DEAR Technical Note IR-32

DEAR Monte Carlo results for the cryogenic target setup filled with nitrogen

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1 Introduction

The results of the DEAR Monte Carlo simulation for the cryogenic target setup filled with nitrogen at different pressures (i.e. densities), are presented in this Note. The setup is considered to work with 8 CCDs 22 and 4 CCDs 05, i.e., in the configuration presently under test in the laboratory, ready to be eventually installed.

The present study implements the previous one: "DEAR Monte Carlo results: X-ray signals from different kaonic atoms and different setups", reported in the DEAR Technical Note IR-22.

The goal of this study is to find the density (i.e. pressure) conditions for which the kaonic nitrogen transitions (4.6 and 7.6 keV) are best seen. Increasing the pressure one stops more kaons inside nitrogen; at the same time, more X rays are absorbed inside nitrogen itself. So only a simulation can give the "optimum" working point, in terms of signal rate. A study was performed for pressure of nitrogen varying between 1 and 8 bars - sufficient to optimize the working conditions.

An important warning has to be done. In the present study, the dependence of cascade parameters on the density were not, for the moment, taken into account. However, for the range of pressures (densities) considered, the yields should be affected at most by the order of $10-20\%$.

The setup, as included in the Monte Carlo simulation, is presented in Section 2.

The results, in terms of percentage of kaons stopping inside the target and of X-ray signal detected by CCDs, are presented in Section 3. In Section 4 conclusions are drawn.

2 Cryogenic target setup

The DEAR cryotarget setup is described in detail in ref. [1]. The elements relevant for the simulation are summarized below.

The vacuum jacket is an aluminum cylinder, 10 mm thick, with a radius of 15 cm and a height of 26.5 cm, placed at 4 cm with respect to the DEAR pipe. Inside the vacuum jacket the cryogenic target is placed at 1 cm from the bottom. The target is an aluminum cylinder, 5 mm thick, with a radius of 6.5 cm and a height of 14.3 cm. On the lateral wall of the cylinder 8 windows (sectors of cylinder) are cut, made by Kapton, 50 μm thick, in correspondence with the CCDs. The windows height is 7 cm, while their length (as circle arcs) is 3.8 cm and are starting 3 cm from the target bottom. CCDs are placed at 6 mm distance with respect to the Kapton windows. The active area of a CCD-22 is 2.5×2.5 cm^2 with a depletion layer thickness of 40μm. For CCD-05 the active area is 2.6×1.7 cm^2, with a depletion layer thickness of 30μm.

The windows in front on kaons before reaching the hydrogen target are:

- 125μm of aluminum at the entrance of the vacuum jacket, with a diameter of 8 cm;

- 190μm of Hostaphane, at the entrance of the target cell, with a diameter of 10 cm.

The degrader was optimized to have the maximum number of kaons stopped in front of the CCDs for each situation considered.

All other elements (DEAR pipe, DAΦNE pipe, quadrupoles, DEAR platform, etc.) are the same as in all previous simulations, and are reported in ref. [2].

The DEAR Monte Carlo setup considered in the simulation is presented in Figures 1 and 2 of ref. [3].

3 DEAR Monte Carlo results for nitrogen X-ray transitions for different pressures of the nitrogen inside the target

A study of the dependence of the X-ray signals of 4.6 and 7.6 keV was performed as a function of the pressure of nitrogen inside the target. The pressure in this case is an equivalent of density, since the density can be reached by: increasing the pressure and/or decreasing the temperature. Densities corresponding to pressures at room temperature between 1 and 8 bars were studied and the results are presented in the next Sections.

3.1 Kaons stopping inside the target

The work started by optimizing the degrader in order to maximize the percentage of kaons stopping inside the target for each case.

In Figures 1 and 2 the two extreme situations (1 and 8 bars) are presented in terms of the distributions of kaons stopped inside target. The bi-dimensional as well the the vertical (y) distributions are reported.

As one can see by comparing the two distributions, by increasing the pressure the spread of the y-distribution is smaller and kaons are more concentrated in front of the CCDs. Moreover, by increasing the pressure there are more kaons stopped inside the target. The percentage of kaons stopped inside the target for each of the studied pressures is presented in Table 1.

3.2 X-ray signal

The number of X rays detected by the CCDs was studied for each one of the nitrogen-target pressures mentioned in the previous Section.

The 4.6 and 7.6 keV lines were both studied and it was taken into account that the transmission of X rays decreases by increasing the pressure. The results are presented in Table 1. In order to make a comparison with the present NTP-target the results for this configuration [4] are presented as well.

As mentioned before, no density dependence of the yields was considered at this stage of the calculations. The yields of both transitions were considered to be 80%.

