Photon Detectors and Particle ID POSTER section

Samo Korpar (University of Maribor)

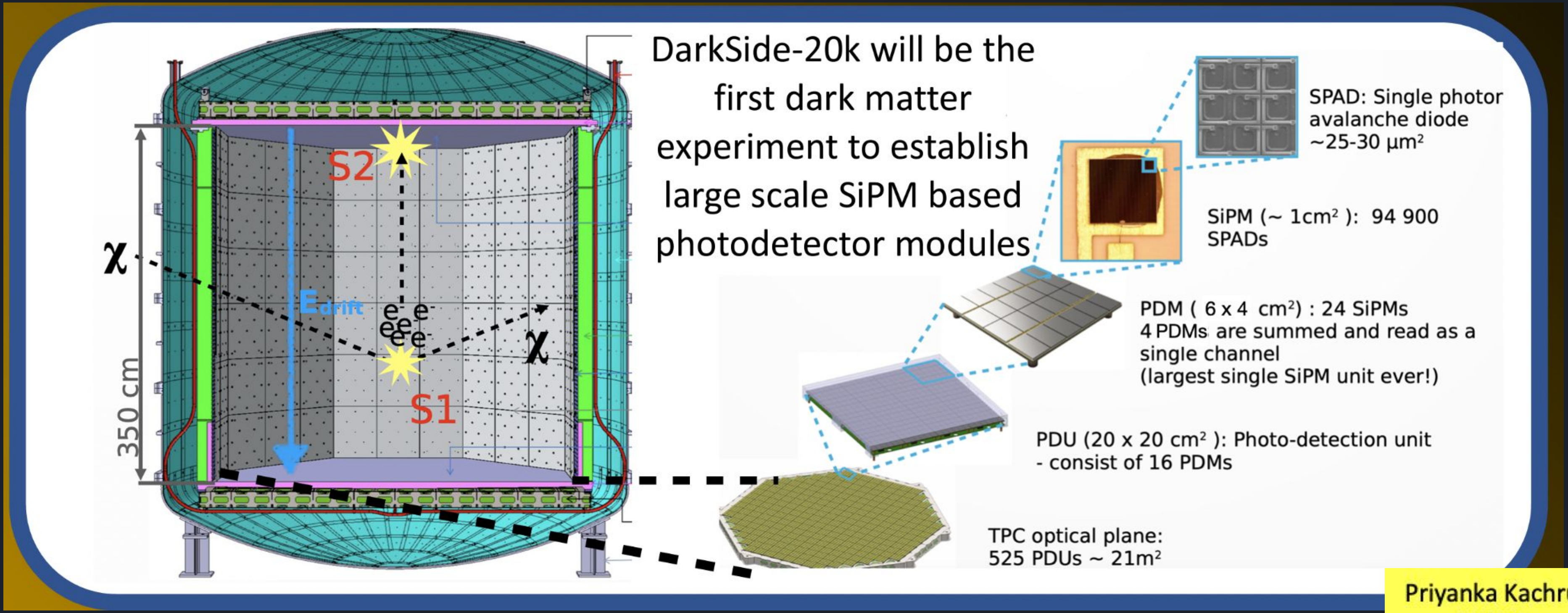
Ana Amelia B. Machado (University of Campinas - UNICAMP)

Frontier Detectors for Frontier Physics
15th Pisa meeting on advanced detectors
La Biodola • Isola d'Elba • Italy
22 - 28 May, 2022

Contributions

Single Photon Timing Resolution study on Silicon Photomultipliers at cryogenic temperatures	eXTP Large Area Detector: qualification procedure of the mass production
Development of CoRDIA: an Imaging Detector for next-generation Photon Science X-ray Sources	The ABALONE Photodetector
Large-Area SiPM Pixels (LASiPs) in SPECT	The Mu3e scintillating fiber detector R&D
Characterization of GaAs avalanche photodiodes featuring separated absorption and GaAs/AlGaAs superlattices multiplication layers using soft X-rays.	The TORCH time-of-flight detector
Characterization of a back thinned scientific CMOS imager with extended ultra violet and soft X-rays.	JUNGFRAU – A hybrid pixel detector for high-performance photon science
TRICK: a Tracking Ring Imaging Cherenkov Detector	Novel imaging technique for thermal neutrons using a fast optical camera
Comparison of new SiPM models for applications in High-Energy physics	Development of Single-Photon Avalanche Diode Array for Particle Physics and Medical Imaging
R&D on organometal halide perovskites for photodetectors	Particle Identification with the Belle II Aerogel RICH

Single Photon Timing Resolution study on Silicon Photomultipliers at cryogenic temperatures



Priyanka Kachru
(INFN)

Development of CoRDIA: an Imaging Detector for next-generation Photon Science X-ray Sources

CoRDIA

Ph source upgrades

need for imagers:
> 100kHz frame rate
continuous readout

goal

- > 100 kHz, continuous
- 100 µm pixel size
- 1-photon sensitive 12 keV
- 10k ph/pix/img (or more)
- compat. w. HZ & int.-ampl. sensors

approach

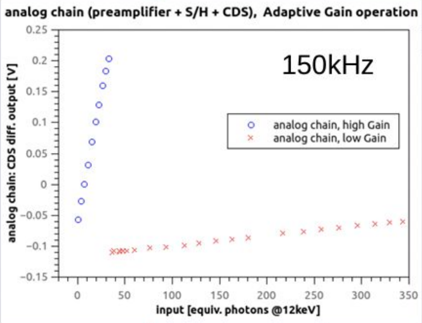
Adapt.-Gn FE → ADCs 11b SAR → T.pix4 GWT devel. Nikhef

integr → digitize → TX

integr → digitize → TX

integr → digitize → TX

pipelinelined 3-stages architecture



MPWs (TSMC65)

timeline

validation of individual circuit blocks → validation of circuit chain as a pixel array → validation as a component of the overall detector system → expansion to full-scale ASIC → performance improvement study → performance improved ASIC

1[st] gen ASIC: by start of Petra IV: ~2027
will target mainly pixel pitch, CWR, >100KHz cont. readout

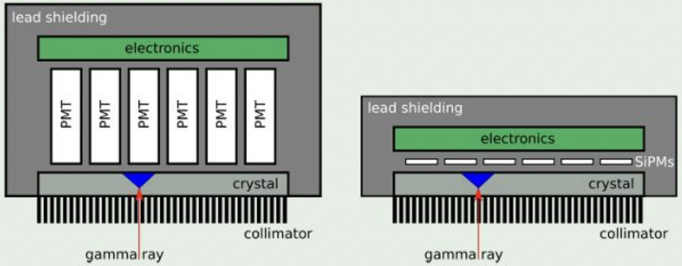
2[nd] gen ASIC: aim at: extend dyn rng, further reduce noise, min. blind areas

BONN DESY.

