Studies on the antikaon-nucleon interaction with the KLOE Drift Chamber

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Low energy QCD

- QCD has been nicely tested in the high momentum transfer region but for low momentum transfer, perturbative techniques are no longer applicable (quarks cannot be considered massless and Chiral symmetry is sponaneously broken).

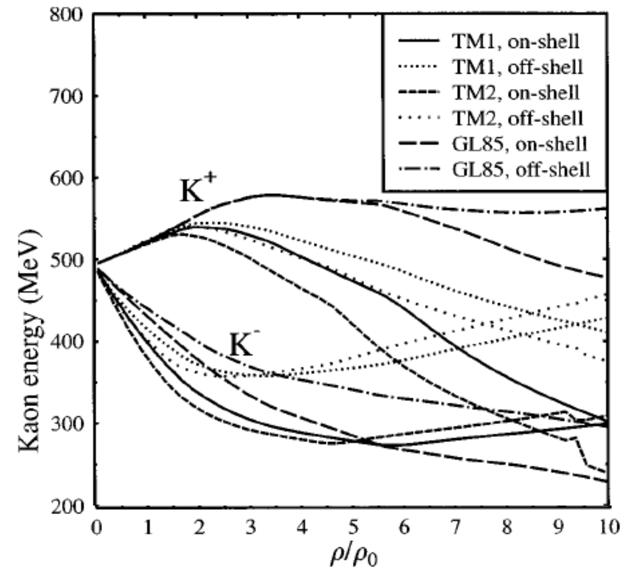
- The most rigorous treatment is in terms of 'chiral perturbation theory' **ChPT**, that works well for low energy ππ and πN interactions, but not for systems with strangeness S=-1 (KN, πΣ, …) since the resonance Λ(1405) lies just below the K^-p threshold, and non-perturbative techiniques, **requiring an indeterminated number of free parameters**, must be used.

- To understand and study the structure of the nucleus, particles with strangeness are excellent, since they can travel deeper inside the nucleus than other particles (no Pauli bocking) and cold dense baryonic matter can be studied.

Kaons in nuclei

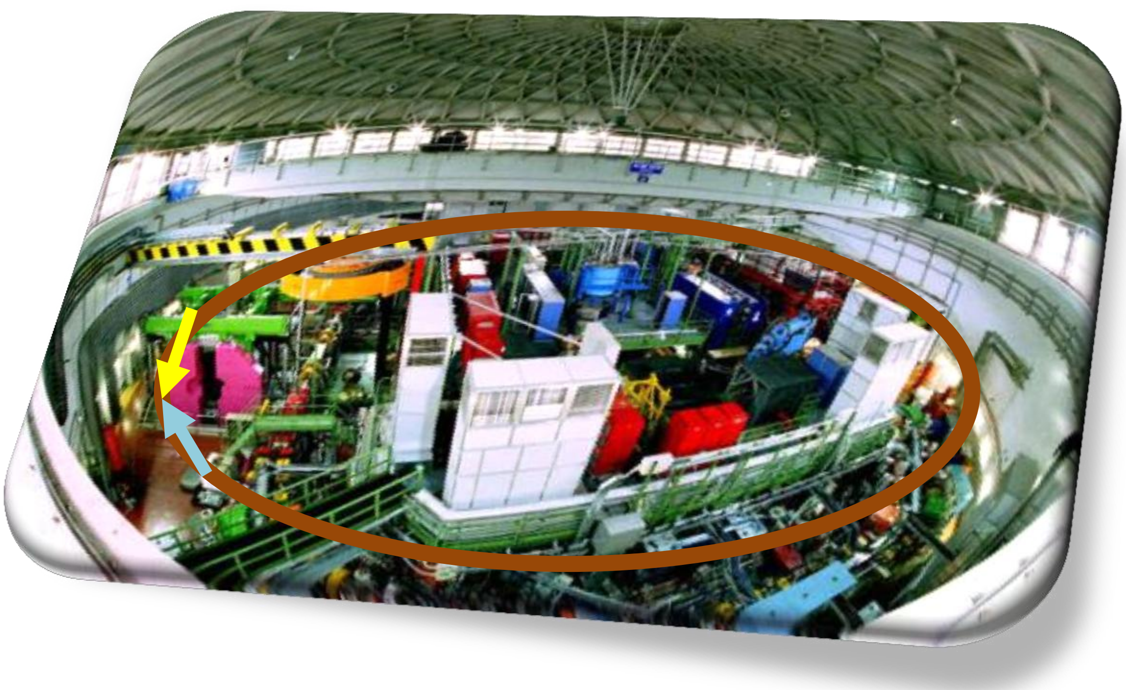
- For kaons, even the scattering amplitudes with protons and nucleons in vacuum are very uncertain
- The theories predict **strong modifications** of the (anti)kaon properties in **dense** hadronic enviroments.
- A **repulsive** KN potential of few MeV for **K+** is expected
- For **K-** could be **attractive** up to 100 MeV depending on the model
- Kaonic atom data and K- yield in heavy ion collisions favour an attractive K- nucleus interaction.

J. Schaffner and I. N. Mishustin
Phys. Rev. **C 53,** 3 (1996)



The DAΦNE accelerator at Frascati

• e+ e- beams at ~ 500 MeV/c
•Φ → K+ K- (49.1%)
•Monochromatic low-energy K- (~127 MeV/c)
•Low hadronic background due to beam characteristics (compared with hadron beam lines, as KEK)



Experimental timeline at DAΦNE

past

KLOE CP violation

FINUDA hypernuclei

present

SIDDHARTA kaonic atoms

KLOE2

future

AMADEUS* kaonic clusters

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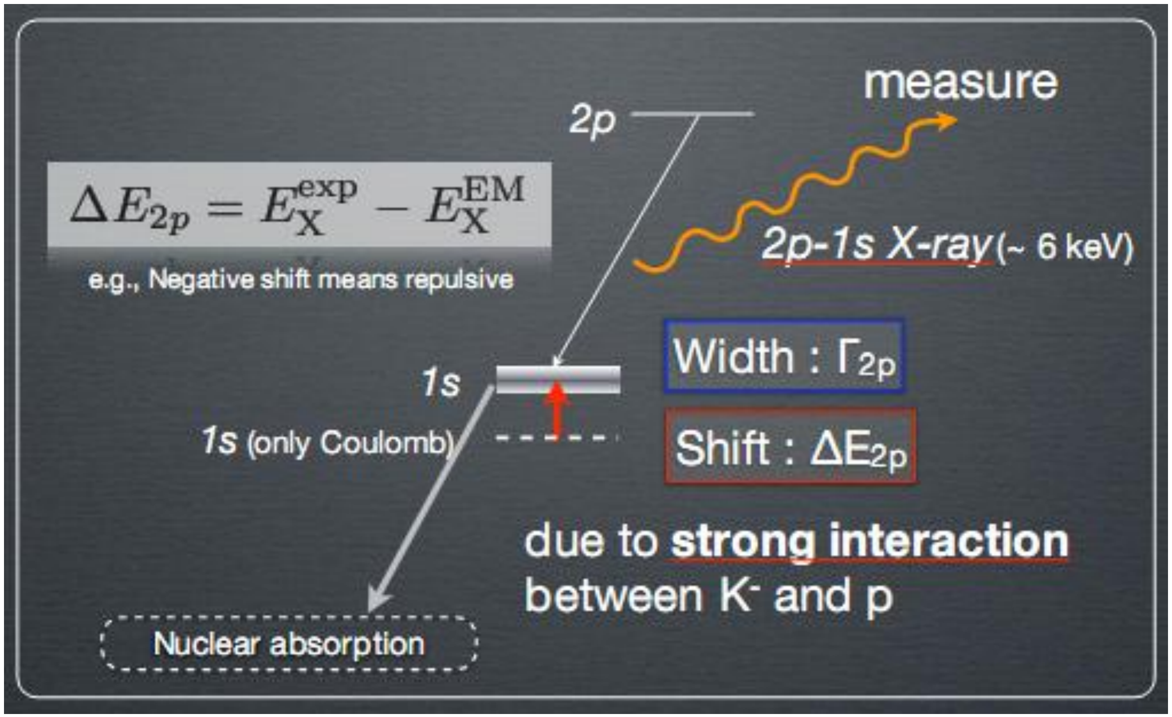
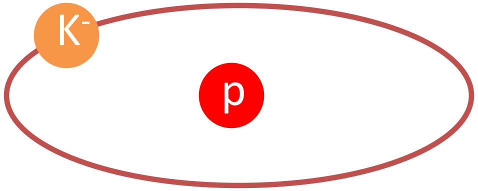
SIDDHARTA experiment: kaonic atoms

Spectroscopy of Kaonic atom x-ray ⇨ Fundamental study of strong interaction between anti-K & nucleus at low energy

The simplest Kaonic atom ⇨ Kaonic Hydrogen





SIDDHARTA experiment: kaonic atoms

Through the precision measurement of the shift and width of the Kα line of kaonic hydrogen and kaonic deuterium, one can determine the isospin dependent KN scattering lengths

Deser-Truman Formula

$$\boxed{\Delta E_1^{s} - \frac{i}{2}\Gamma_1 = -2\alpha^3 \mu_c^2 \, a_{K^-p}}$$

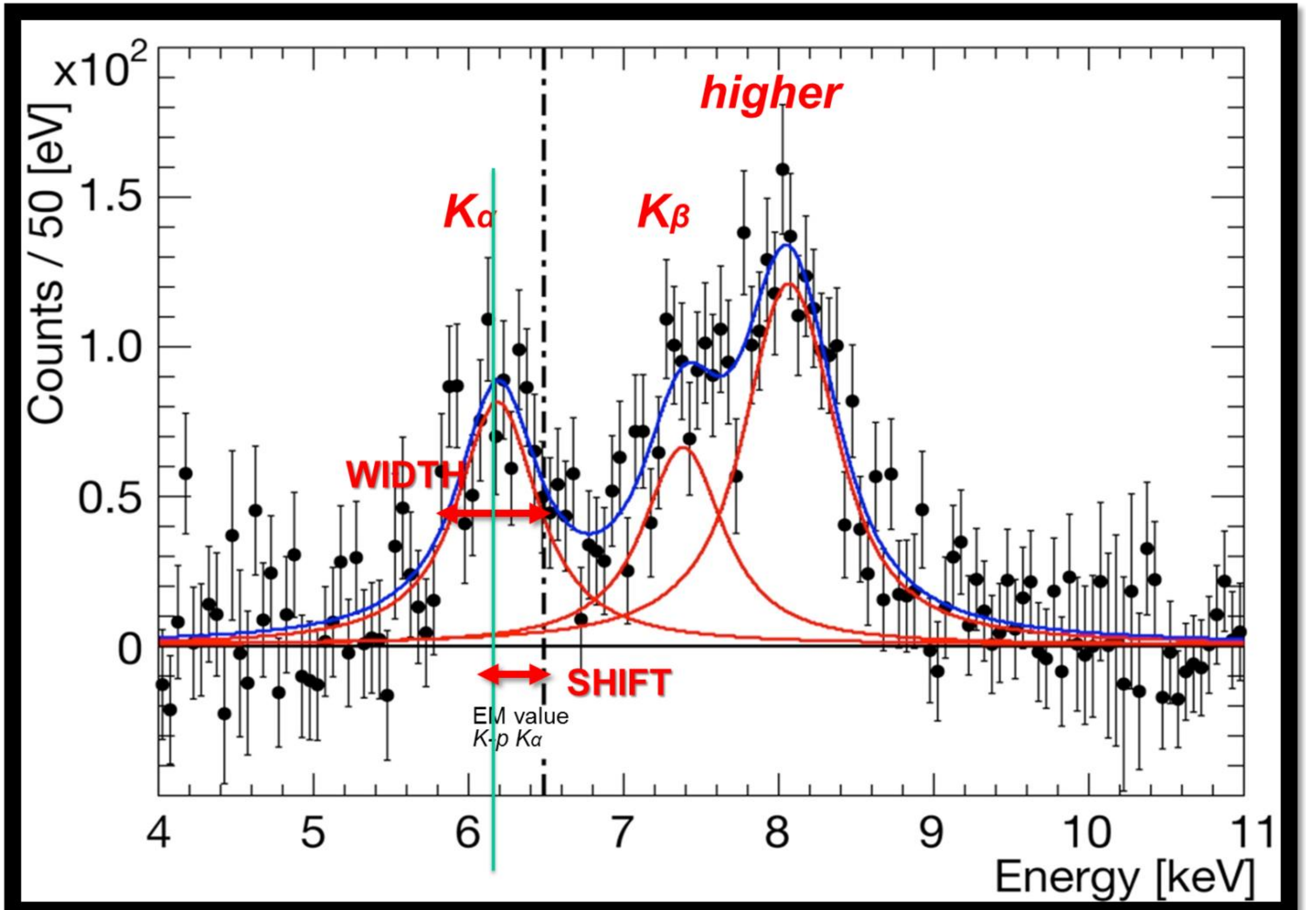
S-wave scattering length "$a_{K\text{-}p}$" expressed with isospin dependent scattering lengths a_0 (I=0), a_1 (I=1)

$$a_{K^-p} = \frac{1}{2}(a_0 + a_1)$$

Kaonic hydrogen
SHIFT & WIDTH

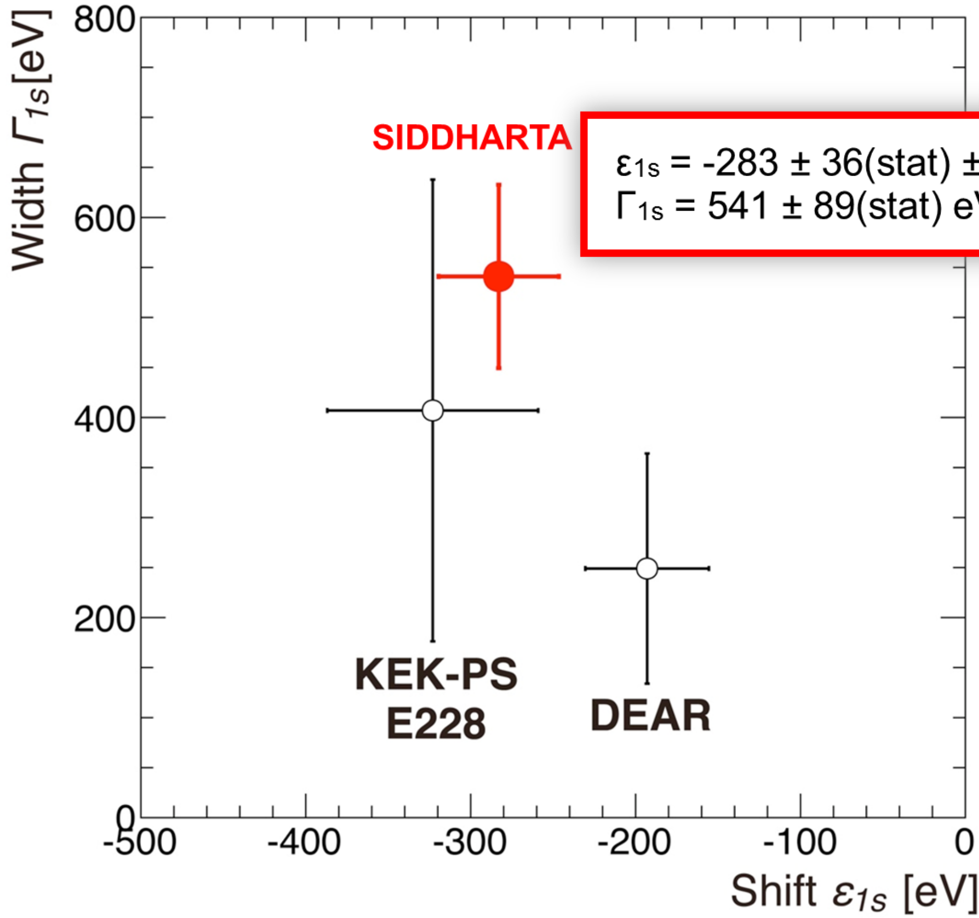
Together with shift & width of K-d atom, a_0 and a_1 can be disentangled by taking into account higher order contributions associated with the K−d three-body interaction

SIDDHARTA experiment: kaonic atoms



SIDDHARTA experiment: kaonic atoms

A New Measurement of Kaonic Hydrogen X rays.
M. Bazzi et al., Phys.Lett. B704 (2011) 113-117



ε_{1s} = -283 ± 36(stat) ± 6(syst) eV
Γ_{1s} = 541 ± 89(stat) eV ± 22(syst)eV

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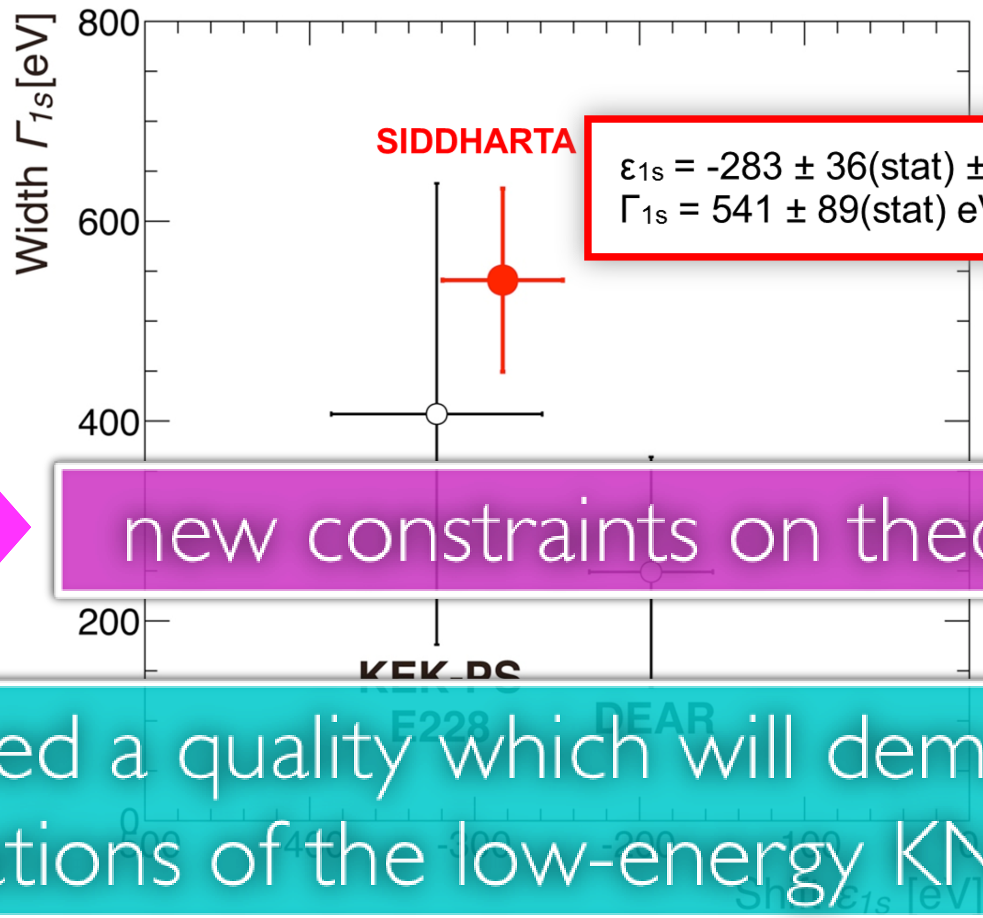

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new constraints on theories

reached a quality which will demand refined calculations of the low-energy KN interaction

SIDDHARTA experiment: kaonic atoms

The first Kd paper of SIDDHARTA

determined the upper limit of Kd K-transitions yields

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Nuclear Physics A 907 (2013) 69–77

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Preliminary study of kaonic deuterium X-rays by the SIDDHARTA experiment at DAΦNE

Upper limit of Kd(2→1) yield < 0.4% (CL 90%)

SIDDHARTA experiment: kaonic atoms

The first Kd paper of SIDDHARTA

determined the upper limit of Kd
K-transitions yi

Coming soon (hopefully…)

SIDDHARTA-2:

a first X-ray measurement of the energy displacement and the width of the kaonic deuterium ground state, a fundamental measurement in low-energy strangeness QCD.

of kaonic deuterium X-rays
IDDHARTA experiment at DAΦNE

Upper limit of Kd(2→1)
yield < 0.4% (CL 90%)

Kaonic nuclei

Kaonic nuclei

Studying the properties of the $\bar{K}N$ potential in the nuclear medium.

How deeply is bound a kaon in a nucleus?
Discussion triggered by the prediction of deeply bound kaonic nuclear states, that require the presence of a strong attractive $\bar{K}N$ interaction in the isospin I=0 channel

Strong attractive I=0 $\bar{K}N$ interaction favors discrete nuclear states **high B** and **small Γ**.

Intense theoretical debate with several different approaches:

- Few-body calculations solving Faddeev equations
- Variational calculations with phenomenological KN potential
- KN effective interactions based on Chiral SU(3) dynamics

For **K^-pp** system, predicted values both for **B** and **Γ** expand over the range **from 0 to 200 MeV**

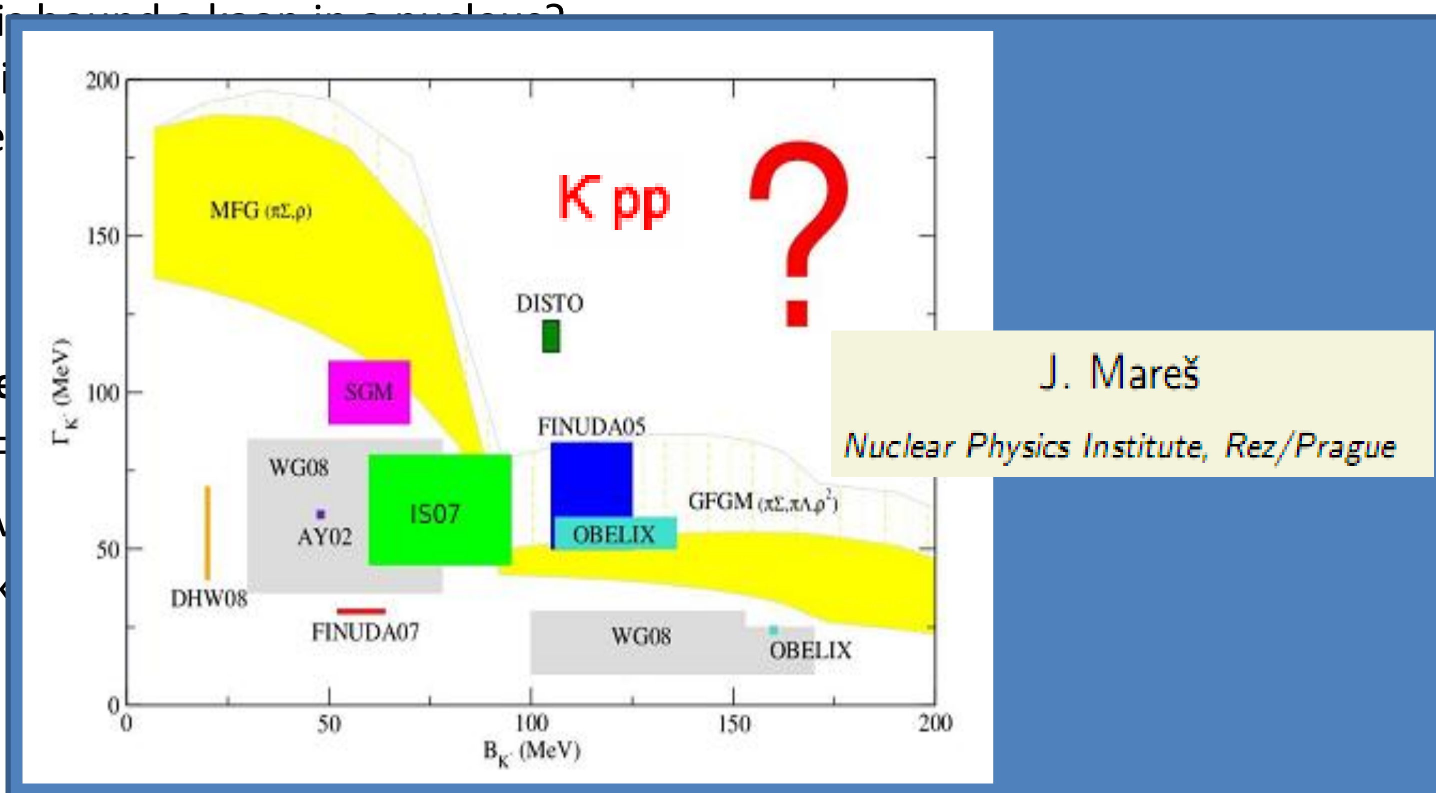
Kaonic nuclei

Studying the properties of the $\overline{K}N$ potential in the nuclear medium.

