Determining the Θ^+ quantum numbers through the $K^+p \rightarrow \Theta^+K^+n$ reaction

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Introduction

□$^+$: 5-quark (4 quark + 1 anti-quark)

LEPS, T. Nakano *et al.*, Phys. Rev. Lett. 91 (2003) 012002

Quantum numbers are not yet determined

Theory prediction

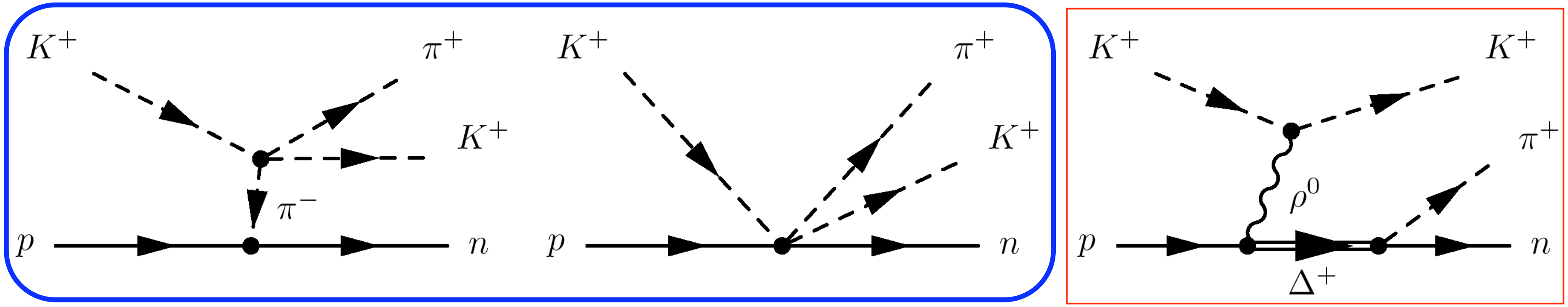
Diakonov *et al.*	(chiral quark soliton)	: $1/2^+$, I=0
Carlson *et al.*	(quark model[QM])	: $1/2^□$, I=0
Stancu *et al.*	(QM + flavor-spin int.)	: $1/2^+$, I=0
Zhu (QCD sum rule)		: $1/2^□$, I=0, 1, 2
Capstick *et al.*	(decay width analysis)	: $1/2^□$, $3/2^□$, $5/2^□$, I=2

