Possibility of experimental study on the (γ,K) reaction mechanism

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- Study on photoproduction of strangeness
  — Motivations and status
- Experimental approach
  — What we can do at SPring-8/LEPS ?
- Summary

Photoproduction of Strangeness (motivation & status)

Study of baryon spectrum

Reflects nature of QCD at non-perturbative region

Quark model predicts many baryons as qqq states

Predicted N*	$1/2^+$	$3/2^+$	$5/2^+$	$7/2^+$	$1/2^-$	$3/2^-$	$5/2^-$	$7/2^-$	sum
$M_N \sim 1.7$GeV	2				2	2	1		7
1.7GeV ~ 2.0GeV	3	4	3	1	1	1			13
2.0GeV ~ 2.2GeV	1	1			4	4	3	1	14

N* and Δ*: extensively studied by the π+N reaction

- π+N threshold: $M_\pi + M_N = 1.08$GeV < Δ(1232), N(1440), …
- $\sigma \sim 10$mb
- Partial wave analysis → spin/parity of resonance

Additional information from the γ+N reaction

- γ+N threshold: $M_N = 0.94$GeV
- $\sigma \sim 10\mu$b
- EM property of resonance

Missing resonances as well known problem

- Predicted resonances are still missing at M>1.7GeV

observed / predicted	N and N*	Δ*
M_N ~ 1.7GeV	7 / 7	3 / 3
1.7GeV ~ 2.0GeV	3 / 13	5 / 8
2.0GeV ~ 2.2GeV	1 / 14	2 / 6

KΛ/KΣ open

- Small coupling to πN channel
- Prediction of possibility of strong coupling to KY channel

  Some quark models predict $\Gamma_K > \Gamma_\pi$ (about 10 states ?)
- Motivates experimental study on KY channel

  Very precise measurement is not easy
  - $\sigma(\pi+N \rightarrow K+Y)$ ~100μb   pol.N, pol.Y
  - $\sigma(\gamma+N \rightarrow K+Y)$ ~1μb   pol.γ, pol.N, pol.Y

