Monitoring the Purification of the Gases in the CLEO III RICH Detector

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Abstract

The RICH is a two gas chamber particle identification device: one being a wire chamber, the other a nitrogen expansion gas volume. Charged particles and photons are detected in the wire chamber layer. The expansion volume allows particles to expand away from each other, so they can be easily distinguishable. Monitoring this expansion gas is what our group is currently researching. Its purity is essential for the detection of the particles. The method used to monitor its purity is to expose a reference volume of nitrogen to photons from a deuterium lamp and measure its output with respect to the light source unhindered by the gas. The same is done with a sample of nitrogen taken from the detector. This ratio gives information leading to the sample gas' purity. I have written the software used to control our device in LabVIEW, a graphical programming language. It images the relative measure of transmittance from the PMT signals, controls gas flow, scans the monochromator, and calculates the chamber exhaust gas transmittance relative to the reference gas transmittance. The apparatus is being assembled by our group and is in its finishing stages. Further research is being done to monitor the purity of the gas in the wire chamber.

Introduction

The RICH is a two gas volume particle identification device: the outer volume consists of thirty wire chambers where particles are detected; the inner chamber is a nitrogen expansion gas volume which allows particles to expand away from each other so they can be easily distinguishable. Our group is currently researching ways to monitor this expansion volume gas. Its purity is essential for the detector's operation. The method used to monitor its purity is to expose a reference volume of pure nitrogen to photons and measure its output with respect to the light source unhindered by the gas. The same is done with a sample of nitrogen taken from the detector. This ratio gives information leading to the sample gas' purity. I have written the software used to control our device in LabVIEW, a graphical programming language. I have also contributed to the assembly and design of the apparatus.

RICH

The RICH detector is used to measure the velocity of an entering charged particle. The particle's mass can then be calculated using its momentum, which is provided by CLEO III tracking devices. The method used to determine the velocity is based on the Cherenkov effect [1]. As a particle travels through a medium exceeding the velocity of light, photons are emitted at a fixed angle. The angle depends on the velocity of the particle and the index of refraction of the medium,

$$\cos\theta = 1/\beta n \qquad (1)$$

where n is the index of refraction and β is the charged particle's velocity (ratio of velocity to speed of light in vacuum). The velocity can be calculated from the measured angle θ, given the index of refraction.

