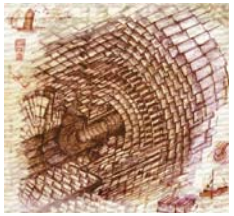
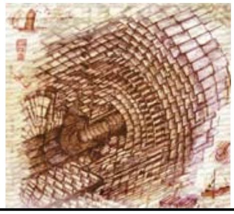


Silicon sensor developments for an upgrade (CMS)
Present status of a collaboration with HPK

Gino Bolla,
gino.bolla@cern.ch

On behalf of the CMS SLHC
Sensor Working Group



Five proposals submitted to the project that involve sensor development

Letter of Intent

for an R&D project to develop materials, technologies and simulations for silicon sensor modules at intermediate to large radii of a new CMS tracker for SLHC.

W. de Boer,

H.-J. Simonis
Institut für Experimentelle Kernphysik, Universität Karlsruhe, Germany

E. Cortina Gil, V. Lemaitre, O. Militaru
Louvain, Belgium

T. Bergauer, M. Dragicevic, J. Hrubec, M. Krammer
Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften, HEPHY, Vienna, Austria

WG: CMS Sensor Upgrade

Study of suitability of magnetic Czochralski silicon for the SLHC CMS strip tracker

The magnetic Czochralski silicon (MCz-Si) material has been studied extensively in the frameworks of RD50 and RD39 collaborations and it has been found to be more radiation hard against charged hadrons than traditional Float Zone silicon material (Fz-Si) used in the current CMS Tracker. The objective of this proposed project is to characterize full-size magnetic Czochralski silicon sensors with a beam telescope and make a systematic study of their properties up to the 2E15 cm^{-2} 1 MeV neutron equivalent fluence.

Contact persons: Panja Luukka, Jaakko Härkönen, Regina Demina, Leonard Spiegel

Development of pixel and micro-strip sensors on radiation tolerant substrates for the tracker upgrade at SLHC

D. Creanza, M. De Palma, F. Fedele L. Fiore, N. Manna.
INFN & Dipartimento Iterateneo di Fisica, Bari,Italy

N. Albergo, S. Costa, C. Tuvè
INFN and University of Catania, Italy

A. Basti, J. Bernardini, L. Borrello, F. Bosi, R. Dell'Orso, F. Fiori, F. Ligabue, S. Linari, A. Messineo, F. Palla, F. Palmonari
INFN and University of Pisa, Italy

L. Demaria, M. Costa
INFN and University of Torino, Italy

R. Horisberger, T. Rohe
Paul Scherrer Institut, Villigen, Switzerland

S. Cihangir, U. Joshi, S. Kwan, P. Tan, L. Uplegger
Fermi National Accelerator Laboratory (FNAL), Batavia, Illinois, USA

K. Arndt,G. Bolla, D. Bortoletto, O. Koybasi
Purdue University, West Lafayette, Indiana, USA

Contact Person: M. de Palma email : mauro.depalma@ba.infn.it

Today we only cover one of the six proposal:

R&D for Possible Replacement of Inner Pixel Layers With Aims for an SLHC Upgrade

Alice Bean,* Timothy Bolton, Aaron Dominguez, Wolfram Erdmann, Cecilia Gerber, Roland Horisberger, Angel López

October 31, 2007

Abstract

We propose to carry out research and development aimed at a possible replacement of inner barrel layer and possibly part of forward pixels using an upgraded PSI46 ROC and possibly new sensor technology. The basic goals of such R&D are to reduce data loss, reduce material, and simplify module production. Such R&D would be helpful if the inner pixel layers need to be replaced part way through the LHC run, but this is also meant as a step towards the SLHC upgrade by using some of the technologies that may play an important role in such a more radical redesign.

WG: CMS Sensor upgrade

CMS Upgrade document n.XX

R&D for Thin Single-Sided Sensors with HPK

Submitted: January 28, 2008

Abstract

The goals of this R&D are to determine the characteristics of Thin (<300um) Single-Sided Silicon Sensors, and establish production techniques and capabilities suitable for high quality, large scale and low cost production of such sensors, for the CMS SLHC Tracker Upgrade. Both p-on-n and n-on-p sensors will be investigated, as will be different substrate types (FZ, MCZ and Epitaxial).

The CMS SLHC Tracker will likely see large scale deployment of short strips (~2cm), and/or long pixels (~2mm).

A first set of masks and prototype runs, described below, is designed to address basic device characteristics and production techniques, for both strip and (long) pixel sensors. More device specific issues, in particular pertaining to pixilated sensors, will be addressed by subsequent mask sets and corresponding prototype runs.