  self analyzing

  Theoretical predictions are quite helpful
- D_{13}(1900) may have large KΛ width

Study on reaction mechanism: $\gamma N \to \pi N$ vs KY channels

Reaction mechanism may be simple

- t-channel

  πN channel: π (0^-; I=1), ρ (1^-; I=1), ω (1^-; I=0), …

  $\Rightarrow$ KY channel: K (0^-; I=1/2), K*(1^-; I=1/2), …

  $\Rightarrow$ K^0Y channel: K*(1^-; I=1/2), …

  Simple isospin structure

- s-channel

  πN channel: N* and Δ* $\Rightarrow$ $K\Lambda$ channel: N*

Complementary with πN channel

- Photoproduction of pseudo-scalar meson

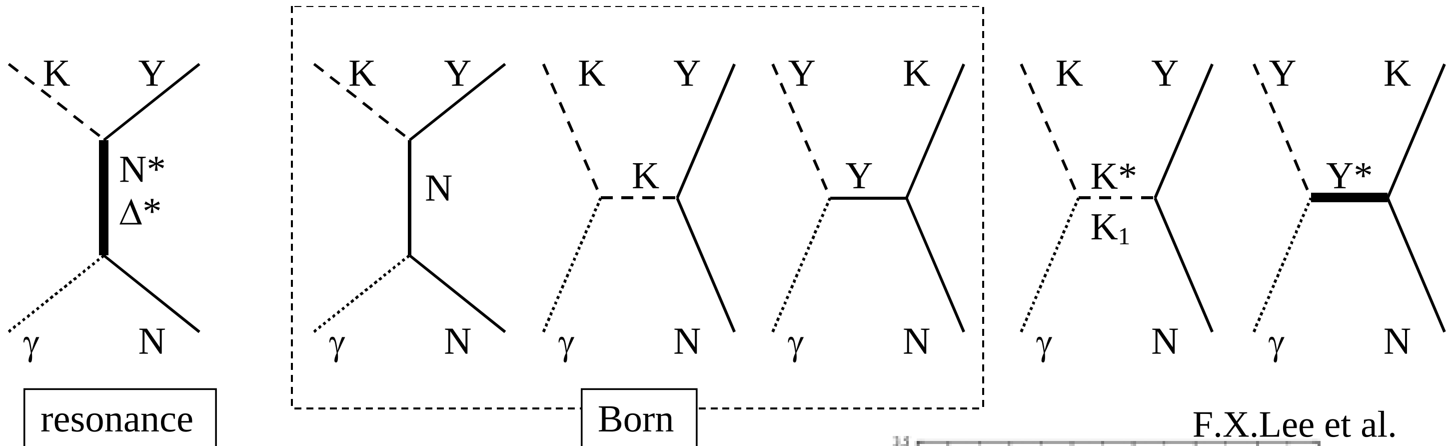
  $\gamma N \to \pi N$, KY, ηN, …

- We can check applicability of models proposed for πN to KY

Status of studies: the (γ,K) reaction at $s^{1/2}$ <2GeV

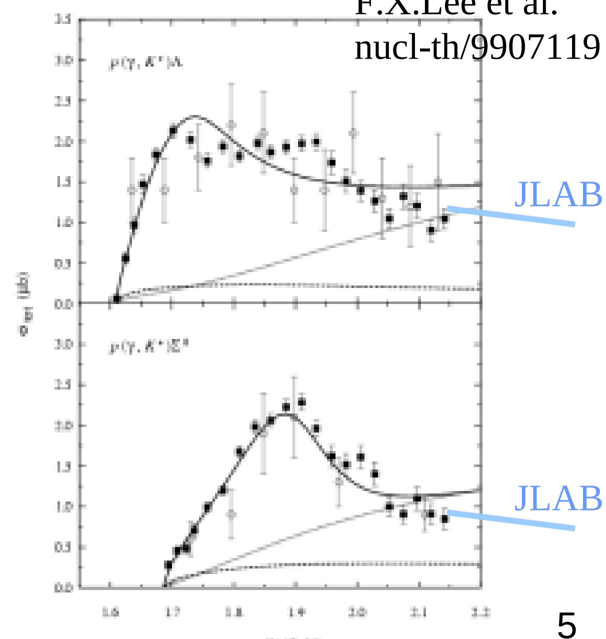
Competition with resonance and non-resonant terms

- Contributions are same order



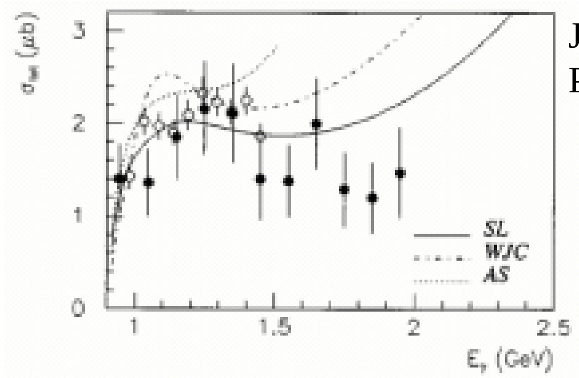
- Non-resonant terms grow with energy
  - Major contribution is t-channel
    - Theoretical prediction
    - Forward peaking of dσ/dΩ
  - Linear increase with photon energy
    - Maybe OK as general tendency
    - Not realistic at higher energy

F.X.Lee et al.
nucl-th/9907119



Recent theoretical improvement is significant

- Old calculations had unphysical divergence



J.C.David et al.
PRC53 (1996) 2613

- Hadronic form factor
- Recovery of gauge invariance

F.X.Lee et al.
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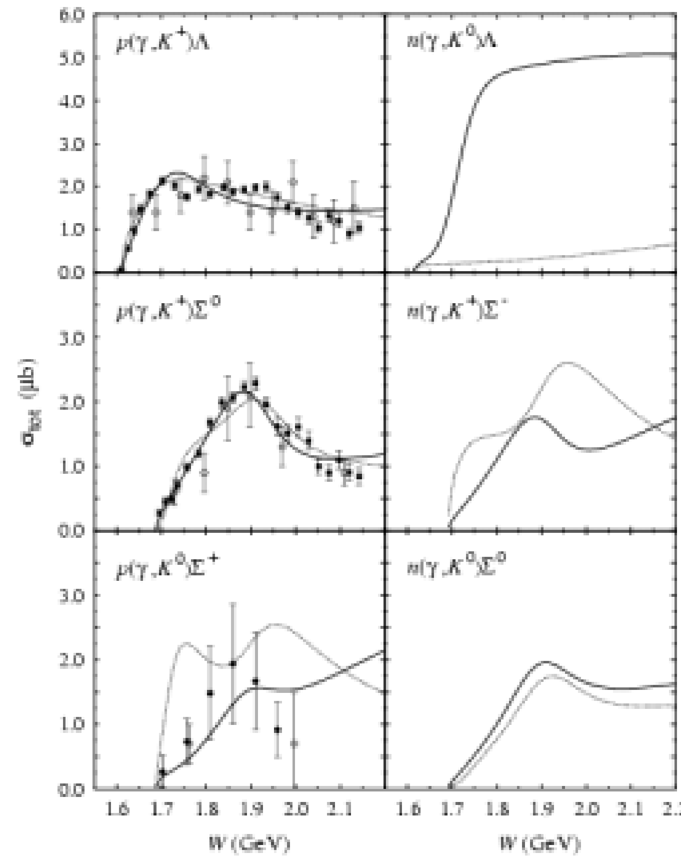