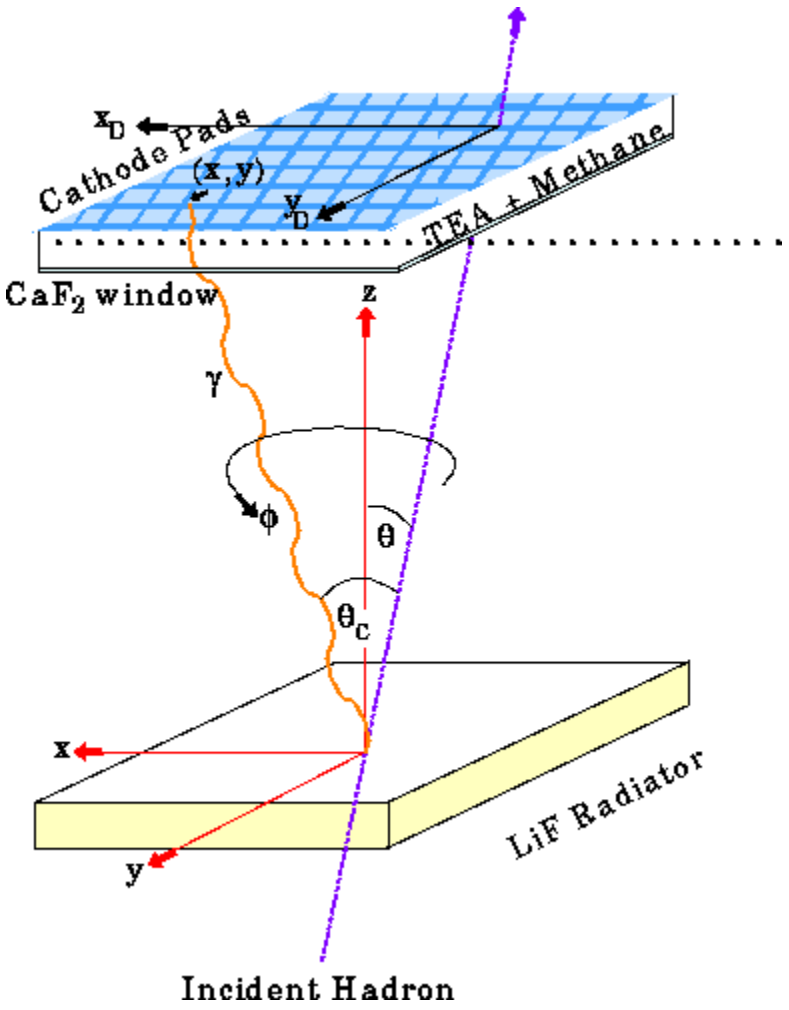

FIGURE 1. The figure shows the structure of the CLEO III RICH cross section. The radiator is LiF, 1cm thick, followed by a 15.7cm expansion volume and photon detector consisting of a wire chamber filled with a mixture of TEA and CH_4 gas. TEA is photosensitive. The high voltage on the wires multiplies the resulting photoelectrons and the resulting signals are sensed by a rectangular array of pads coupled with highly sensitive electronics. [2]

The RICH has several layers (see Figure 1). First is the LiF radiator where the Cherenkov photons are generated. LiF is a medium that emits photons at wavelengths above 130 nm (anything below this is absorbed). The next layer is an expansion volume in which the distance between the charged particle and photons is allowed to expand. This separates the photons' signals from the particle's ionizing track, allowing more precise measurements of their positions. The photons and charged particle then traverse a CaF_2 window. Here, transmission occurs above approximately 135 nm. The CaF_2 separates the gas volumes. The last layer consists of the thirty CH_4/TEA filled wire chambers. The wires are held at a high positive voltage. TEA

(triethylamine) molecules are ionized by photons, causing the resulting free electrons to consequently generate a charge next to the wire. This charge produces an "image charge" [3] on the 235,000 cathode pads, located atop the wire chambers. The Cherenkov angle θ is then determined using the geometry of pads showing charge.

TEA has a very low ionization energy of approximately 8 eV. Photons having an energy greater than approximately 8 eV ionize TEA molecules. This is equivalent to wavelengths less than approximately 165 nm. This effect, combined with the cutoff in transmittance in the CaF_2 windows, causes the RICH to image only a specific band of photon wavelengths (135 nm to 165 nm). A photon passing through the RICH is slightly refracted each time it travels through a boundary. The angle of refraction depends on its wavelength. This motivates the limited region of sensitivity.

Monitoring Hardware

It is imperative that the nitrogen expansion volume is extremely pure and uncontaminated to determine the identity of a particle. Any impurity can cause lost photons by absorbing them. The method used to monitor its purity is to shine photons at different wavelengths, in the range for which the RICH is sensitive, through a reference volume of nitrogen and compare the output of that gas with an unhindered output of the same path of photons. The output of photons are detected by photomultiplier tubes (PMT) [4] and digitized into signals producing a waveform. Two light paths are used to monitor the transmittance of the nitrogen expansion gas. One passes through a gas sample tube (hereafter this will be referred to as the gas path). The other path, which will be called the lamp path, does not include a sample tube, and is used to account for changes in the lamp's output intensity. The two paths are compared and yield the gas path's normalized signal. The same is done for a sample of nitrogen from the expansion volume exhaust. A ratio of normalized reference and exhaust gases is taken. Any peak due to absorption of any kind will be apparent on this graph, therefore indicating an impurity.

