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**Results of the test
of the Threshold Aerogel Cherenkov Detector
at CERN PS T10 test beam channel**

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Abstract:

Construction details and test beam results of a prototype of the ASHIPH type Threshold Aerogel Cherenkov Detector are presented. The spectrometric performance of this prototype based on a silica aerogel radiator with an extremely low refractive index ($n = 1.008$) was investigated. Experimental data required to study the feasibility of an aerogel Cherenkov detector as the ALICE VeryHMPID system have been obtained.

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1 Introduction

One of the main and most interesting results of the experimental study performed at the ultra-relativistic heavy ion facility of RHIC (BNL) [1,2] is the unexpected behaviour of the inclusive hadron yields in central Au + Au collisions at transverse momentum $p_T \geq 2$ GeV/c. At the same time, more recent experiments [3,4] showed that the nuclear modification factor, R_{CP} (central / peripheral Au + Au collisions), assumes different values for different particles: a large enhancement of baryons and anti-baryons relative to pions at $p_T \approx 2-5$ GeV/c is observed. The PHENIX experiment at RHIC showed that the R_{CP} of proton (anti-proton) to neutral pion ratio is enhanced by almost a factor three [3,4]. This fact is called the “baryon puzzle” at RHIC. The apparent disagreement with conventional models has prompted a flurry of theoretical models. Among them the most popular ones are those based on recombination of quarks [5,6] to explain the excess of protons at intermediate momenta.

Regardless of the explanations given it is important to have the possibility to measure the production of baryons in a large momentum range at LHC. Since the effect at RHIC persists up to 6-7 GeV it is therefore important to increase the ALICE identification range up to values of 10 GeV/c and above.

At low momentum, charged particle identification is usually performed via the time-of-flight method while Cherenkov detectors are used at higher momenta. The most powerful type of these latter devices is the Ring Imaging Cherenkov detector (RICH). In the current layout of the ALICE experiment, the High Momentum Particle Identification Detector (HMPID) [7] consists of an array of seven proximity focusing RICH modules using liquid C_6F_{14} , as Cherenkov radiator with a refractive index $n = 1.26$. The Cherenkov photons are detected by MWPCs equipped with a CsI-photocathode.

The HMPID detector discriminates pions from kaons in the range from 1 to 2.7 GeV/c and kaons from protons in the range from 1.5 to 5 GeV/c with a separation power of 3σ . With the aim to extend the momentum interval in which particles are currently identified in ALICE, we have proposed [8] to use a threshold Cherenkov detector with a silica aerogel radiator.

In the present work we report the test beam results obtained with a threshold Cherenkov detector with an Aerogel radiator read-out by means of wavelength SHifter and PHototubes (ASHIPH type). The main goal of these measurements was to evaluate the spectrometric performance of an ASHIPH detector equipped with an aerogel radiator of very low refractive index ($n = 1.008$).

2 Threshold aerogel Cherenkov detectors

At present, threshold aerogel Cherenkov (TAC) detectors of various types are used or proposed to be used by several experiments as particle identification (PID) systems. Modern industrial production technology allows producing the aerogels of refractive indices from 1.005 to 1.05 with a sufficiently long Rayleigh scattering length.

The new technology and methods developed by the collaboration of Budker Institute of Nuclear Physics (BINP) and Boreskov Institute of Catalysis in Novosibirsk (Russia) [9] enable to produce aerogel tiles of very low refractive indices: from 1.008 till 1.002 (crumb-aerogel).

The ASHIPH system [10] for the KEDR detector [11] at BINP uses aerogel tiles of high transparency with a refractive index of 1.05. It provides 4σ π/K separation in the momentum range $0.6 \div 1.5$ GeV/c [9,12]. The basic concept behind the ASHIPH [13] method is to use light guides doped with a wavelength-shifting (WLS) agent to provide a collection of the light along the track of the particle, allowing thus for the use of long aerogel pieces where otherwise, in the classical design where the light is collected on the photomultiplier after the whole aerogel thickness (see Fig.1). An added bonus is that small diameter PMT may be used, very important in the case, as

ALICE, the detector is in a magnetic field. Furthermore the use of the WLS light-guide allows to couple several pieces of aerogel to one PMT thus reducing the number of PMTs necessary. For instance in the KEDR PID system, it were used [9-11] ten times less PMTs than for a conventional design. Examples of applications of TAC counters in current experiments are given hereinafter.

