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

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Motivation : Spin parity determination

No consensus for spin and parity.
It is important to determine the quantum numbers for further theoretical studies.

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

Motivation : Advantage of hadronic process

We propose

$$K^+ p \rightarrow \pi^+ \Theta^+ \rightarrow \pi^+ K^+ n (K^0 p)$$

- Low energy (p_{cm} ~ 350 MeV)
- Decay is considered -> background estimation
- Hadronic process : clear mechanism
  : cross section ~ 10^2 μb

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

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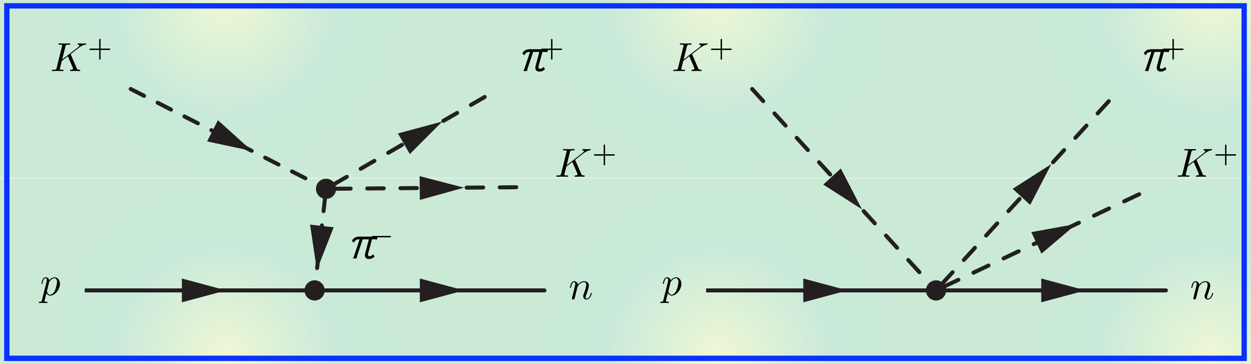
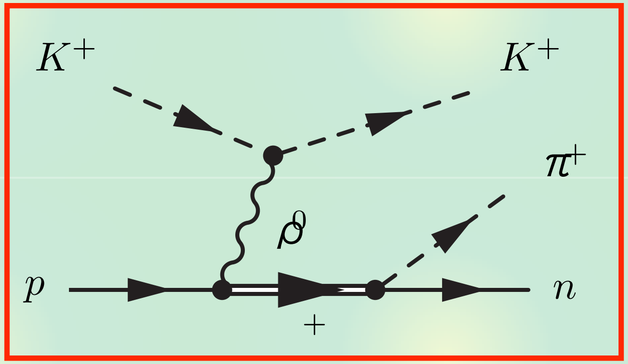
Determination of quantum numbers