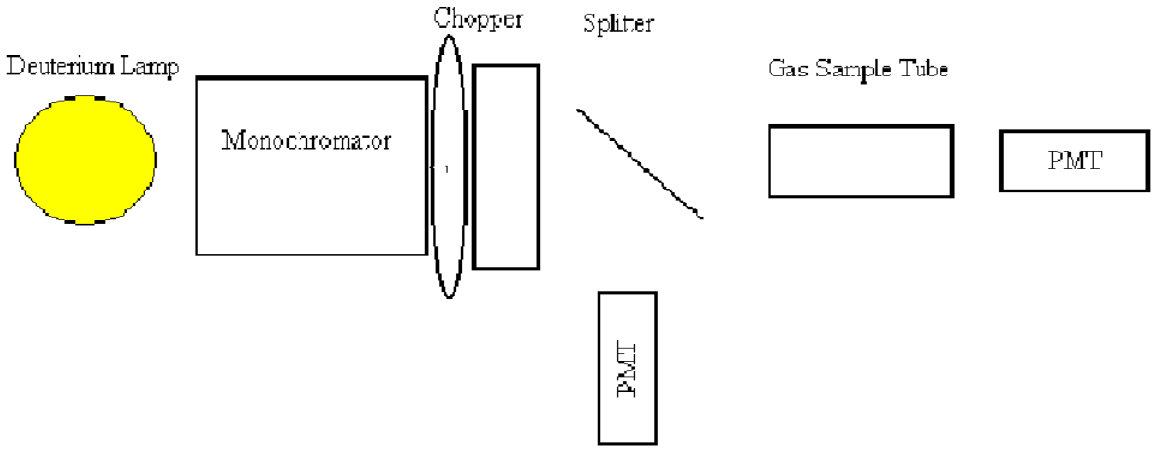

FIGURE 2. The Nitrogen Transmittance Monitor system diagram from the top view. The splitter and PMTs are encapsulated in stainless steel piping and welded together.

The monitoring system consists of a deuterium lamp, monochromator, chopper, splitter, gas sample tube, and PMTs (Fig 2). The deuterium lamp gives off the necessary light (simulating Cherenkov photons in the RICH). The monochromator selects specific wavelengths of light. The chopper is essentially a tuning fork, which modulates the intensity of light out of the monochromator. This causes the output of the PMT to vary sinusoidally in time. The DC offset, which can drift, is not used. The splitter simply splits the light in two paths. I researched the design and calculated the actual measurements and placement of the splitter. The gas sample tube contains either reference nitrogen or exhaust nitrogen from the detector. The PMTs output voltages, which vary as light intensity varies.

The deuterium lamp causes extensive and corrosive damage to the human eye and epidermis, therefore shielding its output was necessary. I have completed the design and assembly of this shield. The attachments of the splitter, gas sample tube, and PMTs to the monochromator needed a support stand, which I have also designed and assembled.

