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MEASUREMENT OF THE PION POLARIZABILITY AT MAMI

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At the Mainz Microtron MAMI a measurement of the π polarizability through the Compton scattering of a photon from the virtual π of the proton in the reaction $\gamma(p, \gamma'\pi^+n)$ is being performed. This contribution outlines shortly the experimental set up for the separation of this three particle final state and the implications of the extraction of the π polarizability from the measured cross sections.

1 Motivation

The π polarizability can be well calculated within the framework of Chiral Perturbation Theory (ChPTh)[1] giving a value of $\alpha_{\pi^\pm} = (2.4 \pm 0.5) \cdot 10^{-4}\ fm^3$ for the electric and $\beta_{\pi^\pm} = (-2.1 \pm 0.5) \cdot 10^{-4}\ fm^3$ for the magnetic polarizabilities. The comparison of these results with experimental determinations represents, therefore, a significant test of ChPTh.

There exist quite a few attempts to determine these interesting quantities, but the overall picture is inconclusive as can be seen from the following table 1 summarizing the results for the $\pi^\pm$.

Reaction	$\alpha_{\pi^\pm}$ [10^{-4} fm^3]	Experiment
$\pi^- Z \to \pi^- Z\gamma$	$6.8 \pm 1.4 \pm 1.2$	Serpukov (1983) [2]
$\gamma p \to \gamma'\pi^+ n$	20 ± 12	Lebedev Phys. Inst. (1984) [3]
$\gamma\gamma \to \pi^+\pi^-$	$19.1 \pm 4.8 \pm 5.7$	PLUTO (1984) [4]
	17.2 ± 4.6	DM1 (1986) [5]
	26.3 ± 7.4	DM2 (1986) [6]
	2.2 ± 1.6	MARK II (1990) [7]

The determinations do not only have still insufficient statistical accuracy but also suffer from the necessity to use models in order to correct for the interaction of the pion with its hadronic spectator. In the case of the two photon production $\gamma\gamma \to \pi^+\pi^-$ the strong s-wave $\pi - \pi$ interaction has to be taken into account. For the Compton scattering of a photon from the virtual π of the proton in the reaction $\gamma p \to \gamma'\pi^+ n$ the results have to extrapolated

*supported by the DFG Sonderforschungsbereich SFB 443

to the unphysical π pole in order to get a value for the π on the mass shell.

2 Experimental set up for the reaction $\gamma p \to \gamma' \pi^+ n$

In order to have the maximal sensitivity of this reaction to $\alpha_{\pi^\pm}$ the kinematics has to be optimized. It turns out that the optimal energy for the photon would be around 1200 MeV, but also at the maximal energy attainable at MAMI B of 800 MeV a promising sensitivity can be reached [8]. The optimal configuration of the three detectors has been determined by extensive simulations with GEANT. The photon γ' is detected by the detector TAPS consisting of 528 BaF modules. The π^+ is measured by a specially designed sandwich of MWPC and scintillators with a sensitive area of $30 \cdot 30\ cm^2$, and the recoil neutron by a large $3 \cdot 3\ m^2$ time of flight wall consisting of 112 scintillators with a total thickness of 40 cm. The target is a liquid hydrogen target of 10 cm length.

A decisive optimization criterion was the suppression of the most important back ground reaction $\gamma p \to \pi^0 \pi^+ n$. Since this abundant reaction has also one γ, one π^+, and one neutron in its final state, an effective suppression is mandatory. Fortunately, the phase space of this reaction is completely different from the kinematics used here and, therefore, the contamination after the appropriate cuts is negligible [8]. The feasibility was proven in a pilot experiment which showed that the physics background is well understood and the instrumental background in accord with the requirements [9].

3 Extraction of the polarizability $\alpha_{\pi^\pm}$ from the measurement

The second difficulty of the experiment is the extraction of $\alpha_{\pi^\pm}$ from the measured cross sections. The traditional method (Chew-Low plot) consists in the "extrapolation to the pion pole". The diagram depicted in fig.1 shows the amplitude for the π pole.

The cross section is factorized in the kinematical part for the nucleon at the pole times the Compton cross section $\gamma p \to \gamma' \pi^+ n$ as shown in eqs. 1, 2.

$$\frac{d\sigma_{\gamma p \to n\pi^+\gamma}}{d\Omega_{\gamma\gamma}^{\mathrm{cm}}} = \frac{1}{\left(t - m_\pi^2\right)^2 \left(s - m_N^2\right)^2}\, F\left(t, s, s_1, t_1, s_2\right) \tag{1}$$

$$\frac{d\sigma_{\gamma\pi^+ \to \gamma\pi^+}}{d\Omega_{\gamma\gamma}^{\mathrm{cm}}} = -\frac{4\pi}{g_{\pi NN}^2} \frac{2\pi}{\left(s_1 - m_\pi^2\right)} \cdot \lim_{t \to m_\pi^2} F\left(t, s, s_1, t_1, s_2\right) \tag{2}$$

In the analysis the function $F\left(t, s, s_1, t_1, s_2\right)$ is calculated from the measured cross sections and than the extrapolation to $t = m_\pi^2$ done. For the extrapola-

