# A search for ($K^-pp$)-bound systems in composite nuclei

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Finuda Collaboration


# Finuda physics program

- $\Lambda$, $\Sigma$ HYPERNUCLEAR SPECTROSCOPY
  essential tool for testing :
- theoretical models of $\Lambda$- and $\Sigma$-N potentials
- single particle nuclear model predictions
- bound states with strangeness

SIMULTANEOUSLY

- HYPERNUCLEAR DECAYS
- study of baryon-baryon weak processes in nuclear matter: $\Lambda \rightarrow \pi N$ and $\Lambda N \rightarrow NN$

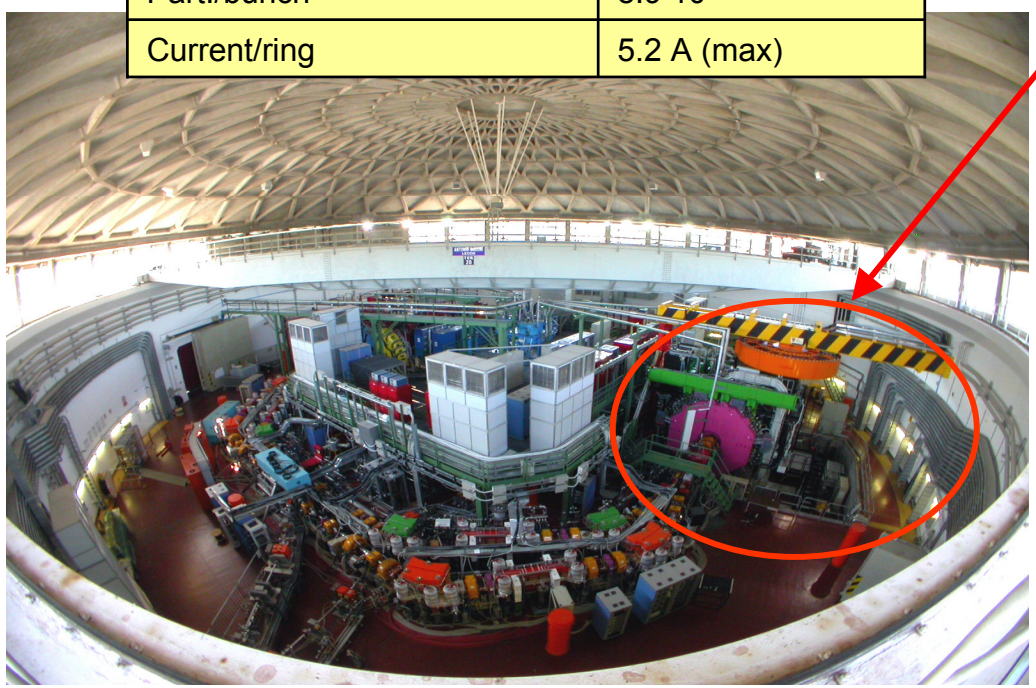
ON DIFFERENT NUCLEI

- SEARCH FOR:

- Deeply bound kaonic nuclei ☺
- Neutron-rich hypernuclei
- Rare decays

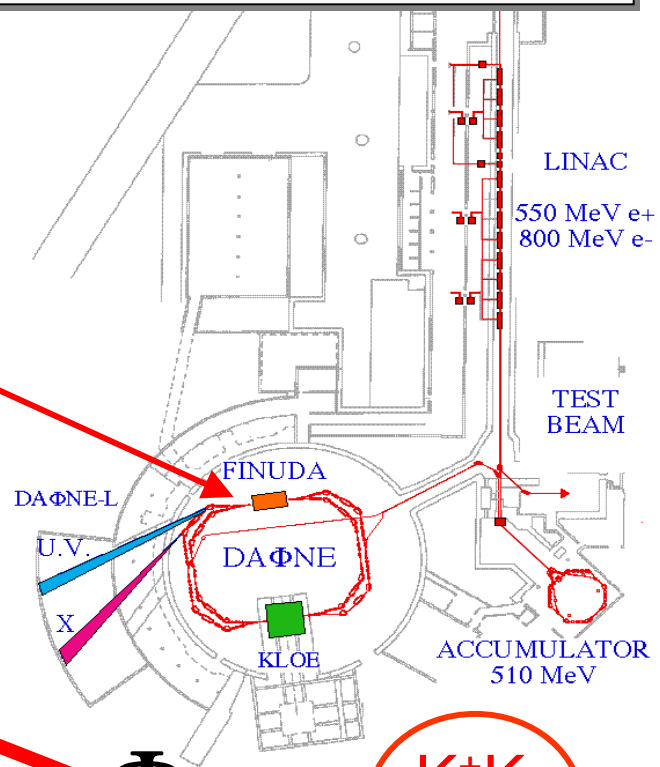
# FINUDA: FIsica NUcleare a DAΦNE

| | |
|---|---|
| energy | 510 MeV |
| Design Luminosity | 5 $10^{32}$ $cm^{-2}$ $s^{-1}$ |
| $\sigma_x$(rms) | 2.11 mm |
| $\sigma_y$(rms) | 0.021 mm |
| $\sigma_z$(rms) | 35 mm |
| Bunch length | 30 mm |
| Crossing angle | 13 mrad |
| Frequency (max) | 368.25 MHz |
| Bunch/ring | Up to 120 |
| Part./bunch | 8.9 $10^{10}$ |
| Current/ring | 5.2 A (max) |



## DAΦNE $e^+$ - $e^-$ Φ-factory

FINUDA



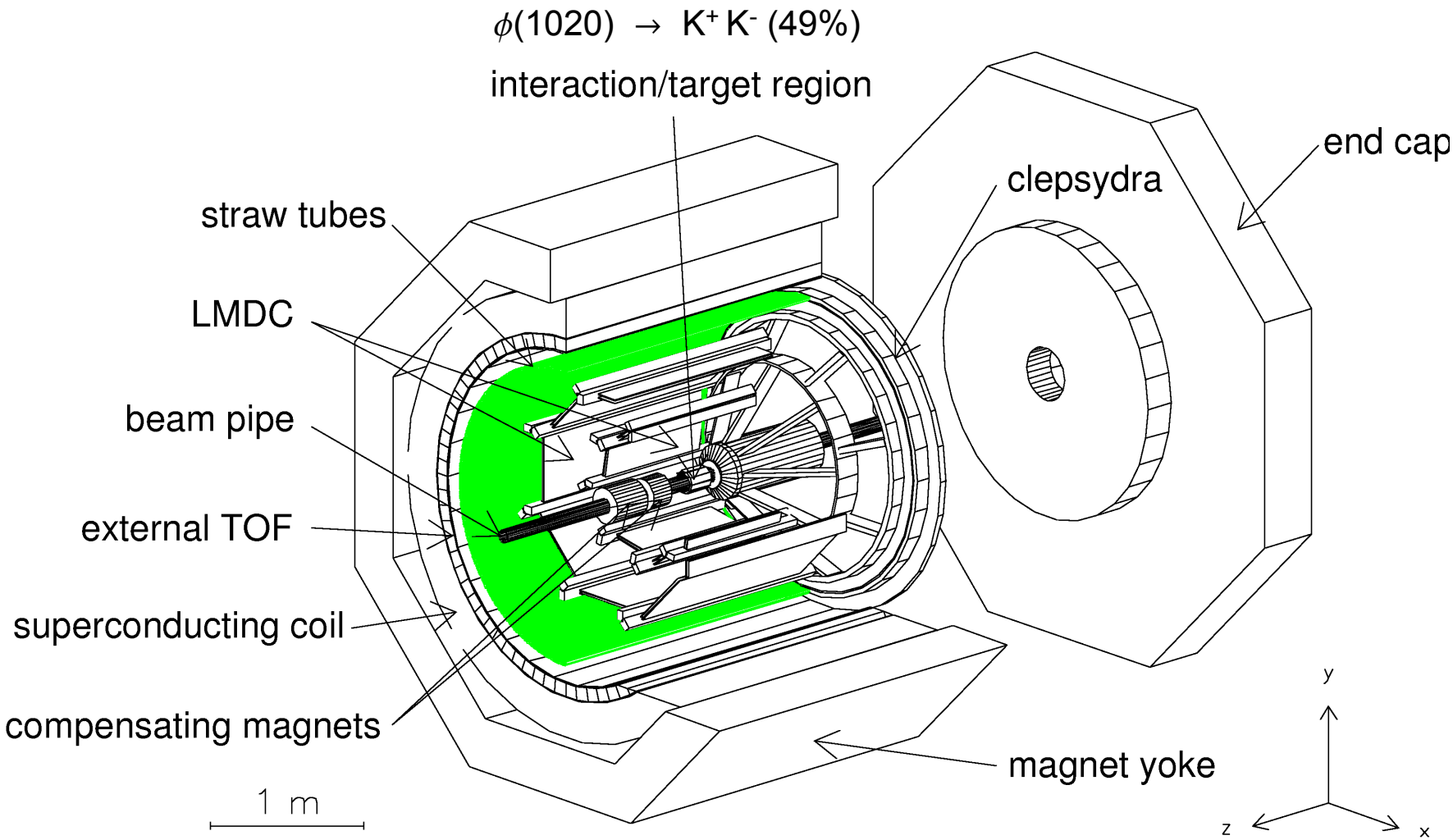

$\rho\pi$ (13%)

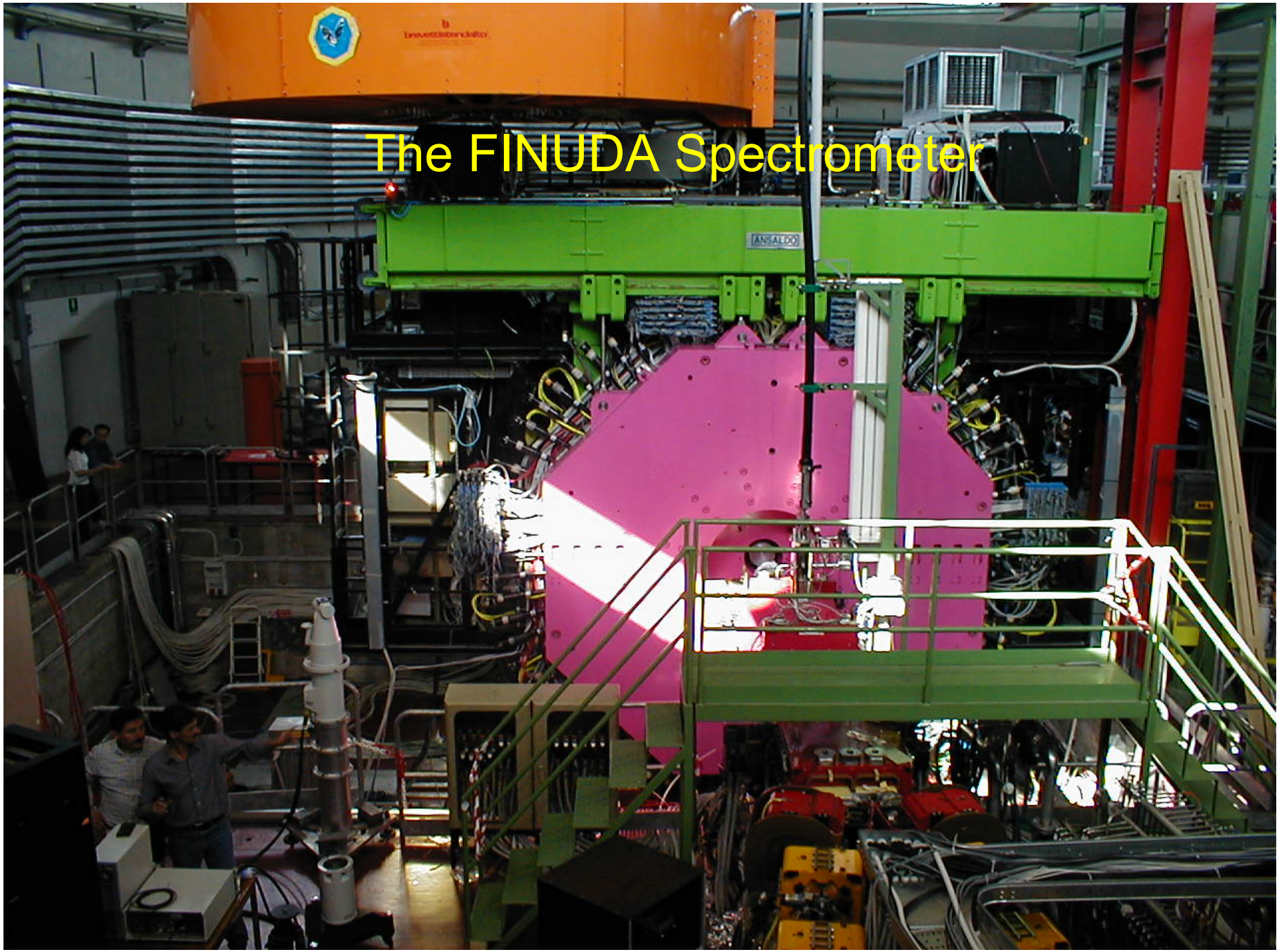
$K_SK_L$ (34%)

