Improved particle identification with probabilistic approach for the HypHI project

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The first experiment of the HypHI collaboration aimed to demonstrate the feasibility of the hypernuclear spectroscopy by means of heavy ion beam induced reactions. The phase 0 experiment was performed with a ^{6}Li beam at 2AGeV impinged on a stable ^{12}C target material. The main goal of the experiment was to produce, reconstruct and identify decay vertexes of Λ particle and $^3_\Lambda$H, $^4_\Lambda$H [**?**]. With the finalized data analysis of Phase 0 experiment, the first results show that the experimental method is viable for the study of hypernuclei [1, 2, 3].

Possible improvement on the particle identification is necessary in order to improve the event reconstruction of the Λ and hypernuclear candidates. During the track reconstruction the particle identification has to define which track corresponds which particle or fragment. The idea for improving the identification is to perform a maximum likelihood ratio test for each particle hypothesis. From the track reconstruction, the kinematics of the track is determine and a partial particle identification is associated to the track thanks to the time-of-flight measurement.

For each track, its velocity $\beta_{measured}$ is calculated from the measured time-of-flight and path length, then a probability of being π, K, proton, deuteron, triton for the case of charge $Z = 1$ species is given. Theoretically, we know that $\beta = p/\sqrt{p^2 + m^2}$, where p and m correspond to the momentum and mass of the particle, therefore for a measured momentum $p_{measured}$ and a given mass we can calculate that should be the velocity $\beta_{likelihood}$. The particle identification are usually defined by a side band as explained in [1]. Following the same PID cut than in [1], the probability of being a given particle $P((\beta_{measured}, p_{measured})|id)$ is then defined by a Gaussian probability density function at $\beta_{measured}$. The mean value and standard deviation of the Gaussian function are β_{theory} and $\beta_{theory} \pm \beta_{sideband}$. This probability of identification is given for each particle hypothesis and correspond how close or how far is the measured momentum and measured velocity of the track from each hypothesis. Finally, the maximum likelihood ratio test is performed for the each hypothesis, $P(a) = P((\beta, p)|a)/\sum_{id}(P((\beta, p)|id)$ where a corresponds to the tested species (π, K, proton, deuteron, triton) and id corresponds for all the species. The particle identification is then decided by the highest ratio.

The probability of identification can also use to improve the selectivity of the good track candidates. This new procedure of the particle identification was tested on the experimental data of the phase 0 experiment. Figure 1 shows the mass spectrum of the track reconstruction calculated from the $m = p * \sqrt{1./\beta^2 - 1.}$ with a first p-value cut at $p > 0.05$. The black line represents the mass spectrum from the current situation of the final results published in [1]. The red line shows under the same conditions that the black line with a additional cut on the probability of identification. A clear separation is now possible with this probabilistic particle identification. A huge background suppression of bad track reconstruction can be seen, and all species can be identified directly in the mass spectrum instead of the β-momentum correlation plot.

The clear improvement of the particle identification shown for the phase 0 experiment data will help to the current data analysis of the phase 0.5 experiment of ^{20}Ne+^{12}C.

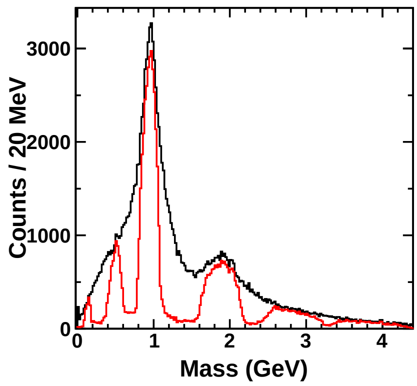

Figure 1: Improved particle identification in the mass spectrum. Initial mass spectrum after the track reconstruction and p-value cut at $pv > 0.05$ is shown in black line. The red line shows the improved mass spectrum of the track reconstruction when the probability of identification is used by setting a minimum probability.

References

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