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UC_x TARGET DESIGN FOR THE SPIRAL 2 PROJECT AND THE ALTO PROJECT

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Two ways of production of radioactive beams using uranium carbide targets are taken into consideration: fission induced by fast neutrons and by bremsstrahlung radiation. For the SPIRAL 2 project, the fission of ²³⁸U in uranium carbide target will be induced by a neutron flow created by bombarding a carbon converter with a 40 MeV high intensity deuteron beam. Calculations and design of the target in order to reach 10¹³ fissions/s with good release time have been done. The second way is the photofission using an electron beam. In 2005 the ALTO project (Accélérateur Linéaire Auprès du Tandem d'Orsay) will give a 50 MeV/10μA electron beam. This facility will allow more than 10¹¹ fissions/s. In this case, the electron beam hits the target without converter. Calculations realised in order to estimate the production are used to choose the best target shape. For the two cases some R & D on targets to improve release is described.

1. The UC_x targets

For both projects: Spiral 2 with fast neutrons and Alto with electrons same kinds of targets will be used. Targets are based on the Isolde method [1]. Such a type of thick target is an assembly of disks (thickness about 1 mm) composed of a mixing of uranium carbide and graphite. These pellets are obtained by compressing a mix of uranium oxide and graphite powders. The carbonation is made by heating the pellets up to 2000 °C under vacuum to make the reaction:

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$\text{UO}_2 + 6\text{C} \rightarrow \text{UC}_2 + 2\text{C} + 2\text{CO}\uparrow$ or $\text{UO}_2 + 6\text{C} \rightarrow \text{UC} + 3\text{C} + 2\text{CO}\uparrow$. The graphite allows limiting the carbide grain size for minimizing diffusion paths. The figure 1 shows the structure of a target. During irradiation, targets are heated up to 2200°C.

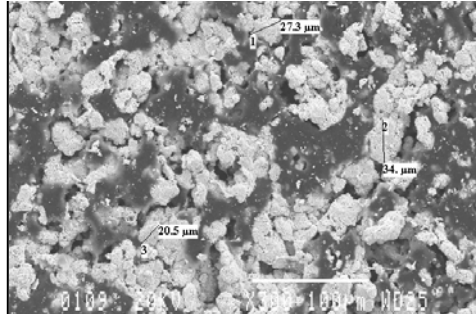


Fig. 1: structure of an UCx target by Scanning Electron Microscopy. The graphite appears in black, the uranium carbide UC and UC₂ in white. The uranium carbide grain size is about 20 to 30 μm.

2. The Spiral 2 target

For the SPIRAL 2 project the specification is to reach 10^{13} fissions/s in the case of UCx target using a 40 MeV/5 mA deuteron beam with a rotating carbon converter [2]. The production of a target irradiated by fast neutrons is estimated using the FICNER code [3]. Thanks to this code one can see the effect of geometrical parameters onto the production. The figure 2 illustrates the importance to put the target as close as possible to the converter.

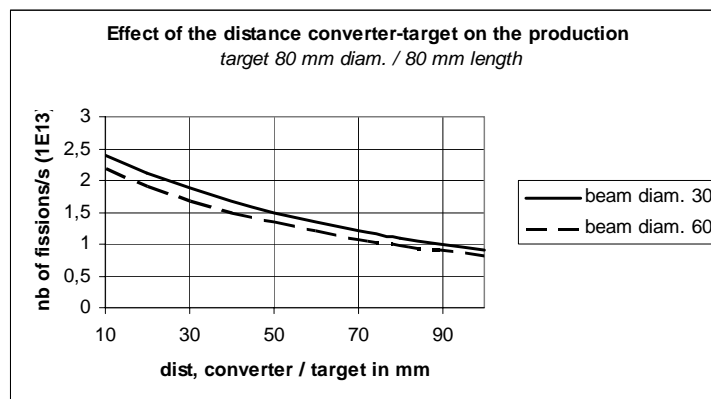


Fig. 2. Effect of the converter-target distance on the production for 2 beam sizes (diameter 30 mm and 60 mm).

With this calculation code it has also been demonstrated that a conical target would not be better for the production than a cylindrical one with the same volume. For the Spiral 2 project we plan to make a target diameter 80-mm, length 80-mm, at about 40 mm from the entrance of the converter (figure 3).

