The ALICE Upgrade Program

Thomas Peitzmann[1] for the ALICE collaboration

[1]Nikhef Amsterdam and Utrecht University, The Netherlands.

DOI: `http://dx.doi.org/10.3204/DESY-PROC-2012-02/345`

While groundbreaking measurements on the properties of strongly interacting matter in p+p, p+A and A+A collisions at the LHC are being performed, it is clear that many important questions in heavy-ion physics will remain unanswered in this first phase of beam times up to 2017. The ALICE is setting up a program of detector upgrades to be installed in the LHC shutdown planned for 2017/18, to address the new scientific challenges. We will discuss examples of the scientific frontiers and will present the corresponding upgrade projects under study for the ALICE experiment.

1 Introduction: the physics frontiers for ALICE

In the first years of operation ALICE has demonstrated its excellent capabilities to measure high-energy nuclear collisions at the LHC, delivering exciting results on *elliptic flow*, which appears to be even larger than at RHIC [1], strong *quenching* of high momentum hadrons including first measurements using *identified open charm* mesons [2] and intriguing results on the centrality dependence of charmonium production [3], to just name a few examples. Further data taking up to 2017 will improve the understanding of heavy-ion collisions significantly and will very likely yield comprehensive results on many experimental probes, as e.g. the details of anisotropic flow of light hadrons, inclusive momentum spectra of heavy flavor mesons including their nuclear modification, or the global features of jets in nuclear collisions, all-in-all the baseline program of the ALICE experiment.

Still, crucial measurements will not be possible. For illustration let us consider the study of collective motion of charm. While the measurement of spectra of open charm mesons is challenging, it has already been shown to be feasible, and a further increase in statistics to $1\,\mathrm{nb}^{-1}$ should allow precision measurements of the most abundant D mesons. However, anisotropic flow studies generally require an order of magnitude higher statistics, thus calling for $\approx 10\,\mathrm{nb}^{-1}$ in Pb+Pb collisions. In addition, it is known from light hadrons, that significant differences essential for theoretical understanding of collective flow are observed between mesons and baryons. This requires a measurement of charmed baryons, as e.g. the Λ_c. Furthermore, it is crucial for studies of equilibration properties to cover the lowest transverse momenta possible. Both, the measurement of the Λ_c, and a significant measurement at very low p_T will profit enormously from an improved background rejection and secondary vertex resolution of the tracking detectors. Similar arguments hold for other important physics signals of the quark-gluon plasma, that will not be accessible with the current apparatus and the available integrated luminosity up to the long shutdown in 2017/18. Overall, an upgraded ALICE setup at high luminosity should allow

1. precision studies of primary charm (open and hidden) including flow and correlations,
2. measurements of low mass lepton pairs and thermal photons,
3. studies of jet thermalization via gamma-jet and jet-jet correlations including particle ID, and
4. the search for heavy nuclear states.

In this context, ALICE is preparing an upgrade program to enhance the rate capabilities of the experiment to allow an inspection of Pb+Pb collisions at an interaction rate of 50 kHz and of p+p collisions at a rate adequate for reference measurements, and to develop and implement a significantly improved inner tracking system (ITS).

Other new detectors are being investigated to possibly further enhance the measurement capabilities for the signals mentioned above. Additionally, with an appropriate detector at large rapidity an opportunity arises for measurements, where the influence of small-x partons is more and more important. This is the region, where effects of gluon saturation [4] should be most prominent. Signals consistent with gluon saturation have been observed at RHIC [5], but the interpretation is hampered by the very limited kinematical reach. The larger beam energy of the LHC will allow us to enter a new physics regime with access to much smaller values of x and a larger phase space for saturation due to the expected larger saturation scale.

