Meson-induced pentaquark productions

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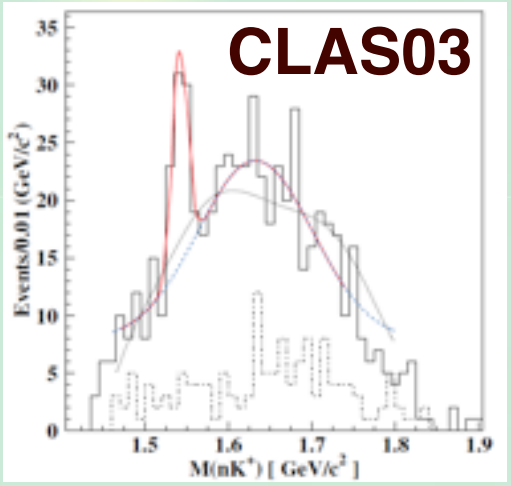
Pentaquark Θ+

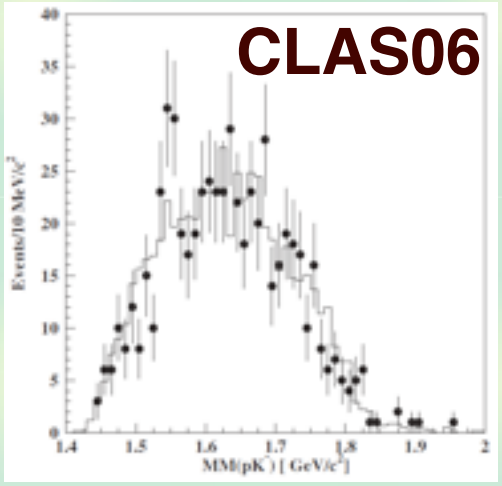
Θ+ : strangeness S = +1**, baryon number** B = 1

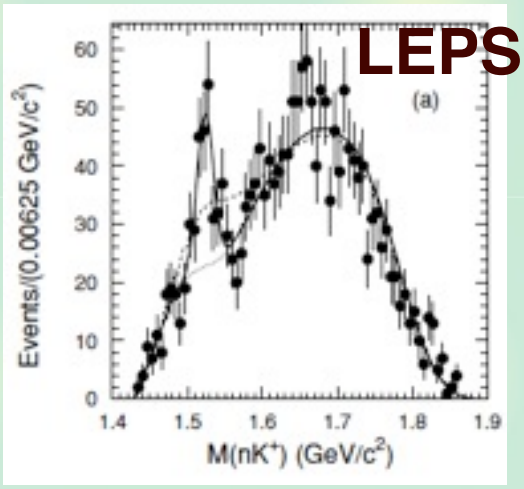
minimal quark content ~ uudd$\bar{s}$ **: exotic!**

