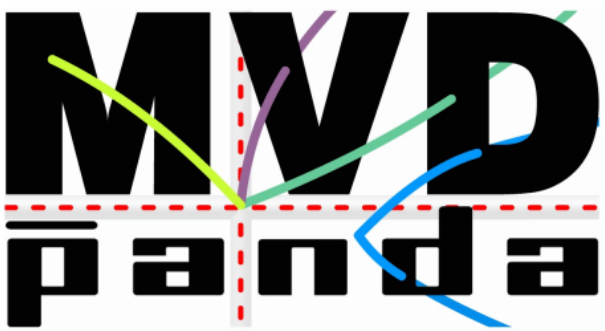
Status of Silicon strip sensor characterisation

Lars Ackermann

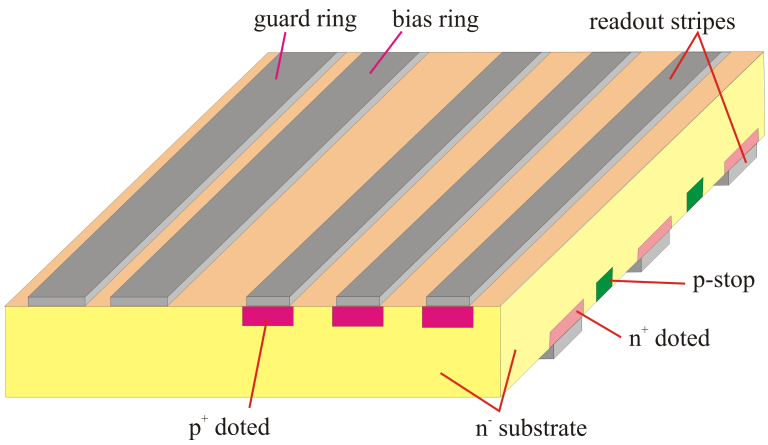
TU Dresden, Germany

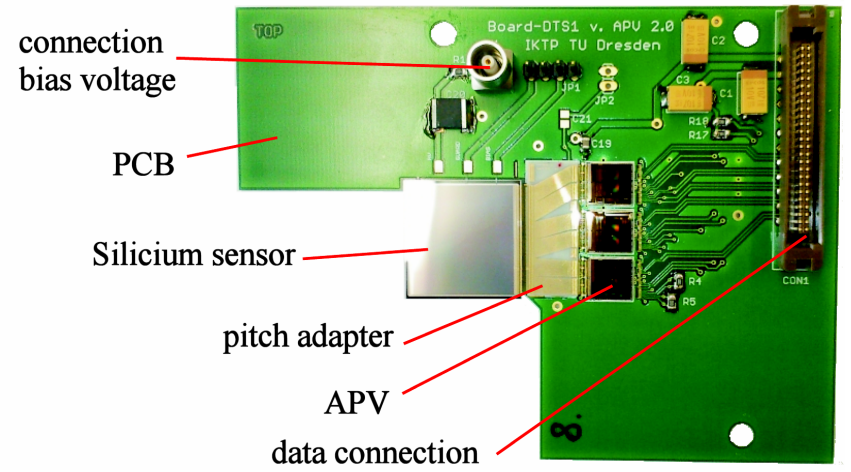


XXX PANDA Meeting, Jülich, September 8, 2009

Outline

The Silicon strip sensor



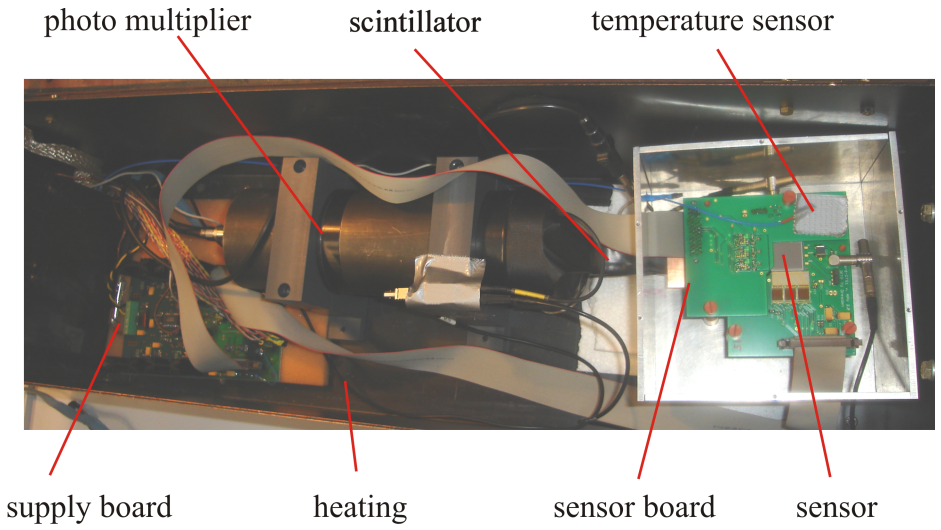


sensor specifications

thickness	300.0	μm
length	2.082	*cm*
width	2.082	*cm*
pitch p-side	50.0	μm
pitch n-side	50.0	μm
stereo angle	90.0	*degree*
channels per side	385	
channels per APV	128	

information about modules

- APV not self triggering
- every 64nd channel unbonded
- sensor not radiation hard
- producer of chips *itc irst*



Inside the test station

- stable place holders of the sensor board(s) to position radioactive sources
- scintillator to trigger on events
- heating to characterise the modules at different temperatures
- characterisation scans as well as measurements possible
- quick change of boards and radioactive sources possible

The first steps with the sensor

- quality check of the sensor
- find the optimal working point of the sensor
- get parameters to switch to physical units

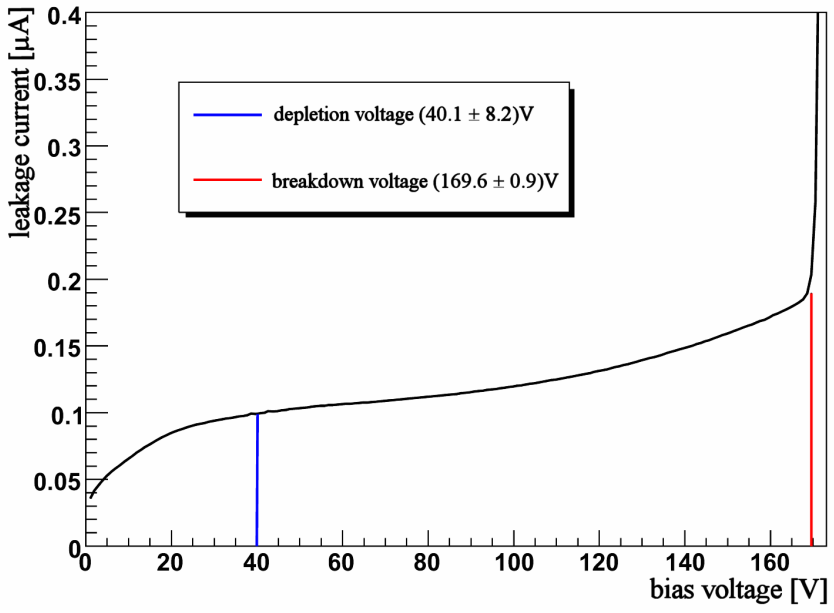
  e.g. converting ADC values to electrons of the deposit energy
- plateau until breakdown

