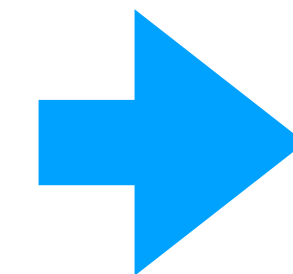# Photo-detector development for nEXO, DarkSide and beyond
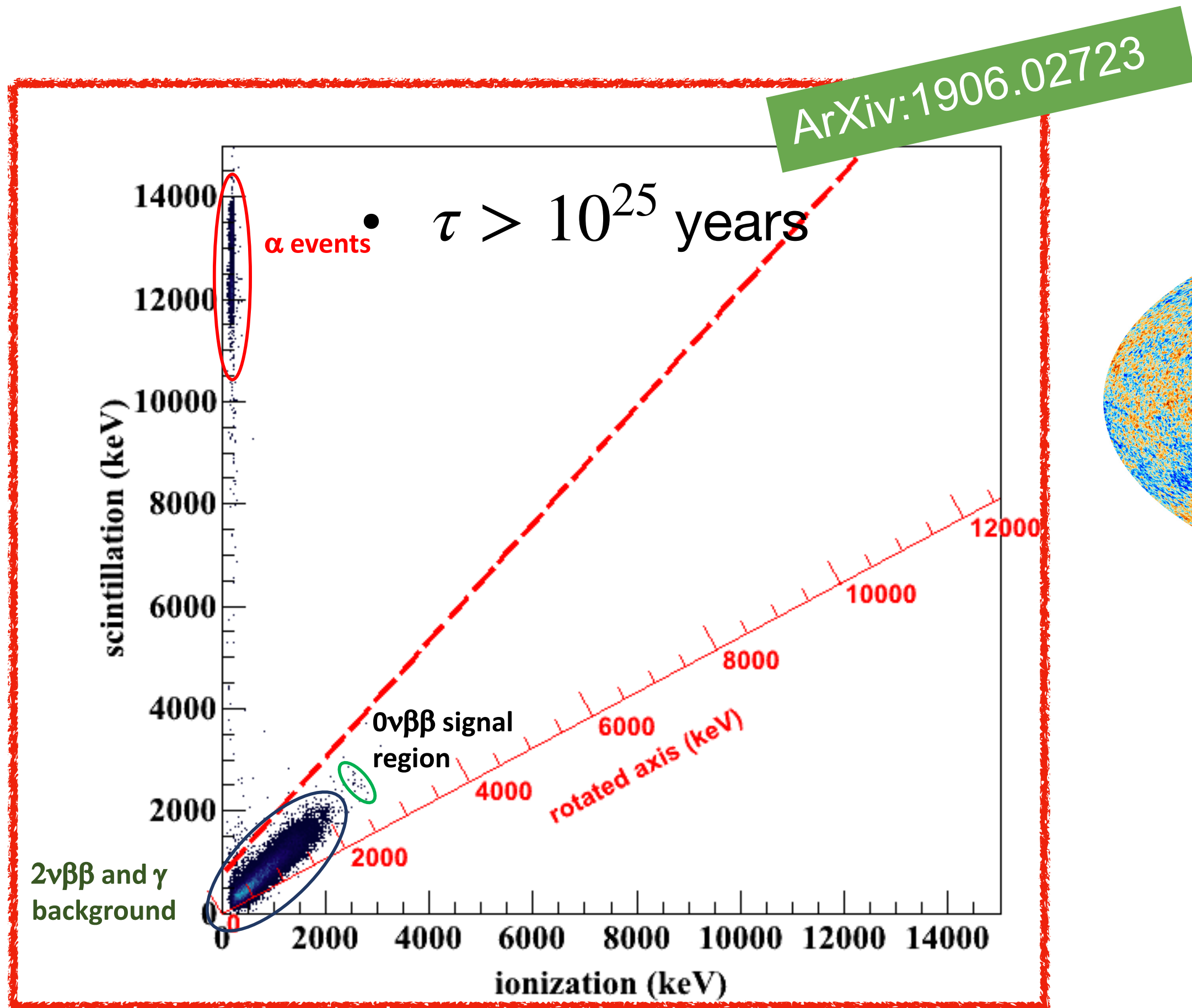
G. Gallina

TRIUMF Data !
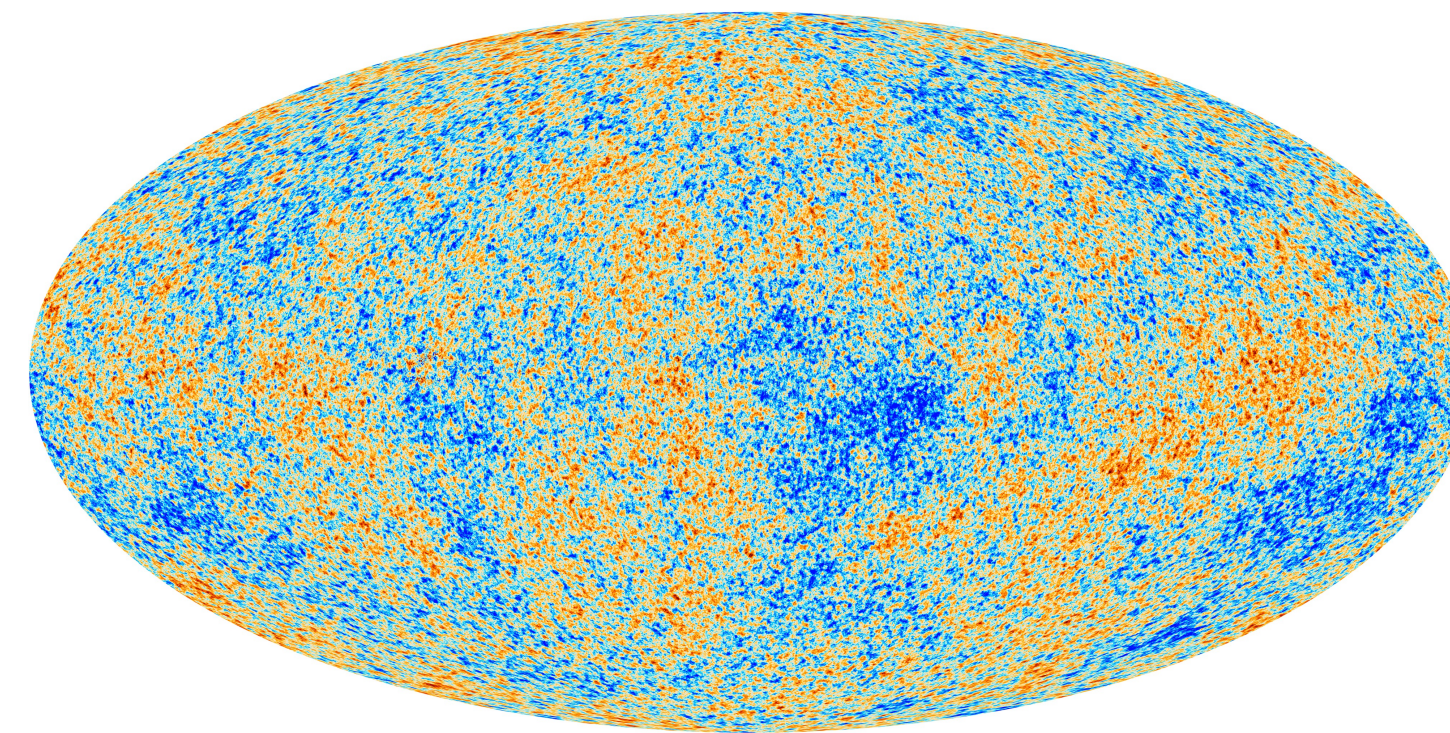
Overview

Signals of new Physics

ArXiv:1906.02723

- $\tau > 10^{25}$ years

α events

0νββ signal region

2νββ and γ background

CMB

Thermal anisotropies

Galactic clusters

Galaxy velocities
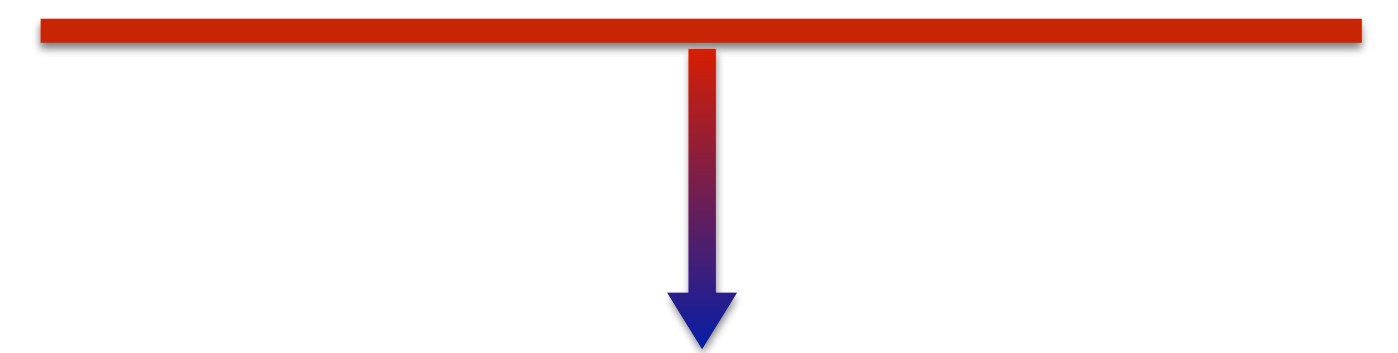
Neutrino Physics: $0\nu\beta\beta$ decay

