Solid State Sensor Poster Review

Karlsruhe Institute of Technology

Frank Hartmann

CERN

27 posters in 20 minutes ➔ 44,44 secs / topic

Be prepared ☺

Overview

ATLAS	Alignment of the ATLAS Inner Detector Tracking System
	ATLAS Silicon Microstrip Tracker Commissioning and Silicon Sensor Performance
	Results from the Commissioning of the ATLAS Pixel Detector with Cosmics Data
CMS	Data Quality Monitoring of the CMS Silicon Strip Tracker Detector
	CMS Silicon Strip Tracker Operation in Cosmic Run at Four Tesla
ALICE	The Silicon Drift Detector of the ALICE Experiment
	The ALICE Silicon Pixel Detector Read-Out Electronics
LHCB	First Experience and Results with the LHCb Silicon Tracker
CDF	Longevity Studies in the CDF Silicon Detectors
	Operational Experience with the CDF Run II Silicon Detector
Future detectors (e.g. B-factories)	
	Silicon vertex detector upgrade for SuperKEKB factory
	The SuperB Silicon Vertex Tracker
	Production and Performance of the Silicon Sensor and Custom Readout Electronics for the PHENIX FVTX Tracker
	The NA62 Gigatracker Pixel Detector System
3D & RD	3D Silicon Detectors for LHC Upgrades
	Characterization and Modelling of Signal Dynamics in 3D-DDTC Detectors
	Recent Advances in the Development of Semiconductor Detectors for Very High Luminosity Colliders
	Characterization of Irradiated P-Type Silicon Detectors by the ALIBAVA System
	Simulation of Electrical Parameters of New Design of SLHC Silicon Sensors for Large Radii
SLIM	SLIM5 Beam Test Results for Thin Striplet Detector and Fast Readout Beam Telescope
	Investigation of an abnormal pattern of the strip leakage currents in microstrip detectors
"other devices"	Laser and Alpha Particle Characterization of a Floating-Base BJT Detector
	Study of Geiger Avalanche Photo Diodes (GAPD) Applications to Pixel Tracking Detectors
	Characterization of CMOS Active Pixel Sensors for Particle Detection: Beam Test of the Four Sensors RAPS03 Stacked System
Generic supporting studies	Development and Experimental Characterization of Prototypes for Low Material Budget Support Structure and Cooling of Silicon Pixel Detectors, Based on Microchannel Technology
	Optimising the Strip Geometry for very Fine Pitch Silicon Strip Sensors
	Lithium Diffusion into Silicon-Germanium Single Crystal

A lot of very interesting information

Go and fetch it

Unfortunately not all slides nor posters are in Indico, Fortunately I have a digital camera.
I tried my best.

LHC DETECTORS

3 ATLAS poster,
All very detailed

Regina Moles (*IFIC – Valencia)*

ALIGNMENT OF THE ATLAS INNER DETECTOR TRACKING

Heinz Pernegger (*CERN Physics Department*)

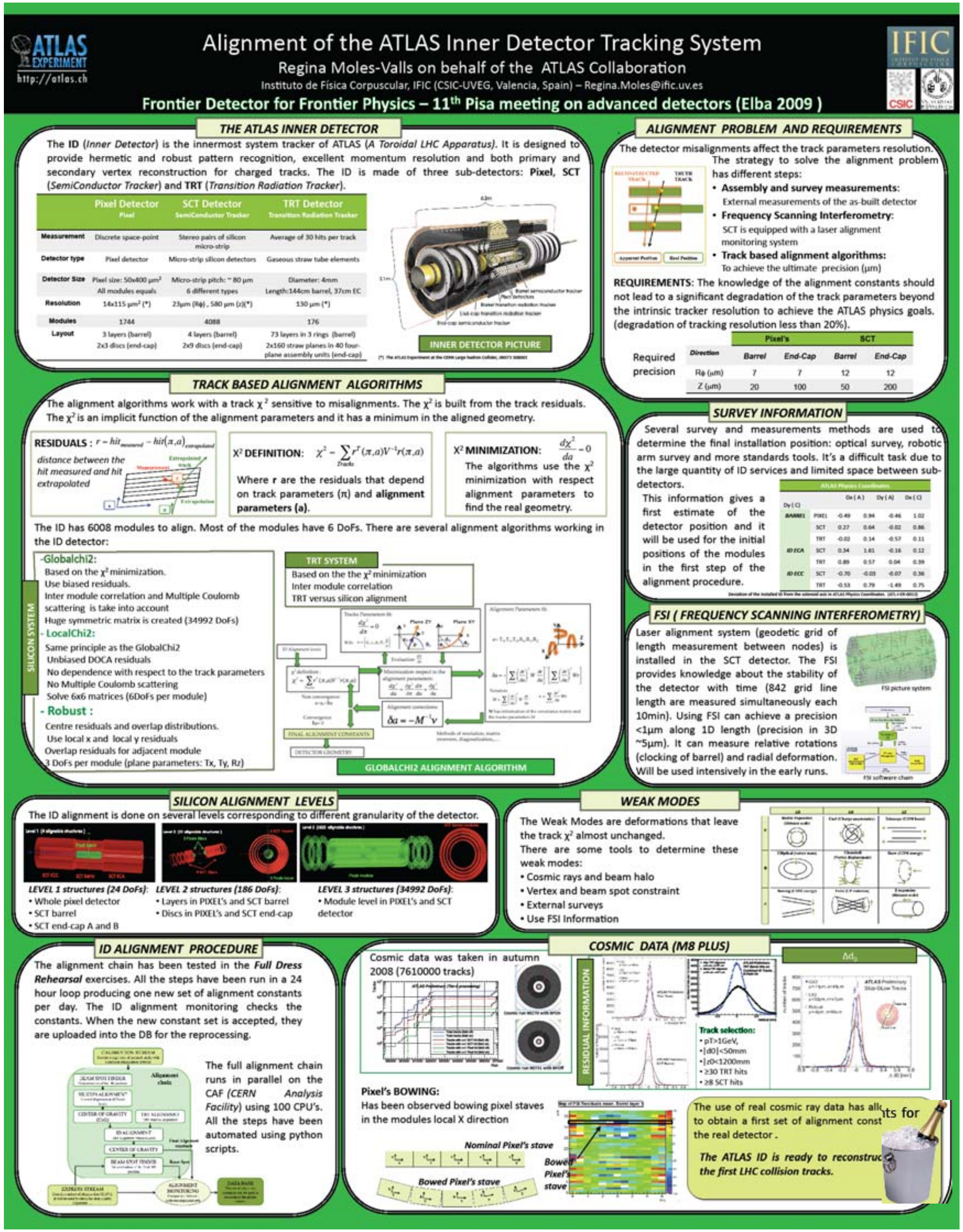
ATLAS SILICON MICROSTRIP TRACKER COMMISSIONING AND SILICON SENSOR PERFORMANCE

Jens Weingarten (*Dortmund University*)

RESULTS FROM THE COMMISSIONING OF THE ATLAS PIXEL DETECTOR WITH COSMICS DATA

A summary was already given on Monday, more details on the posters
They are really worth three looks (each)!

ALIGNMENT



Alignment of the ATLAS Inner Detector Tracking System

Regina Moles-Valls on behalf of the ATLAS Collaboration

Instituto de Física Corpuscular, IFIC (CSIC-UVEG, Valencia, Spain) – Regina.Moles@ific.uv.es

Frontier Detector for Frontier Physics – 11th Pisa meeting on advanced detectors (Elba 2009)

THE ATLAS INNER DETECTOR

The **ID** (*Inner Detector*) is the innermost system tracker of ATLAS (*A Toroidal LHC Apparatus*). It is designed to provide hermetic and robust pattern recognition, excellent momentum resolution and both primary and secondary vertex reconstruction for charged tracks. The ID is made of three sub-detectors: **Pixel**, **SCT** (*SemiConductor Tracker*) and **TRT** (*Transition Radiation Tracker*).

	Pixel Detector Pixel	SCT Detector SemiConductor Tracker	TRT Detector Transition Radiation Tracker
Measurement	Discrete space-point	Stereo pairs of silicon micro-strip	Average of 30 hits per track
Detector type	Pixel detector	Micro-strip silicon detectors	Gaseous straw tube elements
Detector Size	Pixel size: 50x400 μm² All modules equals	Micro-strip pitch: ~ 80 μm 6 different types	Diameter: 4mm Length:144cm barrel, 37cm EC
Resolution	14x115 μm² (*)	23μm (Rϕ) , 580 μm (z)(*)	130 μm (*)
Modules	1744	4088	176
Layout	3 layers (barrel) 2x3 discs (end-cap)	4 layers (barrel) 2x9 discs (end-cap)	73 layers in 3 rings (barrel) 2x160 straw planes in 40 four-plane assembly units (end-cap)

INNER DETECTOR PICTURE

(*) The ATLAS Experiment at the CERN Large Hadron Collider, JINST3 S08003

ALIGNMENT PROBLEM AND REQUIREMENTS

The detector misalignments affect the track parameters resolution. The strategy to solve the alignment problem has different steps:

- **Assembly and survey measurements**: External measurements of the as-built detector
- **Frequency Scanning Interferometry**: SCT is equipped with a laser alignment monitoring system
- **Track based alignment algorithms:** To achieve the ultimate precision (μm)

REQUIREMENTS: The knowledge of the alignment constants should not lead to a significant degradation of the track parameters beyond the intrinsic tracker resolution to achieve the ATLAS physics goals. (degradation of tracking resolution less than 20%).

Required precision

Direction	Pixel's Barrel	Pixel's End-Cap	SCT Barrel	SCT End-Cap
Rϕ (μm)	7	7	12	12
Z (μm)	20	100	50	200

TRACK BASED ALIGNMENT ALGORITHMS

The alignment algorithms work with a track χ^2 sensitive to misalignments. The χ^2 is built from the track residuals. The χ^2 is an implicit function of the alignment parameters and it has a minimum in the aligned geometry.

RESIDUALS : $r = hit_{measured} - hit(\pi,a)_{extrapolated}$

distance between the hit measured and hit extrapolated

X² DEFINITION: $\chi^2 = \sum_{Tracks} r^T(\pi,a)V^{-1}r(\pi,a)$

Where **r** are the residuals that depend on track parameters (π) and **alignment parameters (a)**.

X² MINIMIZATION: $\frac{d\chi^2}{da} = 0$

The algorithms use the χ^2 minimization with respect alignment parameters to find the real geometry.

The ID has 6008 modules to align. Most of the modules have 6 DoFs. There are several alignment algorithms working in the ID detector:

SILICON SYSTEM

-Globalchi2:

Based on the χ^2 minimization.
Use biased residuals.
Inter module correlation and Multiple Coulomb scattering is take into account
Huge symmetric matrix is created (34992 DoFs)

- LocalChi2:

Same principle as the GlobalChi2
Unbiased DOCA residuals
No dependence with respect to the track parameters
No Multiple Coulomb scattering
Solve 6x6 matrices (6DoFs per module)

- Robust :

Centre residuals and overlap distributions.
Use local x and local y residuals
Overlap residuals for adjacent module
3 DoFs per module (plane parameters: Tx, Ty, Rz)

TRT SYSTEM

Based on the the χ^2 minimization
Inter module correlation
TRT versus silicon alignment

GLOBALCHI2 ALIGNMENT ALGORITHM

SURVEY INFORMATION

Several survey and measurements methods are used to determine the final installation position: optical survey, robotic arm survey and more standards tools. It's a difficult task due to the large quantity of ID services and limited space between sub-detectors.

This information gives a first estimate of the detector position and it will be used for the initial positions of the modules in the first step of the alignment procedure.

ATLAS Physics Coordinates

		Dx (A)	Dy (A)	Dx (C)	Dy (C)
BARREL	PIXEL	-0.49	0.94	-0.46	1.02
	SCT	0.27	0.64	-0.02	0.86
	TRT	-0.02	0.14	-0.57	0.11
ID ECA	SCT	0.34	1.61	-0.16	0.12
	TRT	0.89	0.57	0.04	0.39
ID ECC	SCT	-0.70	-0.03	-0.07	0.36
	TRT	-0.53	0.79	-1.49	0.75

Deviation of the installed ID from the solenoid axis in ATLAS Physics Coordinates. [illegible]

FSI (FREQUENCY SCANNING INTERFEROMETRY)

Laser alignment system (geodetic grid of length measurement between nodes) is installed in the SCT detector. The FSI provides knowledge about the stability of the detector with time (842 grid line length are measured simultaneously each 10min). Using FSI can achieve a precision <1μm along 1D length (precision in 3D ~5μm). It can measure relative rotations (clocking of barrel) and radial deformation. Will be used intensively in the early runs.

FSI picture system

FSI software chain

SILICON ALIGNMENT LEVELS

The ID alignment is done on several levels corresponding to different granularity of the detector.

LEVEL 1 structures (24 DoFs):
- Whole pixel detector
- SCT barrel
- SCT end-cap A and B

LEVEL 2 structures (186 DoFs):
- Layers in PIXEL's and SCT barrel
- Discs in PIXEL's and SCT end-cap

LEVEL 3 structures (34992 DoFs):
- Module level in PIXEL's and SCT detector

WEAK MODES

The Weak Modes are deformations that leave the track χ^2 almost unchanged.

There are some tools to determine these weak modes:

- Cosmic rays and beam halo
- Vertex and beam spot constraint
- External surveys
- Use FSI Information

ID ALIGNMENT PROCEDURE

The alignment chain has been tested in the ***Full Dress Rehearsal*** exercises. All the steps have been run in a 24 hour loop producing one new set of alignment constants per day. The ID alignment monitoring checks the constants. When the new constant set is accepted, they are uploaded into the DB for the reprocessing.

The full alignment chain runs in parallel on the CAF *(CERN Analysis Facility*) using 100 CPU's. All the steps have been automated using python scripts.

COSMIC DATA (M8 PLUS)

Cosmic data was taken in autumn 2008 (7610000 tracks)

RESIDUAL INFORMATION

Δd_0

Track selection:
- pT>1GeV,
- |d0|<50mm
- |z0<1200mm
- ≥30 TRT hits
- ≥8 SCT hits

Pixel's BOWING:

Has been observed bowing pixel staves in the modules local X direction

Nominal Pixel's stave

Bowed Pixel's stave

Bowed Pixel's stave

The use of real cosmic ray data has all[...] to obtain a first set of alignment const[...] the real detector .

The ATLAS ID is ready to reconstruc[...] the first LHC collision tracks.

- **Assembly and survey measurements:**

External measurements of the as-built detecto

- **Frequency Scanning Interferometry:**

SCT is equipped with a laser alignment monitoring system

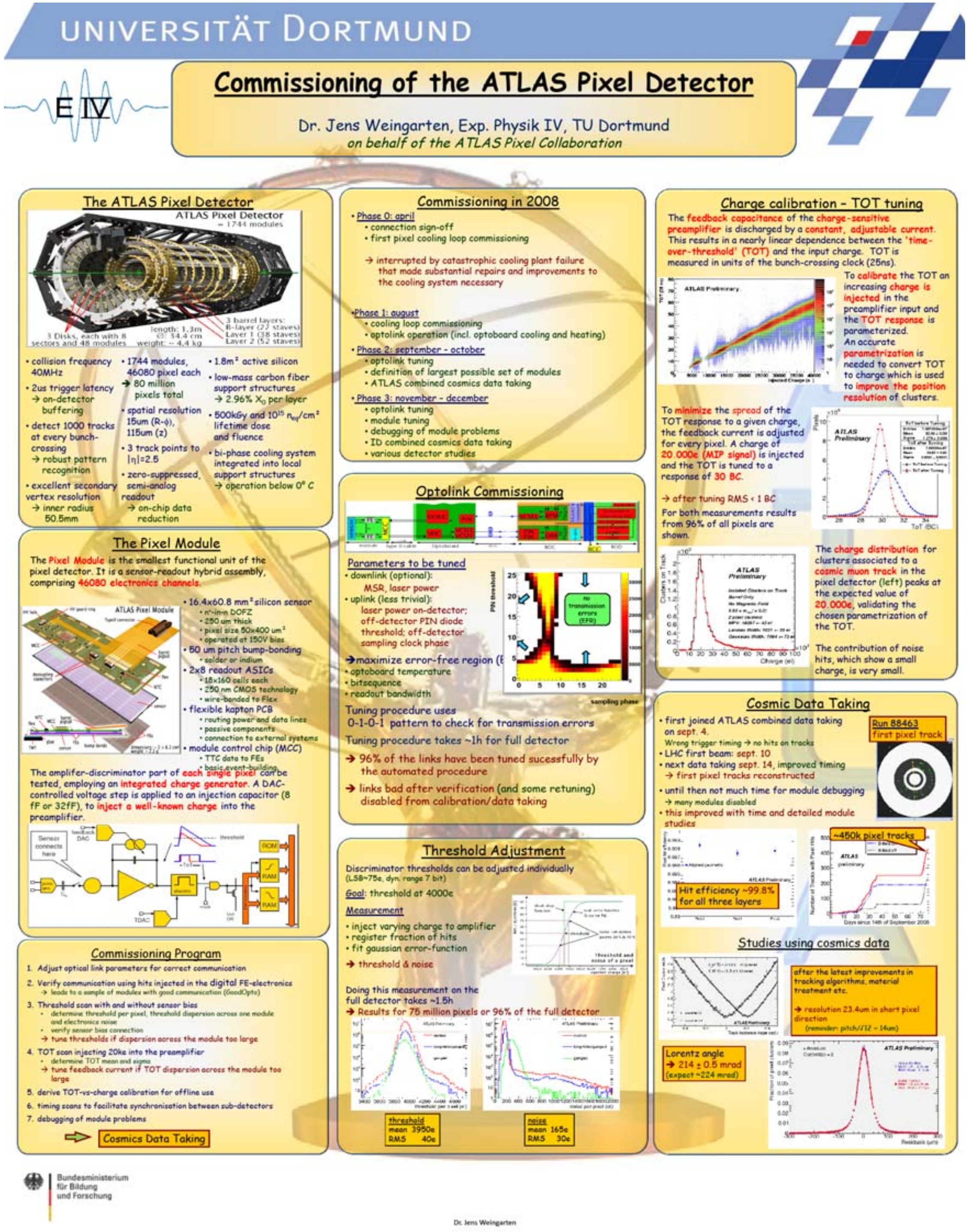
- **Track based alignment algorithms:**

To achieve the ul>mate precision (μm)

The use of real cosmic ray data has allowed us to obtain a first set of alignment constants for the real detector .

The ATLAS ID is ready to reconstruct the first LHC collision tracks.

Pixel Commissioning



UNIVERSITÄT DORTMUND

E IV

Commissioning of the ATLAS Pixel Detector

Dr. Jens Weingarten, Exp. Physik IV, TU Dortmund
on behalf of the ATLAS Pixel Collaboration

The ATLAS Pixel Detector

- collision frequency 40MHz
- 2us trigger latency
  → on-detector buffering
- detect 1000 tracks at every bunch-crossing
  → robust pattern recognition
- excellent secondary vertex resolution
  → inner radius 50.5mm
- 1744 modules, 46080 pixel each
  → 80 million pixels total
- spatial resolution 15um (R-ϕ), 115um (z)
- 3 track points to |η|=2.5
- zero-suppressed, semi-analog readout
  → on-chip data reduction
- 1.8m² active silicon
- low-mass carbon fiber support structures
  → 2.96% X_0 per layer
- 500kGy and 10^{15} n_{eq}/cm^2 lifetime dose and fluence
- bi-phase cooling system integrated into local support structures
  → operation below 0° C

The Pixel Module

The Pixel Module is the smallest functional unit of the pixel detector. It is a sensor-readout hybrid assembly, comprising 46080 electronics channels.

- 16.4x60.8 mm² silicon sensor
  - n⁺-in-n DOFZ
  - 250 um thick
  - pixel size 50x400 um²
  - operated at 150V bias
- 50 um pitch bump-bonding
  - solder or indium
- 2x8 readout ASICs
  - 18x160 cells each
  - 250 nm CMOS technology
  - wire-bonded to Flex
- flexible kapton PCB
  - routing power and data lines
  - passive components
  - connection to external systems
- module control chip (MCC)
  - TTC data to FEs
  - basic event-building

The amplifer-discriminator part of each single pixel can be tested, employing an integrated charge generator. A DAC-controlled voltage step is applied to an injection capacitor (8 fF or 32fF), to inject a well-known charge into the preamplifier.

Commissioning Program

1. Adjust optical link parameters for correct communication
2. Verify communication using hits injected in the digital FE-electronics
   → leads to a sample of modules with good communication (GoodOpto)
3. Threshold scan with and without sensor bias
   - determine threshold per pixel, threshold dispersion across one module and electronics noise
   - verify sensor bias connection
   → tune thresholds if dispersion across the module too large
4. TOT scan injecting 20ke into the preamplifier
   - determine TOT mean and sigma
   → tune feedback current if TOT dispersion across the module too large
5. derive TOT-vs-charge calibration for offline use
6. timing scans to facilitate synchronisation between sub-detectors
7. debugging of module problems

⇨ Cosmics Data Taking

Commissioning in 2008

- Phase 0: april
  - connection sign-off
  - first pixel cooling loop commissioning

  → interrupted by catastrophic cooling plant failure that made substantial repairs and improvements to the cooling system necessary
- Phase 1: august
  - cooling loop commissioning
  - optolink operation (incl. optoboard cooling and heating)
- Phase 2: september - october
  - optolink tuning
  - definition of largest possible set of modules
  - ATLAS combined cosmics data taking
- Phase 3: november - december
  - optolink tuning
  - module tuning
  - debugging of module problems
  - ID combined cosmics data taking
  - various detector studies

Optolink Commissioning

Parameters to be tuned

- downlink (optional):
  MSR, laser power
- uplink (less trivial):
  laser power on-detector; off-detector PIN diode threshold; off-detector sampling clock phase

→maximize error-free region (E

- optoboard temperature
- bitsequence
- readout bandwidth

Tuning procedure uses 0-1-0-1 pattern to check for transmission errors

Tuning procedure takes ~1h for full detector

→ 96% of the links have been tuned sucessfully by the automated procedure

→ links bad after verification (and some retuning) disabled from calibration/data taking

Threshold Adjustment

Discriminator thresholds can be adjusted individually (LSB~75e, dyn. range 7 bit)

Goal: threshold at 4000e

Measurement

- inject varying charge to amplifier
- register fraction of hits
- fit gaussian error-function

→ threshold & noise

Doing this measurement on the full detector takes ~1.5h

→ Results for 75 million pixels or 96% of the full detector

threshold
mean 3950e
RMS 40e

noise
mean 165e
RMS 30e

Charge calibration - TOT tuning

The feedback capacitance of the charge-sensitive preamplifier is discharged by a constant, adjustable current. This results in a nearly linear dependence between the 'time-over-threshold' (TOT) and the input charge. TOT is measured in units of the bunch-crossing clock (25ns).

