



KETEK GmbH Munich - Germany

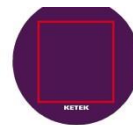
SiPM Solutions

realized by KETEK

W. Hartinger, F. Wiest, P. Iskra, T. Ganka

EPS-TIG – Ravenna (Italy)

Nov. 11-12, 2013



KETEK

Creative Detector Solutions



Creative Detector Solutions

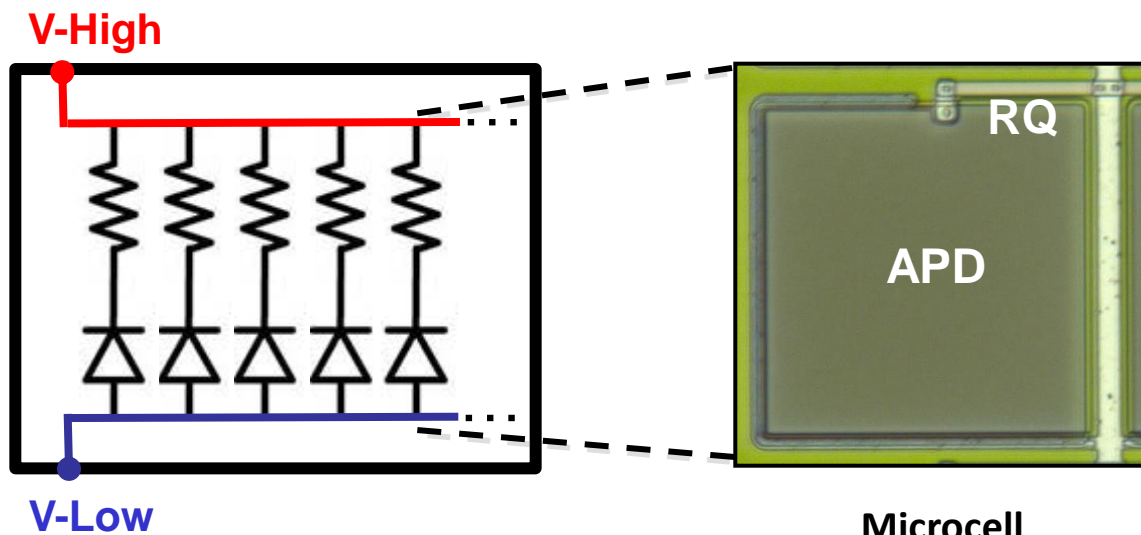
EPS-TIG – Nov 11-12, 2013, Ravenna (Italy)

Werner Hartinger
KETEK GmbH

- SiPM
 - Working principles
 - Characteristics
 - Applications
- KETEK SiPM off-the-shelf devices
 - Key features and standard portfolio
 - Technology
 - GE and PDE of different microcell types
- KETEK customized devices for CERN
 - with very small microcell pitch
 - with very low optical cross talk
- Summary and outlook
- Conclusions



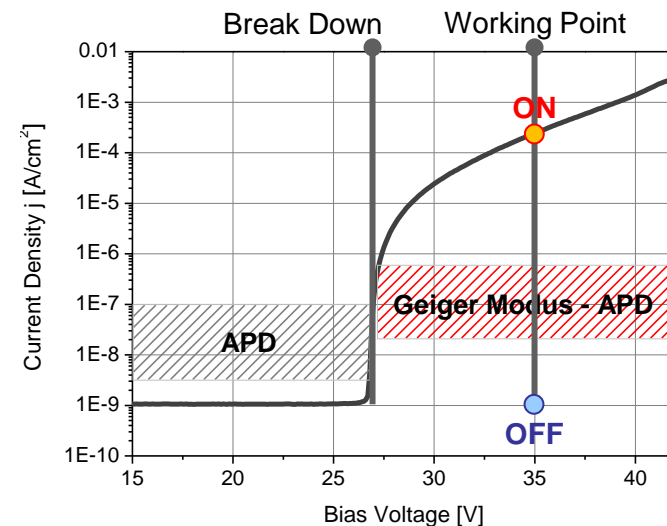
Working Principle of a Silicon Photomultiplier (SiPM)



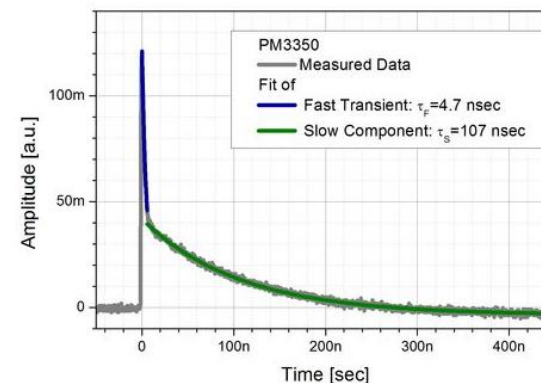
Schematic of a SiPM-Chip

(e.g. 3600 Microcells)

- Micro-APDs are operated above breakdown: Geiger mode (single photon counting)
- Microcell signal is independent of incoming light
- Device signal = sum of all microcells (contains intensity information)



