Solid State Detector

Jerome Baudot (IN2P3 IPHC), Claudia Gemme (INFN Genova)

Poster Summary

22-28 May 2022
15th Pisa meeting on advanced detectors

Several posters received showing the large interest in the field. A lot of systems are running and have reported progress, while new systems are in construction or advanced design phase, finally a plethora of R&D are developing targeting longer term prospects. One of this prospect is precise timing with SS detectors.

This summary is presented by dividing the posters in macro areas, and for each of them going from the current construction activity to short and long-term perspectives. Statistically, the newer the technology the more are the short and long- term posters presented.

	Total	Systems	Strips	Pixels	MAPS	Techno-Mix: LGAD, SPADS, Diamond …
Current	23	8	6	5	2	2
Short-term	13	2	0	2	5	4
Long-term	11	0	0	2	4	5
Total	47	10	6	9	11	11

Systems

Solide State Detectors
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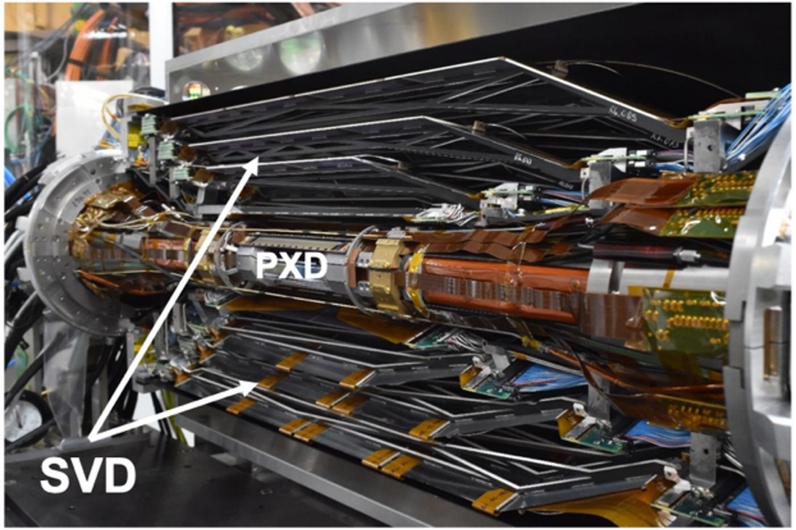
The Silicon Vertex Detector of the Belle II Experiment

15th Pisa Meeting on Advanced Detectors, Isola d'Elba, Italy
Christian Irmler
on behalf of the Belle II SVD collaboration

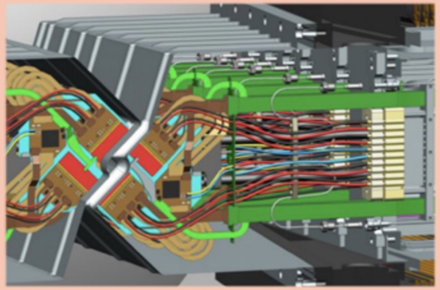
- The Belle II Silicon Vertex Detector (SVD) is located at the SuperKEKB factory, Tsukuba, Japan
- So far recorded 371 fb^{-1}
- 4 layers of double-sided silicon strip detectors
- Reliable operation since spring 2019
- Excellent hit efficiency of >99% in most sensors
- Close monitoring of accumulated radiation dose
  - First effects observed in some parameters, but so far no degradation of SVD performance
- Recently implemented SVD timing based T0 estimation

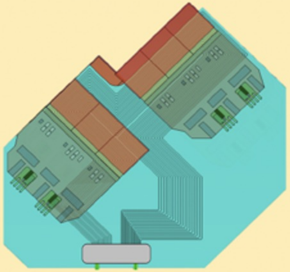


The LHCb VELO Upgrade

Gianluca Zunica, On behalf of the LHCb collaboration

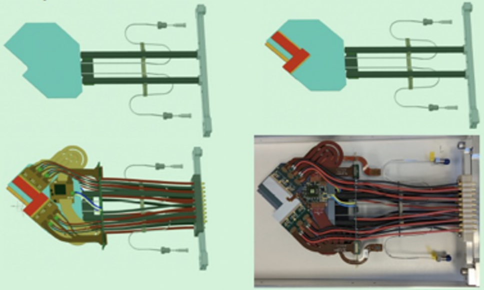
The LHCb VELO Upgrade is the new LHCb silicon tracker replacing the old detector for Run3



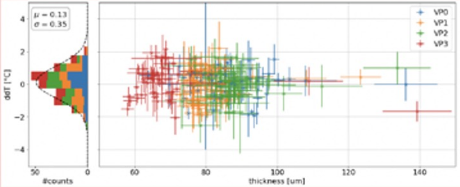


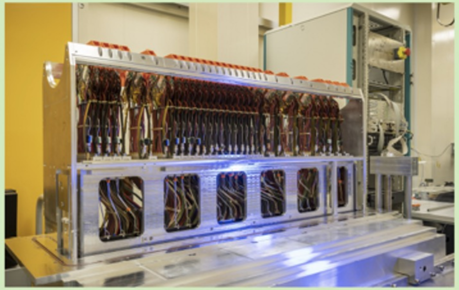
Microchannel silicon substrate provides both structural support and cooling

Module assembly carried out @ Nikhef and Manchester in 4 assembly steps



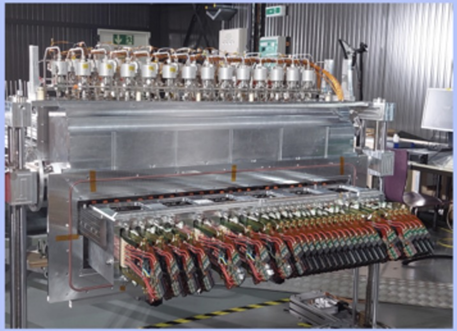
Modules are validated applying vacuum @ -30°C to simulate operation conditions





Detector halves are assembled @ Liverpool

Full detector commissioning @ CERN



Full detector successfully installed

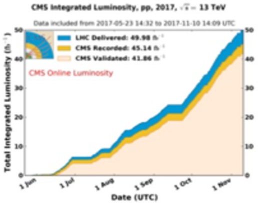
Prospects for automatic data quality monitoring at the CMS pixel detector using machine learning

Luka Lambrecht, on behalf of the CMS Collaboration
e-mail: luka.lambrecht@cern.ch

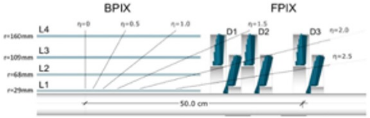
Research Foundation Flanders
Opening new horizons

GHENT UNIVERSITY

Problem

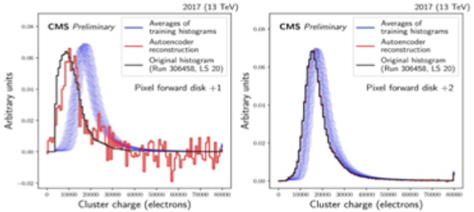


- Goals:
  - optimal usage of the LHC delivered luminosity.
  - filter compromised data from the "good for physics analyses" set.
- Need accurate flagging of detector issues.
- Investigate automatic methods
  - to assist human shifters and experts,
  - to access finer time granularity.



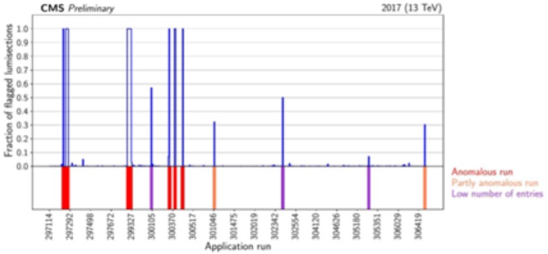
Case study using monitoring elements from the CMS pixel tracker.
Look at distribution of electric charge per cluster for the different regions in the tracker.

Method



- Challenges:
  - no reliably labeled data.
  - large class imbalance (few examples of anomalies).
- Problem formulation:
  - unsupervised anomaly detection.
  - given a large set of histograms, find the anomalous ones.
- Approach:
  - train autoencoders on large data volume.
  - good histograms are accurately reconstructed, while anomalies are not.
  - use the reconstruction error as anomaly measure.

Results



- Accurate flagging of anomalous luminosity sections.
- Both in 'global training' (e.g. for legacy reprocessing) and 'local training' (e.g. for ongoing data taking).
- Some more work needed to reduce the sensitivity to discrete detector condition changes between runs.

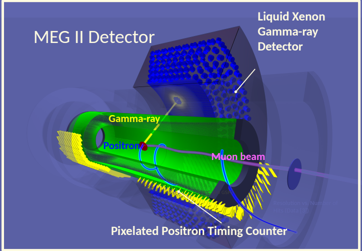
Future developments

- Optimize choice of reference histograms for local training.
- Extend to other monitoring elements.
- Further validation and commissionning in Run-3 data.
- Implement in online DQM software for live data taking.

Luka Lambrecht

Operational results with the pixelated Time Detector (pTC) of MEGII experiment during the first year of physics data taking

Abstract: The experiment MEG II is designed to improve by an order of magnitude the current sensitivity 4.2×10^{-13} reached by MEG on the search for $\mu^+\to e^+\gamma$ decay. A crucial part of MEG II is a pixelated Timing Counter (pTC) developed to measure the positron timing with high accuracy. The pTC is segmented into 512 scintillation counters. Since the positron time is measured independently by several counters (~9 on average), the timing resolution improves significantly compared to single counter resolution. We constructed and installed the pTC and performed commissioning runs at piE5 beam line at PSI starting from 2015. 2021 was the first year of physics data taking. Timing resolution was excellent at ~38 ps since the start, in the following years some problems emerged: SiPM detachment, noise, radiation damage. Those issues are discussed and the steps to solve or mitigate them are detailed. The possibility of an partial upgrade is presented.

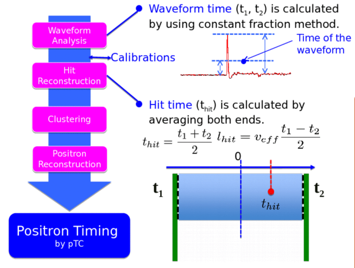


Physics Run 2021

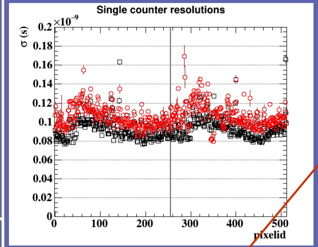
All counters (512) installed and tested in MEG II site, πE5 beam line at PSI.

- **Beam:** DC surface muon beam stopped at
- target (~5×10^7 μ/s).
- **All Detectors installed:** magnet, target, pTC,
- drift chambers, Lxe detcctor, RDC
- **Electronics:** Amplifier (x100), Shaper, Digitizer (WaveDAQ) at 1.4 GHz for pTC [4].

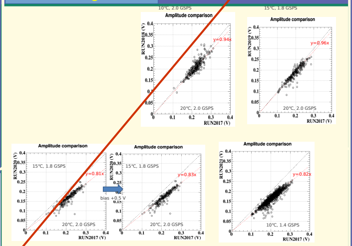
Trigger: $\mu^+\to e^+\gamma$ physics trigger,z



Comparison of pixel timing resolutions



Resolution degradation



Summary

- The full MEGII was installed and tested in PiE5 at PSI.
- MC/Data comparison hit rate for all counters.
- Optimization of CFD fraction
- Time resolution somehow degraded by noise, detachment and radiation damage
- Time resolution improved by a factor of 2 with respect to MEG.

Paolo Walter Cattaneo

Summary:

- The full MEGII was installed and tested in PiE5 at PSI.
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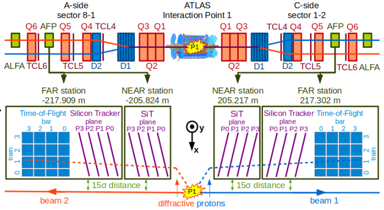
Looking (geometrical) forward …

Overview of ATLAS forward proton detectors for LHC Run 3 and plans for the HL-LHC

Maciej Trzebiński *(Institute of Nuclear Physics Polish Academy of Sciences)*
on behalf of ATLAS Forward Detectors

AFP aims to measure events in which **one or both protons** remain **intact** after interaction. This is possible due to colourless exchange.

Four Roman pot stations, two on each side of ATLAS. All contain **tracking detectors** (6/30 µm resolution in x/y), Far stations consist **Time-of-Flight** (20 ps).



Detectors were installed and took data during LHC Run 2.

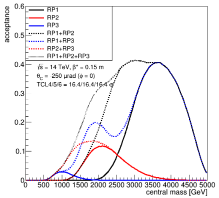
Improvements for Run 3 operation:

- New design of detector flange: Out-of-Vacuum solution for ToF detectors.
- New SiT modules to replace used ones.
- Trigger module: possibility to trigger on a single ToF train.
- New photo-multipliers: address inefficiency issues from Run2 data-taking.

Detectors are commissioned with the first LHC beams and **waiting for Run 3 physics data!**

Run 3 plans: participate in all standard, high pile-up (µ) fills as well as in dedicated low-µ runs.

HL-LHC Roman Pots at IP1



For **Run 4** Roman pots may improve capability to measure/search for photon induced/BSM processes:

- Ongoing discussion in ATLAS.
- Significant constraints in LHC tunnel wrt. Run3 → only few locations possible for pots.
- Location of pots determines accessible mass range.
- Having more stations located at various locations would cost more, but would improve overall detector acceptance.

The CMS Precision Proton Spectrometer timing system: precision timing with scCVD diamond crystals

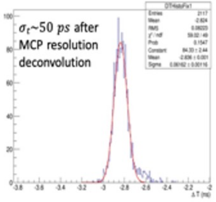
Edoardo Bossini[1,2] on Behalf of the CMS Collaboration

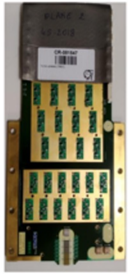
1) Università di Pisa, Pisa, Italy 2) INFN-Sezione di Pisa, Italy

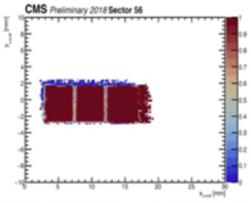
The CMS PPS detector, operating at the LHC, makes use of timing detectors based on planar single crystal CVD diamond to measure the proton time-of-flight with high precision. The time information is used to reconstruct the longitudinal position of the proton interaction vertex and to suppress pile-up background.

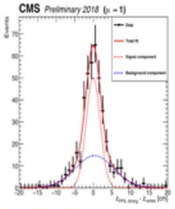
A novel architecture with two diamond sensors read out in parallel by the same electronic channel had been used to enhance the timing performance of the detector.

The PPS timing detector has operated during LHC Run 2. In the poster you will find a description of the detector and its performance in Run 2. The timing system has been upgraded for Run 3, with the goal of reaching an ultimate timing resolution of better than 30 ps on protons in the TeV energy range.







