PoS PROCEEDINGS OF SCIENCE

Low-mass dielectron measurements in pp, p–Pb and Pb–Pb collisions with ALICE at the LHC

Daiki Sekihata[a,*] **on behalf of the ALICE Collaboration**

[a] *Center for Nuclear Study, the University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan*

E-mail: daiki.sekihata@cern.ch

The production of low-mass dielectrons is one of the most promising tools to understand the properties of the quark–gluon plasma (QGP) created in ultra-relativistic heavy-ion collisions. In this contribution, heavy-flavor ($c\bar{c}$ and $b\bar{b}$) production in pp and p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV and the soft-dielectron excess in pp collisions at $\sqrt{s}$ = 13 TeV are presented. Dielectron production in p–Pb collisions plays an important role to investigate initial-state effects due to the presence of the cold nuclear matter in the collision. Heavy-flavor production cross sections have been extracted from the intermediate mass region by fitting to the dielectron invariant mass ($m_{\rm ee}$) and pair transverse momentum ($p_{\rm T,ee}$) in pp and p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV, and the nuclear modification factor $R_{\rm pPb}$ as a function of $m_{\rm ee}$ is firstly extracted at the LHC energy. Results in pp collisions at $\sqrt{s}$ = 13 TeV with the reduced solenoid magnetic field at 0.2 T, allowing us to test very soft dielectron production, are also presented. An excess in the yields is observed at very low $p_{\rm T,ee}$ and the observed excess is described by neither hadronic bremsstrahlung nor thermal radiation.

HardProbes2020
1-6 June 2020
Austin, Texas

*Speaker

https://pos.sissa.it/

PoS(HardProbes2020)047

1. Introduction

Dielectrons are produced by various sources in high-energy heavy-ion collisions, namely, decays of light-flavor hadrons, semileptonic decays of heavy-flavor hadrons, thermal radiation from a partonic phase called quark–gluon plasma (QGP), where quarks and gluons are deconfined from hadrons, and a hadronic phase. In the low-mass region ($m_{\rm ee} < m_{\phi}$), the dielectron invariant mass spectrum is dominated by π^0, η meson decays, vector meson decays (ρ^0, ω and $\phi \rightarrow e^+e^-$) and direct virtual photons emitted from a partonic phase ($qg \rightarrow q\gamma^*$, $q\bar{q} \rightarrow g\gamma^*$) and a hadronic phase ($\pi^+\pi^- \rightarrow \rho\gamma^*$, $\pi^{\pm}\rho \rightarrow \pi^{\pm}\gamma^*$). The intermediate mass region ($m_{\phi} < m_{\rm ee} < m_{{\rm J}/\psi}$) reflects direct thermal radiation from the QGP ($q\bar{q} \rightarrow e^+e^-$) and correlated semileptonic heavy-flavor decays. The high-mass region ($m_{{\rm J}/\psi} < m_{\rm ee}$) contains dielectrons from correlated semileptonic heavy-flavor decays, quarkonia decays and Drell-Yan processes.

ALICE took data in various collision systems at different energies during Run 2 (2015-2018). The data samples collected in pp and p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV allow us to measure heavy-flavor production cross sections in both systems at the same energy, and thus evaluate cold nuclear matter effects, e.g. shadowing. Furthermore, ALICE collected pp data at $\sqrt{s}$ = 13 TeV with a reduced magnetic field B = 0.2 T, which provides the possibility to study soft dielectron production in an unexplored kinetic regime at very low values of invariant mass and pair transverse momentum.

2. Heavy-flavor production in pp and p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV

The dielectron cross sections as a function of $m_{\rm ee}$ are measured in pp and p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV [1], shown in Fig.1. The correlated pairs from open heavy-flavor decays

