ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

Invitation to Tender: IT-2777/EP/CMS

Technical Specification

Supply of Silicon Micro-Strip Sensors for The CMS Silicon Strip Tracker (SST)

Abstract

At the request of the CMS Collaboration, CERN wishes through this Invitation to Tender to award a contract(s) to one or several Contractors for the supply of 19100, 500 µm thick, and of 6450, 320 µm thick, silicon micro-strip sensors. This supply is the baseline requirement for the CMS Silicon Strip Tracker (SST). The sensors must survive high levels of irradiation. They are single-sided with ac-coupled readout and *p*-strips biased through polysilicon resistors. The substrate is n-type silicon of 6" diameter (a provision is made for a compatibility between 4" and 6" for the supply of the 2950 sensors of the inner barrel, IB1, IB2).

On the assumption of the contract being awarded in June 2001, delivery of the Pre-series (approximately 5% of the supply) shall be completed by early November 2001. Series production shall start after Provisional Acceptance of the Pre-series by CERN, no later than the end of February 2002, and shall be completed no later than October 2003.

Geneva, 01 December 2000

1. Introduction

1.1. General

CERN is an Intergovernmental Organization with 20 Member States. Its mission is to provide for collaboration among Member States and associated States in the field of high-energy particle physics research and to this end it designs, constructs and runs the necessary particle accelerators and the associated experimental areas. The LHC project, a large proton-proton Collider, was approved in 1994. It will be the next major research tool for world particle physics, and it is expected to be commissioned in 2005. CMS is one of the main experiments that will be installed on this accelerator, and the CMS Institutes are Universities and Research Laboratories that collaborate together to build the experiment and subsequently to explore the new physics that will come from the data.

The CMS Silicon Strip Tracker (SST) will instrument the Central Tracking region of the CMS apparatus being designed for the Large Hadron Collider (LHC) at CERN. This must be operated in a high radiation environment for at least 10 years, maintaining a satisfactory detector performance despite the expected changes in the material characteristics due to the irradiation. The levels of radiation due to primary interactions will be very high around the collision region; in addition a high flux of neutrons will be present due to back scattering of neutrons evaporated from nuclear interactions in the material outside the tracker. In 10 years of LHC running the first layer of the SST inner barrel will be subject to a fluence of 1.6×10^{14} 1 MeV equivalent neutrons per cm^2. The first layer of the outer barrel will be subject to a fluence of 3.5×10^{13} 1 MeV equivalent neutrons per cm^2.

The survival of Silicon Sensors in the LHC radiation environment depends strongly on the sensor design and on a suitable material choice. The radiation damage suffered by the sensors can be divided into two classes: surface and bulk damage. Surface damage occurs when the oxide-silicon interface charge increases; this change can lead to a decrease in the inter-strip isolation and a variation in the inter-strip capacitance affecting the electronic noise of the system. Bulk damage leads to substantially increased leakage currents; a change in the effective doping concentration, which eventually results in a type inversion of the bulk, requires biasing the sensor to several hundred Volts to reach a satisfactory charge collection efficiency. An extensive plan of design, simulation, processing and evaluation of appropriate micro-strip sensors has been in progress for several years within CMS laboratories and several industrial Companies. This has resulted in a sensor design suitable for the operation of silicon devices in the LHC environment.

The CMS baseline SST consists of about 19100, 500 µm thick (“thick”), silicon strip sensors (including spares) with 8 different designs from 6” wafers and about 6450, 320 µm thick (“thin”), sensors with 6 designs (2 for the Inner Barrel, 4 for the end-cap) if 6” wafers are used. An optional layout exists for the production of the Inner Barrel sensors on 4” wafers: it consists of about 5900 sensors with 2 designs. The sensors are single-sided, with p^+ strips on an n-type substrate, of a resistivity of about 2KΩcm (thin detectors) and about 4KΩcm (thick detectors), and of <100> crystal lattice orientation. Metal strips are AC coupled to the implant strips, which are biased through integrated resistors. The strip pitch ranges from 80 to 205 µm. The SST will be operated at a temperature of $-10\ ^0$C.

All sensors must be qualified according to results of tests performed before and after irradiation. Post irradiation requirements must be satisfied after a fluence of 1.6×10^{14} (thin sensors) and of $3.5\ 10^{13}$ (thick sensors) 1 MeV equivalent neutron per cm^2.

