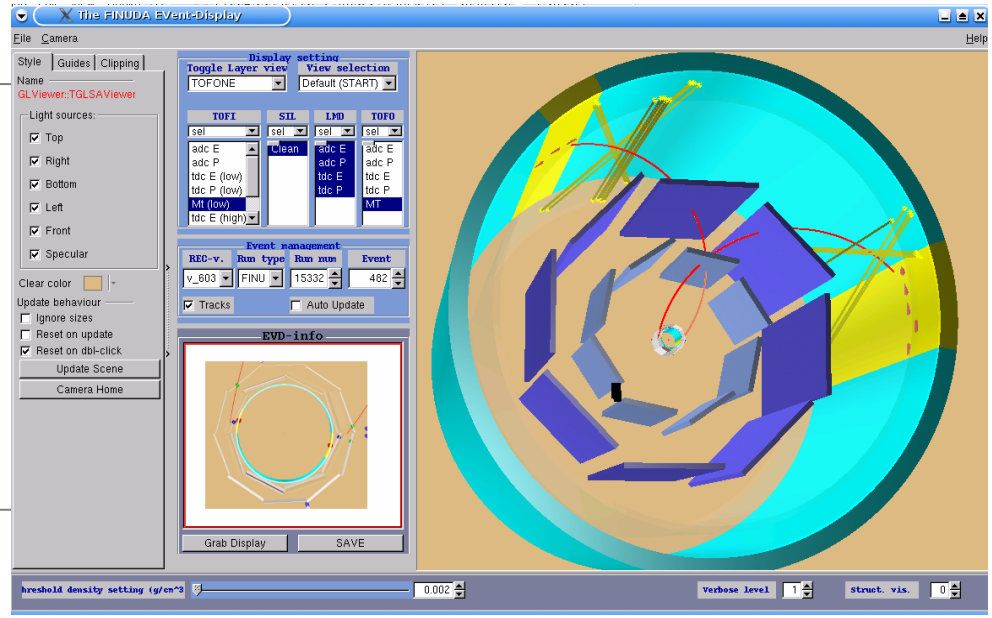
Proton Energy Spectra

from NMWD

Track Selection

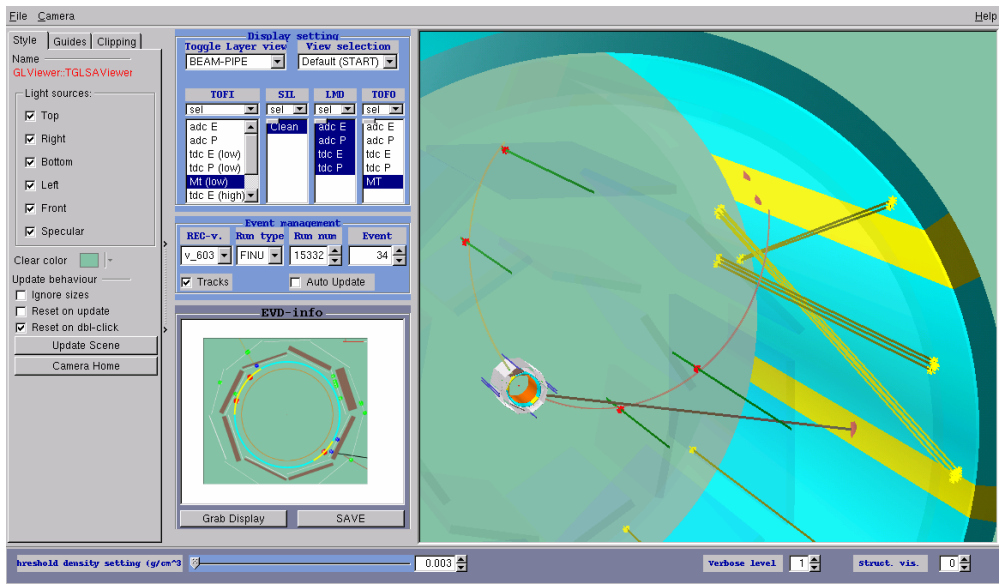
Four hits pattern

- ✓ ISIM-OSIM-DCH1-DCH2
- ✓ OSIM-DCH1-DCH2-STRAW
- ✓ ISIM-OSIM-DCH1-STRAW
- ✓ ISIM-OSIM-DCH2-STRAW



Three hits pattern

- ✓ OSIM-DCH1-DCH2
- ✓ ISIM-OSIM-DCH1
- ✓ ISIM-OSIM-DCH2



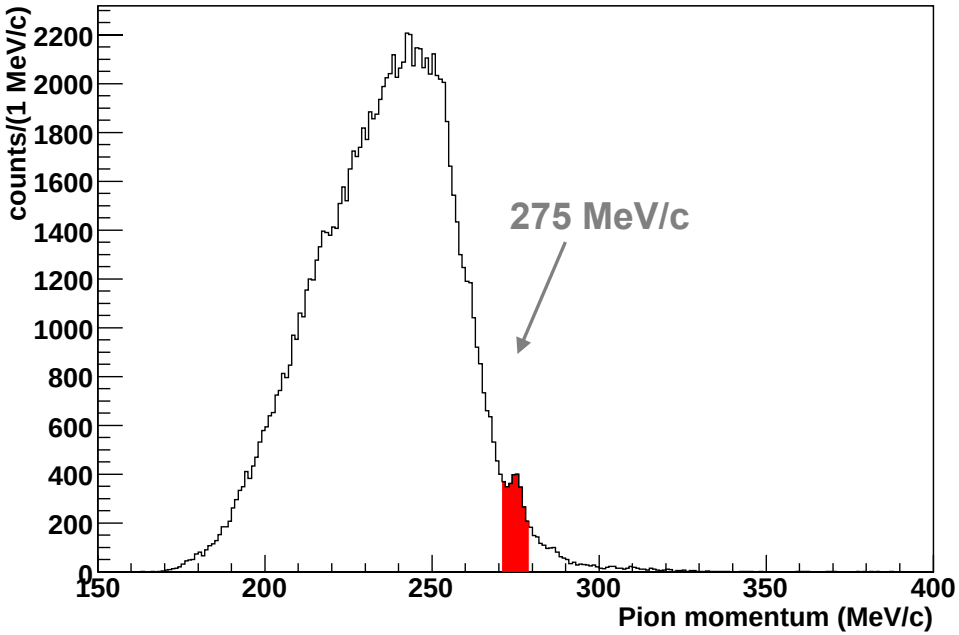
Proton Energy Spectra

from NMWD of

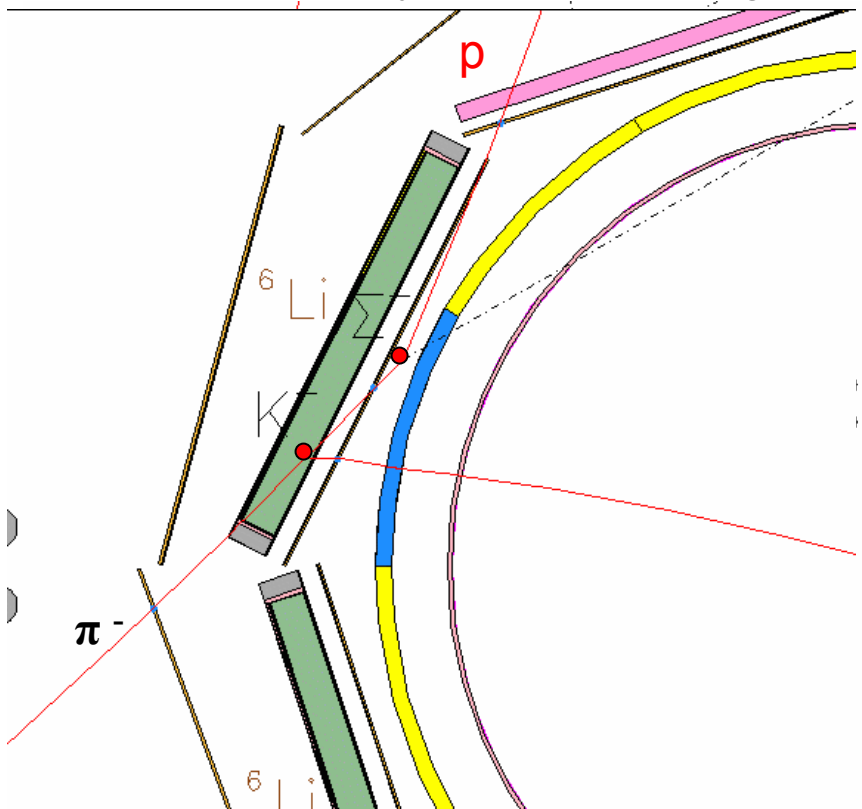
$^{7}_{\Lambda}$Li

π^- spectrum for ^{7}Li targets (1)

