Status of AMADEUS studies of low-energy kaons interactions in nuclear matter

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INFN LNF

STRANU: HOT TOPICS IN STRANGENESS

NUCLEAR AND ATOMIC PHYSICS

FONDAZIONE BRUNO KESSLER

ECT* EUROPEAN CENTRE FOR THEORETICAL STUDIES IN NUCLEAR PHYSICS AND RELATED AREAS

Plan

1. Motivation and scientific case
2. AMADEUS @ DAΦNE
3. Analysis results
4. Conclusions

Motivation and Scientific Case

The investigation of the **in-medium modification of the $\bar{K}N$ interaction** is of **fundamental** for the low-energy QCD (Quantum Chromodynamic)

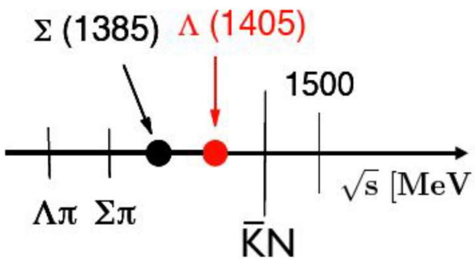
Chiral perturbation theory (ChPT): effective field theory where **mesons and baryons** represent the effective degrees of freedom instead of the fundamental quark and gluon fields.

$$\mathcal{L}_{eff} = \mathcal{L}_{mesons}(\Phi) + \mathcal{L}_B(\Phi, \Psi_B)$$

- The chiral symmetry is **spontaneously broken** → the existence of massless and spinless Nambu-Goldstone bosons which are identified with the pions. Explicitly broken by **q** masses.
- **Very successful** in describing the πN, ππ and NN interactions in the low-energy regime and is considered as the theory of the low-energy strong interaction **in the SU(2) flavour sector**.

The extension of the theory to the sector with the quark s turns out to be more problematic since it is not directly applicable to the $\bar{K}N$ channel.

The χPT is not applicable to the $\bar{K}N$ channel due to the emerging of the Λ(1405) and the Σ(1385) resonances just below the $\bar{K}N$ mass threshold



Λ(1405) I=0 $J^P = ½^-$
M = $(1405.1^{+1.3}_{-1.0})$ MeV Γ = (50.5 ± 2.0) MeV
decay modes: Σπ (I=0) 100%

Σ(1385) I=1 $J^P = 3/2^+$

decay modes: Λ π (I=1) (87.0 ± 1.5) %
Σ π (I=1) (11.7 ± 1.5) %

Possible solutions:

- **Non-perturbative Coupled Channels approach: Chiral Unitary SU(3) Dynamics**
- **Phenomenological $\bar{K}N$ and NN potentials**

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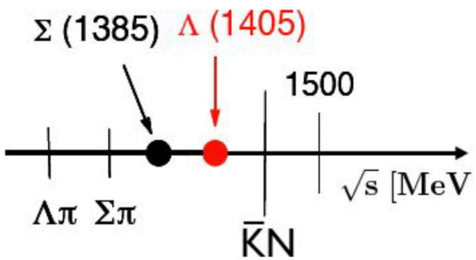

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Possible solutions:

- **Non-perturbative Coupled Channels approach: Chiral Unitary SU(3) Dynamics**
- **Phenomenological $\bar{K}N$ and NN potentials**

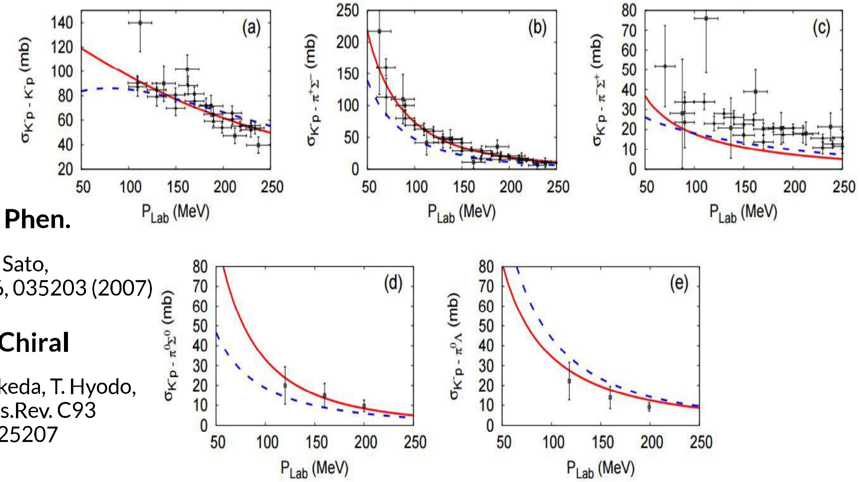
The parameters of the models are constrained by the existing scattering data

Phen.

Y. Ikeda and T. Sato, Phys. Rev. C76, 035203 (2007)

Chiral

S. Ohnishi, Y. Ikeda, T. Hyodo, W. Weise, Phys.Rev. C93 (2016) no.2, 025207



...but... large differences in the subthreshold extrapolations!

Significantly weaker attraction in chiral SU(3) models than in phenomenological potential models.

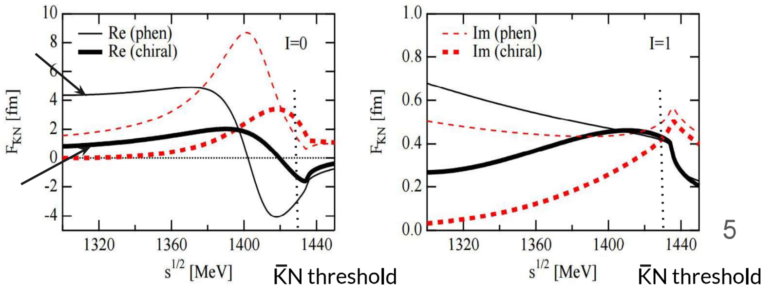
Re Im

Phen. [Y. Akaishi, T. Yamazaki, Phys. Rev. C65, 044005 (2002)]

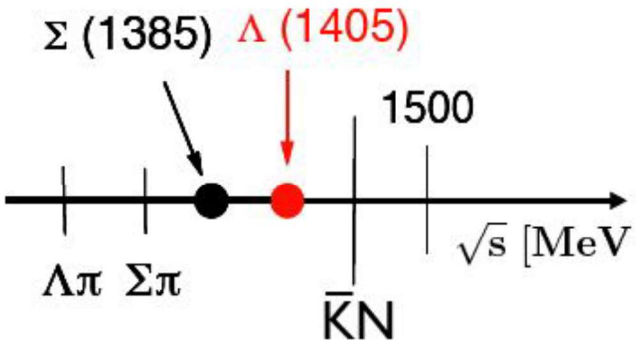
Chiral [Y. Ikeda, T. Hyodo, W. Weise, Phys. Lett. B706, 63 (2011)]

Phenomenologic potential model

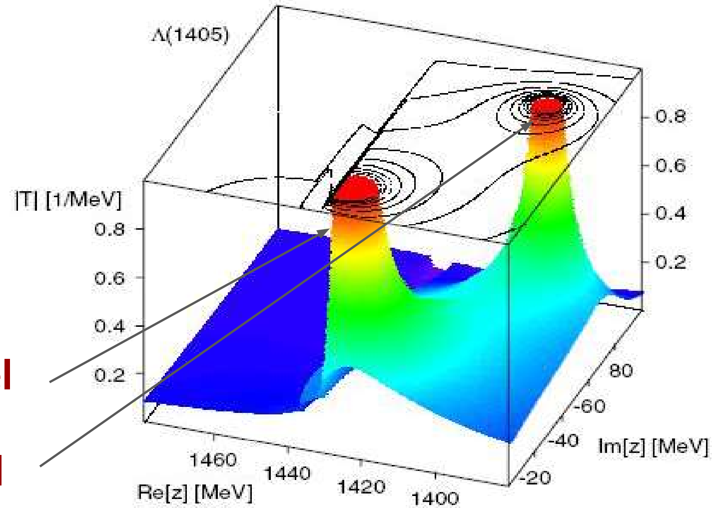
Chiral SU(3) dynamics



The controversial nature of the Λ(1405)



The Λ(1405) state does not fit with the simple three quarks model (*uds*) and it is commonly accepted that **it is, at least partially, a K̄N bound state**.



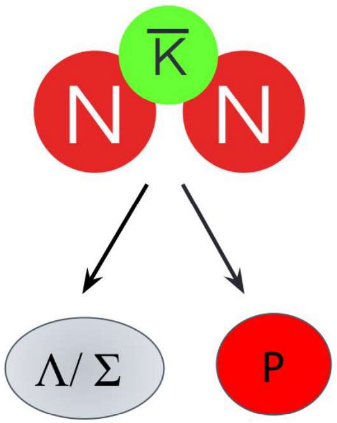
- **Chiral SU(3) coupled channel dynamics:** the state is given by the superpositions of **two poles of the K̄N scattering amplitude**.

