VINIA AND NEPMC CODE NUMERICAL EVALUATION OF NEUTRON SCATTERING FOR NEUTRON DIAGNOSTICS ON ASDEX

B. V. Robouch
Associazione EURATOM-ENEA sulla Fusione
Centro Ricerche Energie Frascati, I-00044 Frascati

K. Hübner, R. Bätzner, M. Roos
Institut für Angewandte Physik II, Universität Heidelberg
D-6900 Heidelberg

L. Ingrosso, H. Rapp, H. Wurz, ASDEX Team
Max-Planck-Institut für Plasmaphysik
EURATOM Association, D-8046 Garching

Neutron diagnostics near a tokamak suffer from neutron scattering in the material of the facility and the large extension of the neutron source. We investigate these problems for nuclear emulsion measurements at ASDEX using the VINIA-3DAMC software with a plasma neutron source and the ASDEX structure as input to follow the migration and scattering of neutrons, and the NEPMC software to calculate the nuclear emulsion response.

Input data

We consider ASDEX discharges with D^{o}-injection into a D^{+}-plasma. To simulate the local neutron production, we use measured plasma data, the FREYA code (deposition profile) and our interpretation code [1] for the measured neutron rate.

The material structure of the ASDEX facility is represented by its vacuum vessel, a quartz window with support, 16 toroidal field coils, the ohmic coils, the central core of 3 different regions, the collimator for exposing and shielding a nuclear emulsion, as well as the glass support of the emulsion. To check for special effects, we also introduced for some calculations certain parts of the divertor, material between toroidal field coils, and the experimental torus hall.

We consider measurements with two different collimators, viewing radially to the plasma, one in front of a large port closed with a quartz window (collimator 1), the other beside a toroidal field coil in front of the vessel (collimator 2).

VINIA-3DAMC software

The software, a strict analogical Monte Carlo, uses the nuclear data bank files in ENDF/B4 format in extenso in order to avoid imparing the precision of avaliable data: no truncation (of Legendre polynomials or tables), no discretization of either energy (no group treatment) or space (no ray effects), both taken as continua. This Monte Carlo follows the neutrons from birth as long as its story is relevant to the problem (absorption, loss or energy threshold) through each "forced" collision as to: position, weight attenuation, nuclide and reaction branch, anisotropic reemission with definite or continuous energy selection. The "flux-at-a-point" method is used with due account at each event (emission/collision) of all probabilistically determined possible contributions. Complimentary to this basic Monte Carlo, is a built-in data extracting software that gathers information pertinent to the specific problem under study.

NEPMC-software

To calculate the response function of the nuclear emulsion, we use a Monte Carlo code taking into account the proton track statistics and the statistical errors of track measurement. Furthermore the real angle of incidence for each neutron is used and thus the effects caused by the large extension of the neutron source for both emitted and collided neutrons are included.

Results

The shape of the collimator 1 defines 3 distinct spatial regions important for interpreting the results: the free aperture (zone 1) defining the observed plasma volume, a "soft edge" of the aperture (zone 2) with shine-through from the neighbourhood of the observed region, and a well-shielded region (zone 3).

The VINIA calculations deliver the spectral neutron flux per emitted neutron arriving at the emulsion, resolved into contributions of emitted and collided neutrons from each of the 3 zones and each of the different structural parts of the ASDEX device. From a calculation with 34,575 emitted neutrons we get the following fluxes (in cm^{-2}):

neutron energy [MeV]		1.0 < E < 2.1	2.1 < E < 3.0	
flux total		$0.265 \cdot 10^{-8} \pm 15.1\%$	$0.250 \cdot 10^{-8} \pm 2.4\%$	$\widehat{=}$ 100%
emitted,	zone 1		$1.55 \cdot 10^{-8} \pm 3.0\%$	$\widehat{=}$ 62.1%
	zone 2		$0.21 \cdot 10^{-8} \pm 6.5\%$	$\widehat{=}$ 8.4%
	zone 3		$0.551 \cdot 10^{-11} \pm 11.5\%$	$\widehat{=}$ 0.02%
collided,	zone 1	$0.227 \cdot 10^{-8} \pm 17.3\%$	$0.586 \cdot 10^{-8} \pm 6.3\%$	$\widehat{=}$ 23.4%
	zone 2	$0.035 \cdot 10^{-8} \pm 19.1\%$	$0.146 \cdot 10^{-8} \pm 12.1\%$	$\widehat{=}$ 5.8%
	zone 3	$0.002 \cdot 10^{-8} \pm 29.6\%$	$0.004 \cdot 10^{-8} \pm 31.1\%$	$\widehat{=}$ 0.16%

