Measurement of basic static characteristics (I-V, C-V) of silicon detectors

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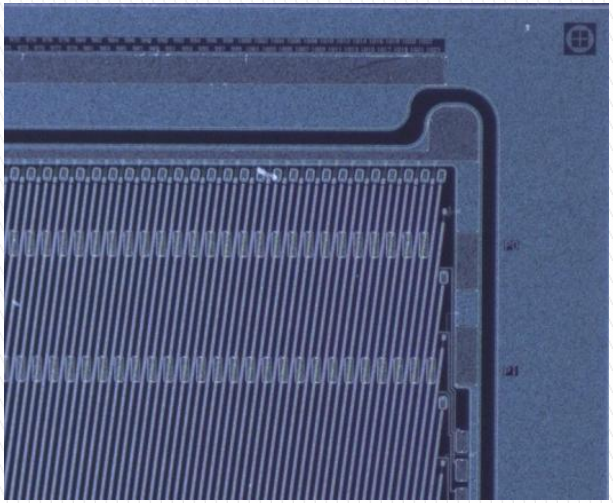
Why it is necessary to measure the static parameters of silicon detectors

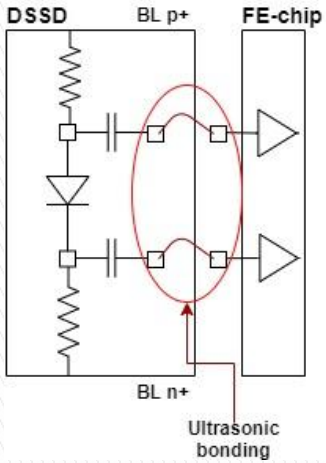
- The use of microstrip detectors in creating coordinate track systems for high energy physic (HEP) experiments with high geometric efficiency (~ 100%), a large number of strips (measuring channels) over 10^6 and accuracy h / √12 (h-pitch) requires careful preliminary selection of detectors by main parameters (ALICE: several mln chanels, ATLAS: 6 mln chanels, CMS: 9,6 mln chanels);
- Modern systems for testing and selection of microstrip detectors make it possible in the automated mode to identify strips with high dark currents, possible short circuits and breaks in interstrip metallization, etc;
- The basic rule for testing detectors is not to introduce additional defects during measurements and the minimum number of tangencies of the measuring probes to the detector surface to extract the maximum information about the detector.

Topology of AC-coupling double side microstrip silicon detectors (Hamamatsu, CBM experiment)

Parameter	Rait
Chip thickness	300 μm
Chip size	62000±10 × 22000±10 μm
Number of strips	1024 Ch
Strip pitch	58 μm
Strip implant width	10 μm
Strip metal width	20 μm
Strip angle of P side	7,5˚
Strip angle of N side	0˚



