Machine learning approach for studying dielectrons in LHC Run 3 data with ALICE

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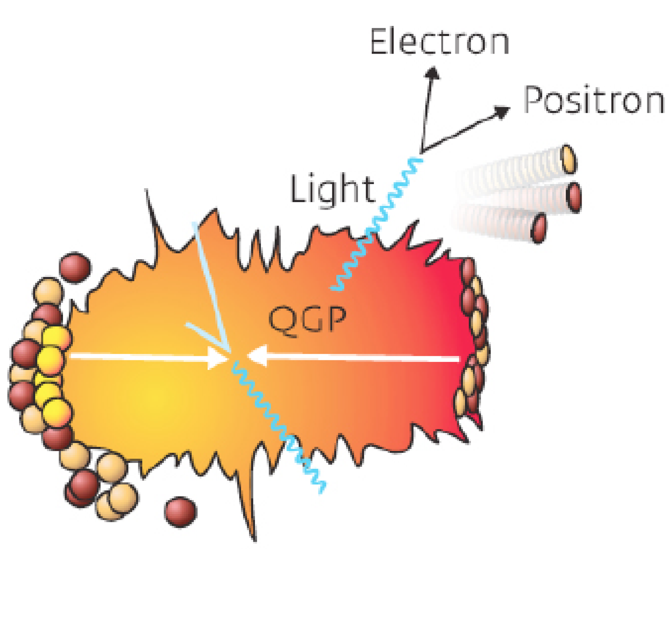
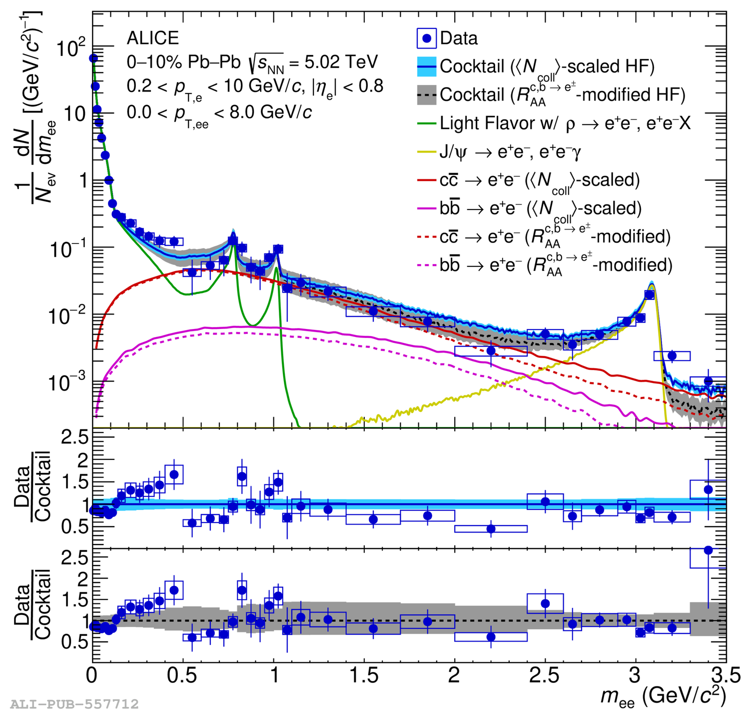
Electromagnetic probes

- Photons and leptons experience no strong interactions
  - ➞ Transparent to medium (quark-gluon plasma (QGP) and hadronic gas)
- Dielectrons are produced during all stages of the collision
  - ➞ Investigate the whole history of the medium



- Dielectrons from different sources
  - Decays of light-flavored (LF) mesons (π, η, $\eta\prime$, ϕ, ρ, ω)
  - Semi-leptonic decays of correlated heavy flavor (HF) hadrons
  - Thermal radiation $$\frac{\mathrm{d}N_{ee}}{\mathrm{d}m_{ee}} \sim m_{ee}^{3/2}\,\mathrm{e}^{-m_{ee}/T}$$ Allows to measure temperature of QGP



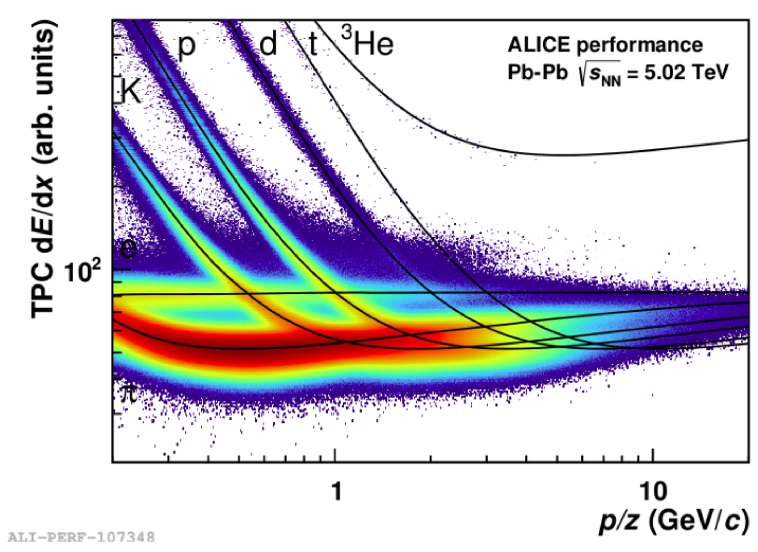
Run 2 results for dielectron spectrum [1]

