A critical analysis of deeply bound kaonic states in nuclei. A critical analysis of the FINUDA experiment on deeply bound kaonic states in the pp system

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Unitarized Chiral Perturbation Theory

Skillful combination of the information of the Chiral Lagrangians and unitarity in coupled channels.

- Pioneering work of *Kaiser, Siegel, Waas, Weise 95-97* using Lipmann-Schwinger eq. and input from Chiral Lagrangians as potential.

- Subsequent work

Truong

- Inverse Amplitude Method (IAM)→ { *Dobado, Peláez '97*; *Oller, E.O., Peláez '98* }

- (N/D) method→ { *Oller, E.O. '99*; *Oller, Meissner '01* }

– Bethe-Salpeter eq.→ { *Oller, E.O. '97*; *Nieves, Ruiz-Arriola '00* }

Hosaka, Hyodo ; Lutz, Kolomeitsev ; Borasoy, Nißler, Weise

–Applications→ { *Ramos, Vicente, Marco, Parreño, Toki, Hirenzaki*
Hosaka, Oka, Nacher, Palomar, Jido, Inoue, Roca
Cabrera, Okumura, Takahashi, Mizobe, Chiang
Kamalov, Bennhold, Hernández, García Recio }

Meson-Baryon interaction

$$\mathcal{L}_1^{(B)} = \langle \overline{B} i\gamma^\mu \nabla_\mu B\rangle - M_B \langle \overline{B} B\rangle + \\ + \frac{D}{2}\langle \overline{B}\gamma^\mu\gamma_5\{u_\mu, B\}\rangle + \frac{F}{2}\langle \overline{B}\gamma^\mu\gamma_5[u_\mu, B]\rangle$$

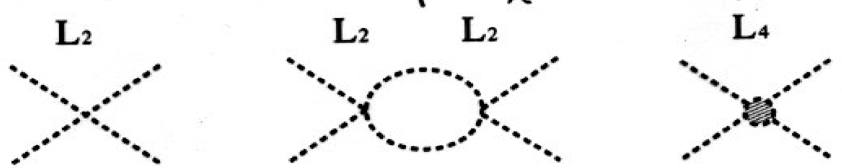
$$u_\mu = i u^\dagger \partial_\mu U u^\dagger \quad ; u^2 = U = e^{i\frac{\sqrt{2}}{f}\Phi}$$

$$\nabla_\mu B = \partial_\mu B + [\Gamma_\mu, B] \; ; \; \Gamma_\mu = \frac{1}{2}(u^+\partial_\mu u + u\,\partial_\mu u^+)$$

$$B(x) \equiv \begin{pmatrix} \frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda^0 & \Sigma^+ & p \\ \Sigma^- & -\frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda^0 & n \\ \Xi^- & \Xi^0 & -\frac{2}{\sqrt{6}}\Lambda^0 \end{pmatrix}$$

χ **PT:** (mesons)

$$\Phi \equiv \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & \pi^+ & K^+ \\ \pi^- & -\frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & K^0 \\ K^- & \bar{K}^0 & -\frac{2}{\sqrt{6}}\eta \end{pmatrix}$$



Successful at low energies

Problems $\rightarrow \begin{cases} \text{Limited energy range of applicability} \\ \text{Cannot deal with resonances} \end{cases}$

General scheme *Oller, Meissner PL '01* (meson baryon as exemple)

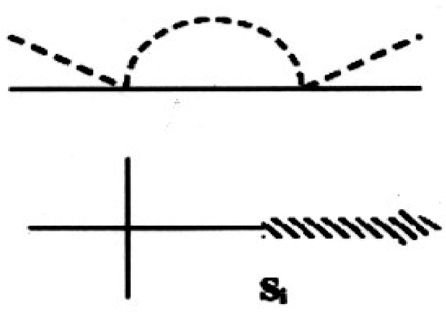
- **Unitarity** in coupled channels $\bar{K}N$, $\pi\Sigma$, $\pi\Lambda$, $\eta\Sigma$, $\eta\Lambda$, $K\Xi$, in $S=-1$

$$\begin{aligned} \mathrm{Im}T_{ij} &= T_{il}\sigma_{ll}T^*_{lj} \\ \sigma_l &\equiv \sigma_{ll} \equiv \frac{2Mq_l}{8\pi\sqrt{s}} \\ \sigma &= -\mathrm{Im}T^{-1} \end{aligned}$$

- Dispersion relation

$$\begin{aligned} T^{-1}_{ij} &= -\delta_{ij}\left\{\hat{a}_i(s_0) + \frac{s-s_0}{\pi}\int_{s_i}^{\infty} ds' \frac{\sigma(s')_i}{(s-s')(s'-s_0)}\right\} + \\ &+ V^{-1}_{ij} \equiv -g(s)_i\delta_{ij} + V^{-1}_{ij} \end{aligned}$$

g(s) accounts for the right hand cut



V accounts for local terms, pole terms and crossed dynamics. V is determined by matching the general result to the χPT expressions (usually at one loop level)

$$g(s) = \frac{2M_i}{16\pi^2}\left\{a_i(\mu) + \log\frac{m_i^2}{\mu^2} + \frac{M_i^2 - m_i^2 + s}{2s}\log\frac{M_i^2}{m_i^2} + \right. \\ \left. + \frac{q_i}{\sqrt{s}}\log\frac{m_i^2 + M_i^2 - s - 2q_i\sqrt{s}}{m_i^2 + M_i^2 - s + 2q_i\sqrt{s}}\right\}$$

μ regularization mass
a_i subtraction constant

Inverting T^{-1}:

$$T = [1 - Vg]^{-1}V$$

Example 1: Take $V \equiv$ lowest order chiral amplitude

In meson-baryon S-wave

$$[1 - V\,g]\,T = V \to T = V + V\,g\,T$$

Bethe Salpeter eqn. with kernel V

This is the method of *E. O., Ramos '98* using cut off to regularize the loops

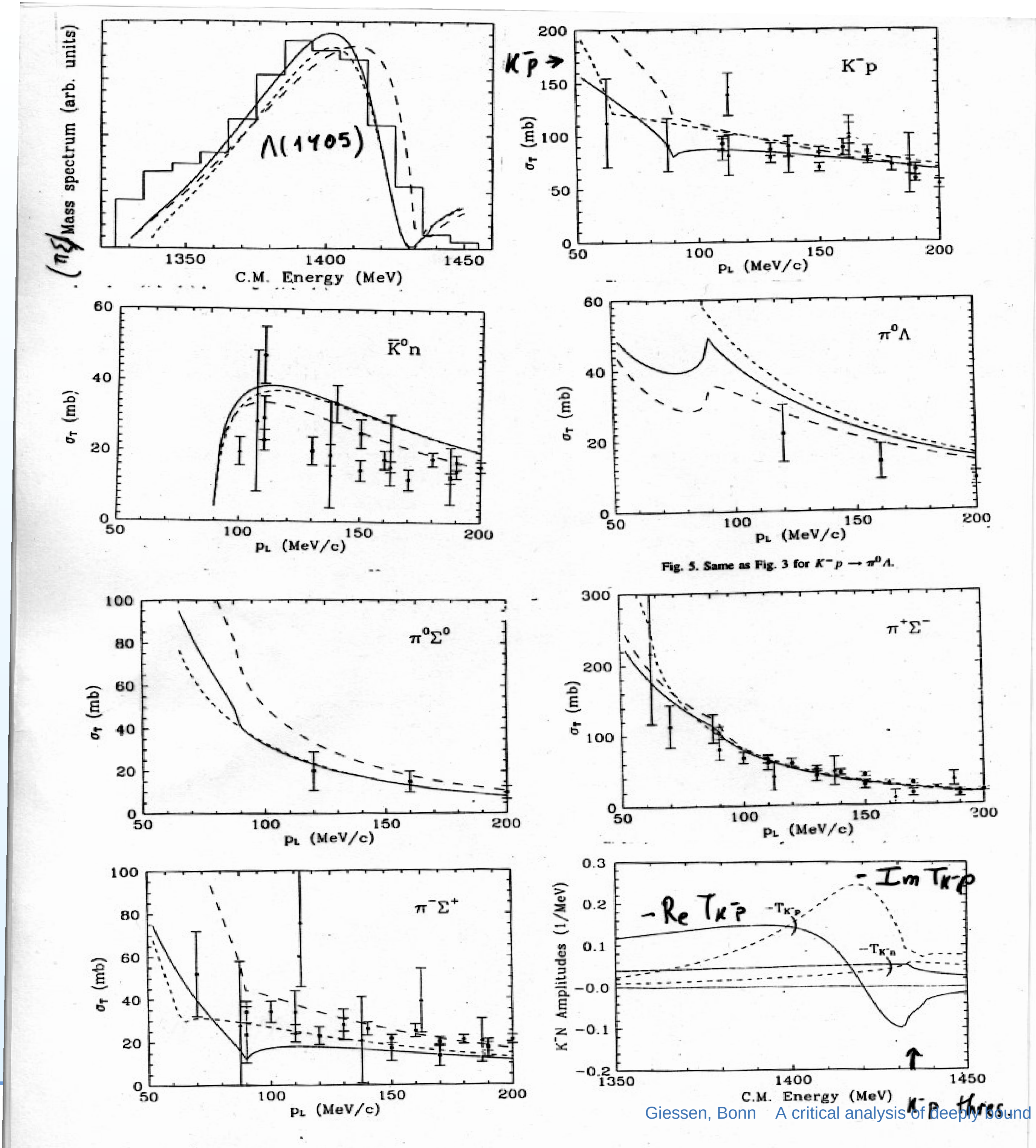
Oller, Meissner show equivalence of methods with

