Project for physics teaching,
making elementary particles visible and study their properties.

In collaboration with the European Physical Society EPS, the Medipix Collaborations and CERN

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Abstract. Project for physics teaching, making elementary particles visible and study their properties.

Besides the air which we breathe, the visible photons from the sun, and photons from our electronic screens, we also are surrounded by many other, invisible elementary quantum particles. These range from trillions of tiny neutrinos, via many free electrons, to a few muons and very rare radioactive atoms, such as radon. Most of the adult population has only a very vague knowledge of the existence of such particles. Using the integrated silicon device 'Minipix', USB-size with a $2cm^2$ sensitive area, and tens of thousands of active cells, now it is possible to view and easily distinguish several types of these elementary radiation quanta, using the screen of a laptop [1]. This particle detection and visualization instrument 'Minipix' is based on developments by the Medipix Collaborations, and R&D work for the large experiments with elementary particles at CERN, in Geneva. These pixel detectors consist of silicon sensor chips, attached to silicon integrated circuits containing the signal processing electronics. The sensor is a matrix, for example 256x256 cells, and each very small cell (a square with 0,055mm sides) is connected to an amplifier and processor, fabricated on the readout chip with an identical matrix of 256x256 cells, as illustrated in figure 1.

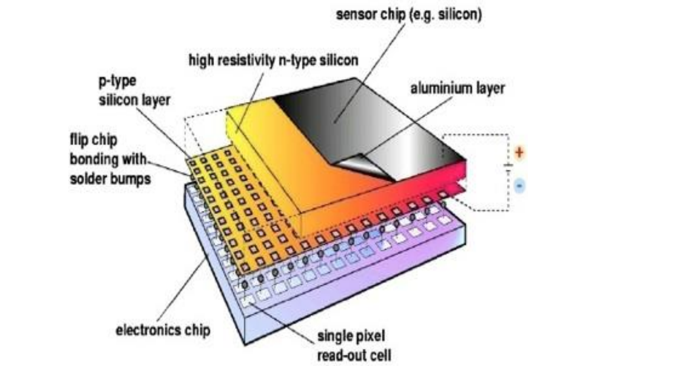

Figure 1. Schematic view of the assembly of a silicon sensor (top) and a readout chip with the matrix of processing circuits. The sensing cells are connected to the signal processing cells by very small solder bumps, which take only <15µm on the 55µm pixel dimension.

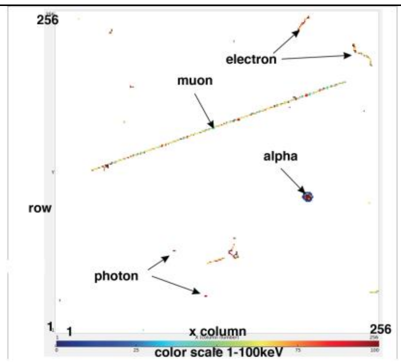

Figure 2. Elementary quantum particles can be distinguished with a Minipix imaging detector. The recording shows a few different particles, with their deposited energy per pixel, in keV, on a color scale. The muon crosses the thin Si slice under a glancing angle. The alpha gives a big blob of energy.

An ionizing elementary particle which crosses the semiconductor silicon sensor cell, generates thousands of free electrons, which remain free for a moment (a few milliseconds), and cause a signal current to flow towards the input of the corresponding amplifier connection. The electronics in each pixel can measure the amplitide of this signal, and also put a very precise timestamp (~ns) on each measurement. Most importantly, in the absence of a pulse of electrical charge from an interacting particle, a pixel will not react, and the image produced in real time will be sharp. A new measurement in the same pixel already is possible after a few tens of µs, so that even in a high radiation environment these detectors can be used. This is needed in the CERN experiments, or in a space trip to the sun or to Jupiter, but fortunately is not needed at all, in our normal environment on earth.