Aims of the leakage current scan

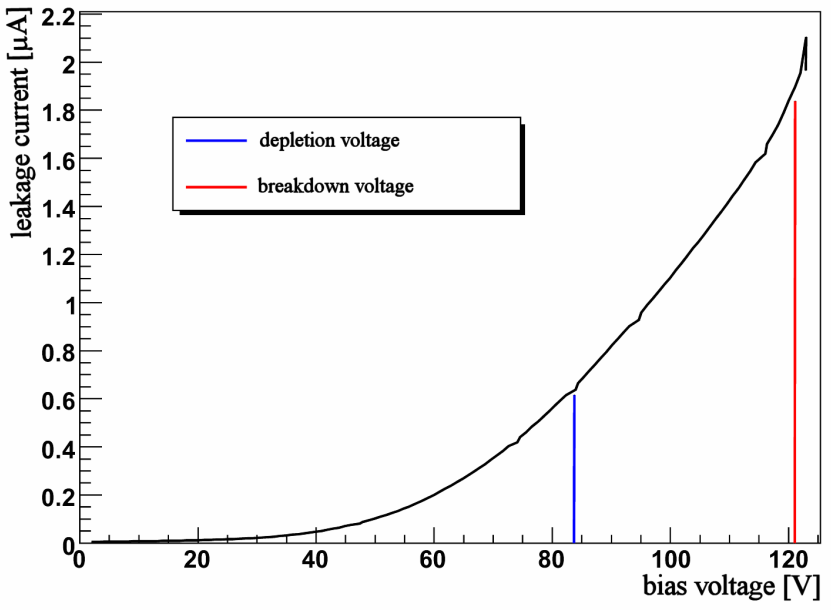
- quality check of the sensor
- depletion and breakdown voltage
- until depletion voltage rising leakage current
  $I_{lc} \propto \sqrt{V_{bias}}$
- plateau until breakdown

Leakage current scan

single sided readout module 15



double sided readout module 24



Results

- for single sided readout modules known operation voltage
- no information for the double sided read out

→ leakage current behavior not understood

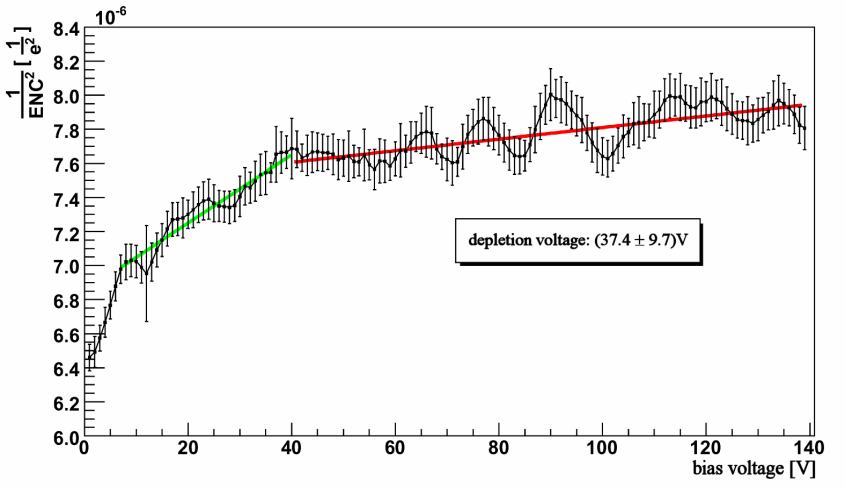
Aims of the noise scan

- quality check of the sensor noise
- depletion voltage
- until depletion voltage rising noise
- noise proportional to capacitance of sensor

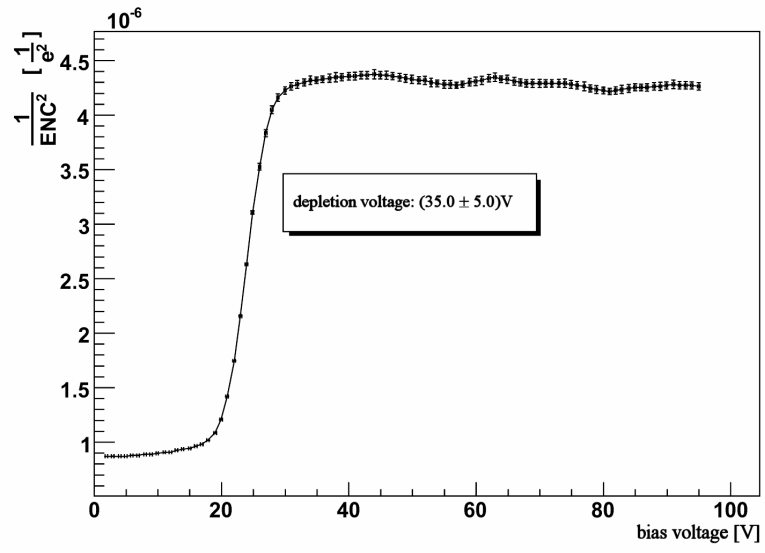
$$C \propto \frac{1}{\sqrt{V_{bias}}}$$

Noise scan

single sided readout module 15



double sided readout module 24



Results

- stable noise after full depletion
- depletion voltage found for both modules

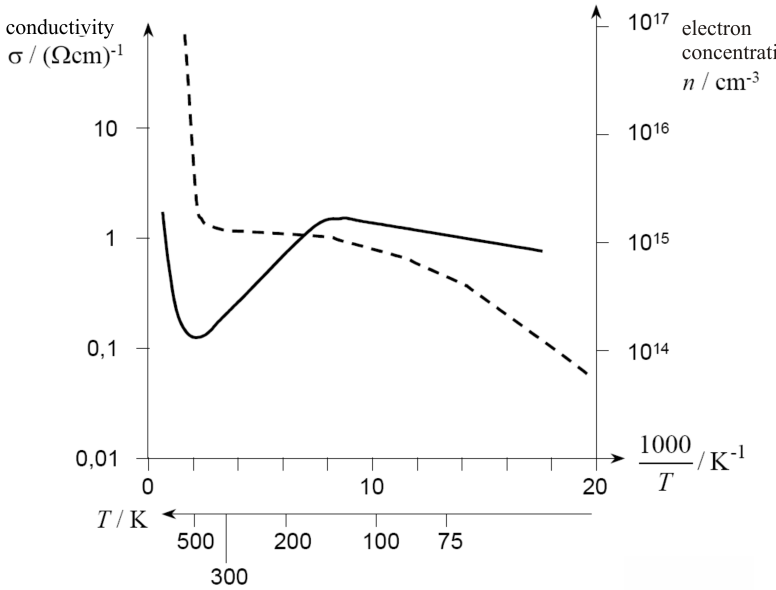
→ working voltage also known for double sided readout module

Temperature influence

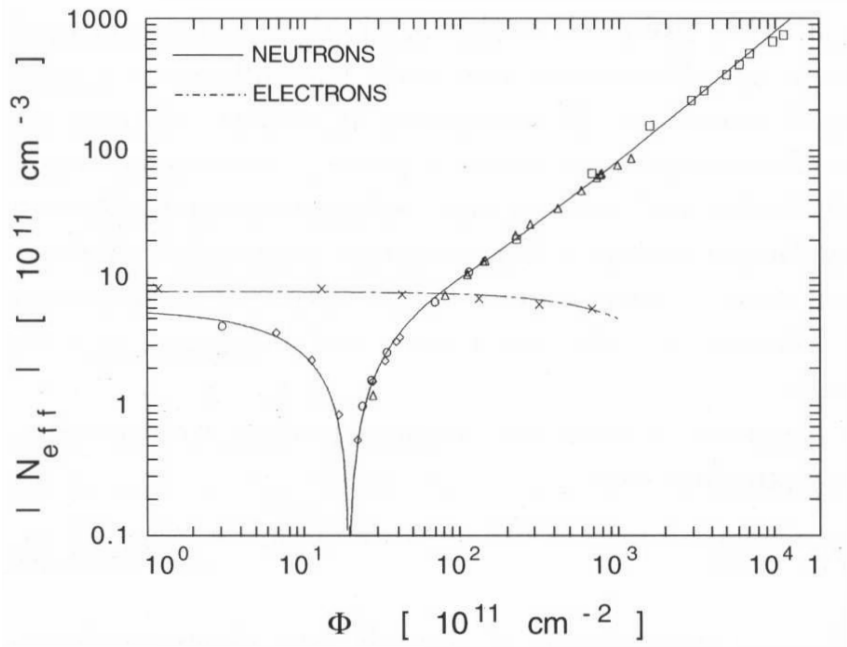
- influence on the sensor
- influence on the electronics

Radiation damages

- changing the structure of atomic lattice
- at high fluencies type inverting



Frank Thuselt "Physik der Halbleiterbauelemente"

