NUCLEAR LEVEL DENSITIES OF ^{47}V, ^{48}V, ^{49}V, ^{53}Mn, ^{54}Mn FROM NEUTRON SPECTRA

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The experimental data on the nuclear level densities for many nuclei are derived, in the main, from the analysis of low-lying level and neutron resonance data. However, this information is limited to rather narrow ranges of excitation energy, and spin, and its extrapolation can lead to essential errors both in absolute value of the nuclear level density and its energy dependence, especially, in transition field from well-identified discrete states to continuum part of excitation spectrum. Obviously, it is necessary to attract other experimental methods of the nuclear level density determination with scope of more wide ranges of excitation energy and spin. Such method has been the study of the spectra of particles emitted in nuclear reactions. In this case the type of reaction and the energy of incident particles should be chosen so that the contribution of nonequilibrium processes was minimum. These conditions are satisfied with (p,n) reaction at proton energy up to 11 MeV.

In the present work the neutron spectra from (p,n) reaction on nuclei of ^{47}Ti, ^{48}Ti, ^{49}Ti, ^{53}Cr, ^{54}Cr in proton energy range of (7 - 11) MeV have been measured and analyzed in the framework of statistical theory of nuclear reactions to study the nuclear level densities of ^{47}V, ^{48}V, ^{49}V, ^{53}Mn, ^{54}Mn.

