PROCEEDINGS OF SCIENCE

The CYGNO experiment

F.D. Amaro,[a] R. Antonietti,[b,c] E. Baracchini,[d,e] L. Benussi,[f] S. Bianco,[f] C. Capoccia,[f] M. Caponero,[f,g] D.S. Cardoso,[h] G. Cavoto,[i,j] I.A. Costa,[b,c] G. D'Imperio,[j] E. Dané,[f] G. Dho,[d,e] F. Di Giambattista,[d,e] E. Di Marco,[j] F. Iacoangeli,[j] E. Kemp,[k] H.P. Lima Júnior,[h] G.S.P. Lopes,[l] G. Maccarrone,[f] R.D.P. Mano,[a] R.R. Marcelo Gregorio,[m] D.J.G. Marques,[d,e] G. Mazzitelli,[f] A.G. McLean,[m] A. Messina,[i,j] C.M.B. Monteiro,[a] R.A. Nobrega,[l] I.F. Pains,[l] E. Paoletti,[f] L. Passamonti,[f] S. Pelosi,[j] F. Petrucci,[b,c] S. Piacentini,[i,j] D. Piccolo,[f] D. Pierluigi,[f] D. Pinci,[j] A. Prajapati,[d,e] F. Renga,[j] R.J.d.C. Roque,[a] F. Rosatelli,[f] A. Russo,[f] G. Saviano,[f,n] N.J.C. Spooner,[m] R. Tesauro,[f] S. Tomassini,[f] S. Torelli[d,e] and J.M.F. dos Santos[a]

[a] *LIBPhys, Department of Physics, University of Coimbra, 3004-516 Coimbra, Portugal*
[b] *Dipartimento di Matematica e Fisica, Università Roma TRE, 00146, Roma, Italy*
[c] *Istituto Nazionale di Fisica Nucleare, Sezione di Roma Tre, 00146, Rome, Italy*
[d] *Gran Sasso Science Institute, 67100, L'Aquila, Italy*
[e] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Gran Sasso, 67100, Assergi, Italy*
[f] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, 00044, Frascati, Italy*
[g] *ENEA Centro Ricerche Frascati, 00044, Frascati, Italy*
[h] *Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro 22290-180, RJ, Brazil*
[i] *Dipartimento di Fisica, Università La Sapienza di Roma, 00185, Roma, Italy*
[j] *Istituto Nazionale di Fisica Nucleare, Sezione di Roma, 00185, Rome, Italy*
[k] *Universidade Estadual de Campinas, Barão Geraldo, Campinas 13083-970, SP, Brazil*
[l] *Universidade Federal de Juiz de Fora, Faculdade de Engenharia, 36036-900, Juiz de Fora, MG, Brasil*
[m] *Department of Physics and Astronomy, University of Sheffield, Sheffield, S3 7RH, UK*
[n] *Dipartimento di Ingegneria Chimica, Materiali e Ambiente, Sapienza Università di Roma, 00185, Roma, Italy*

E-mail: rita.antonietti@uniroma3.it

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Innovative experimental techniques are needed to further search for dark matter weakly interacting massive particles. The ultimate limit is represented by the ability to efficiently reconstruct and identify nuclear and electronic recoil events at the experimental energy threshold. Gaseous Time Projection Chambers (TPC) with optical readout are very promising candidates thanks to the 3D event reconstruction capability of the TPC technique and the high sensitivity and granularity of last generation scientific light sensors. The CYGNO experiment is pursuing this technique by developing a TPC operated with He-CF_4 gas mixture at atmospheric pressure equipped with a Gas Electron Multipliers (GEM) amplification stage where visible light is produced. The combined use of high-granularity sCMOS cameras and fast light sensors allows the reconstruction of the 3D direction of the tracks, offering good energy resolution and very high sensitivity in the few keV energy range, together with a very good particle identification useful for distinguishing nuclear recoils from electronic recoils. We present the design and the sensitivity of a 50L prototipe which is currently being installed underground at LNGS and will be operated already in 2022. The performances of the prototype are evaluated with an advanced Monte Carlo simulation and by calibration runs with radioactive source. We show that good energy and spatial resolution as well as discriminating power between nuclear and electronic recoils is achieved in the keV energy range. The Cygno collaboration plans to demonstrate the scalability of such detector concepts to reach a target mass large enough to significantly extend our knowledge about DM nature and solar neutrinos.