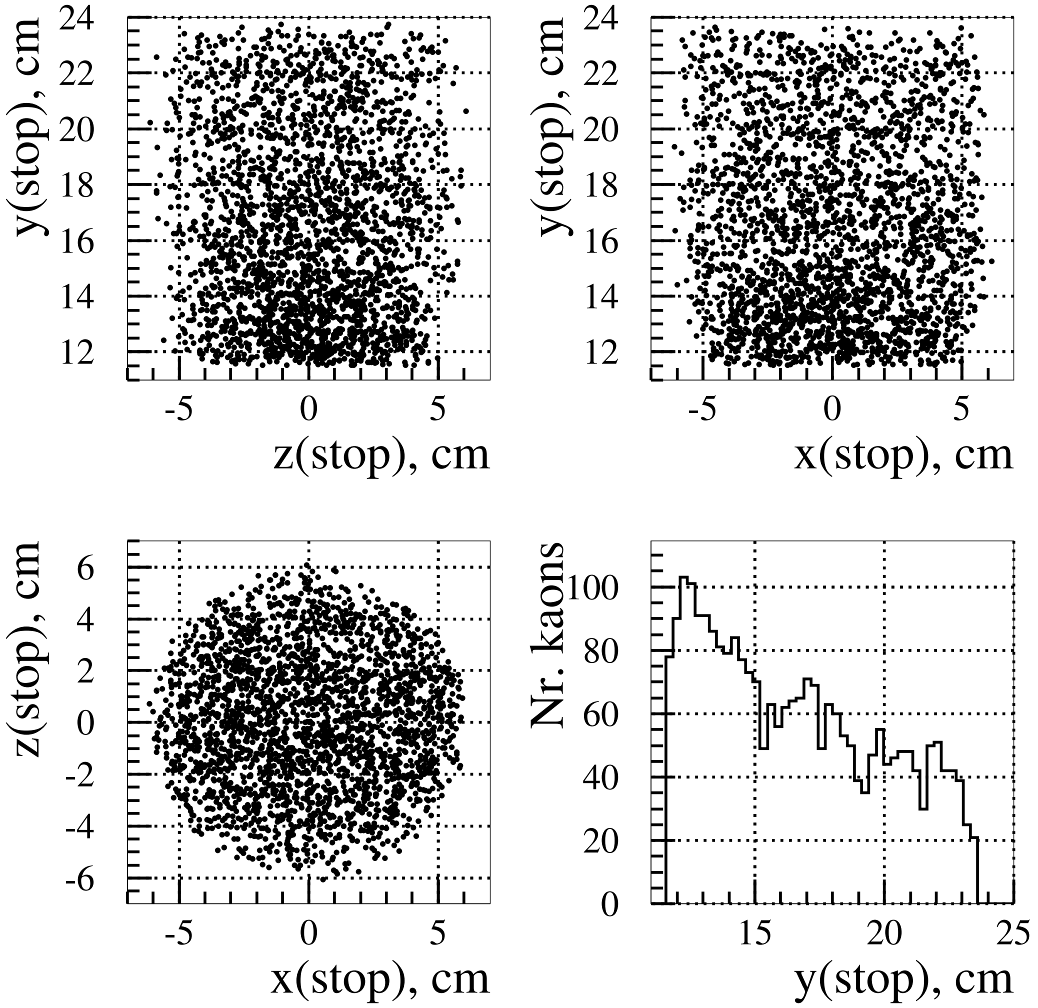

Figure 1: Distributions of kaons stopping inside the nitrogen target at a pressure of 1 bar.

