FOCAL PLANE DETECTOR FOR THE S800 HIGH RESOLUTION SPECTROMETER

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The Focal Plane Detector Array of the S800 Spectrometer consists of a series of two x/y Position Sensitive Cathode Readout Drift Counters (CRDCs) separated by 1 meter, a segmented Ionization Chamber that is 41 cm deep and three scintillators that are 5 cm, 10 cm and 20 cm thick respectively. All detectors have an active area of 30 cm x 59 cm. The detectors have met the design goals of allowing 1 part in 10,000 energy resolution.

1. Introduction

The S800 Spectrometer is a high resolution, wide acceptance magnetic device for charged particle spectroscopy that requires high resolution performance from its focal plane detectors. Specifications of the S800 that are relevant to the design of the focal plane are summarized in Table 1. Rather than apply correcting magnetic fields in the the spectrometer for higher order abberations, corrections are made by ray reconstruction2 using two position sensitive focal plane detectors.

Table 1: S800 Spectrometer Parameters

Energy Resolution	1 in 10,000 FWHM
Dispersion	9.6 cm/% [ΔP/P]
Acceptance	5% [P]
Angular Acceptance in Dispersive	7 deg.
Angular Acceptance in Non-Dispersive	10 deg.
Angular Resolution	2 mradians
Position Resolution	0.4 mm

A schematic of the focal plane detector system can be seen in Figure 1.

The positions of the particles are measured in x and y by Cathode Readout Drift Counters1 that are separated by 1 meter. CRDC2 is immediately followed by a segmented Ionization Chamber that is 41 cm deep. After the Ion Chamber, there are three scintillators to perform additional time of flight, energy loss and total energy measurements of the incident particles. The details of the detectors will be discussed in the following.

2. Cathode Readout Drift Counters

The S800 has a desired Energy Resolution of 1 part in 10,000 and has a momentum dispersion of 9.6 cm/%. Thus, a position resolution of better than 0.48 mm is needed. Since the particle beam will have an intrinsic width of about 0.4 mm the detector resolution will need to be better. Simulation of the optics have shown that 0.4 mm should be adequate. The CRDC's have an active area of 30 cm x 59 cm and an active depth of 1.5 cm. The particles are dispersed in momentum along the 59 cm. The principle of operation of these counters are those of a Single Wire Drift Detector, except that the position along the wire is obtained by induced cathode readout1. In the S800 CRDC, the pads have a pitch of 2.54 mm. A conceptual view of the counter is presented in Figure 2 and a drift line plot produced by the code GARFIELD3 is shown in Figure 3. The Gas fill chosen is 140 Torr of 80% CF_4 and 20% C_4H_{10}. This gas has the advantage of low

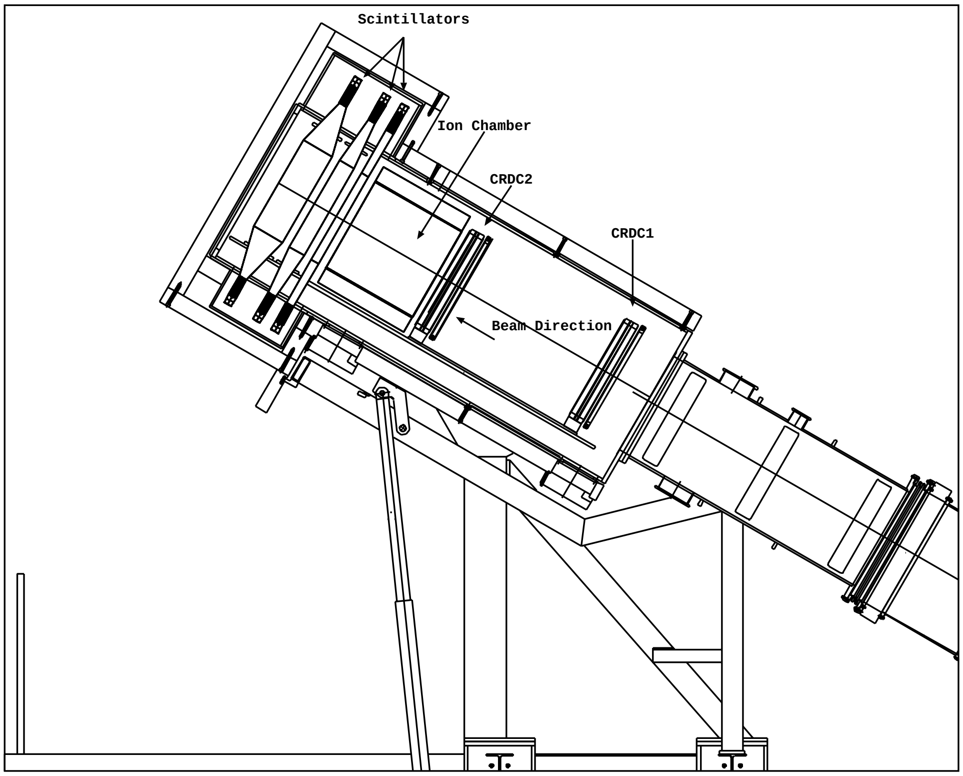

Figure 1: S800 Focal Plane.

aging characteristics, high drift velocity and low avalanche spread due to photon mediation.

