FONDAZIONE BRUNO KESSLER | SENSORS AND DEVICES

Silicon based radiation detectors at FBK-SD

An Overview.

@DESY, Hamburg, 02.03.2021

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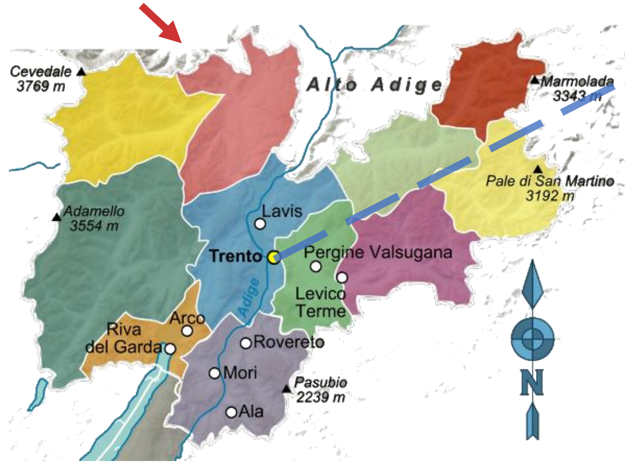
Webinar overview
Contributors

- About us — Giancarlo Pepponi pepponi@fbk.eu
    - FBK
    - FBK-SD
        - Research units working on Si radiation sensors
            - MNF
            - IRIS
        - Infrastructure
- Radiation sensor technologies
    - SDDs — Giacomo Borghi gborghi@fbk.eu
    - LGADs
    - SiPMs — Alberto Gola gola@fbk.eu
    - CMOS imagers — Matteo Perenzoni perenzoni@fbk.eu
    - Si-3D — Maurizio Boscardin boscardi@fbk.eu
    - edgeless pixels

about us

FBK
Fondazione Bruno Kessler

Italy → Trentino → Trento → FBK



FBK
Fondazione Bruno Kessler

Mission: Future built on knowledge

Our mission is excellence of science to extend our innovation capability and involve the community and the economy in the circulation of knowledge and derived technologies (impact)

FBK at a glance

11
centres

400+
researchers

100+ PhD
national and international PhD students

20
Joint labs and co-located companies

27
start-ups

FBK-SD
Centre for Sensors and Devices

FBK-SD at a glance

- ~ 90 researchers
- ~ 30 technicians
- ~ 20 PhD students
- ~ 2000 sq metres labs

~9Meuro total budget
- ~50% from local government
- ~30% from competitive funds
- ~20% from directly commissioned activities

Mission. Impact through scientific excellence and open innovation

Our mission is to pursue scientific excellence and bring our results to market and fruition through an open innovation model. The main value of FBK-SD rests on the combination of a wide base of diverse know-how and competences, supported by state of-the-art research infrastructures, to attain outstanding results in both research and innovation.

FBK-SD

Units – units involved in current presentation

FMPS
FUNCTIONAL MATERIALS & PHOTONICS STRUCTURES

R&D focused on surface engineering and advanced materials to create novel functionalities or to improve existing ones in the fields of advanced materials and integrated photonic circuits.

IRIS
INTEGRATED RADIATION AND IMAGE SENSORS

Design and development of advanced solid state sensors, based on custom in-house technology or state-of-the-art, deep submicron CMOS. It responds to the needs of the applications implementing special and fully customizable features.

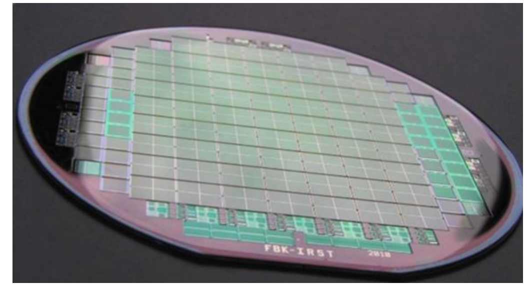
MST
MICROSYSTEMS TECHNOLOGY

Design, fabrication, characterization and packaging of innovative devices based on silicon compatible technology, like microfluidcs and lab on chip, electrochemical and tactile sensors, MEMS Gas and Flow sensor, MEMS for RF, microwave applications.

MNF
MICRO NANO FACILITY

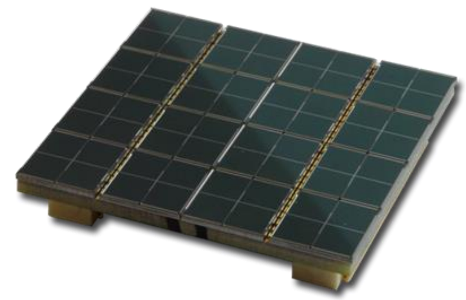
The MNF groups the major micro-fabrication and materials analysis laboratories of the centre. It performs and supports R&D activities and provides expertise and assistance to get access or service activities. MNF is certified ISO 9001:2015 as a key element of its business model bridging the gap between research and small scale production.

Research unit: IRIS
Integrated Radiation Image and Sensors



Competence areas

- Single-photon detectors (full-custom and standard CMOS tech.)
- Silicon Drift Detectors
- Custom Radiation detectors
- Multispectral Imaging Camera (Visible, IR and THz)
- Ultra-low power imagers for Wireless Camera
- Low-level light detectors for UV light



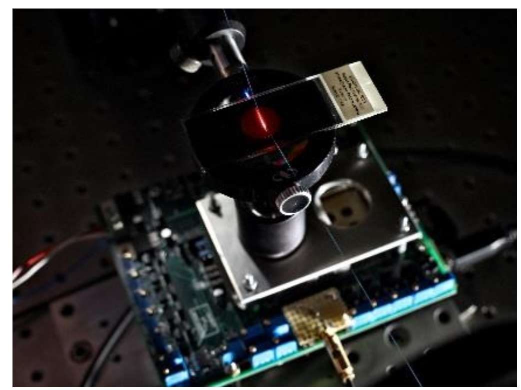
Skills

- Detector design, modelling and technology development
- Analog and Digital IC Design of state of art CMOS technology
- Functional, Parametric Testing, and prototyping

Application areas

Science
- Nuclear and particle physics
- Astronomy
- Space science
- Quantum Science

Industry
- Automotive
- Security and environmental monitoring
- Industrial Quality Control
- Analytical instrumentation
- Applied Quantum Technologies



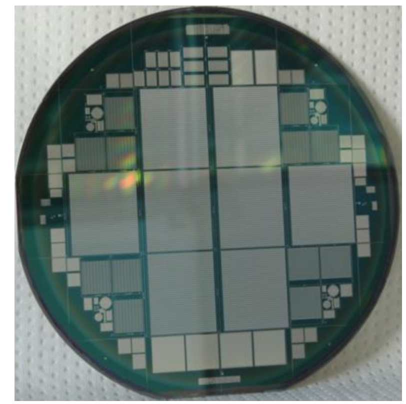
Infrastructure: MNF
Micro Nano characterization and fabrication Facility

Competence areas

- Design, production and packaging of innovative devices based on silicon compatible technology, in particular:
  - ✓ Radiation Sensors
  - ✓ MEMS-devices
- Development and application of analytical techniques for the characterization of materials at the micro and nano scale

Skills

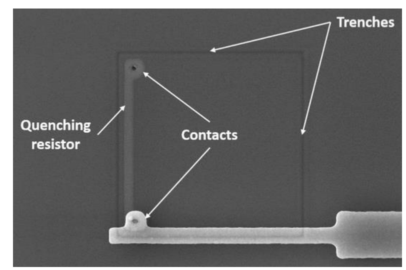
- Silicon Microtechnologies (Flow sensors, Optical sensors, Radiation sensors, Bolometers, CMUT, RF switches, Pressure sensors)
- State of art analytical infrastructure (for semiconductors, thin films, dopant distributions, materials for energy, optoelectronics, coatings)
- Instrumentation development
- Data mining
- Silicon compatible material science



Application areas

Science
- Radiation sensors for Science (Particle, nuclear physics, space applications)
- Bio-sensors
- Quantum Science and Technology

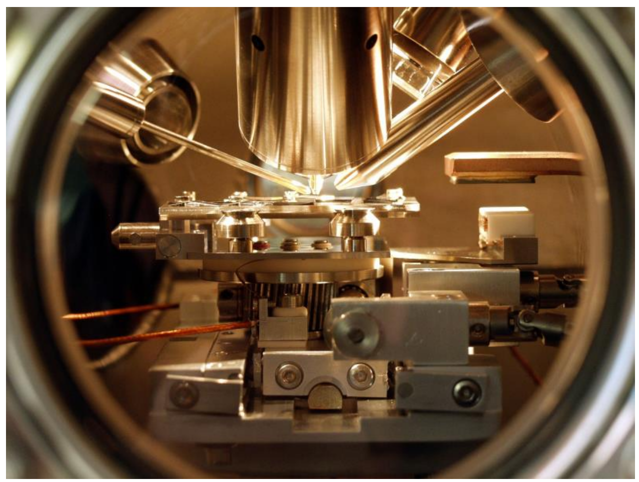
Industry
- Detectors for X-ray analysis
- Gas sensors
- Environmental monitoring
- Applied Quantum Technologies



FONDAZIONE BRUNO KESSLER SENSORS AND DEVICES

MNF infrastructure

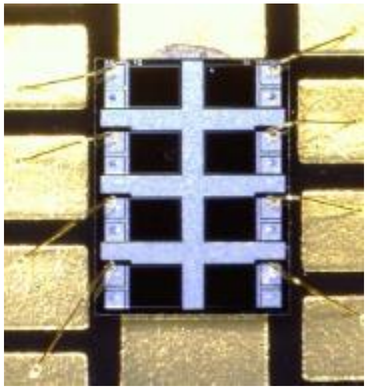
Over 1200 square metres of laboratories:
- 2 microfabrication cleanrooms (1 specifically dedicated to radiation detectors)
- 1 integration/packaging cleanroom
- parametric testing equipment
- materials characterization labs



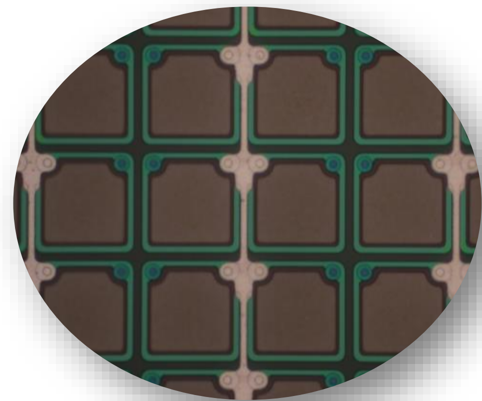
Main partners – radiation sensors

HORIBA	Sensors
Thermo Fisher - INEL	XRF + XRD, radiation sensors
Lfoundry	SiPMs, process control, materials analyses
Broadcom	SiPMs
PSI	Radiation sensors, UFSD/LGAD
Elettra	SDDs
CERN	Radiation sensors
ASI	Radiation sensors
ESA	Radiation sensors, microdevices
INFN	Radiation sensors, irradiation tests
OPTO-I	Spin-off – optical sensors, packaging
Italian Universities	Different colaborations on radiation sensors

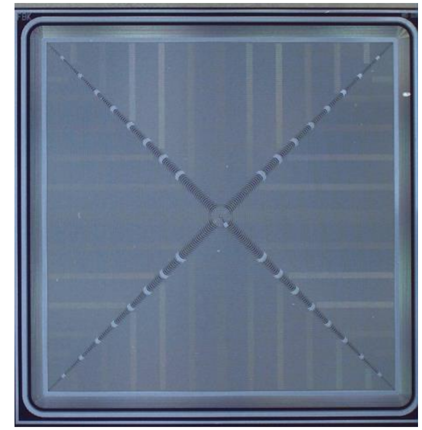
Radiation detectors – examples



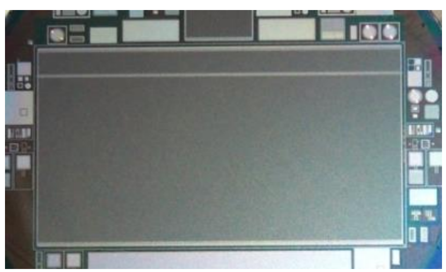
PhotoTransistor



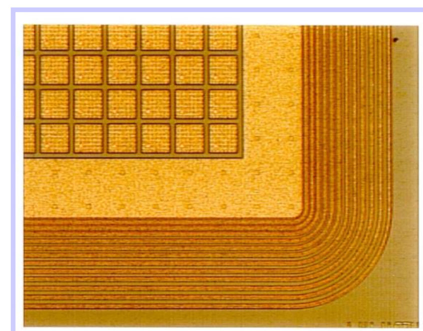
Silicon Photomultiplier



Silicon Drift

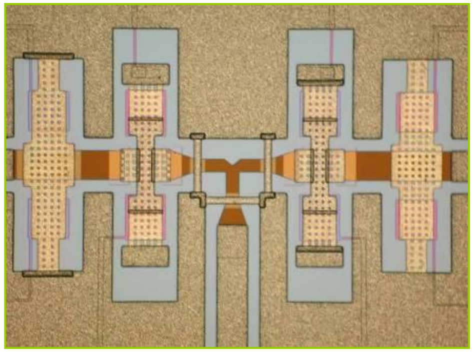


Single and Double Side Microstrip

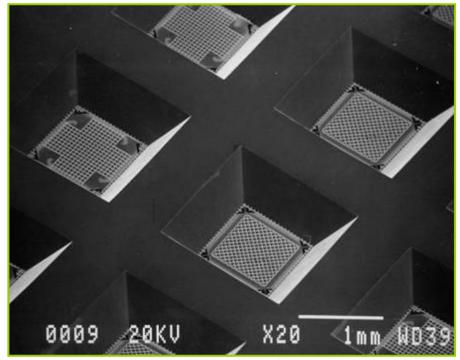


Pixel

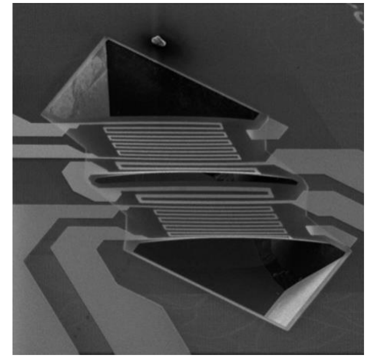
MEMS devices – examples



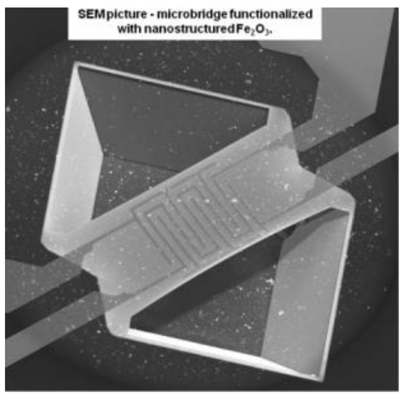
RF-MEMS



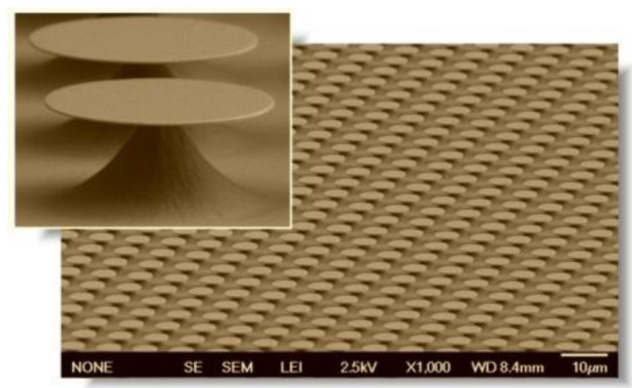
Capacitive Microphones



Flow sensors



Microheaters (for gas sensing)



Microresonators

The Near Future

3D integration

IPCEI-ME-1 - FBK
3D integration for SiPMs

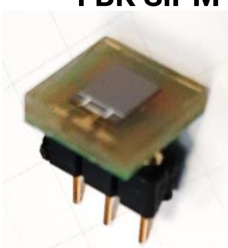
IPCEI on Microelectronics

The „Important Project of Common European Interest“ (IPCEI) programme allows EU Member States to promote innovation up to the first industrial deployment. At the end of 2018, the European Commission approved the „Important Project of Common European Interest (IPCEI) on Microelectronics“ under state aid law.

