QUANTUM NUMBERS OF Θ^+ through the $K^+p \to \pi^+ K^+ n$ reaction

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- Most present theories of reactions creating the Θ^+ contain a fair amount of unknown parameters

- The $KN \to K\pi N$ reaction is well studied theoretically

Θ^+ can appear through KN final state interaction

The production cross sections depend upon I, J, P of the Θ^+. In particular, the polarization observables

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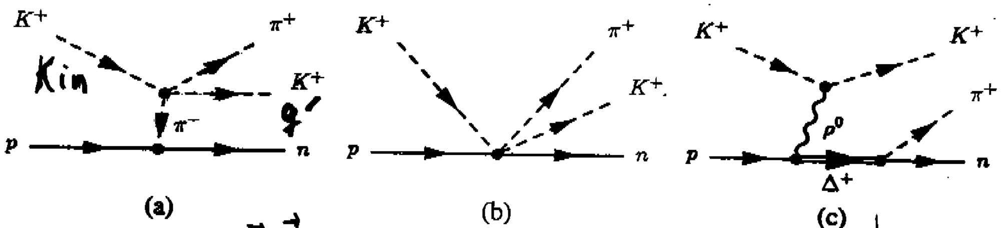
MODEL:



$a\,\vec{\sigma}\,\vec{K}_{in} + b\,\vec{\sigma}\,\vec{q}\,'$

Figure 1: Feynman diagrams of the reaction $K^+p \to \pi^+K^+n$ in the model of Ref. [15].

$\vec{S}\,\vec{p}_\pi\ \vec{S}^{+}\vec{p}_\rho \to \frac{2}{3}\,\vec{p}_\pi\vec{p}_\rho - \frac{i}{3}(\vec{p}_\pi \times \vec{p}_\rho)\vec{\sigma}$

non spin-flip

If we select $\vec{p}_{\pi^+} \approx 0$
then only spin-flip amplitude

K^+n rescattering

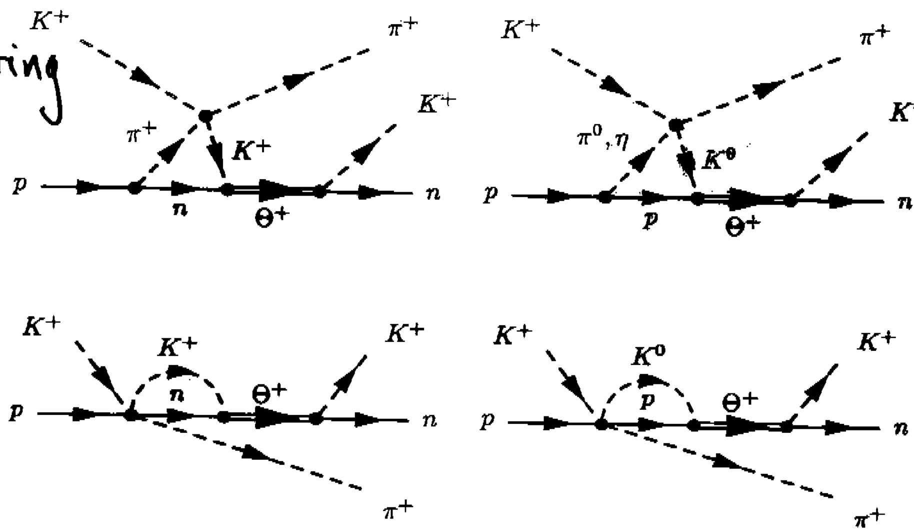
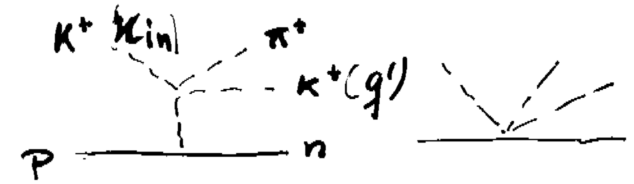


Figure 2: Feynman diagrams of the reaction $K^+p \to \pi^+K^+n$ with the Θ^+ resonance.

