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Silicon Sensor Quality Assurance for the CDF Run2b Silicon Detector

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Abstract

This document describes in detail the quality assurance (QA) program for the CDF Run2b silicon sensors. The scope of the QA program, the responsibilities of the participating institutions and the measurement procedures are defined.

1. Introduction

The CDF collaboration is building a new silicon tracker system for Tevatron collider Run2b, replacing the present L00 and SVXII detectors. The new silicon system will be a six-layer device located between 2.1 cm and 16 cm radius, consisting of ~2300 single sided silicon sensors. The planned silicon detector is expected to become operational in 2005.

A thorough, reliable, and efficient silicon sensor probing and characterization, defined in a well-organized silicon quality assurance (QA) program, are critical for the sensor quality and hence the success of the silicon detector. This document describes the procedures, responsibilities and the organization of the silicon sensors quality control for Run2b. In particular this includes:

- Organization and responsibility of testing
- Testing procedures and acceptance criteria
- Testing setups
- Accounting, documentation and database

2. General CDF Run2b silicon sensor QA organization issues

Quality assurance will be a collaborative effort and is shared among different institutes. The Procurement Institutes and other institutes (Testing Institutes), which are participating in the QA program, have to perform the quality checks in a consistent manner as defined in the QA program described here. The responsibility for the complete QA program implementation will be the task of the local coordinator of each of Testing and Procurement Institutes. Before a Testing Institute will start to take part in the silicon QA program, it has to be certified by the Run2b silicon group.

The Procurement and Testing Institutes presently foreseen are listed with the names of local coordinators:

Procurement and Testing Institutes

- University of Tsukuba, Japan. Local coordinator: Kazuhiko Hara
- Kyunpook National University, Korea. Local coordinator: Dong-Hee Kim

Procurement Institute

- Fermilab, Batavia, USA. Local coordinator: Nicola Bacchetta

Testing Institutes

- University of New Mexico: S. Seidel
- Purdue University: D. Bortoletto
- University of California at Davis: D. Pellet

The three Procurement Institutes, University of Tsukuba, Fermilab, and Kyunpook National University, perform dedicated testing and coordinating tasks. Its main tasks will be:

(1) Initial registration of the sensors
(2) Visual inspection on and I-V measurement of the sensors
(3) - Distribution of the sensors to outside Testing Institutes, or
- Performance of an additional sensor characterization measurement program on sensor sub-samples
(4) Shipping and handling of the rejects which are returned to the supplier
(5) Overall monitoring of the QA program

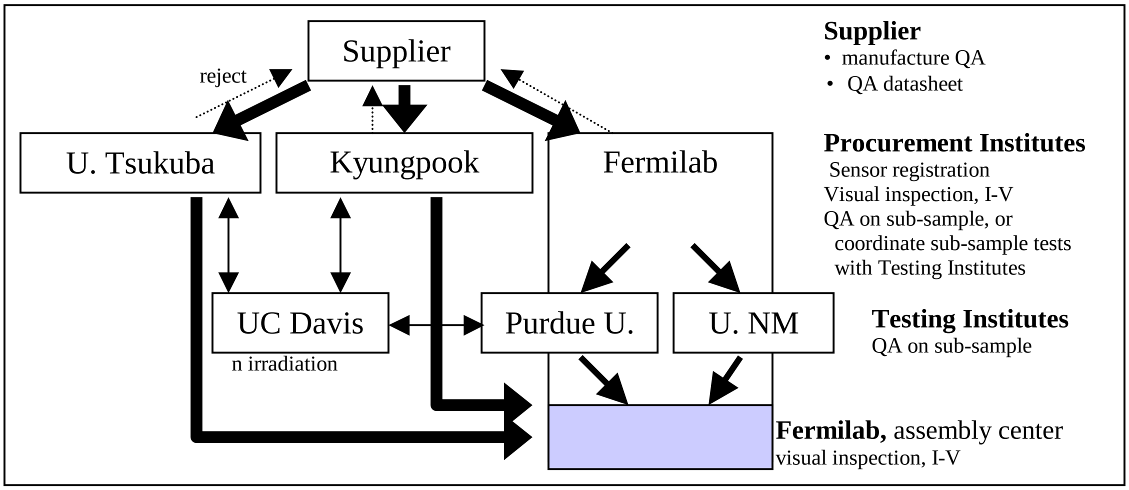
The sensor characterization in Item (3) is carried out by Testing Institutes, and hence the sensors procured by Fermilab will be tested by outside institutes, Purdue University and University of New Mexico. University of California at Davis will conduct irradiation programs.

The qualified sensors will be gathered to Fermilab where sensors are assembled to the staves. As the Assembly Institute, Fermilab will perform:

(6) Collection of the test data and grading of the sensors
(7) Visual inspection and I-V measurement of the sensors just before assembling into the module

The above items (1) to (7) require coordinated work between the Procurement and Testing Institutes and their completion will be the responsibility of the appointed Run2b silicon sensor coordinators together with the local coordinators at these institutes.

Among the above items, item (2) can be skipped later once the quality production is established. Such changes in the described procedures have to be agreed by the Run2b silicon group. Figure 1 shows a graphical representation of the QA program with the silicon sensor flow.



3. Overview of Sensor Design, Specifications and Terms of Acceptance

3.1. General

All silicon detectors are p^+n type single sided sensors, with AC coupling and biased through polysilicon resistors. The silicon sensors will have a guard ring with peripheral n-well design. We envision three sensor types for Run2b:

Layers/ Type	Active Length (mm)	Active Width (mm)	Strip pitch /readout pitch (µm)	# readout channels	# of sensors + spares
0 /Axial	77.36	12.8	25/50	256	144+30%=190
1-5 /Axial	94.35	38.5	37.5/75	512	1512+20%=1800
2-4 /Stereo	94.35	39.0	40/80	512	648+23%=800

All the sensors will be manufactured on 6’’ wafers.

Schematic drawings of the sensors, on which the location of strips, fiducial marks, bonding pads as well as the strip numbering definition and other features are indicated, exist on http://hep-www.px.tsukuba.ac.jp/~hara/run2bsi.html. The sensors carry a 16-field scratchpad for unique sensor identification[1].

3.2. Specifications

The detailed sensor specifications are attached in the appendix of this note. The following table gives an overview:

[1] The serial numbers are given in BCD codes (each group of 4 digits represents one decimal number).

