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Heavy Gas efficiency for year 2010

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Abstract

Aim of this note is investigation of the Heavy Gas efficiency for year 2010. More detailed description of procedures and criteria which are used in the analysis is given below.

1 Introduction

The Heavy Gas Cherenkov counter [1] separates kaons and protons from pions and can be used in coincidence for the $\pi^+\pi^-$-atoms measurement to reduce contamination from other particle types, or in anti-coincidence for πK-atom observation. The C_4F_{10} (the refraction index: n = 1.00137) gas used as radiator is cleaned permanently to achieve a very high purity. Each module is read out by four photomultipliers.

This counter detects particles with momenta $\sim$ 3 - 10 GeV/c. For electrons and pions (both signs) signals are in whole momentum range, kaons and protons thresholds are out of the momentum range.

For year 2010, 340 measured runs are available. The analysis of efficiency of CHF to π^+ (π^-) included the first subrun of each run. This subrun is, in fact, only compressed by the track finder (a part of the T4 processor) for all types of events ($\pi^+\pi^-$, πK and e^+e^- pairs) in order to provide data with unbiased ratio of different types of particles. Runs from 2009 and the first part of 2010 have no subruns with compression by the track finder only.

2 The efficiency to pions

The applied method for determination of the CHF efficiency is based on so-called "soft-hard" events. It includes particles with opposite charge by using the assumption that these events originate in one proton-nucleus interaction (i.e. they have the same out-going time from the target). If we know the type of "soft" particle and time difference between positive a negative particle measured by the VH, we can identify "hard" particle and estimate the CHF efficiency.

“Soft” particle means that the particle has a low momentum (less than 2 GeV/c), while “hard” particle has a high momentum (higher than 3 GeV/c). The method based on the “soft-hard” events is suitable for a precise estimation of the CHF efficiency, but due to a great reduction of statistics caused by strict momentum criteria not for the analysis of individual particles and pairs in DIRAC measured data.

The “soft” particle has to be pion (π^- for the π^+ efficiency and π^+ for the π^- efficiency). Because we study the CHF efficiency to pions, it is required the “hard” particle to be pions as well.

So, only pion pairs are selected as “soft-hard” events. “Soft” π^- - “hard” π^+ for the π^+ efficiency and “soft” π^+ - “hard” π^- for the π^- efficiency. “Soft” pions are well separated by TOF between upstream and downstream detectors. By using the time difference between “soft” and “hard” particles in the VH, “hard” pions can also be correctly identified. For their separation the difference between measured and theoretical time in the VH is used.

Because the main goal is a study of the efficiency dependence on momentum, the momentum of “hard” pions is divided into intervals with a width of 200 MeV/c. The interval width was set up to correspond to the momentum interval width used for the analysis of yields of π^+, π^-, p, $\bar{p}$, and their pairs in high momenta.

The limitation of this method has a value 5 GeV/c (the study includes 10 intervals between 3-5 GeV/c). In higher momenta the overlapping of pion and kaon peak for events without signal in the CHF is large and particles can not be successfully separated, as can be seen in Figure 1 for momentum interval P=(3400,3600) MeV/c for positive particles (the time condition).

In each momenta interval of “hard” particles, the number of detected and non-detected π^+ for the π^+ efficiency, resp. π^- for the π^- efficiency, is determined. This can be done in two ways. The first one includes conditions to the CHF amplitude. The reasonable amplitude limits for detected and non-detected particles in 2010 are set up to 300 and 10, respectively (i.e. if the CHF amplitude is greater or equal to 300, pion is considered as detected; if the amplitude is less than 10 as non-detected). Interval between 10 and 300 is empty as can be seen in Figure 3 where the CHF ADC-spectrum with a pedestal at zero is plotted.

