Progress of Lithuania in Research and Education

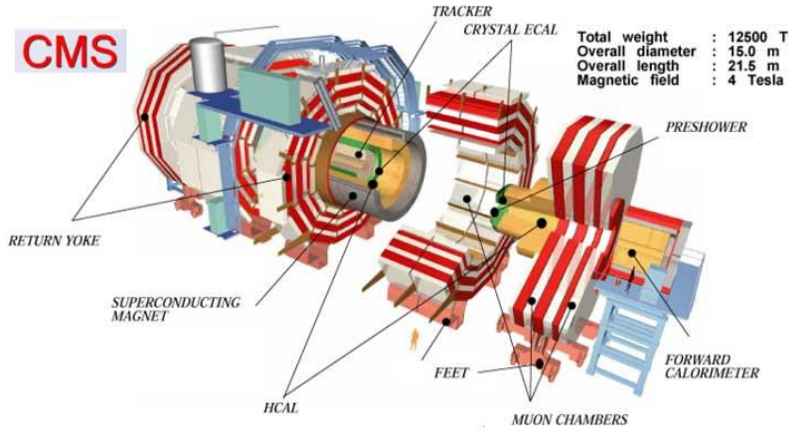
Presented by dr. Ramūnas Aleksiejūnas

Vilnius

2022-11-24

Development of scintillators for fast radiation detectors

CRYSTAL CLEAR COLLABORATION **(RD18)**

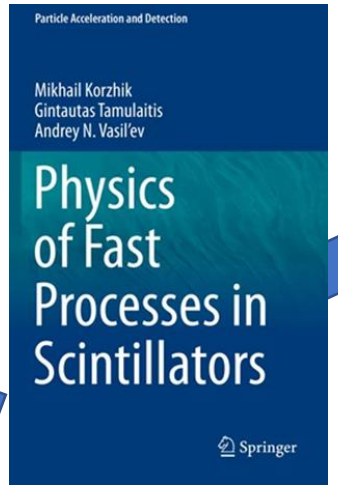


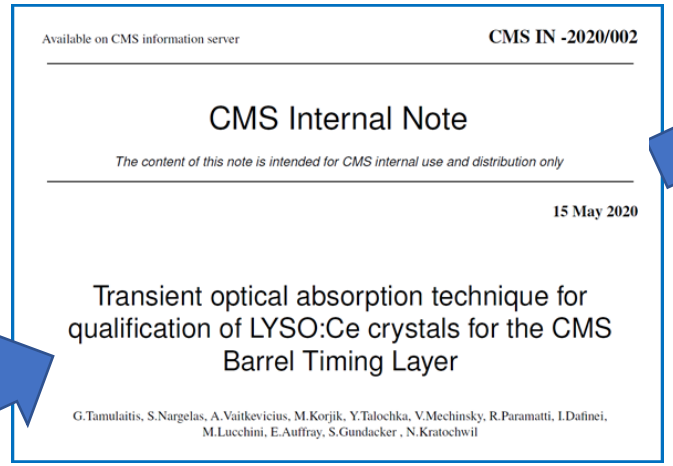
Main goal is *development of scintillation materials for fast radiation detectors for current updates and future CERN experimental facilities*

Development of scintillators for fast radiation detectors: evolution of the field

Two Lithianian Science Awards on semiconductor spectroscopy as a background

31 research papers
+




Available on CMS information server CMS IN -2020/002

CMS Internal Note

The content of this note is intended for CMS internal use and distribution only

15 May 2020

Transient optical absorption technique for qualification of LYSO:Ce crystals for the CMS Barrel Timing Layer

G.Tamulaitis, S.Nargelas, A.Vaitkevicius, M.Korjik, Y.Talochka, V.Mechinsky, R.Paramatti, I.Dafinei, M.Lucchini, E.Auffray, S.Gundacker , N.Kratochwil

Testbench for routine testing of scintillators for the coming update of CMS experiment

165 000 such crystals will be installed in the Barrel Timing Layer of CMS

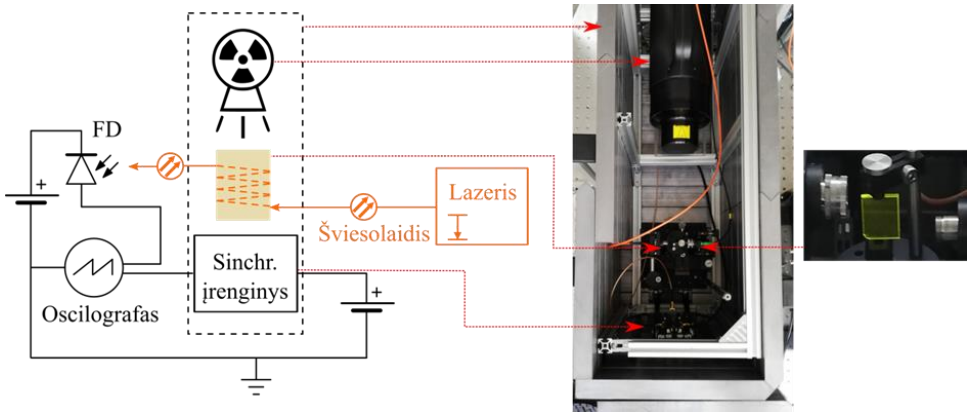
As a result of 4 months of Experimental Physics Responsibilities (EPR) in 2021, one co-authorship in > 60 CMS research papers in 2022.

Development of scintillators for fast radiation detectors: theoretical studies

- Study of carrier dynamics important for response time of multicomponent scintillators initiated in 2020;
- PhD student Yauheni Talochka started his PhD studies on this topic in 2020;
- At least 4 papers with substantial support by calculations of Yauheni in 2021-2022;
- First basically theoretical paper by Yauheni on this topic in 2022:
  Y. Talochka et al., Impact of compositional disorder on electron migration in lutetium–yttrium oxyorthosilicate scintillator, J. Appl. Phys. 132, 053101 (2022);
- Development of the code to make it available for CERN users as a simulation tool in 2024-2025;
- The model has been applied and compared with experimental data in another topic of charge transport in disordered semiconductors.

Development of scintillators for fast radiation detectors: national projects

The European Regional Development Fund project under grant agreement with the Research Council of Lithuania (project No. 01.2.2-LMT-L-718-01-0041) *Neutron flux detection system with optical readout*, 2018-2022, total budget 529 447 Eur.



The European Social Fund under grant agreement with the Research Council of Lithuania (project No. 09.3.3-LMT-K-712-01-0013) *Fast scintillators for radiation detectors* (*FARAD*), 2018-2022, total budget 591 144 Eur.

13 pier-reviewed papers published, mostly in Q1 and Q2 journals (10 such papers planned)

Local support from the Lithuanian Academy of Sciences for the Compact Moun Solenoid Barrel Timing Layer Upgrade.

Development of scintillators for fast radiation detectors: projects

- Participation in CERN-lead Horizon project: Horizon 2020 programme RIA project „Advancement and Innovation for Detectors at Accelerators“, AIDAinnova (101004761) 2021 – 2025;
- Application of Phase II for ATTEACT grant in collaboration with partners from Crystal Clear Collaboration and industry (rejected): Development of industrial technology for mass production of cost-effective Ce-doped gadolinium–silica scintillation glass for radiation detectors used in research instrumentation, medical imaging and security (SCINTIGLASS) (Phase I project is successfully completed in 2021).

Development of scintillators for fast radiation detectors: young researches

- Arnoldas Solovjovas started his PhD work on nanostructures scintillators
- 3-4 undergraduates work in the research labs in the field of scintillators
- Erasmus lecture course on radiation detectors for PhD students at CERN CCC partners institution Università Politecnica Delle Marche, Ancona (Italy)

Development of scintillators for fast radiation detectors: dissemination

Research papers:

1. S. Nargelas et al., Influence of matrix composition and its fluctuations on excitation relaxation and emission spectrum of Ce ions in (Gdx Y1-x)3Al2Ga3O12: Ce scintillators, J. Lumin. 242, 118590, (2022).
2. K. Nomeika et al., A new method for remote detection of ionizing radiation using transient optical absorption, Nuclear Inst. and Methods in Physics Research, A 1029, 166408 (2022).
3. M. Korzhik et al., Ultrafast PWO scintillator for future high energy physics instrumentation, Nuclear Inst. and Methods in Physics Research, A 1034, 166781 (2022) .
4. G. Tamulaitis et al., Transient optical absorption as a powerful tool for engineering of lead tungstate scintillators towards faster response, J. Materials Chemistry C, 10, 9521 (2022).
5. Y. Talochka, A. Vasil'ev, M. Korjik, G. Tamulaitis, Impact of compositional disorder on electron migration in lutetium–yttrium oxyorthosilicate scintillator, J. Appl. Phys. 132, 053101 (2022).
6. L. Martinazzoli et al., Compositional engineering of multicomponent garnet scintillators: Towards an ultra-accelerated scintillation response, Materials Advances, 17, 6842 (2022).

