Journal of Instrumentation

SISSA

OPEN ACCESS

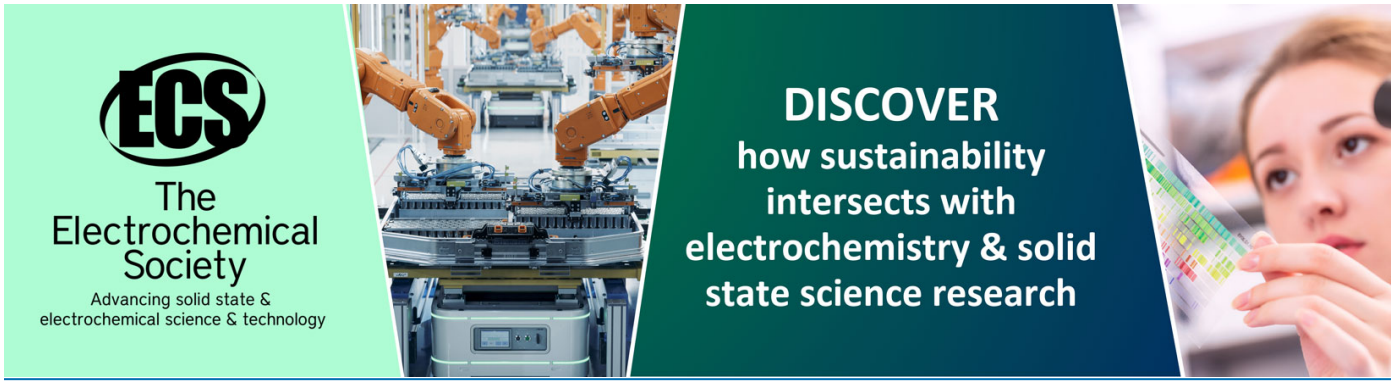
iPadPix—A novel educational tool to visualise radioactivity measured by a hybrid pixel detector

To cite this article: O. Keller *et al* 2016 *JINST* **11** C11032

View the article online for updates and enhancements.

You may also like

- The toppling iPad
M Ziese
- Stonex F6 and iPad Pro M1 2021 for Cave Graffiti Inspection in Barong Cave, West Java, Indonesia
G. A. Jessy Kartini, Irwan Gumilar, H. Z. Abidin et al.
- First-year university Physics students' knowledge about direct current circuits: probing improvement in understanding as a function of teaching and learning interventions
Richard Newman, Brandon van der Ventel and Crischelle Hanekom



This content was downloaded from IP address 18.116.36.192 on 25/04/2024 at 07:38

Published by IOP Publishing for Sissa Medialab

Received: *October 10, 2016*
Accepted: *November 14, 2016*
Published: *November 23, 2016*

Pixel 2016 International Workshop
September 5 – September 9, 2016
Sestri Levante, Genova, Italy

2016 JINST 11 C11032

iPadPix — A novel educational tool to visualise radioactivity measured by a hybrid pixel detector

O. Keller,[a,b,1] **S. Schmeling,**[a] **A. Müller**[b] **and M. Benoit**[b]

[a] *CERN,*
Geneva, Switzerland
[b] *University of Geneva,*
Geneva, Switzerland

E-mail: oliver.michael.keller@cern.ch

Abstract: With the ability to attribute signatures of ionising radiation to certain particle types, pixel detectors offer a unique advantage over the traditional use of Geiger-Müller tubes also in educational settings. We demonstrate in this work how a Timepix readout chip combined with a standard 300 µm pixelated silicon sensor can be used to visualise radioactivity in real-time and by means of augmented reality. The chip family is the result of technology transfer from High Energy Physics at CERN and facilitated by the Medipix Collaboration.

This article summarises the development of a prototype based on an iPad mini and open source software detailed in ref. [1]. Appropriate experimental activities that explore natural radioactivity and everyday objects are given to demonstrate the use of this new tool in educational settings.

Keywords: Real-time monitoring; Hybrid detectors; Pattern recognition, cluster finding, calibration and fitting methods; Electronic detector readout concepts (solid-state)

[1]Corresponding author.

