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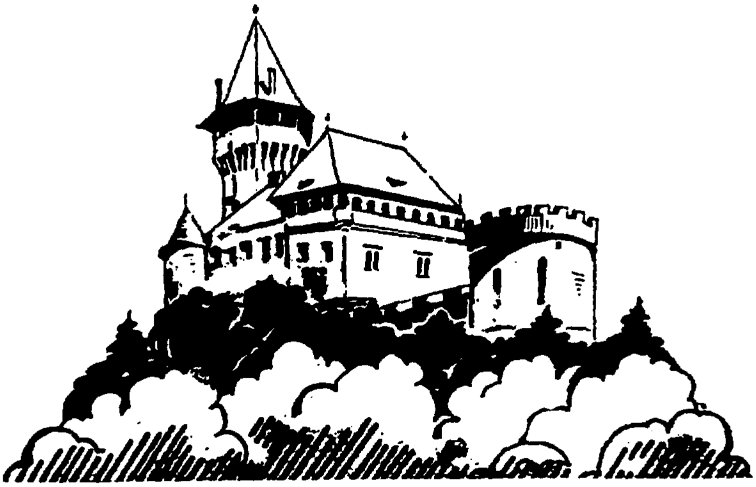

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Fissility of highly excited $Z \geq 85$ nuclei, obtained from (HI,xn) reaction cross sections

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Formation cross sections of evaporation residues (ER) produced in the heavy ion fusion reactions and survival probabilities of excited fissile nuclei related to these cross sections are of interest from the point of view of fusion-fission dynamics and fission barriers studies and synthesis of new heavy nuclides. During the last few years we obtained the data on the production cross section of ER [1] for a wide range of excitation energy and Z of compound nuclei. Together with the earlier available results (see refs in [1]), these data allow to make a close examination of survival probabilities i.e. the related to them values of the Γ_n/Γ_f.

We used the approach proposed in [2] with some modification for the analysis of the data. We considered the values of $\sigma_{ER}(E^*)/\sigma_{lim}$, where $\sigma_{ER}(E^*) = \Sigma\sigma_{xn}(E^*)$ is the experimental production cross section for the xn-evaporation channels at the compound nuclei excitation energy E^* and $\sigma_{lim} = \pi\bar{\lambda}^2 l_{lim}^2$ is the fusion reaction cross sections well above the Coulomb barrier with $l_{lim} \simeq 15$ for highly fissile nuclei [2]. We approximated the values of $\sigma_{ER}(E^*)/\sigma_{lim}$ for each of the studied compound nuclei by an exponential at the energies well above the Coulomb barrier. The influence of the Coulomb barrier at the lower excitation energy was excluded by the extrapolation of exponential to this region. Being possible the data for the adjacent compound nuclei (Z, A and the $Z, A + 1(2,3)$) were compared. This has allowed us to obtain the Γ_n/Γ_f values at the first steps of the deexcitation process and their excitation energy dependence for some of the nuclei.

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Divers low energy fission data and fission dynamics

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Abstract:

This paper brings together and analyses the different types of available fission data on proton and neutron pairing odd-even effects δ_p and δ_n, the conditional charge variance $\langle \sigma_Z^2(Z|A) \rangle$, the total fission kinetic distribution and the neutron conditional covariance $\mathrm{Cov}(\nu_1, \nu_2 | M, E_K)$ in order to try to understand the low energy fission dynamics. These data indicate that the movement of the fissioning nucleus between the saddle point and the scission point is mostly collective in nature. As a result, a major part of qp-particle excitations - hence pair-breaking, seem to be produced during a fast neck-rupture at scission.

TWO-DIMENSIONAL LANGEVIN APPROACH TO HEAVY-ION INDUCED FISSION AND LIGHT-PARTICLE EVAPORATION

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The two-dimensional Langevin equations for the symmetric fission of ^{213}At and ^{200}Pb were solved using computer generated stochastic forces. Two dissipation mechanisms have been studied : a typical weak one (hidrodynamical viscosity) and a typical strong one (nucleonic excitations due to the modification of the self consistent potential). The transient time necessary to attain the stationary regime was found to depend strongly on the dissipation strength (fig.1).

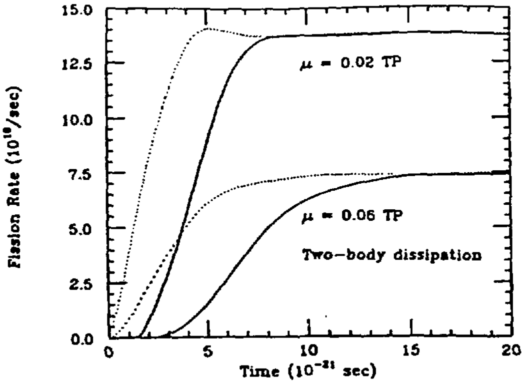

Fig.1 : Time dependence of the fission rate for ^{213}At at saddle (dashed) and at scission (solid) for two values of the viscosity coefficient μ.

Calculations were done for different values of T (nuclear temperature) and L (angular momentum). Including particle evaporation in the continuous limit, prescission multiplicities of neutrons (ν_{pre}), protons (π_{pre}), and α particles(α_{pre}) have been calculated for ^{200}Pb. The number of pre-scission neutrons and the average total kinetic energy of the fission fragments(TKE) calculated assuming the one-body dissipation are consistent with the experimental data [1, 2] obtained at two excitation energies E* (Table 1). Unusually strong hydrodynamical two-body viscosity ($\mu = 0.2$ TP) also reproduces the experimental neutron multiplicity but it significantly underestimates the average kinetic energy.

E^*(MeV)	ξ	σ_{fusion}	$\sigma_{fission}$	σ_{res}	ν_{pre}	π_{pre}	α_{pre}	TKE	σ_{TKE}
80.7	0.014	1150	790	360	2.93	0.0092	0.0037	135.1	8.46
	0.009	1150	758	392	3.08	0.0091	0.0036	135.5	8.33
	exp.	1150	767	383	3.2±0.3	–	–	–	–
195.8	0.014	1400	1244	156	7.33	0.363	0.140	137.0	10.2
	0.009	1400	1223	177	7.64	0.385	0.140	137.5	9.82
	exp.	1400	–	–	7.7±0.3	–	–	139	16.5
	(MeV-2)	(mb)	(mb)	(mb)				(MeV)	(MeV)

Table 1 : Symmetric fission of ^{200}Pb calculated with one-body dissipation. ξ is the coefficient for the temperature dependence of the surface energy.

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A Study of Ternary Fission in Low Energy Fission Resonances of ^{235}U

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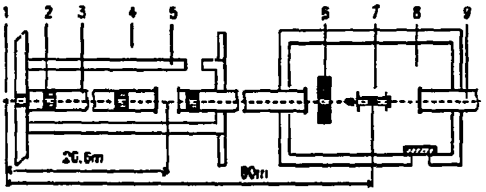
Some measurements of the ratio of ternary to binary fission T/B in the neutron energy region below 40 eV were performed at a 60 m flight path of the Dubna Pulse Reactor IBR-30 (ternary fission - fission into two fragments and a long-range α- particle).

The main goal of this work is not only to check the existing data but to see are there any correlations different from "T/B ratio - resonances spins J"-correlations, "T/B ratio - spins projections K" for example.

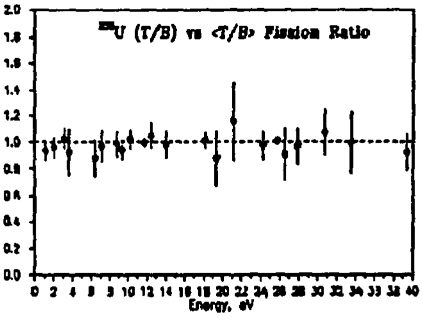
The experimental set-up and the preliminary results are shown in the figures below.

A multi-plate fission chamber as a fragments and α detector was used. In the center of it 4 double-faced and 1 single-faced ^{235}U layers are mounted. Double-faced are covered on each side by 30μm Al screens to cut-off the natural α-particles and heavy fission fragments (ternary fission). Single-faced layer is not covered but an appropriate discriminator level was used (binary fission).
The thickness of the layers is $\approx$ 0.5 mg/cm^2 and the total amount of ^{235}U is about 100 mg.

Two time-of-flight (TOF) spectra were collected for about of 400 h.
Because of relatively large errors it is not possible any strong conclusions to be made. To achieve a good results new measurements will be performed.



1 - IBR-30 pulsed reactor core; 2, 6 - collimators
3,9 - vacuum pipes: 4, 5 - shielding
7 - multiplate fission chamber; 8 - experimental hall



A Method and Experimental Facility for Measurement of Delayed Neutron Fast Components and Studing Fission Isomers

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Recently, Filip and D'Angelo [1] have shown that owing to the permanent progress in nuclear reactor technology measurements of enhanced accuracy are required of $\nu_{DN}(th)$-values for thermal neutron induced fission (ν_{DN} is the total yield of delayed neutrons (DN) per fission).

