Research Enhanced Learning with Silicon Lab for Characterization of Silicon Detectors

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Abstract—**In 2025, the Large Hadron Collider (LHC) will be upgraded to the High Luminosity (HL). This will challenge the CMS silicon-based detector performance with very high fluences and long operation time. Sensors have been designed to survive severe radiation damage and tools and methods are developed in order to predict and understand the long-term evolution of the sensor properties. Transient Current Technique (TCT) is one of the important methods to characterize silicon detectors and it is based on the time evolution of the charge carriers generated when a laser light is shone on it. University of Montenegro shows an interest in silicon detector R&D and has recently designed project in order to install first silicon laboratory with TCT setup and a probe station, on its own premises. In the meantime, initial TCT workshops promoting research enhanced learning were conducted. In this paper we share our experiences in relation to designing the lab and creation of outreach program for undergraduate students of physics.**

Keywords-research enhanced learning, silicon laboratory, CMS, TCT, probe station, LHC timing detector, LGAD

I. INTRODUCTION

Research enhanced learning and teaching (RELT) program within Learning Excellence and Development (LEAD) framework is a complex notion, and consequently is based on different understandings and practices across disciplines, institutions and countries [1-2]. There are two major aspects to RELT that we can look to for understanding. First is the way in which we as educators use research to inform our own teaching practice - that is, in the content of our lectures and other materials. Second is how regularly we use ideas and examples from our own research to enrich co-curricular program. In this view of RELT the research is not made explicit, but rather it is embedded within the resources that are presented to the students. However, what is required is a student-focused perspective where links between what is being taught and research are made explicit. The task of bringing research and teaching together potentially affects all the ways in which we think about the university as a site of scholarly practice.

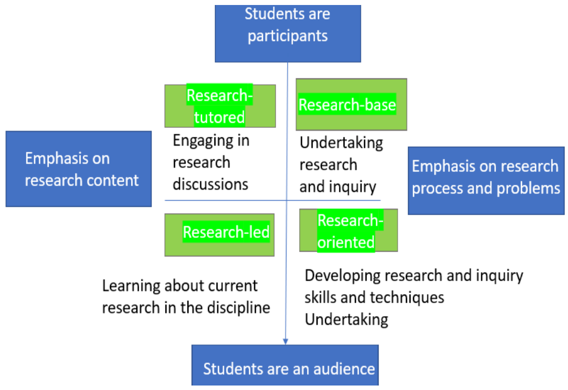

Figure 1. Types of research enhanced learning

There are some crucial guiding open questions: Are our students an audience for research, or are they engaged in research actively, or both? Is the teaching emphasis on the content of the research, the processes of research, or both? How accessible to students is the research carried out in Faculty for Natural Mathematics and Sciences Department? For example, do students know about publications in scholarly journals or other research? The question is also if students are taught only curriculum-based program or they are involved in extra-curricular, co-curricular program. For instance, if students are participants and emphasis in teaching is on research content then we come to *Research-tutored learning*; if students are participants and emphasis in teaching is on research process and problems then we arrive to so called *Research-based learning* where students are undertaking both research and inquiry (Figure 1). Importantly, teaching thus acts as a trigger by allowing those who are researchers and also teachers to think about the material differently and by serving as a catalyst for new research projects.

How to implement research enhanced learning at the BSc level at UoM? The objective of this papers is twofold. Paper presents 1) the program dedicated to developing a silicon laboratory; 2) along with setting up the laboratory, young researchers from the University of Montenegro (UM) will master semiconductor characterization techniques. These techniques will be used in studying state-of-the-art Low Gain Avalanche Detectors. The latter were developed within CERN-

RD50 collaboration ("Radiation hard semiconductor devices for very high luminosity colliders") and have since been identified as most promising detector technology for precise timing measurements and will be used in both large general-purpose experiments ATLAS and CMS after the upgrade of Large Hadron Collider (LHC) around 2026. As these sensors are considered as the main candidates for the future advanced beam monitors allowing detection of each proton delivered to the patient during the therapy, the knowledge gained in the framework of this project will have a much wider use.

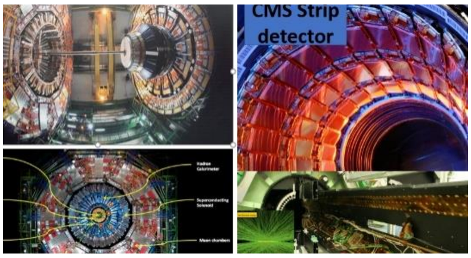

Figure 2. CMS detector; CMS silicon strip tracing and vertex silicon pixel detector

II. SILICON LAB AS A LAB FOR RESEARCH ENHANCED LEARNING AND TEACHING

Why silicon lab? University of Montenegro has strong link to HEP community and from 2017, UoM is officially involved in CMS experiment. CMS is nowadays the world larges silicon detector (Figures 2 and 3). With a total surface area of 205 m^2, the CMS Silicon Strip Tracking Detector is by far the largest semiconductor silicon detector ever constructed. Its silicon sensors are patterned to provide a total of 10 million individual sensing strips, each of which is read out by one of 80,000 custom designed microelectronics chips. Furthermore, group of scientists from UoM joined MIP Timing Detector (MTD), which will play essential role during LHC-HL. The MTD detector [3] (Figure 4) includes a very advanced, state-of-the-art, silicon detector system that, when completed, will be the first high precision, large area, silicon timing detector. These state-of-the-art silicon detectors will be characterized in Si-lab and tests measurements will be based on TCT technique and probe station.

