

Determining the Θ^+ quantum numbers through $K^+ p \rightarrow \pi^+ KN$



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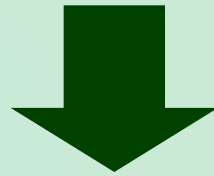
2004, July 21st 1

Motivation : Spin parity determination

Many theoretical studies for Θ^+ :

**Chiral soliton model, quark model,
hadron molecule, sum rule, lattice,...**

No consensus for spin and parity.



**Find a reaction where qualitatively
different results depending on the
quantum numbers are observed.**

Motivation : Advantage of hadronic process

We propose



- Low energy ($p_{\text{cm}} \sim 350 \text{ MeV}$)
- Decay is considered \rightarrow background, interference,...
- Hadronic process : clear mechanism
: cross section $\sim 10^2 \mu\text{b}$

to extract a qualitative behavior which depends on the quantum numbers of Θ^+ .

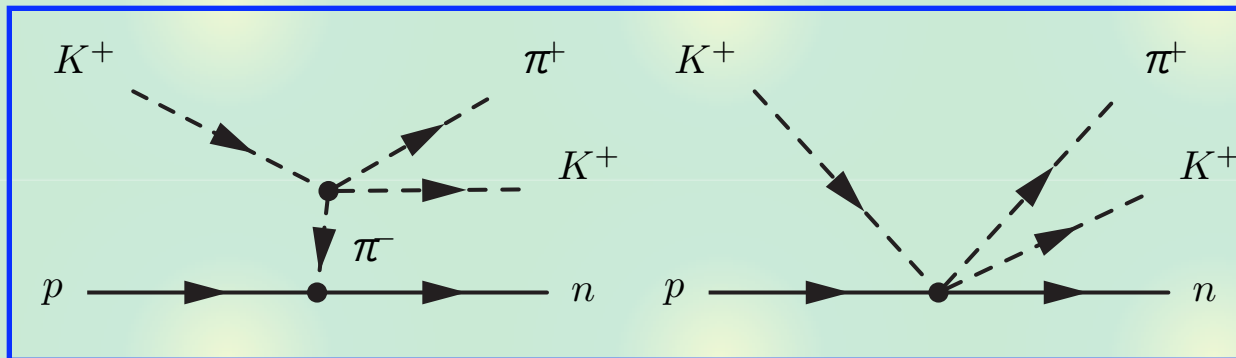


Determination of quantum numbers

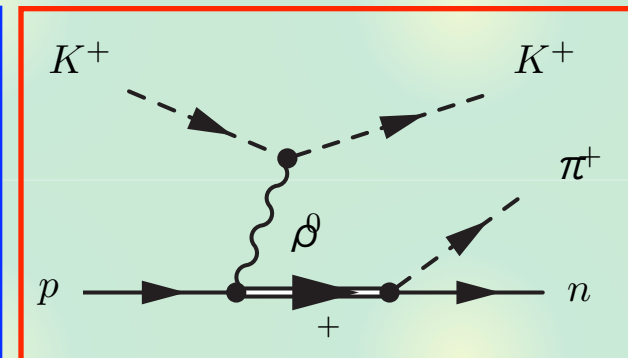
Chiral model for the reaction: Background

