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Ion-induced effects in GEM and GEM/MHSP gaseous photomultipliers for the UV and the visible spectral range

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Abstract

We report on the progress in the study of cascaded GEM and GEM/MHSP gas avalanche photomultipliers operating at atmospheric pressure, with CsI and bialkali photocathodes. They have single-photon sensitivity, ns time resolution and good localization properties. We summarize operational aspects and results, with the highlight of a high-gain stable gated operation of a visible-light device. Of particular importance are the results of a recent ion-backflow reduction study in different cascaded multipliers, affecting the detector's stability and the photocathode's lifetime. We report on the significant progress in ion-blocking and provide first results on bialkali-photocathode aging under gas multiplication.

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1. Introduction

Most particle physics, experiments having Ring Imaging Cherenkov (RICH) systems with gaseous photon imaging detectors, employ large-area CsI UV-sensitive photocathodes (PC) and wire-chamber electron multipliers [1]. In recent years there has been considerable progress in the development of other gaseous photomultipliers (GPMs) [2–7]. The R&D efforts have been generally motivated by the necessity to overcome some basic limitations of wire chambers. In these multipliers the avalanche develops at the wire vicinity, in an "open geometry", at a short distance (a few mm)

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from the PC. It results in significant photon- and ion-mediated secondary-avalanches formation, limiting the detector gain and its single-photon detection efficiency, and also affecting photon localization by broadening the charge induced on the readout elements. The ion-induced secondary-electron emission is particularly important in GPMs with visible-sensitive PCs, due to their low electron emission threshold [8]. Another important limitation of wire-chamber GPMs is the PC damage by avalanche-ion impact [9]; in wire chambers, like in parallel-plate avalanche chambers (PPAC) and in resistive-plate chambers (RPC), all avalanche ions are collected at the photocathode.

Our R&D efforts in recent years have therefore concentrated on the search for electron multipliers of a "closed geometry", with reduced photon- and ion-feedback probabilities. We have chosen cascaded "hole multipliers" of different structures, in which the avalanche that develops in successive multiplication stages is confined within the holes. We have investigated their physical properties and developed methods for reducing the avalanche-ion backflow (IBF), defined as the fraction of total avalanche-generated ions reaching the PC in a GPM; the methods discussed below are relevant to the stable operation of time projection chambers (TPC), where the IBF relates to the fraction of ions reaching the drift volume. Recent results of ion-induced bialkali PC aging under gas-avalanche are presented.

2. UV GPMs

The operation mechanism and properties of GPMs comprising cascaded gas electron multipliers (GEM [10]) with semitransparent or reflective CsI UV-PCs, are summarized in [3,11]. Fig. 1 shows a 4-GEM "reflective"-GPM with a PC deposited on top of the first GEM in the cascade [11]. It reaches gains $>10^6$, in a variety of gases, including CF_4 [12,13]. The resulting high sensitivity to single photons is due to the efficient GEM's optical screening, preventing avalanche-induced photons to hit the PC. The reflective-PC GPM has, in addition, very low sensitivity to charged-particles background, as discussed in [14]; relati-

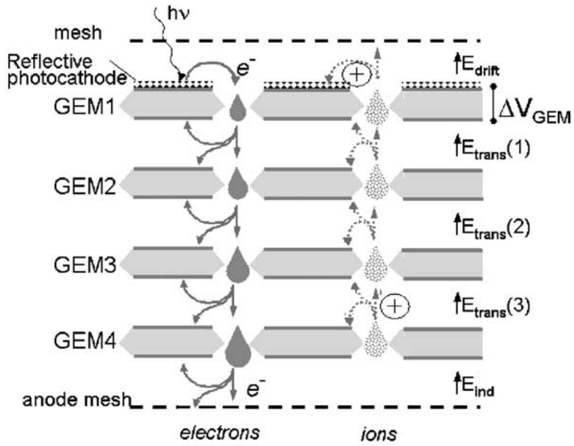

Fig. 1. A 4-GEM "reflective" GPM. Shown are the photoelectron trajectories, avalanche development and ion backflow in opposite direction.

vistic-particle rejection factors >100 were recently demonstrated [15]. This property is of prime importance in Cherenkov detectors operating under intense background, such as in relativistic heavy-ion experiments. The photoelectron detection efficiency, dictated by its extraction and transport into the holes, approaches unity at reasonable gains, as summarized in [3].

The compact structure of multi-GEM GPMs results in short multiplication times, yielding pulse-widths in the 10–20 ns range and single-photon time resolutions <2 ns [16]. The narrow avalanche width permits resolving close-by successive events; the width of the charge induced on the segmented readout anode can be tailored to cope with the readout scheme [17], e.g. by means of a resistive anode in front of the readout circuit [18]. 2D localization resolutions of the order of 100 μm RMS were measured with a 3-GEM detector coupled to a delay-line [17]. The IBF in cascaded GEM GPMs, reaching at best 10–20%, is discussed below.

The UV-sensitive "reflective" multi-GEM GPM is a mature technique; large-area detectors are under construction for a Hadron–Blind Cherenkov detector (HBD) of the PHENIX (RHIC-BNL) relativistic heavy-ion experiment [15]; others are developed for RICH [19]. Similar photon detectors, operated at cryogenic temperatures,