In order to meet such requirements a new experimental facility based on utilization of the Dubna IBR-2 pulsed reactor (PR), a slow neutron chopper (SNC) and a ^{3}He-filled multicounter neutron detector (ND) was designed and tested for measuring $\nu_{DN}(th)$.

The PR IBR-2. It exhibits an average thermal power of 2 MW, a peak power of 1500 MW, and the power released between pulses is $\approx$ 0.1 MW. It provides a thermal neutron flux density from the surface of the reactor moderator at the burst maximum of about 10^{16} n/cm^2·s. The repetition rate of neutron pulses is 5 Hz and the half-width of the fast neutron pulse is 215 μs.

The SNC. The SNC consists of a horizontal-axis cylindrical rotor made of borated polyethylene and steel, a stepping electric motor and electronics, which synchronizes rotation of the SNC rotor with the reactor neutron bursts. The electronics synchronization system allows to change the phase (expressed in time units) between the reactor burst and the position of the rotor hole from 10 μs up to 100 ms. and the rotation frequency (RF) of the SNC rotor from 5.0 Hz to 2.5 Hz; 1.66 Hz; 1.25 Hz; 1.0 Hz , that increase the time interval T between the neutron bursts from 200 ms up to 1 s. However, the exposure time Δt of the target is, then, enhanced proportionally.

ND. The ND is of the same type as previously described by Avdeev et al. [2], for example. It is a multicounter detection system, which consists of 36 utilized ^{3}He filled SNM-33 type proportional counters (3.2 cm in diameter, 52 cm long, with a gas pressure of 2 atm and an operating voltage equal to 1850 V, Russian made.); a 45 x 45 x 50 cm polyethylene moderator with 36 holes, for inserting the ^{3}He counters; and detector electronics. At present we use a simplified version of our ND with only 12 proportional counters.

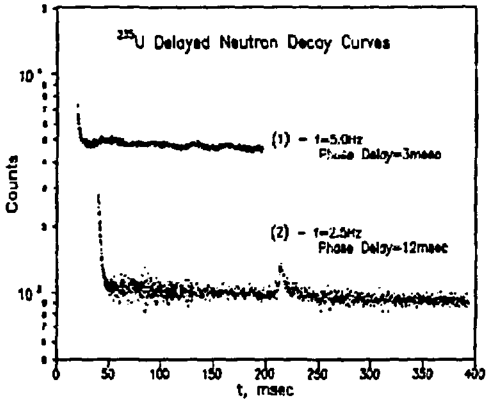
The method of periodical irradiation (MPI) first was applied by Brunson and Huber [3] at their "band-saw" facility. The periodical irradiation of fissionable targets allows an equilibrium intensity of DN from all groups to be achieved in between the iradiation cycles.

Most of test measurements were done with a metal sample of highly enriched uranium, containing 7 g of ^{235}U, and a small lead sample of 22.33 g used for determination of the neutron background.

Our preliminary results are shown in the figure below. The slope that can be found from here is $\approx$ 12% which is close to the calculated value of about 14%. The values of ϵ(DN) and ϵ(FN) can be raised from 10% up to at least 30% by adding the remaining 24 counters.

Comparing this facility with those used by other authors [4] one finds that it offers some unique experimental possibilities like the use of an extremely powerful pulsed neutron source based on the IBR-2 PR, the possibility of DN detection in between the neutron bursts starting a few "ms" after termination of the neutron beam by the SNC etc.

We would also like to note that this is actually a multipurpose facility, which could be utilized in solving some other problems relevant to nuclear fission, fission isomers, (n, γ)-reactions, etc.[5].



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Investigation of light charged particles emitted in spontaneous fission of ^{252}Cf

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A telescope consisting of a double parallel-plate ionization chamber measuring energy losses dE1,dE2 and a E Si-detector was used to measure the yield and energy spectra of light particles in spontaneous fission of ^{252}Cf . The ^{252}Cf source (0.2 μg) covered with a 6.2 μm Al foil was placed at a distance of $4cm$ in front of another Al foil (14.9μm) located at the entrance of the ionization chamber. The whole assembly were placed in common vessel filled with $Ar + 5\%CO_2$. Such an arrangement having a solid angle of 30 msr enables us to lower the detection threshold by varying the pressure in the vessel and to eliminate the events which cause an abnormal energy loss in one of the two dE detectors. In the off-line processing the matrices (dE1,dE2) and (dE1+dE2, dE1+dE2 + E) were built to separate various isotopes. For each event the total energy E_t= dE1+dE2 + E was corrected for losses in the foils, in the gas layer between the foils and in the detector dead layer.

The yields of ^{4,6,8,10}He and $^{7,8,9}Li$, together with their experimental thresholds E_{th},the most probable energies E_p and widths, are given in the table. The yields are related to 10^4 alphas. Y_o denotes the relative yield of the particles observed experimentally while the extrapolated yield Y_e results from the entire Gaussian distributions. The statistical significance of 2 events which were found to correspond to ^{10}He is too low to draw definite conclusion about the existence of the stable ^{10}He nucleus. The separated energy spectra of Li isotopes in s.f. of ^{252}Cf are obtained for the first time.

TABLE

Number of part.	E_{th}	Y_o	Y_e	E_p(MeV)	FWHM(MeV)
^{4}He $3.3x10^6$	7.8	10^4	10^4	15.9±0.1	10.1±0.2
^{6}He $9.5x10^4$	9.0	290	403±26	11.6±0.2	10.5±0.2
^{8}He $4.3x10^3$	10.0	13.1	25±4	10.1±0.4	9.6±0.4
^{7}Li $2.6x10^3$	15.6	8.08	17±4	15.0±0.7	15.5±0.8
^{8}Li $1.1x10^3$	16.3	3.60	10±6	13.6±1.4	13.8±1.7
^{9}Li $1.5x10^3$	16.9	4.66	25±11	12.1±1.5	12.1±2.0

COLD SHAPE-ASYMMETRIC FISSION*

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Direction-sensitive spectroscopy of fission fragments (twin ionization chamber with Frisch grids) was combined with the measurement of neutron multiplicity distribution P(ν), average total γ-ray energy (2x2π Gd-loaded scintillator) as well as energy and angular distribution of neutrons and γ-rays. Based on the careful account for necessary corrections, scission configurations given by mass asymmetry A_1/A_2, elongation (total kinetic energy TKE of fragments), and shape asymmetry (ν_1/ν_2) are studied exclusively in conjunction with differential distributions of emission products. Fine structures of experimental mass yield distributions for fixed neutron multiplicity ratio indicate the cold shape-asymmetric fission. The distribution in neutron multiplicity P(ν_1, ν_2 : $A_1/A_2, TKE$) bears information on the potential energy surface in deformation space close to scission. Various correlations will be presented.

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Review of Nuclear Charge Distributions from (n_{th},f) experiments at the Lohengrin spectrometer

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Abstract

One of the classical domains of study using the Lohengrin mass spectrometer lies in the determination of the nuclear charge distribution of light fission fragments originating from a source of a fissile isotope, placed near to the core of the ILL high-flux nuclear reactor. The high mass and energy resolution of the spectrometer and the progress in the charge determination by using an ionization chamber operated in ΔE-E mode, allow the separation of nuclear charges up to Z=41. Until now the fissioning systems ^{230}Th*, $^{234-236}$U*, ^{239}Np*, ^{240}Pu*, ^{243}Am* and ^{250}Cf* have been investigated; the major results will be reviewed and discussed. A draft of the future experimental program at the improved Lohengrin spectrometer, where additional target isotopes may be available, will also be presented.

High–Energy γ–rays in Heavy–Ion Fusion–Fission*

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Calculations based on energy systematics and experimental measurements of energy release, as a function of fragment mass, via low-energy γ–ray emission ($E_\gamma \leq$3MeV), neutron emission and fragment kinetic energy, [1] suggested that, for the system ^{197}Au(^{19}F,*f*) at 120MeV, fissions with one fragment near A=132 might show an enhanced high-energy γ-ray yield ($E_\gamma >$3MeV). The observation of just such a component in a measurement with the Heidelberg-Darmstadt Crystal Ball prompted the investigation of this new component in a range of heavy-ion fusion-fission reactions. The comparison of excess high-energy γ-ray yield (of the order of MeV per fission for A$\simeq$130–135) as a function of mass for systems of differing total (compound nucleus) mass can provide information on which fragment of a pair is emitting the "γ bump". Moreover, the systems studied probe different regions of the N/Z chart. Identification of the mechanism responsible for the "gamma bump" remains a challenge, but a unified description of the yield distribution as a function of mass and N/Z ratio has been achieved which reproduces the yields in the above heavy-ion fusion-fission reactions as well as in the spontaneous fission of ^{252}Cf [2].

