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COORDINATE GASEOUS PHOTOMULTIPLIER WITH SOLID PHOTOCATHODES FOR USE IN FUTURE COLLIDERS

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Abstract

We report the latest results on developing fast gaseous detectors with solid photocathodes. Such detectors could be used for the readout of the crystal calorimeters, preshower counters and in RICH. Results obtained with new efficient photocathodes are also presented.

Introduction

It is commonly acknowledged that the main requirements for the detectors to be used at future colliders such as the large hadron collider (LHC) and the superconducting super collider (SSC), are high speed (time resolution < Ins), high radiation resistance (up to 0.1 MGy), good energy resolution (approx. 4% $(E(GeV))^{-0.5}$) and high spatial resolution (approx. Imm). These requirements exceeds the capabilities of existing detection systems and therefore new techniques are required. Recently, a new type of photosensitive detector, called the coordinate gaseous photomultiplier (CGPM) has been proposed as a promising candidate for future colliders [1]. It has a time resolution of better than Ins, a quantum efficiency over 40% for wavelengths less than 200nm, and an energy and spatial resolution typical of gaseous detectors. These characteristics may fit some requirements of frontier physics. It can find wide range applications in astrophysics, plasma diagnostics, positron emission tomography, and in other areas. In high energy physics, it could be used for fast RICH and for the readout of crystal calorimeters, emitting in the VUV. In this work, we will give a review of the latest (mostly unpublished) results obtained in the development and application of the CGPM.

Design

There are different modifications for the CGPM (see ref. [2-4] for examples). The simplest one is presented in fig.1 [2]. It contains a VUV transparent window, an

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anode mesh, and a photocathode deposited on pads. The detector is typically filled with He plus 10 torr of CH_4 to a total pressure of 1 atm. it could also be operated at low pressure [4]. The detector is operated in the following way. The VUV photons passing the entrance window extract electrons from the photocathode and then initiate the avalanches. The coordinates of the avalanche are detected by the pad system. One can see that the essential part of the detector is the photocathode. Different photocathodes were tested [2,5,6]. A brief review of the most important results will be presented in the following section.

1. Photocathodes

1.1 CsI Photocathodes

The first proof that the CsI photocathode can be used in the CGPM was shown by the authors of ref. [2]. The main advantage of this photocathode is that it has a very high efficiency at 200 nm (greater than 10%). On the other hand, high quantum efficiency of the photocathode may restrict the value of the gas gain achievable due to photon feedback. This question was studied carefully for both atmospheric and low pressure operation. In both cases, the CGPM reached gains of up to 10^6 without noticeable feedback, has a time resolution of about 500 ns FWHM, and an energy resolution of 8.2% FWHM for 3×10^3 photoelectrons. At 1 atm breakdown appears at a total charge in the avalanche of approximately 10^{10}. The breakdown was always a slow trip, which develops in a few μs. It is thus possible for practical applications to use an active protection against such breakdown by pulsing off the voltage in the ampligying gap when the current grows well above the normal avalanche level.

Aging of the CsI photocathode, due to positive ion feedback, has been studied. The best results were obtained at a pressure of 1 atm, when the decay of the quantum efficiency was observed at a total charge of about 50 μ C/mm^2.

1.2 CsI with an adsorbed layer

As is described in ref. [3,7], a CsI photocathode exposed to TMAE or decamethylferrocene (DMFc) vapour gains new properties. First, there is an increase in quantum efficiency due to the double electric layer (Chemisorbtion) formed on the surface. Secondly, it becomes much more insensitive to air. The quantum efficiency stays practically unchanged after being exposed to air for a few hours.

These two factors make the CGPM very simple from the technological point of view. For example, the authors of ref. [4] demonstrated that the CsI can be coated by TMAE vapour in the vacuum immediately after the CsI evaporation and then remain stable in air.

Another important feature of this type of photocathode is a considerable improvement in the aging properties [8]. Probably with the presence of an adsorbed layer, the positive ions from the avalanche transfer their charge to the adsorbed molecules by the penning process which plays a protective role. This may be due to the lower drift velocity of their positive ions or to refreshing of the adsorbed layer on the CsI substrate.

