

Measuring the P-Odd πN Coupling $h_{\pi NN}^{(1)}$ in $\vec{\gamma} p \rightarrow n\pi^+$ Near the Threshold

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1) Introduction

Why $h_{\pi NN}^{(1)}$? Why single nucleon system?

Why chiral perturbation and near threshold?

2) Measuring $h_{\pi NN}^{(1)}$ in $\vec{\gamma} p \rightarrow n\pi^+$ near the threshold

3) What happens at higher energies?

4) Conclusions

Parity Violation in the Garden

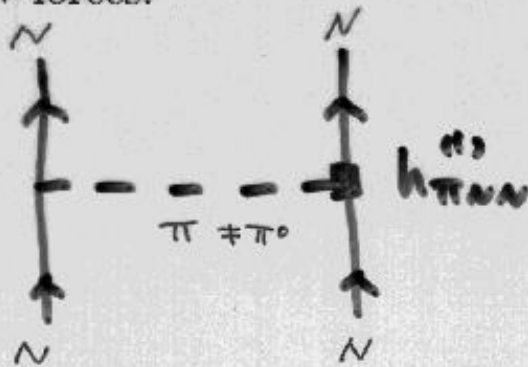


Right handed plants.

"We like antineutrinos!"

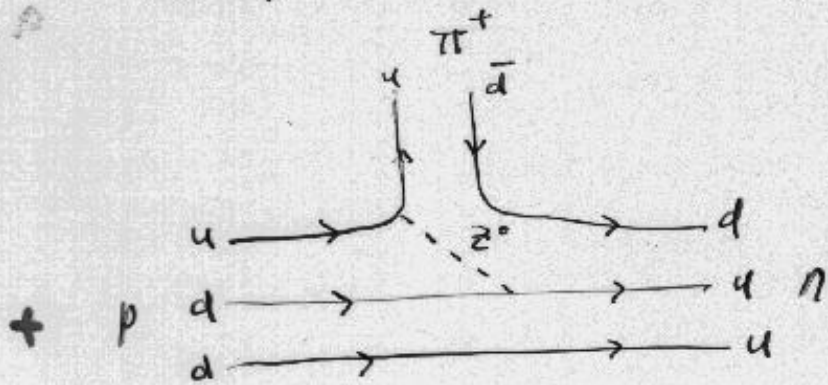
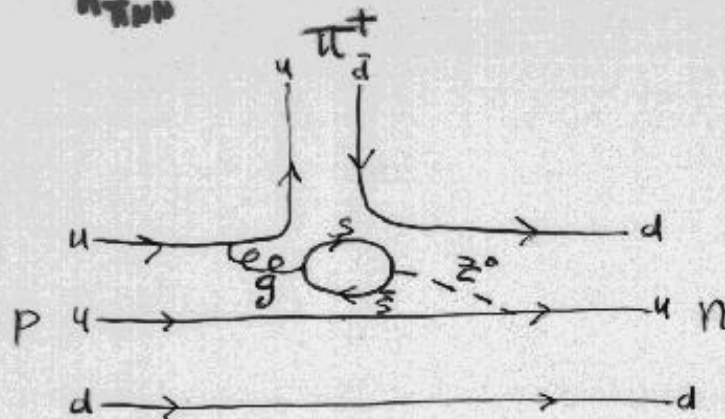
Why $h_{\pi NN}^{(1)}$?

⇒ Longest range part of the parity-violating (PV)
 $\Delta I = 1$ NN forces.



⇒ Contributing to anapole moments,
PV in ^{18}F radiative decay,
 $\vec{n}p \rightarrow d\gamma \dots$

$h_{\pi NN}^{(1)}$ dominated by neutral current & strange quark contribution



+

+ ...

Why HB χ PT? Why Near Threshold?

1) Chiral perturbation theory (χ PT)— a low energy effective field theory of QCD

a) Most general Lagrangian with the symmetry of QCD

b) Derivative and chiral expansion, expansion

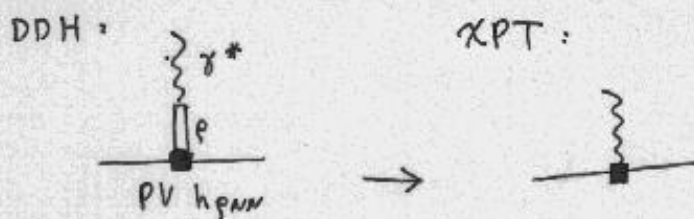
$$\text{parameter } \frac{m_\pi, p}{\Lambda_\chi, m_N}$$

2) Electroweak symmetries ($SU(2)_L \times U(1)$) naturally incorporated

3) Heavy baryon chiral perturbation theory (HB χ PT)— successful for low energy processes ($p \sim m_\pi$).