The contract shall be structured in two distinct phases: The first part of the delivery is considered as a Pre-series production, the remainder as the Series production. The start of the Series production shall be contingent on completion of the Pre-series according to the delivery schedule (refer to article 7 of the Tender Form), and compliance of the Pre-series sensors with the requirements of this Technical Specifications. CERN reserves the right to terminate the entire contract in case of failure of the Pre-series to meet these conditions, in accordance with article 10 of the Tender Form.

Once pre-series sensors have been delivered and qualified both before and after irradiation, it is the responsibility of the contractor to ensure that no changes in the processing, or in the substrate material properties, occur during production, which could compromise the sensor performance.

2. Scope of the Invitation to Tender

The scope of this Invitation to Tender as defined in the Tender Form is the supply of 19100, 500 µm thick, and 6450, 320 µm thick, silicon micro-strip sensors.

The persons in charge of the technical aspects of the Tender are listed in Annex B.

The Contractor's obligations include:
- procurement of the polished silicon substrate material;
- design and manufacture of the detector masks;
- processing and dicing the silicon detectors;
- quality control, inspection, acceptance testing and documentation;
- packing;
- delivery to CERN

CERN reserves the right to order the detectors on an Ex-works basis and to organise the transport itself.

CERN shall require the Contractor to produce a Pre-series to demonstrate his ability to comply fully with the specifications, requirements and delivery schedule set out in these Tender documents. CERN's agreement to start the Series production is subject to the Provisional Acceptance by CERN of the Pre-series.

3. Sensors specifications

Unless stated explicitly otherwise, all dimensions quoted are those to be found in the processed devices, and not the dimensions for the corresponding mask designs, which may vary between suppliers. The technical description is separated in four sections. The first (3.1) describes the substrate properties. The second (3.2) describes the dicing quality and flatness requirements. The third (3.3) describes all the details of the different mask designs for the sensor geometries needed. The fourth (3.4) describes the sensor electrical properties.

3.1. Substrate

The supplier shall provide the silicon substrates. They have 6” diameter for thick sensors and thin wedge sensors, and either 6” or 4” for the thin inner barrel sensors. They are:

- n-type, phosphorus doped, float-zone, <100> crystal orientation
- resistivity in the range of $\rho = 1.5 – 3.0$ KΩ cm (thin sensors)
- resistivity in the range of $\rho = 3.5 – 7.5$ KΩ cm (thick sensors)
- thickness: 320±20 µm (thin), 500±20 µm (thick)
- Both sides polished.

3.2. Dicing and Flatness

The sensors shall be diced by the supplier. The dicing tolerance is ±20 µm. The quality of the cut edges shall be such that there are no chips greater than 40 µm and no cracks. The sensors shall be clean, with no residual on the surface when delivered.

We require a sensor flatness (unstressed) <100 µm.

3.3. Mask requirements

The Contractor shall be responsible for the final mask designs and shall produce engineering drawings or mask designs to be submitted to CERN for approval in writing before the start of Pre-series and Series production.

The detailed geometry of the sensors will be provided by CMS. The suppliers shall submit mask designs to CMS for approval. Tables 3.1-3.3 describe the physical dimensions of the sensors (from cutting line to cutting line), indicative pitches, number of strips and quantities. Wedge sensors have trapezoidal shape and radial strips (see next figure). Rectangular sensors have L1=L2.

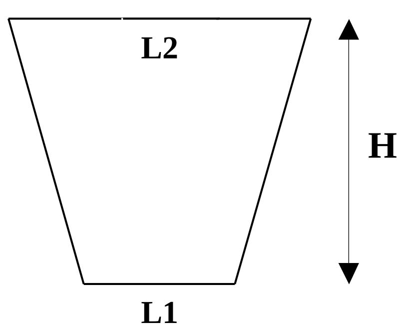

Table 3.1 describes the thick sensors. Table 3.2 describes the thin sensors in the 6” wafer production scheme. Tables 3.3 describe the thin inner barrel sensors in the 4” production scheme.

