

Nonresonant background signal in the polarization transfer in the weak pion production off the nucleon

Krzysztof M. Graczyk & Beata E. Kowal

Institute of Theoretical Physics, University of Wrocław, Poland

Abstract

Polarization transfer (PT) observables in the single pion production induced by the charged current ν -nucleon interaction are examined within two models. It is demonstrated that the PT observables: the degree of polarization and the polarization components of outgoing fermions are sensitive to the details of the nonresonant background model. It is shown that the normal component of the polarization of the outgoing nucleon and the charged lepton are determined by the interference between the resonant (RES) and nonresonant (NB) amplitudes. Moreover, the sign of the normal component of the polarization of the charged lepton is related to the relative sign between the RES and the NB amplitudes. The presentation is based on Ref. Graczyk and Kowal (2018).

Motivation and Goal

1. A progress in studies of neutrino oscillations and the CP -violation requires a development of new experimental methods as well as an improvement of the theoretical models describing the ν -nucleon and ν -nucleon scattering.
2. Single pion production (SPP) in νN scattering gives sizable contribution to the total cross section for ν -nucleon scattering. Two SPP mechanisms are distinguished: (i) resonance and (ii) nonresonance. In the first nucleon is excited to the resonance state and it decays to $1\pi N$ nucleon system, while in the other 1π occurs without nucleon-resonance transition.
3. Predictions of the resonance (RES) and the nonresonance (NB) contributions are model-dependent. Moreover, the analysis of the measurements of the spin averaged νN cross sections does not allow to distinguish between resonance and nonresonance components. One needs to analyze new measurements of ν -nucleon scattering in order to constrain and to falsify the SPP models.
4. We demonstrate that the polarization transfer (PT) observables in SPP processes contain new unique information about resonance and nonresonance dynamics.

Polarization transfer - method and results

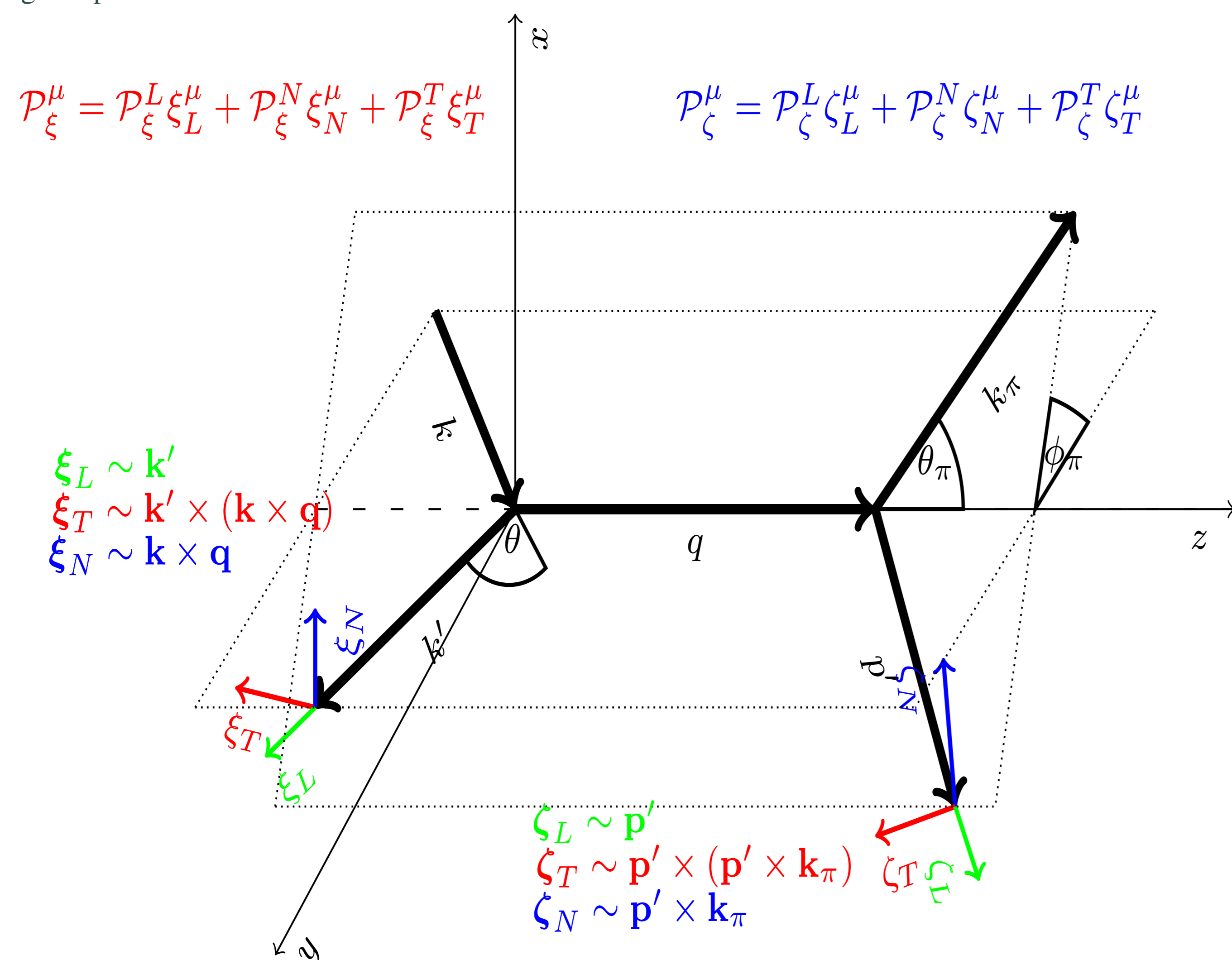
Consider two polarization transfer (PT) processes

