A Straw Chambers' Tracker for the High Rate Experiment 835 at the Fermilab Accumulator

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Abstract

Two layers of proportional drift tubes (aluminum mylar straws) are staggered in two cylindrical light chambers to measure charged particles' azimuthal angle. To stand the high rates ($\sim$ 10 kHz/cm^2) and minimize the pile-up of the high luminosity experiment 835 at FNAL, a fast ASIC Amplifier-Shaper-Discriminator (ASD-8B) was chosen. The front-end electronics, designed exclusively with SMD components, was mounted on the downstream end plug of each chamber to avoid oscillations and noise. Design, construction and operational performances of these detectors are presented.

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1 Introduction

The Fnal experiment 835 [1] is an upgrade of the previous experiment 760 (data taking in 1990-1991), to study charmonium spectroscopy in $\bar{p}p$ annihilations with higher instantaneous luminosity ($\mathcal{L}$). To achieve running conditions at $3 \times 10^{31} cm^{-2} s^{-1}$ ($\sim 5 \times \mathcal{L}_{E760}$) both the interaction source ($10^{11} \div 10^{12} \bar{p}$ in the Accumulator and H_2 jet target density up to $3 \times 10^{14} at/cm^2$) and the detectors (new tracking system and faster electronics) were upgraded. The whole apparatus, designed to detect the e.m. decays of charmonium states, is a compact cylinder around the antiprotons' beam line where the polar angle acceptance is limited upstream ($\theta \sim 60^0 \div 70^0$) by the jet target body and pumping system. As part of the new charged tracking system, two straw chambers were built to give the azimuthal angle φ, measuring drift time. To withstand the high rates expected on the chambers ($\sim 5MHz$ @ $R \sim 3cm$ and $\sim 1.5MHz$ @ $R \sim 15cm$) a fast front-end electronics was chosen, which required to be mounted directly on the detector to minimize noise. E835 is taking data since September '96 for one year.

2 Mechanical design and construction

The requirements for the two chambers' design were light weight (0.11 % X_0 into the straws acceptance and 5÷10 % X_0 in the limited regions of the supporting flanges) to minimize multiple scattering and photon conversions and fine granularity to limit occupancy of each element. Tight geometrical constraints determined a structure of two staggered layers of 64 straw tubes in each chamber, to solve left-right ambiguity. The common use of end plugs on every tube was discarded. The straws are self-supporting onto two grooved flanges to allow gas fluxing. Each flange (glass epoxy composite Stesalit 4411W, Switzerland) was numerically controlled machined into two pieces that were glued together with a dedicated jig to garantee the best precision in straws and pin positioning and aligning. Errors on the machined diameters and centers were measured to be within $\sim$ 10 μm, never exceeding 50 μm. Mylar tubes ($80\mu m$ thickness) with inner Al coating ($1000\AA$) [2] were inserted in the proper location and glued onto the flange. On one of the two flanges, an evaporated layer of gold provides the grounding connection to all the tubes, glued with a conductive glue (Tra-Duct 2902 TRACON, U.S.A.). A $20\mu m$ goldplated tungsten wire (Luma Metall, Swedom) was strung with a tension of 20 g and 40 g on inner and outer chamber respectively, crimping goldplated copper pins (150 μm inner diameter) inserted in the dedicated holes of the flanges. In fig. 1 a sketch of the mechanical structure is shown. The geometrical parameters of the two chambers are summarized in table 1.

3 Front-end electronics and system layout

The final choice for the chambers' front-end electronics was the full custom analog bipolar integrated circuit developed for high energy physics wire chambers experiments at University of Pennsylvania [3]. The chip used is the ASD-8B, 8 channels Amplifier-Shaper-Discriminator (Tektronix SHPi bipolar process), 1 cm $\times$ 1 cm (64 pin). The fast peaking time (6-7 ns) and the good double pulse resolution (25 ns) are crucial to avoid pile-up. The signal amplitude is of the order of 20 mV/fC and a voltage programmable threshold is linear up to 30000 e^-. The total power dissapation per channel is 23 mW. Both signal to noise losses and pickup can be minimized by mounting the electronics on the chambers. Due to the limited space available, only SMD components were used. Four different multilayer boards were designed:

- HV distribution, directly mounted on the pins (HV resistors and blocking capacitors): HV on the anode wires and the tubes grounded to the flange
- test-in circuits
- ASD boards where analog and digital ground should be carefully separated
- thresholds, low voltage regulators and output signals

The last 3 boards are connected through SMD connectors (Conan - BERG Switzerland). They are also used in the custom made cables that run along the beampipe to the receivers/stretchers located close to the apparatus. The output signals are differential small diameter (2$\times$ 2 mm by Polyfil - Switzerland) cables, thresholds and test-in are 50 Ω Fileca coaxial cables. The signals are then processed in the counting room by the 32 channels LeCroy multihit TDC 3377 used in common stop. The whole system layout is shown in fig. 2.

