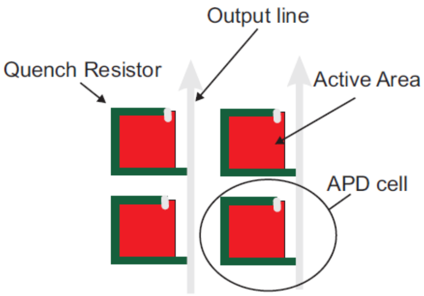
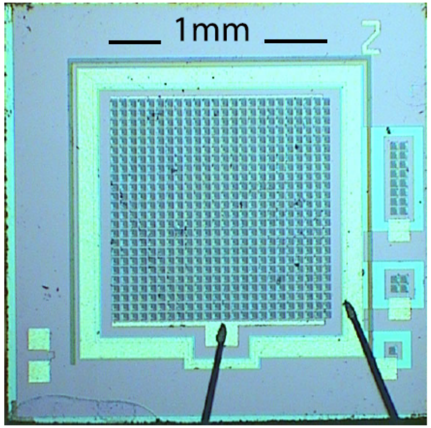
WG7 Photodetecor Summary

Nepomuk Otte

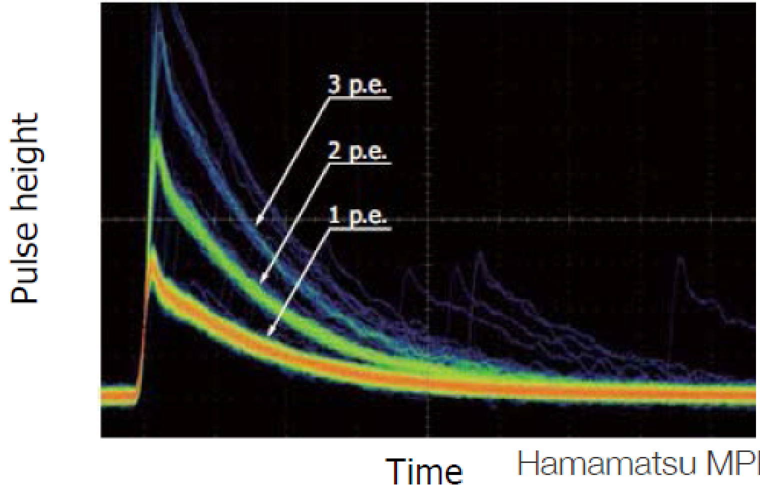
Georgia Tech College of Sciences
School of Physics

The SiPM





MEPhI/Pulsar SiPM 2004



Hamamatsu MPPC techinfo

The SiPM concept provides multi-photon resolution:

Many passively quenched SPADs are connected in parallel

Recover information about number of photons

if photons per cell per recovery time <1

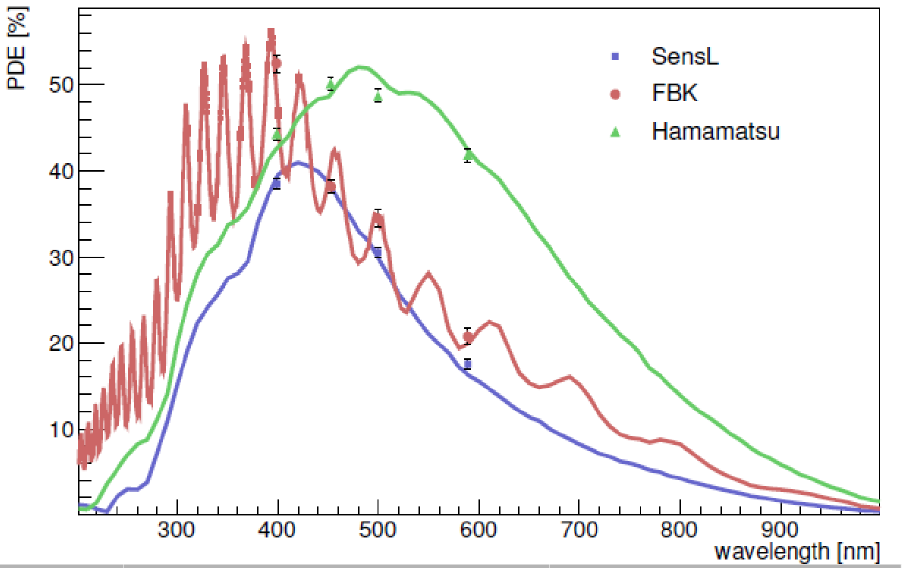
Pioneered in the 90's

Key persons: Dolgoshein, Golovin, and Sadykov

For an extensive review on the history of solid state photon detectors see D. Renker and E. Lorentz (2009)

SiPM Development Status

- SiPMs are mature devices

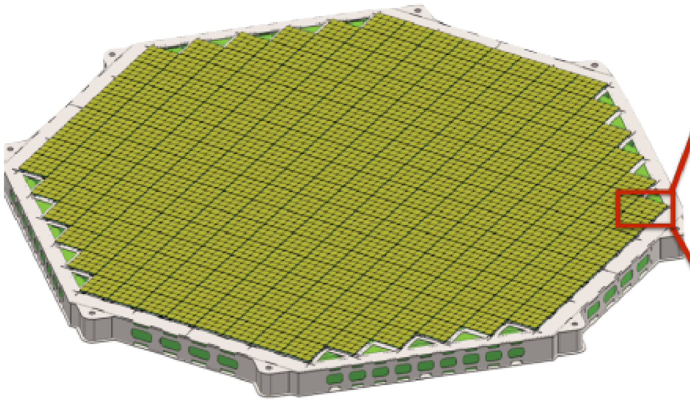


Parameter	2004	2013	2017	Wish List
Spectral Response	Green Sensitive **n-on-p structure**	Blue and Green **p-on-n structure**	Blue and Green Enhanced below 350 nm	Tailored to application
Photon Detection Efficiency	~10%	~45%	~55%	>70%
Dark Noise At room temperature	1MHz/mm^2	~100kHz/mm^2	50 kHz/mm^2	As low as possible
Optical Crosstalk	>20%	<10%	1%	As low as possible
Afterpulsing	>20%	<1%	<1%	As low as possible
Temperature dependency of gain	5-10 %/$^{\circ}$C	5-10 %/$^{\circ}$C	1 %/$^{\circ}$C	
Sensor Size	1mm^2	1mm^2-36mm^2	1mm^2-36mm^2	