Presentations at scientific conferences: **Keynote** talk by prof. G. Tamulaitis in 16th Int. Conference on Scintillating Materials & their Applications, September 19-23, 2022, Santa Fe, USA; other **4 oral** and **2 poster** presentations.

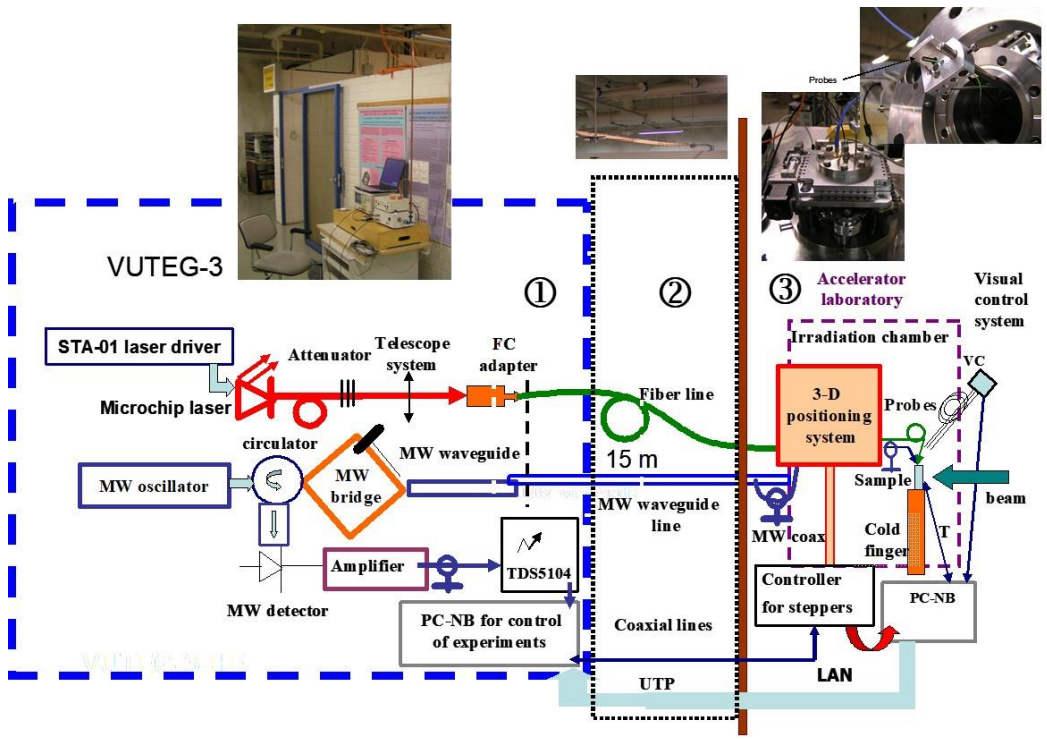
CERN RD50 related activities

VU activities related to RD50 (Radiation hard semiconductor devices for very high luminosity colliders) research program:

- Technologies and instrumentation for spectroscopy and contactless-remote dosimetry of the large fluences of high energy radiations.
- Search of radiation hard materials and development of radiation tolerant structures.
- Technologies and instruments for the remote in situ measurements in harsh irradiation environments.
- Development of advanced material characterization techniques and instruments.
- Engineering of defects for development of radiation hard particle and photo sensors capable to operate in cosmic space and modern particle accelerators.
- Technologies and instrumentation for spectroscopy of high energy radiations for medical diagnostics and monitoring of radiation safety within nuclear power plants and storage facilities of radioactive waste.

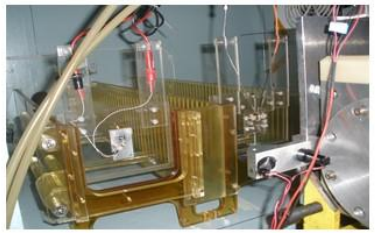
CERN RD50 related activities: evolution

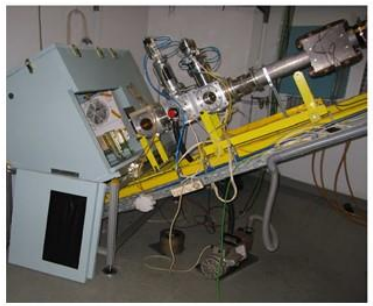
In situ control of of the radiation defects introduced by 8 MeV protons at Helsinki University accelerator laboratory.

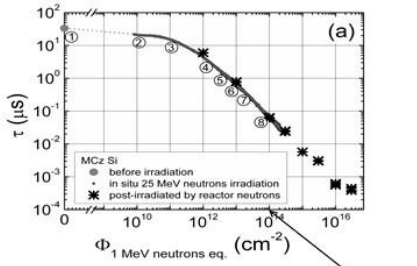


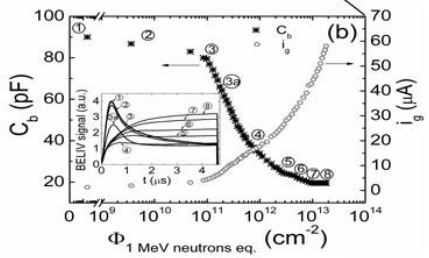
In situ variations of carrier recombination (a- MW-PC), of barrier capacitance (b-BELIV) and of detector response (c-TCT/ICDC) during irradiation by spallator neutrons.

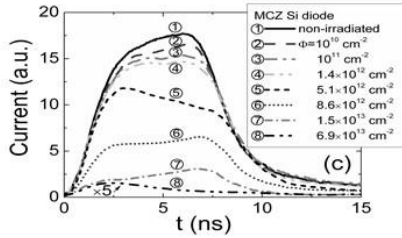
Correlated evolution of the MW-PC, BELIV and ICDC characteristics during spallator neutrons irradiation:
transients registered every 10 ms, irradiation - bunches of 4 ns duration.







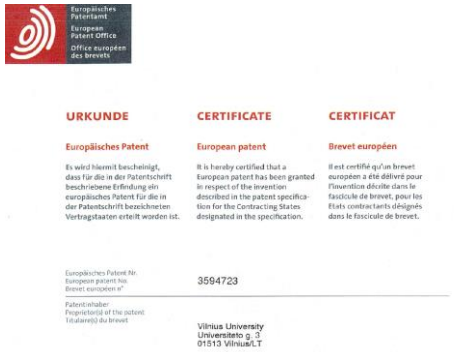




E. Gaubas et, Appl. Phys. Lett. **101** (2012) 232104.

CERN RD50 related activities: evolution

Patented method and equipment for the measurements of high cumulative doses collected under ionizing irradiations by gamma rays, leptons and hadrons.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URKUNDE | CERTIFICATE | CERTIFICAT

Europäisches Patent | European patent | Brevet européen

Es wird hiermit bescheinigt, dass für die in der Patentschrift beschriebene Erfindung ein europäisches Patent für die in der Patentschrift bezeichneten Vertragstaaten erteilt worden ist.

It is hereby certified that a European patent has been granted in respect of the invention described in the patent specification for the Contracting States designated in the specification.

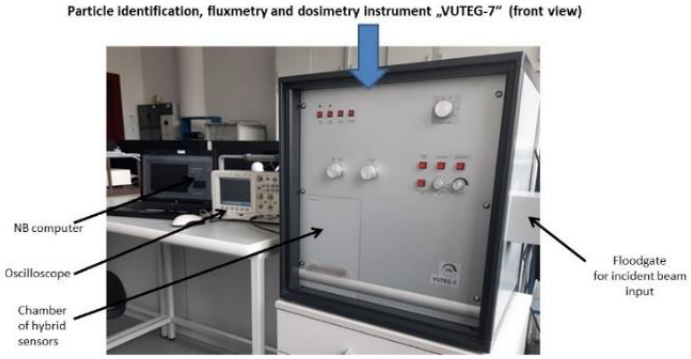
Il est certifié qu'un brevet européen a été délivré pour l'invention décrite dans le fascicule de brevet, pour les Etats contractants désignés dans le fascicule de brevet.

