Low energy kaon scattering: present status and open possibilities

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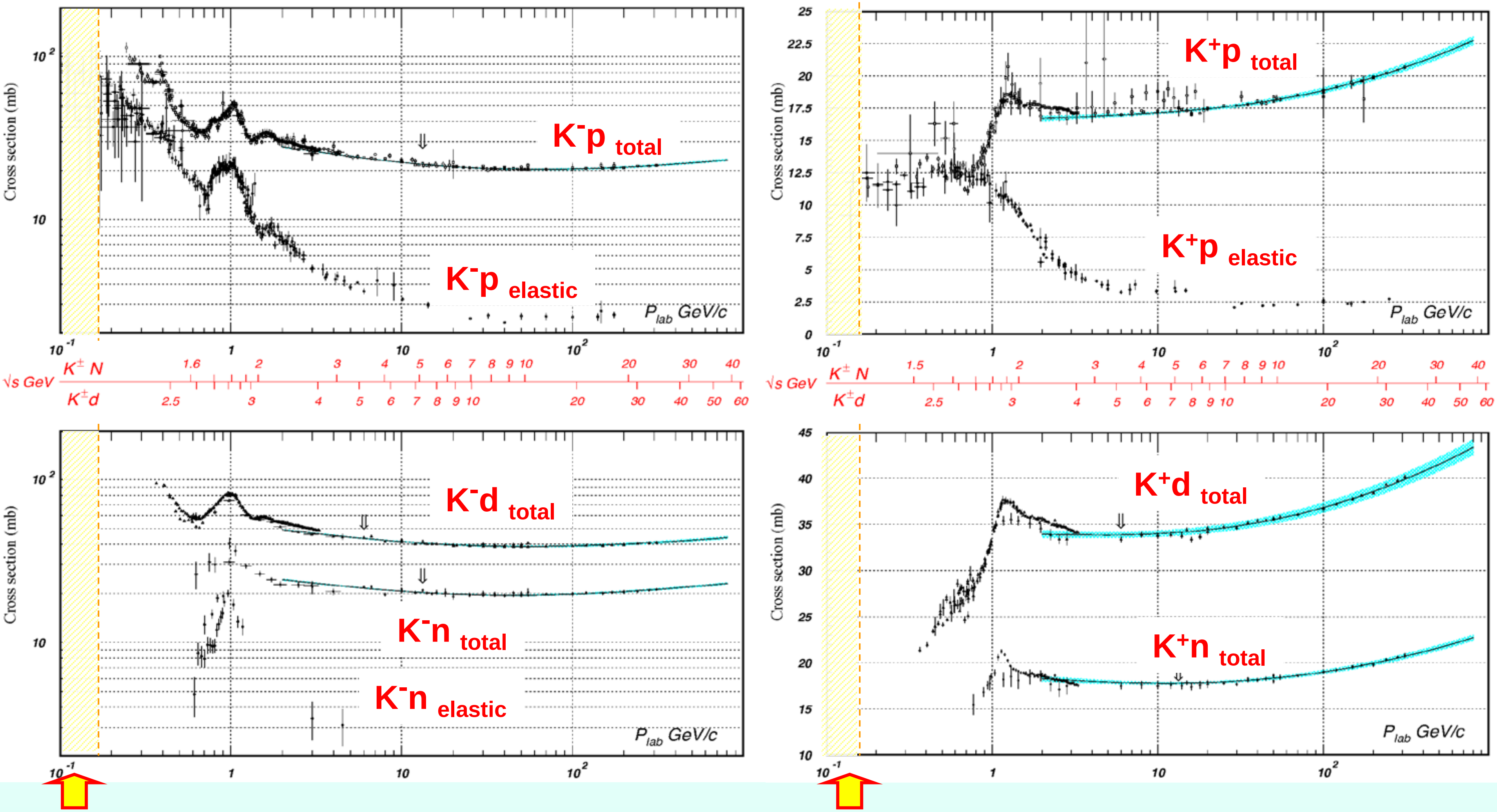
Outline

- Low energy kaon scattering physics: a short experimental overview
  - Kaon vs antikaons, charged vs neutral kaons
- Why is kaon scattering still instructive?
- What can we learn more from reactions induced by neutral kaons?
  - Unmeasured cross sections at low energy – no data exist
  - $\overline{K}N$ Scattering lengths determination
  - Subthreshold behavior of $\overline{K}N$ interaction – free space and in-medium
    - The $\Lambda(1405)$ problem
    - Existence of aggregate $\overline{K}$-multi N clusters
  - Information on mirror hypernuclei
- Conclusions

Charged Kaon-Nucleon scattering database



DAΦNE

DAΦNE

- At low energy (<350 MeV/c) : **SCARCE DATABASE, LARGE ERRORS**
- Old measurements: < 1982, bubble chamber & emulsion experiments

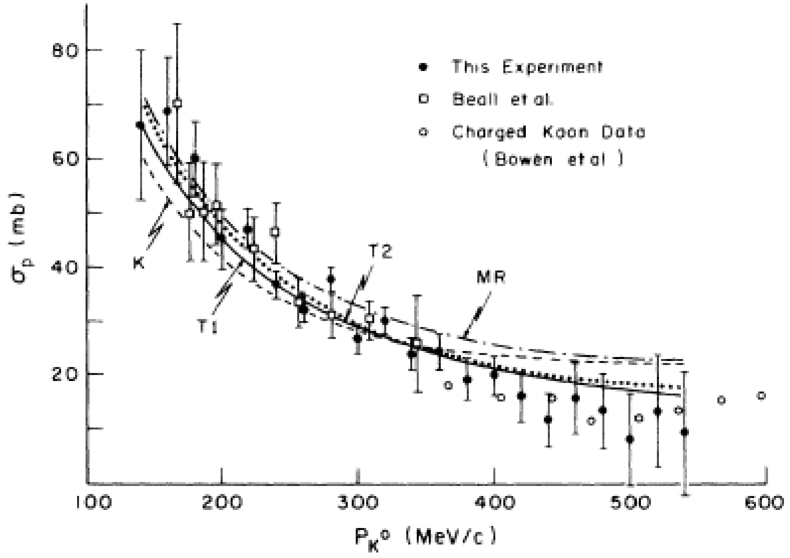
Neutral kaon interactions: total cross section on p and n

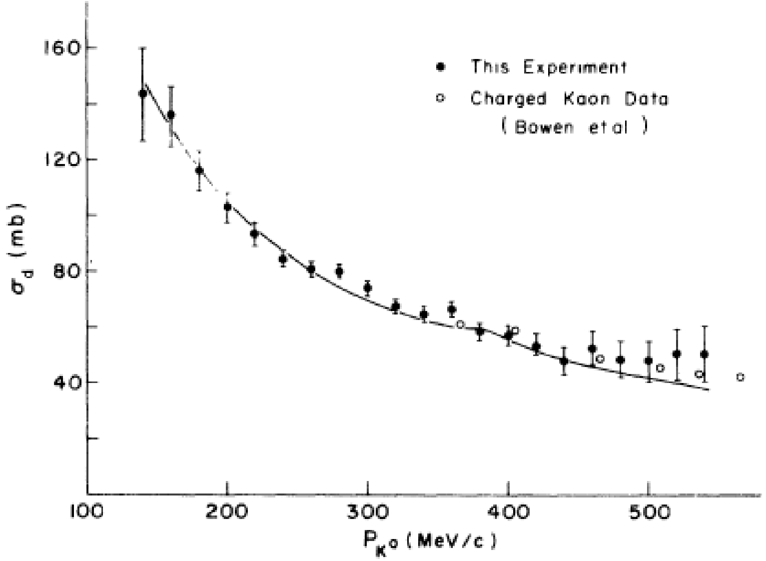
- Few measurements and dated, limited statistical accuracy
- K_L momenta down to 130 MeV/c
  - $\sigma_{tot}(K_L p)$ ~ 70 mb
  - $\sigma_{tot}(K_L d)$ ~ 150 mb
- Precision:
  - $K_L p$: 10-20%
  - $K_L d$: 5-10%

- The $K^0{}_L p$ total cross section is a the average of the $K^0 p$ and $\overline{K}{}^0 p$ cross sections

- Charge symmetry assumed (and confirmed):
  - $\sigma_{tot}(K^0 p) = \sigma_{tot}(K^+ n)$
  - $\sigma_{tot}(\overline{K}{}^0 p) = \sigma_{tot}(K^- n)$

W Cleland et al, PR**D12**, 1247 (1975)





Neutral kaons scattering

- Neutral kaons: two different kinds of particles according to their strong or weak interactions
- K_S and K_L : weakly interacting particles
  - linear combinations of the strongly interacting K^0 and $\bar{K}^0$

- Neutral kaon scattering:
  - In dense material: almost all of the $\bar{K}^0$ component is lost (absorption)
  - On protons: the final states may contain both K^0 and $\bar{K}^0$ with different amplitudes
    - K^0p: mixture of I=0 and I=1
    - $\bar{K}^0$p: pure I=1 system
  - From the interference of amplitudes one may determine the relative sign of the K^0 and $\bar{K}^0$ potentials

G Sayer et al, PR**169**, 1045 (1968)

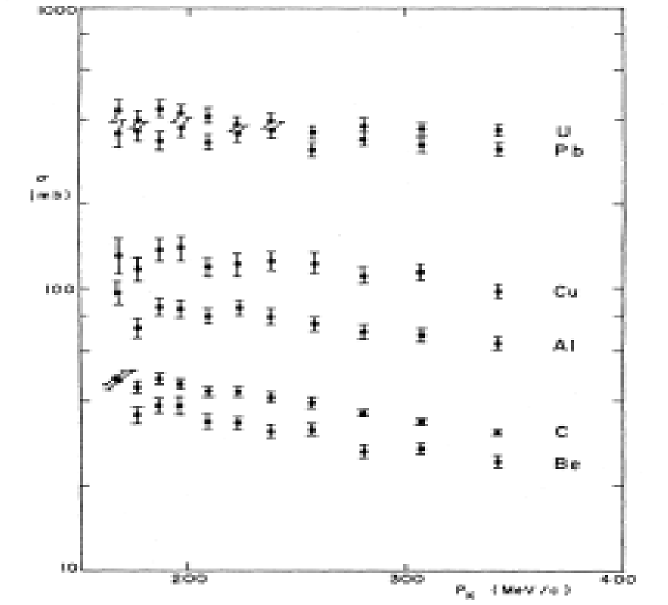


FIG. 10. K_2^0-nuclear cross sections.