Type	L1	L2	H	pitch	strips	quantity
OB1	96.4	96.4	94.5	122	768	5520
OB2	96.4	96.4	94.5	183	512	4896
W5a	99.0	112.4	84.0	126-143	768	1440
W5b	112.4	123.0	66.1	143-156	768	1440
W6a	86.1	97.5	99.0	163-185	512	1008
W6b	97.5	107.6	87.8	186-205	512	1008
W7a	74.1	82.9	109.8	140-156	512	1440
W7b	82.9	90.9	98.8	157-172	512	1440

Table 3.1- Sensors from 6” wafers 500±20 µm thick: physical dimensions (mm), pitch (µm), the number of strips, and quantity for each type of sensor (not including spares). Two sensors are assembled into a single module, with the read-out strips electrically daisy-chained.

Type	L1	L2	H	pitch	strips	quantity
IB1_6	63.4	63.4	119.2	80	768	1584
IB2_6	63.4	63.4	119.2	120	512	1224
W1_6	64.1	88.1	89.5	81-112	768	576
W2_6	88.2	112.4	90.3	113-143	768	864
W3_6	65.0	83.2	112.8	124-158	512	880
W4_6	59.9	73.4	117.4	113-139	512	1008

Table 3.2 - Sensors from 6” wafer 320±20 µm thick: physical dimensions (mm), pitch (µm), the number of strips, and quantity for each type of sensor (not including spares). A single sensor is assembled into a module.

Type	L1	L2	H	pitch	strips	quantity
IB1_4	63.4	63.4	59.5	80	768	3168
IB2_4	63.4	63.4	59.5	120	512	2448

Table 3.3- Sensors from 4” wafer 320±20 µm thick: physical dimensions (mm), pitch (µm), the number of strips, and quantity for each type of sensor (not including spares). Two sensors are assembled into a module, with the read-out strips electrically daisy-chained.

- **Implant strips:** the width of the implant strips depends on the strip pitch; a constant width/pitch ≈ 0.25 will be used; the tolerance is 1 µm.
- **Metal strips:** Aluminum strips capacitively coupled over the p-implant; metal overhang, ranging from 4 to 8 µm, as function of the pitch, is foreseen on each side of the implant strips. The thickness of the metal layer will be ≥1.5 µm.
- **Polysilicon bias resistors:** an array of polysilicon resistors is used to bias the strips. These resistors are connected to each strip at one end of the sensor.
- **n^+ ring and back contact:** a uniform, metallized, n^+ Ohmic layer is required on the backside. In addition, an n^+ implant, also metallized, is required over the entire cutting area of the junction side.
- **Sensitive region to cut edge distance:** the distance of the active area (situated inside the inner edge of the bias line) from the cutting edge is 1140 µm along the strip direction and 1000 µm orthogonal to the strip direction for 320 µm thick sensors and 1500 µm x 1350 µm respectively for 500 µm thick sensors
- **Guard design:** a metallised p^+ guard ring is required around the sensitive region; a multi-guard layout can be provided to the vendor if necessary.
- **Bonding pads:** two rows of bonding pads on each end of the strips with dimension 60 µm x 300 µm and centers spaced 400 µm apart. The position of the first row should be as close to the edge of the sensor as possible. In the case of the trapezoidal sensors a constant pitch in each row is chosen to simplify both testing & bonding
- **P-bias contacts:** a metallised bias ring all around the active sensor area.
- **Strip evaluation:** metallised probe contact pads (60 µm x 100 µm) at the point where the bias resistor connects with the implanted strip.
- **Passivation:** sensors shall be passivated on the front side, except as required for contacts and bonding to the metal layer. The vendor shall discuss with CMS the details of the choice of passivation.
- **Test structures:** on each wafer test structures and mini-sensors are required. They are used to measure the following parameters: the sheet resistance of the implant, metal and polysilicon layers; the currents generated in the silicon bulk or at the silicon-silicon oxide interface; the thickness of the dielectric layers; the bulk depletion voltage; the inter-strip capacitance and resistance; the metal surface quality
- **Identification:** every second strip shall be numbered. Sets of reference marks, specified by CMS, shall be incorporated in the metallization mask. Each sensor will be identified by a row of scratch pads located in the edge region of the detector. A similar identification scheme is needed in the test structure region. The numbering scheme shall allow the identification of vendor, ingot, batch and wafer. The details of these are shown in the appended drawings.
- **Mask alignment tolerances:** 1 µm misalignment with respect to any other mask

3.4. Sensor Electrical Properties

- **Implant strips:** <200 KΩ/cm (400 Ω/square)
- **Metal strips:** Aluminum <18 mΩ/square, (thickness ≥1.5 µm)
- **Bias resistors:** the resistance between the strip and bias line implants, R_{poly} = 1.5 ± 0.5 MΩ; within a single sensor we require a uniformity of ± 0.3 MΩ with respect to the average value of R_{poly} for that sensor.
- **Inter-strip resistance:**> 1 GΩ.
- **Resistance between bias and guard lines :** > 1 GΩ.

