New measurements in the subthreshold K^- N system

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1) Expected nuclear consequences
   work in progress

2) DD → ^{3}He π^- p - estimates

Wojciech Krzemień ... $\sigma \approx 2$ nb for bound state

6.2 Upper limit for the $dd \to ({}^4\mathrm{He}\eta)_{bound} \to {}^3\mathrm{He}p\pi^-$ cross-section 96

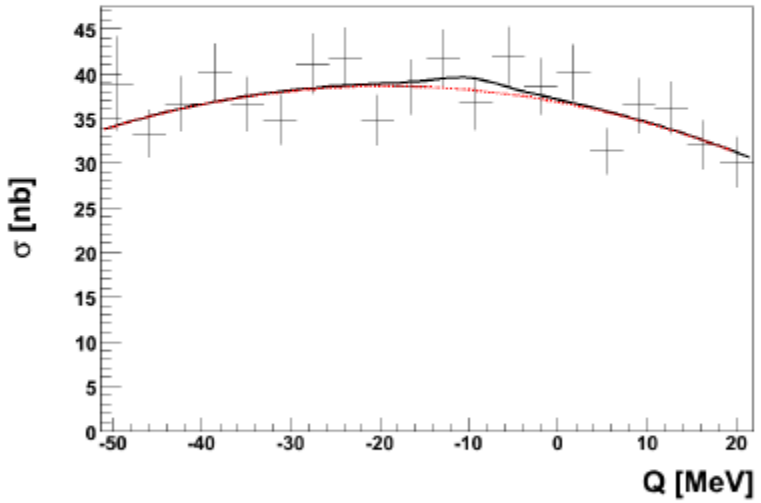
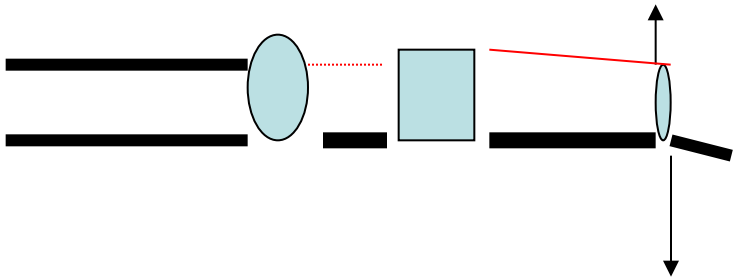


Figure 6.2: Excitation function for the $dd \to {}^3\mathrm{He}p\pi^-$ reaction obtained by normalizing the events selected in individual excess energy intervals by the corresponding integrated luminosities. The solid line represents a fit with second order polynomial combined with a Breit Wigner function with fixed

X-section dd -> (BS) -> ^{3}He π^{-} p

Phenomenological estimate



$|V_{(dd \rightarrow {}^4He\,\eta)}(p)|^2 \leftarrow \sigma/p = 0.3$ nb /MeV/c

BS propagator $|\Phi><\Phi|\,(E - E_B)^{-1}$

wave function $\Phi \sim \exp -1/2(p\,R)^2$

Off shell extension of $V \sim \Phi(q)$

Decay operator expressed by width

$\sigma(DD \rightarrow {}^3He\ \pi\ p)$

$\sim \Gamma^{\pi} / [(\Gamma^{Tot}/2)^2 + (E-E_B)^2]\ \sigma(DD \rightarrow {}^4He\ \eta) / (p_\eta m_\eta) / R^3$

Example $\Gamma^{\pi} = 10$, $\Gamma^{Tot} = 20$ MeV, $R = 2.5$ fm

$\sigma(DD \rightarrow {}^3He\ \pi\ p) \sim 4$ nb at peak

Experimental limits 3-6 nb

Interference with direct production !

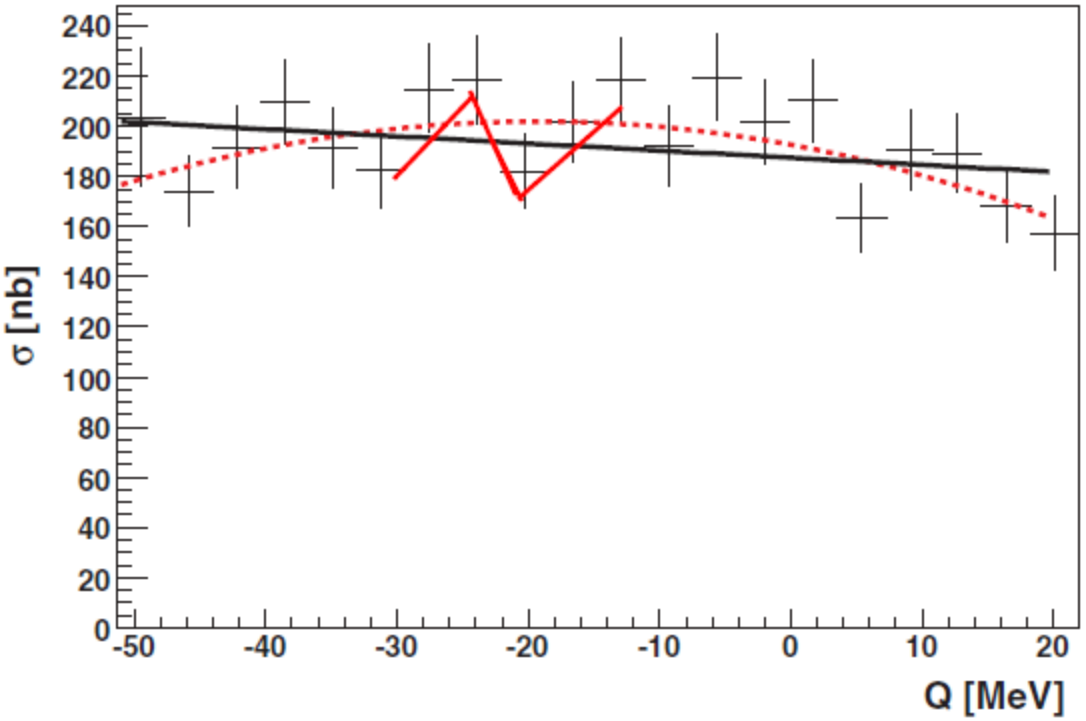


FIG. 8. (Color online) Experimental excitation function for the $dd \rightarrow {}^{3}\mathrm{He}\,p\pi^{-}$ reaction obtained after the normalization of the events

conclusions

- Estimated cross section is close to experimental limits , model is necessary to go further