How deeply i
Discussion tri ire
the presence

Intense

- F
- V
- K



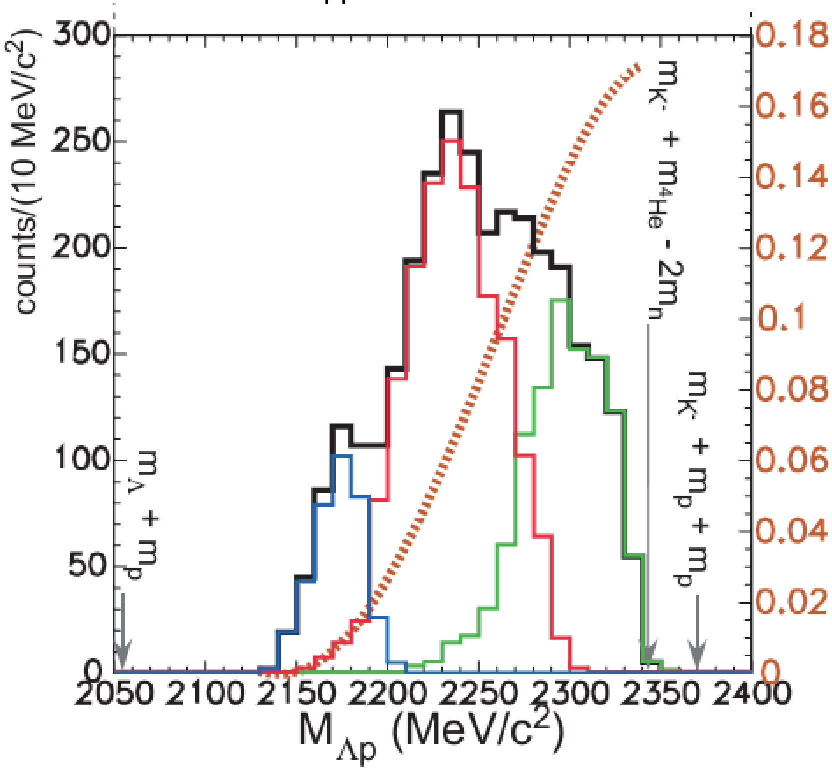
expand over the range **from 0 to 200 MeV**

Λp analysis

-Search in the invariant mass Λp for a signal of a **K^-pp** bound state, trying to measure the with and the binding energy, asuming the formation of a cluster

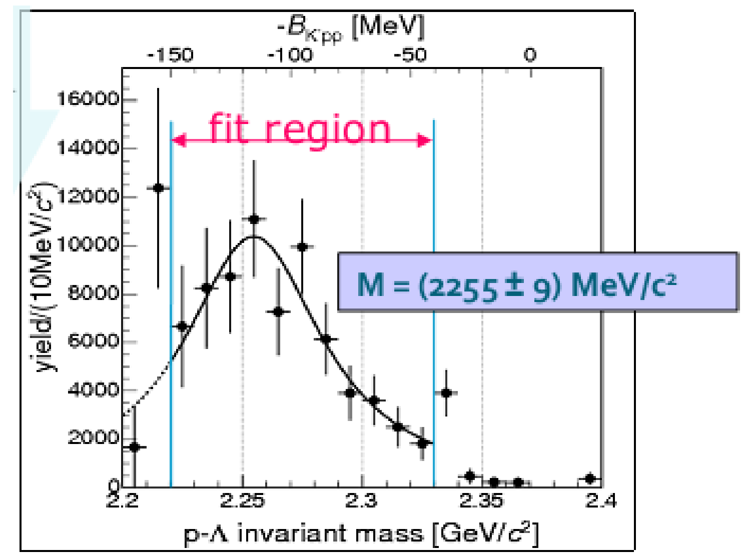
Previous experiments

@KEK K^-_{stopped} + 4He -> Λp X



arXiv:0711.4943v1

FINUDA K^-_{stopped} + X -> Λp X'   X = ^{6}Li, ^{7}Li, ^{9}Be



B = 115$^{+6}_{-5}$ (stat)$^{+3}_{-4}$ (sys) **MeV**
Γ= 67$^{+14}_{-11}$(stat)$^{+2}_{-3}$ (sys) **MeV**

PRL94 (2005) 212303

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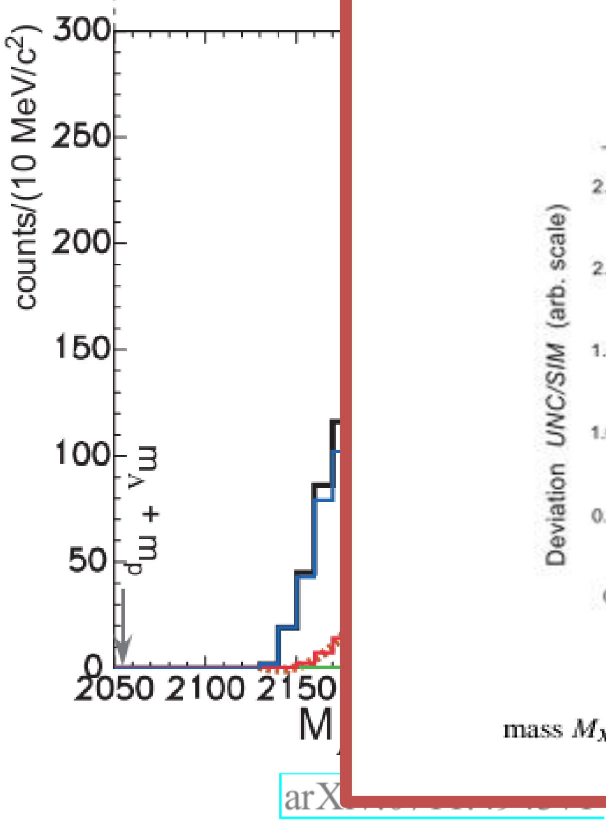
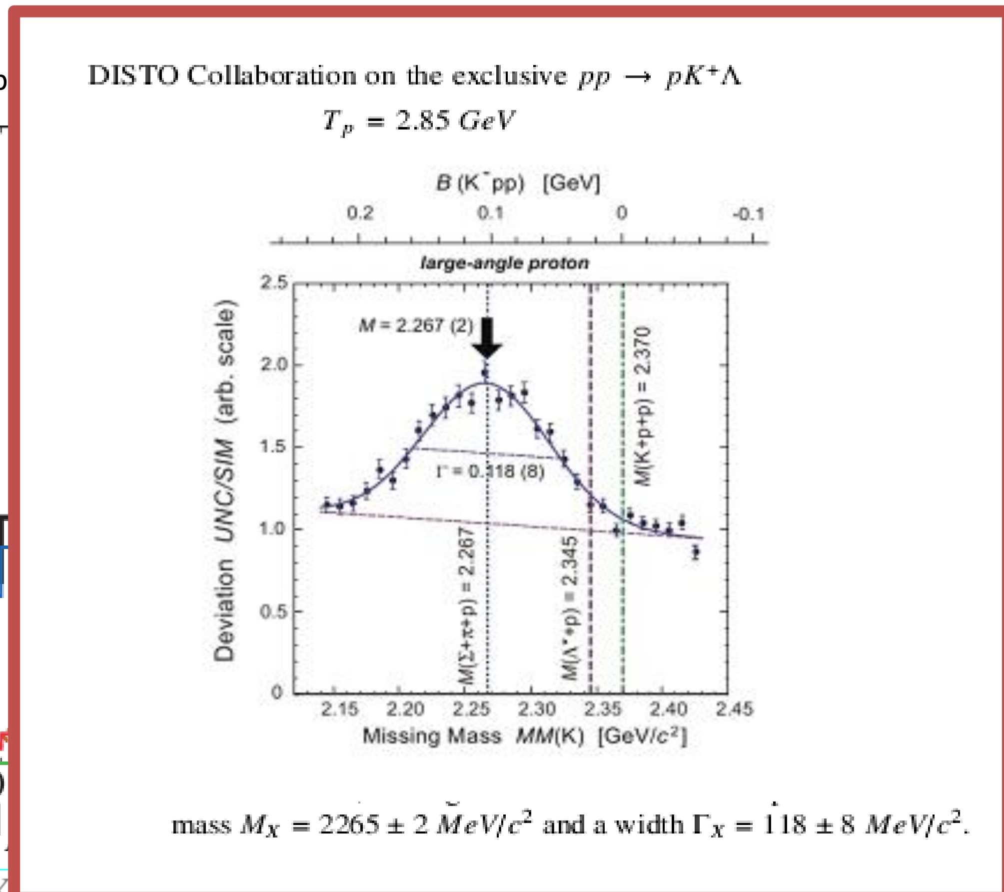
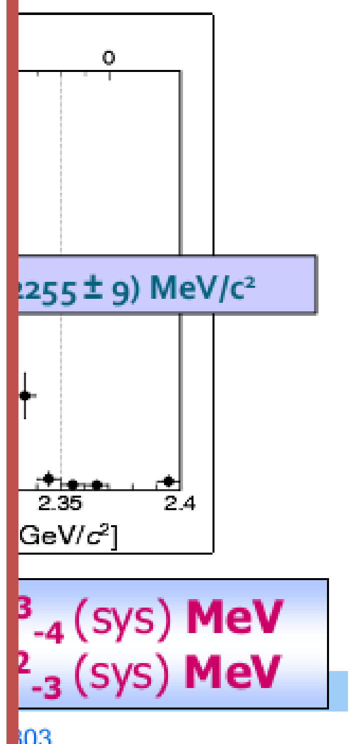
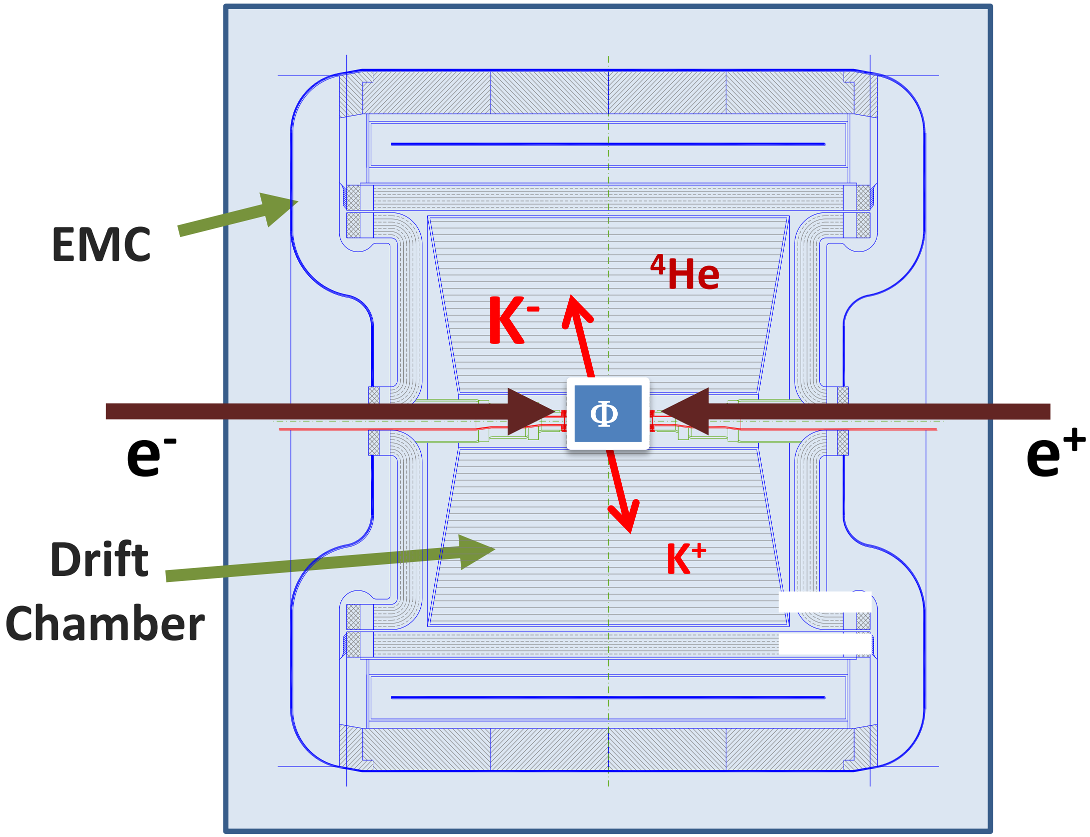






KLOE data analysis by the AMADEUS collaboration

how K+/K- events looks like now in **KLOE:**



•From analysis of KLOE data and Monte Carlo: **0.1 % of K^- should stop in the DC volume, filled mainly by ^{4}He (**90%, 10% *isobutane*)

•In the whole data set: hundreds of events with K- hadronic interactions at rest

Active detector:

\+ Excellence acceptance
\+ Excellence resolution
\+ Charged+neutrals
\- low statistics
\- interacting nuclei difficult to identify

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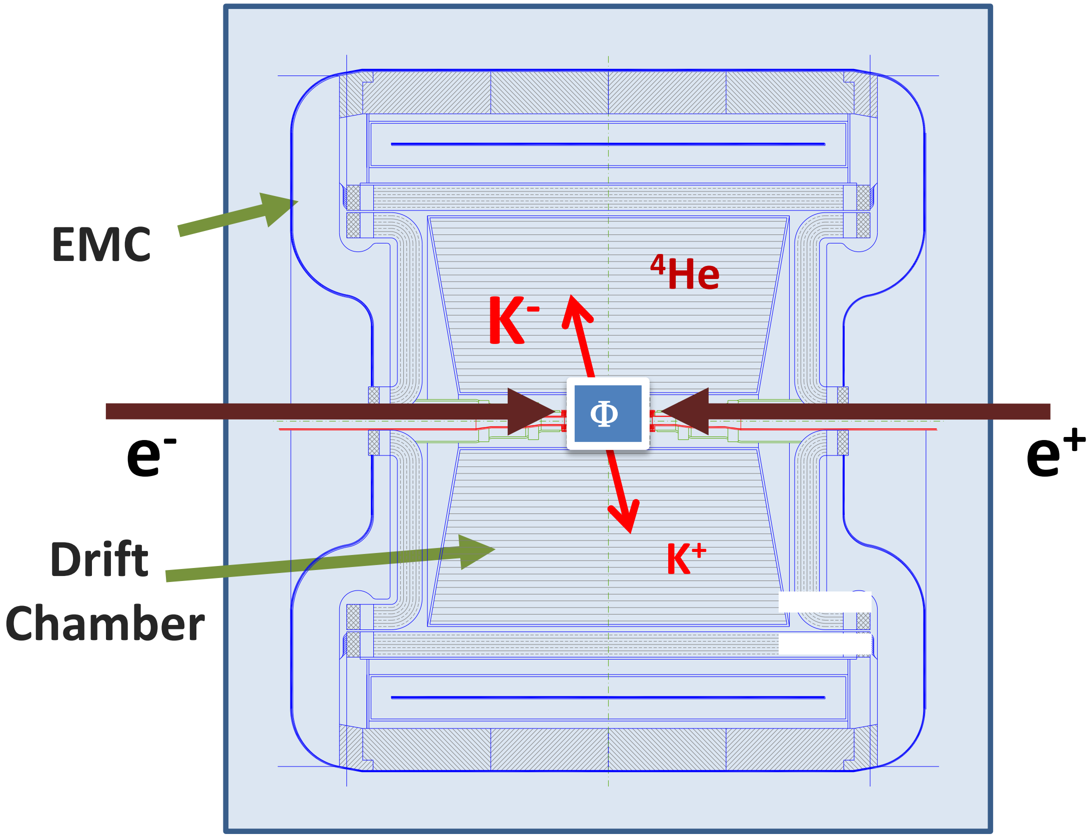

The implementation of the **AMADEUS** setup will modify the events by the introduction of a **target** around the beam pipe, inner to the DC

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Analysis status

- Analyses of the **2002-2005 KLOE data**: Stopped K^- absorption in light nuclei **(^{9}Be, ^{12}C, ^{4}He)**

  - **Λp** from 1NA or 2NA (single or multi-nucleon absorption)
  - **Λd** and **Λt** channels
  - Λ(1405) -> **$\Sigma^0\pi^0$**
  - Λ(1405) -> **$\Sigma^+\pi^-$**
  - Σ(1385) -> Λ **π^-**
  - Σ(1385) -> Λ **π^0**
  - ΣN/ΛN internal conversion rates

- Dedicated **2012** run with pure **Carbon target** inside KLOE

- R&D for more refined setup

- Future possible scenario

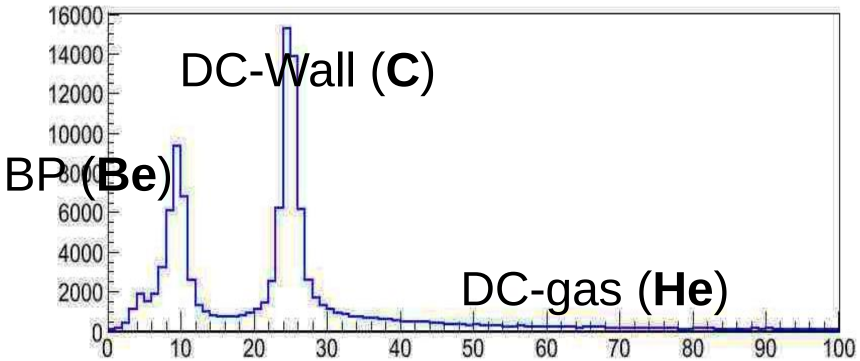
KLOE data on K- nuclear absorption

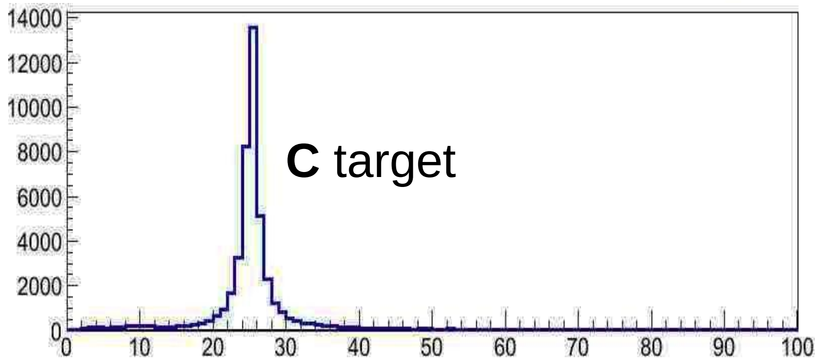
Use of two different data samples:

- KLOE data from 2004**/2005** (2.2 fb^{-1} total, 1.5fb^{-1} analyzed)

- Dedicated run in november/december **2012** with a **Carbon target** of 4/6 mm of thickness (~90 pb^{-1}; analyzed 37 pb^{-1}, x1.5 statistics)

Position of the K^- hadronic interaction inside KLOE:





Performance of the KLOE detector

Performance of the KLOE detector

- Resolution study with MC simulation:

p_Λ	$0.49 \pm 0.01 \ MeV/c$
p_p	$2.63 \pm 0.07 \ MeV/c$
$M_{\Lambda p}$	$1.10 \pm 0.03 \ MeV/c^2$
r_{vertex}	$0.12 \pm 0.01 \ cm$

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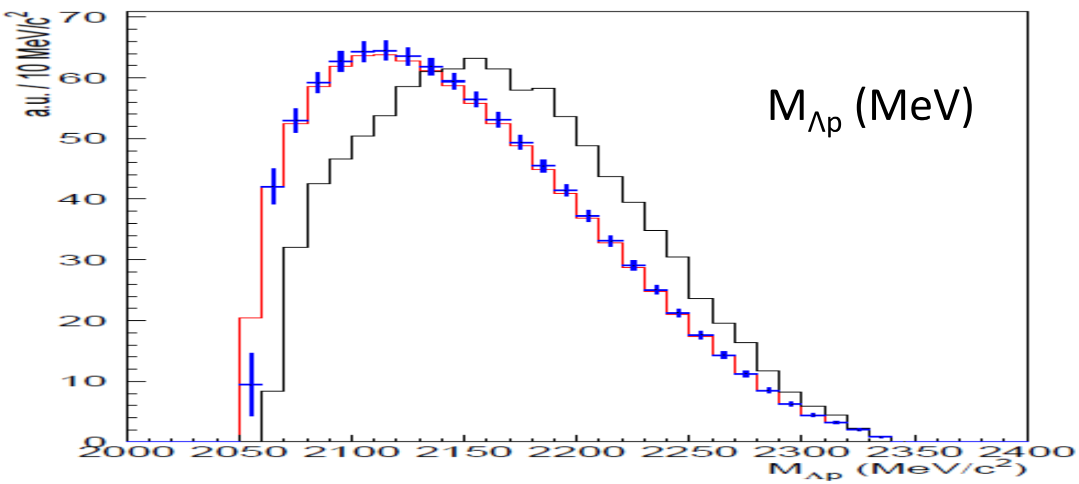
- **Acceptance** study with phase space **$K^- + {}^4He \to \Lambda\ p\ n\ n$** MC simulation

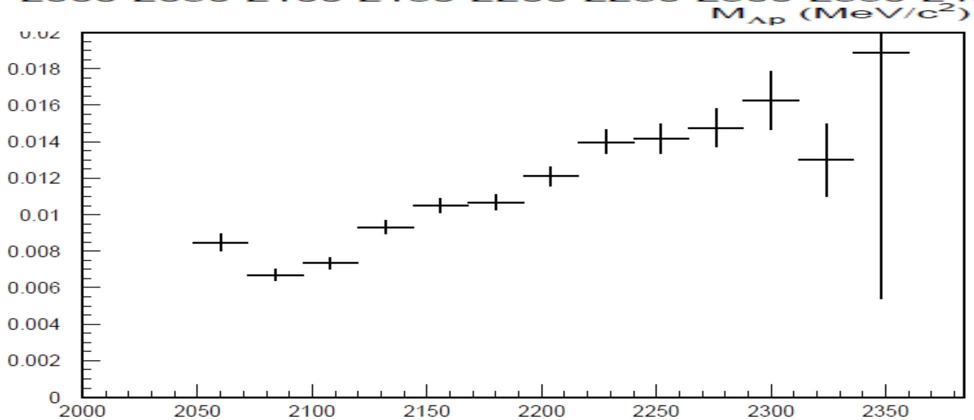


Projection of acceptance function depending on (P_Λ,P_p,Minv Λp) on the Invariant mass plane

True phase space MC

Reconstructed MC

Corrected MC with acc. Corr.



