R&D, Accelerators, Aplications

Yorgos Tsipolitis

NTUA

Contents

- R&D
  - RD50
  - RD51
  - Future
- Accelerators
- Applications

GR-RD50

- Activity centered around the “Silicon Instrumentation Laboratory” of the National Research Center DEMOKRITOS (NCSR “D”)

- **Main activity : Monolithic CMOS sensors**

The MIDAS Project

A consortium led by a Greek Company:
ADVEOS Microelectronics Systems Company

With participation of laboratories from:
Greek Atomic Energy Commission,
National Center of Scientific Research Demokritos
Physics Department of the University of Cyprus

- **The Demokritos Personel**
  - **-- Dimitrios Loukas**
  - **-- Aristoteles Kyriakis**
  - **-- Ioannis Kazas**
  - **-- Panagiotis Assiouras (until 2021)**
  - **-- Patrick Asenov (until 2020)**

DEMOKRITOS

GR-RD50

Based on the The LFoundry HVCMOS commercial process

Concept : Develop on the same Si substrate the sensor and the preamplification stage

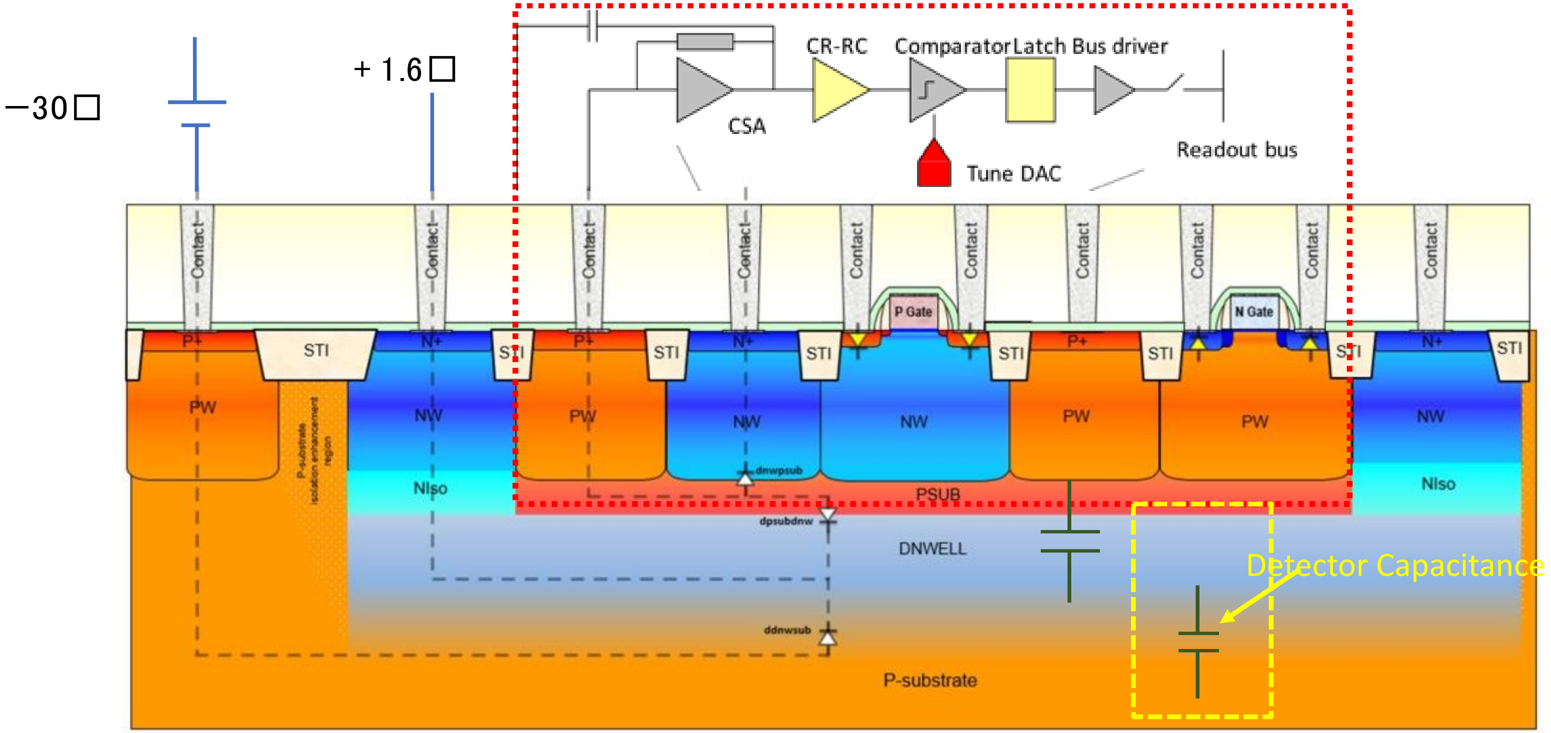
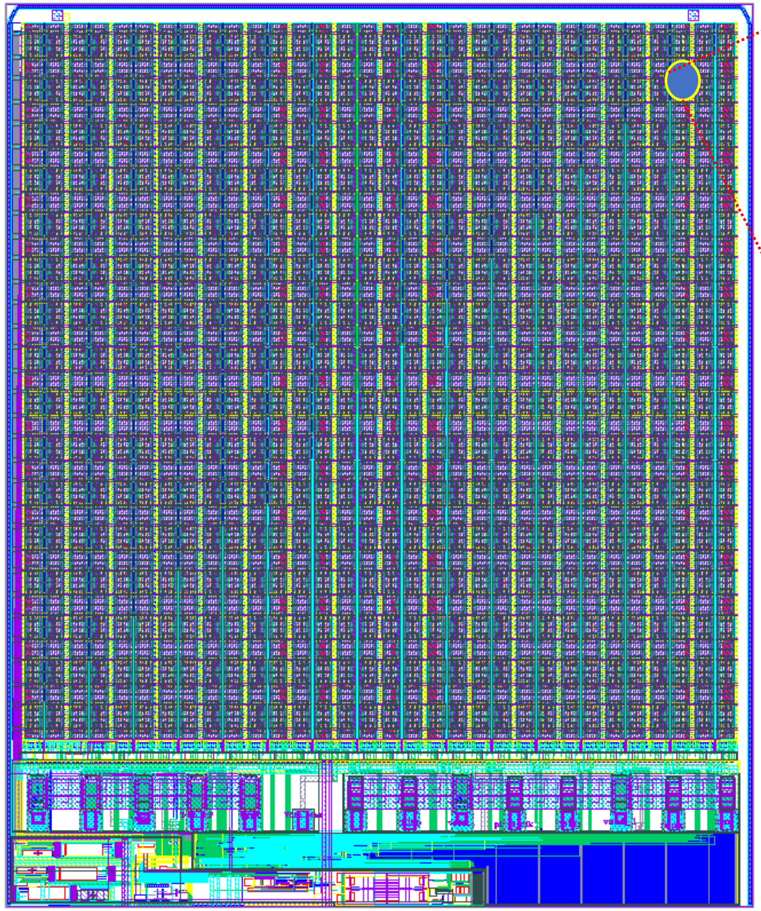
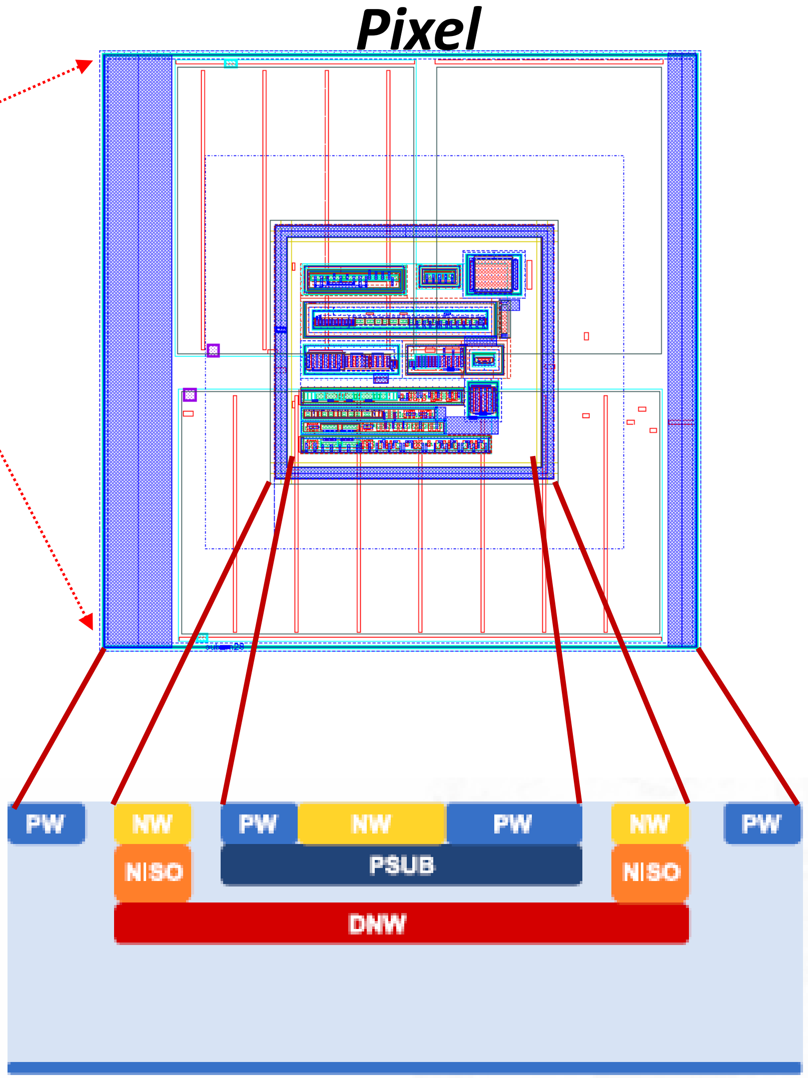


Figure 4.25.: DNWELL isolation scheme with indicated junction diodes

GR-RD50

The MIDAS v1 monolithic chip

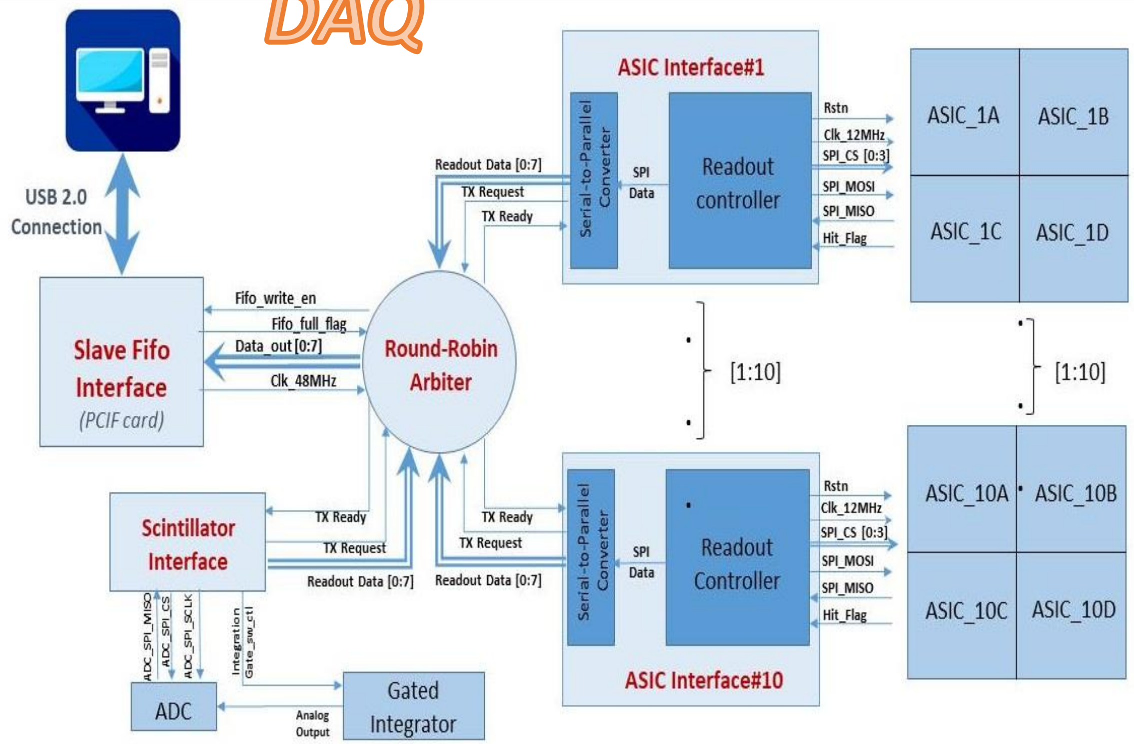


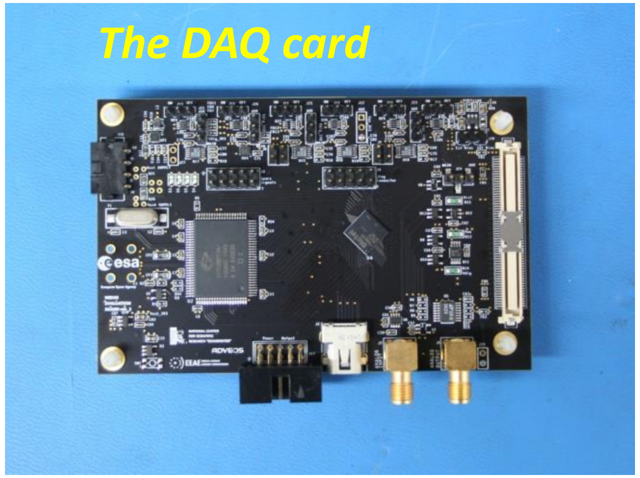


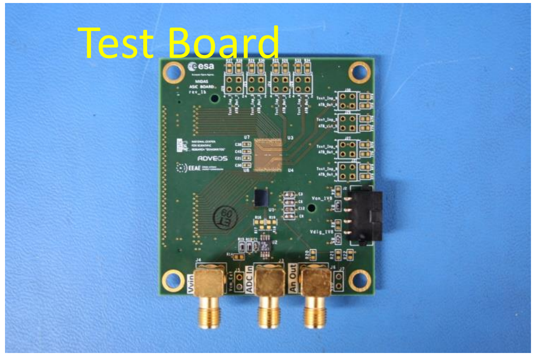
- ✓ 32 rows x 32 columns
- ✓ 105.5 um pixel pitch
- ✓ Charge signal dynamic range: Min:0.5 fC, Max:6 pC ***(80db)***
- ✓ Pixel consumtion < 10 mW/cm^2
- ✓ Embedded ADC (11 bits)
- ✓ Only hit pixels are readout
- ✓ 2-3 events/cm^2/sec for Galactic Cosmic Rays
- ✓ 10^3 events/cm^2/sec for Solar Event Particles
- ✓ Information output: Hit flag and from pixels hit: Serially, 10 bits address, 22 bits charge signal

