Isotopes Production Calculation for the Direct SPES Target

C. Petrovich 2, A. Andrighetto 1, C. Antonucci 2, M. Barbui 1, S. Carturan 1, S. Cevolani 2, M. Cinausero 1, P. Colombo 4, A. Dainelli 1, P. Di Bernardo 3, F. Gramegna 1, G. Meneghetti 4, M. Lollo 1, G. Prete 1, V. Rizzi 1, M. Tonezzer 1, P. Zanonato 3, D. Zafiropoulos 1

1) INFN Laboratori Nazionali di Legnaro, Viale dell’Università 2, 35020 Legnaro (Pd), Italy; 2) ENEA, Via M.M.Sole 4, 40129 Bologna, Italy; 3) Dipartimento di Scienze Chimiche, Via Marzolo, 1 - 35131 Padova, Italy; 4) Dipartimento di Ingegneria Meccanica, Via Venezia, 1 - 35131 Padova, Italy.

INTRODUCTION

The R&D of the direct SPES target, assumes a 40 MeV proton beam impinging on a UCx target (the isotopic ratio of the uranium compared to the carbon is assumed to be U:C=1:4) of density 2.5 g/cm³. The fundamental parameters of the target system: fission rates, fission fragment distribution and power deposition, have been calculated by means of the Monte Carlo radiation transport code MCNPX [1]. The code is briefly described and some results are reported in the following sections.

THE MCNPX CODE

The MCNPX code allows a detailed 3D definition of the system to be analyzed and a full transport calculation, starting from the proton particles. The interaction physics in MCNPX is determined in two ways: through table-based cross-section data and through on-line calculations by means of physics models. For neutrons below 20 MeV, the nuclear reactions are accounted for by cross-section evaluations. Whenever evaluated cross-section libraries are missing, MCNPX offers different physics models describing the nuclear interactions by the transition of different stages: in the first stage the incident particle interacts with the single nucleons via particle-particle cross-sections emitting high-energy particles and light ions. This phase is called Intra-Nuclear Cascade (INC) and is followed by a pre-equilibrium stage. In the second stage, the residual nucleus either undergoes evaporation, releasing neutrons and light ions, or fissions. In the final stage the excited nucleus decays by gamma emission. Among these physics models there are the Bertini-Dresner Model and the CEM2k (Cascade-Exciton-Model). The fission model used to describe the fragmentation distribution is the RAL (Rutherford Appleton Laboratory) fission model.

Since evaluated cross-section data for protons interacting with 238U are missing (the most important interaction for this target system), a validation of the fission process described by the above mentioned models has been performed [2]. The proton fission cross-section obtained from the MCNPX calculations using the Bertini model and the CEM2k model have been compared with the experimental data found in [3]-[4] (see Fig. 1). CEM2k is in good agreement (discrepancies below 15%) with the data of [3] in the whole energy range. It has some discrepancies (up to 35%) with the data of [4] in the range 35-50 MeV. The Bertini model has discrepancies with the experimental data and with CEM2k in the range 10%-35%. These comparisons are considered here to be good enough for an analysis of the target system by means of MCNPX. The Bertini model has been chosen for these calculations.

ISOTOPE PRODUCTIONS

The Monte Carlo calculations were performed assuming a 40 MeV proton beam with gaussian shape and the target configuration described in the introduction. The calculated fission rate in all the 5 discs turns out to be about $9 \times 10^{12}$ fissions per second ($1.8 \times 10^{13}$ atoms per
second are thus produced). Obviously they are not uniformly distributed in the 5 discs because of the decrease of the disc thickness and of the beam energy: the fission reactions in the last disc are 40% less than those of the first disc.

The distribution of the fission products for the mass numbers $70<A<170$ is shown in Fig. 2. It can be noticed here that the local minimum that is present in thermal neutron induced fissions at about $A=115-120$ is almost absent. This was a desired result since the RIB to be produced lie in the mass range $80<A<160$. The isotope production distribution for some interesting atoms (Ag, Sn, Cs) is shown in Fig. 3, reaching values up to $8 \times 10^{10}$ atoms/s. However it should be remarked that the neutron rich and the neutron deficient sides are over-predicted by the RAL fission fragmentation model.

### CONCLUSIONS

A possible solution for producing exotic nuclei is a configuration with a proton beam with energy of 40 MeV and a current of about 0.4 mA impinging directly on a multiple thin disc UC$_x$ target. The fission fragment distribution and the amount of some interesting atoms have been estimated by means of calculation codes.