T. Hyodo, Doctoral Thesis (2006)

γd --> K+K-pn **reaction**







New results from LEPS

Y. Kato, Talk at FB20

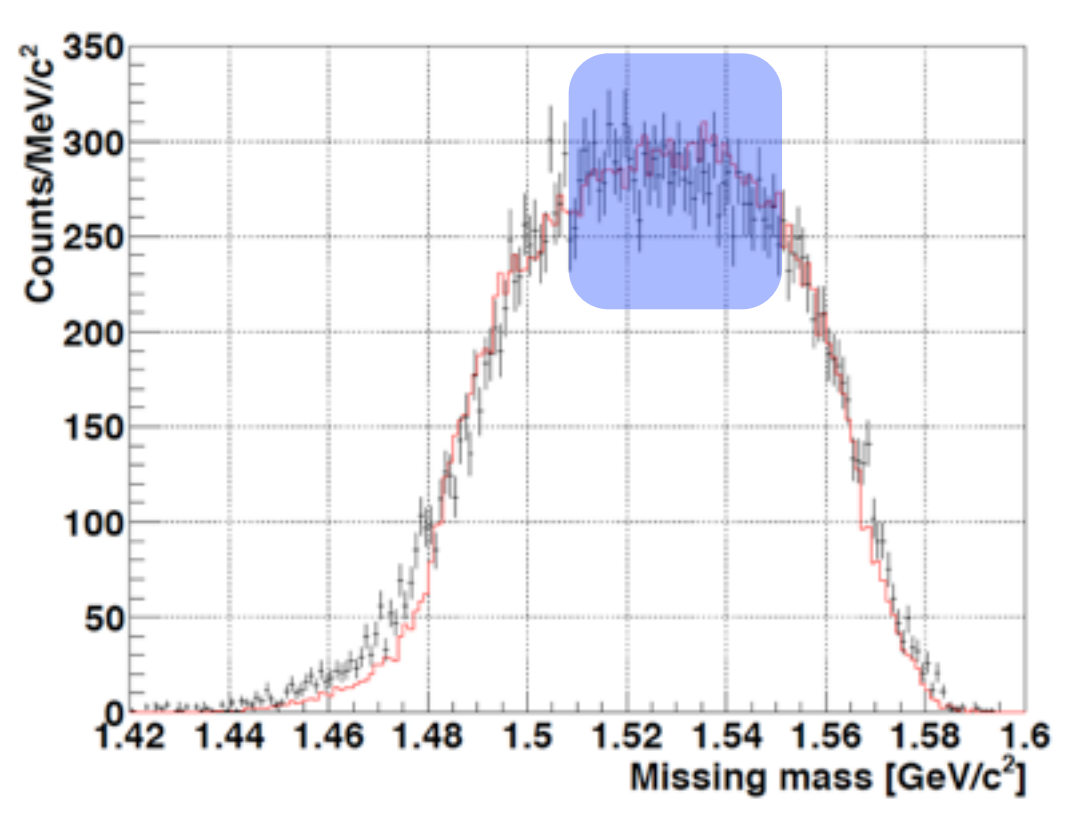
- K+, K- **detected. momentum of** n **is determined by MMSA.**
- **significance of the peak in new data: 1.6-1.9 σ**
- **event selection by start counter: peak grows**