$$\nu_l(k) + N(p) \rightarrow \bar{l}^-(k', \xi) + N(p') + \pi(k_\pi), \quad \nu_l(k) + N(p) \rightarrow l^-(k') + \bar{N}(p', \zeta) + \pi(k_\pi), \quad (1)$$

where ξ_μ and ζ_μ are spin four-vectors of the final lepton and the nucleon. The differential cross sections for the above processes read

$$d\sigma \sim |\overline{\mathcal{M}}_{fi}|^2 (1 + \mathcal{P}_\xi^\mu \xi_\mu), \quad d\sigma \sim |\overline{\mathcal{M}}_{fi}|^2 (1 + \mathcal{P}_\zeta^\mu \zeta_\mu) \quad (2)$$

where $\overline{\mathcal{M}}_{fi}$ spin averaged matrix element whereas \mathcal{P}_ξ^μ and \mathcal{P}_ζ^μ are the polarization four-vectors of the charged lepton and the final nucleon.

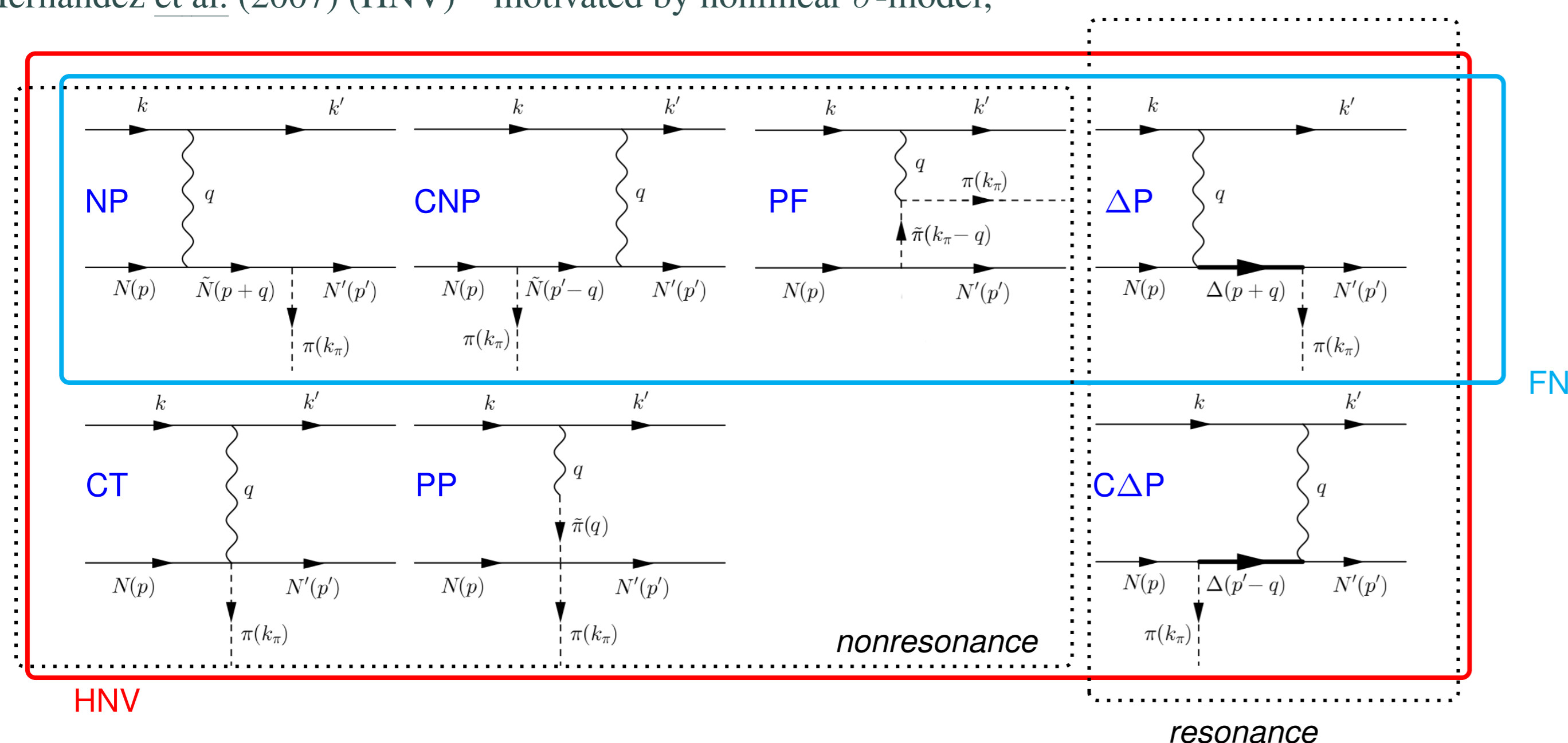


Goal: investigate how the polarizations of the final lepton and the nucleon depend on details of the resonance and the nonresonance model.

