Data analysis for spectrometry on fusion plasmas

Neutron spectrometry in plasma diagnosis requires complex data analysis procedures. A method which combines the procedures of the Bayes's statistics and the maximum entropy allows parameters to be investigated which describe the plasma in fusion experiments.

In recent years, a series of measurements with a completely characterized neutron spectrometer based on the organic scintillator NE213 has been performed at the Joint European Torus (JET) within the scope of a cooperation with ENEA, Frascati (IT) and EFDA-JET, Culham (UK). To apply neutron spectrometry for the diagnosis on fusion plasmas, it is decisive to use optimized data analysis procedures which allow the required information about relevant parameters of the fusion plasma to be extracted. For this purpose, special data analysis methods have been developed which combine Bayes's methods and deconvolution procedures in accordance with the maximum entropy principle. This two-stage procedure allows optimal data analysis which can be adapted to the concrete information to be derived from the measurement. To clarify these methods, measurements were performed under controlled conditions at the accelerator facility of PTB and analyzed. A detail work dealing with this subject was submitted for publication in "Review of Scientific Instruments”.

Figure 1 shows a comparison between measured and calculated neutron spectra for two irradiation conditions. For the analysis of these data, a procedure has recently been developed which combines deconvolution according to the maximum entropy method with the determination of an optimal parameter to define the quality of the solution spectrum. The agreement between the calculated spectra and the spectra determined with the deconvolution procedure is very good and demonstrates both the high quality of the response functions of the neutron detector and the excellent quality of the data analysis which can be achieved with a negligibly small statistical uncertainty in the measurements. In cases in which the statistical uncertainty of the measurement cannot be neglected, the method of the maximum entropy deconvolution must, however, be completed with Bayes's procedures.

As an example of a concrete application of Bayes's methods, Figure 2 shows the probability distribution of the full width at half maximum (*FWHM*) of an almost monoenergetic neutron spectrum for four measurements with similar measurement time and statistical uncertainty. A good estimate for the full width at half maximum is obtained from the maximum of the probability distribution. The uncertainty assigned to this value can be derived from the width of the probability distribution. All four probability distributions have a maximum at approx. the same value of the full width at half maximum and overlap. This is an evidence for the internal consistency of the data evaluation. In addition, the uncertainty in the full width at half maximum - which is determined from a single measurement analyzed in accordance with the Bayes's procedure - agrees with the uncertainty determined from the dispersion of the values of the full width at half maximum for the four single measurements. This means that it is sufficient to analyze a single measurement with Bayes's procedures to determine the full width at half maximum and its associated uncertainty.

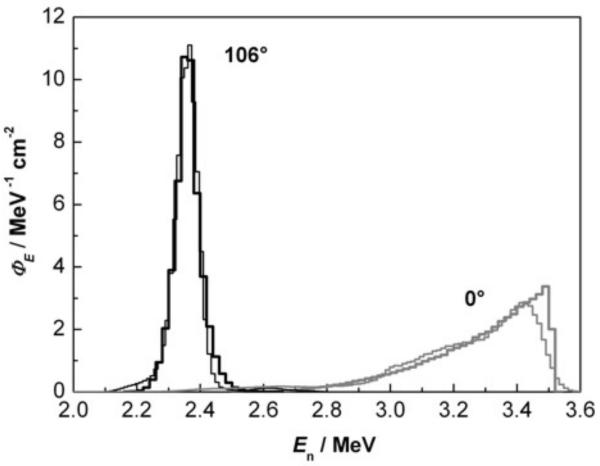

Figure 1: Calculated (thin line) and measured (bold line) spectral fluence for a neutron spectrum generated with the reaction $d + d \rightarrow {}^3He + n$ for different positions of the neutron detector (angle of the neutron emission relative to the deuteron beam of 106° or 0°). The calculations were adapted to the measurements for an identical total neutron fluence.

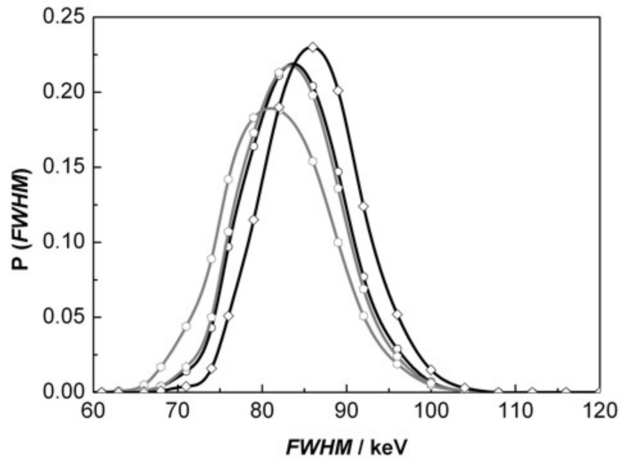

Figure 2: Probability distribution of the full width at half maximum of an almost monoenergetic neutron spectrum with a neutron energy of approx. 2.5 MeV (emission angle of 106° (see Figure 1)) as result of a Bayes's parameter determination for a Gaussian model of the neutron spectrum. The figure shows the result for four different measurements with approx. 250000 events each time.

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