RICH DETECTOR AT JEFFERSON LAB, DESIGN, PERFORMANCE AND PHYSICS RESULTS

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Since 2004 the hadron spectrometer of Hall A at Jefferson Lab is equipped with a proximity focusing RICH. This detector is capable of identify kaon from pion and proton with a angular separation starting from 6 sigma at 2 GeV/c. The RICH design is conceptually similar to the ALICE HMPID RICH; it uses a C₆F₁₄ liquid radiator and a 300 nm layer of CsI deposited on the cathode pad plane of an asymeetric MWPC. The RICH has operated for the Hypernuclear Spectroscopy Experiment E94-107, which took data in the last two years. Design details and performance along with first physics results from the hypernuclear experiment are shortly presented.

1. Introduction

A proximity focusing RICH has been designed, built and operated in the first hypernuclear spectroscopy experiment (E94-107) performed in Hall A at the Jefferson Laboratory in 2004 and 2005.

The Hall A is dedicated to high resolution and high luminosity electron scattering experiments, served by a continuous electron beam with energy up to 6 GeV. It is equipped with two identical, Quadrupole-Quadrupole-Dipole-Quadrupole High Resolution Spectrometers ¹ that accept particle momenta up to 4 GeV/c. The spectrometers are dedicated to the electron and hadron detection, having slightly different detectors packages.

The E04-107 experiment has performed the first systematic study on ⁹Be(e,e'K⁺)9 Li_Λ, ¹²C(e,e'K⁺)12 B_Λ and ¹⁶O(e,e'K⁺)9 N_Λ hypernuclei. The Λ hyperon represents an important probe in the nuclear medium due to the fact that it is not blocked by the Pauli principle and has a relatively weak coupling with the nuclear core, being reasonably well described by the shell models. Moreover, the Λ – N interaction represents an important aspect of the Neutron Start ³.

The lepton probe offers some advantages respect to the hadron probes in hypernuclear physics:

- presence of strong spin transitions (spin terms are relevant in Λ – N potential)
- generally higher energy resolution

Moreover the electron probe permits the study of complementary (Z-1) hypernuclei. On the other side, the cross section are quite small resepct to the hadronic ones, forcing to investigate phase space with high background, which therefore represents a challenging aspect of such experiment.

In fact, for a clean kaon identification, the required π rejection factor in E94-107 has been estimated of one order of magnitude larger than standard Hall A PID system based on time of flight and two aerogel Čerenkov

counters (with $n = 1.015$ and $n = 1.055$) in the hadron arm.

Figure 1. Schematic view of the proximity focusing RICH

2. Proximity focusing RICH layout

Figure 1 presents the conceptual layout of the Hall A RICH, which is based on the ALICE HMPID design⁴. The Čerenkov photons are produced by over threshold particles in the liquid freon C_6F_{14} ⁶ with refractive index of 1.28 and thickness of 1.5 cm. Then they refract on a quartz window of 0.5 cm and diverges in a 10 cm proximity gap. Eventually they are converted to electrons by a thin layer of CsI (300 nm) deposited on 3 pad planes that represent the cathode of a Multiwire Proportional Chamber. The induced charge of the electric avalanche is readout by a sample and hold analogically multiplexed front-end electronics⁵. Spatial information is obtained from the segmented pads, whose size is $8 \times 8.4 \text{ mm}^2$.

The relevant parameters of the RICH are in table 1.

Table 1. Relevant parameters of the Hall A RICH

Radiator	15 mm thick Liquid Freon (C_6F_{14} , $n=1.28$)
Photon converter	300 nm CsI film coated on Pad Planes
Position Detector	$1940 \times 403 \text{ mm}^2$ - Multi Wire/Pad Proportional Chamber filled with Methane at STP, HV= 1050 ÷ 1100 V
FE Electronics	11520 analog chs, multiplexed S&H

3. Evaporation System and Quantum Efficiency Measurement

One of the most important aspect of the RICH is the deposition of the proper layer of CsI on the pad plane. This is obtained by means of the evaporation of a pure CsI powder in a high vacuum chamber (few 10^{-7} mbar).

The Rome group has therefore built and installed at JLab an evaporation chamber for large area pad (up to about $650 \times 650 \text{ mm}^2$). The desired vacuum is obtained in less than 24 hours by three vacuum pumps (scroll, molecular and cryogenic). The CsI powder is heated at 500 °C by four crucibles evaporates toward the pad plane.

A quantum efficiency (QE) online measurement system ⁷ has been integrated into the evaporation chamber. An UV light generated by a deuterium lamp is directed on the evaporated pad passing through one of three wavelength filters (160, 180 and 220 nm). A small wire chamber at 2 mm from the pad collects the photoemitted electrons, whose current (few nA) is measured by a picoamperometer. A mirror can divert the UV beam to a reference PMT. The wire chamber over PMT currents ratio times the known reference PMT QE provides a measure of the deposited CsI QE; a typical measure is reported in figure 2.

4. RICH performance and physics results

The RICH has operated during the E94-107 experiment providing a clean kaon identification as shown in figure 3. The mean number of photoelectrons measured on a sample of pions is slightly more than 13 with an angular resolution (σ) of 5 mrad which corresponds to a kaon-pion separation of 6σ at 2 GeV/c.

Moreover, a pion rejection factor of more than 1:1000 has been estimated from a sample of pion selected by the two aerogel counters requiring the kaon discrimination by the RICH.

Eventually, the RICH has increased the peak detectability in the excitation energy spectra providing a signal to background of more than 7 (is 2.5

Figure 2. Typical QE distribution

using time of flight and aerogels only) for the smallest detectable peaks.

The obtained excitation energy spectra have been compared to some theoretical models, showing:

- a good agreement for the $^{12}\text{B}_\Lambda$, even afor the cross section of the ground state.
- an overall agreement on the $^{16}\text{N}_\Lambda$, with larger discrepancy in the relative strenghts of the most excited multiples
- substantial disagreemnt with the $^9\text{Li}_\Lambda$ hypernuclear level.

5. Conclusion and Perspectives

The RICH build and successfully operated in the E94-107 experiment, is now available in Hall A for a effective PID of hadrons up to 2-2.5 GeV/c. Extension of the momentum range to about 4 GeV/c could be done with

Figure 3. PID: effect of the RICH

relatively small effort, replacing the present freon with one with smaller index of refraction (e.g. with C_5F_{12}) and increasing the proximity gap of few centimeters. Some of the upcoming Hall A experiments and proposals are considering the advantage using the RICH.

References

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