UNIVERSITÄT SIEGEN
Naturwissenschaftlich- Technische Fakultät
Department of Physics

MAX-PLANCK-GESELLSCHAFT

Sub-Pixel Resolution of a pnCCD for X-Ray White Beam Applications

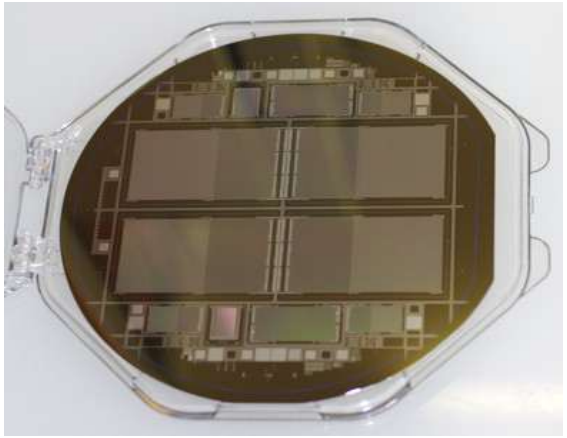
Ali Abboud*[1], Sebastian Send[1], Nadija Pashniak[1], Wolfram Leitenberger[5], Robert Hartmann[4], Lothar Strüder[1,2,3], Ullrich Pietsch[1]

[1]Universität Siegen, FB Physik, Siegen, Germany (*abboud@deph.physik.uni-siegen.de)
[2] Max-Planck-Institut für extraterrestrische Physik (MPE), Garching, Germany
[3]MPI Halbleiterlabor, München, Germany, [4]PNSensor GmbH, München, Germany
[5] University of Potsdam

14TH INTERNATIONAL WORKSHOP
ON RADIATION IMAGING DETECTORS

Motivation

CCDs or charge-coupled devices were invented in 1969 at AT&T Bell Labs by Willard Boyle and George E. Smith.



•**A pixel (picture element)** is a physical point in a raster image, or the smallest, addressable element in a display device.

Position resolution: <1μm optical CCDs

~50μm Xray CCDs

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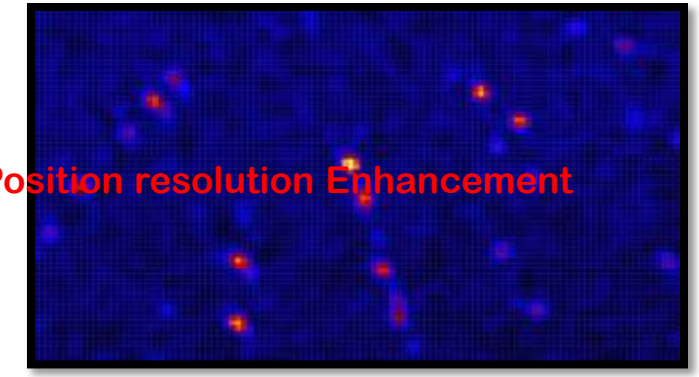
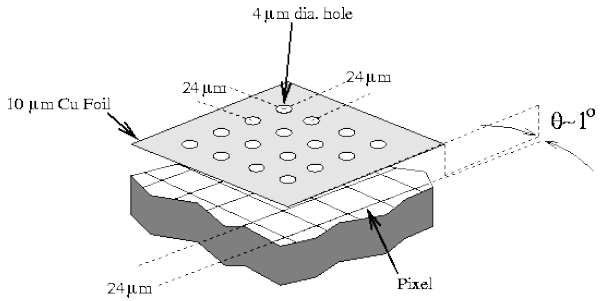


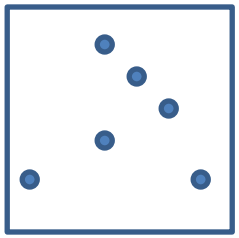
Method of Choice

To improve the spatial resolution of a CCD image we will follow the following path:

1. **Determine the Charge Cloud Size generated by photons in the Bulk of the Detector as a function of energy.**

2. **Relocate the Charge center using a simplified Cylindrical model of the Charge cloud.**





