

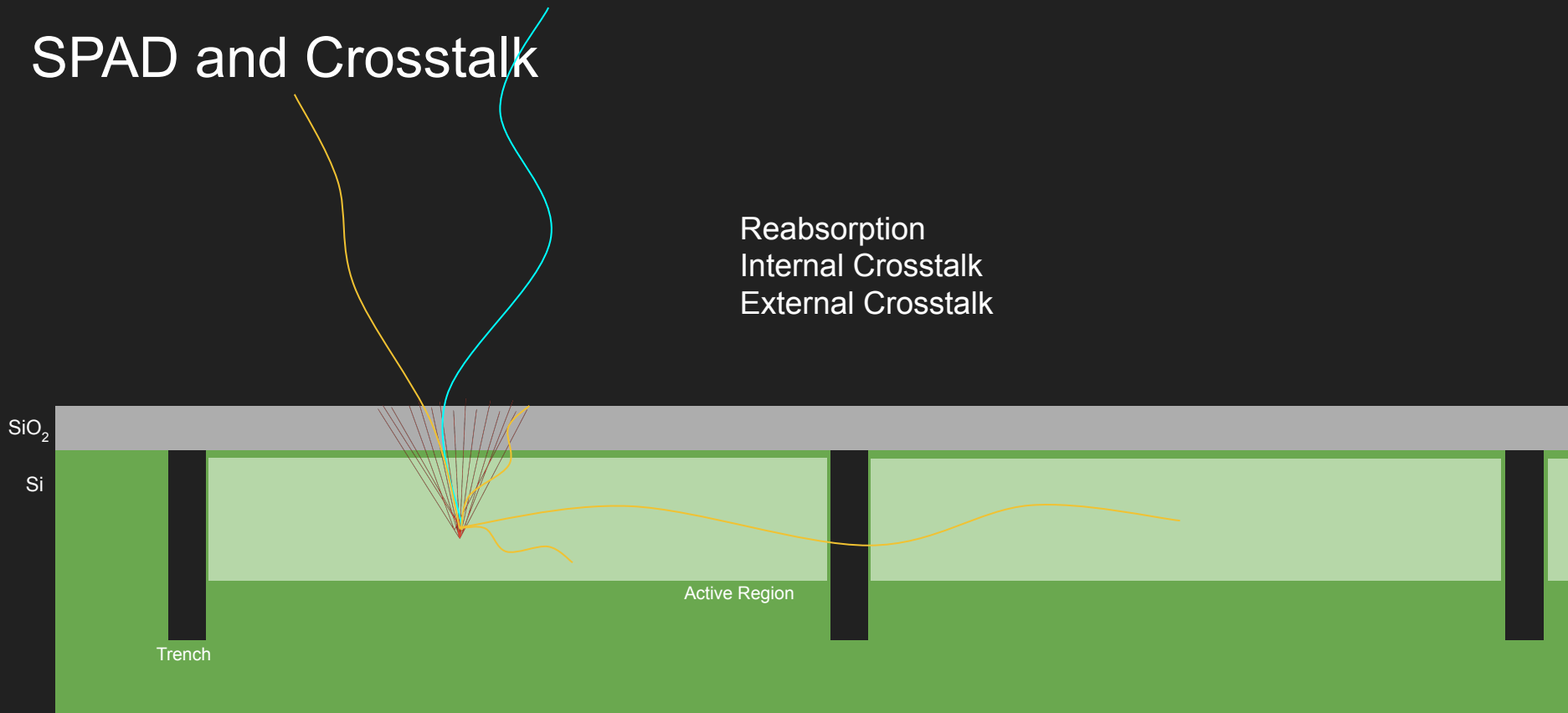
# Stimulated Light Emission of Silicon Photomultipliers

*Giacomo Gallina*, Peter Margetak, Nicolas Massacret, *Juliette Martin*, **Duncan McCarthy**, Kurtis Raymond, Fabrice Retière (TRIUMF, Canada)

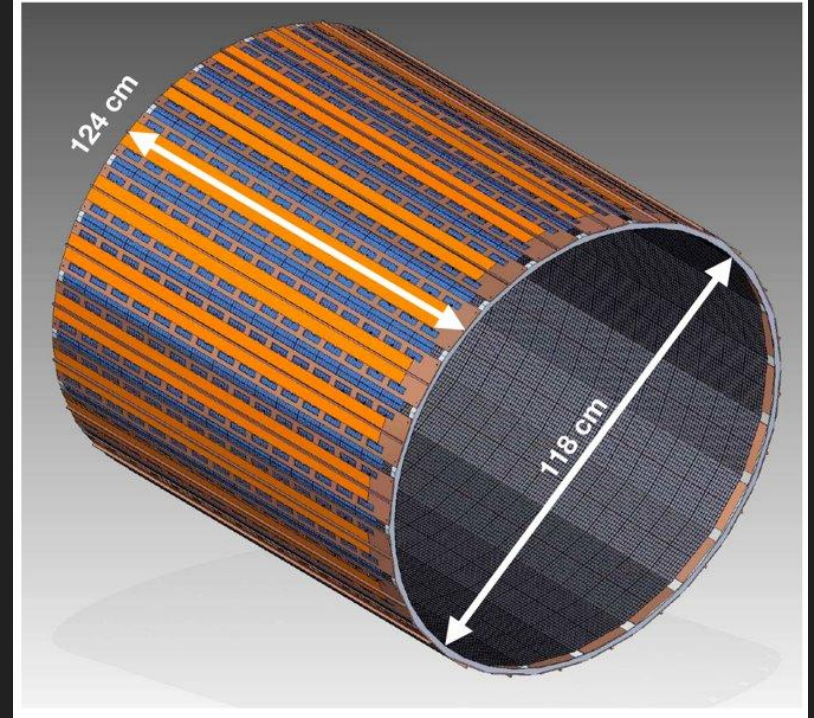
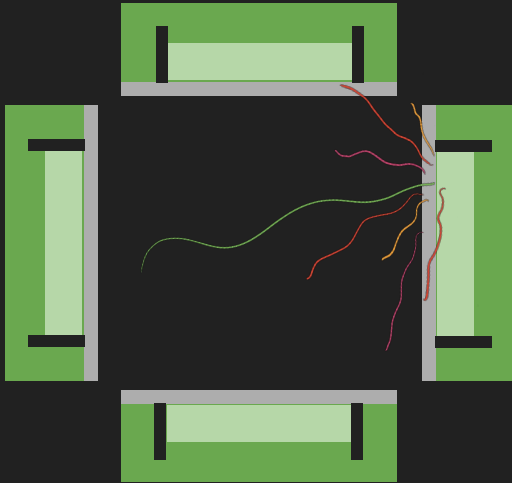
Joe McLaughlin, Seraphim Koulosousas, Jocelyn Monroe (RHUL, UK)