Kaons/Antikaons as hadronic probes

- Unique and complementary features of $K^{\pm,0}$ ($\bar{K}^0$) as hadronic probes
- BUT: dramatically different strong interaction of $K^{+,0}$ and $K^-/\bar{K}^0$ with the nucleons and nuclei (unlike pions)

Key role: STRANGENESS conservation

KN

$K^+ = (u\bar{s})$

$K^0 = (d\bar{s})$

$S = +1$

- Small K^+N cross sections (O(10 mb))
- Absence of “ordinary” resonances
  - Only S=+1 systems ($q^4\bar{q}$) could be formed, p>800 MeV/c
- Only elastic and CEX reactions possible

$\bar{K}N$

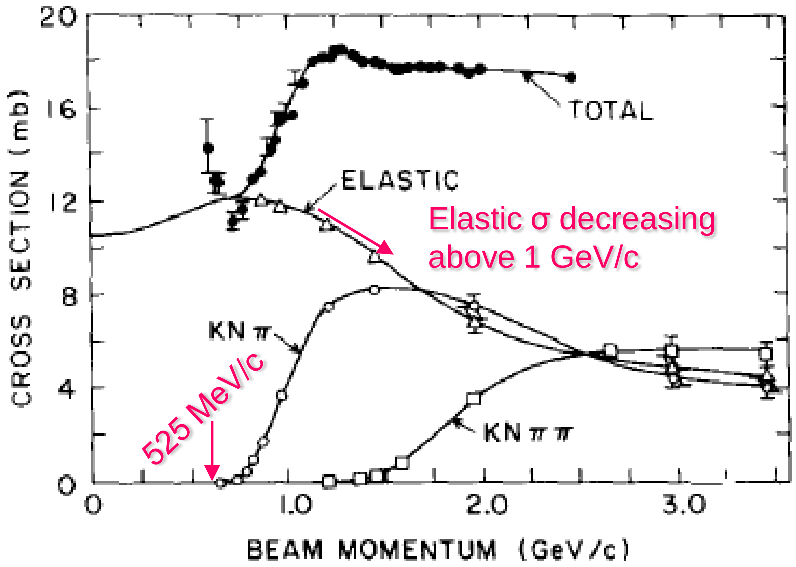
$K^- = (\bar{u}s)$

$\bar{K}^0 = (\bar{d}s)$

$S = -1$

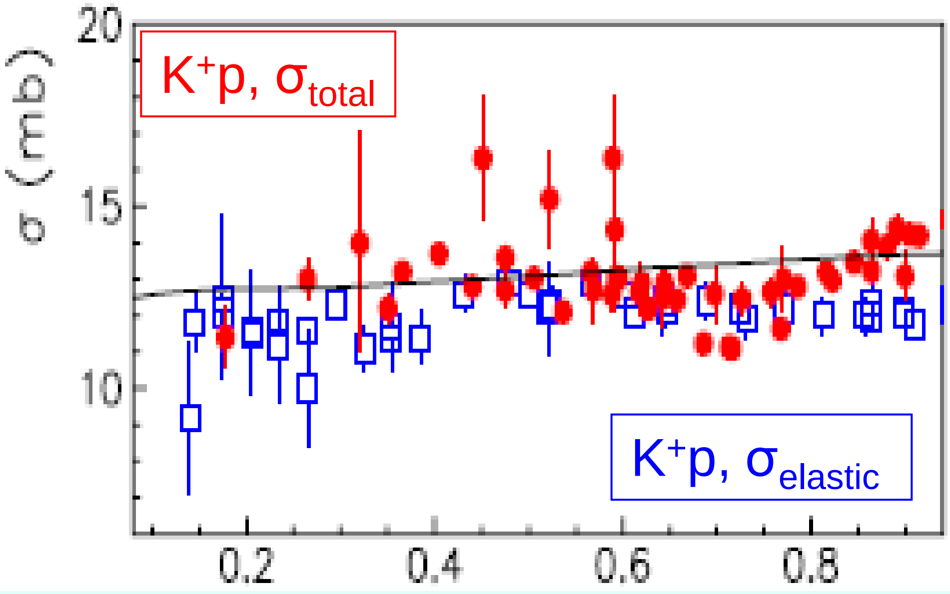
- Large cross sections (> 50 mb)
- Excitation of I=0,1 Y* resonances (baryonic: q^3), even below threshold
- Strong coupling to many channels: Λπ, Σπ, Yη,…
- Strongly absorbed in nuclei

K$^+$ nucleon scattering at med-low momentum: I=1



Elastic σ decreasing above 1 GeV/c

525 MeV/c

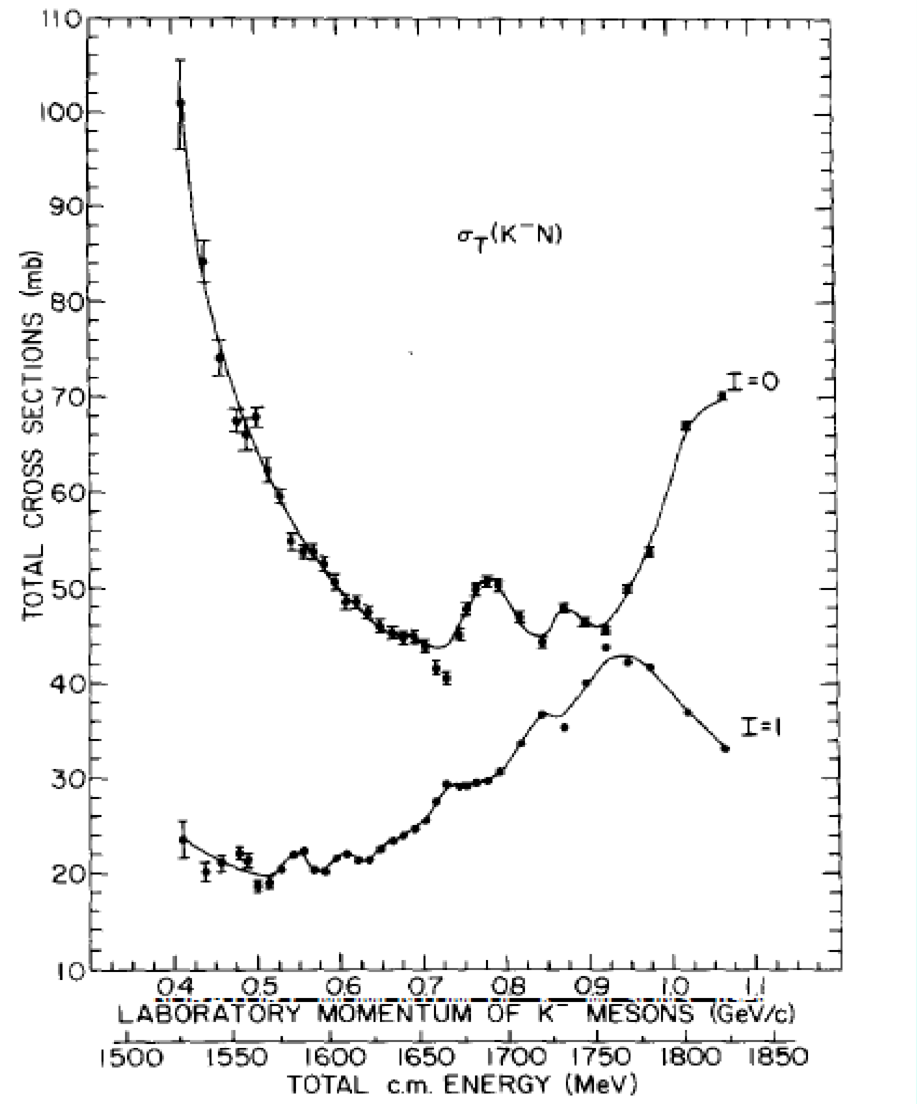


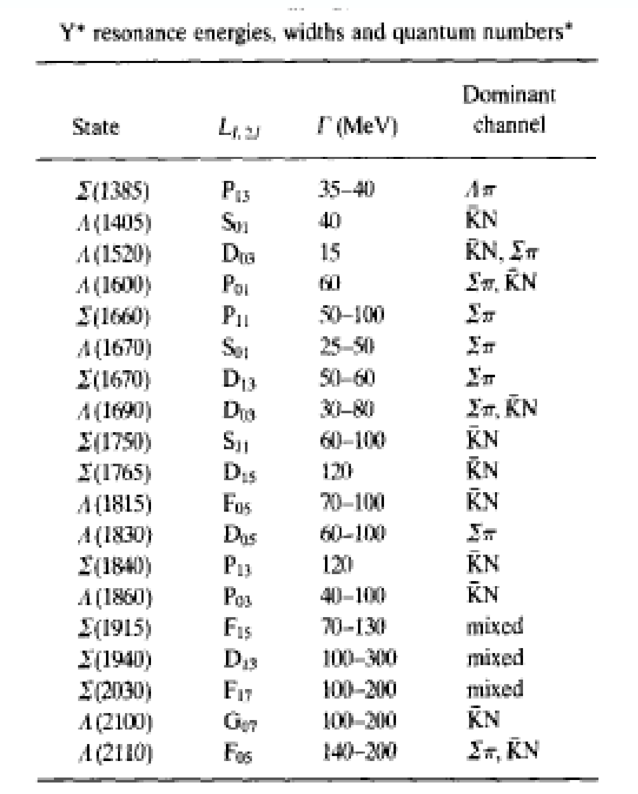
K$^+$p interaction (in H_2)

- elastic channel dominant up to 800 MeV/c
- S-wave dominance
- Pure I=1 source
- Strong contribution on Coulomb interaction at small angles, comparable to nuclear one
  - Sign of nuclear phase shift
    - Negative, S-wave, constructive interference at all momenta below 400 MeV/c
  - S-wave scattering length assessed with a precision of 1%
  - Low energy parameters evaluation

K$^-$ nucleon scattering

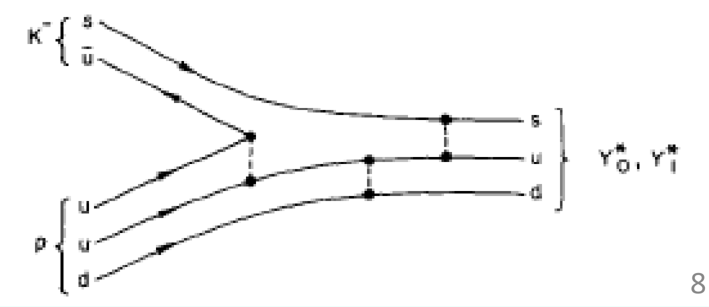
Excitation of I=0 and I=1 baryonic resonances