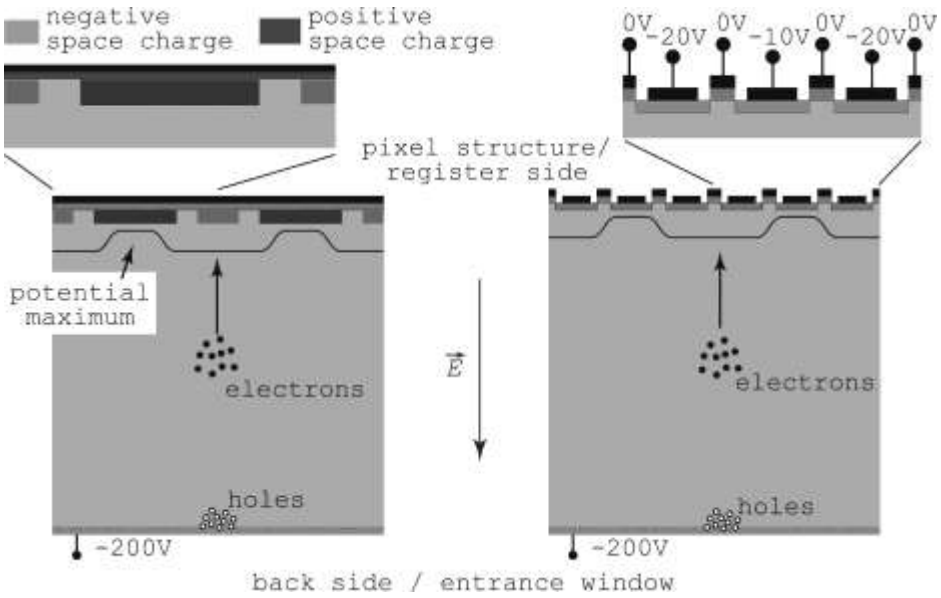
? Photon hit location

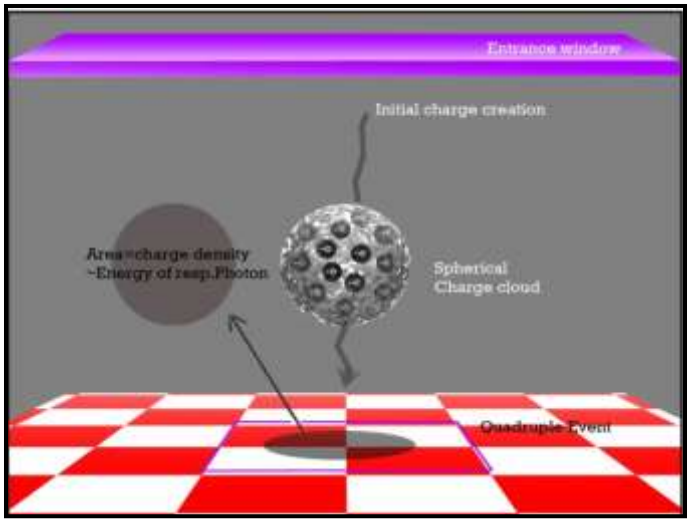
Pixel

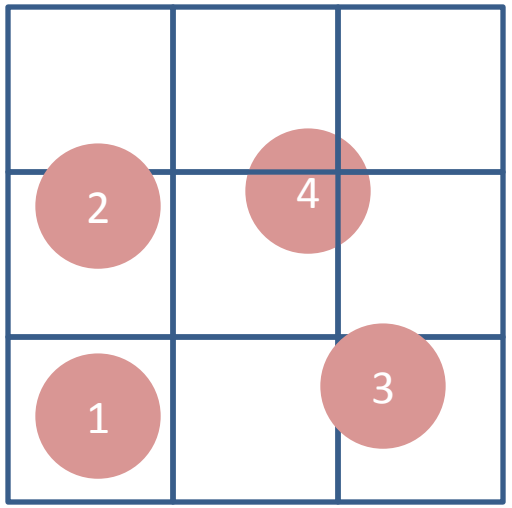
Some Concepts: The pnCCD (pn-junction CCD)

Inside the Detector

- Photo effect
- Initial charge cloud ($N_e \sim E$)
- Diffusion and Drift of charges/charge density
- Collection of charges in pixels
- Events Creation and recombination







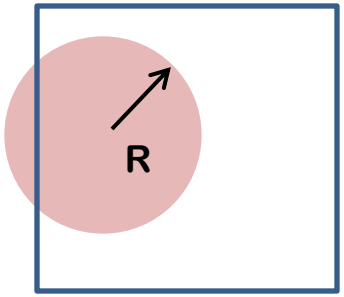
1: Single
2:Double
3:Triple
4:Quadruple

Charge cloud size determination

Events type distribution is a finger print of the photon energy !!