“Heavy baryon”— consistent power counting

4) Relation to meson exchange model (DDH)



PV Chiral Lagrangian

Non-leptonic \mathcal{L}^{PV} (Kaplan & Savage, '93)

$$\mathcal{L}^{PV} = -ih_{\pi NN}^{(1)} p^\dagger \pi^+ n + h.c. + \dots$$

\dots = terms of higher derivatives or more powers of π fields

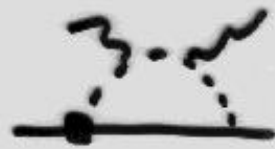
$$h_{\pi NN}^{(1)} \sim \frac{G_F F_\pi \Lambda_\chi}{\sqrt{2}} \sim 5 \times 10^{-7}$$

- 1) close to DDH's "best guess"
(Desplanques, Donoghue & Holstein, '80)
- 2) QCD sum rules $h_{\pi NN}^{(1)} \sim 3 \times 10^{-7}$
(Henley, Hwang, Kisslinger, '98)
- 3) SU(3) Skyrme model $h_{\pi NN}^{(1)} \sim 0.8 - 1.3 \times 10^{-7}$
(Meissner & Weigel, '99)

Measuring $h_{\pi NN}^{(0)}$ in Single Nuclear Systems 9.1

- $\tau \bar{p} \rightarrow \tau p$

(Bedaque, Savage '99)



- $\bar{\nu} p \rightarrow \tau p$

(Chen, Cohen, Kao '00)

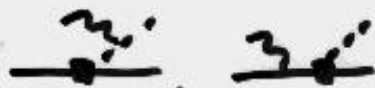


- $\bar{\nu} p \rightarrow \pi^+ n$

(Woloshyn, '79; Li, Henley, Hwang, '82;

Chen & Ji '00)

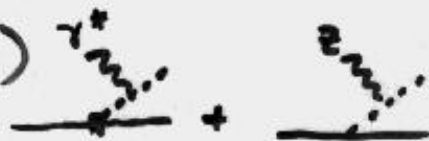
(Zhu, Puglia, Holstein, Ramsey-Musolf '00)



- $\bar{e} p \rightarrow e \pi^+ n$

(Li, Henley, Hwang '82; Hammer, Drechsel

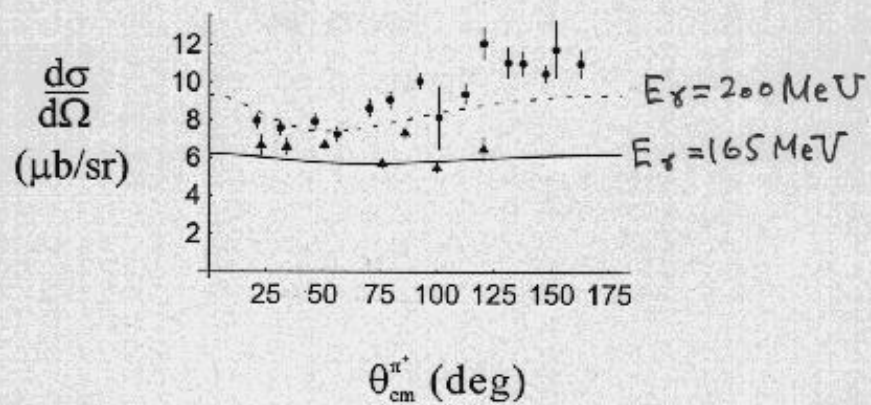
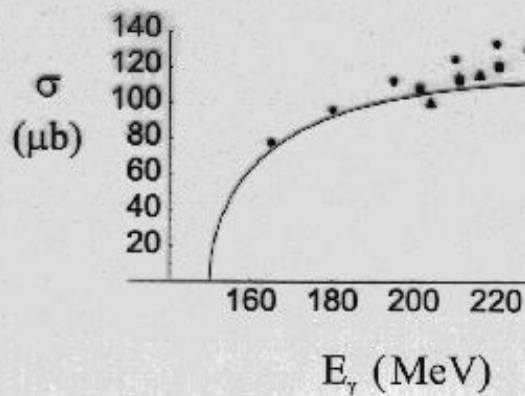
'95, Chen & Ji '00)