Inclusive spectrum of negative pions
summing the two ^{7}Li targets



- pion momentum reconstructed and corrected for energy loss in the crossed materials and quality cut on track fitting

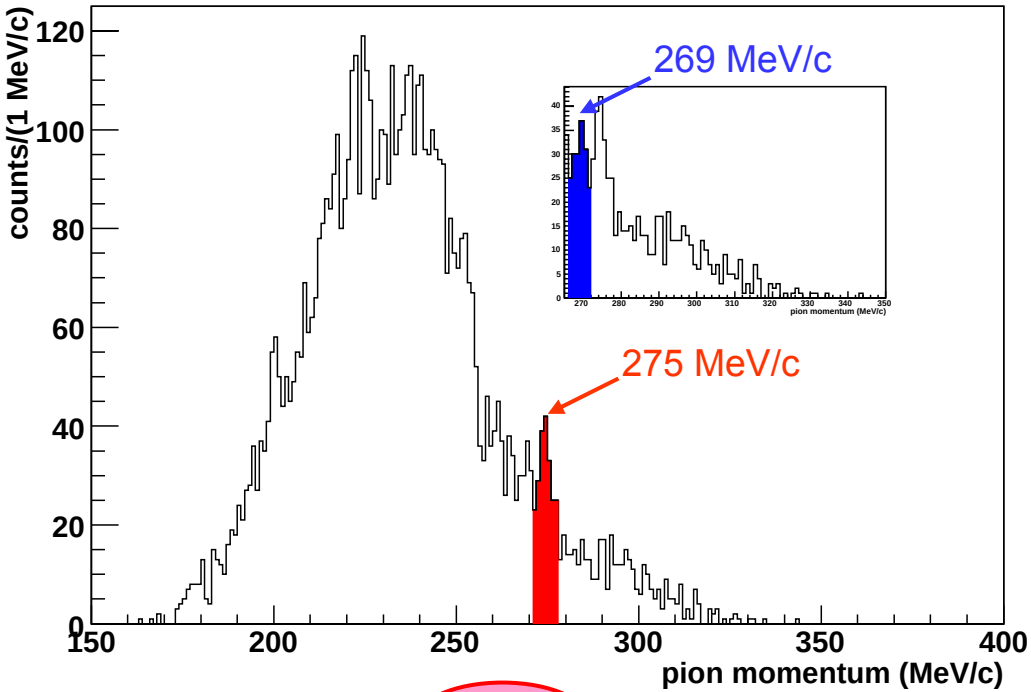


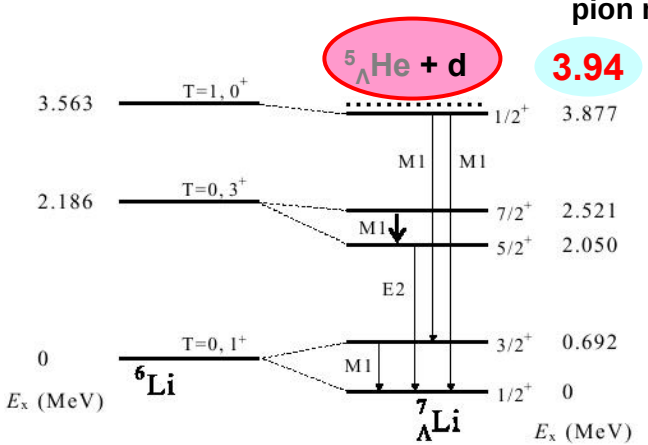
Background reduction

cut on the distance between the π^- extrapolated track point and the K^- vertex (d<0.3 cm)

→ Optimization of the signal to background ratio

π^- spectrum for ^{7}Li targets (2)





- Spectrum of negative pions for events with an additional proton
- Asking for the proton coincidence close to the ground state peak (275 MeV/c) a second peak appears (269 MeV/c)
- when a K^- is stopped in a ^{7}Li target one can produce: $^7_\Lambda$Li, ($^6_\Lambda$He+p), ($^5_\Lambda$He+d), ($^4_\Lambda$He+t), ($^3_\Lambda$He+α).
- Hypernuclear systems with the lowest masses →

$K^-_{stop} + {}^7\text{Li} \rightarrow {}^7_\Lambda\text{Li} + \pi^-$

$K^-_{stop} + {}^7\text{Li} \rightarrow {}^5_\Lambda\text{He} + \text{d} + \pi^-$

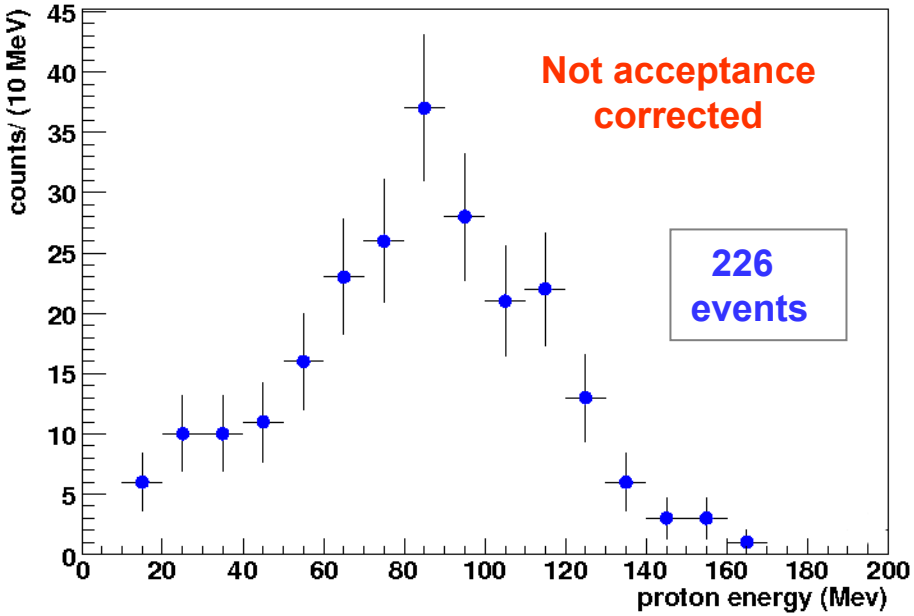
Maximum momentum value

(272,67 MeV/c)

Experimentally

ΔB_Λ = 3.98 MeV

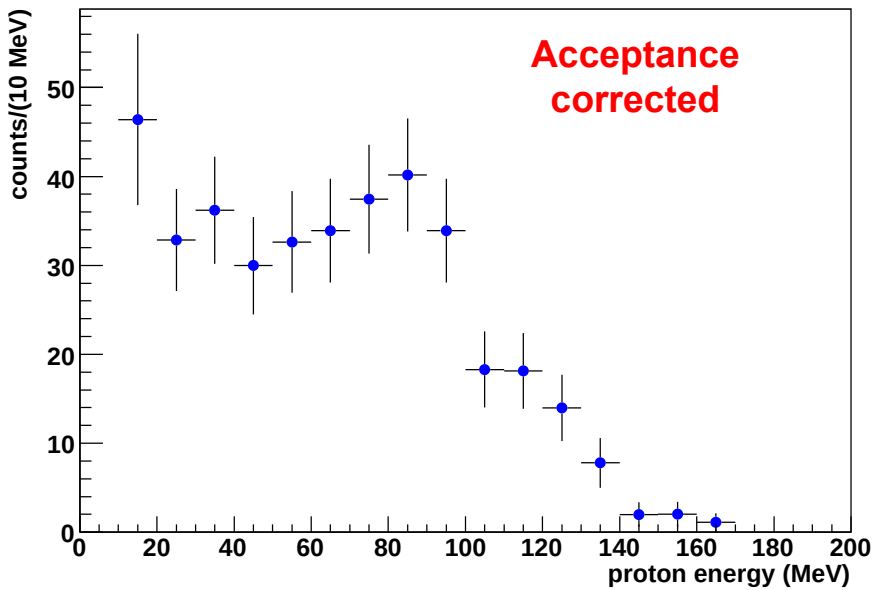
Proton spectra from $^{7}_{\Lambda}$Li NMWD