Mn K-alpha 5850 keV	Fe K-alpha 6403 keV	Cu K-alpha 8040 keV
19% single event	15% single event	10% single event
45% Doubles	43% Doubles	40% Doubles
17% Triples	20% Triples	20% Triples
19% Quadruples	22% Quadruples	30% Quadruples

Charge clouds created by mono energetic photons will always produce the same probability of splitting into singles, doubles, triples and quadruples in a CCD detector of defined pixel size

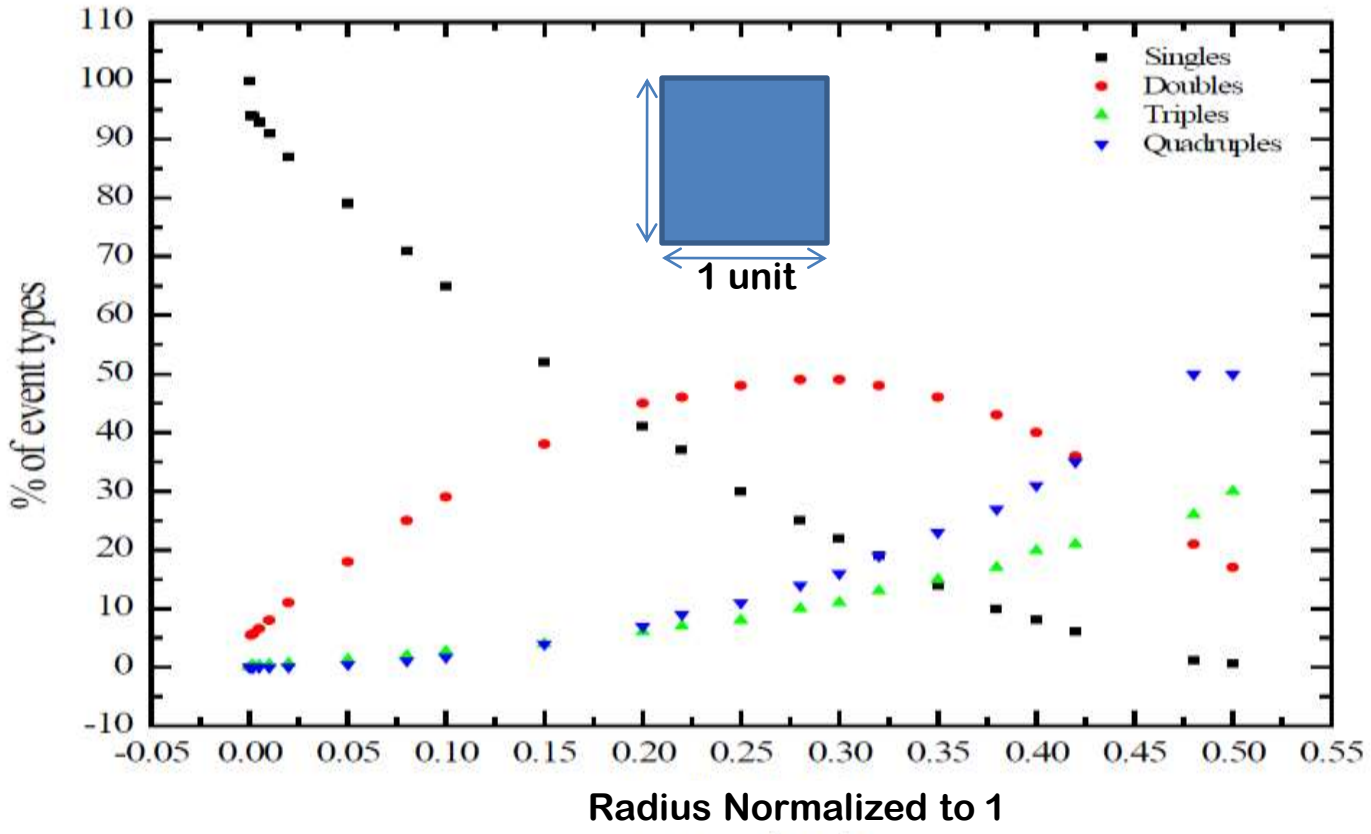


→ ? Events Distributions → Radius vs Energy relation

$$S(X,Y) = \{R, \quad |X| < R; \quad |Y| < R$$

$$S(X,Y) = \{0, \quad |X| > R; \quad |Y| > R$$

Simulations :determination of split ratios

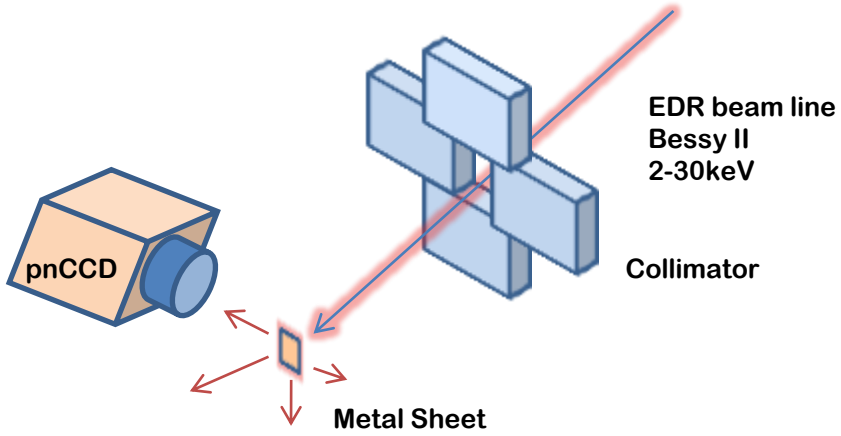


•Sensitivity better than 1µm

Experimental determination of split ratios

We excited five different metals (Fe, Cu, Rb, Pb, and Mo) by white synchrotron radiation.

10k frames in the SPC mode of Fluorescence photons were recorded.