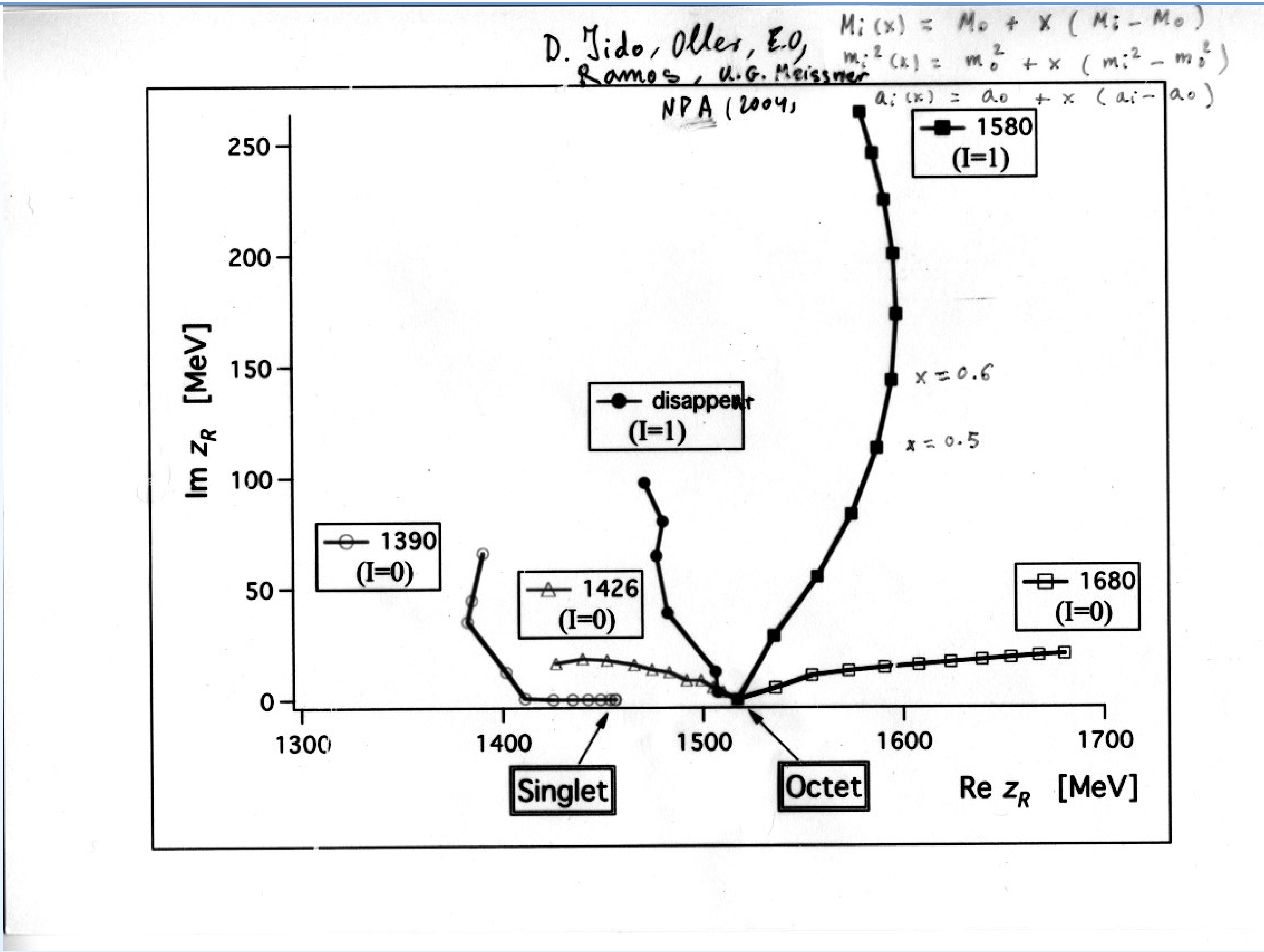
$$a_i(\mu) \simeq -2\ln\left[1 - \sqrt{1 + \frac{m_i^2}{\mu^2}}\right]\;;$$

μ cut off

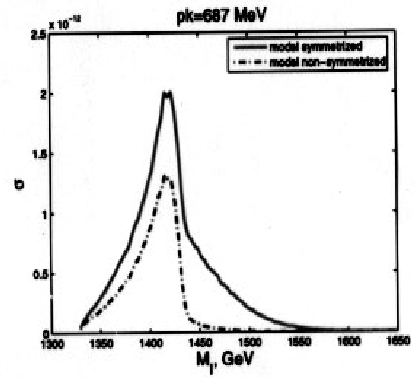
$$a_i \simeq -2 \to \mu \simeq 630\,\text{MeV in } \bar{K}N$$

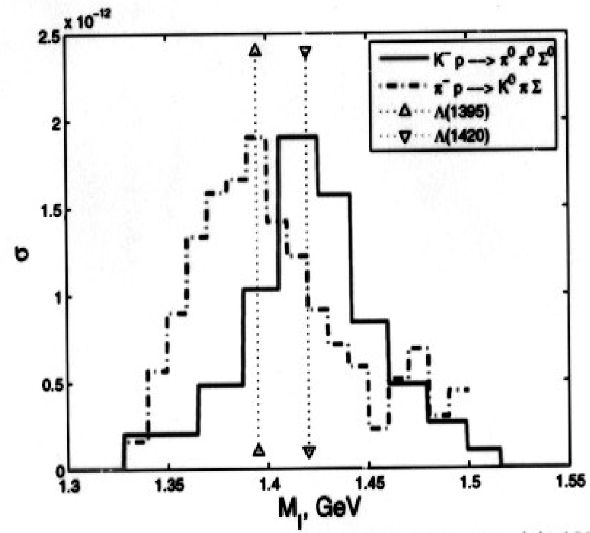
If higher order Lagrangians not well determined then fit a_i to the data


(πΣ) Mass spectrum (arb. units)
Λ(1405)
C.M. Energy (MeV)
K⁻p →
K⁻p
σ_T (mb)
p_L (MeV/c)
K̄⁰n
π⁰Λ
Fig. 5. Same as Fig. 3 for K⁻p → π⁰Λ.
π⁰Σ⁰
π⁺Σ⁻
π⁻Σ⁺
K⁻N Amplitudes (1/MeV)
−Re T_{K⁻p}
−Im T_{K⁻p}
−T_{K⁻p}
−T_{K⁻n}
K⁻p thres.


D. Jido, Oller, E.O, Ramos, U.G. Meissner
NPA (2004)
$M_i(x) = M_0 + x(M_i - M_0)$
$m_i^2(x) = m_0^2 + x(m_i^2 - m_0^2)$
$a_i(x) = a_0 + x(a_i - a_0)$
1580 (I=1)
disappear (I=1)
1390 (I=0)
1426 (I=0)
1680 (I=0)
x = 0.6
x = 0.5
Im z_R [MeV]
Re z_R [MeV]
Singlet
Octet
0
50
100
150
200
250
1300
1400
1500
1600
1700

Evidence for the two pole structure of the $\Lambda(1405)$





$\Gamma \simeq 30$ MeV

$M \simeq 1420$ Me

$\Gamma \simeq 65$ MeV

$M \simeq 1396$ Me

Puri, March 2005

Evidence for the two pole structure of the $\Lambda(1405)$ resonance and the nature of the $\Lambda(1520)$ – p.6/1

One does many body corrections in the $\bar{K}N$ amplitude

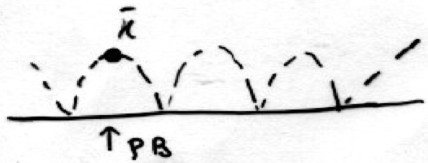
$$t(s) \rightarrow \underset{K\uparrow}{\tilde{t}}(q, \underset{\uparrow N}{p})$$

$$\Rightarrow \quad \Pi_{\bar{K}}(q^0, \vec{q}, \rho) = 2\int \frac{d^3p}{(2\pi)^3}\, n(\vec{p})\left[\tilde{t}_{\bar{K}p}(q,p) + \tilde{t}_{\bar{K}n}(q,p)\right]$$

$$N \rightarrow \frac{1-n(\vec{p})}{p^0-\varepsilon(p)+i\epsilon} + \frac{n(\vec{p})}{p^0-\varepsilon(p)-i\epsilon}$$

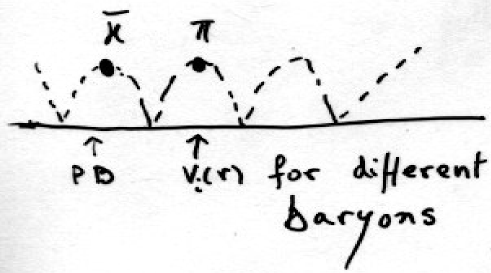
Pauli blocking — Koch 94, Waas, Weise 97

Shifts the $\Lambda(1405)$ at higher energies



Selfconsistent use of $\bar{K}$ selfenergy in the loops — Lutz 98

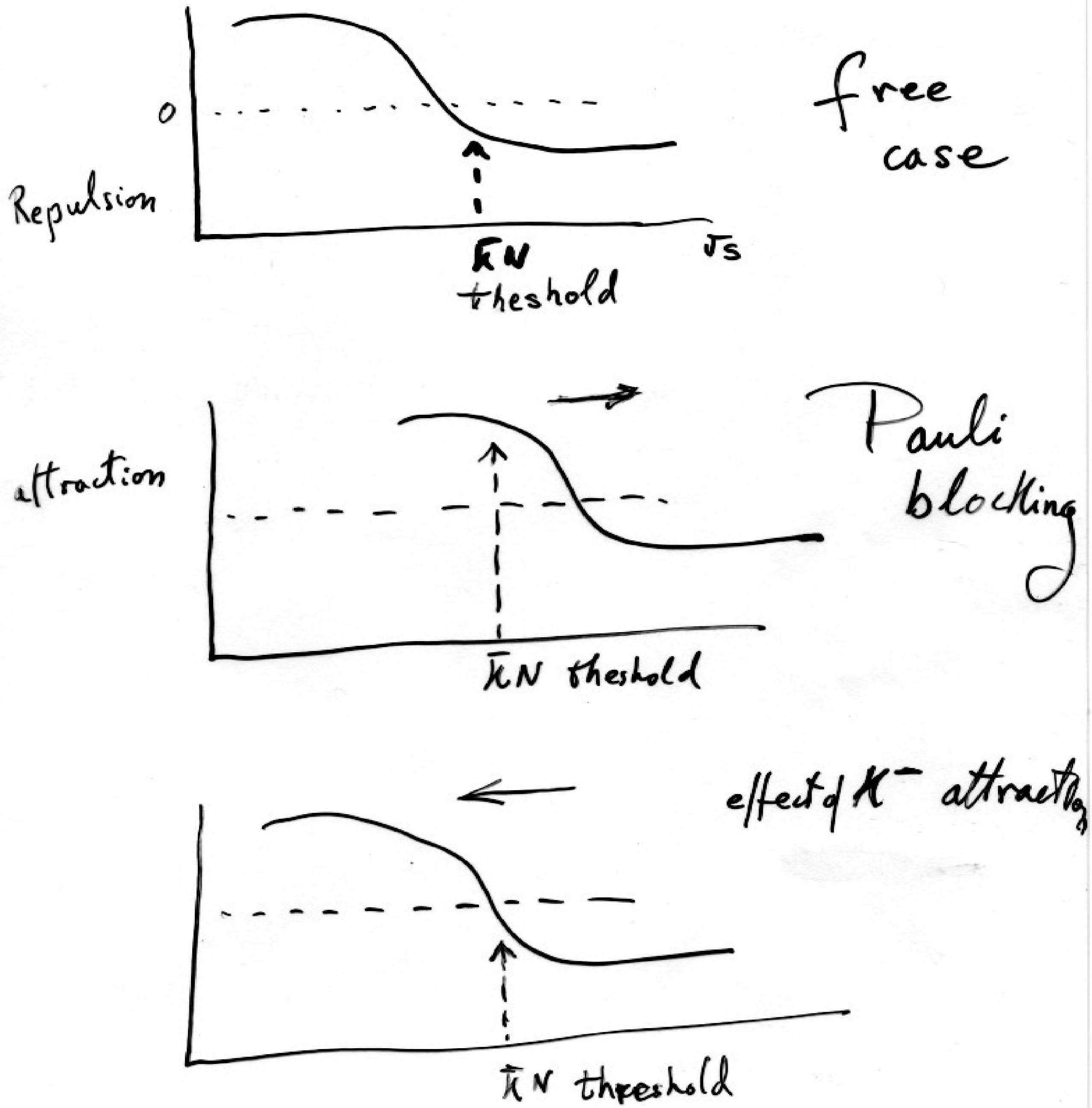
Brings back the $\Lambda(1405)$ to the free position



Sefcons. $\bar{K}$
+ π selfenergy
+ mean field baryon potential

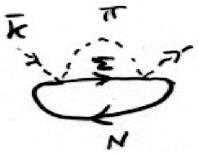
Ramos, E.O. NPA (2000)