4 Detectors performances

A test of the new front-end electronics was performed at CERN in Nov '95. The four different boards were designed, built and ready to be installed by April-June '96. Chambers were fully operational during testing of thresholds and noise after installation. When the whole apparatus was closed, a cable corrisponding to 8+8 tubes was probably damaged, resulting in one dead/noisy octant on the inner chamber. The high rates prevented us to use the tested and known gas: the chambers are now operated with $Ar:C_4H_{10}:[(OCH_3)_2CH_2]$ 82:15:3, respectively at 1320 V and 1530 V on the inner and outer chamber. This gas was chosen because it's efficient at relative low HV (drift velocity not saturated $\sim$ 40 μm/ns) and effective in limiting radiation damage [4].

4.1 Test beam results

A 16 channels ASD prototype board was tested on the PS T10 beam at CERN ($\pi^{\pm}$ @ 2.5÷5 GeV/c) with the inner straw chamber positioned transversally to the beam line. Four layers of straws were crossed by particles triggered by 3 scintillator counters. The gas used in the test, Ar:CO_2:CH_4 (90:9:1) was the one previously used by E760, not flammable and with saturated drift velocity ($\sim$ 45 $\mu m/ns$). Adjusting ASD thresholds and chamber HV operating conditions were found. We obtained efficiencies up to 95% per layer, corresponding to the calculated geometrical efficiency (this mechanical design cannot avoid cracks between two adjacent tubes). The best resolution measured was $\sim 110 \pm 3$ μm.

4.2 Efficiency and resolution measurement

In the nominal E835 acceptance ($15^0 < \theta < 60^0$), without correction for dead channels and inner chamber noisy octant (8% loss) the measured efficiency of reconstructing a track with at least two layers of straws is 97 %, with an efficiency of about 89.8 % per layer. The average efficiency across the diameter of a straw is shown in fig. 3 for one of the four layers; tracks were fitted using the other three layers over a $\Delta\varphi$ region where both the chambers were fully operational. For selected two body events, $J/\psi \rightarrow e^+e^-$, the measured resolution per track is $\sigma_\varphi \simeq 9$ mrad, which corresponds to a resolution of 220÷300 μm per layer, as shown in fig. 4.
The decision of mounting the front-end electronics on the chambers came afterwards in our project and it was not taken into account in the original design: the downstream weight could modify the electric field and affect the resolution. We are still investigating to achieve better results.
No dead channels were due to ageing effects (over 200 rads in nine months of data taking); we expect to collect about 250 mC/cm by the end of the run.

5 Acknoledgements

The authors would like to thank Mitch Newcomer who provided the tested ASD-8B chips, the prototype board and many useful advices. M. Sancez at CERN provided suggestions and support in the design of the front-end PCBs, while C.Millerin assembled them with our tight time constraint. E. Rosso was always available to discuss mechanical issue and provided us the pins and the counterpins to support the HV board on the pins themselves. Fermilab Physics Department helped in the construction of the receivers. We would like to thanks all the collaborators who supported this project.

References

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[2] LAMINA Dielectrics Ltd, England.

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List of Figures

Table 1
Geometrical parameters of the two chambers

	R [cm]	θ	$\O_{straw}$ [mm]	L_{straw} [mm]
Inner	5.4	$15^\circ \div 58^\circ$	5.0, 5.4	182
Outer	12.0	$15^\circ \div 65^\circ$	11.1, 12.1	414

