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VALUE OF EQUILIBRIUM CHARGE STATES DISTRIBUTION WIDTH FOR PARAMETRIZATION OF HEAVY RECOIL SPECTRA

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Recently, gas filled magnetic separators are extensively used to study heavy ion induced reactions leading to the formation of isotopes of heavy elements[1-5]. To detect the products under investigation a different techniques is applied for the detector design. In the case of the Dubna Gas-Filled Recoil Separator [6] the detecting module consists of 12 strip position sensitive detector to measure the energy(E)/position and two low pressure multiwire proportional chambers to generate time-of-flight (TOF) signal. The chambers operate in pentane renewed (20 ml/week of liquid pentane) atmosphere (ab. 1.5 torr) separated from the separator working volume (hydrogen, ab. 1 torr) by an ultra thin mylar entrance window. Such a design was chosen to have the ability to detect products of reactions with high asymmetry (projectile to target mass ratio) which having high mass and atomic numbers are characterized by low (lower than 10 MeV) initial (after target) energy. The scheme of the above detecting module is presented in Fig.1.

This letter reports on a computer code using an equilibrium charge states standard deviation as the only free parameter to describe the measured E-TOF spectra of ^{217}Th and ^{216}Ac nuclei. To this goal a simplified assumption by Ninov et al. [2], namely: electronic stopping dominates in the region of nuclei velocities $v > v_0$ has been used. Here v_0 is the Bohr velocity equal to 2.19E+08 cm/s. According to this paper the stopping force scales with q^2, where q-is the actual value of the recoil charge in hydrogen. Hence,