In the Belle Spectrometer (at KEKB e^+e^- collider), PID systems based on TOF, dE/dx and a Barrel with Endcap TAC-counters enable to identify high p_T particles – pions and kaons in the momentum range from 1.2 to 3.5 GeV/c. In the TAC-counter's layout of the so called KEK-Belle Type design [14], the Cherenkov photons, produced inside the Counter Box with Goretex reflectors on its surfaces, are detected by two PMTs. Recently, KEK in cooperation with Matsushita produced new hydrophobic aerogel samples ($n = 1.03 - 1.05$) with better optical quality for the forthcoming high p_T PID upgrade of the Belle Spectrometer [15].

For a more detailed study of the baryon puzzle observed by the experiments at RHIC [1-4], an extension to higher p_T of the present PID system was approved by the PHENIX collaboration. The upgrade is being achieved by employing a wall of TAC counters of the Integration Sphere Type (“detector with integration parallelepiped”) [4,16]. PHENIX TAC detectors with an index of refraction of 1.01 provide the separation pions to kaons in the range from 1 to 5 GeV and kaons to protons in the range from 5 to 9 GeV.

The use of TAC detectors for PID in the high p_T range has also been proposed in the CBM experiment [16] at FAIR (GSI, Germany). The related ongoing R&D activity will evaluate the performance of TAC prototypes of the Belle and Integration Sphere types.

For ALICE we are investigating two basic detector designs [8]: one option based on the Belle Integration Sphere concept [14,16] using an integration parallelepiped with one or two three-inch PMTs to detect photons, whereas the second design exploits the ASHIPH method [13].

The particle momentum ranges of identification of pions, kaons and protons by using two TAC-detectors with aerogel tiles of $n = 1.008$ and 1.005 are shown in Fig.2. Two layers of aerogel with these refractive indices, run in trigger logics: “signal” or “no signal” in one or both detectors, could achieve an efficient discrimination between pions and kaons in the momentum range from 1.4 to 7.3 GeV/c and between kaons and protons in the range from 4.8 to 13.9 GeV/c. The logic mode: “signal” in RICH-detector and “no signal” in ASHIPH-detector with $n = 1.005$ enables to extend the present capability of the HMPID detector for pions and kaons separation up to 5.0 GeV/c. The momentum thresholds shown in Fig.2 for pions, kaons and protons are calculated by imposing the detection of at least two photoelectrons in the ASHIPH detectors and assuming that the momentum of the charged particles is provided by the ALICE tracking detector (TPC and ITS detectors).

A further extension of the particle momentum range could be achieved by using two aerogel layers with lower refractive indices: $n = 1.008$ and $n = 1.002$. In this case, the range for pion and kaon separation could be extended up to 12 GeV/c and for the proton identification up to 15 GeV/c still keeping a minimum detection of two photoelectrons.

3 Construction details of the Threshold Aerogel Cherenkov Detector Prototype

The layout of the TAC (ASHIPH) Prototype is shown in Fig.3. It consists of a 56 x 56 x 310 mm aluminium container housing aerogel tiles for a total volume of about 0.5 liters (with a thickness of 200 mm). A multi-layer Tetratex PTFE UV-film is used as reflector. A plastic focusing light-guide brings the photons produced in the wavelength shifting plates (a 3 x 10 x 250 mm plexiglas bars doped with the BBQ wavelength shifter), to the micro-channel plate (MCP) PMT with a multi-alkali photocathode of 18 mm in diameter ($QE \approx 22\%$). The WLS-plates are glued to the plastic light-guide by a Bycron optical glue compound.

The innovative aspects of the proposed detector scheme are the use of a silica aerogel radiator with extremely low refractive indices ($n = 1.008$ and $n = 1.002$ (crumb-aerogel)) and of light-guides doped with a WLS-admixture for collecting and focusing the Cherenkov-light on the MCP-

PMT. The new technology and production methods developed at the Budker Institute of Nuclear Physics (Novosibirsk) [9] enable to manufacture aerogel tiles of very low refractive indices characterized by remarkable optical properties.

4 Experimental procedure

The test of the TAC prototype was performed at the CERN PS T10 facility using a negative polarity of the beam, π^- and e , at a momentum of 7 GeV/c.