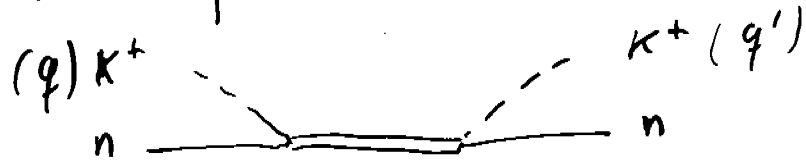
- Tree level amplitudes



evaluated using the meson-meson and meson baryon chiral Lagrangians

$$-it = a\,\vec{\sigma}\cdot\vec{K}_{in} + b\,\vec{\sigma}\cdot\vec{q}\,'$$

- KN resonant amplitude



$$t^{(s)} = \frac{g^2_{K^+n}}{M_I - M_R + i\frac{\Gamma}{2}}$$

(-) sign if $K^0 p \to K^+ n$ and $I=0$

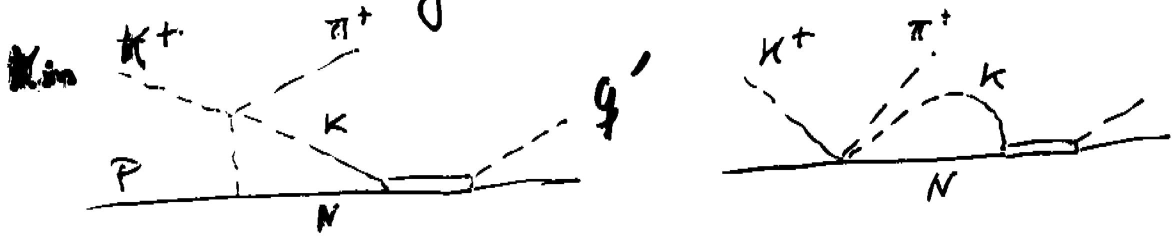
$$t^{(p)} = \frac{\bar{g}^2_{K^+n}\ \vec{\sigma}\,\vec{q}\,'\ \vec{\sigma}\,\vec{q}}{M_I - M_R + i\frac{\Gamma}{2}}$$

$$t^{(p,3/2)} = \frac{\tilde{g}^2_{K^+n}\ \vec{S}\cdot\vec{q}\,'\ \vec{S}^{+}\vec{q}}{M_I - M_R + i\frac{\Gamma}{2}}$$

$$g^2_{K^+n} = \frac{\pi M_R \Gamma}{M q}\ ;\quad \bar{g}^2_{K^+n} = \frac{\pi M_R \Gamma}{M q^3}\ ;\quad \tilde{g}^2_{K^+n} = \frac{3\pi M_R \Gamma}{M q^3}$$

with Γ summing $\Theta^+ \to K^+ n\,,\,K^0 p$

- Rescattering terms



$$KN \begin{cases} K^+ n \\ K^0 p \end{cases}$$

$$-i\tilde{t}^{(s)} = \frac{g^2_{K^+n}}{M_Z - M_R + i\frac{\Gamma}{2}} \quad c \; \vec{\sigma}\vec{K}_{in} \quad S_I$$

$$-i\tilde{t}^{(p,\frac{1}{2})} = \frac{\bar{g}^2_{K^+n}}{M_Z - M_R + i\frac{\Gamma}{2}} \quad d \; \vec{\sigma}\,\vec{q}\,' \quad S_I$$

$$-i\tilde{t}^{(p,\frac{3}{2})} = \frac{\tilde{g}^2_{K^+n}}{M_Z - M_R + i\frac{\Gamma}{2}} \left(f\,\vec{\sigma}\vec{K}_{in} + g\,\vec{\sigma}\vec{q}\,' \right) S_I$$

