DEAR Technical Note IR-27

Energy spectrum improvement and the effect of minimum ionizing particles on CCDs resulted with a new analysis software

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1 Introduction

We revisited the data of CCDs recorded in DAΦNE for beams colliding at the DEAR I.P. which were already analyzed in Ref. [1] with a different analysis method. The data were taken with the NTP setup with Zr foils attached to the kaon entrance window for the energy calibration. The setup consisted of 4 CCD chips read out on both sides, resulting in 8 data files named as CD1 to CD8 together with the run number. We analyzed in this note data from CD5 to CD8.

2 Charge distribution of single hits

The position of the noise peak fluctuated during the measurement time. Applying a Fourier analysis, the position was corrected to be zero. Thus, only one energy threshold level is needed for the data analysis after the Fourier analysis. This was already studied in Refs. [2] and [3]. Although the threshold determination is not straightforward, it defines whether an event is a single-pixel hit or a double-pixel hit.

The most important reason to have a good single-to-double event separation is to study the data of the pixels surrounding the fired pixel.

Let us assume that the fired pixel is located in the position $(i,\ j)$, where i and j is the column number and the row number, respectively. Since the read-out direction is opposite in the two halves of one CCD chip, the data are stored in opposite directions in CD5 and CD6. This is the same for CD7 and CD8. Therefore, the successive read-out pixel is the pixel $(i-1,\, j)$ for CD5 and CD7, and the pixel $(i+1,\, j)$ for CD6 and CD8. In these pixels, we can expect that the signal due to charge-transfer loss is recorded.

Thus, in Fig. 1, we plotted correlations between the energy of the fired pixel $(i,\ j)$ and the energy stored in the pixels $(i-1,\, j)$ and $(i+1,\, j)$. Signals around 15.8 keV come from a Zr fluorescence peak. As shown in the figure, there are clear correlations between the fired pixel and the pixels $(i-1,\, j)$ in CD5 and $(i+1,\, j)$ in CD6. However, the correlation is not as expected. If the signals in successive pixels are due to the charge-transfer loss, the correlation with the fired pixel should be linear, and the Zr fluorescence x-ray signals should have a sharp energy correlation with it. As it is shown in Fig. 1, the global correlation is energy squared. It is also shown that the position of the Zr fluorescence peak does not have any correlation with the successive pixel. This means that we can not improve the energy resolution by the correction of the transfer loss.

It is also clearly seen that the energy threshold should be set to approximately 300 eV, otherwise the analysis routine treats the Zr peak as a double-pixel event. The energy spectrum at 300 eV threshold is shown in Fig. 2. There is a bump around 10 - 12 keV. This is due to the high threshold, as described below.

To set a lower threshold, we need to resolve the correlation between the fired pixel and the successive read-out pixels. Thus, we corrected for this correlation by the fitted function: $f(E) = a \cdot E^2$, where E is the energy of the fired pixel.

Figure 3 shows the results with the lower threshold energy of 100 eV, and

Fig. 4 shows the corresponding energy spectrum. Due to the correction for the correlation and the setting of the threshold to a lower level, the background originating from double-pixel hits is reduced. This is clearly seen in Fig. 3 and 4. As a result, the x-ray peaks of aluminum and silicon are clearly improved in separation against the background.

3 High energy electron hits in the CCD chips

Figure 5 shows an energy spectrum of double-pixel events. As shown in Fig. 5a, there are many events recorded around 10 - 12 keV. The background spectrum shape is much different from what we obtained in the single-pixel spectrum (see Fig. 4).

To check whether the double-pixel events are spurious or not, we plotted the energy correlation of the pixels in double-pixel events, as shown in Fig. 5b. A clear correlation between the two pixels of the double-pixel events can be seen.

Which might be the source of the double-pixel events ? The thickness of the depletion layer of the used CCDs is about 30 μm. The energy loss of minimum ionizing particles is 11 keV if they pass through the CCDs perpendicularly. This is exactly the energy observed in the double-pixel events. Therefore, most probably, these double-pixel events come from electrons and/or positrons passing through the CCDs.