The TAC prototype was placed along the beam axes and aligned in between two scintillation counters, denominated “IN” and “OUT”, of small sizes: 2 x 20 mm² and 40 x 20 mm², respectively. The electronics trigger, formed by the coincidence of the “IN” and “OUT” detectors, provided the GATE of the ADC (QDC) LeCroy unit 2249W. The narrow pion beam, as defined by the two scintillation counters in coincidence, enabled to scan the entrance window of the TAC prototype. The ALICE test beam DAQ-system was used for the data acquisition.

Two types of aerogel radiators with refractive indices $n = 1.008$ and $n = 1.05$ were compared in the test.

The front-end electronics consisted of a spectrometric preamplifier mounted inside the container near the PMT anode followed by a CAMAC amplifier unit. The total amplification gain was about 50.

5 Main results

The ADC spectra obtained for the aerogel radiator of $n = 1.008$ and thickness of 200 mm are shown in Fig.4. The experimental conditions for this case were: beam spot centered on the aerogel radiator (no particle crossed the WLS-plate, neither the plastic focusing light-guide nor the PMT), HV (PMT) = -2660 V. In the left and right histograms of Fig.4, the ADC spectra for the case “with Aerogel” and for the case “without Aerogel” (empty radiator), respectively, are shown. Taking into account the number of events in the pedestal (zero number of photoelectrons) one can estimate that the efficiency for the detection of π^- 's, for the radiator of $n = 1.008$, is about 65-70%.

The TAC prototype ADC spectrum for the aerogel radiator of $n = 1.008$ and thickness of 200 mm is compared in Fig.5 with the ADC spectrum for the Aerogel radiator of $n = 1.05$ and thickness of 203 mm. The experimental conditions are the same as in Fig.4. The efficiency for the π^- 's detection with the Aerogel radiator of $n = 1.05$ is about 99.3 %.

During the test, the effects related to sources of background as the scintillation light from the WLS-plates and the Cherenkov radiation in the plastic focusing light-guide and PMT glass window caused by primary beam pions were also investigated. The ADC spectra for the configuration “without Aerogel” are shown in Fig.6 for the following two different experimental geometrical conditions: 1) beam spot centered on the WLS-plates, plastic focusing light-guide and PMT glass window (left hand side histogram in Fig.6) and 2) beam spot centered on the plastic focusing light-guide only (right hand side histogram in Fig.6). These ADC spectra were measured with a HV (PMT) = -1950 V, much less than the HV applied to the PMT for the measurements “with Aerogel” (Figs. 4 and 5).

6 Conclusions

New data for the TAC prototype with an aerogel radiator of extremely low refractive index of $n = 1.008$ have been obtained.

The efficiency for 7 GeV/c π^- 's detection for the aerogel radiators with refractive indices of $n = 1.008$ and 1.05 is about 65-70 % and 99.3 %, respectively.

The number of “0” photoelectron events in the ADC pedestal (Figs.4 and 5) shows that in the TAC prototype, particles above Cherenkov threshold produce on the average 1-1.2 photoelectrons for the aerogel radiator of $n = 1.008$ and about 5.0 photoelectrons for aerogel radiator of $n = 1.05$.

The pulse height of the signals from the aerogel radiator with $n = 1.05$ is about 5 times bigger than that from the aerogel radiator with $n = 1.008$, in good agreement with the results obtained by simulating the production of Cherenkov photon in aerogel of the two cited refractive indices.

The background events in the spectra for the configuration “without Aerogel” (empty radiator, Fig.4) are probably caused by delta-electrons created by the beam’s particles in the entrance aluminum window thick about 4 mm. Delta electrons are detected by either the WLS-plates or the light-guide emitting the scintillation light and/or Cherenkov-photons.

As our test results show, the main drawback of the TAC detector with a low refractive index aerogel is the low Cherenkov photon yield, even for particles of momentum much above the Cherenkov threshold. Therefore the identification of protons, below threshold, will be affected by large uncertainty because the efficiency for pion and kaon detection will never reach 100 %. An additional drawback for the TAC detectors of the ASHIPH type is the need to use WLS-plates, which introduce in the aerogel cell an active element of high refractive index, which may scintillate and emit Cherenkov photons from particles of much lower momentum than the aerogel radiators.

