Recent results on K^- multinucleon absorption by FINUDA

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K^- absorption by few nucleons (in nuclei)

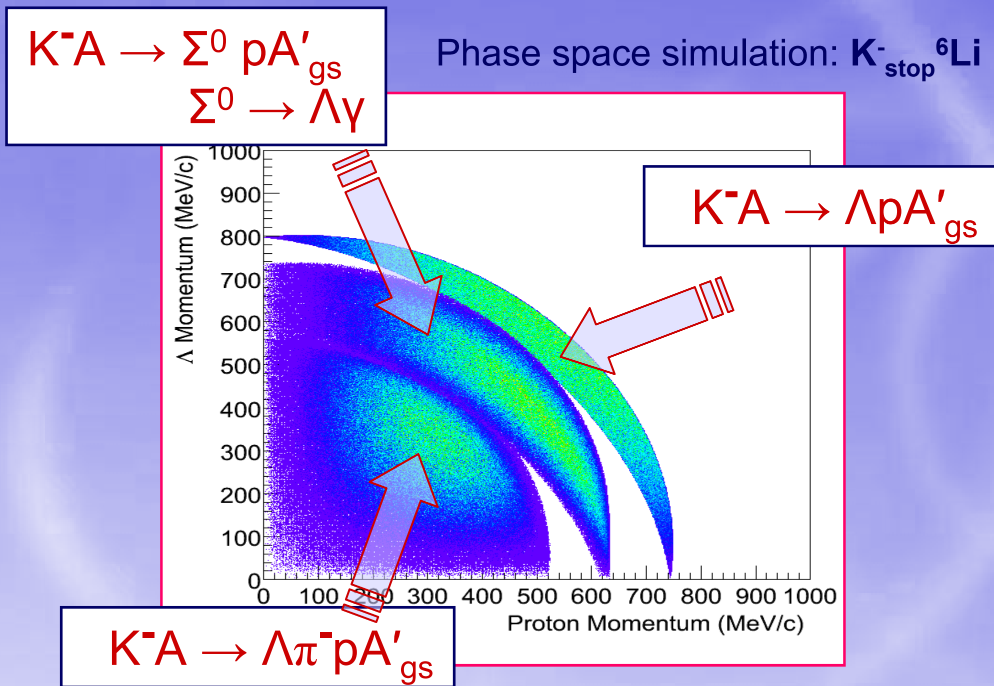
- One nucleon absorption (**with** pion emission)
  - **$K^-N \to \pi Y$** $\Rightarrow K^-A \to \Lambda(\Sigma)\,\pi X$
    - Study of hypernuclear formation
    - Study of Quasi-Free reactions (see talk by S. Piano this afternoon)

- Absorption by few nucleons (**without** pion emission)
  - **Two** nucleon absorption
    - **$K^-(2N) \to NY$** $\Rightarrow K^-A \to \Lambda(\Sigma)\,pX$, $K^-A \to \Lambda(\Sigma)\,n\,X$
  - **Three** nucleon absorption
    - **$K^-(3N) \to NNY$** $\Rightarrow K^-A \to \Lambda(\Sigma)\,d\,X$
  - **Four** nucleon absorption
    - **$K^-(4N) \to NNNY$** $\Rightarrow K^-A \to \Lambda(\Sigma)\,t\,X$

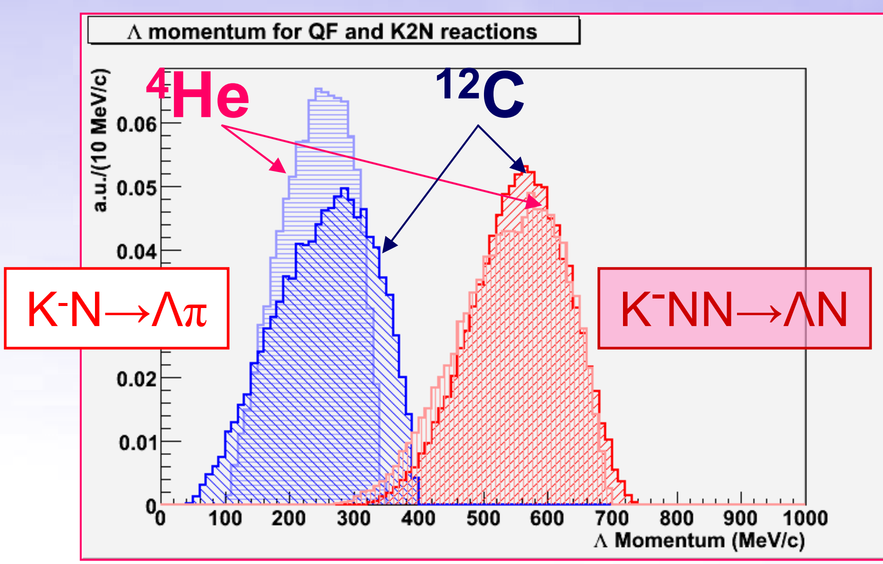
Relevant processes for the study of possible kaon-nucleons bound clusters

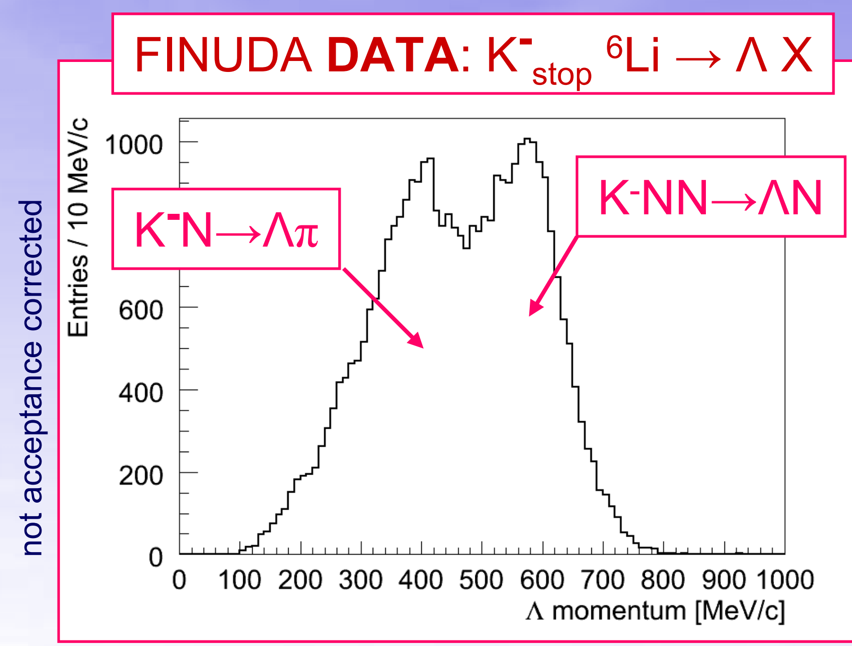
the absorption process involves mainly the nucleus surface but depends also on the nuclear structure $\Rightarrow$ different features for different nuclei

K^{-}_{stop} absorption by one vs many nucleons



Expected signatures:
in pionless reactions
emission of **high momentum nucleons**
(or light nuclei) and
hyperons





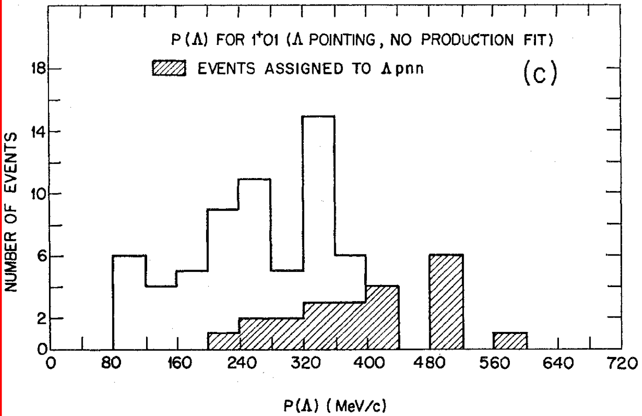
Few data on multinucleon absorption exist…