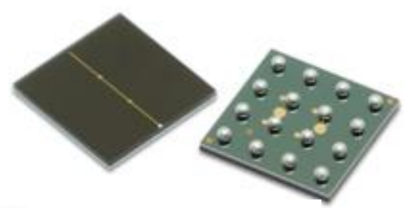
IPCEI-ME-1 in FBK

- Developing new SiPM technologies for **high-density 3d-integration** with CMOS electronics or photonics components (including BSI technology)
- Improving the FBK-SiPM technology integrating **Through Silicon Vias (TSV)**

Standard FBK SiPM

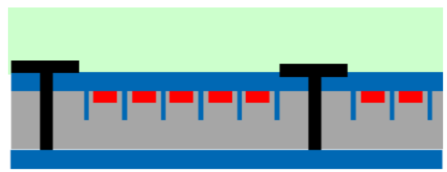


TSV SiPM



BROADCOM
(Based on FBK technology)

Segmented SiPM



3D-integrated SiPM

1 channel | 1 channel | tens of channels | thousands of channels (1 chn per pixel)

SENSORS AND DEVICES
FONDAZIONE BRUNO KESSLER

IPCEI-ME-1 - FBK
Facility upgrade 1

IPCEI on Microelectronics

Cleanroom Detectors

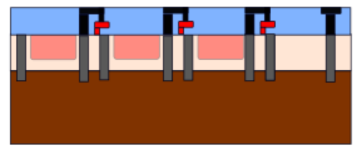
1. Sensor FEOL production

Already existing Detector CR at FBK

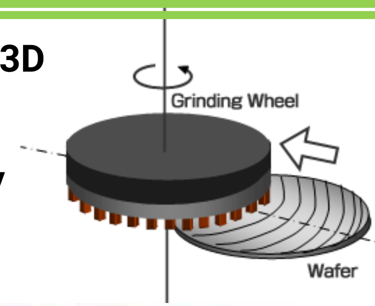
Come back to FEOL & BEOL

3D int. Clean Room

2. TSV and Wafer preparation for 3D integration



u-TSV



Wafer Bonding

Under commissioning (2022)

3. Sensor integration to electronics

IPCEI-ME-1 - FBK
Facility upgrade 2

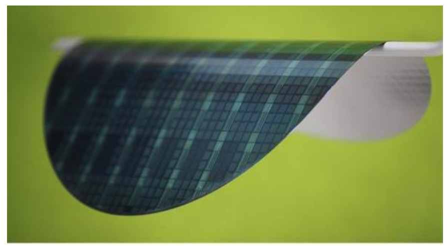
IPCEI on Microelectronics

The new lab will be equipped with state-of-the-art equipment for both 6'' and 8'' wafer processing

Wafer Bonding

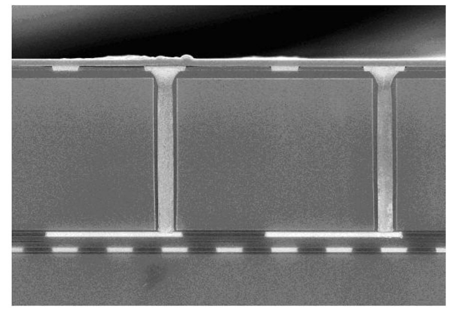
- Temporary Bonding/Debonding
- Permanent Bonding
- Bond Alignment
- Fusion Bonding
- Metal Bonding

Wafer Thinning and Grinding



- Wafer grinding
- Chemical Mechanical Polishing
- Pre-grinding dicing

Through Silicon Vias and interconnections



- Via formation
- Via metal filling

SDDs

Silicon drift detectors

LGADs

Low Gain Avalanche detectors

SiPMs
Silicon photomultipliers

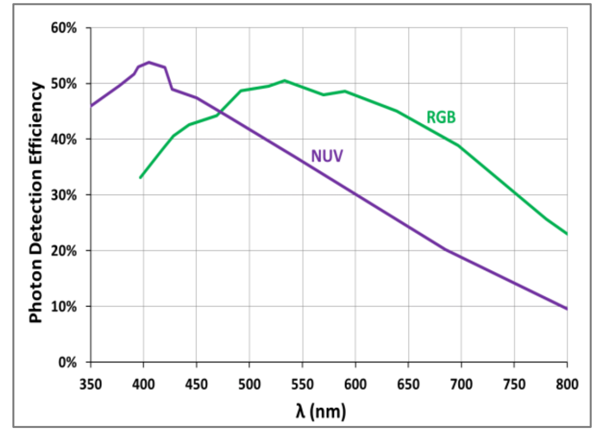
FBK Custom SiPM
technology Roadmap

Original technology *2005*

Electric field engineering

RGB *2010*

NUV *2012*



New cell border (trenches)

RGB-HD *2012*

NUV-HD *2015*

Ongoing Developments

NUV-HD-Cryo

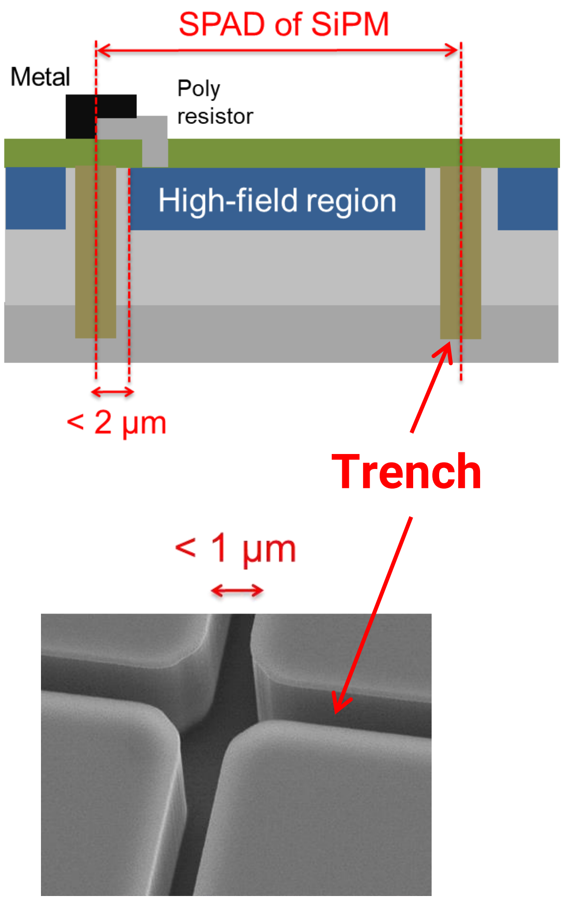
VUV-HD

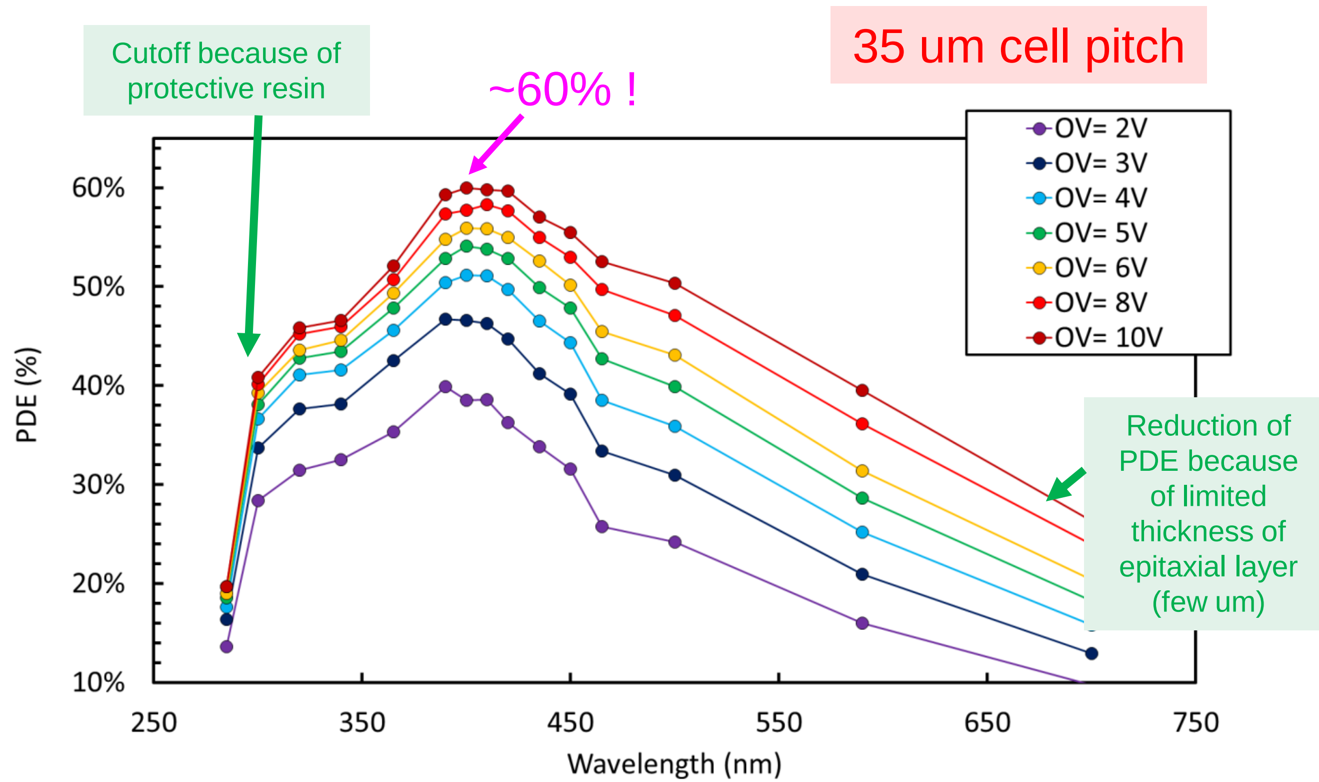
NUV-HD-RH

NIR

NUV-HD SiPM technology
Photon Detection Efficiency

NUV-HD SiPMs provide *state-of-the-art performance for NUV light detection*.

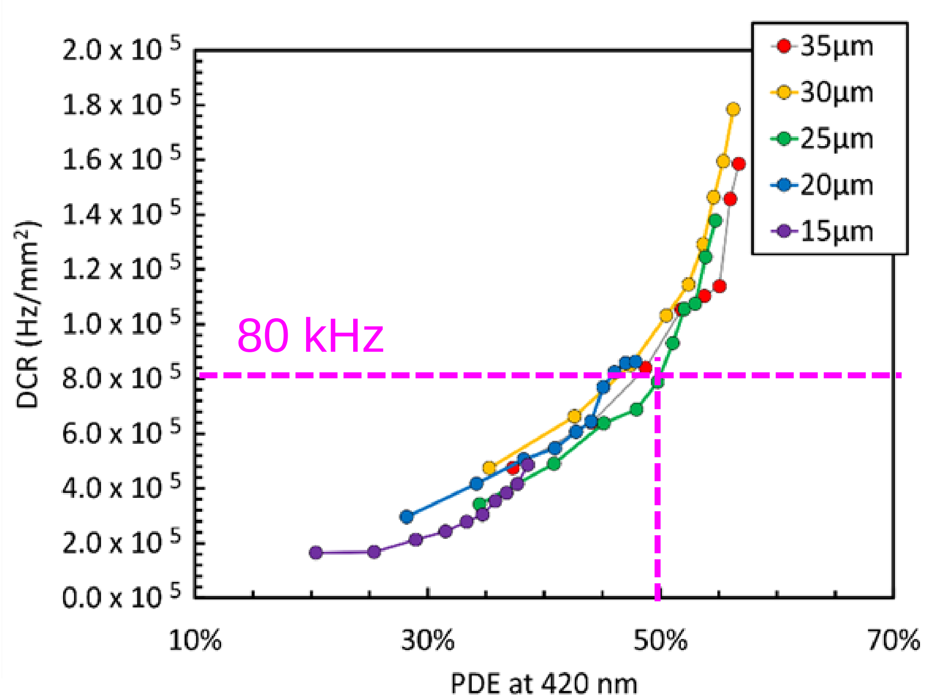




Gola, A et al. (2019). “NUV-Sensitive Silicon Photomultiplier Technologies Developed at Fondazione Bruno Kessler.” *Sensors*, *19*(2), 308.

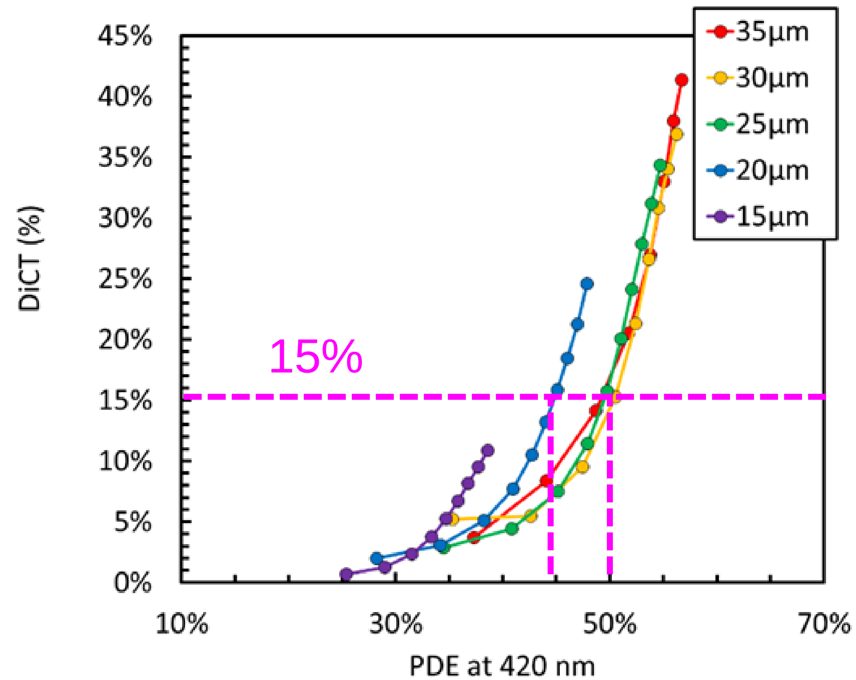
NUV-HD SiPM technology
Nuisance parameters

Nuisance parameters are plotted as a function of the PDE, in order to compare effectively different cell sizes of the same SiPM technology or also different SiPM technologies.



