Knock-On of δ-electrons in Hall A Electron Arm. Effect of the Aerogel Cerenkov.

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07/15/1998

Abstract

In this note we study the production amount of δ-electrons due to pion knock-on in the different detectors of the Hall A electron High Resolution Spectrometer (HRS). We detail the computation method and the inputs used. The main result is that the aerogel Cerenkov counter provides almost 40 % of the total production of δ-electrons.

1 Introduction

The detector packages of Hall A HRSs are designed to provide particle identification and rejection. The π^- rejection rate goal is 10^{-5} [1] and one will investigate if the δ-electrons counting rate in the gas Cerenkov allows to reach such a goal. The $\delta-$electrons are coming from pion knock-on and can be identified as "good" events. The main concern of this note is to give an insight of the amount of δ-electrons produced with and without the aerogel Cerenkov in the detector package. The computation should tell us if the aerogel Cerenkov needs to be removed or not for the E94-010 experiment. Our tolerance for the experiment is to take one "false" event, due to either a pion misidentification or a δ-electron, for one hundred "good" events.

2 δ-electrons

The δ-electrons come from the matter crossing the trajectories of particles They are knocked by the particles passing through the matter. One will care only about the knock-on of electrons by the pions and their possible detection in the gas Cerenkov.

2.1 Electrons knock-on rate

The number of δ-electrons knocked by a single particle of spin 0, over a path of lengh l_0 (cm) is [2], [3]:

$$N_\delta = 2Cl_0\rho\frac{m_e}{\beta}\left[\frac{1}{E'_t} - \frac{1}{E'_{max}}\left(1+\beta^2 ln\frac{E'_{max}}{E'_t}\right)\right] \quad (1)$$

where $C = 0.15\frac{A}{Z}$ cm^2/g, ρ is the density in g/cm^3, E'_t the δ-electron energy threshold to produce some photoelectrons in the gas Cerenkov and E'_{max} the maximum energy given at a δ-electron by a particle.

In a Cerenkov counter the threshold energy for an electron is given [2] by $E'_t = \frac{nm_e}{\sqrt{n^2-1}}$ with n the gas refractive index.

The maximal energy given to the electron ("head-on collision") is [2]: $E'_{max} = 2m_e\left(\frac{k}{m_\pi}\right)^2$ where k and m_π are respectively the momentum and the mass of the pion.

2.2 Thresholds

The first condition for a δ-electron to produce Cerenkov light is to have its energy superior to E'_t, the threshold dictated by the gas index. However, the Cerenkov mirrors acceptance give another constraint on the electron scattering angle. By expressing the relation between this angle and the electron energy we will be allowed to know the acceptance constraint on the energy. Therefore we will have to choose between the "index Cerenkov threshold" or the "acceptance Cerenkov threshold" as the effective threshold used in the formula (1).

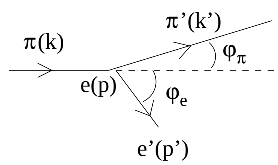

Fig.1: knock-on of an electron by a pion. Definition of the kinematic variables.

In the calculation we assume the electron at rest.

The quadri-momentum conservation gives:

$k' = k + p - p'$ (2)

taking the square of (2), expressing the product and simplifying yields:

$cos(\varphi_e) = \frac{\left(E_\pi E'_e + m_e(E'_e - E_\pi\right)}{\sqrt{(E_\pi^2 - m_\pi^2)(E_e'^2 - m_e^2)}}$ (3)

(3) gives the desired relation between the scattered electron angle and its energy (the pion energy will be taken as a parameter). This relation shows that the wider the angle is, the smaller the electron energy. Thanks to this distribution we can determine an effective threshold for the formula (1) as following: if the angle φ_e, with $E'_e = E'_t$, is inferior to the angular acceptance θ of the mirrors, the electrons reaching the mirrors could have an energy inferior to the "index threshold". Therefore the effective threshold is equal to this latter (see fig. 2). Otherwise all the electrons reaching the mirrors have an energy superior to the "index threshold" and the condition is given by the mirror acceptance. The "acceptance Cerenkov Threshold" is derived from formula (5):

$E'_t = E_\pi - \sqrt{E_\pi^2 - m_\pi^2} cos(\theta)(6)$

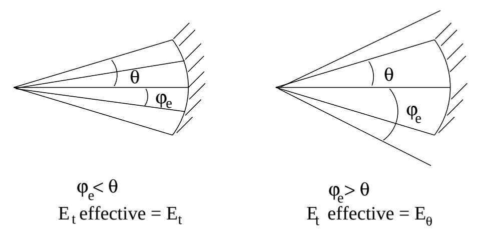

Fig. 2: effective threshold of the δ-electrons.

