SENSE

DESY

MAX-PLANCK-GESELLSCHAFT

Karlsruhe Institute of Technology

Ultimate Low-Light Level Sensor Development

WP2: Current status and future work

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2017/03/06

Tasks of WP2:

2.1 Agreement on R&D cooperation between research groups and industry for advancing LLL sensors

2.2 Linking to other European initiatives

2.3 Fostering the exchange between academia and industry

Working plan for WP2:

1. Define & contact research groups with experience in LLL
2. Establish the measurements/analysis procedure ← Today we are here
3. Prepare cooperation agreement
4. Contact the producers for their latest devices

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Cooperation agreement between research institutes & industry:

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- Form a collaboration between available platforms to:
  - Characterize LLL sensors
  - Characterize platforms and their systematic errors for relevant various measurements
  - Standardize measurements & analysis procedures
  - Minimize duplication efforts in characterizing sensors and establish precision on measured quantities
  - Publication of results
- Formulate and Agreement with companies for providing test products and for the publication of the results

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Define & contact groups with experience in LLL

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Name	Organisation	Response
Giovanni Bonanno	Catania Astrophysical Observatory	Positive
Hans-Christian Schultz-Coulon	University of Heidelberg	Positive
Hiroyasu Tajima	Nagoya University	Positive
Iouri Musienko	CERN	None, so far
Adam Nepomuk Otte	Georgia Institute of Technology	Not Available as lacking of resources/people
Alexander Hahn / David Fink	Max Planck Institute for Physics	Positive

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Establish the measurements/analysis procedure

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- **Collect information about experimental set-ups**

			IdeaSquare / UNIGE	Catania Astrophysical Observatory	Nagoya University	Max Planck Institute for Physics
Light sources	Pulsed	LED	280, 340, 375, 405, 420, 455, 470, 505, 525, 530, 565 & 572 nm	285, 315, 341, 385, 405, 430, 450, 465, 496, 505, 525, 570, 591, 635, 660, 680, 780 & 851 nm	377, 402, 465 & 635 nm	256, 281, 309, 342, 381, 457, 500, 573 & 598 nm
		laser	375 nm			
	Continuous		Xe lamp: 250 – 1200 nm	Xe lamp: 250 – 1000 nm		Tungsten and hydrogen lamp 200 – 800 nm
Temperature range:			~ 23 ^{0}C	0 ^{0}C to 25 ^{0}C	Climatic chamber	-40 °C to 100 °C

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Establish the measurements/analysis procedure

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- **Qualify the the systematic errors of each set-up**
  - Measure the same SiPM:
    1. Monolitic Hexagonal 6 mm side Hamamatsu S10943-2832(X) to establish errors.
    2. *other devices??? Smaller?*

  - Parameters agreed to be measured:
    1. V_{BD} at a given temperature
    2. PDE vs. Overvoltage
    3. PDE vs. wavelength
    4. Optical crosstalk vs. Overvoltage
    5. PDE vs. Optical crosstalk
    6. DCR vs. Overvoltage
    7. …

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Experimental setup at Ideasquare/Unige

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continuous light

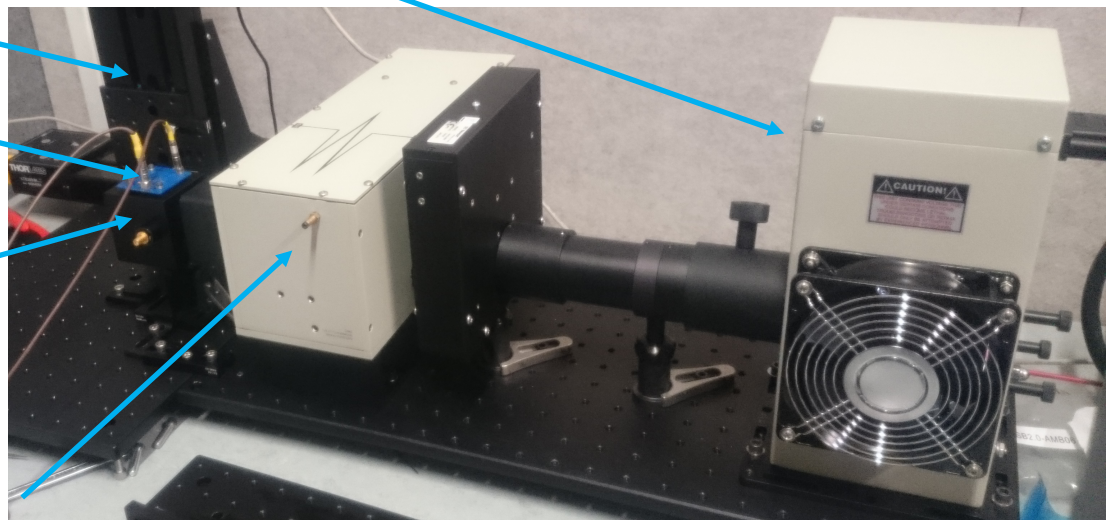
Translation stage

Photodiode (S1337-1010BQ)