Deuterium	Helium	76% CF_3Br + 24% C_3H_8	Nuclear emulsions
0.01	0.16 ± 0.02	0.25	0.15-0.30

Multinucleon capture rates (no pions)

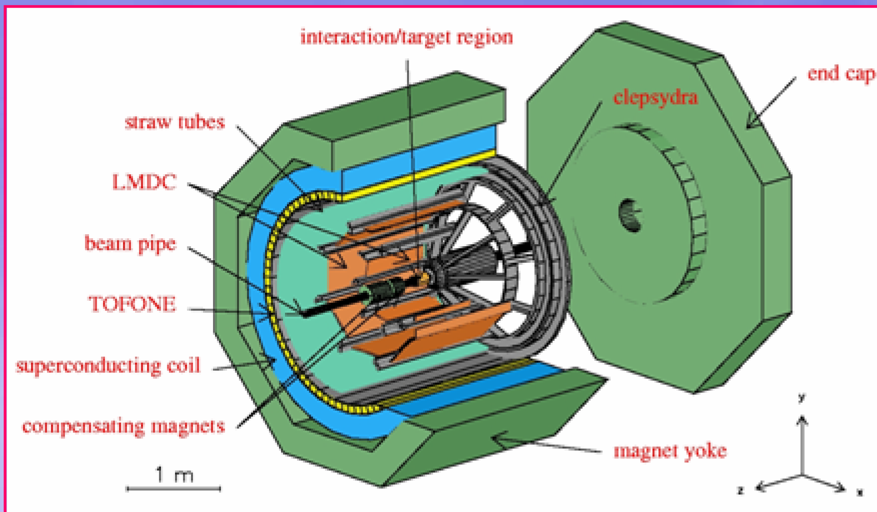
non-mesonic production increasing with A

- Data still belonging to old bubble chamber/emulsions experiments
  - ^{4}He: Katz et al. PR D1 (1970), 1267
    - Non-mesonic Λ (Σ^0): 11.7%
    - Non-mesonic Σ^+:1.0%
    - Non-mesonic Σ^-: 3.6%



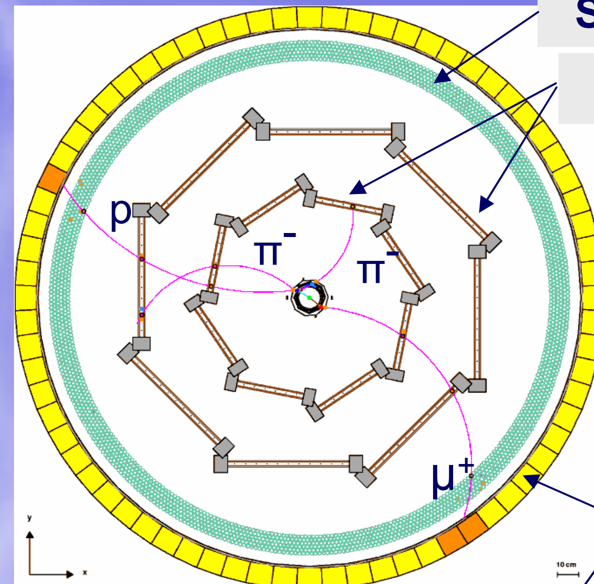
fast Λ - no pion emission

A>4: FINUDA @DAΦNE



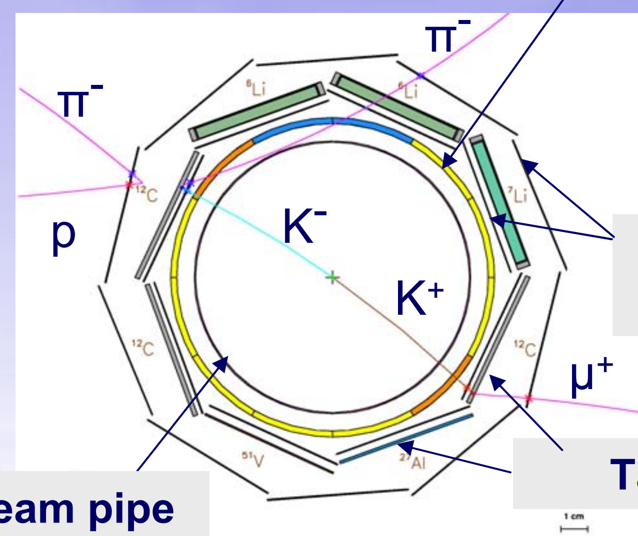
Straw tubes

Wire chambers



Plastic Scintillators

Two data takings in 2003-2004 (~190 pb^{-1}) and 2006-2007 (~960 pb^{-1})



Vertex detector

Simultaneous use of different targets

A = ^{6}Li, ^{7}Li, ^{9}Be, ^{12}C, ^{13}C, ^{16}O, ^{27}Al, ^{51}V

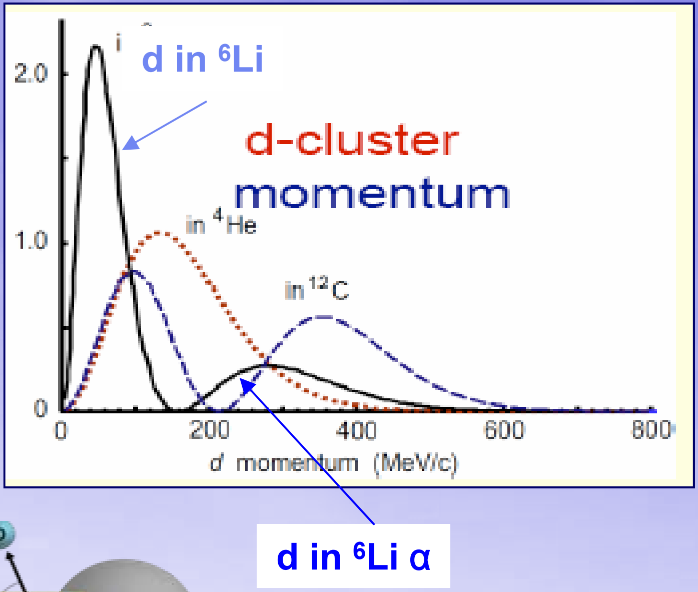
Targets

Beam pipe

K^-_{stop}-2N absorption in ^{6}Li: study of final states with Yp pairs

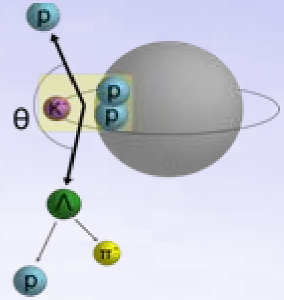
- ^{6}Li is the lightest nucleus available in FINUDA
  - Smallest contribution from Final State Interactions