Note: This way to choose an effective threshold is only valid under the following simplification: all the δ-electrons with a trajectory crossing the gas Cerenkov mirrors will produce photoelectrons registred in the PMs.

3 Overview of the detector package

The elctron arm detector package is made of two wire chambers used for the tracking, two scintillator planes used as trigger (as the second scintillator plan is beyond the gas Cerenkov we will not care about it), an aerogel and a gas Cerenkov used for particle identification. The figure below shows the geometry of the package and the distances between the different detectors.

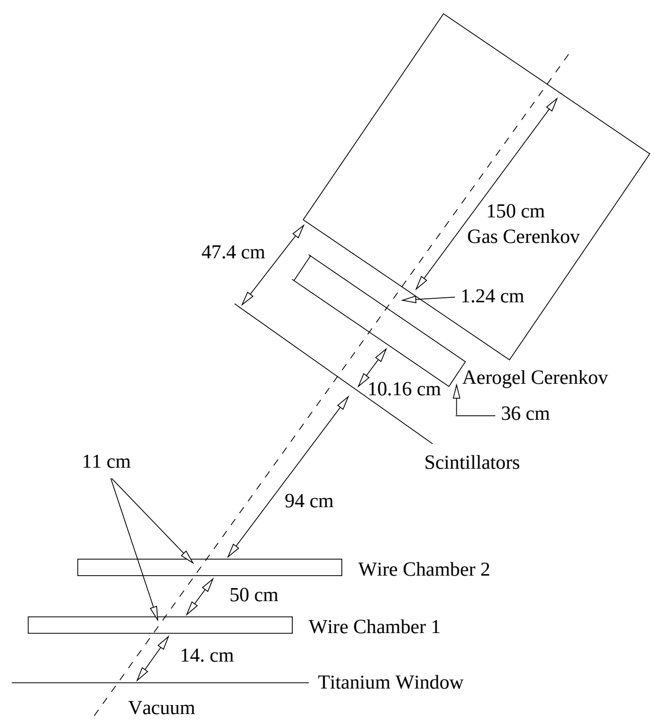

Fig. 3: HRS detector package.

4 Program

4.1 Overview and assumptions

The code, named knock.f, allows to compute the number of δ-electrons knocked by a *single* pion. It gives this number as a function of the pion energy. The number is plotted between 600 MeV and 4000 MeV but the range can be easily changed. However we must make sure to have the minimun pion energy above 600 MeV since it corresponds to the electron threshold in the gas Cerenkov (i.e. the maximum energy transfered to the electrons by pions of energy below 600 MeV is under the Cerenkov index threshold). The program was written in FORTRAN and can be found in the directory: ˜deurpam/cerenkov. In the same directory one can use the kumac knock.kumac to plot the results with PAW. We chose to integrate the formula (1) by steps of l_0=1 cm for the thick detectors like the two Cerenkov counters.

In order to simplify the code we did the following assumptions or simplifications :

-all the δ-electrons with a trajectory crossing the gas Cerenkov mirrors will produce photoelectrons detected in the PM.

-the gas Cerenkov mirrors can be viewed as a single circular mirror of 75 cm diameter.

-the pion follows the optimal trajectory in the hadron arm without being disturbed by its passage through the magnets and the detectors.

-the pion energy remains constant.

- the δ-electron energy remains constant.

-we neglect the presence of wires in the wire chambers.

4.2 Inputs

The different inputs for the code are:

- the gas Cerenkov refractive index: n=1.00041 (CO_2).
- the ratio A/Z$\times$0.15 for the detector materials.
- the material densities.
- the length of matter crossed by the pion.
- the distances to the gas Cerenkov mirrors.

