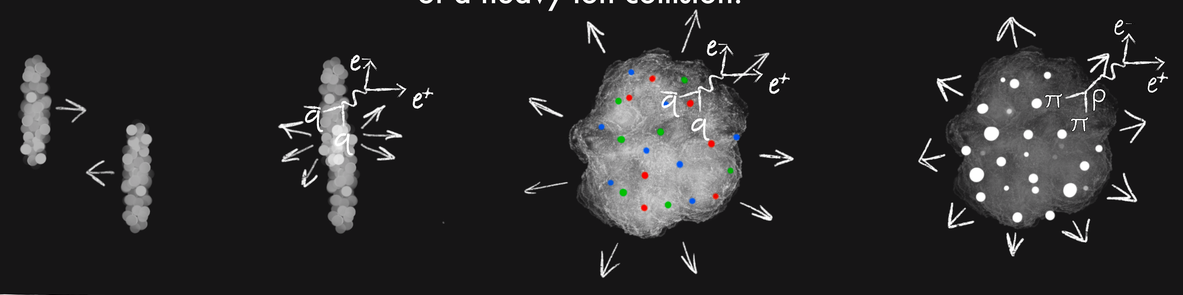
Dielectron measurements with ALICE 3

Sebastian Scheid for the ALICE Collaboration

LHCC Poster Session

Messengers from the Medium

Dielectrons (virtual photons) are produced in all stages of a heavy ion collision. Since the are not interacting via the strong force, they leave the collision unscathed after their production, rendering them ideal messenger to study the whole evolution of a heavy ion collision.



A Next Gen Heavy Ion Experiment

High resolution retractable vertex detector
- 1st layer at 5 mm distance from interaction point (pointing resolution < 20 µm)

Large acceptance silicon tracker
- Barrel + Forward discs

Super-conductiong Magnet system
- Good *momentum* resolution over whole acceptance

Large coverage for particle identification

Electron Identification:
- TOF layers (low p_T)
- RICH (intermediate p_T)
- ECal/Preshower (high p_T)

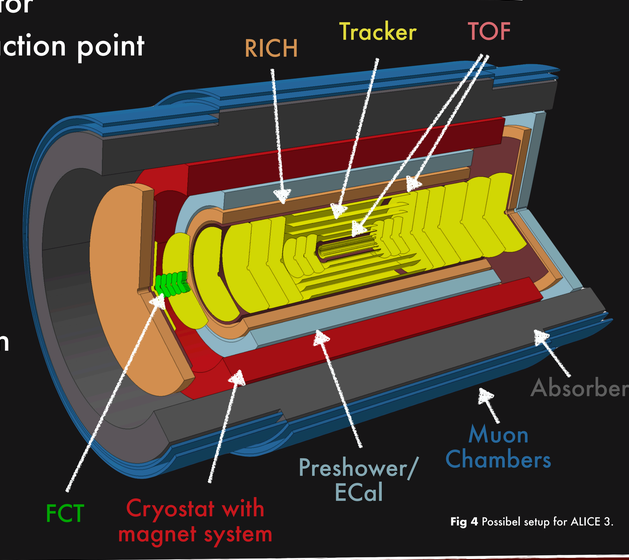
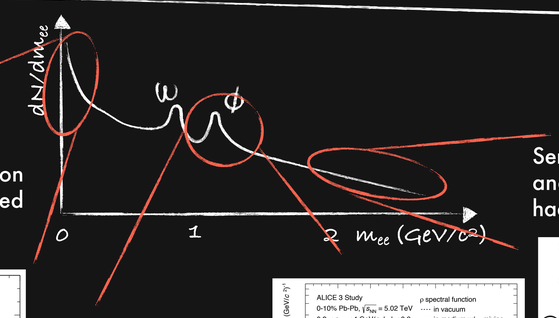


Fig 4 Possibel setup for ALICE 3.

Dielectrons beyond 2030

Transport peak in spectral function at very low photon energy related to electric conductivity



Chiral mixing of ρ-a_1 changes the shape of thermal dielectron spectrum in the mass range of $0.9 < m_{ee} < 1.4$ GeV/c^2

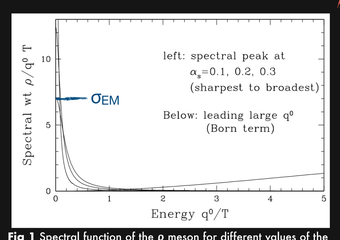
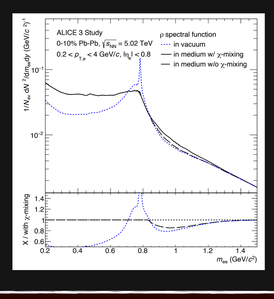


Fig 1 Spectral function of the ρ meson for different values of the strong coupling α_s as a function of the virtual photon energy normalised to the medium temperature [1].