Experiment

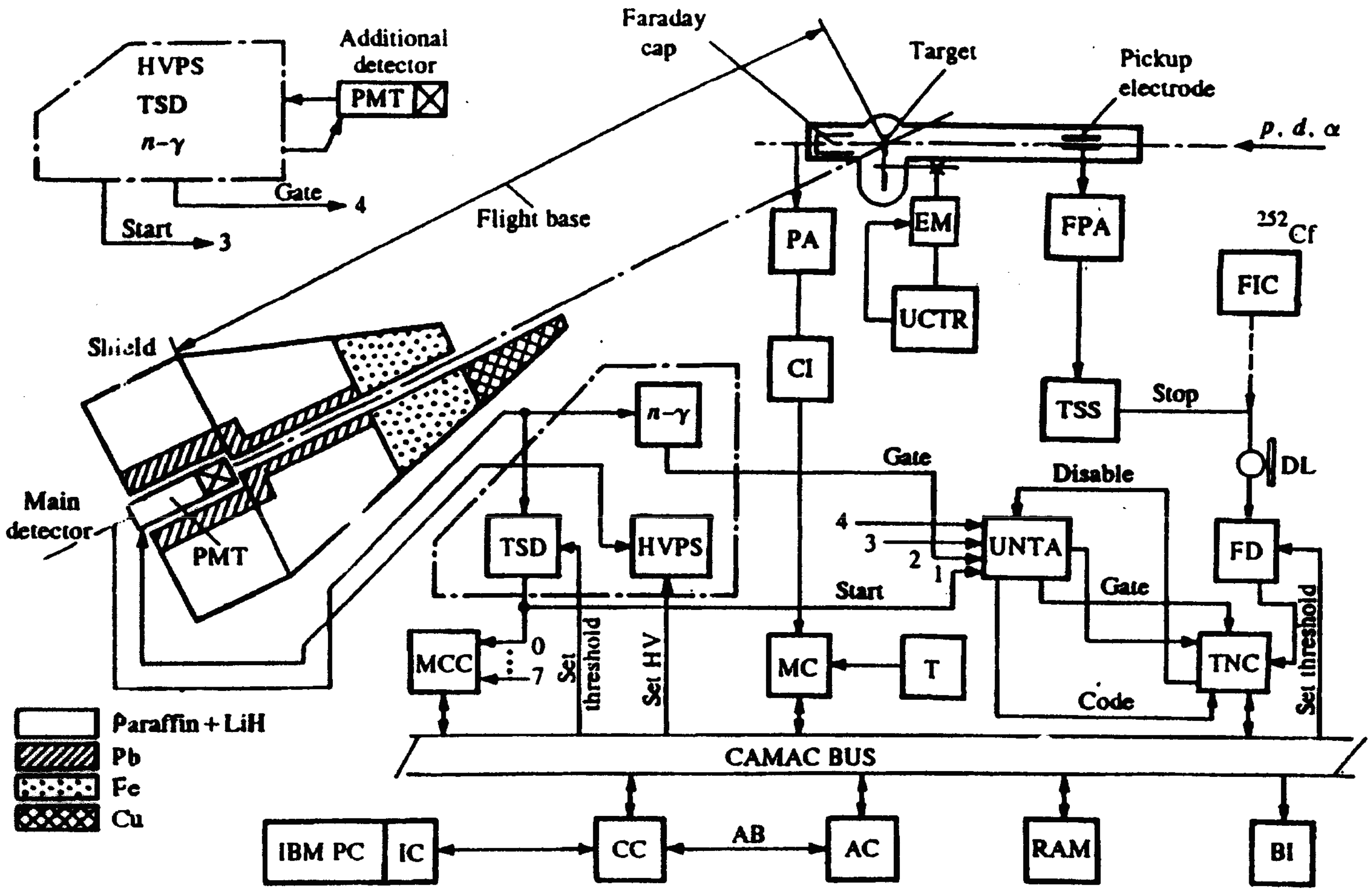