(γ,K⁺) channel

- Agreement up to ~2GeV

(γ,K⁰) channel

- Relatively poor
- Recipe dependence

- Spin observables are sensitive

  Give more clear discrimination of theoretical treatment

F.X.Lee et al.
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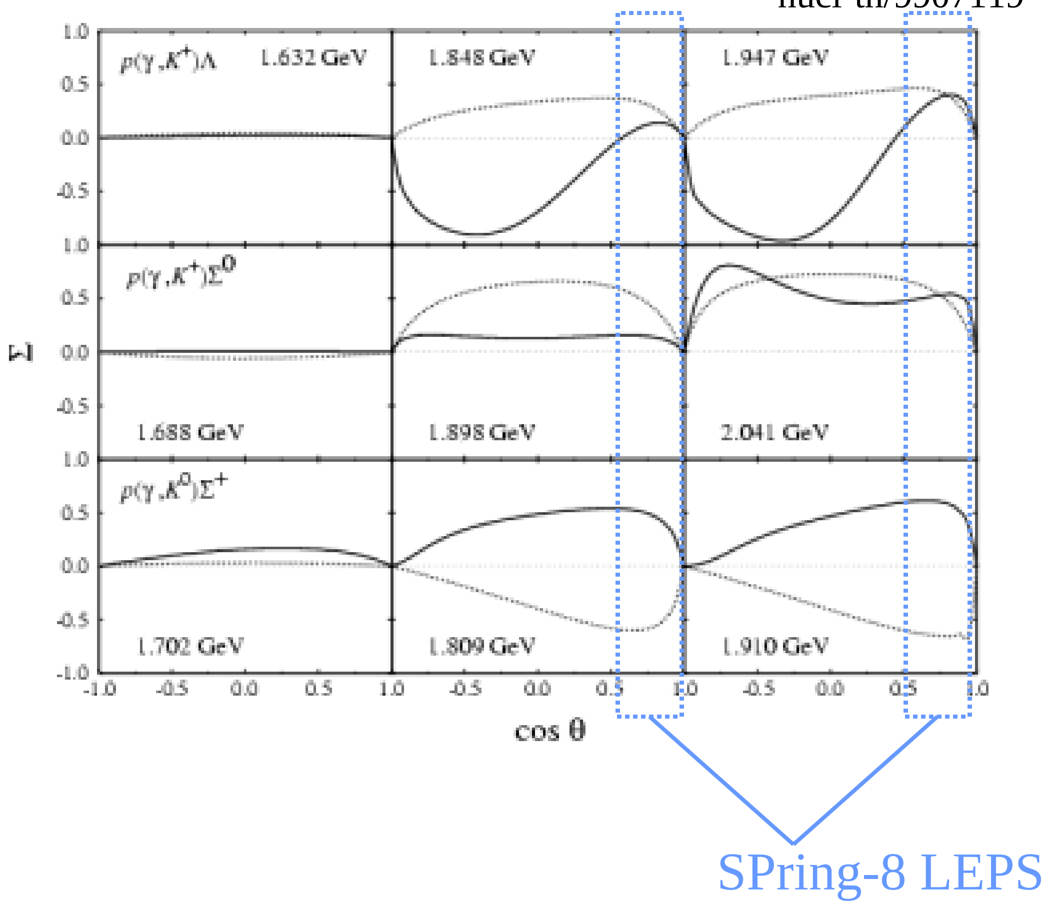
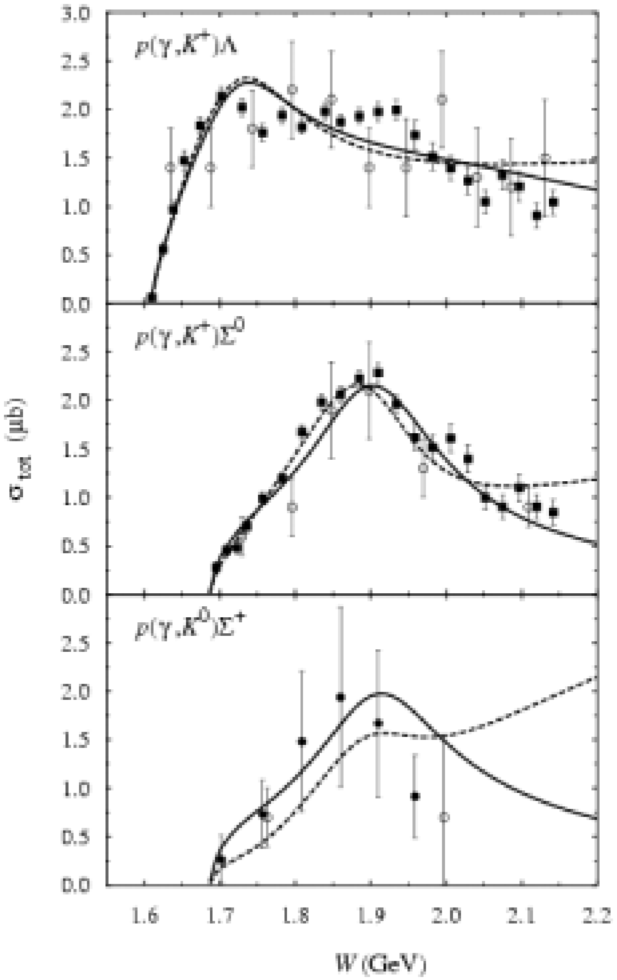