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[2] A. Wiswesser *et al.*, INPC Wiesbaden 1992 Book of Abstracts and Diploma thesis, MPI für Kernphysik, Heidelberg 1992

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Halo–Nuclei Studied via Relativistic Mean–Field Effective Interaction

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ABSTRACT

Density distributions of light neutron-rich nuclei are studied by using the relativistic mean-field approach. The effective interaction which parameterizes the recent Dirac–Brueckner–Hartree–Fock calculations of nuclear matter is used. The results are discussed and compared with other mean-field calculations (both, relativistic and nonrelativistic) with special reference to **neutron halo** in the recent experimental observations. The importance of the isoscalar vector-meson self-interaction term for obtaining proper results is emphasized.

ON THE ANGULAR DISTRIBUTION OF FRAGMENTS IN THE FISSION OF THE ORIENTED NUCLEI OF 235-U BY RESONANCE NEUTRONS.

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The one of possible hypothesis for explanation of the suppression K=0 fission probability in neutron induced fission of the oriented 235-U nuclei are discussed. This may be consequence of the partial conservation of quantum number K in the compound states, i.e. of a nonuniform K distribution. Then large K values in the ingoing neutron channel modulate the distribution in the outgoing fission channel moving it to larger values.

The influence of the missing levels in experiments on the frequency distribution of the A2-coefficient directional distribution of the fission fragments have been concidered.

Some new Aspects of Ternary Fission

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Recent experiments on parity violation in ternary fission induced by polarized cold neutrons demonstrate that the PNC asymmetry in the angular distribution of fission fragments is identical to the one for binary fission within experimental uncertainty. Taken together with former experiments on the PNC asymmetry in the emission of light charged particles from ternary fission, the results are interpreted to indicate that binary and ternary fission follow the same path in deformation space, at least up to the second saddle-point where the distribution of K-quantum numbers is fixing the angular distributions observed. Ternary particles come, therefore, into view only at a rather late stage of the fission process. Most theories of ternary fission have indeed taken this conjecture for granted. The present experiments are thought to provide a sound basis for these models of ternary fission.

In further experiments, the emission of clusters with masses intermediate between α-particles and light fission fragments from the ^{242}Am(n,x)X reaction induced by thermal neutrons has been explored. A mass spectrometric method was employed measuring the masses, charges and kinetic energies of the clusters. The kinetic energy distributions observed point to ternary fission as the emission mechanism for the clusters. Heavy clusters up to mass $A = 34$ in the Si-isotopes have been detected. This considerably extends the mass spectrum of ternary particles hitherto known. The experimental yields are discussed in terms of models of ternary fission with the emphasis put on a novel extension of ideas having been put forward already some decades ago.

Combining a Dynamical and Statistical Approach to the Competition between Fission and Particle Emission

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Langevin Fluctuation Dissipation Dynamics is combined with a statistical description (with a modified fission width) in a model which we abbreviate as Combined Dynamical Statistical Model (CDSM).[1-5]). A crucial role is played by the entropy, which is constructed from a deformation-dependent level density parameter, and determines the driving potential in the Langevin equation and occurs in the formula for the modified fission width, which also contains information on the scission point[2,3]). The heavy-ion induced fission process competes with the emission of neutrons, protons, deuterons, α-particles, and giant dipole γ-quanta, the evaporation of which is calculated by a discrete Monte Carlo evaporation model.

CDSM is able to calculate the following quantities, which have been, if available, already compared systematically with experimental data[4,5]): Complete fusion cross sections, fusion spin distributions, prescission particle (n,p,d,α) and giant dipole γ-multiplicities, ground-state-to saddle and saddle-to-scission contributions to these multiplicities, (n,p,d,α, γ)-spectra and mean energies, evaporation residue and fission cross sections, distributions of evaporation residue and multiple chance fission events with respect to the type and amount of the emitted particles, fission lifetime distributions, and the long-lifetime fission component.

By investigating all these quantities for heavy-ion induced fission simultaneously in one model there is hope to extract unique information on the strength and the coordinate-dependence of nuclear friction and on the level density parameter.

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Time Distributions of Fission Events

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Typical lifetimes of fissioning nuclei can be measured by a number of different methods[1,2]). Usually such measurements are subject of a very complicated processing. Furthermore, it is not always clear what is the meaning of a 'fission time' extracted from such experiments. Conceptually fission should be characterized by a fission time distribution of the time which starts when the formation of a compound nucleus is completed until the fissioning nucleus reaches the scission point. The whole fission lifetime distribution is a quantity which hardly can be obtained from experiment. However, the so called Long Lifetime Fission Component (LLFC) of this distribution can be measured by crystal blocking techniques[1,2]), and some fragmentary data of this kind already exist[3,4]). The LLFC can be characterized by a quantity χ_L which is defined as the relative amount of fission events corresponding to lifetimes longer than a particular time t_L; usually t_L is taken to be 10^{-16}s (χ_{16}) or $3 * 10^{-17}$s (χ_{317}). As it has been shown recently[5]) measurements of LLFC can provide very useful information on the strength and deformation dependence of nuclear friction.

Using the Combined Dynamical Statistical Model (CDSM) developed in refs.[6]) we have calculated fission lifetime distributions and mean fission times for a variety of systems with different fissilities which have been produced in heavy-ion reactions: ${}^{19}F + {}^{159}Tb \rightarrow {}^{178}W$, ${}^{19}F + {}^{169}Tm \rightarrow {}^{188}Pt$, ${}^{30,28}Si + {}^{164,167,170}Er \rightarrow {}^{192,195,198,200}Pb$, ${}^{19}F + {}^{181}Ta \rightarrow {}^{200}Pb$, ${}^{16}O + {}^{197}Au \rightarrow {}^{213}Fr$, ${}^{16}O + {}^{208}Pb \rightarrow {}^{224}Th$, and ${}^{19}F + {}^{232}Th \rightarrow {}^{251}Es$.

We have investigated the LLFC of these systems with respect to the excitation energy, angular momentum, as well as to the mass and charge number of the systems. Our calculations can be considered as predictions for future experiments, and show that the Long Lifetime Fission Component is a quite general phenomenon.

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FISSION FRAGMENTS ANGULAR DISTRIBUTIONS FOR A COLD FRAGMENTATION PROCESS

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ABSTRACT

Global changes have been observed in fragments angular distribution for fission of uranium-236+neutron in the very high kinetic energy range in a vicinity of reaction Q-value when scission point is close to saddle one. It can be due to three possible factors: 1) violation of quantum number K - projection of total angular momentum J on fission axis during post-saddle dynamics, 2) admixture of a vibrational resonance to fission probability excitation function and 3) K-separation on the so-called scission barrier between fission valley and fusion one. Experimental data suggested that energy dissipation process is essential in the descent of fissile system from saddle to scission.

Twin gridded ionization chamber has been used. Some details of data acquisition and evaluation are presented with the analysis of possible uncertainties and corrections.

NEW RESULTS FOR PARITY NONCONSERVATION IN NUCLEAR FISSION OF ^{233}U

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Abstract

The parity nonconserving (PNC) asymmetry coefficient α for the angular distribution of light and heavy fragment emission from binary fission of ^{233}U by polarized thermal neutrons was measured. A high resolution double ionization chamber was used as a detector. The experiment was carried out at the neutron high flux reactor of the ILL, Grenoble. Although the detector provided a mass resolution of single masses in cold fission, it was not possible to determine asymmetry coefficients for individual masses because of low statistics.

For the global effect, integrated over all masses and energies, the result obtained is $\alpha = (3.28 \pm 0.29)\cdot 10^{-4}$, which compares favourably with former experiments. The main aim of the present experiment was to establish the PNC-effect for distinct mass and/or energy ranges of the fragments, like those described by the Brosa-modes standard 1 and standard 2.

The results obtained for the Brosa-mode ranges of fragment masses and energies support the Brosa scission model: within the error bars no difference between the asymmetry coefficients for the different modes was found.

More detailed investigations demonstrate that the Brosa model is a quite good first approximation of the fission process, however, it does not reproduce all of the deatils. The fine structure, due to odd-even effects, is not taken into account. This is demonstrated by a comparison of data with a Brosa simulation.

Recent Fission Investigations at IRMM

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Abstract

Recent fission studies at IRMM (former CBNM) where both of theoretical and experimental nature. From theoretical point of view the multi modal random neck rupture model of Brosa et al. has brought new insights into the fission process and given an instrument in the hands of the experimentalists to interpret the data. At IRMM the programs to calculate the fission modes for any compound system are available and have been used in the calculation of ^{238}Np and ^{252}Cf.

