PROCEEDINGS OF SCIENCE

Measurement of low-mass dileptons in ALICE

Victor Feuillard for the ALICE Collaboration[a,*]

[a] *Physikalisches Institut Heideleberg,*
Im Neuenheimer Feld 226, Heidelberg, Germany

E-mail: victor.jose.gaston.feuillard@cern.ch

The ALICE experiment is optimized for the study of the quark-gluon plasma (QGP), a state of matter where, due to high temperature and density, chiral symmetry is restored, and quarks and gluons are deconfined. In order to obtain information on its properties, it is particularly valuable to study lepton pair production, as leptons are produced in the plasma at all stages of its evolution and carry information about the medium properties at the time of their emission with negligible final state effects. In particular, the production of dileptons is a promising tool for the understanding of the chiral symmetry restoration and the thermodynamical properties of the QGP. To differentiate possible medium contributions to the dilepton yield in nucleus-nucleus collisions from those originating in hadron decays, studies in pp and p–A collision systems are necessary to obtain a medium-free reference. These measurements can also be used to study charm and beauty production, which are an excellent test of perturbative quantum chromodynamics (pQCD) predictions. We will report on the latest results for low mass dilepton production measured with the ALICE detector in various collision systems at mid- and forward rapidity. All the measurements are compared to the expected dilepton yields from known hadronic sources and model calculations. Finally, we will discuss the prospects for future measurements.

**** Particles and Nuclei International Conference - PANIC2021 ****
**** 5 - 10 September, 2021 ****
**** Online ****

[*] Speaker

PoS(PANIC2021)233

1. Introduction

The quark-gluon plasma (QGP) is a state of matter predicted by QCD where quarks and gluons are deconfined. It is possible to recreate the QGP with ultra-relativistic heavy-ion collisions. The production of dileptons is a promising tool for the understanding of the chiral symmetry restoration in the hot medium and the thermodynamical properties of the QGP [1]. Studies of dileptons in pp and p–Pb collisions provide reference measurements, and a way to study cold nuclear matter effects in p–Pb collisions. In the following, a selection of some of the latest dilepton measurements obtained by ALICE in pp, p–Pb, and Pb–Pb collisions are reported. A full description of the ALICE detector and performance can be found in [2].

There are several sources of dileptons. In the low mass range ($0 < m_{\mathrm{ll}} < 1.1$ GeV$/c^2$) the main source are Dalitz decays of pseudo-scalar and vector mesons (π^0, η, ω, η', ϕ), and 2-body decays of light-flavor vector mesons (ρ, ω, ϕ). In particular, the $\phi \rightarrow \mathrm{l^+l^-}$ decay allows to study the strangeness production and ρ is sensitive to the chiral symmetry restoration. In the intermediate mass region ($1.1 < m_{\mathrm{ll}} < 2.7$ GeV$/c^2$), dileptons are coming mainly from the decays of correlated heavy-flavor hadrons ($\mathrm{c\bar{c}} \rightarrow \mathrm{D\bar{D}} \rightarrow \mathrm{XYl^+l^-}$ and $\mathrm{b\bar{b}} \rightarrow \mathrm{B\bar{B}} \rightarrow \mathrm{XYl^+l^-}$). Their yield is sensitive to the production cross section of charm and beauty quarks, $\sigma_{\mathrm{c\bar{c}}}$ and $\sigma_{\mathrm{b\bar{b}}}$. In addition, thermal radiation contributes to the e+e- spectrum over a broad mass range and provides insight into the temperature of the medium. However, the measurement of the thermal radiation is difficult in the intermediate mass range due to the dominant contribution from charm and beauty hadrons.

2. Dimuon Spectra

In pp collisions, new measurements of the ϕ meson cross section at forward rapidity were performed at $\sqrt{s}$ = 5.02, 8 and 13 TeV [3]. The results are compared with measurements at $\sqrt{s}$ = 2.76 and 7 TeV, and are shown in Figure 1 left. The differential cross section as a function of p_T shows a hardening of the p_T spectra with increasing collision energy.

In Pb–Pb collisions, the nuclear modification factor is used to quantify the effect of the medium on the ϕ meson production, and is defined as $R_{AA} = (1/N_{\mathrm{coll}}).Y_{\mathrm{PbPb}}/Y_{\mathrm{pp}}$, with Y_{PbPb} and Y_{pp} the production yield in Pb–Pb and pp collisions and N_{coll} the number of binary nucleon-nucleon collisions. The R_{AA} of the ϕ meson measured at $\sqrt{s_{NN}}$ = 2.76 TeV at forward rapidity [4] is shown in Figure 1 right. A suppression is observed in central collisions, whereas the R_{AA} is compatible with unity in peripheral collisions. Results at forward and midrapidity are compatible within uncertainties, which hints towards similar mechanisms driving the interaction of the ϕ meson with the medium in the two rapidity ranges.