Paolo Agnes, Priyanka Kachru (GSSI, Italy)

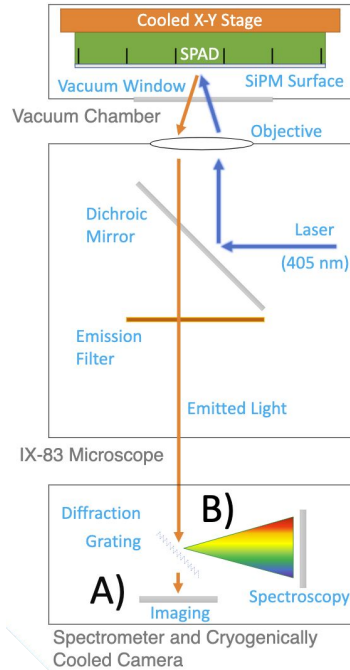
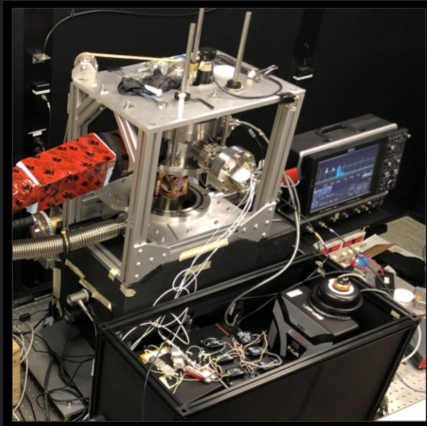
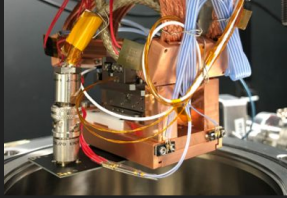
# SPAD and Crosstalk



# The Problem:



# Microscope for the Injection and Emission of Light

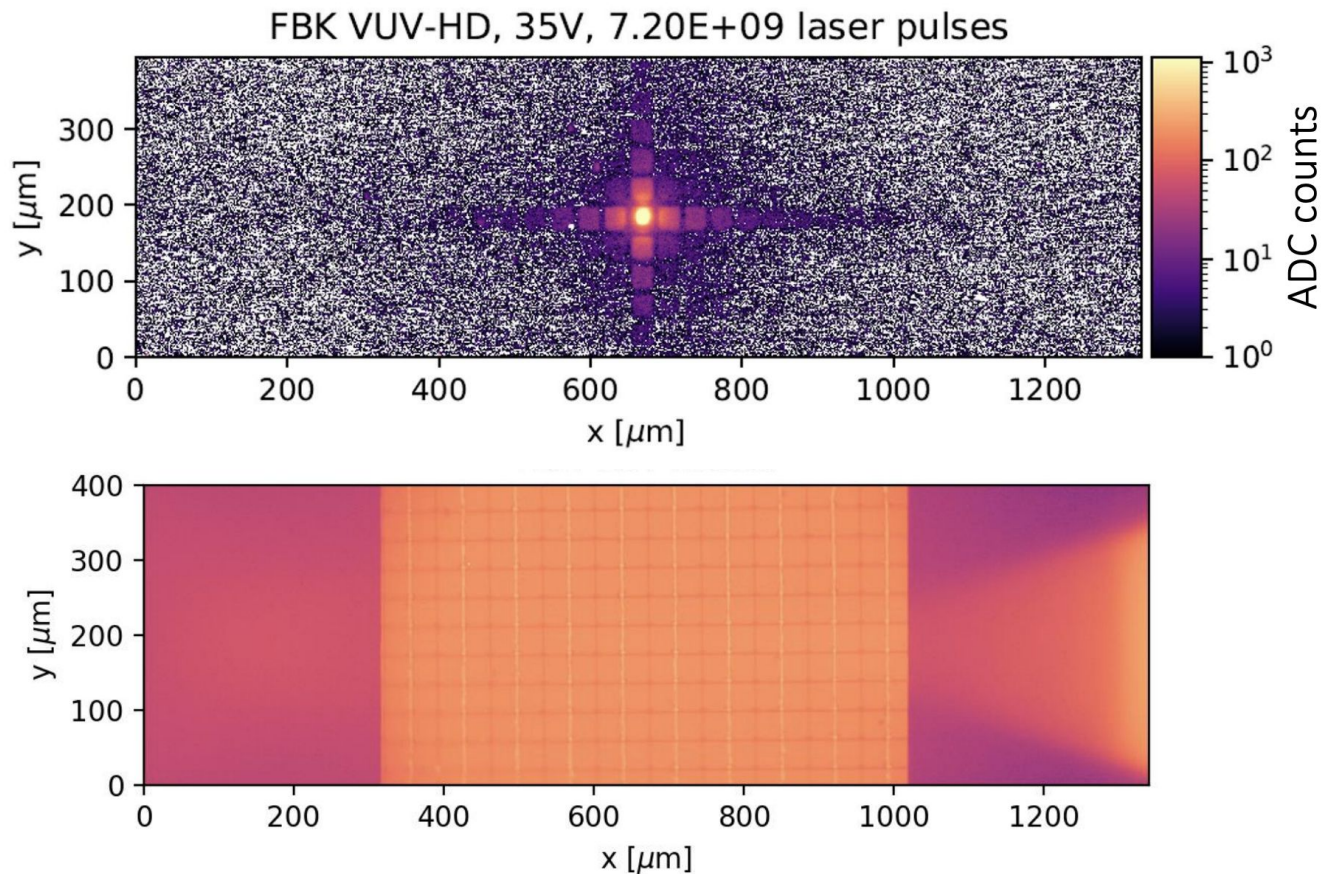
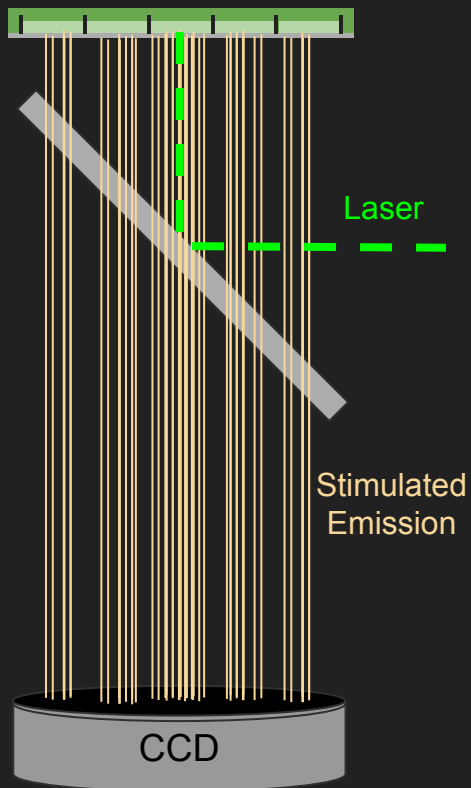


