Inelastic Compton Scattering on The Deuteron

Neutron Polarizability Extraction

Hadron 2015

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Nucleon Scalar Polarizabilities

- Measure stiffness of charge and current distribution in the nucleons
- Nucleon mass splitting \( \sim \beta_{p-n} = \beta_p - \beta_n \)

  \[ \text{Walker-Loud et al PhysRevLett.108.232301} \]
  \[ \text{Gasser et al arXiv:1506.6747} \]

  ➤ Mirror Nuclei

  ➤ Big Bang Nucleosynthesis (BBN)

ChiPT Effective Field Theory

- Effective Lagrangian of Nucleons and Mesons which satisfy unitarity, analyticity, Lorentz, CPT, chiral symmetries.

  ➤ Counting rule and Expansion Parameters:

  \[ Q(= q, m_\pi, m_\Delta - m) \]

  \[ \text{Well-defined uncertainties } \sim Q^{n+1} \]

  \[ \text{Model independent} \]
Latest values from \( p(\gamma, \gamma)p \) and \( d(\gamma, \gamma)d \)

\( \omega \sim m_\pi \) up to \( N^4\text{LO} \)

- Pion and \( \Delta(1232) \) degrees of freedom

\[\begin{align*}
\alpha_p &= 10.7 \pm 0.4\text{(stat)} \pm 0.2\text{(Baldin)} \pm 0.3\text{(theory)} \\
\beta_p &= 3.1 \pm 0.4\text{(stat)} \pm 0.2\text{(Baldin)} \pm 0.3\text{(theory)}
\end{align*}\]

\[\begin{align*}
\alpha_n &= 11.1 \pm 1.8\text{(stat)} \pm 0.4\text{(Baldin)} \pm 0.8\text{(theory)} \\
\beta_n &= 3.1 \pm 1.8\text{(stat)} \pm 0.4\text{(Baldin)} \pm 0.8\text{(theory)}
\end{align*}\]

- Treat all Compton data within the same framework
- Corroborate and improve accuracy of \( \alpha_n \) and \( \beta_n \) independently

\( d(\gamma, \gamma n)p \) in \( \chi\text{EFT} \)

\[ d(\gamma, \gamma n)p \sim n(\gamma, \gamma)n \]

**Non \( \chi \)EFT Approach**

**Why \( \chi \)EFT**

- Model independent
- Well controlled uncertainties
- Treatment of the channel in \( \chi \)EFT
  - All Compton scattering data in the same framework

**NQFP** - neutron quasi-free peak kinematic region
- \( E_p \leq 1.1 \) MeV
- Polarizability sensitive \( E_\gamma \) : 200-400 MeV

**Re-Analysis in \( \chi \)EFT Approach**

- \( \alpha_n = 12.5 \pm 1.8 \text{(stat.)}^{1.1}_{-0.6} \text{(syst.)} \pm 1.1 \text{(mod.)} \)
- \( \beta_n = 2.7 \mp 1.8 \text{(stat.)}^{0.6}_{-1.1} \text{(syst.)} \mp 1.1 \text{(mod.)} \)
Impulse Approximation

\[ \text{Born } + \]

\[ \chi_{\text{EFT}} d(\gamma, \gamma n)p : \chi_{\text{EFT}} \]

\[ \text{IA } \]

\[ \text{FSI } & \text{ MEC } \]

\[ \text{Results } \]

\[ e^2 \delta^2 \]

\[ e^2 \delta^3 \]

\[ e^2 \delta^4 \]

\[ N^3 \text{LP} \]
Final State Interaction

\[ V_{ct} = C_s + \sigma_1 \cdot \sigma_2 C_t \]

- C_s and C_t fixed
- n p bound system: deuteron
  - \( E_b = 2.224 \text{ MeV} \)
- n p scattering
  - scat. length = -23.7 fm

Meson Exchange Current
Currently established values
\[ \alpha_n = 11.55 \quad \beta_n = 3.65 \]
\[ \chi^2 / d.o.f = 1.2 \]

No significant deuteron wave function dependence.
Currently established values

\[ \alpha_p = 10.65 \quad \beta_p = 3.15 \]

\[ \chi^2 / \text{d.o.f} = 3.4 \]

Scaling Factor : 0.93
Future Goals:

- Improve the description of proton quasi-free region
  - Establish consistent description of data from elastic Compton on the proton and quasi-free proton from inelastic Compton on the deuteron
- Extract $\alpha_n$ and $\beta_n$
- Extract $\gamma^{(n)}_{\pi}$
- Implementation which separates inelastic Compton events from elastic ones for Hiys experiments
Conclusion

- Neutron polarizability from $\gamma n \rightarrow \gamma n$

- $\chi$EFT is - model independent
  - well defined uncertainties

- Analyze all Compton data using the same framework – $\chi$EFT

- data-theory consistency shows discrepancy

- Stay tuned for more!

Thank You