Light detection in DarkSide-20k with Silicon Photomultipliers

Claudio Savarese

TPC optical plane

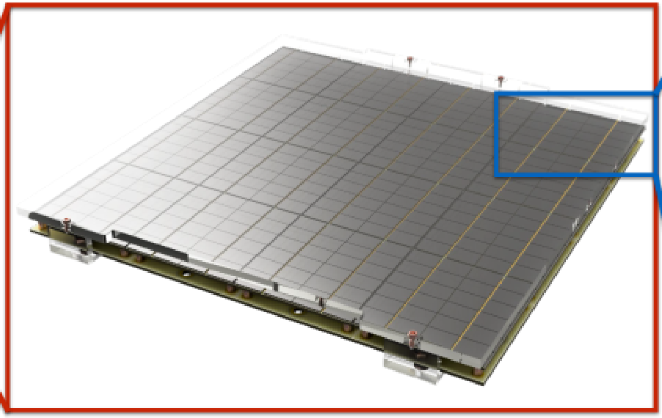


TPC planes area: ~21m²

Organized in 525 PDUs

100% coverage of TPC top and bottom

Photo-Detection Unit



16 tiles arranged in 4 readout channels

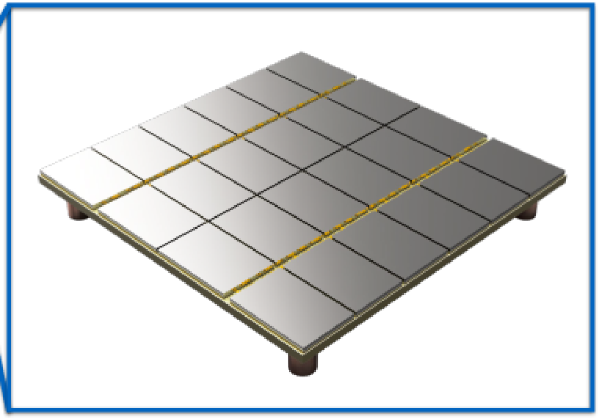
SiPM bias distribution

cryogenic pre-amplifiers bias

Signal transmission

Channels switch-on/off

Tile



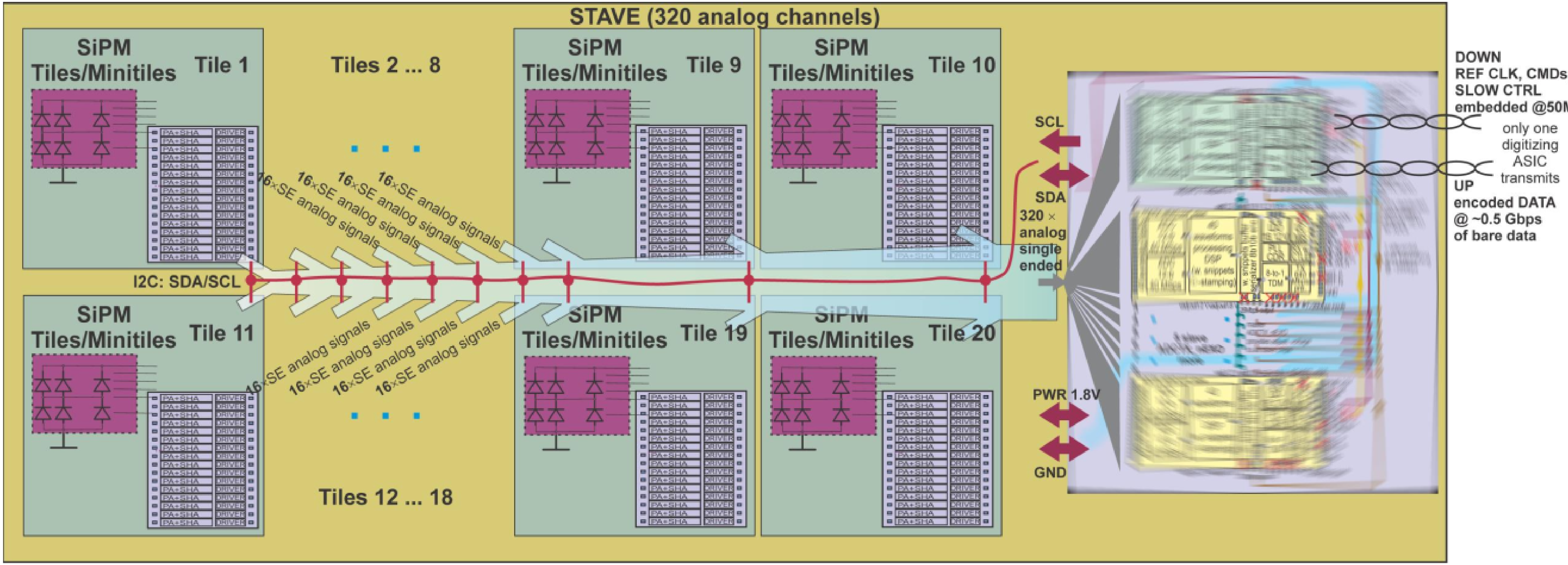
Photosensor

Array of 24 SiPMs

Signal pre-amplification

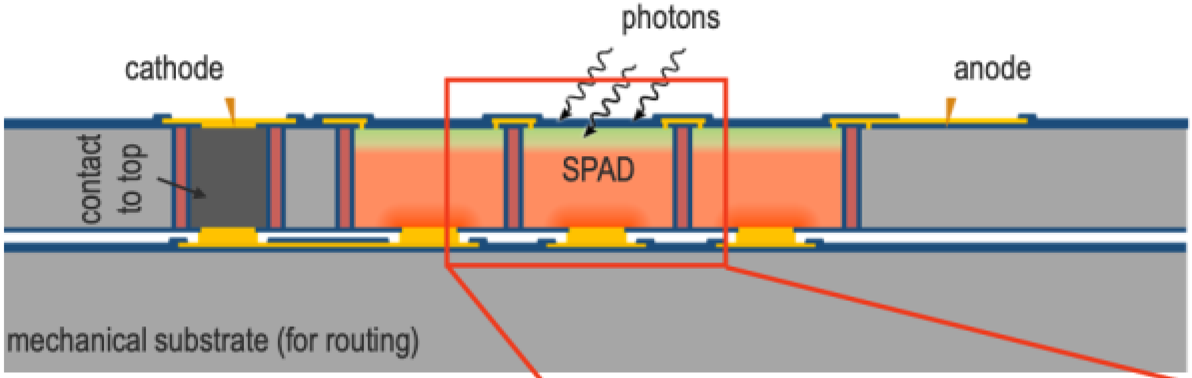
Stave-Oriented Photon Detector Readout with Event Waveform Recording

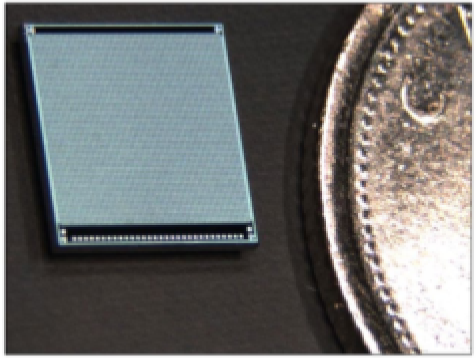
G. W. Deputch



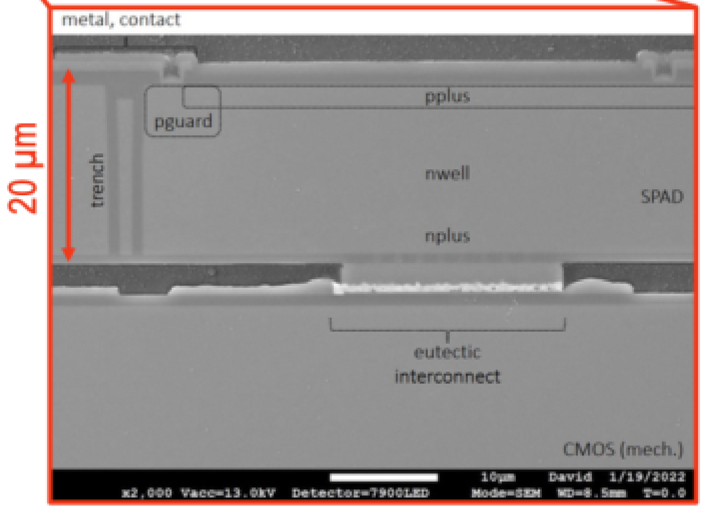
3D SiPMs aka the Digital SiPM

- Idea is >10 years old.
- It is not easy.
- Need to keep these developments going.



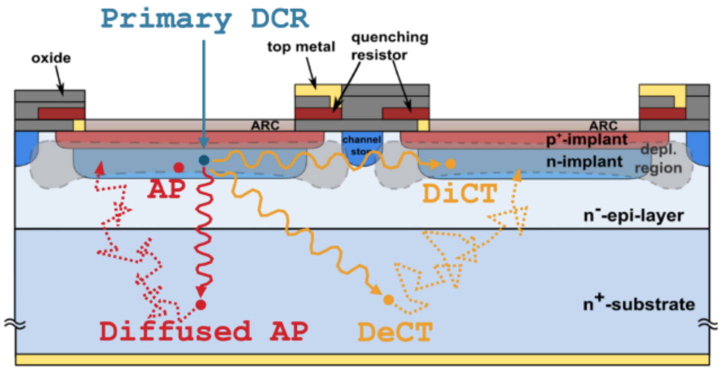


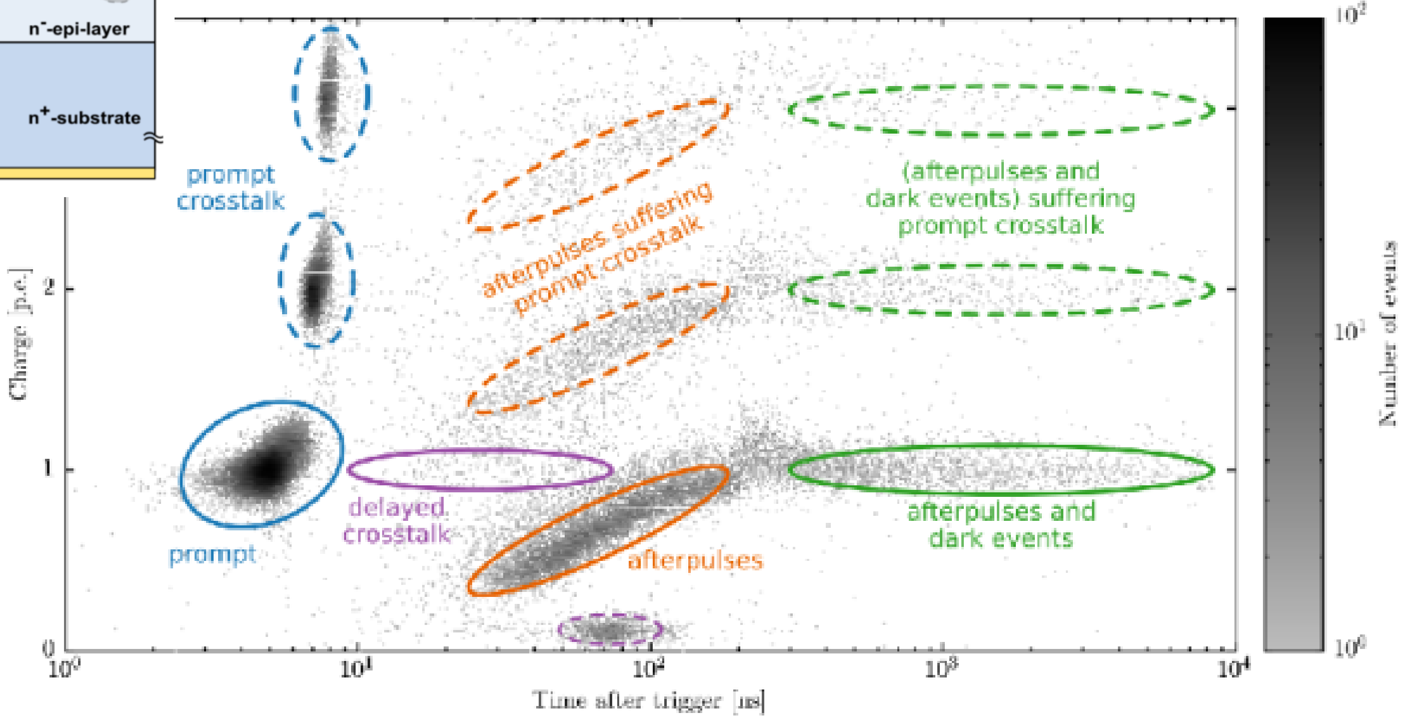
3D SPAD main die macro image
(canadian 10¢ for reference)