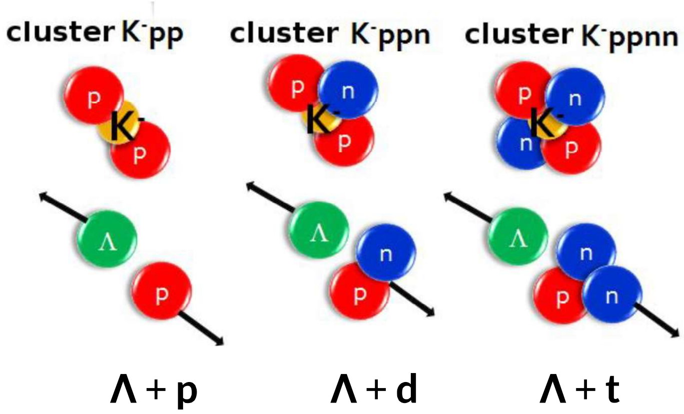
  M = 1425 MeV ⟶ **mainly coupled to the K̄N channel**

  M = 1380 MeV ⟶ **mainly coupled to the Σπ channel**

- **Phenomenological potentials models:** the **Λ(1405) is a pure K̄N bound state** with mass M=1405 MeV, binding energy BE = 27 MeV and width Γ=50 MeV.

Possible existence of kaonic bound states





Wycech (1986) - Akaishi & Yamazaki (2002)

Predicted in the **$\overline{K}$N interaction in the I=0** channel due to the strong interaction (deeply bound kaonic nuclear states)

The central densities are expected to be large enough to activate the strangeness production:

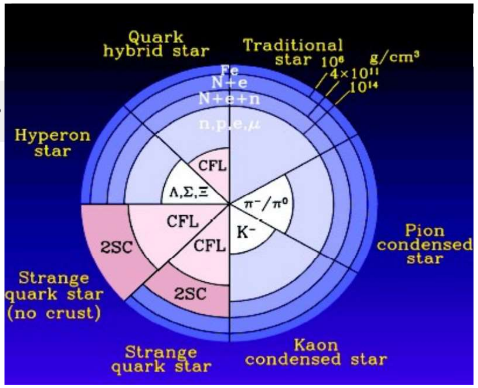
$$p + e^- \rightarrow n + \nu_e$$
$$n \rightarrow p + K^-$$

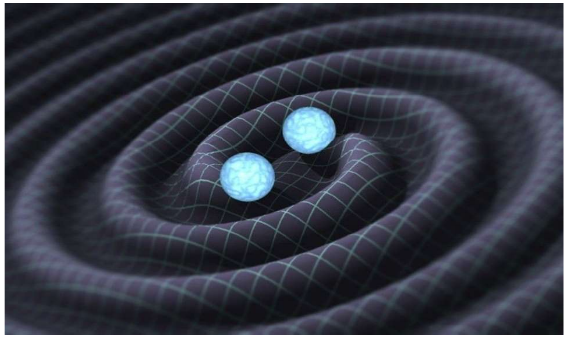
largely compressed due to the strong attraction

Kaonic Nuclei	Binding Energy [MeV]	Width [MeV]	Central Density
K^-p	27	40	$3.5\rho_0$
K^-pp	48	61	$3.1\rho_0$
K^-ppp	97	13	$9.2\rho_0$
K^-ppn	118	21	$8.8\rho_0$

$\rho_0 = 0.17\ fm^{-3}$

EoS of the Neutron Stars





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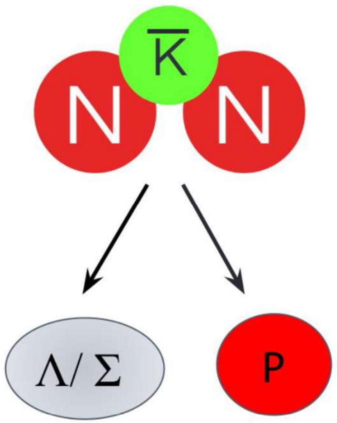
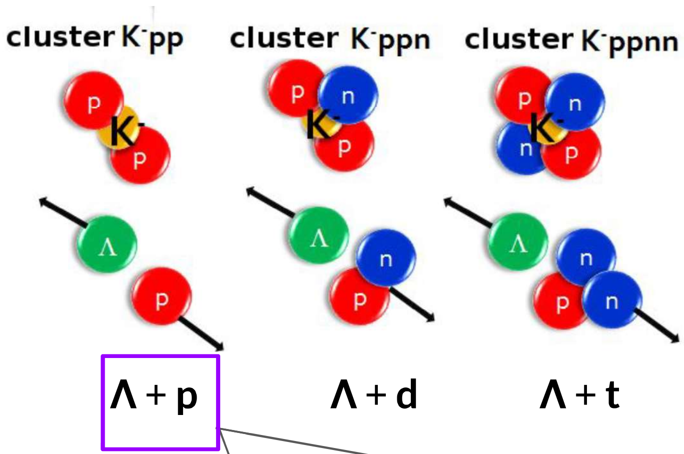




Wycech (1986) - Akaishi & Yamazaki (2002)

Predicted in the **K̄N interaction in the I=0** channel due to the strong interaction

Essential impact on the EoS of Neutron Stars

gravitational waves signal emitted by binary system of Neutron Stars

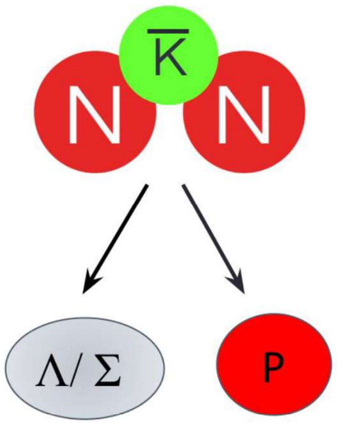
Theory

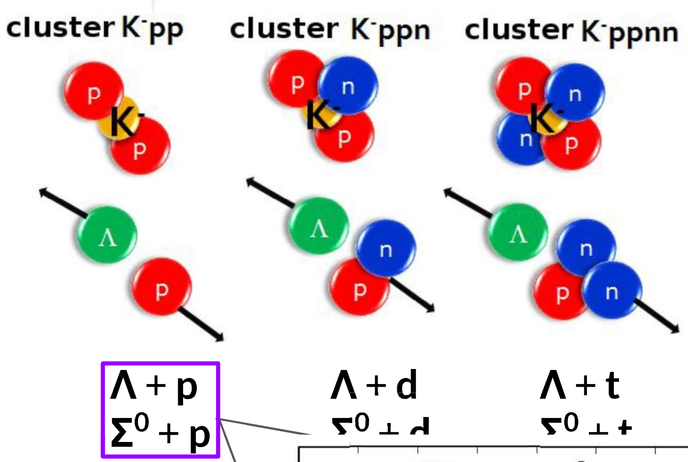
Chiral models	BE [MeV]	Γ [MeV]	Reference
Dote, Hyodo, Weise	17 - 23	40 - 70	Phys. Rev. C 79 (2009) 014003
Barnea, Gal, Liverts	16	41	Phys. Lett. B 712 (2012) 132
Ikeda, Kamano, Sato	9 - 16	34 - 46	Prog. Theor. Phys. (2010) 124 (3)
Bicudo	14.2 - 53	13.8 - 28.3	Phys. Rev. D 76 (2007) 031502
Bayar, Oset	15 - 30	75 - 80	Nucl. Phys. A 914 (2013) 349
Dote, Inoue, Myo	21.2 - 32.2	9 - 31.7	Prog. Theor. Exp. Phys. 2015 (2015) 043D02
Sekihara, Oset, Ramos	16	72	Prog. Theor. Exp. Phys. 2016 (2016) 123D03
Phen. approach	**BE [MeV]**	**Γ [MeV]**	**Reference**
Akaishi, Yamazaki	48	61	Phys. Rev. C 65 (2002) 044005
Ikeda, Sato	60 - 95	45 - 90	Phys. Rev. C 76 (2007) 035203
Shevchenko, Gal, Mares	55 - 70	90 - 110	Phys. Rev. Lett. 98 (2007) 082301
Revai, Shevchenko	32	49	Phys. Rev. C 90 no. 3 (2014) 034004
Maeda, Akaishi, Yamazaki	51.5	61	Proc. Jpn. Acad. B 89 (2013) 418
Wycech, Green	40 - 80	40 - 85	Phys. Rev. C 79 (2009) 014001

Experiments

Experiment	BE [MeV]	Γ [MeV]	Reference
FINUDA	115^{+6}_{-5}(stat.)$^{+3}_{-4}$(syst.)	67^{+14}_{-11}(stat.)$^{+2}_{-3}$(syst.)	PRL 94 (2005), 212303
OBELIX	160.9±4.9	$<$24.4±8.0	NPA 789 (2007), 222
E549	-	-	MPLA 23 (2008), 2520
DISTO	103±3(stat.)±5(syst.)	118±8(stat.)±10(syst.)	PRL 104 (2010), 132502
LEPS/SPring-8	Upper limit		PLB 728 (2014), 616
HADES	Upper limit		PLB 742 (2015), 242
E27	95^{+18}_{-17}(stat.)$^{+30}_{-21}$(syst.)	162^{+87}_{-45}(stat.)$^{+66}_{-78}$(syst.)	PTEP (2015), 021D01
AMADEUS	Upper limit		PLB 758 (2016), 134
E15 1st run	15^{+6}_{-8}(stat.)±12(syst.)	110^{+19}_{-17}(stat.)±27(syst.)	PTEP (2016), 051D01
E15 2nd run	47±3(stat.)$^{+3}_{-6}$(syst.)	115±7(stat.)$^{+10}_{-20}$(syst.)	PLB 789 (2019), 612

