Nuclear Emulsions

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M. C. Montesi has carried out research activities in the field of Bio-Engineering and Applied Physics to Medical-Biological Sciences, with particular interest in the study of different types of detectors (hybrid semiconductor detectors, silicon photomultipliers, emulsion cloud chambers). Since 2011, the main research activity was in the field of nuclear emulsion detectors. The sub-micron spatial resolution and the impressive development of automated optical microscopy in the last decades make nuclear emulsions optimal detectors for some applications in particle physics and in the medical physics.

1) Nuclear Emulsions and Particle Physics

In the field of particle physics, the emulsion detectors have a special role in the international experiment Scattering and Neutrino Detector (SND@LHC, https://snd-lhc.web.cern.ch/), in which INFN (Istituto Nazionale di Fisica Nucleare) is heavily involved. The experiment is based on the use CERN's Large Hadron Collider (LHC) as a source for studying neutrinos, elementary particles having a very weak interaction with matter. The SND@LHC experiment, approved in 2021, has the purpose to study a high number of neutrinos of all three flavours (electron, muon, and tau) produced by LHC. SND@LHC was designed with the goal of detecting these particles, which are of great interest to physics since characterised by very high energies not yet explored. SND@LHC has smaller dimensions compared to the other types of experiments dedicated to study neutrinos. It consists of two regions. In the upstream region, there are tungsten plates (having an overall weight of approximately 800 kg) alternated with nuclear emulsion films, able to detect the interaction of neutrinos with high precision. Electron tracking systems, based on scintillating fibres, are embedded in this structure, and allow the momentum and energy measurements. The final region is equipped with a hadron calorimeter and a muon recognition system. The compactness of this experimental set-up for neutrino detection was favoured by the large number of neutrinos and by their high energies.

In the sample of data acquired in 2022, consisting of several billion muons, SND@LHC has observed 8 muon neutrino interaction candidate events, with a statistical significance above 5 sigma, which is needed to confirm an observation in physics. With these first results of the analysis of data collected in 2022, the SND@LHC experiment has opened a new frontier in studying neutrinos and searching dark matter.

2) Nuclear Emulsions and Hadrontherapy

The FOOT experiment - Fragmentation of target - (funded by INFN since 2017, https://web.infn.it/foot/en/home/) has been conceived for measuring the target fragmentation in proton therapy and the target and projectile fragmentations in the therapy with beams of helium, carbon and oxygen ions. The energy range explored (80-700 MeV/n) is relevant also for to space radiation protection.

To this aim, two complementary detector set-ups were realized: a magnetic spectrometer for high Z and low angles (≤ 10°) particles, and a nuclear emulsion spectrometer for low Z and high angle fragments. The experiment employs an inverse kinematic approach, in which a particle beam (oxygen or carbon ions) impinges on hydrogen-enriched targets, generating secondary fragments. Because a pure hydrogen target would lead to several experimental complications, two different materials, carbon and polyethylene, are used and the fragmentation cross-section for hydrogen is estimated as a linear combination of the cross-sections obtained for these materials. The nuclear emulsion spectrometer, composed of alternating layers of nuclear emulsion films and passive materials, is designed for the reconstruction of interaction vertices and the measurement of the charge and momentum of secondary particles. Several measurement campaigns (GSI, Darmstadt; CNAO, Pavia) have been carried out; the fragments produced in the interactions have been identified and the dedicated data analysis quantifying the fragment production cross-section is being finalized.

These lines of research are conducted in close collaboration with the Nuclear Emulsions group of Dipartimento di Fisica "Ettore Pancini"., which reports to Prof. G. De Lellis.

Montesi is also participating to the University Task Force named SHiP-FedII, coordinated by Prof. Giovanni De Lellis, together with other members of the Chemistry Department. This task force is meant to explore a new domain of the elementary particle physics with tools and expertise from different areas of Science and Technology.