Contact Person (Project Leader/responsible): Marcello Mannelli

Participating Institutes include:

CERN, UCSB, Purdue, FNAL, Perugia, Bari, Pisa, Karlsruhe, Vienna, PSI

3D detectors for inner pixel layers

Submitted: 7/11/2007

Abstract (≤ 1 page)

At SLHC luminosities the performance of silicon pixel layers located at a distance of less than 20 cm from the interaction region are limited by charge trapping. A promising technology for the inner layers is the so called 3D architecture which is currently been pursued by ATLAS and by RD50. In 3D sensors the p+ and n+ electrodes form arrays of columns in the silicon bulk, instead of being implanted on the wafer surface. Consequently when a voltage is applied to the electrodes the electric field is parallel to the detector surface, and for electron and holes the charge collection distance may be reduces to 50-100 μm compared to the typical planar geometry value of 300 μm . This leads to a faster collection time and lower voltage to achieve full depletion. Therefore 3D detectors are more radiation hard than planar ones. Measurements of 3D sensors have shown radiation resistance up to 8.6×10^{15} 1 MeV equivalent neutrons/cm^2. We propose a program to study, evaluate, and possibly participate in the commercialization of this technology to provide precise position detection at the innermost layers of the CMS tracking system.

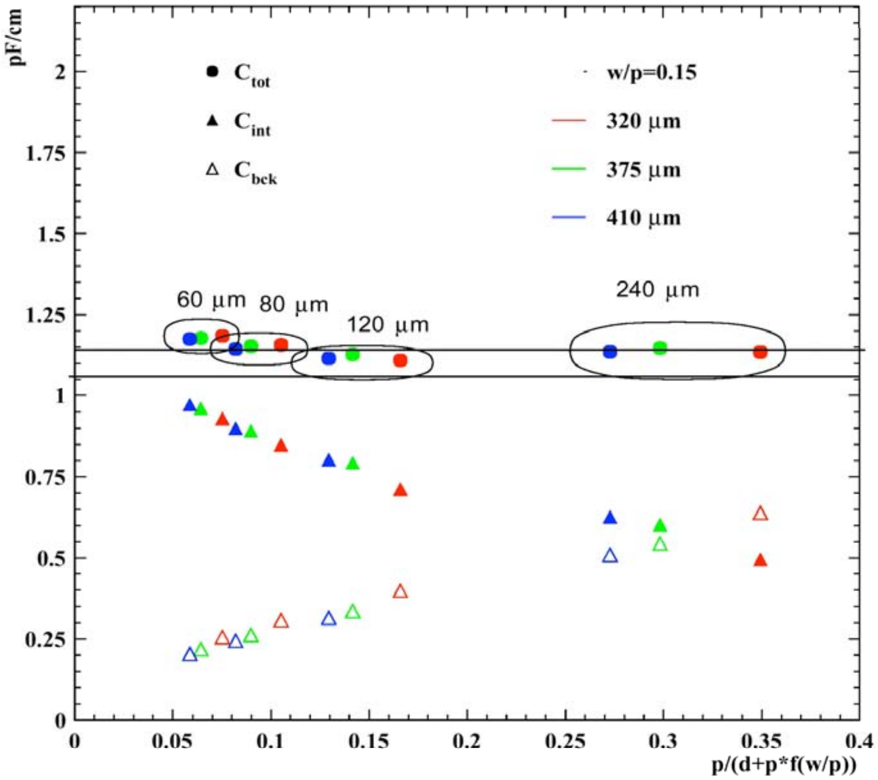
Contact Person (Project Leader/responsible): Daniela Bortoletto/Simon Kwan

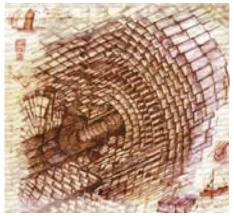
Goals of this collaboration with HPK

This specific collaboration with Hamamatsu photonics is a natural development of the work done in the 90s for the present strip tracker.