Working Principle



SiPM Pulse Shape

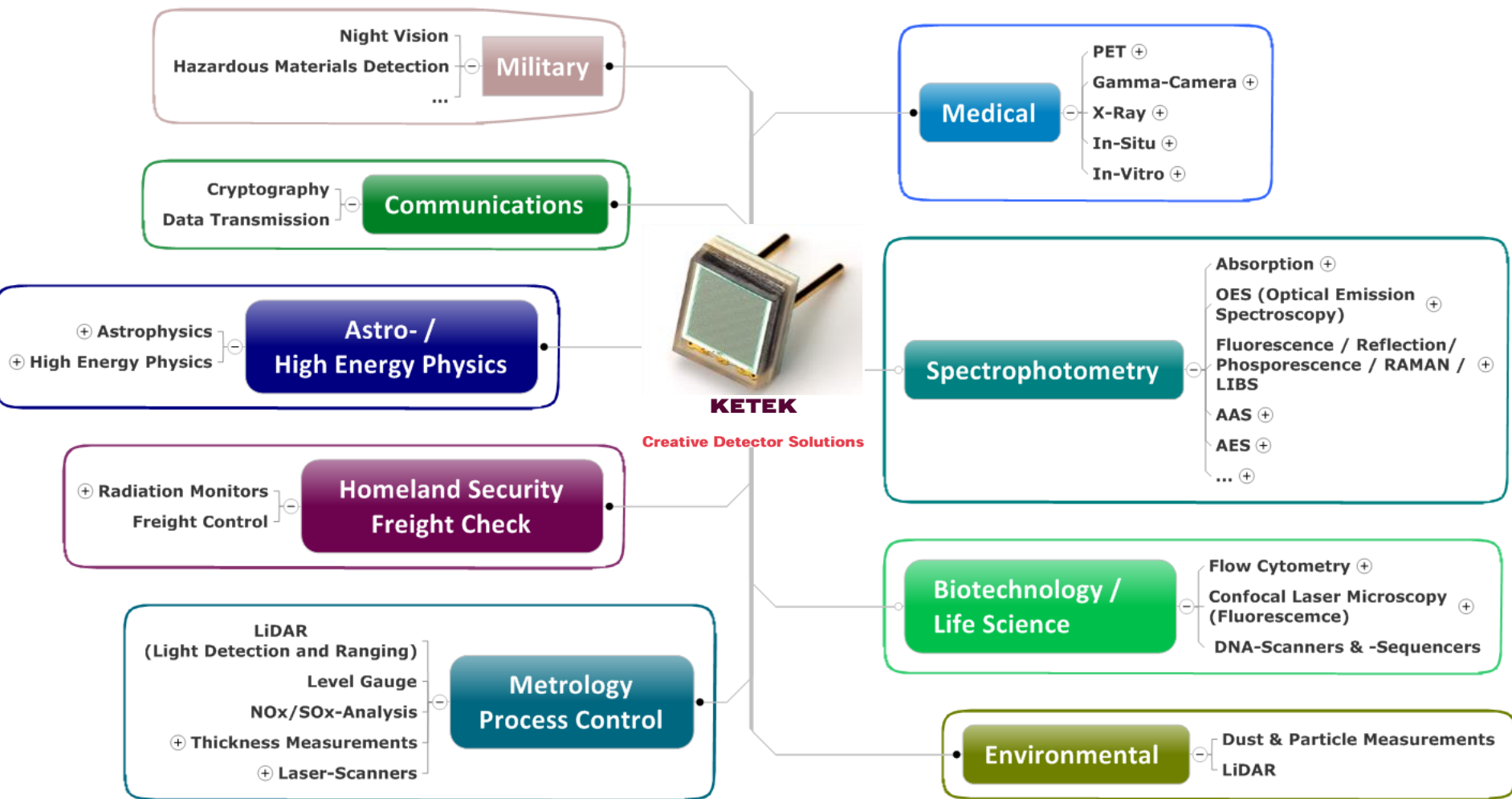


Comparison of Low Level Light Sensors

	PMT Photomultiplier Tube	APD Avalanche Photodiode	SiPM Silicon Photomultiplier
Quantum Efficiency	25% ... 40%	60% ... 80%	... 80%
Single Photon Resolution	✓	-----	✓
Operation Voltage	1 - 3 kV	100 - 500 V	20 ... 80 V
Gain	$10^4 - 10^9$	30 - 300	$10^5 - 10^7$
Insensitivity to Magnetic Field	-----	✓	✓
Miniaturization	-----	✓	✓
Production Costs	Medium	Low	Potentially Low

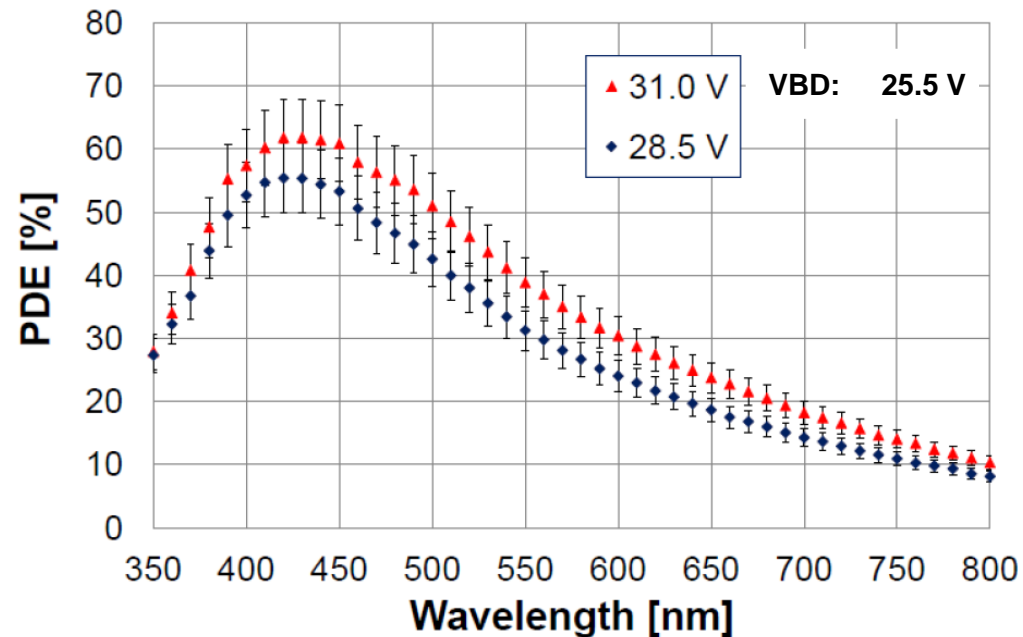


SiPM Applications



Key Features of KETEK's SiPM Sensors Overview

- Very high PDE
 - up to 60 % for 50 μ m cell type @420 nm
- Huge gain
 - min. 10^6
- Optimized for blue light sensitivity
 - 420 nm peak sensitivity
- Low dark rate and excess noise
 - DR typically below 300 kHz/mm²
 - XT below 25% at 20% OV
 - DR and XT dep. on cell- and device type
- Huge bias voltage range of stable operation
 - up to 30% overvoltage
- Extremely low temperature coefficient
 - below 1% above 10% overvoltage
- Single channel portfolio
 - 4 chip / package sizes
 - 5 micropixel types