Chiral model for the reaction: Background

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

Vertices <- chiral Lagrangian





Dominant

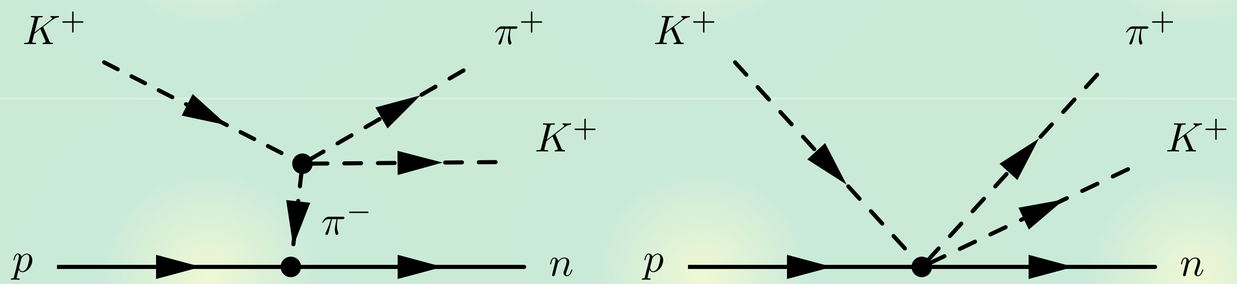
Proportional to $S \cdot p_{\pi^+}$

vanishes

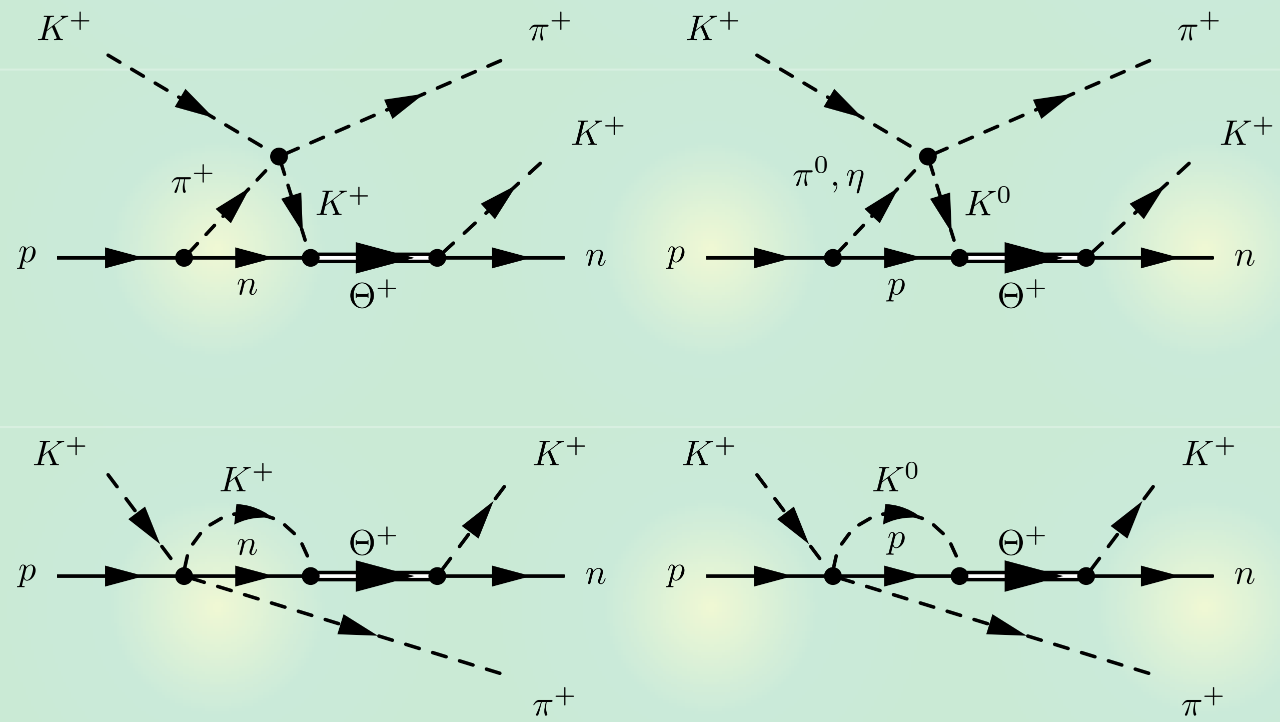
Assume the final π^+ is almost at rest

Chiral model for the reaction: Resonance term

Background (tree level)



Resonance (one loop)



Spin and parity : KN -> Θ -> KN

- M_R = 1540 MeV
- Γ_R = 20 MeV

1/2⁻ (KN s-wave resonance)

1/2⁺ , 3/2⁺ (KN p-wave resonance)

$$t^{(s)}_{K^+n(K^0p)\to K^+n} = \frac{(\pm) g^2_{K^+n}}{M_I - M_R + i\Gamma/2}$$

$$t^{(p,1/2)}_{K^+n(K^0p)\to K^+n} = \frac{(\pm) \bar{g}^2_{K^+n} (\boldsymbol{\sigma}\cdot\boldsymbol{q}')(\boldsymbol{\sigma}\cdot\boldsymbol{q})}{M_I - M_R + i\Gamma/2}$$

$$t^{(p,3/2)}_{K^+n(K^0p)\to K^+n} = \frac{(\pm) \tilde{g}^2_{K^+n} (\boldsymbol{S}\cdot\boldsymbol{q}')(\boldsymbol{S}^\dagger\cdot\boldsymbol{q})}{M_I - M_R + i\Gamma/2}$$

