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A PROPORTIONAL CHAMBER RECOIL DETECTOR FOR
ELASTIC POLARIZATION EXPERIMENT WA6 AT THE SPS

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ABSTRACT

A set of proportional wire chambers is used in an elastic scattering experiment to measure direction and momentum of recoil particles using the magnetic field of a polarized target assembly. This recoil spectrometer has been operated satisfactorily at high rates and it has been implemented in a fast decision system to improve the trigger selection. Construction criteria and performances of this detector are discussed.

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1. INTRODUCTION

In two-body or quasi two-body reactions at SPS energies, the almost complete independence of the recoil kinematics on the incident particle momentum, makes it possible to design a detector to measure the four-momentum of recoil particles with configuration and characteristics essentially constant with energy¹⁾.

For polarization experiments the magnet providing the field for the polarized target (PT) can be used as a recoil spectrometer in much the same way as it was at lower energy²⁾. The momentum and the emission angle of the recoil particles at the target as well as the interaction point position in a vertical plane through the beam axis are determined from the direction measured outside the region of significant magnetic field and from the coordinates of a few points on the trajectory inside this region. This information, combined with the measurement of time of flight (TOF) could allow the determination of the masses of the recoil particles.

At a lower energy this had been obtained with a set-up consisting of magnetostrictive wire spark chambers and scintillation counters. For the SPS experiment WA6³⁾ aiming for statistics about 100-1000 times larger than the previous ones and running with a beam intensity of $\sim 5 \times 10^7$ ppp, the wire spark chambers were replaced by MWPC's connected to a fast read-out and giving the possibility of an on-line data preprocessing. Up to now this experiment has been taking data on pp elastic scattering⁴⁾. The recoil telescope built at CERN has been used in association with a forward arm consisting of MWPC's built at the Institut f. Hochenergiephysik d. ÖAdW, Vienna, and two bending magnets, to determine the direction and the momentum of the forward particles (Fig. 1)

2. THE RECOIL DETECTOR

A magnified view of the recoil detector is given in Fig. 2. It consists of the PT-magnet, three sets of MWPC, namely B1, B2, B3 to B6, and a hodoscope of scintillation counters, BH and BV. The PT-magnet is a C-type magnet having cylindrical symmetry around a vertical axis through the centre of the target: such a configuration is particularly suitable for fast pattern recognition and momentum reconstruction, owing to the possibility of obtaining a relatively simple analytical track parametrization in spite of the rapid radial variation of the field⁵⁾.

The chamber B1 is a module with three gaps, compactly packed, placed in a 25 kG field, between the poles of the PT magnet; the gaps are close and parallel to the target and beam axis. The module B2 consists of two cylindrical gaps placed at a smaller field value (~ 10 kG), while B3 to B6 are four planar modules with one vertical and one horizontal wire plane each, which are used to detect the recoil particle direction outside the magnetic field.

By installing the first chamber B1 very close to the magnet centre, almost all of the bending power ($0.95 \text{ T}\cdot\text{m}$) can be exploited for the momentum measurement: the resolution is optimized by placing the intermediate chamber B2 at a radial position where the sagitta of the trajectory is maximal.

The hodoscopes give only a rough determination of the direction of the recoil particle but a precise measurement of TOF ($\propto 1/\beta$).

The momentum resolution $\Delta p/p$ measured in the WA6 experiment is plotted in Fig. 3, together with its approximate value $\Delta p/p \sim 0.02$ (p in GeV/c). At low momenta, where the multiple scattering contribution is dominant, the momentum resolution is improved by the TOF measurement. The recoil mass spectrum in the present WA6 trigger consists almost completely of protons, as shown in Fig. 4a: for comparison, the mass spectrum from Ref. 2 (3.5 GeV/c incident pion beam) is reproduced in Fig. 4b.

3. CHAMBER CHARACTERISTICS AND CONSTRUCTION

The main features of the proportional chambers used in this detector are listed in Table 1. The complete detector consists of about 5500 wires with an overall thickness of 0.3 g/cm^2 equivalent to 1.5×10^{-2} radiation lengths.

For the modules inside the magnet gap particular care has been taken in obtaining a compact construction (Fig. 5a) compatible with the limited space available: the preamplifier boards are connected to the chamber via a printed-circuit interface; adjacent gaps have in common double-face printed-circuit foils as cathode planes, giving an efficient high voltage decoupling.

Sense wire and cathode planes for the cylindrical module (Figs. 5b, c) are fixed on thin planar vetronite frames (1.5 mm thick) which are then brought to a cylindrical shape by sliding them in circular grooves precisely machined on top and bottom of the cylindrical gas-tight box containing the gaps. This method of construction simplifies considerably the operations of assembling the whole module or removing a single plane.