18

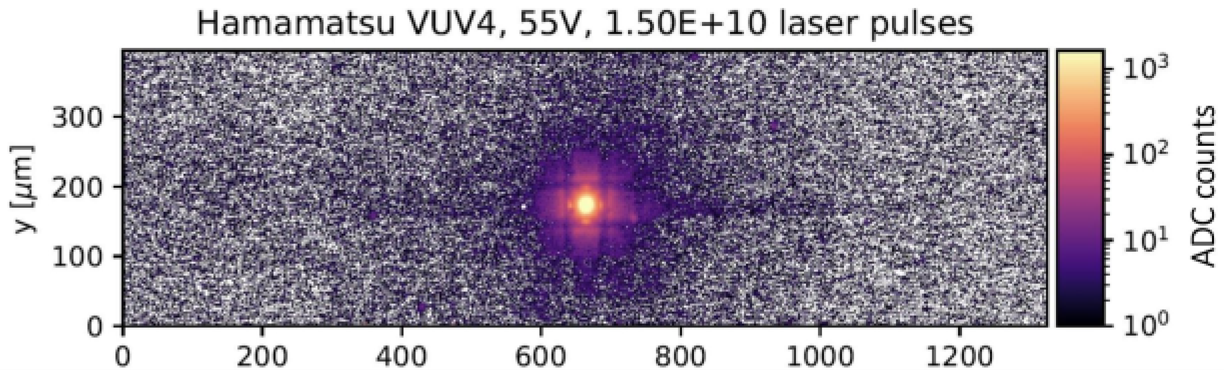
SiPM correlated noise

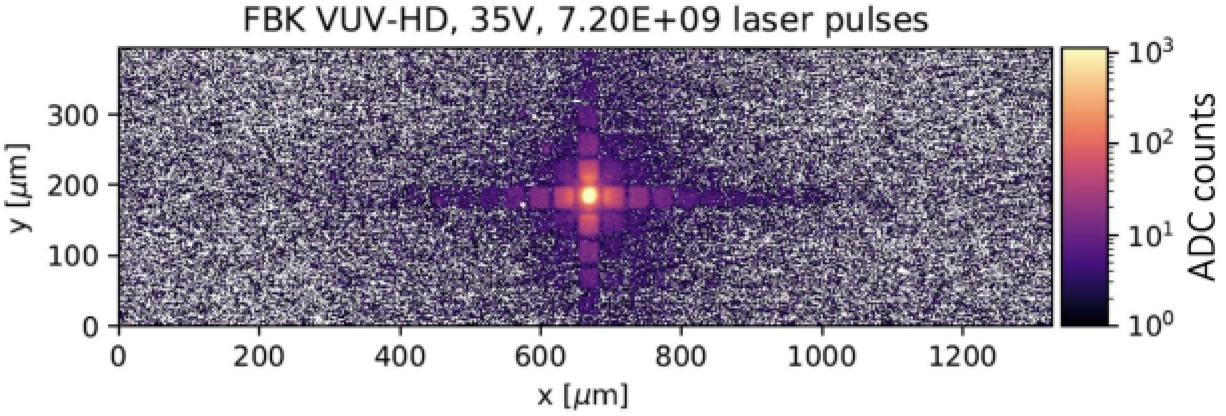


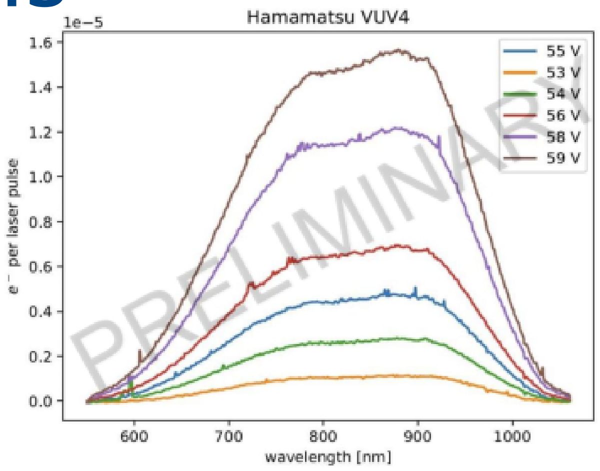


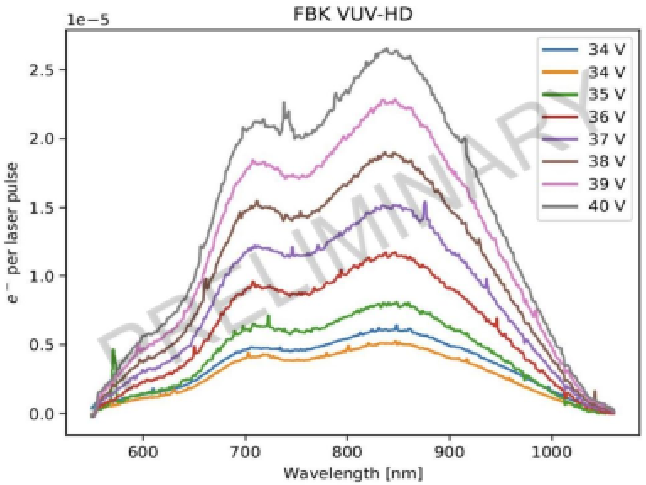
Stimulated Emission from SiPMs

McCarthy



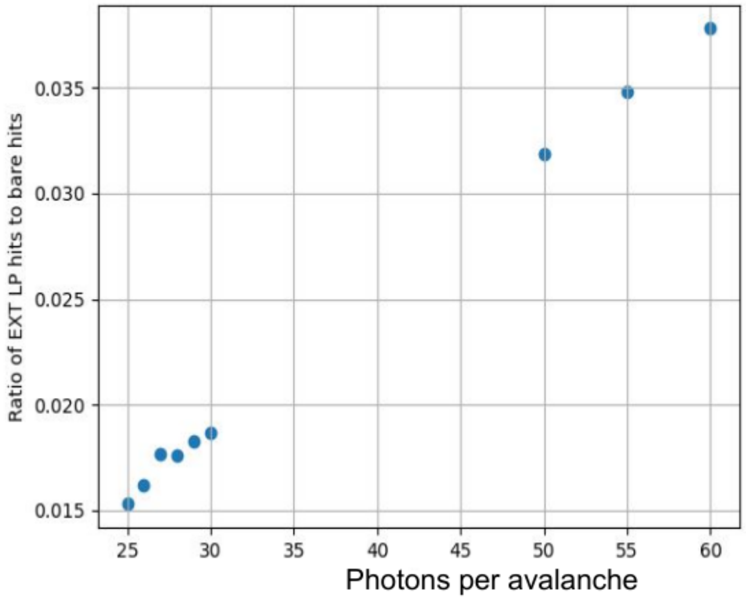


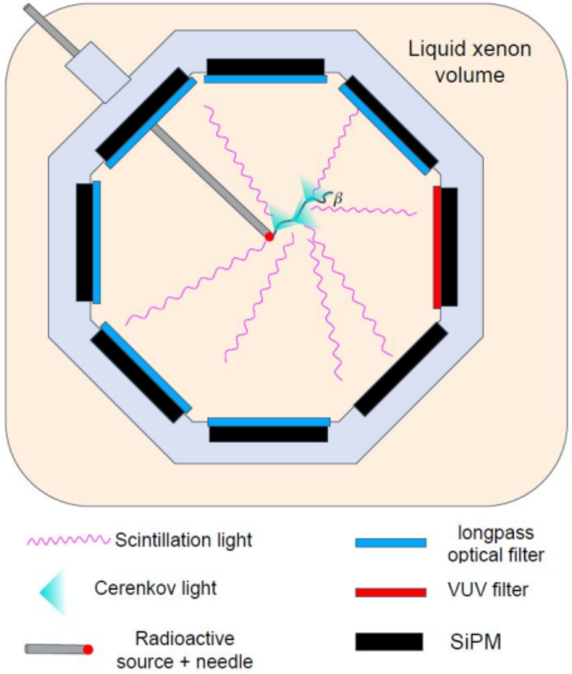




LoLX : studying light in liquid Xenon using SiPMs

Bernadette Rebeiro



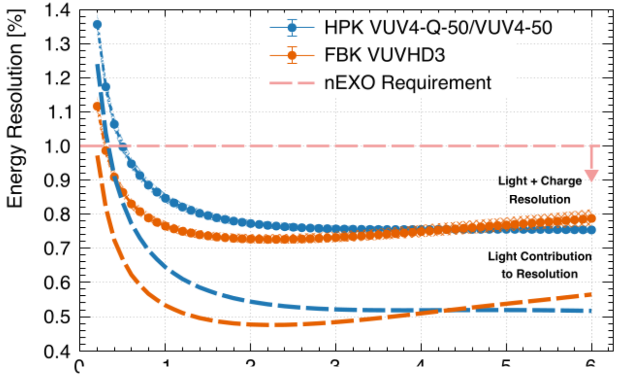


Performance of novel VUV-sensitive SiPMs for nEXO

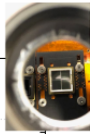
Gallina

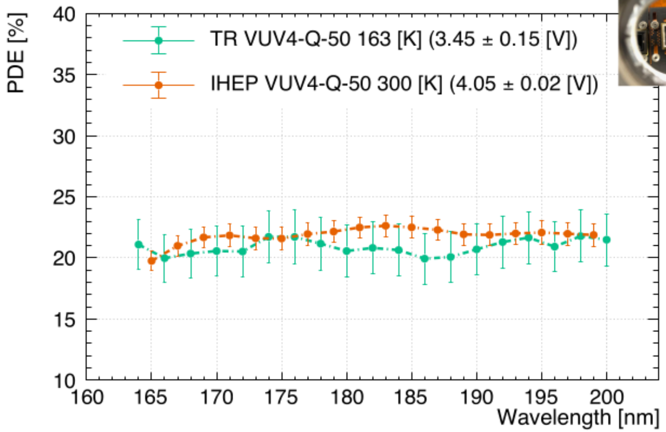
$$\frac{\sigma_n}{\langle n\rangle} = \frac{\sqrt{\left(\frac{(1-\epsilon_p)n_p}{\epsilon_p} + \frac{n_p}{\epsilon_p}\cdot\frac{\sigma_\Lambda^2}{(1+\langle\Lambda\rangle)^2} + n_p^2\sigma_{lm}^2\right) + \left(\frac{n_q t}{\tau} + \frac{\sigma_{q,noise}^2}{\epsilon_q^2}\right)}}{\langle n\rangle}$$

