MDPI

Communication

Timing Detectors

Matteo Centis Vignali [1,†*] and Eraldo Oliveri [2,†*]

[1] Fondazione Bruno Kessler, Povo, Italy; matteo.centis.vignali@cern.ch
[2] European Organization for Nuclear Research (CERN), CH-1211 Geneva 23, Switzerland; eraldo.oliveri@cern.ch
* Correspondence: matteo.centis.vignali@cern.ch (M.C.V.); eraldo.oliveri@cern.ch (E.O.);
† These authors contributed equally to this work.

Detecting particles and radiation with picosecond time resolution is today of large interest and it is a challenging research that can offer interesting possibilities in different fields. High Energy Physics experiments at the LHC are targeting tens of picosecond time resolution in the detection of Minimum Ionizing Particles with the aim of improving the capability of distinguishing events and rejecting background. Similar resolutions for 511 keV gammas will improve the Positron Emission Tomography (PET) resolution profiting from the accurate Time Of Flight (TOF) information. Several and different detector technologies are collaborating and competing in these fields and have proven to be able to reach or approach this precision. The wide spectrum of specifications and properties of the different technological solutions offers the possibility to identify the most suitable solution with the specific requirements of each possible application.

This Special Issue aims to summarize the state-of-the-art of timing detectors exploring different and innovative technologies, modeling and simulation tools, readout strategies and electronics, and applications. It should provide a reference for further technological developments and contain the necessary information to be an aid in finding new applications of timing detectors. It should in parallel highlight synergies between technologies (strategies and concept, modelling and simulation, signal processing, data analysis, instrumentation, common tools) to support and enlarge the existing *R&D* framework around timing detectors.

We would be honoured if you would consider to contribute with a short communication, research paper or focus review to this Special Issue and we would consider it a valuable support to the large community of groups working on application and solutions related to timing detectors.

The official deadline for submission is 30 April 2021. Please don't hesitate to contact us if you are interested, if you have any question or if you would like to give us suggestions linked to this Special Issue.

---

1. Introduction

Nowadays timing detectors are very often playing in the picosecond scale. Several technologies can achieve such performances, finding applications in different areas. This Special Issue aims to summarize the state-of-the-art of timing detectors exploring different and innovative technologies, modeling and simulation tools, readout strategies and electronics, and applications. It should provide a reference for further technological developments and contain the necessary information to be an aid in finding new applications of timing detectors. Contributions are expected to address but are not limited to the following areas:

- Applications (particle, astroparticle, and nuclear physics, fundamental research, medicine, etc.).

- Detector concepts, existing and future solutions.
- Detector technologies (silicon with and without gain, diamond, gas based, detecting Cherenkov or scitillation light, using MCP-PMT or SiPM, etc.).
- Detector modeling and simulation.
- Signal processing and Readout electronics.
- Timing electronics, synchronization, and clock distribution.

Short communications, research papers, or focus reviews that can cover these research fields will be appreciated. The official deadline for submission is 30 April 2021. You may send your manuscript now or up until the deadline. We can organize a very fast peer-review. If accepted, the paper will be published very soon. For further reading, please follow the link to the Special Issue website at https://www.mdpi.com/journal/instruments/special_issues/Timing_Detectors.
For assistance in the submission process or for questions related to the journal and publication, please contact Ms. Shayna Tang at instruments@mdpi.com.

Instruments (ISSN 2410-390X) is a new open access journal led by Editor-in-Chief Prof. Dr. Antonio Ereditato (University of Bern, Switzerland). It is an international journal which provides an advanced forum for studies related to the design and applications of instruments and apparatus, experimental techniques, as well as instrumentation methods in disciplinary and interdisciplinary research. Instruments is recommended by CERN.

In the next part, we will briefly describe how we would like to structure the special issue, hoping that this could help you on finding the right context and place for your work and research.

2. Timing Applications

One of the aim of this special issue is to collect contributions that highlight set of measurements and experiments where precision on timing can be very beneficial. Applications for High Energy Physics experiments [1,2] in colliders as well as beyond, Nuclear and Astroparticle physics, Medical applications [3] are a few examples of fields that we would like to cover. The interest in this field is highlighted by numerous workshops [4–7]. Even if you are not directly interested on submitting, any suggestions of applications, colleagues or groups that could significantly enrich this part would be appreciated. The Special Issue aims to be an aid in finding new applications.

3. Basic Principles of Precise and Fast Timing

Despite the fact that technologies to achieve precise and fast time resolution can be very different, some basic and common rules exist. This section of the Special Issue would like to address that part, touching sensors [8], electronics [9], and other system components. Starting from requirements on the signal and going through all the signal processing with their contributions to the final resolution. It will be interesting to cover different strategies and algorithms already used in the community or foreseen. We would appreciate as well if you could eventually address us to experts in the field that you consider appropriate for this part.