Single Pion Production models

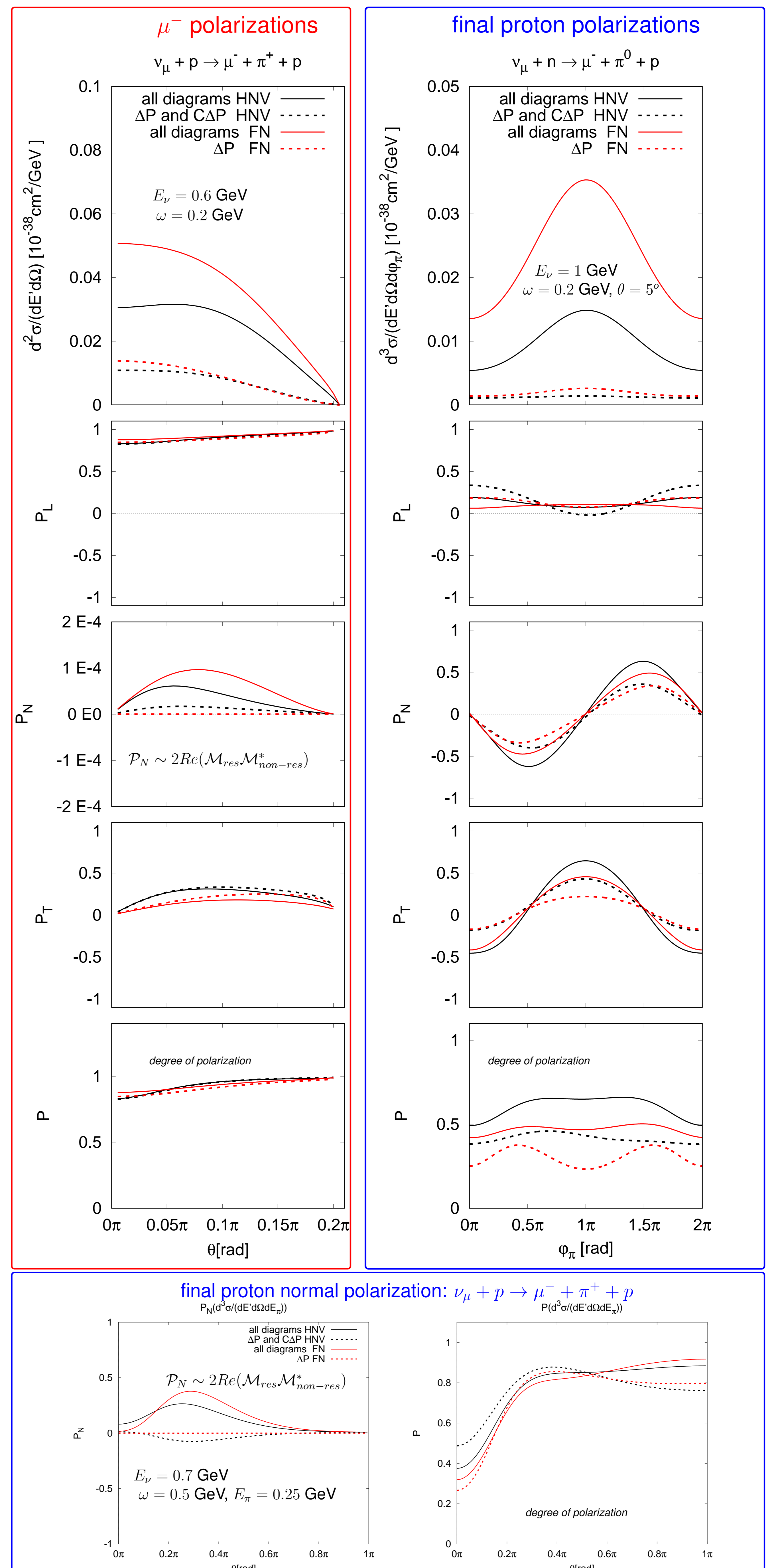
Assumptions: Consider neutrino energy of the order of 1 GeV (typical for long baseline experiments) \rightarrow RES contribution dominated by: $N \rightarrow \Delta(1232)$ weak transition.

Two SPP models are discussed: Fogli and Nardulli (1979) (FN) – motivated by linear σ -model and Hernandez et al. (2007) (HNV) – motivated by nonlinear σ -model;



The FN model: NP and CNP diagrams have the pseudoscalar πNN coupling, while the HNV model has pseudovector coupling terms. In the FN model the structure of the transition current for $N \rightarrow \Delta$

is oversimplified. The HNV and FN model use different transition form factors.



Summary

The polarization components of the charged lepton and the final nucleon are sensitive to the resonance and the nonresonance background contributions. In particular the normal component of the polarization is determined by the interference between the RES and the NB amplitudes. Hence it contains unique information about: relative phase between both types of amplitude amplitudes and relative strength of both contributions. The analysis of the polarization transfer observables should allow to constrain and falsify significantly the SPP models.

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References

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