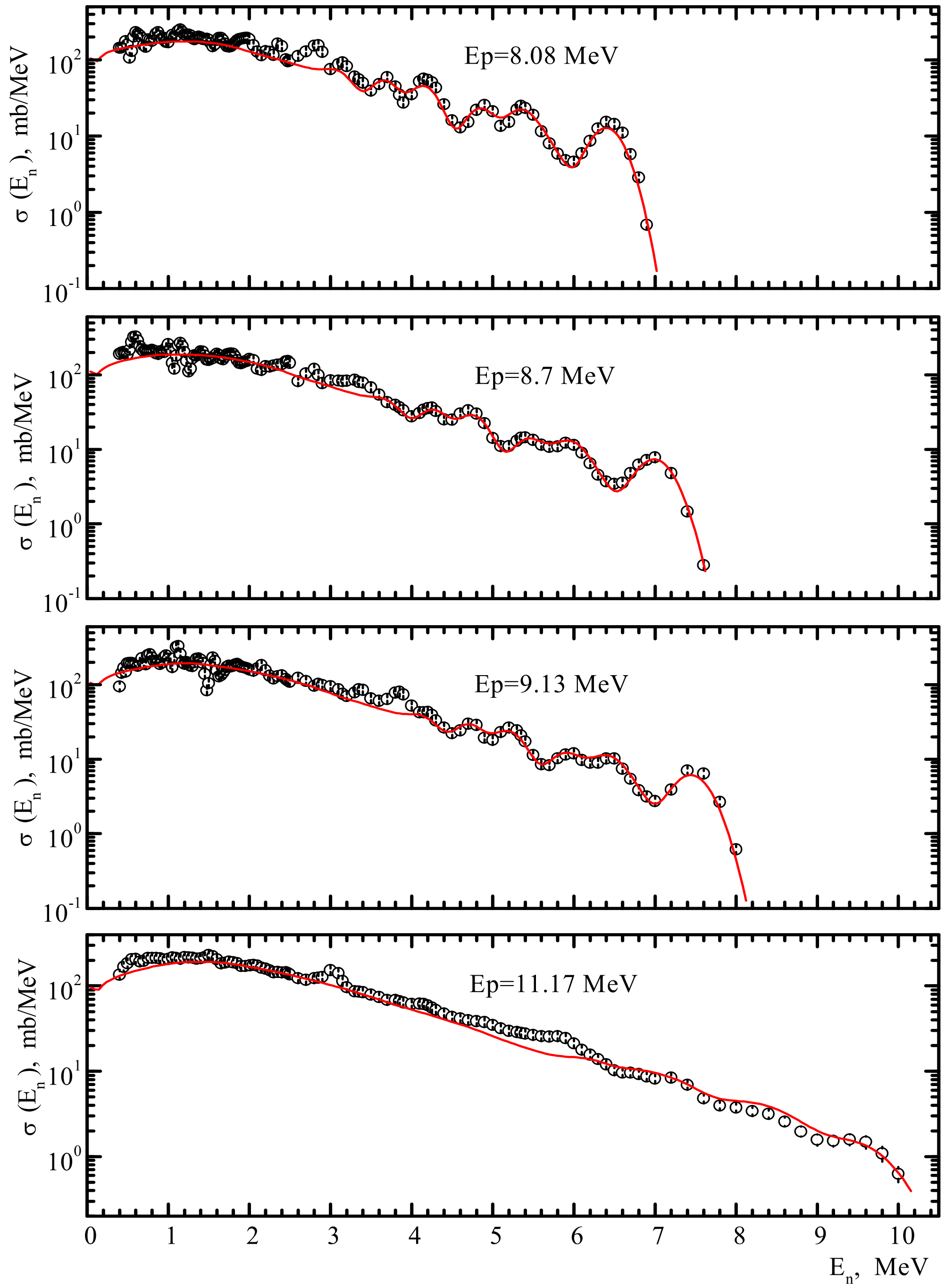
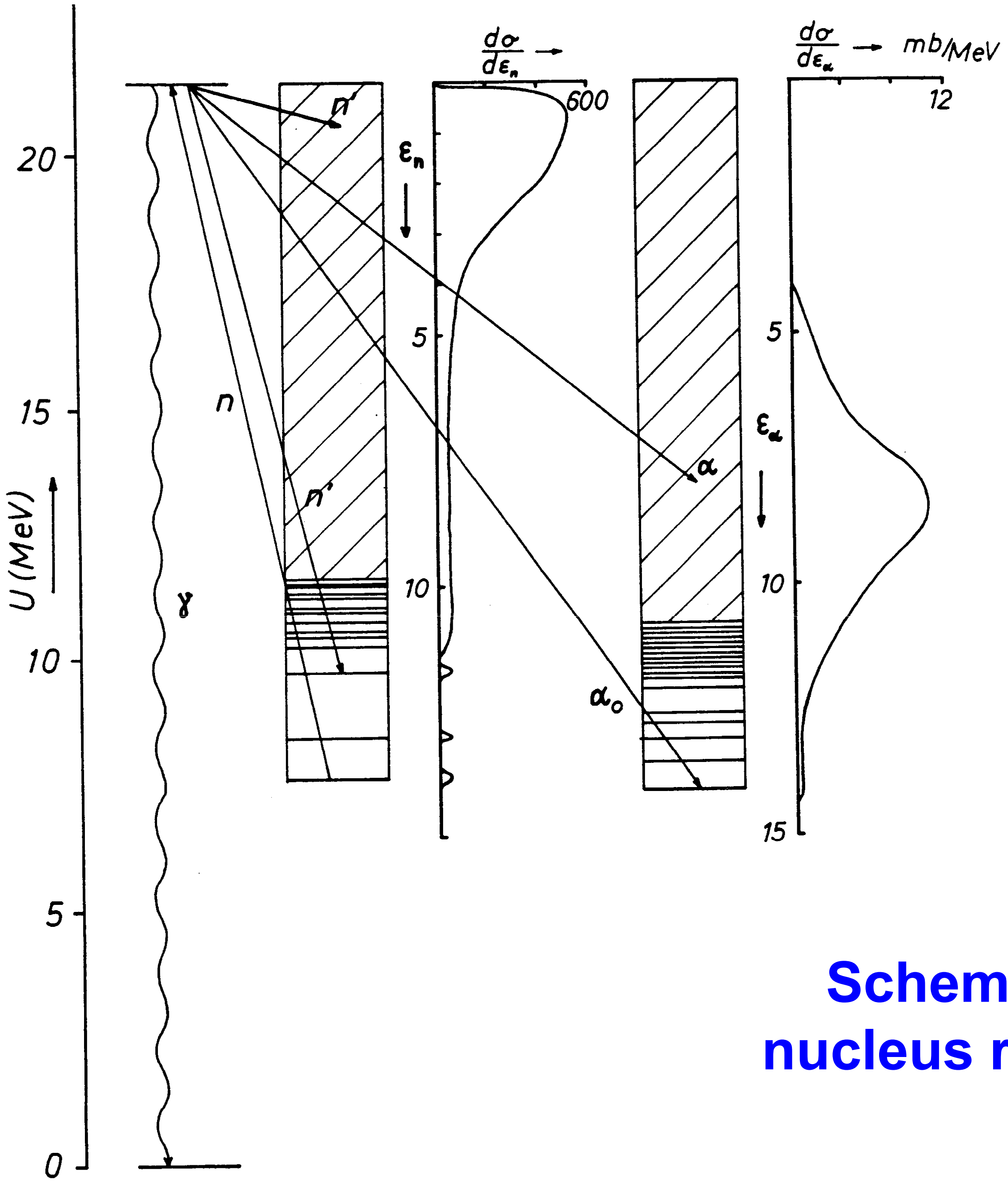


