Semiconductor detectors @ LAL

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Outline

- Silicon planar pixel sensors
  - High energy physics - ATLAS @ HL-LHC
- Diamond sensors
  - Accelerator physics - ATF2
- Silicon Photomultiplier sensors (SiPM)
  - Tool for semiconductor physics (i.e. avalanche, defects)
  - Applications:
    - Medical imaging
    - High energy physics

summary

R&D ATLAS pixel LAL

UNIVERSITÉ PARIS SUD
Comprendre le monde, construire l'avenir®

R&D Activity Pixel detectors

SESAME îledeFrance Labex P2IO

CAPTINOV

- New Equipement : Creation of an infrastructure for mesurementss, tests caractérization
- Comprehension of radiation dommages: partenarship with solid state specialists: IEF, CNRS Versailles
- Developpement of close relations with funderies in Europe (Cis Allemagne, VTT : Finlande)

TCAD simulation

- TCAD : Conception of new architectures to increase Pixels efficiency

  (active géometry)
- Study theoretical models théoriques of radiation dammages of material ; suggest new solutions

RD50

LAL+ LPNHE+OMEGA

Readout Electronics

ANR VITESSE BLANC

- Launch activity in Electronics submicronic CMOS 130 nm Projet 3D
- Implication in 65 nm : electronics for HL-LHC 65 nm

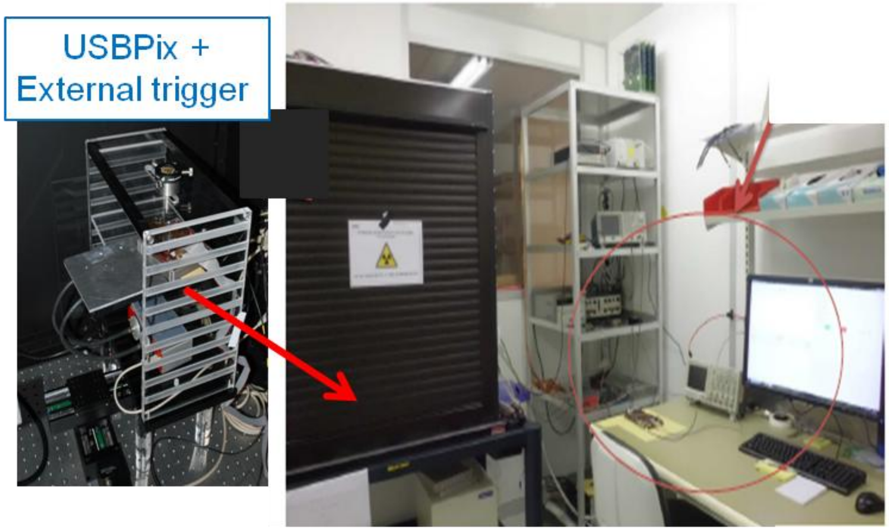
RD53 ?

LAL LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

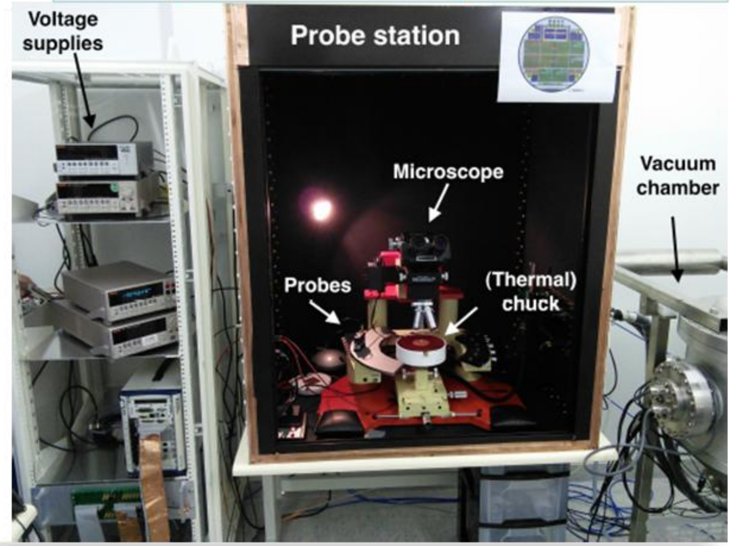
Experimental tools for sensors characterization (1)

