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FIRST OBSERVATIONS OF HYPERNUCLEAR NON MESONIC WEAK DECAYS WITH FINUDA

The FINUDA Collaboration *

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ABSTRACT

The FINUDA experiment has successfully completed the first round of data taking at DAΦNE. The excellent detection capability for the hypernuclear decay products and the low momentum threshold on the proton spectra(20 MeV) will allow the measurement of the proton stimulated non-mesonic decay with an improved accuracy. Furthermore, for the first time, non mesonic decays such as ${}^{4}_{\Lambda}He \rightarrow d + d$ were observed.

1 First Observation of proton spectra from Non Mesonic Weak Decay

From the beginning the FINUDA detector [1)] was designed to measure the charged particles (pions, protons,deuterons) and the neutrons emitted in the Mesonic and Non-Mesonic(NM) decay of hypernuclei. It was clear that it was mandatory to perform measurements of the decay products in coincidence with the π^- emitted in the hypernucleus formation reaction $K^- +^A Z \rightarrow {}^{A}_{\Lambda}Z + \pi^-$. Thanks to the good energy resolution on the hypernuclear final states (better than 1 MeV) of FINUDA we can associate the detected particles to the decay of the ground state ${}^{A}_{\Lambda}Z$ or of an hypernucleus of lower mass. Due to the very small thickness of the stopping targets, the energy spectra of the charged particles should have quite a low energy acceptance cut, estimated around 20 MeV for protons-which is a nice figure of merit of FINUDA in comparison to the best SKS result [2)], whose cut is set to 40 MeV. We present here some preliminary results of Weak Decays of hypernuclei, essentially on a qualitative level because a quantitative data analysis would require further development of the reconstruction code, presently in progress. The particle identification of the charged products, associated to the reconstructed vertex of the K^- stopped in a nuclear target, is performed by means of the $\Delta E/\Delta X$ measurement by the microstrip detectors facing the targets [3)]. Fig.1 shows the bidimensional plot of the $\Delta E/\Delta X$ as a function of particle momentum measured by the tracker. The plot refers to the charged positive particles emitted from the ${}^6Li$ targets(sec.2). Similar spectra were obtained from all the nuclear targets [1)] and all the $\Delta E/\Delta X$ plots were equalized by suitable software corrections [4)]. Fig.2 shows the proton spectrum measured in coincidence with the π^-, emitted in the three ${}^{12}C$ targets in the binding-energy range of the Λ bound states [1)].

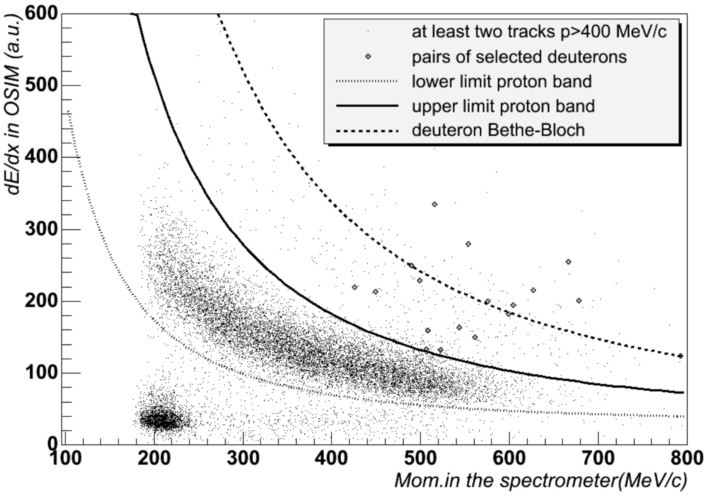

Figure 1: $\Delta E/\Delta X$ *(in arbitrary units)in* μ*strip detector vs measured momentum of the particle.*

However, the spectrum is still contaminated by residual background contributions (e.g.Σ decay in flight): the background suppression analysis is under way.

