Summary of Discussions of Electron Volt Spectroscopy

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For purposes of discussion, we define these spectrometers to be those which use sharp nuclear resonances to define the neutron energy before or after scattering. We heard descriptions of tests of two types of these spectrometers, the Resonance Filter Beam Spectrometer (RFBS) (Brugger & Taylor, these proceedings) and the Resonance Detector Spectrometer (RDS) (Carpenter and Watanabe, these proceedings).

The diagram shows the general plan of these spectrometers; letters designate the position of the resonance device.

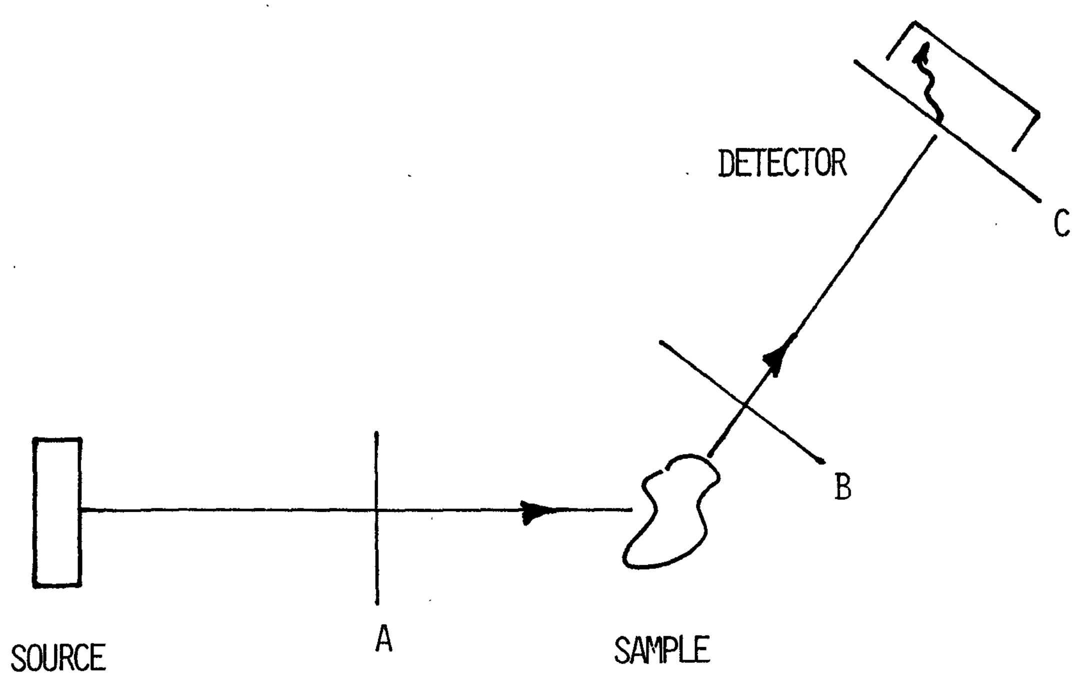

Fig. 1 Schematic diagram of Electron Volt Spectrometers.

The table summarizes the distinctions between the two methods, and introduces a third, prospect, that of the Resonance Filter Detector Spectrometer (RFDS), which has been prototyped (Brugger and Taylor; Williams and Penfold, these proceedings).

Methods of Electron-Volt Spectroscopy

Statistical Method \ Particle Detected	Neutron	Secondary (γ)
Difference	RFBS (A) and RFDS (B)	
Direct		RDS (C)

In the RFBS resonance interactions remove neutrons of definite energy from the incident beam and the distribution of scattered neutron energies is determined by time of flight. The difference between spectra measured with and without the filter gives the net scattered intensity distribution for fixed initial energy. In the RFDS, resonance interactions remove neutrons of definite energy from the scattered beam, and the distribution of incident neutron energies is determined by time of flight. The difference between spectra with and without the filter gives the net scattering for fixed final energy. In the RDS, resonant interactions in an absorber are detected through the prompt secondary particles produced, and the incident neutron energy distribution is determined by time of flight. The measured spectrum is directly proportional to the desired intensity distribution.

