NNUF MC40 proposal May 2021

Proton cross section measurements on Tantalum and Tungsten

High quality validated nuclear data is crucial for many applications, it underpins our ability to design nuclear facilities be that fission, fusion or accelerator based systems. Historically nuclear data has focused on reactions of interest to the fission industry but there is increasing use of accelerators both for science and medical purposes. In this work we propose to perform proton cross section measurements on Ta and W in the range of 10-36 MeV at the MC40 cyclotron at Birmingham.

This energy range is interesting because it spans the traditional change from evaluated nuclear data libraries, e.g. ENDFB up to 20 MeV, to physics models although some more recent libraries such as TENDL stretch to 200 MeV. Ta and W are of interest as they are used in fusion reactors and as targets in spallation neutron facilities. In particular there are many compact neutron sources under development including laser driven sources, which typically use proton energies in the range 14 MeV-100 MeV, including the High Brilliance Source in Germany. Some of the Ta and W reaction products also have potential uses as medical isotopes, e.g. W178 for use in SPECT.

An examination of Exfor and the literature shows several measurable reactions although many reactions do not have data points covering the full energy range possible at MC40 or have discrepant data between experimental data sets or with evaluations. Several key target reactions have been identified as possible to measure with discrepancies are:

* 181Ta(p,n)181W
* 181Ta(p,3n)179W
* 181Ta(p,4n)178W
* 186W(p,n)186Re
* 182W(p,2n)181Re

These reactions have been judged measurable based on half-life, decay emissions, magnitude of the expected cross section and previous measurements using a similar technique.

The experiments use a stack of high purity foils of the target material, which will be irradiated by the MC40 proton beam at 100nA for approximately 1 hour. Then the decay radiation from the activation products will be measured using HPGe or X-ray detectors as appropriate. These measurements may be repeated at several decay times to reduce statistical and systematic errors for longer lived products as the short lived radionuclides decay. Whilst the experimental procedure is relatively straight-forward the challenge is to make high quality measurements by minimising all the uncertainties and careful calculation/measurement of all the correction factors such as coincidence summing, self-shielding, accurate knowledge of the incoming proton flux etc. The MC40 cyclotron is a good choice for these experiments as it has very good energy resolution (via a bespoke silicon-detector-based beam-energy measurement system), quick access to the sample and has recently performed similar experiments on europium. It also has a well defined procedure for determining the proton flux hence helping to minimise this particular uncertainty.

It is expected that students from both ISIS and the University of Birmingham would be involved in the project, helping to train them in nuclear data methods. The project will help to develop the breadth of the UK nuclear data capability, which has recently seen reinvestment through AFCP at NNL, UKNDN and UKAEA fusion research.

Time request:

3 days beam time split into 3 session separated by 2-4 weeks. Following each irradiation experiment there will also be several (3) days of decay spectra measurement for the different foils.

From the cyclotron team’s experience with such measurements, to optimise target foil handling and counting, along with attempting a number of initial beam-energies, three days of beam time will be required.

Group experience and funding:

The ISIS neutronics group has an active experimental nuclear data program focusing on neutron cross sections and thermal scattering law development for moderators. Members of the group have previously performed cross section measurements at the ASP facility, Aldermaston, at ISIS using the Vesuvio instrument and at the LENS facility in Indiana. The group has extensive experience of performing benchmarking and validation work including involvement in NEA WPEC sub groups and IAEA CRPs. This would be a slightly new area in as much as being proton induced reactions but the methodology and techniques required are very similar. The group is mostly funded through the ISIS core budget. A separate UK Nuclear Data Network proposal may be submitted in the current call (deadline 2nd July 2021) to support the purchase of X-ray detectors/electronics to improve efficiency in the 10-100 keV region, which may be used in the future for subsequent nuclear data work at the high flux facility and cyclotron. Such an improvement would lead to further cross sections being measurable.

Publication:

The expectation is that, if the experiments are successful & following careful analysis of the uncertainties, the results would be published in a relevant journal and that an entry would be prepared for inclusion in Exfor.

Data:

In terms of raw data we expect to obtain decay photon spectra from HPGe or Si detectors at multiple decay times and for multiple sample foils representing different proton energies. We would also record associated MC40 parameters e.g. proton energy, current, flux data. We would also record calibration data for the detectors and efficiency parameters.

This will be used to derive reaction cross sections.

Samples:

High purity foils (99.99%) of Ta and W are available in different thicknesses as standard products from suppliers such as Advent or Goodfellow.

Sample Prep:

Minimal sample preparation is needed beyond cutting the foils to appropriate size for the beam.

UK priorities:

This project directly fits within the core priorities of the industrial strategy via clean growth and ageing society due to supporting fusion reactor materials, accelerator technology & potential use of radiopharmaceuticals. It also indirectly fits in to future materials research due to the relevance to neutron sources and their use to investigate a wide range of materials from bio membranes to catalysts. It is also complementary to the UKNDN and AFCP nuclear data work.

Apparently the online form doesn’t like tables;

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| --- | --- | --- | --- | --- |
| Reaction | Expected XS range (mb) | Product decay radiation | Existing data | Notes |
| Ta181(p,n)W181 | 0-70 | 121 d half life  136 keV  152 keV +X-rays | 3 sets, up to 20 MeV | Discrepancy between measured and Tendl data above 15 MeV |
| 181Ta(p,3n)179 W | 0-1000 | 37m half-life, 30 keV, 134 kev | 1 data point |  |
| 181Ta(p,4n)178 W | 0-800 | 22 d half life,  x-ray only  but daughter is T178 (9 min half life and 1.3mev gamma emitter) | 3 data sets | Discrepancy between data sets and with evaluation  In equilibrium with measurable decay product |
| 186W(p,n)186Re |  | 3.7 d half life, 122 keV gamma | 2 data sets | Discrepancy between data sets and with evaluation |
| 182W(p,2n)181Re | 0-1000 | 19.9 h half life, Lots of gamma rays main one at 360 keV | 1 data set up to 20 MeV | Discrepancy between measured and Tendl data |