CERN Summer Student 2010

Student Sessions, August 17th 2010

Sensor R&D for ATLAS-IBL and sLHC

Student

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Supervisors

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Overview

Aim of the project

Characterization of 3D/FBK Silicon Pixel detectors

Thematics

Interaction of radiation and particles with matter, silicon detector properties, lab characterization, irradiation induced effects

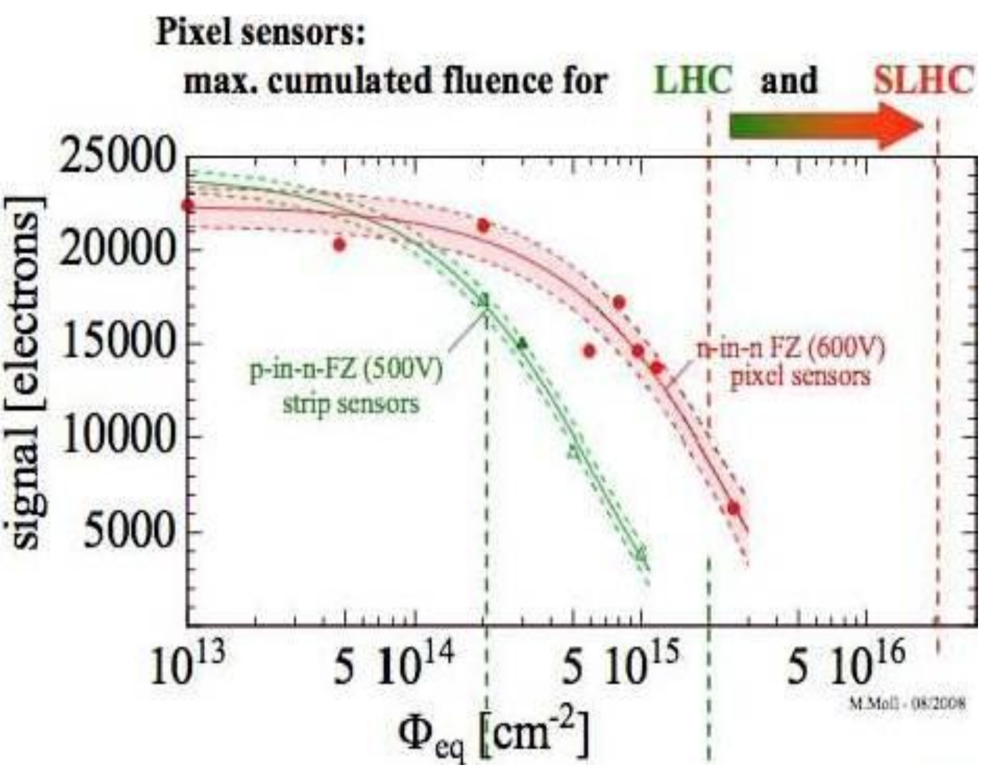
Work

Study of ATLAS Pixel front-end chip (FE-I3), FE tuning and calibration, sensor source-tests and automatization of the measurements, testbeam data taking

This project has been supported by CERN ATLAS Team (CAT) and PH-DT in the framework of White-Paper/ WP4 Rad Hard Detectors studies

https://twiki.cern.ch/twiki/bin/view/Main/CernAtlasPixelSensorsRD

Motivation for radiation-hard detectors



sLHC versus LHC

higher radiation level

-> higher radiation tolerance needed

higher multiplicity

-> higher granularity needed

sensor issues

increase of full depletion voltage

-> limited by maximum operation voltage

increase of leakage current

-> sensor dissipates significant power

charge trapping

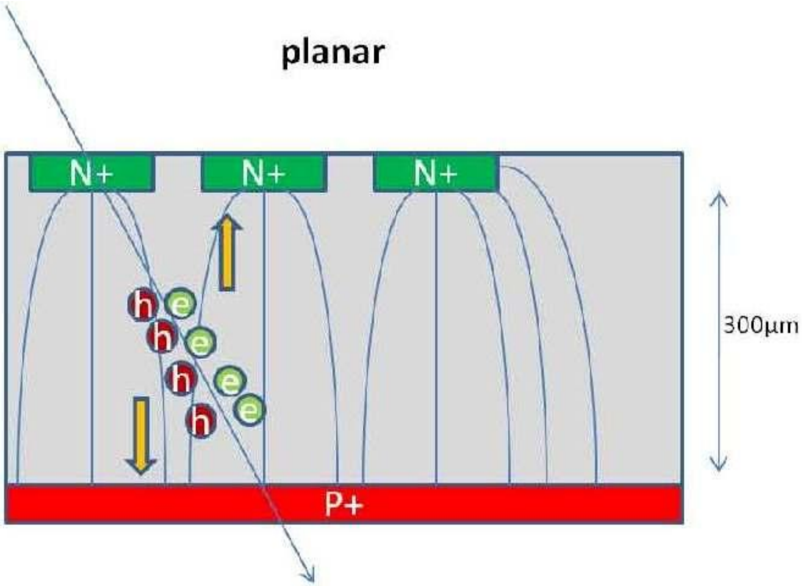
-> smaller signal after irradiation

-> R & D is needed

Two geometries for Silicon pixel detectors

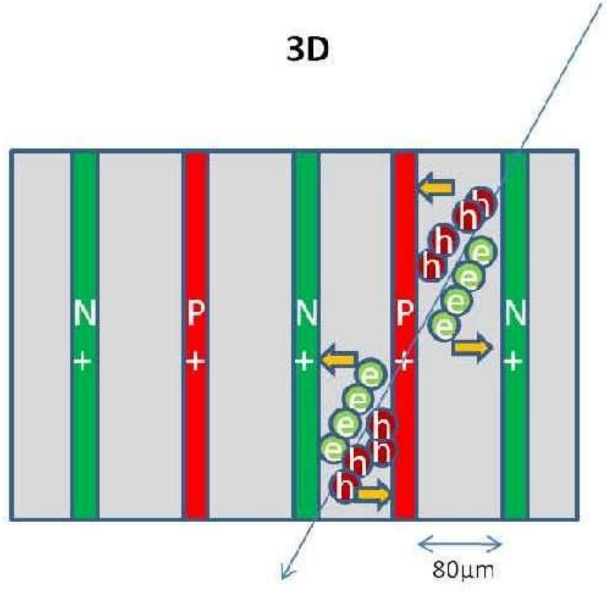
planar sensors

- well known technology
- high availability
- (high) depletion voltage
- new n-in-n and n-in-p technology