We study K^+p -> □$^+K^+n$ reaction to determine the quantum numbers of □$^+$

A model for □□p -> K^0□□

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

Vertices are derived from the chiral Lagrangian



Proportional to $\boldsymbol{S} \cdot \boldsymbol{p}_{\pi^+}$

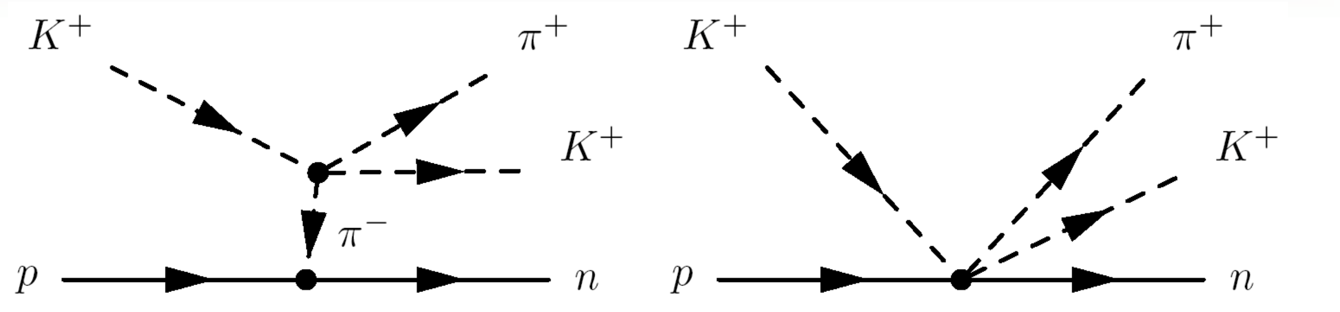
Dominant

vanishes

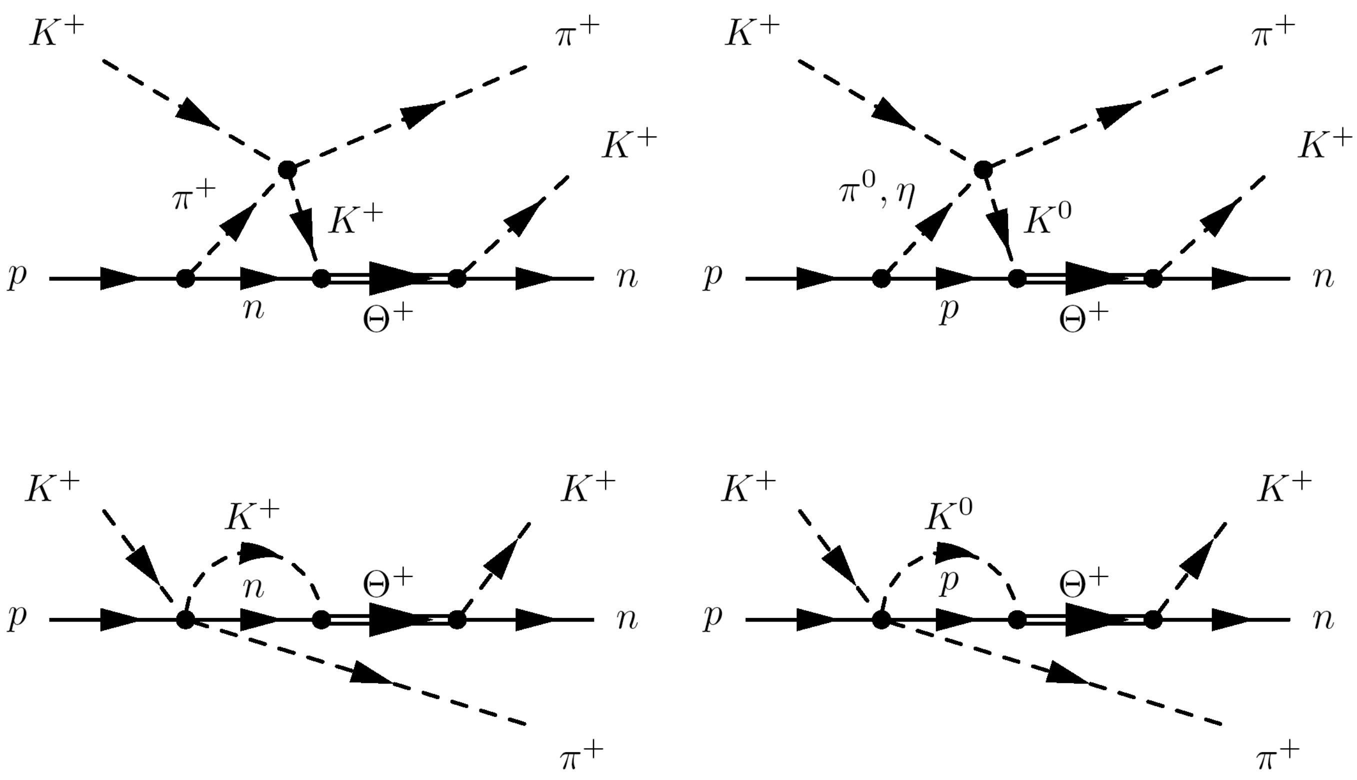
Assume final □+ is almost at rest

Diagrams

Tree level (background)



