average incident energy, this value strictly depends on the beam energy value on the first target and the thickness of each foils (W, Al and Ti).

At the end, the cross-section data obtained for the $^{nat}W(p,xn)^{18x}Re$ reactions have been compared both with the values reported in the literature and with the model calculation using EMPIRE-II release 2.19.

RESULTS AND DISCUSSION

The measured excitation functions are shown below compared with the literature values and, in the ^{186g}Re case, the theoretical one; it is important to stress that the energy range of these graphs is cut so that our data are more visible. In the end, where possible, the computation was carried out using more than one gamma emission.

Rhenium 186g

In this single case the cross-section data are presented divided by the natural isotopic abundance (28.6%). As we can see from Fig.1 present data just lie in the middle between the ones of Zhang and all other authors.

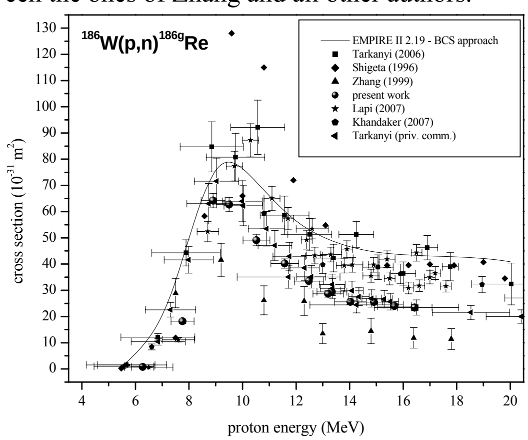

Figure 1: Excitation function of the $^{186}W(p,n)^{186g}Re$ reaction

Rhenium 184g

In comparison with the literature data, it is possible to see in Fig. 2 good agreement at low energy with all authors but while the energy increases, good agreement is kept only with the Zhang values.

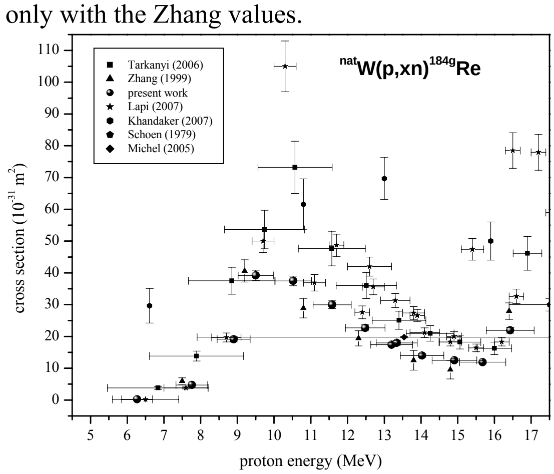

Figure 2: Excitation function of $^{nat}W(p,xn)^{184g}Re$ reactions

Rhenium 183

As we can see from Fig. 3, our set of data is in strong agreement with the one of Tárkányi, while others authors present values that are spread in comparison with our trend, at least at energies up to 17 MeV.

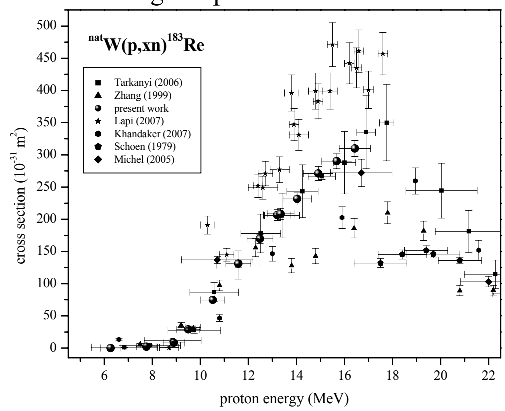

Figure 3: Excitation function of $^{nat}W(p,xn)^{183}Re$ reactionss

Rhenium 182m

In this case (Fig. 4), our data are in very good agreement at energies up to 12 MeV more or less. Then, some authors data present a slowly increase, Zhang a decrease while our values reach a plateau.

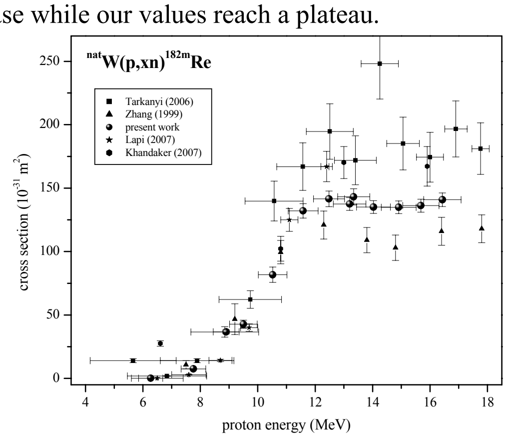

Figure 4: Excitation function of $^{nat}W(p,xn)^{182m}Re$ reactions

Rhenium 182g

For this radioisotope, our data (Fig. 5) and the Lapi's ones are in good agreement while the others present a spread at energies higher and higher.

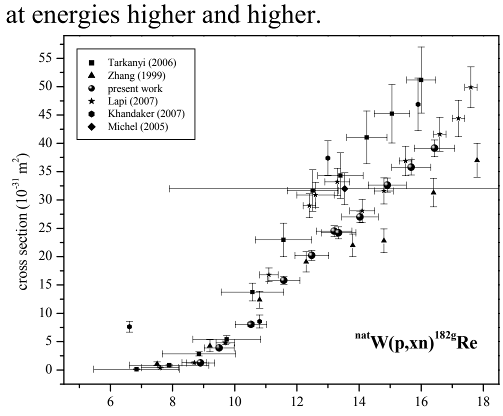

Figure 5: Excitation function of $^{nat}W(p,xn)^{182g}Re$ reactions

Rhenium 181

As we can see from Fig. 6, at lower energies (up to 3 MeV more or less) there is strong agreement within all the authors, but even in this case, as the energy rises, the spread of the values becomes bigger too.