Normalization 1:1
(no efficiency evaluation)

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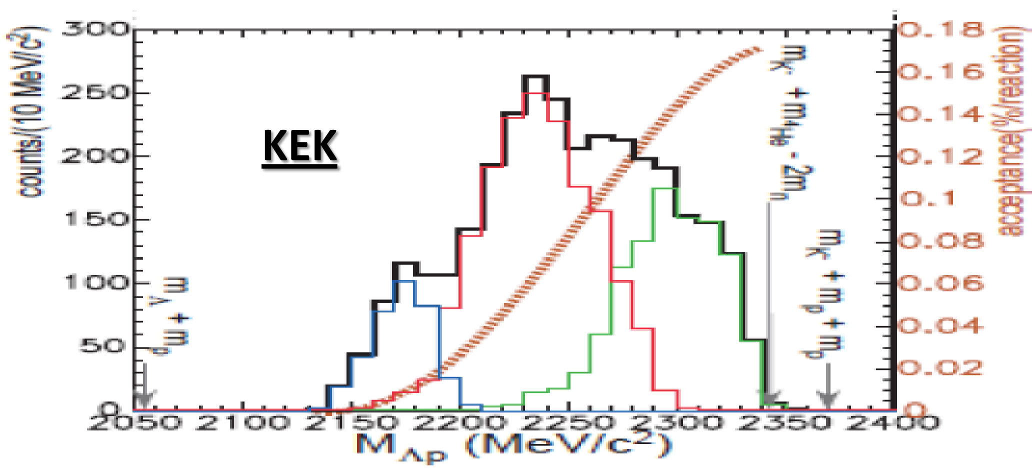

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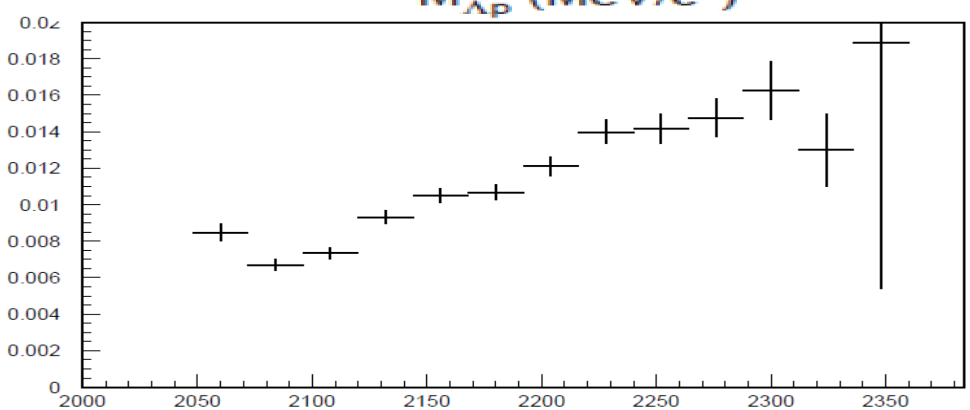

Normalization 1:1
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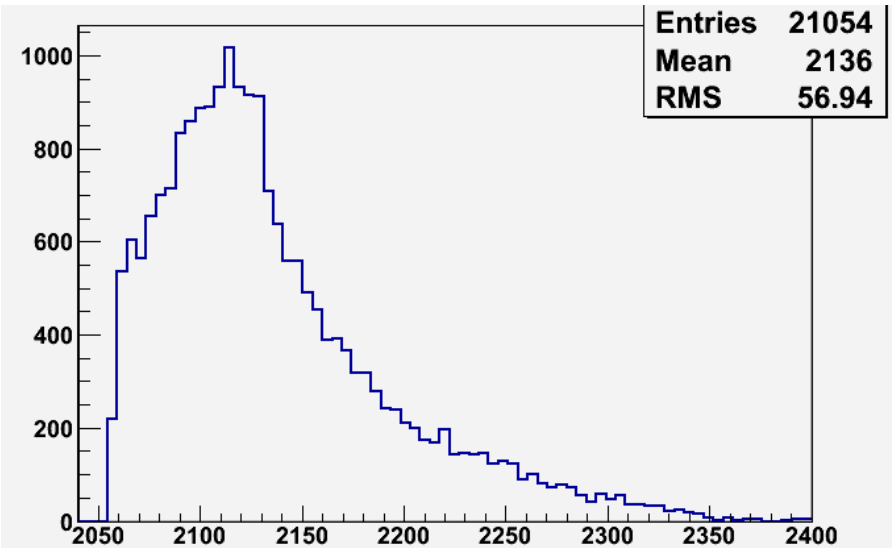
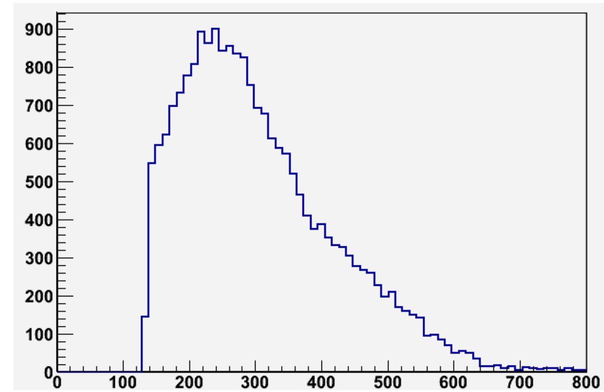
Λp analysis: events in DC GAS

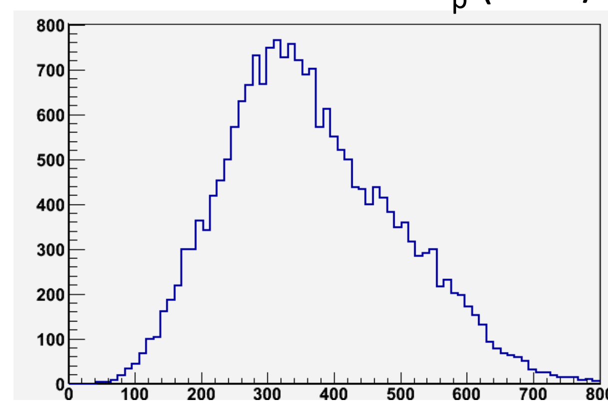
- Events in the DC gas volume (^4He)
- The detection of the single nucleon absorption process iss necessary to complete the picture



$M_{\Lambda p}$ (MeV/c^2)



P_p (MeV/c)



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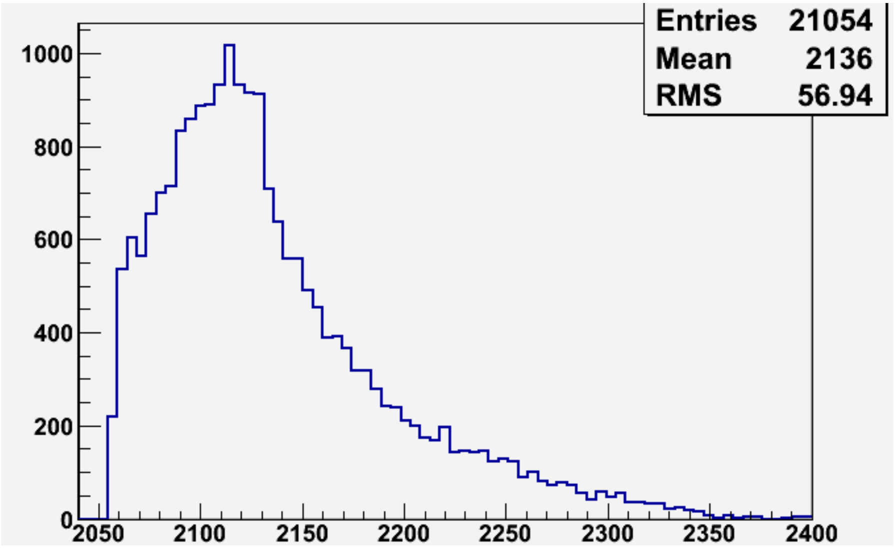


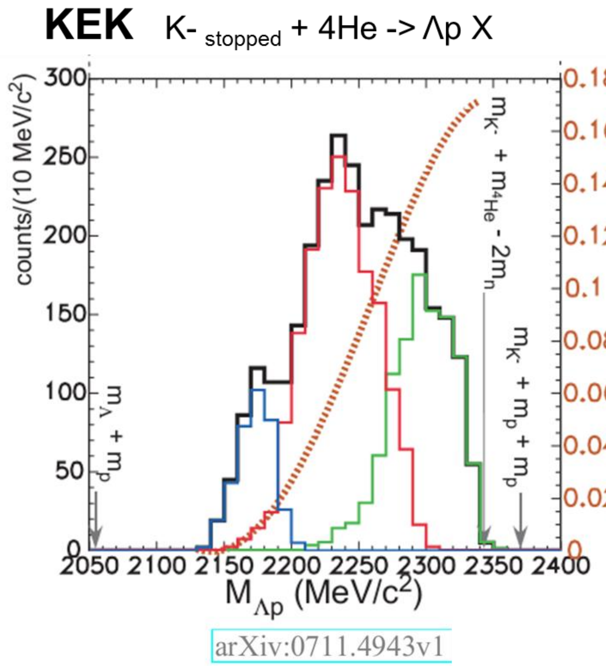
$M_{\Lambda p}$ (MeV/c^2)

KEK Conclusions:

Blue -> 1NA

RED -> ?

Green -> 2NA



1NA: $\mathbf{K^-N \rightarrow \Lambda\pi^-}$ (N spectator)

2NA: $\mathbf{K^-NN \rightarrow \Lambda N}$ (pionless)

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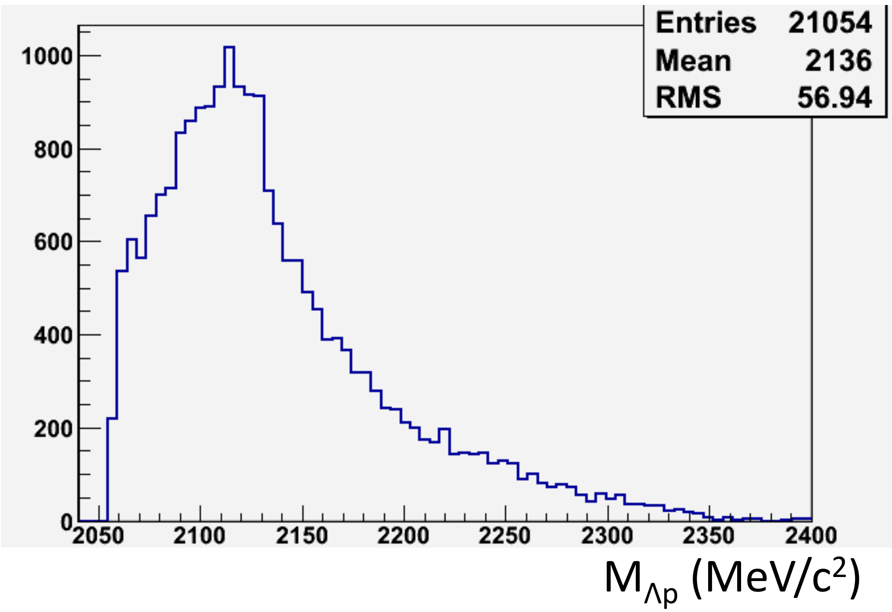

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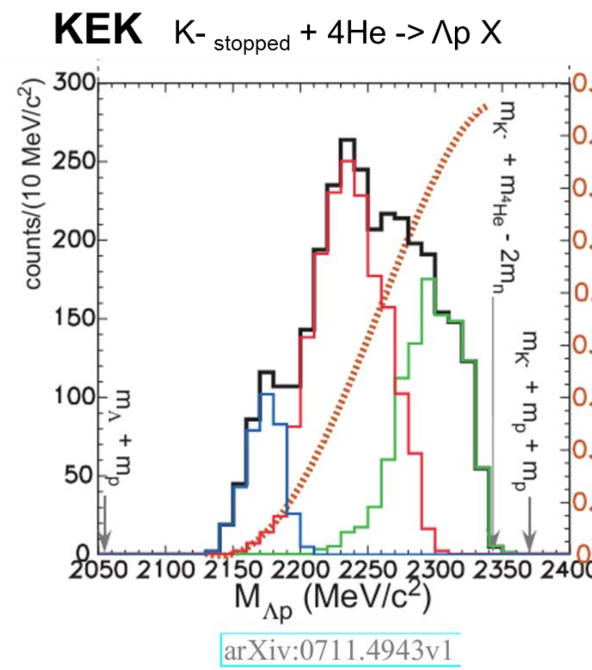

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1NA: **$K^-N \rightarrow \Sigma\pi^- \rightarrow \Lambda N\pi^-$** (N from **Σ/Λ conversion**)

Λp analysis: events in DC GAS

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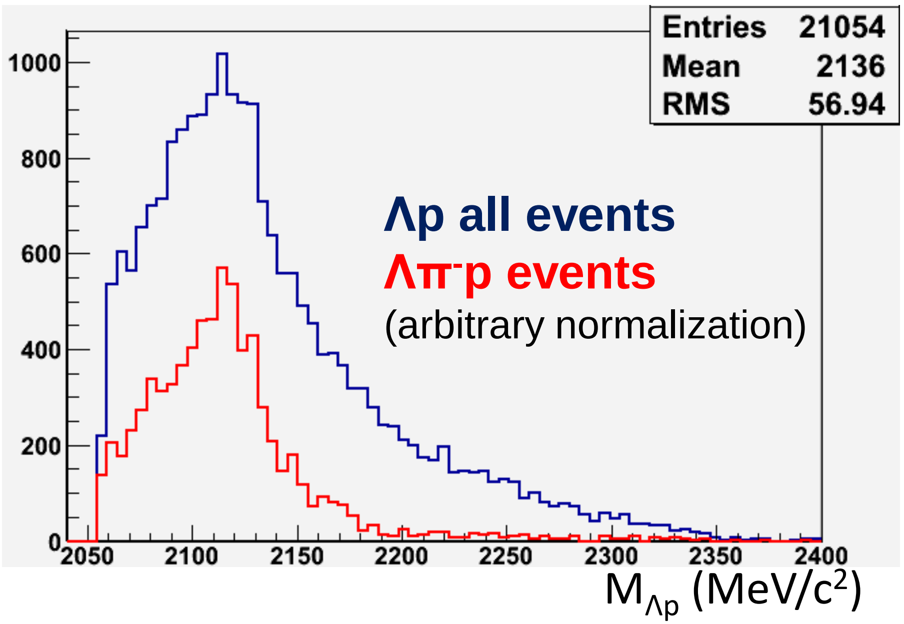

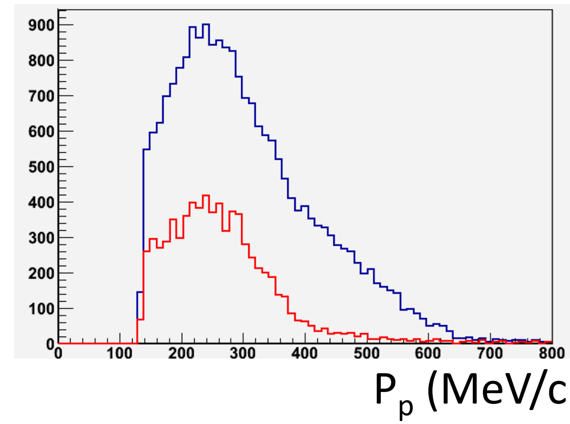

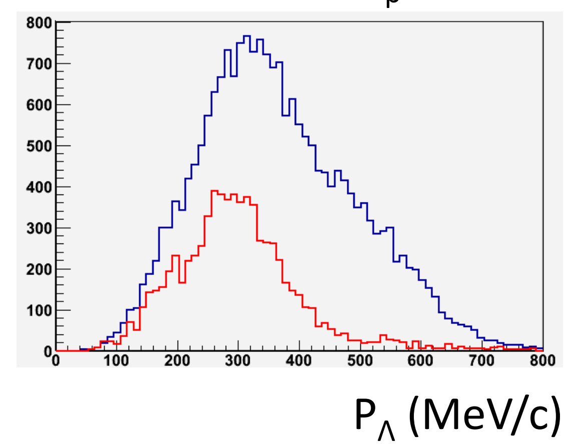

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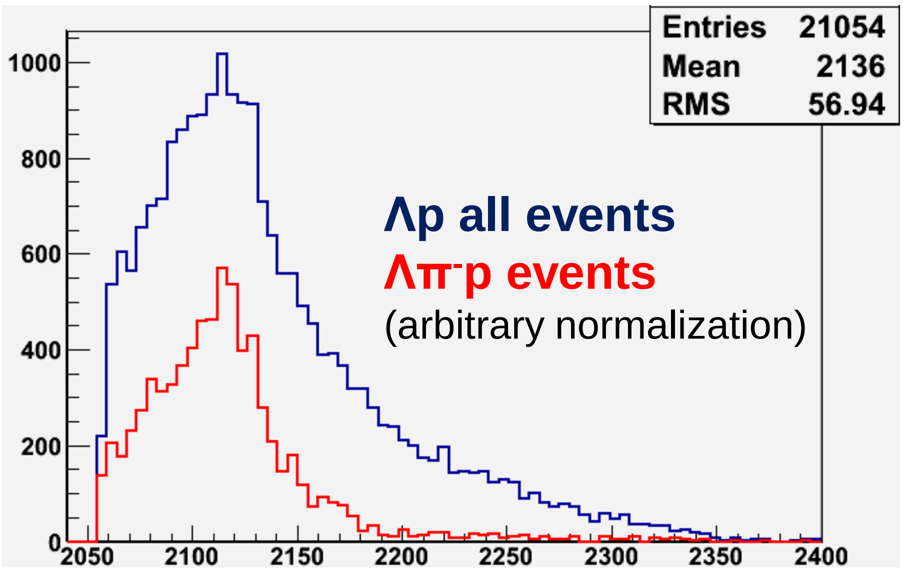
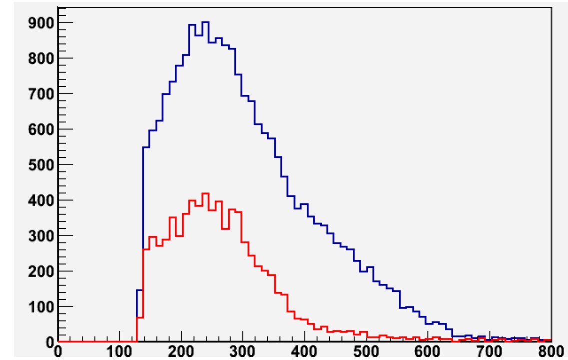
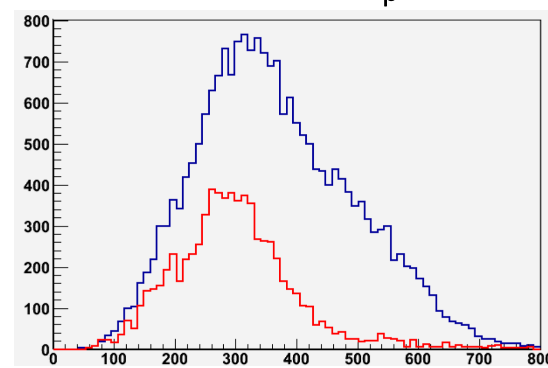
- The detection of the **single nucleon absorption** process iss necessary to complete the picture



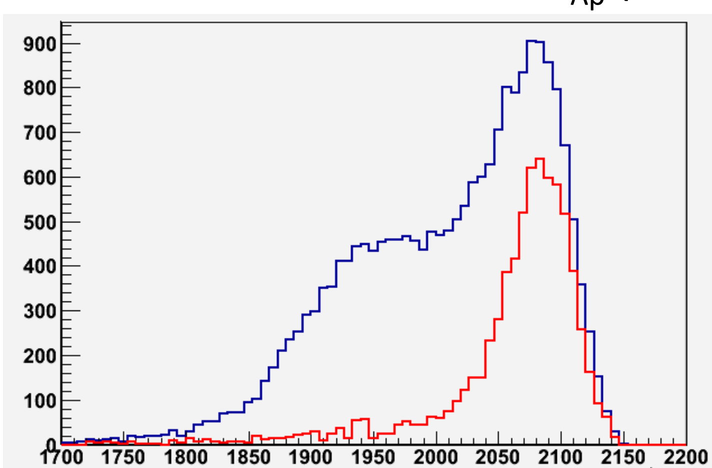
$M_{\Lambda p}$ (MeV/c^2)



P_p (MeV/c)



P_Λ (MeV/c)



Λp missing mass (MeV/c^2)

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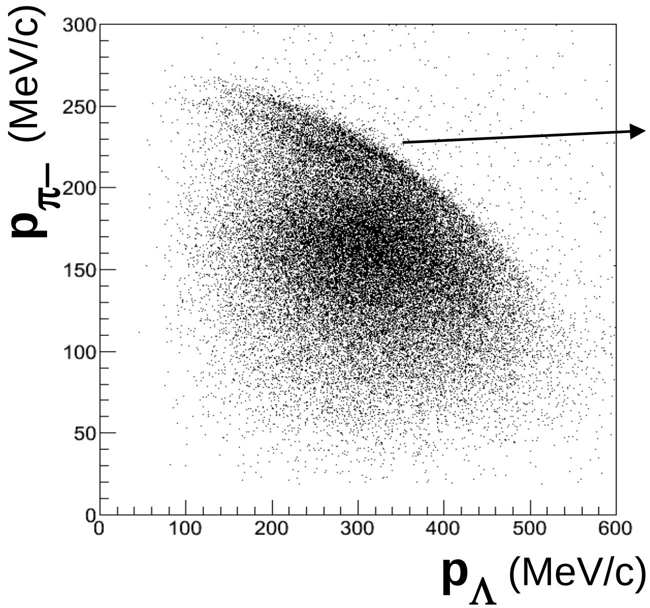
Σ/Λ conversion in the nuclear medium

- **$\Lambda\pi^-$ analysis:** 1N absorption process **$K^- N \rightarrow Y\pi^-$**

DC-wall carbon!!!!