GR-RD50

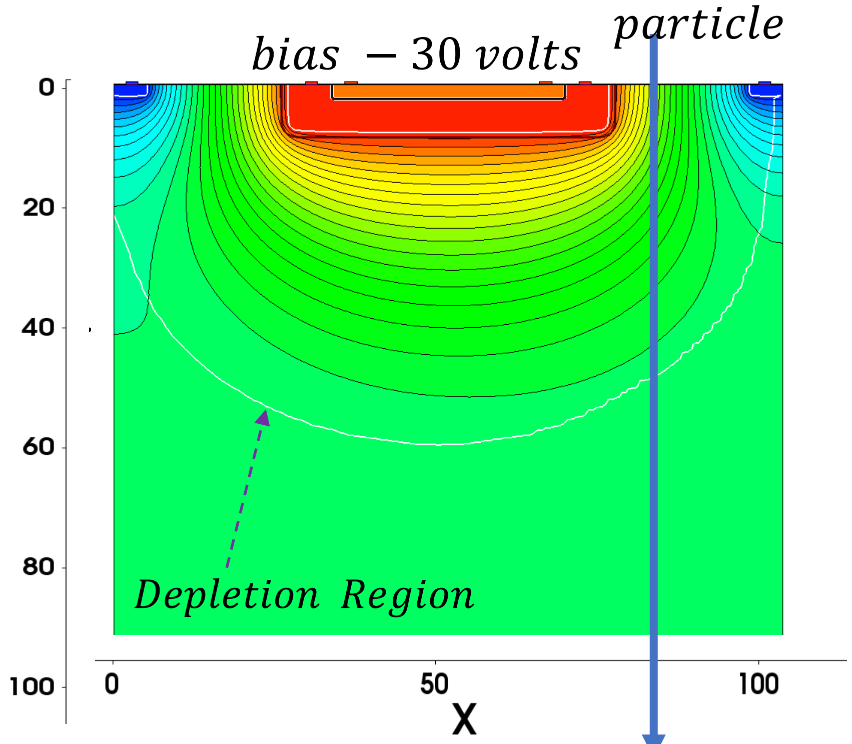
DAQ

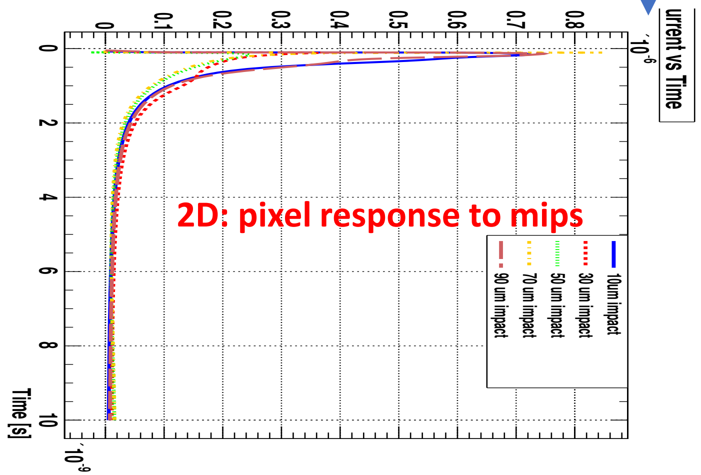






TCAD Simulation of the HVCMOS sensor





INP Local Instrumentation & Funding

EDA Tools : Access via Europractice
- *Cadence IC*
- *Synopsys TCAD*
- *OrCad)*

Climatic Chamber

Funding

- European project. :
  Highly Miniaturized ASIC Radiation Detector: 43 k€
- ELIDEK:
  New Generation of sensors and electronics for LHC: 41 k€

GR-RD51

Participating teams

NKUA

AUTH

NCSR “Demokritos”

DEMOKRITOS

NTUA

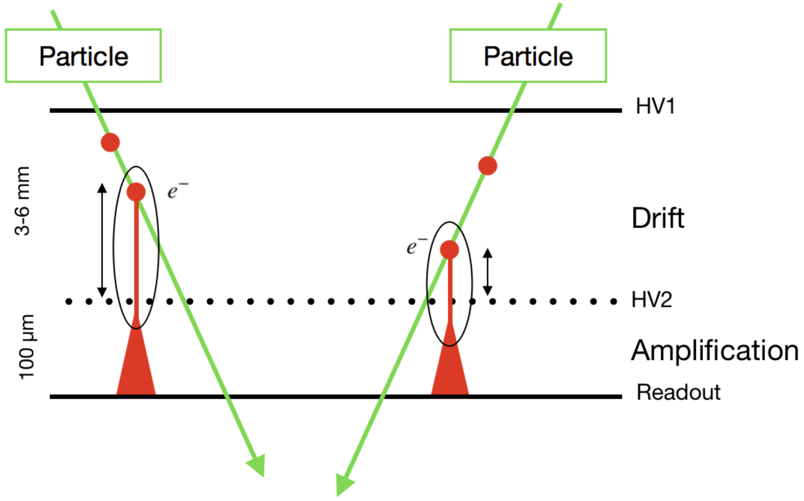
Mainly on micromegas detector R&D. Started in 2009 with the development of the resistive micromegas which continued as an ATLAS R&D project that resulted to the ATLAS-NSW (see talk by D. Sampsonidis.
Now focus mainly on the PICOSEC micromegas.

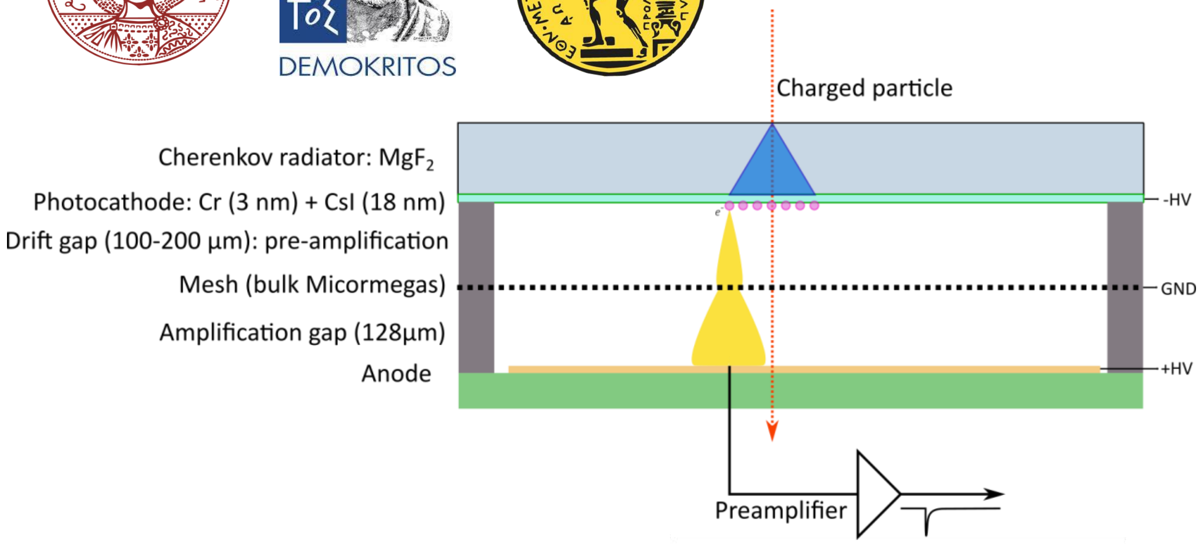
Responsibilities/Coordination:

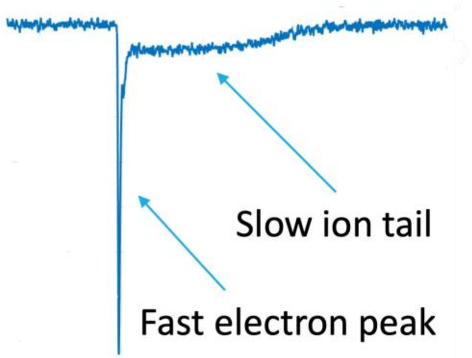
G. Tsipolitis :
Co-Coordination of the WG7 – Common Test facilities (2009 – today)
Member of the Management board (2016 – today)
Deputy CB chair (2020 – 2022)

GR-RD51 PICOSEC

Standard Micromegas





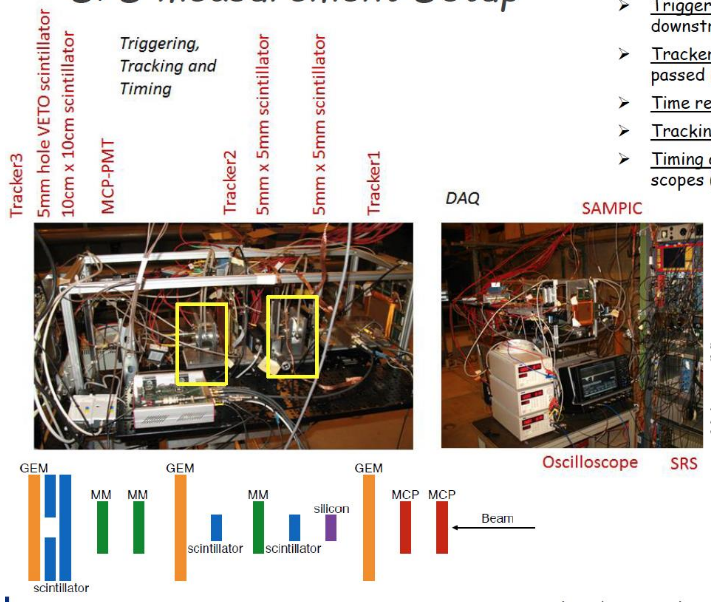


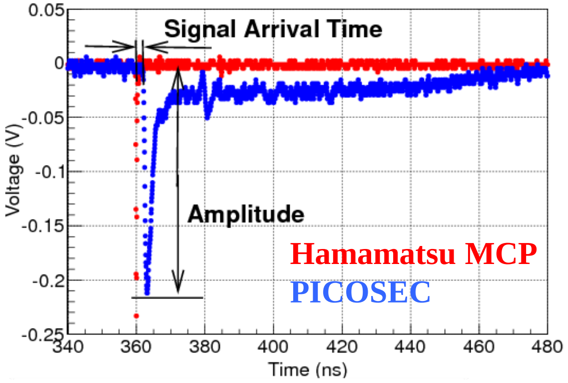
- ✓ Reduce the drift gap (100 – 200 nm)
  - limit diffusion
  - Preamplification possible
    - Reduce the effect of the longitudinal diffusion
    - Limit contribution of gas ionization
- ✓ Use a Cerenkov radiator
  - Photoelectrons from the photocathode (all produced at the same distance from the mesh)

GR-RD51 PICOSEC

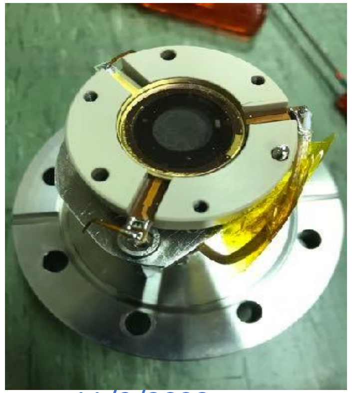
SPS measurement Setup

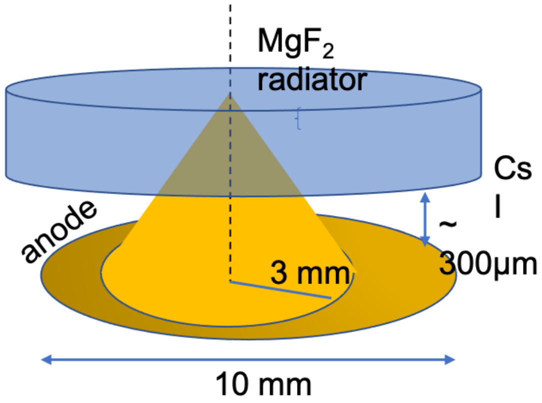
- Trigger: coincidence of two 5x5 mm2 scintillators and a veto downstream (avoid showers)
- Tracker: three GEMs to measure where the triggered particle passed (reject showers too)
- Time reference: two Hamamatsu MCP-PMTs (160 ps rise time)
- Tracking acquisition: APV25 + SRS
- Timing acquisition: CIVIDEC C2 preamp + 2x 2.5 GHz LeCroy scopes (synchronised with the tracker) and SAMPIC





The First Prototype

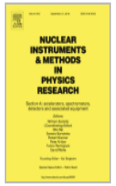




ELSEVIER

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 903, 21 September 2018, Pages 317-325



PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector

J. Bortfeldt [b], F. Brunbauer [b], C. David [b], D. Desforge [a], G. Fanourakis [e], J. Franchi [b], M. Gallinaro [g], I. Giomataris [a], D. González-Díaz [i], T. Gustavsson [j], C. Guyot [a], F.J. Iguaz [a], M. Kebbiri [a], P. Legou [a], J. Liu [c], M. Lupberger [b], O. Maillard [a], I. Manthos [d], H. Müller [b], V. Niaouris [d], E. Oliveri [b], T. Papaevangelou [a], K. Paraschou [d], M. Pomorski [k], B. Qi [c], F. Resnati [b], L. Ropelewski [b], D. Sampsonidis [d], T. Schneider [b], P. Schwemling [a], L. Sohl [b 1], M. van Stenis [b], P. Thuiner [b], Y. Tsipolitis [f], S.E. Tzamarias [d], R. Veenhof [h 2], X. Wang [c], S. White [b 3], Z. Zhang [c], Y. Zhou [c]

24 ps Timing Resolution

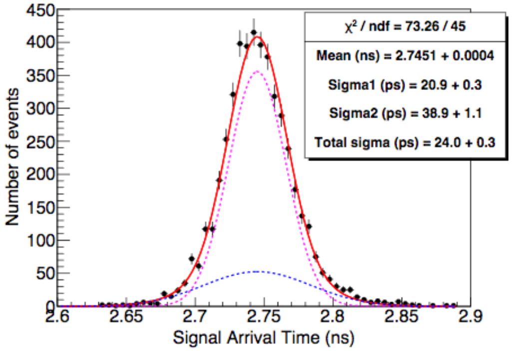


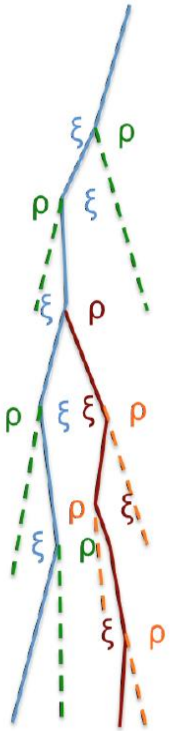
Figure 12: Beam test: An example of the signal arrival time distribution for 150 GeV muons, and the superimposed fit with a two Gaussian function (red line for the combination and dashed blue and magenta lines for each Gaussian function), for an anode and drift voltage of 275 V and 475 V, respectively. Statistical uncertainties are shown.

