Relativistic Chiral representation of the πN scattering amplitude

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Part I

Introduction

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- There have been many attempts to study this process using ChPT, but every one has had their own problems:
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    - Describes well the physical region. **[Fettes, Meißner and Steininger, NPA 640 (1998) 199]**
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- This scheme removes explicitly the power counting breaking terms (PCBT) appearing in the loop integrals in dimensional regularization.
- These PCBT terms are absorbed in the LECs (IR result).
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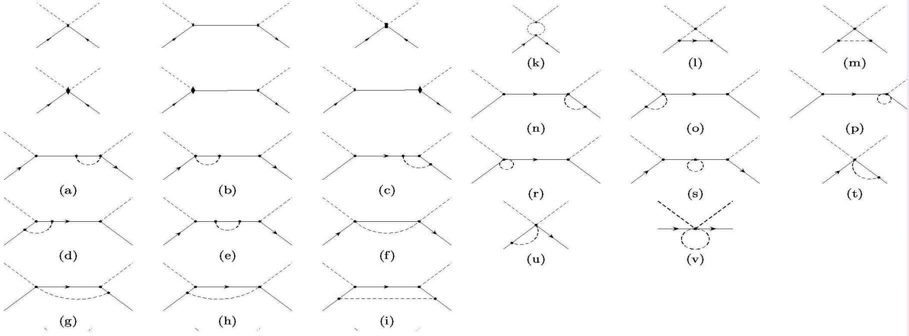
Part II

Perturbative Calculations

We calculate the amplitude up to $\mathcal{O}(p^3)$. From the usual power counting, we have the following contributions:



Perturbative Fits

In order to obtain the LECs we consider:

- PWA of the Karlsruhe group (KA85) **[Koch, NPA 448 (1986) 707]**
- Current PWA of the GWU group (WI08)
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Fitting procedure (strategy-I):
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- Fit phase shifts up to $\sqrt{s}_{max} = 1.13$ GeV.
- We assign an error to every point as the sum in quadrature of a systematic (e_s) plus a relative error (e_r):
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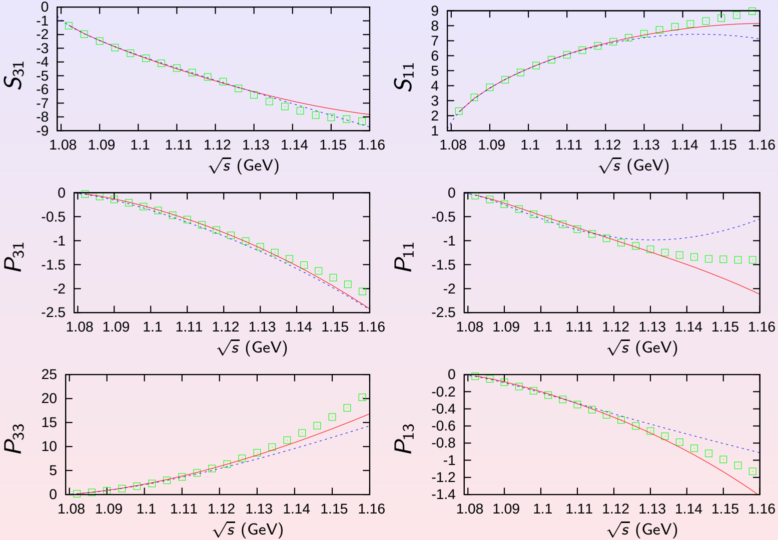
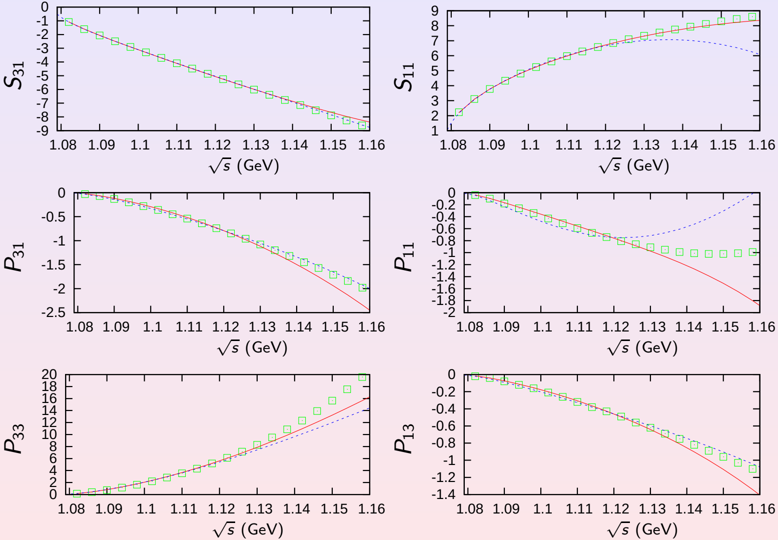


Solid line: EOMS. Dashed line: IR.