- Look for dd → ^{4}He η → d np

collimated background symmetric signal

Eta mesic → K mesic nuclei

Similar binding mechanism : a resonance

ηN	N (1535)	above threshold
KN	Λ(1405), Σ(1385)	below threshold

Essential problem : continuation from physical region to resonant region is parameter unstable

- Σ(1385) Λ(1405) KN (experiments)

- Look below threshold
- Experiments : Σπ- final state spectra
- bound K-meson -K atoms, nuclear capture

- Models : effective (chiral) approach,
- K matrix + dispersion relations

Old data M(Σπ)
a typical fit Akaishi

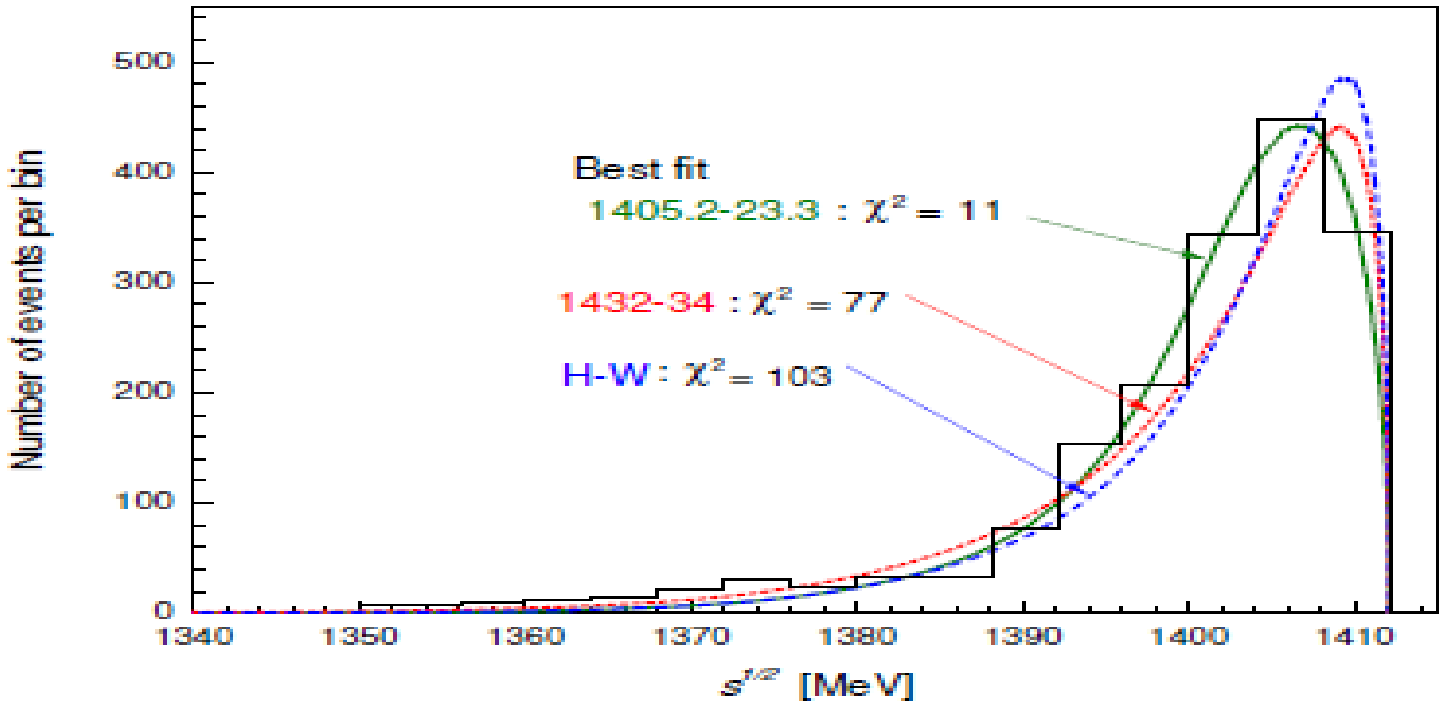


Figure 6: Detailed differences in $M_{\Sigma\pi}$ spectra among the Hyodo-Weise prediction and the present model predictions.