- **Total capacitance:** total effective coupling of each strip, measured as sum of coupling capacitance to the two neighboring strips on each side and the capacitance to the back-plane (Ctot = Cint + Cback at 1 MHz), should not exceed 1.3 pF/cm at depletion voltage.
- **Coupling capacitance:** each strip implant must be provided with an integrated capacitor with aluminized read-out strip. Multiple thin layers of SiO_2 and Si_3N_4 are preferred as dielectric. The coupling capacitance, Cac, is required to be at least 1.2 pF/cm per µm of implanted strip width.
- **Depletion voltage :** V_{dep} < 300 Volts
- **Breakdown and Leakage current:**. Sensors are required to operate in stable conditions, without breakdown below 500V bias and excess of noisy strips before and after irradiation. The contractor shall only deliver devices meeting leakage current acceptance criteria such that the fraction of sensors rejected due to noisy strips (refer to article 5.2), once assembled into a module, is kept below 2%. To this end, limits are set on the total leakage current of a sensor, as well as on the leakage current of individual strips, at various values of the bias voltage. We require that:

- the total leakage current shall not exceed 10 µA@300 Volts , 20 µA @450 Volts(6” wafers) and 5 µA@300 Volts, 10µA@450 V (4” wafers)
- and that the slope of the total leakage current shall satisfy the condition $\Delta I_{leak} / \Delta V$< 100 nA/V, in the range 450-550 Volts

Sensors satisfying these criteria shall be further classified as:

- Class A, if the total leakage current does not exceed 5 µA@300 Volts, 10 µA @450 Volts(6” wafers) and 2 µA@300 Volts , 4µA@450 V (4” wafers)
- Else as Class B.

- We define as defective any strips which draw more than 100nA at 400V. We require a list of such strips for all Class B sensors.

All the above leakage current measurements are to be performed at 21 ^{0}C and less than 50% relative humidity (RH).

These leakage current acceptance criteria will be valid for the pre-series, and may be revised for the production as required in order to meet the required rejection rate due to noisy strips.

4. Tests

4.1. Tests performed by the Contractor

CERN shall accept sensors delivered by the Contractor and qualified as good according to the results of two series of tests:

- Tests performed by the supplier.
- Tests performed by the CMS collaboration before and after the exposure to irradiation.

Suppliers will process sensors, test the production, and deliver sensors that satisfy the acceptance criteria. The following list of measurements shall be used to characterize and qualify a sensor. The measurement results shall be documented and provided in electronic format. Each measurement scheme must be agreed between CERN and the Contractor.

We classify the tests in three different categories:

1. Tests to be performed on each sensor before and after dicing, to assess the overall device characteristics;

2. Test to be performed on strip-by-strip basis for each sensor, to point at defective strips;

3. Tests to be performed on dedicated test structures, for each batch, to monitor the process quality.

For each category of tests, CMS indicates corresponding acceptance criteria.

Based on experience gained with the pre-series, CMS may agree to revise the following testing requirements, provided compliance with the acceptance criteria listed in Section 5 can still be assured. In particular, this may apply to tests for each strip, outlined in section 4.1.2.

4.1.1. Tests for each sensor

- Measurement of the leakage current as a function of the reverse bias (IV curve). This measurement shall be performed at room temperature (21 $\pm$ 1 ^{o}C) and RH < 50%, up to 600 V or at the measuring instrument compliance of 1mA. This measurement shall be performed also after dicing.
- Optical inspection after dicing.
- Measurement of the polysilicon resistance values (R_{poly}), or the sheet resistance value on test structures at several locations on the corresponding wafer.
- Measurement of the depletion voltage, either by the measurement of the capacitance between the back-plane and the bias-ring at 1 kHz frequency as function of the reverse bias, or by a similar measurement performed on a test diode produced on the corresponding wafer.

4.1.2. Tests for each strip

- Measurement of the resistance between the strip and bias line implants, R_{poly}, as required to ensure compliance with the specification.
- identification of the strips with the following defects:
    - shorts of the metal line among neighboring strips
    - pinholes through the dielectric layer between the metal strip and the implant
    - leakage current above 100nA at a bias voltage of 400V (Only for class B sensors).

