Experimental Study on the Nature of the Λ(1405) @ LEPS/SPring-8

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for the LEPS collaboration

Outline

- Motivation
- LEPS Experiment
- Results and Discussion
- Summary and Outlook

Motivation

Is the Λ(1405) a *KN* Bound State or a q^3 System or anything else? $|B\rangle = \alpha|q3\rangle + \beta|q3^*qq\rangle + \gamma|q3^*g\rangle + \ldots$

- ***J^p=1/2$^-$ Λ(1405) 4-star Resonance***
  - It must be mass-degenerate with ***J^p=3/2$^-$*** Λ(1520)
  - ***J^p=1/2$^-$*** N(1535) is heavier than Λ(1405)
- ***KN Bound State***
  - Low-energy ***I=0 KN*** interactions are strongly attractive
  - There must exist a new, as yet undetected, ***J^p=1/2$^-$***Λ(1520)
- ***Hybrid***
  - ***uds+g?*** $m_{\Lambda(1405)} - m_{\Lambda(1116)} \sim 290$ MeV only

Λ(1405) and Σ(1385)

Λ(1405) S_{01} $\quad I(J^P) = 0(\frac{1}{2}^-)$

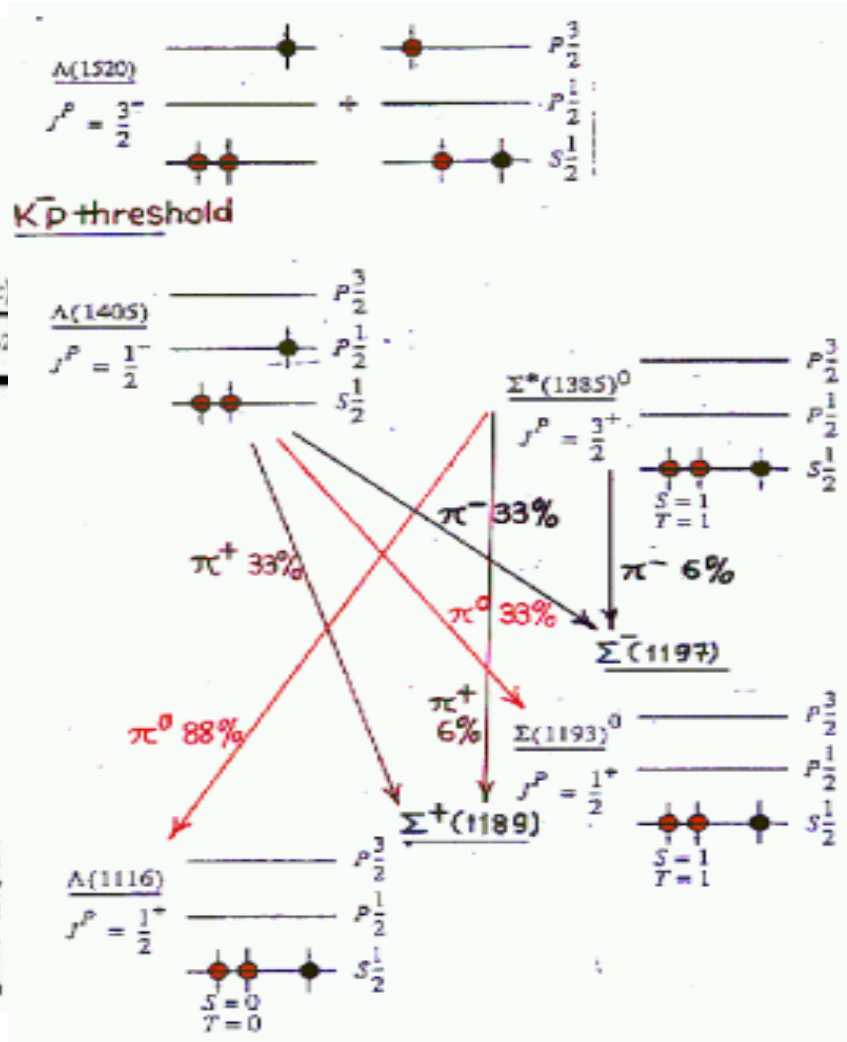
Mass $m = 1406 \pm 4$ MeV
Full width $\Gamma = 50.0 \pm 2.0$ MeV
Below $\bar{K}N$ threshold

Λ(1405) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Sigma\pi$	100 %	152

Σ(1385) P_{13} $\quad I(J^P) = 1(\frac{3}{2}^+)$

$\Sigma(1385)^+$ mass $m = 1382.8 \pm 0.4$ MeV (S = 2.0)
$\Sigma(1385)^0$ mass $m = 1383.7 \pm 1.0$ MeV (S = 1.4)
$\Sigma(1385)^-$ mass $m = 1387.2 \pm 0.5$ MeV (S = 2.2)
$\Sigma(1385)^+$ full width $\Gamma = 35.8 \pm 0.8$ MeV
$\Sigma(1385)^0$ full width $\Gamma = 36 \pm 5$ MeV
$\Sigma(1385)^-$ full width $\Gamma = 39.4 \pm 2.1$ MeV (S = 1.7)
Below $\bar{K}N$ threshold

Σ(1385) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Lambda\pi$	88±2 %	208
$\Sigma\pi$	12±2 %	127



Coupled-channel χ-dynamics

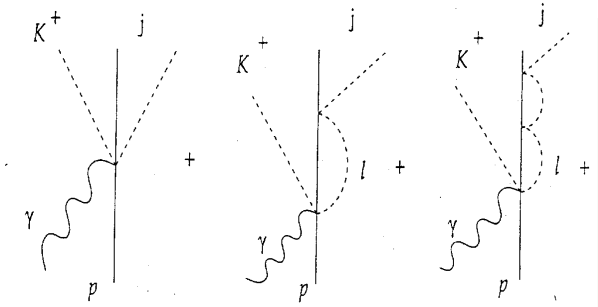
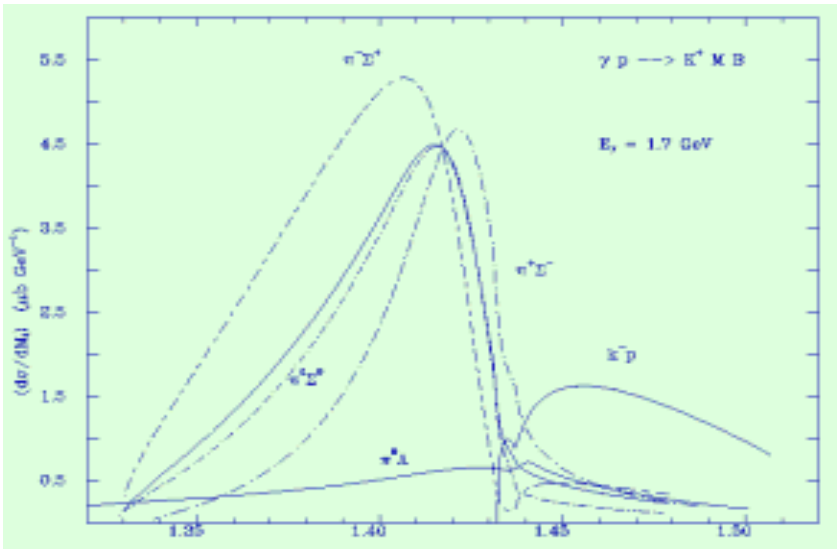


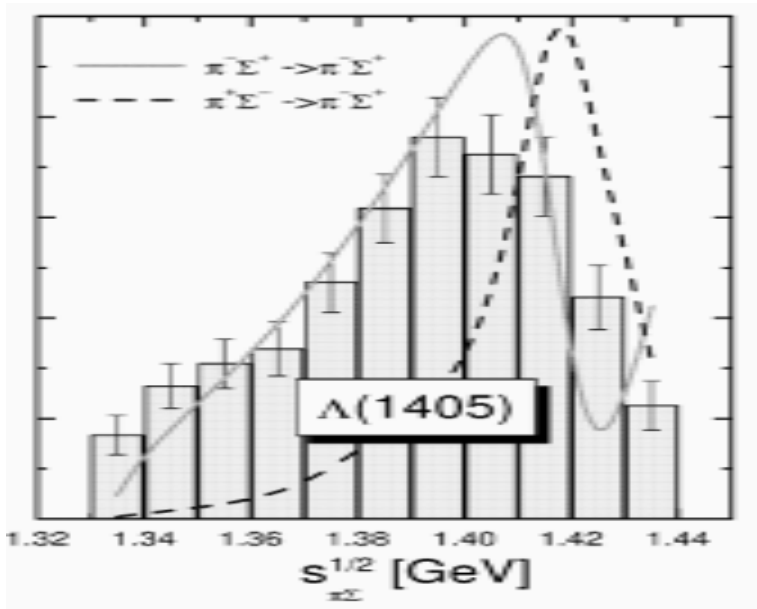
Fig. 2. Diagrammatic representation of the meson-baryon final state interaction in the $\gamma p \to K^+\Lambda(1405)$ process.

$$\frac{d\sigma(\pi^+\Sigma^-)}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2 + \frac{1}{2}|T^{(1)}|^2 + \frac{2}{\sqrt{6}}Re|T^{(0)}T^{(1)*}|$$

$$\frac{d\sigma(\pi^-\Sigma^+)}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2 + \frac{1}{2}|T^{(1)}|^2 - \frac{2}{\sqrt{6}}Re|T^{(0)}T^{(1)*}|$$