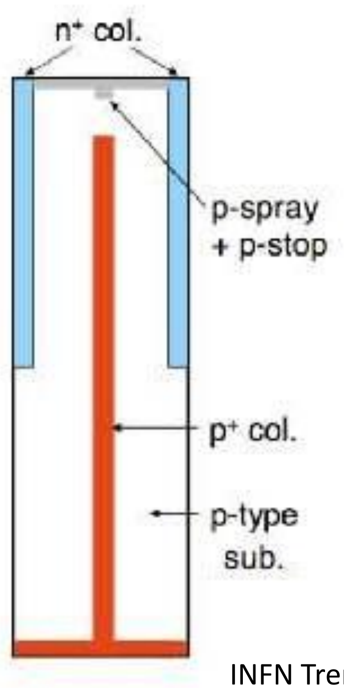
3D silicon sensor

- decoupling of substrate thickness from electrode distance
- low depletion voltage, larger active area
- smaller trapping probability
- fast signal collection
- larger capacitance
- reliable production (yield)



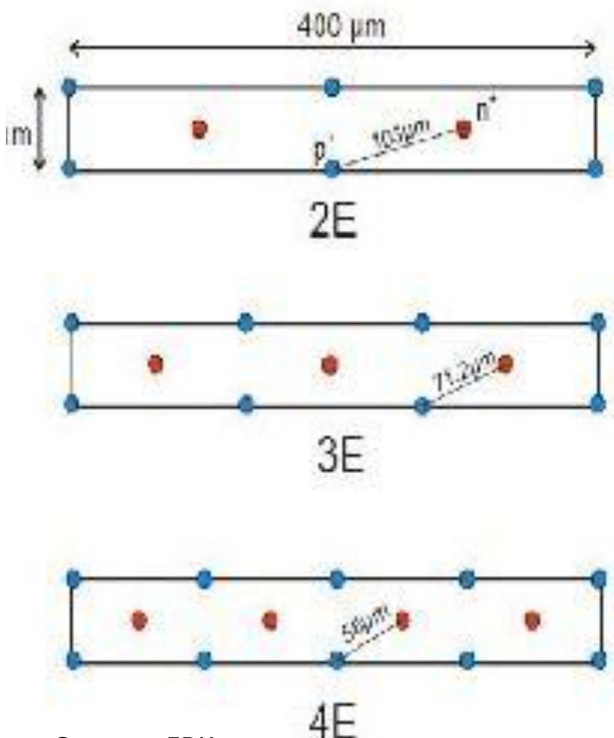
More about 3D sensors

- double side double type column



INFN Trento, Genova, FBK

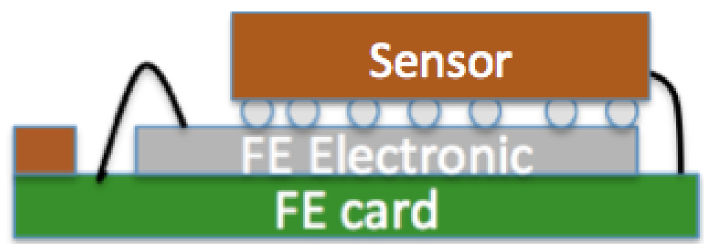
- three different electrode distances



- some properties

Substrate thickness	200 µm
Overlap	95 µm
Full depletion voltage	12 V
Breakdown voltage	70 V

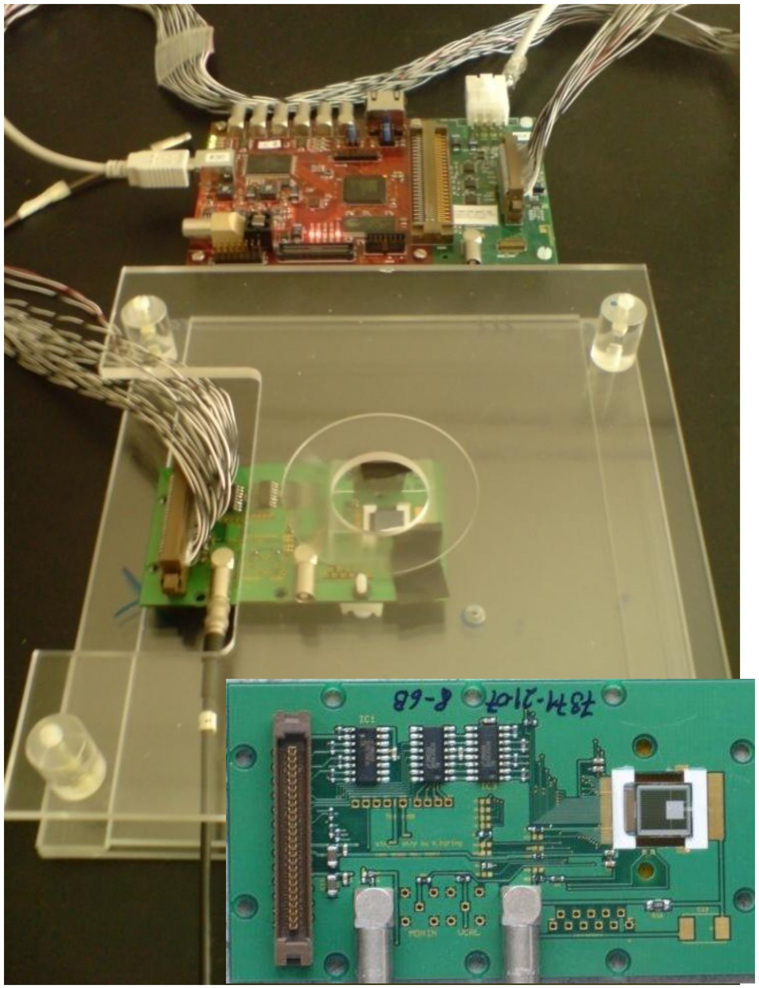
- connection sensor-frontend



sensor size 400 µm x 50 µm

Experimental Setup

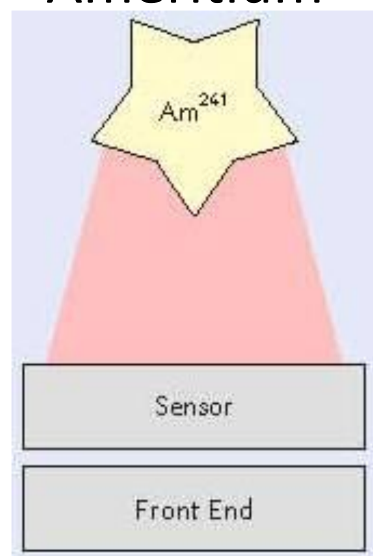
DAQ based on ATLAS Pixel USBPix set-up



advantages

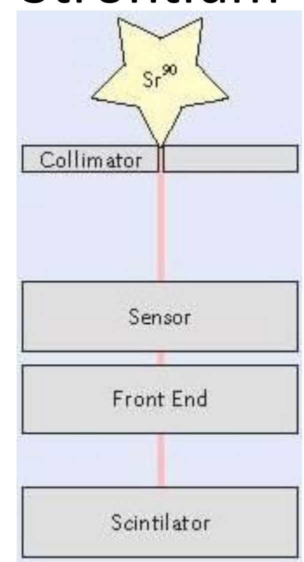
- no changing in relative positions
- source is placed directly above the sensor

