Nuclear Instruments and Methods in Physics Research B 410 (2017) 134–138

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Estimation of the R134a gas refractive index for use as a Cherenkov radiator, using a high energy charged particle beam

N. Charitonidis [a,*], Y. Karyotakis [b], L. Gatignon [a]

[a] CERN, EN-EA, 1211 Geneva 23, Switzerland
[b] LAPP, Lab. d'Annecy-le-Vieux de Physique de Particules, 74941 Annecy-le-Vieux Cedex, France

ARTICLE INFO

Article history:
Received 24 April 2017
Received in revised form 29 July 2017
Accepted 17 August 2017

Keywords:
Refractive index measurement
R134a
Cherenkov gas radiator

ABSTRACT

Gases with relatively high refractive index, $n-1 \geq 500 \times 10^{-6}$ at atmospheric pressure, giving a satisfactory photoelectron yield at relatively low pressures ($\leq 5bar$) are rare. These gases are often the only practical solution for low momentum particle identification in conventional secondary beam lines. The refractive index of R134a, one of the most common gases available to the physics community, has never been measured or reported. In the present note, the results of a dedicated experiment to estimate the refractive index of R134a, using mixed hadron/electron beams in the range 0.5–10 GeV are presented.

1. Introduction

In the framework of the Neutrino Platform project, two new beam lines able to provide mixed hadron/electron beams in the range of 0.5–12 GeV will be constructed. 'H2-VLE' (and similarly'H4-VLE') constitute extensions of approximately 40 meters to the existing infrastructure of the H2 (H4) beam lines in the SPS North Area Complex [1]. In each case, the low energy particles are produced by the interaction of a secondary beam of medium intensity ($\sim 10^6$ per spill) and momentum ($\sim$60–80 GeV/c) in a secondary target material. The particle identification instrumentation for H2-VLE is presented in ref [2] while a similar schema is being prepared for H4-VLE. As discussed in detail in the above reference, the particle identification includes two Cherenkov counters, with an approximate length of 2 m each. In ref [2], the use of Freon-12 gas (dichlorodifluoromethane) with a well measured refractive index $n-1$ equal to 1050×10^{-6} at a temperature of 20 °C at atmospheric pressure was assumed for the calculations. However, following EU legislation to control F-Gases [3] the purchase and import of Freon-12 gas at CERN is discouraged. For that reason, alternative gases similar to Freon must be studied in order to achieve the hadron identification in this low momentum range.

R134a (1, 1, 1, 2-tetrafluoroethane) is a halo alkane refrigerant with insignificant ozone depletion potential and lower global warming potential, thus more environmental friendly than Freon-12. However, even if the refractive index for similar gases of the same family as R134a has been measured and presented in a very systematic study by Chae et al. [4] for several temperatures and pressures, the refractive index of R134a gas could not be easily retrieved.

For the aforementioned reasons, a dedicated experiment using two gas Cherenkov counters filled with R134a and CO_2 was designed and performed in T9 test beam at CERN's East Area, using a low energy hadron beam in the range of 0.5–10 GeV/c.

2. Experimental setup

The T9 test beam area, part of CERN's East Hall, is a multipurpose facility able to provide mixed secondary hadron and electron beams in the range from 0.5 to 10 GeV/c. More specifically, a primary proton beam is extracted from CERN's Proton Synchrotron at a momentum of 24 GeV/c and targeted onto a multi-head target, described in detail in [5]. Mixed secondary hadron/electron beams are produced, and then, after the momentum selection process, they are transported over approximately 55 m to the experimental zone. The momentum selection station allows the control of the momentum bite of the beam line within a few percent from the nominal value. A detailed presentation of the optics of the secondary beam line can be found in Ref. [6]. The beam line offers the flexibility to choose the target material enhancing either the hadron or the electron content of the beam.

A schematic of the last straight section of the T9 beam line, equipped with two gas Cherenkov counters, designated "A" and "B", is shown in Fig. 1.

* Corresponding author.
E-mail address: nikolaos.charitonidis@cern.ch (N. Charitonidis).

http://dx.doi.org/10.1016/j.nimb.2017.08.020
0168-583X/© 2017 Published by Elsevier B.V.

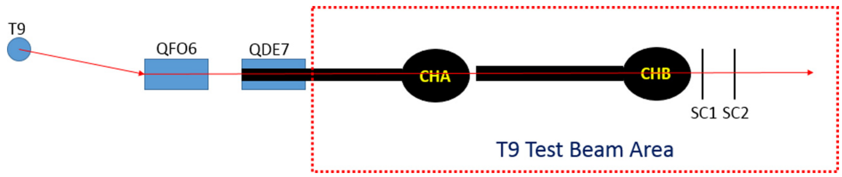

Fig. 1. Schematic drawing of the experimental setup in T9. The red arrow corresponds to the beam trajectory, passing through two quadrupoles designated "QF06" and "QDE7" and then traversing the two Cherenkov detectors "A" and "B", filled with CO_2. After the Cherenkov detectors two scintillators in coincidence (SC1 and SC2) are placed.