1.3 Other Photocathodes

As described above, an adsorbed layer of TMAE or DMFc, on the CsI substrate increase the quantum efficiency. We have checked this effect with small ionisation potential organometallic substances. Some of the results are presented in fig. 2. Although the quantum efficiency of these photocathodes is much smaller than CsI, but they are very stable in air. These substances practically di not change their quantum efficiencies after being exposed to air for over one year. Another important advantage of these substances is that the technology for covering the surface is very simple. See ref. [9] for the preparation of photocathodes from organometallic compounds. For all substances tested, an absorbed layer of TMAE increased their quantum efficiencies by factor of 2 to 10. A typical result for TMAE adsorbed layer is presented in fig.2 (curve5). After treatment, the photocathode remained stable in air for several hours.

2. Optimisation of the CGPM'S Gas Filling

Another important element of the CGPM is its filling gas. The light emission of the avalanche in the CGPM depends on the gas composition and ratio of electric field to pressure. By skillfully choosing these parameters, one can considerably reduce the photon feedback. As we mentioned before in the case of the CsI photocathode one of the best gas fillings was He plus 10 torr of CH^4. at a total pressure of 1 atm. At low pressures, optimisation of filling gas was studied in ref. [4]. One atmosphere operation of the CGPM is simpler than at low pressures and therefore may find wide range applications. A systematic study of different gas mixtures at a pressure of 1 atm is given in ref. [10]. The light emission of the avalanches from the CGPM was recorded by photosensitive wire chambers.

The photosensitive wire chamber had a CaF_2 window and was filled with a mixture of Ar and he plus TEA or TMAE vapurs at a total pressure of 1 atm. Other gases such as methane or ethane could also be introduced into the wire chamber. Typical results obtained for different mixtures in the CGPM are shown in fig.3. These results indicate that for all photocathodes the best choice of the filling gas is He plus a few tens of Torr of CH_4 or C_2H_6. In this case the CGPM can be operated at gains of about 10^6 and be sensitive to single photoelectrons.

3. Applications

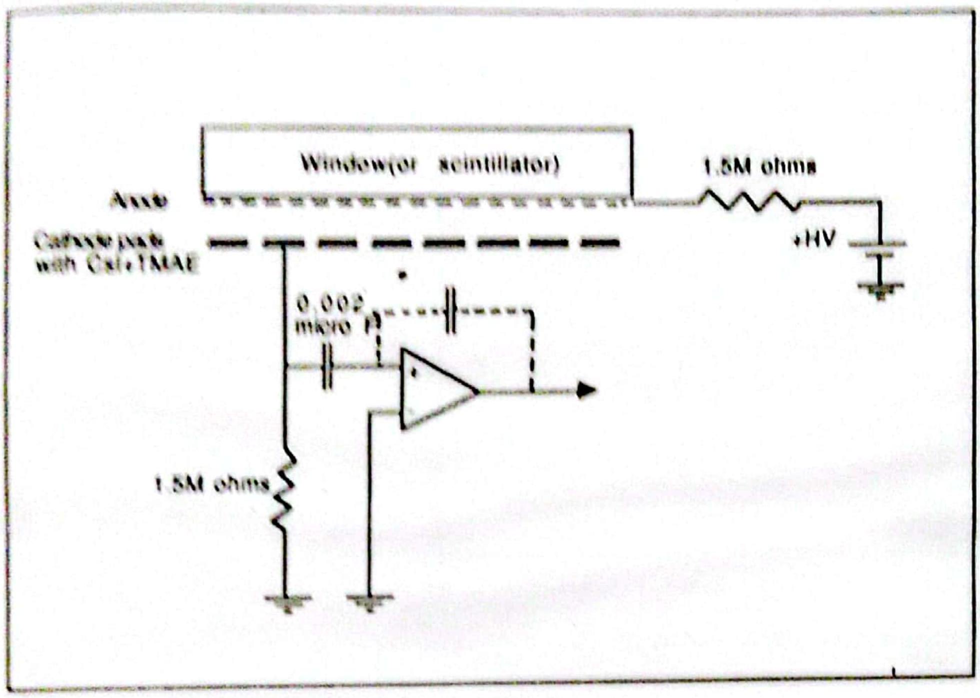
As we mentioned in the introduction, the CGPM can find a wide range of applications such as plasma diagnostics and astrophysics. In high energy physics they can be used for the readout of fast RICH detectors and crystal scintillators. RICH detectors based on the CGPM has now been developed by several groups [4,11]. In this section, we will concentrate on the application of the readout of the fast scintillation from BaF_2 crystal.