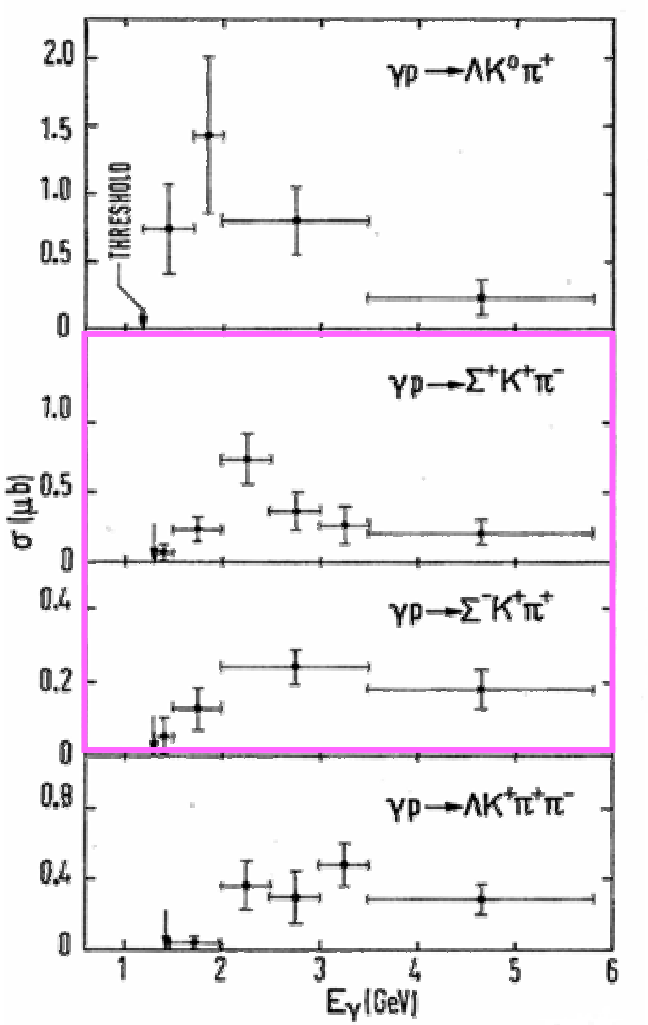


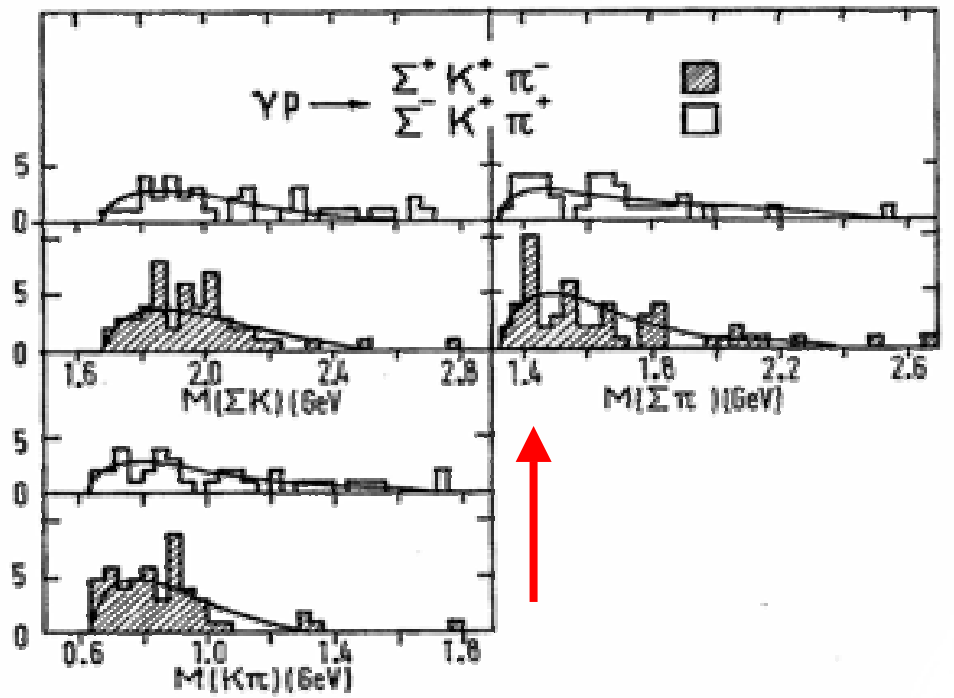
Nacher,Oset,Toki,Ramos PLB 455 (1999) 55



Lutz,Kolomeitsev NPA 700 (2002)193

Old Λ(1405) Data



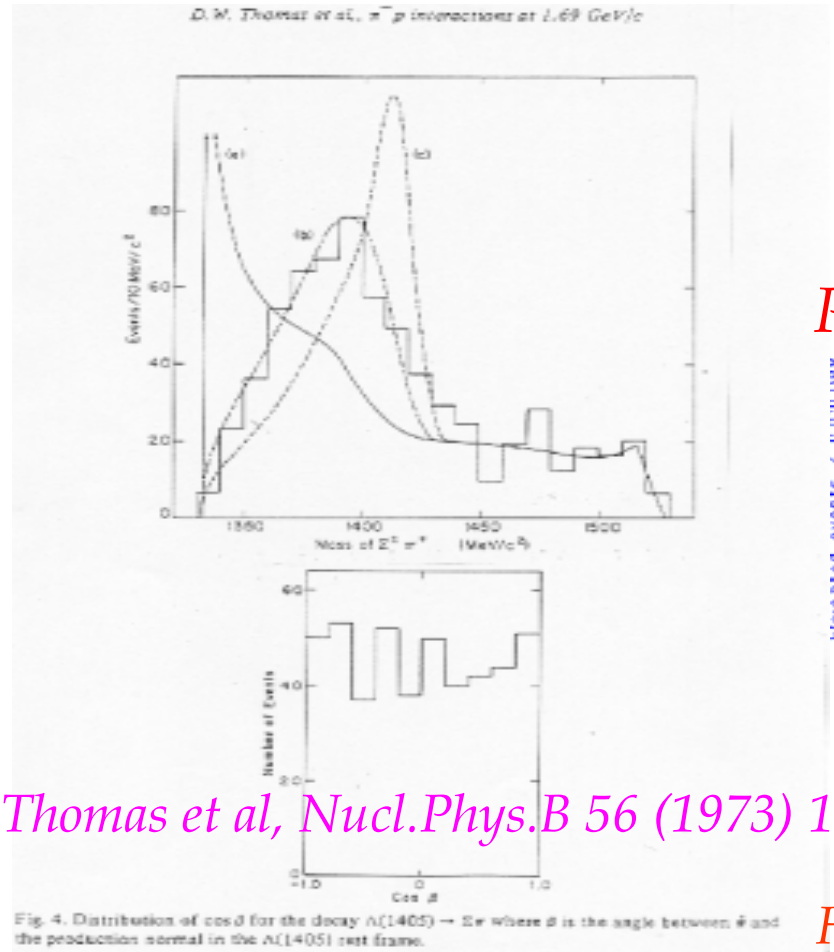


ABBHHM Collaboration (1969) HBC Data

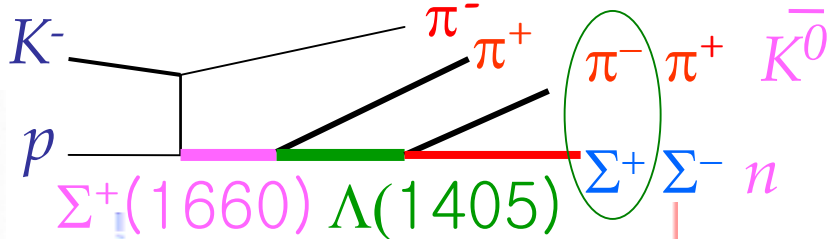
"*Multipion- and Strange Particle Photoproduction on Protons at Energies up to 5.8 GeV*"