Direct Dark Matter Search

Search with liquified noble elements

4

- High density ✔

    Self screening

    Good scalability

- Easy(-ish) purification, also

  online ✔

- Scintillation: good light yield ✔

- Ionisation ✔

- ER rejection ✔
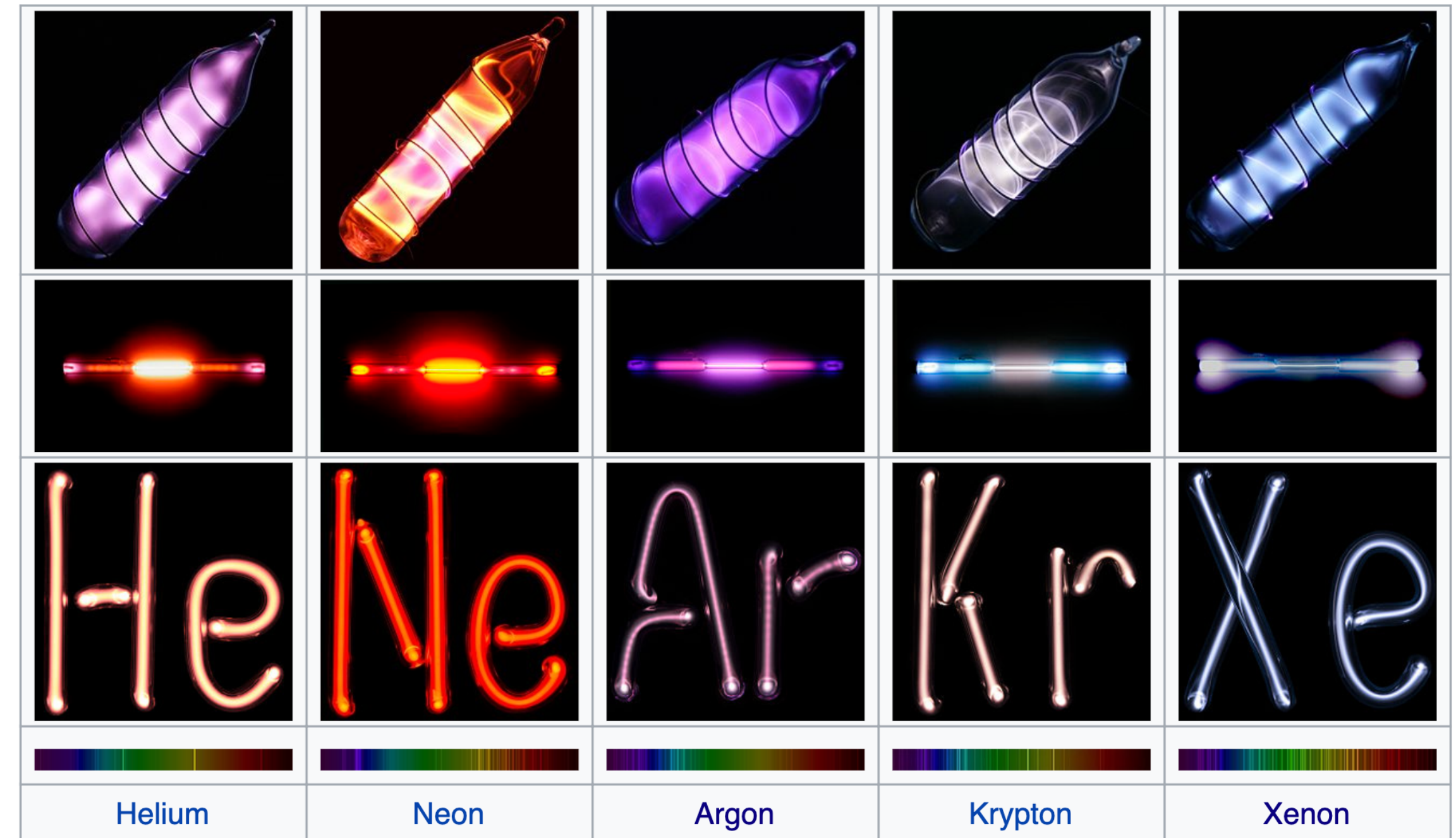
Excellent detection medium!

and even source !

		Helium	Neon	Argon	Krypton	Xenon

			LAr	LKr	LXe
Physical properties	Atomic number	18	36	54
	Boiling point at 1 bar, T_b (K)	87.3	119.8	165.0
	Density at T_b (g/cm^3)	1.40	2.41	2.94
Ionisation	W (eV)[1]	23.6	20.5	15.6
	Fano factor	0.11	~0.06	0.041
	Drift velocity (cm/μs) at 3 kV/cm	0.30	0.33	0.26
	Transversal diffusion coefficient at 1 kV/cm (cm^2/s)	~20		~80
Scintillation	Decay time[2], fast (ns)	5	2.1	2.2
	slow (ns)	1000	80	27/45
	Emission peak (nm)	127	150	175
	Light yield[2] (phot./Mev)	40000	25000	42000
	Radiation length (cm)	14	4.7	2.8
	Moliere radius (cm)	10.0	6.6	5.7

Excellent discrimination power!