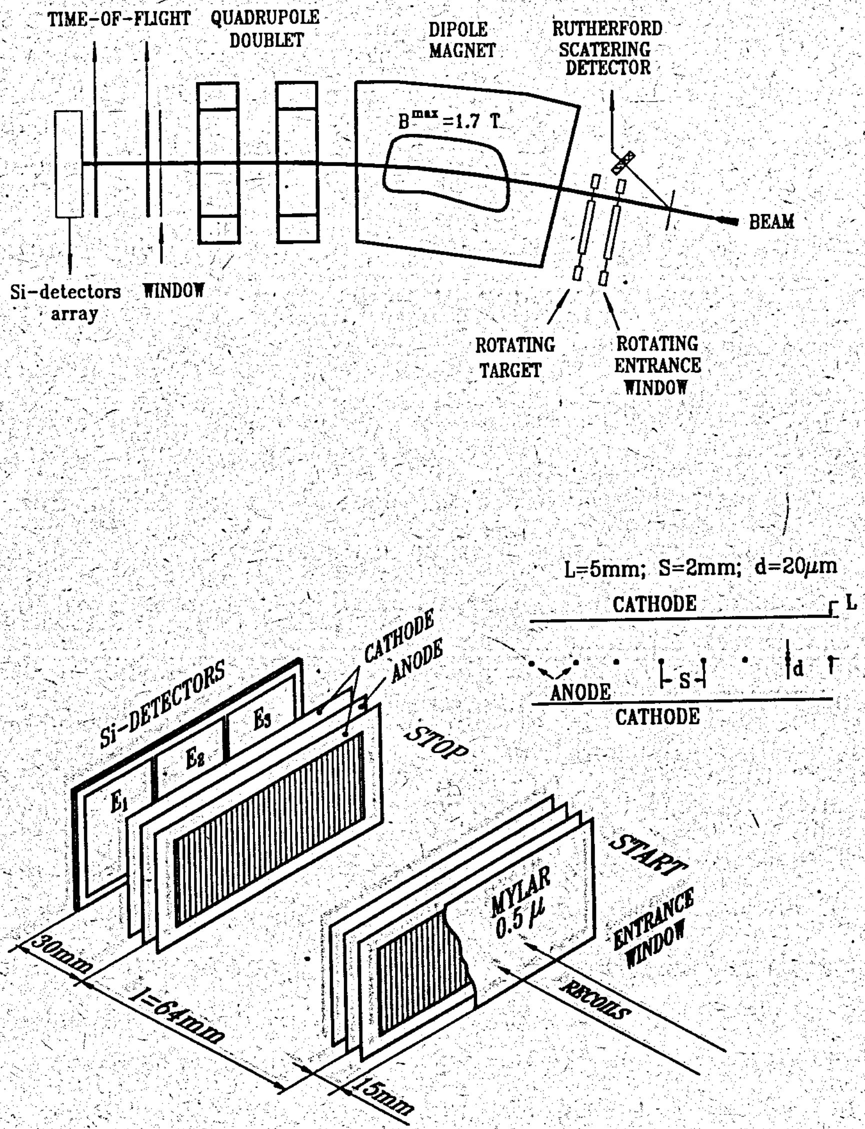


Fig.1 Schematics of the separator(a) and the detector system (b)

the actual and mean loss in hydrogen are linked by the formula $S = \langle S\rangle (q/\langle q\rangle)^2$. To generate the equilibrium charge states spectra we used the χ^2-distribution as described in Ref. [8]. The value of $\langle q\rangle$ was obtained from the established empirical charge states systematic [12] for the velocities region $1 < v/v_0 < 2.6$ and the atomic number interval $88 < Z < 109$. As concerns other sources of E/TOF spectra broadening, formulas from Ref. [9] to calculate contribution of neutron evaporation and energy straggling in the target and mylar window were used. In the last case some simplification takes place, the mylar window is assumed to consist of only carbon atoms. The value of the mean temperature of evaporated neutron was taken as 2 MeV (2T) according to [10] (1 MeV for ^{252}No, as it was recommended by the author of Ref.10 in a form of a private communication). The nonmonochromacity of the initial beam required in formulas from [9] is taken to be 1% (FWHM). All the statistical distributions except for the q value was assumed to be Gaussian ones. For the calculation of the pulse height defect in the silicon detector the empirical formula by Wilkins [11] was used, whereas for the dispersion calculation there has been applied the LSS formalism technique by Haines and Whitehead [12].

As to the experimental spectra, they were obtained in the three following reactions ^{197}Au+^{22}Ne=^{216}Ac+3n, ^{nat}W+^{34}S=^{217}Th+3n and ^{206}Pb+^{48}Ca=^{252}No+2n (Ref.13). Ions of ^{22}Ne, ^{34}S and ^{48}Ca were accelerated by the U-400, the main cyclotron of FLNR. The measured spectra were obtained via the extraction of appropriate recoil-alpha correlated sequences. Having used the spectra generation in the above mentioned manner and having set the minimization of the function

$R(\sigma_q) = ((\sigma_{tof} - \sigma^{t,exp})/\sigma^{t,exp}))^2 + ((\sigma_e - \sigma^{e,exp})/\sigma^{e,exp}))^2$, as the criteria of success, and having taken into account the value of the TOF detector response to a monochromatic particle like (Ar 180 MeV, Ne 100 MeV, B 40 MeV) equal to about 2.7 ns (FWHM), the optimum parameter of σ_q has been found. In the last expression σ_{tof}, $\sigma^{t,exp}$ - standard deviations in TOF distribution, calculated and measured respectively, σ_e, $\sigma^{e,exp}$ the same values for energy distribution.

In Figs. 2,3 the measured and simulated spectra of ^{216}Ac and ^{217}Th are shown. In the next step the spectrum of heavy recoil of ^{252}No obtained in the ^{206}Pb+^{48}Ca reaction is reproduced. An additional Al degrader of 1.06 mg/cm^2 was introduced in the vicinity of the target to obtain a heavy ^{252}No recoil velocity in an appropriate region. Fig.4 a,b demonstrate both the measured and calculated spectra. The role of the degrader was accounted in a manner similar to the case of the target. In all the calculations the Northcliffe and Schilling tables [15] were used. As regards the optimal value of σ_q used in this calculations it is necessary to state the following: It would be attractive to attribute this parameter to the one defining the selectivity of the separator. Moreover, both the values are definitely linked to each other, but since the above used value was extracted via the comparison with the spectra of nuclei after passing