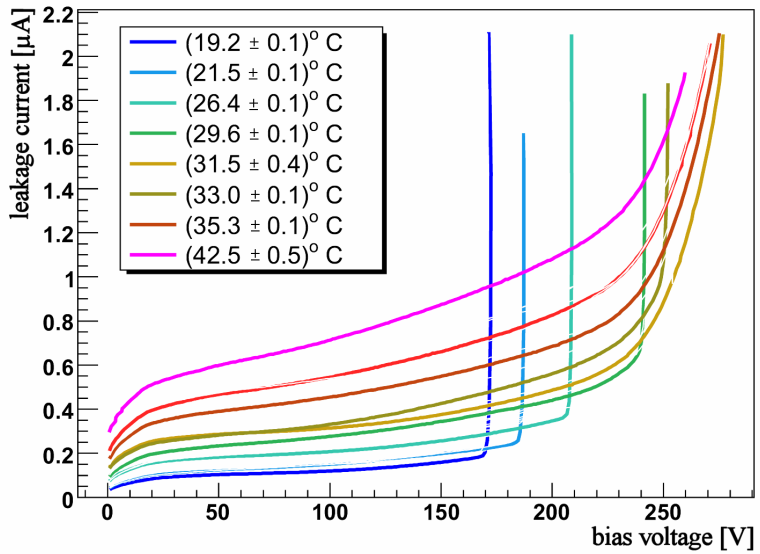


Gerhard Lutz "Semiconductor Radiation Detectors"

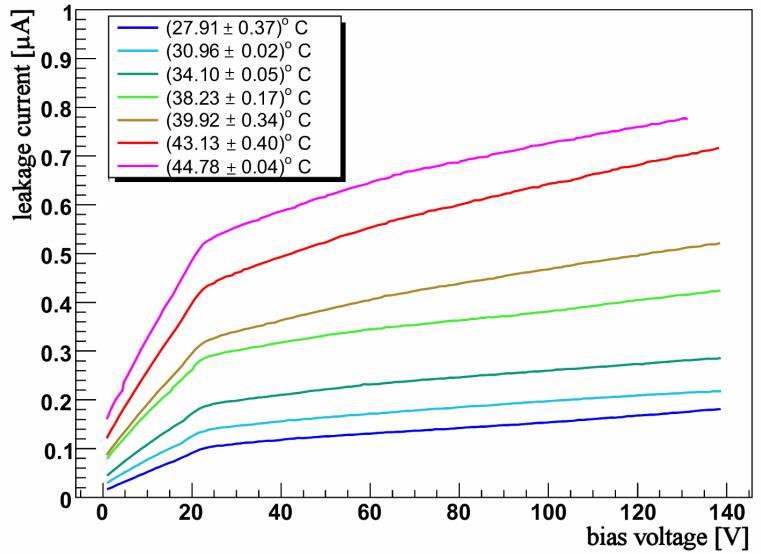
Temperature Scan results

- breakdown and plateau mix with higher temperature
- depletion voltage not temperature dependent

Module 3



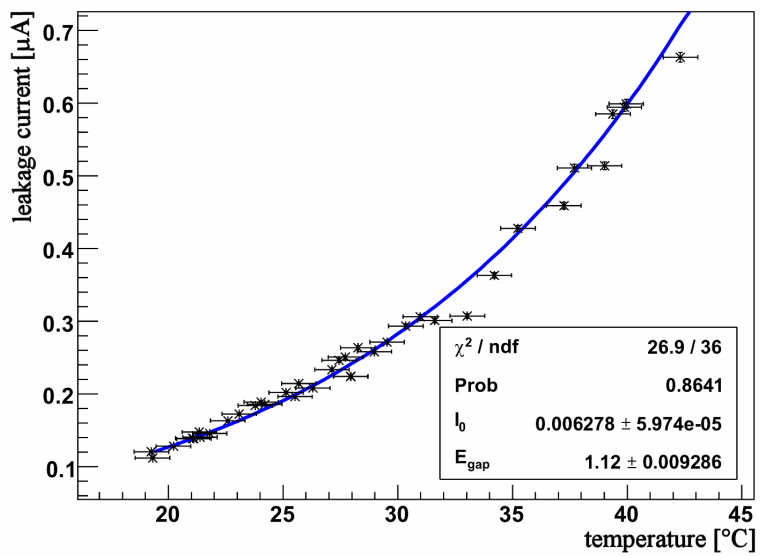
Module 16



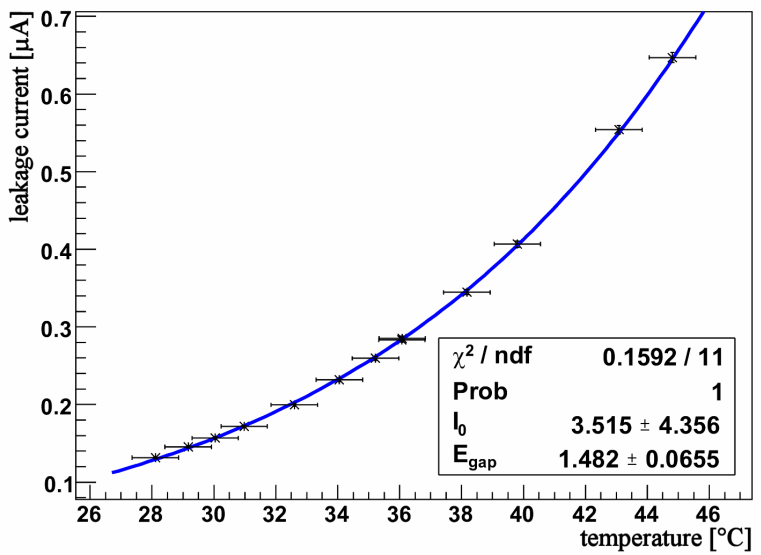
Getting energy gap

- Energy gap from temperature scan
- parameterize with $I_{LC} = I_0 \cdot T^2 \cdot e^{-\frac{E_{gap}}{2 \cdot k_B \cdot T}}$
- near the value of $E_{gap} = 1.12\,eV$ from literature