Y* resonance energies, widths and quantum numbers*

State	$L_{I,2J}$	Γ (MeV)	Dominant channel
$\Sigma(1385)$	P_{13}	35–40	$\Lambda\pi$
$\Lambda(1405)$	S_{01}	40	$\bar{K}N$
$\Lambda(1520)$	D_{03}	15	$\bar{K}N$, $\Sigma\pi$
$\Lambda(1600)$	P_{01}	60	$\Sigma\pi$, $\bar{K}N$
$\Sigma(1660)$	P_{11}	50–100	$\Sigma\pi$
$\Lambda(1670)$	S_{01}	25–50	$\Sigma\pi$
$\Sigma(1670)$	D_{13}	50–60	$\Sigma\pi$
$\Lambda(1690)$	D_{03}	30–80	$\Sigma\pi$, $\bar{K}N$
$\Sigma(1750)$	S_{11}	60–100	$\bar{K}N$
$\Sigma(1765)$	D_{15}	120	$\bar{K}N$
$\Lambda(1815)$	F_{05}	70–100	$\bar{K}N$
$\Lambda(1830)$	D_{05}	60–100	$\Sigma\pi$
$\Sigma(1840)$	P_{13}	120	$\bar{K}N$
$\Lambda(1860)$	P_{03}	40–100	$\bar{K}N$
$\Sigma(1915)$	F_{15}	70–130	mixed
$\Sigma(1940)$	D_{13}	100–300	mixed
$\Sigma(2030)$	F_{17}	100–200	mixed
$\Lambda(2100)$	G_{07}	100–200	$\bar{K}N$
$\Lambda(2110)$	F_{05}	140–200	$\Sigma\pi$, $\bar{K}N$



K^-N interaction at low energy

- **NO ChPT**
- **Baryonic resonances, I=0,1:**
  Λ(1115), Σ(1190), **Σ(1385), Λ(1405)**…
- Non-perturbative coupled-channel approach to describe all aspects of the K^-N interaction
- Low-energy data crucial input to enhance the predicting power of the KN models
  - Lack of experimental constraints close to threshold
    - scarcely selective models
    - poor below-threshold predictive power
    - Exp.data with inconsistencies
      - No model able to account for them

Scattering cross sections for elastic & inelastic processes

Hadronic branching ratios close to threshold

Data for below threshold resonance excitations: $\Sigma\pi$ spectra

Energy shift & width of kaonic atoms

6 parameters needed to fully describe low energy K^-N scattering

S-wave scattering parametrization

- Low energy $\overline{K}$N systems (p_K < 300 MeV/c) may be parametrized in terms of S-wave scattering lenghts (Dalitz, Tuan, Ann. Phys. 3, 307 (1960))
- Assumptions:
  - The energy is sufficiently low for the scattering to be in S-wave only
  - The S-wave phase shift in each channel with defined isospin and strangeness is determined by a single (complex) parameter, the scattering length
  - The “effective-range term” is negligible: “zero-effective range” treatment

$$\cot\delta = 1/kA \qquad A = a + ib$$

- General expression for the cross section in a single channel

$$\sigma = 4\pi \frac{a^2 + b^2 + b/k}{k^2 a^2 + (1+kb)^2}$$

- The determination of the complex K^-p scattering length is complicated due to the presence of both I=0 and I=1 sources, and to the Coulomb force

Zero-effective range parametrizations of neutral kaons cross sections

- S-wave zero-effective-range approximation:
  - **strangeness +1, I=0 and I=1** scattering lengths: **a_0, a_1 REAL** (no absorption)
  - **strangeness -1, I=1** scattering length: **$\bar{A}_1 = \bar{a}_1 + i\,\bar{b}_1$ COMPLEX** (absorptive)

$$\sigma_{tot} = 2\pi\left[\frac{1}{2}\frac{a_0^2}{1+k^2a_0^2} + \frac{1}{2}\frac{a_1^2}{1+k^2a_1^2} + \frac{\bar{a}_1^2 + \bar{b}_1^2 + \bar{b}_1/k}{k^2\bar{a}_1^2 + (1+k\bar{b}_1)^2}\right]$$

total

$$\sigma(K_L^0 p \to K_L^0 p) = \pi\left|\frac{1}{2}\frac{a_0}{1-ika_0} + \frac{1}{2}\frac{a_1}{1-ika_1} \boxed{+} \frac{\bar{a}_1 + i\bar{b}_1}{k^2\bar{a}_1^2 + (1+k\bar{b}_1)^2}\right|^2$$

elastic

$$\sigma(K_L^0 p \to K_S^0 p) = \pi\left|\frac{1}{2}\frac{a_0}{1-ika_0} + \frac{1}{2}\frac{a_1}{1-ika_1} \boxed{-} \frac{\bar{a}_1 + i\bar{b}_1}{k^2\bar{a}_1^2 + (1+k\bar{b}_1)^2}\right|^2$$

regeneration

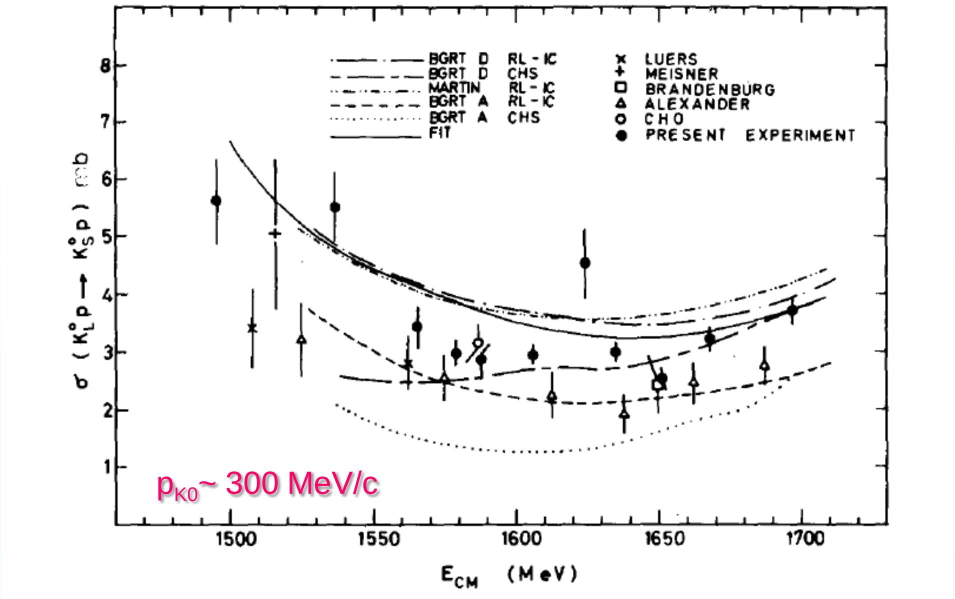
$$\sigma(K_L^0 p \to Y\pi) = \frac{2\pi}{k}\frac{\bar{b}_1}{k^2(\bar{a}_1^2 + \bar{b}_1^2) + 2k\bar{b}_1 + 1}$$

1-N absorption

Regeneration K^0_L cross section

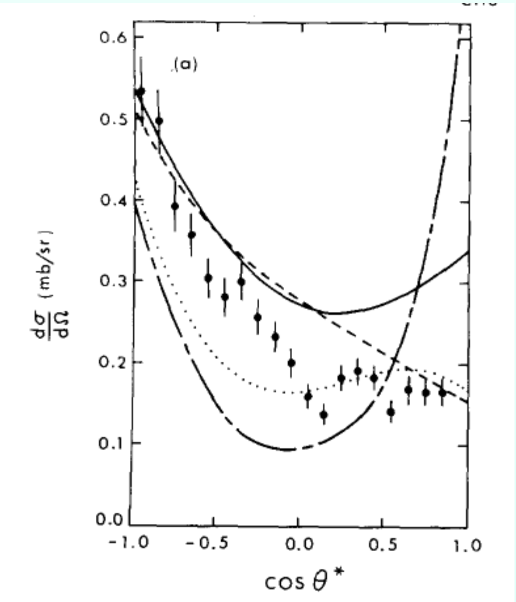
$$\boxed{K_2^0 p \rightarrow K_1^0 p \qquad K_1^0 \rightarrow \pi^+\pi^-}$$

$$T = \underbrace{\frac{1}{4}(Z_0 + Z_1)}_{\text{I=0 + I=1 KN}} - \underbrace{\frac{1}{2}Y_1}_{\text{I=1 }\bar{\text{K}}\text{N}}$$



p_{K0}~ 300 MeV/c

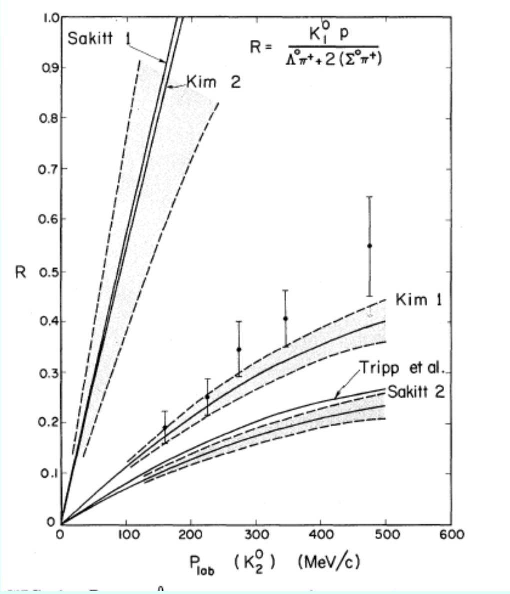
- Interference between S=+1 and S=-1 amplitudes
- 300-800 MeV/c (A Bigi, NP**B110**, 25 (1976))
  - ~ 5 mb
- Main purpose:
  - Y^*_1 (=Σ(1385)) spectroscopy
  - Get information on possible I=0, S=+1 Z* states (unsuccessful)
- Differential cross section backward peaked (Y Cho, PL**B60**, 293 (1976))



Hyperon production in K$_L$p interaction

$$\begin{array}{ll} K_L^0 p \to \Lambda\pi^+ & \Lambda \to p\pi^- \\ \quad\;\; \to \Sigma^0\pi^+ & \Sigma^0 \to \gamma\Lambda \\ \quad\;\; \to \Lambda\pi^+\pi^0 & \end{array}$$

$$R = \frac{\sigma(K_S^0 p)}{\sigma(Y)} = \frac{\sigma(K_S^0 p)}{\sigma(\Lambda p) + 2\sigma(\Sigma^0 p)}$$