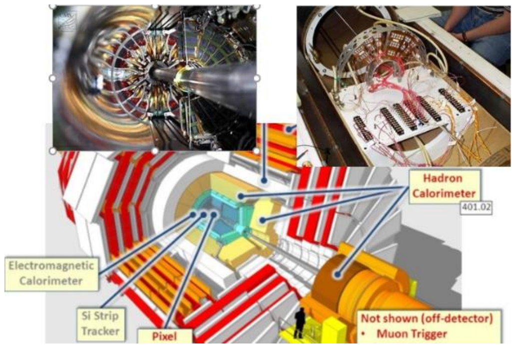

Figure 3. Design of CMS (pixel tracking system is magnified)

There are many more interesting opportunities in sensors testing, radiation hardness studies, and optimization of timing algorithms. This activity in CMS is strongly linked with the CERN-based Silicon R&D RD50. This will foster the integration of a new group from UoM into the Silicon sensors R&D community. One of the great benefits of the participation in RD50 is the access of many types of sensors, and excellent students training. CMS MIP endcaps (ETL) will be also based on the state-of-the-art: Low Gain Avalanche Diode (LGAD).

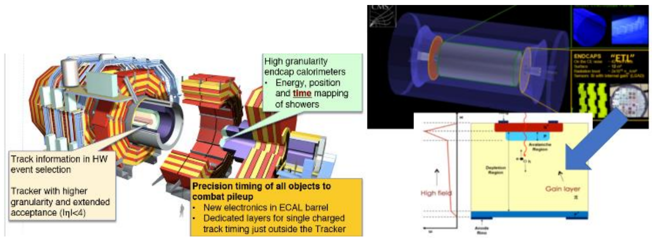

Figure 4. MIP Timing detector (to be integrated into CMS) – LHC Phase II (with increased luminosity); Endcap is based on LGAD sensor.

Reasons for the wide-spread use of silicon detectors in HEP, astrophysics, medicine is as follows: proportional response, good efficiency, good signal-to-noise ratio, segmentation technologically is easily achieved (strips, pixels) but radiation damage affects measurement precision due to worsening of S/N. However, there is limit with time resolution due to saturation of drift velocity. The solution to this problem is to improve silicon detector's performance by increasing the S/N with internal gain, and this gives birth to LGAD. Further optimization of timing performance of LGAD gives birth to UFSD (ultrafast silicon detector) – discovery enabling detector with huge potential to be exploited also for beam monitoring in particle therapy.

Thus, participating in development of radiation hardness detectors such as LGAD would allow us to expand our research not only in particle physics but also in the fields of biomedical engineering and hadron/heavy ion therapy.

Thus, Silicon lab presents rich environing for fostering both, scientific research and technology enhanced learning.

III. SCIENTIFIC MOTIVATION

Besides a few indirect signals of new physics, particle physics today faces an extraordinary drought. Very little help in the direction of this path is coming from nature, the burden is on the accelerator and experimental physicists to provide the means for this crossing. Timing is one of the enabling technologies to cross the desert. The inclusion of track-timing in the event information has the capability of changing radically how we design experiments. For instance, timing at each point along the track leads to 4D tracking while timing at each point along the track at high rate leads to 5D tracking – all extremity innovative, and complex concepts.

Low Gain Avalanche Detectors [4] are, as already said, the current state of the art detectors for timing measurements of minimum ionizing particles [5] and will be used both in CMS and ATLAS collaboration [6] experiments. They can be segmented to cell sizes below 1 mm^2, i.e. position sensitive, and hence offer wide range of applications also outside high energy physics. They are based on silicon n^{++}-p^{+}-p-p^{++} structure where the so-called gain layer of 1-2 μm is sandwiched between the highly doped n^{++} implant and p bulk of the sensor. Electric field high enough for charge multiplication is established in highly doped p^{+} layer and results in initial gains of up to 100 (depending on the doping profile), thus allowing operation of very thin (i.e. fast) sensors. Special isolation techniques are used to allow multi-electrode design that prevents the cross-talk and early break down. Recently, a lot of studies have been triggered around the world after the original proposal in 2014 [4] (JSI were among them) with several major silicon detector foundries including Hamamatsu Photonics embarking on their development and production.

The major issue of LGAD is relatively fast degradation of performance with hadron irradiations [7]. After receiving around 10^{15} hadrons cm^{-2} the gain almost vanishes. At LHC experiments the most exposed sensors will receive around $6\cdot10^{15}$ hadrons cm^{-2}, which requires replacement of part of the detectors during the lifetime of the experiment [4]. The loss of gain is attributed to decrease of effective doping concentration in gain layer (effective acceptor removal) and consequently the electric field. This is a problem for experiments in high energy physics as well as for potential use in hadron/proton beam monitor for therapies where during patient treatments similar fluence is received in a year.

Understanding of radiation damage and consequences such as degradation gain, breakdown voltage, leakage current of the detectors and changes of their properties in relation to the operation conditions can be studied by employing the probe station and enabling this way CV-IV analyses and TCT (Transient Current Technique). With the help of the CV-IV setup one measures the change in capacitance by varying Voltage and the Change in Current with Voltage. From the I-V plot, for instance, we get information about leakage current and the breakdown voltage for the sensor and from the CV plot we get to know the value of end capacitance once the silicon bulk gets fully depleted. On plotting $1/C^2$ versus Voltage, the value of full depletion voltage is defined from the point of inflection in the curve. Furthermore, since most of the time we do one set of measurement per sensor keeping the varying parameters constant, we don't know till what extent our measurements are true or consistent with the real values. Therefore, by repeating the measurements with different varying conditions, we can determine the systematic error of the set up. Systematic error (or systematic bias) refers to the consistent, repeatable error associated with an equipment or experimental design. The changing factors in an I-V measurement are temperature and in C-V measurement, the changing factor is temperature and frequency. Similarly, for TCT set up, the varying parameters are temperature and laser intensity which can be altered by changing the shutter opening for both red and Infra-red lasers.