Module 3 at 80V

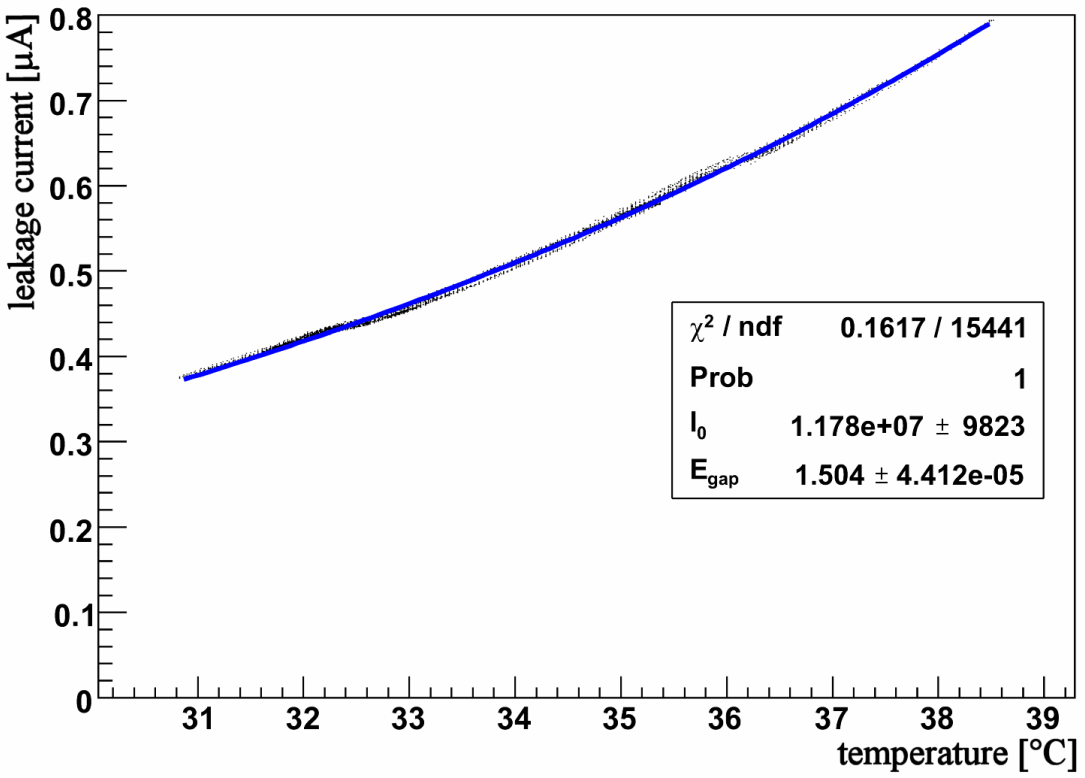


Module 16 at 60V



After long time measurement

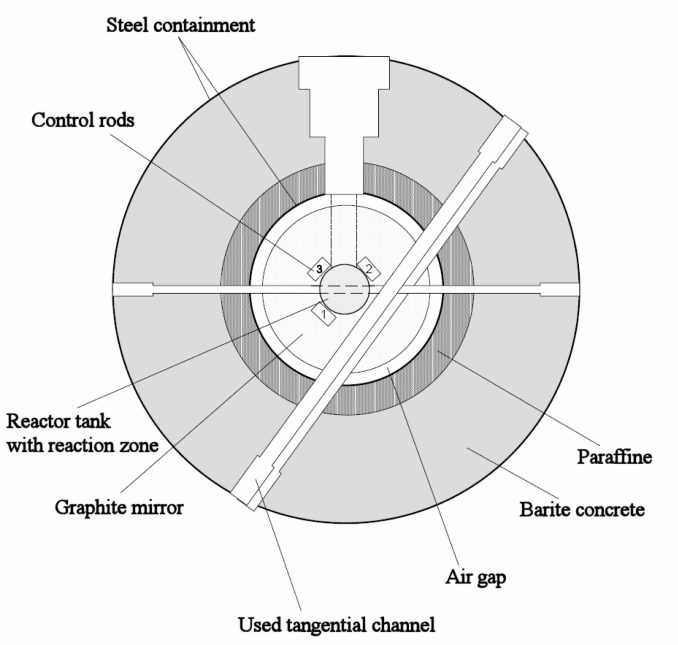
- behavior during a five weeks measurement
- module 15 and 16 were used
- parameterize with $I_{LC} = I_0 \cdot T^2 \cdot e^{-\frac{E_{gap}}{2 \cdot k_B \cdot T}}$



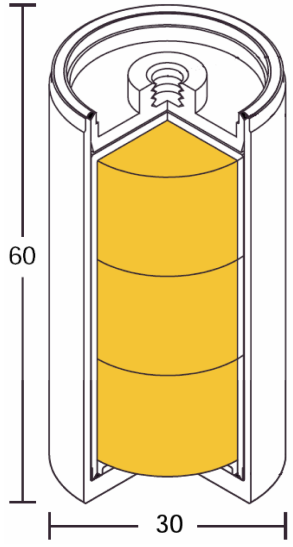
neutron radiation sources

- Low power educational reactor of the TU Dresden
- Americium-241/Beryllium source
- breaks between irradiation to scan leakage current

reactor cross section



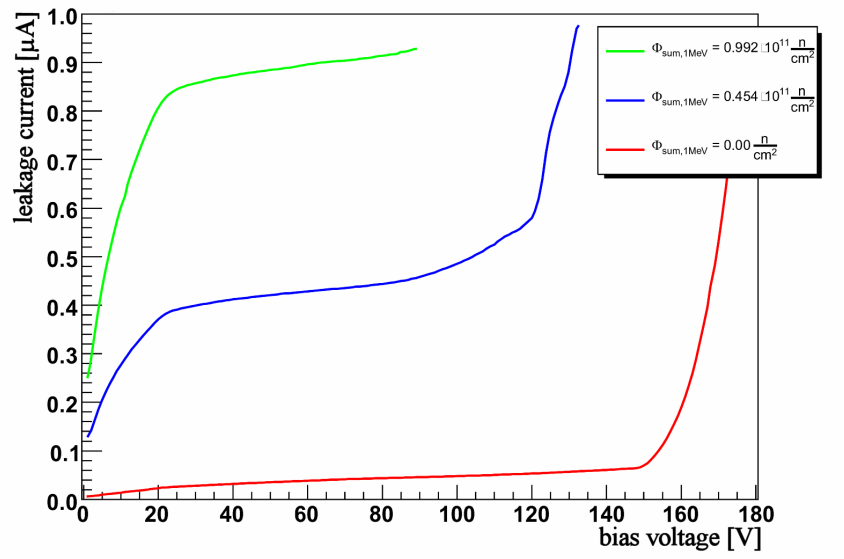
radioactive source



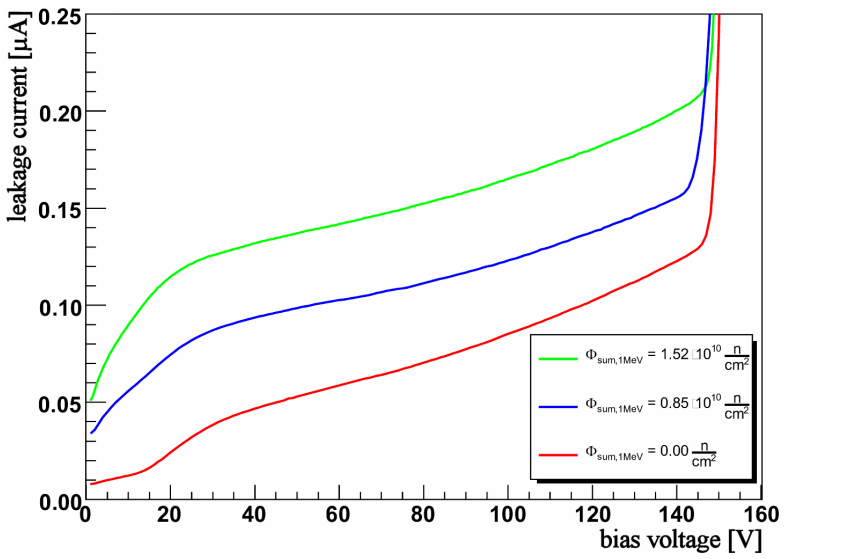
Behavior of leakage current

- fluence calculated to 1 MeV neutron equivalent
- depletion voltage shows no significant shift

reactor module



source module



The differential volume current

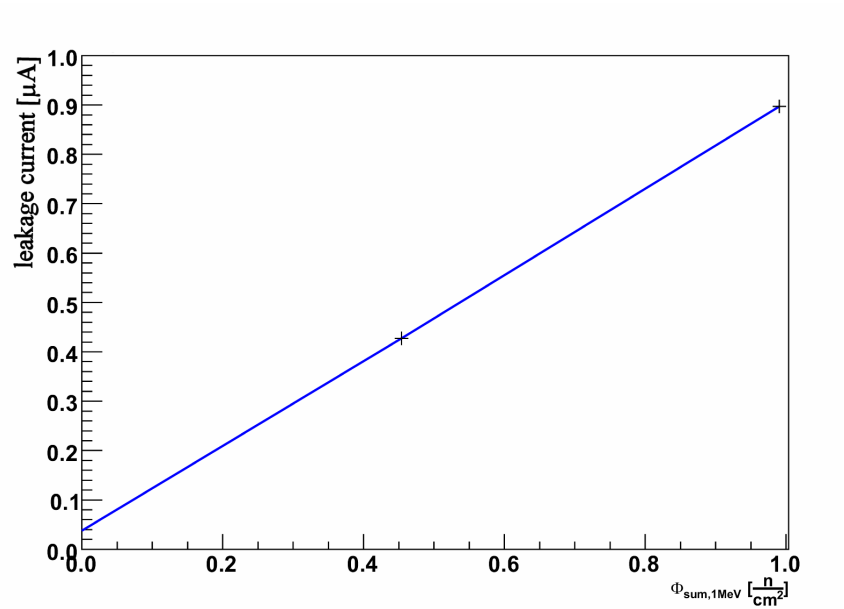
- linear parameterisation of the volume current

$$\frac{\Delta I_{Vol}}{V} = \alpha \cdot \Phi \qquad \text{with } \alpha = 8.0 \cdot 10^{-17} \frac{A}{cm}$$