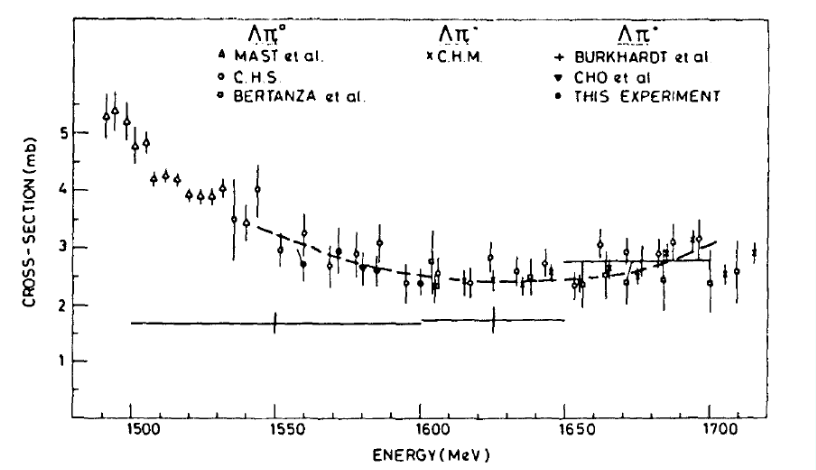
J Kadyk et al, PRL**17**, 599 (1966)

- K$_L$p interaction: I=1, S=-1
- Most of the old assessments deduced from scattering lengths evaluations
  - Wide errors, large ambiguities
  - 30-50 mb
- To discriminate among the different solutions for $\bar{K}$N scattering length: measurements of the relative yields of the regeneration to the inelastic processes

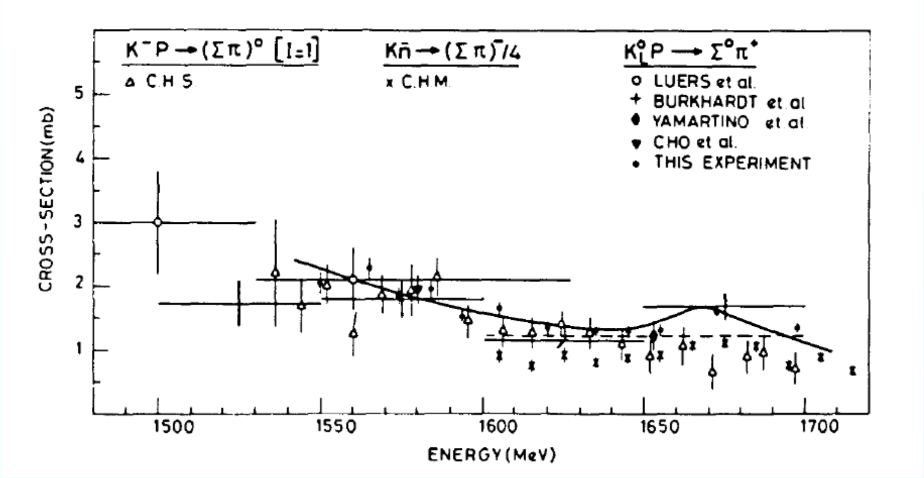
K_Lp inelastic cross sections, 300-800 MeV/c

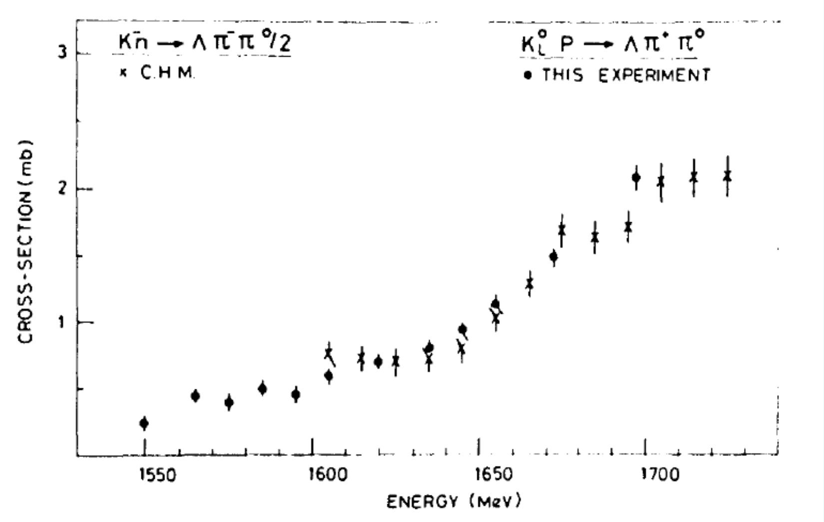
BEGPR Coll, W Cameron et al, PRL**17**, 599 (1978)

- $K_Lp \rightarrow \Lambda\pi^+$: ~ 5 mb



- $K_Lp \rightarrow \Sigma^0\pi^+$: ~3 mb





- $K_Lp \rightarrow \Lambda\pi^0\pi^+$: < 1 mb

dominated by $\Sigma^{0,+}(1385)$ production

$\bar{K}N$ interaction: open problems

- Dynamics of antikaons interacting with nucleons and nuclei

- $\bar{K}N$ interaction at low energy: strongly attractive
  - Generation of $\Lambda(1405)$ as a quasi-bound state embedded in the $\pi\Sigma$ continuum
  - Investigations of $\bar{K}$-few nucleon systems, and possible bound states of a $\bar{K}$ in heavier nuclei
  - Test of chiral (non-perturbative) models
- Strong coupled-channel dynamics: $\bar{K}N \Leftrightarrow \pi\Sigma$
- Large uncertainties in the extrapolation of $\bar{K}N$ interactions to the subthreshold region
- Limited available experimental inputs
  - K^- scattering cross sections in elastic and inelastic channels
  - Threshold branching ratios
  - Real and imaginary part of the K^-p scattering length from kaonic hydrogen measurements
  - New inputs from K_Lp in Coulomb-free I=1?

K^-N interaction description via ChPT

- General theoretical framework: effective field theory with coupled-channels, based on the chiral $SU(3)_R \times SU(3)_L$ meson-baryon effective Lagrangian
  - Fits combining all available experimental inputs: improved constraints on chiral SU(3) couplings
  - The present accuracy of the K^-p cross sections and threshold branching ratios do not constrain the scattering amplitudes sufficiently well
  - Other precise inputs needed

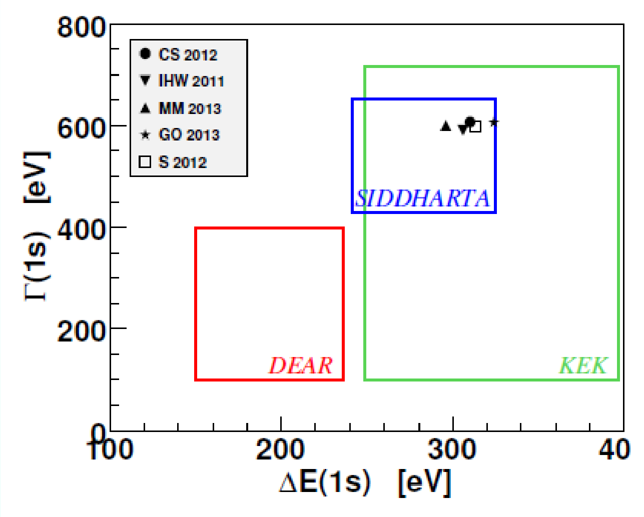
- Essential ingredient: measurement of the shift and with of the 1S kaonic hydrogen line (and kaonic deuterium, if possible)
  - directly linked to the scattering length through the Trueman-Deser formula (including second order isospin breaking corrections)

$$\Delta E - i\Gamma/2 = -2\alpha^3 \mu_T^2 a(K^- p)\left[1 + 2\alpha\mu_T(1-\ln\alpha)a(K^- p)\right]$$

Kaonic hydrogen ground state shift and width

M Bazzi et al, PL**B704**, 113 (2011)

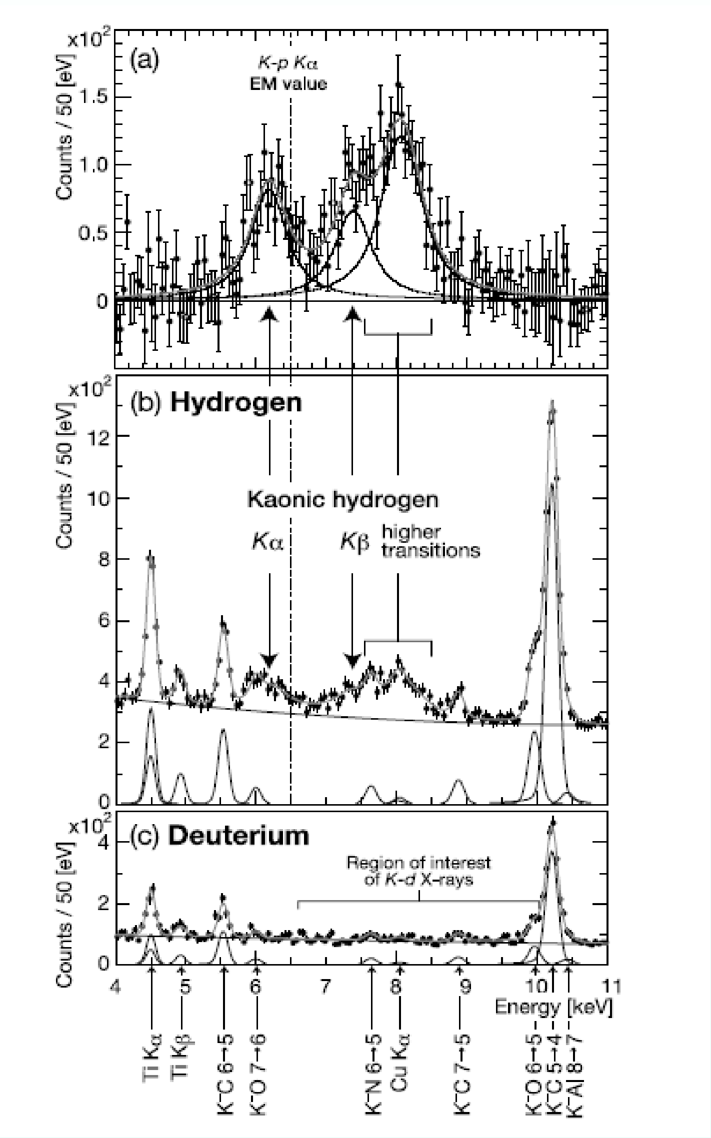
- Several measurements have been performed, with large inconsistencies



