INSTITUT MAX VON LAUE - PAUL LANGEVIN

NEUTRONS FOR SCIENCE ®

Single Neutron Counting Using CCD And CMOS Cameras

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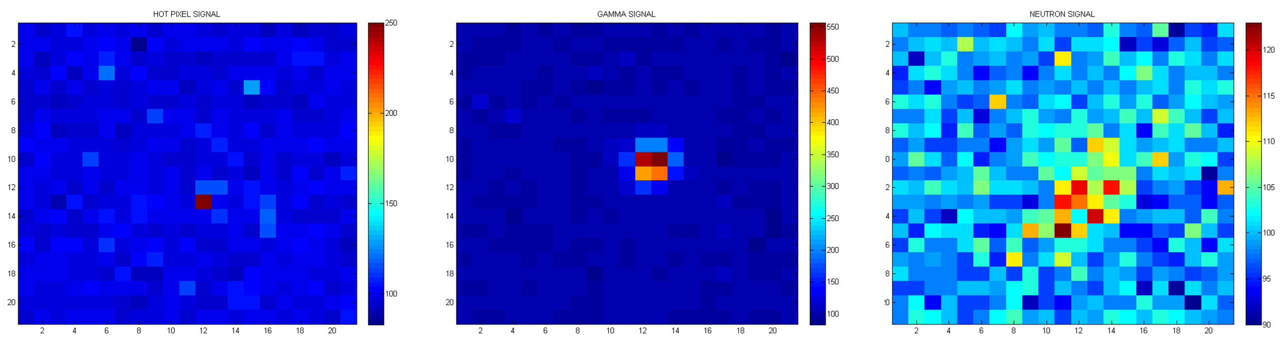
Abstract: Neutron detection traditionally takes place with detectors based upon particle detection technologies like gas or scintillation detections. These detectors have a high dynamic range, and are very performing at low counting rates and fast timing (time of flight) applications. At high counting rates however, continuous imaging detectors such as CCD or CMOS camera's optically linked to scintillators, can have very good performances concerning linearity and spatial resolution but the dynamic range of these systems is limited by noise and gamma background. We explore a technique that allows us to use imaging detectors as counting detectors at lower counting rates, and transits smoothly to continuous imaging at higher rates. Neutron detection involves reactions releasing energies of the order of the MeV, while X-ray detection releases energies of the order of the photon energy, (10 KeV range). This 100-fold higher energy allows the individual neutron detection light signal to be significantly above the noise level, as such allowing for discrimination and individual counting. The theory is next confronted with experimental measurements on CCD and CMOS type commercial cameras.

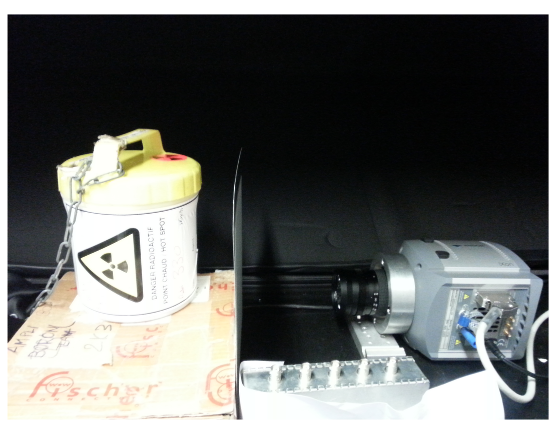
Neutron Recognition



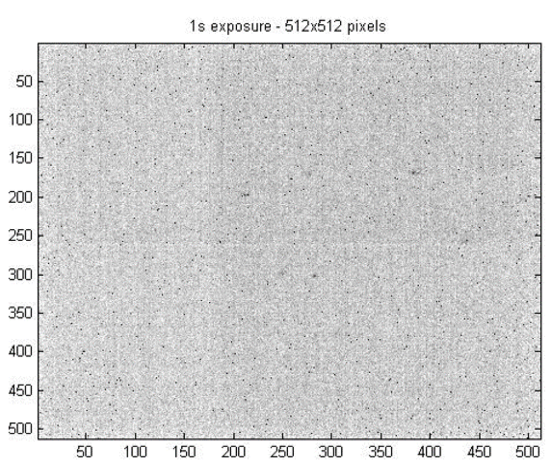
Hot pixel signature   Gamma signature   Neutron signature

Because of the very different pixel distribution between hot-pixel, gamma and neutron signals we can apply a threshold as one would do with gas proportional counters.