Old Λ(1405) Data

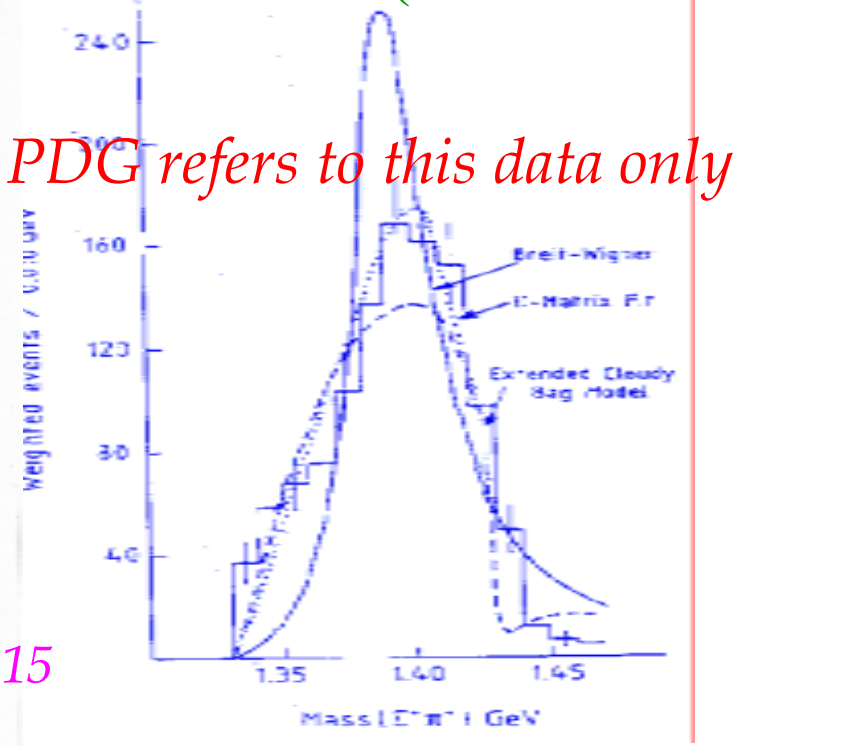
$\pi^- p$ *interactions at 1.6 GeV/c*



Thomas et al, Nucl.Phys.B 56 (1973) 15

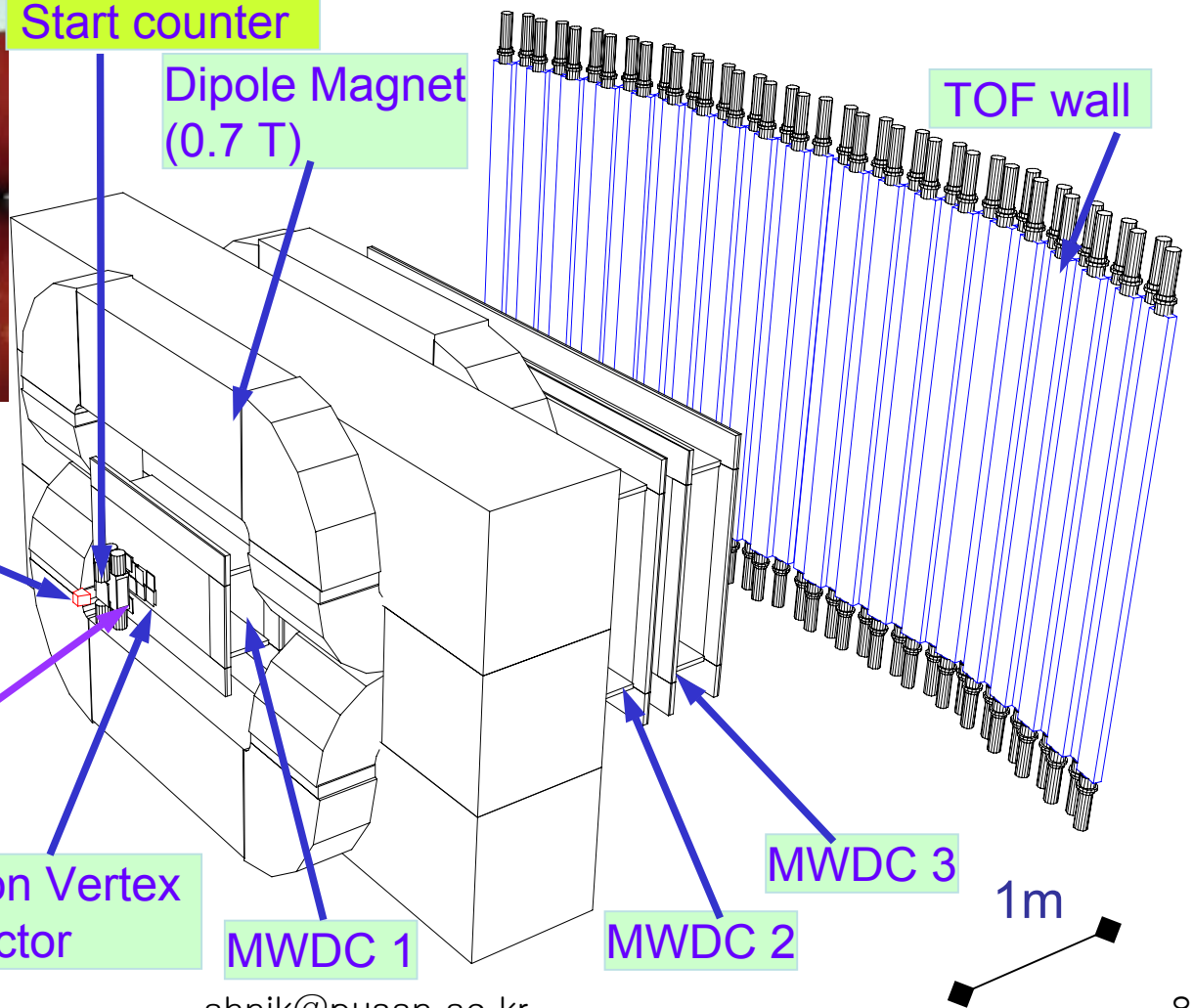


PDG refers to this data only



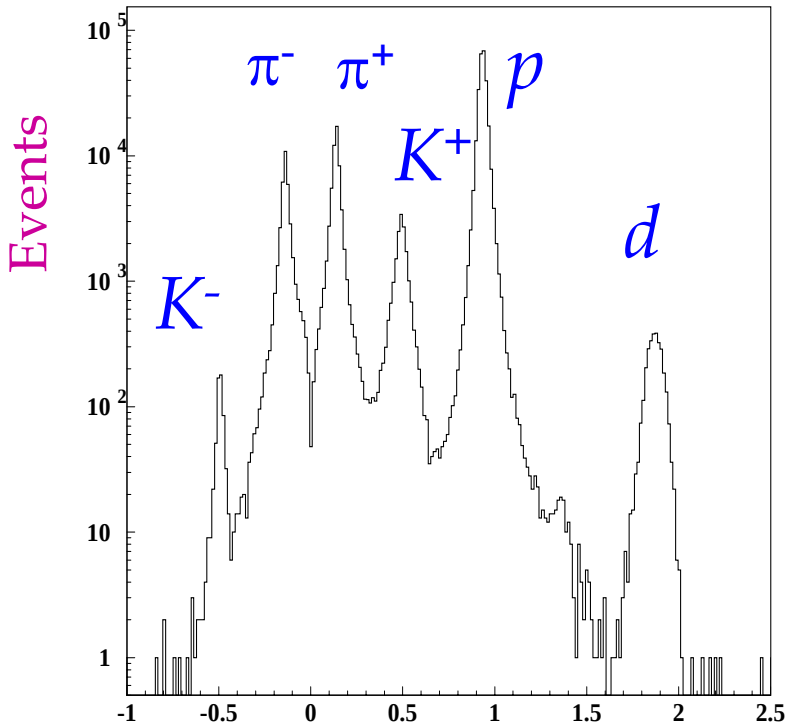
Hemingway's Data NPB253(1984)742

LEPS@SPring-8

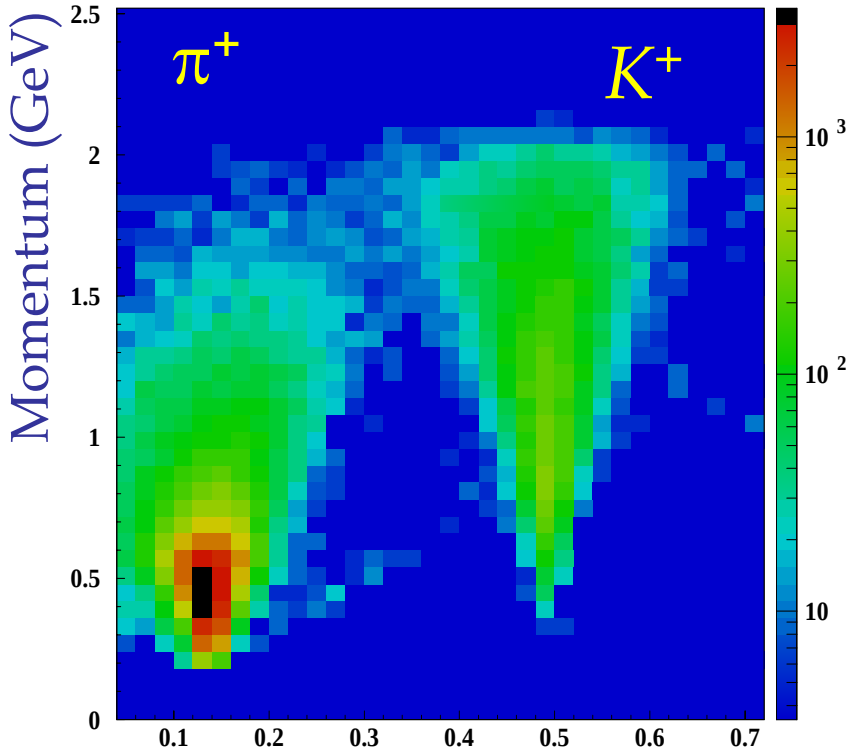


Particle Identification

Reconstructed mass



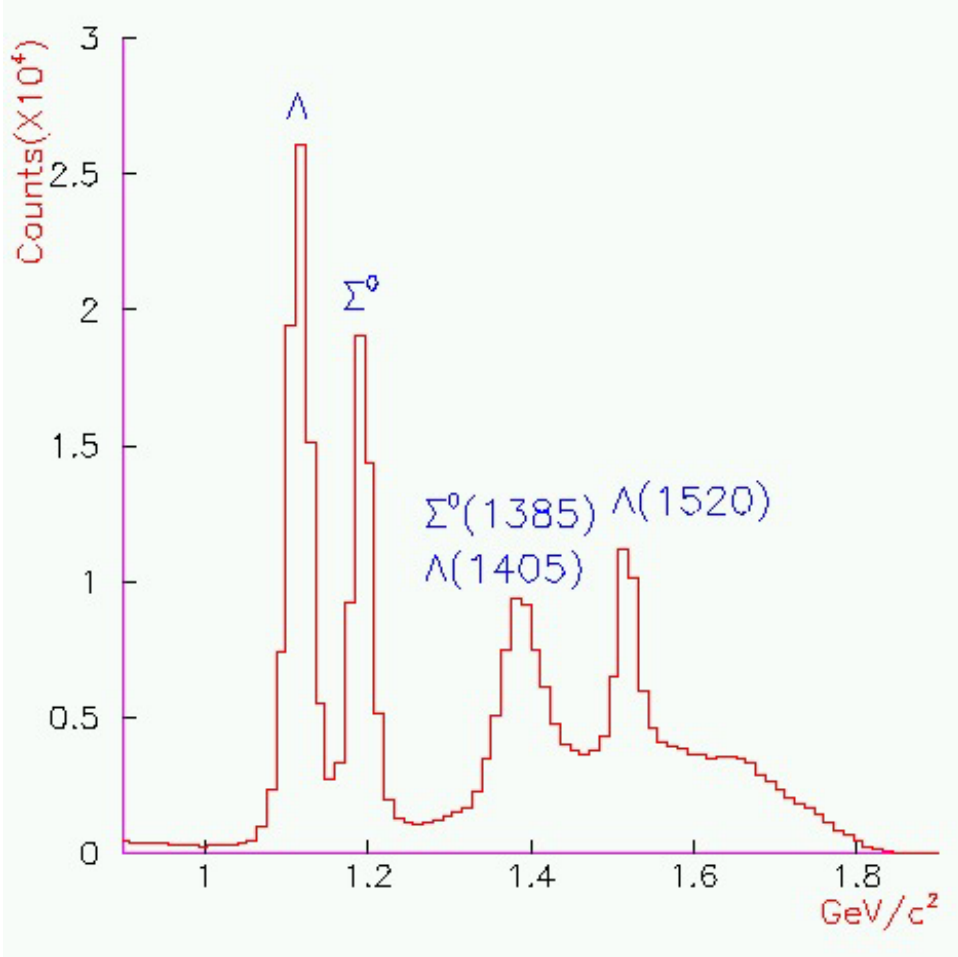
K/π separation (+ve charge)