For ^{238}Np a complete fission channel picture from ground-state to the scission point has been achieved. In total four fission channels have been found, three standard and the superlong channel. For the first time the standard III-channel could be theoretically confirmed. In case of ^{252}Cf more channels are expected from the analysis of the experimental data than theoretically found up to now. Therefore we have been searching for a complete channel picture in ^{252}Cf too. This work is still in progress.

In both cases experimental studies have been performed. For ^{237}Np(n,f) the incident neutron energy has been varied from 0.5 MeV to 5.5 MeV, so that the data can be compared to other already existing results. For ^{252}Cf(sf) in total about $2.5 \cdot 10^8$ events have been acquired. For both actinides the experimental distributions will be compared to the theoretical ones.

+ former Central Bureau for Nuclear Measurements (CBNM)

MASS-ENERGY DISTRIBUTIONS OF FISSION FRAGMENTS, LIQUID DROP MODEL, ANGULAR MOMENTUM AND BUSINARO-GALLONE POINT

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The research of heated nuclei's fission gives us rich information about drop properties of nuclear matter and might be used for verification of different modifications of liquid-drop model (LDM). The stiffness on the relation to mass-asymmetric deformation is one of the main parameters of LDM and this one is required to be checked experimentally by measuring the dispersion of mass distribution σ_M^2, which is connected with mentioned deformation directly. Earlier we have taken magnitudes of stiffness ($d^2V/d\eta^2$) in region of heavy nuclei with $Z^2/A \geq 30$. Now the results of researches of mass and energy fragment's distributions in fission of nuclei with $Z^2/A \leq 30$ formed in reactions with heavy ions are reported. This region is important and interesting with the fact that in this region of fissioning nuclei ($A = 100 - 140$) the existence of Businaro-Gallone point ($d^2V/d\eta^2 = 0$) is predicted by all variants of LDM.

Our measurements were carried out with time-of-flight spectrometer DEMAS and accelerator U-400 FLNR JINR. The reactions ^{20}Ne + ^{99}Ru, ^{106}Cd, ^{110}Cd, $^{112,118,124}Sn$ have been studied. Reactions ^{12}C + ^{112}Sn and ^{25}Mg + ^{99}Ru (fissioning nucleus ^{124}Ba) were investigated for clearing up the influence of angular momentum ℓ on mass and energy distributions. It was shown that magnitude of coefficient $d\sigma^2/d\ell^2 < 0$ is in agreement with theoretical predictions for this nuclei's region. Having taken into account this fact the information about $d^2V/d\eta^2$ for nuclei with $20 \leq Z^2/A \leq 30$ has been obtained. We found that neither of the existing modifications of the LDM does not reproduce the whole of the dependence $d^2V/d\eta^2$ on Z^2/A, although the Droplet model and the Sierk LDM predict correctly the Businaro-Gallone point position, which we have defined experimentally as $(Z^2/A)_{BG}^{exp} = 22.9 \pm 0.7$.

The shapes of differential energy distributions of fragments and fission modes

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The investigations of the shapes of differential (with fixed mass of fragments) energy distributions had been shown to be important for the verification of some theoretical notions about nuclear fission dynamics.

The present work is devoted systematical experimental investigations of the coefficients of dissymmetry and excess of the differential energy distributions of fragments in the fission through independent modes for the large group of nuclei from Os up to U in the wide interval of excitation energies.

As a result of the present work the following statements can be performed:

1) The coefficients of dissymmetry γ_1 and excess γ_2 of unimodal differential energy distributions of fission fragments, inside the experimental errors achieved in the present work, are practically independent on a mass-asymmetry parameter of fragments and parameters of fissioning system, namely its excitation energy and nucleon composition;

2) As a result of the comparison of the main dependences of γ_1 and γ_2 the following supposition has been put forward: the values of γ_1 and γ_2 for this or that independent mode characterize the present mode on the whole and are conditioned only by the nature of their origin. Namely, by liquid-drop properties of nuclear matter for the symmetric mode and by the influence of the shell effects for the asymmetric one;

3) Theoretical calculations, at which visible positive values of γ_1 for unimodal energy distributions of fragments appear, might be recognized as not quite reliable.

Correlated Fission Fragment Independent Yields for Mo/Ba charge asymmetry of the ^{252}Cf(s.f.).

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We present some preliminary results of the experiments [1] carried out at the Holifield Heavy Ion Research Facility (Oak Ridge) performed with Close-Packed Ball spectrometer consisting of 20 Compton suppressed Ge detectors . In this experiment coincidence prompt γ-rays with multiplicity $\geq$2 from spontaneous fission of ^{252}Cf (5x10^5 sf/sec) were recorded during a time interval one week.
Detection of the coincident γ-rays from the correlated pairs of fragments appears to be informative indication of allowing for their A and Z identification and yield evaluation. For the charge division Z_L/Z_H=42/56 (Mo/Ba) the set of relative independent yields of about 70 pairs for light and heavy mass region is presented ($A_L = <100, 108>$ and $A_H = <139, 148>$).
Based on the correlated fragment yields data, the neutron multiplicities as a function of number of dissipated neutrons has been deduced. For the first time mean multiplicity of neutrons $<\nu_{42/56}> = 4.0 \pm 0.4$ for the charge asymmetry 42/56 was obtained.
The data on the prompt γ-ray emission from individual fragments give also information on the angular momentum of the scissioning systems. We present some examples of the ground states band level population for the complementary fragments with charge division 40/58 (Zr/Ce). On the base of this data we obtained the mean angular momentum populated just after scission. The values of J_{rms} are calculated taking into account the angular momentum carried out by evaporated neutrons and γ-rays.

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THE FISSION TIME OF EXCITED NUCLEI

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For the last years the interest in studying of excited nuclei fission has grown as the investigations of this process turn out to be the basic method of getting the information about the dynamics of collective motion in nuclei, nature character of energy dissipation.

Experiments on measuring fission neutrons multiplicity showed that with the increasing of excitation energy the number of prescission neutrons ν_{pre} increases as quickly as a total number of fission neutrons ν_{tot}, that clearly indicates that the main part of additional excitation energy of a compound nucleus is taken due to prescission particles emission and by the moment of scission point the temperature of fission fragments practically is not changed. On the base of these data there was made a conclusion that fission is a slow process while evaporation processes become more quick with energy increase. In connection with this one should reconsider the application of a traditional variant of statistical model of transition state which is found to be widely used for description of fission competition and evaporative channels, the basic parameters of which have been chosen from the analysis of nuclei fission cross-sections, production cross-sections of evaporative residues and also the analysis of angular distributions of fission fragments. One should note at once, that the correct number of ν_{pre} fails to be obtained in this model even by variation of model parameters in a wide range [1,2].

Some authors suggest a simple model that is a competition between fission and evaporation begins since the compound nucleus is cooled up to the energy of $\leq 30-40$ MeV due to particles evaporation [3].

The diffusion model modification named by LFDD (the Langevin fluctuation-dissipative dynamics) has a great progress. However trying to describe ν_{pre} in a wide range of Z^2/A and excitation energy with one set of parameters this model is also a matter of some difficulty. In recent calculations where statistical model has been combined with the LFDD [4,5] one succeeded in satisfactory description of neutron multiplicity only because of insertion of a critical and rather unusual dependence of the given friction coefficient β on nucleus elongation, that corresponds to the assumption about the very fast increase of friction coefficient at neck nucleus manifestation. At the same time, as shown by one of the authors the mean kinetic energy is sufficiently well described by the Langevin equation solution at standard assumptions about the coefficient β both in one-body and two-body viscosity mechanisms, where nothing happens with β like it (see the Figure). It was also shown that if one chooses a condition of random nucleus decay in the region of deformation as a criterium of fissionable nucleus transition to splitted fragments state between points where the condition of forces equality of the Coulomb and nuclear interaction has been already performed and the condition of a vanishing small neck $r_{neck} \simeq 0$ has not come yet, then one can describe also the highest momenta of energetic distribution, in this connection the descent time to the scission point obtained in these calculations and the fission time described from experimental values ν_{pre} are sufficiently close to each other although the first one has been obtained with a standard β versus deformation [6].

In the given work we also tried to calculate the value ν_{pre} for fission of excited compound nucleus ^{250}Cf in the one-dimensional LFDD approach for fission degree of freedom taking account of a possibility (by the Monte-Carlo method) of the light particles evaporation (n,p,α) using different constant values of β coefficient. The table lists the results of calculation for ν_{pre} and mean fission time $< \tau_f >$ for the compound nucleus ^{250}Cf with excitation energy of 80 MeV and mean angular momentum $40\hbar$ (experimental value of $\nu_{pre} = 3.45 \pm 0.2$). One should note that by choosing β-constant the main part of ν_{pre} is emitted prior nucleus yield to the saddle point whereas in case of a critical dependence β on deformation the main part of ν_{pre} is emitted at the descent from a saddle point to the scission one.