- Other efforts in theory

  Use Regge propagator instead for Feynman propagator

T.Mart et al.
nucl-th/0002036

- Better property at higher energy
- Significant improvement for
  (γ,K^0) channel
- Prediction on other observables ?
- Recipe is not established yet



N* resonance in (γ,K^0) channel

- Δ* dominance in p(γ,K^+)Σ^0 channel
- Inclusion of a I=1/2 resonance, P_{13}(1720), improve the total cross section fit
- p(γ,K^+)Σ^0 and p(γ,K^0)Σ^+ are complimentary

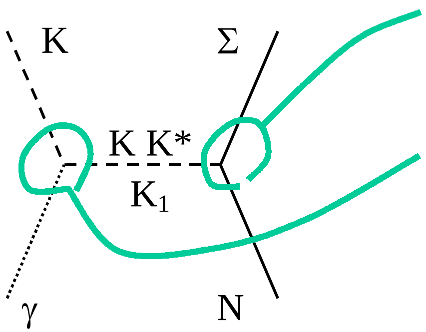
N*

T.Mart et al.
nucl-th/0008001

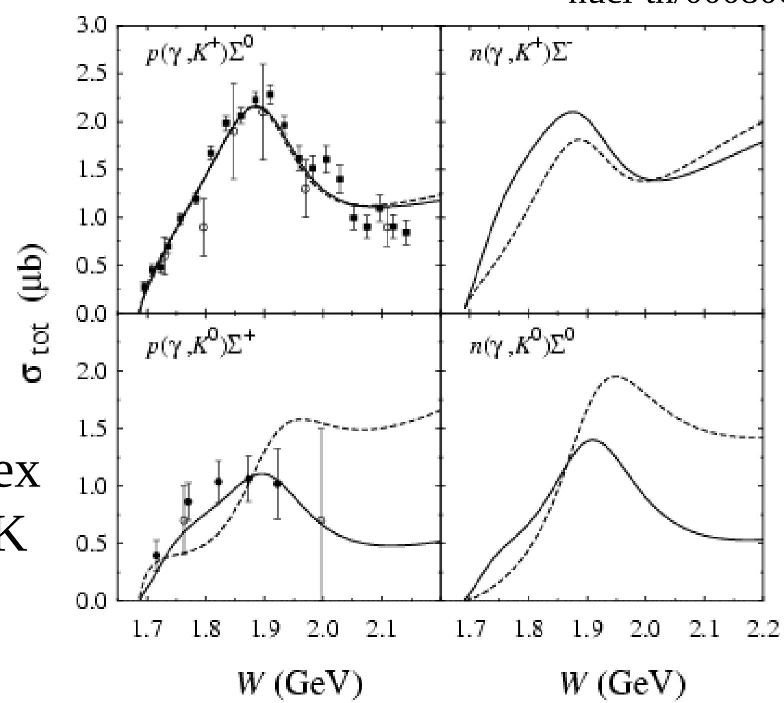
$\Delta^* \to K\Sigma$: $\sigma_{K+} = 2\,\sigma_{K0}$

