COMPARATIVE ANALYSIS OF SCISSION-NEUTRON COMPONENT EXTRACTION

I.S. Guseva

National Research Centre "Kurchatov Institute"
B.P. Konstantinov Petersburg Nuclear Physics Institute

The emission of prompt fission neutrons

Neutrons evaporated after fully acceleration of fission fragments

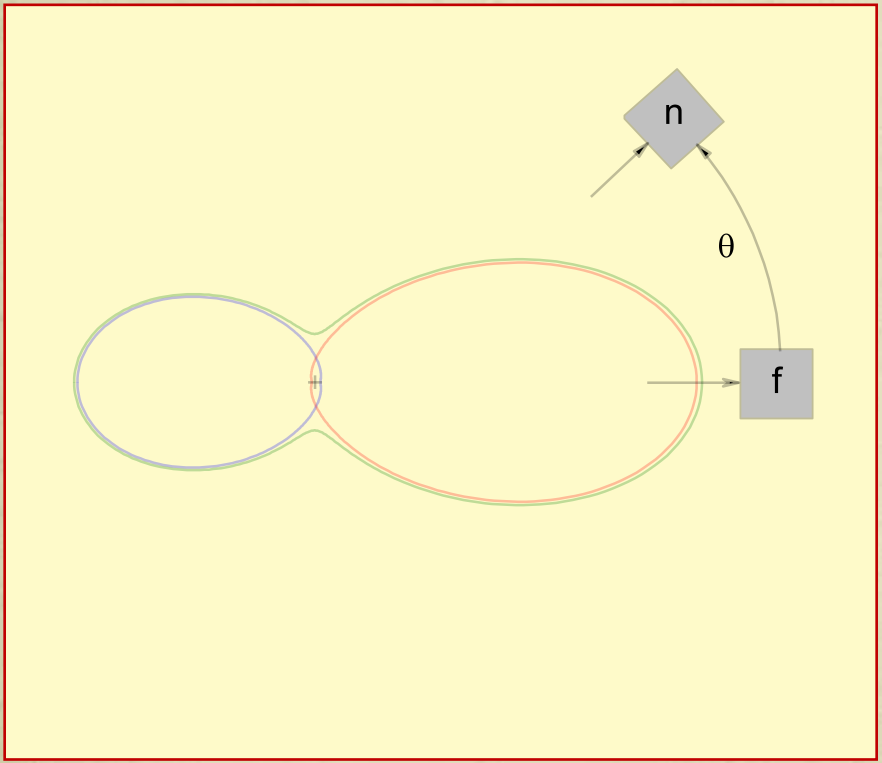
Scission neutrons

Contrary to light-charged particles, scission neutrons are not focused by the Coulomb field of the nascent fragments.

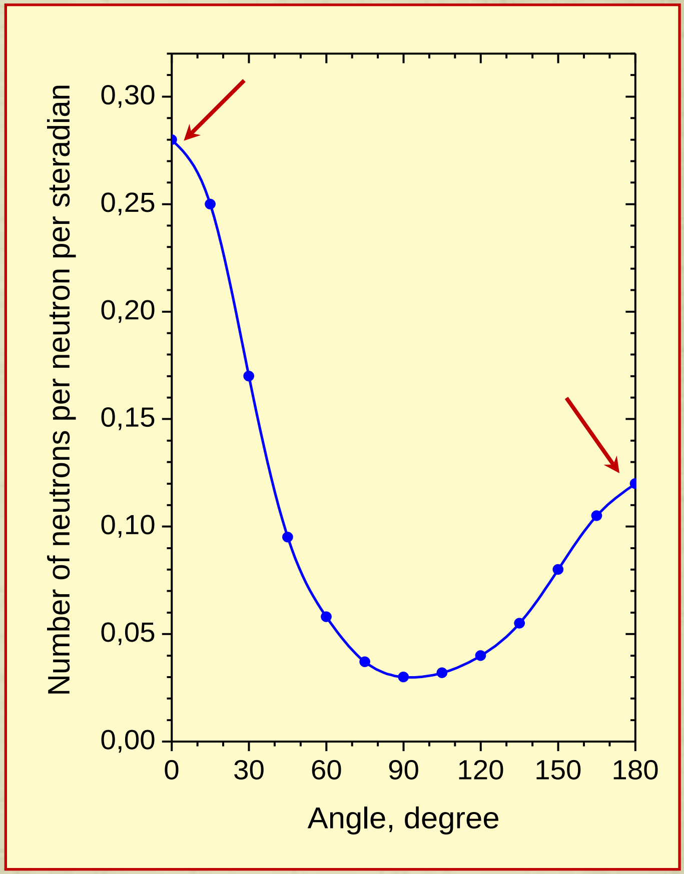
To distinguish the «scission» component from the neutrons emitted after fully acceleration of fission fragments, the difference in the angular and energy distributions is normally used.