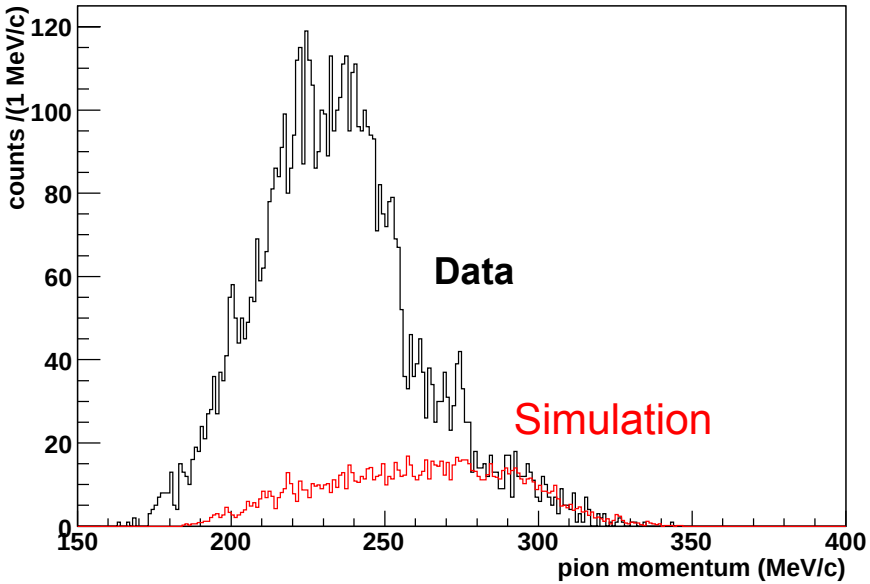
Proton energy spectrum in **coincidence** with a π^- from $^{7}_{\Lambda}$Li formation in the g.s. region.

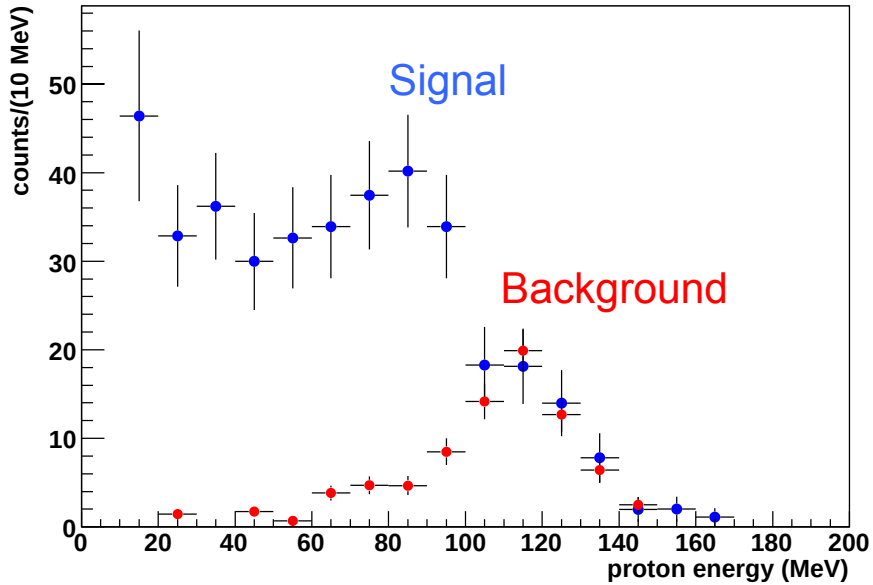
Use of thin target and the inclusion of short tracks for the proton selection allows to reduce the E_p low energy threshold. Spectrum shape at 15-40MeV important for FSI nucleon induced effects and possible two-nucleons absorption.

It is possible to study an energy range never studied before



Proton spectra from $^{7}_{\Lambda}$Li NMWD





Background Simulation: 4 millions of events generated in all the spectrometer → 3.6×10^{5} events with a K^- stopped in each ^{7}Li target

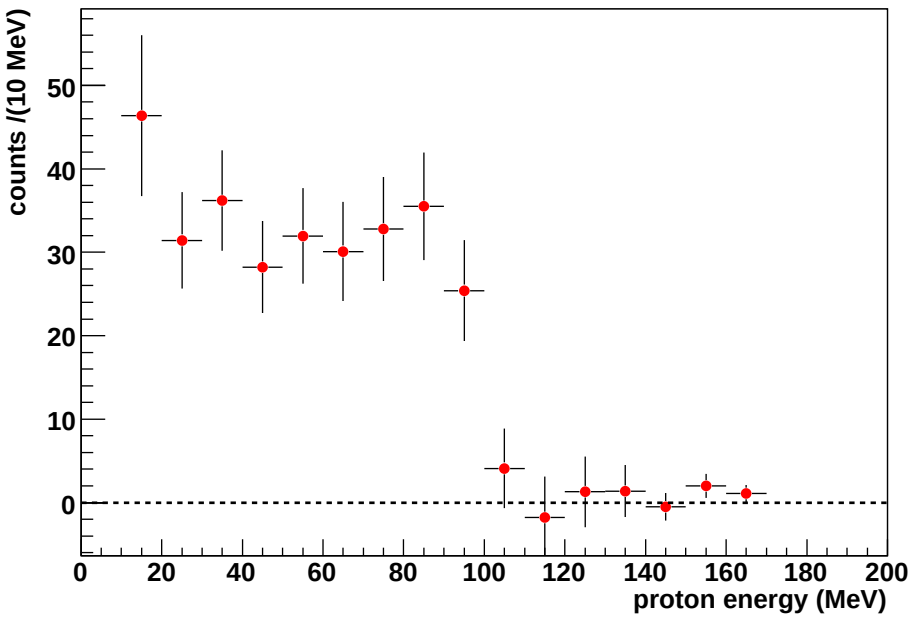
- ✓ Simulation of the background reaction

$$K^- np \rightarrow \Sigma^- p$$

Followed by the decay $\Sigma^- \rightarrow n\pi^-$

- ✓ the nucleons have a momentum according to a Fermi distribution
- ✓ selection criteria and quality cuts used for real data

$^{7}_{\Lambda}$Li NMWD



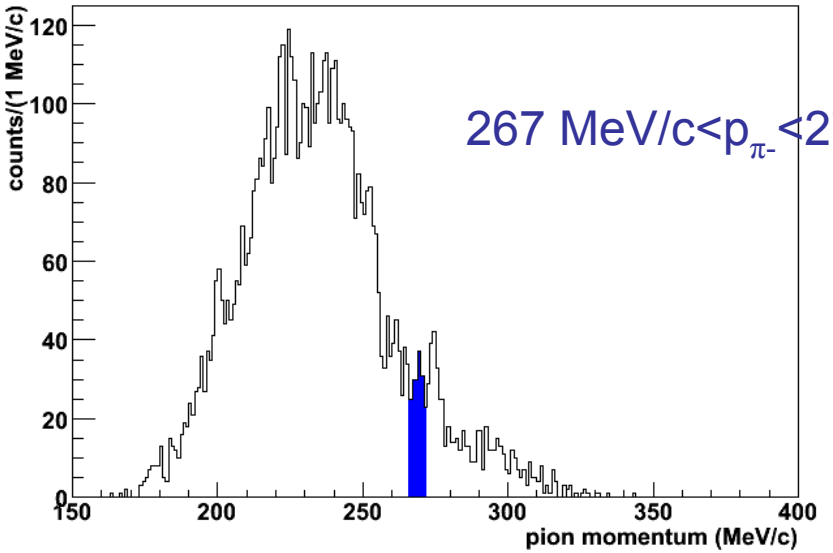
- **Proton energy spectrum** for the NMWD of $^{7}_{\Lambda}$Li
- Enhancement of the low energy region due to the proton rescattering inside the nucleus (FSI)
- The FSI is not so strong to eliminate the signal at 80 MeV.
- Statistical errors taking into account the errors on the acceptance calculation and on the background subtraction

