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GEANIE AT WNR/LANSCE -- A NEW INSTRUMENT FOR NEUTRON SCIENCE

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Abstract

GEANIE, an array of escape-suppressed high-resolution Ge detectors now installed at the white-neutron source at the Los Alamos Neutron Science Center, is the first large Ge detector array to be used at a high-energy spallation neutron source. GEANIE consists of 20 Ge detectors including both coaxial Ge detectors and planar Ge detectors to enhance capabilities for low-energy γ-ray spectroscopy. The array is located on a 20 m flight path with a neutron flux spanning the energy range from 1 to over 200 MeV. Installation of the first phase of GEANIE was recently completed and data were acquired on a number of samples, including actinides. The unique combination of GEANIE with the neutron source at LANSCE provides new capabilities for neutron science. The status of the array and recent results are presented, and new opportunities for physics and nuclear data are discussed.

1 Introduction

The Germanium Array for Neutron-Induced Excitations (GEANIE) is a large, high-resolution γ-ray spectrometer now in use at the Weapons Neutron Research (WNR) high-energy spallation neutron source at the Los Alamos Neutron Science Center (LANSCE). The array is funded and operated as a joint effort of the Lawrence Livermore and Los Alamos National Laboratories. The array was constructed using elements of the HERA detector that was built and operated by the Nuclear Structure Group at the Lawrence Berkeley National Laboratory. The unique combination of GEANIE with the WNR high-energy broad-spectrum neutron source creates new opportunities in nuclear science.

The experimental program with GEANIE at WNR includes both basic and applied measurements. A large fraction of the current applied effort is directed toward measurements of (n,2n) and (n,3n) cross sections on Pu and U samples. The basic physics experiments include studies in the areas of astrophysics, nuclear structure, level densities and reaction mechanisms at high energy, and complete spectroscopy.

We describe here the GEANIE spectrometer, the WNR neutron source, and some of the current and proposed experiments.

2 The GEANIE Spectrometer

The GEANIE spectrometer currently consists of 20 BGO escape-suppression shields surrounding high-purity Ge detectors. The array is presently configured with 7 planar Ge detectors (15 mm long by 50 mm diameter, nominal) and 13 coaxial Ge detectors (25% efficient). All of the planar and coaxial detectors are interchangeable within the BGO shields.

Typical γ-ray energy resolutions obtainable with the coaxial Ge detectors are 2.2 keV (FWHM) at $E_\gamma = 1332$ keV, while resolutions for the planar Ge detectors are 0.85 keV at 122 keV. The timing resolution of the Ge detectors is important because it is used to deduce the incident neutron energy from the time-of-flight (TOF). Typical time resolutions for 25% coaxial Ge detectors are about 5 ns (FWHM) for a 1 MeV γ ray. The planar Ge detectors provide improved timing with resolutions on the order of 2 ns possible. The BGO escape-suppression shields give a peak-to-total ratio of about 0.45 for a 1.33 MeV γ ray. Neutron damage to the Ge detectors does not noticeably degrade the energy resolution during months of routine array operation as long as the Ge detectors are maintained at liquid nitrogen temperatures.

The Michigan State University 4π array data acquisition system is used to store event data that include the escape-suppressed γ-ray pulse height and incident neutron TOF information for each detector. We note that only states with lifetimes less than a few nanoseconds are generally useful in our measurements due to the TOF requirement. γ-γ coincidences enable the determination of level schemes and reduction of backgrounds versus those in singles spectra.

3 WNR/LANSCE

The WNR facility is one of two main neutron sources driven by the 800 MeV LANSCE (formerly LAMPF) proton linac. The facilities at LANSCE include (1) a moderated neutron source driven by a proton storage ring for experiments with high-intensity thermal and epithermal neutron beams, (2) the WNR facility for experiments with neutrons in the energy range from below 1 MeV to as high as 600 MeV, and (3) experimental areas where the proton beams are utilized.

