August 2020

THE QUEST OF PROGRESS IN THE FIELD OF CHERENKOV IMAGING DETECTORS

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Detectors utilizing Cherenkov imaging techniques, one of the premier approaches for **Particle IDentification** (PID), are an absolute necessity in future particle and nuclear physics experiments. A shining example is **flavour physics** and **hadron physics**, as demonstrated by these few examples among a many: LHCb [1] at CERN LHC, BELLE2 [2] at SuperKEKB at KEK, COMPASS [3] at CERN SPS and CLAS12 [4] at JLab CEBAF12. A **wide and lively community** is dedicated to these detectors, including detector developers and users: more than 100 participants attend the International Workshops on Ring Imaging CHerenkov (RICH) Counters [5], despite the highly specialized character of the workshop. **Important progress** has been registered in recent years: [1]various detector designs derived from the pioneering experience of BABAR DIRC have been proposed (the TOP detector for BELLE2 is in operation), [2]the control of the quality and parameters of aerogel has been improved for the needs of the BELLE2 ARICH [6], and [3]the CLAS12 RICH, gaseous detectors of single photons have been upgraded making use of MicroPattern Gaseous Detector (MPGD) technologies (previously used in the HBD [7] of the PHENIX experiment at RHIC) [4]for the recent upgrade of the COMPASS RICH. Nevertheless, **key questions remain open** whose answers are mandatory to continue physics progress in these vital domains and expand capability for planned future experiments. We note that **all proposed detector concepts for the future electron-ion collider (EIC)**, include Cherenkov imaging detector concepts. In the following missive, we will highlight the open questions that regard as particularly urgent and crucial. Our examples are mainly related to PID at high momenta (well above 10 GeV/c), a sector that recently has received less attention. We conclude this short note by underlying the synergies among the developments for Cherenkov technologies and other applications for particle and nuclear physics and beyond.

RICHes for PID at high momenta require a gaseous radiator and **FluoroCarbons (FC)** are most often used due to their comparatively high density (ensuring good Cherenkov photon rates), and their low chromaticity (enabling good θ_C resolution); the necessary ingredients for PID at high momenta. The FC Global Warming Potential (GWP) is extremely high and, therefore, their use is subject to increasing restrictions, and will likely also affect future procurement. **Alternatives** are urgently needed and so far, the only proposal [8] able to mimic FC in terms of density and chromaticity is **noble gas pressurized to several bar**. This conceptual proposal needs confirmation, and other alternatives to FCs could come from further dedicated studies.

Photo-electron statistics are one of the primary driving factors in RICH ultimate performance. Visible and/or UltraViolet (UV) photons are detected in present RICHes. The design of a precision RICH balances the desire for high photon statistics (broadest possible range of wavelength sensitivity) against the dispersion of the refractive index (chromaticity), whose negative impact is most pronounced in the deep UV. This optimization process has typically driven the design toward detecting a larger number of photons via **visible light sensors**. Two open questions naturally follow.

- **First**, the privileged role of visible light sensors is challenged by a limited development of these devices with characteristics adequate for Cherenkov imaging applications. This remains true despite large progress in general-purpose photodetectors. PhotoMultiplier Tubes (PMT) and derived devices cannot operate in presence of strong magnetic field and also present high material budget (made worse in case magnetic shielding is used). So far, established gaseous photon detectors can operate only with CsI as a deep UV photoconverter. Alternatives like commercial MicroChannel Plates (MCP)-PMTs are presently limited in size and extremely expensive. In this panorama, the development of **Large Area Picosecond PhotoDetectors (LAPPD)** [9] must be pursued up to the end with care. Current efforts on LAPPD development prioritize time resolution over and above the specific requirements for effective single photon detection and localization (critical to consideration for RICH usage). The effective and reliable use **Silicon-PhotoMultiplier (Si-PM)** for RICH application requires wide and keen attention, in a manner specific to utilization in a RICH. We note that all Cherenkov imaging techniques, both for low and high momenta, will benefit from advancement in visible light detection of single photons.

- **Second**, there is the quest for investigations towards **non-standard UV light photoconverters**, with increased Quantum Efficiency (QE) with particular attention on application in gaseous photon detectors. A larger QE breakthrough in this arena would make UV light detection a competitive alternative. The evaluation of the potential of **hydrogenated-nanodiamond** powder [10] is a first step. Further investigation is required, with dedicated attention to novel C-materials.

The use of RICHes for high momentum PID is limited in hermetic collider experiments because of the space required by the gaseous radiators. The availability of **meta-materials**, like optical crystals, designed to provide the **refractive index needed for PID at high momentum by material with much higher density** than a gas, would represent a breakthrough in the field. A long-term investigation and development is needed, already started [11] by conceptual studies dedicated to identify adequate couple of materials that, arrange in nanoparticle, can match the requirements.

Synergies between Cherenkov-based PID technologies and other applications offer a wide panorama, that we recall by some representative examples, not aiming at an exhaustive list and additional examples abound. The **p-sec project** [12] dedicated to developing MPGDs with time resolution in the few ps range, is based on the detection of the isosynchronic Cherenkov light. The same property of the Cherenkov effect is considered in Time Of Light (TOF) measurements in the **TORCH** project [13]. The detection of Cherenkov light is at the base of the successful studies of **neutrino physics at the Kamiokande experiment** [14] and its evolution. The **underwater neutrino experiments** are also based on the detection of Cherenkov light [15]. A number of **astroparticle** experiments are based on the detection of **Cherenkov light produced in the atmosphere** [16], as AUGER, MAGIC, HESS, CAT and others. In the medical sector, Cherenkov light is proposed to improve **Positron Emission Tomography (PET)** technology [17]. The detection of Cherekov light in air generated by atmospheric muon is considered for **vulcano studies** [18].

In conclusion, upgrading Cherenkov imaging technologies is necessary, challenging and, most likely, highly rewarding.

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