The vacuum system consists of 3 oil pumps, 2 oil diffusion pumps, a turbo molecular pump and an ion-sputtering pump (see Fig.1.).

The results of testing experiments confirm the expected parameters. The observed mass spectrum of stable Barium's ions at the focal plane can be seen in Fig.2. The distance between the mass lines 138 and 134 at the collector was about 32 mm. The half width of the mass line was about 1.5 mm, and its height about 4 mm. These characteristics lead to the value of the mass resolution near to 700. The measured efficiency of the mass separator is about 80%.

At present a few sources, which are planned to be installed at the on-line mass separator IRIS, in particular, a new version of the laser ion source [4] at the off-line mass separator, are tested.

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(p,2p) AND (p,np) REACTIONS ON ^{90}Zr AND ^{208}Pb NUCLEI AT 1 GEV. EVOLUTION OF PARAMETERS OF DEEP NUCLEAR SHELLS

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These experiments [1] are continuation of a series of the fulfilled earlier analogous experiments on a study of neutron and proton hole states of $2s - 1d$-shell nuclei ($16 \leq A \leq 40$) in $(p, 2p)$ and (p, np) reactions at 1 GeV proton beam of Gatchina synchrocyclotron [2]. Using the missing mass correlation spectrometer with overall energy resolution FWHM = 3.5 MeV, described in previous papers, the difference sections $d^3\sigma/d\Omega_1\ d\Omega_2 dT_1$ of quasielastic knock out of proton and neutron from different shells of magic nuclei ^{90}Zr and ^{208}Pb were measured. The obtained energy spectra of hole states of these nuclei are shown in the figures.

At separation of deep s and p levels with large dead widths it was used that in the maximum of knock out of a nucleon from s levels the contributions of p levels in cross section are suppressed, and near the maximum of knock out from p levels the contributions of s levels are suppressed. In order to separate the unresolved peaks, caused with spin-orbit splitting of shells ($1p_{3/2}$, $1p_{1/2}$, $1d_{5/2}$, $1d_{3/2}$, $1f_{5/2}$, $1f_{7/2}$ ...), their relative strengths were fixed in accordance with ratios of their spectroscopic factors. For 2p and 2d states it was succeeded to determinate only the centers of weights of their spectral distributions. The results are presented in the table.

Using these data and the results, obtained in previous experiments, empirical A-dependencies of energies and widths of proton and neutron deep hole states are discussed.

