Master thesis proposals in University of Padova for 2020-2021

1. Study of the detection system prototype for a UAV system in the environmental radioactive monitoring

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Abstract
The DRAGON project funded by INFN, involves the design and development of a radioactivity monitoring system (gamma and neutrons) on a drone. The thesis proposal concerns the study of the laboratory response of the gamma counter and fast neutrons detectors. The work will be devoted on laboratory measurements and data analysis, optimization of neutron / gamma separation algorithms, realization and measurement for the verification of the IAEA standards. The work also includes field tests on the drone of the complete system.

2. Study and realization of a prototype of a neutron detection system for the ENTRANCE H2020 European project.

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Abstract
The ENTRANCE project, funded by the European community in the H2020 program, aims to develop and validate a complete system of different non-intrusive inspection techniques for the risk of cross-border movements of goods, with particular attention to

EU customs and the borders of the 'Union. In particular, the Department of Physics is the coordinator of the tagged neutron system. The thesis will be aimed to the simulation of a new radiological shield for the new experimental sites; the simulation of the dose rate map in the field.
The thesis will also be focused on the field integration of the complete system and on measurements of the complete system in Cadarache (France) for its characterization.

3. Neutron Ancillary detector for the Active Target ATS (Active Target for SPES)

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Abstract
The Active Target ATS (Active Target for SPES) is a new active target/time-projection chamber, designed for reaction and decay studies with nuclei far from stability. This class of instruments, initially developed for high-energy physics, has found profitable applications in medium- and low-energy nuclear physics as shown by a successful series of experiments.

The physics cases for the new-generation active target are related to the ongoing developments of facilities for radioactive ion beams. Thanks to its flexibility, this instrument will be capable of taking advantage of the most exotic beams which will become available at the SPES facility under construction at the Legnaro National Laboratory in Italy.

The thesis will be focused to couple the ATS with ancillary detectors for neutrons.

The proposed study has to take into account a compact device and the capability of the system to discriminate between neutron and gamma, due to the high gamma background. A potential compact system aimed to discriminate neutron and gamma ray pulses by the Pulse Shape Discrimination (PSD) technique can take advantage of recent improvements in silicon photomultiplier (SiPM) technology and the development of plastic scintillators exhibiting the PSD phenomena.

In particular, the thesis will be focused on the studies of SiPM coupled with CsI(Tl), EJ276G and EJ276 with different configurations, like, for example, different SiPM models

and different area coverage, different preamplifiers. The student will work at Legnaro National Laboratory for the experimental part. The data analysis will be also part of the present study.

4. **Experimental Nuclear Structure studies on the neutron-magic nucleus 90Zr with AGATA and VAMOS++**

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Abstract
This work will be based on an experiment performed at GANIL laboratory using AGATA (array of HPGe detectors with tracking capability) and VAMOS++(tracing magnetic spectrometer). In this experiment the Nuclear Structure of ^{90}Zr will be studied via lifetime measurements using a differential plunger. The proton-rich nuclei of interest was produced in a multi-nucleon transfer (MNT) reaction using a ^{92}Mo stable beam and a ^{92}Mo target. The target was mounted inside the differential plunger with a Mg foil down stream used to degrade the energy of the reaction products to measure the lifetime with the Recoil Distance Doppler Shift (RDDS) technique. The reaction products of interest were uniquely identified with the magnetic spectrometer VAMOS++, while the gamma-rays were measured using AGATA. The activity of the student will be focused on the lifetime determination of the first quadrupole and octupole levels in 90Zr, acquiring expertise in the programs and software (root, gammaware, femul, radware, cubix) used for the data analysis and processing of the AGATA-VAMOS system together with the plunger. The student will be trained in the processes of Pulse Shape Analysis (PSA) and gamma ray tracking of AGATA and in the use of VAMOS and its detectors for the identification of the products of MNT reactions. In addition, the student will acquire experience in the lifetime analysis process with RDDS techniques. Finally, the results on the obtained lifetimes will be interpreted on the basis of theoretical calculations.

5. **Low-energy heavy-ion fusion. Upgrade of the PISOLO setup with coincidences between evaporation residues and charged particles**

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Abstract

In the field of nuclear physics, measurements of fusion cross sections far below the barrier are of deep interest to understand fusion dynamics and the structure of interacting nuclei. When medium-mass and light systems are considered, the interest goes beyond nuclear physics, and the astrophysical implications of the process come into play.
The PISOLO electrostatic deflector, installed at Legnaro National Laboratories, presently allows to measure cross sections down to 0.5-1 μb through the detection of fusion-evaporation residues. The sensitivity of the setup could be increased detecting the light charged particles evaporated by the compound nucleus in coincidence with the fusion-evaporation residues. Indeed, the coincidence may allow to significantly suppress the background of beam-like particles that cannot be rejected by the electrostatic deflector.
In order to verify the effectiveness of the coincidence technique, a test experiment will be performed at the Tandem accelerator of Legnaro National Laboratories. For the experiment, light particles will be detected by an array of Silicon detectors installed around the target. The amplified sensitivity could allow us to reach unexplored energy regions and give decisive information in reaction systems where the low-energy trend of the fusion cross section is still unclear.
The student will take part in the setup preparation, data taking (depending on the Tandem beam time schedule), and data analysis.