Phenomenological model: A deeper look under the hood

Identify the main microscopic parameters that correspond to the macroscopic (experimental) observables: SAT and Resolution

- Identify the processes which are responsible for varying the main microscopic parameters
- Build a phenomenological model to describe the mechanisms of variation and compare with the Garfield++ predictions

- An ionizing electron in the avalanche, every time it ionizes, will gain a time **ξ** relative to an electron that undergoes elastic scatterings only.
- A new produced electron by ionization starts with low energy, suffers less delay due to elastic backscattering compared to its parent. Relative to its parent it will have a time-gain **ρ**
- Parameters **ξ** and **ρ** should follow a joint probability distribution determined by the physical process of ionization and the respective properties of interacting molecules



Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 993, 21 March 2021, 165049

Modeling the timing characteristics of the PICOSEC Micromegas detector

J. Bortfeldt [b 1], F. Brunbauer [b 1], C. David [b 1], D. Desforge [a 1], G. Fanourakis [e 1], M. Gallinaro [g 1], F. García [k 1], I. Giomataris [a 1], T. Gustavsson [i 1], F.J. Iguaz [a 1], M. Kebbiri [a 1], K. Kordas [d 1], C. Lampoudis [d 1], P. Legou [a 1], M. Lisowska [b 1], J. Liu [c 1], M. Lupberger [b 1 2], O. Maillard [a 1], I. Manthos [d 1], H. Müller [b 1], V. Niaouris [d 1], E. Oliveri [b 1], T. Papaevangelou [a 1], K. Paraschou [d 1], M. Pomorski [j 1], B. Qi [c 1], F. Resnati [b 1], L. Ropelewski [b 1], D. Sampsonidis [d 1], L. Scharenberg [b 1], T. Schneider [b 1], L. Sohl [a 1], M. van Stenis [b 1], Y. Tsipolitis [f 1], S.E. Tzamarias [d 1], A. Utrobicic [b 1], R. Veenhof [h 1 3], X. Wang [c 1], S. White [b 1], Z. Zhang [c 1], Y. Zhou [c 1]

Towards PICOSEC MM detector for HEP experiments

Next steps: Multiple directions in detector development

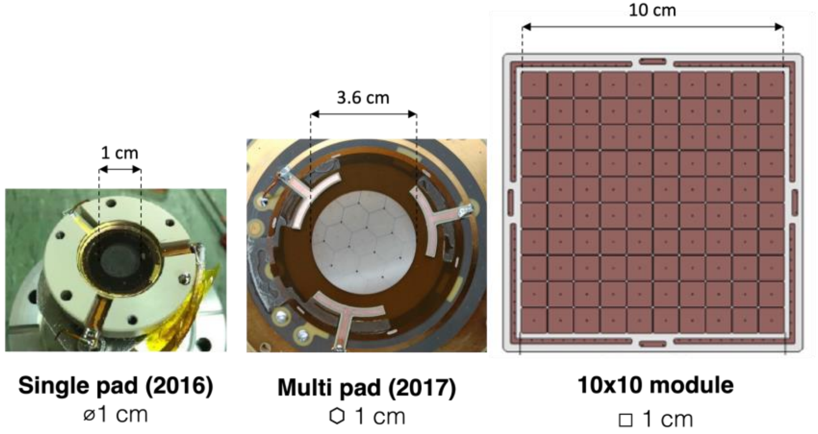
Large area coverage
Developemnt of large area prototypes and readout electronics

Detector optimisation
Detector fields
Operating gas
Gaps thickness

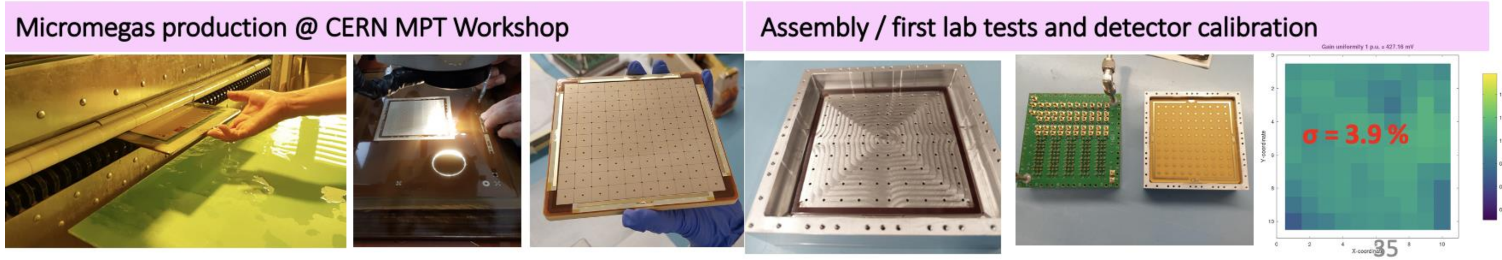
- Development of a large area 100 channel detector.
- Development of a 100 ch. readout electronics.
- Timing techniques for a large area detector and Detector timing improvement.

Improvement of stability
Development of detector prototypes with resistive MM

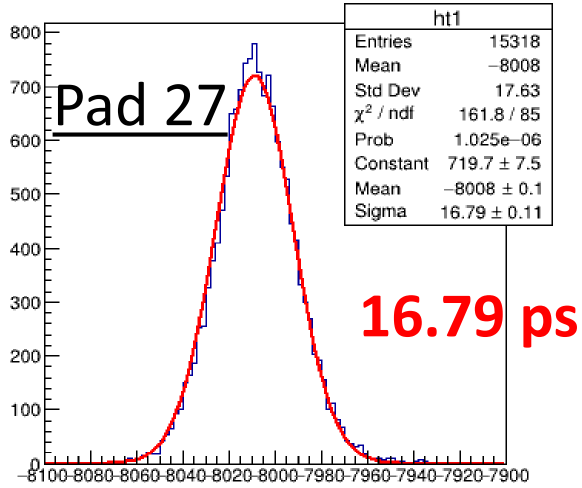
Robustness
Research on various photocathode materials

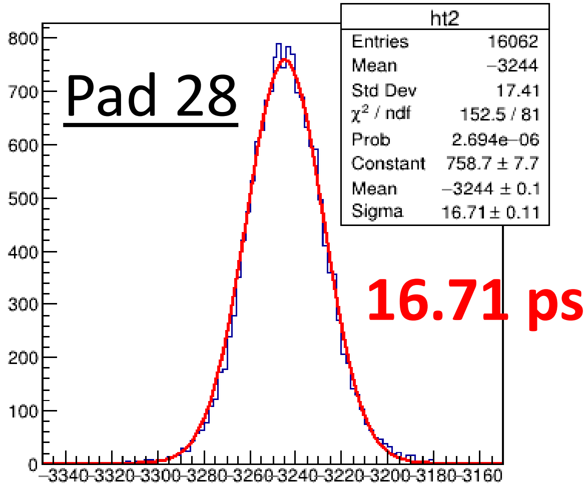


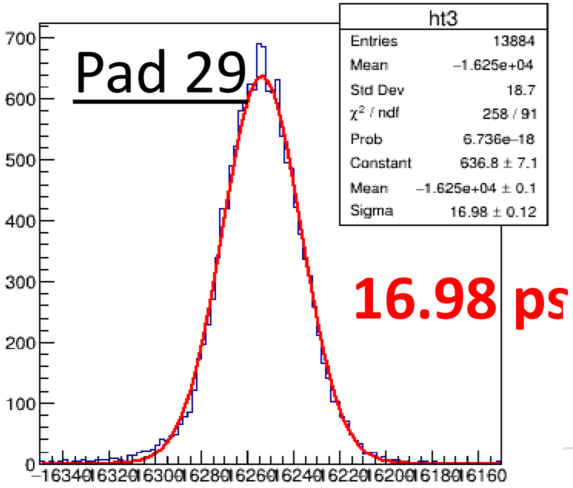
LARGE scale PICOSEC



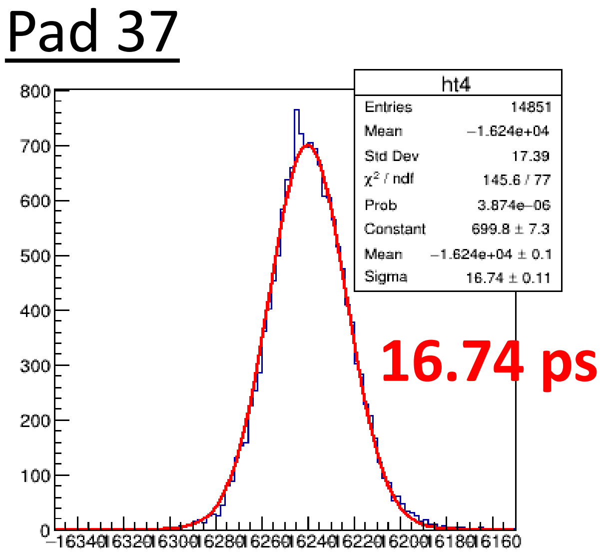
A. Utrobicic, RD51 Coll. Meeting: https://indico.cern.ch/event/1040996/contributions/4398412/

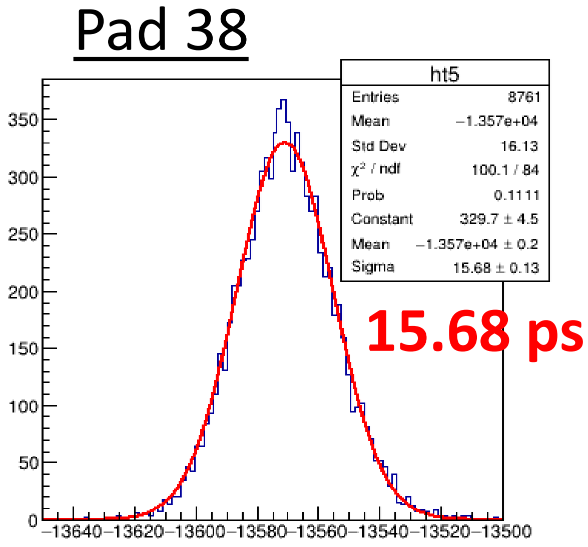


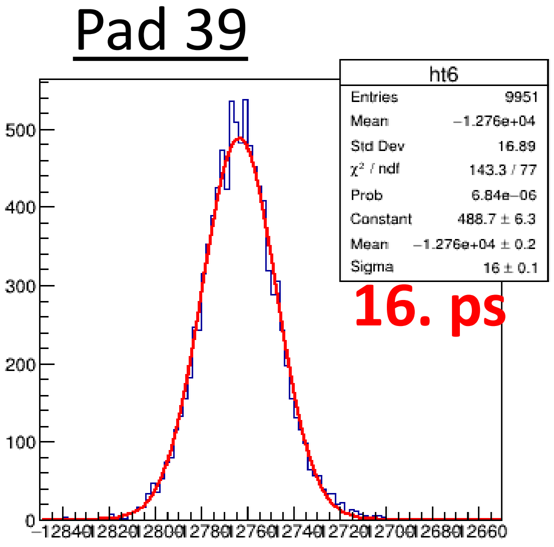


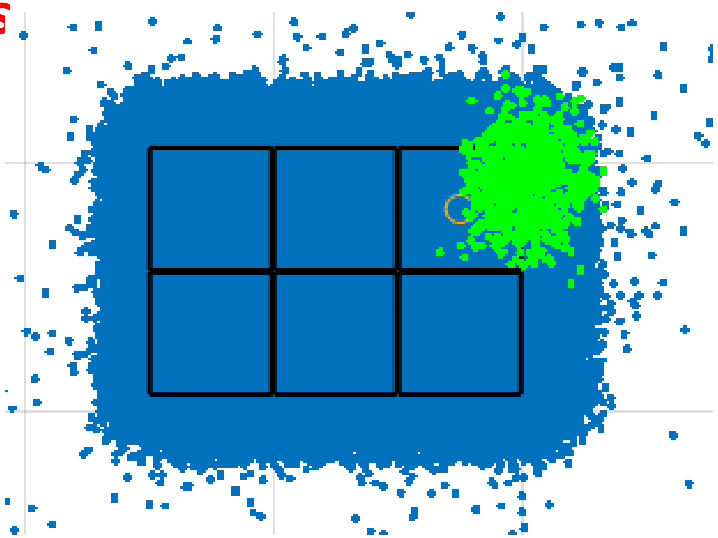


RD51 test beam October 2022: pads scan, V_c=-460 V, V_a=+275 V









Time resolution of a large (10x10 - 1x1cm^2 pads) detector is found below 17 ps per muon for all measured pads.