To calibrate the TOT an increasing charge is injected in the preamplifier input and the TOT response is parameterized. An accurate parametrization is needed to convert TOT to charge which is used to improve the position resolution of clusters.

To minimize the spread of the TOT response to a given charge, the feedback current is adjusted for every pixel. A charge of 20.000e (MIP signal) is injected and the TOT is tuned to a response of 30 BC.

→ after tuning RMS < 1 BC

For both measurements results from 96% of all pixels are shown.

The charge distribution for clusters associated to a cosmic muon track in the pixel detector (left) peaks at the expected value of 20.000e, validating the chosen parametrization of the TOT.

The contribution of noise hits, which show a small charge, is very small.

Cosmic Data Taking

- first joined ATLAS combined data taking on sept. 4.
  Wrong trigger timing → no hits on tracks
- LHC first beam: sept. 10
- next data taking sept. 14, improved timing
  → first pixel tracks reconstructed
- until then not much time for module debugging
  → many modules disabled
- this improved with time and detailed module studies

Run 88463
first pixel track

Hit efficiency ~99.8%
for all three layers

~450k pixel tracks

Studies using cosmics data

after the latest improvements in tracking algorithms, material treatment etc.

→ resolution 23.4um in short pixel direction
(reminder: pitch/√12 ~ 14um)

Lorentz angle
→ 214 ± 0.5 mrad
(expect ~224 mrad)

Bundesministerium für Bildung und Forschung

Dr. Jens Weingarten

Impressive results achieved during commissioning and cosmic data taking last year

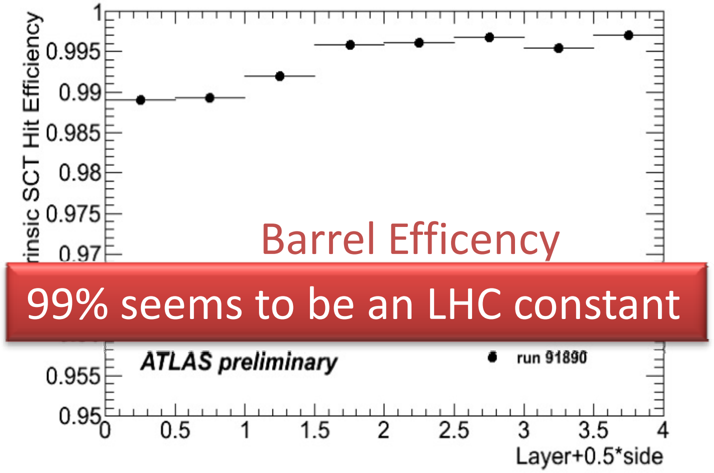
- TOT threshold scan
- Lorentz angle
- Hit efficiency 99.8%

To name a few

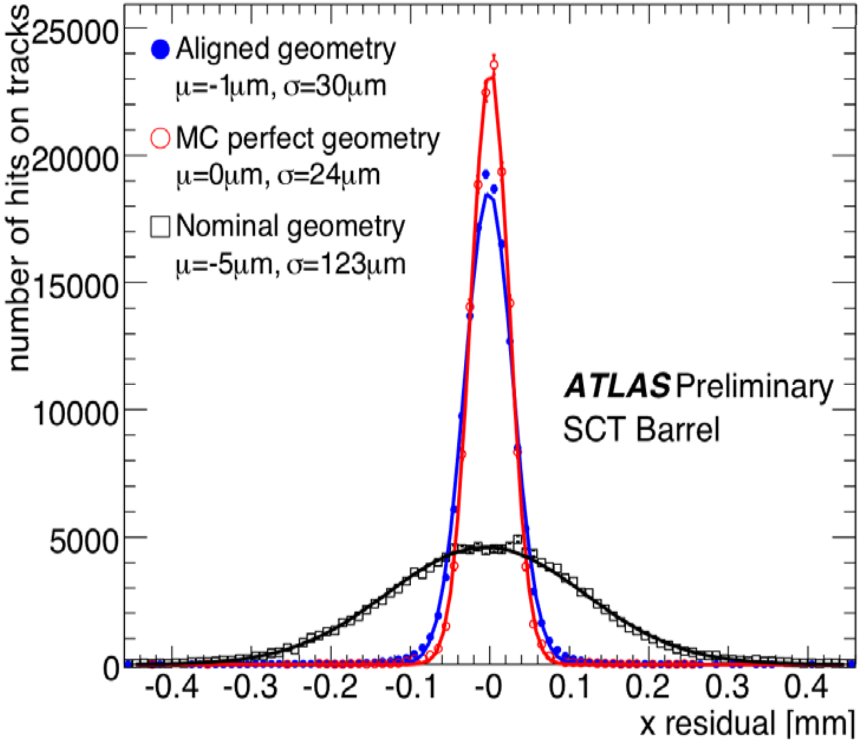
- Heinz Pernegger (*CERN Physics Department*)

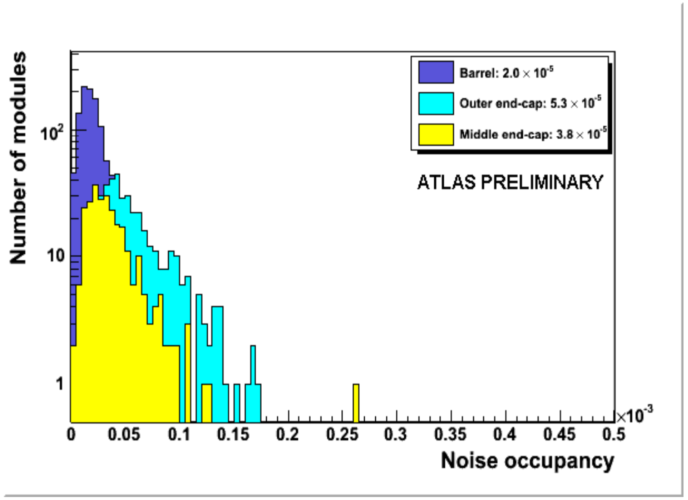
ATLAS Silicon Microstrip Tracker Commissioning and Silicon Sensor Performance

- Commissioned ATLAS Silicon Strip SCT during 2008
  - Stable readout in ATLAS with low noise
  - Test SCT tracking performance with Cosmics
- Readout in 2008 99% of Barrel and 97% of Endcap modules
- Efficiency >99%
- Noise Occupancy ~2-5 x10^{-5} (specs 5x 10^{-4})
- First round of alignment with cosmics tracks (2M tracks in SCT) very sucessful



99% seems to be an LHC constant





2 CMS poster,
both very detailed

Leonardo Benucci (*University of Antwerp*)

DATA QUALITY MONITORING OF THE CMS SILICON STRIP TRACKER DETECTOR

Vitaliano Ciulli ((*Univ. di Firenze e Sez. dell' INFN,*)

CMS SILICON STRIP TRACKER OPERATION IN COSMIC RUN AT FOUR TESLA

Data Quality Monitoring of the CMS Silicon Strip Tracker Detector

Leonardo Benucci - University of Antwerp, Belgium

*Data Quality Monitoring (**DQM**) is being built to provide complete and coherent monitoring data (online and offline) at low latency, to ensure the optimal working of the hardware and software and to certify the quality of the data for analysis in an efficient way*

WHAT DQM MONITORS (Monitor Elements, ME):

- RAW data (readout and unpacking errors)
- DIGIS and Cluster (related or not to a track)
- track parameters
- Hit residuals

The data quality is assessed through **histograms** (about 300,000 histograms defined).

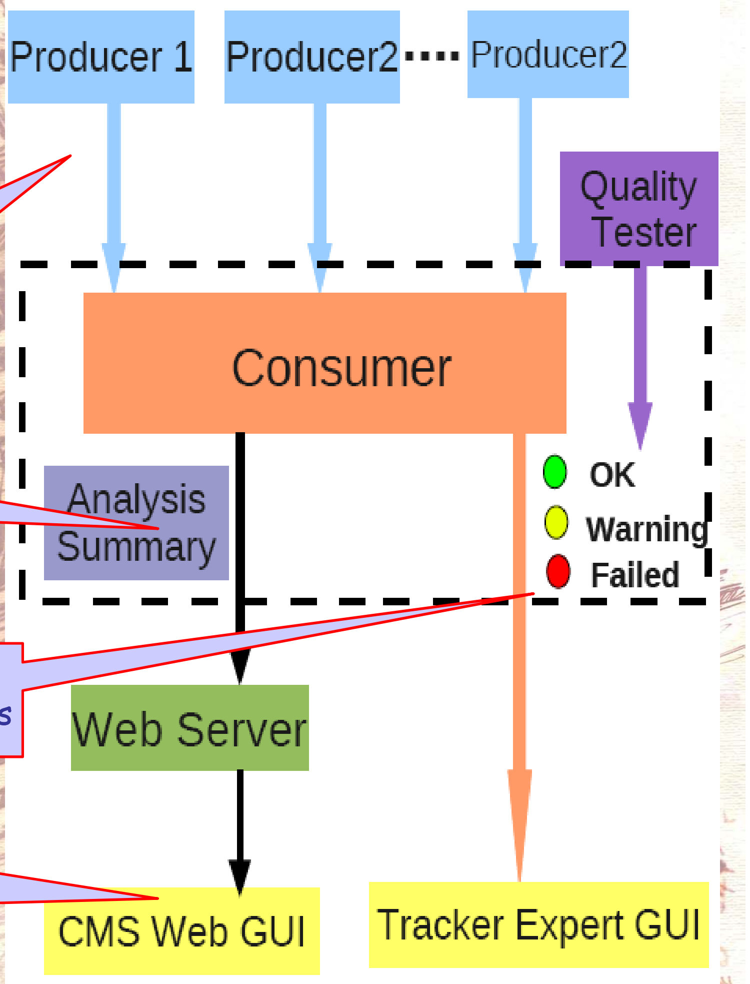
HOW DQM MONITORS:

- **Producers** (source) book and fill ME

Consumers (client) access ME and produce Summaries to merge informations from each histogram of each module

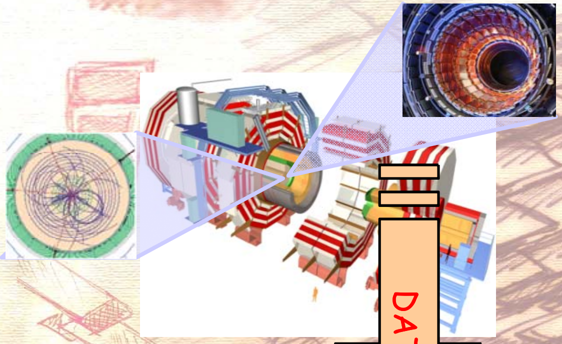
Quality tests:
compare with reference histograms or reference values

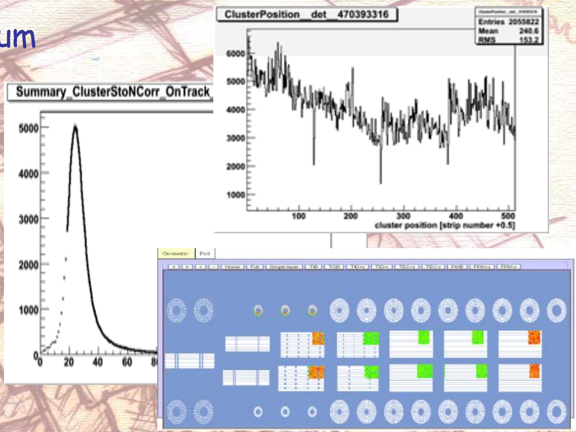
visualize with Graphical User Interface (GUI)
→ *CMS DQM GUI is web based: it is accessible from everywhere a web browser is available*



Data Quality Monitoring of the CMS Silicon Strip Tracker Detector

Leonardo Benucci - University of Antwerp, Belgium

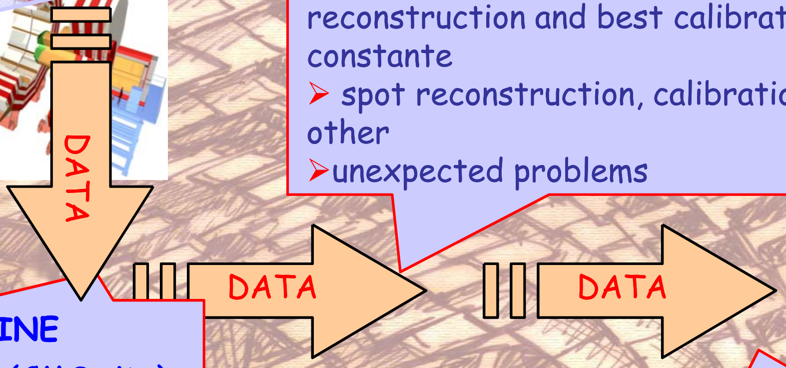




DQM OFFLINE

operates @ Tier 0/1 - **within day/hours**

- ➢Re-assess Tracker status using full reconstruction and best calibration constante
- ➢ spot reconstruction, calibration or other
- ➢unexpected problems



Data Bookeeping System

(data for Physics)

DQM ONLINE

operates @ Point5 (CMS site)

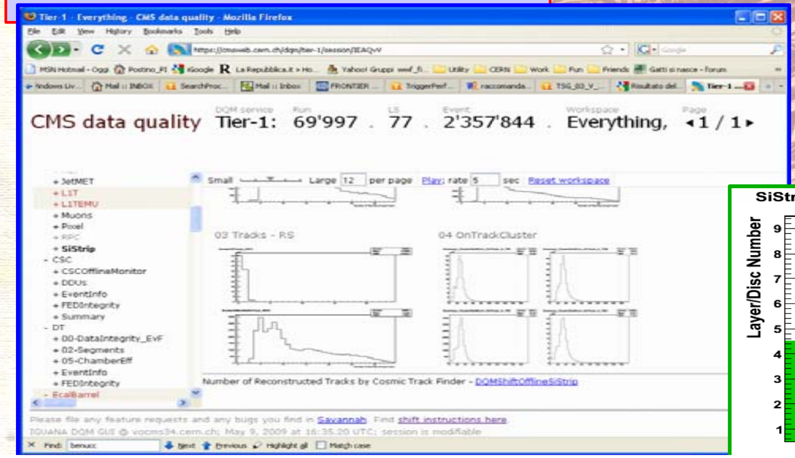
during data taking

- ➢give prompt feedback to Tracker experts about hardware status
- ➢ identify problems very efficiently during data collection to take prompt actions

CERTIFICATION PROCEDURE

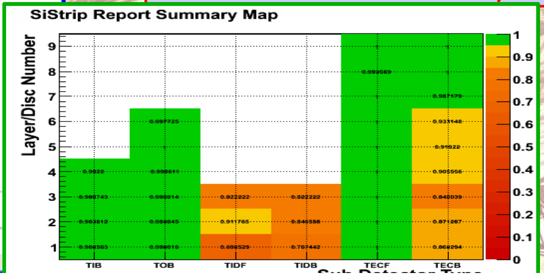
prepare Tracker flag on data quality before storage

- ➢checks from shifters
- ➢ detect and flag new or temporary Tracker problems and classify each run according to hardware, reconstruction and calibration conditions
- ➢→ *Enable any user to consult the certification results and select suitable runs for specific commissioning/physics analysis tasks*

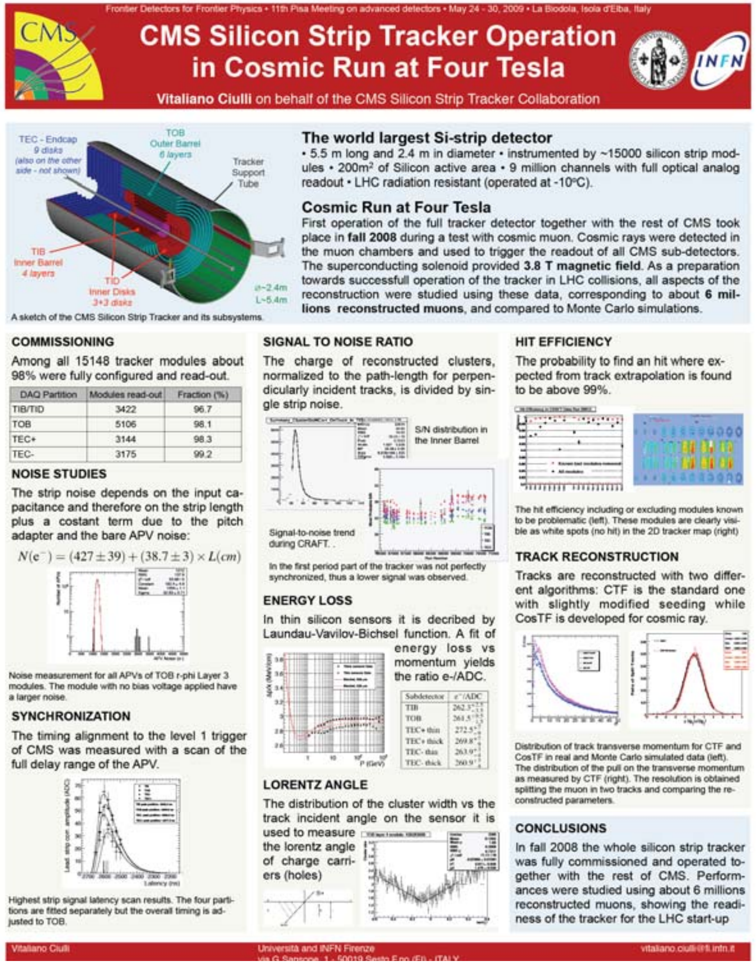


CMS data quality Tier-1: 69'997 . 77 . 2'357'844 . Everything, ◂1 / 1▸

Number of Reconstructed Tracks by Cosmic Track Finder - DQMShiftOfflineSiStrip


SiStrip Report Summary Map

Summaries of both topics have been presented in the general session on Monday, details on the poster



Frontier Detectors for Frontier Physics • 11th Pisa Meeting on advanced detectors • May 24 - 30, 2009 • La Biodola, Isola d'Elba, Italy

CMS Silicon Strip Tracker Operation in Cosmic Run at Four Tesla

Vitaliano Ciulli on behalf of the CMS Silicon Strip Tracker Collaboration

A sketch of the CMS Silicon Strip Tracker and its subsystems.

The world largest Si-strip detector

• 5.5 m long and 2.4 m in diameter • instrumented by ~15000 silicon strip modules • 200m^2 of Silicon active area • 9 million channels with full optical analog readout • LHC radiation resistant (operated at -10°C).

Cosmic Run at Four Tesla

First operation of the full tracker detector together with the rest of CMS took place in **fall 2008** during a test with cosmic muon. Cosmic rays were detected in the muon chambers and used to trigger the readout of all CMS sub-detectors. The superconducting solenoid provided **3.8 T magnetic field**. As a preparation towards successfull operation of the tracker in LHC collisions, all aspects of the reconstruction were studied using these data, corresponding to about **6 millions reconstructed muons**, and compared to Monte Carlo simulations.

COMMISSIONING

Among all 15148 tracker modules about 98% were fully configured and read-out.

DAQ Partition	Modules read-out	Fraction (%)
TIB/TID	3422	96.7
TOB	5106	98.1
TEC+	3144	98.3
TEC-	3175	99.2

NOISE STUDIES

The strip noise depends on the input capacitance and therefore on the strip length plus a costant term due to the pitch adapter and the bare APV noise:

$$N(e^-) = (427 \pm 39) + (38.7 \pm 3) \times L(cm)$$

Noise measurement for all APVs of TOB r-phi Layer 3 modules. The module with no bias voltage applied have a larger noise.

SYNCHRONIZATION

The timing alignment to the level 1 trigger of CMS was measured with a scan of the full delay range of the APV.

Highest strip signal latency scan results. The four partitions are fitted separately but the overall timing is adjusted to TOB.

SIGNAL TO NOISE RATIO

The charge of reconstructed clusters, normalized to the path-length for perpendicularly incident tracks, is divided by single strip noise.

S/N distribution in the Inner Barrel

Signal-to-noise trend during CRAFT. .

In the first period part of the tracker was not perfectly synchronized, thus a lower signal was observed.

ENERGY LOSS

In thin silicon sensors it is decribed by Laundau-Vavilov-Bichsel function. A fit of energy loss vs momentum yields the ratio e-/ADC.

Subdetector	e^-/ADC
TIB	262.3
TOB	261.5
TEC+ thin	272.5
TEC+ thick	269.8
TEC- thin	263.9
TEC- thick	260.9

LORENTZ ANGLE

The distribution of the cluster width vs the track incident angle on the sensor it is used to measure the lorentz angle of charge carriers (holes)

HIT EFFICIENCY

The probability to find an hit where expected from track extrapolation is found to be above 99%.

