CPAD R&D COLLABORATION WHITE PAPER

DELTA

Wei Shi, Stony Brook University

CPAD Community Meeting

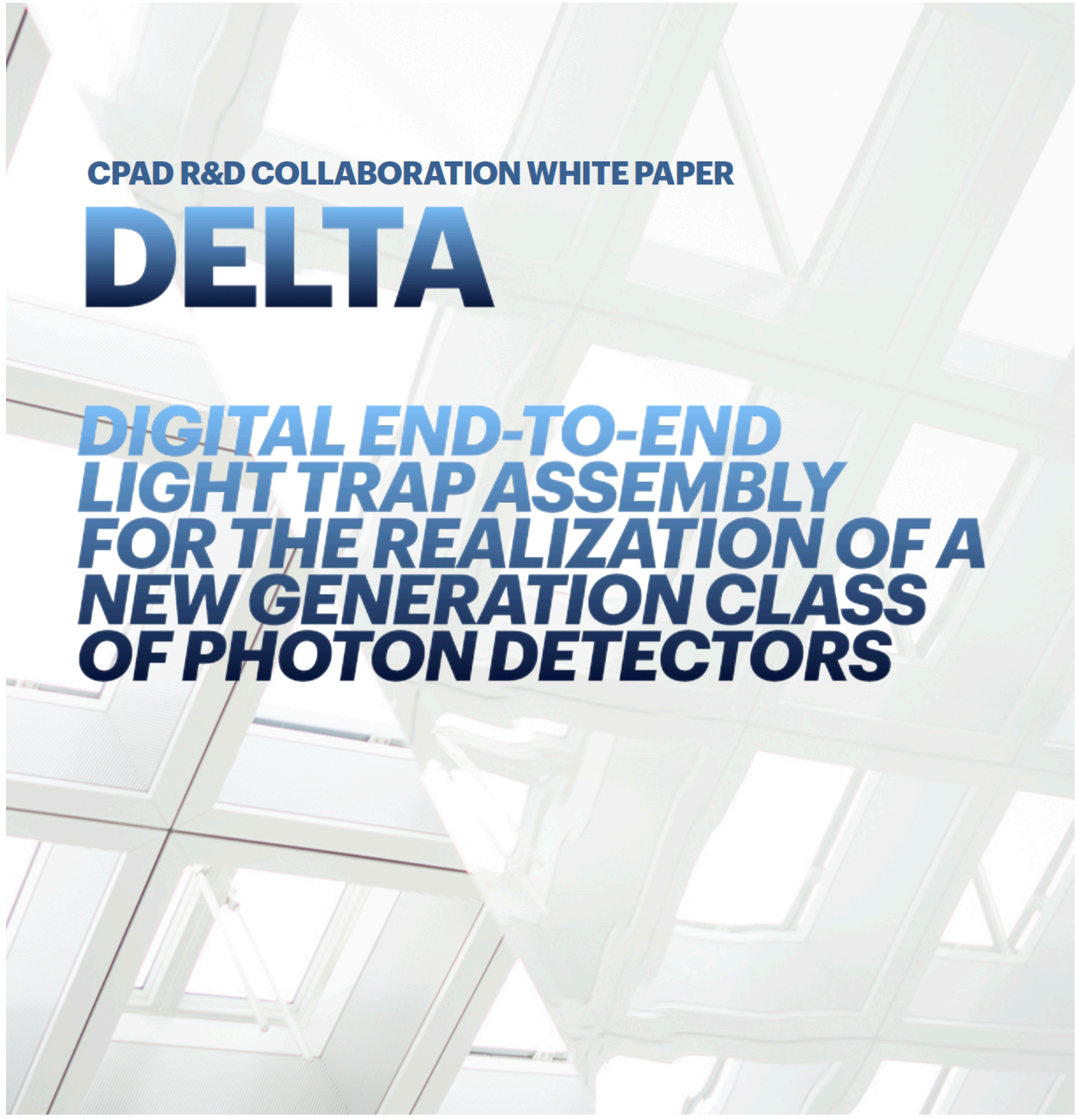
July 29, 2024

DIGITAL END-TO-END LIGHT TRAP ASSEMBLY FOR THE REALIZATION OF A NEW GENERATION CLASS OF PHOTON DETECTORS

DELTA
- Digital End-to-end Light Trap Assembly
for the realization of a new generation class of photon detectors

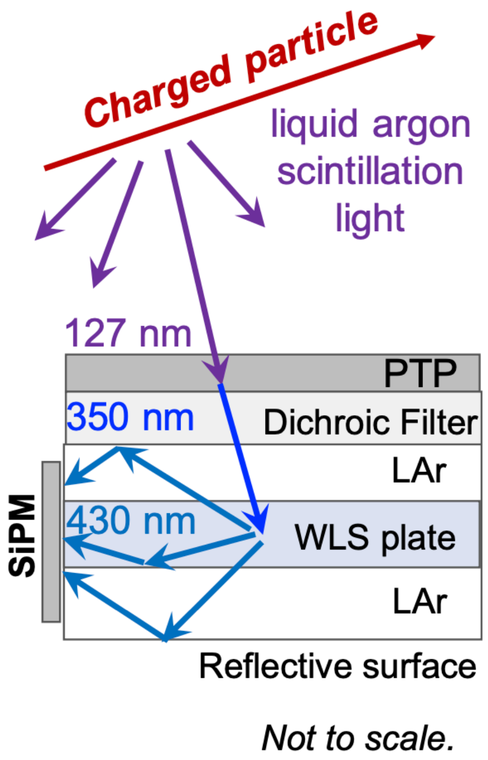
- Proposed mainly under **RDC2 - photodetectors**

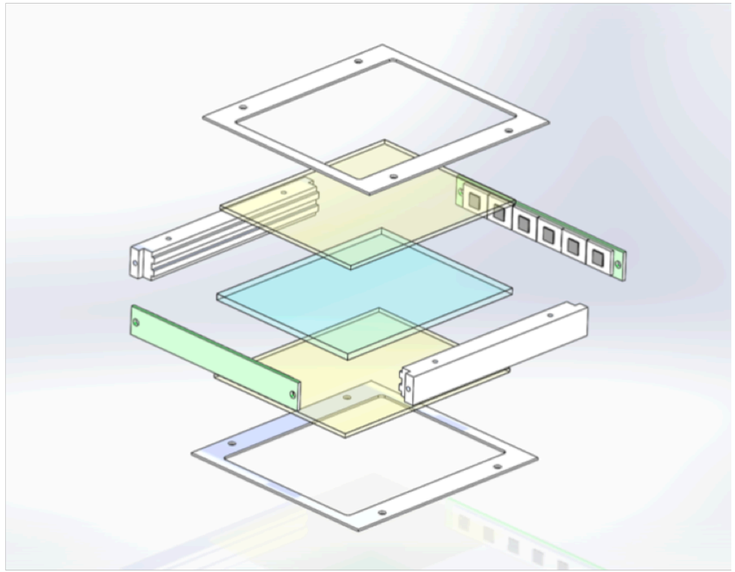
- **Motivation**
  - **Emerging technologies** in many fields
    - Microelectronics, photonics, material science…
  - A next-generation photodetector can build on these emerging technologies
  - **Broad applications** in HEP, NP, medical, security…
  - **Versatility**
    - Large-scale (fast, cost-effective) industrialized production
    - Harsh environments: rad-hard/HV/cryogenics
    - Low-background experiment

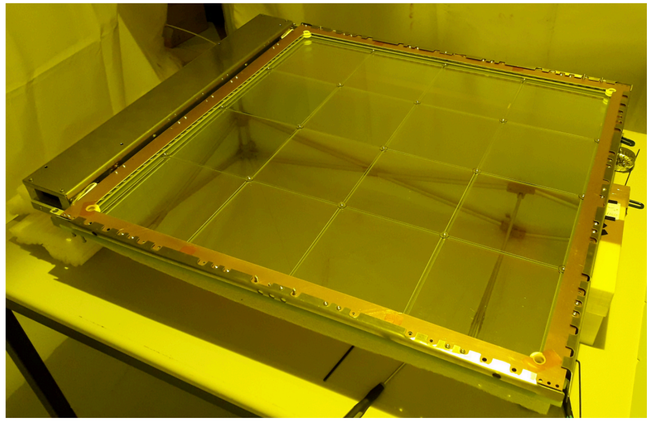


Light Trap Based Photodetector

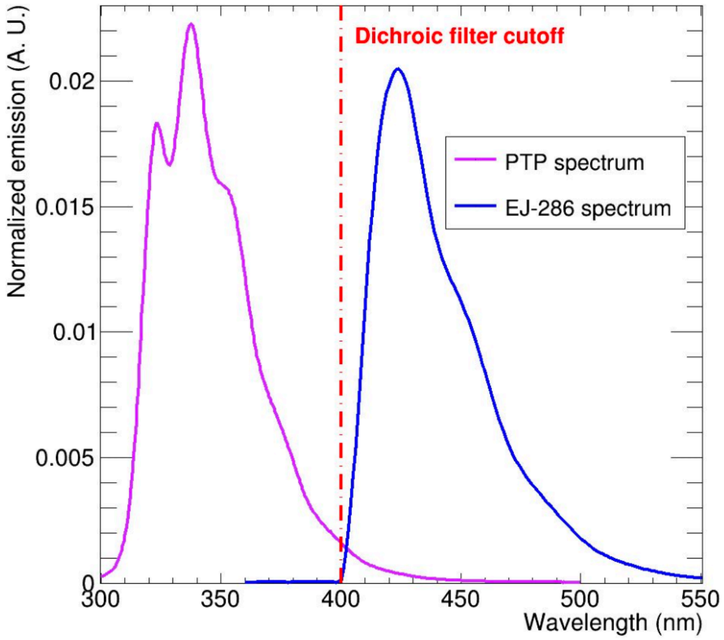
- Single (multi)-stage wavelength shifting + dichroic filter for light trapping
  - An example: 127 nm → 350 nm → 430 nm → SiPM
- **Still a very young technology**
  - Foresee many potentials once fully developed
- **Compact device**
  - Save space for more detector fiducial volume
  - Easy to scale up for large area coverage







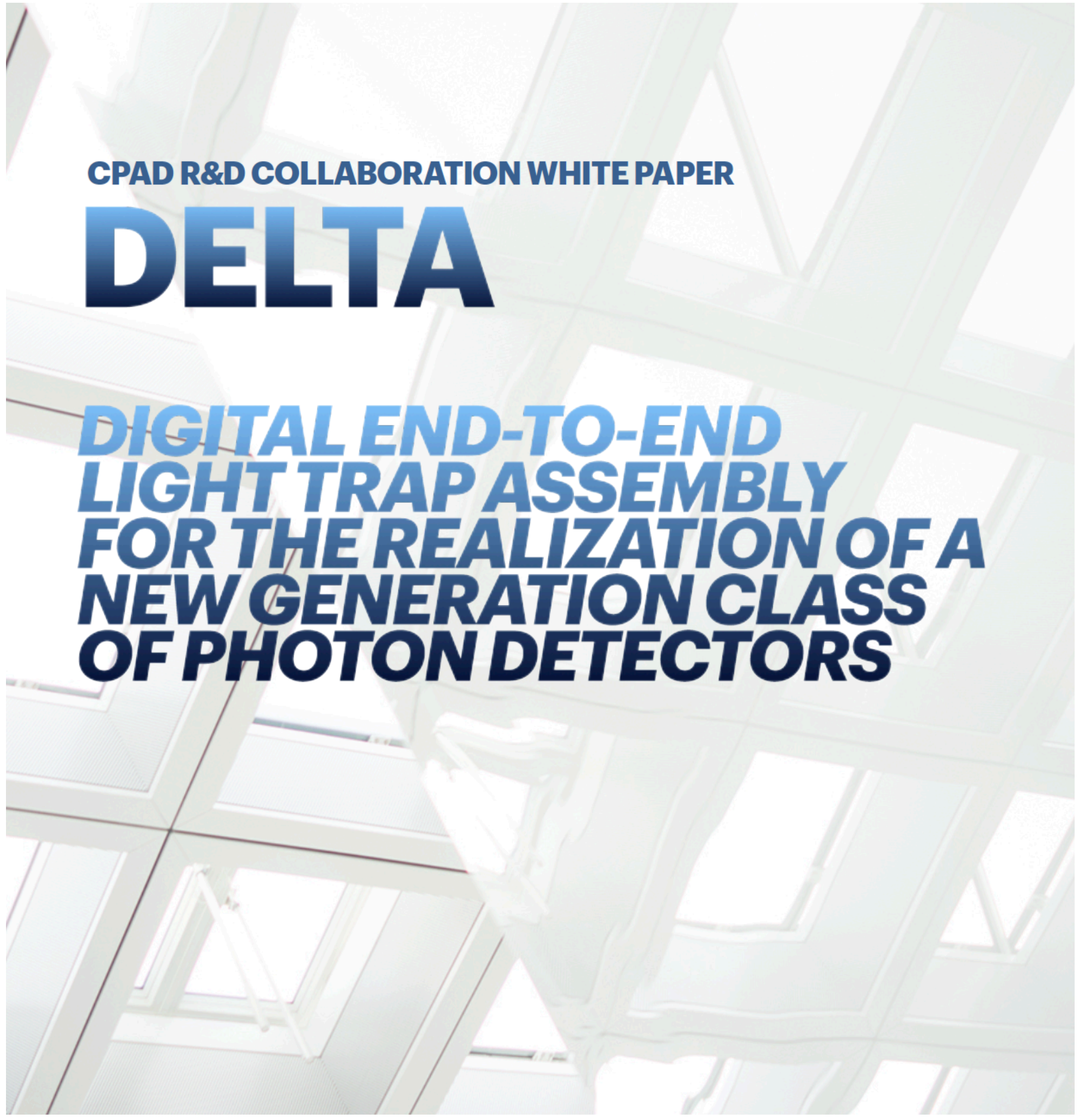
X-arapuca in ProtoDUNE-VD



DELTA
- Digital End-to-end Light Trap Assembly
for the realization of a new generation class of photon detectors

- Proposed mainly under **RDC2 - photodetectors**

- **Overarching R&D goal**
  - **Prototype a class of next-generation fully packaged digital photodetectors based on light trapping mechanism**
    - Large-area photo-collector: traps light inside
    - Small area photosensor optically coupled
    - On-board fast signal processing and digitization
    - Laser photonics for power & signal transmission

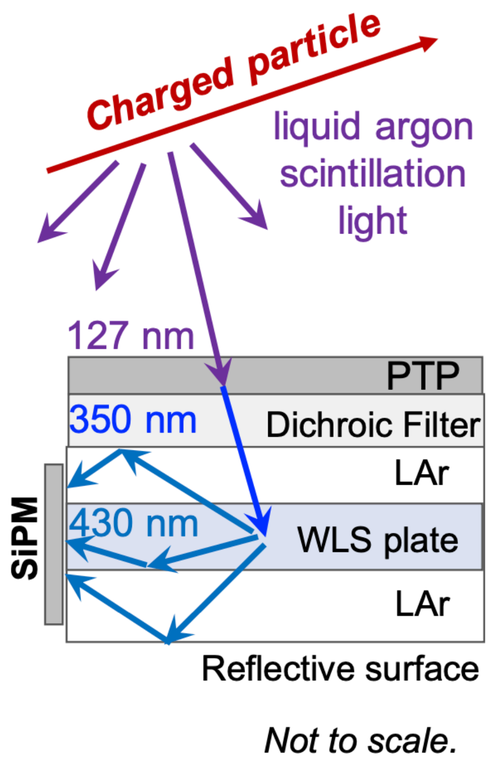


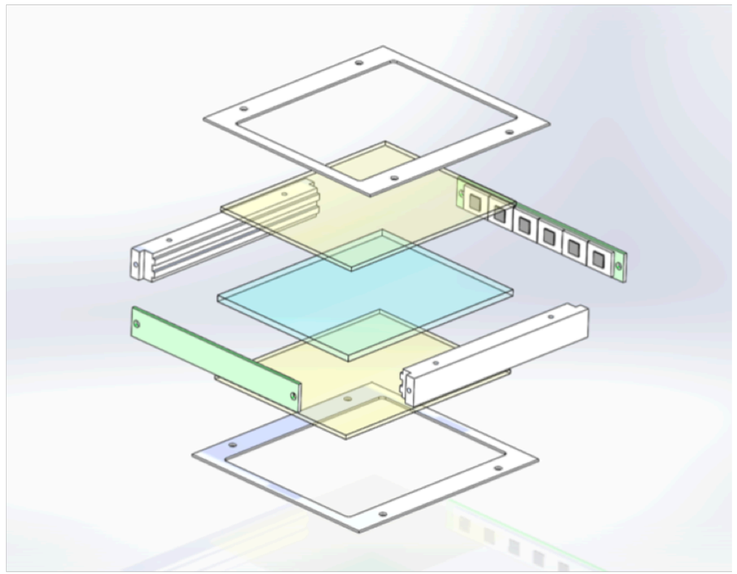
DELTA
Institutions

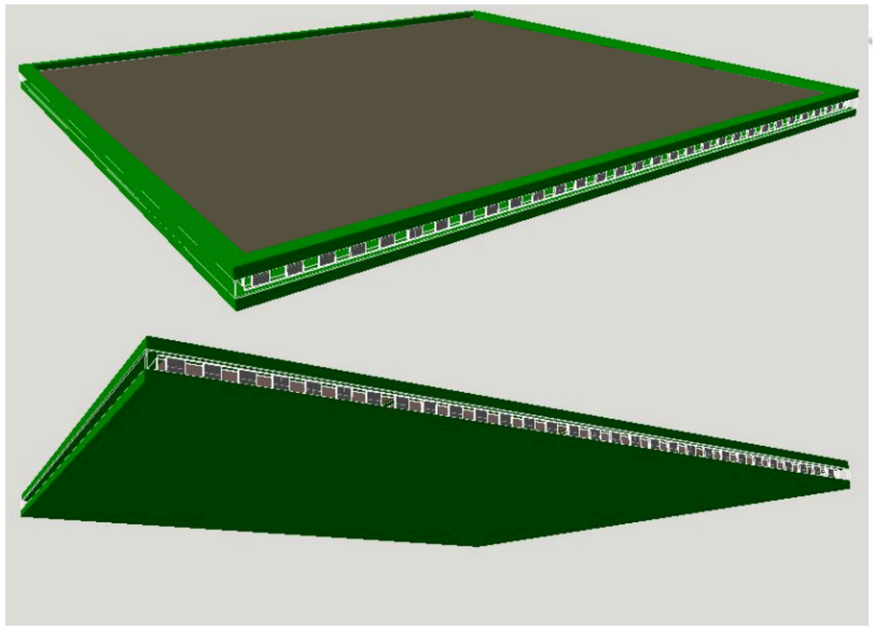
- US:
  - **Stony Brook University**: C. Jung, W. Shi, C. Riccio
  - **SDSMT**: D. Martinez, B. Behera
  - **Fermilab**: F. Cavanna, W. Pellico, P. Rubinov
  - **UC Santa Cruz**: Shiva Abbaszadeh
- Non-US:
  - **APC - Laboratoire Astroparticules et Cosmologie (Paris, France)**: S. Sacerdoti
  - **IFIC (Valencia, Spain)**: A. Cervera
  - **ITA - UFABC (São Paulo, Brazil)**: F. Marinho, L. Paulucci

DELTA
R&D Thrust 1

- Materials search, selection, and development for **photo-collectors with enhanced trapping capabilities**. Optical properties at the surface and the bulk of different composites, thin film deposits, and chromophore dilutions will be tuned for best photoresponse in different incident wavelength ranges - depending on the targeted application.
  - **Stony Brook University**: C. Jung, W. Shi, C. Riccio
  - **IFIC (Valencia, Spain)**: A. Cervera
  - **ITA - UFABC (São Paulo, Brazil)**: F. Marinho, L. Paulucci

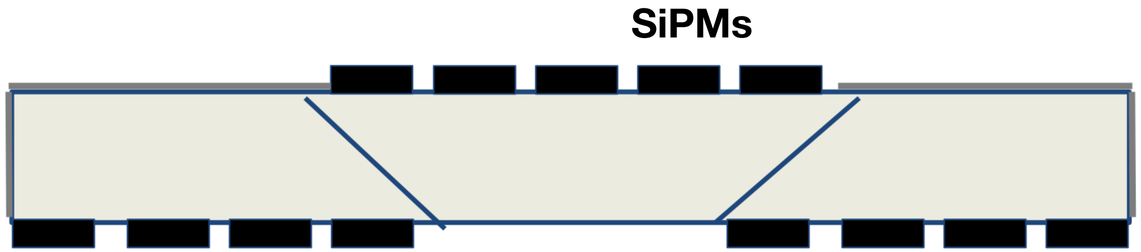


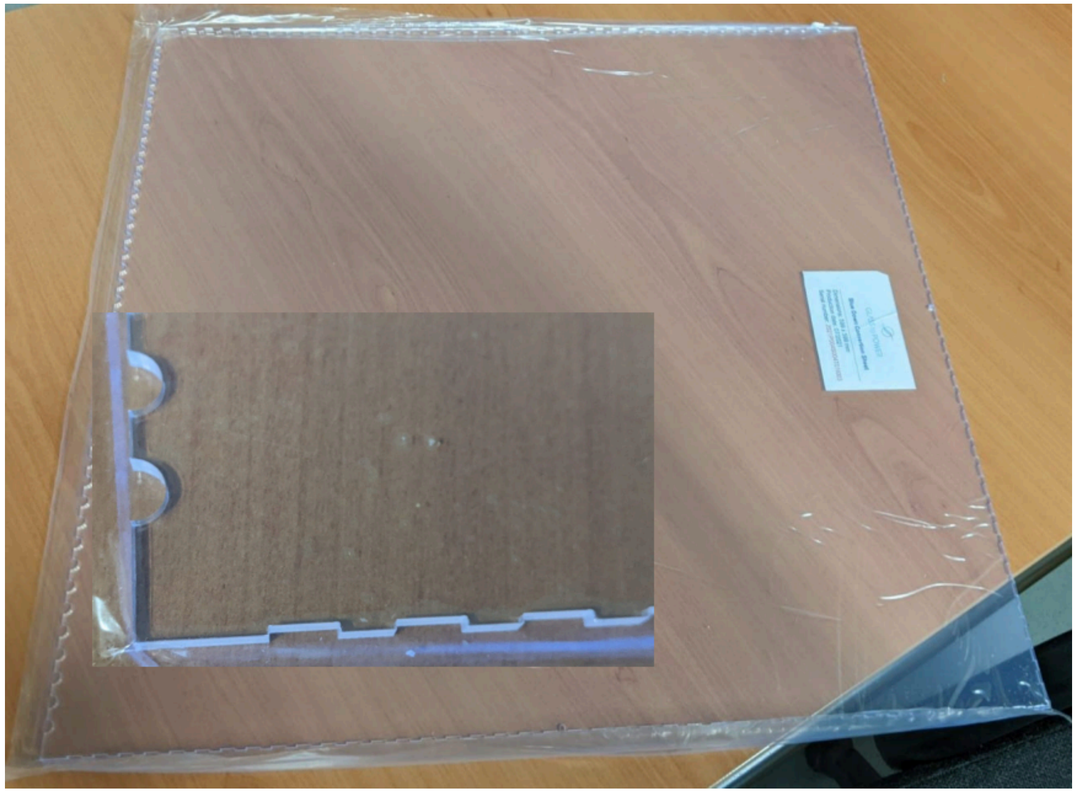




DELTA
R&D Thrust 2

- Solid state photo-sensor selection and dedicated development of optimal **optical interface with photo-collector material**.
  - **Fermilab**: F. Cavanna, W. Pellico, P. Rubinov
  - **IFIC (Valencia, Spain)**: A. Cervera

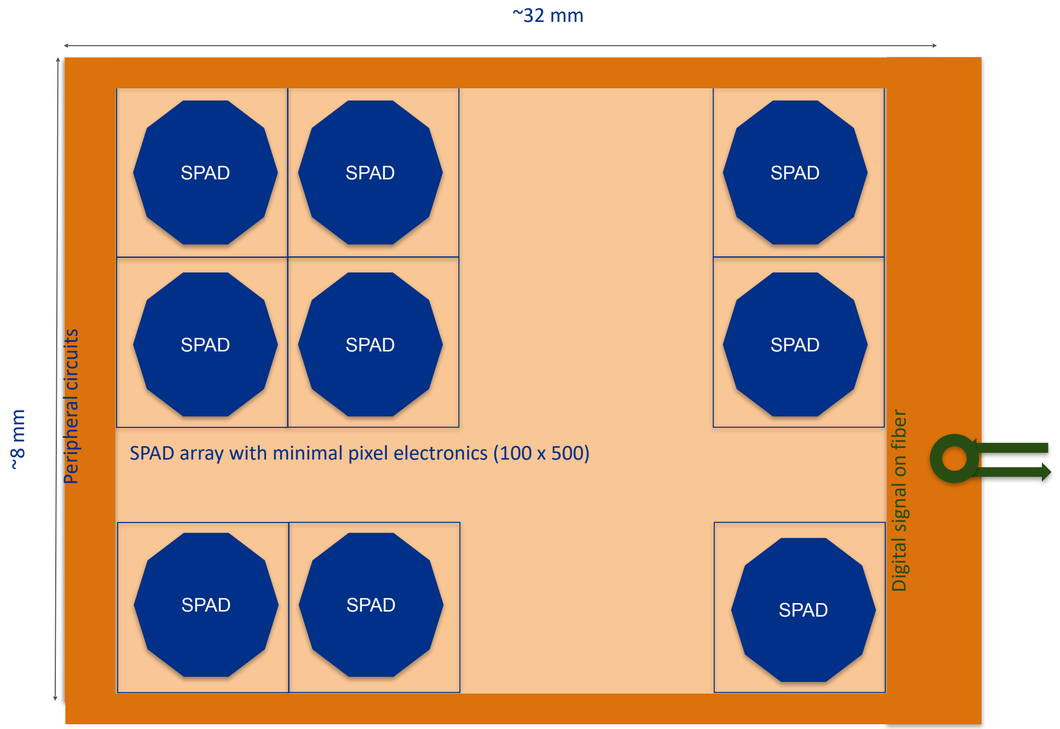




DELTA
R&D Thrust 3a & 3b

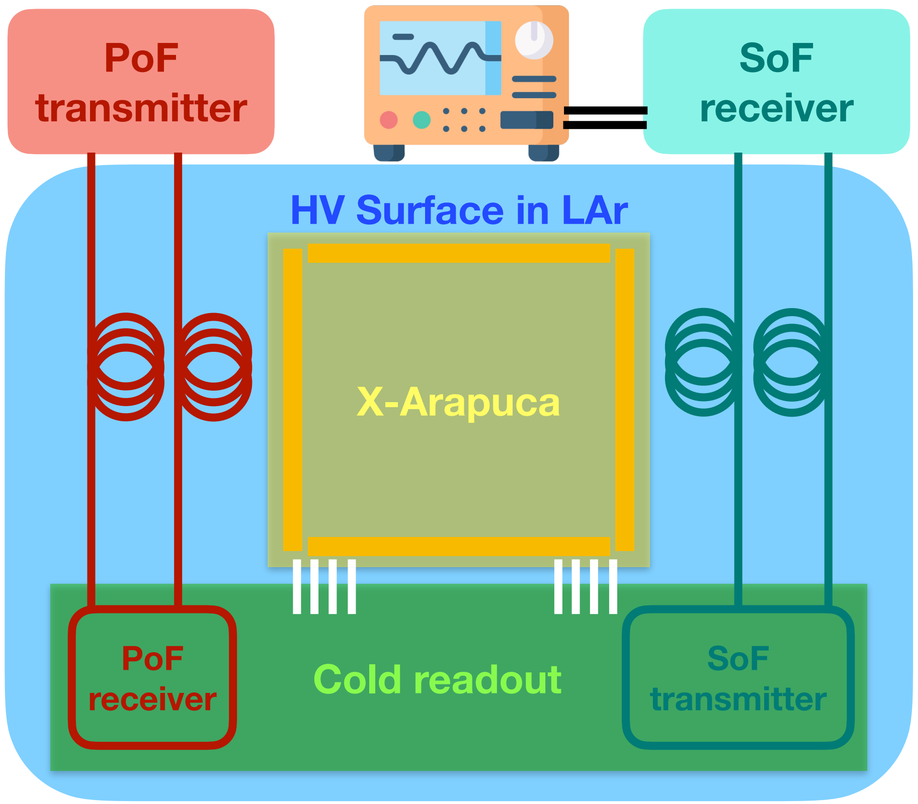
- 3a: Microelectronics for **analog** signal processing and transmission - **dedicate CMOS with integrated photonics** - with optimized photon counting or best timing resolution - depending on the targeted application.
  - **APC - Laboratoire Astroparticules et Cosmologie (Paris, France)**: S. Sacerdoti
  - (other Institutions are interested - TBC)

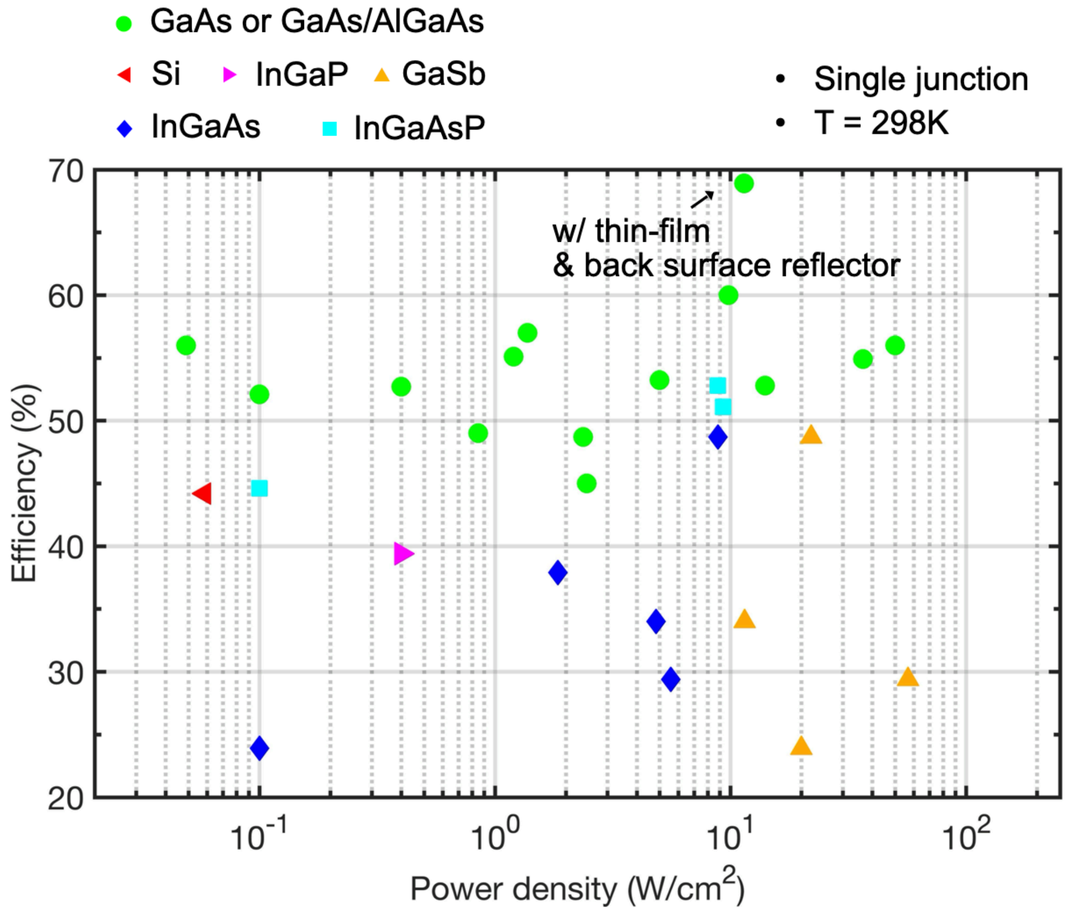
- 3b: Microelectronics for analog signal processing and **digitization** - support to development and integration of **digital SiPM solutions** (dSiPM, 3D-dSiPM) in photon detectors for HEP.
  - **Fermilab**: F. Cavanna, W. Pellico, P. Rubinov
  - (other Institutions are interested - TBC)



DELTA
R&D Thrust 4

- **Laser photonics** technology development/customization and implementation for **noise immune power transmission and digital signal high bandwidth transmission via optical fibers**.
  - **SDSMT**: D. Martinez, B. Behera
  - **Stony Brook University**: C. Jung, W. Shi, C. Riccio





DELTA
Overlap with RDCs

- **Δ** is a multi-institutional proposal conceived to foster the formation of an ***RDC2 Photodetector (PD) Collaboration*** within **CPAD**

- Components live in multiple RDC's
  - **RDC2 - Photodetectors**
  - **RDC4 - Readout and ASICs**
  - **RDC1 - Noble Element Detectors**
  - **…**

- **Δ** is **open and welcoming the joining of interested groups** across national and international university communities and laboratories who are active in the specific technology areas outlined in the **Δ** *R&D Thrusts.*

DELTA
Timeline and Deliverables

- Propose a 3-year funding period: **2025-2028**

- **Year 1 (2025-2026):**
  - Search, selection, and development of different photo-collector **materials with enhanced trapping capabilities** - wavelength shifting (WLS) materials and composition, exploration and development of different film deposition methods and material coating techniques - for reflectors, dichroic films, WLS films,..
  - Dedicated development of optimal **optical interface photo-sensor to photo-collector material** - development connection with industrial partners
  - Support the development of **digital SiPM** solutions
  - Search, and develop with industrial partners of **(Laser) Photonics instrumentation** in photon detection

DELTA
Timeline and Deliverables

- Propose a 3-year funding period: **2025-2028**

- **Year 2 (2026-2027):**
  - Integration of selected detector components into **first prototyping**. **Simulate** response in full-scale detectors
  - Develop **test facilities** for detector performance characterization
  - Continue material (photo-collector) development and photo-sensor read-out electronics

DELTA
Timeline and Deliverables

- Propose a 3-year funding period: **2025-2028**

- **Year 3 (2027-2028):**
  - **Implementation of (Laser) Photonics** instrumentation in photon detection
  - Integration of selected detector components into **end-to-end Δ prototype**
  - Characterization in test facilities

CPAD R&D COLLABORATION WHITE PAPER

DELTA

The End

DIGITAL END-TO-END LIGHT TRAP ASSEMBLY FOR THE REALIZATION OF A NEW GENERATION CLASS OF PHOTON DETECTORS