Σ(1385) and Λ(1405) from CLAS, HADES,KLOE

new data 2012- 2013

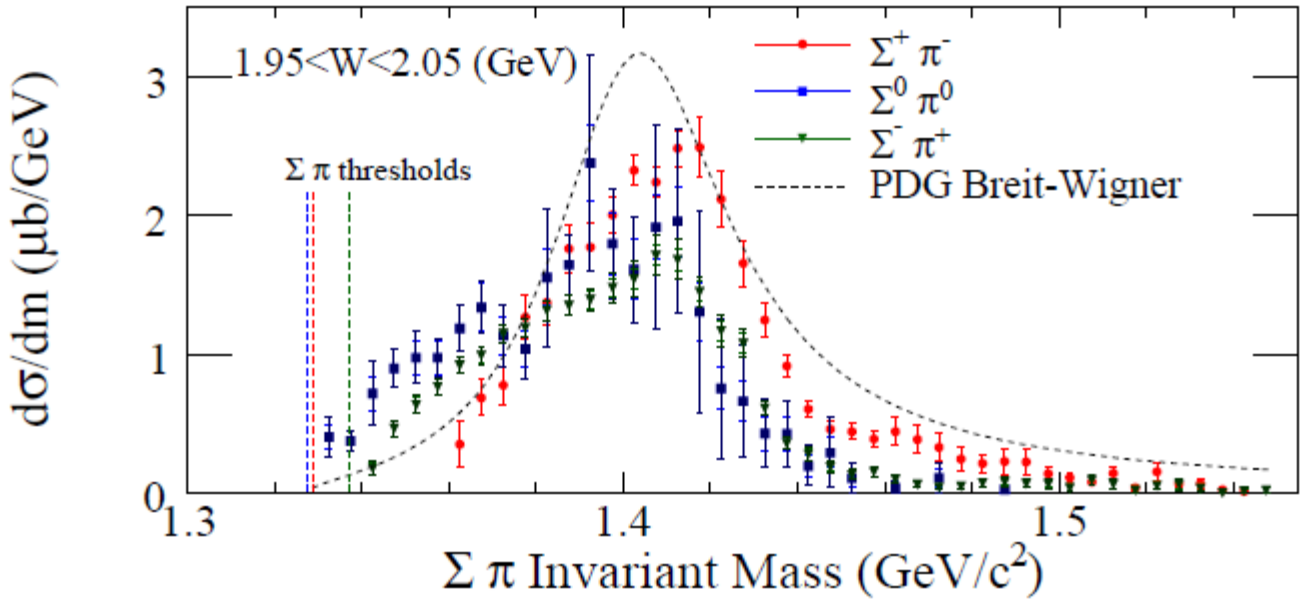
Recent measurements

TABLE I: Maxima in the $\Sigma\pi$ spectra, recent experiments

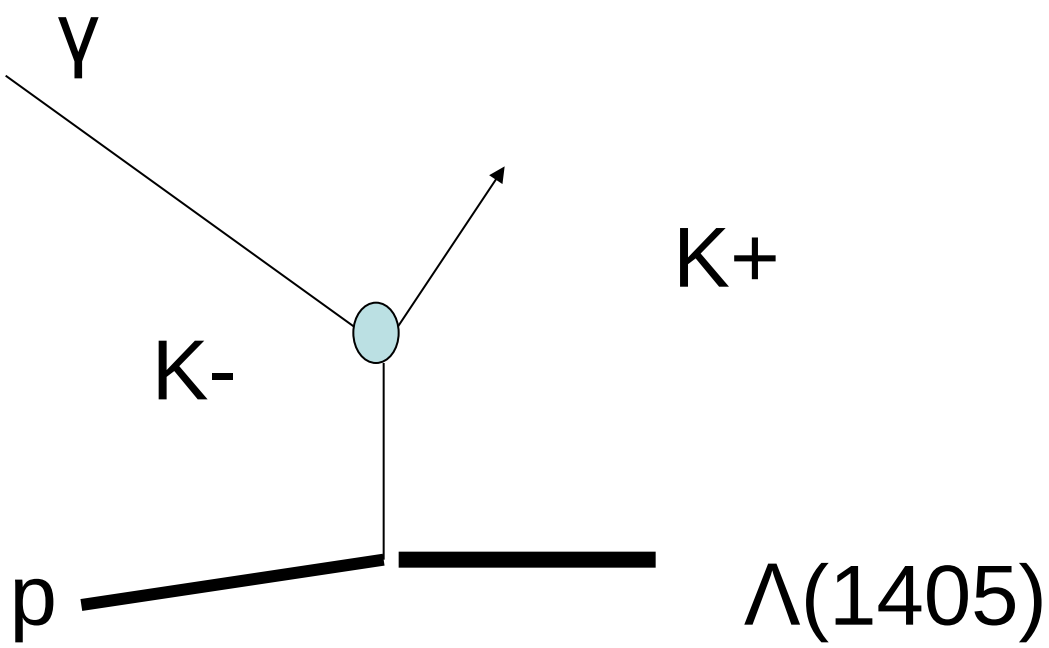
channel	$ep \to K^+ \Sigma \pi$ CLAS	$pp \to p K^+ \Sigma \pi$ ANKE, HADES
	E_{max}	E_{max}
Σ^+, π^-	1420	1400
Σ^0, π^0	1415	1390
Σ^-, π^+	1410	1400

Positions , order , dfferences ?

CLAS


1.95<W<2.05 (GeV)
Σ π thresholds
Σ⁺ π⁻
Σ⁰ π⁰
Σ⁻ π⁺
PDG Breit-Wigner
dσ/dm (μb/GeV)
0
1
2
3
1.3
1.4
1.5
Σ π Invariant Mass (GeV/c²)

CLAS – entrance mechanism



Peak depends_weakly on W (γp-energy)

Interference in „ Kaonic formation”

$$T(K^- p \to \Sigma^+ \pi^-) = \frac{1}{\sqrt{6}} T_0 + \frac{1}{2} T_1$$

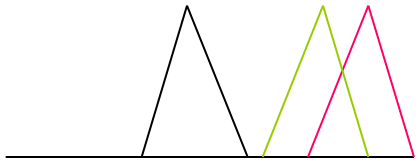
$$T(K^- p \to \Sigma^- \pi^+) = \frac{1}{\sqrt{6}} T_0 - \frac{1}{2} T_1$$