The nEXO and the Darkside-20k experiment
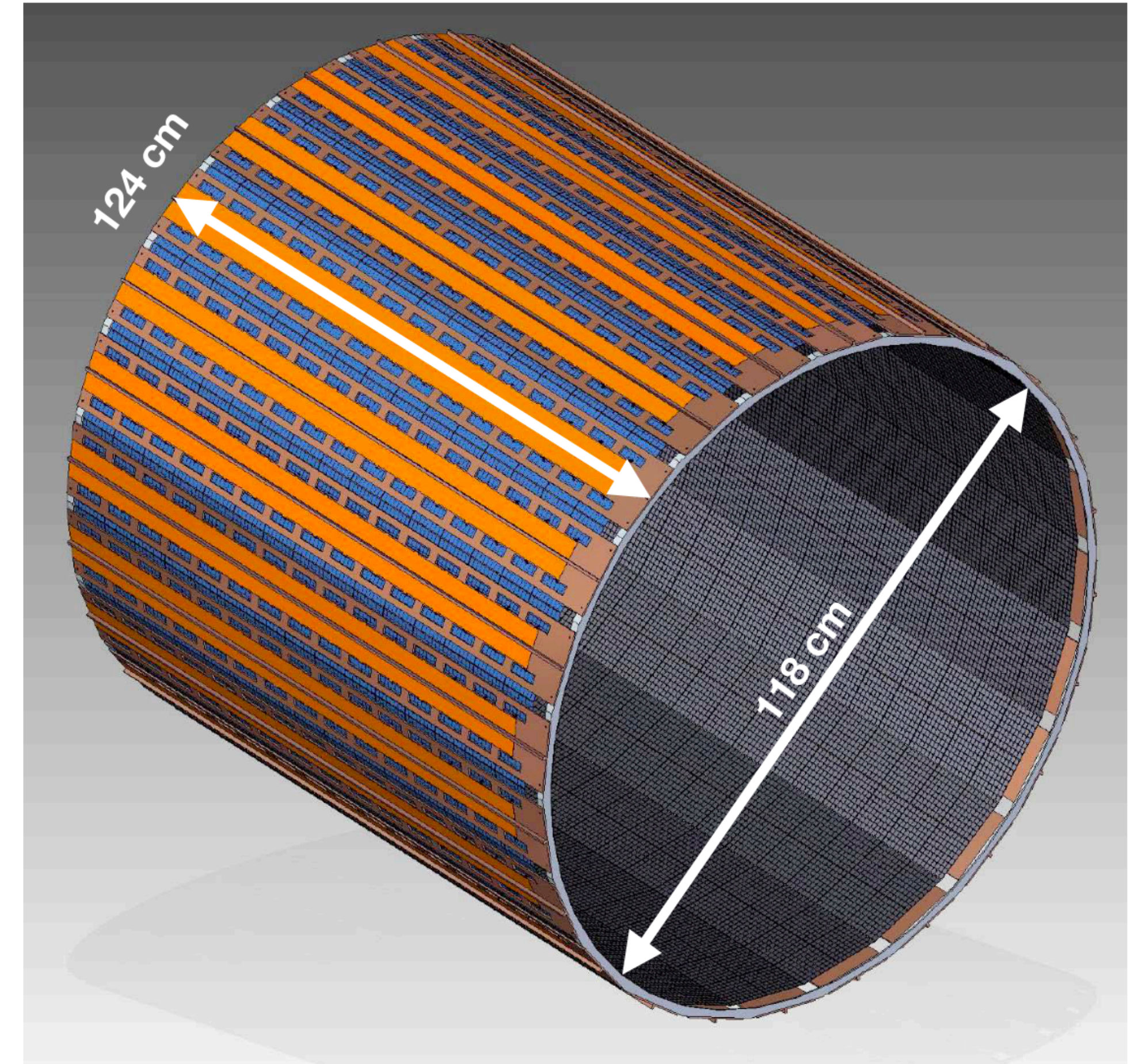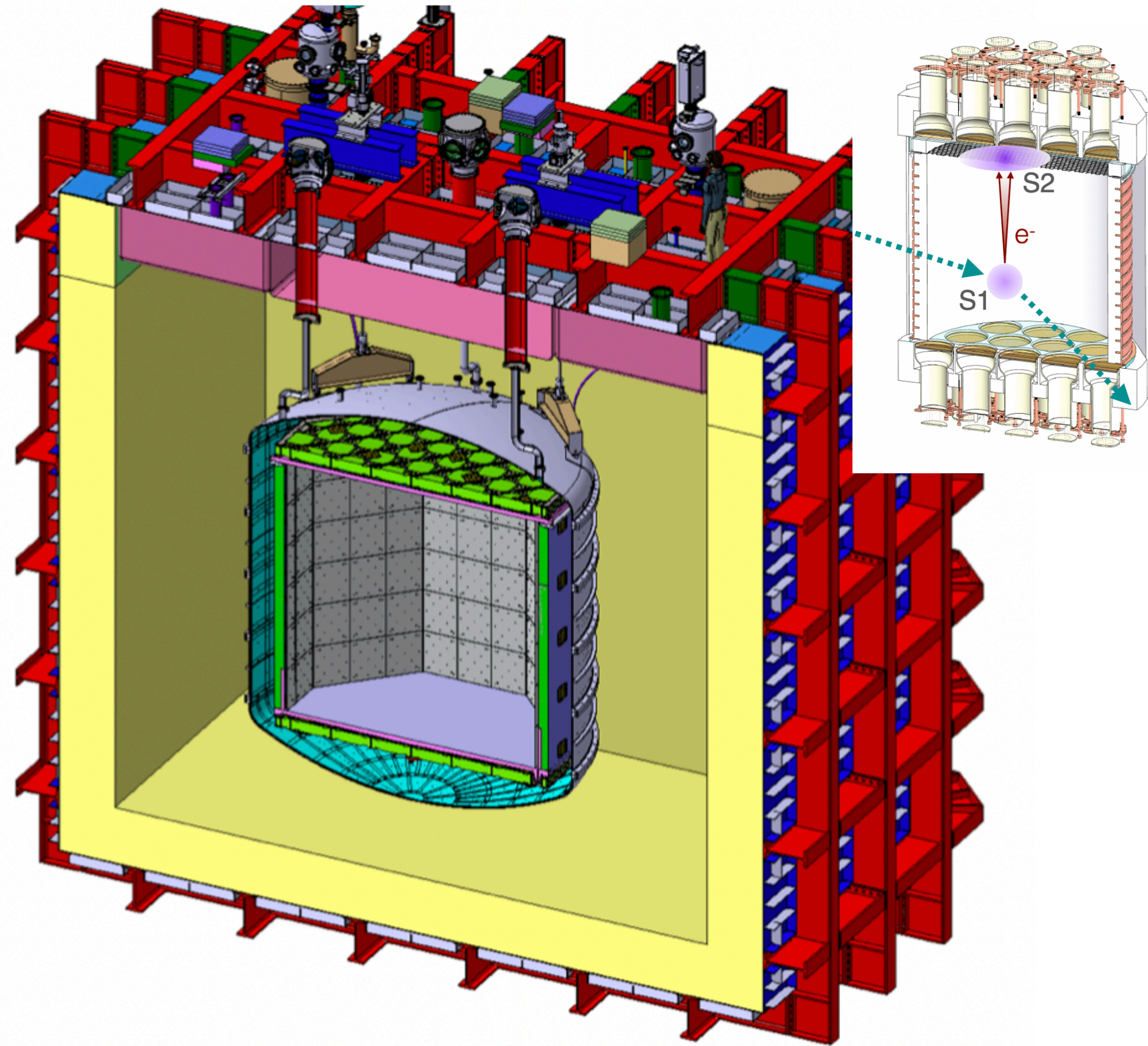
- **>20 m^2 covered with NUV-sensitive SiPMs**

- **>4.5 m^2 covered with VUV-sensitive SiPMs**

SiPMs technology

Main Characteristics :

- SPADs connected in parallel operated in reverse bias mode

- Incoming photon triggers charge avalanche

- Single pixel is discharged

Advantages:

- High gain at low bias voltage

- Single photon detection resolution

- High radio purity possible

- Suitable at cryogenic temperature

- **High Photon Detection Efficiency (PDE)**
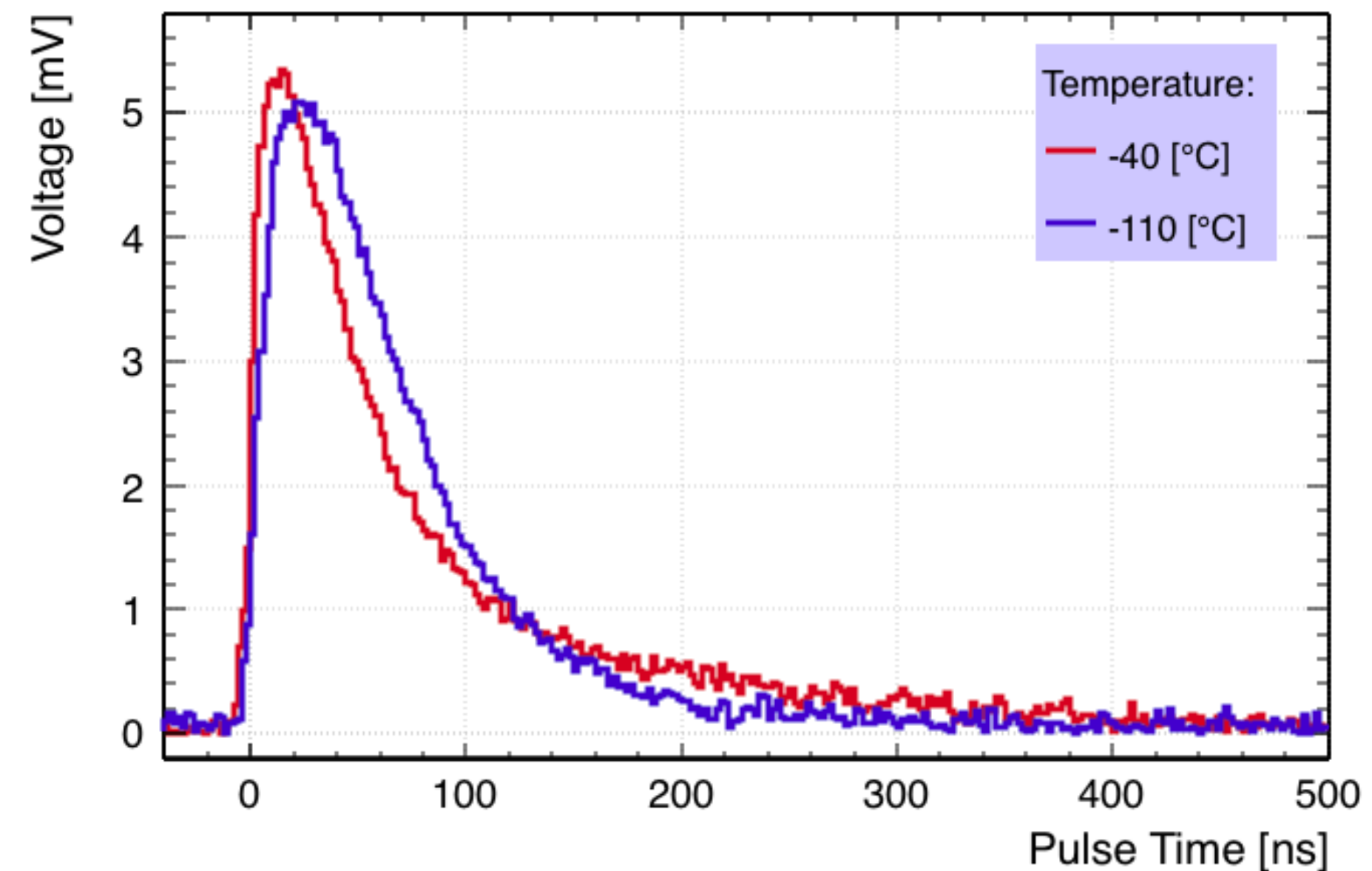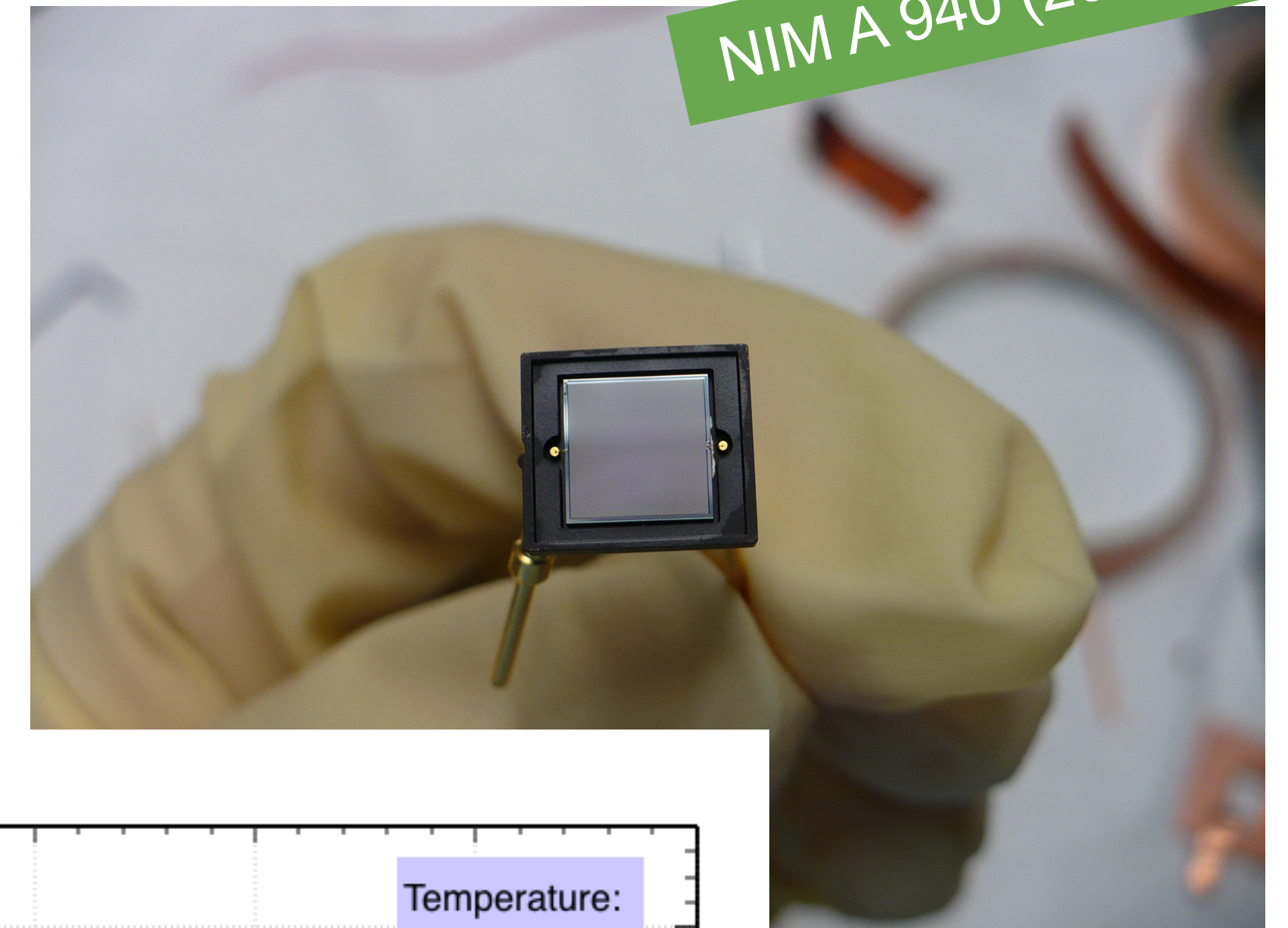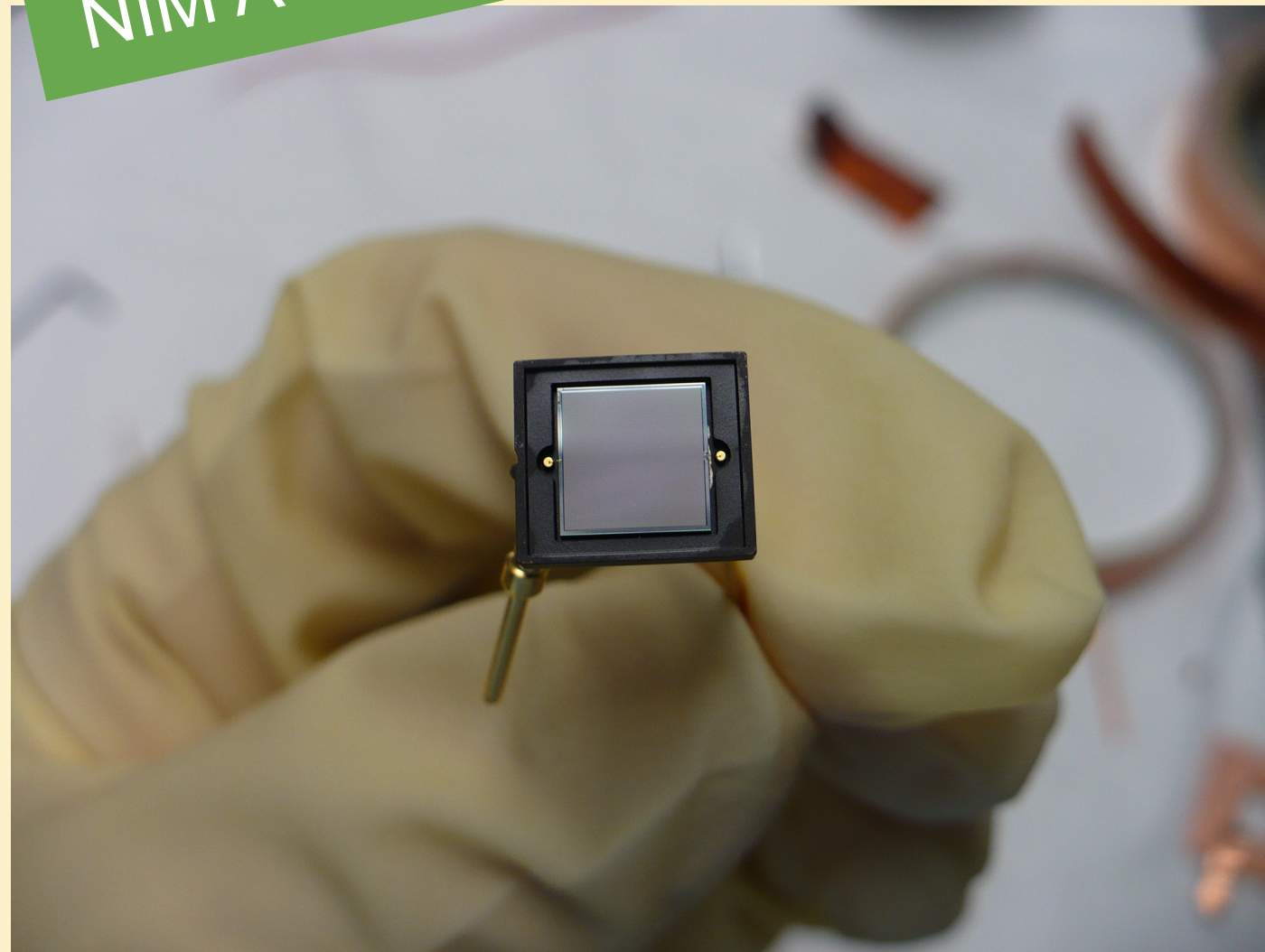
NIM A 940 (2019)

nEXO PhotoDetector Development

nEXO SiPMs candidates

FBK SiPM

Hamamatsu MPPCs

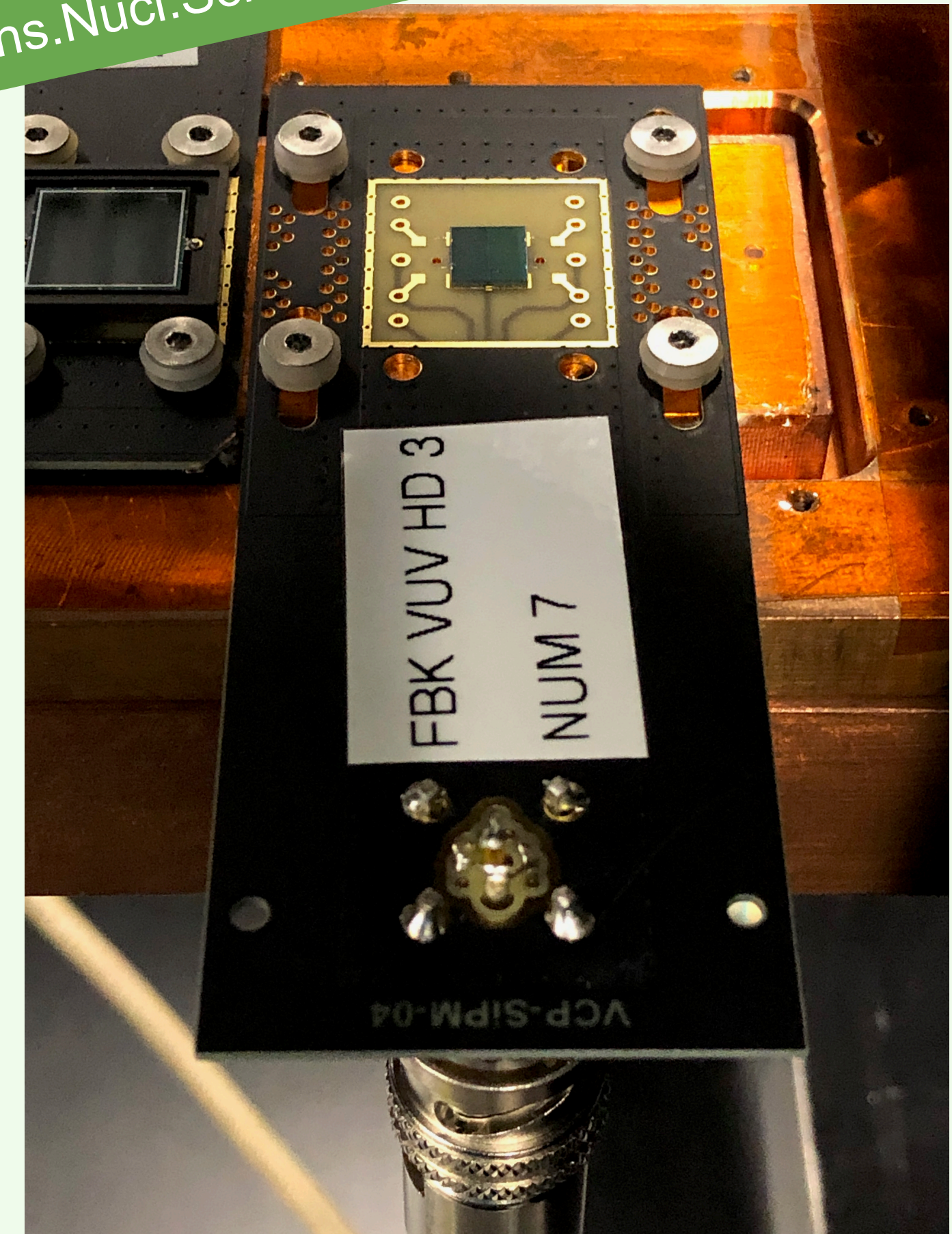NIM A 940 (2019)