Figure 5 shows image of the Probe station.

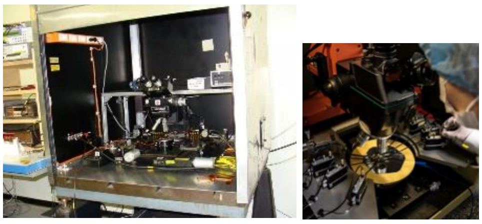

Figure 5. Image of probe station [http://ssd-rd.web.cern.ch/ssd-rd/labo28/default.htm]

Another key player of S-lab is the Scanning Transient Current Technique (Scanning-TCT), which is a powerful tool for probing electric field and carrier transport properties in various semiconductors structures. The Scanning-TCT system has the following feature: Wide band current amplifier; Bias-T; High voltage low pass filter; Laser diode (650 nm, 1064 nm); Programmable laser driver for sub-nanosecond laser pulses; Laser beam optics, beam spot 8 μm FWHM; XYZ moving stages for precise DUT positioning in the beam and focus tuning; Water cooled Peltier mounting block for DUT temperature control; Aluminum closure for light and RF shielding and atmosphere control; Dimensions: 80x40x40 cm' Weight: 20 kg; Hardware control software (connection via USB); Data acquisition software; ROOT based package for data analysis. An image of fiber coupled laser with optics on translation stage is shown in Figure 6. It contains: Laser diode 660 nm or 1064 nm; Tunable pulse width 0.4 ns - 4 ns; Tunable pulse power equivalent to 10 MIP - 100 MIP in Si; Single pulse mode 50 Hz to 1 MHz, including 1024 bits deep pulse sequence, NIM logic trigger output, NIM external trigger

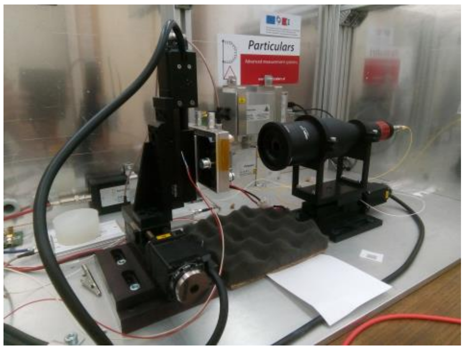

Figure 6. Advanced Scanning TCT system

Figure 6 shows Advanced (for research) Scanning TCT system, while simpler version for education is shown in Figure 7.

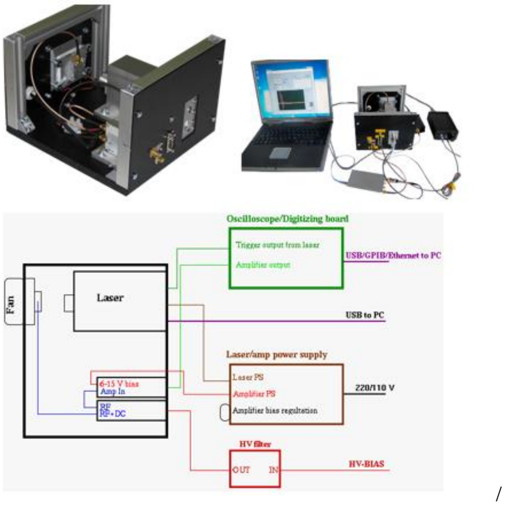

Figure 7. Educational TCT system

The scientific part of the Si-lab lab is characterization of Low Gain Avalanche Detectors after irradiations. Precise knowledge of the degradation of their performance and identified reasons for it will enable projection and better understanding of their use at ATLAS and CMS experiments after the LHC upgrade. The results will also broaden the knowledge of radiation damage in silicon in general.

A. TCT Working principle

Transient Current Technique (TCT) exploits the signal induced in electrodes by motion of non-equilibrium free charge carriers in a semiconductor structure. It is one of the important methods to characterize silicon detectors and is based on the time evolution of the charge carriers generated when a laser light is shone on it. The Transient Current Technique (TCT) is used to investigate the electric field profile and the collected charge of silicon detectors

The basic scheme of a TCT system is shown in the Fig. 8

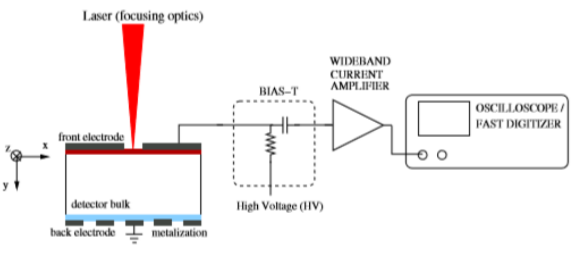

Figure 8. The basic scheme of a TCT system

The detector is connected to input of the transimpedance amplifier. Its output is fed to the oscilloscope. There are two ways of connecting the detector to the amplifier. Either back of the electrode of the detector is at high potential and the front of the electrode at ground or high potential is brought to the front side through so called bias-T which decouples detector bias voltage from the input to the amplifier (AC coupling).