Specifications:	Inner Axial	Outer Axial/Small Stereo
Wafer thickness	320±15μm wafer warp less than 130μm	320±15μm wafer warp less than 130μm
Full depletion voltage	120<Vdep<250V	120<Vdep<250V
Leakage current	<50nA/cm2 at RT and at 500V	<50nA/cm2 at RT and at 500V
Junction breakdown	>500V	>500V
Implant width	7μm	8μm
Al width	1-3 μm overhanging metal	2-3 μm overhanging metal
Coupling capacitance	>12pF/cm	>12pF/cm
Coupling capacitor breakdown	>100V	>100V
Interstrip capacitance	<1.2pF/cm	<1.2pF/cm
Polysilicon bias resistor	1.5±0.5 MΩ	1.5±0.5 MΩ
Defective strips	<1%	<1%

3.3. Terms of Acceptance

The silicon sensors will be delivered to three procurement institutes: University of Tsukuba (64% of Outer Axial and 44% of Outer SAS), Fermilab (36% of Outer Axial, 56% of Outer SAS, and a% of Inner Axial), and Kyungpook National University (100-a% of Inner Axial)[2]. The procurement institutes will initially accept the silicon sensors delivered by the supplier and preliminary qualify them as good according to the test results of the supplier, if the criteria described in the sensor specifications are fulfilled. These institutes will carry out on every delivered sensor an electrical I-V measurement and a visual inspection. For a sub-sample of the delivered sensors, thorough measurements of the QA program will be performed to confirm the specifications. Fermilab will distribute the sensors to outside institutes for this program. Based upon the results of these measurements, the procurement institutes will reject a sensor within 6 months after delivery. The supplier will be notified and upon request the sensors will be returned for re-measurements. The supplier and the procurement institutes together with the Run2b silicon sensor coordinators can agree upon the acceptance of individual sensors if specifications are missed only marginally.

4. The QA Program

We describe in the following the complete QA program for the Run2b silicon sensor testing. The QA program consists of three main parts:

1. The visual inspection and I-V measurement are most critical and yet can be done in a reasonable time. These tests are to be performed on every received sensor at the Procurement Institutes. The same tests are carried out at Fermilab prior to assembling the sensors into modules. As we gain the experience and if the QA group agrees, the tests at the Procurement Institutes could be skipped: We maintain the tests at Fermilab prior to assembling.

[2] The percentage a is under discussion, while we aim it to be 0.

2. The tests on subsets of the sensors will be conducted on a certain fraction of delivered sensors. The fraction depends on the quality of the products and the stage of production but keeps at least one senor per batch. The main goal of the subset tests is to verify the specifications more in detail. The subset tests are mostly done in an automatic electrical measurement procedure on an automatic probe station at Testing Institutes. The mechanical test measurements are also included to verify the mechanical tolerances. Fermilab will conduct the mechanical tests for their delivery.
3. Diagnostic tests are to be performed primarily on the sensors with observed irregularities. The tests on irradiated samples are also included. The diagnostic tests may measure in much more detail complex electrical parameters, depending on the irregularity, in order to get a deeper insight into the sensor qualities.

4.1. General Conditions/Requirements of Testing

4.1.1. Clean Room Conditions and Handling of Sensors

A clean room or a clean room housing is necessary at the Testing Institute. The temperature and humidity (50+/–20%) must be controlled and recorded appropriately. The recommended testing systems/methods described in this document are our guideline, hence Testing Institutes can adopt them depending on the availability.

Before handling prototype or production type sensors at the Testing Institutes, a certain amount of practice and experience of the testing personnel is required. Protective clothes, masks and gloves shall be used always near exposed silicon detectors. When setting the sensors on the stage, use the protective paper provided by the supplier to slide in/out the probe stage. When vacuum tweezers is used, verify that it will not create damages to the sensor[3]. Anti-electrostatic procedure must be always obeyed. The sensors should only be stored in dry storage containers.

4.1.2. QA Database and Color Coded Classification

The supplier will provide Excel-based datasheets. The items for each sensor will be Lot Number, Serial Number, Leakage Currents at 0 to 1000 V in steps of 10 V, Full Depletion Voltage, and a list of dead channels. On a lot basis, polysilicon resistance range is measured. Procurement Institutes must add five columns (C through G, keeping separately the original file) of Location (C), QA (D), Assembled (E), V.I. (F), and I-V (G). Visual Inspection and I-V results are recorded in columns “V.I.” and “I-V”. The overall QA pass/fail judgment should be provided in column “QA” based on the criteria described below. It is a responsibility of Procurement Institutes to track the location until the tested sensors are gathered to Fermilab updating column “Location”. It is a responsibility of Testing Institutes to crosscheck the shipment and update the column “QA”. The test data used for the updates are also to be recorded in an Excel and attached when the sensors are shipped to Fermilab. Any new data of mechanical or electrical measurements of the QA program should contain the following data appropriately:

[3] The <100> sensors are easier to charge up than <111> sensors because the inversion potential is smaller.

Measurement data, Temperature/humidity, Date, Testing Institutes, Comments

Table 1 summarizes the new columns and color codes to help understand the status. The cells of the Excel files are originally not colored when the sensors are delivered. As the QA is underway, the color of cell “QA” is updated based on the QA result. The column “Assembled” shows sensor usage: Fermilab colors in blue when the sensor is used, Testing Institutes color in gray when the sensor is spent for destructive tests, and Procurement Institutes color in red if the sensor is rejected and sent back to the supplier.

Table 1: New Excel cells and color codes. Note that Columns A and B are filled with Lot Number and Serial Number by the supplier

Col.	Column title	Maintained by	
C	Location	Procurement Institutes (Fermilab when received from Japan/Korea)	
D	QA	Coded by Procurement Institutes and Testing Institutes	
		Red	QA failed
		Green	QA passed
E	Assembled	Coded by Fermilab, Testing Institutes, or Procurement Institutes	
		Blue	Assembled: Fermilab
		Gray	Used for destructive tests: Testing Institutes
		Red	Rejected and sent back to supplier: Procurement Institutes
F	V.I.	Procurement Institutes /Fermilab	
G	I-V	Procurement Institutes /Fermilab	

Table 2: An example of Page-1 of Excel datasheet. The leakage current and other data columns continue further to the right.

							Leakage Current[nA]	
Lot No.	Serial No.	Location	QA	assembled	V.I.	I-V	0V	10V
SWA61457	0002	Tsukuba	OK		OK	OK	4.982	40.59
SWA61457	0010	Tsukuba	OK		OK	OK	4.919	40.66
SWA61457	0011	Tsukuba	OK		OK	OK	4.784	47.6
SWA61457	0016	Tsukuba	OK		OK	OK	4.944	38.86
SWA61457	0020	Tsukuba	OK		OK	OK	4.934	43.35
SWA61457	0021	Tsukuba	OK		OK	OK	4.935	38.64
SWA61457	0023	Tsukuba	OK		OK	OK	4.899	41.32
SWA61457	0026	Tsukuba	OK		OK	OK	14.443	51.93
SWA61457	0027	Tsukuba	OK		OK	OK	4.948	41.64
SWA61457	0032	Tsukuba	OK		OK	OK	5.574	37.15

One Excel file will be created including all the sensors in the same delivery container. Each container must be labeled properly such that one-to-one correspondence is clear between the container label and Excel file name. The container and the Excel file must be always carried together. When sensors are shipped to outside institutions, both have to be shipped. If only a part of the sensors are to be shipped, create a new Excel file including only those sensor data. Adding/updating the test results is to be made directly to the

Excel file attached. Testing Institutions have to record the most updated data. When different Testing Institutes add a new set of data, add new page (I-V (2), for example) to the same book. The MainPage, though, has to be updated directly under the responsibility of Test Institute where the latest QA is carried out.