Fig. Block diagram of the spectrometer, its detecting, storing, and data processing circuits: HVPS) high-voltage power supply; TSD) tunable threshold discriminator; n–γ) separation circuit; PA) preamplifier; CI) current integrator; EM) electric motor; UCTP) unit controlling the target position; FPA) fast preamplifier; TSS) time signal shaper; FIC) fission ionization chamber; DL) delay line; FD) fast discriminator; UMTA) unit of multidetector time analysis; MCC) multichannel counter; MC) monitoring counter; T) timer; TNC) time-to-number converter; BI) bus indicator; RAM) random-access memory; AC) additional controller; CC) 106A crate controller; IC) interface circuit; AB) additional bus.



Angle-integrated neutron emission spectra from $^{49}Ti(p,n)^{49}V$ reaction.



Scheme of a compound nucleus reaction for specific example.

Data analysis

The method of nuclear level density determination from emission spectra is based on the fact that the nuclear level density is one of the most critical component of statistical model calculations. The procedure of nuclear level density determination consisted in following:

The model parameters of the level density are adjusted such that the cross-section calculated by means of Hauser-Feshbach formula fits the measured value in the energy range of well-known low-lying levels. It means that the total decay width of compound nucleus is determined.

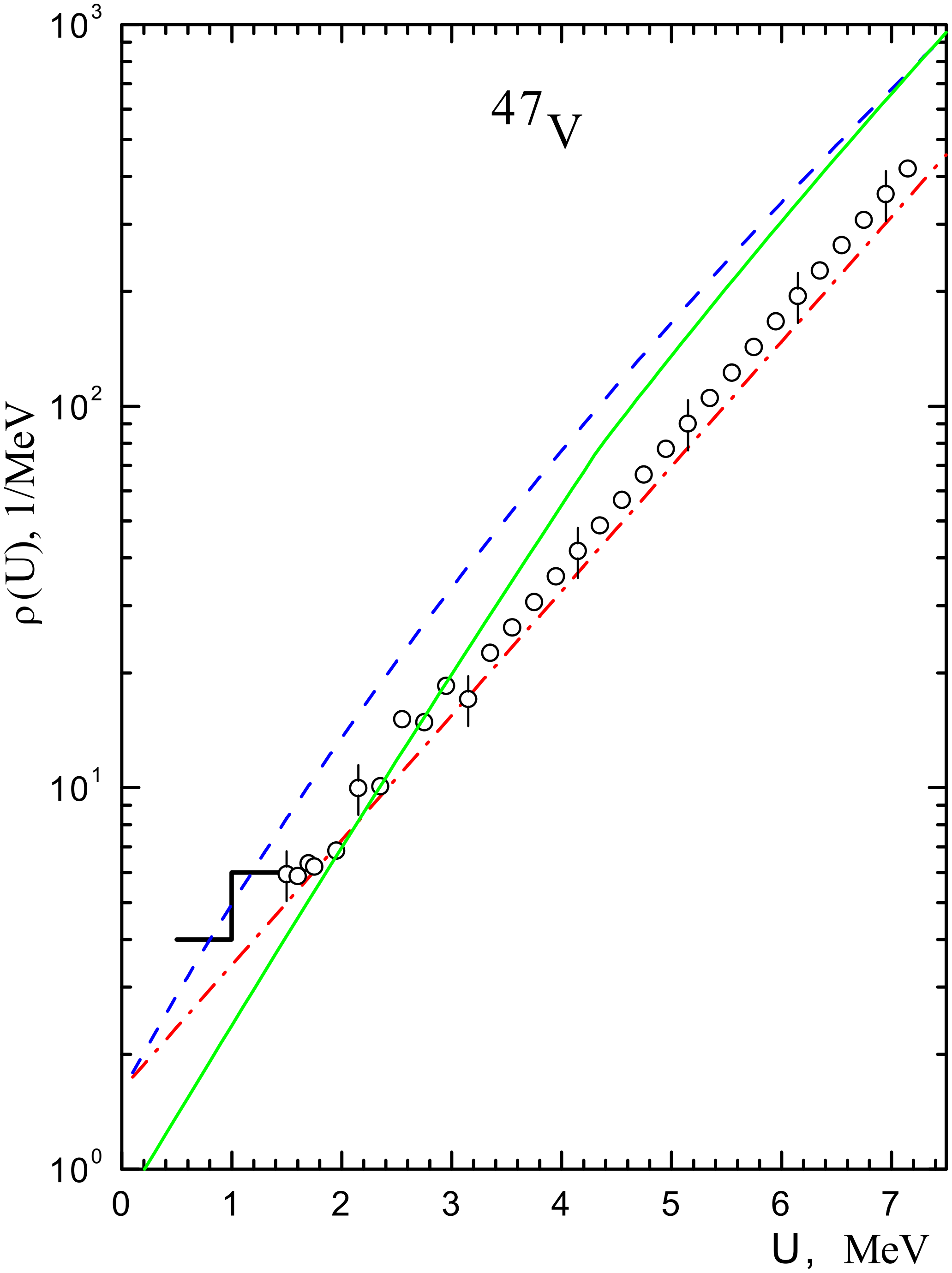
Using, at first, the chosen model of the level density and, in next iterations, the absolute values of the level density, the differential cross-section for continuum part of spectrum is calculated and the absolute level density is determined in a wide range of excitation energy from the best fit with the spectra measured.

$$\frac{d^2\sigma(E_0,E_2,\theta)}{dE_2 d\Omega}=\frac{1}{4K_0^2}\cdot\sum_{kJ_1}\sum_{l_0 j_0 l_2 j_2}\frac{2J_1+1}{(2S_0+1)\cdot(2J_0+1)}\cdot B_k(l_0,S_0,j_0,J_0,J_1)\cdot\sum B_k(l_2,j_2,S_2,J_2,J_1)\cdot\tau\cdot\rho(E_0+Q_{\alpha,n}-E_2,J_2)\cdot P_k(\cos\theta),$$

$$\tau=\frac{T_{l_0 j_0}(E_0)\cdot T_{l_2 j_2}(E_2)}{\sum_c\left(\sum_{l,j}T_{l,j}+\sum_{l,j,J}\int_{U_c}T_{l,j}\cdot\rho(E_0+Q_{\alpha,n}-E_2,J_2)\cdot dU\right.},$$

$$B_k(l,S,j,J_f,J_i)=(-1)^{J_f-J_i-S}\cdot(2J_i+1)\cdot(2j+1)\cdot\langle l_0 l_0|K_0\rangle W(J_iJ_ijj;KJ_f)\cdot W(jjll;KS)$$