The subsections below, each related to a subroutine of knock.f, give a description of the crossed material and the input numerical values. A stared value means an assumption, a broad measurement done in the Hall or an averaged value. The material characteristic values were taken in [3].

4.2.1 Vacuum Window

Before reaching the first wire chamber the particles travel in vacuum. The Titanium window sealing this vacuum is crossed with a 45^0 trajectory (see Fig. 3).

A/Z×0.15	density (g/cm^3)	length (cm)	Distance to mirrors (cm)
0.0688	4.54	0.01/cos(45^0)	377.6

4.2.2 Wire Chambers

The description of the HRS Vertical Drift Chambers (VDC) is given in [4]. The wire chamber gas is a mixture of C_2H_6 and Ar in equal amount plus 1% of isopropanol. Four gas regions of 1.3, 2.6, 2.6 and 1.3 cm length, five Mylar windows of 6 cm each and two aluminium windows of 25 μm are crossed at a 45^0 inclination. As the wire chambers are thin and far from the gas Cerenkov its acceptance remains almost constant at the crossing of one wire chamber. We have simplified the chamber as to be made of one material. The density and A/Z ratio are the average of the different materials weighted by the thickness of each material. We have computed separately the effect of the two wire chambers.

A/Z×0.15	density (g/cm^3)	length (cm)	Distance to mirrors (cm)
0.0776	3.84 10^{-3}	7.808/cos(45^0)	363.4* (first VDC), 312.4* (second VDC)

4.2.3 Scintillators

A description of the scintillators can be found in the Hall A web pages.

A/Z×0.15	density (g/cm^3)	length (cm)	Distance to mirrors (cm)
0.0805* (polyvinyltoluene)	1.032	1.27*	197.4*

4.2.4 Air Columns

We have computed the knock-on in the air separating the different detectors and the vacuum window. The aerogel Cerenkov CO_2 content was also taken into account in this subroutine.

The different thicknesses can be found in figure 3. We have assumed the air humidity negligeable and taken the density at 20 ^{0}C and 1 Atm.

A/Z×0.15	density (g/cm^3)	length (cm)	Distance to mirrors (cm)
0.075*	1.205 10^{-3}	cf. fig 3.	cf. fig 3.

4.2.5 Aerogel Cerenkov

The aerogel Cerenkov is detailed in [5]. The figure below presents a cross section of the detector including the different materials, their A/Z×0.15 ratio, their density and thickness. The effect of the two CO_2 layers is computed in the previous section.

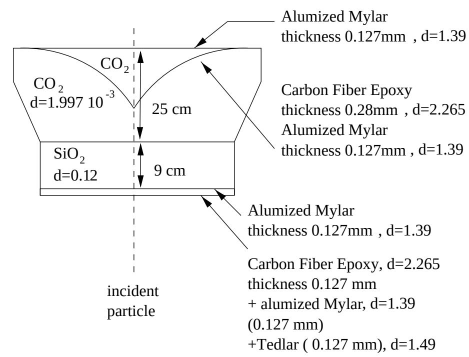

Fig. 4: cross section of the aerogel Cerenkov. The densities (d) are in g/cm^3.

4.2.6 Gas Cerenkov

The gas Cerenkov is a 150 cm length detector filled with CO_2 and sealed by two Tedlar layers of 37.5 μm thickness.

A/Z×0.15	density (g/cm^3)	length (cm)	Distance to mirrors (cm)
0.075* (tedlar)	1.49	37.5 10^{-6}	150
0.075 (CO_2)	1.997 10^{-3}	150	150

5 Results

In order to see the effect of the aerogel Cerenkov on the number of knocked electrons we have run knock.f, first taking in account the aerogel and then removing it. The two figures below show the results of the computation.