The measurements of neutron-fragment coincidences

<u>Symbolic designations:</u>
n, f – neutron and fission fragment detectors
red and blue curves – angular distributions of neutrons from light and heavy fragments

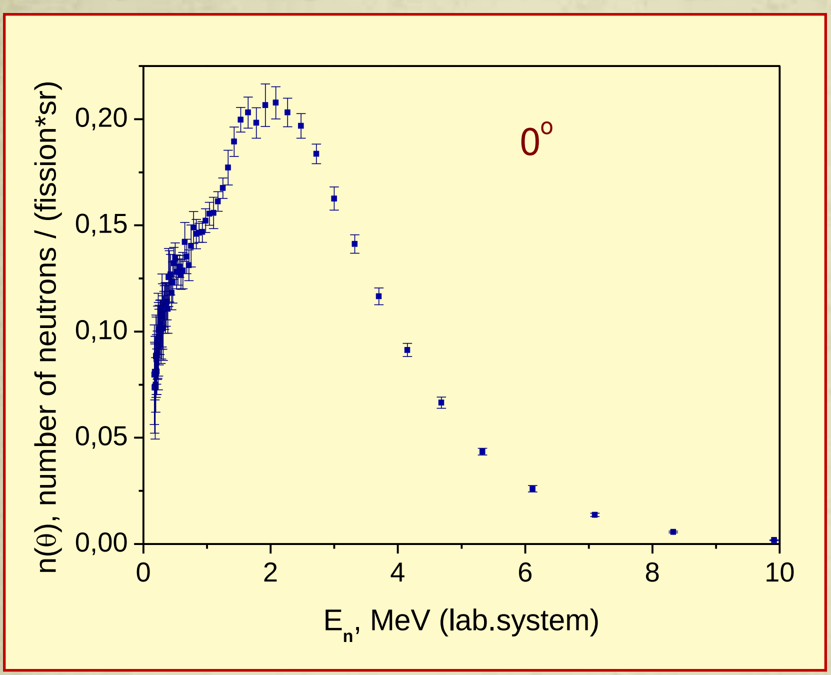


The angular distribution integrated over neutron energy

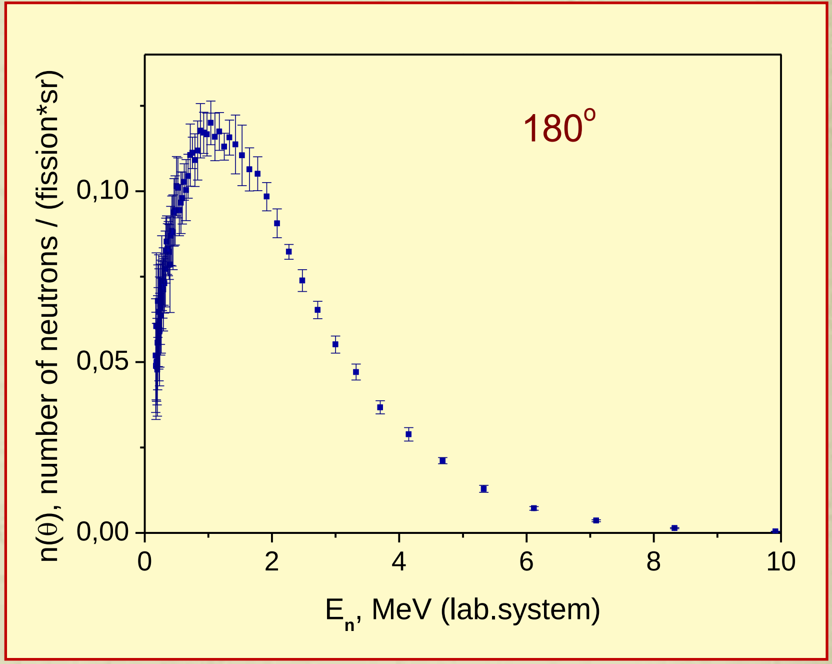


To determine the neutron spectra in the center-of-mass of fission fragments the neutron spectra at 0º and 180º in laboratory system are used

The direction of light fragment motion



The direction of heavy fragment motion



Using Jacobian of transformation the neutron spectra at 0 and 180 in lab. system can be converted to the CM system of light and heavy fragments:

$$N_{L(H)}(E_{lab},\mu_{lab}) = \varphi_{L(H)}(\mu_{cm})\cdot\Phi_{L(H)}(E_{cm})\cdot D$$

$\Phi(E_{cm})$ – the energy spectrum for neutrons in fragment CM-system

D – Jacobian of transformation

E_v – kinetic energy per nucleon in the fission fragment

$\mu_{lab} = \cos(\theta_{lab})$ $\theta_{lab,\ cm}$ – the angle between $\vec{V}_n$ and $\vec{V}_L$