Dark Count Rate

T = 20 C



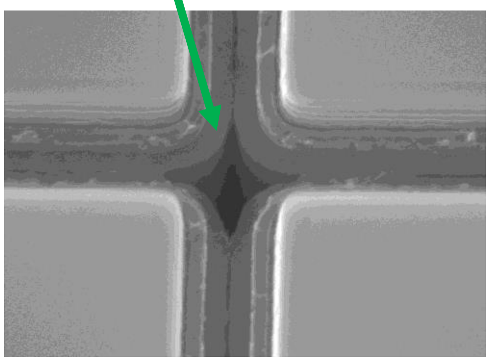
Optical Crosstalk
(Correlated Noise)

NUV-HD-LowCT SiPM technologies
Increased PDE with decreased Optical Crosstalk

Low optical crosstalk technologies can be obtained by inserting material that absorbs or reflects secondary photons, emitted by the avalanches in the microcells.

Electric field engineering increases PDE compared to standard NUV-HD technology.

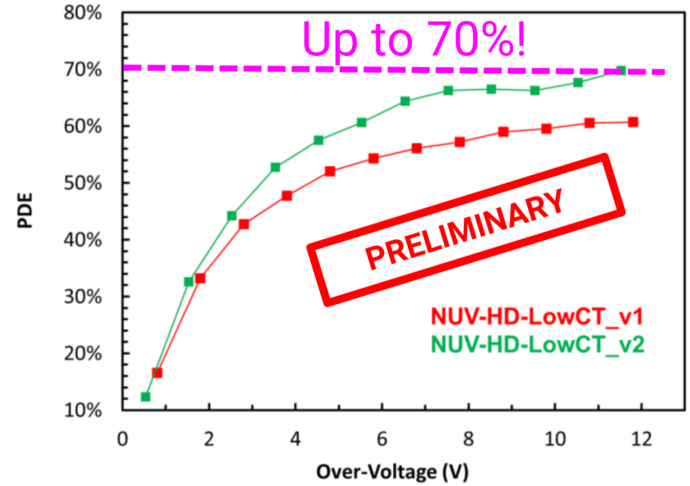
Light absorbing material is placed inside trenches, between adjacent microcells



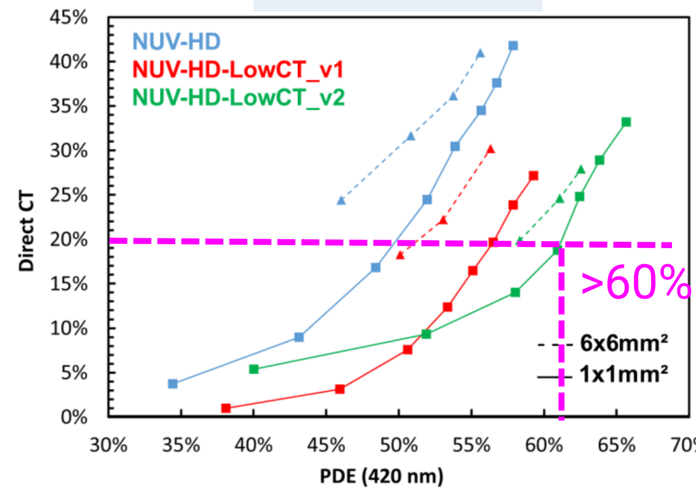
SEM image of trenches, separating adjacent microcells.

Measurements on 40 µm cell size SiPMs, with silicone resin coating

PDE at 420 nm vs. OV

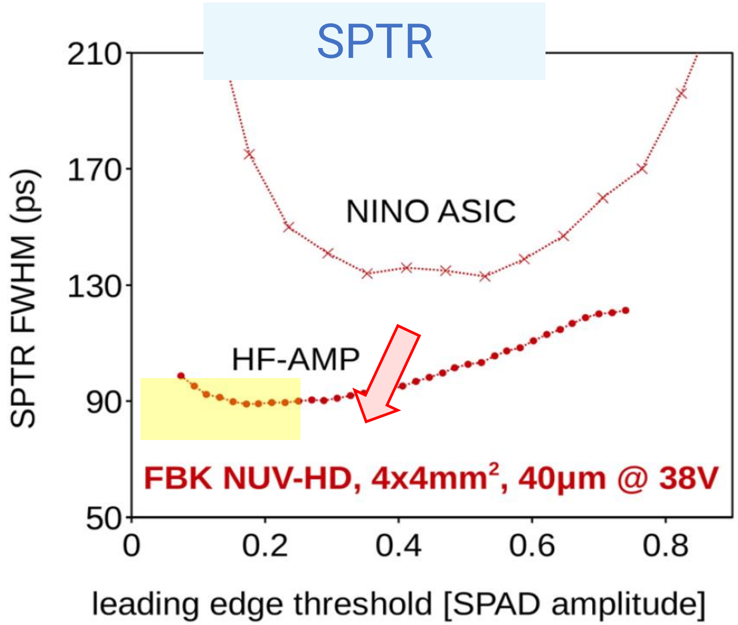


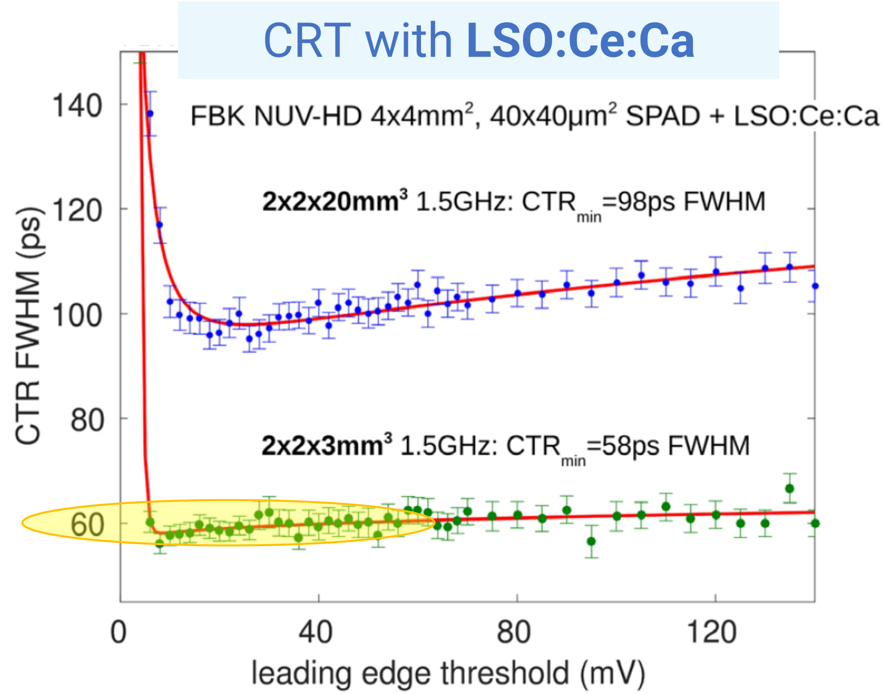
DiCT vs. PDE



NUV-HD SiPM technology

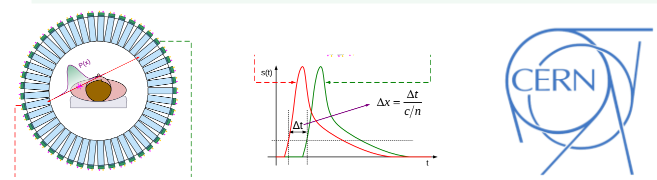
Single Photon Time resolution and timing performance with scillators





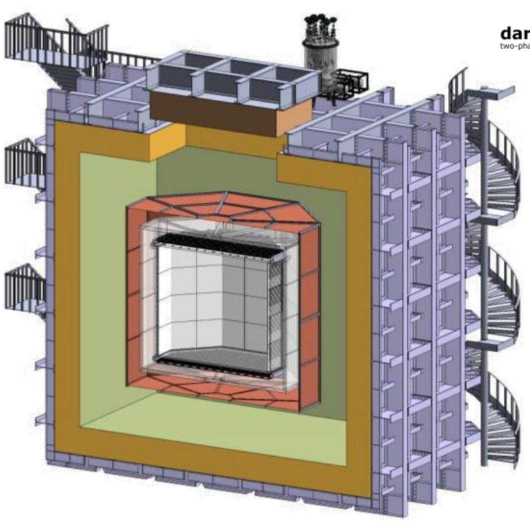
Significant reduction of SPTR with improved electronics

Work carried out in collaboration with S. Gundacker (P. Lecoq)



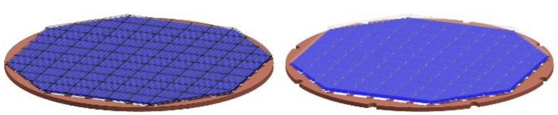
Big Physics experiments
DarkSide-20k

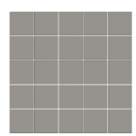
NUV-HD-Cryo SiPMs, developed at FBK as a partner of the DarkSide-20k collaboration, are an *enabling technology for the experiment*.



~ 23t of UAr

TPB WLS:
emission at
400 – 450 nm

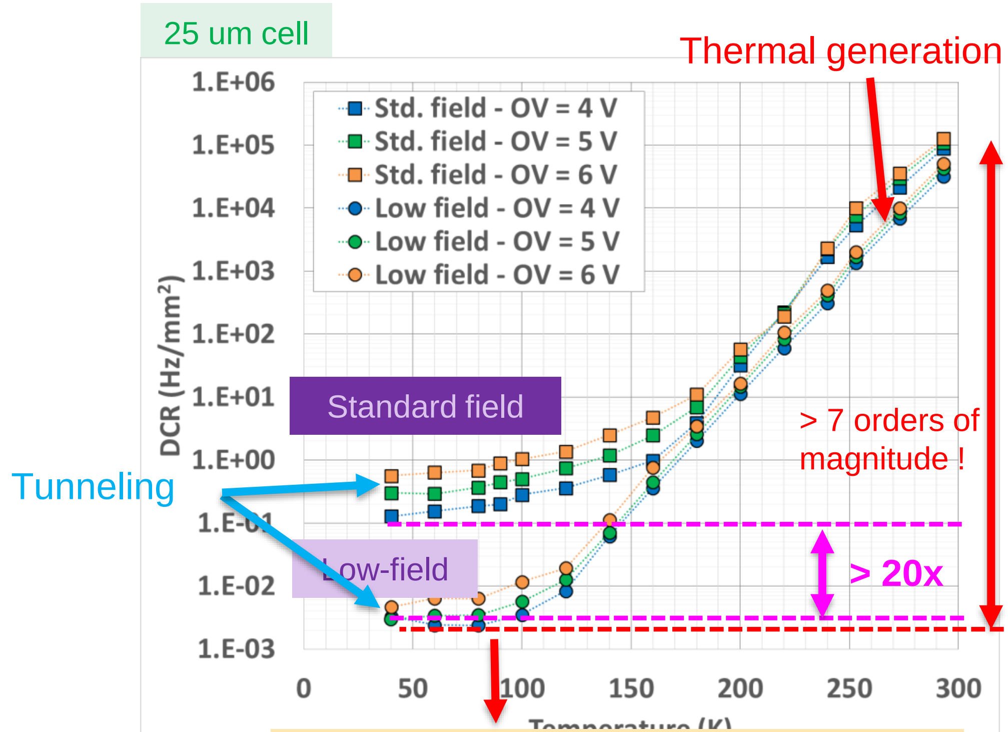




2 light readout planes: 20 m^2
(+ veto)

SiPM tiles

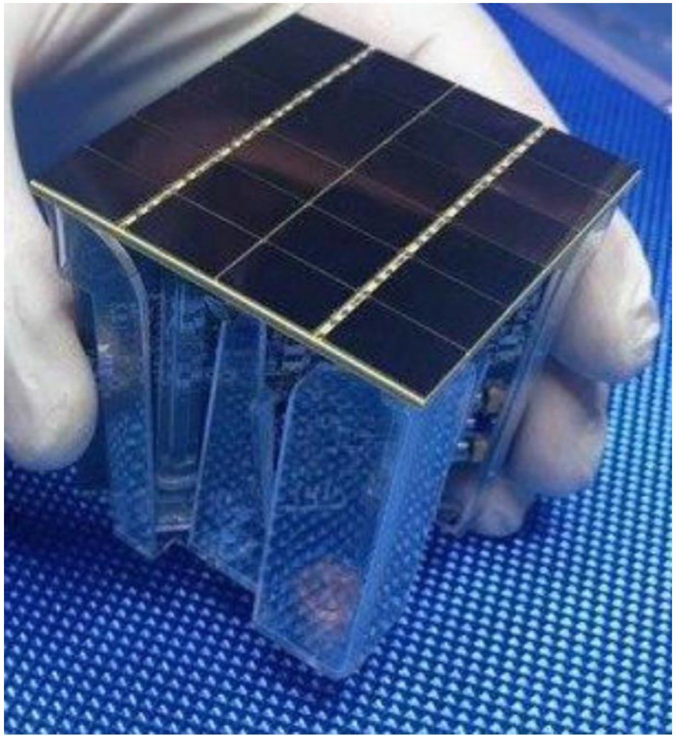
DarkSide-20k
SiPM-based TPC



0.3 counts per day per cell at 77 K!

A 10x10 cm^2 SiPM array would have a total DCR < 100 cps!