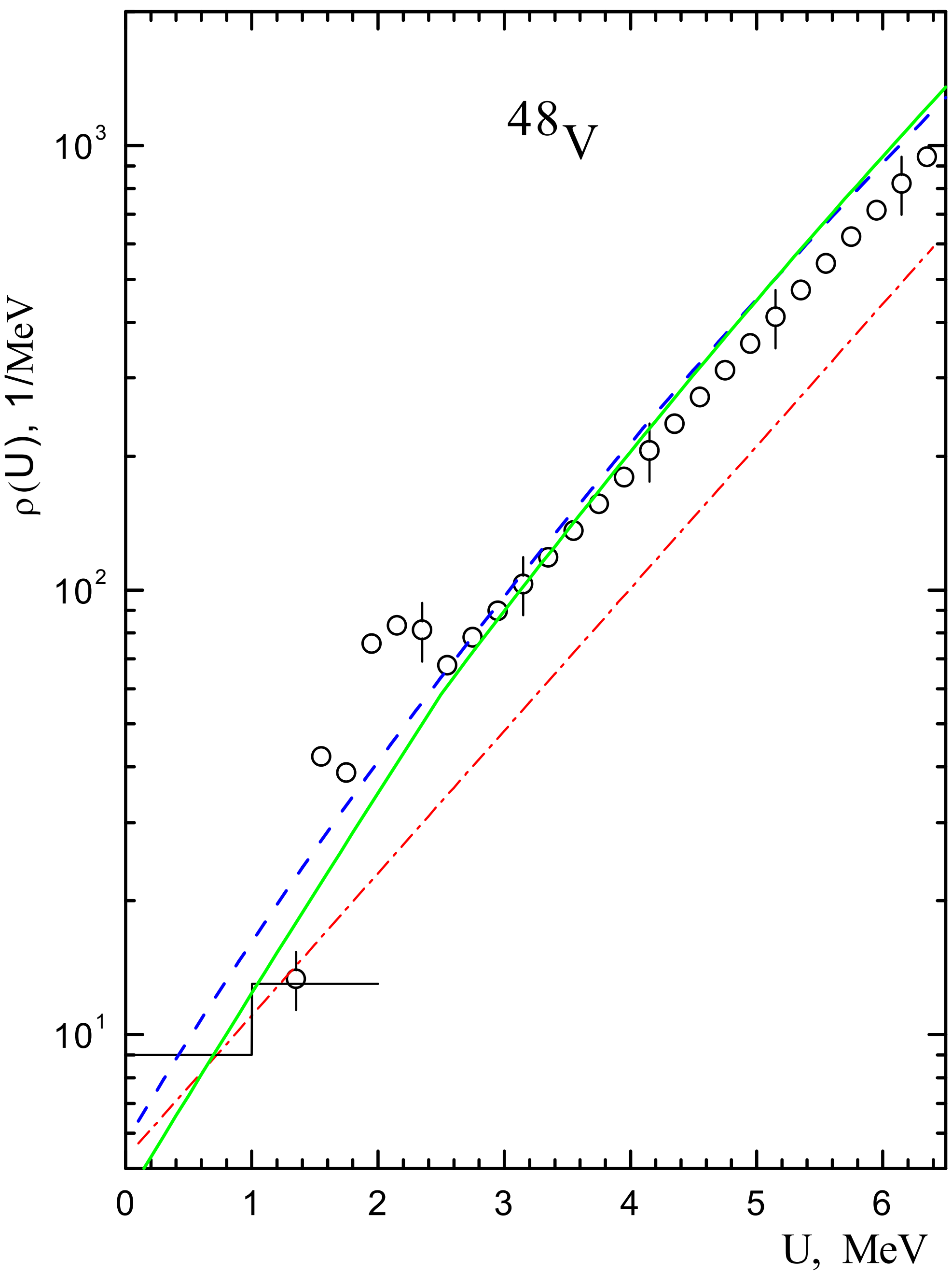
$$\rho(U)=\rho(U)\text{assumed}\cdot[(d\sigma/dEn)\text{meas.}/d\sigma/dEn)\text{calc.}]$$



Results: **The extracted level densities for residual nuclei of ^{47}V, ^{48}V, ^{49}V, ^{53}Mn and ^{54}Mn excited in reactions studied are presented in the next figs. The total uncertainties of the level densities are about 17 %.**

