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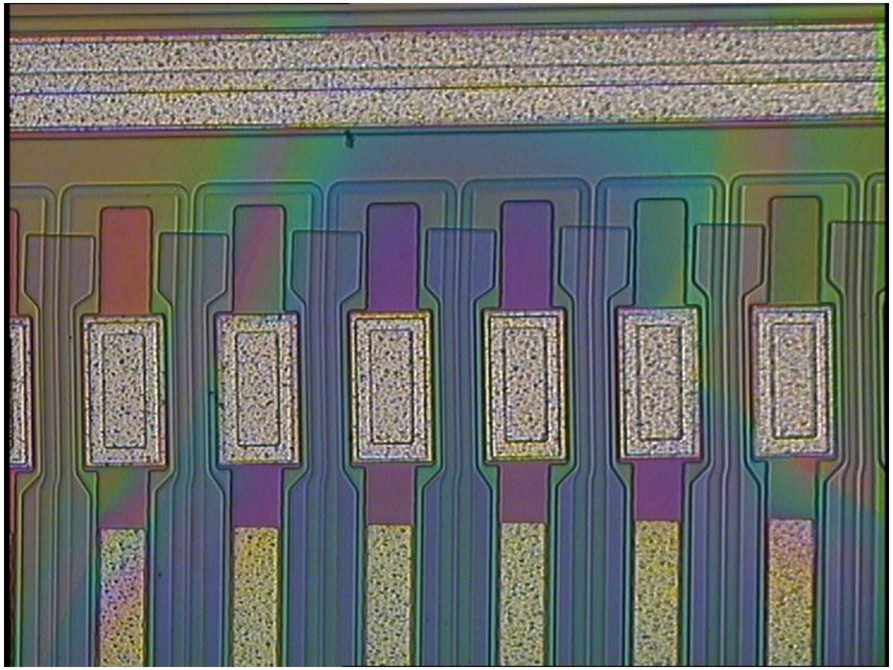
Electric characterisation and test of double sided
Silicon Strip Detectors
Silicon Drift Detectors
Large area Linear Silicon Drift Detectors



Rashevskaya Irina
TIFPA
03 June 2020

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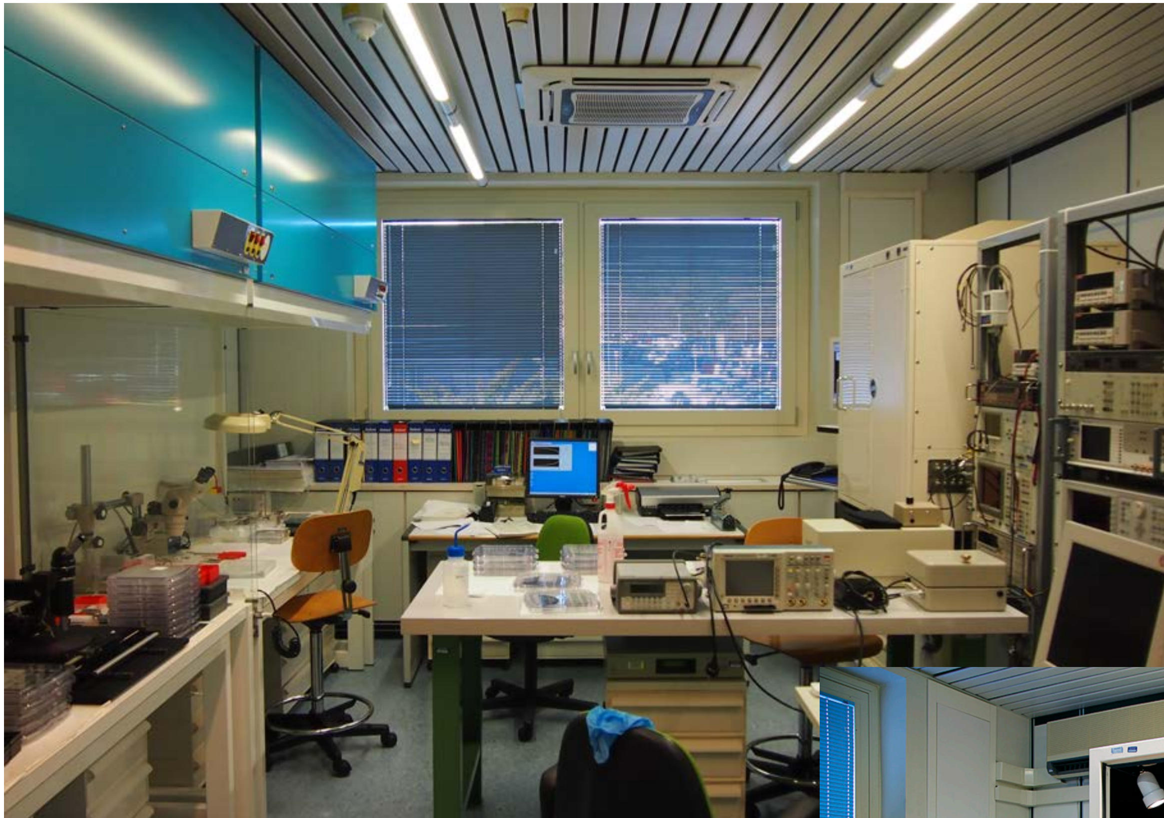
Laboratory



- Two semiautomatic probe station: Alessi e Karlsus PA200
- Complete instrumentation for parametric measurements on semiconductor devices:
  2 HP4141 HP4156A
  HP4156C
  2 HP4284A
  KT237 KT6487 KT6517

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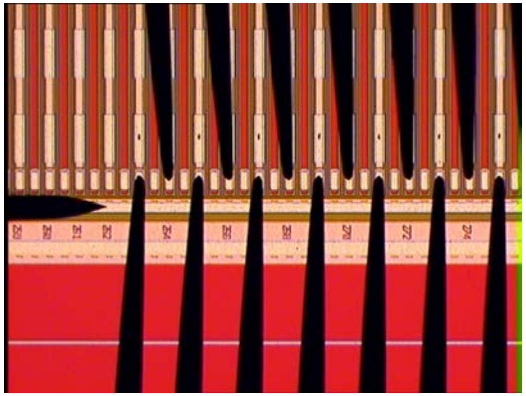
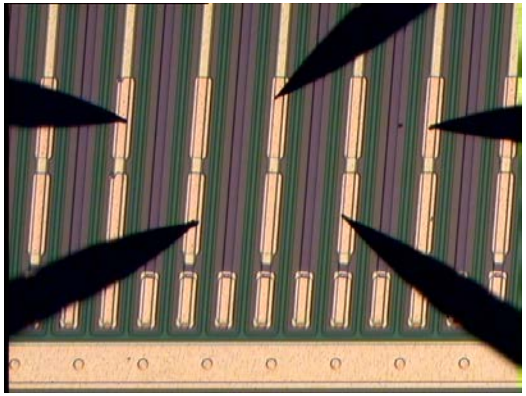
Characterization of double-sided silicon devices

- 400 Strip Detectors for Babar (SLAC)
- 3 batches of 20 wafers for IRST (now FBK)
- 2500 Strip Detectors for Alice (CERN)
- 80 Strip Detectors for LIMADOU (CSES)
- 100 Strip Detectors for Bell2 (Giappone)
- 5 batches (FBK) of DRIFT sensors 20 wafer for Redsox
- 2 batches (FBK) of 20 wafers of Linear DRIFT Detectors





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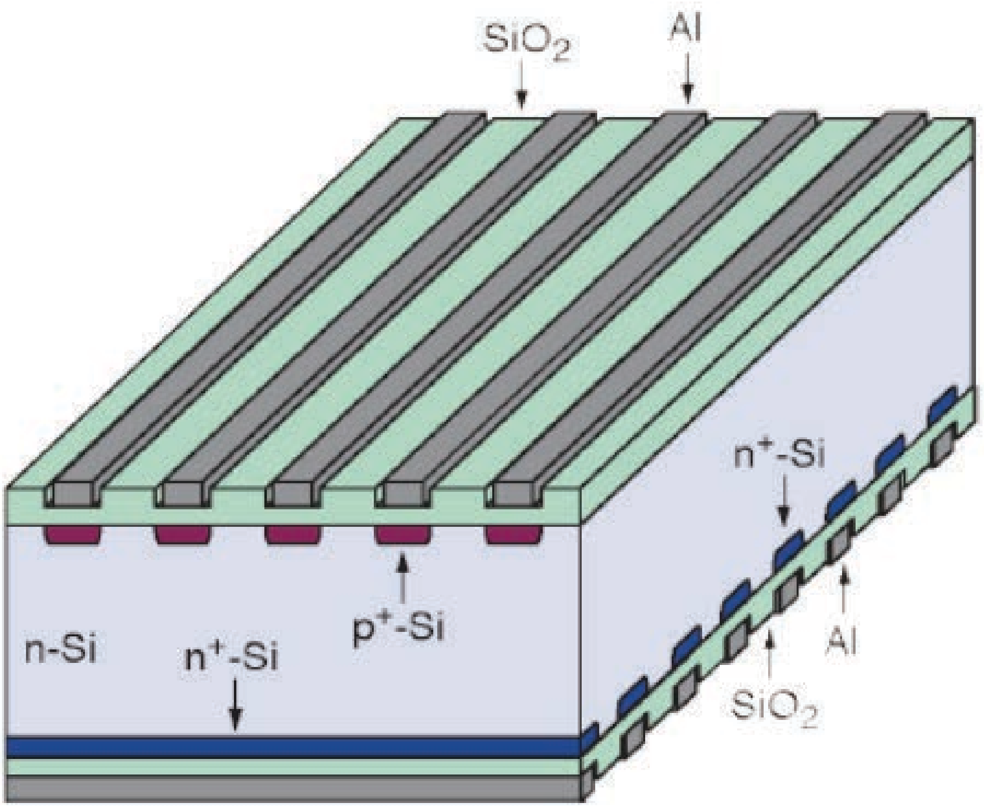
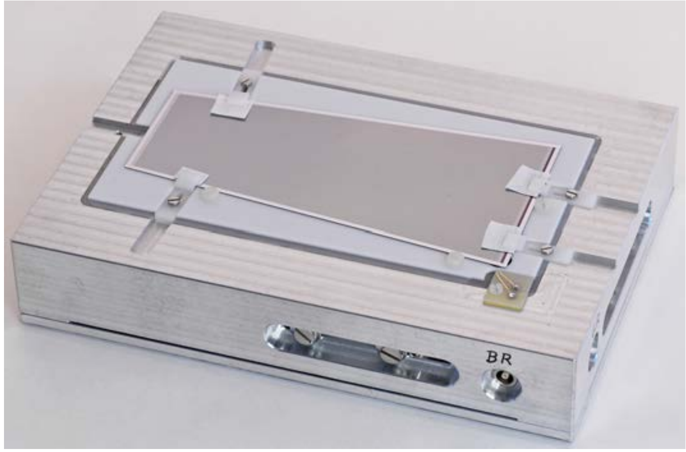
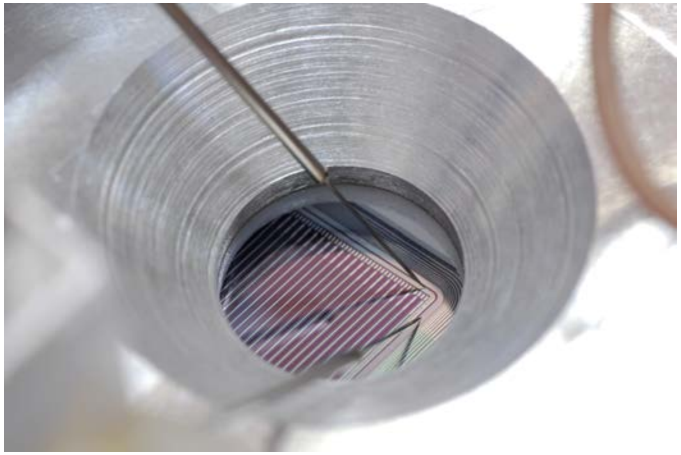
Silicon Strip Detector Bell2