σ(mass) = 30 MeV(typ.) for 1 GeV/c Kaon

$p(\gamma,K^+)X$ Reaction

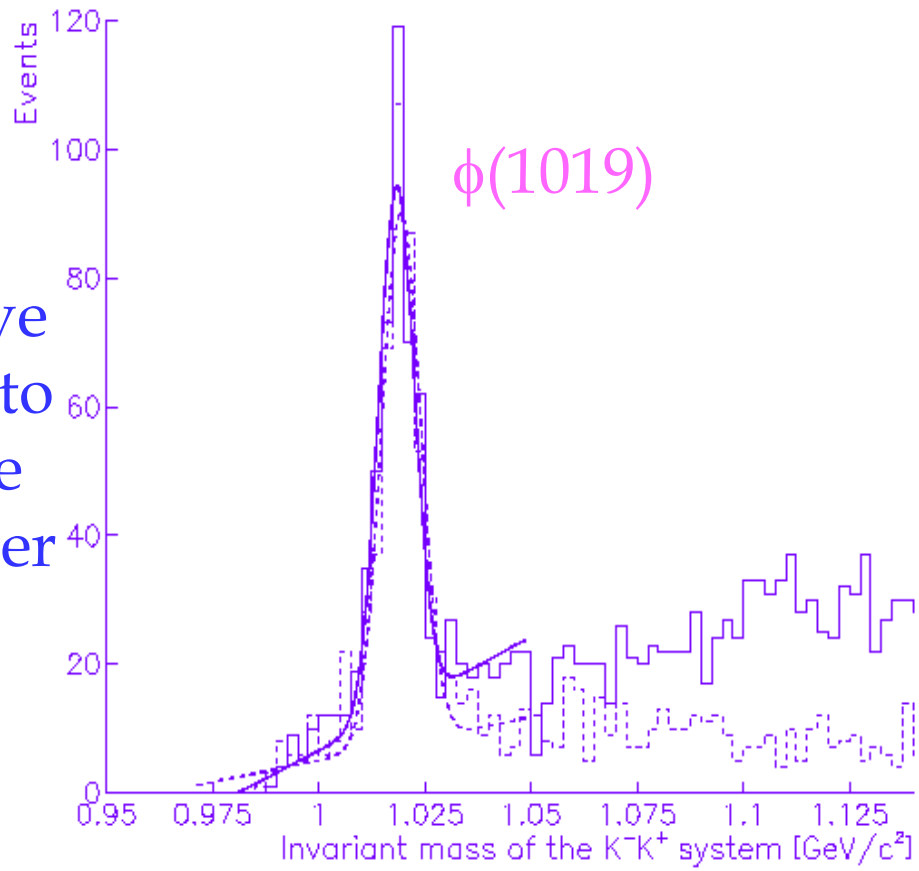
- 50mm LH2 target run
  (Dec 2000 – Jun 2001)
- 2×10^6 γ/s flux
- $2\times10^{12}\gamma$ in 1.5-2.4 GeV
- 3×10^5 (γ,K^+) events
- # of tagged γ's =1
- Tracking $P(\chi^2)>0.02$
- $4\sigma(p)$ PID cut
- ToF hit consistency
- Vertex cut



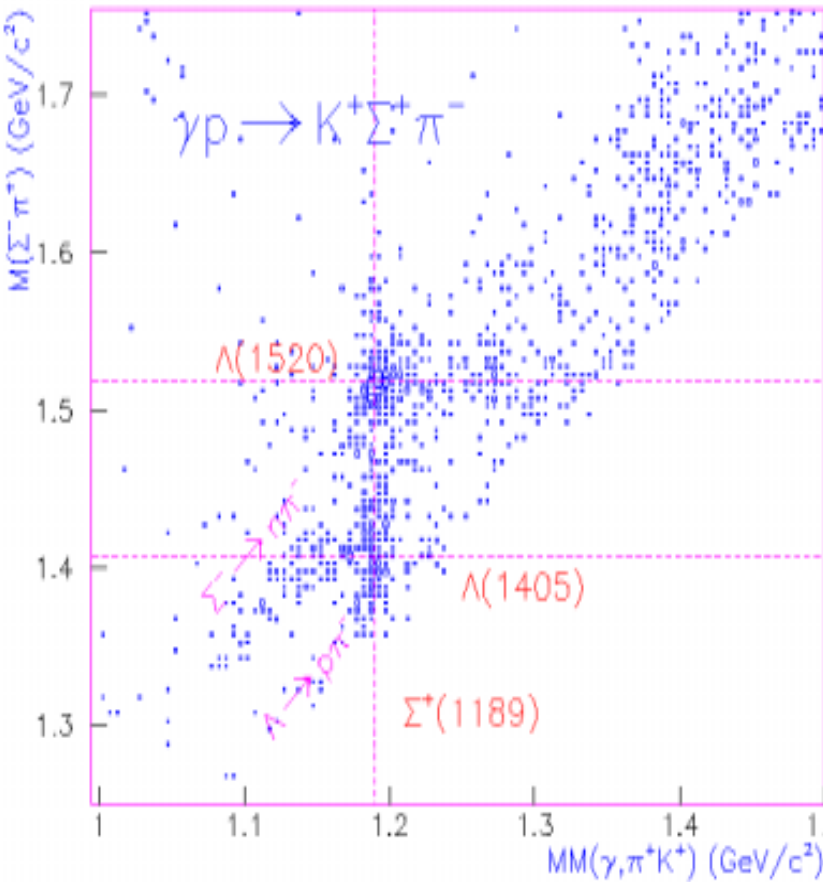
Acceptance for +/− Particles

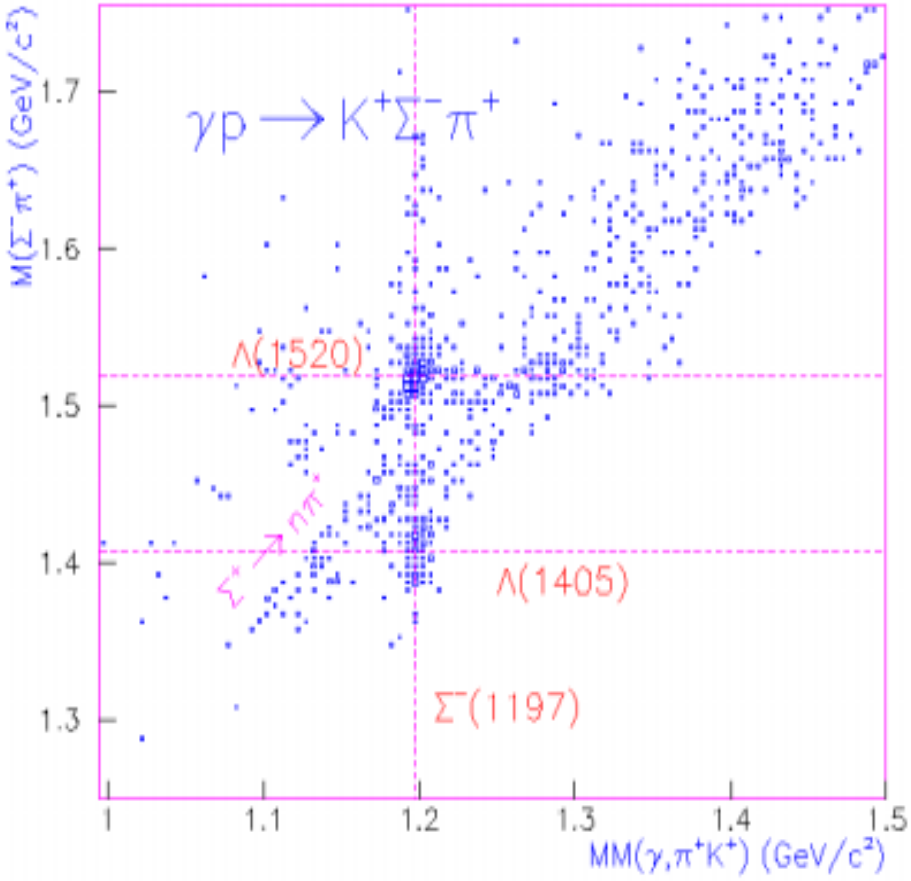
$$\gamma p \rightarrow K^+ \Sigma^+ \pi^-$$
$$\gamma p \rightarrow K^+ \Sigma^- \pi^+$$

- Equal Acceptance for +ve and –ve particles thank to good performance of the LEPS dipole spectrometer
- $\phi(1019)$ reconstruction from $p(\gamma,K^-p)K^+$ and $p(\gamma,K^+p)K^-$