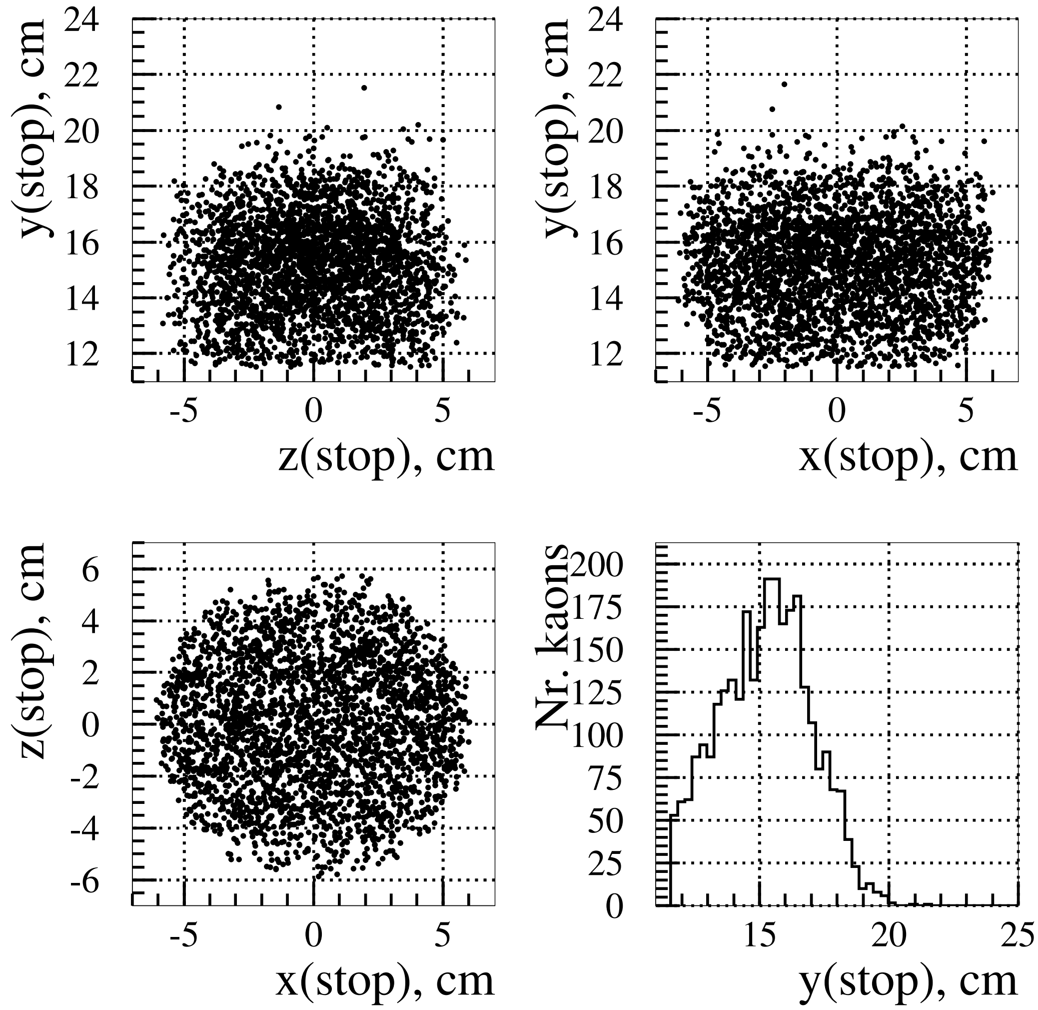

Figure 2: Distributions of kaons stopping inside the nitrogen target at a pressure of 8 bar.

Table 1: The Monte Carlo results for nitrogen X rays transition as function of the target pressure. (Yields of transitions = 80%).

Geometry	Pressure (bar)	K^- stopped (%)	X rays of 4.6 keV (for 1 pb^{-1})	X rays of 7.6 keV (for 1 pb^{-1})
NTP	1	2.4	45-55	55-65
Cryo-target	1	0.68	500-600	500-600
Cryo-target	2	1.33	700-800	1000-1100
Cryo-target	3	1.9	900-1000	1300-1400
Cryo-target	5	2.6	700-800	1700-1800
Cryo-target	8	3.0	500-600	1600-1700

4 Conclusions

As one can see by comparing the first raw of Table 1 with the second one, there is already almost a factor of 10 gained in the X-ray signal by simply changing from "classical NTP" geometry to the cryogenic-target one at 1 bar pressure. This is due to:

- a larger number of CCDs, part of those being CCD-22 which have an area larger than that of a CCD-05;

- an efficiency of CCD-22 larger than that of a CCD-05;

- an improved geometry - where the factor which plays the most important role was recognized to be the distance between CCDs and target (Kapton window): in the new geometry the distance was reduced by a factor of 2.

Then, in the framework of the cryogenic setup one can gain another factor of about 3 by changing the pressure (density) of the target from 1 to 3-5 bars. This therefore means a gain of about a factor of 30 with respect to the NTP-target setup.

References

[1] J. Zmeskal *et al.* (DEAR Collaboration), "The DEAR Target and Detector System", Physics and Detectors for DAΦNE, Frascati Physics Series, Vol. XVI, to appear.

[2] S. Bianco *et al.* (DEAR Collaboration), The DEAR case, Rivista del Nuovo Cimento Vol. **22**, N. 11, 1999.

[3] C. Petrascu, "DEAR Monte Carlo results for the "16 CCD-22" cryogenic target setup", DEAR Technical Note IR-20, 10 April 2000.

[4] C. Petrascu, "Monte Carlo calculations for the new NTP DEAR setup", DEAR Technical Note IR-13, 16 June 2000.