PM1150: Measurements performed by CERN / Iouri Musienko
(1.0 mm² active area, 50 μ m cell pitch, 70% GE, no trench)



KETEK Standard SiPM Modules

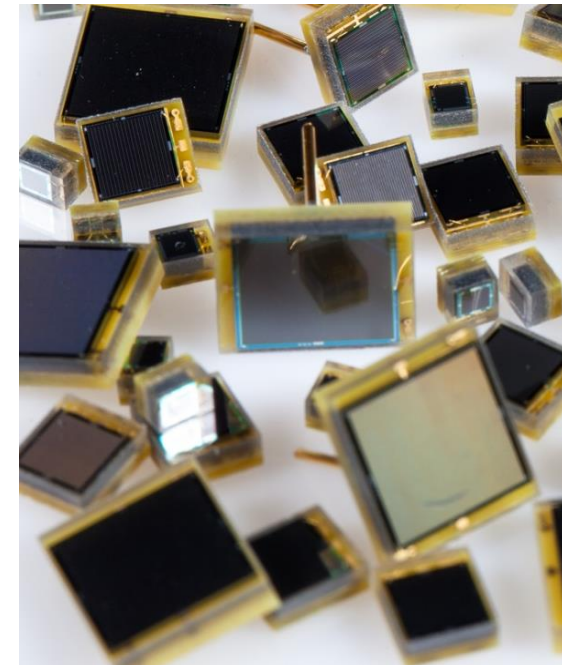
Type	Active Area [mm ²]	Cell Pitch [μm]	Geometrical Efficiency [%]	PDE @ 420 nm [%]	Dark Rate @ 20% OV [MHz]	Package Size [mm ²]	Connection	Order Code
PM11*	1.2 x 1.2	25	48	> 30	< 0.7	2.0 x 2.5	SMD	PM1125-B48N50S-Q3*
	1.2 x 1.2	50	70	> 45	< 0.7	2.0 x 2.5	SMD	PM1150-B70N75S-Q3*
PM22*	2.0 x 2.0	50	70	> 45	< 2.0	2.8 x 3.3	SMD	PM2250-B70N75S-Q3*
PM33	3.0 x 3.0	50	70	> 50	< 4.5	3.8 x 4.3	SMD or Pin	PM3350-B70N75S-P4

KETEK SiPM Modules with Optical Trench Isolation

Type	Active Area [mm ²]	Cell Pitch [μm]	Geometrical Efficiency [%]	PDE @ 420 nm [%]	Dark Rate @ 20% OV [MHz]	Package Size [mm ²]	Connection	Order Code
PM11*	1.2 x 1.2	50	63	> 40	< 0.7	2.0 x 2.5	SMD	PM1150-B63T75S-Q3*
	1.2 x 1.2	75	72	> 45	< 0.7	2.0 x 2.5	SMD	PM1175-B72T85S-Q3*
	1.2 x 1.2	100	81	> 50	< 0.7	2.0 x 2.5	SMD	PM11100-B81T95S-Q3*
PM22*	2.0 x 2.0	50	63	> 40	< 2.0	2.8 x 3.3	SMD	PM2250-B63T75S-Q3*
	2.0 x 2.0	100	81	> 50	< 2.0	2.8 x 3.3	SMD	PM22100-B81T95S-Q3*
PM33	3.0 x 3.0	50	63	> 40	< 4.5	3.8 x 4.3	Pin or SMD	PM3350-B63T75S-P4/Q3
	3.0 x 3.0	60	66	> 42	< 4.5	3.8 x 4.3	Pin or SMD	PM3360-B66T75S-P4/Q3
	3.0 x 3.0	75	72	> 45	< 4.5	3.8 x 4.3	Pin or SMD	PM3375-B72T89S-P3/Q3*
PM66	6.0 x 6.0	60	66	> 42	< 18	6.8 x 7.8	Pin	PM6660-B66T80S-P4

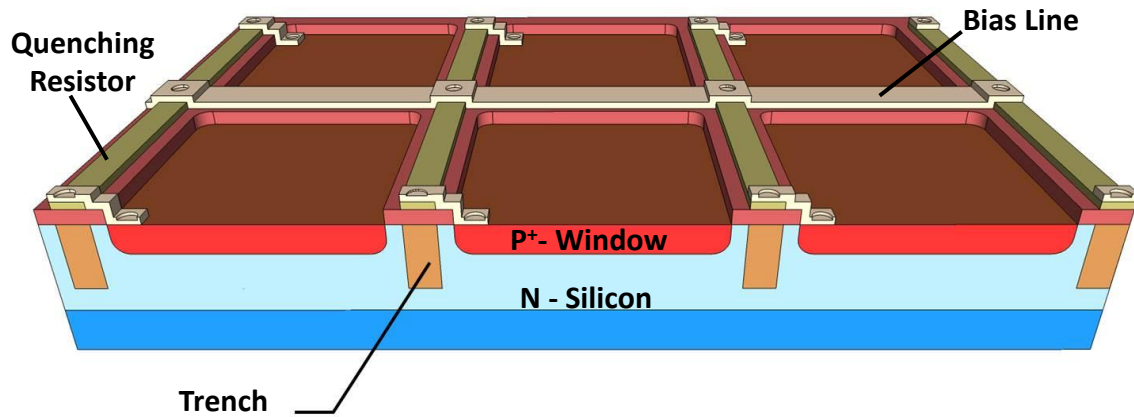
New devices 2014:

- PM6660 - SMD
December 2013
- PM55xx: Chip size package
June 2014
- 9-Channel-Array
Q2 2014



Basic Construction of the KETEK Microcell

Section of KETEK SiPM Microcell



- Silicon P on N structure with high Geiger efficiency
 - **Shallow entrance window** with high quantum efficiency
 - Optimized **geometrical fill factor**
- ⇒ **High photon detection efficiency**

- Available in two technologies -

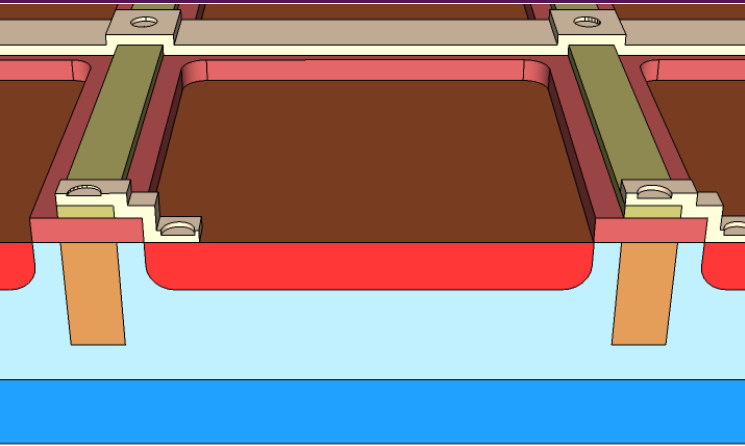
KETEK Standard Technology

- Technology optimized for maximum GE
- Devices with very high PDE
- Particularly suitable for small microcells and small active area

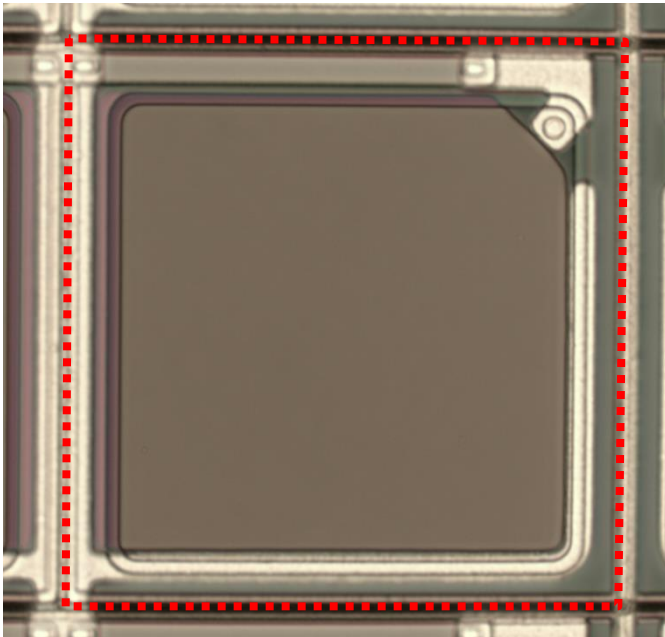
KETEK Trench Technology

- Technology with improved optical barrier and low-RC readout
- Devices with low crosstalk and improved timing
- Particularly suitable for large microcells and large area devices