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1. Introduction

The presence in the Universe of large amount of not-luminous matter, called Dark Matter (DM), is suggested by several astrophysical and cosmological observations. One of the most appealing candidates for particle DM are the Weakly Interacting Massive Particles (WIMPs), they are electrically neutral with a mass around 1-10 GeV/c^2 and can induce few keV nuclear recoil (NR) on light element.
For an observer on the Earth, due to the motion of the Sun and of the Earth around the center of the Galaxy, an apparent WIMP wind generates which happens to point towards the Cygnus constellation. Moreover, a few percent seasonal modulation of the flux originates from the motion of the Earth around the Sun.

2. CYGNO experiment

The CYGNO experiment aims to build a large direct directional detector of DM using a Time Projection Chamber (TPC) with optical readout based on a Gas Electron Multiplier (GEMs) stack working with a helium/fluorine gas mixture at atmospheric pressure and room temperature in order to study rare events with energy releases in the range 1-100 keV.
The electrons produced by the interaction of the ionizing radiation with atoms of the gas drift in the electric field towards the triple GEM stack. Thanks to the characteristic of the gas mixture, during the electron avalanche in the GEMs, scintillation light is produced and an optical readout system acquires the signal. The combined use of high-granularity sCMOS camera, used to acquire the signal in the x-y plane (the GEM plane), and fast light sensors, used to acquire the signal long the z axis (drift direction), provides a 3D track reconstruction with a very good energy resolution and very high sensitivity in the few keV energy range, together with a very good spatial resolution and granularity that can be exploited to distinguish nuclear and electron recoils.
The CYGNO project is concluding the R&D phase with the LIME prototype, which is an important step in order to build the final Cygno detector.

3. The LIME prototype

The LIME (Long Imaging ModulE) is the largest prototype built to conclude the R&D phase. It is based on a TPC with the same drift length (50 cm) and the same optical readout of the final demonstrator. It is filled with a He:CF_4 (60:40) gas mixture operated at atmospheric pressure and room temperature.
LIME is based on a single sCMOS sensor and 4 PMT, symmetrically placed around the sensor. The Hamamatsu Orca-Fusion camera, which has 2304 x 2304 pixels, low noise and high granularity, is installed to acquire the images, while the Hamamatsu R7378 PMTs are installed as fast light sensors to measure signal timing.
For several months the LIME prototype operated overground at Frascati National Laboratories (LNF-INFN) to study the long term stability. In order to perform an energy scan the LIME prototype has been exposed to different X-ray source and a good linearity in the detector response has been observed.

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A Data - Monte Carlo comparison has been performed resulting in a good agreement in the detector response considering for example the collected light integral and the event spot size.
At the beginning of the 2022 the LIME prototype has been installed underground at the INFN Gran Sasso Laboratories (LNGS) to study and to characterize the detector's performance in low radioactivity and low pile-up configurations.
The demonstrator will be also operated exploiting radiation shielding in different configurations and with different purposes. A 100 mm copper box, serving also as a faraday cage and ensuring light tightness, will be used as radiation shielding while the neutron shielding will be implemented with 1100 mm of water.

4. Outlook

The LIME prototype has been installed at the LNGS at the same condition of the future CYGNO_04 demonstrator (Figure 1). It will be a 0.4 m^3 Time Projection Chamber, the two 50 cm field cages will be able to produce a very uniform electric field using low radioactive materials. The two field cage will be installed in one vessel with a common cathode installed in between them. In order to multiply the signal two triple GEM stack, given by 500 x 800 mm^2 GEM foils, will be installed at a 500 mm distance from the central cathode. The same optical readout will be used: two cameras and six PMTs will be installed on each anode.
The final goal is to build the CYGNO detector with a volume of the order of several tens of cubic meters which would be able to give a significant contribution to the search and study of DM in the mass region below 10 GeV, both for Spin Independent and Spin Dependent coupling.

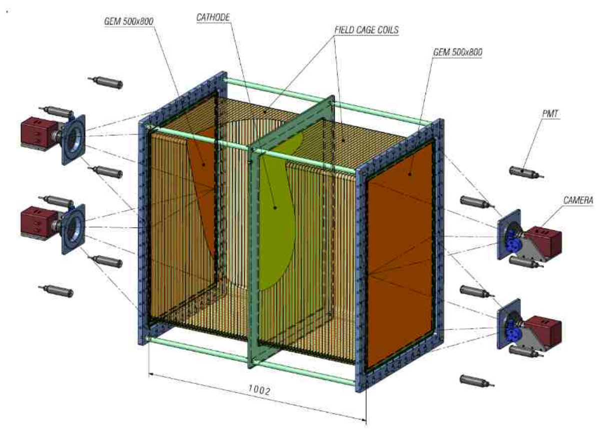

Figure 1: The Cygno_04 demonstrator project.

References

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