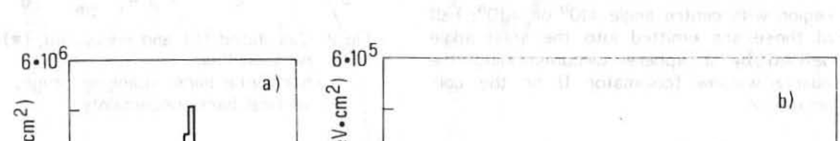

Fig. 1: Energy spectra for emitted (a) and collided (b) neutrons from VINIA and NEPMC calculations

Fig.1 shows for collimator 1 the energy spectra for the emitted and collided neutrons (summed over all zones) from the VINIA calculation as well as the expected response of the nuclear emulsion calculated with the NEPMC software. As expected, the spectrum of emitted neutrons is centred at 2.45 MeV, but the spectrum of collided neutrons also substantially contributes to this region.

For nuclear emulsion diagnostics it is only the energy region above 2.1 MeV that is of interest. Here we find in the case of collimator 1 a contribution of 31.8% from the scattered flux. This flux originates in zones 1 and 2. The shine-through of the collimator in zone 2 may be reduced by proper design, but the contribution in zone 1 is unavoidable. The scattered component in zone 1 is mainly produced in the quartz window (73%), the rest coming from the inner wall of the vessel (15%), the window support (7%), the ohmic coils (3%), and the toroidal field coils in the core (2%).

Weighted emission of neutrons

For the VINIA calculations the neutrons are emitted with the radial distribution and the energy spectrum defined by the input parameters. Now, the dominant contributions to the neutron flux at the emulsion are produced in zone1 and here the few collisions in the material between plasma and emulsion are the main source for the collided component.

To adequately fill the distribution for these components, we resort to a weighted emission: half of the neutrons are emitted in front of the considered collimator in a region with centre angle ±10° or ±30°; half of these are emitted into the solid angle defined by a sphere circumscribing the quartz window (collimator 1) or the collimator 2.

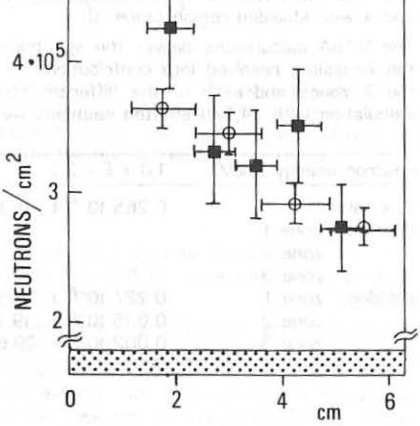

Fig.2: Calculated (○) and measured (■) neutron flux,
horizontal bars: scanning range,
vertical bars: uncertainty

Comparision with measurements

The calculated integral fluxes per emitted neutron are multiplied by the measured total neutron yield (U-counter) to get the neutron fluxes at the emulsion. These are now compared with the fluxes measured by the emulsions for two discharges for which the two different collimators were used.

ASDEX discharge	no. 16910, coll. 1	no. 19111, coll. 2	
neutrons in VINIA	34,575	4,000	
neutron yield	$1.3 \cdot 10^{-13} \pm 15\%$	$3.2 \cdot 10^{-13} \pm 15\%$	neutrons
VINIA calculation	$0.250 \cdot 10^{-7} \pm 2.4\%$	$0.891 \cdot 10^{-7} \pm 8\%$	cm^{-2}
resulting flux	$3.25 \cdot 10^{5} \pm 15\%$	$2.85 \cdot 10^{6} \pm 17\%$	neutrons/cm
measured flux	$3.41 \cdot 10^{5} \pm 13\%$	$2.55 \cdot 10^{6} \pm 13\%$	neutrons/cm^2

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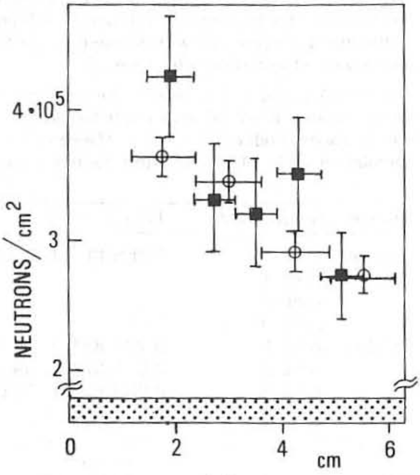

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