- The newest measurement by SIDDHARTA are fully consistent with the existing scattering data

$$\Delta E_{1S} = 283 \pm 36_{stat} \pm 6_{sys} \quad eV$$

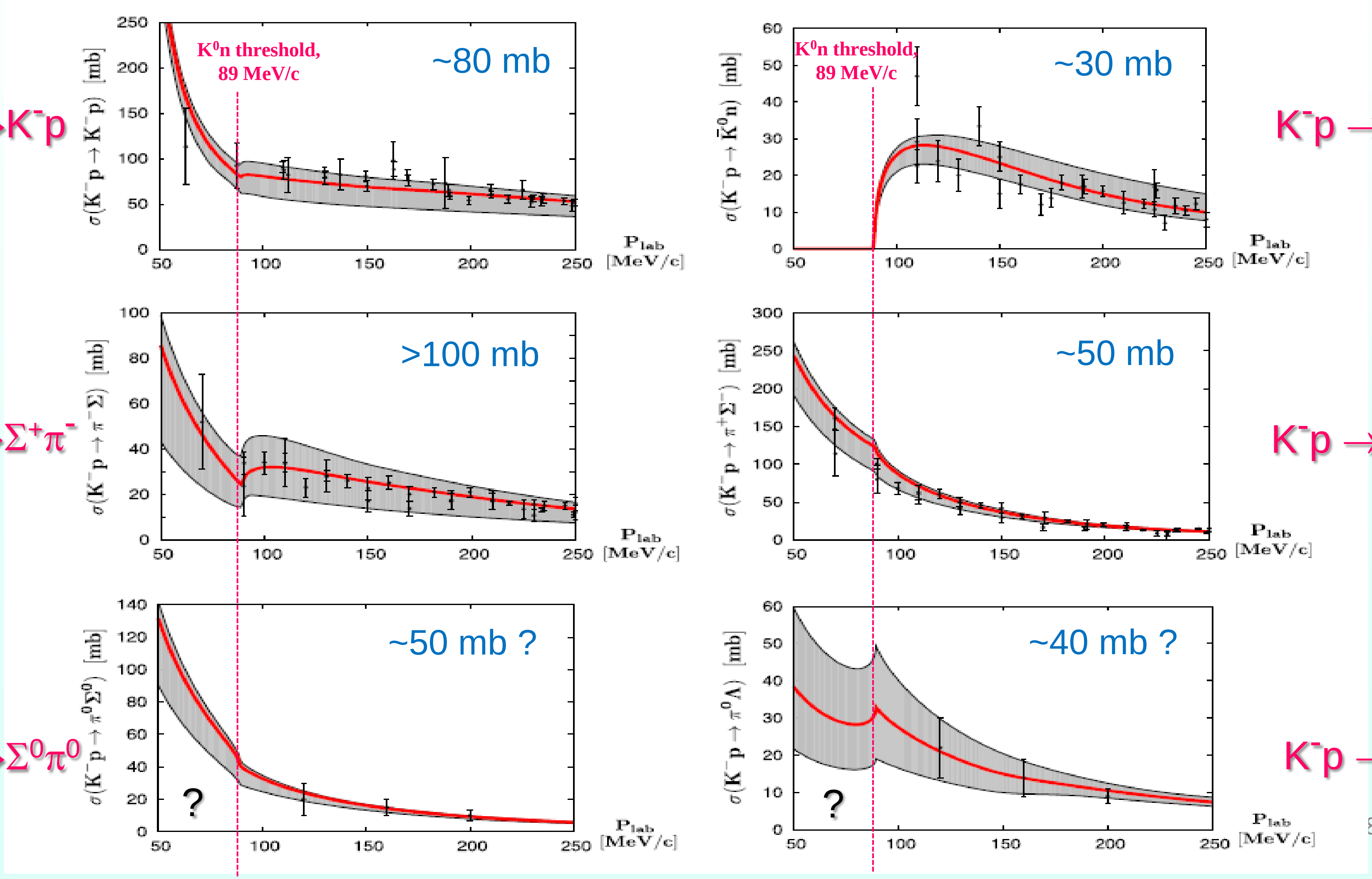
$$\Delta \Gamma_{1S} = 541 \pm 89_{stat} \pm 22_{sys} \quad eV$$



Best fit of K^-p observables: cross section data

Y Ikeda, T Hyodo, W Weise, PL**B706**, 63 (2011)

The available data have a maximum precision of ~ 20%



$K^-p \to K^-p$

$K^-p \to \bar{K}^0n$

$K^-p \to \Sigma^+\pi^-$

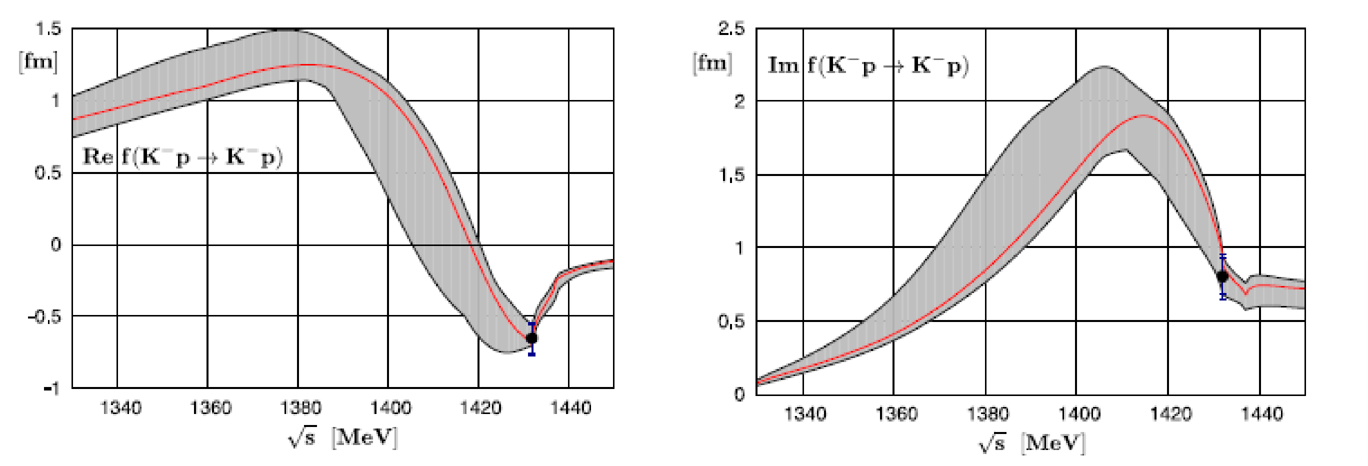
$K^-p \to \Sigma^-\pi^+$

$K^-p \to \Sigma^0\pi^0$

$K^-p \to \Lambda\pi^0$

Fits outcome: subthreshold behavior

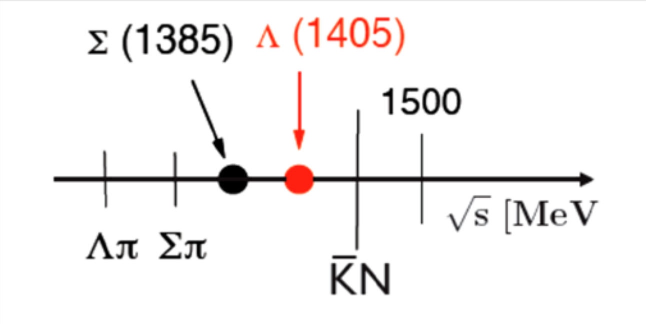
Y Ikeda, T Hyodo, W Weise, PL**B706**, 63 (2011)



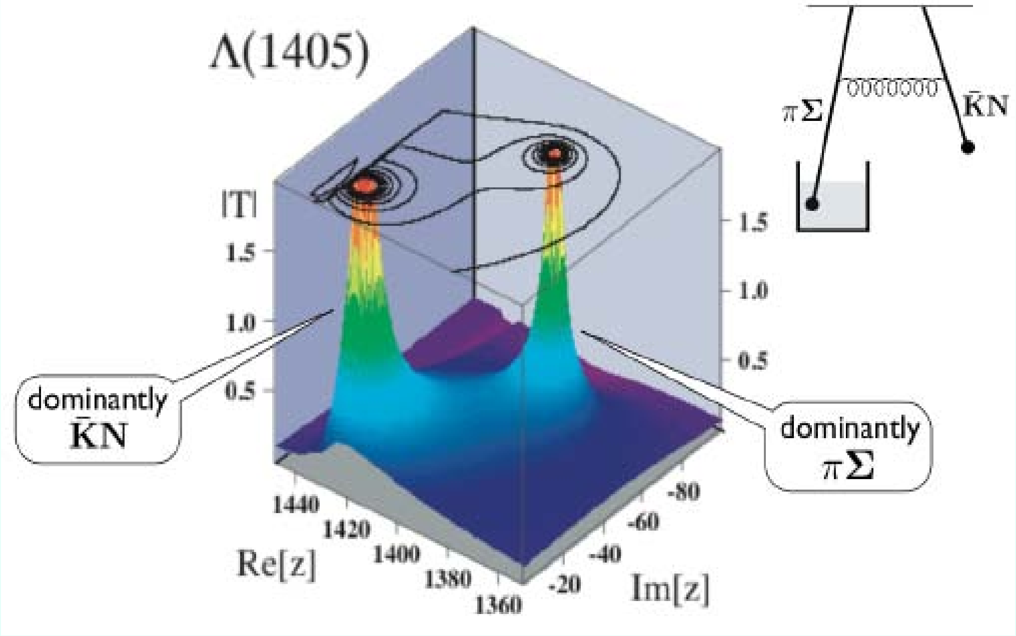
- Extrapolation of the K^-p forward scattering amplitude to the subthreshold region
- Experimental point: real and imaginary part of the K^-p scattering length extracted from the kaonic hydrogen data (with the inclusion of Coulomb corrections)
  - Re $a(K^-p) = -0.65 \pm 0.10$ fm (shifted quite significantly from older values)
  - Im $a(K^-p) = 0.81 \pm 0.15$ fm
- The calculation confirms the existence of the $\Lambda(1405)$ resonance as a quasi-bound I=0 $\bar{K}N$ state embedded in the $\Sigma\pi$ continuum
  - Two poles scenario of the coupled $\bar{K}N \Leftrightarrow \Sigma\pi$
    - Upper pole $\bar{K}N$ dominated: 1424 – i 26 MeV
    - Lower pole $\Sigma\pi$ dominated: 1381 – i 81 MeV