Cryo CCD Camera  
Spectrometer

4x-50x microscope magnification  
Sub  $\mu\text{m}$  precision xy translation

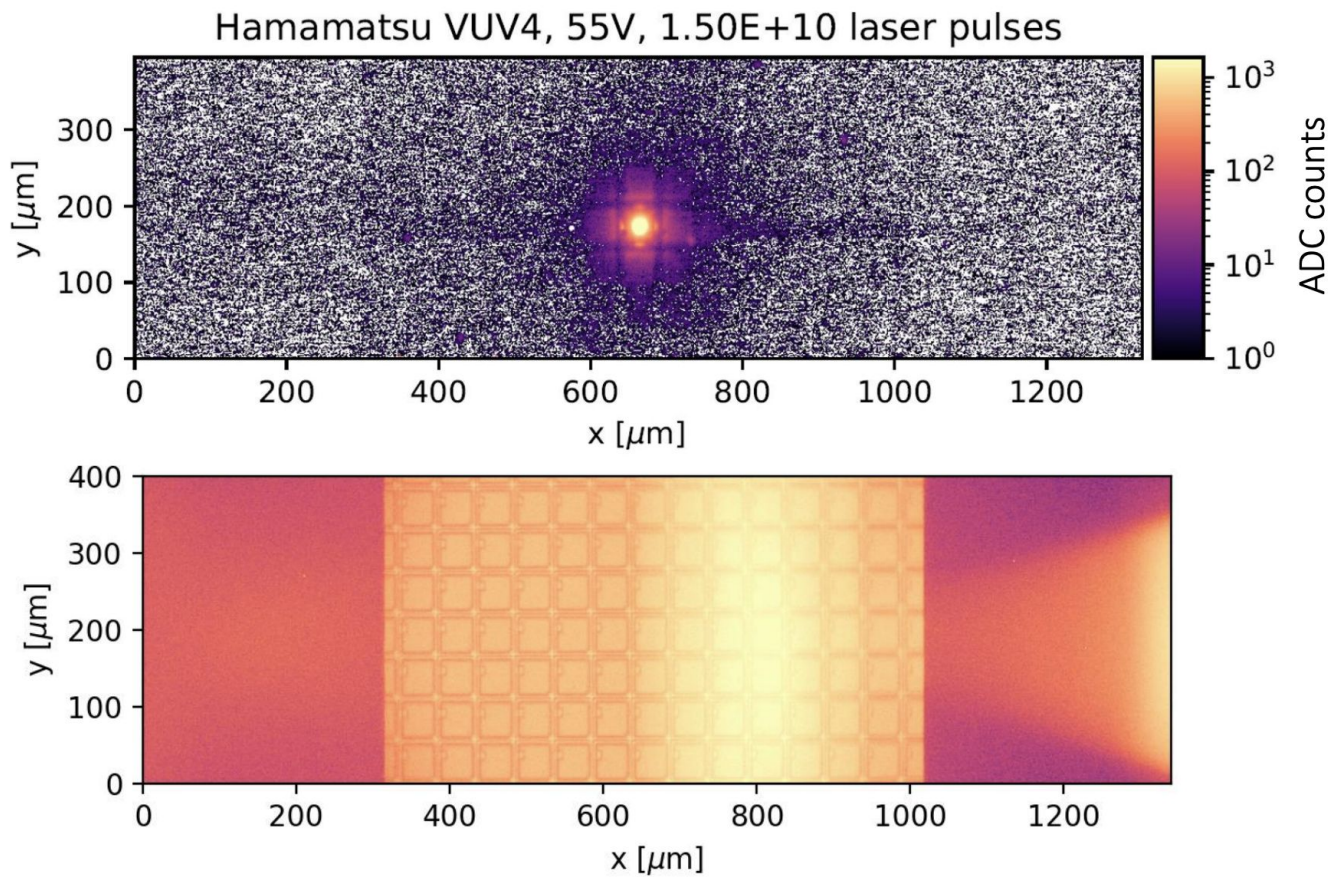
LN2 PID Cryocontroller (down to LAr/LXe temps)

