PR12-13-008: *Measuring the Charged Pion Polarizability in the* $\gamma\gamma \to \pi^+\pi^-$ *Reaction*

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Pion polarizabilities reflect the response of the pion at rest to changing electric and magnetic fields. For charged pions these determine the corrections to the one pion exchange Born amplitude that dominates Compton scattering on a pion. Current phenomenological attempts to determine the pion polarizabilities using data on the crossed-channel process $\gamma\gamma \to \pi^+\pi^-$ are hampered by the fact that only one experiment (Mark II at PEP) has measured this cross-section close enough to threshold to impact on the determination of the polarizabilities. While data of enormous statistics (but with sizeable systematic uncertainties) have been taken by Belle above $W(\pi\pi) = \sqrt{s}$ of 0.8 GeV, the five low $\pi\pi$ mass datapoints from Mark II from the 1980's have 25% uncertainties, as seen in Fig. 2 of the proposal. The need is take data in this same mass region but with 21st century technology.

All two photon results on the production of charged pion pairs with e^+e^- colliders have to cope with two crucial limitations:

(i) only limited angular coverage of the pion pairs is possible because the $\pi^\pm$ cannot be identified close to the on-going scattered leptons. This typically restricts determination of the cross-section to the domain $|\cos\theta^*| \leq 0.6$,

(ii) the production rate for muon pairs is an order of magnitude greater than the pion signal that is to be extracted.

While difficulty (i) is less restrictive for two pion production on a nucleon, muon pairs still dominate the pion pairs by orders of magnitude To this must be added a new "background": the coherent production of ρ^0's. The proposal addresses these issues. However, they still present their planned results for the $\gamma\gamma \to \pi^+\pi^-$ cross-section (Fig. 32) restricted to $|\cos\theta^*| \leq 0.6$, when a larger range would produce more discrimination.

Indeed, extraction of the $\gamma\gamma \to \pi^+\pi^-$ cross-section with the precision shown in Fig. 32 of the proposal are essential if the polarizabilities $\alpha \pm \beta$ are to be determined with the certitude claimed of $\pm 0.6.10^{-4}$ fm^2. The polarizabilities depend on the difference from the Born amplitude. While

the Born amplitude contributes more than 90% of the charged pion cross-section below 360 MeV, there is no Born amplitude in the neutral pion case and so the effect of uncertainties in the polarizabilities easier to understand. Dispersive studies, in which the charged and neutral pion cases are intimately intertwined, show that the low energy $\pi^+\pi^-$ cross-section is changed by a few percent by movement of the chiral zero in the $\gamma\gamma \to \pi^0\pi^0$ S-wave amplitude from $s = (0.5 \text{ to } 2)m_\pi^2$ (ChPT predicts $\sim 1.1m_\pi^2$), while the polarizabilities change by factors of 4 by such a small shift. Consequently, precision in the two photon production of charged pions is the challenge, if this experiment is to have the impact on the polarizabilities the proponents claim.

In discussing lepton pair backgrounds, two queries arise about Fig. 16:

(a) the caption states that the angular distributions for e^+e^-, $\mu^+\mu^-$ and $\pi^+\pi^-$ are the curves in red, green and blue, whereas the figure itself labels these as blue, green and red.

(b) on page 17 above Fig. 16, the text states $\pi^+\pi^-$ angular distribution is "assumed isotropic", and in Fig. 16 this is indeed shown as flat. This is just not possible. Even at the lowest energies the charged pion angular distributions should be strongly peaked forward and backwards, because of the pion poles in the Compton process at $\cos\theta^* = \pm\sqrt{s/(s-4m_\pi^2)}$, just outside the s-channel physical region. To repeat polarizabilities are a measure of the difference from the forward-backward peaked Born cross-section, and so the shape of the angular distribution is critical to their proposed measurement. This mistake needs to be corrected urgently and the implications for separating the lepton pair backgrounds deduced.