FBK VUVHD1
IEEE Trans.Nucl.Sci. 65 (2018)

HPK VUV4-50
Single devices
50 um pitch
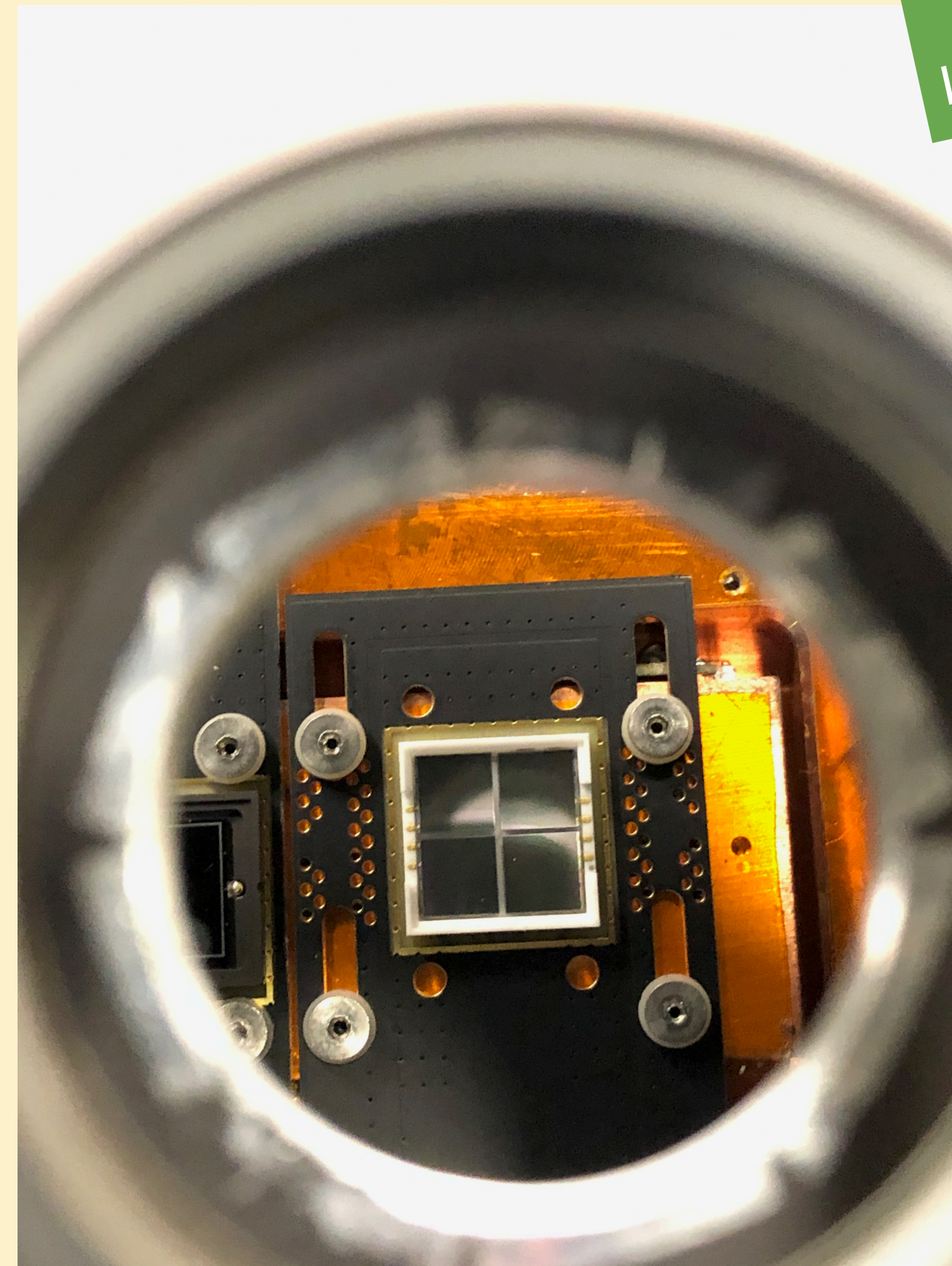
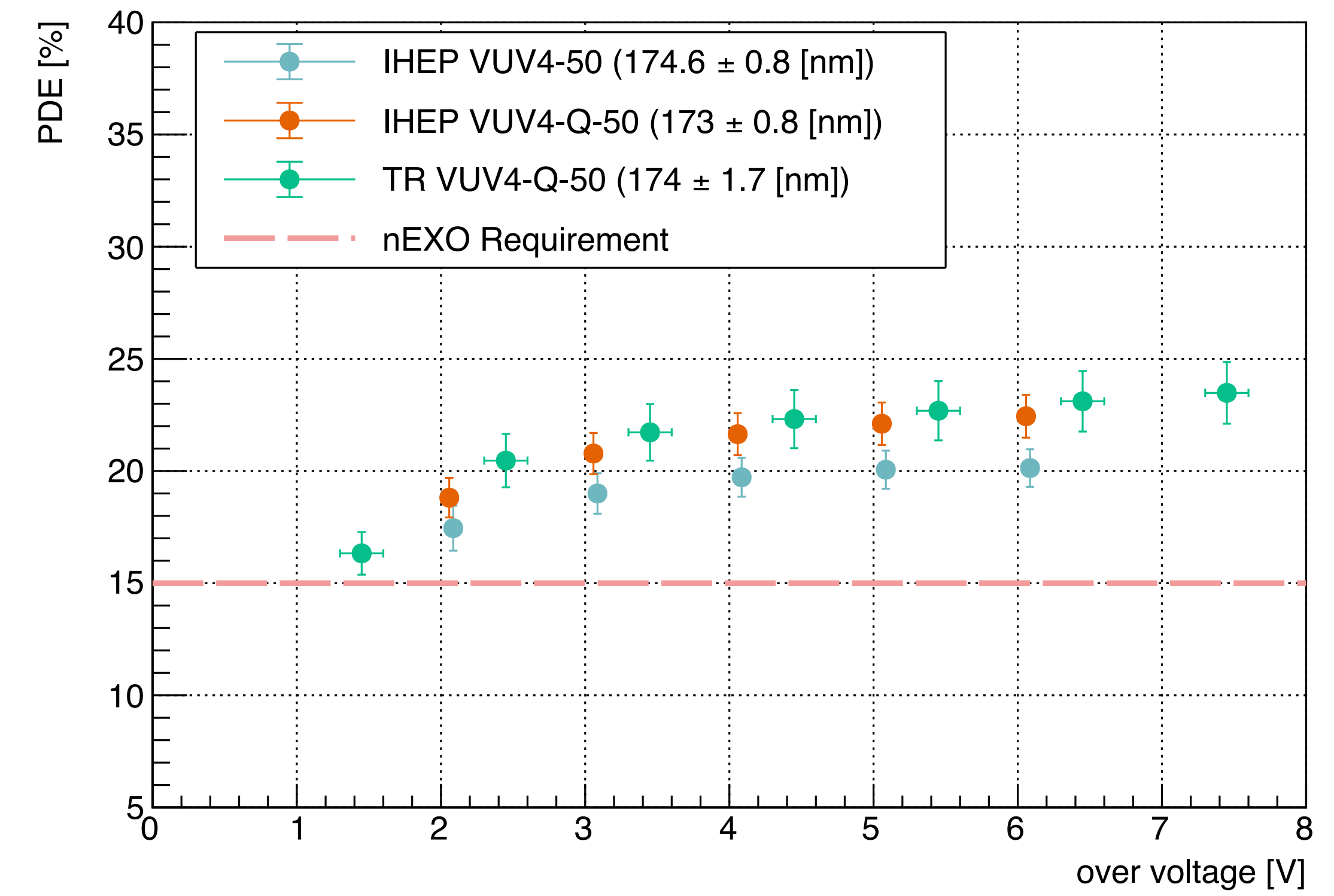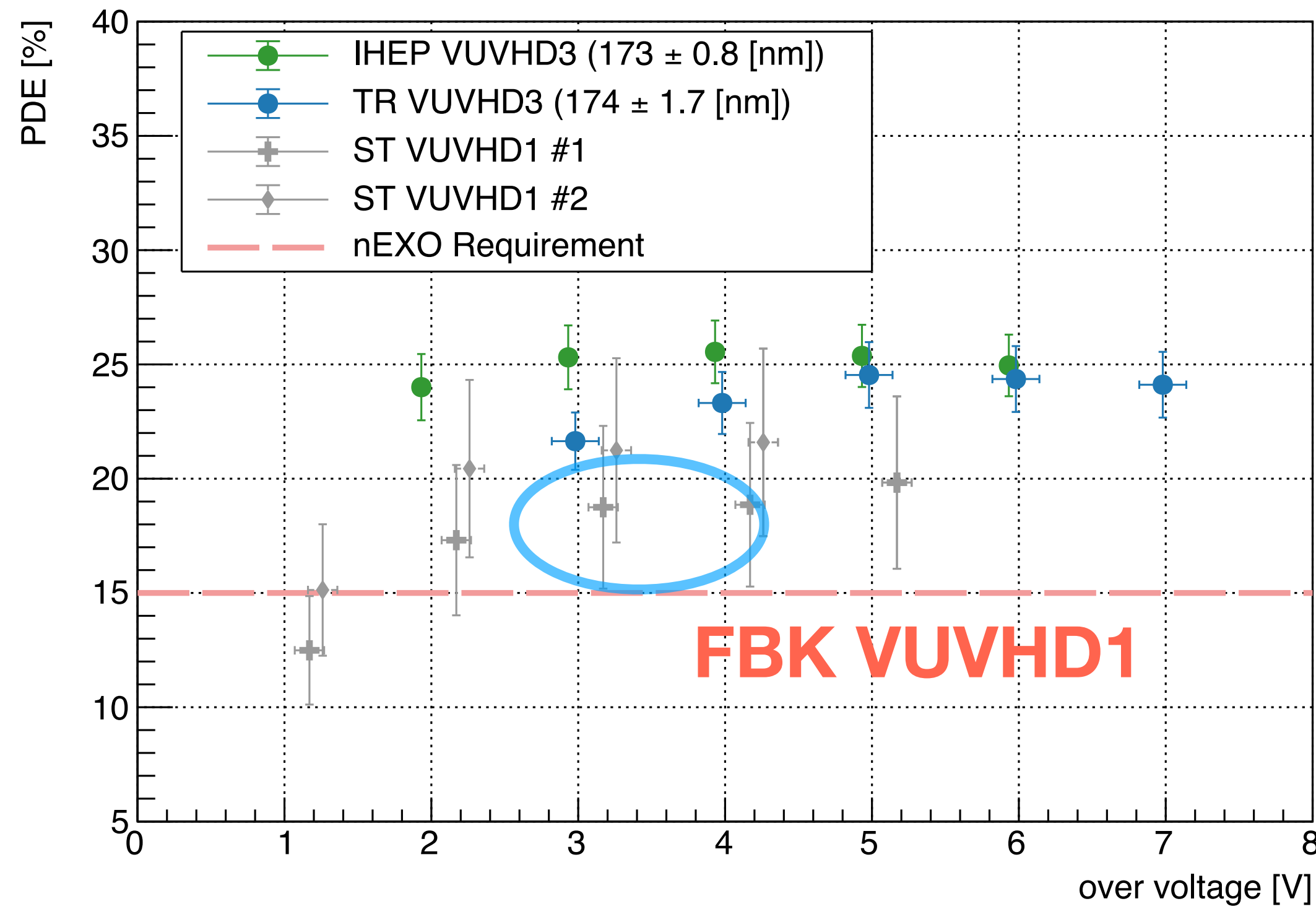**HPK VUV4-Q-50**
Quad devices.
50 um pitch