Opens new decay channels and widens spectral function


free case
0
Repulsion
K̄N theshold
√s
Pauli blocking
attraction
K̄N theshold
effect of K⁻ attraction
K̄N threshold

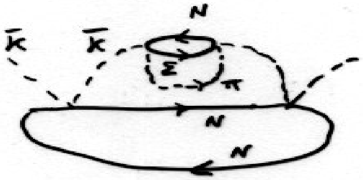
Medium decay channels

Koch
Waas, Weise



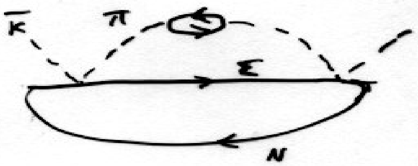
$\bar K \Rightarrow (\Sigma h)\,\pi \;,\; (\Lambda h)\,\pi$

Lutz

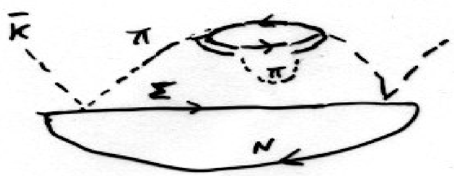


$+\ \bar K \to (\Sigma h)(ph)\pi,\ (\Lambda h)(ph)\pi$

Ramos

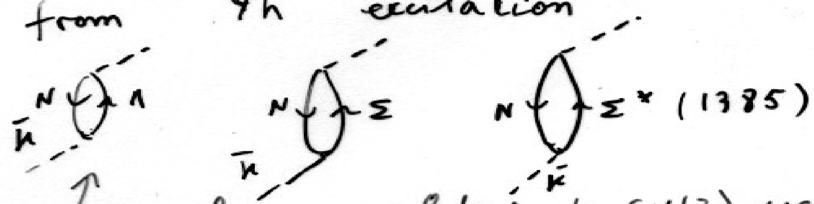


$+\ \bar K \to (\Sigma h)(ph),\ (\Lambda h)(ph)$

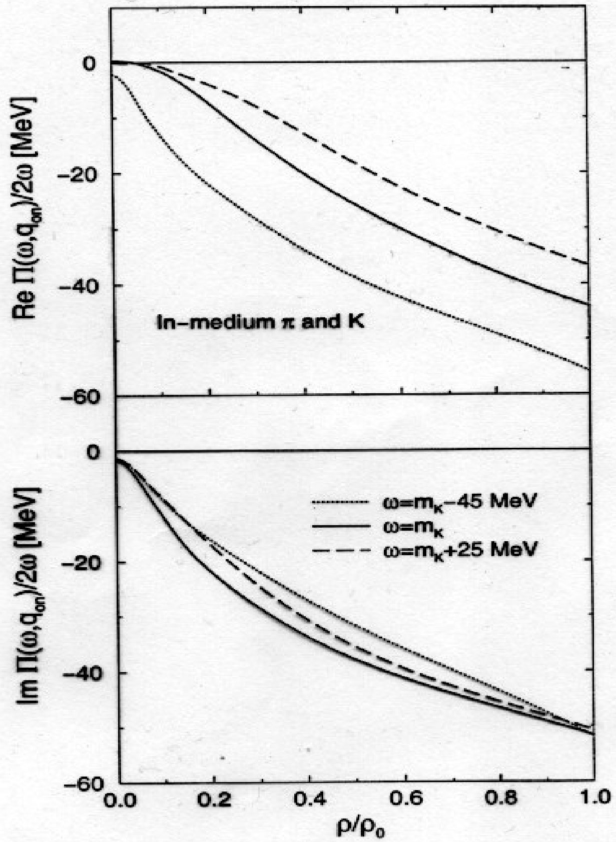


$+$ extra $(\Sigma h)(ph)\pi,\ (\Lambda h)(ph)\pi$

In addition we have p-wave $\bar K$ selfenergy from Yh excitation



Couplings related to SU(3) coeff. D, F of original chiral Lagrangian



Re V_{opt}

Im $V_{opt} \equiv -\frac{\Gamma}{2}$

FIG. 7. Real (top) and imaginary (bottom) parts of the K^- optical potential as a function of density obtained from the *In-medium pions and kaons* approximation. Results are shown for three different K^- energies: $\omega = m_K - 45$ MeV (dotted lines), $\omega = m_K$ (solid lines) and $\omega = m_K + 20$ MeV (dashed lines).

Similar results in

Schaffner-Bielich, Koch, Effenberg NPA 2000

Cieply, Friedman, Gal, Mares NPA 2001

25

Hirenzaki, Okumura, E.O., Ramos, Toki
PRC 2000

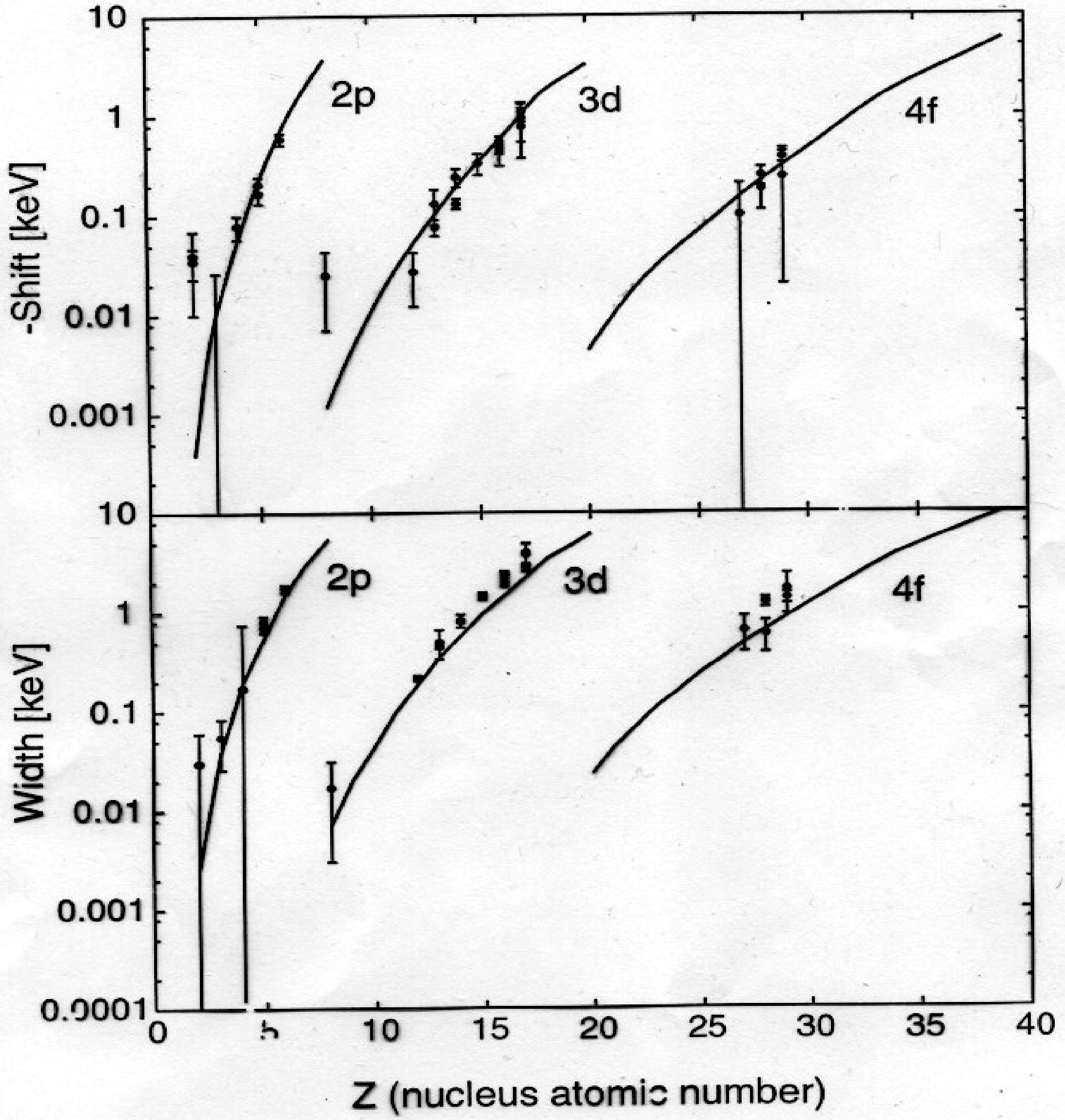
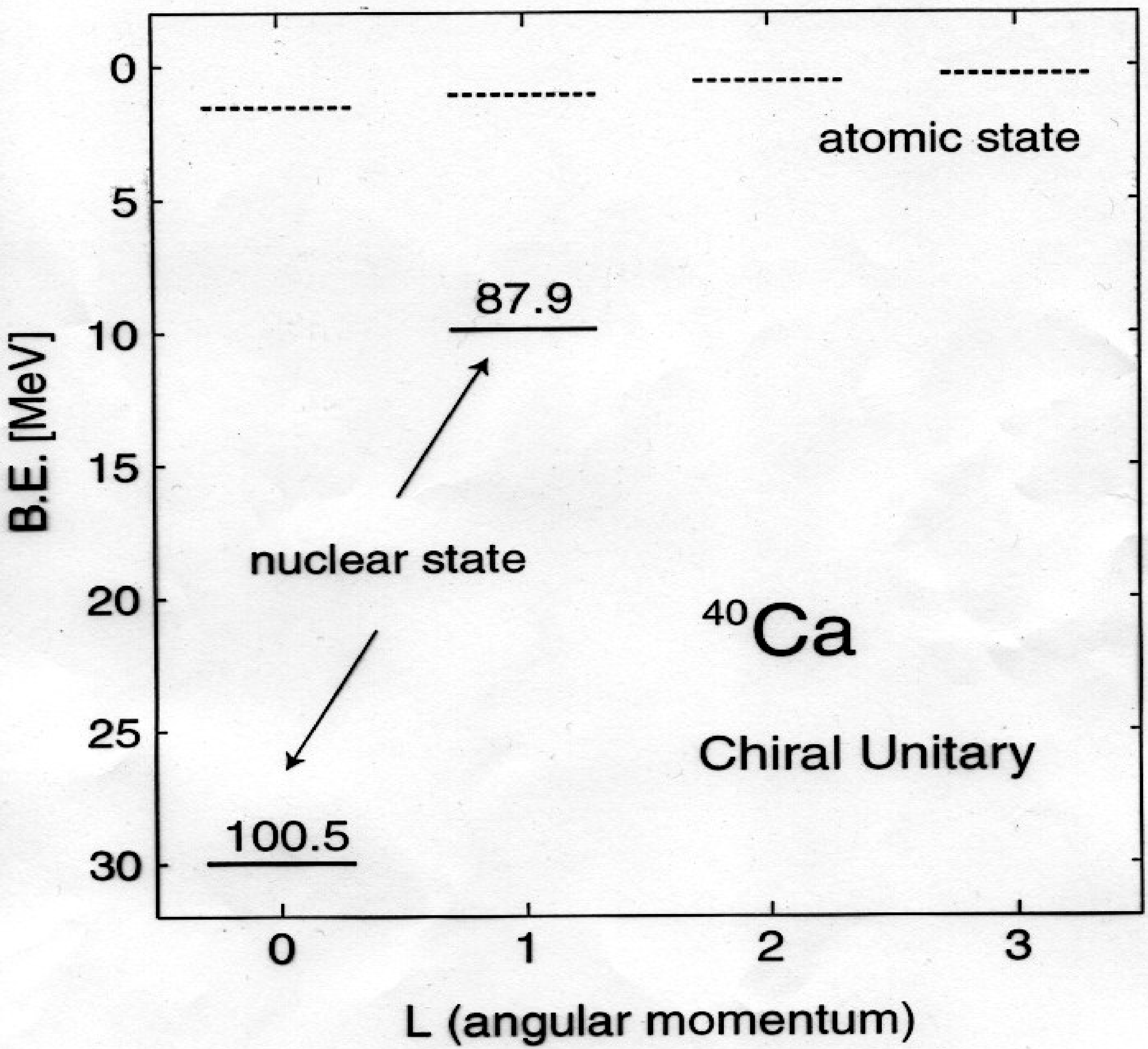