Φ → $K^+K^-$ (49%)

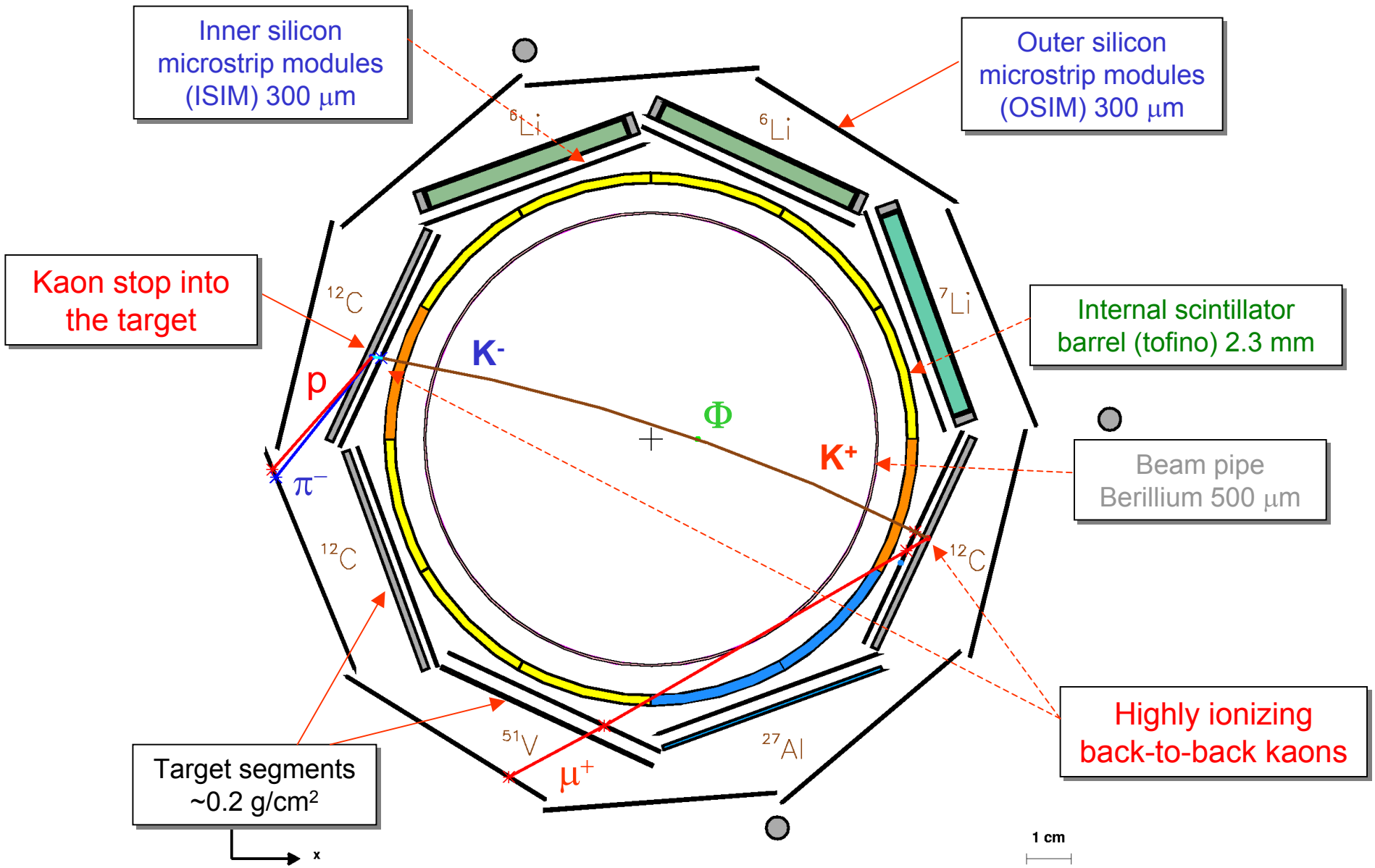
"K- beam":
- Monochromatic
- Low momentum (127 MeV/c)
- $K^-_{stop}$ events tagged using the $K^+$
- no hadronic background