The hit efficiency including or excluding modules known to be problematic (left). These modules are clearly visible as white spots (no hit) in the 2D tracker map (right)

TRACK RECONSTRUCTION

Tracks are reconstructed with two different algorithms: CTF is the standard one with slightly modified seeding while CosTF is developed for cosmic ray.

Distribution of track transverse momentum for CTF and CosTF in real and Monte Carlo simulated data (left). The distribution of the pull on the transverse momentum as measured by CTF (right). The resolution is obtained splitting the muon in two tracks and comparing the reconstructed parameters.

CONCLUSIONS

In fall 2008 the whole silicon strip tracker was fully commissioned and operated together with the rest of CMS. Performances were studied using about 6 millions reconstructed muons, showing the readiness of the tracker for the LHC start-up

Vitaliano Ciulli

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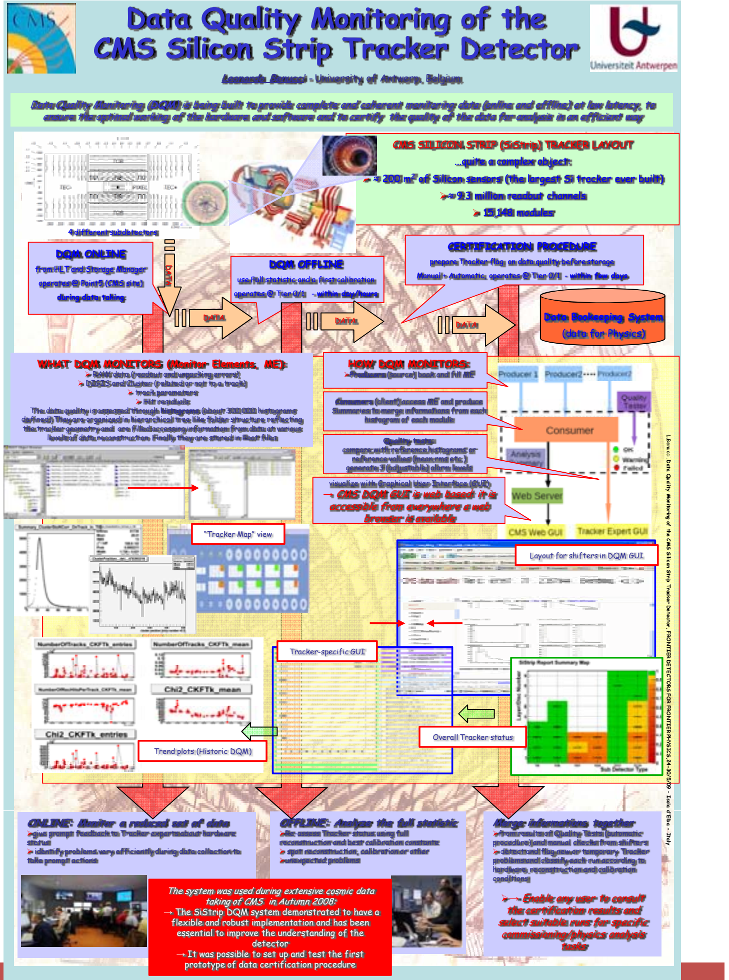
vitaliano.ciulli@fi.infn.it

Just to repeat:
CMS is, as
everybody else,
waiting for beam

4&5/27



Data Quality Monitoring of the CMS Silicon Strip Tracker Detector

Leonardo Benucci - University of Antwerp, Belgium

Universiteit Antwerpen

Data Quality Monitoring (DQM) is being built to provide complete and coherent monitoring data (online and offline) at low latency, to ensure the optimal working of the hardware and software and to certify the quality of the data for analysis in an efficient way

4 different subdetectors

CMS SILICON STRIP (SiStrip) TRACKER LAYOUT

...quite a complex object:
- ≈ 200 m^2 of Silicon sensors (the largest Si tracker ever built)
- ≈ 9.3 million readout channels
- 15,148 modules

DQM ONLINE
from HLT and Storage Manager
operates @ Point5 (CMS site)
during data taking

DQM OFFLINE
use Full statistic and a first calibration
operates @ Tier 0/1 - **within day/hours**

CERTIFICATION PROCEDURE
prepare Tracker flag on data quality before storage
Manual + Automatic, operates @ Tier 0/1 - **within few days**

Data Bookeeping System
(data for Physics)

WHAT DQM MONITORS (Monitor Elements, ME):
- RAW data (readout and unpacking errors)
- DIGIS and Cluster (related or not to a track)
- track parameters
- Hit residuals

The data quality is assessed through **histograms** (about 300,000 histograms defined). They are organized in hierarchical tree like folder structure reflecting the tracker geometry and are filled accessing information from data at various levels of data reconstruction. Finally they are stored in Root files

HOW DQM MONITORS:
- **Producers** (source) book and fill ME

Consumers (client) access ME and produce Summaries to merge informations from each histogram of each module

Quality tests:
compare with reference histograms or reference values (mean,rms etc.)
generate 3 (adjustable) alarm levels

visualize with Graphical User Interface (GUI)
→ *CMS DQM GUI is web based: it is accessible from everywhere a web browser is available*

"Tracker Map" view

Layout for shifters in DQM GUI

Tracker-specific GUI

Trend plots (Historic DQM)

Overall Tracker status

ONLINE: Monitor a reduced set of data
- give prompt feedback to Tracker experts about hardware status
- identify problems very efficiently during data collection to take prompt actions

OFFLINE: Analyze the full statistic
- Re-assess Tracker status using full reconstruction and best calibration constants
- spot reconstruction, calibration or other
- unexpected problems

Merge informations together
- from results of Quality Tests (automatic procedure) and manual checks from shifters
- detect and flag new or temporary Tracker problems and classify each run according to hardware, reconstruction and calibration conditions

→ *Enable any user to consult the certification results and select suitable runs for specific commissioning/physics analysis tasks*

The system was used during extensive cosmic data taking of CMS in Autumn 2008:
→ The SiStrip DQM system demonstrated to have a flexible and robust implementation and has been essential to improve the understanding of the detector
→ It was possible to set up and test the first prototype of data certification procedure

L.Benucci, Data Quality Monitoring of the CMS Silicon Strip Tracker Detector, FRONTIER DETECTORS FOR FRONTIER PHYSICS, 24-30/5/09 - Isola d'Elba - Italy

Commissioning	The strip tracker has been fully commissioned and operated together with the rest of CMS. Performances were studied using about 6 millions reconstructed muons, showing its readiness for the LHC start-up.
DQM	• all relevant Tracker quantities are accessible as histograms in web-based GUIs (300.00 histograms defined) • ONLINE and OFFLINE • detailed shifter procedures to assess run quality are in place

2 ALICE poster

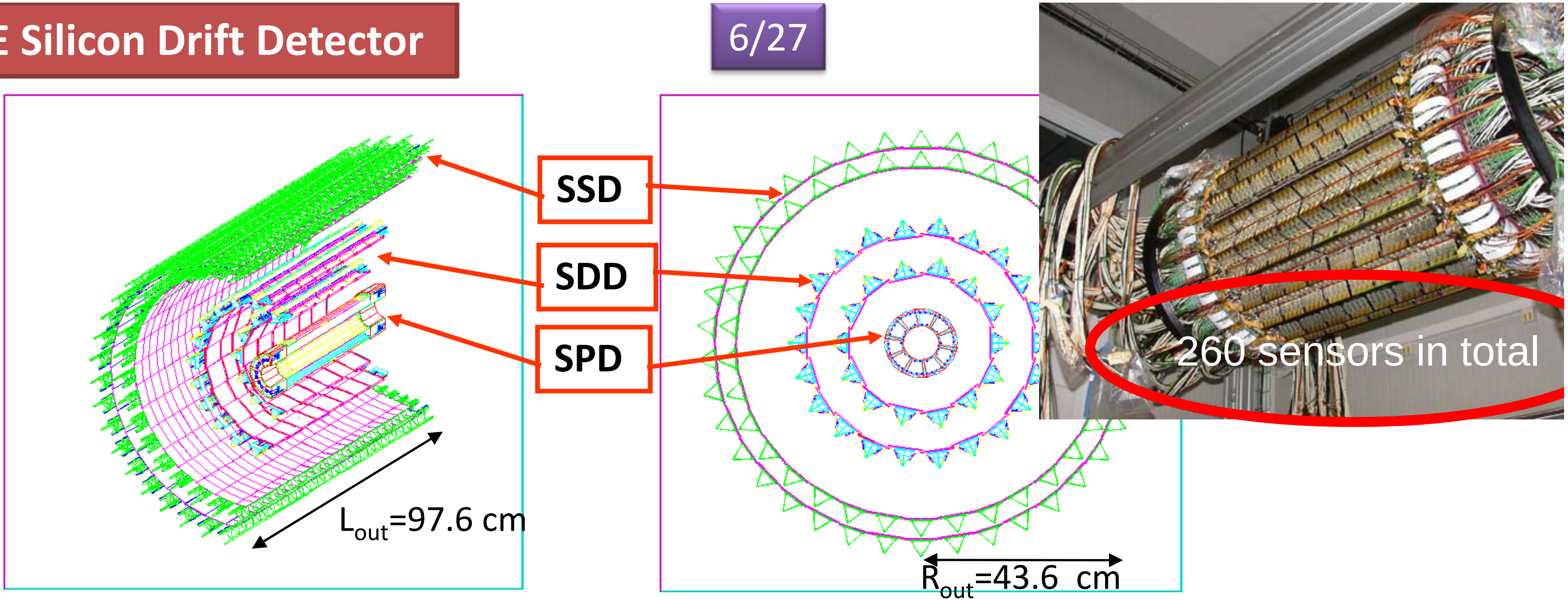
Mario Sitta (*INFN - Torino*)

The Silicon Drift Detector of the ALICE Experiment

Marian Krivda (*IEP - Košice*)

THE ALICE SILICON PIXEL DETECTOR READ-OUT ELECTRONICS

ALICE Silicon Drift Detector



SSD

SDD

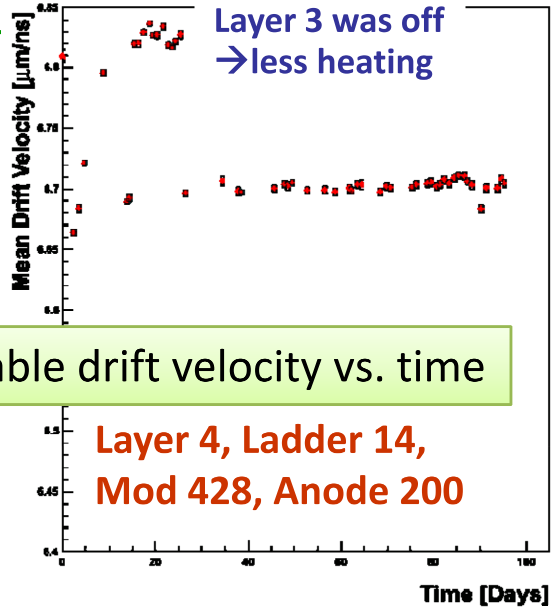
SPD

Silicon Pixel Detector (SPD):
~10M channels

Silicon Drift Detector (SDD):
~133k channels

Silicon Strip Detector (SSD):
~2.6M channels

Mainly calibration is described, e.g. Drift velocity and compensation efforts due to (due to non-linear voltage divider or dopant concentration inhomogeneties)

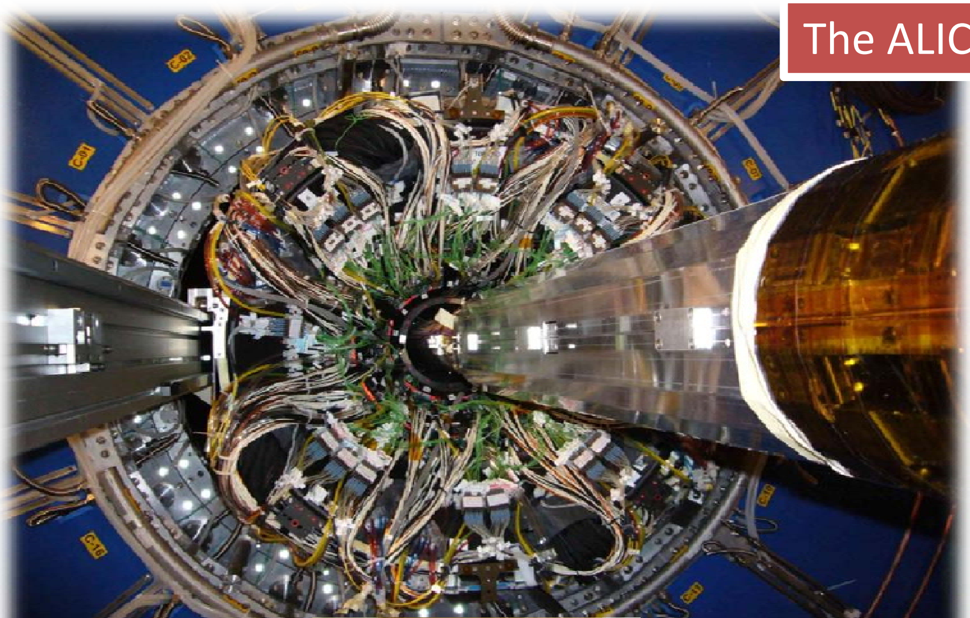


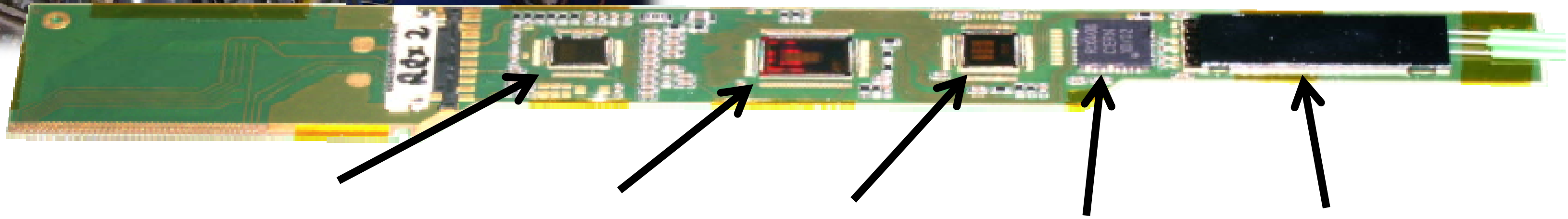
Layer 3 was off
→less heating

Stable drift velocity vs. time

Layer 4, Ladder 14,
Mod 428, Anode 200

The ALICE Silicon Pixel Detector Read-Out Electronics





ANALOG PILOT chip

DIGITAL PILOT chip

GOL chip

RX40 chip

Optical transceiver

The readiness of the ALICE pixel detector is shown as well as detailed descritption of ist readout electronics is given

1 LHCB Poster

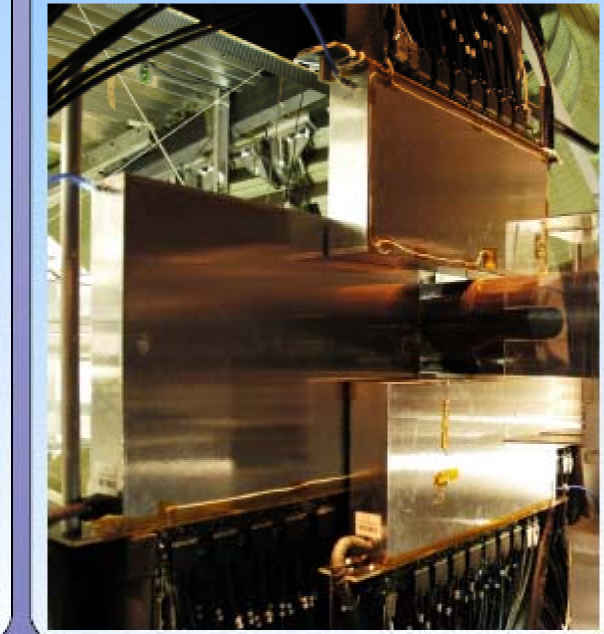
Vincent Fave (*EPFL*)

FIRST EXPERIENCE AND RESULTS WITH THE LHCB SILICON TRACKER

LHCB Tracker

Tracker Turicensis

Inner Tracker



Ready for BEAM!

99% of the TT is fully working

SN, delay scan, Track finding and alignment done

Tracker Turicensis Status

99% of the TT is fully working

- 🟧 broken bonds
- 🟨 HV problems
- 🟩 optical path or acquisition board not ok
- 🟩 problem with the SB
- 🟩 commissioned

Status of August 2008 (Time of TED data taking)
The majority of problems are fixed for the runs of 2009-2010.

TED Data

- This is the main data-set so far. The particles are produced by dumping injection test bunched in a tungsten absorber 300m 'behind' LHCb.
- TED events are high multiplicity events, with an occupancy 20 times greater than in normal physics.
- It has been used for the spatial alignment of IT and TT, beyond the survey results that is 500µm accurate for boxes and 100µm for Layers and Ladders.

THESE LHC DETECTORS ARE PROBABLY OVERCOMMISSIONED ☺

2 posters on CDF*

Miguel Mondragon (*Fermilab*)

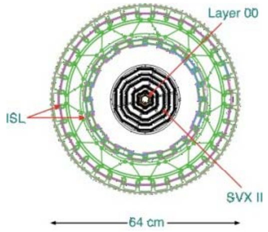
OPERATIONAL EXPERIENCE WITH THE CDF RUN II SILICON DETECTOR

Roberto Martinez-Ballarin (*CIEMAT-Madrid*)

LONGEVITY STUDIES IN THE CDF SILICON DETECTORS

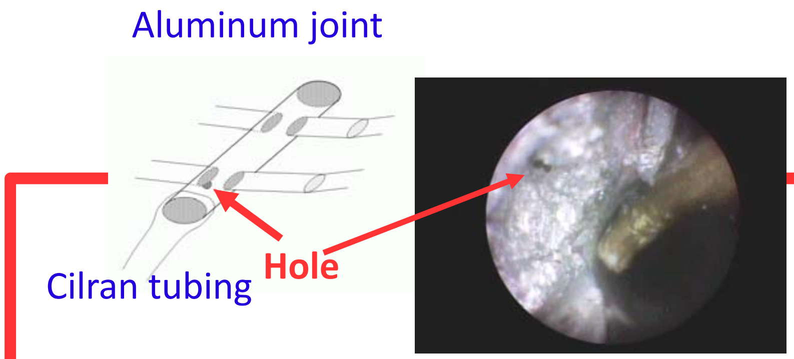
* Where LHC detectors can learn from

Operational Experience with the CDF Run II Silicon Detector

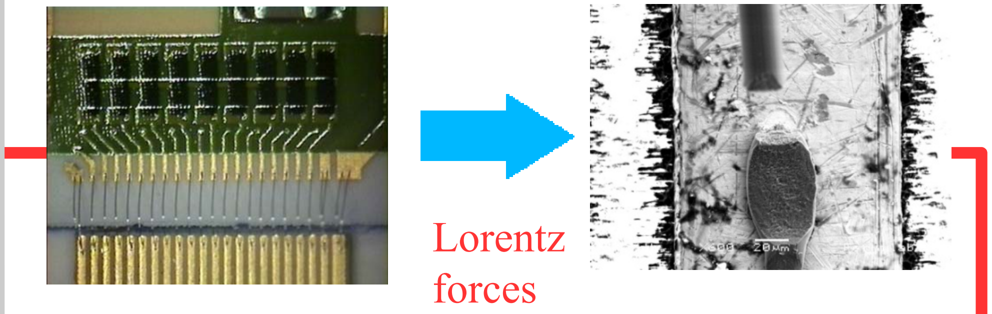


THE LEARNING OF EIGHT YEARS OF OPERATIONS

- The battle against corrosion in cooling lines and a remarkable repair



- The story of wirebond resonances and a protection system

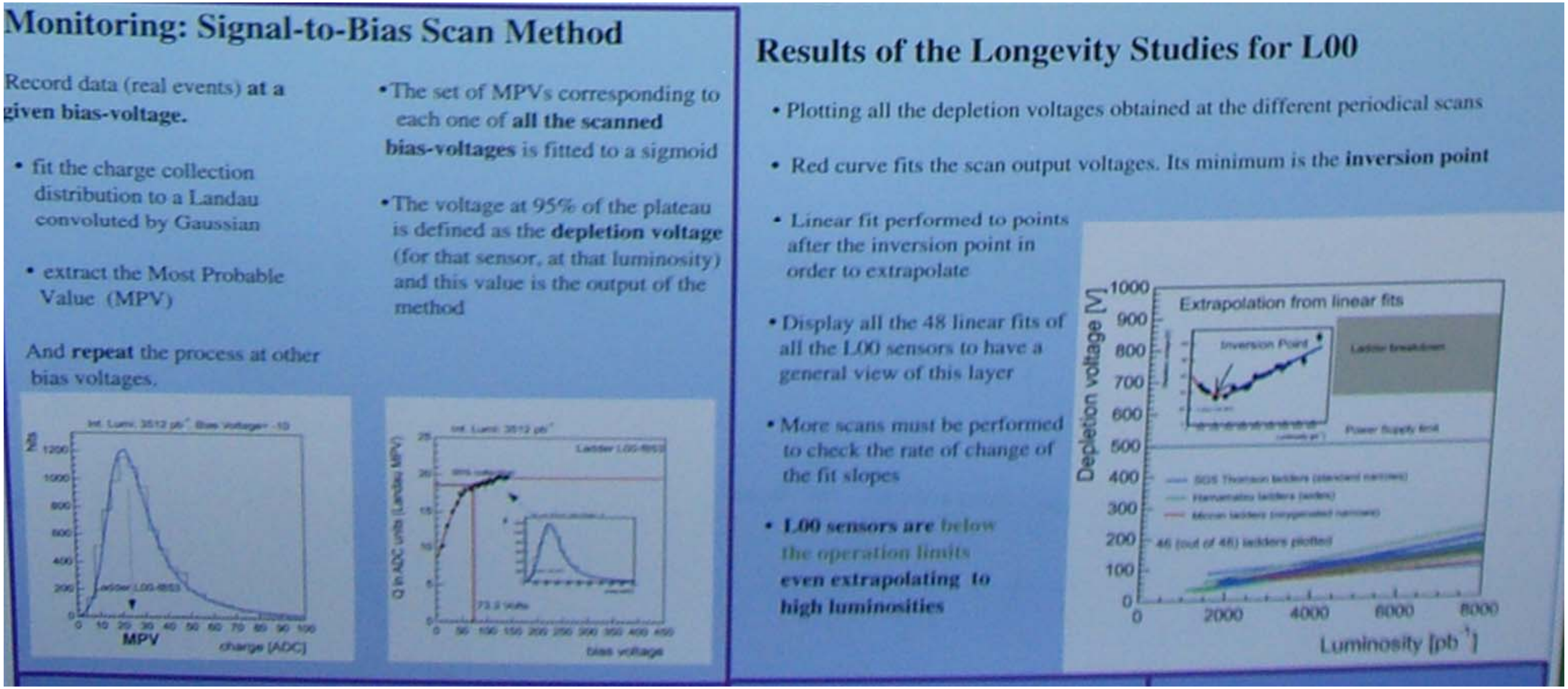


And also...

