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IHEP 96-74

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USE OF HEAVY FREONS
IN GAS IONIZATION CALORIMETRY



SW9704

Submitted to *PTE*

Protvino 1996

Abstract

Denisov S.P. et al. Use of Heavy Freons in Gas Ionization Calorimetry: IHEP Preprint 96-74. - Protvino, 1996. - p. 6, figs. 6, refs.: 10.

The results of the first study of a gas ionization calorimeter filled with heavy freon C_3F_8 are reported. C_3F_8 is fast gas. Its density is 4.4 times higher than that of the 90%Ar + 10%CF₄ mixture previously used. The dependence of the calorimeter response on C_3F_8 pressure is presented.

Аннотация

Денисов С.П. и др. Использование тяжелых фреонов в газовой ионизационной калориметрии: Препринт ИФВЭ 96-74. - Протвино, 1996. - 6 с., 6 рис., библиогр.: 10.

Представлены результаты первых исследований газового ионизационного электромагнитного калориметра с C_3F_8 в качестве рабочего газа. C_3F_8 - "быстрый" газ. Плотность C_3F_8 в 4,4 раза превосходит плотность газовой смеси 90%Ar + 10%CF₄, которая использовалась в предыдущих исследованиях. Приведены зависимости характеристик калориметра от давления газа, напряжения на электродах и ширины строба АЦП.

During the last 4 years extensive developments in gas ionization calorimetry have been made [1–8]. In particular it has been shown that hadron gas ionization calorimeters with a planar electrode geometry filled with 90%*Ar* + 10%*CF*₄ gas mixture have a number of important advantages like good energy and time resolutions, high uniformity and stability, fine granularity, simple calibration, high intrinsic radiation resistance and low cost [5–7]. The only disadvantage of these calorimeters is a high gas pressure necessary to reach a low enough level of signal to noise ratio. One possible way to reduce the pressure is to use gases with higher densities.

In this paper the results of the first study of a gas ionization calorimeter filled with heavy freon *C*₃*F*₈ are reported. There are several reasons for the choice of *C*₃*F*₈:

- Its density is 4.4 times higher than the density of the 90%*Ar* + 10%*CF*₄ mixture previously used [5–7],
- *C*₃*F*₈ is fast gas; its electron drift velocity is close to that for 90%*Ar* + 10%*CF*₄ mixture and pure *CF*₄,
- *C*₃*F*₈ is nontoxic and nonflammable.

Its saturated density and pressure at $t = 20^\circ C$ are 0.0759 *g/cm*³ and 7.57 *atm*.

1. Calorimeter

The calorimeter tested consists of a stack of 12 ionization chambers interleaved with a 30 *mm* thick steel absorbers (fig.1). Signal pads of 1 *mm* steel were placed between the absorbers forming two 3 *mm* drift gaps. There are 4 × 4 pads in the signal plane. Pad size is 76 × 76 *mm*². The total calorimeter thickness is 21 *X*₀. The average *X*₀ is 2.1 *cm* and the Moliere radius is 1.5 *cm*.

Six consecutive pads were connected to each other forming two sections in each longitudinal tower. The absorbers were grounded and *HV* was applied to signal electrodes. The ratio of *HV* to *C*₃*F*₈ pressure was 830 *V/atm* which gives the electron drift velocity of 0.07 *mm/ns* [9]. For comparison, a gas mixture of 90%*Ar* + 10%*CF*₄ was also used at $HV/P \approx 185 \text{ V/atm}$ ($v_d \approx 0.1 \text{ mm/ns}$) [10]. The calorimeter was designed to operate at pressure up to 16 *atm*.

