The unexpected role of D waves in low-energy neutral pion photoproduction

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Introduction

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- S-wave soft due to the Nambu-Goldstone nature of the pion

The aim is to extract accurately the S-wave E_{0+} and D waves play an essential role

Latest experimental data from MAMI A2 Collaboration

Schmidt et al. PRL87, 232502 (2001)

Differential cross sections from threshold up to 167 MeV and photon beam asymmetry at one single energy (159.5 MeV)

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Is this approximation sensible?

Standard arguments to restrict ourselves to S and P waves

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- The analysis up to $\mathcal{P}_2(\theta)$ is enough

$$\sigma_T(\theta) = \frac{q_\pi}{k_\gamma}\left[T_0 + T_1\mathcal{P}_1(\theta) + T_2\mathcal{P}_2(\theta) + T_3\mathcal{P}_3(\theta) + T_4\mathcal{P}_4(\theta)\right]$$

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- P-wave dominance
  - Good argument for T_0 and T_2 which are dominated by the $|M_{1+}|^2$ and $|M_{1-}|^2$ contributions
  - But not for T_1 which is pure interference

$\rightarrow$ M_{1+} can enhance D waves through interference

T_1 up to D waves

$$T_1 = \underbrace{2\,\mathrm{Re}\left[\left(3E_{1+}^* + M_{1+}^* - M_{1-}^*\right) E_{0+}\right]}_{S\times P}$$

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$$T_1 = \underbrace{2\,\mathrm{Re}\left[\left(3E_{1+}^* + M_{1+}^* - M_{1-}^*\right) E_{0+}\right]}_{S\times P} + \underbrace{\delta T_1}_{P\times D},$$

$$\delta T_1 = 2\,\mathrm{Re}\Big[\,\frac{27}{5} M_{1+}^* M_{2+} + \left(M_{1+}^* - M_{1-}^*\right) E_{2-}$$
$$+ \left(\frac{3}{5} M_{1+}^* + 3 M_{1-}^*\right) M_{2-}$$
$$+ E_{1+}^* \left(\frac{72}{5} E_{2+} - \frac{3}{5} E_{2-} + \frac{9}{5} M_{2+} - \frac{9}{5} M_{2-}\right)\Big]$$

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Pedagogical approximation: M_{1+} dominance

$$T_1 \approx 2\,\text{Re}\left[\,M_{1+}^* \left(E_{0+} + \frac{27}{5} M_{2+} + E_{2-} + \frac{3}{5} M_{2-}\right)\right]$$

Fitting data with S, P and D waves

- S and P waves: HBCHPT

  Bernard et al., Z. Phys. C70, 483 (1996); EPJA11, 209 (2001)

