# PROJECT OF ROTATING CARBON HIGH-POWER NEUTRON TARGET. CONCEPTUAL DESIGN.

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*Abstract*

The project of high intense neutron source for SPES project in LNL, Legnaro has been developed. The source is based on rotating carbon target. The target is bombarded by deuteron beam with energy 20 MeV, diameter 1 cm, average power 100 kW, and cooled by its thermal radiation. The source can produce up to $10^{14}$ neutron per second with energy within a range of several MeV and has lifetime of about a thousand hours.

## 1 INTRODUCTION

For the experiments with the radioactive nuclei beams, the high intensity ($10^{13}$ - $10^{14}$ particles per second) source of fast neutrons is necessary. Our paper presents the project of such source proposed in the framework of SPES project in LNL (Legnaro, Italy) [1]. The source is based on the neutron target irradiated by the deuteron beam with the energy 20 MeV, average current 5 mA, diameter 1cm, average beam power is 100 kW. The stationary design of the target is impossible because the heat extraction in it can reach 850 W/mm$^3$, and it is necessary to provide the heat flux density up to 130 kW/cm$^2$. Such operational conditions are unacceptable for possible target materials. Thus, the target effective area and volume must be increased. We propose the rotating target with graphite operatoinal area. The use of graphite makes possible to cool the target by its thermal radiation.

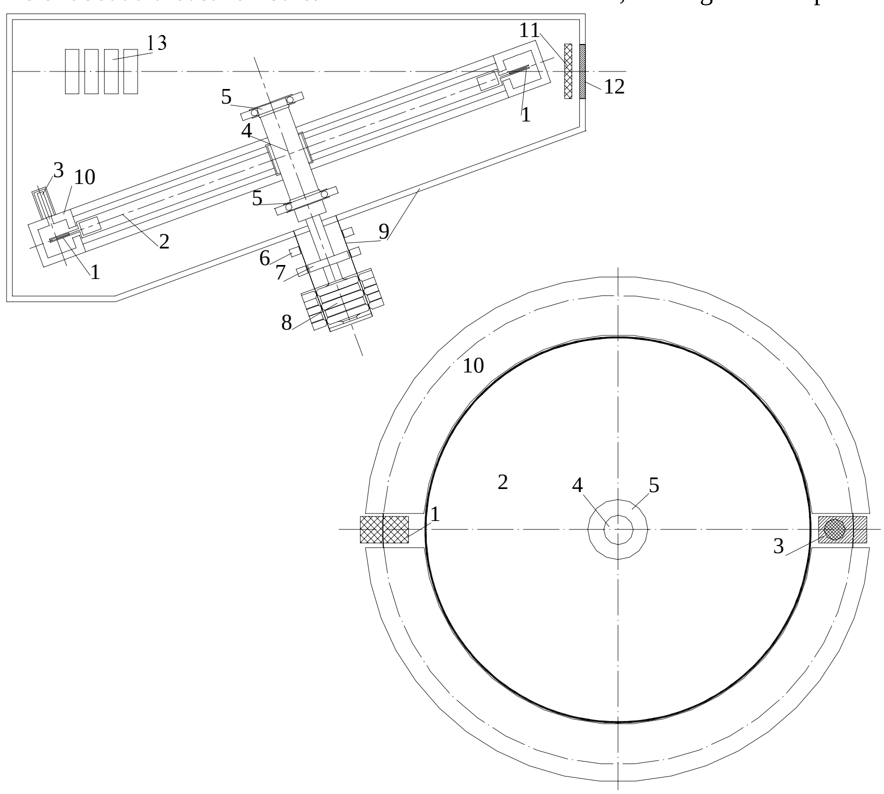


**Figure 1** *Neutron target design.*

1 - *graphite plates*, 2 - *titanium disk*, 3 - *bolometer*, 4 - *shaft*, 5 - *bearings*, 6 - *vibration pick-up*, 7 - *magnetic sensor of rotation*, 8 - *magnetic clutch*, 9 - *vacuum chamber walls* 10 - *cooling channels*, 11 - *capacitance-type sensor*, 12 - *neutron beam output window*,13 - *collimator*