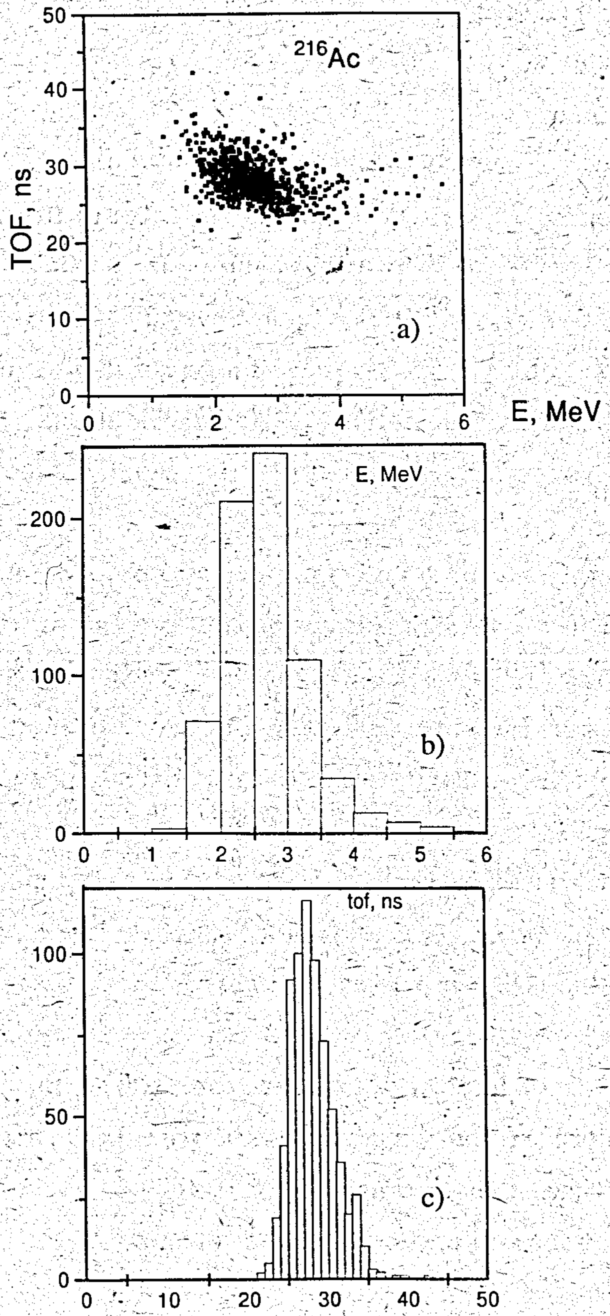


Fig.2

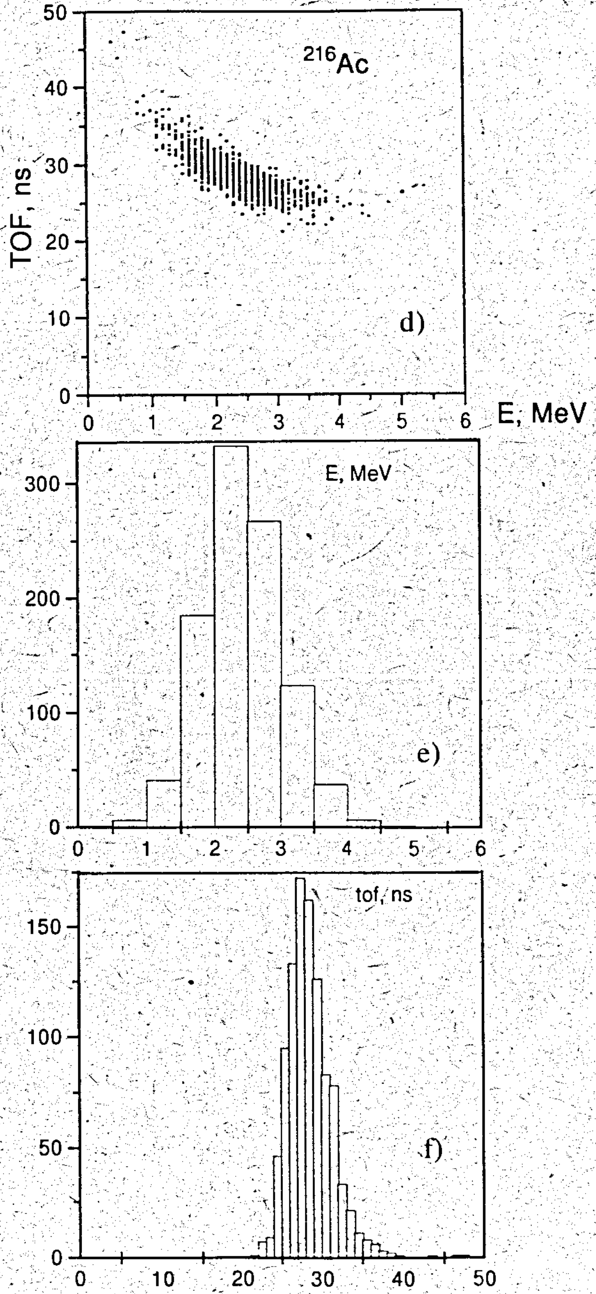