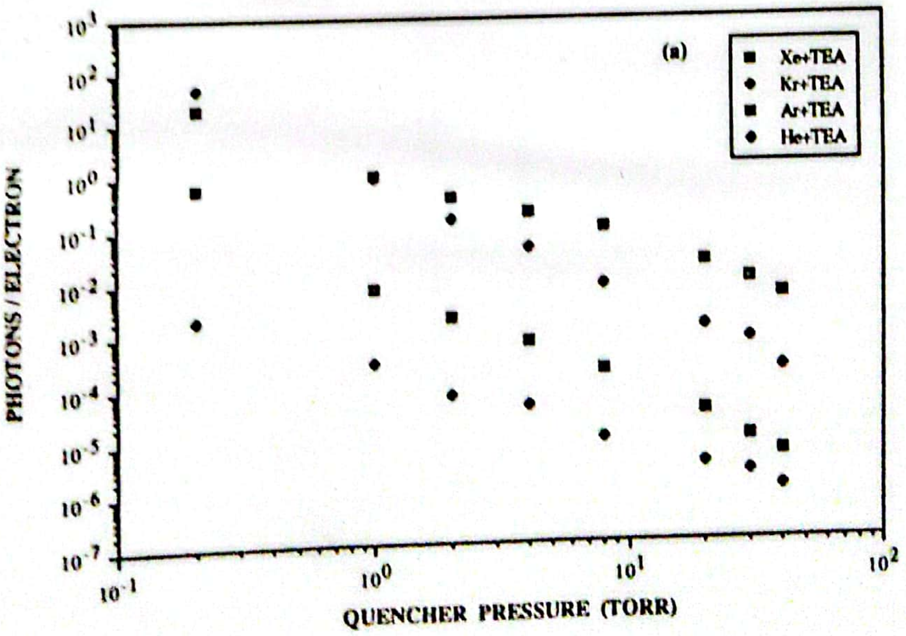
3.1 BaF_2

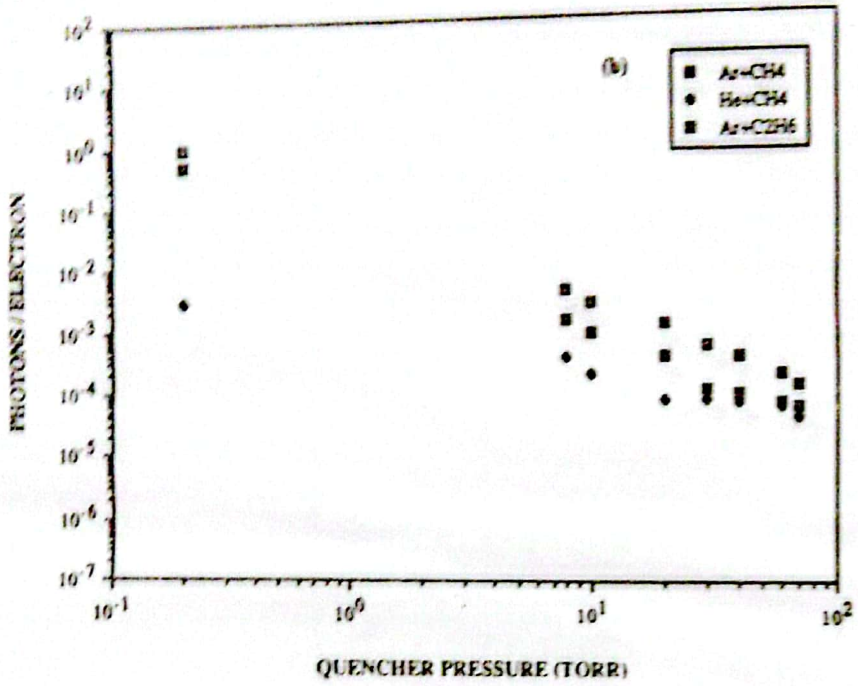
CGPMs with CsI photocathodes have been used for the readout of BaF_2 scintillators for a deposited energy in the crystal of a few GeV, and operated with moderate gains ($<10^4$) [12]. The energy resolution obtained at a gain of about 10^4 was about 7% $E^{1/2}$ (Gev). The energy resolution obtained with unity gain was about 3% $E^{3/2}$ (Gev) which is quite good. Possibly the ability to work at unity gain is important from the point of view of stability of calibration. No aging of the CsI photocathode was observed under there conditions for a collected charge of about 1 C/mm^2. This corresponds to tens of Gy deposited energy in the crystal.