Charge division does not yield the desired resolution for such a large counter due to the electronic noise created by the resistance of the wire. Delay line readout of the pads would give better resolution, but the low impedance of the delay line, in addition to the differentiation of the signal, would require that the counter be operated at a relatively high gain. This limits the dynamic range of the detector. It was therefore decided to read out the linear signal from each cathode pad individually for the best noise performance. Since the detector is essentially a slice of a Time Projection Chamber, it made sense to utilize electronics already developed for TPC's. We chose to use the Front End Electronics (FEE)4 cards developed by the STAR collaboration. In this case, we only use the Preamplifier Shaper portion of the FEE card and digitize the output using LeCroy 2249 QDC's5.

Several methods for determining the position of the track were investigated. Simple center of gravity of all the pads, the center of gravity of several pads around the peak and a Gaussian fit of the charge distribution were compared. While limiting the number of pads used in finding the center of gravity improved the response, it did not yield the necessary position resolution and it introduced some differential non-linearity. Fitting the peak improved the resolution dramatically and avoids problems with finite sampling of the charge distribution.

The individual responses of the FEE Cards and the LeCroy QDC's are calibrated by applying a tail-pulse to the anode wire of the CRDC. The capacitive coupling of the anode wire to each pad then induces a fixed charge. This is done for two pulser settings and a linear correction is then applied to each pad before processing. This method not only corrects for differing amplifier gains, but also compensates for any non-uniformity in the Cathode pad size.

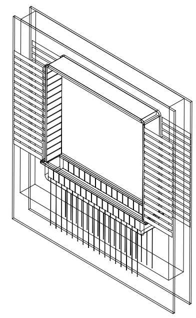

Figure 2: Conceptual View of CRDC.

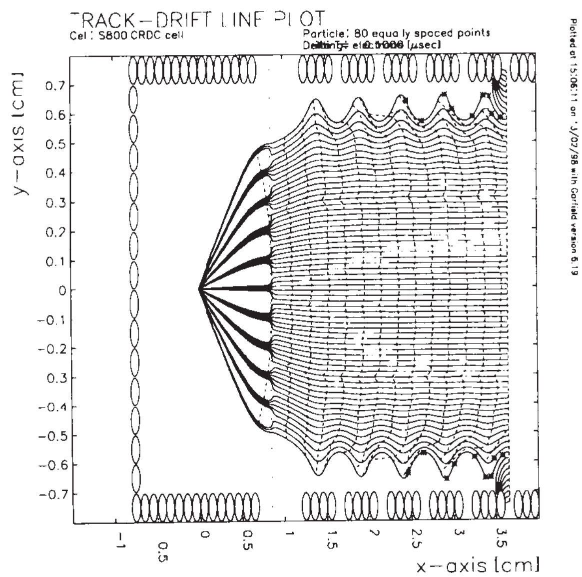

Figure 3: Drift Line Plot for CRDC.

An example of the resolution of the entire S800 Spectrometer and Focal plane detector system was made by using a beam of 80 MeV/u ^{22}Ne. The spectrometer was operated in a dispersion matched mode with the beam line. Figure 4 is the position spectrum obtained in this case and demonstrates a resolution of better than 0.51 mm FWHM. Since the beam spot size is approximately 0.4 mm, this implies a detector resolution of about 0.3 mm. A problem with the detector is that the drift field is perturbed by the finite width of the field shaping electrodes. This causes some of the charge to be lost, depending on the Y position of the track. Figure 5 is an expanded view of a typical energy loss vs. Y position spectrum from this detector. Notice that the signals grow in magnitude with the position, that the signal oscillates in amplitude vs Y position corresponding to the shaping electrode pitch and that this growth and oscillation is larger than the spread at a given point.