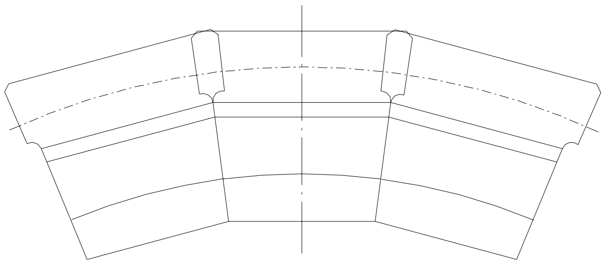

**Figure 2** *Graphite plates design*

## 2 GENERAL DESIGN

The neutron target can represents (Fig.1) the wheel, arranged with the graphite plates (Fig.2) of 3cm width and 1.5-2 mm thickness. The plates are set on the titanium disk of 60 cm diameter and 1cm thickness. The disk is set on the shaft of 5 cm diameter and rotated with the frequency 50 Hz. The input of rotation into the vacuum volume is carried out by the magnetic clutch. The deuteron beam hits the graphite surface to the angle $20^0$. The dissipation of heat is carried out by the water in the aluminium channels that are rigidly attached to the vacuum chamber (Fig.3) and performed as two semicircles. The operational (beam) and diagnostic (bolometer) regions are placed in the semicircles gaps. Collimator, that also acts as the beam position monitor, is placed before the target. A window for neutrons output is located behind the operational area. Before the window the graphite plate is placed. This plate serves as an indicator of graphite damages and, at the same time, protects the vacuum chamber from the deuteron beam. For target control and protection, the rotation sensor and vibration pick-up are provided as well as the flow meters and manometer in the hydraulic system.

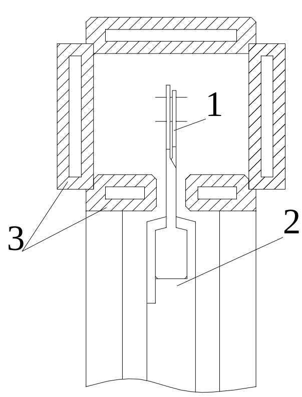


**Figure 3** *Layout of cooling channels. 1 - graphite plates, 2 - titanium disk, 3 - heat dissipation channels*

## 3 COOLING CHANNELS

The cooling channels represent two semicircle boxes made of nielloed aluminium with the channels of rectangular cross-section 5 cm x 0.5 cm. For hydraulic system parameters calculations one assumes that het flux into the water $Q = kS\Delta T$ [1] is transferred through the channels walls directed to the graphite plates. Here $\Delta T$ - the temperature gradient between the wall and the water, $S$ – the area of transferring surface and heat transfer ratio

$$k = 2.3 \cdot 10^{-2}\,\mathrm{Pr}^{0.4}\,\mathrm{Re}^{0.8}\,\frac{\lambda}{2b}$$

[2] where Pr = 4.39 – Prandtl number for water, $\lambda$ = 0.63 W/K·m – water thermal conductivity, $b$ – channel width, Re – Reynolds number. If we assume maximum admissible $\Delta T = 50^0$ and suface area – as a inside surface of channel, the minimum required water flow velocity will be 0.9 mps. It gives the total water consumption 1.8 lps and pressure differential in the channel around 0.5 at, when all the water channels are connected up in parallel.

This target can produce up to $10^{14}$ neutron per second with the energy within a range of several MeV (Fig.4). Maximal temperature of target operation area can reach $1800^0$C

## 4 DIAGNOSTICS AND BLOCK-SYSTEM

Four groups of diagnostics and block-system are suggested for of target control:

1. target operational area control group:
   - capacitance-type sensor (also the resistance-type sensor)
   - bolometer
2. group of mechanical sensors
   - vibration pick-up
   - inductive sensor of rotation
3. hydraulic system pick-ups
   - liquid manometers
   - flow meters
4. vacuum gauges.