Graphs based on the difference between measured and expected time in the VH are used for separation of detected and non-detected pions from other types of particles. In Figure 2 is such graph for detected particles for momentum interval P=(3400,3600) MeV/c. The visible peak is created by detected pions. Their number is estimated as number of particles in this peak with subtraction of a fitted uniform background. The analysis of non-detected pions is more difficult, because there appears an overlapping of the pion and kaon peaks as shown Figure 1. Therefore, a Gaussian fit is used to find out the mean of the pion peak and the number of pions is calculated as two-times the number of particles in the left half of the pion peak with subtraction of a fitted uniform background. The left part of peak does not (especially in low momenta) include an admixture of kaons. The efficiency is calculated as a ratio between detected pions and all pions which crossed the CHF in appropriate “hard” momentum interval.

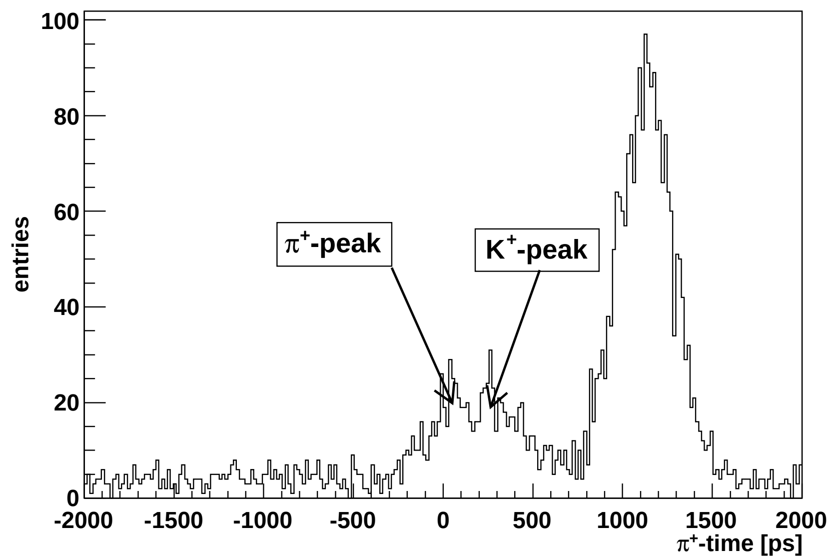

Figure 1: Pion and kaon peak for momentum interval P=(3800,4000) MeV/c for positive particles without signal in the CHF (the time condition). The right peak is formed by protons.

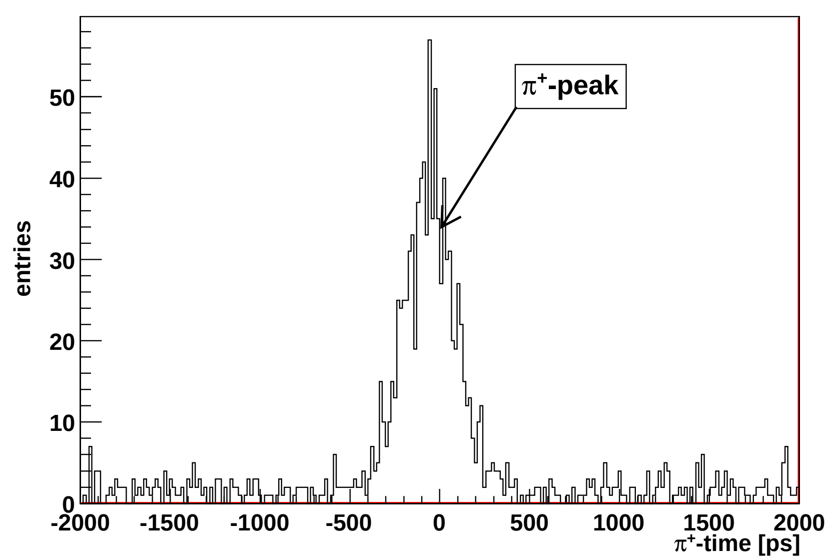

Figure 2: Pion peak for momentum interval P=(3400,3600) MeV/c for positive particles with signal in the CHF (the time condition).