© CERN 2016, published under the terms of the Creative Commons Attribution 3.0 License by IOP Publishing Ltd and Sissa Medialab srl. Any further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation and DOI.

doi:10.1088/1748-0221/11/11/C11032

Contents

1 Educational tools for discovering radioactivity **1**

2 Implementation of iPadPix **1**

2.1 Display and classification of clusters 3

3 Outlook on experimental activities for educational settings **4**

2016 JINST 11 C11032

1 Educational tools for discovering radioactivity

Conventional approaches for demonstrating the nature of radioactivity in education involve the use of Geiger-Müller tubes. These detectors are able to sense particles from radioactive decays but cannot distinguish between different types of particles. Another, more visual and revealing device is a cloud chamber, where particles leave a variety of visible traces in the form of clouds as they cross the chamber. This work describes a prototype to visualise radioactivity in a novel way, inspired by cloud chambers. With its mobile form factor, iPadPix enables out-of-school learning activities about exploring natural radioactivity through space and over time [2].

Measuring radioactivity with a hybrid pixel detector. To record and qualify impinging particles, this prototype uses a hybrid pixel detector. Similar to the ionisation process inside a could chamber, particles leave different traces within a segmented sensor depending on their energy, type and direction of incidence. If the energy is large enough to ionise the sensor material, liberated charges are collected in a readout chip connected to each pixel. The chosen hybrid pixel detector assembly consists of a 300 µm thick silicon sensor bump-bonded to a Timepix readout chip [3]. The sensitive area of $2\,\mathrm{cm}^2$ is divided into 256×256 pixels, each covering $55\,\mu\mathrm{m} \times 55\,\mu\mathrm{m}$. A notable prior work which uses the same detector principle and inspired iPadPix as well is GAMPIX: a camera to visualise gamma radiation in highly irradiated work environments [4].

2 Implementation of iPadPix

Means of *augmented reality* are used to visualise radioactivity with iPadPix. In the visual domain, this technique is a composition of an image depicting reality and a transparent overlay featuring additional information or highlighting certain aspects of the visual content. Applied in a measurement device for radioactivity, it allows to extend the human senses to recognise naturally invisible particles. Radioactive transformation processes such as α-, β- and γ-decays become observable in a visual way. Their origins can be directly related to physical objects and areas in the environment of the user. In order to achieve this direct link, measured pixel detector data is evaluated in real-time and displayed on top of a live video feed. Therefore, hardware and software related implementation aspects need to facilitate fast data flow and real-time processing in a mobile package.

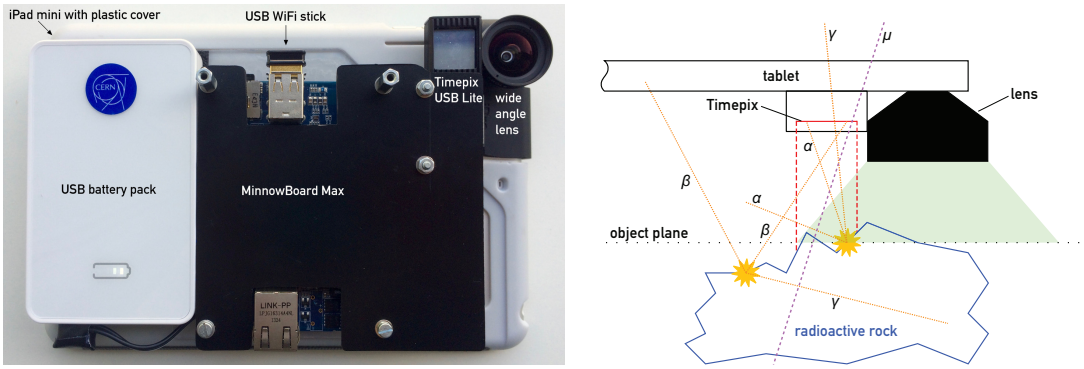


Figure 1. Left: back view of iPadPix with all the components. Right: the optical setup. Some of the shown decay products originate from the projected area (red dotted lines) of the Timepix sensor and impinge on it. Collimation is intentionally omitted, which is why particles from outside this area can be also recorded.