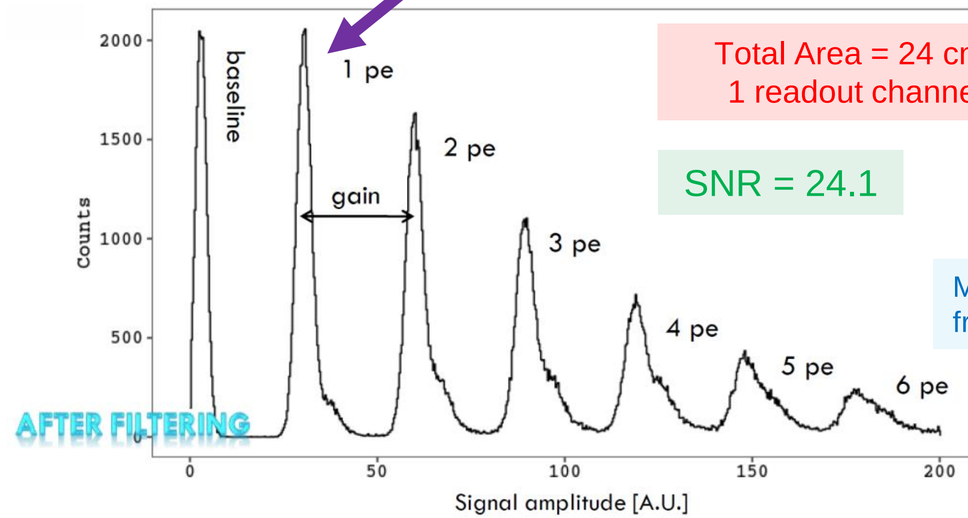
Big Physics experiments
DarkSide-20k



24x 12x8 mm^2 SiPMs (~ 1 cm^2)

Front-end cryogenic pre-amplifier with differential output

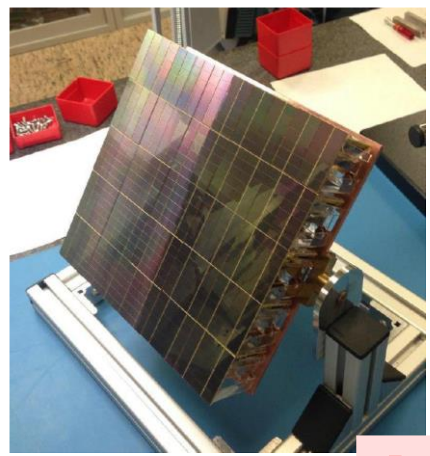
Good gain uniformity of ~ 3M SPADs at 77 K

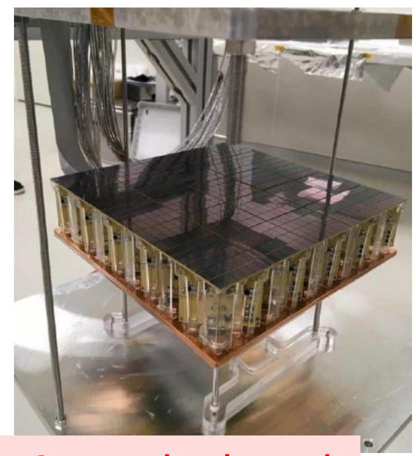


Total Area = 24 cm^2
1 readout channel

SNR = 24.1

Measurements from LNGS



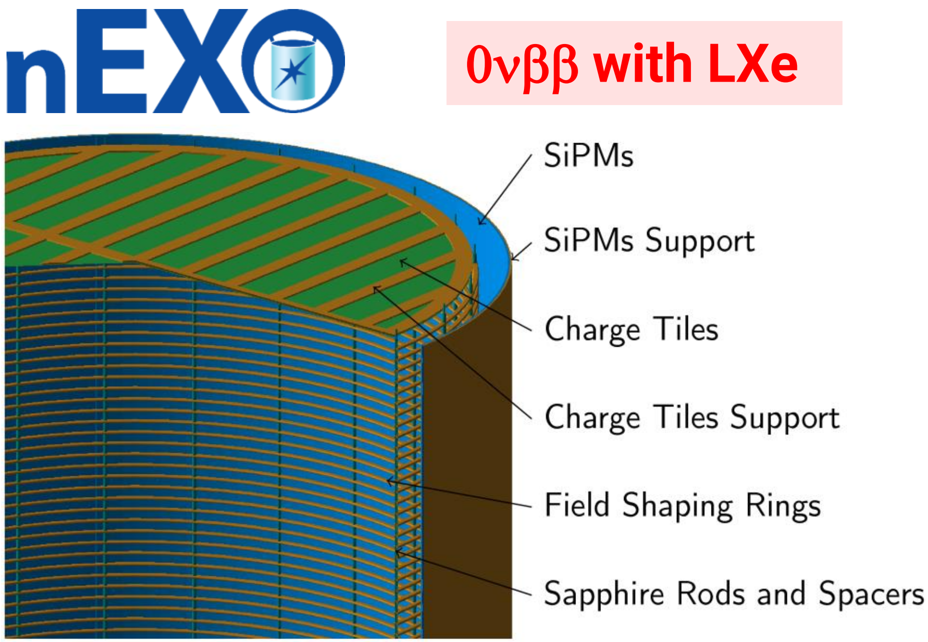


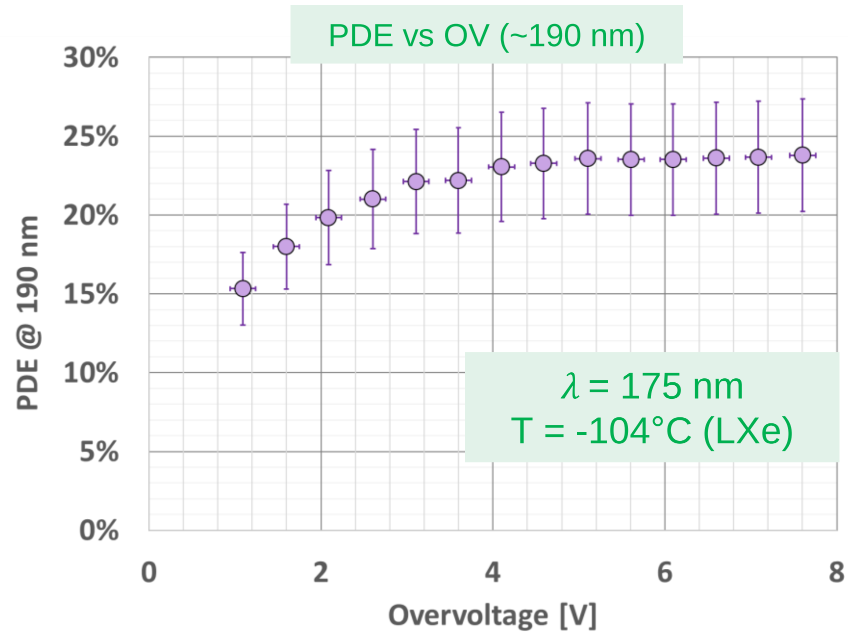
Proto0 - motherboard

Big Physics experiments
nEXO

R&D carried out for nEXO to develop SiPMs capable of *direct detection of photons at 178 nm and operation at -100°C.*

TPC Filled with LXe. 4-5 m^2 SiPM: production carried out in FBK

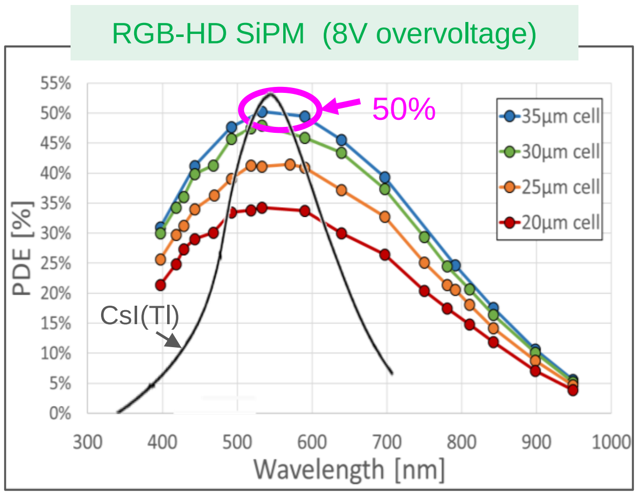




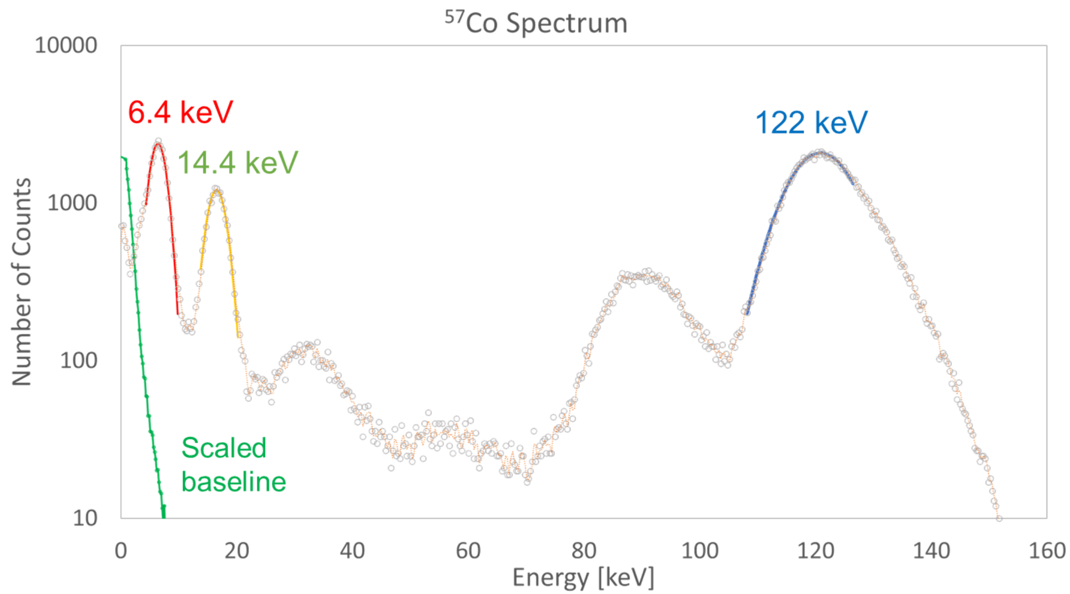
Best result reported in literature: arXiv:1904.05977

RGB-HD SiPMs
Low-energy X-ray spectroscopy with scintillator

RGB-HD technology has a sensitivity spectrum that is *better suited for the readout of yellow-green emitting scintillators*, such as GAGG:Ce or CsI:Tl.



PDE of RGB-HD SiPMs with different cell sizes, compared to the CsI:Tl emission



Low-energy x-ray spectroscopy, obtained with *3x3x5 mm³ CsI(Tl) crystal, coupled to a 4x4 mm² SiPM with 25 µm cell size*.

R&D on radiation hardness of SiPMs
Activities at FBK and partners

Improving radiation hardness of SiPMs is the *next frontier of development at FBK* for very important applications, both in big science experiments and in space.

Calorimeters for collider experiments:
from 10^{10} n/cm² to $>10^{14}$ n/cm²

FAIR
Facility for Antiproton and Ion Research in Europe GmbH

Geostationary orbit space experiments: ~$5 \cdot 10^{10}$ n/cm²

FBK is carrying out / planning several irradiation campaigns with *several research partners* to allow improvement of radiation-hard SiPM technologies.

Proton therapy facility in Trento.

Jožef Stefan Institute, Ljubljana

INFN – LNS, Catania

Ongoing collaborations also with:

GSI

U.S. NAVAL RESEARCH LABORATORY

Università degli Studi di Napoli Federico II

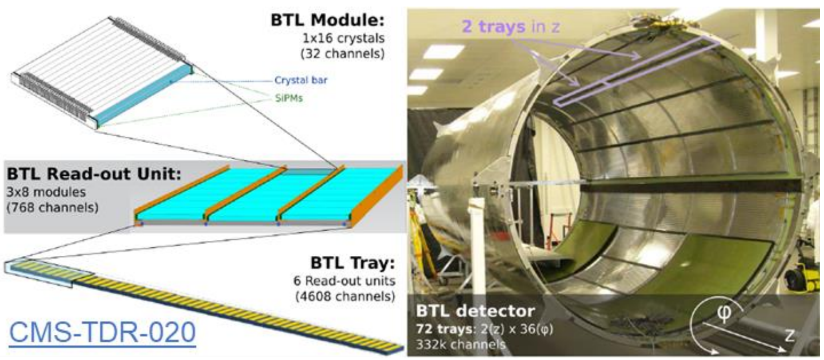
isae SUPAERO
Institut Supérieur de l'Aéronautique et de l'Espace

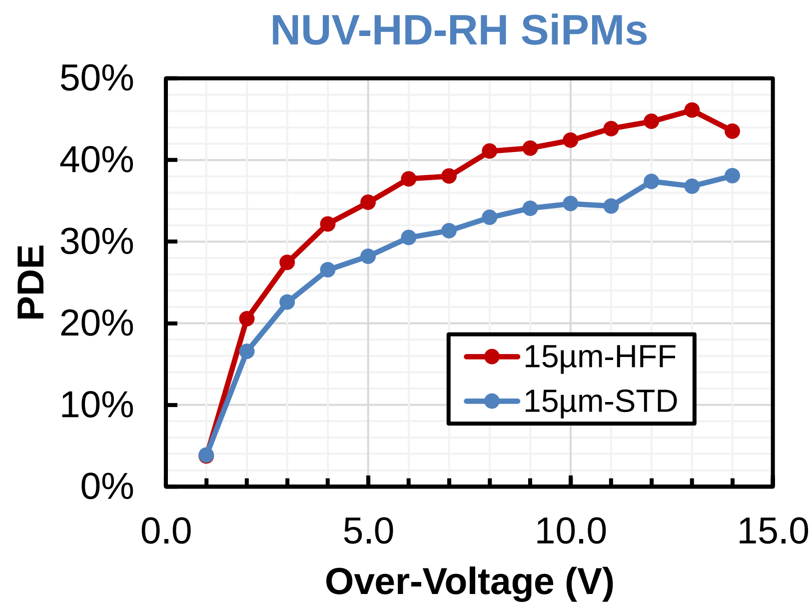
FBK SENSORS AND DEVICES
FONDAZIONE BRUNO KESSLER

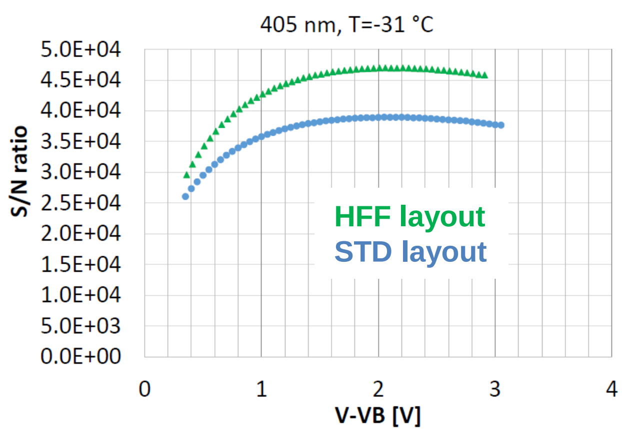
NUV-HD-RH
R&D for the Barrel Timing Layer of CMS

SiPMs with extreme radiation tolerance are required: 1.9×10^{14} 1 MeV n_{eq}/cm^2.

Custom SiPM technology was developed, combining *electric field engineering with small-pitch SiPM technology*, for enhanced radiation hardness.







FoM measured by from CMS collaboration:
A. Heering, Y. Musienko, M. Lucchini et al.)