Experiment at J-PARC

J-PARC E19: π-p --> K-X, first result from J-PARC hadron hall

K. Shirotori, *et al.*, arXiv:1203.3604 [nucl-ex], Phys. Rev. Lett. in print;

12pSL-10 M. Moritsu, *et al.*,



- Cross section < 0.26 μb/sr

Impact on the existence of Θ⁺? --> theoretical analysis

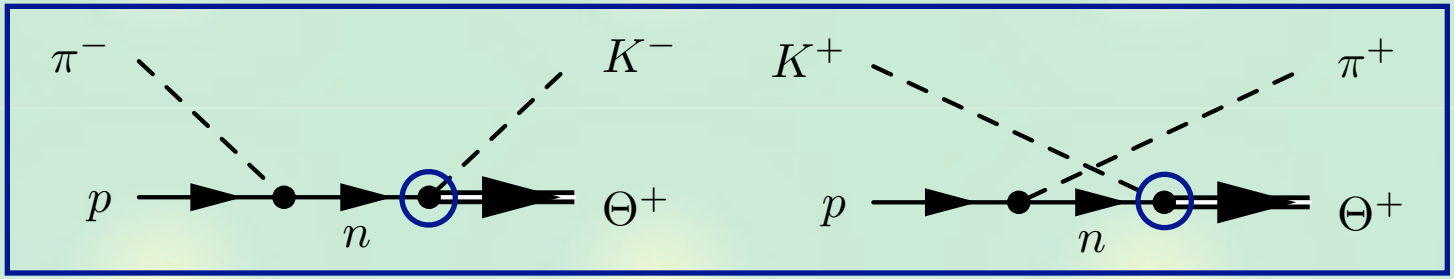
Theoretical study of reactions

Meson-induced Θ+ production: relatively simple

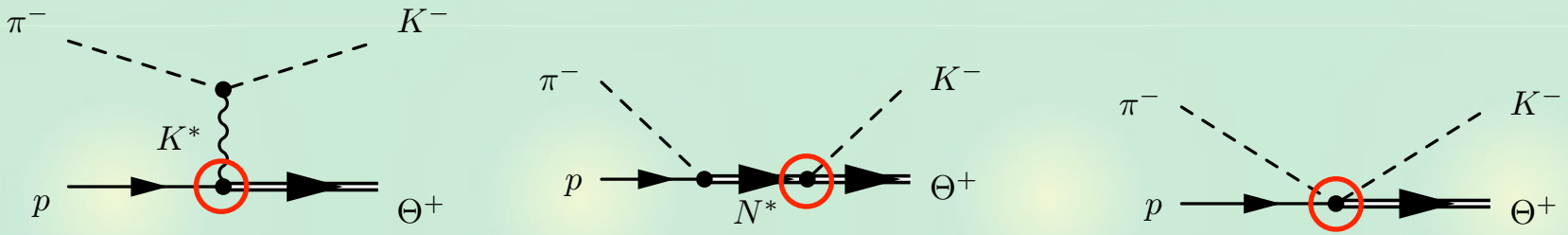
Effective Lagrangian approach --> upper limit of Γ_Θ

We examine isospin I=0, spin-parity J^P=1/2±, 3/2± cases.

- Born terms (must exist if Θ+ decays into KN)



- Other possible contributions: unknown couplings



Born terms only--> σ is proportional to Γ_Θ

Interference with other contributions

Our aim: upper limit of cross section --> upper limit of Γ_Θ

- Destructive interference --> underestimation

$$\sigma \propto |T_{\mathrm{Born}}|^2 = \left|\bar{T}_{\mathrm{Born}}\sqrt{\Gamma_\Theta}\right|^2 < 1$$

1

$$\sigma \propto \left|\bar{T}_{\mathrm{Born}}\sqrt{\Gamma_\Theta} + T_{\mathrm{other}}\right|^2 < 1$$

10 **-9**

Interference pattern in general depends on the reaction.

- Negative result in various low energy reactions
(π-p --> K-X, K+p --> π+X, pp --> Σ+X, γp --> K^{0}X, **...)**

It is unnatural that all the negative results are explained by destructive interference.