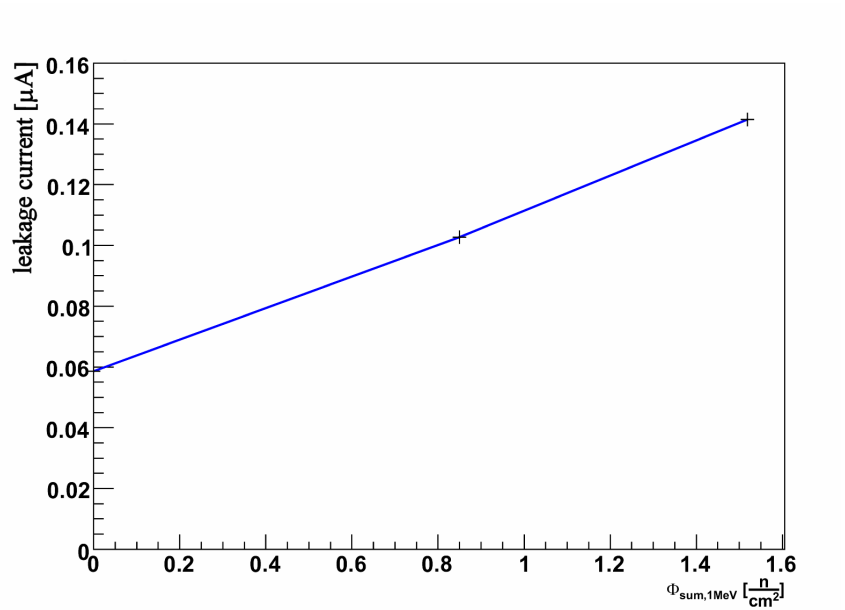
(Gerhard Lutz "Semiconductor Radiation Detectors")

- measurement in the same order of magnitude, but very low statistic

reactor module



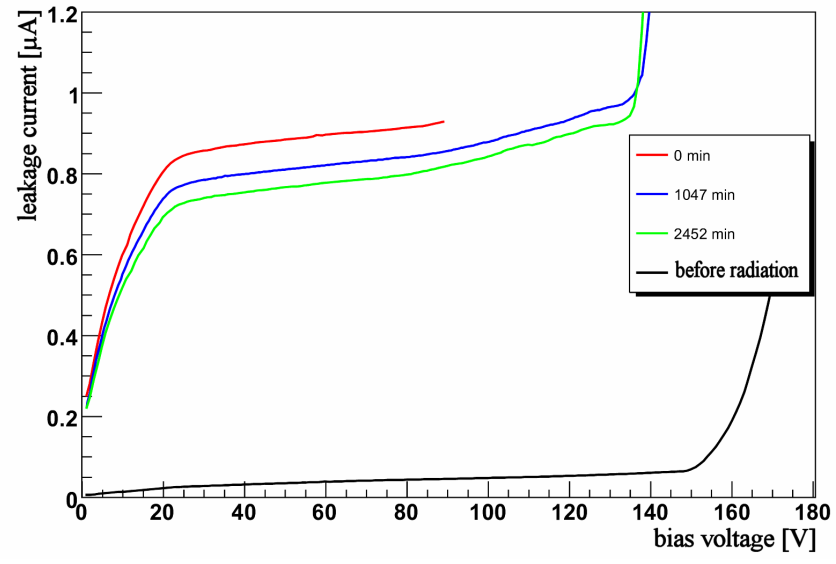
source module



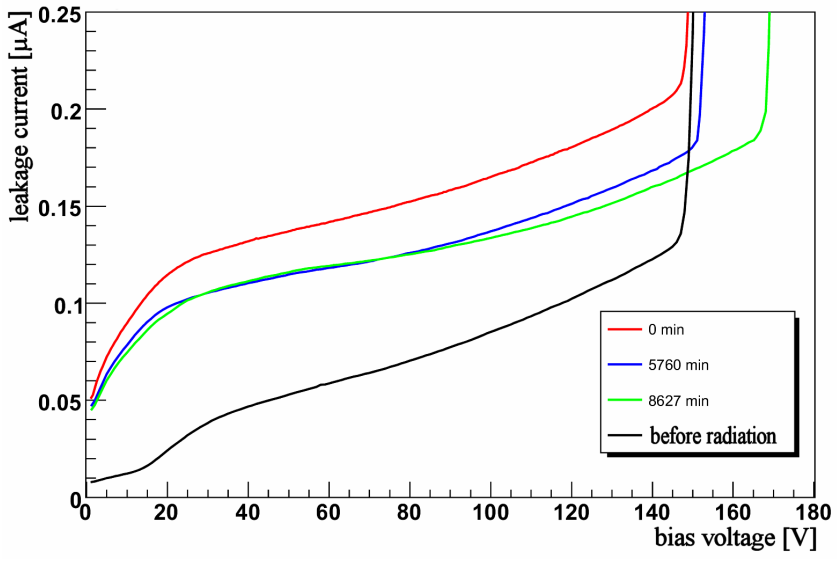
Annealing effects after irradiation

- back drifting caused by thermal movement
- activating electrically inactive effects
- temperature dependent