S_I	K^+n	K^0p
$I=0$	1	1
$I=1$	-1	1

Interference between Tree level and rescattering amplitudes

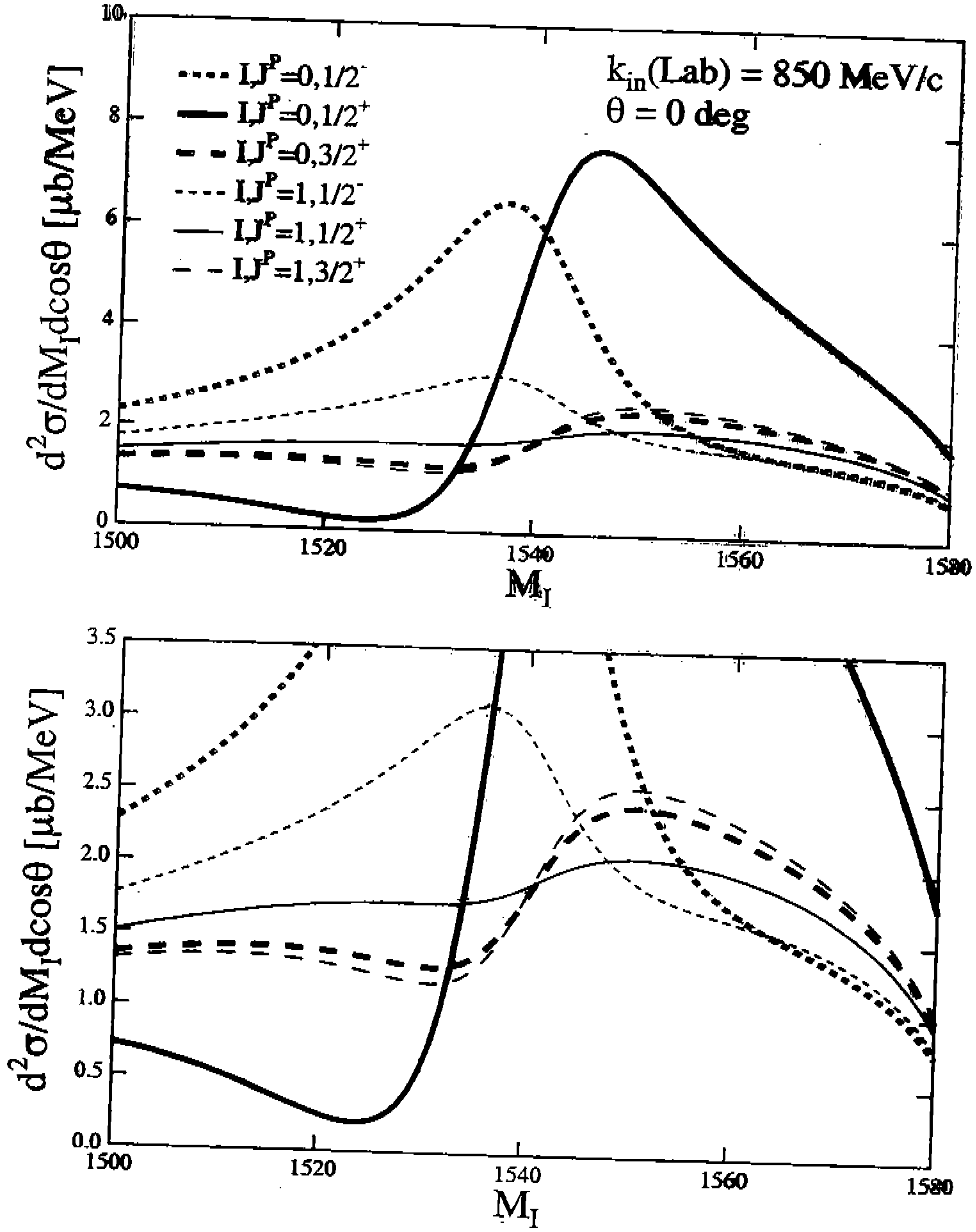


Figure 4: The double differential cross sections $d^2\sigma/dM_I d\cos\theta$ with $\theta = 0$ (forward direction) for $I = 0, 1$ and $J^P = 1/2^-, 1/2^+, 3/2^+$. Below, detail of the lower part of the upper figure of the panel.