Contact set-up for a trapezoidal sensors:

- one needle contact Bias Ring
- one needle contact Guard Ring

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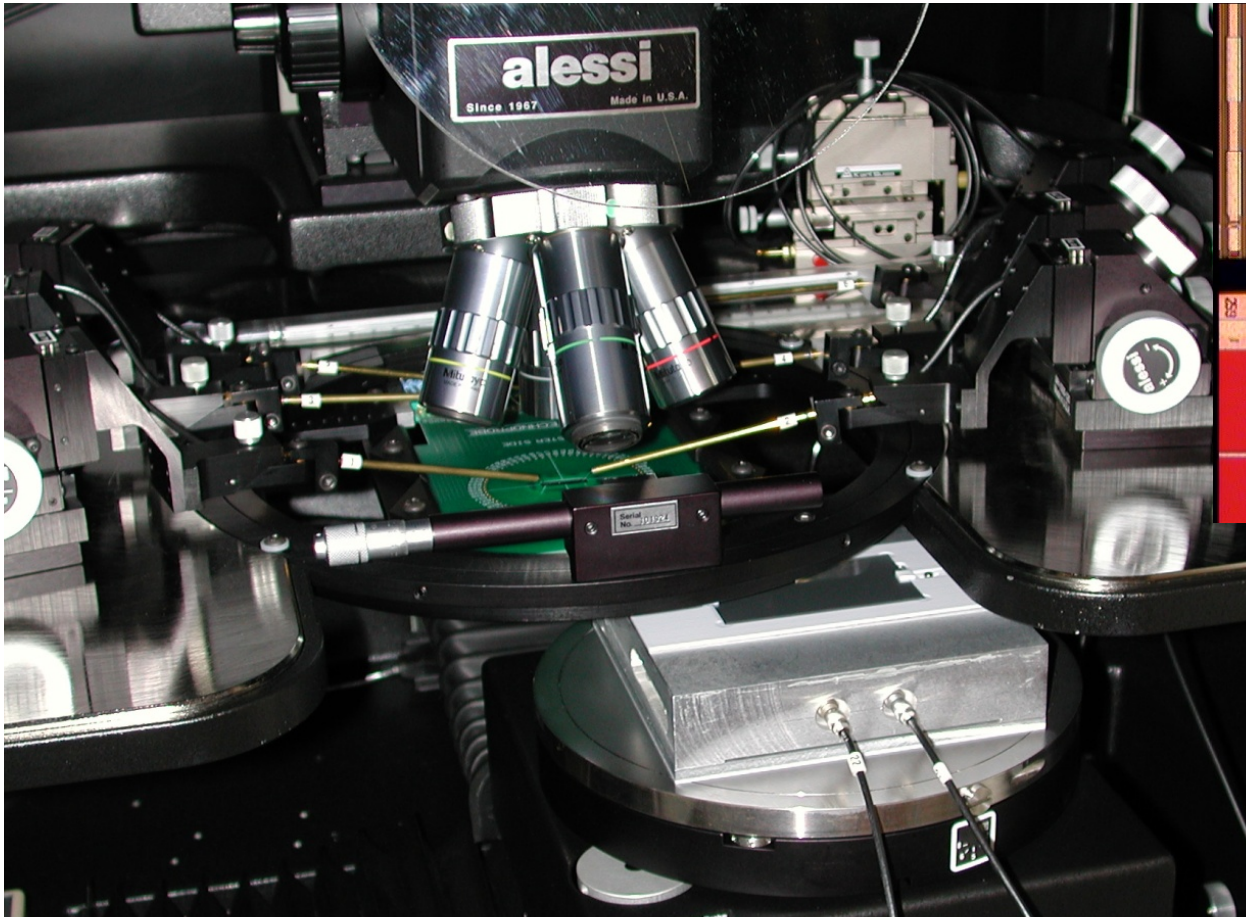
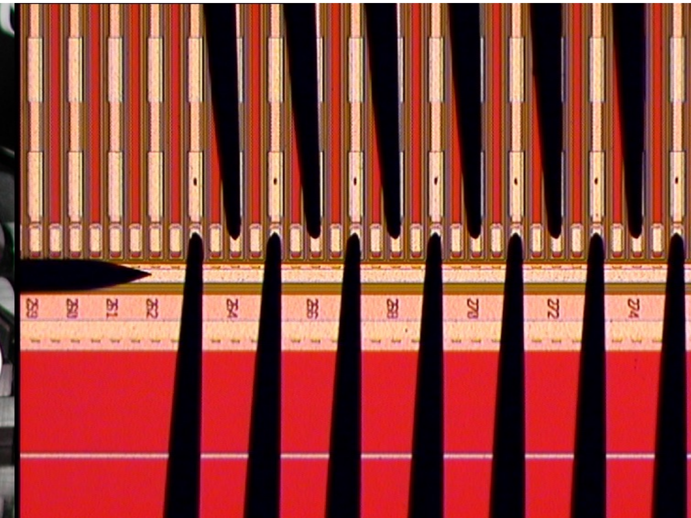
Set-up for sensor testing

INFN TRIESTE Istituto Nazionale di Fisica Nucleare Sezione di Trieste





The detector support is mounted on the probe station chuck

- held by vacuum
- contacts to back-side available through coaxial connectors

Standard Sensor Testing Procedure

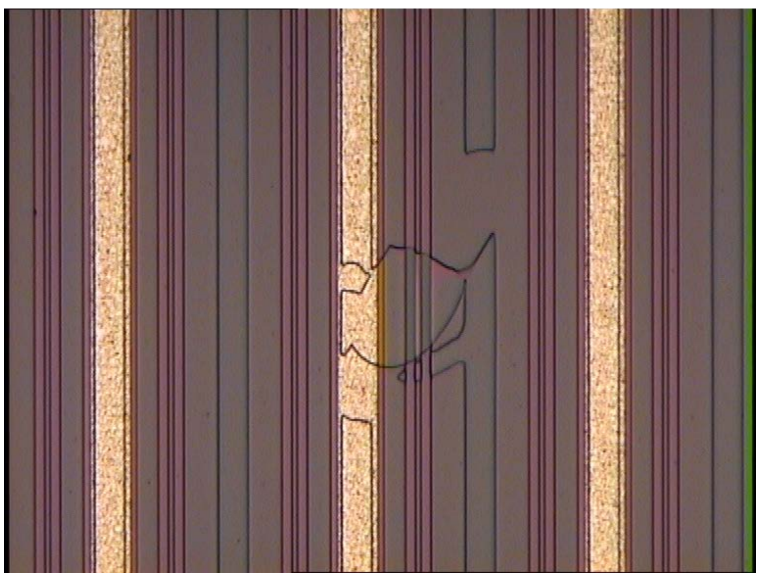
The applied testing sequence is:

- Mount the sensor *n*-side-up on the jig
- *I-V* measurement for the whole sensor and one *n*-side strip
- AC (metal) strip Scan on *n*-side (along the long edge), using the 160 µm probe card
- DC (implanted) STRIP SCAN on *n*-side, using the 160 µm probe card to contact the readout strips (the non-readout strips are not accessible: no contact pad is present)
- Mount the sensor *p*-side-up on the jig, after repositioning one of the clamps
- AC strip Scan on *p*-side (along the short edge), using the 100 µm probe card to contact (in two successive steps) all 50 µm pitch metal strips
- DC STRIP SCAN on *p*-side, using the 100 µm probe card to contact (in two steps) the 50 µm pitch implanted readout strips (the non-readout ones are not accessible)

Types of defects

The standard test allows detecting all types of defects affecting strips:

- DC strip with leakage current above spec (20nA)
- DC strip with insulation resistance below spec (50 MΩ)
- Broken AC capacitors
- Metal short between adjacent AC strips
- Interruption of the metal strip (metal open)

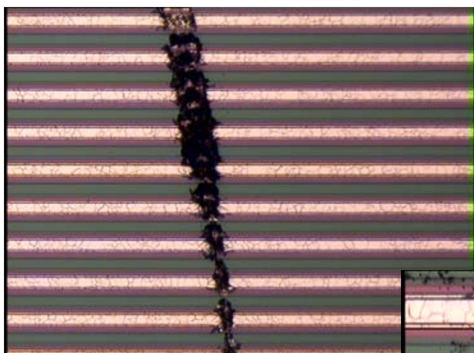


Defect 3 in 1

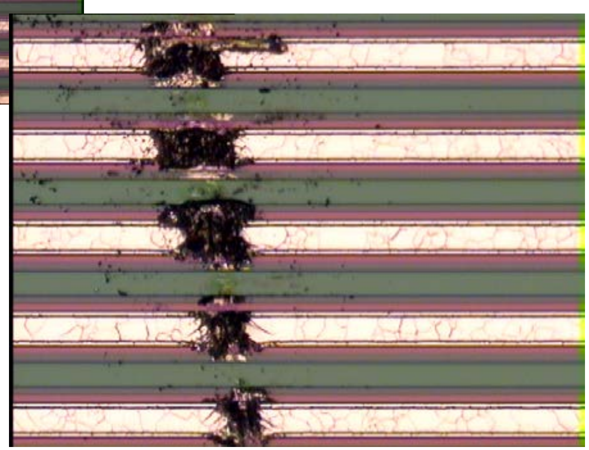
- open n strip
- open p-stop
- high current p – n contact

Bell2 Sensors tested

- The standard acceptance test includes:
  - immediate analysis of each measurement to identify defective strips
  - optical inspection of dubious cases
  - separation of shorts whenever possible



- From the AC scan:
  - No broken AC capacitors
  - Five shorted metal strips



- Shorts separated with a tungsten probe mounted on a manipulator
- Involved AC capacitors retested after separation. OK:
  - No broken AC capacitors
  - No shorts
  - No opens

