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a constant incident flux [see Fig. 7.3.4.2(*c*)]. On this curve, the width of the plateau and a value of the slope about 10^{-4} (in relative variation of counts per mV) give an indication of the detector quality. A good compromise is to set the threshold T at the middle of the plateau.

It is also necessary to verify that the detector high voltage, *i.e.* the gas-amplification coefficient M (see Subsection 7.3.3.1), is well adapted. With the value of the threshold T adjusted as above, the number of counts per unit time is plotted as a function of the high voltage [see Fig. 7.3.4.2(*d*)]. Typical values for the width of the plateau and its slope are 200 V and a few per cent per 100 V. If the high-voltage setting given by the manufacturer must be modified (owing to the worsening of the gas or constraints from the electronic chain, *etc.*), the complete adjustment procedure of the G and T parameters must be repeated.

The electronic adjustments and controls of types of detector other than $^{10}BF_3$ gas detectors are basically the same once the changes in the amplitude spectrum have been taken into account. We present in Fig. 7.3.4.2(*e*) the amplitude spectra for an ^{3}He gas detector with significant wall effects, for a ^{10}B solid-deposit detector with very low efficiency, and for a scintillator. The energy of the secondary particles produced in an ^{3}He gas detector is 765 keV, about three times less than in $^{10}BF_3$, reducing the signal-to-noise ratio; the relative importance of the wall effect is greater and extends to $A_0/4$. In the case of the ^{10}B deposit detector, only one of the secondary particles escapes the foil, so that we do not detect an amplitude A_0 corresponding to the full capture-reaction energy, but only that corresponding either to an average α or Li trace. The quality of the valleys depends on the t/r (foil thickness/particle range) ratio in the ^{10}B solid (see Fig. 7.3.3.2). The figure corresponds to a monitor where $t \ll r$. For the scintillator, the valley in the amplitude spectrum is not very good, even for good glasses and without γ radiation. The discrimination is therefore always much inferior to that of a gas detector. Moreover, the gain of the photomultiplier is very sensitive to the high voltage and has long-term stability problems.