Europäisches Patent Nr. / European patent No. / Brevet européen n° 3594723

Patentinhaber / Proprietor(s) of the patent / Titulaire(s) du brevet
Vilnius University
Universiteto g. 3
01513 Vilnius/LT

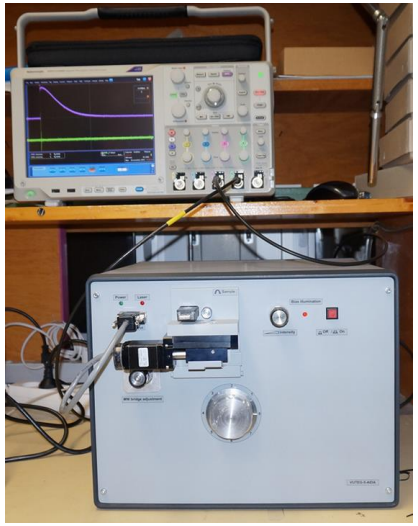
EU patent: E. Gaubas, T. Čeponis, et al, „DOUBLE RESPONSE IONIZING RADIATION DETECTOR AND MEASURING METHOD USING THE SAME“- App No.: 18213254.8, Patent No.: 3594723.

Instrument and technology for dosimetry and fluxmetry of high energy electromagnetic and particle radiations.

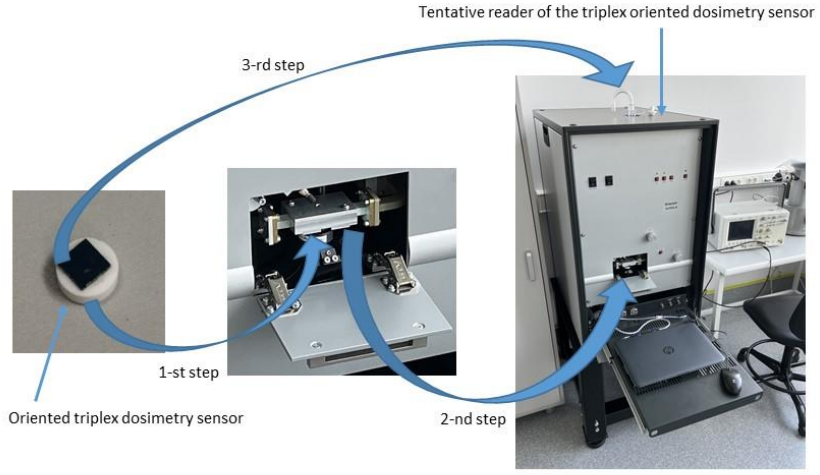


HYBRID MULTI-LAYER SENSOR AND METHOD FOR LARGE FLUENCE DOSIMETRY AND FLUXIMETRY, Authors: Eugenijus Gaubas, Tomas Čeponis, Laimonas Deveikis, Jevgenij Pavlov, Vytautas Rumbauskas. Application No. 21 165 145.0, submission date: 2021 03 26.

Dosimeter VUTEG-5-AIDA has been installed at CERN in 2012 for the RD50 program and other CERN research. The dosimeter VUTEG-5-AIDA is devoted for dosimetric control of hot irradiation zones of large areas.



The prototype system for the control of radiation doses in a wide range. This prototype system allows measuring low and very high fluences and to identify the spectrum of high energy radiations.

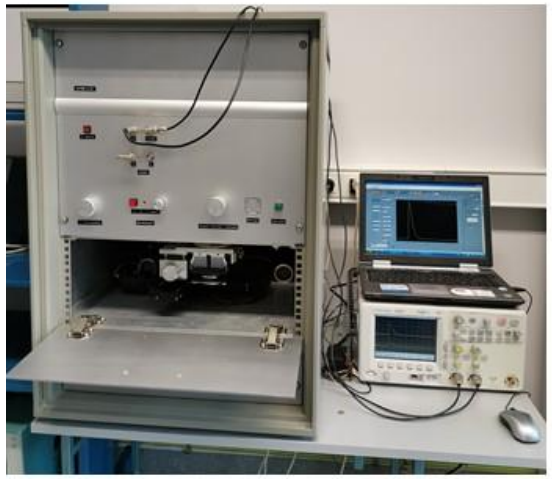


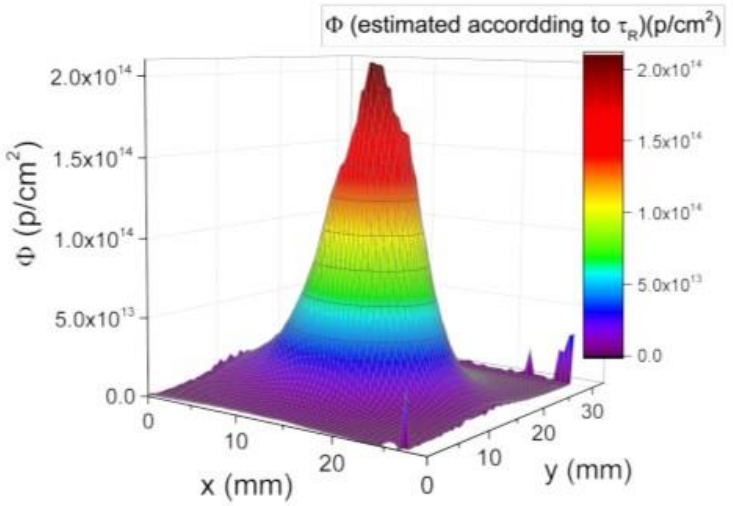
The oriented sensor is in succession set in PL as well as MW-PC opening and into the EPR insert of the tentative reader

E. Gaubas, T. Čeponis, L. Deveikis, J. Pavlov, V. Rumbauskas, Oriented triplex sensor and method of identification of the radiation source location and its dosimetry, EU patent application No. EP22171639.2, submission date: 2022 05 04.

CERN RD50 related activities: Technology and instruments for particle beam profiling

The particle beam profiling techniques based on dosimetry of the hadron irradiated Si and GaN sensors have been developed. The fluence distribution profiles for high energy penetrative particles are recorded by carrier lifetime measurements within Si wafer. For beams of rather low energy particles, sensors with thin active layers are preferable. Then, the scintillation techniques are eligible to have recordable responses from thin sensor layers.





Recorded profile of 26 GeV/c proton beam.

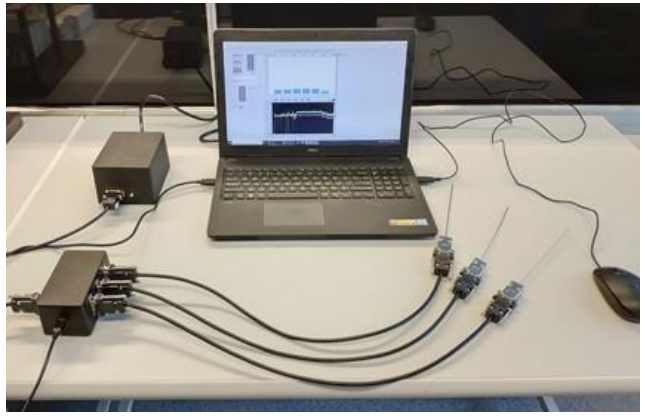
- L. Deveikis, J.V. Vaitkus, T. Čeponis, M. Gaspariūnas, V. Kovalevskij, V. Rumbauskas, E. Gaubas, *Profiling of proton beams by fluence scanners*, Lith. J. Phys. **61** (2021) 75–83.
- T. Ceponis, L. Deveikis, E. Gaubas V. Rumbauskas, M. Moll, Particle beam profilers based on fluence dependent variations of carrier lifetime and scintillation intensity in Si and GaN materials, Presentation at RD50 workshop, CERN 2022-06.