Old ATLAS clean-room – class 100000, 12 m²

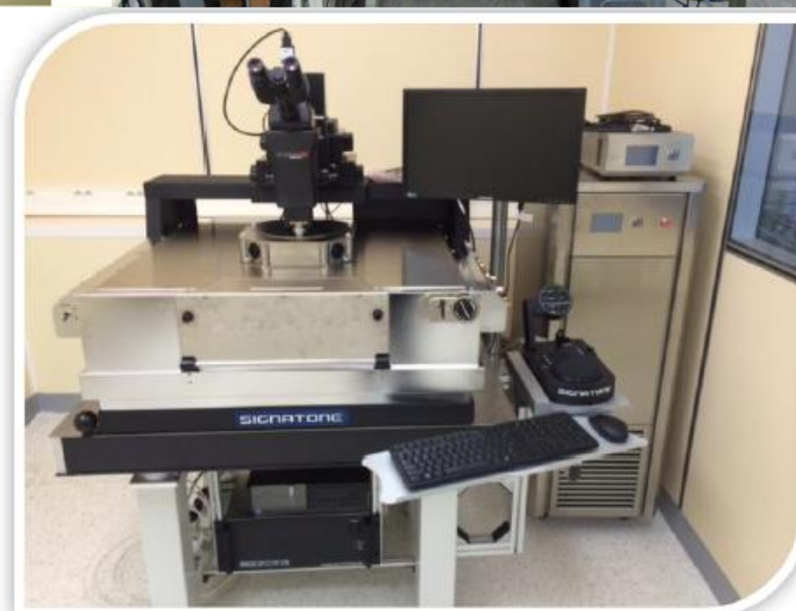
Set-up for CCE tests of pixel sensors



Set-up for DC tests of pixel sensors



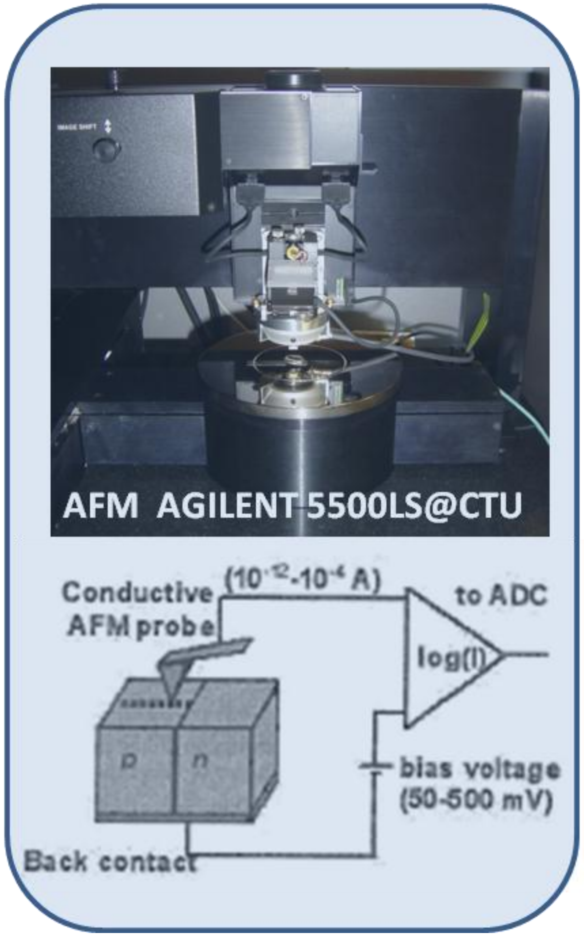
New clean-room at LAL, class 10000, 100 m²
equipped with a semi-automatic probe-station
(R. Cornat, P2IO – CAPTINOV project)



Experimental tools for sensors characterization (2)

Collaborations with GEMAC and CTU-IEF laboratories for doping profiles characterizations