Thus the most important problem is the searches for experimental possibilities of fission time separation into fragments connected with the yield to saddle and descent time from the saddle to scission point.

As characteristic times of the light particles emission (n,p,α,d,γ) are comparable between themselves for heated rotating nuclei and angular and energetic distribution of charged particles and γ-quanta of the giant dipole resonance bears an information about a shape of fissionable nucleus at the moment of their emission, then studying these characteristics in coincidence with fission fragments and possibly with precision neutrons one can try to get the additional information about fission time distribution. One might have checked these assumption studying the probabilities of evaporative residues production in reaction channels (xn,pxn,αxn) [7].

Moreover, the analysis of differential characteristics of evaporative fission neutrons (ν_{pre} and ν_{post} versus mass and kinetic energy of fragments) also could give the additional information about distribution of fission time fragments.

At present we have carried out experiments on measuring differential characteristics of fission neutrons in reaction ^{238}U(^{12}C,f) and ^{232}Th(^{18}O,f) with simultaneous measuring of spectrum and multiplicity of γ-quanta for the second reaction [8].

In conclusion one can mark that in spite of a great amount of experimental and theoretical works in this region up to now there is no absolute conception of energy dissipation character during fission and one needs additional experiments in order to check one or another assumptions.

$\beta, 10^{21}s^{-1}$	1	3	6	9	12	15	18
ν_{pre}	0.92	1.91	2.24	2.72	3.16	3.27	3.71
$< \tau_f >, 10^{-21}s$	12	36	49	86	114	146	200

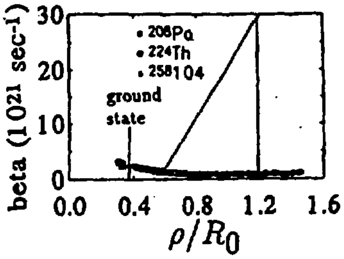

Fig. Reduced friction coefficient β versus nucleus elongation. Open symbols – $\beta(\rho)$ calculation for two-body viscosity. Solid line – $\beta(\rho)$ dependence up to scission point (1,19) from work [4]. ρ – *the distance* between mass centres of future fragments ($R_0 = A^{1/3}r_0$).

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New investigation of induced fission of aligned ^{235}U nuclei.

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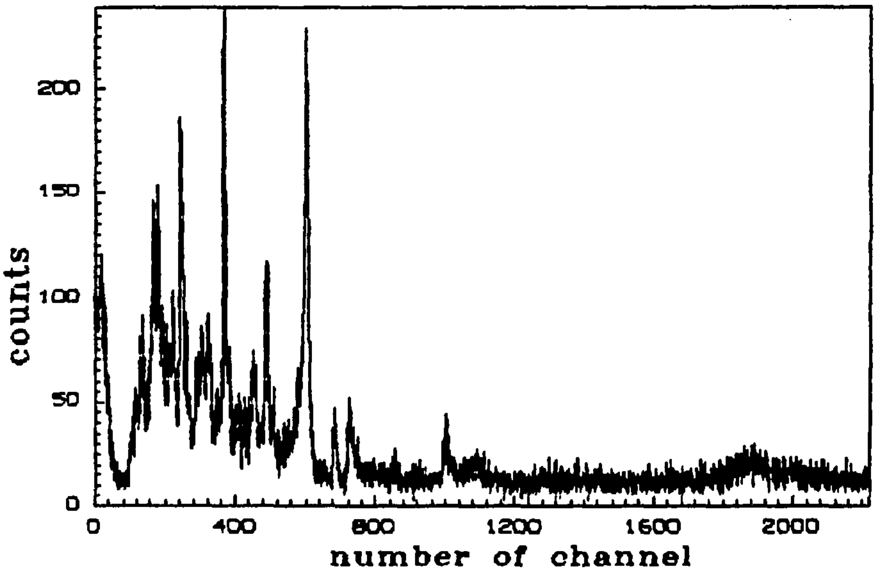
The objective of our investigations is repetition and development of unique research of the angular anisotropy of fragments from neutron-induced fission of aligned ^{235}U, carried out earlier by Pattenden and Postma /1/, the results obtained by them allowed to come to the conclusions of that fission probability being dependant of quantum number K and to show that maximum on K doesn't correspond to K=0, as had been predicted by Bohr , but K ~ J/2, the explanation of which hasn't been found yet.

The nuclei were aligned in single crystals of rubidium uranyl nitrate / $UO_2Rb(NO_3)_3$ / cooled to approximately 0,15 K, crystal C-axis oriented along neutron beam. The thickness of the ^{235}U layer was about 1,5 mg/cm^2.The sample consists of two mosaic layers (areas 24 cm^2 and 20 cm^2), fixed on cooled to approximately 0,15 K plate inside ^{3}He - ^{4}He dilution refrigerator /2/.

Fragments of each mosaic are registered by three Si-detectors of 20x50 cm each at the angles of 0°, 45° and 90° to C-axis of crystal, what allows to derive coefficients A_2 and A_4 at Legendre polynomials from experimental data.

The refrigerator with the sample is placed in the flight path length of 30 m of the booster of IBR-30 + LEA-40, what allows to obtain the anisotropy neutron parameters for energy interval (0,3 - 30) eV. At present this equipment has been tested on neutron beam and some measurements has been taken. Time-of-flight spectrum from 0°-detector is shown below. In future the experiment will be prolonged on the IREN booster.



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INVESTIGATION OF NEUTRON EMISSION AT FISSION OF EXCITED COMPOUND NUCLEI WITH $Z \geq 92$

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The recent progress in studying the fission of excited compound nuclei is connected with the more detailed study of fission product characteristics including the possibility to reveal the pre-scission (ν_{pre}) and post-scission (ν_{post}) components from the total spectra of fission neutrons [1]. The essential excess of ν_{pre} compared to statistical model [2,3] calculations and. also, the unusual dependence of ν_{pre} and ν_{post} on excitation energy have led to the understanding of the important role of nuclear viscosity not only at the first stage of the reaction induced by heavy ions, i.e. the fusion stage, but also in the fission channel of excited compound nucleus. On the basis of the data obtained recently in a number of works on ν_{pre} a conclusion was made that fission is a slow process while evaporation processes become faster as the energy increases [4].

A diffusion model modification called LFDD (the Langevin function dissipative dynamics) has been widely developed. However, in an attempt to describe ν_{pre} in a wide range of Z^2/A and excitation energy with only one set of parameters, this model met with difficulties. Hence one should insert a sufficiently unusual dependence of viscosity parameters on the fissioning nucleus deformation [5].

Therefore, in spite of the great quantity of experimental and theoretical works in this region up to now there is no full conception of the behaviour of energy dissipation in the fission process and one needs additional measurements of the characteristics of fission neutron emission. One also can mark that in the region of compound nuclei $Z \geq 92$ there are only separate experiments on studying of ν_{pre}, ν_{post} and ν_{tot} values.

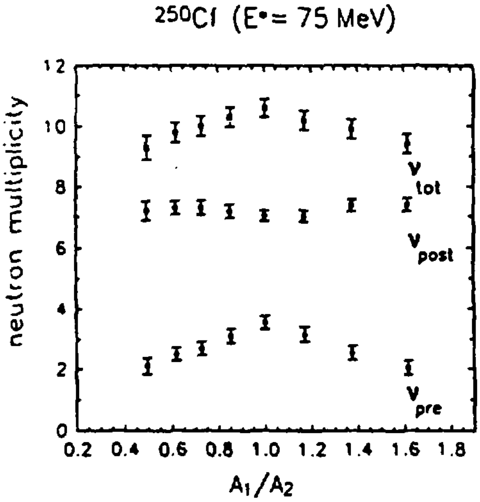
In the present work the first results are presented of experiments on measuring of differential characteristics of fission neutron emission in the region of compound nuclei with atomic number $Z \geq 92$, carried out at HMI(Berlin) on the VICKSI accelerator and on the FLNR U-400 heavy ion cyclotron. At HMI, 47- and 82-MeV α-particle beams and 66.6-, 85.8- and, 104.2-MeV ^{12}C beams were used. At the FLNR, 95- and 120-MeV ^{18}O beam was used and earlier measurements of ν_{pre}, ν_{post} and ν_{tot} values in reaction $^{238}U +^{12} C$ (105 MeV) were carried out.

The time-of-flight technique was applied for identification of fission fragments at HMI. Fission fragments were detected by two position-sensitive low-pressure multiwire proportional counters MWPC. One small MWPC of active area 61mm x 61mm was located on one side of the beam, at a distance of 236.7 mm from the target. On the other side of the beam, there was a large area MWPC (219.5 mm x 109.8 mm) located at 261.5 mm from the target. The detectors provided better than 0.1 cm position resolution and better than 200 ps time resolution.