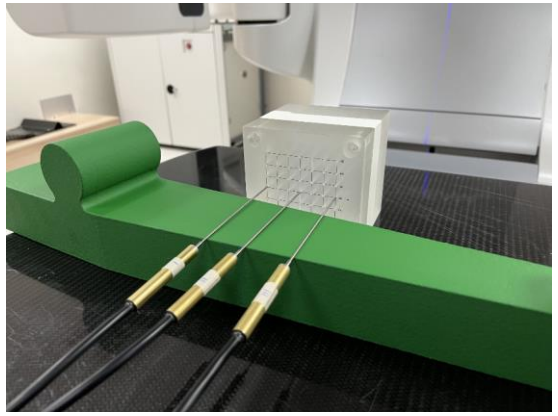
CERN RD50 related activities: joining the project for developing novel particle detectors

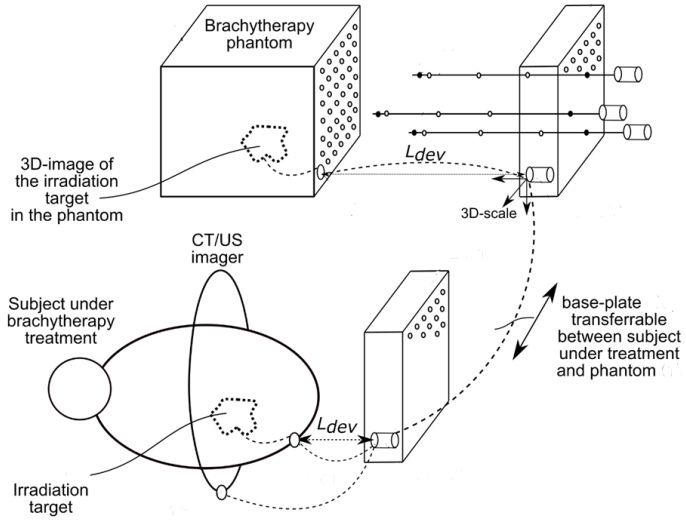
- In 2022 the VU group joined the project “Defect engineering in PAD diodes mimicking the gain layer in LGADs” within the frame of CERN RD50 collaboration.
- The VU group will be responsible for direct measurements of carrier recombination lifetime and correlation with parameters obtained by electrical measurements in LGAD structures.
- The unique instruments and techniques (developed by VU group) of carrier lifetime profiling and electrical characterization will be employed in this study.

Radiation dose monitoring systems for medical applications

- Development of technology and instrumentation for time-resolved positioning of radiation emitters and for dosimetry during the brachytherapy planning and a subsequent in vivo brachytherapy treatment stages, where the method and apparatus are based on triangulation of needle-type probes fixed within time-space resolved coordinates.
- The technology and instrumentation have been approved at The National Cancer Institute.
- The first in vivo measurement of radiation dose during brachytherapy therapeutic procedure has been performed in October 2022.







E. Gaubas, T. Čeponis, K. Pūkas, V. Rumbauskas, M. Užgirytė, J. Venius, K. Akelaitis, A. Cicinas. SYSTEM AND METHOD FOR BRACHYTHERAPY PROCEDURE PLANNING AND VERIFICATION, EU patent application No. EP21210650.4, submission date: 2021 11 26.

CERN RD50 related activities: main achievements during 2022

Published articles:

- J. Pavlov, T. Ceponis, K. Pukas, L. Makarenko, E. Gaubas, 5.5 MeV electron irradiation-induced transformation of minority carrier traps in p-type Si and Si1-xGex alloys, Materials 15 (2022) 1861.

EU patent applications:

- E. Gaubas, T. Čeponis, L. Deveikis, J. Pavlov, V. Rumbauskas, Oriented triplex sensor and method of identification of the radiation source location and its dosimetry, EU patent application No. EP22171639.2, submission date: 2022 05 04.

Presentations at conferences:

T. Ceponis, L. Deveikis, E. Gaubas V. Rumbauskas, M. Moll, Particle beam profilers based on fluence dependent variations of carrier lifetime and scintillation intensity in Si and GaN materials, Presentation at RD50 workshop, CERN 2022-06.

Implemented projects:

- LMT „SMART“ project 01.2.2.-LMT-K-718-01-0013 „Creation of the prototype wide-spectrum dosimetry system for various purpose monitoring of irradiations“, 600000 EUR/2018-2022 yr.
- Lithuanian Academy of Science project CERN-VU-2022-4 „Radiation tolerant semiconductor detectors for high luminosity colliders“, 33700 EUR/2022 yr.

PHD thesis defence:

- Two students defended the PHD thesis in topics related with CERN activities.

Awards:

- T. Ceponis, E. Gaubas, J. Vaitkus received the Lithuanian National Science Prize in the area related with CERN activities.

Physics of Subatomic Particles at CERN CMS experiment (project DaFi2021): Participation in the CMS experiment

1. Analysis of the proton-proton collision data recorded with the CMS detector is focused on precision studies of the Drell-Yan process
   - Group uses data-driven methods to estimate the number of the background process events in data recorded in 2016-2018
   - Collaboration with Université Libre de Bruxelles University, University of Nebraska in Lincoln, Univeristy of Montenegro, and Yonsei University
   - Work towards differential cross section measurement is on-going, planning results in 2023
2. Calibration of the pixel silicon sensor for the CMS Tracker Phase II upgrade
   - Work supervised by S. Mersi (CERN)
   - Software development and remote testing on actual sensor (RD53B)
   - Hands-on work during 1 month visit in August
3. 30 remote CMS DAQ shifts to control data-taking with the detector
4. Participation in CERN LHC Electroweak Work group (EW WG) activities continues
   - Impact of uncertainty correlations on the estimated data-theory (dis)agreement

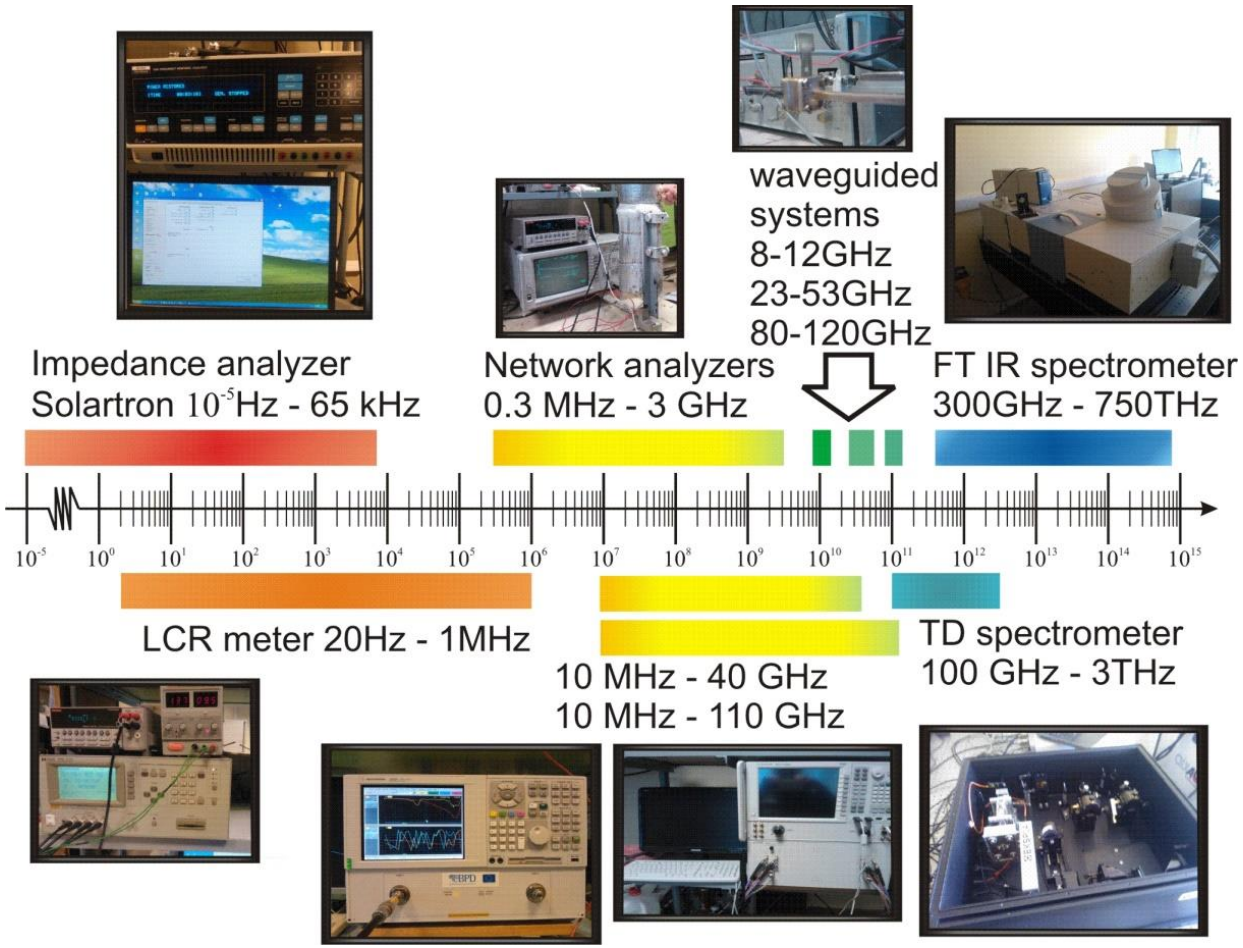
Physics of Subatomic Particles at CERN CMS experiment (project DaFi2021): Phenomenological studies

