ID de Contribution: **34** Type: **contribution**

NFS: a powerful tool for Nuclear Data Measurements ready for operation

This contribution to the on-going prospective on the future of GANIL/SPIRAL-2 aims at detailing the potentialities of the SPIRAL-2/Neutrons for Science (NFS) [1] facility for nuclear data measurements.
Applied nuclear physics is omnipresent in our daily lives and has many strong links to the Sustainable Development Goals set up by the United Nations [2]. From energy to health applications, through environmental, space and societal applications, nuclear data are basic inputs for these fields [3]. Also the NUPECC Long Range Plan 2017 - perspectives in Nuclear Physics, realizes this and a wide range of nuclear physics applications in need of nuclear physics knowledge is described. To this end, great efforts are still conducted all over the world to increase our basic nuclear physics knowledge and enable us to produce modern nuclear databases which will be quality assured and at the accuracy level needed by the applications.
The nuclear physics knowledge needs from the applications are often very advanced, e.g. in the energy and medical sector. Reasons are, among others linked to safety and economy. Therefore, they need well-understood, traceable and reproducible nuclear data input with well-defined uncertainties. To meet this goal we need to improve our theoretical understanding of nuclear physics and develop reliable nuclear model codes. Such efforts need in turn high-quality experimental data and it is here where the unique capabilities of the NFS facility come into play.
Neutron induced reactions play an important role in a wide range of applications including nuclear power reactors, accelerator driven systems (ADS), fusion technology, medical diagnostics and therapy, radio-isotope production, materials research, non-destructive testing, dosimetry and dose effects, radiation damages and upsets in electronic devices as well as in basic nuclear physics. As an example, research and development on nuclear reactors both for optimization of current generation or for study of next generation plants require highly detailed and sophisticated simulations. Indeed, reactor operation and safety parameters, fuel burnup, nuclear waste production, etc. can be studied by simulation with Monte Carlo or deterministic codes. These codes simulate the fundamental interaction of multi particles with matter and use as inputs nuclear data like reaction cross sections, angular distributions, fission yields, decay constants, etc. These inputs are called evaluated nuclear data. They are compiled in evaluated nuclear databases and determined from experimental data and complemented by state of the art nuclear reaction models. The increase of calculation power allows today precise sensitivity studies, which reveal that the limiting factor for accuracy simulations of reactor parameters is the accuracy of input evaluated nuclear data. International community is thus continuously working on the improvement of evaluated nuclear data libraries like the European - JEFF (Joint Evaluated Fission and Fusion), the US - ENDF (Evaluated Nuclear Data File), Japanese - JENDL (Japanese Evaluated Nuclear Data Library) and some others. The quality of evaluated nuclear data with their variance-covariance matrices can be improved with efforts both from the experimental and theoretical sides, as reliance on nuclear models is common today for nuclear data evaluation. In some cases, where experimental data are scarce or known with low precision, new measurements are mandatory to provide new and relevant constraints for nuclear modeling. To help experimentalists and theoreticians to stimulate and guide their research, a reference tool has been created by the OECD/NEA, the High Priority Request List (HPRL)[4] which compiles requests for new measurements, selected after rigorous sensitivity studies for various applications (fission, fusion, dosimetry, standard and others) and for which a target accuracy is specified.
There is a large demand on fast-neutron induced-reaction data as well as proton and deuteron induced-reaction in the energy range between 1 and 40 MeV. For many cases, like (n,fission), (n,n'), (n,xn), (n,Light Charged Particle), (p,X), (d,X) reactions, the cross sections are unknown or known with insufficient precision. In this context, the new NFS facility with its various beams (charged particles and quasi mono energetic or continuous neutron beams) and tools (flight path areas, irradiation station, pneumatic transfer system and more) is ready to play a significant role in the field to produce new nuclear data relevant for applications.
The particle induced activation reactions have a great interest for the assessment of induced radioactivity in the accelerator components, targets, beam stoppers and biological shielding, which is an important matter for safety aspects during facility operation and also for decommissioning operations including identification of the right waste repositories [5]. This is particularly true for the radioactive inventories in activated parts with high contribution from pure beta emitting radioisotopes that are very difficult to measure. Therefore, their contribution to the total activity, which strongly influences the further waste management, can only be calculated by activation codes using evaluated nuclear data libraries. Neutron beams available at NFS will allow validating the calculation tools by irradiating samples in well-known conditions and therefore improve the decommissioning strategies and reduce the associated costs. There is an increasing demand from the industry on this matter especially for medical accelerators (radiation therapy and isotope production for medical applications) considering the large number of facilities in operation (more than 4000 in Europe and 500 in France,

