# Proposte di Tesi : ALICE - Bari

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**Title**: Study of strange particle production with ALICE at LHC

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While the ALICE experiment at CERN is re-starting data taking during the upcoming LHC Run 3 phase in 2022, large statistics samples are already available from Run 1 and Run 2 (2009-2018) for a variety of colliding systems (pp, p-Pb, Pb-Pb and Xe-Xe) and at different center-of-mass energies. The measurement of particles containing strange quarks (like Lambda, Xi and Omega hyperons) is a key tool to investigate the properties of the strongly interacting matter created by ultra-relativistic heavy-ion collisions. Candidate decay selection, transverse momentum spectra reconstruction and production yield estimation as well as comparisons between different colliding systems and energies and with physics models provide several thesis themes, to be developed in close collaboration with the ALICE Collaboration activities at CERN.

Keywords: ALICE experiment, heavy-ion physics, data analysis

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**Title**: Silicon vertex performance study for future detectors at EIC and ALICE

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The Electron Ion Collider (EIC) at BNL is planned to start its activities in the early 2030s. The accelerator will be able to collide polarised electrons with a large variety of heavy and light polarized nuclei. The EIC central tracking system will be a combination of a silicon vertex detector and an outermost gas tracker. The CMOS Monolithic Active Pixel Sensors (MAPS) in 65 nm technology would fullfill all performance requirements for the EIC vertex tracker. This novel technology is currently targeted by the R&D activities for the upgrade of the ALICE inner tracking system (ITS3), to be installed before the LHC Run 4 (2027). The thesis activity will focus on the basic performance study for the EIC vertex detector and the consequent impact on the measurement of golden physics channels. This exercise will be done in close collaboration with CERN and synergistically with similar studies performed for the development of the ALICE ITS3.

Keywords: ALICE experiment, heavy-ion physics, Monte Carlo simulation, detector performance

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**Title:** Charm and multi-charm baryon measurements with the upgraded ALICE detectors

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A fundamental ingredient of the ALICE physics programme for the new decade is a comprehensive study of the charm and multi-charm baryon production: since charm is exclusively produced in initial hard scatterings, such measurements may indeed provide unique insight into the Quark Gluon Plasma medium as well as hadronization from proton-proton to lead-lead collisions.
A new method for the detection of multiply charmed baryons via their decays into strange baryons has been recently developed. In such a method, the state-of-the-art upgraded silicon detectors in ALICE during Runs 3 and 4, and possibly beyond with a new heavy-ion detector concept for LHC Run 5, will enable the novel possibility of tracking strange hadrons directly before they decay. This will lead to a very significant improvement in the impact-parameter resolution, potentially crucial to distinguish secondary strange baryons, originating from charm decays, from primary strange baryons. A particularly interesting possibility is to first apply the method to the charged Omega baryons coming from decays of the neutral Omega_c. Additionally, due to the large number of tracks in the heavy-ion collision environment, such analyses typically require the application of several selection cuts to the topological variables in order to reduce the combinatorial background. Since different topological parameters are often correlated, there is great potential for improvement through multivariate analysis such as Machine Learning (ML) techniques.
Thesis themes will focus on the study of the achievable performance of such strangeness tracking method, also using ML, starting from the ALICE inner tracking detector in Run 3 and investigating its potential in a future experiment with an extensive silicon tracking detector having a first layer very close to the interaction point.

Keywords: ALICE experiment, heavy-ion physics, machine learning, detector performance

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**Title**: Silicon vertex development for future detector at ALICE and EIC

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The Inner Tracking System project within the ALICE collaboration at CERN is developing an highly innovative vertex detector (ITS3) to be installed before the LHC Run 4 (2027). ITS3 will be the very first example of a detector based on curved wafer-scale ultra-thin silicon sensors arranged in perfectly cylindrical layers. The accomplishment of such a goal requires many technological leaps, like the design of a new Monolithic Active Pixel Sensors (MAPS) based on 65 nm technology, the implementation of stitching technique to produce wafer-size chips and the usage of carbon foam for the mechanical support structures. Performances of 50 micron thick bent silicon sensors have been already proven to be similar to those for sensors in flat position. Such a system will allow to largely improve tracking and vertexing performances of the present detectors. The Bari ALICE group, in close collaboration with CERN, is involved in

R&D activities for the ITS3 development and can offer a variety of thesis proposals including silicon detector characterisation as well as prototyping and characterisation of electrical and mechanical components. Large synergies on the same activities are present in connection with the design of silicon vertex trackers for EIC experiments at BNL.