Principles of operation are as follows: The Transient Current Technique is used to measure the current induced by motion of free carriers in a semiconductor device. Free carriers in a semiconductor can be thermally generated but can be also excited (from valence to conduction band) by laser light providing that the photon energy is larger than the band-gap of the semiconductor. Each photon creates therefore an electron and a hole – a so called e-h pair. Upon creation these free carriers: 1) drift if they enter/are generated in the region with electric field; 2) randomly move due to thermal energy (diffusion). The free carriers can be swept by collection electrodes: electrons by anode and holes by cathode. However, on their way to electrodes they can:1) recombine with oppositely charged carriers; 2) get trapped in the energy levels in the band gap of an imperfect semiconductor. They are eventually reemitted (de-trapped) or recombine.

If a reverse-biased detector is being illuminated from the front side, the measured signal originates from the charge carriers equal in sign to the majority carriers in the bulk as presented in Figure 9. The figure shows how the TCT signal in a p-type detector is caused by holes when illuminated from the front side. Illumination from the back-side results in a signal originating from electrons

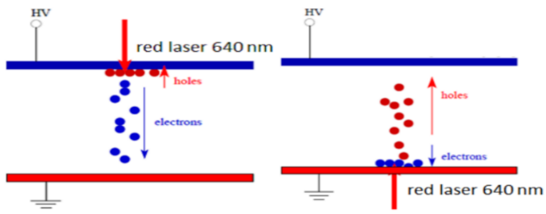

Figure 9. Schematic view of the charge creation process, Top-TCT: The back side of a diode is being illuminated, and the resulting TCT signal comes from electrons. b) Illumination of the front side of the same diode structure results in a TCT signal caused by holes.

The wavelength of the light determines the penetration depth in semiconductor, i.e. the pattern of generated e-h pairs in the semiconductor. For example, the red light generates carries only in first few microns at the surface of a silicon wafer, while infra-red light (1064 nm) generates e-h in few mm (exponential absorption).

The movement of the carries induces the current in the electrodes which is amplified and recorded in the oscilloscope. The current is given by a simple equation:

$$I(t) = e_0 N_{e-h} \exp(\frac{-t}{\tau_{eff,e,h}}) \cdot \frac{v(t)}{W},$$

(1)

where N_{e-h} is the number of e-h created at a given place in the detector e0 elementary charge W thickness of the sensor, $1/\tau_{eff,e,h}$ probability of carriers to be trapped and v(t) velocity of their travel, which is proportional to the electric field v=μ(E)·E. In a device where trapping is negligible (most silicon devices) the shape of electric field and mobility can be measured from the shape of the current. In order to be able to measure meaningful results the laser pulses have to short enough, few 100 ps.

IV. PROCUREMENTS AND SETTING THE LABORATORY

Procurements and setting the Laboratory is designed to follow a few steps:

- Procurement and setting up a Probe station for testing silicon sensors and Capacitance-Voltage and Current-Voltage measurements.
- carried out on selected samples to qualify and validate all the measurement techniques. This will include standard pad detectors as well as LGAD sensors
- Irradiation of prototype sensors: The sensors from ATLAS-CMS and RD50 prototype productions will be irradiated at Jožef Stefan Institute's research reactor. This is a reference facility for neutron irradiations in high energy physics with well-known neutron spectrum and dosimetry. One of the aims of the project will be to evaluate the impact of thermal neutrons to acceptor removal in gain layer. Around 20% of natural B which is used in gain layer doping is 10B, which has a large cross-section for capturing thermal neutrons although their displacement damage (NIEL) is very low. As thermal neutron component in both ATLAS and CMS will be different than at reactor it is important to establish the effect. Thus, samples will be irradiated in Cd envelopes to select only fast neutrons. A comparison of acceptor removal rates determined by CV and TCT with and without Cd will give the answer to that question. The dependence removal rate on fluence of fast and thermal neutrons will be evaluated for different gain layer doping. The values will be compared to the past measurements. Devices from different producers (FBK-Trento; Italy, CNM-Barcelona; Spain, HPK-Hamamatsu; Japan and Micron; UK) will be investigated. The annealing properties [8] of standard silicon detectors are well known. However, the annealing behavior of heavily doped p-type silicon is not well studied. We will concentrate on annealing studies of effective acceptor removal rate and at different temperatures in order to establish the temperature scaling. This will allow the prediction of detector operations at HL-LHC

V. FIRST WORKSHOP: TCT AND DEVICE CHARACTERIZATION

While developing strategies for Si-lab design, the first steps towards research enhanced teaching were taken on board. Full TCT (state of the art TCT setup for educational purposes) was brought by Gregor Kramberger from Jozef Stefan Institute to UoM. Figure 10 shows list of workshop's objectives. The data acquisition was fully controlled by a computer. The data taken were stored to disk and analyzed with custom written software SimKDet [9]. The samples were mounted into an aluminum box to assure radio frequency shielding and working principle of TCT were demonstrated using different samples: Float Zone (FZ) 15 kΩcm p-n diode (300 µm), LGAD n-p diode (300 µm) with with moderate gain and LGAD n-p diode (45 mm (SOI)) with very high gain.

The free charge carriers are generated in consequence of illuminating the detector by red laser light. If the front side implantation of the reverse-biased diode is illuminated, the charge carriers, that are collected from the front side, drift to the contact faster than the read-out electronics can respond. On the other hand, the carriers opposite in sign drift through the whole detector to the back side. This transient current is the measured signal. Additionally, TCT working principle were demonstrated when detector was illuminated from 1) back and 2) front side so students were able to spot the differences. If the back side of a n^+-p^--p^+ diode is being illuminated the resulting TCT signal comes from electrons. Oppositely, the illumination of the front side of the same diode structure results in a TCT signal caused by holes.