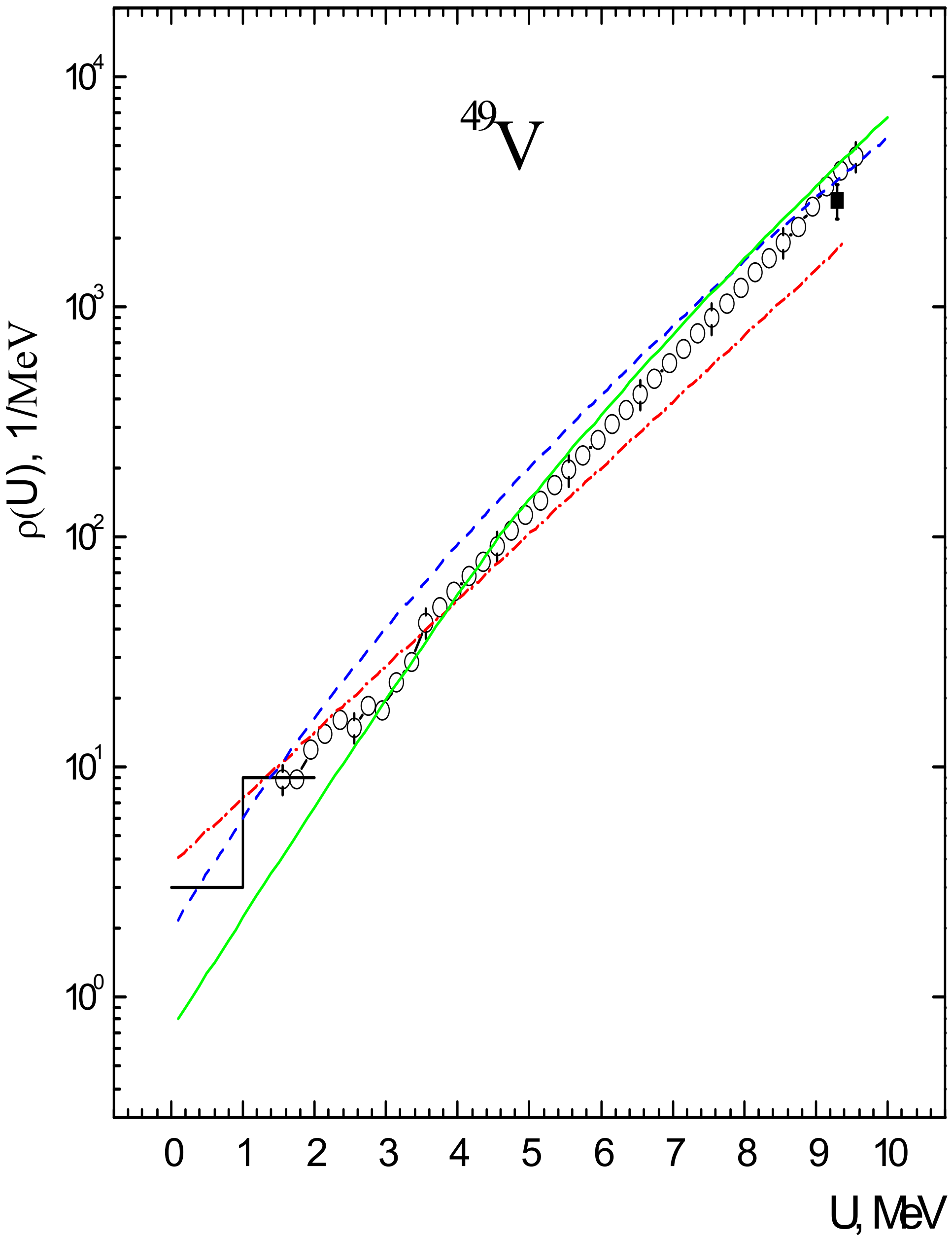
Nuclear level density of ^{47}V.

Experimental data: o - present work, histogram - low-lying level data. The curves are calculated results: solid - GSN, dashed - BSFG, dash-dotted - G-C systematics.



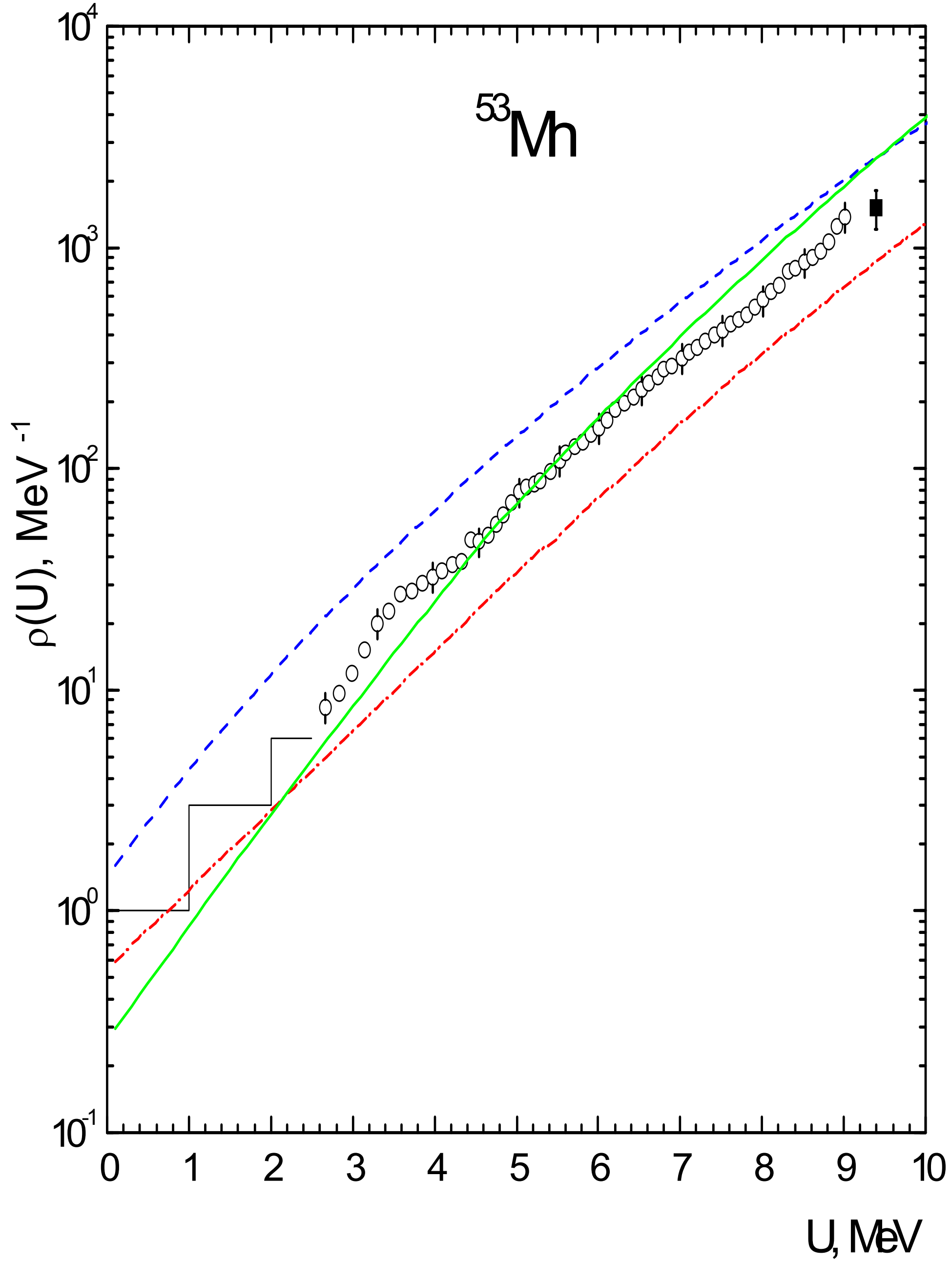
Nuclear level density of ^{48}V.