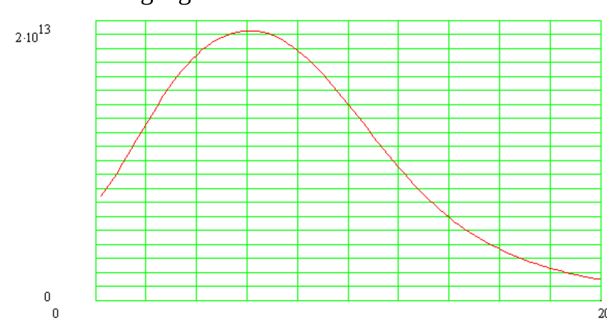


**Figure 4** *Neutrons energy spectrum (neutrons per MeV) versus neutron energy(MeV) at the output of the thick carbon target.*

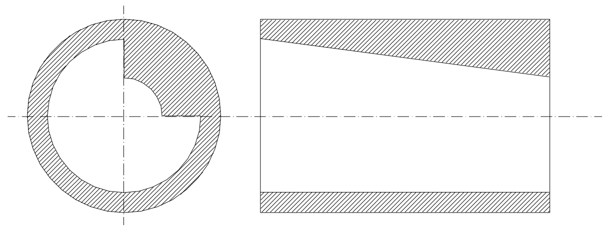

**Figure 5** *Part of collimator.*

Capacitance-type sensors is performed as a graphite plate with dimensions 5 cm x 2 cm x 0.5 cm ( ~3 mean free path of deuterones with the energy 20 MeV). One end of it is fixed on the insulator, another one is connected with the ground potential through the around 1 kOhm ballast resistor. As the target defect appears, the deuterons hit the plate and the resistance indicates a signal. At the defect, for example, with the size 1 cm x 1 mm (crack or erosion), the pulses of near 5 V amplitude and around 100 μsec width appear on the resistor. Moreover, the change in plate resistance due to its heating by the deuteron beam is applied as the additional diagnostic.

At the same time, this plate protects the vacuum chamber wall from the deuterons beam hit in the case of the target break-down. If the full power (100 kW) deuteron beam hits the plate, its heating time of up to the break-down temperature ($2500^0$) will be about 30 ms. This time is accepted as the response time for fast block-systems.

## 5 COLLIMATOR

Collimator consists of the four identical graphite parts as shown in Fig.5. Each detail has the conical lug with angular size $90^0$. All parts are located along the beam axis one by one, each next lug is rotated from the previous one by $90^0$. Such design allows to use the collimator not only for beam halo cut, but also as the beam position monitor. The diameter of the collimator inlet corresponds to the deuteron source aperture, its outlet diameter corresponds to the beam size on the target. The minimum admissible length of the collimator $L$ depends on the power distribution in deuteron beam halo, maximum admissible surface temperature, collimator inlet and outlet diameters: $L_{\min} = 2Q \big/ \sigma\varepsilon T^4 (D_{in} + D_{out})$, where $Q$ - beam halo average power, $T$ - surface temperature, $D_{in}$ and $D_{out}$ - collimator inlet and outlet diameters respectively. For example, for $Q$ = 5kW, $T = 2100^0$C, $D_{in}$ = 2 cm and $D_{out}$ = 1 cm, the minimum length of the collimator will be 5.9 cm, the current from each part will be 62.5 μA.

Collimator is surrounded by the special jacket for heat dissipation.

## 6 CONCLUSION

Neutron sources based on accelerators can be developed as the target from light materials (Li, Be, C) irradiated by $H^+$, $D^+$ beams. There are a number fundamentally possible scheme of target that fit to our parameters. However, Li can be used only as liquid target, and Be requires cooling by liquid agent through rotating cooling channel.

Graphite seems to be the most attractive material. The use of it allows to do without the forced cooling of the rotating target (the operational region is cooled by the thermal radiation). That essentially simplify the target and make it inexpensive, reliable and safe. Moreover, graphite itself is more technologically acceptable and safe than lithium or beryllium.

## 7 REFERENCES

[1]. SPES Project Study. Rep. LNL-INFN 145/99.

[2]. *S.S.Kutateladze*. Heat transfer and hydrodynamical resistance. Moscow, Energoatomizdat, 1990. (in Russian).