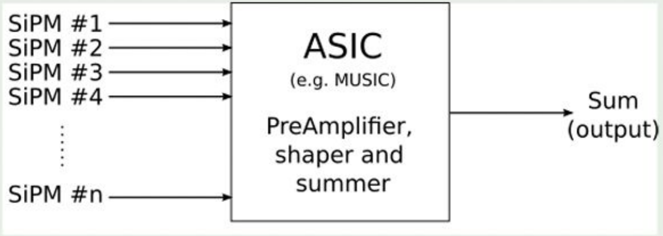
Alessandro Marras (DESY)

Large-Area SiPM Pixels (LASiPs) in SPECT

- **Weight and size of a gamma camera for full-body Single Photon Emission Computed Tomography (SPECT)** could be **significantly reduced** using **silicon photomultipliers (SiPMs)** instead of photomultiplier tubes (PMTs).content...



- Few thousands channels needed to fill a camera with SiPMs due to their limited area
- Solution: **Large-Area SiPM Pixels (LASiPs)** which are built by **summing individual currents of several SiPMs** into a single output.



Feasibility of using LASiPs in SPECT

- We built a **proof-of-concept SPECT micro-camera** for lab measurements
- We used those measurements to **validate Geant4 simulations of the system**
- We extended the **simulations to a full-body SPECT camera** and evaluated the **impact of LASiP size** (number of SiPMs summed) and **noise** in its performance.

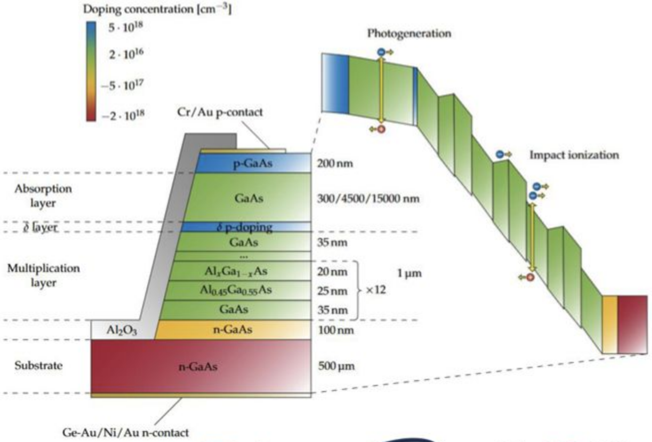
Check details and results on our poster!

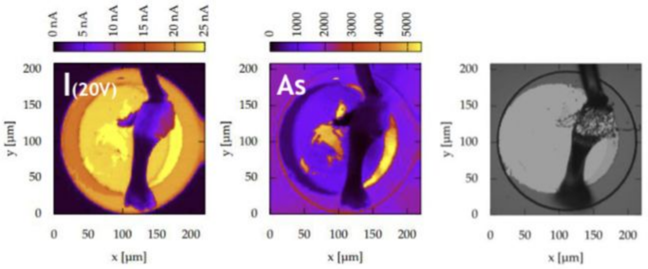
Carolin Waltraud Wunderlich (INFN Pisa/Univ.Siena)

Characterization of GaAs APDs featuring separated absorption and GaAs/AlGaAs superlattices multiplication layers using soft X-rays

Colja M., Cautero M., Menk R.H., Pierpaolo Palestri P., Gianoncelli A., Antonelli m., Biasiol G., Dal Zilio S., Steinhartova T., Nichetti C., Arfelli F., De Angelis D., Driussi F., Bonanni V., Pilotto A., Gariani G., Carrato S. and Cautero G.

- GaAs SAM-APDs
  - Efficient and sensitive
  - Shorter absorption length for high energy X rays
  - Minimization of noise using a super-lattice structure





- Fabrication and Simulation procedures
  - Different device thicknesses
- Measurements
  - Excess noise factor
  - Gain
- Synchrotron radiation Measurements
  - Absence of traps in the interfaces
  - Efficiency independence from thickness
  - High photocurrents

Università degli Studi di Trieste · Elettra Sincrotrone Trieste · INFN Trieste · IOM Istituto Officina dei Materiali

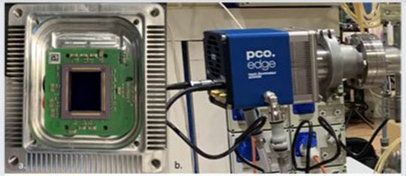
Marco Cautero (Univ.Trieste)

Characterization of a back thinned scientific CMOS imager with extended ultra violet and soft X-rays

Elettra Sincrotrone Trieste

Menk, R.H.[1,2,3]; Arfelli, F.[2,4]; Cautero, M.[4]; DiFraia, M.[1]; Coreno, M.[5]; Tutsch, W.[6], P. Hönicke[7]

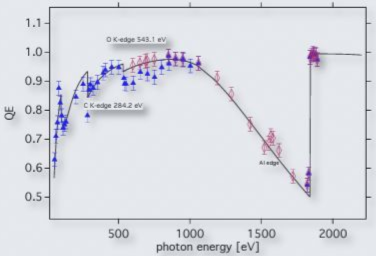
[1]Elettra – Sincrotrone Trieste S.C.p.A., SS14 – km 163.5, Trieste, Italy; [2]INFN Trieste, Padriciano 99, Trieste, Italy; [3]University of Saskatchewan, 103 Hospital Drive, Saskatoon, Canada; [4]University Trieste, Via Valerio, Trieste, Italy; [5]Consiglio Nazionale delle Ricerche. CNR-ISM, LD2 Unit, Elettra Laboratory, Trieste, Italy; [6]PCO AG, Donaupark 11, 93309 Kelheim, Germany, [7]Physikalisch-Technische Bundesanstalt, X-Ray Spectrometry, Abbestr. 2-12, 10587 Berlin, Germany



Current version: Gpixel's GSENSE2020BSI-APM-NUN PulSa sCMOS, 2048 x 2048 pixels with a pixel size of 6.5 µm x 6.5 µm, intrinsic readout noise of 1.6 e− (rms) and a full well capacity of 55000. Sealed PC board (UHV), readout in air. USB 3.1 data interface - > 48 full frames per second.

