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The NA62 straw detector read-out system

P. Lichard¹

*CERN,
Geneva, Switzerland*

E-mail: peter.lichard@cern.ch

ABSTRACT: The NA62 straw detector, made of 7200 cylindrical straws, is a combined spectrometer and veto detector, which is part of the NA62 experiment at the CERN SPS accelerator. A new version of the full read-out system has been designed and tested on a detector prototype. A description of this system will be given, as well as plans for future scaling.

KEYWORDS: Electronic detector readout concepts (gas, liquid); Front-end electronics for detector readout

¹Corresponding author.

Contents

1	Introduction	1
2	NA62 straw tracker	1
2.1	Straw detector	1
2.2	Electrical properties of straw detector tube	2
3	Straw detector electronics	3
3.1	Frontend electronics	3
3.2	Backend electronics	4
4	Conclusion	5

1 Introduction

The NA62 experiment is a new project being designed and constructed for measuring CP-violation [1]. It will use particles generated at SPS (Super Proton Synchrotron) accelerator at CERN, Geneva. It aims at measuring rare K^+ (positive kaon) decays to positive pion and neutrinos, $K^+ \rightarrow \pi^+ \nu \bar{\nu}$. Due to the branching ratio of the order of 10^{-10} , it is expected to collect only about 100 such events in 2 years lifetime of the experiment. The experiment consists of a number of various detectors both for positive detection of the searched event and for vetoing other K^+ decays (figure 1).

2 NA62 straw tracker

2.1 Straw detector

The purpose of the STRAW Tracker is to measure with good accuracy the direction and the momentum of secondary charged particles originating from the decay region, mainly single positive pions with missing mass which indicates the searched event. Multiple charged tracks, on the other hand, indicate different type of the event. The spectrometer (see figure 2) consists of four chambers intercepted in the middle by a high aperture dipole magnet providing a vertical B-field of 0.36T. Each chamber is equipped with 1'792 straw tubes, which are positioned in four layers with different straw orientation (Views) providing measurements of four coordinates (x,y,u,v).

The detector is placed in vacuum to avoid multiple scattering of particles and must have less than 0.5% radiation length for each chamber. The spatial resolution should be better than $130 \mu\text{m}$ per coordinate. For straws near the beam, operation in a high rate environment (up to 40 kHz/cm, and up to 500 kHz/Straw) must be envisaged.

Figure 1. Schematic view of the NA62 experiment showing the main sub-detectors (not to scale).

Figure 2. Schematic view of the magnetic spectrometer.

The main building block of the detector is an ultra-light straw tube which is 2.1 m long and 9.8 mm in diameter. The tubes are manufactured from 36 μm thin PET¹ foils, coated — on the inside of the tube — with two thin metal layers (0.05 μm of Cu and 0.02 μm of Au) to provide electrical conductance on the cathode. The anode wire ($\varnothing=30 \mu\text{m}$) is gold-plated tungsten.

2.2 Electrical properties of straw detector tube

The straw cathode is formed by a very thin layer of copper and gold, few atom layers thick, so the electrical properties are determined by quantum physics effects and one does not need to consider the skin effect as the thickness of the material does not exceed the skin effect depth at working frequencies. Indeed, the measured DC resistivity of the cathode is $\sim 70 \text{ Ohms}$ (2.1 m) instead of $\sim 16 \text{ Ohms}$ calculated from Ohms law, entirely determined by surface effects. The straw can be considered as a very lossy transmission line and termination effects on both ends should be taken into consideration for the choice of shaper transfer function. The straw works as a proportional drift tube filled with working gas Ar/CO₂(70/30). For the standard working conditions the output

¹PET = polyethylene terephthalate.

current generated by particle passage has a hyperbolic form with $t_0=2.2\text{ns}$ decay. The electron total drift time is 150ns . The signal propagation time along the full straw length is $\sim 7\text{ns}$.

3 Straw detector electronics

3.1 Frontend electronics

The on-detector electronics consist of an 8-channel analogue front-end chip containing a fast preamplifier, semi-gaussian shaper, a tail cancellation circuitry, base line restorer and a discriminator. The ion tail cancellation is of utmost importance for straws with high rate of particles. Pile-up at high particle rate would cause loss of both efficiency and time resolution. As a baseline for the frontend analog electronics it is proposed to use the CARIOCA [2] chip developed for the LHCb muon chambers. However, given the relatively small number of channels and the fact that this chip is not tuned for the straw tube signal shape, electronics built from discrete components could be used if this chip could not provide optimal performance. The first prototype of the discrete electronics is already built and being tested. Both leading and trailing edges from the straws' signals provide useful information. The leading edge time depends on the particle track distance from the wire so by measuring this time one can obtain the precise crossing position of the particle through the straw. The trailing edges occur at the same time for all straws hit by the same particle, independently from their crossing distance from the wire. This is due to the arrival of the last primary ionization cluster close to the wall. The trailing edge time is used as a validation of straws on a track, thus reducing false hits and improving track fitting.