Fig.3


0
5
10
15
20
25
30
B.E. [MeV]
atomic state
87.9
nuclear state
^{40}Ca
Chiral Unitary
100.5
0
1
2
3
L (angular momentum)

Claims for deeply bound Kaon atoms

Theoretical claim of deep potential, Y. Akaishi and T. Yamazaki, Phys. Rev. C 65 (2002) 044005.
Quoting the authors textually,
"we construct phenomenologically a quantitative $\bar{K}N$ interaction model that is as simple as possible using free $\bar{K}N$ scattering data, the KpX data of kaonic hydrogen and the binding energy and width of $\Lambda(1405)$, which can be regarded as an isospin I=0 bound state of $\bar{K}+N$".
They use as input $v_{\bar{K}N,\bar{K}N}$, $v_{\bar{K}N,\pi\Sigma}$, $v_{\bar{K}N,\pi\Lambda}$, which are fitted to data, and set $v_{\pi\Sigma,\pi\Sigma}$, $v_{\pi\Lambda,\pi\Lambda}$ equal zero "to simply reduce the number of parameters".
The last condition implies that they miss the second pole of the $\Lambda(1405)$
The chiral Lagrangian gives

$$v_{\pi\Sigma,\pi\Sigma} = \frac{4}{3}\, v_{\bar{K}N,\bar{K}N}$$

Theoretical claims

The claim of the $\Lambda(1405)$ as a bound state of $\bar{K}N$ is not supported by the chiral theory.
This assumption leads to a I=0 $\bar{K}N$ amplitude below threshold twice as big as a standard chiral amplitude.

AY take into account Pauli Blocking of intermediate states to get $\bar{K}$ nucleus potential.

For the A=3 and 4 systems leads to binding energies of the kaon of the order of 70 MeV with widths around 75 MeV, (from $K^- N \rightarrow \pi\Sigma$).

Next, the nucleus is allowed to shrink to densities $\rho = 10\rho_0$

Then, K^- bound in ^3He by 108 MeV and in ^4He by 86 MeV

$\Gamma = 20 - 24$ MeV from $K^- p \rightarrow \pi\Lambda$

Extra defficiencies in the K^- potential

No selfconsistency in the calculation: Overestimate

No many body decay channels, $K^- NN \to \Lambda N, \Sigma N$

Rough estimate made of these channels, $\Gamma = 12 MeV$

More realistic is 22 MeV at $\rho = \rho_0$

But if $\rho = 10\rho_0$, $\Gamma = 2000 MeV$, or at least 200 MeV if ρ_{av} is used.

Experimentalist "find" a possible deeply bound K^- state. Suzuki et al. PLB597 (2004)

$K^- \, {}^4He \to Sp$, S(3115) Strange tribaryon.
But I=1, and if K^- state, B=195 MeV

Contradiction with AY with I=0 and 108 MeV!!

The saga continues

AY strike back:

Introduce relativistic corrections (use Klein Gordon equation) (The chiral theories always did)

some spin orbit corrections

Increase ad hoc the $\bar{K}N$ interaction

B=195 comes out then

At this point the K^- potential in the center of the nucleus has become 618 MeV!!!

Experimental reconversion: ..... Sato in BadHonnef, PANIC05... claim the state seen is indeed a K^- bound state.

Discussion of the KEK experiment, Suzuki et al.

- Kaons at rest absorbed: $K^- \; ^4He \to S \; p$, They see a peak in the p spectrum around 500 MeV/c.
- Auger emission of the p. Binding energy taken by K^-.
- Alternative explanation
  ..
  .. Many possible conventional mechanisms studied and discarded
- The one passing all tests
- $K^- NN \to \Lambda N \qquad p_N = 562 MeV/c$
- $K^- NN \to \Sigma N \qquad p_N = 488 MeV/c$
  The other nucleons left as spectators
- exp. peak seen at $p_p = 475 MeV/c$ (some energy loss in thick target)
  But what about a peak at $p_p = 562 MeV/c$ from $K^- pp \to \Lambda p$?

KEK Suzuki et al

cs Letters B 597 (2004) 263–269

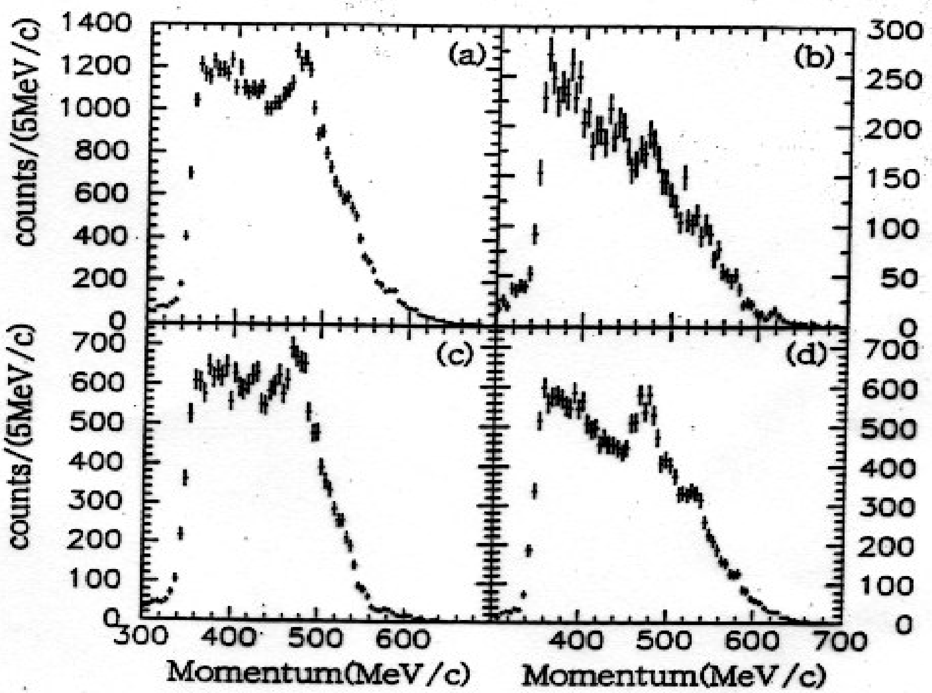


Fig. 5. Proton momentum spectra without energy-loss correction, with cut conditions defined in Fig. 4: (a) with the "π"-cut, (b) with the "p"-cut, (c) with "fast-π"-cut, and (d) with "π"-cut excluding the fast pions.

Further tests of K^- absorption mechanism

- Peak at 545 MeV/c seen in experiment !!
- Further tests
- $K^- pp \rightarrow \Lambda p$
$$\Lambda \rightarrow \pi N \quad p_\pi = [61 - 146] MeV/c$$
- $K^- pp \rightarrow \Sigma p$
$$\Sigma \rightarrow \pi N \quad p_\pi = [162 - 217] MeV/c$$
- A cut in the pion momenta could help
Test partially done: cut done that accepts 90 % of 255 MeV/c ("fast pions") and complementary
- Peak from $K^- pp \rightarrow \Sigma p$ seen in boths cuts
- Peak from $K^- pp \rightarrow \Lambda p$ seen in basically only the non "fast pions"

Further considerations

- Why more strength in Σp peak than in Λp peak?
- Katz et al. PRD 1 (70) $K^- \ ^4He \rightarrow$

  $\Sigma^- p\, d \quad 1.6 \;\; percent$

  $\Sigma^- ppn \quad 2.0 \;\; percent$

  $\Lambda(\Sigma^0)pnn \quad 11.7 \;\; percent$
- 2.3 % for Σ^0 and 9.4 % for Λ, using isospin symmetry
- Another estimate

$$\frac{Y\ (\Sigma^0 NN)}{Y\ (\Lambda NN)} = \frac{\sigma(K^- p \rightarrow \pi^0 \Sigma^0)}{\sigma(K^- p \rightarrow \pi^0 \Lambda)} \tag{1}$$

  This ratio is about 1 experimentally
- Using these estimates: ratio of Σp to Λp about [1.2-2.5]
- Rates of K^- absorption around 1%, in agreement with strength of peak estimated by Suzuki.

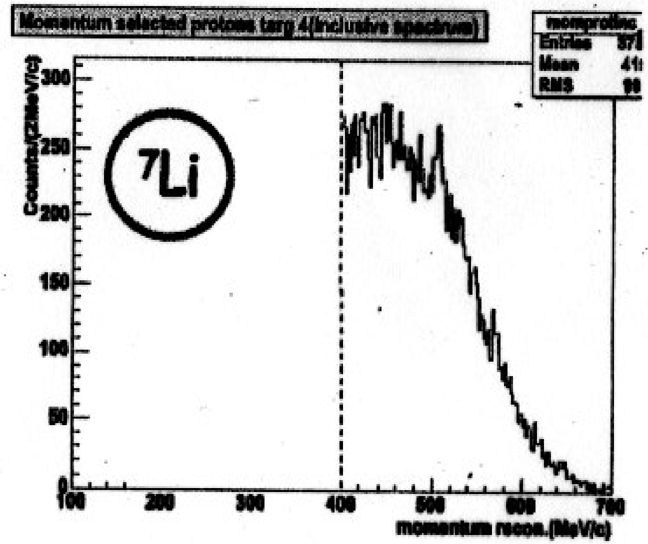
Further tests

- These peaks should be seen in other nuclei!!, what can we predict?
- In K^- absorption two protons are removed. Binding energy smaller than 28 MeV of ^4He breakup. Hence, bigger energy of emitted p in heavier nuclei.
- Estimates
  502 MeV/c for Σp
  574 MeV/c for Λp
- FINUDA sees peaks in ^7Li (and other nuclei) at
  505 MeV/c and 570 MeV/c
- Peaks should get narrower in heavier nuclei, because of smaller recoil energy of the nucleus
- Signals should gradually disappear for heavier nuclei because of p distortion
  These are indeed features of the FINUDA experiment

