Photo-Absorption of Nuclei and Decay Observation for Reactions in Astrophysics

PANDORA WORKSHOP 2021

9th September - 10th September 2021

<u>Report</u>

Summary of the Updates from UHECR and Reaction Theory session:

Chair - Elias Khan

The discussion focused on the relative impact of the nuclear physics uncertainties, compared to the astrophysical ones. Namely, it seems that the uncertainty on the Galactic magnetic field, or the source composition, dominates over the one on the photonuclear cross-section. The former impacts quantities deduced from observations, such as the UHECR energy spectrum, or their anisotropy.

It is nevertheless emphasized that the E1 strength description should be still better described, using both theoretical approaches and benchmark measurements, in order to build photodisintegration models as robust as possible. This raises the question of the magnitude of the present uncertainties on UHECR predictions, from the nuclear physics inputs, and how strong they should be reduced.

Finally, the relevance of better characterizing source models was addressed. On the one hand, simple models have already been used, but on the other hand, it could be interesting to consider a given type of models, allowing for a composition different from a totally free parameter. For instance, photodisintegration cross sections may be useful in several source acceleration models.

Summary of the Experiments session:

Chair - Pär-Anders Söderström

The experimental session for this workshop focused on the recent status of the iThemba LABS, the RCNP, and the ELI-NP facilities as well as current activities at the HigS and the S-DALINAC facilities. At iThemba LABS the first experiment, not related to PANDORA, has been carried out although not yet with the facility at maximum energy. All 21 of the ALBA detectors have been delivered to the facility and the first PANDORA beam time is estimated to take place in the beginning of 2022. At RCNP the technical work on the accelerator is ongoing and the hope from there is that in the beginning of 2022 to be able to have a commissioning beamtime of the SCyLLA array, with an estimate of a beam-time for PANDORA experimentalists in the second half of 2022. At ELI-NP, the cooling and electrical infrastructure installation of the LINAC accelerator is completed and the installation of the actual LINAC is expected to start in October 2021, for first beams for experimentalists in 2023. From an instrumentation side, the ELIGANT-GN setup has been completed and commissioned with sources, and is awaiting beams for the first in-beam commissioning in 2023.

The recent work performed by the group of Prof. Pietralla at the HIgS and S-DALINAC facilities were presented. In particular, the light nuclei, especially 6Li and 12C has been recent high-profile measurements at the S-DALINAC, where 6Li was measured using the self-absorption technique with the NRF method, obtaining very interesting results on chiral two-body currents. For 12C, using electron scattering, new high-precision information of the quadrupole moment of the first excited state was obtained. At HIgS, the NRF technique with polarized gamma beams was presented, with an example from 40Ar, but more recently with very interesting results on the GDR of 154Sm. While this nucleus is outside the scope of the PANDORA project, the method presented and used in this measurement can provide very valuable structure information also for nuclei in the PANDORA regime.

- The discussion was general about all the facilities presented. One important point that was made was the possibility to use broadband Bremsstrahlung beams to cover a broad range of the nuclear excitation energy as a complementary method to the narrow-bandwidth gamma-ray beams. In these cases, the regions of specific interest can easily be identified in the Bremsstrahlung experiments that would provide important guidance for more focused measurements at ELI-NP-like facilities.

Summary of the Structure Theory session:

Chair - Stephane Goriely

The Structure Theory session was an opportunity to present three important works concerning the determination of the photoreaction cross section. The first one by Yutaka Utsuno summarized the recent effort to estimate the E1 and M1 photon strength functions within the large-scale shell-model approach for pf-shell nuclei. Comparison with experimental data is extremely encouraging though theory tends to slightly overestimate measurements in the GDR region and above. The extension of the calculation to sd-shell nuclei opens an interesting perspective to cover a large number of nuclei of interest within the PANDORA collaboration, both for comparison with experiments and application to UHECR.

The second contribution by Nadia Tsoneva presented the achievements obtained within the microscopic theoretical approach which incorporates the energy density functional theory and the three-phonon quasiparticle-phonon-model (QPM). The theory has been mostly applied to the low-energy E1 photon strength function of medium-mass and heavy nuclei but also recently of 56Fe. It brings extremely valuable extension to the QRPA approach since it involves multi-phonon coupling.

Finally, Raphael-David Lasseri showed that it is possible to refine existing photoreaction predictions using neural networks. In particular, a committee of Neutral Networks trained on 88 well-measured photon strength functions was found to predict an additional of 22 E1 strength with a rather good accuracy when compared with existing theories. This method could be used to extract unknown strength functions as well as to favour some experimental sets when different conflicting sets exist.

The discussion during the Structure Theory session also highlighted that many different approaches are available (RPA, QPM, SMLO, AMD, Shell model, ...) as presented at the PANDORA workshops this year and last year. A particularly well-suited approach for the light nuclei of interest in UHECR applications could consist in using the neural network approach together with a training set supported by the shell model predictions, since the latter remains the most suited theory for the calculation of the E1 and M1 photon strength functions of light nuclei.