FBK VUVHD3
substitutes
its previous generation
FBK VUVHD1

PDE at 174 nm

Paper under review!

- PDE has been measured by TRIUMF and IHEP at 163 K and 233 K, respectively as a function of over voltage and wavelength
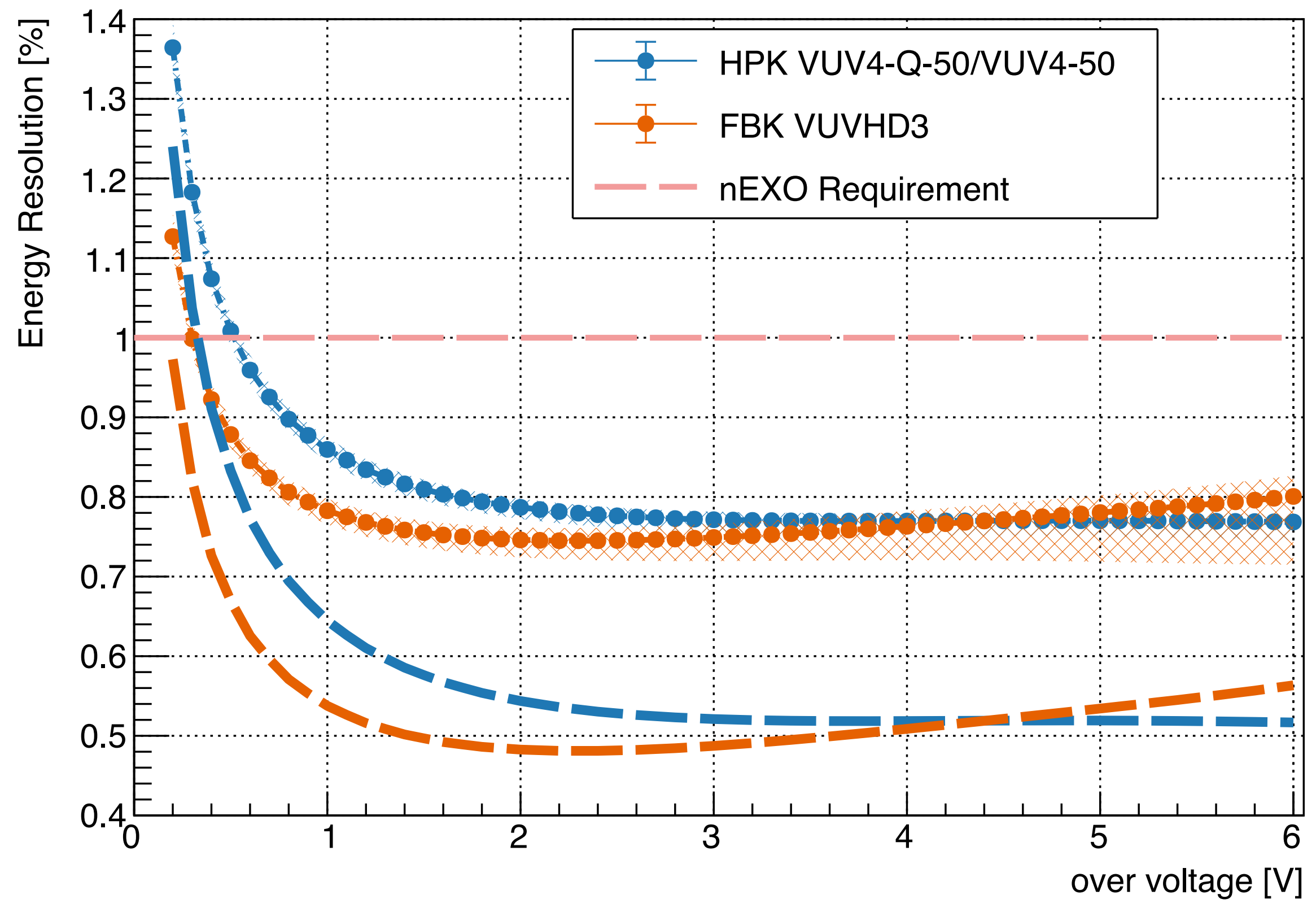

Requirement > 15% at ~ 175 nm

nEXO Energy Resolution

$$\frac{\sigma_n}{\langle n \rangle} = \frac{\sqrt{\left(\frac{(1-\epsilon_p)n_p}{\epsilon_p} + \frac{\epsilon_p n_p \sigma_\Lambda^2}{(\epsilon_p(1+\langle\Lambda\rangle))^2} + n_p^2 \sigma_{lm}^2\right) + \left(\frac{n_q t}{\tau} + \frac{\sigma_{q,noise}^2}{\epsilon_q^2}\right)}}{\langle n \rangle}$$

nEXO Requirement: $\frac{\sigma_n}{\langle n \rangle} \leq 1\,\%$

Paper under review!