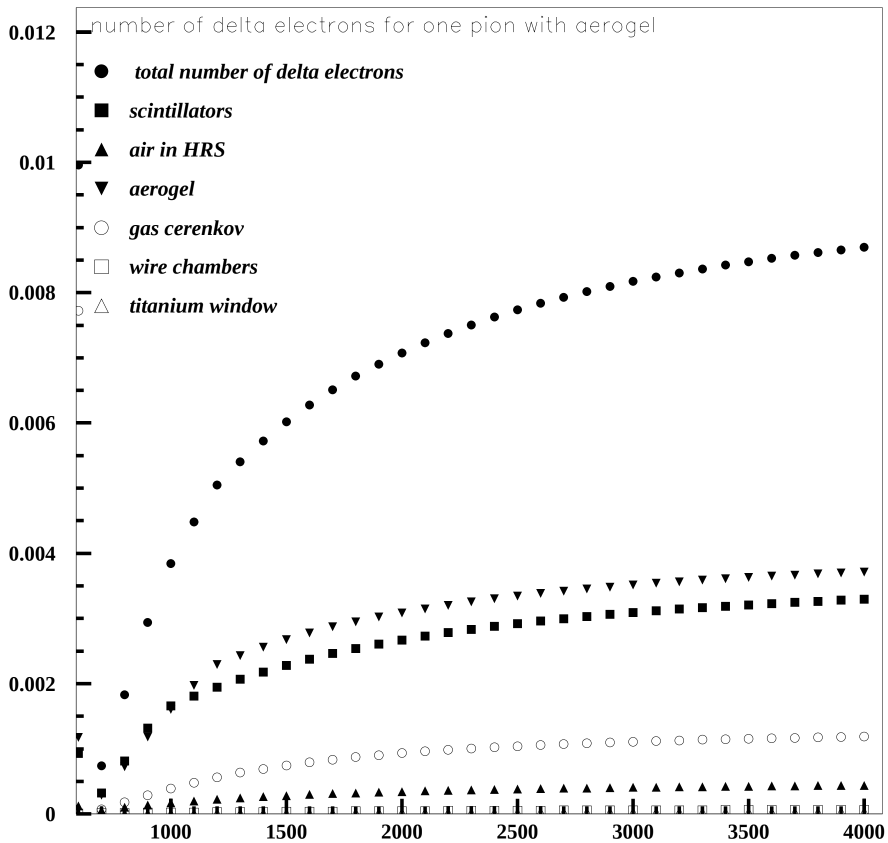

Fig. 5: number of δ-electrons knocked by one pion taking in account the aerogel Cerenkov. The energies of the pion are given in the horizontal axis (MeV) while the vertical axis gives the number of electrons.