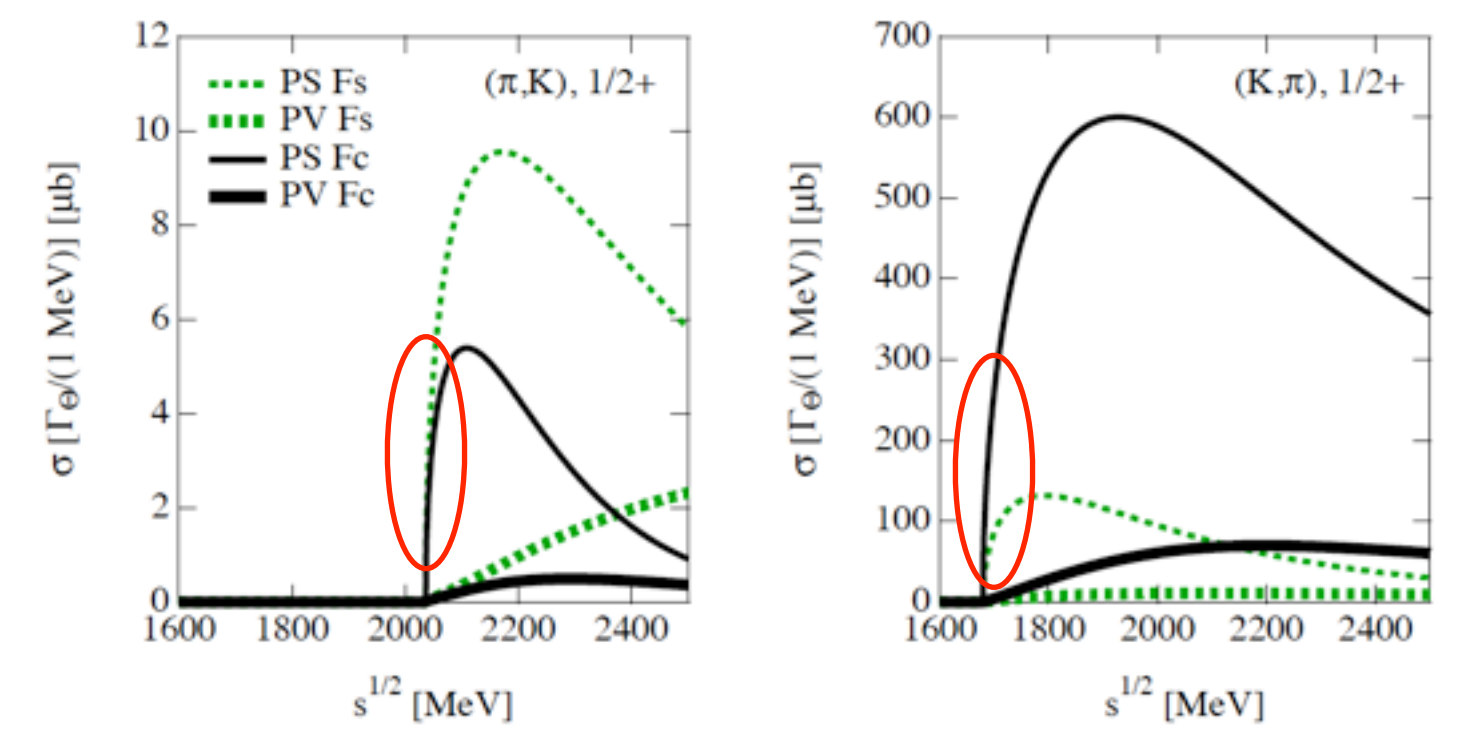
--> Born diagrams will provide a conservative upper limit.

Total cross sections

Theoretical uncertainties:

- two schemes of meson-baryon coupling (PV, PS)
- two types of hadron form factor (Fs, Fc)

Total cross sections with $J^P=1/2+$ case (Γ_Θ = 1 MeV)



- Threshold behavior of PS is different from PV.
  --> chiral low energy theorem

Total cross sections for various quantum numbers

Upper limit in experiments (isotropic production)

- **J-PARC E19:** π-p --> K-X **σ ≲ 10^{-1} μb**
- **KEK E559:** K+p --> π+X **σ ≲ 10^{0} μb**