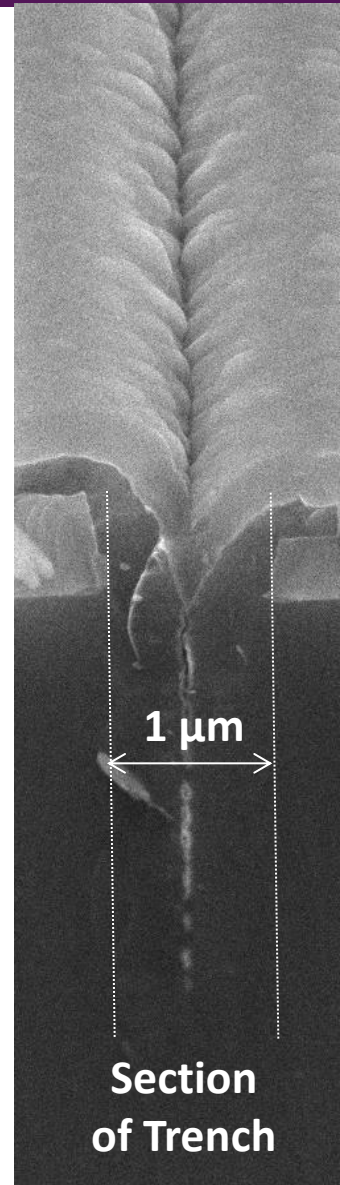




Section and Top View

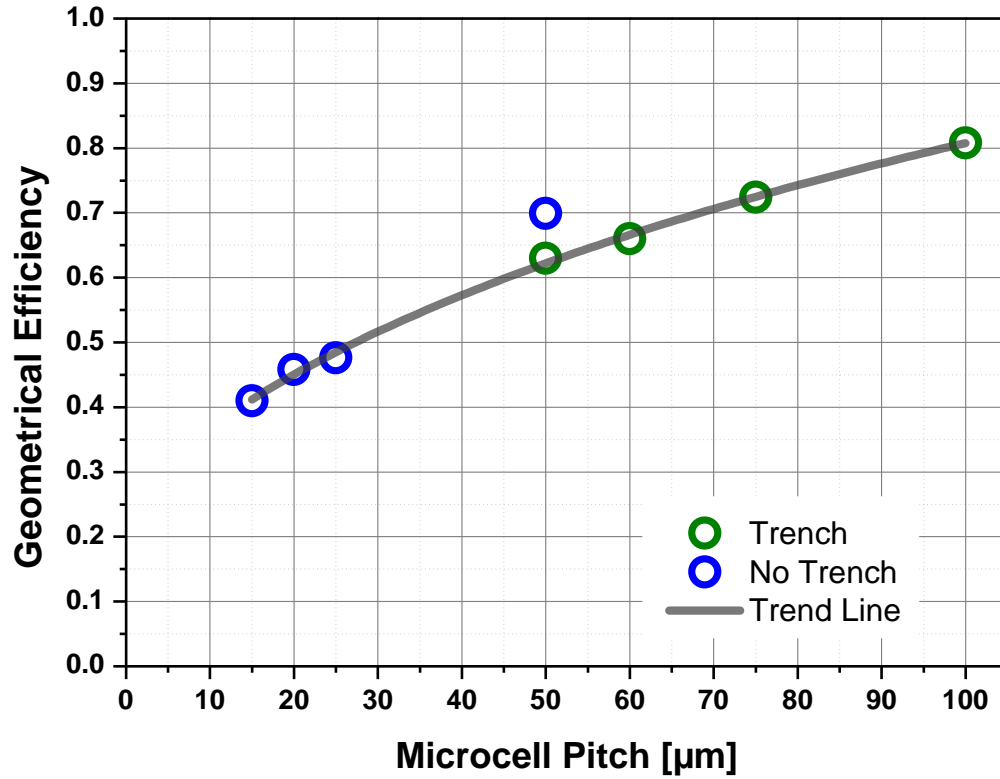


- Each microcell is completely surrounded by an optical trench isolation
- The trench is very narrow with a width of $1.0\ \mu\text{m}$

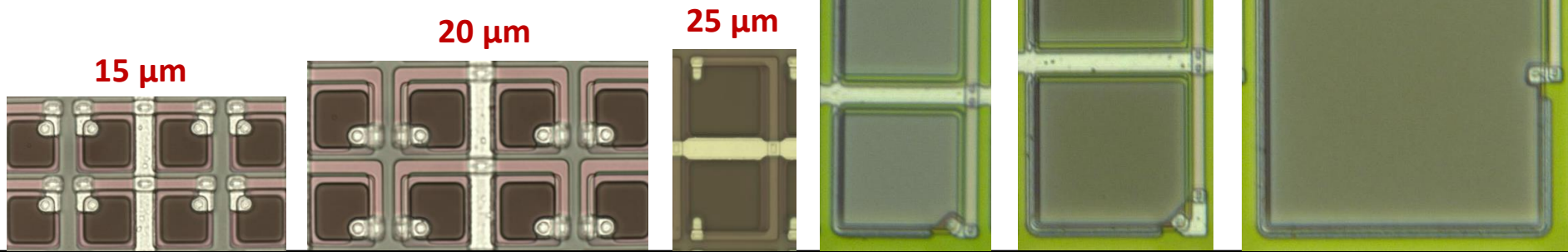


Section of Trench

Geometrical efficiency of different microcell types



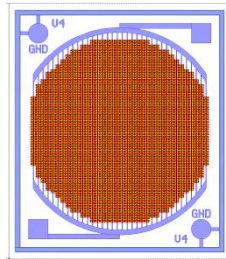
- Microcell sizes from 15 μm up to 100 μm realized
- Geometrical efficiency up to 70% for 50 μm microcell type



KETEK SiPM devices with small microcell pitch

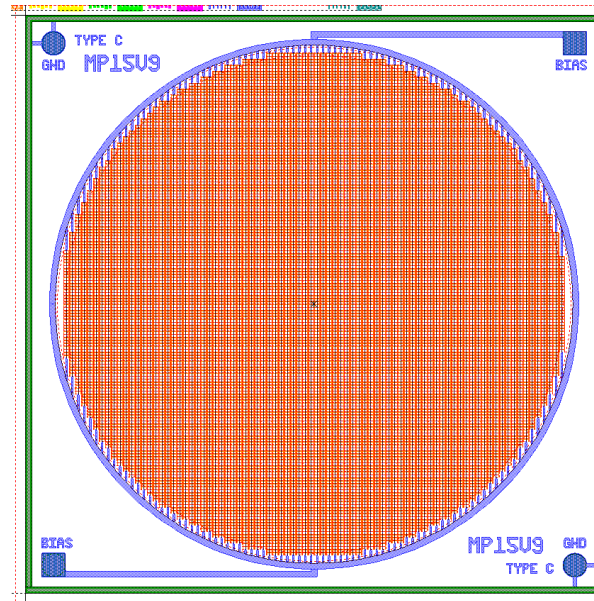
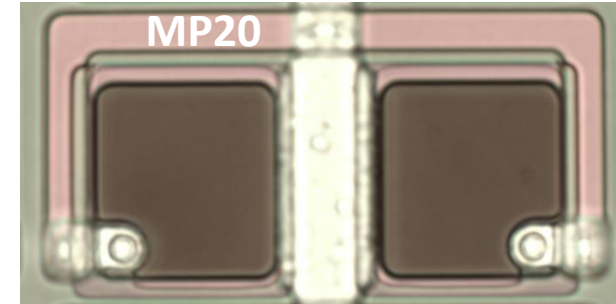
Chip Type A:

- Active area: 4.84 mm²
- 12100 cells with 20 μm pitch
- PDE at 515nm: 20% ... 23%
- PDE at 420 nm: 30% ... 35%



Chip Type B:

- Active area: 1.0 mm²
- 4384 cells with 15 μm pitch
- PDE at 515nm: 14% ... 15%
- PDE at 420 nm: 20% ... 23%