Fluctuation due to number of photons detected (PDE)

Fluctuation Due to Correlate Avalanche Noise (CA/RMS)
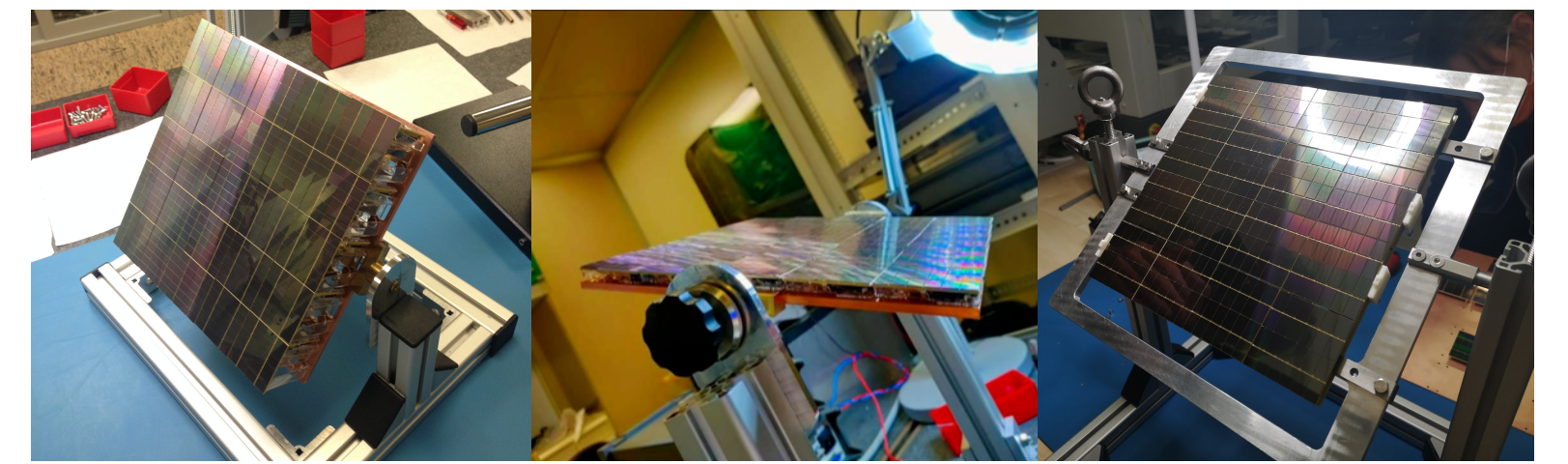
Fluctuation Due to Light Map Error

Fluctuation due to the number of charges detected
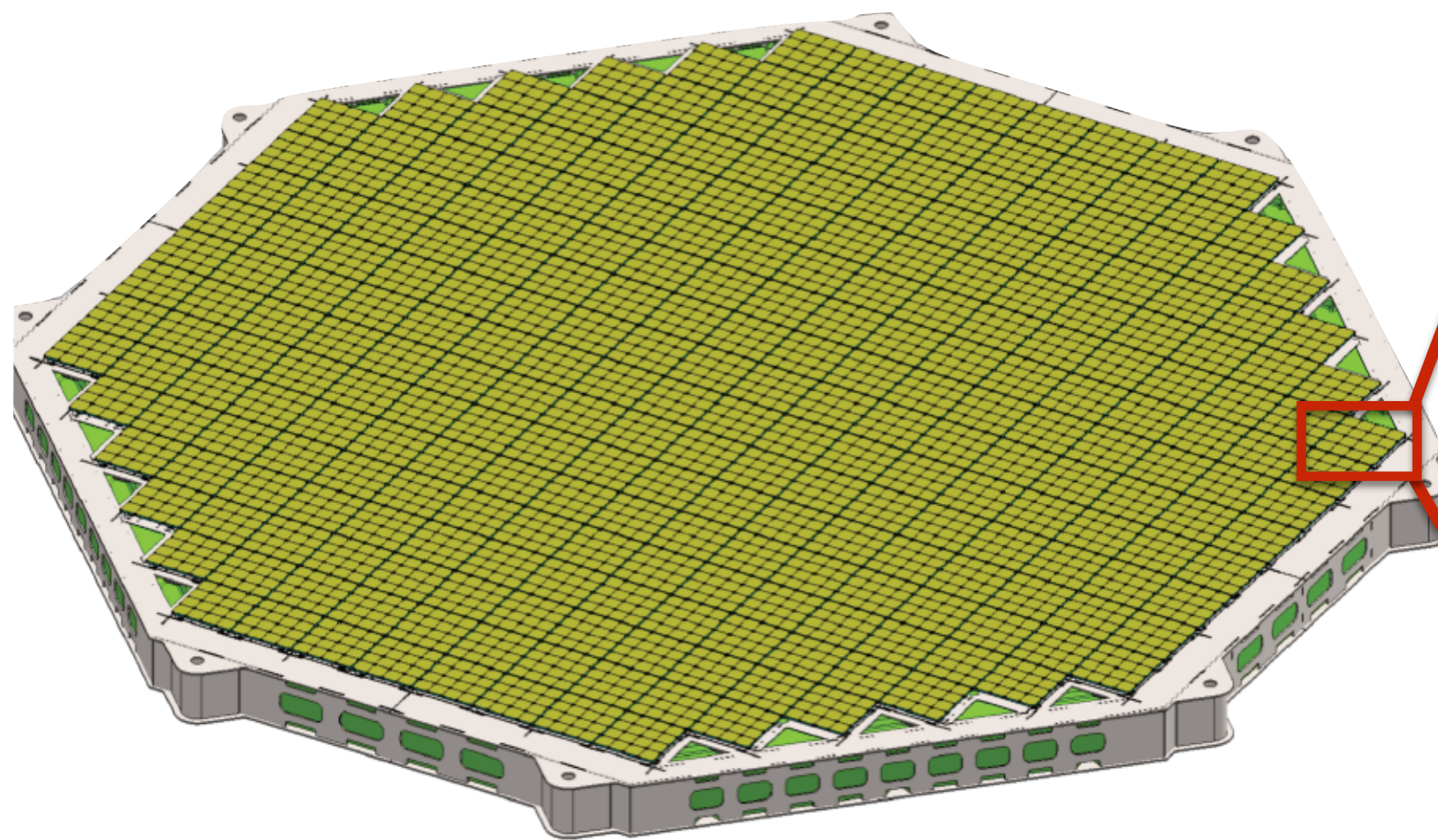
Fluctuation due to electronics in charge channel

DarkSide-20k Photo Detector Development

The Darkside Photo-detection system
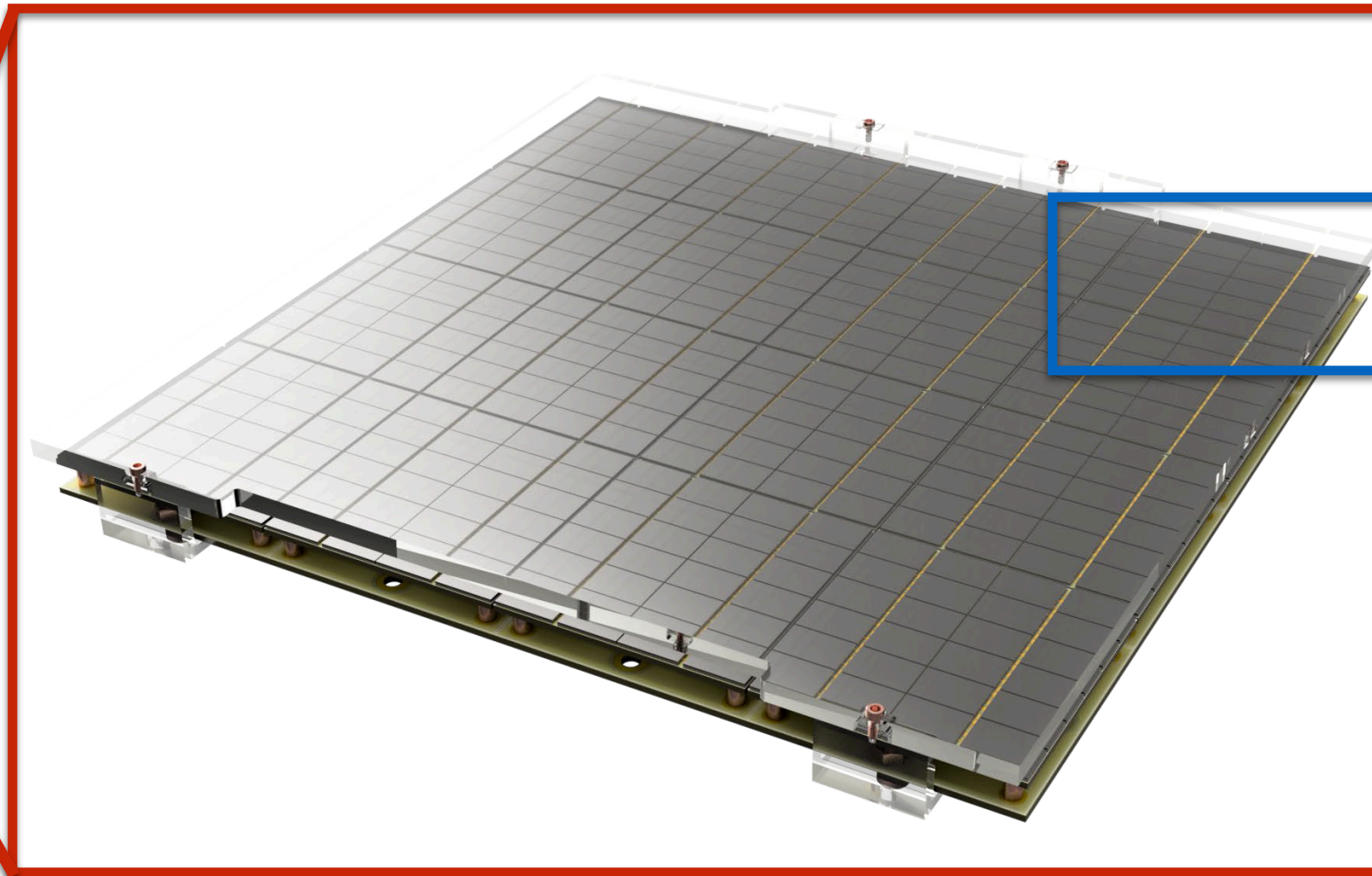
TPC optical plane	Photo-Detection Unit	Tile