Sensitivity to initial anisotropies and η/s, not accessible with hadronic probes

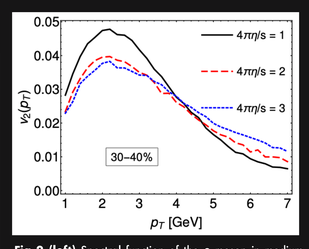


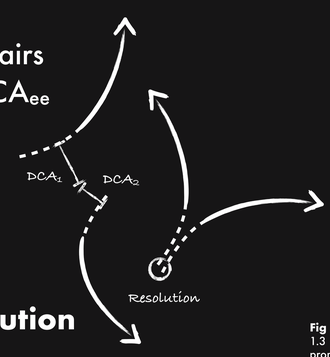
Fig 2 (left) Spectral function of the ρ meson in medium with and without chiral mixing and the vacuum expectation [2].
Fig 3 (bottom) Elliptic flow v_2 of dielectron pairs for $m_{ee} > 1$ GeV/c^2 as a function of $p_{T,ee}$ for different values of shear viscosity η/s[3].

Heavy Flavour Rejection via DCA

Separation of prompt and non-prompt pairs via pair Distance-of-Closest-approach DCA_{ee}

$$DCA_{ee} = \sqrt{\frac{DCA_1^2 + DCA_2^2}{2}}$$

Expectation:
DCA_{ee}(prompt) < DCA_{ee}(HF)
Separation power driven by resolution



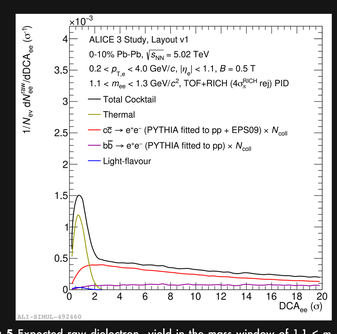


Fig 5 Expected raw dielectron yield in the mass window of 1.1 < m_{ee} < 1.3 GeV/c^2 as a function of the pair distance of closest approach for prompt thermal dielectrons calculated by Ralf Rapp, and the contributions from light flavour decays, as well as the decays of charm and beauty hadrons.

Signal, Background and Prefilter

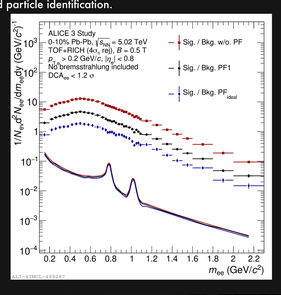
Signal based on previous measurements [4,5] and calculations by Ralf Rapp [2]

The main background sources are combinatorial pairs from different hadron decays.

Statistical uncertainties significantly smaller than expected systematic uncertainties

After DCA_{ee} selection thermal signal dominates over wide mass range.

Fig 5 Expected signal (lines) and combinatorial background (points) as a function of the dielectron invariant mass for different scenarios of prefilters. The detector response for the TOF and RICH detector was simulated and applied. In addition electrons with a $p_T > 0.2$ GeV/c were selected. Only pairs with a DCA_{ee} smaller than 1.2σ were selected (rejecting HF). In the PF1 case a pre selection on the pair level was performed and electrons belonging to a pair with an opening angle < 100 mrad and a $m_{ee} < 50$ MeV/c^2 were rejected (mainly LF). These electrons were selected with a $p_T > 0.08$ GeV/c. In the ideal PF case, electrons with $p_T > 0.02$ GeV/c were selected, assuming an ideal tracking and particle identification.



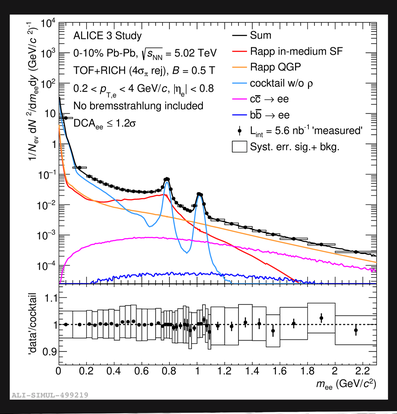


Fig 6 Expected raw dielectron yield in central Pb–Pb collisions with statistic and systematic uncertainties. The statistic uncertainties are based on a stochastic sampling approach. The expected significance of the measurement was estimated based on the signal and background shown in Fig 5. The systematic uncertainties are assumed to be 5% from tracking and particle identifications well as 0.02% on the background estimation. The different sources to contribute are shown in coloured lines.