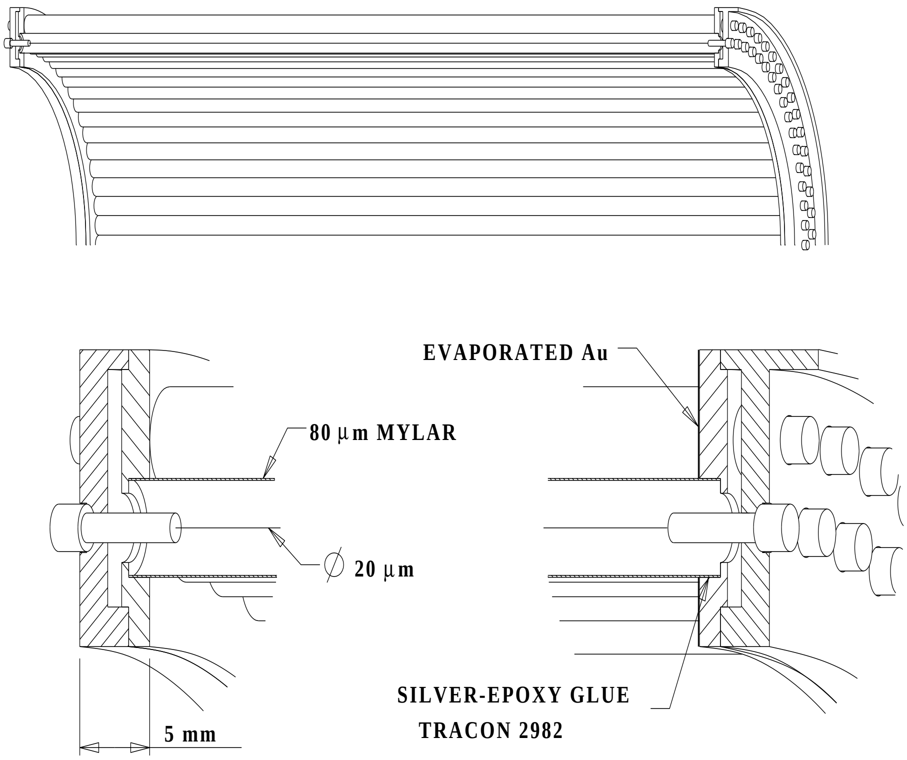

Fig. 1. Sketch of the mechanical structure

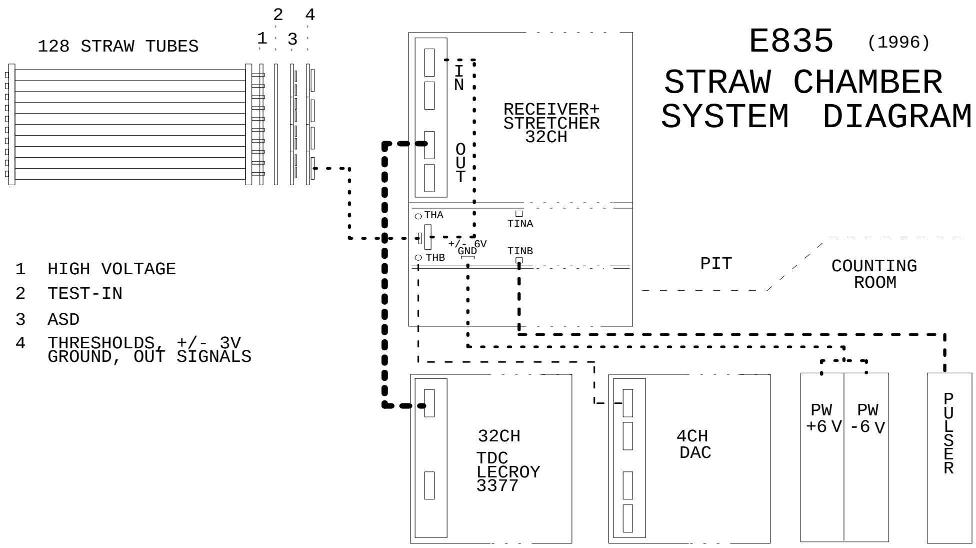

Fig. 2. System layout

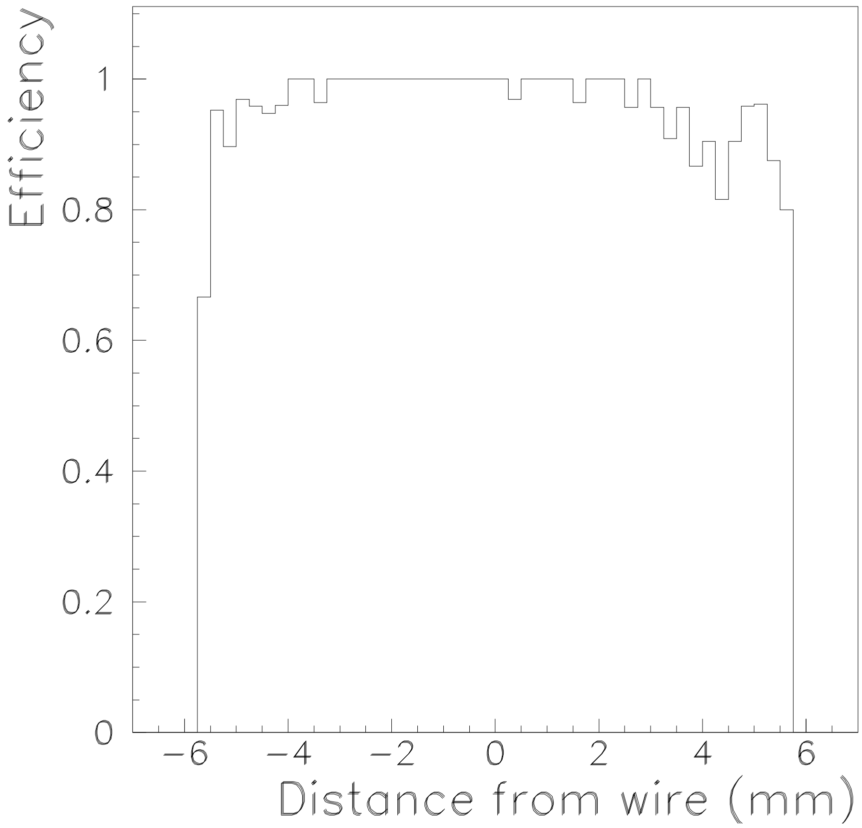