reactor module



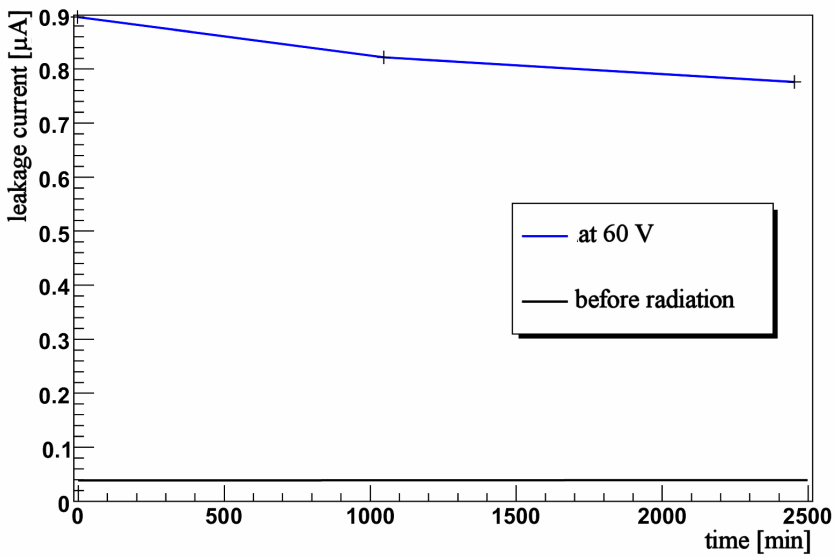
source module



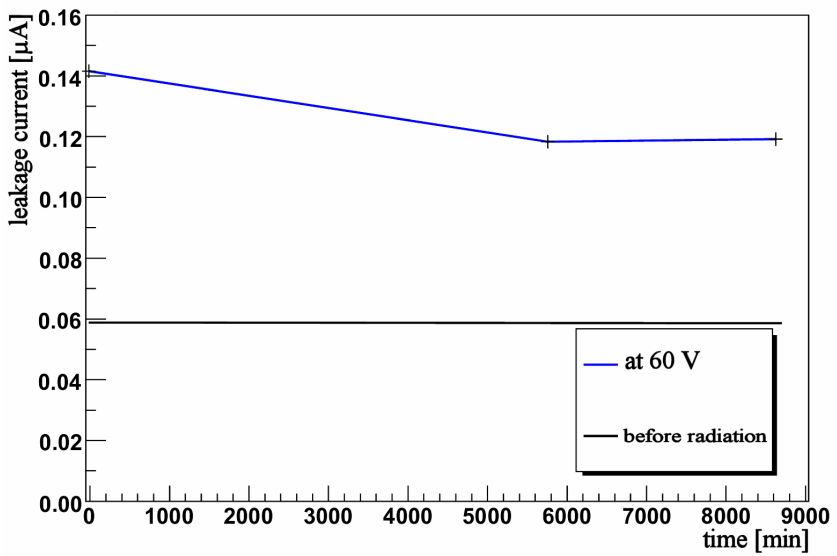
Annealing effects after irradiation

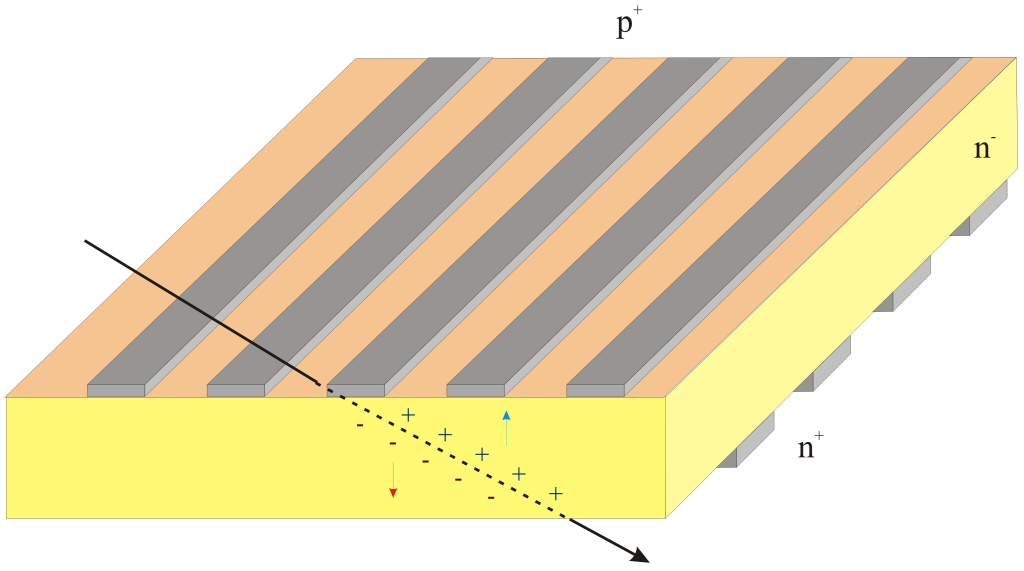
- reactor module got damaged during measurement
- source module anneals very fast

reactor module



source module





Aims of the detector

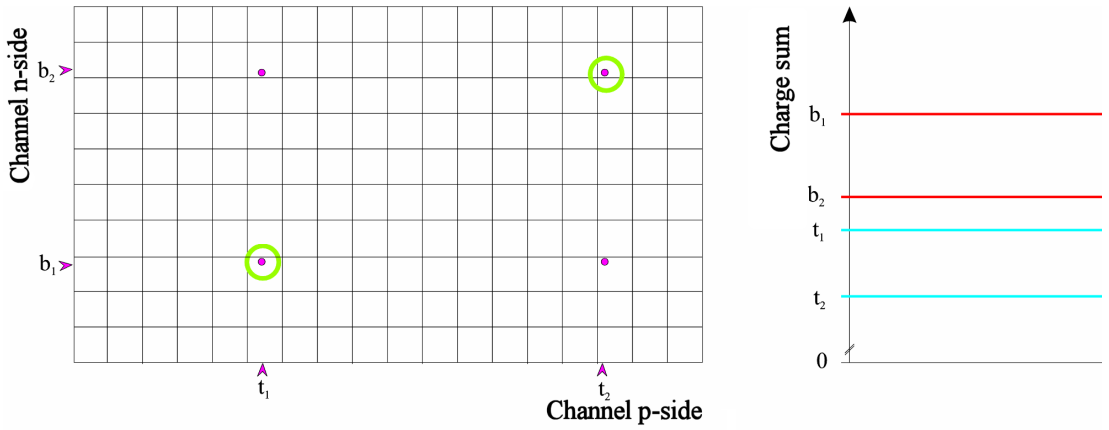
- crossing charged particle causes charge cloud in sensor

↪ detect all electron hole pairs

→ reconstruct interaction point

→ reconstruct energy loss

Hit Finder



Reconstruction problem

- merge the appropriate clusters from n and p side

↪ no individual cells causes ghost hits

→ find clusters with nearly same charge sum

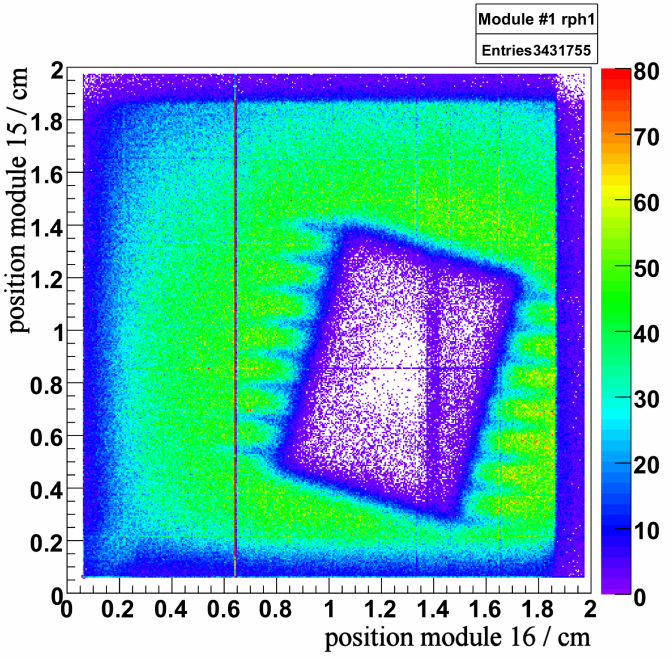
→ finding optimal combination with all hit candidates

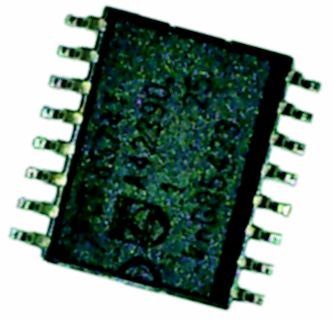
↪ get Likelihood value for every combination from charge differences of all hit candidates

Reconstruction results

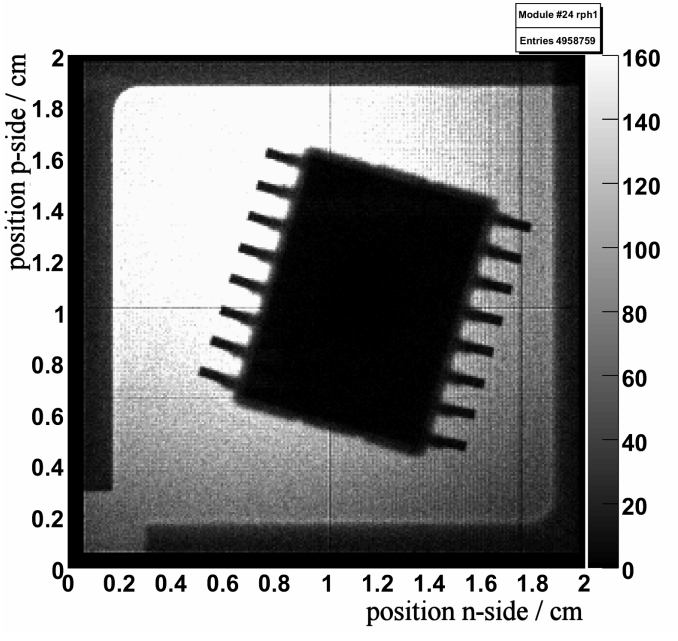
- measurement with an SOIC as object
- single sided readout with two modules causes multi scattering
- reconstruction algorithms work fine