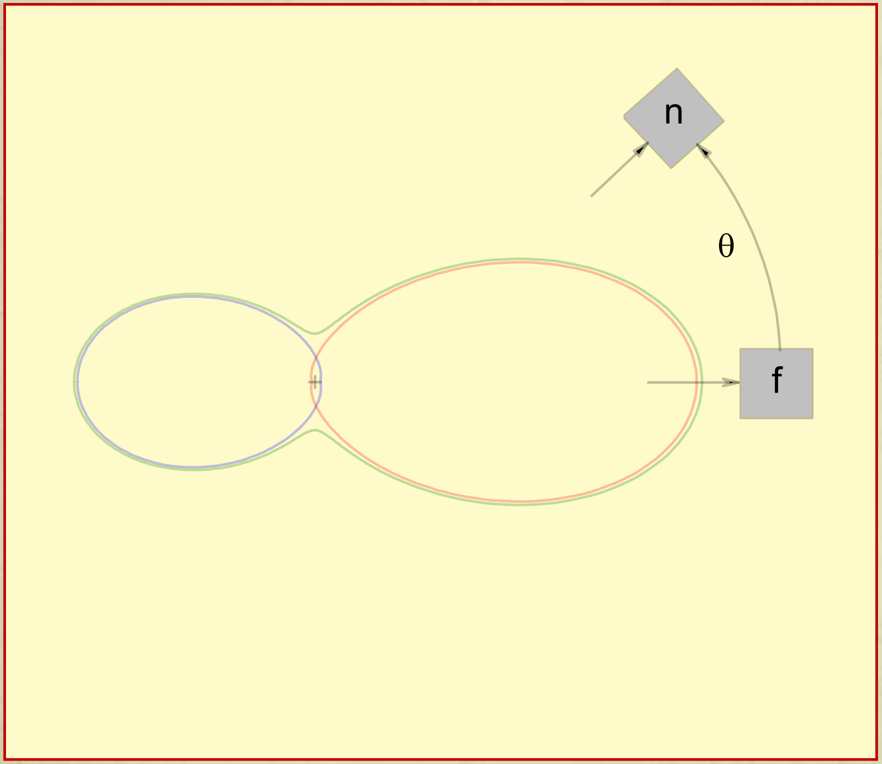
$\mu_{cm} = \cos(\theta_{cm})$

$$D = \begin{vmatrix} \frac{\partial E_{cm}}{\partial E_{lab}} & \frac{\partial E_{cm}}{\partial \mu_{lab}} \\ \frac{\partial \mu_{cm}}{\partial E_{lab}} & \frac{\partial \mu_{cm}}{\partial \mu_{lab}} \end{vmatrix} = \sqrt{\frac{E_{lab}}{E_{cm}}} \qquad \mu_{cm} = \frac{\mu_{lab}\sqrt{E_{lab}} - \sqrt{E_v}}{\sqrt{E_{cm}}} \qquad E_{cm} = E_{lab} + E_v - 2\mu_{lab}\sqrt{E_{lab}\cdot E_v}$$

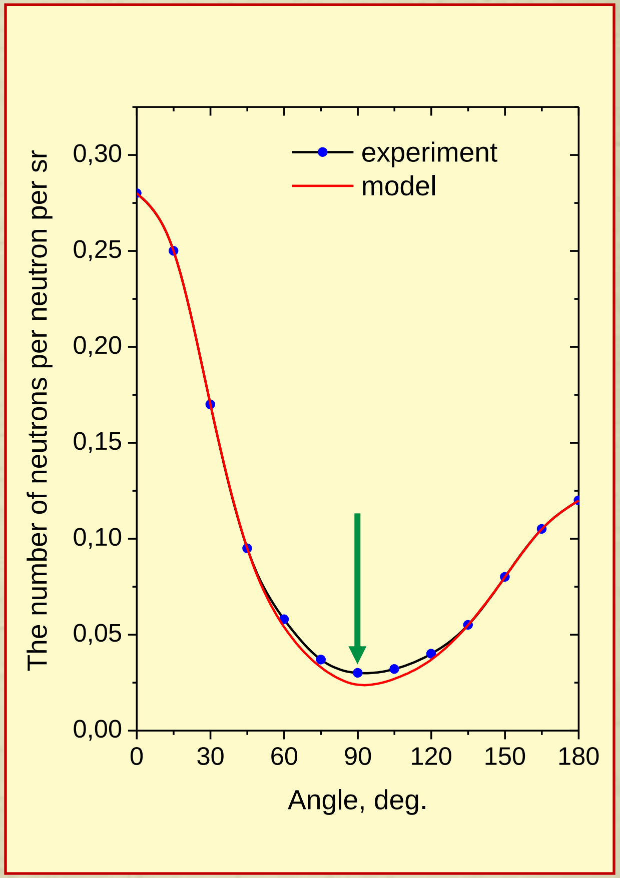
$\varphi(\mu_{cm}) = (1 + bP_2(\mu_{cm}))$ – the angular distribution for neutrons in CM-system

The measurements of neutron-fragment coincidences

<u>Symbolic designations:</u>
n, f – neutron and fission fragment detectors
red and blue curves – angular distributions
of neutrons from light and heavy fragments

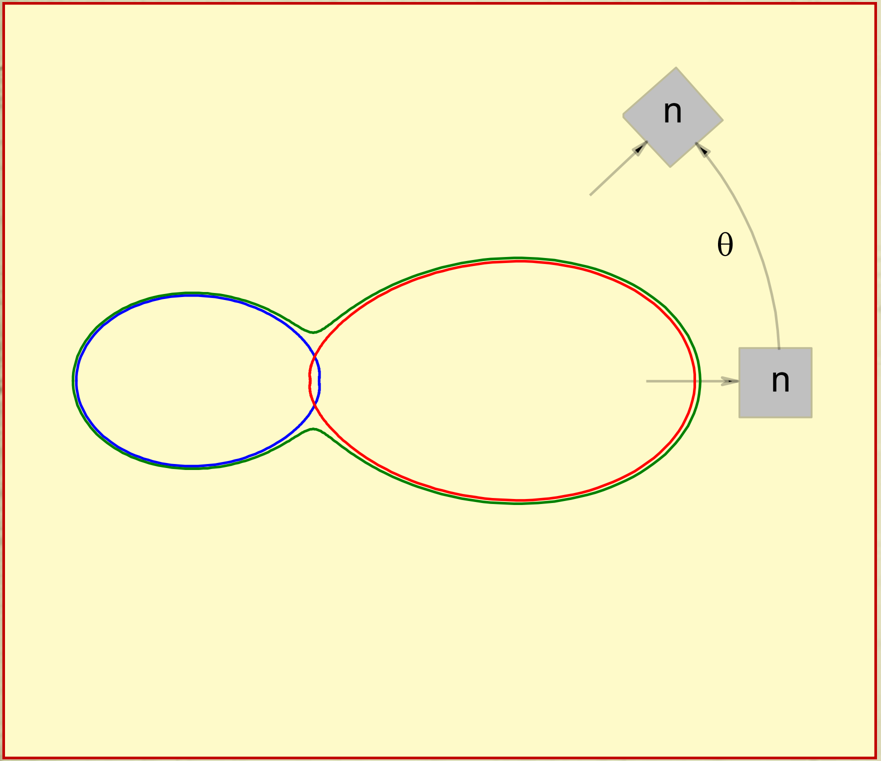


The comparison of experimental and calculated values



The measurements of neutron-neutron coincidences

Symbolic designations:
n – neutron detectors;
red and blue curves – angular distributions of neutrons from light and heavy fragments.