The chambers outside the magnetic field region are of conventional type, with construction criteria based on modular elements, giving the possibility of building up, without design changes, chambers with sides ranging from 50 to 150 cm, with overall tolerances less than ± 0.02 mm.

4. CHAMBER OPERATING CONDITIONS AND PERFORMANCE

The chambers, filled with a "magic gas" mixture (argon, 25% isobutane, 5% methylal, 0.3% freon), are operated on the low side of the high voltage plateau (Fig. 6) in order to prevent ageing effects due to high particle fluxes (of the order of 10 MHz in B1, 5 MHz in B2 and between 5 and 2 MHz in B3 to B6), corresponding to peak currents during the burst of about 250 μ A for B1, 100 μ A for B2 and 50 μ A for B3 to B6. High overall efficiency is guaranteed by the redundant number of planes per module.

The chambers are read-out, with an electronic threshold of 2 μ A and a strobe width ranging between 50 and 100 nsec, on occurrence of a signal from the scintillation counter trigger; an event selection is then performed by using the hit wire addresses before transferring the chamber information to the on-line HP21MX computer. Only a part of the chambers participate to the decision stage, while the rest is read-out when the overall decision is taken.

The first ones are equipped with a read-out system suitable for high input rates with cable delay and fast non-destructive multiple read-out⁶⁾.

A decision system made of modules which perform fast comparison of hits in pairs of chambers⁷⁾ reads the wire addresses of the

active chambers and compares them with stored precalculated acceptable hit combinations: a sketch of the operation scheme is given in Fig. 7.

An example of the application of this system is illustrated in Fig. 8. Negative particles are rejected according to the sign of their trajectory projection on the beam axis.

CONCLUSION

The relatively simple set-up of proportional chambers and scintillation counters for the recoil spectrometer described here, gives a complete information on recoil protons of an elastic scattering experiment with a precision of approximately 1 mm in the position of the interaction vertex, $\lesssim 10$ mrad in the emission angle and typically $\Delta p/p \sim 0.02$ at 1 GeV/c momentum.

The spectrometer operates with high beam fluxes (up to 5×10^7 ppp); the large associated background is reduced by hardware selection systems.

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TABLE I

CHAMBER	SHAPE	USEFUL SURFACE (cm ²)	NUMBER OF GAPS	GAP WIDTH (mm)	WIRE SPACING (mm)	NUMBER OF WIRES	(g/m ² , rad. length)	EQUIVALENT THICKNESS
B1	plane	32 x 5	2X 2Y	4.0	1.0	688	0.1	6 x 10 ⁻³
B2	cylindrical	64 x 33	2X	5.5	2.0	640	0.1	6 x 10 ⁻³
B3	plane	102 x 102	1X 1Y	8.0	2.0	1024	0.02	1 x 10 ⁻³
'							<div style="display: flex; align-items: center; justify-content: center;"> <div style="margin-right: 10px;">0.08</div> <div style="border-top: 1px solid black; width: 100px; height: 10px;"></div> </div>	
'								
B6	plane	102 x 102	1X 1Y	8.0	2.0	1024	0.02	1 x 10 ⁻³

FIGURE CAPTIONS

Fig. 1 : Experiment WA6:

- a) General layout.
- b) Expanded-scale top view of the recoil detector.

Fig. 2 : A sketch of the recoil detector configuration.

Fig. 3 : Momentum resolution for recoil protons; dash-dotted line represents the measuring error contribution $\Delta p/p \sim 0.02 p$ (p in GeV/c).

Fig. 4 : a) Mass spectrum of recoil particles of WA6 experiment (Ref. 4) at 150 GeV/c.

- b) Mass spectrum of backward particles from Ref. 2.

Fig. 5 : a) The first chamber (B1) of the recoil detector.

- b) Assembling of the cylindrical chamber B2: the wire and cathode planes are inserted in the supporting box.
- c) Top view of B2 equipped with preamplifiers.

Fig. 6 : High voltage plateau curves for B1, B2 and B3.

Fig. 7 : Scheme of operation of the Fast Decision Logic.

Fig. 8 : Selection of recoil tracks:

- a) Target profile in B1. The contributions from PT and DT (Dummy Target, see Ref. 4) are shown.
- b) Projections on beam axis of tracks in B3-B6: separation of positive and negative particles. Positive recoil particles are selected with FDL.

Fig. 1

a)

b)

Fig. 2

Fig. 3

Fig. 4

a)

b)

c)

Fig. 5

Fig. 6

Fig. 7

Fig. 8