Integration sphere

Monochromator

Xe 75 W lamp: 250nm to 1800 nm



pulsed light

Motorized wheel with 12 filters (transmission from 81.3% to 0.01%)

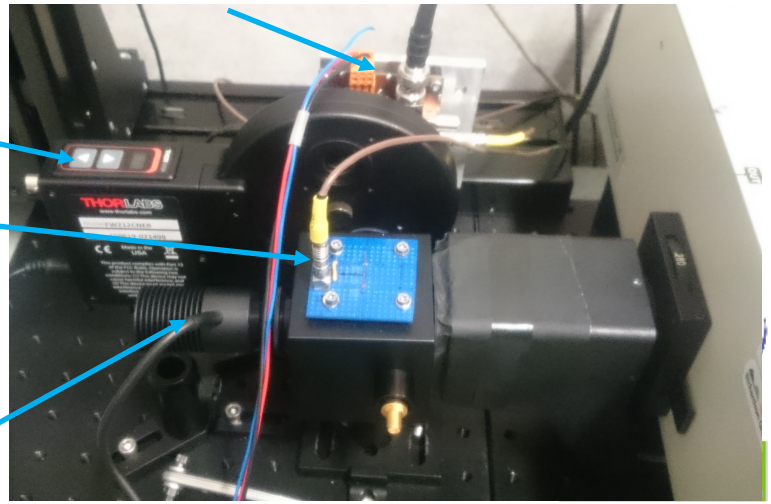
Photodiode 10x10 mm^2 (S1337-1010BQ)

LED`s :

280, 340, 375, 405,
420, 455, 470, 505,
525, 530, 565 & 572 nm

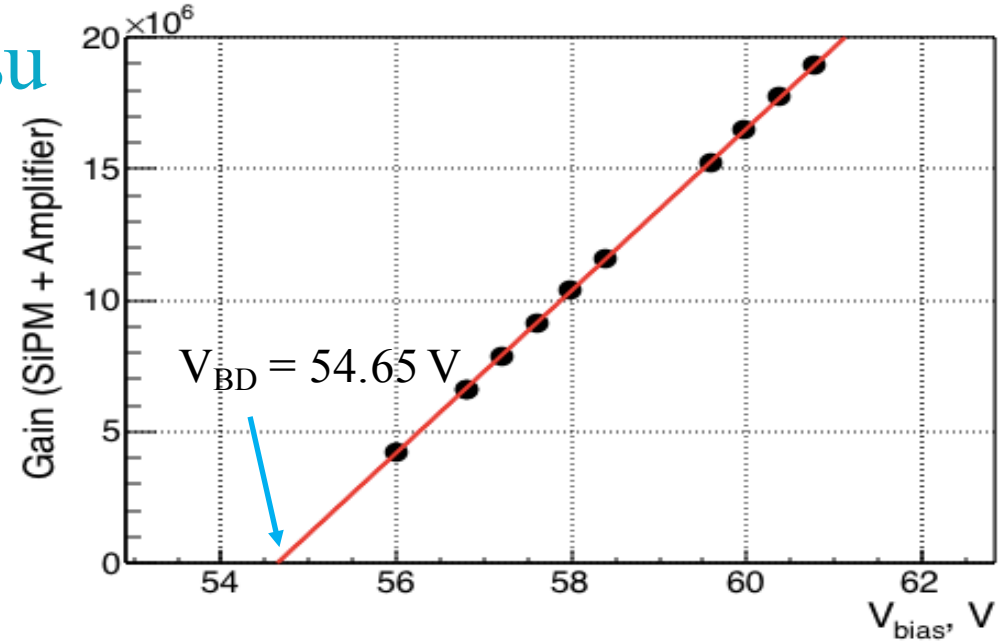
SiPM

LED



Measurements of Hamamatsu S10943-2832(X)