For the neutron multiplicity measurement 10 liquid scintillator neutron detectors were used. They were placed outside the 1m diameter scattering chamber at different angles to the ion beam. Eight of them were placed in the reaction plane, two of them out of the plane, at distances ranging from 550 to 1150 mm. The time resolution of the detectors varied from 0.9 to 2 ns, depending on their size and lower threshold setting. The energy spectra of the neutrons were measured by time-of-flight techniques and pulse-shape discrimination between neutrons and γ rays were used.

At the FLNR, the $E_1 \times E_2$ correlation technique of registration of pair fragments was used. The set-up includes two identical fragment detection systems which detect the reaction products in mutually perpendicular planes. Each system consists of two position-sensitive semiconductor detectors located at the fission-fragment correlation angle.

To detect neutrons scintillation detectors prepared on the base of stilbene monocrystals of 50 mm diameter and 30 mm height are used. In the given set-up two identical neutron channels located at the angles of 0 and 90 degrees with respect to each fragment tract are used. The measurement of the neutron energy spectra at angles of 0 and 90 degrees with respect to the fission axis allows one to separate neutrons emitted by the double nuclear system or the compound nucleus from neutrons emitted by the excited fragments.



The set-up includes also a spectrometer for measuring γ-quanta multiplicity in reactions induced by heavy ions. This spectrometer consists of six NaJ(Tl) detectors of Ø63×63 mm which are located in lead collimators and set in the back hemisphere at a distance of 20 cm from the target. The full γ-quanta registration efficiency is 3 percent. At present, the obtained information is in the stage of processing. As an exmaple of the obtained results one can give the dependence of ν_{pre}, ν_{post} and ν_{tot} on the A_1/A_2 value for the fission of ^{250}Cf with an excitation energy of 75 MeV.

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Is the λ - attachment probability in hyperonic fission a chronometer or a thermometer ?

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Lambda and muon-accompanied fission of heavy nuclei have been observed and the attachment probability of the spectator particle to a fission fragment was measured as a function of its size. Observed deviations from a pure adiabatic behavior, where the λ or μ is always attached to the heavy fragment, was interpreted as a measure of the velocity of the fissioning system along the fission path. It turns out that the μ - attachment probability should be sensitive to the velocity in the separation degree - of - freedom at scission, whereas the λ - attachment probability is sensitive to both, the necking and the separation velocities.

In this line of reasoning it is assumed that originally the spectator particle is in its lowest eigenstate. For a hot. λ - hyperonic nucleus it is more reasonable to assume a thermal distribution of the λ - particle over the lowest eigenstate at the fission saddle - point. The effects of the temperature and of the fission velocity on the λ - attachment probability are exhibited and commented.

STUDY OF THE ^{206,207}Pb+^{34}S REACTIONS AT THE DUBNA GAS-FILLED RECOIL SEPARATOR

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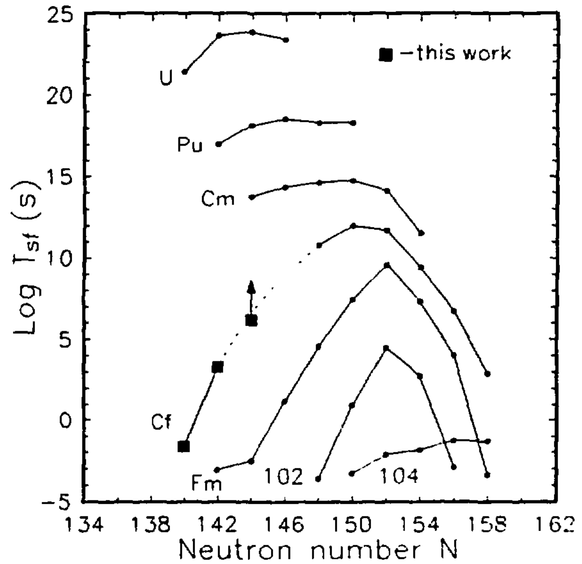
To synthesize and study nuclei around the predicted new deformed shells N=162 and Z=108 [1,2], we are preparing a series of experiments based on the use of fusion-evaporation reactions between ^{238}U and ^{34}S or ^{36}S whereby the production of the isotopes ^{268}108 and ^{270}108 can be attempted. In order to explore this "sulphur" way, we have performed studies of the reactions ^{206,207,208}Pb+^{34}S by using two different techniques - the gas-filled separator [3] and the wheel technique [4]. Thus the collection efficiency of the separator was determined to be 35±10 %. In the ^{207}Pb+^{34}S reaction, for the total beam dose of $0.8 \cdot 10^{17}$, it allowed us to detect between cyclotron beam pulses 46 SF events originating from the new, spontaneously fissioning isotope ^{238}Cf with $T_{1/2}=23\pm5$ ms [4] produced with a cross section of the order of 1 nb. This means that the sensitivity level of several pb can be reached in a 10-day ^{238}U+^{34}S experiment. As an additional result of our Pb+^{34}S studies, the SF stability of the light Cf nuclei (^{238}Cf, ^{240}Cf, and ^{242}Cf) was determined [4]. The dramatic effect of the neutron-deformed shell N=152 on the SF half-lives was demonstrated by revealing a T_{sf} decrease from $7 \cdot 10^{10}$ s known for ^{246}Cf down to $2 \cdot 10^{-2}$ s we have established for ^{238}Cf (see the Figure). A task of far-reaching importance now is to probe the effect of changing ^{34}S to ^{36}S on the Pb+S fusion-evaporation cross sections. The semi-magic (N=20) neutron-rich projectile ^{36}S can give a cross section enhancement similar,to some extent, to that known for the fusion-evaporation reactions induced by the famous projectile ^{48}Ca.



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GLOBAL AND FINE STRUCTURES OF FISSION DISTRIBUTIONS*

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The structures of fission fragment distributions as well as fragment de-excitation processes are related to the energy conditions of the scissioning nucleus by applying an energy-conservation-consistent scission point model (including temperature-dependent shell and pairing effects) together with statistical emission models. Emphasis is put on (i) the global structure of fragment distributions in mass, charge, and energy (fission modes), (ii) odd-even effects indicating various modes of cold fission (compact, deformed, shape-asymmetric), (iii) neutron multiplicity distributions and correlations as function of fragment mass and energy, (iv) folding angle distribution of complementary fission fragments. Calculational results are compared with recent experimental data.

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MULTIPARAMETER SYSTEM FOR NUCLEAR MEASUREMENTS BASED ON PC - CAMAC

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A modular system to determine correlations among many detectors in radiation measurement is described. The system is based on CAMAC standard and IBM PC computer. Software has been written in C language. It makes it possible to perform the following tasks: acquisition of digital and analog signals, disk data storage (in list mode), event sorting using different criteria, construction of (1-3) dimensional spectra and their display. These tasks can be carried out in on-line or off-line mode.

The capabilities of the system are illustrated in measurement of correlation between positron annihilation life-time and momentum of electron-positron pair using four detectors setup.

The aim of the work was to build up acquisition system suitable for:

- coincident and non-coincident multiparameter measurements in nuclear physics;
- recording of multiparameter data in list mode;
- data sorting based on definable conditions;
- amplitude analysis of data (1, 2, 3 parameter, also conditioned);
- on-line or off-line (from list file) working mode;
- data visualization (1, 2, 3 parameter spectra, scatter plots);
- spectra processing (peak position determination, fits, background subtraction, smoothing, ...).

These activities should be carried out in parallel. The system should be:

- flexible, i.e., the configuration modifiable by user;
- modular;
- simple, fast, cheap;
- user friendly in communication with operator.

HOT FUSION REACTION CROSS-SECTIONS AND NUCLEAR FISSILITY

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During recent years, the interest to "hot" fusion reactions, using actinide targets, in which compound nuclei with excitation energy of 40-50 MeV are produced, has increased [1]. At present there is a great amount of experimental data on cross-sections of such reactions with evaporation of 4-6 neutrons leading to different isotopes of the transfermium elements up to the element 106, that allows one to carry out a systematic analysis of these data.