View corner of the P-side of 62×22 mm microstrip detector

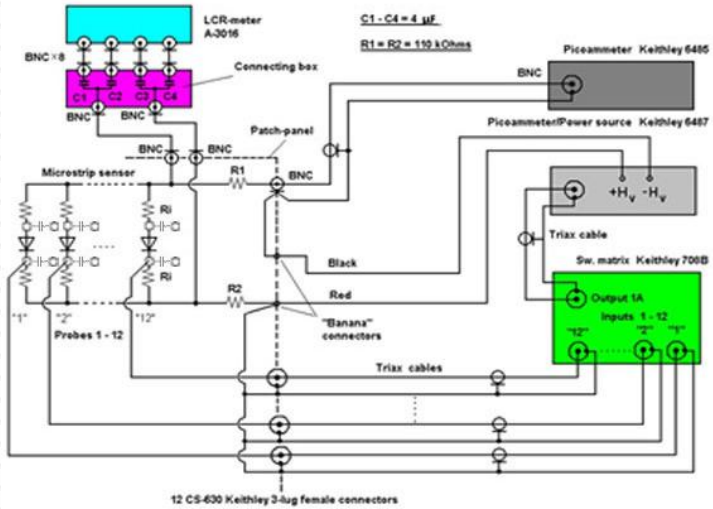


Electrical equivalent circuit of AC-coupling DSSD

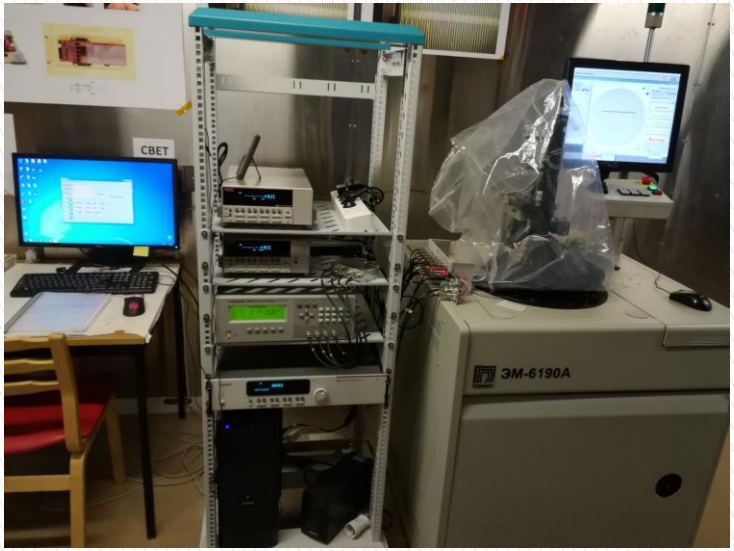
Instruments (setup of JINR-LHEP) for measuring the I-V and C-V characteristics of microstrips detectors (DSSD)

- Probe automat EM-6190A;
- Microscope;
- Semiconductor Switch Matrix Keithley 708B;
- LCR meter AM-3016;
- Picoammmeter Keithley 6487/ Voltage source with output voltage from 200 μV to 505 V;
- Picoammmeter Keithley 6485;
- Software package “DMS” to control the measuring complex.

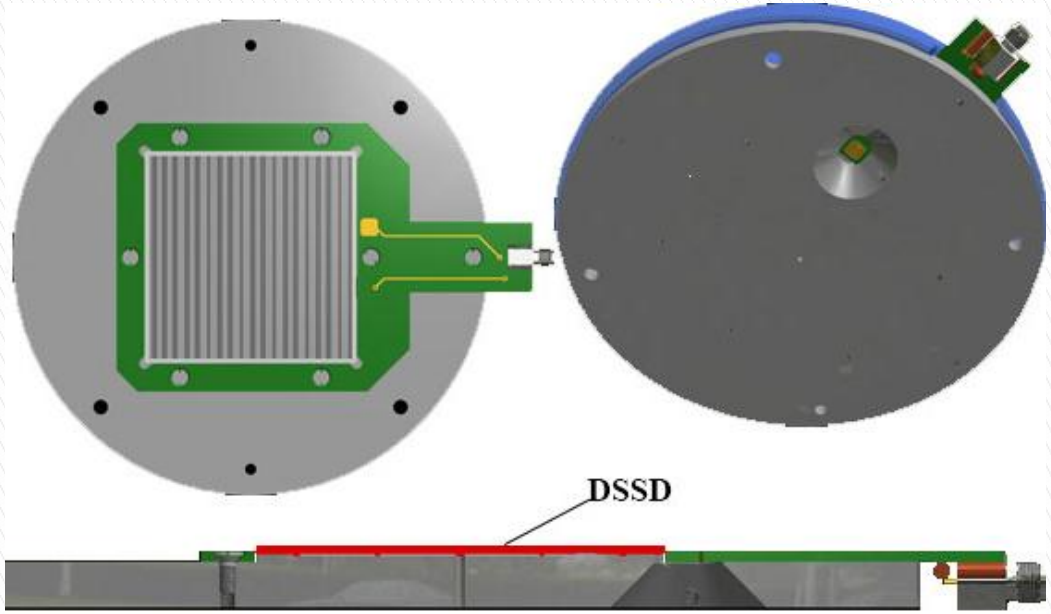
Jointly developed by LHEP (JINR) – SINP (MSU) – Planar (Minsk)