Possible existence of kaonic bound states





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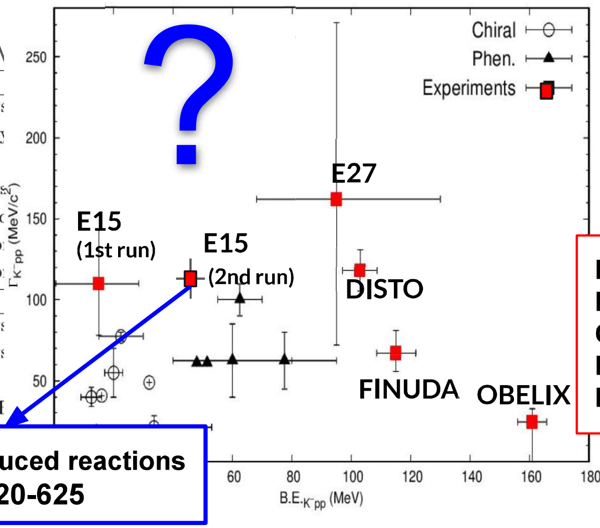
Revai, Shevchenko	32	49	Phys. I
Maeda, Akai			
Wycec			



E15 → **first clear evidence** in K⁻ induced reactions
Phys.Lett.B 789 (2019) 620-625

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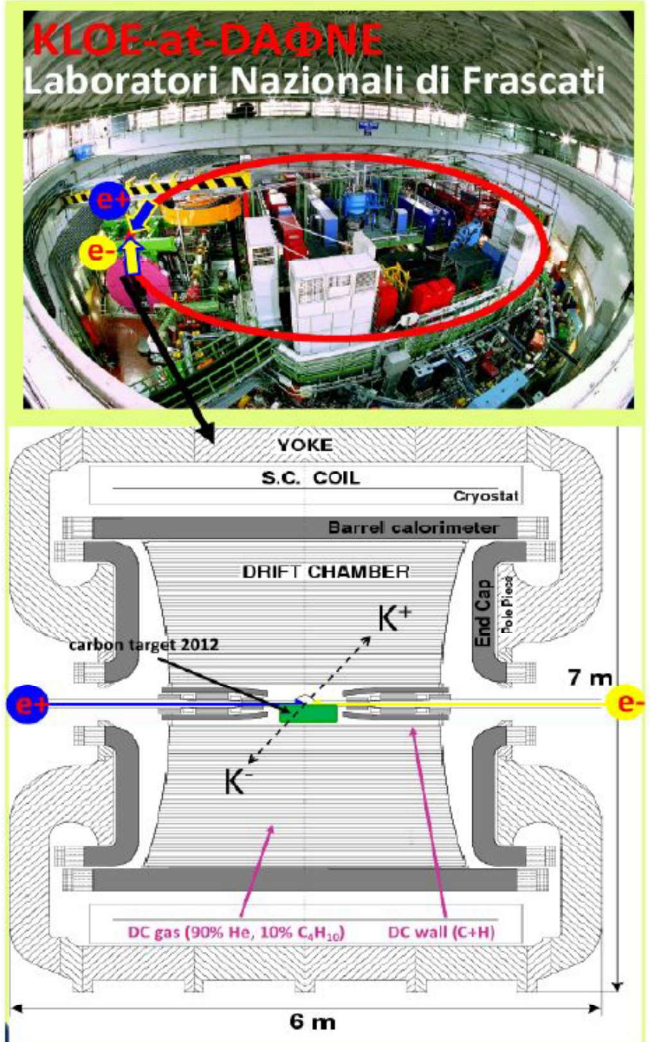
160.9±4.9	<24.4±8.0	NPA 789 (2007), 222
-	-	MPLA 23 (2008), 2520
$_{-8}$(stat.)±12(syst.)	110_{-17}(stat.)±27(syst.)	PTEP (2016), 051D01
±3(stat.)$^{+3}_{-6}$(syst.)	115±7(stat.)$^{+10}_{-20}$(syst.)	PLB 789 (2019), 612

FINUDA, E549, E15, AMADEUS: K⁻ induced reactions
DISTO, HADES: p-p collisions
OBELIX: anti-p annihilations
E27: π induced reactions
LEPS/SPring-8: photoproduction

AMADEUS @ DAΦNE



DAΦNE

- $\phi \rightarrow K^- K^+$ (49.2%), ≈1000 ϕ/s
- monochromatic **low momentum** Kaons ≈127 Mev/c
- **back to back** K^- K^+ topology
- **small hadronic background** due to the beam

KLOE

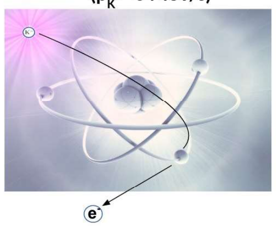
- Cilindrical DC with **4π geometry** & electromagnetic calormeter
- **96% acceptance**
- **high efficiency and resolution** for charged and neutral particles

⬇

- exclusive measurement of the considered

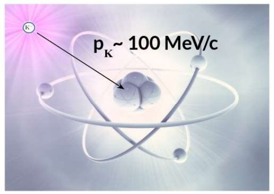
AT-REST

K^- absorbed from atomic orbitals (p_K ~ 0 MeV/c)



IN-FLIGHT

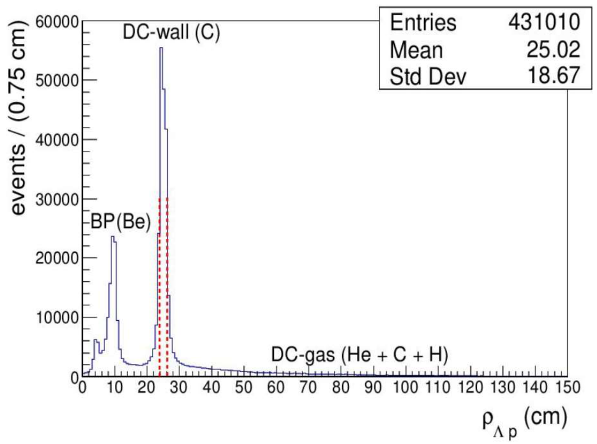
(p_K ~ 100 MeV/c)



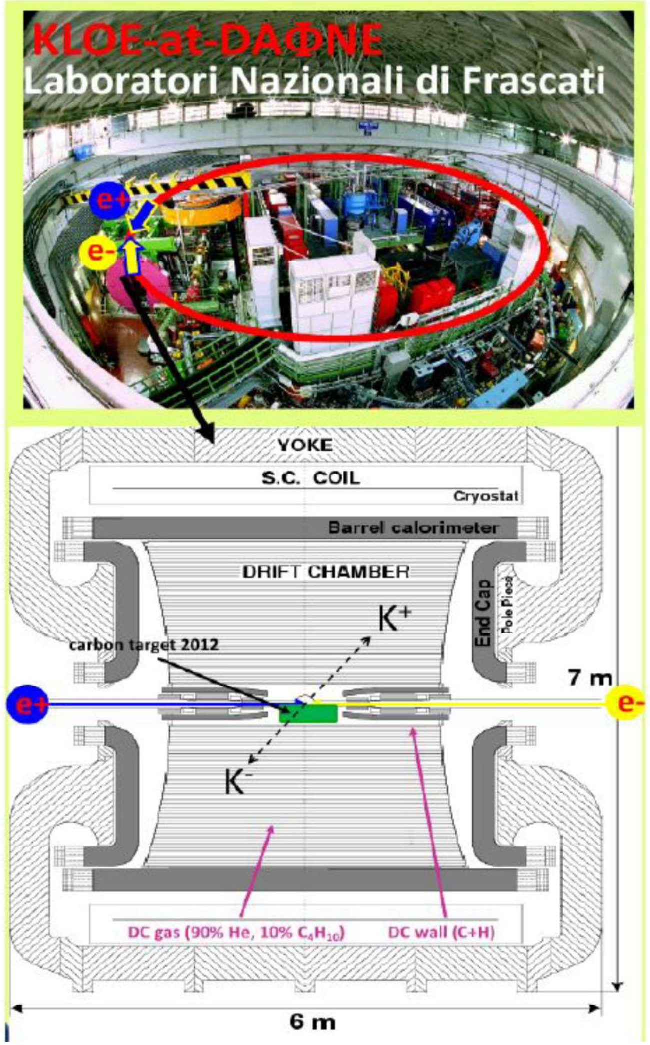
AMADEUS: KLOE 2004-2005 dataset analysis ($\mathcal{L}$ = 1.74 pb-1)

Possibility to use **KLOE materials** as an **active target**

- DC wall (750 μm C foil , 150 μm Al foil);
- DC gas (90% He, 10% C_4H_{10}).