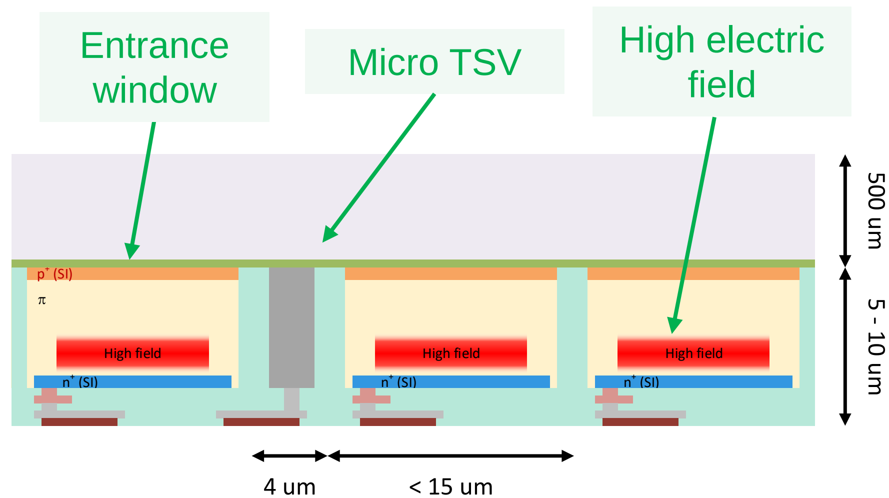
The advantage of using small cells for radiation hardness is relevant *only if they can still provide very high PDE*

Next-generation developments
BSI SiPM approach

Motivation: challenging development that will provide truly next-generation upgrade of SiPM performance.

Advantages:

- It is the only way to achieve high FF and PDE with the smallest cell sizes.
- Target cell pitch: <= 10 um pitch.
- Allows additional optimizations of the high electric field regions, not possible in FSI.
- Minimal topology on light entrance window: well-suited for advanced entrance window processing to improve NUV sensitivity (e.g. 355 nm).
- Very successful approach in CIS industry.



Example of a possible BSI SiPM structure

3D Integrated SiPM:

- When ultra-high performance or local processing is needed, BSI approach allows 3D interconnection of readout electronics, combining the benefits of scaled CMOS ASIC layer with higher performance of custom sensor layer.

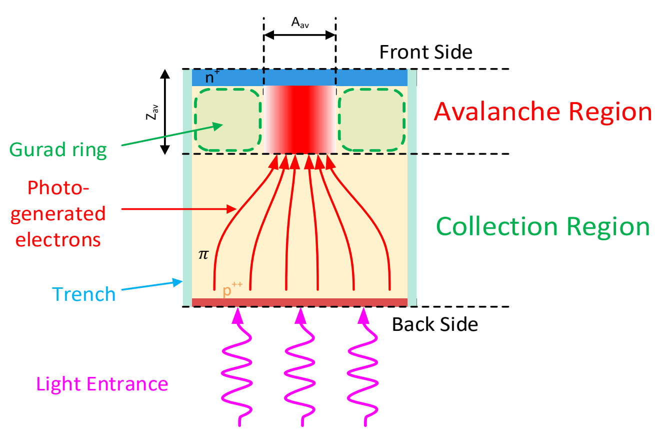
BSI SiPMs
Improved Radiation Hardness

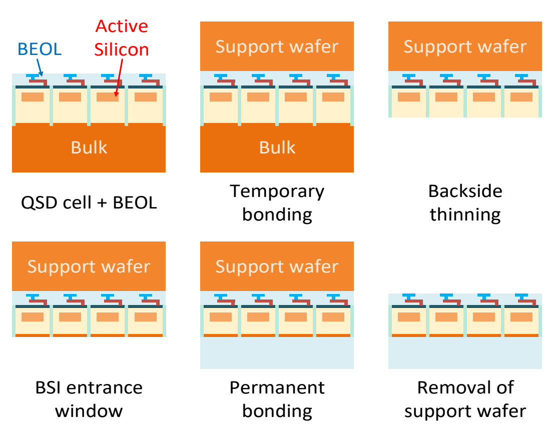
FBK is currently *researching a family of BSI-illuminated technologies*, featuring:

- Clear separation between charge generation / collection and charge multiplication.
- Charge multiplication region is much smaller than charge collection region, thanks to a *charge focusing mechanism*.
- First implementation is for a NIR-sensitive SPAD.

A very important advantage of this approach is that the *area of the device sensitive to radiation damage is much smaller than the area of the device sensitive to light*.

- Decouples PDE from radiation hardness, *generational improvement* over previous SiPM technologies.
- Effective under the assumption that most of the radiation damage contributing to DCR happens in the high-field region. Supported by preliminary indications, to be verified during the proposed project.





Enoch, S., Gola, A., Lecoq, P., & Rivetti, A. *"Design considerations for a new generation of SiPMs with unprecedented timing resolution"*. 2021 *JINST* **16** P02019

CMOS imagers

CMOS Imagers
Smart imaging solutions: outline

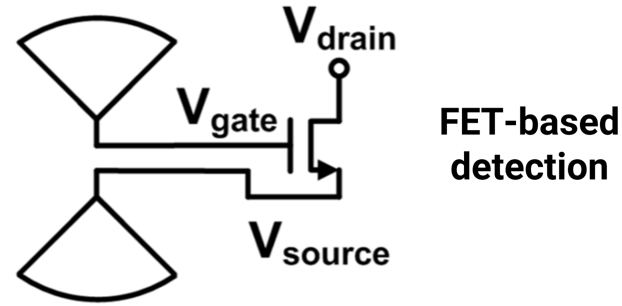
- THz Imaging
- Low-Power Vision Sensors
- SPAD Image Sensors
- 3D Imaging

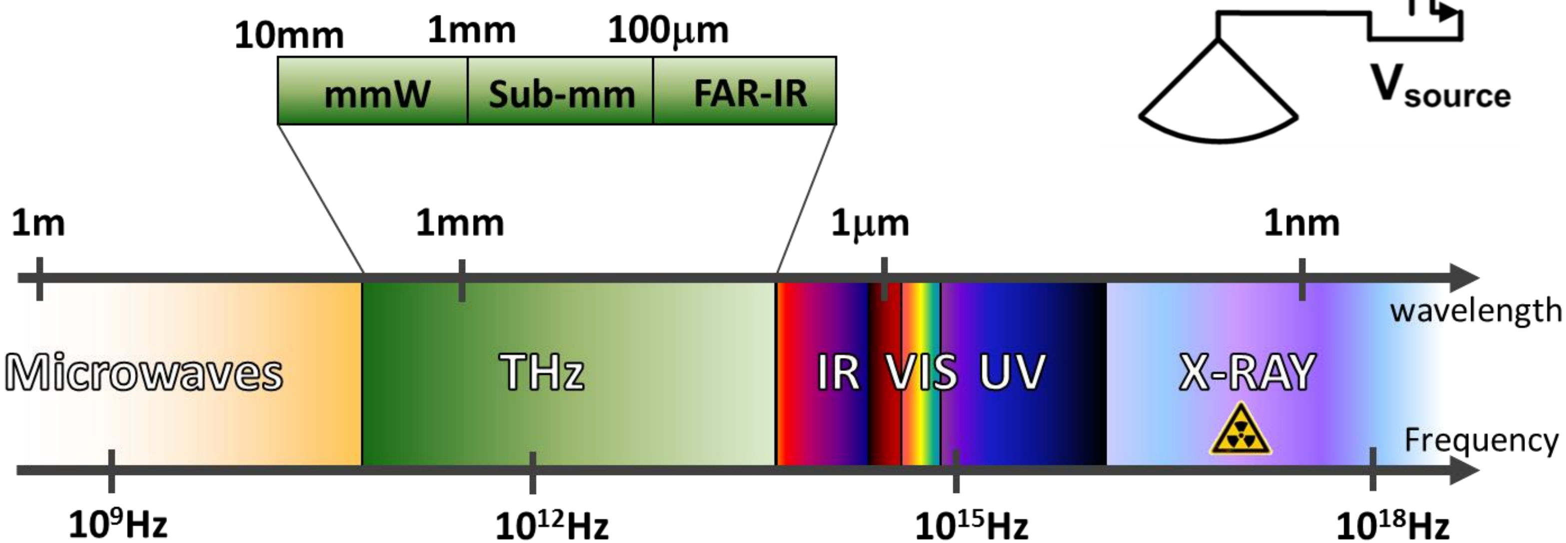
Terahertz Imaging

What you see is NOT what you get

CMOS Imagers: THz

What is terahertz radiation?





Frequency from ≈ 100GHz to 10THz

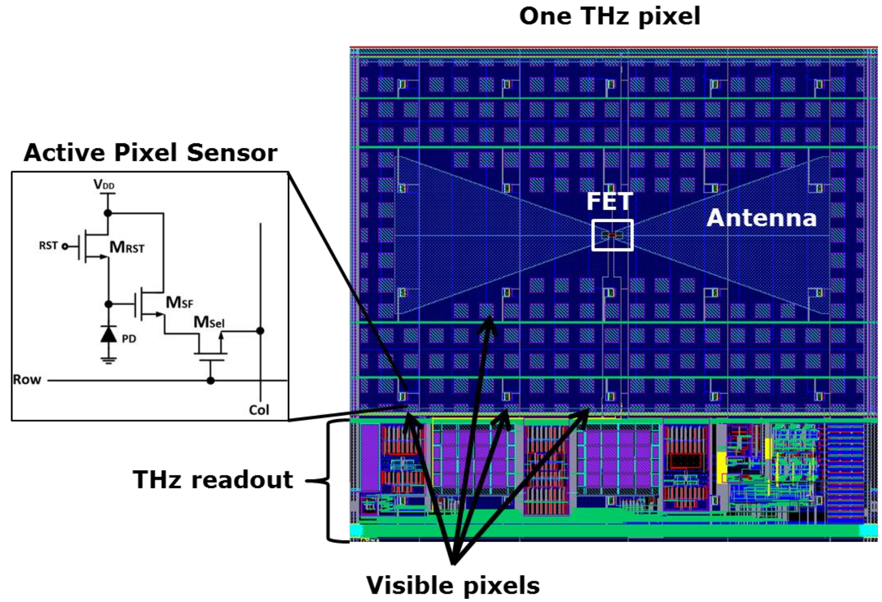
Few, weak, complex sources and detectors

Some interesting properties

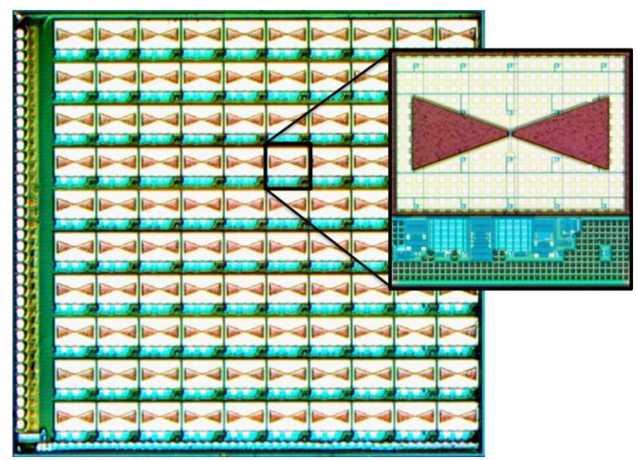
CMOS Imagers: THz

Multispectral terahertz and visible image sensor

- Prototype in 150nm CMOS
  - 10x10 THz pixels
  - 50x50 VIS pixels
- ≈5x5sqmm



- P_{diss}=2.84mW
  - 28µW/pixel (16µA)
  - Scalable!



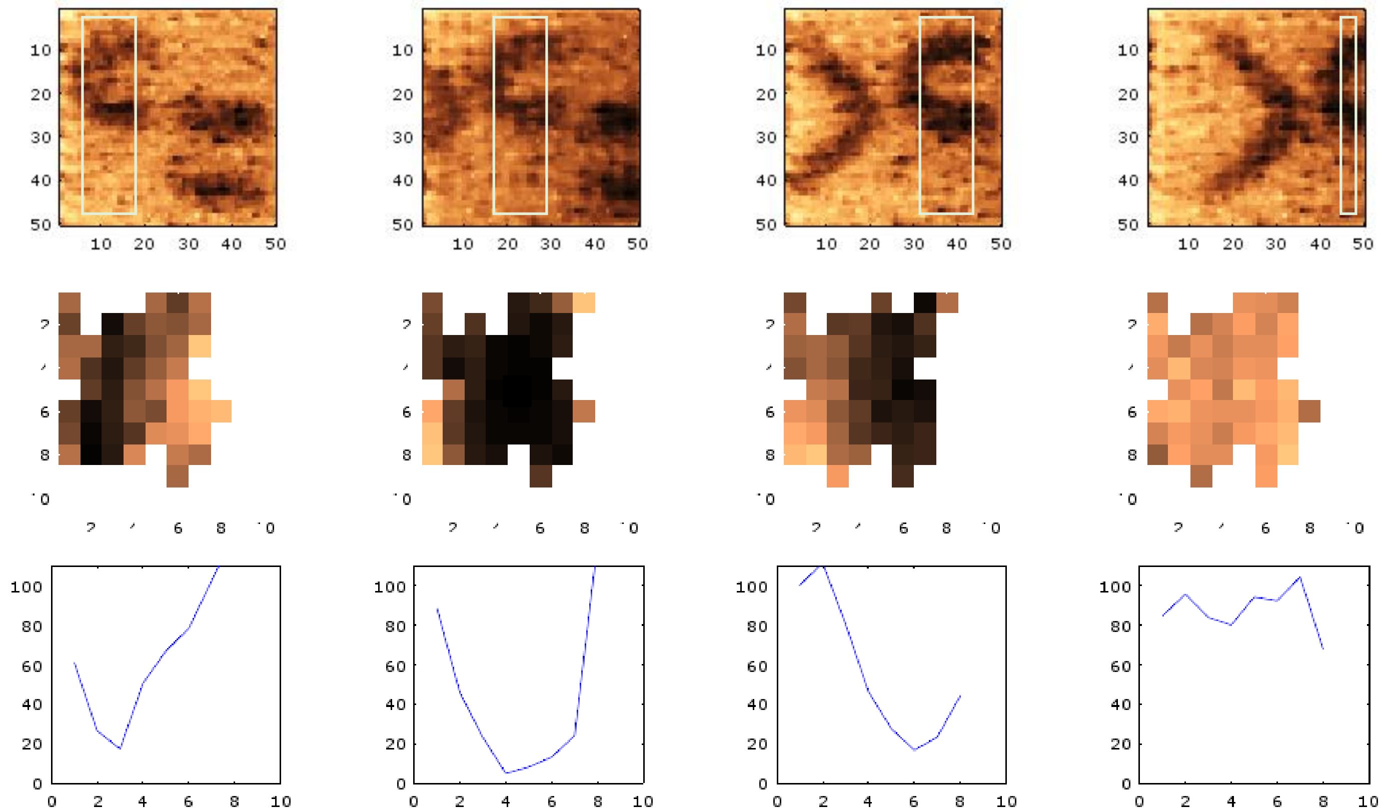
CMOS Imagers: THz

First example of real-time multispectral THz+VIS imaging

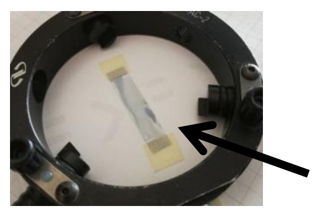
VIS image

THz transmission

Transmission profile



Target

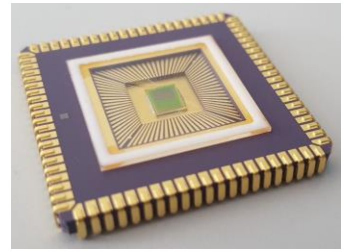


Conductive film

Low power VISION SENSORS

Do more with less

CMOS Imagers: Vision Sensors
QVGA with intelligent event detection



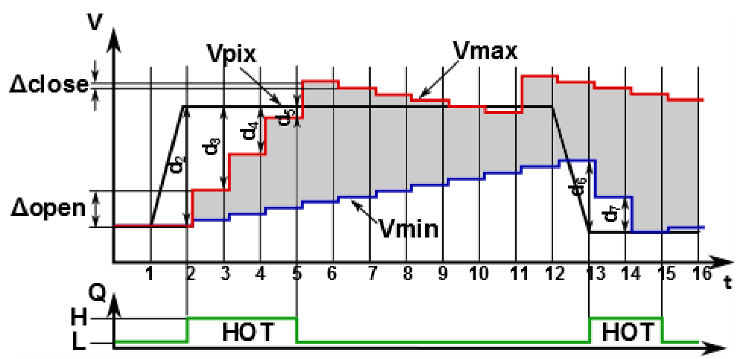
M. Gottardi et al, IEEE JSSC 2020

Features

- *Array format: 640H x 480V;*
- *Rolling shutter, Monochrome;*
- *ADC: 8-bit column parallel;*
- *Motion detection through double-threshold dynamic background subtraction;*
- *Event detection on motion;*
- *Window Size: VGA, QVGA;*
- *Data output:*
  - *alert on motion*
  - *160H x 120V motion bitmap*
  - *640H x 480V 8-b image*
  - *local binary pattern coding*