- High automation of operations
- Ongoing maintenance
- Performance

Newer and future silicon detectors can make profit from these experiences

Longevity Studies in the CDF Silicon Detectors



Monitoring: Signal-to-Bias Scan Method

Record data (real events) **at a given bias-voltage.**

- fit the charge collection distribution to a Landau convoluted by Gaussian
- extract the Most Probable Value (MPV)

And **repeat** the process at other bias voltages.

- The set of MPVs corresponding to each one of **all the scanned bias-voltages** is fitted to a sigmoid
- The voltage at 95% of the plateau is defined as the **depletion voltage** (for that sensor, at that luminosity) and this value is the output of the method

Results of the Longevity Studies for L00

- Plotting all the depletion voltages obtained at the different periodical scans
- Red curve fits the scan output voltages. Its minimum is the **inversion point**
- Linear fit performed to points after the inversion point in order to extrapolate
- Display all the 48 linear fits of all the L00 sensors to have a general view of this layer
- More scans must be performed to check the rate of change of the fit slopes
- **L00 sensors are below the operation limits even extrapolating to high luminosities**

A real life study about radiation damage in silicon

The inner layers already passed the point of space charge inversion

➔ depletion voltage increases but will still stay for a while below the applicable bias voltages

B-factories
In alphabetical order

Samo Stanic (*University of Nova Gorica*)

SILICON VERTEX DETECTOR UPGRADE FOR SUPERKEKB FACTORY

Not yet waiting for beam

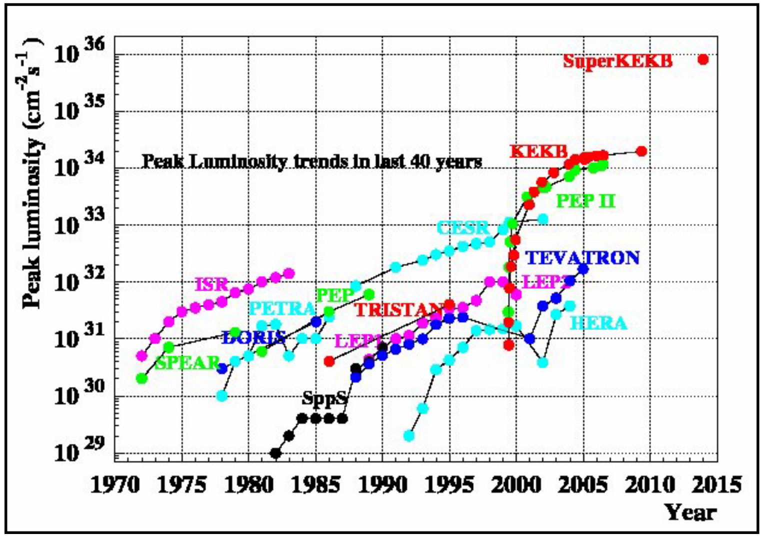
Giuliana Rizzo (*Università di Pisa/INFN*)

THE SUPERB SILICON VERTEX TRACKER

Design progresses
Both will use additionally pixel sensor
Several technology choices under evaluation
    Hybrid pixels, DEPFET, CMOS, SOI (SOIPix; CAP)
Somehow also a test bench for ILC detectors

Silicon Vertex Detector Upgrade for the Belle II Experiment

S. Stanič for the Belle SVD Group



Physics at extreme luminosity SuperKEKB collider: ($8{\cdot}10^{35}$/cm^2/s after upgrade, ~$2{\cdot}10^{34}$/cm^2/s presently achieved by KEKB ⇒ **Realistic!**)

Precision measurements of CPV in B decays

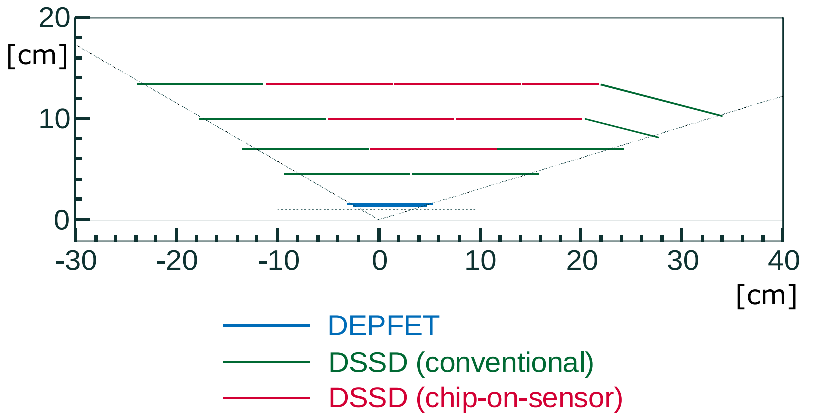
- Study of **time dependence of B^0 - anti-B^0 decays**
- Study of **rare decay modes** of beauty and charm hadrons and τ

Design requirements for the Silicon Tracker:

- Good resolution in the beam direction
- Small amount of material inside the acceptance region
- Operation at high radiation background rates and high track density (40 x present)

Silicon tracker upgrade plan:

- **PXD - Pixel** Detector (2 inner layers) - high precision
- **SVD - Strip** Detector (4 outer layers) - larger acceptance



Possible layout of the Belle II Silicon Tracker

SVD Layout:

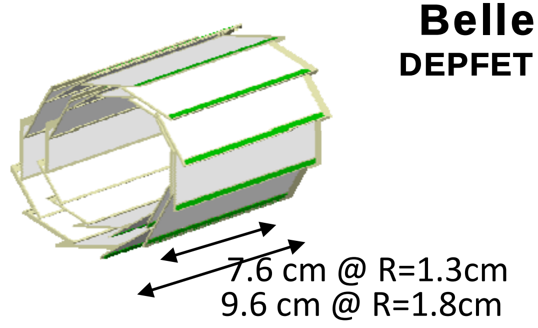
- System size 3-4x of the present Belle SVD2 (4 layers)
- Use of **DSSD sensors** from 6” wafer, well established technology
- Additional use of alternative “chip-on-sensor” sensor types (Lower number of readout chips, less material and power dissipation in acceptance region)
- Readout with **APV25** (~ 50ns shaping time, sensitive window ~160ns)+ FADC+COPPER (Full DAQ chain already successfully tested in a beam test at KEK)

Conceptually proven, after finalizing the geometry ready for production.

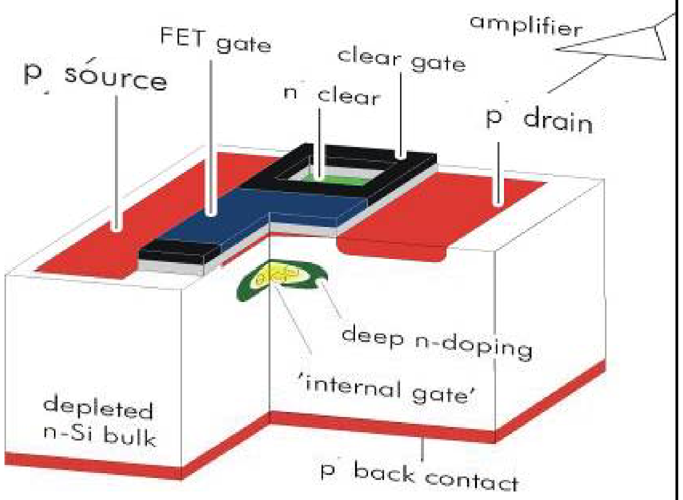
Belle II PXD Layout (based on DEPFET):

- Small radius, as close as possible to the beampipe
- High granularity sensors, pixel size about **50x75μm²**
- Small detector 20-24 single sensor modules in two layers
- Total of ~6Mpixel, frame readout rate <10μs
- Possibility of variable pixel in z pitch to optimize charge sharing at large z and improve resolution in the central part

Belle II
DEPFET PXD



Layout of the Pixel Vertex Detector, 1cm BP



DEPFET Schematics

PXD Sensor R&D Status - 3 variants pursued:

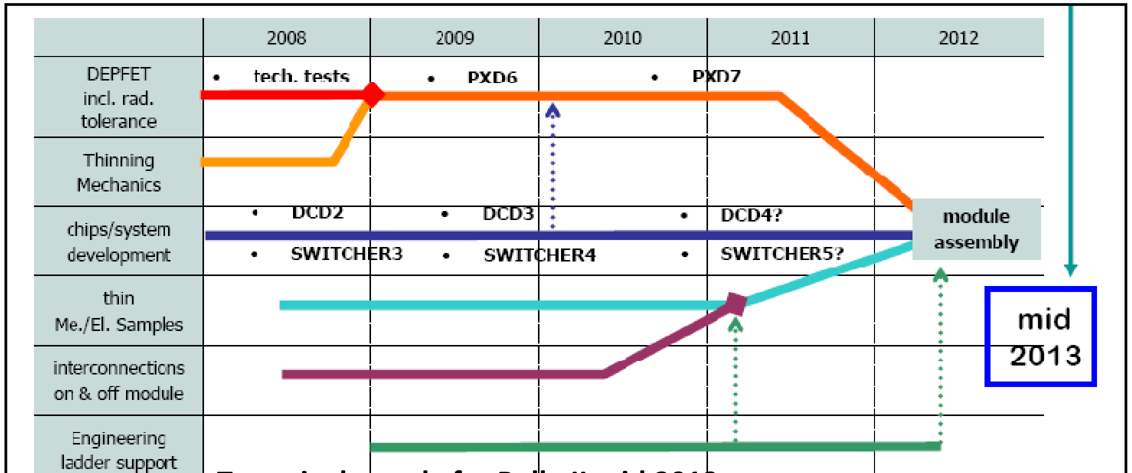
- **CAP, KEK SOIPIX** (promising concepts, **at basic R&D**)
- **DEPFET** (**Most promising candidate -** Evolving from basic R&D to production for Belle II)

-Pixel is a p-channel FET on a completely depleted bulk, deep n-implant creates a potential minimum for electrons under the gate

-50 x (75-115) μm² pixels

-Frame readout time <10μs, sequential readout of pixels or rows

-Low power, ASICs at the periphery



Tentatively ready for Belle II mid 2013

Done:

-Successful beam tests

-Rad. hardness tests (80kGy): low noise

-GEANT4 simulation started

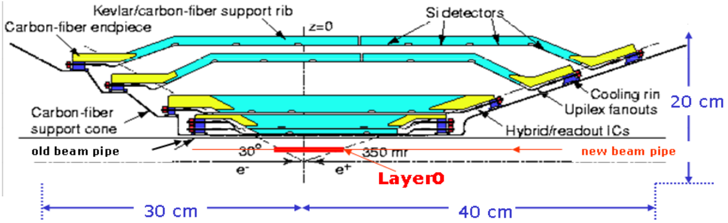
To do:

-Solve radiation related issues (threshold voltage shift is large)

-Consider mechanics/cooling design

-Consider DAQ interface (PXD may deliver up to 70Gbit/s)

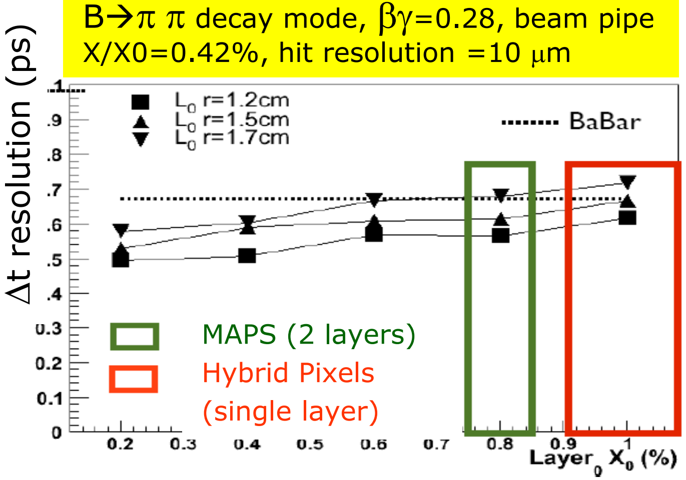
The SuperB Silicon Vertex Tracker



Reduced beam energy asymmetry of SuperB (7x4 GeV) requires improved vertex resolution to reach performance similar to present B-Factories

Fast Simulation

B→π π decay mode, $\beta\gamma=0.28$, beam pipe X/X0=0.42%, hit resolution =10 μm



Vertex detector design based on current BaBar SVT + an innermost Layer0

Radius~1.5 cm, pitch 50 μm, X/X_0 ~1%, backg. > 5MHz/cm2, TID ~1MRad/yr

Layer0 options under study for TDR-2010

Hybrid Pixels: viable option → baseline for TDR

- Front-end pitch reduced to 50x50 μm^2 in a first prototype chip submitted by the end of 2009.

CMOS MAPS: new & challenging technology but very promising → sensor & readout in 50 μm thick chip!

- Extensive R&D (SLIM5-Collaboration) on Deep N-Well devices 50x50μm^2 with fast readout architecture.
  - CMOS MAPS matrix (4k pixels) with in pixel sparsification and timestamp successfully tested with beams.

Thin pixels with Vertical Integration:

- Reduction of material and improved performance achievable with VI
- First DNW MAPS (2 tiers) submitted with Chartered/Tezzaron 130 nm

Striplets: thin double sided silicon sensor with short strips

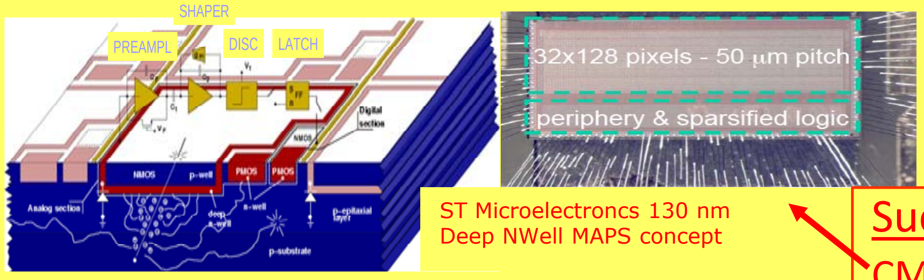
- mature technology, less robust against background occupancy.

Lower material & improved performance

4 options

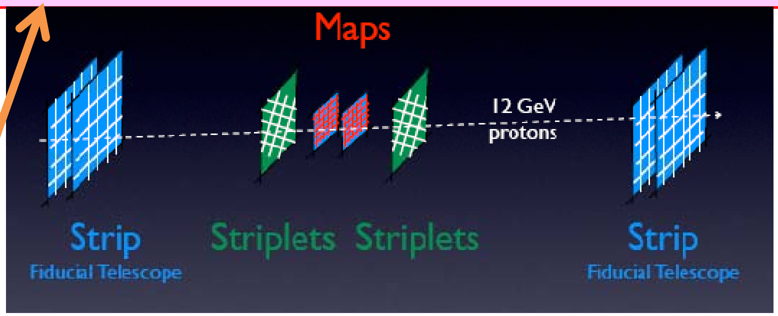
Under test

Layer0 R&D Recent Results



ST Microelectroncs 130 nm
Deep NWell MAPS concept

SLIM 5 Testbeam @ CERN (Sept 2008)



Successfully tested two options for Layer0

CMOS MAPS matrix with fast readout architecture (4096 pixels, 50x50 μm pitch, sparsification and timestamp)

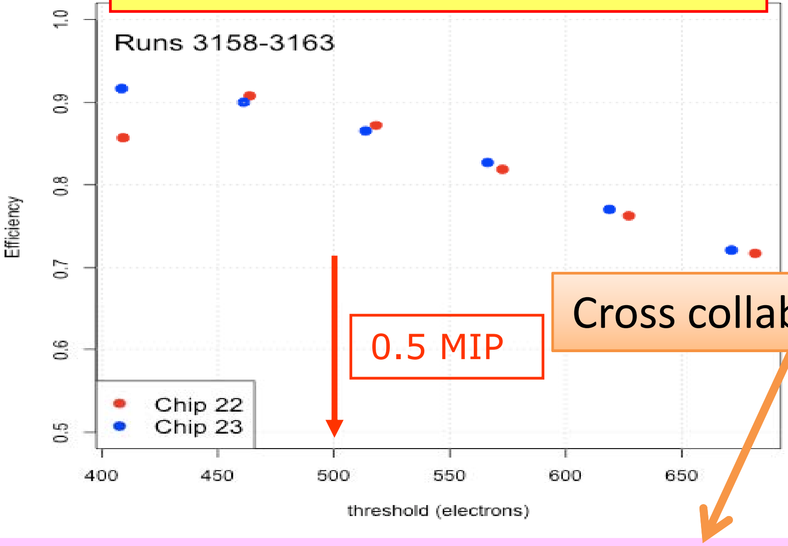
- Hit efficiency up to 92% with room for improvement
- Intrisinc resolution ~ 14 μm compatible with digital readout.

Striplet module with FSSR2 readout chips

  – S/N=25 (thickness 200μm), Efficiency > 98%

- More details: M. Villa - talk, L. Vitale - poster

MAPS Hit Efficiency vs threshold



Cross collaborative efforts:

Light support with integrated cooling for pixel module ($P=2W/cm^2$)

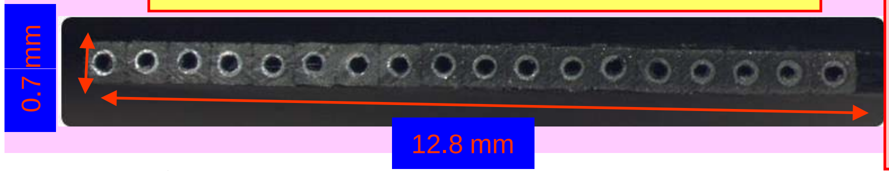
Carbon Fiber support with integrated microchannel with coolant fluid developed:

  – Total support/cooling thickness ~ 0.3 % X_0

First thermo-hydraulic measurements on prototypes in good agreement with simulation.