# The FINUDA Spectrometer

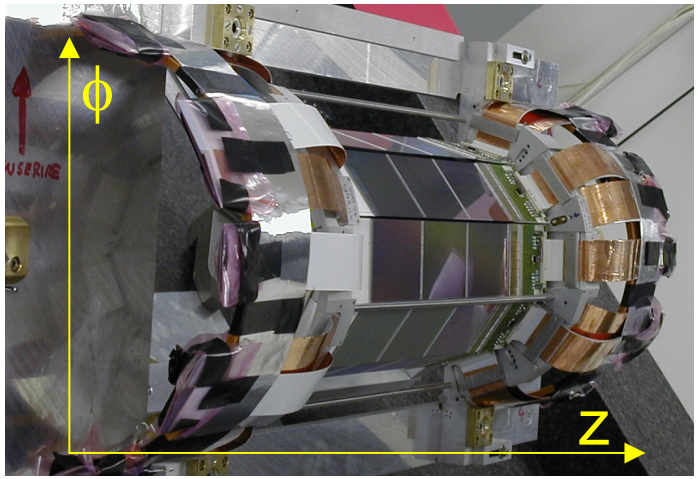



The FINUDA Spectrometer
ANSALDO

# The interaction-target region

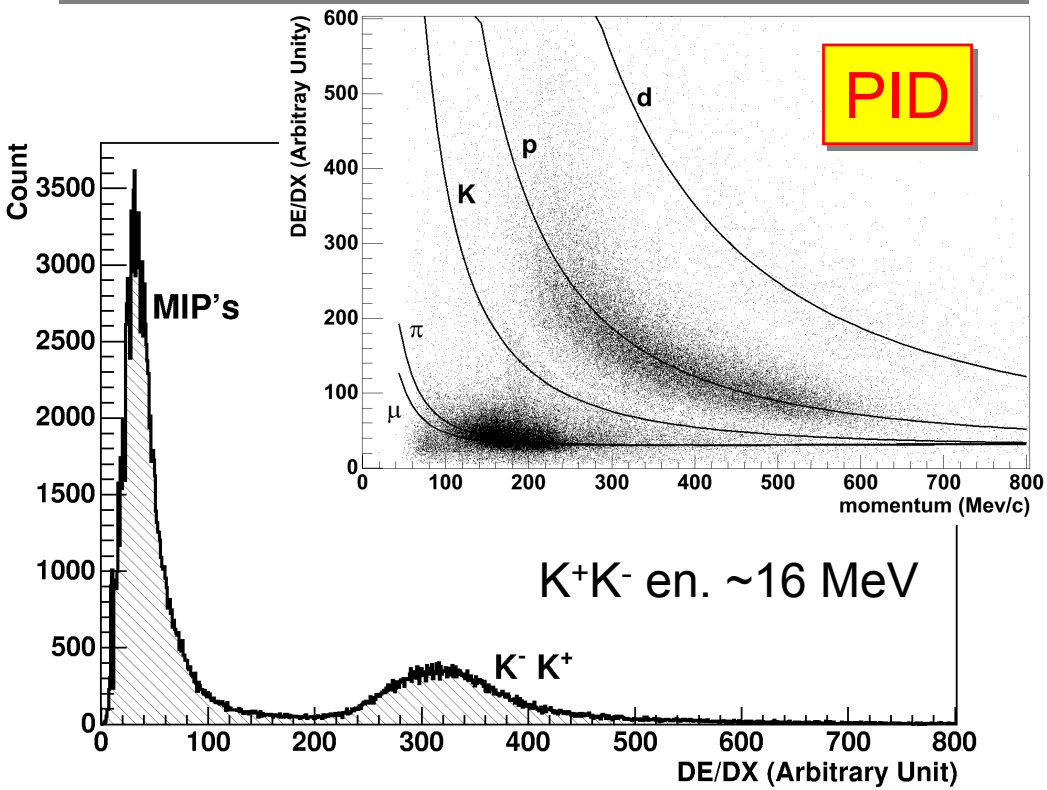


# The Silicon Vertex Detector

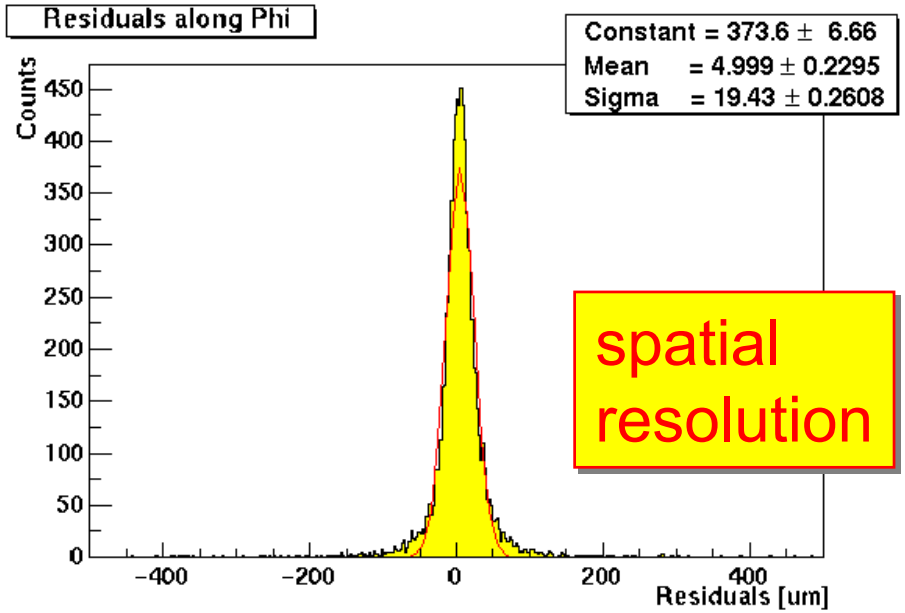


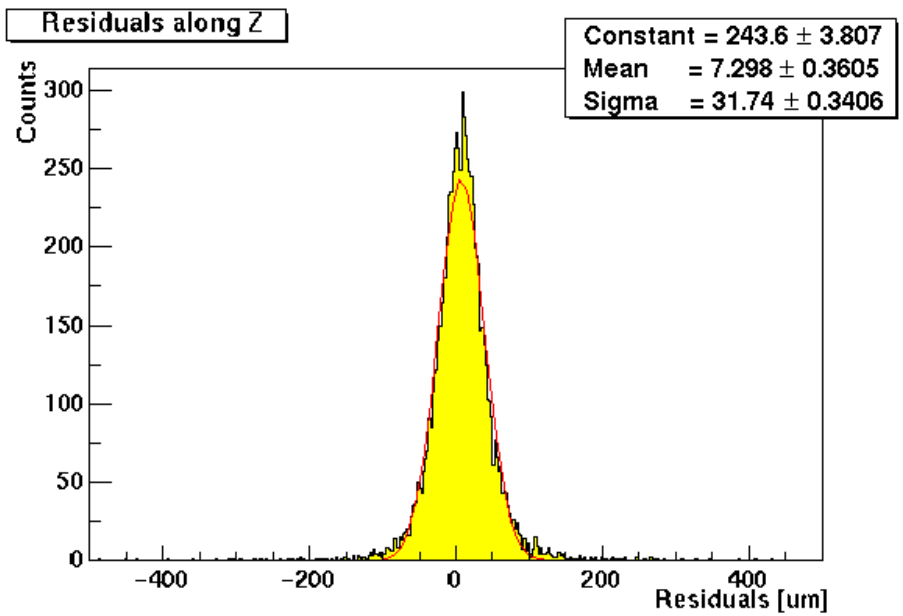

Inner and outer silicon microstrip

PID

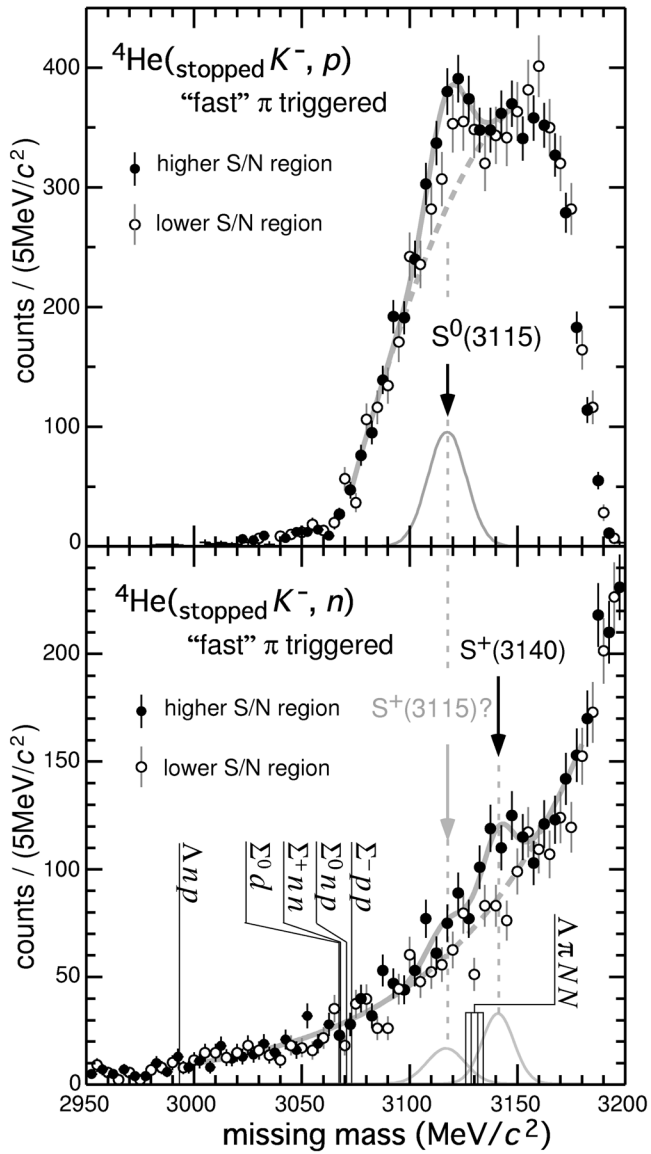



spatial resolution



# Early experiments of deeply bound kaonic states




missing mass measurement

$^4$He(stopped $K^-$,p)X

$S^0(3115) \equiv K^-npn$

$\Gamma$ < 21 MeV, T=0

Suzuki et al, Phys. Lett. B597 (2004) 263

$^4$He(stopped $K^-$,n)X

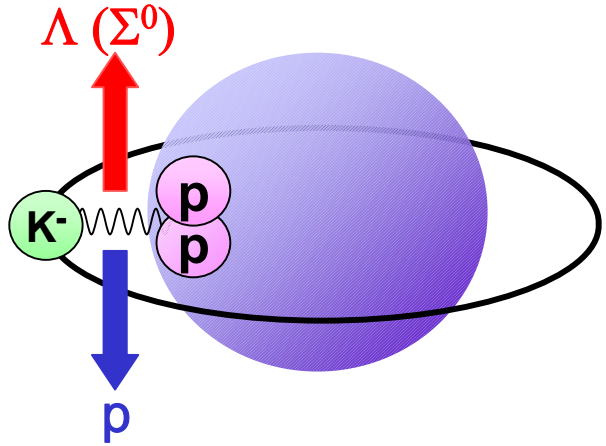
$S^+(3140) \equiv K^-npp$

$\Gamma$ < 21 MeV, T=1

Iwasaki et al, nucl-ex/0310018

# FINUDA for DBKS

Idea:



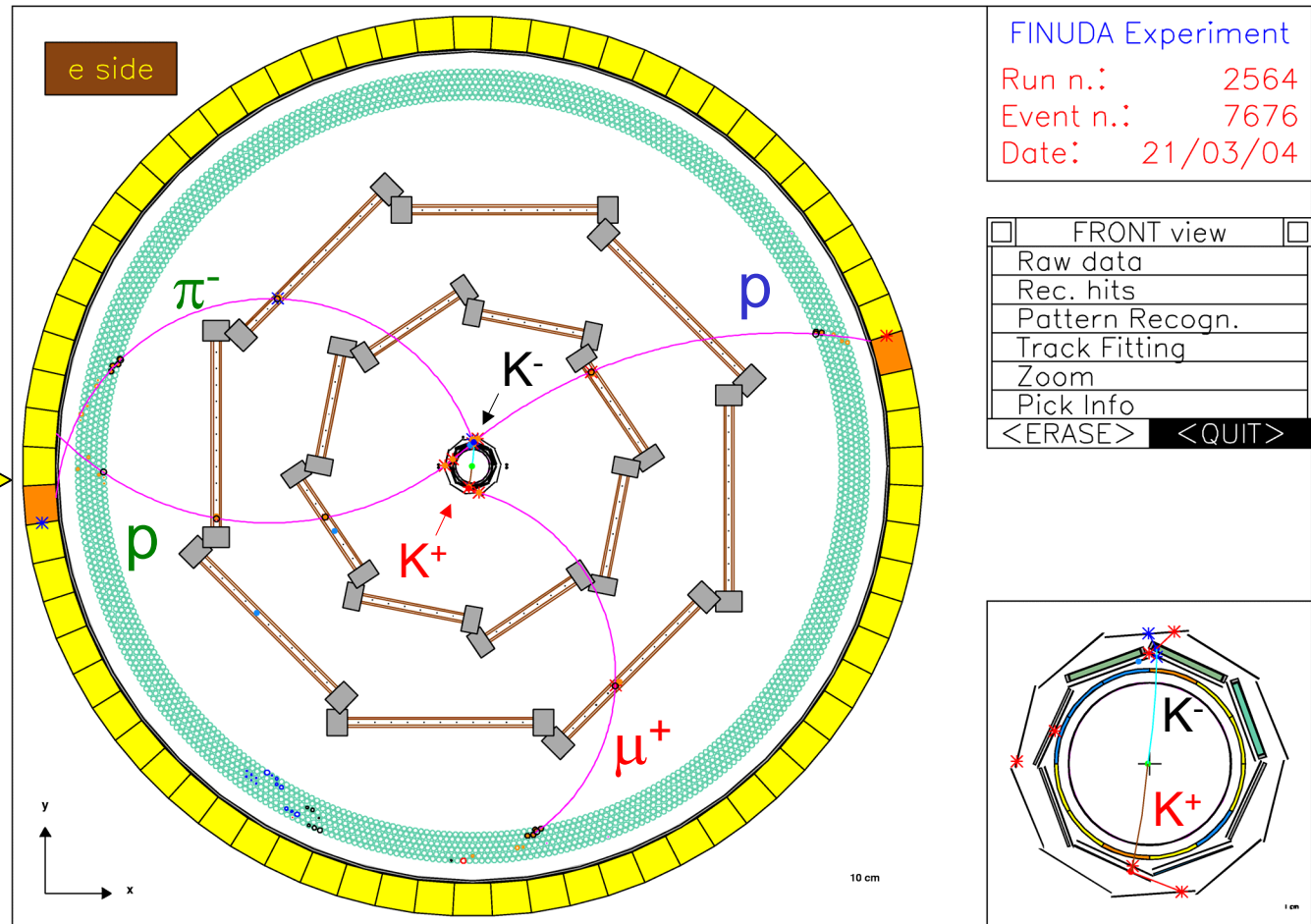

## invariant mass measurement

reaction studied:

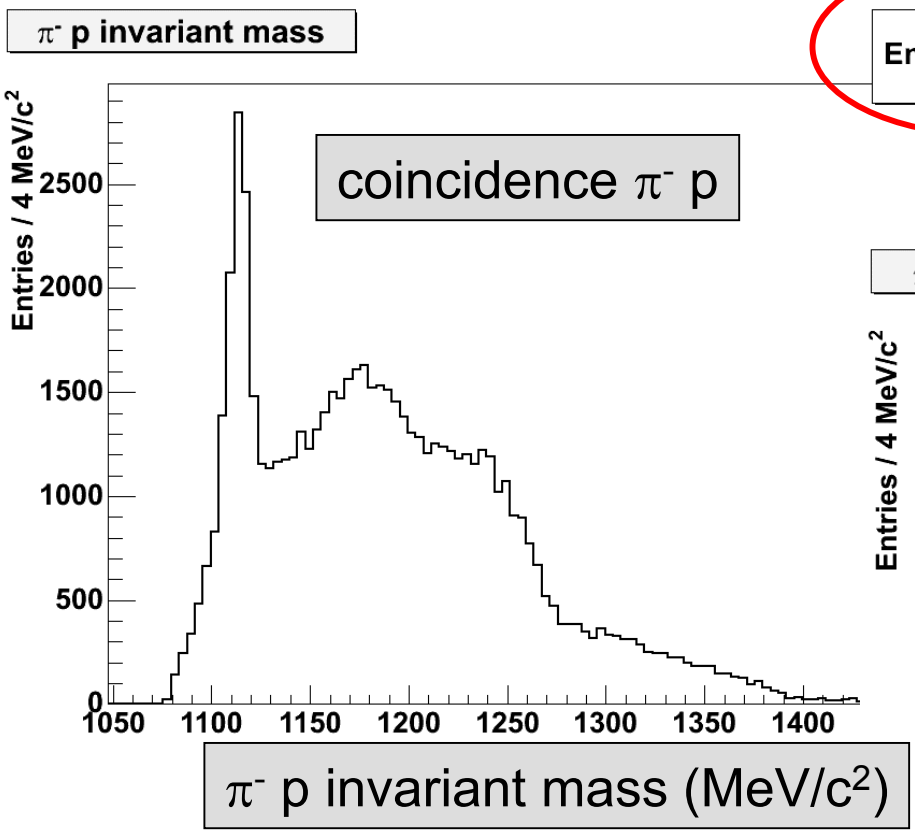
$A(K^-_{stop}, pp\pi^-)X$

analyzed the $pp\pi^-$ invariant mass with Finuda

constraint: $p\pi^- \equiv \Lambda$

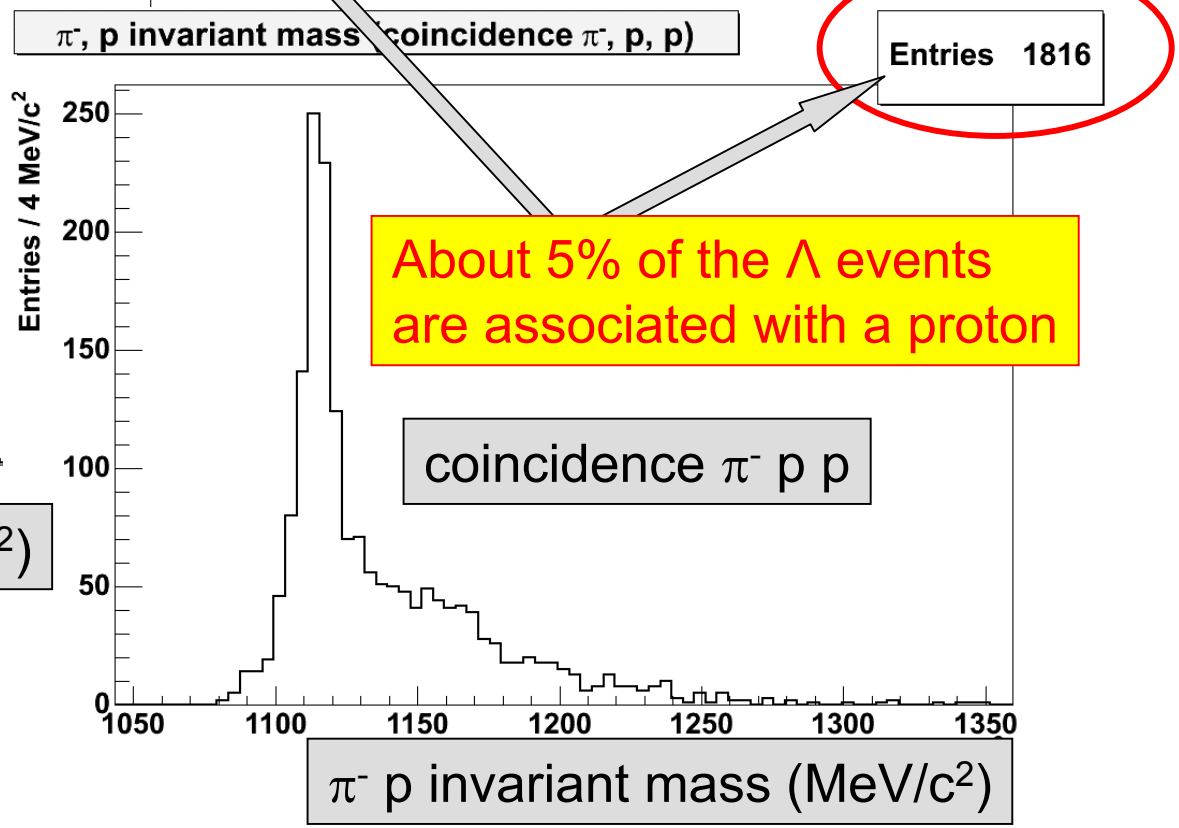


# Direct observation of a Λ hyperon on $^6$Li



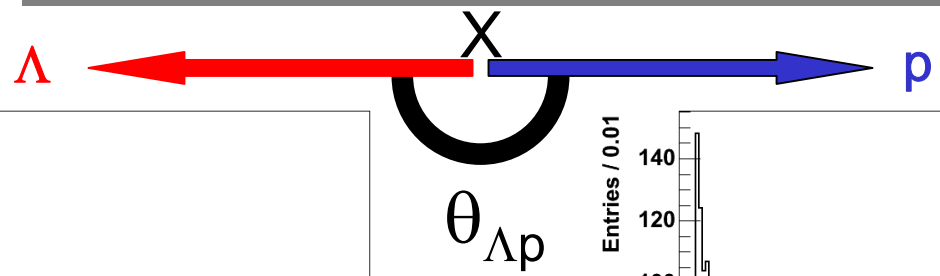

Entries 66419

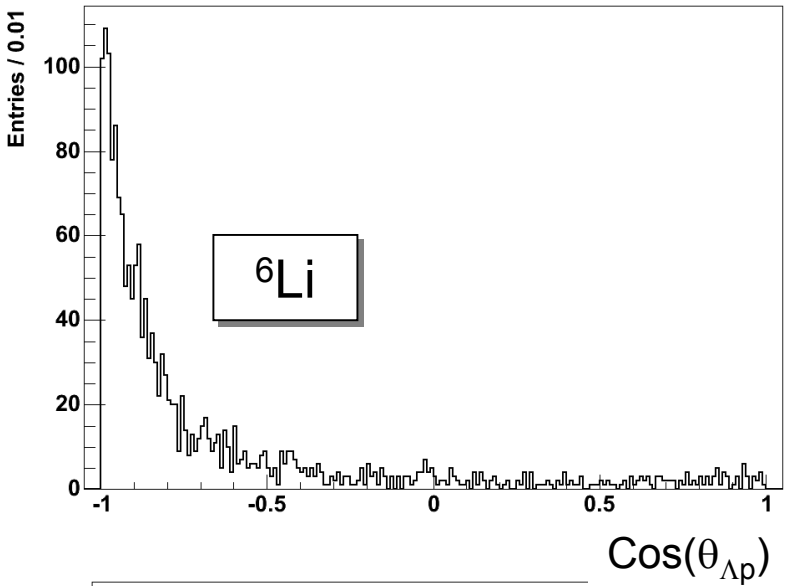
## Λ-p coincidence events

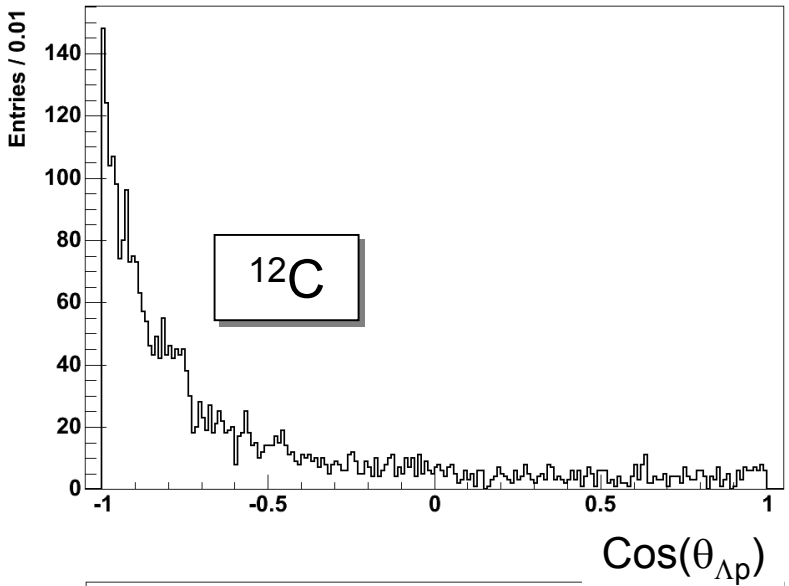


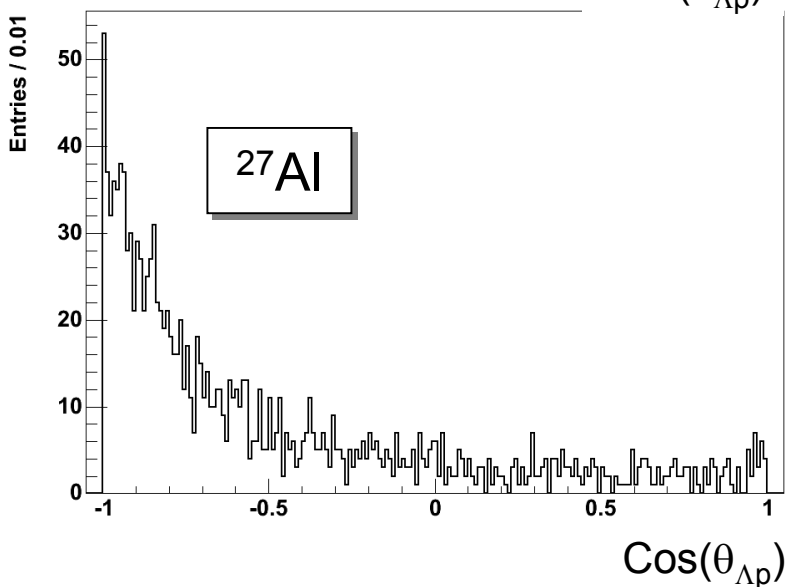

About 5% of the Λ events are associated with a proton

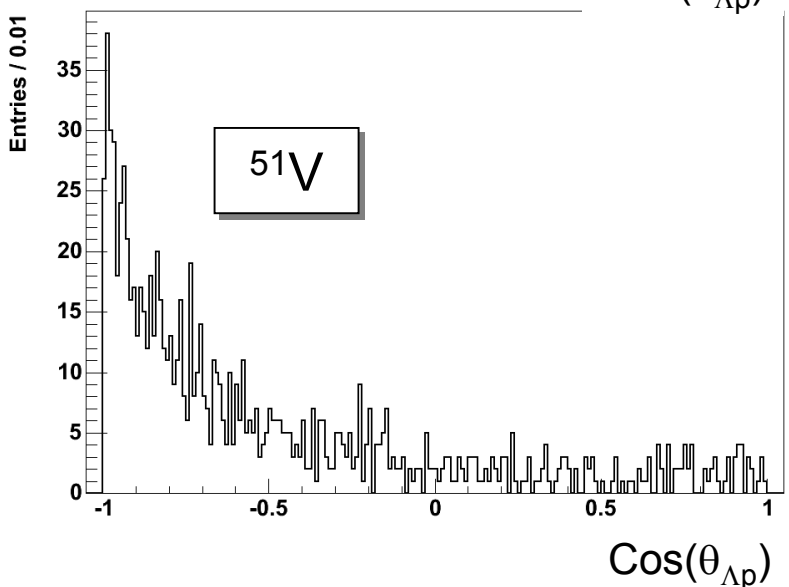
