way to minimize possibilities of accidental contamination of the other components of accelerator installation and build a heavy shield in order to minimize contribution to the ambient equivalent dose rate in the neighboring area, and to make a separate ventilation subsystem and a separate cooling water system.

Shielding calculations have been made on the same assumptions as for the cyclotron vault, but having in mind that the main ion beams would be:

- protons of energy 11 - 16 MeV (up to ≈ 50 μA),
- protons of energy 21 - 36 MeV (up to ≈ 40 μA),

for routine production, and

- protons of energy 40 - 75 MeV (up to ≈ 2 μA), and
- deuterons of energy 43 - 70 MeV (up to ≈ 20 μA),

for experimental radioisotope production.

The layout of the radioisotope production shielding vault with three separated target stations and switching magnet and transport lines room are considered [9].

The thickness of the shielding walls was calculated according to the accepted nuclear reactions for routine radioisotope production with optimal particle energy and maximal available ion current. For the predicted worst case from the radiation shielding point of view, the ^{201}Tl production in nuclear reaction

$$^{203}\mathrm{Tl}\ (p,3n)\ ^{201}\mathrm{Pb} \rightarrow\ ^{201}\mathrm{Tl}$$

with 40 μA of 30 MeV protons, preliminary option for optimal shielding design is defined [9].

Shielding walls built from ordinary concrete with a density of 2.4 t·m^{-3}, with a thicknesses of 2.5 and 2 m will assure that the neutron ambient equivalent dose rate in the areas occupied by professionally exposed workers would be considerable smaller then 10 μSv/h. Having in mind that the contribution of gamma radiation to the total ambient equivalent dose rate, for the actual energy range of accelerated particles and thickness of the shields is less then 10 % of the neutron ambient equivalent dose rate, the total ambient equivalent dose rate will stay within safe limits.

3. CONCLUSION

The radiation safety programme is part of a comprehensive occupational health programme on the accelerator installations. One of the basic elements of the radiation safety programme is shielding design. Shielding design strongly influences other elements of the radiation safety program, such as radiation monitoring programme, definitions of controlled and supervised areas, and exclusion and high radiation areas, as well as working protocols and procedures.

As on many of the other similar accelerator installations, in designing radiation shielding on the TESLA accelerator installation, we have made some compromises in order to get optimal radiation safety programme, which could be able to facilitate the safe [8] and effective operation of the accelerator, according to the needs of the operating installation.

4.REFERENCES

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