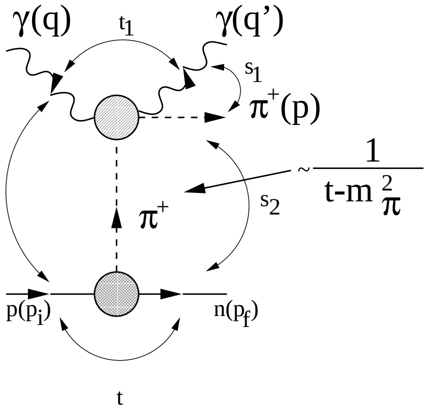

Figure 1. π-pole diagram

tion an empirical analytical form is used:

$$F(t, s, s_1, t_1, s_2) = e^{A(t-\mu^2)}(A_0 + A_1(t-\mu^2)) \tag{3}$$

where A, A_0, and A_1 are fit parameters. The only dependence of $F(t, s, s_1, t_1, s_2)$ on s is contained in $\left(s - m_N^2\right)^2$ and, therefore,

$$A_0 = lim_{t \to m_{\pi^2}} \; F(t) \tag{4}$$

is the desired limes of $F(t)$ where the values for s_1, t_1, and s_2 determined by the experimental setting have been omitted.

In order to check this traditional method extensive model calculations have been performed by two groups [10,11] and [12,13] independently (see also [8] and references therein). The first class of models are effective pion field models with pseudo vector (PV) and pseudo scalar (PS) coupling [10,12]. One example[12] with PV coupling is depicted in fig. 2. Though the general trend seems to be alright a closer analysis shows that there is a considerable uncertainty in the extrapolation. By restricting the used interval to $-6\mu^2 \leq t \leq -2\mu^2$ one gets reasonable values for α, however, with a considerable systematic error. The extrapolation procedure can be still improved by using different extrapolation functions and accepting an empirical dependence on the invariant mass $s = m_{proton}^2 + \omega^2$. The calculations using the PS coupling deviate considerably from those with PV coupling, though PV coupling seems to be favored by other results on π^+ production [14].

An alternative model class are the calculations in the frame work of heavy baryon ChPTh (HBChPTh) [12,13]. They agree better with the PV than with

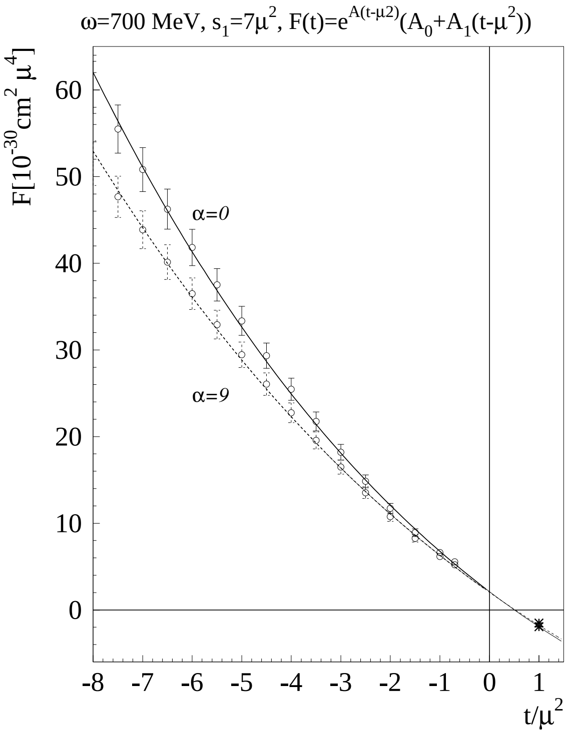

Figure 2. The function $F(t)$ for $\alpha = 0 \cdot 10^{-4} m_\pi^2$ and $9 \cdot 10^{-4} m_\pi^2$. The open points represent the calculation and the curves are fits of eq. 3. The error bars show the expected accuracy of the experiment. The stars indicate the values for $F(t)$ at the unphysical point $t = m_\pi^2$.

the PS calculations, but should be considered still incomplete, since they are of order $\mathcal{O}(p^3)$ only. This means that still some work is needed for the optimization of the extrapolation function, once one has found from the measurements which of the calculations are describing the data best. Since the experiment covers a rather broad kinematical range in $t, s1$ and ω the extrapolation function finally used, will be well constrained.

A different method is the direct fit of the polarization α in the effective field theoretical calculations to the data. α is a parameter in these calculations, as indicated in fig. 2, and there is no need to go through the extrapolation, since one can apply the model directly. The model chosen for the extraction of α will again be thoroughly tested by the request that it describes the data in the full kinematical range. Any deviations can be translated reliably in a systematic error.

4 Conclusions

The experiment taking data at the Mainz Microtron MAMI promises to produce a new and hopefully better constrained value for the polarizabilities $\alpha_{\pi^\pm}$ and $\beta_{\pi^\pm}$. As all quantities of particles which are bound to or close to a hadronic spectator, they can only be determined via some reaction model. Other examples of this difficulty are the magnetic and electric form factors of the neutron and the meson form factors. The test of the used reaction models is the key for extracting finally credible values for these quantities which are so significant to test hadron models. It is only through these hadron models that one can make connection to QCD at low energies, its untested domain.

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