- VUV SiPMs have significant improved correlated noise characteristics

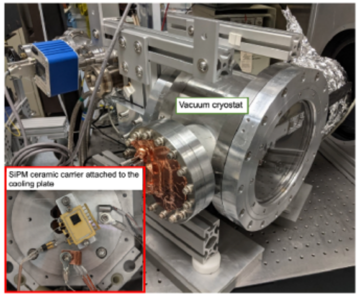


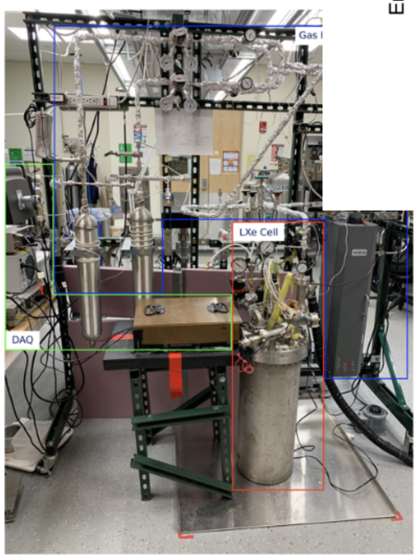
TRIUMF + IHEP

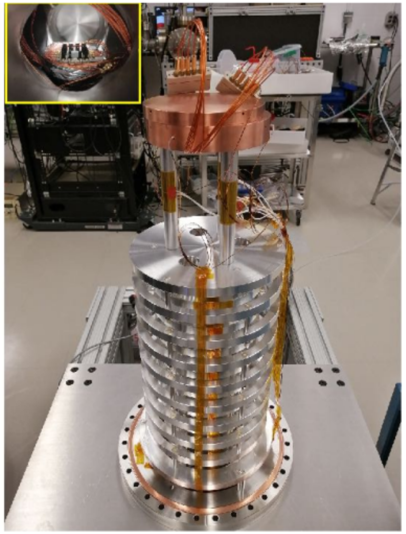




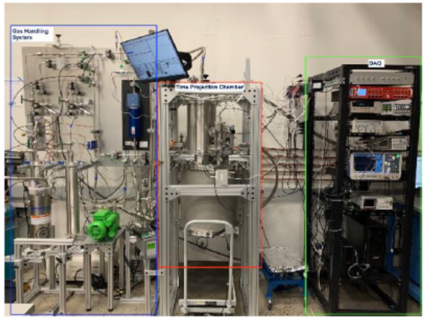
BNL Setup







McGill Setup



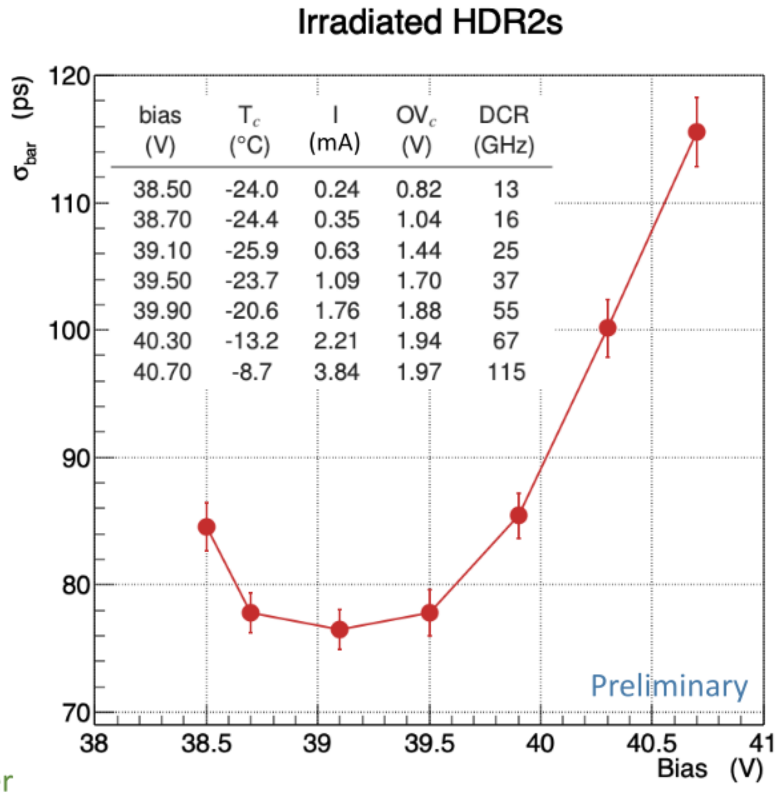
UMass LXe Setup

Yale LXe Setup

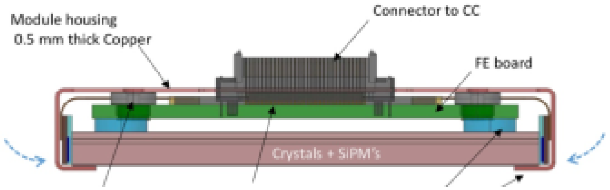
Performance of highly irradiated SiPMs

Carlos E. Pérez Lara

Coupled to LYSO:Ce Crystals for the CMS MTD Barrel Timing Layer

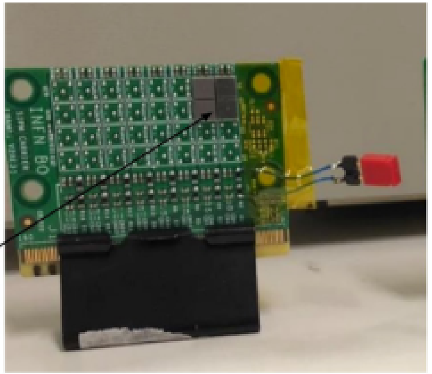


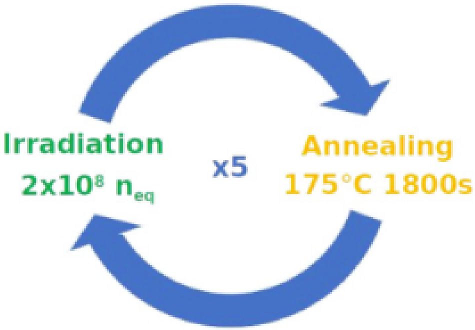
er

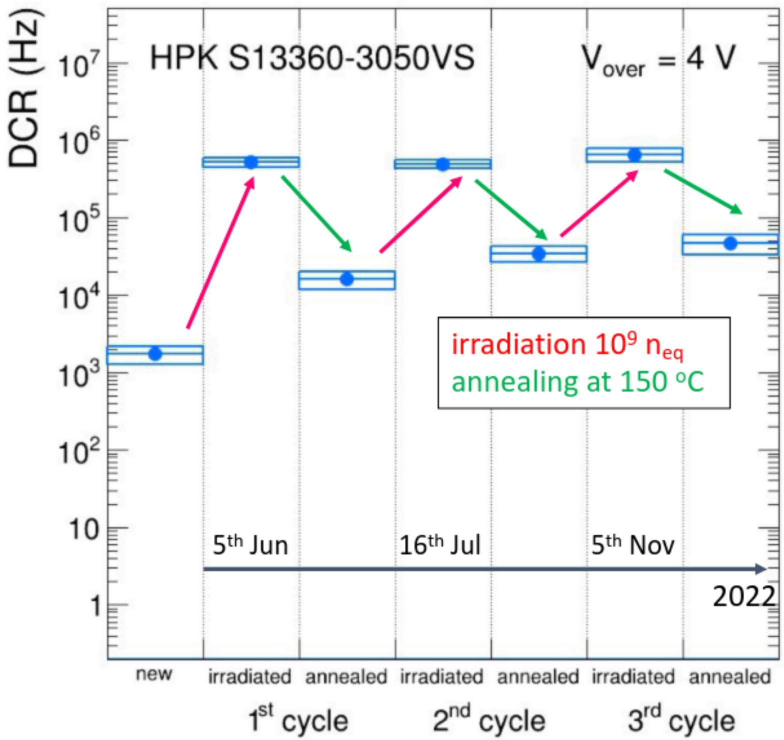


SiPMs for EIC's dRich

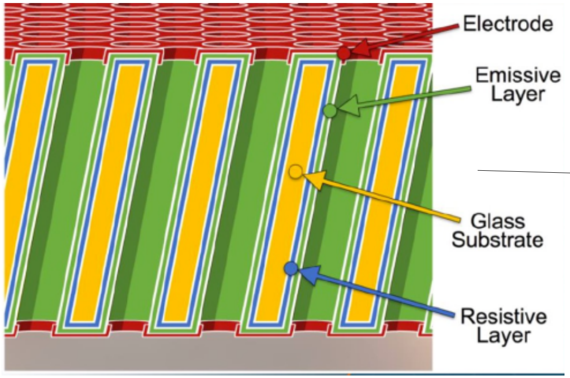
P. Antonioli

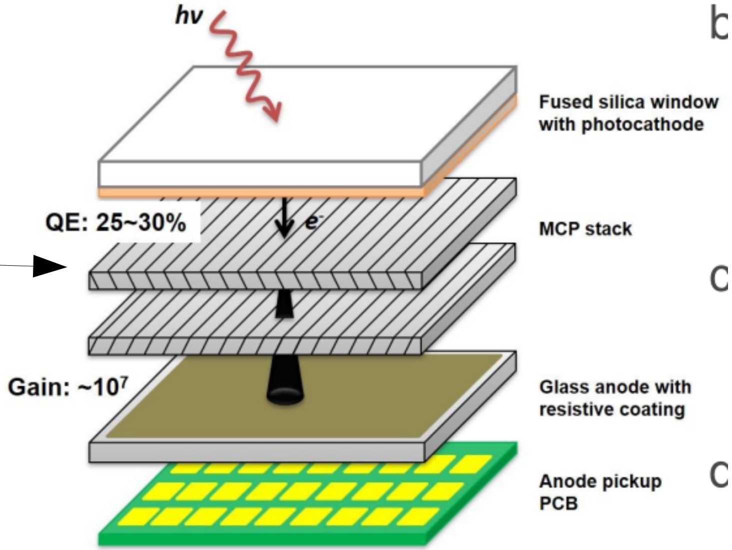






MCP Photo Detectors

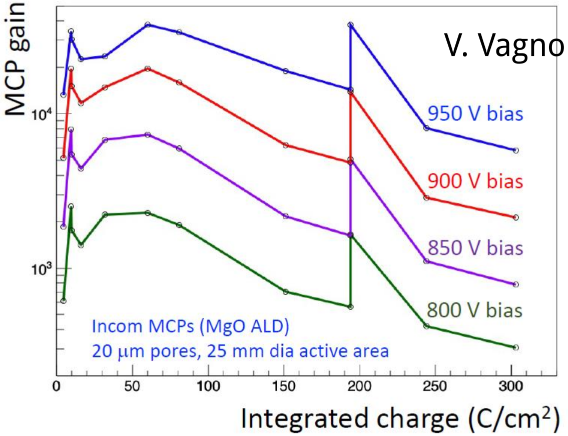