6. MACS measurements with neutron activation method

Supervisor: Pierfrancesco Mastinu
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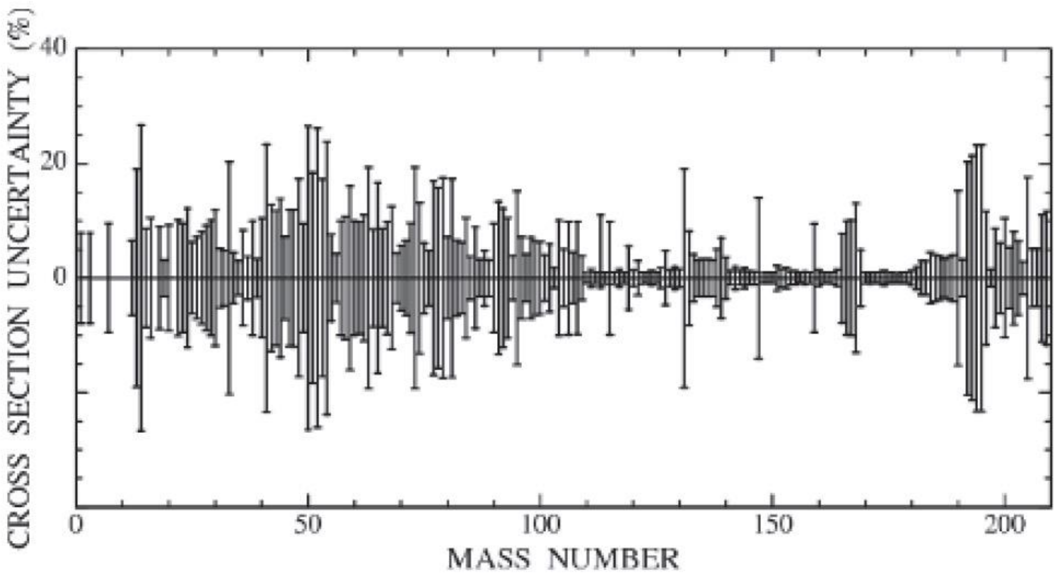
Abstract

All elements of mass greater than iron are produced in stellar nucleosynthesis, both through the s (slow) process and the r (rapid) process. In particular, the elements of the stability valley and those adjacent to it are produced trough s- process by neutron capture and subsequent decay.

In order to try to reproduce the observed abundance of elements in the universe, stellar models have to calculate the nuclear reaction rates that occur in stars and therefore need to have the precise measurement of the neutron capture cross section and beta decay lifetime.
At LNL, we have a pulsed neutron beam line for Time of Fligth measurements and devised a method to produce a neutron spectrum very similar to the stellar one. Thanks to the

availability of the spectrum, the measurement of the cross section can be made by irradiating the target with the neutron stellar-like spectrum, so measuring directly the cross section integrated over the stellar neutron spectrum (the us the so called MACS, Maxwellian Averaged Cross Section). This is the only ingredient necessary for calculating reaction rates in stars, a fundamental input of the stellar evolution model.

The thesis topic can be either the measurement of the stellar like neutron spectrum at different temperature (kT) experienced by then star during its like (8<kT<100 keV) or the measurement of a MACS of particular relevance, as it is not measured or measured with too high uncertainty.
The figure below shows the elements for which the MACS has been measured and the related uncertainty. Since an accuracy of no more than 3% is required for the elements of s-process , it can be seen that the measurements that need to be made are really a lot.



7. **Position correlation by beta-plastic scintillator using a series of SiPM readouts.**

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Abstract

This is a master thesis project which focus on developing a new method of position correlation by beta-plastic scintillator using a series of Silicon Photomultiplie (SiPM) readouts which locate on different sides of detector. The beta-plastic scintillator is used in the decay spectroscopy (DESPEC) experiment at GSI, usually giving better time resolution for electrons and other decayed particles. This thesis aims at using readouts of beta-plastic by a series of SiPM glued to each side of the detector to reconstruct the position as well as the time information of the measured implantation events.

The work foresees on-site works at GSI, if health conditions allow. A remote data analysis and on-site work at LNL-INFN is expected otherwise.

8. **Study of the octupole-quadrupole degrees of freedom in heavy actinides: lifetime in 224Th.**

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Abstract
investigation of quadrupole-octupole correlations is gaining more and more interest in nuclear physics. Recent calculations, based on the framework of relativistic energy density functionals, indicate the occurrence of a simultaneous phase transition from spherical to prolate shape and from prolate to octupole shape in 224Th, for which previous spectroscopic experiments date back about 25 years. The work aims at studying the spectroscopy of 224Th, with the main aim to extend the yrast octupole band and search for new non-yrast structures in 224Th, analogous to that observed in 222Th. The experiment is also aimed to assess the feasibility of the measurement of lifetimes of the lower-spin (< 10 hbar) members of the yrast octupole bands using direct-timing methods with LaBr3(Tl) detectors, and measure lifetimes of states where possible.