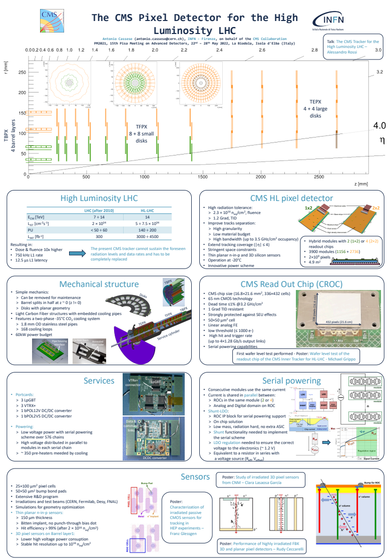


15th Pisa Meeting on Advanced Detectors , 22-28 May 2022, La Biodola, Italy

The pixel detector for High Luminosity LHC

- High luminosity LHC: a new exciting challenge for detectors (high dose, high fluence, trigger needs, …)
- The new CMS pixel detectors concept to satisfy the stringent needs of HL
- Mechanical design and innovations
- Services solutions
- CROC: The pioneering Read Out Chip of CMS tracker
- Serial powering concept and working design
- Innovative sensors choice

Antonio Cassese

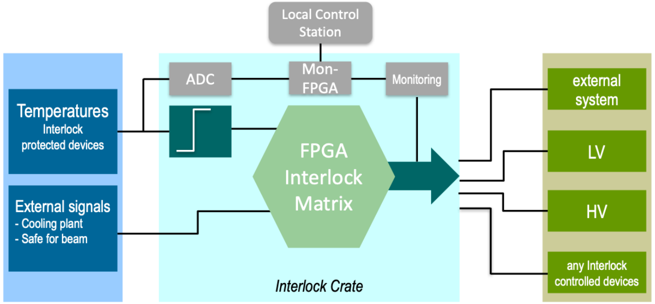


Susanne Kersten

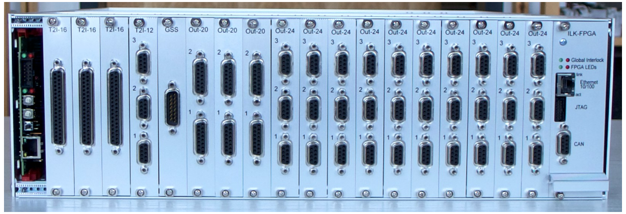
The ITk interlock hardware protection system

from concept to realization

- Heat-ups can cause irreparable damages to silicon detectors. This must be avoided by all means, specially as the ITk detector elements - once installed - are not accessible over years.
- The ITk Interlock system protects the detector elements against upcoming risks. It acts between devices to be protected and units which can be a risk to the devices. FPGAs house the interlock matrix decision tables.
- To keep the number of detector elements, which are out of service, low, a high segmentation is required. As ca. 13000 channels must be handled, a custom made solution was chosen.



concept of the ITk Interlock System

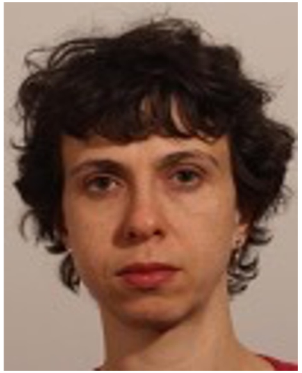


*the **L**ocal **I**nterlock **S**afety **Sys**tem crate*

- To fulfill the requirements of the ITk strip and pixel detector, a modular design was chosen. Besides the Interlock and the Monitoring FPGAs, three types of IO-modules were designed. The users can equip their interlock crate according to their needs. Up to 576 interlock signals can be handled by one interlock crate.
- The pre-production is actually ongoing and first crates are delivered to the sub-detectors.

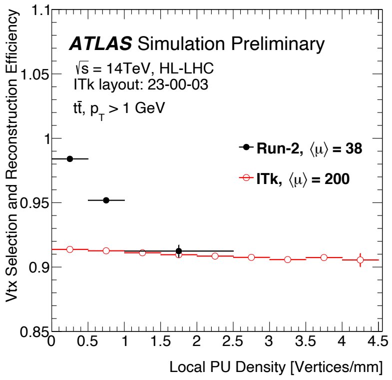
Expected reconstruction performance with the new ATLAS Inner Tracker at the High-Luminosity LHC

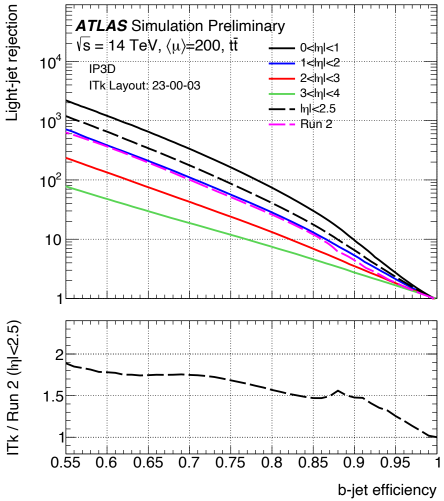
Marianna Testa, for the ATLAS Collaboration

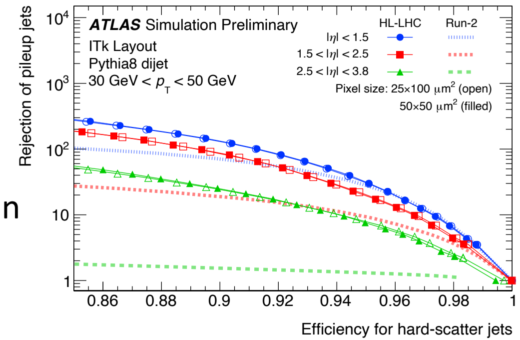


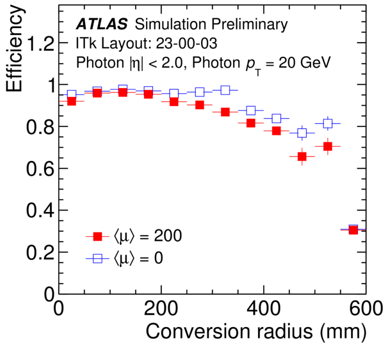
Marianna Testa

- The new all-silicon Inner Tracker (ITk) of the ATLAS detector will be built for the High Luminosity phase of LHC.
- The reconstruction and Identification of high-level objects is improved mainly due to smaller pixel pitch giving an improved track parameter resolutions
- The performances is stable against pile-up conditions
- The extension up to |η|<4 enables reconstruction of (b)-jets, electrons and photon conversion in the forward region.



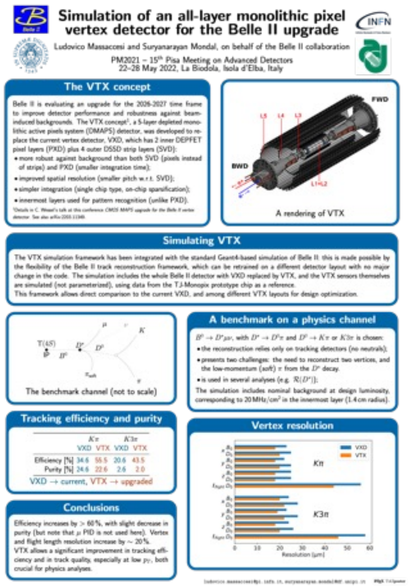


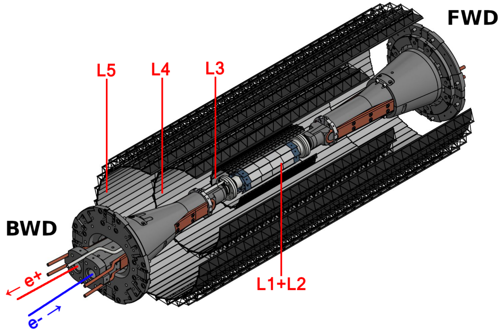




Simulation of an all-layer monolithic pixel vertex detector for the Belle II upgrade

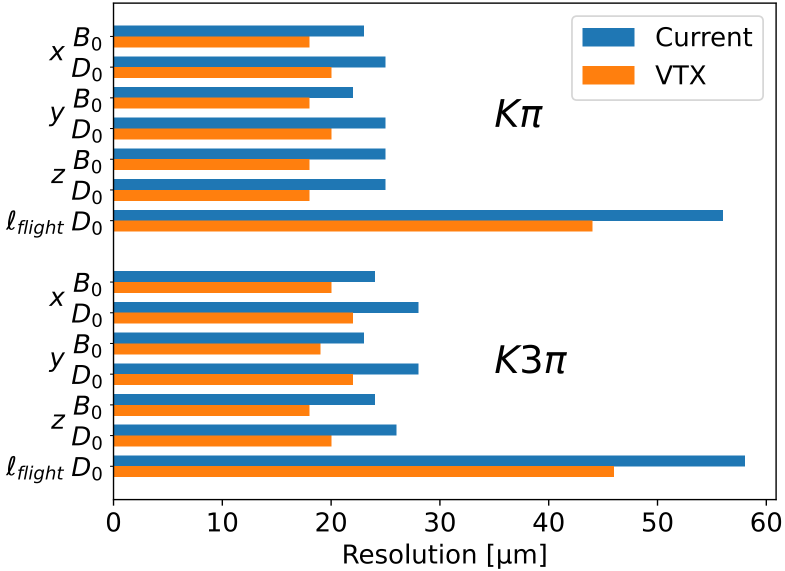
Ludovico Massaccesi on behalf of the Belle II collaboration





The VTX all-pixel concept is proposed to replace the current Belle II pixel-and-strips vertex detector.

Full simulation of the upgraded Belle II on a benchmark channel shows significant improvement in tracking efficiency and resolution, especially at low p_T.



Pixel Detector

Solide State Detectors
Poster Summary

22-28 May 2022
15th Pisa meeting on advanced detectors

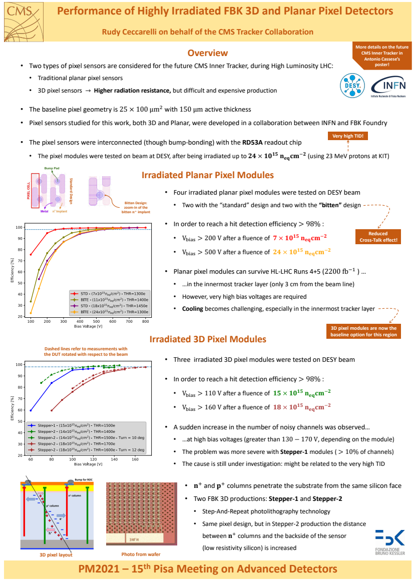
Performance of Highly Irradiated FBK 3D and Planar Pixel Detectors

Rudy Ceccarelli on behalf of the CMS Tracker Collaboration

- Two types of pixel sensors are considered for the future CMS Inner Tracker, during High Luminosity LHC:
  - Traditional planar pixel sensors
  - 3D pixel sensors $\rightarrow$ **Higher radiation resistance,** but more expensive production

- Irradiated FBK 3D and planar pixel sensors, interconnected to the RD53A readout chip, were tested at DESY
  - In this poster, test beam results of these modules are reported

- These studies will help the optimization of the pixel sensor technology to use in the future CMS tracker


Performance of Highly Irradiated FBK 3D and Planar Pixel Detectors

Rudy Ceccarelli on behalf of the CMS Tracker Collaboration

More details on the future CMS Inner Tracker in Antonio Cassese's poster!

Overview

- Two types of pixel sensors are considered for the future CMS Inner Tracker, during High Luminosity LHC:
  - Traditional planar pixel sensors
  - 3D pixel sensors $\rightarrow$ **Higher radiation resistance,** but difficult and expensive production
- The baseline pixel geometry is $25 \times 100\ \mu m^2$ with $150\ \mu m$ active thickness
- Pixel sensors studied for this work, both 3D and Planar, were developed in a collaboration between INFN and FBK Foundry
- The pixel sensors were interconnected (though bump-bonding) with the **RD53A** readout chip
  - The pixel modules were tested on beam at DESY, after being irradiated up to $\mathbf{24 \times 10^{15}\ n_{eq}cm^{-2}}$ (using 23 MeV protons at KIT)

Very high TID!

Irradiated Planar Pixel Modules

- Four irradiated planar pixel modules were tested on DESY beam
  - Two with the "standard" design and two with the **"bitten"** design
- In order to reach a hit detection efficiency $> 98\%$:
  - $V_{bias} > 200$ V after a fluence of $\mathbf{7 \times 10^{15}\ n_{eq}cm^{-2}}$
  - $V_{bias} > 500$ V after a fluence of $\mathbf{24 \times 10^{15}\ n_{eq}cm^{-2}}$
- Planar pixel modules can survive HL-LHC Runs 4+5 ($2200\ fb^{-1}$) …
  - …in the innermost tracker layer (only 3 cm from the beam line)
  - However, very high bias voltages are required
  - **Cooling** becomes challenging, especially in the innermost tracker layer

Reduced Cross-Talk effect!

3D pixel modules are now the baseline option for this region

Irradiated 3D Pixel Modules

Dashed lines refer to measurements with the DUT rotated with respect to the beam

- Three irradiated 3D pixel modules were tested on DESY beam
- In order to reach a hit detection efficiency $> 98\%$:
  - $V_{bias} > 110$ V after a fluence of $\mathbf{15 \times 10^{15}\ n_{eq}cm^{-2}}$
  - $V_{bias} > 160$ V after a fluence of $\mathbf{18 \times 10^{15}\ n_{eq}cm^{-2}}$
- A sudden increase in the number of noisy channels was observed…
  - …at high bias voltages (greater than $130 - 170$ V, depending on the module)
  - The problem was more severe with **Stepper-1** modules ($> 10\%$ of channels)
  - The cause is still under investigation: might be related to the very high TID

3D pixel layout

Photo from wafer

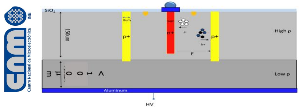
- $\mathbf{n^+}$ and $\mathbf{p^+}$ columns penetrate the substrate from the same silicon face
- Two FBK 3D productions: **Stepper-1** and **Stepper-2**
  - Step-And-Repeat photolithography technology
  - Same pixel design, but in Stepper-2 production the distance between $\mathbf{n^+}$ columns and the backside of the sensor (low resistivity silicon) is increased

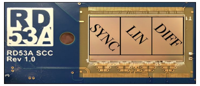
PM2021 – 15th Pisa Meeting on Advanced Detectors

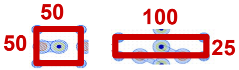
Study of irradiated 3D pixel sensors from CNM

- **CMS needs to be upgraded to face an unprecedented high-luminosity environment**. In particular, the tracker will be substantially replaced to sustain the foreseen high radiation levels.
- **3D pixel sensors** have proven to be the best option **for the innermost layer of the tracker barrel pixel** due to their harsh-radiation tolerance → **CNM is one of the main manufacturers**.

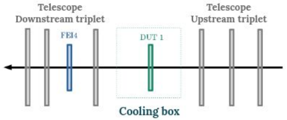
Hybrid pixel detectors: RD53A readout chip + n-in-p sensors

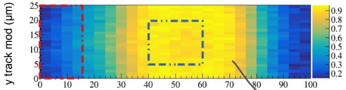




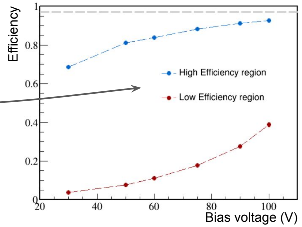


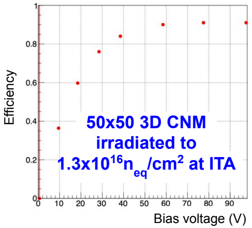
- **Irradiations up to a fluence of 2x10^{16} n$_{eq}$/cm^2** and **data taking in test beams** at several facilities.
  - Irradiations: ITA with protons at 400 MeV, Strasbourg with protons at 23 MeV and KIT wit protons at 25 MeV.
  - Test beams: DESY with e-/e+ beam at 5 GeV, FERMILAB and SPS CERN with proton beams at 120 GeV.