- D waves
  - Standard Born terms

    Equivalent to Born contribution to HBCHPT

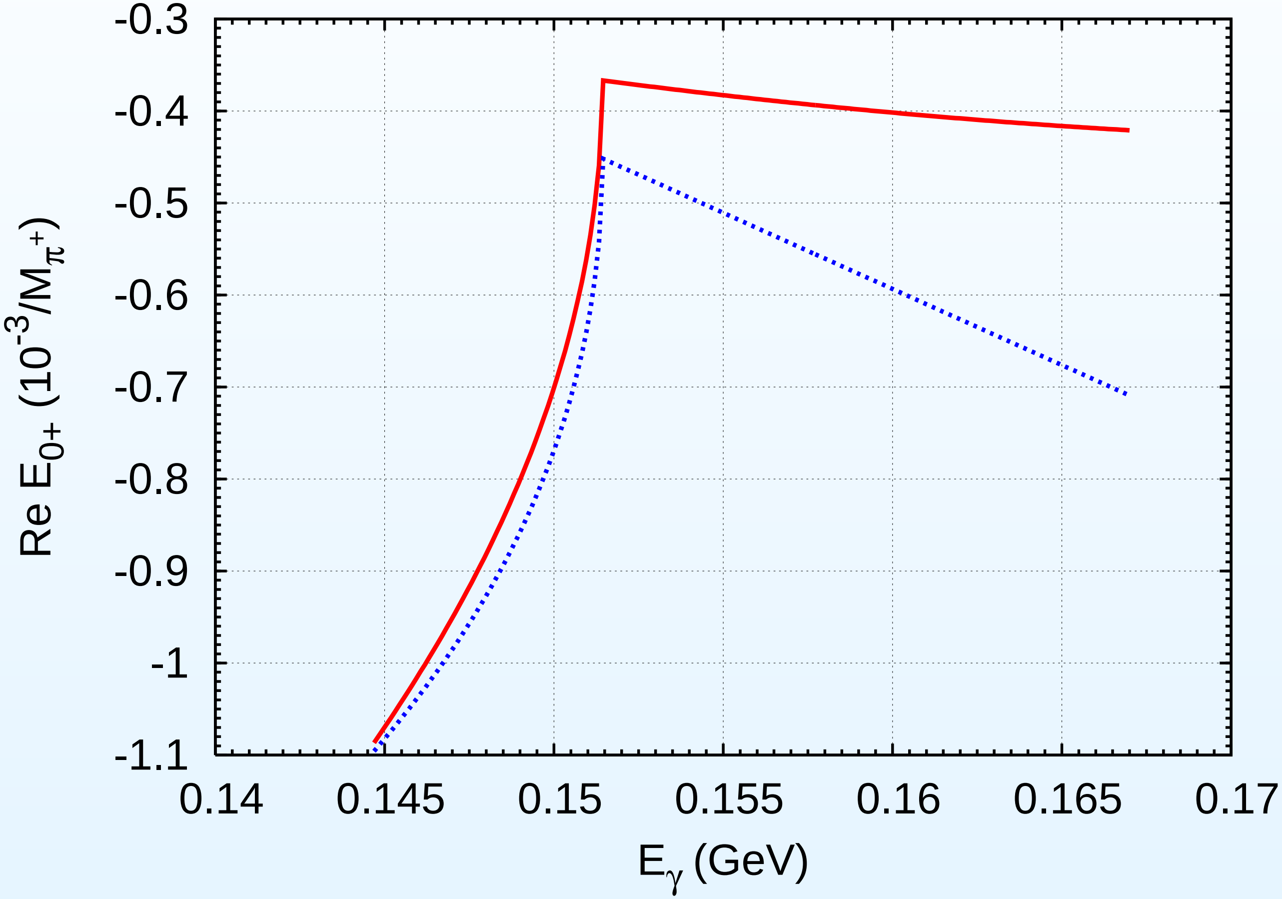
  - Vector mesons contribution

    Coupling constants from: Mergell et al., NPA596, 367 (1996)

We fit for SP and SPD using a hybrid optimization routine:
Genetic algorithms+gradient-based

Fernández-Ramírez et al., PRC77, 065212 (2008)