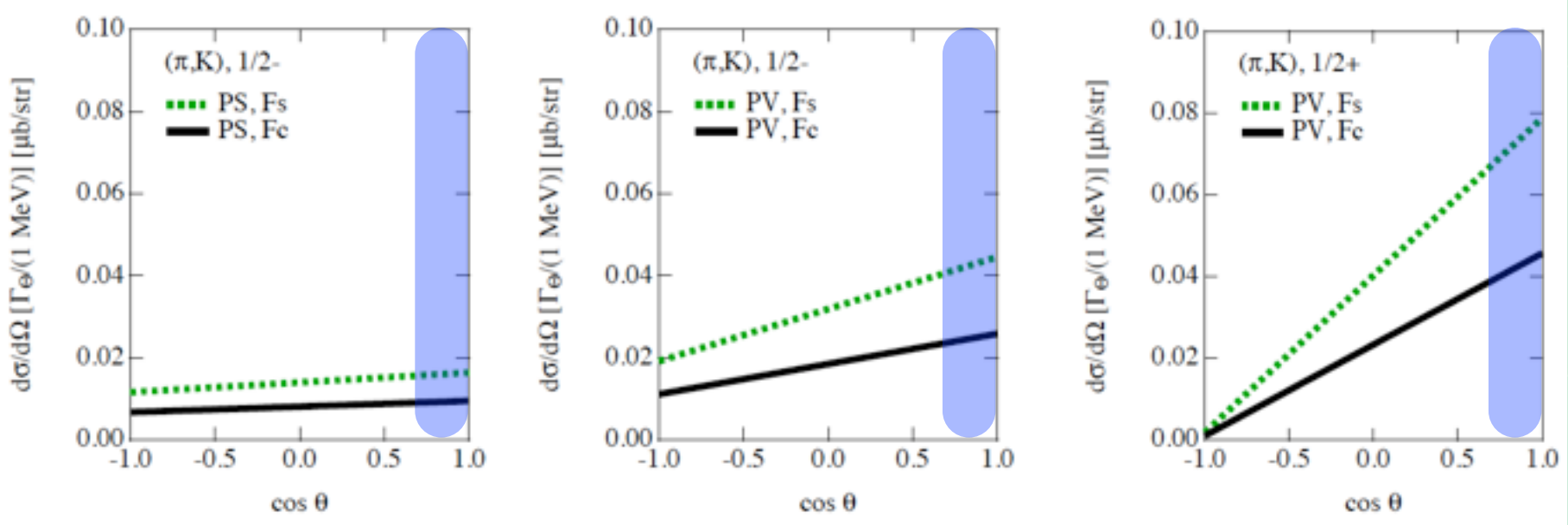
Total cross sections at experimental energies (Γ_Θ = 1 MeV)

	$\pi^- p \to K^- \Theta^+$		$K^+ p \to \pi^+ \Theta^+$	
$J^P = 1/2^+$	PS	PV	PS	PV
static	$9.2\ ^{+1.4}_{-1.3}$	$0.51^{+0.07}_{-0.08}$	$119\ ^{+14}_{-14}$	$9.6^{+1.1}_{-1.1}$
covariant	$5.3\ ^{+2.8}_{-2.0}$	$0.29^{+0.16}_{-0.11}$	$595\ ^{+16}_{-20}$	$46\ ^{+1}_{-2}$
$J^P = 1/2^-$	PS	PV	PS	PV
static	$0.18^{+0.02}_{-0.03}$	$0.40^{+0.06}_{-0.06}$	$1.9^{+0.3}_{-0.2}$	$4.2^{+0.5}_{-0.5}$
covariant	$0.10^{+0.06}_{-0.04}$	$0.23^{+0.12}_{-0.09}$	$9.6^{+0.3}_{-0.3}$	$20\ ^{+1}_{-1}$
$J^P = 3/2^+$				
static	$10\ ^{+2}_{-1}$		$94\ ^{+11}_{-11}$	
covariant	$5.9\ ^{+3.1}_{-2.2}$		$478\ ^{+12}_{-14}$	
$J^P = 3/2^-$				
static	$5.5\ ^{+0.8}_{-0.8}$		$8572\ ^{+1019}_{-992}$	
covariant	$3.2\ ^{+1.6}_{-1.2}$		$40544\ ^{+1511}_{-1824}$	

If we consider the width should be larger than 0.1 MeV;
--> spin 3/2 cases are ruled out.

Comparison with J-PARC data

Differential cross section at P_{lab} = 1.92 GeV (Γ_Θ = 1 MeV)



- Angular dependence is not so strong.
  J-PARC E19 experiment: K+ detected in forward angles.

J-PARC experiment --> upper limit of Γ_Θ

- (narrow width of 1/2- is theoretically unreasonable)

Summary

We study pentaquark productions in meson-induced reactions with Born diagrams.

- **Cross sections for $J^P = 1/2^{\pm}$, $3/2^{\pm}$ cases.**
- **Spin 3/2 cases --> large cross section**

  Γ_Θ << 0.1 MeV: unlikely for hadrons
- **Spin 1/2 cases may be possible.**

  upper limit of Γ_Θ with J-PARC exp.

T. Hyodo, A. Hosaka, M. Oka, arXiv:1203.0598 [nucl-th] PTP in print.