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Prospects for heavy-flavour measurements with the ALICE inner and forward tracker upgrade

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Abstract. During the second long shutdown (LS2) of the LHC the ALICE detector will be improved with the installation of an upgraded Inner Tracking System (ITS) and a new Muon Forward Tracker (MFT). These detectors will crucially contribute to the precise characterization of the high-temperature, strongly-interacting medium created in ultra-relativistic Pb–Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV. In the central barrel, the upgraded ITS will consist of seven cylindrical layers of silicon pixel detectors, starting at a radial distance of 22.4 mm from the beam axis. At forward rapidity, the MFT will be composed of five silicon pixel planes added in the acceptance of the existing Muon Spectrometer ($-4 < \eta < -2.5$), upstream to the hadron absorber. Detailed results on the expected performances for heavy-flavour (HF) measurements down to low transverse momentum, with the upgraded ITS and MFT, will be given for central Pb–Pb collisions for various benchmark analyses, assuming an integrated luminosity of 10 nb^{-1} , as foreseen for the ALICE upgrade programme.

Introduction. The primary goal of ALICE (A Large Ion Collider Experiment) is to explore the properties of the strongly-interacting matter at high temperature and energy density, where the existence of the Quark–Gluon Plasma (QGP) is expected. Heavy quarks, i.e. charm and beauty, are primarily created in initial hard scatterings, therefore they may carry information from the system at its early stage. The heavy-flavour production in heavy-ion collisions is related to the following physics topics.

- The in-medium parton energy-loss mechanism, studied through measurements of the nuclear modification factor (R_{AA}). In particular, it is crucial to characterize the dependencies of energy loss on the parton colour-charge, mass, and energy, as well as on the properties of the medium itself.
- The thermalization of charm and beauty quarks in the QGP through measurements of the azimuthal-flow anisotropy (v_2). This is especially sensitive to the partonic equation of state.
- The in-medium hadronization of heavy quarks, studied by measuring the baryon/meson ratio for charm-hadrons (Λ_c/D) and for beauty-hadrons (Λ_b/B), as well as the D_s production w.r.t. the non-strange D mesons.

Covering a wide rapidity range is crucial for a comprehensive understanding of the observed phenomena and to constrain theoretical models. In particular measurements at large rapidities will give access to the study of the gluon dynamics at small Bjorken- x values, where phenomena related to the saturation of low-momentum gluons can be best investigated.



Goals of the future ALICE heavy-flavour programme. The ALICE [1] detector consists of a central barrel ($|\eta| < 0.9$) placed inside a large solenoidal magnet providing a 0.5 T field, and a Muon Spectrometer located at forward rapidity ($-4 < \eta < -2.5$).

At central rapidity the R_{AA} and the v_2 of D mesons in Pb–Pb collisions were measured from LHC Run 1 data (2009–2013), down to $p_T = 1$ and 2 GeV/ c , respectively. Very precise measurements down to $p_T = 0$ for D mesons, including also D_s , represent one of the primary goals of the future ALICE HF programme. Another important target is the exclusive Λ_c baryon reconstruction, which is the most challenging HF measurement, because the small mean proper decay length ($c\tau = 59 \mu\text{m}$) prevents an effective background rejection based on the decay topology selection. A sizable part of the HF programme at central rapidity includes the reconstruction of beauty-hadrons, both via inclusive and exclusive decay channels. Another ambitious goal is the full reconstruction of the Λ_b baryon that will open the possibility to investigate the beauty baryon sector in Pb–Pb collisions.

At forward rapidity the existing Muon Spectrometer provided interesting results from Run 1 data. However it has an important limitation since no track constraints in the region of the primary vertex are available. This is mainly due to the large distance of the tracking stations from the primary vertex in combination with the multiple scattering induced on the muon tracks by the frontal absorber. Therefore the details of the vertex region are completely smeared out. The installation of a high-position-resolution tracker would improve the resolution of muon tracks in the primary vertex region, allowing to disentangle open charm and beauty contribution to muon production and enabling the separation between prompt and displaced J/ψ mesons. Furthermore it would help in rejecting background muons coming from semi-muonic decays of pions and kaons, which represent a large background source both in single muon and dimuon analyses.