- Group theorists study several models beyond the standard model trying to address

1. **Neutrino flavor oscillations**
   - ➢ Study of Grimus-Neufeld model (this is the standard model extended by one extra Higgs doublet, and one heavy Majorana neutrino) lead to general questions about the accepted theory-experiment matching (renormalization) procedures
     - Acta Phys. Polon. Supp. 15 (2022) 2, 1, a15.
     - Acta Phys. Polon. Supp. 15 (2022) 2, 1, a17.
2. **Lepton flavor violating reactions**
   - ➢ Within the Grimus-Neufeld model
     - JHEP 09 (2022) 174
   - ➢ A 2HDM model with soft breaking terms
     - JHEP 03 (2022) 106
3. **Description of the stable dark matter**
   - ➢ Symmetry groups which could be used to describe the dark matter particles
     - e-Print 2210.12133 [hep-ph]

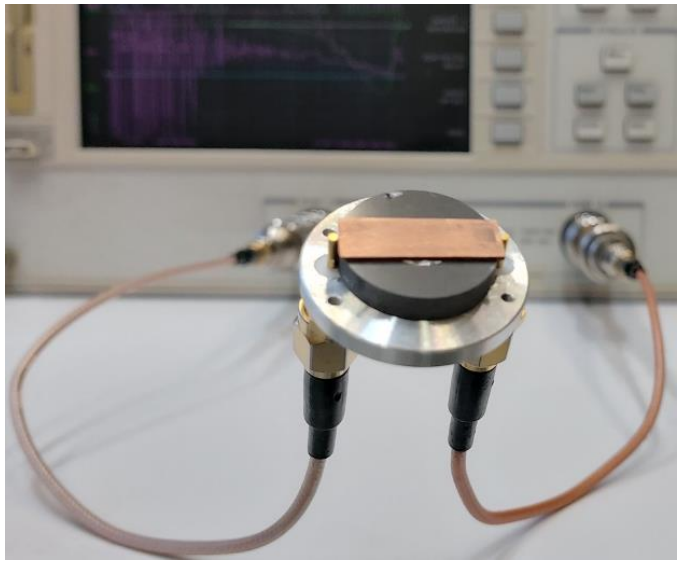
- Collaboration with Lisbon CFTP, Dresden TU, Warsaw NCBJ, CERN TH

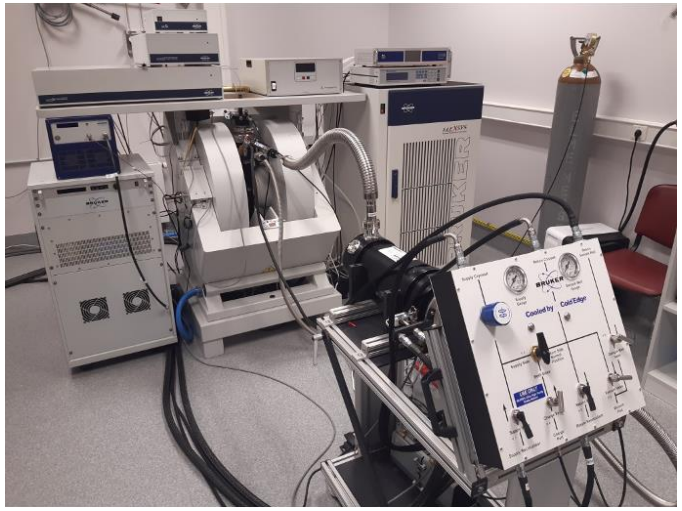
Investigation of ferrite materials



Microwave Spectroscopy Laboratory performs investigations of structural phase transitions in ferrite materials using broadband dielectric and magnetic permeability spectroscopy. Temperature dependence spectra of complex dielectric conductivity (4 - 500K) in a wide frequency range (10 mHz - 110 GHz) can provide important information about the type of phase transition, temperature and nature of phase transitions.