Yamazaki, Akaishi NPA792 (2007),229



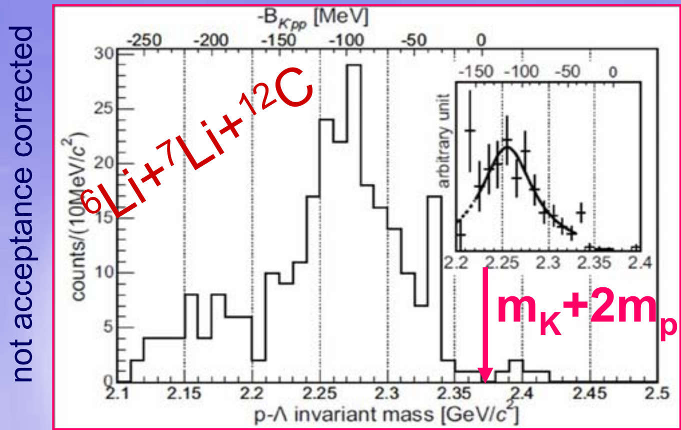
- ^{6}Li has a well known cluster structure
  - Absorption can occur on d or ^{4}He subclusters

- Study of:
  - **^{6}Li(K^-, Λp) X (K^-pp)**
  - **^{6}Li(K^-, Σ^-p) X′ (K^-pn)**



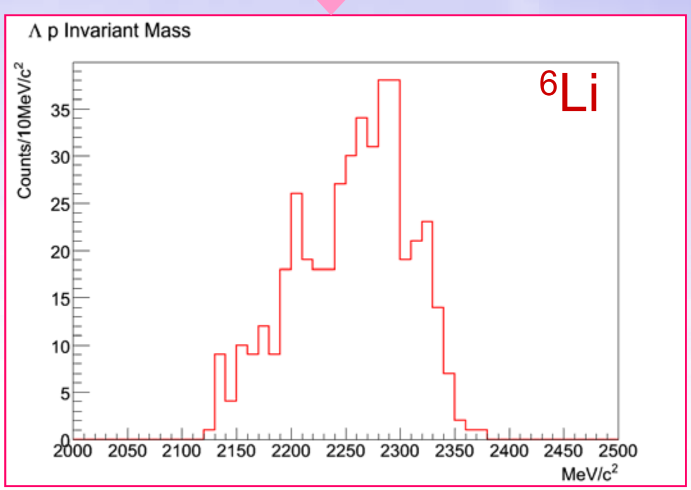
^{6}Li (K^-_{stop}, Λp) X: semi-exclusive analysis

FINUDA Coll., PRL 94(2005)212303



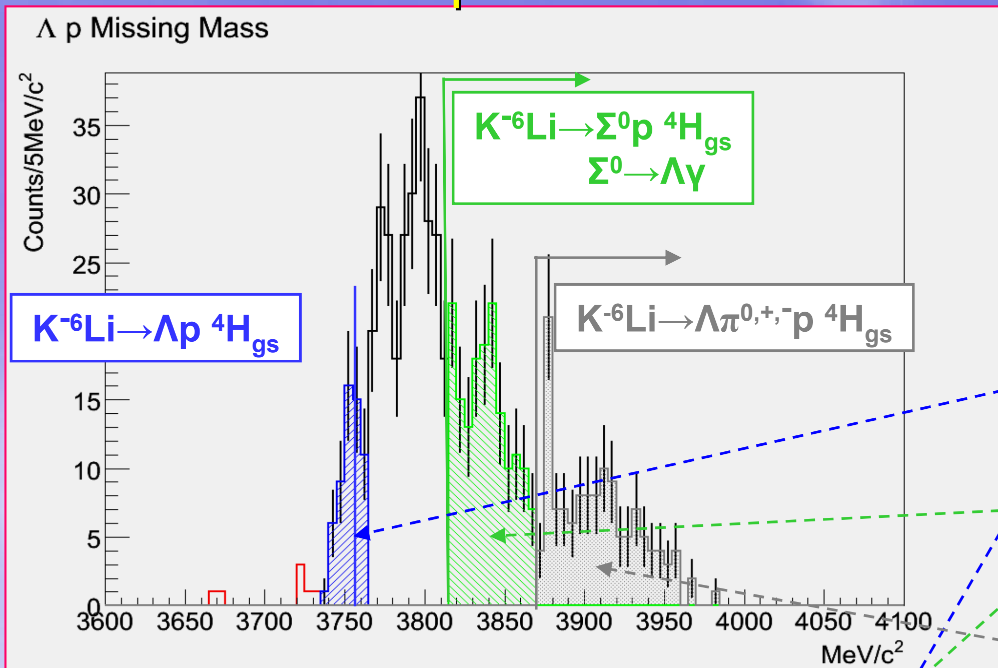
- Partial statistics on light targets only (i.e. ^{12}C mainly), first run
  - (Λp) invariant mass: bump lower than expected for QF reaction
  - Signature of a (K^-pp) bound state?
    - Back-to-back emission of (Λp) pairs

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



- 6Li targets only, 2nd run (8x statistics)
  - Same cuts, compatible (Λp) i.m. spectrum shape
  - Same back-to-back features
  - Missing mass analysis feasible
    - Separation of QF contributions to the spectra