with an increasing rate of 14% over the last five years).
EUROfusion/ENS (Early Neutron Source project)[6] or the SPIRAL-2 facility itself need such kind of data for estimation of the potential radiation hazards from the accelerating cavities and beam transport elements. Some important cross sections are needed in the energy range from the activation reaction threshold 2 - 10 MeV up to 40 MeV both for deuterons and protons, while the account of particular processes as the deuteron breakup needs at the same time a suitable knowledge of the corresponding data for breakup-neutrons/protons induced reactions within the related energy ranges.
Monoenergetic neutron spectra with variable energy up to 31 MeV enable the measurements of differential cross sections and thus direct validation of theoretical models and evaluated libraries for given energies, i.e. leading to excitation functions of the reactions of interest. There are thus pointing out and eventually endorsed issues of the reaction-mechanism energy dependence while the emission-spectra analysis concerns firstly the excitation-energy dependence of various nuclear structure questions.
The high neutron fluxes with large and tunable energy spectra available with energy up to 40 MeV at the NFS facility as well as the pulsed beam and the long time-of-flight area are very attractive to obtain accurate data. The high neutron fluxes would allow the measurements of small reaction cross-sections and/or with very small targets, which might be rare, expensive, and in some cases radioactive. The energy range and conditions offered by the NFS time-of-flight facility is complementary to other facilities in Europe, notably GELINA at JRC-Geel, Belgium and the n_TOF facility at CERN. Working at GANIL-SPIRAL2 in the same environment with physicists engaged in cutting edge research in nuclear physics and astrophysics and using forefront experimental devices will be an important asset for the entire nuclear data community.
NFS was strongly supported by the physicists of the nuclear data community and was involved in the former CHANDA European project [7] and is now in the ARIEL European project [8], where its role will be strengthened by an important nuclear-data production from experiments.
Most of the experiments mentioned above can be performed at NFS, whose characteristics (neutron flux, energy, sample purity and/or possibility of using actinide targets) are well adapted. There is an opportunity for GANIL-SPIRAL-2 to welcome a new community of physicists working on nuclear data and contribute significantly to the international effort for high quality nuclear data measurements. NFS is ready to become a reference facility in this field and thus fulfill entirely one of the missions for which it was built. This will only be possible if a significant part of the beam time is dedicated to these measurements. These experiments must be examined by the Program Advisory Committee (PAC) of GANIL-SPIRAL-2 on an equal basis with the long-established physics themes of GANIL, and also taking into account their above-mentioned own physics context. NFS can in this way play an important role in the future of GANIL.

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Auteurs principaux: LETOURNEAU, Alain (CEA Saclay); Dr PROKOFIEV, Alexander (Uppsala University, Uppsala, Sweden); Dr FRELIN, Anne-Marie (GANIL); Dr KLIX, Axel (Karlsruhe Institute of Technology, Karlsruhe, Germany); Dr LAURENT, Benoit (CEA/DAM); Dr BORCEA, Catalin (IFIN-HH Bucharest, Romania); Dr GUSTAVSSON, Cecilia (Uppsala University, Uppsala, Sweden); Dr DE SAINT JEAN, Cyrille (CEA); Dr RIDIKAS, Danas (IAEA); DORÉ, Diane (CEA/Saclay, IRFU/Service de Physique Nucléaire); Dr TARRIO, Diego (Uppsala University, Uppsala, Sweden); Dr SIMECKOVA, Eva (NPI, Rez, Czech Republic); GUNSING, Frank (CEA Saclay); LECOLLEY, François-René (LPC Caen (ENSICAEN - CNRS/IN2P3 - UCN)); BÉLIER, Gilbert (CEA, DAM, DIF); HENNING, Greg (IPHC); LEHAUT, Gregory (LPC Caen, CNRS/IN2P3); Dr NOVAK, Jan (NPI, Rez, Czech Republic); Dr MRAZEK, Jaromir (NPI, Rez, Czech Republic); Dr SUBLET, Jean-Christophe (IAEA); Dr DUCRET, Jean-Eric (GANIL); Dr LECOUEY, Jean-Luc (LPC, Caen); Dr MANDUCI, Loredana (LPC, Caen); Dr AVRIGEANU, Marilena (IFIN-HH Bucharest, Romania); Dr KERVENO, Maëlle (IPHC/CNRS); Dr MAJERLE, Mitja (NPI, Rez, Czech Republic); Dr MARIE-NOURRY, Nathalie (LPC, Caen); SEROT, Olivier (CEA-Cadarache); Dr BEM, Pavel (NPI, Rez, Czech Republic); Prof. POMP, Stephan (Uppsala University, Uppsala, Sweden); MATERNA, Thomas (CEA DRF IRFU); Dr FISCHER, Ulrich (Karlsruhe Institute of Technology, Karlsruhe, Germany); Dr BLIDEANU, Valentin (CEA); Dr AVRIGEANU, Vlad (IFIN-HH Bucharest, Romania); LEDOUX, Xavier (GANIL)