# FBK VUV-HD3

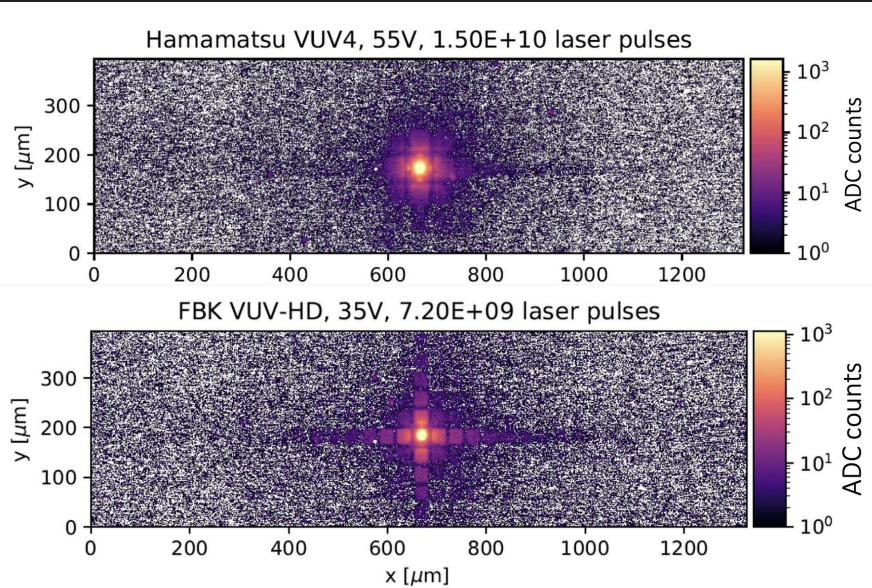




# HPK VUV4

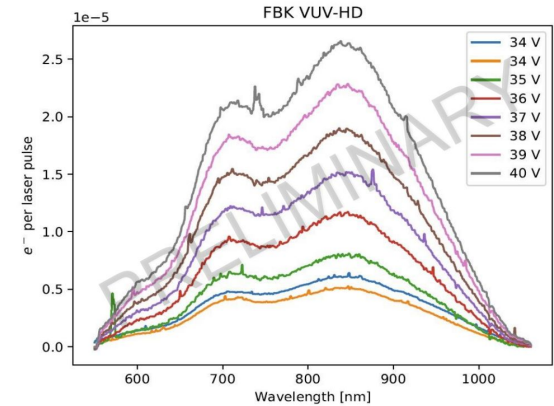
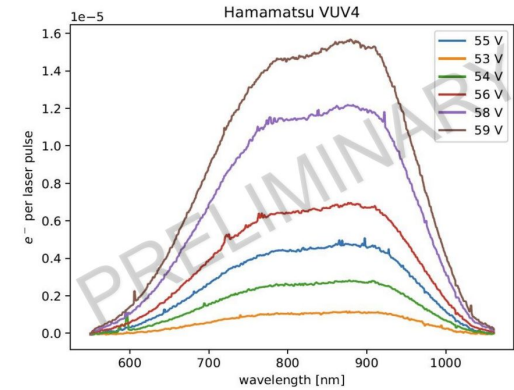


# HPK vs FBK

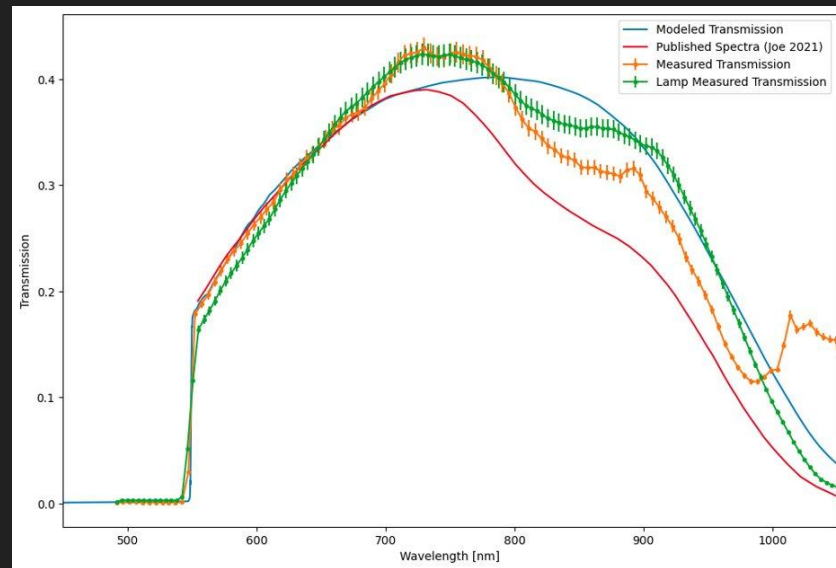
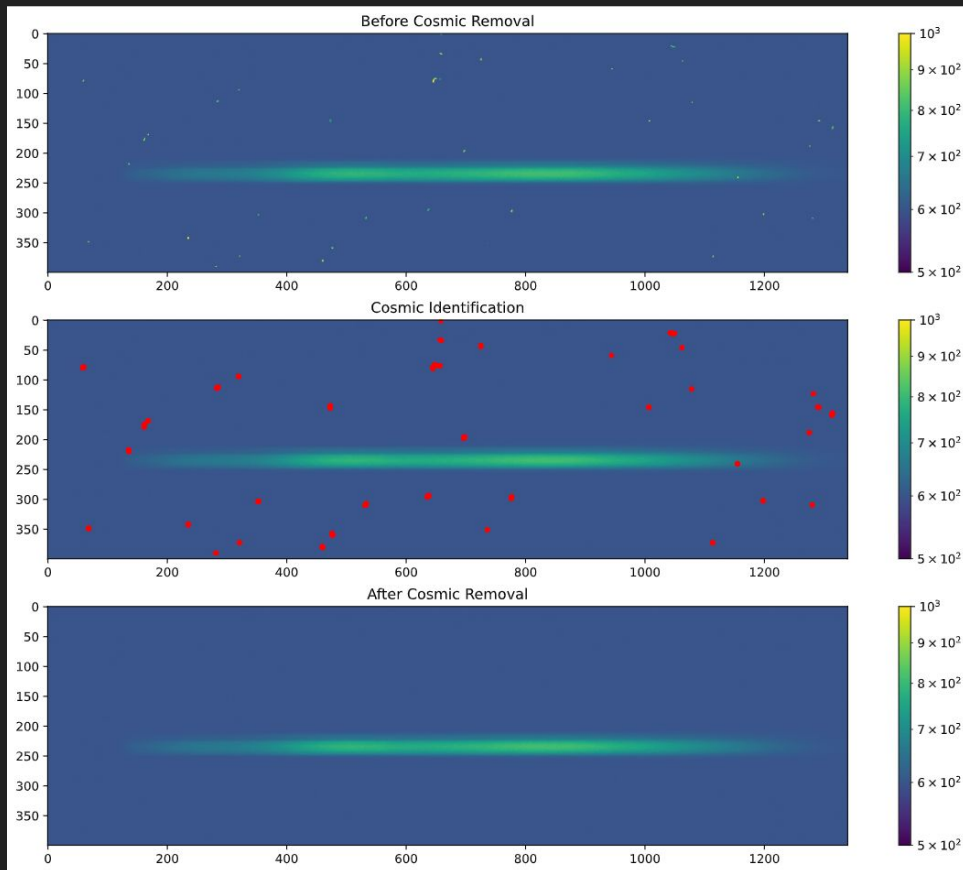


