Understanding neutral Pion Photoproduction using Chiral Perturbation Theory.

Lloyd Cawthorne
Judith McGovern
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Motivated by new data from the A2 and CB-TAPS collaborations at MAMI.
First ChPT theories

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Theory only agrees with data for \(~25\) MeV.

Chiral Perturbation Theory
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Mass of the proton $\sim 100 \times$ mass of its constituent quarks.
Chiral Perturbation Theory

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The pions are the Goldstone bosons of this broken symmetry.
Chiral Perturbation Theory

Take required symmetries from QCD and write them in their simplest form.
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Effective field theory. Work below a large energy, $\Lambda_{\chi} \sim 1$ GeV.
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Accuracy determined by number of derivatives, $(q/\Lambda_x)^n$. 
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Effective field theory. Work below a large energy, $\Lambda_\chi \sim 1$ GeV.

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Work with pions and nucleons, not quarks or gluons.
Each term in the Lagrangian has a constant.
Low Energy Constants

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$$\mathcal{L}_{\pi N}^{(1)} = \bar{\Psi} (i\gamma^\mu D_\mu - \tilde{m}) \Psi + \ldots$$
Low Energy Constants

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\[ \mathcal{L}^{(1)}_{\pi N} = \bar{\Psi} \left( i \gamma^\mu D_\mu - \hat{m} \right) \Psi + \frac{1}{2} g_A \bar{\Psi} \gamma_\mu \gamma_5 \omega_\mu \Psi \]
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Fit these parameters to data.
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Fit these parameters to data.

For 4\textsuperscript{th} order Neutral Pion Photoproduction we have 5 LECs.
Feynman Diagrams

Tree Level:
Feynman Diagrams

Tree Level:

Class 1:
Feynman Diagrams

Tree Level:

Class 1:
Feynman Diagrams

Tree Level:

Class 1:

Class 2:
Feynman Diagrams

Tree Level:

Class 1:

Class 2:

Class 3:

The Fit So Far

![Graphs showing data and fits with labels and energy values: $\theta = 93^\circ$, $E_\gamma = 168$ MeV, $E_\gamma = 187$ MeV, $E_\gamma = 206$ MeV.](image)

- Red circle: Rel. $\chi^2$PT $O(p^3)$

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The Fit So Far

- HBχPT $O(p^4)$
- Rel. $χPT \ O(p^3)$

$\theta = 93^\circ$

$E_\gamma = 168$ MeV

$E_\gamma = 187$ MeV

$E_\gamma = 206$ MeV
The Fit So Far
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The Delta (1232) Resonance
The Delta-Nucleon mass difference is small, $M_{\Delta} - M_N \approx 293$ MeV.

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Including the Delta
Including the Delta
Including the Delta
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\[
\frac{d\sigma}{d\Omega} \quad (\mu b/sr) \\
E_\gamma \quad (MeV)
\]

\[
\theta = 93^\circ \quad (\text{degree})
\]

\[
\theta_{cm} \quad (\text{degree})
\]

\[
E_\gamma = 168, 187, 206 \quad (MeV)
\]

\[
\chi^2_{\text{red.}} \\
E_\gamma \quad (MeV)
\]
Summary

ChPT is a simpler systematic approach to QCD.
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ChPT can accurately describe experimental data.
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ChPT can include low-lying hadronic resonances.
We would like to thank David Hornidge for providing us with the data and the STFC for funding the research.