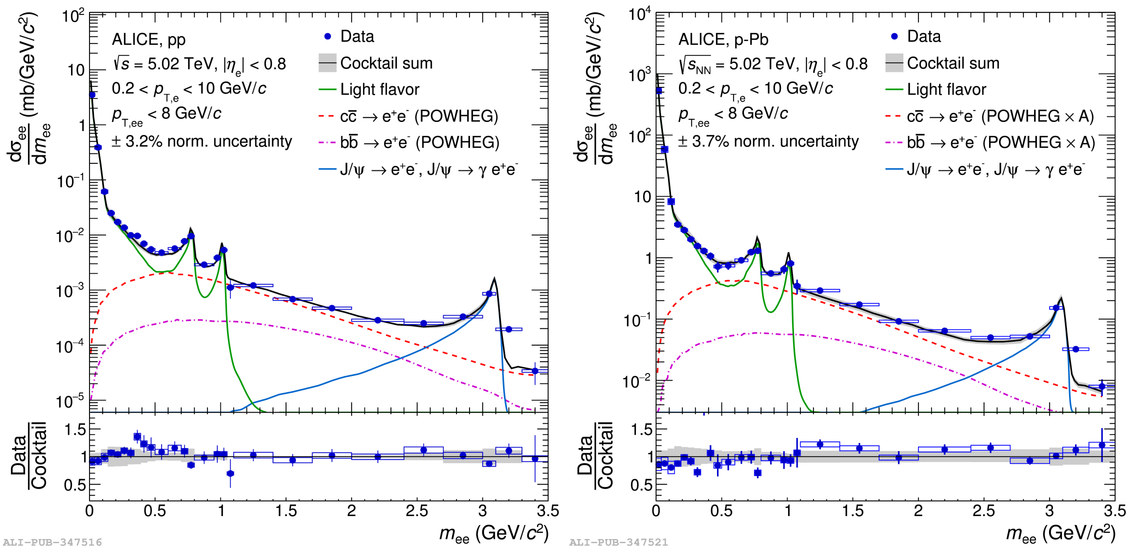

Figure 1: Dielectron invariant mass spectra compared with hadronic cocktails (i.e. sum of all known hadronic sources) in pp (left) and p–Pb (right) collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV [1]. The heavy-flavor components are fitted to the pp data in the intermediate-mass region. Their contributions are scaled by the atomic mass number of Pb (A = 208) in p–Pb collisions.

are calculated with the POWHEG event generator and transported into detector responses in pp collisions. In p–Pb collisions, the heavy-flavor contributions are scaled by the atomic mass number of Pb (A = 208). Then, the nuclear modification factor R_{pA} defined as

$$R_{\mathrm{pA}}(m_{\mathrm{ee}}) = \frac{dN^{\mathrm{pA}}_{\mathrm{ee}}/dm_{\mathrm{ee}}}{\langle T_{\mathrm{pA}} \rangle \times d\sigma^{\mathrm{pp}}_{\mathrm{ee}}/dm_{\mathrm{ee}}},$$

where $d\sigma^{\mathrm{pp}}_{\mathrm{ee}}/dm_{\mathrm{ee}}$ is the m_{ee}-differential cross section in pp collisions and $dN^{\mathrm{pA}}_{\mathrm{ee}}/dm_{\mathrm{ee}}$ is the m_{ee}-differential yield in p–Pb collisions, has been measured. The nuclear overlap function T_{AA} is to scale the cross section in pp collisions. This is the first measurement of R_{pA} at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV to study cold nuclear matter effects. The R_{pA} as shown in Fig. 2 is consistent with unity in the intermediate-

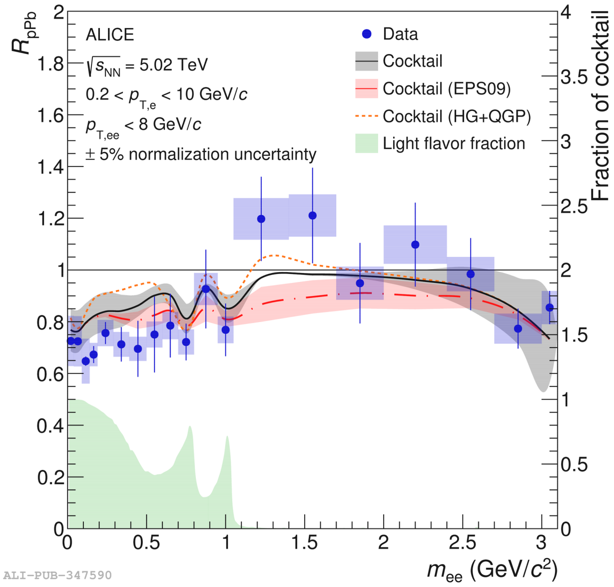

Figure 2: The nuclear modification factors R_{pA} as a function of m_{ee} in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV [1]. The hadronic cocktail is shown by the black curve with a gray band indicating its systematic uncertainties. The cocktail with a modified charm production by the red dashed curve and with thermal radiation from hadronic and partonic phase by the orange dashed curve are also shown respectively.

mass region. An additional cocktail with a modification of the open-charm contribution (e.g. shadowing according to EPS09) is shown by the red dashed curve, which indicates that cold nuclear matter effects to dielectron production could be small and no conclusion can be made by the current measured results. On the other hand, the orange dashed curve includes additional contributions from hadron gas and QGP in p–Pb collisions, which compensates the cold nuclear matter effects.