Tungsten trench  
Photon absorption  
Thin surface coating

Polysilicon trench  
More reflection  
SiO<sub>2</sub> surface coating

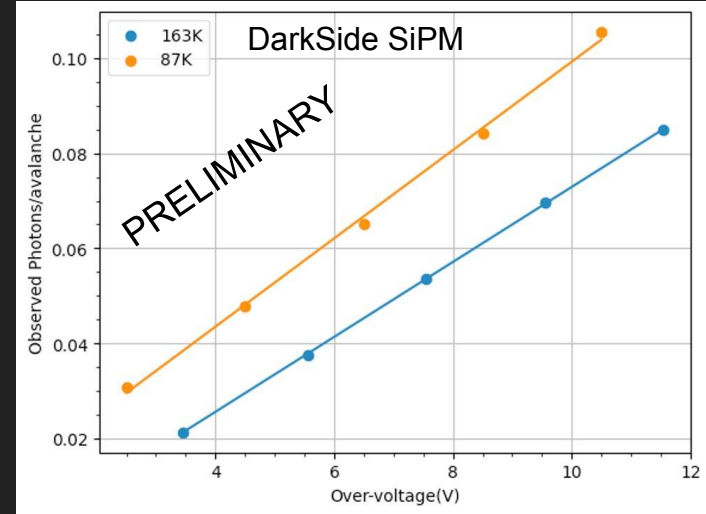
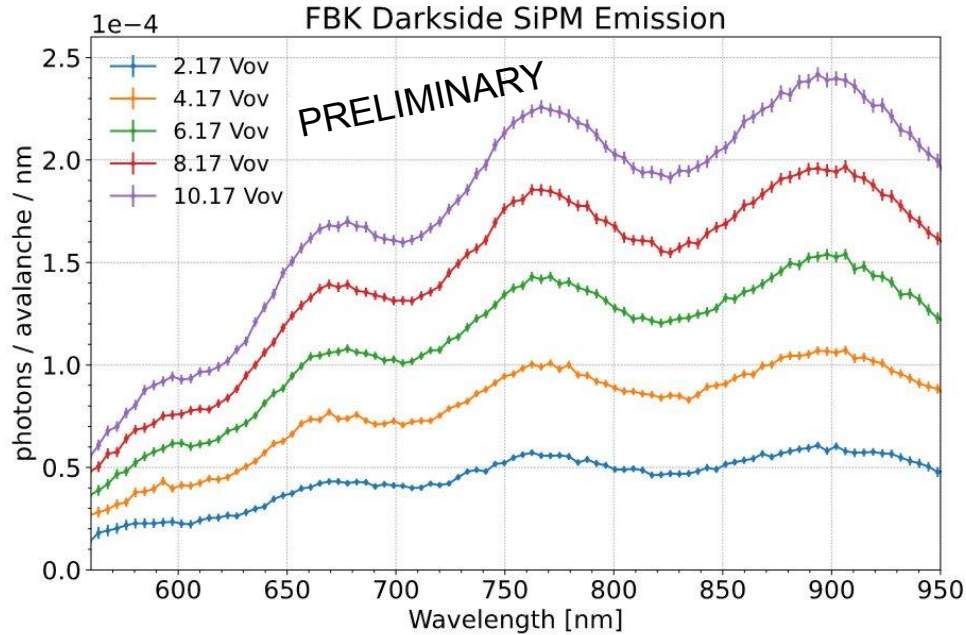