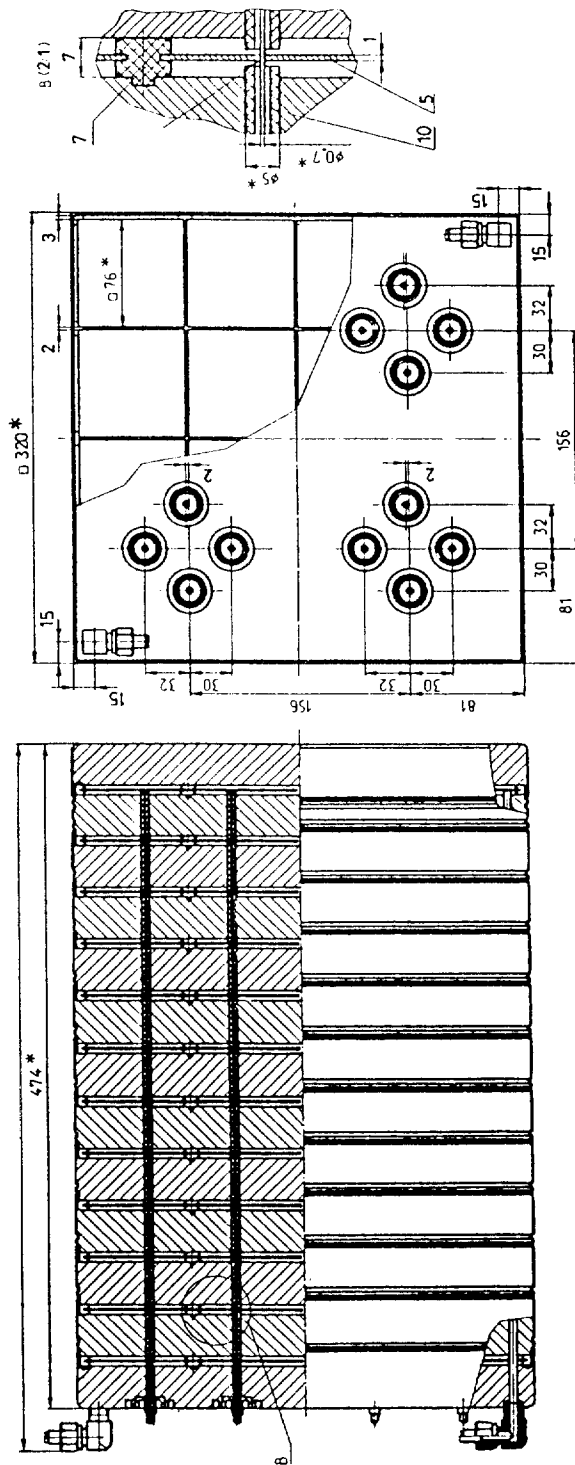


Fig. 1. The calorimeter design.

Signals from each section were connected to low noise amplifiers and then to ADCs. ADC gates of 30, 59, 100 and 145 ns were used. A dependence of the noise level for one tower on the gate width is shown in fig.2. The *RMS* of noise distribution for all 16 towers at $t_g = 59$ ns is equal to 80 ke which is to be expected for uncorrelated noise.

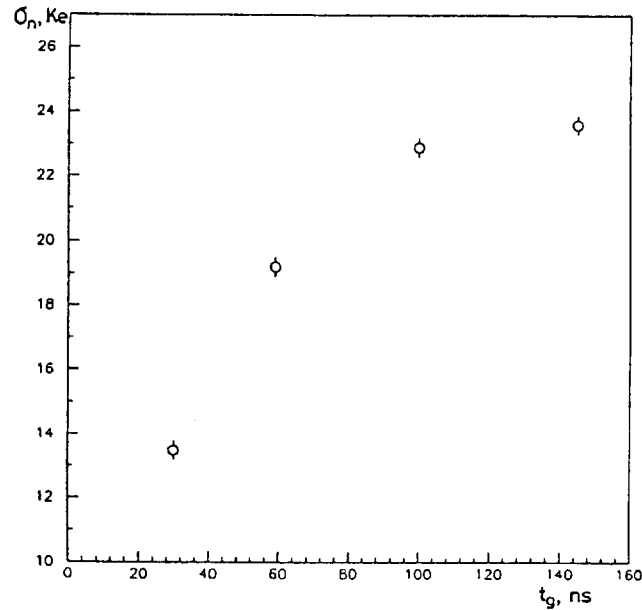


Fig. 2. The *RMS* of noise distribution for one tower vs gate width.

2. Measurements and results

Measurements were performed with a 26.6 GeV/c electron beam at the 70 GeV IHEP accelerator. The beam momentum spread was about 3% and hadron and muon contamination was less than 4%. Five scintillation counters placed along the beam line were used to measure an electron flux. The last counter of ϕ 2 cm was positioned in front of the calorimeter at the center of one of the towers. An anticoincidence counter with ϕ 3 cm hole was used to reject the background from beam halo.

The studies consisted in measuring a pulse height spectra at different values of *HV*, *ADC* gate width and gas pressure. The gate delay was set at the signal maximum. Noise and calibration measurements were taken periodically.

The events satisfying the following criteria were selected for the analysis:

- signals in any tower around the tower hit by beam electrons (beam tower) had to be less than 10% of the signal in the beam tower,
- signals in the forward section of the beam tower had to be higher than the signals in the backward one and the noise signal.

These criteria allow one to reject the events connected with muons, hadrons and beam halo.