Ameritium



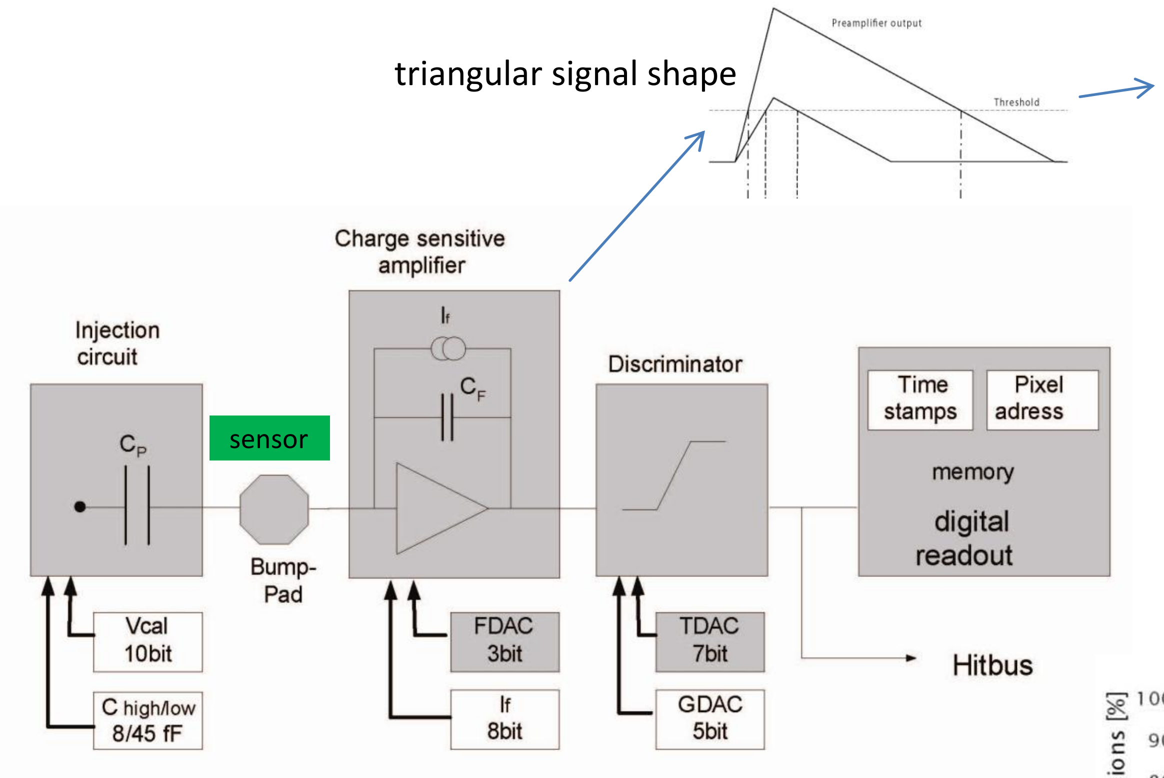
Photon E=59.9 keV

Strontium



Electron E=546 keV

Front-End electronics and evaluation methods



- ToT

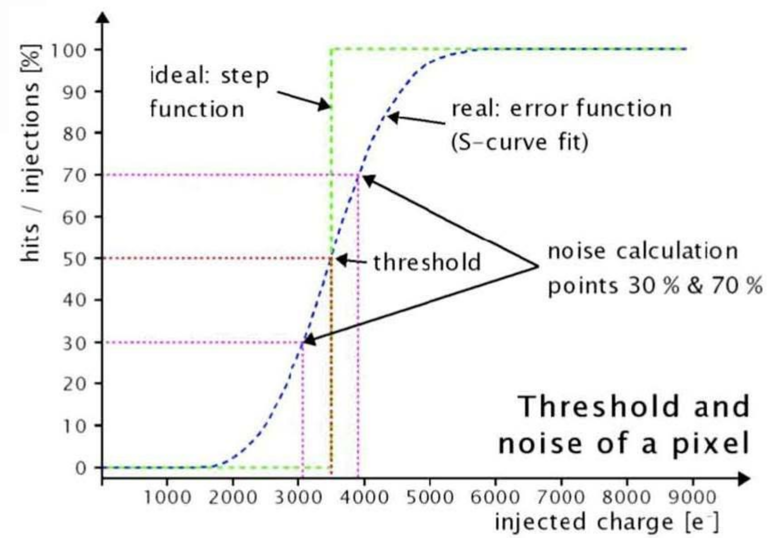
- measurable value

- is *proportional* to the *deposited energy* in the sensor

- S-Curve

- convolution of a stepfunction and a gaussian

- defines the *threshold* and *noise*



- Injection of a known charge via Charge=Capacitance*applied Voltage
- Feedback current can be set with two DACs -> slope of ToT
- Threshold can be set with two DACs-> height of diskriminator

Measurements list

- leakage current versus bias voltage
- threshold and noise scans
- noise versus bias voltage
- gamma and beta source-tests at different bias voltages