Direct formation $K^- n \rightarrow \Lambda\pi^-$

Clearly visible the 2 bands:

-in flight

-at rest

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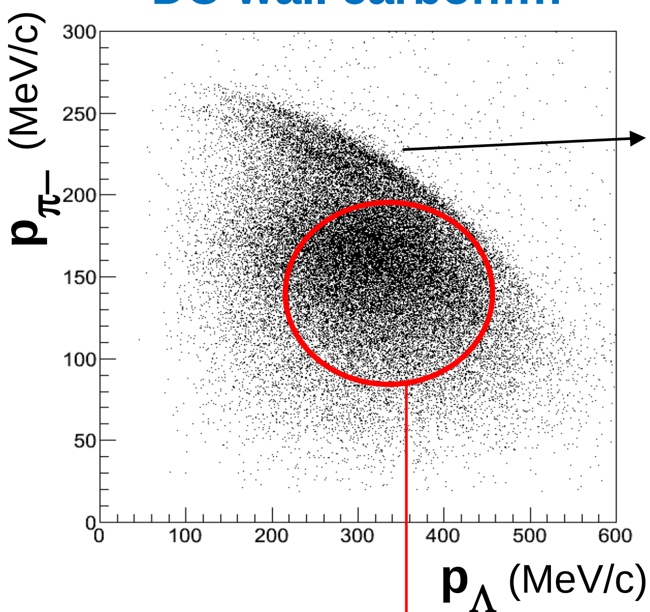


Direct formation $K^- n \rightarrow \Lambda\pi^-$
Clearly visible the 2 bands:
-in flight
-at rest

Two-step process involving sigma:
$K^- n \rightarrow \Sigma^0\pi^-$

Decay $\Lambda\gamma$

Undergo internal conversion within the residual nucleus $\Sigma N \to \Lambda N$

- The data in this channel is of great value to confirm the predicted branching ration modifications in medium for $^{A}Z(K^-,\pi^-)$

-Σ/Λ internal conversion rates can be obtained as well in function of the nucleus material

Σ/Λ conversion in the nuclear medium

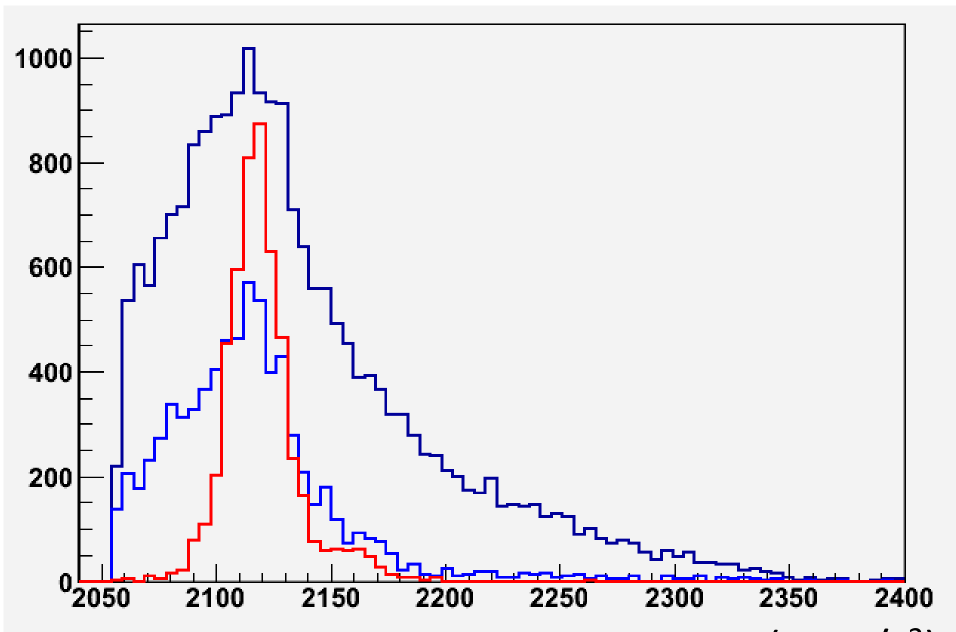
MC simulations of **1NA, 2NA, $\Sigma N/\Lambda N$** and taking into account:
- Available phase space of decays and absorptions
- Fermi momentum of nucleons
- Recoil KE of residual nucleus
- Binding energy of last nucleon of ^{12}C and ^{4}He
- Initial momentum of K^-

Σ/Λ conversion in the nuclear medium

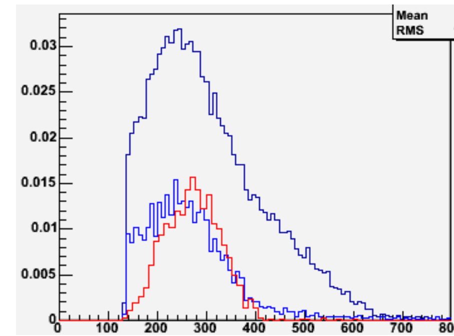
1NA + Internal Conversion Σ(n)→Λ(p)
$K^-p \to \Sigma^+\pi^- \to \Lambda(p)\pi^-$

DATA Λp all events
DATA $\Lambda\pi^-p$ events
MC: $K^-p \to \Sigma^+\pi^- \to \Lambda(p)\pi^-$

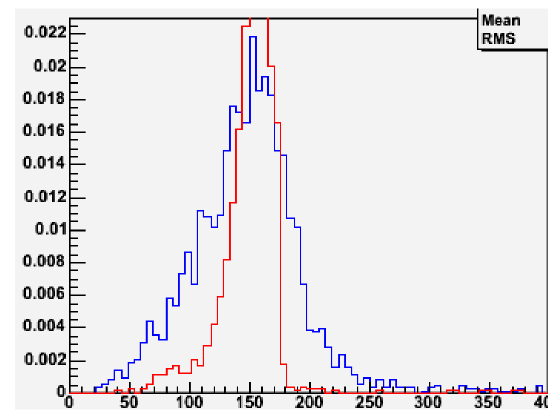
(arbitrary normalization)



$M_{\Lambda p}$ (MeV/c^2)



P_p (MeV/c)



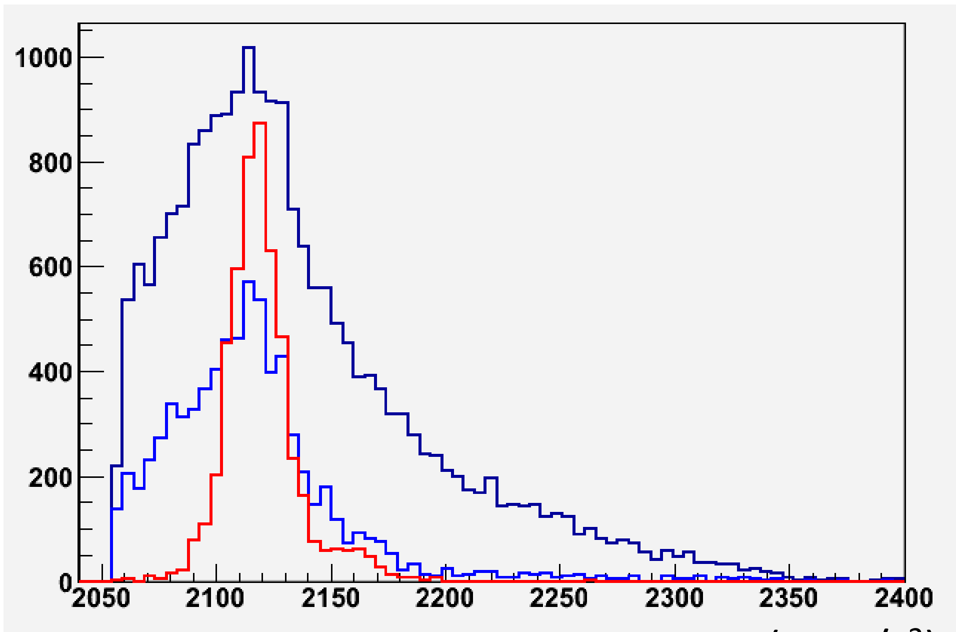
$P_{\pi-}$ (MeV/c)

Σ/Λ conversion in the nuclear medium

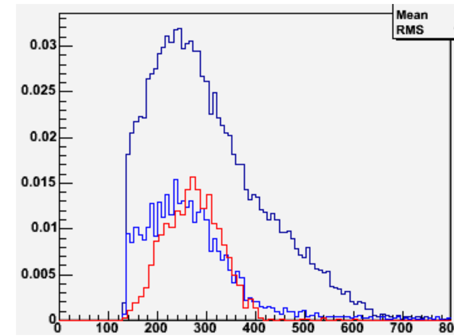
1NA + Internal Conversion Σ(n)→Λ(p)
$K^- p \rightarrow \Sigma^+\pi^- \rightarrow \Lambda(p)\pi^-$

DATA Λp all events
DATA $\Lambda\pi^- p$ events
MC: $K^- p \rightarrow \Sigma^+\pi^- \rightarrow \Lambda(p)\pi^-$

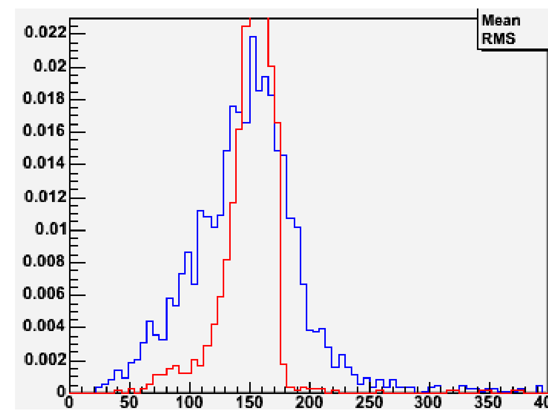
(arbitrary normalization)



$M_{\Lambda p}$ (MeV/c^2)



P_p (MeV/c)



$P_{\pi-}$ (MeV/c)

- Direct Λπ formation process not well described
- Collaboration with S. Wycech for a complete description taking into account, besides the S-wave, isospin I=1 non resonant transition amplitude, also the P-wave process, with the intermediate state Σ(1385).

Λp analysis

Conclusions

- **ΣN/ΛN** conversion process **dominates** both low and high invariant mass regions
- Low invariant mass structure well reproduced by 1NA
- High invariant mass region well reproduced by 2NA
- Excess of **low momentum protons** in the low invariant mass region **could be explained by a 2 step process involving deuteron.**
- Very **small contribution** from direct production of **Λ in 2NA** processes. Unexpected if this comes from ^{4}He mainly, according to Katz et. al.

‘Non pionic channels: $\Sigma^+ \sim 1\%$
$\Sigma^- \sim 3\%$
$\Lambda \sim 10\%$
$\Sigma^0 \sim 2\%$

PHYSICAL REVIEW D VOLUME 1, NUMBER 5 1 MARCH 1970

Reactions of Stopping K^- in Helium*

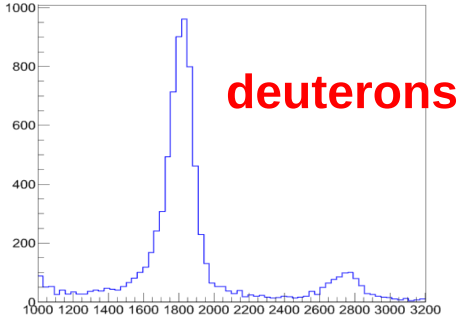
P. A. Katz†
Argonne National Laboratory, Argonne, Illinois 60439
and
University of Minnesota, Minneapolis, Minnesota 55455
AND
K. Bunnell‡
Argonne National Laboratory, Argonne, Illinois 60439
and
Northwestern University, Evanston, Illinois 60201
AND
M. Derrick, T. Fields, L. G. Hyman, and G. Keyes§
Argonne National Laboratory, Argonne, Illinois 60439
(Received 24 October 1969)

Conclusions (II)

- The extraction of the signal of a bound state in processes involving more than 1 nucleon is very **difficult** unless it is very **narrow** and with **high** formation rate.
- ΣN/ΛN conversion process rates for this energy range can be extracted for ^{4}He and ^{12}C...
- ...but we need some **INPUTS**: double scattering process probability, correct efficiency treatment, P-wave and S-wave resonant/non-resonant Λπ formation.

Λd analysis

- Search for signal of bound states in the **Λd** channel. Candidate to be a **K^{-}ppn** cluster. Observed spectra from FINUDA and KEK again showing possible bound states in the in the high invariant mass region.



TOF Particle Mass (MeV)

Λd analysis

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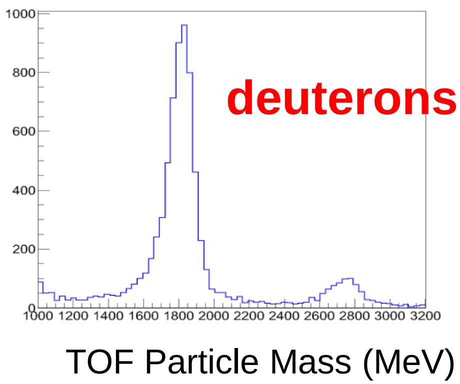

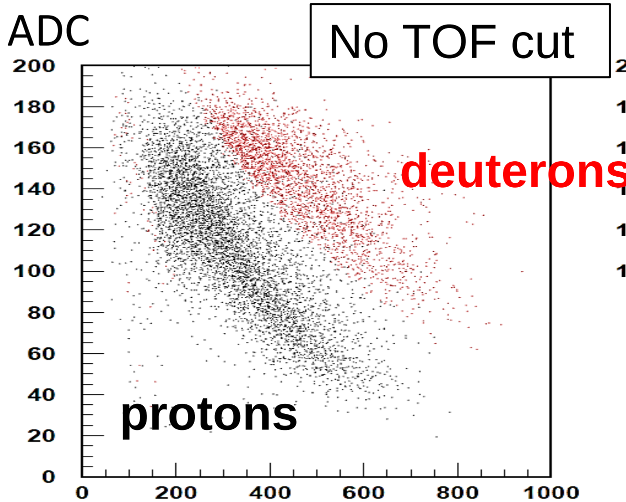

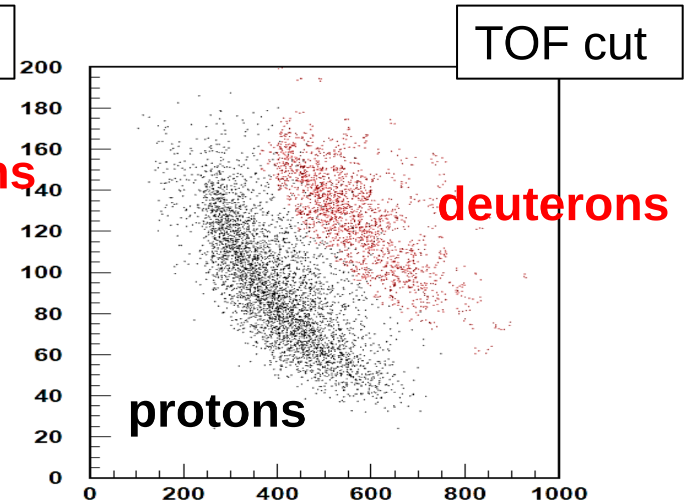

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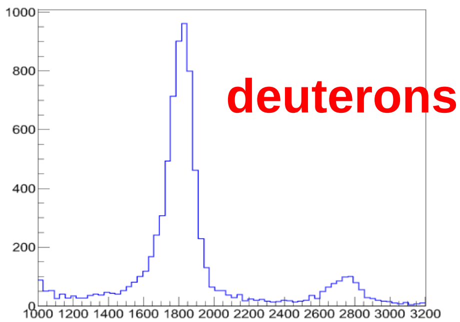
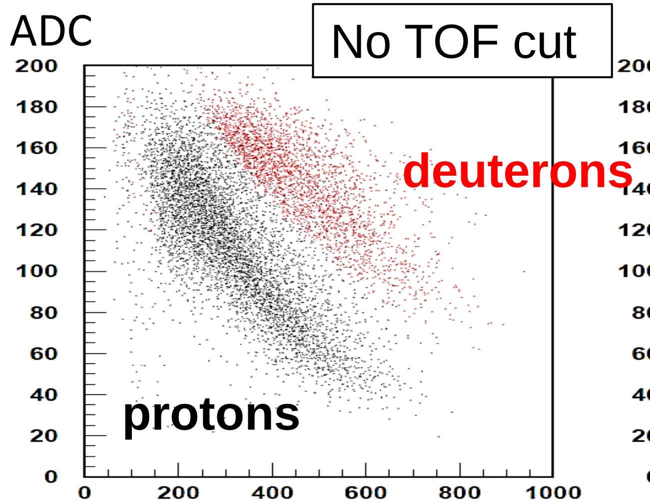
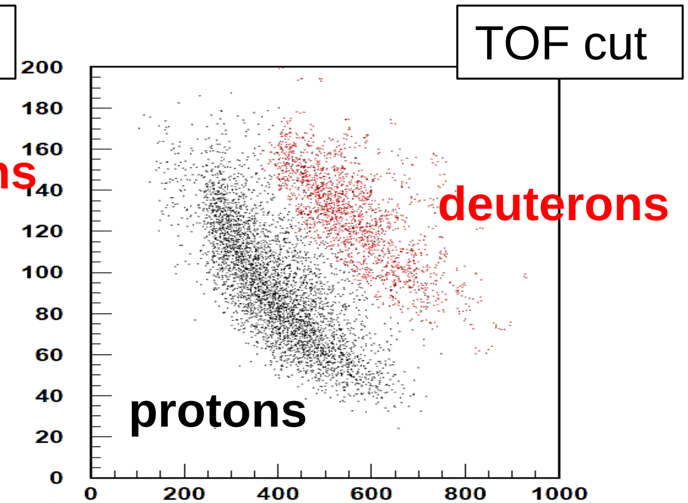
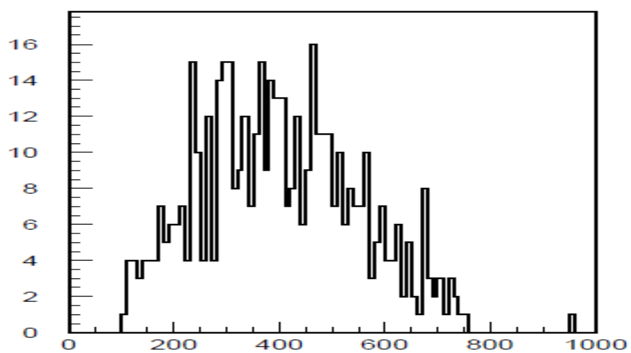


TOF Particle Mass (MeV)

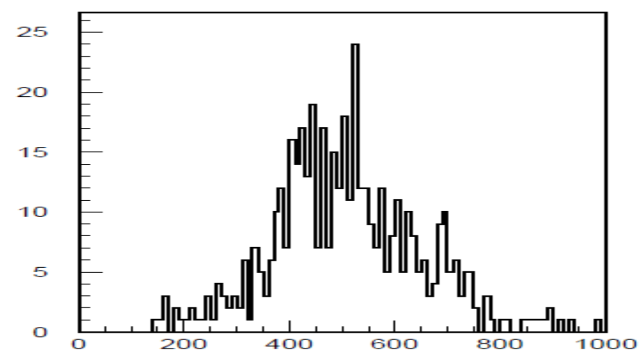




P(MeV)



P_{Λ}(MeV)



P_d(MeV)

Λd analysis

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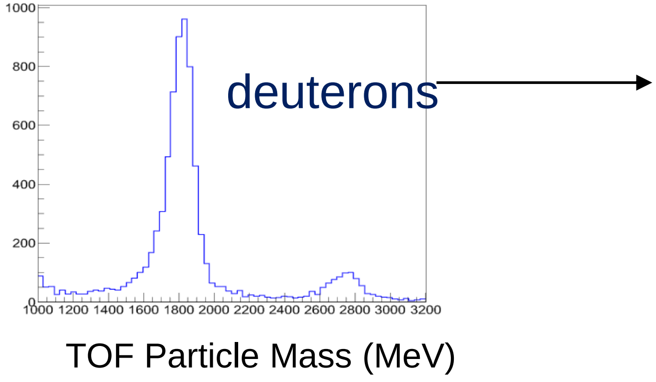

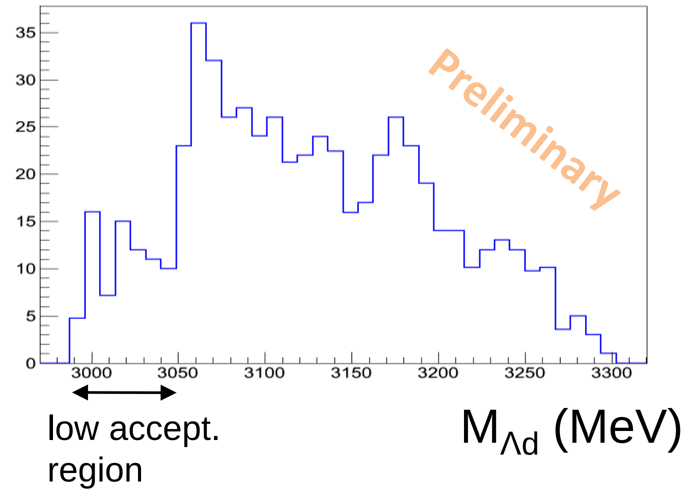

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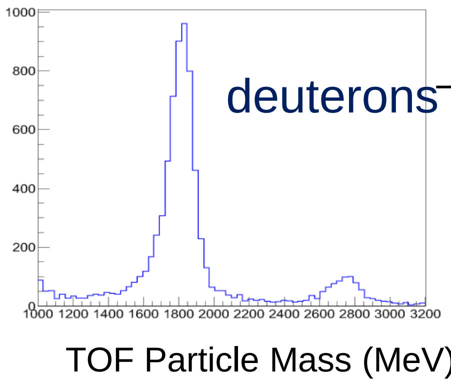
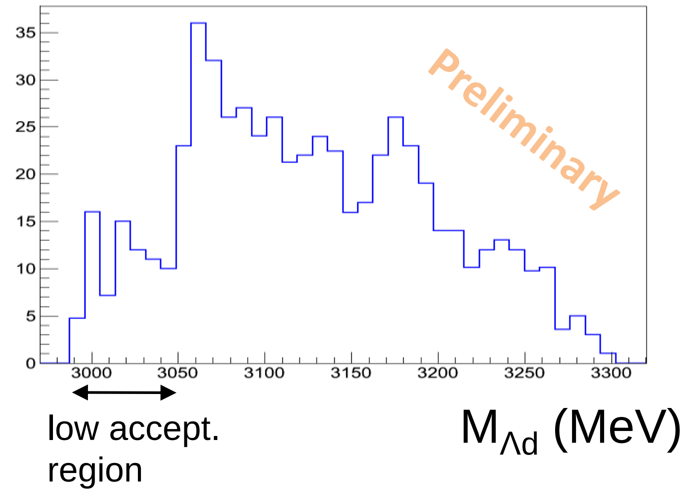
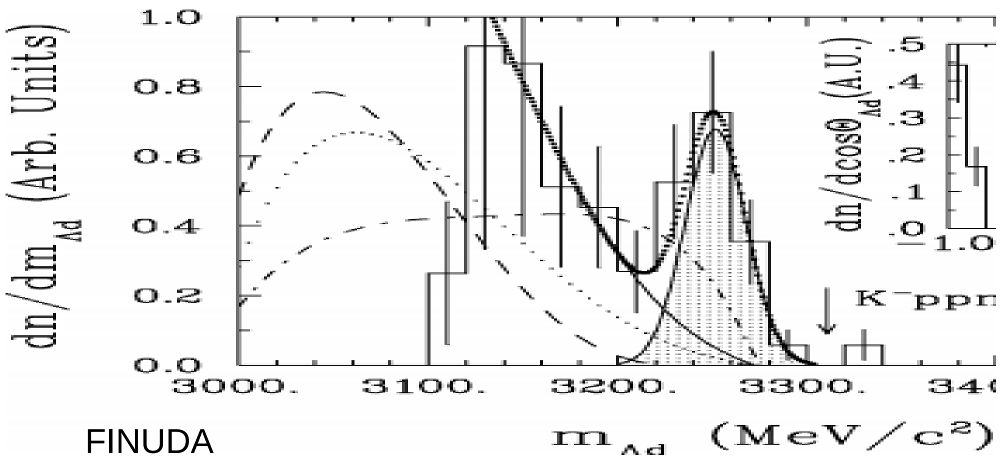