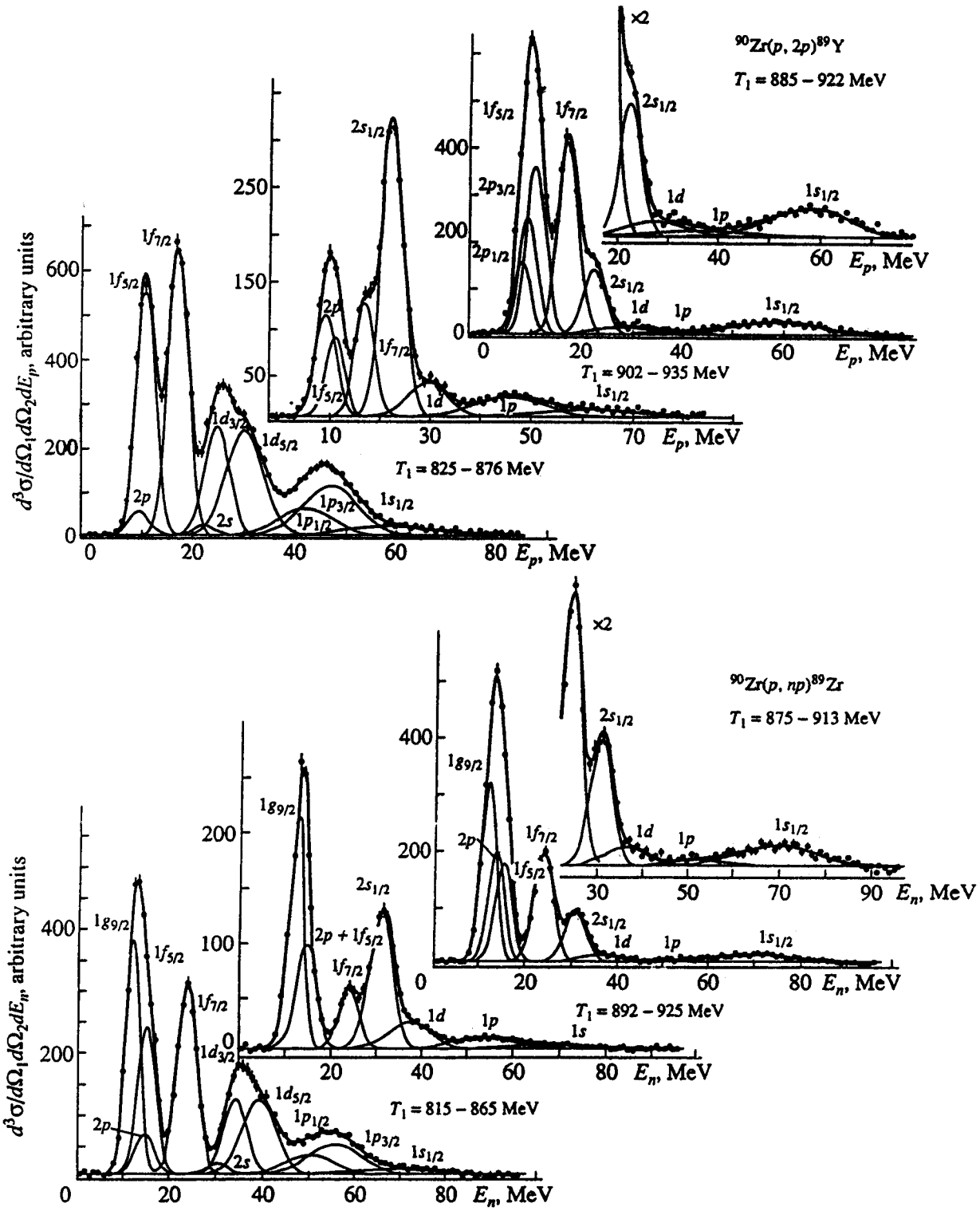

Fig.1. Energy spectra for proton and neutron hole states [these spectra were obtained in the reactions $(p, 2p)$ and (p, np) on ^{90}Zr nuclei in kinematic boundaries that favor the isolation of s states]