2 First observation of the rare two body decay ${}^{4}_{\Lambda}He \to d + d$

The observation of Schumacher [5] of a possible violation of the $\Delta I = \frac{1}{2}$ rule in NM decays of hypernuclei induced an increased effort on the study of NM decays of hypernuclei (for a recent review see [6]). A convincing argument about a possible violation of the $\Delta I = \frac{1}{2}$ rule could only come from measurements of exclusive NM decays from selected hypernuclei, i.e. a measurement of :

$$ {}^{A}_{\Lambda}Z \rightarrow^{A-2} Z + n + p \qquad \text{and} \qquad {}^{\rm A}_{\Lambda}{\rm Z} \rightarrow^{\rm A-2} ({\rm Z}-1) + {\rm n} + {\rm n} \tag{1} $$

in which the nucleons are not only detected in coincidence with the signal of the formation of ${}^{A}_{\Lambda}Z$, but also their momenta are measured with the precision necessary to determine unambiguosly the state of the residual nucleus ${}^{A-2}Z$ or ${}^{A-2}(Z-1)$. This is unfortunately impossible in FINUDA, and also in previous experiments, because the neutrons are hardly spectroscopized with the required precision. An alternative way to obtain information about exclusive NM decays

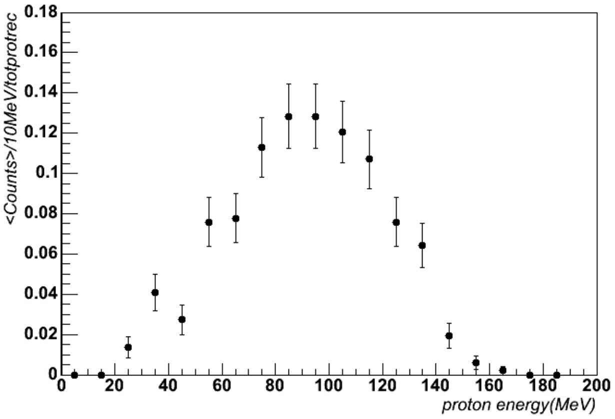

Figure 2: *Proton energy spectrum not acceptance-corrected, normalized to the number of protons reconstructed.*

could be to study rare two body decays of s-shell hypernuclei, like, e.g.:

$$^4_\Lambda He \rightarrow d + d \; ; \; ^4_\Lambda He \rightarrow ^3 H + p \; ; \; ^4_\Lambda He \rightarrow ^3 He + n \tag{2}$$

$$^5_\Lambda He \rightarrow ^3 H + d \; ; \; ^5_\Lambda He \rightarrow ^4 He + n \tag{3}$$

and similar decays for heavier hypernuclei. The branching ratios for such decays are expected to be small (10^{-3} of the total decay rate) and they have never been observed up to now. Light hypernuclei like $^4_\Lambda He$ cannot be formed in two-body reactions in FINUDA for experimental reasons. Nevertheless they are produced abundantly as hyperfragments from heavier targets, like ^6Li. Even though rare, the NM decays (Eq.2-3) show a very clean signature: a monochromatic charged particle, with high specific ionization. In some cases (first two channels (Eq.2) and the second one (Eq.3)) two of these particles are back-to-back emitted in the center of mass, with very peculiar and clean topologies. Reminding that the $^6_\Lambda Li$ is unstable for proton emission, we searched for the following chain of reactions:

$$K^- + ^6 Li \; \rightarrow \; ^4_\Lambda He + p + n + \pi^- \quad \text{and} \qquad ^4_\Lambda \text{He} \rightarrow \text{d} + \text{d} \tag{4}$$

$$K^- + ^6 Li \; \rightarrow \; ^4_\Lambda He + n + n + \pi^0 \quad \text{and} \qquad ^4_\Lambda \text{He} \rightarrow \text{d} + \text{d} \tag{5}$$

in order to find candidates for the rare decay (Eq.2). Its signature consists in two deuterons of 570 MeV/c, emitted back-to-back. The estimated momentum