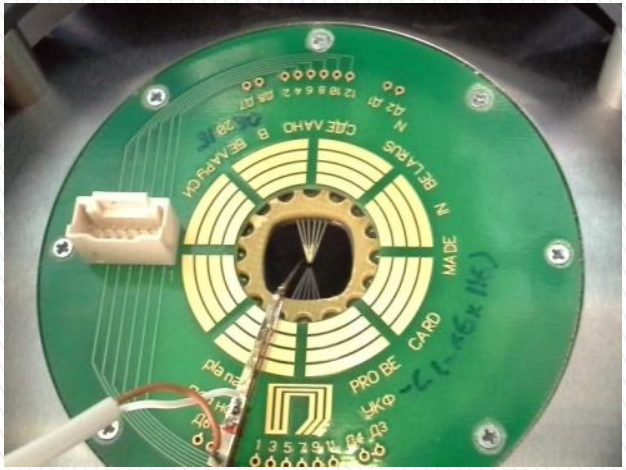


General circuit for measuring leakage current and capacity integrated capacitors



Measurement equipment

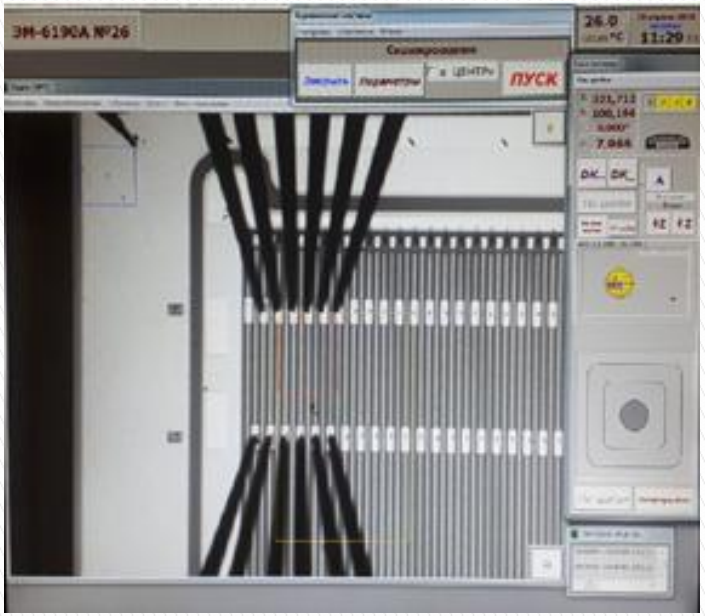




Probe card with 12 probes and control sensor

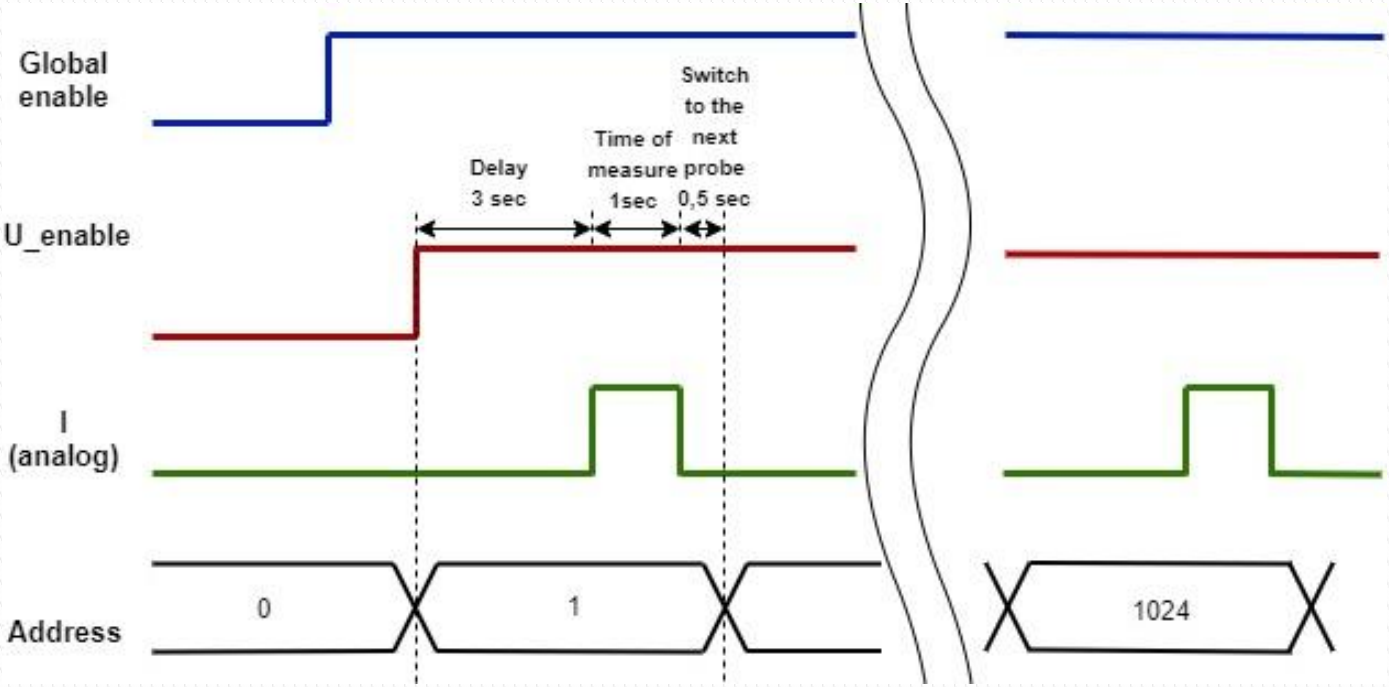
Special equipment for vacuum fixing sensors

