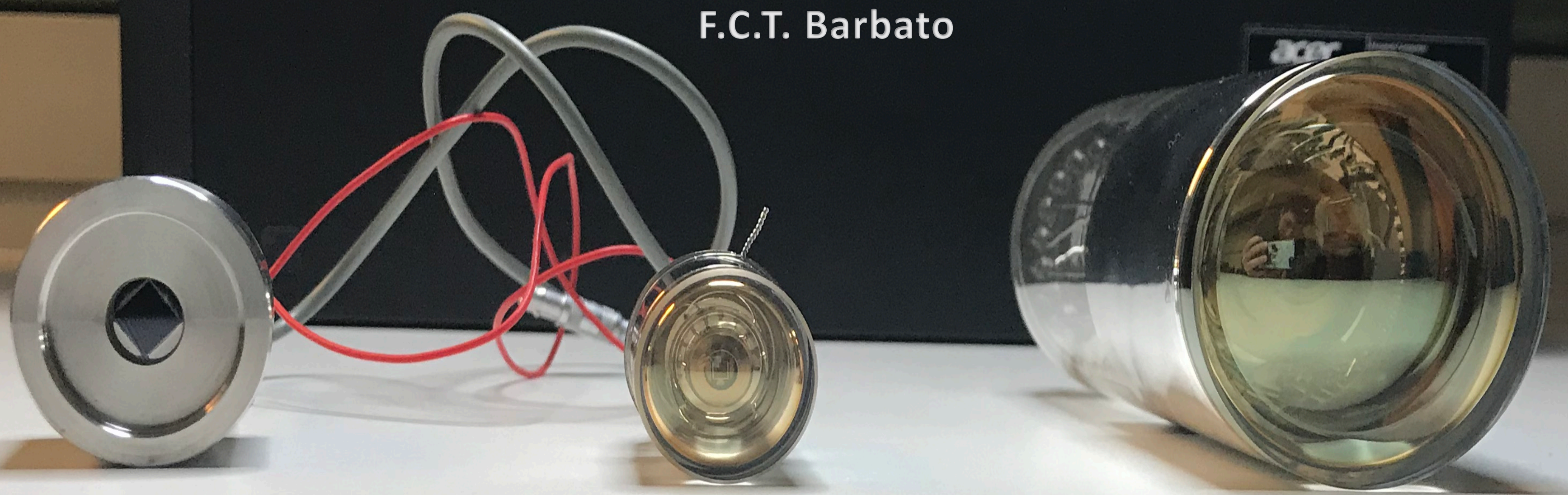
VCI 2019 - WIEN

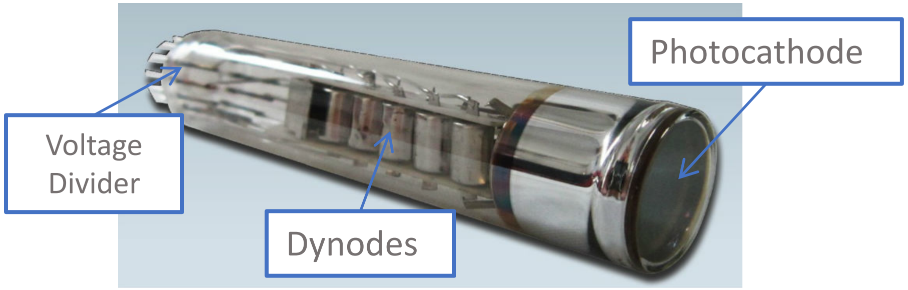
The 2-inches VSiPMT industrial prototype

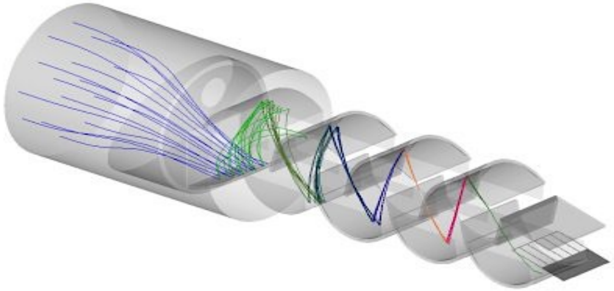
F.C.T. Barbato



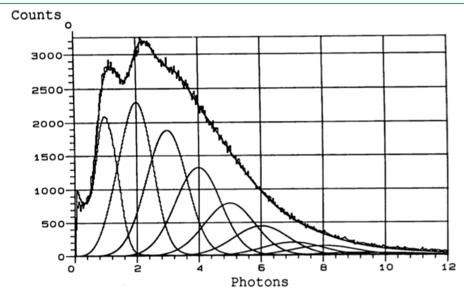
Photodetectors: state of the art

PMTs

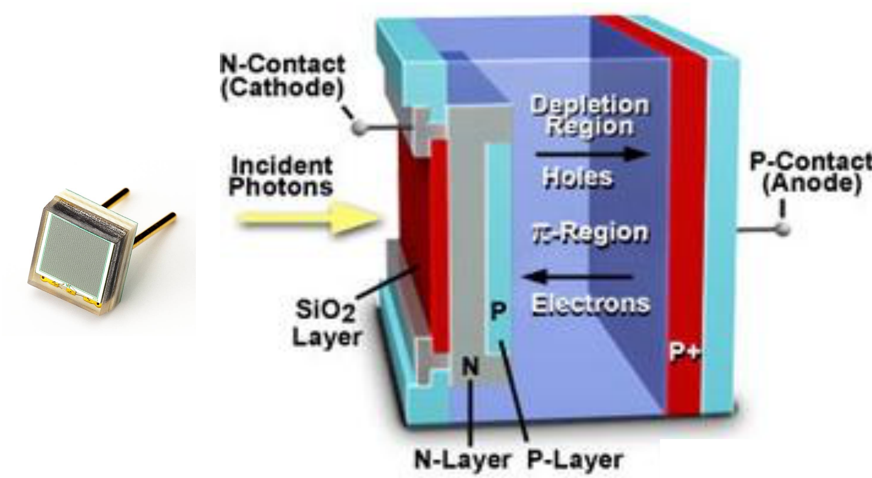




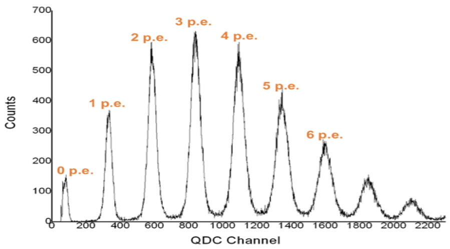
SERIAL GAIN: obtained by multiplying the photoelectrons in the dynodes



SiPMs

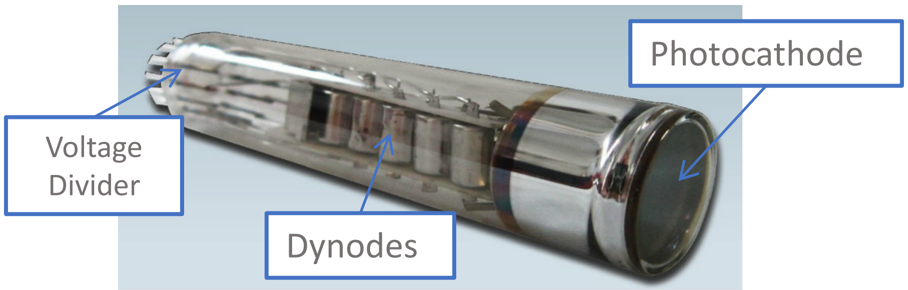


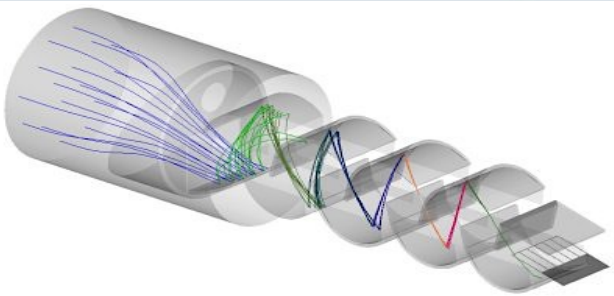
PARALLEL GAIN: obtained with the Geiger-avalanche generated in the p-n junction



Photodetectors: state of the art

PMTs



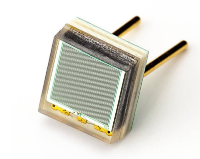


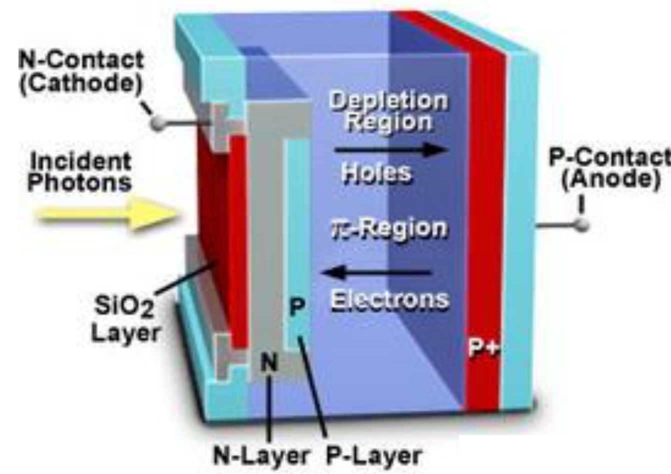
SERIAL GAIN: obtained by multiplying the photoelectrons in the dynodes

CHARACTERISTICS:

- Large sensitive surface (~cm^2)
- Good time performances
- Poor resolution

SiPMs





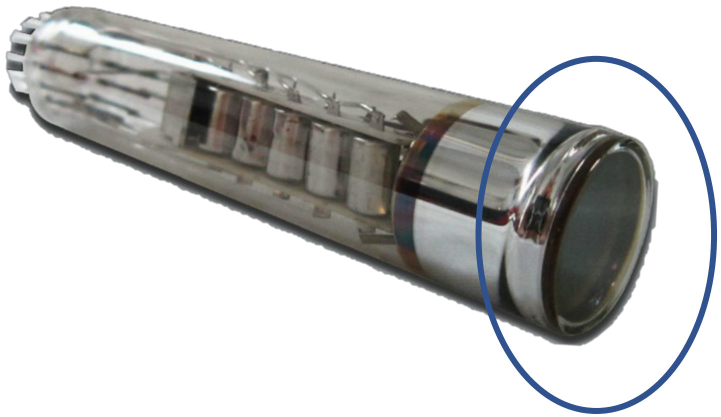
PARALLEL GAIN: obtained with the Geiger-avalanche generated in the p-n junction

CHARACTERISTICS:

- Small sensitive surface (~mm^2)
- Good time performances
- Excellent resolution

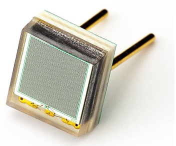
The goal: increase the SiPM surface

PMT



+

SIPM



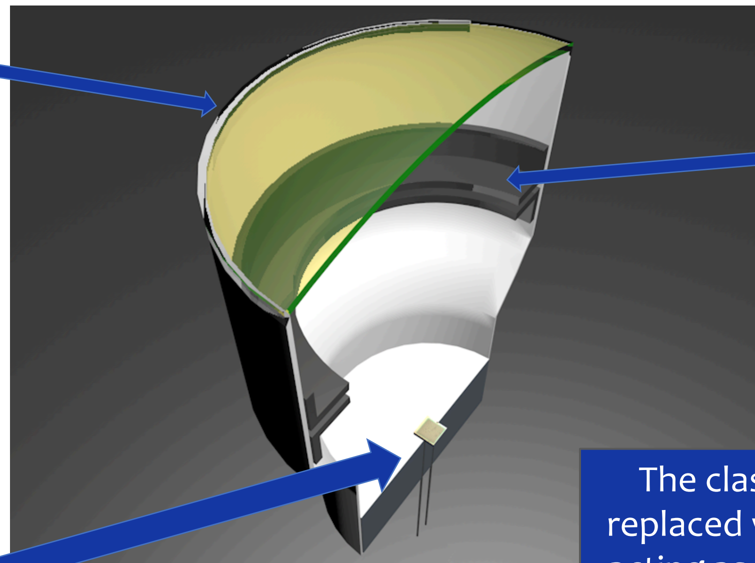
VacuumSiliconPhotoMultiplierTube:
an hybrid solution for a large area photodetector
with excellent performances

The goal: increase the SiPM surface

Photocathode

Focusing Ring

SiEM

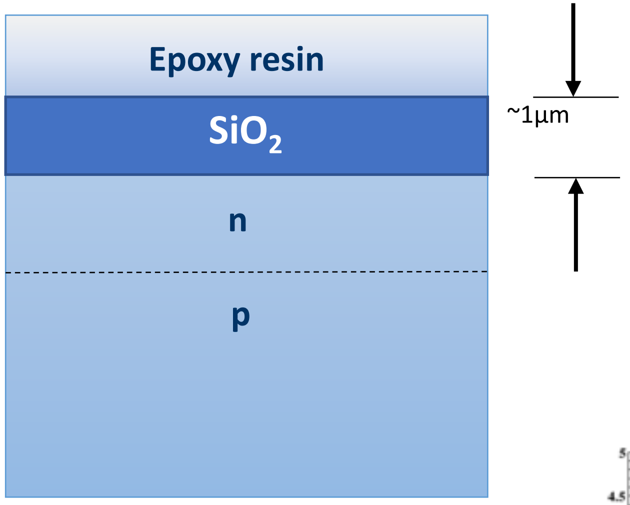


The classical dynode chain of a PMT is replaced with a special windowless SiPM, acting as an electron multiplying detector (SiEM).

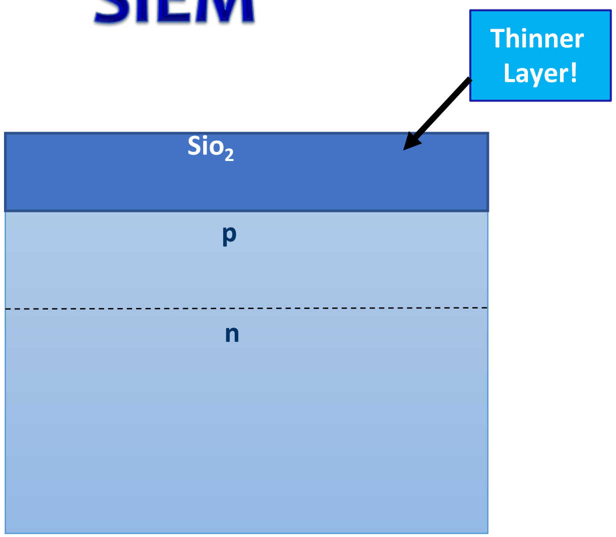
An innovative design for a modern hybrid photodetector based on the combination of a Silicon PhotoMultiplier (SiPM) with a hemispherical vacuum glass PMT standard envelope

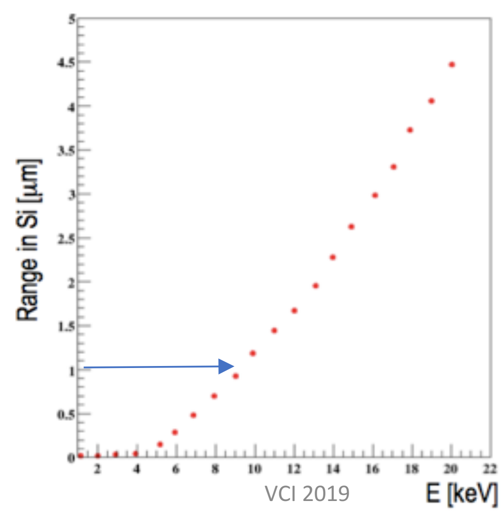
The SiEM

SIPM



SIEM

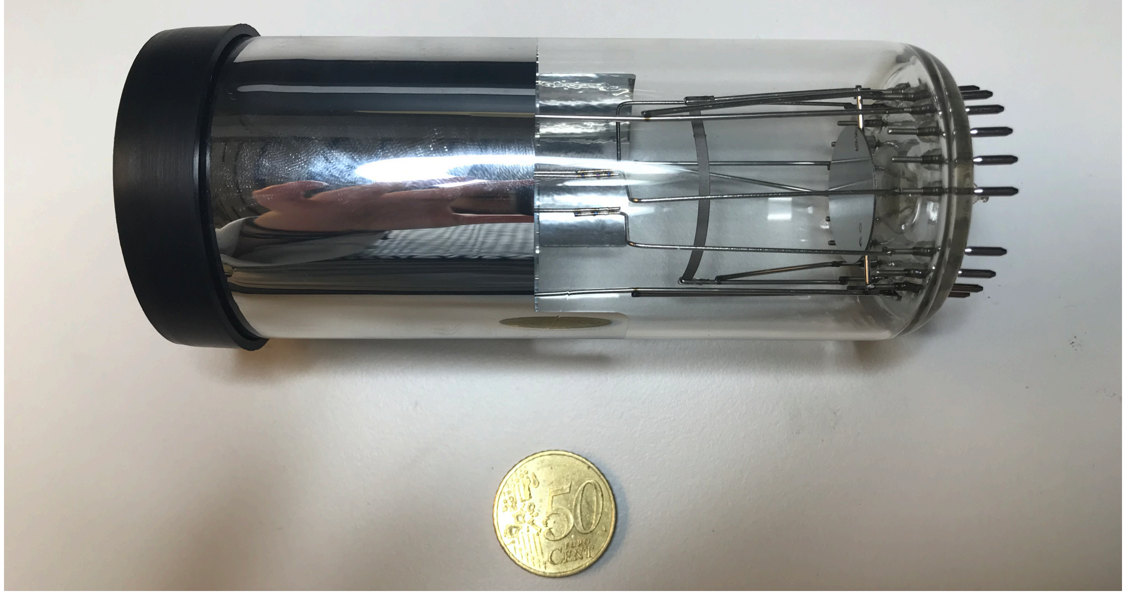




SiEM (Silicon Electron Multiplier)