Each Cherenkov detector was attached to a ~2.5 m long tube allowing for sufficient pressure variations of the radiator gas. The pressure adjustment could be done remotely, through a gas rack installed outside the experimental area, for a range from 50 mbar up to 2.5 bar. During the experiment, Cherenkov-A was always filled with CO_2 gas, and Cherenkov-B could be filled with either R134a or CO_2 gas. The Cherenkov light is detected using two photomultiplier tubes, model Thorton EMI 9813 KA with a maximum quantum efficiency of 25% for a wavelength of $\lambda \sim 380$ nm [7]. Two scintillator counters in coincidence, SC1 and SC2, located downstream of Cherenkov-B, were providing the initial trigger to which the signal from the detectors could be eventually added in coincidence. A scaler unit was used to count the trigger and the detectors' discriminated signals.

3. Data analysis and results

Many pressure scans at different momenta using both gases were performed, with the purpose to derive an estimation of the unknown R134a refractive index.

3.1. Tuning the Cherenkov counters

The beam line was tuned to transport a positive hadron beam of 7 GeV/c. The exact beam composition reaching the experimental area is not precisely known, however it is estimated based on empirical measurements to be about ~40% pions, ~ 47% protons, ~ 5% kaons and a small number of positrons and muons at a percentage of ~8%. Both Cherenkov counters were filled with CO_2, and the coincidence of scintillators SC1 × SC2 was used as the trigger, counting the total beam. After tuning the high voltage and discriminator thresholds, we performed a pressure threshold scan starting well above the pion threshold, $Pth^{\pi} = 0.470$ bar. Fig. 2 shows the ratio of the Cherenkov detector counts with respect to the trigger counts. When the detectors operate in full efficiency, this ratio is very close to the pion, muon and positron content of the beam, as the kaon and proton thresholds are at much higher pressures.

From the results shown in Fig. 2, we conclude that the setup is well tuned, as both Cherenkov counters reach full efficiency above the pion threshold and both count ~50% of the beam, comparable with the beam composition estimation as mentioned above. In order to validate our experimental setup and the index estimation method, the following procedure was followed: a) both Cherenkov's were filled with CO_2 whose refractive index is known b) the pressure of Cherenkov-A was fixed at 1.2 bar corresponding to 100% efficiency for pions. Then a pressure scan was performed with a step of ~200 mbar and recorded the ratio of Cherenkov-B detector counts in coincidence with the beam (S1 × S2 × Cherenkov-B) over the trigger counts in coincidence with Cherenkov-A detector (S1 × S2 × Cherenkov-A).

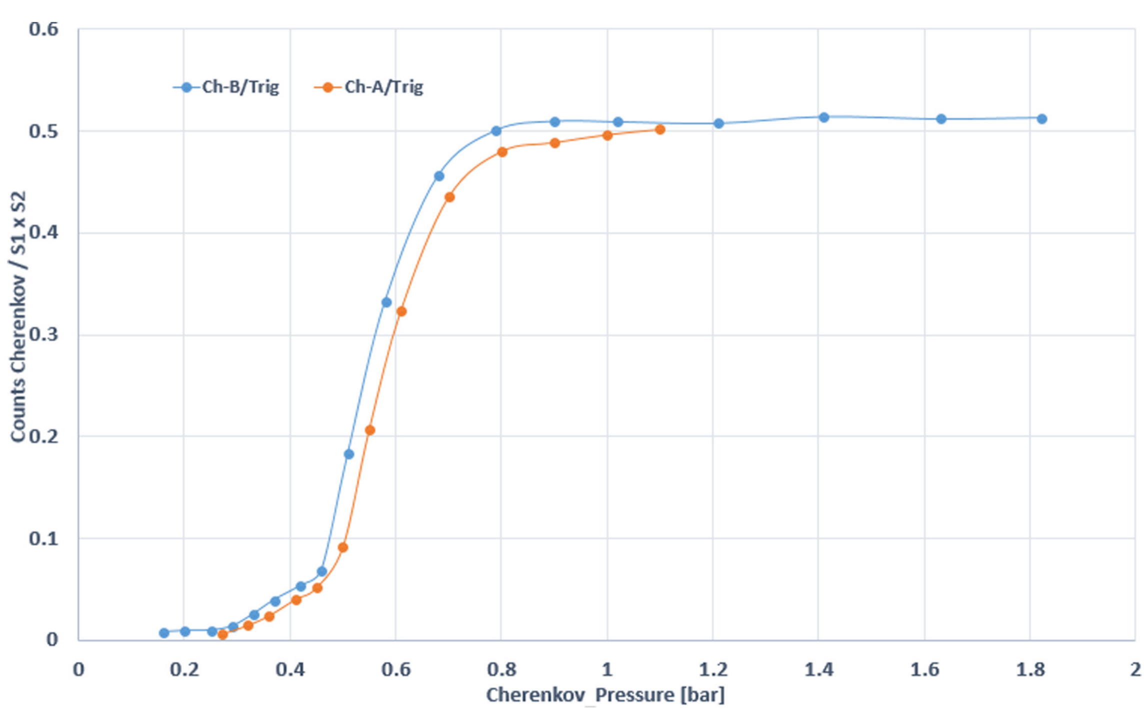

Fig. 2. Pressure scan for both Cherenkov A and B detectors, starting from the Cherenkov light threshold pressure for pions. The y-axis is the ratio of the counts of each detector divided by the trigger counts.