The provisional Excel file name is

030122_SVX2B-OUT0-SSD_TKB_to_FNAL_14.xls

indicating the shipping date, project name (SVX2B), sensor type (OUT0 for outer axials, OUTS for outer stereos, and IN0 for inner axials), shipping institute, receiving institute, and the number of sensors packaged.

4.2. Tests performed by Procurement Institutes

Procurement Institutes perform on every sensor a visual inspection and I-V measurement. The initial sensor registration includes checking of the supplier datasheet and color code classification of the delivered sensors.

4.2.1 Initial Sensor Registration

This task is performed at each of Procurement Institutes. The procedure is as follows:

(1) On receiving the supplier's datasheet in Excel, copy the original Excel file to a new one and add new five columns as described in Table 1. This page is referred to Page-1 or Main Page.

(2) The shipment of the sensor batch is checked for the content with the supplier's datasheet. Cell "Location" is filled with the name of the Procurement Institute with checking:

- batch/lot number
- serial ID-number of sensor

(3) Cell "QA" is colored based on examination of the supplier's data on

- leakage current values up to 1000V in a step of 10V (less than 2μA at 500V)
- depletion voltage (120V to 250V)
- number of bad channels/strips as claimed by vendor (less than 6)
- polysilicon resistor values (1 MΩ to 2 MΩ: data given on a lot basis)

The examination must be done automatically using Excel by checking the leakage current at 500V, depletion voltage range, and number of dead channels. The polysilicon resister values measured on a lot basis are provided on a separate paper, which are also to be checked.

(4) It is mandatory to create a plot showing I-V curves and check irregular sensors.

The sensors with irregular I-V characteristics are selected for I-V stability test described below.

The sensors are now ready for visual inspection and I-V measurement.

4.2.2 Visual Inspection

A visual inspection on all arrived sensors is a key sensor test especially at early stage of production, which will ensure that the sensor is free from physical defects and scratches. The results of the visual inspections in case of sensor flaws should point to the strip regions, guard/bias ring regions or edges, which look bad and doubtful, so that further electrical measurements have to be conducted.

The visual inspection is carried out at Procurement Institutes on an x-y moving table equipped with a microscope having high magnification optics (5x-50x). A camera hooked up to the microscope and a monitor with recording capability are necessary.

Procedure:

1. Ensure that the x-y table is completely clean.
2. Remove sensor from its envelope/shipping container.
3. Search for any signs of silicon debris in the sensor envelope. If debris is present, be sure to remove it before eventually returning the sensor to the envelope, and identify the source of the debris during the visual scans of the sensor.
4. Examine the back surface by eye with placing the sensor on the protective paper, which can be found in the envelope. If there are indications of edge chipping, or any blemishes or scratches, place the sensor on the x-y stage without removing the protective paper. Measure the size of the defect and take a picture if appropriate.
5. Place the sensor with the strip side up on the x-y stage. It is recommended to use the protective paper under the sensor.
6. Check that the serial number scratched on the identification pads matches the serial number on the sensor envelope.
7. At high magnification, scan along all four edges, searching for edge chipping, scratching or other damage.
8. Check the visibility and quality of the fiducial marks
9. With the same high magnification, scan along the bias resistors, searching for breaks, signs of processing defects or non-uniformity.
10. Scan along the AC-bonding pads.
11. At lower magnification, scan the full area of the sensor, taking note (and taking pictures where appropriate) of blemishes, scratches or other non-standard features.
12. Comments and findings from visual inspections are recorded in an appropriate way in a separate sheet (Page-2 or VI Page) in the same Excel book.

Acceptance:

The sensor should be flagged “Fail” in Column “V.I.”, if any edge chipping (front or back) exceeds 50μm, or if there is severe scratching or other gross defects, or there are signs of a processing abnormality. If in doubt, select the sensor for a full strip test to confirm any defects electrically.

4.2.3. I-V Curve and Leakage Current Determination

This measurement is carried out by Procurement Institutes for every sensor. The test requires a power supply and a pico-ammeter such as a Keithley-486/487. The sensor backside is placed on the chuck of a probe station and probe needle is put on the biasring. The I-V characteristic between the biasring and the backside is measured. The current is measured every 10V step up to 1000V with a 5 second delay between steps. A current limit of 50μA is imposed throughout the measurement. The temperature of the probe station environment should be recorded as well. The measurement schematic is sketched in Figure 2.

The obtained leakage current values and temperature have to be stored in Page-3 (or VI Page). Select the sensors with irregular I-V curve, which are to be checked for leakage current stability and DC scan described later.

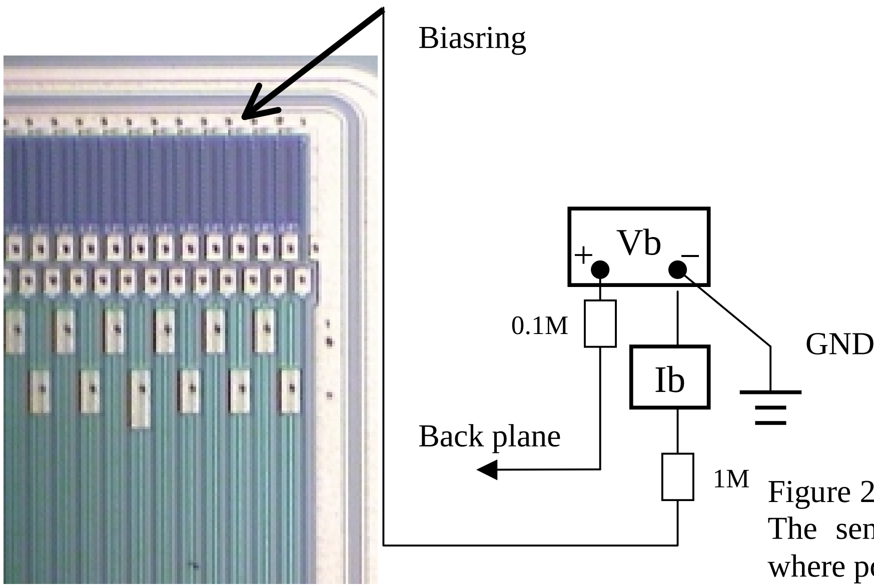


Figure 2: I-V measurement setup. The sensor is vacuum chucked, where positive voltage is applied.

Acceptance:

The leakage current is below 2 μA at RT up to 500 V.

At this stage, the sensor is ready for assembly or further QA tests. An example Excel datasheet at this stage is shown in Table 2. Note that Cell "QA" on Page-1 must be final and should be updated as other QA measurements are performed.

