Charge sharing of single photons in finely segmented pixel detectors

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**Introduction**

- Photon source are common for calibration of silicon pixel detector
- Spectrum characterized by a photoelectric peak and a low energy shoulder
- Width of the peak and shoulder size are sensitive to the non-containment effects diffusion, cross talk and photoelectric range
- purpose of this study is to understand the effects of these features and to provide a good detector simulation

\[
\sigma = \sqrt{2D\mu T}
\]

- Diffusion: charges are divided into different pixels, with a distribution of \( \sigma \)
- Cross talk: capacitive coupling between two adjacent pixels
- Range of photon electrons: partial deposit of energy

**KC53A chip and LFCPIX Demonstrator**

The KC53A demo chip is realised in BCD8 and contains 4 passive pixels and 8 active pixels (with amplifier). The pixel dimensions are 50×250 \( \mu m^2 \) and the substrate resistivity is 125 \( \Omega \) cm. Passive pixels have been characterized.

Each pixel shows an injection capacitance with a nominal value of 2 fF. Matrix of 36×158 pixel, 2 prototypes LFCPIXv1/2 (results from 2).

**LFCPIX simulation: diffusion and photoelectron range**

A single monochromatic peak varied between 10 and 60 keV. Depletion voltage is at 160 V with a noise fixed at 50 electrons.

Charge motion is simulated inside the material, charge division on pixels. It is assumed a linear electric field and a cross talk between close pixels.

**LFCPIX Experimental measurements**

For each run one day of data taking, LFCPIXv1 limited in range because of a limit in the breakdown voltage:

- Peak as a superposition of contained/not contained events
- Data shape in agreement with simulation
- Photoelectric peak not described by this simplified model

**HVR-CMOS sensors**

HV CMOS sensors features high voltage and low voltage electronics on the same chip. CMOS circuitry (preamplifier, comparator…) is separated from the HV substrate with an N well. They can be capacitively coupled to the FE chip, instead of being bump bonded.

The inverse polarization voltage creates a depletion region which increases the probability that a particle interacts. This is the sensible zone of the detector.

**GEANT4 Simulation**

Simulation to understand the non-containment effects

Simulation of the interaction:
- Definition of the source of radiation: monochromatic photon source
- Definition of the geometry of the detector: 250 \( \mu m \) Si, source material
- Digitalization (charge collection):
  - Definition of the electrodes size and their distance and their cross talk
  - Implementation of the characteristics of the detector, as temperature, type (n or p), geometry, material and inverse polarization
  - Calculation of the electric field and diffusion
  - Conversion of energy in number of electron-hole pairs
  - Determination of the number of involved pixels and their collected charge

**KC53A Simulation**

\( K_{\alpha} \) and \( K_{\beta} \) of Copper and Yttrium analyzed. Plots: \( Y (14.8, 16.7 \text{ keV}) \)

- \( \mu \) for contained events: 4.11±0.03 mm\(^{-1}\) > total absorption coefficient \( \mu = 2.51 \text{ mm}\(^{-1}\) \)
- Most photoelectrics conversion far from surface are dispersed by diffusion

**KC53A Experimental measurements**

X rays (50 keV on a molybdenum anode), different bias voltage scanning different depletion widths

- Good agreement in shape between data and simulation
- Simulation underestimates absolute size of diffusion effects

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