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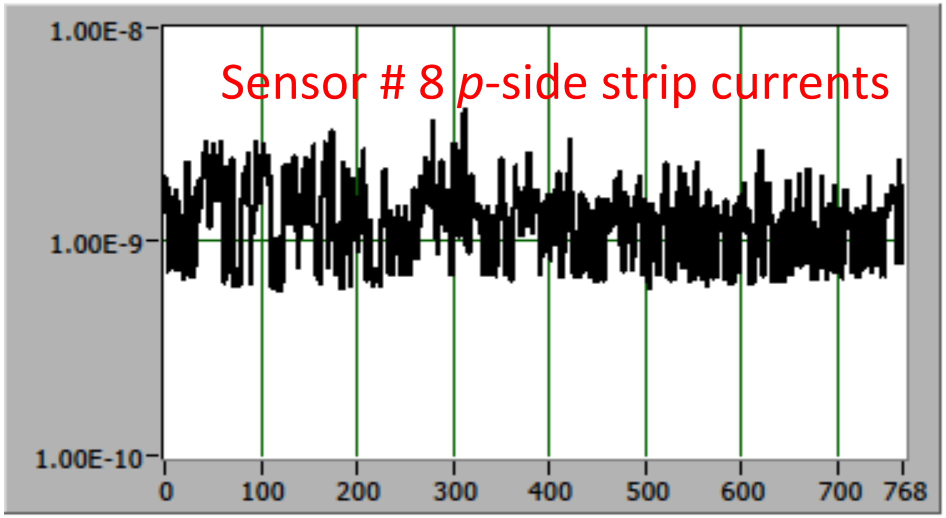
Test of Hamamatsu Sensors

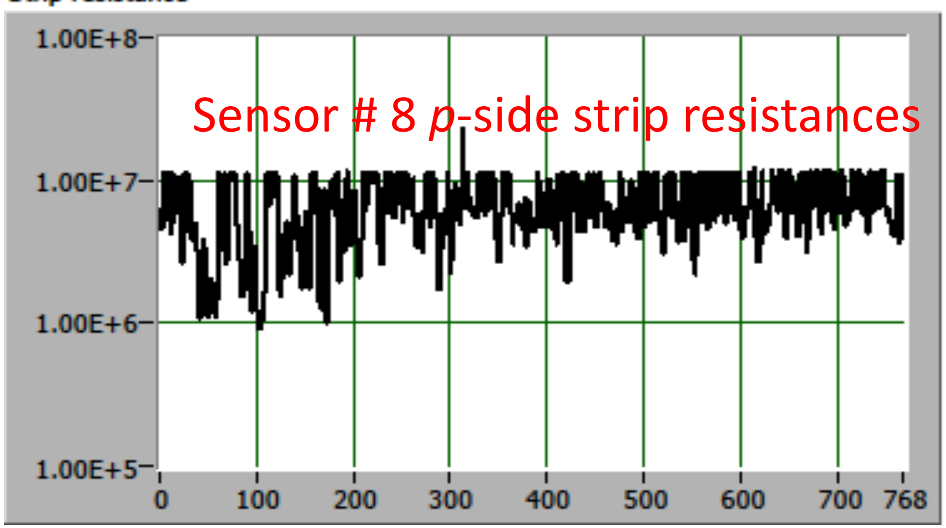
- Many additional dedicated tests were made in order to better clarify some issues emerged from the standard test
- Some inconsistencies in Hamamatsu tests have been found (later acknowledged by HPK).
- A strip insulation problem on *p*-side has been found and extensively investigated.

HPK Sensor # 8
p-side DC scan

Strip current



Strip resistance



Many strips have lower than normal, varying resistance while many others have quite uniform *R*, slightly above 10 MΩ (target value). This suggests the occurrence of local surface inversion spots between the strips.

The fluctuating currents (< 1 nA variations) are due to small voltage offsets between the measuring channels, interconnected by a few MΩ resistance.

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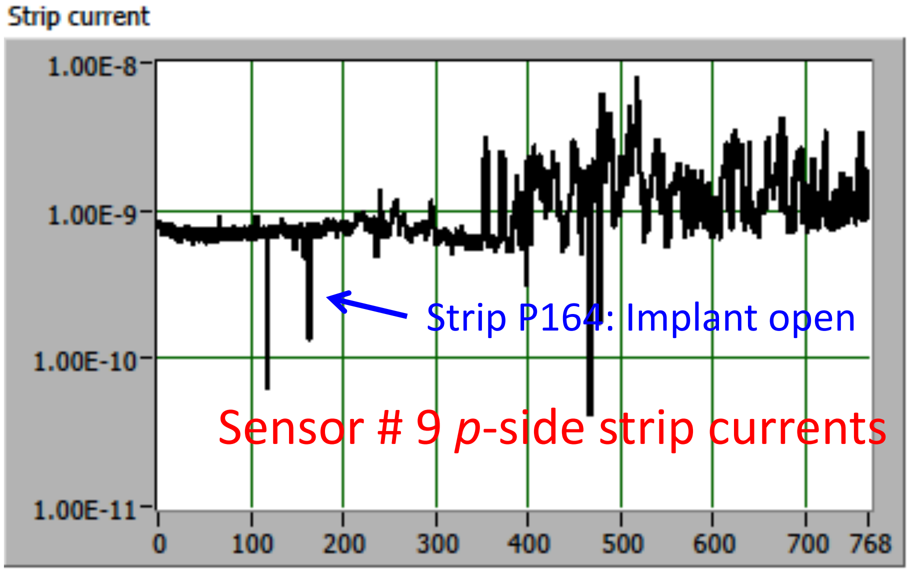
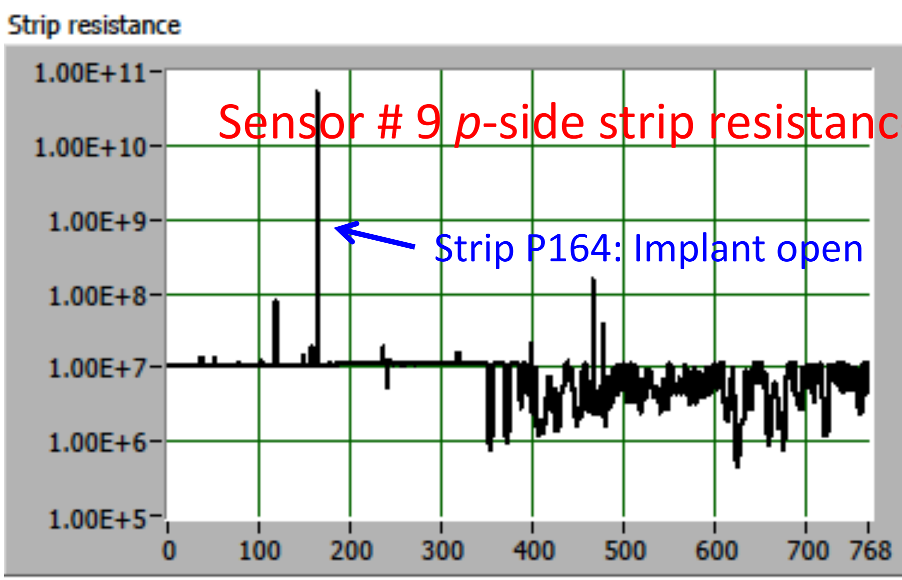
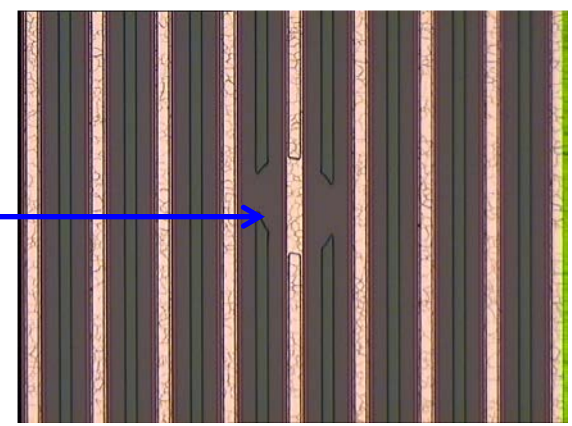
HPK Sensor # 9 *p*-side DC scan



Similar problem as found on sensor # 8, but limited to the second half of the sensor.





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Investigation on the Strip Insulation Issue

- Sensors showed signs of local surface inversion between the strips

- An attempt was made to control the interface condition by applying voltage to the insulated metal AC strips:
  - three contiguous AC strips contacted by manipulators
  - the central DC strip current has been measured as a function of the voltage applied to the three AC strips

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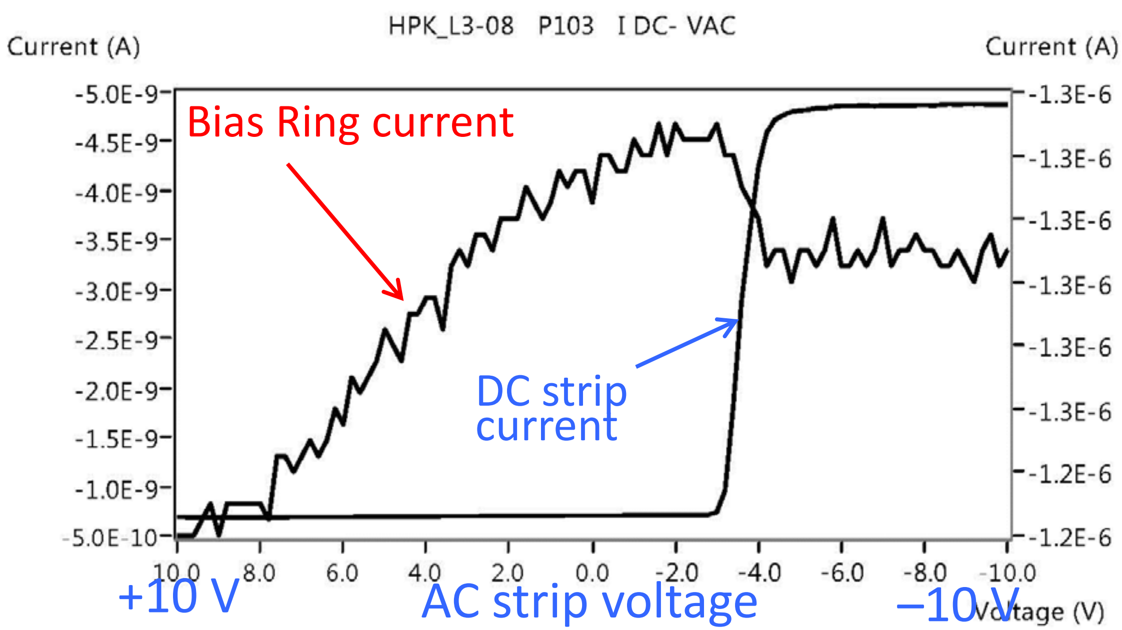
HPK Sensor # 8