2 ALICE rate capabilities and the upgraded ITS

Within the current ALICE apparatus, the TPC with its long drift time is limiting the rate capabilities. Using the multi-wire readout chambers, a gated operation (at a maximum of 3.5 kHz) is necessary to limit ion feedback to the drift volume, which would otherwise lead to intolerable space-charge distortions. To be able to inspect a significantly higher interaction rate, new readout chambers based on triple-GEMs will be developed. These would be continuously read out (no gating) and should have small enough ion feedback to allow an operation at 50 kHz interaction rate. In a pipelined readout data would be shipped from the TPC front-end at 10 MHz for later inspection in a high level trigger system (HLT). This will be a major challenge to the DAQ as a maximum bandwidth of $\approx$ 60 Tbit/s will be required. R&D on the GEM readout chambers is ongoing with an emphasis on achieving the projected low ion feedback and in particular on demonstrating the necessary stability in a high multiplicity/high rate environment.

Such a system would also be ready to work with a significantly higher interaction rate for p+p reactions, which might be necessary to accumulate sufficient signals for reference measurements. The new ITS will be developed according to the rate specifications. The readout electronics of all existing detector systems will be modified to accommodate the rate capabilities. Some systems, like e.g. the TRD will likely share the pipelined electronics with the TPC, other detectors, e.g. the electromagnetic calorimeter (EMCal), might preferably be readout on L1 triggers provide by a hardware trigger unit.

A completely new Inner Tracking System (ITS) will be developed. The most important features of the new design will be:

- A decrease of the radial distance of the first layer to the beam to 22 mm (from 39 mm),
- a reduction of the layer thickness possibly down to 50 μm (from 350 μm), and

- a higher granularity with pixel sizes as small as 20x20 μm^2.

Two detector options are currently under investigation: a combination of the three inner layers consisting of pixel detectors (either hybrid silicon pixel detectors or monolithic active pixel sensors) with four outer layers of silicon strip detectors, or alternatively all seven layers implemented as pixel detectors. Independent of the specific design, the new ITS will improve the secondary vertex resolution by a factor of ≈ 3 and allow measurements down to much lower values of p_T. Furthermore the high efficiency and low contamination of the new ITS should allow for enhanced level 2 trigger capabilities. Examples of the estimated performance of the upgraded ITS are shown in Fig. 1: On the left the considerable improvement in the significance for the D^0 measurement, on the right the achievable statistical uncertainty on the Λ_c/D^0 ratio, which wouldn't be measurable with the current ITS.

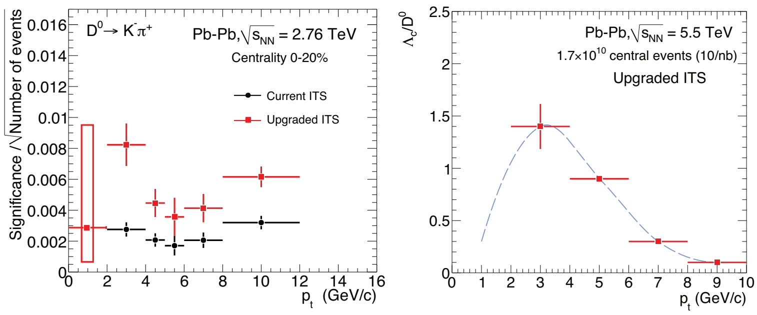

Figure 1: Left: Comparison of the significance for the D^0 obtained for the current and the upgraded ITS as a function of p_T in central Pb+Pb collisions. Right: Estimated statistical uncertainty on the measurement of the Λ_c/D^0 ratio using $1.7 \cdot 10^{10}$ central Pb+Pb collisions.

3 Additional Detector Upgrades

A number of additional upgrades further enhancing the ALICE detector setup is currently under study. The Muon Forward Tracker (MFT), adding tracking in front of the muon absorber, would allow us to reconstruct possible secondary vertices of muon tracks. This would remove the largest limitation of the current forward muon measurements, improving the performance for low mass dileptons and enabling the identification of J/ψ from B decays. The MFT would use silicon tracking with technologies very similar to those considered for the ITS upgrade.