The QGP Temperature

Possibility for multi differential analysis gives access to early stages of the collision

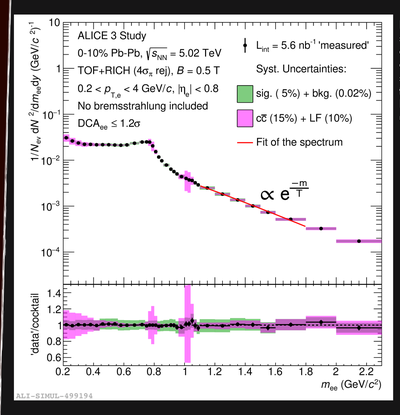
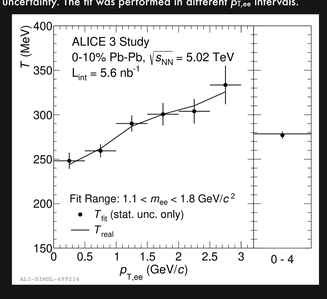


Fig 7 (Left) Dielectron excess yield integrated over pair p_T with the expected statistical uncertainty for the expected integrated luminosity for one month of data taking. The systematic uncertainties expected on the signal and background are shown in green, the uncertainty associated with the cocktail subtraction is shown in magenta. A fit is performed in the 1.1 < m_{ee} < 1.8 GeV/c^2 mass range to extract the temperature.
Fig 8 (Bottom) The extracted temperature and the model input with its statistical uncertainty. The fit was performed in different $p_{T,ee}$ intervals.



Chiral Restoration

Statistic and systematic uncertainties will allow to measure the ρ spectral function with unprecedented precision

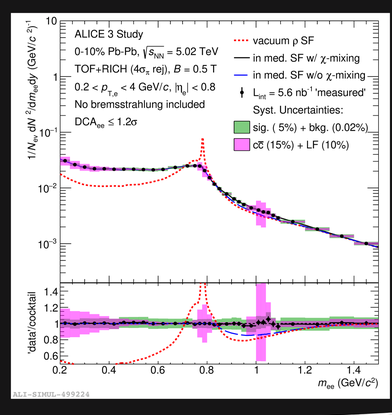
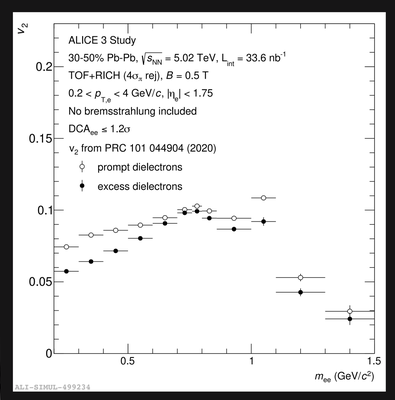
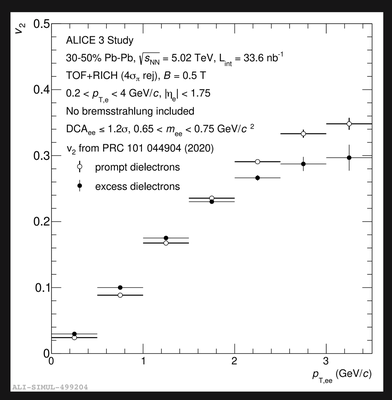


Fig 9 The dielectron excess yield in the mass range of 0.2 < m_{ee} < 1.5 GeV/c^2 integrated in pair p_T with the expected statistical uncertainty for the expected integrated luminosity for one month of data taking. The systematic uncertainties expected on the signal and background are shown in green, the uncertainty associated with the cocktail subtraction is shown in magenta. The data is compared with different calculations of the spectral function (SF) of the ρ. For the calculations the medium modified SF including mixing of the chiral partners was used (black). In addition an in medium SF not explicitly including chiral mixing (dashed blue), as well as the vacuum SF (dashed red) are shown.

Elliptic Flow

Statistical precision of ALICE 3 will allow for multi dimensional analysis of dielectron elliptic flow over a wide range of invariant masses and pair transverse momentum.