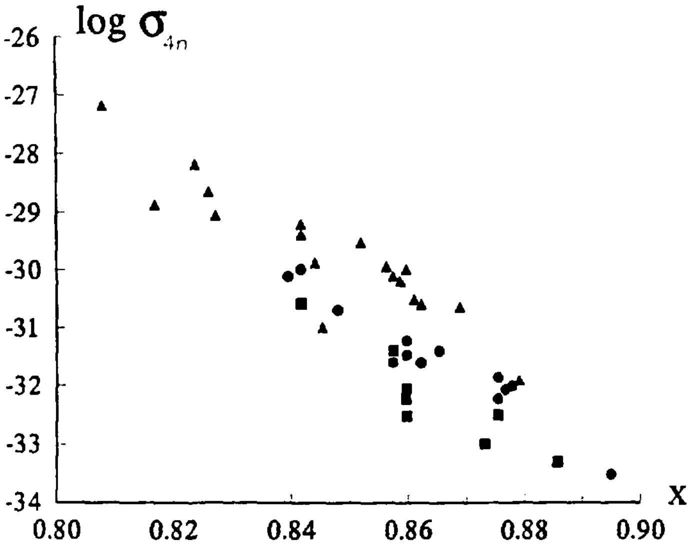

Fig. 1

Figure 1 shows the values of cross-section logarithms in the maxima of excitation functions of 4n-reactions versus X — the fissility parameter of the original compound nucleus. Triangles are the values of σ_{4n}^{max} for reactions induced by B and C ions, squares — N, O, F, circles — Ne, Mg, Al. The "quiet", without any peculiarities behaviour of σ_{4n}^{max} is noteworthy. All points are sufficiently uniformly grouped around one straight line which implies an exponential dependence of σ_{4n}^{max} on X. A similar picture is observed for 5n-reaction cross-sections. It is seen that for the nuclei under consideration no substantial changes occur in the xn-reaction process and all experimental data can be described using an unified algorithm. Usually one uses relations of the statistical theory of nuclear reactions for this purpose, but there exist some doubts in their validity for the fission width calculations when the fission barrier and nucleus temperature are approximately equal. At the same time, the data on the prescission neutrons number obtained during the recent years indicate that fission is a slow process. This circumstance and also the exponential dependence of xn-reaction cross-sections leading to transfermium nuclei on the fissility parameter X indicate that one can try to use formalism of the statistical theory of nuclear reactions. In our calculations a statistical code based on the program ALICE was employed [2]. Calculations were carried out in two variants. In the first one, shell effects in evaporation and fission channels were taken into account:

$$a(E) = a\{1 + [1 - \exp(-0.0054E)]\,\Delta W/E\} \qquad B_f(l) = B_f^{CPS}(l) + \Delta B \qquad (1)$$

where a=A/10, ΔW and ΔB are the shell corrections to the masses of the residual nucleus after neutron evaporation and of the fissioning nucleus, $B_f^{CPS}(l)$ is the fission barrier in the model of rotating charged drop. The ratio a_f/a_n was taken equal to 1.

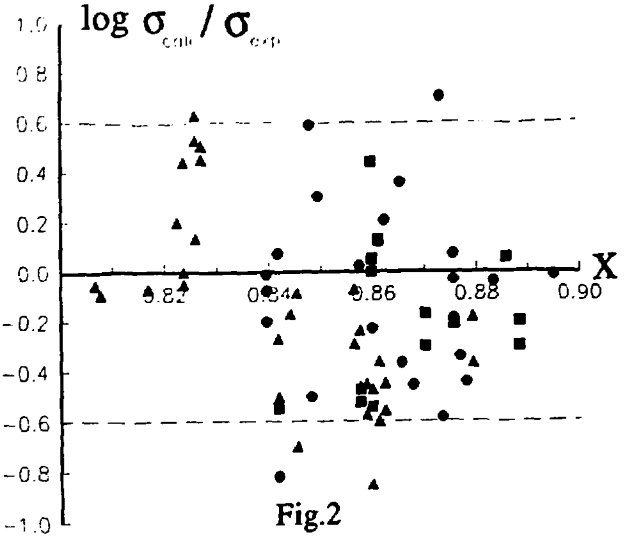

Fig.2

In the second case the relations (1) were used also, but the values ΔW and ΔB were considered to be formal parameters. For their determination the reaction $^{238}U + ^{18}O$ was used, for which excitation functions of the reactions from 4n to 8n were measured with a good accuracy. The best fit was obtained with $\Delta W = 0$ and $\Delta B = 1.1$. These values of parameters were fixed and calulations for all reactions, for which experimental data exist, were performed with them. In both variants of calculations a good fit was obtained. We consider the second variant which is more simple and more convenient for extrapolation. The results are presented in Fig.2, where there is shown a logarithm of the ratios of calculated and experimental values of cross-sections in maxima of excitation functions for reactions 4n, 5n and 6n versus fissility parameter X. Dashed lines limit interval $-0.6 < \log(\sigma_{\text{cal}}/\sigma_{\text{exp}}) < 0.6$, i.e., for the points lying between these lines $1/4 < \sigma_{\text{cal}}/\sigma_{\text{exp}} < 4$. From Fig.2 one can see that overwhelming majority of the points are within this interval.

One must note that the fission barriers of transfermium nuclei B_f are substantialy smaller than their neutron binding energies and therefore after neutron cascade a nucleus can be found with high probability with an excitation energy within interval $B_f - B_n$ and it undergoes fission. Only those nuclei reliably survive that after neutron cascade have the excitation energy smaller than B_f. Calculations show that this factor reduces yield of heavy nuclei by several orders of magnitude and that the value of $< \Gamma_n/\Gamma_f >$ ratio is smoothly varying in the transfermium region and ranges near 0.1. This result qualitatively differs from the generalyy accepted opinion that the ratio σ_{xn}/σ_c is completely determined by $< \Gamma_n/\Gamma_f >$ value which for heavy nuclei is of the order of 0.01.

A good agreement of calculation results and experimental data for reactions induced by Mg and Al, in which isotopes of the elements 102, 103 and 105 were produced, indicates that there are no sensible limitations in fusion for this ions. Some estimates of production cross-sections of several isotopes of the elements 107-110 in maxima of excitation functions for 4n and 5n channels are listed in the table.

	4n			5n		
Reaction	E_l (MeV)	E^* (MeV)	σ (pb)	E_l (MeV)	E^* (MeV)	σ (pb)
^{243}Am+^{26}Mg	138	42.9	110	146	50.1	89
^{249}Cf+^{22}Ne	118	41.2	120	128	50.4	58
^{248}Cm+^{26}Mg	138	42.4	110	146	49.6	150
^{248}Cm+^{27}Al	150	46.9	10	154	50.5	33
^{242}Pu+^{36}S	187	41.2	90	196	49.0	25
^{242}Pu+^{34}S	185	44.5	14	193	51.5	10
^{249}Cf+^{26}Mg	144	42.3	37	154	51.3	10

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SHAPE ISOMERISM IN LIGHT ACTINIDE NUCLEI

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In the past a series of shape isomers in actinide nuclei with $Z > 94$ were found all decaying via the fission channel. For the lighter actinides ($Z < 94$) only a few examples exist, where the shape isomer could be detected. However, in this mass region the cross sections show up the intermediate structure phenomena in subthreshold fission. Its interpretation in terms of the double humped fission barrier leads to discrepancies with the results from calculations on fast-fission data, especially in Uranium. In order to resolve these discrepancies it was proposed to interpret intermediate structure as delayed fission through a shape isomeric state with a halflife of a few ns. In order to search for this reaction path the 721.6 eV - neutron resonance in ^{239}U, a nearly pure class-II state, was investigated in a γ - γ-coincidence experiment.

With the same experimental set-up the neutron resonances in ^{233}Th for $E_n < 4.2$ keV were investigated in order to search for intermediate structure in the relative delayed γ-yield.

New experimental results will be presented and compared with existing systematics on isomeric halflives and barrierparameters.

Mass, charge and total kinetic energy distributions for the photon induced fission of ^{232}Th, ^{235}U and ^{238}U

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We have examined fragment mass, charge and energy distributions for the photofission of ^{232}Th, ^{235}U and ^{238}U as a function of the excitation energy of these compound nuclei.
The results of our experiments will be presented, and discussed in the framework of several theoretical models.
We have found that at low excitation energies for ^{232}Th the <TKE> as well as the yield for N=82 fragments (St.I channel) increase with increasing excitation energy (PIE93). For ^{238}U, on the other hand, the <TKE> also increases in the same excitation energy region, but the yield for N=82 fragments decreases (POM93). The statistical model calculations of Wilkins cannot account for the behaviour we observe. Also the fission channel combined with random neck rupture model as proposed by Brosa is unable to explain this phenomenon. Probably also dynamical effects play have to be taken into account when one wants to describe these results.
We also calculated the odd-even effect from the element distributions. We found that for all three nuclei this odd-even effect remains constant for excitation energies up to about 2 MeV ($\approx 2\Delta$) above the fission barrier (about 29% for ^{238}U, 25% for ^{235}U and 35% for ^{232}Th). For higher excitation energies the odd-even effect quickly drops to zero.
From these results we can conclude that fission with an excitation energy below 2Δ above the barrier is different from fission with a higher excitation energy.
If the results for ^{232}Th are compared with the electron induced fission experiments by Yoneama et al. (YON93), they can provide us with a means to determine the shape of the triple humped fission barrier of ^{232}Th. It will, more particular, provide information to conclude whether the shallow third minimum is located at the inner or at the outer slope of the second maximum.