Hardware. A hand-held iPad mini tablet computer equipped with a 7.9" screen is the base component of iPadPix and holds all other parts of the prototype on its back. The back-side camera is enhanced with an add-on lens named *S2 wide angle lens* and manufactured by Schneider Optics. This lens increases the covered field of view by more than a factor of two and reduces the minimum close-focus distance down to 2 cm. The Timepix-based hybrid pixel detector is placed as close as possible next to the lens such that both fields of view are overlapping. It is mounted inside an *USB Lite* device available from IEAP recording pixels at a maximum rate of 4 frames per second [5]. The USB connection is wired to an Intel Atom-based MinnowBoard Max. This embedded processing board analyses the recorded traces of radioactivity from the pixel detector and forwards the data to the tablet through a small USB-WiFi stick. A USB battery pack is used to power both, the detector and the processing board with 5 V for several hours of mobile usage. Figure 1 shows the back of the tablet with all hardware parts on the left and a scheme of the optical setup on the right.

Software. In order to process data of the pixel detector in real-time, new software consisting of several components was developed. The Linux operating system on the embedded board starts all programs on power-up and forwards pixel clusters to the iPad. If the deposited energy from a traversing particle is greater than the set threshold of 4 keV in Timepix, a data point consisting of the pixel x-, y-coordinate and energy is created. New data points are recorded in intervals of 250 ms which are then analysed pixel by pixel. All data is evaluated in a procedure which groups pixels corresponding to a single interaction between one particle and the sensor together in a so-called cluster. A UDP network connection is used to transmit these pixel clusters to the tablet over WiFi. The AVRO serialisation protocol is a generic and platform independent way to convert data like pixel clusters into a space efficient binary format. Each AVRO-formatted UDP packet holds an array of records that describes every cluster identified in a frame. A cluster record stores an ID number, the coordinates of the geometrical cluster centre, total cluster energy, and the individual pixel data stored in three separate arrays (x, y and energy values). All software sources developed for the iPadPix prototype can be found online: http://github.com/ozel/iPadPix.

2016 JINST 11 C11032

2.1 Display and classification of clusters

On the iPad mini, a custom built iOS application receives the pixel clusters. Per pixel energies are drawn according to a colour map within a yellow viewfinder square that represents the detector area of 2 cm^2. The implemented colour scale uses white and yellow tones to highlight maximum pixel energies in a cluster. Orange colour tones represents mid-range energies while red and black tones represent the minimum values. The live video feed of the camera is shown in the background and updated as well in real-time. The auto-focus setting of the iPad back-side camera, available to application developers since iOS 8, is utilised to draw the size of the viewfinder square always in relation to the distance between the tablet and observed objects. It is also used to realign the horizontal overlap of the camera's field of view with the detector area depending on the distance (cf. the green trapezoid and the dotted red line in figure 1). A digital zoom factor is used to increase the optical magnification of the camera-lens assembly to an overall magnification value of ×8.25. At the minimal focus distance of 2 cm, the area in front of the detector is magnified to a viewfinder square of almost 12 cm × 12 cm, using the entire height of the tablet screen.

Depending on the type and energy of the impinging particle, several cluster shapes can be distinguished. The characterisation of these pixel clusters in Timepix/Medipix assemblies has been described in a number of publications, e.g. [6, 7]. This work presents a further extension, using similar selection criteria as applied in [8], adapted for weak radiation fields and fast real-time processing. Figure 2 shows the complete algorithm which is used to classify clusters according to their shape and total energy. The aim is to estimate the radioactive decay mode which results in the emission of the measured particle. The cluster energy is evaluated according to the following assumptions: iPadpix is designed to observe sources of natural radioactivity such as cosmic particles, potassium-40, the thorium and uranium decay chains. Low-energetic electrons are stopped in the metallisation layer of the silicon. High-energetic pixel clusters of several 100 keV total energy are unlikely to originate from a γ-photon as the thin silicon sensor is almost transparent for photons in this energy range. The result of this classification procedure is shown as a label next to the pixel clusters in the viewfinder. Figure 2 shows a screenshot of iPadPix on the right.