E. Oset and M. J. Vicente Vacas, PLB386, 39 (1996)

Vertices \leftarrow chiral Lagrangian



Dominant

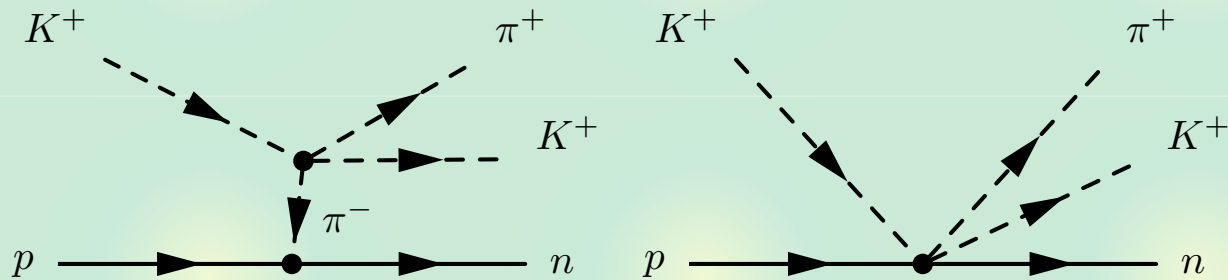


Proportional to $S \cdot p_{\pi^+}$
vanishes

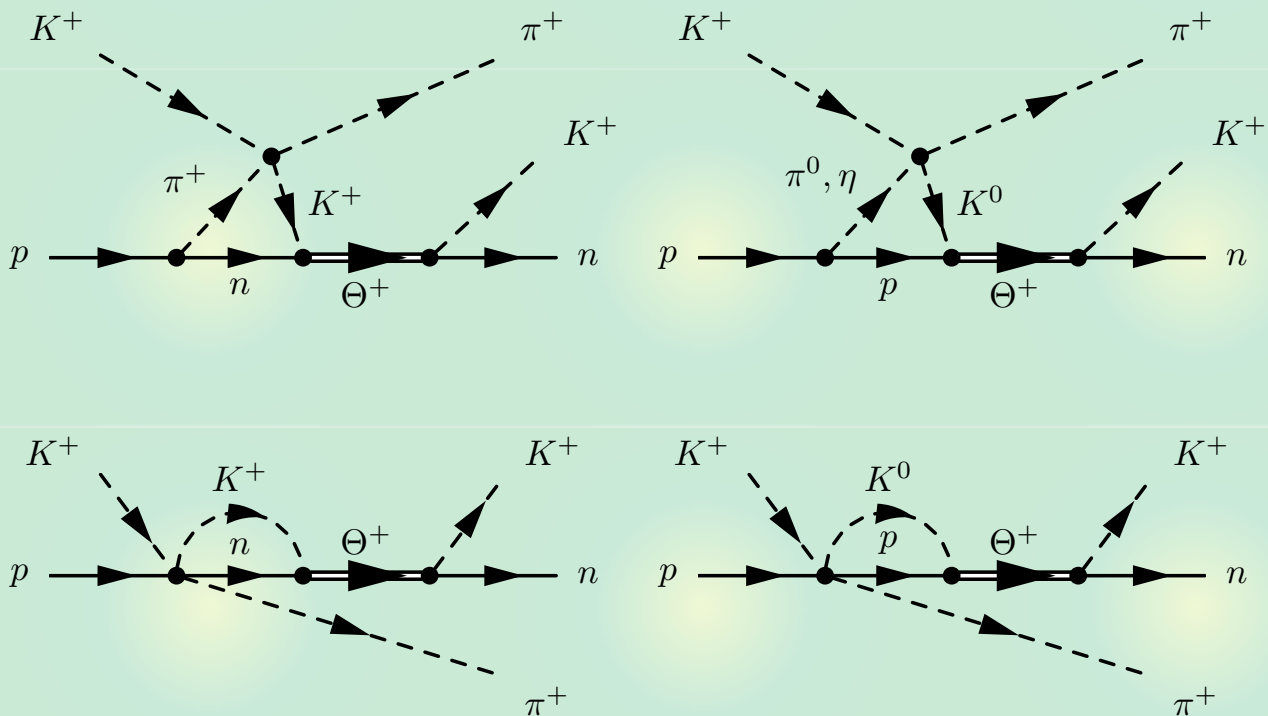
Assume the final π^+ is almost at rest

Chiral model for the reaction: Resonance term


Background
(tree level)



Resonance
(one loop)



Spin and parity : $KN \rightarrow \Theta \rightarrow KN$



$$M_R = 1540 \text{ MeV}$$

$$\Gamma_R = 20 \text{ MeV}$$

$1/2^-$ (KN s-wave resonance)

$1/2^+$, $3/2^+$ (KN p-wave resonance)

$$t_{K+n(K^0 p) \rightarrow K+n}^{(s)} = \frac{(\pm) g_{K+n}^2}{M_I - M_R + i\Gamma/2}$$

$$t_{K+n(K^0 p) \rightarrow K+n}^{(p, 1/2)} = \frac{(\pm) \bar{g}_{K+n}^2 (\boldsymbol{\sigma} \cdot \mathbf{q}') (\boldsymbol{\sigma} \cdot \mathbf{q})}{M_I - M_R + i\Gamma/2}$$

$$t_{K+n(K^0 p) \rightarrow K+n}^{(p, 3/2)} = \frac{(\pm) \tilde{g}_{K+n}^2 (\mathbf{S} \cdot \mathbf{q}') (\mathbf{S}^\dagger \cdot \mathbf{q})}{M_I - M_R + i\Gamma/2}$$

$$g_{K+n}^2 = \frac{\pi M_R \Gamma}{Mq} , \quad \bar{g}_{K+n}^2 = \frac{\pi M_R \Gamma}{Mq^3} , \quad \tilde{g}_{K+n}^2 = \frac{3\pi M_R \Gamma}{Mq^3} .$$

Spin and parity : Resonance amplitude

Resonance term for $K^+ p \rightarrow \pi^+ K^+ n$

$$-i\tilde{t}_i^{(s)} = \frac{g_{K^+n}^2}{M_I - M_R + i\Gamma/2} \left\{ G(M_I)(a_i + c_i) - \frac{1}{3}\bar{G}(M_I)b_i \right\} \sigma \cdot \mathbf{k}_{in} S_I(i)$$

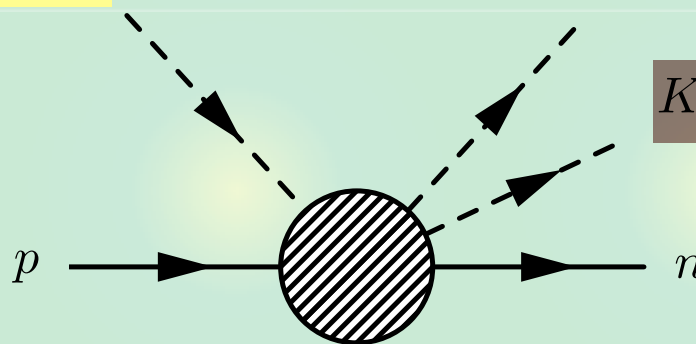
$$-i\tilde{t}_i^{(p,1/2)} = \frac{\bar{g}_{K^+n}^2}{M_I - M_R + i\Gamma/2} \bar{G}(M_I) \left\{ \frac{1}{3}b_i \mathbf{k}_{in}^2 - a_i + d_i \right\} \sigma \cdot \mathbf{q}' S_I(i)$$

$$-i\tilde{t}_i^{(p,3/2)} = \frac{\bar{g}_{K^+n}^2}{M_I - M_R + i\Gamma/2} \bar{G}(M_I) \frac{1}{3}b_i \left\{ (\mathbf{k}_{in} \cdot \mathbf{q}')(\sigma \cdot \mathbf{k}_{in}) - \frac{1}{3}\mathbf{k}_{in}^2 \sigma \cdot \mathbf{q}' \right\} S_I(i)$$