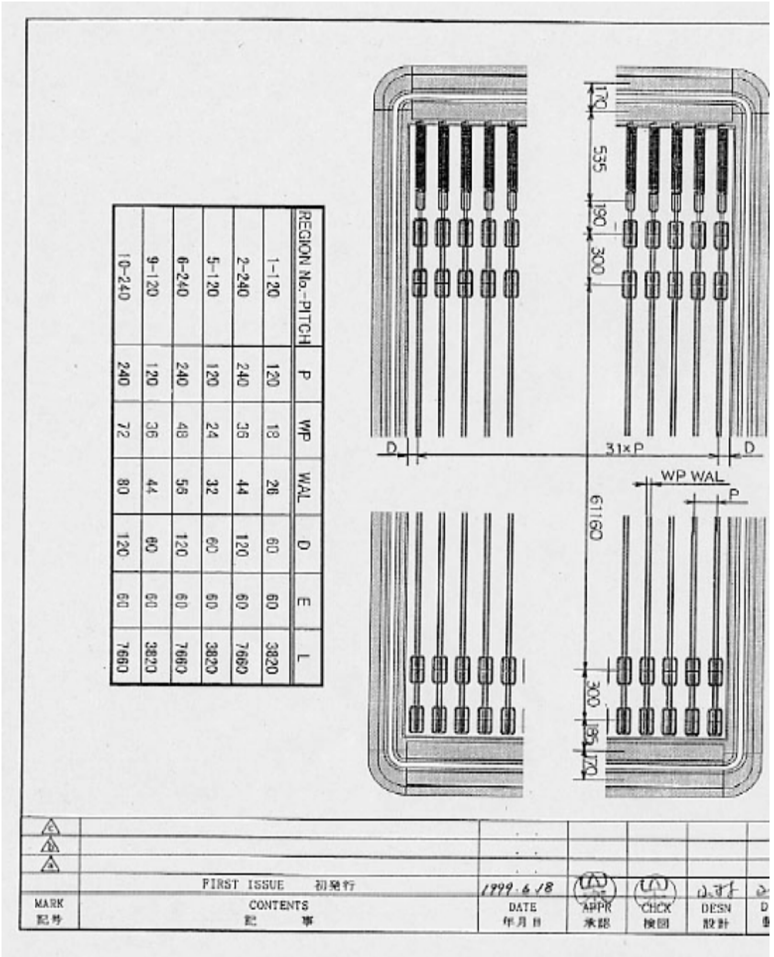
- **Extend previous Multi-Geometry studies from Strips to long Pixels**
- **Extend previous Multi-Geometry studies to substrate thickness less than or equal the pitch**
  - **Strip/Pixel capacitance (back-plane, inter-strip/pixel & total)**
  - **Critical fields, depletion and break-down voltage**
  - **Sensor functionality (charge collection efficiency etc)**
  - **As function of pitch, w/p, metal overhang, substrate thickness, Pixel Length**
- **Extend previous studies from LHC to SLHC fluence**
- **Extend previous studies to include MCZ and Epitaxial substrates**
- **Extend previous studies to include n-on-p**
- **Re-produce complementary sets of measurements and simulation**