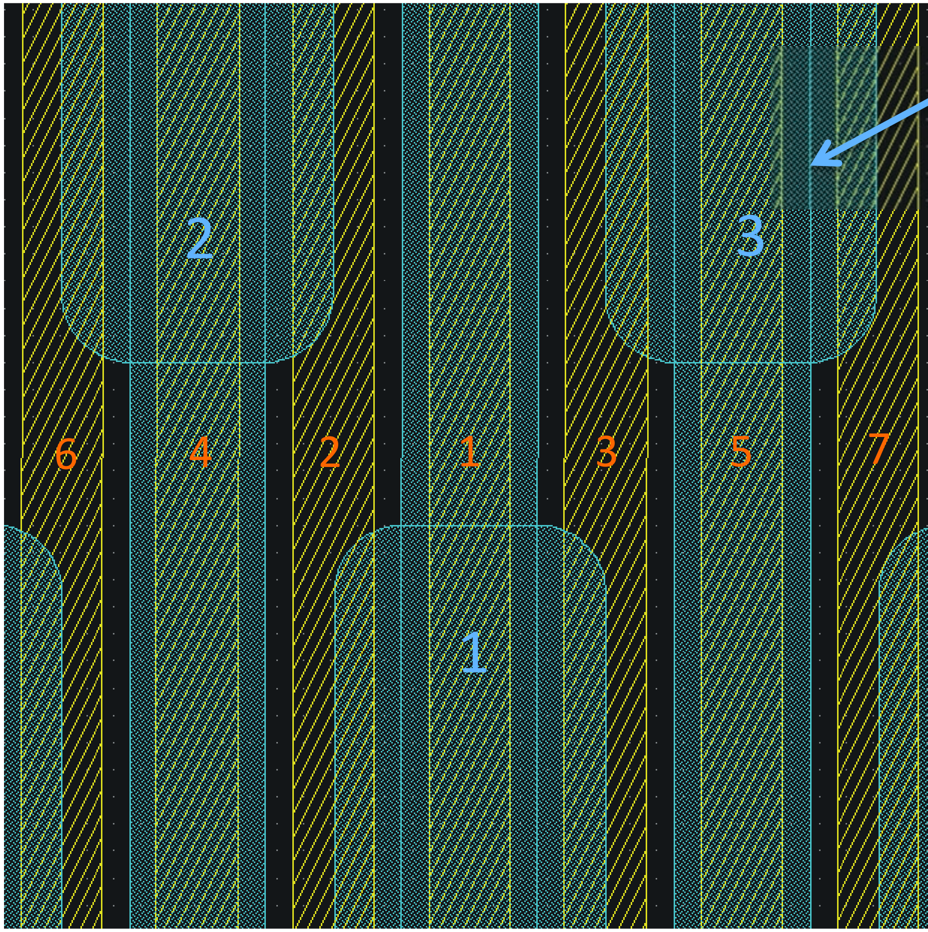
Strip P103 I_{DC} versus V_{AC}



- V_{bias} = 150 V
- V_{AC} of three strips (#102, 103, 104) swept from +10 V to -10 V
- V of DC strips ≈ V_{BR} = 0

- For V_{AC} > -3 V we measure the leakage current of a single p^+ strip (≈ 0.7 nA)
- For V_{AC} < -4 V the DC strip current becomes ≈ **seven times higher**, indicating that it is collecting the current of seven contiguous strips
- A corresponding drop of current is observed on the Bias Ring
- The transition is rather sharp and reversible, with no appreciable hysteresis

Parasitic MOSFET on p-side

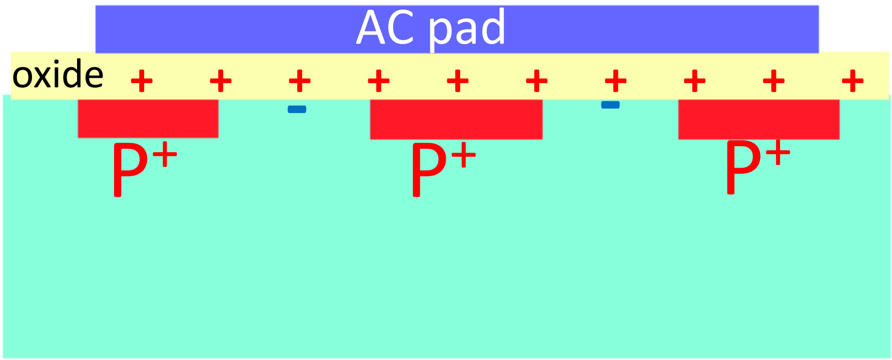


Note: The layout detail shown actually belongs to a wedge (Micron) sensor, but the situation is very similar for rectangular (HPK) sensors.

- The AC pad overlaps the two adjacent implanted strips, acting as the metal gate of a parasitic P-MOSFET.
- If a negative voltage < V_{thr} is applied, say, to *three* contiguous AC strips, then *seven* implanted strips (3 readout and 4 non-readout) get shorted together.
- This effect is immediately reversible by changing the voltage applied to the AC pads.
- However, the parasitic MOSFET may also be switched on by *ions slowly drifting* on the outer sensor surface or in the dielectric layers. This may lead to *inversion of portions of the interface not directly controlled by the metal gate*, an effect that is subject to large and poorly controllable hysteresis.

Parasitic MOSFET on p-side

$V_{AC} = 0$ V

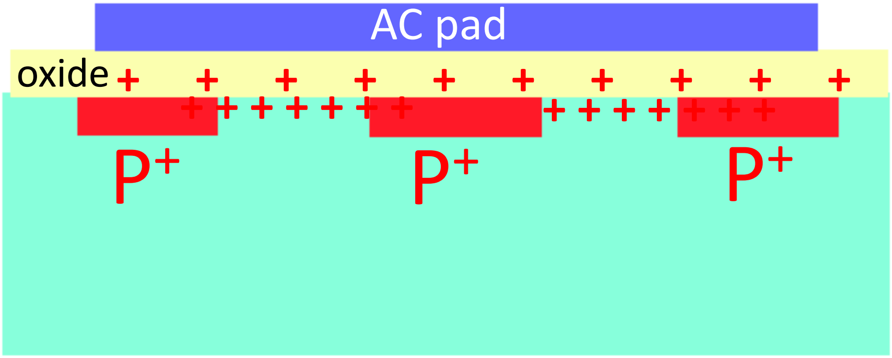


When $V_{AC} = 0$ (or a value $> V_{thr} \approx -3$ V)

surface is accumulated/depleted

==> strips are insulated

$V_{AC} = -3$ V



When $V_{AC} \leq V_{thr} \approx -3$ V , surface is inverted

==> strips are shorted together

HPK Sensor # 8
p-side DC scan # 2

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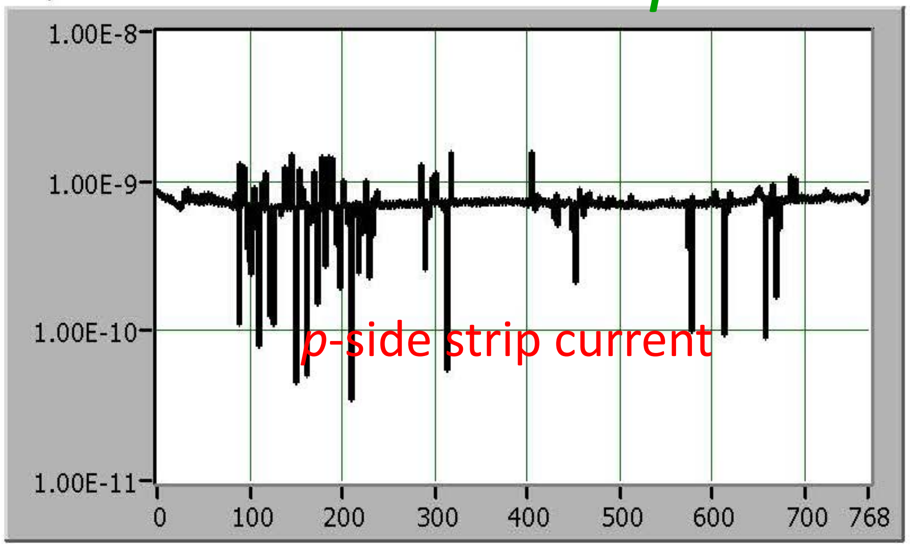
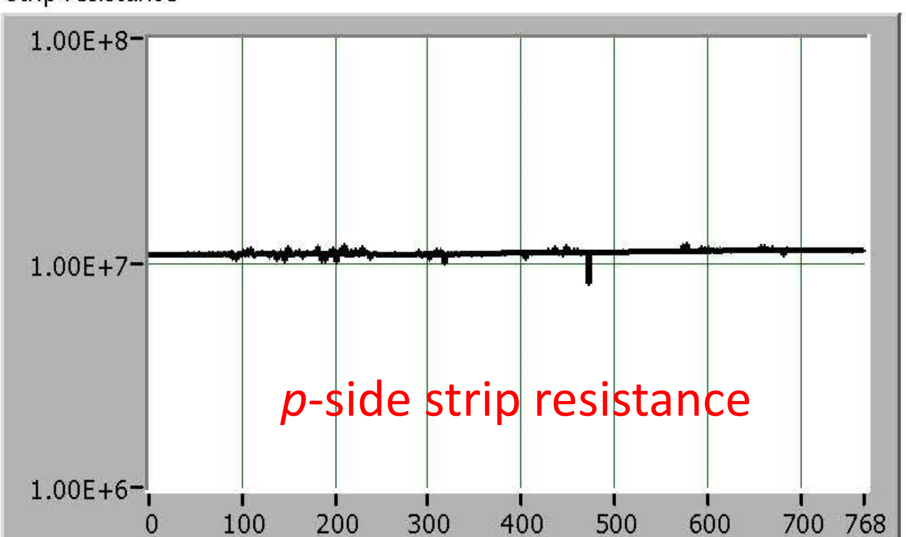
Strip current



Strip resistance



After AC scan with

V AC = + 10 V

0 strips have R < 10 MΩ

(the one shown in the plot had a probe contact problem)

By biasing all AC strips at +10 V for a short time (10 s) strip insulation has been recovered

Summary of strip insulation on HPK sensors

It's easy to invert the surface because of two reasons:

- Low oxide charge on (100) oriented substrates
- Small pitch of p strip and AC pad that completely cover the gap between adjacent strips

The problem could likely come up during the following manipulati ons of the sensor, in particular during the complex assembly phas e (contact with teflon-covered jigs, kapton…).

A final recommendation

Because of the danger of surface inversion, the voltage applied to the readout chips (relative to the Bias Ring) should never become more negative than about -2.5 V (taking into account the fact that the APV25 input is at +0.75 V relative to the local reference).