SIMS at GEMaC laboratory, Versailles
Cameca IMS 7F

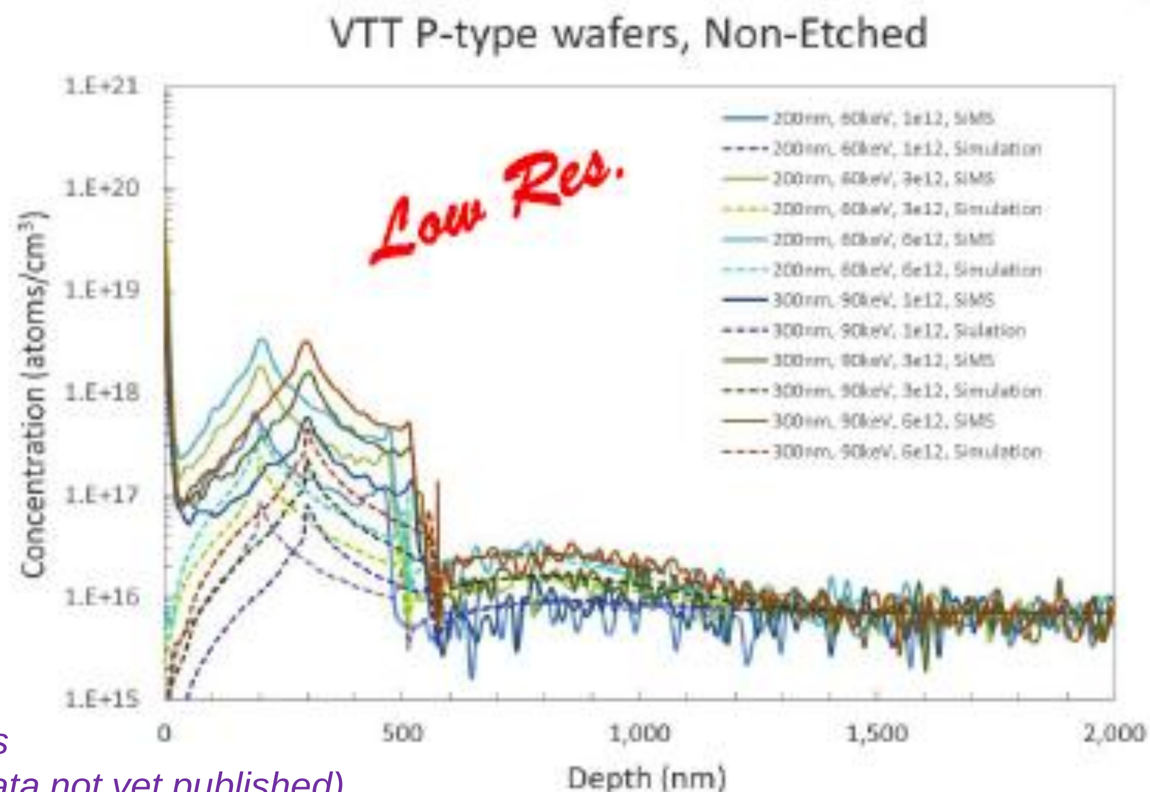


AFM at CTU-Minerve, IEF, Orsay

SYNOPSYS TCAD simulations

Comparison: SIMS measurements/ SYNOPSYS simulations

- very promising results

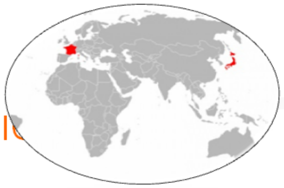


SIMS: N. Dinu, F. Jomard
SYNOPSIS simulations: V. Gkougkousis
(TIPDOC project, Labex NanoSaclay, data not yet published)

