R&D of GAGG single crystals for fast timing detectors in high rate and radiation environments

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Cerium-doped $Gd_3Al_2Ga_3O_{12}$ (GAGG:Ce) single crystals gained an increasing interest in the scintillator research community thanks to the high light yield and relatively fast decay time [1], paired with outstanding radiation hardness tested up to 1 MGy [2]. Amongst the garnets, it has better stopping power than $Y_3Al_5O_{12}$ (YAG), it does not present radioactive background, unlike $Lu_3Al_5O_{12}$ (LuAG), and it is under consideration for thermal-neutron detection thanks to the large neutron-capture cross-section of the Gd isotopes. Moreover, its scintillation properties can be tuned engineering the Ga-Al ratio and the dopants levels, optimising light yield, energy resolution, or decay time [3,4]. For these reasons, GAGG is the baseline option for the SPACAL modules of the LHCb PicoCal [5].

Amongst commercial GAGG, significant differences were observed between producers, with light yield of 2x2x3 mm^3 pixels ranging between 27900 and 49500 photons per MeV and decay time down to 50 ns. The fastest samples achieved coincidence time resolution (CTR) of 87 ps full width at half maximum, close to LYSO:Ce crystals. [6]

However, such crystals have long scintillation decay that, in the high-rate environment of the High-Luminosity LHC, causes the pulse to spill over from one bunch crossing to the next. For this reason, novel compositions of GAGG were studied with ultra-accelerated scintillation, reducing decay time to a few nanoseconds without loss of time resolution. [7]

This contribution will first give an overview of the optical and scintillation properties of the state-of-the-art commercial GAGG. We will then present the current R&D ongoing with various partners to optimise the GAGG composition in order to fulfil the LHCb PicoCal rate requirements and to optimise the growth process for large-size samples.

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