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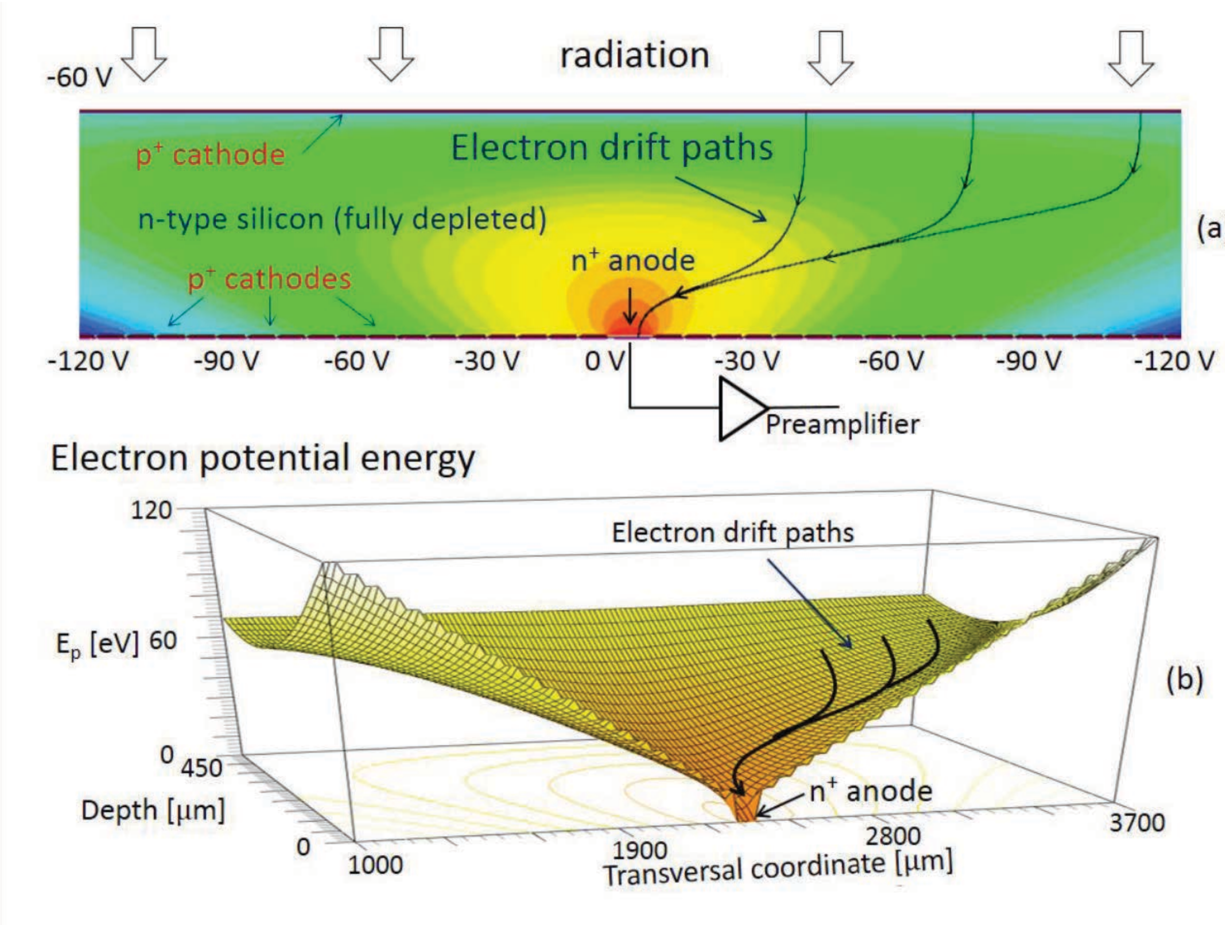
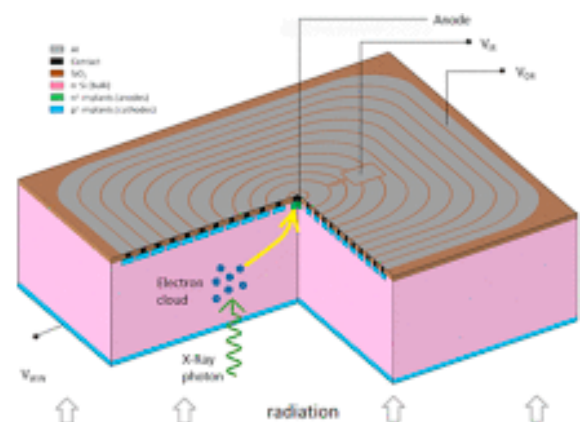
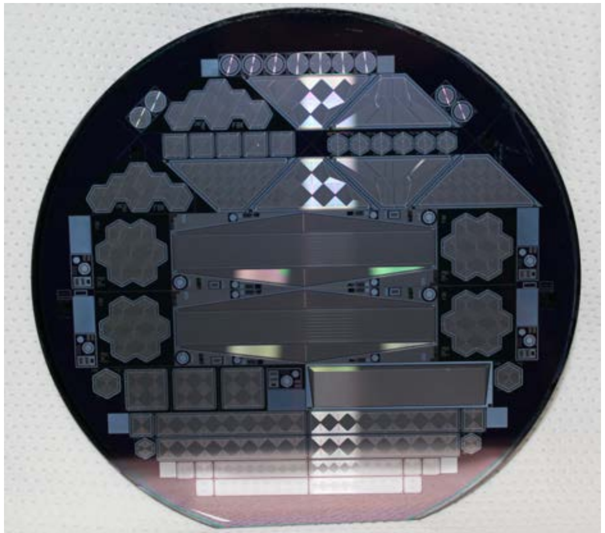
Silicon Drift Detector

