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NEUTRON BACKSCATTERING SPECTROSCOPY

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1. INTRODUCTION

Neutron backscattering (BS) spectroscopy is an important scattering technique for achieving high energy resolution and thus for accessing long times. What does backscattering mean? The term "backscattering" signifies, that the neutron energy is determined by Bragg reflection from crystals under a Bragg angle Θ of 90° in order to minimize the energy resolution. To avoid misunderstanding among newcomers, we note that backscattering is not related to the scattering process at the sample (BS measurements are of course possible at small scattering angles). Thus "backscattering" concerns only the neutron optics such as monochromators and analyzers. As we will see later, the principle is to define the incident wave vector $|\boldsymbol{k}_i|$ precisely and to vary its length for energy analysis, whereas the final wave vector $|\boldsymbol{k}_f|$ is always kept constant.

The neighbouring neutron instruments of BS in phase space are neutron spin echo (NSE) and time-of-flight (TOF) instruments. Neutron-BS, like TOF, measures in frequency space, thus determines $S(\boldsymbol{Q},\omega)$, whereas NSE measures in time space and determines $S(\boldsymbol{Q},t)$. Neutron-BS is a unique technique for measuring low lying, in frequency peaked excitations down to energy transfers of 0.2 μeV and it is complementary to NSE with respect to quasielastic scattering. Concerning inelastic X-ray spectrometers, there is no equally versatile spectrometer with similar energy resolution today.

We show in figure 1 the energy-momentum-range (phase space or (Q,ω)-range), which can be covered by neutron backscattering. The different dark grey areas belong to the already available regions on reactor-BS (r-BS) instruments. The light-grey areas indicate possible extensions. The Q-range is normally covered for BS in one run simultaneously (e.g. not so for IN15) and one can potentially access a time

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range between 0.01 microseconds and 100 picoseconds. All regions are limited by the instrumental resolution towards the low energies. On TOF spectrometers, in order to achieve a high energy resolution, one has to work with a long wavelength, which consequently limits the maximum Q strongly. We compare the NSE spectrometer IN15 in its longest time resolution mode and IN11 optimized for short times. These spectrometers cover with an excellent energy resolution a wide time range.

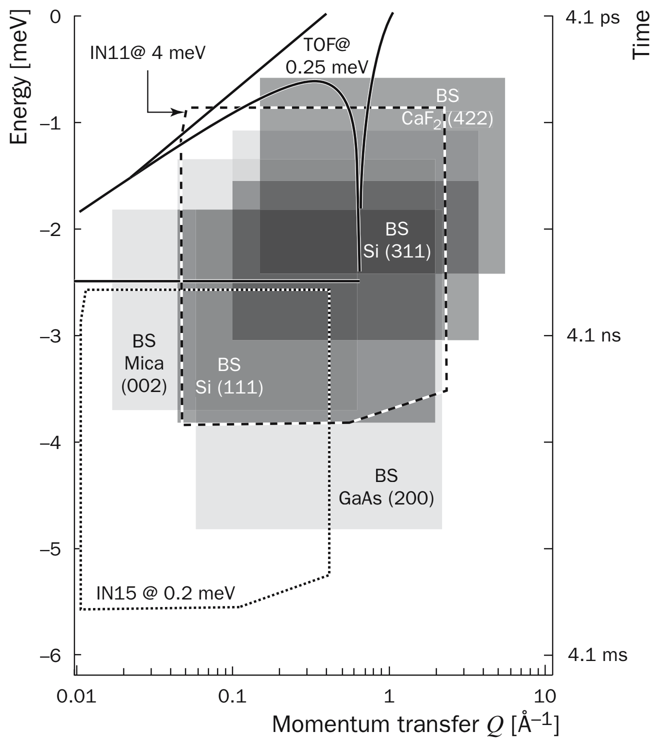

Figure 1 - Region in energy momentum transfer or (Q,ω)-range which is accessible to neutron backscattering instruments. The lowest accessible energy is limited by the instrumental resolution. Regions for existing reactor-BS instruments are presented by the dark areas, their possible extensions by grey areas. NSE and TOF spectrometers are compared at certain incident energies (IN11 at 4 meV, IN15 at 0.2 meV and a typical chopper TOF instrument at 0.25 meV) and the lines show the limits of the accessible range. BS instruments on spallation sources are not shown. Their energy resolution is somewhat better (typically 2-4 μeV) than for TOF spectrometers, but worse than for reactor-BS instruments. The main advantage of BS over TOF is that the excellent energy resolution can also be achieved at high Q values.