$N^* \to K\Sigma$: $2\,\sigma_{K+} = \sigma_{K0}$

Different structure in non-resonant terms



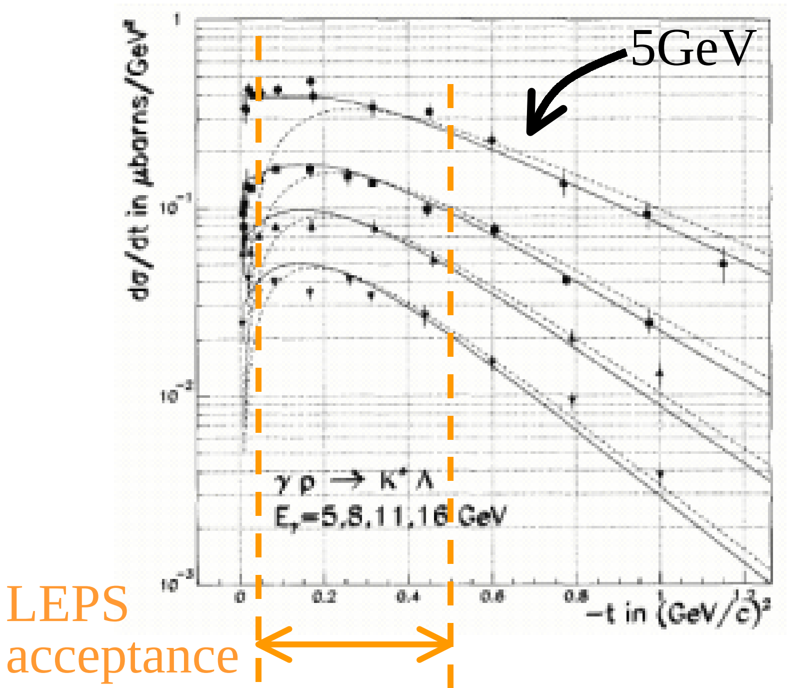
Similar couplings at (K/K*/K_1)NΣ hadronic vertex but different at γ(K/K*/K_1)K EM vertex

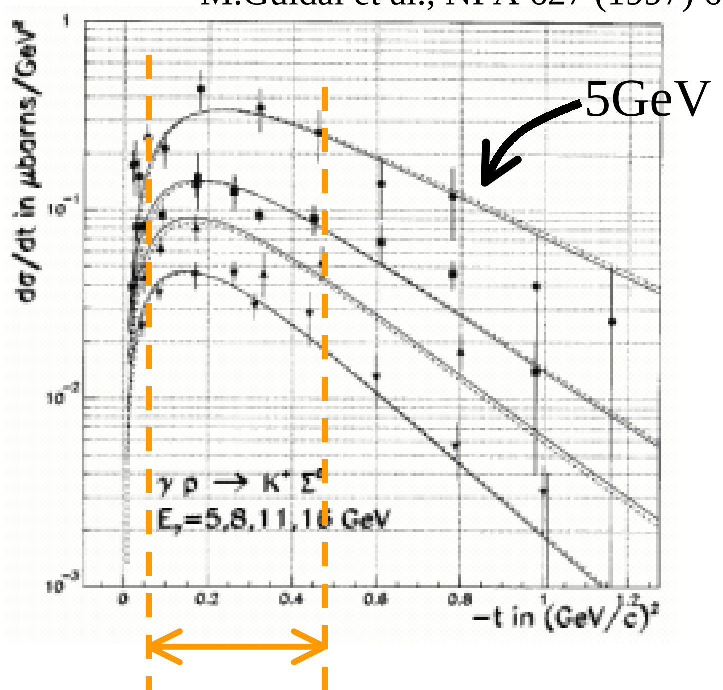


High energy behavior (Eγ > 5 GeV)

- Mechanism is relatively well established
  - Simple due to dominance of t-channel
  - Treatment with Regge propagator
    - K/K_1 and K^* trajectories
  - Keep gauge invariance
- K/K_1 and K^* separation may be possible

