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STATUS OF COMPTON RECOIL GAMMA-RAY SPECTROSCOPY

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"STATUS OF COMPTON RECOIL GAMMA-RAY SPECTROSCOPY" †

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SUMMARY

Compton recoil gamma-ray spectroscopy(1-3) was developed for observations in radiation fields which arise in such applied disciplines as reactor physics,(4-8) shielding, dosimetry,(9) health physics,(10) radiobiology and environmental science.(11,12) In such applied environments, gamma-ray spectra are continuous and the absolute magnitude as well as the general shape of the gamma continuum are of paramount importance.

A particularly significant example is the gamma continuum found in reactors. Indeed, the gamma-ray component of the reactor radiation field can produce effects which impact strongly upon reactor design, shielding, and safety.(7) Radiation effects arising from the gamma-ray component are induced by interaction of the absolute gamma-ray energy spectrum in the reactor environment. Hence, the most fundamental quantity underlying effects produced by the reactor gamma-ray field is the absolute gamma-ray energy continuum.

To this end, the current status of Compton recoil gamma-ray spectrometry in Light Water Reactors (LWR) and Fast Breeder Reactors (FBR) environments is described. Particular emphasis is given to continuous gamma spectrometry experiments in a LWR pressure vessel mockup at the Oak Ridge National Laboratory

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Poolside Critical Assembly (PCA).(13) Gamma spectrometry plans for FBR environments are outlined with special attention placed on start-up experiments in the Fast Test Reactor (FTR).(14)

Improvements in Compton recoil gamma-ray spectroscopy are presented. Si(Li) solid state detectors are used in advanced probes of cylindrical design, as shown in Figure 1. For in-situ reactor spectroscopy, a miniaturized vac-ion pump (0.1 ℓ/s) maintains sufficient vacuum to permit cooling of the Si(Li) detector within the vacuum chamber. Thermoelectric cooling (TEC) is utilized to provide a detector temperature of up to 52°C below ambient. The pre-amplifier is a version of the ORTEC-142A design, which has been rebuilt for cylindrical geometry. However, the first stage field effect transistor (FET) is incorporated within the vacuum chamber. This pre-amplifier configuration possesses near optimum characteristics for Compton recoil gamma-ray spectroscopy, with a rise time of $\sim$ 40 nsec and a detector-pre-amplifier noise level of $\sim 50\,\mu$V(RMS).

On-line two parameter data acquisition provides both pulse-height (electron energy) and pulse rise time spectra. Pulse rise time spectra are used to reject defective pulses, which arise principally from electron interactions in the dead regions of the Si(Li) detector. A typical rise time spectrum is presented in Figure 2. Additional work has focused on extending the upper energy limit of applicability, $\sim$ 2 MeV, as originally determined with 1cc Si(Li) detectors.(3) In an attempt to extend this upper limit, investigation of the response characteristics of a 12cc coaxial Si(Li) detector has been carried out and will be presented.

While it was not the original intent of this method to identify peaks in absolute gamma continua, it has turned out to be possible to recognize peaks of sufficient intensity above the general level of the continuum. Using data obtained in reactor environments, the interdependence of neutron and gamma-ray components of the reactor radiation field is highlighted through the identification of many intense gamma peaks which stand out and above the general level of the continuum. An analysis has been advanced (15) to provide estimates of high energy gamma and neutron flux from the absolute intensity of identified peaks in the gamma continuum. This description is based on the relationship between the absolute intensity of such resolvable peaks and the production of such monoenergetic gamma-rays in the in-situ radiation environment. Actually these gamma production rates are simply integral reaction rates produced by either the neutron or gamma-ray components of the radiation field, depending on the origin of the specific gamma peak in question. This analysis will be illustrated by using the resolvable peak of annihilation radiation to obtain high energy gamma-ray flux estimates.