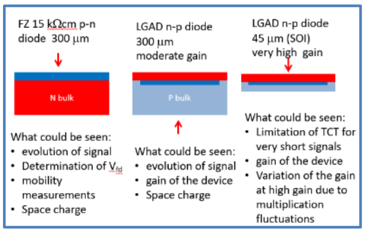

Figure 10. Objectives of TCT workshop at UoM.

Here are some of the parameter's students investigated:

- Depletion Voltage: To find the depletion voltage, the charge collected at certain position between strips for the deferent bias voltages has to be integrated. After reaching the depletion voltage charge stops to increase and becomes constant. Plotting the charge with square root of voltage, the dependency can be obtained, which has to be fitted with two lines - one fits the rising part, second one - the constant part, when all charge is collected (detector is fully depleted). The intersection of these curves gives the value of the full depletion voltage (see Figure 11).

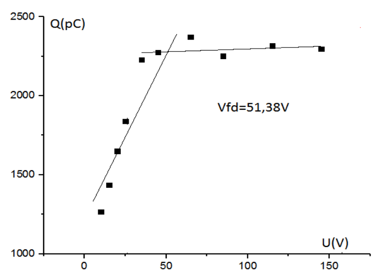

Figure 11. Depletion voltage search, Top-TCT

- Gain of LGAD as explained in Figure12. LGAD was n-p diode 300 mm with moderate gain. Students looked at the evolution of signal in order to recognize different regions of the signal and to determine the gain of depletion layer. They observed the space charge sign and estimated gain from the shape of the current.

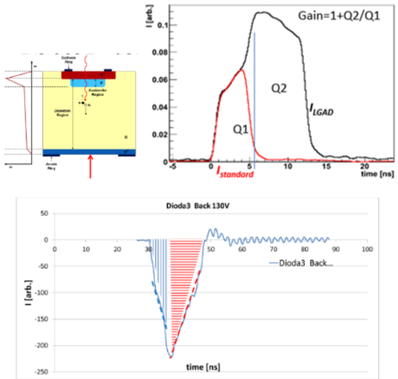

Figure 12. Determination of LGAD gain

- Mobility: The TCT is used to calculate the charge carrier mobility. The 80% of the red light is absorbed after 5 μm of silicon - this is used to measure the charge carrier mobility of deferent type. After applying positive voltage to the strips (p-type bulk sensor from Particulars) and negative to the back side, holes drifting to the back side and electrons to the strips. Shooting from the top side: electrons are collected immediately, and the transit time is the time of the hole drift. The average hole drift velocity through the sensor is given by $v_h = W/t_{transit}$, where $t_{transit}$ is the duration of the signal, W is the thickness of the sensor.

Some photos taken during workshop with TCT are shown in Figures 13-15.

Figure 13. Photos taken during TCT workshop at UoM: Gregor Kramberger demonstrates working principles of TCT.

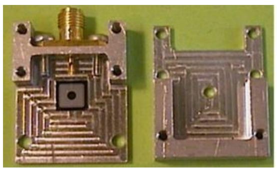

Figure 14. Photos taken during TCT workshop: The aluminum box providing the RF shielding. The sample can be seen on the left-hand side.

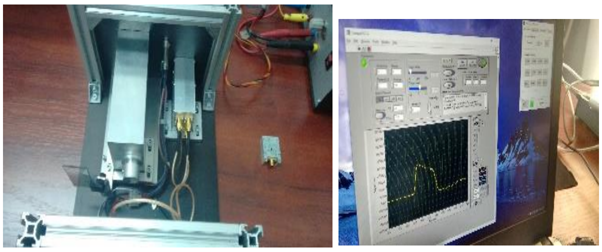

Figure 15. Photos taken during TCT workshop at the University of Montenegro.

VI. CONCLUSION

In this paper we present an approach of research enhanced teaching which we apply while setting up Silicon lab for development and characterization of silicon detectors which are designed for HEP discoveries under huge radiation environment. Here an excellent tracking of time and radiation hardness property of sensors will play crucial role towards enabling new discoveries.

ACKNOWLEDGMENT

We are very grateful to Gregor Kramberger from Josef Stefan Institute for his effort to bring UoM closer to the advanced R&D world of the radiation hardness silicon sensors and the TCT technique.

REFERENCES

[1] Homewood, Brendan Rigby, Angela Brew and Anna Rowe, Ed Glyn Mather, “Research Enhanced Learning and Teaching: Learning through scholarship”, ISBN 978-0-9805685-7-8, Macquarie University NSW 2109 Australia CRICOS Provider Code 000002J.

[2] S. Laursen et al., G. Melton (Eds.), “Undergraduate research in the sciences: Engaging students in real science”, New York: Jossey-Bass, 2010.

[3] MIP Timing (Technical Proposal): https://cds.cern.ch/record/2296612 . TDR Q1 2019.

[4] G. Pellegrini et al., “Technology developments and first measurements of Low Gain Avalanche Detectors (LGAD) for high energy physics applications”, Nucl. Instr. and Meth. A 765 (2014) 12.

[5] H.F-W. Sadrozinski, N. Cartiglia, A. Seiden, “4-Dimensional Tracking with Ultra-Fast Silicon Detectors”, Reports on Progress in Physics 81(2) · April 2017.

[6] Technical Proposal for a Mip Timing Detector in the CMS experiment Phase 2 Upgrade, CERN-LHCC-2017-027, LHCC-P-009.