The WNR high-energy neutron source and flight paths are described in detail in [1]. Neutrons are produced by spallation reactions of pulsed 800 MeV protons incident on a small tungsten cylinder. Typical proton beam currents are of the order of 2 μA. The production target is shielded by a massive steel and concrete bulk shield that contains penetrations for the neutron flight paths and shutters for controlling the beams. Charged particles are deflected from the neutron beams by arrays of permanent magnets located just beyond the shutters and the bulk shield. A fission ionization chamber containing thin ^{235}U and ^{238}U foils is used to monitor the neutron flux during experiments. GEANIE is located at a distance of 20.3 m from the production target on a neutron flight path that is at 60° with respect to the incident proton beam. The useful neutron flux for GEANIE experiments extends from below 1 MeV to over 200 MeV. The beam for GEANIE is well collimated with 4 sections of steel collimator producing a 1.5 cm diameter beam spot at the center of the array.

4 Current Experiments

Applied nuclear science is an important part of the experimental program at LANSCE with GEANIE. A major part of this is the determination of neutron reaction cross sections from partial γ-ray cross sections using Hauser-Feshbach theory. The GNASH [2] preequilibrium + Hauser-Feshbach code is both tested by our measurements and used to calculate cross sections of transitions not directly observed in our experiments. The use of partial γ-ray cross sections to determine reaction cross sections for actinide nuclei is superior to other techniques because the production of neutrons from fission interferes with direct measurements of (n,xn) [x=1,2,3,...] reactions. The good peak-to-total ratio of the GEANIE detectors assists in observing individual low-lying γ-ray lines above the continuum from fission and other γ-rays, and the high energy resolution of the detectors allows unique transition assignments. The use of planar Ge detectors is often crucial in measurements on actinides because of their excellent energy resolution and relative insensitivity to neutrons. These measurements also contain useful information on the fission process. At present (n,xn) measurements on ^{239}Pu and ^{235,238}U are in progress.

Experiments with GEANIE at WNR complement measurements with heavy-ion beams. In general, high-spin states near the yrast line are populated in heavy-ion reactions, but the off-yrast region of nuclear excitations receive greater population in neutron-induced reactions. Because neutron inelastic scattering tends to populate all levels below a given spin, it is expected to be a good tool for complete spectroscopy studies in s-d and f-p shell nuclei. Complete level information from the ground state to a few MeV in excitation energy exists for only two nuclei, ^{26}Al and ^{30}P [3]. These data are from proton-induced reactions. Extension of these studies to heavier nuclei requires the use of neutrons. Complete level sequences allow stringent tests of symmetry breaking and of chaos theory predictions in nuclei [4].

Figure 1 shows a 3-dimensional plot of the singles data from the sum of 7 coaxial Ge detectors in the array in 1996. These data were taken with an Al sample in about 12 hours, and demonstrate the large amount of data that can be acquired in a relatively short period with GEANIE at WNR. The many γ-ray peaks in the range, $0.1 < E_\gamma < 1.85$ MeV observed for neutron energies from 2 to 200 MeV are evident. Figure 2 shows a small region of the same data from $E_\gamma = 1.69$ to 1.85 MeV. Ridges corresponding to three different reactions are identified in this plot. The different reaction thresholds can be seen from the varying positions along the incident neutron-energy axis at which the ridges first appear. Note that the incident neutron energy axis is nonlinear. The data in Figures 1 and 2 have been normalized to the neutron flux.

Other experiments proposed to the 1996 LANSCE Program Advisory Committee cover a wide variety of topics: A measurement of the ^{181}Ta(n,2nγ)^{180}Ta reaction to identify states that could aid in explaining the cosmic abundance of ^{180}Ta. A search for the existence of a triaxial rigid rotor configuration in the Pt isotopes [5]. Searches for two-phonon octupole states in ^{208}Pb and multiphonon states in ^{170}Er. Studies of level densities at high energies in Pb and other nuclei. Attempts to produce and determine the levels of the N=Z nucleus ^{84}Mo as a precursor to trying to produce ^{100}Sn.

In previous work with a single Ge detector the (n,9n) reaction on ^{208}Pb was observed at WNR [6]. More recently we have observed the (n,13n) reaction on ^{196}Pt [5].

These experiments show the potential for studying the structure of neutron deficient nuclei using GEANIE.

