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A VERSION OF THE RADIATION-RESISTANT FAST CALORIMETER

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The forward hadron calorimeter of the Collider Detector at Fermilab (CDF) is composed of proportional tube chambers and steel sheets [1]. Forward calorimeters at SSC and other new colliders have to operate in zones with essentially higher radiation [2]. This causes wire coating, which results in loss of gas gain [3]. Naturally, it would be very attractive to use a unity gain readout technique. Such a technique may be based on using compressed gas and low-noise preamplifiers [4-7]. A version of the forward calorimeter with a 100 atm argon-methane mixture is considered in ref. [8]. There ionization tubes have a diameter of 4 mm and a wire diameter of 50 μm. They are placed at a small angle (~ 1°) to the incident particle direction. According to measurements of ref. [9], the charge collection time is 60 ns/mm. Though this version of the calorimeter is very attractive, it cannot distinguish events in two SSC beam bunches following one another in 15 ns.

Proportional chambers with a CF_4/isobutane gas mixture [10] at the normal pressure with a small distance between cathode and anode places are much faster. The new technology [11] allows a high degree of accuracy in positioning the planes with the gap of 1.5 mm and anode wire spacing of 1 mm. Such a chamber with a sensitive area of 55x60 cm^2 and anode wires 30 μm in diameter was constructed and investigated. With the radioactive source ^{90}Sr a time jitter was FWHM = 6 ns. For a time interval of 15 ns an efficiency was 98% in the 2700 ÷ 3150 voltage interval. It has been shown that the utilization of a thick anode wire (of diameter 30 μm) in a narrow-gap chamber creates, at the time of the discharge, a "quasiuniform" electric field, in which the discharge proceeds via a sole stage, owing to ionization by electron impact [12]. This is related, first, to the average value of E/p in the gap of such a chamber being by about an order of magnitude higher, than in standard chambers. Secondly, the utilized gas mixture (80 CF_4 + 20 i - C_4H_{10}) totally excludes development of the gas discharge based on a photon mechanism. The above circumstance makes more preferable the use of narrow-gap chambers with small steps between the thick sense wires for ionization measurements. All technological operations are developed enough to construct larger chambers. Below we consider a 1.2x X1.2 m chamber with wires 0.1 mm in diameter (D).

Wire coating depends on a charge q collected on a wire unity surface. A value of q is proportional to M = Kd/ND, where K is the gas gain, d is the gas density, N is the number of wires in a certain volume. It is possible to have M even smaller than for the calorimeter with ion tubes at high pressure (in ref.8).

Figure 1 shows a schematic view of two modules of the calorimeter with proportional chambers. Steel plates 1 are used as a basis for fixing chamber electrodes 9, 10, 11. A plate is 2 cm thick and the distance between the cathode planes 9-1 and 9-2 is 6 mm. The cathode planes are made of mylar with a conductive carbon surface. Mylar surrounds the plate 1 and is located over the rods 3. The rod 4 presses mylar to the plate by means of screws. It results in stretching the cathodes. It´s necessary to note that the diameter of the rods 4 together with the double mylar thickness is exactly equal to the distance between the rods 3. But this diameter in fig.1 is smaller than the real one to make the cathode 9-1 fixing easy to grasp.

A relative disposition of the cathode and anode planes is adjusted by means of the calibrated rods 3, 6, 7, the distributing plates 5 and 8 and the guiding calibrated rods 2 (2 mm in diameter). The latter are stretched and attached to the plate 1 with compound "Durmetal AG". The copper-wire spiral with the enamel covering is wound on the rod 6. This wire 1 mm in diameter determines the anode wire spacing. An anode wire is wound on the rod 6 by rotating the module around the axis which passes through its center perpendicular to the plane shown in fig.1. The second cathode 11 has a conductive carbon surface on both sides. It is stretched by means of screws to the movable holder 12, which is attached to the slat 13. After the cathode is stretched, one installs the distributing plate 8. Then the rod 7 together with the cathode are pressed to a side of this plate. In the course of assembly a gap between the cathode 11 and the anode plane 10-2 is determined by a template on the edges of the anode rods 6 by regulating screw rests 14.