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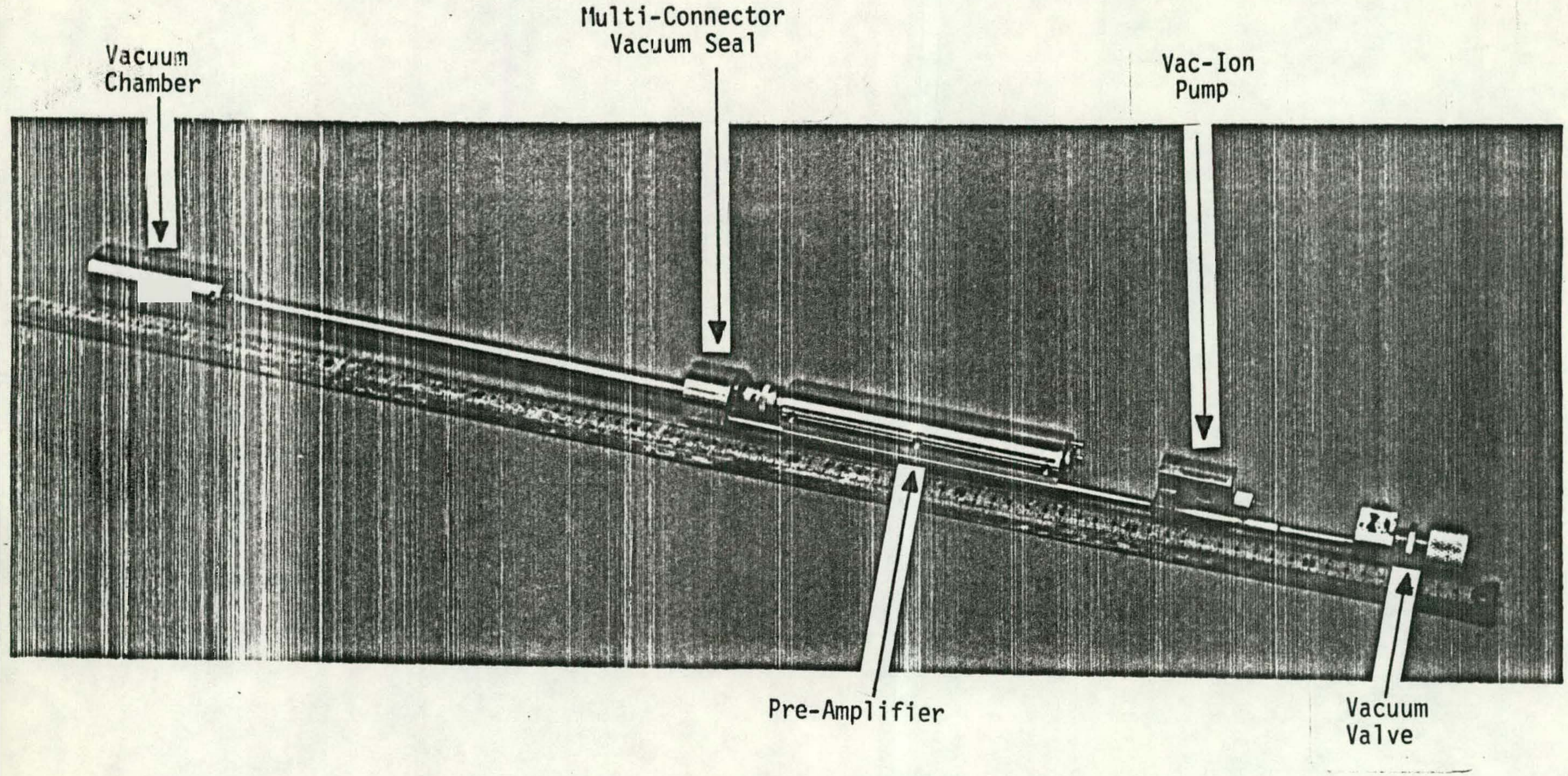