[7] G. Kramberger et al., “Radiation effects in Low Gain Avalanche Detectors after hadron irradiations”, JINST Vol. 10 (2015) P07006.

[8] G. Kramberger, G. Medin et al., “Radiation hardness of thin low gain avalanche detectors”, NIM A 891, 2018, p. 68.

[9] M. Moll. Radiation damage in silicon particle detectors: microscopic defects and macroscopic properties. PhD thesis, Hamburg Univ., Hamburg, 1999.

Modern Technologies in Increase the Flow of Tourists and the Profitability of the Airline on the Example of Montenegro Airlines

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Abstract—**In the modern world airlines have to face number of challenges. They have to suit fast changing economy and fast developing technologies. Nowadays one of the most extensive trends is implementation of virtual and augmented reality technologies into the different areas. Therefore authors in this paper consider how this technology could be applied in the context of working practice of the airlines based on the example of Montenegro Airlines.**

Keywords-airlines; income; virtual reality; augmented reality; Montenegro Airlines

I. Introduction

The development of modern society and a large number of tourism products in different price categories encourage companies related to the tourism industry to break the prevailing stereotype of providing services to the consumer. In other words, with the development of the media and with the access to the Internet that has become unlimited in many countries, a potential tourist already has many offers, he compares prices and he always looks for the "most interesting", some kind of service that would attract him. And in an environment of fierce competition is the entire tourism industry, including the airlines.

Many aspects of human life are connected with digital technologies and in the near future this connection will become closer. In no time, such an aspect of the digital world as an augmented, virtual and mixed reality will enter everyday life. The future will be characterized by intelligent devices and innovative technologies supplying digital services into all areas of activity.

Many research and analytical companies make forecasts regarding the development of technologies and digital technologies in particular. As an example we decided to consider reports of Gartner research company, which makes a report on the hype cycle every year [1]. Technology analysis in the forecast period reflects the attitude of consumers towards innovative technologies and developments. It is illustrated in Figure 1:

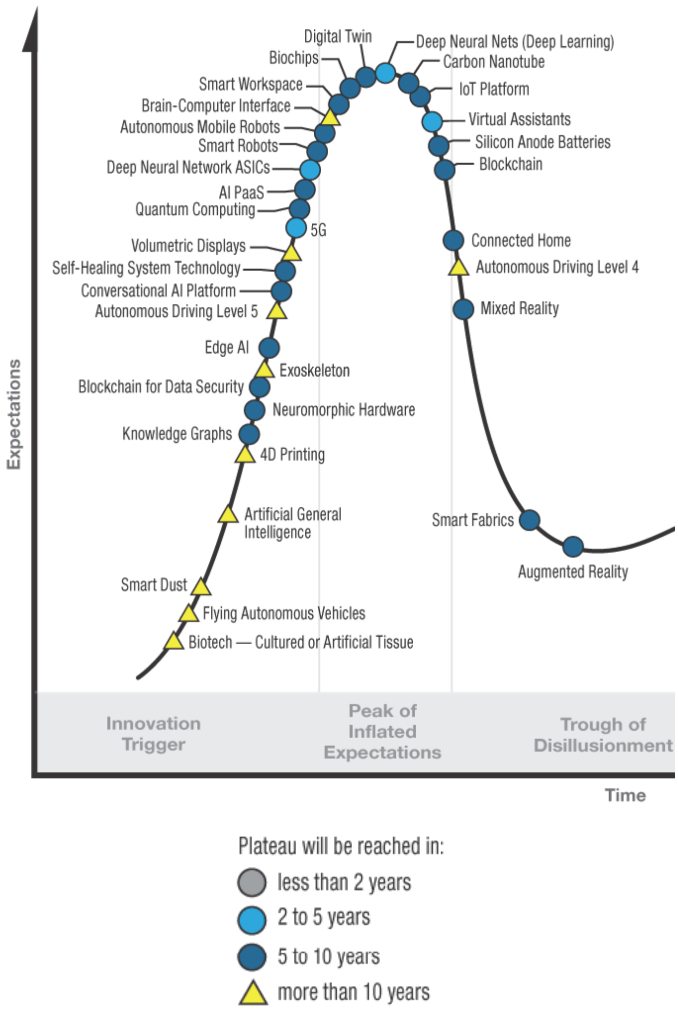

Figure 1. Hype cycle for emerging technologies 2018, Gartner [1].

This diagram shows innovative technologies and helps to assess the relative risk and timing of the appearance of new technologies, as well as evaluates the trade-offs between risk and innovation. As we can see, augmented and mixed reality has been presented on the market for a long time and, according to Gartner forecasts, it will need more than 5 years for the market in this area to become mature enough.

The Gartner forecast notes that augmented reality will have a greater impact on the consumer than the virtual one, because it is richer, it allows you to improve the experience of real life and has great potential for real changes in the world [2].

The trend includes both augmented and mixed reality, that are blurring the boundaries between the real and virtual world.

These technologies will become available and will continue to be implemented in various fields of activity, including the tourism industry. Augmented, virtual and mixed reality will have a huge impact on consumers, because they allow to improve the experience of real life. It is worth to say that these technologies have great potential for forthcoming changes in the future.

Even successful companies still have to face fast-growing technological innovations, which have a profound impact on how a company copes with its workforce, customers and partners. The trends revealed by these emerging technologies should be the next most effective technologies that can destroy the business and should be actively monitored by the company's executive team.