$$T(K^- p \to \Sigma^0 \pi^0) = \frac{1}{\sqrt{6}} T_0$$

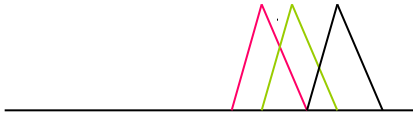
Symbolic ordering of M(πΣ) peaks

Σ_+ Σ_o Σ_-

CLAS

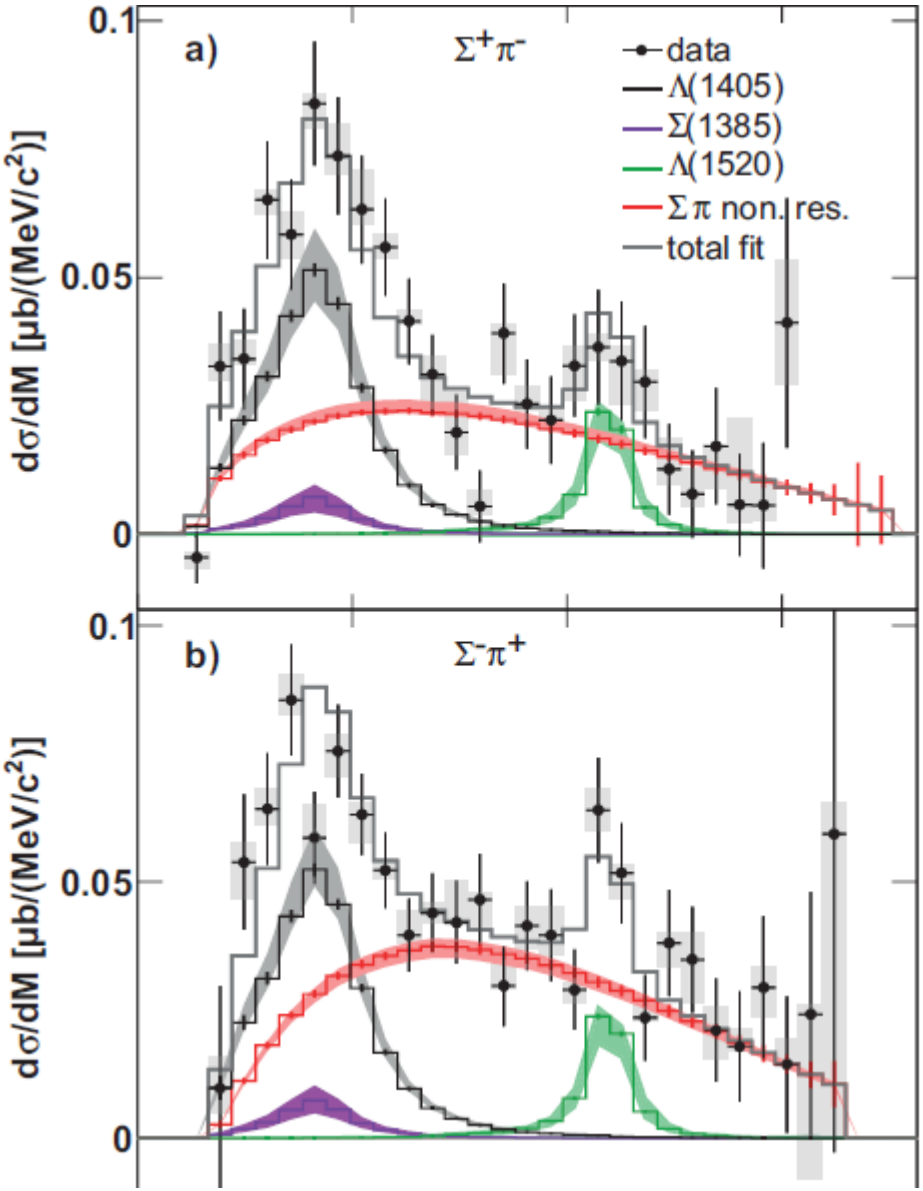


Chiral
(Nacher)



Disp+K
(Martin A)

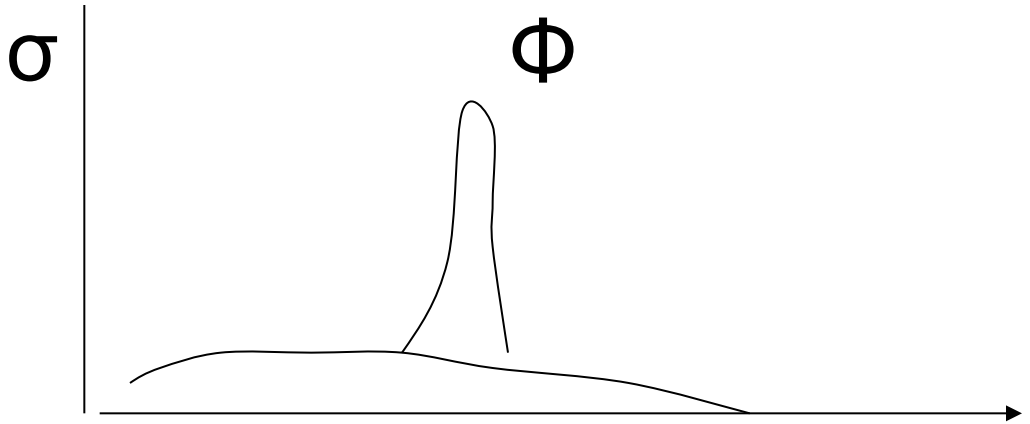
HADES


a)
$\Sigma^+\pi^-$
data
$\Lambda(1405)$
$\Sigma(1385)$
$\Lambda(1520)$
$\Sigma\pi$ non. res.
total fit
$d\sigma/dM$ [μb/(MeV/c^2)]
0.1
0.05
0
b)
$\Sigma^-\pi^+$
$d\sigma/dM$ [μb/(MeV/c^2)]
0.1
0.05
0