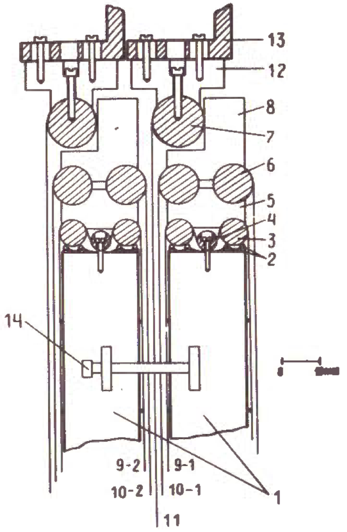

Fig.1. Schematic view of two modules of the calorimeter section.

An assembly of 9 steel sheets and 8 sensitive 6 mm gas layers between them is one section for the calorimeter. There are additional thin insensitive gas layers between the first cathodes and the sheets. Their thickness is 1 mm at one edge and ~ 2.2 mm at the other edge. This increase is provided by using screws 3 of larger diameter at this edge. It results in some widening of one side of the section (from 26 cm to 28 cm).

Figure 2 shows a schematic view of the calorimeter composed of these sections (I-V). Installed as far as 10 m from the interaction point it covers a pseudorapidity region of $3 \leq \eta \leq 5$. The calorimeter consists of two almost identical parts to measure energies $E \lesssim 5$ TeV. The first one absorbs hadrons with $E \lesssim 200$ GeV. We shall discuss only it below.

This calorimeter has 16 sections. Only 5 of them are shown in fig.2. There are small angles α between the shower axis and the nearest wires. In the central horizontal plain A $\alpha \simeq 1.5°$. The total hadronic shower width is 25 ÷30 cm. Minimum ionization losses of relativistic particels are 11 MeV/cm in steel and ~ 5 keV/cm in CF_4/isobutane.

Taking into account the total thicknesses of the sensitive gas layers and steel in one section, one can find a relation of ionization losses in them to be equal to $1.2 \cdot 10^{-4}$.

Let´s assume that only half of the particle energy E is observed in our sampling device. In this case $2 \cdot 10^3$ electron-ion pairs are expected for $\Delta E = 1$ GeV in a shower.

The chamber wires make up lines with an impedance of $\rho =$ = 150 Ohm. One will need transmission lines to take electronics out of the high radiation zone. (If the lines are long, low attenuation in them can be obtained by cooling [13]). Each line must have the same value of ρ and be connected to preamplifier through a resistor of value ρ too. The preamplifier can serve as a fan-in, if its layout impedance is much smaller than ρ.

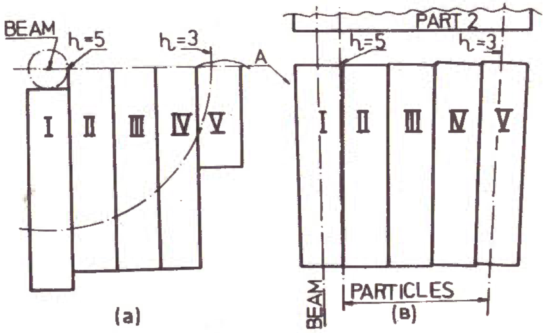

Fig.2. Schematic view of one quater of the calorimeter: (a) is the face side, (b) is the view in the central horizontal plain A. I-V are separate sections consisting of proportional chambers and sheets directed along the beam.

Such a circuit is shown in fig.3. A load of n lines for the preamplifier is $R = 2\ \rho/n$. The lower R the higher is the noise which was measured with signals 5 ns long. The Table shows the result of the measurements.