WI08 Fits



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LECs

Results for the LECs:

LEC	KA85-EOMS	WI08-EOMS	KA85-IR $\mathcal{O}(p^3)$ [1]	WI08-IR $\mathcal{O}(p^3)$ [1]	HBCHPT $\mathcal{O}(p^3)$ [2]
c_1	-1.26 ± 0.07	-1.50 ± 0.06	-0.71 ± 0.49	-0.27 ± 0.51	$(-1.71, -1.07)$
c_2	4.08 ± 0.09	3.74 ± 0.09	4.32 ± 0.27	4.28 ± 0.27	$(3.0, 3.5)$
c_3	-6.74 ± 0.08	-6.63 ± 0.08	-6.53 ± 0.33	-6.76 ± 0.27	$(-6.3, -5.8)$
c_4	3.74 ± 0.05	3.68 ± 0.05	3.87 ± 0.15	4.08 ± 0.13	$(3.4, 3.6)$
$d_1 + d_2$	3.25 ± 0.55	3.67 ± 0.54	2.48 ± 0.59	2.53 ± 0.60	$(3.2, 4.1)$
d_3	-2.72 ± 0.51	-2.63 ± 0.51	-2.68 ± 1.02	-3.65 ± 1.01	$(-4.3, -2.6)$
d_5	0.50 ± 0.13	-0.07 ± 0.13	2.69 ± 2.20	5.38 ± 2.40	$(-1.1, 0.4)$
$d_{14} - d_{15}$	-6.10 ± 1.08	-6.80 ± 1.07	-1.71 ± 0.73	-1.17 ± 1.00	$(-5.1, -4.3)$
d_{18}	-2.96 ± 1.44	-0.50 ± 1.43	-0.26 ± 0.40	-0.86 ± 0.43	$(-1.6, -0.5)$
$\chi^2_{d.o.f.}$	0.35	0.22	$\lesssim 1$	$\lesssim 1$	-
Δ_{GT}	$9 \pm 4\%$	$2 \pm 4\%$	$(20 - 30\%)$	$(20 - 30\%)$	(input)

[1] J. M. Alarcón, J. Martín Camalich, J. A. Oller, L. Alvarez-Ruso, Phys. Rev. C 83 (2011) 055205.

[2] N. Fettes, U. G. Meißner and S. Steininger, Nucl. Phys. A 640 (1998) 199.

Goldberger-Treiman deviation

- Method:

We consider the process $\pi^- p \to \pi^- p$ (pure s-channel):

$$\lim_{s\to m_N^2} \frac{T_{P_{11}}^{\mathcal{O}(p^3)}}{T_{P_{11}}^{\mathcal{O}(p)}} = \left(\frac{g_{\pi N}}{g_A m_N/f_\pi}\right)^2 = (1+\Delta_{GT})^2$$

$$\Delta_{GT} = -\frac{2M_\pi^2 d_{18}}{g_A} + \Delta_{loops}$$

- IR: $\Delta_{loops} = 20 - 30\%$ (scale dependent)
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σ-term

This topic deserves a specific talk:

The chiral representation of the πN scattering amplitude and the pion-nucleon sigma term

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Tuesday, September 20

Parallel Session B

San Rocco, Feynman Lecture Hall. 19:35 - 19:55

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Part III

Unitarized Calculations

Unitarized Calculations

In order to implement unitarity to the πN amplitude and take care of the analyticity properties associated with the right-hand cut we write our unitarized amplitude $T_{IJ\ell}$ by means of an interaction kernel $\mathcal{T}_{IJ\ell}$ and the unitary pion-nucleon loop function $g(s)$:

$$T_{IJ\ell} = \frac{1}{\mathcal{T}_{IJ\ell}^{-1} + g(s)}$$

- $T_{IJ\ell}$ satisfies unitarity exactly.
- The interaction kernel is determined order by order by matching with the perturbative ChPT result **[J. A. Oller and U. G. Meißner, PLB 500:263-272 (2001)]**.
- a_1 is fixed by requiring $g(m^2) = 0$ (in order to have the P_{11} nucleon pole in its right position).

