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of the Russian Academy of Sciences

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The Methods for Direct Detection of WIMP with Mass ≤ 0.5 GeV/c^2

The chamber for direct detection of WIMP with mass ≤ 0.5 Gev/c^2 was developed. The chamber is filled with gas mixture Ne+10%H_2 (0-1bar) +0,15ppm $Ge(CH_3)_4$. For events detection used GEM+pin-anodes, which provides the energy threshold about eV. The electron background is suppressed owing to photosensitive addition $Ge(CH_3)_4$. It is proposed also for direct detection of WIMP the liquid argon chamber with H_2 dissolved in liquid argon at a concentration 100ppm+0,015ppm $Ge(CH_3)_4$.

Keywords: Search the low mass WIMP, metallic GEM+pin-anodes, the energy threshold about eV.

Б.М. Овчинников, И.И. Ткачев, В.В. Парусов

Методы прямого детектирования WIMP с массой ≤ 0.5 ГэВ/c^2

Создана камера для прямого детектирования WIMP с массой ≤0.5 ГэВ/c^2. Камера заполняется газовой смесью Ne+10%H_2 (0-1bar)+0,15ppm $Ge(CH_3)_4$. Для детектирования событий используется система GEM+аноды-острия, которая обеспечивает энергетический порог в несколько эВ. Фон электронов подавляется фоточувствительной добавкой $Ge(CH_3)_4$. Такие предложения детектировать WIMP малой массы жидкоаргоновой камерой с растворенным в аргоне водородом с концентрацией 100ppm+0,015ppm.

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1. Introduction

The measurement of cross section of WIMP scattering on proton is necessary to clear up the dark matter nature[1, 2].

Astronomical observation give strong evidence for existence of nonluminous and non-barionic matter, presumably composed of a new type of elementary particles. The detectors with pure NaI[3] , Xe or Ar allow to search the WIMP with large mass (of dozens or hundreds GeV), because the energy of nuclear recoils in these detectors from low mass WIMP are low. The experiments with nobles gases are shown in Table1. To account for yearly modulation effect in DAMA-LIBRA experiment [3] J.Va'vra [4] have supposed that this effect is explained by low mass WIMP scattering on protons in H_2O molecules which contamination about 1ppm in NaI crystals.

2. Spherical proportional detector

The spherical proportional detector was developed for search the low mass WIMP [5].

This detector was filled with H_2 or Ne and has the energy threshold about 100 eV.

3. Double-phase argon chamber

The double-phase argon chamber with mass up to 10^4 tons was proposed for WIMP detection in our work [6]. For electron background suppression was proposed the photosensitive addition Ge $(CH_3)_4$ [7].

For detecting events in gas-phase was developed the system metallic GEM[8]+ pin –anode with 10% H_2 addition and $K_{ampl}=5\cdot10^7$ [9]. The concentration H_2 in liquid Ar is equal about 100 ppm, this allows to detect the low mass WIMP (≤0.5GeV) also because the concentration H_2 is 100 time more then in [3].

By comparing the work[5] ,where the energy threshold is equal ~100 eV ,with amplification factor of detecting system~10^4,we can to estimate the threshold of our experiment as 100 eV $\cdot10^4/5\cdot10^7$ ~1eV.

4. The chamber with Ne+10%H2(0-1bar) filling

On Fig. 1 is shown the system GEM+ pin-anode, which is used for events detecting in this chamber and in double-phase argon chamber. The fronts of signal in this system is equal ≤3 μsec. The detecting of front allows to measure the event dimension in z-direction for electron background suppression [5].

For purification of gases are used the methods with Ni/SiO_2 adsorbents[10].

The addition in chamber of Ge $(CH_3)_4$ allows to suppress the electron background (gamma-background , Ar^{39} and tritium decays).

On Fig. 2 the dependence of $K_{ampl.}$ on potential difference between the pin-anode and GEM is shown .The use in chamber of spectrometric amplifier allows to obtain the energy threshold about eV. This energy threshold allows to search the WIMP with mass ≤0.5 GeV/c^2 (see table2).Double-phase Ar chamber or the chamber with Ne+10% H_2 filling are placed in low background laboratory in low background shielding for search the yearly or daily modulation effects.

The double-phase argon chamber and chamber with Ne-filling allow to search the axions, emited from the sun.

The chamber with Ne+10% H_2 filling is shown on Fig.3.