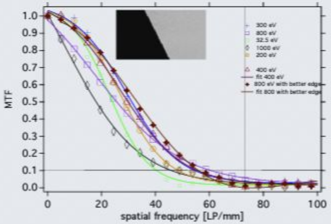
Quantum efficiency using calibrated IUX photo diode

$$QE_{th}(E_\gamma) = F\left\{\frac{\mu_i(E_\gamma)}{\rho_i}\right\} = e^{-\sum_{i=1}^{N}\frac{\mu_i(E_\gamma)}{\rho_i}\cdot\rho_i\cdot x_i}\cdot\left(1 - e^{-\frac{\mu_{Si}(E_\gamma)}{\rho_{Si}}\cdot\rho_{Si}\cdot x_{Si}}\right)$$



least square fitting results: 0.5 ±0.1 nm of atomic C, 12.3 ± 0.4 nm fatty acid, a 0.9 ± 0.2 nm insensitive Si layer and 9.9 ±0.1 nm SiO_2 passivation, Si epi layer of 10.3 ±0.2 µm

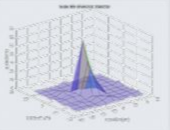
Spatial resolution slanted edge

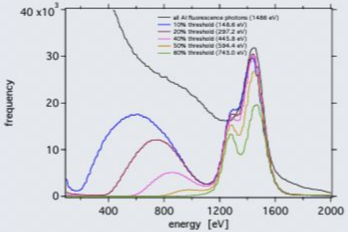


Energy resolution

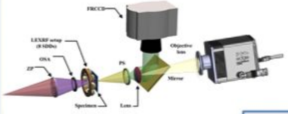
Single photon cluster 800 eV

Charge spread

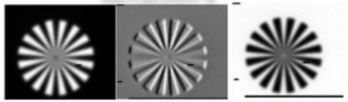




TwinMic soft X-ray microscope



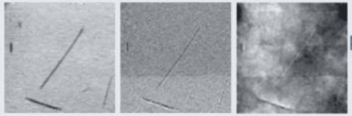
Refraction x



Absorption scattering

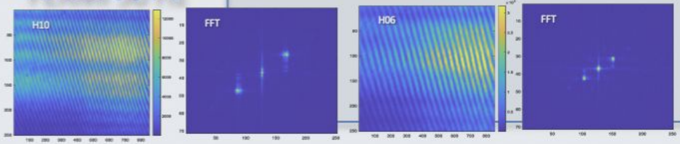
Pixel size 300 nm

Asbestos in lung cells (at 2.2 keV)

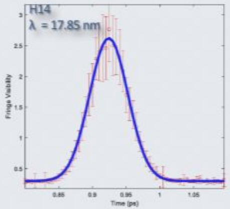


phase

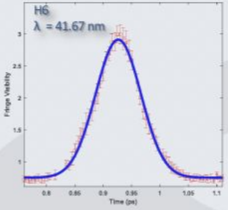
FERMI 50 Hz



Autocorrelation at different harmonics



$\tau_{FEL} \approx 47.5$ fs



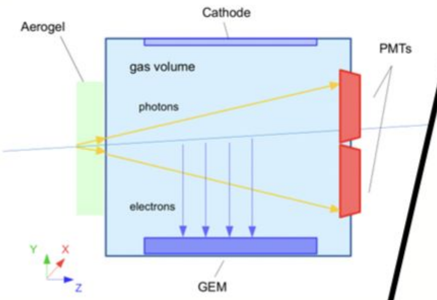
$\tau_{FEL} \approx 66.4$ fs

Ralf Hendrik Menk (Elettra Sincrotrone Trieste)

The idea: Combine TPC+RICH in one volume to perform 5D reconstruction

The electronics: Use two versions of TIGER ASIC to simultaneously readout the TRICK-box

The TRICK-box



The software: GEANT4 simulation to study geometry

ANSYS to perform study of the drift field

Build a unifed reconstruction algorithm starting from simulated data

TRICK

Immerse yourselves in extra dimensions of PID

gmezzadr@fe.infn.it - G. Mezzadri

Giulio Mezzadri
(INFN)

15th Pisa Meeting on Advanced Detectors - La Biodola, Isola d'Elba (Italy), 22-28 May 2022

Comparison of new SiPM models for applications in High-Energy physics

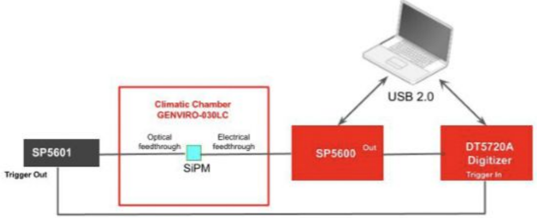
M. Bonesini[1], A. Menegolli[2,3], M.C. Prata[3], G.L. Raselli[3], M. Rossella[3], R.Rossini[2,3]

[1]Istituto Nazionale di Fisica Nucleare, Sezione di Milano Bicocca (Italy)

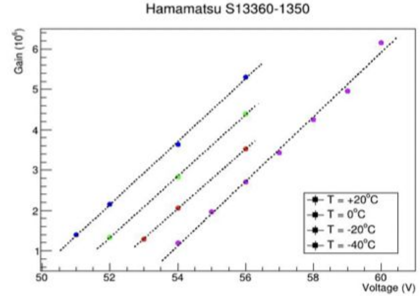
[2]Università degli Studi di Pavia (Italy),

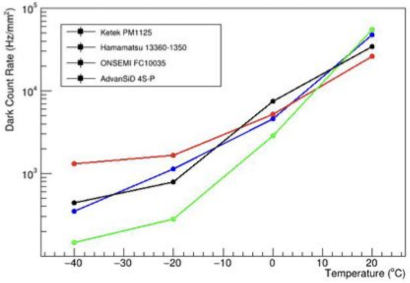
[3]Istituto Nazionale di Fisica Nucleare, Sezione di Pavia (Italy)

Silicon Photo-Multipliers (SiPMs) are widely used as light detectors for the new generation of experiments dedicated to high energy physics. For these reasons, we tested several recent devices from different manufacturers: Hamamatsu 13360-1350; Ketek PM1125; ONsemiconductors FC10035 and AdvanSid NUV4S-P. Particular emphasis has been put on measurements of dark counts and gain, performed at different temperatures by means of a climatic chamber (F.lli Galli model Genviro-030LC) with a temperature range from −60 ◦C to +60 ◦C, housing the SiPM under test. This latter also allowed evaluating the temperature coefficient of all models.