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We introduce the contribution of the $\Delta(1232)$ in P_{33} through a CDD **[Castillejo, Dalitz and Dyson, PR 101 (1956) 453]**, **[Oller and Oset, PRD 60, 074023 (1999)]**:

$$T_{\frac{3}{2}\frac{3}{2}1} = \left(\mathcal{T}^{-1}_{\frac{3}{2}\frac{3}{2}1} + \frac{\gamma}{s - s_P} + g(s) \right)^{-1}$$

- The CDD pole conserves the discontinuities of the partial wave amplitude across the cuts.
- The CDD pole corresponds to a zero of the partial wave amplitude along the real axis and hence to a pole in the inverse of the amplitude.

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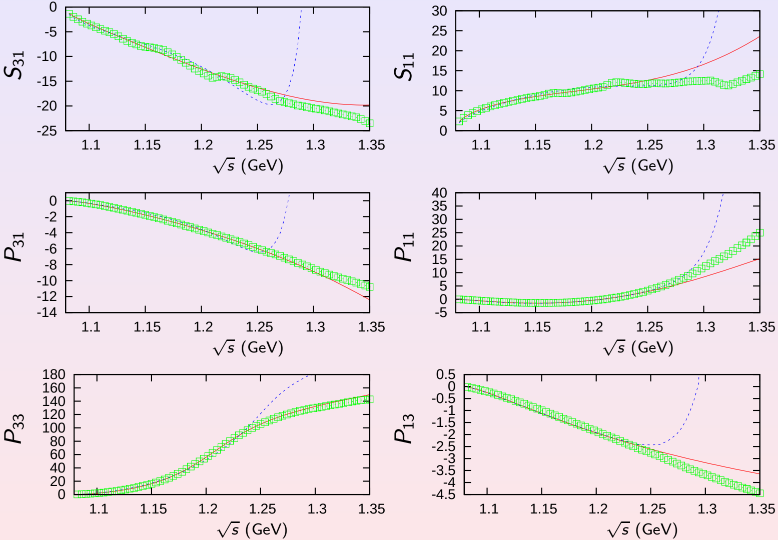
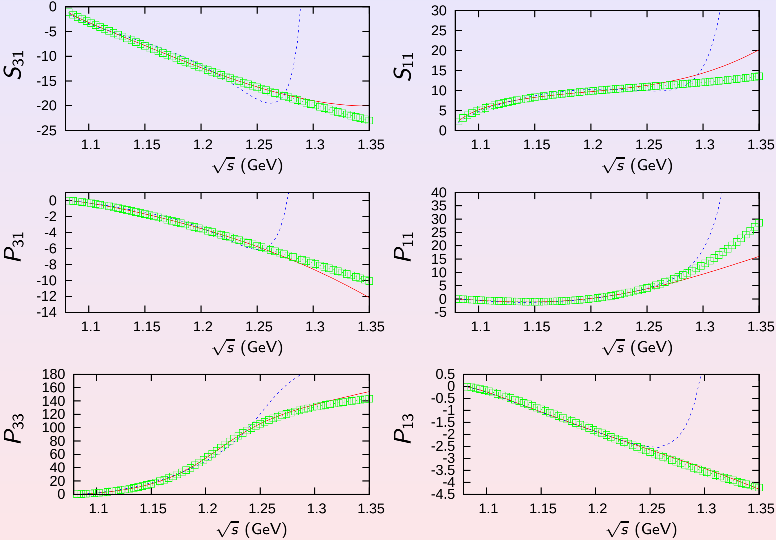
KA85 Fits



Solid line: EOMS. Dashed line: IR.

WI08 Fits



Solid line: EOMS. Dashed line: IR.

Part IV

Summary and Conclusions

Summary and Conclusions

- πN scattering is the fundamental process in BChPT.
- *Full Covariant* ChPT→ Problems with the standard power counting.
- Solutions:
  - *HBChPT*→ Does not converge in the subthreshold region ($\sigma_{\pi N}$).
  - *IR*→ Relativistic resummation:
    - Scale dependent.
    - Unphysical cuts ($u = 0$)⇒ limits UChPT.
    - Unphysical value for the Δ_{GT} ⇒ Jeopardizes the applicability of BχPT.
  - *EOMS*:
    - Scale independent.
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    - Accurate and reliable determination for Δ_{GT} from PWA.
    - Allows a determination of $\sigma_{\pi N}$ (Jorge Martín Camalich. Tuesday)

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