M.Guidal et al., NPA 627 (1997) 645

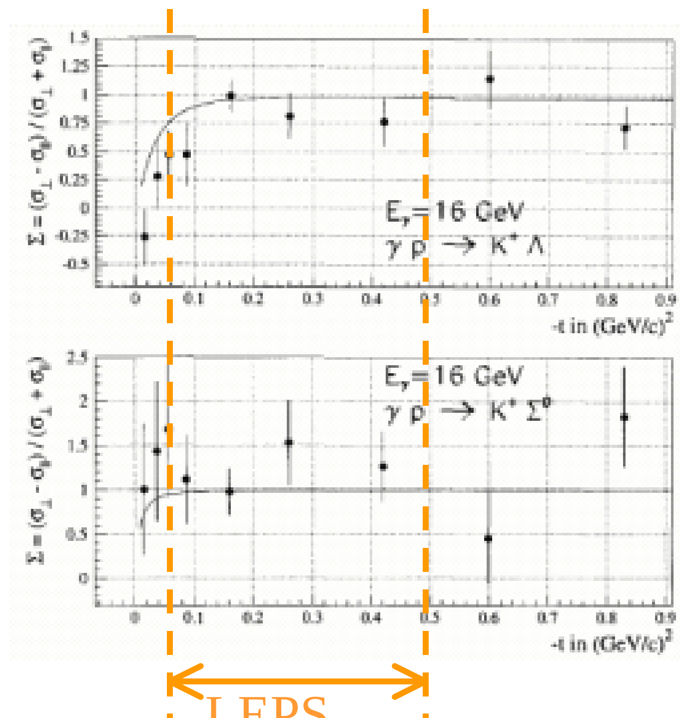




- Spin observables

  Σ~1 is interpreted with K* exchange dominance

  - Natural parity exchange → Σ= +1
  - Unnatural parity exchange → Σ= −1



M.Guidal et al.
NPA 627 (1997) 645

LEPS acceptance

Good guide line for experiments at 2~3GeV region

Possible Experimental Approach at SPring-8/LEPS

LEPS parameters

Photon beam

- Eγ = 1.5 ~ 2.4 GeV and tagged
- Nγ = 500 kcps
- Alomost 100% polarized

  Linear and Circular

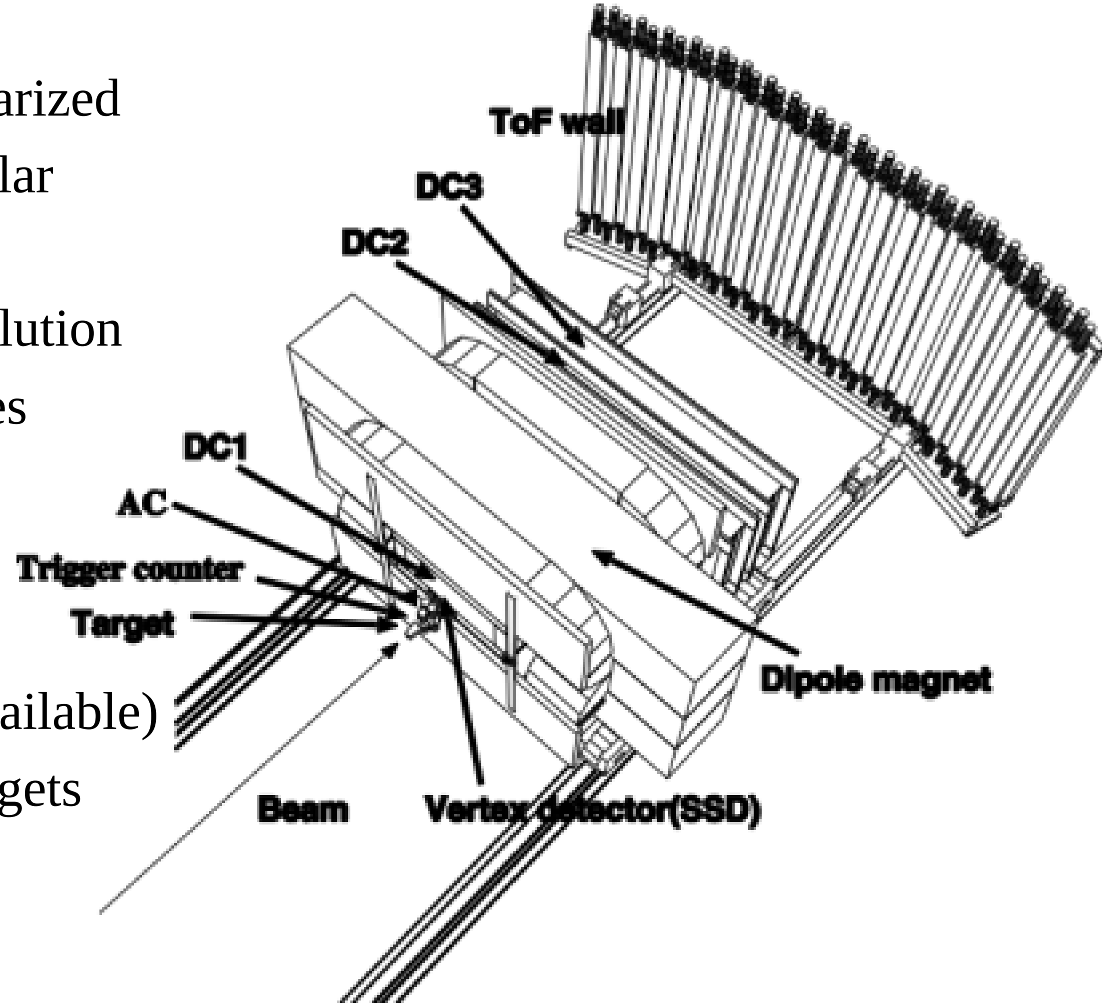
Spectrometer

- Good PID and resolution
- θ_K(lab) < 20 degrees

  $\cos\theta_K$(cm) > 0.6

Target

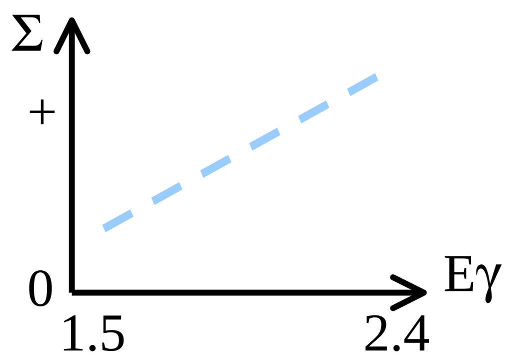
- Liquid H_2
- Liquid D_2 (to be available)
- Various nuclear targets