$^{6}Li\ (K^{-}_{stop}, \Lambda p)\ X$: missing mass analysis



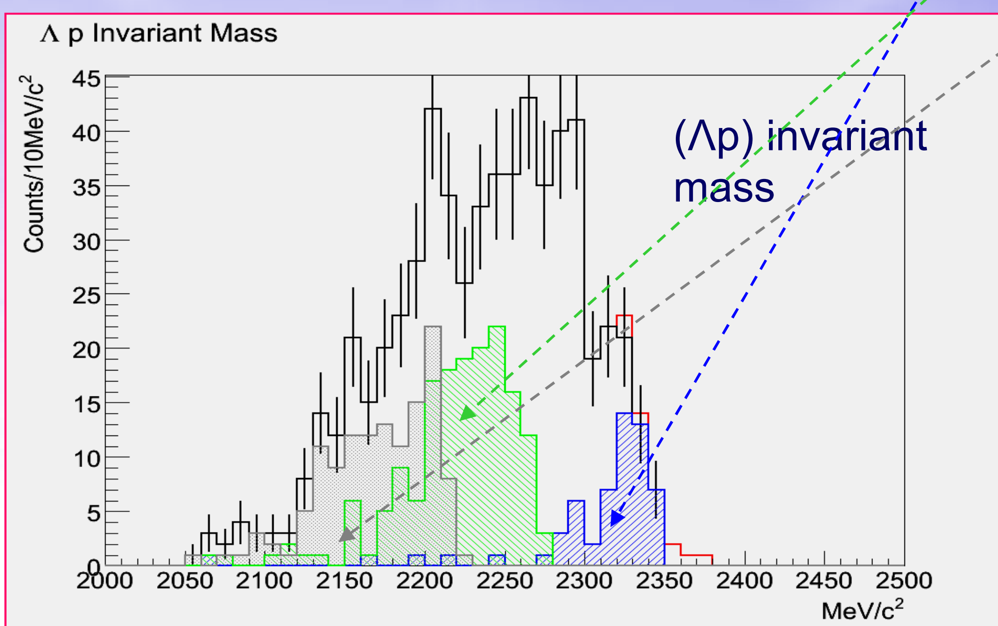
not acceptance corrected

Different QF-2NA contributions open at fixed m.m. thresholds

$K^{-}A \rightarrow \Lambda p\ X$

$K^{-}A \rightarrow \Sigma^{0} p\ X$

$K^{-}A \rightarrow \Lambda \pi^{0+-} p\ X$



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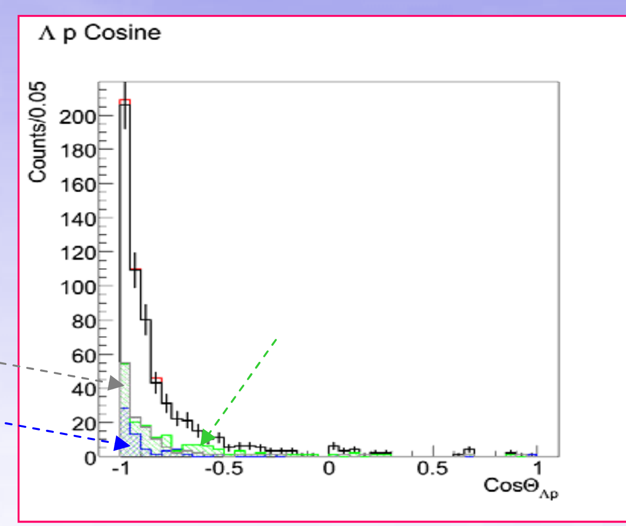
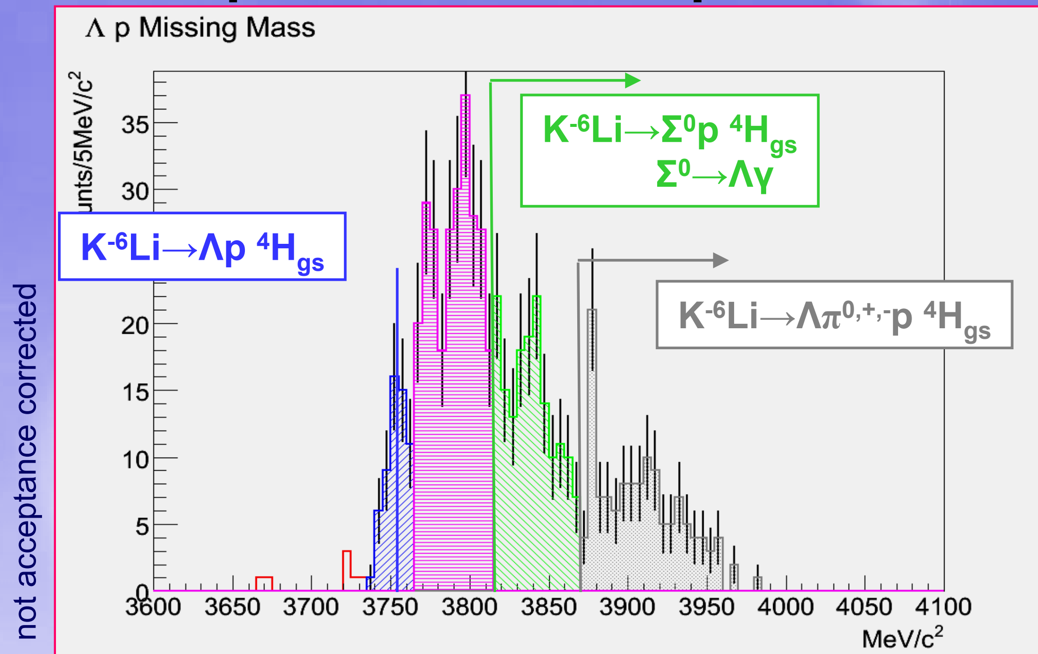
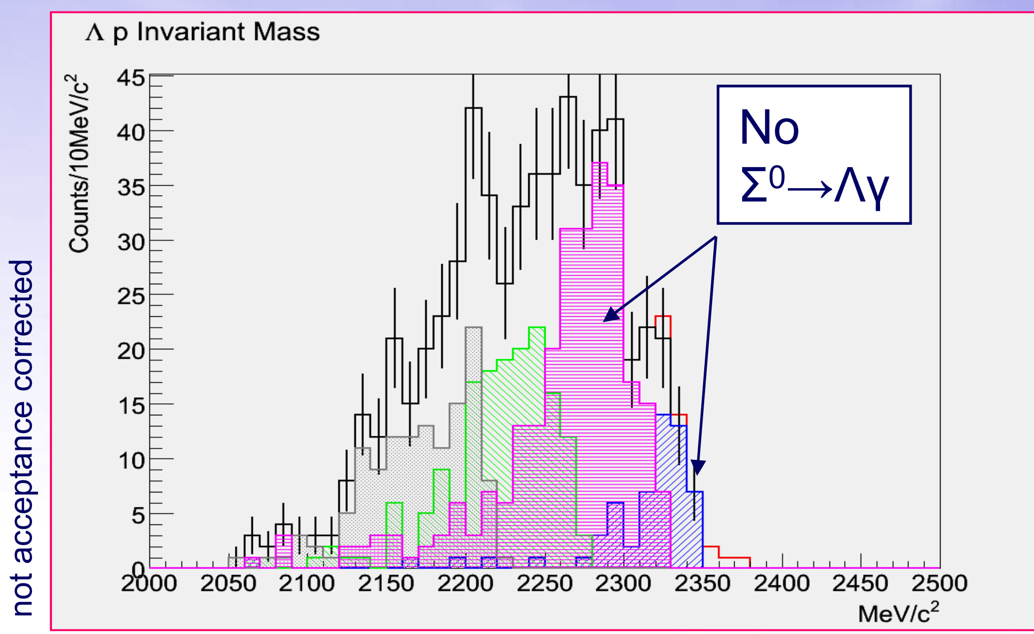


not acceptance corrected

A part of the spectrum cannot be explained





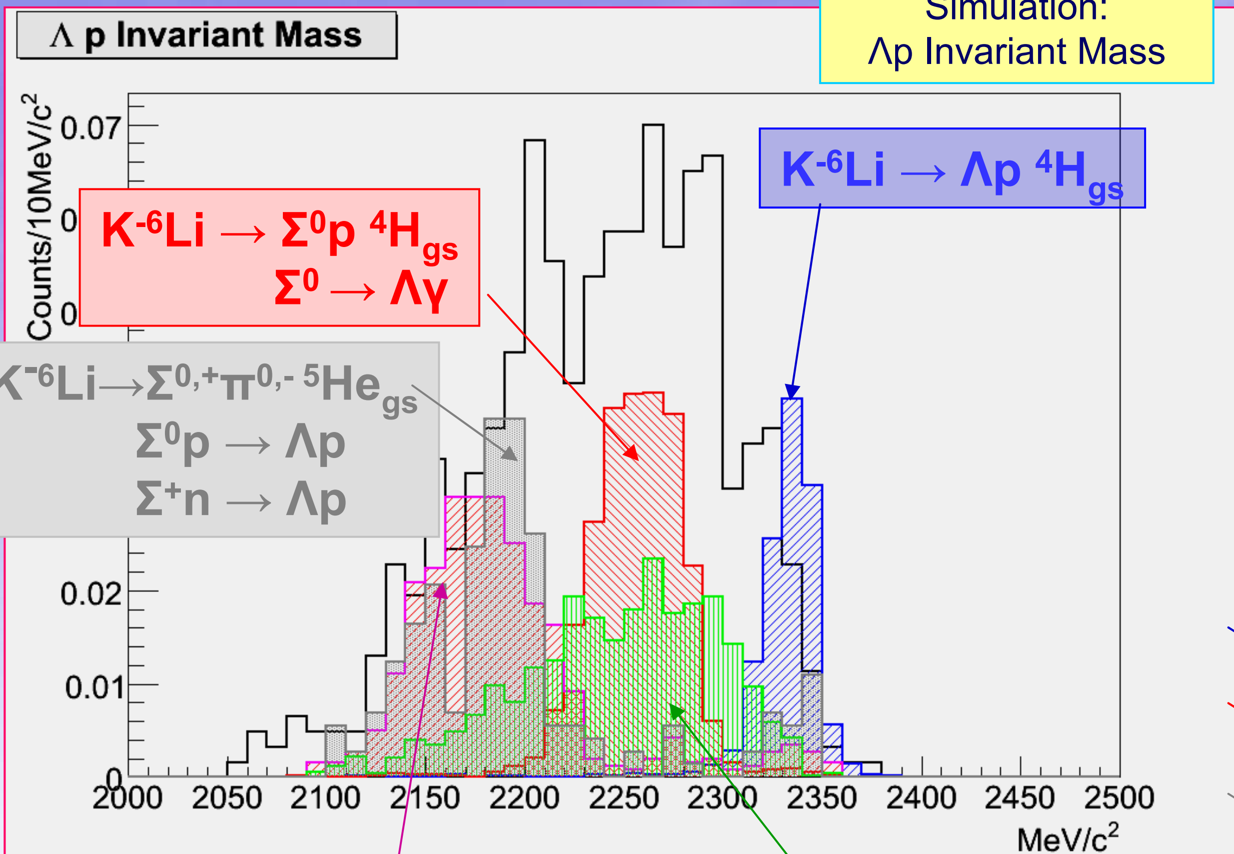
- Only a fraction of the bump can be explained by $\Sigma^0 p$ production
- M.M. method unsensitive to Conversion Reactions
  - Some of them could play a role