Massimo Rossella
(INFN)





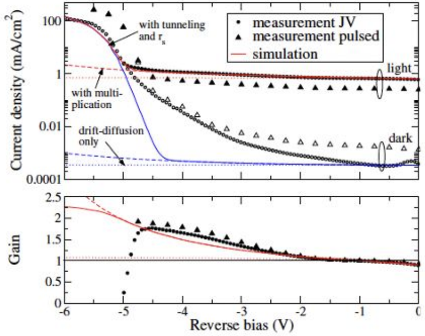
R&D on organometal halide perovskites for photodetectors

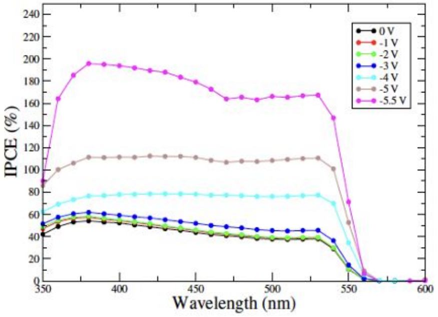
Marianna Testa, for the PEROV Collaboration

- Several devices with $CH_3NH_3PbBr_3$ perovskite of various thickness

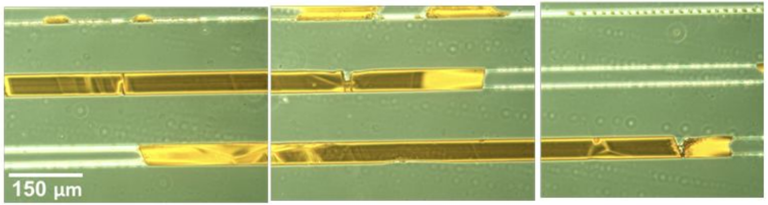
- Polycrystalline film 300 nm thick
  Developed model of the observed IV curve and gain
  - *tunneling-assisted electron extraction at the interface*
  - *carrier multiplication*
  - Both mediated by the electric field due to *mobile ions Br-*

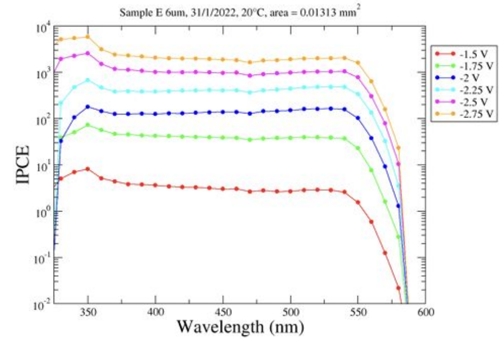
Appl. Phys. Lett. **120**, 113505 (2022)





- Micro-wires W x L x H = 150 μm x 500 μm x 6(2) μm
  - Direct deposition of single crystals on patterned Indium Tin Oxide





Deposited patent: 102022000010469

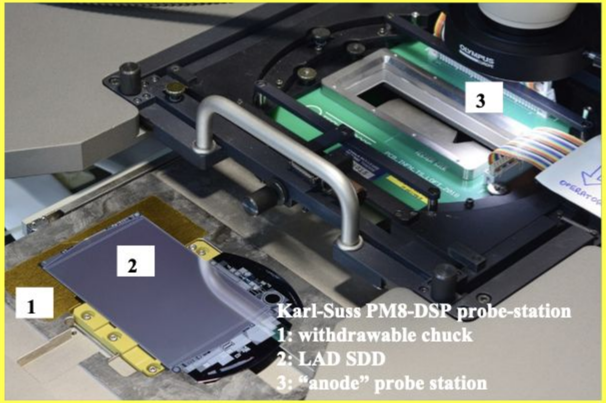
eXTP Large Area Detector: qualification procedure of the mass production

A. Rachevski[1], M. Antonelli[1], P. Bellutti[2,6], V. Bonvicini[1], G. Borghi[2,6], R. Campana[7], F. Ceraudo[4], D. Cirrincione[3,1], E. Del Monte[4,5], Y. Evangelista[4,5], M. Feroci[4,5], F. Ficorella[2,6], G. Orzan[1], G. Pepponi[2,6], A. Picciotto[2,6], I. Rashevskaya[6], G. Zampa[1], N. Zampa[1], N. Zorzi[2,6] and A. Vacchi[3]*

**) corresponding authour, 1) INFN Trieste, Padriciano 99, I-34149, Trieste, Italy, 2) Fondazione Bruno Kessler, Via Sommarive 18, I-38123, Trento, Italy, 3) Dipartimento di Matematica ed Informatica, Università di Udine, Via Italy, 6) TIFPA – INFN, Via Sommarive 14, Idelle Scienze 206, I-33100, Udine, Italy, 4) INAF-IAPS, Via del Fosso del Cavaliere 100, I-00133, Roma, Italy, 5) INFN Roma Tor Vergata, Via della Ricerca Scientifica 1, I-00133, Roma, -38123, Trento, Italy, 7) INAF-OAS, Via Piero Gobetti 93/3, I-40129, Bologna, Italy*

A 7.24 x 12.03 cm^2 sensor, Silicon Drift Detector (SDD), has been developed for the enhanced X-Ray Timing and Polarimetry (eXTP) mission of the Chinese Academy of Science, with a large contribution by a European consortium inherited from the ESA-M3 LOFT mission study. In the frame of the project X-Ray Observatories (XRO), active in the National Scientific Commission 2 of the INFN, we report the details of the qualification procedure to select from the mass production the 640 sensors that will equip the Large Area Detector (the eXTP instrument dedicated to the X-ray spectroscopy in the range 2-30 keV), with energy resolution below 240 eV FWHM at 6 keV during the entire mission duration of at least 5 years. This stringent requirement dictates the need to thoroughly verify the characteristics of each single sensor before integration in the final layout. We describe the dedicated testing facilities that have been developed. We report on the detector selection criteria and test results obtained in the pre-series production.