The ALICE Upgrade Strategy. The ALICE upgrade plans foreseen for the LS2 (2018–2019) are discussed in the ALICE Upgrade Letter of Intent [4]. The primary goal of ALICE is to perform high precision measurements of rare probes down to low transverse momentum. These probes, characterized by very low signal-to-background ratios, cannot be selected by a dedicated trigger. Improved performance for such measurements can be obtained with the following strategy.

- A large increase of the luminosity integrated for minimum-bias collisions: the upgrade of the readout capability of several detectors, combined with the new Offline-Online computing system (the “O²” project [3]), will allow us to record Pb–Pb collisions at an interaction rate of about 50 kHz. In particular, the goal is to collect a Pb–Pb sample of at least 10 nb^{-1} (corresponding to about 10^{11} interactions). The largest project within this context concerns the upgrade of the Time Projection Chamber [2] consisting of the replacement of the existing Multi-Wire Proportional Chambers (MWPC) readout by the Gas Electron Multipliers (GEM) detectors¹.

- Improvement of the tracking and vertexing resolution: at central rapidity an upgraded Inner Tracking System (ITS) will significantly improve the tracking performance, in particular the installation of a thinner beam pipe with a smaller radius (from the present value of 29.4 mm down to 18.6 mm) will allow us to position the first detection layer closer to the interaction point. At forward rapidity a new telescope of silicon pixel detectors, the Muon Forward Tracker (MFT), will be added to the Muon Spectrometer upstream of the hadron absorber.

The installation of the upgraded ITS and the MFT, combined with the high then available statistics, will enable several precise HF measurements in a wide rapidity window and down to zero transverse momentum. In this respect ALICE will be unique at the LHC.

¹ The GEM detectors, unlike the MWPC, provide intrinsic ion blocking capabilities preventing back-drifting of ions from the amplification region to the drift volume and therefore enabling the TPC to operate in a continuous, “ungated” readout mode at high rate.

The upgrade of the Inner Tracking system at central rapidity. The new ITS, described in the ITS Technical Design Report (TDR) [6, 5], will improve the impact parameter resolution (by a factor 3 and 6 in $r\varphi$ and z , direction respectively), the tracking efficiency, the transverse momentum resolution and the readout capabilities. The improvement of the impact parameter resolution will be realized by placing the first ITS layer at 22.4 mm from the beam line (present value: 39 mm) as well as by reducing the total material budget per layer: the usage of Monolithic Active Pixel Sensors (MAPS) and the optimization of front-end electronics can reduce it from the present value of 1.14% X_0 to 0.3% X_0 for the three innermost layers. Both the impact parameter at high p_T and the transverse momentum resolution will be improved by increasing the detector segmentation: all layers will be segmented in pixels with dimensions $30 \times 30 \mu\text{m}^2$ (to be compared with $50 \times 425 \mu\text{m}^2$ for the present ITS). Finally the tracking efficiency and the p_T resolution will be further improved by increasing the number of detector layers to seven (present ITS: six layers).

The new Muon Forward Tracker. The MFT detector layout and the expected physics performance are described in the MFT Technical Design Report [7]. The MFT detector will surround the vacuum beam-pipe and will be positioned inside the ITS outer barrel (four outermost ITS layers), in front of the hadron absorber of the Muon Spectrometer. It will consist of 5 layers (each one made by two half-disks) of silicon pixel sensors sharing the same pixel technology as the new ITS [6]. Each layer will be equipped by two detection planes and the corresponding total material budget is expected to be 0.6% X_0 . The muon tracks reconstructed in the muon spectrometer will be extrapolated through the absorber and matched with track segments reconstructed in the MFT planes, enabling the precise determination of the muon production vertex. Detailed performance studies show that the offset resolution is better than 100 μm above 1 GeV/ c , which is enough to perform a reliable separation of muons from charm-hadron ($c\tau \sim 100 \mu\text{m}$) and beauty-hadron ($c\tau \sim 500 \mu\text{m}$) decays.