The work includes on-site works at LNL-INFN, if health conditions allow. A remote data analysis will be proposed in alternative.

9. **Measurement of charm-baryon production in proton-proton, proton-Pb and Pb-Pb collisions at the LHC with ALICE**

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Abstract

The student will analyse recent data samples collected with ALICE (A Large Ion Collider Experiment) at the LHC, with the goal of measuring and characterise the production of baryons with charm quarks, as ⍰$_c^+$,L_c^+ or $S_c^{0,++}$ in proton-proton, proton-Pb, and Pb-Pb collisions. Heavy quarks are among the most useful probes to investigate the properties of the Quark-Gluon Plasma formed in ultra-relativistic heavy-ion collisions. They are produced in hard-scattering processes with high-momentum transfer in the early stages of the collisions, before the formation of the QGP. Therefore, by interacting with the medium quarks and gluons, they witness the whole evolution of the expanding and cooling systems. The study of the kinematic properties of the final-state hadrons that contain charm quarks, allows to retrieve information on the microscopic interactions occurring in the QGP and thus on the properties of the medium itself. In particular, the comparison of the production yields of different hadron species (e.g. D^0, D_s^+, ⍰$_c^+$,L_c^+ or $S_c^{0,++}$) can clarify how hadrons are formed in the medium and help understanding the coupling of charm quarks to the system and their degree of thermalisation.

The production of charm baryon was observed to be higher than expected in pp collisions. Further measurement are needed to better quantify and characterize their production. Many models expected a significant enhancement of their production in heavy-ion collisions, because of the possible formation of hadrons via “coalescence” of charm quarks with ligher quarks, a mechanism not expected to be effective in pp collisions. The goal of the thesis is to study the production of one among ⍰$_c^+$,L_c^+ or $S_c^{0,++}$ baryons, measuring its kinematic properties (transverse-momentum spectrum) via the reconstruction of their decay into hadrons. To this purpose the decay topology should be studied in order to best exploit the excellent spatial resolution and particle-identification capabilities of the ALICE detector.

With the foreseen work of thesis, the student will have the opportunity to learn and practice with some of the fundamental techniques used to reconstruct unstable particles in particle physics. She/he will get familiar with invariant mass analyses, particle-track reconstruction and particle-identification techniques in modern detectors at accelerators, event selection, analysis on grid network, and other concepts which are fundamental ingredients for researchers in high-energy particle and nuclear physics. The usage of multi-variate analysis techniques and neural network can also be considered.

10. The 22Ne(p,⍰)23Na reaction in Novae and Supernovae explosions

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Abstract:

The $^{22}Ne(p,\gamma)^{23}Na$ reaction takes part in the neon-sodium cycle of hydrogen burning and it has a strong influence on the synthesis of neon and sodium isotopes in several astrophysical scenario. In particular, at the typical energies of classical nova and supernova explosions the ^{22}Ne+p cross section is dominated by a large number of poorly-known resonances. In order to reduce the uncertainty on such reaction, an experiment has been performed at the Helmholtz – Zentrum Dresden – Rossendorf (HZDR), Germany. The goal of the experiment is to determine the strengths of most intense resonances of the 22Ne+p reaction with unprecedented high precision, exploiting gamma spectroscopy techniques. The student will perform a complete analysis of the data acquired at HZDR and evaluate the impact of the new results on the astrophysical reaction rate.

11. Study of the CLYC scintillator as a fast neutron spectrometer

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Abstract

The student will work with the new CLYC scintillator and study its viability as a fast (100 keV - 5 MeV) neutron spectrometer using the output signal amplitude. He will work at LNL with neutron sources like AmBe and 252Cf and/or mono-energetic neutrons beams from the CN accelerator to optimize the algorithms for pulse-shape neutron/gamma discrimination with digital electronics, in particular at low neutron energies (<500 keV). He will also investigate the neutron energy resolution which could be achieved with CLYC scintillators in comparison with the standard time-of-flight technique by studying the better digital treatment of the signal (trapezoidal filters). The studying of the CLYC scintillator response function will allow one to measure complex neutron spectra, like the one from spontaneous fission, by deconvoluting the experimental energy emission distribution. This work will pave the way for the future use of the CLYC scintillators in the beta-delayed neutron spectroscopy of exotic beams and other applications

12. Study of compact high intensity linear accelerators.

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Abstract:

In recent years there have been important developments in the low energy components of linear accelerators, for applications such as materials testing for fusion (IFMIF), transmutation of

radioactive waste (TRASCO, MYRRHA), materials testing with neutron probes (spallation sources), fundamental nuclear physics (radioactive beam production), medical applications (therapy, BNCT, or radioisotope production). The development of ion sources, RFQ and DTL are the key elements to obtain high intensity beams. The purpose of this study will be the use of the results achieved and the components developed for new compact high-performance accelerators.