4.3. Tests on Sensor Subsets

The tests on sensor subsets are conducted on a sampling basis by Testing Institutes. The tests should allow us to evaluate the general quality of the sensor batches and to verify the sensor specifications in much more detail. The tests should primarily be carried out on those sensors which showed significant deviations in the I-V curve from that in the supplier's datasheet, showed non standard I-V curve, and have relatively large number of defective strips. We also test the sensors that are doubtful in visual inspections.

Intensive probing to verify detailed characteristics may have a risk of damaging the sensor. We therefore minimize this risk once we are confident that sensors with uniform characteristics are being delivered. The guideline of the sampling fraction is as follows:

- Prototype phase: the subset sample is about 30-50% of all delivered prototypes. All the candidate Testing Institutes should examine their testing system and make efforts to increase this fraction.
- Pre-production phase: the subset sample is about 10-20% plus the sensors with irregular I-V and visual inspection results.
- Production phase: the subset sample will be decreased to about 5% or at least one sensor per batch. The sensors with irregular I-V and visual inspection results should be tested in addition, where the definition of "irregularity" should be updated from that in the pre-production phase after gaining experiences.
- Irradiation test: neutron irradiation will be carried out at a rate of 3-4 sensors every two months.

4.3.1 I-V Curve Stability

This I-V curve stability test should verify that the sensor shows a consistent and small leakage current characteristics over a 10-hour period. As described in 4.2.3, the current is measured every 10V step up to 1000V with a 5 second delay between steps. This measurement is repeated every 30 min whereas the bias voltage is set to the operation voltage (full depletion voltage plus 20V, or 200 V typically) between the I-V measurements. A current limit of 50μA is imposed throughout the measurement period.

A good selection of sensors for this test is to pick a sensor with irregular I-V curve and/or visual inspection results. The data should be recorded in Page-4 of Excel book.

Acceptance:

The leakage current after correction of the temperature variation should be constant to 20%. In case a tendency of increase in the current is observed, the sensor has to be tested further longer.

4.3.2 Full Strip Test (AC scan)

This test probes the AC pad of every readout strip in order to evaluate the coupling capacitance (this provides information on strip metal shorts and opens), to check the pinholes in capacitor dielectric, and to evaluate the uniformity of the polysilicon resistances. The AC scan should be made with an automatic probe station.

Procedure:

The test requires a separate bias voltage source (Vb) to deplete the sensor, and a voltage source (Vcp) and pico-ammeter system to check for pinholes. An LCR-meter in Cs-Rs mode is used for measuring the coupling capacitance and resistance in series. Two probe-tips on an automatic probe station (probes move relative to the sensor) are used to contact the every readout AC pad (probe A) and baisring (probe B) while the bias voltage is provided via contact to the backside.

The schematic of the measurement is presented in Fig.3. A current limit in the power supply of 50nA should be always applied while charging or discharging the capacitors.

Under computer control, probe all readout strips according to the following instructions.

1. Ramp up the bias voltage (Vb) to the operation voltage.
2. Step to strip N and contact both probes A and B.
3. Increase the test voltage Vcp to +10V, wait 0.5 seconds. If the current runs into the current limit of 50nA, a pinhole is found. Skip step 4 and go to step 5.
4. Increase the test voltage Vcp to +100V, wait 1 second and measure the current to verify the coupling capacitor insulation.
5. Decrease the test voltage to 0V and wait for 0.5 seconds.
6. (Switch the relays on.) Measure C and R at 1kHz and in Cs-Rs mode. (Switch the relays off)
7. Repeat the measurement cycle from point 2 above for strip N+1.

Acceptance:

We require <1% defective strips. Defective or bad strips in general have:

- Pinholes – current through the capacitor >10 nA at 100 V and RT
- Short – coupling capacitor >1.2 times the typical value
- Open – coupling capacitor <0.8 times the typical value
- Polysilicon resistor out of specs

The first three defects can be detected with the AC-scan. If you detect metal short or open, try to verify the defect by visual inspection of the bad strip. The measured value of R (Step 7) represents the polysilicon resistance in series and the implant resistance. The

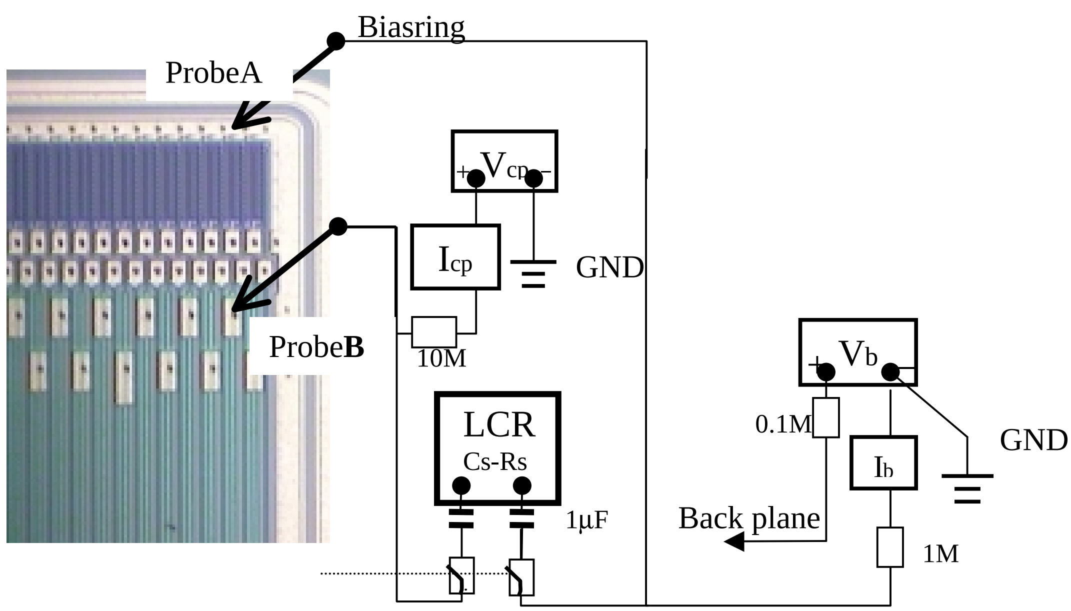


Figure 3: Setup for the full strip scan (AC scan)

polysilicon resistance is typically 0.4-0.5 MΩ smaller than the measured R. Although the polysilicon value is not directly measured, uniform R implies a good uniformity in polysilicon resistances. For the strips with irregular R, the polysilicon resistance should be measured directly as described in 4.4.2.

Note that the relays are used to protect the LCR meter at Icp measurement: Step 6. These relays could create paths to ground, which adds finite leakage current to Icp value. The protection resistors (10MΩ and 1MΩ) limit the Icp to a 10 μA level for complete pin-holes. The delay of 1 sec in Step 4 may not be long enough compared to the decay time due to possible residual impedance. The 1 sec delay should be taken as a compromise from the total measurement time.

The measured data should be stored in Page-5 of Excel book. The newly found defective strips should be added to the list in Page-1 and the corresponding Cell "QA" is updated accordingly.