Experimental data: o - present work, histogram - low-lying level data. The curves are calculated results: solid - GSN, dashed - BSFG, dash-dotted - G-C systematics.



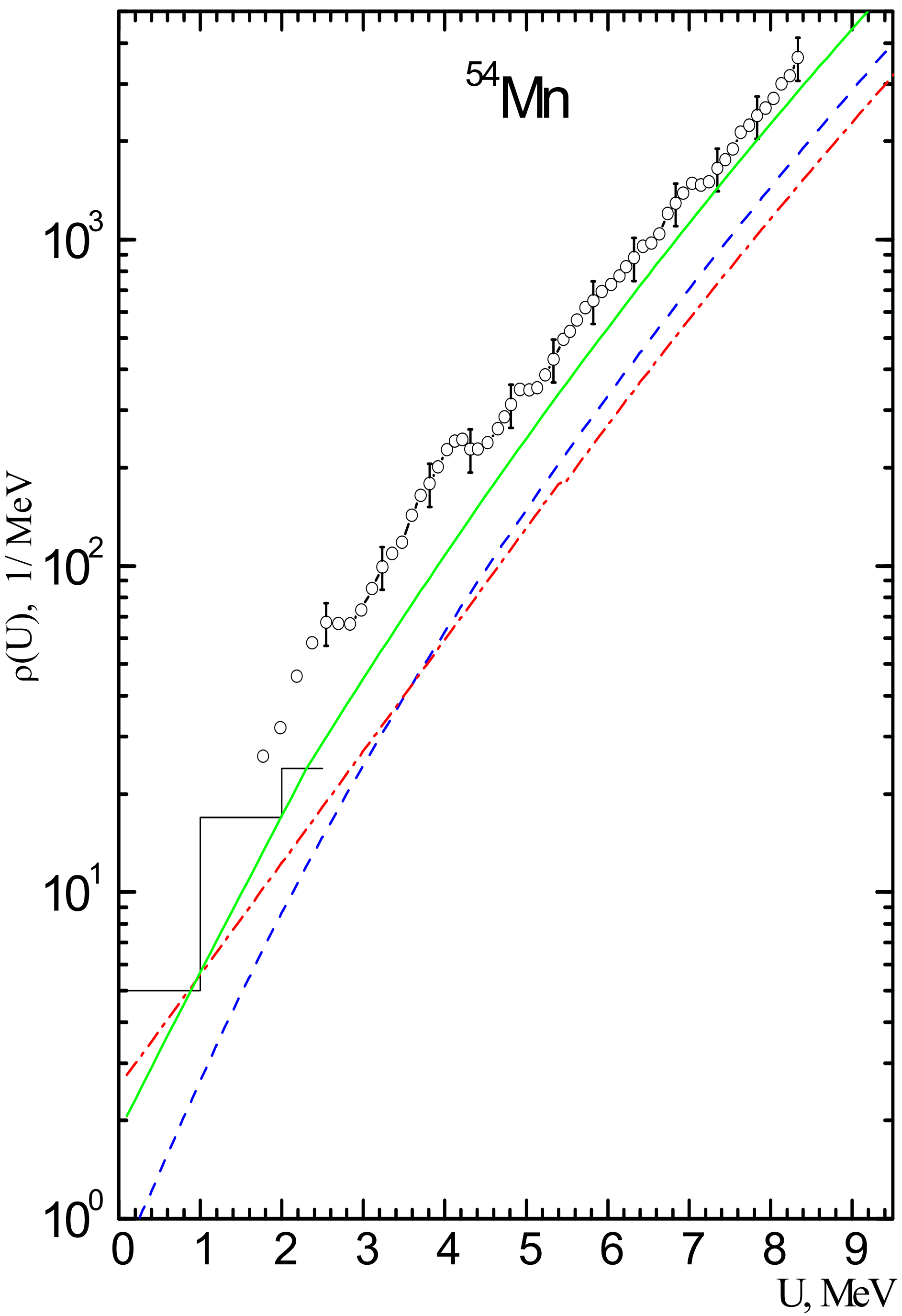
Nuclear level density of ^{49}V.