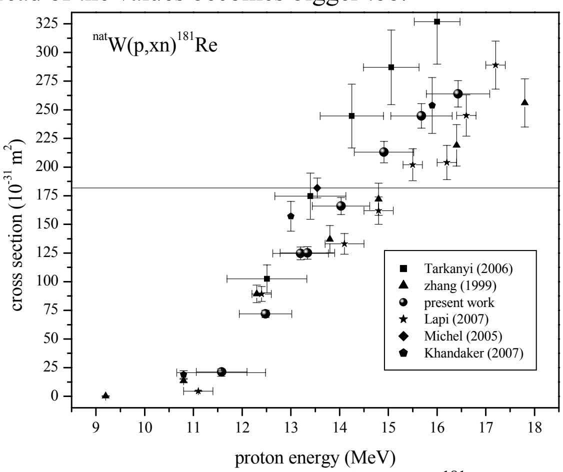

Figure 6: Excitation function of the $^{nat}W(p,xn)^{181}Re$ reaction

Rhenium-186g Thick Target Yield

The integrated yield and experimental thick-target yield have been compared in Fig. 7. The computed values have been calculated by measuring thin-target yield and then fitted by using an analytical way (Mathcad 13). The curve obtained was integrated at different energies in the case of total proton energies absorption, taking into account the self-absorption of photon at 137.15 keV [12]. As it is easy to observe, there is an agreement between the calculated values and the experimental ones as regard the behaviour.

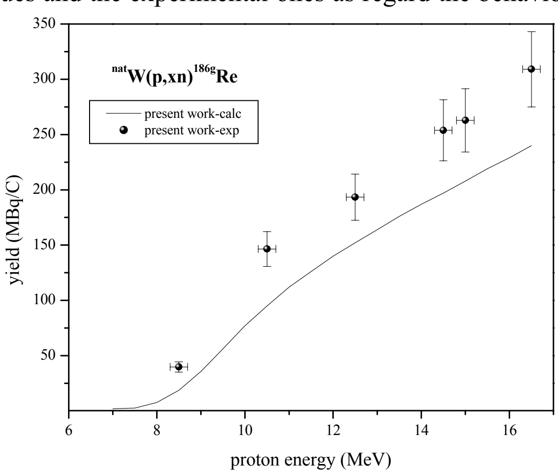

Figure 7: Calculated and experimental thick-target yield for Re-186g on natural W target.

RADIOCHEMICAL SEPARATION

In order to obtain the NCA (No Carrier Added) ^{18x}Re, a separation of the Re radioisotopes from irradiated W target is mandatory, without any addition of either isotopic or isomorphous carrier. The wet–chemistry method is a selective radiochemical separation based on the dissolution, under heating and stirring, of the W target with a HNO_3 (14.5 M)/HF(24 M)~3/1 solution, the addition of pre-heated H_2O and final warming to remove the HF. The last step is the separation of Re with a radiochromatographic method, using an activated aluminium oxide (acidic–AAO) minicolumn, that retains tungsten and elutes quantitatively ^{18x}Re only.

CONCLUSIONS

Cross-sections for the production of rhenium isotopes ($^{181\text{-}186}Re$) from natural tungsten target have been presented together with the thick-target yield of rhenium-186g. Thick-target yields of the other rhenium isotopes will be presented in a full extension version of this article.

Anyway, what it is immediately clear from the results discussed above is: first of all the discrepancies between the authors as regard the rhenium-186g excitation function, and then the importance to verify the behaviour of thick-target yield of this nuclide bombarding an enriched tungsten target.

AKNOWLEDGEMENTS

Special thanks to the whole staff of the cyclotron of JRC of Ispra (VA), INFN for financial support (GrV - RENIO experiment, 2006-08) and Doctorate School in Physics, Astrophysics and Applied Physics of Università degli Studi di Milano.

REFERENCES

[1] S. Kanuya, K. Yokoyama, *et al.*, Cancer Lett., **219** (2005), 41-48.

[2] R.B. Firestone, C.M. Baglin and F.S.Y. Chu, Table of Isotopes, 8-th Ed., 1998 Update on CD-ROM, John Wiley and Sons, New York, USA, 1998.

[3] S. Lapi, W.J. Mills et al., Appl. Radiat. Isot., **65** (2007), 345-349.

[4] F. Tárkányi, S. Takács et al., Nuc. Instr. Meth., **B 252** (2006), 160-174.

[5] M.U. Khandaker, M.S. Uddin, *et al.,* available on line at http://arvix.org/ftp/nucl-ex/papers/0703/0703035.pdf.

[6] N. Shigeta, H. Matsuoka, *et al*., Radioanal. Nucl. Chem., **205** (1996), 85-92.

[7] X. Zhang, W. Li et al., Radiochim. Acta, **86** (1999), 11-16.

[8] R. Michel, A.S.M.F. Choedhury et al., in S.M. Quaim (ed.), NEA/NSC/DOC(2005)27, ONDC(GER)-0051, Jül-4194, FZJ, 2005, p. 31.

[9] F. Tárkányi, A. Hermanne *et al.*, private communication, submitted to Nucl. Instr. Met., **B**

[10] J.F. Ziegler, J.P. Biersack and U. Littmark, http://www.SRIM.org.

[11] IAEA, TECDOC 1211, available on line at http://www-nds.iaea.org/reports-new/tecdocs/iaea-tecdoc-1211.pdf

[12] http://physics.nist.gov/PhysRefData/Xcom/Text/XCOM.html