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YON93: M.-L. Yoneama, J.D.T. Arruda Neto, E. Jacobs, D. De Frenne, S. Pommé, K. Persyn, K. Govaert. This conference.

Fission of ^{239}Pu by Resonance Neutrons

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We present some unpublished results of the experiment with ^{239}Pu [1]. In this experiment the fission of ^{239}Pu by resonance neutrons was studied. All results are based on the prompt γ-ray spectroscopy.

A special method [2] allowed us to evaluate the independent yields of fission fragments at individual resonances in energy region of (0.296 -75) eV. From the dependence of independent yields on fission width we estimated the average pre-scission width as $\overline{\Gamma}_{\gamma f}^{1+}$=(4.8±2.5)meV.

The value of charge dispersion σ_z^2=0.36±0.03 which we obtained from our data allowed us to discuss other quantities which can be deduced from it (collective temperature, duration of the charge relaxation).

The used multidimensional analysis allowed us to change the time window between fission and γ-quanta detection inside the time interval from zero to 300 ns. From this time analysis we deduced the lifetime of the exited levels of some fission fragments. We calculated the ratio of reduced transition probability $B(\sigma\lambda)$ to Weisskopf single particle transition probability $B_W(\sigma\lambda)$ in order to investigate the properties of long lifetime levels. We present the alternative level schemes of ^{95}Sr and ^{137}Xe as well.

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Investigation of Fission Dynamics of Hot Nuclei at HENDES 4π-array

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During the last year the construction of a new multidetector system HENDES (High Efficiency Neutron DEtection System) has begun. The basic element of this neutron detection system is a position sensitive neutron detector (PSND) which is a 100cm long quartz glass tube with a diameter of 6 cm filled with liquid scintillator. A tube is viewed by two photomultipliers from both ends. About 50 PSND will be placed around a scattering chamber at the distance 50-60 cm from a center. The geometrical effeciency of this detector ring is approximatly 0.5 and the position resolution is about 10 cm. Neutron energy spectra, angular distribution and parameters of neutron multiplicity distribution are planned to be measured in coincidence with fission fragments or reaction products. The parallel-plate avalanche counters (PPAC) will be used for fission fragment detection. A near 4π-array of position sensitive PPAC is planned to be constructed in order to measure fission fragment mass and angular distributions. A new data aquisition system VENLA designed at the accelerator laboratory of the University of Jyvaskyla will be integrated with HENDES facility to provide monitoring and processing of data. The investigation is proposed to run in three directions:(i) fission dynamics of hot rotating heavy nuclei in fusion-fission reactions. (ii) dynamics of double fission fragment system at the descent from saddle point and near scission, (iii) ternary fission in heavy ion reactions. The some results of description of fission dynamics of hot rotating nuclei in the framework of fluctuation dissipative Langeven theoretical model are also discussed.

THE TREATMENT OF (15 MeV/u) U + Ag REACTION BY FOKKER-PLANCK EQUATION

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We have been used CR-39 detectors to study the reaction ^{238}U + Ag at 15 MeV/u in a 2π geometry. Results of the kinematical analysis for four-pronged events support deep inelastic reaction mechanism with a three-step process in the 85% of the total number of four-pronged events. Other four-pronged events could be explained as a quasi-fission process i.e. as a two-step process. Kinematical analysis for five-pronged events indicates a three-step process in all examined events. The mass transfer between the projectile and target nucleus in the first reaction step has been estimated employing Fokker-Planck equation. Experimental results and solutions of the Fokker-Planck equation for four- and five-pronged events indicate a important drift of nucleons from target to the projectile nucleus in the first reaction step.

Fission barrier parameters calculation of ^{232}Th and ^{236}U

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Fission fragment angular distributions and the electrofission cross sections for ^{232}Th and ^{236}U were measured in the electron energy range between 3.5 and 8.0 MeV.The photofission cross sections for three different fission channels, namely $(J^{\pi},K)=(1^{-},0)$, $(1^{-},1)$ and $(2^{+},0)$, were deduced. For ^{232}Th an excited isomeric state was observed at ~ 4.50MeV, corresponding to a $(2^{+},0)$ vibrational level. This state shows up as a resonance in the photofission cross section or as a shelf in the electrofission cross section. Fission barrier parameters are being calculated for both nuclei by determining a single set of a suitable double or triple-humped barrier parameters, which reproduces the observed structures in the photofission cross section near the fission threshold as well as the observed resonance in the deep sub-barrier photofission cross section. The photofission cross section for a specific fission channel $\sigma(J^{\pi},K)$ is proportional to the barrier penetrability associated with this channel $T_f(J^{\pi},K)$. Therefore, by comparing directly the $\sigma_{\gamma,f}(\omega)$ obtained experimentally to $T_f(\omega)$ calculated for different kind of barrier shapes, it is possible to determine the nature of the fission barrier. The fission barrier penetrabilities through a 2 or 3-humped fission barrier are calculated using the model developed by Bhandari and Kharam [1] which parametrizes the fission barrier by smoothly joining three (for 2-humped barrier) or five (for 3-humped barrier) parabolas (the penetrability calculations are carried out in WKB approximation). For ^{232}Th $(2^{+},0)$ fission channel very preliminary results were obtained. The barrier which reproduces best the observed resonances is a 3-humped fission barrier with a shallow third well. The calculations of the parameters are in progress.

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NEUTRON MULTIPLICITY MEASURMENTS AND NEUTRON EMISSION FROM PRIMARY FRAGMENTS

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Abstract

In recent investigations of J. van Aarle et. al. [1] and I. Düring et. al. [2] the number of neutrons emitted by the fission fragments and its correlations with the total kinetic energy relased in a particular fission event are used as an information source about the energetical conditions at scission point. One of the crucial points of such procedure is the correction of the secondary fragment masses for neutron evaporation from primary fragments. Such correlation has been calculated using statistical model. Results will be also presented for neutron multiplicity distribution and correlations between neutrons emitted from light and heavy fragment, respectively.

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NEW RESULTS ON THE FISSION FRAGMENT ENERGY AND MASS CHARACTERISTICS IN SPONTANEOUS AND THERMAL NEUTRON INDUCED FISSION

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Abstract:

In the frame of a systematic study, the energy and mass characteristics of fission fragments emitted in the thermal neutron induced fission of ^{239}Pu and ^{243}Am and in the spontaneous fission of ^{242}Pu and ^{244}Pu are being investigated.

Special attention is given to the presence of fission channels and their dependence on excitation energy and neutron and proton number of the fissioning nucleus.

Also cold fission fragmentations are looked for.

PRELIMINARY PROGRAMME

MONDAY I session	14:00 O P E N I N G			14:30 U.Kneissl Photofiss. at intermediate en. : Absolute cross ...	15:30 Yu.Ts.Oganessian Cluster emission at magic region	16:30 Š.Gmuca Halo-nuclei studied via relativ. mean...	17:30 Welcome party
TUESDAY II + III session	9:00 J.B.Fitzgerald High-en. γ-rays in comp. nucleus and spont. fission	10:15 R.P.Schmitt Fiss. shapes and time scales from neutron multipl...	11:00 P.Siegler 11:30 S.Oberstedt	15:30 I.Düring Cold shape-asymetric fission	16:15 A.Goverdovski Fission frag. angular distrib. for a cold fragm. process	16:45 J.Pyatkov The Cf-isotopes cold-fission analysis	17:10 S.Pommé 17:35 K.Persyn
WEDNESDAY IV session	9:00 C.Wagemans New results on the fiss. fragm. en. and mass char. ...	10:15 H.Märten Global and fine structure of fiss. distributions	11:15 G.Fioni 12:15 F.Steiper	14:00 EXCURSION 18:30 BARBECUE			
THURSDAY V + VI session	9:30 U.Graf Parity non-cons. in fiss. of ^{233}U	10:15 V.I.Furman Binary and tern. fiss. at neutr. resonances	11:00 E.M.Kozulin 11:30	15:30 I.Gontchar Combining a dyn. and statis. approach to...	16:15 N.Carjan Langevin approach to nucl. fiss.	16:45 R.Reif Light partic. emission in the the Langevin...	17:10 17:35
FRIDAY VII session	9:00 H.J.Krappe Is the λ-attachm. prob.in hyper. fiss. a chrono...	10:15 V.A.Rubchenya Invest. of fiss. dyn. at HENDES 4π-array	11:00 F.Gönnenwein Some new asp. of ternary fiss.	12:00 Summary	Good Bye		