HADES

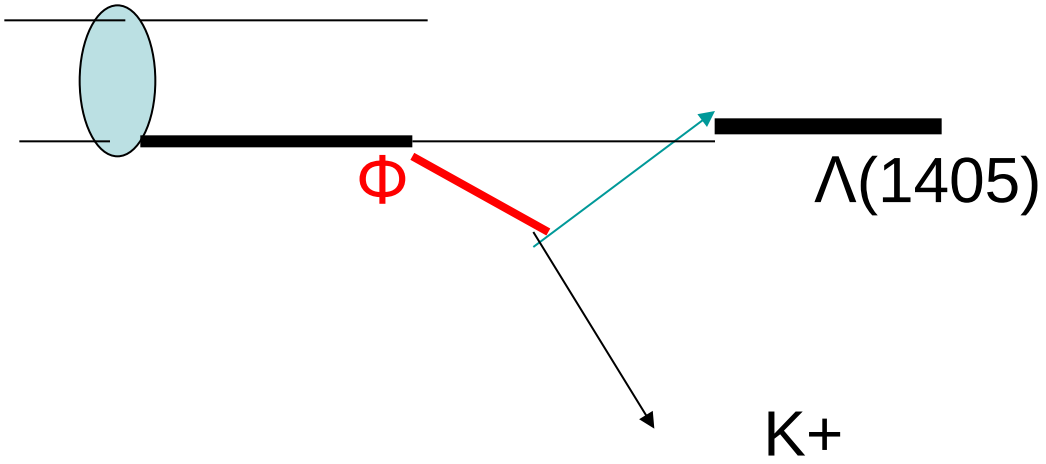
dependence on entrance mechanism

PP→ K+ K- , pp



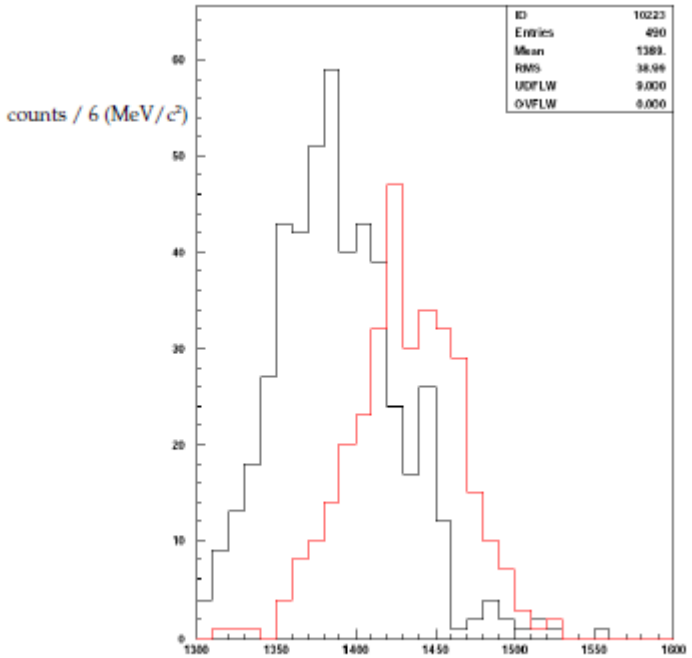
Final

HADES mechanism (?)



May deform the line in a different way

Good news from KLOE capture in H,He, C from flight and atoms



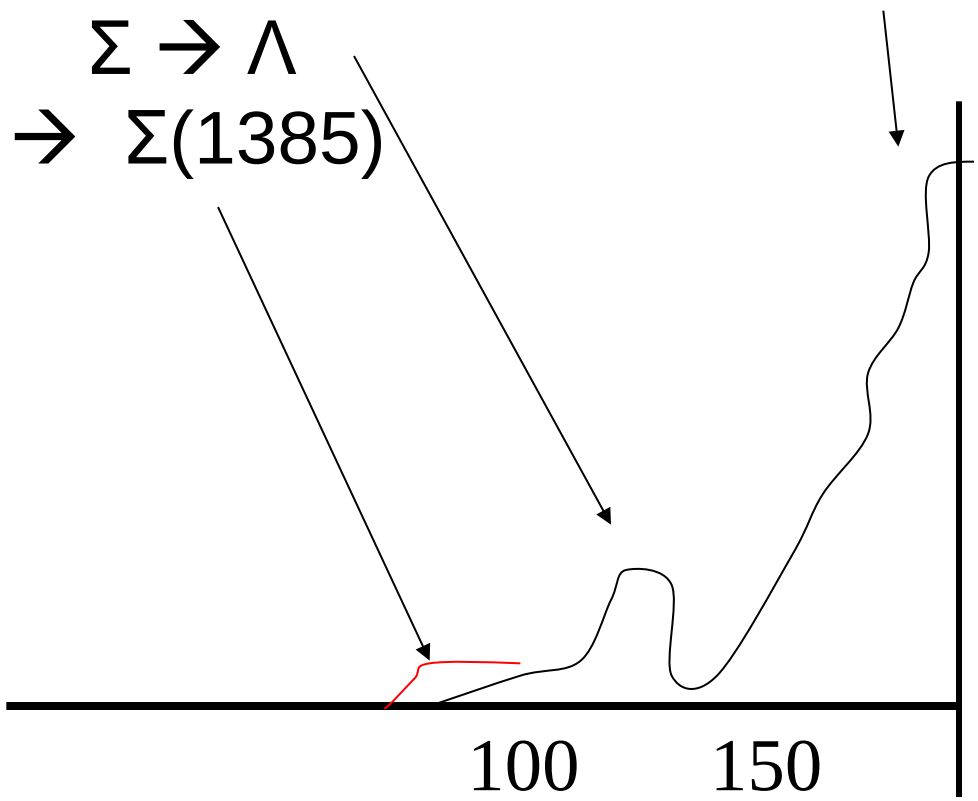
Data. $m_{\pi^0\Sigma^0}$ (MeV/c^2), black HM component, red LM component