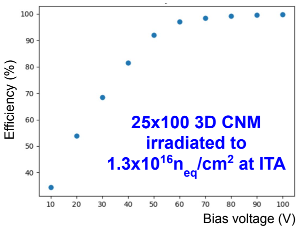


25x100 3D CNM irradiated to 2x10^{16}n$_{eq}$/cm^2 at KIT



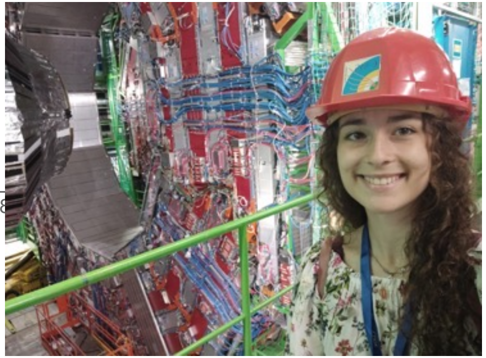


50x50 3D CNM irradiated to 1.3x10^{16}n$_{eq}$/cm^2 at ITA



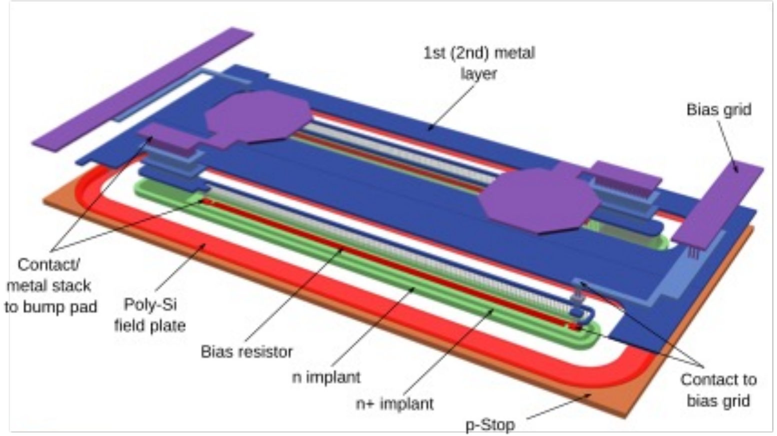
25x100 3D CNM irradiated to 1.3x10^{16}n$_{eq}$/cm^2 at ITA

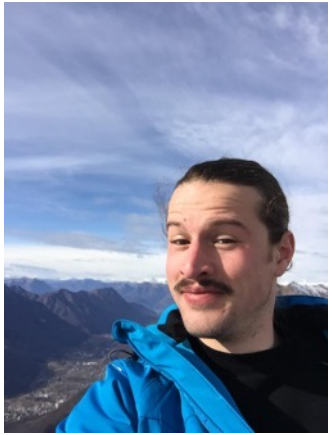
Clara Lasaosa-Garcia



Characterization of irradiated passive CMOS sensors for tracking in HEP experiments

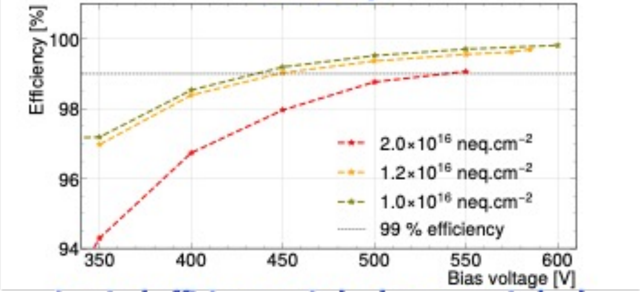
Planar hybrid n^{+}-in-p sensors with a pixel size of 25x100 μm^{2} were developed for the Phase II upgrade of the CMS Inner Tracker. The sensors are built in a 150 nm CMOS process where no active components are used (they are thus named passive CMOS sensors). The CMOS production is promising in terms of throughput and costs and gives access to new sensor features. The sensors were irradiated up to fluences of 2x10^{16} neq.cm^{-2} and intensively tested in particle beams. The performances of the sensors match the requirements for the HL-LHC Inner Tracker Upgrade and are comparable to established technologies.



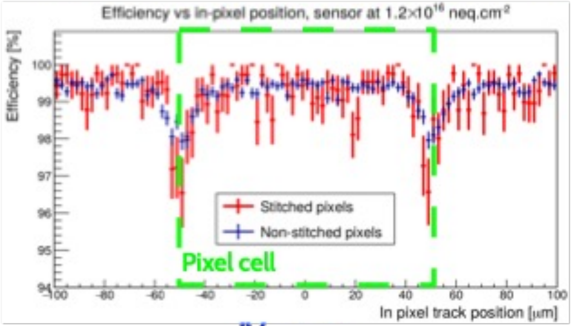


Franz Glessgen, on behalf of the CMS Tracker Group

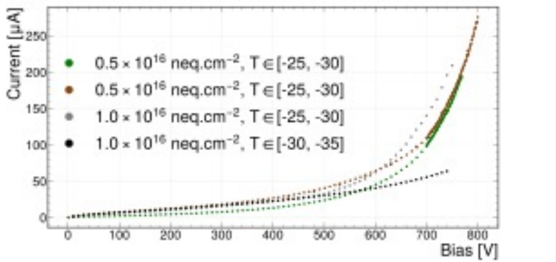
Efficiency



In-pixel efficiency, stitched vs non-stitched



IV curves



Module development for the ATLAS Phase II Pixel Inner Tracker

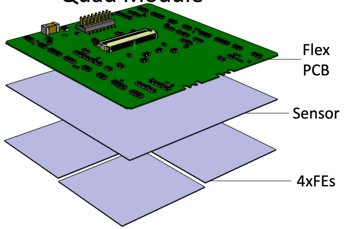
- The ATLAS experiment will undergo substantial upgrades to cope with the higher radiation environment and particle hit rates foreseen for HL-LHC. The phase II upgrade will include the replacement of the inner detector with a completely new silicon-based tracker. The ATLAS phase II Inner Tracker (ITk) will consist of hybrid pixel detectors and silicon strip detector layers. The innermost five-barrel layers and several endcap rings will be equipped with hybrid pixel detector modules.

- The modules are consisting of bare silicon modules connected to flexible printed circuits. Bare silicon modules are made of a silicon pixel sensor connected to either four FE chips to form a quad module or one FE chip to form a single chip module.

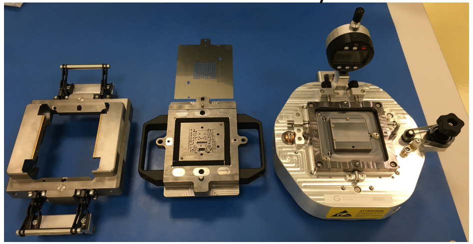
- The ITk phase II pixel community has conducted many developments geared towards meeting the necessary module production quality and throughput. These include establishing quality checking routines of bare module components, tooling developments for their assembly as well as electrical testing infrastructure to assess their operability to specification.

- A dedicated program to set in motion this effort and streamline these various stages was established using the RD53A front-end chip. Subsequent test and assembly work is being carried out using the ITkPix chips which are final size FE chips. Numerous developments in the module assembly tooling, testing infrastructure and intermediary production stages have taken place in preparation for the ATLAS ITk pixel phase II upgrade module production.

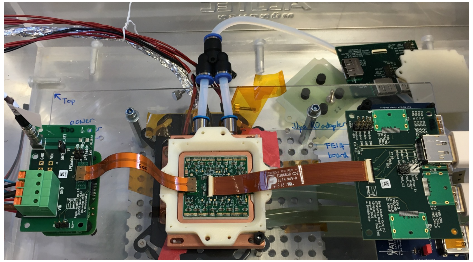
Quad Module



Module Assembly



Module Testing

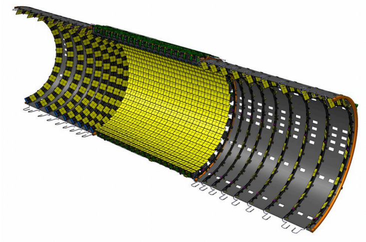


Abhishek Sharma

An environmental monitoring and control system for the ATLAS Outer Barrel QC and Integration

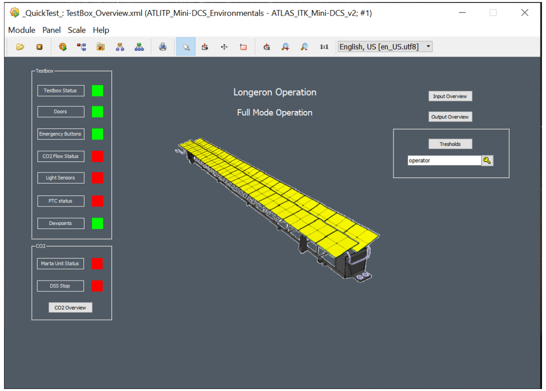
Diego Alvarez Feito, Susanne Kühn, Nicola Pacifico, Jarl N. Pettersen, Xavier Pons, Benedikt Vormwald

CERN - European Organization for Nuclear Research



For the ATLAS ITk Outer Barrel loaded local supports QC and integration, a modular DCS/Interlock system was developed by CERN EP-DT to monitor the environmental parameters and intervene in case of anomalies that could result in damage to the structures.

Nicola Pacifico



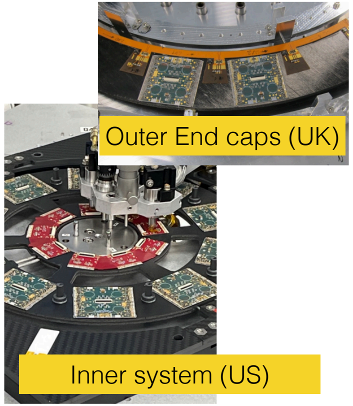
In order to guarantee the required scalability and modularity, the system has been implemented using Programmable Logic Controllers (PLC) with a WinCC OA Interface.

The system will be used either as a standalone unit for loaded local or paired with a dedicated NTC readout matrix (LISSY) during integration of the Outer Barrel layers.

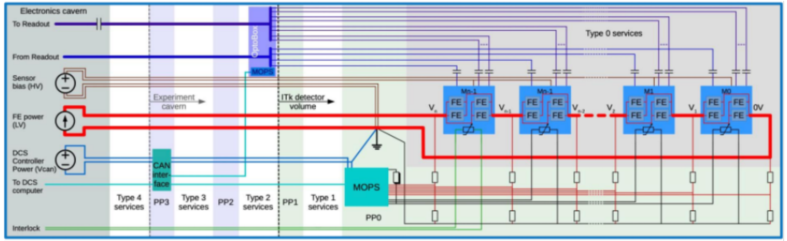
ITk Pixel Demonstrators

The ATLAS tracking system will be replaced by an all-silicon detector for the HL-LHC upgrade around 2025. The innermost five layers of the detector system will be pixel detector layers which will be most challenging in terms of radiation hardness, data rate and readout speed. A serial powering scheme will be used for the pixel layers to reduce the radiation length of the detector and the power consumption in the cables. The elements required to operate and monitor a serially powered detector are being prototyped for all ITk subsystems to verify and test the concepts involved.

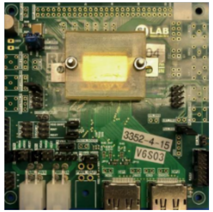
RD53A serial powering with quad modules

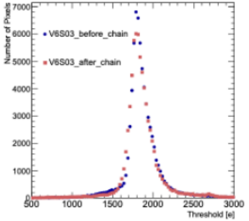


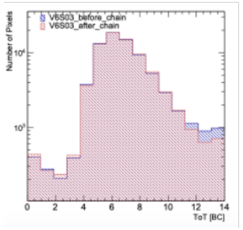
Serial powering and services scheme for ITk Pixel quad modules. serial powering chains of quad modules are constructed with up to 13 modules

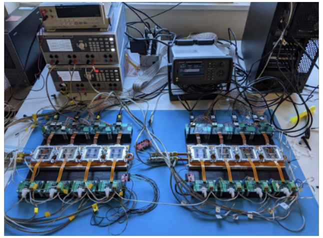


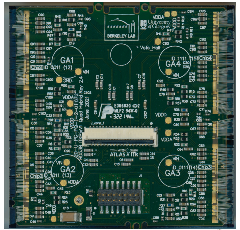
Serial powering chain with irradiated RD53A modules



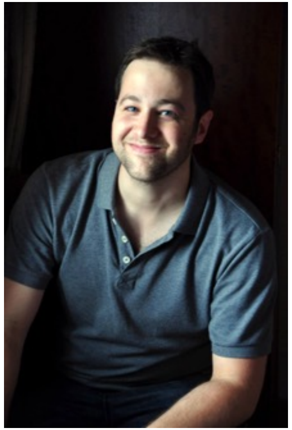








ITkPixv1.1 (RD53B) serial powering quads



Jon Taylor

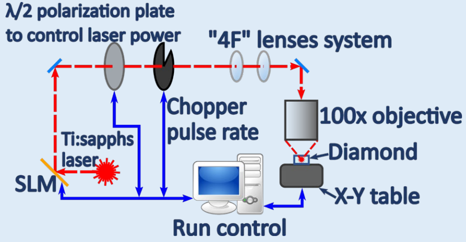
Construction and characterization of high time resolution 3D diamond pixel detectors

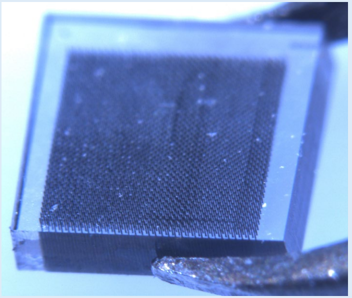
Lucio Anderlini, Marco Bellini, Chiara Corsi, Stefano Lagomarsino, **Chiara Lucarelli** (chiara.lucarelli@fi.infn.it), Giovanni Passaleva, Silvio Sciortino, Michele Veltri

We present the results on the characterization of innovative 3D pixel diamond detectors optimised for timing applications, fabricated by laser graphitisation of resistive electrodes in the bulk of 500 µm thick single-crystal diamonds. The combination of diamond with 3D geometry allows to exploit its excellent timing properties and to enhance its well-known radiation hardness, as required by the challenge posed by the unprecedented density of charged particles foreseen at the next generation of experiments.

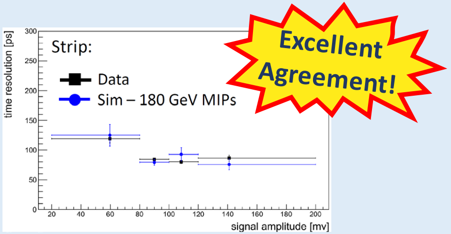
Chiara Lucarelli

Fabrication of all Carbon sensors

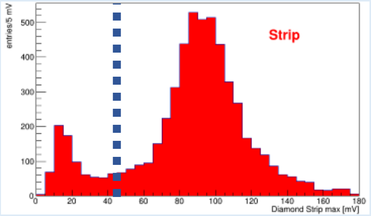




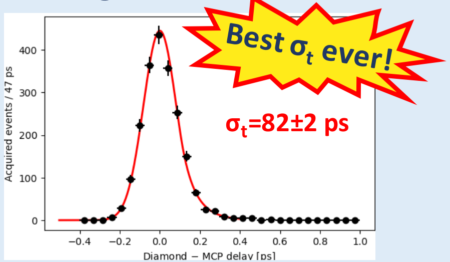
Simulation of full signal formation chain and comparison with data



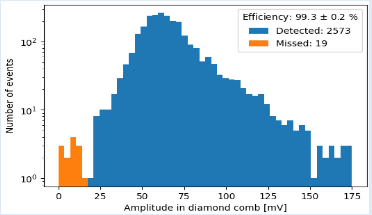
Amplitude distribution



Timing characterization



Efficiency



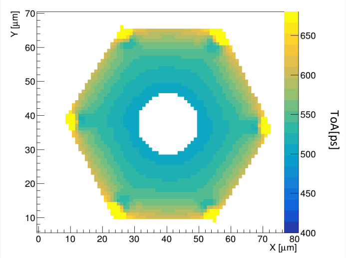
Matthew Addison

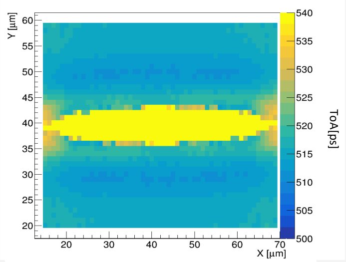
The development of high precision, fast-timing 3D silicon sensors with a focus on the high luminosity upgrades of the ATLAS detector

Matthew Addison[1], Cinzia Da Via[1], Adriano Lai[2], Gian-Franco Dalla Betta[3], Michela Garau[2], Andrea Lampis[2], Mauro Aresti[2], Alessandro Cardini[2], Angelo Loi[2], Gian Matteo Cossu[2].
1. Physics and Astronomy, The University of Manchester, UK 2. INFN, Cagliari, Italy 3. University of Trento, Trento, Italy

High luminosity upgrades at the LHC require the development of fast-timing, radiation-hard detectors. 3D silicon sensors are being development that have the capabilities to withstand the project new radiation levels of HL-LHC, and keep within the estimated required timing response of 50 ps.