The necessary input parameters for the Monte-Carlo calculations:

Fixed parameters:

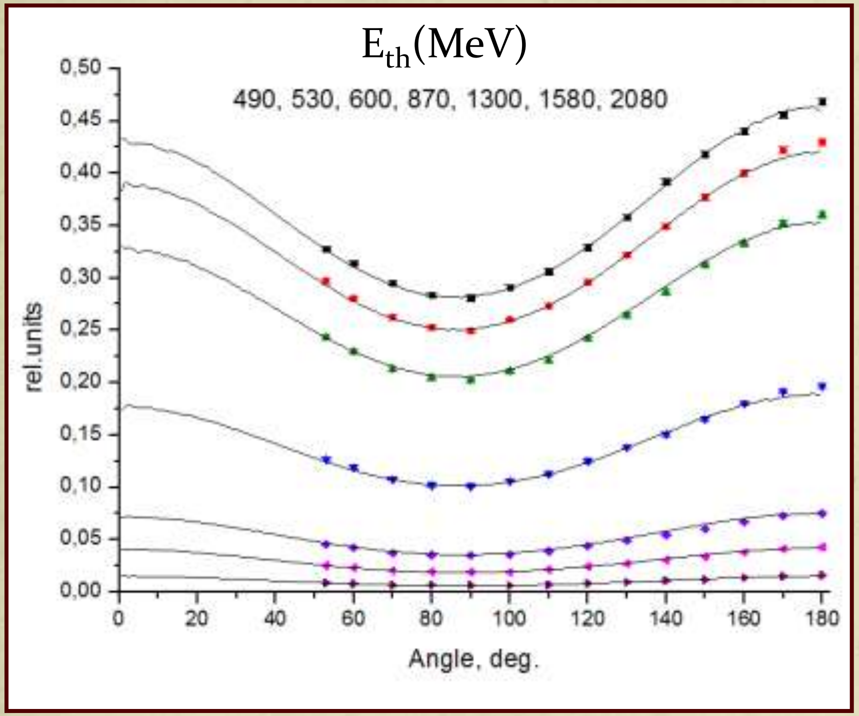
1. The energy spectra of neutrons in the fragment CM;
2. The average multiplicity and dispersion of emitted neutrons from each fragment together with the parameter of a covariance;
1. The most probable final velocities of light and heavy fission fragments.

Fitting parameters:

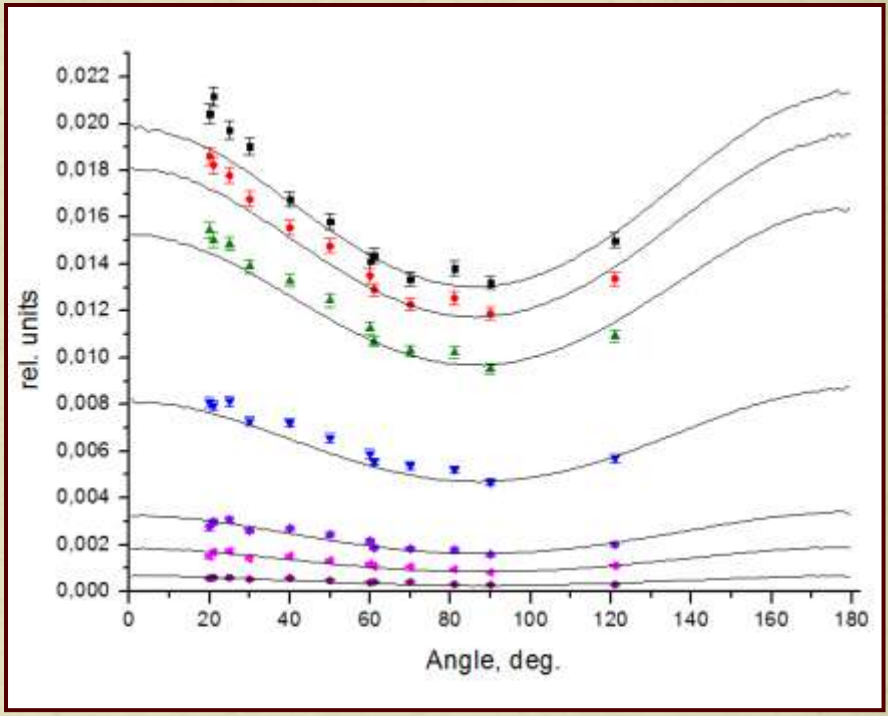
1. The share of “scission”-component
2. Temperature of “scission”-component spectrum

The experimental and calculated results for n-n correlation in spontaneous fission of ^{252}Cf

Short base



Long base



The difference between experimental and calculated values in the figure for long base corresponds to cross-talks evaluation

