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SPECTROMETER INSTRUMENTATION FOR

CERN SPS SECONDARY BEAMS

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Summary

At the CERN SPS (Super-Proton-Synchrotron) most of the secondary beams are provided with a momentum measuring section. Each spectrometer consists of four multiwire proportional chambers with a fast readout system allowing a multi-user access. The chambers are operated with an Ar/CO₂/Freon gas mixture so as to withstand beam intensities of $\leq 10^7$ particles/s with efficiency close to 100 % and without significant ageing effects. The system, being fully computer-controlled, has a fast diagnostics capability through a powerful software.

1. Introduction

Many experiments at the CERN SPS require an accurate momentum measurement (corresponding to a typical resolution $\Delta p/p$ of one pion mass) of the incoming beam particle associated with their event. In order to provide this facility, the following points had to be considered:

- i) the high fluxes in the secondary beams ($\leq 10^7$ particles/s), which greatly influenced the definition of the detector and consequently the associated electronics,
- ii) the multi-user access to the spectrometer readout in case of several experiments using the same beam line,
- iii) the small number of people dedicated to the installation and maintenance of the spectrometers.

A set of four multiwire proportional chambers, a very fast readout, a fully computer-controlled system driven by a powerful software, have fulfilled the above requirements.

2. Description of the system

Each spectrometer consists of four chambers, of a type currently built at CERN, having a sensitive area of $100 \times 100 \text{ mm}^2$. Each module consists of a single sense plane, made of gold-plated tungsten wires (10 μm in diameter) 1 mm-spaced and of two cathode planes, made of 10 μm thick Al foil, 5 mm apart from the wire plane.

To minimize ageing effects, which would be caused by the high beam intensity, we decided to replace the commonly used "magic" gas¹ by an almost completely inorganic mixture of 50 % Argon + 49.7 % Carbon dioxide + 0.3 % Freon 13B1, premixed in single cylinder. On the other hand, the major difficulty in using such a gas mixture is a charge amplification much smaller than the one obtained by the "magic" gas. Consequently the weakness of the signals and the need of a fast resolving time has led to great difficulties in the first amplifying stage of the electronics; furthermore, a very careful shielding has to be used to minimize the environmental noise.

3. The electronics

3.1 Input stage. Attached to the chamber, one pluggable motherboard receives the printed circuit cards, each one grouping four channels (Fig. 1). Each channel has

two amplifying stages and one discriminator-line driver (Fig. 2).

Low threshold (0.5 μA), wide bandwidth ($> 60 \text{ MHz}$) and transmission to long distances (up to 300 m) are the main problems associated with the input stage.

In order to preserve the fast rise time of the chamber ($\leq 2 \text{ ns}$) and to minimize capacitive coupling among wires, the input impedance has to be kept as small as possible, but high enough to damp the self-resonance of the wires; a load of 75 Ω was found to be optimum. Considering the need of such low impedance and of a sensitivity of 0.5 μA we have used "low noise figure" transistors in a grounded base configuration. To reduce the time-over-threshold on the discriminator, due to the rather long tail of the chamber pulses, a "pulse equaliser" has been introduced before the amplifier, which consists of two ECL stages. The discriminator (a Schmitt trigger) has a threshold adjustable from 0.5 μA to 2.5 μA , a minimum width of 15 ns (necessary for a transmission up to 300 m) and a double pulse resolution of $\leq 30 \text{ ns}$. To compensate high frequency losses and to avoid pile-up effects up to 20 MHz a differentiating network follows the discriminator.

3.2 Transmission - line receiver. Considering the distances between the chamber location and the experimental huts and the need to wait for the "physics" strobe the signals have to be delayed up to 1.5 μs avoiding the use of an active delay with its associated dead-time. This is done by means of 16-twisted-pairs cables with low attenuation (6 db/100 m for a 15 ns wide pulse) and a small delay dispersion among pairs ($\pm 0.2 \%$).

At the end of the transmission cables, a balanced line receiver allows an adjustment of the delay dispersion among pairs to $\pm 1 \text{ ns}$, fixes the output pulse width to 10 ns and performs also the OR function of 16 channels.