Y Ikeda et al., NP**A881**, 98 (2012)

The Λ(1405) case: present status



Produced below the K^-N threshold



Nature of Λ(1405): dinamically generated resonance

1. Double pole in the complex energy plane one coupled to K̄N the other to Σπ
2. Weakly bound K̄N state with Σπ decay

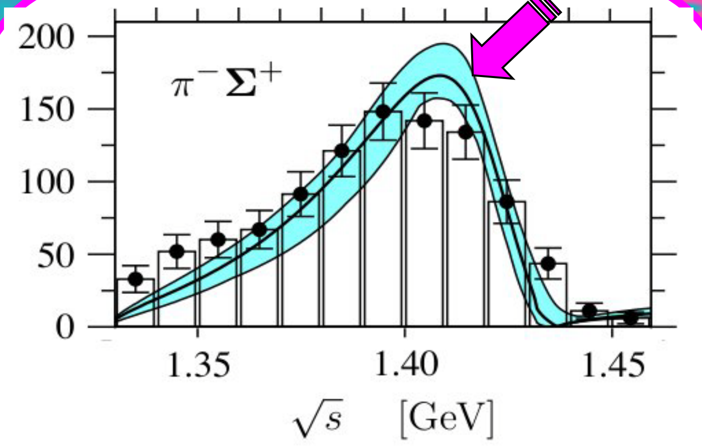
Models based on below-threshold extrapolations

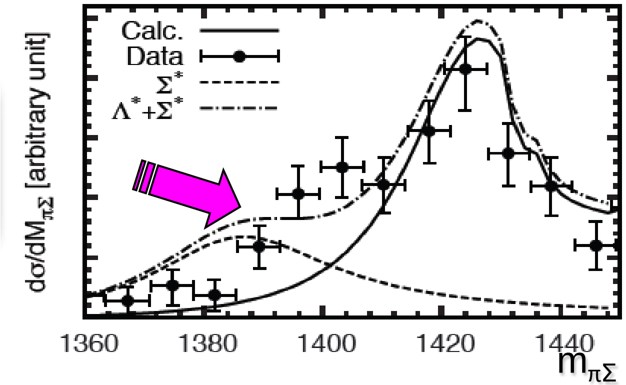
	Λ(1405)	Σ(1385)
$\Sigma^+\pi^-$	0.33	0.06
$\Sigma^0\pi^0$	**0.33**	**no**
$\Sigma^-\pi^+$	0.33	0.06
$\Lambda\pi^0$	**no**	**0.88**

Experimental difficulty:

close-by I=0 and I=1 baryons with shared decay modes

Σπ system: existing data





OLD MEASUREMENTS, charged Σπ

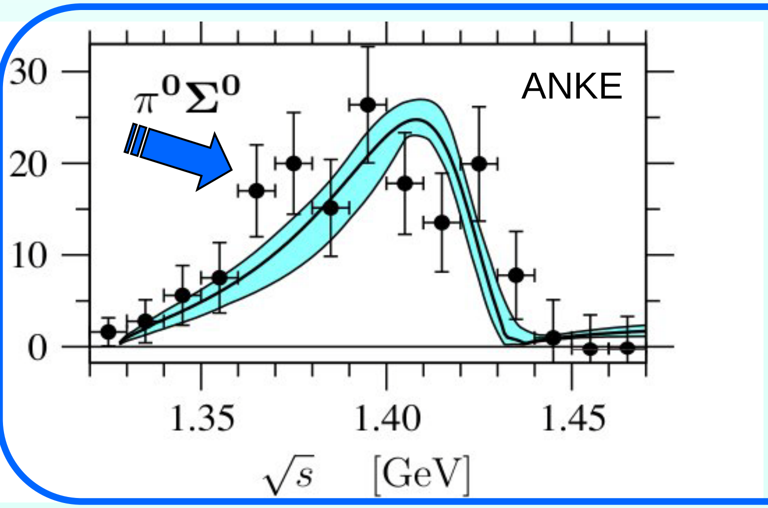
- Hemingway (1985)
- Braun, $K^-d \rightarrow \Sigma\pi\, n$ (1977)   (high mom)

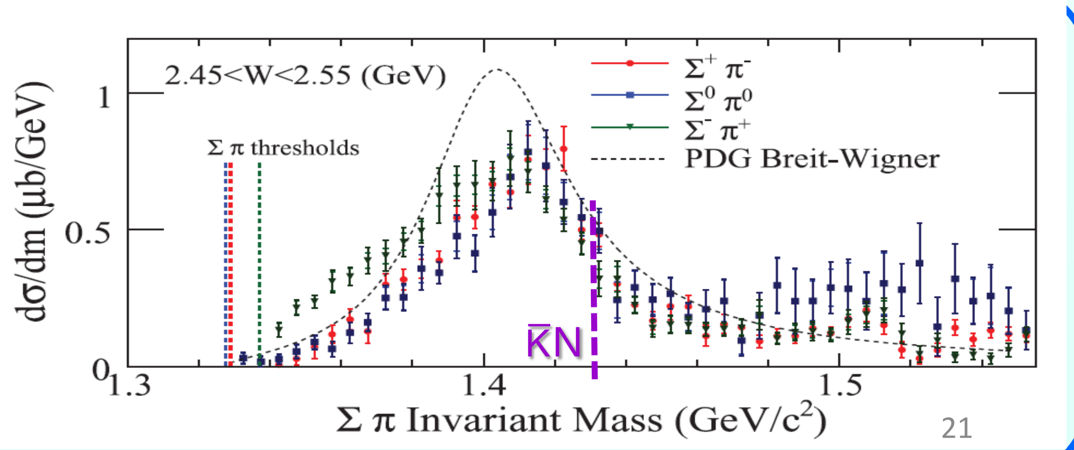
Models do not reproduce satisfactorily the spectra line shapes

RECENT MEASUREMENTS, also $\Sigma^0\pi^0$

- ANKE (2008)
- CLAS, photoproduction PR**C87**, 035206 (2013)

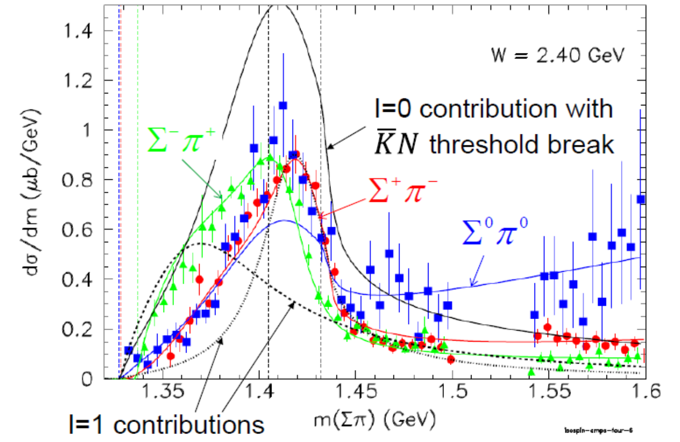
Best measurement performed so far

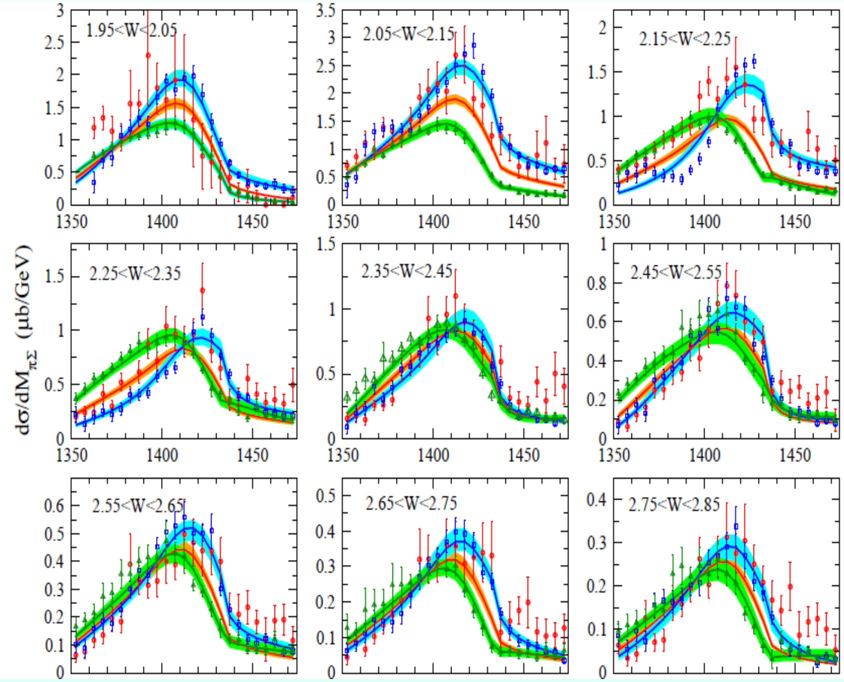




CLAS data best fit: isospin interference

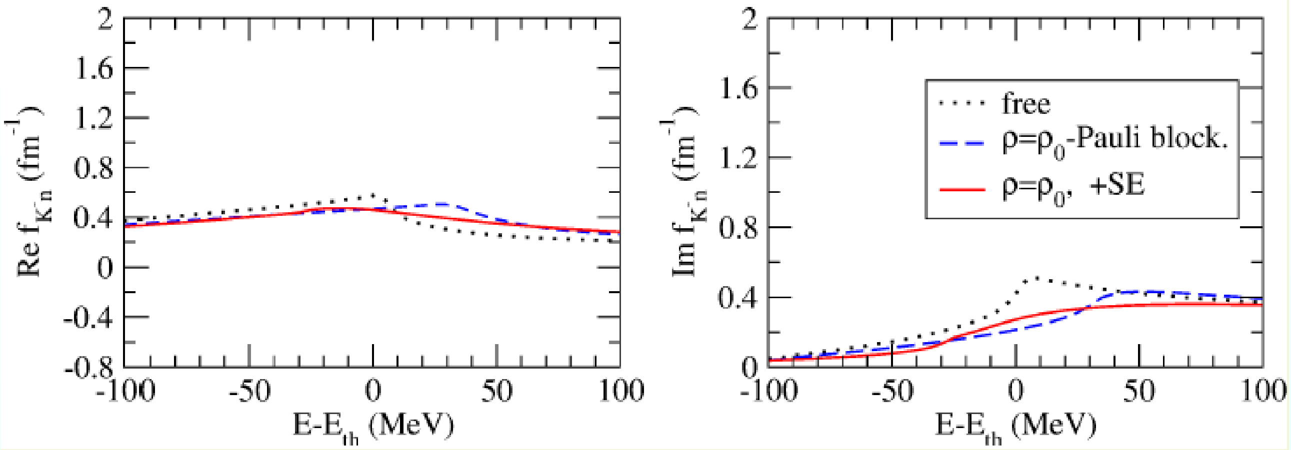
- **I=0 dominant contribution**, mass centroid near ($\Sigma^+\pi^-$) threshold:
  - m = 1338 ± 10 MeV/c^2
  - Γ = 85 ± 10 MeV/c^2
- **I=1 half as big** (not negligible!)
- 2x I=1 amplitudes:
  - 1) narrow and at higher mass
    - m= 1413 ± 10 MeV/c^2
    - Γ = 52 ± 10 MeV/c^2
  - 2) broader, lower mass
    - m= 1394 ± 20 MeV/c^2
    - Γ = 149 ± 40 MeV/c^2
- Sizeable effect of $\bar{K}N$ coupled channels
- **Additional I=1 component** foreseen by L Rocas, E Oset (PRC**88**, 055206 (2013))
  - Resonant amplitude, ≠ Σ(1385)
  - New 5-quarks Σ baryon? (BS Zou, NPA**835**, 199 (2010))





