Helicity dependence of pion photoproduction on the nucleon and the GDH sum rule

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The subject of the presentation concerns the study of the internal spin structure of the nucleon and the nucleon resonances in intermediate energy physics. In particular, the nucleon is investigated here through the experimental verification of the Gerasimov-Drell-Hearn (GDH) sum rule and the helicity dependent study of pion photoproduction. Results from the Gerasimov-Drell-Hearn experiment on the proton carried out by the GDH collaboration at the accelerator facility MAMI in Mainz in 1998, are presented. The results are the first of their kind as a similar measurement had not been done before.

The GDH sum rule [1, 2] on the nucleon reads:

$$\int_{\nu_0}^{\infty} \frac{\sigma_{1/2} - \sigma_{3/2}}{\nu} \mathrm{d}\nu = -\frac{2\pi^2\alpha}{m_{\mathrm{N}}^2} \kappa_{\mathrm{N}}^2.$$

It is a powerful relation between the excitation spectrum of the nucleon and its anomalous magnetic moment. The total photoabsorption helicity cross sections $\sigma_{1/2}$ ($\sigma_{3/2}$) correspond to the absorption of circularly polarised photons by longitudinally polarised target nucleons with an anti-parallel (parallel) relative polarisation orientation. The cross section difference $\sigma_{1/2} - \sigma_{3/2}$ is weighted with the inverse photon energy and integrated over energies ranging from pion production threshold up to infinity. The right hand side contains the anomalous magnetic moment of the nucleon κ_{N}, the nucleon mass m_{N} and the fine structure constant α. The GDH sum rule is based on basic physical principles: causality, flux conservation, gauge invariance and Lorentz invariance. It also relies on one non-verified no-subtraction hypothesis. Since the first publications in the sixties, the need for an experimental verification of the sum rule was stressed, in order to verify our understanding of the internal nucleon structure. Only recently, i.e. in the nineties, the high technical requirements to perform the experiment have become available.

Pion photo- and electro-production and pion-nucleon scattering are invaluable tools in the study of nucleon resonances. In spite of many efforts —both experimental and theoretical— the precision with which the resonance properties are known, is not fully satisfactory. This is evident from the large ranges given by the Particle Data Group. In particular this is so for resonances that occur in the second resonance region and above. Extra input which can e.g. come from doubly polarised pion photoproduction is therefore very welcome. These conclusions were the inspiration for the second goal of the GDH experiment in Mainz.

The GDH collaboration, in which institutes from Germany, Belgium, Italy, France, Russia, Japan, Sweden and the UK are involved, was set up with the experimental verification of the GDH sum rule as a main goal. The measurement is spread over two accelerator facilities: MAMI in Mainz and ELSA in Bonn, both in Germany. The combined measurement provides a large photon energy range. The experimental setup at the Mainz site, with the central DAPHNE detector is ideally suited to also study helicity dependence of the partial pion photoproduction channels. This is the second goal of the GDH experiment.

The presented data include the measured GDH sum rule in the photon energy range up to 800 MeV (maximum energy at MAMI) and the helicity cross sections for the pion photoproduction channels, open in this energy range: $\gamma\mathrm{p} \to \mathrm{n}\pi^+$, $\mathrm{p}\pi^0$, $\mathrm{p}\pi^+\pi^-$ and $\mathrm{n}\pi^+\pi^0$. These results allow the verification of the relative strength of the different nucleon resonances in these processes. Some of these results have recently been published [3, 4]. Further, the contribution of the partial reaction channels in the measured energy range to the total GDH sum rule is also obtained. This reveals information on their relative importance to the sum rule.

References

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