More details: F. Bosi's poster

Carbon Fiber Support with microchannels



jon kapustinsky (*Los Alamos National Lab)*

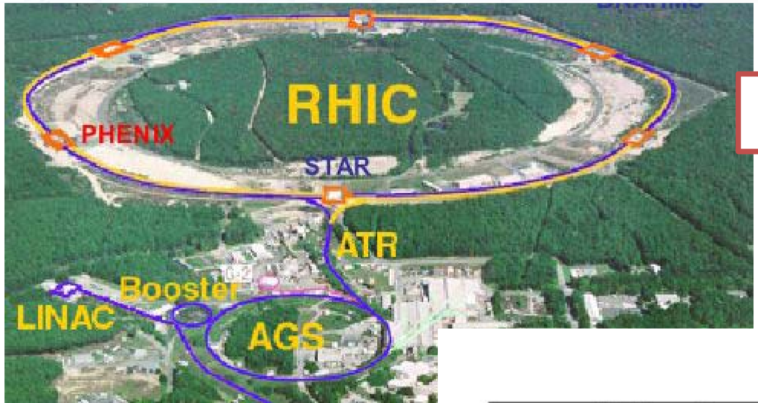
PRODUCTION AND PERFORMANCE OF THE SILICON SENSOR AND CUSTOM READOUT ELECTRONICS FOR THE PHENIX FVTX TRACKER

RHIC Experimental program in Heavy Ions

Center of Mass Energy: √s = 200GeV

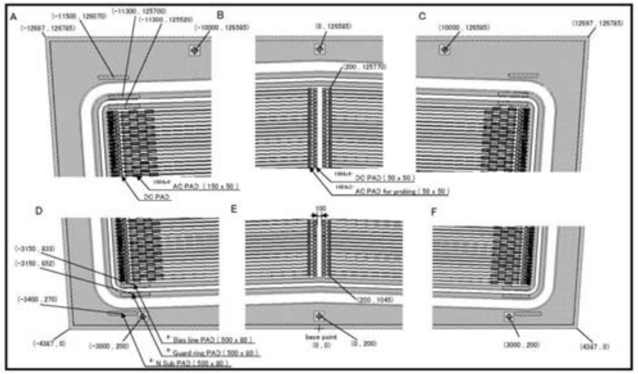
and

Polarized Protons (Spin Program) √s = up to 500GeV

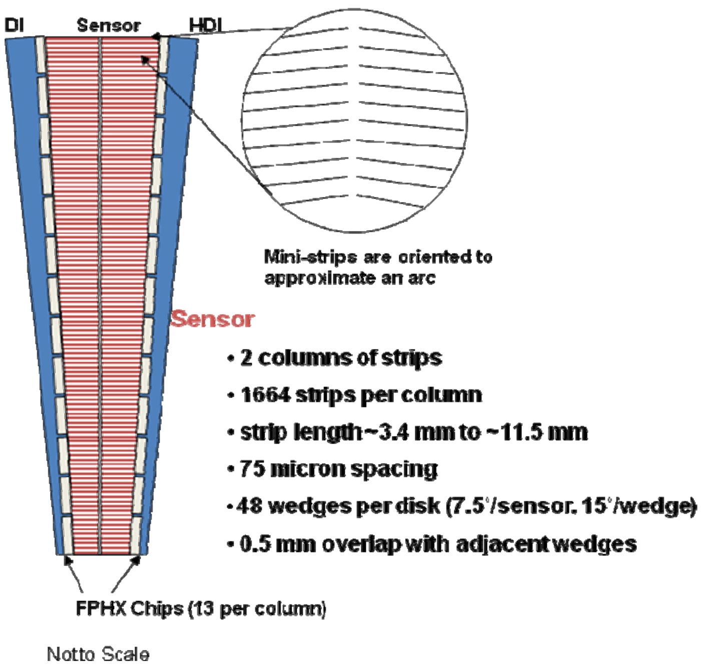


Extension into the forward regions of the Phenix Detector

Small detector but interesting sensor layout
Wedge; short strips 3.4mm -11.5 mm



FVTX Sensor Long Wedge



Mini-strips are oriented to approximate an arc

Sensor

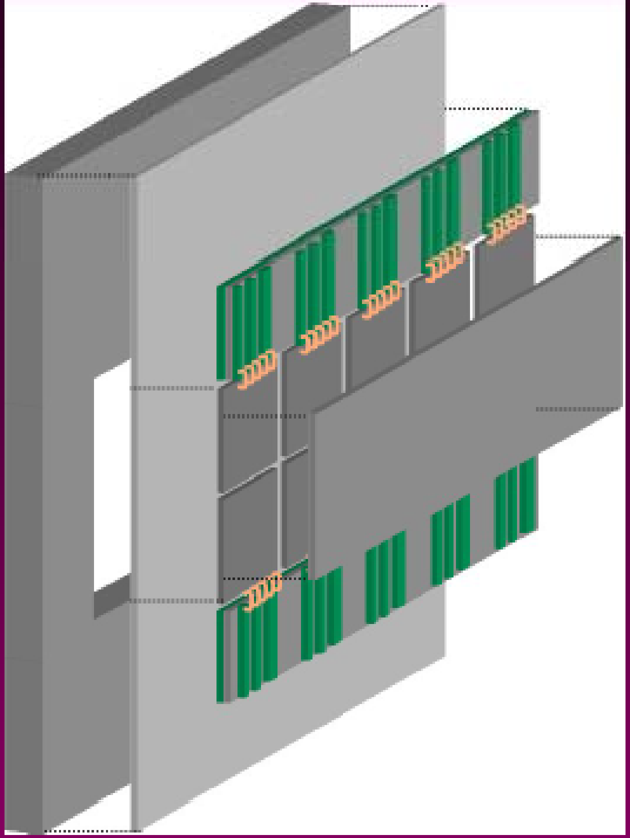
- 2 columns of strips
- 1664 strips per column
- strip length~3.4 mm to ~11.5 mm
- 75 micron spacing
- 48 wedges per disk (7.5°/sensor. 15°/wedge)
- 0.5 mm overlap with adjacent wedges

A custom front-end chip, the FPHX, has been designed for the FVTX by the ASIC Design Group at Fermilab. The chip combines fast trigger capability with data push architecture in a low power design. The chip was fabricated in the TSMC 0.25 micron CMOS process

Giovanni Mazza (*INFN - Torino*)

THE NA62 GIGATRACKER PIXEL DETECTOR SYSTEM

THE NA62 GIGATRACKER PIXEL DETECTOR SYSTEM



GigaTracker : 3 silicon pixel sensor stations for precise measurement of particle direction and timing.

Pixel size : 300 µm × 300 µm
Sensitive area : 27 mm × 60 mm
Time resolution : 150 ps rms (total)
200 ps rms (per station)
Data rate : 0.8÷1 GHz (total)
1.5 MHz/mm^2 (max)
Operational environment : vacuum

Detector to be operated below 5 °C to keep the leakage current under control

Design challenge : obtain a 200 ps resolution with silicon pixel detectors at very high particle rate.

Sezione di Torino

ASIC prototypes

Two readout options are under investigation :

Pixel matrix : 40 × 45 cells.
Time walk compensation : Constant Fraction Discriminator (CFD).
Time measurement : on pixel TAC based TDC.
Reference clock : 160 MHz.
Four event buffers for data derandomization (on pixel).
SEU protected control logic.

- \+ each pixel operate independently.
- \+ only one long distance time critical signal (clock).
- \- complex pixel circuitry.
- \- more control logic on the beam trajectory.

Pixel matrix : 40 × 45 cells.
Time walk compensation : Time over Threshold (ToT) correction.
Time measurement : DLL based TDC at the end of the pixel column.
Reference clock : 320 MHz.
Pre-emphasis for signal transmission.

- \+ simple and low power pixel circuitry.
- \+ only one DLL based TDC needed (plus column registers).
- \- many time critical signals to be sent to the EoC (one per pixel).
- \- hit arbitration needed (possible event loss).

→ *Prototypes of the analog part for the two options (preamp+CFD and ToT correction) have been designed in CMOS 0.13 μm and successfully tested.*

→ *Two test chip with the full pixel and column circuits are currently in production* various

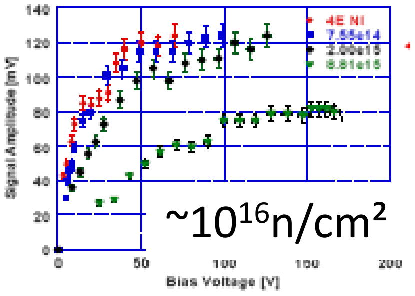
3D & RD

3D gets more and more mature!

CINZIA DAVIA (*THE UNIVERSITY OF MANCHESTER*)

3D SILICON DETECTORS FOR LHC UPGRADES

3D Silicon Detectors for LHC Upgrades



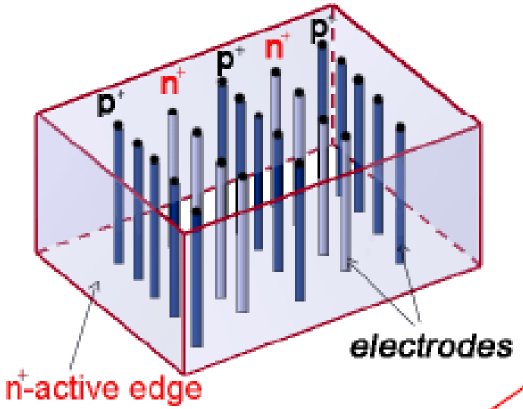
$\sim 10^{16}$n/cm^2

From ideas to real pieces and real results

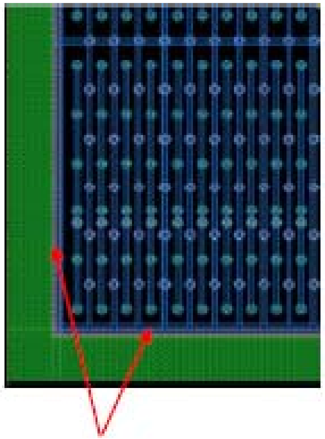
Manchester University (UK), University of Hawaii, SLAC/MBC (USA),
SINTEF and Oslo University (Nor),Technical University Prague (Cz)
University of New Mexico, SLAC and LBL (USA), Bonn University (D), and CERN

ATLAS3D collaboration for pixel upgrades includes Bergen., Glasgow, the University of Calabria, Freiburg, FBK-IRST, CNM, Genova.

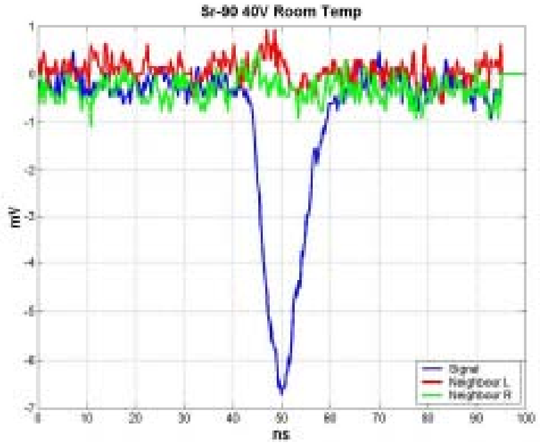
Fabricated at Stanford



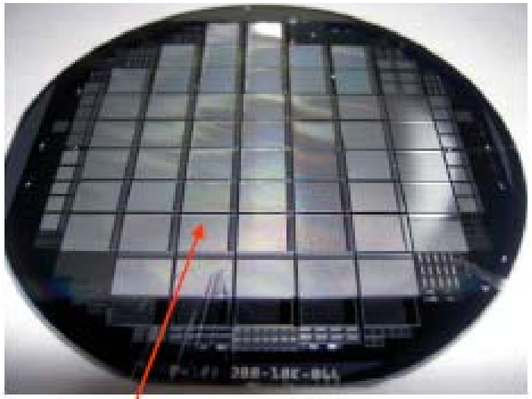
- Micromachined electrodes
- Active edges (dead edge <4μm)
  large area coverage
- Fast+Radiation Hard (up to 10^{16}n/cm^2)
- Atlas pixel run completed - 10 wafers
  test beam shows 99.0% efficiency
  at 15° from incoming beam



Active Edges (C. Kenney): Wall electrodes enclosing the entire detector perimeter Measured to be ~4 microns



Oscilloscope trace of a 3D detector+0.25μm CMOS RO (design G. Anelli et al. CERN)

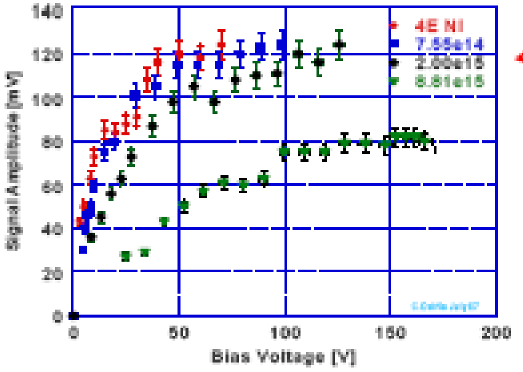


7.2 x 8 mm^2

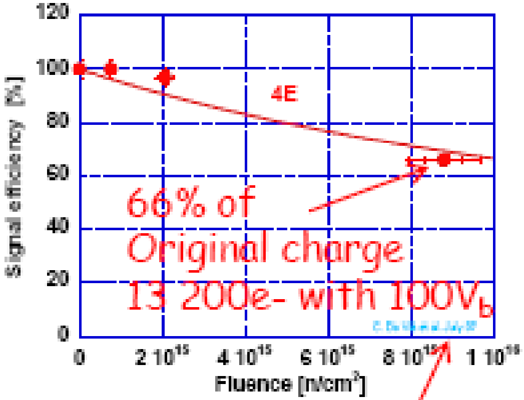
Yield = 80%

Cinzia Da Via/Manchester May 2009

Highlights from test beams



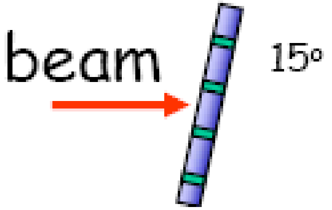
- ❖Radiation hard due to high field and short inter-electrode spacing

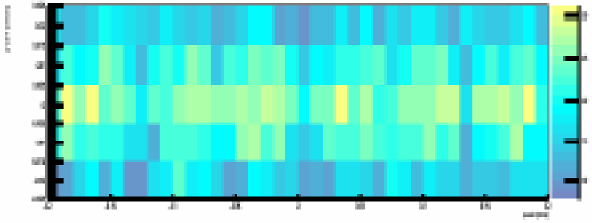


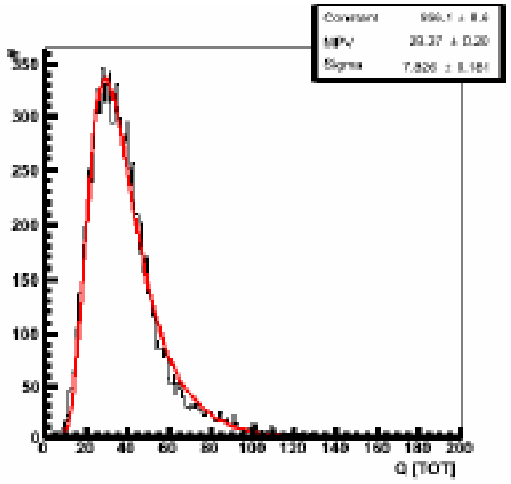
66% of Original charge 13 200e- with 100V_b

9×10^{15}ncm^{-2}

- ❖test beam shows 99.0% efficiency at 15° from incoming beam -

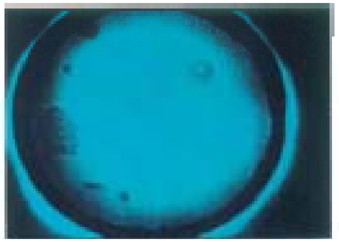




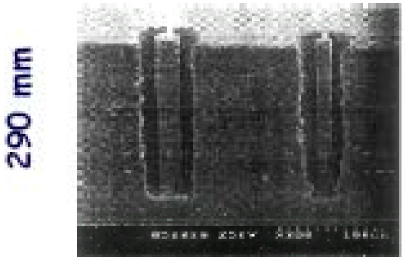


IEEE Trans.Nucl.Sci.55:3731-3735,2008

Key processing steps (25-32)



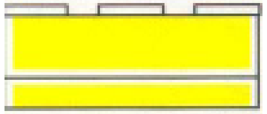
WAFER BONDING
(mechanical stability)
Si-OH + HO-Si -> Si-O-Si + H_2O



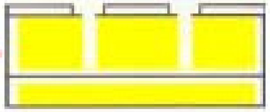
DEEP REACTIVE
ION ETCHING (STS)
(electrodes definition)
Bosh process
SiF_4 (gas) +C_4F_8 (teflon)

1- etching the electrodes

Step 1-3 oxidize and fusion bond wafer

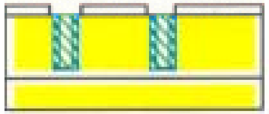


Step 4-6 pattern and etch p^+ window contacts

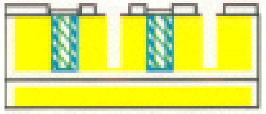


Step 7-8 etch p^+ electrodes

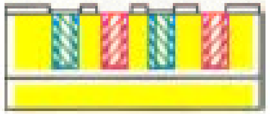
2-filling them with dopants



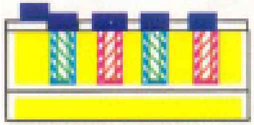
Step 9-13 dope and fill p^+ electrodes



Step 14-17 etch n^+ window contacts and electrodes

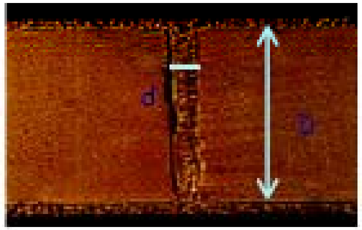


Step 18-23 dope and fill n^+ electrodes



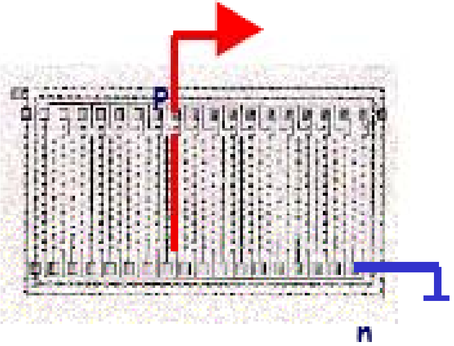
Step 24-25 deposit and pattern Aluminum

Aspect ratio:
D:d = 11:1



LOW PRESSURE
CHEMICAL VAPOR
DEPOSITION
(Electrodes filling with conformal doped polysilicon SiH4 at ~620C)
$2P_2O_5 + 5\,Si \rightarrow 4P + 5\,SiO_2$
$2B_2O_3 + 3Si \rightarrow 4\,B + 3\,SiO_2$

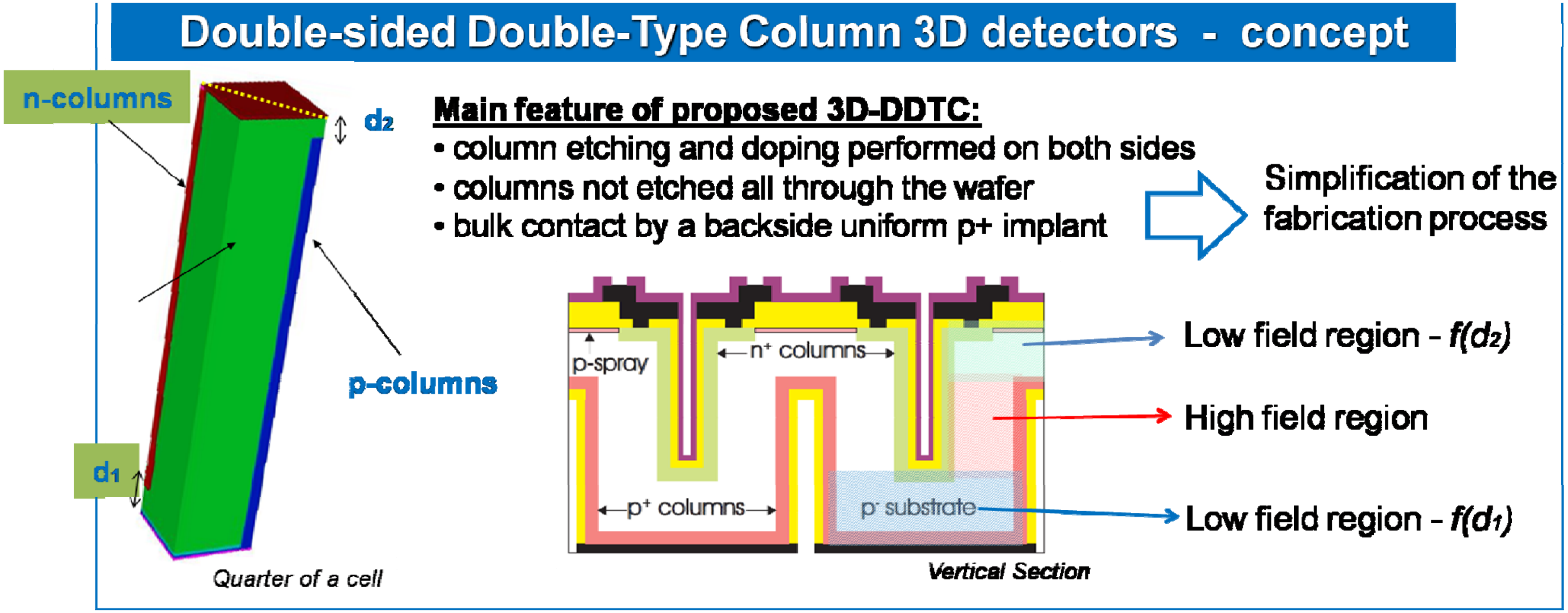
Both electrodes appear on both surfaces



METAL DEPOSITION
Shorting electrodes of the same type
with Al for strip electronics readout
or deposit metal for bump-bonding

Andrea Zoboli (*Università di Trento*)

CHARACTERIZATION AND MODELLING OF SIGNAL DYNAMICS IN 3D-DDTC DETECTORS



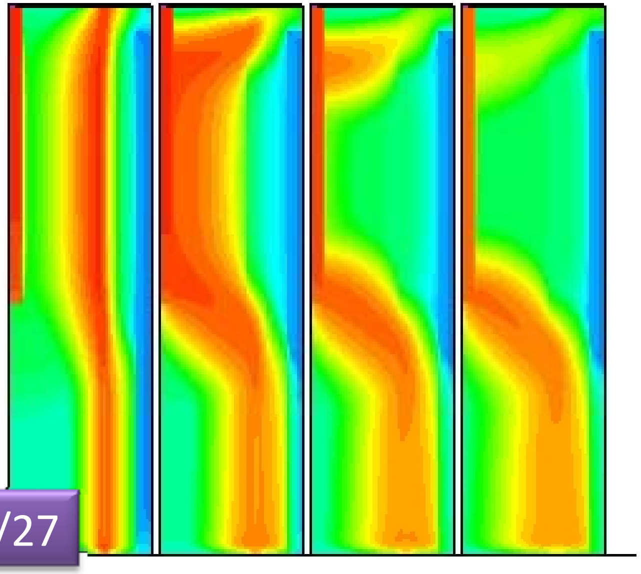
Double-sided Double-Type Column 3D detectors - concept

Main feature of proposed 3D-DDTC:

- column etching and doping performed on both sides
- columns not etched all through the wafer
- bulk contact by a backside uniform p+ implant

Simplification of the fabrication process

MIP penetrating from (30,30,0)



- MIP penetrating the device from (30,30,0)
- Evaluation of the current signal
- Two dimensional domain
- Full depletion not reached at the bottom
- Slow tail due to diffusion