AMADEUS @ DAΦNE



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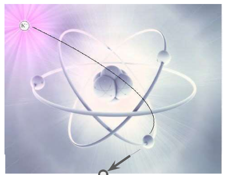
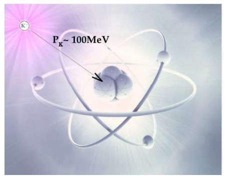
K^- absorption on light nuclei AT REST & IN FLIGHT



K- absorbed from atomic orbit



AMADEUS: KLOE 2004-2005 dataset analysis (ℒ = 1.74 pb-1)

AMADEUS scientific case

- nature of Λ(1405) and K^-N amplitude below threshold

- low-energy charged K cross section (for p=100MeV)

⇩

Yπ correlation studies (Λπ, Σπ final states)

- K^- multiN absorption

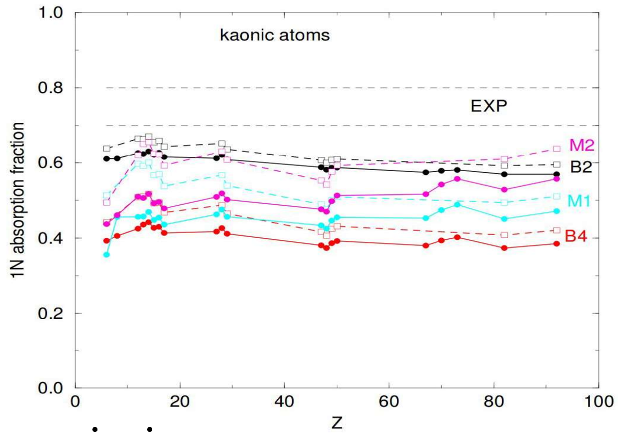
- kaonic nuclear clusters

⇩

YN correlation studies (Λp, $\Sigma^0 p$, Λt final states)

K^- multi-nucleon absorptions

In K^--nuclei optical potential a K^- multi-nucleon absorption term is necessary to fit the kaonic atoms data:



$$V_{K^-}(\rho) = V_{K^-}^{(1)}(\rho) + V_{K^-}^{(2)}(\rho)$$ → **multi-nucleon term**

[E. Friedman, A. Gal, Nucl. Phys. A 959, 66 (2017)]
[Hrtánková, J. & Mareš, J. Phys. Rev. C96, 015205 (2017)]

single nucleon term from chiral models

- **Single nucleon absorption (1NA):** K^- "N" → Y π → pionic processes
- **Two nucleon absorption (2NA):** K^- "NN" → Y N
- **Three nucleon absorption (3NA):** K^- "NNN" → Y (NN) → non-pionic processes
- **Four nucleon absorption (4NA):** K^- "NNNN" → Y (NNN)

bound nucleons = "N", "NN", "NNN", "NNNN"
bound or unbound nucleons = (NN), (NNN)
Y = Λ, Σ

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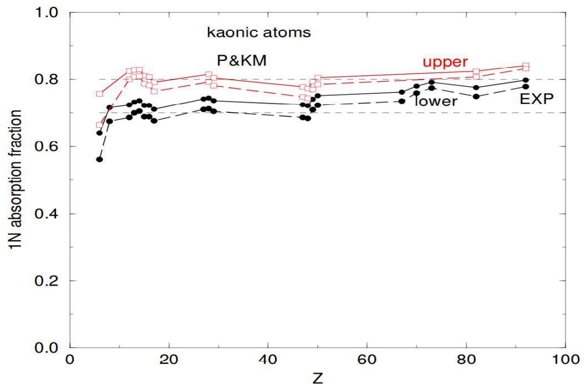

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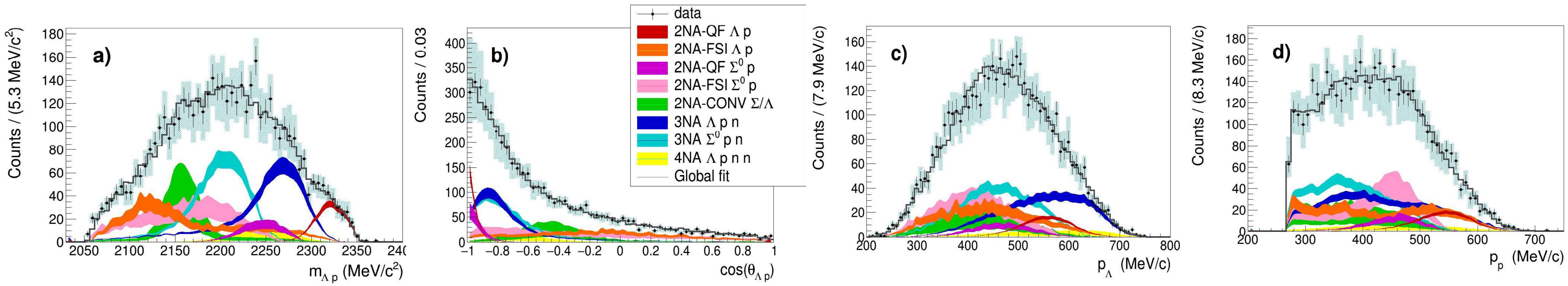
Λp analysis: K^- multi-nucleon absorption BRs and σ



R. Del Grande et al., Eur.Phys.J. C79 (2019) no.3, 190

Simultaneous fit of:

- Λp invariant mass;
- angular correlation;
- proton momentum;
- Λ momentum.

Process	Branching Ratio (%)	σ (mb)	@	p_K (MeV/c)
2NA-QF Λp	0.25 ± 0.02 (stat.) $^{+0.01}_{-0.02}$ (syst.)	2.8 ± 0.3 (stat.) $^{+0.1}_{-0.2}$ (syst.)	@	128 ± 29
2NA-FSI Λp	6.2 ± 1.4 (stat.) $^{+0.5}_{-0.6}$ (syst.)	69 ± 15 (stat.) ± 6 (syst.)	@	128 ± 29
2NA-QF Σ^0p	0.35 ± 0.09 (stat.) $^{+0.13}_{-0.06}$ (syst.)	3.9 ± 1.0 (stat.) $^{+1.4}_{-0.7}$ (syst.)	@	128 ± 29
2NA-FSI Σ^0p	7.2 ± 2.2 (stat.) $^{+4.2}_{-5.4}$ (syst.)	80 ± 25 (stat.) $^{+46}_{-60}$ (syst.)	@	128 ± 29
2NA-CONV Σ/Λ	2.1 ± 1.2 (stat.) $^{+0.9}_{-0.5}$ (syst.)	-		
3NA Λpn	1.4 ± 0.2 (stat.) $^{+0.1}_{-0.2}$ (syst.)	15 ± 2 (stat.) ± 2 (syst.)	@	117 ± 23
3NA Σ^0pn	3.7 ± 0.4 (stat.) $^{+0.2}_{-0.4}$ (syst.)	41 ± 4 (stat.) $^{+2}_{-5}$ (syst.)	@	117 ± 23
4NA Λpnn	0.13 ± 0.09 (stat.) $^{+0.08}_{-0.07}$ (syst.)	-		
Global $\Lambda(\Sigma^0)$p	21 ± 3 (stat.) $^{+5}_{-6}$ (syst.)	-		

cross sections and BRs

Λp analysis: K⁻ multi-nucleon absorption BRs and σ

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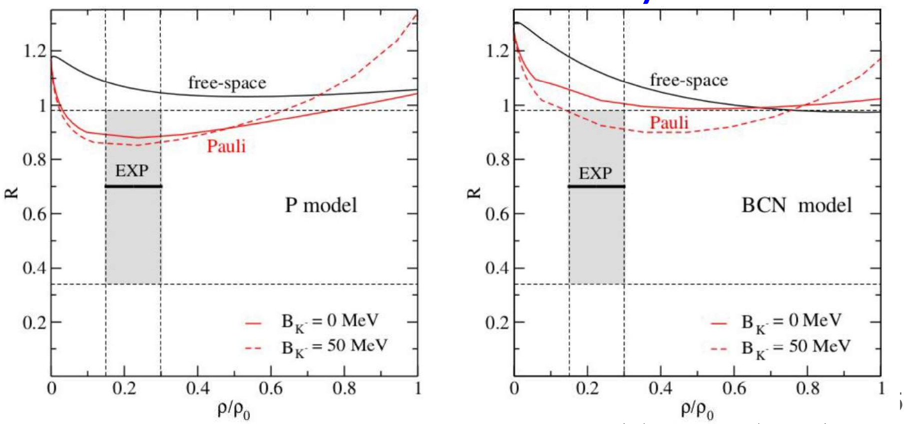
R. Del Grande et al., Eur. Phys. J. C79 (2019) no.3, 190

The ratio between the branching ratios of the 2NA-QF in the Λp channel and in the Σ^0p is measured to be:

$$\mathcal{R} = \frac{BR(K^- pp \to \Lambda p)}{BR(K^- pp \to \Sigma^0 p)} = 0.7 \pm 0.2(stat.)^{+0.2}_{-0.3}(syst.)$$

and the ratio between the corresponding phase spaces is $\mathcal{R}' \simeq 1.22$.