- **V_{BD} @ 24 ^{0}C**



- **PDE vs. Overvoltage**

Poisson distribution:

$$P(n_{p.e.}) = \frac{(k)^{n_{p.e.}}}{n_{p.e.}!} \cdot e^{k}$$

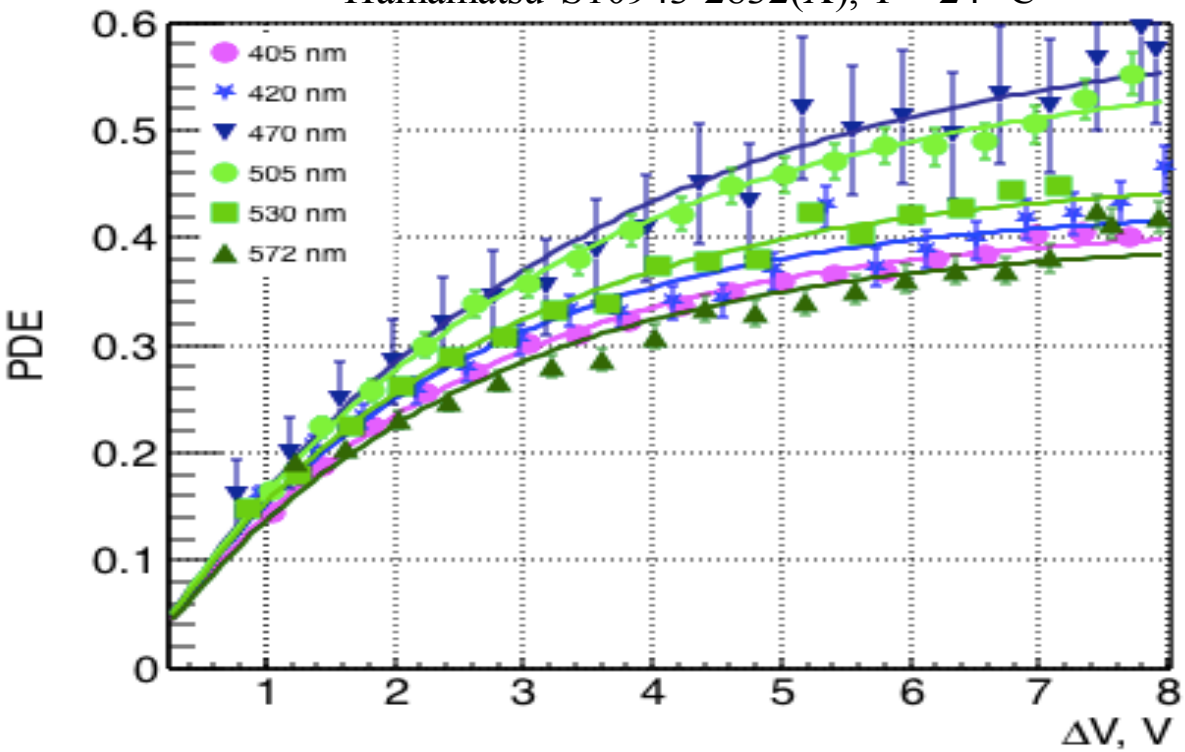
Probability to detect 0 p.e. :

$$P(0) = e^{k} = \frac{N(0)}{N(total)}$$

Average number of detected photons:

$$k = -\ln(P(0)_{LED}) + \ln(P(0)_{dark})$$

$$\mathrm{PDE} = \frac{k}{N_{photons}} = \frac{k \times QE \times e^{-} \times R}{I_{Photodiod}}$$



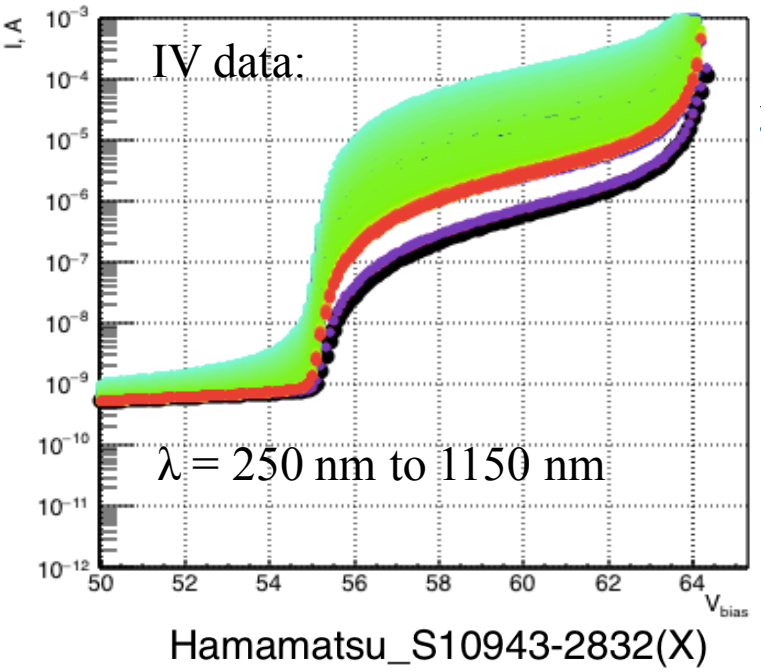
Measurements of Hamamatsu S10943-2832(X)