As shown in the figure 2, different elementary particles can be distinguished from the shape of their pixel clusters. Low energy X-ray photons only deposit a small amount of energy in the silicon, liberating locally a few thousand electrons, and then they can only give a signal in 1 or 2 pixels. The electronics has a pixel threshold of typically 1000 electrons, below which no recording takes place. An energetic electron, however, can fly over a fairly long distance in the silicon, even some mm, and is deflected and scattered by the successive encounters with other electrons in the semiconducting crystal. They appear as shorter or longer 'worms'. Such an electron may generate 10 to 20 thousand free electrons in each successive pixel. A nice and simple exercise could be to make a histogram of the energies of the recorded electrons, by determining their sum of deposited energy through all the pixels hit, during their journey. The view in figure 2 also shows a muon, which passed through the thin chip (0.3mm) nearly all the way, straight and at high energy. This muon deposited varying amounts of energy per pixel, along its track. Making a histogram of those values, would result in the well-known Landau energy deposition distribution in thin layers of matter.

Proposal for a Europe-wide project

While over the last 15 years, several efforts progressively have been developed [2,3,4] to use Minipix instruments for educational purpose, in universities and in secondary schools, now it could be a good time to discuss a proposal for Europe-wide use of the mature Minipix-Edu. Initially, a fair number of 'Minipix' educational kits could be provided to interested entities by the Medipix team at CERN, at no charge for the users. The instrument could be on loan, or later even given as a donation to a local educational organization, a (secondary) school or university. The authors, after consultations with the European Physical Society, Medipix collaboration members, and national physics Societies and Institutes, intend to begin discussions about the setting up of locally organized volunteer organizations. In many European countries, already one or several enthusiastic teams are active, and contributing members in the Medipix Collaborations. These often might help in educational activities as well [see the list on the web, reference below]. The conditions for obtaining a Minipix instrument by a school or organization could be defined by the EPS, together with these national Physics Societies, and the Medipix members. Such an approach already has been successfully used, in the Czech Republic, in the UK with 'CERN at school' and in the Spanish ADMIRA project.

A condition for receiving the instrument would be that at least one of the physics teachers or professors in the school has obtained a "Minipix-Project" licence/certificate, after following a training and a sort of examination. The details of these steps have to be discussed, with EPS, the CERN team and Medipix scientists from the participating institutes in the various countries.

The Czech team in the Institute for Experimental and Applied Physics IEAP at the Czech Technical University in Prague has produced a manual for the use of Timepix chip, which is the key component of the 'Minipix' instrument. This manual also describes a number of physics experiments, that can be conducted with the instrument [4]. Some of these experiments are quite simple and teach basic ideas, but others are of university level, and may even lead to results that could be published in scientific literature. The project ADMIRA was set up in Barcelona [3], and several schools exchanged on loan the instrument Minipix, which became a potent stimulus of collaboration between teachers. Supervision and teacher training was set up by the Medipix team in Barcelona. In figure 3 we show the experiment kit for the Minipix instrument, as it has been prepared by the Czech team.

Figure 3. SESTRA School Education Set with Timepix for Radiation Analysis. IEAP-CTU Prague [4]

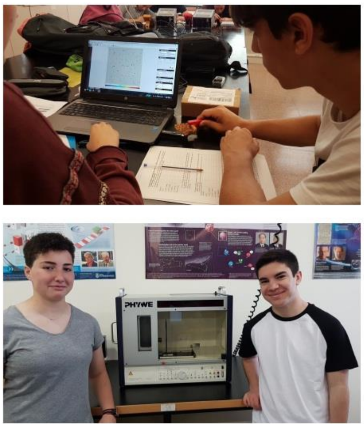

Figure 4. ADMIRA project, top: students measuring radiation from a mineral sample; bottom: student visit to the Barcelona university lab, which coordinates the project. [3]

A similar kit would be designed for use in the proposed project, taking into account the practical experience so far. It has to be kept in mind that the detector assembly in the Minipix has not been designed with regular manipulations in mind. Often, when demonstrated with a school visit, one finds a fingerprint on the sensitive surface. This is not good, because the sodium from he finger fluid can then diffuse into the silicon, which degrades the performance. Care should be taken, but the devices seem to be relatively sturdy, after all, and work mostly for several years without problems.

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