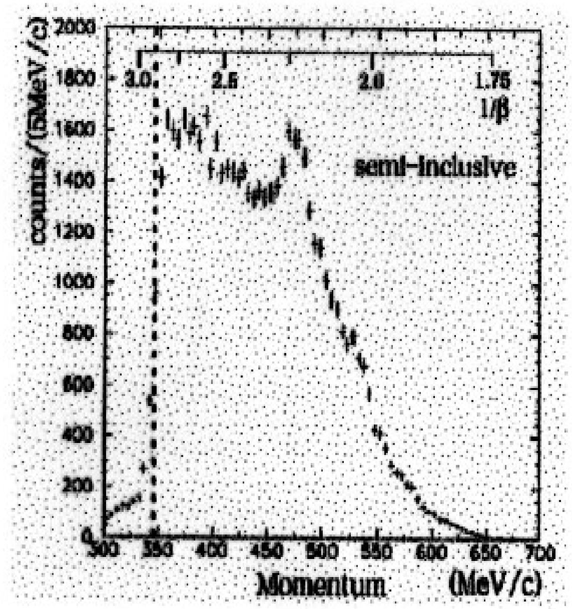
Pre

Monoenergetic protons at 510 MeV/c

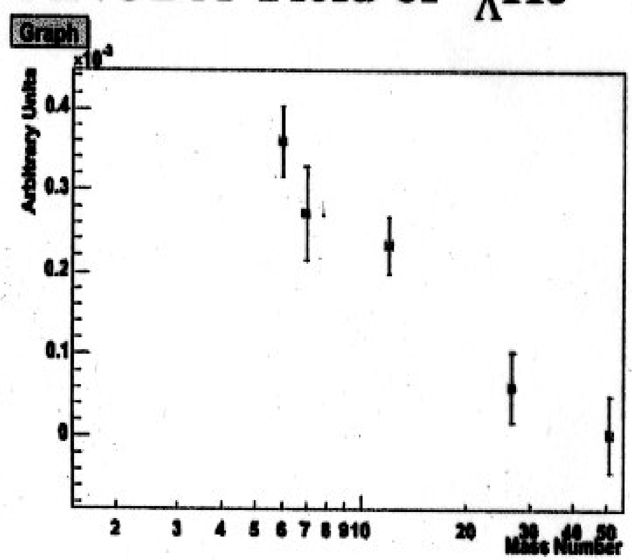
FINUDA from 7Li,…



KEK E471 from ^{4}He



FINUDA Yield of $^4{}_\Lambda$He



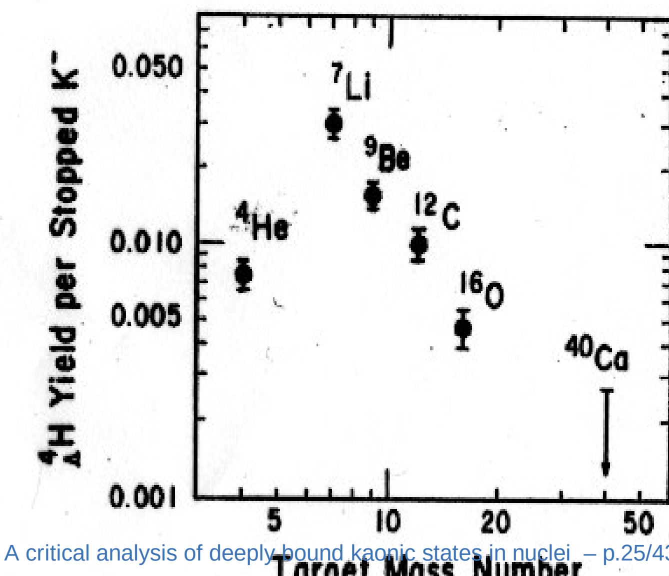
Tamura et al.

Yield of $^4{}_\Lambda$H

^{4}He/^{7}Li ~ 1/4

Yield of $^4{}_\Lambda$He

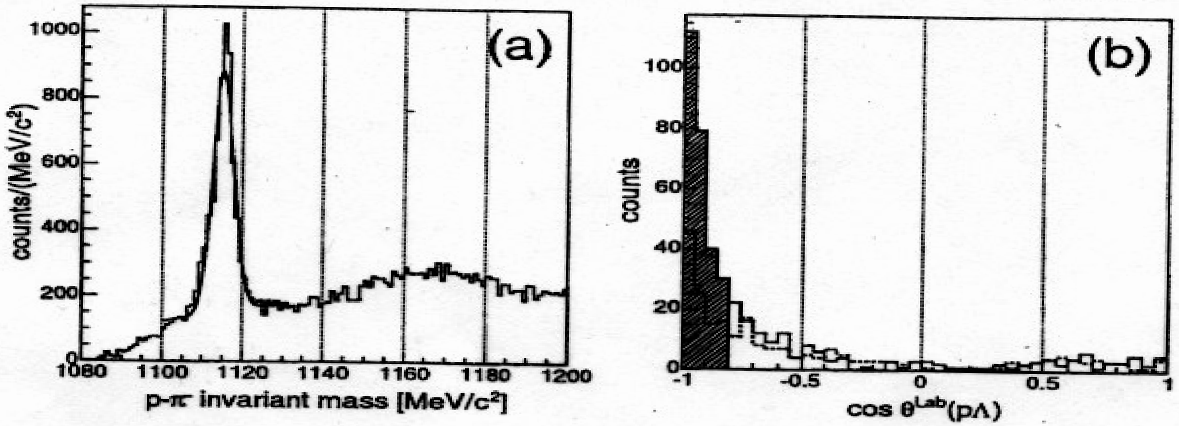
^{4}He/^{7}Li ~ 1/3



FINUDA experiment, M. Agnello et al. PRL 94 (2005)

- K^- absorption at rest from $^6Li,^7Li,^{12}C....$
  They look for events back to back. Find two peaks in Λp invariant mass: a narrow one at higher energies and a broad one at lower energies. The latter is identified with a bound K^- state.
- Cuts: $p_\Lambda > 300MeV/c$ to eliminate $K^-p \to \Lambda\pi$
  $|cos(\theta)| > 0.8$
- Narrow peak identified as $K^-pp \to \Lambda p$ removing binding energy
  Broad one at lower energies: "bound K^- state in pp " with B=115 MeV.
- Questions:
  where does the binding energy of the kaon go?
  Where is the strength if $K^-pp \to \Lambda p$ exciting the nucleus (largest part)?

FINUDA Agnello et al



) Invariant-mass distribution of a proton and a π^- for all the events in which these two particles are observed, ssian together with a linear background in the invariant-mass range of 1100–1130 MeV/c^2. (b) Opening angle Λ and a proton: solid line, ^{6}Li, ^{7}Li, and ^{12}C; dashed line, ^{27}Al and ^{51}V. The shaded area ($\cos\theta^{\rm Lab} < -0.8$) is sele k event.

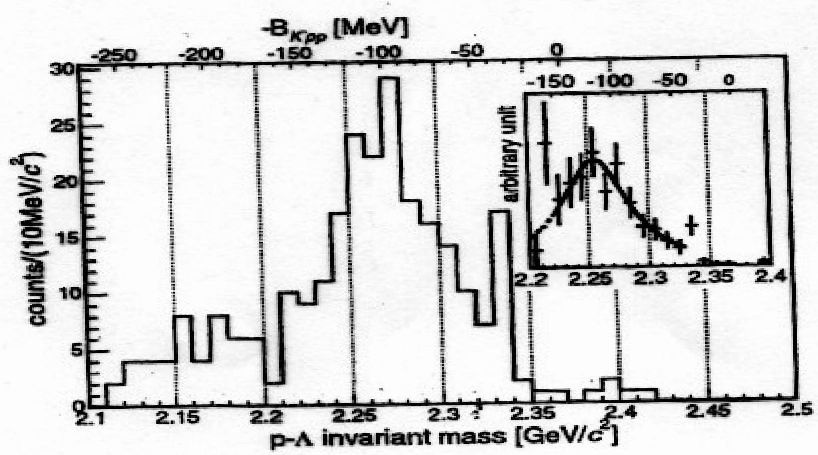


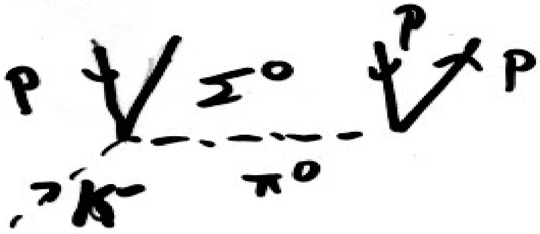
FIG. 3. Invariant mass of a Λ and a proton in back-to-back correlation ($\cos\theta^{\rm Lab} < -0.8$) from light targets before the acceptance correction. The inset shows the result after the acceptance correction for the events which have two protons with well-defined good tracks. Only the bins between 2.22 and

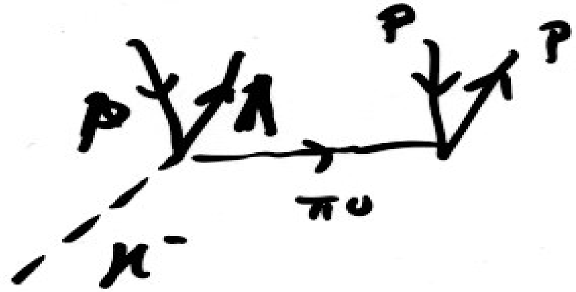
Our description of the peaks

- We run a computer simulation code for K^- absorption in nuclei by pp and pn pairs:
- $|\Psi(r)|^2$ distribution for K^- peaked around surface of nucleus
- K^- absorbed by pp or pn, with momenta randomly chosen from local Fermi sea.
- energy and momentum conservation including nuclear potential
- Λp, Λn emitted according to phase space
- p, n have further collisions
  pN -> p' N   np -> pn   (fast n to fast p)
  done according to $\sigma\rho$ probability per unit length and experimental angular distributions ($\sigma_\Lambda = \frac{2}{3}\sigma_N$)
- Λp invariant mass reconstructed from final events.

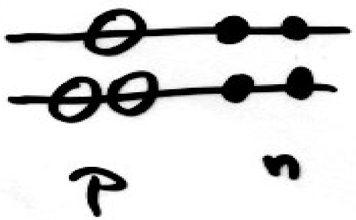
Analysis of first peak: g.s. formation of residual nucleus

- Analogy to α decay:
  p and Λ survival probability without collisisions times formation probability.
- Survival probability
  P= $exp(-\int \sigma \rho dl)$
  Calculated by MC simulation, P ~ 0.4
- Formation probability:
  $|<\Phi(r, A-2, final)|\Phi(r, A-2, initial)>|^2, \; |\sim 0.3-0.7|^2$
- Rate of g.s. formation $\sim 0.4 * 0.25 \sim 0.1$
- THE LARGEST PART OF THE K^- ABSORPTION EVENTS GO INTO NUCLEAR EXCITATION, MOSTLY TO THE CONTINUUM
  where is this strength in the experiment?