4.3.3 Total Capacitance (C-V curve)

The total capacitance is measured with the system shown in Fig.4. Measurement with smaller LCR frequency results in actual total capacitance. Positive bias voltage is provided to the backplane as usual. The Nsub pad (See drawing) and the biasring which is set to GND are used to measure the bulk capacitance: The biasring and Nsub pad probes are connected to L and H, respectively, of LCR-meter through capacitors of 1 μF. The LCR frequency can be as low as 100Hz with this configuration. The frequency should be optimized when the bias is supplied from the backplane. Measure and record the capacitance in 10V steps up to 500V. The full depletion voltage is defined as the intersection of two straight lines when the data are plotted in1/C^2 versus bias voltage. The fit rang should be optimized such that χ^2/NDF is minimum in each range. Data are stored in Page-6. Note that this system can also be used for I-V measurement.

Acceptance:
The full depletion voltage should be in the range 120 to 250V.

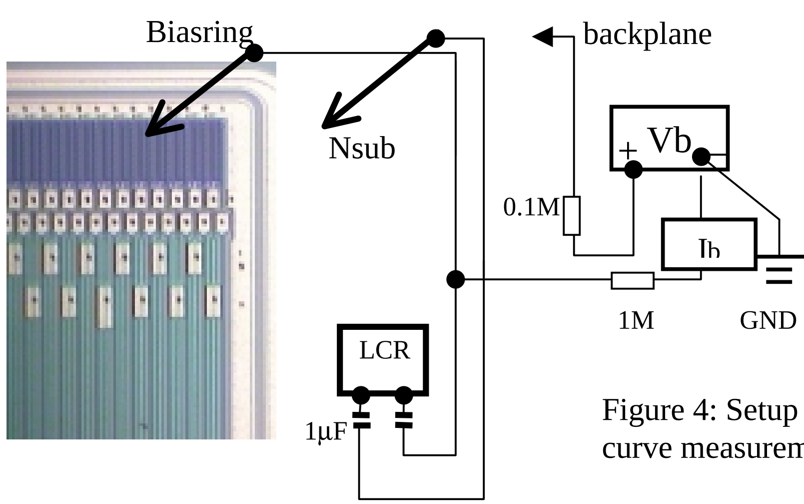


Figure 4: Setup for C-V curve measurement

4.3.4 Mechanical Tests

The warp of single-sided sensors is substantially larger than of double-sided sensors. We recommend that several mechanical measurements on silicon sensors should be performed at a random sampling. The measurements should verify the mechanical specification of wafer warp and cutting accuracy on an optical metrology system. The data has to be stored in Excel Page-7 in an appropriate format.

4.3.4.1 Sensor Warp

The sensor warp is measured in a free state of the sensor on an optical metrology machine. Measurement should be made at grids of every 1 cm including four positions in close vicinity to the corners. The measured data are expressed as deviations from the reference plane that is defined by the data at three of the four corners. The maximum deviation, RMS of the deviation, and twist (deviation of the corner which are not used for the reference plane definition) are recorded. The maximum deviation must be smaller than 130 μm.

4.3.3.2 Sensor Cutting Accuracy

The cutting accuracy is surveyed with an optical metrology machine. The nominal distance from the fiducial mark to the edge is 330 μm for outer sensors. Measure this distance at four corners (in total 8 data points). They have to be accurate to ±20μm.

4.3.3.3 Wafer Thickness

The wafer thickness is measured at the sides by ensuring that the detector is touching the stage of the metrology machine. Use a vacuum chuck. The thickness is determined as the height difference between the stage and the sensor surface. The thickness should be in the range 320 ±20μm (5μm is added to the specification accounting for possible uncertainty in this measurement procedure). If the Z resolution of the system is limited, measure the thickness with holding the sensors vertically. Take data at middle of the two shorter sides.

4.4. Diagnostic Tests

This subsection lists recommended procedures for a more detailed evaluation of the electrical parameters of the sensors. The tests are either done on single strips of the sensors with irregularities or every strip for detailed overall performance evaluation such as for irradiation tests. We recommend that the Testing Institutes perform these tests routinely keeping a rate at least one per batch even if no irregular sensor is found from other tests. After each diagnostic test, the I-V measurement on the sensor should be repeated. The data has to be stored in the Excel datasheet appropriately.

4.4.1 Strip Leakage Current (DC-scan)

If the I-V test shows irregularly large leakage currents or the IV stability test gives unstable results, it is recommended to perform the strip leakage current test (DC scan) in order to try to find out the source of the big or unstable leakage.

The schematic of measurement is presented in Fig.5. Under computer control, probe all readout/intermediate strips according to the following instructions.

Procedure:

1. Ramp up the bias voltage Vb to the operation voltage or the voltage to test.
2. Step to Strip N and contact the biasring (probe A) and DC pad (probe B).
3. Measure the bias current Ib with the pico-ammeter Ibias. The bias current reading must be consistent with the known value, otherwise check the contacts.
4. If Step 3 is OK, then measure the strip current Istrip with the pico-ammeter.
5. Repeat the measurement cycle from Step 1 onward for Strip N+1.
6. Ramp down the bias voltage to 0V.

Acceptance:

If the strip current exceeds 100 nA at the operation voltage and RT, the strip is counted as defective. The newly found defective strips are added to the defective strip list on Page 1 and "QA" Cell is updated accordingly. The DC scan data are stored in a separate page appropriately.

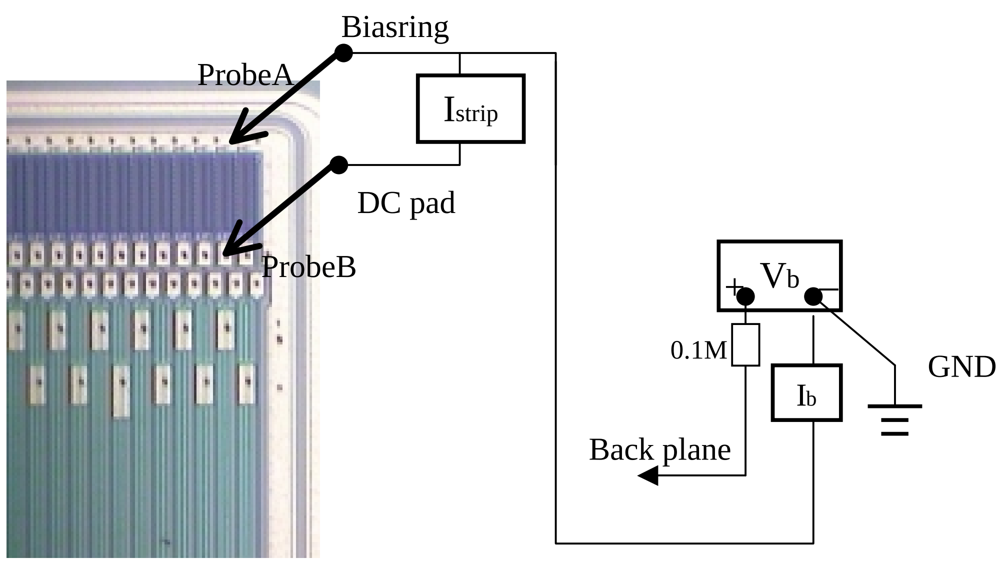


Figure 5: Setup for strip leak current measurement (DC scan).