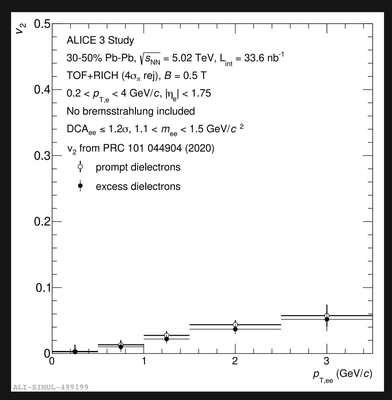
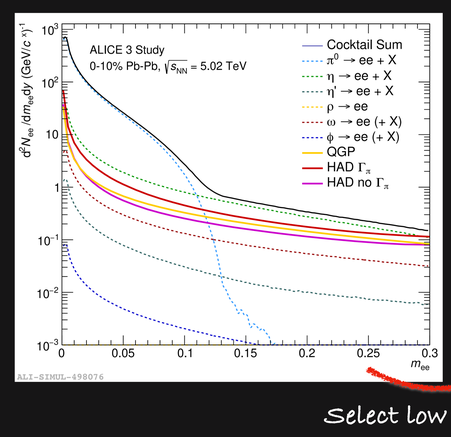
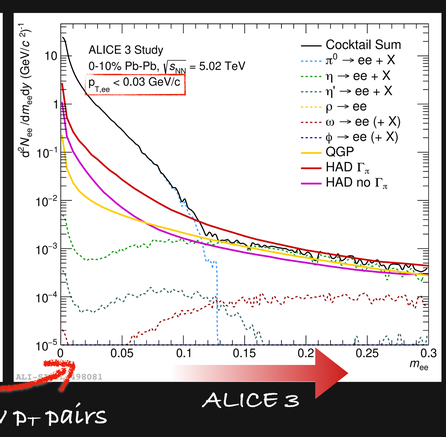


Fig 10 (left) Expected elliptic flow v_2 of prompt (open) and thermal (closed) dielectrons as a function of the invariant mass in semi cetral Pb–Pb collisions. No systematic uncertainties are shown.
Fig 11 (middle) Expected elliptic flow v_2 of prompt (open) and thermal (closed) dielectrons as a function of the $p_{T,ee}$ in the mass range 0.65 < m_{ee} < 0.75 GeV/c^2 semi cetral Pb–Pb collisions. No systematic uncertainties are shown.
Fig 12 (right) Expected elliptic flow v_2 of prompt (open) and thermal (closed) dielectrons as a function of the $p_{T,ee}$ in the mass range 1.1 < m_{ee} < 1.5 GeV/c^2 semi cetral Pb–Pb collisions. No systematic uncertainties are shown.

Electric Conductivity

Measurement of super soft part of thermal radiation (sensitive to electric conductivity) within reach in ALICE 3





Select low p_T pairs

ALICE 3

Fig 13 (left) The different contributions from hadronic decays are shown together with calculations by Ralf Rapp for thermal radiation. In addition to the QGP contribution two different calculations for the hadronic radiation are shown with (magenta) and without (red) ππ-Bremsstrahlung (Γ_π). No efficiencies were taken into account.
Fig 14 (right) The same contributions as in Fig 11 are shown, after selecting only pairs with $p_{T,ee}$ < 0.03 GeV/c.

Summary

Dielectron measurements will yield deeper understanding on properties of strongly interacting matter beyond the LHC Run 3 program

ALICE 3 is designed as a detector well suited to provide detailed measurements of dielectrons in heavy ion collisions

Insights into the details of chiral restoration, electric conductivity as well as multi differential analysis of the QGP temperature and thermal photon elliptic flow in reach

References

[1] G. D. Moore and J.-M. Robert, arXiv:hep-ph/0607172
[2] Ralf Rapp, private communication, based on R.Rapp and J.Wambach, Eur. Phys. J. A6(1999)415; H.van Hees and R.Rapp, Nucl Phys. 806 (2008) 339; R.Rapp, Adv. High Energy Phys. 2013 (2013) 148253.
[3] B. S. Kasmaei and M. Strickland, PRD 99 (2019) 3, 034015
[4] ALICE Collaboration, Phys. Rev. C 101, (2020), 044907
[5] ALICE Collaboration, Phys. Lett. B 804 (2020), 135377

Link to Zoom Room

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

18th November 2021
Sebastian Scheid
s.scheid@cern.ch
Institute for nuclear Physics,
Goethe University Frankfurt