In average more than 98% of the selected events energy was released in the beam tower. As most of the signals in the other channels were lower than noise, only beam tower signals were used in the data analysis.

A typical distribution of noise and *EM* shower pulse heights are presented in fig.3. All the spectra measured were fitted well by a Gaussian.

The dependencies of average pulse height (*A*) on gas pressure (*P*) and *HV* are shown in fig.4 and 5. From fig.5 it follows that for the 90%*Ar* + 10%*CF*₄ gas mixture *A* is proportional to *P* up to 11 *atm* while for *C*₃*F*₈ *A* approaches plateau at pressures above 4 *atm*. The nonlinearity of *A* vs *P* (*C*₃*F*₈) can be explained either by electronegativity of *C*₃*F*₈ itself or by electronegativity of contaminations in *C*₃*F*₈. Fig.6 demonstrates that the energy resolution (after noise subtraction) does not depend on the *C*₃*F*₈ pressure in the range from 2 to 6.5 *atm*.

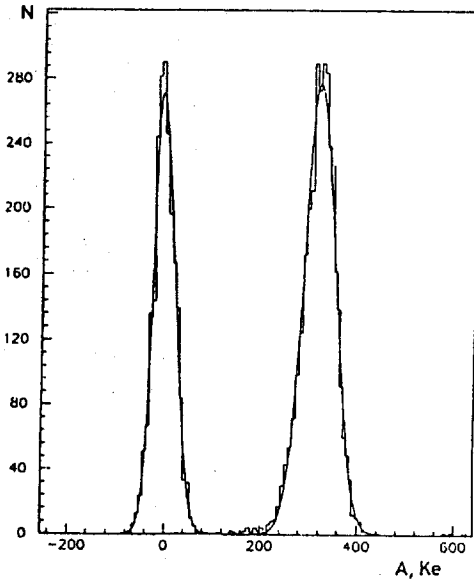


Fig. 3. Noise and signal spectra measured at $t_g = 100 \text{ ns}$ and C_3F_8 pressure of 6 *atm*.

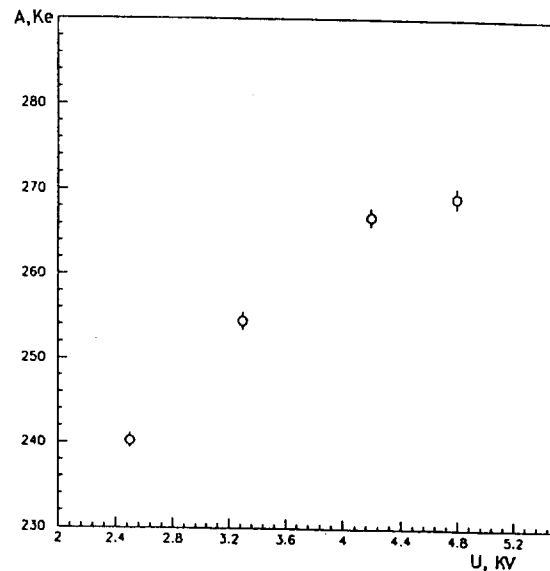


Fig. 4. The average pulse height vs *HV*; $t_g = 100 \text{ ns}$, $P_{C_3F_8} = 6 \text{ atm}$.

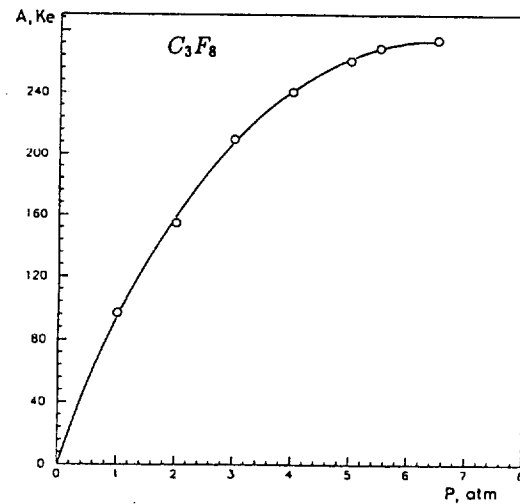
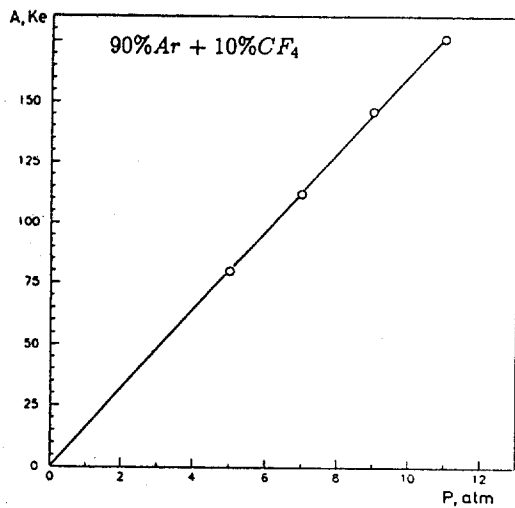


Fig. 5. The average pulse height as a function of 90%*Ar* + 10%*CF*₄ ($t_g = 30 \text{ ns}$) and *C*₃*F*₈ ($t_g = 59 \text{ ns}$) pressure.