Fig.2 Measured (a-c) and simulated spectra (d-f) of ^{216}Ac nuclei produced by the ^{197}Au + ^{22}Ne = ^{216}Ac + 3n reaction

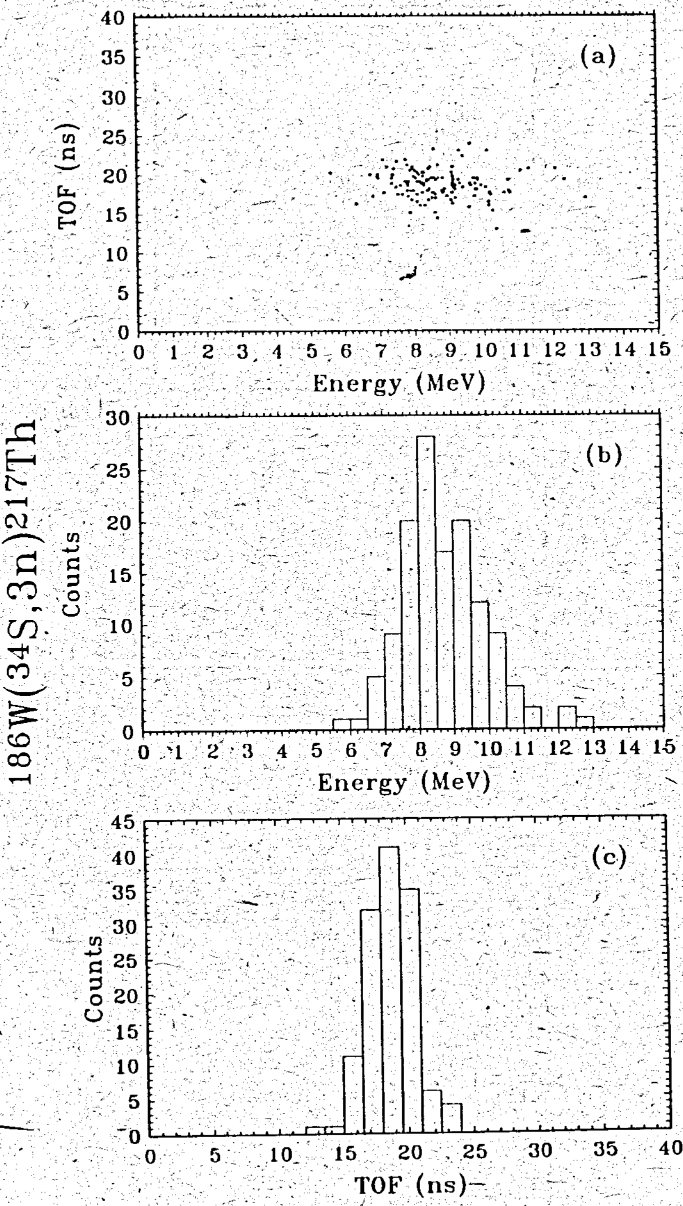
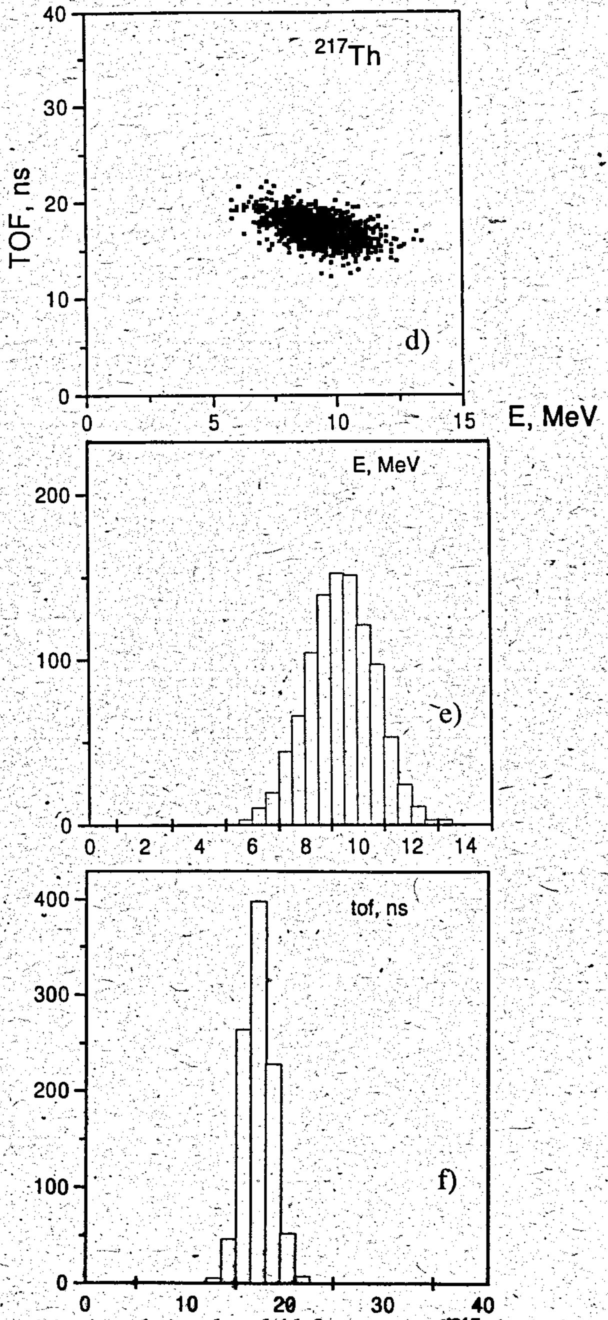