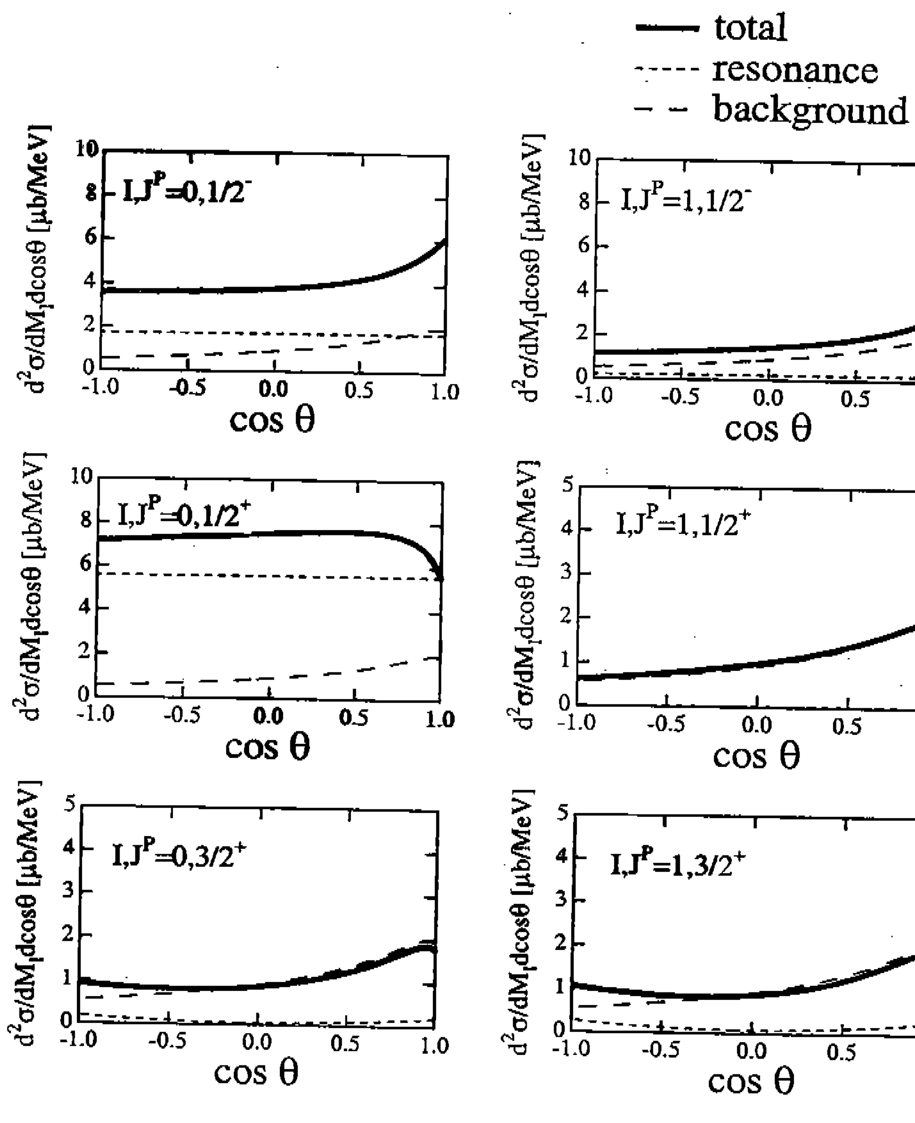


Figure 5: Angular dependence of the double differential cross sections $d^2\sigma/dM_I d\cos\theta$ with $M_I = 1540$ MeV at the resonance peak for $I = 0, 1$ and $J^P = 1/2^-, 1/2^+, 3/2^+$.