Applications

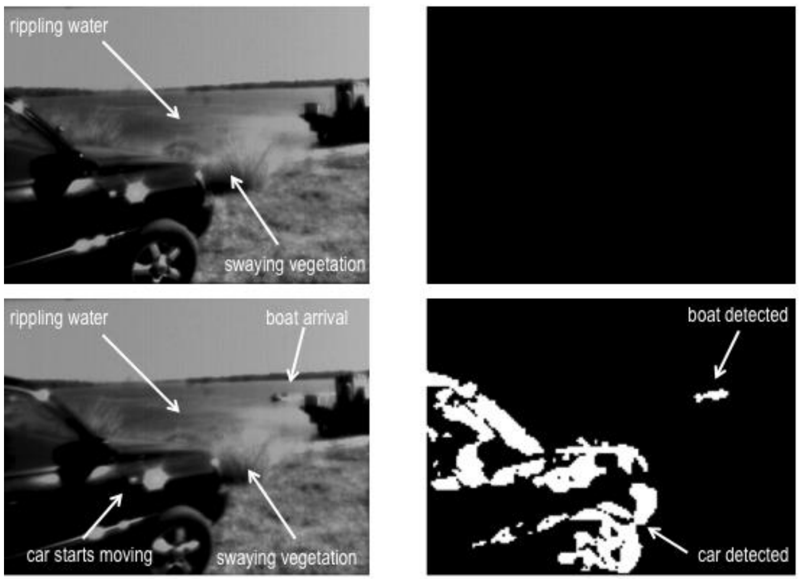
- *Security surveillance systems, Smart vision, Machine vision, Robotics*



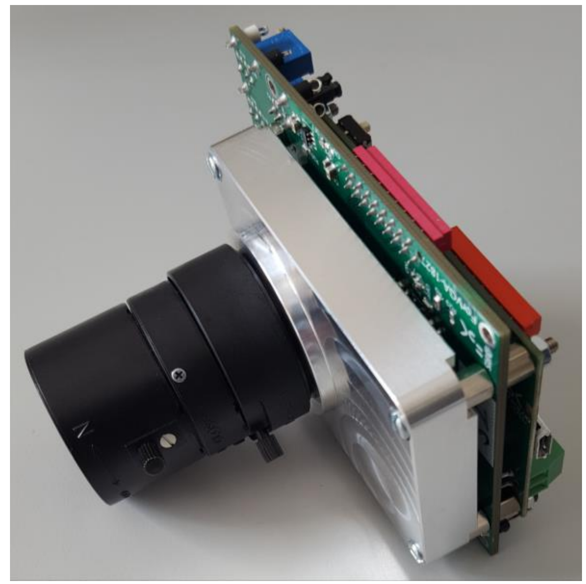
PARAMETER	VALUE
Technology	110 nm CMOS 1P4M
Optical format	1/6-inch
Active pixels	640H x 480V
Pixel size	4.0µm x 4.0µm
Fill Factor	49%
Output format	Monochrome
Shutter type	Rolling shutter
Frame Rate	8 – 30 fps
ADC resolution	8-bit column parallel
Supply voltage	3.3V analog / 1.2V digital
Power consumption	**350 µW alert detection** 1.35 mW full operation (8fps)
Packaging	Ceramic 84-pin JLCC

CMOS Imagers: Vision Sensors
QVGA with intelligent event detection

- Sensor operation

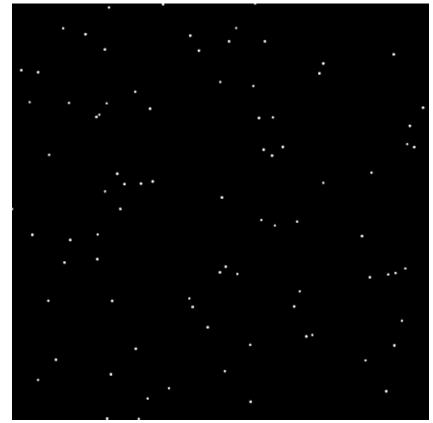


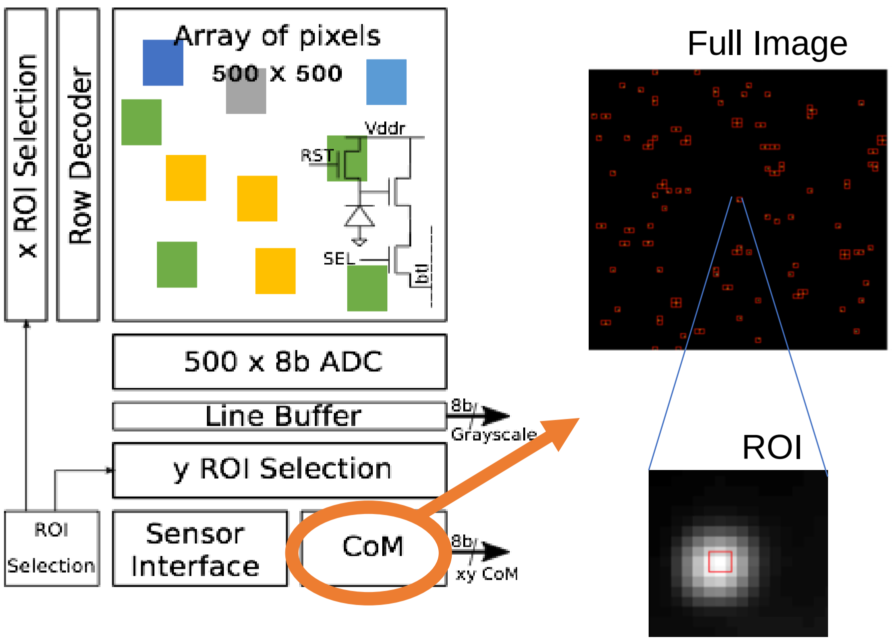
- Sensor prototype



CMOS Imagers: Vision Sensors
Miniaturized StarTracker for Nanosatellites

- Miniaturization via on-chip processing
  - Image processing
  - Stars centroid identification
- System level
  - FPGA pattern matching



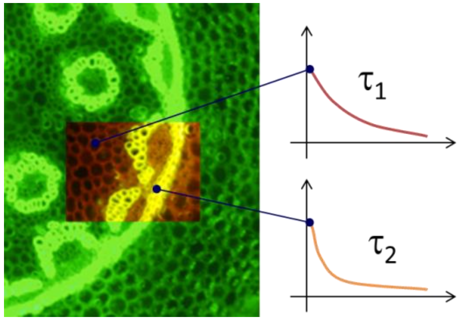


Main characteristics
- Resolution: 500 x 500 pixels
- Pixel pitch: 8um
- Die area: 5.3 mm x 5.8 mm
- Frame rate: 30 fps rolling shutter
- Max ROI size (128 x 128 pixels)
- Max no. of 32 x 32 pixels ROIs: 225
- Operating Modes:
  - Imaging Mode (**IM**): full resolution gray-scale
  - ROI Mode (**ROI**): arbitrary numbers of ROIs
  - Center of Mass (**CoM**) estimation for each ROI

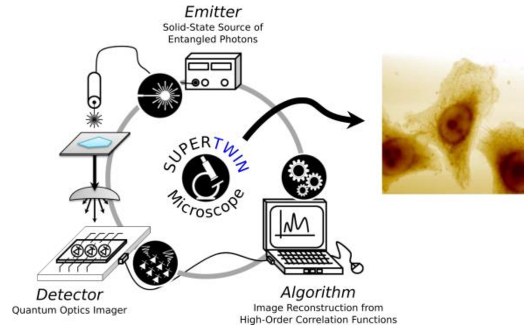
SPAD Image Sensors

Exploiting Single Photons

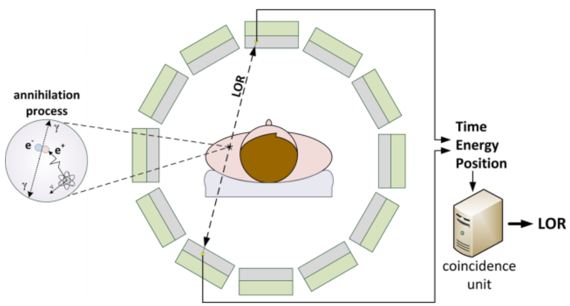
CMOS Imagers: SPAD Imagers
Applications of SPAD image sensors



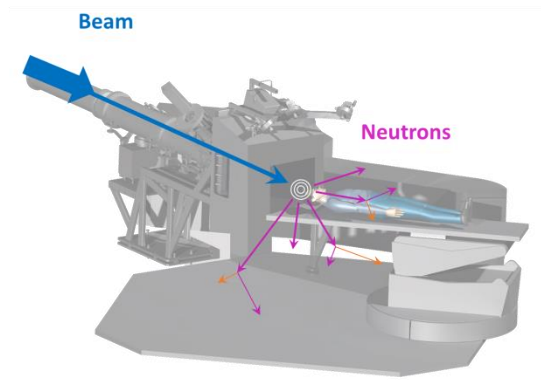
Biophotonics (FLIM)



Quantum Imaging



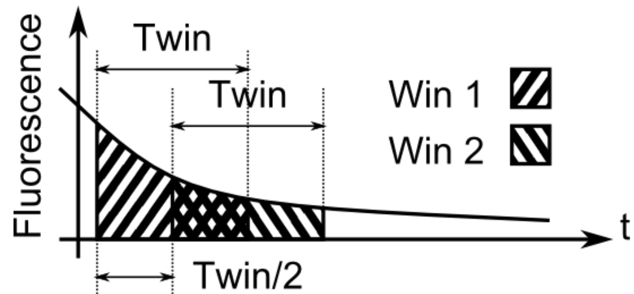
Positron Emission Tomography

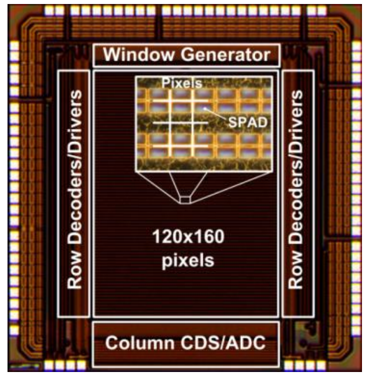


Proton Therapy Monitoring

CMOS Imagers: SPAD Imagers
Biophotonics: FLIM

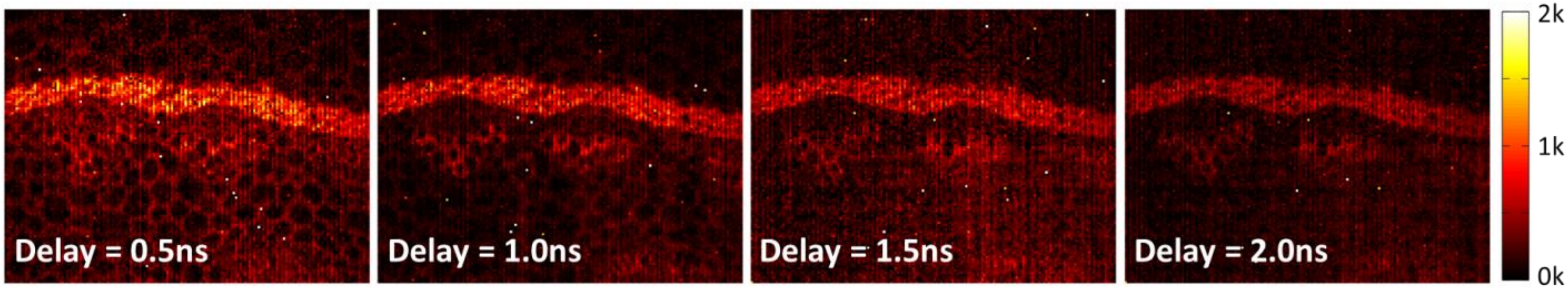
- Time-gated analog photon counting
  - In-pixel analog counter
  - Self-referenced column A/D
  - 160x120 array
  - 15um pitch, 21% FF
  - 486fps, 8bit/pixel





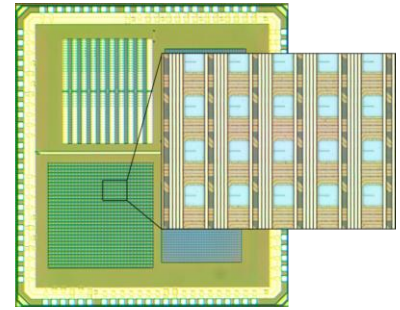
M. Perenzoni et al, IEEE JSSC 2016

3ns gating windows, delayed intensity image of Lily of the Valley: fluorescence decay



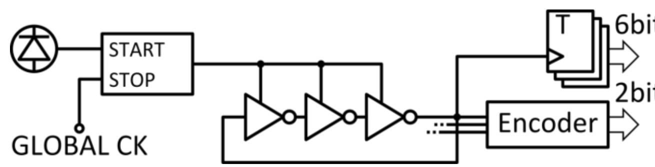
CMOS Imagers: SPAD Imagers
Quantum imaging: super-resolution

- Detection of non-local photon correlations
  - Simultaneous photons
    - → TDC
  - Efficient readout
    - → Global threshold
  - 200ps resolution
  - Framerate 250kfps