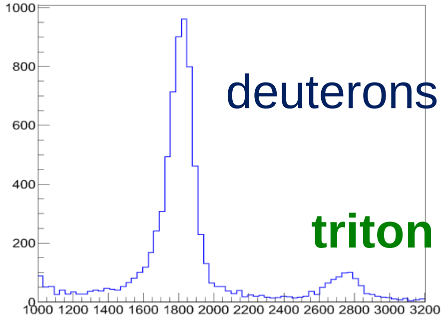
Λd events
In ^{4}He



FINUDA
Nucl.Phys.A835, 43 (2010)

Λt analysis

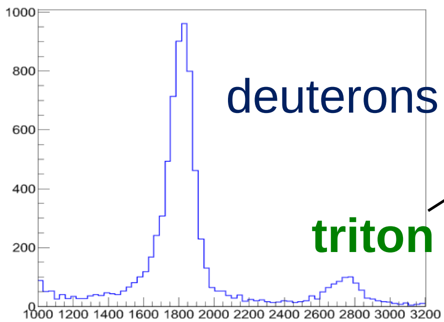
Only FINUDA and an old experiment (with only 4 events!) have shown Λt spectra from K^- absorption



TOF Particle Mass (MeV)

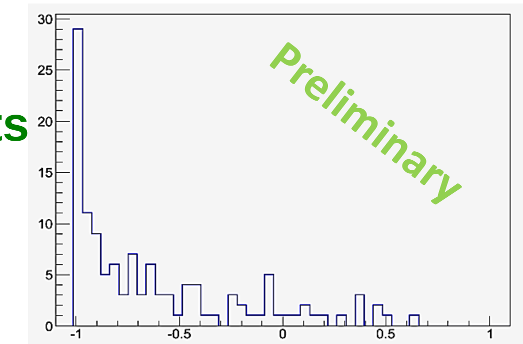
Λt analysis

Only FINUDA and an old experiment (with only 4 events!) have shown Λt spectra from K^- absorption



TOF Particle Mass (MeV)

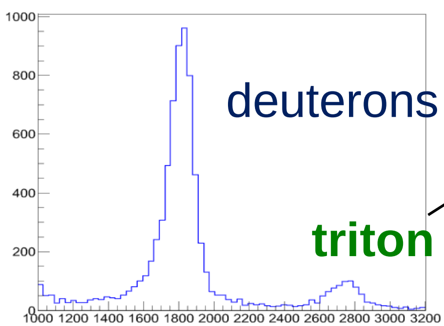
Λt events
In ^{4}He



$\mathrm{Cos}(\theta_{\Lambda t})$

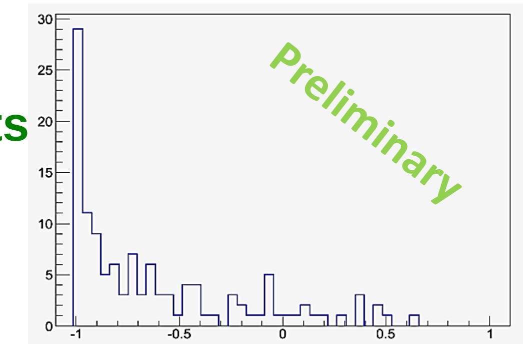
Λt analysis

Only FINUDA and an old experiment (with only 4 events!) have shown **Λt** spectra from K^- absorption

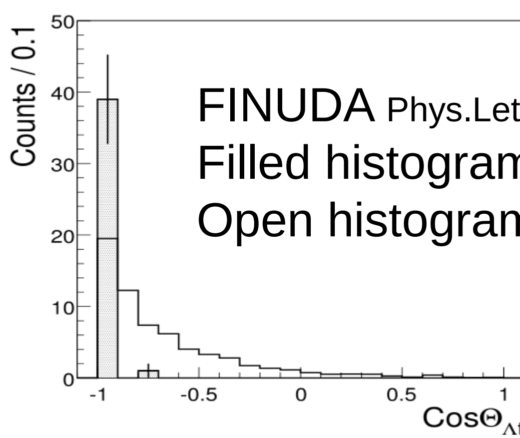


TOF Particle Mass (MeV)

Λt events
In ^{4}He



Cos($\theta_{\Lambda t}$)

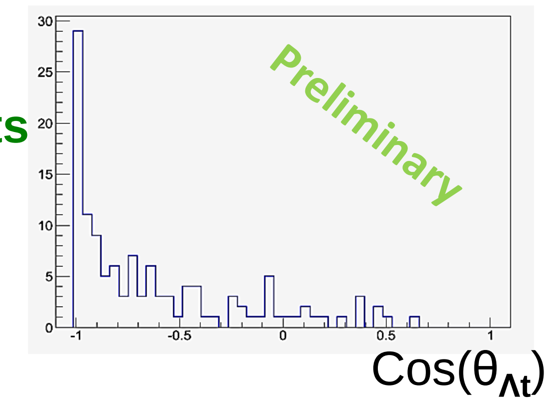


FINUDA Phys.Lett.B 229, 229 (2008)
Filled histogram= data
Open histogram = Phase space simulation

Λt analysis

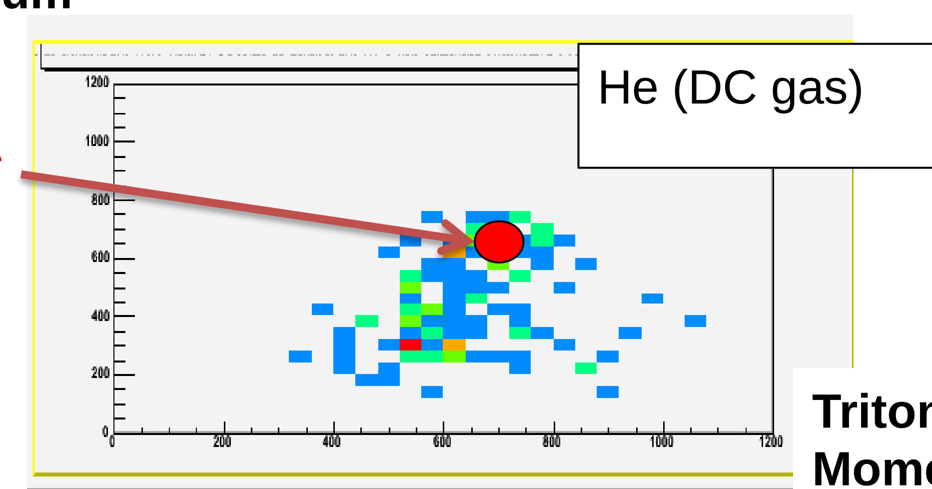
Only FINUDA and an old experiment (with only 4 events!) have shown Λt spectra from K^- absorption

Λt events
In ^{4}He

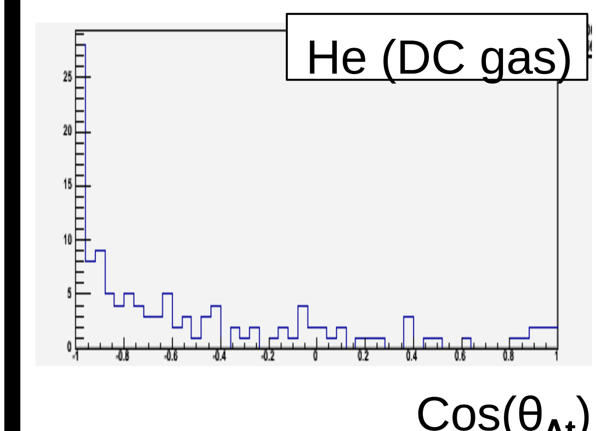


Lambda Momentum (MeV)

~FINUDA SIGNAL



Triton Momentum (MeV)



Conclusions

- KLOE has been proved to be an ideal detector for the study of the K^-N interactions.
- Inclusive **Λp** and exclusive **$\Lambda p\pi^-$** analysis completed and ready to be fitted with background distributions.
- Other analysis (**Λd , Λt, $\Sigma^0\pi^0$, $\Sigma^+\pi^-$,hypernuclei**, etc) undergoing. See next talk by A. Scordo.
- Big expectations for data from **^{12}C solid** (half)cylindrical target.

Conclusions

- KLOE has been proved to be an ideal detector for the study of the K^-N interactions.
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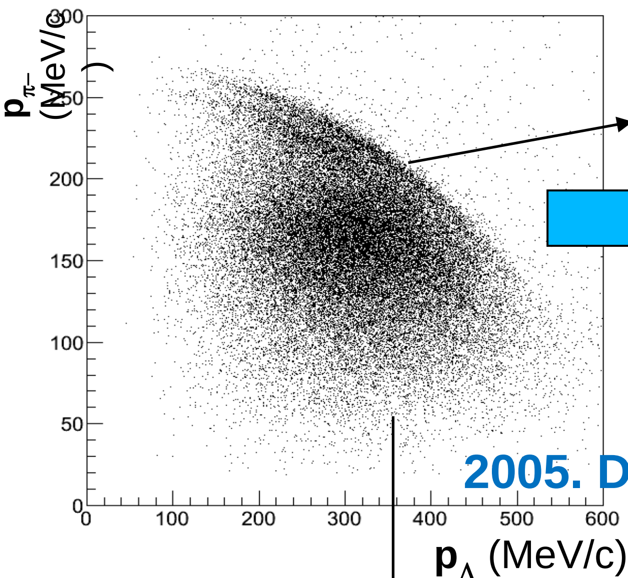
- Big expectations for data from **^{12}C solid** (half)cylindrical target.

thanks!

SPARE

Σ/Λ conversion in the nuclear medium

- **$\Lambda\pi^-$ analysis:** 1N absorpt



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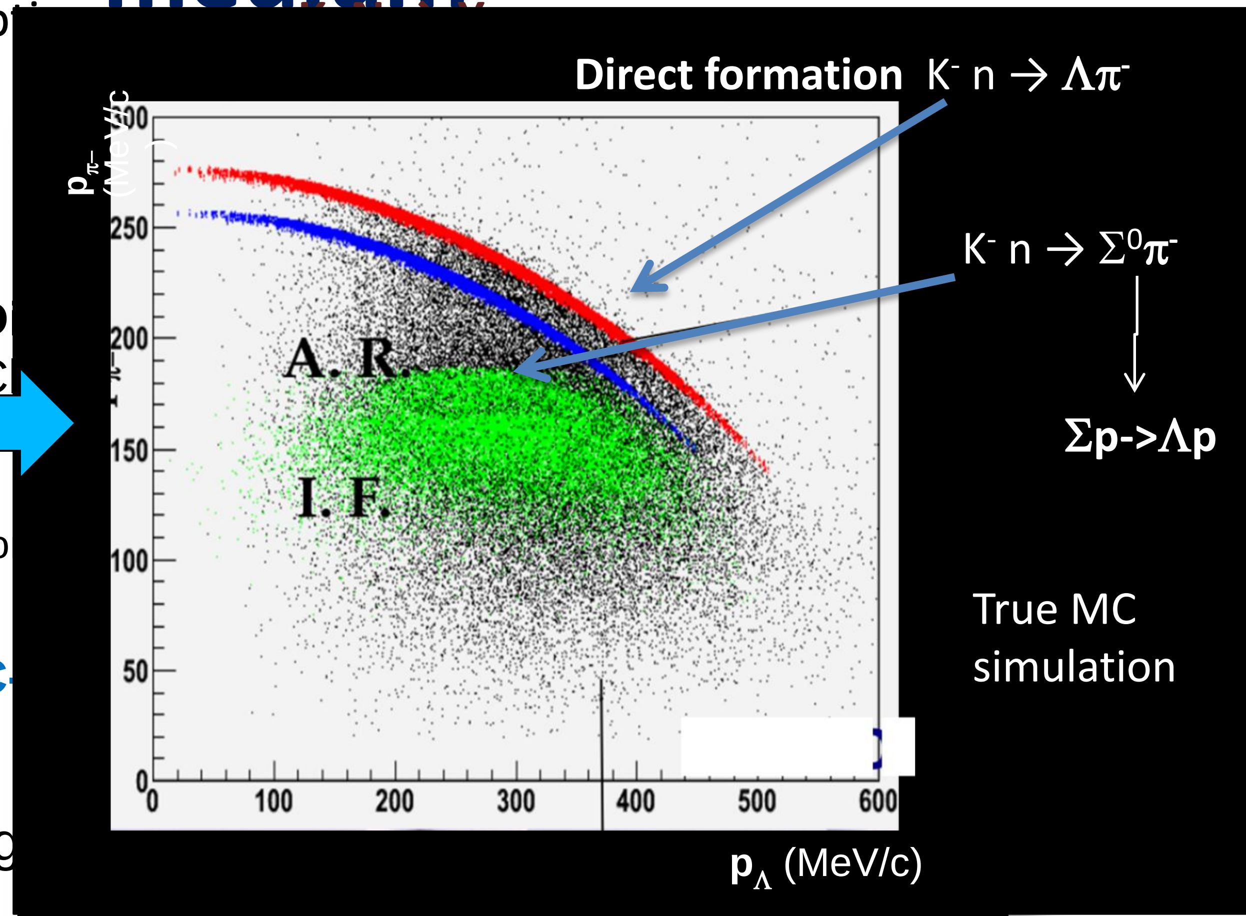


Two-step process involving
$K^- n \rightarrow \Sigma^0\pi^-$

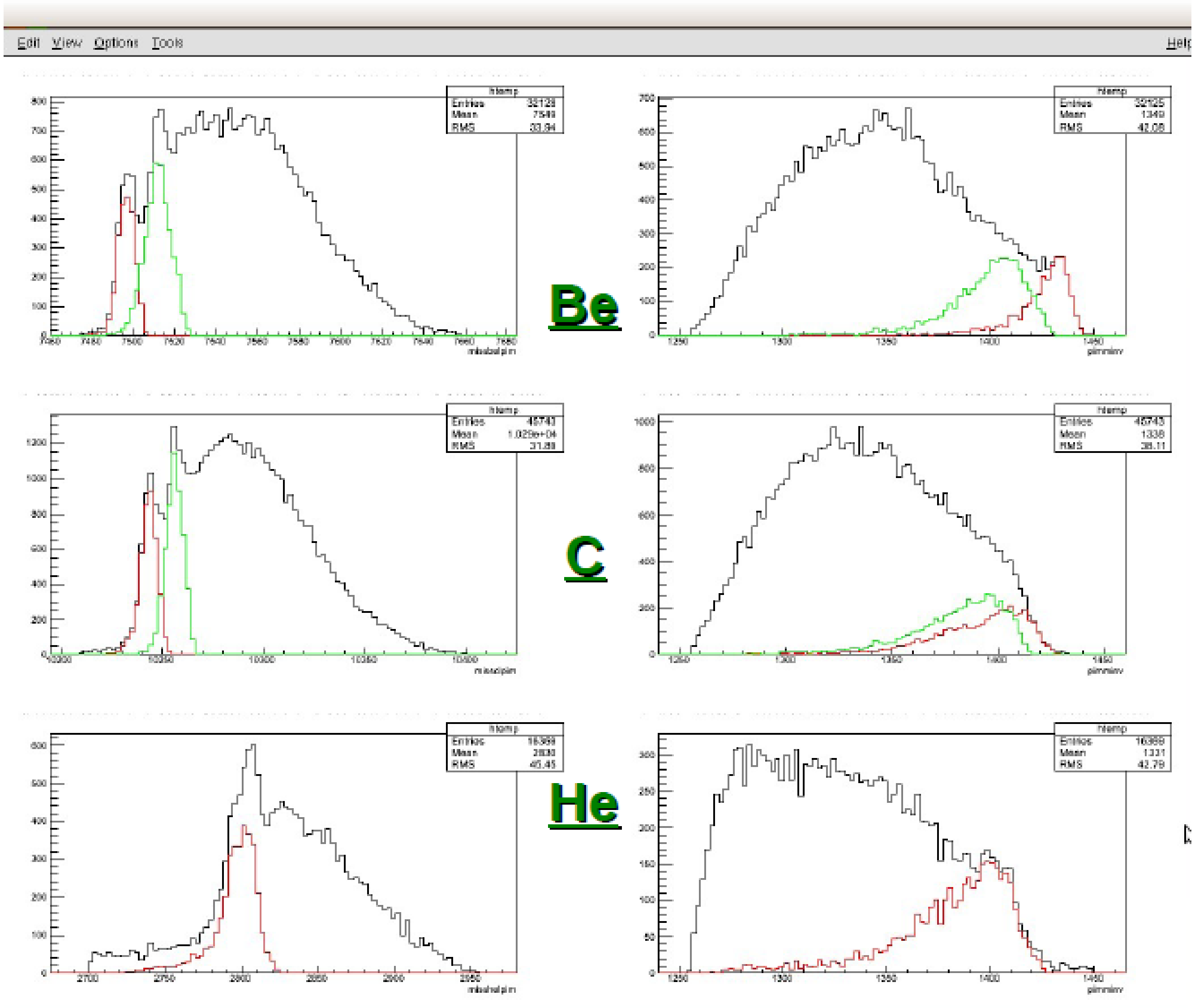
Decay $\Lambda\gamma$

Undergo internal conversion within the residual nucleus $\Sigma N \rightarrow \Lambda N$

value to confirm the predicted branching ration modifications in medium for $^AZ(K^-,\pi^-)$

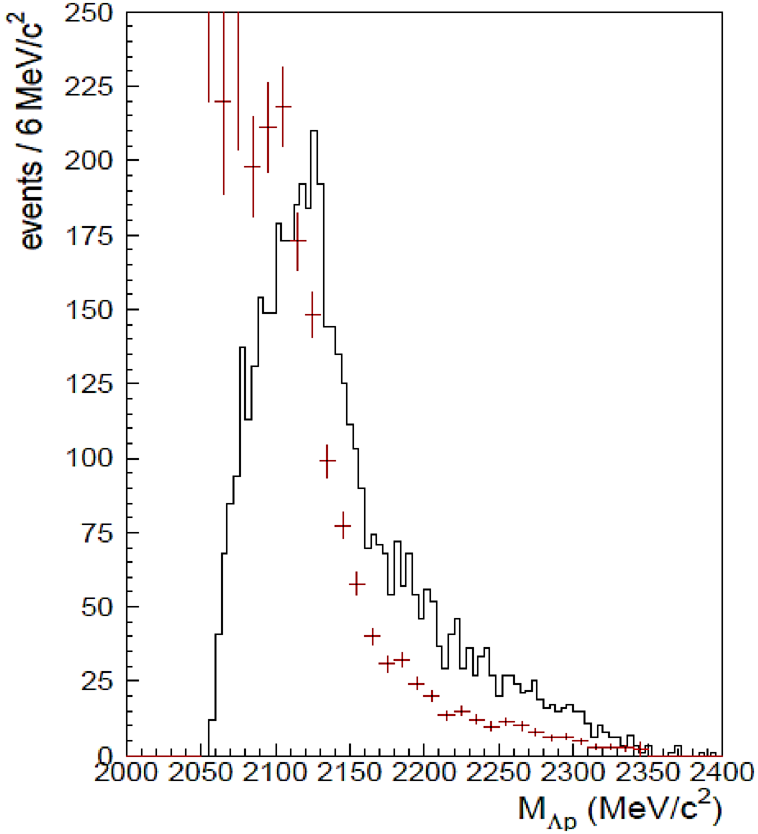
-Σ/Λ internal conversion rates can be obtained as well in function of the nucleus material