Comparison between ALICE SDD (active area 7.53x7.00 cm^2) and LAD SDD (active area 10.86x7.00 cm^2)



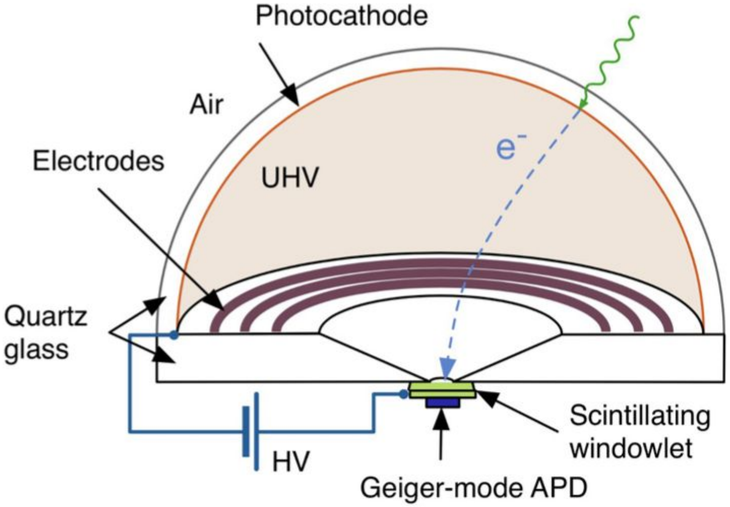
Karl-Suss PM8-DSP probe-station
1: withdrawable chuck
2: LAD SDD
3: "anode" probe station

Alexandre Rachevski (INFN)

The ABALONE Photodetector

Cecilia Ferrari, Riccardo Biondi, Valerio D'Andrea, Alfredo D. Ferella, Joern Mahlstedt, Giulia Pieramico

The ABALONE is a new type of photosensor produced by PhotonLab with cost effective mass production, **robustness** and **high performance.** This modern technology provides sensitivity to visible and UV light, exceptional radio-purity and excellent detection performance in terms of intrinsic gain, afterpulsing rate, timing resolution and single-photon sensitivity. This new hybrid photosensor, that works as light intensifier, is based on the **acceleration in vacuum of photoelectrons** generated in a traditional photocathode and guided towards a window of scintillating material that can be read from the outside through a Silicon PhotoMultiplier (SiPM). In this contribution we present the extensive characterization of the ABALONE as a possible photosensor for future astroparticle physics experiments.



The Mu3e scintillating fibre detector R&D

A. Papa [123] , G. Rutar [34], M. Hildebrandt [3], S. Bravar [5], K. Briggl [5], A. Buonaura[4], S. Corrodi [4], A. Damyanova [5], Y. Demets [5], L. Gerritzen [4], C. Grab [4], C. Martin Perez [4]

[1] Dipartimento di Fisica Università di Pisa (IT), [2] Istituto Nazionale Fisica Nucleare, sez. Pisa (IT), [3] Paul Scherrer Institute (Villigen, CH), [4] ETH Zurich (CH), [5] Département de physique nucléaire et corpusculaire, Université de Genève (CH)

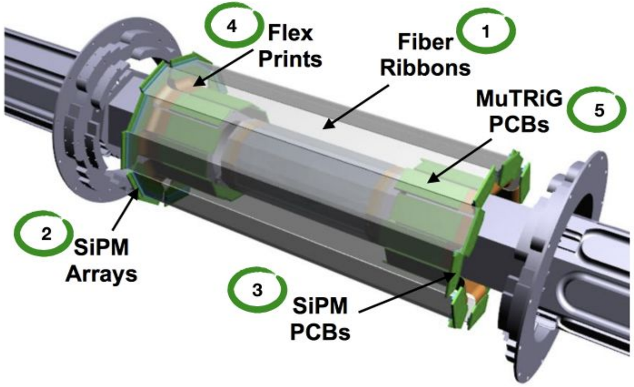
Goal Detect m.i.p. with high efficiency, minimum amount of material for a sub ns time resolution with just few photoelectrons/fiber

Requirements

- < 900 μm total thickness
  < 0.3 % X_0
- time resolution σ < 1 ns
- rate up to 250 KHz/fiber
- very tight space for cables, electronics and cooling

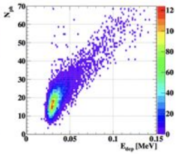
Parts

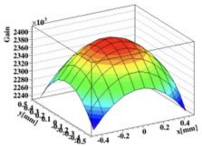
- cylindrical at ~ 6 cm (radius); length of 28-30 cm;
- 3 layers of multi-clad 250 μm fibers
- fibers grouped onto SiPM array
- MuTRiG readout

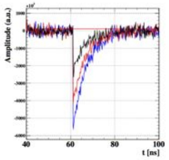


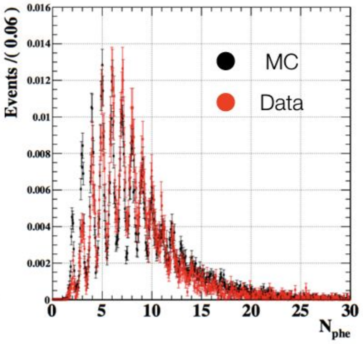
Contact:
angela.papa@unipi.it, angela.papa@pi.infn.it, angela.papa@psi.ch

GEANT4 | MPPC | DAQ | Analysis: Data vs MC









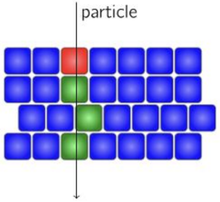
- Physical processes by GEANT4: From the first particle interaction in the medium to the photosensor

- PDE, gain/variation
- Cross-talk
- Saturation effect/ timing recovery
- Dark Counts