One loop



Possibilities of spin & parity

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

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

M_R = 1540 MeV

Γ = 20 MeV

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

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

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

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

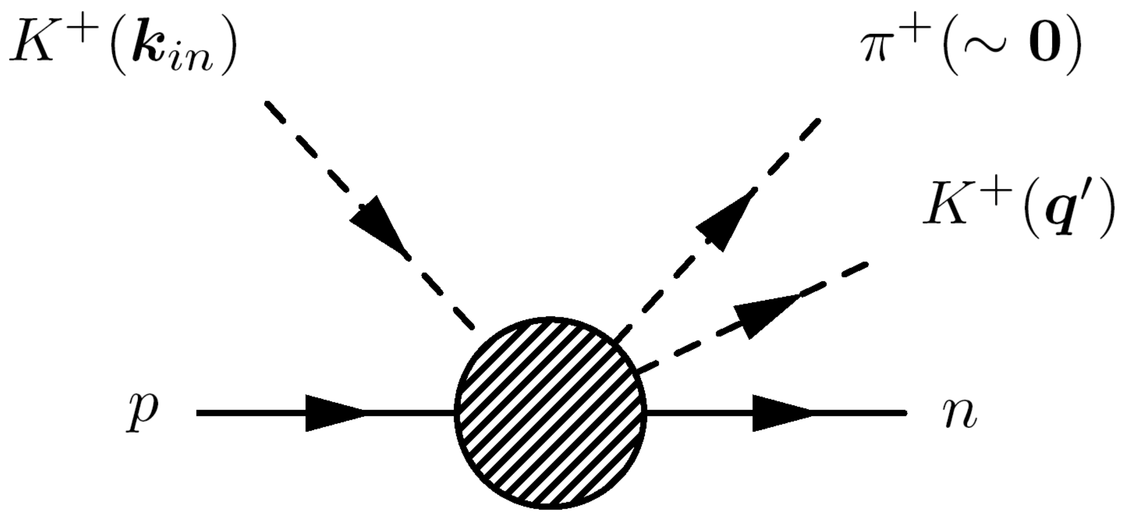
Resonance term

Amplitude of resonance term for K^+p -> □$^+K^+n$:

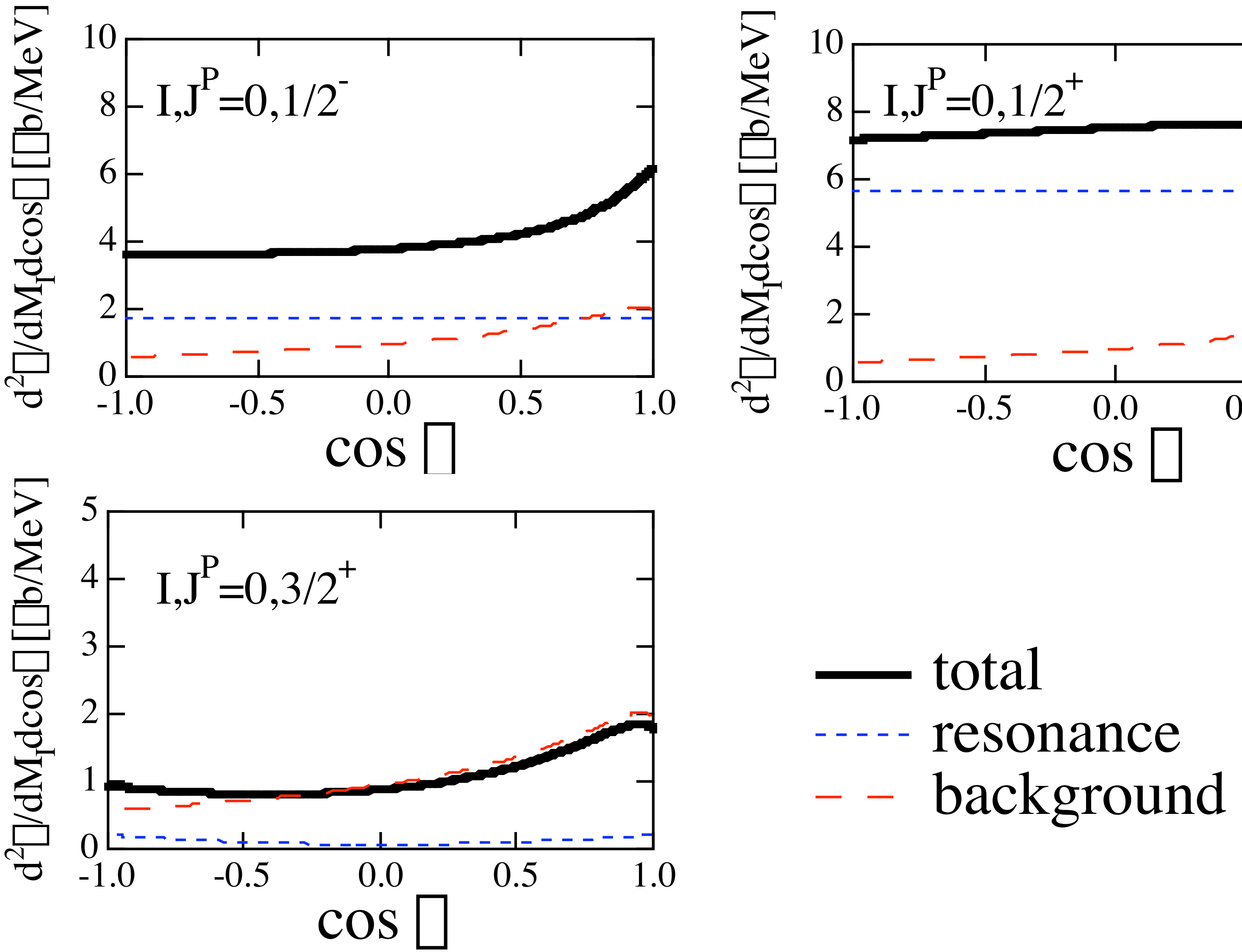
$$-\tilde{t}_i^{(s)} = \frac{g_{K^+n}^2}{M_I - M_R + i\Gamma/2} \left\{ G(M_I)(a_i + c_i) - \frac{1}{3}\bar{G}(M_I) b_i \right\} \boldsymbol{\sigma} \cdot \boldsymbol{k}_{in} S_I(i) ,$$