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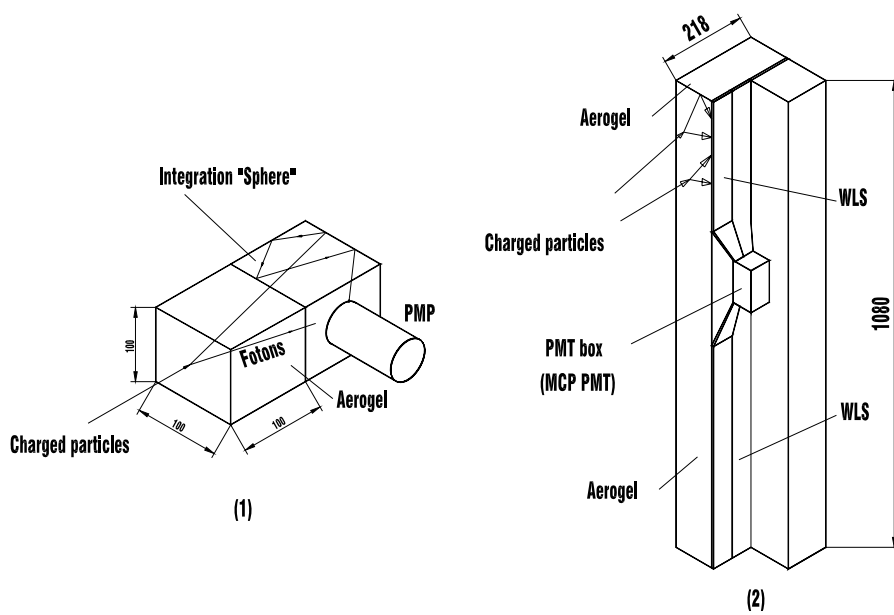
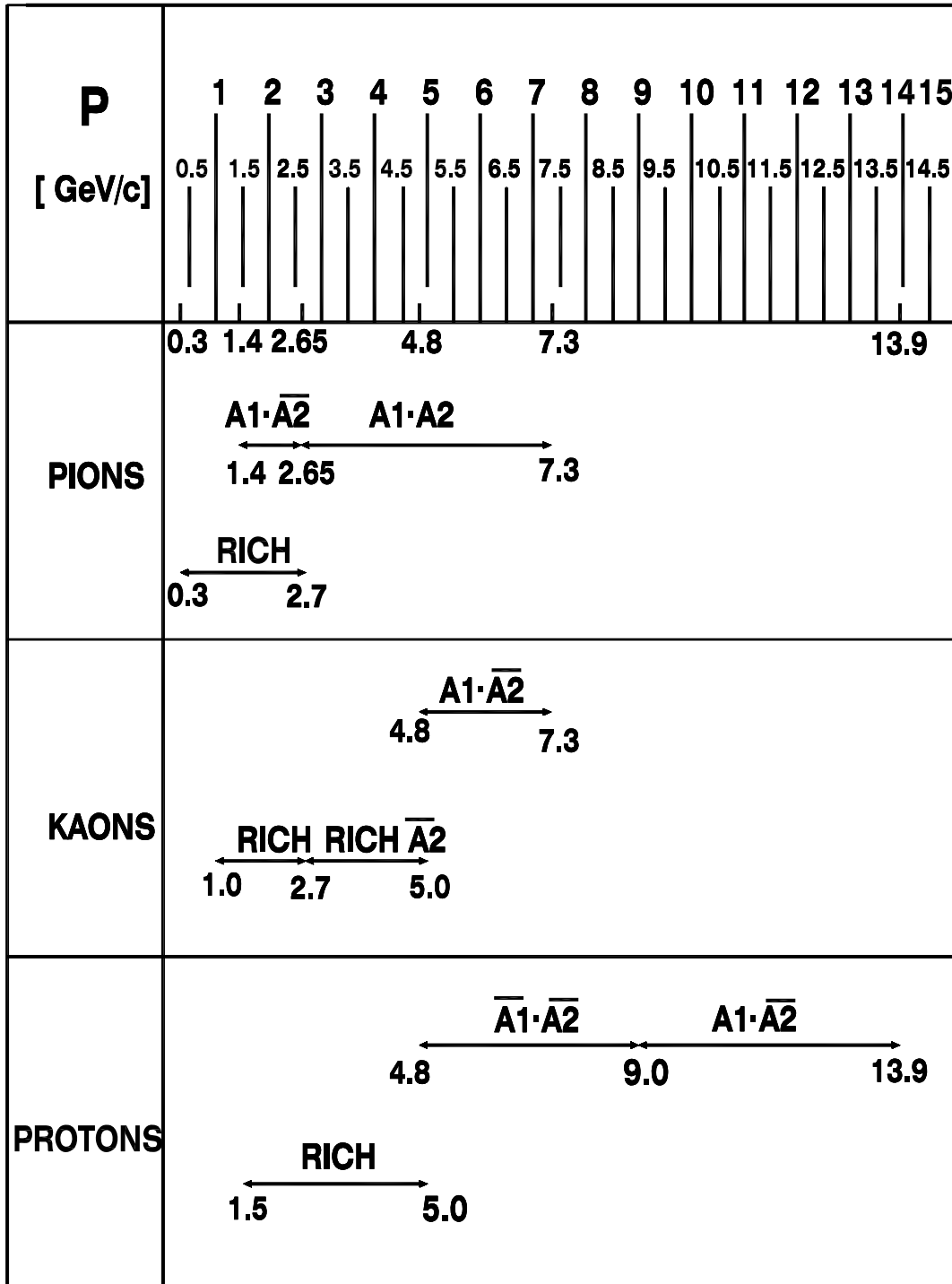


