Measurement of low transverse momentum electrons from heavy-flavour hadron decays in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with ALICE

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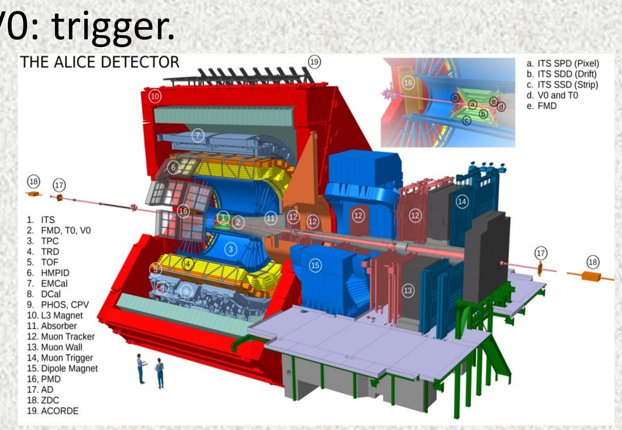
The ALICE experiment

- A Large Ion Collider Experiment (ALICE) is one of the four large experiments at the LHC.
- The main goal of the experiment is the study of Quark-Gluon Plasma (QGP), a state of the strongly interacting matter in which quarks and gluons are not confined inside hadrons. This plasma is supposed to have been the state of matter in the early universe.
- The detectors used in this analysis are:
  - Inner Tracking System (ITS): vertex reconstruction, tracking and PID;
  - Time Projection Chamber (TPC): tracking and particle identification (PID);
  - Time Of Flight (TOF): PID;
  - V0: trigger.



Open heavy flavour – physics motivation

- Quark-Gluon Plasma is produced in relativistic heavy-ion collisions, ex. Pb-Pb.
- Heavy quarks ($m_c \approx 1.5$ GeV$/c^2$, $m_b \approx 4.8$ GeV$/c^2$), predominantly produced in initial hard scatterings, lose energy while traversing the medium, via collisional and radiative processes.
- One observable that allow quantifying the energy loss is the nuclear modification factor, R_{AA}, defined as

$$R_{\mathrm{AA}} = \frac{\mathrm{d}N_{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}}{\langle T_{\mathrm{AA}}\rangle \, \mathrm{d}\sigma_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

- $\mathrm{d}N_{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}$: p_{T} differential distribution in Pb-Pb collisions
- $\mathrm{d}\sigma_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}$: p_{T} differential cross section in pp collisions
- $\langle T_{\mathrm{AA}}\rangle = \langle N_{\mathrm{coll}}\rangle/\sigma_{\mathrm{inel}}^{\mathrm{AA}}$: average of nuclear overlap function for the considered centrality interval, where $\langle N_{\mathrm{coll}}\rangle$ is the mean number of binary collisions among nucleons

Expectation: $R_{\mathrm{AA}} < 1$ at moderate/high p_{T} if heavy quarks undergo energy loss.

Electrons from heavy-flavour hadron decays

Data sample: Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV recorded in 2015 with ALICE