II. Situation in the Airline Industry Worldwide

The International Air Transport Association (IATA) expects that in 2019 the net profit of the global aviation industry will be $ 35.5 billion, which slightly exceeds the profit forecast for 2018 in the amount of $ 32.3 billion.

Next year passenger traffic will grow by 6%, to 4.59 billion people, according to IATA. At the same time, total revenue will rise by 7.7% to $ 885 billion, from passenger traffic alone - by 7.5% to $ 606 billion. According to IATA, the number of air passengers will double by 2035 and world passenger traffic will reach 7.2 billion[3].

Low cost airlines are the most popular in Europe: they account for 32% of all passenger traffic. At the same time, the border between low-cost airlines and airlines with a traditional economic model has become blurred. At the present time, it makes sense to talk about hybrid carriers that offer a wide tariff network, including low-cost fares with a minimum baggage allowance, and the usual economy class tickets that provide free meals on board, as well as premium and business fares.

Global airlines and airports are increasing the use of digital technology both in internal control and in communicating with passengers. 6% of airlines are already testing, and 17% plan to begin testing artificial intelligence over the next five years. Among airports, the share is slightly higher: 21% of airports intend to test applications using artificial intelligence in the next five years, according to a study by the supplier of IT solutions for aviation Société Internationale de Télécommunications Aéronautiques (SITA).

According to SITA, 55% of travelers in the world have used any self-service technology when making a flight. Interest in digital services is increasing: about 76% of passengers would like to receive notifications about the start of baggage claim on their mobile devices, almost as many (74%) would like to know about changes in flight schedules via mobile applications [4].

III. Montenegro Airlines Statistics

Montenegro Airlines is the national airline of Montenegro and the second largest enterprise in the country, with a fleet of 6 aircraft and a total number of passenger seats is about 700. According to the results of statistical studies that were conducted by Montenegro Airlines, from July 1 to September 30, 2017, directly and indirectly brought Montenegrin tour industry income in the amount of about 120 million euros. The airline brings to tour industry about 170 million euros annually, despite the fact that the company's annual income is 70 million euros.

The 2018 was the most successful year in Montenegro Airline's history, passenger traffic in the first 10 months has increased by almost 13% compared to 2017 for the same period, that is more than a quarter of the total number of passengers, namely 576 thousands. Despite this, the airline faces various difficulties, such as an increase in fuel prices in 2018 by 27% and additional costs for it, a reduced amount of tourist traffic in winter, thus most of the revenue falls on 4-5 months of the summer season. It causes difficulties to conduct a company development policy, code-sharing agreements, government assistance and so on.

The authors of this article want to offer another indirect income for the airline, as well as additional advertising for Montenegro itself as a tourist destination [5, 6].

Firstly, it is the availability of Internet on board the aircraft and the provision of such a service for an additional fee.

Secondly, providing the opportunity to use 3D glasses and watch virtual tours with virtual and augmented reality. And sell a service such as games with augmented reality.

In this paper we consider the second aspect and the first one will left for the future research.

IV. Revealing Current Problems

Virtual tourism today is one of the most pressing and promising topics in the development of the tourism industry, but it is still underdeveloped at present. Virtual tourism means a set of activities of individuals and legal entities that organize or carry out virtual tours using modern computer equipment and technologies, as well as telecommunications connections to form the most realistic information about the desired tourist direction. Virtual travel technologies are based on a virtual tour, which is understood as a realistic way to display three-dimensional space. This type of travel is much more convenient, affordable and safer. A virtual tour is an activity of an individual who due to the modern technologies and communication networks usage creates the most realistic and reliable information about the desired tourist destination [7].

Virtual tourism is developing rapidly because it has a large number of positive features for both the manufacturer of this service and the potential tourist. Virtual tour, which is an integral part of virtual tourism, has a number of positive qualities: Firstly, it is a minimization of the consumption of personal resources such as time and money for customers. And in the case of air travel, people spend this time in the sky anyway and it is likely for everyone to spend it sensibly in order to choose the places that one would like to visit for a limited time of one's rest, and this product will help one to do that.

Secondly, it is an opportunity to visit sights and regions that are not available during the normal traditional travel. For instance, on a virtual tour one could walk up Bobotov Kuk, the highest point in the Durmitor mountain range, while traveling with two children one will not be able to do that.

Thirdly, this is of course, a safety and contactless way of exploring some of the sights during virtual tour. For example, one really want to see the canyon of Nevideo, but canyoning is a dangerous and extreme kind of recreation, and during the flight you enjoy it during a virtual visit, anticipating the rest in Montenegro itself.

Fourth, it is a great opportunity to advertise not only Montenegrin sights, which will help the tourist to make plans for visiting them during the holidays, but also will help to choose the additional infrastructure of interest for a good rest. In other words, one could choose restaurants, shops, cafes, nightclubs and open discos, water park and other forms of entertainment and eating places. This is the main idea of our project.

On-board magazines are presented in the back pocket of every seat in front of the passengers in Montenegro Airlines airplanes, but magazines have high costs of printing, plus not everyone can read in Montenegrin or English, and in one magazine it’s impossible to fit all possible advertising articles in all languages and sights of this beautiful country - the way out is to create a special information platform, which the authors discuss in this article.

V. Concepts and Solutions

Based on the above facts, it becomes clear that the problem is possible to become solved with implementation of an information platform that will use augmented and virtual realities.

Modern research shows that the more receptors are involved in perception, the more real the feeling of presence is created.