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

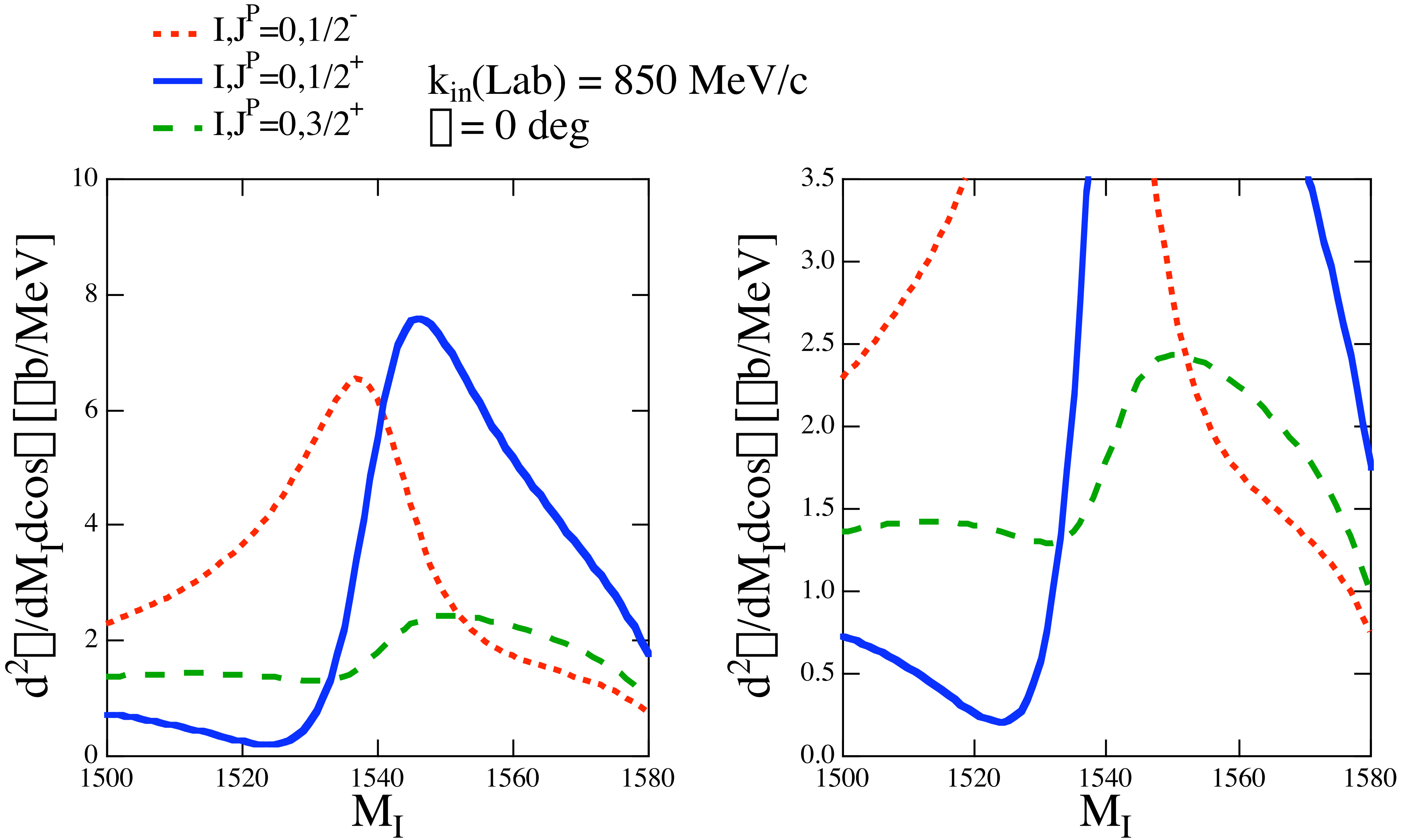
$$-\tilde{t}_i^{(p,3/2)} = \frac{\tilde{g}_{K^+n}^2}{M_I - M_R + i\Gamma/2} \bar{G}(M_I) \frac{1}{3} b_i \left\{ (\boldsymbol{k}_{in} \cdot \boldsymbol{q}')(\boldsymbol{\sigma} \cdot \boldsymbol{k}_{in}) - \frac{1}{3} \boldsymbol{k}_{in}^2 \boldsymbol{\sigma} \cdot \boldsymbol{q}' \right\} S_I(i)$$