Investigation of ferrite materials

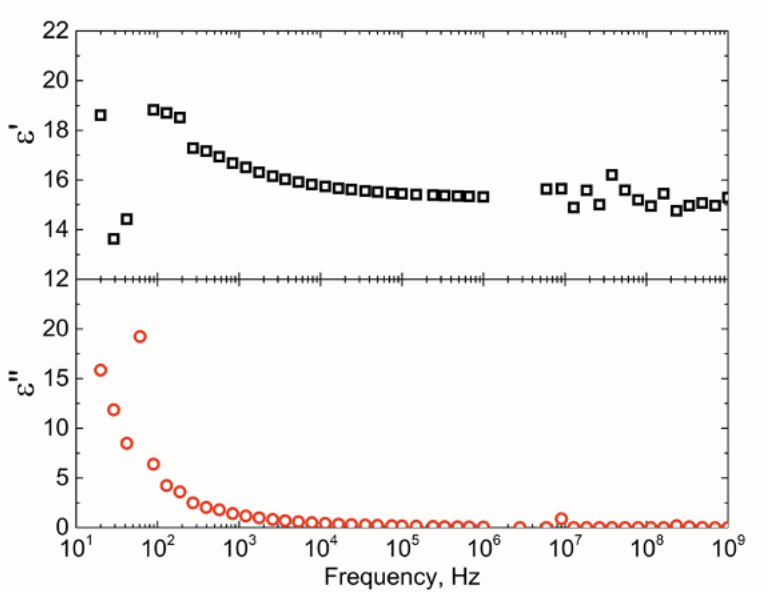


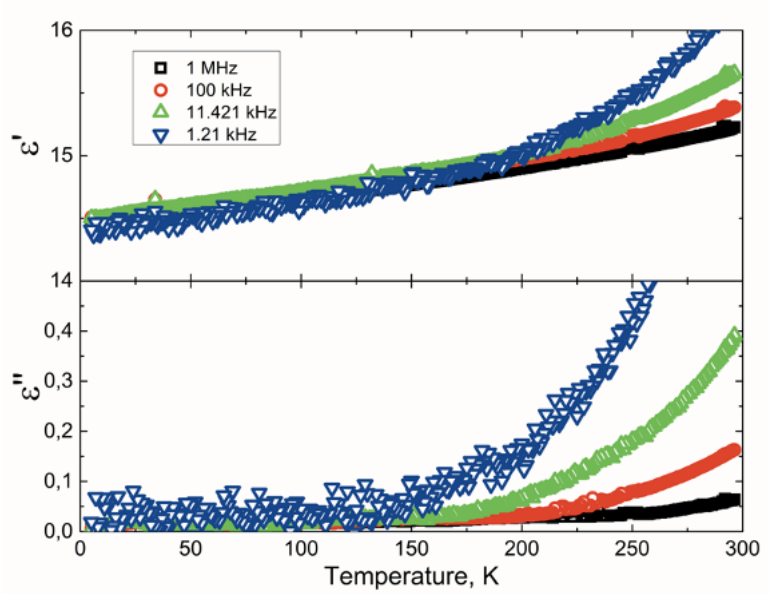


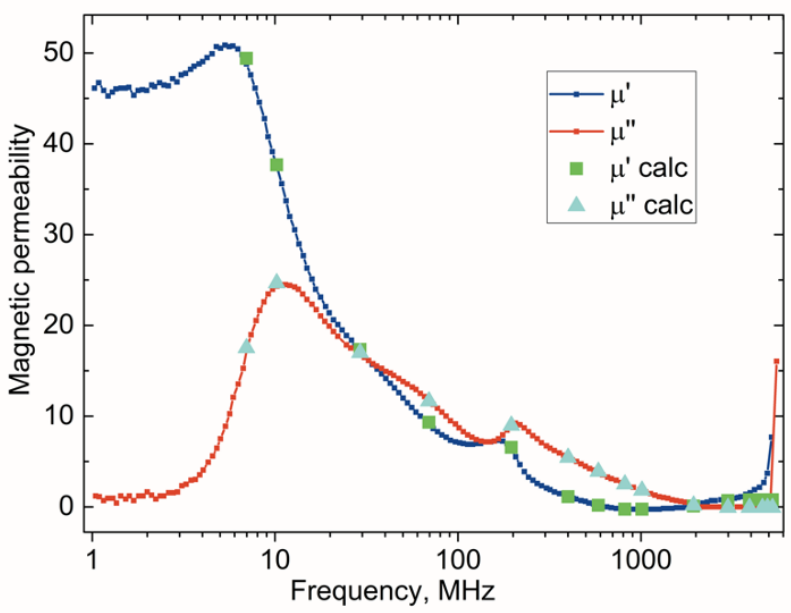
The aim of the research is to find out which ferrite materials are promising for CERN's particle beam introduction and extraction devices from the CERN accelerator rings.

Currently investigated ferrite materials will be used in the high-speed ferrite tuner, in one of the upgraded facilities at the proton synchrotron, which is one of the most important components in the CERN accelerator complex. This device will operate at a high frequency of about 80 MHz, which places special demands on the parameters of the ferrites used in it.

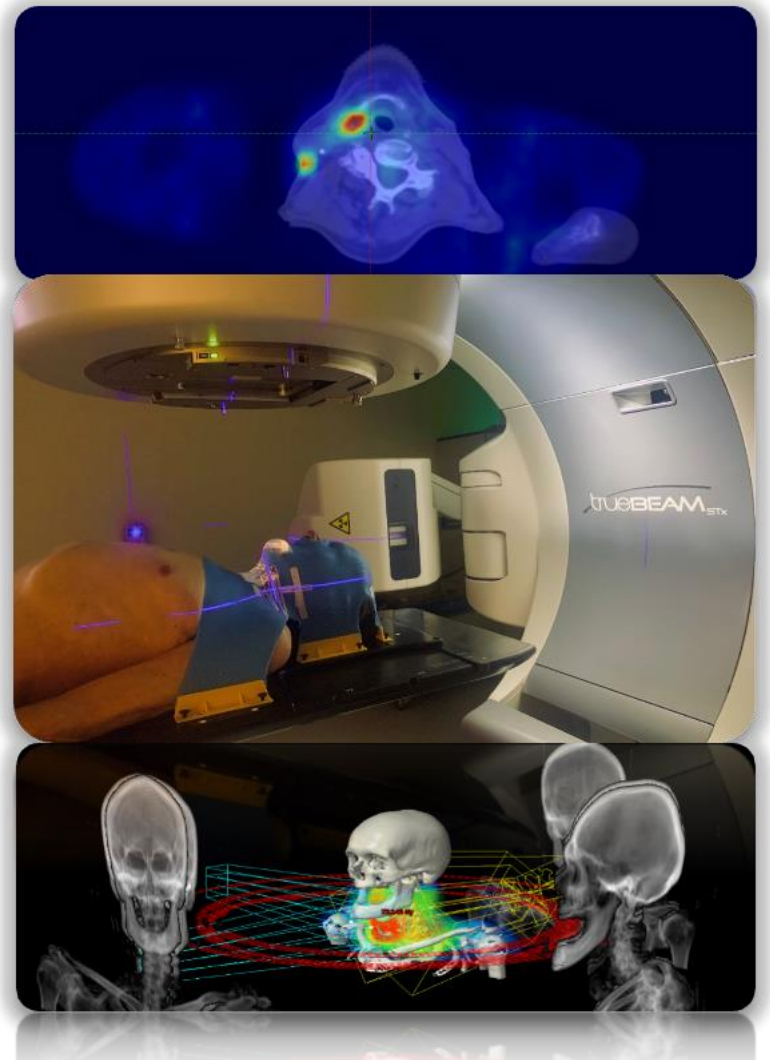
Investigation of ferrite materials: an example of data on AL-800 ferrite







LSMU-CERN: research areas in radiotherapy and radiobiology



- **Prognostic and predictive molecular markers of solid tumors;**
- **Molecular mechanisms of sensitivity and resistance to radiotherapy in breast cancer or other cell lines;**
- Radiotherapy optimisation using ^{18}F-FDG-PET/CT images;
- Association between common genetic variations with individual patient variability in normal tissue late radiation toxicities;
- Linac-based fractionated stereotactic radiotherapy vs. intensity modulated radiotherapy;
- New brachytherapy techniques.

LSMU-CERN: evolution

- During the last years training of medical physicists and radiation oncologists was organized in collaboration with CERN.
- Development of nuclear medicine is closely related to the deployment of cyclotron at LUHS University Hospital.
- Oncology institute: CERN- activities related to 4 projects in Radiobiology.

2017.07.01 – 2017.12.31

“Molecular mechanisms determining breast cancer cells resistance to radiotherapy”

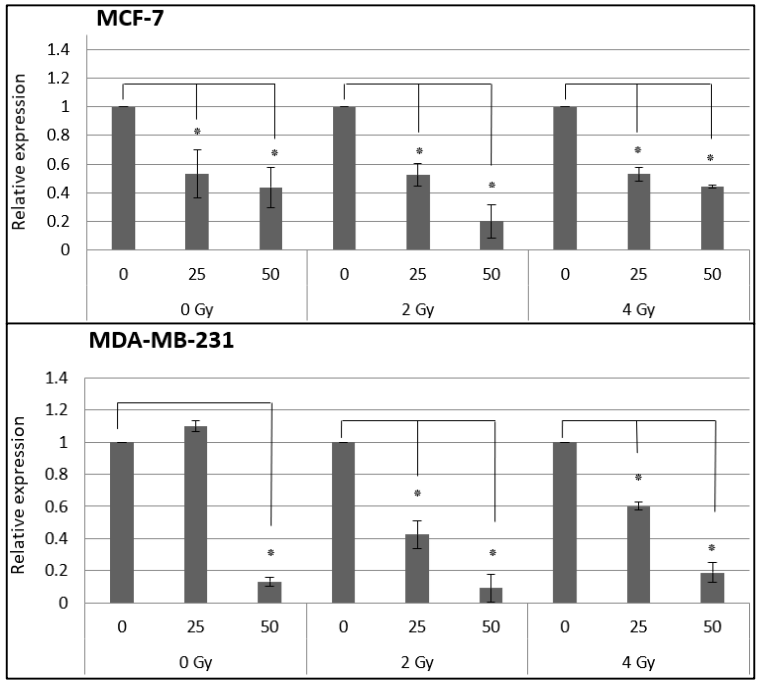
2018.07.01 – 2018.12.31

“The identification of biomarkers responsible for head and neck cancer radioresistance“

2019.07.01 – 2020.12.31

“Molecular mechanisms of resistance to radiotherapy in breast cancer cells and the effect of radio-sensitizing agents“

LSMU-CERN: current project 2021 – 2022



SFN and SFN+IR **decreased the expression of *BCL-2* gene** in both cell lines.

"The search for radiosensitizing phytochemicals and the analysis of their effect on apoptosis mechanism in breast cancer cells in vitro"

The purpose: to continue the search for radiosensitizing phytochemicals and their analysis on breast cancer cells.

Sulforaphane (SFN), which is one of the strongest natural antioxidants, was chosen for this study.

Cell viability, the intensity of apoptosis, apoptosis-related gene expression at RNA and protein levels following the combined effect of SFN and ionizing radiation are currently under investigation on MDA-MB-231 and MCF-7 breast cancer cells.