4.4.2 Polysilicon Resistance

The sensors which show irregular R values in the AC scan are subjected to check the polysilicon resistance. Since this measurement is sensitive to detect sensor charge-up, testing at a constant rate is recommended depending on the achievable frequency of AC scan. Also a random sampling test must be made to evaluate directly the polysilicon resistance. The schematic is given in Fig.6. The resistance is evaluated by probing the DC pad and biasring and by measuring the resistance with an LCR meter. The sensor is biased such that the surface isolation is established. Recommendation is 200V to fully deplete. Note that the resulting resistance will be substantially smaller than the real polysilicon resistance if the strip leakage current is extremely high (irradiated sensors for example). In this case, a system of DC power supply and current meter provides reliable values. Subtract the measured current with no external voltage from that with external voltage applied.

Measure neighboring strips as well for comparison. At a random sampling test, measure the strips at different (at least five) locations to detect possible non-uniformity.

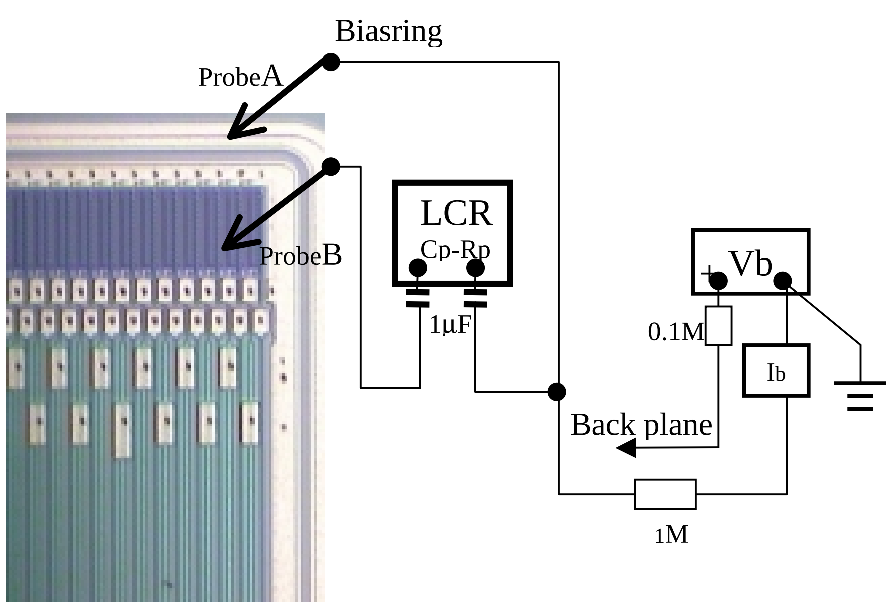


Figure 6: Setup for the polysilicon bias resistor measurement. A system based on external voltage source and ampere meter is an alternative, which can be configured from the interstrip resistance measurement setup (Fig. 8).

Acceptance:
The polysilicon resistor values have to be within 1.5±0.5 Mohms.

4.4.3 Interstrip Capacitance

The major contributions to the total strip capacitance, which represents the total load capacitance for the preamplifier, are the interstrip capacitance, i.e. the contribution from one strip to the neighbor strips, and the capacitance of one strip to the backplane. Among these, the interstrip capacitance is measured with a system shown in Fig 7.

Procedure:
Place the sensor with the backplane and biasring connected to the high and grounded-low sides respectively of the voltage source. Ramp up the bias to the operation voltage. Place two coaxial probes on the AC pads as shown in Fig.6, and measure the capacitance value at 1 MHz frequency. Note a certain contribution of the strip capacitance to the backplane is present in so measured capacitance. We take the measured capacitance as the interstrip capacitance.

Acceptance:
The interstrip capacitance has to be less than 11.2 pF (1.2 pF/cm).

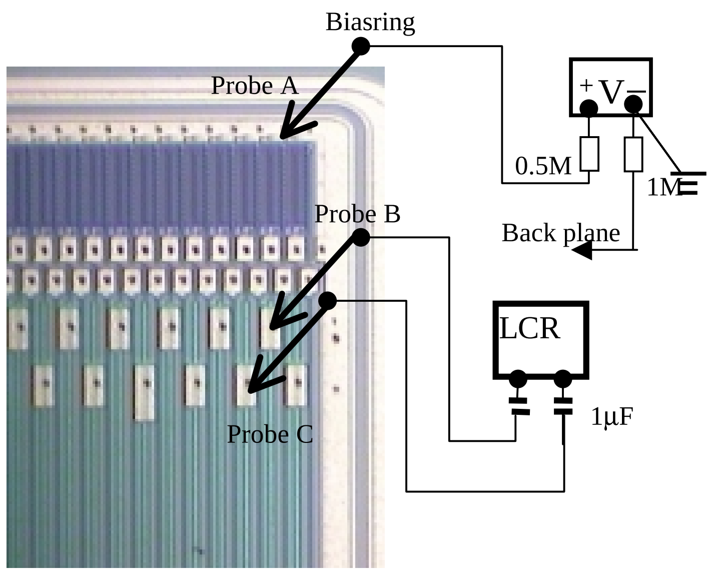


Figure 7: Setup for interstrip capacitance measurement.

4.4.4 Interstrip Resistance

The interstrip resistance is determined by measuring the induced currents while applying voltages to the neighboring intermediate strips, as shown in Fig.8. Two probe needles connected to a voltage source are added to the strip leak current measurement system (Fig.5).

Procedure:
1. Ramp up the bias voltage to the operation voltage.
2. Set the testing voltage (V_{DC}) from -1V to +1V with 0.5V step.
3. Read the strip current (I_{DC}) after reading is stabilized, typically 1s.
4. Calculate a value of interstrip resistor from the I(V) curve: $R_{intrstr} = \Delta I_{DC}/V_{DC}$, where ΔI_{DC} is the difference of the readings with respect to I_{DC} at V_{DC}= 0V.

5. Repeat Steps 2 to 4 for other readout strips.

Acceptance:

The interstrip resistance should be higher than 1 Gohms, while it must be much higher for non-irradiated sensors. Note the supplier checks the every interstrip resistance. If the resistance turned out to be small, surface charge-up is a most probable cause. Put the sensor back in the original envelope. Keeping such sensors in the envelope should remove the surface charge in a day. Or illuminate the sensor with UV to remove the surface charge.