Figure 1: Classical TAC detector design – Belle Integration Sphere Type (1) and TAC detector design of ASHIPH type (2)

A1: n=1.008

A2: n=1.005

$N_{R\Sigma} > 2_{R\Sigma}$



charge track identif. needs to be done

Figure 2: Particle momentum ranges for the identification of pions, kaons and protons by means of two TAC-detectors with aerogel tiles of $n = 1.008$ and $n = 1.005$

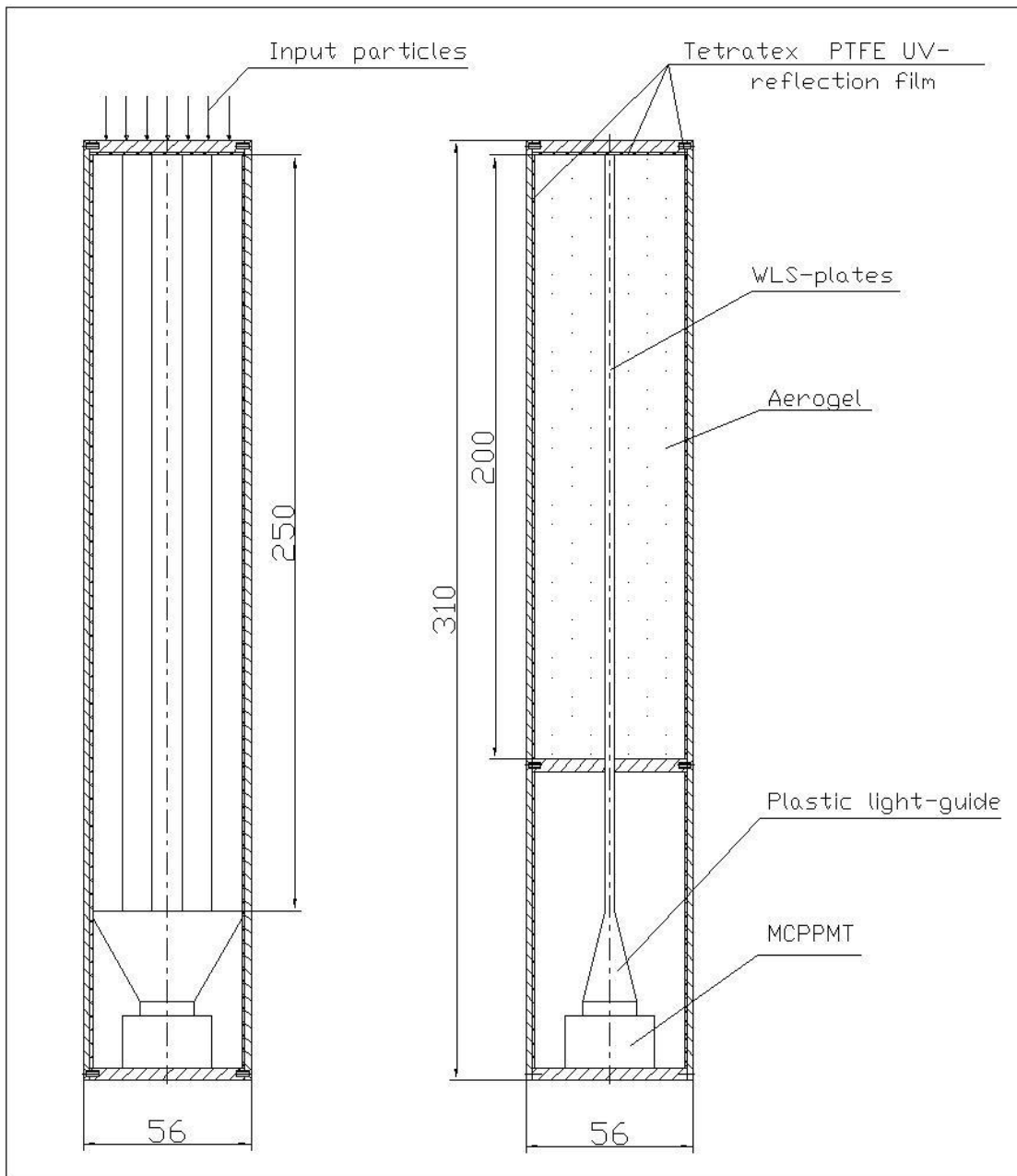


Figure 3: TAC (ASHIPH) Prototype

AEROGEL $n=1.008$, $t=200$ mm

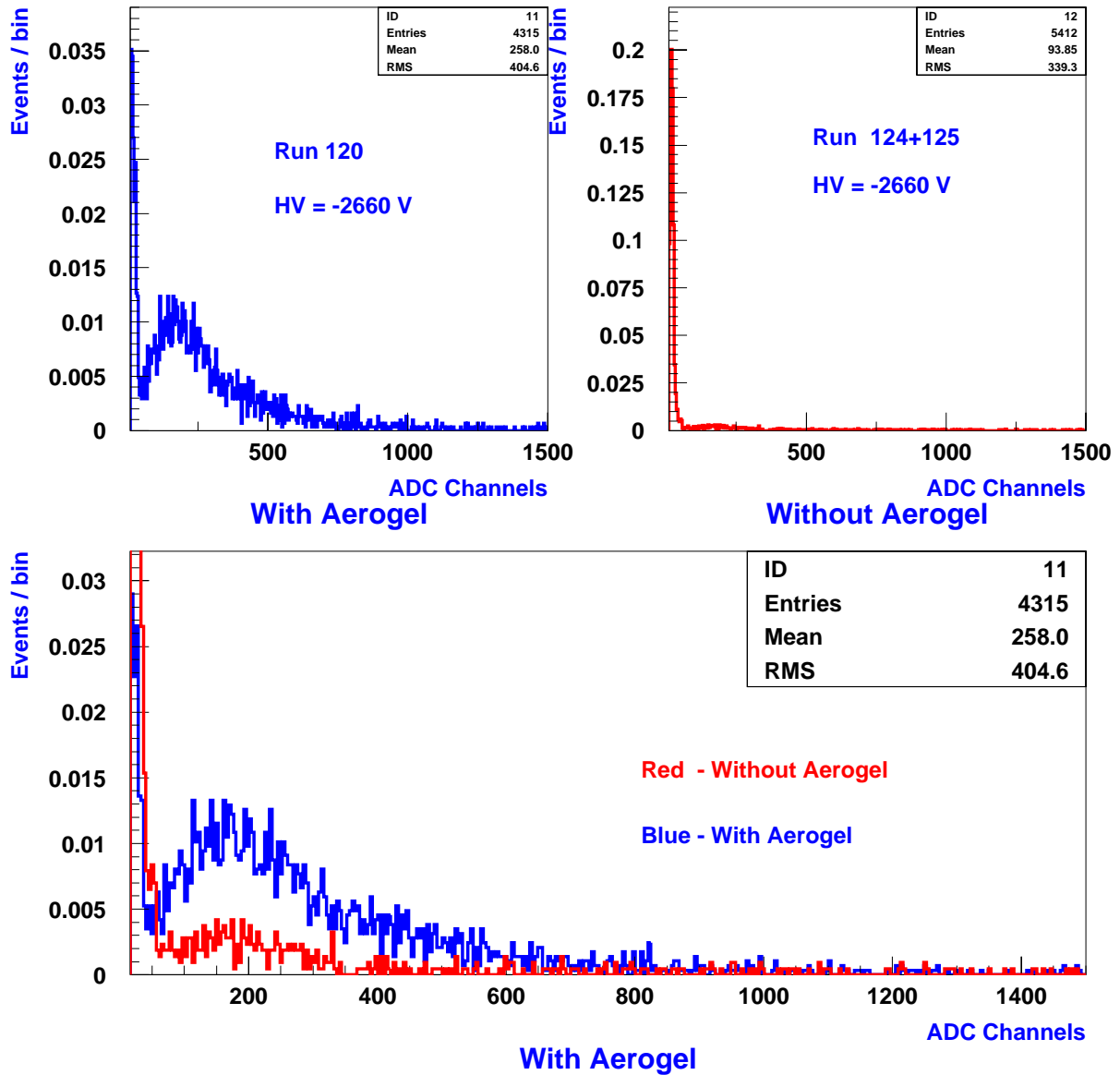


Figure 4: ADC-spectra for the Aerogel radiator with the refractive index of $n = 1.008$