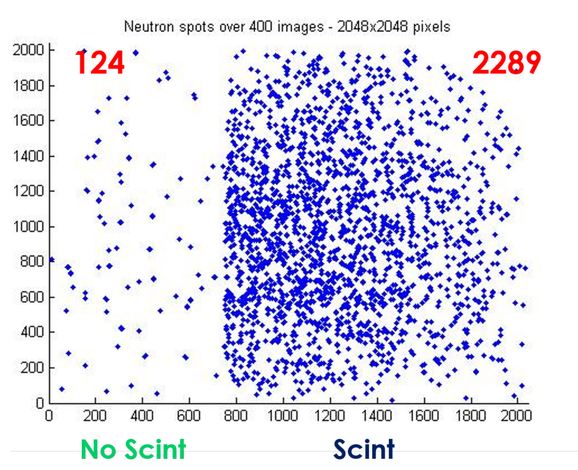
Low Count Rate Test



The camera is partially looking At a ZnS(Ag) scintillator. The neutrons are provided by a 3.7 GBq AmBe source.



Raw image data

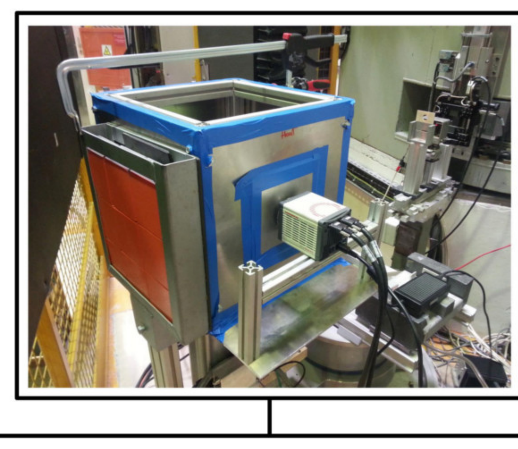


Detected neutrons. The scintillator edge is clearly visible

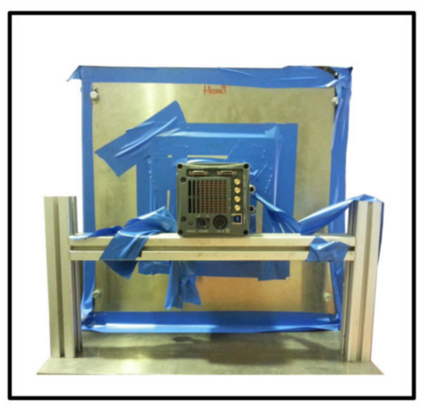
High Count Rate Test

The CMOS camera was mounted on the T13C test neutron beam and exposed to a monochromatic neutron beam of about 10^4 n/cm^2/s.