- An affordable large area (finely pixelated) vacuum photose
- 10x10 cm^2 or 20x20 cm^2 active area
- DC- (Gen I) or capacitively (Gen II) coupled species
- DC-coupled 1D strips or 2D pixellation
- Expected to be (very) cost efficient in mass production
- Quantum efficiency above 30% and uniform high gain up to ~10^7
- Sub-mm spatial resolution for finely pixelated tiles
- Single-photon timing resolution on a ~50ps level or higher

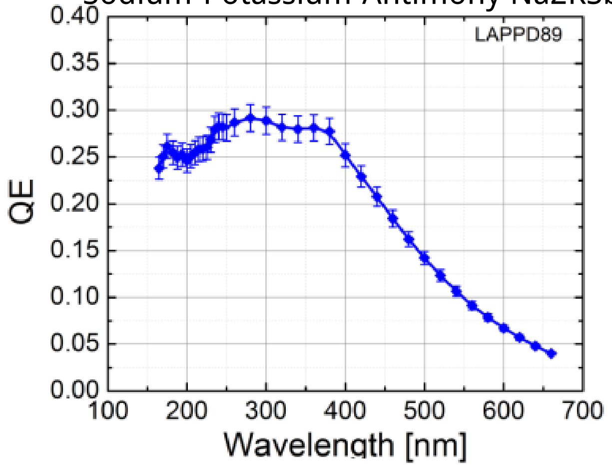
New Developments in Large Area MCP-PMTs

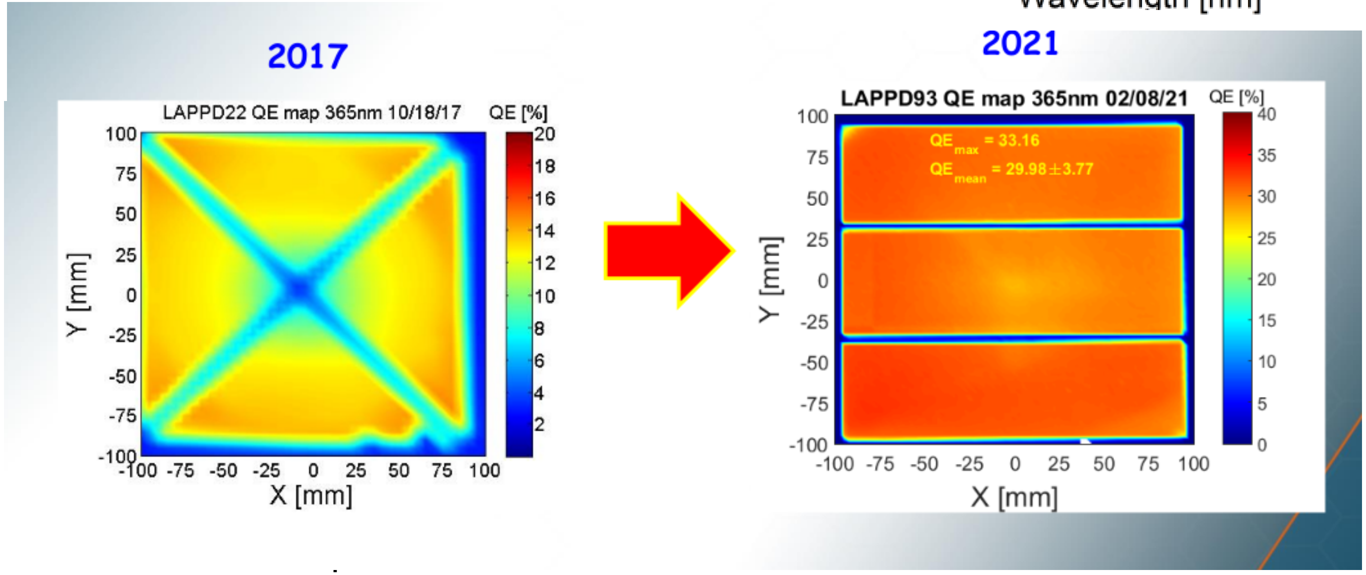
A. Lyashenko



V. Vagnoni

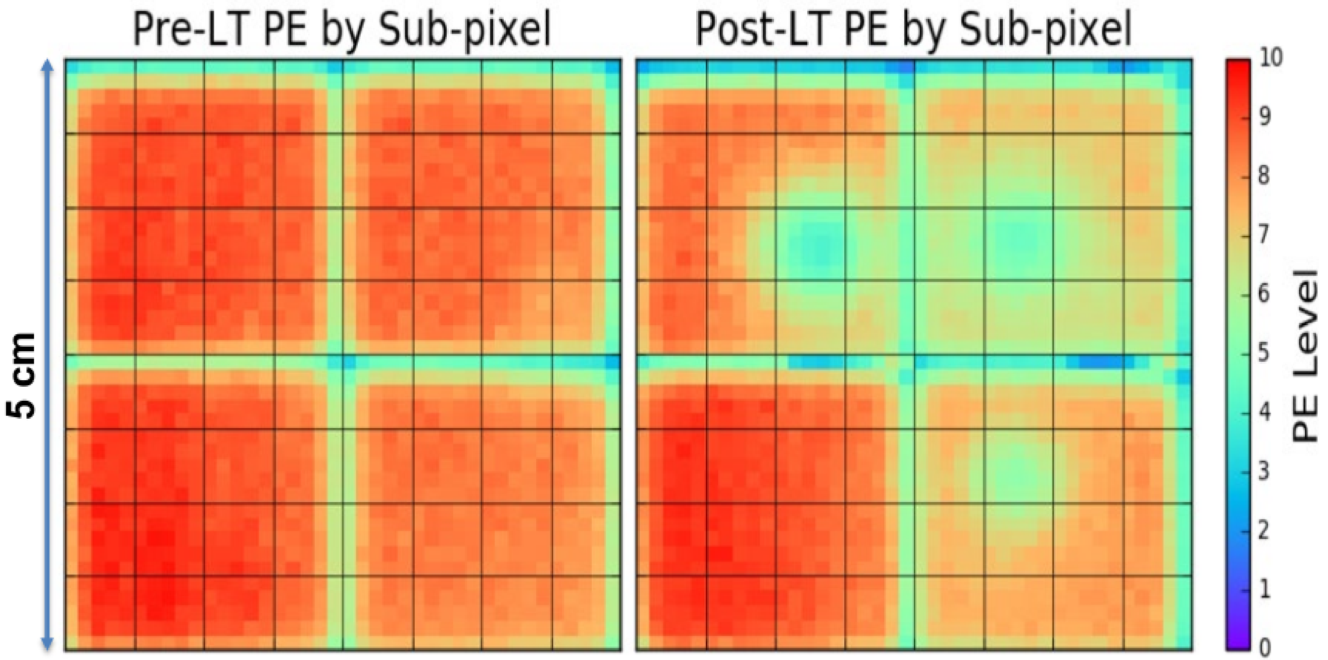
Sodium-Potassium-Antimony Na2KSb





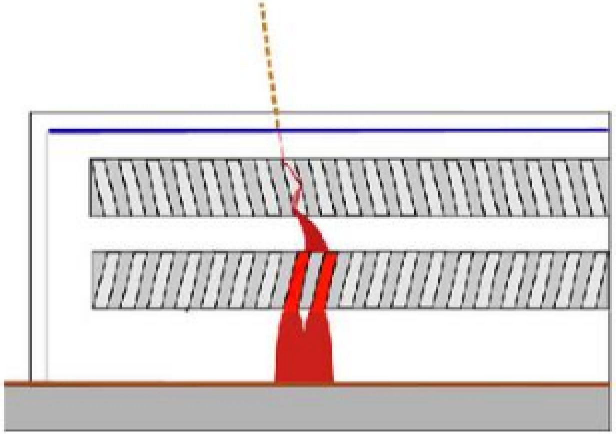
Recent results from the pixel-based accelerated aging of Large Area Picosecond Photodetectors (LAPPDTM)