3. Excess of soft-dielectron production in pp collisions at $\sqrt{s}$ = 13 TeV with B = 0.2 T

An excess over hadronic sources was observed at small invariant mass in proton-proton collisions at the Intersecting Storage Rings (ISR) [2], which is not explained by hadronic bremsstrahlung. ALICE reduced solenoid's magnetic field from 0.5 T to 0.2 T for a period of time during pp collisions at 13 TeV to enhance the acceptance for the pairs with low m_{ee} and $p_{\mathrm{T,ee}}$. This experimental setup allowed us to measure electrons at lower p_{T} down to 75 MeV/c, which opened the unexplored kinetic regime for $m_{\mathrm{ee}} < m_{\eta}$ and $p_{\mathrm{T,ee}} < 0.4$ GeV/c at the LHC. The main contribution to the hadronic cocktail in the kinematic region of interest is the η meson. Thus, a parameterization the of η/π^0 ratio as a function of p_{T} with ALICE measurements is performed and extended by the CERES/TAPS results down to $p_T < 0.4$ GeV/c [3], assuming no dependence on collision energy. The dielectron cross section as a function of m_{ee} for $p_{\mathrm{T,e}} > 0.075$ GeV/c and $p_{\mathrm{T,ee}} < 0.4$ GeV/c

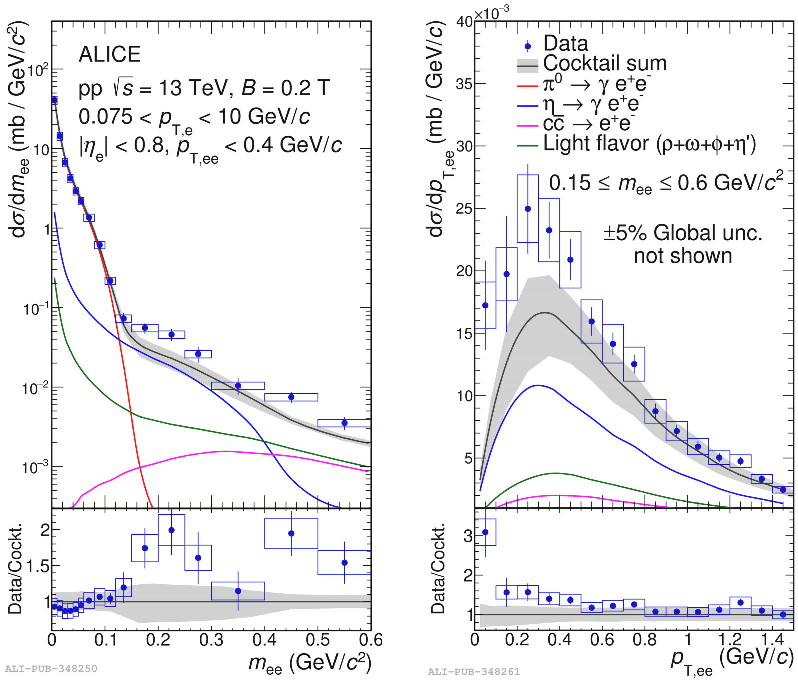

Figure 3: Dielectron invariant mass spectrum m_{ee} (left) and pair transverse momentum $p_{\mathrm{T,ee}}$ spectrum (right) in pp collisions at $\sqrt{s}$ = 13 TeV [3]. The different sources of the hadronic cocktail are shown as solid lines. The error bars and boxes indicate the statistical and systematic uncertainties of the data points respectively. The cocktail uncertainties are shown as gray bands. The ratios of data over cocktail are shown in the bottom panels.