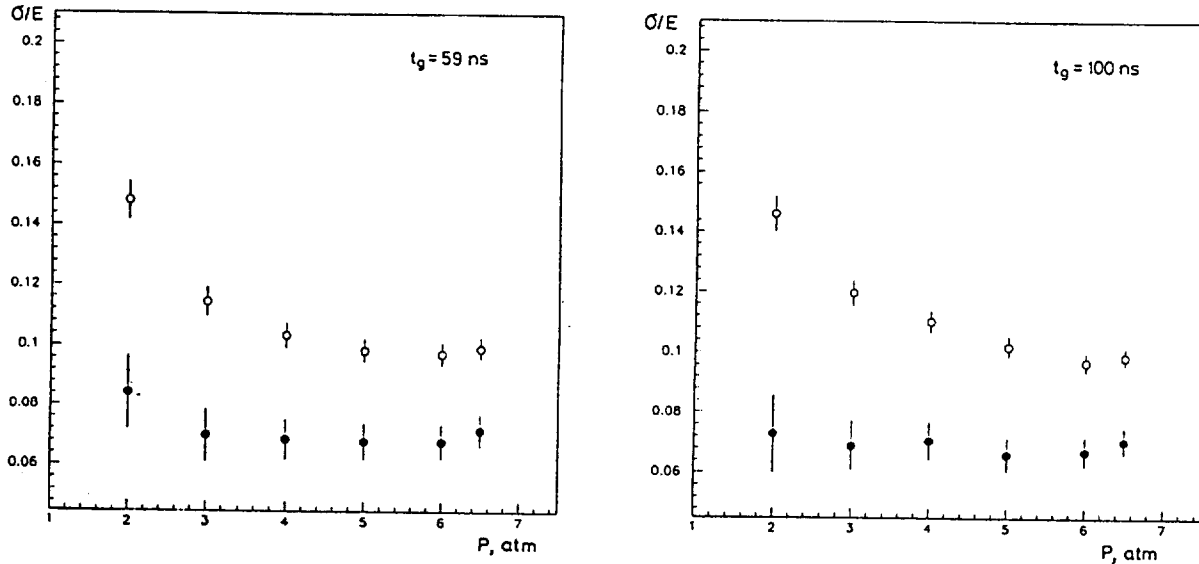


Fig. 6. The dependence of the energy resolution on C_3F_8 pressure with (●) and without (○) noise subtraction for $t_g = 59 ns$ and $100 ns$.

Conclusions

The first study of a gas ionization calorimeter filled with heavy freon C_3F_8 has been performed. The equivalent noise energy is equal to 2 GeV per tower at 4 atm of C_3F_8 pressure. The stochastic part of energy resolution is independent of gas pressure in the range from 2 to 6.5 atm. We plan to study the origin of the signal saturation at the C_3F_8 pressure above 4 atm.

A detailed study of the gas ionization calorimetry performed during the last few years shows that this technique can play an important role in future experiments of high energy physics.

Acknowledgements

We wish to thank I.Belyakov, V.Kostyuchenkov, O.Romashov and V.Volkov for their help in calorimeter assembling and testing. This work was partially supported by Russian Fund for Basic Research (grant $N^{\circ}96 - 02 - 16856a$).

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Received September 5, 1996

С.П.Денисов и др.

Использование тяжелых фреонов в газовой ионизационной калориметрии.

Оригинал-макет подготовлен с помощью системы L^AT_EX.

Редактор Е.Н.Горина.

Технический редактор Н.В.Орлова.

Подписано к печати 06.09.96. Формат 60 × 84/8. Офсетная печать.

Печ.л. 0.87. Уч.-изд.л. 0.67. Тираж 240. Заказ 771. Индекс 3649.

ЛР №020498 06.04.92.

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142284, Протвино Московской обл.

Индекс 3649

ПРЕПРИНТ 96-74, ИФВЭ, 1996