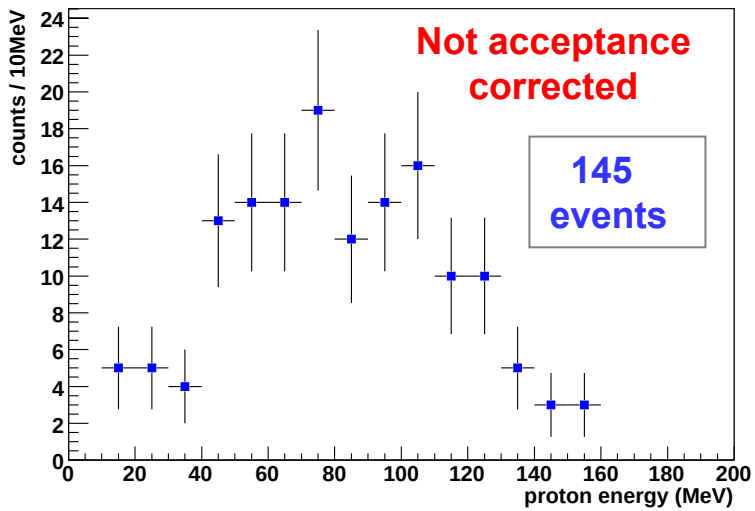
Proton Energy Spectra

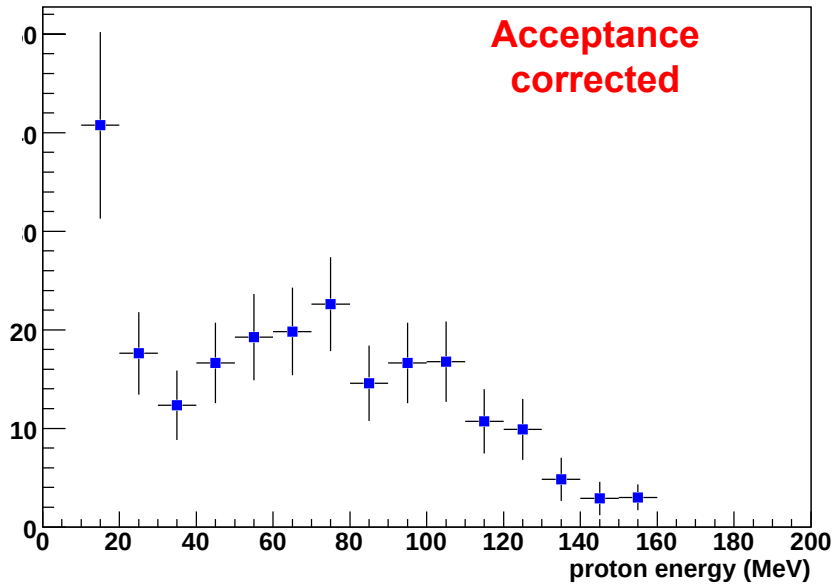
from NMWD of

$^{5}_{\Lambda}$He

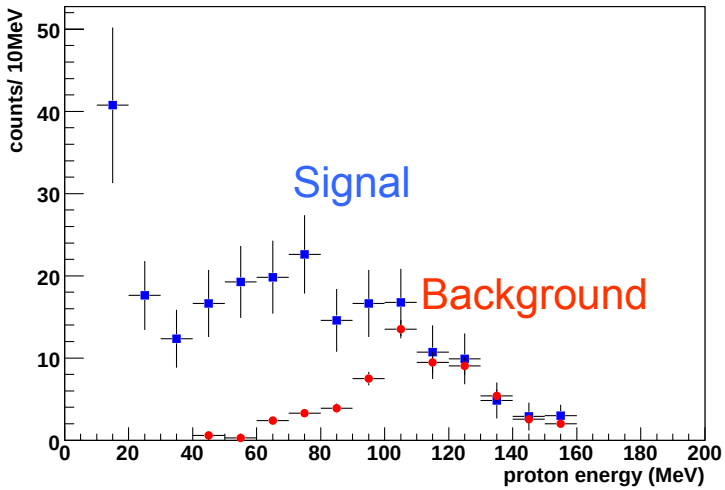
Proton spectra from $^{5}_{\Lambda}$He NMWD with ^{7}Li targets







Proton spectra from $^{5}_{\Lambda}$He NMWD

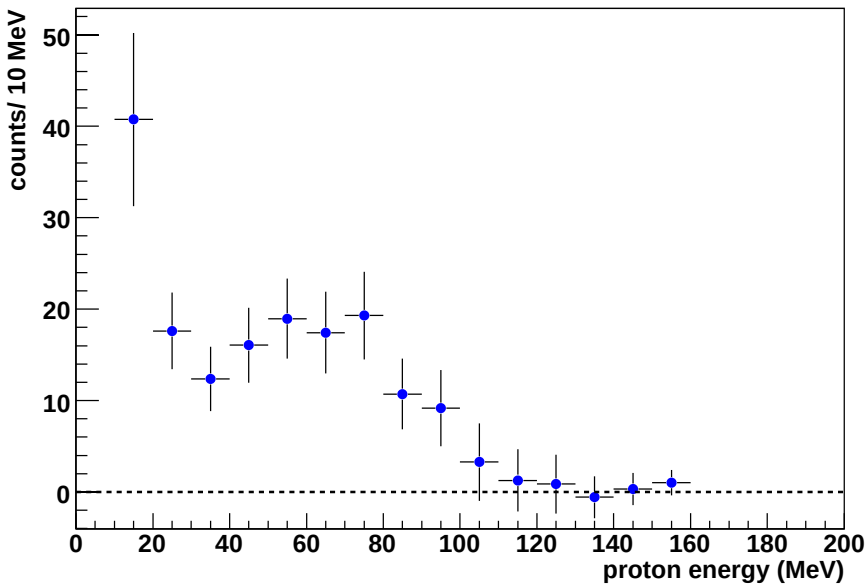


The background for the $^{5}_{\Lambda}$He has been evaluated taking with simulation of the $K^{-}np$ absorption reaction by subtracting the spectrum of the protons in coincidence with a π^{-} in the momentum region 267-272 MeV/c

- **Proton energy spectrum**

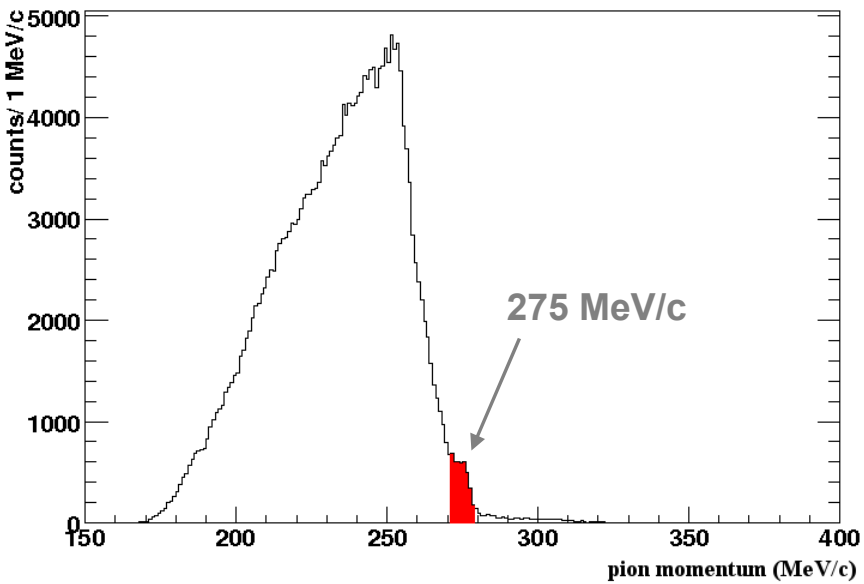
NMWD of $^{5}_{\Lambda}$He after the background subtraction

- Enhancement of the low energy region due to the FSI and multinucleons induced effects
- Bulk of the signal at 80 MeV (half of the Q value of the reaction)



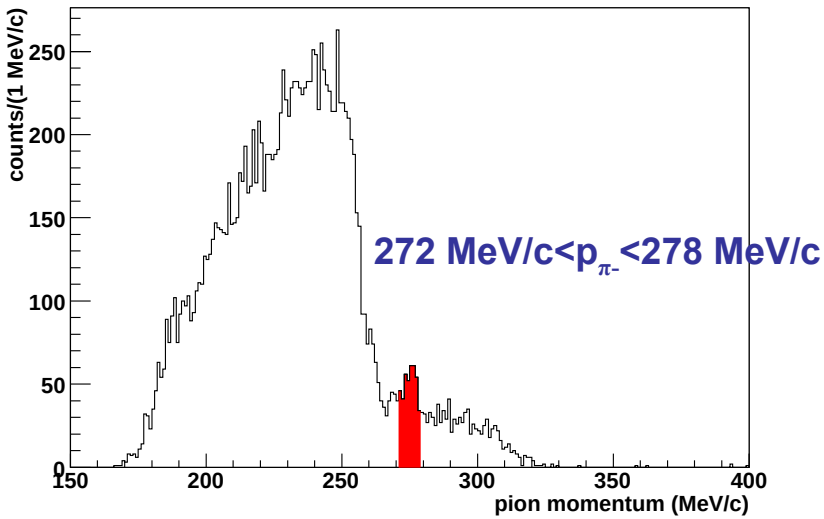
π^- spectrum for ^{6}Li targets

Inclusive spectrum of negative pions
(two ^{6}Li targets)