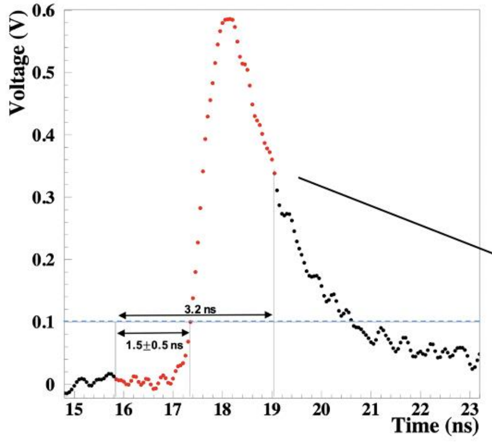
Using A.N.N. embeded in the Digitization Electronics (SAMPIC) the PICOSEC-MicroMegas can provide very fast, accurate timing for event selection

SAMPIC

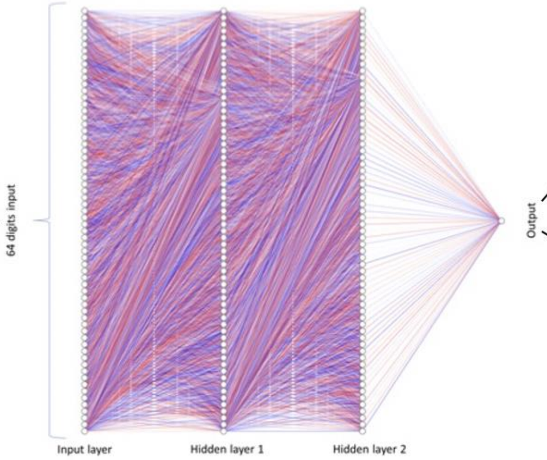
Mezzanine board can host two SAMPICS: 32-channel system
- **MCX connectors and UBS-Ethernet-Optic fiber readout**
- **5V voltage supply, 1 Amp.**

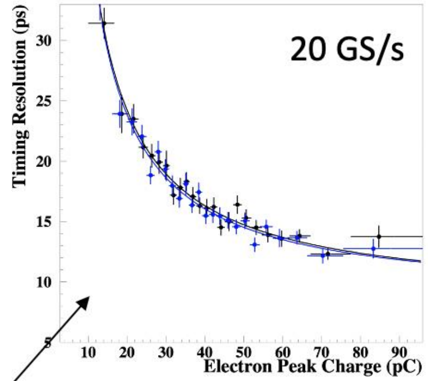
Towards scalable electronics & Fast Trigger

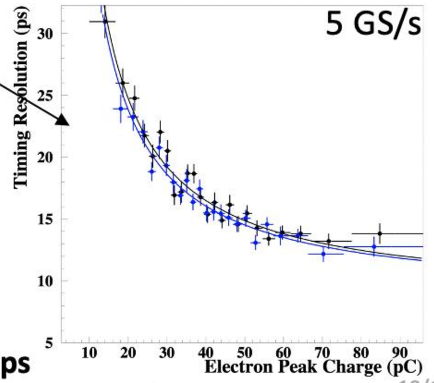
- Digitize only the Leading edge and using artificial Neural Networks (SAMPIC electronics)



Network input: 64 bits (red)





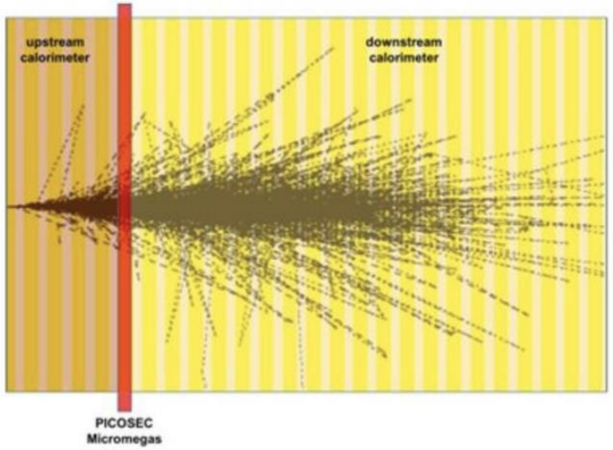


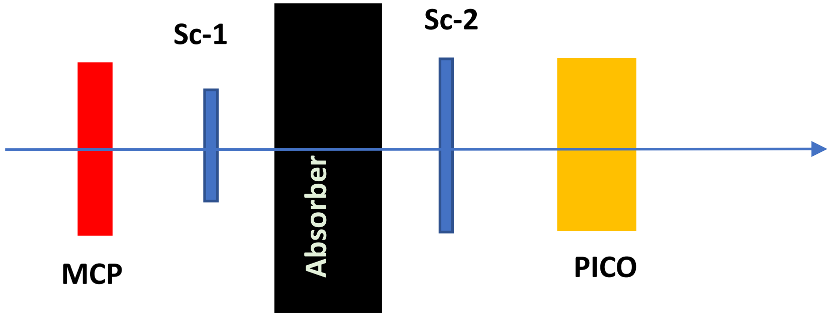
Blue: Offline analysis **18.3ps**
Black: Neural Network **18.3ps** (20GS/s) – **19.2ps** (5Gs/s)

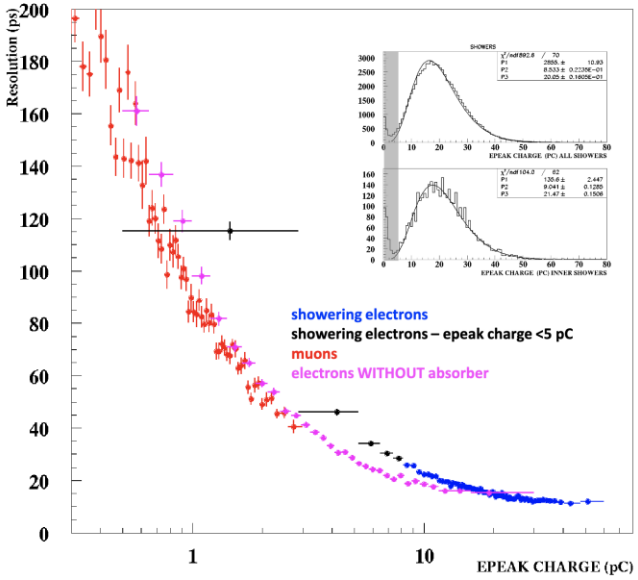
"Timing techniques with picosecond-order accuracy for novel gaseous detectors" A. Tsiamis,

S.E. Tzamarias et al., to be published

- Simulation studies with PICOSEC embedded in an EM calorimeter: a 30 GeV electron produces ~200 pes in MgF_2 radiator with a metallic (Cr) photocathode after 2 radiation lengths
  - Timing resolution <10ps!!
  - No need for: high efficiency photocathode or extremely high electric fields.







Funding

ELIDEK:

- Micromegas detector in New Physics Searches 30 k€
- Development of innovative instrumentation and new methods for the selection/analysis of experimental data for New Physics research at the HL-LHC. 41 k€

PRELIMINARY Electron Test Beam Results – Metalic Photocathode – 14ps Resolution

FUTURE

DRD1

(Development of Gaseous Detectors Technologies)

https://drd1.web.cern.ch

Proposal submited (31/10/2023)

Aristotle University of Thessaloniki

NCSR “Demokritos”

National Technical University of Athens

DRD3

(Solid State Detectors)

Proposal in preparation

NCSR “Demokritos”

National Technical University of Athens

University of Ioannina

Accelerators

Greek Accelerator Team

- E.N.Gazis, E. Adamidi, Th. Xenofontos, E. Trachanas

1. Institute Accelerating Systems & Applications-IAS

- A. Georgakilas, T. Alexopoulos, S. Maltezos, I. Kominis

2A.National Technical University of Athens-NTUA, School of Applied Sciences

- V. Spitas, E. Tsolakis, Y. Vassileiou, C. Vakouftsis

2B. NTUA-School of Mechanical Engineering

- E. Hristoforou, K. Politopoulos, S. Kokossis, N. Voudoukis, E. Alexandratou

2C. NTUA-School Electrical & Computing Engineering

- V. Kostopoulos

3. Univ. Patras, Mechanical & Aeronautical Engineering

- D. Bantekas, N. Vordos

4. International Hellenic University-IHU, Physics Department

- I. Andreadis, G. Syrakoulis

5. Democritus Univ. of Thrace-DUTH, Electrical & Computing Engineering

- T. Apostolopoulos, K. Pramatari, D. Kotsopoulos, A. Karagiannaki

6. Athens Univ. of Economics & Business – AUEB, School of Information Sciences & Technology

- D. Sampsonidis, S. Tzamarias, C. Lampoudis

7. Aristotle University of Thessaloniki, Laboratory for Accelerator Physics and Instrumentation

IASA

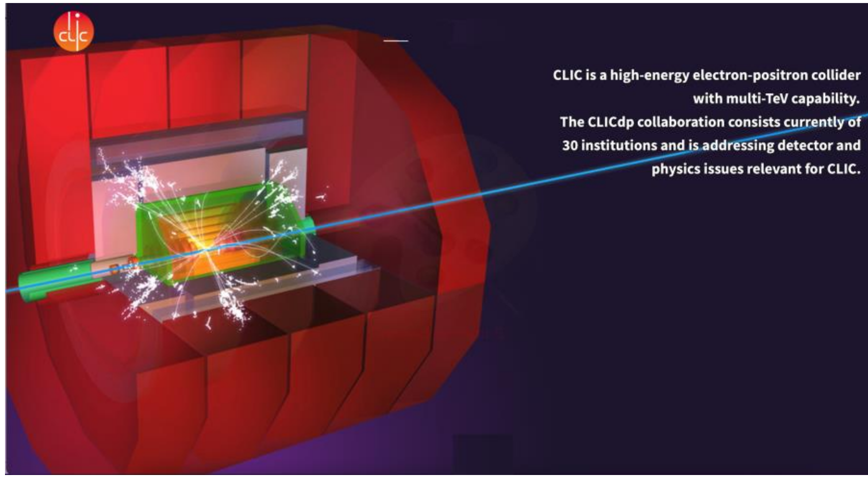
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ UNIVERSITY OF PATRAS

INTERNATIONAL HELLENIC UNIVERSITY

ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ DEMOCRITUS UNIVERSITY OF THRACE

ΟΙΚΟΝΟΜΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

CLIC/CTF3/CLeAR Collaboration 2008 - Today



- **COMPACT LINEAR COLLIDER – CLIC**, https://clic.cern **2008 – Today**
- **70** Research teams & Universities from **30** Countries, **NTUA, IASA, UoPatras, IHU, DUTH** from Greece.
- This is new generation for $e^{+}\ e^{-}$ **collider** at **3 TeV** total energy at CERN; with about **50 km** total length.
- Enormous innovative technology has been developed; where a world record of an accelerator structure has arrived to accelerating field of **100MV/m**
- **The major purpose of the CLIC Collaboration is the search for NEW particle physics concepts**
- The **NTUA/IASA/UoPatras/IHU/DUTH Team** has a consistent contribution to the CLIC Collaboration, integrating **6 PhD** and more than **15 MSc** theses in the subjects:
  - Beam Dynamics, **CLIC**
  - Physics of Damping Rings, **CLIC**
  - Mechanical Design, Construction & Commissioning of the Beam Girders, **CLIC**
  - Mechanical Design of the Accelerating Discs, **CLIC**
  - Longitudinal Instabilities in RF system, **LHC**
  - Beam optics for proton beam, **HL-LHC**
  - Mechanical Design & Construction of New SC Magnets, **HL-LHC**

Funding of the project (NTUA):
2008 – 2018 : 200 k€
2012 – 2022 : 50 k€

ESS Project, in Kind-Contribution 2017 - 2023

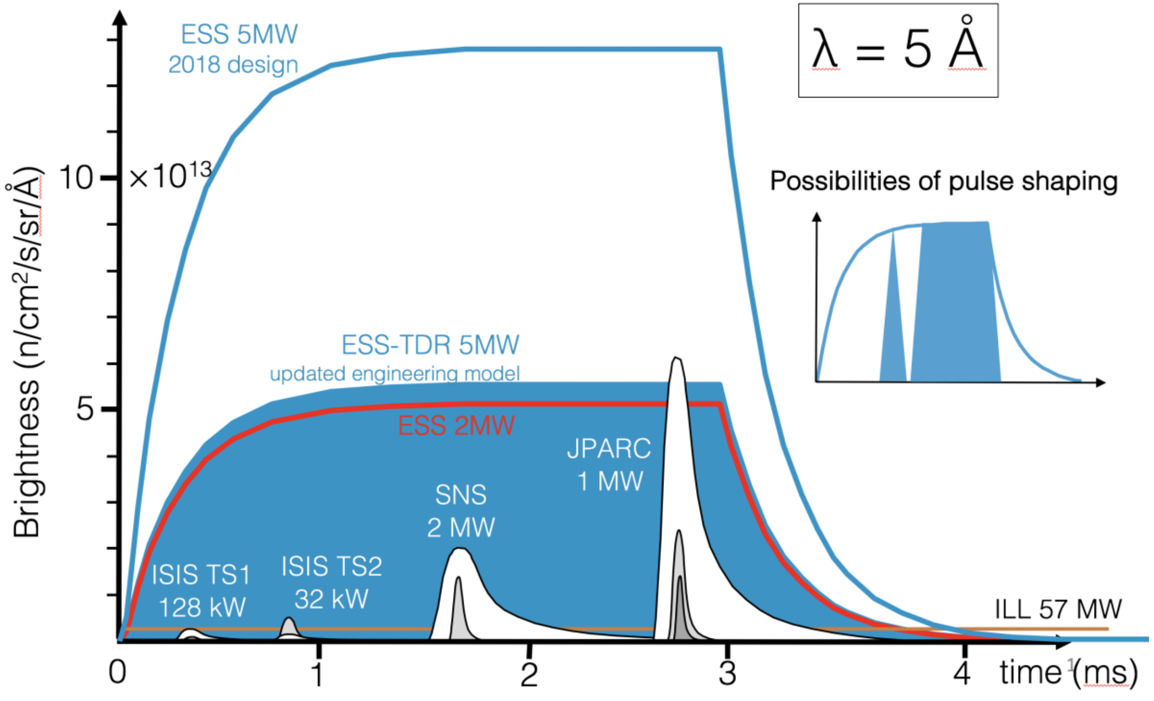
▪ European Spallation Source - ESS

- **3** Research teams & Universities from **5** European Countries, **NTUA, IASA, IHU** from Greece.