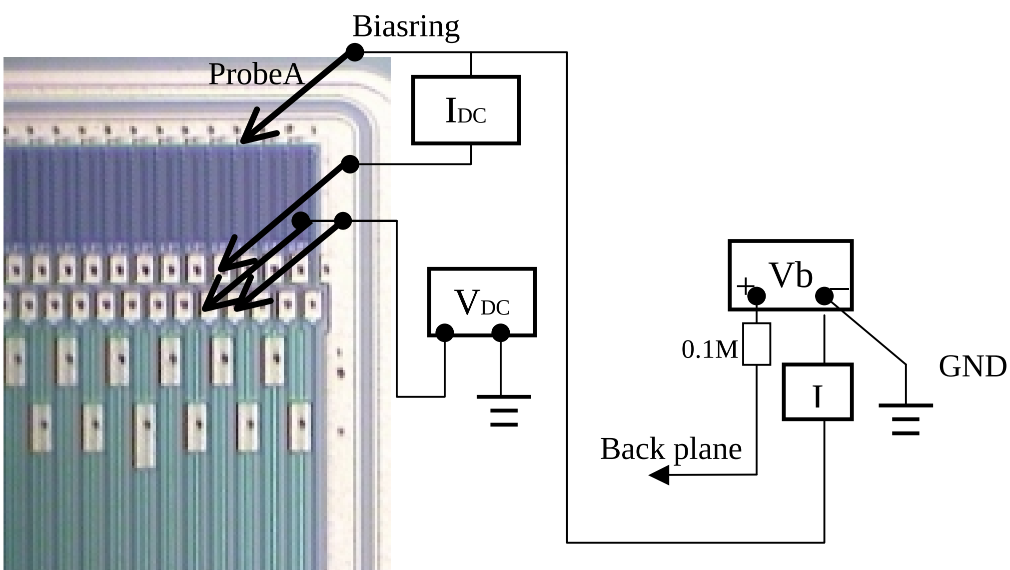


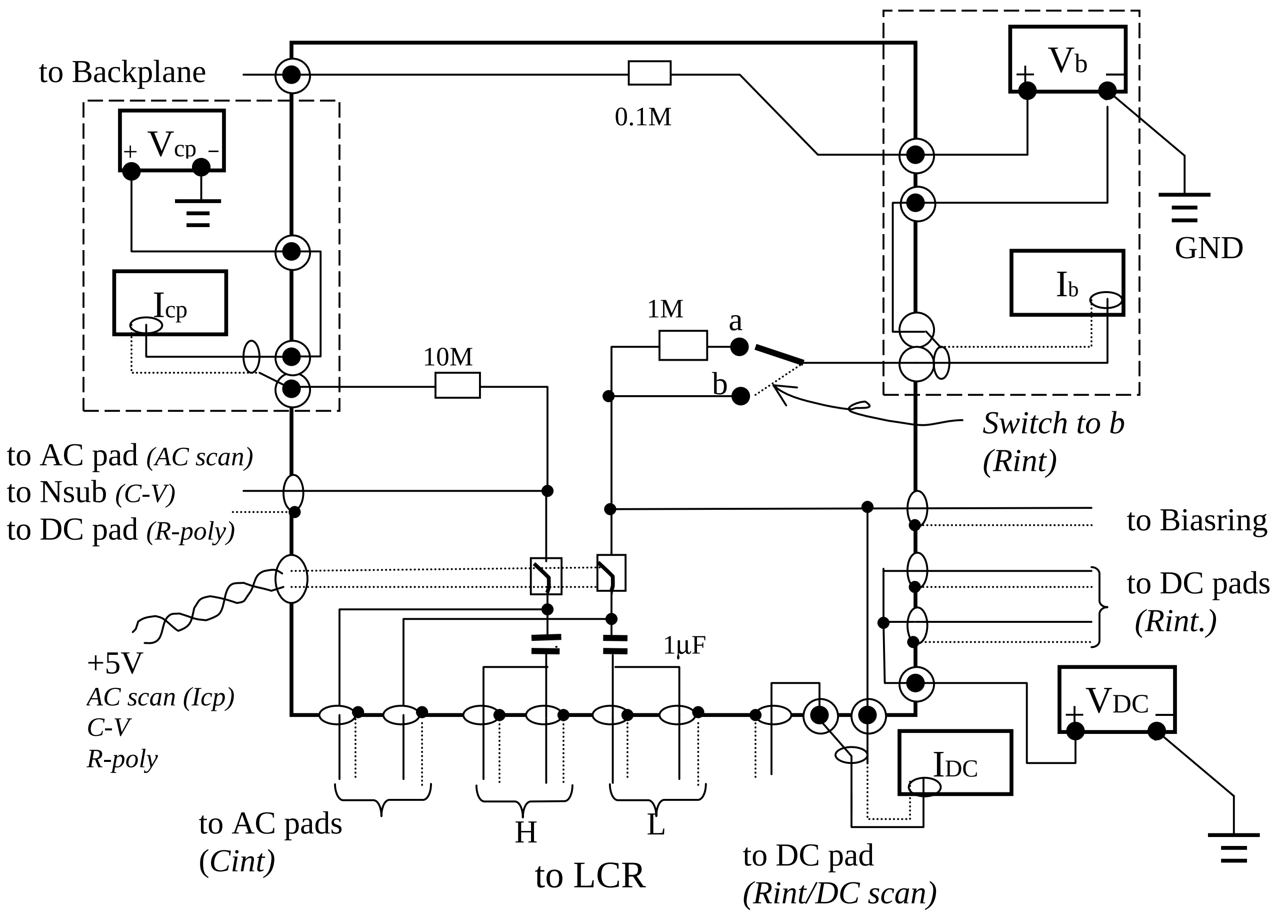
Figure 8: Setup for interstrip resistance measurement.

5. Summary of the QA Program.

The following table summarizes the QA program. The frequency is for the prototype deliveries and numbers in parentheses are for the deliveries after production is stabilized. The fractions at the pre-production phase are between the two numbers. Items (8) through (11) are performed whenever problems are found, while the rate of at least one detector per batch has to be maintained even if no such problem is found. Items (2) and (3) will be replaced with Item (12) after quality sensor delivery is established. Neutron irradiation is carried out at a rate of 3-4 sensors every two months.

QA item	QA performed by	Frequency (production)	Comments	Excel book page number
(1) Initial registration	Procur. Inst.	100%		Page-1
(2) Visual Inspection	Procur. Inst.	100%		Page-2
(3) I-V	Procur. Inst.	100%		Page-3
(4) IV-stability	Testing Inst.	30% (5%)	Sensor subsets	Page-4
(5) AC-scan	Testing Inst.	30% (5%)	Sensor subsets	Page-5
(6) C-V	Testing Inst.	30% (5%)	Sensor subsets	Page-6
(7) Mechanical Tests	Testing Inst.	10% (5%)	Sensor subsets	Page-7
(8) DC-scan	Testing Inst.	10% (5%)	Diagnostic+subsets	
(9) Polysilicon resistor	Testing Inst.	10% (5%)	Diagnostic+subsets	
(10) Interstrip capacitance	Testing Inst.	10% (5%)	Diagnostic+subsets	
(11) Interstrip resistance	Testing Inst.	10% (5%)	Diagnostic+subsets	
(12) IV, visual inspection	Fermilab	100%		Page-1
Neutron irradiation	Testing Inst.	3-4 /2 mon	destructive	

Appendix **Diagram of a switch box**



The probes are coaxial with the connections provided through Lemo connectors. The inputs to the LCR meter are switched, switching being controlled by a computer. Additional switch is used to by-pass 1MΩ resistor for interstrip resistance (Rint) measurement. Two voltage and pico-ammeter systems can be replaced with source meters.