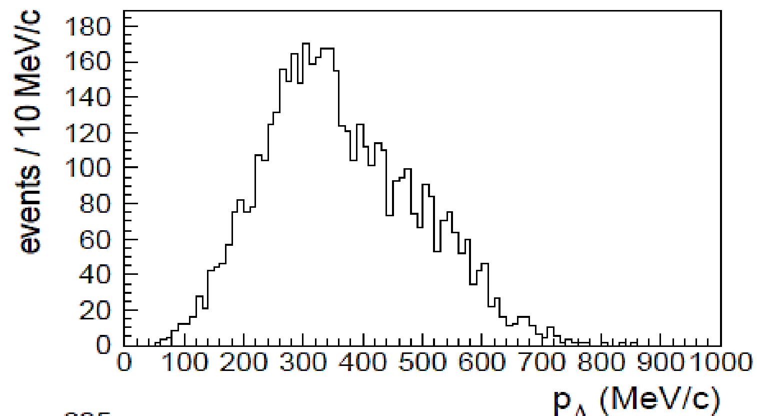
L pi-

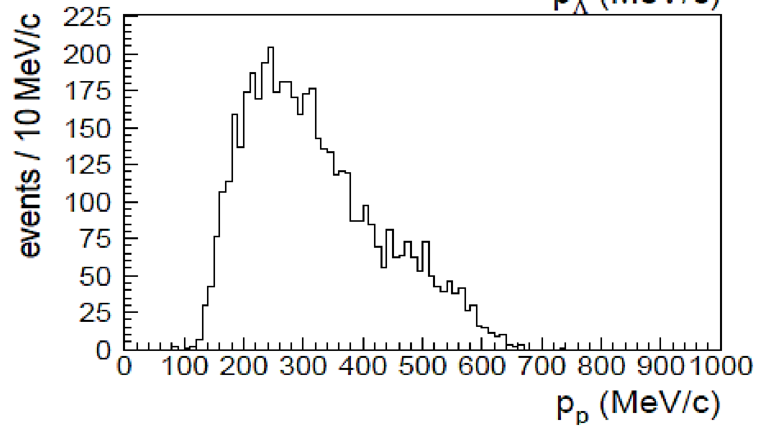


Missing mass INV MAss

Invariant masses Λp



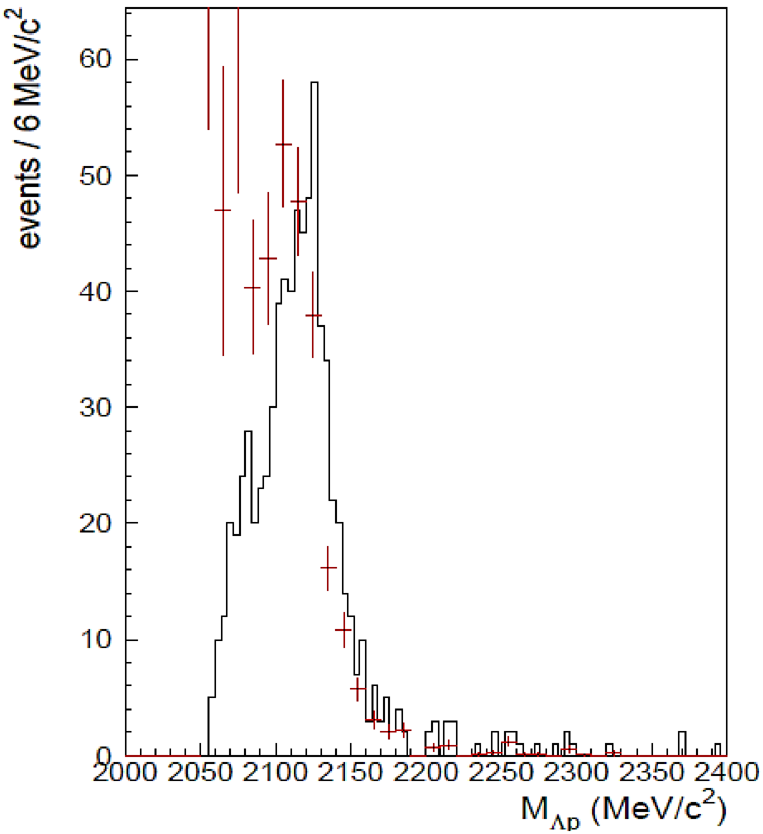


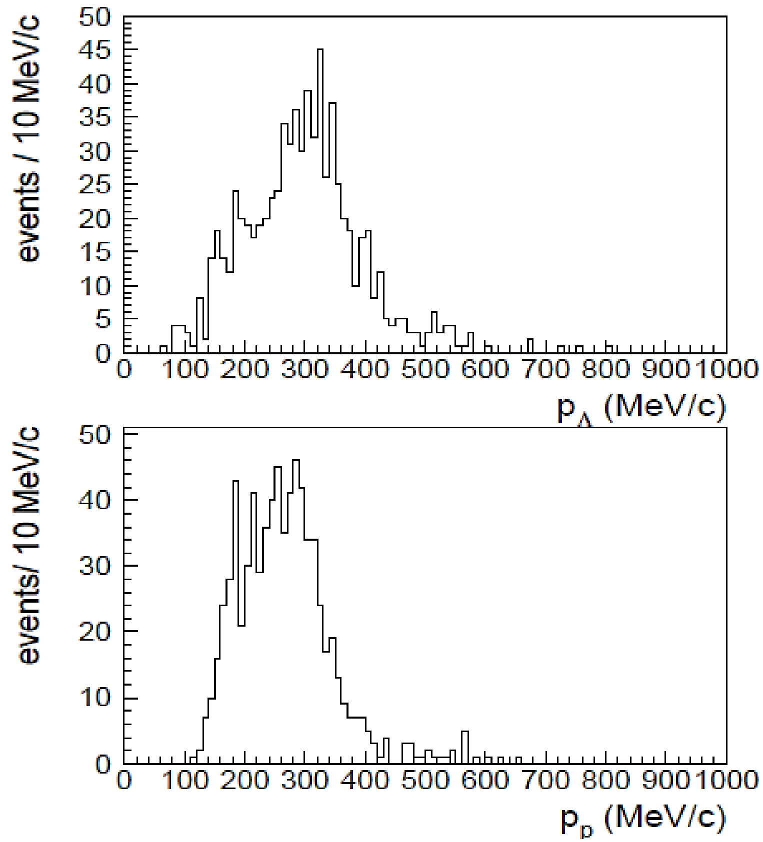


Acceptance corrected

Inclusive analysis
ALL Λp events

Invariant masses Λp





Acceptance corrected

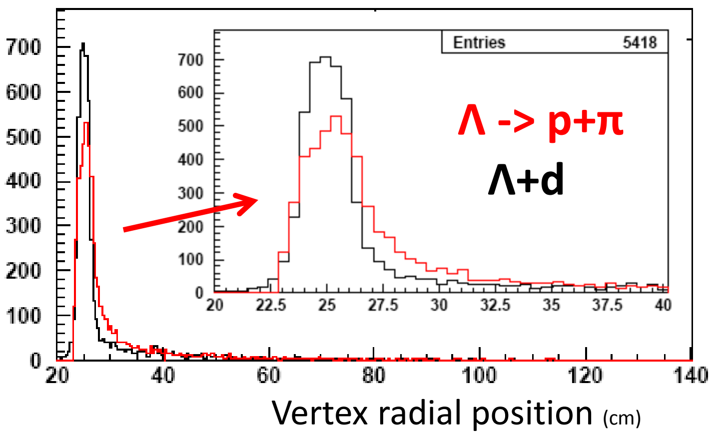
Exlusive analysis

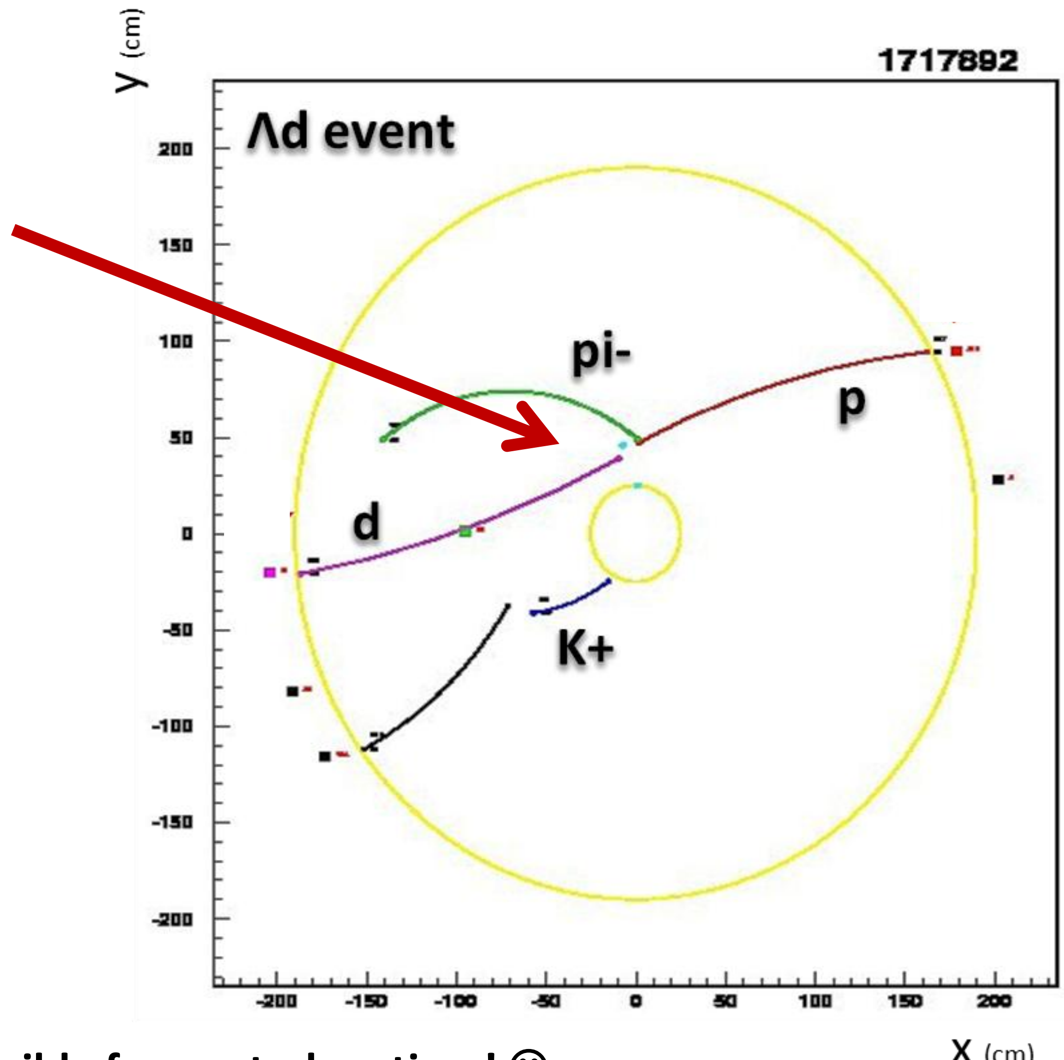
$\Lambda p + \pi^-$ events

- High invariant mass and momentum components are lost
- **CHECK**: Missing mass OK!

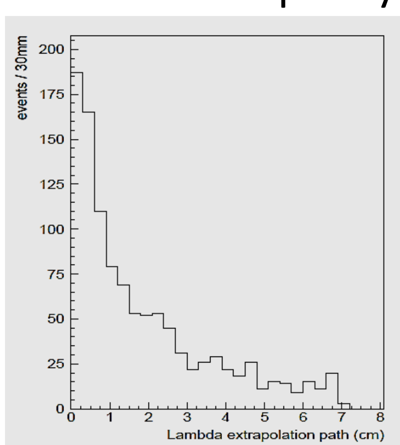
Tools for identifying ΛN events

-A good vertex resolution in esential to identify the “interaction” and “lambda” vertices .





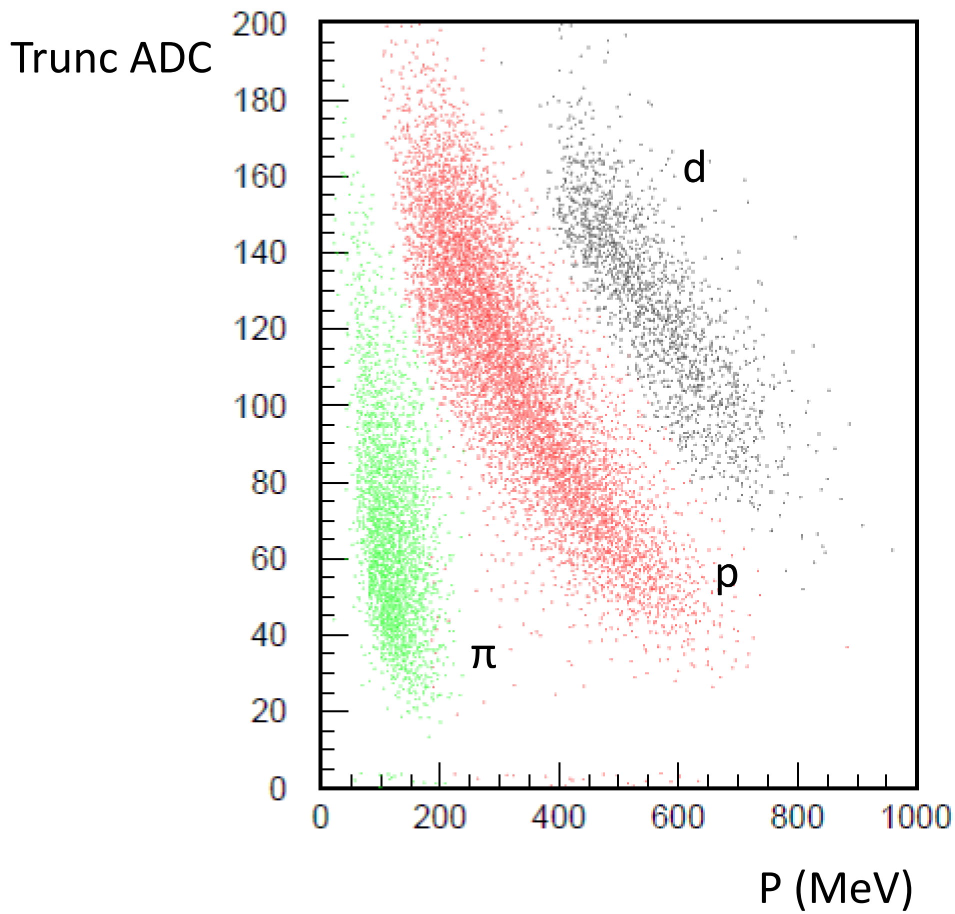
Use Λ lifetime as quality cut



-Not possible for neutral vertices! ☹

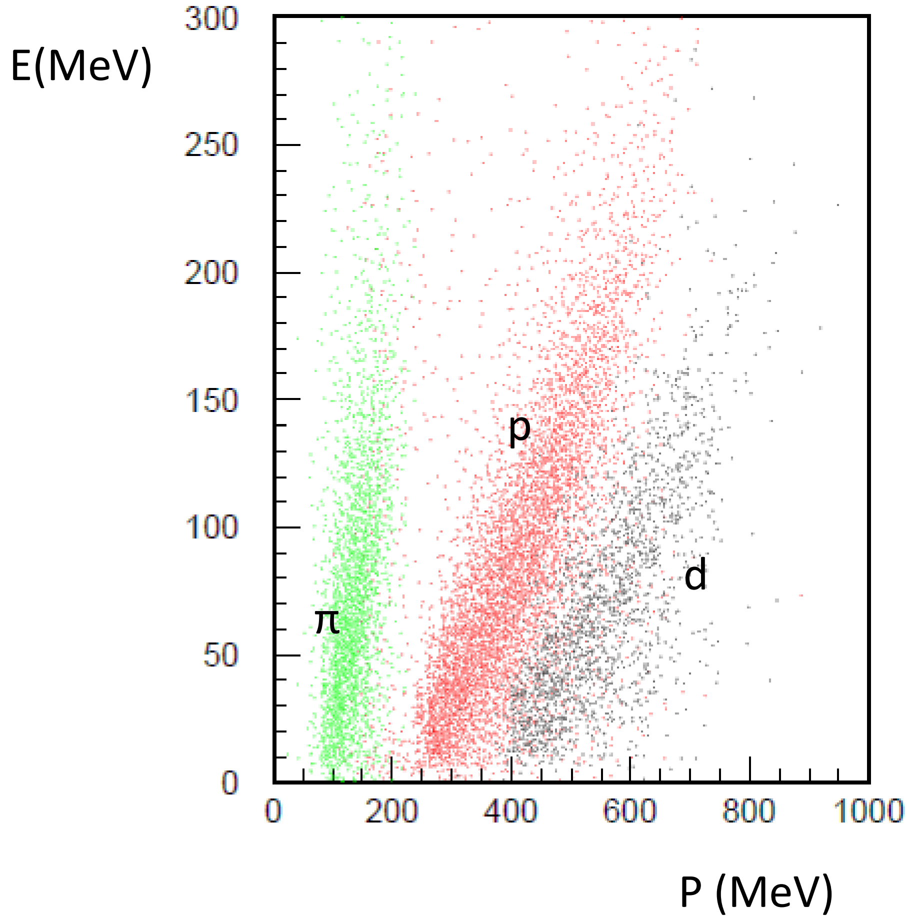
Tools for identifying ΛN events

- **dE/dx** in the DC wires
- (actually the only study
- using this information)



Tools for identifying ΛN events

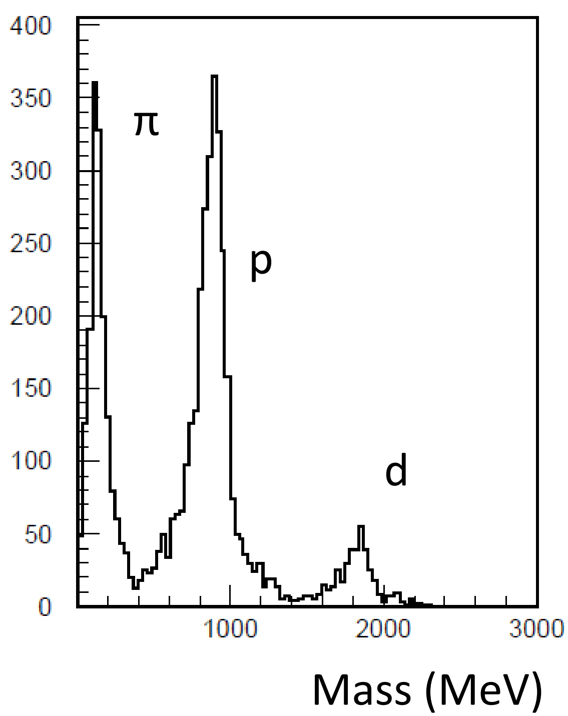
- dE/dx
- **E@EMC**

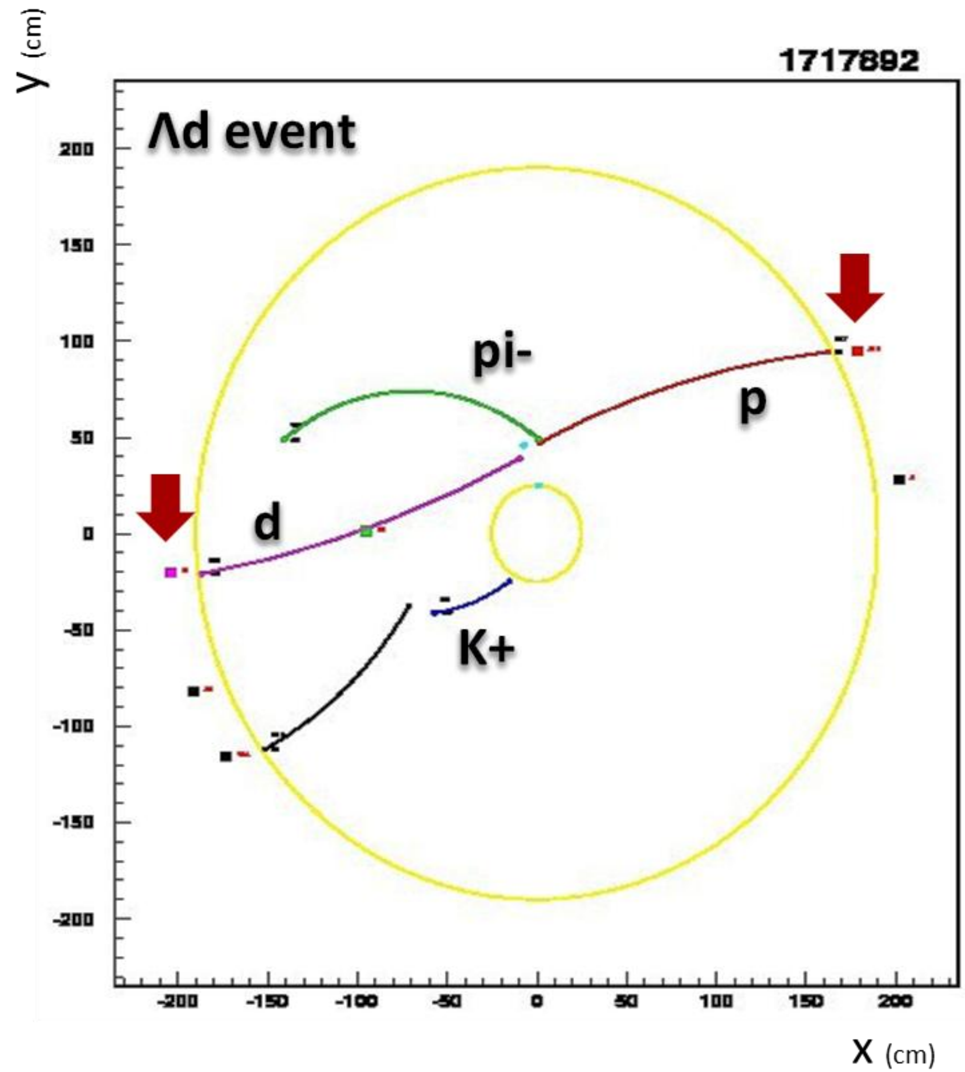


Tools for identifying ΛN events

-The use of the EMC clusters associated to tracks allows to calculate particle masses

- dE/dx
- + = **Mass by TOF**
- E@EMC





Tools for identifying ΛN events

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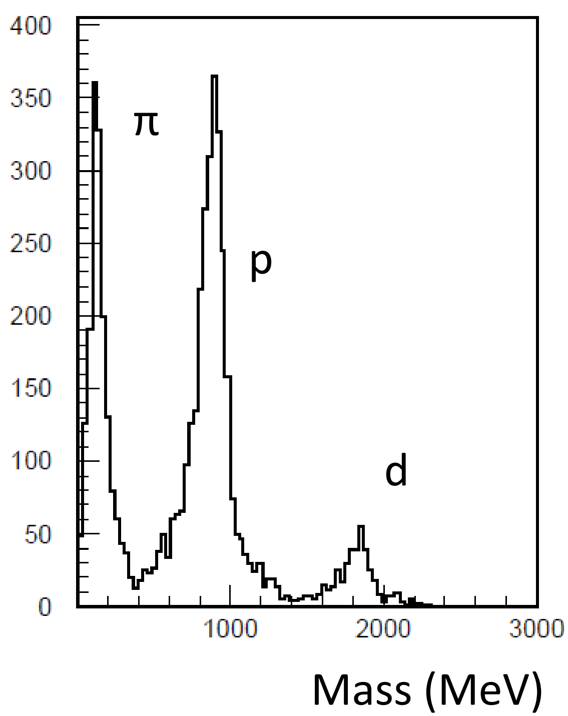
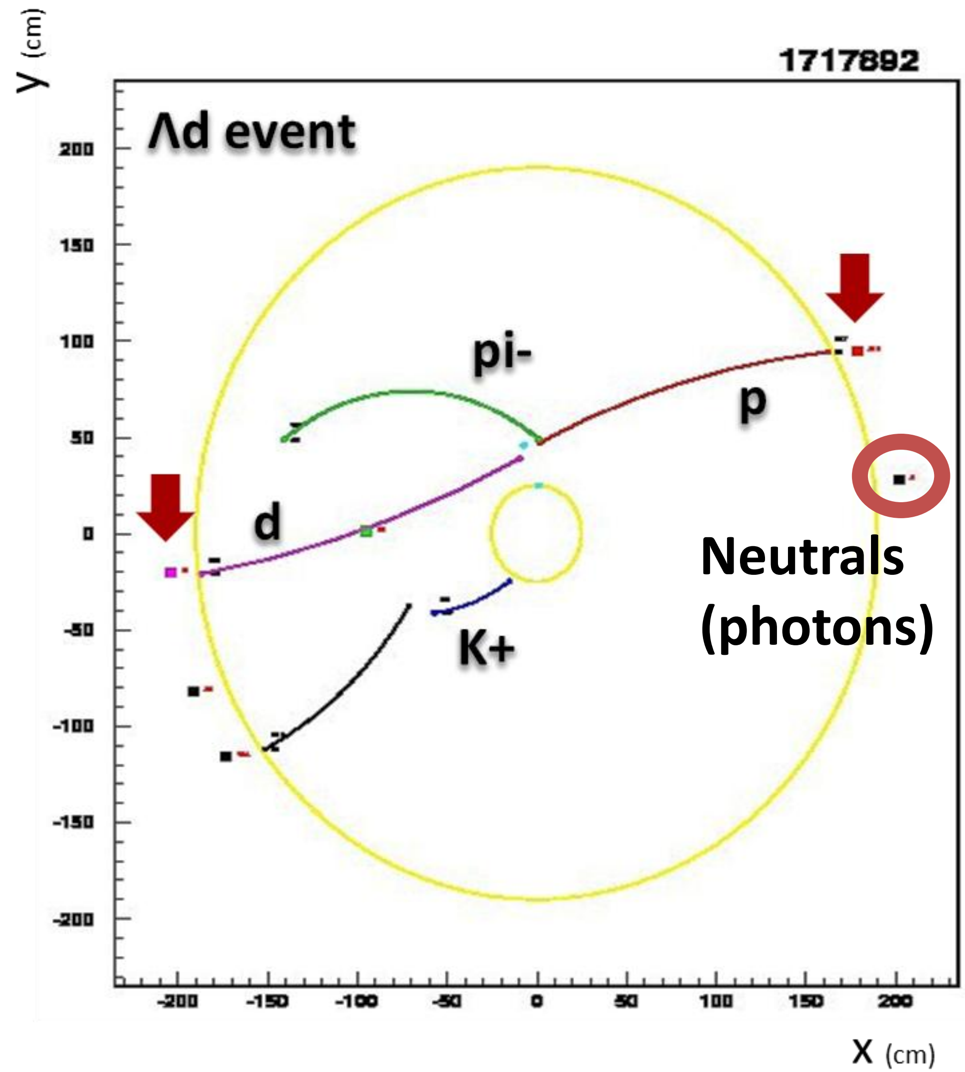
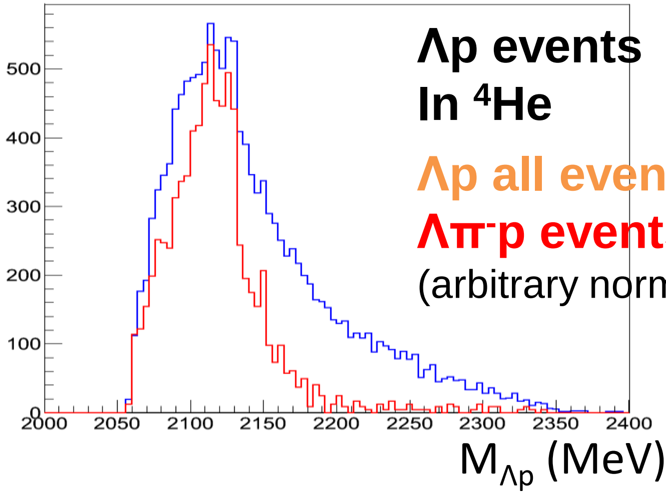