3. Dielectron spectra

The heavy-flavor cross section in pp collisions at midrapidity was measured recently at $\sqrt{s}$ = 5.02 TeV [5]. The cross section is compared with results at $\sqrt{s}$ = 7 and 13TeV [6, 7], derived using the same event generators, i.e. PYTHIA [8] or POWHEG [9]. The extracted cross sections are all in agreement with FONLL calculations [10] within uncertainties. The results are shown in Figure 2. However, a new measurement of the charm quark fragmentation fractions was performed [11],

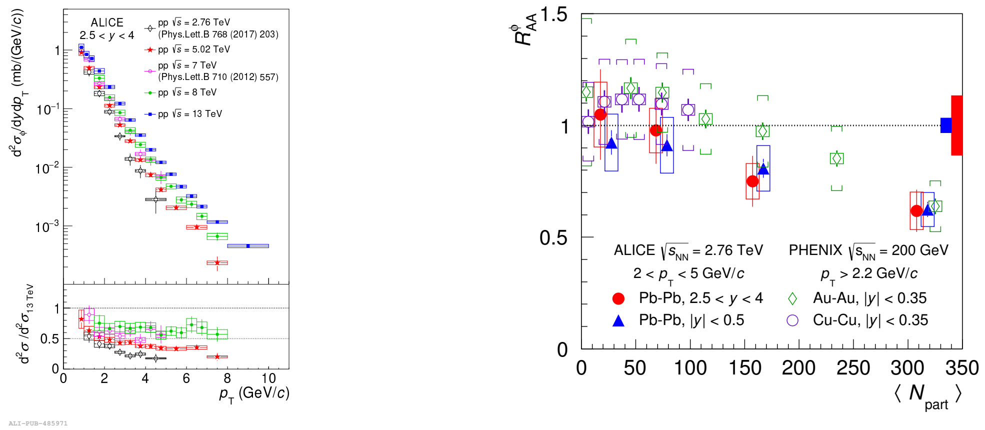

Figure 1: Left: Differential ϕ meson cross section as a function of p_T [3]. Right: R_{AA} of the ϕ meson as a function of $\langle N_{\text{part}} \rangle$ [4].

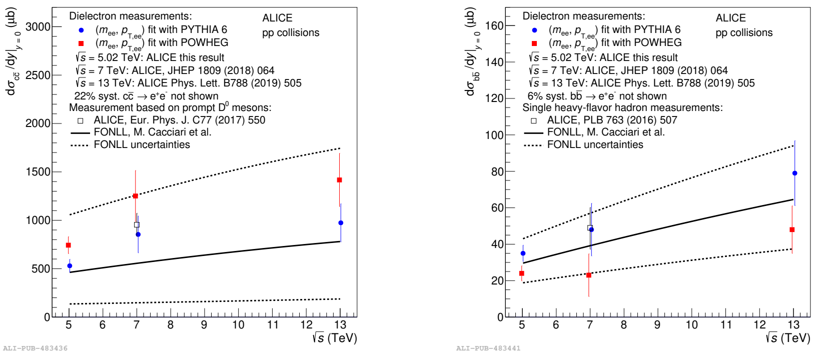

Figure 2: Cross sections at midrapidity for $c\bar{c}$ (left) and $b\bar{b}$ (right) as a function of $\sqrt{s}$ in pp collisions [5]

which leads to a modification of the value of $\sigma_{c\bar{c}}$ measured via open-charm hadrons and the effective branching ratio for c$\rightarrow$e. Consequently the charm production measured via e^+e^- will be updated accordingly.

In p–Pb collisions, a new measurement of the $R_{\text{p–Pb}}$was performed at $\sqrt{s_{NN}}$ = 5.02 TeV [5]. The nuclear modification factor is defined as $R_{\text{p–Pb}} = (1/A).(d\sigma^{\text{p–Pb}}_{\text{ee}}/dm_{\text{ee}})/(d\sigma^{\text{pp}}_{\text{ee}}/dm_{\text{ee}})$, with $\sigma^{\text{p–Pb}}_{\text{ee}}$ and $\sigma^{\text{pp}}_{\text{ee}}$ the cross section for dielectron production in p–Pb and pp collisions respectively, and A denoting the mass number of the Pb nucleus. The result is shown in Figure 3 left. For $m_{ee} < 1.1$ GeV/c^2, $R_{\text{p–Pb}} < 1$ whereas in the intermediate mass region, $R_{\text{p–Pb}}$ is compatible with unity within uncertainties. This suggests a different scaling behavior of the light-flavor production from binary NN collision scaling.