At the INFN in Cagliari, position-resolved timing characterisation tests were performed on individual pixels of **hexagonal** and **trench** 3D silicon sensors. An infra-red laser was used to deposit energy equivalent to 1 MIP, with a spatial resolution of 1 µm and a custom designed fast read-out electronics chip.

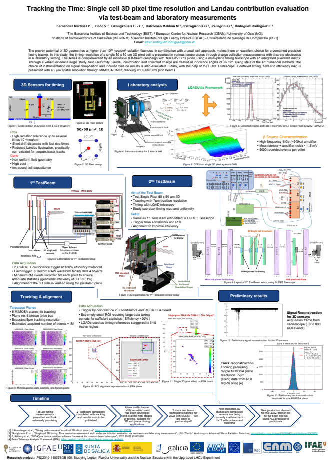




Tracking the Time: Single cell 3D pixel time resolution and Landau contribution evaluation via test-beam and laboratory measurements

- 3D Sensors for timing: Small introduction on structure and functioning
- Setup and results of a first analysis of this sensors by β source characterization
- Setup for TestBeam with timing telescope (2 LGADs) and alignment and trigger through a pixelated 3d plane (FEi4). Acquisition made with an oscilloscope for 2 single 3D pixel and 2 LGADs
- Setup for 2nd TestBeam with timing telescope (2 LGADs) and spatial EUDET telescope aiming to track with 7 μm position resolution
- Trigger with 2 scintillators and small ROI on FEi4 board to increase efficiency after alignment of 3D sensors
- EUDET Telescope has 6 MIMOSA planes (1 not working) used to achieve in preliminary results a single hit resolution ≈5 μm
- Results soon to be published
- 3 more test beam campaigns planned for 2022 with EUDET

Efren Rodriguez Rodriguez



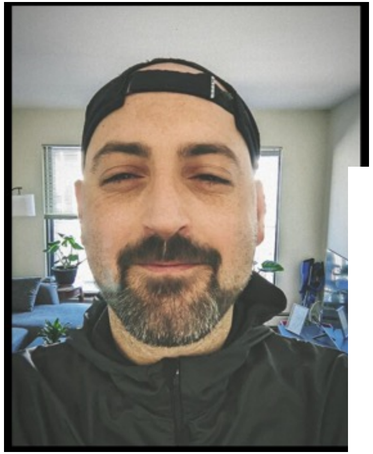
15th Pisa Meeting on Advanced Detectors

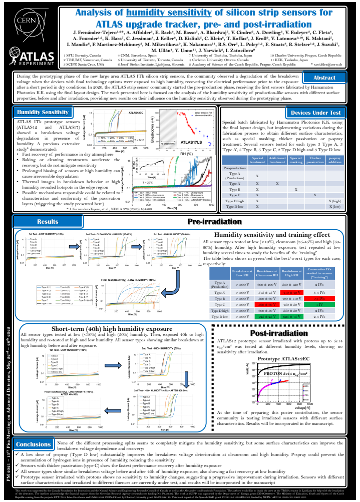
Strip Detector

Solide State Detectors
Poster Summary

22-28 May 2022
15th Pisa meeting on advanced detectors

Javier Fernandez-Tejero





Analysis of humidity sensitivity of silicon strip sensors for ATLAS upgrade tracker, pre- and post-irradiation

ABSTRACT

- During the prototyping phase of the new large area ATLAS ITk silicon strip sensors, the community observed a degradation of the breakdown voltage when the devices with final technology options were exposed to high humidity. In 2020, the ATLAS strip sensor community started the pre-production phase, receiving the first sensors fabricated by Hamamatsu Photonics K.K. using the final layout design. The work presented here is focused on the analysis of the humidity sensitivity of production-like sensors with different surface properties, before and after irradiation.

DEVICES UNDER TEST

- Special batch fabricated by Hamamatsu Photonics K.K., implementing variations during the fabrication process to obtain different surface characteristics, such as “special treatment” (Type A, production-like), “additional treatment” (Type A’), “special masking” (Type B), “thicker passivation” (Type C) and “p-spray addition” (Type D high and low). Several sensors tested for each type.

RESULTS PRE-IRRADIATION

- Humidity Sensitivity and training effect: All sensor types tested at low (<10%), cleanroom (35-45%) and high (50-60%) humidity. After high humidity exposure, test repeated at low humidity several times to study the benefits of the “training”. Type D low shows the better performance at cleanroom and high humidity. Type C the fastest recovery.
- Short-term (40h) high humidity exposure: All sensor types tested at low (<10%) and high (50%) humidity. Then, exposed 40h to high humidity and re-tested at high and low humidity. All sensor types showing similar breakdown at high humidity before and after exposure.

RESULTS POST-IRRADIATION

- Prototype sensor irradiated with protons up to 5e14 neq/cm2 was tested at different humidity levels, showing no sensitivity after irradiation.

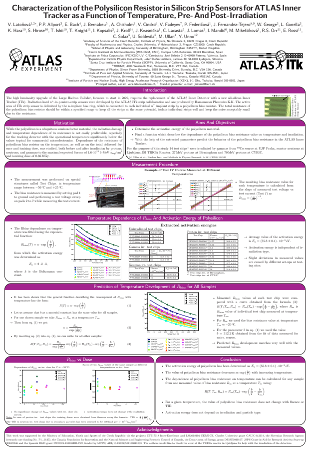
CONCLUSIONS

None of the different processing splits seems to completely mitigate the humidity sensitivity, but some surface characteristics can improve the breakdown voltage dependence and recovery:

- ✓ A low dose of p-spray (Type D low) substantially improves the breakdown voltage deterioration at cleanroom and high humidity. P-spray could prevent the accumulation of hydrogen ions in presence of humidity, reducing the sensitivity.
- ✓ Sensors with thicker passivation (Type C) show the fastest performance recovery after humidity exposure.
- ✓ All sensor types show similar breakdown voltage before and after 40h of humidity exposure, also showing a fast recovery in low RH.
- ✓ Prototype sensor irradiated with protons shows no sensitivity to humidity changes, suggesting a progressive improvement during irradiation. Sensors with different surface characteristics and irradiated to different fluences are currently under test, and results will be incorporated to the manuscript.

Characterization of the Polysilicon Resistor in Silicon Strip Sensors for ATLAS Inner Tracker as a Function of Temperature, Pre- And Post-Irradiation

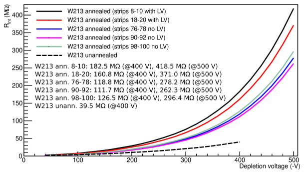
- After the high luminosity upgrade of the Large Hadron Collider, the strip part of the Inner Tracker (ITk) detector will be exposed to the total particle fluences and ionizing doses reaching the values of $1.6 \cdot 10^{15}$ $1\,\mathrm{MeV}\ \mathrm{n_{eq}/cm^2}$ and $0.66\,\mathrm{MGy}$, respectively, including a safety factor of 1.5.
- → Radiation hard n$^+$-in-p micro-strip sensors were developed by the ATLAS ITk strip collaboration and are produced by Hamamatsu Photonics K.K.
- For the purpose of this study 14 test chips were irradiated by gammas from ^{60}Co source at UJP Praha, reactor neutrons at Ljubljana JSI TRIGA Reactor, $27\,\mathrm{MeV}$ protons at Birmingham and $70\,\mathrm{MeV}$protons at CYRIC.
- Rbias dependence on temperature was fitted using the exponential function: $R_{\mathrm{bias}}(T) = a \cdot \exp\left(\frac{b}{T}\right)$, from which the activation energy was determined as $E_a = 2 \cdot k \cdot b$, where k is the Boltzmann constant.
- → Average value of the activation energy is $E_a = (55.8 \pm 0.1) \cdot 10^{-3}\,\mathrm{eV}$.
- → Activation energy does not depend on irradiation.
- Since the activation energy does not depend on irradiation, it is possible to fit all measured data using the same function by shifting it only in the direction along the initial resistance.
- Measured R_{bias} values of each test chip were compared with a curve obtained from the formula: $R(T; T_m, R_m) = R_m(T_m) \cdot \exp\left(\frac{b}{T} - \frac{b}{T_m}\right)$, where R_m is R_{bias} value of individual test chip measured at temperature T_m.
- For the parameter b we used the value $b = 312.2\,\mathrm{K}$ obtained from the fit of data measured for unirr. sensor.
- → Predicted R_{bias} development matches very well with the measured values.
- → By measuring just one R_{bias} value at certain temperature, it is possible to extrapolate R_{bias} values for other temperatures, which can be used for R_{bias} temperature normalization.
- By plotting the dependence of R_{bias} vs irr. dose, it is obvious that R_{bias} is independent of irradiation dose and particle type.

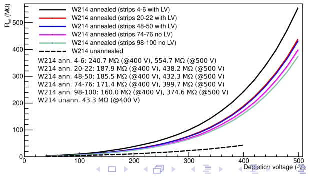


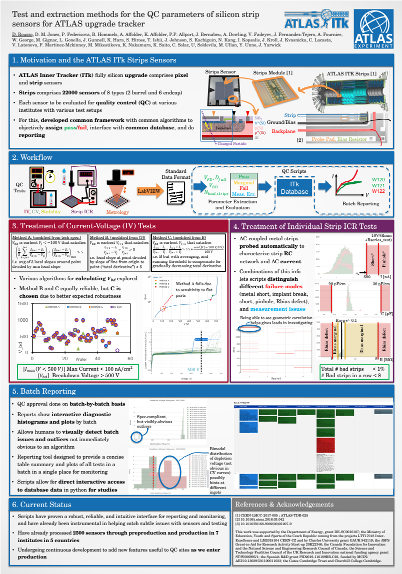
Jiri Kroll

Effect of irradiation and annealing performed with bias voltage applied across the coupling capacitors on the interstrip resistance of ATLAS ITk silicon strip sensors

- 4 ATLAS17LS miniature sensors developed by the ATLAS ITk strip collaboration were gamma irradiated by ^{60}Co source to the TID of 57.2 Mrad - samples W213 and W214 were irradiated with $V_{\mathrm{bias}} = 0.5$ V applied across their coupling capacitors.
- All irradiated samples were annealed for 80 minutes at +60°C, with the $V_{\mathrm{bias}} = 0.5$ V applied across the coupling capacitors of roughly half of the strips of samples W213 and W214 during the annealing process.
- Measured data indicates that R_{int} values of samples irradiated with V_{bias} applied over the coupling capacitors are reduced by 25% compared with samples irradiated without V_{bias}.
- Application of V_{bias} during the annealing process seems to compensate this effect - the ratio between averaged R_{int} value measured for sensor W213 (W214) and the averaged R_{int} obtained for W215 and W219 with no wire bonds is 0.90 (1.07) and 0.62 (0.87) for strips annealed with and without the V_{bias} applied across the coupling capacitors, respectively.
- The presented findings confirm our planning and viability of the sensor technology for the ATLAS ITk strip program.







Test and extraction methods for the QC parameters of silicon strip sensors for ATLAS upgrade tracker

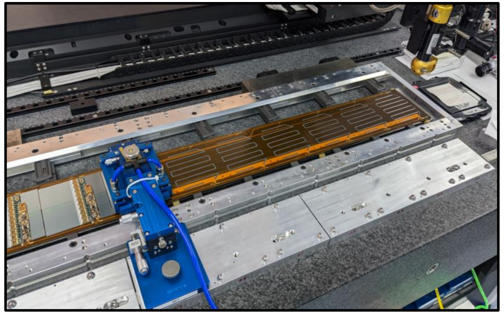
- ATLAS Inner Tracker (ITk) fully silicon upgrade includes 22000 strips sensors that all need to be evaluated for quality control (QC) at various institutes with different setups
- For this, a QC framework has been developed to take data files produced with QC tests and use algorithms to extract parameters, evaluate specification compliance, upload to a common database, and do batch reporting
- In particular, algorithms were developed to aid with the most common tests: IV, CV, individual strips, current stability, and metrology.
- For IV tests, several algorithms for determining breakdown voltage were explored and evaluated for robustness and accuracy
- For individual strip tests, particular work has gone into identifying the type of fault from various combinations of measurements of the AC metal current and the RC network
- Reporting summarizes all QC tests for a batch concisely for QC approval, which is done batch-by-batch
- Reporting gives interactive diagnostic histograms and plots by batch to allow technicians to qualitatively detect outliers or batch issues not immediately obvious to algorithms.
- Scripts have successfully processed 2500 preproduction and production sensors in 7 institutes and we are about to begin production.

Electrical Characterization of Pre-Production Staves for the ATLAS ITk Strip Detector Upgrade

Punit Sharma , on behalf of the ATLAS collaboration

ITk BARREL STAVES ASSEMBLY AT BNL

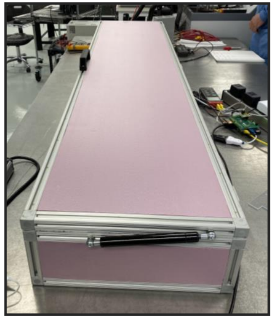
- In the assembly stage, modules are precisely glued on the stave-core while making the electrical connections at the same time.
- The first Pre-Production stave was assembled at BNL with the long strip modules with ABCStarV1.
- Mounting was only done for the side J and the mounting on the side L will be done in May.



Side J of LS stave being assembled at BNL.

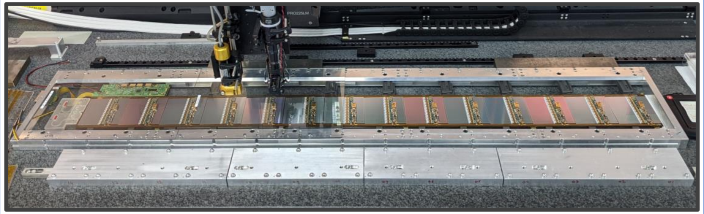
ITk BARREL STAVES TESTING SETUP AT BNL

- The Stave is tested in the coldbox which acts a Faraday cage with Relative Humidity and Temperature control.
- The EoS hosts the **Low Power Giga Bit Transceiver** (lpGBT), a radiation tolerant ASIC that is used to implement multipurpose high speed bidirectional optical links between the DAQ (Genesys or FELIX) and the front-end ASICs.
- The data from the lpGBT is decoded at the DAQ, which is then passed on to the DAQ software(ITSDAQ or YARR) for analysis



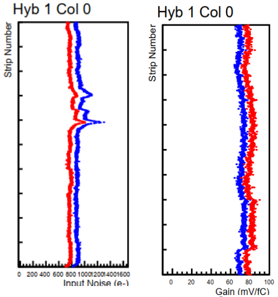
Stave Coldbox

ITk BARREL STAVES TESTING AT BNL



Electrical stave built at BNL in the early 2022 with only side J loaded

- The stave was tested at T=20C and T=-26C (temperature of the coolant at stave inlet) and V bias of -400V.
- Uniform noise performance was observed for all the modules on the side J and the testing setup did not add any additional noise.



Input Noise and gain from one of the 14 hybrids

- The noise performance over the modules on the side J was uniform. No anomalous behavior was observed.
- The side J of the stave is loaded for now, the slave side will be loaded in May 2022.
- Once finished the stave will be shipped to CERN for further testing.