3. Ionization Chamber

The Ionization chamber used in the S800 is a standard Frisch Gridded Ion Chamber that is segmented into 16 one inch anodes perpendicular to the path of the ions. The gas fill is 300 Torr of

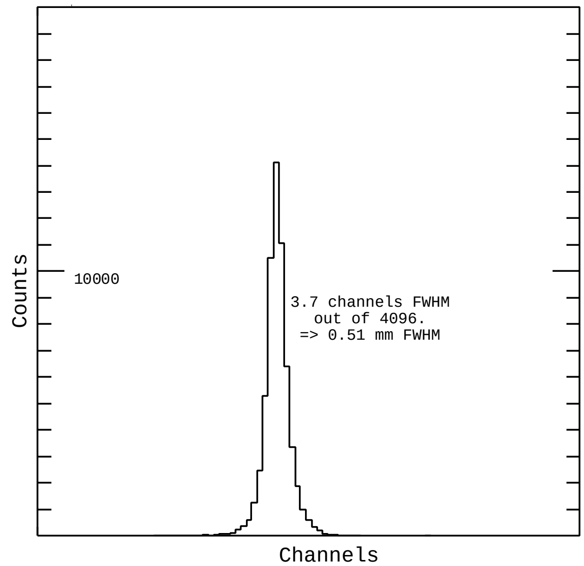

Figure 4: CRDC Spectrum for 80 MeV/u ^{22}Ne.

P10. Sampling of the energy loss along the path allows us to apply the Maximum Likelihood Estimator for Vavilov type energy loss and to reduce the noise by summing for more Gaussian type energy loss. The reduction of the noise by summing occurs because the electronic noise is proportional to the detector capacitance. Dividing the anode into N sections reduces the capacitance and in turn the noise by N. However, the noise in each strip is not correlated and therefore adds in quadrature. Each anode has a small postage stamp size preamplifier attached to it inside of the Ion Chamber and has a charge gain of 500 mV/pC. The preamplifier signals are then shaped by a Silena 761F sixteen channel Spectroscopy Amplifier. The 761F allows remote adjustments of all parameters for each channel as shown in Figure 6.

4. Scintillation Detectors

The Scintillation detectors are closely coupled with the Ionization Chamber and provide energy loss, total energy and timing information. The first scintillator is used as the exit window of the Ionization Chamber in order to reduce the straggling that would be associated with an exit window. This scintillator is 5 cm thick. The next two scintillators are 10 and 20 cm thick respectively. The scintillators are read out at each end with an EMI 9807B photomultiplier. This allows for mean timing. The 10 cm thick detector was tested with a direct beam of 60 MeV/u ^{16}O. The timing response obtained was 160 psecs FWHM.

5. Summary

The configuration chosen for the S800 focal plane provides a wide dynamic range detection system for isotopes with a wide range of energies and stopping powers.

References

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2. M. Berz, K. Joh, J. Nolen, B. Sherrill and A Zeller, Physical Review C, 47, 2:537, 1993.
3. R. Veenhof, GARFIELD, a Drift Chamber Simulation Program User's Guide,Version 6.19, CERN Program Library W5050, 1997.

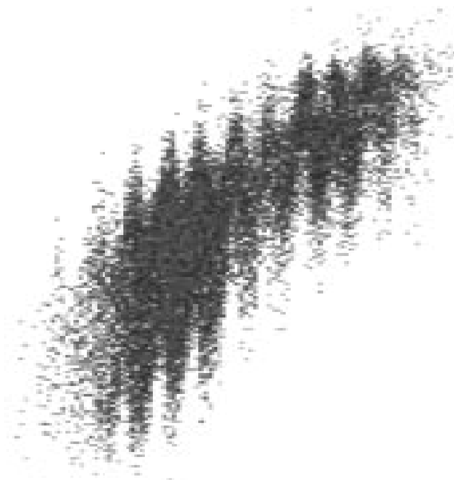

Figure 5: CRDC Energy Loss Signal. Energy Loss vs Y Position.

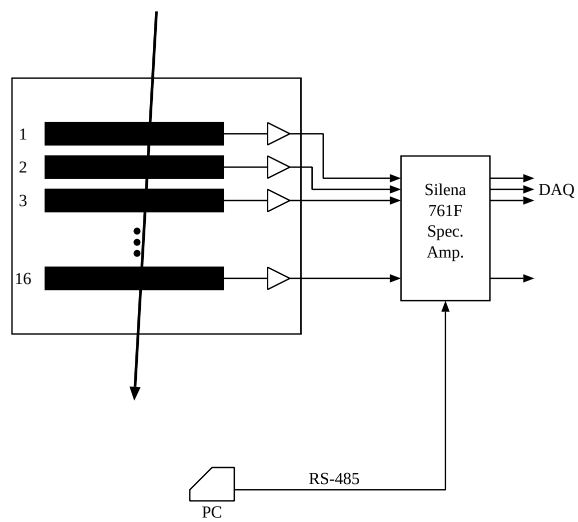

Figure 6: S800 Ionization Chamber Readout.

4. The STAR Collaboration, LBL Pub-5347 (1992).
5. LeCroy Research Systems, 700 Chestnut Ridge Road, Chestnut Ridge, NY 10977-6499.