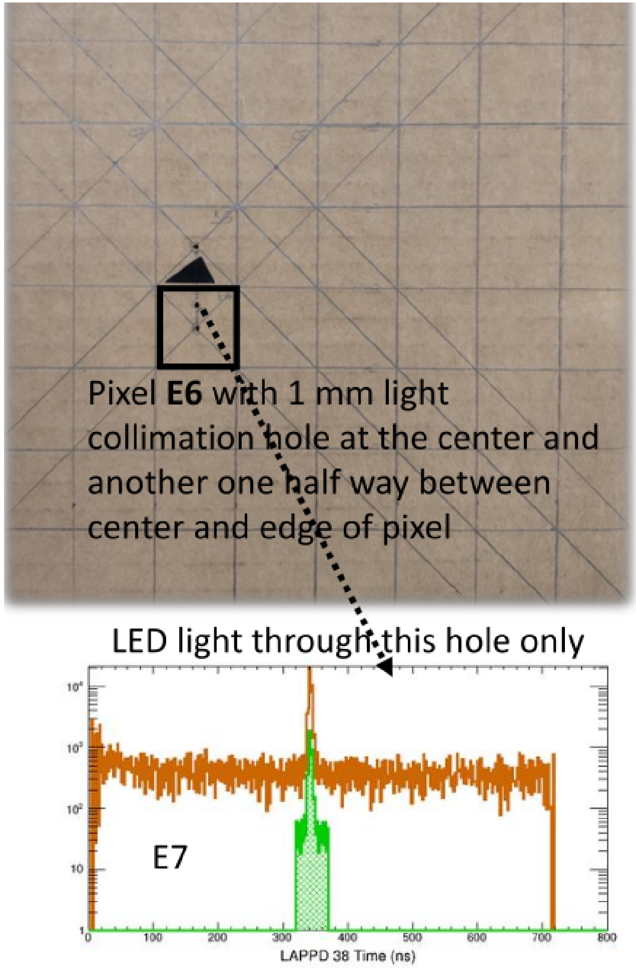
V. A. Chirayath



Results on LAPPD 38 single photoelectron detection and measurements of charge cloud radius

Simona Malace



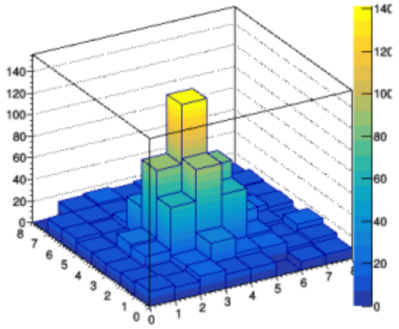


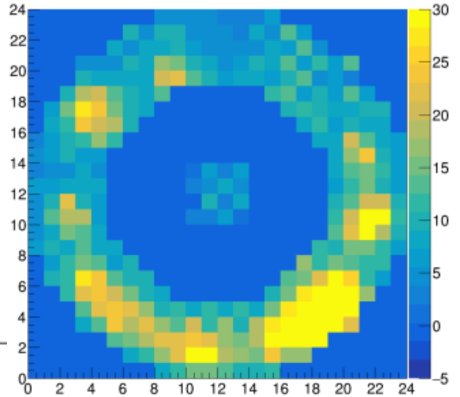
2D Pixelated LAPPDs for Ring Imaging Cherenkov Detectors in High Energy and Nuclear Physics Experiments

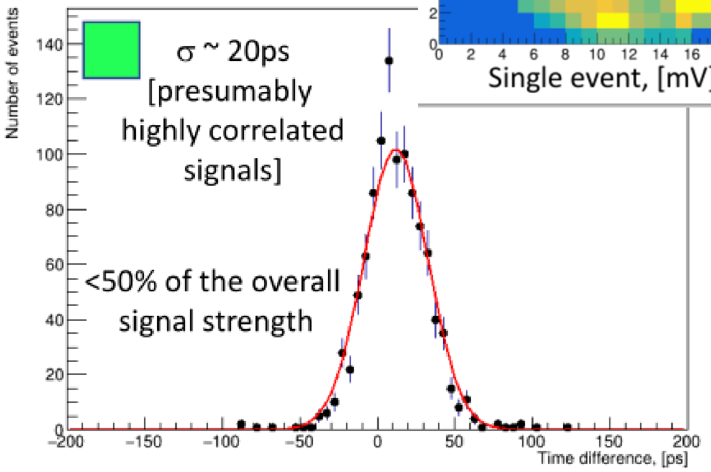
Alexander Kiselev

- For a capacitively coupled LAPPD with a "standard" stack and 2mm thick anode base cluster size RMS ~3.5mm

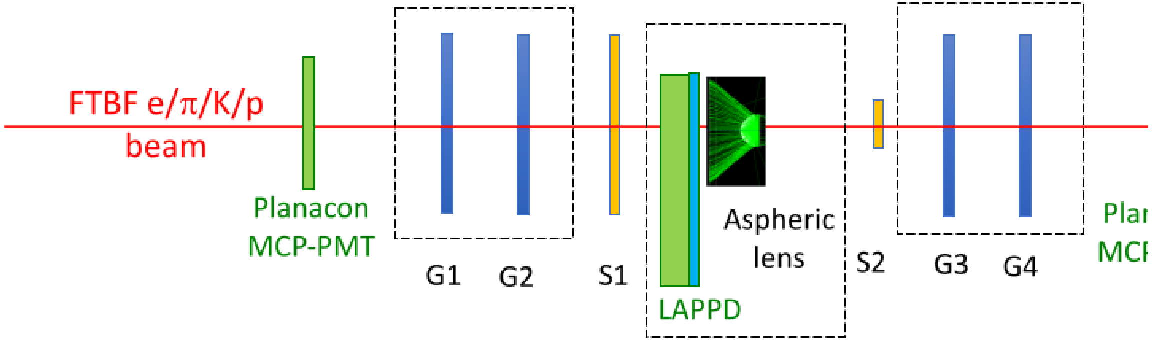
3mm pixels







DRS4 chip#0: time(ch#03) – time(ch#02)



Nepomuk Otte

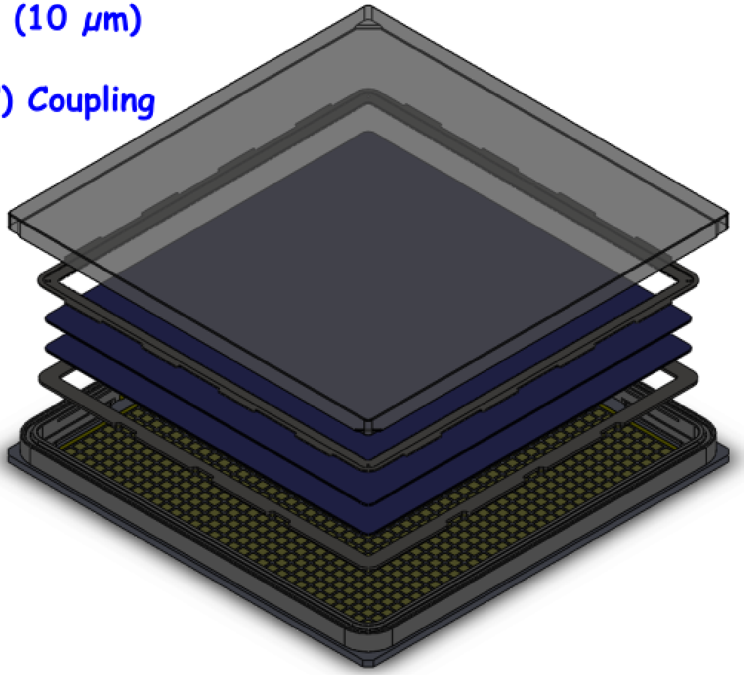
HRPPD – High Rate Picosecond Photodetector

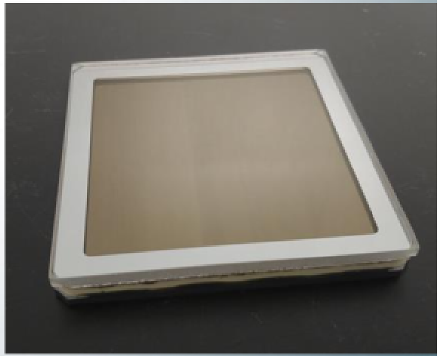
- 10 cm x 10 cm MCP-PMT

  Chevron pair GCA-ALD-MCPs (10 μm)
  Ceramic package
  Capacitive (CC) or Direct (DC) Coupling
  100 cm^2 active area
- High Gain ($5*10^6$)

Dark Rates: <10kHz/cm^2

- Photocathode Na_2KSb
  - >20% QE at 365 nm
  - >80% spatial uniformity
- Timing Resolution
  - SPE: <50 psec
  - Position Resolution (TBD)