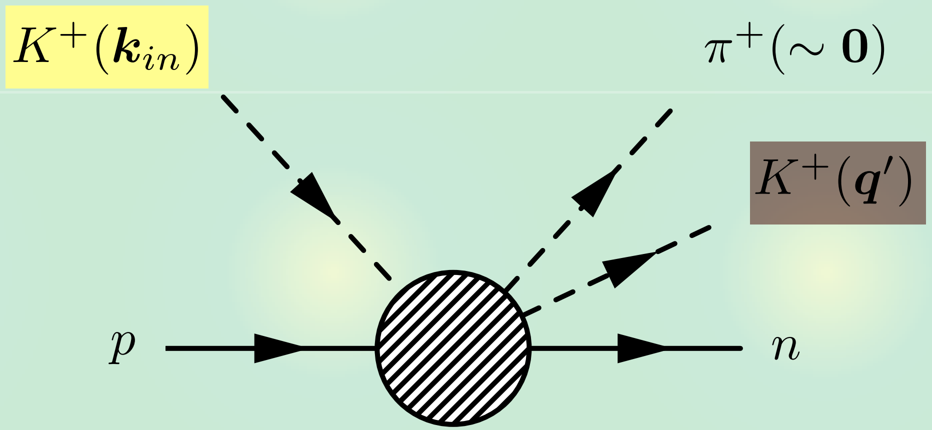
$$g^2_{K^+n} = \frac{\pi M_R \Gamma}{M q}, \quad \bar{g}^2_{K^+n} = \frac{\pi M_R \Gamma}{M q^3}, \quad \tilde{g}^2_{K^+n} = \frac{3\pi M_R \Gamma}{M q^3}.$$

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

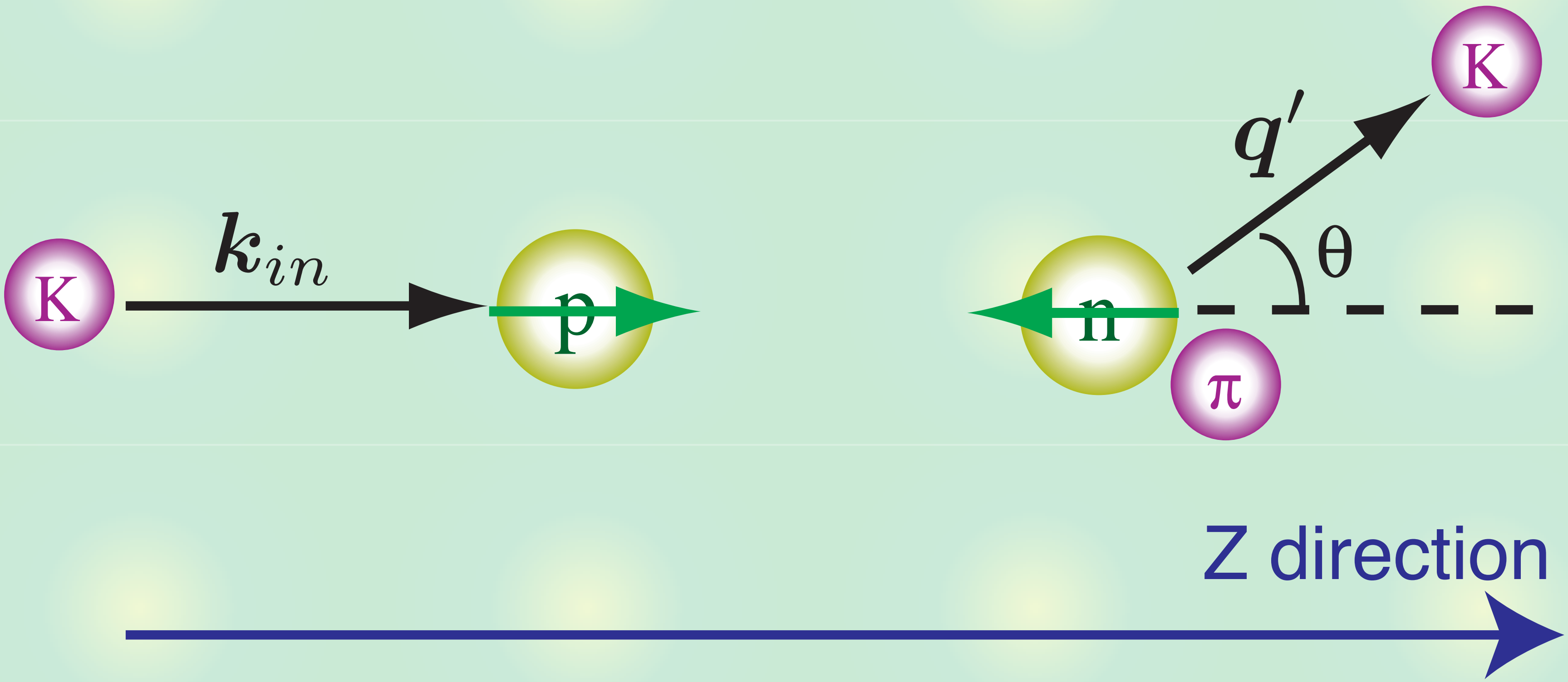
$$-i\tilde{t}_i^{(s)} = \frac{g_{K^+n}^2}{M_I - M_R + i\Gamma/2}\left\{G(M_I)(a_i + c_i) - \frac{1}{3}\bar{G}(M_I)b_i\right\}\boldsymbol{\sigma}\cdot\boldsymbol{k}_{in}S_I(i)$$