4 Conclusion

Applying an analysis method which takes into account the correlation between the energy of the fired pixel and the energy stored in the preceding and following pixels,
we find that :
(1) the energy spectrum shows a clear improvement of the resolution at the low-energy side, and
(2) the CCDs recorded double-pixel events can be explained as minimum-ionizing particles passing through the CCDs perpendicularly.

Acknowledgement

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References

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[2] D. Chatellard, Ph. D. Thesis, University of Neuchâtel, 1995.

[3] T. Ishiwatari, Master Thesis, Tokyo Institute of Technology, 1999.

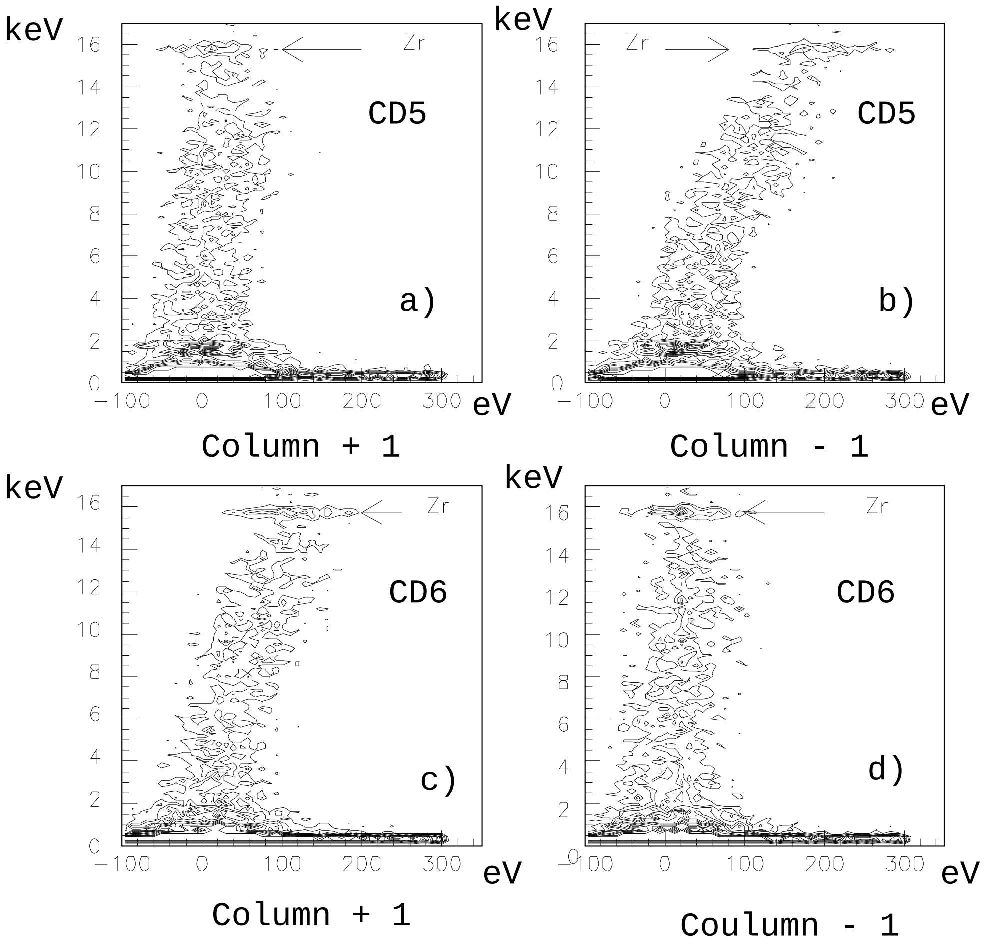

Figure 1: Contour plot of the events in the energy scale of the fired pixel (i, j) and ($i+1$, j), and between (i, j) and ($i-1$, j) for CD5 (up) and CD6 (bottom). The horizontal axis gives the energy of the pixel preceding [a), c)] or following the hit pixel [b), d)]. The vertical axis gives the energy of the hit pixel. Signals around 15.8 keV come from a Zr x-ray peak. The energy squared correlation is clearly seen in figs. b) and c). No correlation is seen in figs. a) and d).