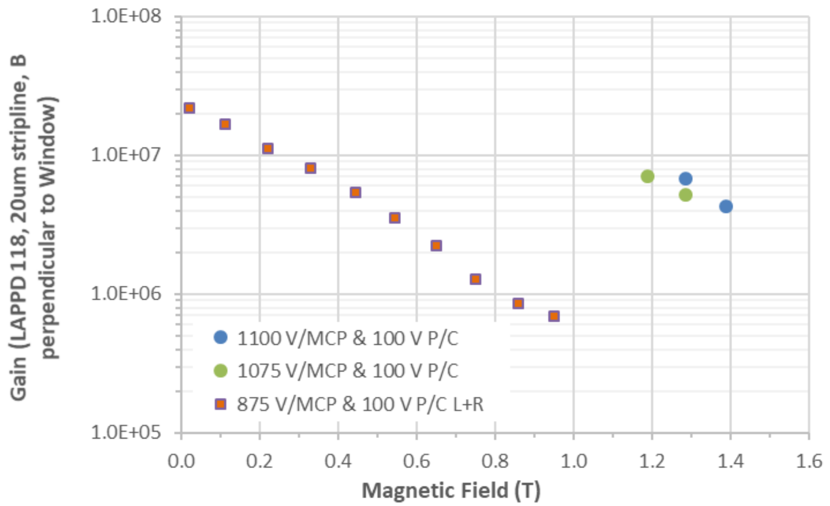


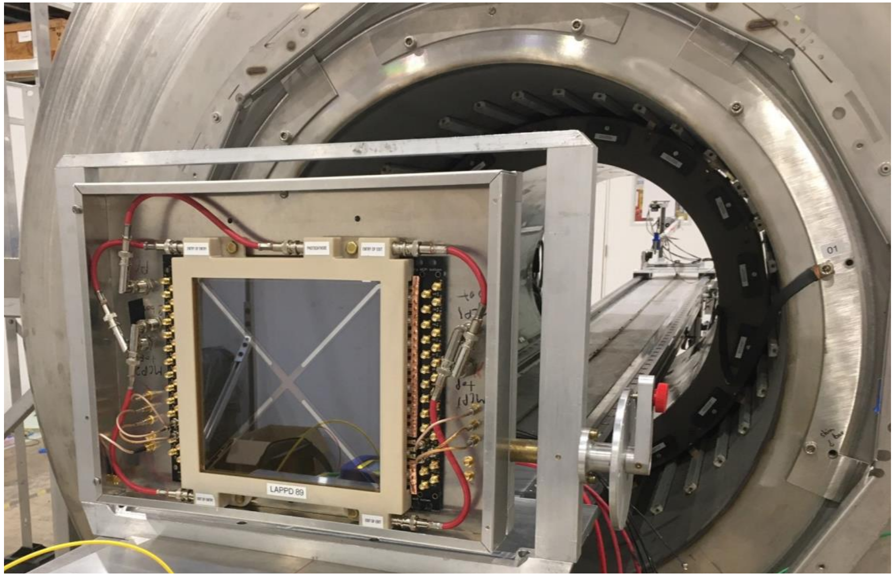


PERFORMANCE OF MCP-PMT AND LAPPD IN MAGNETIC FIELD FOR RICH DETECTORS

Junqi Xie

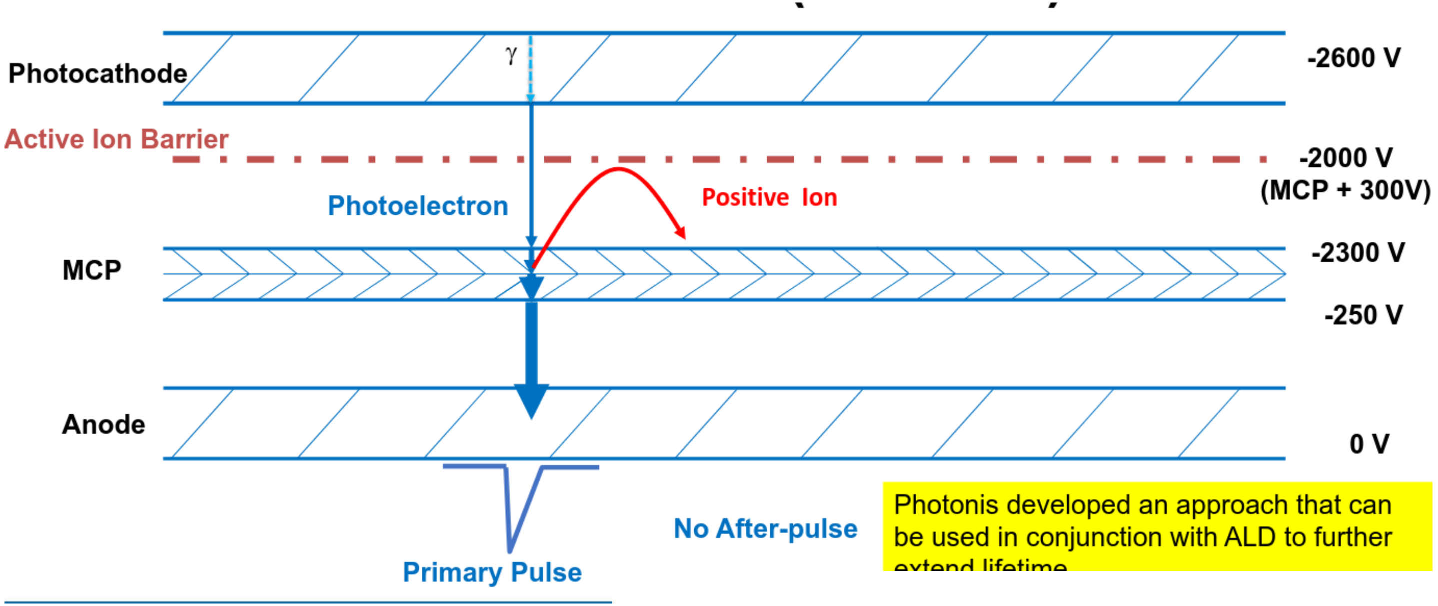
- Smaller pore sizes and reduced spacing is the way to go



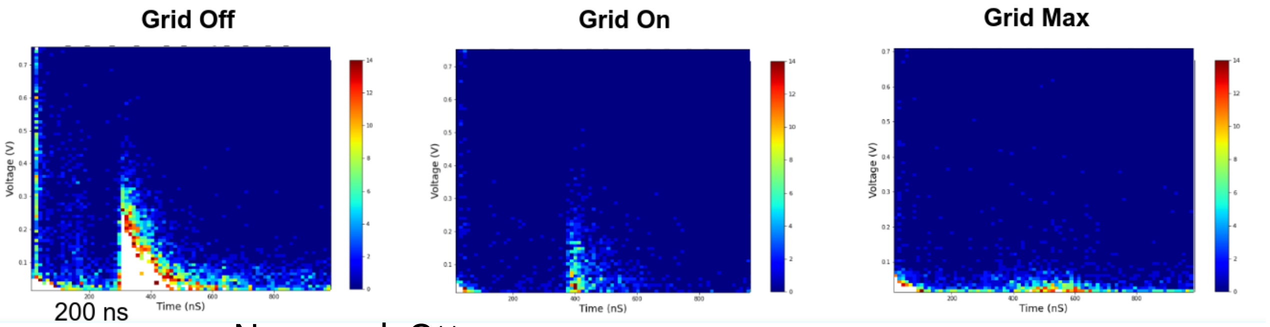


Tests of an MCP-PMT with an Active Ion Barrier

A. Brandt

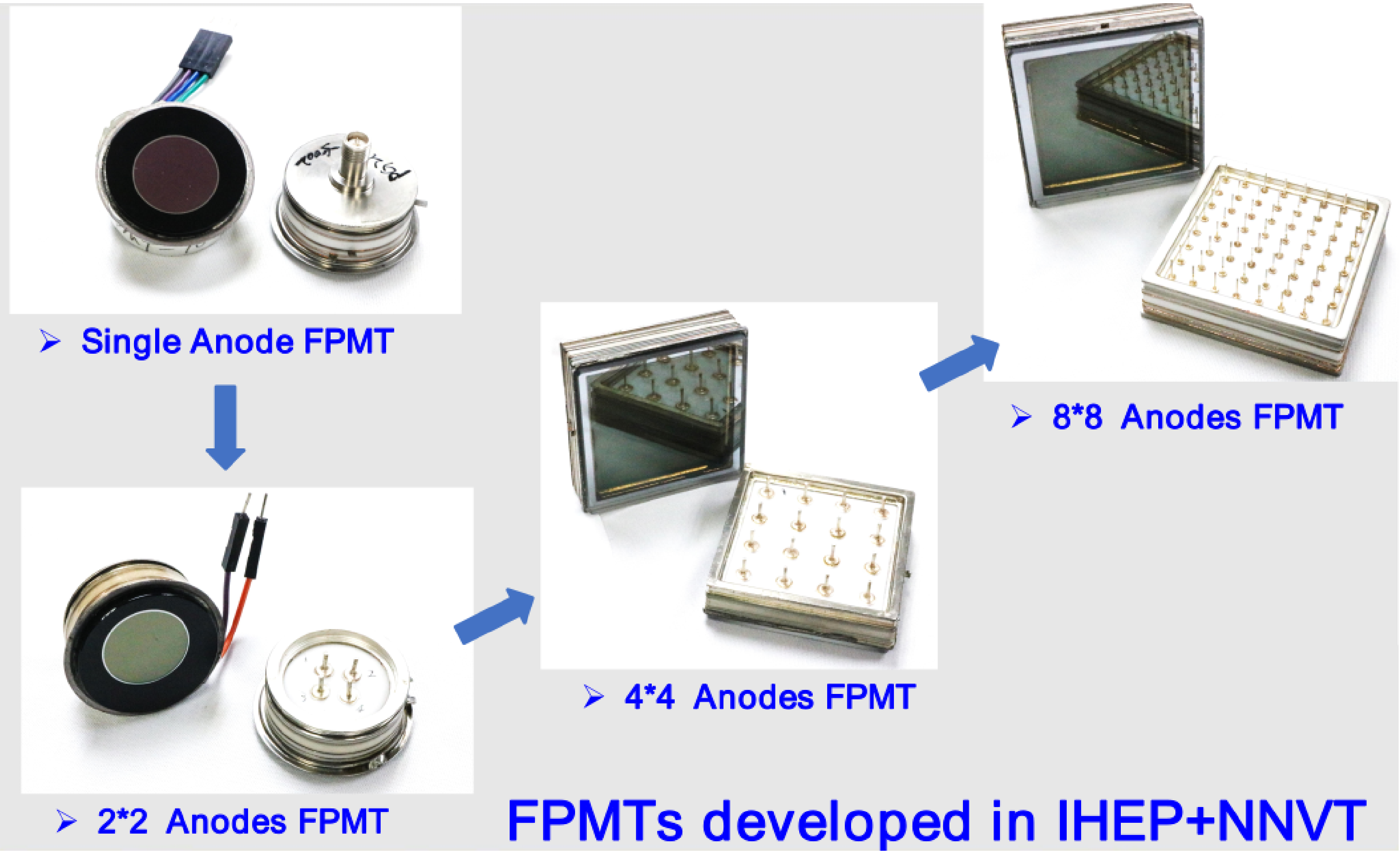


Photonis developed an approach that can be used in conjunction with ALD to further extend lifetime