According to the numerous scientific results of research in cognitive psychology - about 80% of the information received about the world around us, people acquire it through visual perception. Thanks to various modern technologies, virtual reality makes it possible to fully use these 80% of the information received by a person with the help of organs of sight, but it is worth considering the fact that people remember about 20% of what they can see, about 40% if they are not only see, but also hear, and as much as 70% in the event that they both see, and hear, and do.[8]

Based on this consideration, we obtain the following concepts:

1. Creation of an information platform like an electronic journal.
2. Creation of virtual tours of existing objects, both the cultural heritage of Montenegro, and objects of interest related to the tourism industry.
3. Creation of a virtual reality, for complete immersion and as close as possible perception of finding and interacting with the recreated environment.
4. To create a sense of presence, it is better to use VR glasses or a virtual reality helmet.
5. To transfer the material of the object, you can use existing gloves today VR.
6. To transmit sound information using a headset or a virtual reality helmet.

To fill this information platform, you must also perform some actions:

1. Collect the information about the sights of Montenegro, best of all from competent places, so that this information is reliable
2. Create 3D panoramas of natural beauty, 3D models of objects, etc.
3. Conclude contracts with representatives of restaurants, night clubs and etc., all those who has a need in advertising services on board of the aircraft and to fix the duration of the advertising campaign.
4. To translate the information not only into the Montenegrin and English but also into several most disseminated languages and languages of the countries where the airline most often flies (Russian, Italian, German, French, etc.).
5. Purchase all the special equipment for installation on board aircraft.

The use of these services should be ensured using personal devices (mobile phones, smartphones, tablets), and using rented devices provided to passengers by the airline.

VI. Implementation and Technical Details

To create an information platform, some research has already been conducted in the field of the tourism industry, involving experts from this field [9], in order to identify the most attractive places of both cultural heritage and natural attractions, to be the first to enter the beta version of the information platform. Also, some experiments were carried out in the laboratory with regards to the equipment necessary for the implementation of this platform on board of the aircraft.

In previous studies, the authors of this article have already created a 3D model of one of the cultural heritage of the city of Kotor [10], which has been under the protection of UNESCO since 1979, this is the building of the Maritime Museum [11]. Therefore used the help of a qualified land-surveyor, since the building-up in Kotor is very dense and it is impossible to make a simple scan. Also, 3D panoramas of various natural sights were created, such as the entrance to the Bay of Kotor overlooking the Arza and Mamula fortresses, filming of the Niegos mausoleum on Lovchen from a bird's eye view, photos of national parks, Ostrog Monastery and Tsetinsky Monastery, and other objects deserving Attention.

The created information platform can be launched under various operating systems, such as Android, IOS, Windows, MacOS. Also important is the fact that the possibility of using virtual reality glasses is realized. Control is possible with the help of the motion controller for glasses and on the passenger's personal device if VR glasses are not used.

Modules that provide information in text form on the screen and in the radio format on the device were also developed and implemented. Information is translated into several languages.

VII. CONCLUSION

In the modern world, information technologies are used very actively in various fields of activity. The authors of this work emphasized the need to apply modern technologies for the development of the tourism potential of Montenegro, and the implementation of an information platform into the onboard customer services of Montenegro Airlines in order to attract additional income and promote Montenegro as a tourist destination.

In this paper, the authors proposed concepts that need to be implemented in order to create the possibility of obtaining a holistic perception of this project on board of the airline's aircraft in order to maximize the attention of passengers and tourists heading for holidays in Montenegro.

Thus, the involved information technologies, as well as the technology of virtual and augmented reality in particular, that are being used in the proposed information model could help to increase the profitability of both the Montenegro Airlines and Montenegro in general as a tourist destination.

REFERENCES

[1] Top Trends from Gartner Hype Cycle for Digital Government Technology, 2018. URL: https://www.gartner.com/smarterwithgartner/top-trends-from-gartner-hype-cycle-for-digital-government-technology-2018/

[2] A.D. Garibova, M.M. Miheeva. Dopolnennaja ili virtualnaja realnost v muzejnom prostranstve (in Russian) // Molodoj uchenij. – 2017. - №18. - №357-362

[3] URL: https://www.aviaport.ru/digest/2018/12/12/567799.html (Source: Finmarket news agency. Published: 12.12.2018, 19:48)

[4] URL: https: // www. gazeta.ru/business/2017/02/09/10516919.shtml#page1 (Elena Platonova. Published: 02.02.2017, 19:17)

[5] Montenegro Airlines magazine. Issue 14. URL: https://montenegroairlines.com/Data/Files/Luxury/montenegro_airlines_inlight_luxury_broj_14.pdf

[6] Montenegro Airlines magazine. Issue 15. URL: https://montenegroairlines.com/Data/Files/Luxury/montenegro_airlines_inlight_luxury_broj_15.pdf

[7] N. Podzharaya, A. Sochenkova, "Innovation in Tourism. Virtual tourism", in press

[8] URL: http://ve-group.ru/3dvr-resheniya/obrazovanie-i-nauka/

[9] A. Sochenkova, N. Podzharaya, P. Trofimov and G. Novikova. Design and implementation of information retrieval mechanism for the virtual museum creation //2018 7th Mediterranean Conference on Embedded Computing (MECO). – IEEE, 2018. – pp. 1-4.

[10] N.S. Podzharaya, A. S. Sochenkova. The virtual museum development with the use of intelligent and 3d technologies on the basis of the Maritime museum in Kotor //2018 23rd International Scientific-Professional Conference on Information Technology (IT). – IEEE, 2018. – pp. 1-4

[11] URL: http://www.museummaritimum.com/kotor/14/02/2018.htm

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