Expected performance for Heavy-Flavour measurements. A few selected highlights of the HF physics performance expected for the LHC Runs 3 and 4 (foreseen from 2020 onwards after the LS2), assuming $L_{\text{int}} = 10 \text{ nb}^{-1}$, are shown in the following.

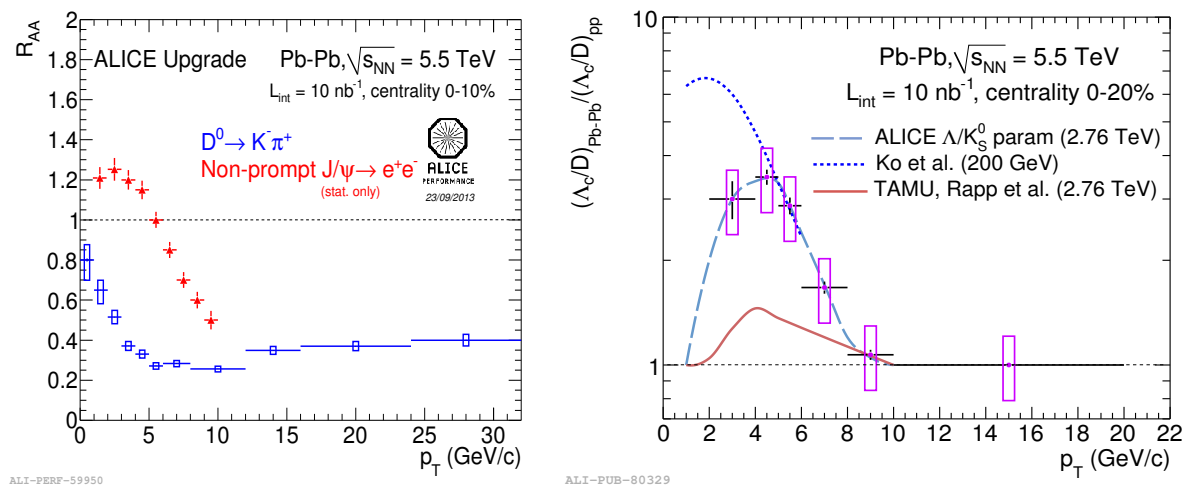


Figure 1. Left: Nuclear modification factor of prompt D^0 and J/ψ from beauty-hadron decays [6]. Right: Double ratio (Λ_c/D) in most central Pb-Pb (0-10%) w.r.t. pp collisions [6]. Both figures refer to the central rapidity region.

The left-hand panel of Fig. 1 shows the R_{AA} of prompt D^0 and the one of J/ψ from beauty-

hadron decays. The precision of the measurements will give the possibility to study the mass-dependence of the charm and beauty quarks energy loss in the QGP in a wide transverse momentum range. In the right-hand panel of the same figure the expected performance for the double ratio Λ_c/D is shown and it is compared to theoretical predictions. The achievable precision will allow us to distinguish among several models providing a better understanding of the hadronization mechanisms.

The left panel of Fig. 2 shows the expected performance for the measurement of muons from charm-hadron decays down to $p_T^\mu = 1$ GeV/c (similar results, not shown here, will be available for beauty decay muons down to $p_T^\mu = 3$ GeV/c). The small statistical uncertainties suggest that precise measurements of charm and beauty production cross sections will be available at forward rapidity down to very low p_T . In the right-hand side of Fig. 2 the non-prompt D^0 R_{AA} at central rapidity is shown with the expected performance for the R_{AA} of non-prompt J/ψ at forward rapidity. Both measurements represent a key tool for accessing beauty production in Pb-Pb collisions down to zero p_T and covering a large rapidity window.