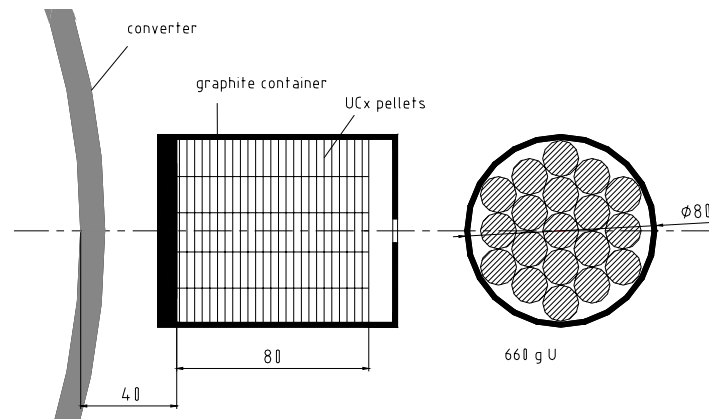


Figure 3. The SPIRAL 2 target: 19 series of about 60 pellets diameter 15 mm, thickness 1 mm, spacing about 0.3 mm between each pellet.

The target has to work at a temperature higher than 2000 °C in order to allow an efficient release of the produced radioactive elements. The power deposited inside the target by the fission reactions is about 500 W for $1.6 \cdot 10^{13}$ f/s. Then, an extra heating must be added in order to reach convenient temperatures. A tantalum oven prototype is under construction. The pellets will be in a graphite container surrounded by a tantalum foil to avoid reaction between carbon and the oven. The main difficulty will be to obtain a homogeneous temperature of the target for a long duration (3 months). Moreover the transfer tube between the target and the ion source has to be heated at 2000°C too for the ionization of non volatile nuclei.

3. The Alto target

For this project the goal is to reach 10^{11} fissions/s using a 50 MeV/10 μ A electron beam to produce radioactive beams in the PARRNE separator already existing at IPN Orsay [4]. The production of the target is estimated using the FICEL code [5]. Due to the absorption of photons the production does not increase proportionally with the target density. The case of a conical shape has

been also studied. The table 1 shows that a conical target 3 times larger would produce only 30 % more fission events than the cylindrical one.

| 1 st diameter Mm | 2 nd diameter mm | Length mm | Volume cm ³ | Nb fission/s for 10 μ A |
|--------------------------------|--------------------------------|--------------|---------------------------|--------------------------------|
| 14 | 14 | 100 | 15 | 1.0 10 ¹¹ |
| 14 | 34 | 100 | 47 | 1.3 10 ¹¹ |

Table 1. Comparison of a cylindrical and a conical target for photofission (target density = 2.4 g/cm³)

For ALTO project we'll use an assembly of about 90 pellets of 14 mm diameter, 1 mm thickness and within a small spacing between each pellet. For such a target, 350 W of the 500 W incident beam will be absorbed in the target, 150 W being re-emitted out of the target as photon radiation.

3.1. The case of a converter

The production in the target using a tungsten converter has been studied. In this case a part of the fission events is due to the photons emitted from the converter. Another part is due to bremsstrahlung radiations produced in the target by the electrons which hit the target if the converter thickness is lower than the electron range in the tungsten.

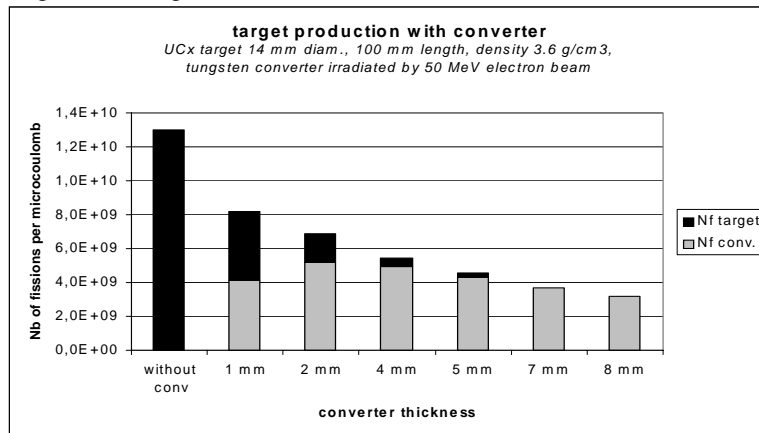


Figure 3. Fission produced in the target with various converter thicknesses. In black: fission induced by photons produced in the target. In gray: fission induced by photons produced in the converter. The converter is in direct contact with the target.