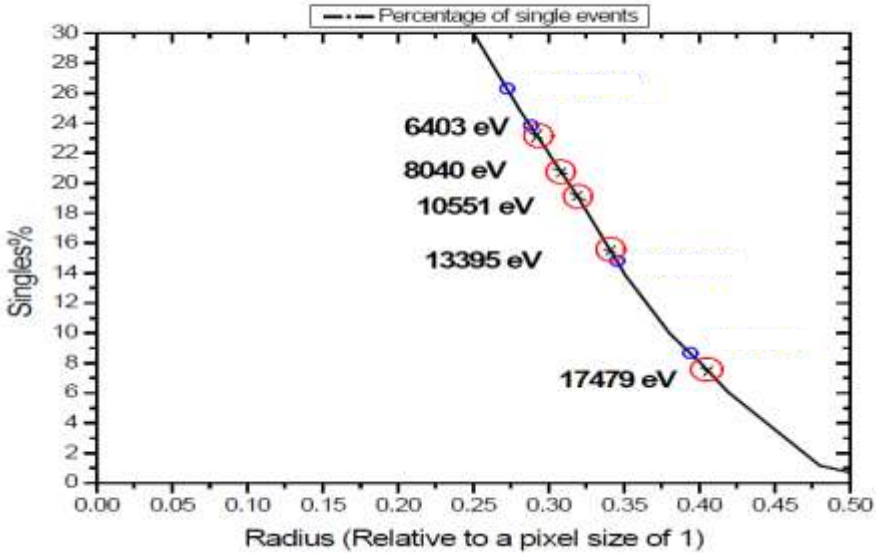


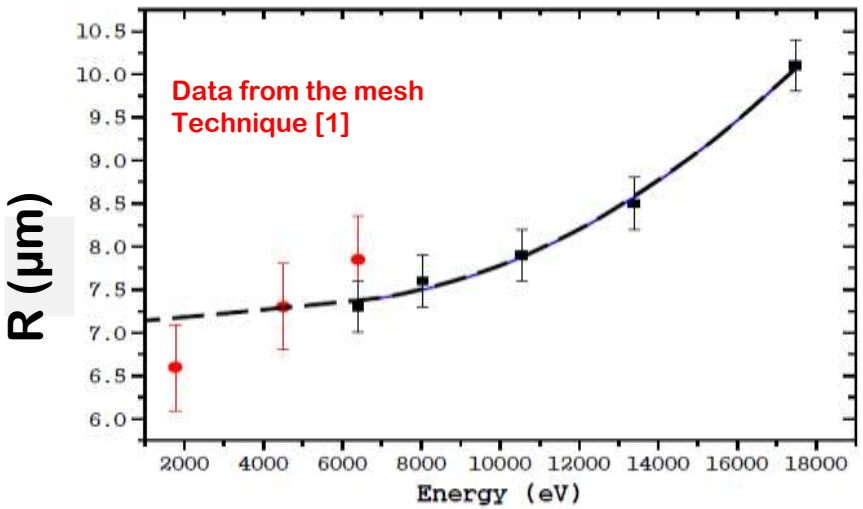
Experimental setup

Energy (eV)	S%	D%	T%	Q%
6403	23.10	52.68	12.10	12.12
8040	20.98	52.36	13.31	13.35
10551	19.27	52.28	14.55	13.89
13395	15.64	52.60	17.18	14.58
17479	7.34	53.54	23.35	15.77