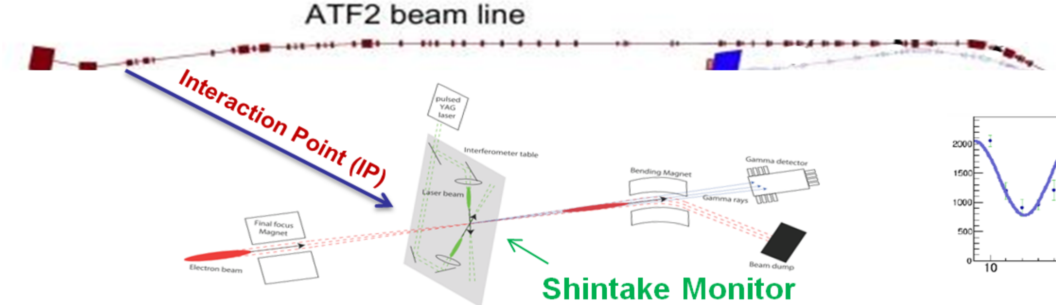
N in P, VTT production, <100> orientation						
Oxide thickness	200nm			300nm		
P implantation doses	$1X10^{12}$ cm^{-2}	$3X10^{12}$ cm^{-2}	$6X10^{12}$ cm^{-2}	$1X10^{12}$ cm^{-2}	$3X10^{12}$ cm^{-2}	$6X10^{12}$ cm^{-2}
Implantation energy	60 KeV			90 KeV		
Annealing	3hours, 1000 °C					

✓ $\rho = 2\ \Omega/cm\ (7 \times 10^{15})$ – 380µm thickness

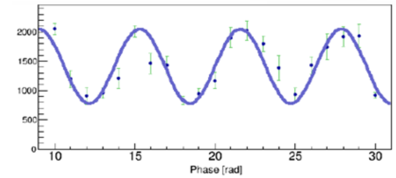
Accelerator Test Facility (ATF) @ KEK



- Low energy (1.3GeV) prototype of the final focus system for ILC and CLIC
- Focus system to validate "compact local chromaticity correction"



Slides by S. Liu



Goals of ATF2

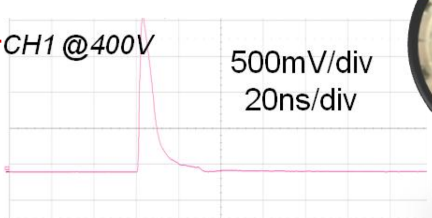
- ***goal 1—achieving the 37 nm design vertical beam size at the IP;***
- ***goal 2—stabilizing the beam at that point at the nanometer level;***

In Vacuum Diamond Sensor

Diamond sensor R&D for Beam Halo investigation

- ✓ **Tests in the clean room to study the diamond characteristics**
- ✓ **Tested in air at PHIL from 10^5 -> 10^8 e-**
- ✓ **Tests to be continued in vacuum**
- ✓ **Installation at ATF2 for beam halo measurements in Nov. 2014**

First Test In Vacuum @ PHIL

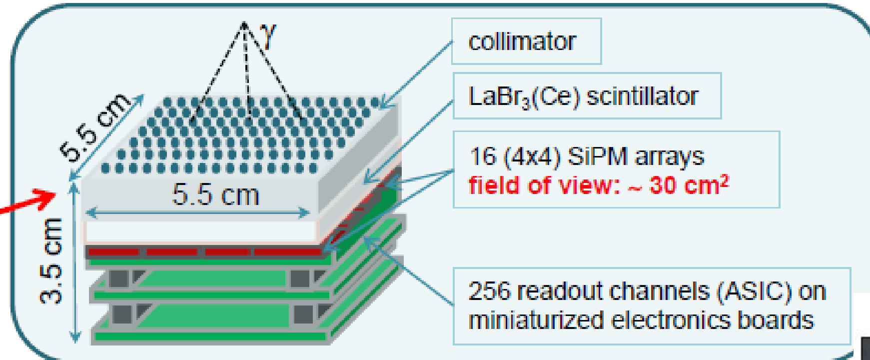


Installed in Sept. 2014

Tests to be continued before installation @ ATF2 in Nov. 2014

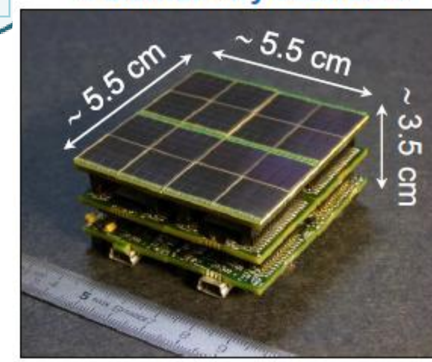
SIPMED project - SiPM for medical imaging