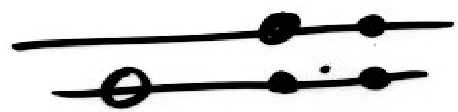


Schematic



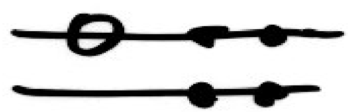
^7Li

$K^-\,{}^7Li \to pp\,{}^5H$ g.s



^5H

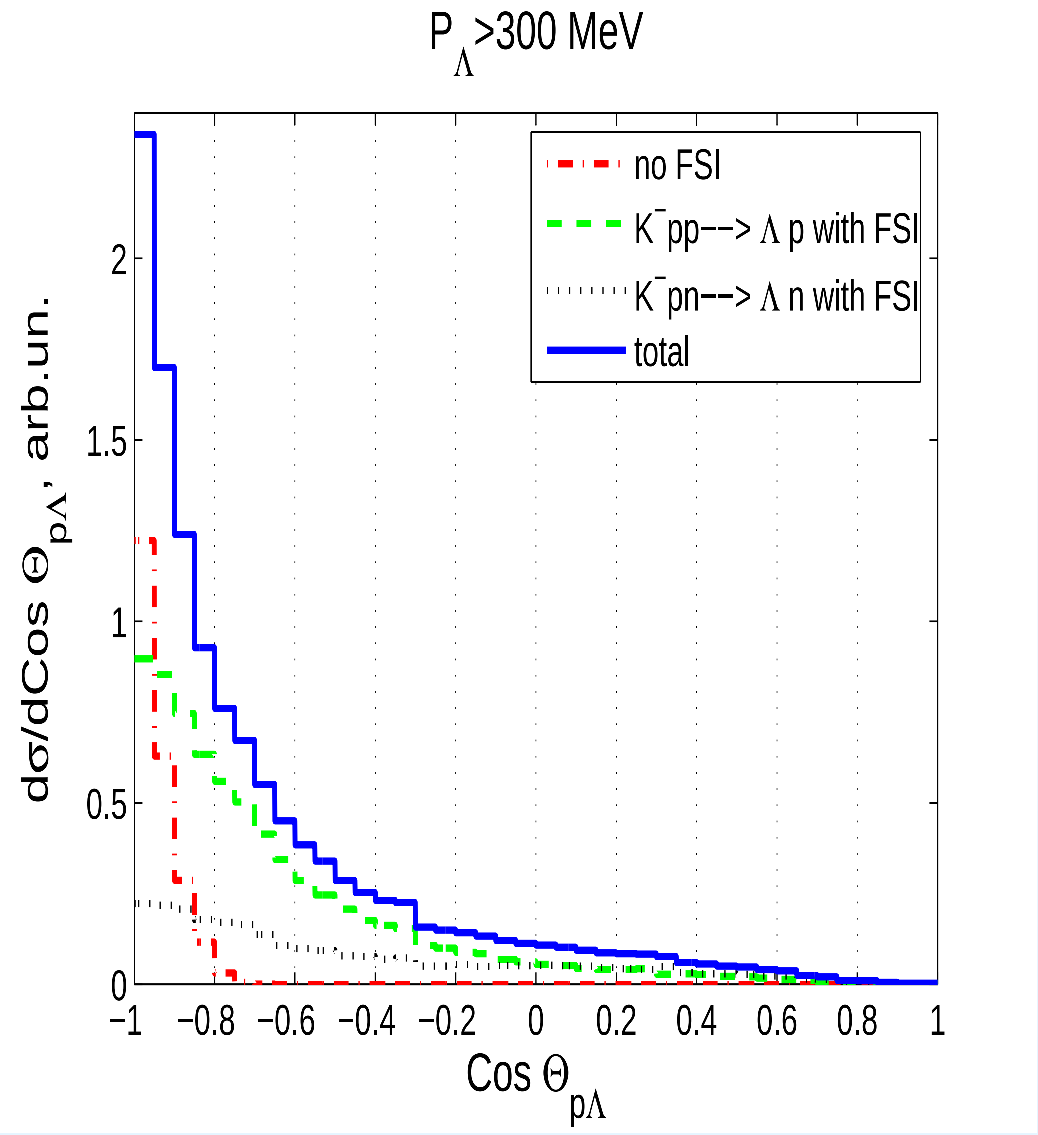
excitation

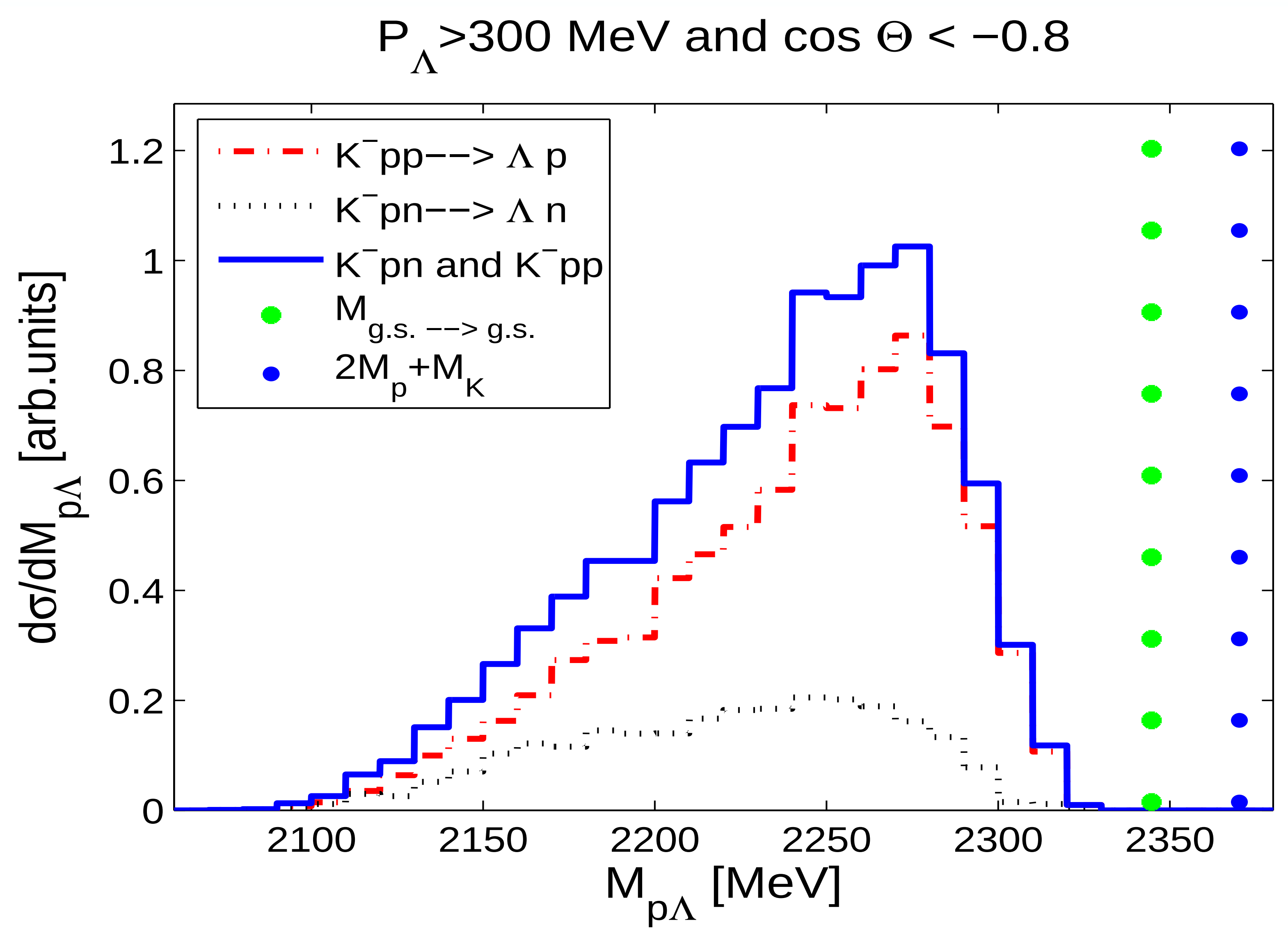


little overlap with ^5H breakup channels

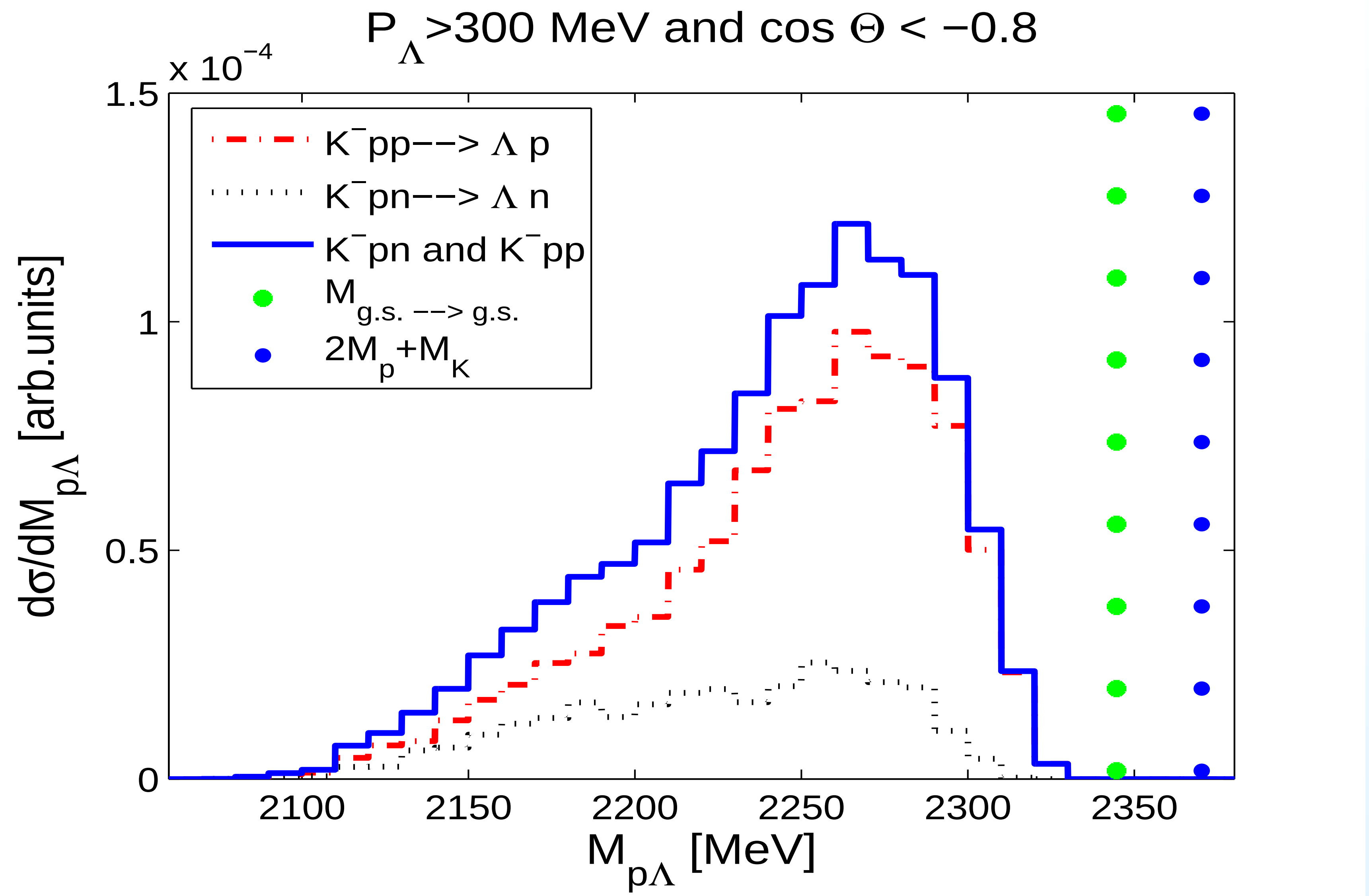
MC simulation of K^- absorption: inclusive