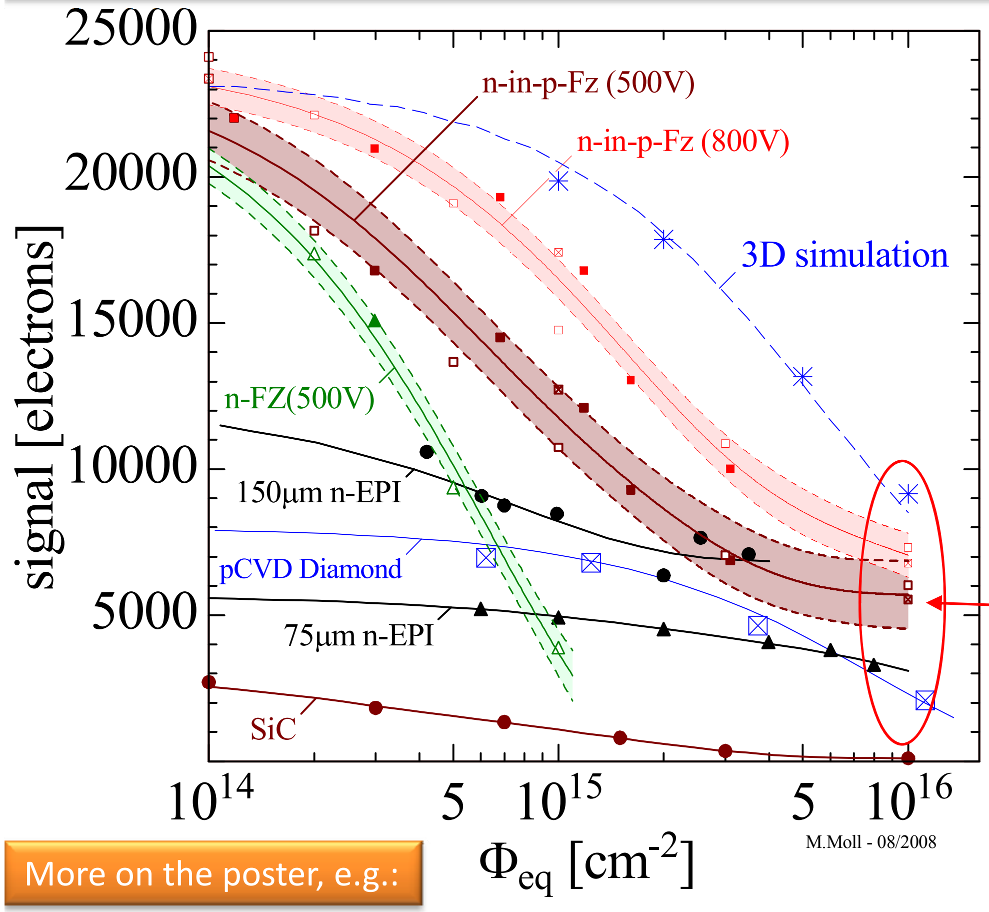
Very interesting, have a look

Frank Hartmann (*IEKP Karlsruhe)*

RECENT ADVANCES IN THE DEVELOPMENT OF SEMICONDUCTOR DETECTORS FOR VERY HIGH LUMINOSITY COLLIDERS

Recent advances in the development of semiconductor Detectors for very high luminosity colliders

Frank Hartmann on Behalf of CERN RD50 Collaboration
http://www.cern.ch/rd50



Silicon Sensors

- ● p-in-n (EPI), 150 µm [7,8]
- ▲ p-in-n (EPI), 75µm [6]
- ■ n-in-p (FZ), 300µm, 500V, 23GeV p [1]
- □ n-in-p (FZ), 300µm, 500V, neutrons [1]
- ⊠ n-in-p (FZ), 300µm, 500V, 26MeV p [1]
- ■ n-in-p (FZ), 300µm, 800V, 23GeV p [1]
- □ n-in-p (FZ), 300µm, 800V, neutrons [1]
- ⊠ n-in-p (FZ), 300µm, 800V, 26MeV p [1]
- ▲ p-in-n (FZ), 300µm, 500V, 23GeV p [1]
- △ p-in-n (FZ), 300µm, 500V, neutrons [1]
- ✳ Double-sided 3D, 250 µm, simulation! [5]

Other materials

- ● SiC, n-type, 55 µm, 900V, neutrons [3]
- ⊠ Diamond (pCVD), 500 µm [4] (RD42)

References:

[1] p/n-FZ, 300µm, (-30°C, 25ns), strip [Casse 2008]
[2] p-FZ,300µm, (-40°C, 25ns), strip [Mandic 2008]
[3] n-SiC, 55µm, (2µs), pad [Moscatelli 2006]
[4] pCVD Diamond, scaled to 500µm, 23 GeV p, strip [Adam et al. 2006, RD42]
Note: Fluenze normalized with damage factor for Silicon (0.62)
[5] 3D, double sided, 250µm columns, 300µm substrate [Pennicard 2007]
[6] n-EPI,75µm, (-30°C, 25ns), pad [Kramberger 2006]
[7] n-EPI,150µm, (-30°C, 25ns), pad [Kramberger 2006]
[8] n-EPI,150µm, (-30°C, 25ns), strip [Messineo 2007]

Note: Measured partly under different conditions!
Lines to guide the eye
(no modeling)!

Beware:
No MCz nor Cz material displayed

Beware:
Signal shown and not S/N !

More on the poster, e.g.:

- For fluences above ~ 10^{15} neq/cm² trapping becomes the dominant problem (depletion voltage remains important but less relevant)
- n-strip readout (n-in-n or n-in-p) looks very promising at least for outer layer, probably even for inner with higher voltage
- At high fluences p-material does not anneal with respect to CCE (maintenance periods easier to control?)
- It seems, that in MCz material charged particles introduces more donor and neutral more particle acceptor levels ➔ compensation
- 3D detectors are promising candidates for the very inner layers (enormous progress by several groups)
- Systematic studies of RD50 and WODEAN improves or understanding of microscopic defects to macroscopic device behaviour

Mercedes Miñano (*Instituto de Física Corpuscular (IFIC)*)

CHARACTERIZATION OF IRRADIATED P-TYPE SILICON DETECTORS BY THE ALIBAVA SYSTEM

Liverpool

Barcelona

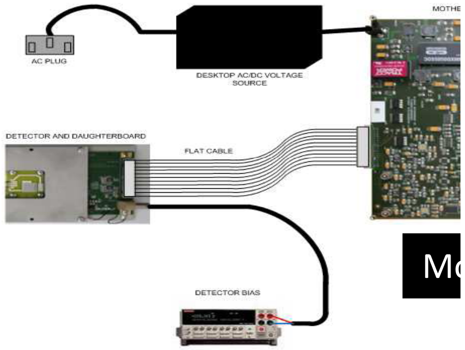
Valencia

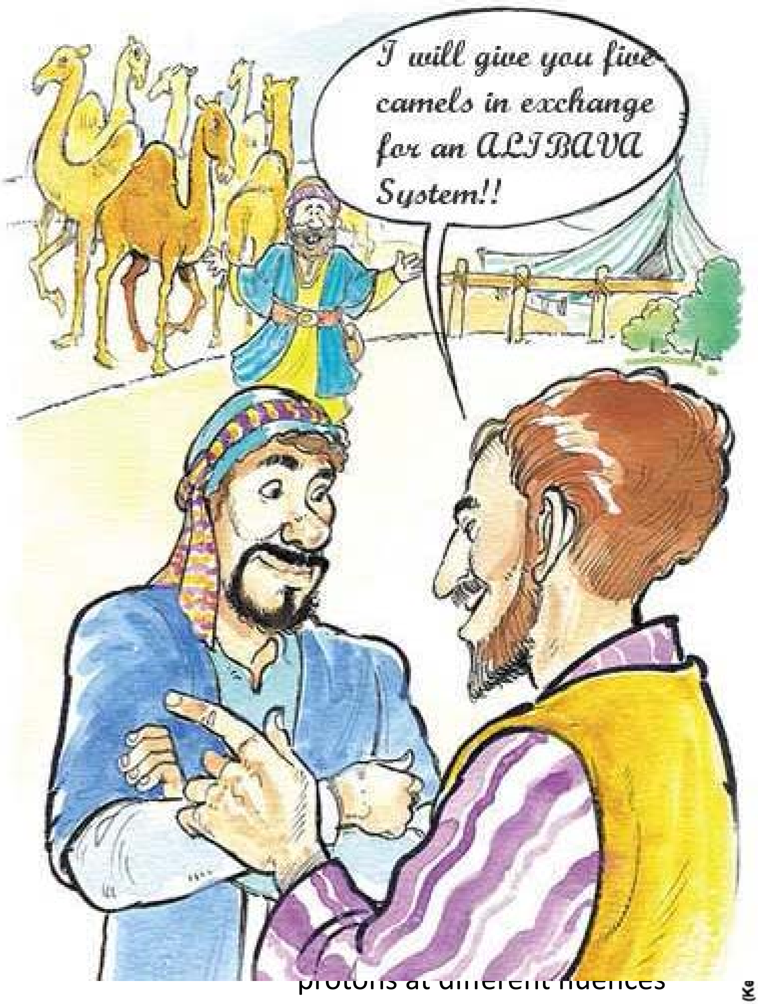
Characterization of Irradiated P-type Silicon Detectors by the ALIBAVA System

Irradiated test sensors have been characterized in terms of their charge collection efficiency.
A new acquisition systen

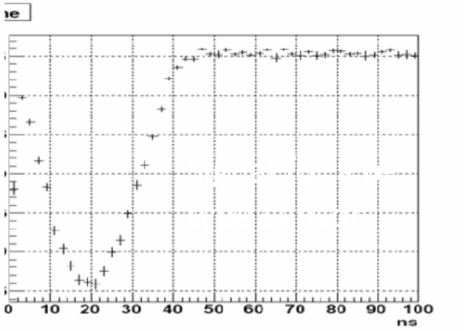
- The sensors: High resistivity N-or
  Area 1 cm^2

- The ALIBAVA acquisition system:
a Beetle based system to read out t
in strip silicon detectors by illumina
radiation sources.

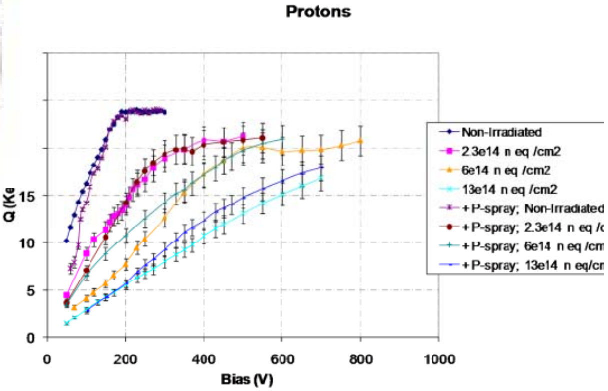




have been irradiated with
on and proton irradiation
e expected doses of the
ded Large Hadron Collider
r-LHC)
minosity peak: 10^{35} cm^{-2} s^{-1}



protons at different fluences
and a non-irradiated sensor as
reference.



➔ n-in-p is a viable option for SLHC

Central European Consortium
- Aachen
- Desy
- Hamburg
- Karlsruhe
- Louvain La Neuve
- Santander
- Vienna
- Vilnius
- Warsaw

Otilia Militaru (*Université Catholique de Louvain)*

SIMULATION OF ELECTRICAL PARAMETERS OF NEW DESIGN OF SLHC SILICON SENSORS FOR LARGE RADII

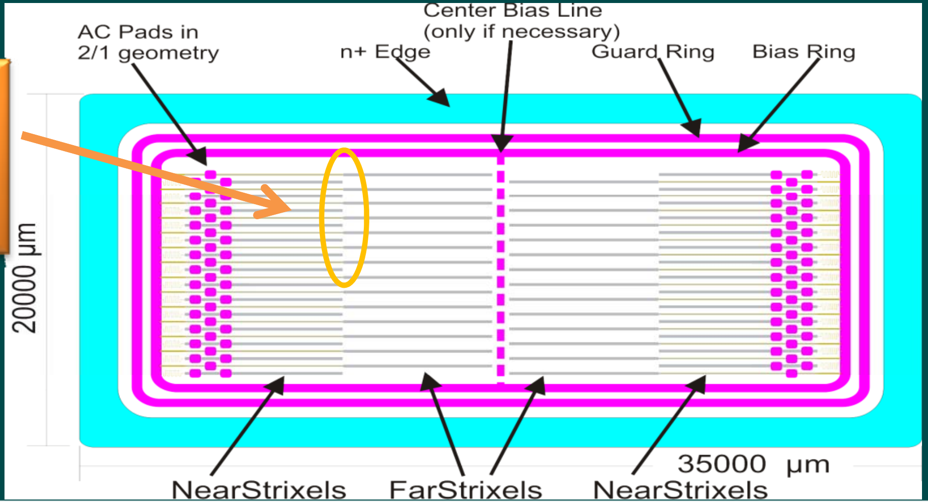
Simulation of electrical parameters of new design of SLHC silicon sensors for large radii

O. Militaru5), T. Bergauer7), M. Bergholz2), P. Blüm4), W. de Boer4), K. Borras2), E. Cortina Gil5), A. Dierlamm5), M. Dragicevic7), D. Eckstein3), J. Erfle4), M. Fernandez6), L. Feld1), M. Frey4), M. Friedl7), E. Fretwurst3), E.Gaubas8), F. J. Gonzalez6), P.Grabiec9), M. Grodner9), F. Hartmann4), S. Hänsel7), K-H Hoffmann4), J. Hrubec7), R.Jaramillo6), W. Karpinski1), V.Kazukauskas8), K. Klein1), V. Khomenkov3), R. Klanner3), M. Krammer7), K. Kucharski9), W. Lange2), V. Lemaitre5), D. Moya6), J. Marczewski9), A.Mussgiller2), T. Rodrigo6), T. Müller4), J. Sammet,1) P. Schleper3), J. Schwandt3), H-J. Simonis4), A. Srivastava3), G. Steinbrück3), D. Tomaszewski9), S.Sakalauskas8), J.Storasta8), J.Vaitkus8), A. Lopez Virto6), I. Vila6), E.Zasinas8)

(Central Europe Consortium for CMS tracker upgrade)

1) Aachen University, Germany,
2) Deutsches Elektronen-Synchrotron DESY, Germany,
3) Institut für Experimentalphysik, Universität Hamburg, Germany
4) Institut für Experimentelle Kernphysik, Universität Karlsruhe (TH), Germany,
5) Universite catholique de Louvain, Belgium,
6) Instituto de Física de Cantabria (UC-CSIC), Santander, Spain
7) Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften, HEPHY, Vienna, Austria,
8) Institute of Materials Science and Applied Research, Vilnius University, Lithuania
9) Institute of Electron Technology, Al. Lotnikow 32/46, 02-668 Warsaw, Poland

e.g.
This region
is simulated



As a result of the high luminosity at SLHC, the CMS tracking system with high granularity will be needed and the sensors will have to withstand an extreme radiation environment.

On this basis, a new geometry with silicon short strip sensors (strixels) is proposed. In order to understand the behaviour of such devices, test geometries are developed whose performance can be verified and optimized using simulation of semiconductor structures. used the TCAD-ISE (SYNOPSYS package) software in order to simulate the main electrical parameters of different strip geometries, for p-in-n type wafers.

Otilia Militaru

UCL Université catholique de Louvain

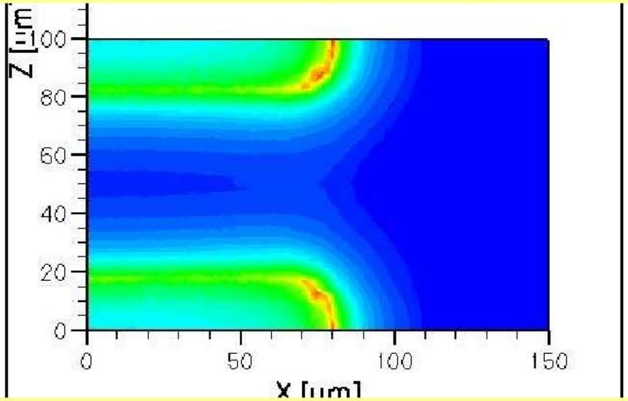
Simulation of electrical parameters of new design of SLHC silicon sensors for large radii

Otilia Militaru

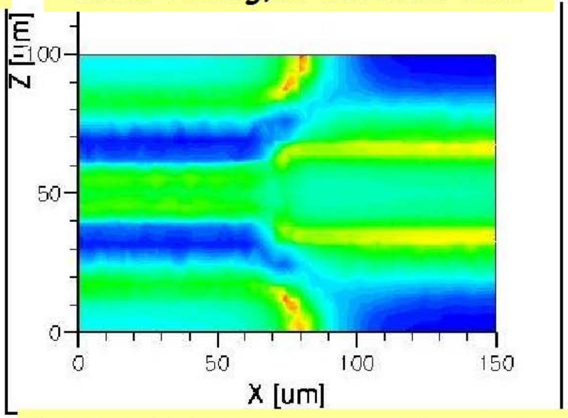
To the readout electronics noise, crucial contribution is given by the backplane capacitance of the bulk and the capacitance between adjacent electrodes (strips). These factors have been studied in order to evaluate the effect of cross talk between nearby Near-Far strips.

For the avalanche breakdown process, the structure demonstrates a good resistivity, the metal routing lower the electric field at the Near Strips junction. From simulations, can be seen the clear variation of the different components of the interstrip capacitance between neighbour strips. The influence of the opposite strip to this parameter starts to be significant when the Far Strip junction is at the same level or closer to Near Strips.

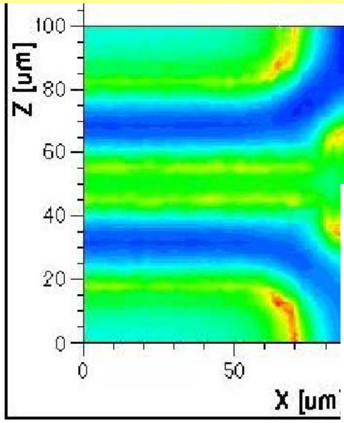
Layout 1: Two strips (for comparison)



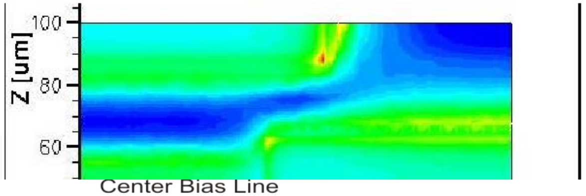
Layout 2: Three strips, with metal routing, at the same level

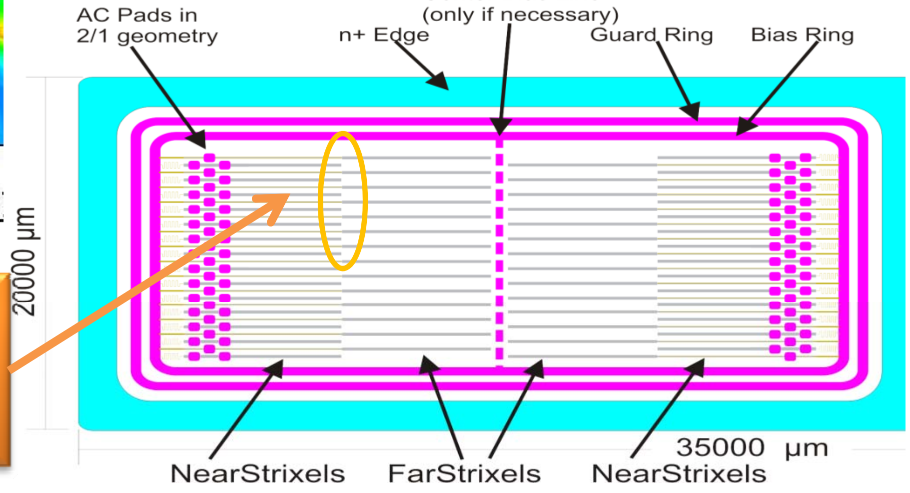


Layout 3: Three strips, with metal routing, at 20 µm distance far



Layout 4: Three strips, with metal routing, at 20 µm distance overlapping





e.g.
This region
is simulated

2 posters from SLIM

Silicon detectors with Low Interactions with Material

by INFN group **5 & eight Italian Universities**

Lorenzo Vitale (*Università di Trieste / INFN)*

SLIM5 BEAM TEST RESULTS FOR THIN STRIPLET DETECTOR AND FAST READOUT BEAM TELESCOPE

Irina Rashevskaya (*INFN – Trieste)*

INVESTIGATION OF AN ABNORMAL PATTERN OF THE STRIP LEAKAGE CURRENTS IN MICROSTRIP DETECTORS

A successful beam test is described in detail

Detector options

The collaboration identified two detector options to reach this goal:

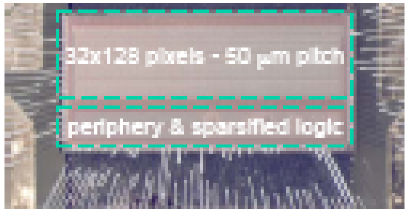
➔A new and challenging triple well CMOS Monolithic Active Pixel Sensor (**MAPS**) with in-pixel signal processing and sparsified capabilities.

Pixel cell is 50x50 µm²,

active area close to 90%

and 100-200 um thick.

For more details, talk by M. Villa



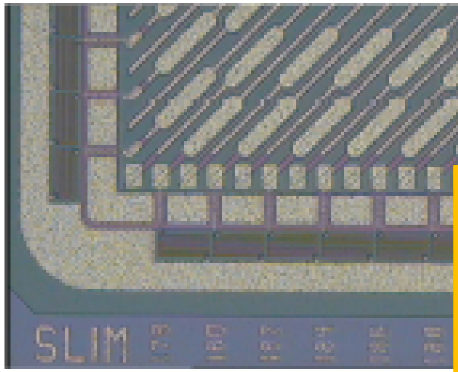
The APSEL4D chip bonded to the chip carrier.

➔A more traditional, but **thin** high resistivity double-sided silicon detector with short strips "**striplets**".

Strips are tilted by 45°,
50 µm pitch,
active area 27 x 12.9 mm²
and 200 µm thick.
Strip cap. ~4 pF

For more details, see
Poster by I. Rashevskaya

Designed and fabricated by FBK-IRST.