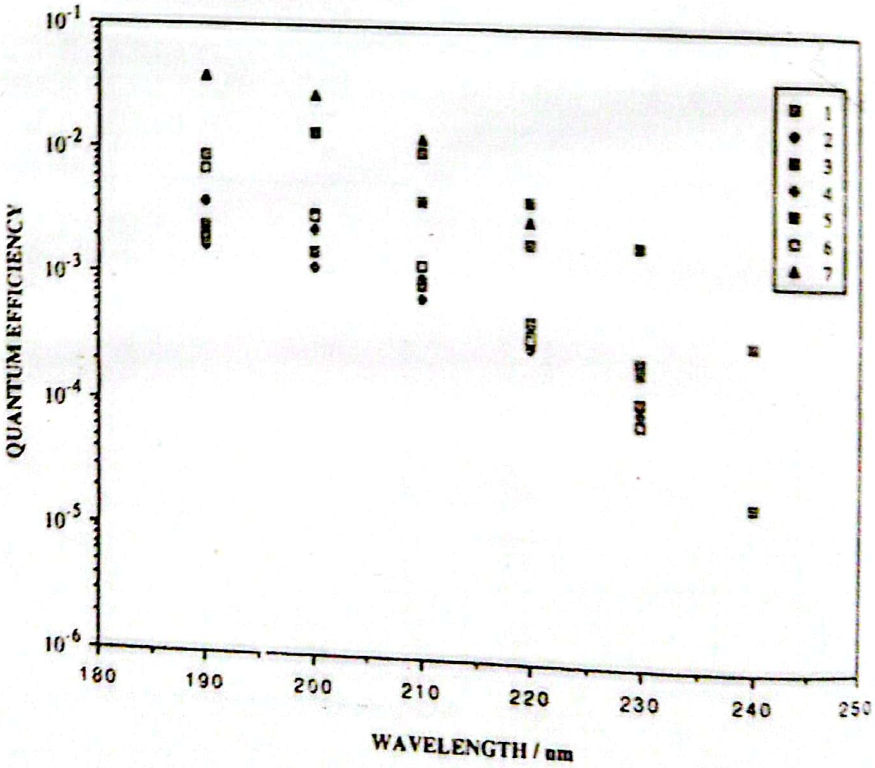
3.2 Preshower Detectors

preshower detectors in front of a calorimeter provides an improved e/π rejection [13] and may supply also information about the position of the electromagnetic shower. Estimations, based on the tests, show that a two radiation length thick BaF_2 slab, combined to the CGPM, could serve as a preshowerr detector. The main advantages of this type of preshower detector are the following: 1) it is radiation hard; 2) it can measure the position of the shower and the deposit energy; 3) in the case of BaF_2 calorimeter, following the BaF_2 preshower detector all system becomes homogeneous, which allows to reach better energy resolution.


Window(or scintillator)
Anode
Cathode pads with CsI+TMAE
1.5M ohms
+HV
0.002 micro F
1.5M ohms


(a)
■ Xe+TEA
● Kr+TEA
■ Ar+TEA
● He+TEA
PHOTONS / ELECTRON
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-1}
10^{0}
10^{1}
10^{2}
QUENCHER PRESSURE (TORR)


(b)
Ar+CH4
He+CH4
Ar+C2H6
PHOTONS / ELECTRON
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-1}
10^{0}
10^{1}
10^{2}
QUENCHER PRESSURE (TORR)


1
2
3
4
5
6
7
QUANTUM EFFICIENCY
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
180
190
200
210
220
230
240
250
WAVELENGTH / nm

Conclusion

CGPM have more efficiency in the VUV region than conventional PM. Additionally they have several other advantages:

1. They are coordinate sensitive;
2. They could be produced with large sensitive surfaces (few 100 cm2 in our case);
3. They have low noise;
4. They are not sensitive to magnetic fields, usually used in experiments, and
5. They are very simple, cheap and could be fabricated in the laboratory.

Figure Captions

1. Schematic of the CGPM.
2. Quantum efficiency of some organometallic photocathodes: (1) d,d–dimthil–trimethilen-ferrocenophane (2) trifenilphosfine gold-ferrocene; (3) 1,1–bis (trifen–ilphsfin-gold) etoksimethil–ferrocene; (4) bis (dimethilamino methilferrocenilen) –mercury; (5) decamethylferrocene; (6) dimethylaminoferrocene; (7) substrate No.2, covered by adsorbed layer of TMAE.
3. Dependence of the no. of photons, emitted from the CGPM (per electron in the avalanche), as function of its gas composition, measured in photosensitive wire chamber.

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