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

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



Numerical results : Polarization test



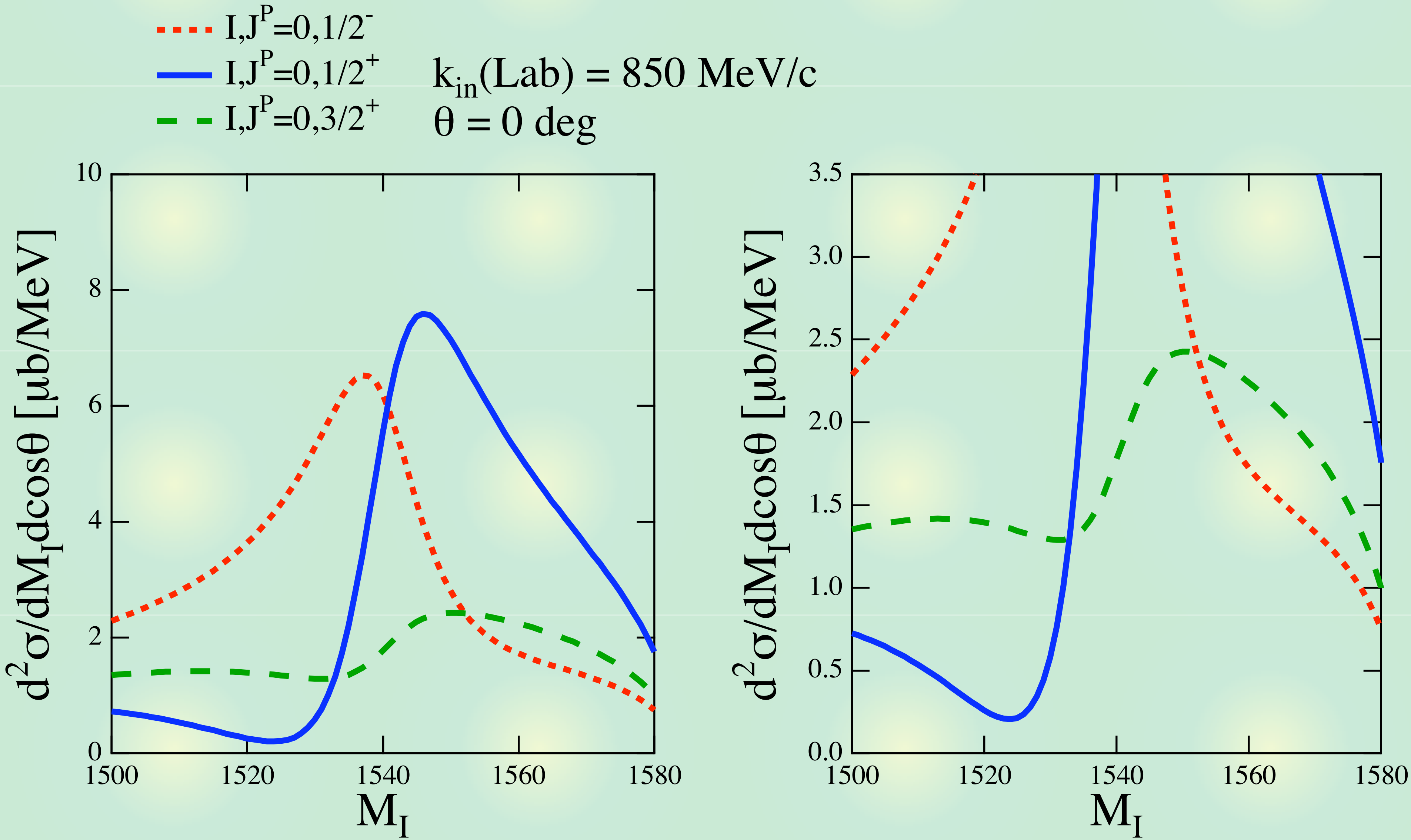
$$\langle -1/2 | \boldsymbol{\sigma} \cdot \boldsymbol{k}_{in} | 1/2 \rangle = 0$$