Measuring $h_{\pi NN}^{(1)}$ in $\vec{\gamma} p \rightarrow n\pi^+$ near the threshold

(JWC & X. Ji, '00) ~~PRL~~

Leading order (LO) HB χ PT Results for unpolarized PC cross section:

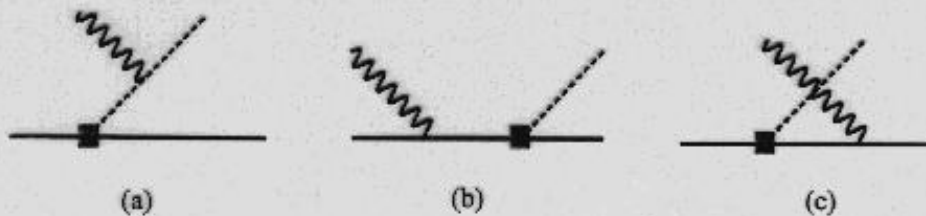


Lower figure:

lower curve: $E_\gamma = 165$ MeV, upper curve: $E_\gamma = 200$ MeV

Measuring $h_{\pi NN}^{(1)}$ in $\vec{\gamma} p \rightarrow n \pi^+$ near the threshold

PV diagrams:

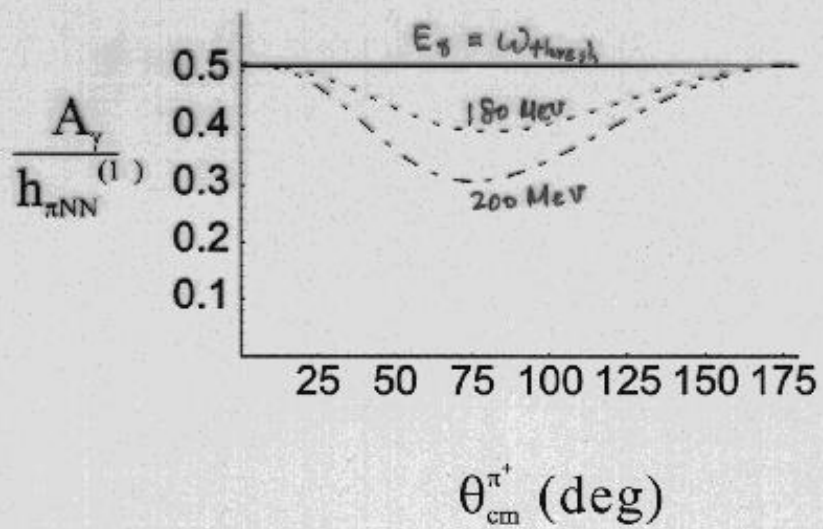


Helicity asymmetry:

$$A_{\gamma}(\omega, \theta) \equiv \frac{d\sigma(\lambda_{\gamma} = +1) - d\sigma(\lambda_{\gamma} = -1)}{d\sigma(\lambda_{\gamma} = +1) + d\sigma(\lambda_{\gamma} = -1)}$$

Low energy theorem at the threshold and chiral limit:

$$\begin{aligned} A_{\gamma}(\omega_{\text{th}}, \theta) &= \frac{\sqrt{2} f_{\pi} (\mu_p - \mu_n)}{g_A m_N} h_{\pi NN}^{(1)} \\ &= 0.52 h_{\pi NN}^{(1)} \end{aligned}$$



$E_\gamma = \omega_{th}$ (upper), $E_\gamma = 180 \text{ MeV}$ (middle) & $E_\gamma = 200 \text{ MeV}$ (lower)

New Proposal to Jefferson Lab PAC 19

Measurement of the Weak Pion-Nucleon Coupling
Constant, h_{π}^1 , in Parity-Violating Backward Pion
Photoproduction near Threshold off the Proton

W. Bertozzi, S. Gilad, D. W. Higinbotham, S. Kowalski,
S. Sirca, R. Suleiman (spokesperson), Z. Zhou
Massachusetts Institute of Technology