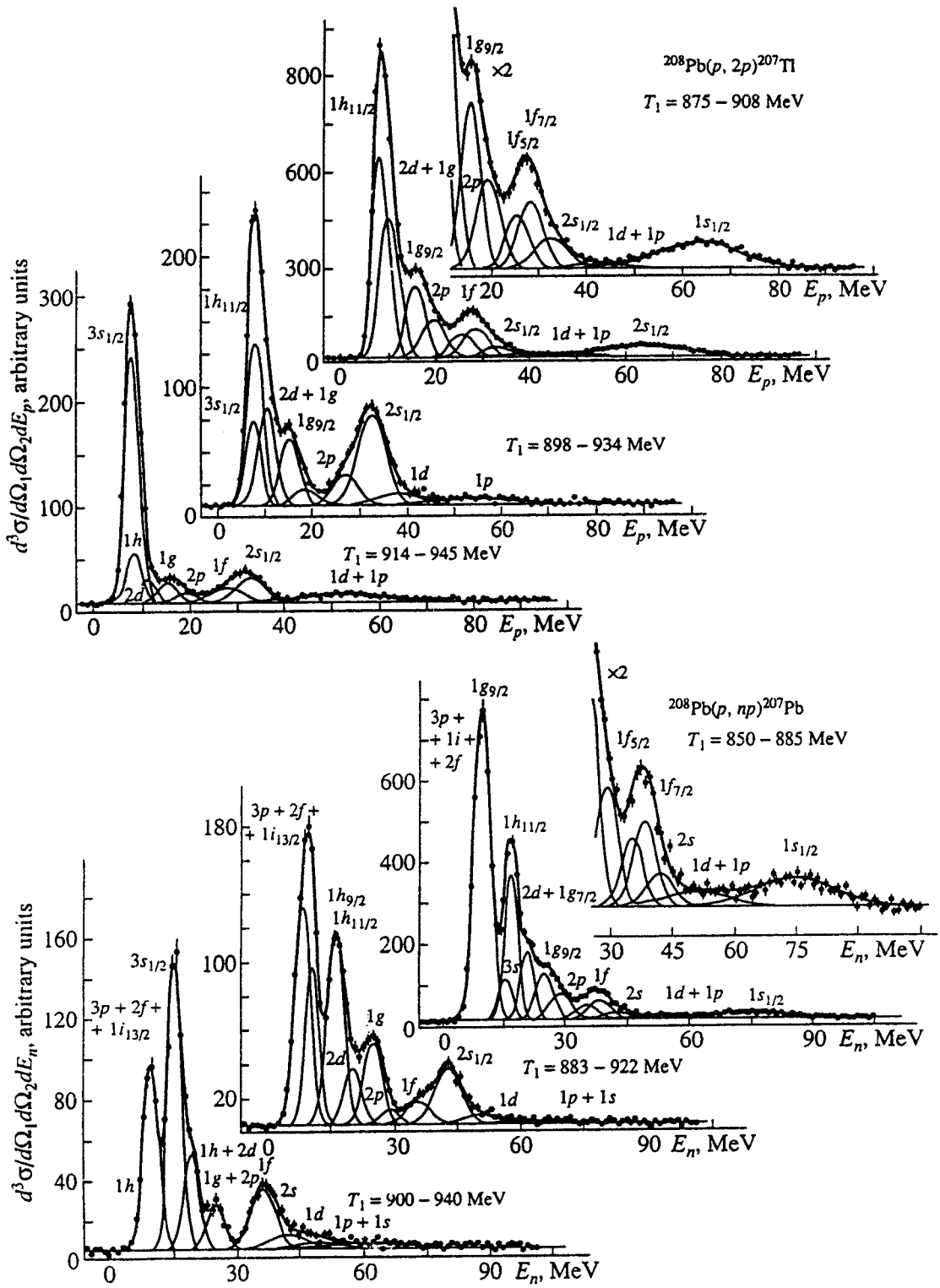

Fig.2. As in Fig.1, but for ^{208}Pb nuclei

Table

Parameters of proton and neutron states in ^{90}Zr and ^{208}Pb nuclei

Nucleus	Shell	Ω^{π}	E_p, MeV	Γ_p, MeV	E_n, MeV	Γ_n, MeV
^{90}Zr	$1g_{9/2}$	$9/2^+$	–	–	11.94 (0.28)	0.83 (0.75)
	$2p_{1/2}$	$1/2^-$	9.14 (0.37)	1.65 (0.73)	13.60 (0.56)	1.86 (1.1)
	$2p_{3/2}$	$3/2^-$				
	$1f_{5/2}$	$5/2^-$	11.04 (0.43)	1.51 (0.95)	15.27 (0.51)	2.03 (0.69)
	$1f_{7/2}$	$7/2^-$	17.18 (0.48)	2.03 (0.89)	23.81 (0.55)	3.54 (0.65)
	$2s_{1/2}$	$1/2^+$	22.30 (0.53)	3.65 (0.63)	30.66 (0.60)	4.12 (0.56)
	$1d_{3/2}$	$3/2^+$	24.81 (0.58)	4.46 (0.79)	34.47 (0.66)	4.55 (0.61)
	$1d_{5/2}$	$5/2^+$	30.17 (0.82)	7.57 (0.76)	39.43 (1.0)	7.58 (0.70)
	$1p_{1/2}$	$1/2^-$	41.88 (1.1)	9.18 (0.88)	50.71 (1.4)	9.27 (0.79)
**	$1p_{3/2}$	$3/2^-$	46.83 (1.5)	15.55 (0.95)	56.06 (1.9)	15.70 (1.0)
	$1s_{1/2}$	$1/2^+$	59.42 (2.1)	18.78 (1.0)	70.02 (2.3)	18.89 (1.2)
^{208}Pb	$3p_{1/2}$	$1/2^-$	–	–		
	$2f_{5/2}$	$5/2^-$	–	–	8.17 (0.33)	0.75 (0.69)
	$3p_{3/2}$	$3/2^-$	–	–		
	$1i_{13/2}$	$13/2^+$	–	–		
	$2f_{7/2}$	$7/2^-$	–	–	10.07 (0.45)	0.89 (0.95)
	$1h_{9/2}$	$9/2^-$	–	–	11.02 (0.48)	1.12 (0.98)
	$3s_{1/2}$	$1/2^+$	8.04 (0.21)	0.54 (0.45)	15.44 (0.50)	1.20 (0.64)
	$1h_{11/2}$	$11/2^-$	8.51 (0.32)	0.85 (0.74)	16.76 (0.53)	1.47 (0.60)
	$2d_{3/2}$	$3/2^+$	9.63 (0.37)	2.96 (1.0)	19.13 (0.57)	3.05 (1.2)
	$2d_{5/2}$	$5/2^+$				
	$1g_{7/2}$	$7/2^+$	11.78 (0.32)	2.66 (0.90)	20.78 (0.58)	2.86 (0.67)
	$1g_{9/2}$	$9/2^+$	15.77 (0.35)	3.14 (0.21)	24.96 (0.63)	3.33 (0.72)
	$2p_{1/2}$	$1/2^-$	19.90 (0.46)	5.17 (1.0)	28.93 (0.78)	6.26 (1.2)
	$2p_{3/2}$	$3/2^-$				
	$1f_{5/2}$	$5/2^-$	25.80 (0.51)	4.63 (0.75)	35.22 (0.85)	4.74 (0.68)
	$1f_{7/2}$	$7/2^-$	28.61 (0.57)	5.11 (0.85)	38.13 (0.93)	5.21 (0.77)
	$2s_{1/2}$	$1/2^+$	32.84 (0.68)	5.63 (0.89)	42.05 (1.0)	5.73 (0.82)
	$1d_{3/2}$	$3/2^+$	35.48 (0.79)	6.53 (0.91)	44.86 (1.1)	6.62 (0.96)
	$1d_{5/2}$	$5/2^+$	39.55 (1.1)	9.78 (0.90)	49.75 (1.3)	9.89 (1.0)
	$1p_{1/2}$	$1/2^-$	49.76 (1.3)	11.21 (1.0)	58.63 (1.6)	11.30 (0.92)
	$1p_{3/2}$	$3/2^-$	54.37 (1.6)	17.55 (1.1)	63.68 (2.2)	17.63 (1.2)
	$1s_{1/2}$	$1/2^+$	64.81 (2.6)	20.55 (1.2)	74.69 (2.8)	21.63 (1.3)