Developed in detectors division LHEP-JINR



Fragment of alignment of the contact pads of the sensor with probes

Timing chart of measurements on one side of the microstrip detector at constant voltage

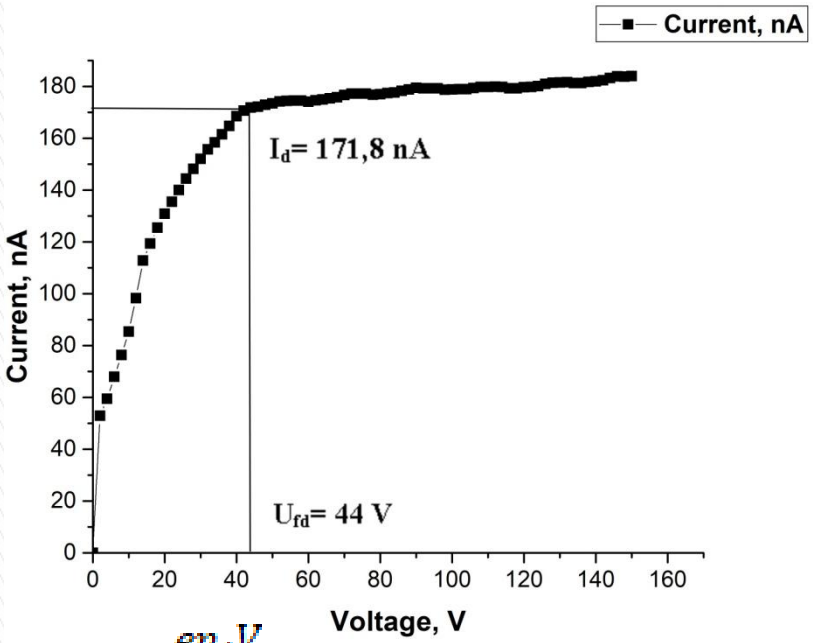


Performance measuring complex for 12, 6, 4 probes

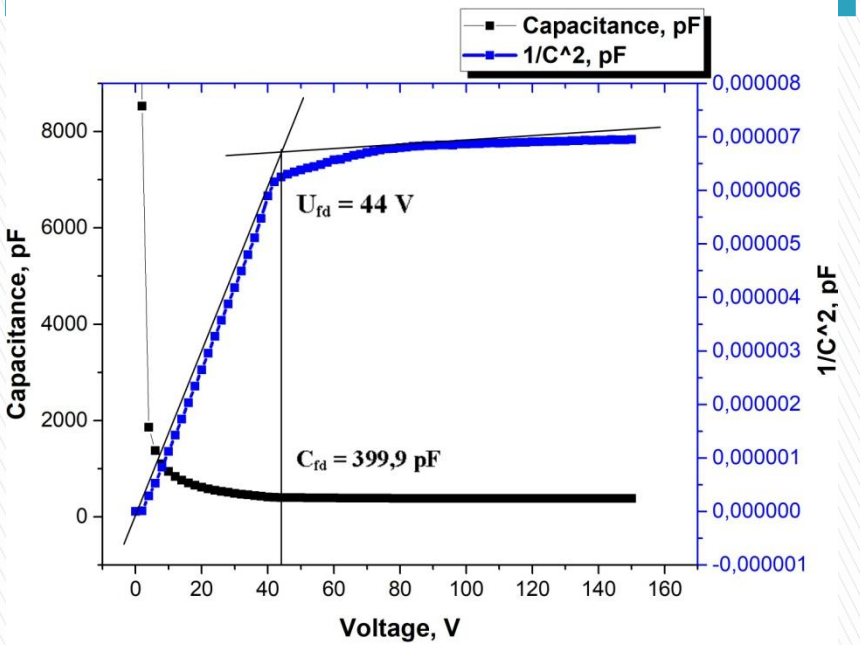
Number of probes	Number of positions for measuring 1024 strips on one side	Measurement time of 1 integrated capacitor on one side, sec	Measurement time of 1 position (12 probes) on one side, sec	Total measurement time on one side, min
12	85	4,5	54	76,5
6	170	4,5	27	76,5
4	255	4,5	18	76,5

Basic static characteristics for sensor CBM62HDS0424 (Hamamatsu)

I-V characteristic of silicon microstrip detector (62×22x0,3) mm^3



C-V characteristic of silicon microstrip detector (62×22x0,3) mm^3



$$I_d = \frac{en_iV}{2\tau_d}, \quad d(\mu) = 18\sqrt{\rho(kOhm \times U_d(V)}$$

e – electron charge,
n_i – intrinsic carrier concentration at 20˚C for Si (1,5×10^{10} cm^{-3}),
V – volume of space charge region (SCR = d × S),
τ_d – charge carrier lifetime,
U_d – voltage applied to the detector,
ρ – resistivity.

Frequency of measurements 5 kHz
Temperature of measurements +20˚C
Delay between measurements 1 sec
Time of measurements 10 min

Measurement results of AC-coupling (1024×1024) strips DSSD for sensor CBM62HDS0424 (Hamamatsu)

The capacitors leakage currents and capacitance value on the P-side at 10 and 20 V