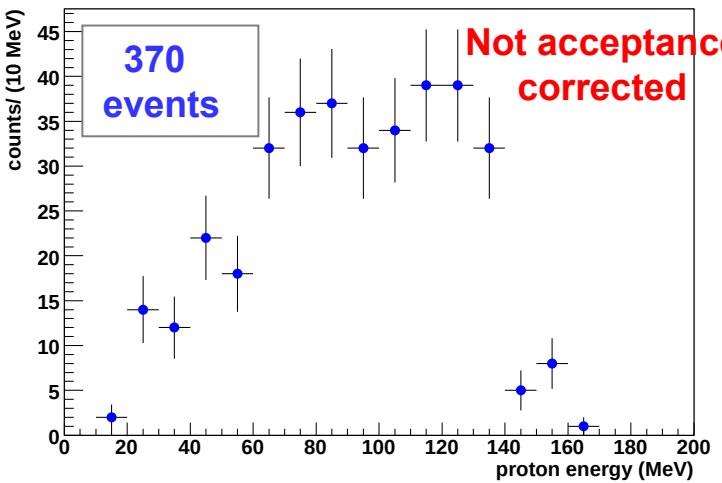
- pion momentum reconstructed and corrected for energy loss in the crossed materials and quality cut on track fitting
- The momentum region selected in red corresponds to the **$^6_\Lambda$Li ground state** formation (272 MeV/c<p_{π^-}<278 MeV/c).
- cut on the distance between the π^- extrapolated track point and the K- vertex (d<0.25cm)

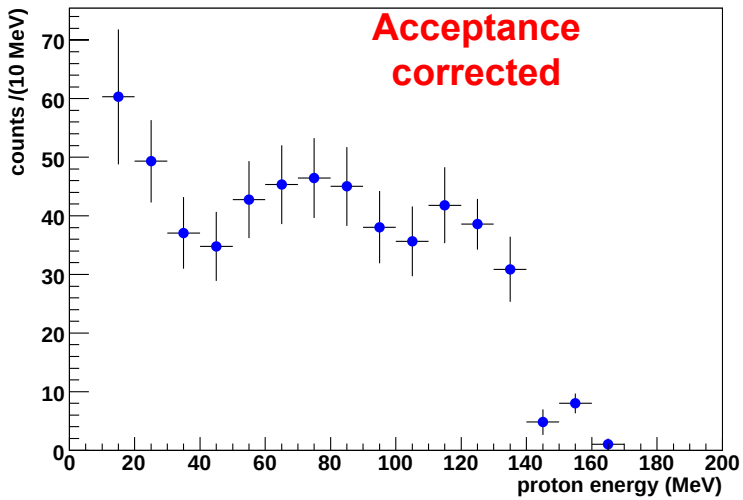
Proton spectra from $^{5}_{\Lambda}$He NMWD with ^{6}Li targets



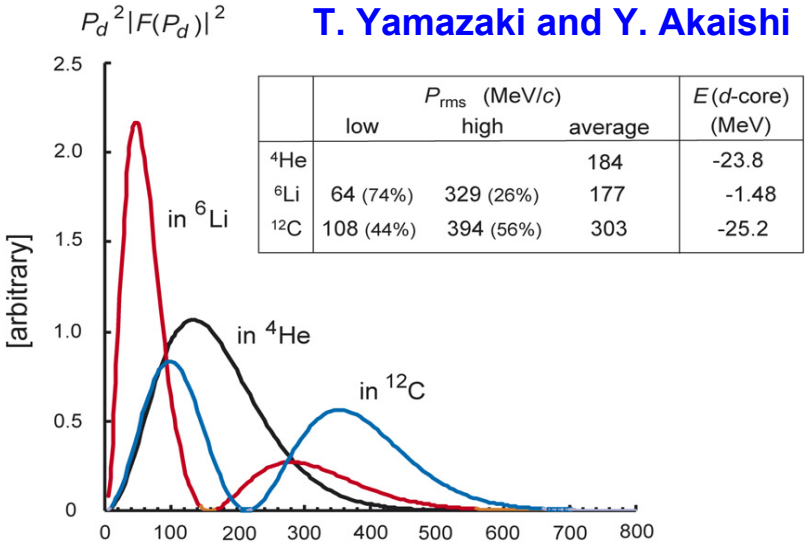
for events with an additional proton

- proton coincidence: a clear peak emerges at 275 MeV/c (ground state)
- The proton spectrum shows a shape different from the proton spectra obtained for the $^{7}_{\Lambda}$Li
- The difference can be addressed to the cluster substructure of the ^{6}Li nucleus





Background study for ^{6}Li target



	P_{rms} (MeV/c) low	high	average	E(d-core) (MeV)
^{4}He			184	-23.8
^{6}Li	64 (74%)	329 (26%)	177	-1.48
^{12}C	108 (44%)	394 (56%)	303	-25.2

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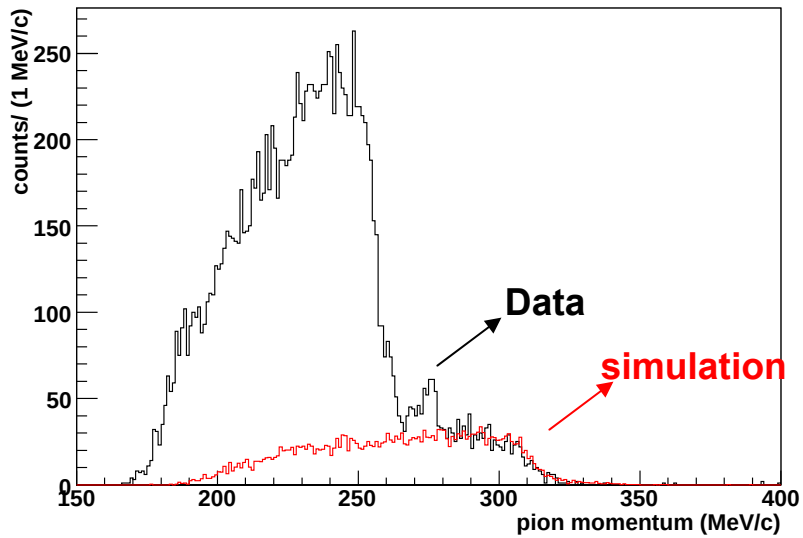
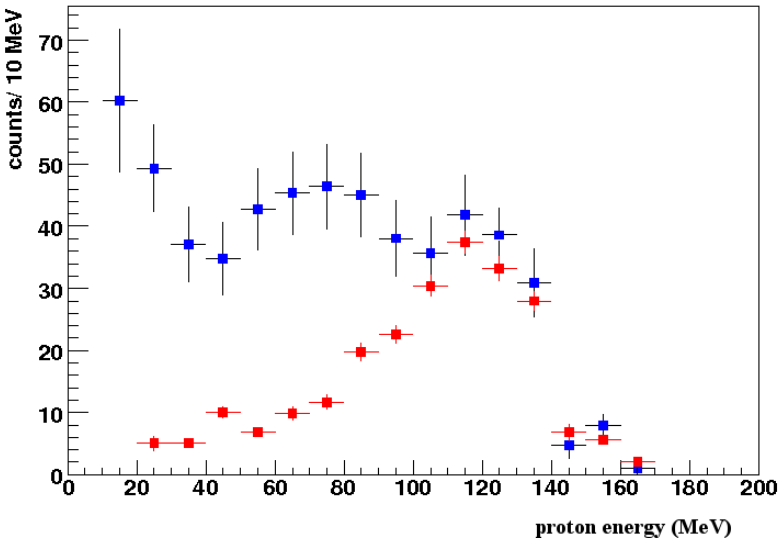
✓ The two-clusters structure of the **^{6}Li (α+d)** is a well known feature and it emerges from (π^+,2p) in flight reaction and (π^-, 2n) reactions at rest

✓The simulation of the background reaction takes into account the momentum distribution of a deuteron inside a ^{6}Li nucleus



Background Simulation: 3.5 millions of events generated in all the spectrometer → 4 ×10^5 events with a K^- stopped in a ^{6}Li target

