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The Activities of the European Consortium on Nuclear Data Development and Analysis for Fusion

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This paper presents an overview of the activities of the European Consortium on Nuclear Data Development and Analysis for Fusion. The Consortium combines available European expertise to provide services for the generation, maintenance, and validation of nuclear data evaluations and data files relevant for ITER, IFMIF and DEMO, as well as codes and software tools required for related nuclear calculations.

I. INTRODUCTION

The European Fusion Programme builds on the availability of qualified computational tools and data as prerequisites for reliable neutronic design calculations of fusion devices like ITER, irradiation facilities such as the IFMIF neutron source and future power plants including DEMO as important intermediate step towards electricity producing fusion facilities. To serve this end, the European Consortium on Nuclear Data Development and Analysis was formed combining available European expertise to provide the services requested by Fusion for Energy (F4E), Barcelona, for the generation, maintenance, and validation of nuclear data evaluations and data files relevant for ITER, IFMIF and DEMO, as well as codes and software tools required for related nuclear calculations. This paper presents an overview of the current efforts spent by the Consortium on the development of nuclear data for fusion technology applications. The organization of the related work conducted within the European Fusion Programme is briefly outlined, the ongoing activities are reviewed and detailed to some extent.

II. ORGANIZATION OF THE NUCLEAR DATA DEVELOPMENT PROGRAMME IN THE EU

In the European Union, the programme on the nuclear data development for fusion technology is organized by Fusion for Energy (F4E), the European Joint Undertaking for ITER and the Development of Fusion Energy, located in Barcelona, Spain. F4E has three main objectives: (i) providing European contributions to the ITER project, (ii) providing European contributions to joint projects (including IFMIF) with Japan that aim at accelerating the development of fusion, the so-called "Broader Approach", and (iii) coordinating a programme of R + D activities in preparation for DEMO. To meet these objectives, F4E is conducting a dedicated nuclear data development programme which aims at providing a well-qualified nuclear database and validated computational tools for neutronics and activation calculations as required for the design, licensing and operation of ITER, the IFMIF neutron source and DEMO. The programme is executed by a Consortium on Nuclear Data Development and Analysis which combines available European expertise on nuclear data evaluation, processing, validation and benchmarking.

The Consortium consists of the research institutions of KIT, (Karlsruhe, Germany), CCFE (Culham, UK),

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NRG (Petten, The Netherlands), JSI (Ljubljana, Slovenia), TUW (Vienna, Austria), CIEMAT (Madrid, Spain) and IFIN-HH (Bucharest, Romania). The Consortium provides the services which are requested by F4E to meet their objectives in the field of nuclear data development. These services include nuclear data evaluations relevant to the various fusion applications including neutron, proton and deuteron induced reactions, the generation of associated co-variance data for uncertainty assessments, the development of advanced nuclear models and codes, the processing and benchmarking of the evaluated data against integral experiments, as well as the development of suitable software tools for sensitivity and uncertainty analyses of fusion systems.

According to the actual priorities of the ITER project, the IFMIF task agreement, and the DEMO R+D programme, F4E specifies, in close coordination with the Consortium, dedicated work programmes on the development of nuclear data and awards grants to the Consortium for conducting the requested activities. These work programmes are complemented with a parallel scheme on nuclear data experiments and measuring techniques.

III. CURRENT EUROPEAN ACTIVITIES ON THE DEVELOPMENT OF NUCLEAR DATA FOR FUSION

The current F4E work programme, which extends over a two years period from 2012 to 2014, includes various activities on the evaluation of nuclear data, the production of data files and libraries, the improvement and development of models and tools, as well as related verification and validation analyses.

A. Evaluation of Neutron Induced Cross-section Data for General Purpose Applications up to 150 MeV

The current activities encompass general purpose data evaluations on ^{55}Mn, ^{63,65}Cu, and ^{181}Ta including the generation of associated co-variance data, ENDF data file generation, checking and processing, and verification/validation analyses. The evaluation work is performed by JSI (^{55}Mn) [1], KIT (^{63,65}Cu) [2] and TUW (^{181}Ta). Each research institution utilizes its own specific approach for performing the nuclear model calculations and evaluating the data, and generating the co-variance data.

As for the nuclear model calculations, JSI relies on the EMPIRE code [3] while KIT and TUW utilize the TALYS code of NRG [4]. The resulting cross-section data, based to a large extent on model parameters adjusted to experimental data, serve as input ("prior") to the various Bayesan approaches for updating the evaluation and generating the co-variances. With JSI's approach, model uncertainties are treated through tuning parameters within EMPIRE, which are defined with uncertainties and implied correlations. The co-variances of the cross sections are produced using the Monte Carlo technique of random sampling of the model parameters; these co-variances are fed as "prior" into the GANDR system [5] using experimental data to constrain the uncertainties by the generalised least-squares method. KIT employs the Universal Monte Carlo (UMC) approach [6] to generate covariance data taking into account both nuclear model and experimental uncertainties as implemented in KIT's BEKED code system [7]. TUW developed the Full Bayesian Evaluation Technique (FBET) [8], implemented in the GENEUS code system [9] to provide evaluated cross-sections and associated uncertainty information. Emphasis is given on a proper determination of the prior accounting for model parameter uncertainties as well as for deficiencies of the models, so-called "model defects". The prior represents a-priori knowledge which is consistently improved by inclusion of experimental data via a Bayesian update. Unphysical fluctuations are avoided by introducing the smoothness of model cross sections as a-priori knowledge.

B. Analyses of Fusion Relevant Benchmark Experiments

These activities include benchmarking analyses of neutron cross section data evaluations of the stable Pb and Fe isotopes, which are of highest importance for ITER and DEMO. The objective is to assess the quality of the existing JEFF evaluations for nuclear design analyses, and check if the evaluations need to be updated.

Pb is a neutron multiplier material which is utilized for the HCLL (Helium-Cooled Lithium-Lead) breeder blanket, one of the two European concepts for use in a DEMO reactor and irradiation tests in ITER. The benchmark analyses build on the results obtained in a previous neutronic mock-up experiment and are complemented by analyses of benchmark experiments on pure materials.

For the Fe data benchmarking, available integral benchmarks which are sensitive to iron cross sections are analysed to check the consistency of trends indicated by individual benchmarks. The present version of the SINBAD compilation [10] is used as primary source for the data on the experimental benchmarks. SINBAD includes a series of experiments on iron and steel assemblies which are suitable for the Fe data benchmarking. Some of them were recently reviewed and revised for a better and complete description of the information required for a proper computational analysis.

The benchmark activities comprise also analyses of deuteron induced reactions on Cu and Al, the most relevant elements for the IFMIF accelerator, to check the quality of the data provided with the TENDL library for the predicting the neutron yield and its energy-angle distribution. The analyses are performed by CIEMAT/UNED with the MCUNED code [11] which is