- Miniaturized Gamma Imager for Cancer Surgery (MAGICS)

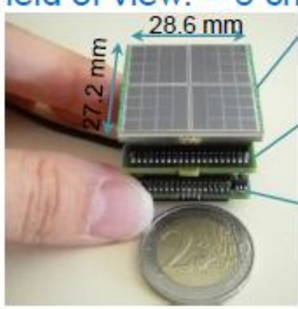


Collaboration IMNC, LAL, Hôpital Lariboisière

4 elementary modules



Elementary module
Field of view: ~ 8 cm^2

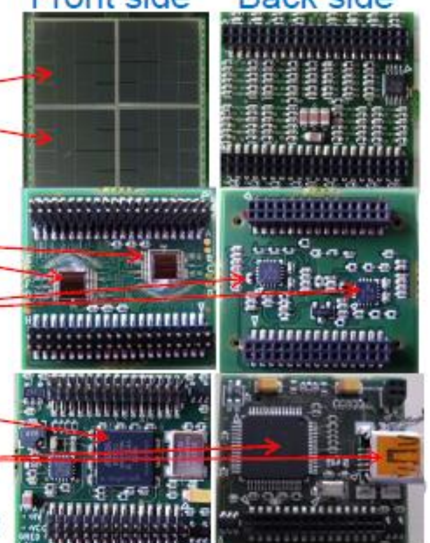


Board 1:
4 (2x2) SiPM arrays
64 channels

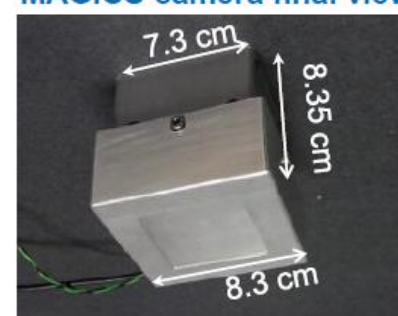
Board 2:
2 EASIROC chips
64 readout channels
2 ADC 12 bits

Board 3:
ALTERA ciclone III FPGA
FTDI FT2232H (USB, 2.0 Hi-speed, 440MBit/s)
DC/DC converter for SiPM bias

Front side Back side



MAGICS camera final view



Dimensions: 8.3 x 8.3 x 8.35 cm^3
Weight: 1.2 kg
Field of view : 5.1x5.1 cm^2

T. Ait Imando & al., PhotoDet2012, PoS
N. Dinu & al., NDIP 2014, NIM A

SONIM project under development

- New miniaturized probes for charged particles detection (β^+)

Intra-operative clinical imaging

Miniaturized beta imaging camera for real time guide of cerebral tumors surgery

Collaboration IMNC, LAL, Hôpital H. Mondor

Pre-clinical studies

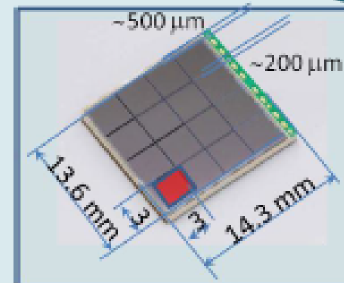
Implantable and stand-alone counting probe for neurological studies on small animal

Collaboration LAL, IMNC, CERMEP (Lyon), Centre de Neurosciences de Paris-Sud

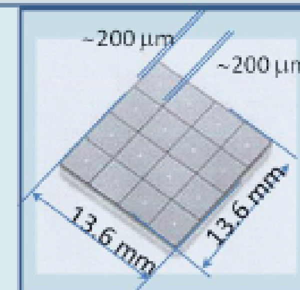
R&D on SiPM detectors (1)

- Requirements for intra-operative β camera for cancer surgery
  - arrays of SiPM covering a field of view ~3x3 cm² (8x8 SiPM's)
  - reduced dead area
  - low noise (DCR, afterpulses)
  - low T dependence