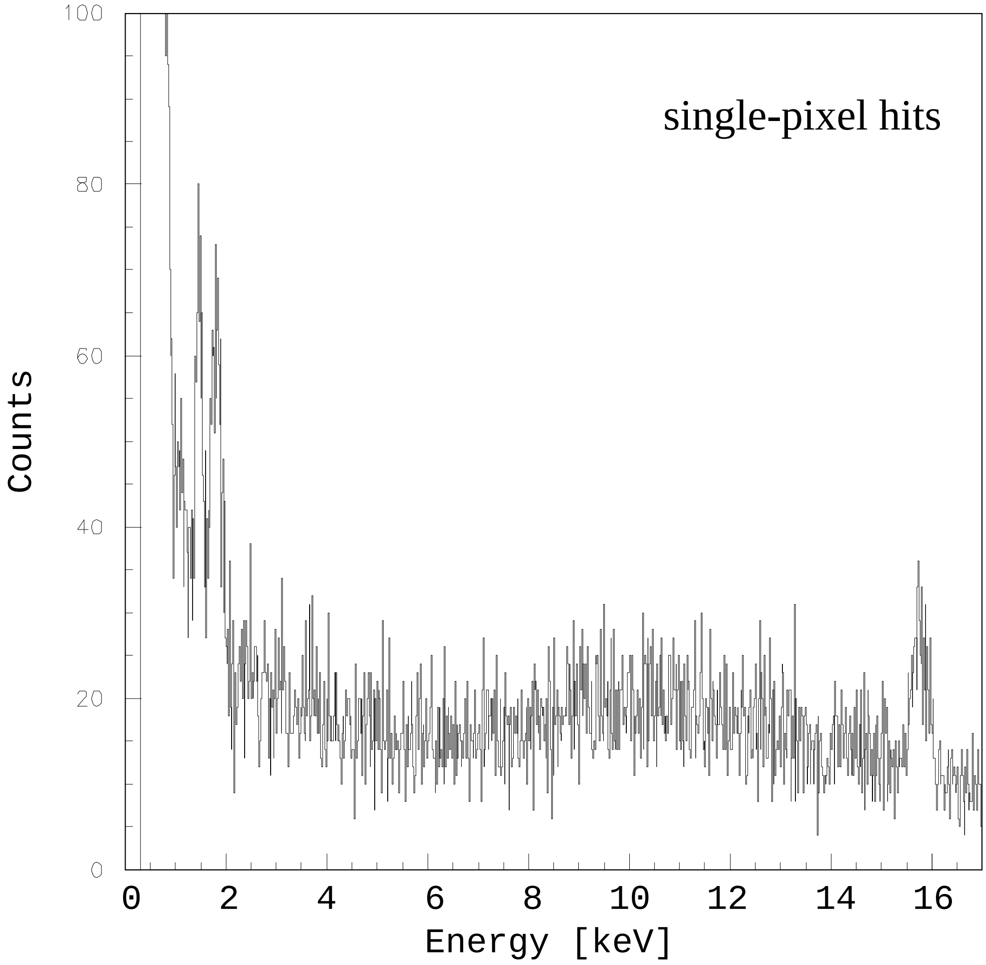

Figure 2: Energy spectrum of single-pixel events analyzed with the threshold energy of 300 eV. There is still a small contamination of double-pixel hits, which is visible as a bump around 10 - 12 keV.