Note: Experimental errors are indicated in parentheses.

The experimental data are compared to calculations in the self-consistent Hartree-Fock model with various Skyrme forces and Moszkowski modified delta interaction. It is found that for description of deep levels more nonlocality of the internucleon interaction (corresponding to the effective mass m* of nucleon m*/m $\approx$ 0.5) is required then for the description of levels near the Fermi surface.

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STUDY OF MESIC ATOMS AT THE PROTON BEAM OF THE MOSCOW MESON FACTORY (MMF) WITH A TWO-CRYSTAL DIFFRACTION SPECTROMETER (PROJECT "MADIS")

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1. Measurement of the energy shift and width of 1s-level of the pionic hydrogen atom, caused by the strong πN-interaction and derivation of πN scattering lengths

Pion-nucleon scattering lengths are usually determined from the phase-shift analysis of the low-energy πN-scattering data using dispersion relations and the extrapolation to zero energy. Such an indirect method leads to ambiguous results due to the experimental data dispersion as well as because of the difference in the phase-shift analyses results [1].

There exists however another way to obtain the πN-scattering lengths, namely the study of the $(np-1s)$ transitions in the pionic hydrogen atom. In this case one should measure the energy and width of the transition in pionic hydrogen. Experimental transition energy determines the shift ϵ_{1s} of the 1s-level, caused by the strong interaction, while the width of the transition is almost equal to the width of the 1s-level Γ_{1s}, caused by the pion absorption by the proton. The shift and the width of the pionic hydrogen 1s-level can be expressed by a Deser formulae [2] via πN scattering lengths a_1 (isospin $T=1/2$) and a_3 (isospin $T=3/2$):

$$\epsilon_{1s} = -\frac{4E}{3R}(2a_1+a_3) \quad (1)$$

$$\Gamma_{1s} = \frac{16QE}{9R}(1+1/P)(a_3-a_1)^2, \quad (2)$$

where E is the binding energy of the 1s-level, R is the pionic Bohr radius, Q is a kinematic factor and P is the Panofsky ratio.

The scattering lengths a_1 and a_3 thus obtained do not contain theoretic uncertainties so the accuracy is determined by the experimental errors in the energy shift and width. To obtain the values a_1 and a_3 with an accuracy (1-3)% one should measure the 1s-level shift