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

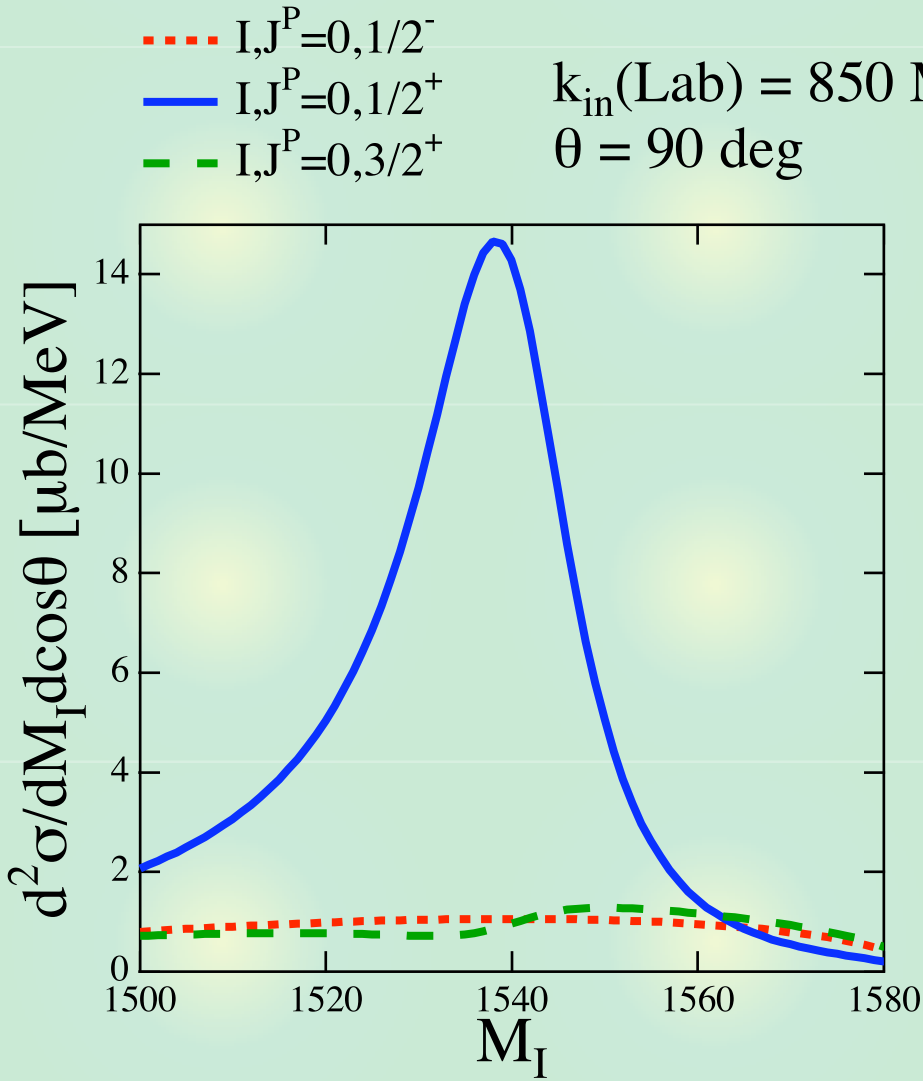
 # Same result is obtained for final pK^0