Results of similar studies for the present tracker

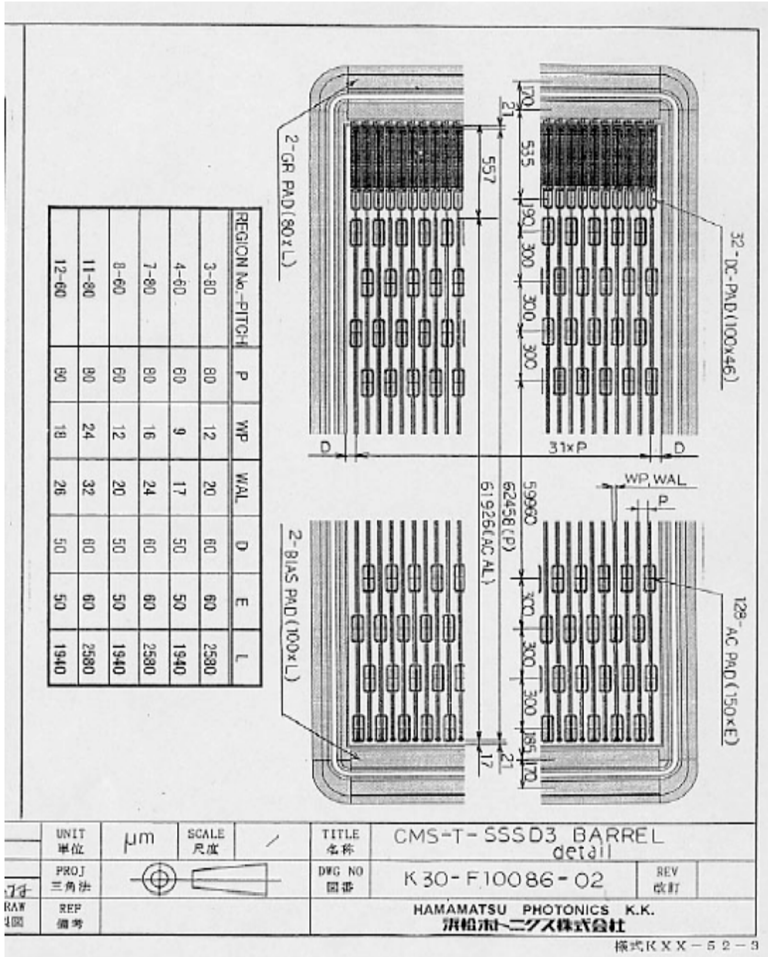




Strips multigeometry

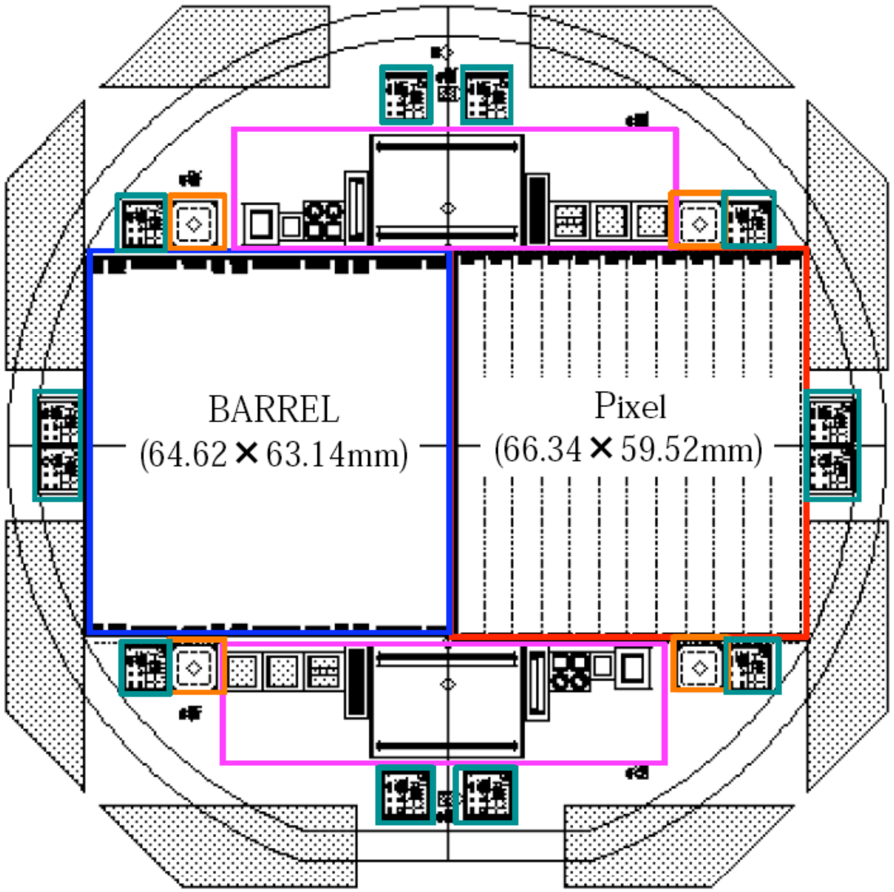


REGION No.-PITCH	P	WP	WAL	D	E	L
1-120	120	18	26	60	60	3820
2-240	240	36	44	120	60	7660
5-120	120	24	32	60	60	3820
6-240	240	48	56	120	60	7660
9-120	120	36	44	60	60	3820
10-240	240	72	80	120	60	7660



REGION No.-PITCH	P	WP	WAL	D	E	L
3-80	80	12	20	60	60	2580
4-60	60	9	17	50	50	1940
7-80	80	16	24	60	60	2580
8-60	60	12	20	50	50	1940
11-80	80	24	32	60	60	2580
12-60	60	18	26	50	50	1940

Wafer layout



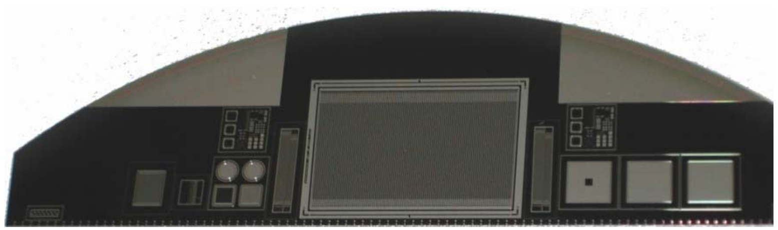
Being finalized with HPK.