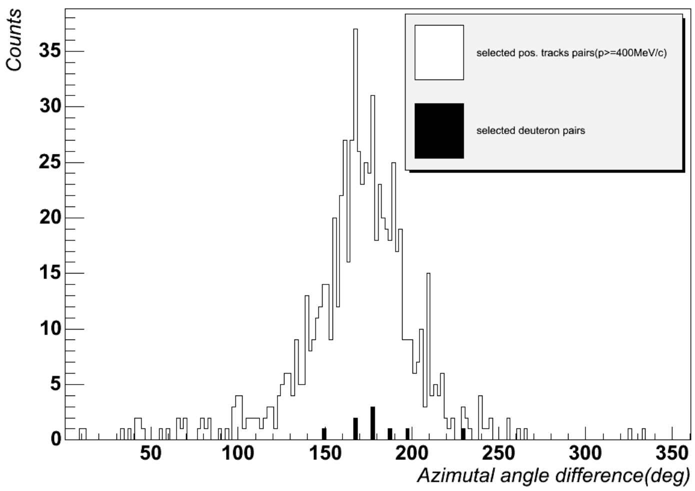

Figure 3: *The azimuthal angle between two positive tracks with momentum larger than 400* MeV/c*, emitted from* K^-*vertex. The selected deuteron pairs are shown in black.*

resolution for these deuterons is 2% FWHM and the angular acceptance about 32% [7].

We looked for events with: 1) at least two tracks corresponding to positive particles emitted from the K^- vertex in ^6Li targets, 2) with $\Delta E/\Delta X$ beyond the chosen upper limit of the proton band (Fig.1), 3) momentum larger than 400 MeV/c and 4) a loose back-to-back angular correlation. We chose these cuts since the exact geometrical description of the complex mechanical structure of the Lithium targets is still under way and we expect quite important corrections after this improvement on the evaluation of both the momenta and the angles of the deuterons emitted from ^6Li targets. Fig.3 shows the angular correlation observed for the tracks fullfilling 1) and 3): only nine events, black distribution in the figure, satisfy also 2) for both particles. The $\Delta E/\Delta X$ values of these particle pairs are marked with the crosses in Fig.1. This event topology is shown in Fig.4 ; the μ^+ track corresponding to the $K_{\mu 2}$ decay of the K^+ stopping in the opposite target is tracked too.

It is quite interesting to observe that also the events with two positive tracks and momenta larger than 400 MeV/c show a strong back-to-back correlation which can be an indication of different rare exclusive decays, like, e.g. ${}^4_\Lambda He \rightarrow d + p + n$.

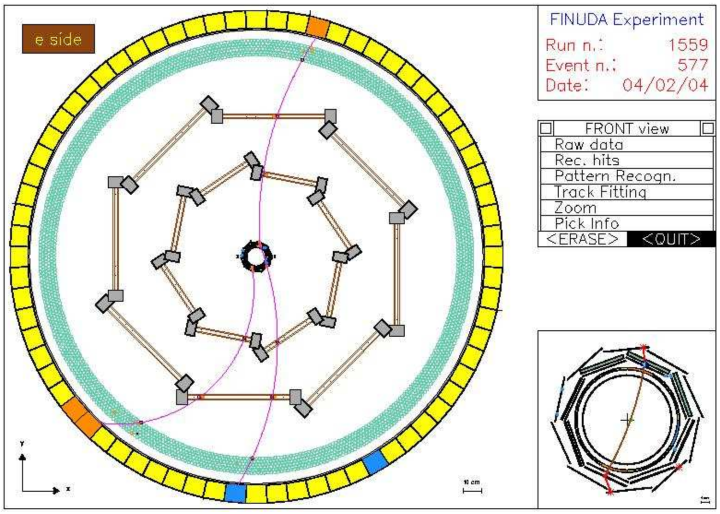

Figure 4: *Candidate event for the rare non mesonic decay* ${}^{4}_{\Lambda}He \rightarrow d + d$.

3 Conclusion

On the road of measuring with FINUDA Weak Decays of hypernuclei in several targets and in many channels, we have started with the observation of the rare two-body decay ${}^{4}_{\Lambda}He \rightarrow d + d$, never reported before. The cleanliness of the events promises us that we will be able to provide the branching ratios.

References

1. P. Gianotti, these proceedings.

2. H. Bhang for The FINUDA Collaboration, these proceedings.

3. P. Bottan et al., *Nucl. Instr. and Meth.* **A427**, 423-436 (1999). , P. Bottan et al., *Nucl. Instr. and Meth.* **A435**, 153-160 (1999).

4. S. Piano for The FINUDA Collaboration, these proceedings.

5. R. Schumacher, *Nucl. Phys.*, **A547** (1992),143c.

6. W. Alberico and G. Garbarino, *Phys. Rep.* **369** (2002), 1.

7. A.Feliciello, *Nucl. Phys.*, **A691**,(2001),170c.