Production 1 : $K^+ p \rightarrow \pi^+ K^+ n$

Numerical results : Mass distributions

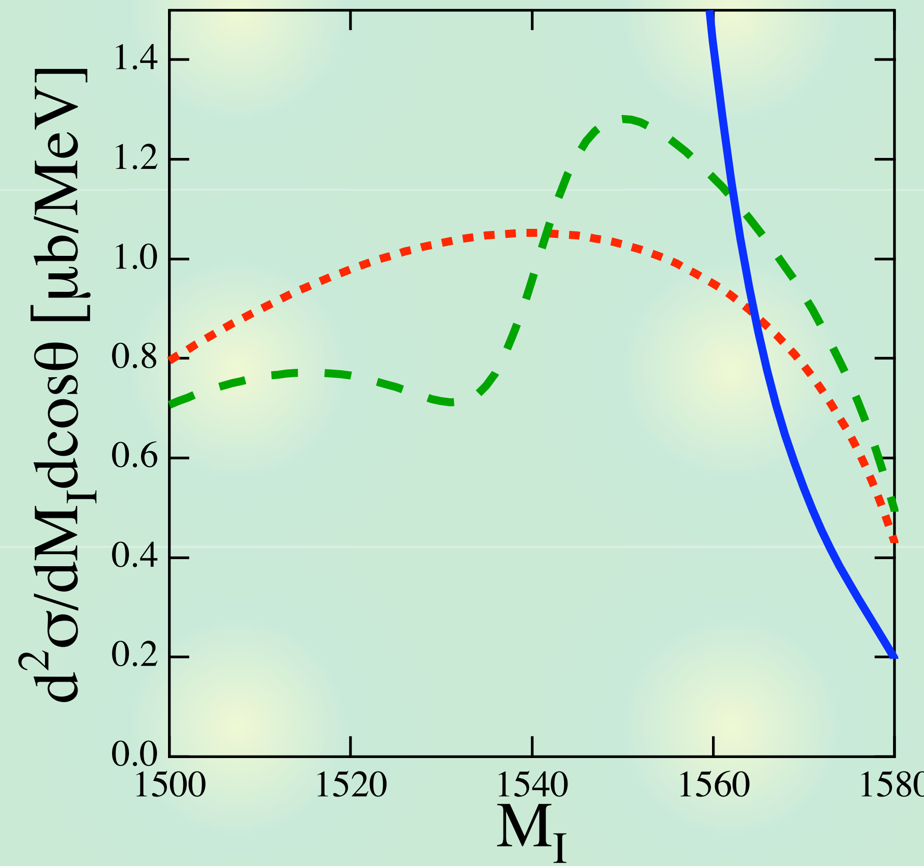


Numerical results : Mass distributions

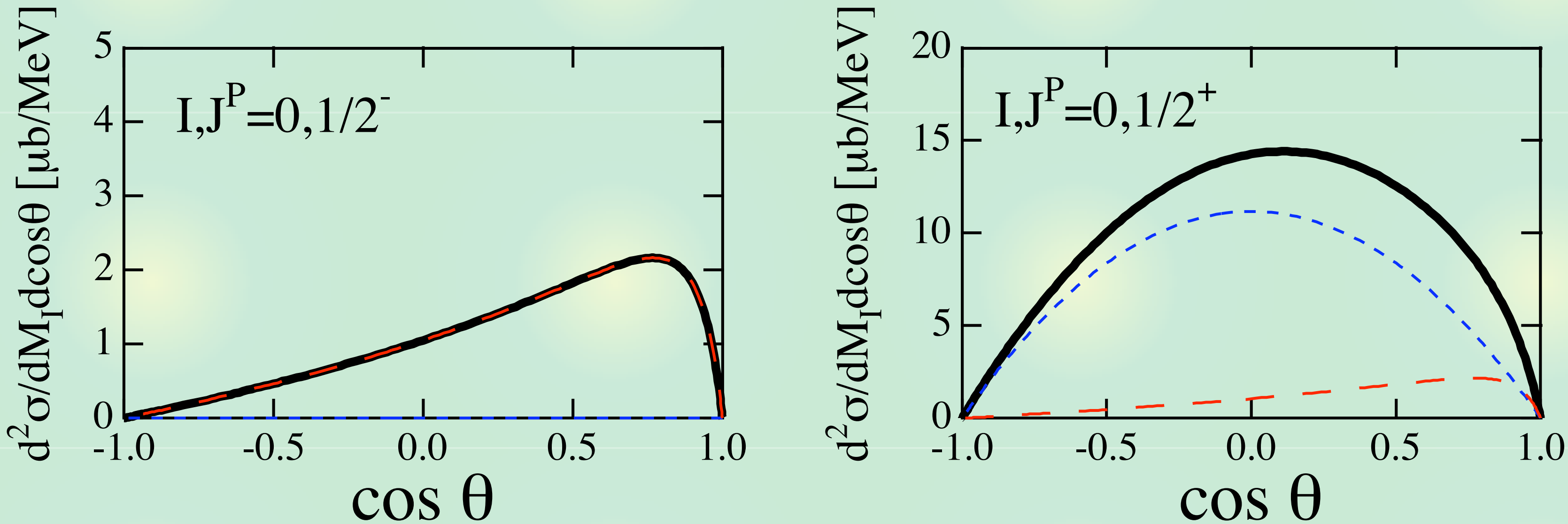


