CYGNUS-RD

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1 Introduction

The CYGNUS-RD aim to exploit the scintillation light accompanying the electronic avalanches in a triple GEM structure to develop an hight precision particle taking detector over a large gas volume. The read out is performed by a CMOS-based camera sensor provides a high granularity along with low noise and a very high sensitivity. Once operated with a large aperture and suitable focal length lens, large areas can be imaged at reduced costs.

Such a detector can be an interesting candidate for future large scale experiments searching for Dark Matter (DM) searches with directional sensitivity and for measurements of coherent neutrino scattering on nuclei. Additional applications of this detector might be in the realm of neutron detection, X-ray polarimetry and hadrons/ions beam monitor.

Based on the promising results of previous years, in 2017 a new a 7 litre sensitive volume prototype (called LEMOn) was designed and tested with the 450 MeV electron of the Frascati Beam Test Facility (BTF)

Finally, gas scintillation characteristics and mixture stability has been investigated to qualify the optimal conditions for electors, photons and neutrons energy resolution, tracking performance and particle identification.

2 2017 activities

2.1 NITPC

The NITPC detector aim to study the negative ion drift velocities and mobilities for innovative particle tracking detectors using gas mixtures based on SF6. This gas has recently received attention in the context of directional Dark Matter searches, thanks to its high Fluorine content, reduced diffusion and multiple species of charge carriers, which allow for full detector fiducialization. In 2017 we perform measurements at the BTF with a 5 cm drift distance Negative Ion Time Projection Chamber, showing the possibility of negative ion operation in pure SF6. After having reproduced the measurements of SF6 mobilities in pure SF6 available in the literature, we obtained the first evidence of SF6 drift in a He mixture at nearly atmospheric pressure, namely He:CF4:SF6 at 360:240:10 Torr. The results demonstrate for the first time the feasibility of SF6 negative ion drift and gas gain in He at nearly atmospheric pressure, opening very interesting prospects for the next generation of directional Dark Matter detectors ?).

2.2 ORANGE

The ORANGE (Optically ReAdout GEm) prototype was tested in December 2016 with 450 MeV electrons at the Frascati Beam Test Facility. The detector consist of 0.1 litre volume read by a

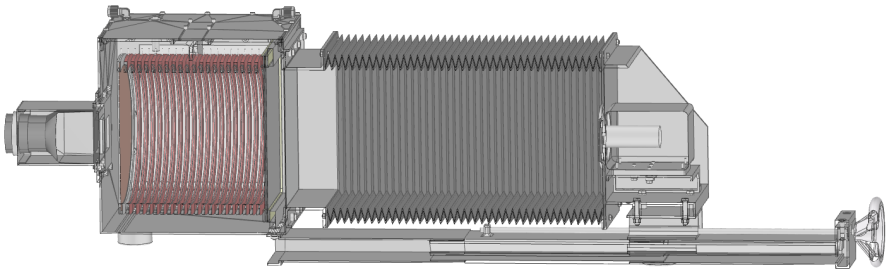

Figure 1: *LEMOn 3D printing design: left PMT holder, semi-transparent cathode, field cage rings, triple GEM stack and large transparent windows, optical bellow and ORCA Flash camera holder.*

standard 10×10 cm^2 Triple GEM system equipped with an high granularity and low noise CMOS and a PMT for signal timing analysis. The device was flushed with He/CF_4 (60/40) mixture and operated with a 1.5-2.0 kV/cm transfer fields. In this condition the space resolution obtained was of the order of tens of μm with an energy resolution of 20%÷30%. The analysis of the PMT waveform allows a 3D re-construction of each single clusters with a resolution of $100\mu m$. Moreover, from the PMT signals it is possible to obtain a fast reconstruction of the energy released within the detector with a resolution of the order of 25% even in the tens of keV range [?].