is shown in the left panel of Fig. 3. The hadronic cocktail agrees with data at $m_{\mathrm{ee}} < m_{\pi^0}$ within uncertainties, while an excess over the cocktail is observed at larger masses. The right panel of Fig. 3 shows the $p_{\mathrm{T,ee}}$-differential cross section in the mass range $0.15 < m_{ee} < 0.6$ GeV/c^2, showing that the excess is most pronounced at $p_{\mathrm{T,ee}} < 0.4$ GeV/c. The enhancement factor is 1.69 ± 0.14 (stat.) $\pm$ 0.18 (syst.) $\pm$ 0.36 (cocktail) for $0.15 < m_{\mathrm{ee}} < 0.6$ GeV/c^2 and $p_{\mathrm{T,ee}} < 0.4$ GeV/c. An excess yield is extracted by subtracting the hadronic cocktail from the measured m_{ee} and $p_{\mathrm{T,ee}}$ spectra. Then, the excess yield is corrected for the single-electron acceptance, assuming isotropic decay in the pair center-of-mass frame. Fig. 4 shows the comparison of the excess yield with theoretical models. A calculation of bremsstrahlung from initial- and final-state hadrons [4] does not describe data. Also a calculation of thermal dielectrons from a hadronic many-body system with a fireball lifetime of 2 fm/c [5] fails to reproduce data.

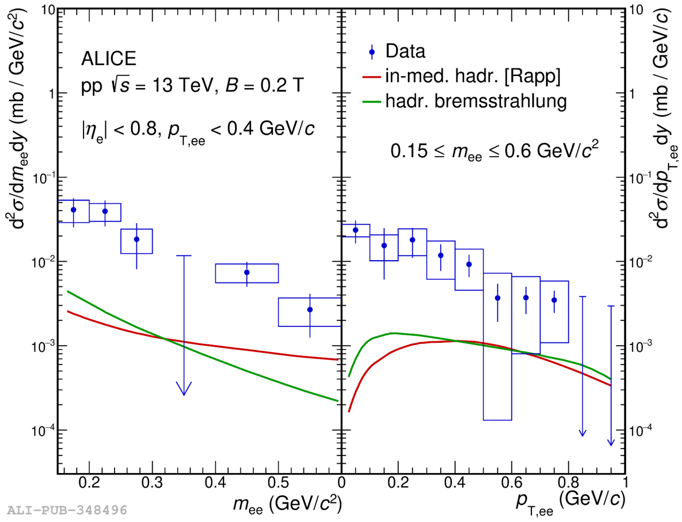

Figure 4: Dielectron excess spectra as a function of m_{ee} (left) and $p_{T,ee}$ (right) after subtracting the hadronic cocktail [3]. Arrows indicate upper limits at 90% confidence level. Theory curves are calculations based on bremsstrahlung from initial- and final-state hadrons [4] and thermal dielectron production [5].

4. Summary and outlook

Heavy-flavor production cross sections are extracted from the intermediate-mass region in pp and p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. An interplay between cold nuclear matter effects and a thermal contribution can not be ruled out. Therefore, it is important to separate dielectrons from heavy-flavor decays and those from prompt thermal radiation by their life time.

An excess of soft-dielectrons over the hadronic decays is observed in pp collisions at $\sqrt{s}$ = 13 TeV. The excess yield is explained by neither bremsstrahlung from initial- and final state hadrons nor by thermal dielectron production. Forthcoming precision measurements with the upgraded ALICE detector will elucidate the mechanisms of soft-dielectron production.

References

[1] S.Acharya et al., Dielectron production in proton–proton and proton–lead collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:2005.11995

[2] T. Åkesson et al., The production of prompt positrons at low transverse momentum increases with the square of the associated charged multiplicity, Phys. Lett. B 192 no. 3, (1987) 463-470

[3] S.Acharya et al., Soft-dielectron excess in proton–proton collisions at $\sqrt{s}$ = 13 TeV, arXiv:2005.14522

[4] V. Balek, N. Pisutova, and J. Pisut, A search of a mechanism responsible for bremsstrahlung enhancement in hadronic reactions. III; Low mass dilepton production, Acta Physica Slovaca; 41 no. 4, (1991).

[5] R. Rapp, Dilepton Spectroscopy of QCD Matter at Collider Energies, Adv. High Energy Phys. 2013 (2013) 148253