Fig.3



g.3 Measured (a-c) and simulated (d-f) spectra of ^{217}Th nuclei produced by the ^{nat}W + ^{34}S = ^{217}Th + 3n reaction

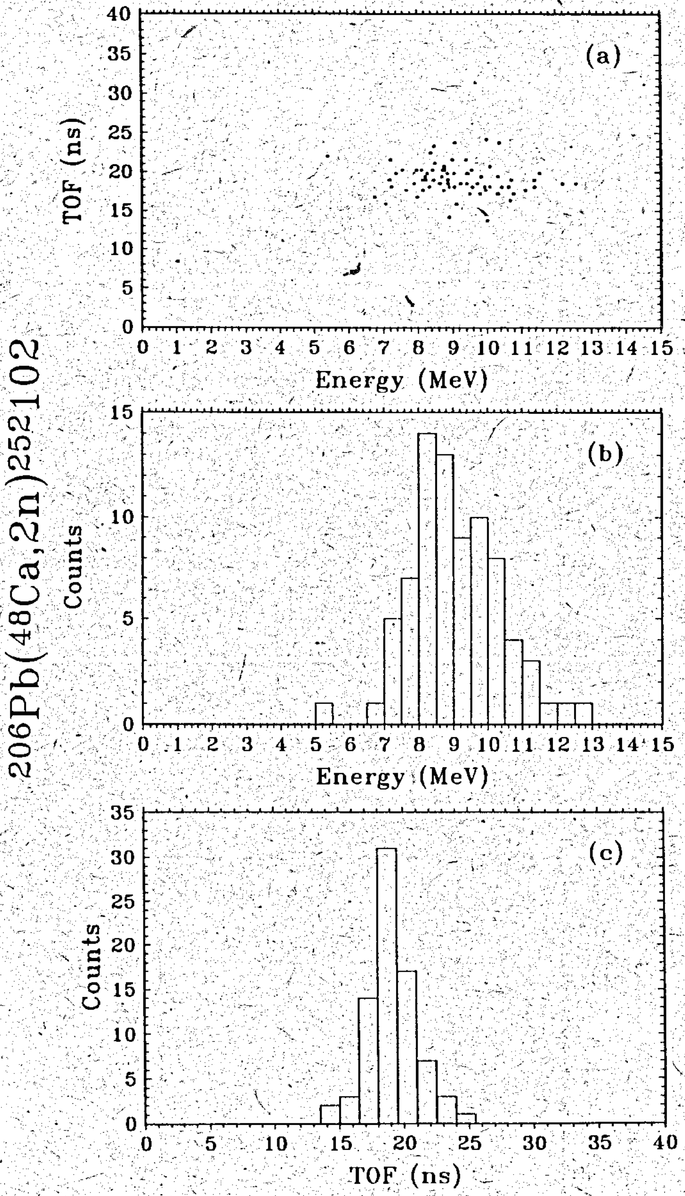


Fig.4

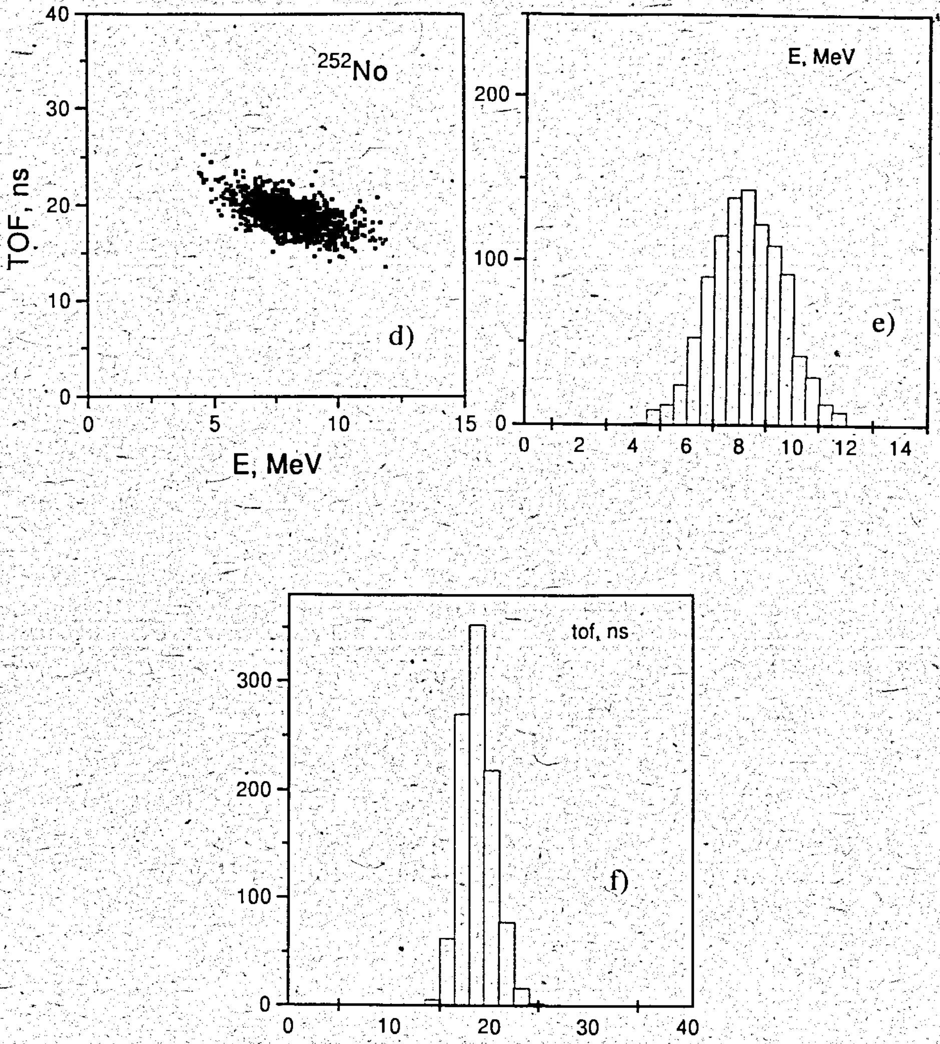


Fig.4 Measured (a-c) and simulated (d-f) spectra of ^{252}No nuclei produced by the