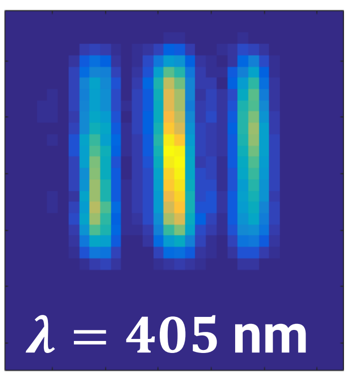


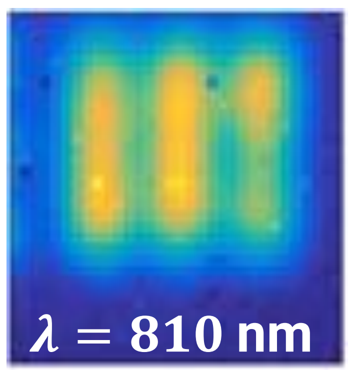
L. Gasparini et al, IEEE ISSCC 2018

Pixel architecture

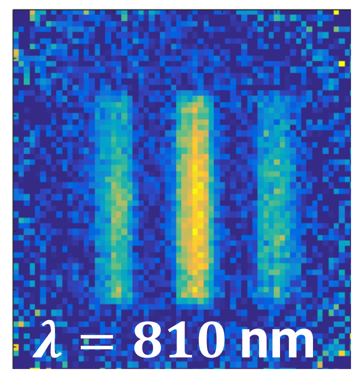


Rayleigh limit $\boldsymbol{R} \propto \frac{\lambda}{\mathrm{NA}}$



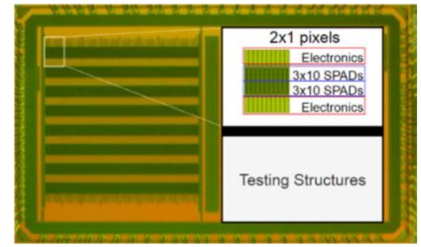


Heisenberg limit $\boldsymbol{R} \propto \frac{\lambda}{2\,\mathrm{NA}}$

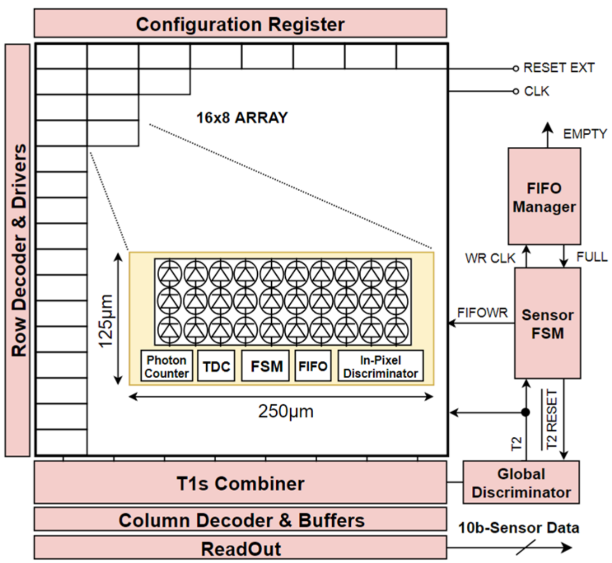


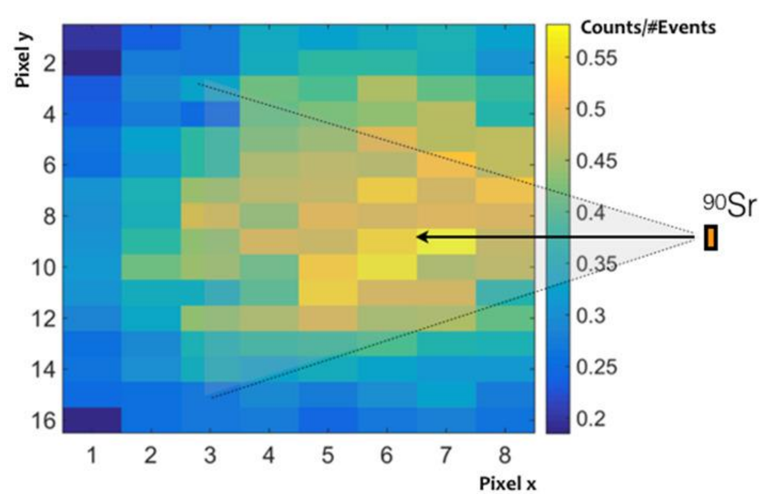
CMOS Imagers: SPAD Imagers
Biomedical imaging: proton therapy monitor

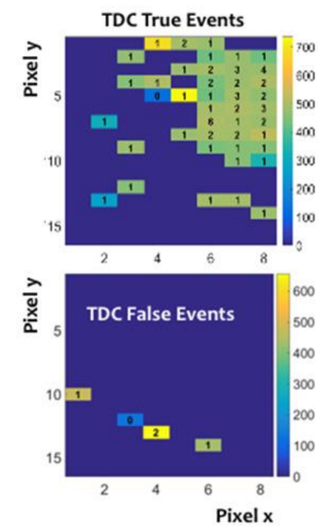
- Digital SiPM pixel
  - 30 SPADs
  - Photon counting
  - Time-to-digital converter
  - Local discriminator
- Architecture
  - Event combiner
  - Global discriminator
  - Multi-chip coordination



E. Manuzzato et al, IEEE SSCL 2019







3D Imaging

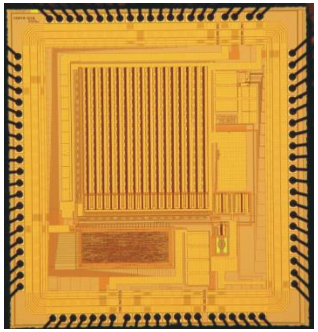
Add one dimension

CMOS Imagers: 3D Imaging

Indirect and direct Time-of-Flight Imaging: our history

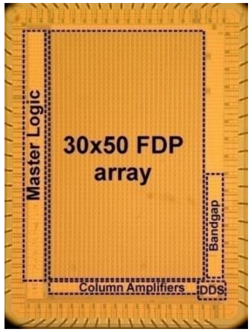
I-ToF

2003



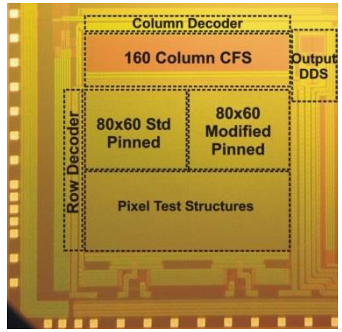
16x16-pixel
0.35um

2005



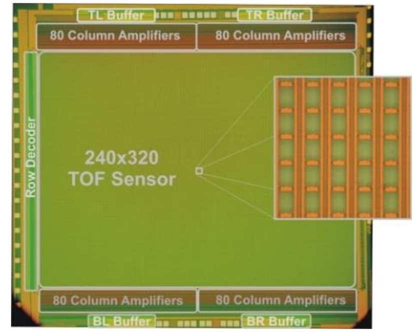
30x50-pixel
0.35um

2009



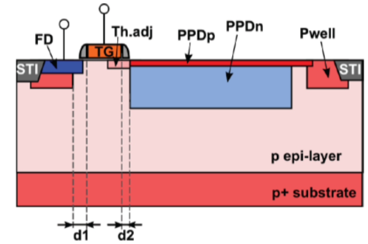
80x60-pixel
180nm CIS

2010



320x240-pixel
180nm CIS

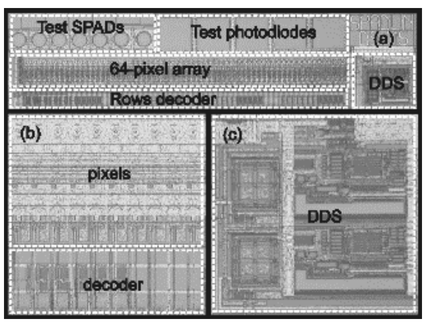
2017



Optimized
Transfer-gates

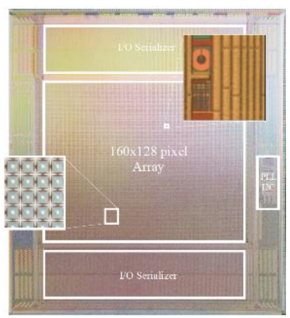
D-ToF

2006



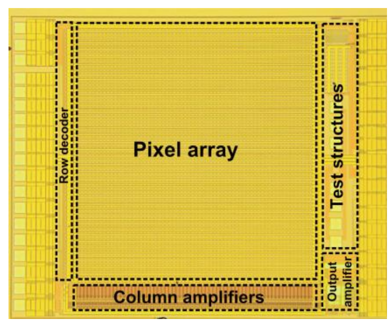
64-pixel linear
0.8um HV

2012



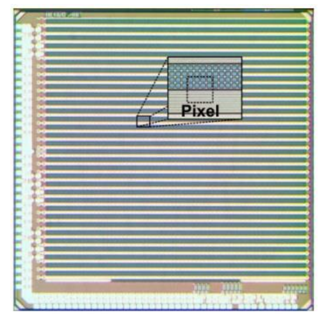
128x160-pixel
130nm CIS

2013



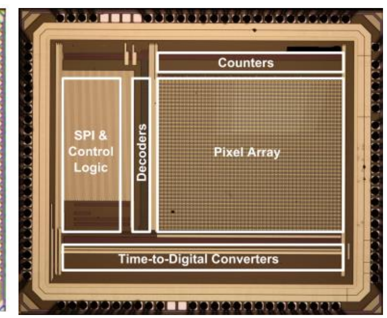
64x64-pixel
0.35um

2016



64x64-pixel
150nm CMOS

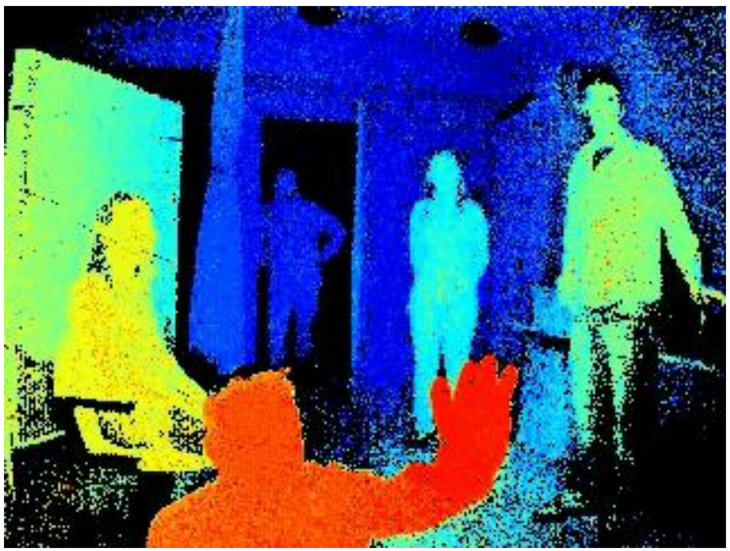
2019

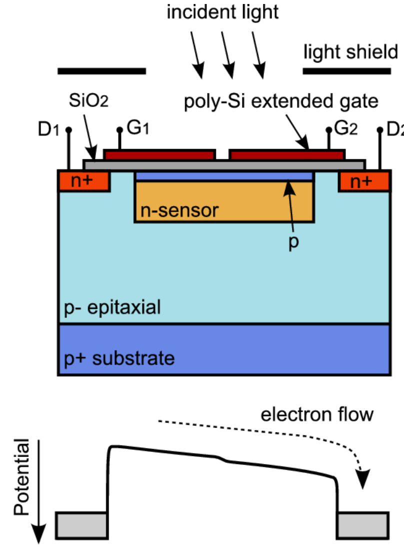


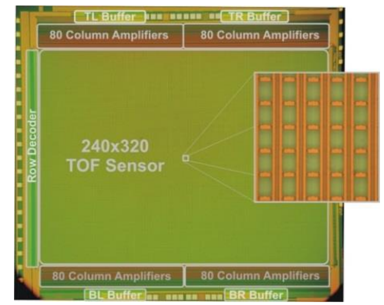
50x40-pixel
150nm CMOS

CMOS Imagers: 3D Imaging
Indirect Time-of-Flight Imaging

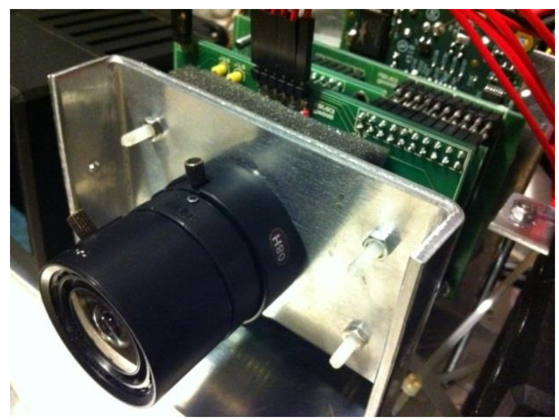
- Special CMOS-based photo-demodulating device
  - 14µm pixel size
  - 320x240-pixels
  - High-dynamic range





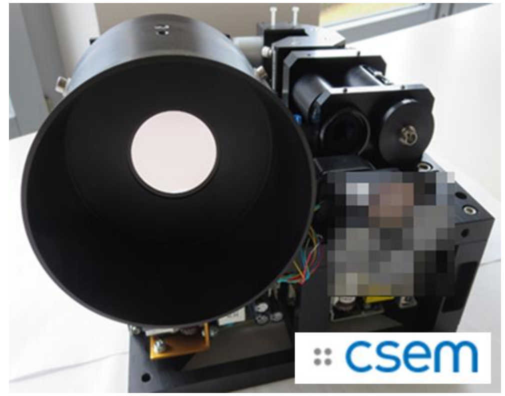


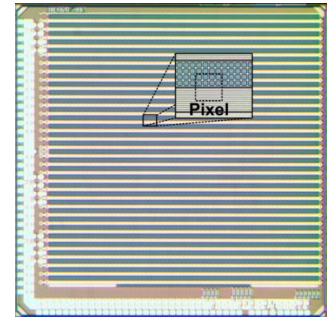
L. Pancheri et al., IEEE ISSCC 2012



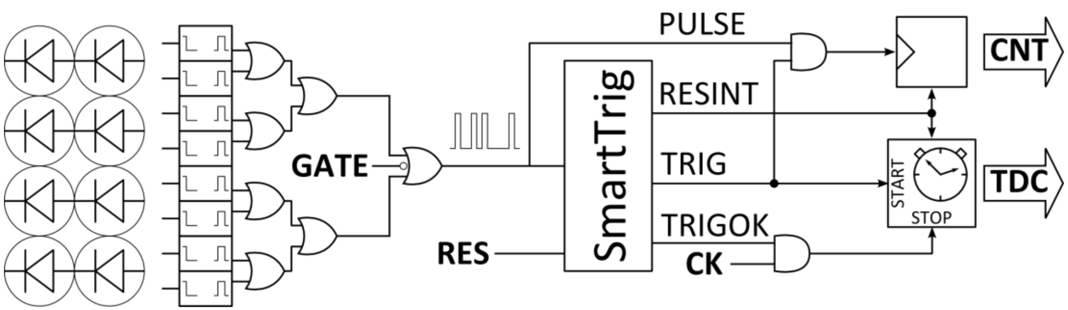
CMOS Imagers: 3D Imaging
Direct Time-of-Flight Imaging