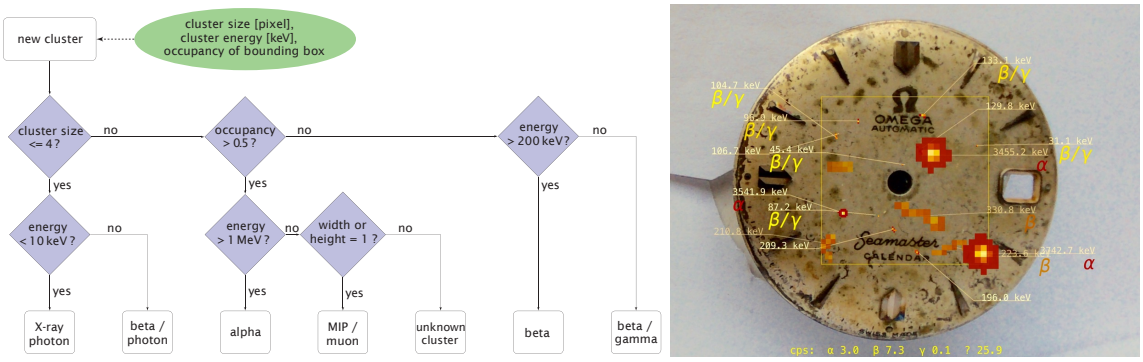


Figure 2. Left: the classification procedure for pixel clusters. Right: iPadPix screenshot of an old radioactive watch face with Radium paint on the hour markings. All main decay modes of Radium and its daughters can be observed. The yellow viewfinder rectangle indicates the sensitive area (1.4 × 1.4 cm^2).

2016 JINST 11 C11032

3 Outlook on experimental activities for educational settings

Several studies show that the use of augmented reality in education impacts many factors positively: learning performance, motivation, student engagement and collaboration [9]. In addition to enabling these advantages in educational settings on radioactivity, iPadPix offers new possibilities in teaching its nature. A common misconception is the mix-up of radioactivity with non-ionising electromagnetic radiation and other notions of radiation in general. The described tool demonstrates that ionising radiation — regardless whether it is embodied by a single photon or a particle with mass — leaves a relatively confined trace in the detector, reassembling a point-shaped interaction. Moreover, it is possible to localise the origin of the radiation within certain limits (cf. figure 1) by exploring a radioactive object or area via manual movement of the tablet. These fundamental features of iPadPix can be used to show aspects of the wave-particle dualism which would not be possible with a traditional, non-segmented detector such as a Geiger-Müller tube.

By observing the recorded count rate per particle type on the screen, it is possible to compare the characteristic radioactivity of objects and the environment across space and over time. Weak emitters such as potassium-40 in certain foods or fertilisers, can be distinguished by a slightly increased overall count rate compared to the background. In this case, the advantage of the pixel detector is its high sensitivity towards low-energetic particles. The natural abundance of radon in samples of filtered environmental air or drinking water is verified by an increased α-particle count rate. Out-of-school learning activities profit from the mobility of iPadPix and can target the exploration of radioactivity in the environment. For example, hunting rocks that contain natural occurring compounds of the thorium and uranium series. In urban areas, steps and walking paths made of granite represent interesting opportunities. On flea markets and in antique shops, everyday objects such as uranium-coloured glasses or dials painted with radioluminescent paint from old watches (cf. figure 2, right side) pose worthwhile targets. Figure 3 shows the use of iPadPix in two of such hands-on activities, indoors and outdoors.