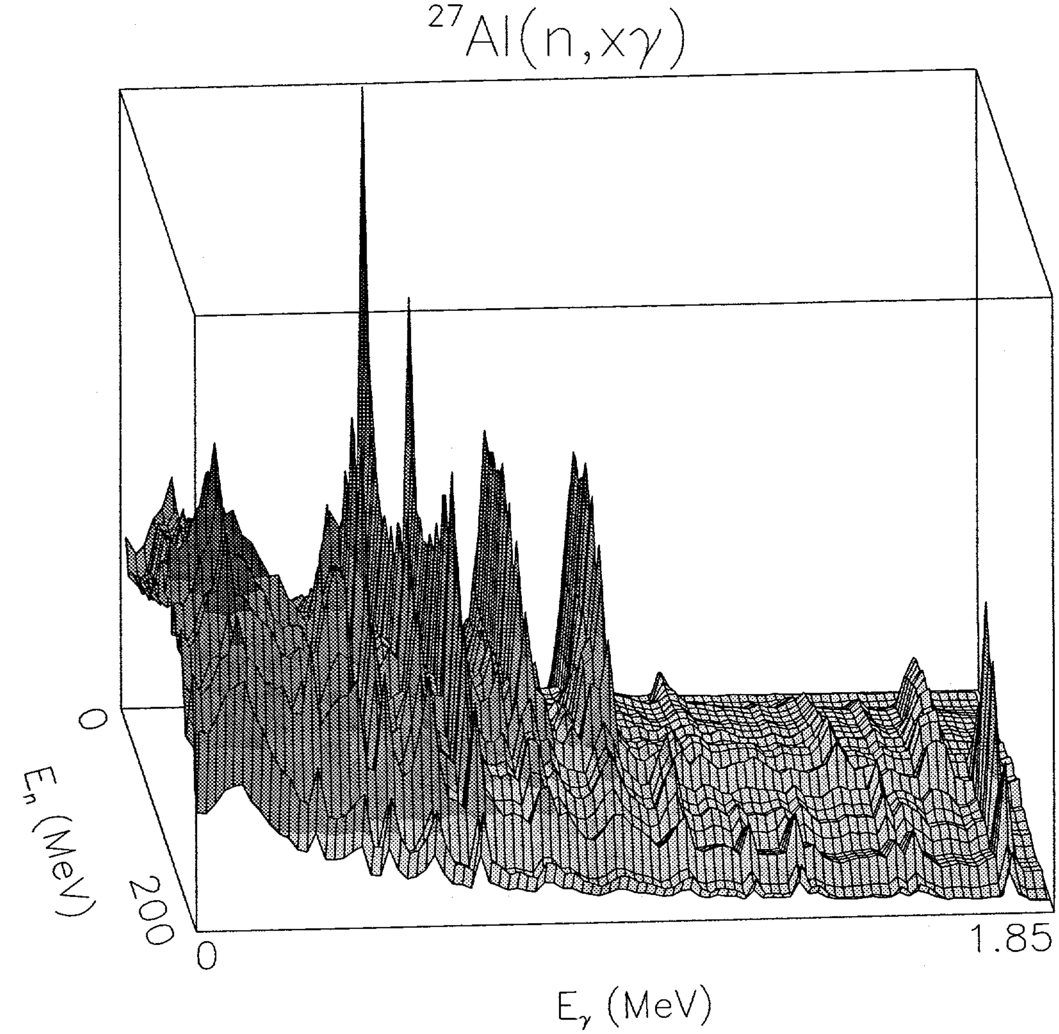

Figure 1: Singles data from a short run with the $^{27}Al(n,x\gamma)$ reaction. One half of the γ-ray energy range of the experiment is shown with coarse resolution for plotting purposes. The data are normalized to neutron flux. The neutron axis is nonlinear in neutron energy.

5 Summary

GEANIE at WNR/LANSCE is a unique instrument for nuclear science. The WNR high-energy, broad-spectrum neutron beam used with the high-resolution GEANIE spectrometer allows new nuclear physics studies and important nuclear data to be acquired. Expansion to a 30 Ge (20 coaxial, 10 planar) detector array is planned.