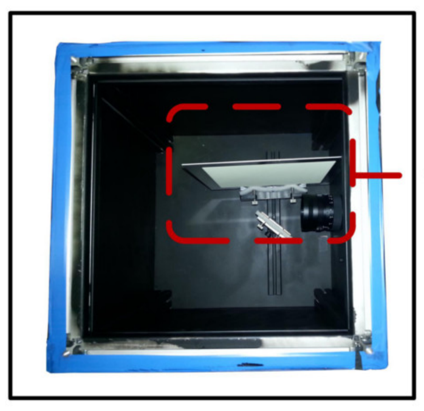
General View



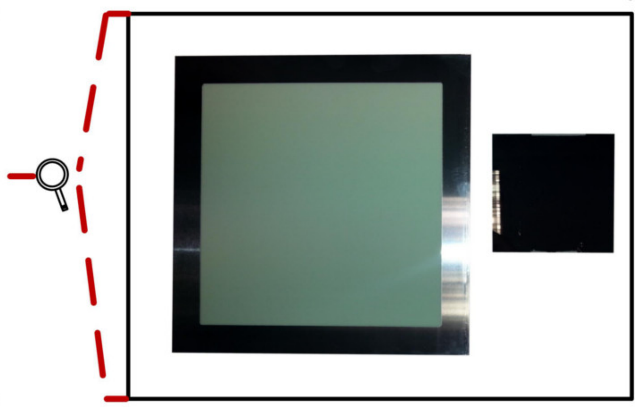
General view of the experimental setup



Front View

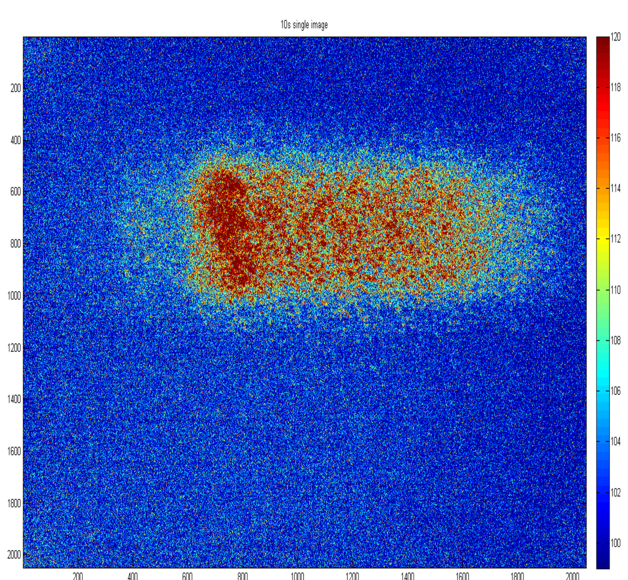


Inner View



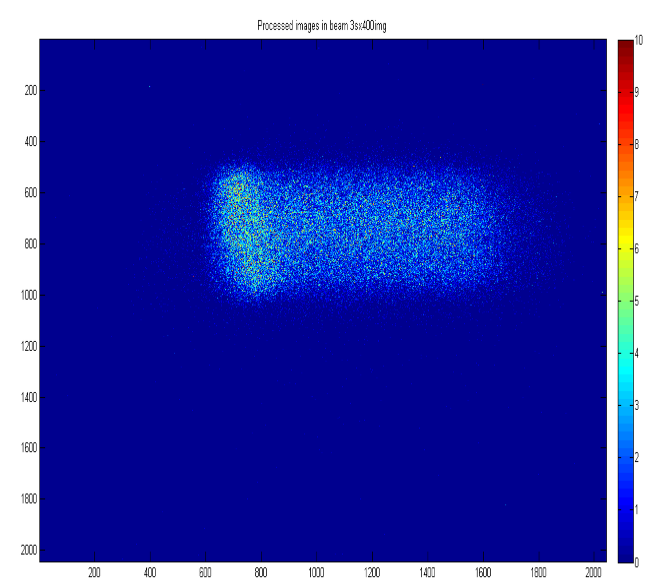
Scintillator & mirror

10 s exposure



Raw camera data

400 images 50 ms exposure



Reconstructed image

Conclusions

Starting from the theoretical concept that a threshold-based neutron counting system can in principle be obtained using a CMOS camera looking at a scintillator, we verified experimentally that single neutron impacts could indeed be identified using an AmBe source as well as in a beam experiment. The recent advances in camera technology now permit us with a commercial camera at relatively low cost, and without the need of light amplification, to detect individual neutrons. A camera-based neutron counting detection system can combine the good background rejection and the capability to sustain very low count rates, which is typical of neutron counting detectors, with the classical advantages of integrating detectors, such as absence of dead time and hence the capacity to sustain very high local count rates, and high spatial resolution