LAL 86-36
Oct. 1986

Laboratoire de l'Accélérateur Linéaire

The Scintillating Fibre Detector in the UA2 Upgrade Programme

The UA2 Collaboration

Presented by B. MERKEL

*Invited talk presented at the 2nd Topical Seminar on Perspectives for
Experimental Apparatus at Future HE machines,
San Miniato, Italie, 5-9 Mai 1986*

U.E.R
de
l'Université Paris-Sud

Institut National
de Physique Nucléaire
et
de Physique des Particules

Bâtiment 200 - 91405 ORSAY Cedex

THE SCINTILLATING FIBRE DETECTOR IN THE UA2 UPGRADE PROGRAMME

The UA2 Collaboration

Presented by B. MERKEL

Laboratoire de l'Accélérateur Linéaire - Bât. 200 - 91405 Orsay France

Abstract : A study of a compact and cylindrical tracking detector based on the use of scintillating fibres is presented. A prototype has been built and tested with 40 GeV/c electrons and hadrons.

I. INTRODUCTION

The UA2 detector took its first data in 1981 and has been operating smoothly since then. The very successful performance of the SppS collider has given the opportunity to collect a large amount of very fruitful data. After a long shut-down in 1986, the collider will resume operation with a substantially higher luminosity than presently available. In order to make the best use of the increased luminosity in terms of physics results the performance of the present UA2 detector has to be improved. Detailed descriptions of the modifications of the UA2 detector have been given elsewhere (ref. 1) ; two major modifications are made.

The installation of a new end cap calorimeter and preshower detector will expand the acceptance of the present central calorimeter to polar angle coverage between 10° and 170° , which

implies instrumentation down to 5° and 175° , it will cover 2π in azimuth.

The vertex detector is redesigned, to substantially reduce the two most significant sources of backgrounds faking electrons : converted photons from π^0 decays and unresolved pairs composed of a π^0 and a charged hadron (overlaps). A matrix of silicon counters (see description in these proceedings by K. Borer (ref. 2)) is installed to identify ionisation loss from track pairs created by photon conversions in the inner part of the UA2 detector. The insertion of a transition radiation detector, to gain rejection against overlaps, is at the price of devoting to it a major fraction of the space available in the central region of UA2, half of the radial range (see description in these proceedings by B. Merkel (ref. 3)). In turn this implies very efficient and compact tracking devices fitting in the remaining available space : a jet chamber vertex detector surrounding the beryllium vacuum pipe as inner tracking device and a multilayer scintillating fibre detector as outer tracking and preshower device ; description of this detector and early test results have already been reported (ref. 4). The jet chamber vertex detector and silicon array in the inner region and the scintillating fibre detector in the outer region have the ability to measure track segments. While inner tracking provides direct localisation in space by charge division on the jet chamber vertex detector wires and the silicon pads, the scintillating fibre detector measures three stereoscopic projections. The stereo angle has been chosen small enough to reduce ghost tracks to a satisfactory level while retaining sufficient localisation accuracy. The outer layers of the SFD act as a preshower counter, thus providing a compact and unified design in the angular range covered by the central UA2 calorimeter.

II. SCINTILLATING FIBRE DETECTOR (SFD)

Recent developments in scintillating plastic fibres made at Saclay offer an attractive possibility to construct a compact position detector with good track reconstruction efficiency and adequate spatial accuracy. As emphasized above, compactness is absolutely necessary to provide space within the UA2 apparatus for the transition radiation detector. The present design of the SFD is based upon extensive tests that we have made with fibres, image intensifiers, and CCD's since the middle of 1984.

II.1 Detector construction

The choices for the design of the detector are based on the standard fibres which we have tested, currently produced by Saclay (STIPE). They are made of a core of polystyrene, doped with POPOP and butyl-PBD, with a diameter of 1mm surrounded by a 12μ thick cladding. The refractive index of the core and the cladding are 1.6 and 1.46 respectively, the numerical aperture is 0.62. The possible benefit of using smaller diameter fibres is limited both by the resolution of the

read-out system and by the attenuation length which becomes shorter at smaller diameter. The fibres are aluminized in order to suppress cross-talk between adjacent fibres .