single sided readout with module 15 and 16





double sided readout with module 24

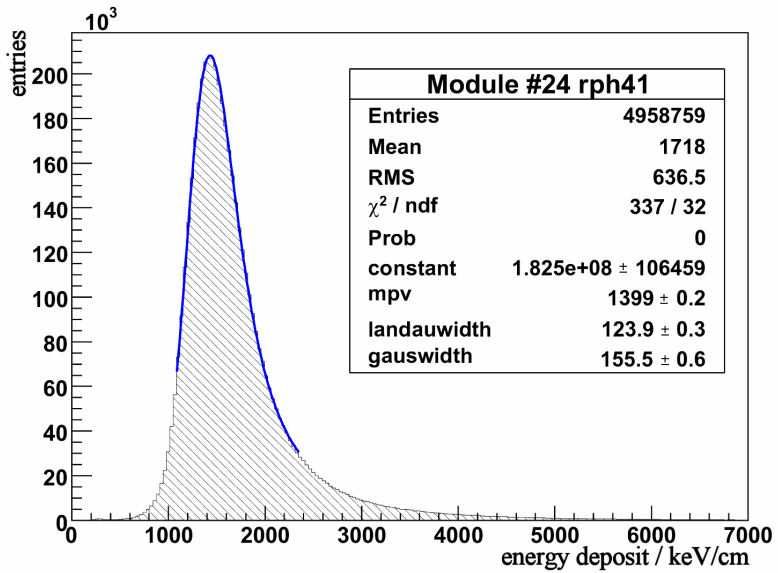


Energy loss and energy correlation

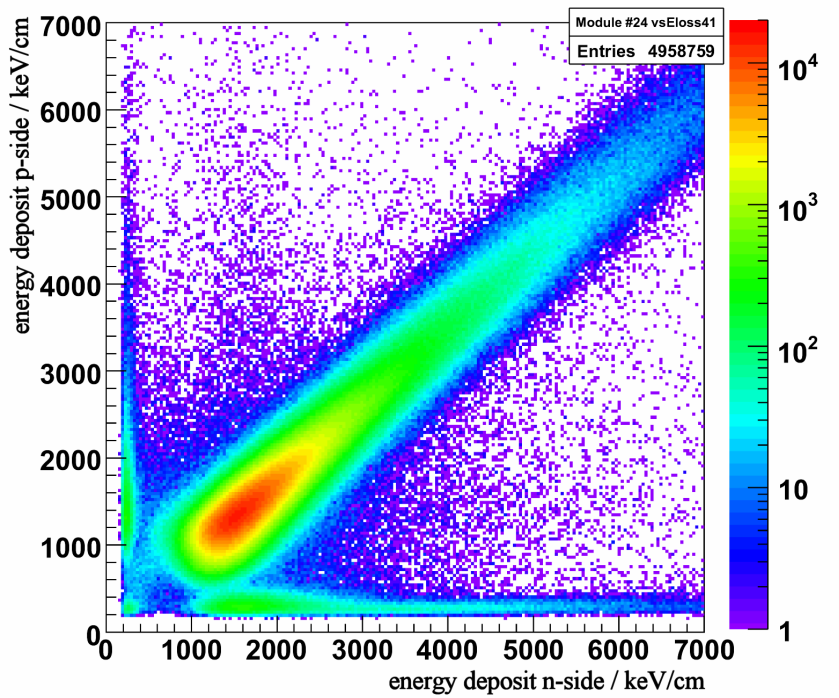
- energy loss fitted with function of GAUSS and LANDAU functions
- correlation show hit misidentifications
- mobility of holes lower than for electrons

→ difference is a factor of 0.87

energy loss



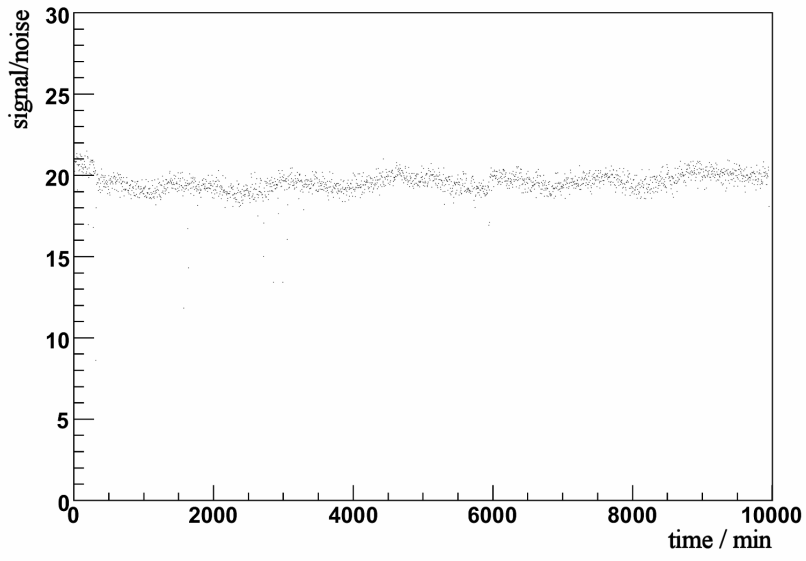
energy loss correlation



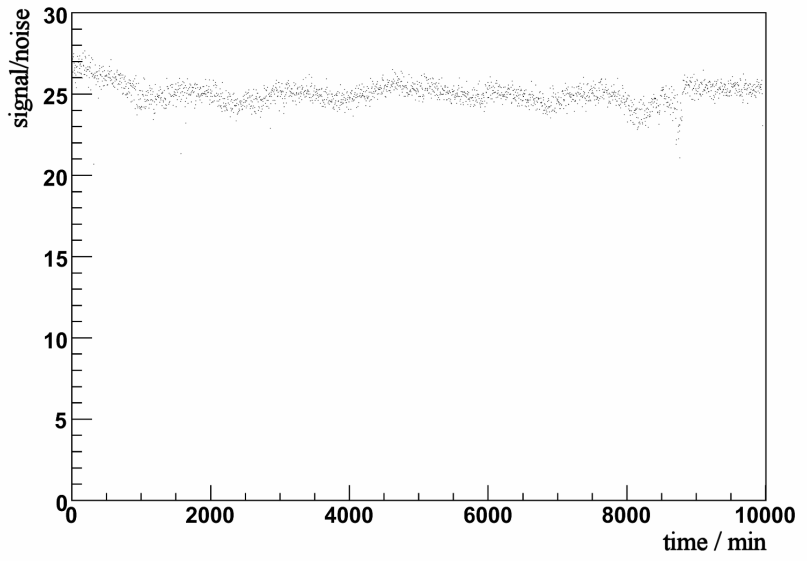
Noise during measurement

- signal to noise ratio p-side (25.0 ± 0.9)
- signal to noise ratio n-side (19.6 ± 0.8)
- caused by different mobility of the charge carriers