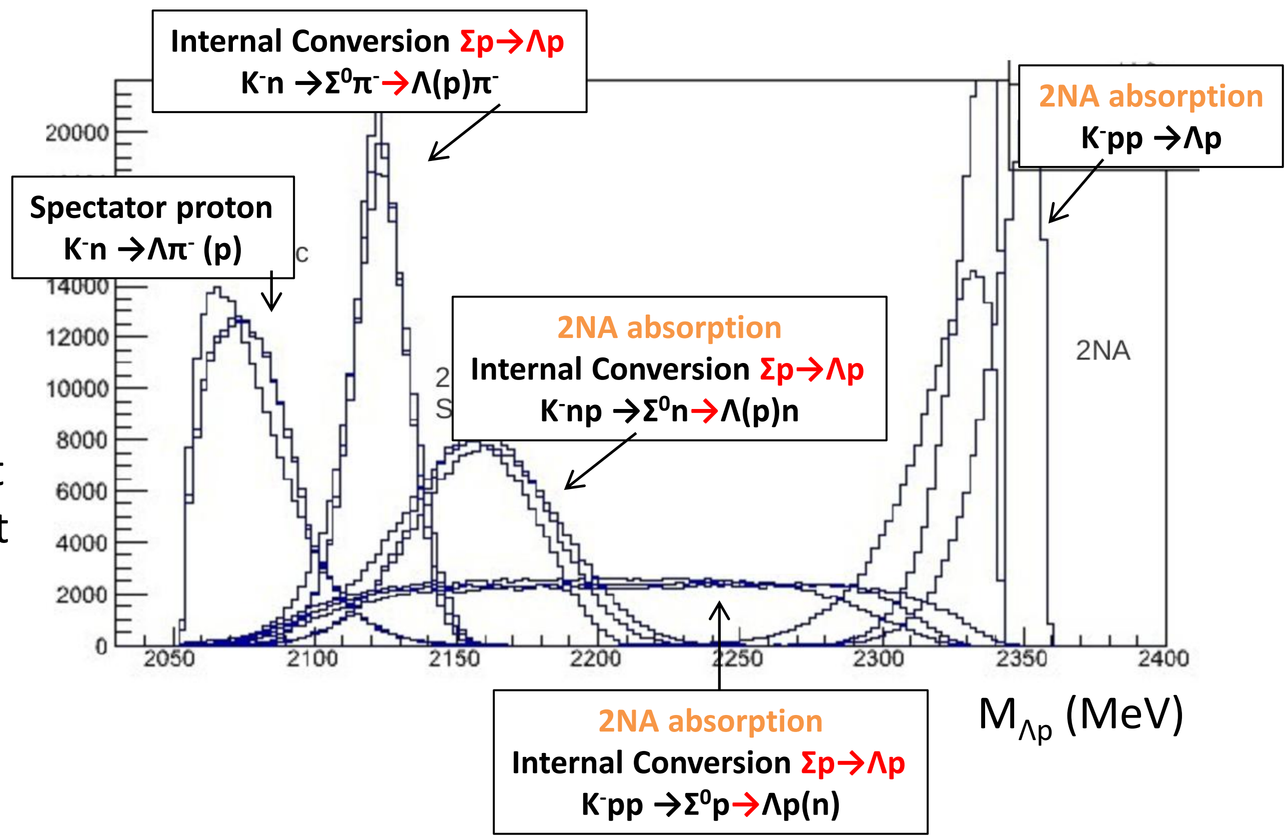
Λp analysis



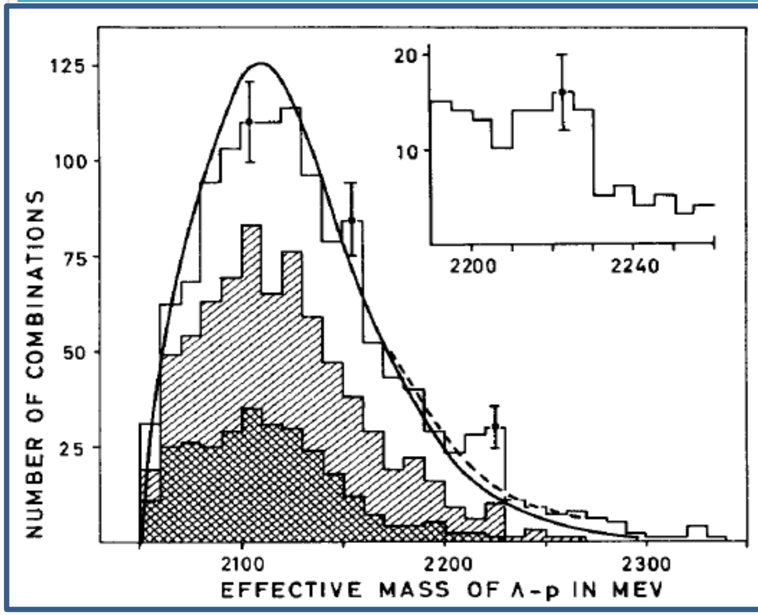
- 1NA: **$K^-N \rightarrow \Lambda\pi^-$** (N spectator)
- 1NA: **$K^-N \rightarrow \Sigma\pi^- \rightarrow \Lambda N\pi^-$** (N from **Σ/Λ conversion**)
- 2NA: **$K^-NN \rightarrow \Lambda N$** (pionless)

True MC simulation
(no accept.)

3 processes simulated:
- interaction in C at rest
- interaction in C in flight
- interaction in He at rest



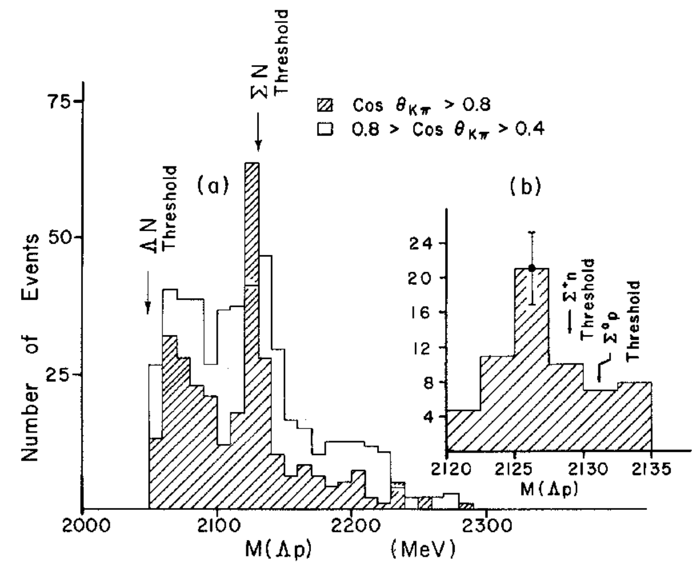
Bubble Chamber $K^-(CF_3Br) \rightarrow \Lambda p X$
T. Buran et al., Phys. Lett. 20, 318 (1966)



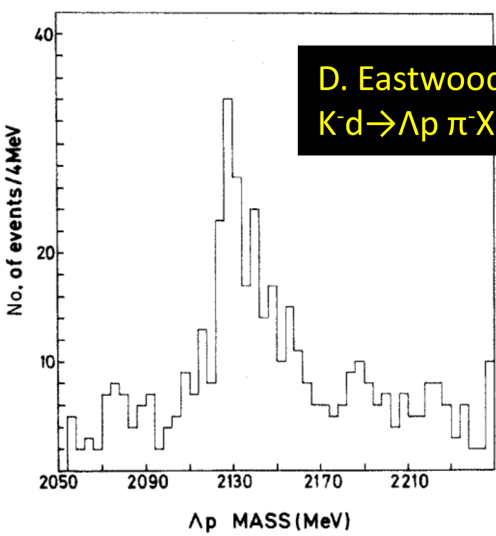
Slide from A. Filippi & S. Piano

The signal is compatible with a K^-d absorption with pion production

$$K^-d \rightarrow (\Sigma^+ n)\pi^- \rightarrow (\Lambda p)\pi^-$$



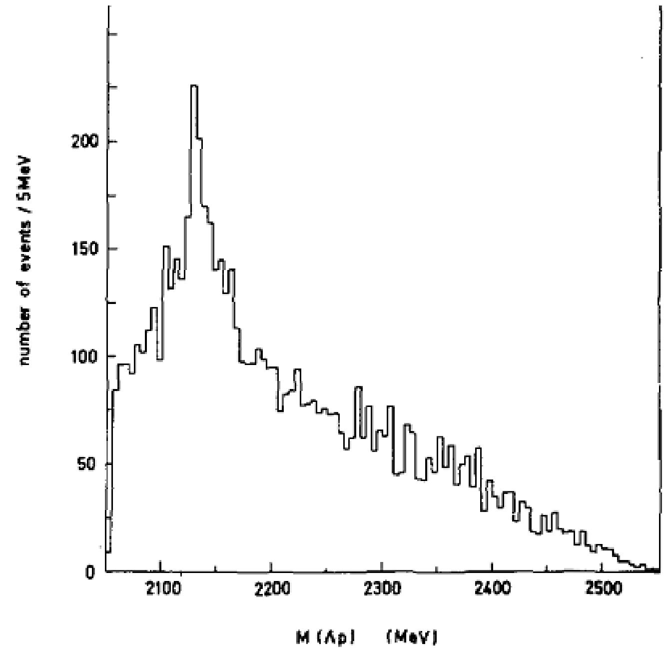
D. Eastwood et al., PRD3(1971)2603
$K^-d \rightarrow \Lambda p\, \pi^- X$ (1.45 GeV/c and 1.65 GeV/c)



Signal also compatible with a threshold (ΣN) cusp effect (no resonance needed)

D. Cline et al., PRL20(1968)1452
$K^-d \rightarrow \Lambda p\, \pi^- X$ (400 MeV/c)

Nuclear Physics B124 (1977) 45–60



ON THE Λp ENHANCEMENT NEAR ΣN THRESHOLD

O. BRAUN, H.J. GRIMM *, V. HEPP, H. STROEBELE,
C. THOEL ** and T.J. THOUW ***
Institut für Hochenergiephysik der Universität Heidelberg, BRD

F. GANDINI ‡, C. KIESLING ‡‡, D.E. PLANE ‡‡‡ and W. WITTEK
Max-Planck-Institut für Physik und Astrophysik, München, BRD

Received 17 February 1977

New high statistics bubble chamber data on $K^-d \rightarrow \Lambda p \pi^-$ at incident K^- momenta between 680 and 840 MeV/*c* were used to study the enhancement in the effective Λp

Nuclear Physics B124 (1977) 45–60

ON THE Λp ENHANCEMENT NEAR ΣN THRESHOLD

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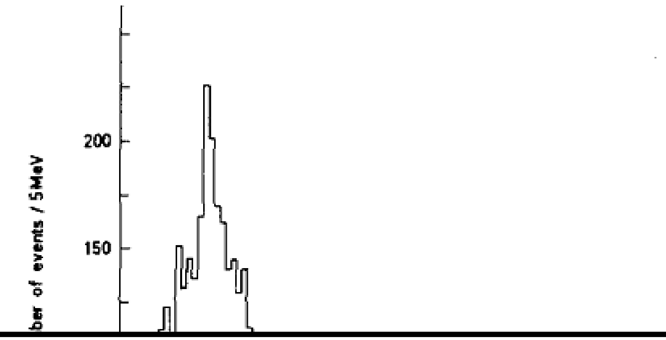
Institut f

F. GAN
Max-Plan

Received

New
between



PHYSICAL REVIEW VOLUME 187, NUMBER 5 25 NOVEMBER 1969

Search for a Λp Resonance

P. L. Jain
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(Received 11 July 1969)

In the analysis of K^- capture at rest with nuclear emulsions, we reported,[1] in 1963, with rather limited

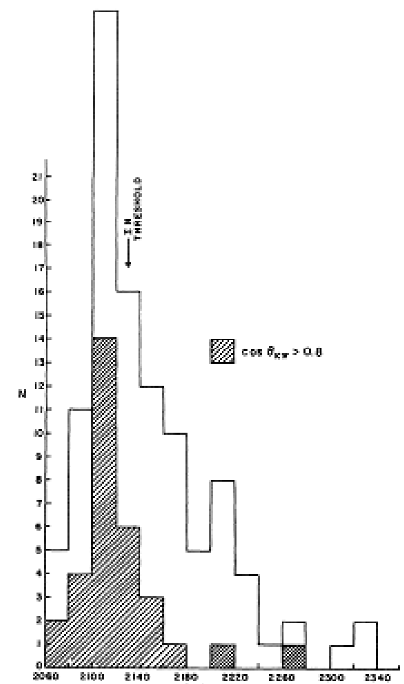


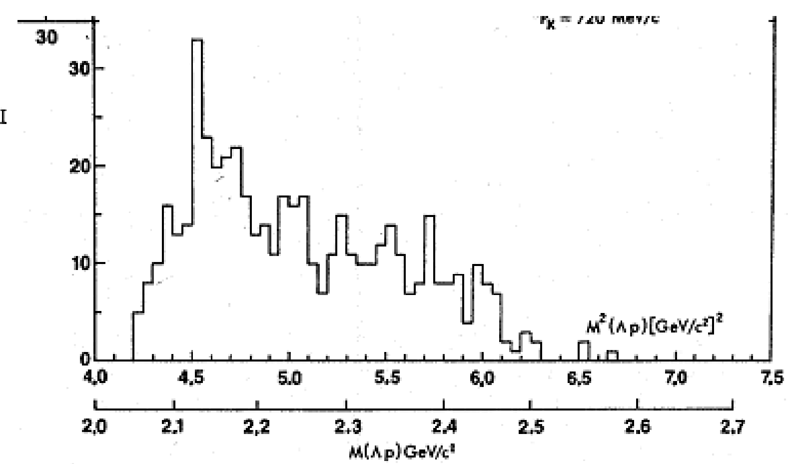
Fig. 4. Λp invariant-mass spectrum for reaction Eqs. (2) and (4). The dashed spectrum is for events with $\cos\theta_{K\pi}>0.8$, where $\theta_{K\pi}$ is the angle between the incident K and the outgoing π in the K^-N c.m. system.

PHYSICAL REVIEW D VOLUME 3, NUMBER 5 1 MARCH 1971

Study of the Nonimpulse Events in the Reactions $K^-d \to \Lambda\pi p$ and $\Lambda\pi\pi N$ at 670–925 MeV/c*

W. H. SIMS,† J. S. O'NEALL,‡ J. R. ALBRIGHT, E. B. BRUCKER,§ AND J. E. LANNUTTI
Department of Physics, The Florida State University, Tallahassee, Florida 32306

(Received 24 September 1970)



PHYSICAL REVIEW D VOLUME 3, NUMBER 5 1 MARCH 1971

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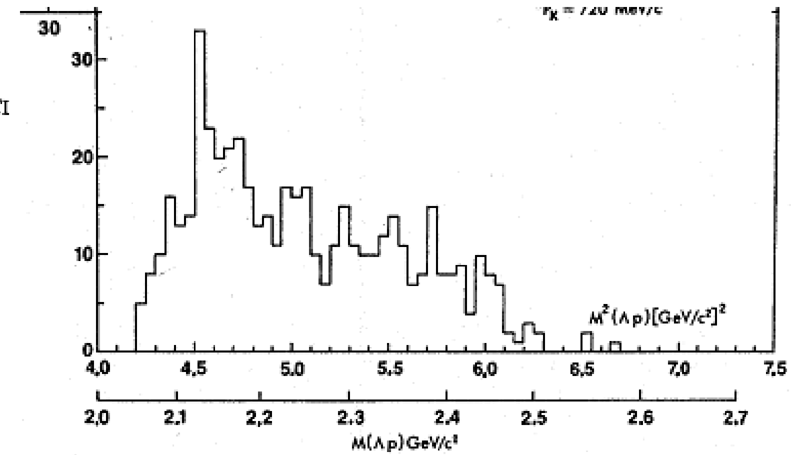
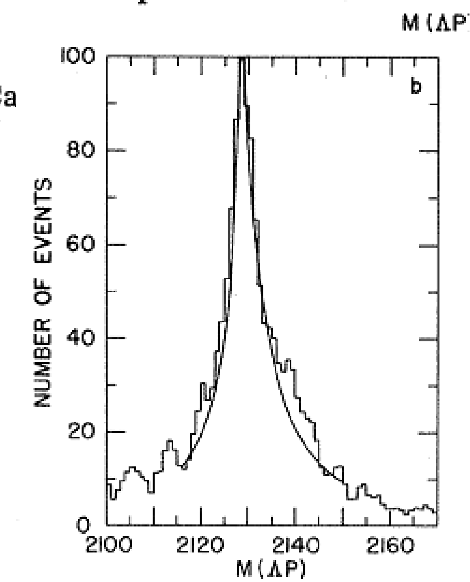


VOLUME 23, NUMBER 7 PHYSICAL REVIEW LETTERS 18 AUGUST 1969

STUDY OF HYPERON-NUCLEON INTERACTION IN THE REACTION $K^{-}d \to \pi^{-}p\Lambda$ AT REST*

Tai Ho Tan
Stanford Linear Accelerator Center, Stanford University, Stanford, Ca
(Received 30 June 1969)



PHYSICAL REVIEW D VOLUME 3, NUMBER 5 1 MARCH 1971

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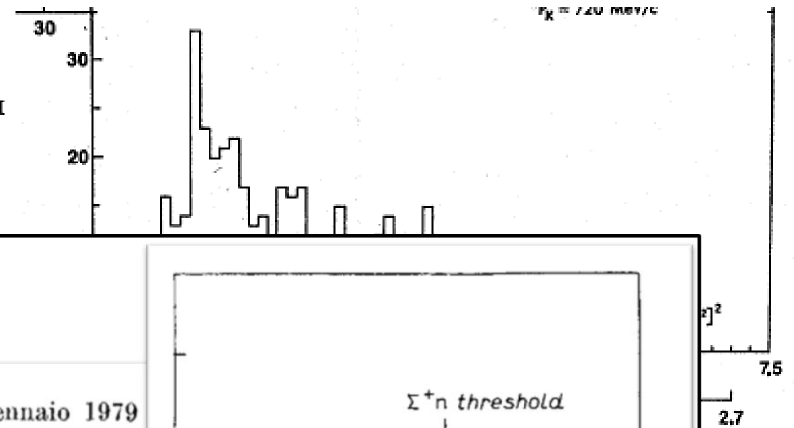
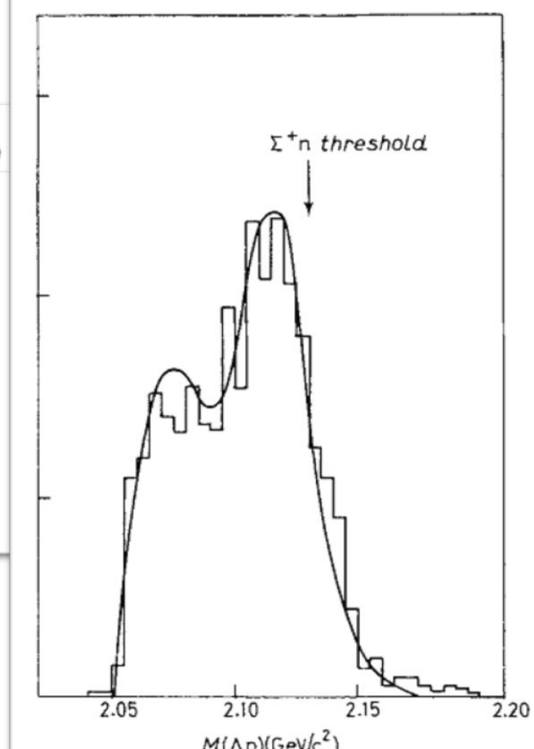


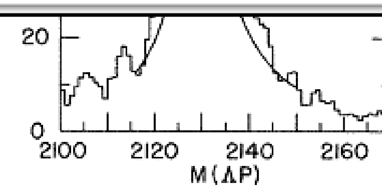
IL NUOVO CIMENTO Vol. 49 A, N. 2 21 Gennaio 1979

A Study of the $\Lambda\pi^-$pd Final State Produced in K^--Meson Interactions at Rest in Helium (*).

