Charged-hadrons production in pp and A-A collisions and characterization of the components for the upgrade of the Inner Tracking System of the ALICE experiment at LHC

Abstract: PhD thesis of Ivan Ravasenga

The ALICE experiment was specifically designed for the characterization of the nuclear matter at high densities and temperatures, studying the properties of the so-called Quark-Gluon Plasma (QGP) exploiting nucleus-nucleus (A–A) and proton-proton (pp) collisions at the CERN Large Hadron Collider (LHC). The identified-hadrons distributions carry information on the collective expansion of the system.
The ALICE Collaboration already analyzed the identified-hadron transverse momentum (p_{T}) distributions up to $p_{\mathrm{T}} = 20$ GeV/c in several colliding systems. Recent observations suggest the presence of collectivity even in small systems (pp, p–Pb). Current research therefore aims to verify whether a unified description in terms of collective effects in pp, p–A and A–A collisions can be established. A comparison to the main theoretical models shows how the low-p_{T} particle production can be described by hydrodynamical models and QCD-inspired models which go beyond an incoherent superposition of parton-parton scatterings (e.g. color ropes, color reconnection and core-corona).
This thesis is inserted in the described research scenario studying for the first time the π, K and p spectra in pp collisions at $\sqrt{s} = 13$ TeV and 5.02 TeV, in Pb–Pb collision at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and in the recent Xe–Xe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV, thus giving an additional contribution to the understanding of the available results in the field. The study is performed by using the tracking and particle identification (PID) capabilities of the current ALICE Inner Tracking System (ITS) allowing the reconstruction of pions, kaons and protons at low p_{T} (< 1 GeV/c). The low-p_{T} distributions are then combined to the ones at higher transverse momenta based on the global track samples analyzed with different PID approaches of other detectors in ALICE.
By looking at the π, K and p spectral shape, it's possible to see that for high-multiplicity events, particles are pushed to higher momenta (spectrum hardening) as expected from the presence of radial flow effects. Hints of these effects are visible even in small systems as in pp collisions. Extracting the particle yields, it's possible to see how the hadron chemistry is independent of the collision system at similar charged-particle multiplicities. A comparison of the measured data to the available theoretical models shows how the low- and mid-p_{T} particle production is described better by models including hadron cascade (what happen between the chemical and thermal freeze-out) and Color Glass Condesate (CGC) model calculations.
The results on the temperature of the kinetic freeze-out (T_{kin}) and on the average of the transverse expansion velocity distribution ($\langle\beta_{\mathrm{T}}\rangle$) from the Boltzmann-Gibbs blast wave model show very similar features between pp

and p–Pb collisions at mid-low event multiplicities, and between p–Pb and Pb–Pb systems. The data are consistent with the presence of radial flow in small systems. In addition, the larger $\langle\beta_{\mathrm{T}}\rangle$ observed in p–Pb with respect to Pb–Pb at similar multiplicities, could be explained by color reconnection effects.
The present ALICE detectors fully meet the design requirements; however, to reach high-precision measurements of the QGP state, a major upgrade of the experimental apparatus is planned for installation during the Long Shutdown 2 of LHC in 2019-2020. A new, ultra-light, high-resolution ITS will play a key-role for the improvement of the determination of the distance of closest approach to the primary vertex, the tracking efficiency at low p_{T} (< 1 GeV/c), and the read-out rate. It will be equipped with seven cylindrical and concentric layers of silicon Monolithic Active Pixel Sensors (MAPS) called ALPIDE and produced by Towerjazz with its 0.18 μm CMOS imaging process. They feature a pixel dimension of about 27×29 μm^2 and a full CMOS circuitry within the active volume. The detection efficiency and the fake-hit rate of irradiated and non-irradiated chips were measured at beam test facilities demonstrating a sufficient operational margin even after $10\times$ lifetime Non-Ionizing Energy Loss (NIEL) dose.
In the new ITS apparatus, the ALPIDE chips are arranged into Modules featuring a Flexible Printed Circuit (FPC) wire-bonded to the chips to allow clock, control signals and data transmission towards and from the outside electronics. The layout of each cylindrical layer is segmented in longitudinal Staves hosting the Modules glued onto a Cold-Plate for chip cooling and a Power-Bus for chip powering.
After about five years of R&D, the ITS upgrade project has started the production phase.
This thesis contributes to the big effort that was performed to test the working parameters of the ALPIDE chip prototypes such as the electronic noise, discrimination thresholds and power supply voltages, in view of the final design of the ALPIDE chip. This thesis work also aims to define the final design aspects of the Outer Barrel FPC. For this purpose, various electrical tests and simulations have been performed on different prototypes (1) to understand the quality of the signal transmission by means of eye-diagram analysis software and a four-ports Vector Network Analyzer; (2) to define the best configuration of the power planes for chip powering by means of the Cadence Allegro Sigrity simulation tool; (3) to define the best production strategy in terms of circuit design and choice of materials. Finally, a statistical study of the first produced Staves all around the world will give a comprehensive picture of their working parameters.