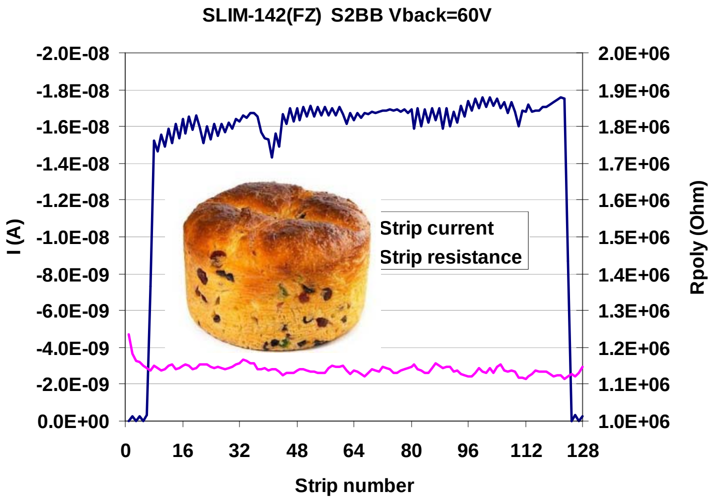


Detail of a corner of the SLIM5 striplet detector.

On some of the sensors a „strange“ current patter was observed.

The panettone effect

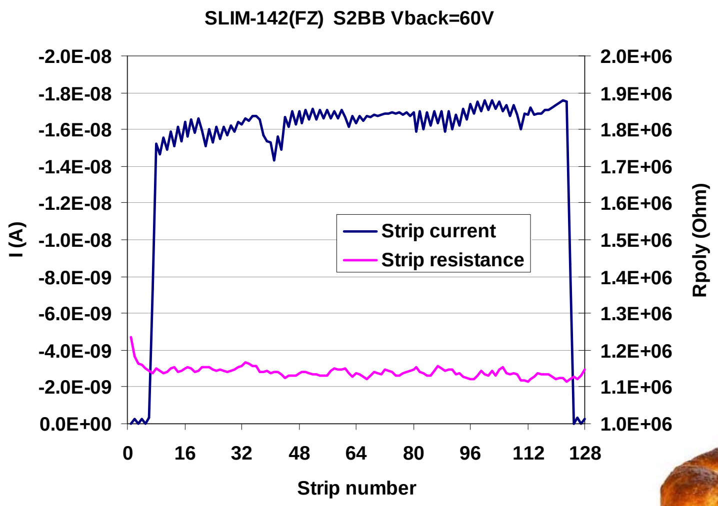
(2nd poster)



Applications

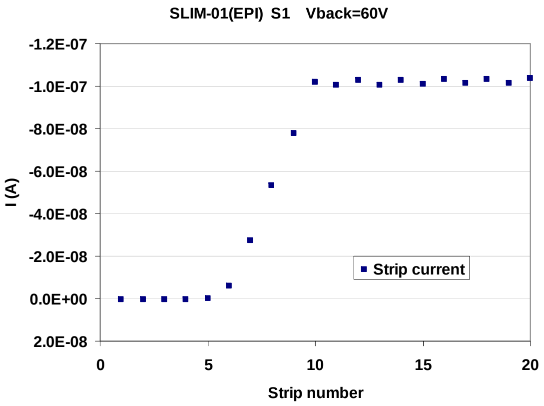
Such detectors can be used for the layer 0 in a future high-luminosity collider, such as the **Super B-factory** or the **International Linear Collider**.

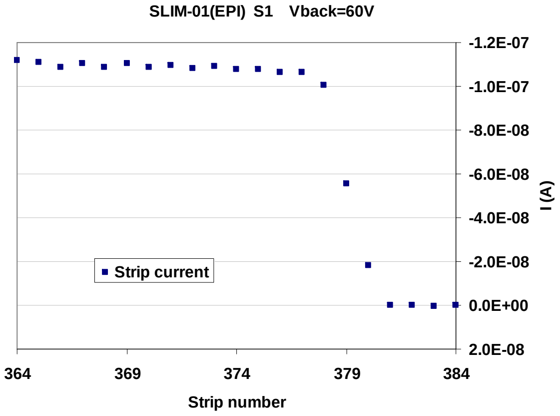
Investigation of an abnormal pattern of leakage currents in silicon microstrip detectors

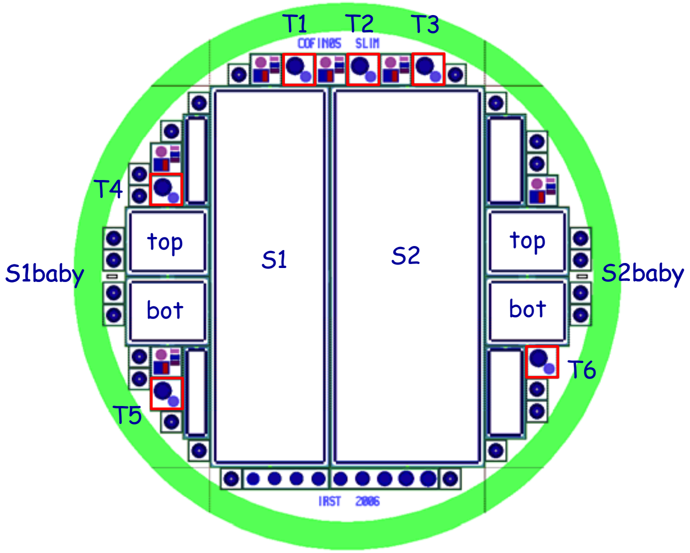


Some batches of microstrip detectors fabricated by FBK-irst showed an odd and peculiar pattern of the strip leakage currents :the current of the first and the last few strips is low, whereas all the strips in between have very high current (3-5 orders of magnitude higher). This peculiar phenomenon, common to ALL six different detectors in EACH wafer of the batch, has been called

“Panettone effect”.



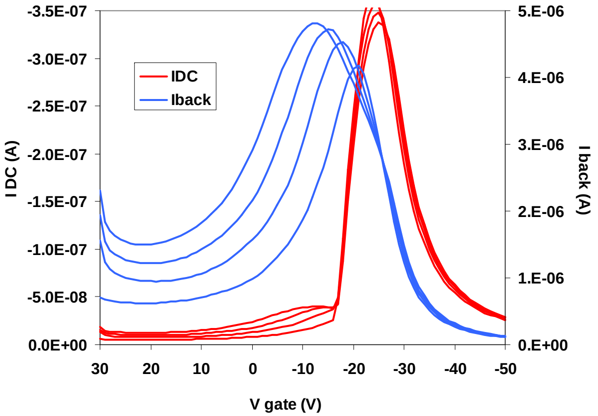




I. Rashevskaya on behalf of the ***Slim5*** *Collaboration, Trieste Group*

Role of surface generation current

Silver paint



<u>Surface generation played a major role.</u>

The high current measured on strip detectors is quantitatively compatible with this surface-generated current in the interstrip gaps. It must be concluded that in the gaps between the strips of the detectors the interface has much worse characteristics than in the gated diodes.

Proposed explanation for the origin of the effect

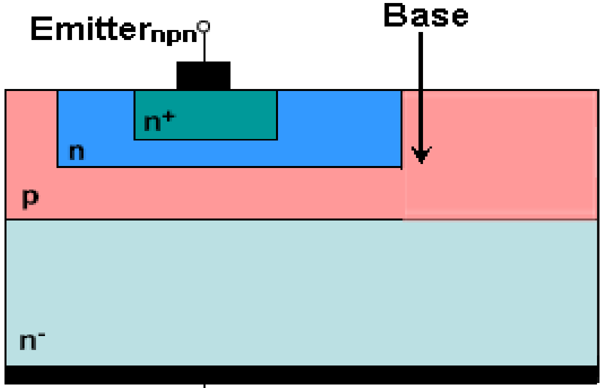
By comparing the technologies of different detector lots fabricated by FBK-irst, we observe that the peculiar 'Panettone Effect' is correlated with the combined presence of two LPCVD-deposited dielectric layers: <u>silicon nitride and TEOS oxide.</u>
This combination produces a high level of stress, which induces defects at the silicon/oxide interface, leading to a high rate of surface generation. These dielectric layers are interrupted in the contact areas between metal and (implanted) silicon. This locally releases the stress in a region around the contact. Since the Bias Rings of the detectors have a continuous contact opening along their length, the local release of the stress can explain the fact that the strips within a certain distance from the Rings have low leakage current.
Making use of a modified technology excluding the TEOS oxide, a batch of striplet detectors has been fabricated. They showed no “panettone effect”, and have been successfully employed in the SLIM5 beam test at CERN in September 2008

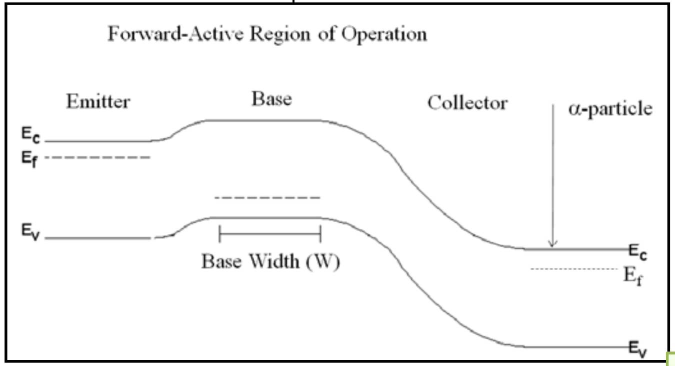
Vladyslav Tyzhnevyi (*Università di Trento / INFN Trento)*

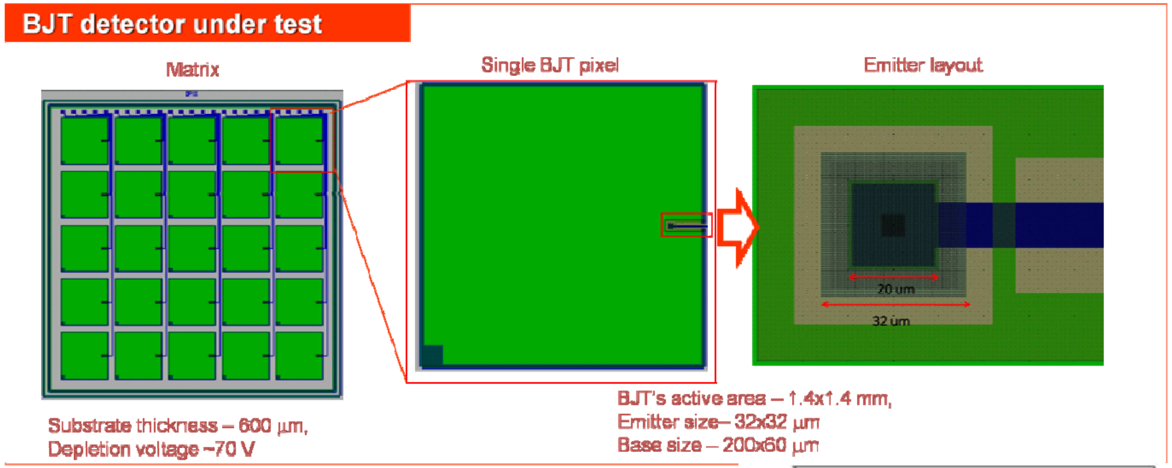
LASER AND ALPHA PARTICLE CHARACTERIZATION OF A FLOATING-BASE BJT DETECTOR

Bipolar junction transistor

BJT detectors are able to measure different types of ionizing radiation: α**-particles (!)**, β-particles, X- and γ-photons.



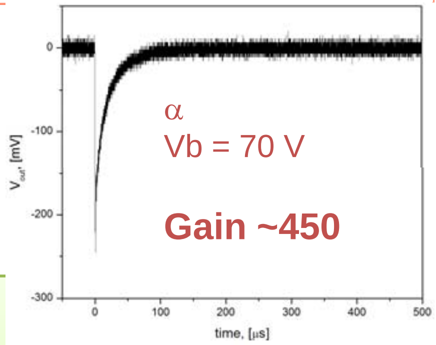




BJT detector under test

Substrate thickness – 600 μm,
Depletion voltage ~70 V

BJT's active area – 1.4x1.4 mm,
Emitter size– 32x32 μm
Base size – 200x60 μm

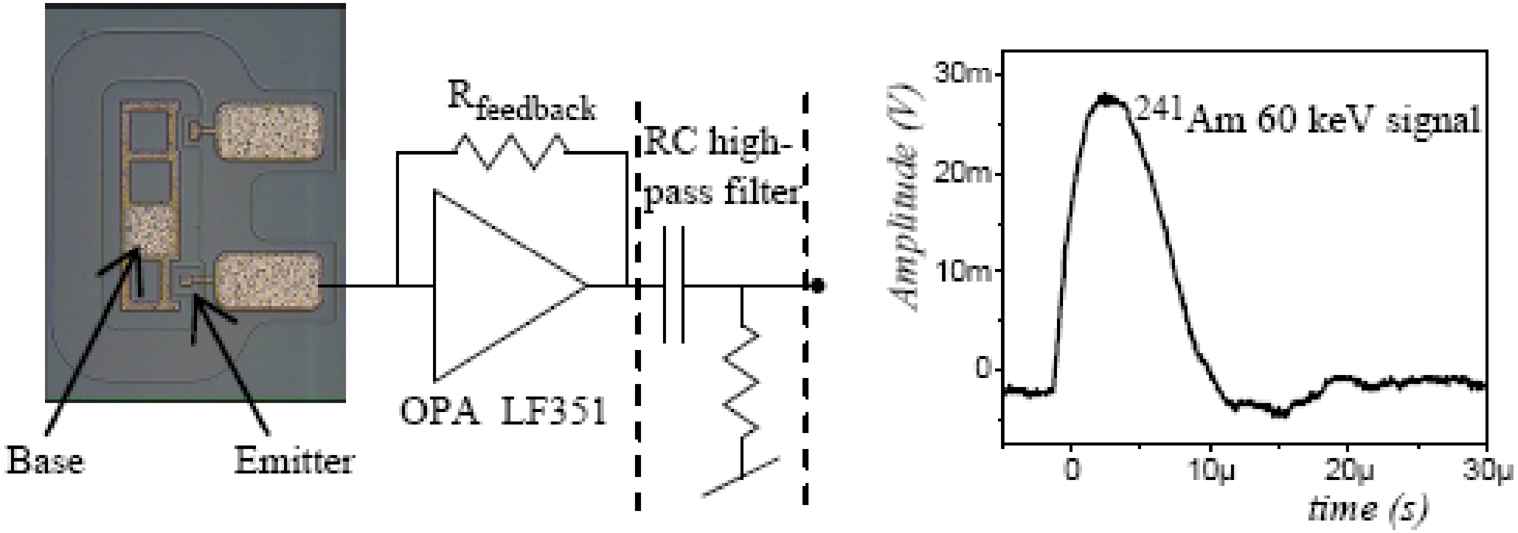


α
Vb = 70 V

Gain ~450

Low cost and simple setups (battery)
e.g. alpha detectors (Radon monitoring)
High current gain ~ 600
Not so fast 50-100μs

BJT detectors



The detector is a Bipolar Junction Transistor whose Collector is the fully depleted high resistivity substrate, while the Emitter and Base implants occupy a few microns under the surface. The reverse biased Base-Collector junction collects the signal charge: as soon as the holes accumulate into the base, due to the BJT effect, an amplified charge is injected from the Emitter to the Collector, generating a few μs wide current pulse. Flowing through the feedback resistor of the OPA, this current pulse is converted into a voltage signal. An Equivalent Noise Charge of 340 e^- has been obtained with the simple - and inexpensive - set-up depicted above [5].

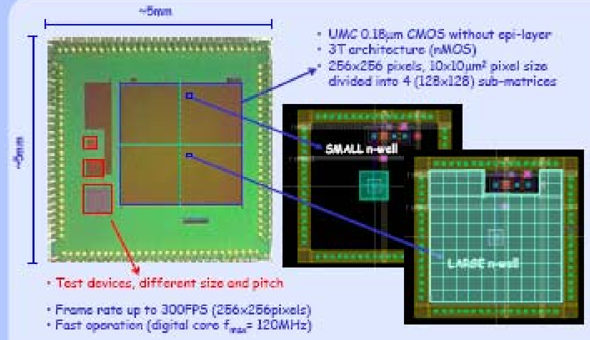
Daniele Passeri (*Università di Perugia*)

CHARACTERIZATION OF CMOS ACTIVE PIXEL SENSORS FOR PARTICLE DETECTION: BEAM TEST OF THE FOUR SENSORS RAPS03 STACKED SYSTEM

Introduction

Following the mainstream of microelectronics CMOS bulk technology, a third generation of monolithic Active Pixel Sensors for particle detection purposes (called RAPS03) has been fabricated in 0.18μm CMOS 1P6M technology and tested. Beside electrical characterization and particle detection principle validation, an extensive detector functional test has been carried out. Actually, single chips have been already characterized in terms of response to X-ray photons and β particles.

In this work, in order to check their suitability for vertexing/tracking applications, four stacked CMOS APS sensors featuring 256×256 pixels with 10μm×10μm pixel size have been tested at the INFN Beam Test Facility (BFT), Frascati (Rome), Italy. To this purpose, a dedicated mechanical and electrical set-up has been devised and implemented, allowing for the simultaneous read-out of four sensors arranged in a stacked structure. This work has been carried out within the framework of the SHARPS experiment, supported by I.N.F.N.



- UMC 0.18μm CMOS without epi-layer
- 3T architecture (nMOS)
- 256x256 pixels, 10x10μm² pixel size divided into 4 (128x128) sub-matrices

- Test devices, different size and pitch

- Frame rate up to 300FPS (256x256pixels)
- Fast operation (digital core f_{max}= 120MHz)

Fig. 1: The RAPS03 sensor laoyut, featuring 256×256 pixels with 10μm×10μm pixel size, and both small and large n-well diodes.

Third generation of monolithic active pixels MAPS (<u>0.18μm CMOS</u>) in a test beam
4 quadrants with different layouts!

Experimental Results

The characterization has been carried out using the Beam Test Facilities at the INFN LNF, Frascati (Rome), Italy. An electron beam featuring energies up to 500MeV has been used. A typical response of the four sensors is illustrated in Fig. 5. The trackin system exploits a self-trigger, using layer and layer IV as telescope.

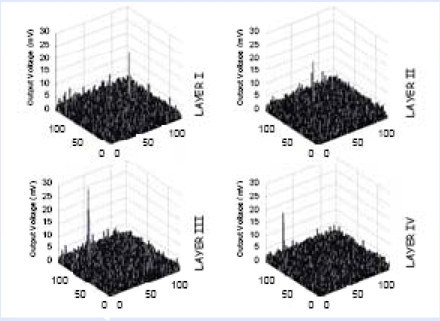


Fig. 5: Response of the four layers to a particle hit.

Signal to Noise and Spatial Resolution

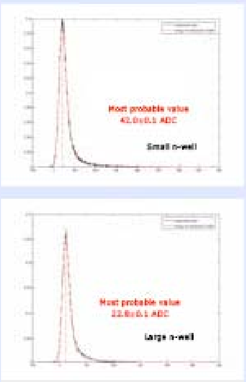


Fig. 11: 5x5 cluster signal distributions: small n-well (top) and large n-well (bottom) diode (465MeV e⁻).

The signal distributions within the cluster are represented in Fig. 10. The Landau signal distributions for a 5x5 pixels cluster are reported in Figs. 11 in terms of ADC counts (1 ADC = 0.62mV). The single pixel noise is 1.67ADC (small n-well) and 1.05ADC (large n-well).

From the generalized η-function distribution [1], the deviation from the "ideal" case of charge division among adjacent pixels can be estimated (assuming that η-functions along x-axis and y-axis are uncorrelated), thus estimating a theoretical spatial resolution limit for particle trajectory of about 0.37μm (Fig. 12).

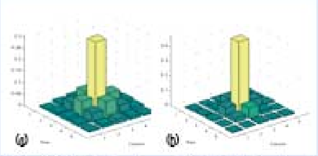


Fig. 10: Cluster signal distribution (small n-well (a) and large n-well (b)).

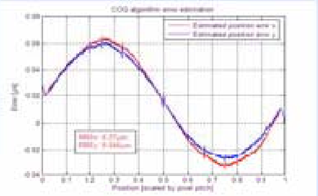


Fig. 12: Estimated theoretical spatial resolution limits.

Ask Daniele about plans of radiation hardness studies?