Keywords: Tracking, detector performance

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**Title:** Feasibility study of an aerogel RICH Cherenkov detector for the next generation heavy-ion program for LHC Run 5

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The next long-term goal of QGP research is to probe the internal dynamics of the Quark Gluon Plasma with the aim of understanding how the observed abundant collective phenomena arise on (sub)fermi time scales and identifying their common dynamical origins. In this context, heavy flavour quarks, offer a direct measure of the randomisation of heavy quarks in phase space during the collision. While this field will see significant advances during High Luminosity – Large Hadron Collider (HI-LHC), based on a detector concept that addresses open challenges in tracking/vertexing and rate capabilities. A new detector concept is also needed to fully exploit the physics opportunities to quantify how the quark-gluon plasma shines electromagnetically. The long-term aim of exploiting electromagnetic radiation as a unique signature for chiral symmetry restoration in the QGP will require a novel detector concept aimed at an unprecedented level of purity of the thermal electron signal. In this context ALICE Collaboration is proposing a new apparatus (ALICE3) for the LHC Run 5 phase. Optimal hadron and electron identification capabilities are required. The Bari ALICE group, in close collaboration with CERN, is involved in R&D activities for the development of a RICH detector for ALICE3, using aerogel as Cherenkov radiator. The photon detection will be provided by a layer of Silicon Photomultiplieris (SiPM). We can offer a variety of thesis proposals including SiPM detector characterisation as well as the studies of the detector performance by means of Monte Carlo simulation, to optimize the proposed detector in term of geometry and radiator optical properties.

Keywords: ALICE experiment, heavy-ion physics, Monte Carlo simulation, detector performance

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**Title**: Study of beauty production in pp collisions with the ALICE experiment at the LHC

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With the end of the second long shutdown of the LHC (LS2) and the start of the so-called “run3” data taking period in 2022, a plethora of new physics analyses will be possible, mainly thanks to the upgrade of the experimental apparatuses. The ALICE apparatus has undergone its major upgrade programme during the LS2, with a completely new Inner Tracking System

(ITS) and an upgrade of the read-out of all other detectors, which permit the collection of data samples with statistical sizes larger by a factor 100 than those taken so far.
The new ITS will allow to reconstruct the exclusive decays of heavy-flavoured (charm and beauty) hadrons down to very low transverse momentum. These are special probes to study the properties of the strongly interacting matter created in ultra-relativistic hadronic collisions since, due to their large rest mass, the c-cbar and b-bbar quark pairs are created in a very short timescale w.r.t. the time evolution of the collisions.
The study of the production of beauty hadrons in the pp system is twofold: it represents the natural baseline for analogous studies in more complex systems (p-Pb and Pb-Pb), and has a great interest *in se:* the first results from the LHC have provided indications that the fragmentations of the heavy-flavour quarks are not universal, with a much larger probability for the quark to fragments into a baryon than at lower energies or in simpler colliding system ($e^+e^-$ or e-p).

Keywords: ALICE experiment, heavy-ion physics, data analysis

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**Title**: Investigation of charm-quark fragmentation via angular correlations of D mesons

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The study of correlations of heavy-flavour particles allows us to shed light on the heavy quark production, fragmentation and hadronization processes. In particular, the analysis of the shape of the azimuthal correlation distribution between prompt D mesons and charged particles produced in the same event enables a detailed characterization of the fragmentation of charm quarks into a jet of final-state particles.
The ALICE Collaboration has already published some results on the topic during the Run1 and Run2 LHC data-taking campaigns. The upcoming LHC Run3 data taking will allow performing such study on a much larger data sample, granting a large gain in statistical precision, and opening the field to unexplored, more differential studies.
Among the proposed thesis activities, the student will perform the reconstruction and selection of D-meson particles on the new proton-proton data samples, correlate them with other reconstructed charged particles and compare the results with predictions from state-of-the art models. The study will be performed exploited the O2 analysis framework, used by the ALICE Collaboration and written in C++, hence a basic knowledge of C++ programming language is requested.
Additional material on the subject can be found in https://arxiv.org/pdf/2110.10043.pdf