16 tiles arranged in 4 readout channels

TPC planes area: ~21m^2	SiPM bias distribution	Photosensor
Organised in 525 PDUs	cryogenic pre-amplifiers bias	Array of 24 SiPMs
100% coverage of TPC top and bottom	Signal transmission	Signal pre-amplification
	Channels switch-on/off	

FBK NUV-HD Low SiPMs

12x8 mm^2
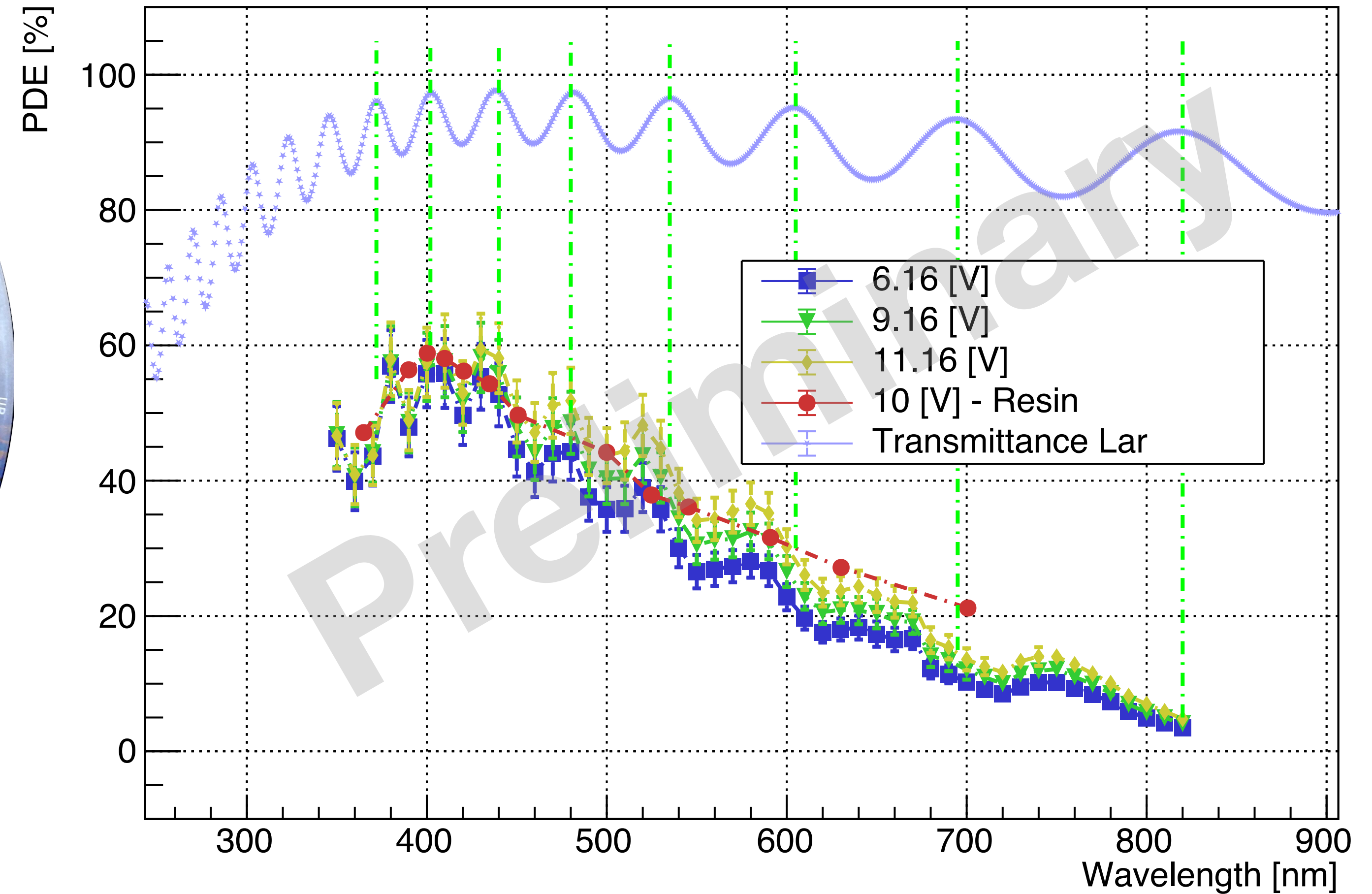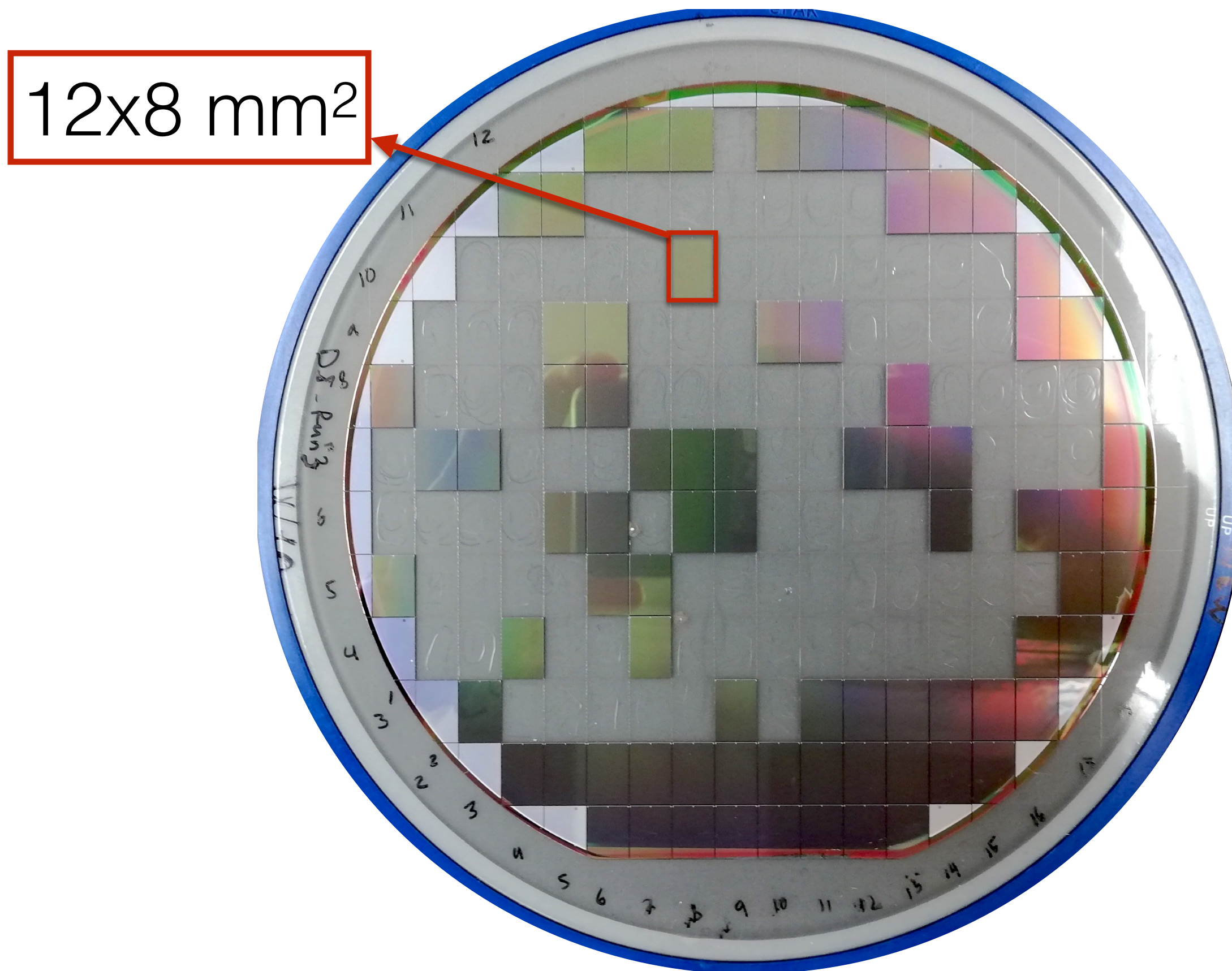
- NUV vs RGB choice (P_{01})
- Cell pitch and fill factor (FF) optimization
- **E** field profile $\Rightarrow$ DCR+CN reduction

PDE ~50% in LAr

Thanks !

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