# Analysis Process

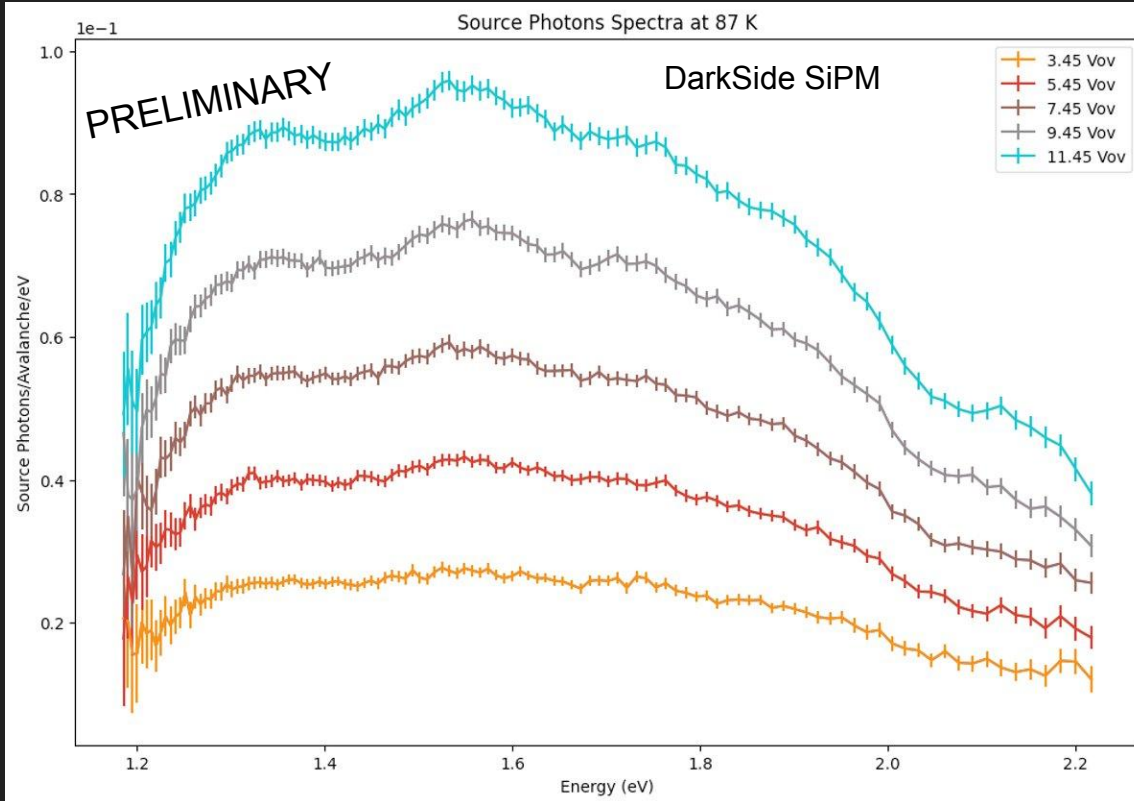




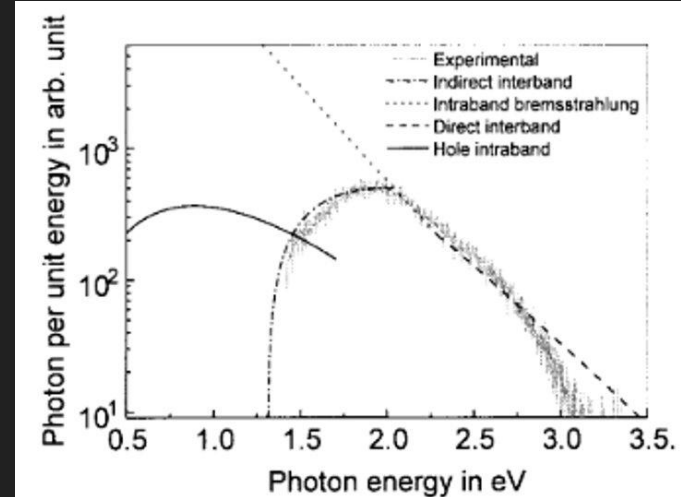
# Recent Measurements: FBK Darkside



# Source Spectrum: Ansys Lumerical



- Simulate interference effects
- Correct spectra to probe source



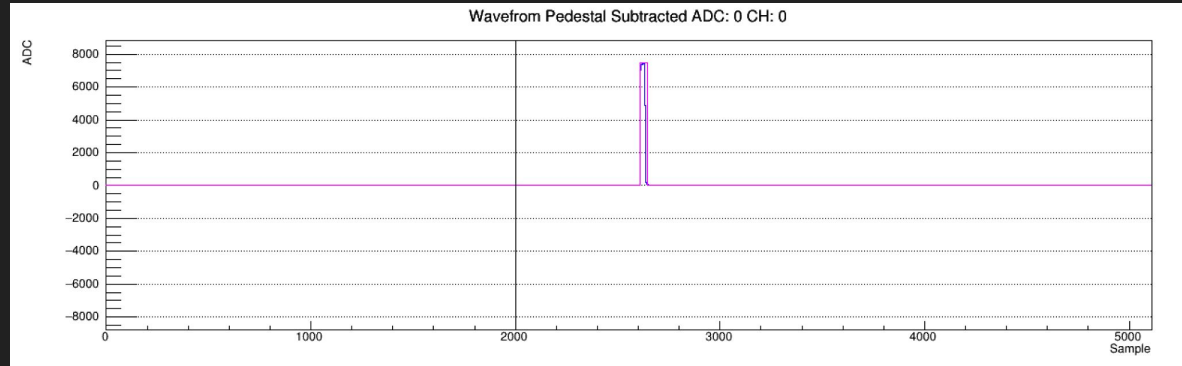
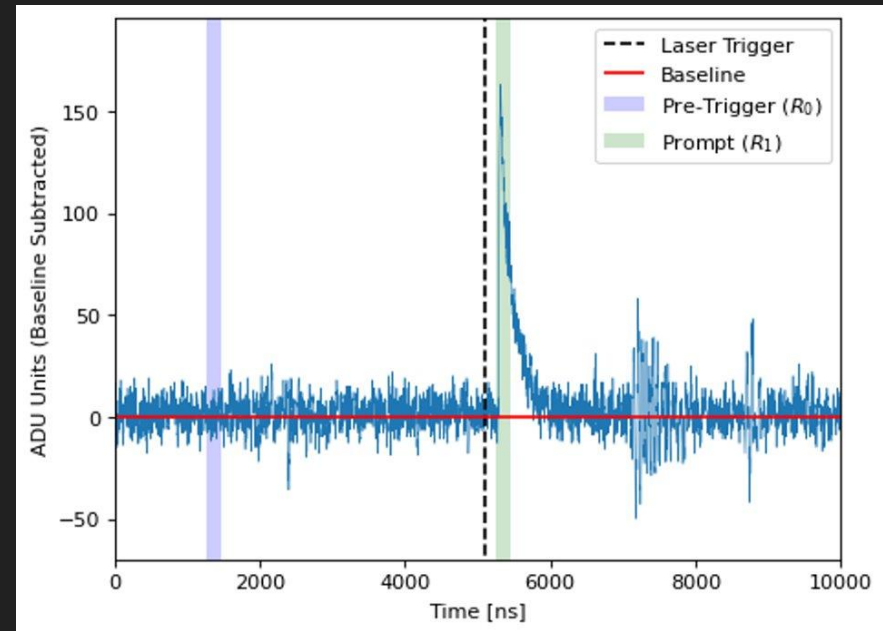
# Analog to Digital

HBK, FBK and DarkSide are analog SiPMs

- All SPADs on single channel
- Analog pulse shape

Digital SiPM

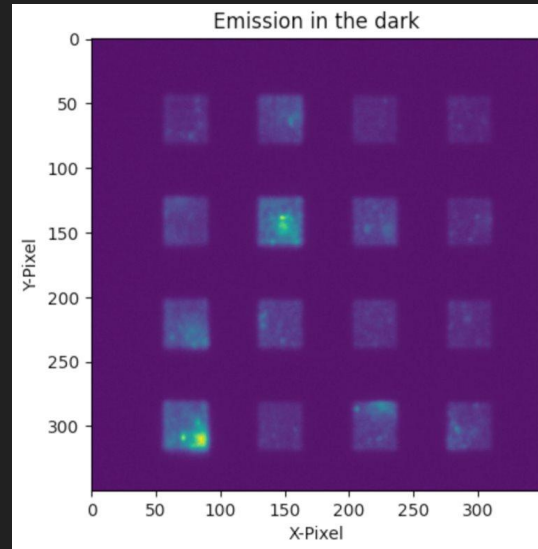
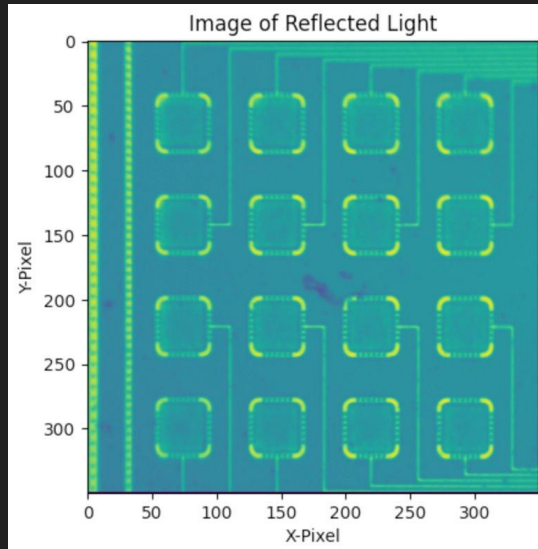
- Control each SPAD individually
- Square pulse signal