- **New and improved test structures**
- **Added some BPIX and FPIX sensor (single ROC)**

Previous Test Structure

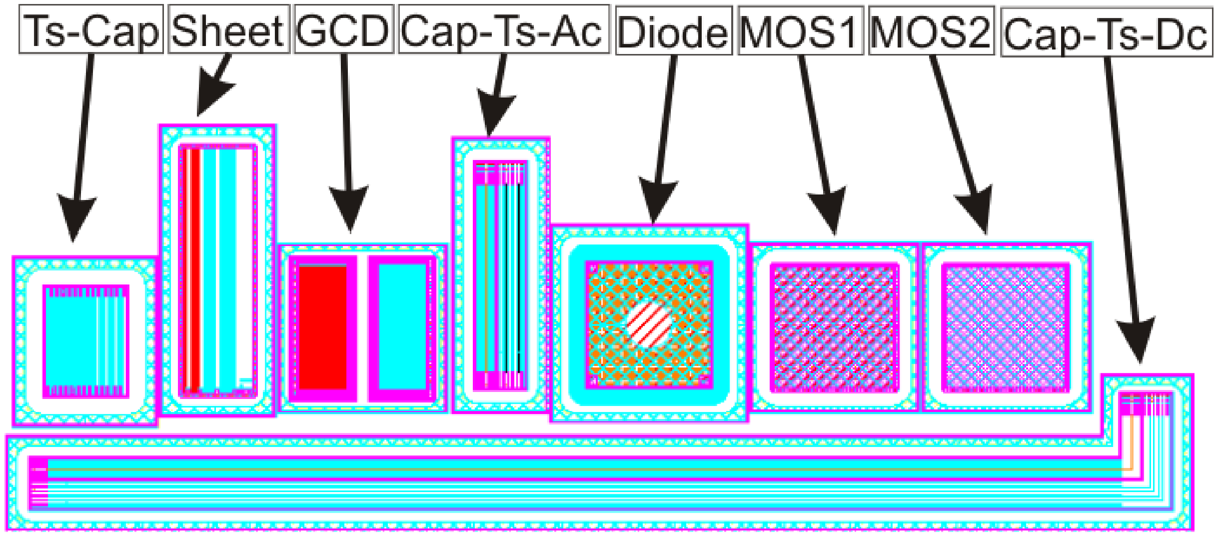
Monitor Diode

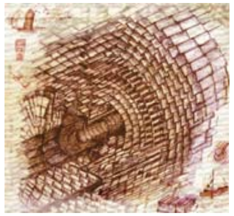
HPK Test structure



Test structures

- Should become a standard for all CMS sensors submission to perform Q&A on process and material.





Long pixel geometry

<u>12 Sets of Pixel Geometries</u>

- Each Set with independent Bias and Guard Rings
- Pixels are DC coupled to Al Layer & Daisy-Chained
  - (see below)
- Fixed Pixel Pitch = 120um
- Fixed Pixel w/p = 0.25; implant width = 30um
- Fixed Over-Metal = Implant width + 8um
  - Both across & along Pixel

