

## ALICE Trieste group - PhD projects 2019

The ALICE Trieste group, composed at the moment of nine University and INFN researchers, has been involved in the ALICE Experiment at LHC since the early phase of the experiment. The group participated in the construction and operations of the original silicon tracker, in the experiment operations and data-taking, and is now strongly involved in multiple physics analysis topics. More recently, the ALICE Trieste group played a crucial role in the development and construction of the Outer Barrel for the Inner Tracking System (ITS) Upgrade, which is entering now the pre-commissioning phase.

The ALICE Trieste group encourages and welcomes students to present PhD projects focused on the topics listed below. If interested, please contact the researchers indicated after the description of each project.

### **Investigation of the properties of the Quark-Gluon Plasma produced in ultrarelativistic heavy-ion collisions at LHC with ALICE**

The ALICE experiment is the LHC experiment dedicated to the study of ultrarelativistic heavy-ion collisions. Its main goal is the investigation of the properties of the strongly-interacting matter in conditions of high energy density and high temperatures, expected to characterize the medium formed in such collisions. Under these conditions, according to lattice Quantum Chromo Dynamics (QCD) calculations, quarks are not confined into colorless hadrons but deconfined in the so-called Quark-Gluon Plasma (QGP).

Within the ALICE Trieste group, PhD theses covering the study of the properties of the QGP can be proposed:

- Study of the production of nuclei and hyper-nuclei. Light nuclei (e.g. deuteron, helium3) and hypernuclei (bound states of nucleons and hyperons) are formed in heavy-ion collisions besides other particle species. The production mechanism of these loosely bound composite objects in QGP is not clear and is still under debate. In addition, hypernuclei are particularly interesting because they can be used as experimental probes for the study of the hyperon-nucleon (Y-N) interaction. The knowledge of this interaction has gained importance in recent years due to its connection to the modelling of astrophysical objects like neutron stars.

- Study of the production of heavy-flavour hadrons. Heavy-quarks (charm and beauty quarks) are created in hard-scattering processes at the early stage of the collision phase and traverse the medium interacting with its constituents allowing the study of QGP properties as the transport mechanisms and the hadronization phase.
- Study of the production of resonances. Since hadronic resonances decay under the strong interaction with a lifetime of the same order of magnitude as that of the fireball they are suited to study the properties of the QGP created after the collision.

In addition, modern techniques of Machine Learning play a fundamental role in different aspects of the study on heavy-ion collisions, spanning from the Monte Carlo production to the analysis of the collected data, to the quality assurance and data quality monitoring. Therefore, PhD projects related to Machine Learning applications are also possible.

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## Study of particle production and correlations in small collision systems with ALICE at the LHC

The ALICE detector is primarily dedicated to exploit the physics of strongly interacting matter at the highest energy densities reached in nucleus-nucleus (AA) collisions. ALICE is also studying proton-proton (pp) collisions, both as reference measurements for AA collisions and in their own right. Indeed, one of the most important discoveries in pp collisions at the LHC is the observation of collective, fluid-like features incredibly similar to those observed in AA collisions, where they are attributed to the production of the Quark-Gluon Plasma.

In this light, at the ALICE Trieste group, we are interested in a variety of PhD projects to study the properties of pp collisions. The first range of topics focuses on particle production as a function of multiplicity. In particular:

- Strangeness production. Recently we observed enhanced production of strange hadrons in high-multiplicity pp collisions, where the strange yields reach values similar to AA collisions. This hints to the possibility of a common underlying production mechanism spanning from small to large systems. Nevertheless, models have a difficult time in describing this phenomenon, and further developments are needed to reach a complete understanding.

- Heavy-flavour production. Recent studies show a stronger than linear increase of the heavy-flavour self normalised yields, which can be described by several models, based both on initial and on final-state effects, posing the need to investigate further also in this direction.

To this hand, we propose projects to exploit the usage of the Underlying Event as a multiplicity estimator to factorize the harder and the softer components of the events. Through these studies, we aim at understanding the role of Multiple Parton Interactions, collective phenomena and auto correlations in pp collisions, for different identified particle types.

All the topics described above can be extended to proton-ion collisions. In fact, they represent a connection between small (pp) and large (AA) systems.

The second range of PhD topics is related to the study of the interaction of un-identical particles force using the “femtoscopia” techniques. The knowledge of the interactions between different particles such as baryon-baryon, baryon-hyperon and hyperon-hyperon is poorly known due to the limited statistics of hyperon-nucleon and hyperon-hyperons pairs that can be produced in a single event in a standard scattering experiment. On the other hand, the high number of particles produced in high energy collisions at the LHC can be used to study the interesting interactions, profiting from the small system size which is created in a pp collision. This is, however, a very challenging analysis. In fact, a large number of non-interesting events (i.e. “background” events) are generated and all the background sources have to be studied in order to separate the relevant signal from the background. On the other hand, the study of the interaction between hyperons and baryons will certainly contribute not only to nuclear physics but also to astrophysics measurements, helping to better understand our Universe.

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## Characterization and commissioning of the MAPS-based silicon tracking detector for the ALICE Experiment at LHC

The Inner Tracking System (ITS) Upgrade for the ALICE experiment is the first large-area silicon vertex detector based on the CMOS Monolithic Active Pixel Sensor (MAPS) technology, which combines the sensitive volume and the front-end readout logic in the same piece of silicon.

This technology allows a reduced material budget thanks to the thin sensors (50-100  $\mu\text{m}$ ) and limited need of cooling, in combination with light-material connection circuits and support structures. The small pixel pitch ( $\sim 30 \mu\text{m}$ ),

the location of the layers (7 cylindrical layers ranging from 2.3 mm to 39.3 cm from the beam interaction line), and the limited material budget will provide the ALICE experiment with extremely precise tracking capabilities: from the data collected by ALICE in the future, it will be possible to reconstruct and study particles with very short decay length, such as the hadrons containing charm and beauty quarks (heavy-flavor hadrons), in the very dense environment produced by Pb-Pb collisions at 50 kHz rate.

The ITS Upgrade is entering now the pre-commissioning phase. Its capabilities will enable the ALICE experiment to improve its understanding of the physics of strongly interacting matter, and in particular of the properties of the Quark-Gluon Plasma (QGP).

The CMOS MAPS technology is now under consideration for the next-generation tracking detectors at LHC and other accelerator facilities, for space applications, and medical applications.

Within the ALICE Trieste group, PhD projects focused on the development and characterization of particle detectors, their integration with the experimental infrastructures, analysis of cosmic ray data, and preparation for beam collision data-taking, can be proposed. The PhD activities will be part of the larger participation of the group in the preparation of the ITS Upgrade detector for the data taking in Pb-Pb collisions.

A broad set of skills and interests, ranging from hardware development to applied software and computing, are welcome within the foreseen activities. The new ITS detector will be assembled on surface at CERN in Summer 2019, and will undergo a long and exhaustive pre-commissioning phase, necessary to develop and tune the calibration procedures, characterize the detector as a whole, exercise the collective data-taking, and perform a first alignment with cosmic rays data. The detector will be then installed in ALICE in May 2020 and integrated with the other systems and infrastructures. Standalone calibrations and cosmic rays data-taking will continue in preparation for the beam collisions data-taking, which is scheduled to take place in Spring 2021.

In parallel with these activities, investigations on specific behaviours and problems observed in the detector will be carried out in the local laboratories in Trieste. The experience gained with the ITS Upgrade will be used to carry out specific detector R&D for future experiments and applications.

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