Keywords: ALICE experiment, heavy-ion physics, data analysis

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**Title**: Characterisation of novel large area monolithic active pixel detectors in curved geometry

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Recent innovations in the field of silicon imaging technology for consumer applications open extraordinary opportunities for new detector concepts, and hence offer strongly improved physics scope. The technique of stitching in lithography process would permit the realization of “chips” (the basic building block of any solid-sate silicon detector device) with a size as large as the silicon wafer itself. ALICE has built the new ITS2 detector entirely based on monolithic active pixel detectors (MAPS) thinned down to 50 microns or less. At similar thickness values, the silicon becomes very flexible. The ALPIDE chips of the ITS2 detectors have been already tested and proven to work in bended geometry at a curvature radius of 1.8 cm.
The combination of the stitching and the possibility to have very thin flexible devices opens the possibility to realize a detector entirely done by its sensitive component, reducing to the bare minimum the mechanical supports and the other services. ALICE has proposed a further upgrade of the recently installed ITS2 detector, to be realized in truly cylindrical shape (see https://cds.cern.ch/record/2703140/files/LHCC-I-034.pdf). This new vertex detector is planned to be installed during the LHC Long shutdown 3 (LS3 2025) to replace the innermost three layers of the ALICE ITS2. An intense R&D activity is ongoing in view of this objective, with the first prototype of the new large-area chips to be tested and characterized. The thesis will focus on the characterisation of these new devices with measurements in the clean-room, participation to test beams, and analysis of the test-beam data.

Keywords: ALICE experiment, detector perfomance

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**Title**: Measuring the inelastic interaction between antimatter and matter nuclei with the ALICE-HMPID apparatus

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The measurement of the inelastic cross section of the (anti-)deuteron and in general of the light anti-nuclei is of interest for the understanding of the anti-nucleosynthesis in the ultra-relativistic heavy ion collisions. In addition, it is of interest for the study of the anti-nuclei production in the cosmic rays.
We propose a precision measurement in the momentum interval $0.2 < p < 2.2$ GeV/c of the (anti-)deuteron inelastic cross section on an aluminium target, using the High Momentum Particle Identification (HMPID) detector in the experiment ALICE, on the LHC at CERN.
The HMPID is based on Ring Imaging Cherenkov modules using MWPC’s flushed with $CH_4$ and using pad-segmented photocathodes, activated with CsI.
The study of the HMPID performance expected in the measurement by using specific simulation programs, and the estimate of the statistical abundances required for the requested precisions using different colliding systems (pp, p-Pb and Pb-Pb), are the main but not the exhaustive subjects of the thesis.

Keywords: ALICE experiment, heavy-ion physics, Monte Carlo simulation, detector performance

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**Title:** Investigating charm hadronization via Xic+ baryon production measurements with ALICE

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One of the most surprising results of the physics investigated at the LHC have been the unexpected failure of the charm-fragmentation universality among different collision systems and energies, assumed by perturbative QCD models, able to precisely describe the charm hadron production in ee, ep collisions and the charm meson production in pp collisions at LHC.

In particular, ALICE has performed systematic and precise production measurements of charmed baryons in pp collisions, and measurements of the charm fragmentation fractions in pp and p-Pb collisions, that have revealed discrepancies between perturbative QCD models and experimental data. This unexpected finding has opened up new avenues for research, particularly in the study of baryons with charm, forcing the theoretical model to hypothesize further hadronization mechanisms, to explain the charm baryon production measurements. What is still challenging is the description of the baryons with charm and strange quarks, suggesting that the process of hadronization of charm+strange quark in high-energy collisions is more complex than previously thought, and that there may be additional factors at play that are not currently accounted for in theoretical models.

ALICE will profit of the large statistics collected in the Run3 of the LHC at CERN, and of the upgraded vertex detectors, the Inner Tracking Systems, that provides a tracking precision of the order of 20 microns down to transverse momentum of 1 GeV/c, for the study of the charmed-strange baryons, Xic+, that decay in few hundred microns. Machine Learning techniques will help to select signal from the huge combinatorial background, that challenge the measurements.

By conducting precision measurements of the production of the strange- charmed baryon Xic+ and refining theoretical models, ALICE aims to shed more light on the mechanisms of hadronization and the behavior of quarks in high- energy collisions.

keywords: ALICE experiment, pQCD, charm baryon, data analysis