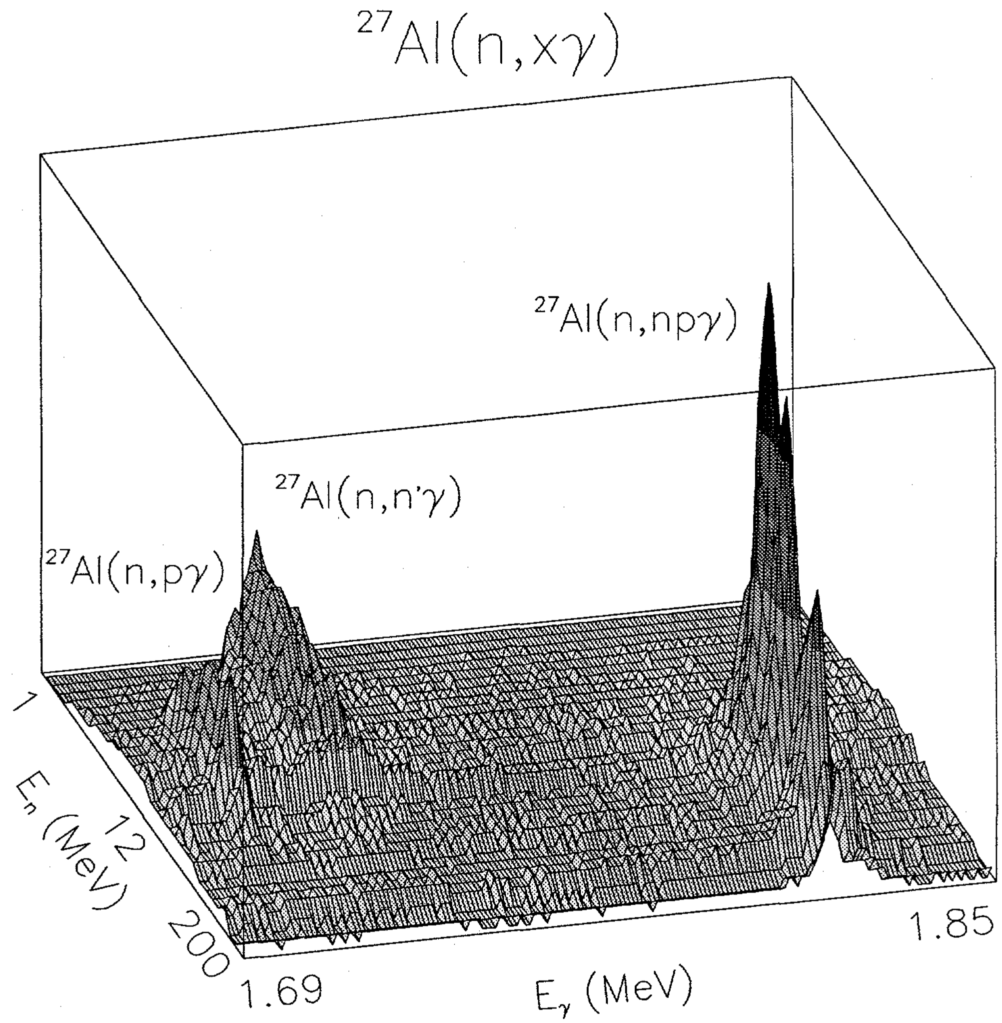

Figure 2: A small section from the high γ-ray energy region of Figure 1 shows peaks from three reactions. The different thresholds for the (n,n'γ), (n,pγ), and (n,npγ) reactions are evident.

References

[1] P.W. Lisowski, et al., Nucl. Sci. Eng. **106** (1990) 208.
[2] P.G. Young, E.D. Arthur, and M.B. Chadwick, *Los Alamos National Laboratory Report* LA-12343-MS, Los Alamos, 1992.
[3] G.E. Mitchell and J.F. Shriner, Jr., in Spectroscopy to Chaos, ed. D. Koltun and A. Das, World Scientific, Singapore (1995) 77 and G.E. Mitchell in Probing the Nuclear Paradigm, ed. R.A. Broglia, P. Kienle, and P.F. Bortignon, World Scientific, Singapore, (1995) 169.
[4] O. Bohigas and H.A. Weidenmueller, Ann. Rev. Nucl. Part. Sci. **38** (1988) 421.
[5] L.A. Bernstein, et al., this conference.
[6] H. Vonach, et al., Phys. Rev. C **50** (1994) 1952.