The SFD has a radial thickness of 60 mm at an average radius of 410 mm. It consists of about 60000 fibres, with a total length of 150 km, arranged in eight groups of three layers (triplets). The tracking part of the SFD contains 6 triplets ; in each triplet, the angles of the fibres with respect to the beam axis are -16° , 0 , and 16° for the three layers respectively. This provides space coordinates from three stereoscopic projections. Within the angular range covered by the central UA2 calorimeter, a converter (1.5 radiation lengths) is inserted in front of the two outer triplets, which are thus used as a preshower detector, in each triplet the angles of the fibres with respect to the beam axis are -21° , 0 , and 21° for the three layers respectively. The choice of the stereo angles offer a good match between the tracking and the preshower parts. The geometry of the SFD have been checked using Monte Carlo studies of the track reconstruction properties.

II.2 Read-out Scheme

We plan to view the fibres from one end only and to place a reflector at the other end. A schematic representation of the read-out system is shown in fig. 1. It is composed of three parts. The light output from the fibres is amplified with a photon gain of 10^4 by the image intensifiers (II). The light is then converted by a charge coupled device (CCD) into a signal which is read by the digitizer and stored in a memory .

The photon gain of the II system is chosen such that the average signal per CCD pixel, within the area corresponding to a fibre hit by a charged particle, is about ten times larger than the noise level of the CCD. From our investigations, it has become clear that three amplifying stages are necessary to meet our gain specifications : a moderate gain unit, a high gain tube with microchannel plate, followed by a second moderate gain unit. The first and the third units demagnify the fibre image. For the complete detector 32 II chains will be used.

On commercial II's, the light output is provided by a phosphor screen with a decay time of several milliseconds. These have to be replaced by faster phosphor screens which are less efficient by a factor $\simeq 3$. We have measured the decay time characteristics of the phosphor screen we plan to use (yttrium silicate doped with cerium). We found that less than 0.1% of the light is emitted after 300 nsec, this value is well below the collider repetition rate (4 μ sec between crossings).

We have studied a simple way to stop the light amplification across the II chain after an event crossing. This is done on the high gain tube. We have also investigated the II lifetime ; this problem appears as a gain decrease with exposure time and may become serious with the microchannel plate. From our measurements we have concluded that the lifetime is adequate for the tracking part of the detector. The amount of light emitted by the fibres in the preshower part of the

detector is higher, we have decided to insert a light attenuator in front of the first II in order to get similar gain variation on the full surface of the II's by equalizing the light output.

The fibre optic window at the exit of the II chain is directly coupled to a CCD where the light is converted to electrical charges which are stored. It is essential that unwanted information can be cleared off from the device during the time available between two interaction crossings ($4\mu\text{s}$). This can be achieved by using the antiblooming system with which some commercial CCD's are equipped. In collaboration with the manufacturer, we have shown that CCD TH7852 which we plan to use can be fast-cleared by applying a pulse of $1.5\mu\text{sec}$ duration to the antiblooming input. The CCD TH7852 has an optical area of $5.8 \times 4.3\text{mm}^2$ with 144×208 pixels. Each pixel has an active area of $19 \times 30\mu^2$ and a geometrical area of $28 \times 30\mu^2$. With the demagnification of the II chain a 1mm diameter fibre may illuminate up to about 15 pixels.

For events satisfying the trigger requirement, the content of all the CCD's is read out by a specially designed Fastbus module. We consider that pulse height information is useful in pattern recognition, and necessary for the preshower part of the SFD. Hence the charge contained in each CCD pixel is digitized using a 8 bit FADC. Since in a typical event particle tracks cross $\simeq 2\%$ of the fibres, data compaction is essential. After subtraction of a pedestal, each digitized pixel value is compared to a threshold. Only pixels above threshold are retained for comparison with a map, which associates each remaining pixel with a particular fibre. This map is held in the Fastbus memory. The final data, containing the fibre number and its associated integrated charge, is encoded in a single 32-bit word for each fibre.