Punit Sharma

ATLAS EXPERIMENT

Brookhaven National Laboratory

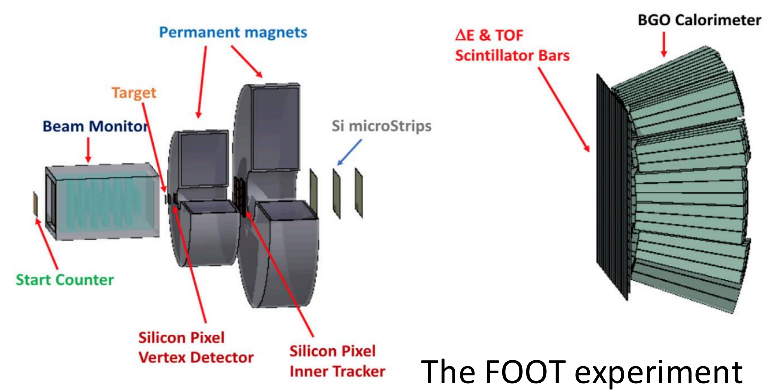
The University of Iowa

Characterization of the Microstrip Silicon Detector for the FragmentatiOn Of Target experiment

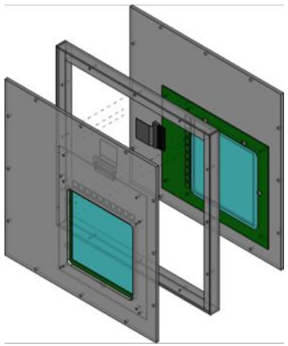
G.Silvestre[1] on behalf of FOOT Collaboration

[1]*I.N.F.N. Sez di Perugia & Università degli Studi di Perugia* ✉*gianluigi.silvestre@pg.infn.it*

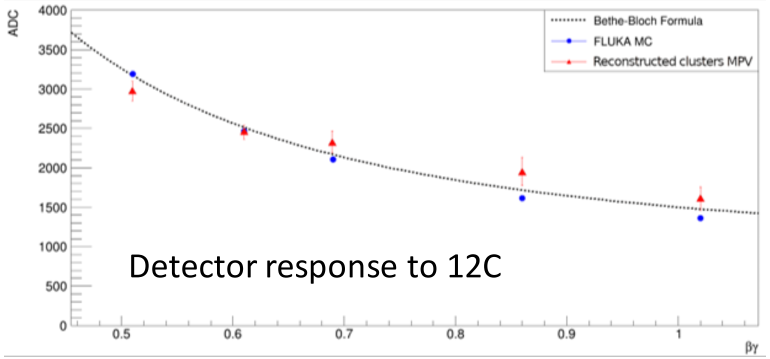
- The main objective of the *FOOT (FragmentatiOn Of Target)* experiment is the measurement of the double differential cross-sections with respect to kinetic energy and emission angle of fragments produced in nuclear interactions at energies of interest for hadrontherapy (up to 400 MeV/u).
- The *Microstrip Silicon Detector* (MSD) is the last station of the FOOT magnetic spectrometer, used to reconstruct the position of the fragments with a spatial resolution < 35μm, to match the reconstructed tracks with the downstream scintillator and calorimeter hits.
- In order to reduce the amount of material needed, two perpendicular *Single-Sided Silicon Detector* (SSSD) sensors thinned down to 150 μm are used for each MSD X-Y plane.
- The sensors produced were tested throughout the production chain first in the laboratory to ensure their correct operation. Further tests were carried out at the accelerators to test the operation of the complete setup that is used by the FOOT experiment.
- The data acquired allowed the characterization of the response of the detectors to heavy charged particles such as Carbon in terms of noise performance, signal, cluster characteristics and spatial resolution.



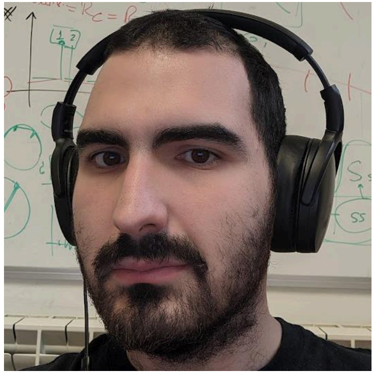
The FOOT experiment



MSD XY Assembly



Detector response to 12C



Monolithic Active Pixel Sensors

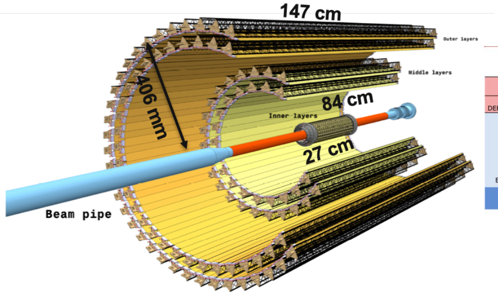
Solide State Detectors
Poster Summary

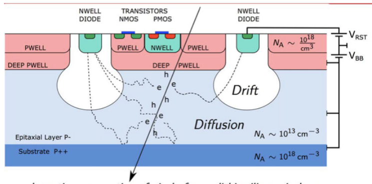
22-28 May 2022
15th Pisa meeting on advanced detectors

COMMISSIONING AND FIRST PERFORMANCE RESULTS OF THE NEW ALICE UPGRADED INNER TRACKING SYSTEM

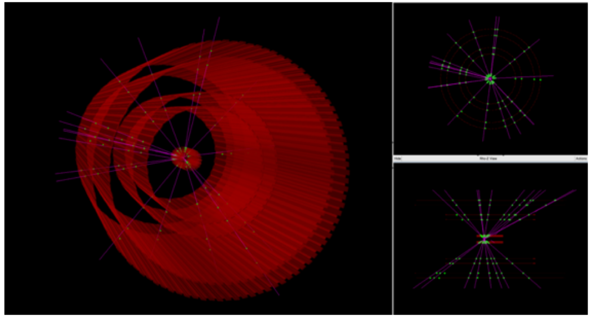
Hartmut HILLEMANNS (CERN), on behalf of the ALICE Collaboration

- ALICE is currently carrying out the final commissioning of the upgraded Inner Tracking System (ITS), a new ultralight and high-resolution silicon tracker consisting of Monolithic Active Pixel Sensors (MAPS), designed to match the requirements of the experiment in terms of material budget, readout speed and low power consumption of the sensors.
- ITS has in total 24120 ALPIDE MAPS Sensors, 12.5 Giga Pixels with 10.3 m^2 Active Surface
- Installation in the ALICE experiment during 1st half of 2021 after two years of surface commissioning
- extensive commissioning (calibration, operation, characterization and optimization at all levels of the detection chain, also during the LHC pilot beam in Oct 2021) confirms the excellent detector performance in terms of performance, stability, uniformity and noise
- ITS2 Detector Control System fully operational and integrated in ALICE DCS





schematic cross section of pixel of monolithic silicon pixel sensor



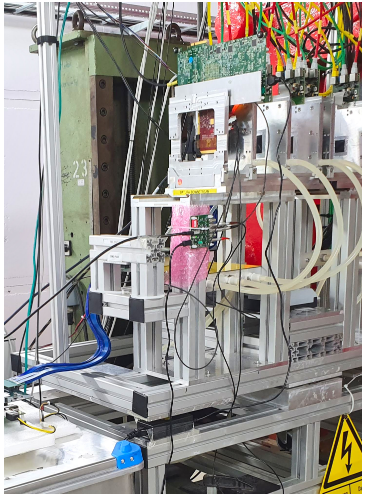
TelePix

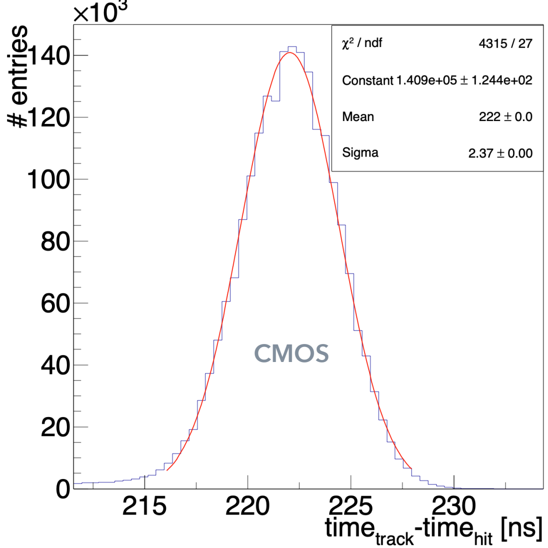
A fast region of interest trigger and timing layer for the EUDET Telescopes

Test beams require precise knowledge of spatial and temporal position of particles. Beam telescopes provide these reference ➔ At DESY with insufficient temporal precision

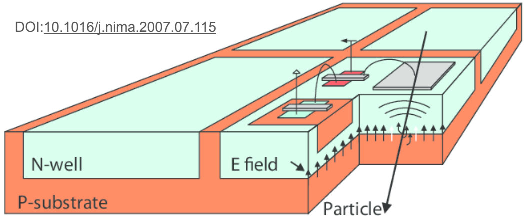
HV-MAPS to trigger on any region of interest and provide precise timing

Two TelePix prototypes in TSI 180nm are studied:
- ➔ Excellent time resolution of 2.4 ns
- ➔ High operational region with >99.9% efficiency
- ➔ Superior performance of second chips with CMOS as input transistor for amplifier, both with particles and charge injections
- ➔ Region of interest trigger with a jitter down to 3.8 ns
- ➔ All requirements for the test beam fulfilled



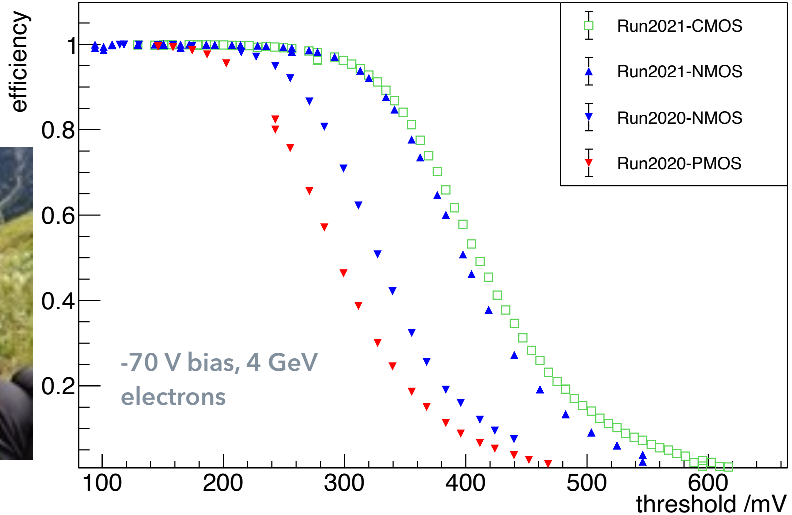


DOI:10.1016/j.nima.2007.07.115



HV-MAPS principle

lennart.huth@desy.de



MALTA monolithic CMOS pixel sensors in Tower 180 nm technology

Heinz Pernegger / CERN EP Department
Heinz.pernegger@cern.ch

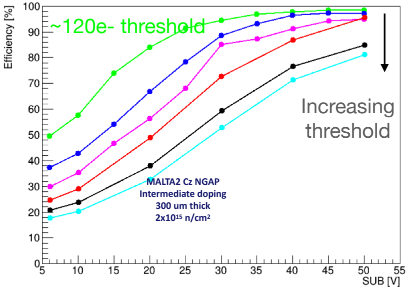
On behalf of H. Pernegger, P. Allport, I. Asensi Tortajada, D.V. Berlea, D. Bortoletto, C. Buttar, F. Dachs, V. Dao, H. Denizli, D. Dobrijevic, L. Flores Sanz de Acedo, A. Gabrielli, L. Gonella, V. Gonzalez, G. Gustavino, M. LeBlanc, K. Oyulmaz, F. Piro, P. Riedler, H. Sandaker, C. Solans, W. Snoeys, T. Suligoj, M. van Rijnbach, A. Sharma, M. Vazque Nunez, J. Weick, S. Worm, A. Zoubir

MALTA = Radiation hard small pixel CMOS sensor for tracking

MALTA sensor parameters and performance

- Pixel Pitch pixel size 36.4x36.4μm^2
- Matrix size 512 x 512 pixel (MALTA1) and 512 x 224 pixel (MALTA2)
- Asynchronous readout architecture to stream all hit data to output (trigger-less operation)
- Sensors data daisy-chain for sensors-to-sensor data transmission
- sensor thickness optimised to application 50μm to 300μm on Cz-substrate
- full efficiency (>98%) 2 x10^{15}n$_{eq}$/cm^2
- TID radiation hardness tested OK to 100Mrad
- time-resolution <2ns
- threshold after irradiation 120 e-

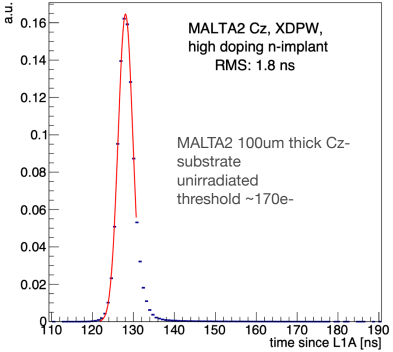
MALTA2 efficiency >98% after 2 x10^{15}n$_{eq}$/cm^2 irradiation



- Good performance of Cz samples at 2x10^{15} n/cm^2
- Expected uniformity at lowest threshold setting
- Cluster size increases with substrate voltage
  - Maximum at ~1.9 at 50 V at 120 e-
- Efficiency better than 98% at 50 V bias at 120 e-

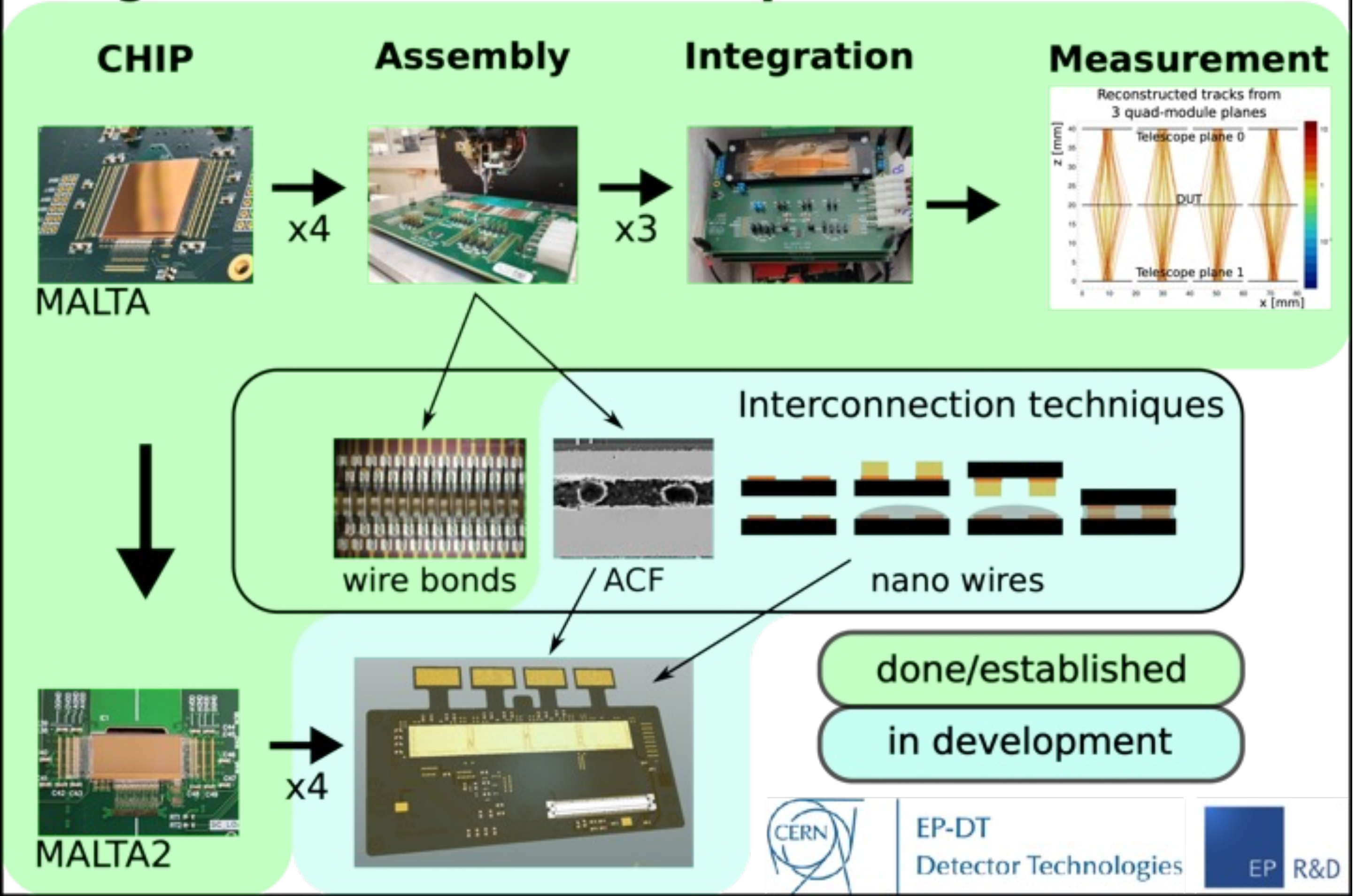
MALTA2 time resolution in beam tests ~2ns