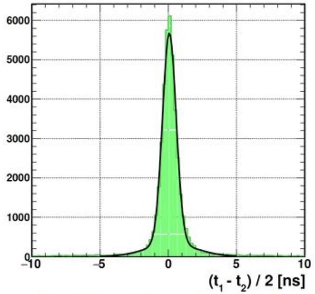
- Pre-amp gain
- Signal digitisation up to 5 GS/s
- Waveform analysis

From detailed MC to Data

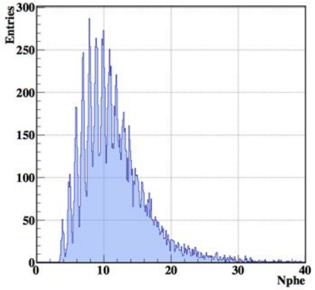
Trigger
offline selection:
hits in 3 layers
MC SQ BCF12 Saint-Gobain
Hamamatsu S13360-1350CS



3 layer time resolution O(550) ps



3 layer offline array charge collection (thr > 1.5 Nphe)

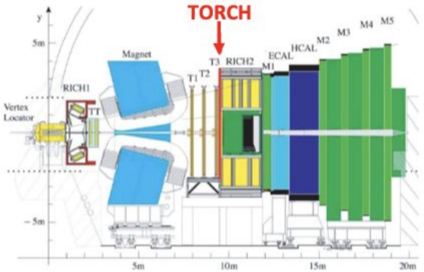


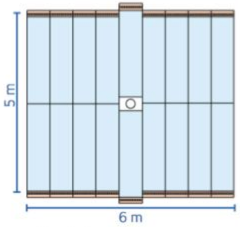
Addressed requirements with one of the first prototypes

Angela Papa
(Univ.Pisa/INFN/
Paul Scherrer Inst.)

The TORCH Time-Of-Flight Detector

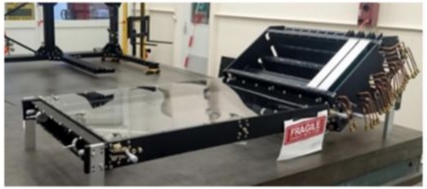
Neville Harnew, University of Oxford, **on behalf of the TORCH Collaboration**



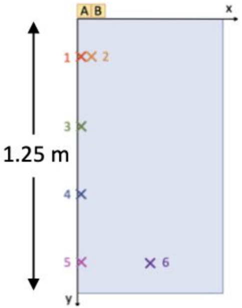


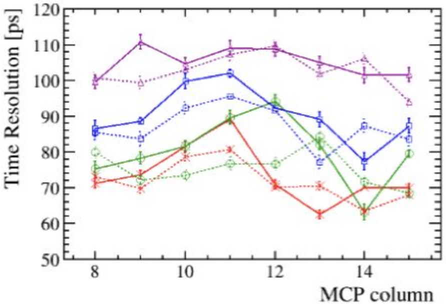
Modular arrangement

- TORCH is a time of flight detector for low momentum π/K (K/p) between 2-10 (20) GeV/c over a 10m flight path, for the Upgrade-II of LHCb.
- Cherenkov photons are emitted in a 10mm thick fused-silica plate, where they are focused onto an array of customised Micro-Channel Plate PMTs, specially developed in industry (by Photek UK).
- The aim is to achieve a timing resolution of 15 ps per incident particle, and with 30 detected photons, this means a resolution of 70 ps per single photon.



- A 1250 x 660 x 10 mm^3 TORCH prototype module has been tested in an 8 GeV/c mixed pion/kaon beam
- The plate has half length and full width of an LHCb TORCH module.
- The prototpe was instrumented with two 53 x 53 mm^2 square MCP-PMTs, each of 64 x 64 pixels (grouped into 64 x 8 pixels).





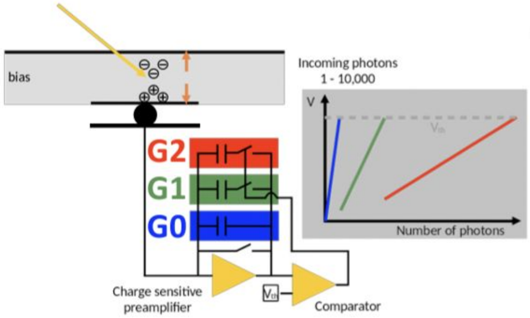
- The single-photon time resolutions have been determined in different columns of the MCP-PMTs for a range of beam positions in the quartz, and for pion and proton samples.
- 70 ps target resolution is achieved for beam positions closest to the MCPs.

Neville Harnew (Univ.Oxford)

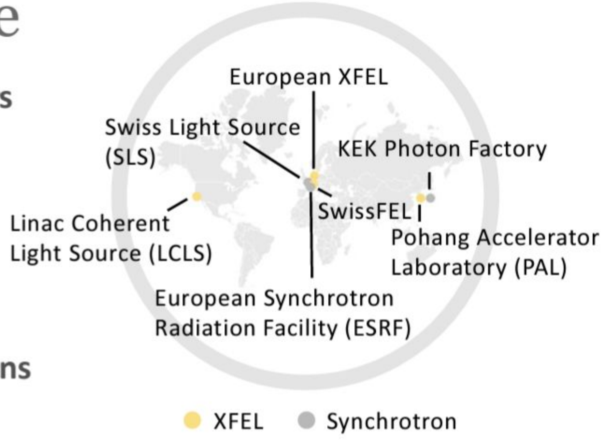
JUNGFRAU – A hybrid pixel detector for high-performance photon science

PAUL SCHERRER INSTITUT PSI

- JUNGFRAU has found widespread use at x-ray **free-electron lasers (XFELs)** and **synchrotron sources** worldwide

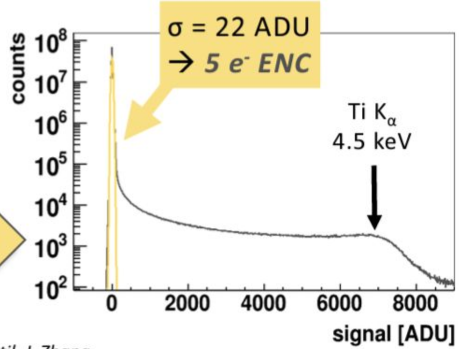


- It combines a **charge-integrating** architecture and three **dynamically switching**, linear gains per pixel
  → Dynamic range from **1 – 10^5 photons** between **1.2 keV – 12 keV**
  → Electronic noise always **below Poisson limit**



- Its success inspires ongoing research to **extend the sensitive energy range** to the low and high ends of the x-ray spectrum
  → 250 eV – 2 keV: **inverse LGAD** sensors (iLGAD)
  → 12 keV – 150 keV: **high-Z** materials

First LGAD results



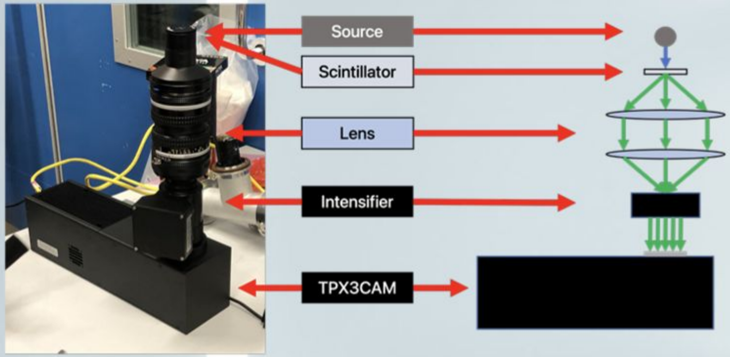
V. Hinger, R. Barten, F. Baruffaldi, A. Bergamaschi, M. Brückner, M. Carulla, R. Dinapoli, S. Ebner, E. Fröjdh, D. Greiffenberg, S. Hasanaj, J. Heymes, T. King, P. Kozlowski, C. Lopez Cuenca, D. Mezza, K. Moustakas, A. Mozzanica, C. Ruder, B. Schmitt, D. Thattil, J. Zhang*

*viktoria.hinger@psi.ch

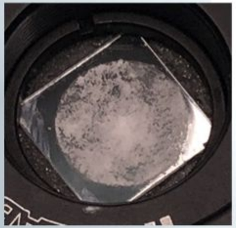
Viktoria Hinger (Paul Scherrer Institute)

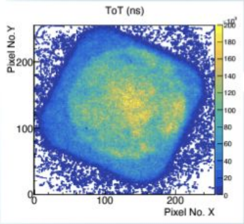
Novel Imaging Technique for Thermal Neutrons Using a Fast Optical Camera

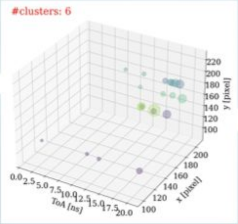
Tianqi Gao, Gabriele D'Amen, Sergey Burdin, Mohammad Alsulimane, Paul Campbell, Cinzia Da Via, Andrei Nomerotski, Adam Roberts, Peter Svihra, Jon Taylor, Alessandro Tricoli



Pre-cut			
Source	Reconstructed event frequency (Hz)	Minus Background (Hz)	Ratio to maxrate
Detector background	34.2	0	-
Neutron	67.5	33.3	1
Neutron @ 0.5 rate	52.5	18.3	0.55
Neutron @ 0.25 rate	40.8	6.6	0.2
Post-cut			
Source	Reconstructed event frequency (Hz)	Minus Background (Hz)	Ratio to maxrate
Detector background	0.8	0	-
Neutron	2	1.2	1
Neutron @ 0.5 rate	1.5	0.7	0.58
Neutron @ 0.25 rate	1.1	0.3	0.25







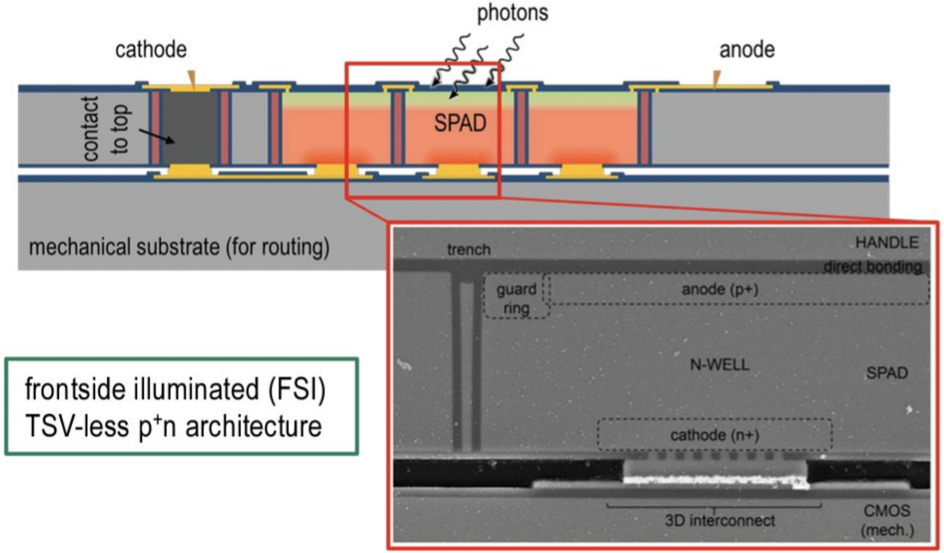
Goal	Develop a spatial and temporal sensitive thermal neutron imager based on timepix3 camera.
Set-up	Lithium-6 rich converter painted on LYSO crystal converts thermal neutron to photons, which is then detected by the camera.
Results	Three effective cutting parameters found for the dataset: 1. Integrated event ToT 2. Hits per event 3. Clusters per event
Conclusion	The thermal neutrons were successfully detected after suppressing the background with ad-hoc data analysis and predict the reduced neutron rate. Further improvements can be made on the experiment set-up and the neutron source.

Tianqi Gao (Univ.Manchester)

DEVELOPMENT OF SINGLE-PHOTON AVALANCHE DIODE ARRAY FOR PARTICLE PHYSICS AND MEDICAL IMAGING

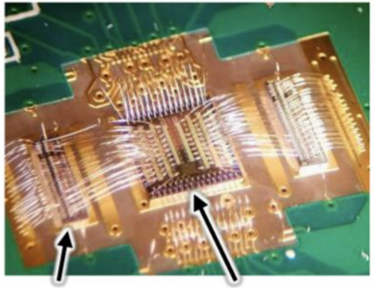
Université de Sherbrooke

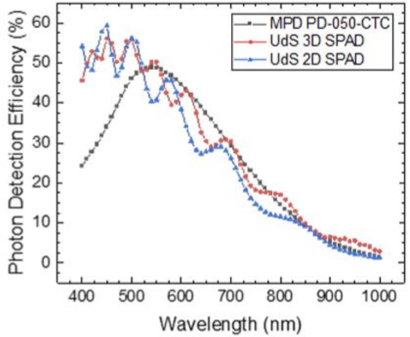
Characterization of 3D-integrated SPADs:



frontside illuminated (FSI)
TSV-less p^+n architecture

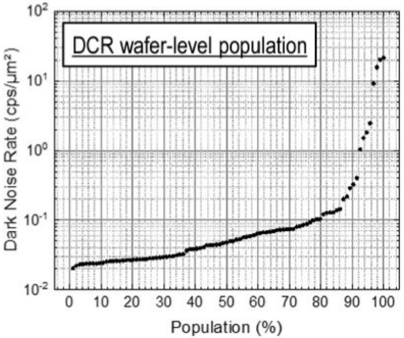
External readout circuit test setup





Wafer mapping

			65E-3	56E-3	288E-3	41E-3	16E+0			
	80E-3	50E-3	39E-3	39E-3	31E-3	26E-3	21E+0	40E-3	47E-3	
82E-3	66E-3	45E-3	2E+0	27E-3	27E-3	23E-3	26E-3	32E-3	53E-3	60E-3
73E-3	59E-3	9E+0	28E-3	24E-3	28E-3	23E-3	25E-3	30E-3	129E-3	72E-3
122E-3	50E-3	29E-3	24E-3	24E-3	30E-3	22E-3	27E-3	32E-3	58E-3	75E-3
2E+0	2E+0	44E-3	30E-3	26E-3	20E-3	24E-3	26E-3	29E-3	45E-3	74E-3
201E-3	68E-3	39E-3	27E-3	25E-3	24E-3	26E-3	27E-3	29E-3	48E-3	70E-3
217E-3	101E-3	324E-3	44E-3	20E+0	37E-3	28E-3	30E-3	44E-3	67E-3	93E-3
	130E-3	102E-3	1E+0	64E-3	73E-3	86E-3	53E-3	89E-3	144E-3	
			75E-3	138E-3	103E-3	405E-3	128E-3			



Frederic Vachon
(Univ.Sherbrooke)

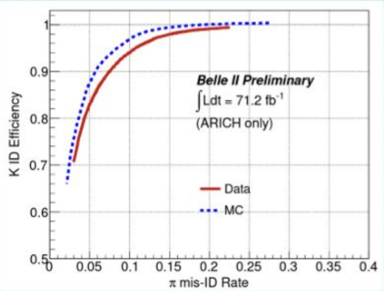
PID with the Belle II Aerogel RICH

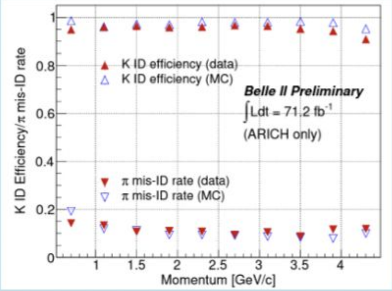
Rok Pestotnik, on behalf of the Belle II ARICH group
Institut "Jožef Stefan", Ljubljana, Slovenija

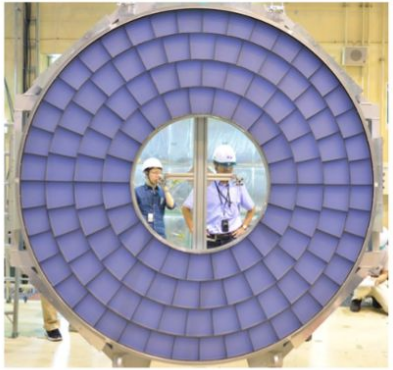
- Ring Imaging Cherenkov Detector with an aerogel radiator (ARICH) in the forward endcap of Belle II (1.5 T magnetic field)
- Cherenkov photons irradiated in two 2cm thick layers of silica aerogel (2x124 tiles) are propagated to the photon detector (420 HAPDs)
- very reliable operation since 2018
  - 94% of channels are fully operational;
  - No significant degradation
  - The ARICH runs almost without any human intervention.

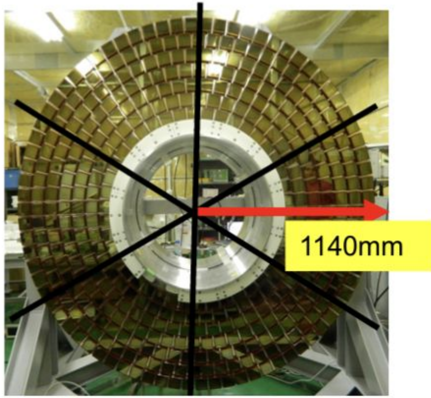
Particle Identification Performance

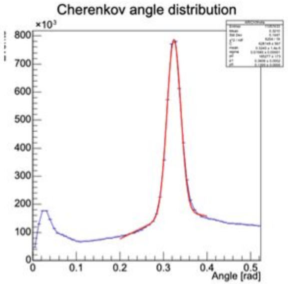
The kaon identification efficiency is above 96% in the wide momentum range from 0.5 to 4 GeV/c at a relatively low pion mis-ID probability of 10%.

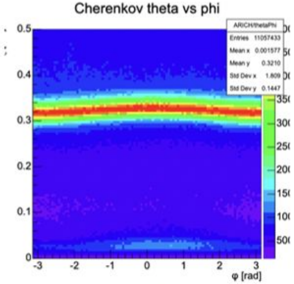


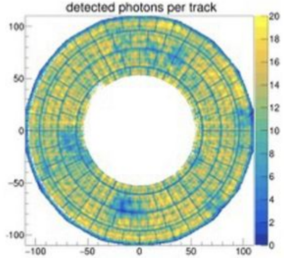












Summary

This poster section hosted a good number of excellent works on photon detection with applications in particle physics and medical imaging with relevant advances in:

- Photosensors development
- X-ray imaging detectors
- Cherenkov detectors
- Semiconductor detectors
- Detectors R&D
- Experiment upgrades

Thank you!