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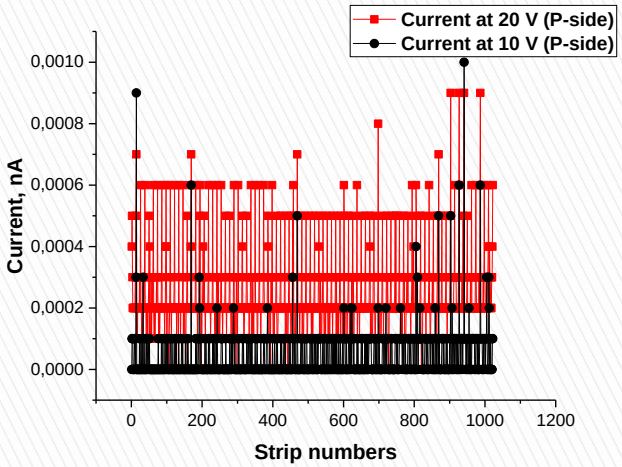
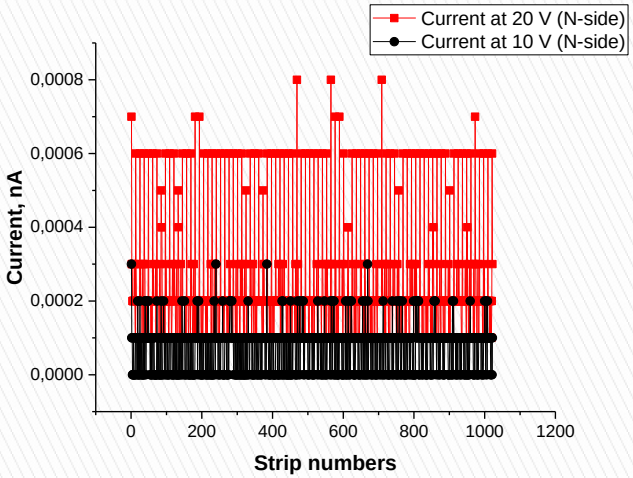
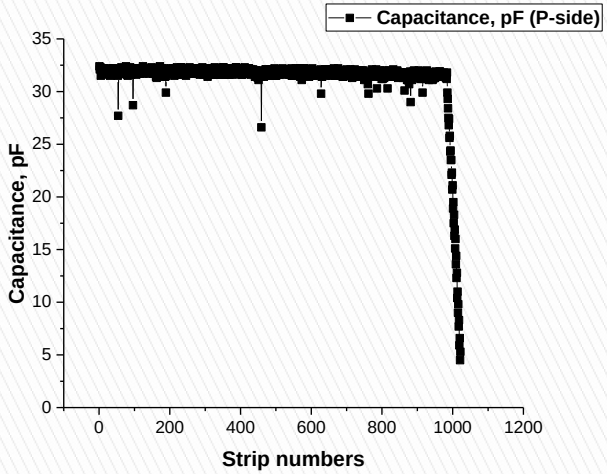
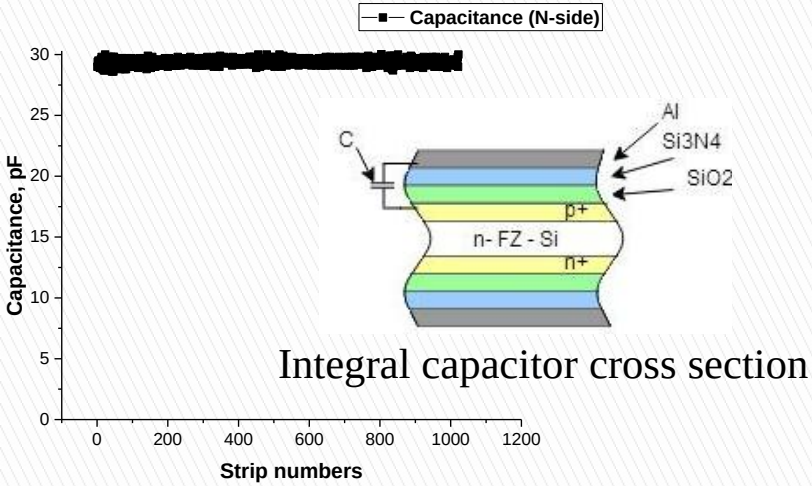