^{206}Pb + ^{48}Ca = ^{252}No + 2n reaction

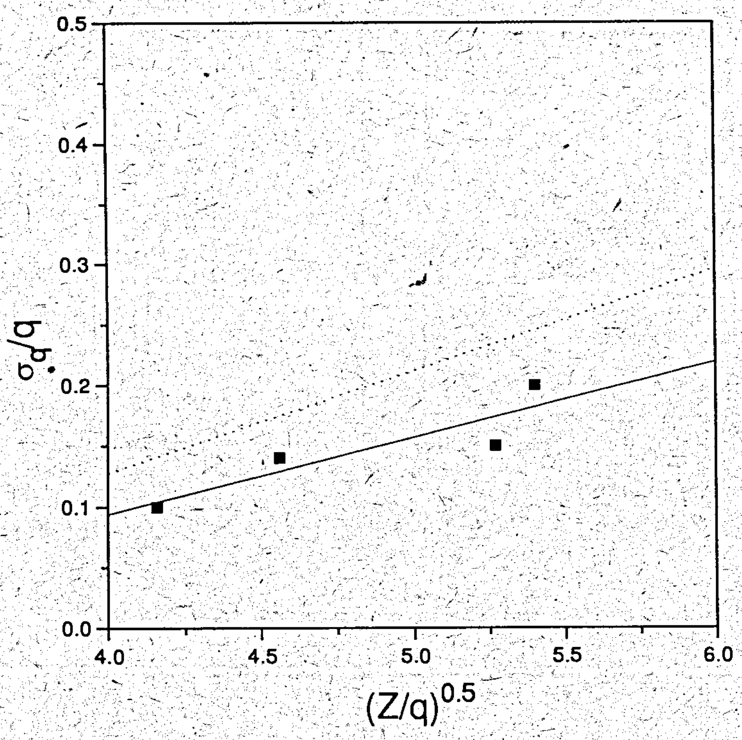


Fig.5 The dependence of the extracted paramter σ_q/q against $(Z/q)^{0.5}$ value, where q is the mean charge state and Z - atomic charge of the nuclide. Dotted line is an estimate of the actual value

the separator and implantation into the detector, one should treat it as the one reduced by the transmission of the facility. According to this, the parameter of σ_q can be considered as a lower level estimate for such a parameter not corrected by the separator transmittance. If, nevertheless, one is interested in the last value, a simplified estimate can be provided in the following way: the dipole magnet is regarded as having a high enough resolution in magnetic rigidity. In this case one should consider the formation of a measured charge dispersion to be attributed only to the path after the dipole magnet, hence corrected by a factor accounting only for the losses after the dipole. The dotted line in Fig.5 is a similar estimate.

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Цыганов Ю.С.
Ширина распределения равновесного заряда
для параметризации спектров тяжелых ядер отда

Рассчитаны энергетический и времяпролети
основе программы для ПК, использующей завис
в водороде, заполняющем рабочий объем газо
давлении около 1 тора. Для описания зарядовых
деление χ^2. Измеренные спектры, используемые
параметра ширины распределения равновесного
ных реакциях с тяжелыми ионами ^{197}Au + ^{22}Ne,

Работа выполнена в Лаборатории ядерных ре

Препринт Объединенного института ядерных и

Tsyganov Yu.S.
Value of Equilibrium Charge States Distribution
Width for Parametrization of Heavy Recoil Spectra

Energy and time-of-flight spectra of heavy
PC-based code with q^2 scaling of the stopping forc
filling the working volume of the gas filled separat
χ^2 distribution is used to describe the charge stat
which are used to extract the optimum paramete
distribution width were obtained in heavy io
^{nat}W + ^{34}S reactions.

The investigation has been performed at the
Reactions, JINR.

Preprint of the Joint Institute for Nuclear Re