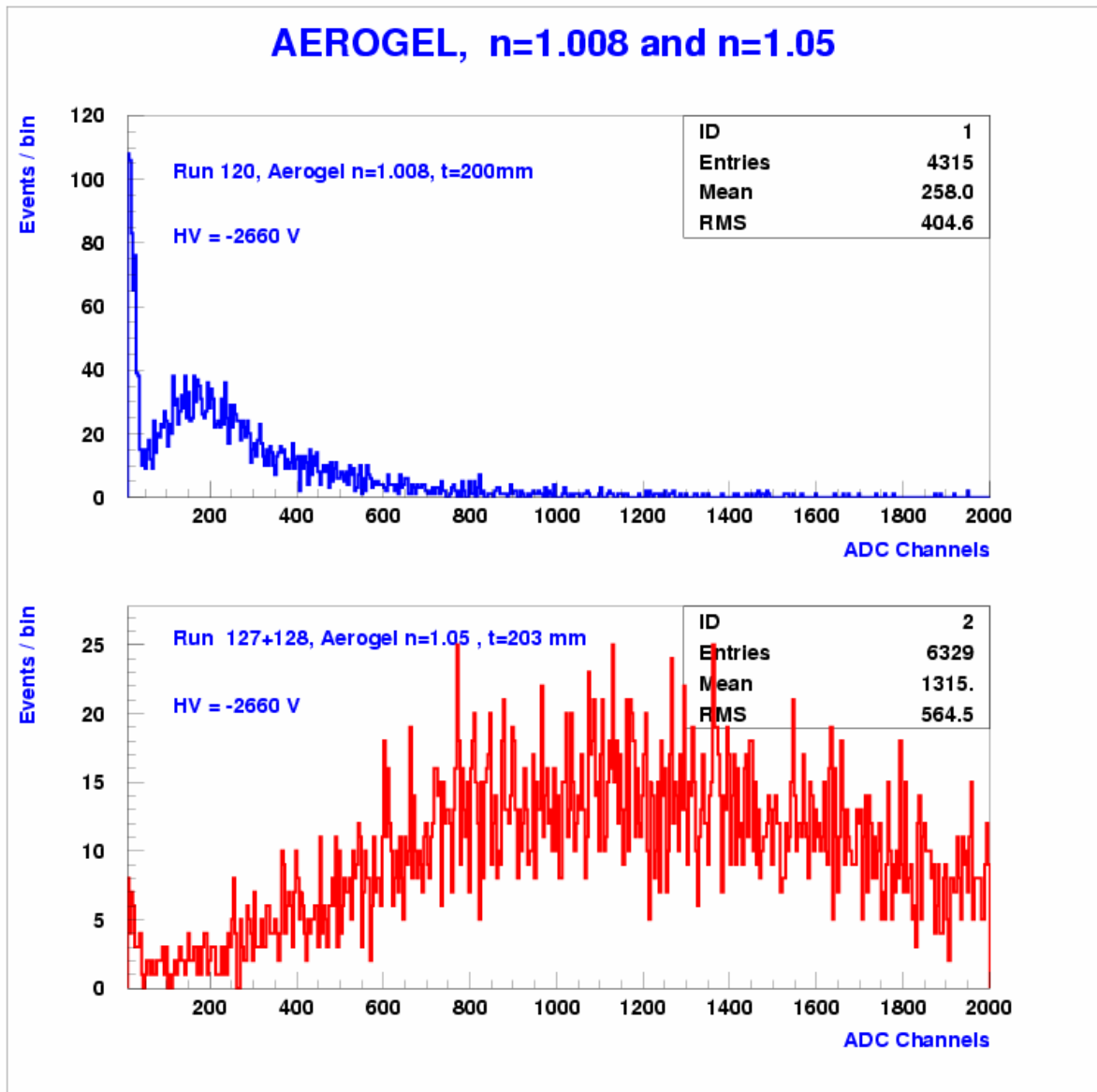


Figure 5: ADC-spectra for the Aerogel radiators with $n = 1.05$ and 1.008

