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M1 / M2 Internship Topic(s) HARPO project 2016

High performance γ-ray astronomy and polarimetry in the MeV - GeV energy range.

- **Analysis of prototype γ-ray-beam test data;**
- **Simulation of the performances of a future flight prototype;**
- **AGN γ-ray emission polarimetry.**

1 Context : A new way to do γ-ray astronomy

High-energy astrophysics suffers from the absence of sensitive detectors between the energy range over which the Compton telescopes are efficient ($E < 1\,\text{MeV}$) and the energy range over which the (e^+e^-) pair telescopes are efficient ($E > 100\,\text{MeV}$). This "hole" in the observed SED (spectral energy distribution) of cosmic sources such as AGN (active galaxy nuclei), GRBs (gamma-ray bursts) and pulsars hinders the understanding of the mechanisms at work in these sources. Furthermore no polarimeter with sensitivity above 1 MeV has ever been <flown to space, in particular as the polarization asymmetry of Compton scattering decreases at high energy.

We are developping a novel approach using a thin, homogeneous, active target, meaning that the 2 electrons of the pair are tracked in the very same detector as that in which the photon converted, to drastically improve the photon angular resolution and therefore the point-like-source differential sensitivity [1]. The low-momentum single-track angular resolution is so good that we can measure the azimutal angle of the conversion plane before this information is ruined by multiple scattering, which gives access to the polarization of the incoming radiation [2].

2 HARPO : Homogeneous ARgon POlarimeter

We have built a prototype based on a TPC (time projection chamber), which we have qualified using comic-rays [3]. We have exposed it to a fully polarized gamma-ray beam produced by the inverse Compton scattering of a fully polarized laser beam on a 1 GeV electron beam of the NewSUBARU storage ring (LASTI, U. of Hyogo, Japan) in 2014. We collected more than 60M event in the γ energy range $1.74 - 74\,\text{MeV}$. The event-reconstruction software [6] that we used intensely for cosmic-ray validations [3] is presently being upgraded to a second-generation version better suited to the analysis of low-momentum track pairs. The Geant4-based simulation software of the Japan data is almost completed.

In parallel with this "ground" work, we are designing a new, different prototype to be tested in real situation during a stratospheric balloon flight : an LoI (letter of intent) has been submitted to the French space agency CNES to that purpose. The main issue here is the design of a self-trigger scheme, in contrast with the "usual" situation in HEP, in which the trigger of the TPC is provided from informations provided from other sub-detectors. To that purpose we will use the real-time information provided by the new-generation digitizing chip developped by our collaborators at Irfu (CEA Saclay) [4].

3 Possible Internship Topics

3.1 Beam data analysis

The work on finalizing the event reconstruction software is proceeding nicely and we expect that in spring 2016 a full processing of all the data with a good quality, reasonnably understood, version will be available, together with equivalent simulated data samples.

The internship work will consist in the analysis of higher-level objects, such as reconstructed tracks, to characterize precisely either the tracking properties of the detector or the kinematic properties of the conversion events up to .. the measurement of the polarization fraction of the beam. **Contact : P. Gros.**

3.2 Simulation of the performances of a flight prototype

The flight prototype will consist of $4 \times 4 \times 4$ module set, each module similar in size with the present "ground" TPC (a 30 cm cube). These TPCs will be arranged in a 1.2 m set-up, in a 2-by-2 back-to-back arrangement with common cathodes for easier high-voltage handling.

- One intership topic will be the design and the optimization of the trigger scheme to suppress the huge (20 kHz/m^2 (charged) cosmic rays) background from the tiny (10^{-3}MeV/(cm^{2}s) for the Crab pulsar) signal. (Physics simulation and analysis, NOT electronics design). **Contact : D. Bernard.**

- An other topic will be the analysis of simulated data, to predict the performances of the detector as a telescope and as a polarimeter, **Contact : P. Gros.**

  Depending on the preference of the student, this work can be oriented to the study of specific sources off particular interest in the γ-astronomy group of the Laboratory, such as blazars, which are AGN, one of the jets of which is pointing towards the observer. The measurement of the polarization fraction allows to decipher the "hadronic" from the "leptonic" model (in the case of the IBL *intermediate BL Lac objects* (3C66A and W Comae) and of the HBL *high-frequency-peaked BL Lac objects* (RBS 0413 and RX J0648.7+1516) read, e.g., [5]). **Contact : D. Horan.**

3.3 Thin micromegas bulk

The amplification of the few "ionisation" electrons deposited in the TPC gas is performed by a "bulk micromegas" system with a distance ("gap") between the high-voltage mesh and the collecting anode of 128μm. The use of smaller gaps, a development by Irfu (CEA Saclay) in which we are involved will yield an optimal gain at higher pressure, and could allow a hands-on-the-detector internship work. **Contact : D. Bernard.**

4 Ecole Polytechnique HARPO Science Team

Denis BERNARD	HARPO	33 1 6933 5534	denis.bernard @ llr.in2p3.fr
Deirdre HORAN	γ astronomy AGN	33 1 6933 5535	deirdre.horan @ llr.in2p3.fr
Philippe GROS	Event reco and simulation	33 1 6933 5573	philippe.gros @ llr.in2p3.fr

links at `http://llr.in2p3.fr/~dbernard/polar/harpo-t-p.html`.

References

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