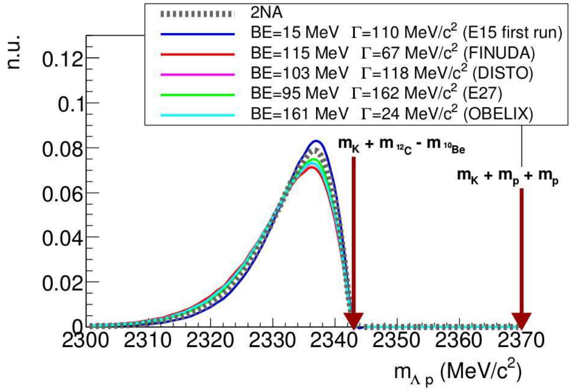
Information on the in-medium dynamics



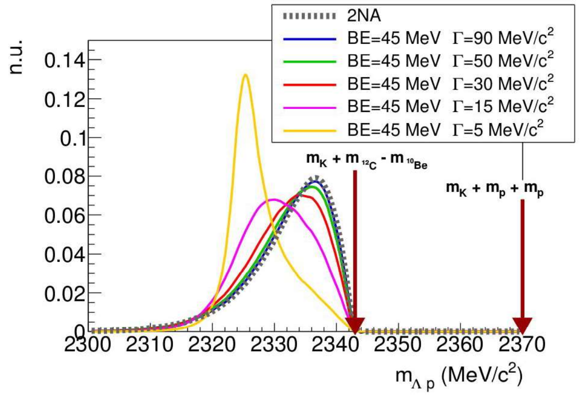
J. Hrtankova and A. Ramos, Phys. Rev. C101 (3) 035204 (2020)

Λp analysis: K^-pp bound state search

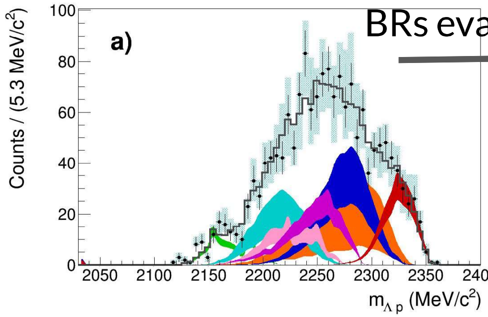
Using BE and Γ from experiments:



Fixing BE and moving Γ:

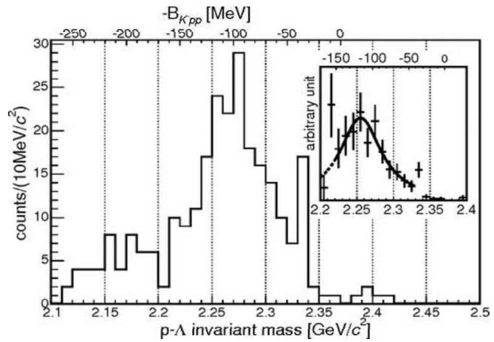


AMADEUS at DAΦNE



BRs evaluation

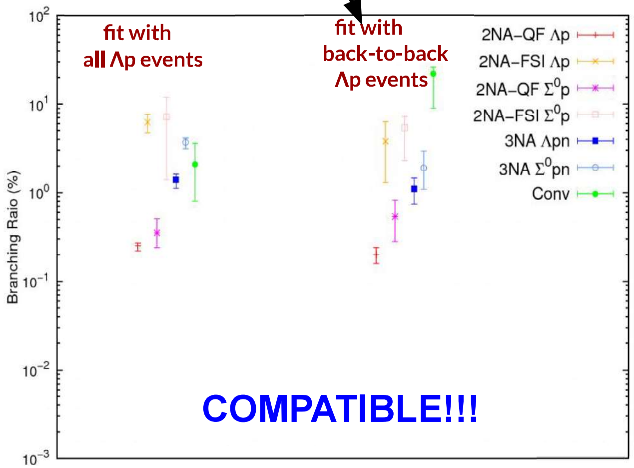
FINUDA at DAΦNE



[M. Agnello et al., Phys. Rev. Lett. 94, 212303 (2005)]

R. Del Grande et al., Eur.Phys.J. C79 (2019) no.3, 190

Process	Branching Ratio (%)
2NA-QF Λp	$0.20 \pm 0.04(\text{stat.}) \pm 0.02(\text{syst.})$
2NA-FSI Λp	$3.8 \pm 2.3(\text{stat.}) \pm 1.1(\text{syst.})$
2NA-QF Σ^0p	$0.54 \pm 0.20(\text{stat.})\ ^{+0.20}_{-0.16}(\text{syst.})$
2NA-FSI Σ^0p	$5.4 \pm 1.5(\text{stat.})\ ^{+1.0}_{-2.7}(\text{syst.})$
2NA-CONV Σ/Λ	$22 \pm 4(\text{stat.})\ ^{+1}_{-12}(\text{syst.})$
3NA Λpn	$1.1 \pm 0.3(\text{stat.}) \pm 0.2(\text{syst.})$
3NA Σ^0pn	$1.9 \pm 0.7(\text{stat.})\ ^{+0.8}_{-0.4}(\text{syst.})$



K^-pp bound state contribution **completely overlaps** with the K^-2NA

Λt analysis: Cross section and BR for 4NA in $K^{-}\,{}^{4}He \to \Lambda t$ process

Previous data:

- in ^{4}**He:** bubble chamber experiment

/M. Roosen, J. H. Wickens, Il Nuovo Cimento 66, 101 (1981)/

only **3 events** compatibile with Λt kinematics found

BR$(K^{-}\,{}^{4}He \to \Lambda t)$ **= (3 ± 2) × 10^{-4} /K$_{stop}$** → **global, no 4NA**

- in **solid targets:** ^{6,7}**Li,** ^{9}**Be** (FINUDA)

/Phys. Lett. B, 229 (2008)/

40 events, only **back-to-back data**

Λt emission yield → $10^{-3} - 10^{-4}$ / K^{-}_{stop} → **global, no 4NA**

Λt analysis: Cross section and BR for 4NA in $K^- \, {}^4He \rightarrow \Lambda t$ process

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BR($K^- \, {}^4He \rightarrow \Lambda t$) = $(3 \pm 2) \times 10^{-4} / K_{stop}$ → **global, no 4NA**

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/Phys. Lett. B, 229 (2008)/

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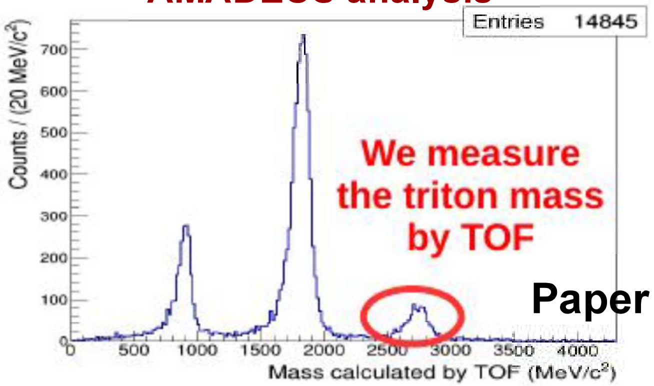
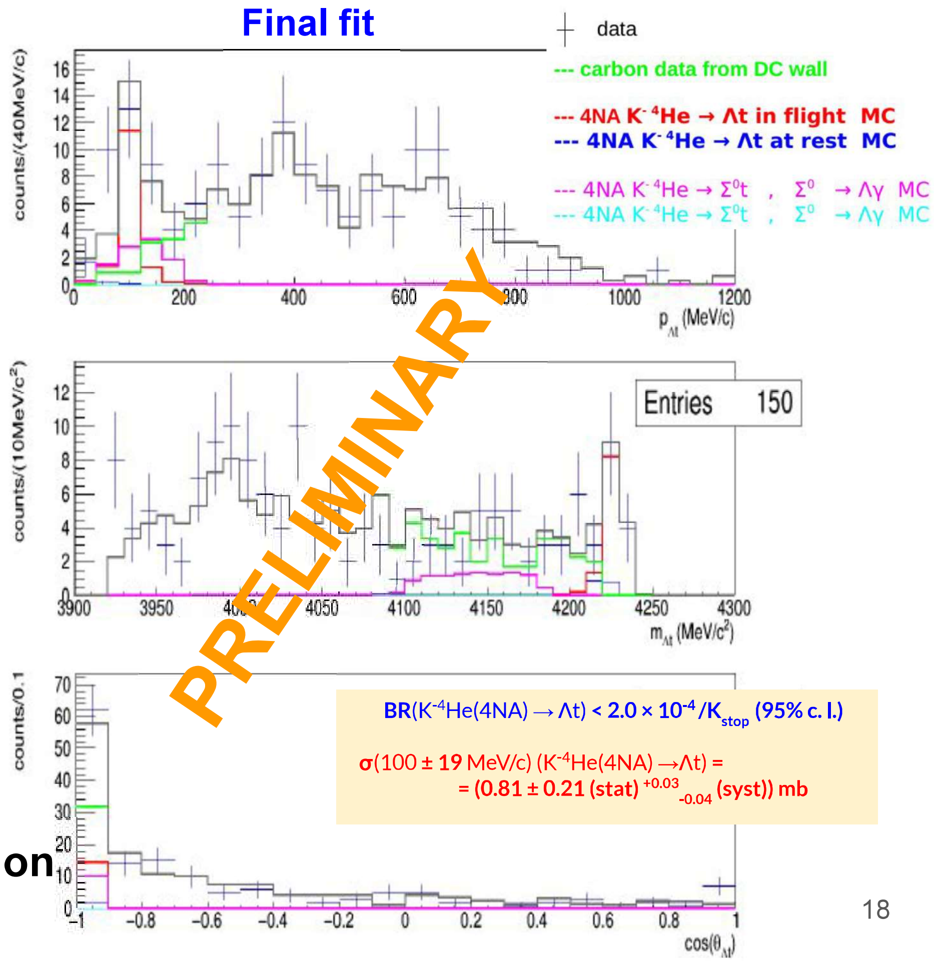
AMADEUS analysis



