Snowmass 2021 Letter of Interest

PICosecond-sub-MICron (PICMIC) Concept for 4D Ultra Precision Detection

I.Laktineh
for the PICMIC Collaboration *

August 2020

1 Introduction

Excellent precision in both position and time measurements are required for many detection applications. For instance, many of the future particles colliders that are proposed, are to run in high luminosity configurations to obtain the needed statistics to assess significantly any deviation from the SM. These configurations produce, however, pileup scenarios where several interaction events occur in a very short lapse of time. It is thus mandatory, in order to eliminate the possible confusion due to the pileup scenarios, to be able to separate the different events by having very precise time information on the particles produced in the interaction events. It is also necessary to improve on the spatial resolution of these detection tools to obtain efficient and precise reconstruction of each of these events. A precise construction of the Higgs boson mass and its decay branching ratios for instance will greatly help to deepen our understanding of the subatomic world. Detectors with excellent performance in both position and time measurements are also needed in many other physics fields. The advent of the Free Electron Laser (FEL) accelerators for instance and the tremendous potential they provide to study the atomic and molecular structure of many materials including biological ones necessitate also such ultra precise 4-dimension detectors. Several detectors have been developed to fulfill those requirements. Unfortunately, the state-of-the-art detectors can either achieve excellent position measurement of a few microns as for the monolithic CMOS silicon detectors or provide excellent time measurement of a few picoseconds like the Micro Channel Plates (MCP) but no detector is currently able to achieve at the same time these excellent time and position resolutions.

2 Goals and General Concept

We are developing a new detection concept that intends to provide ultra precision in both time and position measurements of subatomic particles. In this concept, a new concept of detector called Nano Channel Plate (NCP) is to be used to confine the products of the particles interaction into sub-micron holes where they are amplified to produce a very large charge avalanche. Time and position are then measured in independent but complementary way. The time measurement is performed thanks to very precise fast timing sensors detecting the signal induced by the passage of the charge avalanche with the aim to reach a few picoseconds time resolution. A sub-micron position measurement resolution is also obtained using extremely tiny pixels connected together in a genuine way to reduce significantly the number of readout electronic channels while eliminating ghost particles even at particle fluxes exceeding 10 GHz/cm2. The dual (time-position) readout scheme will follow the recent published patent (WO2020148508-PCT/2020/050058) [3].

2.1 NCP detector

We are using anodized aluminum oxide (AAO) with regularly distributed nanopores of 300 nm and have special shape and and excellent surface wall quality. The AAO needs to be treated to have both a

*Contacts: Imad Laktineh(laktineh@in2p3.fr)

resistive and emissive nanopores walls. We are following several tracks. One is based on using the Atomic Deposition Layer (ADL) technique that was successfully used by the LAPPD collaboration to produce large surface MCP. Other is using specific conductive polymers.

2.2 Dual time-position measurement

For the time measurement, several possibilities are envisaged. SAMPIC[1] device that can reach 2 ps resolution is being tested but other systems combining low-jitters ASIC like PETIROC[2] equipped with the recently developed TDC by the CERN electronics group (PicoTDC) could be a nice solution for a compact device.
For the position measurement we intend to use sub-micronic pixels matrix to exploit the intrinsic spatial resolution offered by the NCP. To offer the luxury to read about 10^{8-9} ch/cm^2 the pixels are connected in a genuine way similar to that published in another patent (WO2018149827-PCT/EP2018/053561)[4]. The way these pixels are connected allows their readout with a reduced number of channels (a few 10^4 ch/cm^2) without losing the spatial resolution they offer. The pixels matrix will be equipped by CMOS discriminators to be embedded on the matrix itself. The latter will be produced using wafer industry techniques.
An acquisition system that combine the time and the position information associated to the passage of a particle is also being developed.

We have startec to build a demonstrator of the dual (time-position) readout concept and apply it to MCP using alpha source. We have already obtained very encouraging results for the time measurement and we expect to obtain excellent spatial resolution in the coming months.

3 Next Steps

Here are what we intend to do in the coming years

- To finish the dual readout demonstrator with MCP detector and test it.
- To complete the NCP development.
- To upgrade the electronics and the acquisition system to be able to deal with high rate fluxes.
- Like MCP the new NCP will be used to detect photons, ions, alphas, betas and neutrons but we want to transform it into a tracker in an appropriate way.

References

[1] *The SAMPIC Waveform and Time to Digital Converter* , E. Delagnes, D. Breton, H. Grabas, J. Maalmi, P. Rusquart, et al., 2014 IEEE Nuclear Science Symposium and Medical Imaging Conference (2014 NSS/MIC), and 21st Symposium on Room-Temperature Semiconductor X-Ray and Gamma-Ray Detectors, Seattle, United States. in2p3-0108 (2014).

[2] J. Fleury *et al.*, *Petiroc, a new front-end ASIC for time of flight application*, in 2013 IEEE Nuclear Science Symposium and Medical Imaging Conference (2013 NSS MIC).

[3] https://patentscope2.wipo.int/search/en/detail.jsf?docId=WO2020148508&_cid=JP1-KEHE1D-51343-1.

[4] https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2018149827&tab=PCTBIBLIO.