The VHMPID[1], a new RICH detector, should be able to identify hadrons on a track-by-track basis up to $p_T = 25\,\text{GeV}/c$. The detector would be placed in front of (part of) the electromagnetic calorimeter to allow efficient hadron identification in jets. It would consist of a focusing RICH with a pressurized gaseous C_4F_{10} radiator of ≈ 50 cm length, using spherical mirrors, a CsI-based photon detector and front-end electronics based on the Gassiplex chip.

An obvious candidate for forward measurement with the generally higher momenta of particles in the lab system is an electromagnetic calorimeter with its intrinsically better resolution at

[1] Very High Momentum Particle ID

higher energies and the possibility to identify photons and neutral hadrons. A possible location of such a detector would be on the A-side (opposite the Muon Spectrometer) at a distance of $\approx 3.5\,\mathrm{m}$. While the demands on energy resolution are moderate at this location, the small opening angle of neutral pion decays and the overall large particle density in Pb+Pb collisions will require good position resolution and two-particle separation power. To achieve this, the Molière radius of the material should be small and the granularity of the signal readout high. The favorite design for the Forward Calorimeter (FoCal) would use W ($R_M = 9\,\mathrm{mm}$) as absorber and Si-sensors as active material. This could provide a granularity $< 1\,\mathrm{mm}^2$ resulting in superior performance for γ/π^0 discrimination and high particle density measurements compared to existing calorimeters. As sensor technologies, conventional pad/pixel sensors with separate readout and monolithic pixels are being investigated. Fig. 2 shows the kinematic reach in x and Q^2 for different detectors at the LHC (assuming LO kinematics). With a direct photon measurement, FoCal would provide significant coverage for small x and a range of Q^2, which is crucial for measurements relevant for gluon saturation, but is not yet covered by existing experiments.

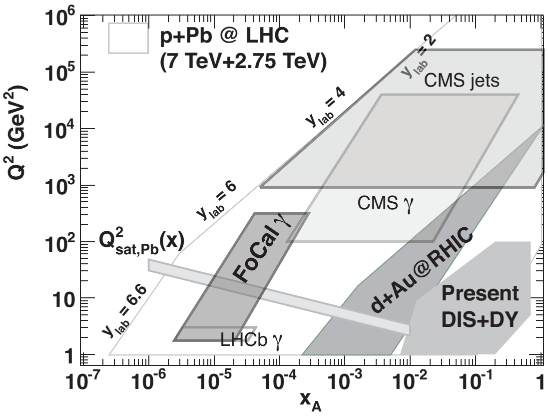

Figure 2: Kinematic coverage in Q^2 and Bjorken-x. Shown are regions where information is available from earlier measurements (DIS, Drell-Yan, and d+A at RHIC) [6], as well as estimates for existing LHC detectors and the ALICE FoCal upgrade.

References

[1] K. Aamodt et al. (ALICE), Phys. Rev. Lett. 105 (2010) 252302.

[2] B. Abelev et al. (ALICE), submitted to JHEP (2012), preprint arXiv:1203.2160

[3] B. Abelev et al. (ALICE), submitted to Phys. Rev. Lett. (2012), preprint arXiv:1202.1383

[4] L.V. Gribov, E.M. Levin, and M.G. Ryskin, Phys. Rept. 100 (1983) 1; A.H. Mueller and J.-W. Qiu, Nucl. Phys. B268 (1986) 427; L.D McLerran and R. Venugopalan, Phys. Rev. D50 (1994) 2225; Phys. Rev. D49 (1994) 3352.

[5] I. Arsene et al. (BRAHMS), Phys. Rev. Lett. 93 (2004) 242303; J. Adams et al. (STAR), Phys. Rev. Lett. 97 (2006) 152302.

[6] C.A. Salgado, J. Phys. G 38 (2011) 124036.