We tabulated the following characteristics of these spectrometers.

Characteristics of Electron-Volt Spectrometers

<table>
<tr><th>Resonance Filter-Beam Spectrometer</th><th>Resonance Filter-Detector Spectrometer</th><th>Resonance Detector Spectrometer</th></tr>
<tr><td colspan="2">Detects neutrons - (a) Simple detector system and simplified shield design if gas proportional counters are used; then efficiency is limited to about 20%, at 5 eV where detector thickness contributes to resolution approximately as the source pulse; dead time and electronic jitter are about 1 μs.

(b) ^{6}Li Glass scintillators may be used, with high efficiency, with dead times about 100 nsec, and smaller electronic jitter. Shield design is then made more complex and a sample-dependent background may exist due to capture-gammas seen by the detector, generated in the sample or filter.</td><td>Detects gamma rays or other secondaries. This is fast but more complex than neutron counting, in the case of gamma counting, necessitates design of shielding effective for both neutrons and gammas. Dead times and electronic jitter are less than about 100 nsec. Efficiency is on the order of 50% but depends on the choice of absorber.</td></tr>
<tr><td colspan="2">Difference spectroscopy automatically accounts for sample-independent backgrounds. Separate, sample-out measurement for sample-dependent background.</td><td>Separate background measurement necessary without absorber.</td></tr>
<tr><td colspan="2">Difference spectroscopy introduces large statistical errors for all energies - favors measurements where scattering is near maximum.</td><td>Direct measurement gives small statistical errors where scattering is small.</td></tr>
<tr><td>Long incident path necessitated by shielding amplifies resonance resolution broadening.</td><td colspan="2">Long incident path useful for resolution, short scattered-neutron path allows larger solid angles with fixed detector size.</td></tr>
<tr><td>Resolution $\sim$ 200 meV demonstrated - can be improved.</td><td></td><td>Resolution $\sim$ 70 meV demonstrated - can be improved.</td></tr>
<tr><td colspan="3">Polarization possible in all cases.</td></tr>
<tr><td colspan="2">Capture, scattering, fission resonances all useful.</td><td>Restricted to capture and fission resonances.</td></tr>
<tr><td>Resonance filter small, $\approx$ size of incident beam.</td><td></td><td>Resonance absorber area proportional to detector solid angle.</td></tr>
</table>

Resonance Filter-Beam Spectrometer	Resonance Filter-Detector Spectrometer	Resonance Detector Spectrometer
Detector far from sample, so small detector solid angle.	Detector close to sample, so large detector solid angle.	Sample - detector distance 10cm accomplished.
Filter independent of detector simplifies cooling to reduce Doppler broadening contribution to resolution.		Cooling of absorber probably requires cooling of secondary-particle detector.
Pulse shape rejection of gamma ray background possible with use of ^{6}Li scintillators.		Backgrounds can be reduced by coincidence counting or spectroscopy of secondaries at sacrifice of efficiency.

We find the RFBS, and the less-tested RFDS to be apparently simple devices, notably useful for testing methods. The RDS requires more complex detector technology, but for statistical reasons will probably be best especially for problems in which the scattering of interest is small compared to the average scattering from the sample, the most-common case.

So far tests have been mostly in measurements characterizable as those of struck-particle momentum distributions. Richard Silver showed that these can include some interestingly-structured, but easily-resolvable features. Much more exploration of magnetic, molecular and electronic excitations is needed, as well as tests of the RFDS, which can be done in more-or-less simple adaptations of TOF diffractometers.

The technique using the difference spectra obtained using resonance devices of two different thicknesses of absorber should be tested. Here, the absorption $(1 - e^{-n\sigma(E)})$ is proportional to $n\sigma(E)$ in the wings of the resonance, but due to self-shielding in the thick case, is less sharp near the peak than in the thin case. The difference spectrum can be made sharper than that in the thin-absorber case. The technique would be applicable to any of the spectrometers discussed here.

Gavin Williams described the potential advantages, particularly for low Q scattering, of using thick composite filters which have strong resonance absorbtion regions on either side of the energy range of interest. When placed in the direct beam, these filters suppress background and greatly enhance signal to noise.