Table. Output pulse height U and r.m.s. noise σ versus R

R |Ohm|		50.0	25.0	19.0	8.0	3.7	1.6
U %		100	99	95	85	74	63
σ |nA|	170	450	500	750	900	1200	1500

The last case corresponds to 180 lines with $\rho = 150$ Ohm. Here the noise is $\sigma = \sigma(Q) = \sigma\ |A| \cdot \Delta t\ |s|/e = 4.6 \cdot 10^4$ electrons. Of course the lines should be carefully screened against outside electromagnetic noises.

Wires can be connected in series to decrease the number of outputs from the chamber. It only increases the dispersion of the signal spreading time along the chamber wires, but not σ |nA|. We connect only two neighbouring wires. Taking into account a real signal duration one can expect $\sigma \simeq 10^5$ e. About 20 fan-ins will measure the total energy E of a shower. Hence the total noise $\sigma_t = \sqrt{20}\ \sigma = 4.5 \cdot 10^3$ e. A number of electrons in a signal is $Q = 2 \cdot 10^3 K\ E$. Let $\sigma_t = Q$ if $E = 1$ GeV. Hence $K = 220$.

In fact one should take $K = f(\eta)$ because the more η the more E and the background. One can have $K < 220$ provided that noise will not be more than the sampling, path length, Landau fluctuations. It´s possible to measure K constantly by means of α-particles of ^{228}To with E = 8.78 MeV. This source can be placed on a steel surface. The energy absorbed in the sensitive gas layer will be about 3 MeV.

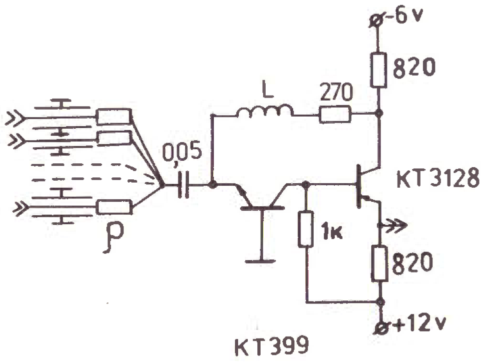

Fig.3. Fan-in, L is 3 winds of 2.5 mm in diameter on a ferromagnetic circle.

This calorimeter has M-factor smaller by three orders of magnitude than that in ref. [1]. It is not more than for the version with ionization tubes at 100 atm in ref.[8].

It seems problematic to use the fast CF_4/isobutane mixture at pressure .

near 100 atm because of too high voltage. It will result in high leakage current and the corresponding noise which can be much more than the electronics noise. Besides that CF_4 is very expensive. But wire aging with CF_4/isobutane is less than with the argon mixture by an order of magnitude [14]. For low aging it is important to have a gas flow. Naturally, the normal pressure is the best condition for it.

Summarizing the factors discussed above we expect radiation hardness of the calorimeter considered to be comparable with that using ionization tubes at high pressure (> 100 Mrad in ref. [8]). The main advantage of the version with proportional chambers with very narrow gaps and signal-wire spacing is fastness. This is very important at high luminosities when pileup can become the main source of pulse heights fluctuations at energy measurements.

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Акимов Ю.К., Залиханов Б.Ж. E13-92-239
Вариант радиационно-стойкого
быстрого калориметра

Предложен новый подход к конструированию переднего адронного калориметра. Он основан на использовании быстрых пропорциональных камер и удаленных предусилителей, которые действуют также как смесители. Сигнальные проволоки камер направлены вдоль пучка, и большое их число подсоединено к одному смесителю, чтобы уменьшить газовое усиление.

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Akimov Yu.K., Zalikhanov B.G. E13-92-239
A Version of the Radiation-Resistant
Fast Calorimeter

A new approach to designing of a forward hadron calorimeter is described. It is based on using fast proportional chambers and remote preamplifiers, which also serve as fan-ins. Signal wires of the chambers are directed along a beam, and a large number of them are connected to one fan-in to decrease the gas gain.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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