P. A. Souder
Syracuse University

J. P. Chen, K. de Jager, J.-O. Hansen, J. LeRose, N. Liyanage,
R. Michaels, S. Nanda, A. Saha
Thomas Jefferson National Accelerator Facility

L. Kaufman, K. Kumar
University of Massachusetts

D. Margaziotis
California State University

C. C. Chang
University of Maryland

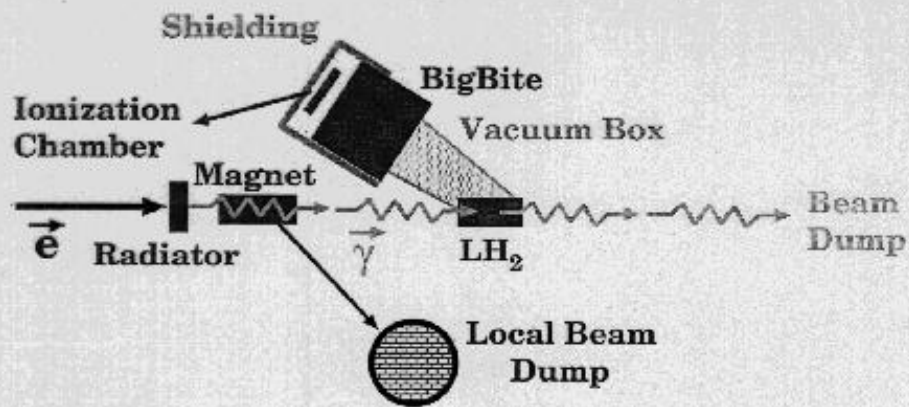
X. Jiang
Rutgers University

(A Hall A Collaboration Proposal)

December 14, 2000

Experimental Hall	Hall A
<u>Beam Energy</u>	<u>230 MeV</u>
<u>Beam Current</u>	<u>400 μA</u>
Beam Polarization	80%
Radiator Thickness	10% τ . l. Cu (0.143 cm)
Photon Energy (E_γ)	230-180 MeV
$f(N_\gamma/N_e)$	0.02
Photon Polarization	75%
<u>Target</u>	<u>80 cm LH₂</u>
<u>Luminosity (\mathcal{L})</u>	<u>$1.6 \times 10^{38} \text{ cm}^{-2} \text{ sec}^{-1}$</u>
BigBite Central Angle	140 $^\circ$
Horizontal Angular Acceptance	$\pm 10^\circ$
Vertical Angular Acceptance	$\pm 20^\circ$
Solid Angle Acceptance	0.3 sr
Average Cross Section $\frac{d\sigma}{d\Omega}(\gamma p \rightarrow n\pi^+)$	$5 \times 10^{-30} \text{ cm}^2/\text{sr}$
Theoretical Asymmetry (A_γ)	2.2×10^{-7}
Experimental Asymmetry (A)	1.7×10^{-7}
Statistics Needed for 100% Accuracy ($1/A^2$)	3.7×10^{13}
Time Needed for 100% Accuracy	40 hours
Extra Time (Pion Decay & Signal Fluctuation)	25%
Total Time (100% Statistical Accuracy)	50 hours
<u>Total Time (20% Statistical Accuracy)</u>	<u>1000 hours</u>

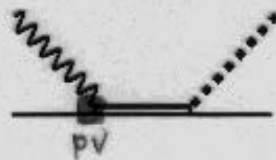
Experimental Considerations



What happens at higher energies?

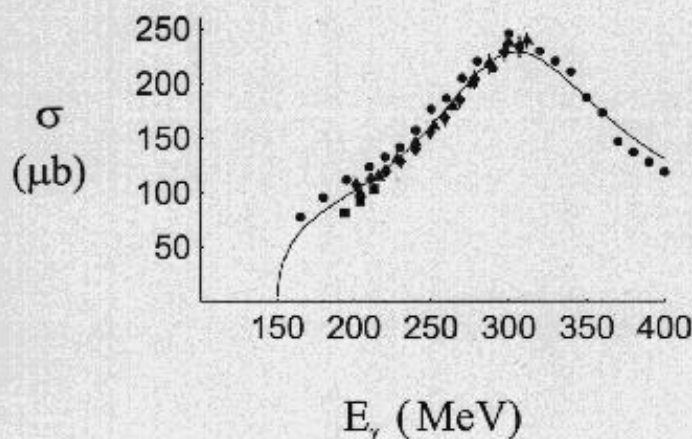
1) Unknown PV Δ effects will contribute

\Rightarrow Dominated by $E1$ $\gamma N \Delta$ coupling \tilde{G} (PV $\pi N \Delta$ vertex is higher order). $\tilde{G} \sim 0.1 h_{\pi NN}^{(1)}$ by dimensional analysis.