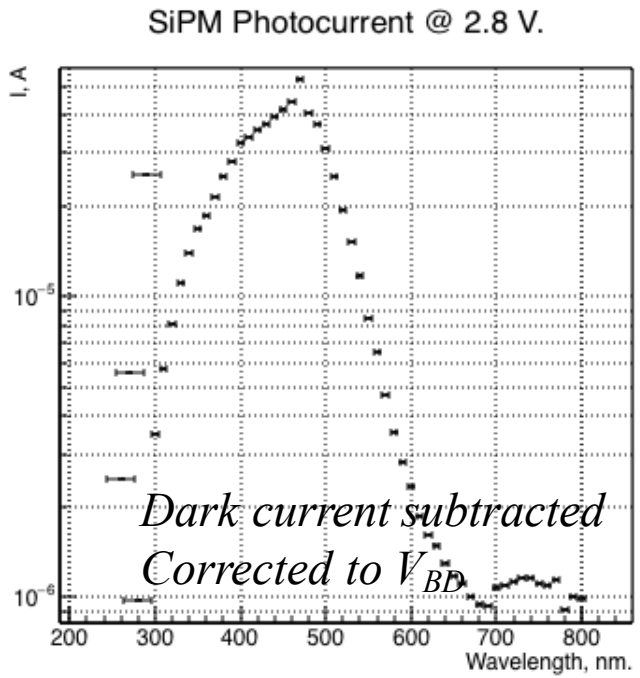
- **PDE vs. wavelength @ ΔV = 2.8 V**

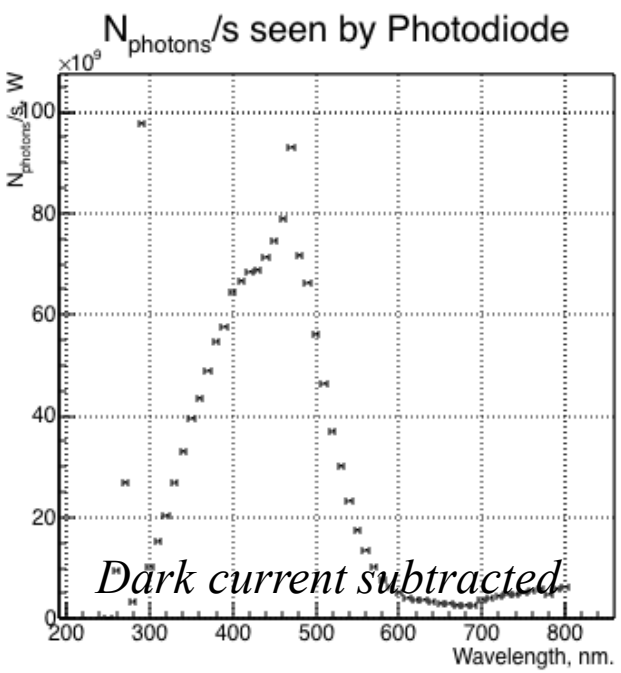
$$PDE = \frac{I_{SiPM}}{N_{photons} \cdot e^{-} \cdot G_{eff.}}$$

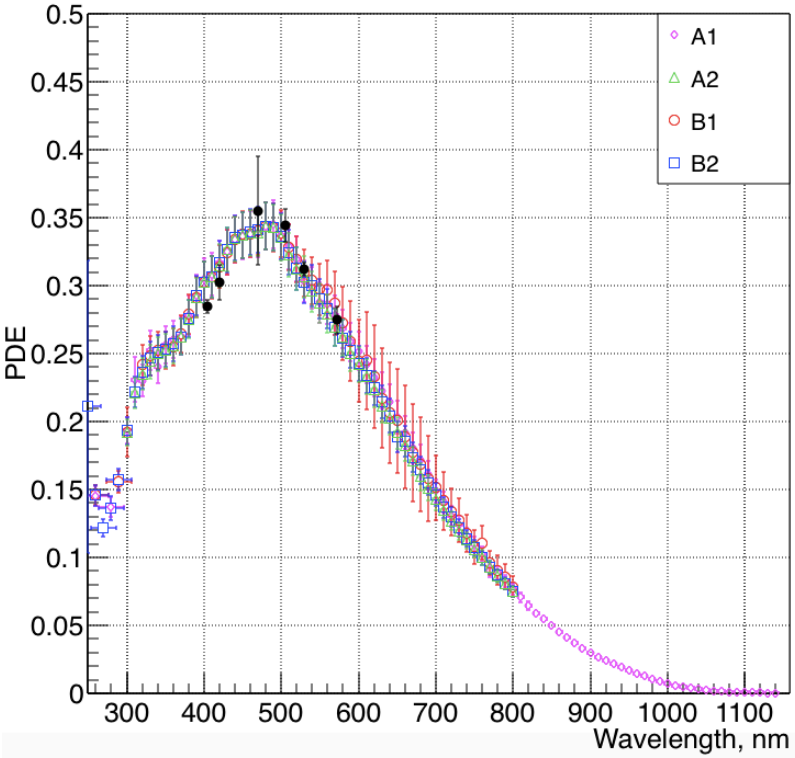
$$N_{photons} = \frac{I_{photodiode}}{QE \cdot e^{-}}$$