The chamber consists of titanium body 1,of detecting system (metallic GEM 4 +36 pin-anodes 5),of wire cathode 2, winded with 0.1 mm in diameter of beryllium bronze wires. The negative voltage on cathode with respect to chamber body suppress the background from cathode. The electrodes 3, produced from pure copper ,forms in volume of the chamber the electric field.

For improvement sensitivity of chamber to low mass WIMP it is necessary to add in Ne-filling of the chamber the 1ppm TMAE (tetrakis dimethylamino ethylene) [7], which has the low ionization potential 5.36eV.When the recoil proton

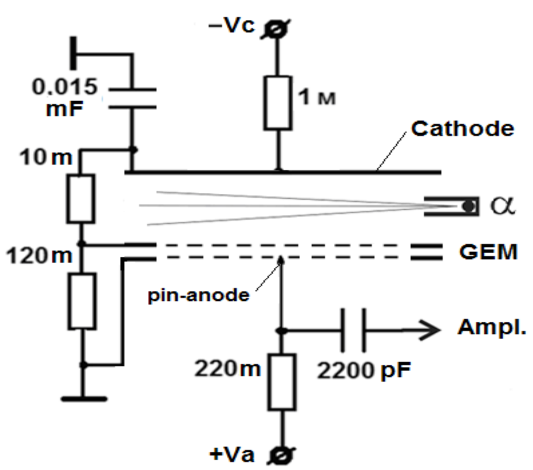

Figure 1. GEM+pin-anode

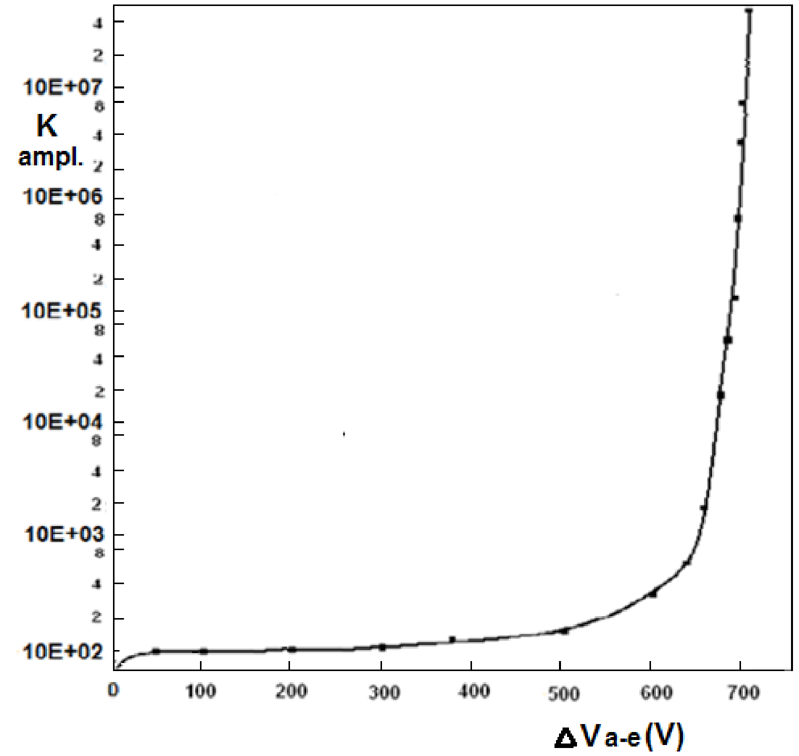

Figure 2. The dependence of $K_{ampl.}$ on potential difference between the pin-anode and GEM. $K_{ampl} = Q_{ampl}/Q_{ioniz}$, where Q_{ampl} — the charge detected, Q_{ioniz} — the ionization charge