- The ESS scientists and engineers have developed a new generation of neutron source based on proton beam accelerator and spallation technology, a much more efficient approach with advanced specifications.

- The **NTUA/IASA/IHU Team** has a fruitful contribution to ESS Project, BY IN-KIND contribution with 2 Electrical Engineers: Chris. Kourkoutis, Emm. Trachanas) have worked for **2 years.**

- The Greek Team contribution is the proton source commissioning, the RFQs installation and commissioning and the Non-Destructive Material Tess needed for the possible material beam damage of the accelerator.



Single-pulse source brightness as a function of time at a 5 Å at ESS, ILL, SNS, J-PARC and ISIS target stations 1 and 2.

Total funding of the project:
ESS + NTUA 76.5 k€

COMPACT LIGHT COLLABORATION – XLS,
https://www.compactlight.eu/, 2018 – 2022, funded H2020

22 International Laboratories, **3** Industries and **7** associate partners from Europe, Asia and Australia, **IASA/IHU**, main partner, plus **NTUA** and **AUEB** associate partners from Greece.

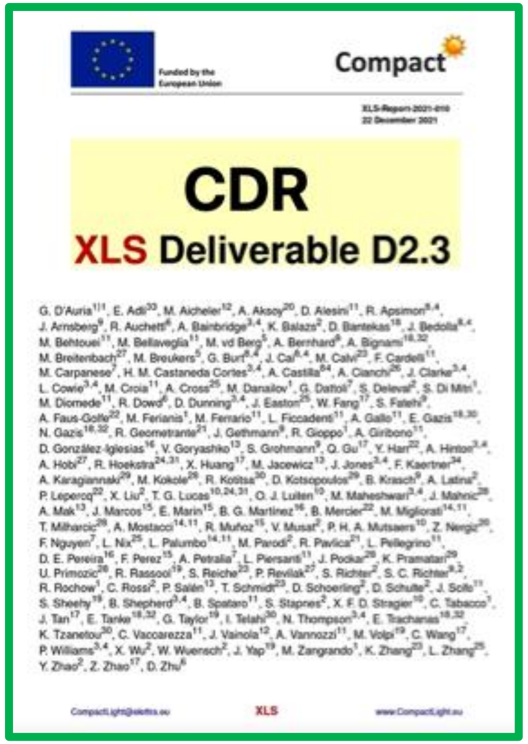
The Greek Team has contributed to **Data Management Plan, Photocathode selection, e-gun Design, Beam Dynamics Simulations**, **3D CAD FEL baseline layout design and 3D machine tunnel design** and **Financial Analysis (Risk-, SWOT-, Cost-to-Benefit- and Market- Analysis, Technology Transfer and Parameters List of design** included to the delivered by the reports **D2.2 CDR** and **D7.2 XLS Integration Cost Analysis**

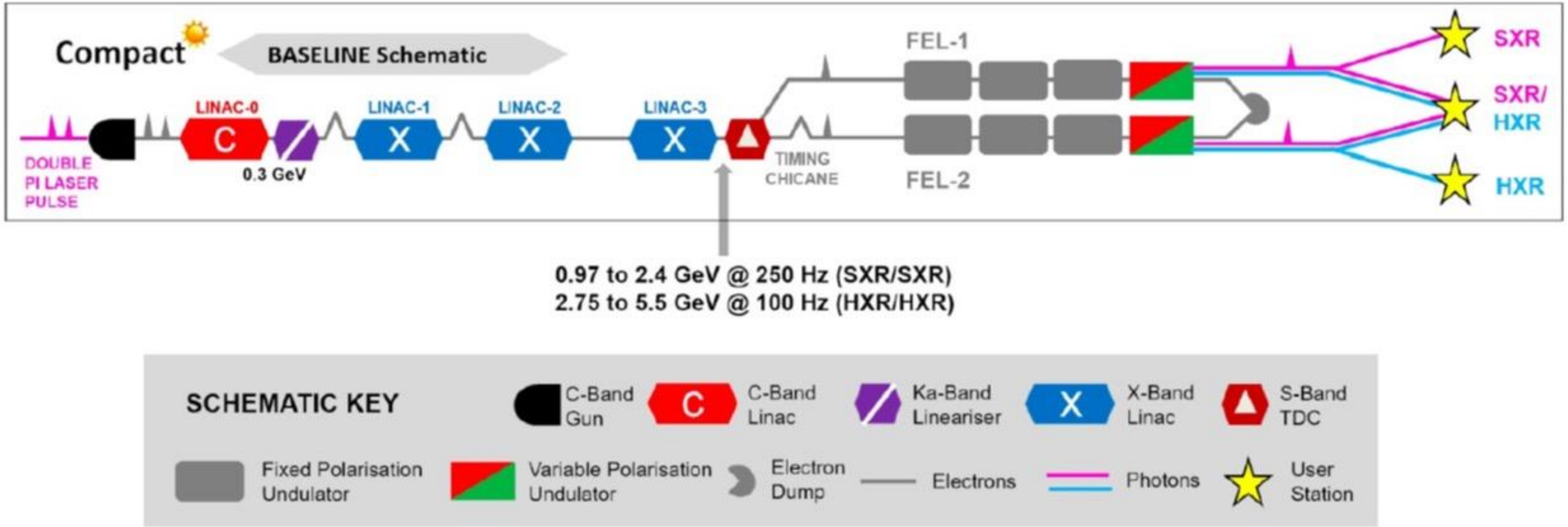
A **C**onceptual **D**esign **R**eport – **CDR** was delivered among many other innovative reports, Greek team contribution:

D1.2 CompactLight Data Management Plan V.1.3
D2.2 Conceptual Design Report - CDR
D3.1 Preliminary assessments and evaluations of the optimum e-gun and injector solution for the CompactLight design
D3.4 Photocathode and Laser System
D7.1 CompactLight global integration and cost analysis
D7.2 Compact Light Integration Cost Analysis

COMPACT LIGHT COLLABORATION – XLS

https://www.compactlight.eu/, 2018 – 2022, funded H2020





Total funding of the project:
EU-H2020 3 M€/ 25 partners
GREEK share: 67.5 k€

IASA/IHU/NTUA/AUEB RESPONSIBILITIES

- ❑ WP1: Co-coordination of the project : Data management plan
- ❑ WP3: Laser/Photocathode (coordinator) : Photocathode options selection, e-Gun, Injector mechanical design
- ❑ WP6: Beam dynamics simulation and generic : algorithms (ASTRA, GIOTTO)
- ❑ WP7: 3D Model design & Parameters List plus:
  - ❖ Solenoid shielding and Magnet design
  - ❖ Cost, SWOT, Risk & Market Analysis
  - ❖ Cost to Benefit Analysis
  - ❖ Transfer Technology to industry & Society

EuPRAXIA PLASMA ACCELERATION 2022 – 2026, funded by EUESFRI Project

http://www.eupraxia-facility.org/

- **15** International Laboratories + **25** Associate Laboratories from Europe, China, USA
- **IASA**, main partner, plus **NTUA, IHU** and **AUEB** associate partners from Greece
- The Greek Team is contributing to the **Beam Dynamics**, **Injector design**, **3D CAD layout design**,
- Applications in **Medicine & Biology research and Advance Materials**, **Extension of the Collaboration**, **Financial Analysis** of the project.

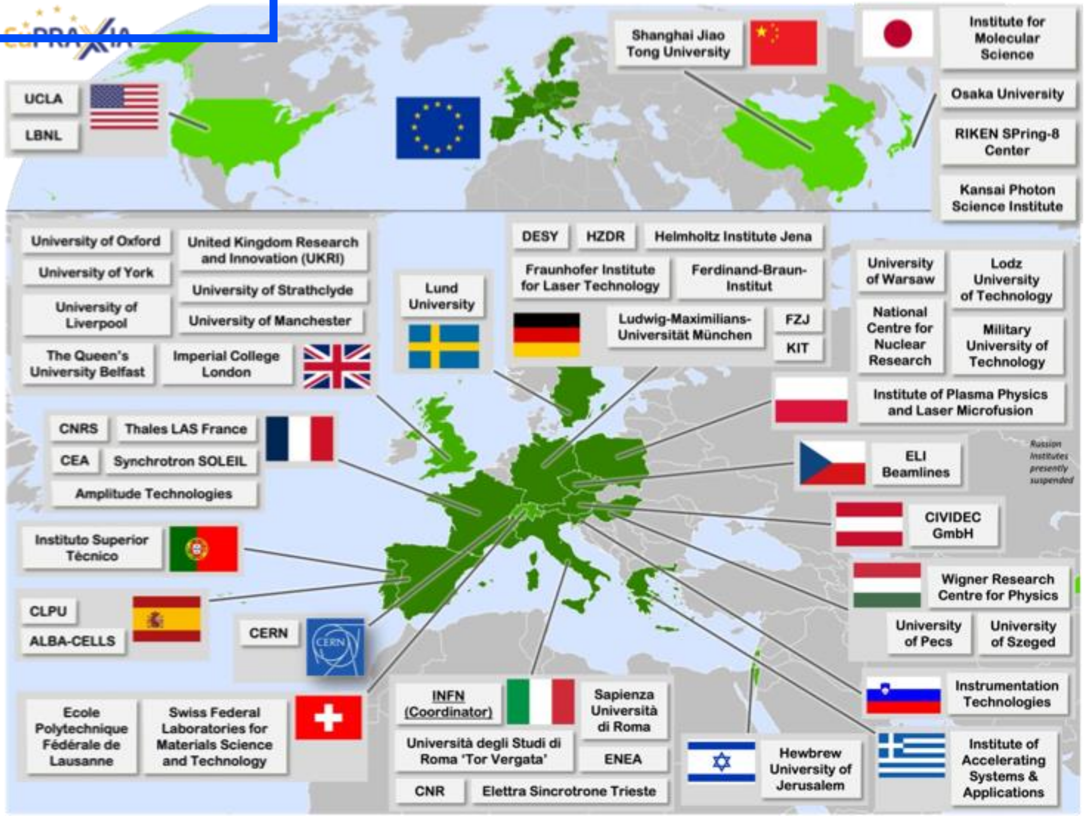
Building a facility with very high field **Plasma Accelerators**, driven by lasers or beams obtain **1 – 100 GV/m** accelerating field

*Delivers 10-100 Hz **ultra-short** pulses*

- **Electrons** (0.1-5 GeV, 30 pC)
- **Positrons** (0.5-10 MeV, 10^6)
- **Positrons** (GeV source)
- **Lasers** (100 J, 50 fs, 10-100 Hz)
- **Betatron X rays** (1-110 keV, 10^{10})
- **FEL light** (0.2-36 nm, 10^9-10^{13})

Topics of research: proteins, viruses, bacteria, cells, metals, semiconductors, superconductors, magnetic materials, organic molecules

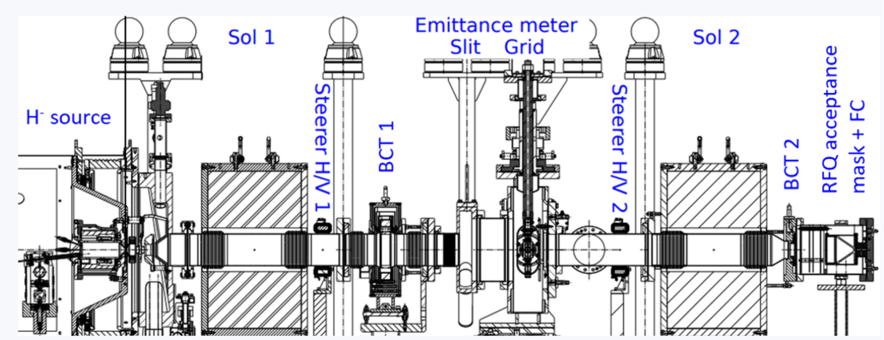
Total funding of the project:
EU-2020 2.5 M€/ 34 partners
GREEK share: 30 k€

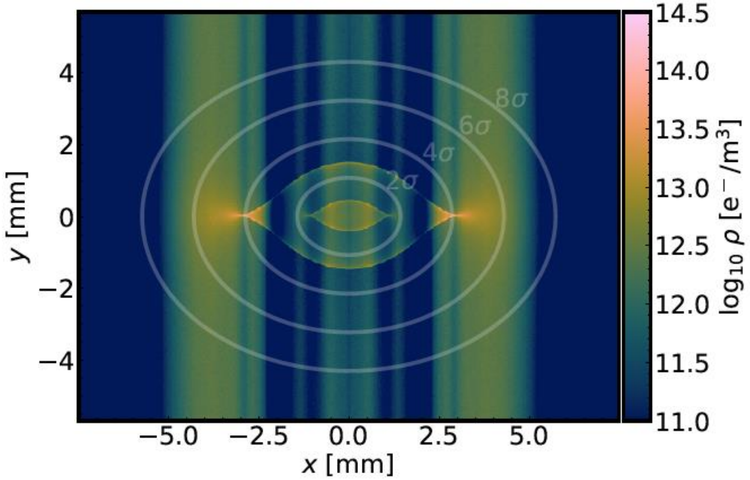


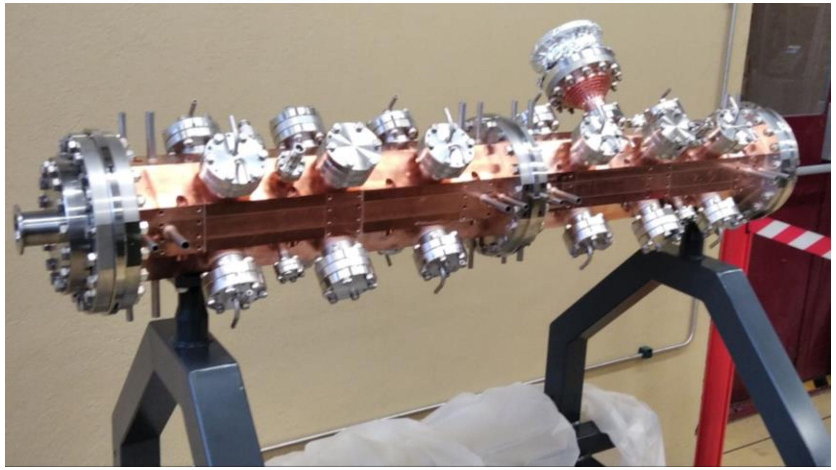
Accelerator Physics and Technological Applications

- Studies of Incoherent effects for the Upgrade of the LHC and Detector Applications (K. Parschou, PhD finished 2023)
- Studies for optimizing optics cycles for the High-Luminosity LHC (I.Angelis, PhD ongoing)
- Optimization of pre-injector systems in hadron accelerators (A. Mamaras, PhD on going)

- Fisibility Studies for the Construction of Movable Small Size Accelerator with Applications in Art and Medicine.