- The MC simulation is done as described before
  This has been applied with success to other physical problems:
  (e,e’) inclusive reactions
  (π, π') inclusive reactions
  (p,p’) inclusive reactions
- In all tese processes a distinct peak appears which collects most of the strength: the quasielastic peak
  The QSE peak comes mostly from one collision of the particles exciting the nucleus to the continuum
- In the present case this QSE peak comes from the collision of the p (or Λ) after $K^- NN \rightarrow \Lambda N$
- THE QSE PEAK ACCOUNTS FOR THE SECOND PEAK OF THE FINUDA EXPERIMENT

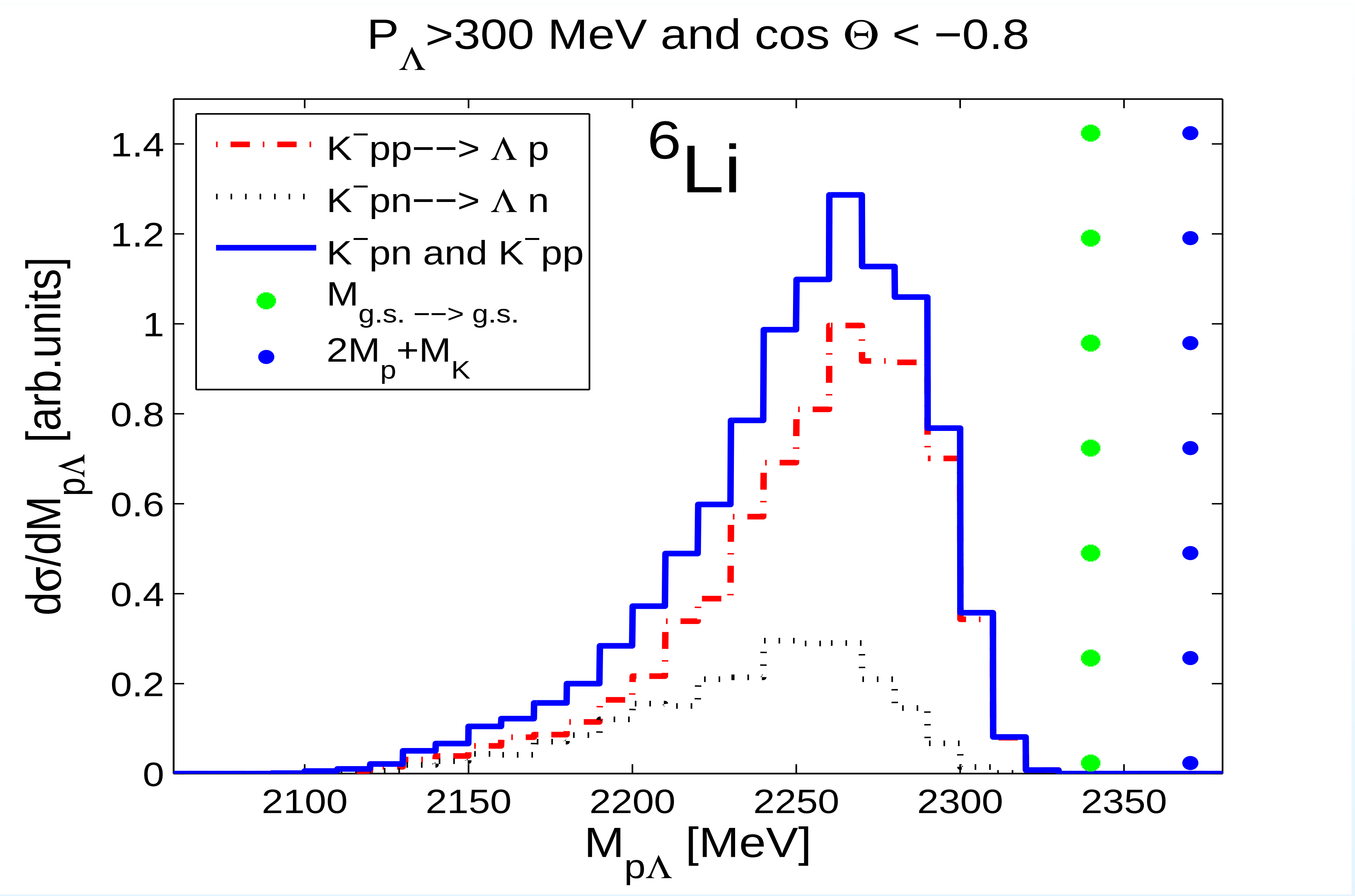

P_Λ>300 MeV
no FSI
K^-pp--> Λ p with FSI
K^-pn--> Λ n with FSI
total
$d\sigma/dCos\ \Theta_{p\Lambda}$, arb.un.
$Cos\ \Theta_{p\Lambda}$
0
0.5
1
1.5
2
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1



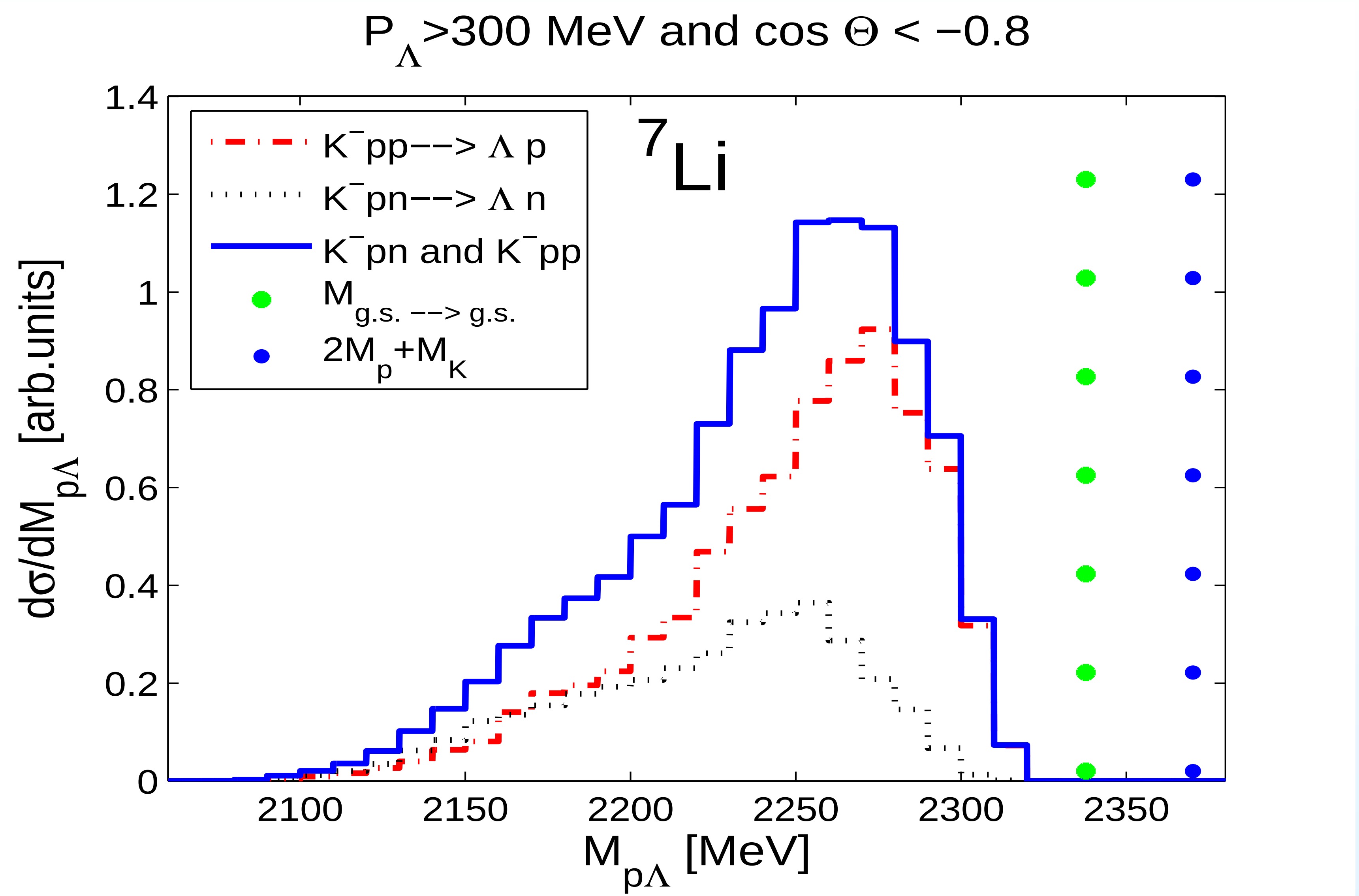
^{12}C Results imposing the experimental angle cut for back to back events, $\cos\Theta_{\vec{p}_\Lambda \vec{p}_p} < -0.8$, and up to three collisions.



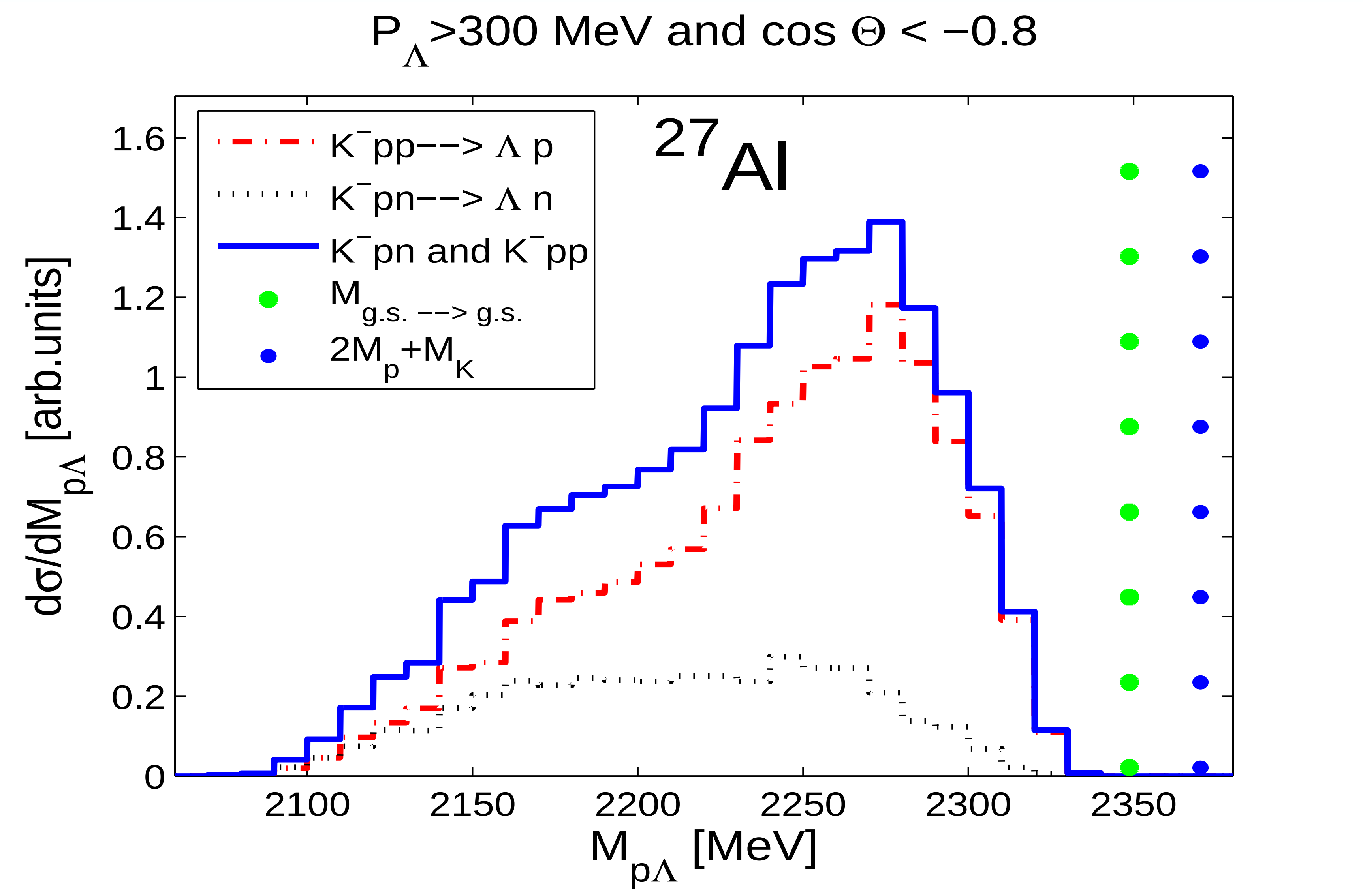
^{12}C Results imposing the experimental angle cut for back to back events, $\cos\Theta_{\vec{p}_\Lambda \vec{p}_p} < -0.8$, and up to three collisions. 3d orbit.