$p(\gamma,K^+\pi)$ Reactions





Vertex Distributions

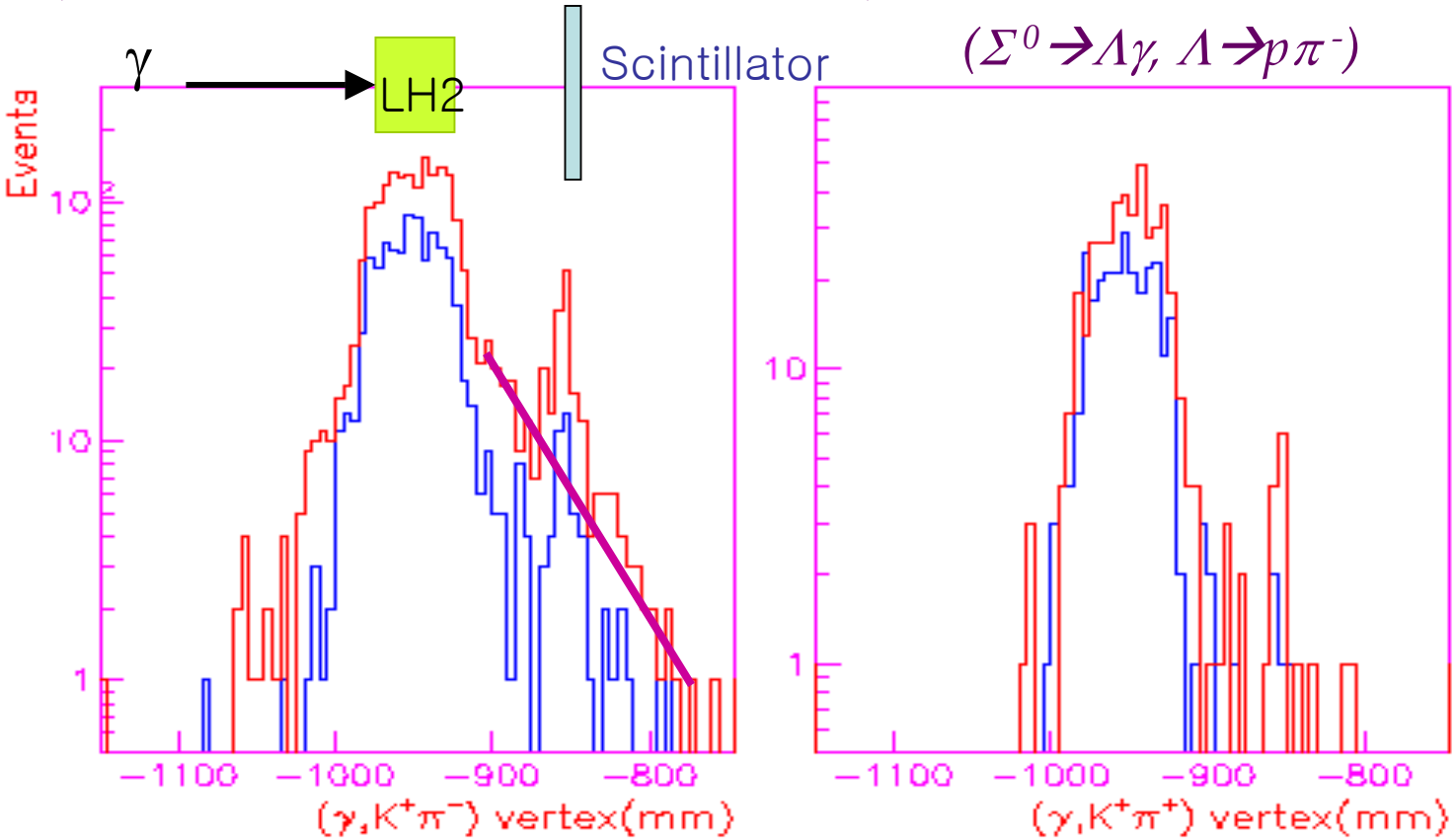
$\gamma p \rightarrow \Lambda(1405)\, K+ \rightarrow \Sigma^{+}\pi^{-}K+$

$\gamma p \rightarrow \Lambda(1405)\, K+ \rightarrow \Sigma^{-}\pi^{+}K+$

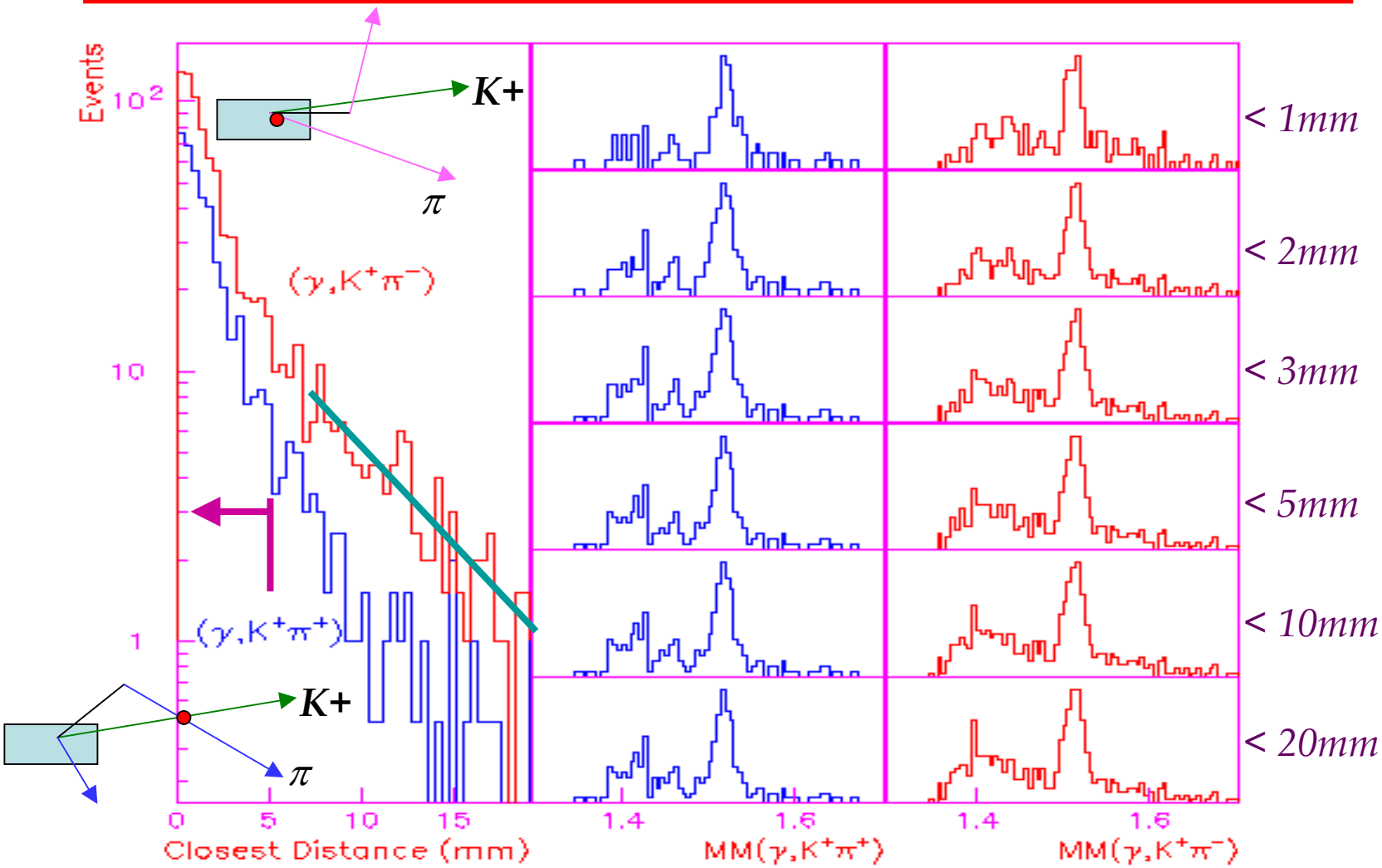
$\gamma p \rightarrow \Lambda(1405)\, K+ \rightarrow \Sigma^{0}\pi^{0}K+$

$\gamma p \rightarrow \Sigma(1385)\, K+ \rightarrow \Lambda\pi^{0}K+$

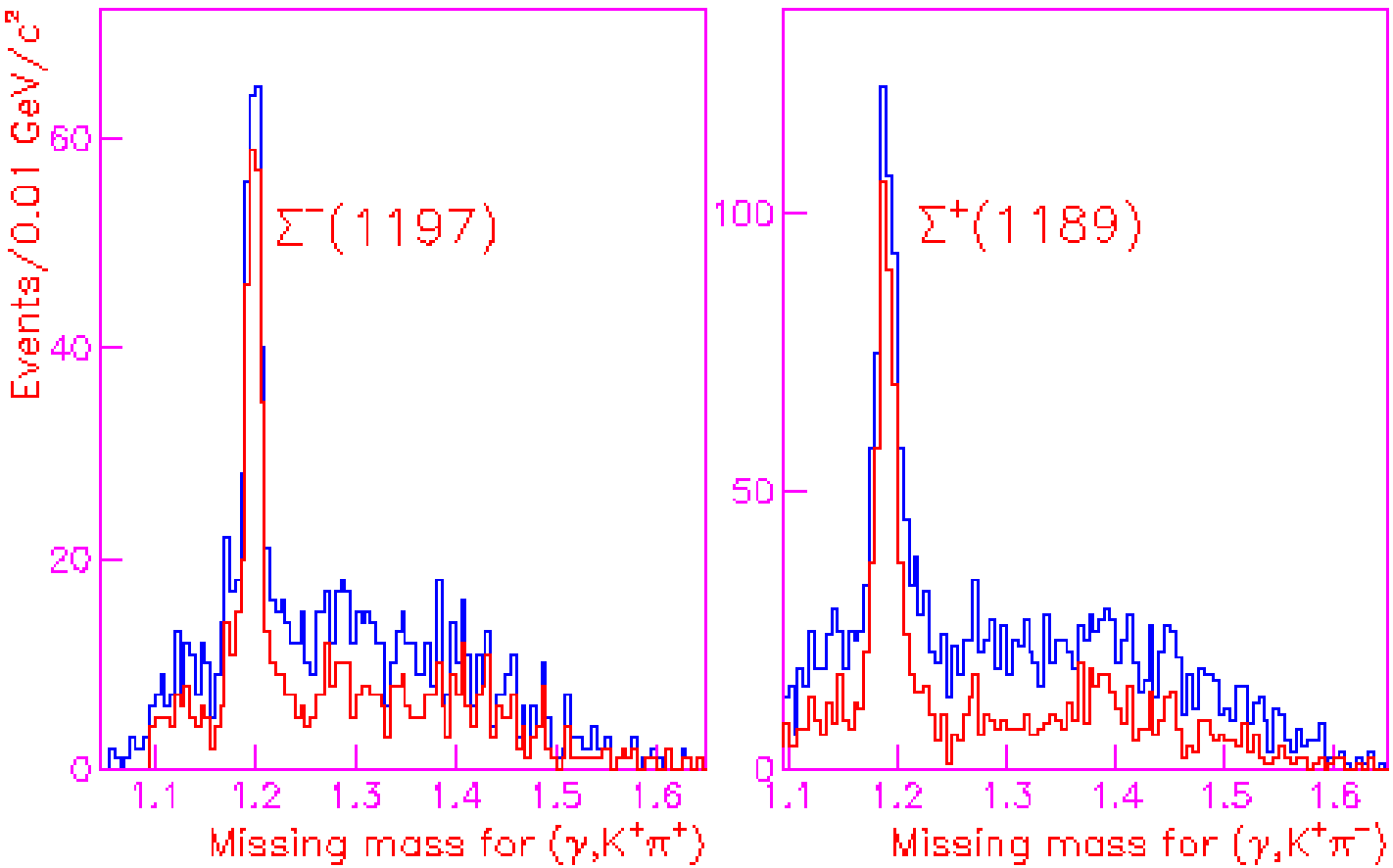
$(\Sigma^{0} \rightarrow \Lambda\gamma,\ \Lambda \rightarrow p\pi^{-})$