<u>RESULT of calculations:</u>

The «scission» neutron contribution is (8 2)%

with average neutron energy ≈ 2.4 MeV

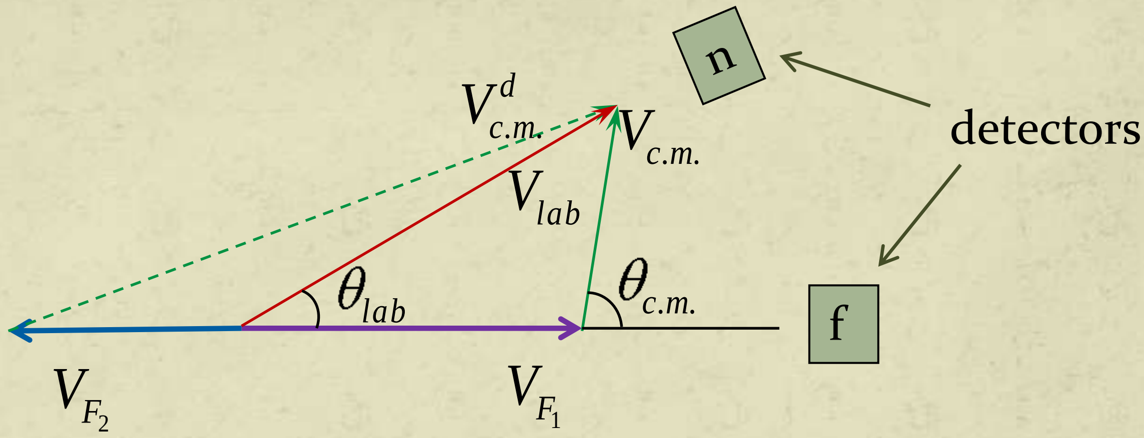
The data in the article of Budtz-Jørgensen&Knitter "SIMULTANEOUS INVESTIGATION OF FISSION FRAGMENTS AND NEUTRONS IN ^{252}Cf (SF)", Nuclear Physics A490 (1988) 307-328, were analyzed **event by event**.

The experimental set-up, which was used by these authors, allowed them to determine for each fission event 6 quantities:

fragment energies $E_{L,H}$,
fragment masses $A_{L,H}$,
neutron energy E, and its emission angle θ_n

The complete experimental determination of all kinematic parameters allowed then to deduce the neutron spectrum in the center-of-mass system of fission fragment.

The kinematic situation of neutron evaporation from moving fragments



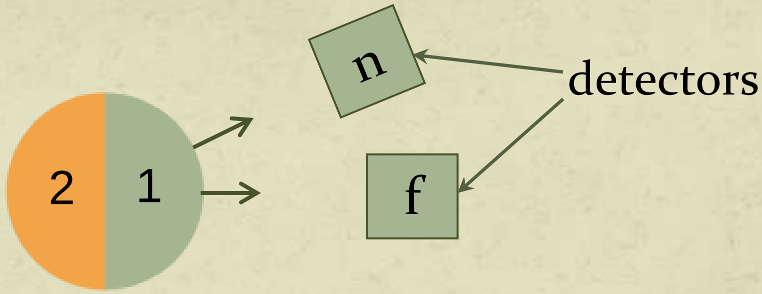
$$V_{c.m.}^2 = V_{F_1}^2 + V_{lab}^2 - 2V_{F_1}V_{lab}\cos\theta_{lab}$$

$V_{F_1}, V_{F_2}, V_{lab}$ - the fragment and neutron laboratory velocities, respectively

$$\cos\theta_{c.m.} = (V_{lab}\cdot\cos\theta_{lab} - V_{F_1})/V_{c.m.}$$

$\theta_{c.m.}, \theta_{lab}$ - the neutron emission angles in center-of-mass and laboratory systems

Selection conditions of events in the experiment performed by Budtz-Jørgensen&Knitter



Since neutron emission in the center-of-mass system is symmetric about 90 the following analysis was restricted to the case:

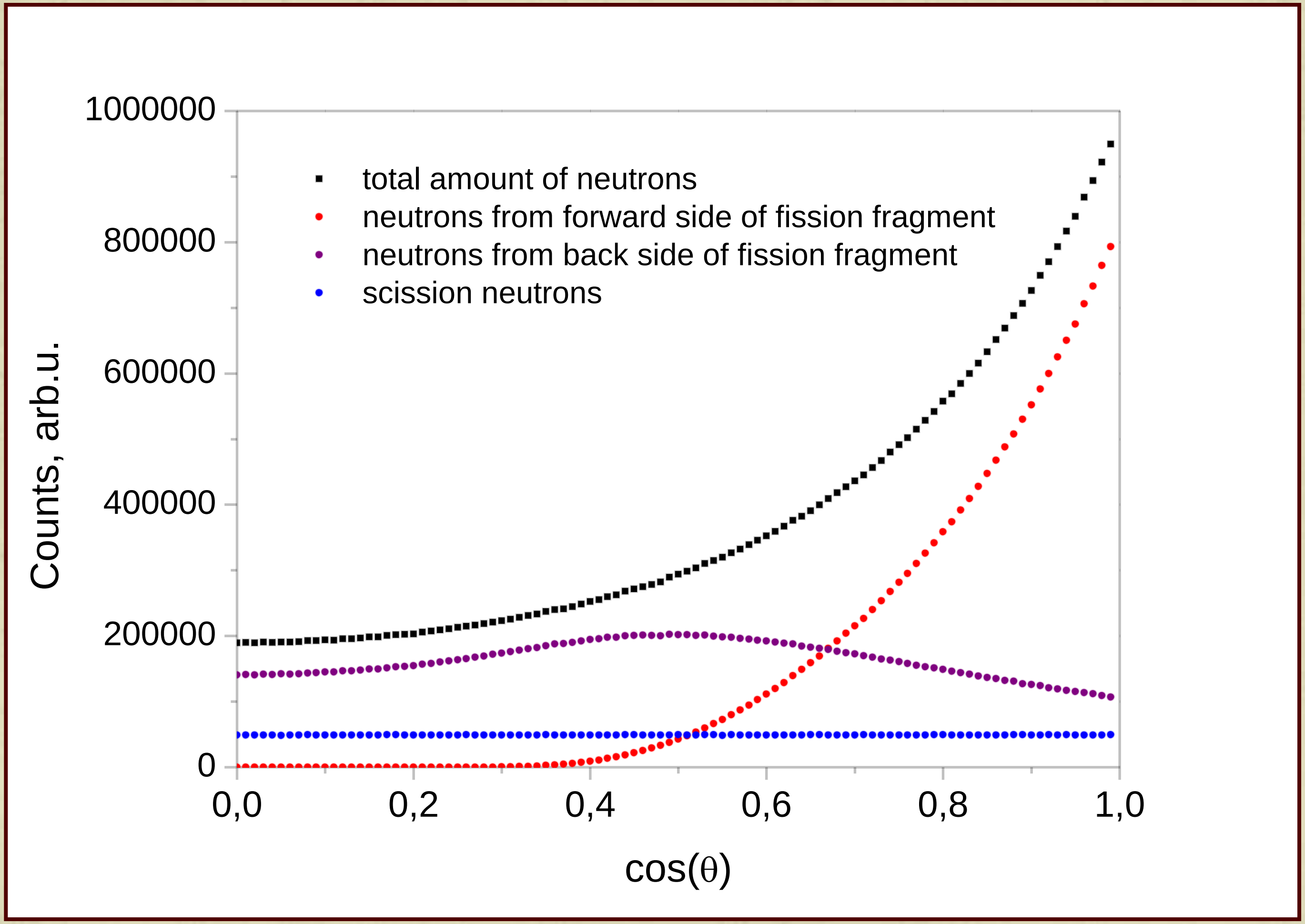
$$0^\circ \le \theta_{c.m.} \le 90^\circ$$

This condition implies that only such events were included in the analysis:

$$V_{lab} \ge V_{F_1} / \cos\theta_{lab}$$

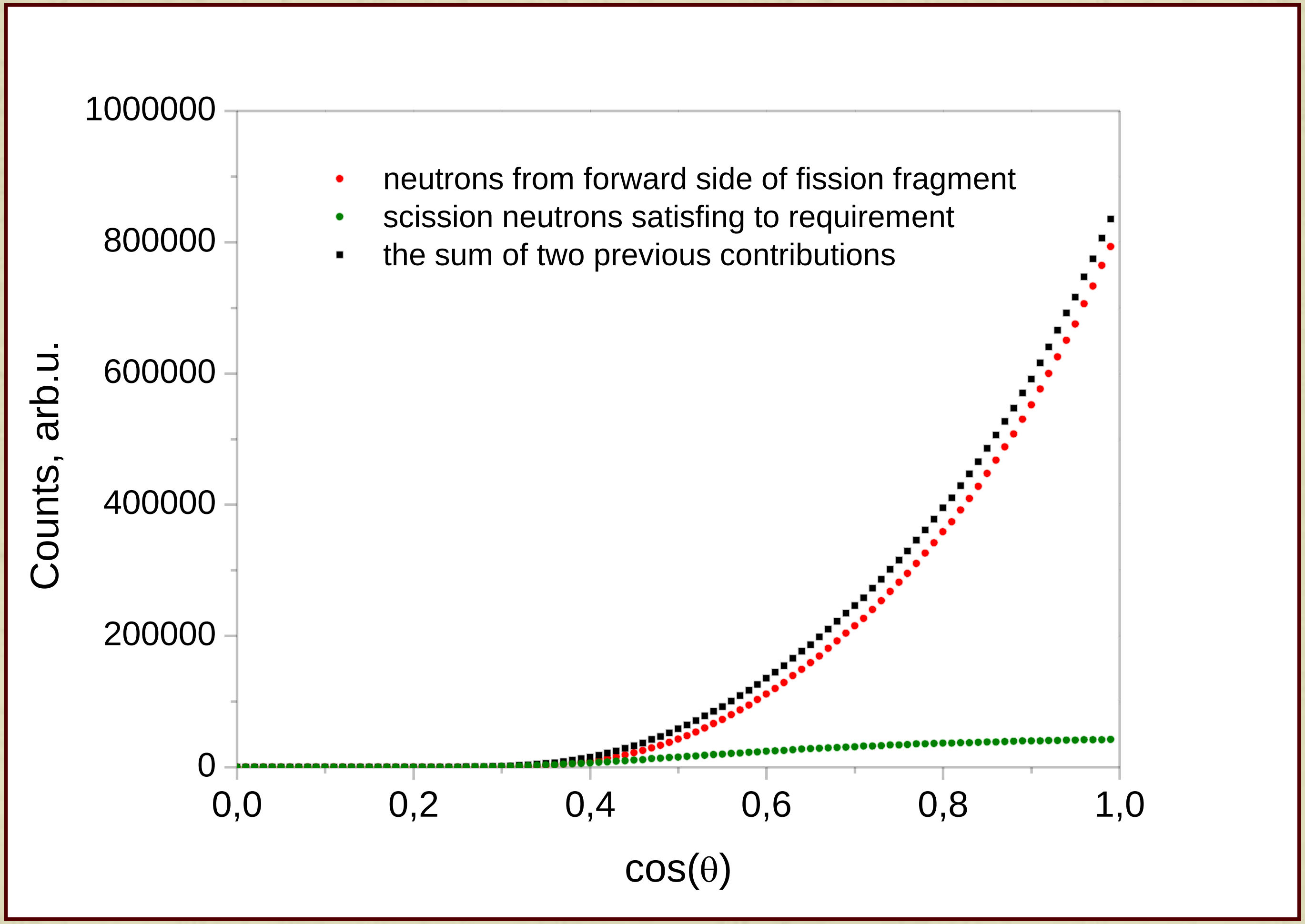
Neutrons, for which this equation is realized, must be emitted with laboratory energies which are larger than the minimum fragment energy per nucleon.