up to now have been performed individually

↓

from now on by automatization

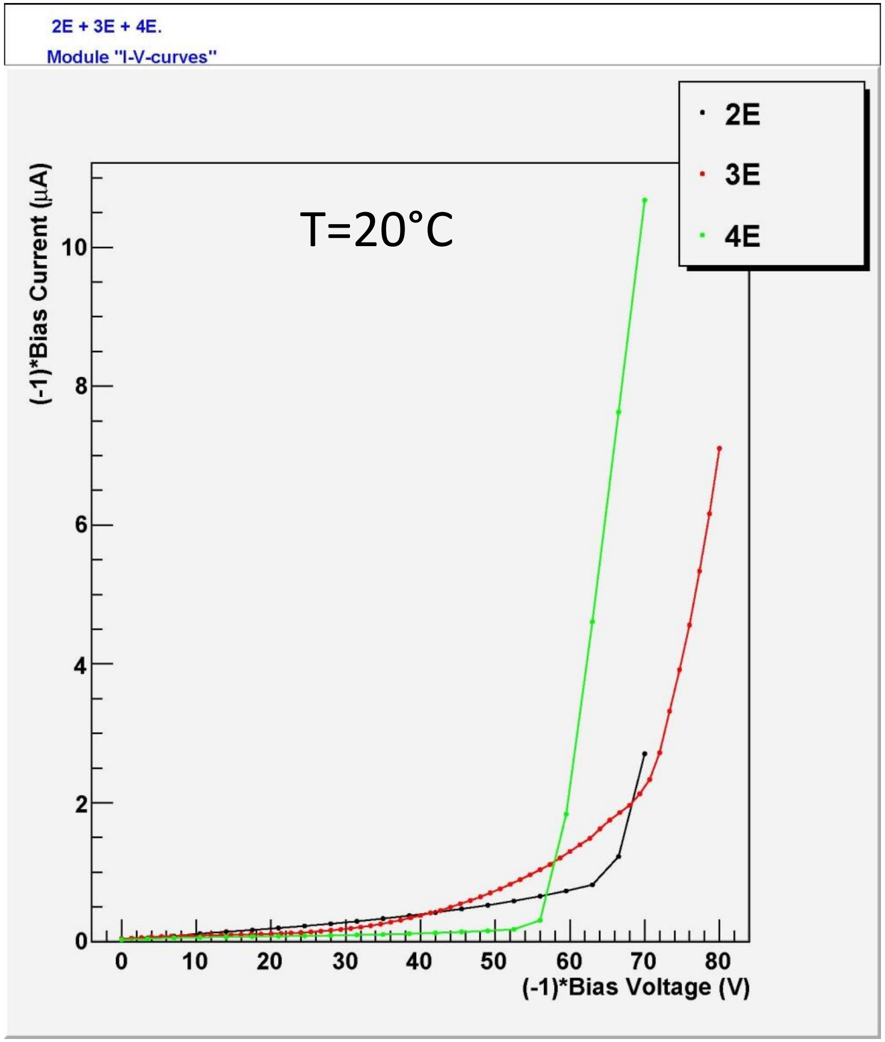
I-V curve of the 3D sensors

General behaviour of the I-V-curve of a diode

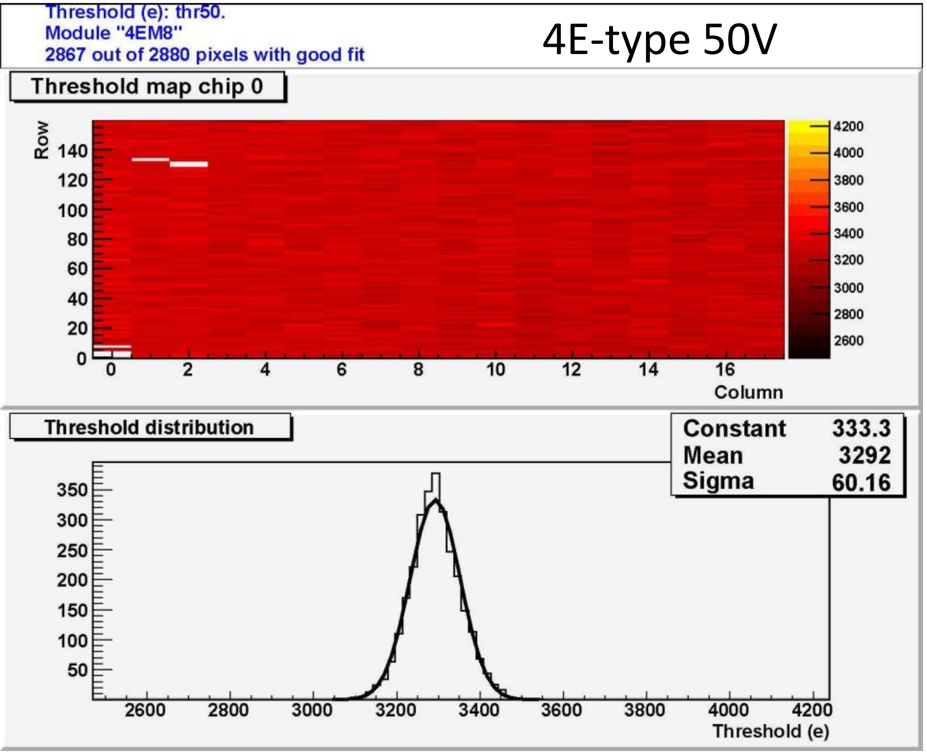
- rise
- plateau
- breakdown region

Properties of the 3D I-V-curve

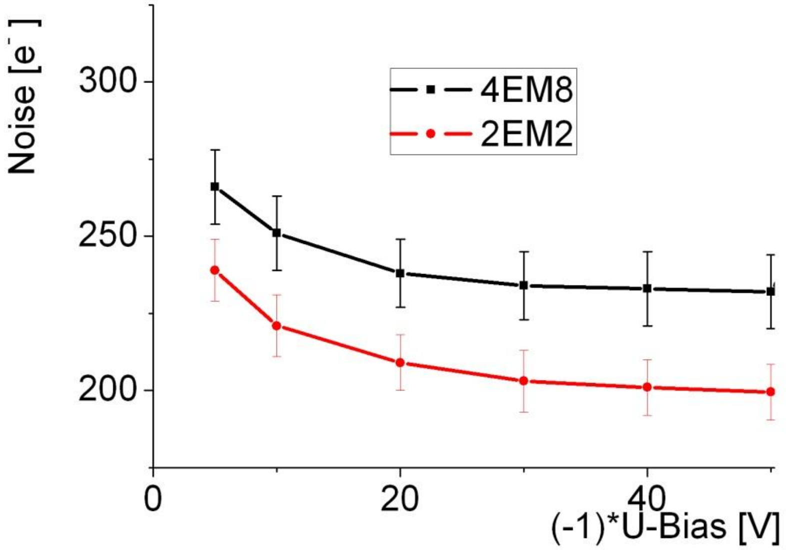
- rise
- plateau from 10 V to 50 V
- breakdown region at 60 V/70 V