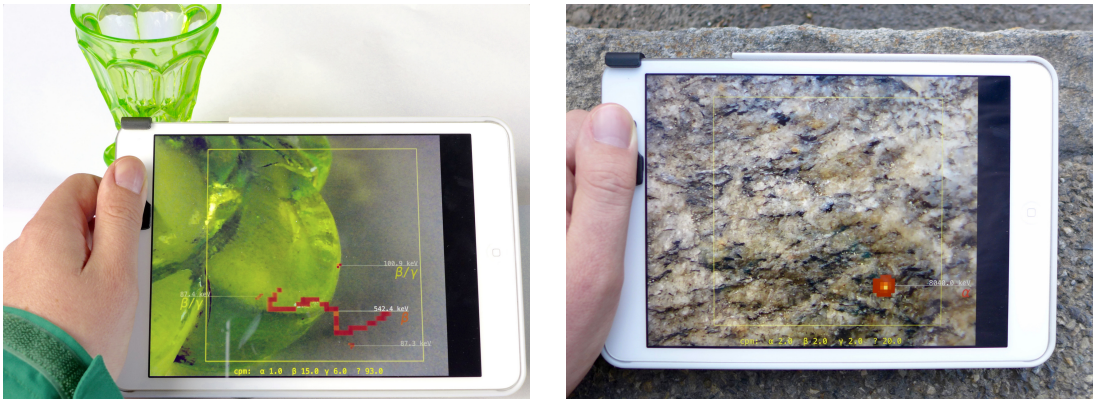


Figure 3. Hands on examples showing how iPadPix is used to explore an antique uranium glass (left) and a radioactive kerbstone made of granite in Geneva (right). Note the different count rates per minute and type.

Technical outlook. On the visual side, many adaptions are possible with the iOS application. One idea is to replace the display of raw pixel data with a simple icon for each particle type (e.g. a blue ball for electron-type clusters etc.).

2016 JINST 11 C11032

Besides visual augmentation of reality, the current implementation was extended with sonification software for performing in two New Music concerts in 2016. In addition to the visualisations, a different tone was played for each particle type. The recorded energy was used to modulate the sound. Because the data transmission is based on network standards, a second wireless UDP connection can be easily established to a regular computer. It converts each copy of cluster data into digital notes that trigger sounds of a synthesiser in real-time and synchronous to the visualisation.

In terms of hardware, we are investigating the mobile use of the more recent Timepix3 pixel detector readout chip [10]. It offers an enhanced energy resolution and provides arrival time information on the nanosecond scale, enabling for example time-of-flight measurements. This would facilitate further interesting educational activities where the incidence direction of particles like atmospheric muons can be revealed.

Acknowledgments

The authors would like to thank John Idarraga for his freely available MAFalda framework; Jerome Alozy and Stuart George for their support in calibrating the detector assembly.

References

[1] O. Keller, *Visualisation of Radioactivity in Real-Time on a tablet Measured by a Hybrid Pixel Detector*, CERN-THESIS-2015-169 (2015).

[2] N. Pachler, B. Bachmair and J. Cook, *Mobile Learning: Structures, Agency, Practices*, Springer, New York (2010).

[3] X. Llopart, R. Ballabriga, M. Campbell, L. Tlustos and W. Wong, *Timepix, a 65k programmable pixel readout chip for arrival time, energy and/or photon counting measurements*, *Nucl. Instrum. Meth.* **A 581** (2007) 485 [*Erratum ibid.* **A 585** (2008) 106].

[4] F. Carrel et al., *GAMPIX: a new generation of gamma camera*, in *Proceedings of the Conference on Design and Architectures for Signal and Image Processing*, Karlsruhe, Germany, 23–25 October 2012, 13243899.

[5] Z. Vykydal and J. Jakubek, *USB Lite — Miniaturized readout interface for Medipix2 detector*, *Nucl. Instrum. Meth.* **A 633** (2011) 48.

[6] T. Holy, E. Heijne, J. Jakubek, S. Pospisil, J. Uher and Z. Vykydal, *Pattern recognition of tracks induced by individual quanta of ionizing radiation in Medipix2 silicon detector*, *Nucl. Instrum. Meth.* **A 591** (2008) 287.

[7] J. Bouchami et al., *Measurement of pattern recognition efficiency of tracks generated by ionizing radiation in a Medipix2 device*, *Nucl. Instrum. Meth.* **A 633** (2011) 187.

[8] S.P. George, C.T. Severino, E. Fröjdh, F. Murtas and M. Silari, *Measurement of an accelerator based mixed field with a Timepix detector*, 2015 *JINST* **10** P03005.

[9] J. Bacca et al., *Augmented Reality Trends in Education: A Systematic Review of Research and Applications*, *Educ. Tech. Soc.* **17** (2014) 133.

[10] T. Poikela et al., *Timepix3: a 65K channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout*, 2014 *JINST* **9** C05013.

2016 JINST 11 C11032