Summary and Recommendations for Microscopic Nuclear Physics Development : Thin Target Benchmark

M. Blann
Lawrence Livermore National Laboratory
(United-States)

We first considered lessons from this benchmarking exercise with respect to the accuracy one may expect from codes on an a priori basis. The better results could, with very good consistency, give neutron and proton double differential cross sections reliable to better than a factor of two, and single differential cross sections to around ±30 percent. This was true for the benchmark nuclei, which were both closed shell targets, and were therefore more difficult to predict than the greater number of non-closed shell nuclei. We exclude very light, and fissile nuclei from these error estimates; they have their own difficulties in calculation.

Large discrepancies were observed between reaction cross sections reported for the codes in this exercise. There are large gaps in the energies for which optical model analyses have been performed on experimental data. We very much encourage a clarification of well documented form factors and parameters and the energy ranges in which they are valid. We need guidance on the upper energy limits for which present optical models are valid, and an investigation of energy and mass ranges for which reaction cross sections from INC codes, or from systematics, may be more accurate. Towards this end, we note that a book by Barashenkov, presently being translated into English, gives systematics for total reaction cross sections and a compilation of experimental data.

The questions of production of "poison" isotopes in waste transmutation schemes, including those from structural materials, makes benchmarking of the calculation of excitation functions a very high priority, second step to the exercise being critiqued this week. We strongly recommend this. Several possibilities are suggested. First, Haight, Vonach et al have unpublished (n,x) excitation functions for ~20-400 MeV incident neutrons on several targets, including 27Al and 56Fe. There are published data for p+197Au at energies between ~ 300 MeV and 3 GeV. We should check the availability of the Haight-Vonach data, and encourage an activation yield benchmarking exercise. The final choice of experimental data used will be the choice of whoever coordinates the exercise. The exercise should not be limited to isotopes near the target, but should include a wide range of masses and atomic numbers so as to test fragmentation and heavy cluster emission. Many codes may not have the latter capability; this is a good way to find out.

We feel that there may not be a good theory for predicting yields of clusters (deuterons and heavier), beyond those which evaporate at equilibrium. It is therefore premature to try to benchmark codes for this aspect; rather we encourage development of models to predict non-equilibrium cluster emission. To aid in this, it would be valuable to compile a data base of available DDCS; if there are none above, e.g. the 62 MeV ORNL results or 90 MeV Maryland results, experimental measurements at higher energies are strongly encouraged. The Obninsk group will collect a data base of these reactions from the literature. Yuri Shubin will advise us of a projected completion date and energy/mass range to be covered. Mark Chadwick reminded us that there is an IAEA-CRP on (n,alpha) emission, calculation and measurement for En ≤ 20 MeV.

We note that this benchmarking activity of the main reaction channels was limited by unavailability of proton spectra at almost any energy, and neutron spectra of good energy resolution at energies above 800 MeV. The SATURNE accelerator is one of few, or the only accelerator worldwide at which these data could be measured - and they are essential to complete code benchmarking as a reliable tool for data generation. We strongly encourage an experimental program to measure proton and light cluster double differential cross sections on a range of targets, including Zr and Pb for incident proton energies above 200 MeV, and neutron DDCS above 800 MeV, with good energy resolution. We strongly endorse the ongoing activation yield measurements being done at SATURNE. Closings of accelerators has made experimental data measurement, needed for ATW and many other technological applications, very difficult. It is hoped that the scientific/technological community does not lose SATURNE.

The questions of photonuclear data was temporarily deferred, noting that the IAEA and NEA will each hold a meeting on this subject in the fall. These will cover gamma-rays in the exit channel. It is however an important subject, especially with respect to reactions initiated by high energy photons, and the question of modelling and testing of theories should be considered soon!

It is important to be able to calculate both fission cross sections and yields of fission/spallation products for fission induced by energetic nucleons. Mashnik and Blann will check respectively on 600 MeV p+238U thin target yields at 600 MeV, and on measurements at GSI on non-fissile targets made using inverse kinematics.

For incident energies above, e.g. 800 MeV, single and at higher energies multiple, pion production becomes significant. It is valuable to test codes for their ability both to predict the pion yields and spectra, and to predict and handle the reabsorption, at least in the near-resonance region. Because only a few codes do this, a formal benchmarking was not endorsed at this time. Mashnik and Ferrari will try to summarise the experimental data base, and organise an informal intercomparison with authors or users of those codes capable of handling this problem.

Chadwick pointed out that there is a strong need for double differential cross sections on elements of human tissue, with the highest priority being 16O followed by 12C. Needed are DDCS for p (and also n) induced reactions for incident energies $\leq$ 250 MeV (p) and 70 MeV (n). These would be inclusive spectra for all ejectiles, preferably good to $\pm$10 percent.

It was recommended that the NEA should begin a pilot evaluation program for protons of up to 100 MeV incident on 56Fe (priority 1) and on 232Th (priority 2). Double differential cross sections for n,p,alpha, product yields, elastic scattering cross sections, total reaction cross sections, photon spectra should be compiled. For 232Th, fission cross sections and product yields should also be compiled. At a later date the 100 MeV upper energy limit may be extended.

Regarding uncertainties in codes, it was suggested that comparing codes with each other may give some indication. It was, however, agreed that this question is best answered for each aspect of data (DDCS, yields etc.) by blind intercomparisons, ideally where more than one group has made the experimental measurement.

The physics used in the codes of this intercomparison is summarised in the questionnaires in the report. Of the codes used, those available for distribution by NEA or by other means with manuals, include HETC, GEANT, HERMES, LAHET (without precompound decay; a version with precompound decay is undergoing review and release procedures), ALICE92, PEQAQ2, GNASH, and KAPSIES. A manual and version of FLUKA should be ready for release in a few months. Similarly it is intended that the FKK-GNASH code will be released in the near future, and the author of CEM92 would like to work with NEA to release that code with a suitable manual.

Subgroup participants:

Fabienne BACHA
Marshall BLANN
Mark CHADWICK
Cheikh M'Back DIOP
Alfredo FERRARI
Zeev FRAENKEL
Arjan KONING
Stepan MASHNIK
Pierre NAGEL
Massimo SALVATORES
Nikolay SOBOLEVSKY
Yuri SHUBIN
Hiroshi TAKADA
Hiroshi TAKAHASHI
Pedro VAZ
Philip YOUNG