# Λ-p angular correlation



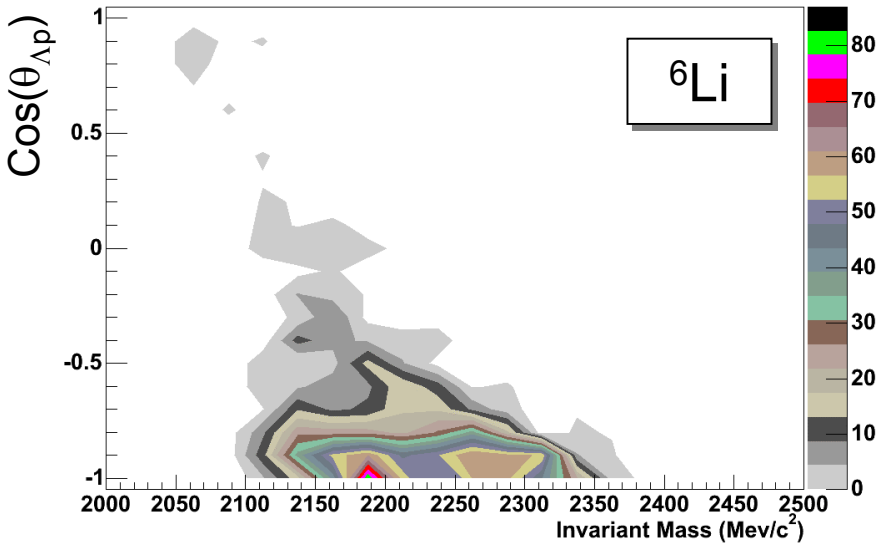



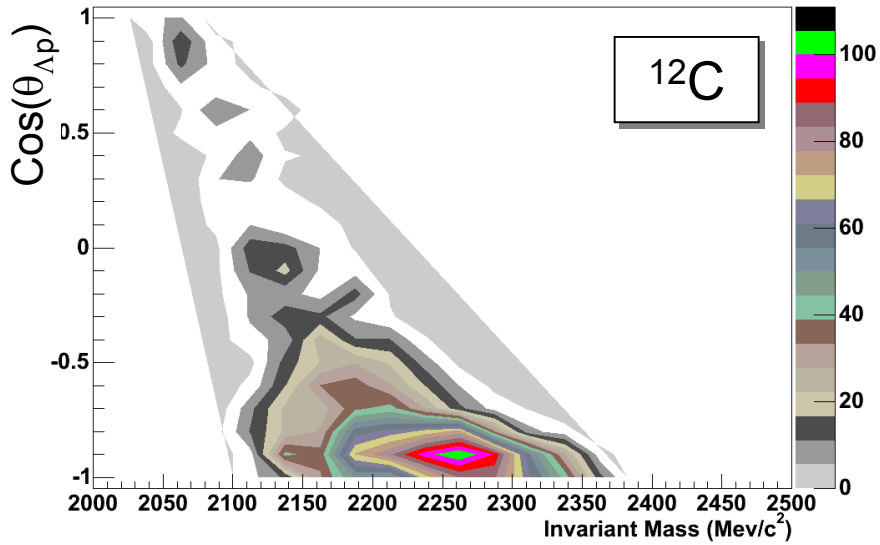



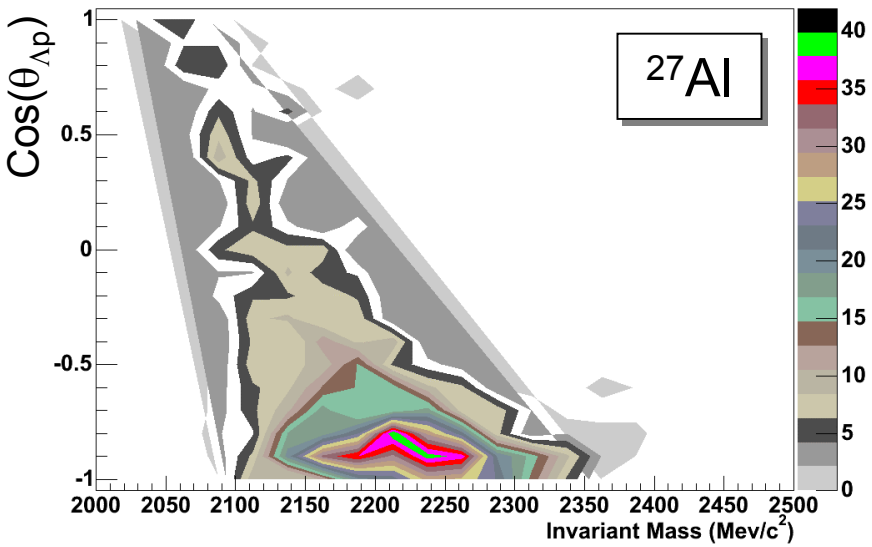



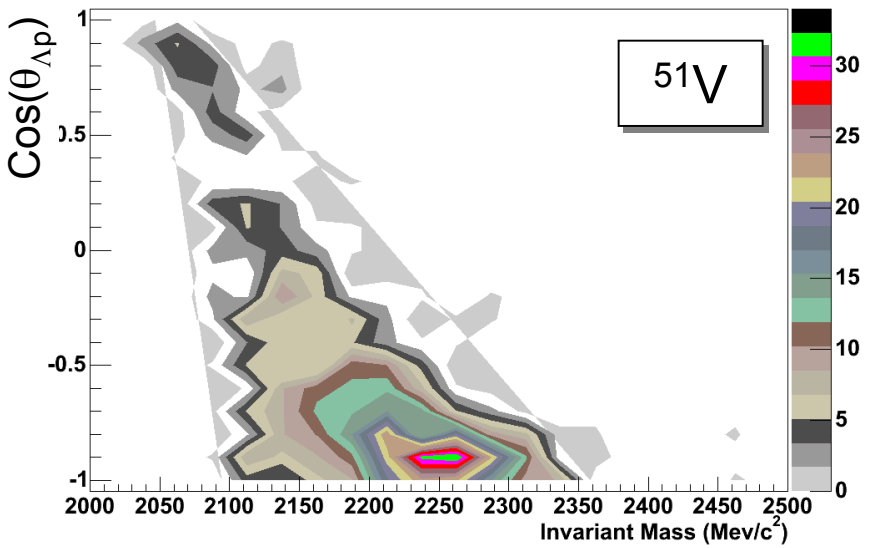



# Λ-p angular correlation vs Λp (≡ $\pi^-$pp) Invariant Mass



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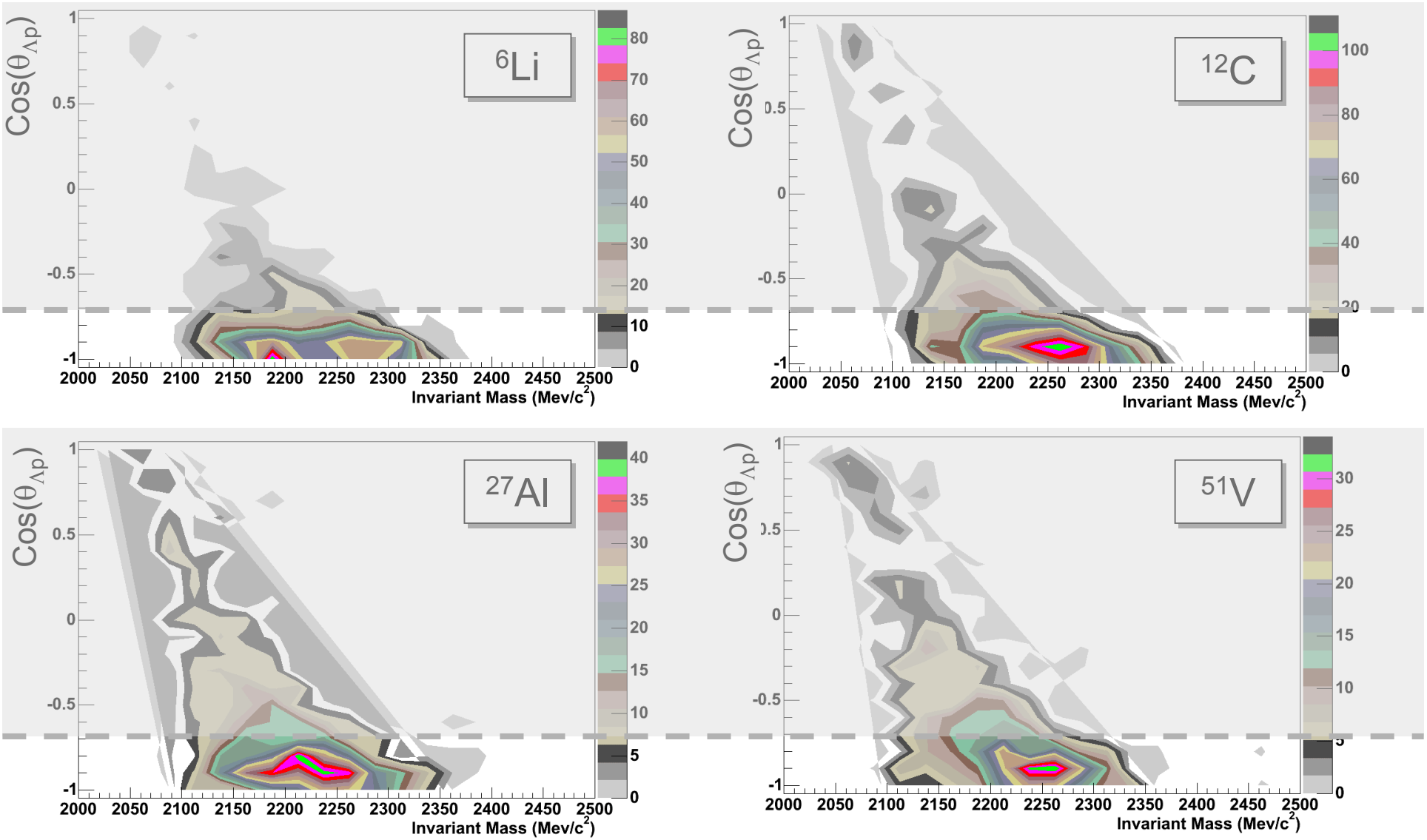
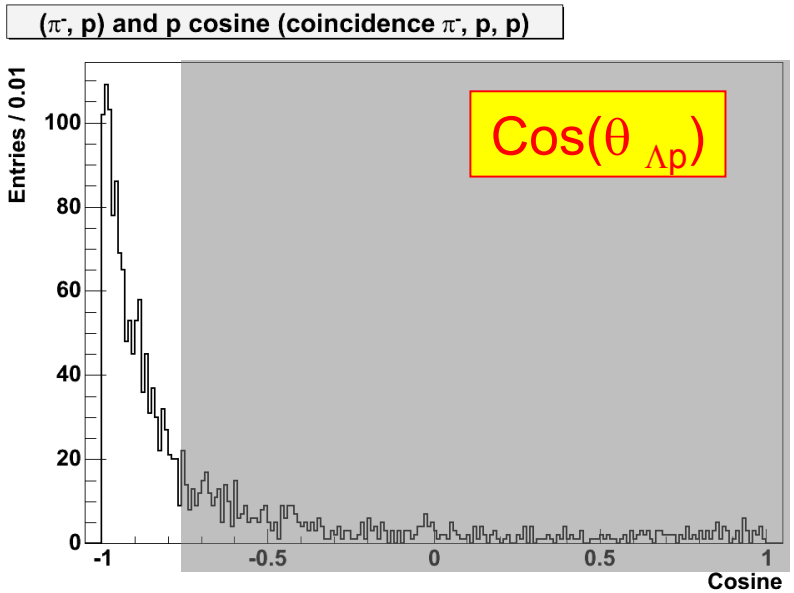
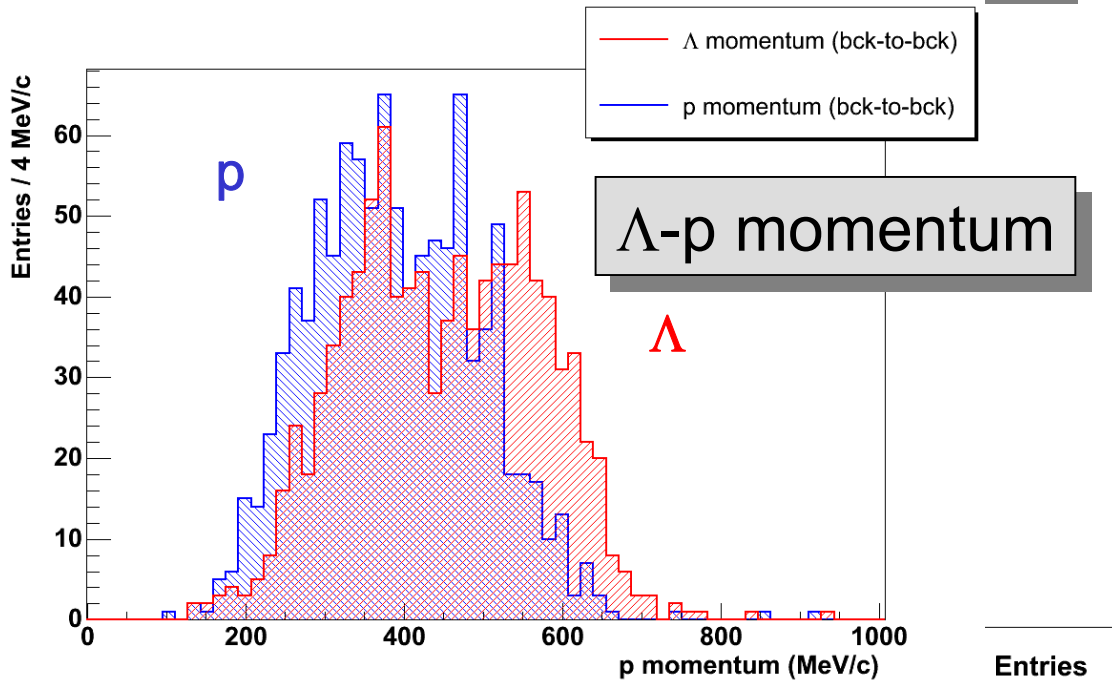
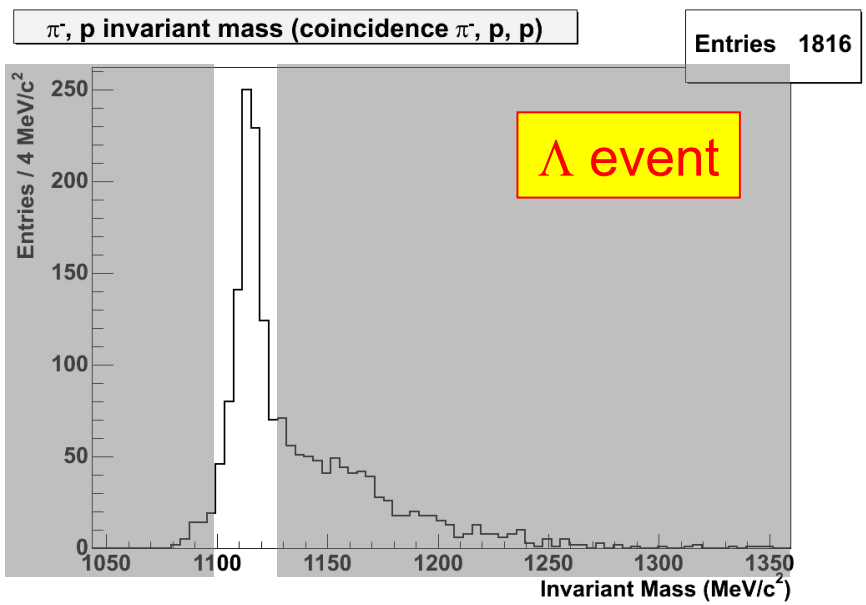
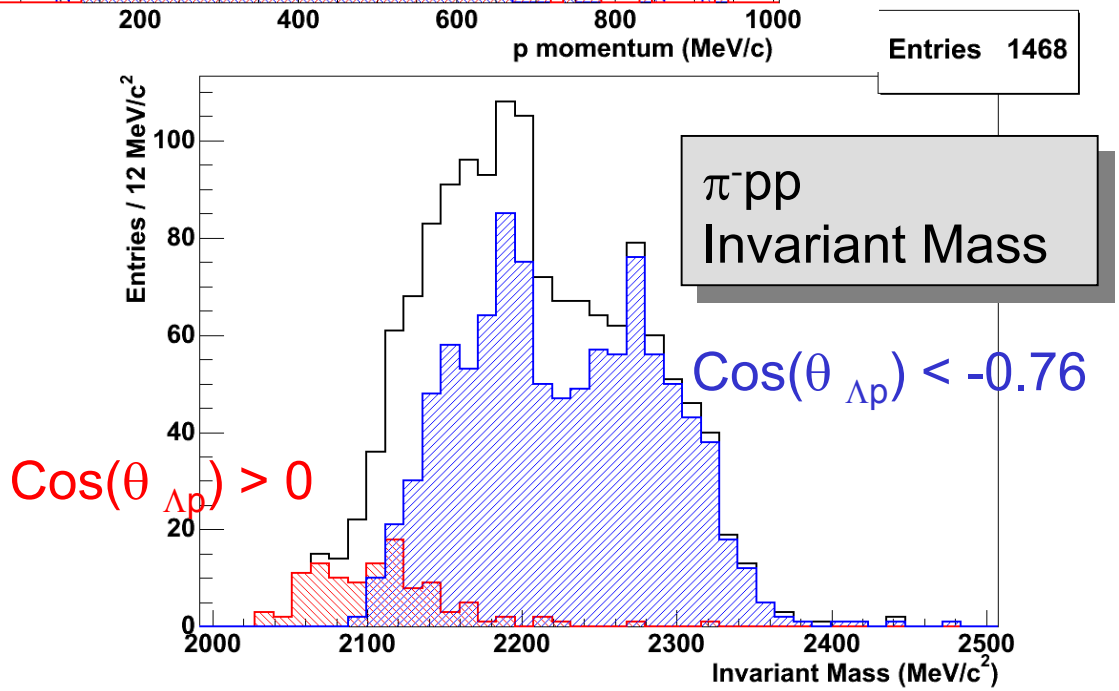