Evaluation of K$^-$n scattering lengths

- The I=1 $\bar{K}$N interaction is still attractive, but weaker than I=0
  - *f*(K$^-$n $\to$ K$^-$n) non-resonant



A Cieply et al., PR**C84**, 045206 (2011)

- The K$^-$n scattering length can only be measured from the kaonic deuterium shift and width
- No measurement ever for the $\bar{K}^0$p scattering length (same isospin, Coulomb free)
- K$^-$n scattering length derivation $a(K^-n) = 0.57^{+0.04}_{-0.21} + i0.72^{+0.26}_{-0.41} \quad fm$
  - Use of coupled-channels amplitudes, Y Ikeda et al., NP**A881**, 98 (2012)
  - Instability of the real part, **large uncertainties** ($\pi\Lambda$ channel)

Consequences on a_0 and a_1 values

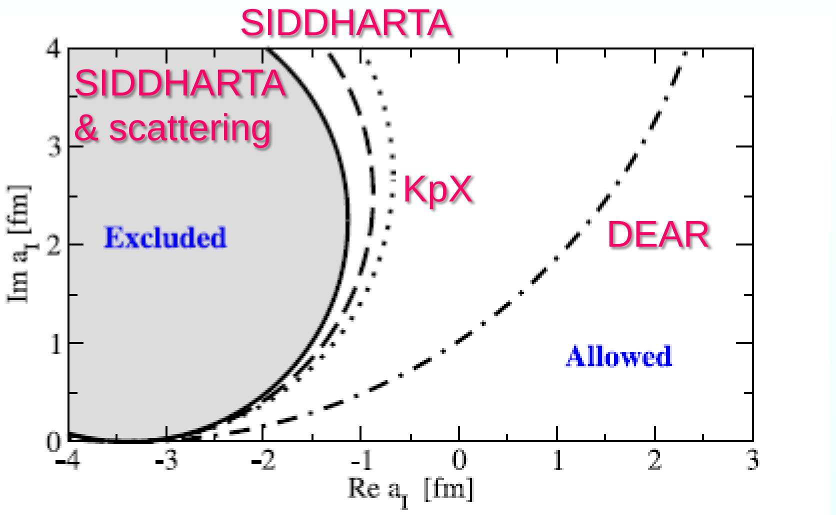
- The shift and width of the kaonic hydrogen are rather insensitive to the I=1 scattering amplitude

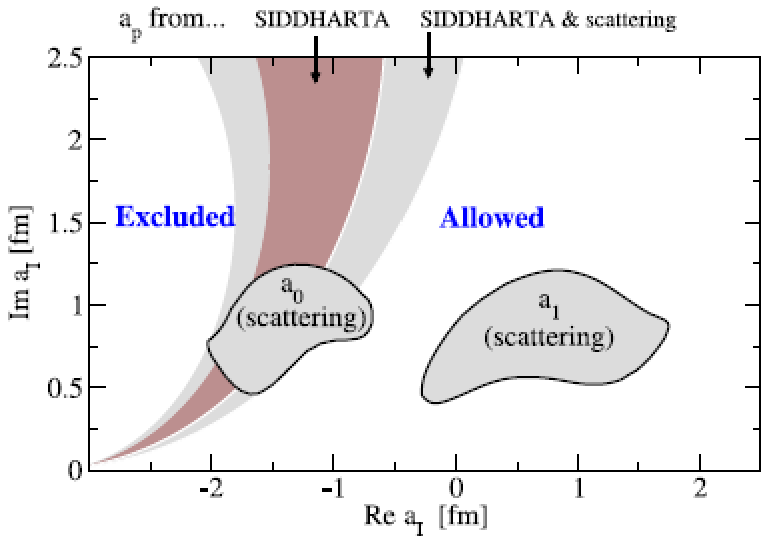
- The K$^-$p scattering length provides constraints on the two isospin components

- The scattering data provide irregularly shaped areas for a_0 and a_1 pinning down their values more precisely

- The measurement of the K$^-$d scattering length from kaonic deuterium would be an unvaluable tool to pose more stringent constraints to the chiral PQCD dynamics

M Döring and U Meißner, PL**B704**, 663 (2011)





Summary: possible $K_L p(d)$ measurements

All of them could be collected *at the same time*

- K_L **elastic scattering** on protons: $K_L p \to K_L p$
- K_L quasi-elastic scattering on neutrons: $K_L d \to K_L np$
- K_L elastic scattering (coherent) on deuterons: $K_L d \to K_L d$

- **Inelastic** K_L reactions on **protons** close to threshold (**Y prod**.)
  - $K_L p \to \Lambda\pi^+$
  - $K_L p \to \Sigma^+\pi^0, \Sigma^0\pi^+$

- **Inelastic** K_L interactions on **deuterons** close to thr. (**Y prod.**)
  - $K_L d \to YN\pi$ $(Y = \Lambda, \Sigma) \Rightarrow$ investigation of $\Lambda(1405)/\Sigma(1385)$

- **Charge-exchange reaction**: $K_L p \to K^+ n$

- **Regeneration reaction**: $K_L p \to K_S p$

For all of them a momentum resolution of the produced particles around 10% would be enough

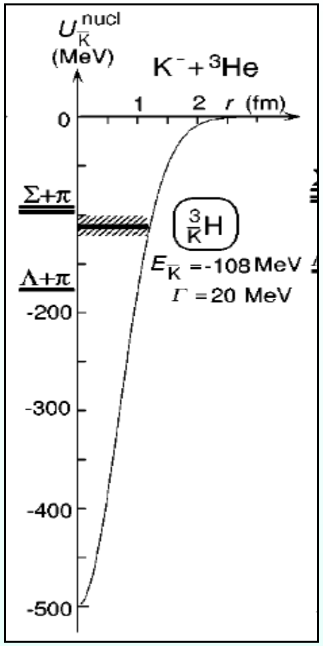
Using heavier targets…

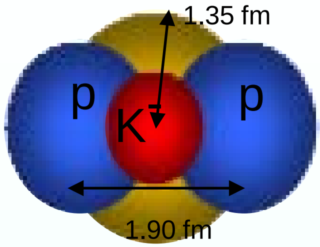
- Gaseous ^{3}He, ^{4}He: study of $\overline{K}^0$-few body interactions
  - No particular requirement on momentum resolution of emitted particles
  - Desirable: secondary vertex reconstruction, for hyperon identification

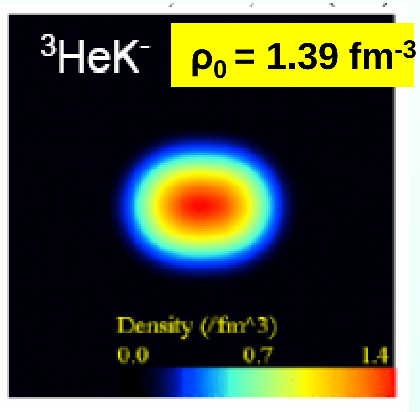
- Solid materials (as additional target disk beyond the LH_2 vessel?)
  - Hypernuclei production
    - High resolution required for formation pion spectroscopy

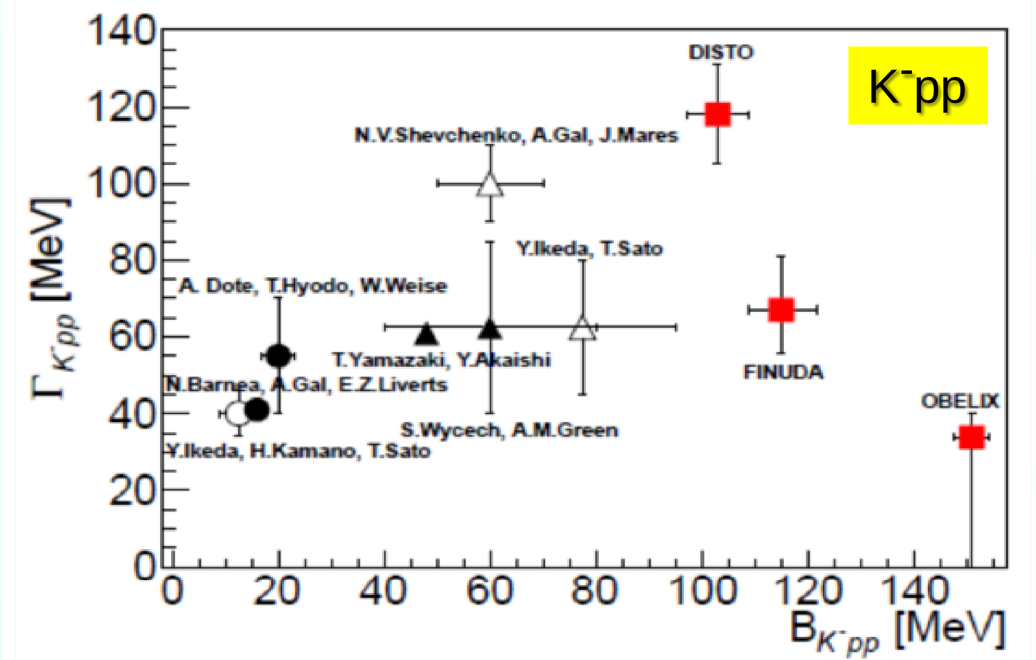
$\bar{K}$-nuclear bound states?

