Performance of CCD22 detectors in exotic atom X-ray measurements

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The application of CCD detectors in exotic-atom X-ray spectroscopy is based on the possibility to provide a precise position information together with a good energy resolution. The CSD detector [1] which consists of a 2 x 3 matrix of CCDs type 22 with frame buffer is used for experiments at PSI. Pixels whose charge (q) exceeds the preselected limit $m\sigma$ (where σ is a width of the noise peak and $m \in \mathbf{N}$) are recorded with three coordinates: ADC contents (q) and the X and Y coordinates. Typically, data of 60 images (frames) of 1 minute exposure time each are collected in one file for the individual chips. Energy and position information of CCDs may be "statically" or "dynamically" distorted and are called defect pixels of the CCD matrix. An analysis of raw data measured at PSI in 2000-2002 [2] with the aim to identify the defect pixels was performed.
Two classes of statically defect pixels may be defined:

- "noisy" or "hot" pixels, which frequently create charge without photon or particle impact and
- "dead" or "blind" pixels, where the ADC contents is zero, i. e., no charge is transferred or converted.

The given definition for hot and blind pixels has been numerically reevaluated. For the search of "statically defect" pixels, the sum of (q) was registered for each hit pixel hit (n) as well as the number of hits for a certain charge (q). Then for the whole CCD matrix the number of pixels n" was counted which have registered the given value of charge q_i and the number of pixels n' which have converted a given value of events n_i. For these frequency distributions $n" = n"(q)$ and $n' = n'(n)$ cuts were set which discriminate "hot" and "blind" pixels. The X,Y distribution of hot pixels is presented in

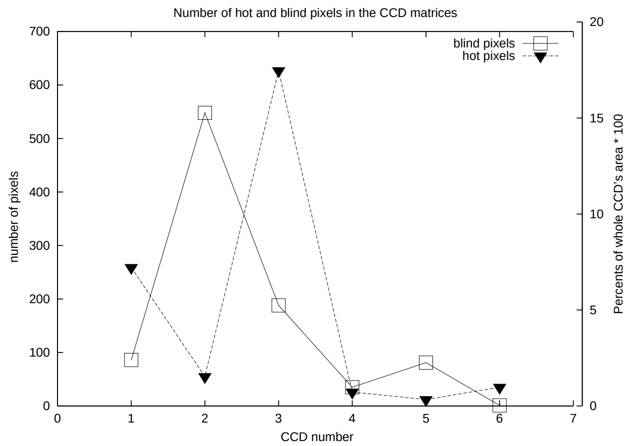

Fig. 1: X,Y scatter plot of the hot pixels in CCDs 1-6

Fig.1. The number of the "statically defect" pixels for the individual CCD chips of the measurements at PSI in 2002 is shown in Fig.2. Such pixels are masked in the analysis.
Pixels showing from time to time nontypical charge contents, often together with coordinates X and Y untypical for real events, may be called "dynamically defect" pixels. They were studied with a beam monitoring technique. The integral of events N with amplitudes above a given ADC threshold Q_{th} was normalized to the integrated charge Q_p of the proton current of the PSI accelerator. Q_p serves as a measure

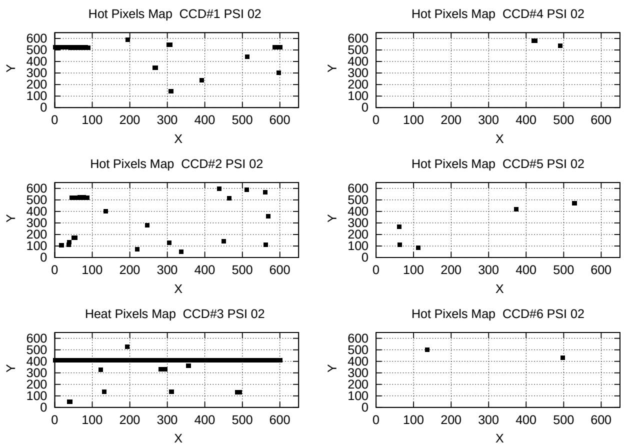

Fig. 2: Number of "statically" defect pixels of CCDs 1-6 (measurement at PSI 2002)

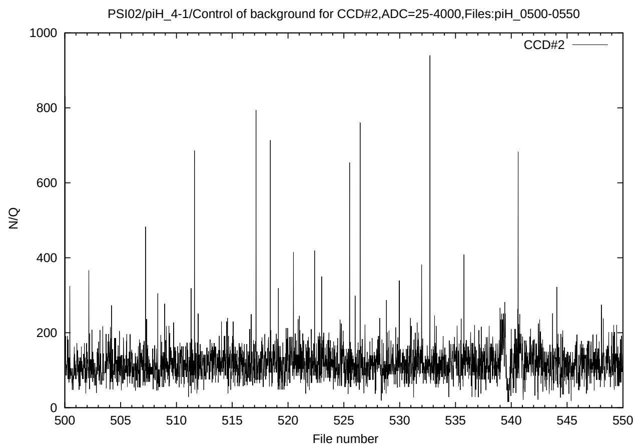

Fig. 3: The $\frac{N}{Q_p}$ ratios for CCD 2 from the measurement of the $\pi H_{4p \to 1s}$ transition (PSI 2002)

of the number pionic atoms produced. The time interval of measurements presented in Fig.3 corresponds to $\approx$ 50 hours. From the $\frac{N}{Q_p}$ graph one can see frames with increased noise level (sharp peaks). The average duration of the such interferences is $\approx$ 1-2 frames. This means that dynamically defect pixels usually are reset by starting the next frame measurement.
With the two described techniques statically defect pixels and an increased noise level are safely identified. Statically defect pixels arising from the manufacturing of the CCD chips keep their coordinates. Dynamical defect pixels fluctuate in amplitude and position and may be caused by the electronics, cabling and/or software malfunctions. It is noteworthy that the developed and applied techniques allow to evaluate and to control both types of defect pixels in CCD matrix easily during the measurements.

[1] N. Nelms et al., NIM A **484** (2002) 419.
[2] Annual report, IKP 2002.

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