$$PDE \sim \frac{I_{SiPM}}{I_{photodiode}} \cdot QE \cdot e^{-}$$









Measurements of Hamamatsu S10943-2832(X)

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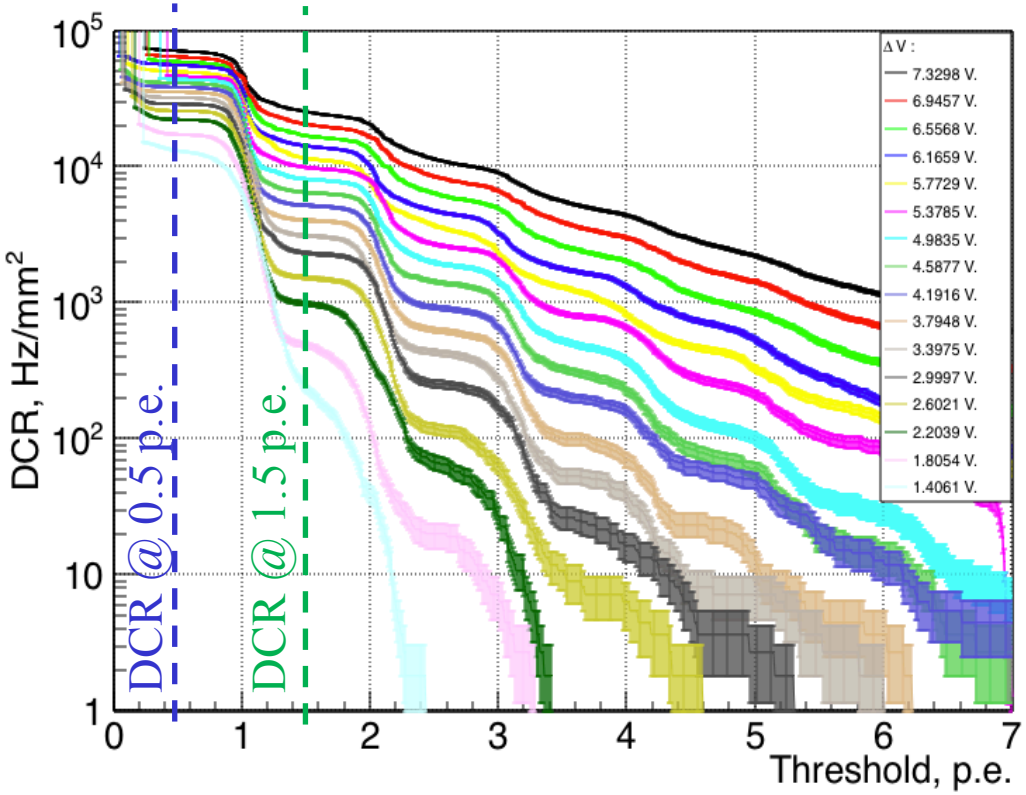
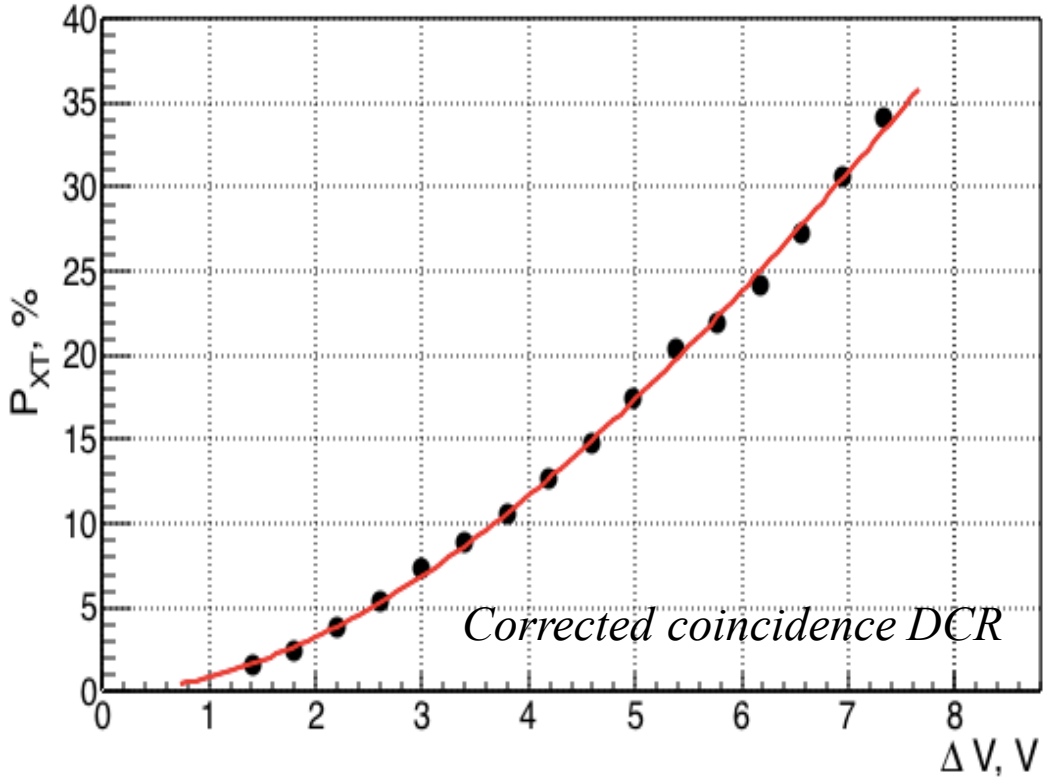
- **Optical crosstalk vs. ΔV @ T = 24 ^{0}C**