<u>4 Pixel Lengths</u>

- Pixel Lengths = 1, 2, 3, 4 mm

For Each Pixel Length

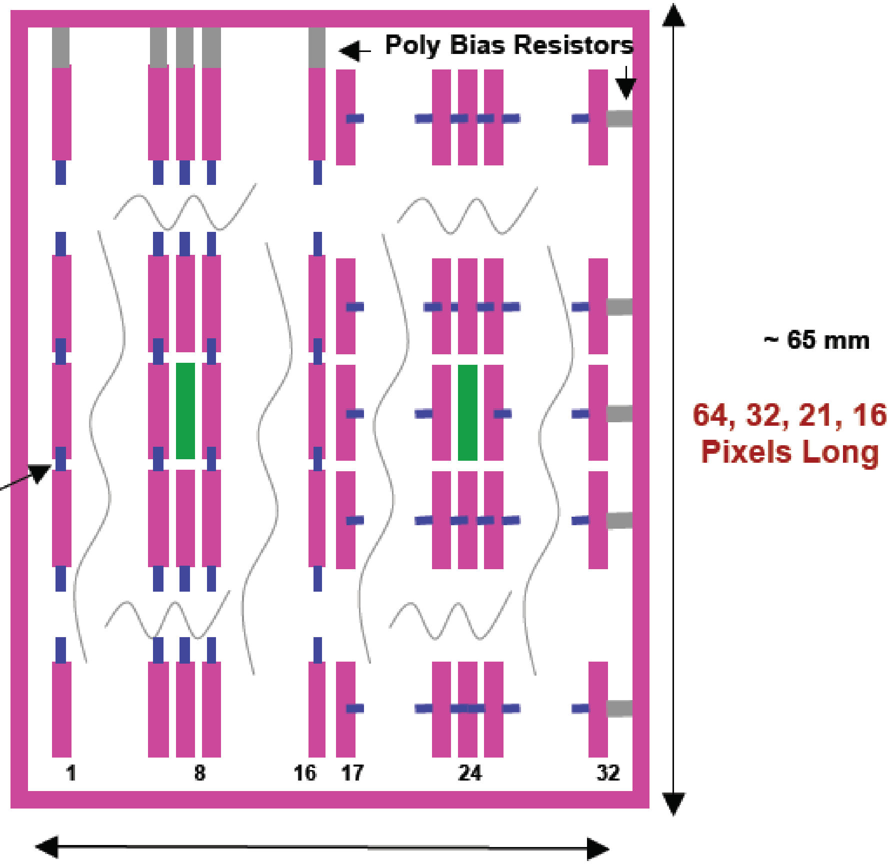
<u>3 Gaps (along Pixel Length)</u>

- Inter-Pixel Gaps = 60, 90, 120 um

<u>32 Pixels (strips) across, in Two Groups of 16</u>

- 16 biased from top & Daisy-Chained Length-wise
- 16 biased from the side & Daisy-Chained Across
- Central Pixel (green) is NOT Daisy-Chained (isolated)

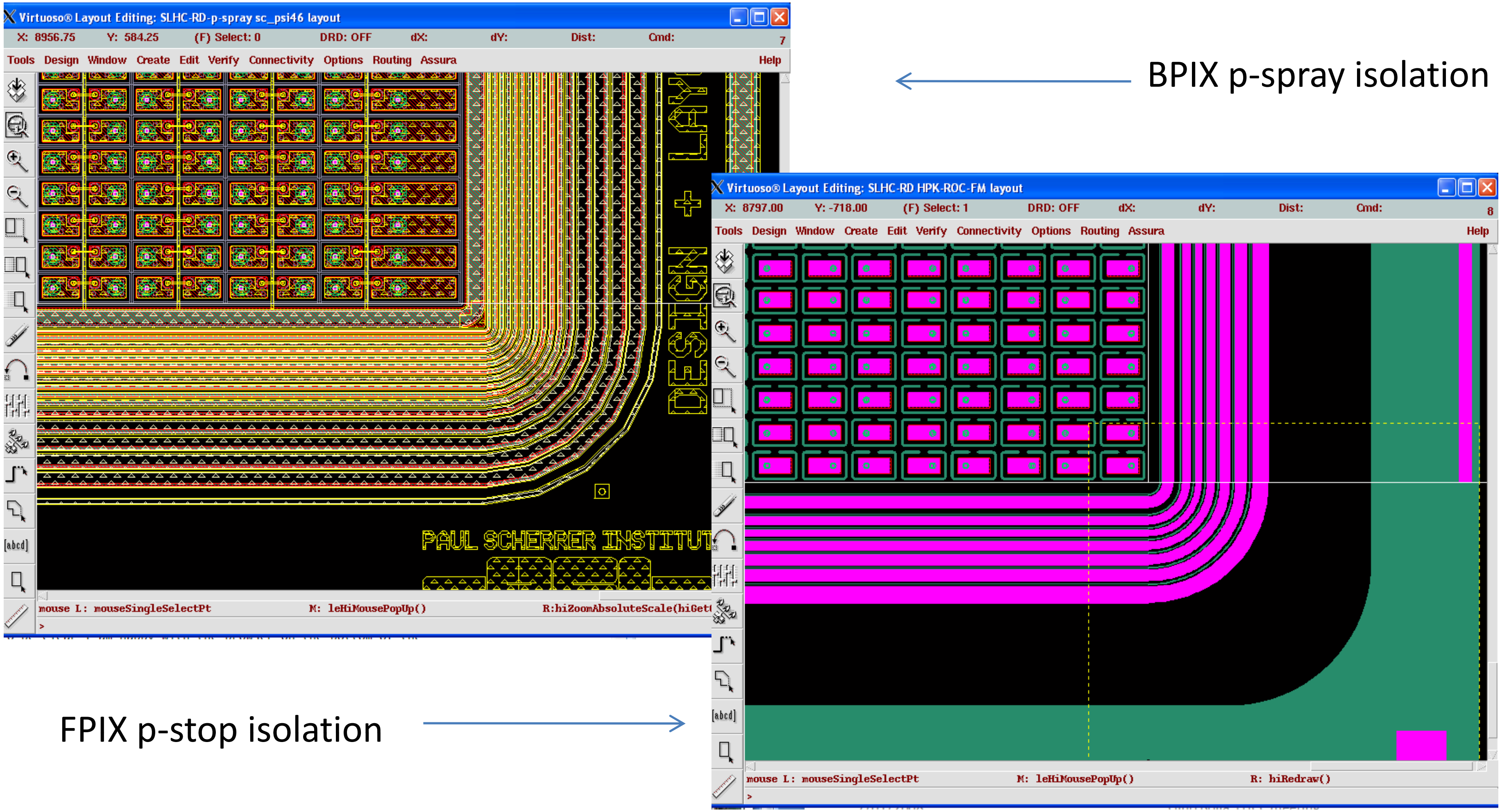
Inter-Pixel Daisy-Chaining
Along Pixel Length / Across Pixel Length