Eugeni Grauges (*Universitat de Barcelona*)

STUDY OF GEIGER AVALANCHE PHOTO DIODES (GAPD) APPLICATIONS TO PIXEL TRACKING DETECTORS

Main Goal

The use of std CMOS tech. APD's in Geiger mode (that is reverse-biased above breakdown) as sensors with integrated logic, for direct particle detection in pixel tracking detectors

Exploit PROS and improve on CONS

The study includes simulation and prototyping (to detailed to explain here)

Pros:

- ***Ionization production of Avalanche starting carrier –> Part. Detect.***
- ***Std CMOS tech mature and supported for custom design***
  - ***Integrated and Active Quenching (& active circuits) to minimize avalanche charge, cross-talk and after-pulsing***
  - ***Gate mode (bunch crossing)***
- ***Monolithic integration –> System on chip***
- ***Moderate (low) cost***
  - ***Very Low material budget: Depletion region ~1 μm ~80 e/h pairs!***
- ***Very high SNR (but only binary detectors)***

Cons:

- ***Fill factor limited to wells width***
- ***Dark count rate (High Geiger eff. even at low excess bias V)***
- ***Cross-talk (to handel lowering the excess bias V)***
- ***After-pulsing (trapped carriers & delayed release; worse w/ cooling)***

Proto's in HV CMOS:

- **APD's w/ output buffer**: To minimize output load (parasitic) capacitance which impacts performance: time response, after-pulsing, dark count, x-talk
- **Double APD and APD array:**
  - Fill factor ↑: pixel separation minimal (Min. DNTUB distance o(10 μm)).
  - Different pixels in the same DNTUB (common cathode).
    - Minimal separation is min. ptub distance (1.7 μm).
  - Problem sharing DNTUB: Electrons diffusing in the deep ntub could reach any pixel: electrical "crosstalk"…

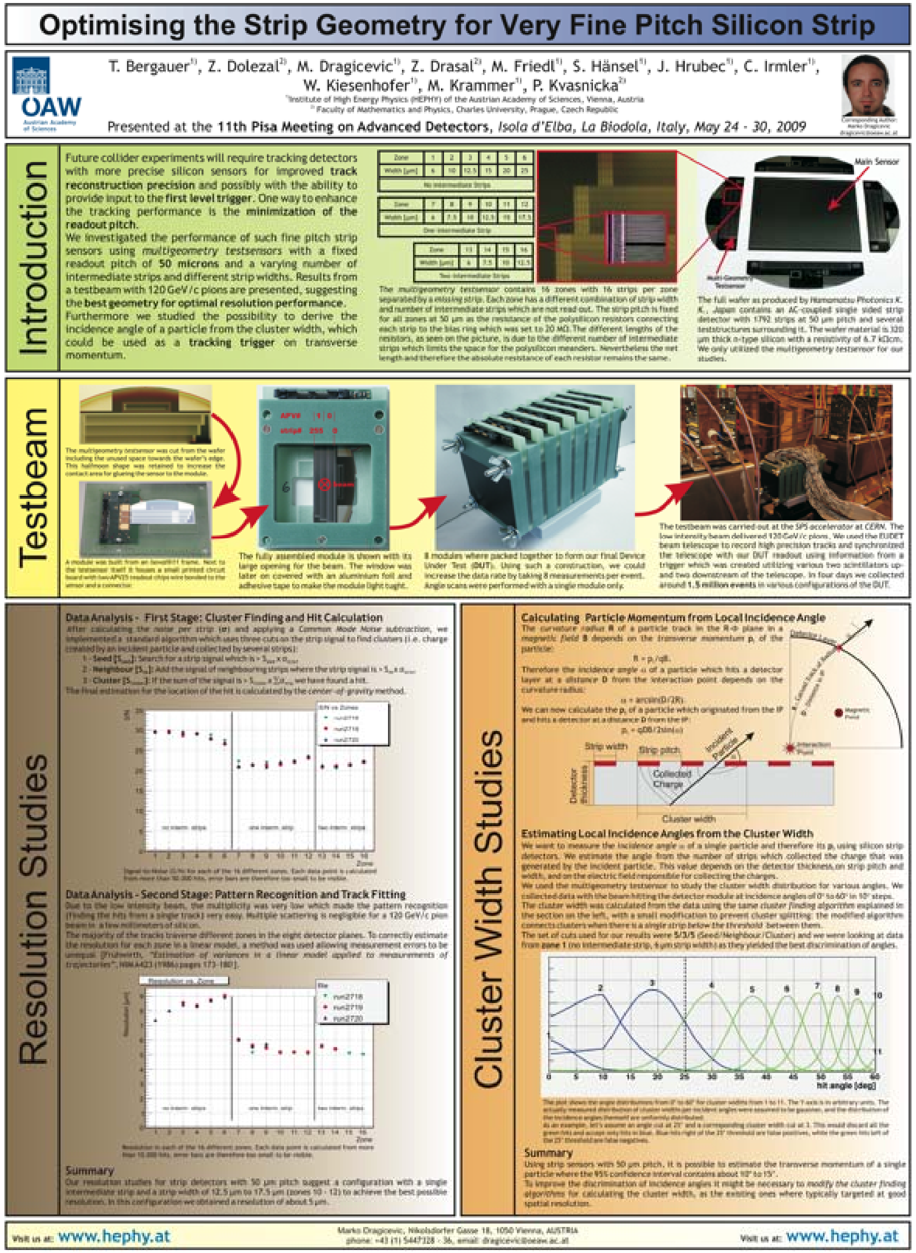
Collateral (std) Application: Single photon detection for (astro-)particle physics, medical devices, etc..

STUDIES SUPPORTING FUTURE DETECTOR OPERATION

Marko Dragicevic (*Institute of High Energy Physics of the Austrian Academy of Sciences (HEPHY)*)

OPTIMISING THE STRIP GEOMETRY FOR VERY FINE PITCH

Austria remains with CERN



Optimising the Strip Geometry for Very Fine Pitch Silicon Strip

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W. Kiesenhofer[1], M. Krammer[1], P. Kvasnicka[2]
[1] Institute of High Energy Physics (HEPHY) of the Austrian Academy of Sciences, Vienna, Austria
[2] Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Presented at the **11th Pisa Meeting on Advanced Detectors**, *Isola d'Elba, La Biodola, Italy, May 24 - 30, 2009*

Introduction

Future collider experiments will require tracking detectors with more precise silicon sensors for improved **track reconstruction precision** and possibly with the ability to provide input to the **first level trigger**. One way to enhance the tracking performance is the **minimization of the readout pitch.**

We investigated the performance of such fine pitch strip sensors using *multigeometry testsensors* with a fixed readout pitch of **50 microns** and a varying number of intermediate strips and different strip widths. Results from a testbeam with 120 GeV/c pions are presented, suggesting the **best geometry for optimal resolution performance.**

Furthermore we studied the possibility to derive the incidence angle of a particle from the cluster width, which could be used as a **tracking trigger** on transverse momentum.

Zone	1	2	3	4	5	6
Width [µm]	6	10	12.5	15	20	25
No intermediate Strips						

Zone	7	8	9	10	11	12
Width [µm]	6	7.5	10	12.5	15	17.5
One intermediate Strip						

Zone	13	14	15	16
Width [µm]	6	7.5	10	12.5
Two intermediate Strips				

The *multigeometry testsensor* contains 16 zones with 16 strips per zone separated by a *missing strip*. Each zone has a different combination of strip width and number of intermediate strips which are not read out. The strip pitch is fixed for all zones at 50 µm as the resistance of the polysilicon resistors connecting each strip to the bias ring which was set to 20 MΩ. The different lengths of the resistors, as seen on the picture, is due to the different number of intermediate strips which limits the space for the polysilicon meanders. Nevertheless the net length and therefore the absolute resistance of each resistor remains the same.

The full wafer as produced by Hamamatsu Photonics K. K., Japan contains an AC-coupled single sided strip detector with 1792 strips at 50 µm pitch and several teststructures surrounding it. The wafer material is 320 µm thick n-type silicon with a resistivity of 6.7 kΩcm. We only utilized the multigeometry testsensor for our studies.

Testbeam

The multigeometry testsensor was cut from the wafer including the unused space towards the wafer's edge. This halfmoon shape was retained to increase the contact area for gluing the sensor to the module.

A module was built from an [illegible] frame. Next to the testsensor itself it houses a small printed circuit board with two APV25 readout chips wire bonded to the sensor and a connector.

The fully assembled module is shown with its large opening for the beam. The window was later on covered with an aluminium foil and adhesive tape to make the module light tight.

8 modules where packed together to form our final Device Under Test (**DUT**). Using such a construction, we could increase the data rate by taking 8 measurements per event. Angle scans were performed with a single module only.

The testbeam was carried out at the SPS accelerator at CERN. The low intensity beam delivered 120 GeV/c pions. We used the EUDET beam telescope to record high precision tracks and synchronized the telescope with our DUT readout using information from a trigger which was created utilizing various two scintillators up- and two downstream of the telescope. In four days we collected around **1.5 million events** in various configurations of the DUT.

Resolution Studies

Data Analysis - First Stage: Cluster Finding and Hit Calculation

After calculating the noise per strip (σ) and applying a Common Mode Noise subtraction, we implemented a standard algorithm which uses three cuts on the strip signal to find clusters (i.e. charge created by an incident particle and collected by several strips):

Data Analysis - Second Stage: Pattern Recognition and Track Fitting

Summary

Cluster Width Studies

Calculating Particle Momentum from Local Incidence Angle

Estimating Local Incidence Angles from the Cluster Width

Summary

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Visit us at: www.hephy.at

Ingredients:

- **50 micron** pitch silicon strip sensor with a varying number of **intermediate strips** and different **strip widths**

- Testbeam at CERNs SPS: **120 GeV/c pions**

25/27

Outcome:

- Resolution study suggesting the **best strip geometry for 50 micron pitch strip sensors**

- First tentative study of dependence of the **cluster width on the incident angle** for a future **p_t trigger** in the tracker

We are waiting for further results from „cluster width on the incident angle “!!!

Filippo Bosi (*INFN Pisa)*

DEVELOPMENT AND EXPERIMENTAL CHARACTERIZATION OF PROTOTYPES FOR LOW MATERIAL BUDGET SUPPORT STRUCTURE AND COOLING OF SILICON PIXEL DETECTORS, BASED ON MICROCHANNEL TECHNOLOGY

Development and Experimental Characterization of Prototypes for Low Material Budget Support Structure and Cooling of Silicon Pixel Detectors, Based on Microchannel Technology

INFN
Istituto Nazionale
di Fisica Nucleare
Sezione di Pisa

Pixel detectors at future colliders will need to match very stringent requirements on position resolution.

The support structure and cooling add important contributions to the total material in the active area.

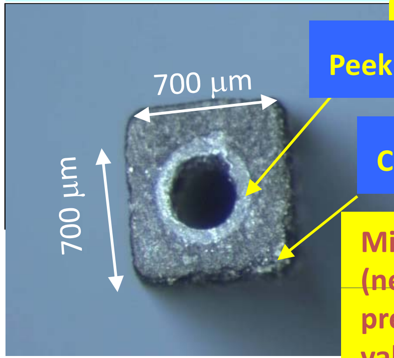
Advantages of the MICROCHANNELS: due to the high surface/volume ratio, heat exchange trough forced convection of liquid coolant is taking place efficiently, obtaining high thermal conductivities without affecting the stiffness of the structure; the contiguity between the fluid and the circuit dissipating power reduces thermal resistances; uniform temperature on the surface covered by the sensors can be obtained.

Several prototypes with different geometries of micro-machined channels have been realized in ceramics (AlN) and composite materials (CFRP). FEA studies have been validated by the experimental tests performed in the thermofluidodynamics test-bench we recently assembled at the INFN-Pisa laboratory .

General Specifications for pixel support :

- need to evacuate electronics power (about 20 kW/m2, sensor temperature below 50 °C)
- Pixel support (w/o cables and sensors) has to remain as low as possible (below 0,30% X_0)

Microchannel CFRP single unit



Peek tube 300 mm int. diam, 50 μm thick

CFRP Poltrusion 700 μm square tube

Minimize Dh → high pressure drop, (need to find a compromise between pressure drops and film coefficient value).

In a thermal convective exchange the film coefficient is:

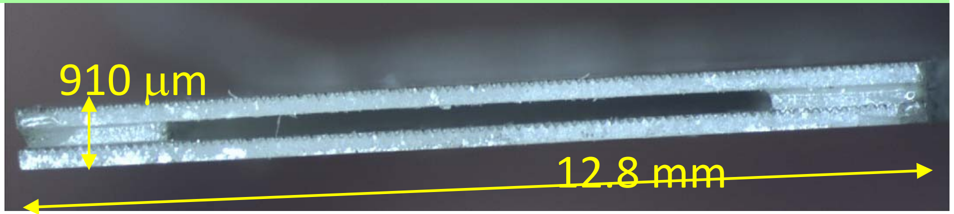
$$h = \frac{Nu \cdot k}{D_h}$$

Nu = Nusselt number
K = Conductive heat transfer coefficient of the liquid
Dh = Hydraulic Diameter of the cooling channel

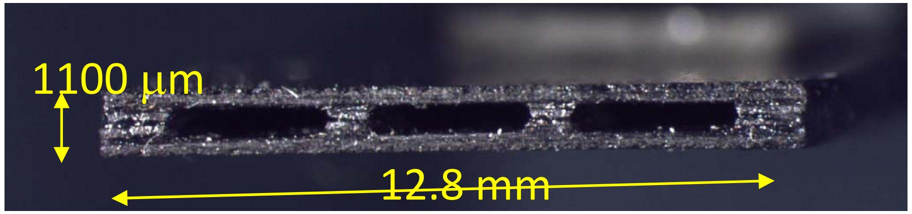
In order to maximize the h value it is important to minimize the hydraulic diameter.
This remark points us to the Microchannel technology.

Prototypes Characterization

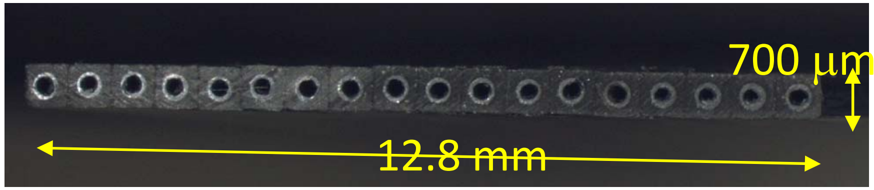
Single Channel AlN additive method:
Thickness = 0.65% X_0



Triple channel CFRP subtractive method:
Thickness = 0.40% X_0



Microchannel CFRP additive method:
Thickness = 0.28% X_0



Microchannel prototype matches the requirements of X_0 and dissipated power.

AlN single channel measurement	
T_{FLUID}	9.5 °C
Power Density δ_P	2 W/cm^2
Flow Rate	0.45 Kg/min
T_IN_AVERAGE	32.4 °C
T_OUT_AVERAGE	42.8 °C
P_IN	1.9 bar

CFRP triple channel measurement	
T_{FLUID}	9.5 °C
δ_P	2 W/cm^2
Flow Rate/ch	0.24 kg/min
T_IN_AVERAGE	41.1 °C
T_OUT_AVERAGE	43 °C
P_IN	2.6 bar

CFRP Microchannel measurement	
T_{FLUID}	9.5 °C
δ_P	2 W/cm^2
Total Flow Rate	0.26 Kg/min
T_IN_AVERAGE	45.1 °C
T_OUT_AVERAGE	47.2°C
P_IN	3.6 bar

Triple Channel FEA Simulation

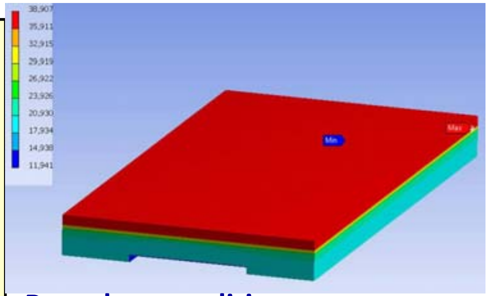
Thermal conductivities :

CFRP support: Kx = Ky = 75 W/mK; Kz = 3 W/mK

Aluminum Tape: K = 180 W/mK

Glue: K = 0.15 W/mK

Heater: K = 0.15 W/mK



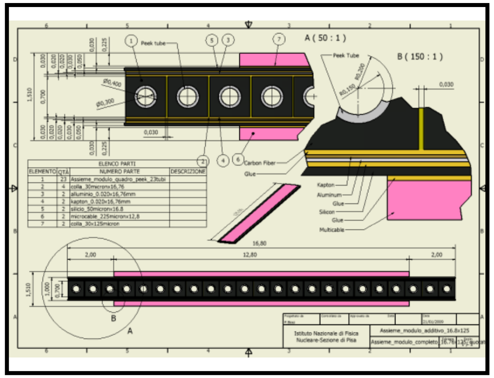
Boundary conditions:

Power density: 2 W/cm2

h = 15000 W/m^{2}K, turbolent flow (total flow rate = 0.7 kg/min, fluid H_2O + Glicole 50 %)

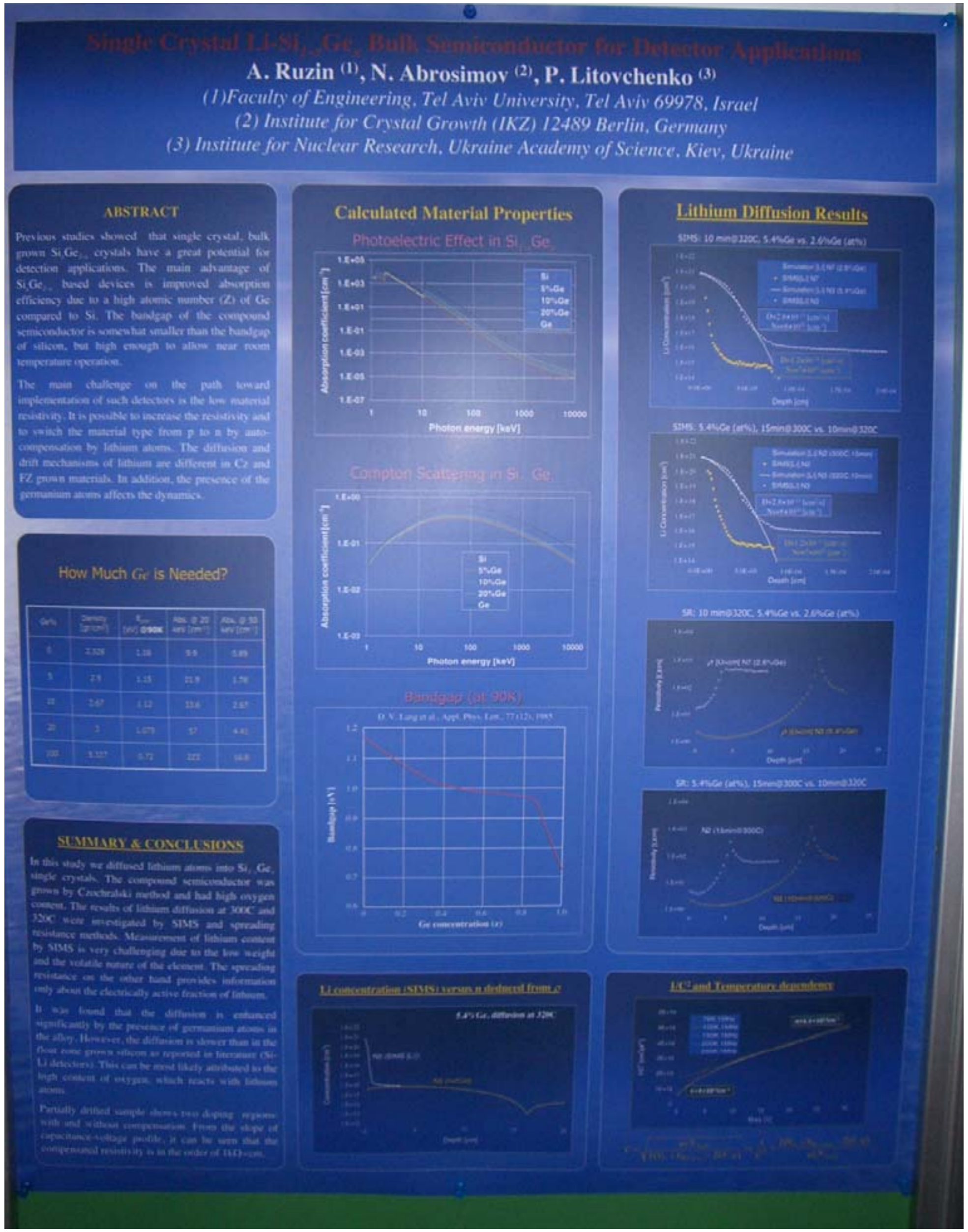
Tfluid = 9.5 °C

Results: *Tmax = 38.9 °C*



Arie Ruzin (*Tel Aviv University*)

LITHIUM DIFFUSION INTO SILICON-GERMANIUM SINGLE CRYSTAL



Single Crystal Li-$Si_{1-x}Ge_x$ Bulk Semiconductor for Detector Applications

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ABSTRACT

Previous studies showed that single crystal, bulk grown Si_xGe_{1-x} crystals have a great potential for detection applications. The main advantage of Si_xGe_{1-x} based devices is improved absorption efficiency due to a high atomic number (Z) of Ge compared to Si. The bandgap of the compound semiconductor is somewhat smaller than the bandgap of silicon, but high enough to allow near room temperature operation.

The main challenge on the path toward implementation of such detectors is the low material resistivity. It is possible to increase the resistivity and to switch the material type from p to n by auto-compensation by lithium atoms. The diffusion and drift mechanisms of lithium are different in Cz and FZ grown materials. In addition, the presence of the germanium atoms affects the dynamics.

How Much Ge is Needed?

Calculated Material Properties

Lithium Diffusion Results

SUMMARY & CONCLUSIONS

In this study we diffused lithium atoms into Si_xGe_{1-x} single crystals. The compound semiconductor was grown by Czochralski method and had high oxygen content. The results of lithium diffusion at 300C and 320C were investigated by SIMS and spreading resistance methods. Measurement of lithium content by SIMS is very challenging due to the low weight and the volatile nature of the element. The spreading resistance on the other hand provides information only about the electrically active fraction of lithium.

It was found that the diffusion is enhanced significantly by the presence of germanium atoms in the alloy. However, the diffusion is slower than in the float zone grown silicon as reported in literature (Si-Li detectors). This can be most likely attributed to the high content of oxygen, which reacts with lithium atoms.

Partially drifted sample shows two doping regions with and without compensation. From the slope of capacitance-voltage profile, it can be seen that the compensated resistivity is in the order of 1kΩ-cm.

Li concentration (SIMS) versus n deduced from ρ

Li/C and Temperature dependence

Basic wafer

Si_xGe_{1-x}

- Smaller bandgap than Si
- Higher absorption coefficient (high Z)
- Ge concentration ~ absorption

Li content can change resistivity even change from p- to n-bulk

This is the very last talk

I WOULD LIKE TO THANK THE ORGANIZERS FOR A TOTALLY PERFECTLY ORGANIZED CONFERENCE

THANK YOU

THE END