$$P_{XT} = 100\times\left[\frac{DCR(@\,0.5\,p.e.)}{DCR(@\,1.5\,p.e.)} - DCR(@\,0.5\,p.e.)\times 10ns\right]$$

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Measurements of Hamamatsu S10943-2832(X)

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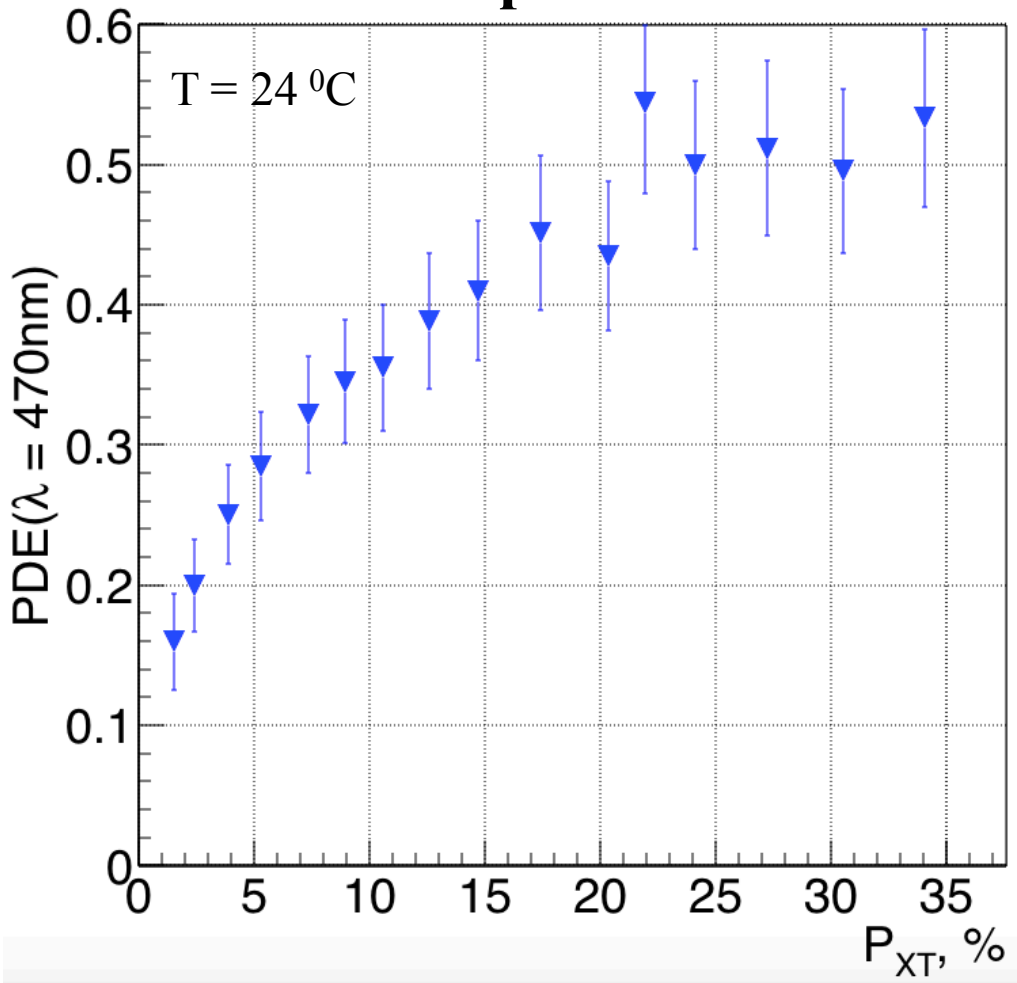
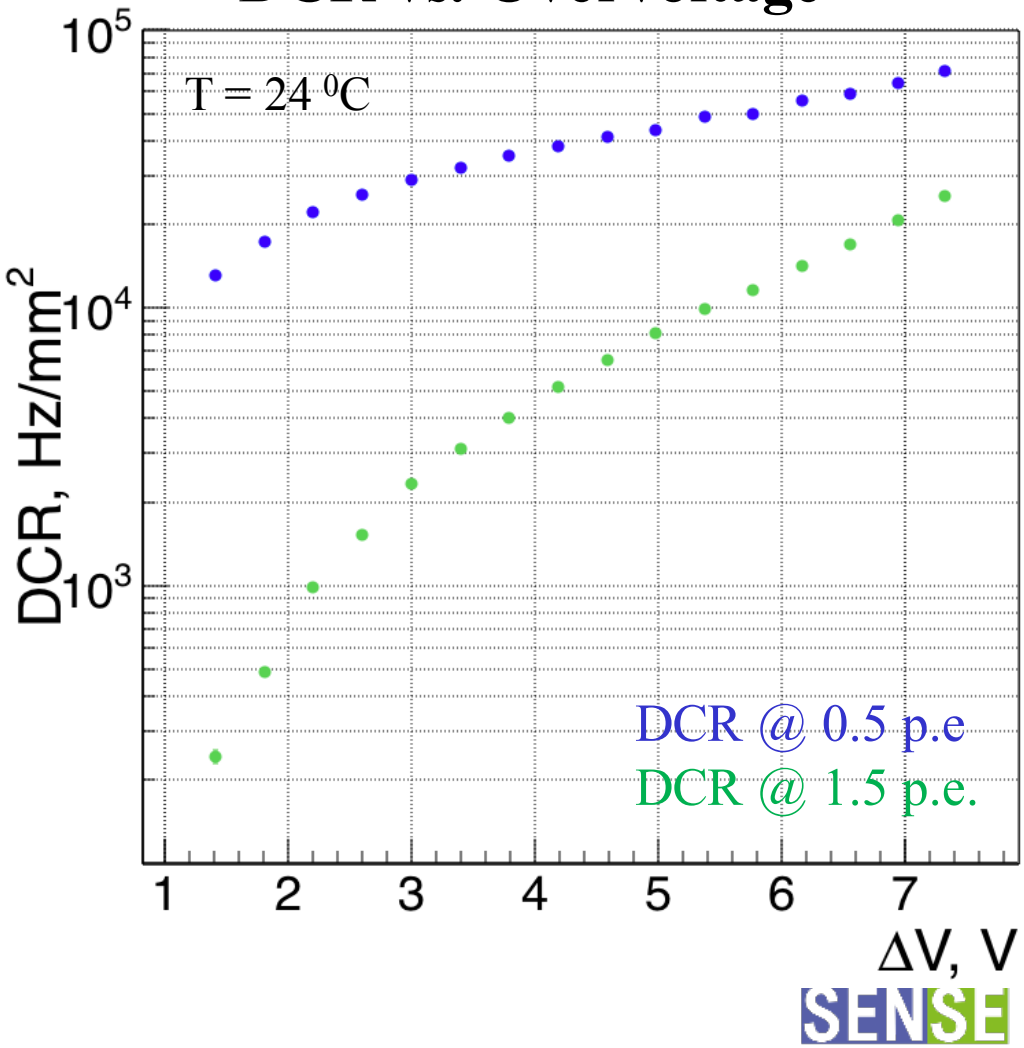
PDE vs. Optical crosstalk