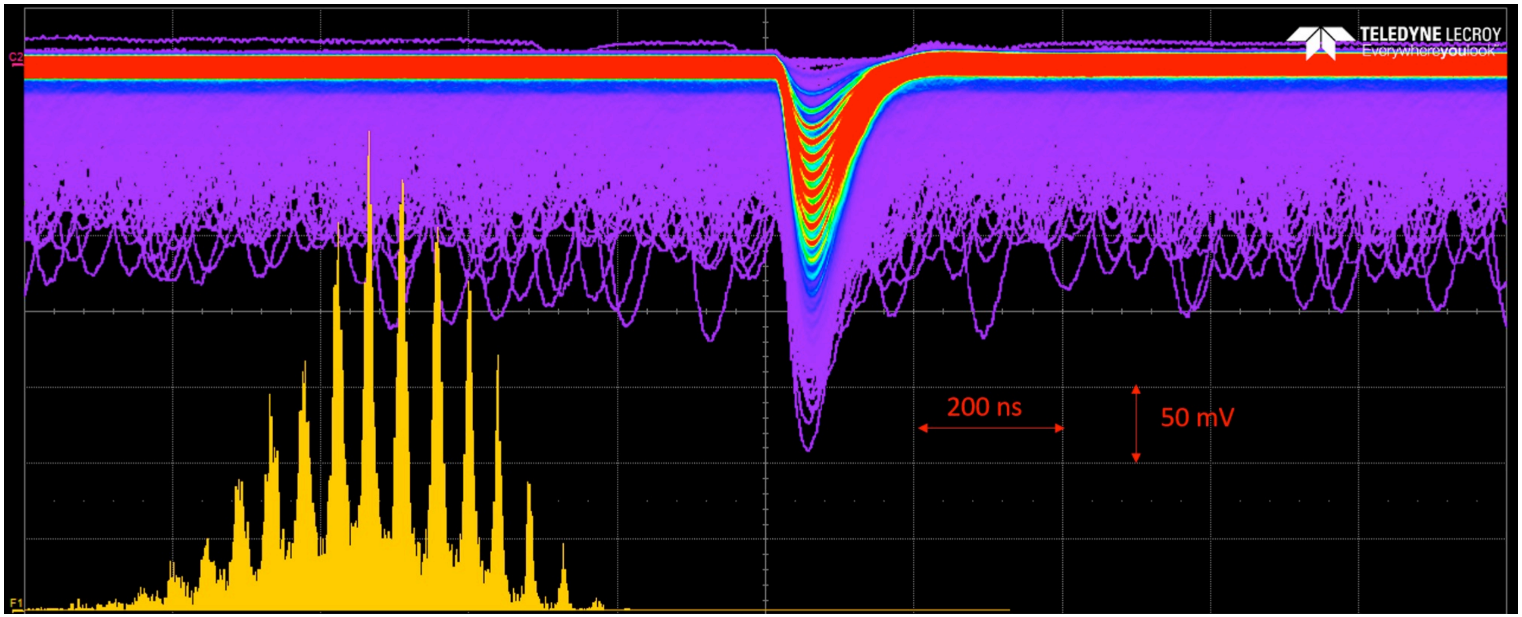
- No epoxy resin
- Thinner SiO_2 layer
- P over n junction

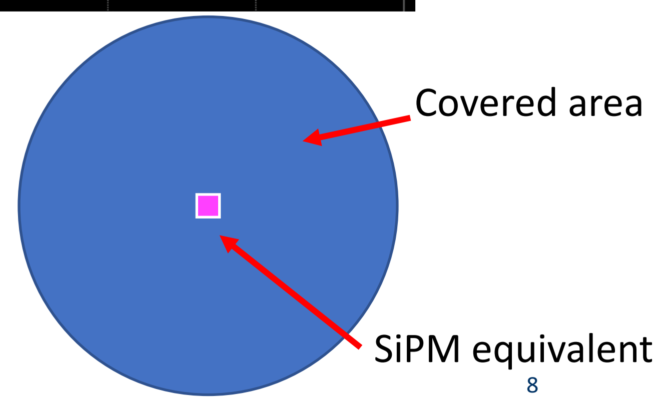
The 2-inches prototypes



Prototipo	**ZJ9496**	**ZJ9498**
Risposta Spettrale (nm)	200-650	200-650
Diametro Fotocatodo (mm)	46	46
Materiale Finestra	Vetro Borosilicato	Vetro Borosilicato
Dimensioni SiEM (mm^2)	3x3	3x3
Dimensioni Pixel (μm^2)	25x25	50x50
Fill Factor	47	74

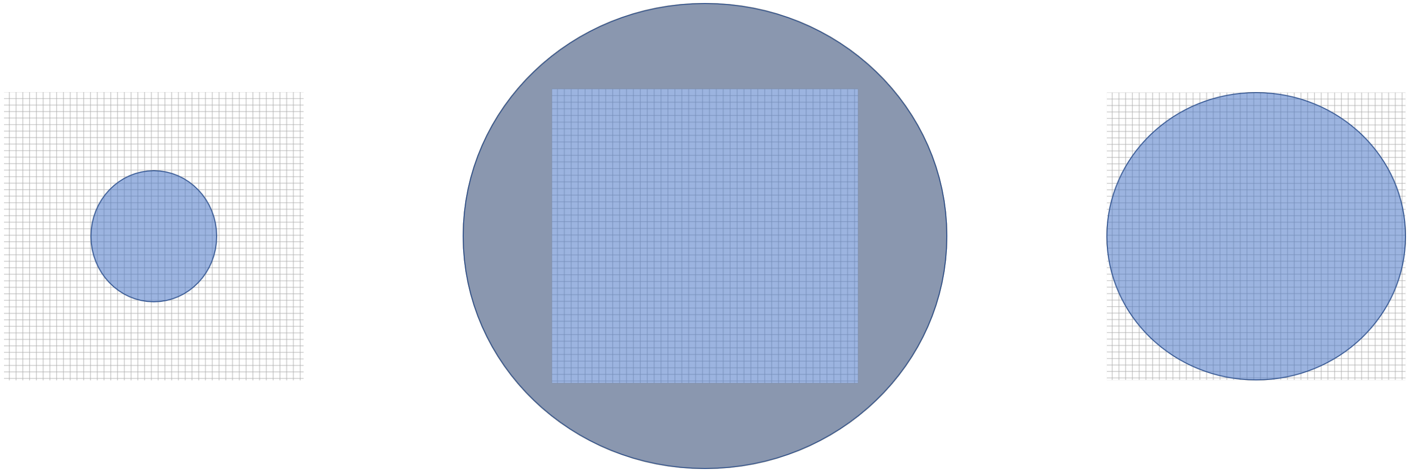
GREAT PHOTON COUNTING CONFIRMED!





Photon Detection Efficiency

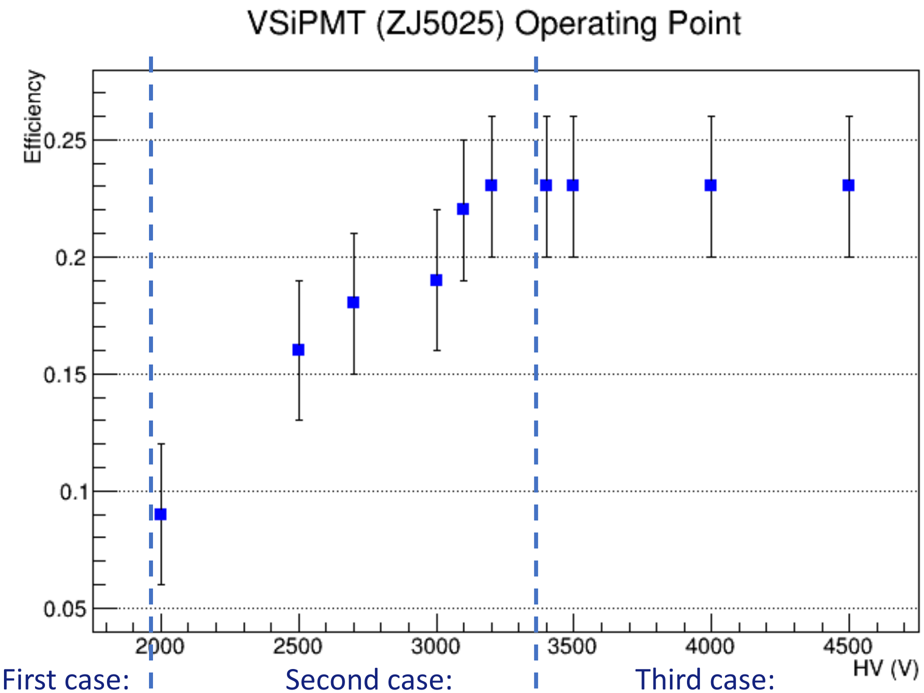
$$PDE = QE \cdot FF \cdot \varepsilon_{focusing} \cdot \varepsilon_{trigger}$$



$\varepsilon_{focusing} = 1$ $\varepsilon_{focusing} < 1$ $\varepsilon_{focusing} = 1$

Photon Detection Efficiency

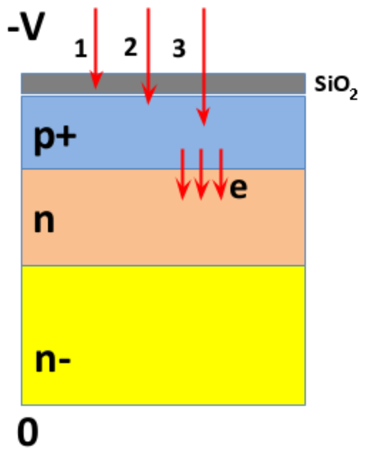
$$PDE = QE \cdot FF \cdot \varepsilon_{focusing} \cdot \varepsilon_{trigger}$$