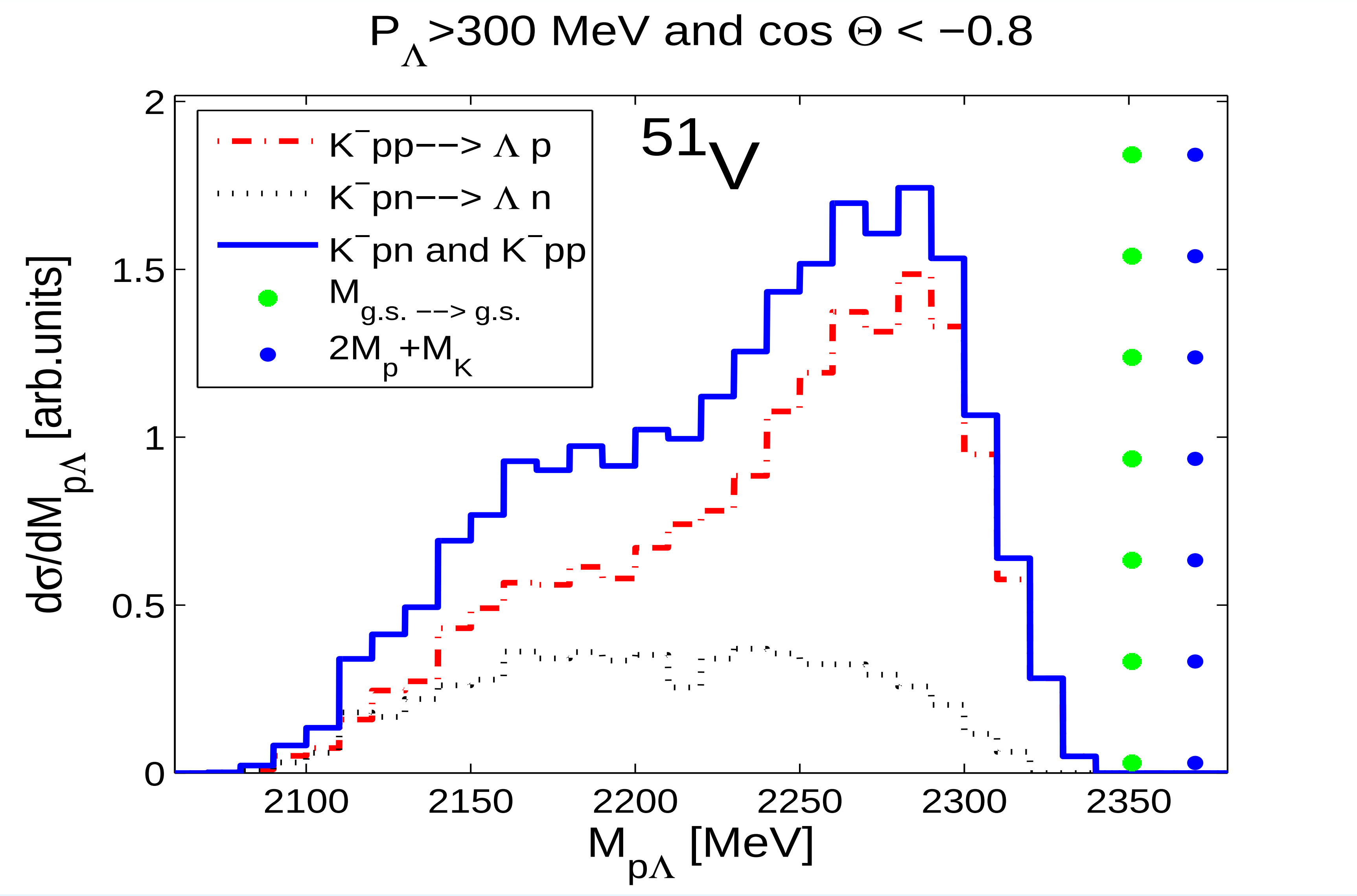
^6Li. K^- absorption from 2p orbit.



^7Li. K^- absorption from 2p orbit.



^{27}Al. K^- absorption from 3p orbit.



^{51}V. K^- absorption from 4f orbit.

Other channels studied

- $K^- pp \rightarrow \Sigma^+ n$, $\rightarrow \Sigma^0 p$
  followed by, $\Sigma^+ n \rightarrow \Lambda p$, $\Sigma^0 p \rightarrow \Lambda p$
  this peaks around the third experimental peak and has smaller strength than $K^- pp \rightarrow \Lambda p$
- $K^- pp \rightarrow \Sigma^0 p$
  $$\Sigma^0 \rightarrow \Lambda\gamma \; , \quad \sqrt{s} = 2240 - 2300 MeV$$
  hence, (Λp) invariant mass in QES peak and all events back to back
  strength smaller, $\sim 10 - 30 \;\; percent$ of $K^- pp \rightarrow \Lambda p$ events.

Conclusions

- The K^- optical potential on which predictions of narrow deeply bound K^- states was done is overly exagerated and incomplete in the decay channels.
- The KEK and FINUDA experiment do not have any support for the interpretation of the data as bound kaons except the " theoretical predictions" of the mentioned work.
- We have shown that all the peaks can be interpreted in terms of K^- absorption on pairs of nucleons,
  in KEK with remnant nucleus as spectator
  in FINUDA, first peak with remnant nucleus as spectator
  second peak with nuclear excitation to the continuum
- These mechanisms passed all tests for which there were available data.

Borasoy

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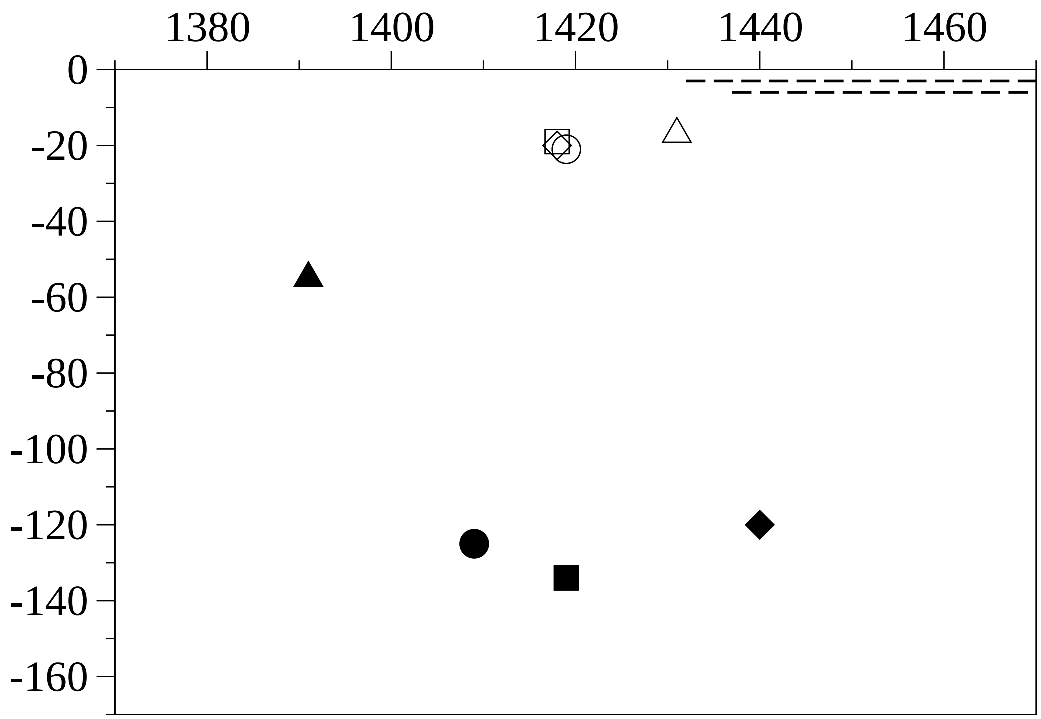

Pole positions of the T matrix in the complex W plane. The triangles, diamonds, squares and circles correspond to the "WT", "c", "s" and "u" approach, respectively. The dashed lines represent the K^-p and $\bar{K}^0 n$ cuts, respectively. Right: Pole positions of the T matrix in the complex W plane. The circles, triangles and squares correspond to the fi ts "1", "2" and "3", respectively.

Summary of DHD06 Workshop, Kyoto Feb 2006

- Akaishi strikes back, confusion of cut off in fi eld theory and range of interaction. No selfconsistency yet, still $10\rho_0$ density.
- Yamazaki strikes back, makes wrong assumption on fi nal state in $K^- \ {}^4He$ absorption going to $p\Sigma\ nn$ instead of $p\Sigma\ d$ (small recoil energy of d, 10 MeV for 200 MeV/c of Fermi motion). Misses the experimental fact of the narrow signal in FINUDA for K^- absorption without extra fi nal state interaction. Disguised offer of compromise, peaks partly from K^- absorption and partly from production of tribaryon. Compromise rejected: too much coincidence that the peaks appear in all nuclei at the K^- absorption kinematics.
- No help from any body else of the japanese community.
- No claims in the experimental talks about deeply bound kaon atoms. Back to tribaryon claim.
- Iwasaki pledge "please understand all this is still preliminary, we are working to understand what happens"
- The paper of 2003 with claims for deeply bound K from the $K^-(at\ rest)$ absorption in ${}^4He$, (K^-, n) has been withdrawn.

Summary of DHD06 Workshop, Kyoto Feb 2006

- Y. Yamagata presents calculations of (K^-, p) in flight and concludes that even if there are deeply bound kaon states the signal would be too weak to be seen in present experiments.
- S. Okada (Hayano exp.) presents results for $3d \longrightarrow 2p$ X-rays of Kaonic Helium. 2p shift: Old experiments 40 eV, chiral unitary model 0.2 eV, Akaishi potential 11 eV. New experiment compatible with zero with 3-4 eV precision.