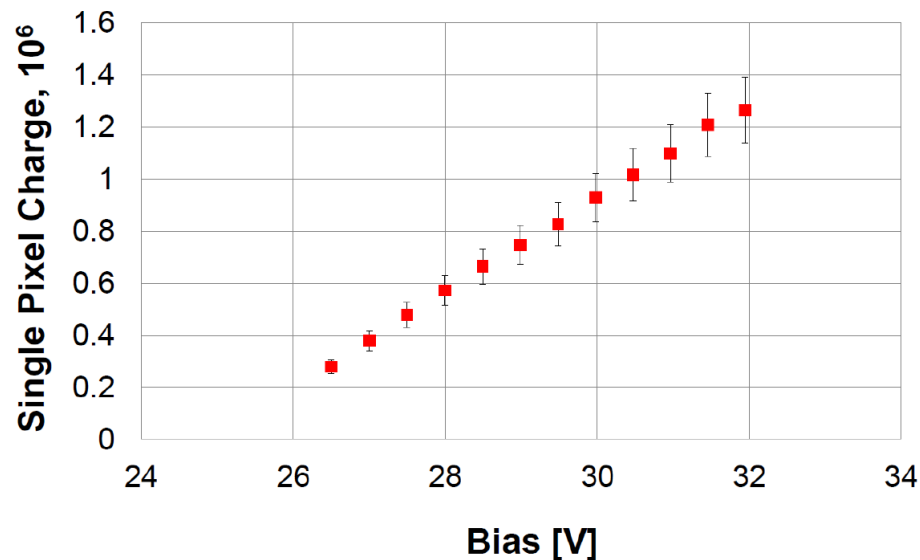
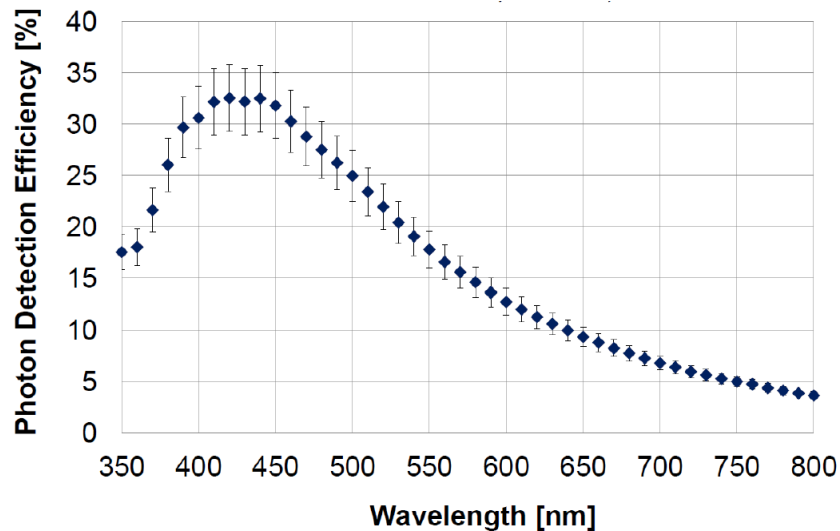
Chip Type C:

- Active area: 5.0 mm²
- 22376 cells with 15 μm pitch
- PDE at 515nm: 17% ... 20%
- PDE at 420 nm: 22% ... 24%



Basic SiPM parameters of chip type A

20 μ m Cell Pitch Type



Basic parameters of chip type A

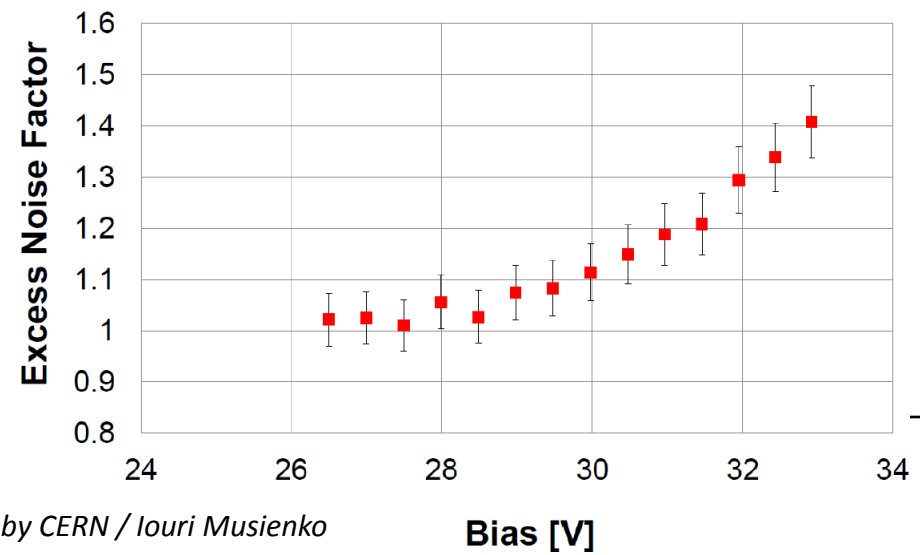
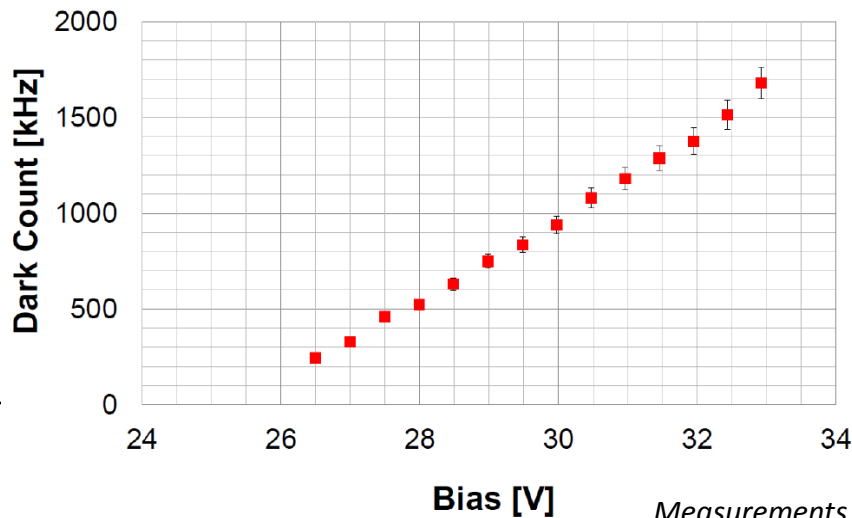
Active Area: 4.8 mm²