The angular dependence of neutron emission probability in the lab. system

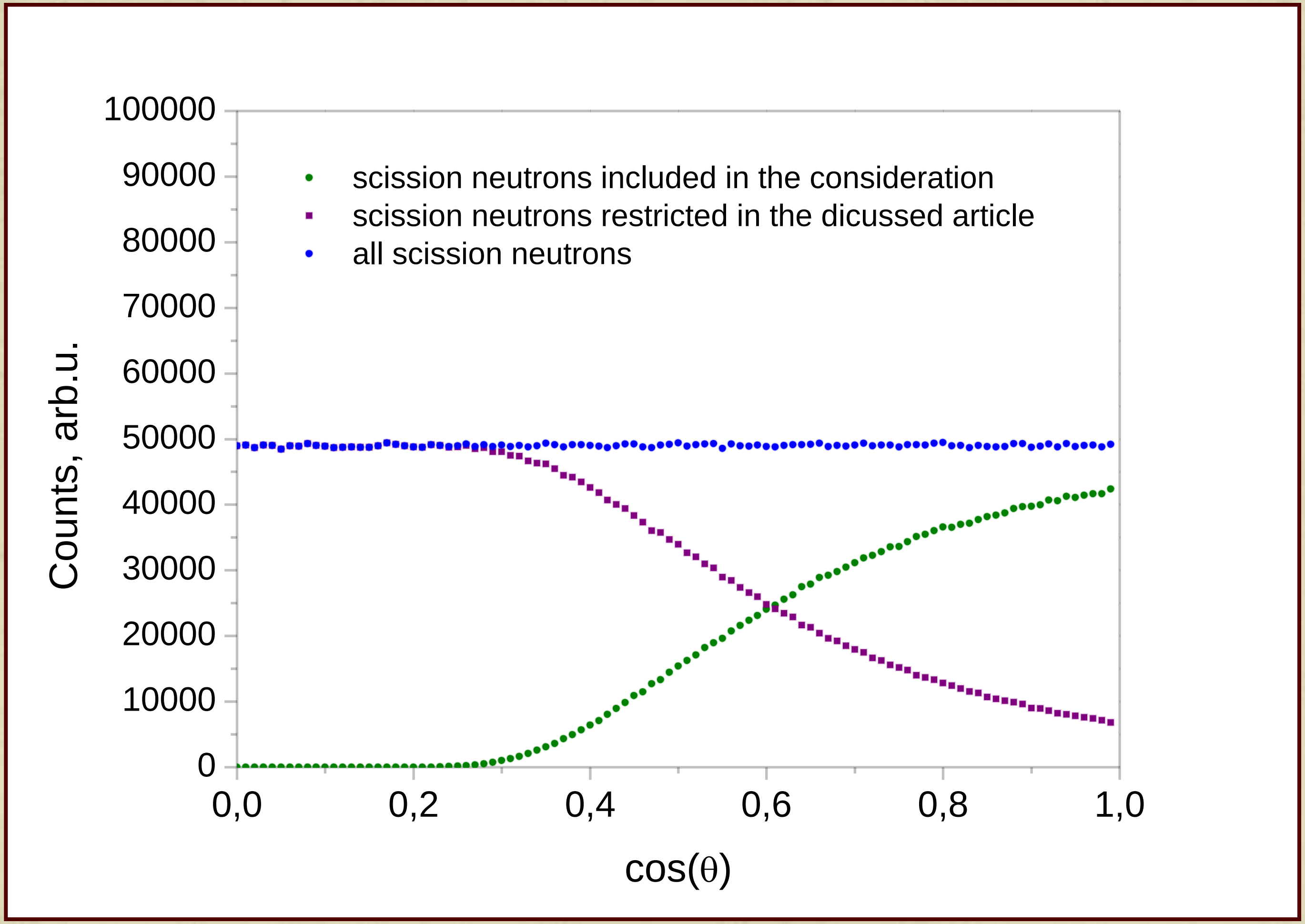


The angular dependence of neutron emission probability in the lab. system

Here only those events are represented, which were took into account for neutron spectrum organization in CM of fission fragment in Budtz-Jørgensen&Knitter experiment



Scission neutrons, which were took into account and rejected in the work of Budtz-Jørgensen&Knitter



The figures from the article of Budtz-Jørgensen&Knitter "SIMULTANEOUS INVESTIGATION OF FISSION FRAGMENTS AND NEUTRONS IN ^{252}Cf (SF)", Nuclear Physics A490 (1988) 307-328