It is also ideal for building a fast hardware trigger or veto for multiple charged tracks. The rising edge (start) of the signal is used for precise drift time measurement and the track position is calculated through known r - t dependence.

The frontend electronics modularity is following the straw mechanical fixation and gas distribution modularity. There are 16 straws in the basic unit of gas, high voltage and readout. The frontend board thus contains 2 CARIOCA chips, each serving 8 straws; one I2C controlled chip with 16 DACs for controlling the threshold; and LVDS buffers for driving output twisted pair lines (figure 3). We use standard halogen-free SCSI cable with VHDCI connectors for transmitting the data and controlling the frontend.

The frontend board is also used as a cover for the working gas volume, so it was built gas tight, always using multiple blind vias for passing the signals from bottom to top side. It contains high voltage filter and connector to provide straws with HV power.

To understand the required drift time resolution, a dedicated study has been performed with different TDC time bin steps. The targeted position resolution was specified to be $130\text{ }\mu\text{m}$. The result indicates (figure 4) that for a straw with known position-time dependence, even a 6 ns time bin of TDC (time to digital converter) would be sufficient, when using an Ar/CO_2 gas mixture.

However, other constraints led to fix the TDC time-binning to a maximum of 3 ns ; these include mainly the matching to the Gigatracker detector in NA62 experiment, where a time binning of 6ns in the straw detector would require opening a too large window for track fitting. On the lower side, using a very small TDC bin is useless as the space resolution is dominated by multiple scattering of particles.

Figure 3. The frontend board serving 16 straws, top side.

Figure 4. Straw resolution versus TDC time binning (blue: unknown space-time dependence; red: known space-time dependence).

We plan to implement the TDC directly in a FPGA (Field Programmable Gate Array), together with other readout functions. A preliminary study shows that one can achieve 1 ns resolution (1.6 ns bin) with a cost-effective version of FPGA.

3.2 Backend electronics

The Straw readout electronics should provide track data to the NA62 DAQ system in the required format, perform online monitoring to check data quality, control the front-end electronics, and possibly trigger on a single charged particle or veto on multiple charged tracks in an event. For data extraction, front-end control and online monitoring a straw detector specific module is being developed: the Straw Readout Board (SRB). For data collection and event building, handling and selection we will use the readout board TEL62 [3], which is common to the majority of detectors in NA62.

The data from 15 front-end boards (half a view) is collected by one SRB, which also provides a control for thresholds and test pulses. The chamber (4 views) is thus served by 8 SRBs housed

Figure 5. Straw readout scheme for one View (1/2 a Chamber).

in one VME 9U crate, positioned about 5 meters from the detector. SRBs will receive precise system clock, timing information and control from the common NA62 TTC system, and will time-align the data from the straws by attaching the required timestamps. 16 SRBs from one VME crate transmit formatted data to one TEL62 board, so for the whole detector two TEL62 boards are required (figure 4). For optical data transmission, the double-width mezzanine board developed for the TEL62 by the LHCb collaboration with 2x12 optical links can be used [4].

The firmware on the TEL62 and its control software will be Straw detector specific: its main tasks will be to check the integrity of incoming data, building events from matched timestamps and event management; in case the Straw detector is used for single charged track (+pion) trigger formation, the evaluation of trigger primitives would also be handled there (see section 2.1).

For clock distribution, control and timing (TTC) of the readout electronics we will use standard NA62 TTC modules, LTU and TTCex [5], TEL62 boards will use the full TTC protocol, while SRB boards need only the clock and “Start Of Burst” signal for synchronization. SRB boards will provide fine tuning of clock delays for timing of the detector. Adjustable delays are needed due to the spread of propagation time through components and cables, and time-of-flight of particles along the beam.

4 Conclusion

The frontend electronics for NA62 Straw detector was designed and produced. It was tested on 64-straw detector prototype together with TELL1 board (previous version of TEL62) both in laboratory and the test beam at CERN. The backend electronics is being designed and the first prototype should be ready for testing at the end of 2010.

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