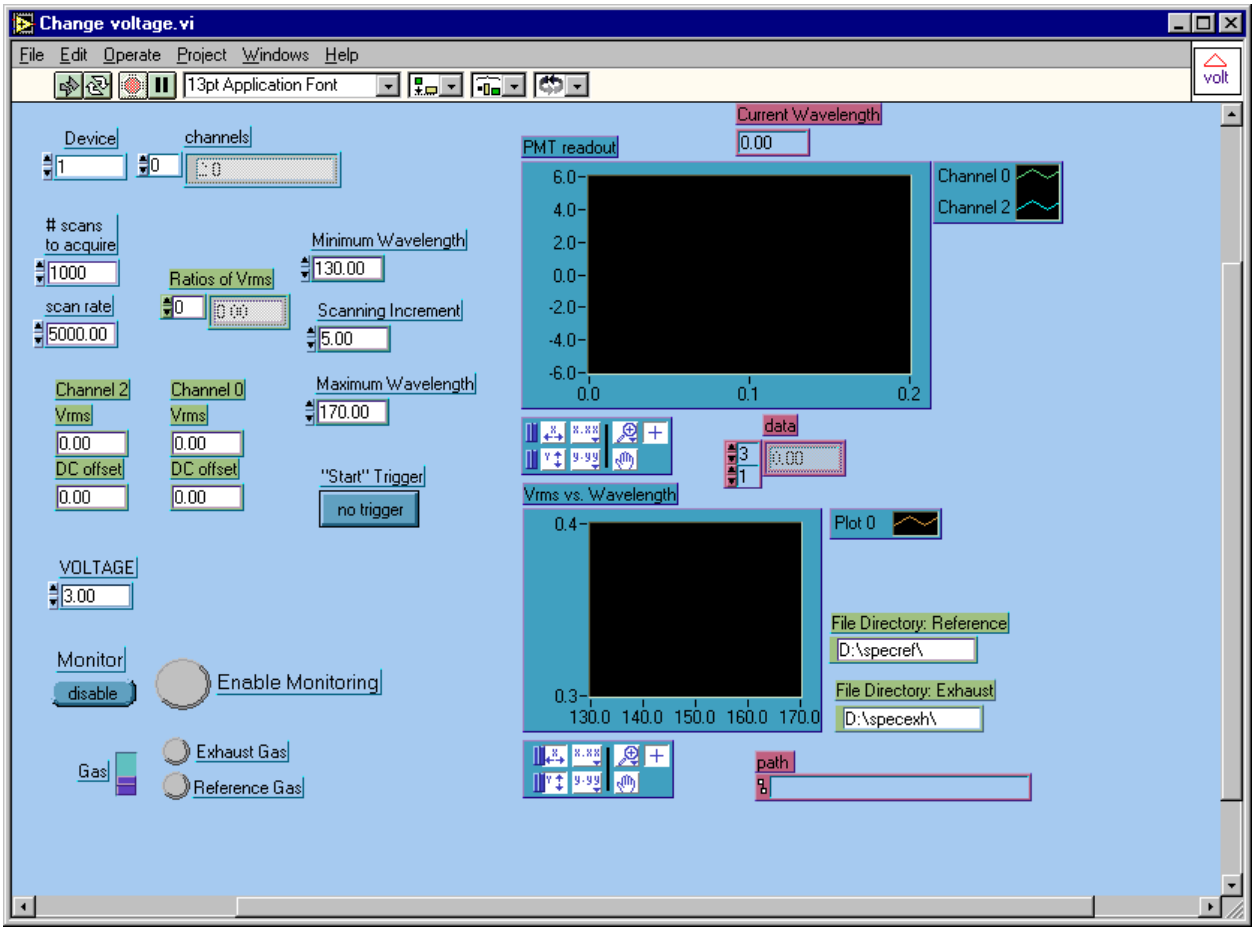

FIGURE 3. This VI shows the sinusoidal analog output from the photons detected from the gas path and the light path (PMT readout graph), the normalized signal (Vrms vs. Wavelength graph), allows control of the gas to monitor: exhaust or reference, allows control of the wavelengths monochromator scans to, and displays the name of the file the data is saved to (path).

Monitoring Software

The software interface utilizes the LabVIEW programming language. It is written as a "VI" or a virtual instrument in which the user interface resembles the actual instrumentation (see Fig. 3). One can switch from an exhaust monitoring scan to a reference monitoring scan from the interface. The software controls the wavelengths at which the monochromator outputs photons. A digital TTL pulse provided by the chopper triggers the data acquisition. The user specifies the beginning wavelength, end wavelength, and increments in between. The VI notifies the user when 150 nm has been reached in order to manually increase the PMT voltage supply due to the sudden drop in light intensity (due to the lamp's output spectrum) at this wavelength. The program reads out the voltage signals detected by the photomultiplier tubes, which vary nearly sinusoidally. The amplitude (Vrms) of wave and DC offset are determined by a VI function for both the gas and the unhindered light source. The normalized signal is calculated by finding the ratio of Vrms of the gas path and lamp path (PMT gas / PMT lamp). The sample signal will always be less than the reference signal due to photons being absorbed by gas. This ratio is calculated at each wavelength scanned, and plotted (this is the normalized signal). The process is repeated switching from exhaust gas to a reference nitrogen gas sample. The ratio of the normalized signals is calculated by a second program (Fig. 4), which reads in a saved file containing the normalized signals of reference and sample gases, shows their plots, and plots the