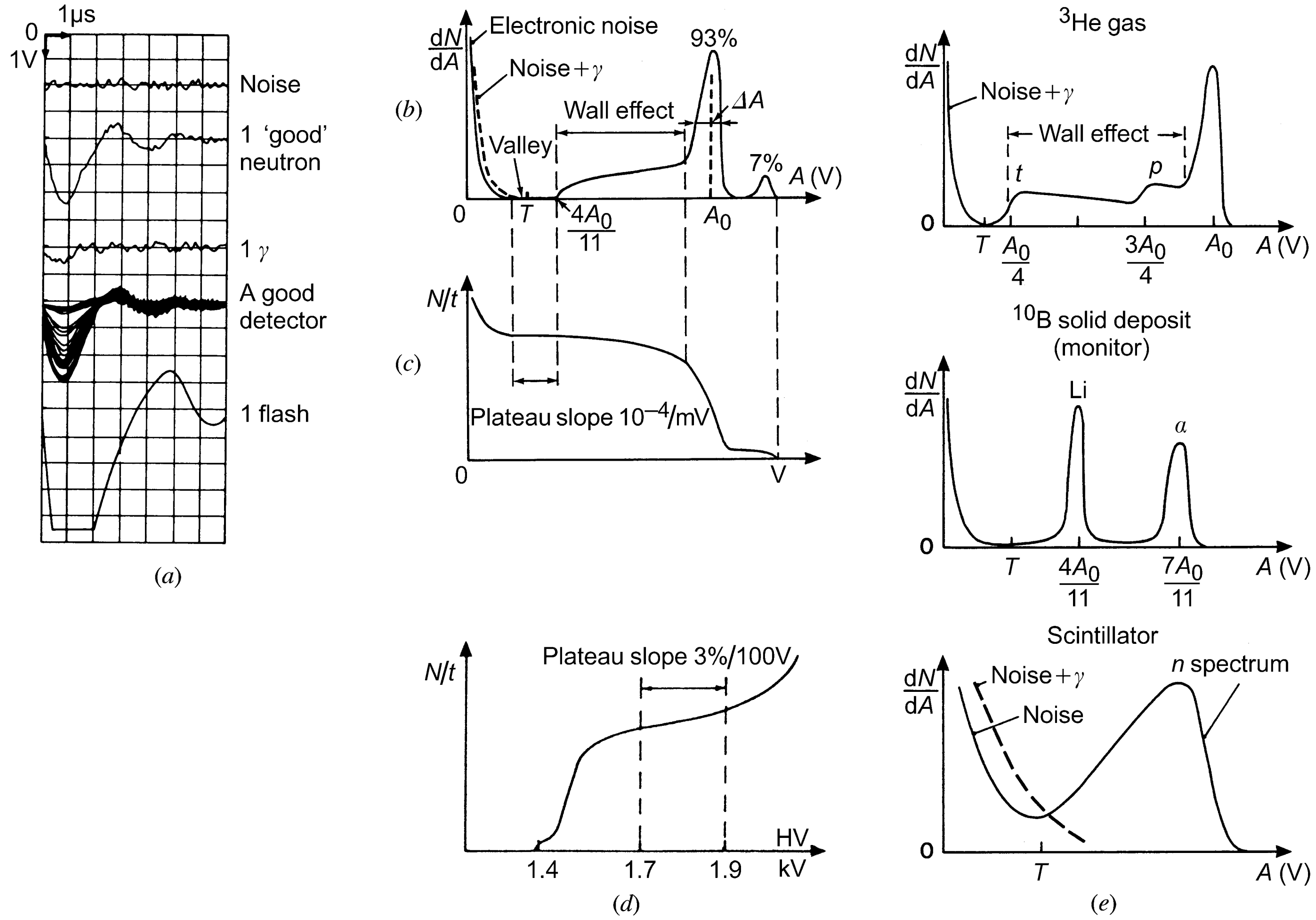
7.3.5. Typical detection systems

7.3.5.1. *Single detectors*

In order to measure the scattered intensities, the single detector is mounted in a shield equipped with a collimator between sample and detector. The collimator is adapted to the sample (5 to 20′ Soller collimator for a powder diffractometer, or a hole adapted to the size of the beam diffracted by a single crystal). The sensitive area of the detector matches the size of the collimated diffracted beam. This geometry allows one to localize the scattered beam with adequate resolution and to avoid parasitic neutrons. In a powder diffraction measurement, the detector is scanned with a goniometer, each step being monitored.

7.3.5.2. *Position-sensitive detectors*

With the advantages of speed and simultaneity of data collection over broad angular ranges, position-sensitive detectors



(*a*)

(*d*)

(*e*)

Fig. 7.3.4.2. (*a*) Characteristic $^{10}BF_3$ gas-detector analogue pulses seen on an oscilloscope. (*b*) $^{10}BF_3$ amplitude spectrum. (*c*) Plateau of a $^{10}BF_3$ detector as a function of the threshold voltage. (*d*) Typical plateau of a $^{10}BF_3$ detector in proportional mode as a function of the high voltage. (*e*) Amplitude spectra of various detectors.

(PSDs) have seen considerable development (Convert & Chieux, 1986). They are based on the fundamental detection processes described in Section 7.3.3. Their dimensions, the introduction of various systems for position encoding and decoding, and the multiplication of the number of detection chains (with necessary adjustments and controls) have produced detection systems of a complexity that can no longer be grasped by a researcher only occasionally involved in neutron-scattering experiments. The following lines give only a very crude introduction to PSDs at a descriptive level.

A PSD is always mounted in a shield that has an opening limited by the cone defined by the sample size and the detection area. Given the large opening in the shield, the PSD is very sensitive to parasitic neutrons, especially those coming from materials in the main monochromatic beam. However, if sufficient care is taken with the sample environment and beam-stop design, the signal-to-noise ratio may be as good as or even better than in a single detector. The scattering angle is determined by the angular position of the origin of the PSD, the sample-to-detector distance, and the location of the neutron capture in the PSD.

In a PSD, each individual neutron-capture reaction in the continuous converter is localized *via* an internal encoding system followed by electronic decoding. There are three types of PSD: the gas resistive wire, the gas multielectrode, and the Anger camera (scintillation).

(*a*) *Gas PSD with resistance encoding*. The simplest examples of this type of PSD are one-dimensional detectors in which the neutron-converter gas is contained in a cylindrical stainless-steel tube with a central, fine resistive wire anode. The amplitudes of the output pulses from charge-sensitive amplifiers attached to each end of the anode are then compared to derive the positional coordinate of the neutron. An alternative method of deriving the positional information is RC (resistance capacitance) encoding followed by time decoding (Borkowski & Kopp, 1975). Two-dimensional RC encoding PSDs have been developed. One of the solutions is to have a group of wires interconnected by a chain of resistors with amplifiers at the resistor chain nodes (Boie, Fischer, Inagaki, Merritt, Okuno & Radeka, 1982).