Old HPK SiPM arrays
- monolithic
- wire bonding
- 3-sides buttable



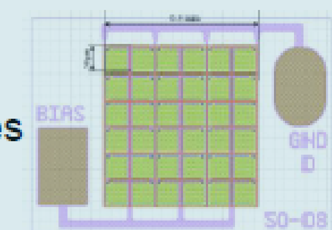
New HPK SiPM arrays
- single SiPM
- TSV technology
- 4-sides buttable



- Requirements for β counting probe in preclinical imaging
  - small SiPM (< 1x1 mm²)
  - low bias voltage (< 30V)
  - low noise
  - low T dependence

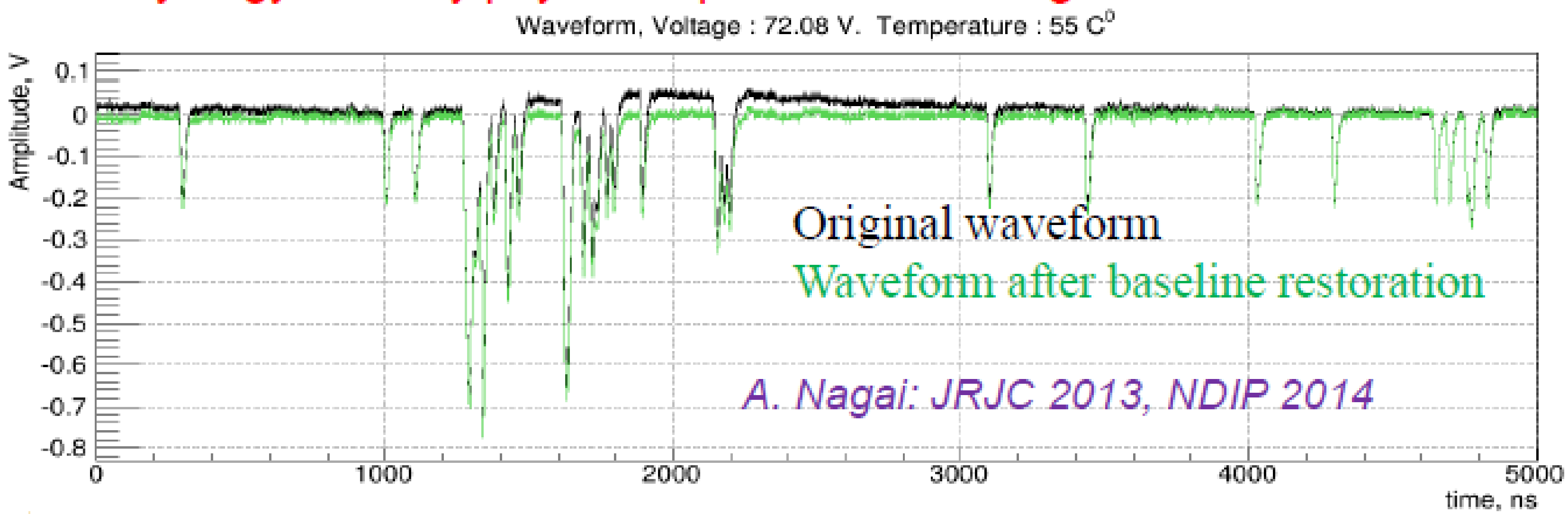
16 Ketek SIPM received
- 0.3x0.3 mm²

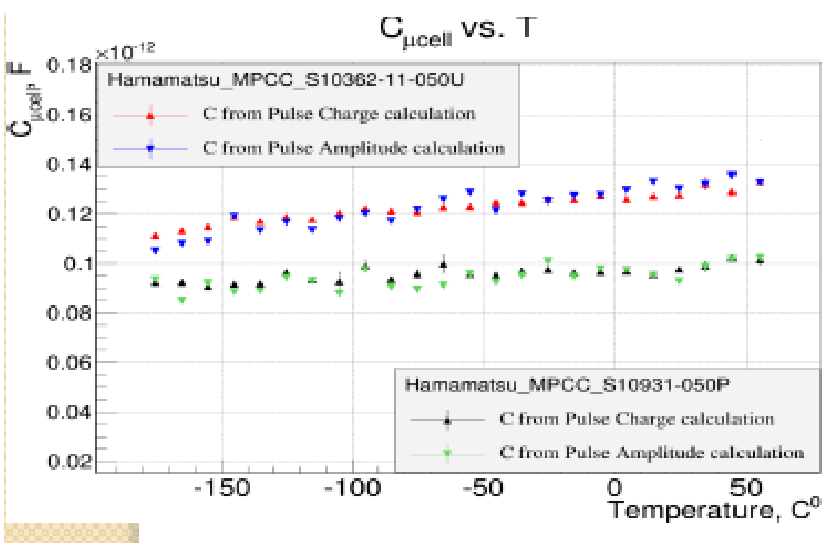
New Ketek SiPM
- 0.5x0.5 mm²