Centrality class: 0-10%

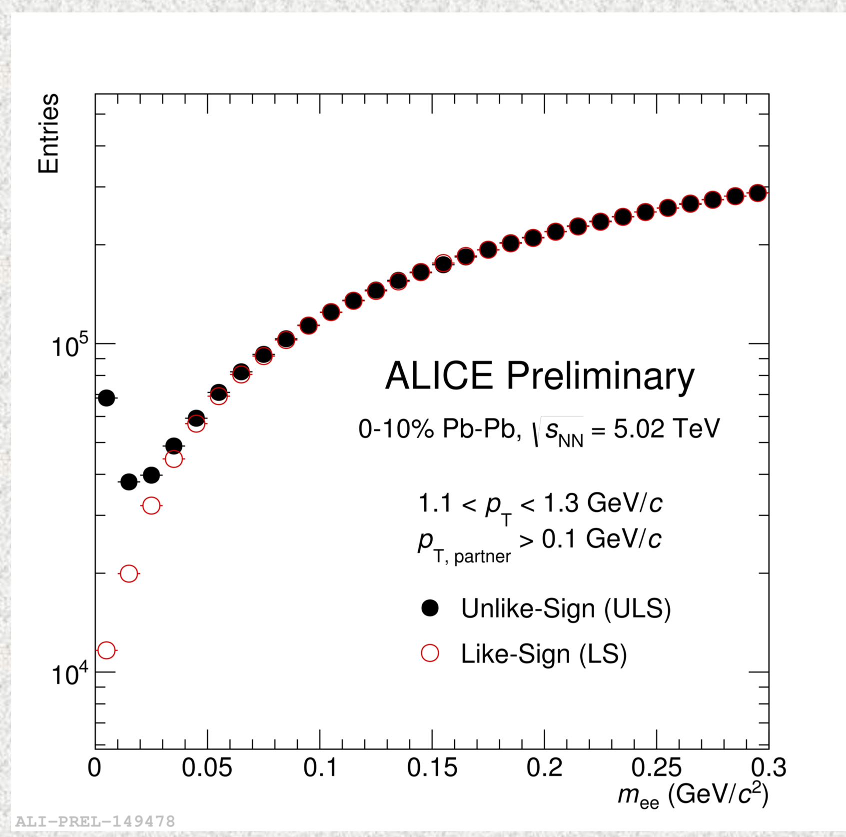
Analysis strategy

- Track quality selections.
- PID and residual hadron contamination estimation ($h(p_{\mathrm{T}})$).
- Photonic background estimation ($N^{\mathrm{phot}}(p_{\mathrm{T}})$).
- Raw heavy-flavour hadron decay electrons (HFe) p_{T} spectrum obtained as:

$$N_{\mathrm{HFe}}^{\mathrm{reco}}(p_{\mathrm{T}}) = N^{\mathrm{tot}}(p_{\mathrm{T}}) - h(p_{\mathrm{T}}) - N^{\mathrm{phot}}(p_{\mathrm{T}})$$

- Correct for acceptance and reconstruction efficiency to obtain the p_{T} -differential invariant yields of heavy-flavour decay electrons.
- R_{AA} measurement.

Photonic background estimation ($N^{\mathrm{phot}}(p_{\mathrm{T}})$)



Main background, referred to as photonic electrons, comes from:

- $\pi^0, \eta \to \gamma e^+ e^-$ (Dalitz decays);
- $\gamma \to e^+ e^-$ (photon conversions).

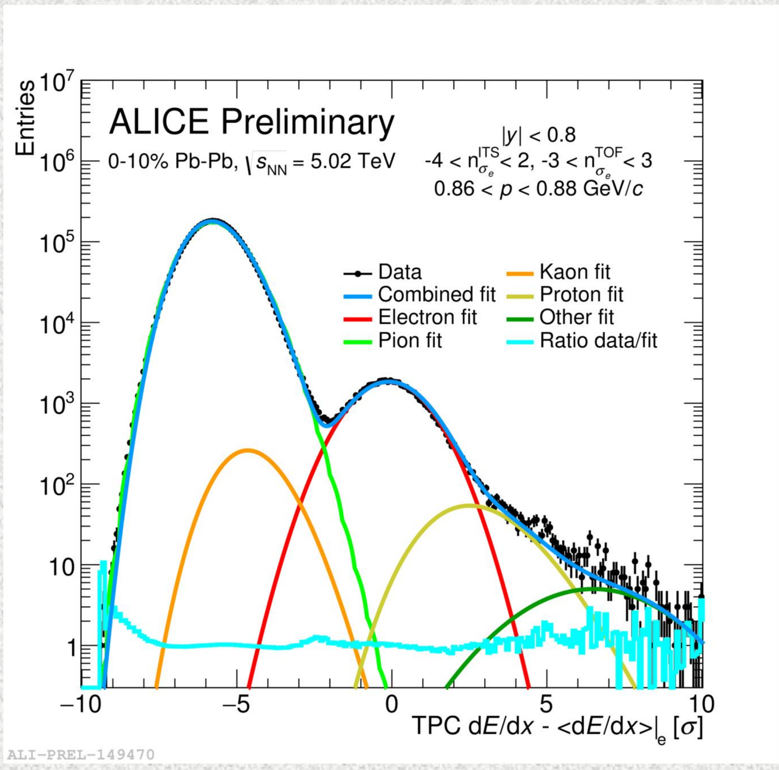
- Background is estimated using invariant mass of ee pairs .
- The reconstructed amount of photonic electrons is