# Λ-p momentum correlation and $\pi^-$pp Invariant Mass on $^6$Li

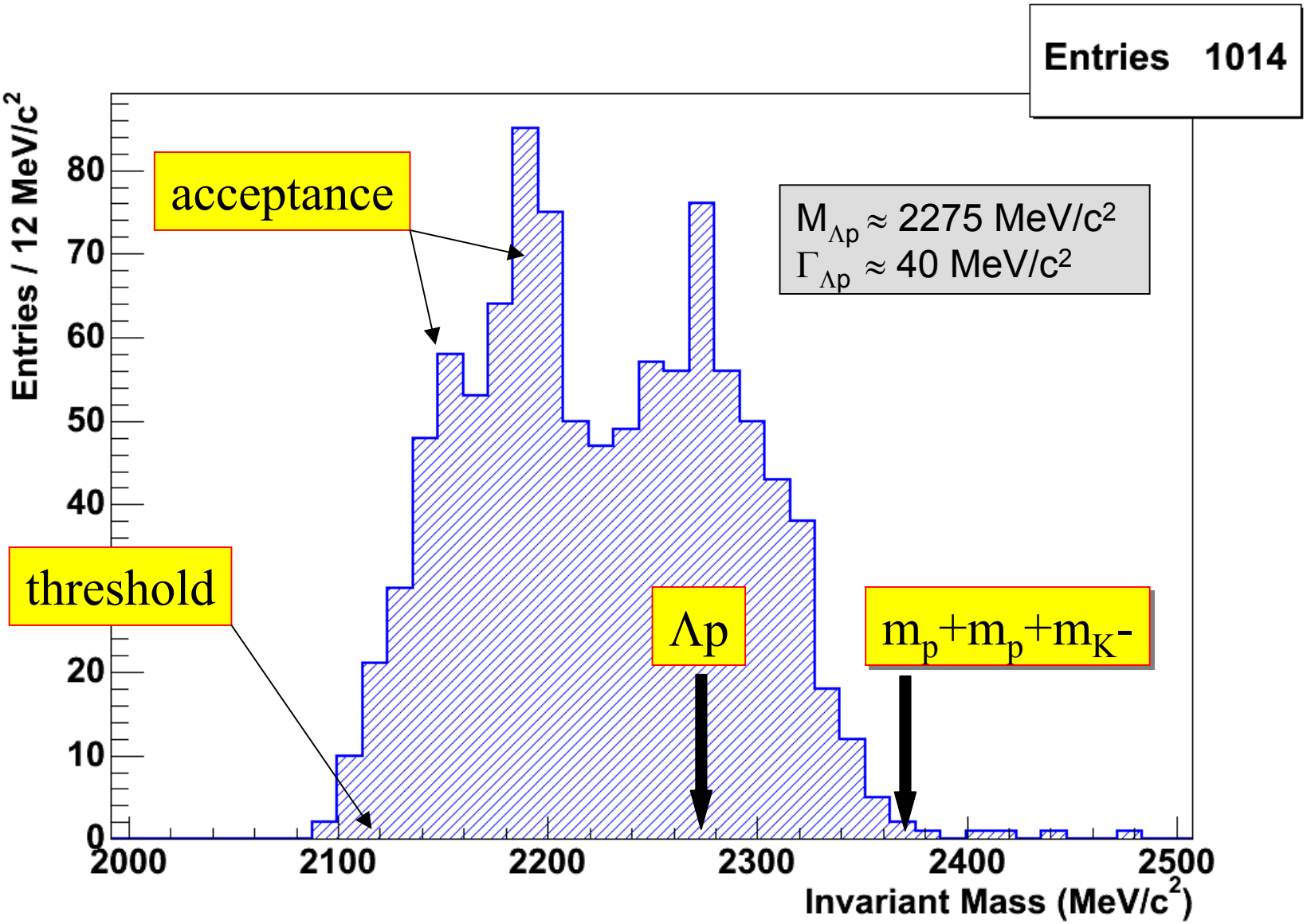


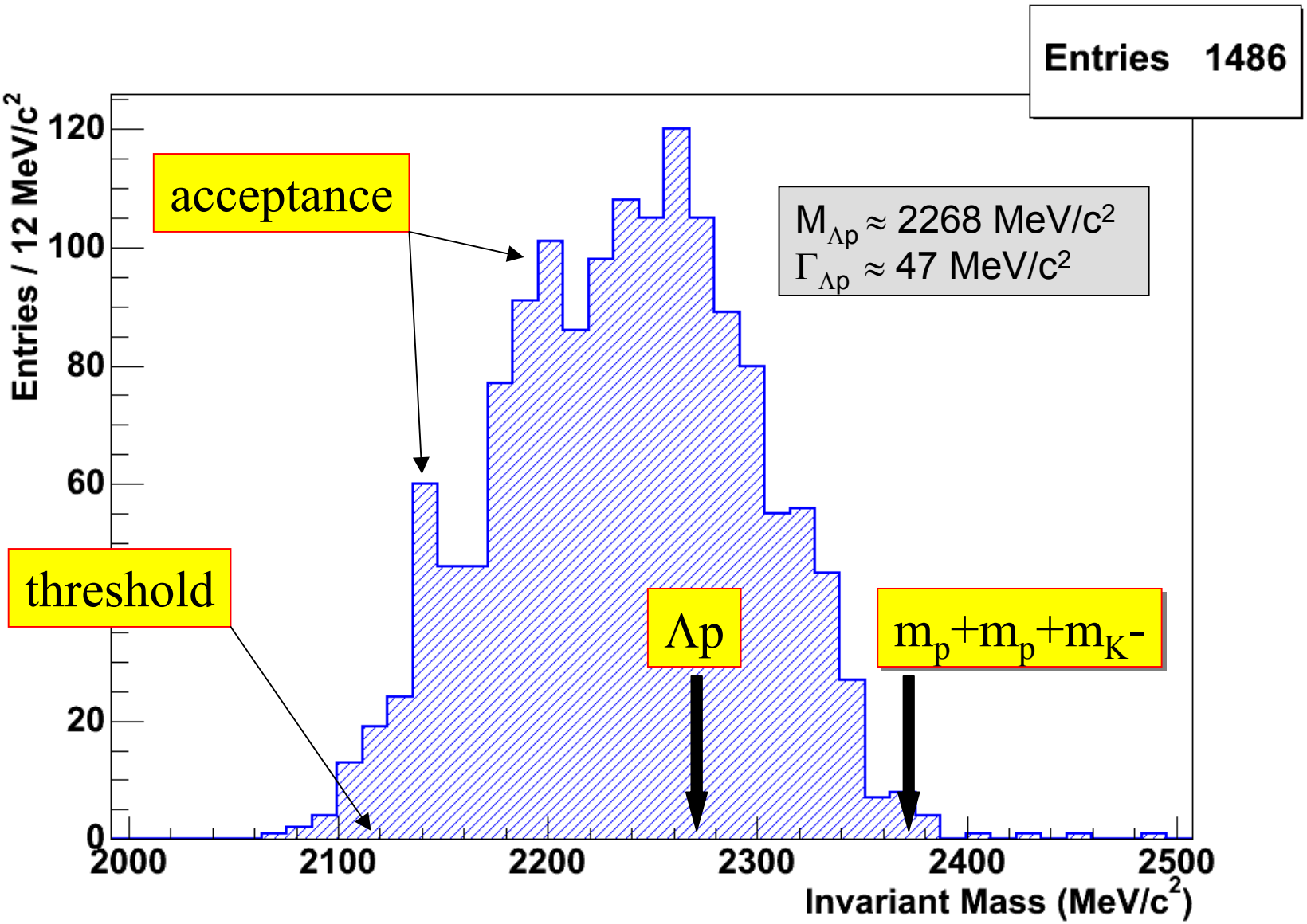



# $\pi^-$pp Invariant Mass on $^6$Li : Evidence of a kaon deeply-bound state ($K^-$pp)$\rightarrow\Lambda$p

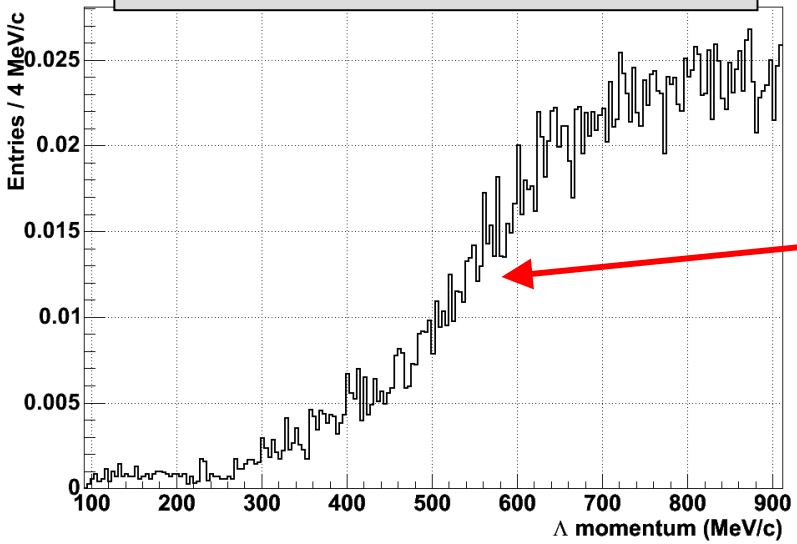


# $\pi^-$pp Invariant Mass on $^{12}$C : Evidence of a kaon deeply-bound state ($K^-$pp)$\rightarrow\Lambda$p



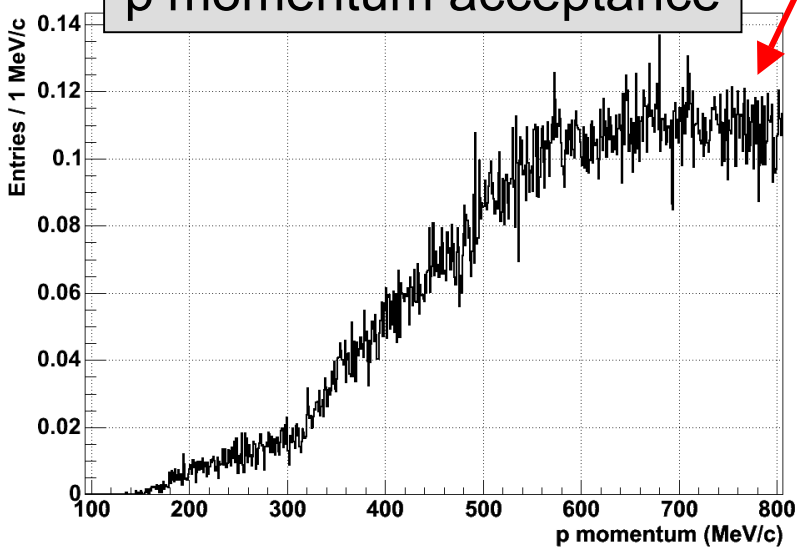
# Acceptance Studies… in progress

## Λ momentum acceptance

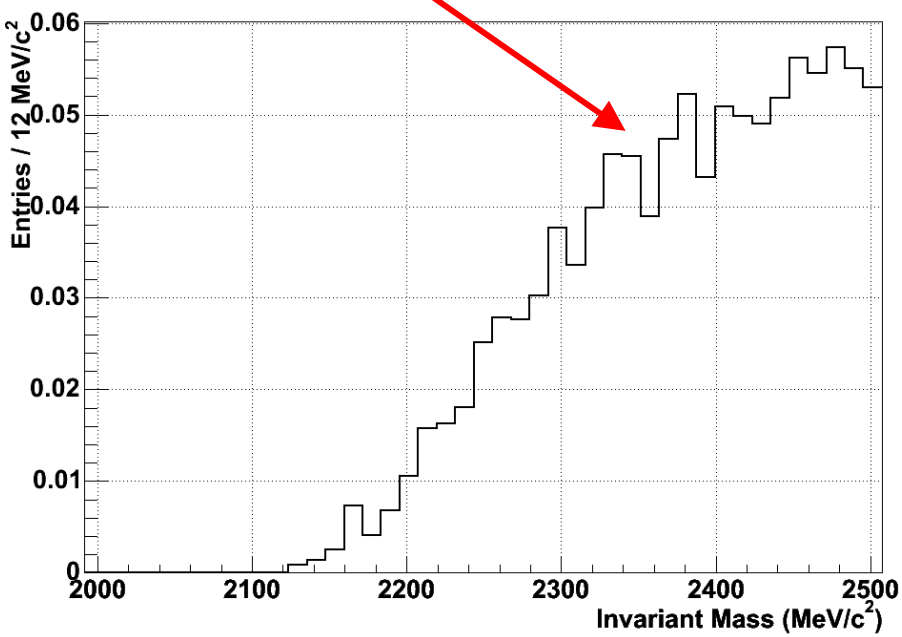