III. TEST OF A SFD PROTOTYPE

III.1 The test set-up

A bundle made of 24 layers of 40 scintillating plastic fibres ($\varphi=1\text{mm}$, $L=2\text{m}$) has been installed on the H2 beam in the North Area of the CERN SpS with the beam direction perpendicular to the layers. This beam can be switched either to a hadron enriched mode or to an electron enriched mode. Each layer is made of 40 contiguous fibres held by a scotch tape ; the separation between the layers is similar to the final design. The production of the fibres for the detector assembly is now under way, the fibres used for this test are part of the full production necessary for the SFD. The bundle is viewed from one end by the chain of image intensifiers shown in fig. 1, the other end of the fibres is equipped with reflecting tape. All the II's have fibre optic windows (input and output), and fast phosphor anode screens. The measured photon gain of the full II system is about $4 \cdot 10^4$, in excellent agreement with requirements.

In order to test the preshower performance of the SFD, slabs of lead had been inserted

along the bundle. The lead covered the full width of the layers over a length of 10 cm. The corresponding configuration along the beam direction was : 18 layers of fibres, $1.5X_0$ of lead, 6 layers of fibres.

III.2 Data analysis and results

We have taken electron data and hadron data. Preliminary results are presented at this Conference.

A distribution of the fibre efficiency is shown on figure 2 for hadron data. 24 layers being aligned on the beam track, it is possible to know the efficiency of each layer. An optical attenuator is installed in order to decrease by a factor 4.5 the light collection from the preshower part of the test set-up ; this attenuation has an effect on the efficiency. The mean value of the efficiency obtained with the other layers is in good agreement with an expected value of 91% at normal incidence angle. For different values of the incidence angle the average efficiency is expected to be closer to 100% .

We present on figure 3 the plot of the residue around the track extrapolated, from beam chambers. The r.m.s. of a gaussian fit to the data is 0.44 mm, in agreement with simple predictions.

The charge distribution derived from the pulse height outputs of the CCD are shown for hadrons in the layers in front of the lead (fig. 4a). Similarly the distribution (fig. 4b) shows the charge, corrected for the light attenuation factor, for electrons after $1.5X_0$ of lead (fig. 4b).

IV. CONCLUSION

We are in the process of modifying the present UA2 detector with the aim to match its performance to that of the improved Sp $\bar{p}$ S collider in 1987. The upgrade consists mainly of a new calorimeter end cap to improve the quality of the missing transverse energy measurement, and a new vertex detector which aims at ensuring that multivertex events can be reconstructed and at improving the detector performance in relation with electron identification.

A component of this new vertex detector is a compact tracking device made of scintillating fibres coupled to image intensifiers and CCD read out. Recent prototype tests have shown that this novel technique is likely to provide a very good detector.

REFERENCES

- 1) B. Merkel, Proceedings of the Fifth Topical Workshop on $p\bar{p}$ Collider Physics, St Vincent (1985) 635.
J. M. Gaillard, Proceedings of the International Symposium on Physics of $p\bar{p}$ Collision, Tsukuba, Japan, KEK Report 85.5, 254.
C. N. Booth, Proceedings of the Sixth Topical Workshop on $p\bar{p}$ Collider Physics, Aachen (1986).
- 2) K. Borer et al., These Proceedings.
- 3) B. Merkel, These Proceedings.
- 4) J. M. Gaillard, Proceedings of the Oregon meeting (Eugene 1985).

Fig. 1 : The image intensifier chain, II_1 is a demagnifying tube with moderate gain, II_2 is a high gain tube, II_3 is a demagnifying tube with moderate gain. The image is stored on a CCD.

Fig. 2 : Track detection efficiency for each layer versus the layer number, the light output from the fibres is attenuated by a factor 4.5 on layer 18 to 24.

Fig. 3 : Space resolution of the tracking part of the detector, the r.m.s. is $\sigma = 0,44\text{mm}$.

Fig. 4 : Normalized charge distribution derived from pulse height outputs of the CCD.
a) 40 GeV/c hadron in the tracking part,
b) 40 GeV/c electrons in the layers after the 1.5 X_0 lead converter.