Tracking in 4 dimensions with Silicon and Diamond detectors

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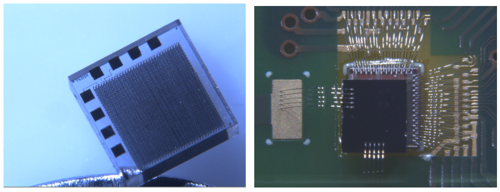
One of the main goals of the LHCb experiment is to discover new physics beyond the Standard Model through precision measurements in the flavour physics sector. To pursue this research, large data samples are needed in order to reduce statistical uncertainties and catch the tiny glimpses of new physics. For this reason, LHCb is preparing a very ambitious upgrade project to collect 30 times more data than recorded so far.

This project is extremely challenging, the most difficult part being the reconstruction of the trajectories and of the production and/or decay vertices of the particles generated at very high rate in proton-proton collisions at LHC. LHCb will need to design and build the most advanced vertex detector ever, able to reconstruct with high precision thousands of tracks originating from about 50 simultaneous proton-proton collisions.

This is possible only with a very precise measurement of the position and the time of the particles along their trajectories ("4D tracking"). To this aim within the LHCb group we are studying and developing new advanced particle detectors with very high space and time resolution to reconstruct the particle positions with a precision of a few microns and their time with a precision of 20-30 ps.



Left: A 3D Diamond detector with graphite electrodes; right: a 3D silicon pixel detector with the readout ASIC on top

In addition, the vertex detector of LHCb will be placed at about 3 mm from the LHC beam and will be therefore subject to an unprecedented level of radiation to which the current detector technology would not survive. We will need therefore to develop innovative detector technologies and/or materials (e.g. Diamond), and a new generation of integrated readout electronics.

In particular we are studying 3D Silicon pixel detectors with a time resolution of 10-20 ps and novel 3D Diamond detectors with readout electrodes made by graphitising (= burning!) diamond crystals with an infrared femto-second laser.

The Ph.D candidates will take part in this exciting research programme covering both physics and technology aspects:

- physics studies: benchmark physics channels must be studied with simulations to define the needed vertex detector performances;
- sensor development: development of 3D silicon and diamond detectors. With diamond detectors, world-first, innovative developments are also envisaged, for what concerns the diamond laser machining;
- test and development of novel high-time resolution ASIC in 28nm technology;
- detector configuration studies: simulations of the vertex detector are needed to optimise its actual configuration.

Further reading

- *Physics case for an LHCb Upgrade II*, arXiv:1808.08865
- *Framework TDR for the LHCb Upgrade II*, LHCB-TDR-023
- *Fabrication and Characterisation of 3D Diamond Pixel Detectors with Timing Capabilities*, Front.in Phys. 8 (2020) 589844
- *Fabrication and First Full Characterisation of Timing Properties of 3D Diamond Detectors*, Instruments 5 (2021) 4, 39
- *First results of the TIMESPOT project on developments on fast sensors for future vertex detectors*, NIMA 981 (2020) 164491

About the group

Giovanni Passaleva is Research Director at INFN - Firenze. He is the founder of the LHCb group in Firenze and he has been Spokesperson of LHCb from 2017 to 2020. He is involved in the TimeSpot INFN experiment (high time resolution 3D silicon and diamond pixel detectors for the LHCb vertex detector) with focus on innovative 3D Diamond sensors fabricated with laser graphitization.

Lucio Anderlini is Researcher at INFN - Firenze. Since 2017 he is contributing to the TimeSpot INFN experiment with a leading role in the development of Diamond sensors fabricated with laser graphitization.

Michele Veltri is Professor of Physics at the University of Urbino. Prof. Veltri is a leading expert on Geant4, a simulation framework used to predict the radiation-matter interactions in High Energy Physics and coordinates the activities related to Geant4 in the LHCb Simulation Project. He is also very active in Diamond sensor simulations.