FIGURE 1. Detector Probe for Continuous Compton Recoil Gamma-Ray Spectrometry

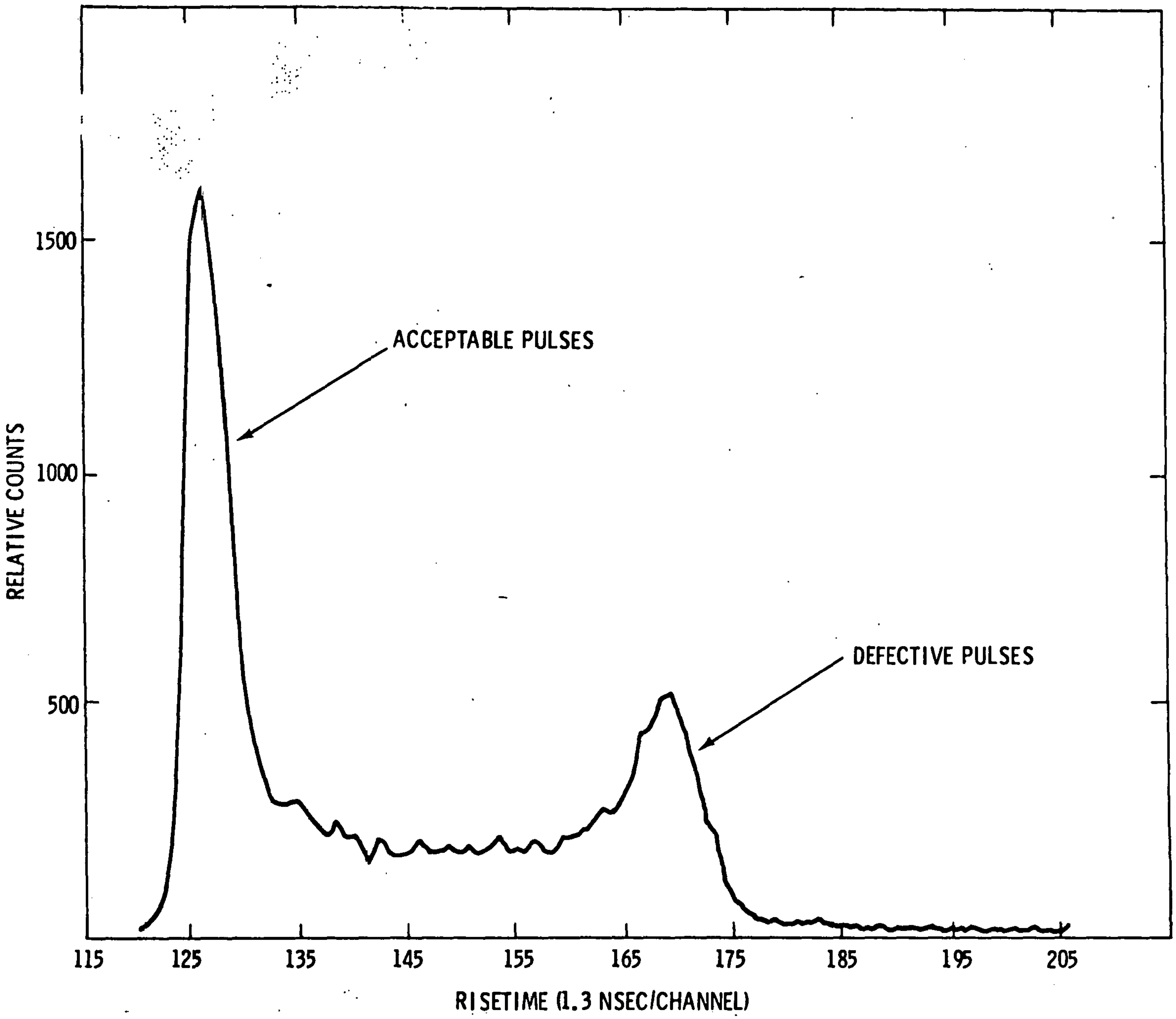

FIGURE 2. Risetime Time Spectrum Obtained from A 1.0 cc Si(Li) Detector at -45°C With a Point Source of ^{54}Mn (0.8348 MeV Gamma-Ray).

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