Aristotle University of Thessaloniki, Laboratory for Accelerator Physics and Instrumentation

Applications

Participation in the EDUSAFE Project 2015 - 2019

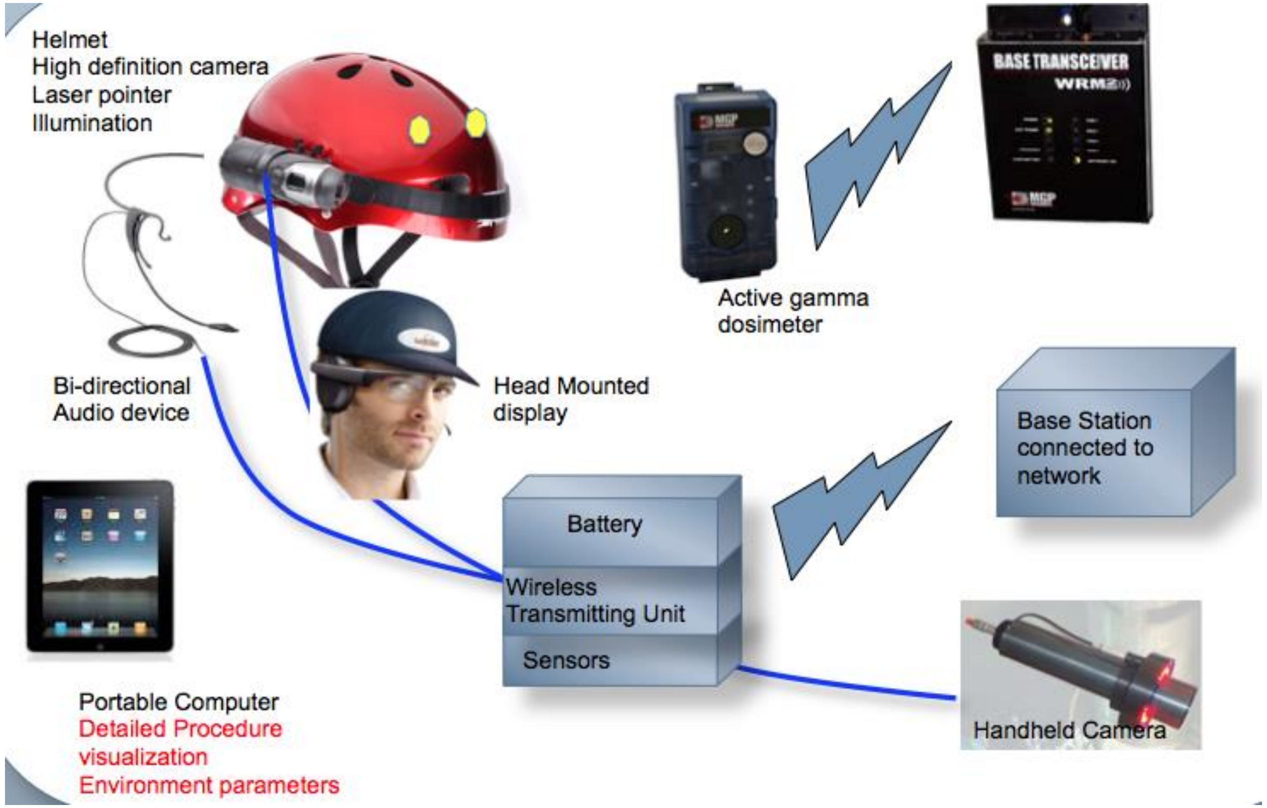
- **EDU**cation in advanced VR/AR **SA**fety Systems **F**or Maintenance in Extreme **E**nvironments **– EDUSAFE** **https://https://edusafe.web.cern.ch/site.php**

- **13** Research teams & Universities from **5** European Countries, **NTUA, IASA, AUEB, DUTH** from Greece.

- The scientific objective of EDUSAFE is research into advanced Virtual Reality **VR** and Augmented Reality **AR** technologies for a **personnel safety system platform**, including features, methods and tools.

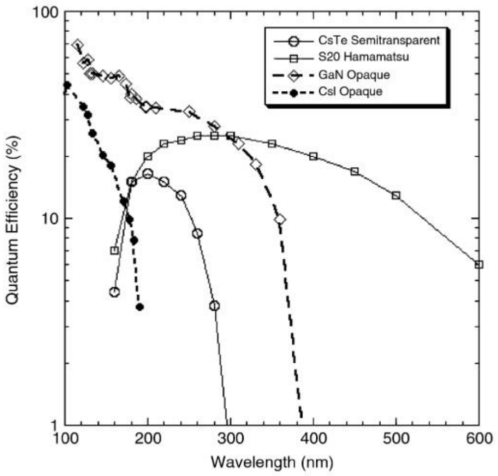
- The **NTUA/IASA/AUEB/DUTH Team** has a consistent contribution to the EDUSAFE Project, integrating **4 PhD's.**

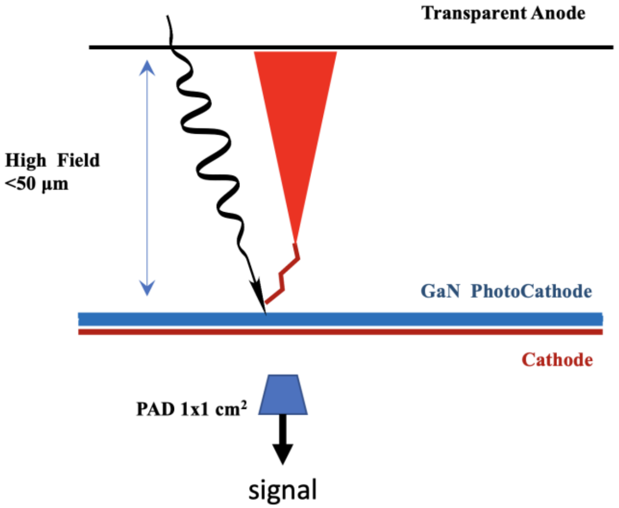
- The Greek Team responsibility was the entire development of the **DAQ** and **Control System** and part contribution of the VR/AR technology for the final product

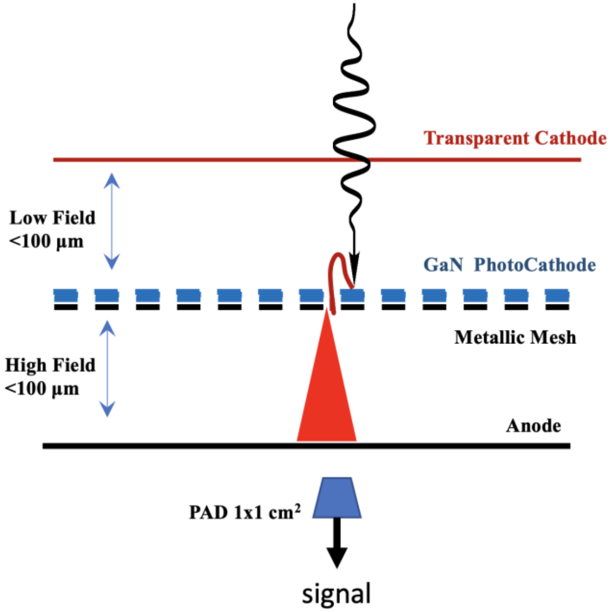


Total funding of the project:
EU-MARIE CURIE3.1 M€/ 8 partners
GREEK share: 70 k€

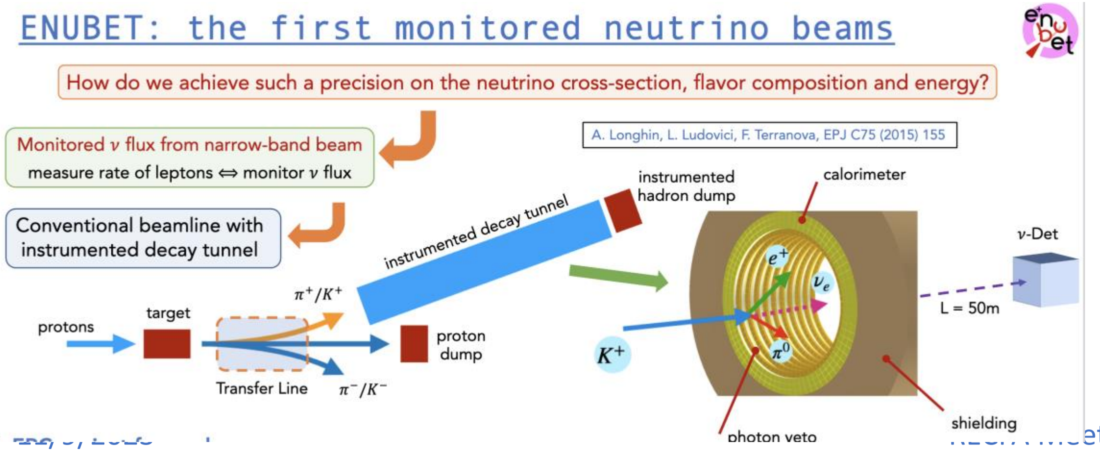
PICOSEC Prototypes for Cherenkov Photon Detection at 300 nm range
Two New Prototypes with reflective (GaN) Photocathods

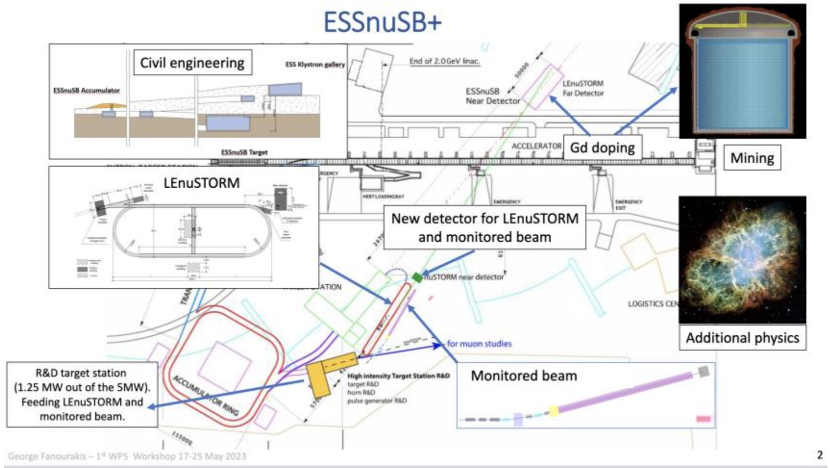




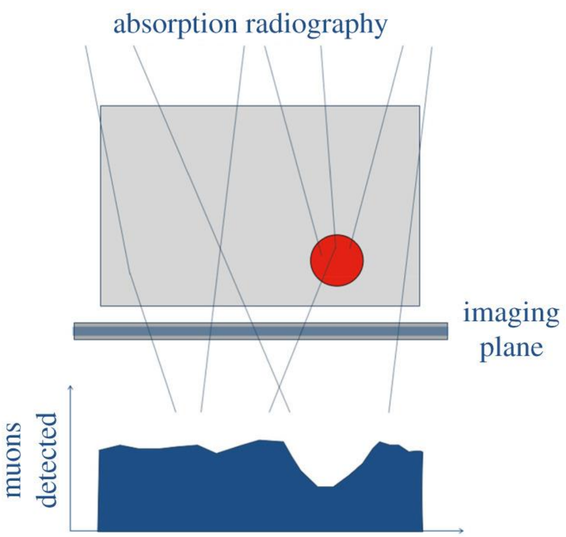


Photodectors for the ENUBET and ESSnuSB+ Neutrino Projects

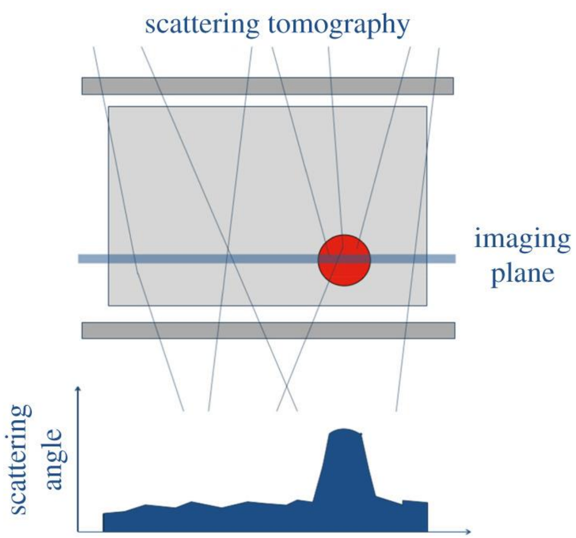




Muon Tomography: imaging method based on muon detection



Imaging via absorption
principle is similar to conventional X-ray radiography



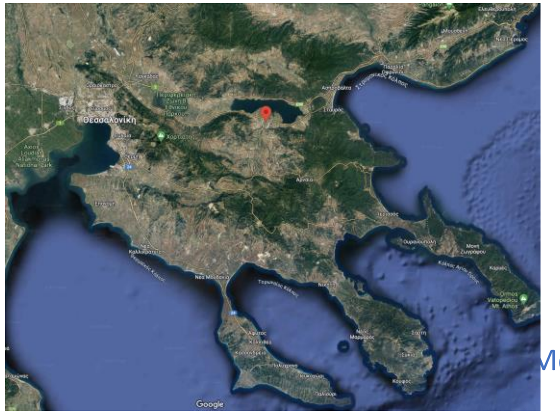
Imaging via scattering
analyze the angles of deflection before and after passing through a volume

- Thickness of a mountain: George (1955)
- Hidden chambers in Chephren (or Khafre) pyramid: Alvarez (1970)
- Volcanology: Nagamine (1995), Tanaka (2001), Diaphane collaboration (2008)

The application of Muon Tomography developed in the framework of EKATY project for : Innovative imaging of the subsurface of archaeological sites and the interior of structural elements of monuments in 3 and 4 Dimensions.