4.1.3. Tests on test structures (1 wafer for each batch)

- measurement of the sheet and implant resistance
- measurement of coupling capacitance breakdown voltage

4.2. Tests performed by CMS

CMS will test sensors from the pre-series both before and after irradiation to qualify the production process. It is the responsibility of the supplier to ensure that no changes in the processing occur that could compromise the performance of the sensors. During production, on a subset of sensors of each delivered batch (selected by the CMS collaboration), the CMS collaboration will verify the measurements performed by the suppliers and will perform further tests before and after irradiation to monitor the stability of the process. Some of these tests are also performed at the operating temperature (T= -10 ^{0}C).

4.2.1. Tests on test structures

- CV on diodes
- C_{int}, Inter-strip capacitance per unit length: the coupling capacitance of each strip to the two neighbouring –two on each side– at 1MHz frequency and at depletion voltage.
- R_{int}, inter-strip resistance per unit length
- R_{poly}.

4.2.2. Tests on sensors

- IV, CV, C_{tot}, C_{ac}
- Charge collection efficiency measured with a source or a laser
- Noise measurement
- Bondability test

5. Acceptance Criteria

The Suppliers will deliver sensors meeting the acceptance criteria outlined in section 5.1. CMS will accept the sensors if they also meet the acceptance criteria of the tests performed by CMS, as outlined in section 5.2.

5.1. Acceptance Criteria for the tests performed by the Suppliers

5.1.1. Tests on sensors and on each strip

Before or after dicing:

- Depletion voltage $V_{dep} < 300$ V

- The producer shall only deliver devices meeting leakage current acceptance criteria such that the fraction of sensors rejected due to noisy strips, once assembled into a module, is kept below 2% (refer to article 5.2). To this end, the leakage current criteria set out in article 3.4 shall apply.

- Number of defective strips **<** 1%. A strip is considered outside specifications if:

  - The strip leakage current is above 100nA (refer to article 3.4)
  - The resistance between the strip and bias line implants, R_{poly}, is outside the range 1.5 ± 0.3 MΩ
  - There are pinholes through the dielectric layer between the metal strip and the implant
  - There are metal shorts to neighbors
  - There are implant shorts to neighbors

After dicing:

- The total sensor leakage current must be shown to satisfy the criteria stated in article 3.4 also after dicing

- Optical inspection: no damage on the cut line region or on the junction side or on the back plane, with a magnification factor of at least 20.

5.1.2. Tests on test structures

- Implant strips: <200 KΩ/cm (400 Ω/square)
- Metal strips: Aluminum 18 mΩ/square, (thickness ≥ 1.5 μm)

5.2. Acceptance Criteria of CMS tests

CMS will repeat the measurements already performed by the suppliers to verify the compliance with the acceptance criteria listed in the previous section. In addition CMS will perform further tests and will accept sensors provided they also meet the criteria listed below.

5.2.1. Irradiation

Sensors and test structures will be irradiated with a fluence of 1.6 x 10^{14}, 1 MeV equivalent neutron/cm^2 for thin sensors and to 3.5 x 10^{13}, 1 MeV equivalent neutron/cm^2 for the thick sensors.

5.2.2. Tests on sensors

Before irradiation

- Measure the sensor total leakage current and verify the corresponding classification, as in article 3.4.

- Leakage current stability test (on a sample basis). We require stable operation over at least 24 hours, both at room temperature (21 $\pm$ 1 ^{o}C) and at operating temperature (–10 $\pm$ 1 ^{o}C), and RH < 50%, and a bias voltage in the range from 450V to 550V. During this time, the total leakage current must not increase more than 30% from the initial value.

Before and after irradiation (measurement done after assembly into a module, and connection to readout electronics with a peaking time of approximately 25 ns). This measurement is done for all non-irradiated sensors, and on samples of irradiated ones.

- Noise on strip (Gaussian): a strip is considered defective if
  - its normal (Gaussian) noise at the depletion voltage is more than 30% larger than the median Gaussian noise of the other strips on the sensor
  - or if its normal (Gaussian) noise increases of more than 30% when the bias voltage is increased from the depletion voltage to 1.5 times the depletion voltage (max 400V).