- Time of arrival of leading hit in the cluster w.r.t. scintillator reference
  - Included scintillator jitter : 0.5 ns
  - Signal latching at FPGA: 3.125/sqrt(12) = 0.9 ns
- Timing distribution integrated on full chip after correction in X and Y direction:
  - Y correction due to time propagation across the column (linear behaviour)
  - X correction compensates for non-uniformities in chip response



CERN
University of Oxford
University of Birmingham
University of Glasgow
Bolu Abant İzzet Baysal University
UiO University of Oslo
DESY.
CSIC Consejo Superior de Investigaciones Científicas

Development of a large-area, light-weight module using the MALTA monolithic pixel detector



Florian
DACHS

MAPS-based tracking and vertexing for EIC

Giacomo Contin - *Università di Trieste and INFN Sezione di Trieste, Italy*

on behalf of the EIC Silicon Consortium and the ATHENA Collaboration

Physics goals

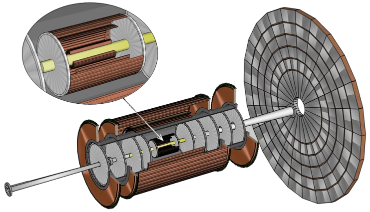
- High-precision primary vertex determination
- Secondary vertex separation capability

Detector requirements

- Spatial resolution:
  - $\leq$ 5 μm in tracking layers and disks
  - ~ 3 μm in the vertex layers
- Material budget:
  - <0.8/0.3% X/X_0 per layer/disk
  - < 0.1% X/X_0 per vertex layer
- Power consumption 20 - 40 mW/cm^2
- Integration time 2 μs

Technology choice and proposed detector layout

- **65 nm MAPS** near the interaction point complemented by MPGD technologies at larger radii
  - 3 ultra-low mass bent MAPS layers for vertexing - 0.05% X/X_0
  - 2 MAPS layers for sagitta measurements - 0.55% X/X_0
  - 6 (hadron) + 5 (electron) MAPS disks - 0.24% X/X_0



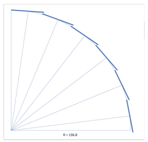
ATHENA proposal

Layers	Radius (cm)	Length (cm)
L0, L1, L2	~ 3.5 – 6.0	~ 28
L3, L4	~ 13 – 18	~ 35 – 48
Disks	**In/out R (cm)**	**z distance (cm)**
6 forward	~ 3.5 - 43	~ 25 – 165
5 backward	~ 3.5 – 43	~ 25 – 145

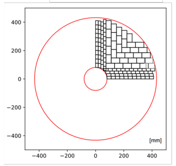
EIC Silicon R&D

- Vertex and tracking detector for EIC developed within the **EIC Silicon Consortium**
- Sensor development and characterization within the **ALICE ITS3** framework
- **Services reduction** via optimised powering and readout schemes *(eRD104 project)*
- **Detector development** *(eRD111 project)*
  - Module concept: adapt size and integrate in light support/bus
  - Stave and disk concepts: segmentation for high yield, low cost, max coverage
  - Mechanics and Cooling: air cooling on carbon foam

L3 segmentation options: 2-reticle wide sensors

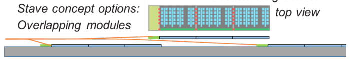


disk tiling options: 2 module variants



Stave concept options: Overlapping modules

3-reticle long sensor top view



Conclusions

- EIC Vertex/Tracker proposed by ATHENA
- Based on 65 nm CMOS stitched sensor
  - Developed for the ALICE ITS3 project
  - Will be adapted to EIC needs
- R&D for Module, Stave, Disk is progressing
- Novel solutions studied for readout/powering

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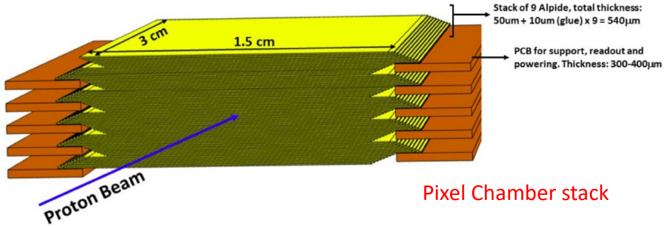
Pixel Chamber: a solid-state active-target for 3D imaging of charm and beauty

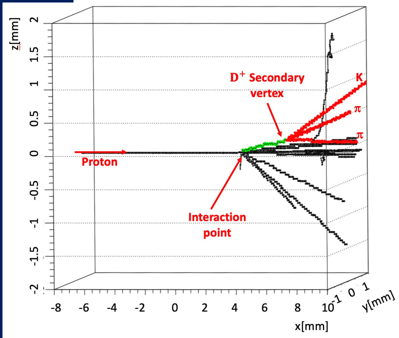
A. Mulliri, M. Arba, P. Bhattacharya, E. Casula, C. Cicalò, A. De Falco, F. Fionda, M. Mager, D. Marras, A. Masoni, L. Musa, S. Siddhanta, M. Tuveri, G. Usai

Pixel Chamber is conceived to be the **first bubble chamber-like high-granularity active target** based on silicon pixel sensors, capable to perform **continuous, high-resolution (O(µm)) three-dimensional tracking**.

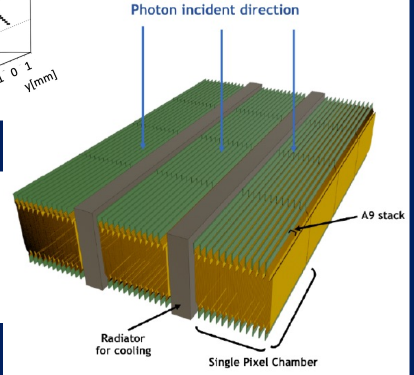
- Pixel Chamber will be a stack of 216 ALPIDE sensors: a **matrix of ~10^8 pixels**
  - R&D towards prototypes construction is ongoing. The **first stack of 3 APLPIDE has been produced**
- Numerical simulations were developed and validated in laboratory to **study cooling solutions**
- **High precision reconstruction of proton-silicon interactions** performed with tracking and vertexing algorithms specifically developed for Pixel Chamber
- Applications and future developments:
  - Pixel Chamber used as fixed target coupled to a silicon telescope: **Charm and beauty cross section measurement at CERN SPS**
  - Pixel Chamber used as scatterer in a Compton camera: the precision of the gamma source position measured with a Compton camera is determined by the number of gammas detected. Pixel Chamber has the potential to reconstruct recoiled electrons tracks with very high precision → **can reduce the number of gamma required for the reconstruction** → applications in astrophysics and for fast online imaging in hadron therapy
  - development of the **first three-dimensional stack with large area monolithic pixel sensors** ever built using large area (stitched) monolithic pixel sensors



Pixel Chamber stack



Proton-silicon interaction inside Pixel Chamber



Assembly of multiple Pixel Chambers to obtain a Compton camera scatterer

High dynamic range radiation detector

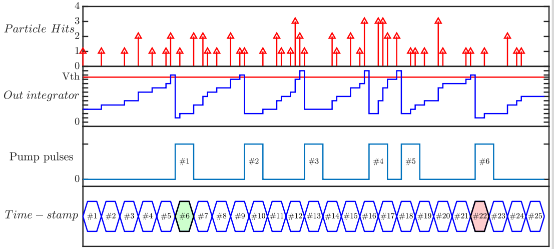
H. Mateos, I. Perić, F. Ehrler, R. Schimassek

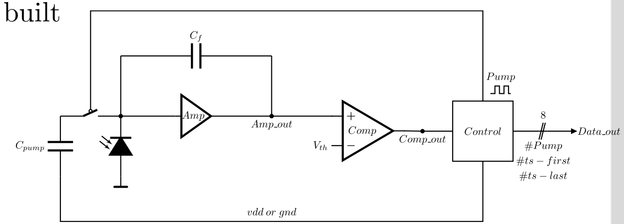
Karlsruhe Institute of Technology

The chip was designed to be used in cancer treatment facilities, for Quality Assurance as well as for monitoring of the beam during irradiation.

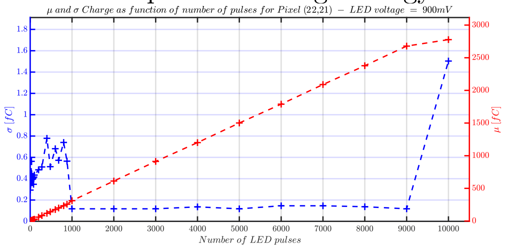
The sensor integrates the charge generated by radiation. By counting how many times a known amount of charge is subtracted out of the integrator and the time difference between the first and last pump, the charge generated by the particle is calculated, and thus the energy of it.

A matrix of 24x24 pixels, with a pixel size of 200x200 µm was built with an 80% of fill factor.





- The sensor presents a linear response along the whole dynamic range.
- It shows a noise floor of 0.8 fC, equivalent to 5000e-, which decrease to 0.1 fC or 620e- at higher intensities.
- Because the system is based on a discharge pump counter, the integrator will not be saturated, which makes possible to measure particles of high energy.



Future improvements:

- Different discharge capacitor sizes.
- Different capacitor voltage.
- Bigger counters.
- Bigger matrix size.
- Read while measuring.
- Other technology to achieve higher fill factor

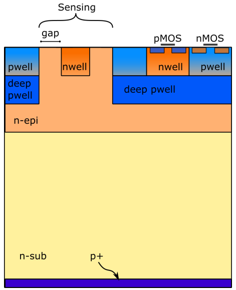
Horacio MATEOS

ARCADIA FD-MAPS: simulation, characterization and perspectives for high resolution timing applications

Coralie Neubüser* on behalf of the ARCADIA collaboration
*INFN-TIFPA, Trento Italy. Email: coralie.neubueser@tifpa.infn.it

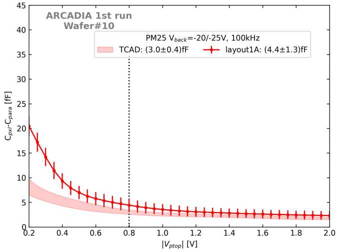
ARCADIA

Advanced Readout CMOS Architectures with Depleted Integrated sensor Arrays



Fully depleted substrate at low front bias → charge collection via drift

- n-in-n device
- pn-junction on backside
- depletion voltage applied through backside, only low bias voltage from top
- low-resistive epi layer delays the onset punch-through currents
- backside processing (diode + GR) for thick sensors (> 100μm)

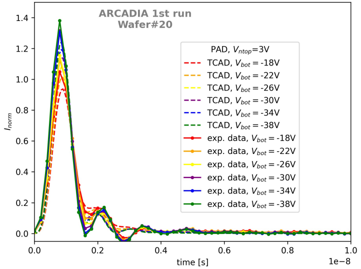


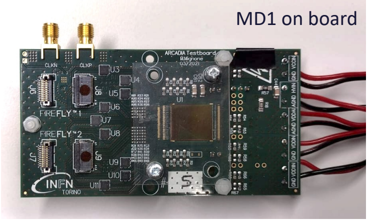
Focused IR laser, 1GHz bandwidth oscilloscope on $(500\times500)\mu m^2$ pad

- Strong impact of 1GHz oscilloscope, well reproduced in simulation with digital low pass filter
- 95% charge collection in < 1.4ns in d_{Si}=50µm

Variety of passive pixel matrices

- Tests of pixels with (10/25/50)μm pitch from different wafers in different thicknesses (50/100/200)μm
- Capacitance of single pixel of MD1 found < 5fF





Main demonstrator (MD1) chip of (1.2×1.2)cm² with 512×512 fully depleted monolithic pixels with 25μm pitch.

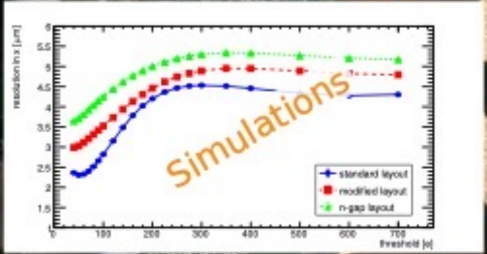
Ongoing development of MAPS for timing:

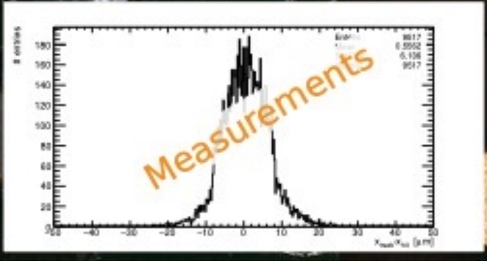
- Pad-like MAPs in 50µm pitch for chip implemented in 2nd run
  - *new large pixels including a charge multiplication layer*

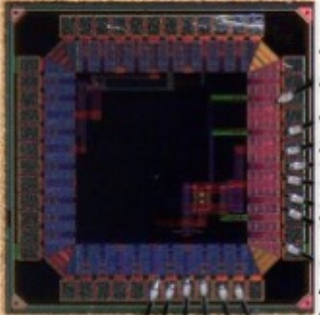
Towards a New Generation of Monolithic Active Pixel Sensors

Finn
FEINDT

The TANGERINE project – MAPS in a 65 nm CMOS Imaging Process







Project Goals

- Spatial resolution: 3 um
- Temporal resolution: 10 ns
- Thickness: < 50 um
- In-pixel charge measurement (time-over-threshold)
- Exploit/ explore capabilities for in-pixel logic

Application

- Beam-line instrumentation at DESY
- Future lepton collider/ Higgs factory

Simulation

- TCAD simulations based on generic doping profiles for detailed electric fields
- Allpix2 simulations to make predictions of sensor performance

Measurements

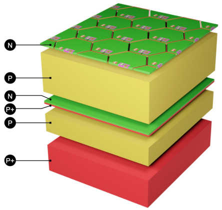
- First test chip investigated at DESY II, CERN PS and MAMI microtron
- Investigated charge sensitive amplifier and sensor performance
- First successful operation of a 65 nm CMOS sensor developed at DESY

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département de physique nucléaire et corpusculaire

MONOLITH - Picosecond Time Stamping Capabilities In Fully Monolithic Highly Granular Silicon Pixel Detectors