The (γ,K^+) reaction

Suitable to study general feature of reaction mechanism

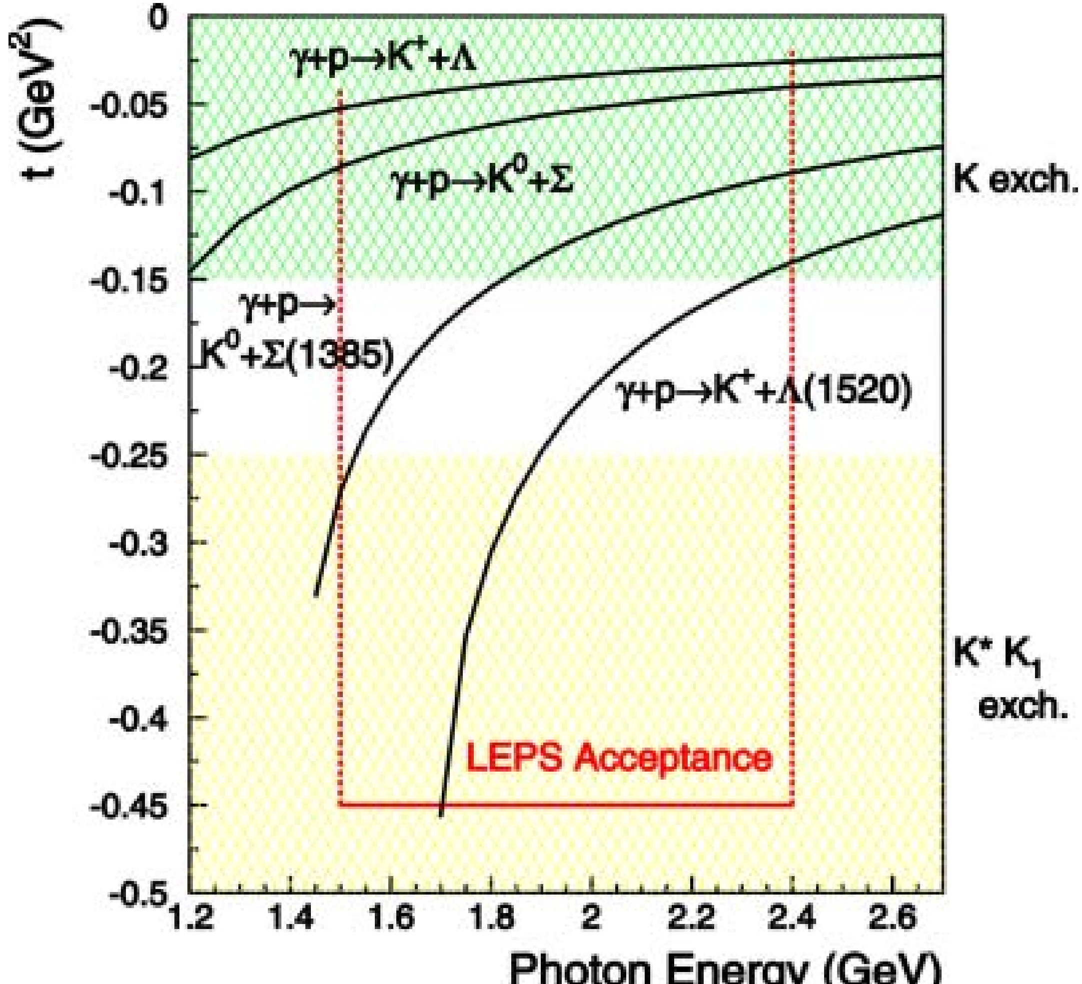
- SPring-8/LEPS already has large amount of data
- Expect large yield
  - Detector acceptance large and analysis efficiency high
  - We can see $E\gamma$, θ_K and t dependences
- Study on $K\Lambda$ and $K\Sigma$ channels
  - On cross section, SAPHIR and CLAS made a good job
    - We have to confirm these data
  - New data on beam polarization asymmetry (Σ) → Sumihama's talk
    - What can we discuss ?