Experimental data: o – present work, histogram - low-lying level data, ■ - proton resonance data. The curves are calculated results: solid - GSN, dashed - BSFG, dash-dotted - G-C systematics.



Nuclear level density of ^{53}Mn.

Experimental data: o - present work, histogram - low-lying level data, ■ - proton resonance data. The curves are calculated results: solid - GSN, dashed - BSFG, dash-dotted - G-C systematics.



Nuclear level density of ^{54}Mn. .

Experimental data: o - present work, histogram - low-lying level data. The curves are calculated results: solid - GSN, dashed - BSFG, dash-dotted - G-C systematics.

Nuclear level density parameters

Model	G–C					BSFG			Dis. Levels	
Parameter Nucleus	**a**	**Δ**	$\mathbf{E_x}$	**T**	$\mathbf{E_o}$	**a**	**Δ**	**I**	$\mathbf{E_c}$	$\mathbf{N_L}$
^{47}**V** a) b)	6.96 5.54	1.21 -0.69	7.18 6.72	1.54 1.51	-2.83 -2.75	5.97 5.54	1.31 -0.69	I_{rig} I_{rig}	2.00	10
^{48}**V** a) b)	7.12 6.77	0.07 0.00	8.66 7.88	1.40 1.36	-2.79 -2.68	5.57 5.80	-1.21 -1.70	I_{rig} I_{rig}	2.00	22
^{49}**V** a) b)	7.15 6.77	1.05 1.54	9.24 11.96	1.51 1.51	-2.51 -2.63	5.95 5.65	1.10 -0.84	I_{rig} I_{rig}	2.00	12
^{53}**Mn** a) b)	5.31 5.87	-0.43 1.30	3.60 5.30	1.22 1.21	-0.44 0.50	5.15 5.46	-0.30 -0.71	I_{rig} I_{rig}	2.50	7
^{54}**Mn** a) b)	5.84 6.21	-1.86 0.00	4.60 5.40	1.20 1.27	-2.49 -1.49	5.57 6.10	-1.91 0.00	I_{rig} I_{rig}	2.50	34

Nuclear level density parameters

Model	GSN						
Parameter Nucleus	ã	Δ_o	δW	γ	C_v	ω_{2+}	Δ
^{47}**V** a) b)	4.17 4.37	1.75 1.75	-0.84 -0.84	0.051 0.051	0.027 0.027	2.3 2.3	1.02 0.00
^{48}**V** a) b)	4.54 4.47	1.73 1.73	-1.26 -1.26	0.051 0.051	0.027 0.027	2.27 2.27	0.97 0.00
^{49}**V** a) b)	4.52 4.56	1.71 1.71	-0.27 -0.27	0.051 0.051	0.027 0.027	2.24 2.24	1.15 0.00
^{53}**Mn** a) b)	3.76 5.49	1.65 1.65	-2.39 -2.39	0.051 0.051	0.028 0.028	2.13 2.13.	0.48 0.00
^{54}**Mn** a) b)	3.81 5.85	1.63 1.63	-2.38 -2.38	0.051 0.051	0.028 0.028	2.10 2.10	0.97 0.00

a) Parameters correspond the best fit of the obtained results,
b) Parameters recommended in systematics.

Conclusions:

1) The neutron emission spectra in (p,n) reaction on nuclei of ^{47}Ti, ^{48}Ti, ^{49}Ti, ^{53}Cr, ^{54}Cr have been measured in proton energy range of (7-11) MeV and analyzed in the framework of statistical model of nuclear reactions.
2) The absolute nuclear level densities of ^{47}V, ^{48}V, ^{49}V, ^{53}Mn and ^{54}Mn, theirs energy dependences and model parameters are determined.
3) In transition field from well-identified discrete states to continuum part of excitation spectrum the structure is observed connected with unhomogeneties of a single-particle state spectrum.
4) In energy dependences of nuclear level densities are displayed odd-even differences.
5) It is shown also that the obtained data differ essentially from the predictions of the nuclear level density model systematics.