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ON THE IONIZATION SCINTILLATION CALORIMETER BASED ON $KMgF_3$ CRYSTAL

Protvino 1990

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Abstract

Buzulutskov A.F. On the Ionization Scintillation Calorimeter Based on $KMgF_3$ Crystal: IHEP Preprint 90-115. - Protvino, 1990. - p. 4, figs. 2, tables 2, refs.: 6.

The development of the ionization scintillation calorimeter, using $KMgF_3$-crystals and high efficiency photocathodes, is proposed. Some characteristics of such calorimeter are compared with those of the high pressure gas one.

Аннотация

Бузулуцков А.Ф. О возможности создания ионизационного сцинтилляционного калориметра на основе $KMgF_3$-кристалла: Препринт ИФВЭ 90-115. - 4 с., 2 рис., табл. 2, библиогр.: 6.

Рассматривается возможность создания ионизационного сцинтилляционного калориметра с использованием $KMgF_3$-кристаллов и высокоэффективных фотокатодов. Проводится сравнение характеристик такого калориметра на сжатом газе.

The idea of the ionization scintillation calorimeter relies on two recent achievements. The first one is the discovery of the fast (< 1 ns) scintillator $KMgF_3$, emitting in the vacuum ultraviolet (VUV) region/1,2/. The second one is the fact, that solid reflective photocathodes CsI and CsI + TMAE can have a very high quantum effeciency in the VUV region/3/. Fig.1 shows an emission spectrum of the $KMgF_3$ scintillator and quantum efficiencies of TEA vapours and CsI, CsI + TMAE photocathodes in the methane atmosphere.

The number of detected photoelectrons N_{pe} per 1 MeV of energy deposited in the scintillator is presented in table 1 for several scintillator/photocathode combinations, as well as the number of photoelectrons per one minimum ionizing particle, that passed through 1 cm scintillator, are presented. The data for $KMgF_3$/TEA and BaF_2/TMAE combinations are taken from refs./3/ and/4/ respectively, while the data for $KMgF_3$/TMAE,CsI,Cs + TMAE are obtained by multyplying together emission and photoionization spectra.

Table 1

Scintillator/ photocathode	$\frac{N_{pe}}{1\ MeV}$	$\frac{N_{pe}}{1\ cm}$
BaF_2/TEA vapour	10	66
$KMgF_3$/TMAE vapour	47	243
$KMgF_3$/TEA vapour	9	47
$KMgF_3$/CsI	40	206
$KMgF_3$/CsI + TMAE	60	314

It was proposed in papers/2,3/ to use sampling calorimeters, whose every layer consists of an absorber and a solid scintillation proportional chamber (SSPC) based on the $KMgF_3$ cristal and the gaseous TEA photocathode. As one can see from table 1, a replacement of the TEA vapour by CsI and CsI + TMAE photocathodes leads to 4÷7 times higher response of the chamber. This allows one to do without the gas amplification and to go from the proportional mode of the chamber operation to the ionization one, i.e. to use a solid scintillation ionization chamber (SSIC) instead of the SSPC.

Thus we are coming to the idea of the ionization scintillation calorimeter (ISC), a sampling scintillation calorimeter, in which the scintillation light is detected by photosensitive ionization chambers. Fig. 2 shows how the base layer of such a calorimeter can look like. It consists of an absorber, a $KMgF_3$ scintillator 1 cm thick and an ionization chamber with a CsI (or CsI + TMAE) photocathode. One can use either the wire anode, or the anode made from semitransparent conductive Ni-Cr film, deposited on the $KMgF_3$ crystal surface. On the opposite side of the crystal a reflective Al coating is deposited, increasing additionally the signal by the factor of 1.3 as compared with the values from table 1. The chamber is filled with the buffer gas CH_4 or CF_4 at atmospheric pressure, which acts only as a medium for the photoelectron cathode-to-anode transport (unlike the high pressure gas calorimeter).