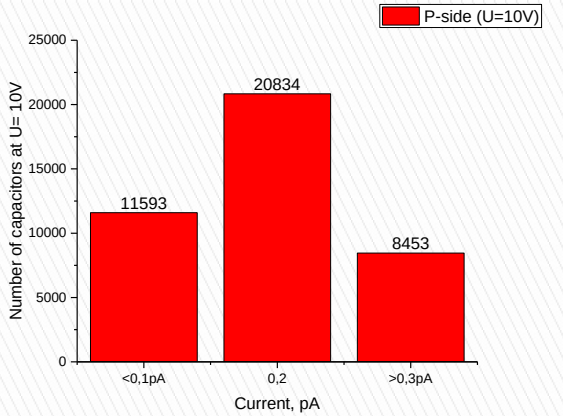
Integral capacitor cross section

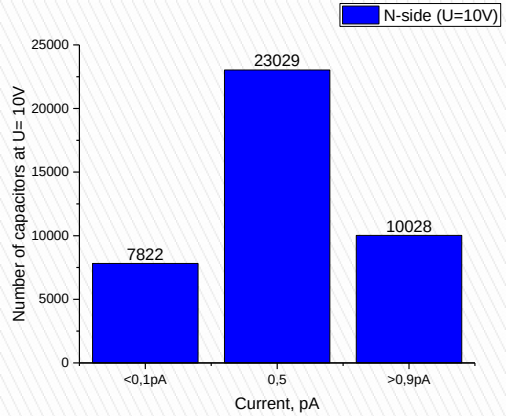
Measurement results of AC-coupling (1024×1024) strips DSSD, 40 pcs = 40 880 (p+) +40 880 (n+)