$K^+(\mathbf{k}_{in})$

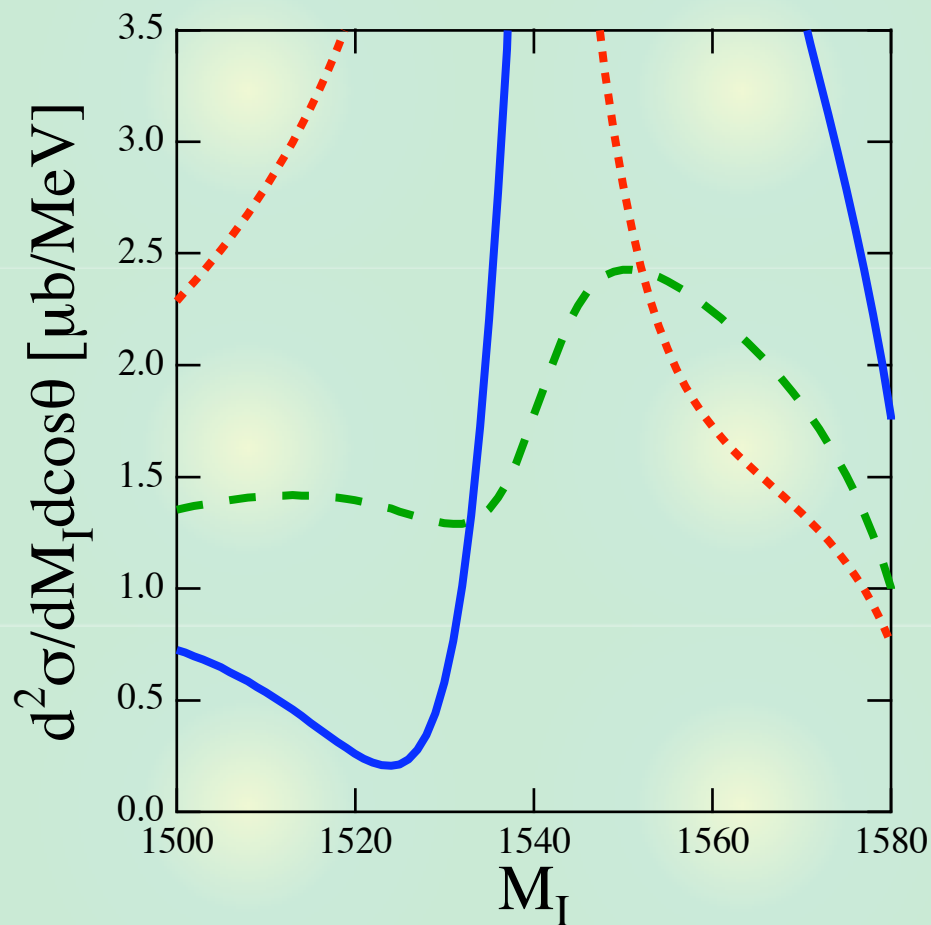
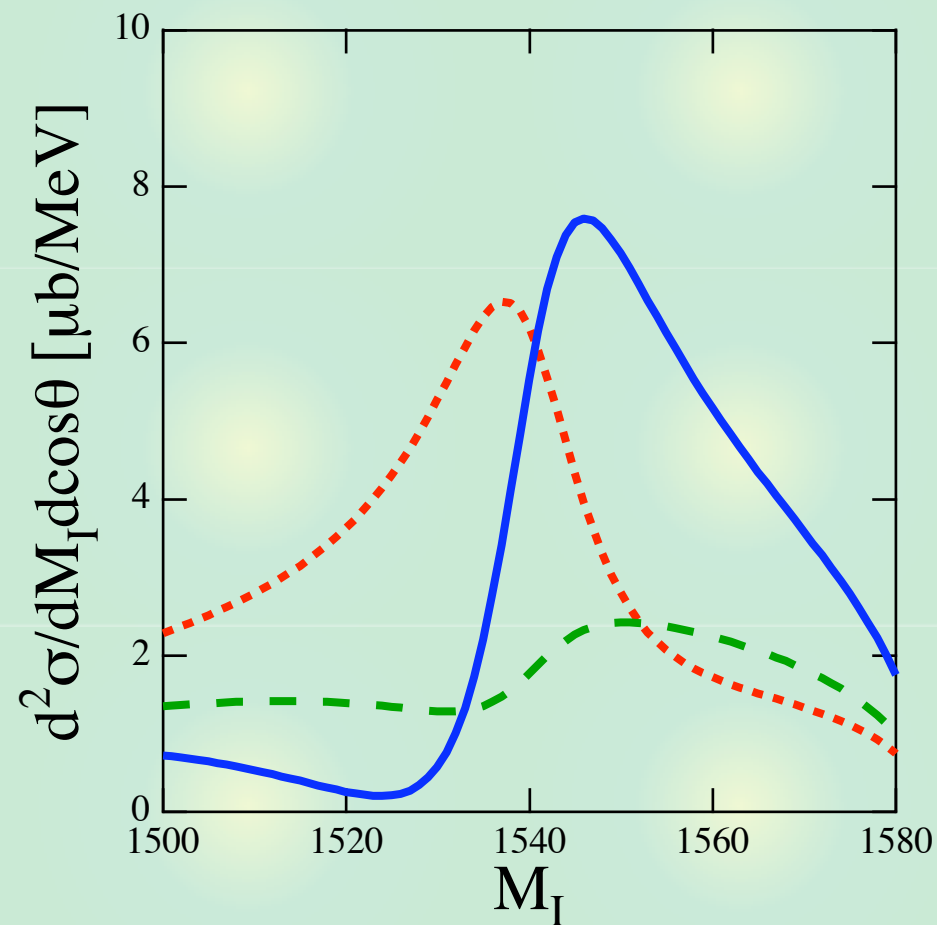
$\pi^+(\sim \mathbf{0})$