Extracted E_{0+} multipole



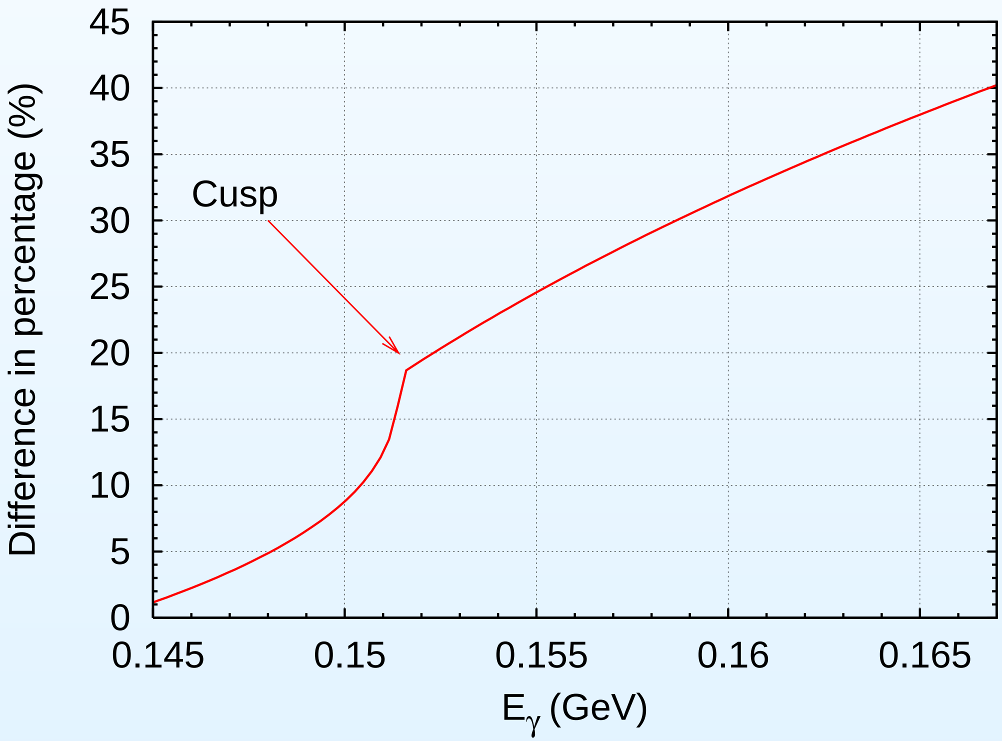
SPD: solid; SP: dotted

Fernández-Ramírez, Bernstein, Donnelly, `arXiv:0902.3412 [nucl-th]`

SP vs SPD

- P waves are stable
- E_{0+} extraction compromised
- LECs compromised

	SP	SPD
χ^2/dof	1.23	1.25
70%	1.27	1.28
90%	1.29	1.30
E_{0+}^{th}	-1.099	-1.090
E_{0+}^{cusp}	-0.478	-0.393



S-wave LECs: Correlation plot

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$$E_{0+}^{ct} = e a_1 \omega M_\pi^2 + e a_2 \omega^3$$

$$a_+ = a_1 + a_2$$
$$a_- = a_1 - a_2$$

a_+ sets E_{0+} at threshold

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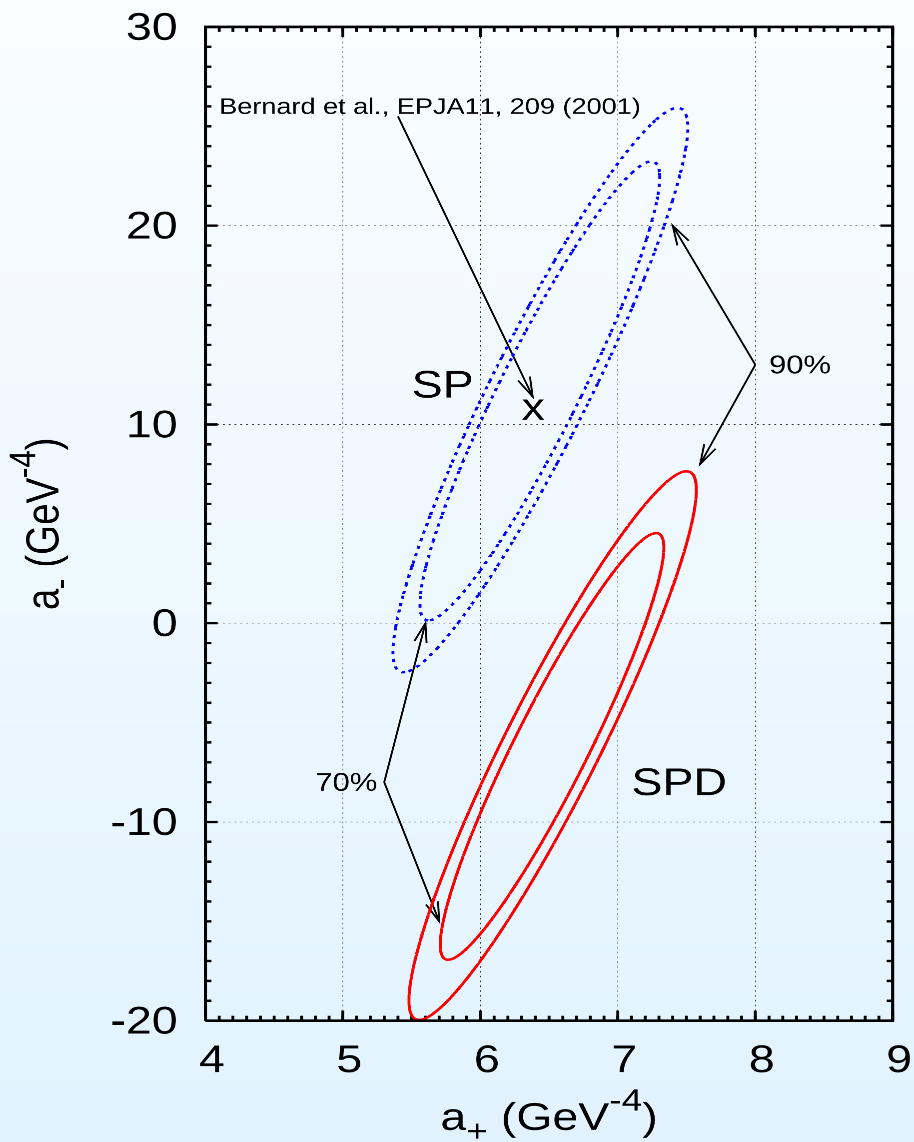

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- ☞ Are D waves measurable? Yes! (work in progress . . .).
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Thanks!