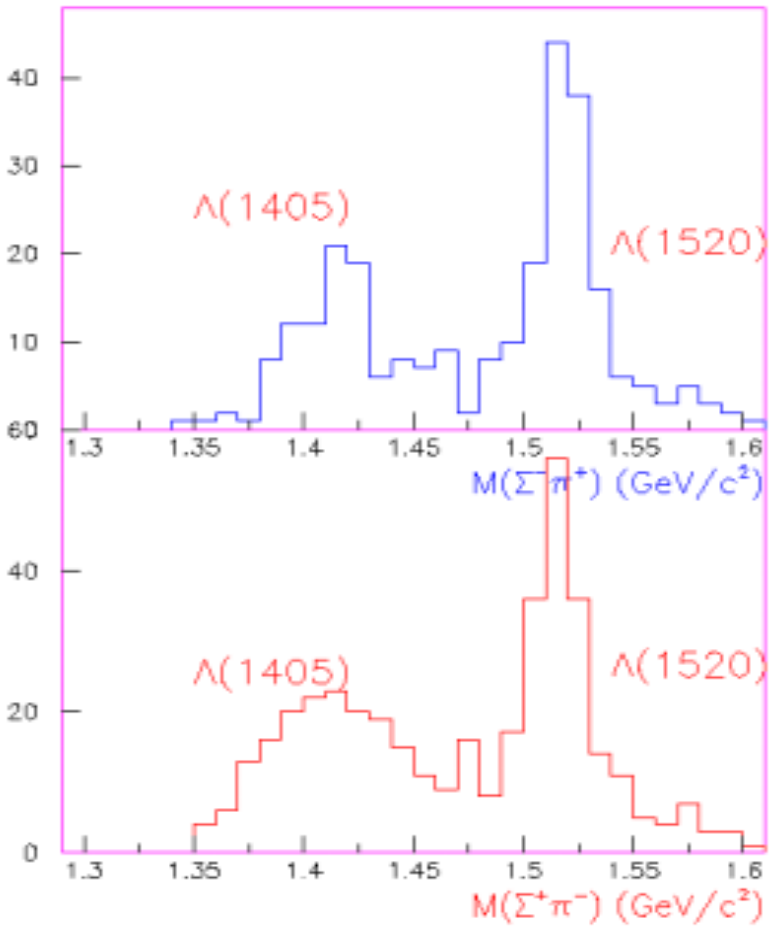
Closest Distance

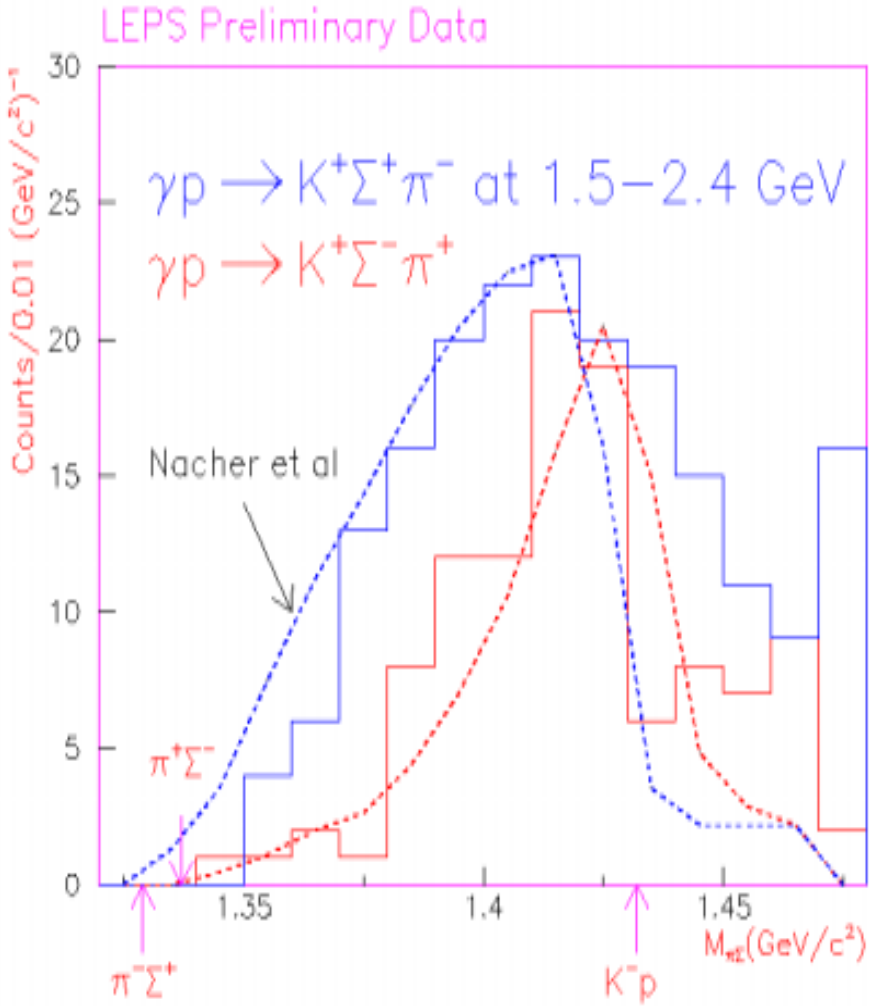


MM for $p(\gamma,K^+\pi)X$



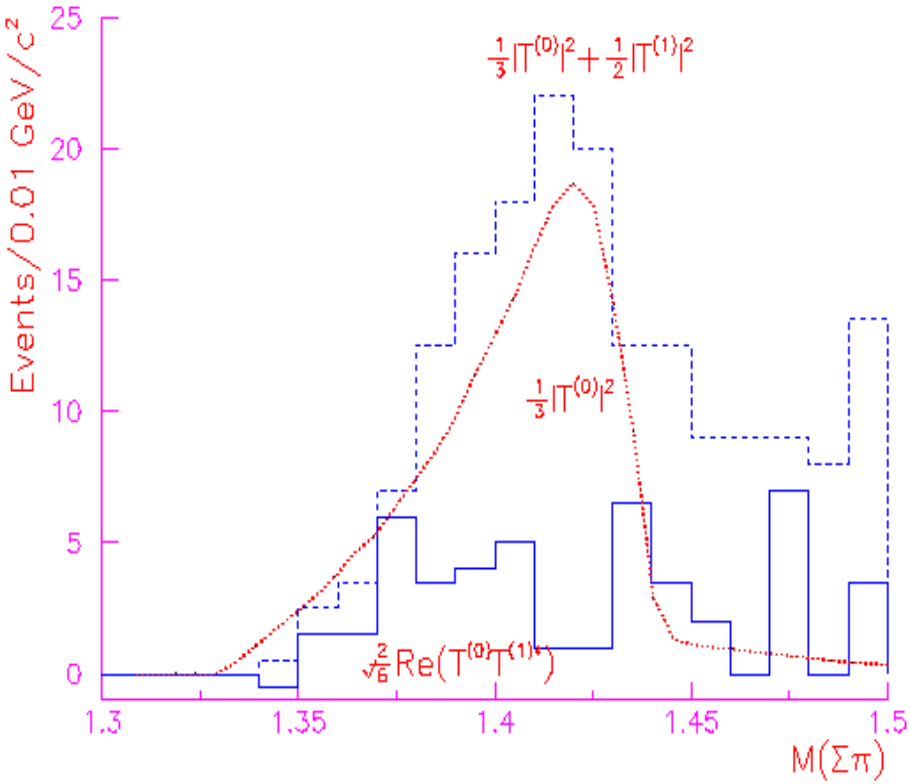
Lineshape of the Λ(1405)





I=0, I=1 Amplitudes

$$\frac{d\sigma(\pi^{\pm}\Sigma^{\mp})}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2 + \frac{1}{2}|T^{(1)}|^2 \pm \frac{2}{\sqrt{6}}Re(T^{(0)}T^{(1)*})$$

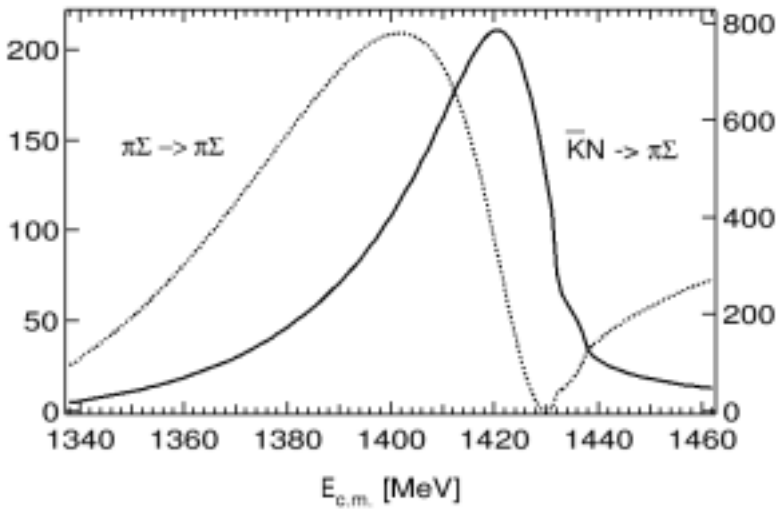


Without negligible I=2 contribution, the difference of the two charged channels shed some light on the I=1 amplitude contribution.