– Polarization observables

KN s-wave $\Theta^+ \to 1/2^-$

KN p-wave $\Theta^+ \to 1/2^+ , 3/2^+$

Resonant term s-wave $\sim \vec{\sigma}\,\vec{K}_{in}$ only

" " p-wave $\sim \vec{\sigma}\,\vec{q}\,'$ also

Take z direction along $\vec{K}_{in}$ (K^+ incident)

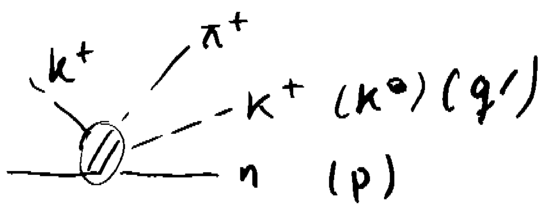
initial N polarization $1/2$ in z direction

final " " $-1/2$ ...

$$\langle -1/2 \,|\, \vec{\sigma}\,\vec{K}_{in} \,|\, 1/2 \rangle = K_{in} \langle -1/2 \,|\, \sigma_z \,|\, 1/2 \rangle = 0$$

$$\langle -1/2 \,|\, \vec{\sigma}\,\vec{q}\,' \,|\, 1/2 \rangle = q' \sin\theta \, \langle -1/2 \,|\, \sigma_x \,|\, 1/2 \rangle$$