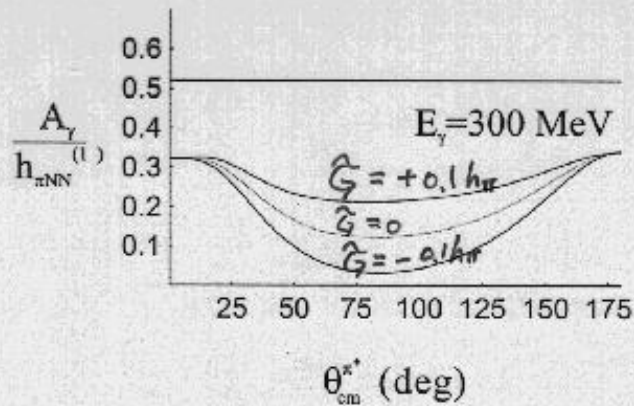
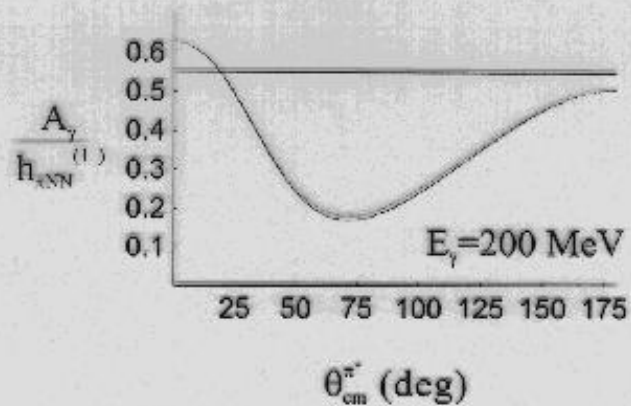


3) Assuming Δ dominance $\Rightarrow A_\gamma \sim \tilde{G} \sim 0.1 h_{\pi NN}^{(1)}$

4) HB χ PT not yet directly applicable to the near Δ resonance region \Rightarrow phenomenology study as an estimation



Photon helicity asymmetry



In both figures:

Straight lines: threshold result

three curves: $\tilde{G} = 0$ (center), $\tilde{G} \sim 0.1 h_{\pi NN}^{(1)}$ (upper) & $\tilde{G} \sim -0.1 h_{\pi NN}^{(1)}$ (lower)

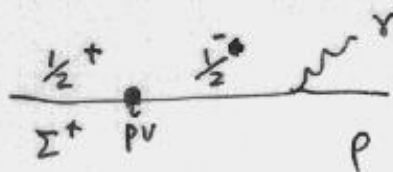
Zhu et al's conjecture:

(Zhu, Maekawa, Holstein, Ramsey-Musolf '01)

PV \in I NGS Couplj

$\approx (1-100) \times$ (Nais dim. analysis)

Motivated by $\Sigma^+ \rightarrow p \gamma$, $\Delta S = 1$, PVEI



Conclusions

1) $\vec{\gamma}p \rightarrow n\pi^+$ in the threshold region— an excellent candidate to measure $h_{\pi NN}^{(1)}$ ($\sigma_{tot} \sim 100\mu b$, $A_\gamma \sim 0.5h_{\pi NN}^{(1)}$ at $E_\gamma = 200$ MeV and backward angles). ~ 1000 hrs beam time at Hall A.

2) At higher energy the PV $\gamma N\Delta$ E1 coupling \tilde{G} can be measured at $\sim 90^\circ$ ($\sigma_{tot} \sim 230\mu b$, $\Delta A_\gamma \sim 0.1h_{\pi NN}^{(1)}$ at $E_\gamma = 300$ MeV), while at backward angles $h_{\pi NN}^{(1)}$ still dominates.