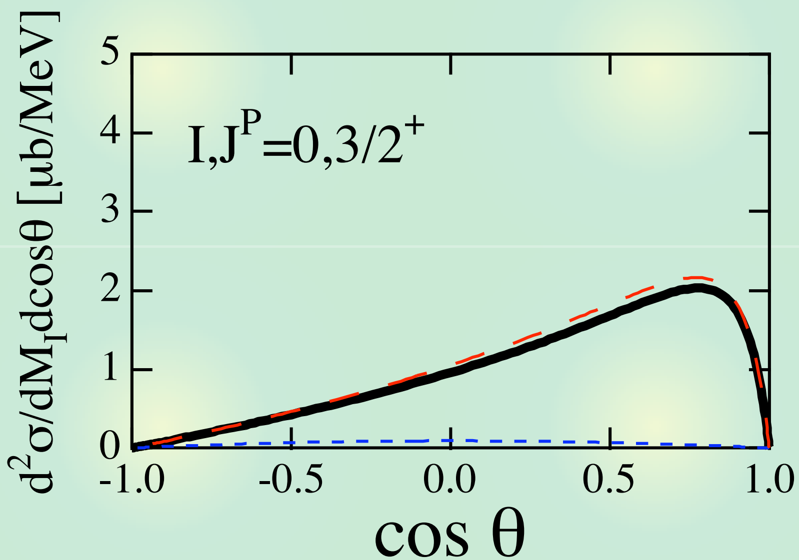
k_{in}(Lab) = 850 MeV/c
θ = 90 deg

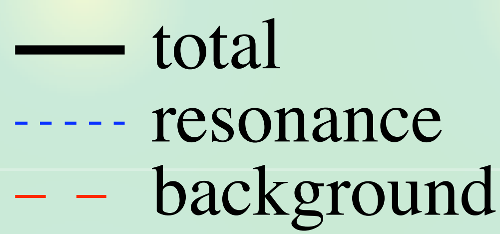
Polarization test



Numerical results : Angular dependence