Proton spectra from $^{5}_{\Lambda}$He NMWD with ^{6}Li targets

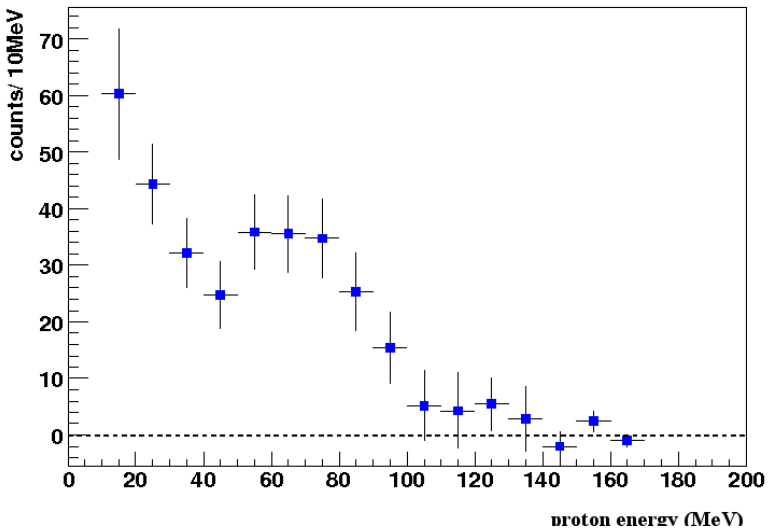


- **proton energy spectrum** for the NMWD of $^{5}_{\Lambda}$He after the acceptance correction
- energy spectrum of the proton detected in coincidence with a π^- from the simulation data

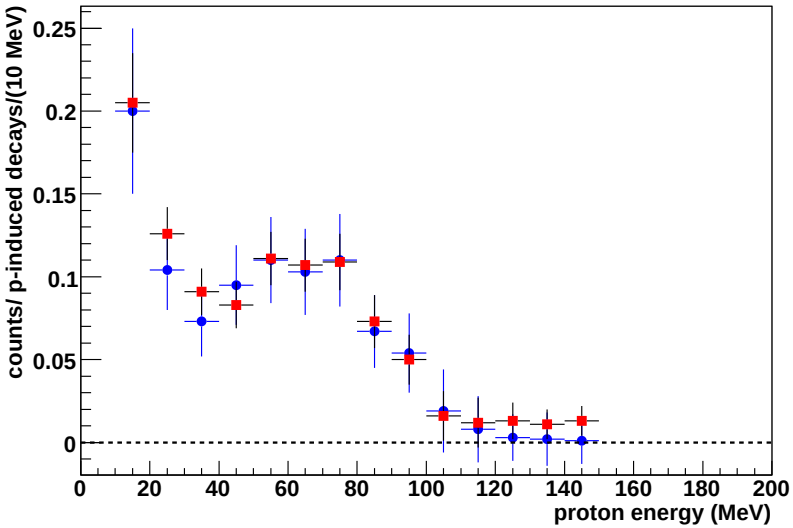
✓ **Proton energy spectrum** for the NMWD of $^{5}_{\Lambda}$He after the background subtraction

✓ Enhancement of the low energy region due to the FSI and two-nucleons induced decay

✓ The FSI contribution is not so strong to eliminate the signal at ~80 MeV half of the Q value of the reaction)



$^{5}_{\Lambda}$He NMWD

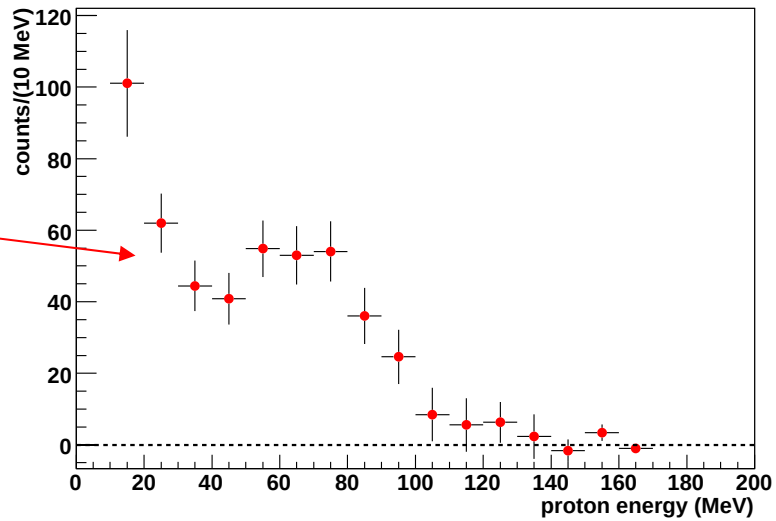


- **proton energy spectrum** for the NMWD of $^{5}_{\Lambda}$He from ^{7}Li targets
- proton energy spectrum for the NMWD of $^{5}_{\Lambda}$He from ^{6}Li targets

The two spectra are normalized to area beyond 15 MeV

- Kolmogorov-Smirnov test applied to the data gives a probability of compatibility P=0.89 at a confidence level of 95%
- The two spectra are fully compatible and can be added

Final spectrum of protons from $^{5}_{\Lambda}$He NMWD



Proton Energy Spectra

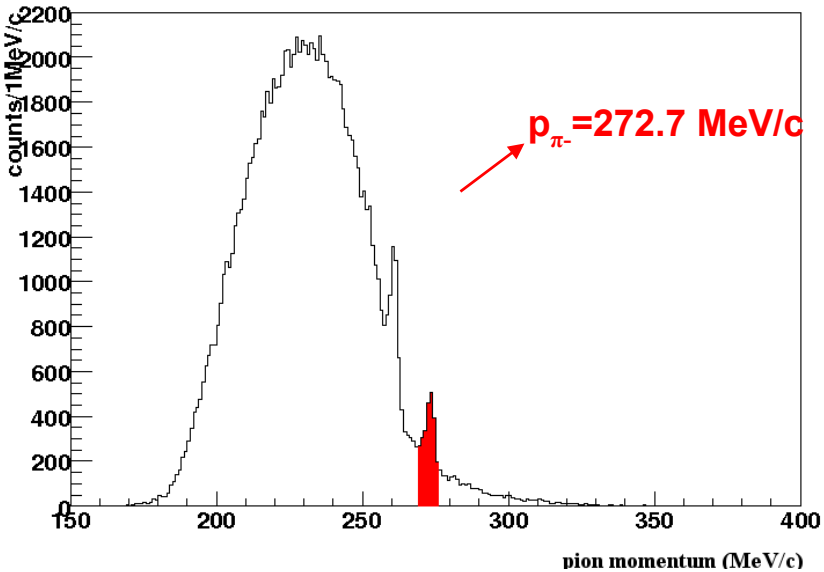
from NMWD of

$^{12}_{\Lambda}C$

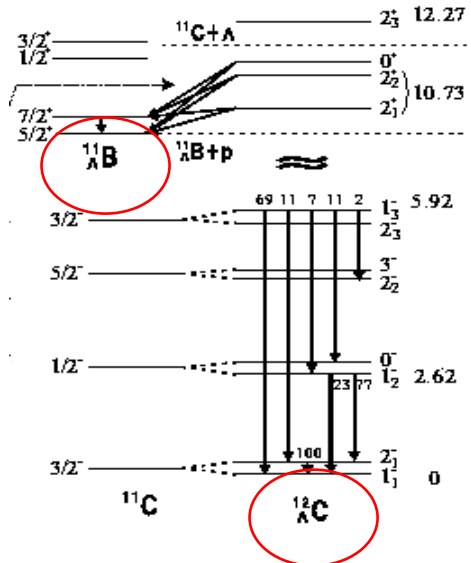
π^- spectrum for ^{12}C targets

Inclusive spectrum of negative pions

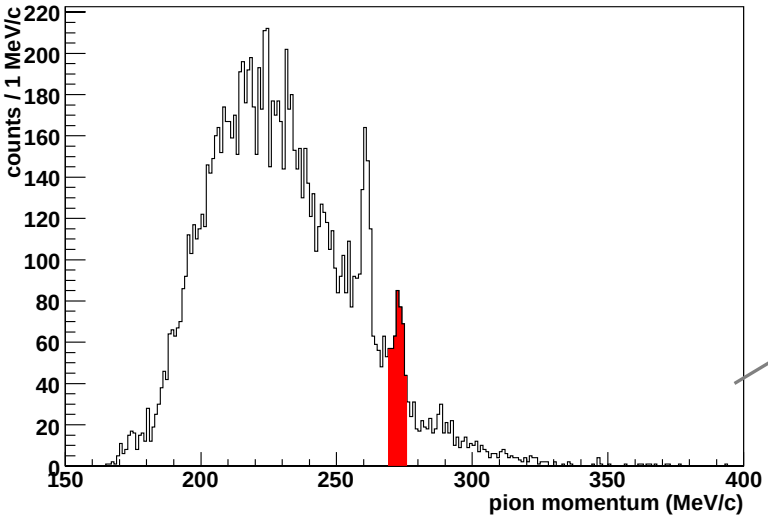
three ^{12}C targets



- The momentum region selected in red corresponds to the **$^{12}_{\Lambda}C$ ground state** formation (270 MeV/c<p_{π^-}<276 MeV/c).
- A second peak at a lower momentum value appears and it is due to the formation of the $^{11}_{\Lambda}B$
- Also for the ^{12}C analysis a cut on the distance between the π^- extrapolated track point and the K- vertex (d<0.3cm) is adopted.

