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FLIGHT PATH 7
NEUTRON CAPTURE CROSS SECTIONS: DATA ANALYSIS PROGRAMS

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Oak Ridge, Tennessee 37830
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INTRODUCTION: DATA ACQUISITION SYSTEM

The ORELA neutron time-of-flight facility is based on a high current (∿20 ampere) short pulse (2.5-25 ns) 140 MeV Electron Linear Accelerator.[1] The standard moderated neutron target and a collimation system for reaction cross section experiments have been described.[2] The technique, suggested by H. Maier-Leibnitz, of pulse height weighting, has been applied to neutron capture cross section measurements[3] and adapted for use at 40.120 meters on ORELA.[4] The subsequent development of a thin ^{6}Li glass scintillator flux monitoring system has also been described.[5]

Further developments are described in some of the subsequent reports.[6-18] The original fast timing electronics has also been described,[19] as well as a thin proton recoil flux monitor.[20]

NEUTRON CAPTURE CROSS SECTIONS: DATA ANALYSIS PROGRAMS

Phase I. Yield data from the SEL-810B acquisition computers at ORELA is compacted, dead-time and time independent background corrected and converted from time-of-flight to energy scale for standard 2.5-5000 keV runs (see Appendix I for details). The output files are stored on IBM-2314 disk packs with least significant run number digits as follows:

---1 GWT - a measure of gamma energy release

---2 GSQ - the variance of GWT from Poisson statistics

---3 TOF - the gamma detector counts per channel

---4 AMON - ^{6}Li glass monitor counts per channel

Headers include much of the information from the first of the five data cards prepared for each run and read in as part of Phase I via subroutine

DATACD. A log log plot of GWT is produced as a check on the plausibility of the data as well as a two-page printed output repeating the data card information used, samples of dead time correction factors, neutron spectral shape factors, backgrounds, etc.

Phase II. Phase I output is processed to cross section and relative standard deviation vs E_n (run numbers ---5 and ---6 respectively) using the thin sample approximation. The latest detector efficiency ratios (TEDEFF from saturated resonance calibrations) are established by Regimes, each applying to a group of sequential run numbers. The appropriate flux shape is taken from the average of several runs (Al or Be moderator can structure, thin ^{6}Li glass monitor in transmission or not used) in FILE.CSTD. The ^{6}Li(n,α) cross section shape is calculated from the parameters in subroutine SNA. Sample dependent and independent backgrounds are selected (by Regime as appropriate) and include options for compounds and lucite binder as well as background scale factors adjustable for each run. The output files are normally transmitted to the PDP-10 (OREL disc with .PCH file extension, decoded and stored on disk ORØ1 via program PP2 CONVERT. Other options include Calcomp plots of cross section and IBM-2314 disk storage in I*2 words, 0.1 mb units and a 1000 mb offset for the cross section (no offset used for the standard deviations).

Further corrections not included at this stage are: resonance self protection, multiple scattering and resonance scattering background. The first two are handled by various R-matrix analysis programs and the last has been evaluated from side experiments using ^{7}Li, C and ^{208}Pb scatterers via subroutine SDBGC. Further processing of data follows two main routes. First is the preparation of sequential energy channel files in CSIRS format

($E,\Delta E,\sigma,SD$) for magnetic tape transmission to the national cross section data center at Brookhaven. Such capture yield data would then be available for evaluation work and analysis at other sites. The second processing route aims at deriving R-matrix parameters for several special cases.

At low enough neutron energy all samples show isolated capture peaks whose centroid and area yield E_γ and the quantity $\Gamma_\gamma\Gamma_n/\Gamma$. Γ_γ is expected to be smaller than our resolution (40 meter flight path, $E_n > 2.5$ keV) in almost all cases. Thus, when the data show a peak width significantly greater than the experimental resolution we also get a measure of Γ_n. (Transmission measurements, when available, are a good source for smaller Γ_n values or upper limits on Γ_n which can remove most of the ambiguity from the resonance self-protection corrections.)

The many peaks showing minimum width are well fitted by a gaussian resolution function ($Y=(1/\sqrt{2\pi})EXP(-X^2/2\sigma^2)$). The peak (and background) fitting subroutine TIZZY is admirably adapted to these cases and the following subroutine RESPAN derives the corrected resonance parameters using area corrections from subroutine RSPAPL. It also computes distributions of the level parameters and averages over reactor (1/E) and stellar neutron spectra.

For wider resonance peaks a further program (DECON) using trial values from RESPAN is being developed to iteratively improve an analytic R-matrix shape fit to neighboring peaks separated by about the sum of their widths (FWHM). For the few very broad peaks where the neutron energy loss on scattering (at $\sim 90°$) is smaller than the width, we must go to a Monte Carlo simulation to calculate the capture probability. Subroutine MC05R developed at ORNL is available for this.

For many isotopes the neutron capture resonances are too crowded above a few keV for us to separate. Up to 90 keV the angular momentum barriers ensure that capture is dominated by $\ell=0$ and $\ell=1$ (s-wave and p-wave) interactions. Thus we can derive average R-matrix parameters in such cases. The theory allows for more parameters than we can hope to determine from average neutron capture alone. Three parameters may suffice to determine the cross section averaged over tens of resonances; S^0, S^1 and $\overline{\Gamma}_\gamma/\overline{D}$. [21]

The fluctuations about this strength function fit are sensitive to a further combination of parameters, particularly the level spacing parameter, through the Porter-Thomas distribution of neutron widths and the Wigner level spacing distribution. Statistical tests for the adequacy of these restricted parameter fits to the data are needed to detect new and interesting nuclear phenomena such as doorway states. The limited sample of resolved levels at low energy also gives estimates of average parameters which can be checked against those derived from the average capture cross section.

APPENDIX I

As the energy resolution varies as E^{-m} with m near 1 at a few kilovolts and increasing toward 1.5 near 1 MeV, data storage is optimized by "crunching". While a variable channel width could be chosen at a small fixed fraction of the resolution width, the much easier factor-of-two steps are nearly as efficient and are used in the SEL-810B data taking computers (DAC's). The particular time of flight channel widths in nanoseconds and numbers of channels at each width we use are: 1.0(7168), 4.0(4096), 8.0 (3072). Prior to August 25, 1971 (run 5190) a fast timing circuit based on a 50 ns oscillator period[19)] was used with channel assignments 1.5625 (4096), 3.125(6144), 6.25(4096). The data from either set are regrouped (subroutines RSELT1, RSELT2, and ENCONV) into energy channels of width (eV) and number: 7/6(3000), 5/2(2400), 5(2600), 10(2500), 25(1600), 50(1400), 100(1500), 250(1160), 500(1000), 1000(500), 2500(360), 5000(500). The first eleven groups are chosen to roughly follow the resolution function with convenient channel widths.

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