$K^- A \rightarrow \Sigma^{0,+} \pi^{0,-} X$
$\Sigma^0 p \rightarrow \Lambda p$
$\Sigma^+ n \rightarrow \Lambda p$

$K^- A \rightarrow \Sigma^{0,+} n\ X$
$\Sigma^0 p \rightarrow \Lambda p$
$\Sigma^+ n \rightarrow \Lambda p$

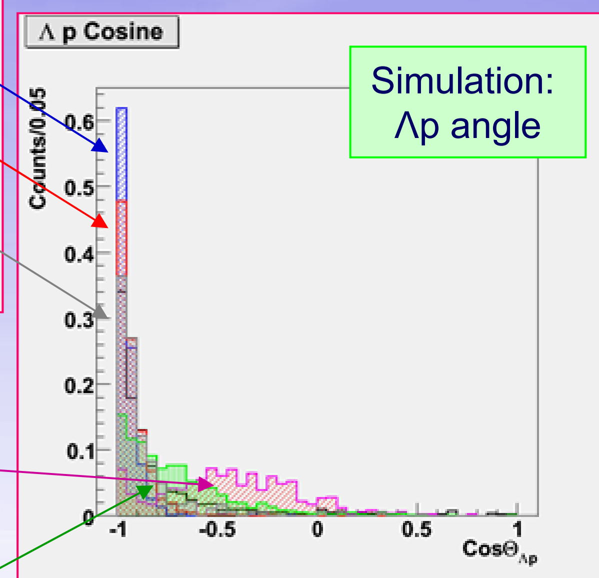
$K^- A \rightarrow \Sigma^{0,-} p\ X$
$\Sigma^0 n \rightarrow \Lambda n$
$\Sigma^- p \rightarrow \Lambda n$

Montecarlo study of ΣN→Λp



Basically, most of the C.R. channels do not fit at the same time *both* the (Λp) invariant mass and the (Λp) angular distribution

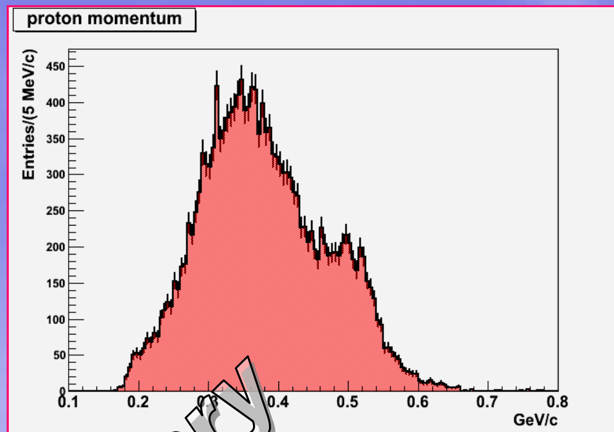
A global fit is required



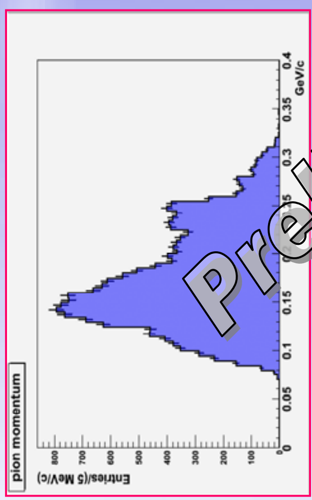
$K^-{}^6Li \rightarrow \Sigma^{0,+} n\ {}^4He_{gs}$
$\Sigma^0 p \rightarrow \Lambda p$
$\Sigma^+ n \rightarrow \Lambda p$

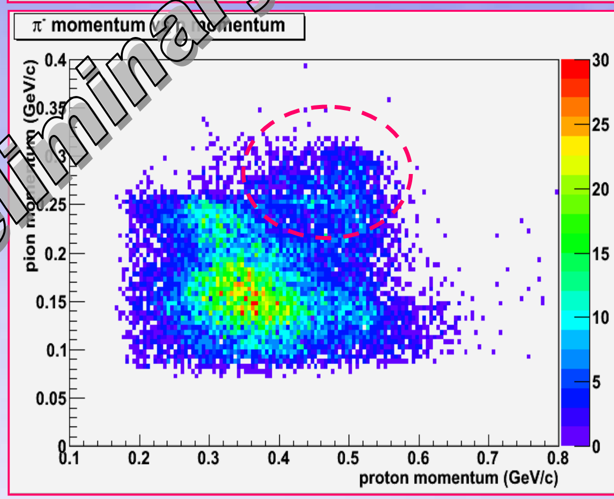
$K^-{}^6Li \rightarrow \Sigma^{0,-} p\ {}^4H_{gs}$
$\Sigma^0 n \rightarrow \Lambda n$
$\Sigma^- p \rightarrow \Lambda n$

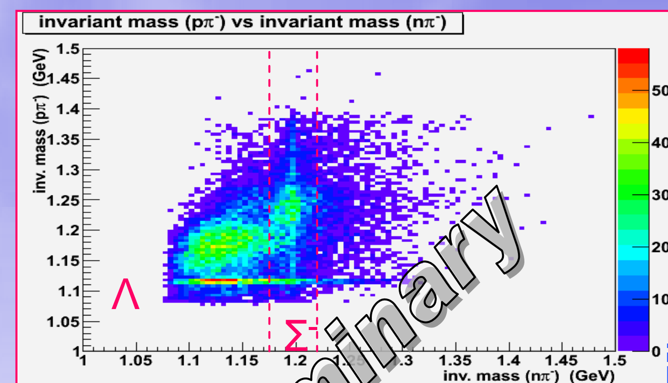
^{6}Li (K^-_{stop}, Σ^-p) X step 1: study of $K^-\,{}^6$Li $\rightarrow n\pi^-p$ X

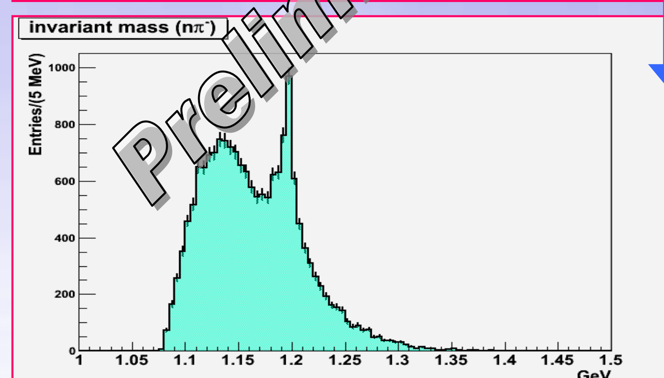


- Selection of the $n\pi^-p$ sample to identify Σ^- + p in the final state
  - 8% neutron detection efficiency
  - Quality cuts on charged tracks
- Clean signal of Σ^- already without applying kinematic cuts: S/N = ~1