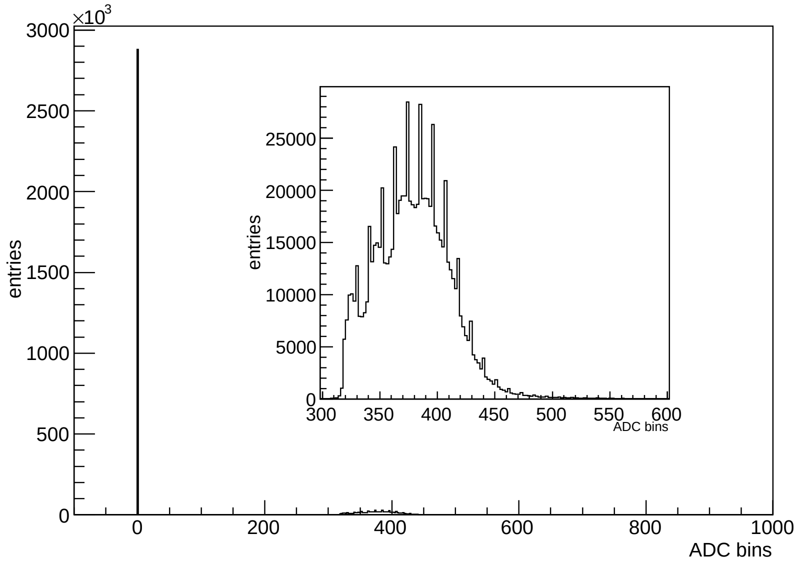

Figure 3: ADC spectrum for the positive arm.

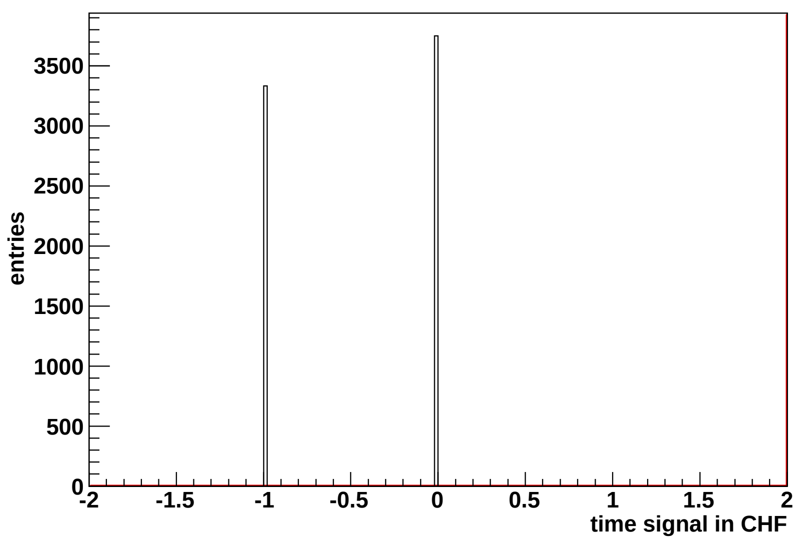

Figure 4: Time in the CHF for the momentum interval P=(4000,4200) MeV/c for positive particles.

The second way is based on conditions of the measured time in the CHF. An example is shown in Figure 4 for momentum interval P=(4000,4200) MeV/c for positive particles, value -1 means particles without signal in the counter, while value 0 means they gave signal. Detected and non-detected pions are selected and the efficiency is calculated in the same process as for amplitude conditions.

These two ways were performed separately both for the π^+ and the π^- efficiency. The obtained results for individual momenta intervals are summarized in Table 1 for the π^+ efficiency and in Table 2 for the π^- efficiency.