Cell Pitch: 20 μ m

GE (layout): 46%

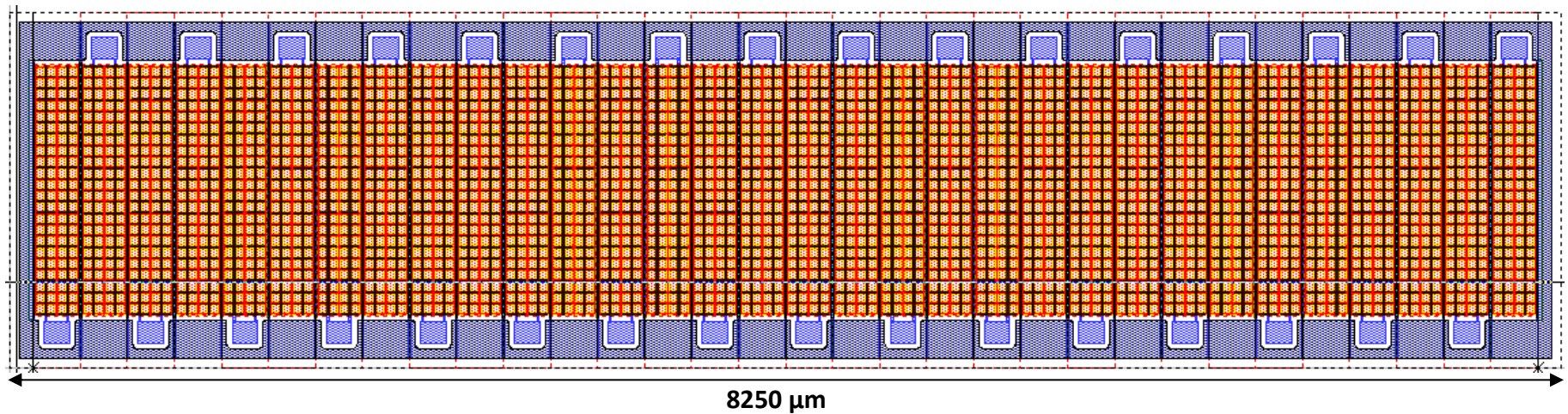
VBD: 25.5 V

Batch: C1-W12-V4



Measurements performed by CERN / Iouri Musienko

KETEK SiPM devices with low optical cross talk

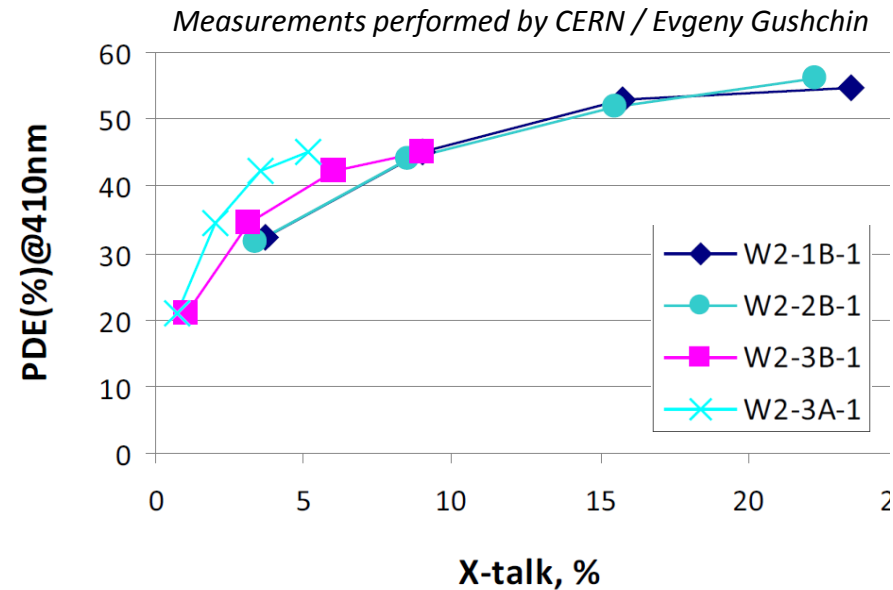


Geometry of device:

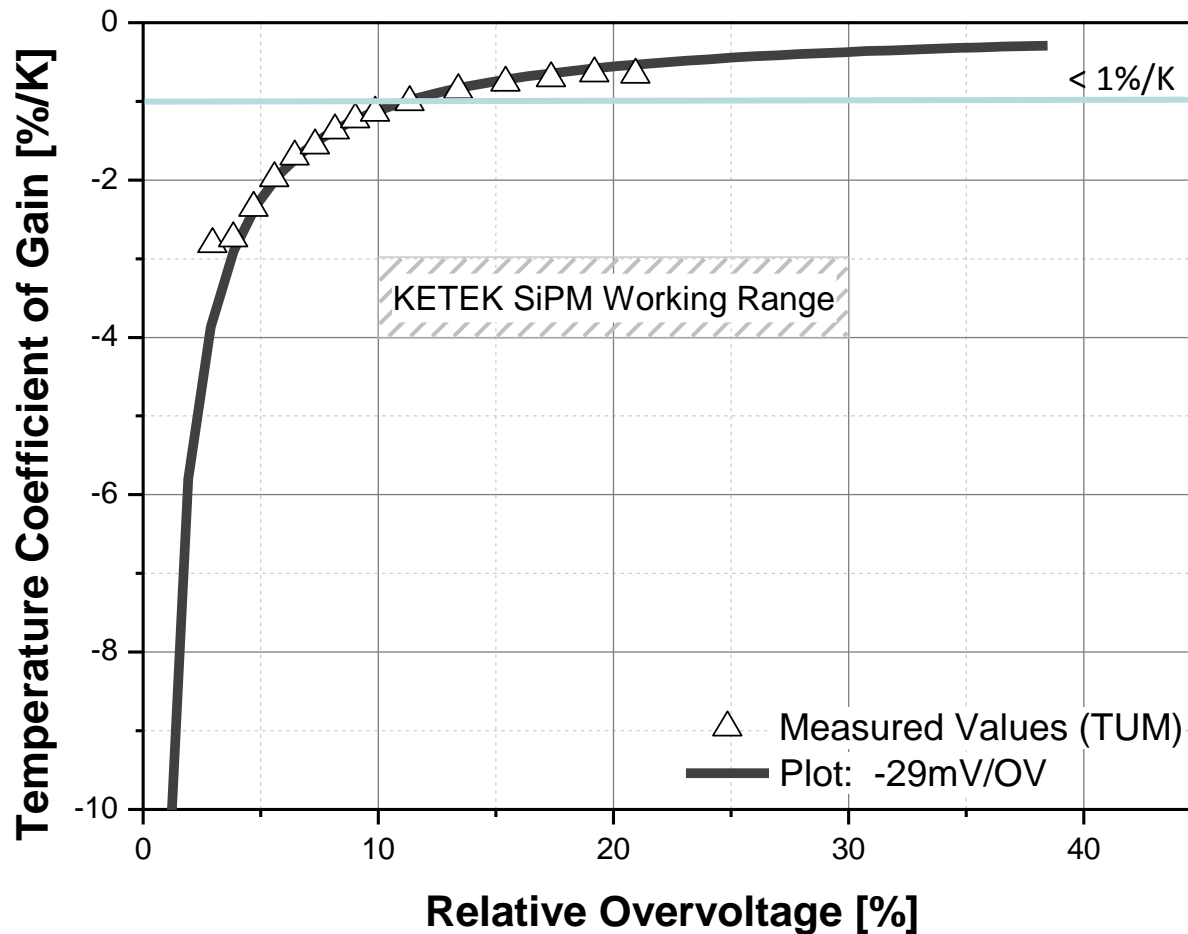
- 32 Bias Bondpads ("Bias") with GND Bond Frame
- Cell Pitch: 60 μm x 57.5 μm
- Quantity of cells: 88 per channel // 2816 per chip

First Spectroscopic results:

- **PDE (410 nm) ~ 45% and XT ~ 5% for Trench-Version ("3A")!**



Temperature Coefficient of the Gain



$$\frac{1}{G} \cdot \left(\frac{\partial G}{\partial T} \right) = -\frac{1}{\Delta V} \cdot \left(\frac{\partial V_{BD}}{\partial T} \right)$$

$$\approx \frac{-22mV}{\Delta V} \cdot K^{-1}$$

G	Gain
ΔV	Overvoltage
V_{BD}	Breakdown Voltage
T	Temperature

- Low temperature coefficient of VBD
 - Operation at high overvoltage
- } Extremely low temperature coefficient of the gain

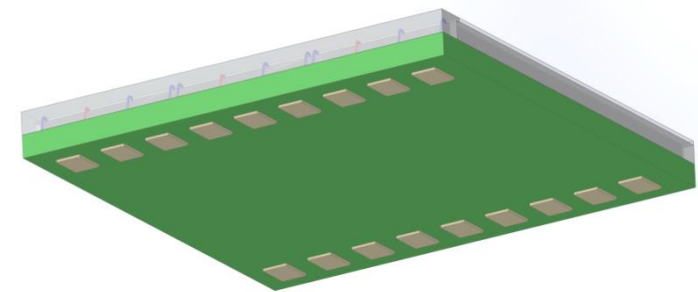
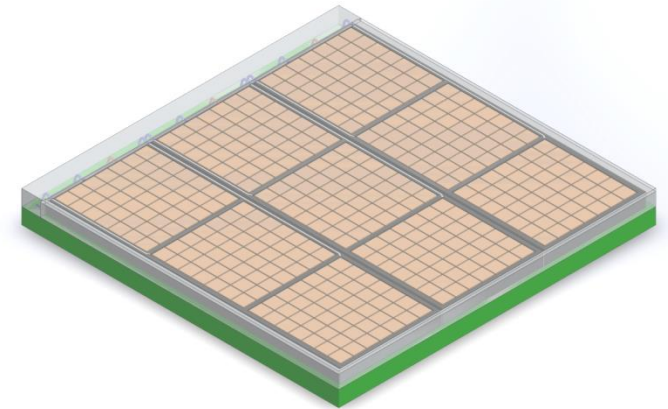
Summary and Outlook

Summary

- KETEK SiPM devices feature a very high PDE, low excess noise and a low temperature coefficient of the gain

Next steps

- Continuous noise reduction (DR, X-Talk) by enhancing the KETEK trench technology
- Enhancement of pulse shape and timing properties by optimizing parasitic elements and readout
- Chip size packages
- Arrays on package level



9-Channel SiPM-Array

Encourage communication

- Workshops & Symposiums
- Direct visits and meetings on expert level
- Concret specifications and requirements

Projects

- Link *Applied Science* with *RnD budgets* and vice versa

WELCOME TO KETEK

SILICON DETECTORS FOR X-RAY AND OPTICAL SPECTROSCOPY



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Silicon Drift Detectors with 7 mm² to 100 mm² active area for X-ray spectroscopy
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AXAS

Analytical X-ray Acquisition Systems complete with SDD, preamplifier and pulse processor
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VIAMP

OEM solution combines Silicon Drift Detector with preamplifier in optional housing
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VICO

Electronic components for optimised use of VITUS SDDs in OEM devices
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Accessories

Additional equipment for Silicon Drift Detectors, e. g. preamps, DPP etc.
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SiPM

Silicon Photo-multipliers with 1.4 mm² to 36 mm² active area for low-level light detection
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