$K^+(\mathbf{q}')$

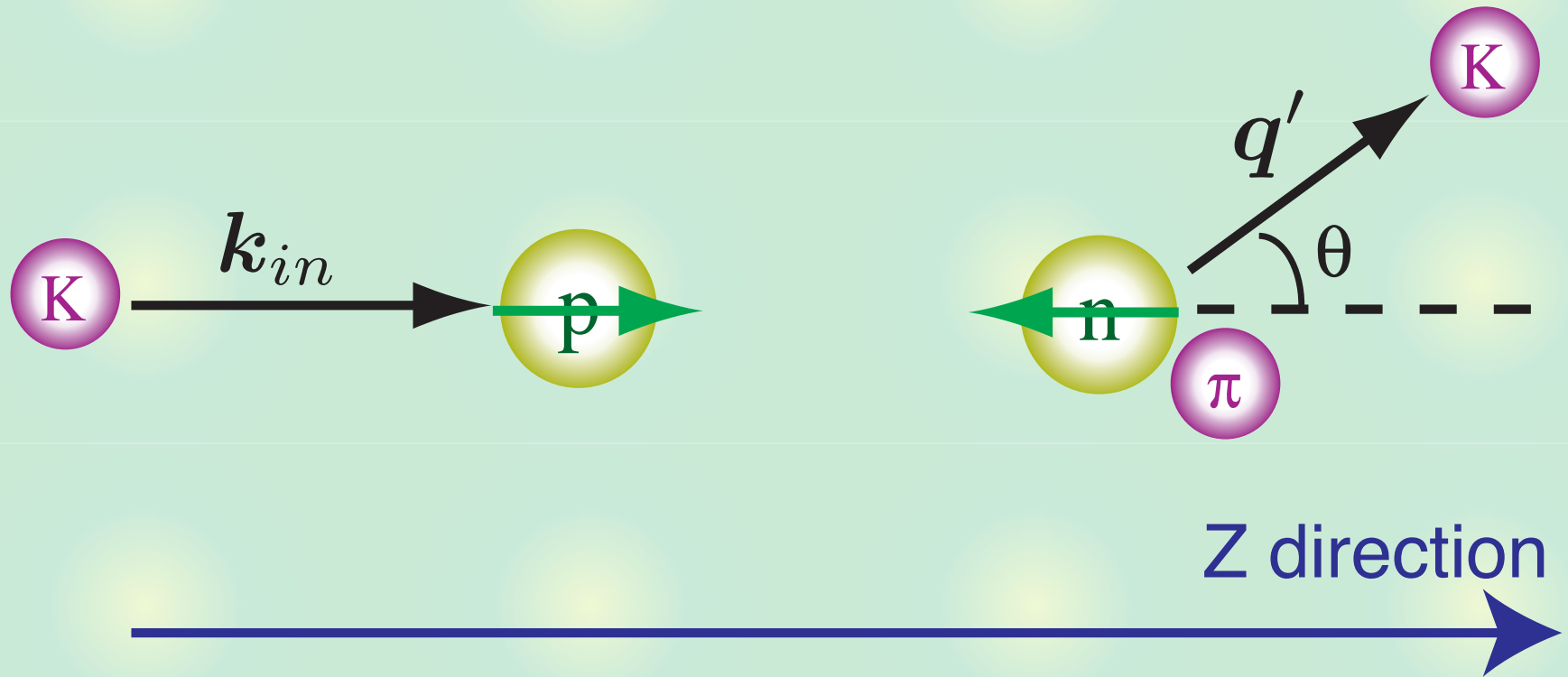


Numerical results : Mass distributions

- $I, J^P = 0, 1/2^-$
- $I, J^P = 0, 1/2^+$ $k_{\text{in}}(\text{Lab}) = 850 \text{ MeV}/c$
- - - $I, J^P = 0, 3/2^+$ $\theta = 0 \text{ deg}$



