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THE LIMITED STREAMER TUBES SYSTEM FOR THE SLD WARM IRON CALORIMETER*

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ABSTRACT

The SLD detector at the Stanford Linear Accelerator Center is a general purpose device for studying e^+e^- interaction at the Z^0. The SLD calorimeter system consists of two parts: a lead Liquid Argon Calorimeter (LAC) with both electromagnetic (22 radiation lengths) and hadronic sections (2.8 absorption lengths) housed inside the coil, and the Warm Iron limited streamer tubes Calorimeter (WIC) outside the coil which uses as radiator the iron of the flux return for the magnetic field. The WIC completes the measurement of the hadronic shower energy ($\sim 85\%$ on average is contained in the LAC) and it provides identification and tracking for muons over 99% of the solid angle.

In this note we report on the construction, test and commissioning of such a large system.

1. CONSTRUCTION AND TEST

The WIC surrounding the magnet consists of eight iron barrel sections and two end caps which complete the solid angle coverage.[1] The iron is segmented into 14 layers 5 cm thick, separated by 3.2 cm gaps instrumented with plastic limited streamer tubes chambers[2] (see Fig. 1).

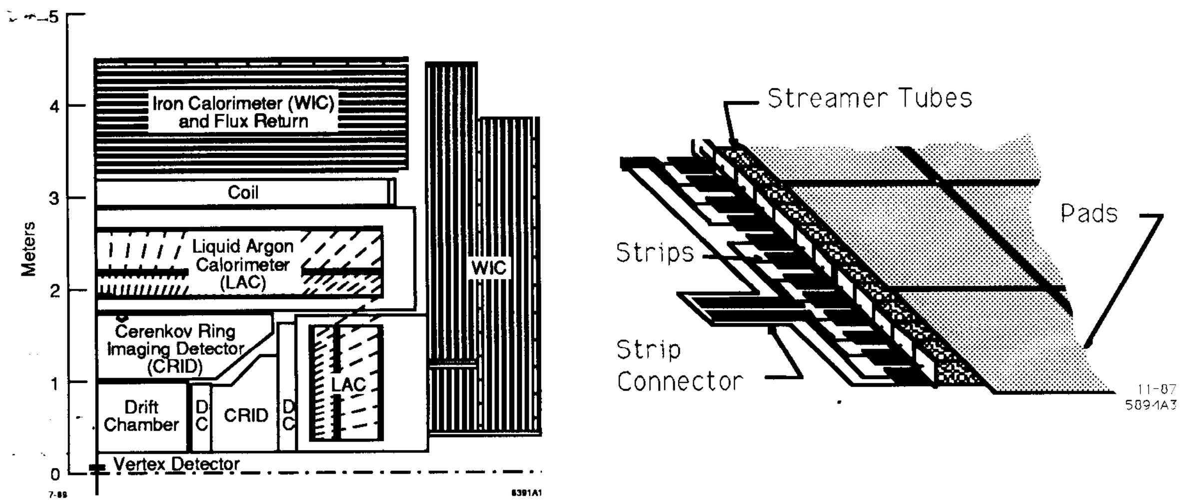

Figure 1. One quadrant of a cross-section of the SLD detector and the streamer tube chamber.

This type of detector has been chosen because it offers several advantages: it allows x and y strips and pad readout, the signals are comfortably large (~ 8 pC from a strip), the modules are robust and rather easy to produce and to assemble, it has full efficiency for minimum ionizing particles, and it is reasonably inexpensive.

A chamber consists of a single layer of streamer tubes sandwiched between two external readout electrode sheets, which pick up the signals induced by streamer discharge. The bottom sheet is composed of long narrow strips parallel to the individual tubes (1 cm pitch). Signals on these strips are recorded as digital hits by a low-cost discriminator/shift register electronics. The opposing electrode sheet is subdivided by quadrilateral pads. Pads of different layers are daisy chained to form projective towers pointing to the interaction region, and the collected signals are recorded through analog amplifiers and digitized.