$K^- {}^4He \rightarrow {}^3He, \pi^- , \Lambda$ Fetkvoich

$K^- n \rightarrow \pi^- , \Lambda$ S wave capture

$\Sigma \rightarrow \Lambda$

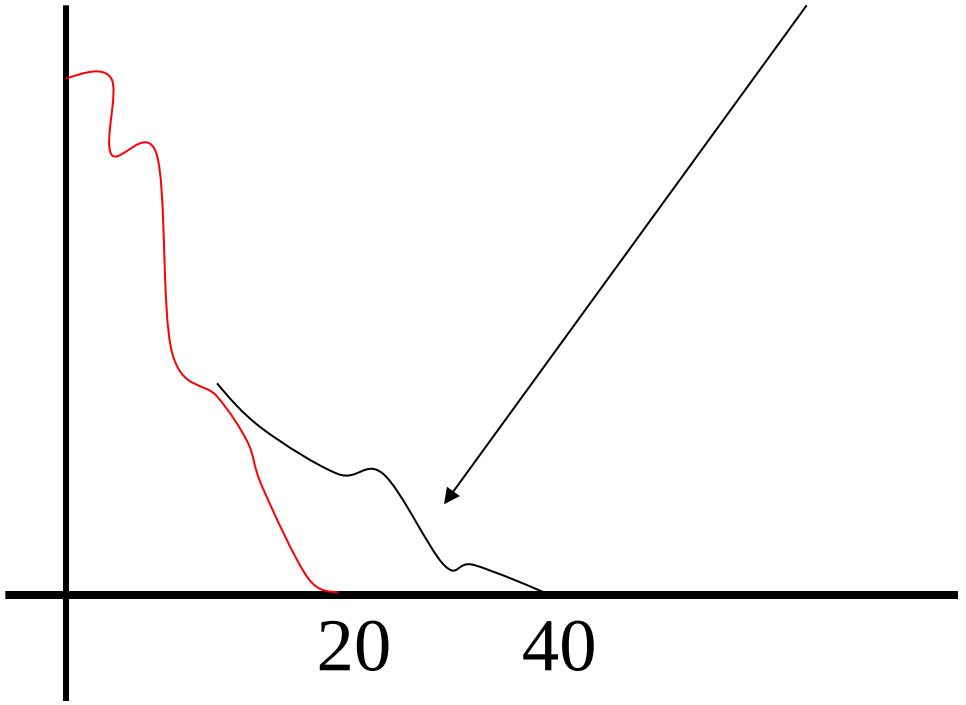
$K^- n \rightarrow \Sigma(1385)$



$K^- {}^4He \rightarrow {}^3He, \pi^-, \Lambda$ Fetkvoich

$K^- n \rightarrow \pi^-, \Lambda$ and convergence $T\pi > 90$

$K^- n \rightarrow \Sigma(1385)$

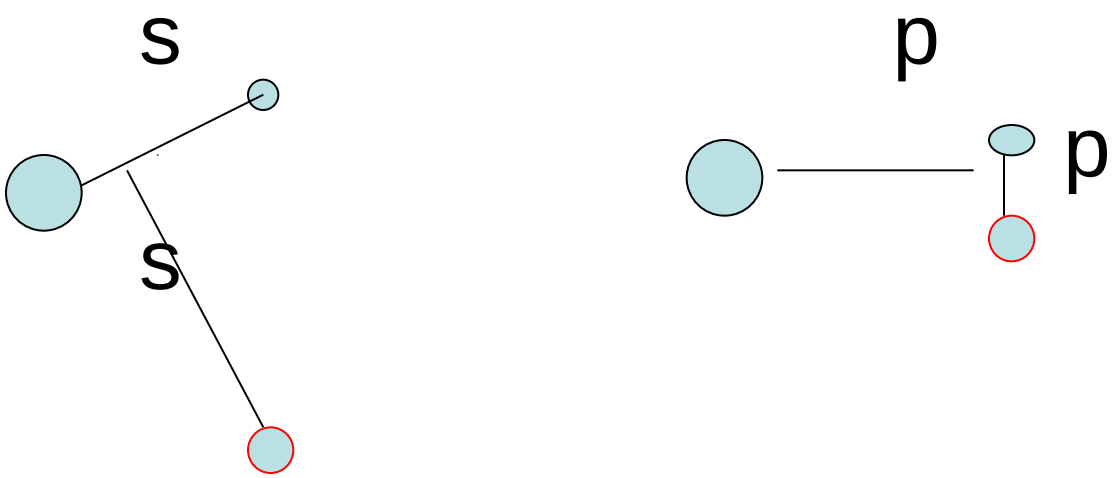


T ^3He

Status

- New data exist
- Analysis of experiments still needed
- Model analysis not done yet
- Nuclear consequenses to follow