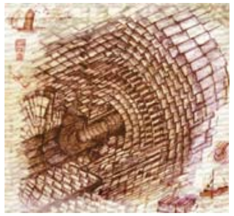
2 * 16 Pixels (strips) Wide

Single ROC pixel sensors

BPIX p-spray isolation

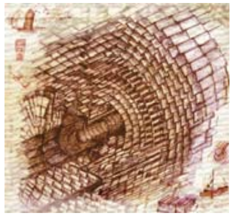


FPIX p-stop isolation



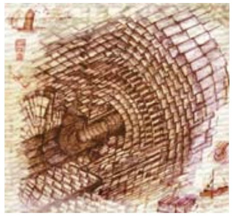
HPK submission Quantities (117 6” wafers)

	N-FZ	P-FZ	P-FZ	n-MCZ	P-MCZ	P-MCZ	N-epi	P-epi	P-epi
		pspray	pstop		pspray	pstop		pspray	pstop
200 um thick by thinning	9	6	6	9	6	6	0	0	0
100 um thick on carrier substrate	9	6	6						
100 um thick epitaxial							9	6	6
50 um thick epitaxial							9	6	6
200 um thick on carrier substrate & double metal	6		6						

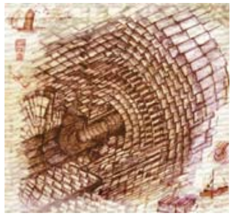


Timeline

- December 2007
  - Call for interest
  - Discuss and agree layout, thickness and material types
  - Discuss and agree program of work and task assignment
  - Discuss and agree financing
  - Submit Proposal for approval
- June-July 2008
  - Place Order with HPK
- February 2009
  - HPK deliver
- End of 2009
  - Results ready for publication

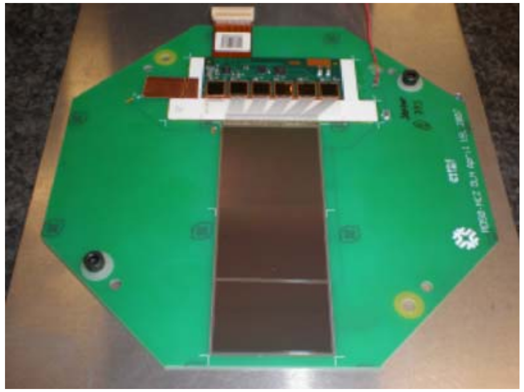


Spares (from now on)

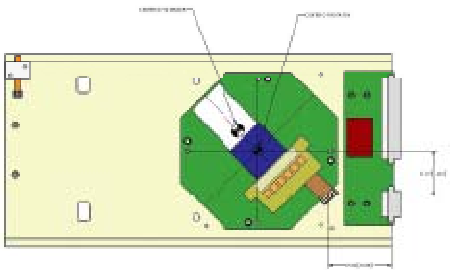


Silicon Beam telescope (SiBT)

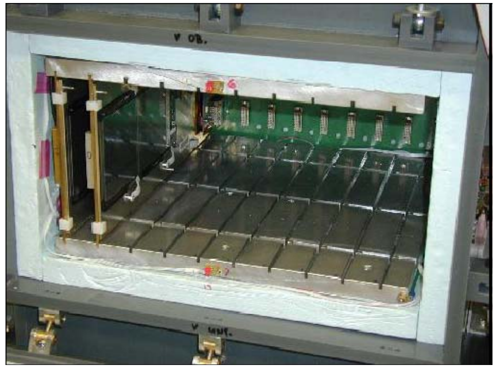
Helsinki Institute of Physics, Fermilab, Universität Karlsruhe,
Université Catholique de Louvain, Università di Padova, University of Rochester