First case: $\epsilon = 0$

Second case: $\epsilon < 1$

Third case: $\epsilon = 1$

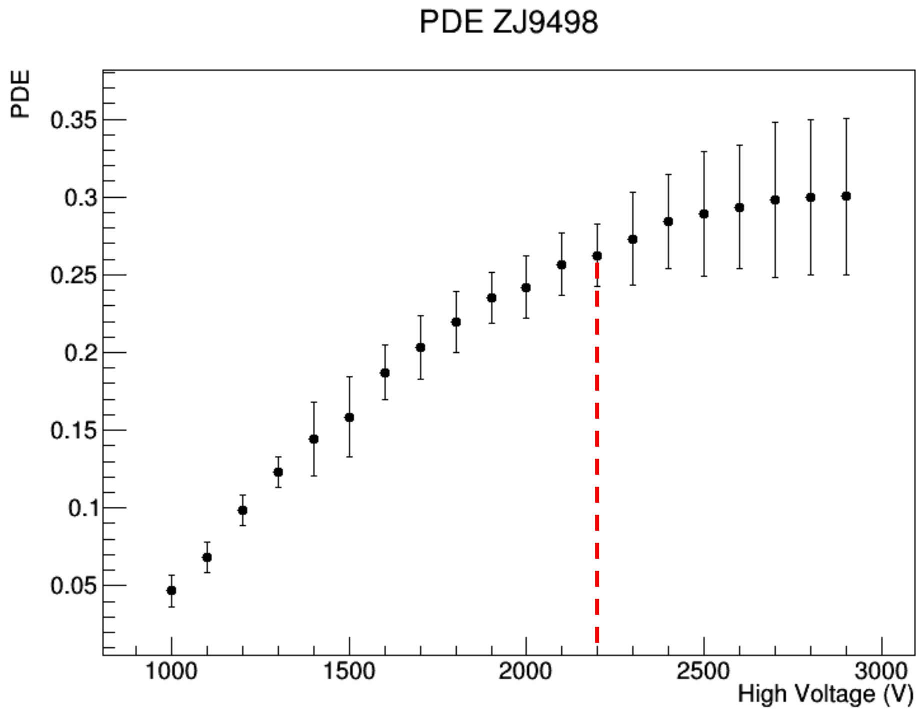


Efficiency is highly stable over 3200 V.
No need for high voltage stabilization.

- HV: photoelectron transfer → NO power consumption (NULL current)
- LV-based gain → EASY STABILIZATION
- Reducing the SiO_2 coating layer it will be possible to reach the plateau region at even lower voltages.

Photon Detection Efficiency

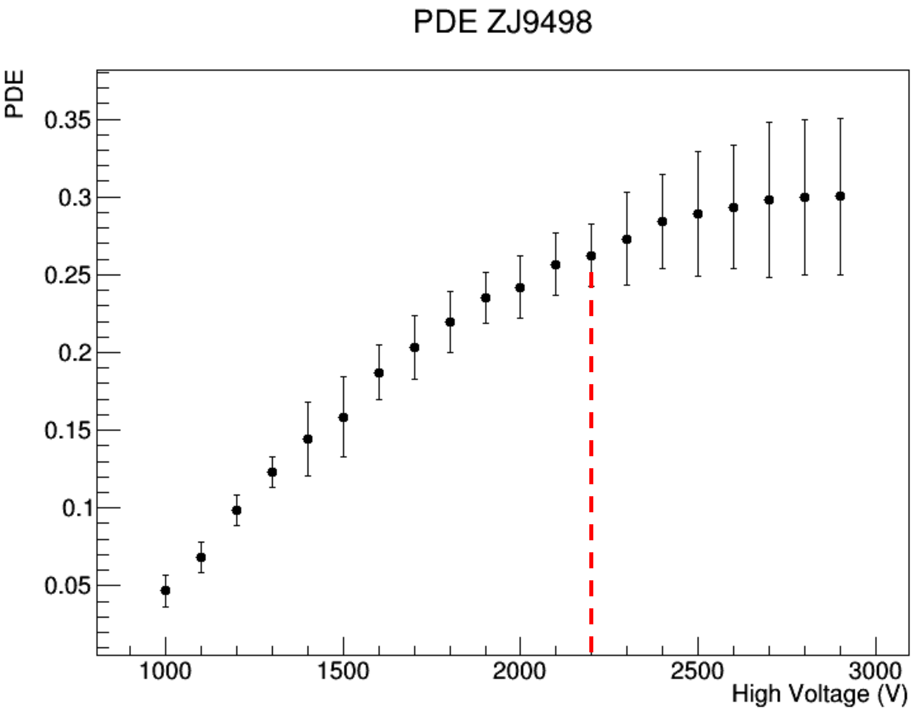
$$PDE = QE \cdot FF \cdot \varepsilon_{focusing} \cdot \varepsilon_{trigger}$$