KTU in CERN activities: International Particle Therapy Masterclass, 11th of February, 2022

Prof. Elona Juozaitytė

Head of the Institute of Oncology, Lithuanian University of Health Sciences

Dr. Jonas Venius

Head of Medical Physics Department, National Cancer Institute

PhD stud. Kirill Skovorodko

Expert of Medical Physics at Vilniaus University Hospital Santaros Klinikos

Practice

„matRad“

Dr. Jurgita Laurikaitienė

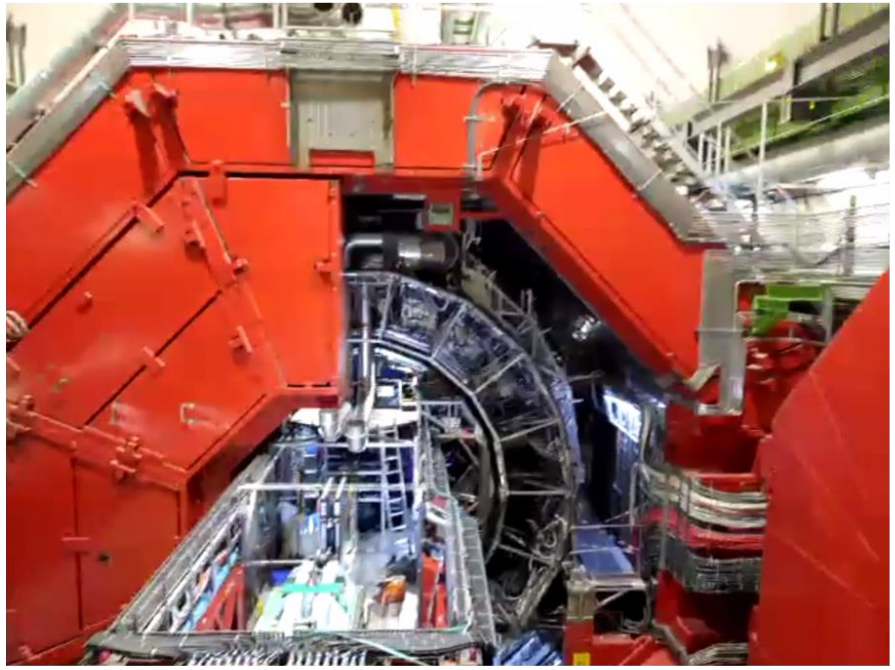
LSMU Kaunas Physics Branch Oncology Hospital, Medical Physicist Expert in Radiotherapy, Assoc. Prof. Dr. at KTU

Dr. Aurelijus Rinkevičius

Head of the Experimental Nuclear and Particle Physics Center, VU

https://indico.cern.ch/event/1120845/

KTU in CERN activities: International Particle Therapy Masterclass, 11th of February, 2022



Dr. Despina Hatzifotiadou (CERN)

https://indico.cern.ch/event/1120845/

KTU in CERN activities: International CMS Masterclass, 30th of March, 2022

https://indico.cern.ch/event/1139363/timetable/

2nd Baltic School of High-Energy and Accelerator Technologies

https://indico.cern.ch/event/1123671/

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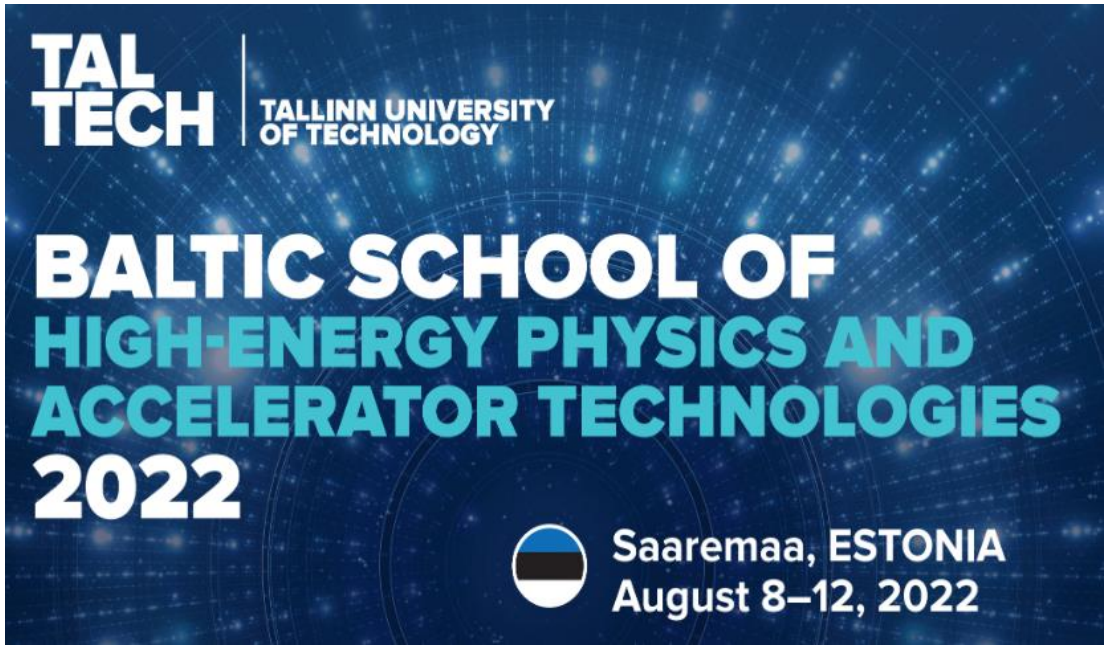

Organizers and Scientific Commitee

Local Organizing Committee

- Prof. Fjodor Sergejev (TalTech, EE)
- Dr. Erki Kärber (TalTech, EE)
- Prof. Veronika Zadin (UT, EE)
- Veiko Viil (TalTech, EE)

Scientific Committee

- Prof. Fjodor Sergejev (TalTech)
- Prof. Veronika Zadin (UT)
- Prof. Toms Torims (RTU)
- Prof. Brigita Abakevičienė (KTU)
- Prof. Mārcis Auziņš (UL)
- Dr. Kristjan Kannike (NICBP)
- Dr. Thomas Gajdosik (VU)
- Dr. Jevgenijs Proskurins (RSU

Co-funded and organized by H2020 ERA Chair MATTER (Grant Agreement No 856705)

2nd CERN Baltic Conference

https://indico.cern.ch/event/1147717/

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CERN Baltic Group

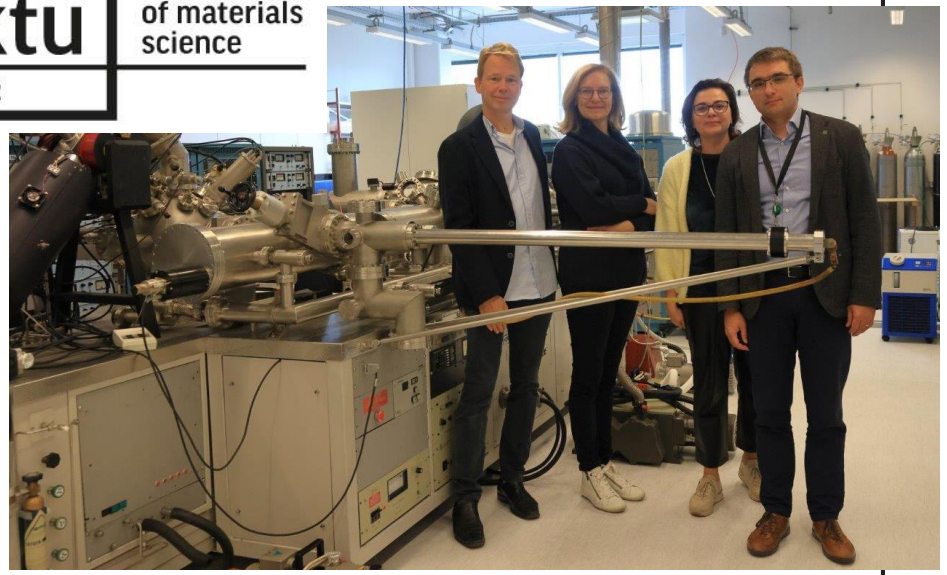
The CERN Accelerator School
Introduction to Accelerator Physics

https://indico.cern.ch/event/1117526/

faculty of mathematics and natural sciences

18th of September – 1st of October, 2022, Kaunas,

institute of materials science



Franc Tecker, Christine Vollinger

Brigita Abakevičienė, Tomas Tamulevičius

Participation in projects

Lithuanian Academy of Sciences

Research and experimental development projects are related to the activities of the European Organization for Nuclear Research (CERN).