Fig. 3. Efficiency across the straw diameter of the inner layer of the Outer Chamber

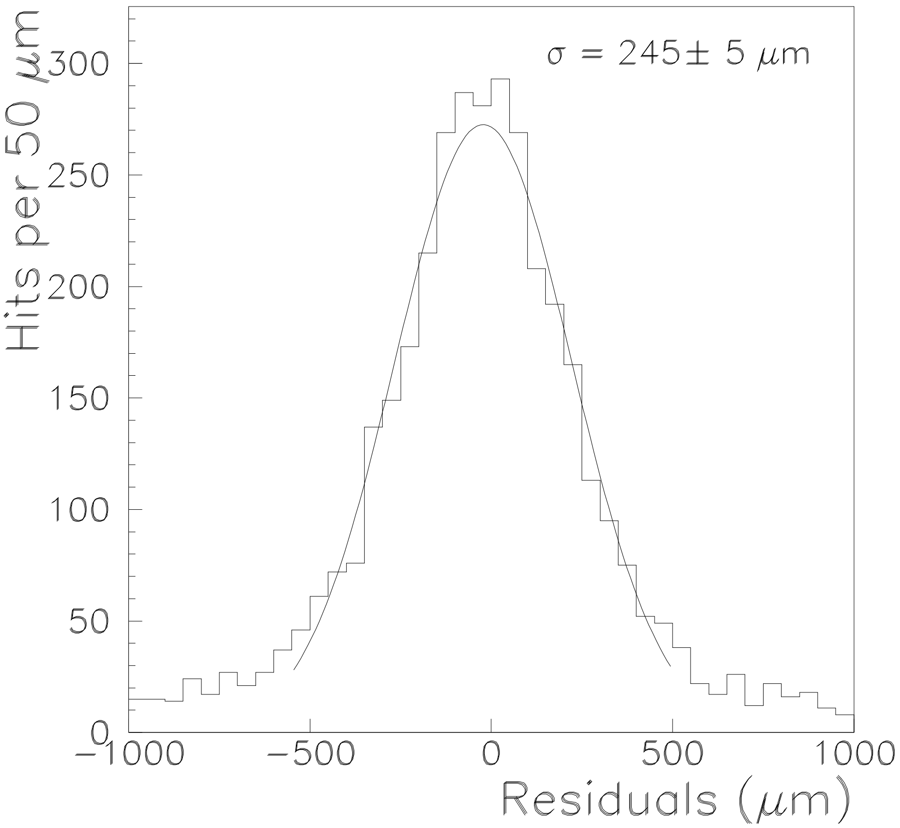

Fig. 4. Residuals in the inner layer of the Outer Chamber using fitted tracks