

# Pion Polarizability Review

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The electric  $\alpha_\pi$  and magnetic  $\beta_\pi$  charged pion Compton polarizabilities are directly linked to the phenomenon of spontaneously broken chiral symmetry within QCD and to the chiral effective Lagrangian. The combination  $\alpha_\pi - \beta_\pi$  was most recently measured by: (1) CERN COMPASS (2) SLAC Mark-II, (3) Mainz MAMI. Only the COMPASS measurement has acceptably small uncertainties. Its value  $\alpha_\pi - \beta_\pi = (4.0 \pm 1.8) \times 10^{-4} \text{ fm}^3$  agrees well with the two-loop chiral perturbation theory (ChPT) prediction  $\alpha_\pi - \beta_\pi = (5.7 \pm 1.0) \times 10^{-4} \text{ fm}^3$ , strengthening the identification of the pion with the Goldstone boson of QCD.

**KEYWORDS:** pion polarizability, Primakoff scattering, Compton scattering, radiative pion photoproduction, two-photon production of pion pairs, chiral perturbation theory, dispersion relations

## 1. Introduction

The pion is believed to belong to the pseudoscalar meson nonet and to be one of the Goldstone bosons associated with spontaneously broken chiral symmetry. The electric  $\alpha_\pi$  and magnetic  $\beta_\pi$  charged pion polarizabilities are directly linked to chiral symmetry, the chiral QCD Lagrangian, and to the dynamics of the pion-photon interaction. Pion polarizabilities affect the shape of the  $\gamma\pi \rightarrow \gamma\pi$  Compton scattering angular distribution at back scattering angles, as well as the  $\gamma\gamma \rightarrow \pi\pi$  absolute cross section. A stringent test of chiral perturbation theory (ChPT) is possible by comparing the experimental polarizabilities with the ChPT two-loop predictions  $\alpha_\pi - \beta_\pi = 5.7 \pm 1.0$  and  $\alpha_\pi + \beta_\pi = 0.16$  [3]. All polarizabilities in this review are given in units  $10^{-4} \text{ fm}^3$ . The combination  $\alpha_\pi - \beta_\pi$  may be measured by the four methods described in Fig. 1. Methods 1,2,3 experiments have been most recently studied at CERN COMPASS [4], SLAC Mark-II [5], and Mainz MAMI [6] respectively; while the method 4 experiment is planned at JLab [7].

## 2. Mark II $\gamma\gamma \rightarrow \pi\pi$ two-photon fusion production of pion pairs

Pion polarizabilities were determined by comparing MARK-II total cross section data ( $\gamma\gamma \rightarrow \pi^+\pi^-$ ) for invariant pion-pair masses  $M_{\pi\pi} \leq 0.5 \text{ GeV}$  with ChPT calculations. A complementary  $\gamma\gamma \rightarrow \pi^+\pi^-$  polarizability measurement is also planned at JLab [7]. The MARK-II data was obtained via the reaction  $e^+e^- \rightarrow e^+e^-\pi^+\pi^-$  at a CM energy of 29