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SUMMARY OF WORKSHOP SESSION ON SPALLATION AND FISSION IN COMPUTATIONAL MODELS

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For spallation neutron source applications using medium-energy (500 MeV to 1 GeV) protons, it is necessary to calculate a variety of quantities including: a) thermal neutron beam fluxes, b) thermal neutron beam contamination by gamma-rays, charged particles, and high-energy neutrons, c) energy deposition in targets, moderators, reflectors, and shields, and d) shielding effectiveness of materials. The most widely used code to calculate spallation processes is the Oak Ridge National Laboratory (ORNL) High-Energy Nucleon-Meson Transport code (HETC). The predecessor to HETC is the ORNL Nucleon-Meson Transport Code (NMTC).

For high-mass target muclei and energies $\gtrsim$100 MeV, there is competition between evaporation and fission at each step of the nuclear de-excitation process. Recently, there have been two high-energy fission models developed for use in HETC (one by Alsmiller at ORNL and one by Atchison at the Rutherford and Appleton Laboratories (RAL)). Takahashi at the Brookhaven National Laboratory and Nakahara at the Japan Atomic Energy Research Institute have (independently) incorporated high-energy fission into NMTC. The inclusion of high-energy fission in spallation reactions is expected to alter predicted values of energy deposition, residual-nuclei mass distributions, neutron multiplicity in thick targets, and neutron spectrum.

Until recently, experimental data relevant to spallation neutron source applications have been relatively sparce (limited primarily to measurements by Fraser (Chalk River) of thick-target neutron yields and a few measurements of neutron production cross sections and neutron spectra from thick targets). Lately, Russell, Gilmore, et al. (Los Alamos) have measured neutron captures in a water bath for a variety of targets bombarded by 800-MeV protons; similar measurements have been done at lower proton energies by Thorson, et al. (TRIUMF). Howe, Russell, et al. (Los Alamos) have measured angle- and energy-dependent neutron production cross sections for a number of targets bombarded by 800-MeV protons. Differential production cross sections for charged particles (protons, deuterons, tritons, and pions) produced by 590-MeV proton bombardment of different materials have just been measured by Howe, Cierjacks, et al. (KFK Karlsruhe). Raupp, Cierjacks, et al. (KFK Karlsruhe) have measured neutron production yields and spectra from 590-MeV proton bombardment of thick uranium targets. Fertile-to-fissile and fission measurements for depleted uranium bombarded by 800-MeV protons have been done by Russell, Gilmore, et al. (Los Alamos). For the 19.7-cm-diam by 30.5-cm-long target used in this latter measurement, the data indicate that when high-energy fission is neglected neutron production is underestimated by ~10%. All of the above experiments provide benchmark data for computer code validation; clearly, more experimental data are required. The experiments, however, need to be done very carefully if they are to be valuable for adjusting model parameters in the computer codes.

A detailed systematic intercomparision of model parameters used in the ORNL and RAL versions of HETC with high-energy fission is being done by Armstrong and Filges (KFA Jülich). They are also comparing these code packages with thin and thick target measurements and with thermal neutron production data. They want to establish a reliable computational capability to use in design calculations for the proposed German spallation neutron source. A quantity B_0 occurs in the analytic expression for the level density parameter used in the computer code models; from various analyses, B_0 ranges from 8-20 MeV. For thick targets, Armstrong and Filges conclude that theoretical predictions of neutron production ($\lesssim$20 MeV) agree with experimental data to within 20-30%, and that this general magnitude of agreement can be attained by neglecting high-energy fission. Armstrong and Filges also conclude: a) for standard B_0 values incorporated into models, the ORNL code predicts ~20% more neutrons than the RAL code, b) neutron production is sensitive to the value of B_0 assumed and varies by ~20% over the possible range of B_0, c) for the same B_0, the ORNL code predicts ~12% more neutrons than the RAL code, and d) the effect of including high-energy fission (compared to spallation without fission) is to increase neutron production by ~7% and to produce a slightly harder spectrum in the energy region from ~2 to ~15 MeV.

For energies $\gtrsim$ 20 MeV, calculated differential neutron production cross sections underpredict measured values by factors of 2-5. For energies $\gtrsim$50 MeV, calculations significantly underpredict measured differential proton production cross sections and overpredict measured differential pion production cross sections.

The possibility of having a hybrid neutron source by explicity combining fission and spallation was briefly discussed. Several laboratories have given cursory thought to booster-targets at spallation neutron sources; perhaps by ICANS-VI more consideration will have been given to this subject, including the effects of pulse broading and potential inter-pulse background.