Quality control was the main issue for such a large system. Besides the high-voltage testing described below, all critical parts of a chamber were checked carefully for quality at each step of manufacturing and assembly. The large number of components ($\sim$ 8700 modules required), together with the inaccessibility of modules after the installation into the SLD iron gaps, were critical points. The devices had to survive inside the iron for many years with as few failures as possible. It was crucial to have a device which could be produced on a large scale with high reliability. Thus it was decided the modules had to undergo a series of stringent high voltage tests during the construction, after the chamber assembly and before the final installation. The whole testing procedure required several days.[3]

Preliminary tests on the modules indicated that there is a strong correlation between eventual failure and earlier abnormal behaviour of the anode current (higher than normal values either continuously or in bursts). We established testing procedures which, on the basis of such short term behaviour, could weed out devices that had inadequate longevity. During these tests anode currents were monitored, and we applied a stringent set of acceptance criteria based on the results. The overall module rejection rate was $\sim$ 30 %. Some of these tests included:

- High-voltage conditioning (ramping up–down to 4.9 KV for three days).
- Preacceptance (applying a constant 4.8 KV high voltage for six days and checking the total current of a group of modules every 12 hours).
- Acceptance (applying a constant 4.8 KV high voltage for three more days and checking each individual module current continuously).

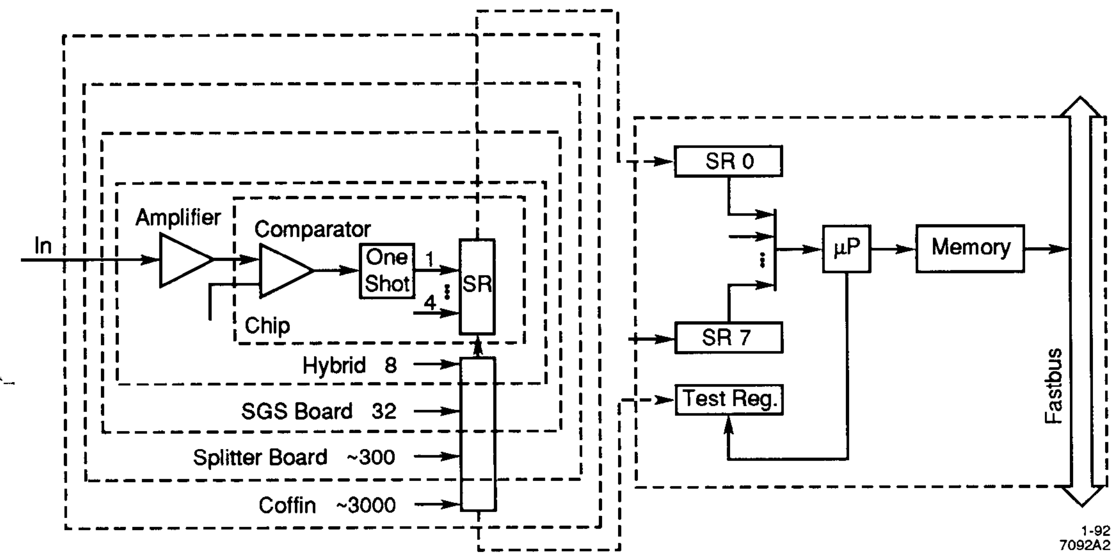

Figure 2. The strip digital electronics data chain

Finally we set up a longevity test which gave us confidence that the adopted acceptance criteria were good. The test gave the reassuring result that the modules we were building and selecting would fail at a measured rate of less than 1.8 % per year at 90% confidence level. In addition, every completed chamber was tested with cosmic rays under operating conditions of gas and high voltage to ensure the correct operation of the finished detector.

2. ELECTRONICS

The WIC electronics is designed to acquire digital data from $\sim$ 80,000 strip channels and analog data from $\sim 8,600$ calorimetric towers.

A block diagram of the digital readout system[4] is shown in Fig. 2. Thirty-two channels of preamplifiers, discriminators, one-shot and shift registers are packaged in a single board (by SGS-Thompson), and all of the boards of each layer of the detector (typically ten boards per layer) are daisy chained together. Subsequently, groups of nine layers (half octant) are further multiplexed by an intermediate controller (Splitter board), and up to eight Splitter boards (half barrel) are read by one of the six WIC Digital Readout Fastbus Modules. The overall readout time is ~ 0.8 ms.

Data from the detector is heavily multiplexed and transmitted by optical fibers, leading to a very small cable plant. All 40,000 barrel strips signals are carried on 36 fibers (control and trigger included) with a cable cross section less than 10 cm^2. As most of all the other SLD subsystems, we have redundant control and data fibers and also redundant control logic in the controllers inside the detector. In this way, during a run a single controller or a cable failure can be isolated switching (software controlled procedures) to a different path, avoiding the loss of important tracking information in any solid angle.