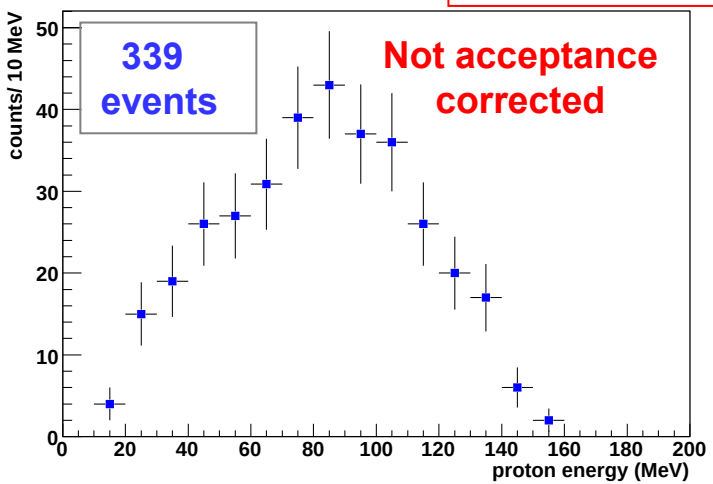


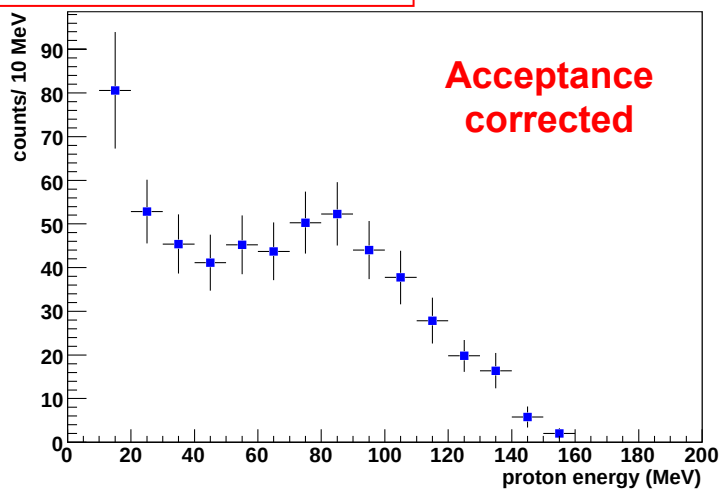
Proton spectra from $^{12}_{\Lambda}$C NMWD (1)



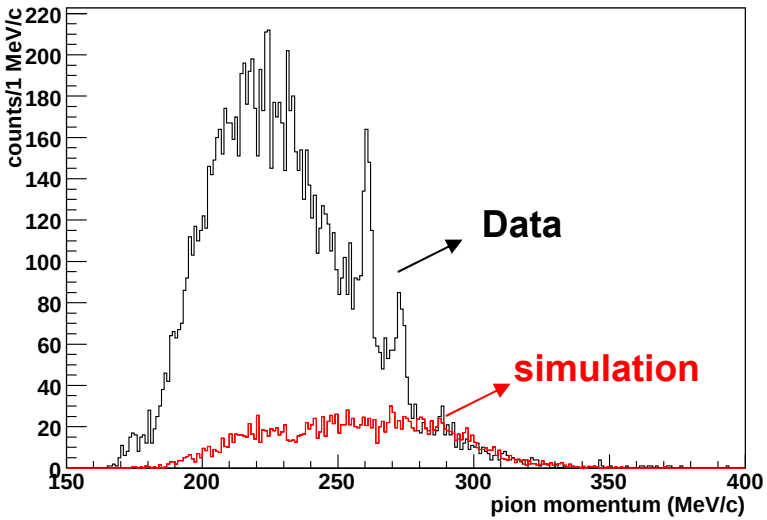
- for events in which a proton is detected in coincidence with a π^-
- Asking for the proton coincidence a clear peak emerge at 272 MeV/c (ground state)

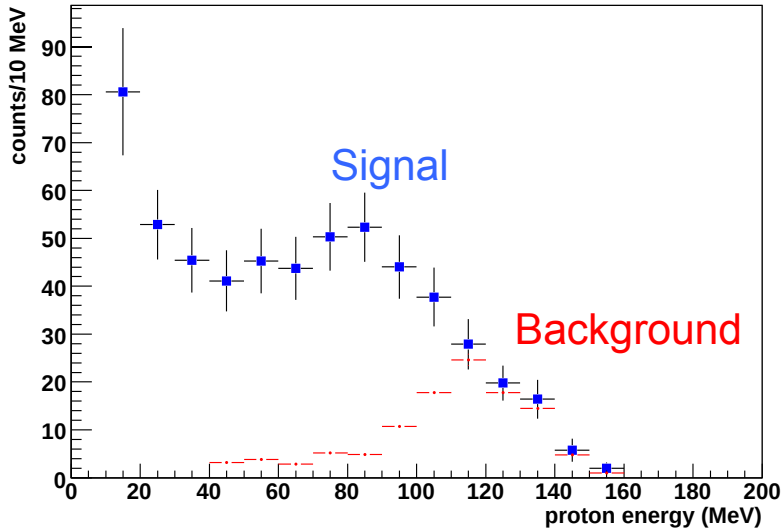
Proton energy spectrum from $^{12}_{\Lambda}$C proton-induced NMWD before and after the acceptance correction





Proton spectra from $^{12}_{\Lambda}$C NMWD (2)





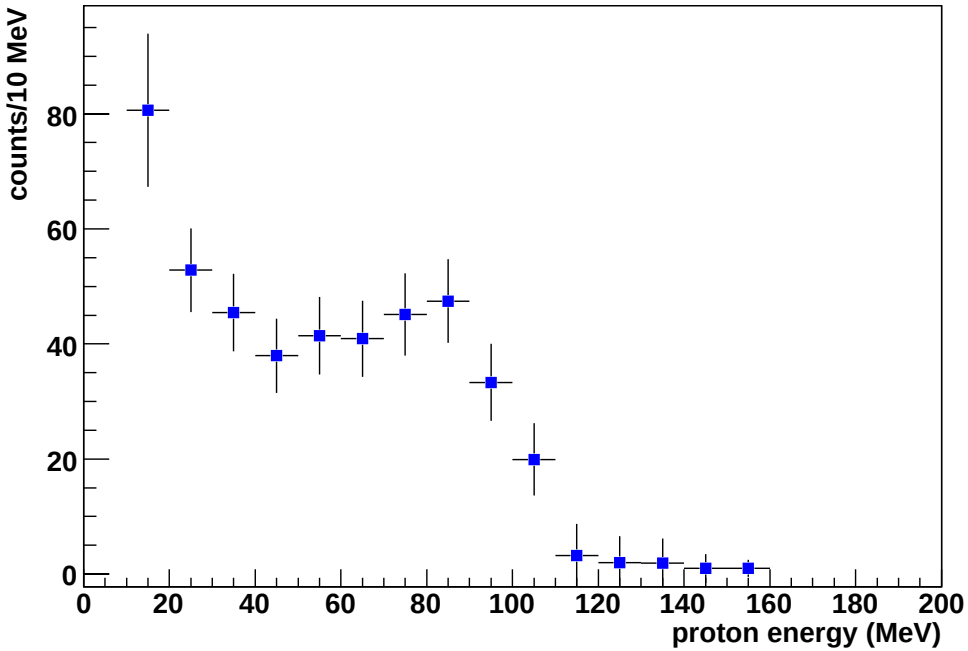
✓ Simulation of the background reaction

$K^- np \longrightarrow \Sigma^- p$

Followed by the decay $\Sigma^- \longrightarrow n\pi^-$

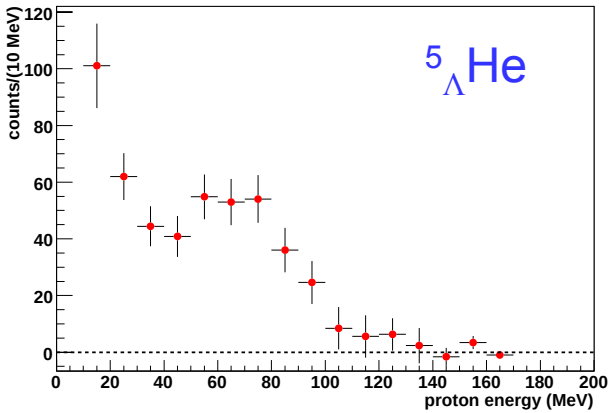
Background Simulation: 4 millions of events generated in all the spectrometer → 3.8×10^5 events with a K^- stopped in a ^{6}Li target