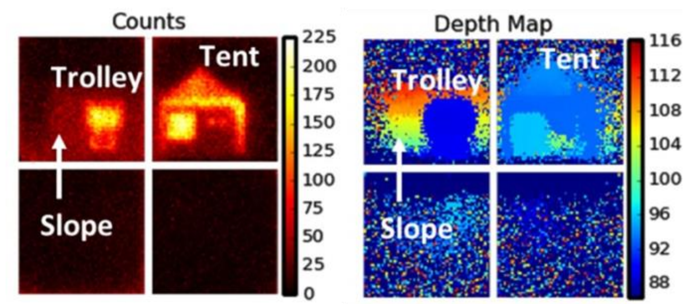
- Lidar Image Sensor
  - 64x64 pixels with TDC/CNT
  - 60-µm 26.5% FF
  - 16-bit 250-ps TDC
  - ESA project for space
  - TRL4 Breadboard





M. Perenzoni, et al., IEEE JSSC 2017





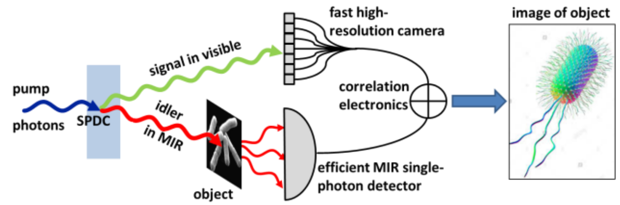
Current research

Imaging and more

CMOS Imagers

Some of the currently ongoing research

- Quantum Ghost Imaging
  - Measuring objects with a light that actually did not interact with them



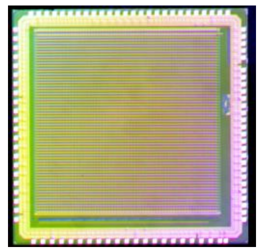
- 4D Imaging for Physics
  - Measuring xyzt using HVCMOS technologies and pixelated sensors

- Quantum Random Number Generation
  - True randomicity exploiting in-silicon generation and detection of light

Detector

Si-LED

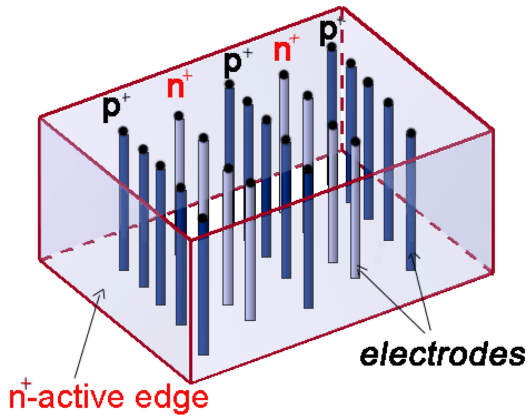
- High-Resolution 3D Imaging
  - Small & smart pixels for high-pixel count 3d direct ToF imaging



3D detectors

Si-3D detectors
Technology - overview

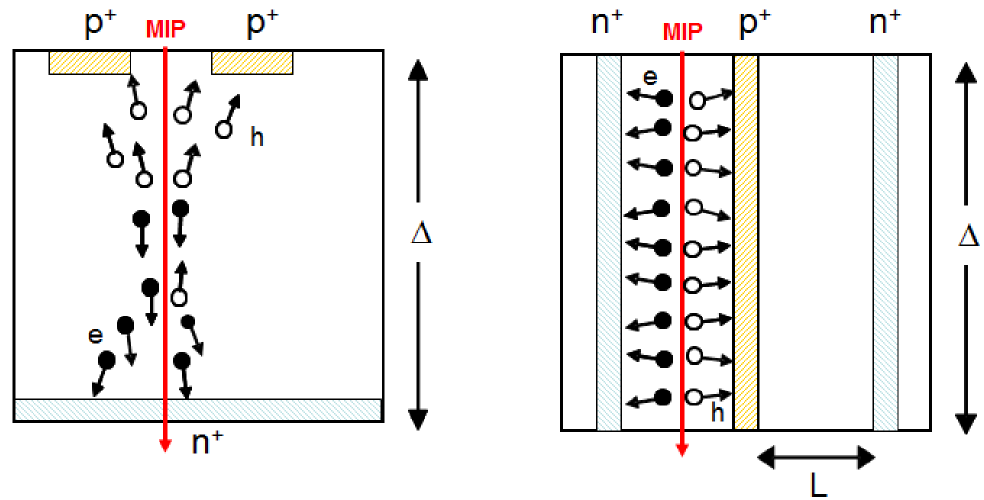
S. Parker et. al. NIMA 395 (1997) 328



ADVANTAGES:

- Low depletion voltage (low power diss.)
- Short charge collection distance:
  - Fast response rise
  - Less trapping probability after irradiation
- Lateral drift → cell "shielding" effect:
  - Lower charge sharing
  - Low sensitivity to magnetic field
- Active edges

Electrode distance (L) and active substrate thickness (Δ) are decoupled → L<<Δ by layout



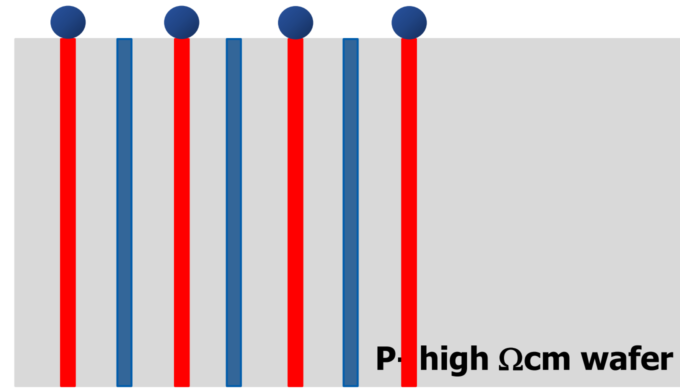
DISADVANTAGES:

- Non uniform spatial response (electrodes and low field regions)
- Higher capacitance with respect to planar (~3-5x for ~ 200 μm thickness)
- Complicated technology (cost, yield)

Si-3D detectors
Technology at FBK

Double-side 3D, produced by FBK for IBL

Δ =230 μm, L~ 67 μm, column diam. ~12 μm
Excellent performance up to 5×10^{15} n_{eq} cm^{-2},
also pushed to ~1.4×10^{16} n_{eq} cm^{-2} in AFP tests

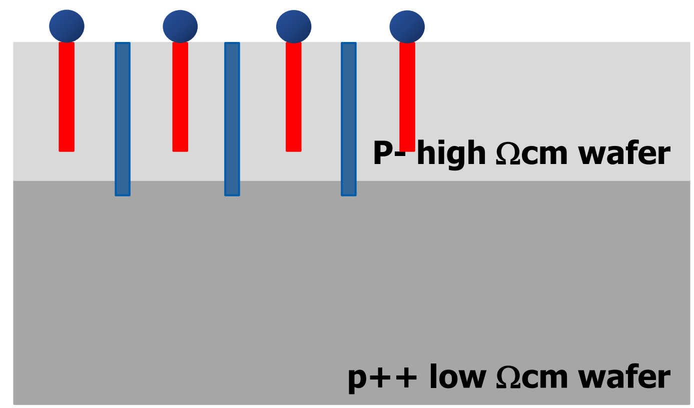


FBK involved in the production of detectors for ATLAS IBL

Da Via et al, NIMA 694(2012) 321- 330

New single-side 3D technology/design for HL-LHC

- thinner sensors (100-150 µm),
- narrower electrodes 5 µm
- reduced inter-electrode spacing (~30 µm)



FBK will be one of the lab involved in the realization of 3D Si for HL LHC ATLAS ITK

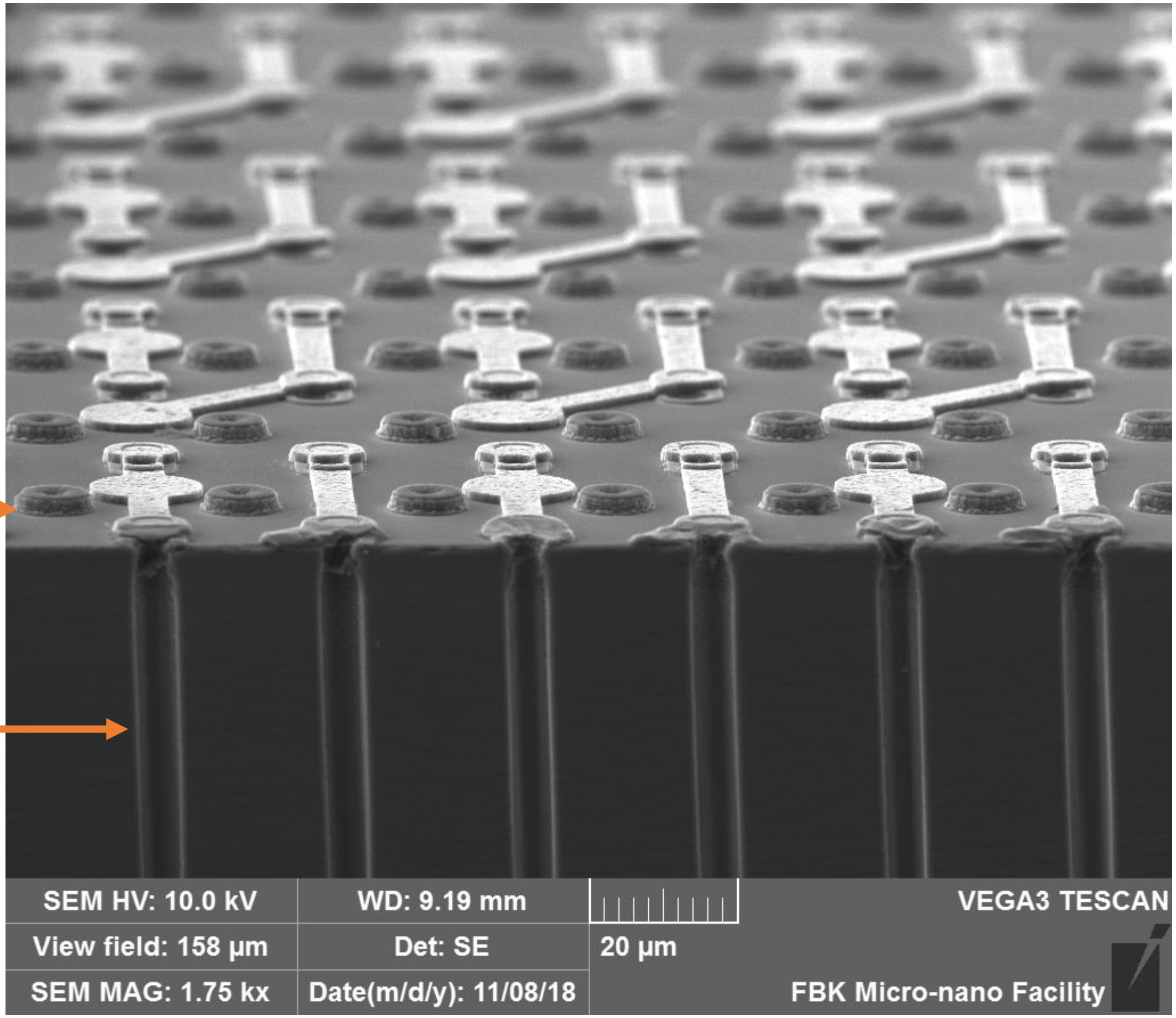
Lapertosa @ TREDI2021

https://indico.cern.ch/event/983068/timetable/#20210218.detailed

Si-3D detectors
Technology at FBK

Ohmic columns

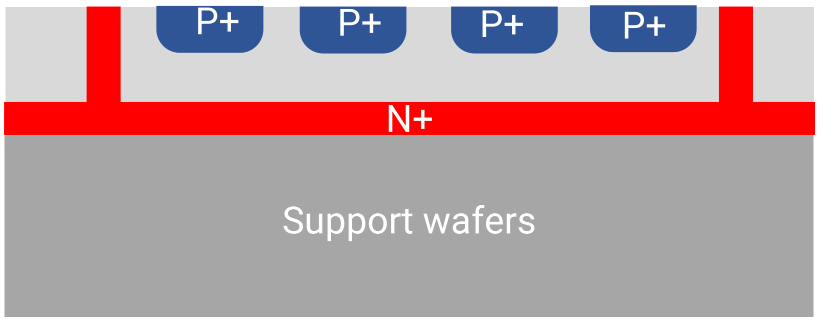
Junction columns



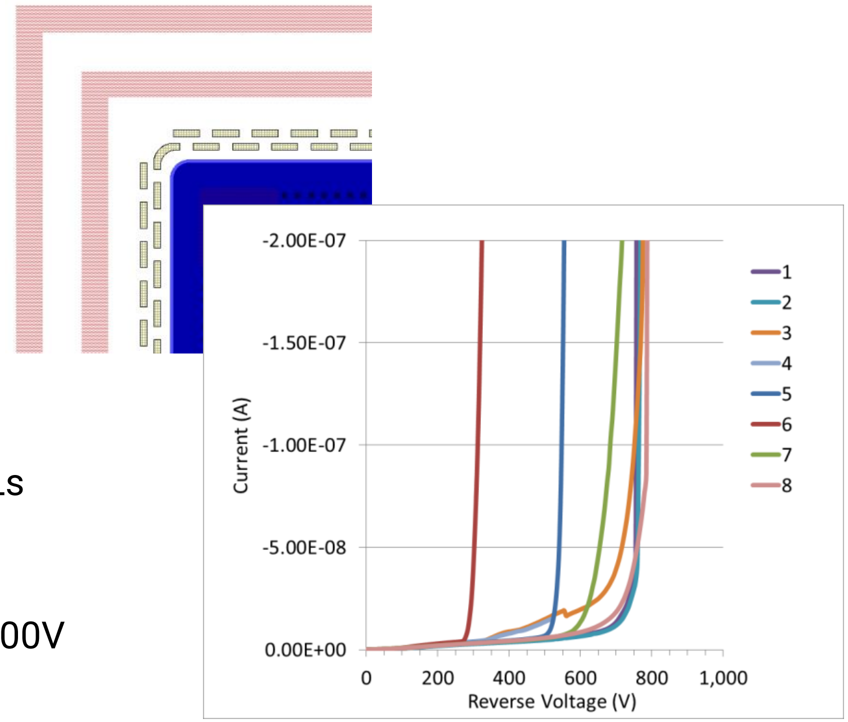
edgeless
technology

Edge-less pixel detectors
R&D at FBK

Goal: reduction of the lateral dead area
Idea: replace large guard ring structures with doped trenches



Application in pixel for HEP
G. Calderini *et al* 2019 *JINST* **14** C07001



PIXFEL INFN Project
Development of high-performance X-ray imaging instrumentation for experiments at the next generation FELs

- Thick wafers (450 -600)
- dead area: as small as possible, 2% seems feasible
- Slim Edge approach: 150um dead area 4GR VBK about 400V

M.A. Benkechkache et al, IEEE TNS vol. 64, no. 4, pp.1062-1070, 2017

FONDAZIONE BRUNO KESSLER
SENSORS AND DEVICES

Thank you for your attention

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