DCR vs. Overvoltage



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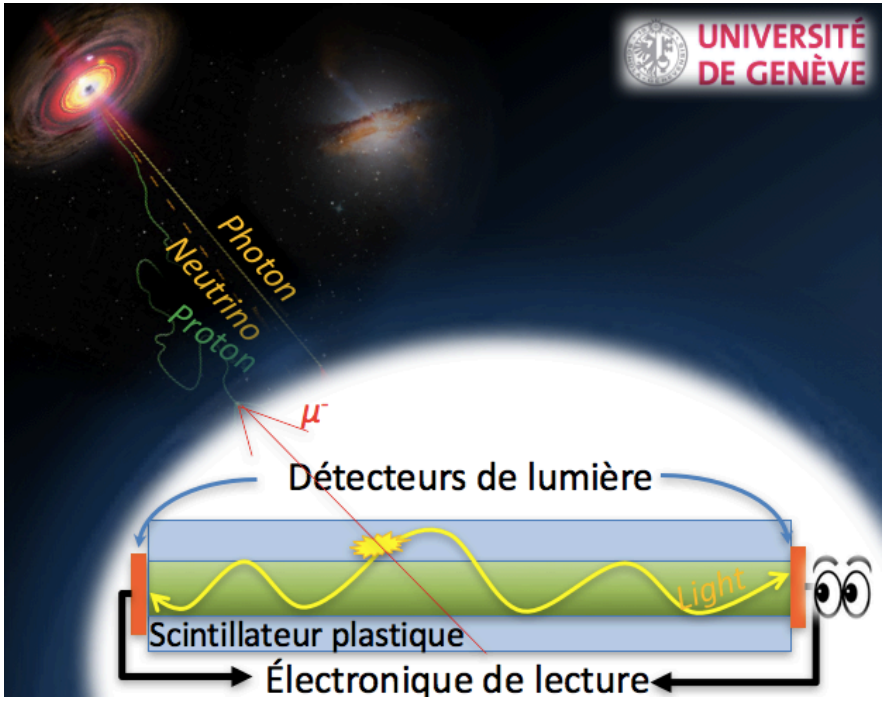
Module on light sensors for lyceum

Should be presented in:

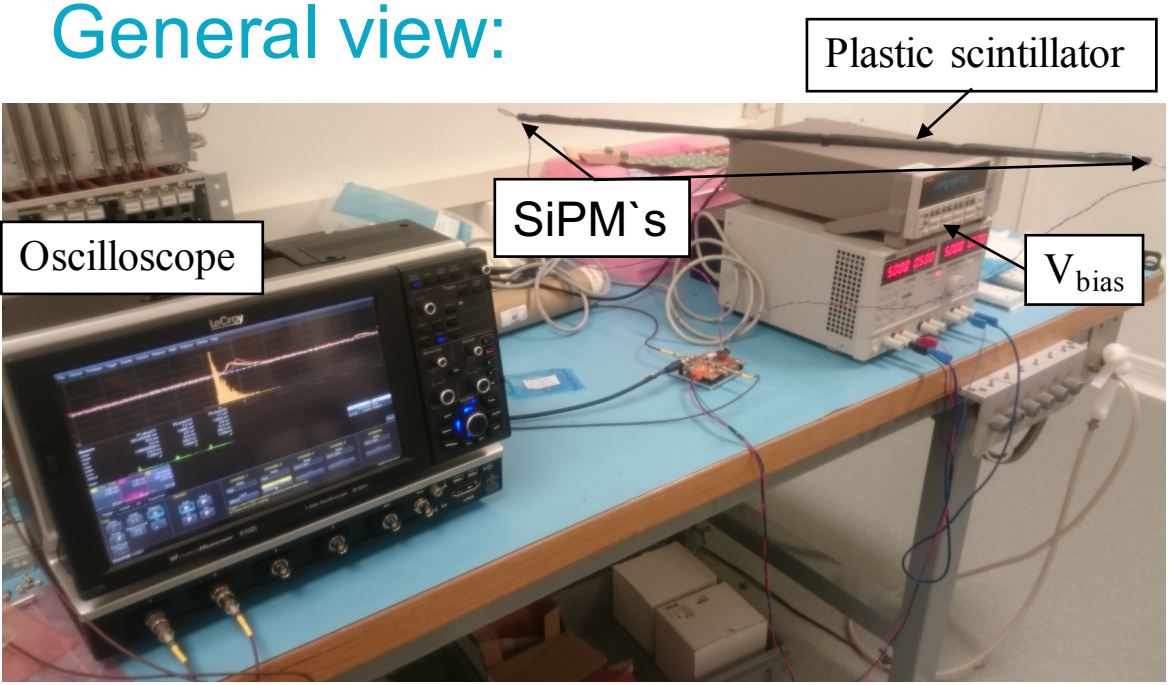
- College Rousseau, Geneva
- 14th of March

Introduce:

- Cosmic rays
- Low light detectors



General view:



First results: