Application to Life Sciences and other societal challenges
Poster session summary

May 24th 2022

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Life Sciences

Spinning of nuclear and particle physics technologies to the benefit of medicine

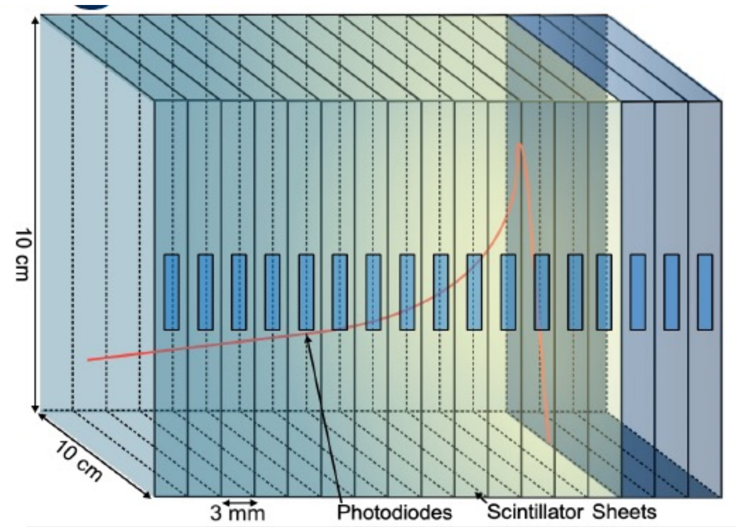
- Increasing accuracy in external and internal radiotherapy
- Novel implant technologies
- Improving cancer diagnostics tools

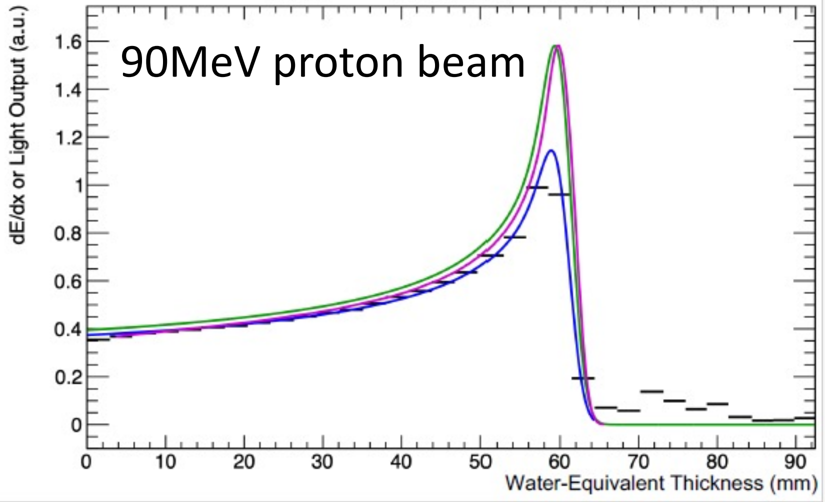
QuARC – A quality assurance range Calorimeter

Saad Shaikh, Raffaella Radogna, Fern Pannell, Ruben Saakyan, Spyros Manolopoulos, Derek Attree, Connor Godden, Simon Jolly

Detector able of fast **real-time range measurements** without compromising accuracy to determine range of protons in proton beam therapy.

- Stack of **water-equivalent** polystyrene plastic scintillator sheets [1] that **sample proton energy deposition** along path.
- Each coupled to a photodiode to **measure light output** proportional to proton energy (with quenching corrections).
- modular 32-channel ADCs for **zero-deadtime measurements at over 5 kHz**, read-out by an FPGA.
- **fit of depth-light curve to reconstruct Bragg curve** and recover proton range.

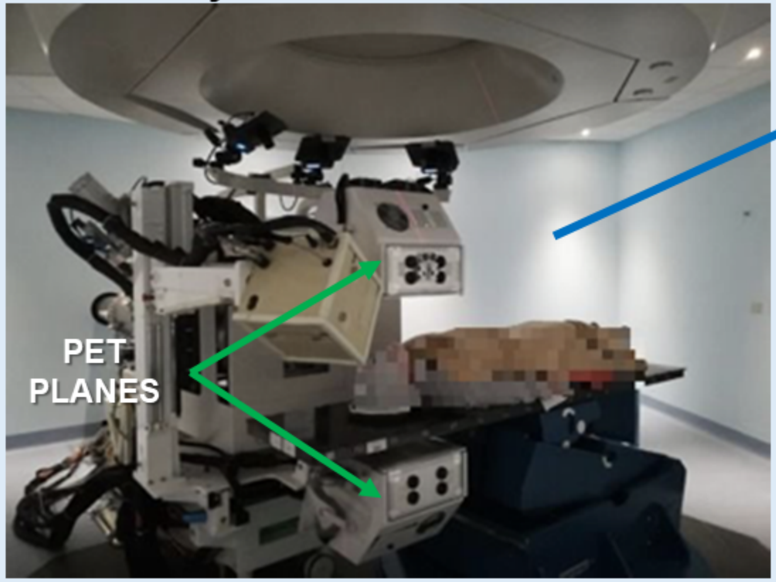




MLS ANALYSIS OF INSIDE IN-BEAM PET IMAGES FOR THE DETECTION OF MORPHOLOGICAL CHANGES IN PATIENT TREATED WITH PROTONTHERAPY

M. Moglioni, A.C. Kraan, A. Berti, P. Cerello, M. Ciocca, V. Ferrero, E. Fiorina, E. Mazzoni, M. Morrocchi, F. Pennazio, A. Retico, V. Rosso, G. Sportelli, V. Vitolo, M. G. Bisogni

Morphological changes in proton therapy are source of **range uncertainty**.



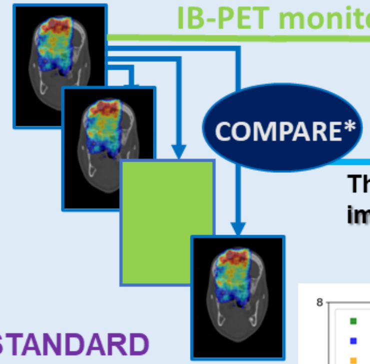
INSIDE

Bi-modal imaging system for in-vivo range monitoring in particle therapy.

fondazione CNAO
Centro Nazionale di Adroterapia Oncologica per il trattamento dei tumori

1. Istituto N
Council (CN
Italy

Our purpose is to assess the **sensitivity** of the **INSIDE IB-PET** system **in detecting anatomical changes**.



IB-PET monitored fraction

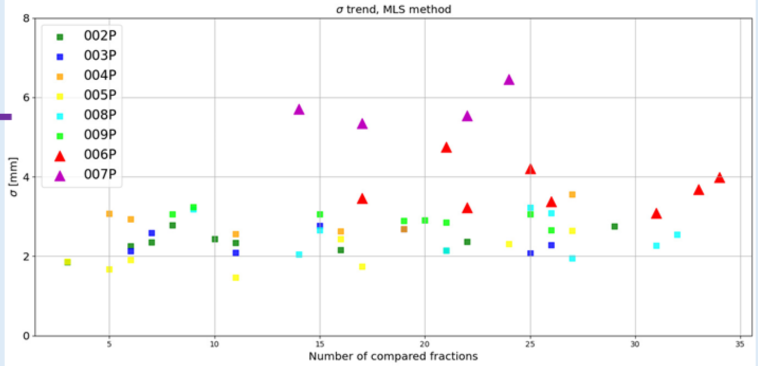
Eight proton treated patients: six patients without and two patients with morphological changes.

RANGE VARIATION ANALYSIS

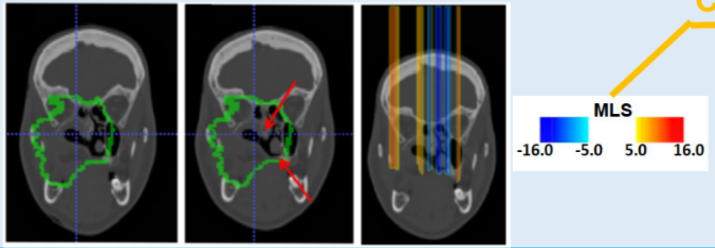
The Most-Likely-Shift (1st time applied to IB-PET images!) was compared with the Beam-Eye-View.

STANDARD DEVIATION

The sensitivity was evaluated by the standard deviation of the range difference distributions in unchanged patients (squares). It was found to be larger for the changed patients (triangles).



The **range differences obtained** were superimposed on the CT scan as **colorized maps**.



CHANGES DETECTED

Were localized in the same zones as the one observed with the control CT scans.

A Reconfigurable Detector for Measuring the Spatial Distribution of Radiation Dose for Applications in the Preparation of Individual Patient Treatment Plans

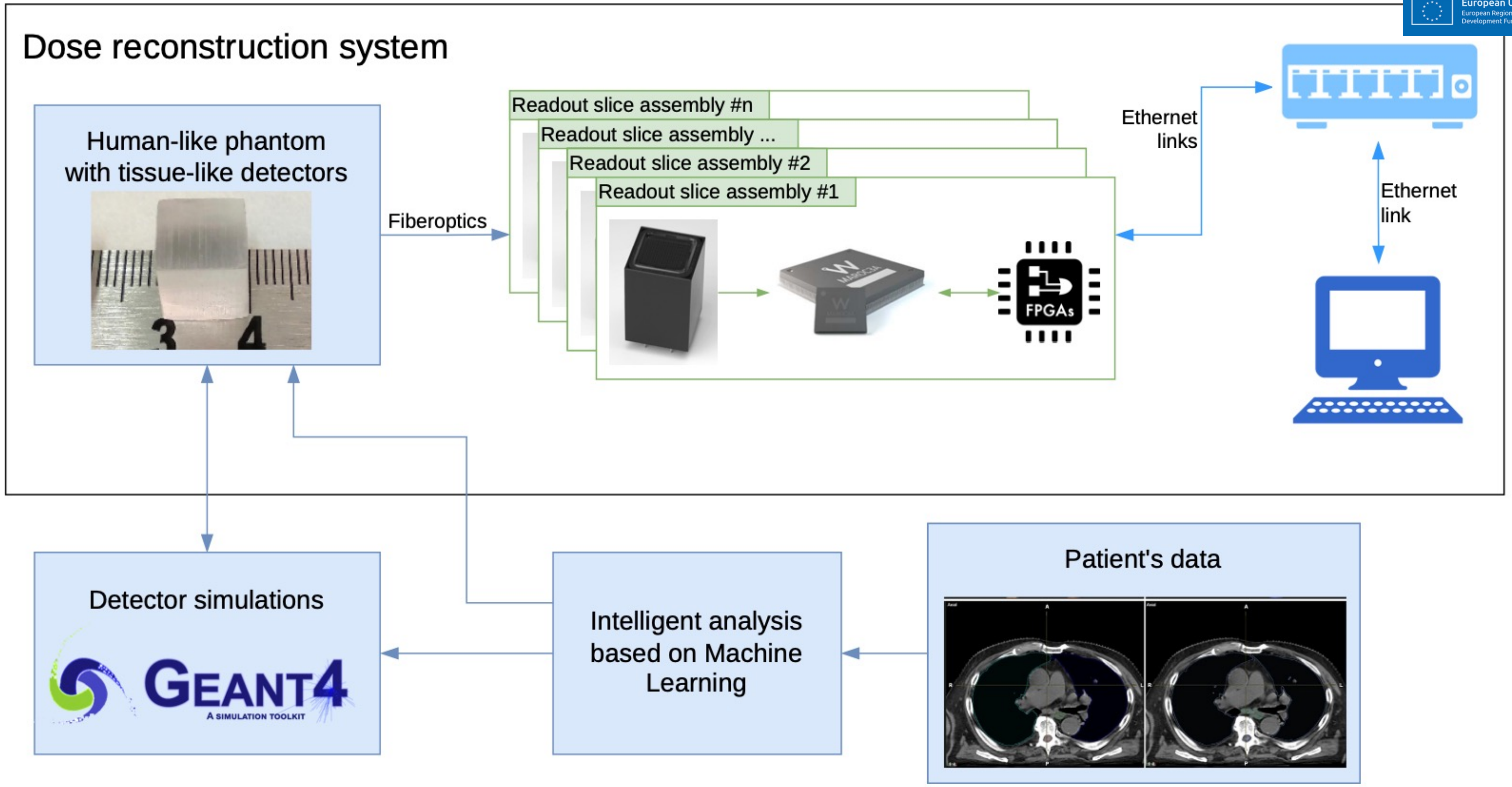
Maciej Kopeć, Tomasz Fiutowski, Paweł Jurgielewicz, Damian Kabat, Kamila Kalecińska, Łukasz Kapłon, Stefan Koperny, Dagmara Kulig, Jakub Moroń, Gabriel Moskal, Antoni Ruciński, Piotr Wiącek, Bartosz Mindur, and Tomasz Szumlak

European Funds Smart Growth
Republic of Poland
FNP Foundation for Polish Science
European Union European Regional Development Fund

Poster Summary

A novel detection system dedicated for personalised radiation therapy planning designed to have:

- a detection head allowing for changes in geometry dependant on patient's needs;
- a scalable Data Acquisition (DAQ) system supporting reconfigurability;
- a high-level software package using machine learning techniques to analyse medical imaging and generate needed detector geometry for the configuration and simulations.



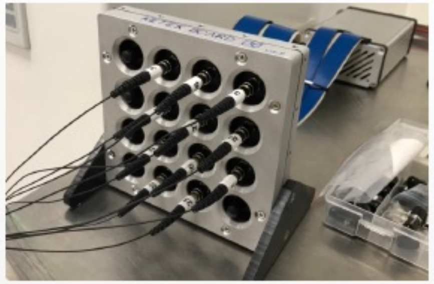
ORIGIN, an EU project targeting real-time 3D dose imaging and source localization in brachytherapy: commissioning and first results of a 16-sensor prototype

A. Giaz, N. Ampilogov, M. Caccia, S. Cometti, W. Kam, S. O’Keefee, M. Martyn and R. Santoro

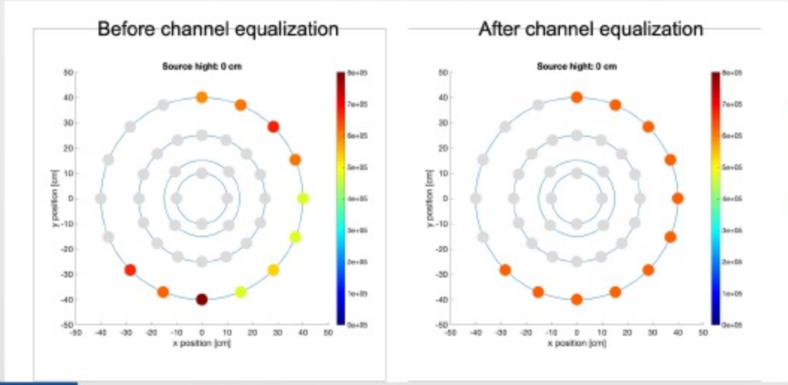
- The ORIGIN project addresses the urgent need to deliver more precise and effective Brachytherapy treatments
- Development of innovative optical fibre dosimeters with inorganic scintillators on the tip.

BRACHYTHERAPY

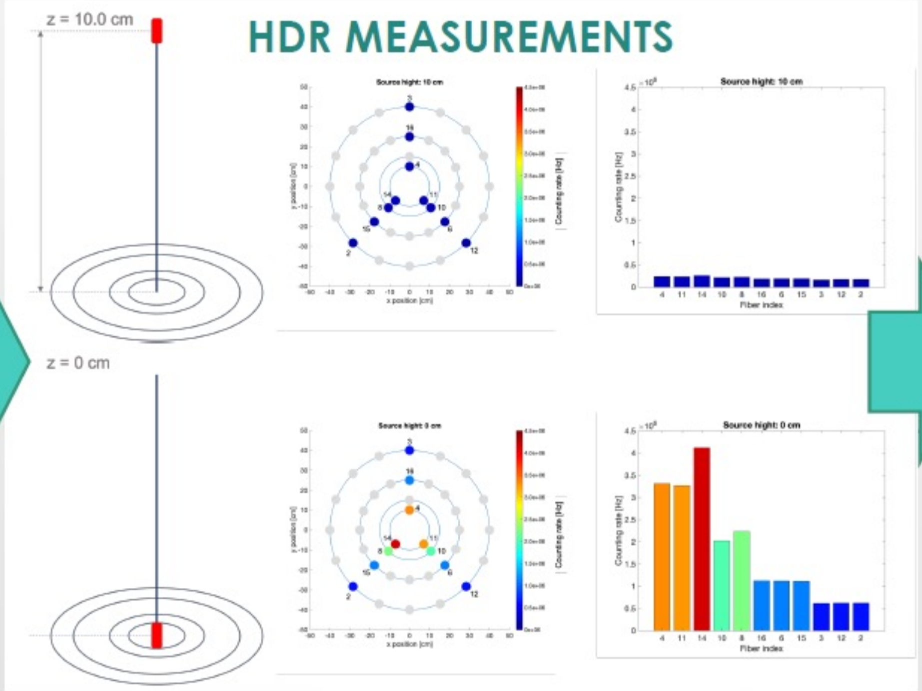
	Source	Activity	Implantation	<Eγ>	λ @ <Eγ>
LDR	^{125}I	15 MBq	Permanent	35 keV	3 cm
HDR	^{192}Ir	~100 GBq	Temporary	380 keV	10 cm



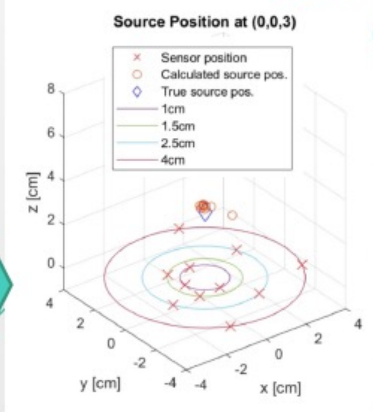
EQUALIZATION



HDR MEASUREMENTS



SOURCE LOCALIZATION



PHOTONICS21
PHOTONICS PUBLIC PRIVATE PARTNERSHIP
ORIGIN

Astroparticle experiments to improve the biological risk assesment of exposure to ionizing radiation in the exploratory space missions

Alessandro Bartoloni , Nan Ding, Gianluca Cavoto, Cristina Consolandi, Lidia Strigari

Research Topic

Astroparticle Experiments to Improve the Biological Risk Assessment of Exposure to Ionizing Radiation in the Exploratory Space Missions

frontiers in Astronomy and Space Sciences

The actual and next decade will be characterized by an exponential increase in the **exploration of the Beyond Low Earth Orbit space (BLEO)**. In this context, a detailed space radiation field characterization will be crucial to optimize radioprotection strategies to assess the risk of the health hazard related to human space exploration and to reduce the damages potentially induced to astronauts from galactic cosmic radiation.

On the other side, **since the beginning of the century, many astroparticle experiments** aimed at investigating the unknown universe components have been collecting enormous amounts of data regarding the cosmic rays (CR) components of the radiation in space.

Such experiments are actual cosmic ray observatories, and the collected data (cosmic ray events) **cover a significant period of time , measuring in large energy windows and in the full range of the CR components and their radiation quality**. The collected data contains valuable information that can enhance the space radiation field characterization and, consequently, improve the radiobiology issues concerning the human space exploration.

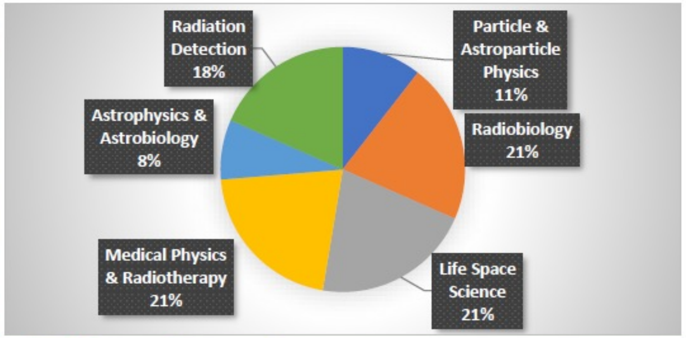
The research topic initiative was launched in

November 2021

- > 1500 views (topic & articles)
- > 20 expected contributions
- > 5 abstracts received
- 1 published manuscript

Open for articles submissions !

Contributors from different research areas



Topic Editors

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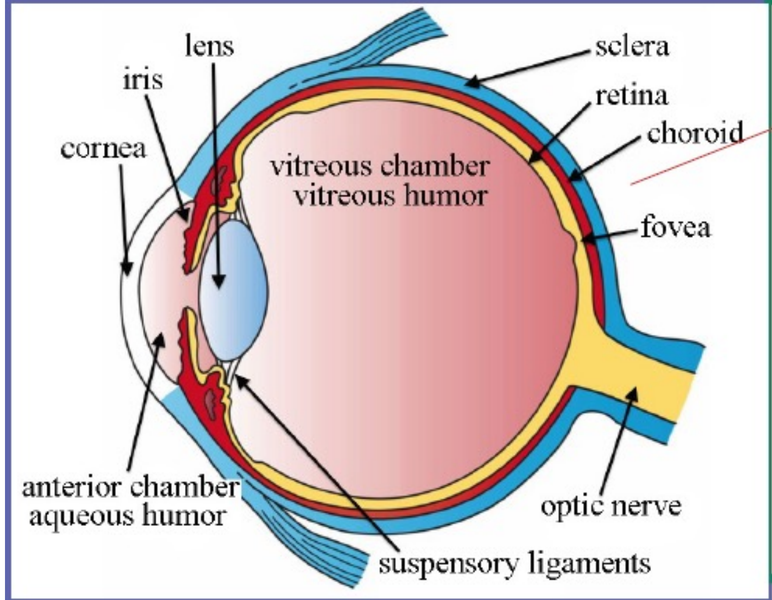
Bologna, Italy

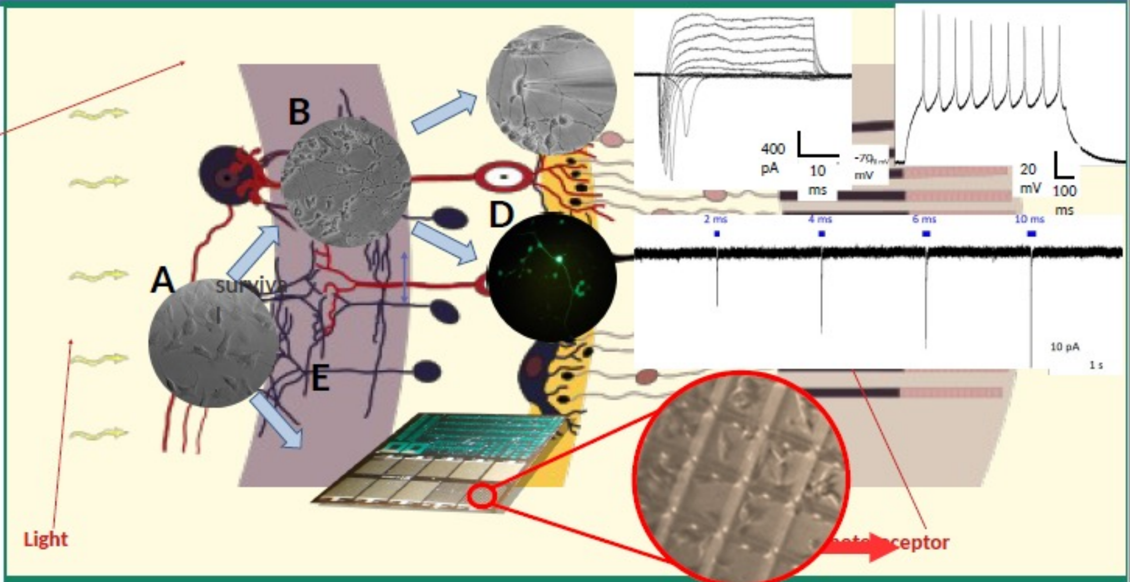
SCAN the QR CODE to participate !

Visual prosthesis based on Silicon PhotoMultipliers: the SPEye project

P.W. Cattaneo on behalf of the SPEye Colllaboration

Abstract: Several retinal degenerative diseases like age-related macular degeneration (AMD) and retinitis pigmentosa (RP) cause total or partial blindness to about 1 over 4000 people in the world for a total of ~1.5 milion. Those diseases cannot be cured, the only possible improvement of life quality for the people affected is a visual prosthesis compensating the retinal damage. Such devices have been developed with interesting but limited results. We suggest an improved version based on subretinal implantation of SiPM arrays which should be able to stimulate the healthy part of the retina at low power and high visual acuity.

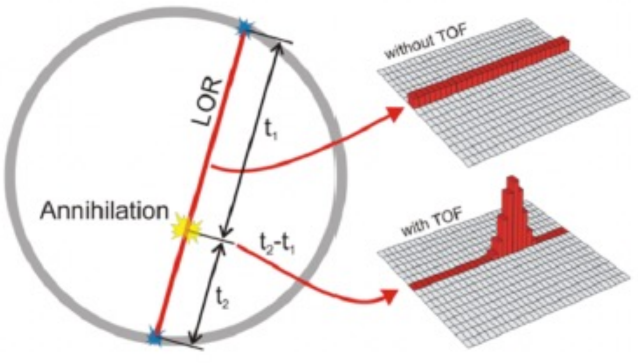




Rods, cones and nerve layers in the retina. The front (anterior) of the eye is on the left. Light (from the left) passes through several transparent nerve layers to reach rods and cones (far right). A chemical change in the rods and cones send a signal back to the nerves. The signal goes first to the bipolar and horizontal cells (yellow layer), then to the amacrine cells and ganglion cells (purple layer), then to the optic nerve fibres.

Fast Timing MPGD for ToF-PET

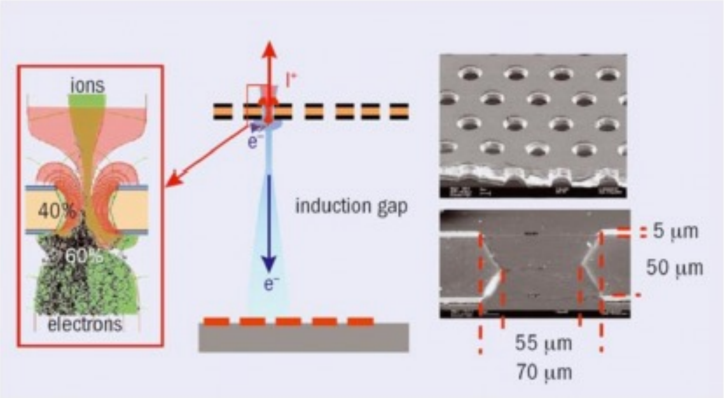
Filippo Errico, Anna Colaleo, Marcello Maggi, Antonello Pellecchia,
Raffaella Radogna, Piet Omer J. Verwilligen



PET is an effective functional imaging technique especially for cancer diagnosis. Its performance is strictly connected to the ability to detect and reconstruct photons emitted by the positron - electron annihilation. Its sensitivity is enhanced when time information are included (ToF-PET). The measure of the detection time difference between the two photons leads to a higher contrast image and more accurate diagnoses.

Studies for a possible development of a ToF-PET based on MPGD will be shown. MPDG has a very good spatial and time resolution and very low price, making it suitable for a full-body scanner.

Further improvement in the time precision (suitable goal is to achieve values of the order of 100 ps) could be reached thanks to the FTM design, where multiple layers of MPGD compete in better measuring time information.



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Sezione di Bari

Performance of monolithic BGO crystals as gamma detectors using a Neural-Network event decoding algorithm

G. Sportelli, M. Morrocchi, M. G. Bisogni, P. Carra, E. Ciarrocchi, V. Rosso, N. Belcari

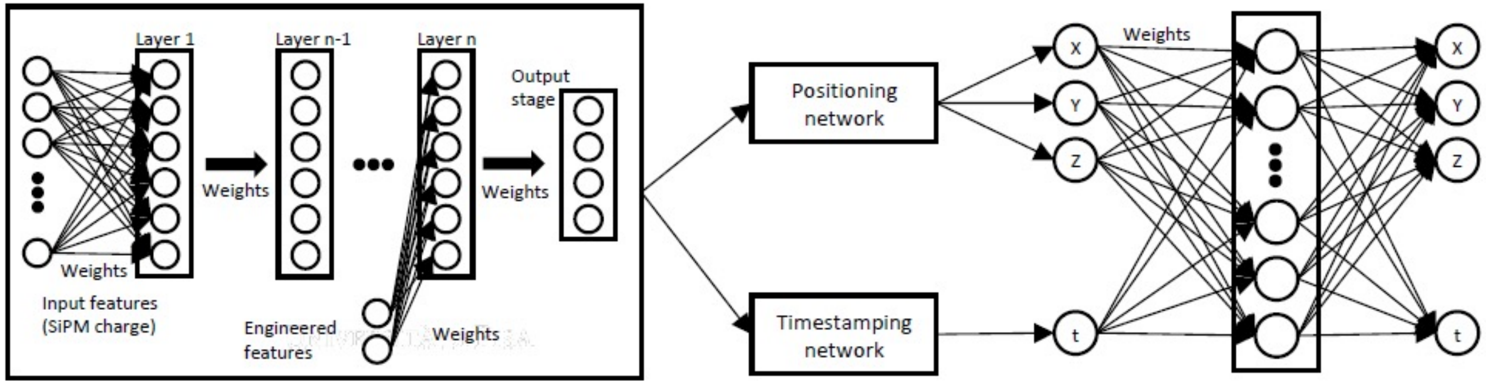
BGO has been the preferred scintillating material in PET applications for decades, until the need for time-of-flight acquisitions moved the preference to LYSO a faster, but more expensive and less versatile scintillator. In this work we demonstrate experimentally and in simulation that with the use of AI decoding algorithms, BGO can comply with time-of-flight speed requirements and thus become a competitive candidate for gamma ray detection.

Achieved performance (experimental data)

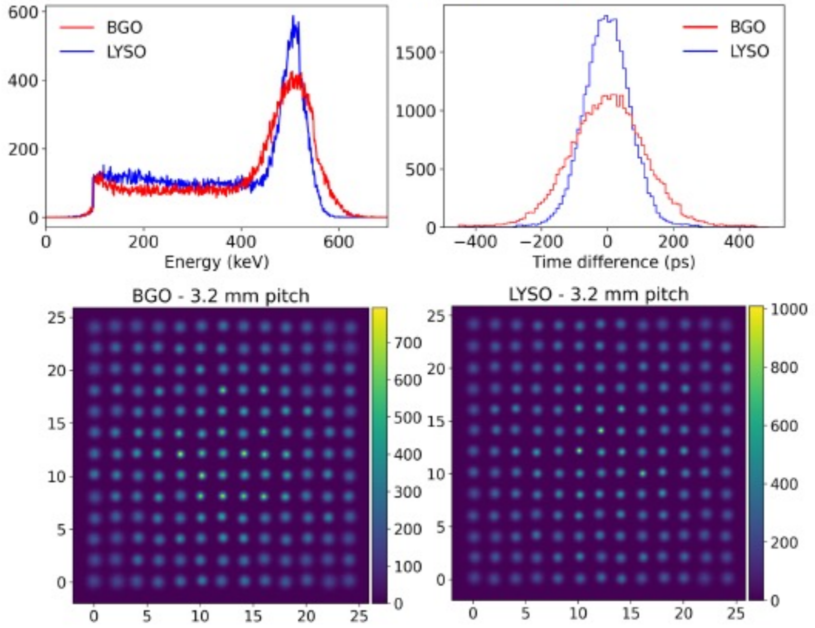
	CTR (ps)	SR (mm)	Energy Res. (%)
3.2 mm LYSO	160	0.8	12.7
3.2 mm BGO	320	0.8	20.2

DAQ based on the HRFlexToT ASIC

Neural network architecture



Energy spectra (top left), CTR (top right) and flood maps (bottom)



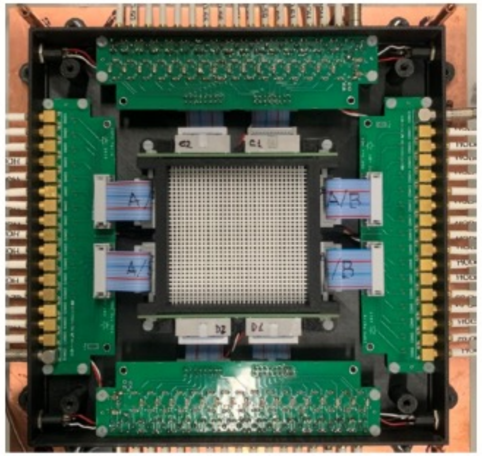
The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n. 688735 (Photonics Based Sensing ERA-NET Cofund), Regione Toscana (PRSE 2012-2015 approval n. 11131/2016) and VLAIO.

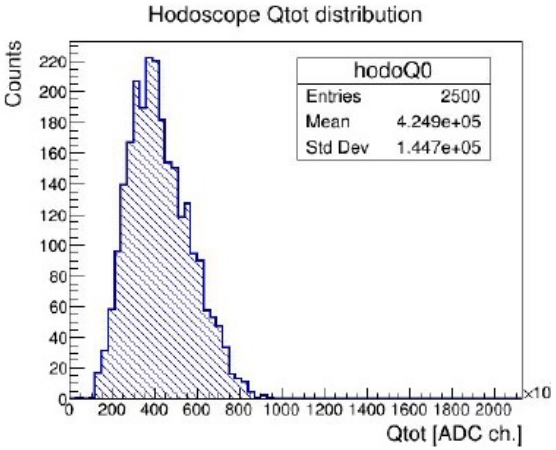
Characterisation of a scintillating fibre-based hodoscope exposed to the CNAO low-energy proton beam

Riccardo Rossini, Roberto Benocci, Roberto Bertoni, Maurizio Bonesini, Massimiliano Clemenza, Alessandro Menegolli, Erik Vallazza, Gian Luca Raselli, Ludovico Tortora, Marco Prata, Marco Pullia, Massimo Rossella

UNIVERSITÀ DI PAVIA
UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA
INFN
CNAO Centro Nazionale di Adroterapia Oncologica

- Beam hodoscope, active area 6x6 cm^2, 64 scintillating 1x1 mm^2 fibres, to be used in the FAMU experiment as a muon beam monitor (at RAL, UK), aimed to perform a precision measurement of the proton Zemach radius in muonic hydrogen atoms
- Calibration with at the CNAO synchrotron in Pavia (Italy) with proton beams at 125, 150 and 175 MeV with very low rate (50 Hz)
- Protons at 150 MeV are chosen as their –dE/dx curve is similar to the one of the 60 MeV/c negative muons in the FAMU experiment
- The single proton signal at 150 MeV allows to calibrate the detector in order to enable muon counting at the high rate RAL muon beam





Characterization of charge sharing and fluorescence effects by multiple counts analysis in a Pixie-II based detection system.

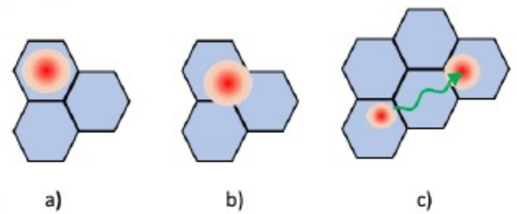
P. Delogu, V. Di Trapani, D. Dreossi, B. Golosio, R. Longo, L. Rigon, P. Oliva

INFN

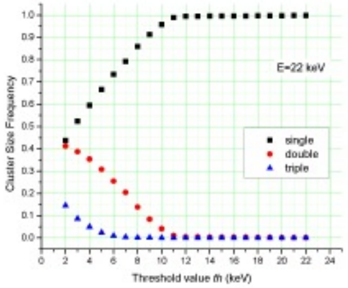
UNIVERSITÀ DI SIENA 1240

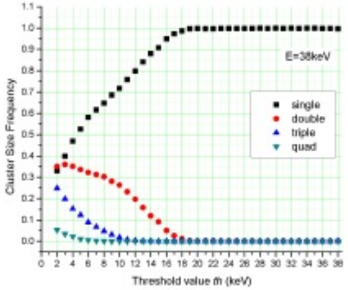
- The imaging performance of X-ray Photon Counting Detectors (XPCD) based on high Z crystal sensors is mainly affected by the simultaneous detection of a single interacting photon by different pixels. Such multiple counts worsen the spatial resolution and cause loss of spectral resolution.
- In this work we presents an experimental study for the systematic characterization of multiple counts detection in a Pixirad-I/Pixie-II system.

The detection system: Pixirad/Pixie II



An interacting photon releasing all its energy can be registered by a single pixel a) or by a "cluster" of different adjacent pixels due to charge sharing b). Fluorescence can lead to multiple counts, even from disjointed clusters c).

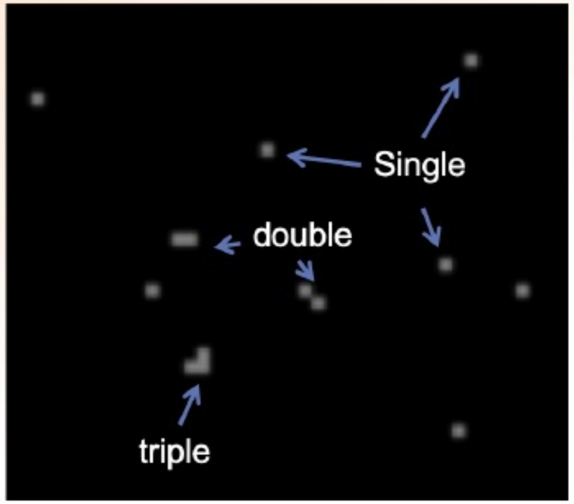




Using photons of energy below the Cd K-edge and relative threshold (Threshold/Energy) set to 0.1, the relative frequencies of clusters corresponding to single, double and triple counts are respectively of 0.4, 0.4 and 0.2. Choosing appropriate values of the discrimination thresholds, multiple counts can be avoided with no loss in detection efficiency.

When imaging with photons having energy above Cd K-edge, clusters of more than 4 pixels are observed. In this case the threshold can be set to record only "primary" events, at the cost of a reduction in the detection efficiency.

We acquired large stacks of images, for each of which only few photons interact in the whole sensor



- We observed, in single images, the presence of "clusters" of different size
- **By counting the clusters of different size, we studied the dependence of the multiple counts on the energy of the impinging photons and on the discrimination threshold**

Other societal challenges

Spinning of nuclear and particle physics technologies to the benefit of society

- Homeland security
- Environmental sustainability
- Cultural Heritage
- Novel science divulgation
- Instrumentation on the crossroads between nuclear and applied physics and beyond

Performances of scintillators applied to Special Nuclear Material (SNM) measurements in the field of Nuclear Safeguards, material verification and Nuclear Security

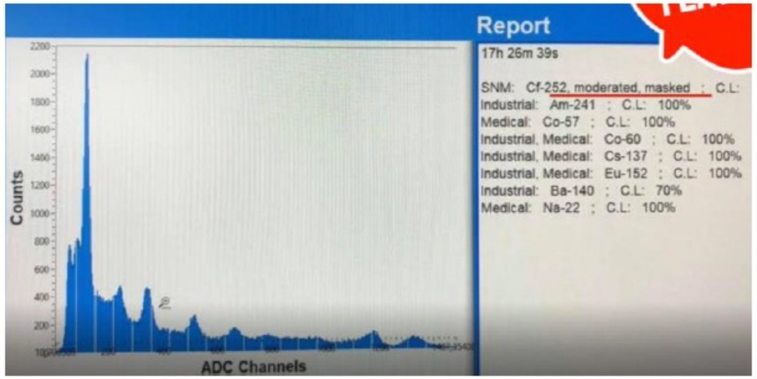
M. Morichi, M. Corbo, G. Mangiagalli

SCENARIO:

- **nuclear threats** are still an actual problem for homeland security and for counter terrorism agency as reported by IAEA through the **ITDB** (3497 incidents from 1993 to 2018)
- **SNM out of regulatory control** can be used by terrorists to produce **dirty bombs** (conventional explosive coupled to radioactive material) to contaminate national strategic areas and to rise panic in the common people

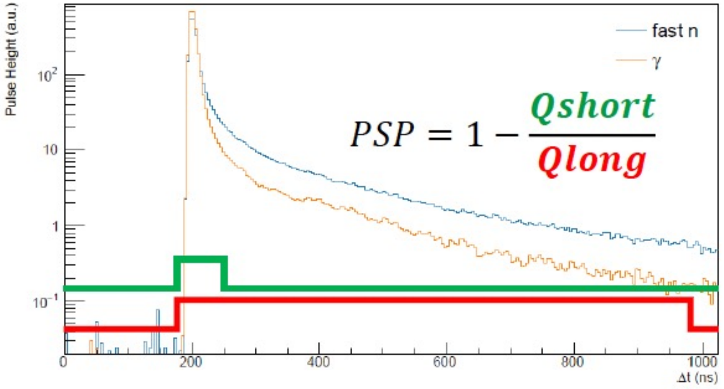
METHOD:

- **Innovative scintillators** coupled to **digital electronics with pulse shape processing (PSP) firmware** allow to new measurements method that are step-change respect the current detection systems.
- **EJ309 liquid scintillator** is used for detect both gamma and fast neutrons (allowing energy measurement of the neutrons) with a double integration charge gate to perform **PSP**
- **$CeBr_3$** is used for gamma spectroscopy as a tradeoff between good resolution plus low intrinsic background and easiness of use



SOLUTION:

- **SNIPER-GN** is a Backpack Radiation Device (BRD) designed by CAEN and equipped with EJ309 and $CeBr_3$. It can perform gamma and neutron counting, gamma spectroscopy identification and **is the only instrument in the world that performs neutron source identification in less than 1 min through the neutron measument**
- **SNIPER-GN patented algorithm** allows for discrimination between Cf-252, Am/Be, Am/Li, U and Pu with. In less than 1 min can also determine the **measurement condition** indicating the presence of **masking source, moderators or lead shielding**
- It exceed international standards like: IEC62327,ANSI N42.34, ANSI N42.53

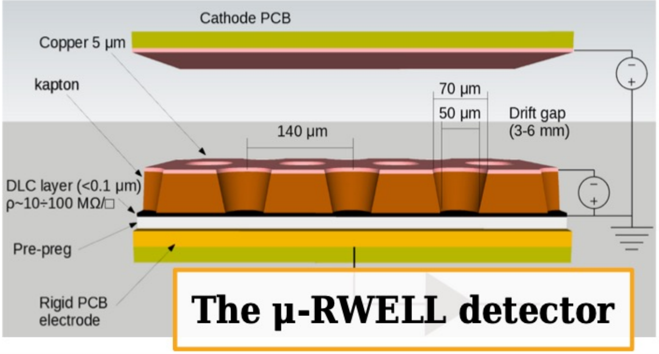


$$PSP = 1 - \frac{Qshort}{Qlong}$$

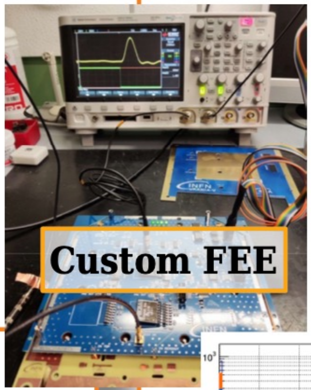
uRANIA: a micro-Resistive WELL for neutron detection

Matteo Giovannetti LNF-INFN on behalf of the uRANIA-V project

u	micro
R	esistive
A	dvanced
N	eutron
I	maging
A	pparatus

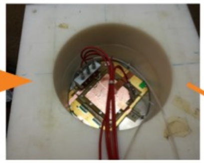


The µ-RWELL detector



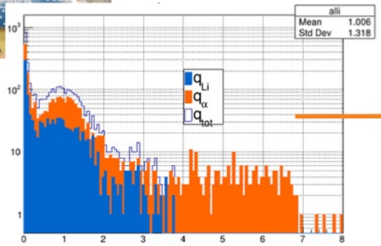
Custom FEE

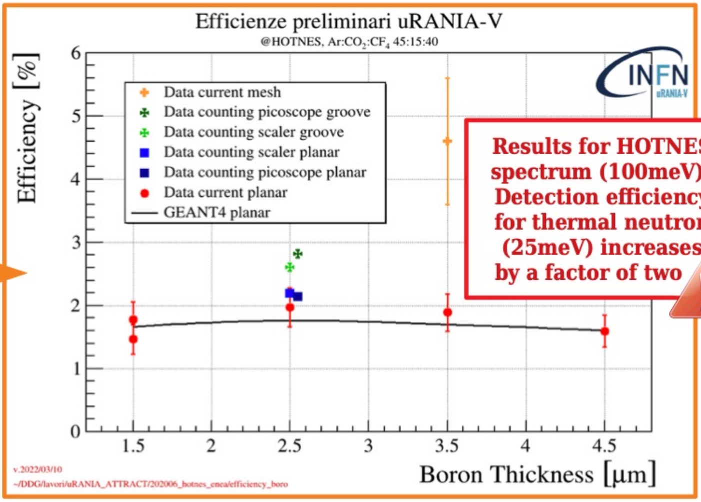
HOTNES ENEA test facility



Summary and results

From **simulations**, to **results**!





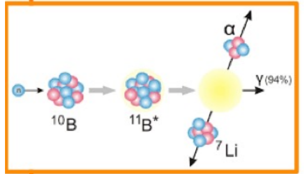
Results for HOTNES spectrum (100meV)! Detection efficiency for thermal neutron (25meV) increases by a factor of two

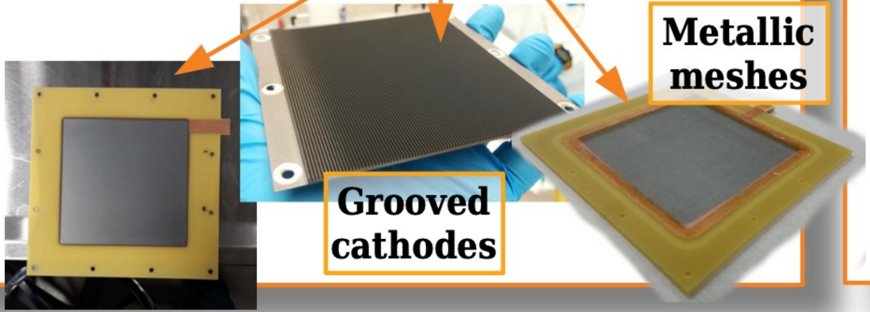
- For the **planar cathode** a scan for different ^{10}B thickness has been performed in current mode, measuring an efficiency ≈ **1.5÷2.0%**
- The palanar ^{10}B-coated **cathode** **+** ^{10}B-coated **mesh** configuration characterized in current mode exhibits an efficiency of **4.6±1.0%**
- The counting mode measurements, performed for the ^{10}B-coated **planar** and **grooved** cathode layouts show the following results:
  - Planar → **2.19±0.05%**
  - Grooved → **2.61±0.06%**

^{10}B neutron converter

Due to the **^{3}He shortage** a call for alternative solutions for thermal neutron detection arise. A **^{10}B conversion stage** facing the gas gap, through **nuclear capture**, transforms a standard µ-RWELL in a **thermal neutron detector,** reaching efficiency up to **10%** for single detector plane.

Different **converter geometries** are accessible:





Planar cathodes

Grooved cathodes

Metallic meshes

Design and characteristics of a novel Single Plane Compton Gamma Camera based on GAGG scintillators readout by SiPMs

Om Prakash Dash, Tomislav Bokulić, Damir Bosnar, Mihael Makek and Petar Žugec
Department of Physics, Faculty of Science, University of Zagreb, Bijenička c. 32, 10000 Zagreb, Croatia

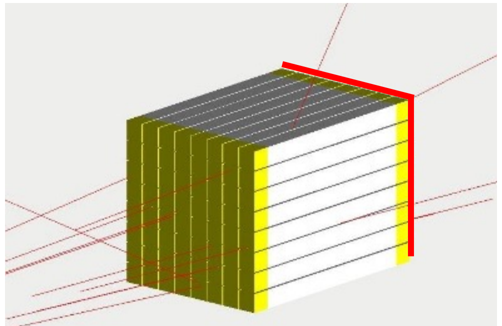


Figure 1. Schematic of the detector module:
Yellow- GaGG, white- lightguide, Red - SiPM.

A novel concept of a Single Plane Compton Gamma Camera based on scintillator pixels read out on only one side by SiPMs. The scatterer layer made of 8x8 array of 3 x 3 x 3 mm^3 GaGG scintillators, with a 3.2 mm pitch. Matching plexiglass lightguides connect the scatterer layer to another 8x8 array of 3 x 3 x 3 mm^3 GaGG scintillators which serves as the absorption layer. The latter is coupled to a matching array of 8x8 silicon photomultipliers. The scatterer and the absorber pixels in one column are read out by the same SiPM thus minimizing the number of readout channels.

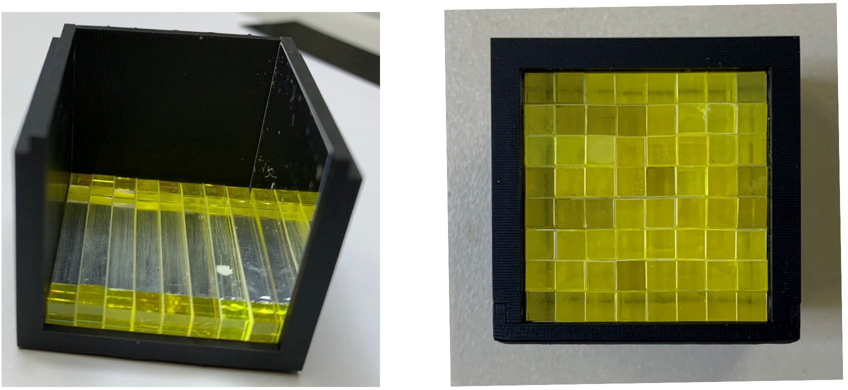


Figure 2. Detector assembly: first row of pixels after placing ESR from three sides in the box (left), the final assembly (right).

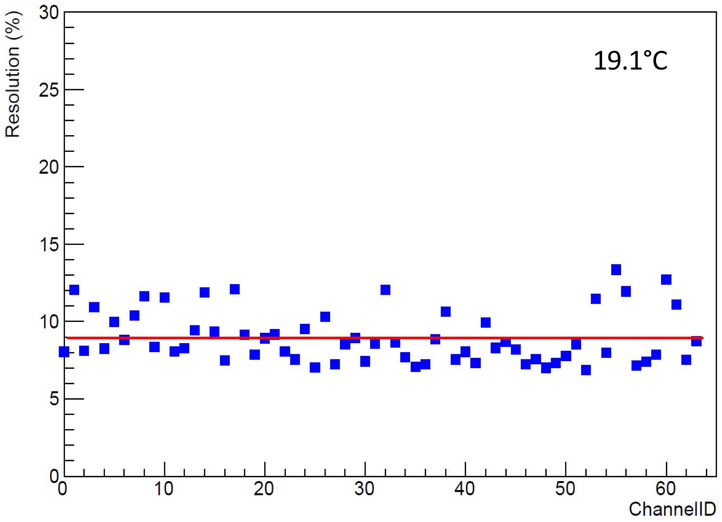


Figure 3. Characterization of the energy resolution in at 662 keV in the front-layer pixels

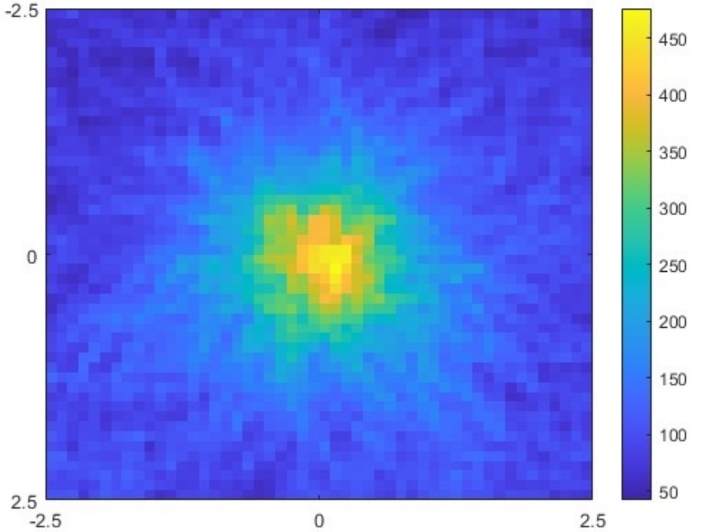


Figure 4. Reconstructed image using back-projection algorithm on the measured Compton events

Open-Sky muon tomography for Glacier Monitoring

A. Cervelli (INFN-Bologna) , S. Rabaglia (Universitá di Bologna) , M. Sioli (Universitá di Bologna)

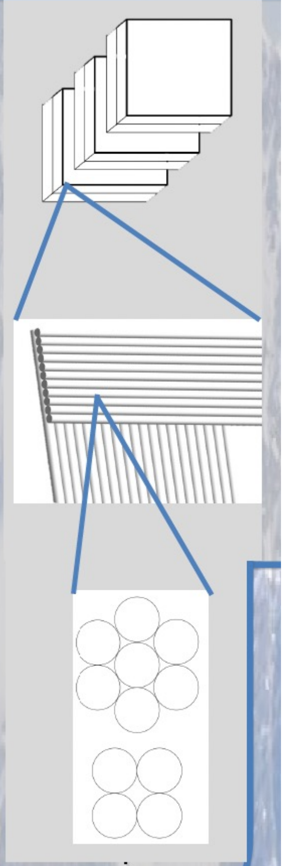
The project goal is to to achieve an ice thickness resolution of O(5m) that corresponds to an **angular resolution** on the incoming muon tracks **of O(7mrad)**.

Open-sky operations needs **fast detector to reduce to negligible level background** tracks not passing through the target.

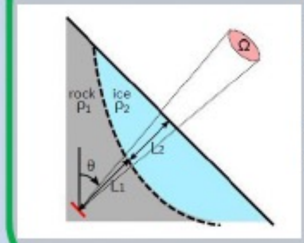
Detector requirements: reduced number of channels, low maintenance needs, able to operate in adverse weather with simple powering scheme.

Detector Design:
- **5 pairs of plastic planes** with embedded scintillating fibers bundles, running on orthogonal axes
- **Plane dimensions 1mx1m**
- Fiber bundle diameter 6cm
- One phodotedector per bundle: **number of channels O(2000)**

Optimization was done with different configurations in terms of detector length and plane spacings.



Glacier melting is one of the most visible effects of global warming.
Muon tomography can shed light on glacier thickness and their melting processes.
Only few glaciers have underground access → **open-sky detectors**



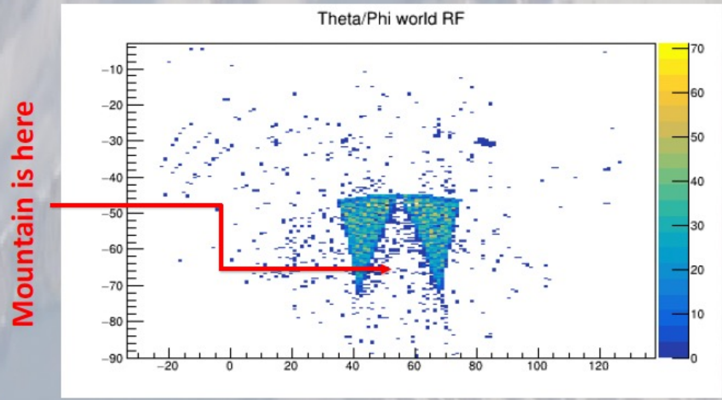
Measuring muon fluxes with good angular resolution allow for glacier-bedrock interface depth.

Only assumption is made on the overall bedrock+ice thickness T.

$$\Phi(p,\theta,l) = \Phi_0 * e^{\frac{l}{X}}$$

$$X = L_1\rho_1 + L_2\rho_2 \;; \quad T = L_1 + L_2$$

A first simulation with reduced statistics showed first results for a direct measurement of bedrock-glacier interface, and a higher statistics simulation is in preparation to understands the exposure time needs for the detector

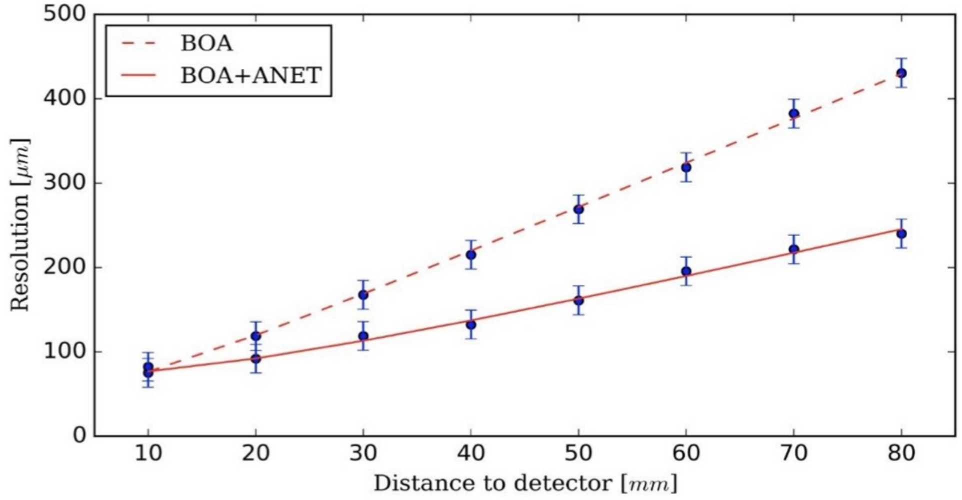


The ANET Compact Neutron Collimator

Valeria Monti on behalf of the ANET collaboration
(Universita degli studi di Torino and INFN Torino, Italy

Development and construction of a **compact multichannel collimator** for neutron imaging

CONCEPT → Compact scalable structure alternating B_4C and air channels. Dynamic continuous path for a homogeneous irradiation of the sample.
RESULTS → Improvement of the resolution measured at two different neutron imaging beams (BOA @ PSI Swiss, PAVIA LENA reactor Italy). First tomography examples.



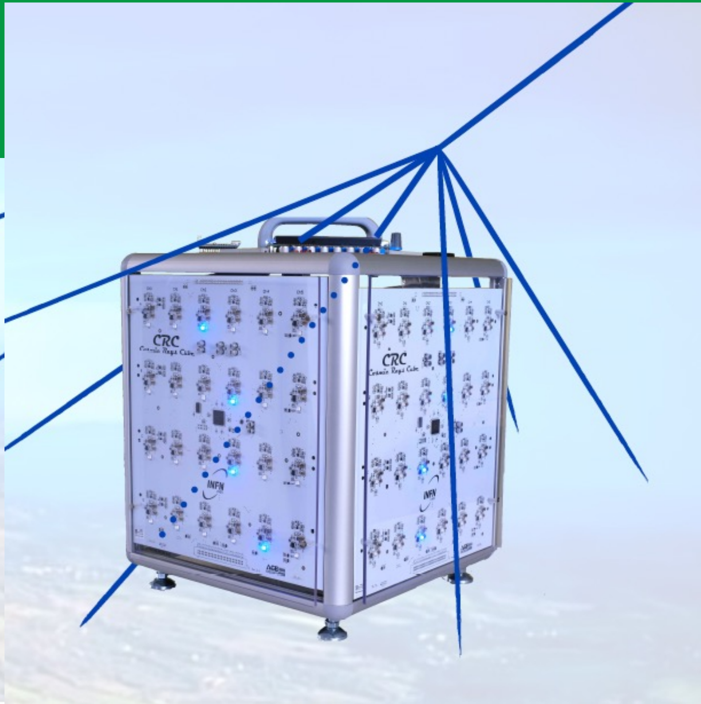
Resolution at different distances of the sample from the scintillator at BOA neutron beam with and without the ANET CNC.

Tomography of a Dane iron fibula (circa X century d.C.). Red areas show a higher attenuation w.r.t green areas and are associated with hydrogen-rich mineral phases, which implies an advanced corrosion stage.

ANET Compact Neutron Collimator CNC.

Measurement of the muon flux in the bunker of Monte Soratte with the CRC detector

Giuliano Gustavino



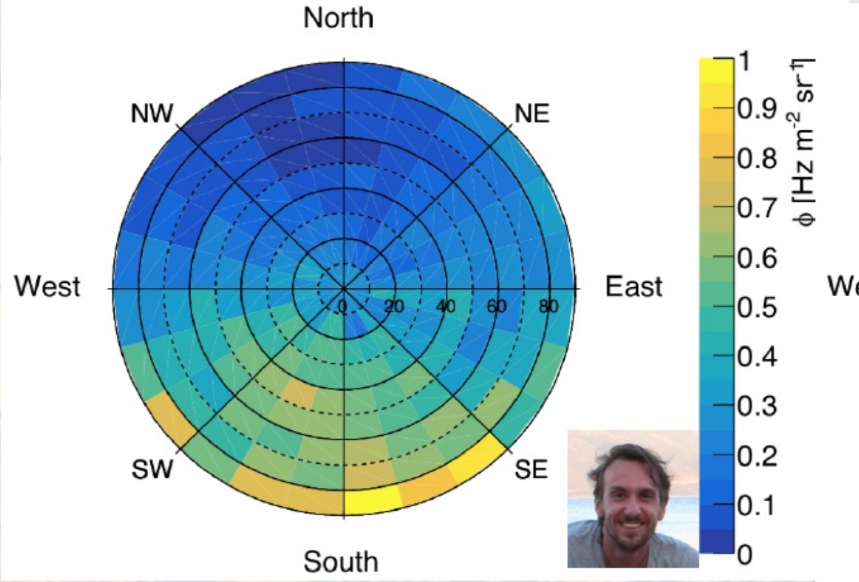
The **Cosmic Ray Cube** is a portable tracking device conceived for outreach activities.

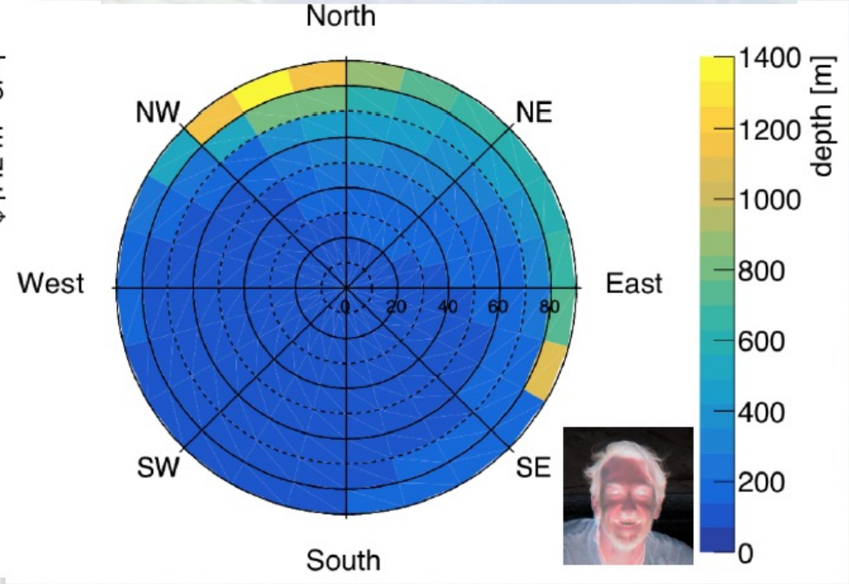
- It consists of 48 scintillating bars with WLS fibres coupled to SiPMs.
- Its operation requires only the standard electrical power.

The detector was used to measure the differential muon flux inside the bunker of Monte Soratte (Italy) a suitable location for the Ptolemy experiment.

The differential muon flux Φ_μ scan highlights the details of the mountain above the bunker:

➡ providing a map of the rock thickness that surrounds the detector.





REFERENCE

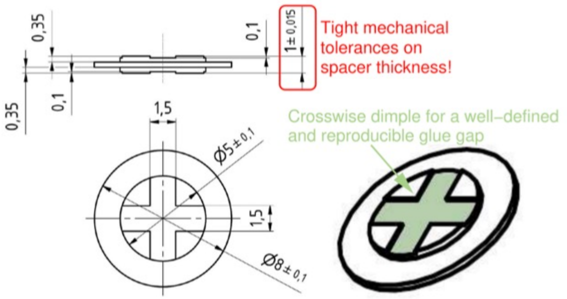
Giuliano Gustavino

Qualification of New Companies for the Production of Resistive Plate Chambers

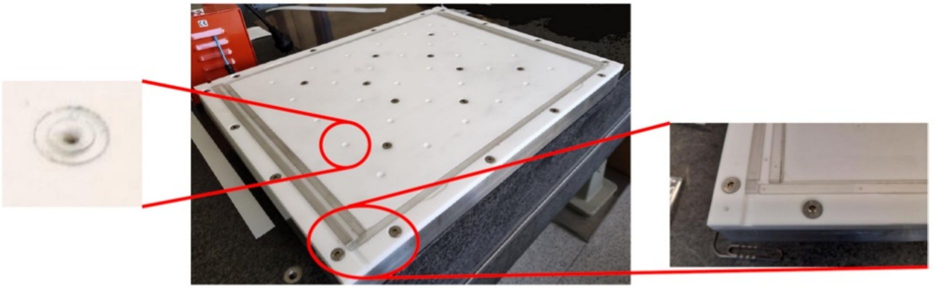
O. Kortner, H. Kroha, D. Soyk, T. Turković, MPI for Physics, Munich, Germany

- Resistive plate chambers (RPCs) with subnanosecond time resolution and mm spatial resolution are cost-effective charged particle detectors for the instrumentation of large areas.
- 1000 Thin-gap RPCs will be installed in the phase-II upgrade of the ATLAS muon spectrometer and experiments searching for long-lived charged particles like ANUBIS plan to use RPCs.
- Huge demand for RPC for future experiments and tight mechanical constraints require new production capacities in industry and industry-style quality assurance.
- The production procedure for thin-gap RPCs was optimized at MPI for Physics and is currently transferred to 4 companies in Germany.

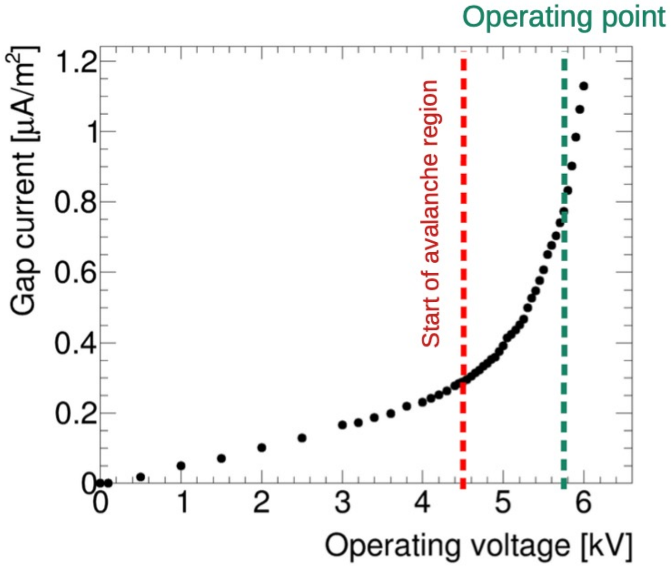
Optimized spacer design



New assembly and gluing template



Successful functional test



The use of Low-temperature Cofired Ceramics technology in Gas Electtron Multiplier Microstructures

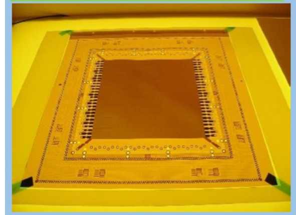
Piotr Belowka, Waclaw University of Science and technology

TECHTRA
TECHNOLOGY TRANSFER AGENCY

Wrocław University of Science and Technology

The use of Low-Temperature Cofired Ceramics technology in Gas Electron Multiplier Microstructures. Piotr Bielówka

Production



Most of GEMa are made by wet etching technology that was invented at CERN.

GEM production at Techtra by chemical wet etching.

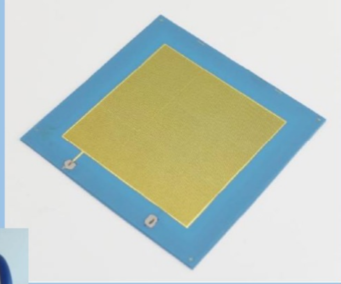
Foreseen advantages of LTCC-GEM structures over polyimide-based ones:

- low outgassing
- low coefficient of thermal expansion
- excellent dielectric properties
- a high amplification
- a high density of vias
- robustness and durability
- many types of conductive layers can be used
- low production costs of prototypes

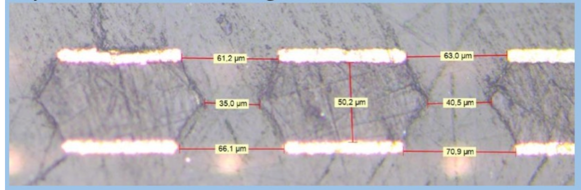
The first LTCC-GEM prototypes were investigated, and the R&D work is ongoing.

R&D work

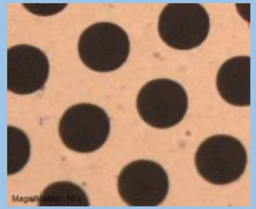
A GEM made on the basis **Low-Temperature Cofired Ceramics** technique.



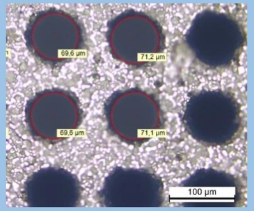
LTCC-GEM microstructure made with LTCC substrate covered by a conductive substrate. Vias were fabricated by a laser beam.



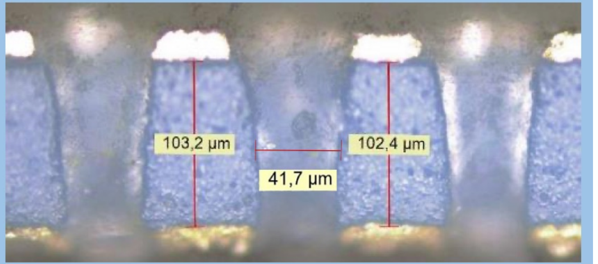
Cross-section of polyimide GEM foils, Techtra.



Cu conductive layer on GEM.



Ag conductive layer on LTCC-GEM.



Cross-section of LTCC-GEM sample.

Beam monitoring detectors for High Intensity Muon beams

Giovanni del Maso, PSI

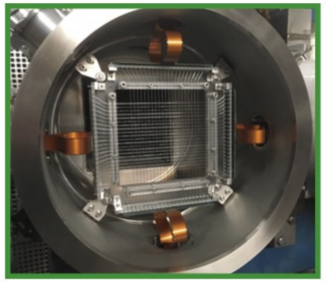
Currently PSI delivers the most intense continuous muon beam in the world with up to few 10^8 μ^+/s, and aims at reaching 10^{10} μ^+/s within the High Intensity Muon Beam (HIMB[1]) project. Usual beam monitoring tools are not suited for μ^+ beams as it is necessary to distinguish μ^+ from the particles contaminating the beam, such as e^+ and π^+.
The performances of these detector as measured along the beamline, their detailed MC simulations and the beam characteristics are presented.

The SciFi detector

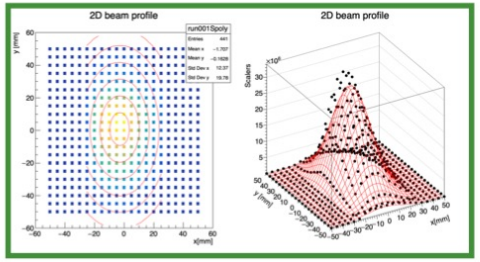
It is a grid of scintillating fibers coupled to plastic scintillators divided in two layers each measuring one transverse direction.

- It can operate in **vacuum** under **high magnetic field** conditions.
- It is **non-invasive**: 80 % of the beam is not affected by the detector. Can be run together with data taking to monitor beam properties.

Can perform particle ID through **energy deposition** and **time of flight** with respect to the proton beam RF.

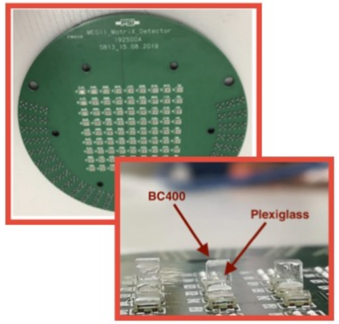


Coincidences between fibers can be exploited to measure a 2D beam profile.

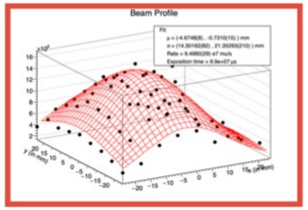


The MatriX detector

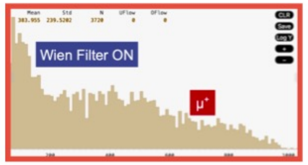
The matriX detector is a matrix of plastic scintillators coupled to SiPMs. It can operate in **vacuum** under **high magnetic field** conditions
Can perform particle ID through **energy deposition**.



It measures by construction a full 2D beam profile.



A **plexiglass light-guide** is placed in between the scintillator and the SiPM to **increase separation** between e^+ and μ^+.



200 μm BC400

+ light guide