# 4D Fast Tracking for Experiments at the High-Luminosity LHC

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## Introduction

The **High-Luminosity (HL) LHC** phase will be characterized by an instantaneous luminosity of $5\times10^{34}$ $cm^{-2}s^{-1}$ for the ATLAS and CMS experiments at CERN, and $1\text{-}2\times10^{34}$ $cm^{-2}s^{-1}$ for **LHCb**. HL-LHC will allow to collect an integrated luminosity up to 250 $fb^{-1}$ per year. As a side effect the average number of visible interactions per bunch crossing will grow up to 140. In such environment precise tracking will be extremely challenging, not only for the high fraction of ghost tracks expected, but also from the radiation-hardness point of view.

## The Idea/Concept

We aim at developing a prototype of an innovative tracking detector with embedded **4-dimension tracking capabilities**, based on accurate time and position particle hit measurements. This detector would allow the full exploitation of the physics potential of the HL-LHC, in particular for **flavor physics**. The precise determination of the time of the track is recognized to be the key feature needed to disentangle many overlapping events and enhance track trigger selection capabilities.

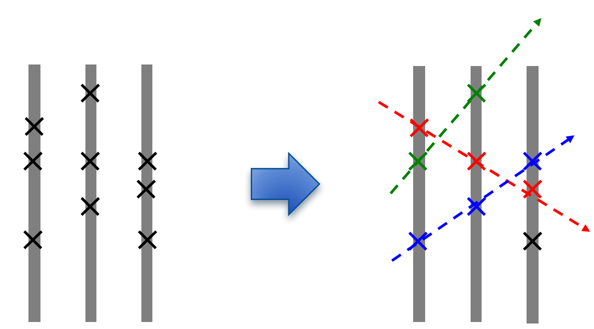

**Figure 1.** Precise hit time information is crucial to correctly associate hits belonging to the same track (colored arrows).

The challenge for HL-LHC operations is that sensors and electronics are required to be able to sustain large hadron fluences, **exceeding $10^{16}$ 1 MeV neutrons equivalent per $cm^2$**.

We propose to use **3D silicon sensors**, specifically conceived to operate in environments requiring extreme radiation hardness. 3D sensors geometry allows a very fast charge collection, a feature of paramount importance for precise time measurements. Excellent position resolution can also be achieved thanks to the small pixel size.

The goal of this proposal is to design a sensor and the front-end electronics capable to provide hit time resolution of the order of **20 ps**, together with a hit position resolution better than **40 microns**.

The front-end chip will be built using **65 nm CMOS technology**, a good candidate that matches the radiation hardness requests of the HL-LHC experiments.

## Potential Impact

The novel detector and technologies that we will study and develop could be employed in future high-luminosity and/or high-energy accelerators and colliders. The impact of a **fast timing pixel detector** with embedded tracking capabilities on the physics reach of the HL-LHC experiments would be of paramount importance. Such developments will allow making significant progress especially for flavor physics experiments at high luminosity, by making accessible experimental evidences of phenomena that cannot be explained within the Standard Model. This is a field of the utmost interest in **fundamental physics research**. The proposed detector will maximize the potential of LHC upgrade, which will be able to continue playing a leading role in the coming years. Foreseeable uses of such technologies in different industrial sectors may turn useful in **space research**, where radiation resistant electronics is needed, and in **medical physics**. Thorough investigation of such technologies may lead to the spin-off creation of products and services that are very innovative and specialized.