$$\sim q' \sin\theta$$



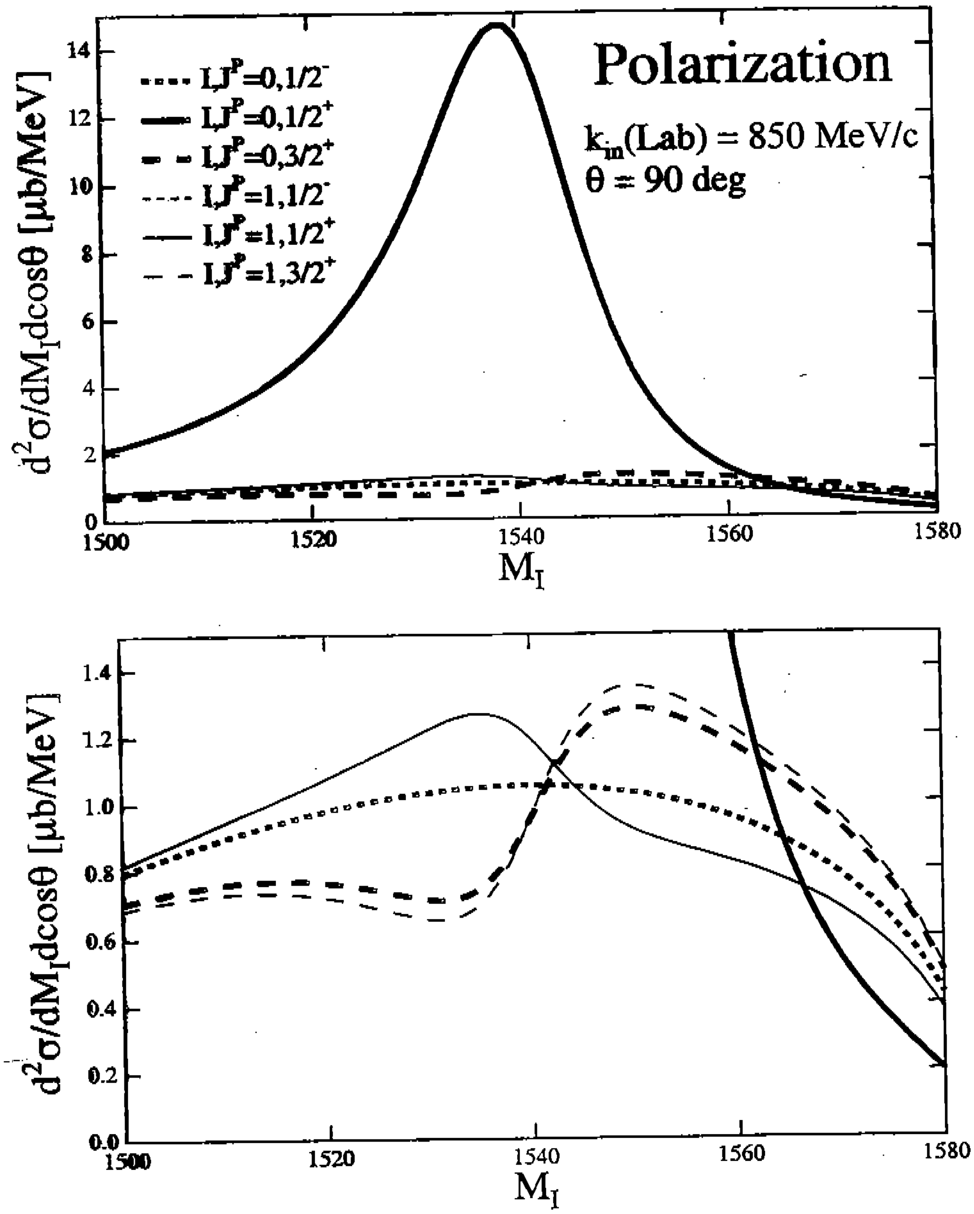


Figure 6: The double differential cross sections of polarized amplitude with $\theta = 90$ for $I = 0, 1$ and $J^P = 1/2^-, 1/2^+, 3/2^+$. Below, detail of the lower part of the upper figure of the panel.