2.3 LEMON

The interesting results obtained with a first small prototype ORAnGE lead to the construction and tests of a second larger prototype (Large Elliptical Module Optically readout: LEMOn) based on standard 20×24 cm^2 GEM with a 20 cm long drift gap (7 litre of active volume). The LEMOn prototype structure was made of ASA, Acrylonitrile Styrene Acrylate, at the 3D printing Facility of LNF. This has offered the opportunity to easily design and to quickly develop detectors and also to test the 3D printing system for the gas detector applications.

The new prototype showed very promising results, confirming the potentiality of a MGPD optical read out to realize a high granularity, high sensitivity, good energy resolution and scalability needed for innovative directional dark matter detectors. Although very preliminary, data showed a resolution in X/Y of about 90 μm. Moreover, a promising exploitation of the electron diffusion for fiducialization gave the possibility to evaluate the track depth within the volume with $\sigma_Z/Z \simeq$ 20%. Finlay, primary scintillation light, emitted by the gas during the ionization processes, and the light emitted by the avalanches in the first GEM foil, were acquired with the aim of extracting the track position from their time difference [?].

Moreover, during the 2017, gas mixture studies and photons gain measurements has been performed in order to better understand how to optimize optical readout performances and detector stability. As expected from the previous measurements an energy resolution is between 22% and 28% has been confirmed for 60-40 and 70-30 gas mixture and a the total number of photon/electors $\simeq 10^{-2}$ was measured.

3 Conclusion

The CYGNUS-RD activities in 2017 has been full of interesting results, that point out the potentiality of optical readout for many kind of application in particular for directional dark matter

detection where a vary high space granularity and energy resolution are required within a very low energy threshold.

4 List of Conference Talks by LNF Authors in Year 2017

1. TPC GEMs R&D for directional Dark Matter searches, CAASTRO-CoEPP Joint Workshop, University of Melbourne, Melbourne, Australia, January 2017 http://www.caastro.org/files/58/1637200254/baracchini_caastro_coepp_jan_2017.pdf

2. UNDER: Underground Neutron DEtection through nuclear Recoils, CAASTRO-CoEPP Joint Workshop, University of Melbourne, Melbourne, Australia, January 2017 http://www.caastro.org/files/58/1345380162/under_proposal_cygnus_australia_jan2017.pdf

3. CMOS-Based Readout for High Precision Tracking Prototype, CYGNUS International Workshop on Directional Detection of Dark Matter, 13th to 16th in Xichang, Sichuan, China http://www.tir.tw/conf/cygnus2017/materials/Giovanni-Mazzitelli.pdf

4. UNDER: Underground Neutral particles DEtection through nuclear Recoils at CSN2, July 2017 https://agenda.infn.it/getFile.py/access?contribId=8&sessionId=1&resId=0&materialId=slides&confId=13739

5. UNDER: Underground Neutral particles DEtection through nuclear Recoils at LNGS Scientific Committee meeting, October 2017 https://agenda.infn.it/getFile.py/access?contribId=26&sessionId=0&resId=0&materialId=slides&confId=14238

6. Latest italian R&D results and the UNDER project, Cygnus international collaboration workshop, 9-10 October 2017, Grenoble, France https://lpsc-indico.in2p3.fr/Indico/event/1671/timetable/#20171009

7. A high resolution TPC based on GEM optical readout, under publication in proceedings of IEEE NSS/MIC 2017 Conference Proceedings, 21-28 October 2017, Atlanta, Georgia. USA https://www.eventclass.org/contxt_ieee2017/online-program/session?s=N-25#1198

5 List of Publications signed by LNF Authors in Year 2017

1. E. Baracchini *et al*, Negative Ion Time Projection Chamber operation with SF6 at nearly atmospheric pressure accepted for publication on JINST - Journal of Instrumentation, https://arxiv.org/abs/1710.01994

2. C. Antochi Vasile *et al*, Combined readout of a triple-GEM detector, submitted for publication on JINST - Journal of Instrumentation

3. G. Mazzitelli *et al*, A high resolution TPC based on GEM optical readout, in proceedings of IEEE NSS/MIC 2017 Conference Proceedings, 21-28 October 2017, Atlanta, Georgia. USA, http://www.nss-mic.org/2017/