From these two tables is seen that the pion efficiency of the counter for 2010 considerably depends on momentum. The efficiency moves between 45-98% regarding momentum. The lowest efficiency is for the lowest momentum interval (i.e. P=(3000,3200) MeV/c) and afterwards growths almost till 98% in higher momenta intervals as expected. As seen in Figures 5 and 6, values for amplitude conditions are a little lower than for time conditions. The reason is the electronics. In 2010 (as in 2009), amplitude and time are measured simultaneously with one device. The amplitude information is only present if signal appears in the counter and if all electronics worked out. But the time information is present even if the electronics did not work properly. Therefore, the CHF efficiency calculated from the amplitude method is used for further analysis.

It is also seen that the efficiency for the negative arm is higher and smoother than for the positive arm. It can be caused by a fact that the number of negative particles is less than positive one and; thus, the dead time of electronics is for the negative arm lower than for the positive one.

Mom. intervals	**Ampl.conditions**			**Time conditions**		
[MeV/c]	π detec.	π total	eff[%]	π detec.	π total	eff[%]
3000-3200	797	1845	43.20±3.31	856	1921	44.56±3.36
3200-3400	822	1414	58.13±4.22	850	1418	59.94±4.30
3400-3600	786	1199	65.55±4.65	940	1316	71.43±4.82
3600-3800	798	1073	74.37±5.05	818	1057	74.09±4.93
3800-4000	766	849	90.33±5.54	779	849	91.76±5.53
4000-4200	645	691	93.34±5.62	659	697	94.55±5.59
4200-4400	487	521	93.37±5.75	532	572	93.01±5.72
4400-4600	423	453	93.38±5.84	465	492	94.51±5.76
4600-4800	325	348	93.39±6.00	315	339	92.92±6.04
4800-5000	241	256	94.14±6.18	250	260	96.15±6.00

Table 1: Numbers of detected and total number positive pions crossing the CHF for both type of conditions depending on momenta intervals with statistic error.

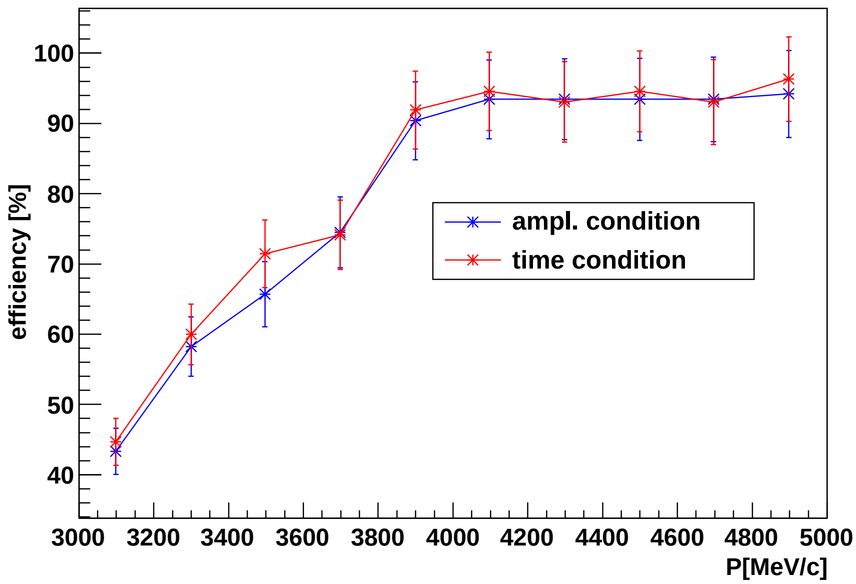

Figure 5: The CHF efficiency dependence on momentum for the positive arm with statistic error.

