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# 5.10 Analyzing Power of $\pi^- + p \uparrow \rightarrow \gamma + n$ in the Region of the $\Delta$ and the Roper Resonances

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Investigations of the reaction

$$\pi^- + p \rightarrow \gamma + n$$

are of particular interest as a unique probe of the radiative decay of neutral $\pi N$ resonances such as $P_{11}(1440) \rightarrow n+\gamma$. Together with pion photoproduction on hydrogen, in which the charged resonances are probed, they can be used to test the validity of quark models, to look for manifestations of color magnetism, and to probe the possible existence of hybrid resonances (states composed of three quarks and gluonium).

The radiative decay of the neutral Roper resonance is of special interest as various quark models are divergent in their predictions of the expected decay amplitude as shown in Table I.

Table I. Quark model predictions of the radiative decay amplitude of the neutral Roper resonance.

| Reference | $A^n 1/2$ ($GeV^{-\frac{1}{2}} \times 10^{-3}$) |
|---|---|
| Feynman et al.[1] | -18 |
| Copley et al.[2] | -20 |
| Koniuk-Isgur[3] | +26 |
| Barbour et al.[4] | +13 |
| Kubota-Ohta[5] | +04 |
| Sugimoto-Toya[6] | +50 |

The radiative decay of the $\Delta(1232)$ resonance provides a unique probe of the proposed hyperfine quark-quark interaction. Because of the formal analogy between magnetism and the one gluon exchange quark-quark[7] interaction based on colored quarks and gluons, it has been named "color magnetism." In the simplest quark model the nucleon and $\Delta$-resonances consist of three quarks in a relative S-state. Photoproduction of the $\Delta$ can only take place via one quark spin flip which requires an $M_{1+}$ or magnetic dipole transition and the c.m. angular distribution is $2+3\sin^2\theta$. The one gluon exchange interaction implies a calculable d-wave component and allows the $E_{1+}$ or electric quadrupole transition which has a $1+\cos^2\theta$ angular distribution. Isgur et al.[8] predict a ratio $E_{1+}/M_{1+} = +0.007$.

QCD leads in a natural way to the prediction of a new type of hadronic matter consisting of a color singlet of 2 or 3 gluons called gluonium. It implies the existence of yet another type of matter called hybrid matter consisting of quarks and gluonium. The lightest such hybrid state is predicted[9] to have the quantum numbers of the Roper resonance with a mass around 1400 MeV. The most recent $\pi N$ partial wave analysis by

the VPI group[10] indicates that the $P_{11}$ has two poles in the complex plane this makes the existence of a $P_{11}$ hybrid not totally implausible. A unique way to identify the $P_{11}$ hybrid is via a detailed investigation of the radiative decays. As pointed out by Barnes and Close[11] $P^{+}_{11}(\text{hybrid}) \not\to p\gamma$ while there is no restriction on the neutral partner, thus $P^{o}_{11}(\text{hybrid}) \to n\gamma$ is allowed.

We have recently completed a measurement of the analyzing power or left-right assymmetry using a transversely polarized target of the reaction $\pi^- + p \to \gamma + n$ from $p_\pi$ = 301 to 625 MeV/c mainly at $\theta^* = 90^o$ and $110^o$. The experiment was performed in the $P^3$ E channel at LAMPF. The polarized hydrogen target was of a conventional type held in a 2.5 T magnetic field. Photons were detected at two angles simultaneously using two sets of Cherenkov counters each set consisting of 15 lead glass counters 15 cm X 15 cm and 25 cm deep. The neutrons were detected in coincidence in two matching sets of 15 neutron counters each 8 cm in diameter and 46 cm long. The $\pi^- p \to \gamma n$ events were identified on the basis of 2-body kinematics using individual gamma-neutron counter matching and the energy of the photon. We obtained excellent separation from the similar $\pi^- p \to \pi^o n$ reaction.

An example of the preliminary results is shown in Fig. 1. The theoretical prediction is due to Arai[12] as presented at the Toronto Baryon Conference. It has the opposite sign as our data. There is no other measurement for comparison except one measurement of the inverse reaction obtained by Beneventano et al.[13] using a deuterium target and a proton polarimeter. Within the large error bar of the inverse reaction the agreement with our results is satisfactory, in happy accord with expectations based on time reversal invariance, and the P-A theorem. More data at different energies are forthcoming and will be presented and compared with a multipole analyses[12] and data on the inverse reaction.[13,14]

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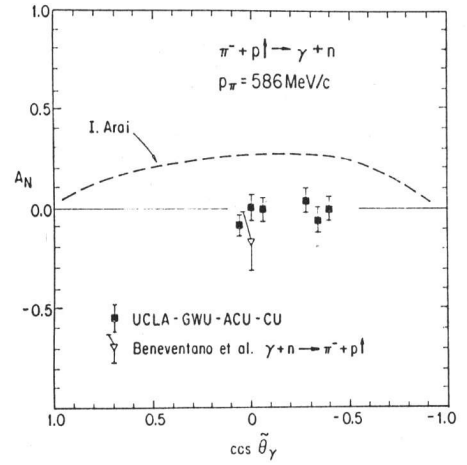


Fig. 1. Preliminary results of our experiment on the analyzing power in $\pi^- + p \uparrow \to \gamma + n$ at $p_\pi$ = 580 MeV. The data point by Beneventano is from the inverse reaction $\gamma + n \to \pi^o + \gamma \uparrow$ measured with a deuterium target and a polarimeter for the outgoing proton. The theoretical curve is the so-called Toky I multipole analyses by I. Arai.[12]