European Research Council
Established by the European Commission
ATTRACT

Matteo Milanesio on behalf of the MONOLITH team

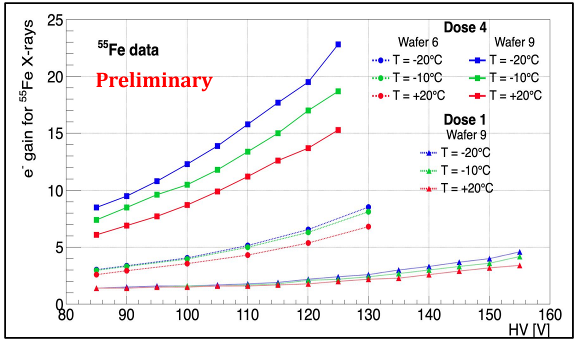


Aim at producing a monolithic silicon pixel ASIC with **picosecond-level time stamping**:

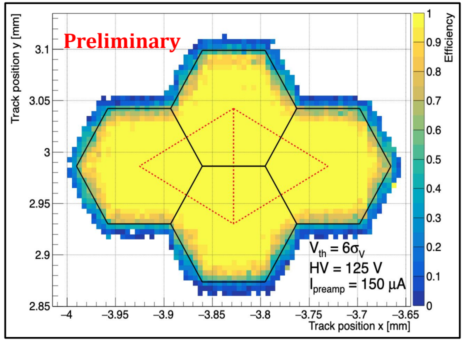
- fast and low-noise SiGe BiCMOS electronics
- novel sensor concept, the **Picosecond Avalanche Detector** (PicoAD)

Proof-of-concept of PicoAD sensor (not yet optimized for timing) and HBT frontend:

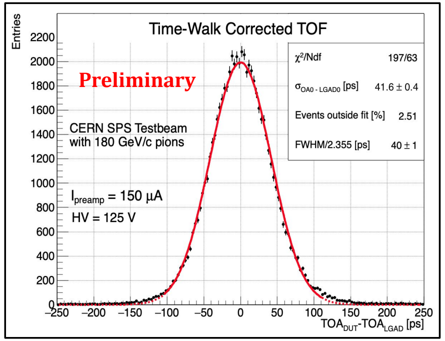
gain for ^{55}Fe X-rays of up to 23



efficiency **> 99.5 %**



time resolution **σ_t = (20.1±0.3) ps**



LGAD

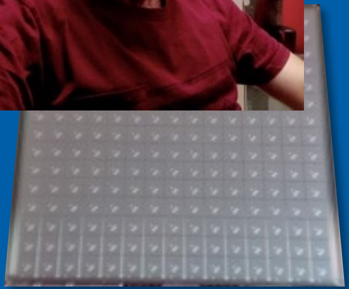
Solide State Detectors
Poster Summary

22-28 May 2022
15th Pisa meeting on advanced detectors

G. Paternoster
Fondazione Bruno Kessler

FONDAZIONE BRUNO KESSLER

Low Gain Avalanche Diodes Technology: state of the art and new developments



LGAD: silicon detector with low internal gain, featuring high concurrent space and time resolution, also at high irradiation fluence

Higher spatial resolution

new developments

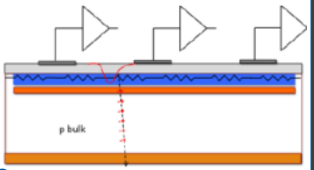
Radiation hardening

1. Trench-isolated LGAD (TI-LGAD)

Pixel pitch down to 50 µm with high fill-factor.

2. AC- and DC- resistive Silicon Detectors (RSD)

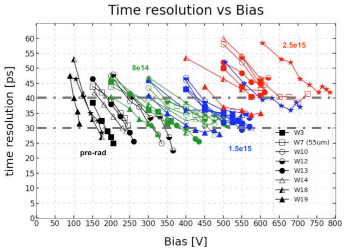
100% fill-factor
Spatial resolution ~ 10um (sigma) even with coarse pads



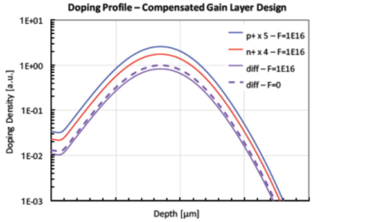
3. LGAD for CMS-ETL and ATLAS-HGTD

Carbon-co-implantation ->

30 ps at 1.5e15 neq/cm²

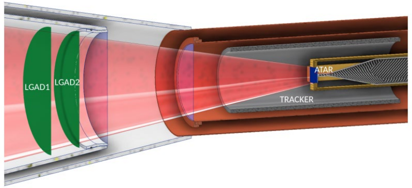


4. Extreme fluence

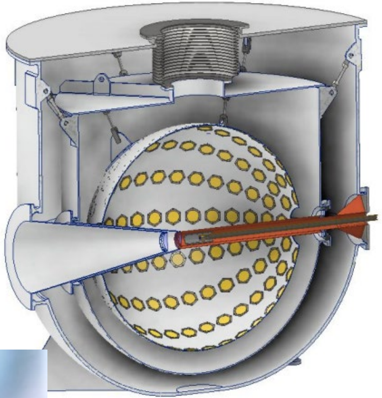


- **n/p co-doping for radiation hardening beyond 2e15 neq/cm²**

A fully active target for the PIONEER experiment



- **PIONEER** is the "successor" of PIENU/PEN/PiBeta experiments
  - https://arxiv.org/abs/2203.01981
- The goal is to **improve the precision of** $\mathbf{R_{e/\mu}}$ and $\mathbf{B(\pi^+ \rightarrow \pi^0 e^+ \nu)}$ by an order of magnitude
  - $\mathbf{R_{e/\mu}}$ is the ratio of pion decay to electron/muon: precision measurement of **lepton flavor universality**
  - $\mathbf{B(\pi^+ \rightarrow \pi^0 e^+ \nu)}$ is the cleanest measurement of Vud: important to test **CKM matrix unitarity**
- PIONEER will take place at the Paul Scherrer Institut (PSI) cyclotron ring



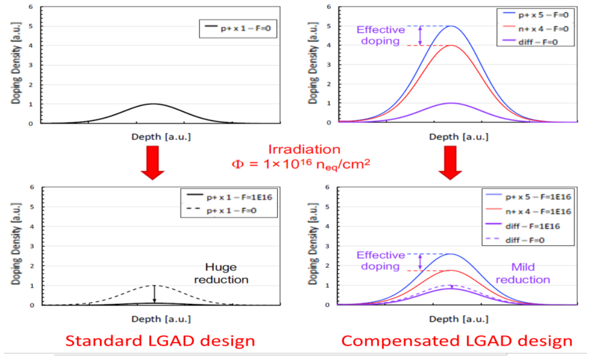
- **The Goal of PIONEER is the separation of deposited energy spectra of $\pi \rightarrow e\nu$ and $\pi \rightarrow \mu\nu \rightarrow e\nu\nu$**
  - Pions stops in an active target where are tagged with energy and timing
  - Exiting positrons are tracked and the total energy is measured in a 3π calorimeter
- **Two main detectors**: Active TARget (ATAR) and 25 X_0 calorimeter
  - **ATAR with fast timing and high segmentation allows to separate and tag $\pi \rightarrow e\nu$ and $\pi \rightarrow \mu\nu \rightarrow e\nu\nu$** this reduces pileup and $\pi \rightarrow e\nu$ energy tail
  - **Calorimeter** with high energy resolution (**liquid Xe** or LSO crystals) to reduce tail correction and pile-up uncertainties, plus improves uniformity
- In the poster a brief introduction to PIONEER is given, then a more detailed explanation of the ATAR and the chosen technology is shown.

Development and test of innovative Low-Gain Avalanche Diodes for particle tracking in 4 dimensions

T. Croci(*), on behalf of the "4DInSiDe" collaboration

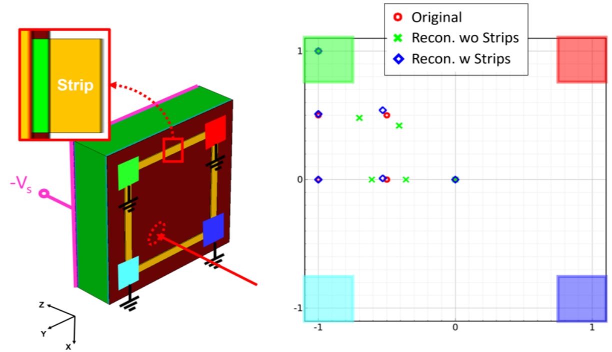
Developing innovative radiation-hard silicon detectors for 4D particle tracking in the future HEP experiments

A compensated design of the LGAD gain layer



- New strategy to overcome the present limit of radiation tolerance for the gain implant, i.e. 1-2×10^{15} n_{eq}/cm^2.
- Use the interplay between radiation induced acceptor and donor removal to keep a roughly constant gain layer active doping density after irradiation.

DC-coupled Resistive Silicon Detectors (DC-RSD)

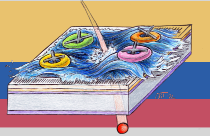


- DC-RSD with low resistivity strip between collecting pads, as an evolution of the RSD paradigm [1].
- Addressing few known issues (e.g. baseline fluctuation, long tail-bipolar signals) and maintaining the advantages (e.g. signal spreading over ~mm distances, 100% fill factor).

[1] M. Tornago *et al.*, 2020 IEEE NSS/MIC

(*) tommaso.croci@pg.infn.it

Silicon sensors with resistive read-out: ML and analytics techniques for ultimate spatial resolution



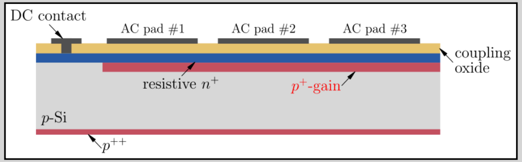
Marta Tornago

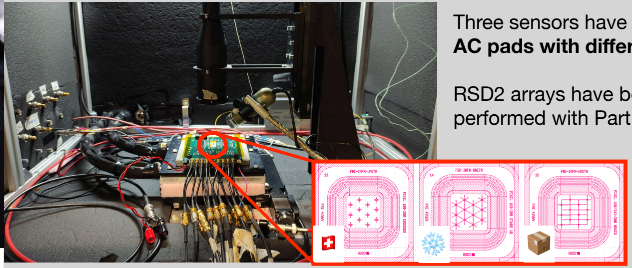
Università and INFN Torino

Resistive AC-coupled Silicon Detectors (RSD) are a new generation of n-in-p silicon sensors with 100% fill-factor designed for high-precision 4D tracking in experiments at future colliders

Key feature: **introduction of resistive read-out in silicon detectors**

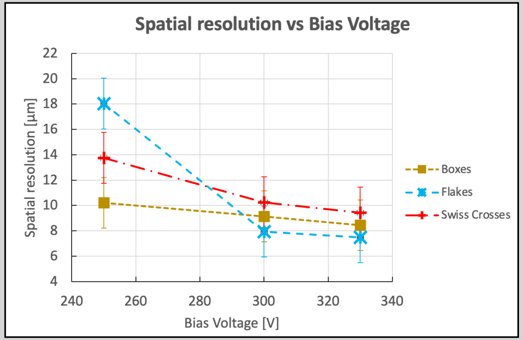
→ **signal sharing** allowing **excellent spatial resolution**





Three sensors have been selected from the **second RSD production**: 700x700 µm active area, 200 µm pitch and 3x4 **AC pads with different layouts** (Swiss crosses, flakes and boxes)

RSD2 arrays have been tested in the **Laboratory for Innovative Silicon Sensors** in **Torino** with precise **laser scans** performed with Particulars **Transient Current Technique setup** for spatial resolution evaluation



Signal properties are used for **position reconstruction** of laser shots

→ **Machine Learning is ideal for data analysis,** with signal properties used as input features and predicted x-y coordinates as outputs

200-µm pitch RSDs can reach a total spatial resolution $\sigma_{\text{tot}} = \sqrt{\sigma^2_{\text{RSD,x}} + \sigma^2_{\text{RSD,y}}}$ ~ 8 µm

→ **Much smaller than corresponding binary readout pitch/$\sqrt{12}$ ~ 58 µm**

Techno-Mix

Solide State Detectors
Poster Summary

22-28 May 2022
15th Pisa meeting on advanced detectors

Diamond detector's response to intense high-energy electron pulses

15th Pisa Meeting on Advanced Detectors, La Biodola, Isola d'Elba, Italy, 22-28 May 2022

A. Gabrielli [2,3], **S. Bassanese**[1], **L. Bosisio**[2], **G. Cautero**[1,2], **S. Di Mitri**[1,3], **M. Ferianis** [1], **D. Giuressi**[1,2], **Y. Jin**[2], **L. Lanceri**[2], **M.Marich**[1,2], **R. H. Menk**[1,2,4], **G. Perosa**[1,3], **L.Vitale**[2,3]

[1] Elettra Sincrotrone Trieste SCpA, [2] INFN-Sezione di Trieste, [3] Università di Trieste, [4] University of Saskatchewan

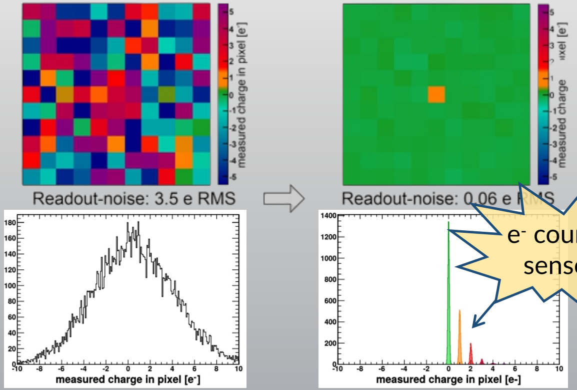
- Owing to their excellent radiation hardness, diamond crystals have been widely used as solid-state particle detectors, beam loss monitors and dosimeters in high-radiation environments;
- Our diamond sensors are characterised using different radiation sources, and all the procedures are validated using a silicon diode as a reference. The calibration with two different radiation sources (β and X) covers a dose rate range from hundreds of nrad/s to tens of rad/s;
- To study the transient response of diamond detectors, we designed an experimental setup that uses a collimated, sub-picosecond, 1 GeV electron beam, with a bunch charge of tens of pC, provided by the FERMI electron linac in Trieste;
- We interpret the experimental results with a two-step numerical approach (TCAD + LTspice), validated using TCT measurements;
- The diamond sensors show a predictable response to these high intensity electron bunches. Measurements and preliminary simulations are in fair agreement, assuming that diamond resistance changes as a function of the charge carrier density in the diamond bulk.

Skipper-CCDs: current applications and future

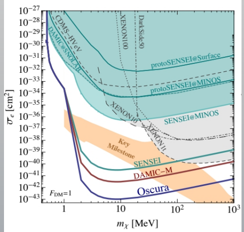
Brenda Aurea CERVANTES VERGARA

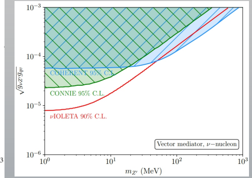
Standard CCD
(charge in each pixel is measured once)

Skipper CCD
(charge in each pixel is measured N times)



- Direct DM searches
(world-leading results with ~2g!)
- CEνNS
(competitive constraining BSM physics)
- Astronomy
- Quantum imaging





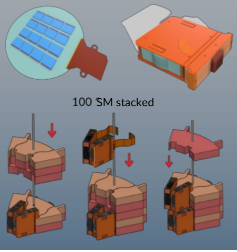
Current experiments are g-size

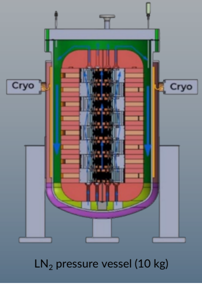
To push for better sensitivities we need to go BIGGER!