- The telescope reference planes + detectors under test are housed inside the Vienna box.
- The temperature can be set down to -20°C
- Reference planes are installed to ±45 degrees (due to the height limitation)
- Reference detectors D0 Run IIb HPK sensors with:
  - 60 micron pitch
  - intermediate strips
  - size 4 cm x 9 cm
  - 639 channels

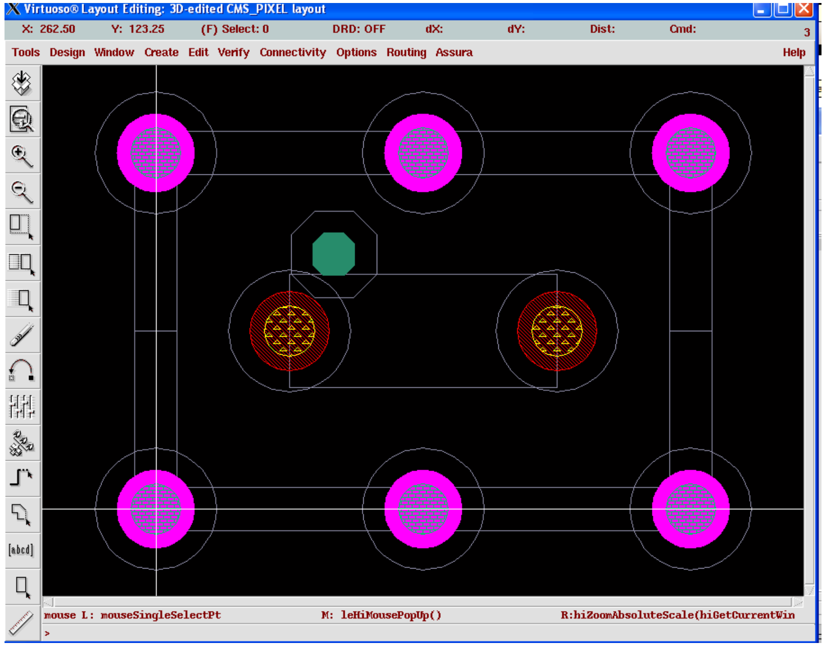


-45 DEG ROTATION

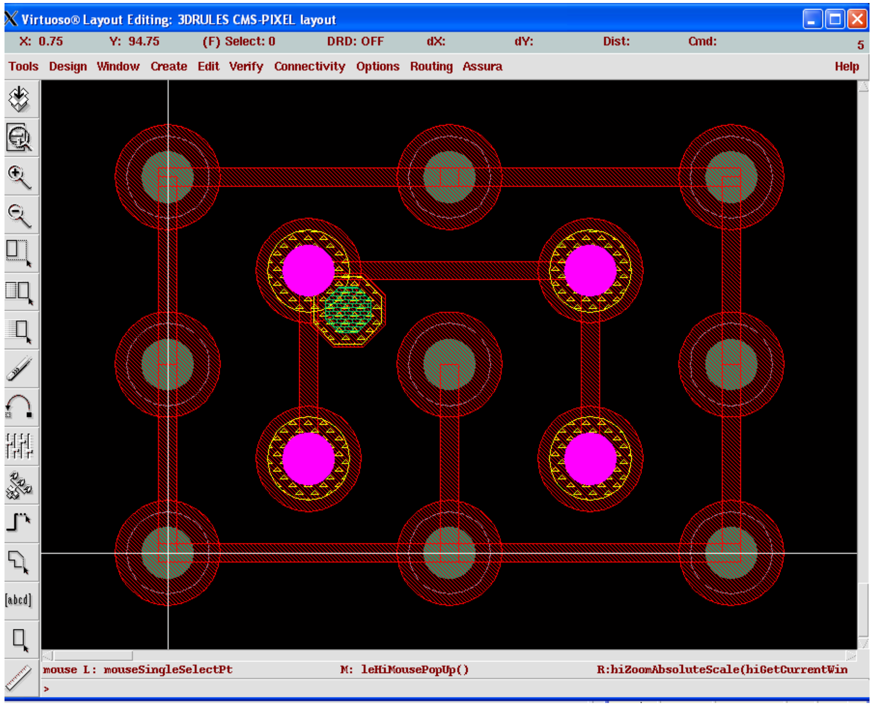


- Readout electronics: CMS 6-APV chip Tracker Outer Barrel hybrids (5 chips bonded)
- DAQ software: a modified version of XDAQ rc1205

3D sensors for the innermost layer/s



3D sensor development is active with Sintef.
Producer of the CMSFPIX sensor.
First prototypes for bumpbonding hopefully by the end of 2008



A two column pixel
And a four columns pixel
implemented in the CMS pixel geometry