Paper in preparation



Λt analysis: Cross section and BR for 4NA in $K^{-}\,{}^{12}C \rightarrow \Lambda t$ process

Previous data:

- in ^{4}**He:** bubble chamber experiment

/M. Roosen, J. H. Wickens, Il Nuovo Cimento 66, 101 (1981)/

only **3 events** compatibile with Λt kinematics found

BR$(K^{-}\,{}^{4}He \rightarrow \Lambda t)$ **=** $(3 \pm 2) \times 10^{-4} / K^{-}_{stop}$ → **global, no 4NA**

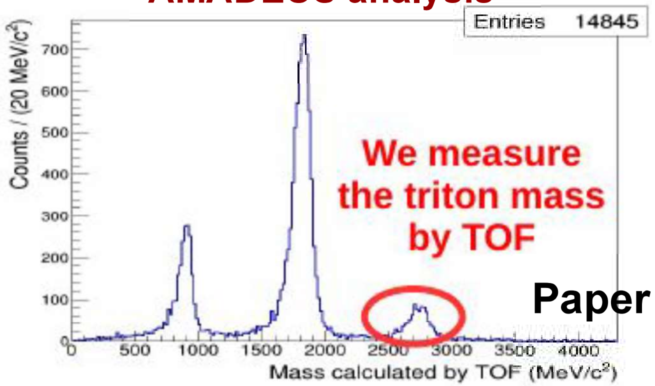
- in **solid targets:** ^{6,7}**Li,** ^{9}**Be** (FINUDA)

/Phys. Lett. B, 229 (2008)/

40 events, only **back-to-back data**

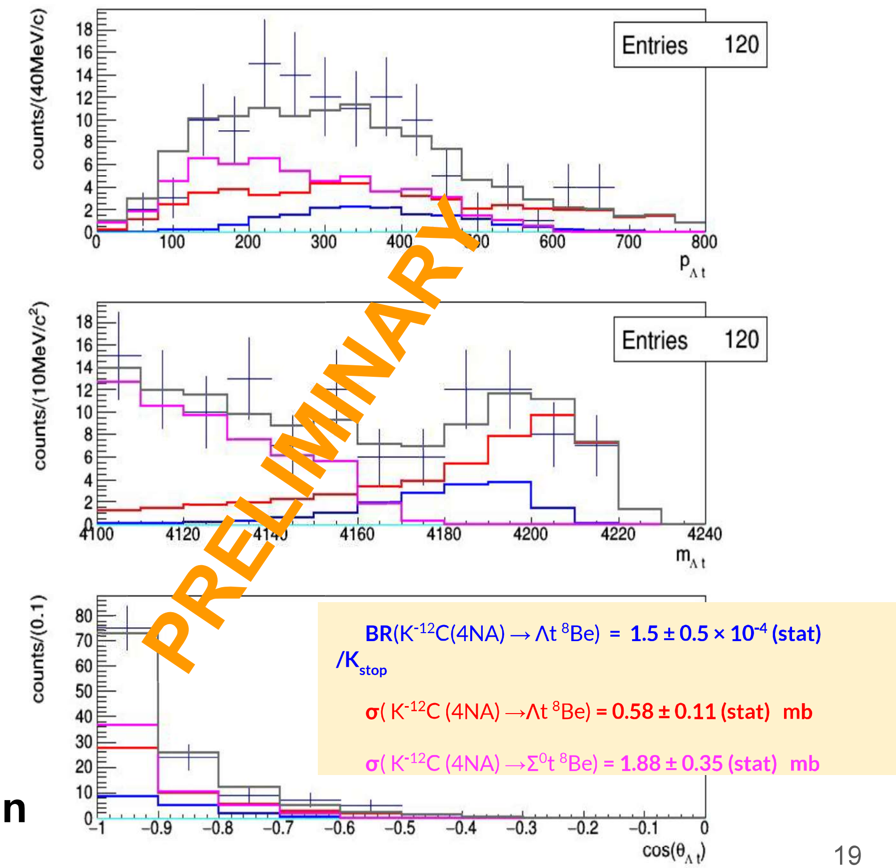
Λt emission yield → $10^{-3} - 10^{-4} / K^{-}_{stop}$ → **global, no 4NA**

AMADEUS analysis



Paper in preparation

Final fit



$\Lambda\pi^-$ analysis: K^-n non-resonant transition amplitude

Λ(1405) case

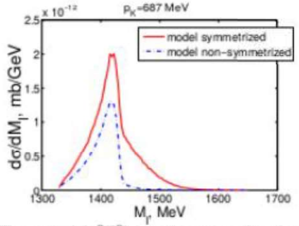


FIG. 4: Theoretical ($\pi^0\Sigma^0$) invariant mass distribution for an initial kaon lab momenta of 687 MeV. The non-symmetrized distribution also contains the factor 1/2 in the cross section.

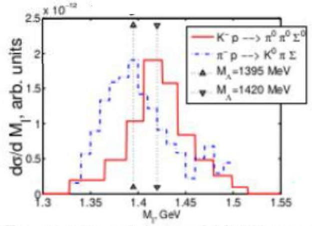
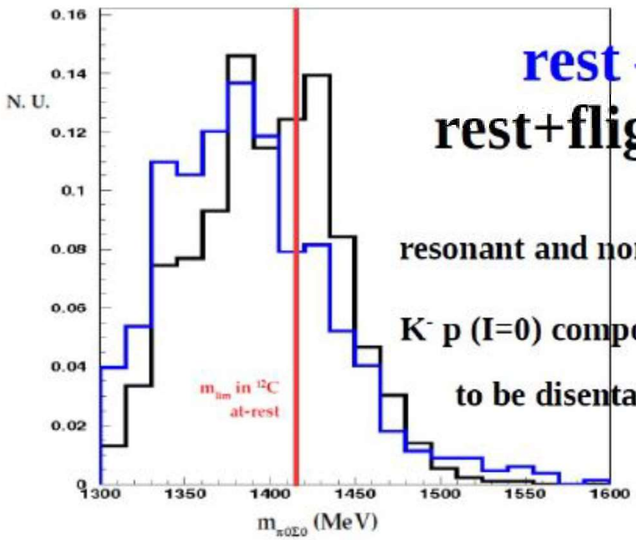


FIG. 5: Two experimental shapes of Λ(1405) resonance. See text for more details.

IN FLIGHT K^- ^{12}C opens window <u>between 1416 MeV and KN threshold</u>



rest –

rest+flight –

resonant and non-resonant

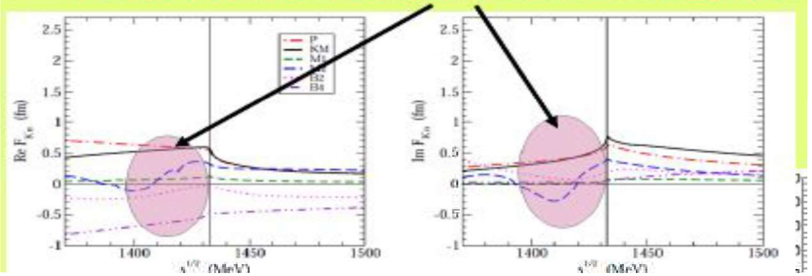
K^-p (I=0) components are

to be disentangled

Goal: how much comes from resonance in **$K^-N \rightarrow Y\pi$**

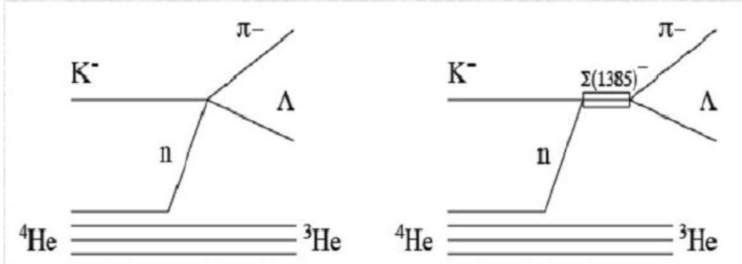
Non-resonant transition amplitude

never measured before below threshold



J. Hrtankova, J. Mares, Phys. Rev. C96, 015205 (2017)
A. Cieply et al, Nycl. Phys. A 954, 17 (2016)

K^- "n" → $\Lambda\pi^-$ direct formation in ^{4}**He**



$|f^{N\text{-}R}_{\Lambda\pi}(I=1)|$ ⇒ $|f^{N\text{-}R}_{\Sigma\pi}(I=0)|$

Λπ⁻ analysis: K⁻n non-resonant transition amplitude

Λ(1405) case

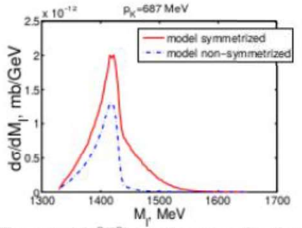


FIG. 4: Theoretical ($\pi^0\Sigma^0$) invariant mass distribution for an initial kaon lab momenta of 687 MeV. The non-symmetrized distribution also contains the factor 1/2 in the cross section.