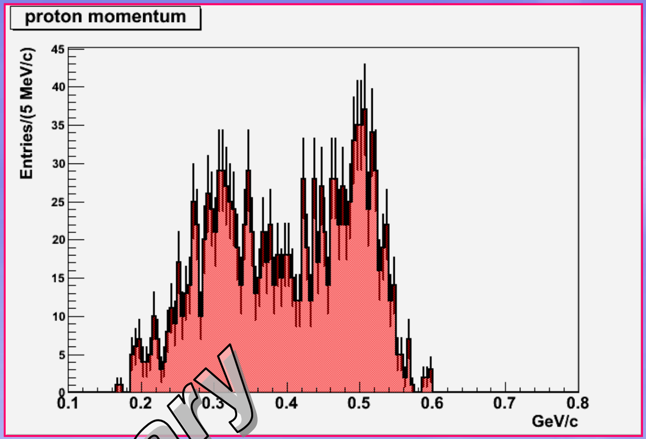


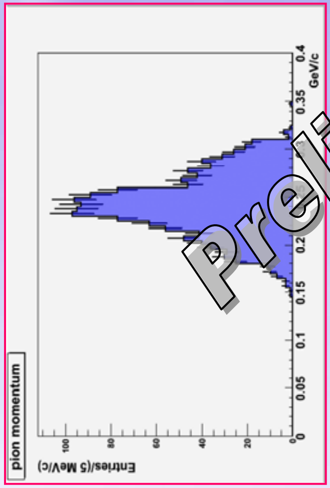


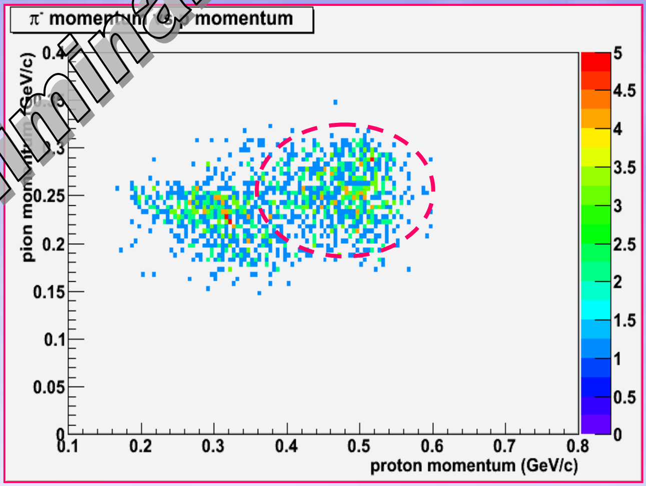


- Remove background contaminations
  - channels with Λ
  - γ contaminations (unphysical events)
- Topological cuts on vertices
- selection of a high quality Σ^- (narrow invariant mass band)

^{6}Li (K^{-}_{stop}, $\Sigma^{-}p$) X step 2: Σ^{-} p identification

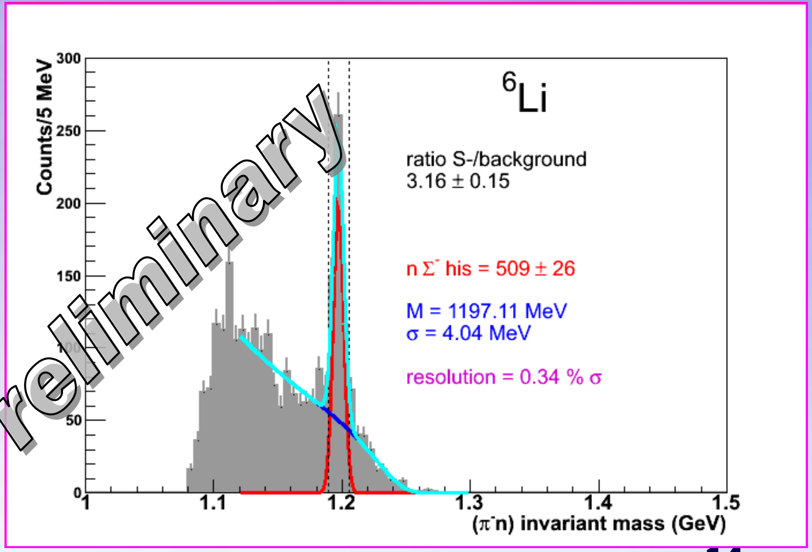






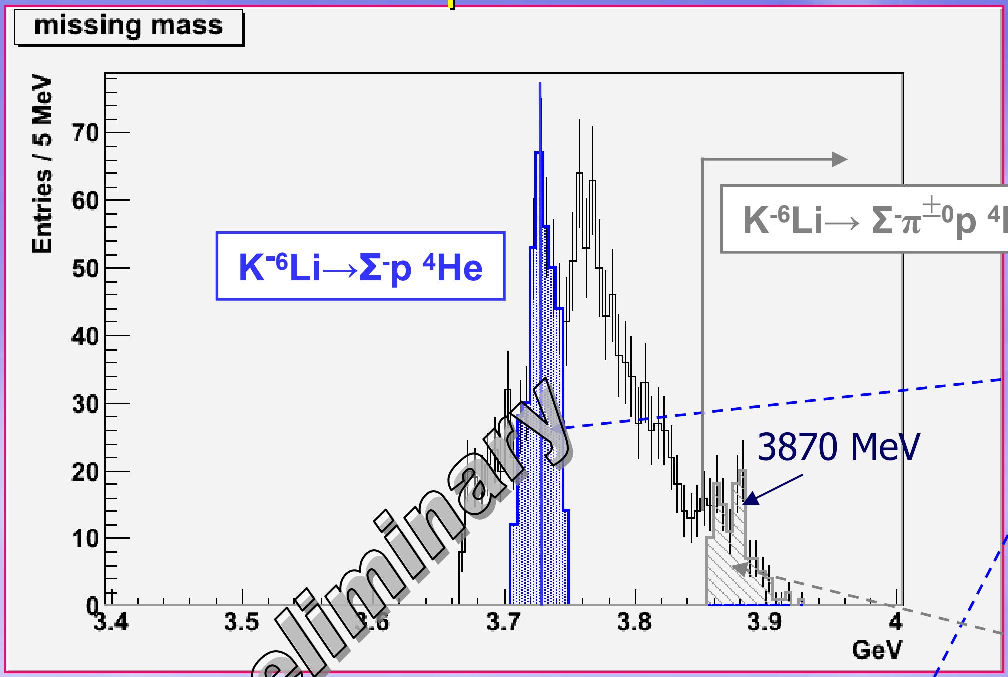
Selection of the $\Sigma^{-}p$ sample:

- narrow ($\pi^{-}n$) i.m. band
- Forward emitted ($n\pi^{-}$) from Σ^{-}
- $\Sigma^{-}p$ QF reaction signatures:
  - Proton momentum > 300 MeV/c
  - Pion momentum > 150 MeV/c
  - Σ^{-} ($n+\pi^{-}$) momentum > 300 MeV/c



- S/N (Σ^{-} peak): ~2 ⇒ > 3.

