EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/88-91
August 4th, 1988

COMPACT FAST RICH DETECTOR USING A SOLID RADIATOR :

PRINCIPLE AND FIRST EXPERIMENTAL RESULTS

T. Francke, F. Montanet, P. Pavlopoulos, C. Rivoiron
and J.C. Santiard

CERN, Geneva, Switzerland
and
M. SUFFERT, CRN, Strasbourg, France

ABSTRACT

The principle and first experimental results for a compact fast RICH detector using a solid radiator (NaF Crystal) are presented. This detector can be very thin (≈ 4 cm) and presents a small percentage of radiation length. First experimental results for $\beta = 0.82$ and $\beta = 1$ particles at different incident angles indicate a good determination of the ring diameter. This type of particle identifier may be quite useful in compact medium energy experiments.

Presented at the

International conference on

ADVANCED TECHNOLOGY AND PARTICLE PHYSICS

Como, Italy, June 13-17, 1988

1. INTRODUCTION

An important component of nowadays particle physics detectors is a particle identifier. Such a device should be compact, in order to reduce the volume of the expensive electro-magnetic calorimeter, it should present a small percentage of a radiation length and it should be capable of very good mass separation. In the case of medium-energy experiments mainly K/π separation around 500 MeV/c is important and the device should be fast.

Identification by time of flight is not always possible due to a too small inner diameter of the e.m. calorimeter. Conventional Cherenkov detectors are satisfactory, if the momentum range is not too wide. As the time of flight method, they need photomultipliers which complicate the construction due to the presence of the magnetic field. Ring-imaging Cherenkov (RICH) techniques are very efficient, but they need usually quite some space if they are fast. In the case of a liquid radiator they need two UV-transparent windows and heating is difficult. So the idea came up in our group to use a solid radiator which would make the detector thin (in our case we had 4 cm at our disposal) and the radiator could replace the two windows.

Of course, such a solid should have a small refractive index (<1.4), good UV transmission down to 150 nm and good physical and chemical properties (in particular insensitive to TMAE). Nature was kind to us : Sodium Fluoride (NaF) presents all these properties*.

In the next section we give the main properties of NaF, the principle of the detector and the results of some simulations. In the last section we present the first experimental results obtained with such a detector.

2. PRINCIPLE OF THE DETECTOR AND SIMULATIONS

2.1 Properties of NaF

Fig. 1 shows the transmission and the refractive index of NaF together with the TMAE quantum efficiency. The transmission is good down to ≈ 130 nm [1]. The variation of the refractive index n with wave length was measured down to ≈ 185 nm [2] and then extrapolated using a dispersion equation. One sees that n stays below $\sqrt{2}$ down to ≈ 175 nm so even for $\beta=1$ and normal incidence particles a good fraction

* We are indebted to Prof. T. Ypsilantis for pointing out to us that these properties are fulfilled by a NaF Crystal.

of the produced Cherenkov light can refract out of the NaF crystal.

The radiation length of NaF is of the order of 9 cm so γ -rays barely interact in 0.5 to 1 cm of NaF.

NaF does not scintillate [3] at least when measured with a quartz-window photomultiplier.

2.2 Principle of construction

Fig. 2 shows the principle of the detector. One sees that the drift space is used twice and that the NaF Crystal is used to separate the photo-sensitive wire chamber from the drift space. As a result the whole detector is extremely thin (<4 cm). The drift distance between the crystal and the mirror was in fact variable.

The 12 cm dia. NaF Crystal* was 1 cm thick. The wire chamber was 15×15 cm², the distance between wires was 1 mm and 5 wires were connected to form a strip (32 strips /plane). The three planes were tilted by 60°. Each strip was equipped with a low-noise, charge-sensitive preamplifier, a shaper and an ADC. The chamber was filled with TMAE and ethane at $\approx 25^\circ\text{C}$ and at low pressure (6 mbar). Low-pressure operation was chosen in this first-step experiment since the charged particle will not be seen. [4].

* Manufactured by BDH, Poole, Great-Britain.

2.3 Simulations

Our detector has two drawbacks. First, since there is no focussing, the Cherenkov ring is thick due to the thickness of the crystal. On the other hand, parasitic reflections in the crystal give rise to photoelectrons inside and outside the ring. These parasitic reflections increase with increasing refractive index i.e. with decreasing wave length. So this phenomenon can be reduced by cutting off small wave lengths, sacrificing some photoelectrons.

Fig. 3 shows simulations for $\beta=0.82$, $\lambda_{\min}=150$ nm and mirror distance of 1.3 cm for 0° and 30° incident angle. One sees clearly the hits outside the ring and the thickness of the ring.

Fig. 4 shows the inner ring diameter for pions and kaons as a function of momentum for a mirror distance of 0.5 cm.

3 FIRST EXPERIMENTAL RESULTS

3.1 Number of photoelectrons

For these measurements the sum of all anode-strip charges was measured for each event.

Fig. 5 shows the anode spectra for $\beta=1$ (cosmic rays) no mirror and full photon absorption for 0° and 25° incident angles. This measurement gives an idea of the maximum number

of photoelectrons (p.e.) one could obtain. This number varies from ≈ 60 (0°) to ≈ 80 (25°). The ratio of these numbers is in agreement with simulations. The lower number of p.e. at 0° is due to trapped photons in the crystal but the absolute value shows that most of the Cherenkov photons refract out of the crystal even in this very unfavorable case ($\beta=1$ particles at 0°).