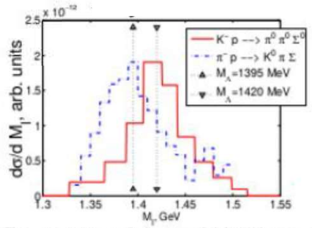
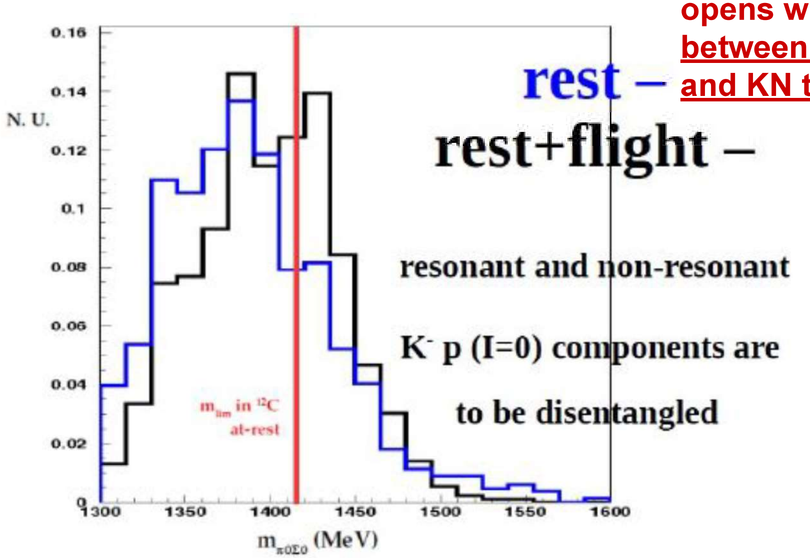


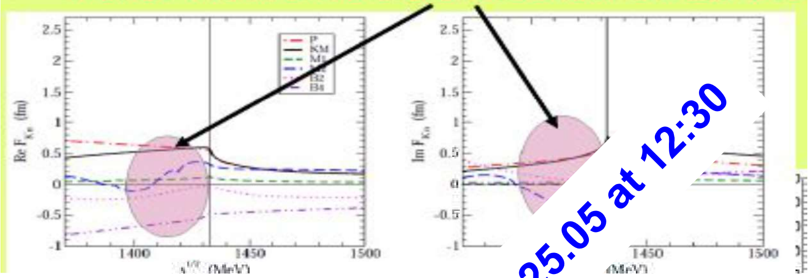
FIG. 5: Two experimental shapes of Λ(1405) resonance. See text for more details.

IN FLIGHT K⁻ ^{12}C opens window between 1416 MeV and KN threshold



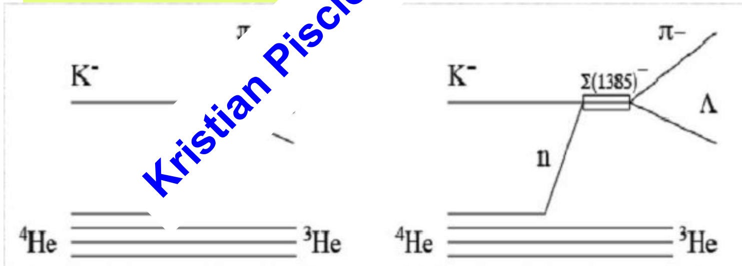
Goal: how much comes from resonance in K⁻N → Yπ

Non-resonant transition amplitude
never measured before below threshold



J. Hrtankova, J. Mares, Phys. R... 015205 (2017)
A. Cieply et al, Nycl. Phys. A ... 2016)

K⁻ "n" → Λπ⁻ ...t formation in ^{4}He



Kristian Piscicchia talk, 25.05 at 12:30

$| f^{N-R}_{\Lambda\pi} (I=1) |$ ⇨ $| f^{N-R}_{\Sigma\pi} (I=0) |$

$\Sigma^0\pi^0/\Lambda^0\pi^0$ analysis

Motivation:

1) The available data for the inelastic $K^- p \rightarrow \Sigma^0 \pi^0$ cross section close to threshold:

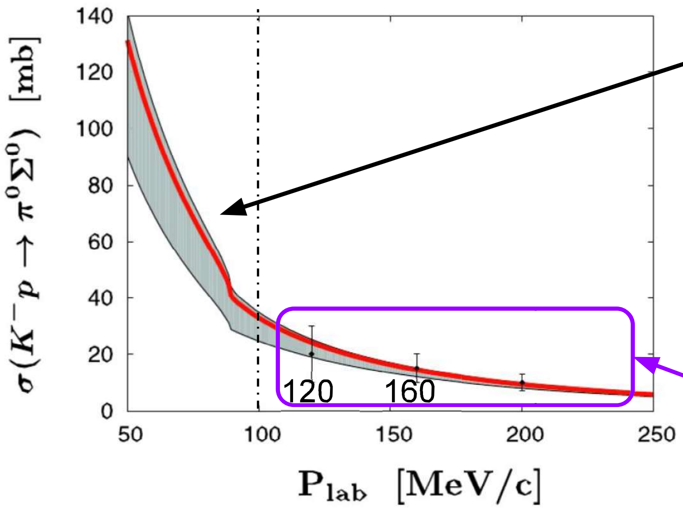
- three points in the p_K=120-200 MeV/c range (bubble chamber experiments),
- uncertainties larger than 30%,
- the $K^- p \rightarrow \Sigma^0 \pi^0$ cross sections are obtained **not directly but** on the basis of the isospin symmetry argument, from the measurement of $K^- p \rightarrow \Lambda\pi^0$ events

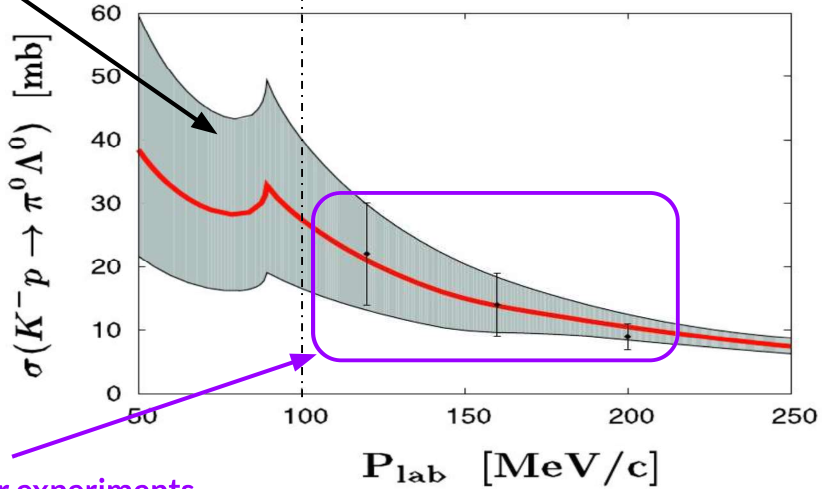
Low momentum K^- scattering cross sections in this Isospin I = 0 channel represent a fundamental input for the non-perturbative low energy QCD models

[1] W. E. Humphrey and R. R. Ross, Phys. Rev. 127 (1962) 1305.
[2] J. K. Kim, Columbia University Report No. NEVIS-149 (1966).

Theoretical calculation:
Y. Ikeda, T. Hyodo, W. Weise, Nucl. Phys. A 881 (2012) 98.