Threshold and noise behaviour



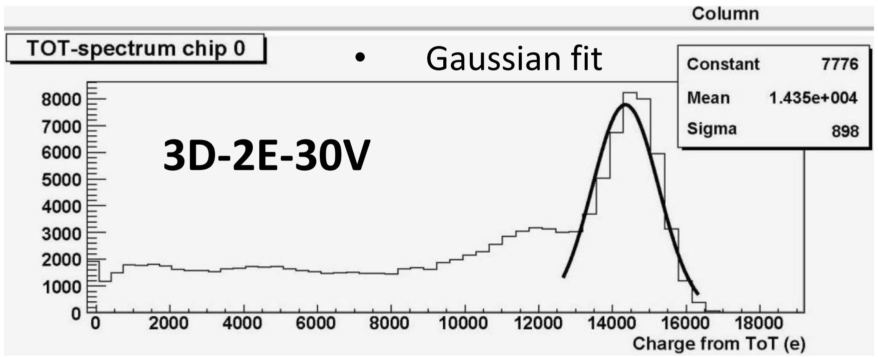
Noise of 3D sensors before irradiation

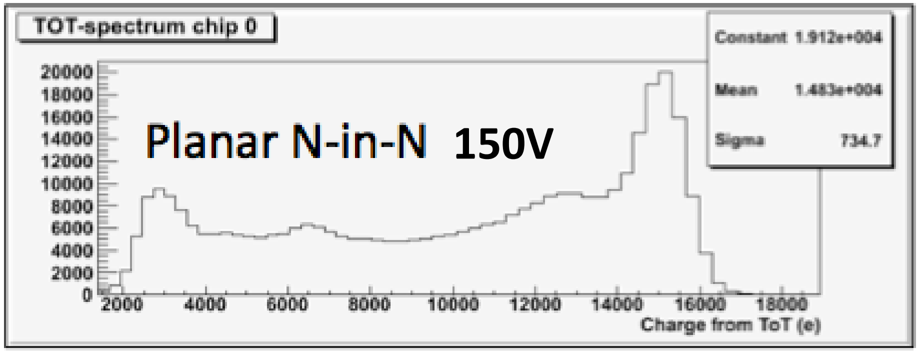


Some values:

	Threshold [e]	Noise [e]	HV [V]
3D-4E	3292±60	232±12	50
3D-2E	3288±43	200±10	50
Planar-n-in-n	3237±33	173±9	150

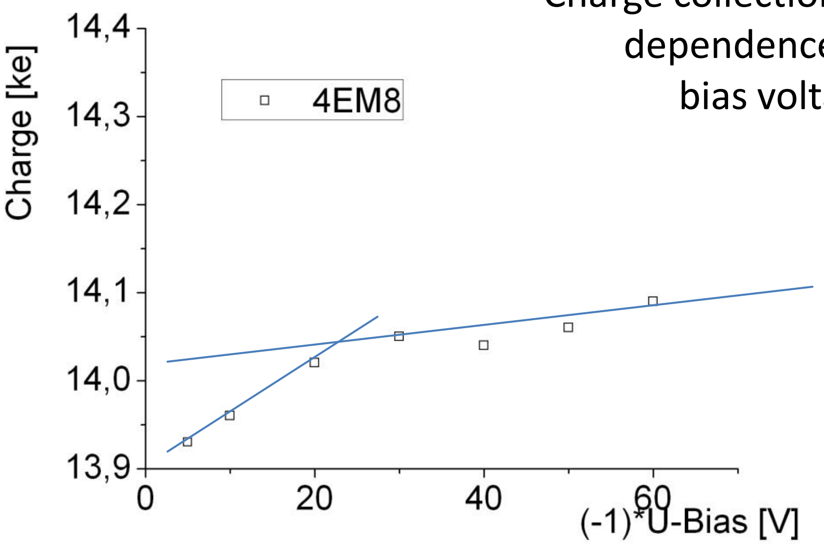
Energy spectrum of Am241





Ameritium	Charge [ke]
Expected value	16.6
Planar n-in-n	14.8±0.7
3D-4E	14.06±0.90

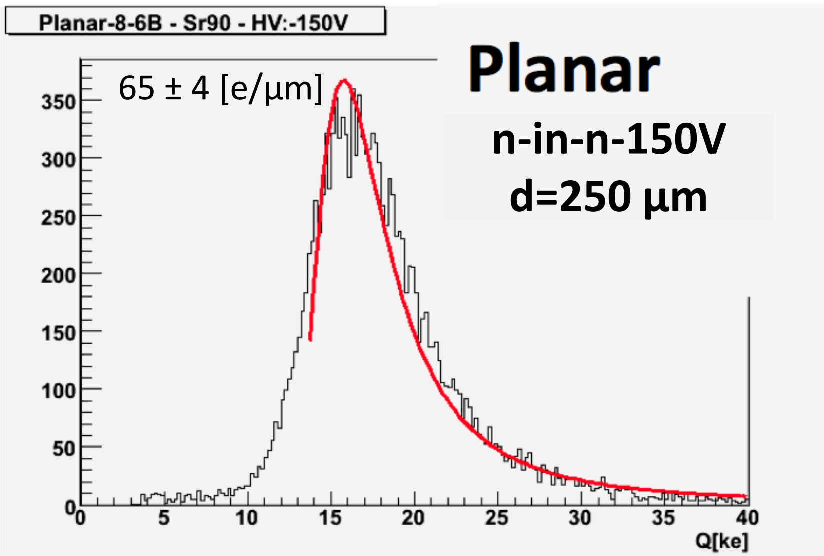
Charge collection in dependence of bias voltage