Recoupling Σ(1385) calculations never done

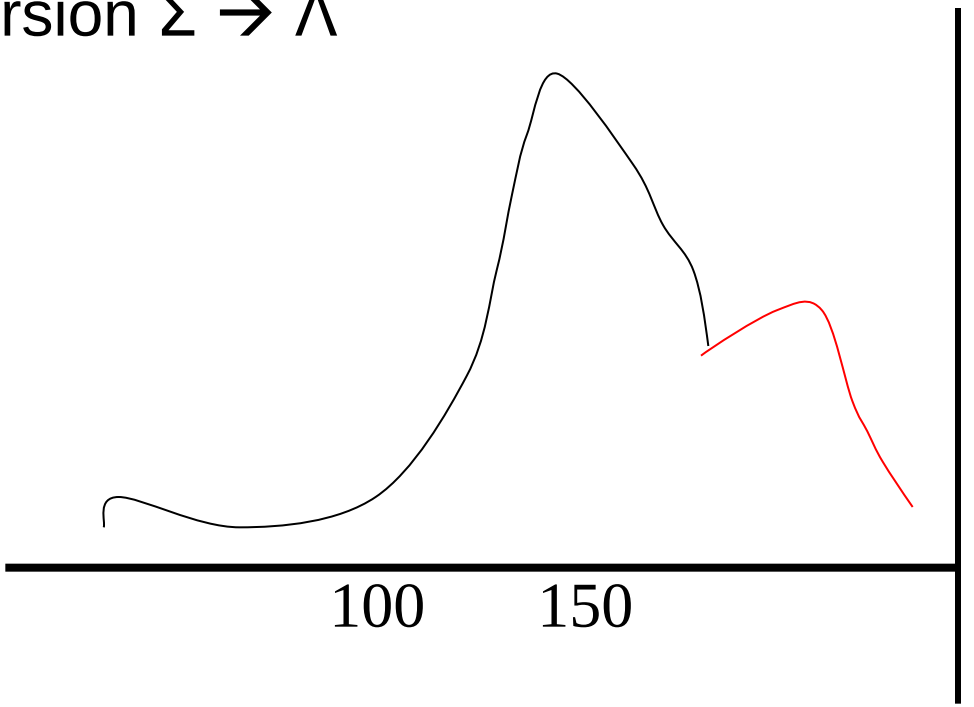


Higher rate for Σ in p –atomic level Calculation may be done

$K^- {}^4He \rightarrow p,d, \pi^- , \Lambda$ Roosen

$K^- n \rightarrow \pi^- , \Lambda$

$K^- N \rightarrow \Sigma \pi^-$ conversion $\Sigma \rightarrow \Lambda$



P π

Calculations exists (not bad) no clear evidence for $\Sigma(1385)$

No interference with initial Σ

$$F(\Sigma^+ \pi^- \rightarrow \Sigma^+ \pi^-) = \frac{1}{3} F_0 + F_1 \frac{1}{2} + F_2 \frac{1}{6}$$

$$F(\Sigma^- \pi^+ \rightarrow \Sigma^- \pi^+) = \frac{1}{3} F_0 + F_1 \frac{1}{2} + F_2 \frac{1}{6}$$

$$F(\Sigma^0 \pi^0 \rightarrow \Sigma^0 \pi^0) = \frac{1}{3} F_0 + \frac{2}{3} F_2$$

Uncertainties

Initial state

clarified for dense He → S_{wave}

Final state interactions

$\Sigma \rightarrow \Lambda$ conversion

important for Σ(1385) extraction

background estimate

ratio $(\Sigma^+ \pi^-)/(\Sigma^- \pi^+) = |A_0 + A_1|^2 \, |A_0 - A_1|^2$

good check for energy dependence in A_1 and A_0

Technicalities : helium wave function , 3-5 body kinematics

Dependence on capture state probably settled to S wave. Not clear- wave function in He, 3 body effects, FSI

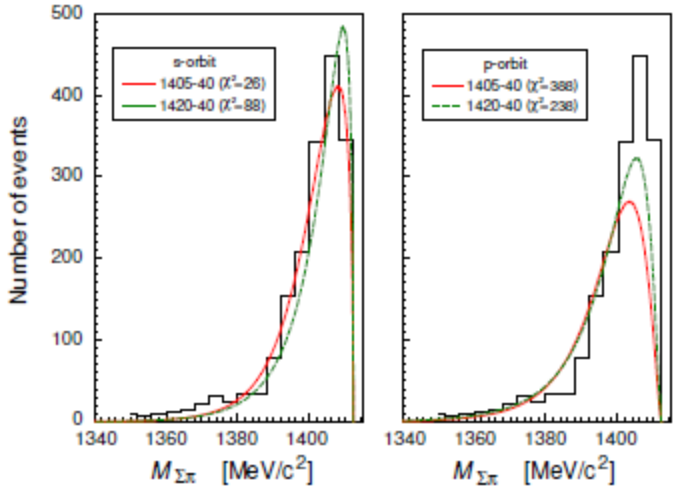


Figure 2: Comparison of a $\Sigma^{\mp}\pi^{\pm}$ invariant-mass spectrum of Riley *et al* [21] from K^- stopped on ^{4}He with best-fit theoretical curves of s and p-orbit absorption with the Harada potential for $\Lambda(1405)$ and $\Lambda^*(1420)$ and $\Gamma = 40$ MeV.

- Riley, Esmaili

Examples : Old K-He data

Bubble chamber experiments detect

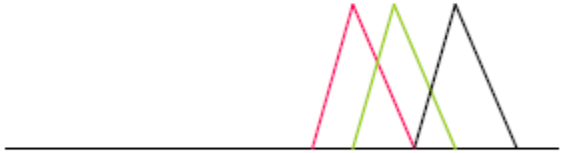
P_{π} , P_{Σ} , T_{3He}

$K^- {}^4He \rightarrow {}^3He, \pi^-, \Lambda$

$K^- {}^4He \rightarrow {}^3He, \pi, \Sigma$

CLAS

Chiral
(Nacher)



Disp+K
(Martin A)

Capture from flight and at stop

$P = \rho \ | t(E_{KN}) \ \Phi(p_N) |^2$

ρ – phase space

$E_{KN} = E_N + E_K - p_{KN}^2/2M_{red}$

$\Phi(p)$ – Fourier transform of $\Phi_N(r)\ \Phi_K(r)$

Flight $p_N = p_{\Sigma\pi} - p_K$ $\quad \Phi_K(r) = \exp(i\, r\, p_K)$

Stop $\Phi_K = \Phi_{ATOM}$; $T_K = 0$; $p_N = p_{\Sigma\pi}$

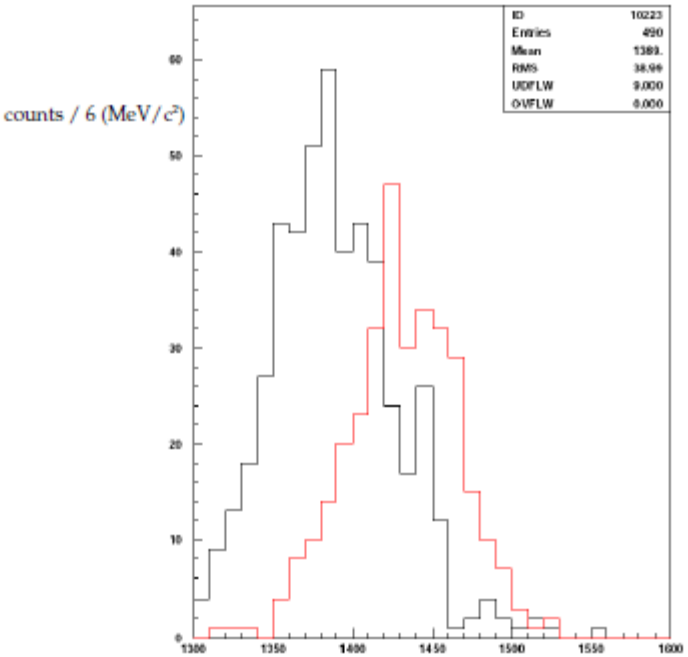
Simple procedure

Stop : $P_{exp}(M) / \rho \, |\Phi(p_{\Sigma\pi}) |^2 \sim | t(E_{KN}) |^2$

Flight : $P_{exp}(M) / \rho \, |\Phi(p_K - p_{\Sigma\pi}) |^2 \sim | t(E_{KN}) |^2$

Look for continuity (?)