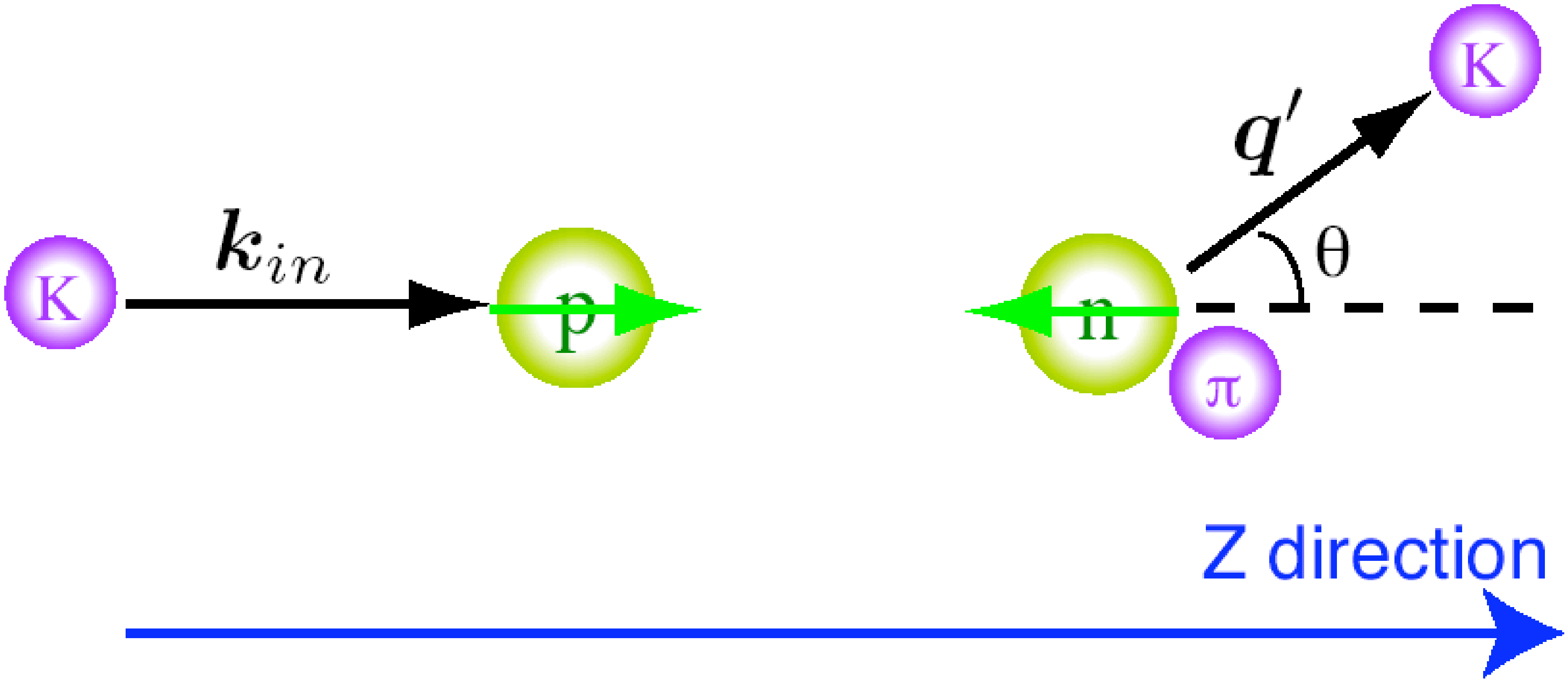
Angular dependence



Mass distributions



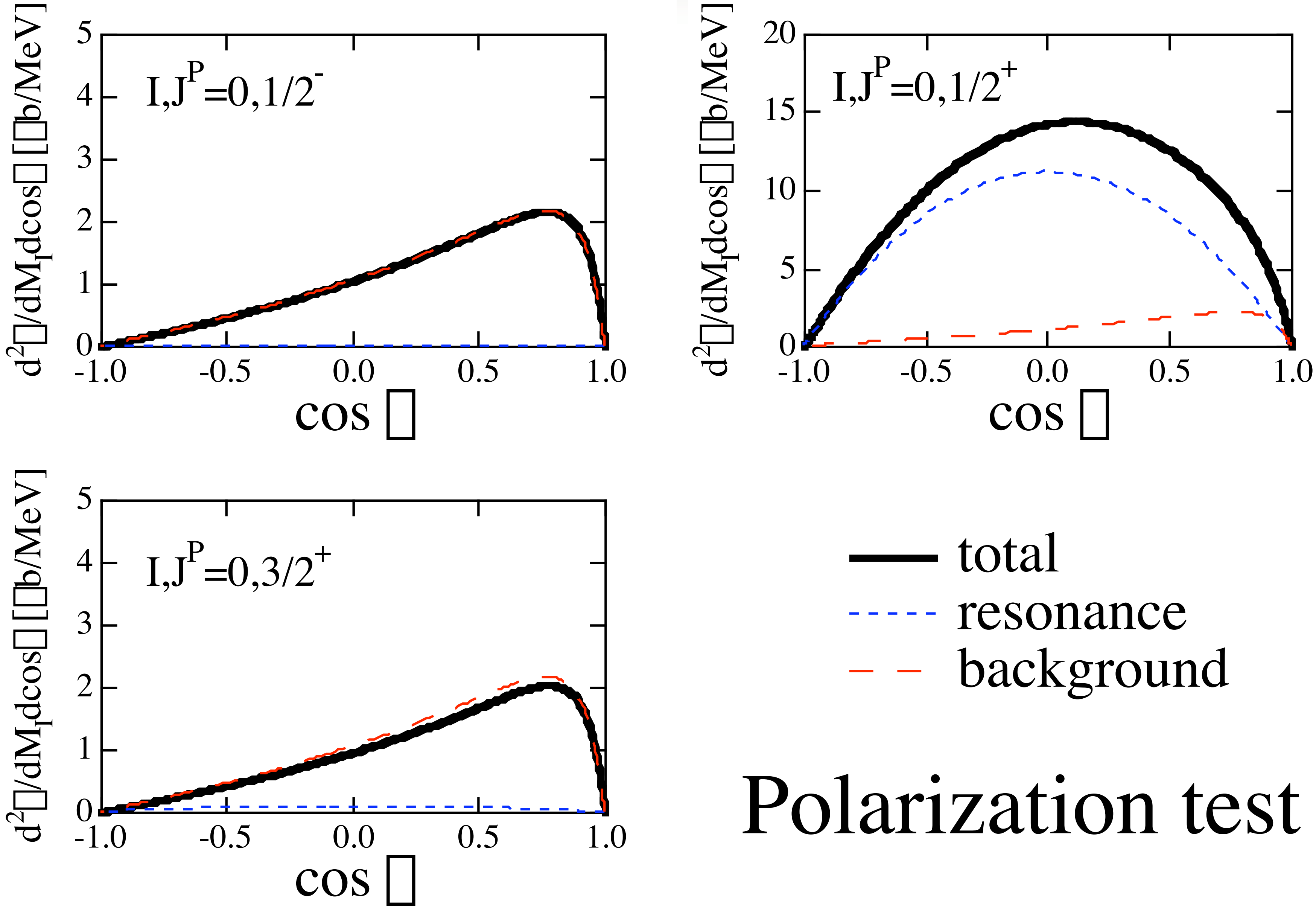
Polarization test



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

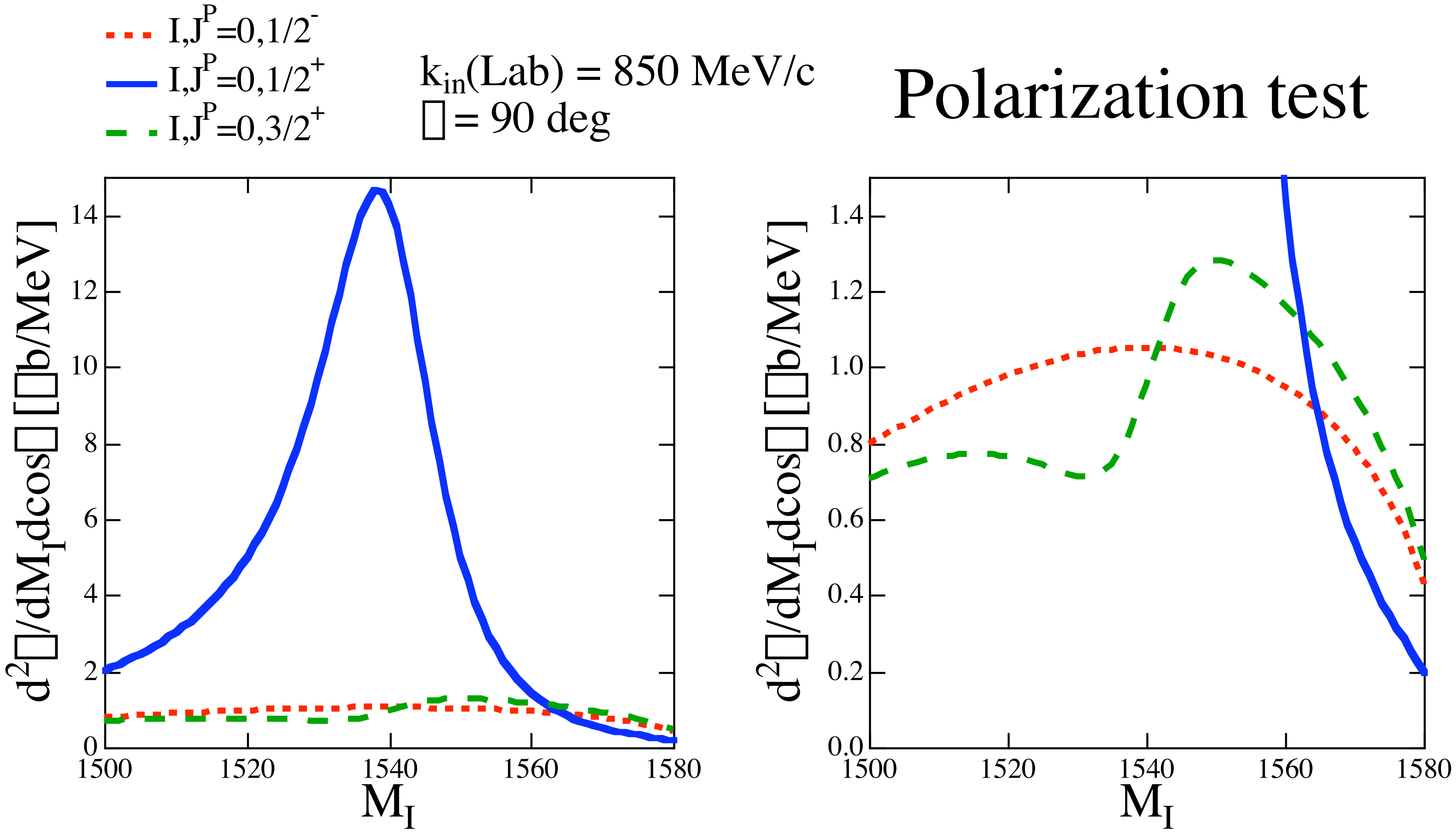
$$\langle -1/2|\boldsymbol{\sigma}\cdot\boldsymbol{q}'|1/2\rangle \propto q'\sin\theta$$

Angular dependence : polarization test



Polarization test

Mass distributions : polarization test



Conclusions

We calculate the □$^{□}$p -> K^0□□ reaction using a chiral model, assuming the possible **quantum numbers of □$^+$ baryon**.

- Resonance signal of the mass distribution is always seen in the forward direction.

- If we find the resonance **with polarization test,** the quantum number of □$^+$ can be determined as **I=0, J^P=1/2$^+$**

T. Hyodo, A. Hosaka, and E. Oset, nucl-th/0307105