The small space available for the installation of the SGS front-end electronics inside the iron, together with cables and many connectors, made the commissioning a heavy task. Nevertheless today, after about one year of operation, the number of dead and noisy channels is only $\sim 1\%$.

For the calorimetry readout,[5] the signals from the towers are sent via shielded cable to 64 VME cards, mounted on the periphery of detector in 16 very easily accessible VME crates. The signal induced on a tower is integrated with a 5 μs time constant by a hybrid preamplifier, read by a sample-and-hold circuit and digitized by an ADC (see Fig. 3). The digitized signals are then serially sent through fiber optic cables to two Fastbus Calorimetry Data Modules. The pad system is very stable and well integrated, with a high degree of data multiplexing, and is supported by a powerful menu-driven, user-friendly, diagnostic software. During the commissioning, these tools allowed us to track down and dramatically reduce the number of problems such as shorted pads, loose connectors, and bad channel hybrids. Today the number of unrecoverable pad channels is just $\sim 0.3\%$, and it is stable.

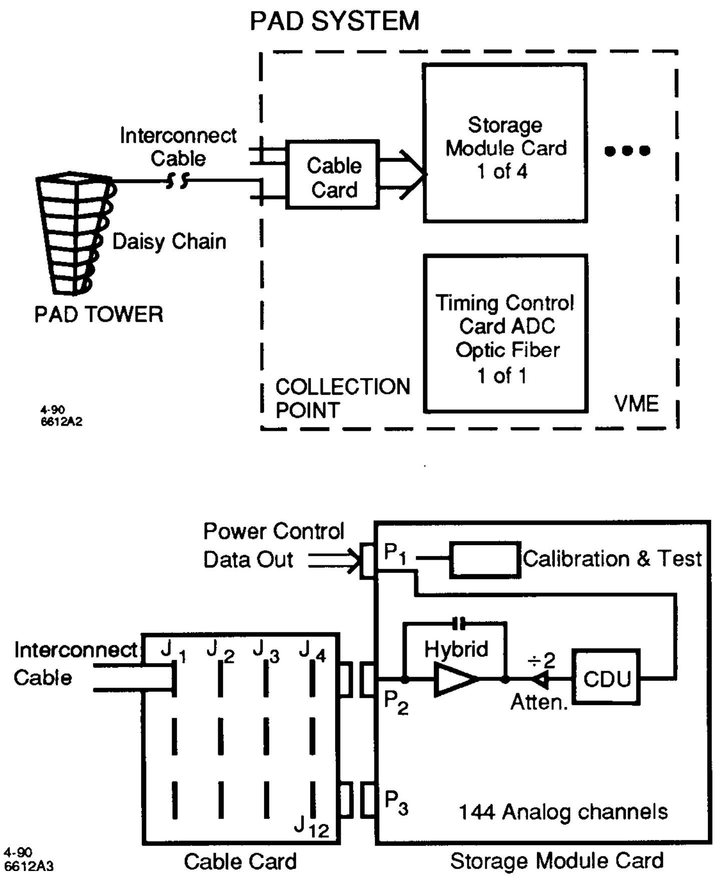

Figure 3. The pad electronics block diagram

3. WIC STATUS

Results from the test beam[6] have confirmed that the energy resolution is about $\sigma_E/E = 80\%/\sqrt{E}$ and is in agreement with the expected performance.

The detector is completely debugged and has been fully operational for approximately one year. Cosmic ray runs have been taken routinely to debug the whole apparatus and study its performance[7] using a new nonflammable gas mixture[8] consisting of 88% carbon dioxide, 9.5% isobutane and 2.5% argon. The fraction of modules that have been disconnected from the HV to date is $\sim 2.5\%$. This number is fully compatible with the life test results.

In the SLD engineering run during the summer of 1991, the WIC demonstrated it was in excellent shape and it performed as expected in the proposal, both as a calorimeter and as a muon identification and tracking device. Nearly 400 Z^0 have been logged on tape, and data analysis is in progress.

4. CONCLUSIONS

The Warm Iron Calorimeter built for SLD has been fully operational for approximately one year, and it successfully participated in the summer physics run. Overall it works well, and it is easy to operate and monitor.

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