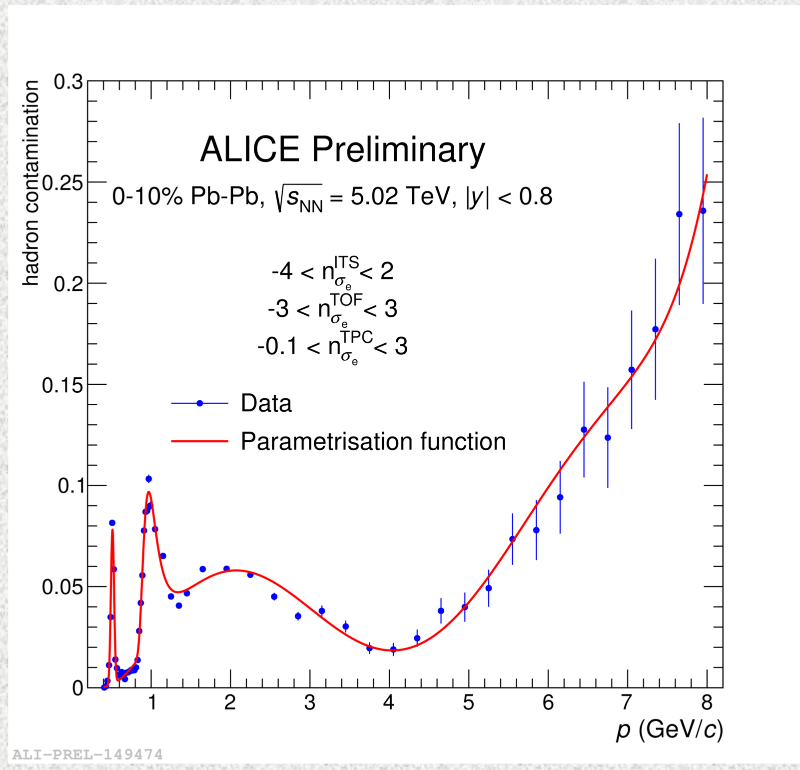
$$N_{\mathrm{reco}}^{\mathrm{phot}}(p_{\mathrm{T}}) = N^{\mathrm{ULS}}(p_{\mathrm{T}}) - N^{\mathrm{LS}}(p_{\mathrm{T}})$$

within $m_{ee} \leq 140$ MeV$/c^2$.
- The total photonic yield is obtained by correcting for tagging efficiency calculated using Monte-Carlo simulations:

$$\varepsilon^{\mathrm{tag}}(p_{\mathrm{T}}) = \frac{N_{\mathrm{ULS}}^{\mathrm{true}}(p_{\mathrm{T}}^{\mathrm{rec}})}{N_{\mathrm{phot,incl}}^{\mathrm{true}}(p_{\mathrm{T}}^{\mathrm{gen}})}$$