Numerical results : Polarization test



$$\langle -1/2 | \sigma \cdot k_{in} | 1/2 \rangle = 0$$

$$\langle -1/2 | \sigma \cdot q' | 1/2 \rangle \propto q' \sin \theta$$

Same result is obtained for final pK^0

Numerical results : Mass distributions

--- $I, J^P = 0, 1/2^-$

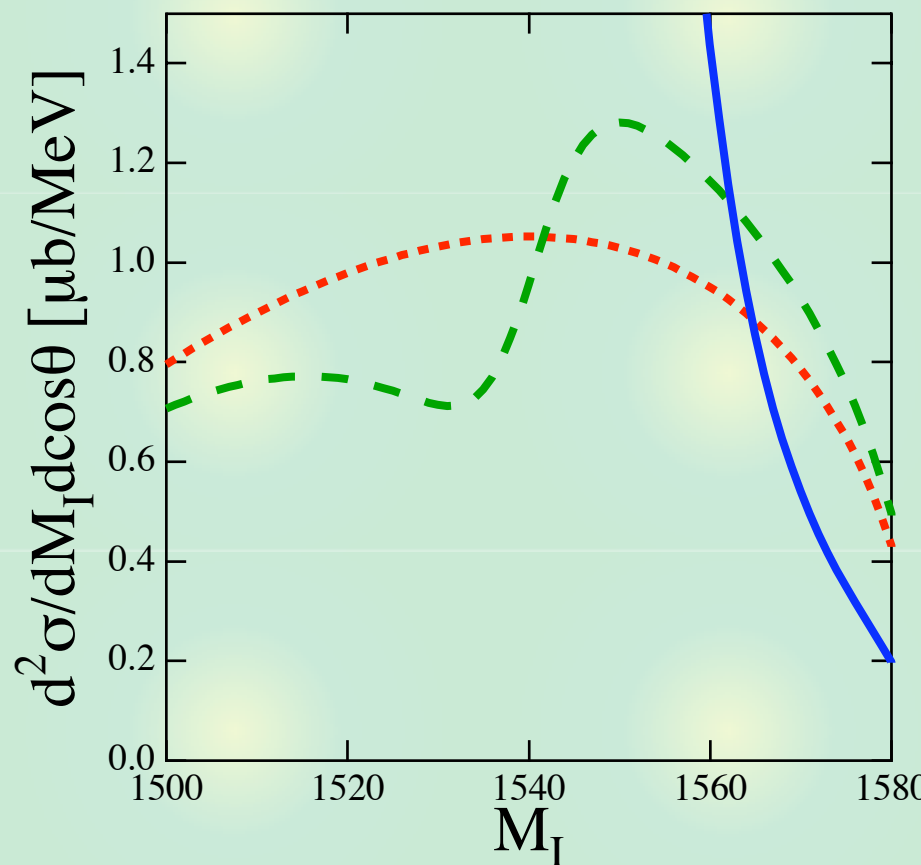
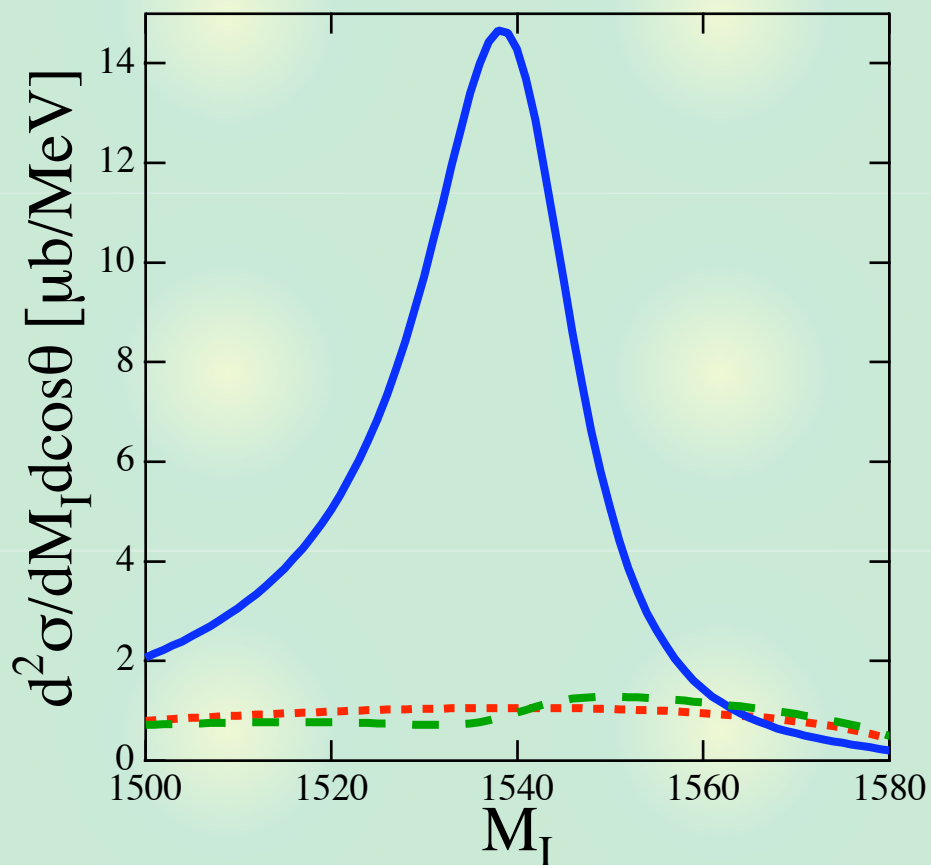
— $I, J^P = 0, 1/2^+$