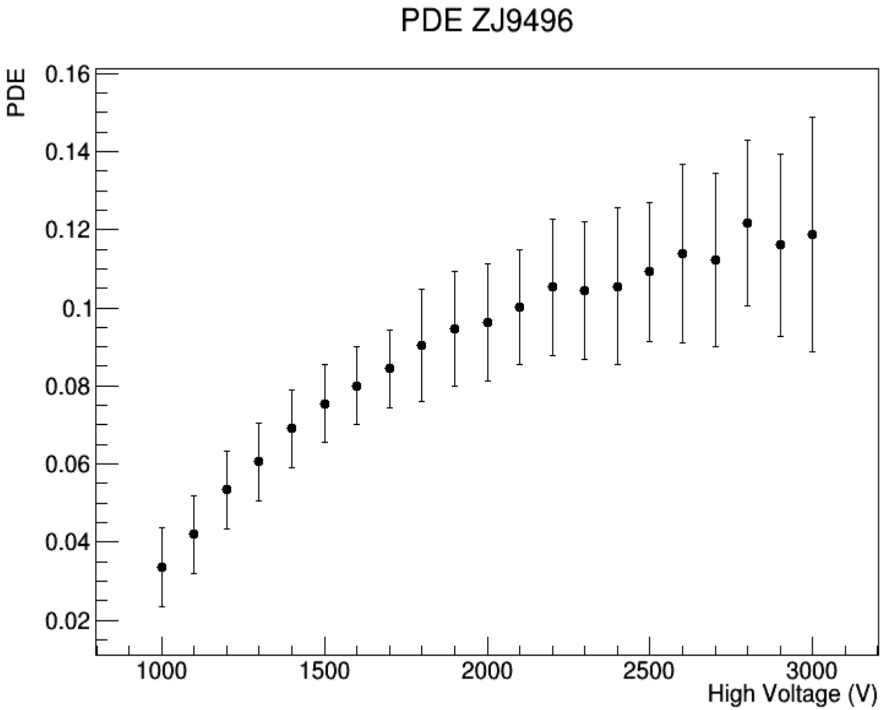
$$PDE = QE \cdot FF = 27\%$$

Photon Detection Efficiency

$$PDE = QE \cdot FF \cdot \varepsilon_{focusing} \cdot \varepsilon_{trigger}$$

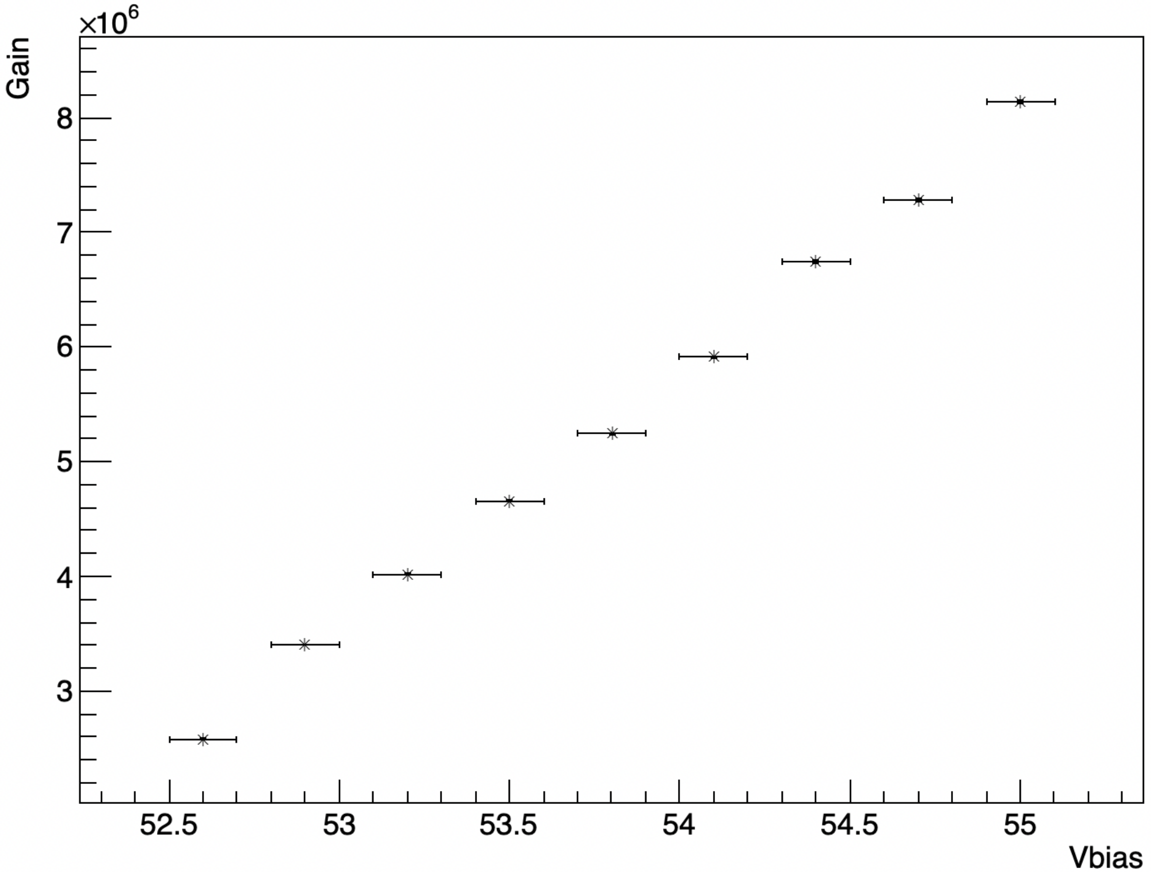


$$PDE = QE \cdot FF = 27\%$$



$$PDE = QE \cdot FF = 13\%$$

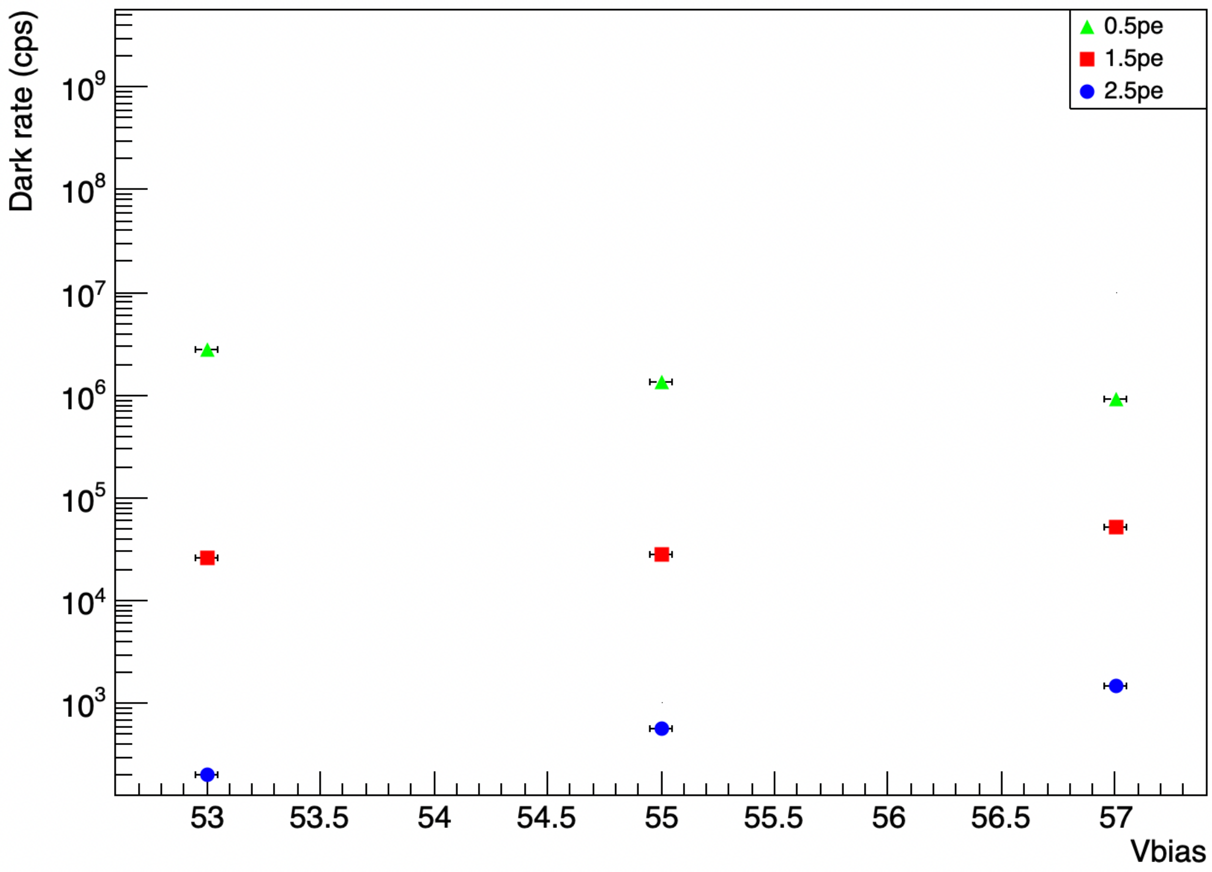
The gain



SAME GAIN OF THE SIEM!

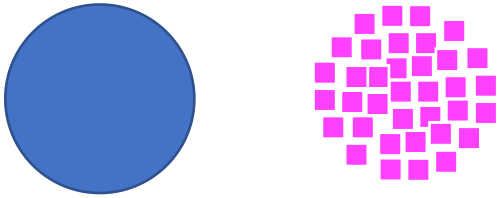
HV NEEDED ONLY FOR FOCUSING

The dark noise



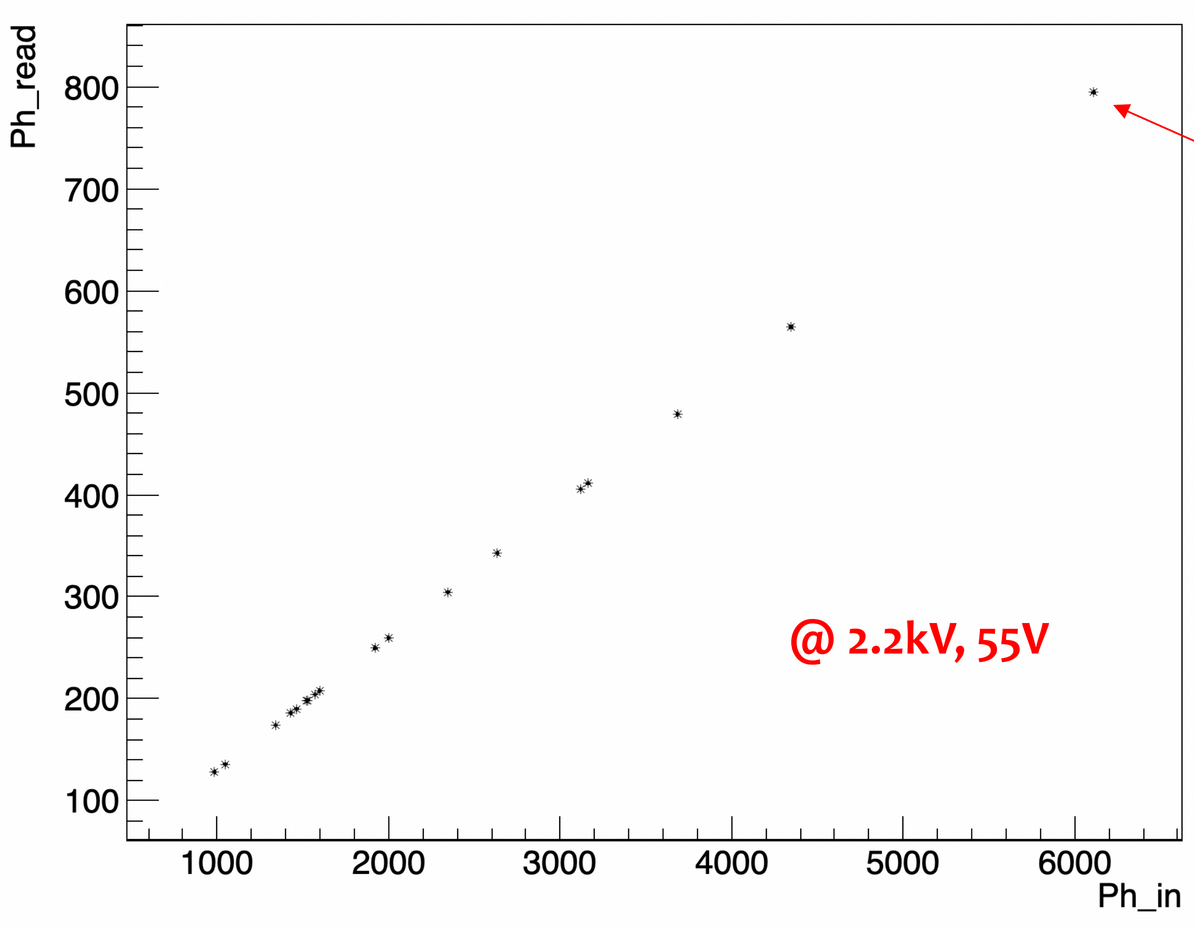
SAME NOISE OF THE SIEM!

COVERING LARGE AREA WITH THE SAME RESPONSE OF 218 SIPMS BUT THE NOISE OF ONLY ONE!