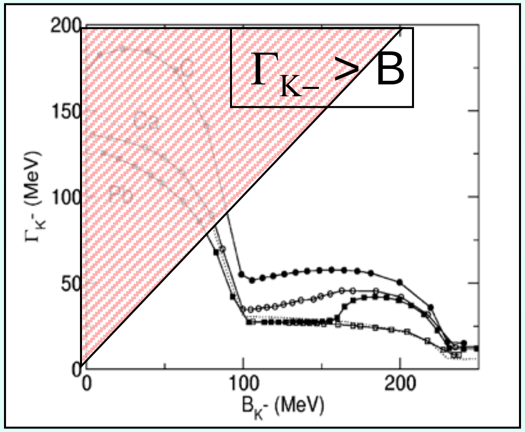
- Existence/observability predicted by Akaishi-Yamazaki (2002):
  - Strongly bound, very dense systems: $\rho > 3\rho_0$
  - Narrow widths: 20÷40 MeV
    - No → $\Sigma\pi$
    - No → $\Lambda\pi$ (isospin conservation)
    - Y+xN only allowed decay channel
  - Where more likely to be observed?
    - light targets (AY)
    - Heavier targets (J Mares at al)











Mirror hypernuclei and the CSB problem

- K_L beams of sufficient intensity interacting on nuclei could be used to produce
  - neutron rich hypernuclei, spectroscopizing the π^+ momentum in the reaction: $^{A}Z(\bar{K}^0, \pi^+)^{A}{}_{\Lambda}(Z-1)$
  - Mirror hypernuclei, spectroscopizing the π^0 in the reaction: $^{A}Z(\bar{K}^0, \pi^0)^{A}{}_{\Lambda}Z$
- Physical interest: Charge Symmetry Breaking effect
  - **Difference in binding energies** measured for a few mirror hypernuclei
    - Considerably stronger than in ordinary nuclear matter
    - **$B_{\Lambda}(0^+_{g.s.}) = B_{\Lambda}({}^{4}{}_{\Lambda}He) - B_{\Lambda}({}^{4}{}_{\Lambda}H) = 0.35 \pm 0.06$ MeV**
    - Predicted to be some ten of keV for p-shell hypernuclei
  - Due to $\Lambda\Sigma$ mixing (A Gal, PL**B744**, 352 (2015))
  - Desirable: measure the formation reactions with the same apparatus, to reduce systematic uncertainties (or with both $\bar{K}^0$/ K^- beams)
- Required resolution on the hypernucleus energy level: < MeV
  - This requires the momentum resolution of the pions to be at the minimum level of the percent: probably out of reach for GlueX in its present configuration

Experimental requirements

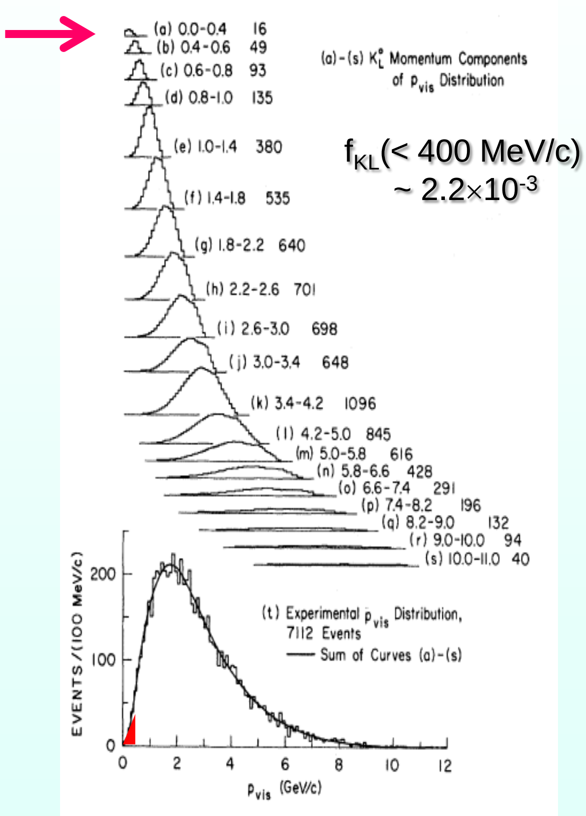
- **Measurement of the reaction cross sections below 350 MeV/c**
  - With a precision of at least 10% (best available measurements: >20%, even for K$^-$)

- **Requirements**
  - K_L momenta produced below 350 MeV/c
  - Good efficiency (~80%) for charged tracks detection
  - Good efficiency for 70 MeV γ (from Σ^0) and π^0
  - No particular requirement on PID
  - Secondary vertex reconstruction (standard tracking)

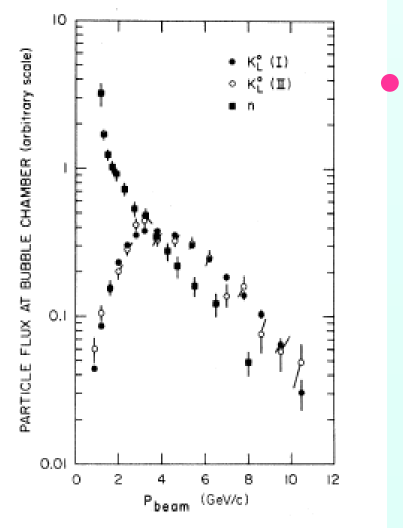
K_L photoproduction on Be

(16 GeV γ on 1.75 r.l. Be)

(GW Brandeburg et al, PR**D7**, 708 (1973))



f_{KL}(< 400 MeV/c) ~ 2.2×10^{-3}

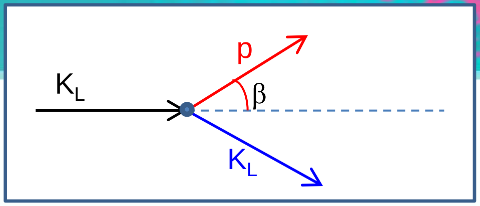


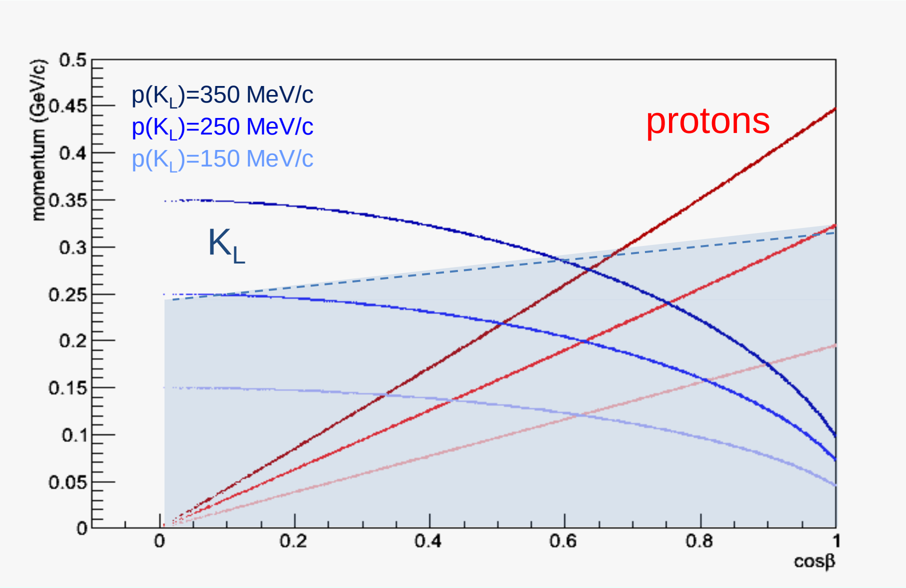
- **Potential pitfalls**
  - Momentum threshold for charged particles? In particular, protons?
  - Can the magnetic field be lowered?
  - Which is the neutron identification efficiency at low momenta? Is TOF separation enough?
  - How many K_L are expected to be produced at low momentum?
  - How many K_L are lost due to their decay in the target?

Expected rates (tentative)

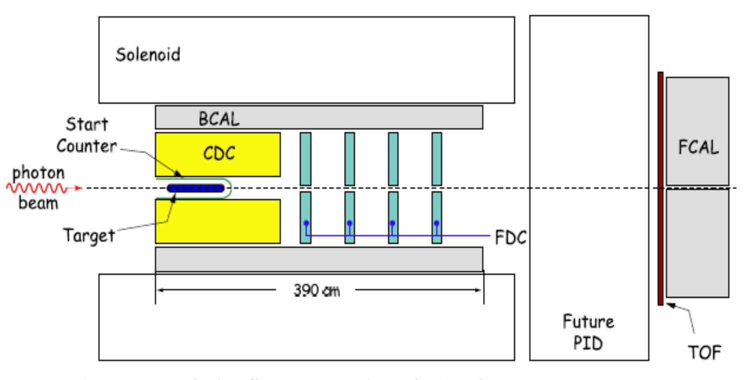
- Simple assumptions
  - 4π acceptance coverage
  - 80% tracking efficiency for charged particles
  - 80% detection efficiency for single photon
  - 60% detection efficiency for π^0
  - 100% neutron rejection power
  - No momentum cutoff for protons (relevant for these reactions)
  - Momentum resolution ~10-20% (enough)
  - I(K_L < 400 MeV/c) ~ 2.2×10^{-3} * 2000 K_L/s on target $\Rightarrow$ 4.4 K_L/s
  - Negligible reduction of beam for K_L

K_L elastic scattering kinematics





Reaction	σ (mb)	Time for 300 evts (10%) , full eff (h)	Time for 300 evts efficiency scaled (h)
$K_L p \to K_L p$	50	0.3	0.4
$K_L p \to K_s p$	5	3	6
$K_L p \to \Lambda\pi^+$	5	3	6
$K_L p \to \Sigma^0\pi^+$	3	5	12
$K_L p \to \Lambda\pi^+\pi^0$	0.5	30	97



Detector is cylindrically symmetric about the beamline

Summary

- Sparse database available for $\bar{K}N$ interactions at low momentum
  - No data in most of the cases - when existing, not sufficiently precise

- New measurements needed to provide a consistent description of (anti-)kaon interaction and as inputs for ChPT based theories
  - Reduce the uncertainty on below-threshold behaviour
    - $\Lambda(1405)$ two-pole nature
    - few-body $\bar{K}NN$- $\Sigma\pi N$ systems
  - Total and differential cross sections close to threshold in several channels
  - $\bar{K}N$ isovector scattering length determination
  - New valuable inputs to set additional constraints on the dynamics of the $\bar{K}N \Leftrightarrow \Sigma\pi$ interaction

- New opportunity to exploit a neutral kaon beam to perform precision measurements of kaon interactions at low energies