- 50x50 µm² cell size with trenches
- specially designed for us to be received by the end of 2014

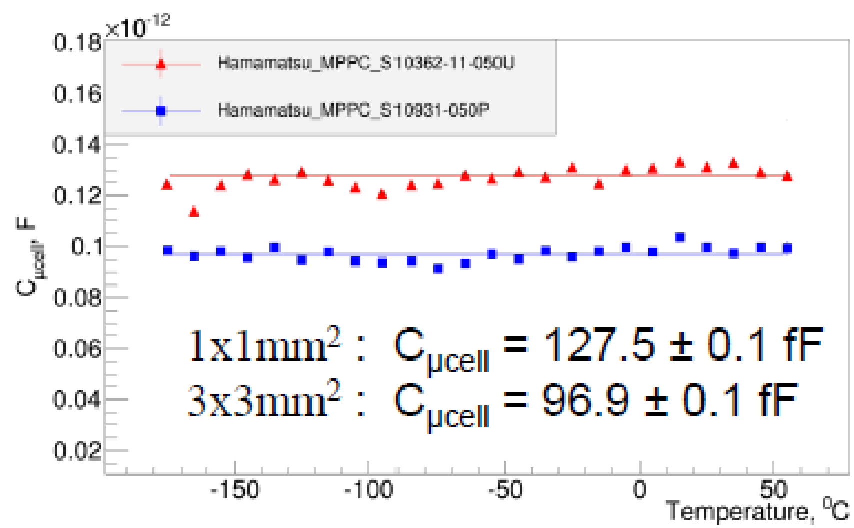


R&D on SiPM detectors (2)

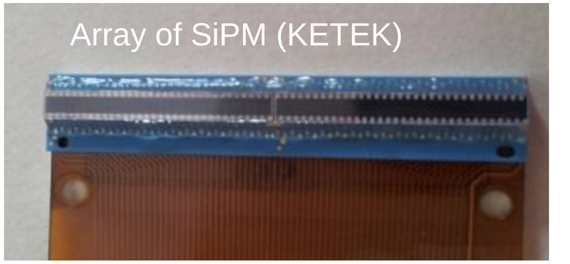
- Development of a calibrated & automatic procedure for SiPM parameters analysis based on ROOT framework
  - collaboration with Fermilab (A. Para)
  - synergy with any physics experiment intending to use SiPM detectors





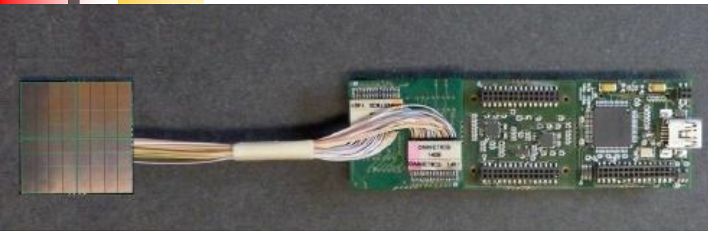


R&D on SiPM detectors (3)



