On the Linearity of the Q3D Magnetic Spectrograph ◇

A. Heusler [a], G. Graw, R. Hertenberger, F. Riess, H.-F. Wirth, and P. von Brentano [b]
[a] Max-Planck-Institut für Kernphysik, Heidelberg, Germany
[b] Institut für Kernphysik, Universität zu Köln, Germany

Some of the excited states in the doubly magic nucleus ^{208}Pb below $E_x = 6$ MeV are still poorly known. Quite a few states predicted by the shell model are still completely unknown. The ^{208}Pb(p,p') experiment performed in 2003 [1] allows to identify all shell model states, in principle. Its evaluation, however, is not yet ready due to specific difficulties. An important one is the calibration of the excitation energies.

In 2004 we performed an experiment with the reaction ^{207}Pb(d,p) using the Q3D magnetic spectrograph. The interpretation of the (d,p) reaction is much simpler, since the g.s. of ^{207}Pb can be described as a pure neutron hole state $|p_{\frac{1}{2}}{}^{-\nu}>$ relative to the g.s. of ^{208}Pb. Only states in ^{208}Pb with an admixture of neutron particle-hole configurations $|LJ^{+\nu}p_{\frac{1}{2}}{}^{-\nu}>$ are expected to be excited by the (d,p) reaction. In contrast, the ^{208}Pb(p,p') reaction via isobaric analog resonances $|LJ^{+\pi}>$ in ^{209}Bi excites all neutron particle-hole configurations $|LJ^{+\nu}lj^{-\nu}>$ coherently. In addition, the slit scattering in the Q3D spectrograph is much lower for the (d,p) reaction since the primary particles and the scattered particles differ.

A previous measurement of the ^{207}Pb(d,p) reaction was done at the Q3D spectrograph with an older detector [2]. Data were taken with the new detector [3] at scattering angles $\Theta = 20°, 25°, 30°$ and with different openings of the entrance slit to the spectrograph. Thus broader lines from ^{12}C, ^{13}C, ^{14}N, and ^{16}O could be discerned by their kinematic shift throughout the entire spectrum taken for $E_x =$ 2.5 - 8.0 MeV. Due to the low background several lines from the isotopes ^{206}Pb and ^{208}Pb could be identified and the enrichment of ^{207}Pb determined to be 99.86± 0.01%.

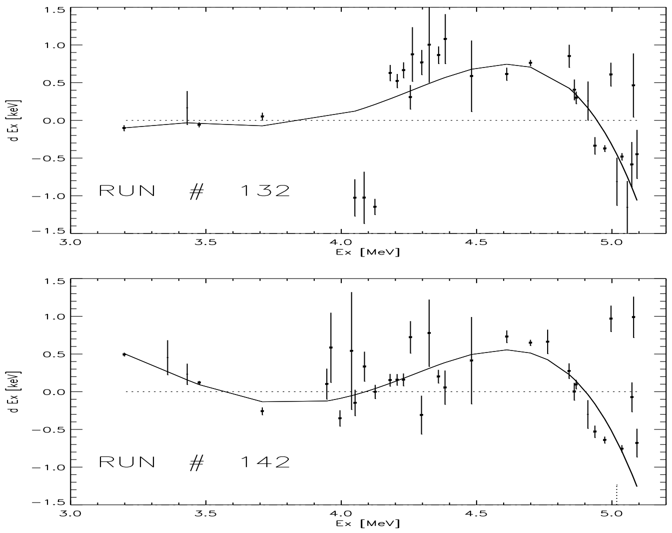

Fig. 1: Deviation $d\,E_x$ of excitation energies E_x determined by GASPAN from calibration values of Ref. [4].

Using the GASPAN code all spectra were fitted by Gaussian lines of varying width and varying tail onto a background reproducing the broad contamination lines. For the calibration of the energies we referred essentially to measurements with GeLi detectors [4]; only for $E_x > 6$ MeV values from the previous (d,p) measurement [1] were used, too.

Figure 1 shows the deviation of energies E_x determined with GASPAN by a fit with a quadratic parabola. A systematic non-linearity up to $3 \cdot 10^{-4}$, especially towards lower channels (higher E_x), is interpreted as due to slight deviations of the straight anode wire in the detector from the curved focal plane of the Q3D. A fit by a polynomial of 3. degree diminishes the deviations (drawn line).

Out of more than 200 states excited by the (d,p) reaction, for about 90 states both detected in our Q3D measurement and identified by [4] the average error is comparable to that from the GeLi measurements. In the region of E_x = 5.0 - 8.0 MeV about 80 new states are identified. Here we could trust the entire equipment to be stable and reproduceable: With unchanged setting of all parameters except the entrance slits to the spectrograph, different runs taken during some hours yield average energies $E_p^{c.m.}$ differing by less than $3 \cdot 10^{-6}$, see Fig. 2. Due to hysteresis effects of the magnets and the manual optimization of the entrance quadrupole magnet, the energies $E_p^{c.m.}$ differ by up to $2 \cdot 10^{-4}$ with different settings of the magnetic field, see Fig. 2 upper vs. lower part. Overlapping spectra allow to use the high linearity of the detector to extend the energy calibration up to $E_x = 8.0$ MeV.

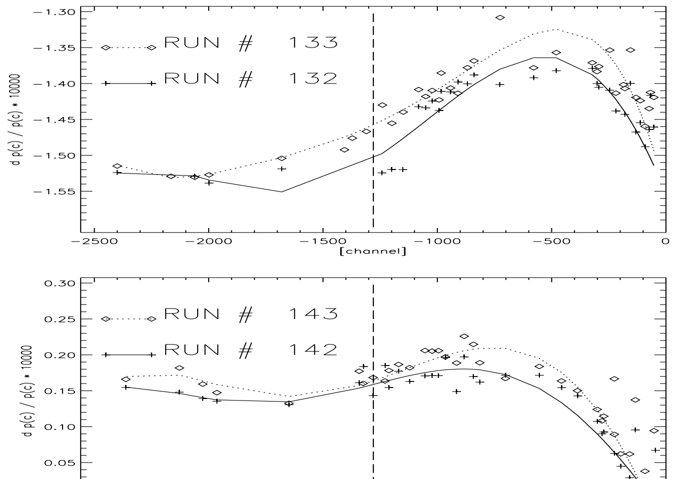

Fig. 2: Relative momentum $p(c)/\sqrt{E_p^{c.m.}} = 1 - f(B,c)/\sqrt{E_p^{c.m.}}$ with a function $f(B,c) = \sum_i a_i \cdot B \cdot c^i$, i = 0, 1, 2 depending on the the measured magnetic field B only. The common constants a_i are adjusted to obtain a smooth function.

References

[1] Annual report 2003, p. 21
[2] B. D. Valnion, Ph.D. thesis, LMU München, 1997
[3] H.-F. Wirth, Ph.D. thesis, TU München, 2001
[4] E. Rademacher, Ph.D. thesis, U Köln, 1996

◇ Supported by MLL and the DFG C4-Gr894/2-3.