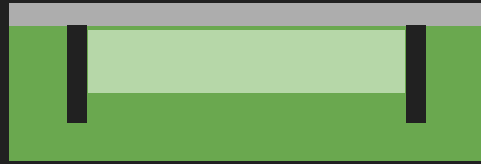
# Photon Digital Converter

Biggest advantage for us:

- Designed by University of Sherbrooke, Fabricated by Teledyne-DALSA
- Fully understand of geometry and doping → use to validate simulations



# Improving SPAD Technology



Analog

Digital 2D

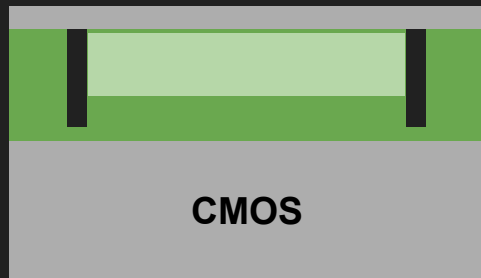
Test Chip



CMOS

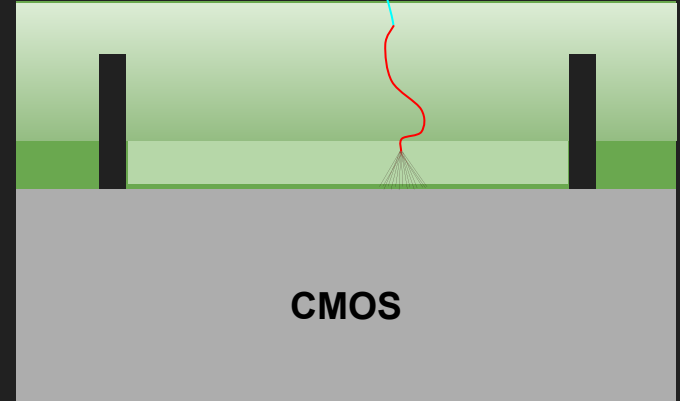
Digital 3D FSI

PDC



CMOS

Digital 3D BSI



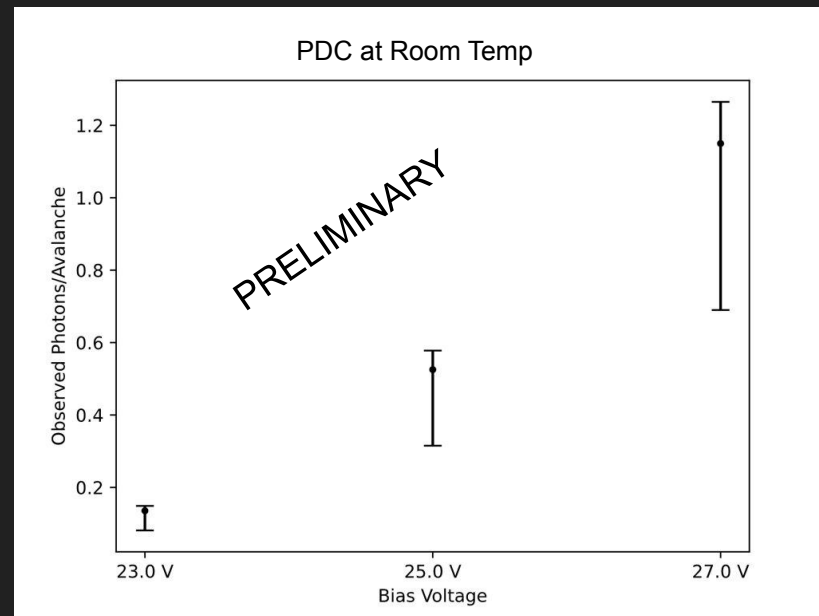
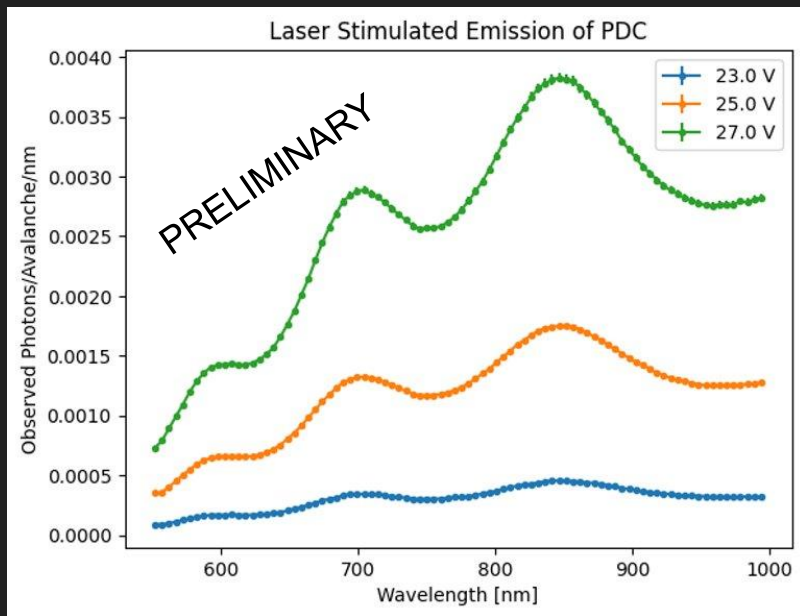
CMOS

## Backside Illuminated

- Better Fill Factor
- Single SPAD Readout
- Higher PDE
- Harder to Manufacture (for now)
- Need to optimize design!