Appendix

Run2b Silicon Sensor Specifications

Introduction:

The CDF detector at Fermilab (Batavia, Illinois USA) will undergo a new upgrade for the Run2b data taking period (2006-2008).

CDF will replace most of the present silicon detector system (the SVXII and L00 parts) with a new detector capable of coping with a substantial increase in the Tevatron Collider luminosity.
The new detector employs microstrip silicon sensors with single sided (p+ implant), AC-coupled, poly-silicon biased, <100> 6” n-type wafers with different geometry and pitches. The total number of Run2b silicon sensors is about 2,300.

The required number of sensors, outer dimensions, and pitches are summarized in the following table for the three types of the sensors.

type	Production Quantity	Dimensions (mm)	Readout Pitch/pitch (µm)
Outer Axial	1512	96.392x40.550	75/37.5
Small Angle Stereo	648	96.392x43.100	80/40
Inner Axial	144	78.5x14.850	50/25
TOTAL	2,304		

The requirements on the wafer are summarized in the following:

Thickness	320 µm ± 15 µm
Wafer diameter	*6 inch*
Wafer type (orientation)	*n*-type (<100>)
Resistivity	(see depletion voltage specs)
Wafer warp	<130 µm

The sensors need to withstand a dose of $1\mathrm{x}10^{14}$ 1 MeV equivalent neutrons/cm^2 and an ionizing dose of 10 Mrad, consequently they should be operational at voltages up to 500 V. All sensors have one floating intermediate strip between readout strips: The readout strip pitch is twice the value of the strip pitch. All sensors have 3 µm overhanging metal except for the inner axial where this value is ~1µm.

– The outer axial sensors have a strip pitch of 37.5 µm (readout pitch of 75 µm).
– The small angle sensors have strips at an angle of about 1.2 degrees with respect to the axial (long side of the detector). Strips not reaching the short edge of the sensor are properly terminated at the other side of the shorter edge.
– Inner axial sensors have a pitch of 25 um (readout pitch is 50 µm).

Specifications:

Axial: Active area dimensions[4]	~ 40.5 x 95.4 mm^2
Axial: Overall dimensions	40.550 x 96.392 mm^2 (2 detectors per 6" wafer)
Axial: Strip Pitch	37.5 μm
Axial: Readout Pitch	75 μm
Axial: Number of Strips	1024
Axial: Number of Readout Strips	512

Stereo: Active area dimensions	~ 42.1 x 95.4 mm^2
Stereo: Overall dimensions	43.100 x 96.392 mm^2 (2 detectors per 6" wafer)
Stereo: Strip Pitch	40 μm
Stereo: Readout Pitch	80 μm
Stereo: Number of Strips	>1024
Stereo: Number of Readout Strips	512

Inner Axial: Active area dimensions	~12.9x78.5 mm^2
Inner Axial: Overall dimensions	14.850x96.392 mm^2 (6-7 detectors per 6" wafer)
Inner Axial: Strip Pitch	25 μm
Inner Axial: Readout Pitch	50 μm
Inner Axial: Number of Strips	512
Inner Axial: Number of Readout Strips	256

Common Specifications:

Depletion Voltage	From 120 to 250 V (200V as upper limit preferable)
Biasing scheme	Poly silicon resistor (see drawings)[5]
Poly-silicon resistor values	1.5 ± 0.5 MΩ (<10% variation within a sensor)
Passivation	SiO_2 0.5 ~ 1.0 μm thick
Implant strip width	~9 μm
Implant depth	>1.2 μm
Doping of implant	> $1x10^{18}$ $ions/cm^3$
Width of aluminum strip[6]	~15 μm (~11 μm for the inner axials)
Thickness of Al strips	>1 μm
Resistivity of Al strips	<30 Ω/cm
Coupling Capacitor value	>10 pF/cm
Coupling capacitor breakdown voltage	>100 V
Interstrip resistance	> 1 GΩ
Total interstrip capacitance	<1.2 pF/cm (<1.5pF/cm total for the 90dgr)
Total sensor current[7] at T=20^o C	grade **"A":** <50 nA/cm^2 at 500V grade **"B":** < 4uA/ cm^2 at 350V and < 10uA/ cm^2 at 500V
Bad channels for grade **"A"**	<1% (No more than 5 per sensor)

[4] 1 mm is allowed from the active area to the physical edge of the sensor, but the active area can grow larger if less space is needed between the end of the active area and the physical edge of the sensor.
[5] Resistor on one side only is an equivalent option but has to be agreed with the customer because it can have an impact on the active area dimensions and the positioning of the small angle stereo sensors.
[6] Only readout strips will be metallized and will have bonding pads. Intermediate strips will have only DC pad (see drawings for details).
[7] For the grade "A" we would like to consider the option of a lower breakdown voltage value of 350V if it comes with some cost saving. In other words the optional specs for the grade "A" detectors would read 350V instead of 500V.

Bad channels for grade **"B"**	<5% (No more than 25 per sensor)

Bad channels definition:

Parameter	**Rule**	**ID of the defect**
Single strip leakage current at 500 V [8]	> 10 nA	Leaky
Coupling capacitor	> 1.1 times the typical value	Short
Coupling capacitor	< 0.9 times the typical value	Open
Coupling capacitor	>1.1 times the typical value but the neighbors are normal	PH (pin hole)
Current through the Coupling capacitor with 80 V across the dielectric	>1 nA	PH (pin hole)

Above bad channel definition is based on measuring the coupling capacitance on each strip. We will consider other means of determining bad strips count based on vendor's proposal. Please attach a description of what measurement you would propose in order to determine the bad strip count and location for each sensor.

Quality Control by manufacturer:

Value of the poly resistor	Measured on Test Structures on each wafer
Value of the depletion voltage	Measured on Test Structures on each wafer
Visual inspection, verifying that no significant scratches, blemishes and/or edge chipping are present	Performed on each sensor
Total leakage current up to 1000 V[9] (or until current=20 μA)[10] in steps of 10 V.	Measured on each sensor
Bad strips identification and count	Measured on each sensor

<u>Quality Control results have to be provided to the customer on an electronic format as well as on a paper format.</u>

[8] The measurement of strip leakage current of individual sensors is foreseen only for the prototypes. For mass-production, based on the prototype data, the measurement will be made only for those sensors with the total leakage current exceeding some criterion to be agreed upon.
[9] Or lower value if there is some instrumental limit. In any case at least up to 500V.
[10] We can accept other values of voltage and/or current if more convenient for the manufacturer.