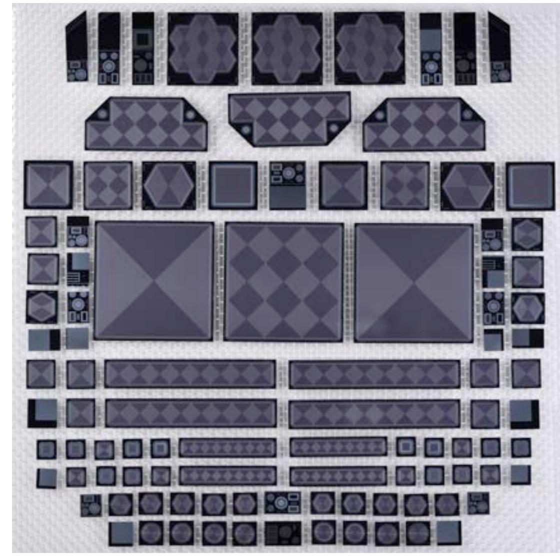




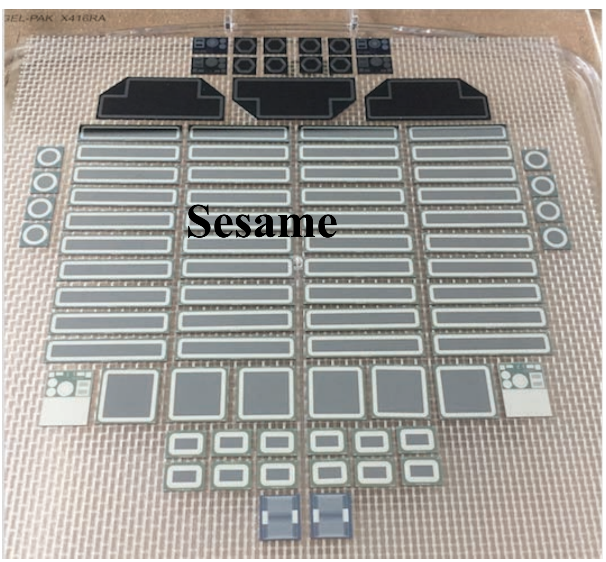
Silicon Drift Detector - FBK



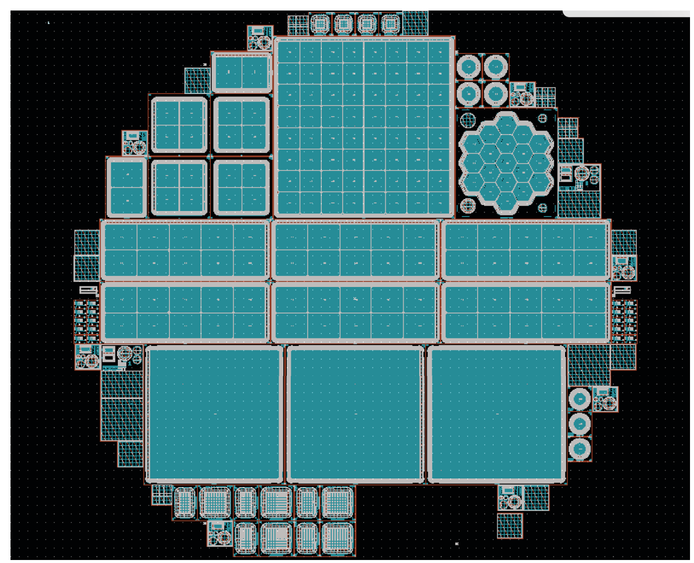
RedSox2 2015



Redsox3 2016

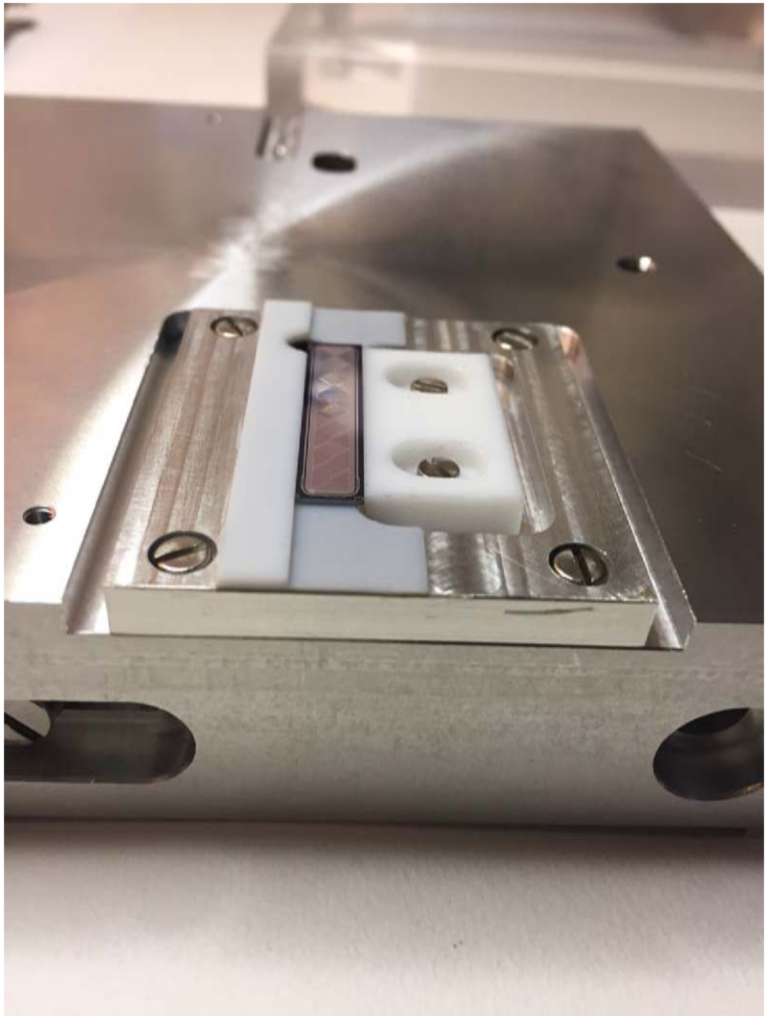


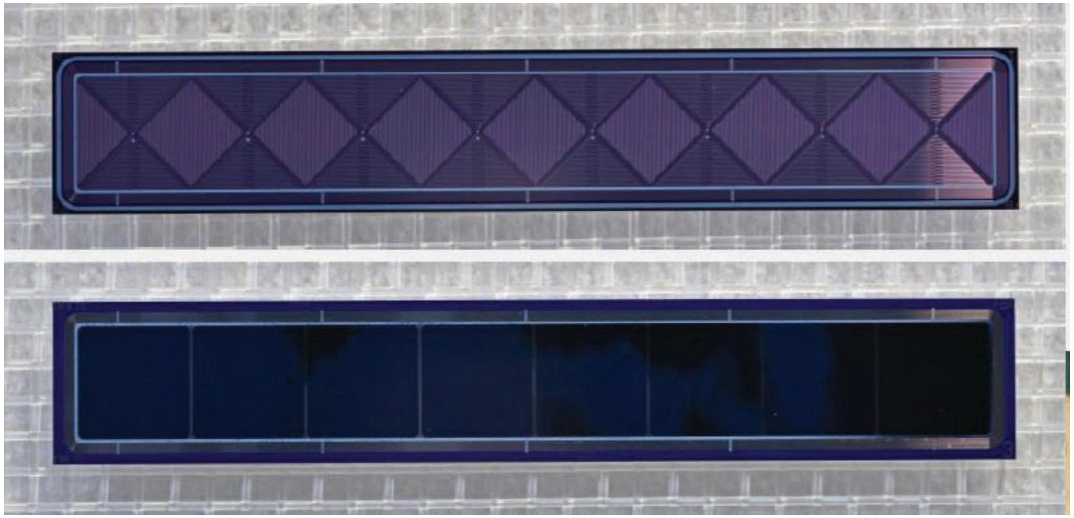
Sesame 2018



Redsox4 2019

Sesame Sensors





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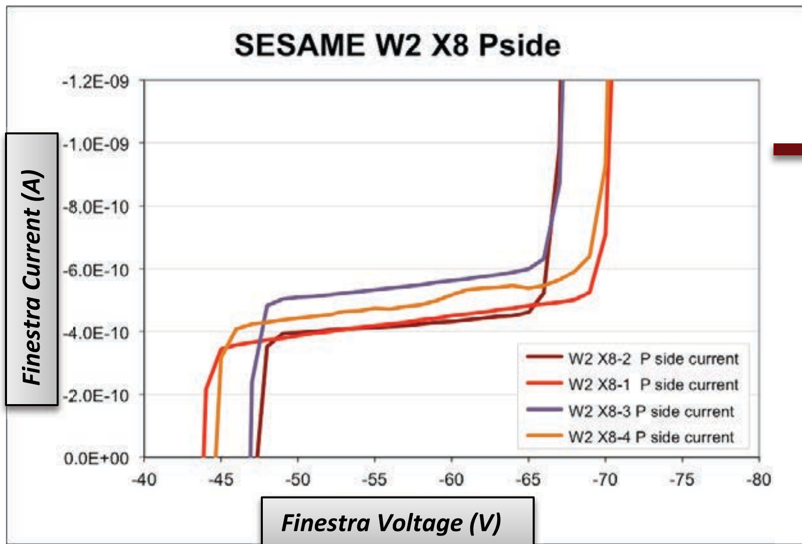
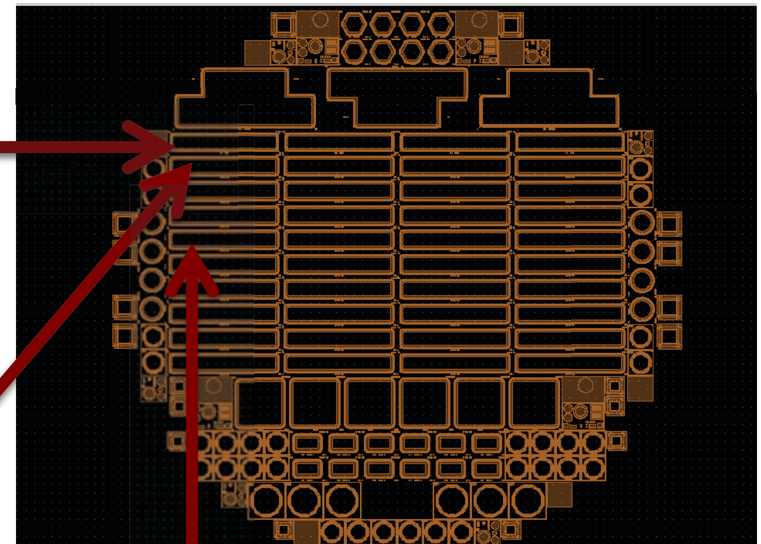
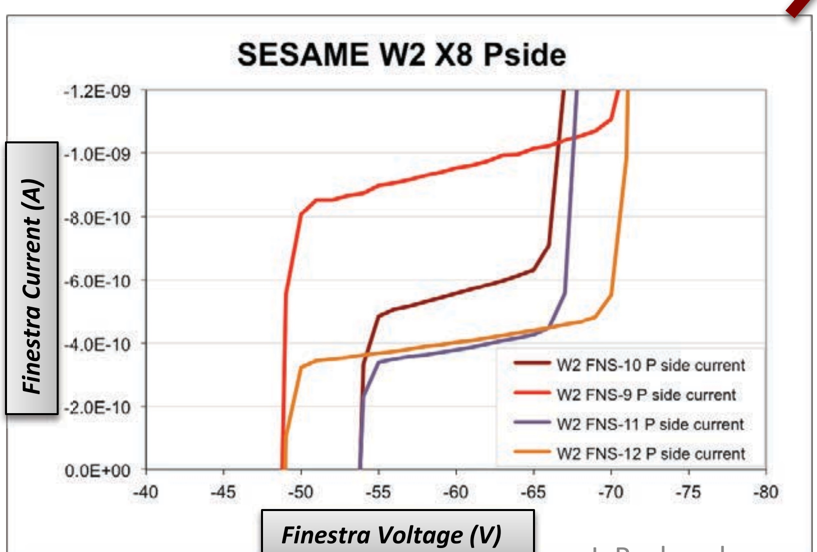
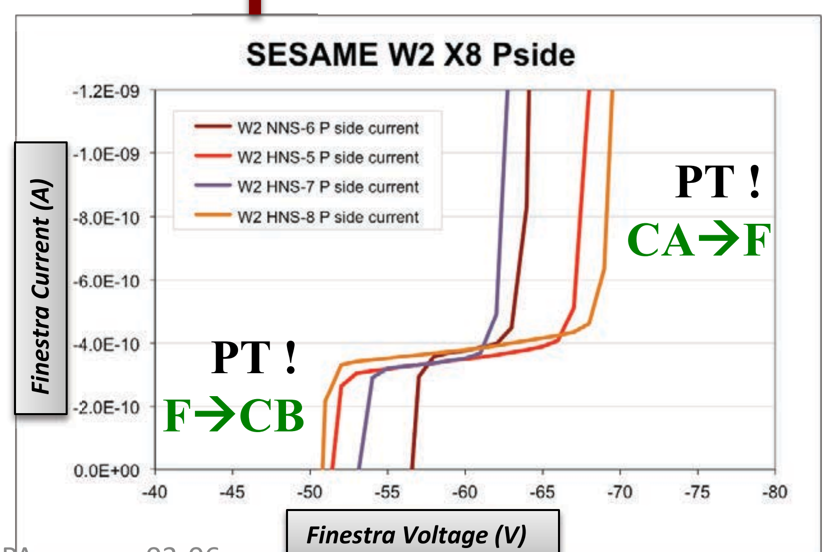
Sesame Sensors

I-V CA -20, CB -120, F -40→-80









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and Applications

Sesame Sensors
19 needles Probe Card test

INFN TRIESTE
Istituto Nazionale di Fisica Nucleare
Sezione di Trieste

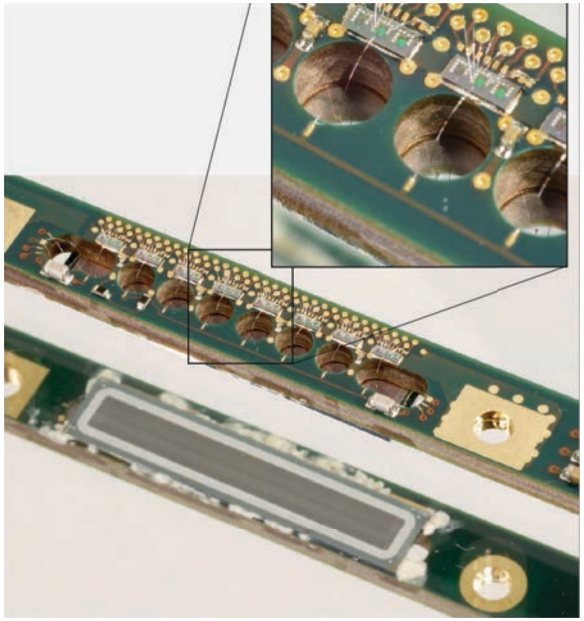
Lotto Sesame	8 cells 9mm2								TEST				
		I-V V	I-V GR CB,CB , N+	Anodo	I Anodo A	R Ohm	I P+ pA	Comments	Tested 8	Excelle 2	Good 4	Total 6	Yield 75%
			T=26 C							20pA	100pA		
W4				1	1.17E-11	1.22E+07	-1.31E-09		1	1			
NNS-9		58V	983	2	1.03E-11	1.08E+07	-1.31E-09						
			207	3	7.05E-12	1.30E+07	-1.31E-09						
21/01/19	V_CA = -20V			4	2.26E-11	1.28E+07	-1.31E-09						
	V_CB= -120V			5	7.00E-12	1.24E+07	-1.31E-09						
	V_P = -60V	150V	666	6	6.65E-12	1.19E+07	-1.31E-09						
			1432	7	6.75E-12	1.15E+07	-1.31E-09						
Scheda 21				8	6.80E-12	1.11E+07	-1.31E-09						
			T=25°C		T=26.4								
W4				1	6.65E-12	1.05E+07	-6.47E-10						
NNS-10		57V	1068	2	3.70E-11	1.03E+07	-6.47E-10						
			298	3	6.60E-12	1.01E+07	-6.47E-10						
21/01/19	V_CA = -20V			4	6.70E-12	9.95E+06	-6.47E-10						
	V_CB= -120V			5	6.60E-12	9.85E+06	-6.47E-10						
	V_P = -60V	150V	1104	6	6.60E-12	9.77E+06	-6.47E-10						
			976	7	6.55E-12	9.70E+06	-6.47E-10						
				8	5.54E-11	9.66E+06	-6.47E-10						
			T=25°C										
W4				1									
NNS-11		55V	1038	2									
			274	3									
28/12/18	V_CA = -20V			4									
	V_CB= -120V			5									
	V_P = -60V	150V	1024	6									
			1076	7									
Misure P'T				8									
			T=25°C										
W4				1	7.25E-12	1.25E+07	-1.47E-09						
NNS-12		56V	1020	2	7.10E-12	1.27E+07	-1.47E-09						
			255	3	7.00E-12	1.26E+07	-1.47E-09						
28/12/18	V_CA = -20V			4	7.00E-12	1.18E+07	-1.47E-09						
	V_CB= -120V			5	3.36E-11	1.10E+07	-1.47E-09						
	V_P = -60V	150V	602	6	9.75E-12	1.08E+07	-1.46E-09						
			1691	7	1.83E-11	1.08E+07	-1.46E-09						
				8	2.59E-11	1.10E+07	-1.46E-09						
			T=25°C		T=26.2								
W4				1	8.50E-12	1.10E+07	-6.45E-10						
NNS-5		57V	986	2	8.20E-12	1.21E+07	-6.44E-10						
			163	3	7.85E-12	1.30E+07	-6.44E-10						
28/12/18	V_CA = -20V			4	7.25E-12	1.29E+07	-6.44E-10						
	V_CB= -120V			5	7.30E-12	1.24E+07	-6.44E-10						
	V_P = -60V	150V	1030	6	7.25E-12	1.18E+07	-6.44E-10						
			778	7	1.92E-11	1.13E+07	-6.44E-10						
Scheda 19				8	7.55E-12	1.09E+07	-6.44E-10						
			T=25°C										