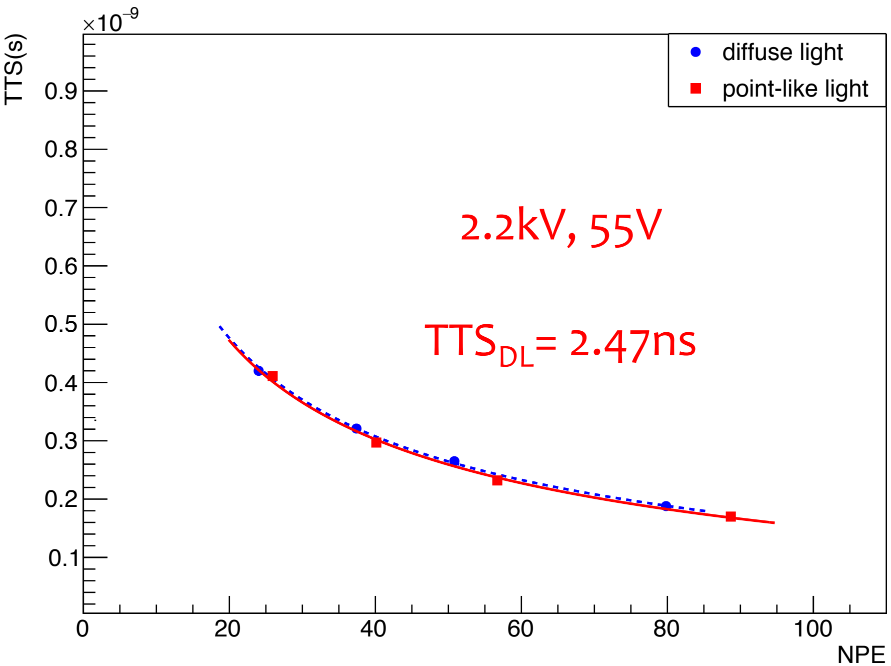
REDUCTION OF THE EQUIVALENT NOISE

Linearity

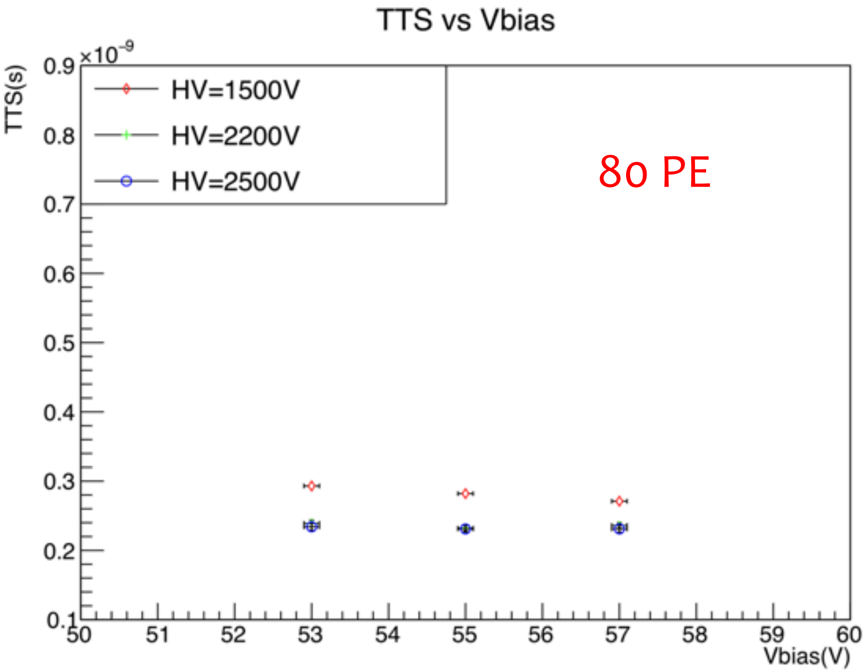


Maximum allowed by OP-AMP

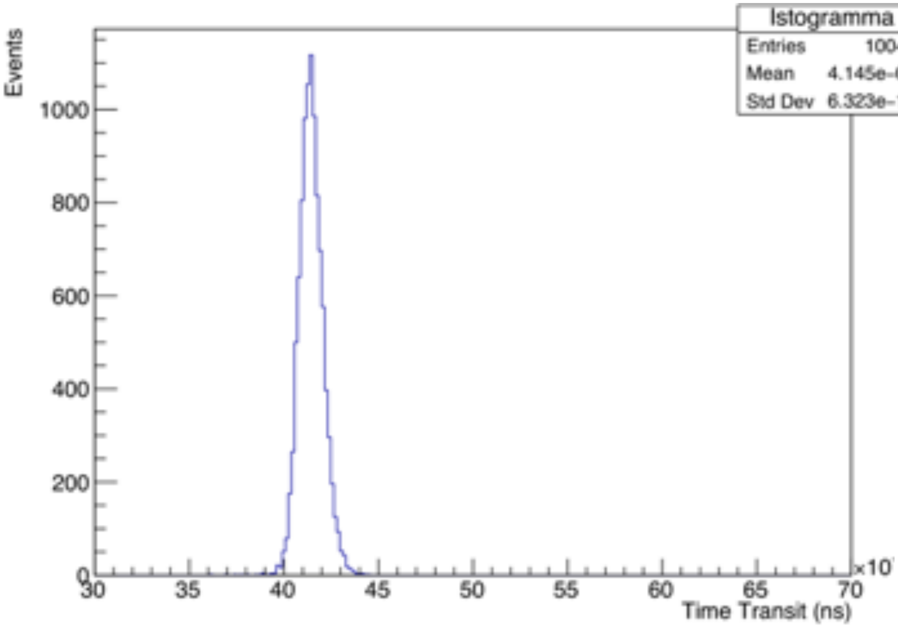
The timing performance

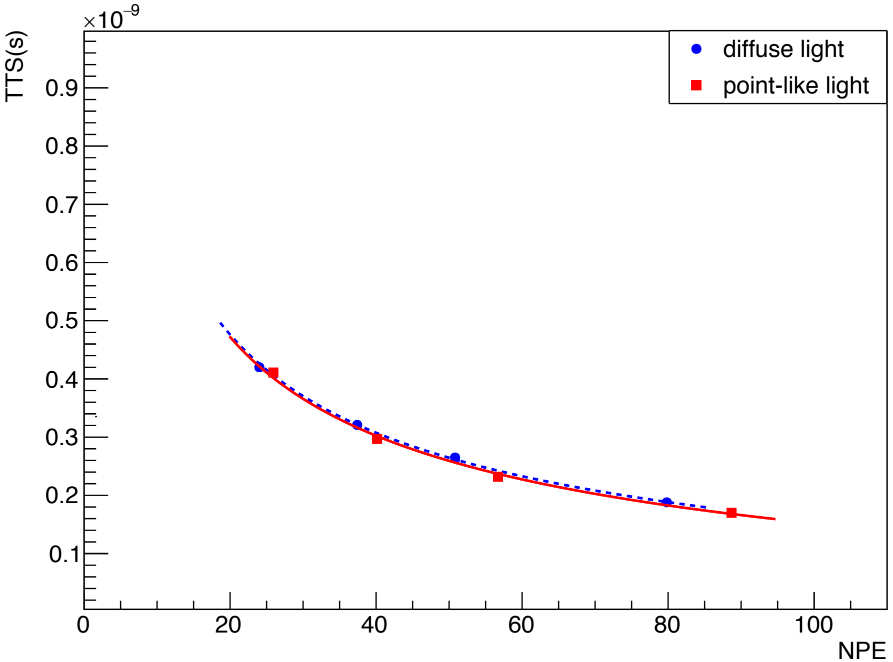


HV	TTS@1PE
1500	2.52±0.03
2200	2.47±0.02
2500	2.46±0.02



The timing performance

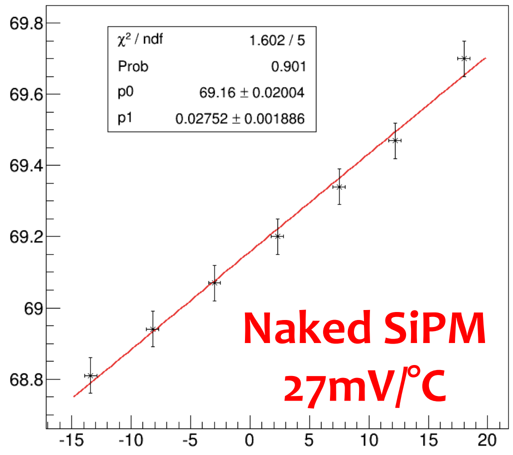




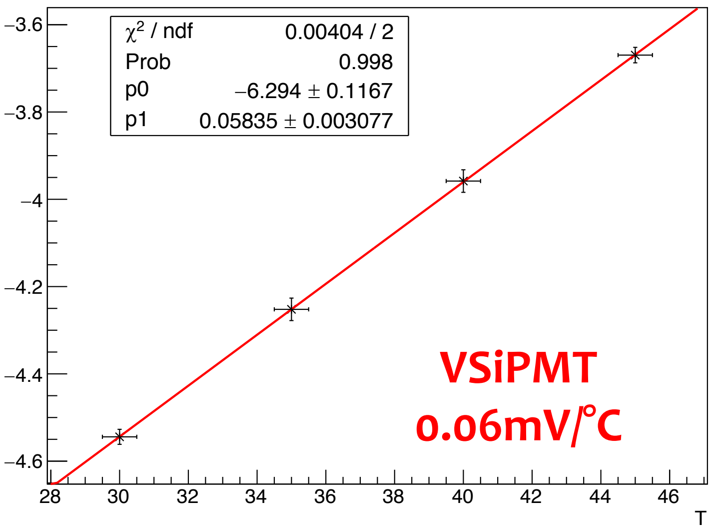
@ 2.2kV, 55V

TT= 41.45ns
TTS= 2.47ns

The temperature dependence

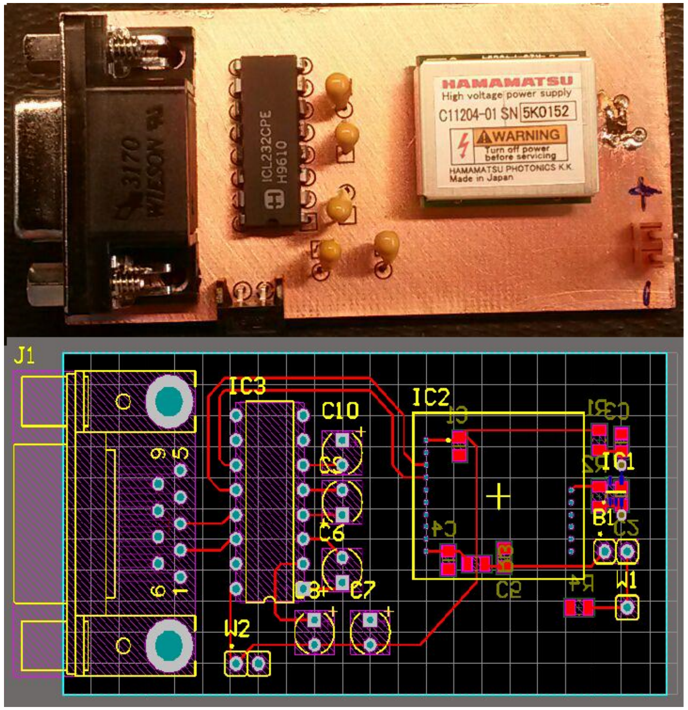


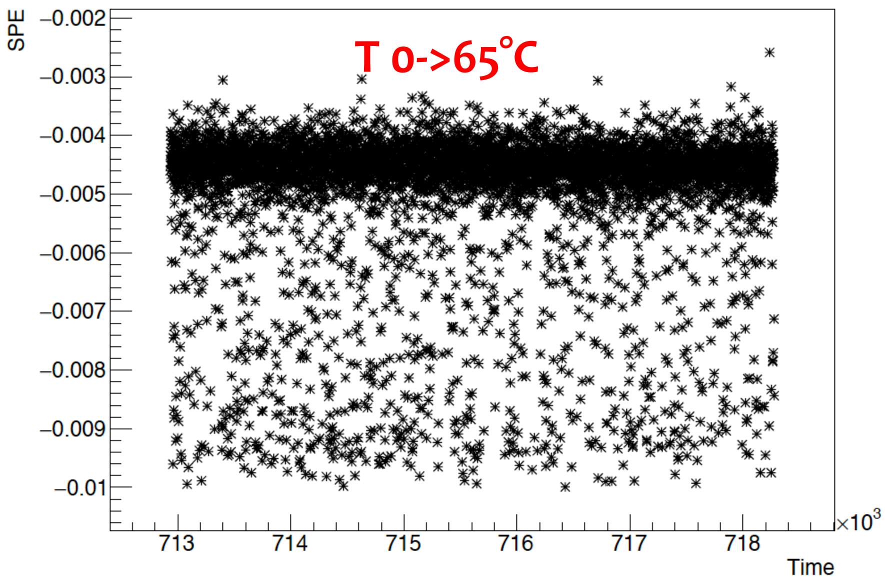
ADAPT FOR HOSTILE ENVIRONMENT



The temperature dependence

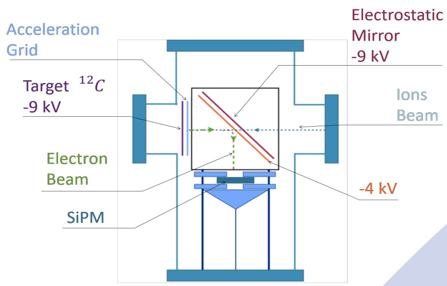
Bias temperature regulator C11204-01 by Hamamatsu

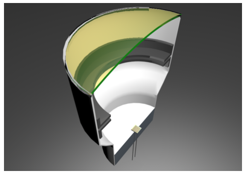




SPE STABLE WITH TEMPERATURE

The history

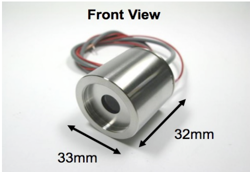




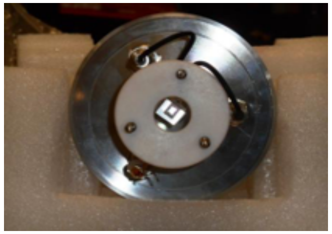
2008
Idea

2012
Proof of feasibility

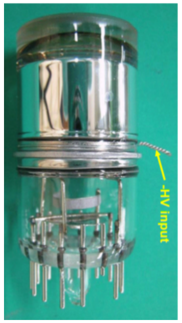
2013
First industrial prototype by Hamamatsu