Highest Sensitivity presented by single events

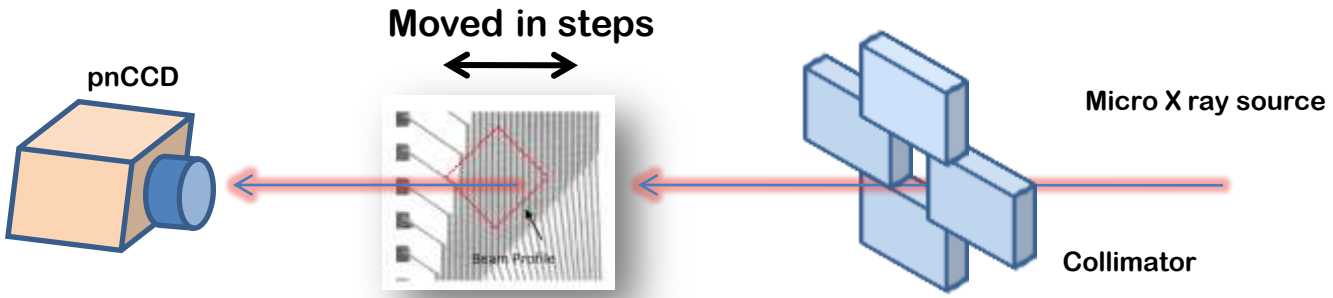
Determination of cloud size

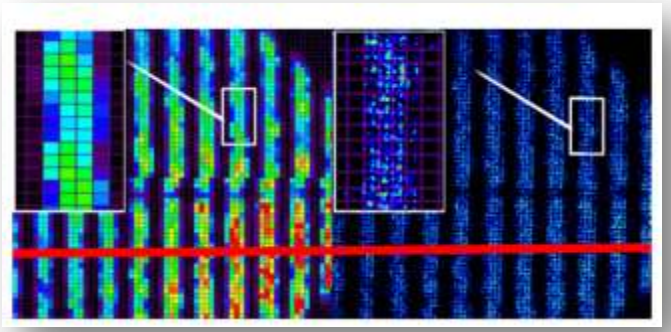


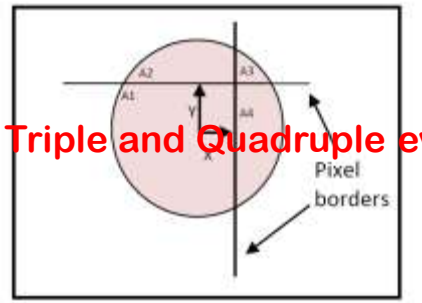


$$R = 7.77 - 1.75x10^{-4}E + 1.75x10^{-8}E^2$$

Reconstruction of an image with sub pixel resolution





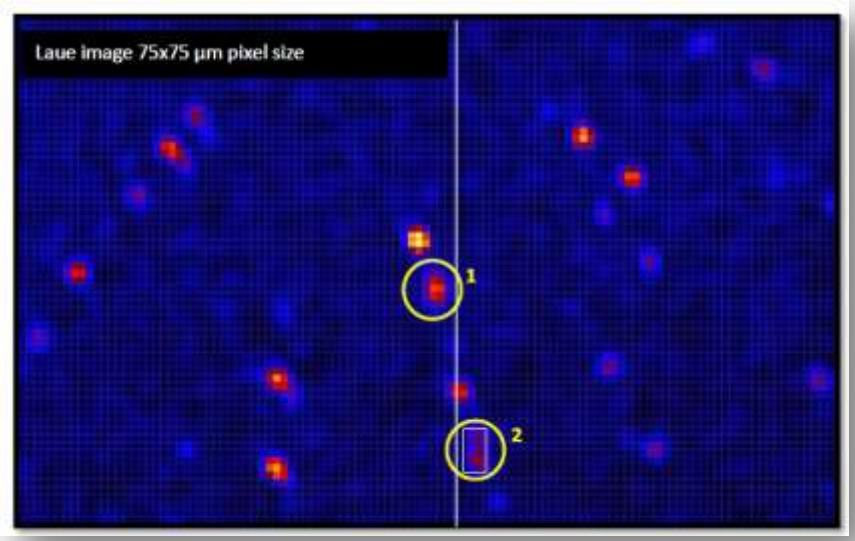


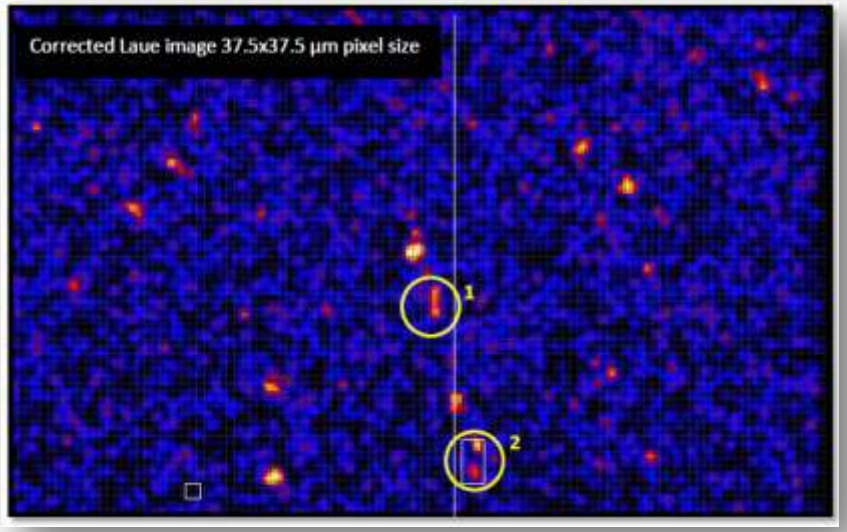
ONLY Triple and Quadruple events

Step 1	Mean	Standard deviation
5 µm±1	2,6 µm	1,2 µm
Step 2	Mean	Standard deviation
30 µm±1	24,1 µm	2,9 µm
Step 3	Mean	Standard deviation
80 µm±1	84,9 µm	3,5 µm

A sub pixel movement was detected which is within the smallest sub unit dimension if 7.5µm

Applications: Laue Spots reconstruction





Two Laue patterns from hen egg-white lysozyme. The left image is without position enhancement and the right one is 4 times position enhanced.

The spot with the circle could be an example of a two spots merging together which cannot be separated in the non corrected image, while in the corrected one we see two central spots.

Conclusion

•A new approach to measure the size of the charge clouds inside a pnCCD has been demonstrated using the percentage of single events

•Results show that the charge cloud size is between 8 µm to 12 µm depending on the photon energy [5-15keV].

•Spatial resolution of a CCD can be improved up to sub micro meter limit <1µm

•Triples and Quadruple event has been used in the restoration of real experimental data (Laue Diffraction) and the enhanced images show structural details that were not visible before.

THANK YOU FOR YOUR ATTENTION

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