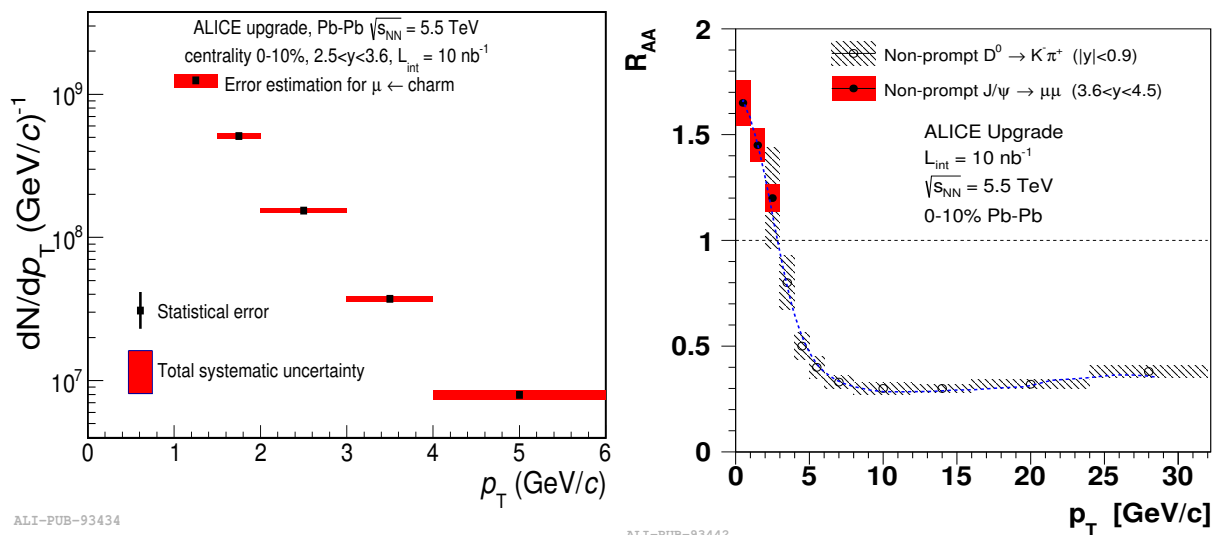


Figure 2. Left: Transverse momentum distribution of single muons from charm-hadrons at forward rapidity [7]. Right: R_{AA} of beauty mesons via displaced J/ψ at forward rapidity, shown together with the expected performance for the displaced D^0 channel at central rapidity [6, 7].

Conclusions. During the LS2 the ALICE detector will undergo a major upgrade. The installation of the upgraded ITS and the MFT within this programme will significantly extend the ALICE physics reach in the HF sector in a large rapidity window. In particular the precision for existing measurements in the charm and beauty sectors will significantly be improved down to $p_T = 0$ and new measurements will be available for the first time in Pb-Pb collisions.

References.

- [1] ALICE Coll. 2008 *JINST* **3** S088002
- [2] ALICE Coll. 2013 *Upgrade of the ALICE Time Projection Chamber* CERN-LHCC-2013-020
- [3] ALICE Coll. 2015 *Technical Design Report of the ALICE Online-Offline Computing System* CERN-LHCC-2015-006
- [4] ALICE Coll. 2012 *J. Phys. G* **41** 087002
- [5] ALICE Coll. 2013 *Addendum to the ALICE Letter of Intent* CERN-LHCC-2013-014
- [6] ALICE Coll. 2013 *J. Phys. G* **41** 087001
- [7] ALICE Coll. 2015 *Technical Design Report of the ALICE Muon Forward Tracker* CERN-LHCC-2015-001