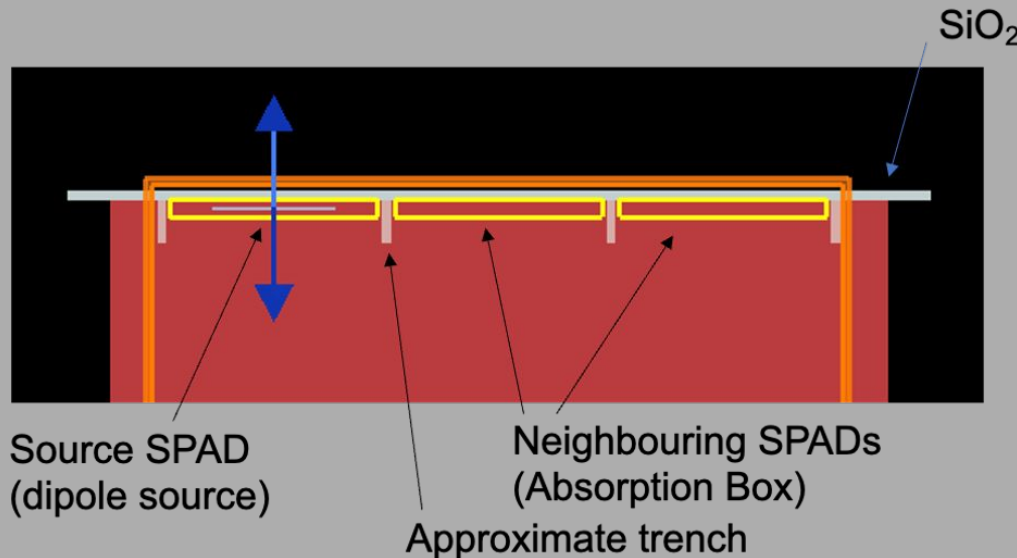
# PDC 2D Test Chip Analysis



# Use to Inform Simulation Efforts

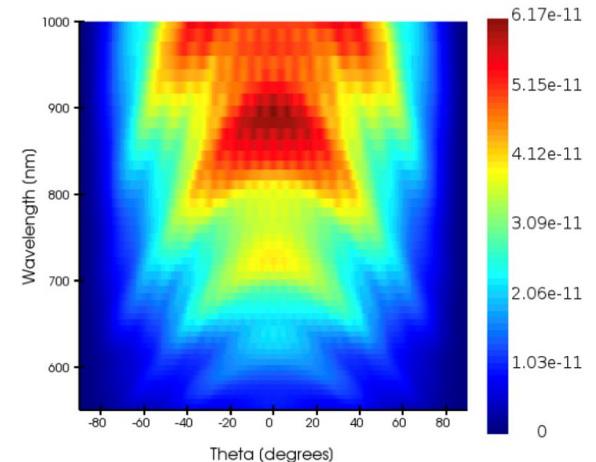
Silvaco TCAD – Manufactured Doping and Electric Field

Anslys Lumerical Finite Difference Time Domain – Interference and Emission



FBK Emission

Far-field photons per charge carrier per wavelength per radian at  $\phi=0$

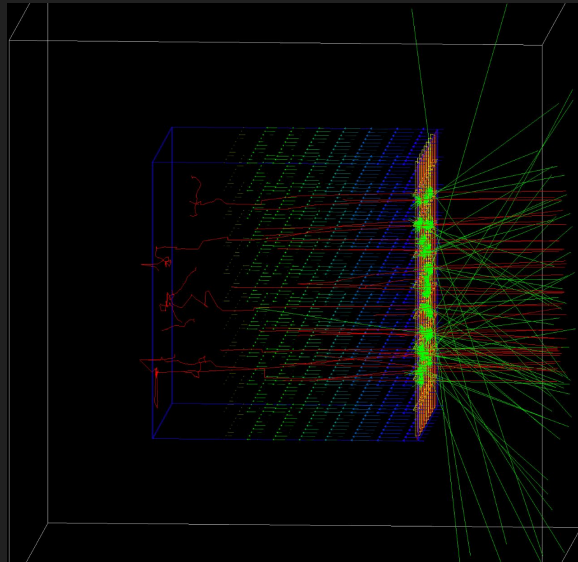


# Effective Simulation

Geant4 might be a solution

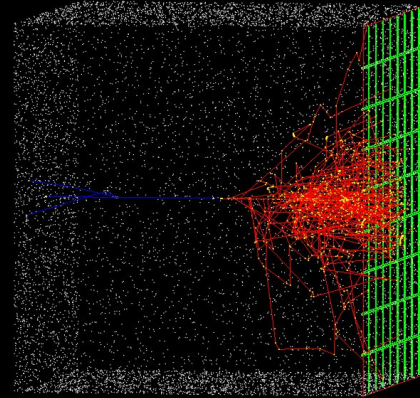
From-scratch may be better

Optical Photon Production



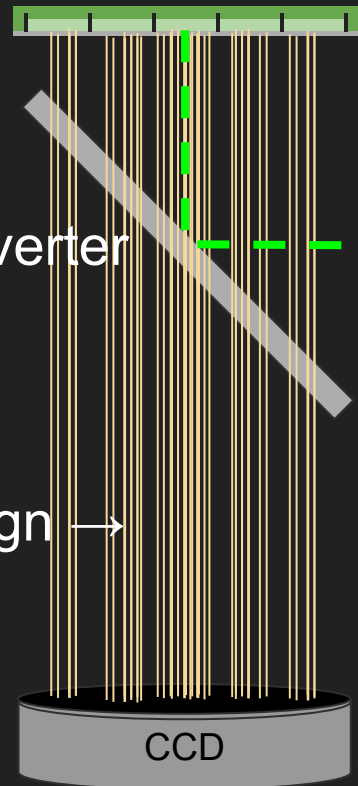
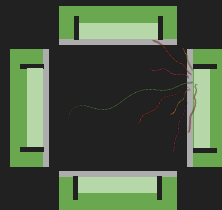
Electron Hole Transport

Using G4CMP package developed for SuperCDMS



# Summary

- MIEL is an effective tool for SiPM characterization
- Preliminary characterization of Photon to Digital Converter underway
- PDC can inform simulation work to further SiPM design backside illuminated



Questions?  
Come work with us!



**CANADA  
FIRST**  
RESEARCH  
EXCELLENCE  
FUND

**APOGÉE  
CANADA**

FONDS  
D'EXCELLENCE  
EN RECHERCHE



**Arthur B. McDonald**  
Canadian Astroparticle Physics Research Institute

Photon to Digital Converter Provided by U. de Sherbrooke



# Back Side Illuminated 3D SPAD