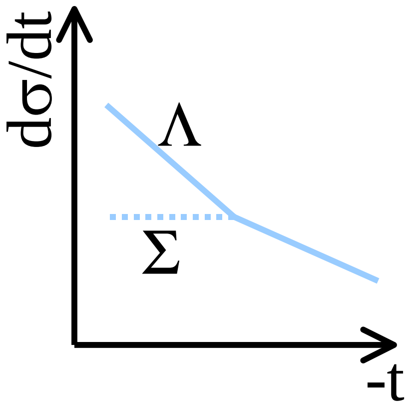


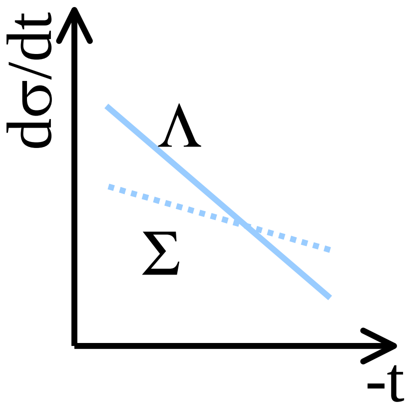
looks to be consistent with K*-exchange dominance, but should be careful to kinematical effect

Detail study on t-dependence

- We have high statistics data at small t region
- Separation of K- and K*-exchanges







The (γ,K^0) reaction

Complementary with the N(γ,K^+)Σ reaction

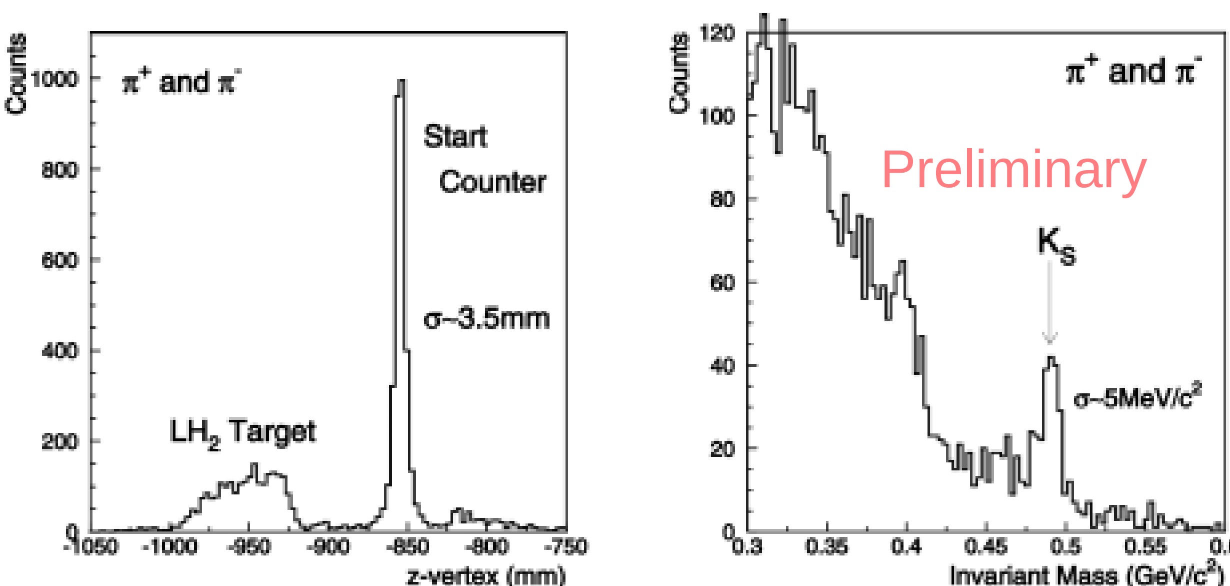
- Experimental study are scarce (SAPHIR up to 1.5 GeV)
- Relatively smaller yield

  Detector acceptance small and analysis efficiency low

  - Measure $K^0 \rightarrow K_S \rightarrow \pi^+\pi^-$ (about 35%)

  Experimental considerations

  - Clear identification from vertex and invariant mass
  - Efficient trigger for $K_S \rightarrow 2\pi$



- Possibility to discriminate theoretical models

  $p(\gamma,K^+)\Sigma^0$ and $p(\gamma,K^0)\Sigma^+$ has

    - different sensitivity to N* and Δ*
    - Similar non-resonant diagram contributions but different EM couplings

  $p(\gamma,K^0)\Sigma^+$ is poorly reproduced by theoretical models

    - Several models were proposed to improve energy dependence of cross section
    - Beam polarization asymmetry may provide new information

Summary

- Study of photoproduction of strangeness motivated by
  - missing resonances in baryon spectra
  - reaction mechanism of photoproduction of pseudo-scalar mesons
  - reaction mechanism may be simple
- Status of experiment and study
  - New data from SAPHIR, LEPS, JLAB …
  - Theoretical treatments in wider energy range become possible
  - Understanding at higher energy may be a good guide line
- What we can discuss with LEPS data ?
  - Energy dependence of beam polarization asymmetry
  - Detail study of t-dependence
  - Comparison between the (γ,K^+) and (γ,K^0) reactions