Without AEROGEL

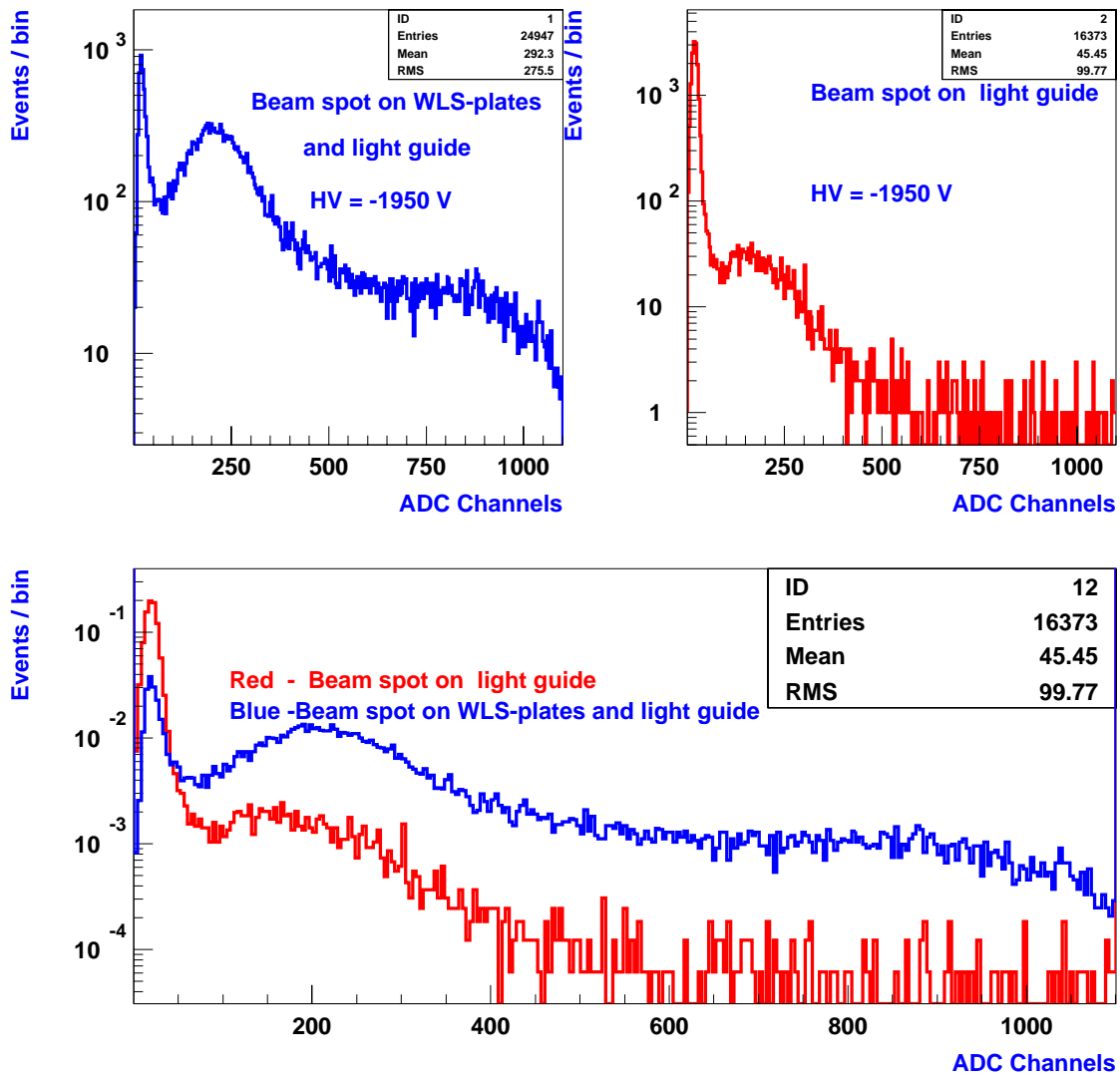


Figure 6: ADC-spectra for the radiator “without Aerogel”