2014
LEGO prototype

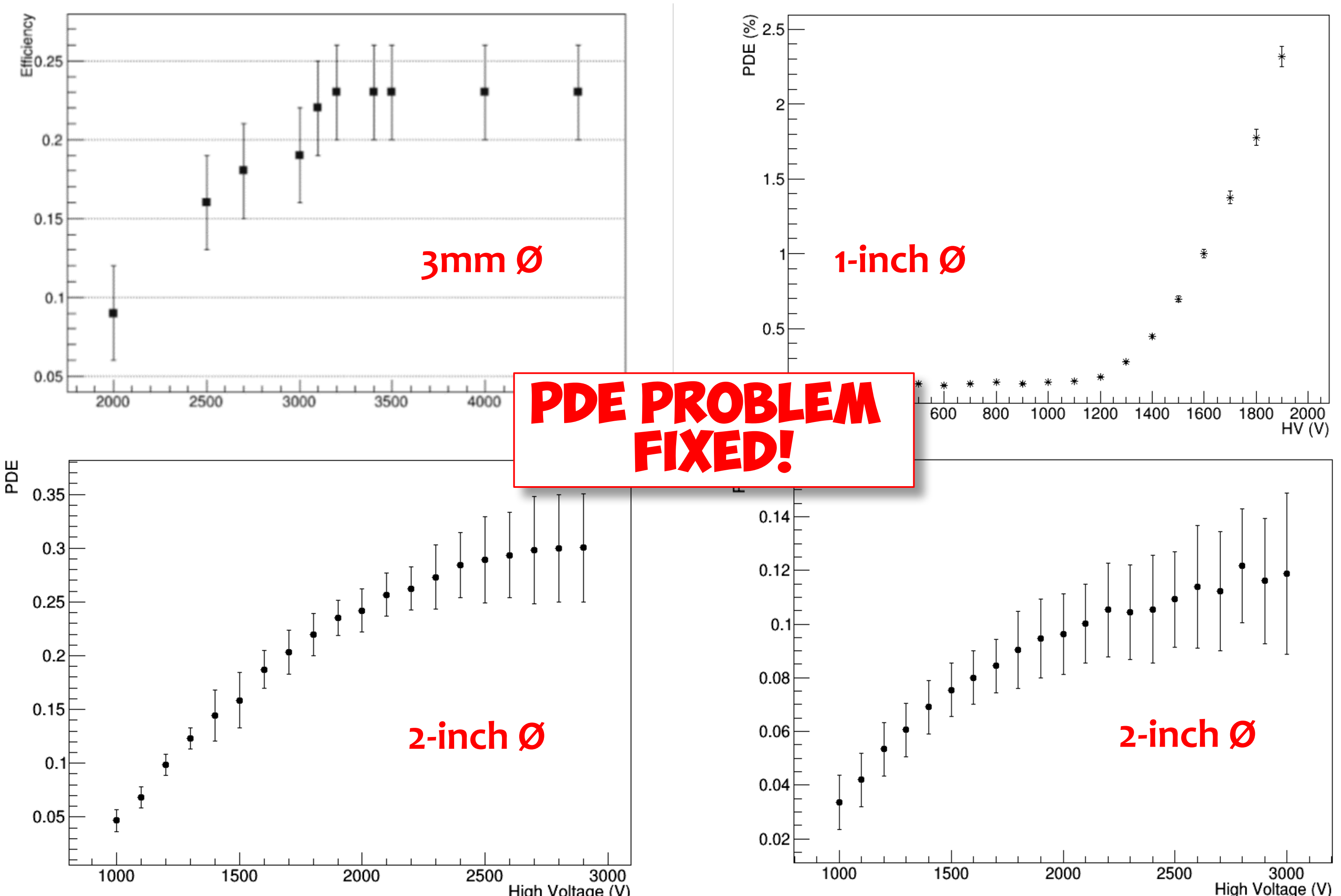


2016
1" prototype



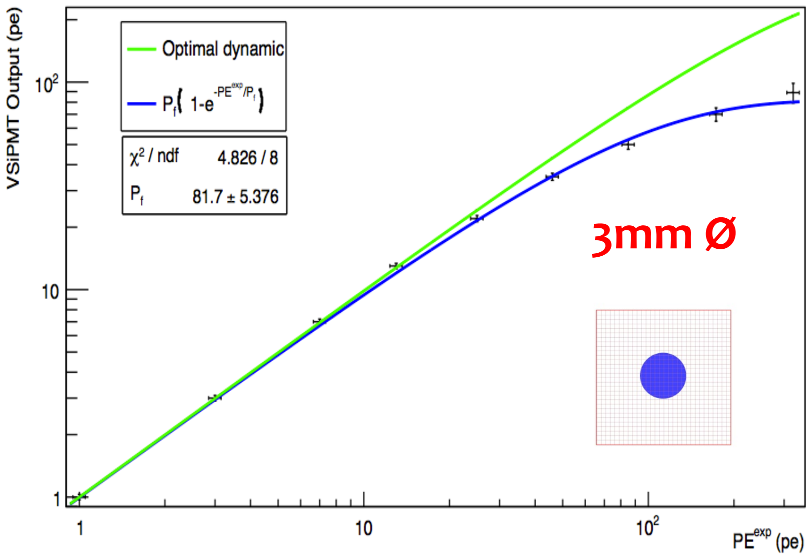
2018
2" prototype

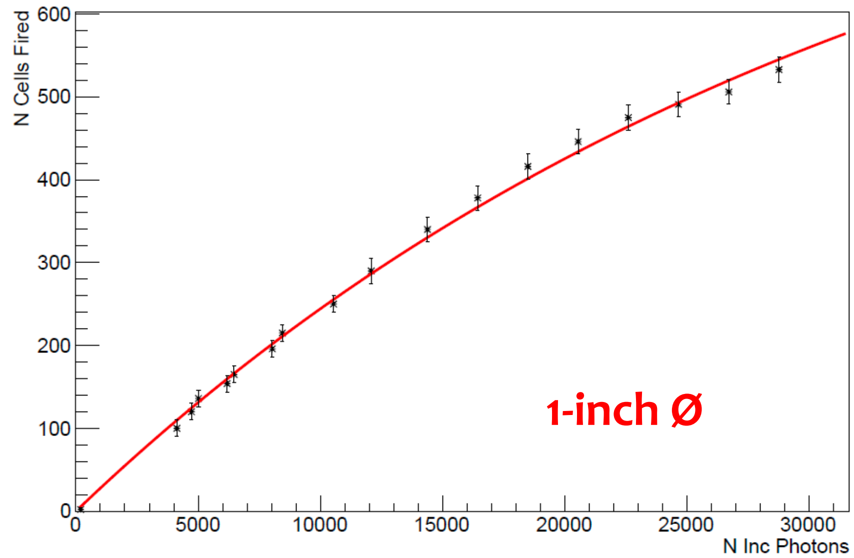
Resume

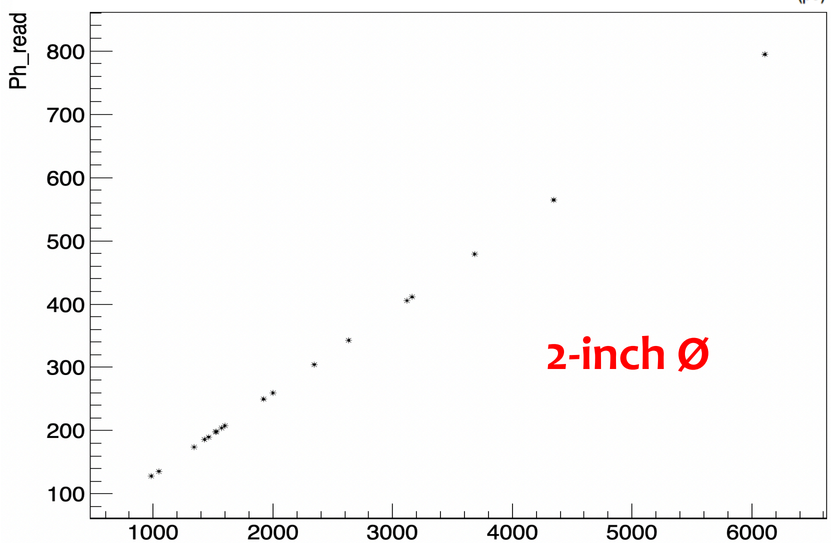


Efficiency
3mm Ø
PDE (%)
HV (V)
1-inch Ø
PDE PROBLEM FIXED!
PDE
High Voltage (V)
2-inch Ø
High Voltage (V)
2-inch Ø

Resume

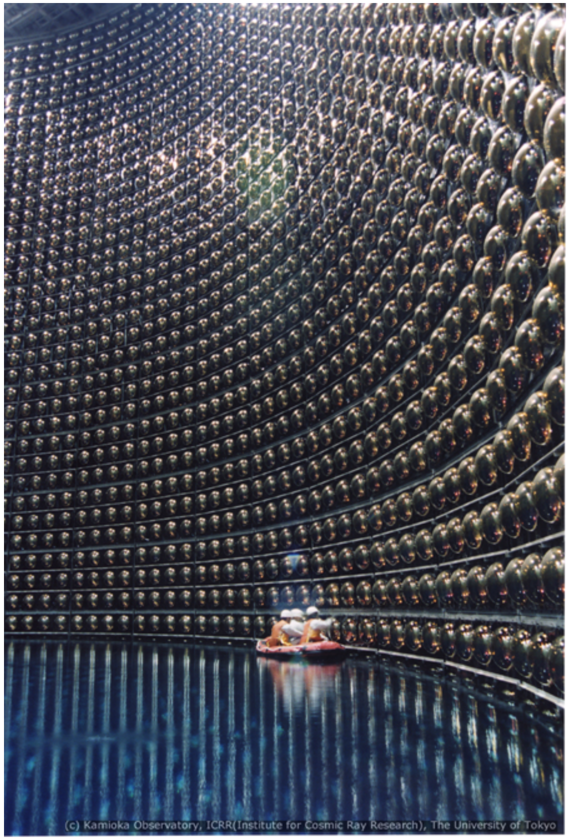


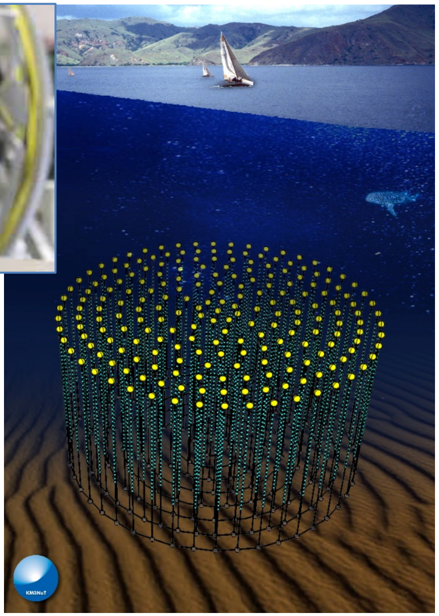




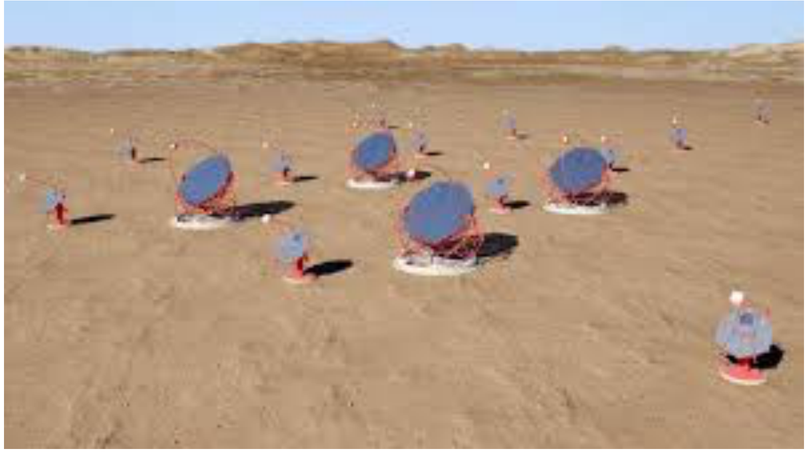
LINEARITY PROBLEM FIXED!

Applications



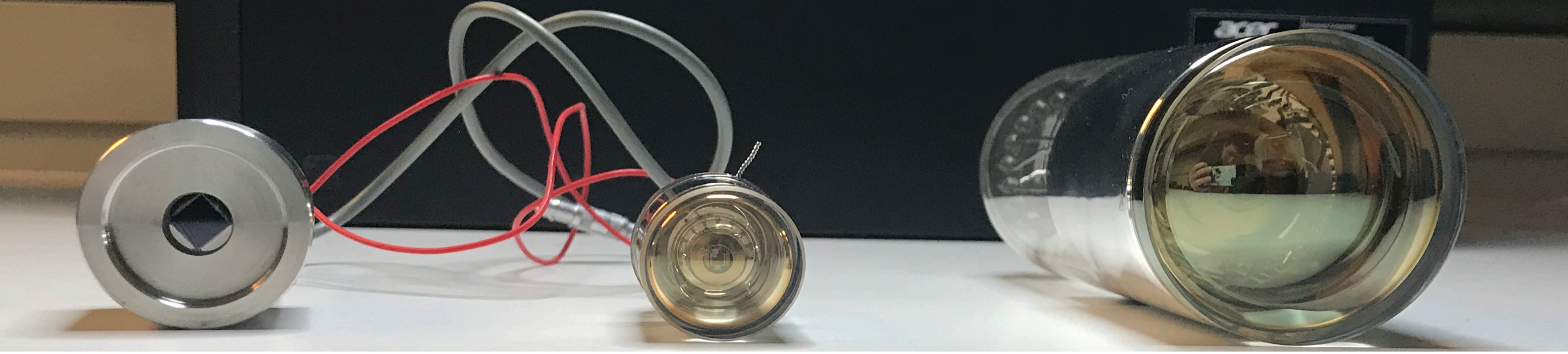


Next future Cherenkov photon counters



Applications

PMT	VSiPMT
	



The VSiPMT is an idea born in Naples in 2007 to fulfill the requirements of current and next future astroparticle experiments.

The VSiPMT project has been financially supported by the Italian Space Agency.
Within this panorama a 1-inch prototype acting in the VUV region has been realized by our group.

The 1-inch prototype manufactured by Hamamatsu Photonics has showed some technical problems that have been totally fixed in the 2-inch prototypes.

Tests on this prototypes are still running.

Next step will be running a little experiment with both VSiPMT and PMT and SiPM and register the actual difference between the objects.

We are confident that the VSiPMT will be a reality for the next future experiments!

Thanks

Prof. G. Barbarino – Inventor of VSiPMT

People involved in the R&D:

G. De Rosa

R. de Asmundis

F. Di Capua

L. Campajola

D. Vivolo

C.M. Mollo

F.C.T. Barbato

SPECIAL THANKS TO HAMAMATSU FOR SUPPORTING OUR IDEA!