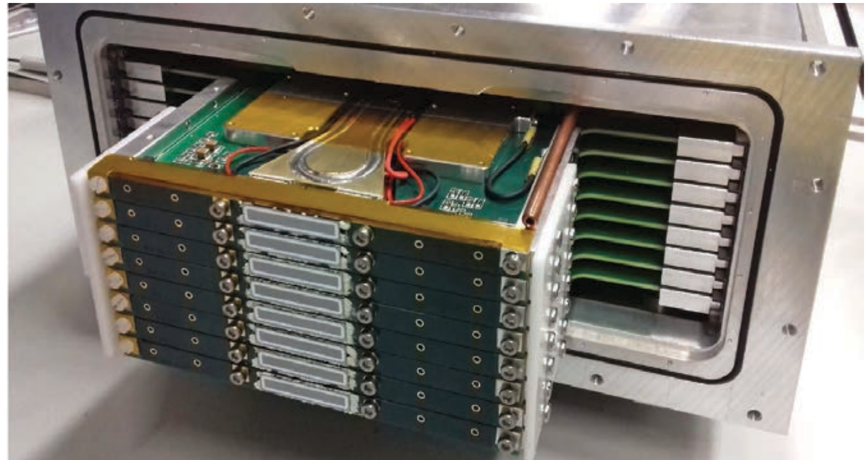
The yield is
75 – 86%

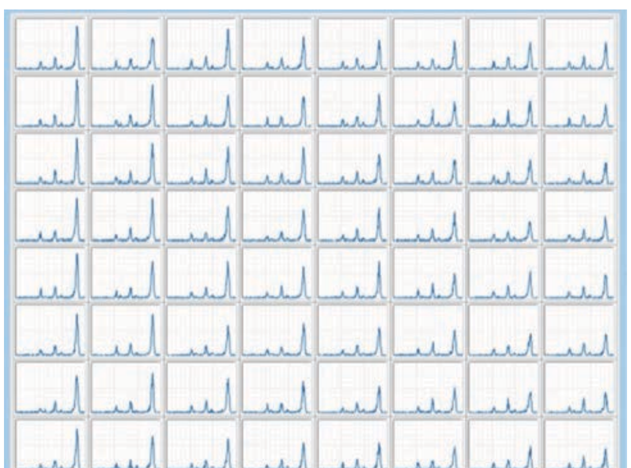
24 Excellent Sensors
were mounted
1 cel < 25pA

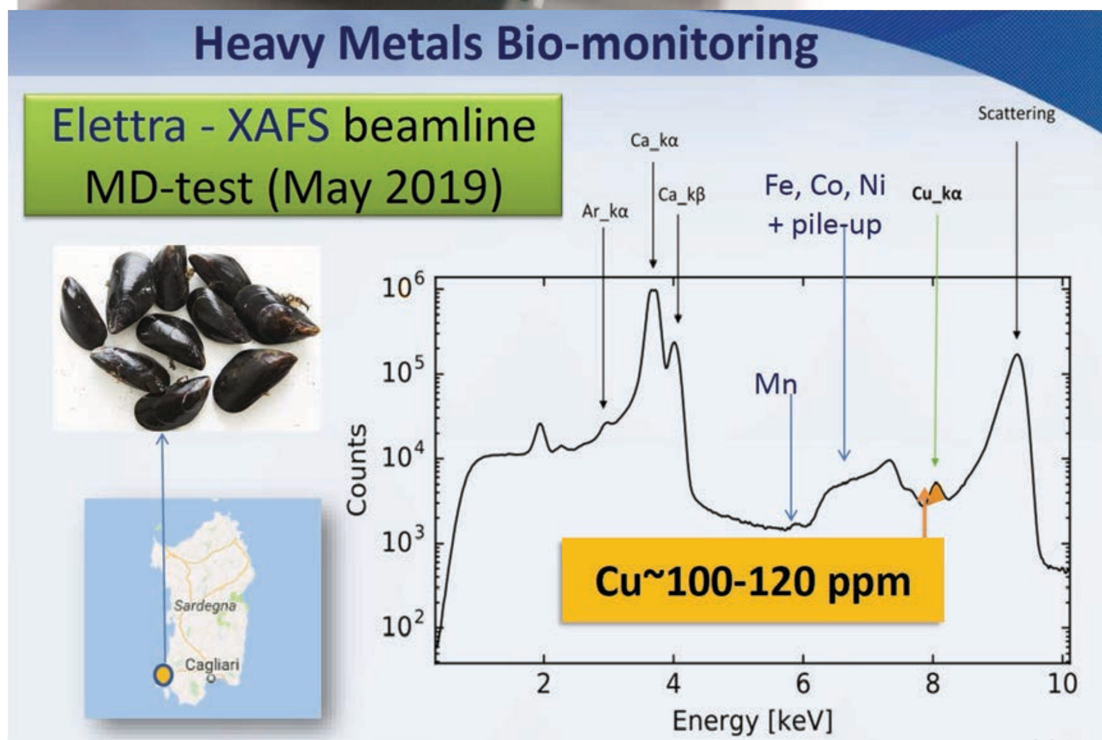
Typical cell
I anodes ~ 3pA
(35 pA/cm^2)

64 channel XAFS-Sesame









XAFS-SESAME Detector System

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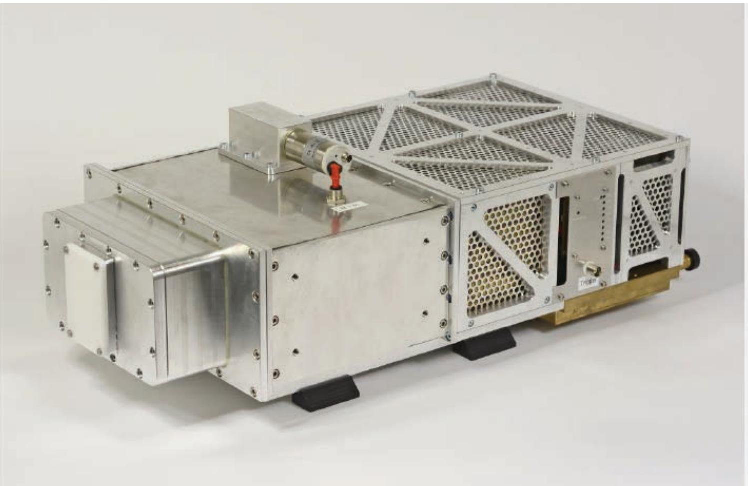
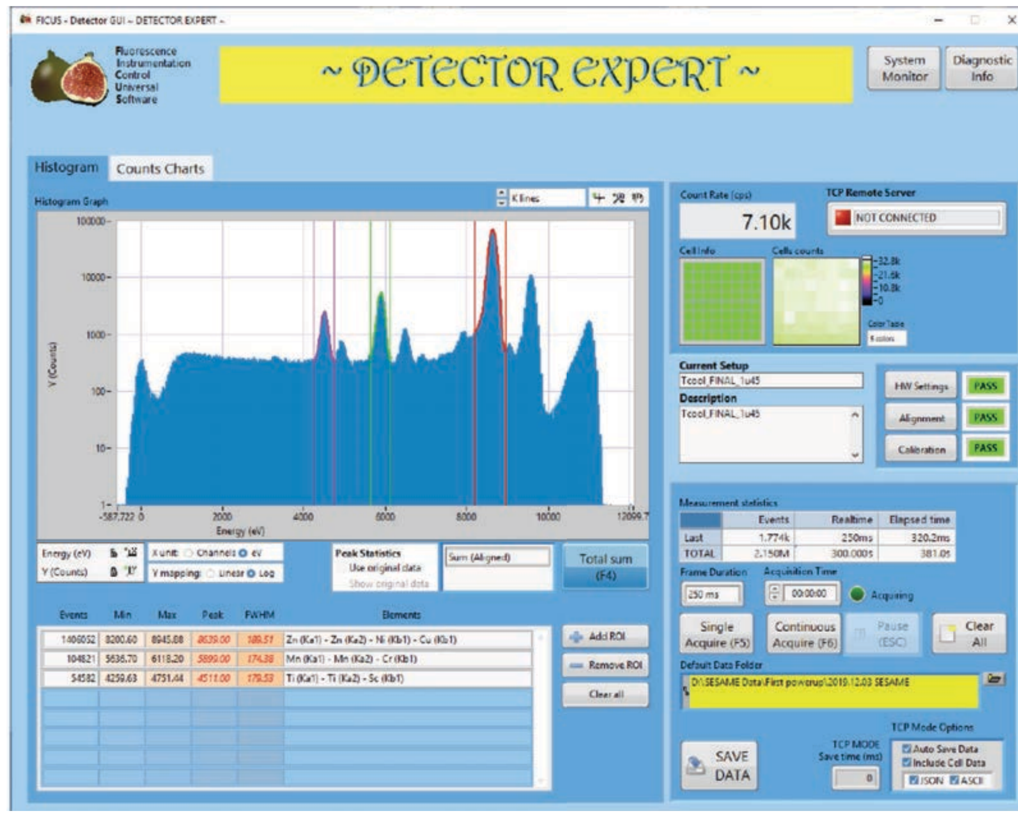


