EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/EP 84-24
29 February 1984

PERFORMANCE OF THE SILICA AEROGEL CHERENKOV DETECTOR
USED IN THE EUROPEAN HYBRID SPECTROMETER

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ABSTRACT

The performance of an 18 module Silica Aerogel Cherenkov Detector, with a total sensitive surface of 2.3 m^2 , situated in the European Hybrid Spectrometer at the CERN SPS, is described. The light yield for $\beta = 1$ particles is on the average 7.5 ± 0.3 photoelectrons. Particle identification with this detector is discussed. First results on the ageing effects of silica aerogel are presented.

Submitted to Nuclear Instruments and Methods in Physics Research

1. INTRODUCTION

The European Hybrid Spectrometer, EHS [1] is a general facility at the CERN SPS for the study of hadronic interactions. The layout of EHS is shown in fig. 1. It consists of a rapid cycling bubble chamber and a large spectrometer. Charged particle identification is provided by the Silica Aerogel Cherenkov Detector, (SAD), the pictorial drift chamber ISIS, a gas filled Forward Cherenkov counter (FC) and a Transition Radiation Detector (TRD). These detectors complement each other to a large extent, and one achieves particle identification in a large momentum region. SAD contributes to the particle identification in the low momentum range, 0.5 - 4.5 GeV/c. Here we report on the performance of SAD under data taking conditions with the complete EHS set-up.

SAD has been in operation in EHS since 1981 and has been used in three experiments, NA22, NA23 and NA27. The data used for this study (accumulated in 1982) come from the strange particle experiment NA22 [2] and the charm experiment NA27 [3].

Sect. 2 describes the design and operation of SAD, in sect. 3 the light yield is discussed, sect. 4 contains the geometrical acceptance estimates and sect. 5 describes the particle identification achieved with SAD. In sect. 6 the ageing effects of the silica aerogel is discussed and sect. 7 finally, contains a summary.

2. DETECTOR DESIGN AND OPERATION

SAD is composed of 18 identical modules and is situated about two metres downstream of the centre of the magnet M1. Fig. 2 shows the arrangement of the modules seen from the target bubble chamber.

A detector module is schematically shown in fig. 3. Each module has a sensitive surface of $23 \times 55 \text{ cm}^2$ and an aerogel thickness between 13 and 15 cm. The volume is filled with aerogel blocks with dimensions of approximately $18 \times 18 \times 3 \text{ cm}^3$ with a refractive index of 1.031. In general five layers of aerogel are placed on top of each other, such that holes through the complete aerogel volume are avoided.

Silica aerogel is a porous material with a refractive index in the range 1.015 to 1.10. The refractive index is determined by the mixture of SiO_2 and air decided at the fabrication process [4].

The reflecting surfaces of the light collection system are made from aluminized mylar 75 μm thick, suspended to a frame of aluminium bars and protected by an additional layer of light tight aluminized mylar 25 μm thick. The reflectivity of the aluminized mylar is 90% for wavelengths greater than 250 nm [5].

The Cherenkov light is collected onto two 11 cm diameter photomultipliers (PM1 and PM2, see fig. 3) of the type RCA 8854. The photomultipliers have to be shielded from the stray field of magnet M1, which can reach 0.1 T in the region where the PM's are located [6]. The presence of this high field seriously affects the optimisation of the PM positions and orientations. In order to make room for the rather thick and long iron cylinders around the PM's, these are placed rather far from the aerogel volume (see fig. 3). Each group of photomultipliers is surrounded by an additional iron box (see fig. 2).

With this construction the amount of material within the acceptance of the spectrometer is practically negligible with the exception of the aerogel itself, which represents 1.8% of an interaction length and 5.6% of a radiation length.

Each group of modules was inclined with respect to the vertical in order to optimise the geometrical acceptance and the light collection.

The complete detector is enclosed in a light tight box with tethlar windows in the geometrical acceptance of the spectrometer. The humidity inside this volume is limited to 30% to avoid the absorption of water by the silica aerogel.