- R&D on SiPM for LHCb SciFi Tracker
  - Arrays of SiPM from Hamamatsu (Japan) and KETEK (Munich, Germany)
    - 1x128 SiPM's (32 x 2 mm^2);
    - SiPM: 0.25 x 1.5 mm^2; 100 (4 x 25) µcells; µcell: 57.6 x 62.5 μm^2
  - Main requirements on SiPM characteristics
    - Small temperature dependence (i.e. $R_q \rightarrow$ signal shape, $V_{bd} \rightarrow$ G)
    - Radiation hardness (DCR)
    - High PDE for broad wavelength range
    - T during experiment: -40°C
  - Future R&D activity at LAL (work package SiPM LHCb):
    - Build a test-bench: cryocooler -200°C<T<+25°C + climatic chamber (SiPM) + readout acquisition system
    - Study of temperature dependence of SiPM parameters, before / after neutron irradiation of ~ 10^{11} neqv (1 MeV)/mm^2
    - Contacts with industrial partners: feedback and parameters improvements adapted for LHCb requirements

Development of miniaturized readout electronics



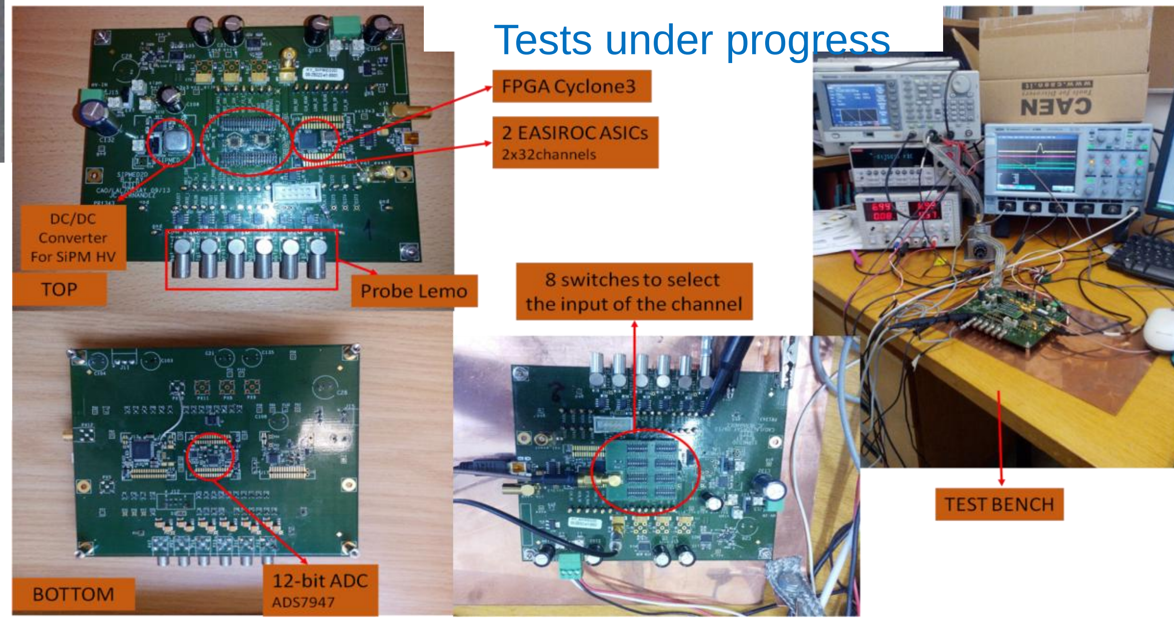
SONIM

SiPM arrays + readout electronics

(based on SIPMED 3D boards)

2D SONIM test board

Tests under progress



Thanks to SERDI technical contributions:
B. Ky, S. Conforti di Lorenzo, D. Breton, JC. Hernandez, P. Favre, B. Debennerot
CMS cabling and EASIROC wire bonding performed at CERN
EASIROC chip from Omega group, LLR

Future development on miniaturized electronics:

- Multichannel readout electronics adapted for intra-operative beta imaging application (i.e. 64 channels, compact geometry, performances of single photon detection)
- Single channel readout electronics for preclinical application (counting and signal digitization, T control, wireless communication, stand alone power supply)