3.3 The readout. A block diagram of the spectrometer readout is shown in Fig. 3. The system can be shared among several users (up to 4) asking for access by sending a STROBE REQUEST (typically a 25 ns wide pulse) to the Strobe Monitor unit. If the system is not busy, the request will be accepted and the data strobed into the Memory Module. The Strobe Monitor which maintains the requested strobe width and also settles the priority of coinciding requests, allows on a second level (not later than 150 ns) to decide whether to clear the Memory Module or to read the data. A "multi-hit" logic can be introduced in this decision to reject odd events characterised by too many hit wires in the same plane. Upon a READ decision, a special controller in the Memory Modules crate extracts the data in a LAM-priority-encoding mode at a rate of 125 ns/16 bits word and transmits the encoded wire numbers into the Buffer Memory assigned to the requesting user. This fast buffer (32 $\times$ 16 bits words, access-time about 100 ns) can be read directly through a standard CAMAC controller, but it may also be operated as a serial transmitter or receiver when the distances between the Memory Module controller and the user's CAMAC exceeds 15-20 m.

4. Controls and software

The digital wire chambers of the spectrometers are, together with other equipment in the experimental zones, controlled by a NORD-10 computer. All controls and data acquisitions are carried out through the interpretative language NODAL². Pure control functions are executed by means of special routines called "data modules" written in assembly code. The data module concept allows the application programs to access the hardware modules as simple program variables. In this way, the high voltage and the threshold current of the chambers can be set and these parameters with the addition of the gas flow rate and various statuses can be read.

The data from the chambers, apart from their use for the momentum tagging of individual particles in the data taking of the various experiments, provide a useful tool during the tuning and setting-up of the beams. For this reason as well as for diagnostic purposes, the data read-out system is driven by a CAMAC module which acts as an autonomous processor sharing the data-way with the crate controller. During the beam spill the events are stored sequentially in the 1 K data memory of the processor.

When the memory is full a LAM is raised which triggers the execution of a NODAL program to read and sort the data into profiles (Fig. 4) or phase space (Fig. 5) representation. Furthermore, a beam momentum distribution can be computed and displayed (Fig. 6).

5. Performance of the system

A typical HV plateau curve, for two different threshold values, obtained with a 25 ns-wide gate, is shown in Fig. 7. This illustrates the reasonably wide flat-top and the high value of the efficiency even with such a narrow gate.

Coincidence delay curves, to measure the time jitter of the chambers, give typical values of 10 ns f.w.h.m.

Some measurements of the cluster size show a proportion of about 10 % of double and 1 % of triple adjacent wire hits.

Four spectrometers are now installed and fully operational in beams where the intensity ranges between 5×10^5 and 5×10^6 particles/s. Three experiments are taking data using the spectrometer information.

Up to now no rate dependent effects have shown up. A preliminary measurement of the chamber efficiency v.s. beam intensity (density), to determine the maximum rate capability of the system, gives results consistent with the ones obtained by other groups³.

References

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Fig. 1 Chamber module mounted in a beam line

Fig. 2 Scheme of the input stage and of the line receiver

Fig. 3 Block diagram of the spectrometer readout

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Fig. 5 Beam phase space plots on both sides of a spectrometer

H3 SPECTROMETER BEAM MOMENTUM DISTRIBUTION 1977-05-04/00:27
 HORIZ AXIS IS DELTA-P/P0 IN PERCENT, BIN WIDTH = .2 %
 VERT AXIS IS WEIGHTED FREQUENCY (NORM)

WEIGHTED MEAN VALUE OF DELTA-P/P0 = -.05 % , DISTR. RMS = 1.39

Fig. 6 Typical beam momentum distribution

H1B / MWPC1 EFFICIENCY MEASUREMENT, THRESHOLD CURRENT = 1 MICROA

HV(VOLT)	EFF.	.5	.6	.7	.8	.9	1
4500	.631	\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$	I*****				
4600	.789	I*****	I*****				
4700	.912	I*****	I*****	I*****			
4800	.967	I*****	I*****	I*****	I*****		
4900	.989	I*****	I*****	I*****	I*****	I*****	
5000	.995	I*****	I*****	I*****	I*****	I*****	I*****
5100	.995	I*****	I*****	I*****	I*****	I*****	I*****
5200	.995	I*****	I*****	I*****	I*****	I*****	I*****
		\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$					

H1B / MWPC1 EFFICIENCY MEASUREMENT, THRESHOLD CURRENT = 1.5 MICROA

HV(VOLT)	EFF.	.5	.6	.7	.8	.9	1
4500	.43	I					
4600	.632	I*****					
4700	.815	I*****	I*****				
4800	.92	I*****	I*****	I*****			
4900	.972	I*****	I*****	I*****	I*****		
5000	.992	I*****	I*****	I*****	I*****	I*****	
5100	.995	I*****	I*****	I*****	I*****	I*****	I*****
5200	.995	I*****	I*****	I*****	I*****	I*****	I*****
		\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$IIII\$					

Fig. 7 Display of high voltage plateau curves for two values of the discriminator threshold (strobe width 25 ns)