R. Roosen (**), C. Vander Velde-Wilquet and J. H. Wickens (***)
Interuniversity Institute for High Energies, ULB-VUB - Brussels, Belgium

C. Comber (***), D. H. Davis and D. N. Tovee (***)
University College London - London, U. K.





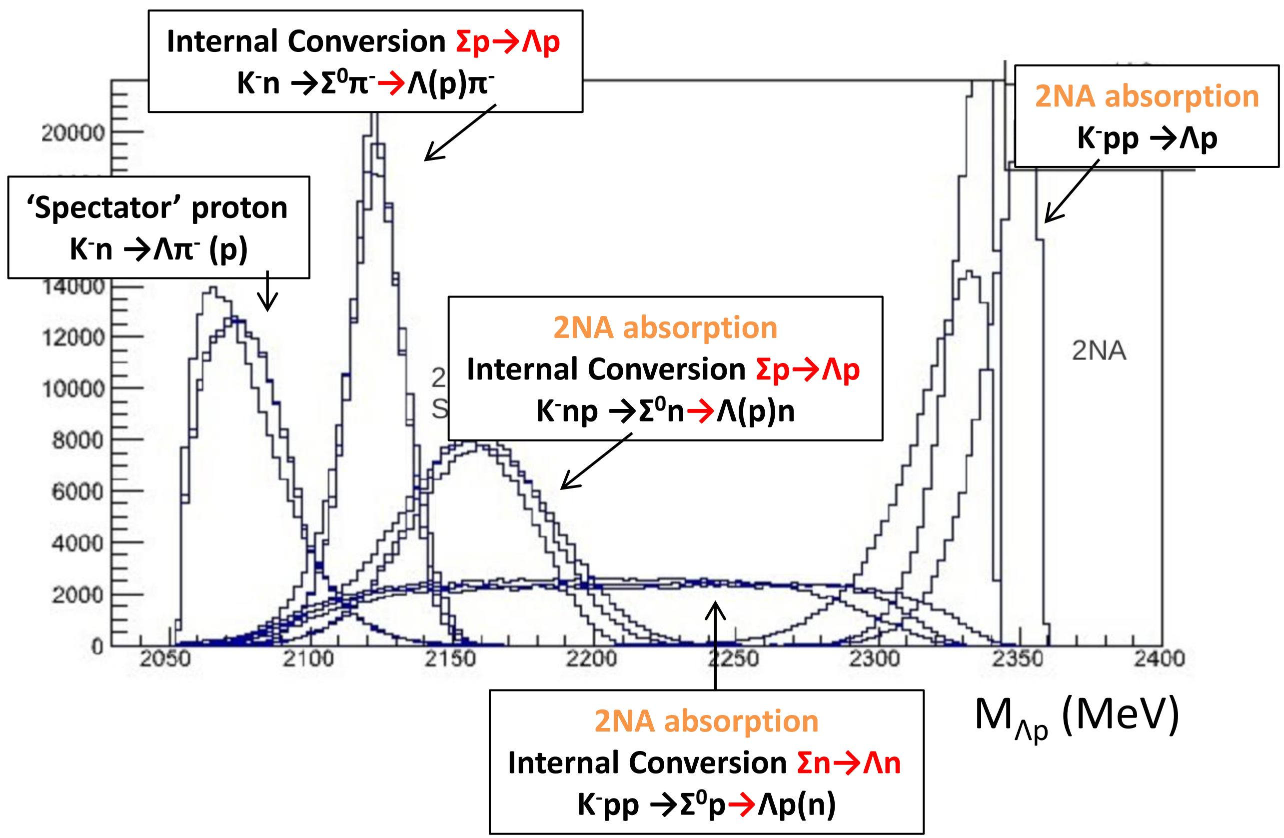
Λp analysis: Monte Carlo

Simple Monte Carlo simulations of **1NA, 2NA, ΣN/ΛN** and taking into account:

- Available phase space of decays and absorptions
- Fermi momentum of Nucleons
- Recoil KE of residual nucleus
- Binding energy of last nucleon of 12C and 4He
- Initial momentum of K-

True MC simulation
(no accept.)

3 processes simulated:
-interaction in **C at rest**
-interaction in **C in flight**
-interaction in **He at rest**



Λp analysis: events in DC GAS

$$\frac{N_{KHe}}{N_{KC}} = \frac{n_{He}\,\sigma_{KHe}}{n_C\,\sigma_{KC}}.$$

$$\frac{n_{He}}{n_C} = 2.263.$$

$$\frac{N_{KHe}}{N_{KC}} = 1.6 \pm 0.2.$$

K^- stopped in the DC gas

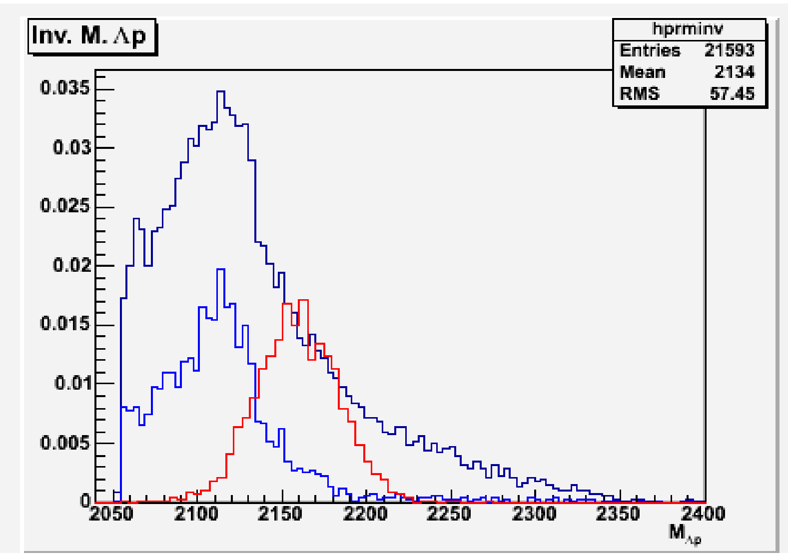
$N_{KHe} / N_{KC} \sim$ **3,6**

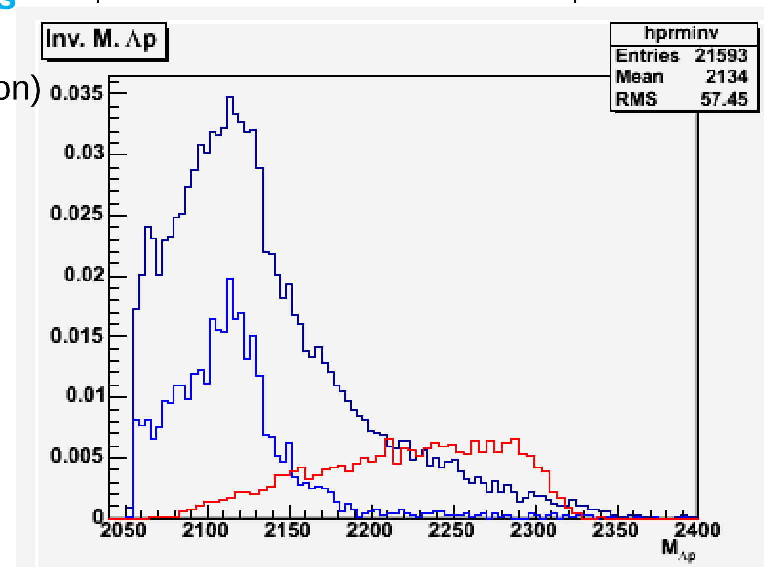
Λp analysis: MC 2NA

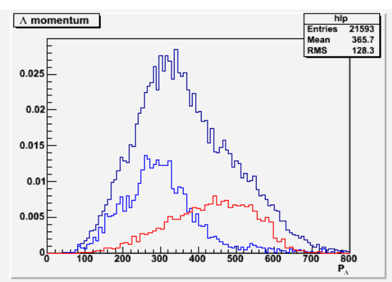
2NA absorption
Internal Conversion $\Sigma(p) \rightarrow \Lambda(p)$
$K^- np \rightarrow \Sigma^0 n \rightarrow \Lambda(p)n$

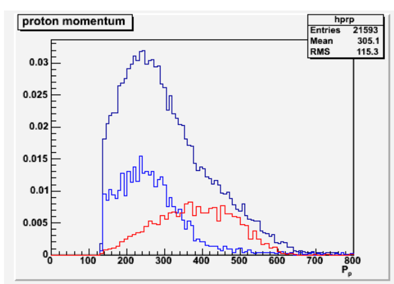
DATA Λp all events
DATA $\Lambda \pi^- p$ events
MC
(arbitrary normalization)

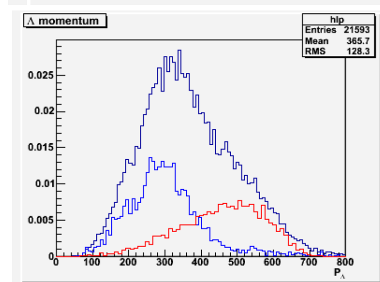
2NA absorption
Internal Conversion $\Sigma(n) \rightarrow \Lambda(n)$
$K^- pp \rightarrow \Sigma^0 p \rightarrow \Lambda p(n)$

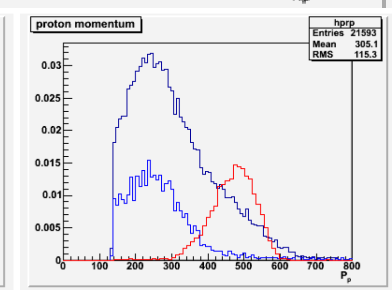






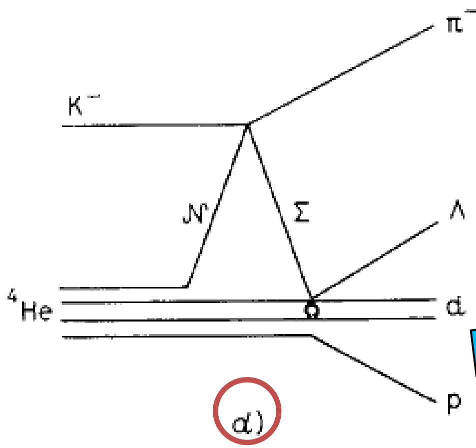


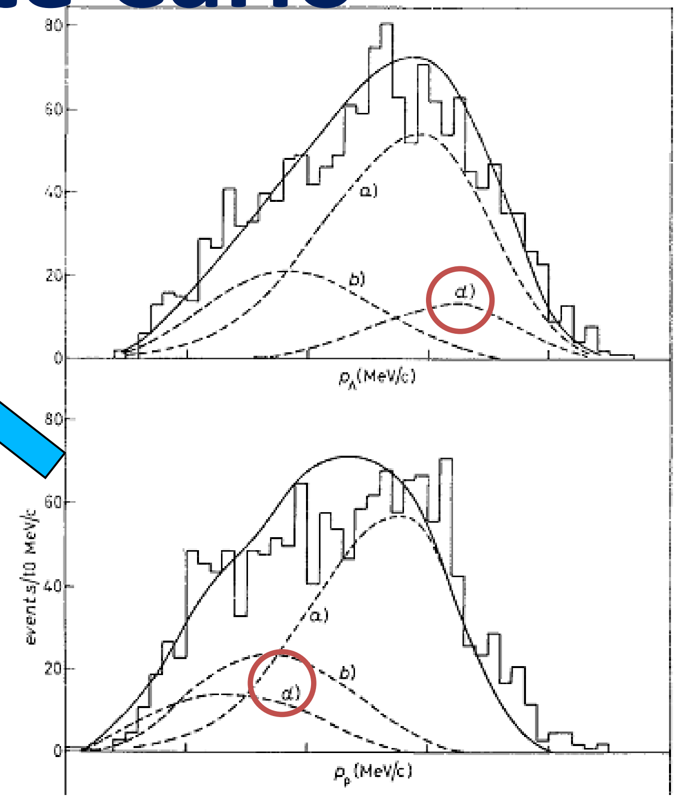




Λp analysis: Monte Carlo

- What was **not simulated**:
  - Low momentum proton process: ‘doble nucleon conversion’





IL NUOVO CIMENTO Vol. 49 A, N. 2 21 Gennaio 1979

A Study of the $\Lambda\pi^-pd$ Final State Produced in K^--Meson Interactions at Rest in Helium (*).

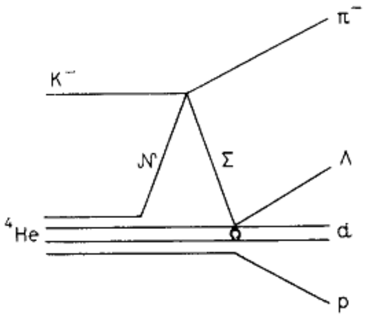
R. Roosen (**), C. Vander Velde-Wilquet and J. H. Wickens (***)

Interuniversity Institute for High Energies, ULB-VUB - Brussels, Belgium

C. Comber (*.*), D. H. Davis and D. N. Tovee (.*.)

University College London - London, U. K.

Λp analysis: coincidence with fast d

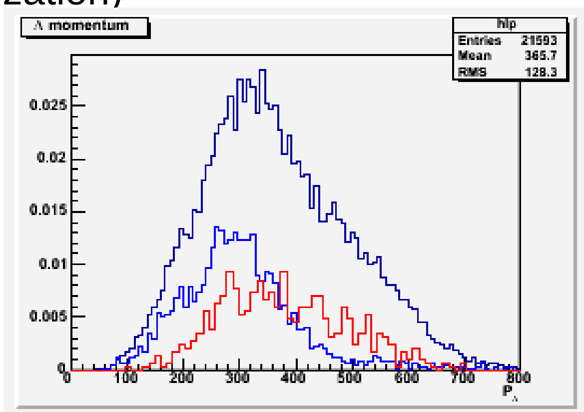


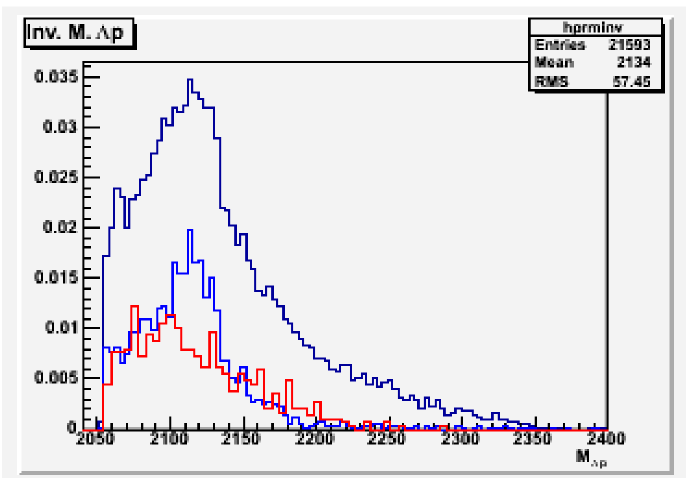
DATA Λp all events

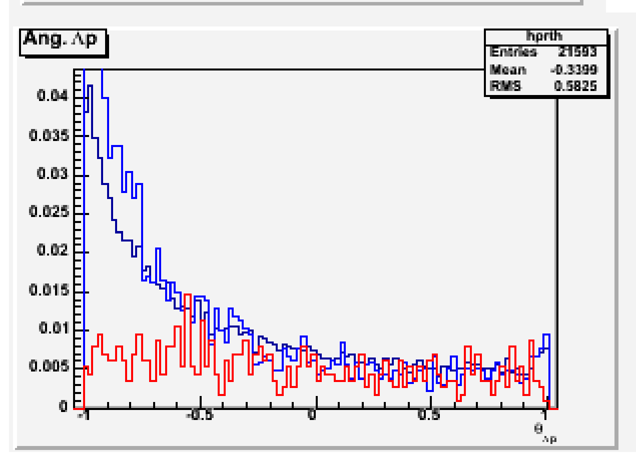
DATA Λπ⁻p events

DATA: Λpd events ← CARBON (DC wall) events

(arbitrary normalization)





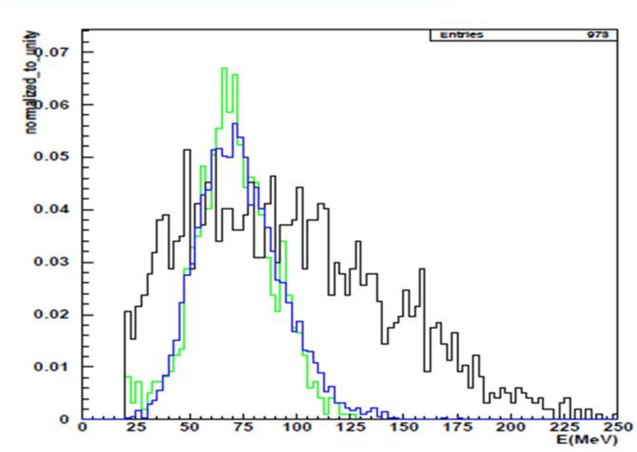


No Lambda-proton angular correlation →

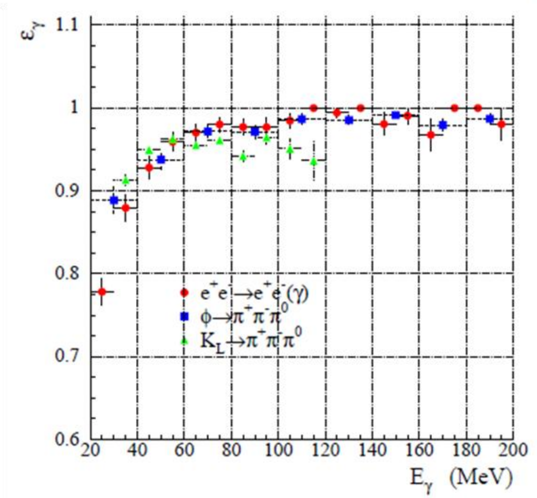
Search for the 2NA: K-(pp) -> **Λp**

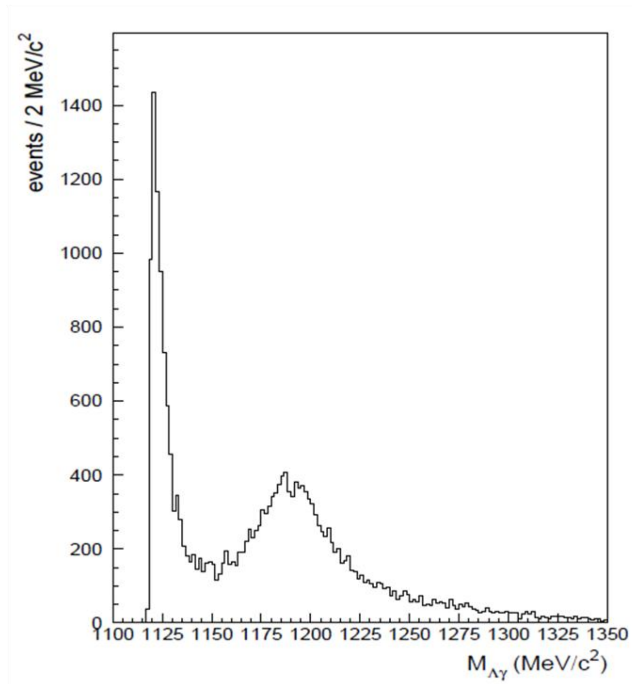
- Use the calorimeter: **remove Σ^0 decay** (-> Λγ) contamination
- Use the **12C data** (more statistics) in the DC wall

Use of the calorimeter: Photon detection



Black -> **energy of photons from π^0**
Blue -> **energy of photons from Σ^0 -> Λγ**

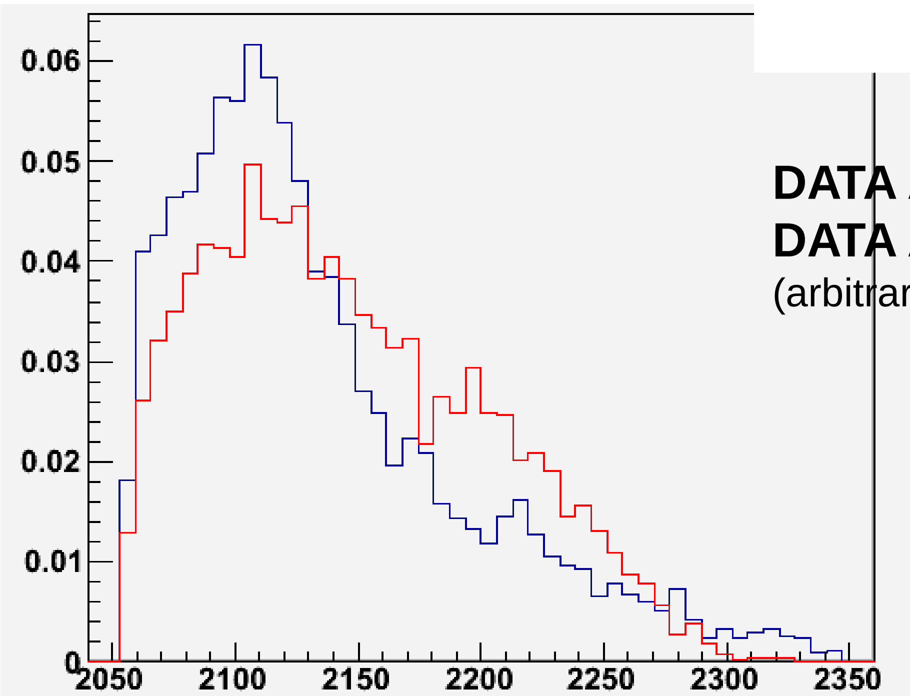




Σ^0 contamination in Λp events

Search for the 2NA: K-(pp) -> **Λp**

- Use the calorimeter: **remove Σ^0 decay** (-> Λγ) contamination
- Use the **12C data** (more statistics) in the DC wall

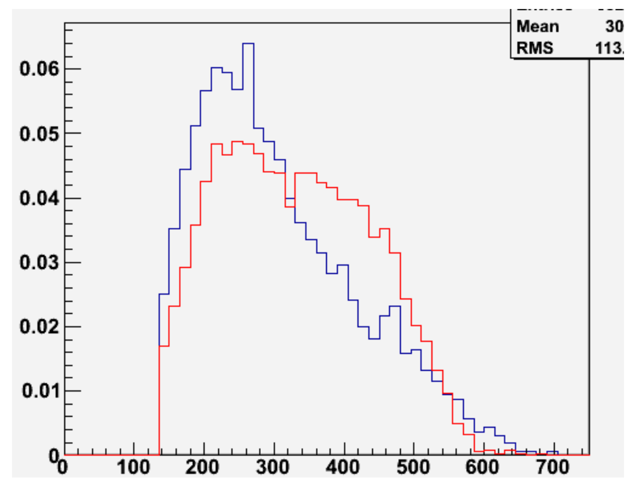


$M_{\Lambda p}$ (MeV)

DATA Λp events in ^{12}C, NO Σ^0 decay

DATA Λp events in ^{12}C with Σ^0 decay contamina

(arbitrary normalization)



P_p (MeV)

Search for the 2NA: K-(pp) -> **Λp**

- Use
- Use