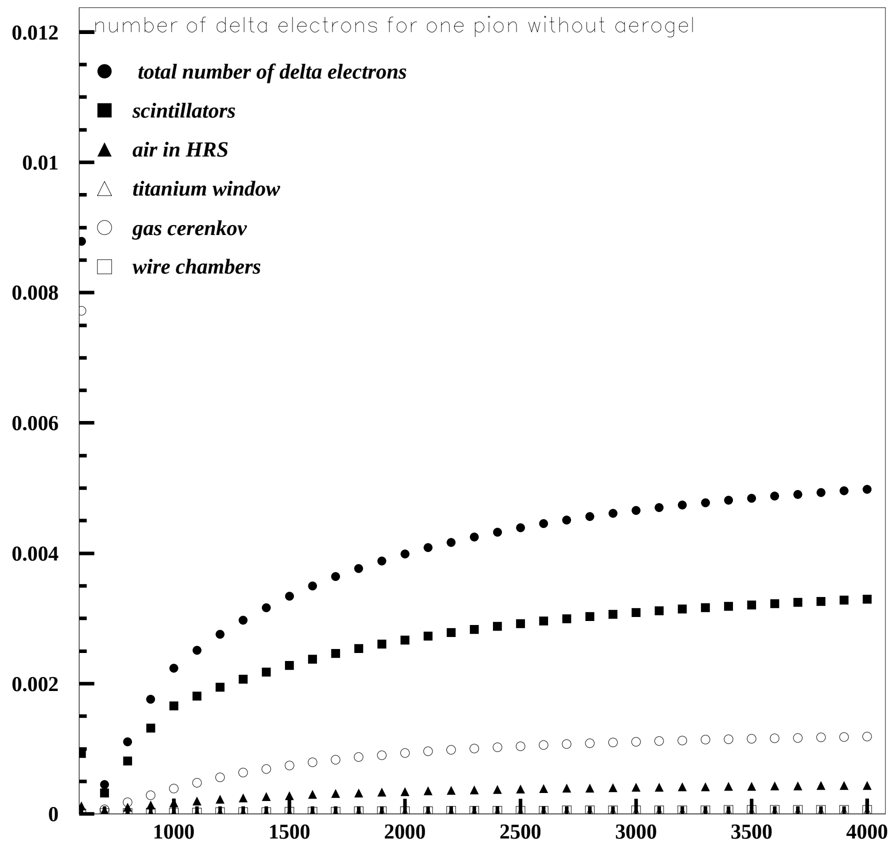

Fig. 6: number of δ-electrons knocked by one pion without the aerogel Cerenkov. The energies (MeV) of the pion are given in the horizontal axis while the vertical axis gives the number of electrons.

The figure 7 shows that the main contribution, for the aerogel Cerenkov, comes from the SiO_2.

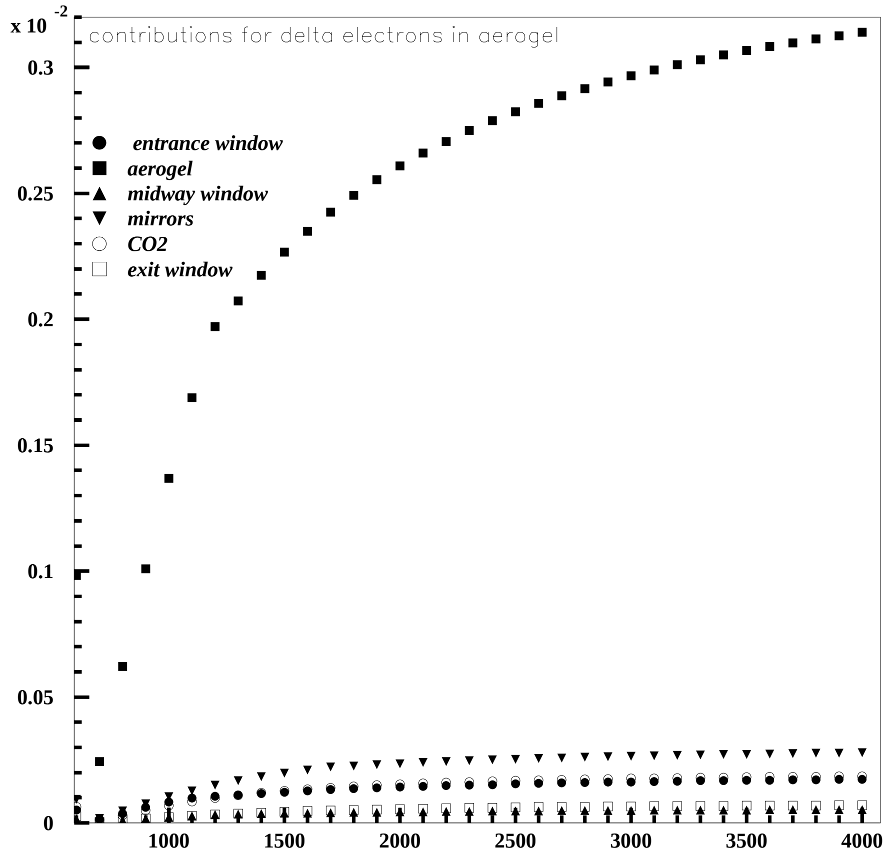

Fig. 7: detail of the different part contributions for the aerogel Cerenkov

6 Conclusion

The amount of δ-electron production is comparable for the aerogel and the scintillators. The approximations done in the code were chosen to simplify it and to give a reasonable upper limit of the δ-electron production. For E94-010 we expect, in the worst case, 500 pions produced for one electron. We assume the shower counter has 0.01 rejection for pions. With the aerogel we will produce (cf. fig.5) 0.007 δ-electrons for one pion at 2 GeV, that is 3.5 % of false events. The false event total is decreased to 2 % by removing the aerogel.

note: some of the inputs are approximate measurements and people are wel-

come to give precise informations about them (deurpam@cebaf.gov). Many of the other inputs were given by Kevin Fissum or Rob van der Meer. I am very gratefull for the time they spent for me. I want to thank also Jian Ping Chen and Pascal Vernin for their help.

References

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