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Nuclear Instruments and Methods in Physics Research A 548 (2005) 439–445
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Further studies of two-phase krypton detectors based on Gas Electron Multipliers

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Received 31 March 2005; received in revised form 18 April 2005; accepted 26 April 2005
Available online 25 May 2005

Abstract

We further study the performance of cryogenic two-phase avalanche detectors, based on Gas Electron Multipliers (GEMs) and operated in an electron-avalanching mode in Kr. Stable operation of the triple-GEM in saturated vapor, above the liquid, has been demonstrated for several hours. The signals induced by 0.5 MeV γ-rays were recorded from the two-phase detector in coincidences with a BGO counter, aiming at potential applications in Positron Emission Tomography. Charging-up effects were observed at high anode current densities in GEM-based two-phase detectors.

PACS: 29.40.Cs; 34.80.My

Keywords: GEM; Cryogenic avalanche detectors; Two-phase detectors; PET

1. Introduction

In recent years, there has been a growing interest in the development of cryogenic two-phase (liquid–gas) detectors based on noble liquids for 'low-energy' physics experiments, where the deposited energy is rather low: of the order of 1 keV in coherent neutrino scattering [1], 10 keV in dark matter searches [2], 100 keV in solar neutrino detection [3] and 1 MeV in Positron Emission Tomography (PET) [4]. The noble liquids in these experiments are argon, xenon, helium and xenon, respectively. The primary ionization signal in such experiments is rather weak; therefore it should be amplified. The development of cryogenic avalanche detectors [5] might solve the problem: such detectors should be able to operate in an electron-avalanching mode in saturated vapor of the noble gas, above the liquid phase.

At present, the operation in pure noble gases at reasonable gains is possible using either Gas Electron Multipliers (GEMs) [6] or Micro-Hole

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doi:10.1016/j.nima.2005.04.055

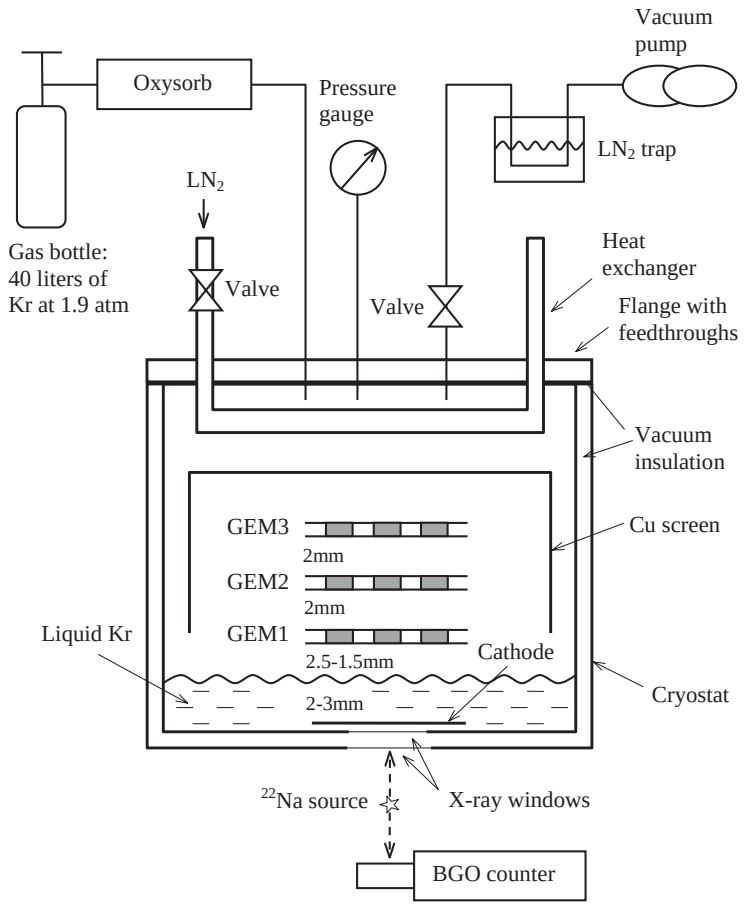

Fig. 1. Schematic view of the GEM-based two-phase avalanche detector.

and Strip Plates (MHSPs) [7,8], the latter structure being a modification of GEM. High-gain operation of GEM structures was demonstrated in all noble gases at room temperature [9–11] and in He, Ar and Kr at cryogenic temperatures [5,12,13]. The first results from the GEM operation at cryogenic temperatures in two-phase Kr detectors have been recently presented in our works [5,12]: gains exceeding 1000 and stable operation for 1 h were reported.

It should be remarked, however, that the stability of electron avalanching in saturated vapor is still under question. In the past, this was the main obstacle preventing the development of two-phase detectors [14]: gain instabilities were observed in two-phase Kr and Xe detectors based on wire chambers. These instabilities were believed to arise due to vapor condensation on wire electrodes, enhanced by an electric field.

Therefore, further studies of GEM performances in two-phase detectors are of primary importance. It should be noted that the GEM operation in Kr is very similar to that in Xe and in less extent to that in Ar [10,11], so that the basic characteristics of two-phase avalanche detectors in heavy noble gases might be obtained by studying their performances in Kr.

In this paper we further study the performance of two-phase Kr avalanche detectors based on GEM structures. The stability of operation, charging-up effects and detector response to γ-rays, aiming at their potential applications in PET, are studied.