The sum of cross-sections for the two channels provides information on the I=0 dominant lineshape.

Two Λ(1405) States?

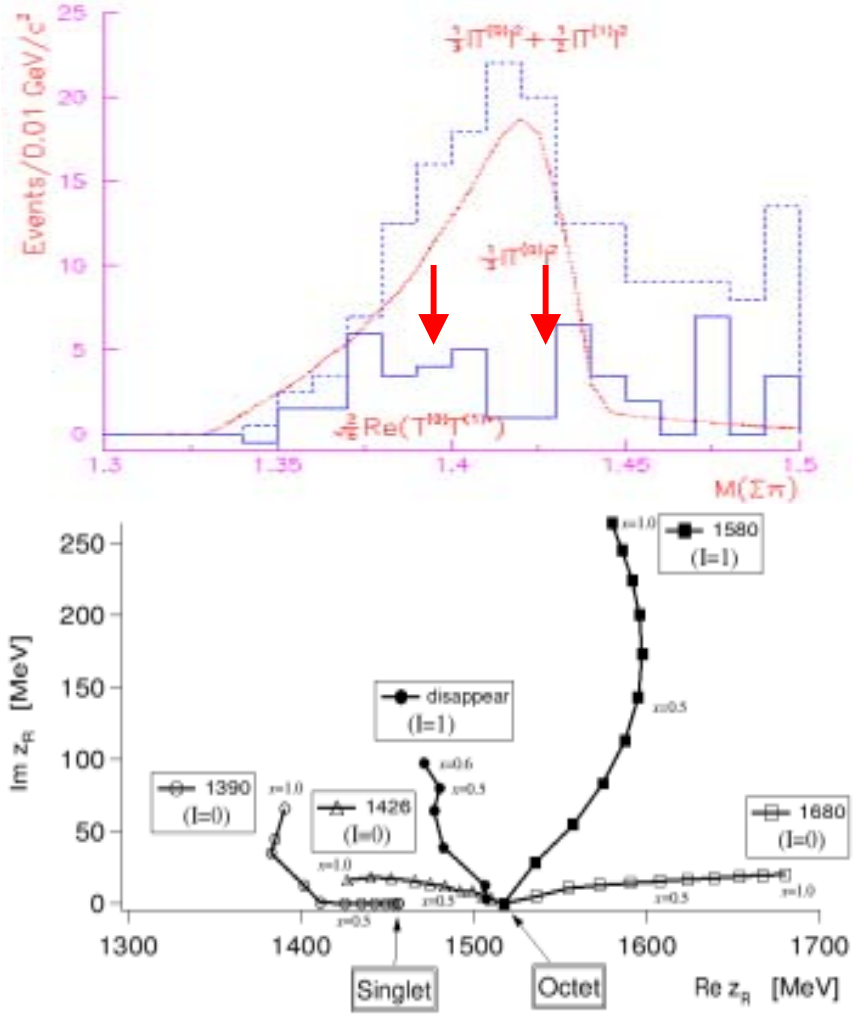
Chiral Unitary Approach



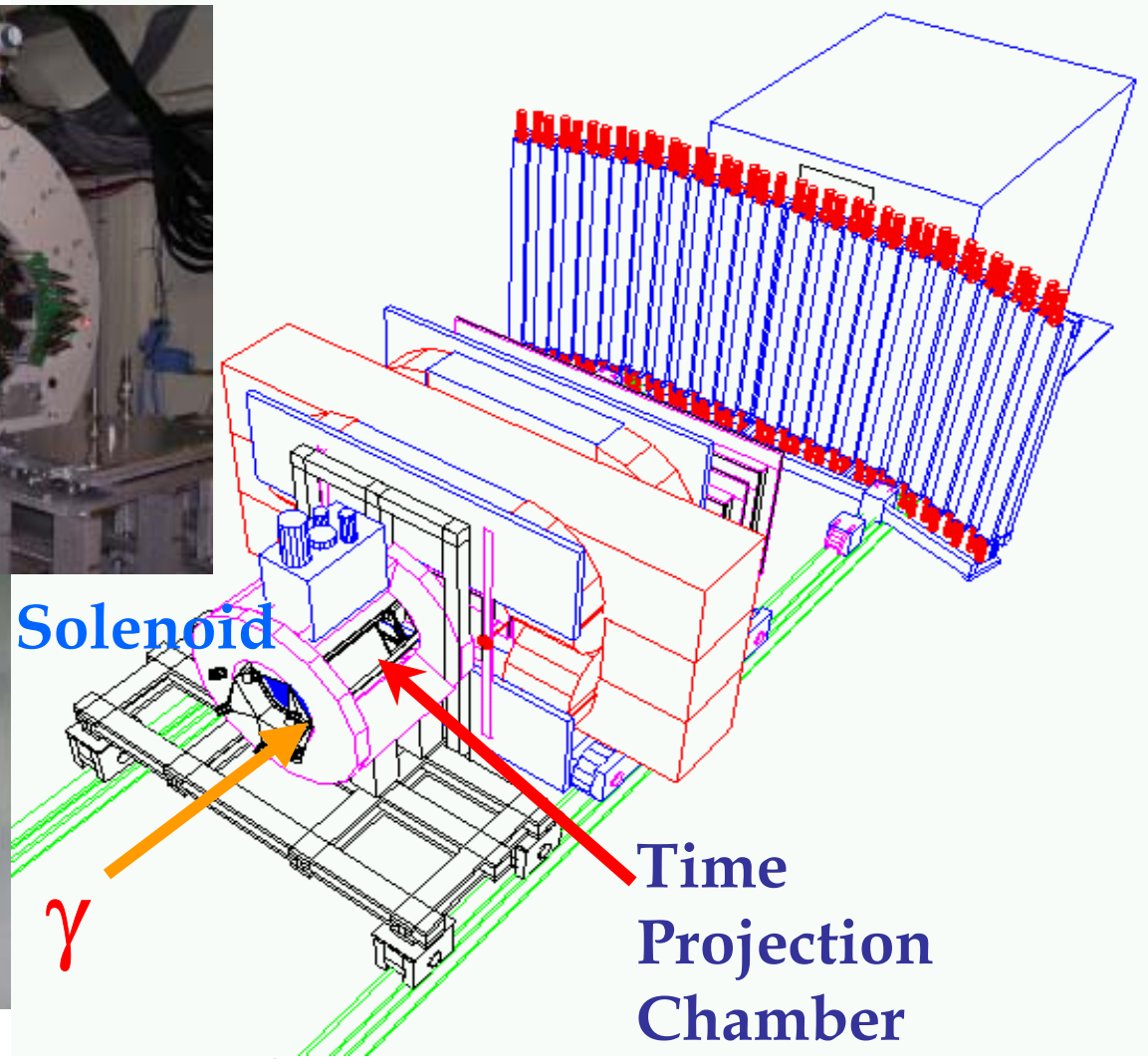
$$\frac{d\sigma}{dM_i} = C\left|T_{\pi\Sigma\to\pi\Sigma}\right|^2 q_{\mathrm{c.m.}}$$

$$\left|T_{\bar{K}N\to\pi\Sigma}\right|^2 q_\pi \ \text{ and } \ \left|T_{\pi\Sigma\to\pi\Sigma}\right|^2 q_\pi$$