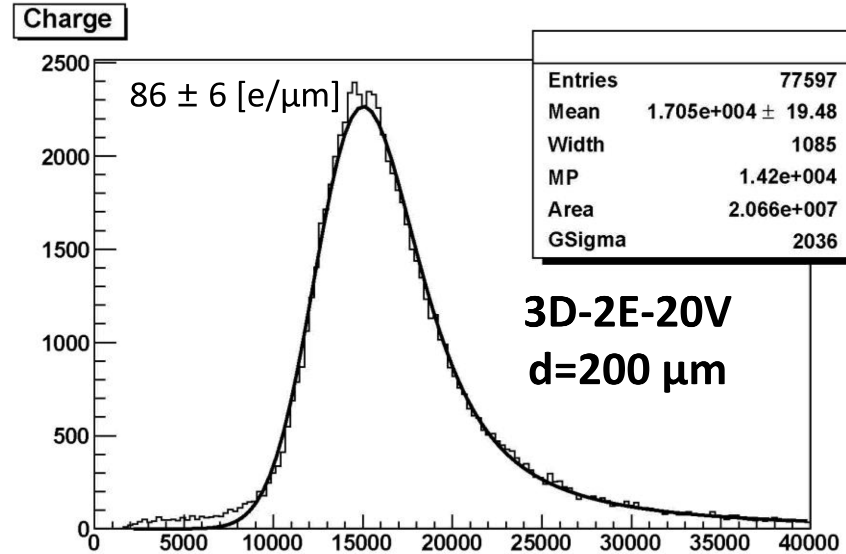


Results

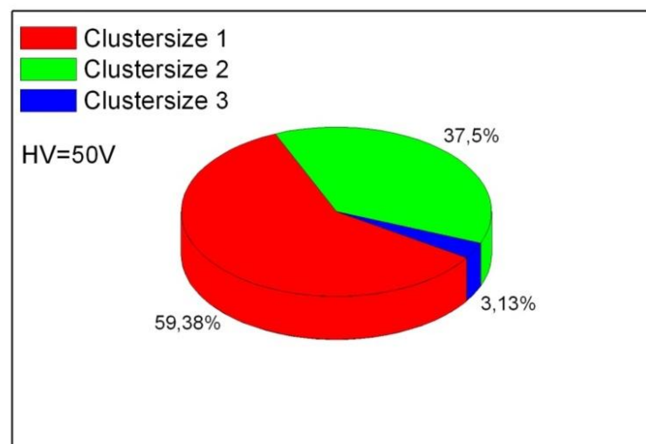
- not all the charge is collected
- performance is in agreement with planar n-in-n sensor

Energy spectrum of Sr90





- percentage of cluster size



- measured at different HV
- fitted with a Landau-Gaussian distribution

Outlook

- characterization of unirradiated sensors has been performed
- automatization of the measurements including programming with C++
- characterization of proton irradiated sensors up to a fluence of $\phi=1x10^{15}[1/cm^2]$
- testbeam involvement with a diamond pixel detector

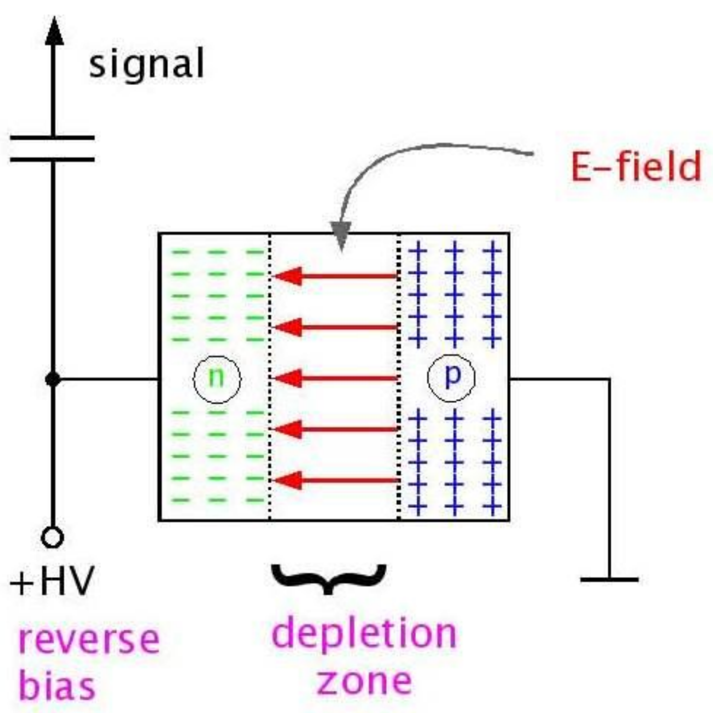
Special thanks to Christian Gallrapp who helped me a lot taking the data.

Thanks for your attention and have a nice break

BACK-UP

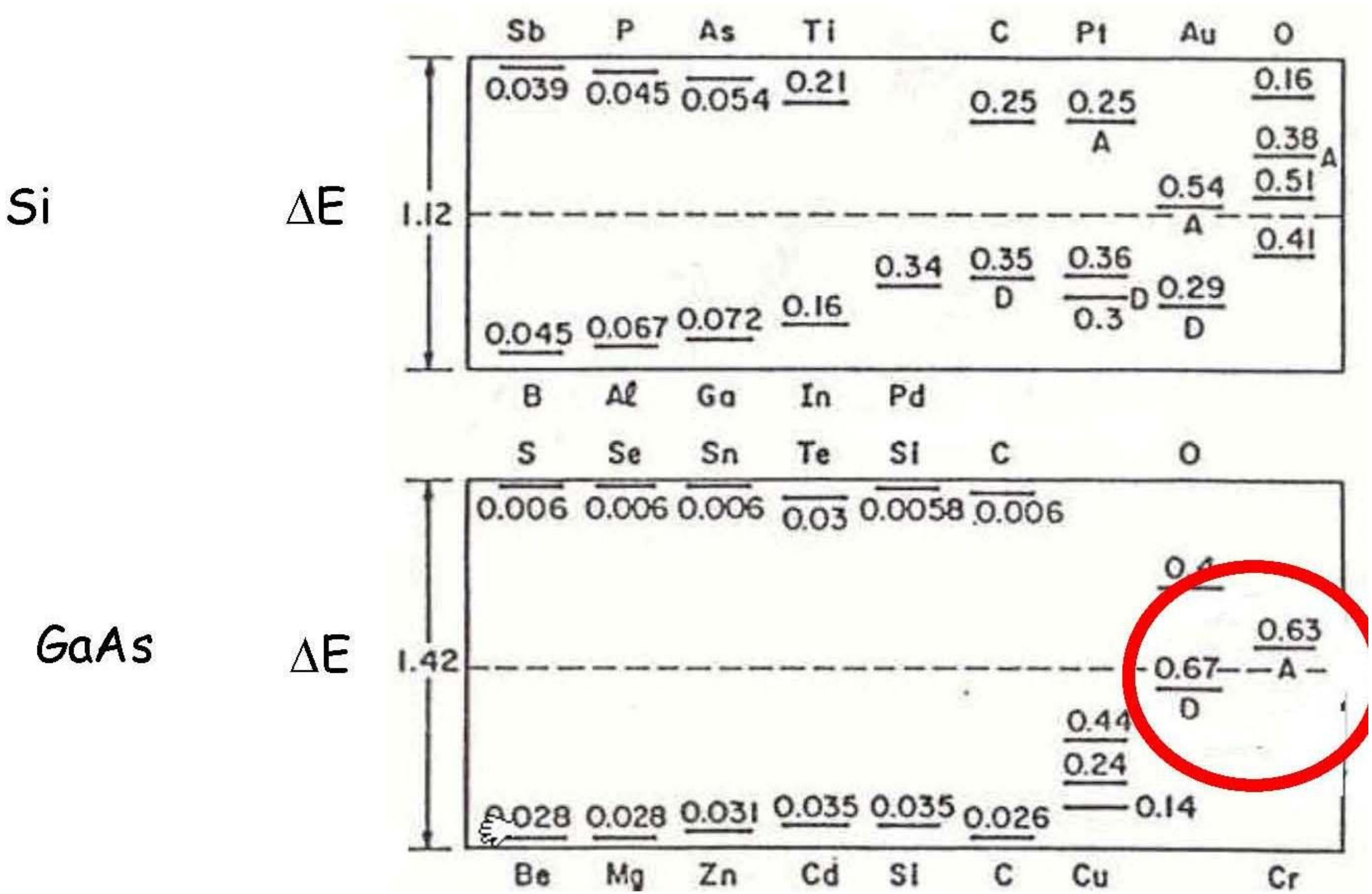
Physics of a silicon detector

pn-junction



- particle/radiation that passes the depleted area creates electron-holes pairs with a cost of 3.61 eV
- this charge is collected by the electrodes
- height of signal is proportional to collected charge and therefore to depsited energy