…more statistics is needed
for a fair correction of spectra
(about 1 month of CPU)…

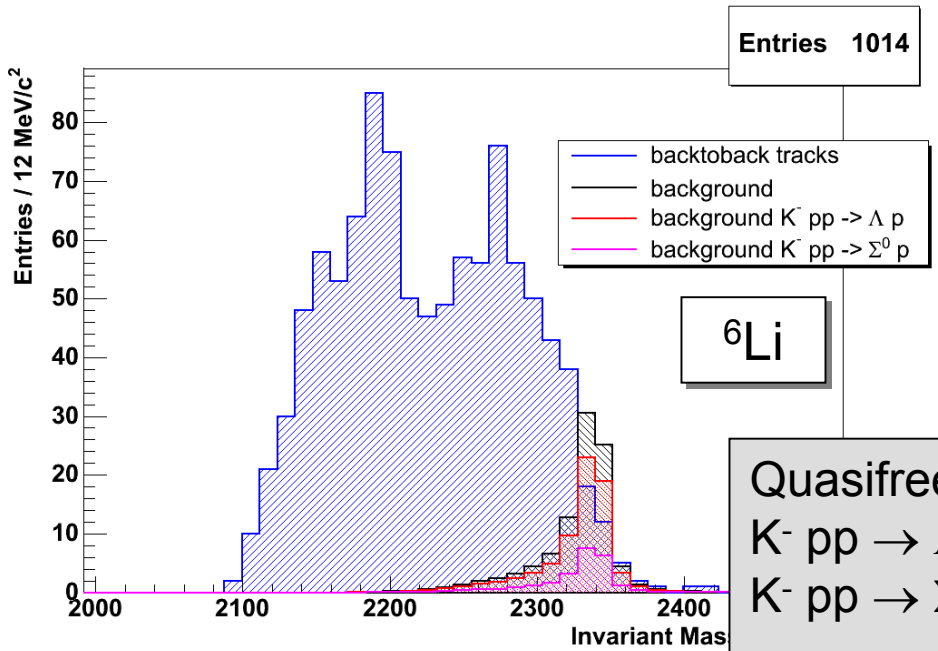
## p momentum acceptance



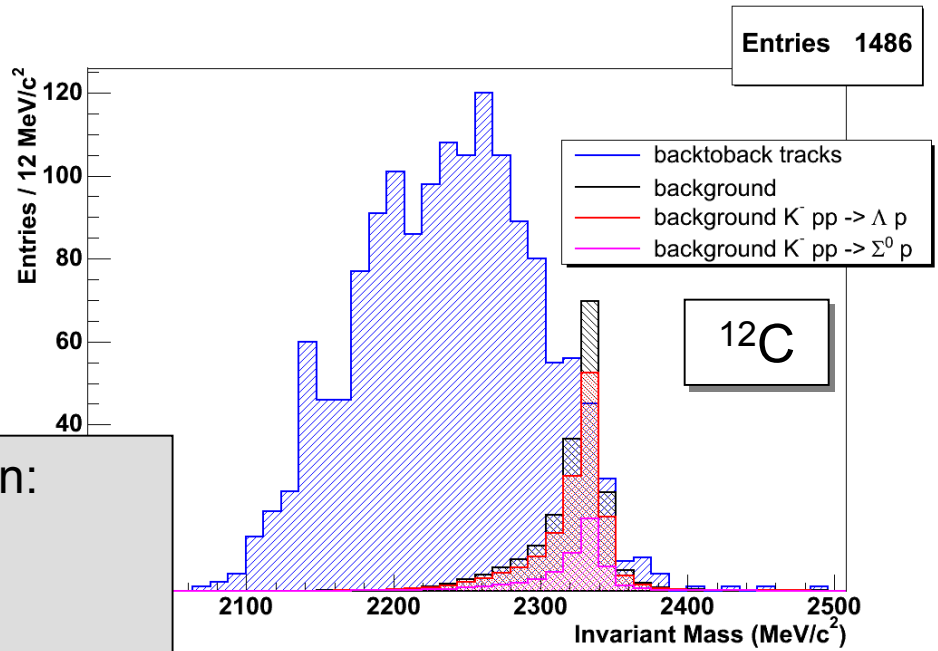

## Λ-p invariant mass acceptance



# Source of Background




$^{6}$Li




$^{12}$C

Quasifree reaction:

$K^- pp \rightarrow \Lambda p$

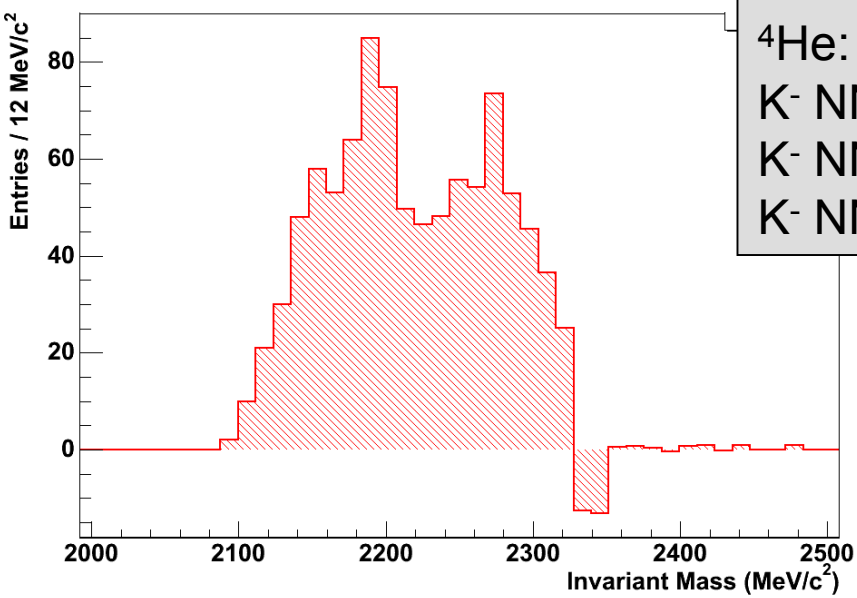
$K^- pp \rightarrow \Sigma^0 p$

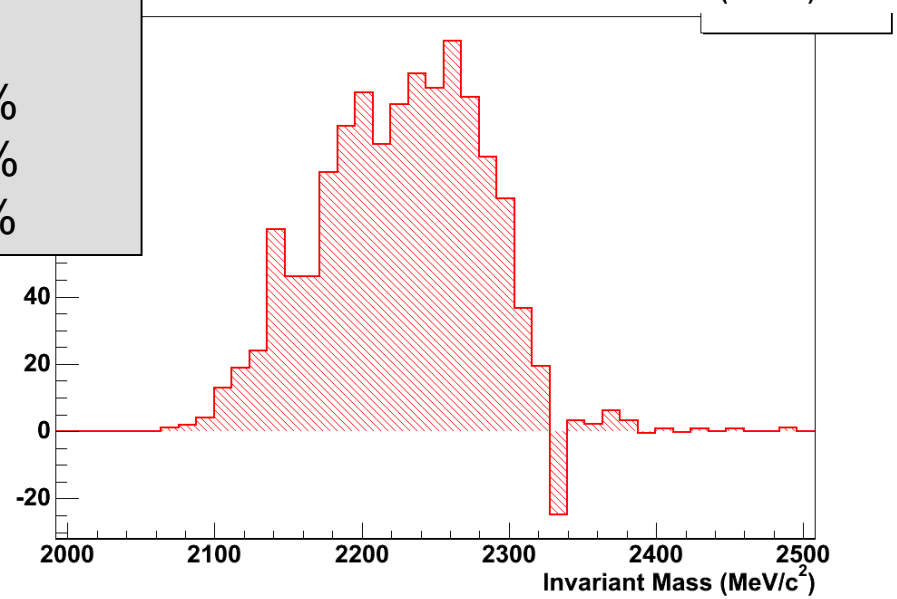
$^{4}$He:

$K^- NN \rightarrow YN$ ~16%

$K^- NN \rightarrow \Lambda N$ ~09%

$K^- NN \rightarrow \Sigma^0 N$ ~02%



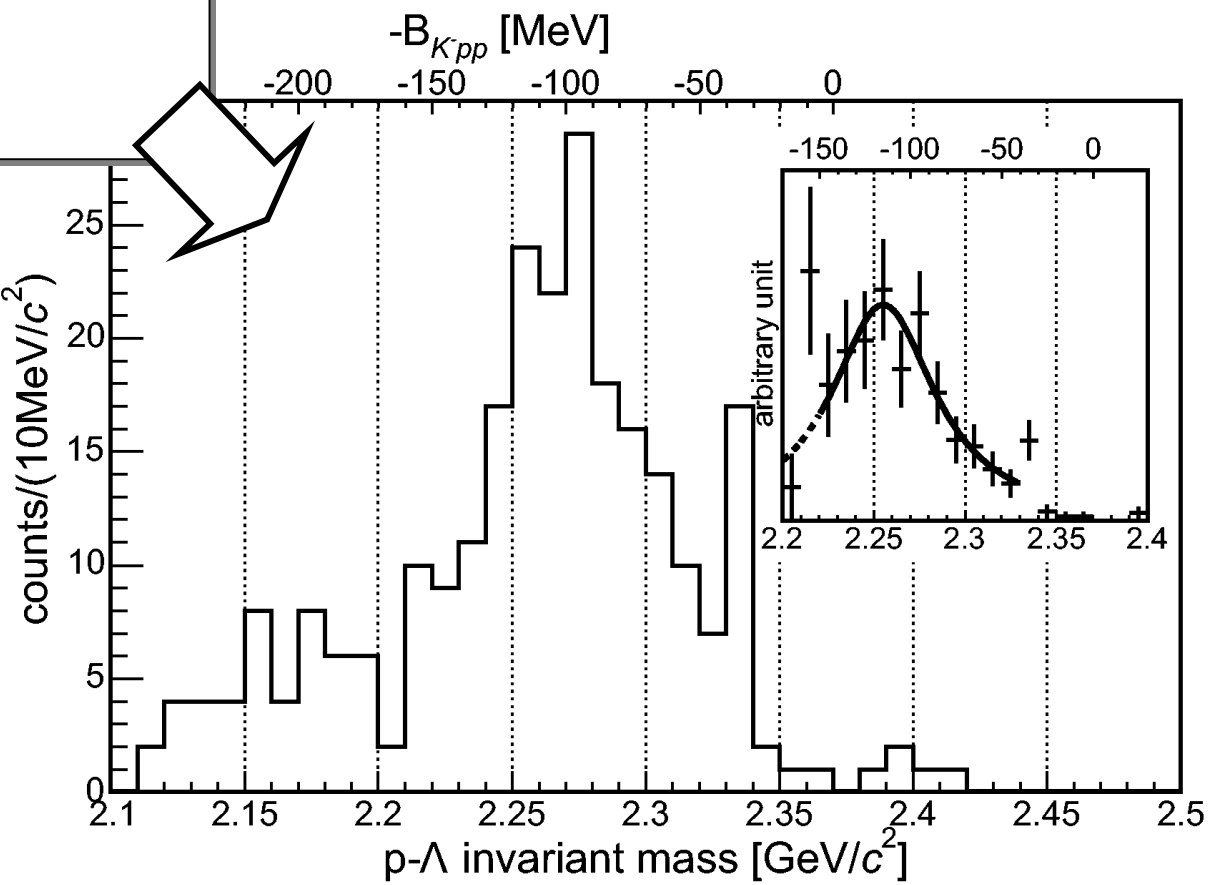



# First result on $^{6}$Li+ $^{7}$Li+ $^{12}$C

Published results for ($^{6}$Li+ $^{7}$Li+ $^{12}$C):

$$B_{K^- pp} = 115^{+6}_{-5}(stat)^{+3}_{-4}(syst)MeV$$

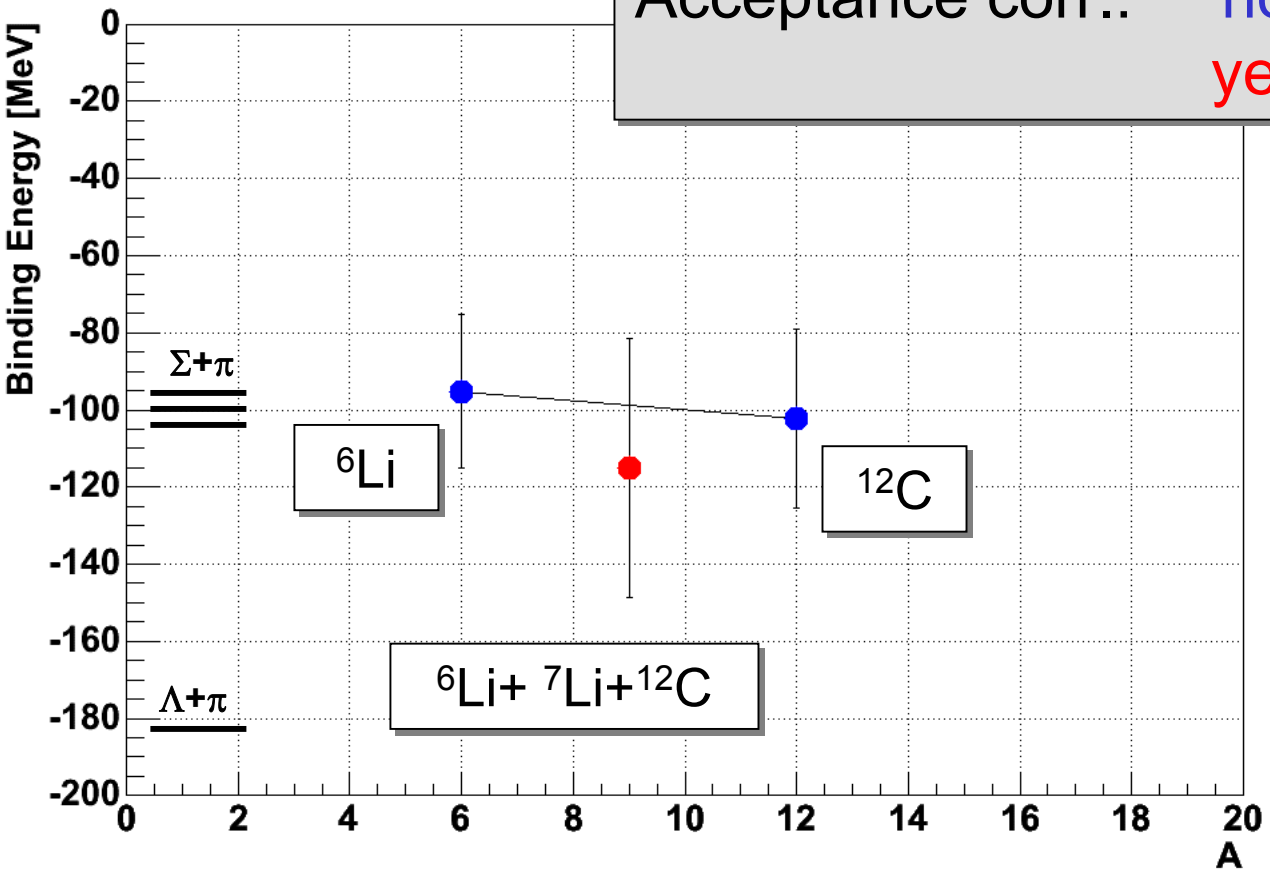
$$\Gamma = 67^{+14}_{-11}{}^{+2}_{\cdot -3} MeV$$

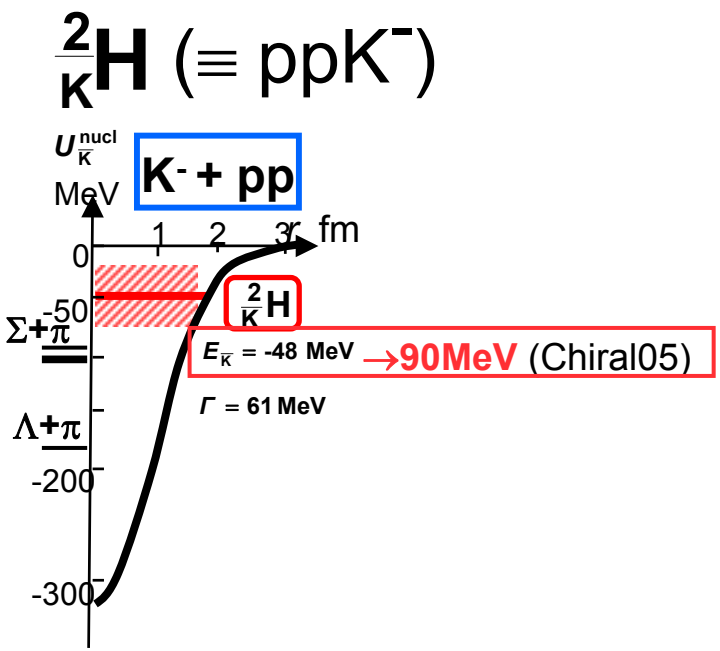



FINUDA Collaboration: Phys. Rev. Lett. 94, 212303 (2005)

# ($K^-pp$) potential vs A: $^6$Li , $^{12}$C

Acceptance corr.: no
yes




Yamazaki,Akaishi,PLB **535**(2002)70

# Summary

- FINUDA/DAΦNE is a unique facility for studies of the K-A interaction.
- We have observed back-to-back Λ-p events in $K^-$ absorption at rest (first time).
- The Λ-p invariant-mass distribution suggests the existence of a $K^-pp$ deeply-bound system on both $^6$Li and $^{12}$C nuclei (the final results depends on acceptance correction).
- It is not clear if the state is below the $\Sigma\pi$ threshold.

- Further analysis will regard the following processes:
  - $K^- pp \rightarrow \Lambda p$ ($^7$Li, $^{27}$Al, $^{51}$V)
  - $K^- pn \rightarrow \Lambda n$
  - $K^- pn \rightarrow \Sigma^- p$
  - $K^- ppn \rightarrow \Lambda d$

statistics