4. Technologies

Several timing detector technologies under investigation have been properly described in recent review papers (see for instance the reviews by J. Va'vra [10,11]). In this section we would like to cover most of them, possibly highlighting, for each of them, all the peculiarity and specifications (not exclusively related to timing) that can be of interest in the selection toward a possible application. LGADs, APDs, silicon and 3D silicon, diamond, scintillator and cherenkov detectors, MCP-PMTs, tynodes, multi gap RPCs, MPGD based detectors are a non exhaustive lists of detector concepts and solutions that would be important to have represented. Limits of the technologies as well future *R&D* plans would be considered important contributions. We are willing to integrate as many research lines

as possible and we will appreciate, even if you are not planning to contribute directly, if you would like to highlight some interesting research that you would consider important to be represented in this Special Issue.

5. Detector Modelling and Simulation

Detector modelling and simulation has shown to be essential in the detector understanding and for the detector optimization required to push the technology to the limit. With this section we would like to highlight all the existing tools available in the different technologies like Tcode [12] and Weightfield2 [13], offering a concise overview of the existing possibility and on the future potentiality. In some cases, tools are crossing technologies. Garfield++ [14] for instance has been developed for gas detectors, it is used for fast and precise timing based on MPGD, but it is today applicable to LGAD silicon technologies to study signal formation [15]. This session should highlight and suggest possible synergies like the one mentioned that can enrich the existing *R&D* framework for timing detectors.

6. Signal Processing, Front And and Timing Electronics

In the aim of precise and fast timing, the interplay between electronics and detector is highly enhanced. Proper coupling and proper design rely on a deep exchange between detector and electronics experts. Once the analog signal is optimal, the digitization of the information, being waveform (digitizer) or directly timing (TDC), has to be done. In advanced projects, all of this is implemented in multichannel ASICs allowing to realize large systems. This section would like to cover from theory to concrete developments. Developments by institutes, laboratories and companies should be well represented. This section should offer a proper representation of existing solutions and future possibilities in the full chain between the detector and the data analysis. Reviews on existing or possible approaches and solutions are welcome in view of the role that they can have on guiding future developments.

7. Time Reference

Precision timing in distributed systems requires a proper clock distribution and synchronization. Experiments, being large or distributed, are working on this field of research. Specific activities or review contribution will be appreciated.

8. Conclusions

We believe that this special issue can offer to the community of groups working with timing detectors a proper collection of information. In order to achieve this result we would really appreciate to have your contribution to the issue or possible comments and suggestions that could help us on reaching this goal. Please do not hesitate to contact us for any question or comment you may have.

References

1. ATLAS Collaboration, A High-Granularity Timing Detector for the ATLAS Phase-II Upgrade https://cds.cern.ch/record/2719855
2. CMS Collaboration, A MIP Timing Detector for the CMS Phase-2 Upgrade https://cds.cern.ch/record/2667167
3. S. Majewski, The future of dedicated Imagers in Nuclear Medicine and the Role of HEP in this Evolution, April 24 2015, CERN Detector Seminar, https://indico.cern.ch/event/381161/
4. RD51 Precise Timing Workshop, February 21-22, 2017, CERN, https://indico.cern.ch/event/607147/
5. Workshop on Pico-Second Timing Detectors for Physics and Medical Applications, May 16-18, 2018, Torino, https://agenda.infn.it/event/15031/
6. FAst Timing Applications for nuclear physics and medical imaging, September 3-5, 2019, Catania, https://agenda.infn.it/event/18991/

7. Workshop on Pico-Second Timing Detectors for Physics, June 16-18, 2021, Zurich, https://indico.cern.ch/event/861104/
8. W. Riegler and G. Aglieri Rinella, Time resolution of silicon pixel sensors. *JINST* **2017** *12* P11017–P11017
9. A. Rivetti, Fast timing techniques, February 21 2017, RD51 Precise Timing Workshop, https://indico.cern.ch/event/607147/
10. J. Va'vra, PID techniques: Alternatives to RICH methods. *NIM A* **2017**, *876* 185–193.
11. J. Va'vra, Picosecond timing detectors and applications. *J. Phys.: Conf. Ser.* **2020**, *1498* 012013.
12. Tcode https://github.com/MultithreadCorner/TCode
13. Weigthfield2 http://personalpages.to.infn.it/~cartigli/Weightfield2
14. Garfield++ https://garfieldpp.web.cern.ch/garfieldpp/
15. H. Schindler, Signal simulation using Garfield++, *34th RD50 Collaboration Meeting*, **2019**, https://indico.cern.ch/event/812761/contributions/3459086/