- - $I, J^P = 0, 3/2^+$

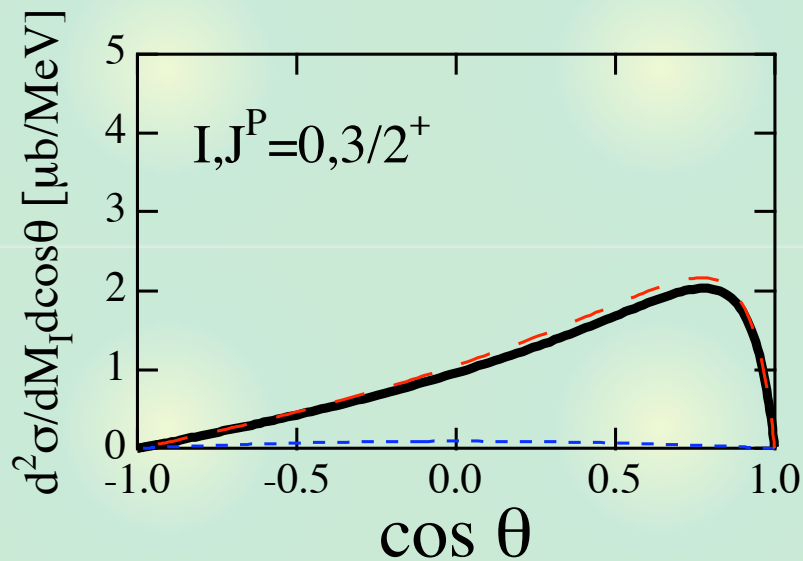
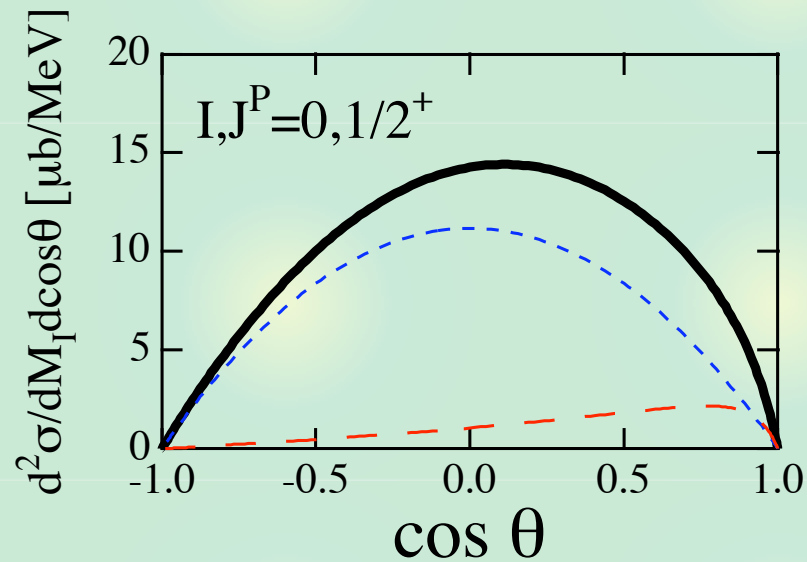
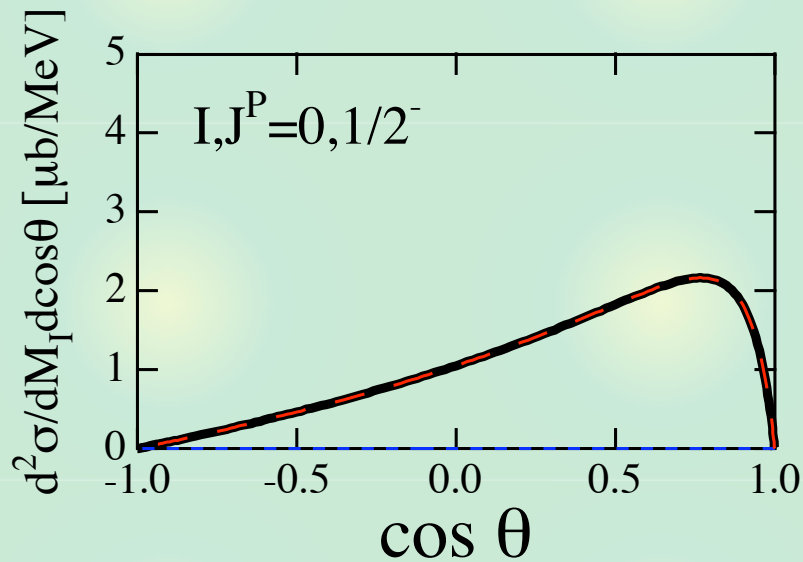
$k_{\text{in}}(\text{Lab}) = 850 \text{ MeV}/c$