n-side



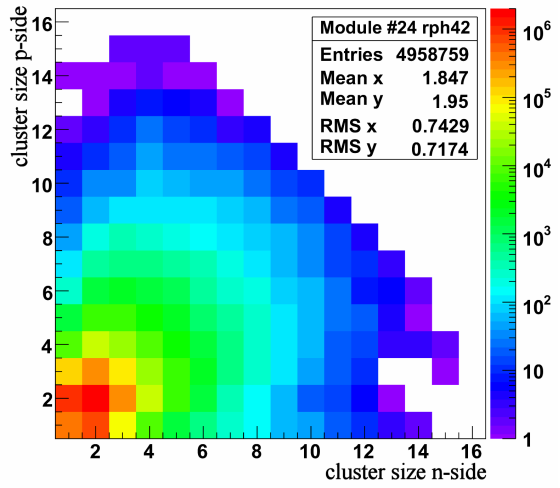
p-side

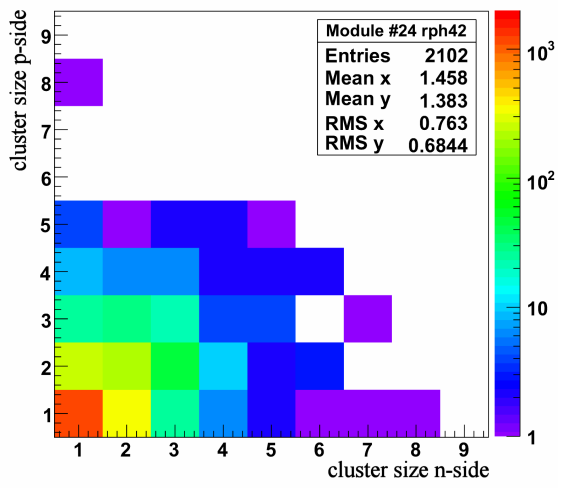


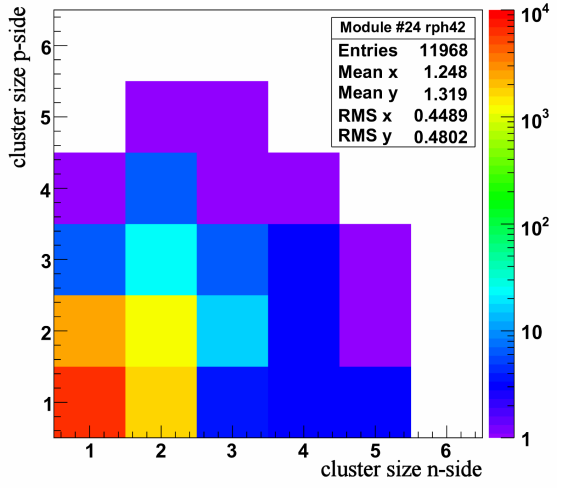
Different cluster sizes

- depending on energy and particle
- Strontium-90 electrons causes multi scattering
- photons activate mainly one strip

Strontium-90 Cosmic Americium-241





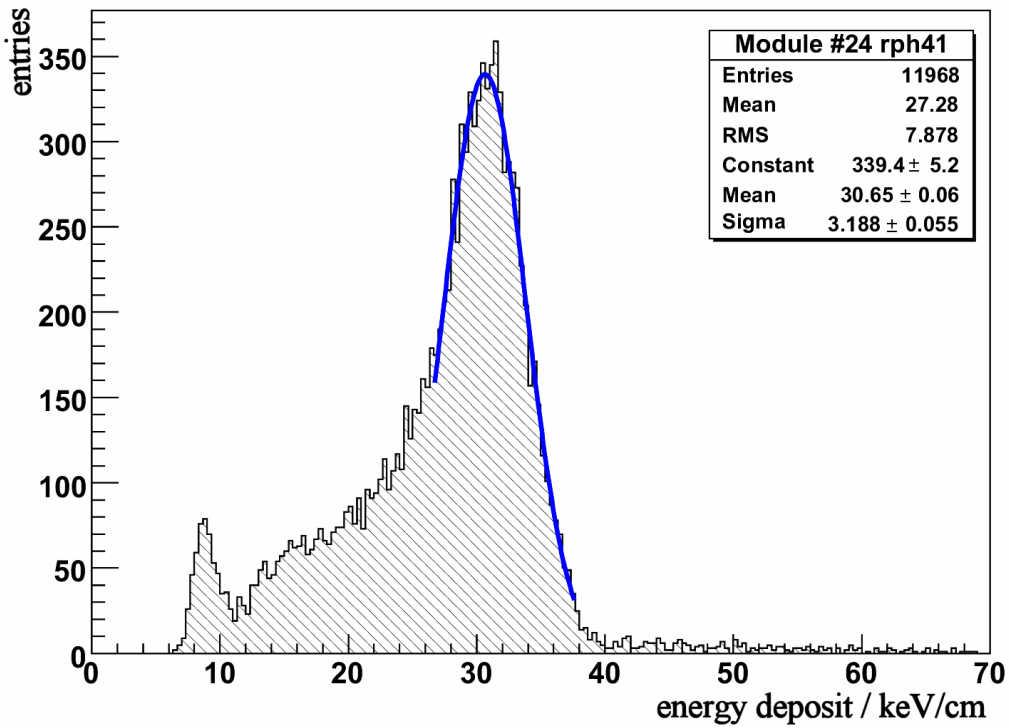


Error in the calibration

- mean of energy loss too low
- measuring photon energy spectrum of Americium-241

→ 59.54 *keV* photon energy

- factor of 2 gives the right energy deposit



Simulation of electrons exposition

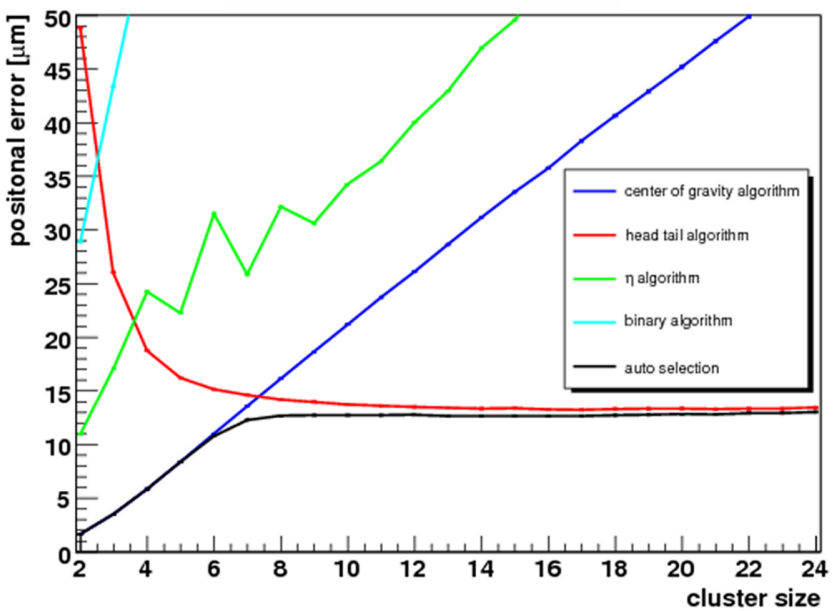
- Simulation with Geant4 by using Panda Root
- electron energy of $E_{Kin,e^-} = (30.0 \pm 5.0)\,MeV$
- simulated noise of 2000 electrons

Simulation results

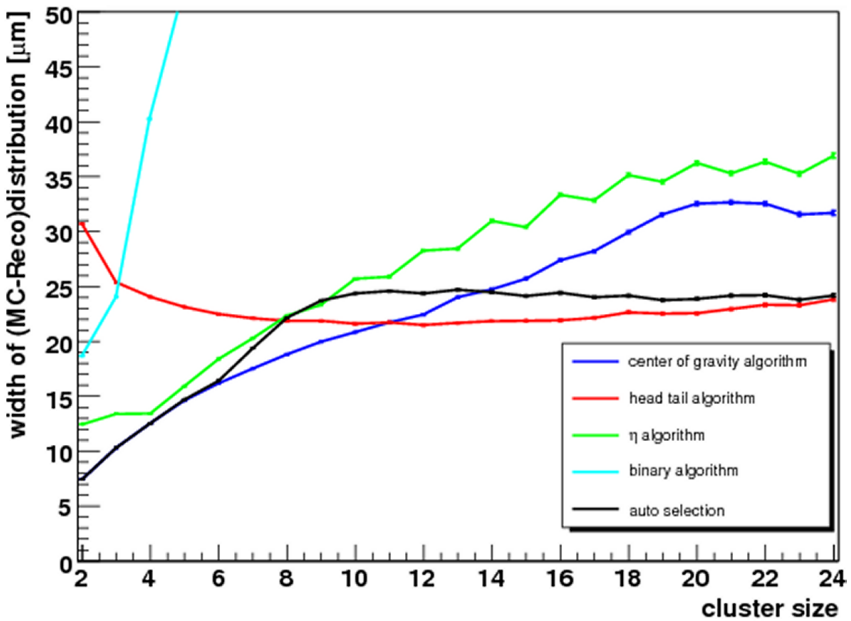
- resolution below the half of strip pitch
- bad values for binary and η algorithms

$\rightarrow$ η algorithm better for sensors with unbonded strips

Algorithm accuracy



Algorithm comparisom



Summary

- characterisation of sensor modules possible
- first tests with double sided readout modules
- temperature behavior is understood
- first experience with behavior during irradiation
- reconstruction algorithm for hits working fine
- found error in calibration by using photon sources

Outlook

- gain experience with double sided readout modules
- measurements during irradiating, especially to understand signal behavior
- tracking station for working with more modules and test tracking algorithms
- fix parameters for new sensors
- implement preprocessing to FPGA