Tamb-1µ45 -5min –Mn Kα

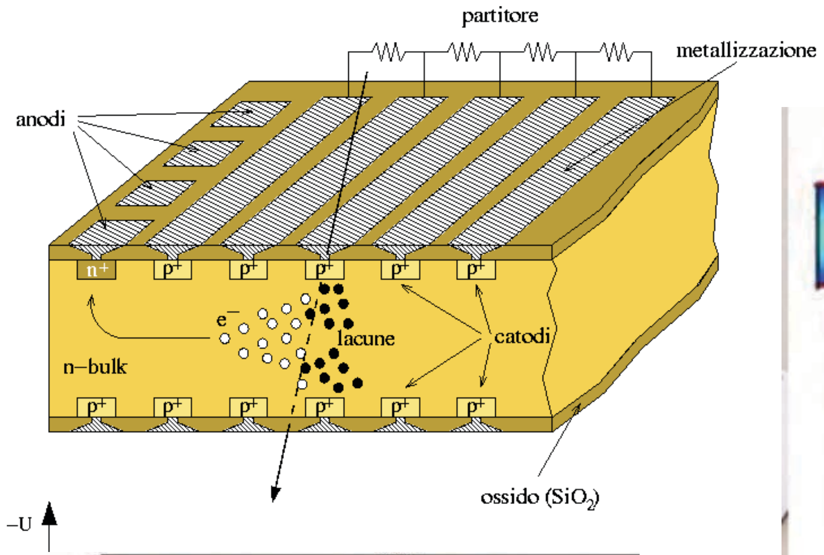
The resolution of the sum of the signal coming from all 64 channels is 168 eV

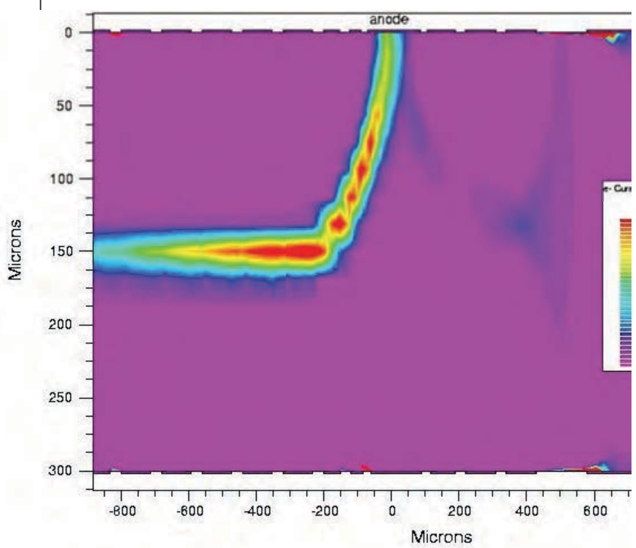
Tcool-1µ45 -5min –Mn Kα

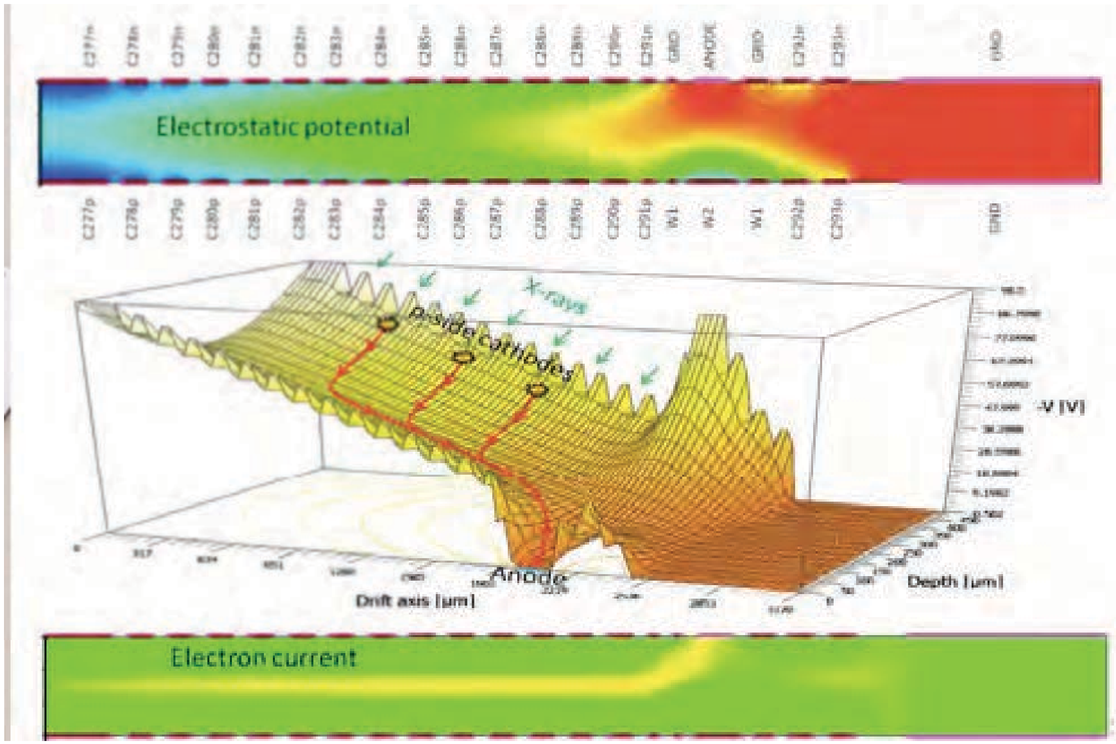
The resolution of the sum of the signal coming from all 64 channels is 162 eV.



Linear Silicon Drift Detector



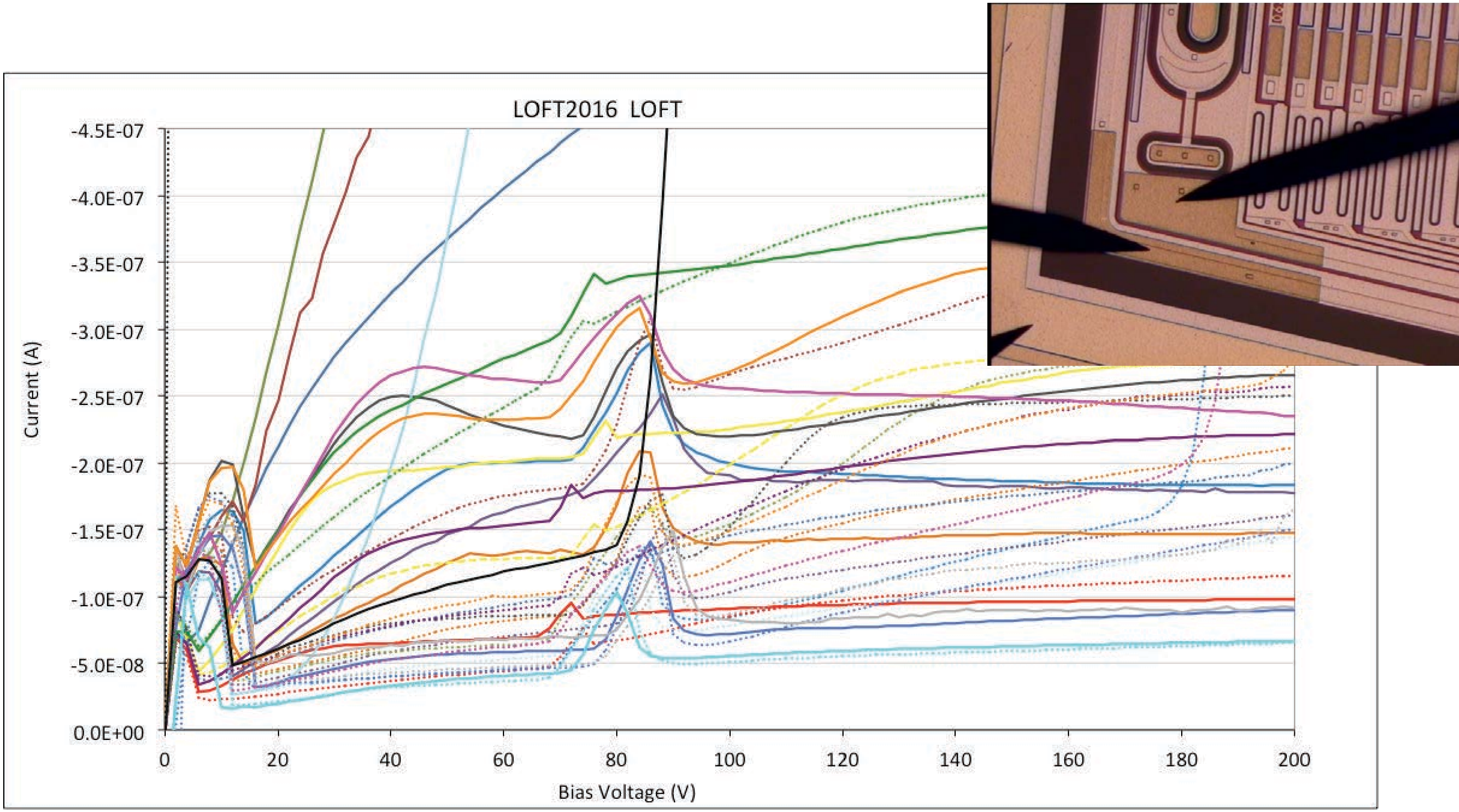




Linear Silicon Drift Detector

Large Area Silicon Drift Detectors for X-ray spectroscopy, timing and imaging designed by INFN Trieste and developed in collaboration with INAF (IAPS Rome, IASF Bo), Fondazione Bruno Kessler, PoliMi, University of Pavia, University of Bologna. More than10 yrs R&D activity

Linear Silicon Drift Detector



The enhanced X-ray Timing and Polarimetry mission (eXTP)

Trento Institute for Fundamental Physics and Applications

eXTP is conceived as a powerful and general observatory for compact Galactic and bright extragalactic objects to date. It will offer for the first time the most complete diagnostics of compact sources: excellent spectral, timing and polarimetry sensitivity on a single payload.

The eXTP Team is open to contributions from the wide scientific community. More info at: http://www.isdc.unige.ch/extp/

The enhanced X-ray Timing and Polarimetry mission will cost around three billion yuan (£340m) and is set to launch by 2025 (courtesy: Institute of High Energy Physics)

the Large Area Detector (**LAD**):
a deployable set of 640 Silicon Drift Detectors, achieving a total effective area of ~3.4 m^2 between 6 and 10 keV. The operational energy range is 2-30 keV and the achievable spectral resolution better than 250 eV. This is a non-imaging instrument, with the FoV limited to <1° FWHM by the usage of compact capillary plates.