$\theta = 90 \text{ deg}$

Polarization test



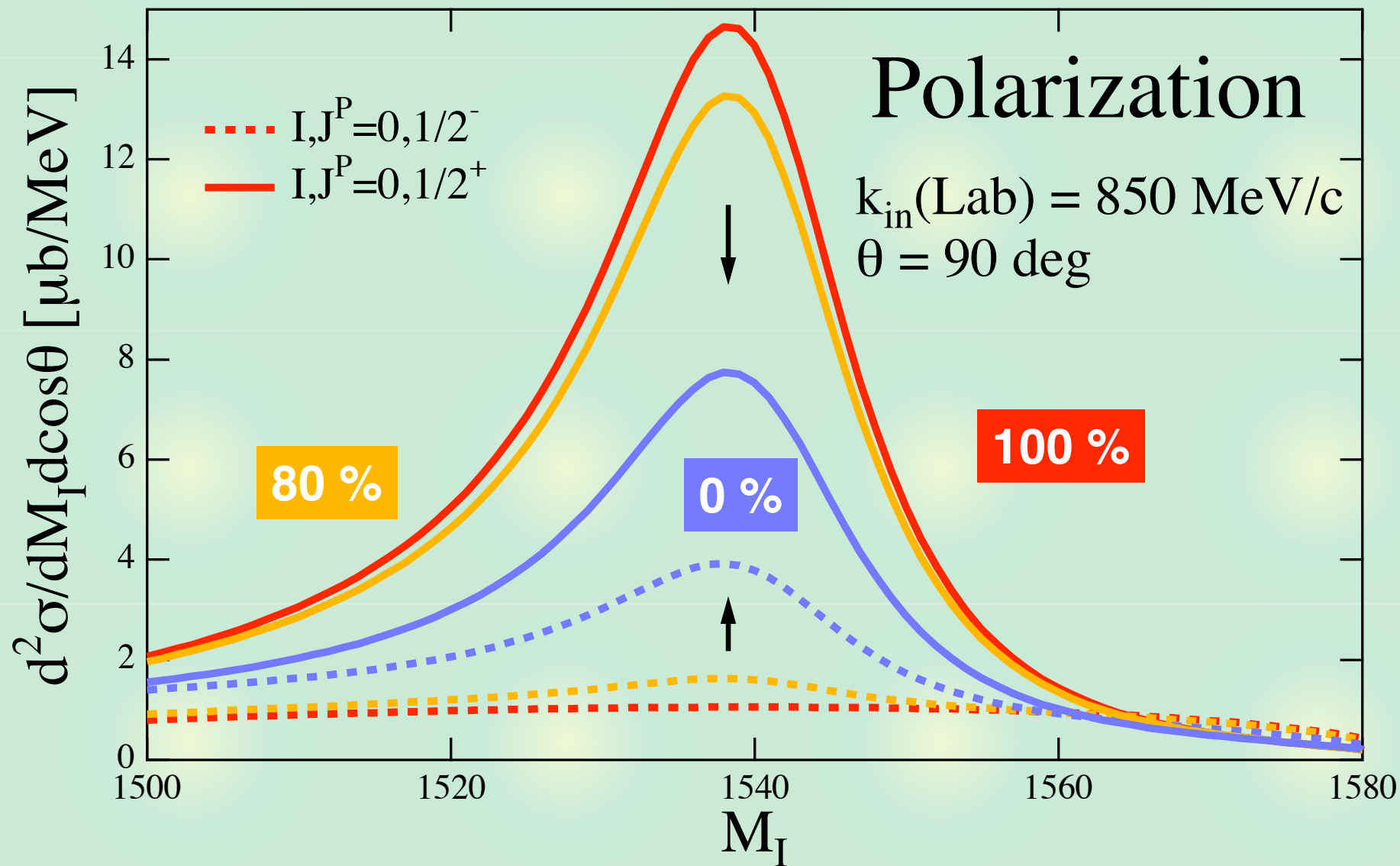
Numerical results : Angular dependence



- total
- - - resonance
- - - background

Polarization test

Numerical results : Incomplete polarization



Conclusion

We calculate the $K^+ p \rightarrow \pi^+ K^+ n$ reaction using a chiral model, assuming the possible quantum numbers of Θ^+ baryon.



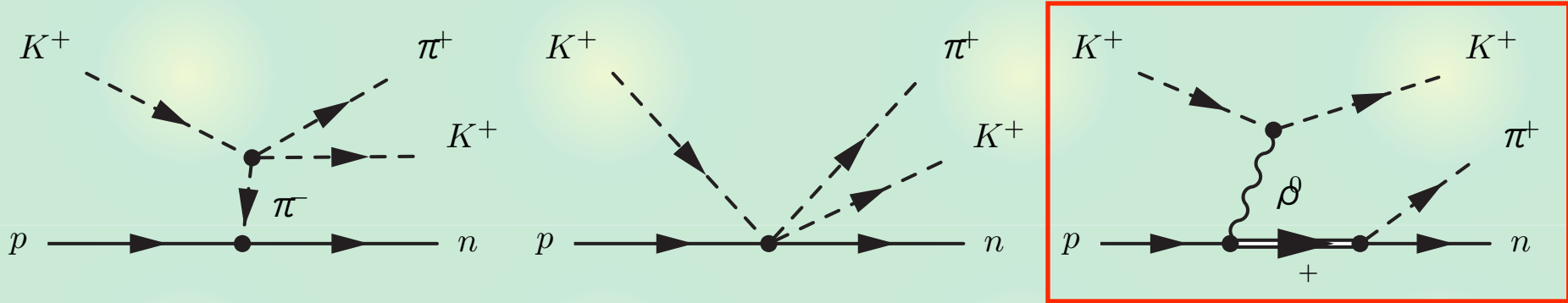
If we find the resonance **in the polarization test**, the quantum numbers of Θ^+ can be determined as **$l=0, J^P=1/2^+$**