D. Jido et al., nucl-th/0303062

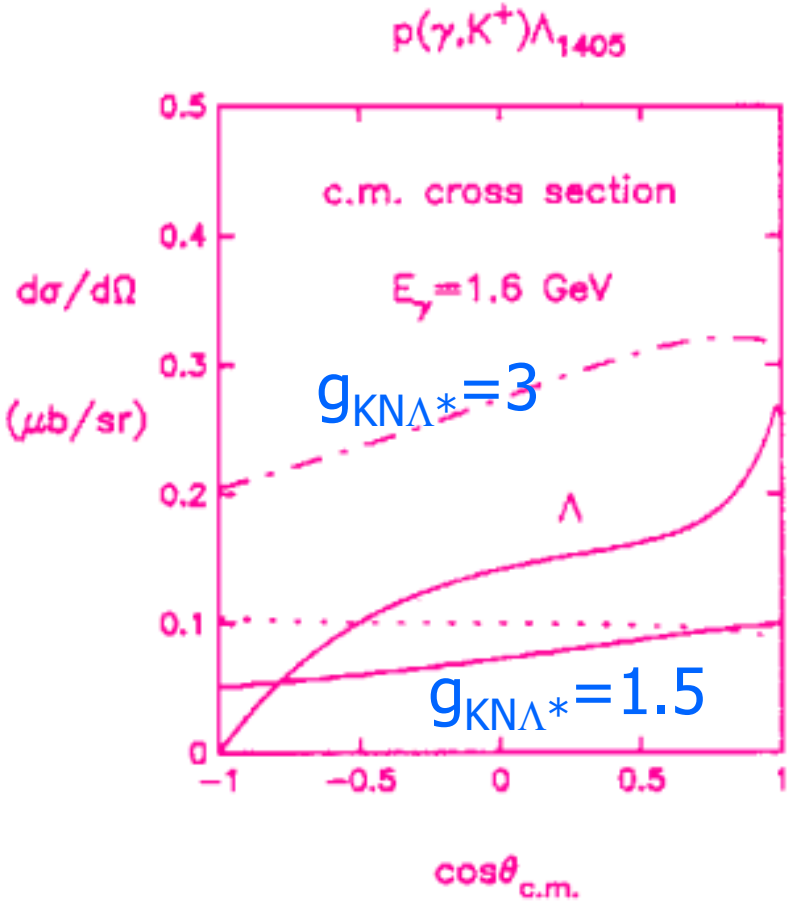


Experiment with TPC

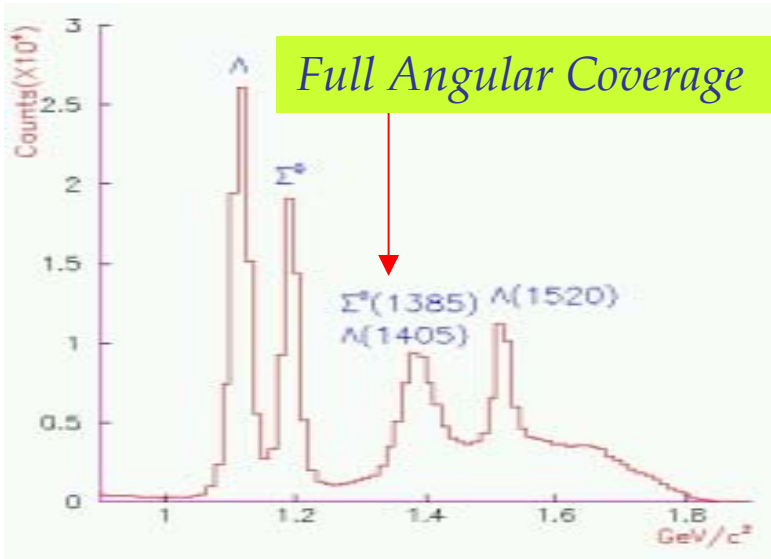


Differential Cross Section

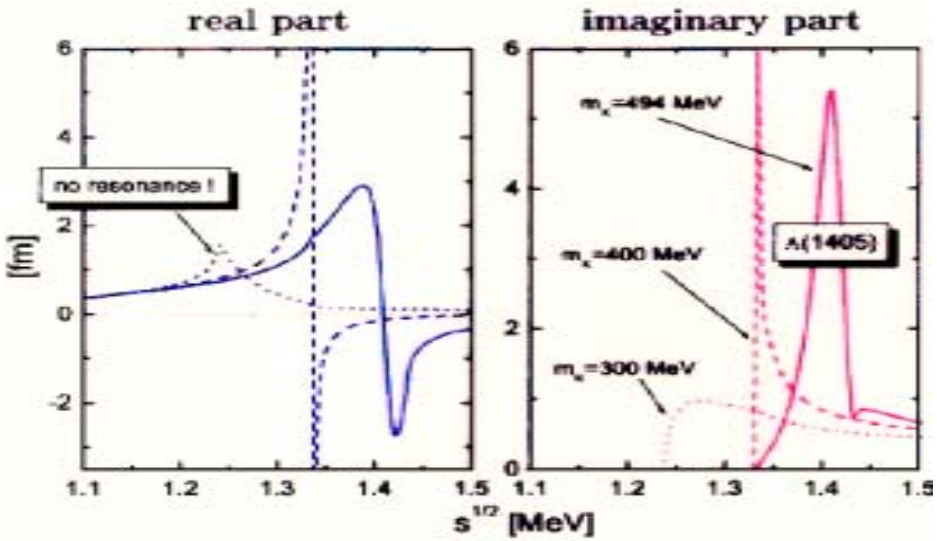
Williams et al, PRC 43 (1991)452



$d\sigma/d\Omega$ *is sensitive to the strong coupling constant* $g_{KN\Lambda(1405)}$



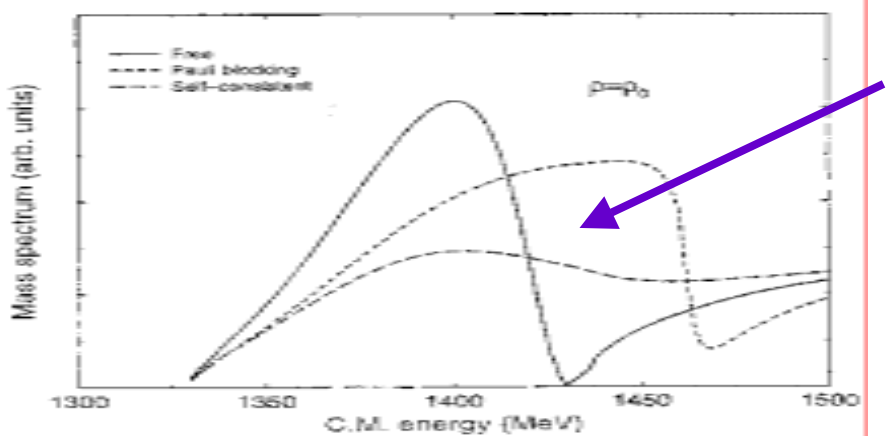
$\Lambda(1405)$ in Nuclear Medium



Lutz, Kolomeitsev
NPA 700 (2002)193

Disappears at m_K=300MeV

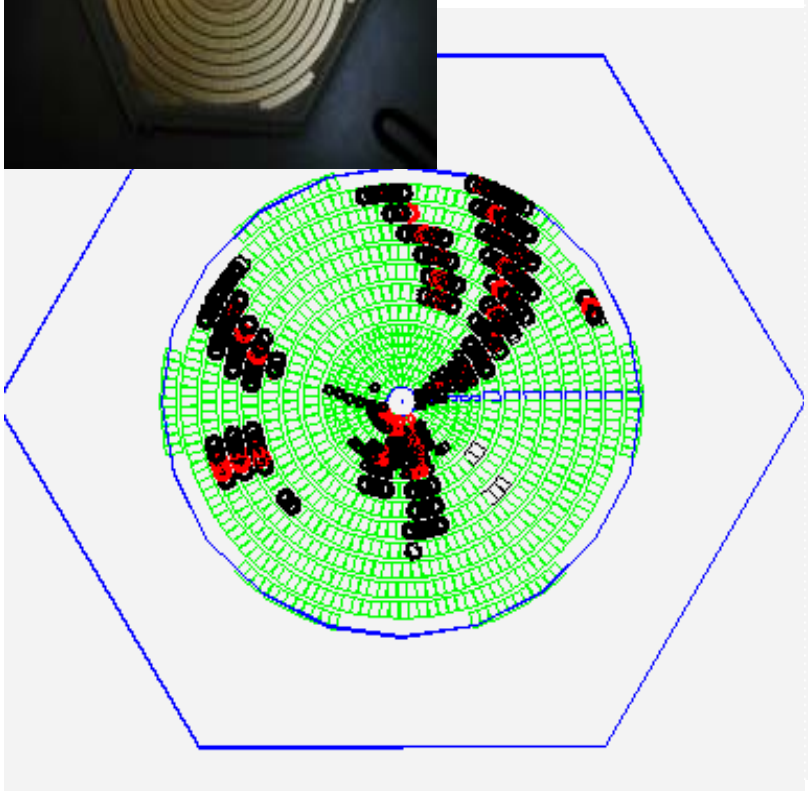
Aiming at Detecting
Any possible change
in Mass and/or Width
of the $\Lambda(1405)$

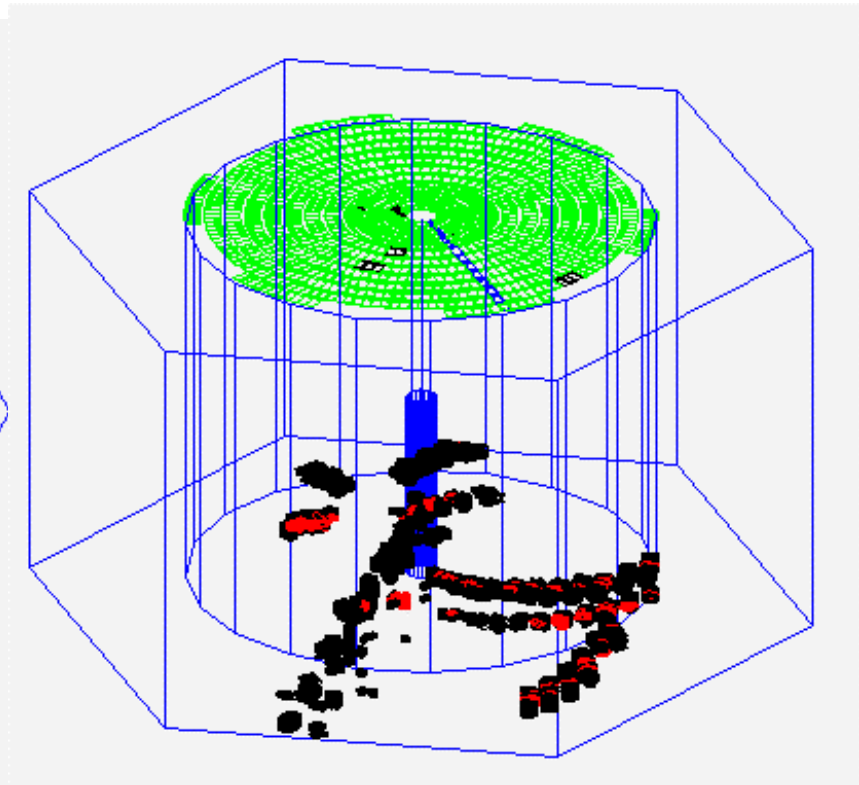


Nacher,Oset,Toki,Ramos
PLB 455 (1999) 55

SPring-8 TPC Beam Test

The First Beam Test Has Yielded Very Good Performance of the SPring-8 TPC





Summary

Photoproduction of Λ(1405) at LEPS

(4π tracking = Dipole + Solenoid Spectrometer)

- *Our preliminary Λ(1405) results supports the interpretation of a meson-baryon coupled-channel resonance.*
- *Physics run with TPC and nuclear targets is planned from this spring through this summer.*