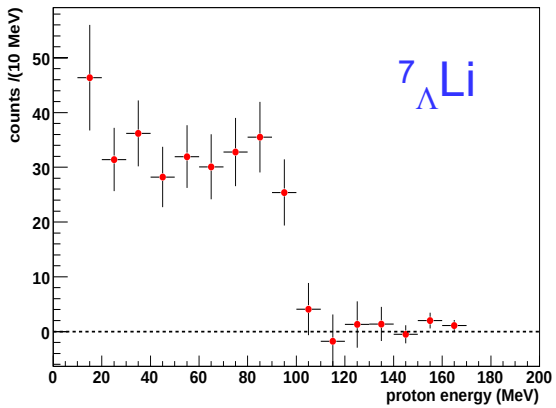
Proton spectra from $^{12}_{\Lambda}$C NMWD (3)

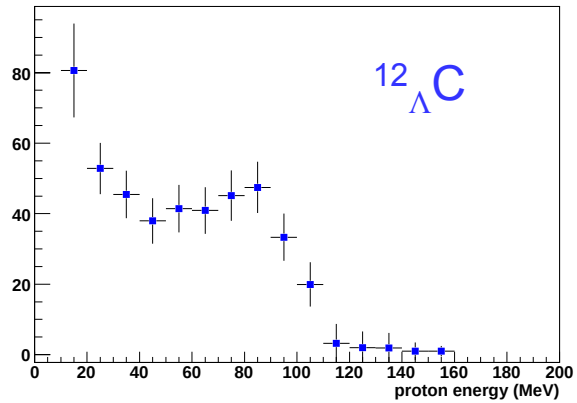


- **Proton energy spectrum** for the NMWD of $^{12}_{\Lambda}$C after the background subtraction (sum of the three ^{12}C targets)
- The low energy region is dominated by the FSI contribution and two-nucleons induced NMWD
- The signal at about 80 MeV half of the Q value of the reaction) still remains

First direct measurement of Γ_p

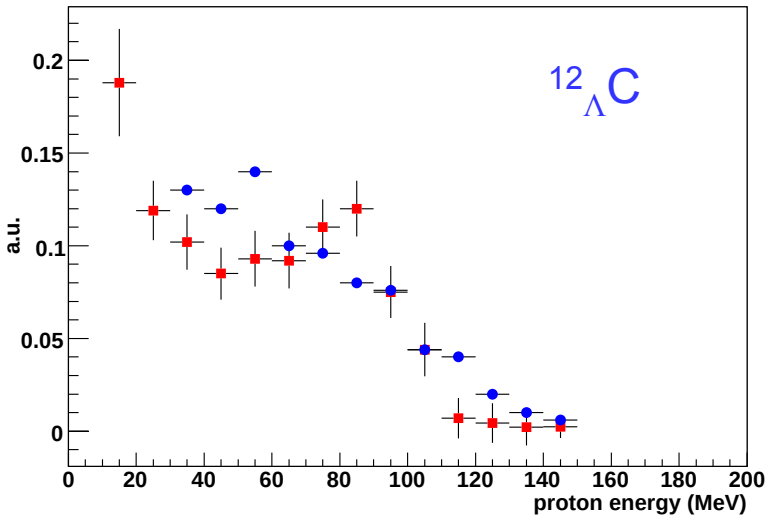






Target	Hypernucleus	Γ_p(units of Γ_Λ)
^{12}C	$^{12}_{\Lambda}$C	0.43±0.07
^{6}Li	$^{5}_{\Lambda}$He	0.28±0.09
^{7}Li	$^{7}_{\Lambda}$Li	0.37±0.09
^{7}Li	$^{5}_{\Lambda}$He	0.21±0.12
Mean of ^{6}Li and ^{7}Li values	$^{5}_{\Lambda}$He	0.25±0.07

FINUDA vs KEK

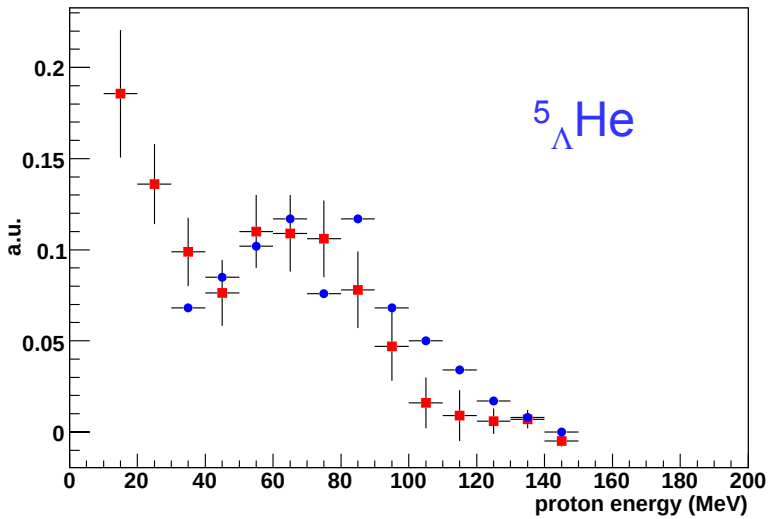


- **proton energy spectrum** from KEK experiment
- proton energy spectrum from FINUDA experiment
- The two spectra are normalized to area beyond 35 MeV

- Kolmogorov-Smirnov test applied to the data gives :

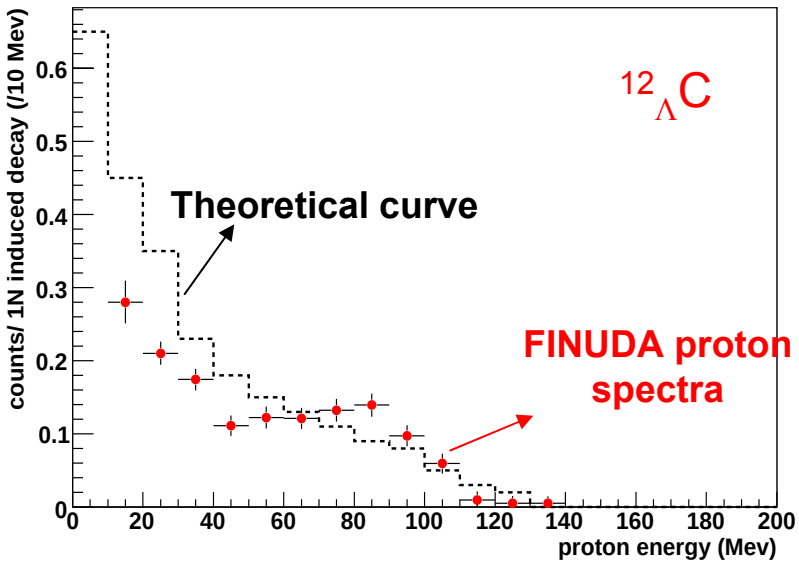
$^{12}_{\Lambda}$C a probability of P=0.52 at a confidence level of 5% → **Low compatibility**

$^{5}_{\Lambda}$He a probability of P=0.78 at a confidence level of 75% → good compatibility



Comparison with theoretical calculations

(Phys. Rev. C 69 054603 [2004])



- Kolmogorov-Smirnov test applied to the theoretical and experimental data gives :

$^{12}_{\Lambda}$C a probability of P=0.5 at a confidence level of 5% → **Low compatibility**

$^{5}_{\Lambda}$He a probability of P=0.65 at a confidence level of 75%

- $^{12}_{\Lambda}$C: the FSI and the contribution of the two- nucleons induced NMWD seems to be too strong to reproduce the data

$^{5}_{\Lambda}$He : accounting for nucleon FSI for light hypernuclei by means of Monte Carlo tecniques is questionable

(Phys. Rev. C 69 054603 [2004])