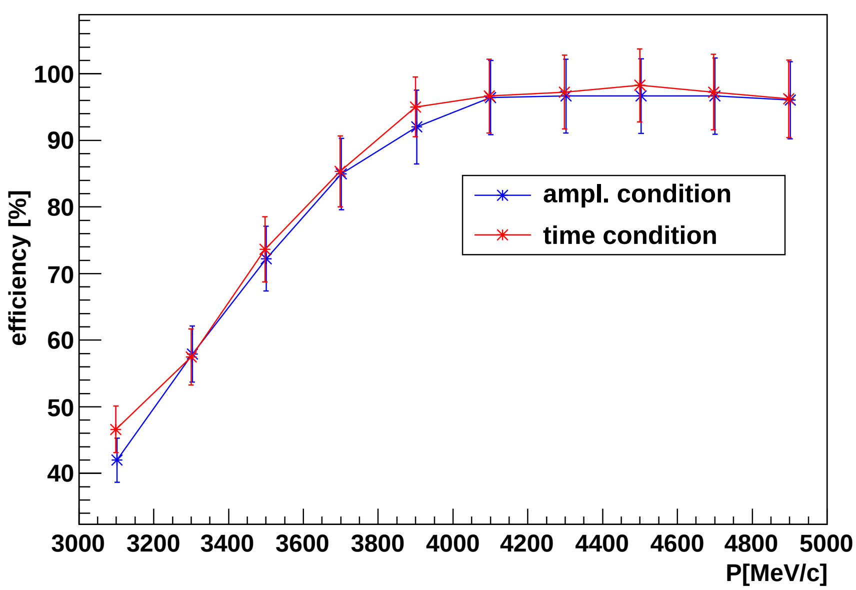

Figure 6: The CHF efficiency dependence on momentum for the negative arm with statistic error.

Mom. intervals	Ampl.conditions			Time conditions		
[MeV/c]	π detec.	π total	eff[%]	π detec.	π total	eff[%]
3000-3200	726	1727	42.04±3.29	812	1744	46.56±3.52
3200-3400	833	1436	58.01±4.20	782	1362	57.42±4.21
3400-3600	937	1295	72.36±4.86	943	1283	73.50±4.91
3600-3800	910	1069	85.13±5.35	961	1127	85.27±5.32
3800-4000	816	886	92.10±5.52	869	916	94.89±5.47
4000-4200	634	657	96.50±5.56	663	687	96.51±5.53
4200-4400	578	598	96.66±5.57	603	621	97.10±5.53
4400-4600	503	520	96.73±5.62	537	547	98.17±5.48
4600-4800	390	403	96.77±5.72	403	415	97.11±5.68
4800-5000	372	387	96.12±5.79	374	389	96.14±5.79

Table 2: Numbers of total and detected negative pions crossing the CHF for both type of conditions depending on momenta intervals with statistic error.

3 Systematic and statistic errors

Because total number of pions which cross the CHF is defined as $\mathrm{N}_{total} = \mathrm{N}_{detected} + \mathrm{N}_{non-detected}$. A correlation between N_{total} and $\mathrm{N}_{detected}$ is present and calculation of standard statistic errors is calculated as:

$$\mathrm{sse} = \mathrm{eff} * \sqrt{\frac{1}{\mathrm{N}_{detec}} - \frac{1}{\mathrm{N}_{total}}}. \tag{1}$$

Other source of statistic error arises from fitting the background by a linear function. This error was established from error of the fit. It depends on momentum and its maximal value moves from 1% to 5%. The next source of error is the estimation of the mean of the pion peak for particles without signal in the CHF. This error was also calculated from the error of the fit and its value is around 6%. Error of region of an integration where pion peaks are located has a value of 2-10%. Finally, the influence of all these statistic errors to the CHF efficiency is about 5%. Total statistic error for each interval are mentioned in Tables 1 and 2. Systematic error including error of kaon admixture within non-detected particles has zero value for momenta of "hard" particles near 3 GeV/c up till 6% for momenta around 5 GeV/c (the influence to the CHF efficiency is about 0.5%). The difference between results for amplitude and time method can not be taken as a source of systematic error, because they are not two independent measurements, but only one which measures at the same time both amplitude and time.

References

[1] A. Kuptsov, Design of C4F10 Cherenkov detectors, DIRAC-NOTE-2008-01, http://cds.cern.ch/record/1369644?ln=en