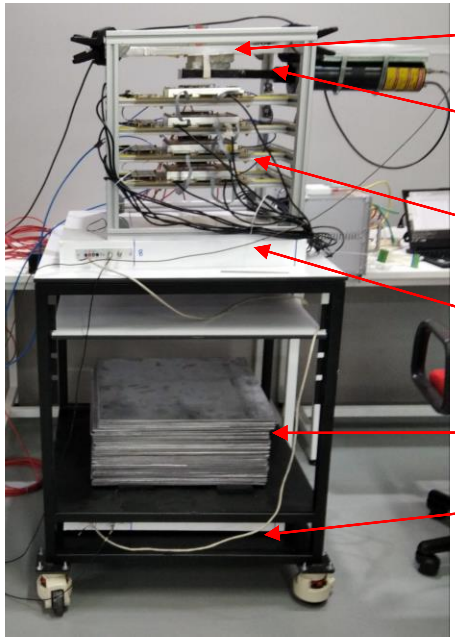
- The project aims to develop innovative methods, instruments and methodological protocols for the **detection, imaging and mapping of buried antiquities.** The detection of structures under the tumuli is specifically addressed.
- Application → at the Great Tumulus of N. Apollonia
- Collaboration of Lab of Nuclear Physics (AUTh), Lab of Geophysics (AUTh), Ministry of Culture, Greek Industry

Great tumulus of Apollonia



A small-scale muon tomography experimental set-up

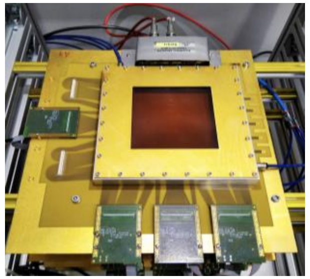
The “mini” Micromegas telescope (@ CIRI – AUTh)



Experimental set-up for imaging of lead cube using both techniques

- **Muon Transmission Radiography**
  - The lead cube’s position: 130 mm from the top Micromegas detector.
  - Cube size: 50mm x 50mm x 50mm
  - Data taking with and without the cube placed above the detectors.
  - Double Coincidence events with Veto.
  - Events within the acceptance of the three scintillators are selected
  - Back projection method applied

- **Muon Scattering Tomography**
  - The cube was placed in the middle of four Micromegas detectors.
  - The cube’s hight reduced to 2.5 cm.
  - Two tracks were reconstructed, the incoming(two upper detectors) and the outgoing (two bottom detectors) one.
  - The deflection angle was calculated.
  - The Point of Closest Approach (POCA) algorithm used

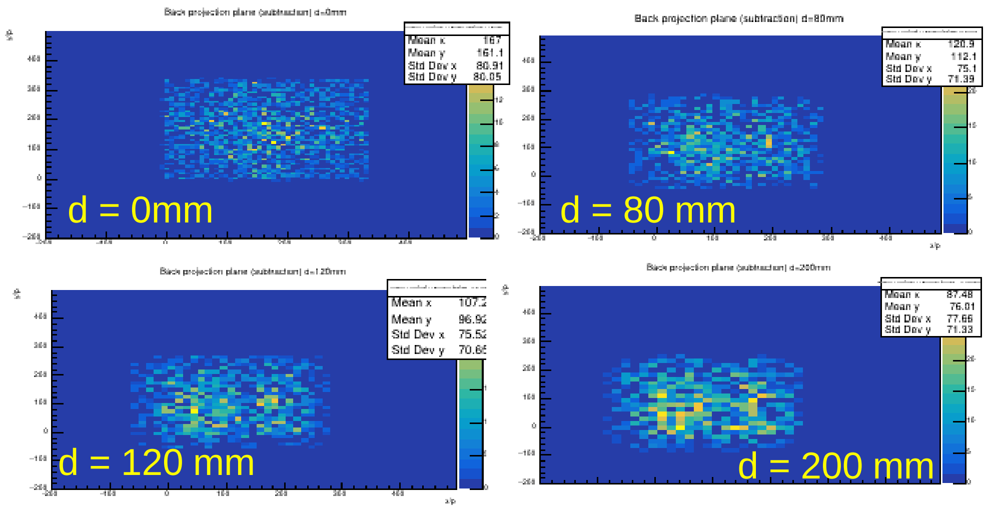


4 Micromegas (10 x 10 cm^2 active area)

- anode board: XY 2-dimensional ~ 384 strips
- detection medium: Ar – CO_2 gas 93%-7%
- APV25 readout cards (x6 per XY plane)
- signal reception via SRS (Scalable Readout System)
- trigger using 2 scintillators in coincidence
- Absorber to veto the high energy muons with 3rd scintillator

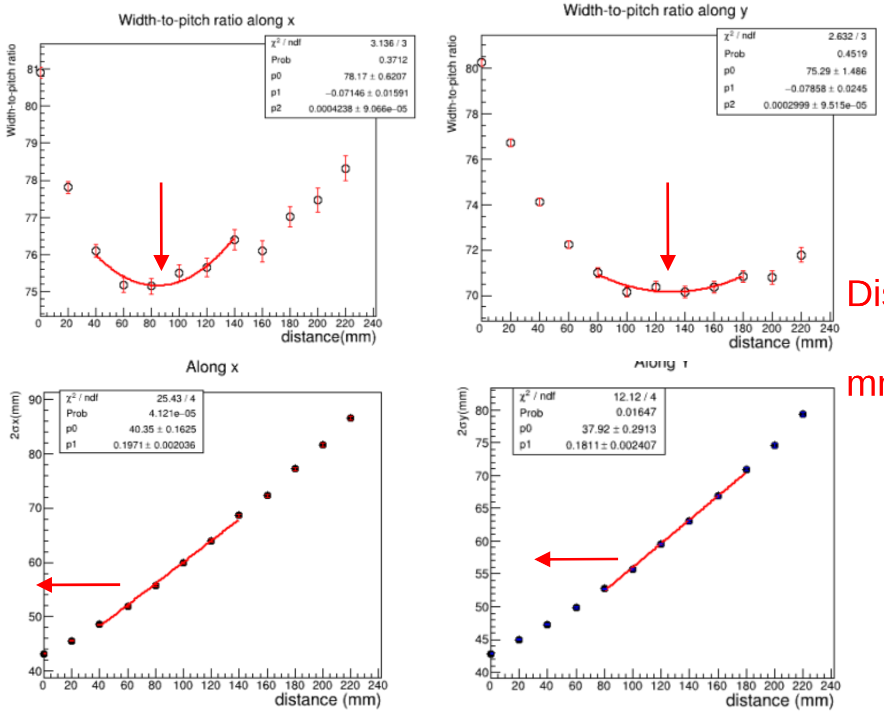
Results

Muon Transmission Radiography (absorption)



Back projection planes at four distances.

Object size: 50mm x 50mm x 50mm at distance 130 mm



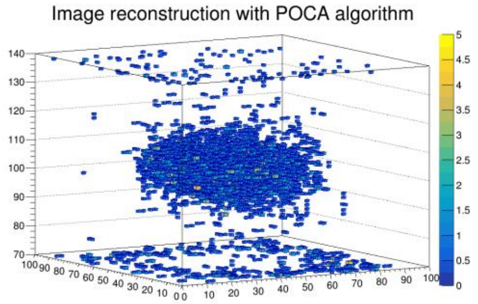
Width-to-pitch ratio along the x (left) and y (right) axis as a function of the distance of the projection plane from the top detector.

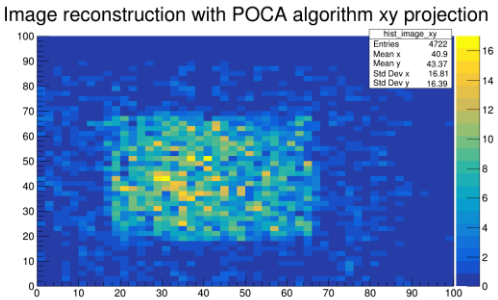
Distance Dx = **84.32** ± 3.16 mm
Dy = **131** ± 4.97 mm

The 2σ of the projections along x(left) and y(right) as a function of the distance.

Size (in X) **56.97** ± 1.4mm,
(in Y) **61.64** ± 1.3 mm

Muon Scattering Tomography





Two dimensional image of the cube

Object size: 50mm x 50mm x 25mm

Object Size (in X) ~ **51** ± 6.4 mm
(in Y) **~ 50** ± 5.7 mm
(in Z) **~ 28** ± 3.7 mm

HEP-2022 IOP Publishing
Journal of Physics: Conference Series 2375 (2022) 012007 doi:10.1088/1742-6596/2375/1/012007

Development of a muon tomography application with Micromegas detectors

D Amperiadou [1,2], C Petridou [1,2], D Sampsonidis [1,2], S Tzamarias[1,2], K Kordas [1,2], C Lampoudis[1,2], A Leisos [3], A Tsirigotis [3], Ch Tsiafis [4,2]

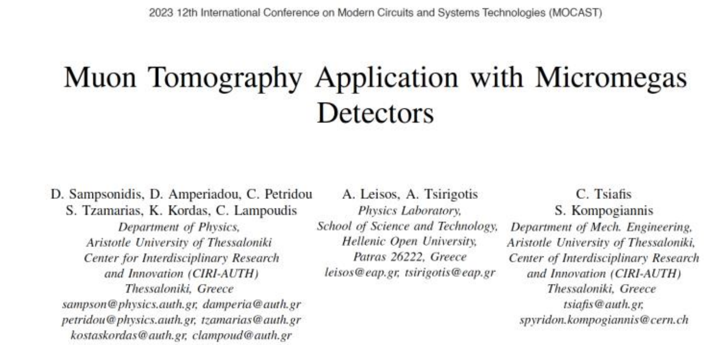
HEP 2021 IOP Publishing
Journal of Physics: Conference Series 2105 (2021) 012017 doi:10.1088/1742-6596/2105/1/012017

Feasibility study of muon tomography application in a non-invasive representation of tumulus

I Kalaitzidou[1,2], G Tsiledakis[1,2], C Lampoudis[1,2], C Petridou[1,2], D Sampsonidis[1,2], K Kordas[1,2], S Tzamarias[1,2], A Leisos[3], A Tsirigotis[3] and Ch Tsiafis[4,2]
[1] Department of Physics, Aristotle University of Thessaloniki, University Campus, GR-54124, Thessaloniki, Greece

MM Telescope: **First Application** at the Apollonia tumulus

- Power: Solar panels & battery array
- Full system powered ON
- Addition of temperature sensors
- Telescope set @ 20 degs
- Test (trigger system + MM pedestal runs + data)
- **Ready for Data Collection**



2023 12th International Conference on Modern Circuits and Systems Technologies (MOCAST)

Muon Tomography Application with Micromegas Detectors

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S. Tzamarias, K. Kordas, C. Lampoudis
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*Work carried out in the framework of the project EKATY (Τ6ΥΒΠ- 00211), in Operational Programme Competitiveness, Entrepreneurship and Innovation 2014- 2020 (EPAnEK) funded after the decision 97476/I2/18-06-2019 (ΑΔΑ:ΩΕ1Ω4653ΠΣ-ΒΑΓ) of the **Greek GSRT***
(Total budget 880K€, for Muon Tomography 425 K€).

EKATY Collaboration :
Geophysics Lab, School of Geology AUTh, Nuclear & Particle Phys. Lab, School of Physics AUTh, Ministry of Culture, (10 Ephorates of Antiquities), Greek Industry (4 Companies)

SPECT-Lab Group at the Physics Department of the NKUA & IASA

Efstathios Stiliaris

Development of small field, sensitive γ-Camera prototypes with a sub-millimeter (0.95±0.05mm) spatial resolution and 0.20μCi sensitivity on a tomographic level for pre-clinical studies of Single Photon Emission Computed Tomography (SPECT).