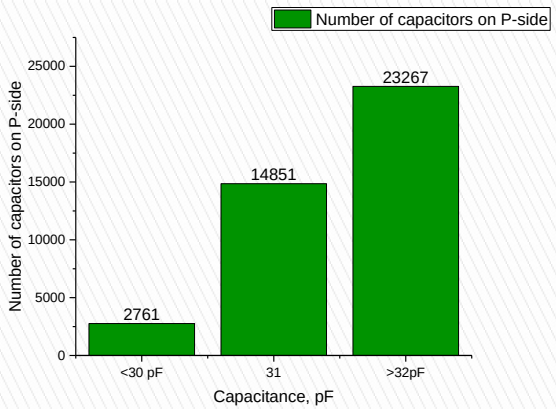
Histograms of capacitors leakage currents on the P-side at 10 and 20 V (40 880 strips)

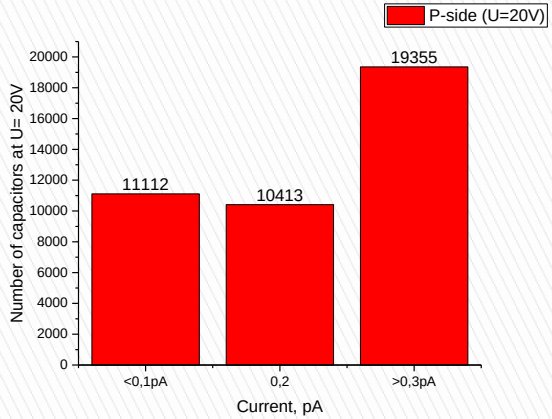
Histograms of capacitors leakage currents on the N-side at 10 and 20 V (40 880 strips)

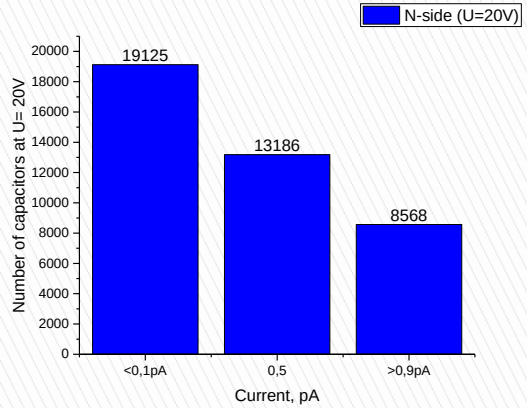
Capacitance values on the P and N-side (40 880 + 40 880 = **81 760 strips**)