Bandgap and energy level of doped detectors



Radiation induced effects – bulk damage

- increase of leakage current
- change of space charge – type inversion
- charge trapping

Tuning of a sensor

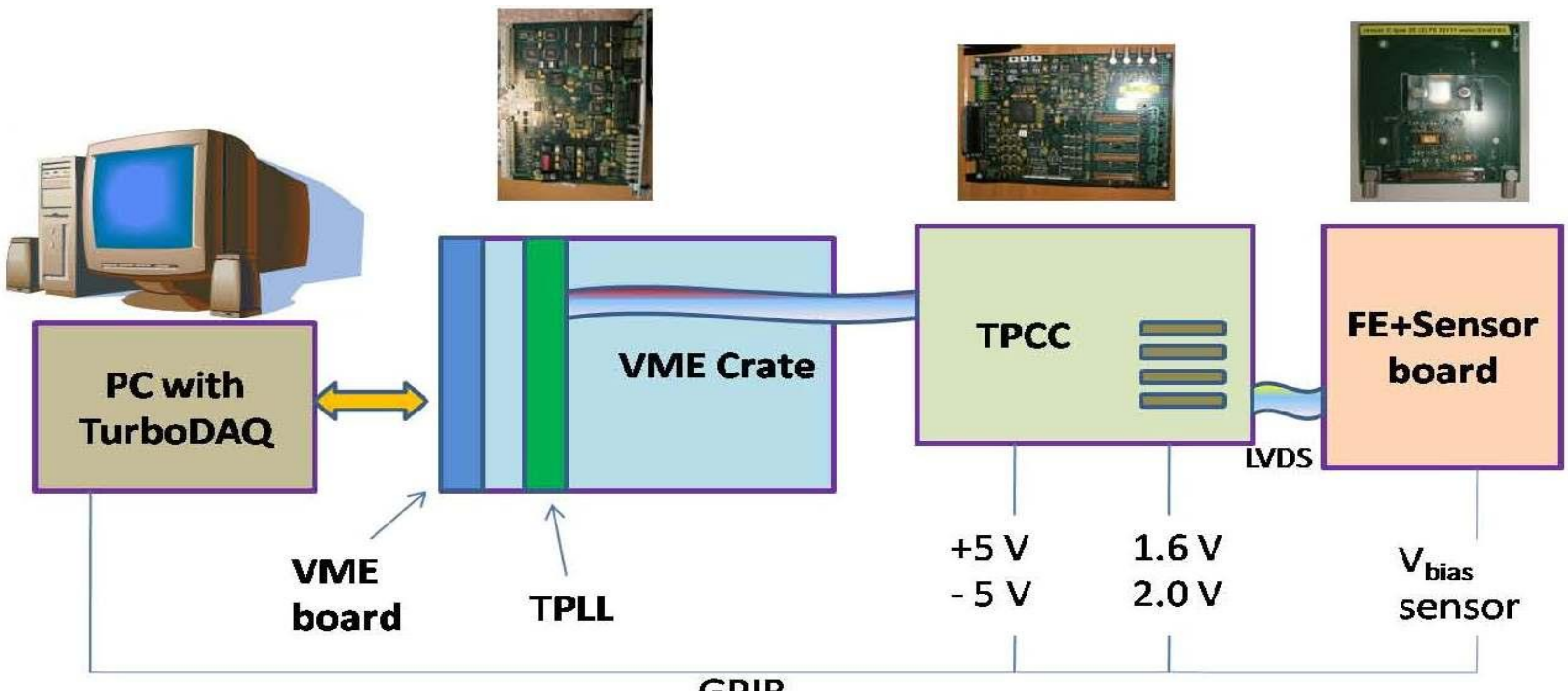
- Threshold: 3200 e
- ToT: 60 (*25ns) @ 20 ke
- 20°C
- System: DurboDAQ