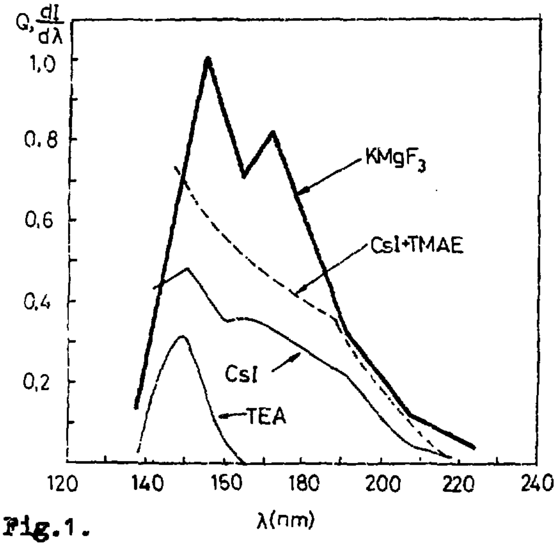

Fig.1.
dI/dλ - emission spectrum of $KMgF_3$-scintillator/1/. Q - quantum efficiencies in 1 atm methane of TEA vapours/6/, and of solid photocathodes CsI and Cs + TMAE/7/.

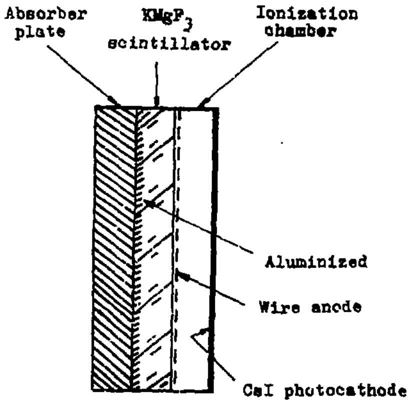

Fig.2.
A possible layer structure of the ionization scintillation calorimeter.

Let us compare the ISC with the high pressure gas calorimeter (HPC)/5/, an interest in which has resumed in connection with the proposals for experiments at super-high luminosity colliders. The results of the comparison are presented in table 2 for the most promising design of hadron calorimeters: the ISC with the SSIC structure of $KMgF_3$ (1 cm)/CsI, CsI + TMAE type and the HPC with the CF_4 gas at 20 atm pressure. Starting parameters are: the gap between the electrodes in the ionization chamber is d = 1mm; pad sizes are 10×10 cm^2; an equivalent noise charge per channel is $ENC = 10^4$ e. The following characteristics are compared: t_c - charge collection time in the chamber; N_e - equivalent number of electrons per track, detected in the ionisation chamber; $\Delta E_{noise} = ENC/(N_e \times N_{tr})$ - noise contribution to the energy resolution (FWHM), i.e. energy equivalent of the noise charge ($N_{tr} \sim 5$ - track number per 1 GeV of deposited energy); E_{th} - threshold energy, starting from which the niose contribution to the energy resolution does not dominate any longer (assuming the dependence $\sigma_E/E = 50\%/\sqrt{E\,(GeV)}$); U_c - chamber operational voltage. One can see, that when using a small gap, the ISC is an a par with the HPC in terms of energy resolution and rate capability, at the same time having advantagies of operating at atmospheric pressure and at low voltage.

Table 2

Calorimeter	t_c ns	N_e e/track	ΔE_{noise} GeV	E_{th} GeV	U_c kV
HPC 20 atm CF_4	10	~ 200	10	72	2
ISC $KMgF_3$(1 cm)/CsI	< 10	270	7.4	39	0.1
$KMgF_3$(1 cm)/CsI+TMAE		410	4.9	17	

Thus, we can make a conclusion, that at high energies (more than several tens of GeV) and at high rates ($\geq 10^8$ sec^{-1}) the ionization scintillation calorimeter, using the $KMgF_3$-scintillator and high efficiency photocathodes, can really compete with other types of calorimeters.

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