Measurement of pion Compton effect and charged pion polarizability.

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Outline

• Introduction
• Proposal for measurement
• Serpukhov experiment and results
• Additional measurements
• Measurement in COMPASS at CERN
• Conclusion
Introduction

• Sometime in 1978 we have started the work on the proposal to measure **pion Compton effect and polarizability** using pion radiative scattering in the Coulomb field of nuclei:

• Lack of information due to the absence of pion or photon targets

• Primakoff-type reactions, where the nucleus at a small momentum transfers provide the field of virtual photons as a target
Introduction

G. Mitselmakher

V. Pervushin

A. Galperin (in the middle)
Proposal

• Study of kinematics, in particular, why the low-energy polarizability parameter is relevant also for high energy pion scattering (Serpukhov case of 40 GeV was assumed)

• Estimate contribution from strong interaction scattering

• Calculate cross section for point-like pion scattering and contribution of polarizability to the (total) cross section (~6%)

• Started to discuss experimental requirements, first of all, resolution on momentum transfer to distinguish Coulomb interaction

• Discussion with L.G.Landsberg -> possibility to perform relative measurement
Proposal

• Established a possibility of relative measurements – significant variation of the polarizability contribution over the scattered photon energy

• Contacts with SIGMA experiment (S.P.Denisov, Yu.M.Antipov et al.) at Serpukhov and worked together on a practical realization of experiment
Experiment at Serpukhov

FIG. 1. The experimental arrangement. $S_1$–$S_4$, $A_1$–Beam scintillation counters; $\bar{C}_1$, $\bar{C}_2$, $D$–gas-filled threshold and differential counters; $H_1$, $H_2$–beam scintillation hodoscopes; $BPC_1$, $BPC_2$–beam proportional counters; $T$–nuclear target; $R$, $G$, $F$–sandwich counters; $CPM_1$, $CPM_2$–proportional counters; $M$–spectrometric magnetic; $CH$–wire spark chambers; $H_4$, $S_\pi$–scintillation hodoscopes; $A_\gamma$, $B$–scintillation counters; $\bar{C}_{50}$, $\bar{C}_{80}$–total-absorption Čerenkov counters.
Experiment at Serpukhov

Observation of the Compton effect at the $\pi^-$ meson

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(Submitted 2 March 1982)


Elastic scattering of $\pi^-$ mesons by photons (the Compton effect at the $\pi^-$ meson) has been detected experimentally for the first time. The polarizability of the charged pion is estimated to be $\alpha_\pi = (5 \pm 4) \times 10^{-43}$ cm$^4$.

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Information on a fundamental structural constant—the polarizability of the charged pion—may be obtained by studying the elastic scattering of $\pi$ mesons by photons. There has been no previous study of the polarizability of the pion, although it has been calculated in several places, on the basis of the quark, dispersion, chiral, and other theories (see the review by Petrun'kin3).

- ~ 7'000 events observed
- ~ 12 MeV resolution in momentum transfer achieved
  (multiple scattering and experimental resolutions)
Experiment at Serpukhov

MEASUREMENT OF $\pi^-$-MESON POLARIZABILITY IN PION COMPTON EFFECT


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and

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JINR, Dubna, USSR

Received 11 November 1982

About $7 \times 10^3$ events of Compton effect on pion in the reaction $\pi^- + A \rightarrow \pi^- \gamma$ at 40 GeV/c were detected and for the first time the charged pion polarizability was obtained $\alpha_p = (6.8 \pm 1.4) \times 10^{-8}$ cm$^3$. 
Experimental Estimation of the Sum of Pion Electrical and Magnetic Polarizabilities

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Abstract: The pion radiative scattering \(\pi^- + N \rightarrow \pi^- + N\) at 40 GeV was investigated. Coulomb scattering, i.e. pion Compton-effect, dominates for small four-momenta transfers. In this reaction the analysis of Compton events pion polarizability was determined under the theoretical assumption that \(\varepsilon_{\pi} = \varepsilon_{\pi}^0 = 0\). More complete analysis of our data is shown in order to test this assumption. The result for \(\varepsilon_{\pi} = \varepsilon_{\pi}^0 = 0\) is in agreement with theoretical predictions.

At 40 GeV was investigated in [3]. Coulomb scattering is the pion Compton-effect, i.e. pion Compton-effect dominates for small four-momentum transfers in this reaction. Earlier, from the analysis of Compton events pion polarizability was determined under the theoretical assumption that \(\varepsilon_{\pi} = \varepsilon_{\pi}^0 = 0\) [5]. More complete analysis of our data is shown in order to test this assumption. The result for \(\varepsilon_{\pi} = \varepsilon_{\pi}^0 = 0\) is in agreement with theoretical predictions.

\[
\beta_{\pi} = -7.1\pm2.8_{\text{syst.}} \pm1.8_{\text{syst.}} / 10^{-38} \text{ cm}^3,
\]

\[
\alpha_{\pi} + \beta_{\pi} = 1.43\pm3.1_{\text{syst.}} \pm2.5_{\text{syst.}} / 10^{-38} \text{ cm}^3.
\]
SIGMA-AYAKS Collaboration

• Detector techniques
  New setup with modern:
  • Tracking and Calorimeters
  • Electronics and Trigger
  • Software and Analyses Tools

• Physics-wise
  Many interesting results including:
  • Elastic scattering
  • Cumulative protons production
  • ...
  • Search for dibaryon
  • ...
Measurement in COMPASS at CERN

Pion and Muon scattering comparison
Measurement in COMPASS at CERN
Polarizability «PR»-value

COMPASS has now achieved a modern Primakoff experiment, using a 190 GeV pion beam from the Super Proton Synchrotron at CERN directed at a nickel target. Importantly, COMPASS was also able to use muons, which are point-like and hence non-deformable, to calibrate the experiment. The Compton $\pi^-\gamma \rightarrow \pi^-\gamma$ scattering is extracted from the reaction $\pi^-\text{Ni} \rightarrow \pi^-\gamma\text{Ni}$ by selecting events from the Coulomb peak at small momentum transfer. From the analysis of a sample of 63,000 events, the collaboration obtained a value of the pion electric polarizability of $2.0\pm0.6$ (stat) $\pm0.7$ (syst) $\times 10^{-4}$ fm$^3$—that is, about $2 \times 10^{-4}$ of the pion's volume. This value is in good agreement with theoretical calculations in low-energy QCD, therefore solving a longstanding discrepancy between these calculations and previous experimental efforts to determine the polarizability.

"This result is admirably complementary to the studies of fundamental interactions performed at the Large Hadron Collider and a testimony to the diversity and strength of CERN's research programme," said Rolf Heuer, Director General of CERN.
Conclusion

• Proposal and the first measurement of charged pion Compton effect and polarizability (performed almost 40 years ago) gave rise to the continuing studies of this very interesting and important physics phenomenon

• But most importantly, this work planted the seed for our primary team, which afterwards very successfully developed in different directions

• Thanks for that to Guenakh Mitselmakher

• and thank you for attention