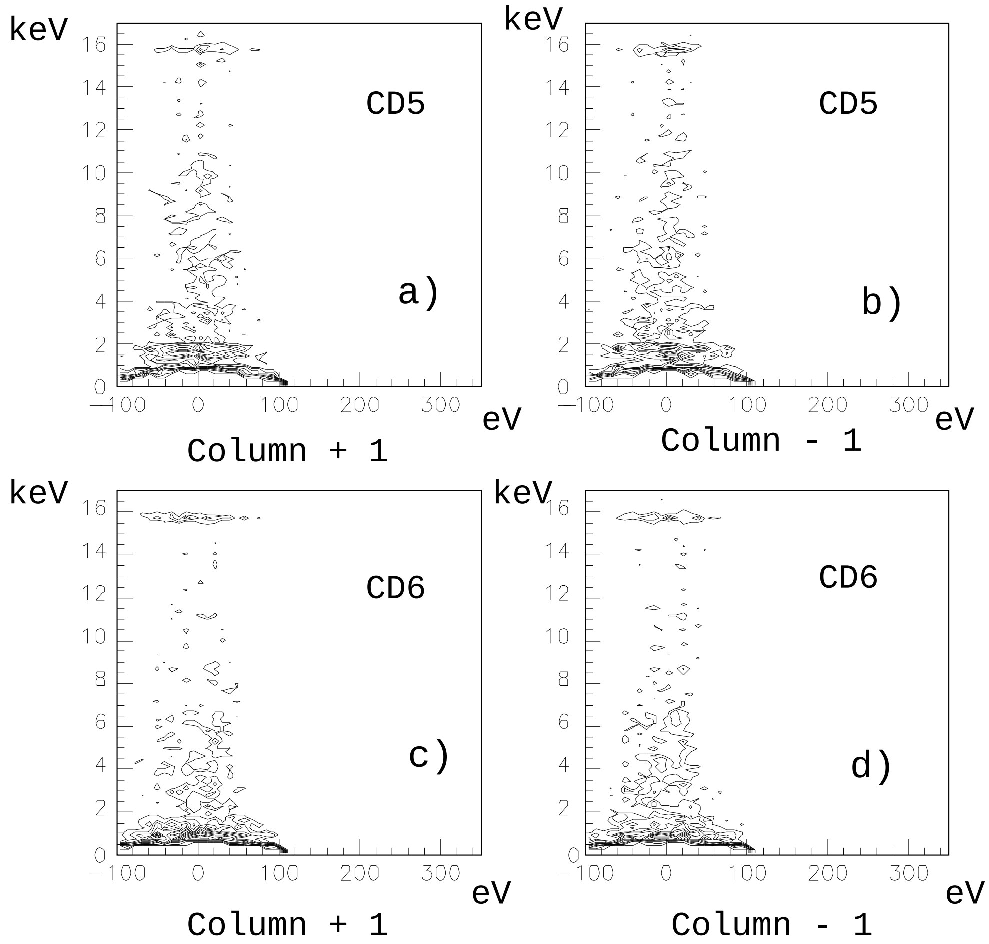

Figure 3: Contour plot of the events after the correction of the energy correlation. The horizontal axis gives the energy of the pixel preceding [a), c)] or following the hit pixel [b), d)]. The vertical axis gives the energy of the hit pixel. Signals around 15.8 keV come from a Zr x-ray peak. The energy threshold can be reduced down to 100 eV.