Some formulas

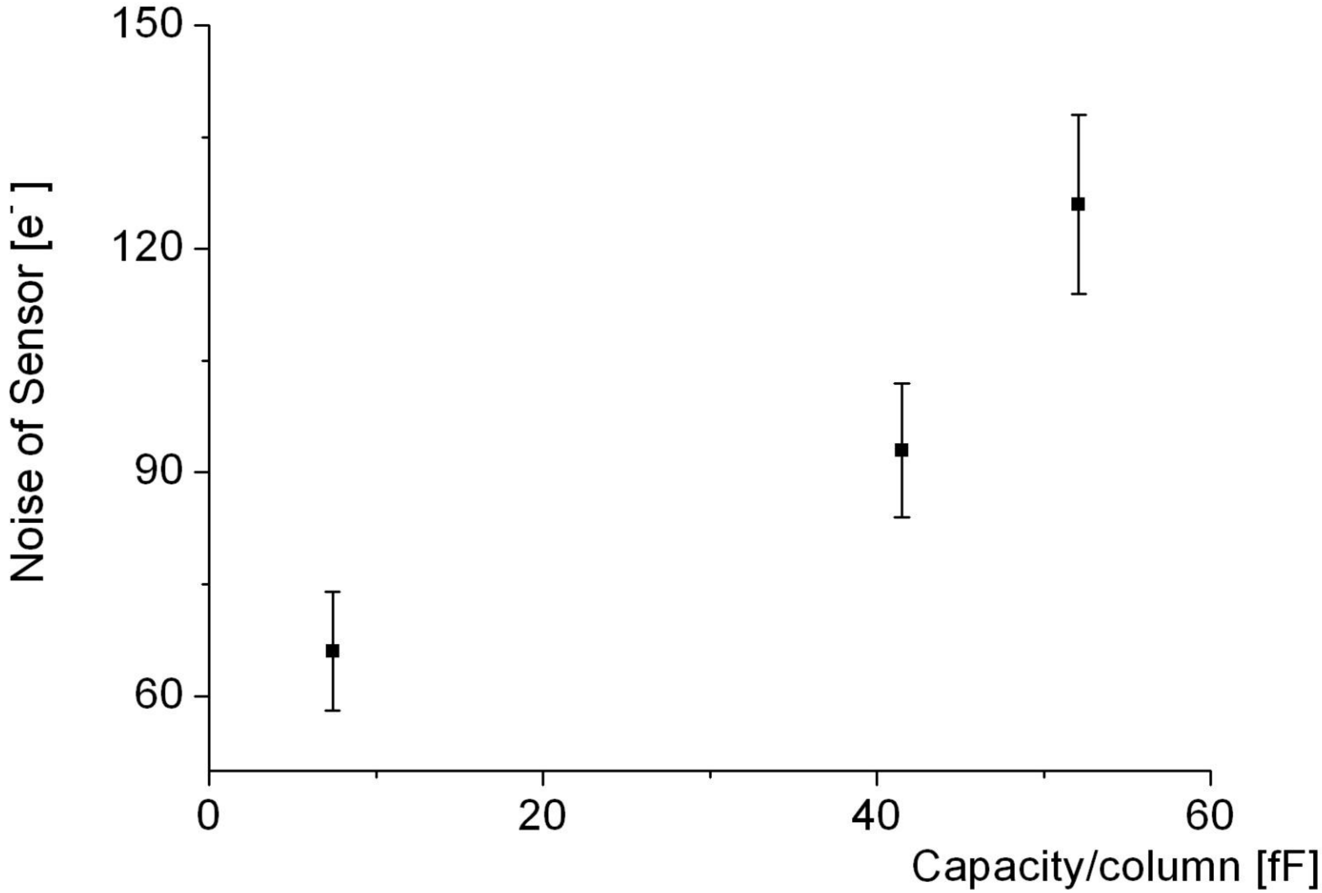
- d=epsilon*A/c_depleted
- E_max=e*N_D/epsilon
- v=mu*E_max
- t=d/v

Method of measurements I

- TurboDAQ Scanprogram



Noise and Capacitance



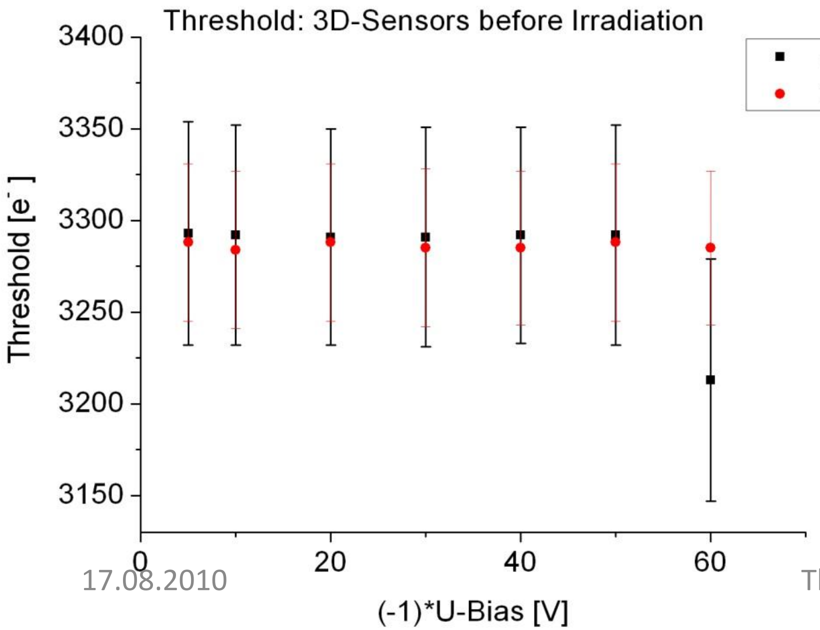
Results of 3D-sensors

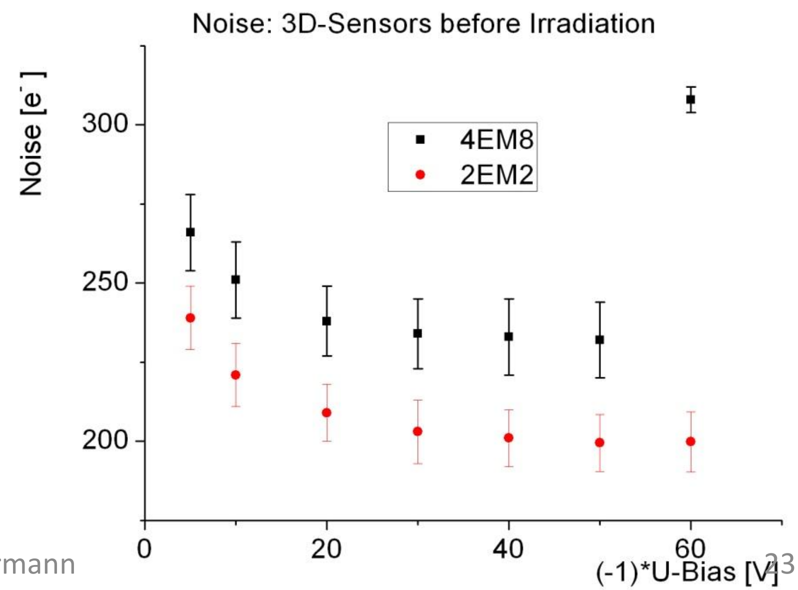
- Threshold

  - independent of voltage

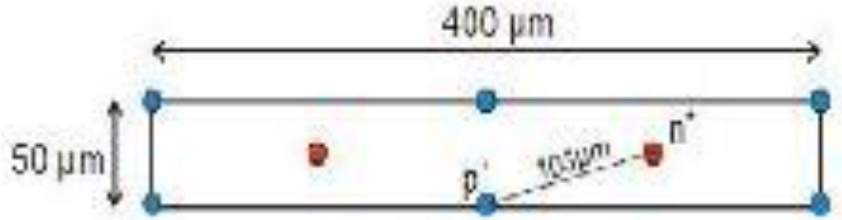
- Noise

  - decreasing with increasing voltage



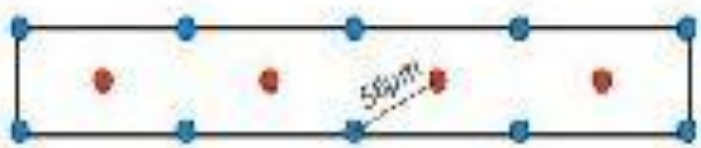


3D-types



2E

3E



4E