Fig. 6 shows the number of photoelectrons as a function of incident angle (α) for $\beta=1$ and $\beta=0.82$ (e^- and π^- at 200 MeV/c) with the set-up of fig.2. The curves are results of simulations and the circles experimental results obtained at the SC-CERN. In order to obtain agreement $\lambda_{\min}$ had to be raised to 165 nm. Also the experimental points were normalized at $\alpha = 30^\circ$, the absolute number of measured photoelectron was about half of the simulated one. We will comment on these facts later.

3.2 Rings and projections

Due to the limited spatial resolution of the wire chamber (5 mm strips) and the number of photoelectrons (≈ 15 per event) the hit reconstruction presents ambiguities. An off-line reconstruction algorithm is in preparation which takes into account the correlation between pulse heights [5] since the single photoelectron spectrum is nearly

exponential. Preliminary results using this method will be presented later on.

Fig. 7 shows the measured projections for $\beta=0.82$ and a mirror distance of 1.3 cm. Comparing these results with the simulation (fig.3) one sees that the general trend is well reproduced, (the cathode 2 projections are reversed) but there is clearly a smearing. For the moment, we suppose that this smearing is due to surface contaminations of the NaF crystal and/or of the mirror. This is corroborated by the fact that we had to apply a $\lambda_{\min}$ cut at 165 nm (fig.6) and that the measured number of p.e. is about half the simulated one. A new experiment with fresh components is in preparation.

Fig. 8 shows a three-dimensional plot again for $\beta=0.82$ and a mirror distance of 1.3 cm at normal incidence. The experimental data were analysed using the pulse-height-correlation method. One sees that the outer diameter of the ring is well defined, but, of course, the center of the ring is quite filled up (see preceding paragraph).

Fig. 9 shows a typical single event ($\beta=0.82$). The number of reconstructed p.e. is ≈ 10 . One should keep in mind that for these measurements only about 1/3 of the Cherenkov photons were absorbed in the TMAE ($T \approx 25^\circ\text{C}$) and that probably

nearly half of the photons were lost due to surface contaminations.

4. CONCLUSION

The principle and first experimental results are presented for a compact fast RICH detector using a solid radiator (NaF crystal). These results, obtained a few days before the conference, are quite encouraging and this study will be pursued. In particular, the chamber readout granularity will be increased, using $5 \times 5 \text{ mm}^2$ pads, in order to cope with the number of photoelectrons which can be reached in such a detector (≈ 50). Also, multistep and normal pressure operation of the wire chamber will be tested.

Acknowledgment

The authors would like to thank the many persons who helped in various stages of this project especially R.RIBEIRO, R.RICKENBACH and C.TOURAMANIS. Special thanks to the SC operator team, the EP mechanical workshop and the EP mechanical technical assistance group. One of the authors (M.S.) gratefully acknowledges financial support by CERN.

References

- [1] R. Arnold, Y.Giomataris, J.L. Guyonnet, P. Petroff, J.Séguinot, J. Tocqueville and T. Ypsilantis.
London Conference on Position-Sensitive Detectors, University College, London, Sept 1987
- [2] A.Smakula, U.S. Dept. of Commerce, Office of Technical Document 111052. page 88-89, Oct. 1952
- [3] M. Moszynski and Th. Lindblad, Nucl. Instr. Meth. A.246(1988) 388
- [4] R. Chechik and A. Breskin, Nucl.Instr.and Meth. A.264 (1988) 251.
- [5] A. Peisert, Thesis, Geneva University (unpublished) p.66

Figure Captions

- Fig. 1 NaF transmission [1], NaF refractive index [2] and TMAE quantum efficiency as a function of photon wave length λ . The dotted part of the index curve corresponds to an extrapolation.
- Fig. 2 Principle of construction of the NaF-RICH detector. The ethane pressure was 6 mbar. The distance between the NaF Crystal and the UV mirror was in fact variable.
- Fig. 3 Simulation of anode and cathode projections and hit pattern of photoelectrons for $\beta = 0.82$ particles incident at 0° and 30° . The mirror distance is 1.3 cm.
- Fig. 4 Simulations of the inner diameter of the Cherenkov ring as a function of particle momentum for pions and kaons. The mirror distance is 0.5 cm.
- Fig. 5 Anode sum spectra for $\beta = 1$ particles incident at 0° and 25° . The direction of the particles was opposite to the one of fig.2 and the distance between the NaF Crystal and the cathode was 35 mm (full photon absorption). The 0° and 25° peaks correspond approximately to 60 and 80 photoelectrons respectively.
- Fig. 6 Number of photoelectrons at 22°C with the set-up

of fig.2. Full curve=simulation. For the experimental results the vertical scale has to be divided by approximately 2.

- Fig. 7 Measured projections for $\beta=0.82$ particles incident at 0° and 30° . The mirror distance was 1.3 cm.
- Fig. 8 Hit plot of Cherenkov photoelectron produced by $\beta=0.82$ particles incident at 0° .
- Fig. 9 Projections and hit plot of a single event for a $\beta=0.82$ particle incident at 0° .

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9