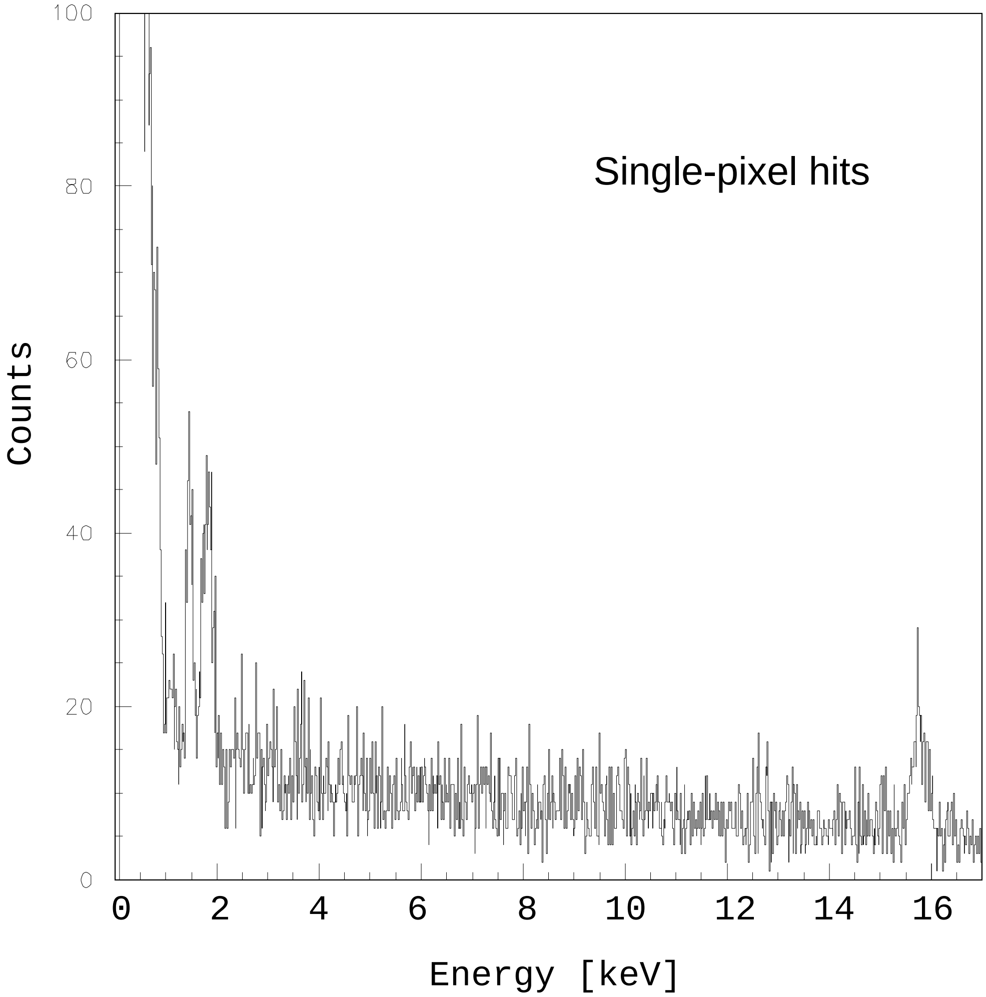

Figure 4: Energy spectrum of single-pixel events with the threshold energy of 100 eV. The shape of the background above 2 keV is relatively flat, since the contamination due to double-pixel hits is not visible anymore.

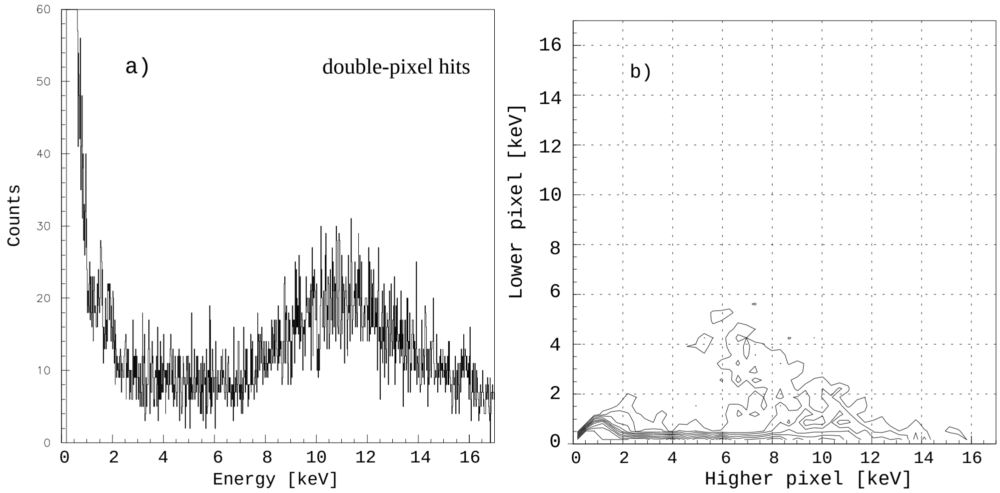

Figure 5: The left figure shows the energy spectrum of double-pixel events. The right figure shows the energy correlation of the two pixels in a double-pixel event. The horizontal axis is for the higher-energy pixel and the vertical is for the lower-energy one.