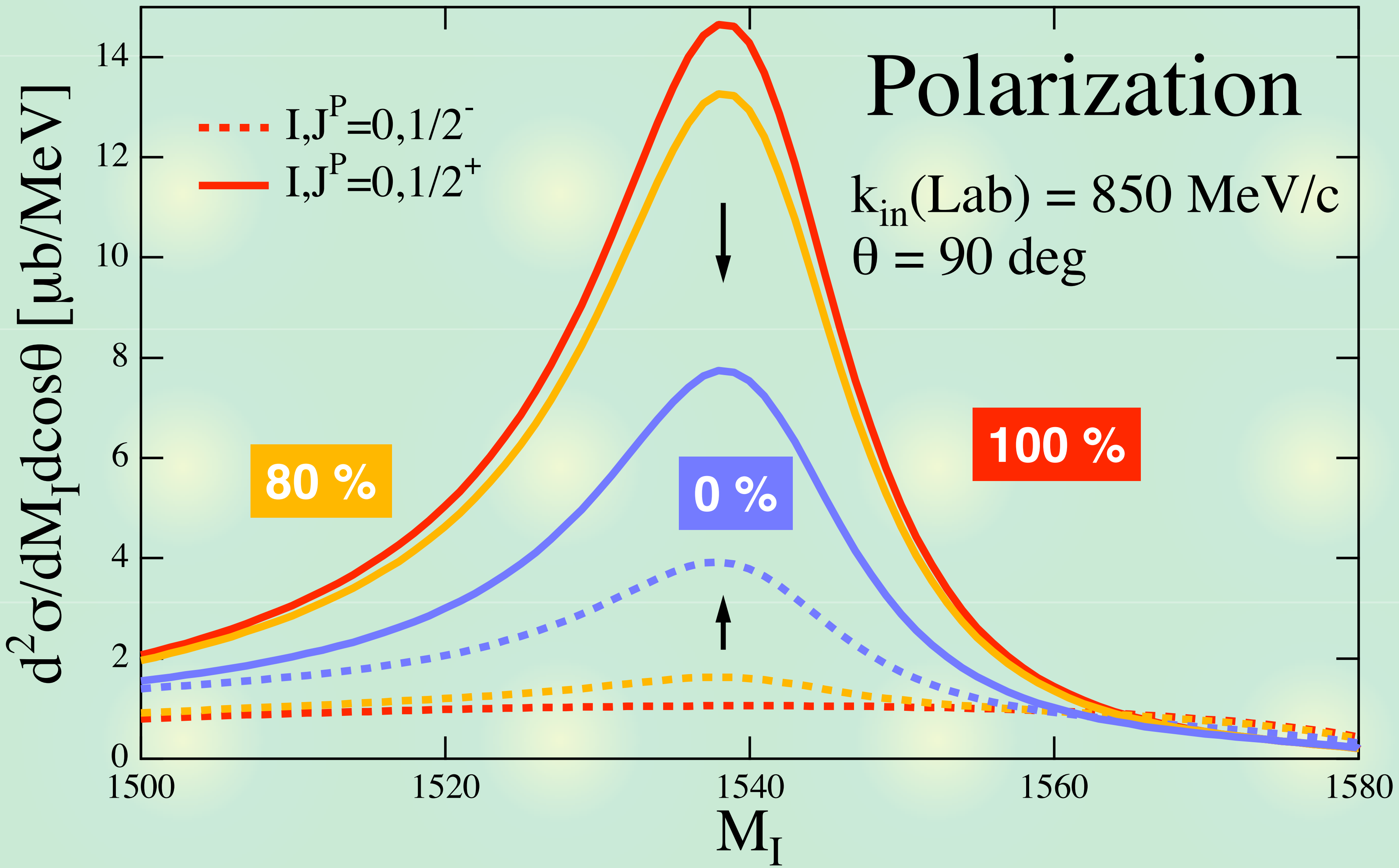






Polarization test

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

T. Hyodo, *et al.*, Phys. Lett. B579, 290-298 (2004)
E. Oset, *et al.*, nucl-th/0312014, Hyp03 proceedings