ktu institute of materials science 1922

2021 - 2022 Materials and technologies for the high-gain Fast Timing MPGD detector (FTM)

(20 kEUR in 2021)

(49 kEUR in 2022)

Project leader Prof. Sigitas Tamulevičius

(In colloboration with Dr. Piet Verwilligen, National Institute for Nuclear Physics and CERN)

Materials and technologies for the high-gain Fast Timing MPGD detector (FTM) (2021 – 2022)

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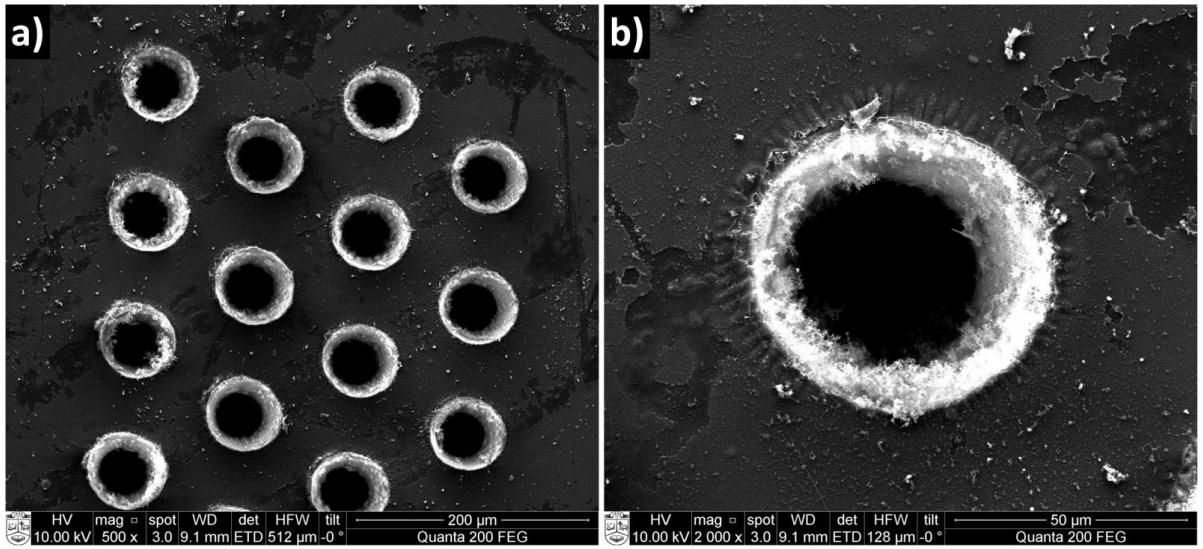
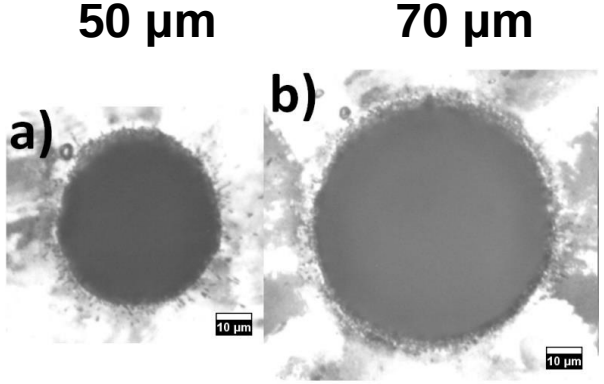
The project aim to improve the technology used in the production of a new type of Micro Pattern Gaseous Detectors (MPGD).

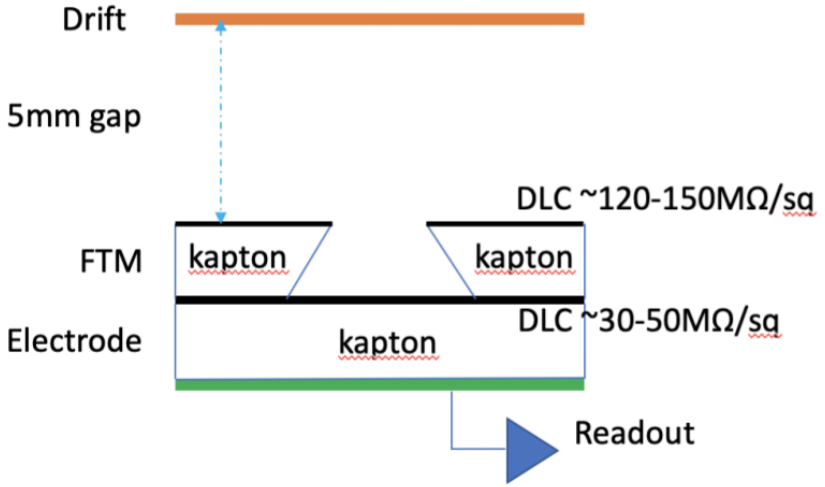


SEM images of holes formed in **KAPTON coated with DLC**:
(a) small fraction of hole array formed by removing DLC prior to drilling,
(b) a single hole from the array, showing DLC crumpling.

KAPTON average hole diameters:



Schematic overview of a single layer of the FTM prototype



Ch. Roskas, P. Verwilligen et al. Proceedings of Science, EPS-HEP2019 (2020) 158. DOI: 10.22323/1.364.0158

The Challenge Based Innovation Program (CBI)

2020

CERN reference KN4677/IPT

- **10 students and lecturers (Fall semester, 2022)**

Contact person:
Assoc. Prof. Dr. Kristina Ukvalbergienė
Director of Department of Academic Affairs
kristina.ukvalbergiene@ktu.lt

Markus Nordberg
Development & Innovation (IPT-DI)
CERN 1211 Geneva 23 Switzerland
Mobile + 41 75 411 4452
markus.web.cern.ch

CERN CMS TIER2 project

ktu

The main goal is to unite high-performance computing resources from multiple academic institutions in a federated HPC resource pool for efficient processing of CERN CMS TIER II workloads.

- To establish framework between individual institutions IT teams for HPC resources availabilities and accessibilities
- To create collaboration and experience sharing platform for best practices of managing HPC resources and serving them to TIER II community.
- Using Baltic NREN's and GEANT optical networks infrastructure interconnect institutional HPC resources at international-Baltic level for at least of 100Gbps lines

Contact person:
Arvydas Žiliukas
Director of Department of Information Technology Services
Computer Networks Centre
arvydas.ziliukas@ktu.lt

Teacher Engagement

I. The **Baltic Teacher Programme 2021 (**from 25-30 April 2021)
10 teachers were selected
The **Baltic Teacher Programme 2022 (***from 3-9 April 2022*)
Cancelled due to COVID-19

The Baltic Teacher Programme 2023 will take place from 23-28 April 2023.
Lectures, on-site visits, exhibitions, and hands-on workshops will introduce its participants to cutting-edge particle physics.

II. ***Modern physics is reinforced in the updated secondary and primary school curricula***

III. ***Initial activities with pupils in STEM centres developed***

IV. ***A "Modern Physics in School" qualification programme for teachers to implement new curricula***

Science outreach center

Our Center aims to attract students to the field of physics, to motivate them by lectures about particle physics, simple and easy experiments. Our current services for school teachers and students are provided by the Particle Physics Outreach Group. In particular, group:

- Team
- Day at the Center
- Lectures
- Particle Tracks
- Resources
- Sponsors

DAY AT THE CENTER

Whole day at the Center, with lectures and an experiments.

Reservation is needed

LECTURES

Lectures for students who have basics of the atomic physics. One lecture is 45 minutes long.

Lectures are ordered. Teleconference with CERN can be ordered if students from few schools reserves same time slot

PARTICLE TRACKS

Particle tracks observation in a cloud chamber. This one hour duration experiment is suitable for all, even without prior knowledge about atomic or particle physics.

Reservation is needed

National Science festival “Spaceship Earth”

About 2 hands-on activities and 2 lectures annually starting from 2015. In 2022 – 2 hands-on activities and a lecture on Energy for Future.

CERN virtual tours for students and publics

2014, 2016, 2017, 2018

Thank you for your attention!