Simple procedure

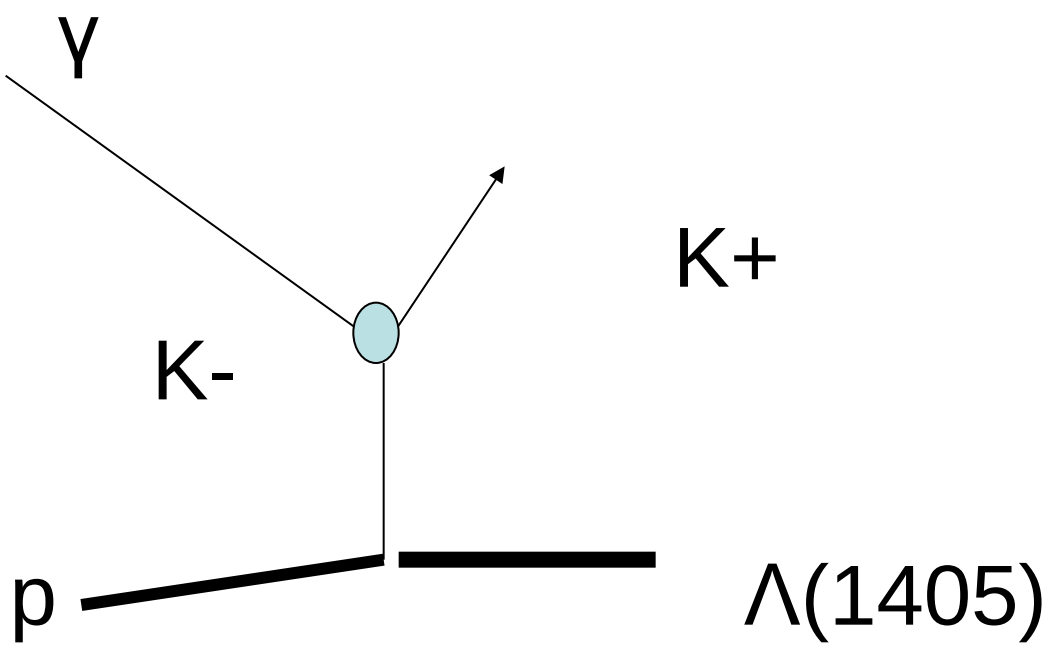


Data. $m_{\pi^0\Sigma^0}$ (MeV/c^2), black HM component, red LM component

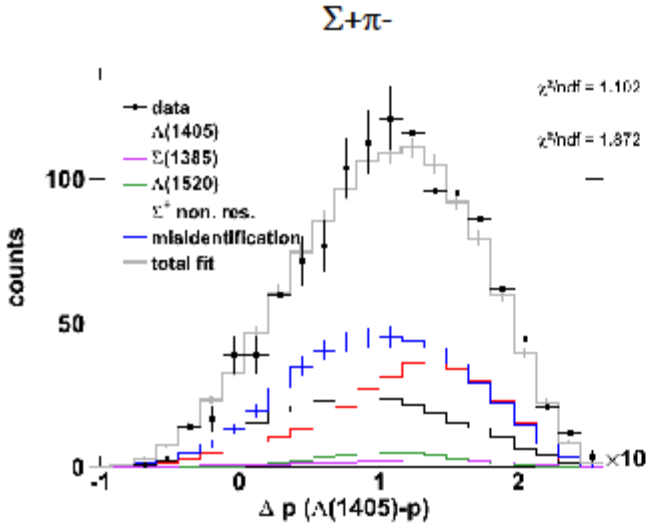
A puzzle – shift larger than 20 MeV

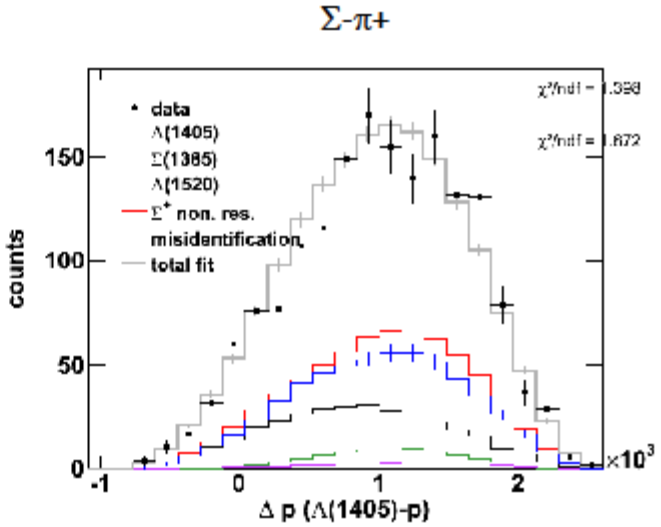
An effect of changed Fourier transform ?

CLAS – entrance mechanism



Peak depends on W (γp-energy)


Σ+π-
data
Λ(1405)
Σ(1385)
Λ(1520)
Σ+ non. res.
misidentification
total fit
counts
Δ p (Λ(1405)-p)


Σ-π+
data
Λ(1405)
Σ(1385)
Λ(1520)
Σ+ non. res.
misidentification
total fit
counts
Δ p (Λ(1405)-p)