Electron identification

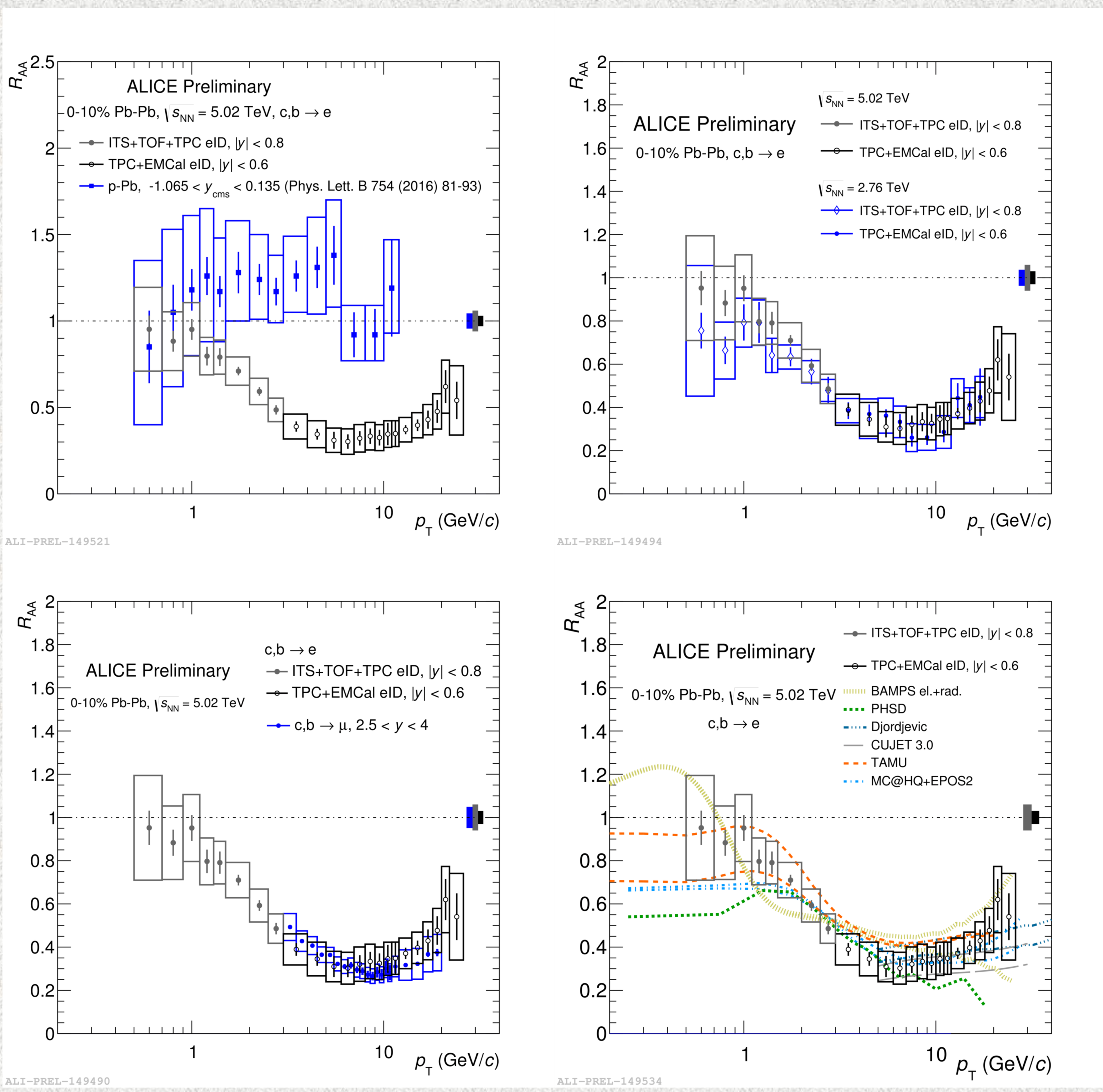




- PID selection applied:
  - ✓ $-3 \leq n_{\sigma}^{\mathrm{TOF}} < 3$
  - ✓ $-4 \leq n_{\sigma}^{\mathrm{ITS}} < 2$
  - ✓ $-0.1 \leq n_{\sigma}^{\mathrm{TPC}} < 3$
- Hadron contamination evaluated in different momentum bins.
- The resulting hadron contamination is parametrised as a function of momentum and the parametrisation function is used to build statistically the p_{T} distribution $h(p_{\mathrm{T}})$.
- Inclusive electrons p_{T} distribution:

$$N^{\mathrm{incl}}(p_{\mathrm{T}}) = N^{e-\mathrm{candidates}}(p_{\mathrm{T}}) - h(p_{\mathrm{T}})$$

R_{AA} measurement



- R_{AA} of heavy-flavour decay electrons measured in central (0-10%) Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV at low p_{T} .
- The invariant cross section measured in pp collisions at $\sqrt{s} = 5.02$ TeV is used as reference for R_{AA} measurement .
- Heavy quarks undergo energy loss in central Pb-Pb collisions and the suppression increases until $\sim 7-8$ GeV$/c$.
- The result is compared to:
  - R_{AA} of heavy-flavour decay electrons measured in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV [9] ⇒ R_{pPb} consistent with unity: suppression of electrons at high p_{T} is due to significant energy loss of heavy quarks in the QGP;
  - R_{AA} of heavy-flavour decay electrons measured in central (0-10%) Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV at low p_{T} ⇒ Similar R_{AA} measured at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV and $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV: possible compensation between higher energy density (→ larger energy loss) and harder initial spectrum (→ tends to increase RAA at moderate/high p_{T}) at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with respect to $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV;
  - R_{AA} of heavy-flavour decay muons measured in central (0-10%) Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV at forward rapidity ($2.5 < y < 4$), showing a compatibility with the R_{AA} of heavy-flavour electrons;
  - Theoretical predictions [1-7].
    - ✓ In the very low p_{T} region, the measured result (central value) is compatible with TAMU [5] prediction, suggesting that heavy quarks mostly lose energy by elastic collisions; at higher p_{T}, the measurement agrees with others models (Djordjevic [4], CUJET 3.0 [1]) which consider also the gluon radiation as an important energy loss mechanism.
    - ✓ As also observed at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV, the data do not favor $R_{\mathrm{AA}} > 1$ at low p_{T}, supporting the presence of shadowing and the necessity of including nuclear PDF in the models.

[1]: arXiv:1508.00552 [hep-ph]; [2]: arXiv:1408.2964 [hep-ph]; [3]: arXiv:1512.00891 [nucl-th]; [4]: Phys. Rev. C 92, 024918; [5]: arXiv:1401.3817 [nucl-th]; [6]: arXiv:1509.07491v2 [nucl-ex]; [7]: arXiv:1305.6544 [hep-ph]