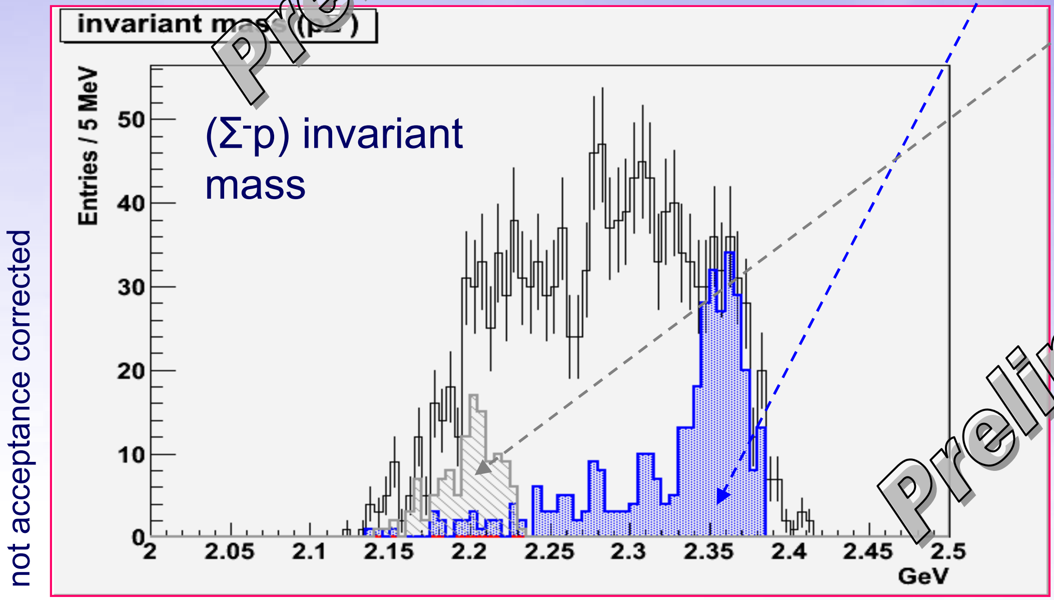
^{6}Li (K^-_{stop}, Σ^-p) X: missing mass analysis

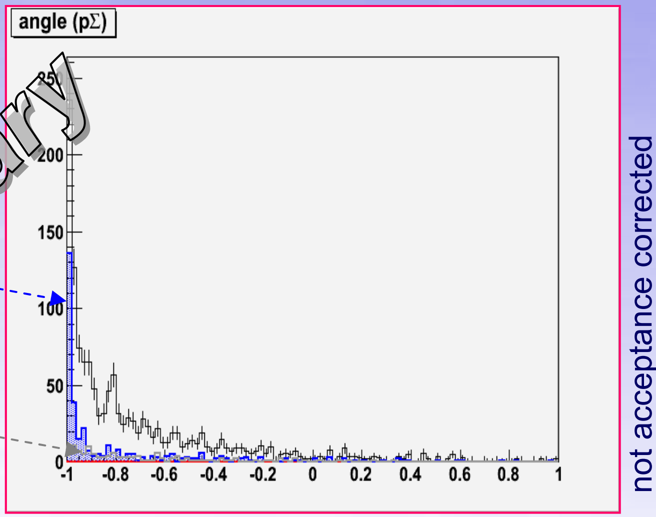


Different QF-2NA contributions open at fixed m.m. thresholds

$K^- A \to \Sigma^- p\ X$

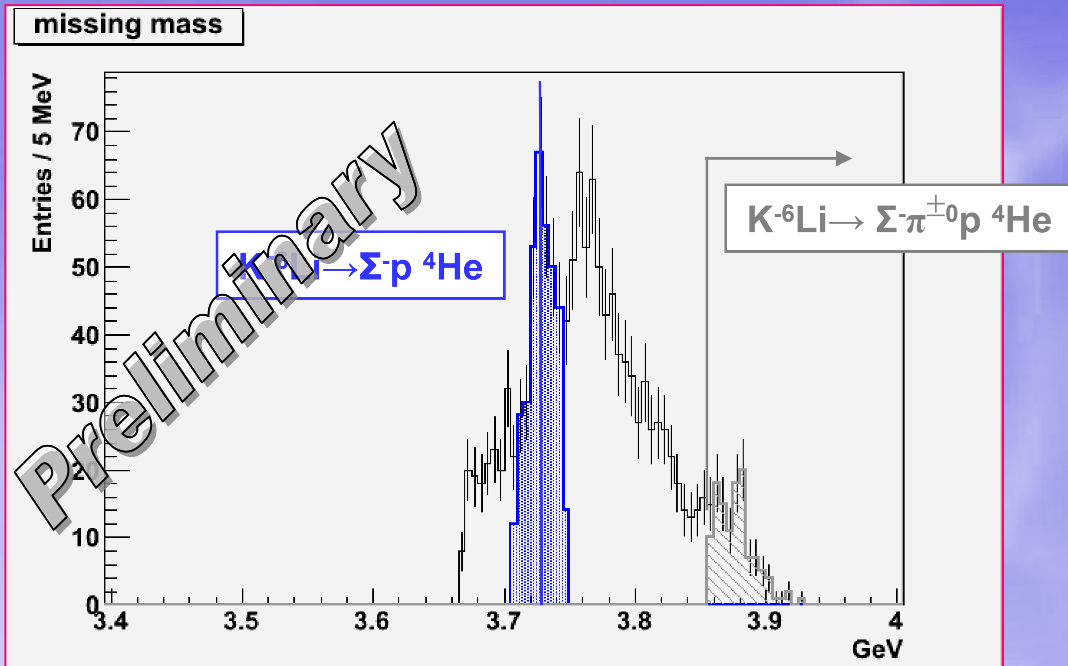
$K^- A \to \Sigma^- \pi^{\pm 0}\ p\ X$



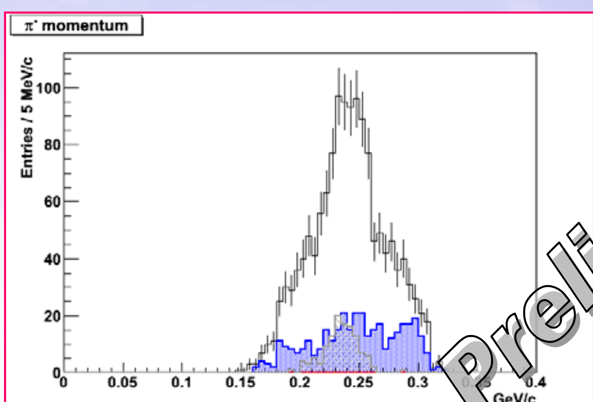


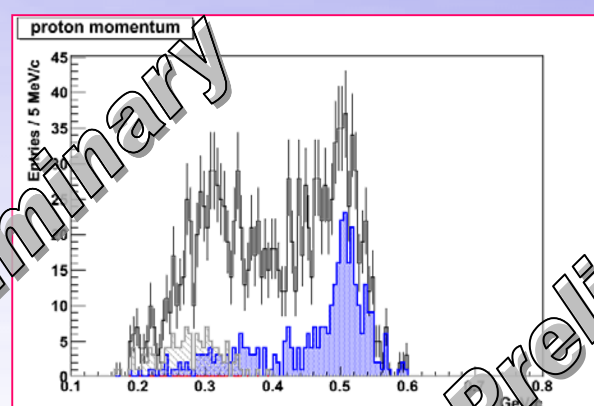
A large part of the missing mass spectrum unexplained by QF reactions