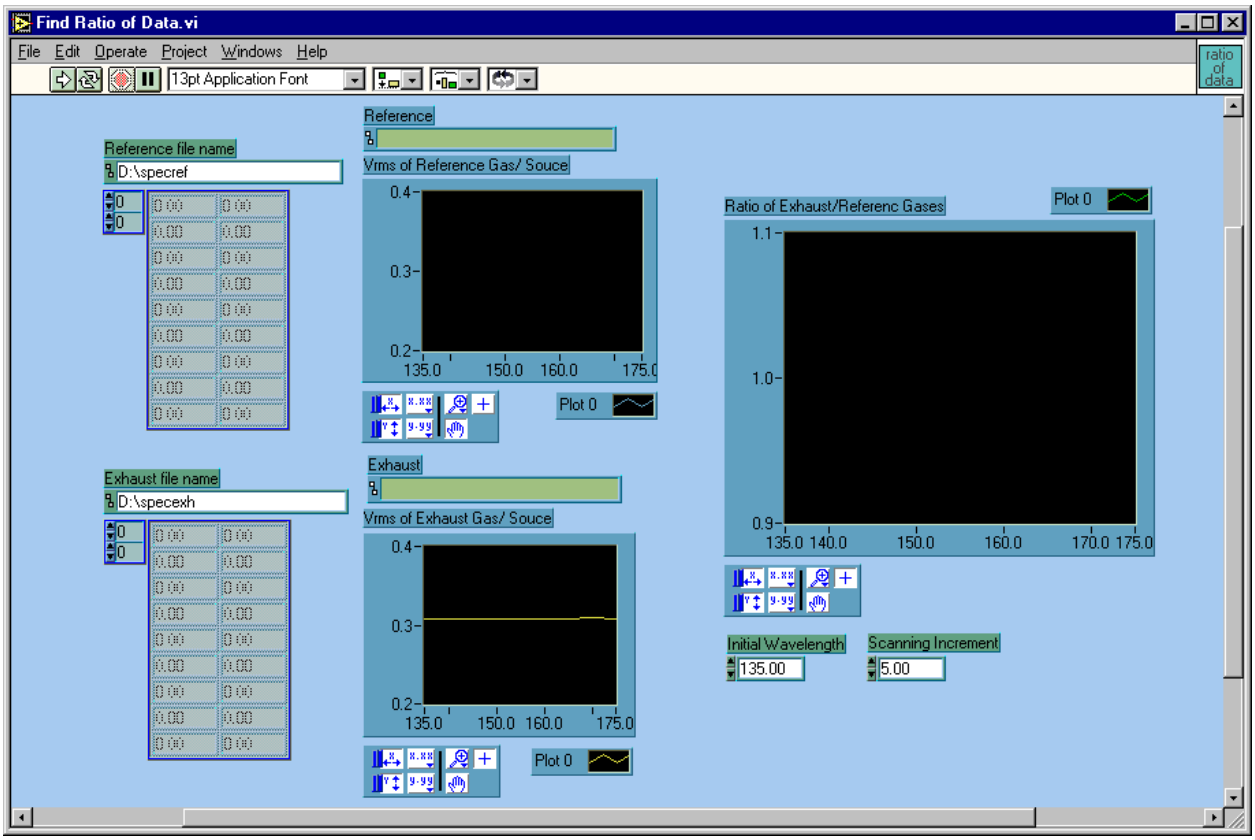

FIGURE 4. This VI reads out files saved by the first program (see Fig 3) for exhaust gas and reference gas scans and finds this ratio, (Ratio of Exhaust/Reference Gases graph).

ratio of exhaust signal divided by reference signal versus the wavelength. Any absorption peaks in transmission at a wavelength shows an impurity. Since LabVIEW is a graphical programming language, the code is also graphical. An example of the code can be seen in Figure 5.