Finally, the dielectron production was measured recently at midrapidity in pp collisions at $\sqrt{s}$ = 13 TeV with a reduced magnetic field [12], allowing to investigate a low m_{ee} and $p_{\text{T,ee}}$ region. The result is shown in Figure 3 right. Within the uncertainties, the dielectron cross section and the hadronic cocktail are in good agreement at $m_{\text{ee}}<m_{\pi\pi}$while an excess over the hadronic cocktail is observed at larger masses, with a significance of 1.6σ. This excess cannot be explained with contributions from known hadronic decays.

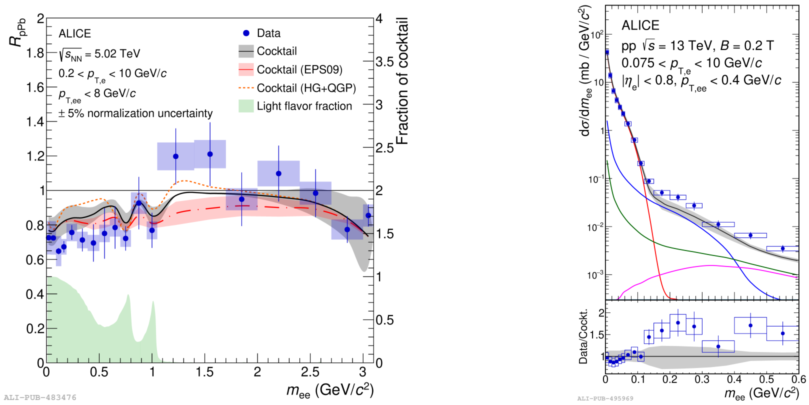

Figure 3: Left : Dielectron $R_{\text{p-Pb}}$ as a function of invariant mass at $\sqrt{s_{NN}}$ = 5.02 TeV [11]. Right : Soft Dielectron cross section as a function of invariant mass [12]

4. Outlook for Run 3 and 4

In the future, dilepton studies will profit from the now installed upgrades of the ALICE detector [13]. The upgrade of the ITS and TPC will allow to improve vertex resolution and increase the readout rate in Pb – Pb collisions by a factor 100. In particular, a better separation of prompt sources from heavy-flavor electrons will be achieved via DCA studies. At the same time, the installation of the Muon Forward Tracker will add vertexing capability to the ALICE muon spectrometer and improve the dimuon mass resolution and the signal over background. Together, these upgrades will significantly increase the precision of dielectron and dimuon, as well as electron-muon measurements. Finally, runs with low magnetic fields will give access to very soft dielectron production at the LHC energies.

References

[1] R. Rapp et al., *The Chiral Restoration Transition of QCD and Low Mass Dileptons*, Landolt Bornstein **23** (2010) 134 [0901.3289].

[2] ALICE collaboration, *Performance of the ALICE Experiment at the CERN LHC*, Int. J. Mod. Phys. **A29** (2014) 1430044 [1402.4476].

[3] ALICE collaboration, *Energy dependence of ϕ meson production at forward rapidity in pp collisions at the LHC*, Eur. Phys. J. C **81** (2021) 772 [2105.00713].

[4] ALICE collaboration, *ϕ meson production at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV*, Eur. Phys. J. C **78** (2018) 559 [1804.08906].

[5] ALICE collaboration, *Dielectron production in proton-proton and proton-lead collisions at $\sqrt{s_{NN}}$ = 5.02 TeV*, Phys. Rev. C **102** (2020) 055204 [2005.11995].

[6] ALICE collaboration, *Dielectron production in proton-proton collisions at $\sqrt{s}$ = 7 TeV*, JHEP **09** (2018) 064 [1805.04391].

[7] ALICE collaboration, *Dielectron and heavy-quark production in inelastic and high-multiplicity proton–proton collisions at $\sqrt{s_{NN}}$ = 13TeV*, Phys. Lett. B **788** (2019) 505 [1805.04407].

[8] T. Sjostrand, S. Mrenna and P.Z. Skands, *PYTHIA 6.4 Physics and Manual*, JHEP **05** (2006) 026 [hep-ph/0603175].

[9] S. Alioli et al., *A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX*, JHEP **06** (2010) 043 [1002.2581].

[10] M. Cacciari et al., *The P(T) spectrum in heavy flavor hadroproduction*, JHEP **05** (1998) 007 [hep-ph/9803400].

[11] ALICE collaboration, *Charm-quark fragmentation fractions and production cross section at midrapidity in pp collisions at the LHC*, Phys. Rev. D **105** (2022) L011103 [2105.06335].

[12] ALICE collaboration, *Soft-Dielectron Excess in Proton-Proton Collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. Lett. **127** (2021) 042302 [2005.14522].

[13] ALICE collaboration, *Upgrade of the ALICE Experiment: Letter Of Intent*, Journal of Physics G: Nuclear and Particle Physics **41** (2014) 087001.