The signal of each individual photomultiplier is recorded with a charge integrating analog to digital converter (ADC) and read out via CAMAC interface together with the rest of the spectrometer data in the EHS data acquisition system. The stability of the photomultiplier and the ADC

convertors is constantly monitored during the run with the help of a light emitting diode. The light of a single light emitting diode is distributed to all the modules with optical fibres.

More details on the module design and optimization are found in refs [5, 7-9]. Aerogel detectors for other experiments using different types of light collection systems have also been constructed [10, 11].

3. LIGHT YIELD

The study of the Cherenkov light yield was mainly done using pions, uniquely identified by ISIS [12]. For a particle to be taken as a pion we required the measured ionisation to be within two standard deviations from the expected value for a pion, and to be at least 2 1/2 standard deviations from the value expected for any other particle. With these requirements the contamination of the pion sample is smaller than 1%. The pions identified by ISIS that also go through SAD all have momenta exceeding 2 GeV/c. We find that the average light yield for the complete detector for $\beta = 1$ particles is 7.5 ± 0.3 photoelectrons using the data from the NA22 experiment, and 7.3 ± 0.2 photoelectrons using the NA27 data.

In figs 4 and 5 the light yield is shown along the short and long side of the modules respectively averaged over all modules. Close to the edges of the modules the light yield is considerably lower as the particles can cross the module at such an angle that only part of the aerogel is traversed. For the edge at $L = 0$ cm in fig. 5 this effect is not present as the impact is always at 90° to the aerogel surface in this projection.

In fig. 6 the light yield for all particles is shown as a function of $(m_\pi/p)^2$, where m_π is the pion mass and p is the momentum. The Cherenkov light yield is a linear function of this variable [13]. In fig. 6 we had to include particles which were not uniquely identified by ISIS in order to have data over the complete $(m_\pi/p)^2$ range. With this caveat the light yield as a function of the particle momentum is in

agreement with the refractive index of 1.031 ± 0.002 as measured in a test beam [14]. The broken line in fig. 6 indicates the expected light yield for this value of the refractive index.

4. GEOMETRICAL ACCEPTANCE

The SAD detector is intended for identification of low momentum particles (see sect. 5 below). Figs 7 and 8 show the proportion of reconstructed secondary particles that go through the detector as a function of the momentum for the NA22 and NA27 geometries respectively. In NA22 the bubble chamber was situated at the centre of the magnet M1, which had a peak field of 2.6 T. In NA27 the bubble chamber was situated about 3 m upstream of the centre of M1, which had a peak field of 1.3 T. (The maximum field of M1 is 3 T). Due to the difference in geometries, the reconstruction efficiency for low momentum particles is however lower in NA27 than in NA22.

When there are several particles through the same module, or when the particle goes very close to the edge, the particle identification becomes unreliable. The first effect affects 30% of all particles, the second one affects about 10%. If all these tracks are removed, the acceptance becomes the one indicated with a broken line in figs 7 and 8. This gives a conservative estimate of the SAD acceptance as some identification may still be obtained for a fraction of these particles.

5. PARTICLE IDENTIFICATION

With a refractive index of 1.031 the threshold momentum is 0.56 GeV/c for pions, 2.0 GeV/c for kaons and 3.8 GeV/c for protons. The average light yield as a function of momentum for pions, kaons and protons is shown in fig. 9. Also shown is the efficiency to detect a signal. SAD is useful for particle identification in the momentum region 0.5 - 4.5 GeV/c.

The detector has been verified using well reconstructed and kinematically fitted neutral particles (γ , K^0 , Λ^0). The majority of the strange particles was K^0 's, but there were also a few (4) Λ^0 's. All the pions and electrons (71) had momenta well above threshold and gave a signal in the detector in good agreement with what was expected. Two of the protons had momenta below threshold and did not produce a signal. The other two protons had momenta somewhat above threshold (4.4 and 4.5 GeV/c) and produced 1.1 and 1.8 photoelectrons in good agreement with expectations.