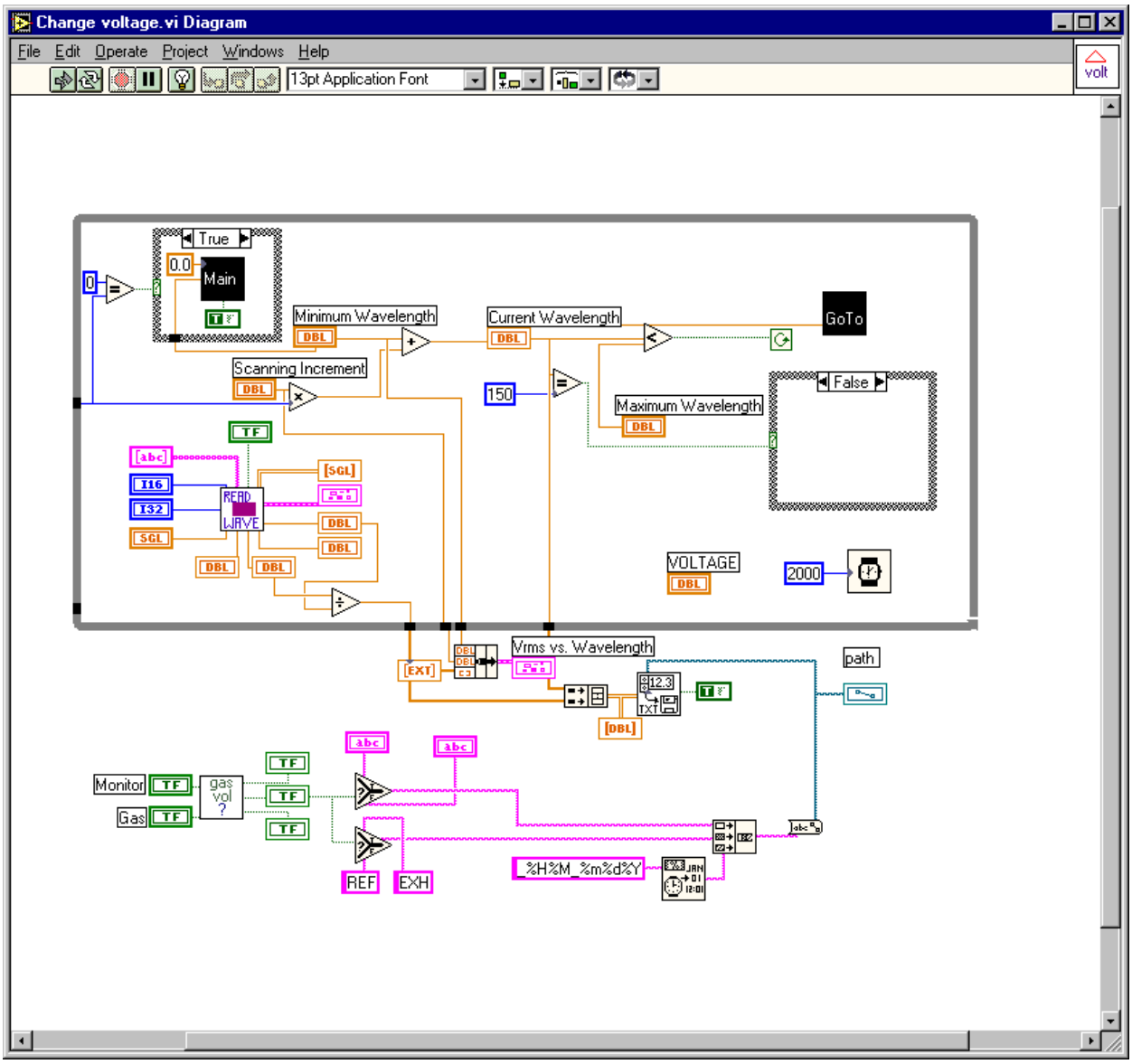

FIGURE 5. This shows the paths information travels through as the program is running. The Read Wave sub VI is used to attain the readouts from the PMTs connected to the computer through a data acquisition card and then graphed. This information is passes outside the loop and graphed as Vrms vs. Wavelength, then saved to a file. The name of the file is specified by the type of gas (REF or EXH), the time, and the date. The program runs through each wavelength (specified by the Minimum, Increment, and Maximum Wavelengths controlled by the user) until it reaches the maximum wavelength, in which case information ceases to be collected.

Results and Conclusions

The nitrogen expansion gas monitoring system is being assembled and will be transferred to Syracuse, where the majority of the RICH research is being done, by mid August. I have contributed to some components of the device and the LabVIEW software used to control all monitoring of the gas. Research is presently progressing for the monitoring of the CH_4/TEA gas in the wire chamber.

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References

1. Richard C.Fernow, *Introduction to Experimental Particle Physics.*
2. Syracuse University's RICH web page. http://www.phy.syr.edu/research/elementary_particles/experimental/rich.html
3. Konrad Kleinknecht, *Detectors for Particle Radiation,* (Cambridge University Press, New York, 1986).
4. W.R. Leo, *Techniques for Nuclear and Particle Physics Experiments: a How-to Approach*, (Springer-Verlag, New York, 1987).