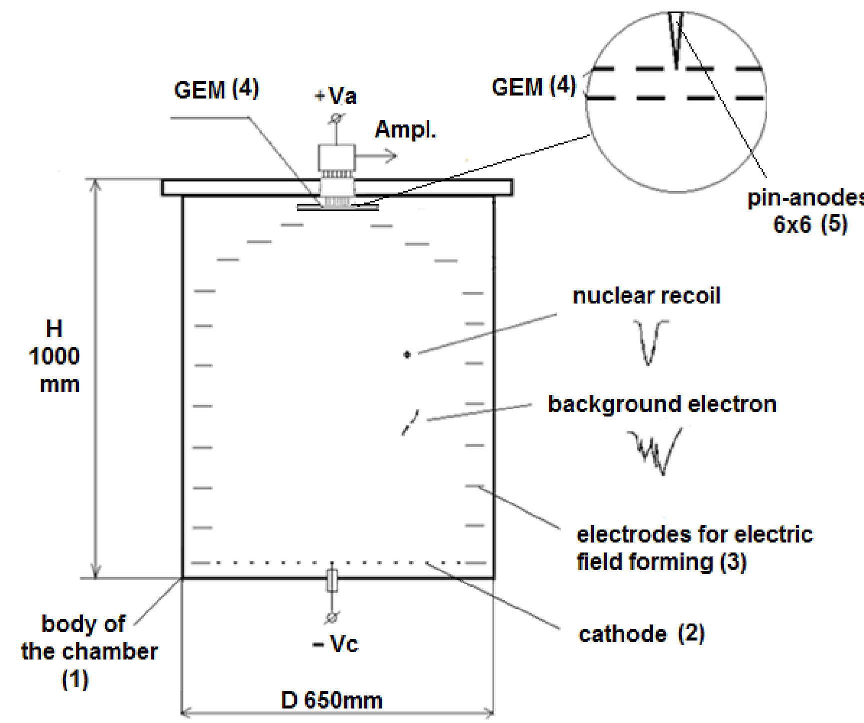

Figure 3. The chamber with Ne+10%H_2 filling

come into collision with TMAE molecule ,the molecule TMAE is ionized and the signal from low mass WIMP is increased.

5. Conclusion

The method of H_2 addition in liquid Ar and method of event detecting , proposed in this paper, allow to search the low mass WIMP in all experiments with Ar chamber.

Table 1.The detectors for direct DM searches

The name of project	The target of detector	The detection method	The threshold of detection	The method for background suppression	Ar^{39} concentration in Ar	The expected result
“ArDM” A.Rubbia [11]	Ar 1000(850) kg double-phase	S_2/S_1+F PMT+GEM	E_{nr}^{min}=30 кэВ	S_2/S_1+F^*	10^2 decays/t·s	σ(WIMP) =10^{-45}cm^2
“MiniClean” Los Alamos [12]	Ar liquid 500(150)kg single-phase	F 92 PMT	E_{nr}^{min}=30 кэВ M^{min}(WIMP) =20 GeV	F	10^3 decay/t·s	10^{-45}см^2
“Deap-3600” Los Alamos [12]	Ar liquid 3600(1000)kg single-phase	F 266 PMT		F	10^3 decays/t·s	10^{-46} cm^2
“Clean” Los Alamos [12]	Ar liquid 40(10)tons single-phase	F PMT	M^{min}(WIMP) =60 GeV	F	<10^2 decays/t·s	6×10^{-47} cm^2
“Darvin” [13]	Ar 20(10)tons double-phase	S_2/S_1+F avalanche photodiodes +GEM	E_{nr}^{min} =30 кэВ	S_2/S_1+F К suppression=10^8	<40 mBq/kg	4×10^{-48} cm^2
	Xe 8(5)tons double-phase	F+S_2/S_1 avalanche photodiodes +GEM	E_{nr}^{min} =10 кэВ	F+S_2/S_1	Background 10^{-4} decays/ kg·day·keV	
Los Angeles Dr.D.Cline [14] (proposal)	Ar 580(500) tons double-phase	S_2/S_1 12000 avalanche Photodiodes	M^{min}(WIMP) ≅20GeV	S_2/S_1+F	<10 decays/t·s	10^{-48} cm^2
	Xe 146(100)tons double-phase	S_2/S_1+F 3740 avalanche Photodiodes	M^{min}(WIMP) ≅6 GeV	S_2/S_1+F К=10^3		

*For suppression of the electron background in some works (Table1) the criterion F used: $F= I_s/I_s+I_t$,

I_s — singlet intensities, I_t— triplet intensities. S_1 — scintillation signal, S_2— ionization signal.

Table 2.Maximum calculated nuclear recoil energy E_{keVnr} as a function of WIMP mass, for 3 targets: hydrogen Na,Ne[3]

WIMP mass [GeV/c^2]	Nucleus	EkeVnr [keV]
0.5	H	1.91
1.0	H	4.30
1.5	H	6.20
2.0	H	7.65
2.5	H	8.78
3.0	H	9.68
0.5	*Na*	0.19
1.0	*Na*	0.73
1.5	*Na*	1.57
4.0	*Na*	9.07

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