These results proved the production is better without converter. Nevertheless, a converter could be useful to reduce the energy deposited in the target. In fact if the converter thickness is equal to the range of electrons, no

electrons will hit the target and only the energy due to photon absorption will be deposited in the target. The results given in the table 2 show that the converter would reduce the production by a factor 5 while the energy deposited would be reduced by a factor 10.

Table 2. Production and energy deposited in the target without converter and with a 10 mm tungsten converter.

| | Nb of fission per μC | Energy deposition in MeV |
|-------------------|---------------------------------|--------------------------|
| Without converter | $1.3 \cdot 10^{10}$ | 35 |
| Converter W 10 mm | $0.26 \cdot 10^{10}$ | 3.4 |

3.2. Gamma dose rate

Knowing the angular and energy distribution of photons $N(E,\theta)$ emitted out of the target, the dose rate is given by :

$$D(\theta) = \int_E \frac{N(E,\theta)}{F(E)} dE$$

$F(E)$ being the photon conversion factor. The figure 4 confirms that dose rate is very high in forwarded direction, but even in other directions some important shielding becomes necessary.

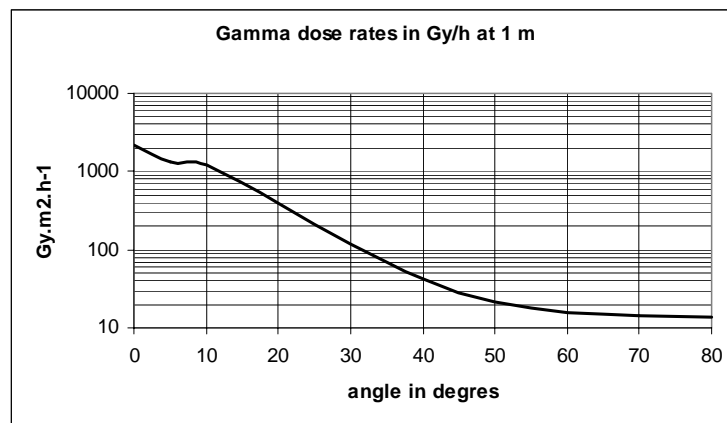


Figure 4: gamma dose rate by an UCx target diam. 14 mm, length 150 mm, density 3.6 g/cm^3 irradiated by a 50 MeV / 10 μA electron beam.

4. The release times (Spiral 2 and Alto)

Some effusion calculations using the Monte-Carlo method have demonstrated that spacing between the pellets can decrease the mean number of collisions of radioactive atoms to get the entrance of the ion source. But in the same time the production will be lower due to the lower effective density of the target. A new kind of target made by an assembly of disks with 3 bumps thickness 0.3 mm has been realized as presented on the figure 4. This new target has been tested on line using the PARRNE set up (25 MeV/1 μ A deuteron beam on a carbon converter).

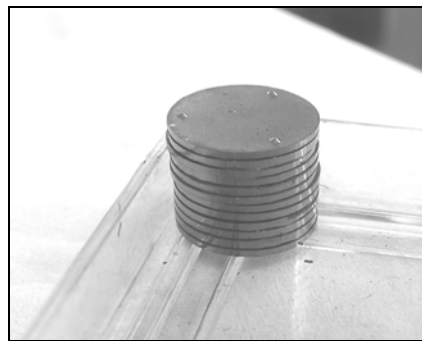


Figure 4: view of a piece of the target with 0.3 mm bumps. The target is constituted of 123 pellets diameter 15 mm. Each pellets thickness is about 1 mm (0.7 mm + 0.3 mm)

Release time measurements on ^{132}Sn and ^{139}Xe have been performed using this new UC_x target. Assuming that the predominant release mechanism is effusion in case of tin and diffusion in case of xenon, the measurement and the analysis have been carried out as indicated in refs. [6,7]. Preliminary results indicate $T_R \approx 40$ s for tin and $T_R \approx 20$ s for xenon. Previous measurements performed with the same target+ion-source temperature conditions ($T_{\text{target}} = 2080^\circ\text{C}$ and $T_{\text{line}} = 2100^\circ\text{C}$) but using a target without bumps had led to $T_R = 55$ s for tin and $T_R = 21$ s for xenon. Consequently, this seems to confirm that with the new target the release time remains the same for diffusion but decreases for effusion.

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