In the NA27 experiment SAD has been used to identify particles originating from charm particle decays. About 16% of the reconstructed tracks from charm candidates go through SAD. When eliminating multitracks through the same module, the proportion of good tracks through the detector becomes 13%. For 57% of the good tracks through SAD it contributes to the particle identification. A particle hypothesis is eliminated if the probability is inferior to 1%. With this criterion the wrong particle assignment is very rare, but ambiguities are frequent. Most of the time there is either a e/π , π/K or K/p ambiguity, which is sometimes resolved by combining the SAD and ISIS information. In particular the number of uniquely identified kaons - a key particle in determining the identity of the charm particle - increases substantially when combining the information from SAD and ISIS.

6. AEROGEL DEGRADATION

The silica aerogel is known to absorb water. This effect affects the light transmission in the aerogel and consequently the light yield. We tried to limit this effect by maintaining the humidity of the air inside the detector at 30%.

The light yield that we observe for SAD in EHS is clearly lower than what was observed before the modules were installed. Fig. 10 shows the relative light yield for $\beta = 1$ particles as a function of time. All the modules were tested at the CERN PS in May 1980, and the average light yield for $\beta = 1$ particles was 10.6 photoelectrons [14]. The NA22 and

NA27 data were accumulated between April and August 1982 (the August 1982 point in fig. 10 is based on NA22 data only). The points for August 1981 and 1983 are based on a simple on-line analysis, renormalized to agree with the August 1982 point.

The light yield has decreased with 30% over three years. The annual decrease is now about 6% per year. We interpret this decrease in light yield as due to changes in the light transmission in the silica aerogel.

7. SUMMARY

The silica aerogel Cherenkov detector has up to now been used in three EHS experiments. With an average light yield for $\beta = 1$ particles of 7.5 ± 0.3 photoelectrons (for a 14 cm thick silica aerogel radiator with refractive index 1.031), the detector is very efficient for particle identification for momenta 0.5 - 4.5 GeV/c.

In the NA27 experiment SAD has been used to identify the particles coming from charm particle decays. For about 50% of the particles through SAD it contributes to the particle identification.

The light yield has decreased with 30% over three years, and the annual decrease is now about 6%. It is likely that this is due to the absorption of water by the aerogel.

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FIGURE CAPTIONS

- Fig. 1 The NA27 configuration of the EHS. M1 and M2 are spectrometer magnets, W2 is a proportional wire chamber, SAD is the silica aerogel Cherenkov detector, ISIS is the pictorial drift chamber and D1-D6 are drift chambers.
- Fig. 2 The arrangement of the 18 identical SAD modules. The photomultipliers are surrounded by iron boxes to shield them from the magnetic field.
- Fig. 3 A schematic view of a SAD Cherenkov module. The mirror light collection system is made of aluminized mylar. PM1 and PM2 are 11 cm diameter photomultipliers.
- Fig. 4 The average light yield for all boxes and all particles along the 23 cm side - the short side - of the modules.
- Fig. 5 The average light yield for all boxes and all particles along the 55 cm side - the long side - of the modules.
- Fig. 6 Light yield for all particles as a function of $(m_{\pi}/p)^2$, where m_{π} is the pion mass and p is the measured momentum. The broken line indicates the expected light yield for a refractive index of 1.031.
- Fig. 7 The fraction of reconstructed tracks in NA22 that go through SAD as a function of the momentum. The full line represents all the tracks through SAD and the broken line those with only one track per module and which should go through the efficient part of the module.
- Fig. 8 The fraction of reconstructed tracks in NA27 that go through SAD as a function of the momentum. The full line represents all the tracks through SAD and the broken line those with only one track per module and which should go through the efficient part of the module.

FIGURE CAPTIONS (Cont'd)

Fig. 9 Detection efficiency and number of photoelectrons as a function of momentum for pions, kaons and protons. The number of photoelectrons for $\beta = 1$ particles is 7.5.

Fig. 10 The relative light yield for SAD as a function of time. The value for May 1980 corresponds to 10.6 photoelectrons.

EHS

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