(*b*) *Gas multi-electrode PSD*. The simplest examples of this type of PSD are one-dimensional detectors with a small number of discrete electrodes, *e.g.* 64 parallel anode wires separated by 2.54 mm. Each anode wire has an amplifier. A logic system analyses the amplitudes of the output pulses corresponding to one neutron that are collected by one, two, or three neighbouring wires, and decides on which wire the neutron was detected. Large curved one-dimensional PSDs have been built on this principle, *e.g.* 800 wires covering 80°. Two-dimensional PSDs based on the same principle use a matrix system in which a neutron gives rise to two sets of signals on two orthogonal systems of electrodes (Allemand, Bourdel, Roudaut, Convert, Ibel, Jacobé, Cotton & Farnoux, 1975).

(*c*) *Neutron Anger camera*. The principle of the Anger camera is to detect an incident photon or particle with a continuous area of scintillator. The light produced is allowed to disperse before entering an array of photomultipliers (PMs) whose analogue output signals are used to derive the position of the incident neutron. In one dimension, the localization is achieved by a row of PMs (Naday & Schaefer, 1983). In two-dimensional PSDs, a close-packed array of PMs allows the location of the scintillation to be determined by calculating the X and Y centroids using a resistor-weighting scheme (Strauss, Brenner, Lynch & Morgan, 1981).

Table 7.3.5.1 gives the characteristics of some PSDs, each example being a good compromise of detector characteristics adapted to the instrument needs, powder diffraction, single-crystal diffraction, and small-angle neutron scattering (SANS). From this table, it seems that the characteristics of the various types of PSD that have been presented are nearly equivalent. The homogeneity of neutron detection over the PSD sensitive area is better than 5% in all cases. Among those PSDs, the gas PSDs, which have been installed since the early 1970s, are the most commonly used. The definite advantage of the gas multi-electrode PSD is to digitize the encoding, thus offering very good stability and reliability of the neutron localization. The resistance-encoding gas PSD has less complex electronics and permits a choice of pixel size (elementary detection area) and thereby definition. The Anger camera also offers the same flexibility in the choice of the pixel size and, because of the small thickness of the scintillator (1–2 mm), has very little parallax and is well adapted to TOF measurements. However, the γ sensitivity of the scintillators is much higher than that of the gas PSDs.

PSDs permit a simultaneous measurement of intensities over relatively large areas. As compared with the scanned single detector, this opens the way to two possibilities, either shorter counting time (*e.g.* real-time experiments) or improved statistical precision. However, the high counting rates achieved, as well as the complexity of the detection, increase the effective dead time and the occurrence of defects. The efficient use of a PSD therefore requires a detailed understanding of its operation (detection process, encoding–decoding, data storage, *etc.*) and periodic tests and calibrations.

7.3.5.3. *Banks of detectors*

When it is useful to have a large detection area without requiring spatial continuity of the detection, the solution is in the juxtaposition of several detectors. The selection of the type of detectors, the way of regrouping them, and the design of the collimation system depend on the measuring instrument. An appropriate geometry will optimize the signal-to-noise ratio and the instrumental resolution.

Banks of single detectors, up to 64 covering up to 160° in the diffraction plane with Soller collimators in front of each detector, are used for powder diffractometers in reactors [D1A and D2B, Institut Laue–Langevin (1988)]. The relative position of the detectors plus collimators and their response to the neutron intensity have to be measured and calibrated. The bank of detectors is scanned in small steps over the interval between two successive detectors in order to obtain a complete diagram over the angular range of the bank.

In a similar way, a juxtaposition of small PSDs with individual collimators is also used [D4, Institut Laue–Langevin (1988)].

In the case of spallation sources, the time-of-flight powder diffractometers are made of arrays of detectors at selected diffraction angles, to increase the detection area (Isis, 1992). Whenever it is possible, the time focusing geometry is used (Windsor, 1981). This implies a particular alignment of the detector array in order for it to become equivalent to one detector at one angle.

On the same instrument [HRPD, SANDALS, LAD (Isis, 1992)], various types of detector are used (^{3}He gas single detectors of small diameter, Li glass or Li+ZnS scintillators). For each selected diffraction angle, the choice of detector depends on the required resolution, which is better for scintillators because of their small thickness, and on other properties of the detectors (background, stability, γ discrimination), which are better for ^{3}He detectors.

references