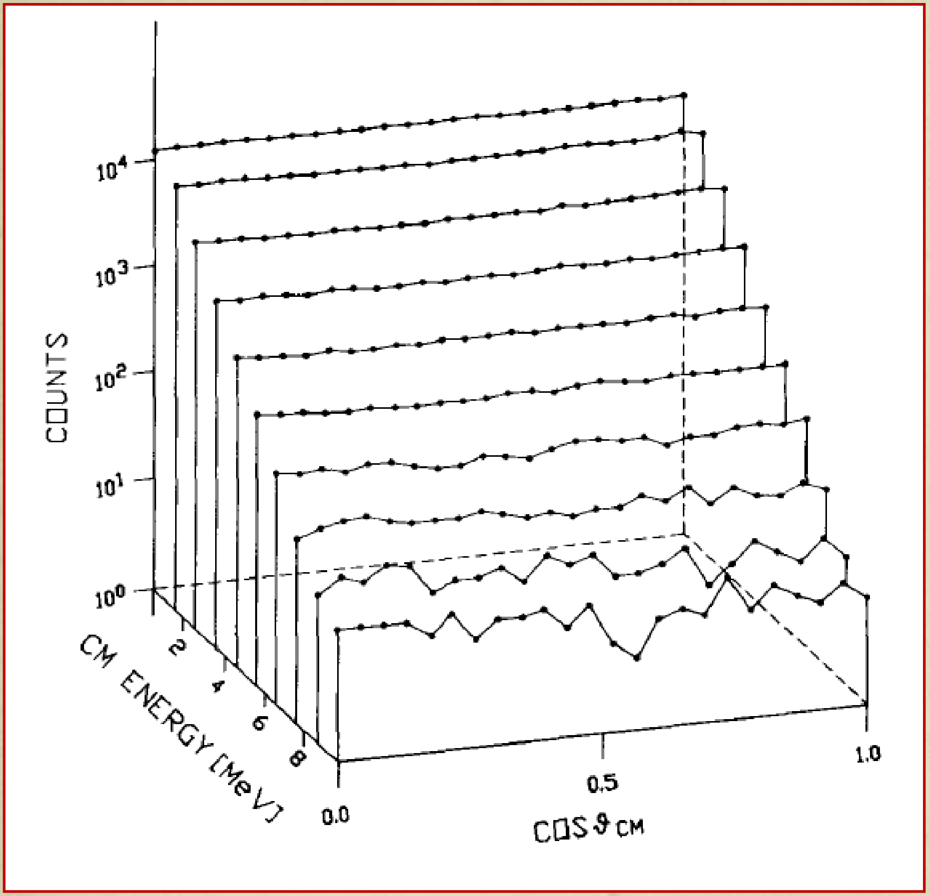


Fig. 9. Fission neutron angular distribution as a function of fragment center-of-mass fission neutron energy.

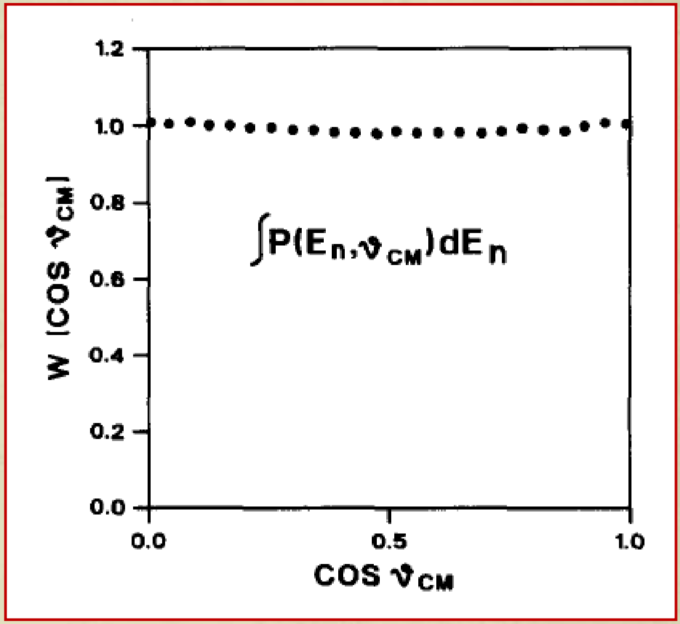


Fig. 10. Fission neutron angular distribution in the fragment center-of-mass system integrated over all neutron energies.

$$W(\cos\theta_{c.m.}) = 1 + (0.01 \pm 0.02) P_2(\cos\theta_{c.m.})$$

The reasons of the underestimation of "scission" component

The anisotropy of angular distribution for neutrons in the center-of-mass system of fission fragment leads to preferential emission of neutrons along the fission axis, while the presence of a certain contribution of «scission» neutrons could somewhat compensate for the first effect.
This can be the reason of underestimation of both factors: the anisotropy and the contribution of «scission» component.

In contrast to the work of Budtz-Jørgensen we did not finish at getting the neutron spectrum for the fragment center-of-mass. On this base the neutron yields were calculated for different angles in the laboratory frame of reference and then they were compared with experimental values without excluding of any event of neutron emission.

Note that particularly sensitive to the presence or absence of «scission» component is the range of angles close to 90 degrees in laboratory system, which in the work of Budtz-Jørgensen & Knitter excluded from consideration at all.

In such a way organized analysis of data is not sensitive enough for the magnitude of the contribution of «scission» component as well as for the possible anisotropy of the neutron emission in the CM system of fission fragment.

Thank you for attention!