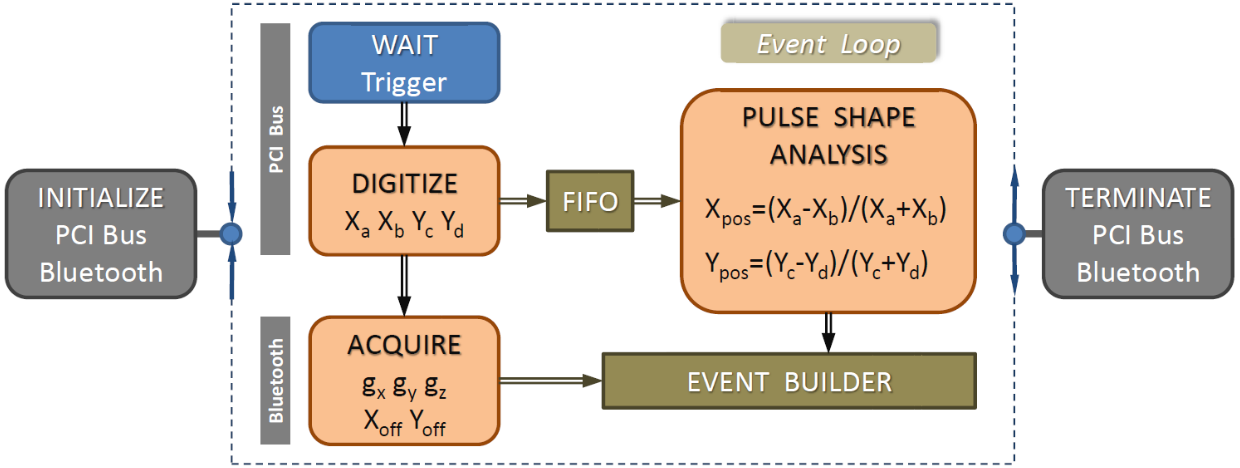
The research focuses on:

- Hand-held small field γ-Camera for clinical scans (LAIKON and ALEXANDRA Hospitals)
- Infra-Red Optical Tomography
- Development of reconstruction algorithms for Compton Camera systems

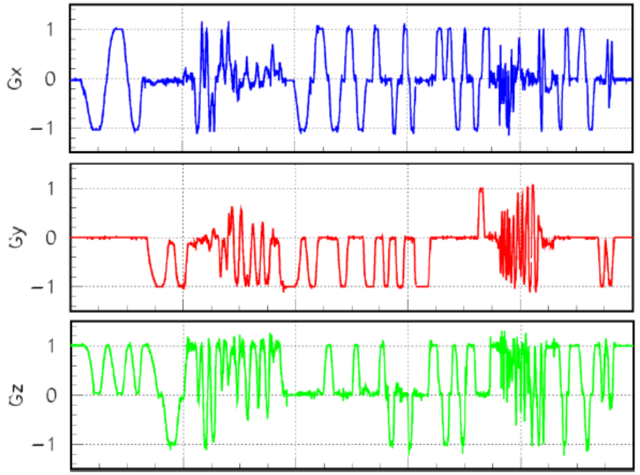
Human Support		Financial Support
PhD Theses (completed)	3	National Programmes 80 k€ (last 5 years)
PhD Theses (in progress)	2	
MSc Theses	12	
Diploma Theses	~100	

Hand-held Small Field γ-Camera with Real-Time Motion Correction

- Small Field γ-Camera with **CsI(Tl)** & **Position Sensitive PMT**
- **3g** Accelerometer (g_x - g_y - g_z)
- **Euler** Angle Reconstruction and Real-Time Correction



DAQ System Flowchart



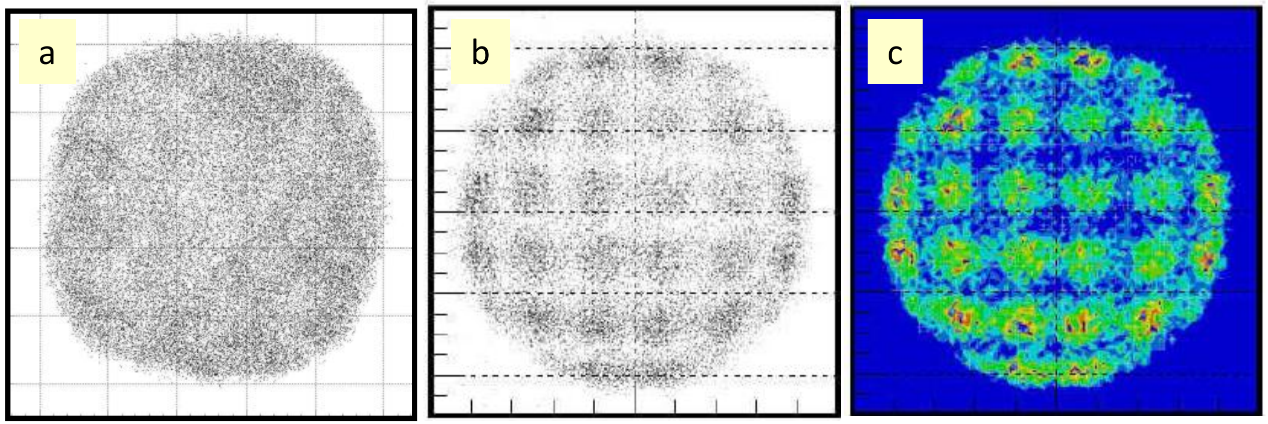
Detection of the g_x g_y g_z Components

^{137}Cs Emission Collimator Pattern

(a) Random movement of the γ-Camera

(b) Corrected pattern through Euler angles

(c) Contour pattern

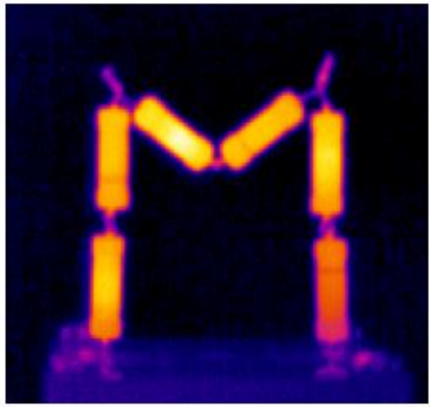


M. Zioga *et al.* (IEEE) https://doi.org/10.1109/NSSMIC.2016.8069436 , https://doi.org/10.1109/NSSMIC.2012.6551576

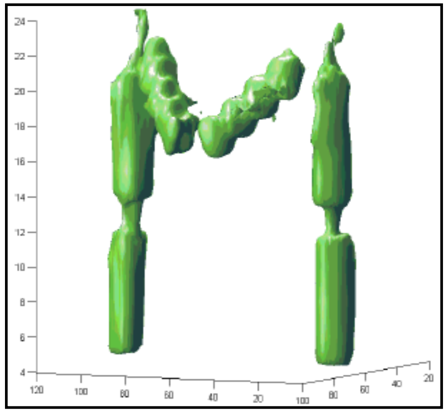
Single Photon Emission Computed Tomography (SPECT) with Time-Resolved Optical Tomography

- Infra-Red (IR) Tomography
- Time-of-Flight filtering of the Ballistic Component
- Double Modality SPECT and Optical

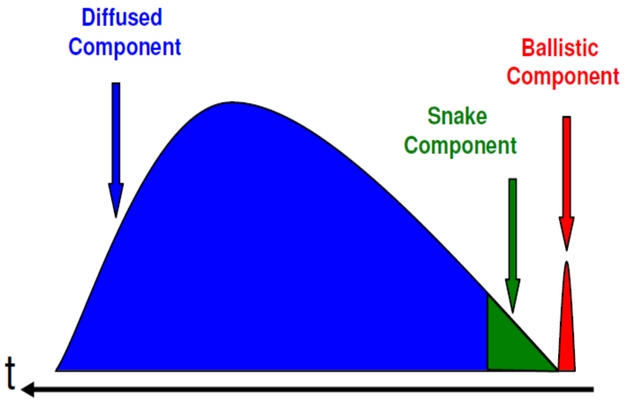
Thermal Phantom



Infra-Red (IR) Tomography

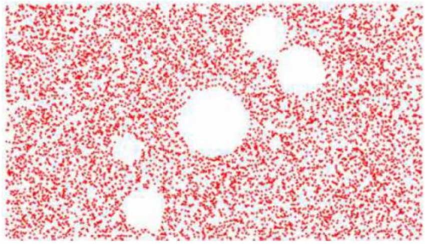


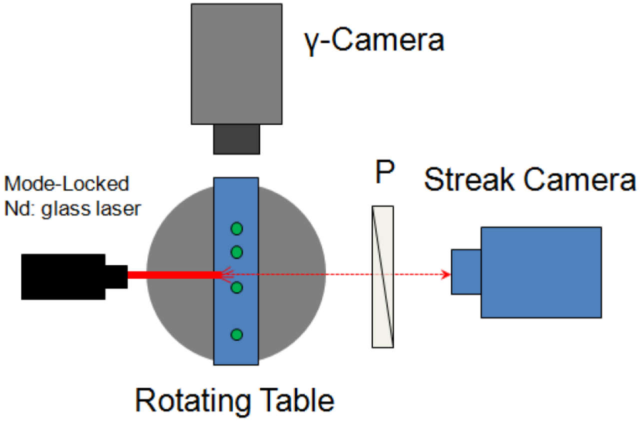
3D Reconstruction



Resulting Pulse Shape

Ballistic Component

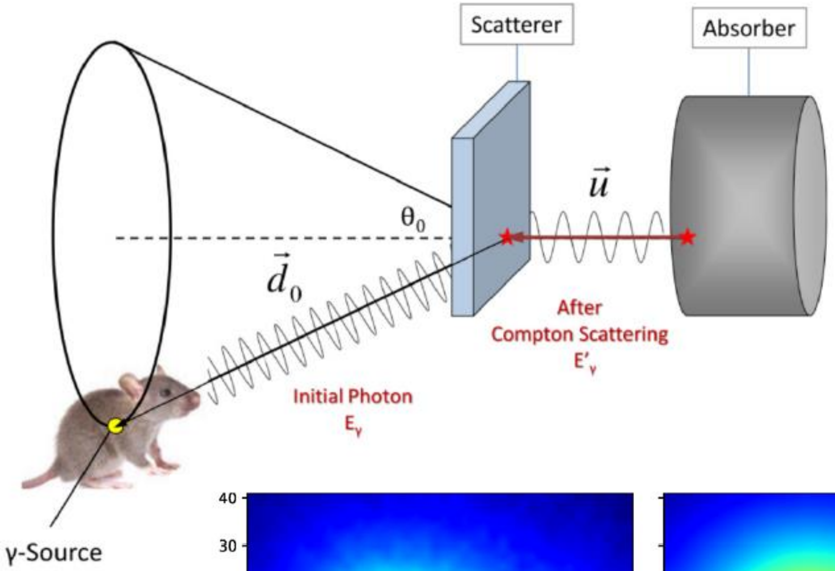


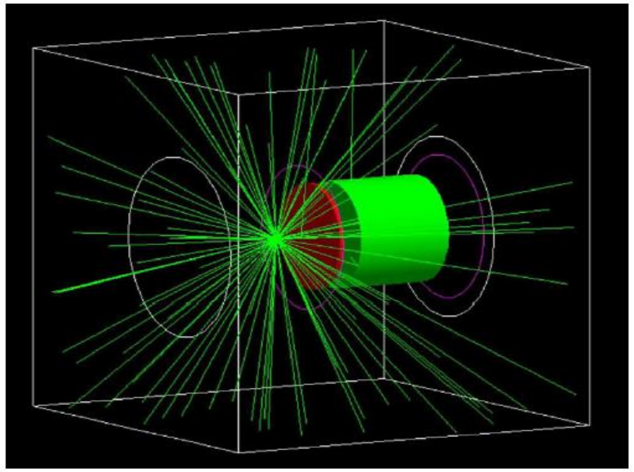


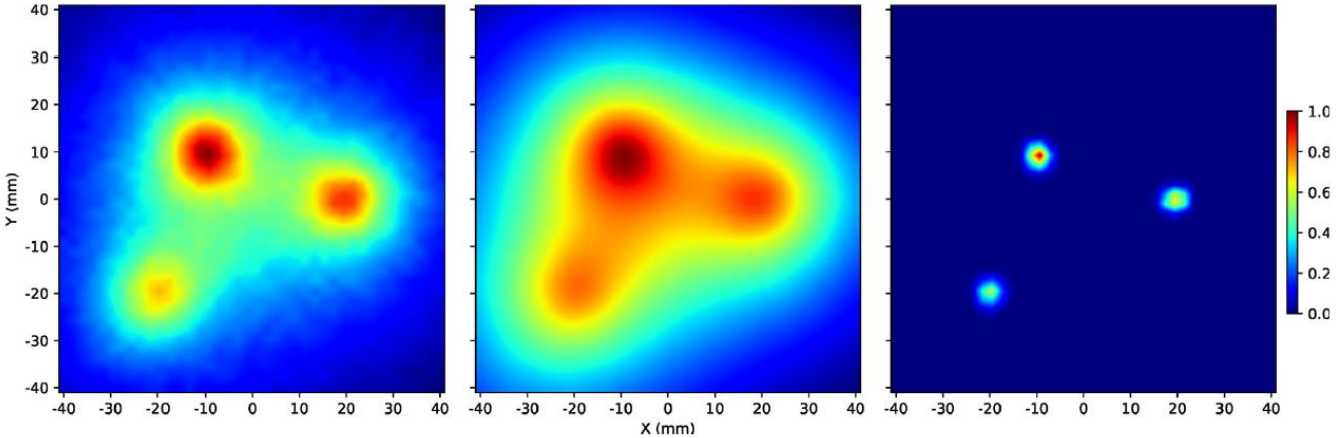
A.-N. Rapsomanikis *et al.* (IEEE) https://doi.org/10.1109/NSS/MIC42101.2019.9059612 , https://doi.org/10.1109/NSSMIC.2016.8069547 https://doi.org/10.1109/NSSMIC.2012.6551834

Reconstruction Algorithms for Compton Camera Events

- GEANT4/GATE Simulation of a Compton Camera
- Conic Sections Geometrical Approach
- Stochastic Algorithms (Max Likelihood – MLEM)







(a) Conic Sections (b) Log-Likelihood (c) This LM-MLEM

M. Mikeli, M.-E. Tomazinaki *et al.* Computers in Biology and Medicine 166 (2023) 107502
https://doi.org/10.1109/NSS/MIC44867.2021.9875470

Where do we stand

- R&D groups are in the shadow/protection of big experiments
- There is a lot of work done with minimal or NO funding
- Funding appears in random times, it is minimal and there is no continuation
- There is no real support to equip R&D labs