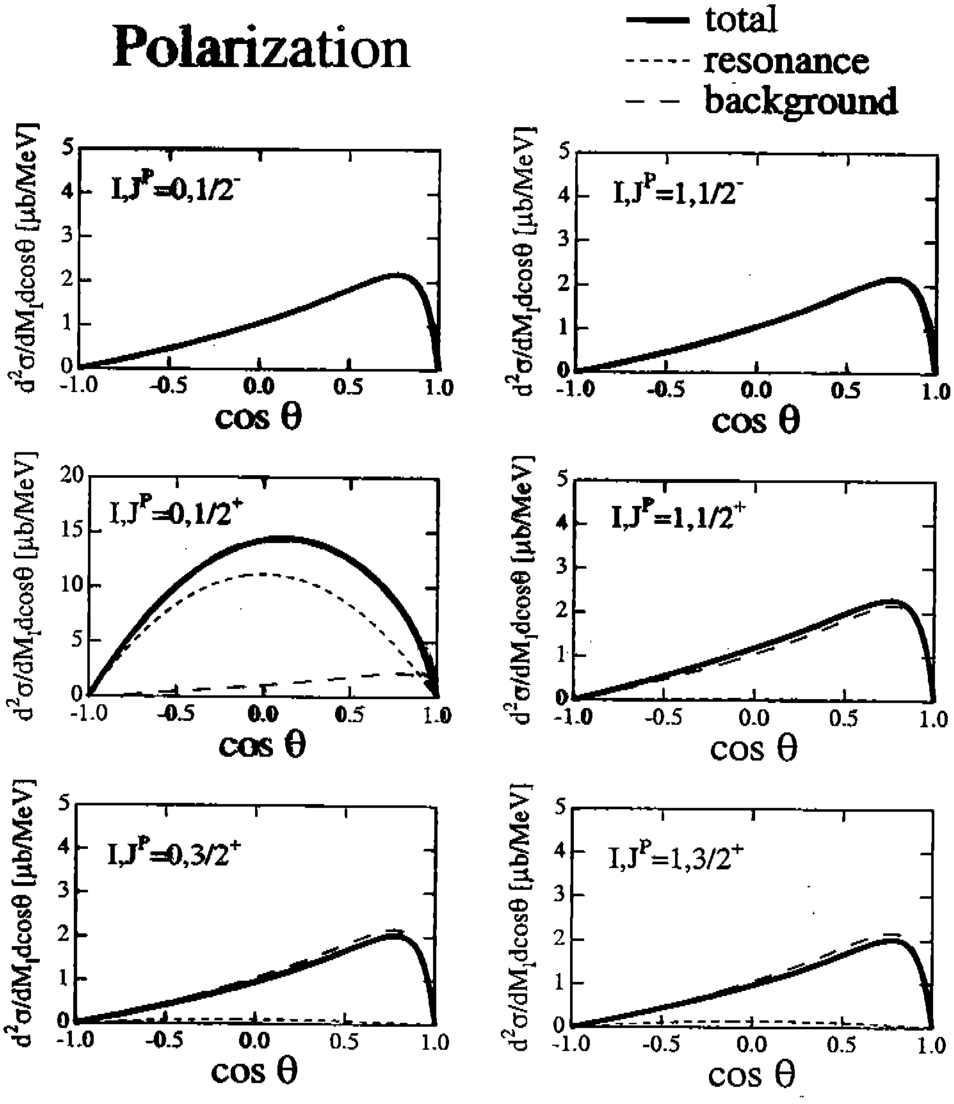


Figure 7: Angular dependence of the double differential cross sections of polarized amplitude with $M_I = 1540$ MeV at the resonance peak for $I = 0, 1$ and $J^P = 1/2^-, 1/2^+, 3/2^+$.

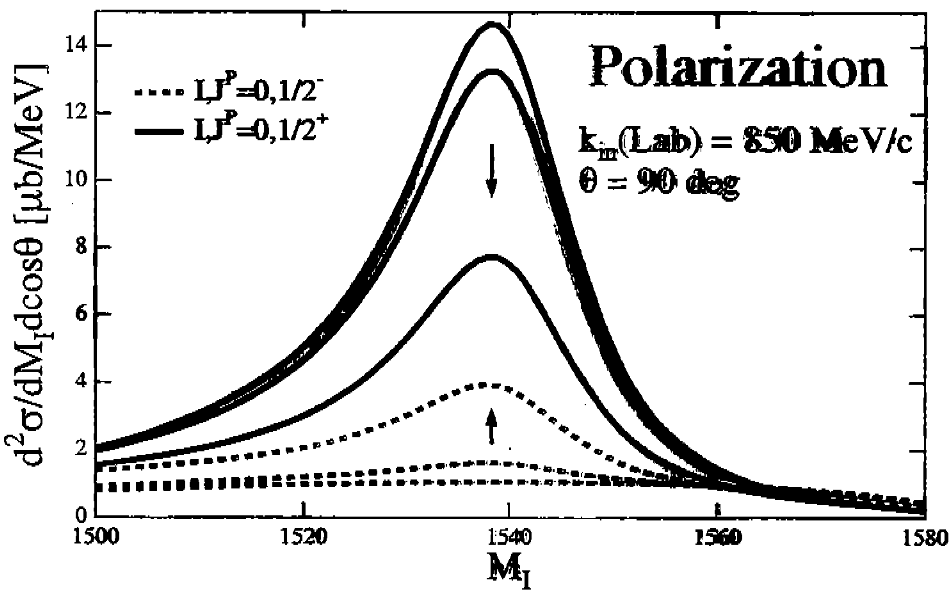


Figure 8: Effects of incomplete polarization on the double differential cross sections at $\theta = 90$ degrees. Three solid and dashed lines are for 100 %, 80 % and 0 % (along the direction of an arrow) polarization for $J^P = 1/2^{\pm}$ and $I = 0$.

CONCLUSIONS

- The $K^+p \to \pi^+ K^+ n$ $(K^0 p)$ reaction is a good tool to determine the spin, isospin and parity of the Θ^+, through studies of invariant mass distributions, angular distributions and polarization

- In particular, a clear signal at $\theta_{K final} = 90°$ of the $\langle -1/2 | t | 1/2 \rangle$ transition would settle the Θ^+ to $I=0$ $J^P = 1/2^+$