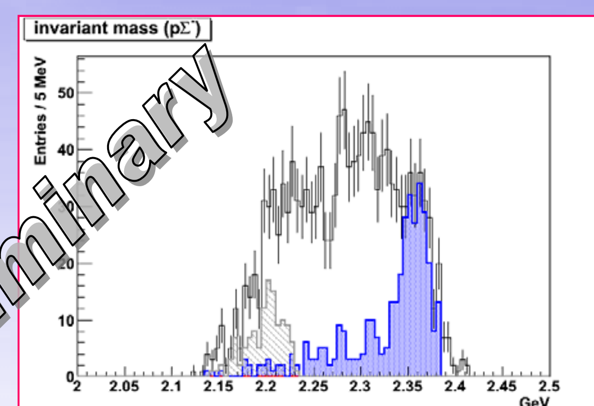
not acceptance corrected



- Σ^-p ($\pi^{\pm 0}$) QF reaction can only explain a part of the spectra
- The peaks in p (lower) and π^- momentum distributions is due the high missing mass side
  - No correlation with the main m.m. peak @ ~3.76 GeV
  - Broad enhancement in (Σ^-p) i.m. distribution @ ~ 2.3 GeV fails to be reproduced as well





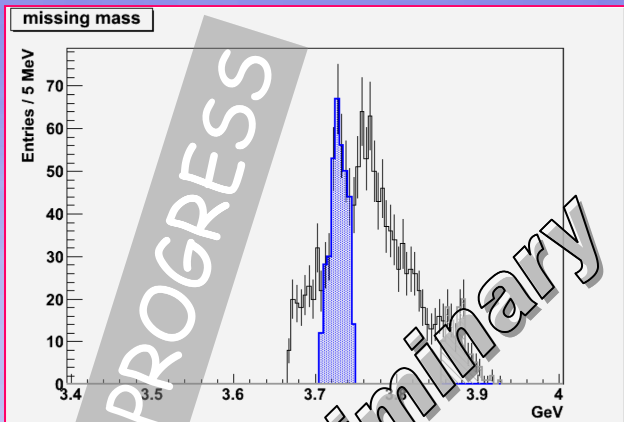


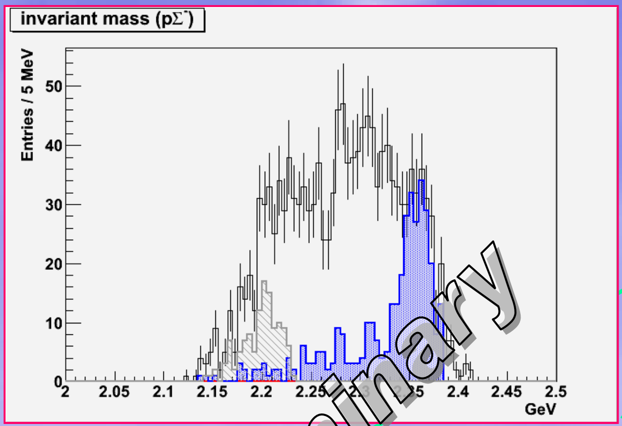
Peak not due to Σ^-p

Missing/invariant mass spectrum interpretation

- Several reactions could feed the spectra

Exp. Data, no acceptance correction





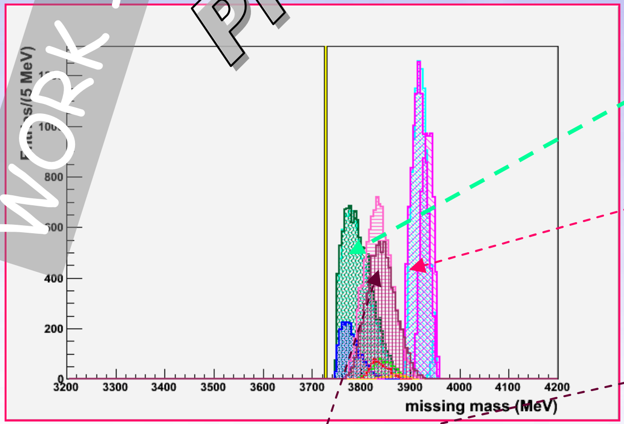
Proton rescattering

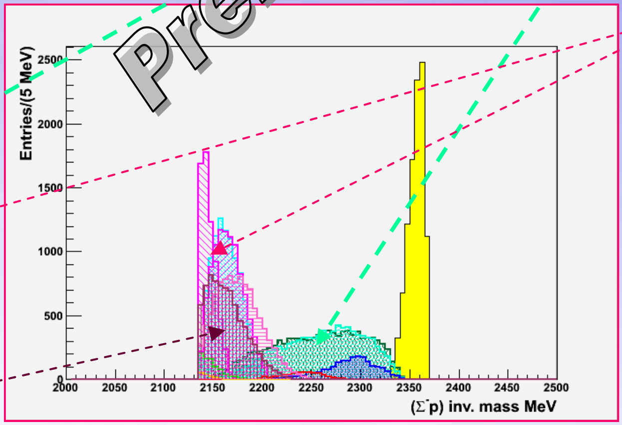
$K^- A \rightarrow \Sigma^- p\ X$

$pn \rightarrow np$

$pp \rightarrow pp$

Raw simulation, no detector acceptance





Pion rescattering

$K^- A \rightarrow \Sigma^- \pi^+ X$

$\pi^+ p \rightarrow \pi^+ p$

$\pi^+ n \rightarrow \pi^0 p$

Σp elastic scattering

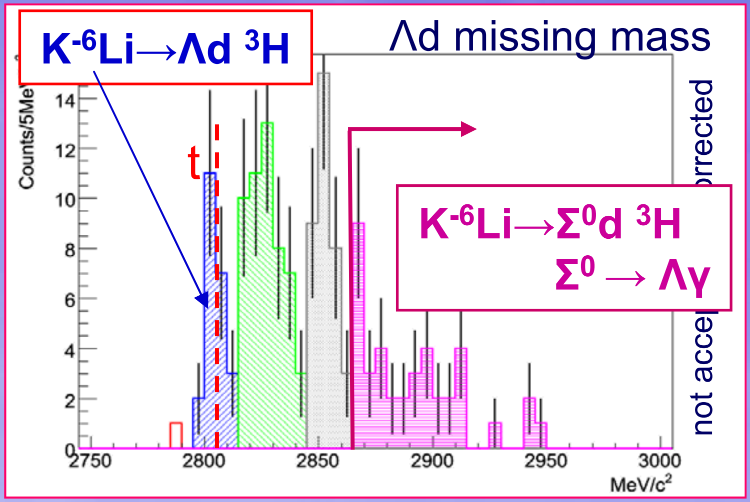
A global multi-projection fit is required

Summary: K^-2N absorption

- FINUDA data: further studies on K^- ^{6}Li interactions to investigate 2N absorption in Yp pairs
  - **K^-[pp] → Λp**
    - $M_{\Lambda p}$ structure observed for K^- absorption with counterpart in m.m. distribution not to be explained by QF-2A mechanism
    - Back-to-back (Λp) correlation
    - Σ^0p useful to explain only a part of the spectrum
    - Role of ΛN conversion reactions
  - **K^-[pn] → Σ^-p**
    - Missing mass spectrum not fully explained by simple QF-2A reactions
    - No enhancement observed in (Σ^-p) invariant mass distribution
    - Back-to-back (Σ^-p) correlation
    - Simple effect of Σ/p/π rescattering not enough
  - Combined studies could help sheding light on the problem

Summary: K^-3N(4N) absorption

- **Semi-exclusive study of Λd final states in K^- ^{6}Li interactions to investigate 3N absorption**
  - back-to-back (Λd) correlation
  - QF-3NA clearly observed + other structures seen in missing mass
  - Negligible role of Σ^0 production



- **Semi-exclusive study of Λt final states in K^- ^{6}Li interactions to investigate 4N absorption**
  - back-to-back (Λt) correlation : $\cos\Theta_{\Lambda t} \sim -1$
  - First direct measurement of K^- absorption on α

- Common analysis method: decomposition of experimental distributions through partial contributions and global fits