The R&D of the MCP based PMTs for High Energy Physics Detectors

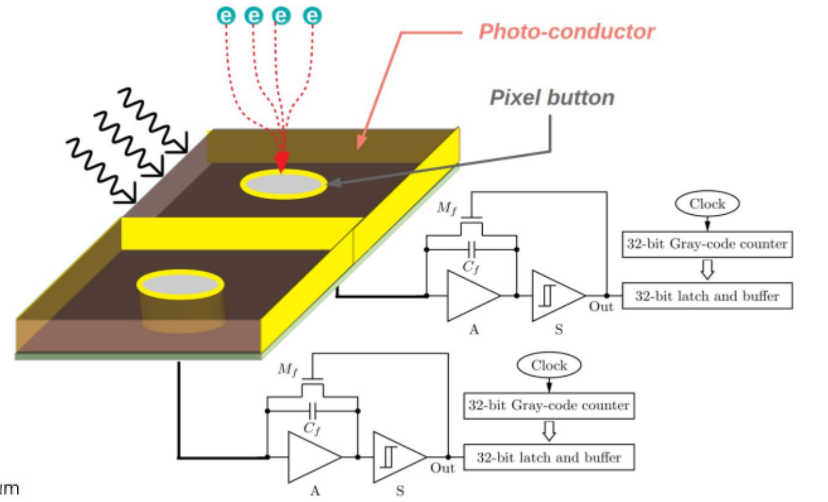
Sen Qian

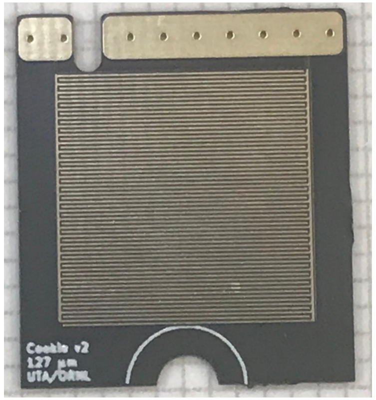


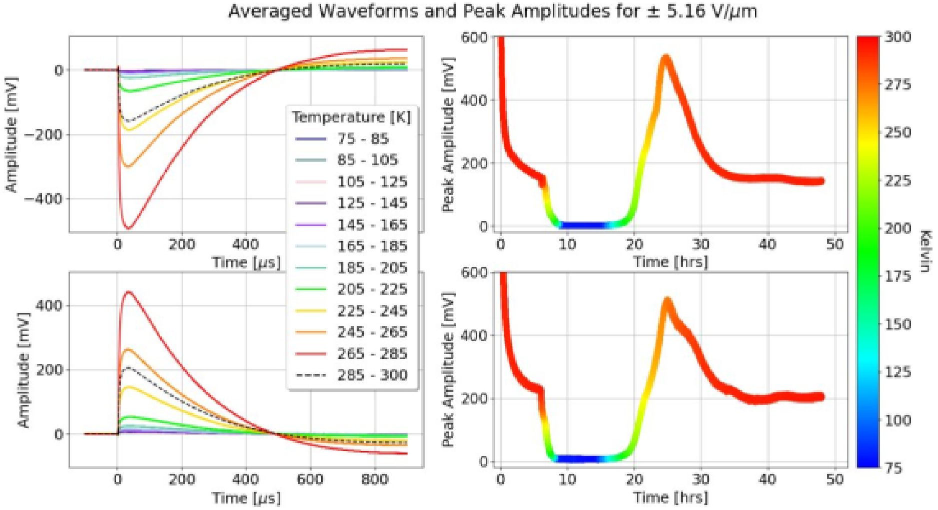
Novel VUV Light Detection in a Pixelated Liquid Argon Time Projection Chambers

Jonathan Asaadi

- Search for detector sensitive to UV photons and ionization charge
- Q-Pix based on amorphous selenium
- Demonstrated to be robust during cryogenic cycling



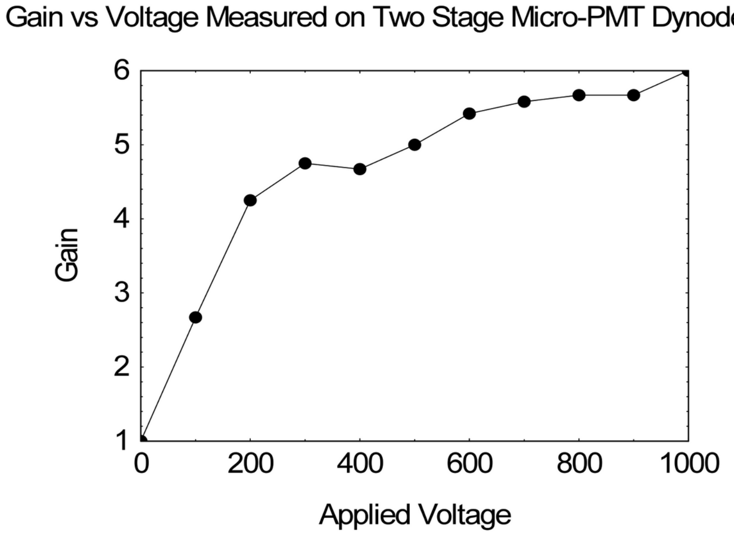


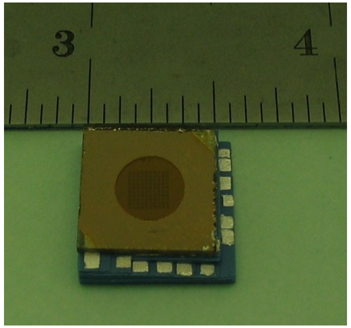


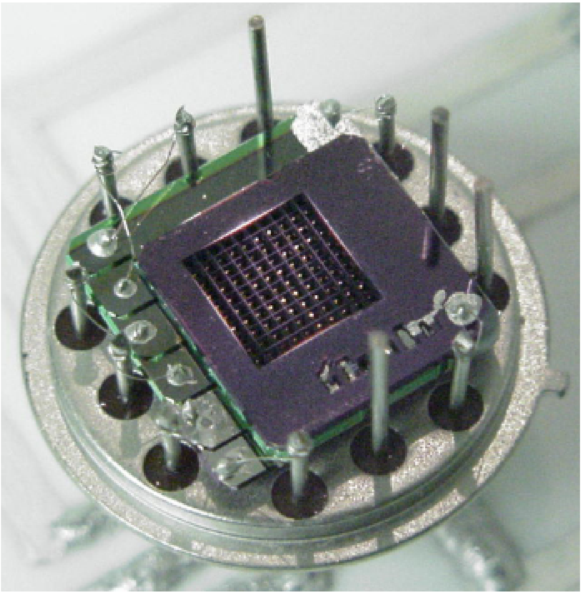
Observe **signal in aSe for 405 nm light** at 35 V/μm down to **~780 photons**
Begin **calibration for VUV**

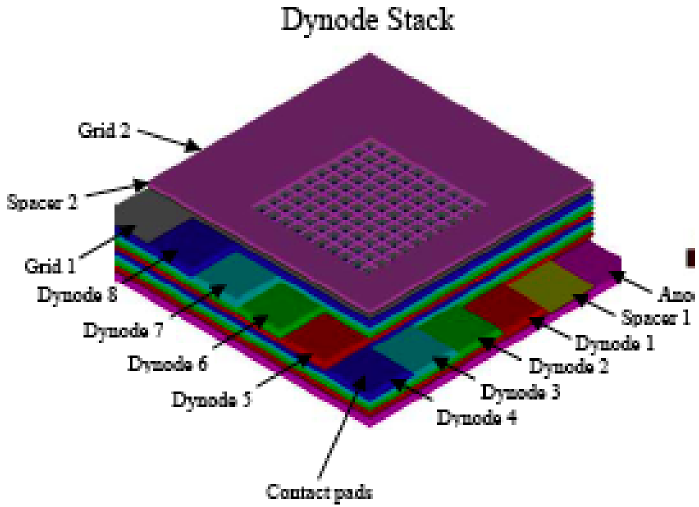
Micro/Nano-Machined Vacuum Photodetectors

David Winn



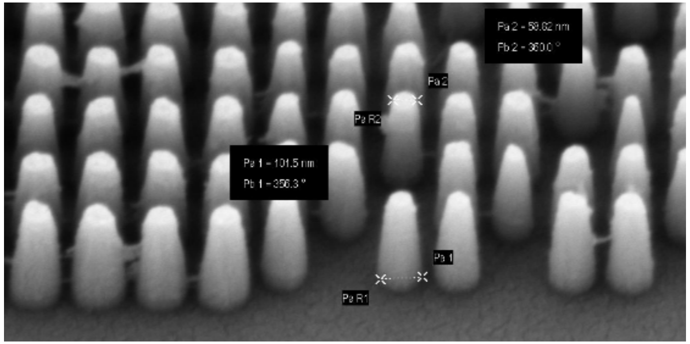


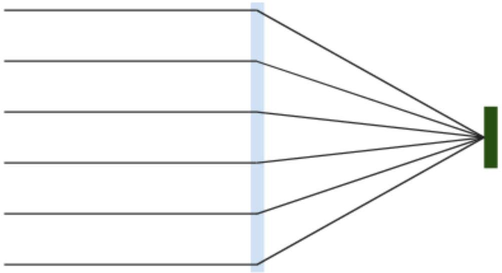




Metalenses

Chris Stanford





- Thin and lightweight
- Cheap, easy to mass-produce, $1/ea
- More flexible