T. H., A. Hosaka, E. Oset, Phys. Lett. B579, 290 (2004)

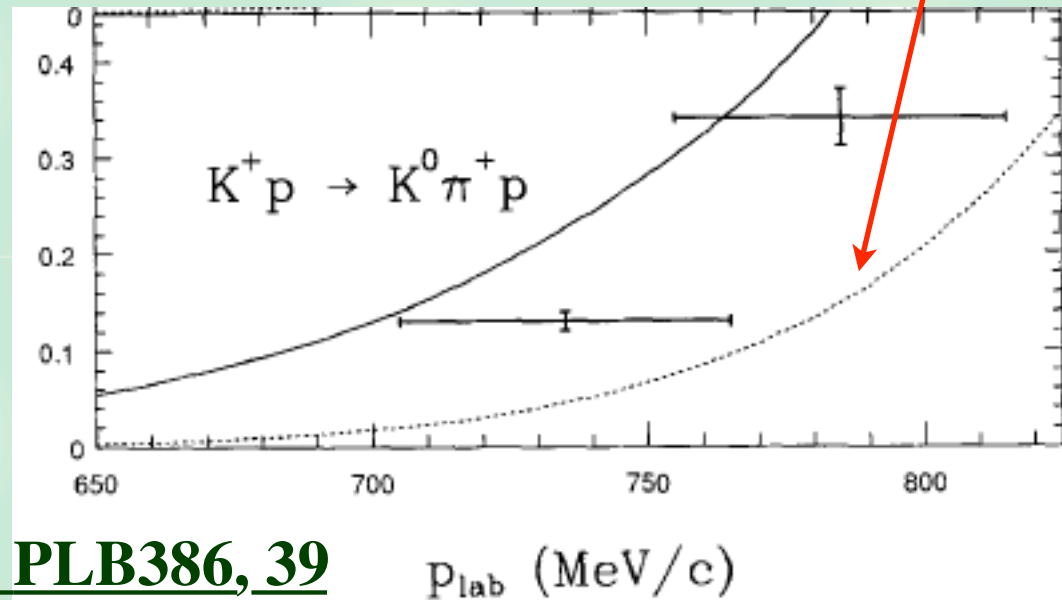
Problems & future work

Problems

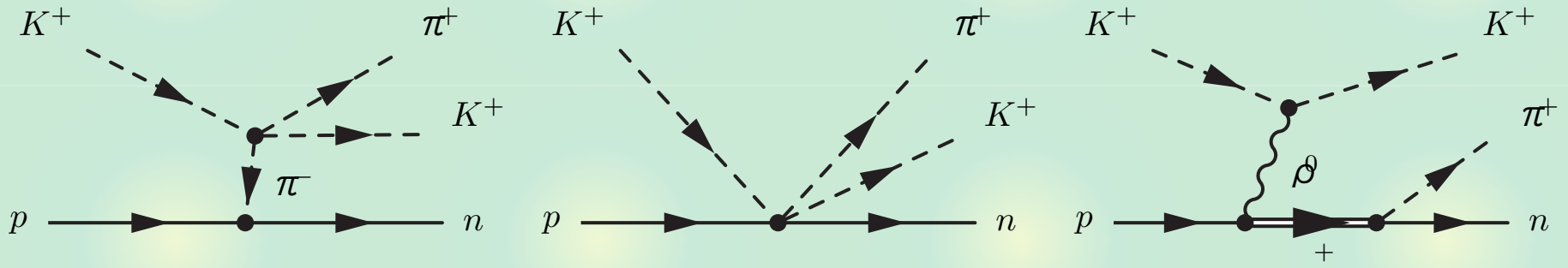
- 0 momentum π
- polarization of final N



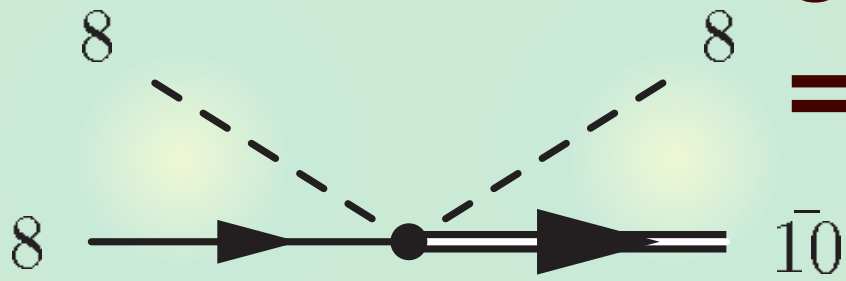
As energy of initial Kaon increases, Δ contribution becomes dominant.



Problems & future work



Resonance terms:



$8 \times 8 \times 8$
 $= \dots + 10 + 10 + 10 + 10 + \dots$
 $\rightarrow 4$ possibilities.

Check the energy at which the Δ contribution masks the Θ^+ structure