NB. Noisy strips resulting from faults due to the assembly procedure are not included in the list of defective strips for sensor qualification. We require that the total number of defective strips on a module be below 2%, including noisy strips, as defined above.

After irradiation (tests performed on a sampling basis)

- Total current: < 30(15) µA cm^{-2} for thin (thick) sensors at T= –10 ^{0}C, RH < 50%, and 500V bias.
- The slope of the total leakage current shall satisfy the condition $\Delta I_{leak} / \Delta V$< 100 nA/V, in the range 450-550 Volts.
- The current must not vary by more than 15% during 24 hours of operation under these conditions.
- CV curve: V_{dep}<300; C_{back} < as before irradiation + 10%.
- Total strip capacitive load: < 1.2 pF/cm at operating voltage measured at 1MHz

- Charge collection efficiency: at a bias voltage of 400V should not be smaller than 80% of the maximum achievable before irradiation
- Defective strips: after irradiation the number of defective strips of each module (see acceptance tests in the previous section) should not be larger than 4%.

5.2.3. Tests on test structures

- CV on diodes: $V_{dep} < 300V$
- $C_{int:}$ <As before irradiation +10 %.
- $C_{tot} < 1.3$ pF/cm
- $R_{int\,:} > 20$ MΩ
- $R_{poly\,:}$ 1.5±0.3 MΩ
- Bondability: failure to bond with standard machine, bonds that fail pull tests (<10 g with 25 µm Al wire) or loss of adherence of the metallization when bonding or as result of the pull test.

6. Packaging and shipping of sensors

The details of the packaging and shipping of sensors and test structures will be defined by mutual agreement between the Supplier and CMS but the following general criteria should be used as guidelines:

- Individual containers should hold sensors and test structures from the same wafer. Bar coded identification on these containers is requested, using the identification code marked on the scratch pads of the devices.

- These containers should allow easy opening and visible access to the front side of the silicon without having to handle the silicon devices, as well as easy extraction and handling of the silicon devices.

- Anti-static and non-scratching surfaces and substances should be used for the packing material coming in contact with the silicon devices.

- Packaging for shipping should be designed to keep the silicon devices clean and dry (<50% RH). Standard precautions to avoid damages arising from handling during transport should be taken.

Packaging should not change during the production without agreement of CMS.

7. Pre-Series

CERN shall require the Contractor to produce a Pre-series to demonstrate his ability to comply fully with this Technical Specification. This Pre-series shall be produced with the same processing and substrate material properties as for the Series. The Pre-series, as defined in the Call for Tender document, will consist of approximately 5% of each sensor type included in the supply.

Manufacture of this Pre-series is intended for:

- Testing the quality of the produced sensors to stabilise the Technical Specifications: these sensors will be tested by the Contractor and the CMS Institutes (see article 5).
- Finalising the testing procedure.
- Testing the inspection and acceptance tests carried out by the Contractor and the supplied documentation and data;
- Testing the production capability of the Contractor;
- Testing the ability of the Contractor to comply with the delivery schedule;
- Testing the effectiveness of the labelling, packing and transportation methods.

CERN's written notification of Provisional Acceptance of the Pre-series is required before the start of the Series production.

8. Delivery Schedule

The required delivery schedule and the conditions attached to late delivery are detailed in articles 7 and 8 of the Tender Form.

9. Provisional Acceptance

The conditions for Provisional Acceptance of detectors are set out in article 12 of the Tender Form.

10. Non-Compliant Detectors

The conditions in case a detector does not comply with the specifications and requirements as set out in these Tender documents are detailed in article 13 of the Tender Form.

11. Documentation

To be supplied for approval four weeks after notification of contract:

Detector engineering drawings or mask designs for at least one detector shape;

Production and Quality Assurance Plan, and schedule for delivery of the Pre-series.

To be supplied with each delivered batch during pre-series and series production:

Test data defined in article 5.

<u>Annex A:</u> CMS Institute taking delivery of the sensors

CERN
Meyrin Site
1211 Geneve 23
Switzerland

<u>Annex B:</u> Persons in Charge for Technical Aspects

E. Focardi	Tel: (+39) 055 2307649 Fax: (+39) 055 229330 E-mail: focardi@fi.infn.it
M. Mannelli	Tel: (++41) 22 767 1665 Fax: (++41) 22 767 7150 E-mail: marcello.mannelli@cern.ch