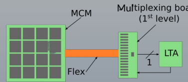
↓

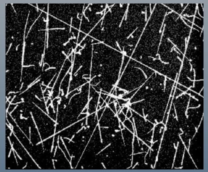
NEW CHALLENGES

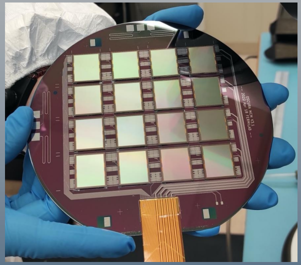
Efforts towards multi-kg skipper-CCD experiments ongoing showing GREAT results!

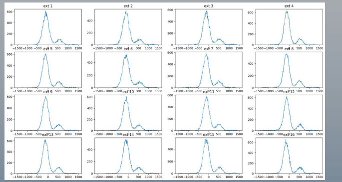










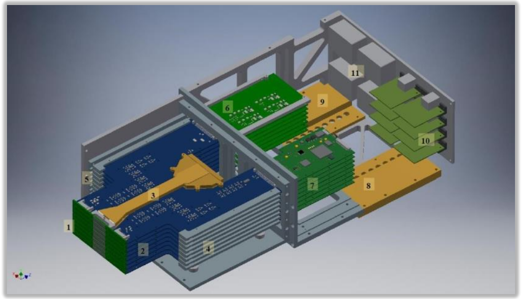


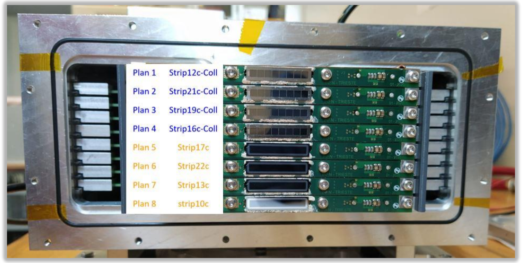
STAY TUNED!

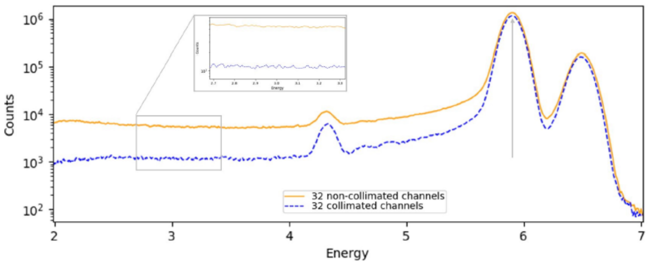
A new collimated multichannel modular detection system based on Silicon Drift Detectors

D. Cirrincione[1,2], M. Antonelli[1], G. Aquilanti[3], P. Bellutti[4,5], G. Bertuccio[6,7], G. Borghi[4,5], G. Cautero[3,1], F. Ficorella[4,5], M. Gandola[4], D. Giuressi[3], F. Mele[6,7], R. H. Menk[3,1], L. Olivi[3,1], G. Orzan[1], G. Pepponi[4], A. Picciotto[4,5], A. Rachevski[1], I. Rashevskaya[5], L. Stebel[3], G. Zampa[1], N. Zampa[1], N. Zorzi[4,5] and A. Vacchi[1,2]

1 - INFN Trieste, Trieste, Italy - 2 - University of Udine, Udine, Italy - 3 - Elettra-Sincrotrone Trieste S.C.p.A., Trieste, Italy – 4 - Fondazione Bruno Kessler, Trento, Italy - 5 - TIFPA - INFN, Trento, Italy - 6 - Politecnico di Milano, Como, Italy - 7 - INFN Milano, Milano, Italy







Intermediate test to compare system characteristics with collimated / non collimated sensors.

The mildly collimated part of the system shows better performance: in particular the peak to background ratio is 4 times better.

	32 collimated channels	32 non-collimated channels
Part of the detector system	top	bottom
Average temperature of the sensors	23 °C	23 °C
FWHM at the Mn 5.9 Kα line	174 eV	178 eV
Best channel - FWHM	159 eV	166 eV
Worst channel - FWHM	199 eV	211 eV
Acquisition time	30 min	30 min
Counts	23,01 M	29,79 M
Peak to background ratio	972	243

After this test, the remaining sensors were collimated and the entire system was optimized, highlighting the improvement in performance.

SDDs for high-rate and high-resolution electron spectroscopy

A.Nava, M.Biassoni, S.Pozzi, M.Carminati - 15th Pisa Meeting on Advanced Detectors

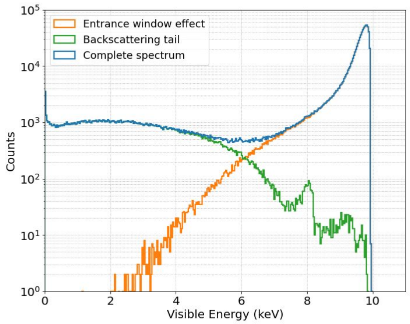
SDDs are fast detectors with an energy resolution close to Fano limit in Silicon→ used for X-ray spectroscopy

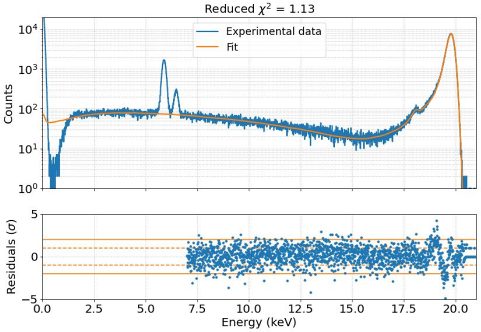
Electron spectroscopy is challanging → electrons can be backscattered and lose energy in the SDDs dead layer

- We have developed a model by combining a **Geant4 Montecarlo simulation** with an empirical description for the dead layer
- This model has been tested by fitting monochromatic and collimated electron spectra from a SEM, finding a good agreement

Applications:

- **Sterile neutrino search with KATRIN** → a fast and high-resolution detector is needed to measure the entire Tritium β spectrum searching for a kink
- **Validation of nuclear models** → forbidden β spectra are sensible to the used nuclear model as well as to the chosen g_A value



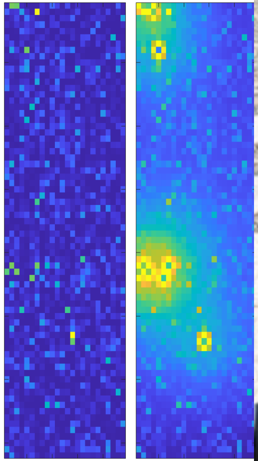


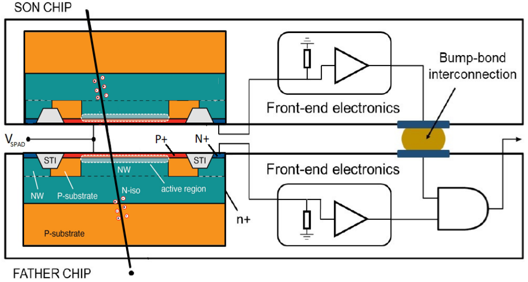
Istituto Nazionale di Fisica Nucleare

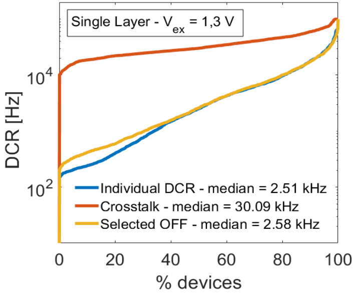
UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

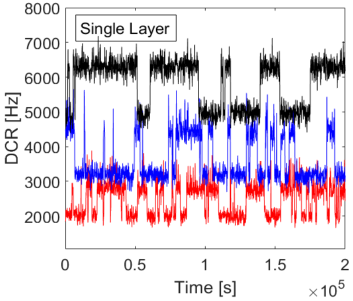
DCR and crosstalk characterization of a bi-layered 24×72 CMOS SPAD array for charged particle detection

- Two chips of **Single Photon Avalanche Diodes** (SPADs), fabricated in 150 nm CMOS technology, were vertically interconnected by means of bump bonding technique, to make up a **dual layer** structure, aiming low noise and reduced material budget, in view of applications to charged particle tracking.
- An array of 24×72 SPADs, with an active area of 44×24 μm^2 was characterized in terms of **dark count rate (DCR)** and **crosstalk**. DCR measurements performed on both single and dual layer chips have demonstrated the beneficial impact of a bi-layer structure.
- From crosstalk measurements, significative DCR degradation, mainly due to a set of 9 particularly noisy pixels, was observed. The **screamer** pixels were found to affect mostly the DCR of adjacent sensors, since emitted photons are more likely to be absorbed in the closer SPADs as compared to the farther ones.
- **RTS** measurements were performed at different excess voltages, with a period of 115 s for a total amount of time equal to 23 days. Two-level, three-level and four-level fluctuations were observed.









Gianmarco TORILLA

INFN Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ DI PAVIA

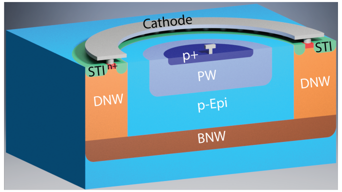
Direct MIP detection with sub-10 ps timing resolution Geiger-Mode APDs

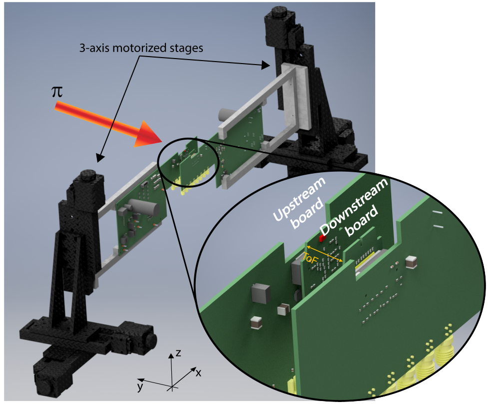
Francesco Gramuglia, **Emanuele Ripiccini**, Carlo Alberto Fenoglio, Ming-Lo Wu, Lorenzo Paolozzi, Claudio Bruschini and Edoardo Charbon

École polytechnique fédérale de Lausanne (EPFL)

Direct MIP detection with SPAD implemented in 180 nm CMOS technology

- Device presentation
- Timing performance with photons
- MIP time of flight measurements
- Radiation hardness studies
- Future developments





Bias (V)	FWHM (ps)	FWTM (ps)	σ (ps)	σ_{single} (ps)
24	27 ± 1	104 ± 4	11.5 ± 0.4	8.1 ± 0.3
27	22 ± 2	62 ± 3	9.4 ± 0.7	**6.4 ± 0.5**

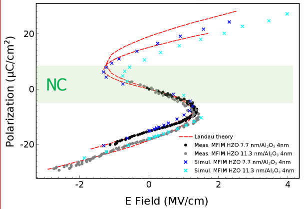
Negative Capacitance Ferroelectric Devices for Radiation Detection Applications

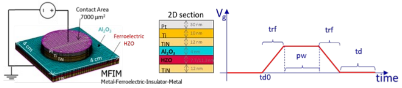
This work was financed by the INFN-CSN5, under INFN Young Researcher Grant "NegHEP".

A. Morozzi[1*] on behalf of the NegHEP Collaboration
(1) INFN of Perugia, via Pascoli 1, 06123 Perugia, Italy.
* arianna.morozzi@pg.infn.it

- ✓ Negative Capacitance (NC) devices in particle detection systems featuring self-amplified, segmented, high-granularity sensors.
- ✓ TCAD modeling to optimize the design/operations of the new generation NC-FET devices.
- ✓ Radiation damage effects evaluation after X-ray irradiation.

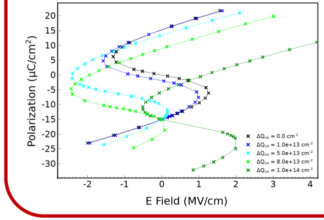
*TCAD modeling of **MFIM** structures*





- ✓ TCAD GLK equation
- ✓ Measured and simulated Polarization-E_f curves for a MFIM structure 4 nm Al_2O_3 over HZO 7.7 and 11.3 nm.

Radiation Damage Effects

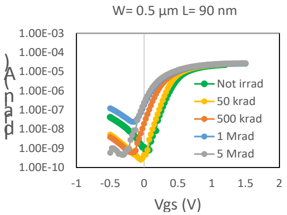


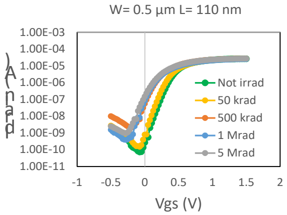
Surface damage effects induced by **X-rays** have been accounted for with the parameter ΔQint(ϕ) in the overall fixed oxide formula:

$$Q_{int}(\phi) = Qint(0) + \Delta Qint(\phi)$$

Negative Capacitance FET

- ✓ Ultra-thin HfO_2-based **n-channel NC-FETs** featuring different W/L characteristics.
- ✓ I_{ds}-V_{gs} transfer characteristics for different W/L options.
- ✓ X-ray irradiation campaign at INFN Genova up to 5 Mrad.
- ✓ Method proposed by McWhorter to assess the oxide charge and interface traps from the subthreshold-current curve of a MOSFET in saturation.





Daniele PASSERI

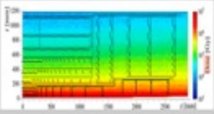
PM2021
2022

Study of p-type silicon MOS, GCD and FET structures irradiated with a ^{60}Co gamma source at HL-LHC radiation levels and TCAD simulations.

P. Assiouras, I. Kazas, A. Kyriakis, D. Loukas

NATIONAL CENTRE FOR SCIENTIFIC RESEARCH "DEMOKRITOS"

- Irradiation studies with C-60 gamma photons (~ 100 kGy). Comparable with the radiation exposure of Outer Tracker layers of ATLAS/CMS at HL-LHC.

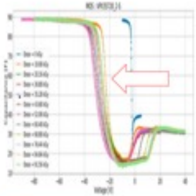


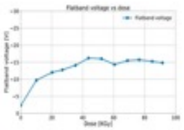
- Picker therapy unit used as Co-60 source
  - Dose rate = 0.96 kGy/h
  - During irradiation, the samples were cooled down to (at8±0.5 ◦ C)

- Automatic probe station (Carl Suss PA 150) for electrical characterization of microelectronic devices
- Environmental conditions are constantly monitored:
  - Relative humidity < 30%
  - Temperature fixed at 20 ◦ C

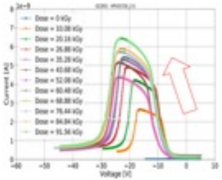
- Test structures fabricated on 6" wafers; thinned at 290 μm produced by Hamamatcu
- Each test structure contains among others a MOS, GCD and FET
- Measurement configuration:
  - MOS capacitor: oscillation level = 250 mV, frequency = 10 kHz, waiting time = 0.5s
  - GCD: diode bias varying from -5 to -11 V, waiting time = 0.5s
  - FET: V_{DS} 100 mV, waiting time = 0.5s

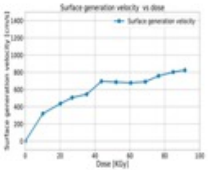
- MOS: The flatband voltage ($V_{fb} \propto N_{ox}$) shifts to higher absolute values with due to the increase of the effective oxide concentration
  - Clear evidence of positive charge induced in the oxide of the MOS capacitor after exposure to gamma photons





- GCD: Increase of surface generation current due to radiation-induced defects in the interface
  - Surface generation velocity (S_0) and surface current (I_s) increase with total irradiation dose ($S_0 \propto D_{it}$)





- FET: Shift of the slope of the IV curve
  - Threshold voltage almost stable. Good quality of channel isolation
  - Mobility degradation due to charged trapped close to the interface
  - Maximum tranconductance decreased, due to reduction in mobility+++