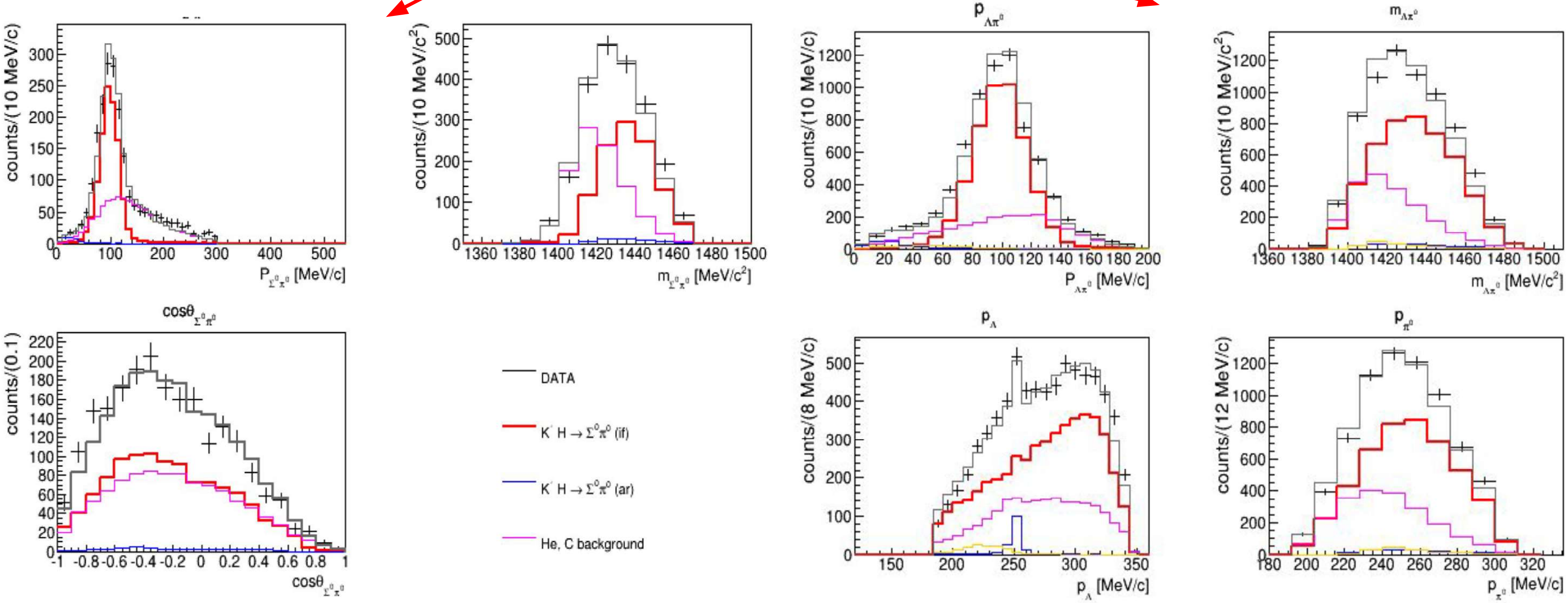
no experimental data





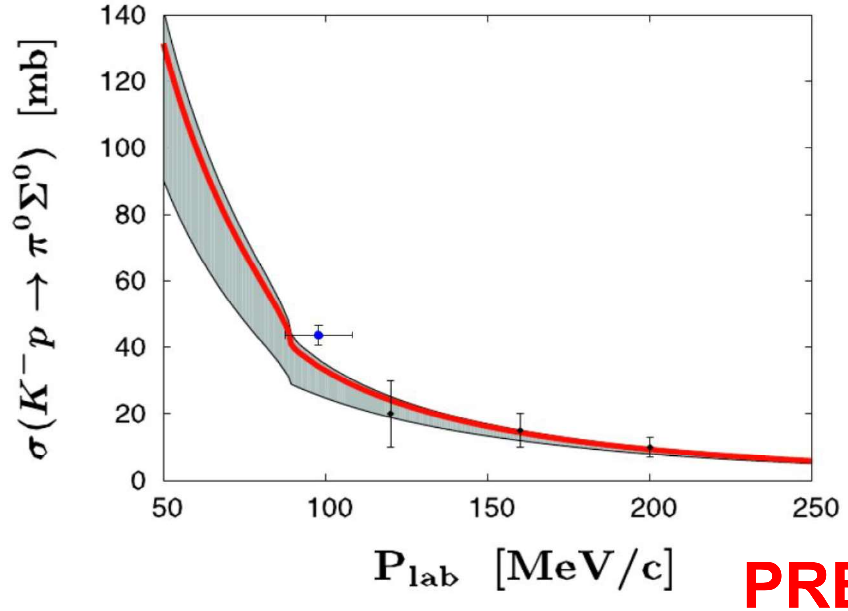
bubble chamber experiments

$\Sigma^0\pi^0/\Lambda^0\pi^0$ analysis

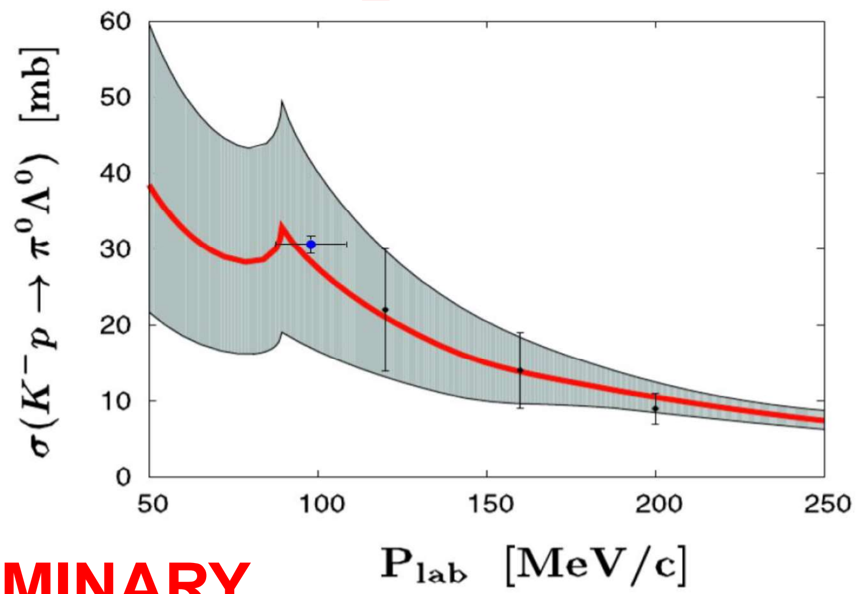


PRELIMINARY

$\Sigma^0\pi^0/\Lambda^0\pi^0$ analysis



PRELIMINARY



$$\sigma(K^-p \to \Sigma^0\pi^0)(p_K = (98 \pm 10)MeV/c) = 42.8 \pm 1.5(stat.)^{+2.4}_{-2.0}(syst.)\ \text{mb}$$

$$\sigma(K^-p \to \Lambda\pi^0)(p_K = (98 \pm 10)MeV/c) = 31.0 \pm 0.5(stat.)^{+1.2}_{-1.2}(syst.)\ \text{mb}$$

Summary

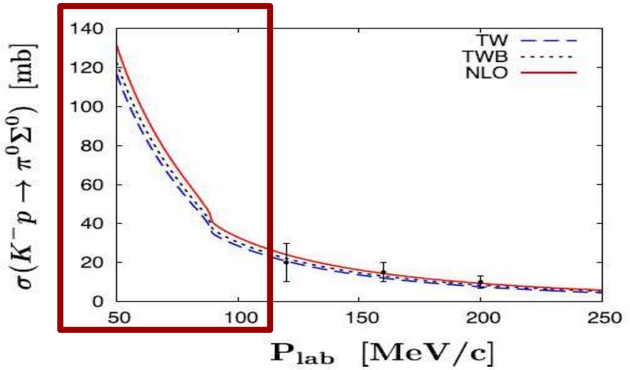
K^-n amplitude below threshold

Kristian Piscicchia talk, 25.05 at 12:30

Λ p channel: 2NA, 3NA and 4NA BRs and σ

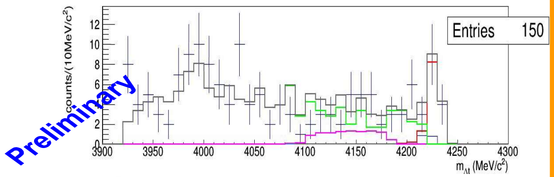
Process	Branching Ratio (%)	σ (mb)	@	p_K (MeV/c)
2NA-QF Λp	0.25 ± 0.02 (stat.) $^{+0.01}_{-0.02}$(syst.)	2.8 ± 0.3 (stat.) $^{+0.1}_{-0.2}$ (syst.)	@	128 ± 29
2NA-FSI Λp	6.2 ± 1.4(stat.) $^{+0.5}_{-0.6}$(syst.)	69 ± 15 (stat.) $\pm$ 6 (syst.)	@	128 ± 29
2NA-QF Σ^0p	0.35 ± 0.09(stat.) $^{+0.13}_{-0.06}$(syst.)	3.9 ± 1.0 (stat.) $^{+1.4}_{-0.7}$ (syst.)	@	128 ± 29
2NA-FSI Σ^0p	7.2 ± 2.2(stat.) $^{+4.2}_{-5.4}$(syst.)	80 ± 25 (stat.) $^{+46}_{-60}$ (syst.)	@	128 ± 29
2NA-CONV Σ/Λ	2.1 ± 1.2(stat.) $^{+0.9}_{-0.5}$(syst.)	-		
3NA Λpn	1.4 ± 0.2(stat.) $^{+0.1}_{-0.2}$(syst.)	15 ± 2 (stat.) $\pm$ 2 (syst.)	@	117 ± 23
3NA Σ^0pn	3.7 ± 0.4(stat.) $^{+0.2}_{-0.4}$(syst.)	41 ± 4 (stat.) $^{+2}_{-5}$ (syst.)	@	117 ± 23
4NA Λpnn	0.13 ± 0.09(stat.) $^{+0.08}_{-0.07}$(syst.)	-		
Global $\Lambda(\Sigma^0)$p	21 ± 3(stat.) $^{+5}_{-6}$(syst.)	-		

$K^-p \rightarrow \Sigma^0\pi^0/\Sigma^0\pi^0$ cross sections

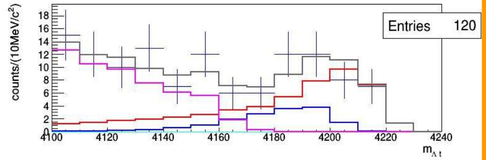


Λ t channel: 4NA BRs and σ

BR(K^{-4}He(4NA) $\rightarrow \Lambda$t) < $2.0 \times 10^{-4}/K_{stop}$ (95% c. l.)
σ(100 ± 19 MeV/c) (K^{-4}He(4NA) $\rightarrow \Lambda$t) =
= (0.81 ± 0.21 (stat) $^{+0.03}_{-0.04}$ (syst)) mb



BR(K^{-12}C(4NA) $\rightarrow \Lambda$t ^{8}Be) = 1.5 ± 0.5 × 10^{-4} (stat) /K_{stop}
σ(K^{-12}C (4NA) $\rightarrow \Lambda$t ^{8}Be) = 0.58 ± 0.11 (stat) mb
σ(K^{-12}C (4NA) $\rightarrow \Sigma^0$t ^{8}Be) = 1.88 ± 0.35 (stat) mb




Thank you for attention!