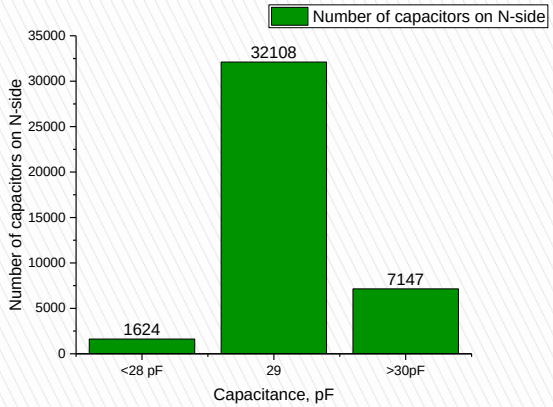










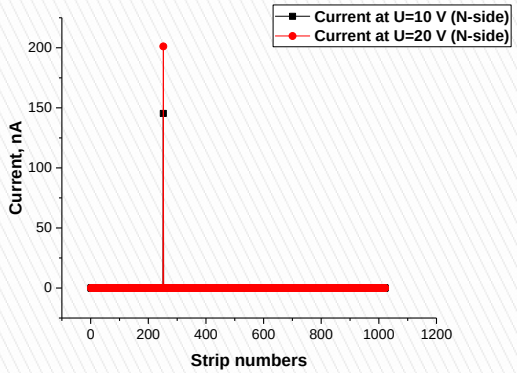


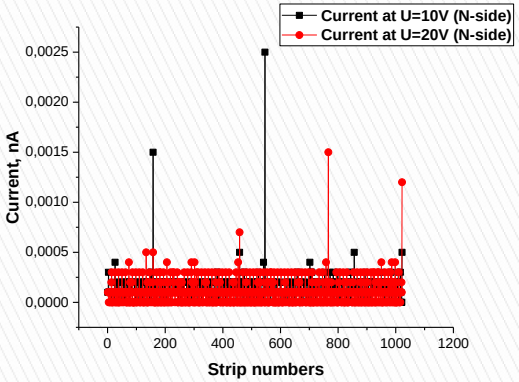
Defects

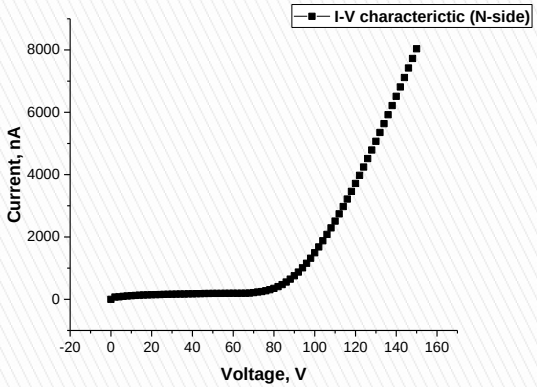
Sensor	CBM62HDS0420
Side	N
Strip number	252
Current (Ic) at 10 V	145 nA
Current (Ic) at 20 V	201 nA
Capacitance	777,4 pF
Defect	Coupling short

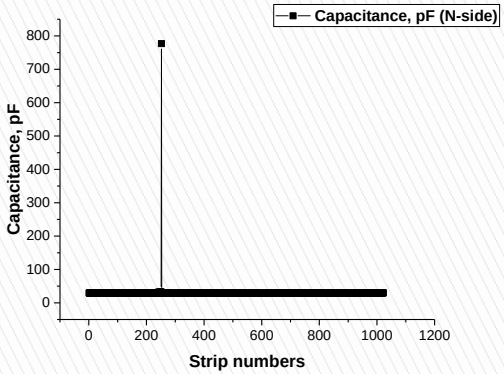
Sensor	CBM62HDS0444
Side	N
Strip number	522
Current at 10 V	0,0001 nA
Current at 20 V	0,0001 nA
Capacitance	6 pF
Defect	Metal break strip

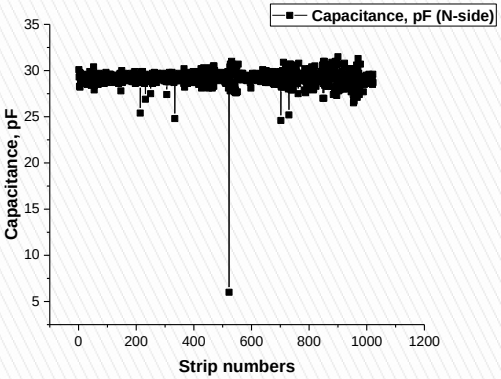
Sensor	CBM62HDS0441
Side	N
Current (Id) at 80 V	350 nA
Current (Id) at 150 V	8036,5 nA
Defect	Breakdown

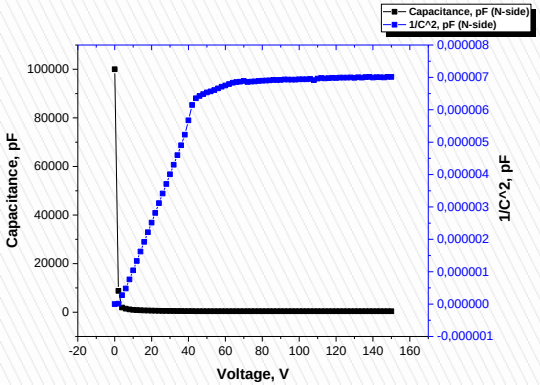












Conclusions

- Measurement of the basic static characteristics (I-V, C-V) of silicon detectors characterizes their quality and the suitability of using the detector in the further process of creating a coordinate plane;
- Measurement technology allows you to obtain the necessary data with the least number of detector touches

I express gratitude to the colleagues from SINP (MSU), Planar (Minsk), E. Zubarev, O. Tarasov for help with measurements, Yu. Murin, N. Zamyatin for help in discussing the results.

Thanks for your attention!