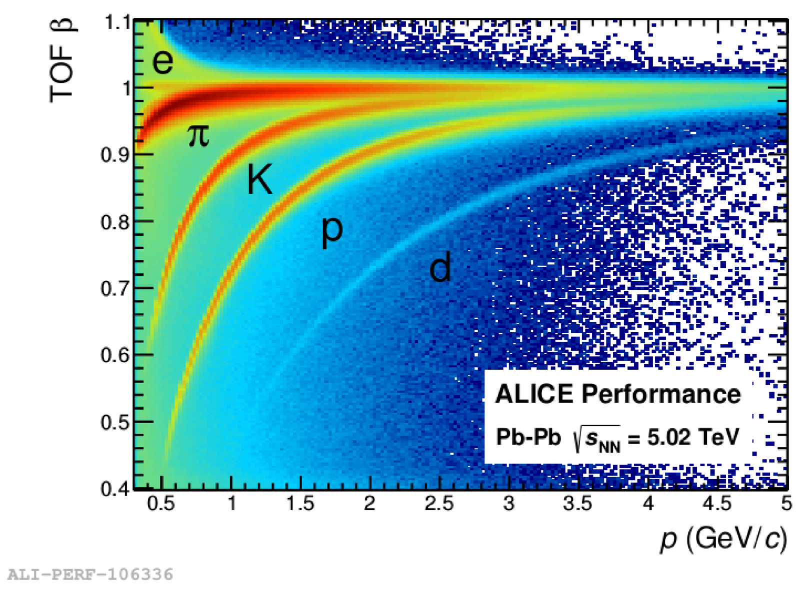
Electron identification with boosted decision trees

- Want to achieve high purity of electron sample while maintaining good efficiency
- Usual approach for particle identification (PID):
  - Use energy loss in Time Projection Chamber (TPC) and Time-Of-Flight measurements (TOF) to distinguish electron tracks from hadrons

  1.) Use TPC dE/dx to select electron candidates while rejecting tracks compatible with hadron hypothesis

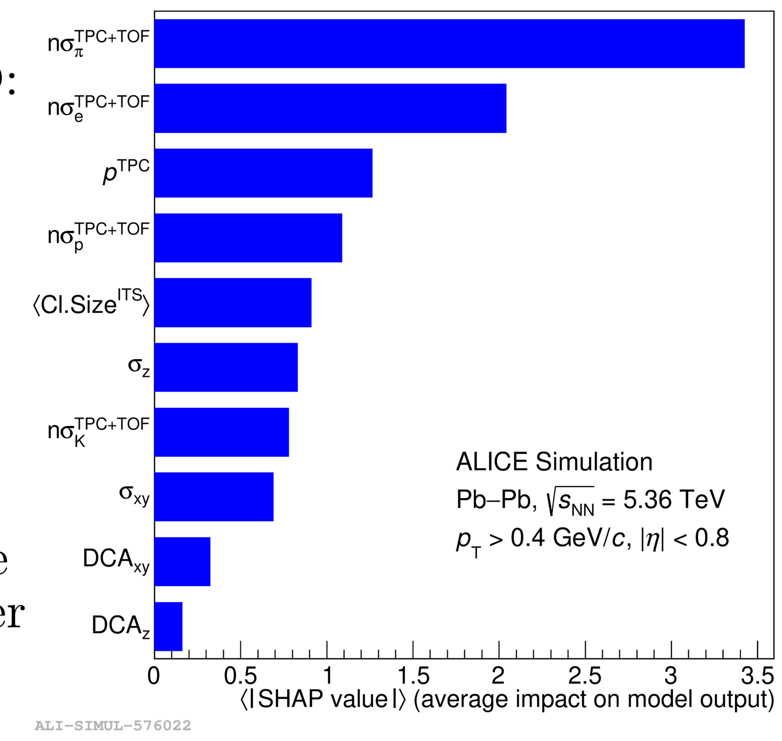
  2.) If available, use TOF beta to recover electrons rejected in the TPC hadron bands

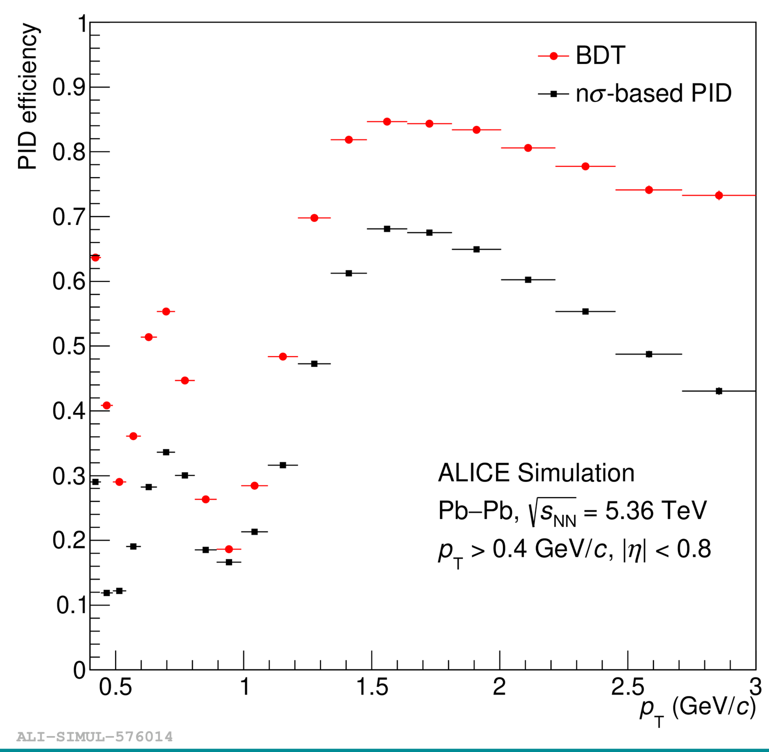


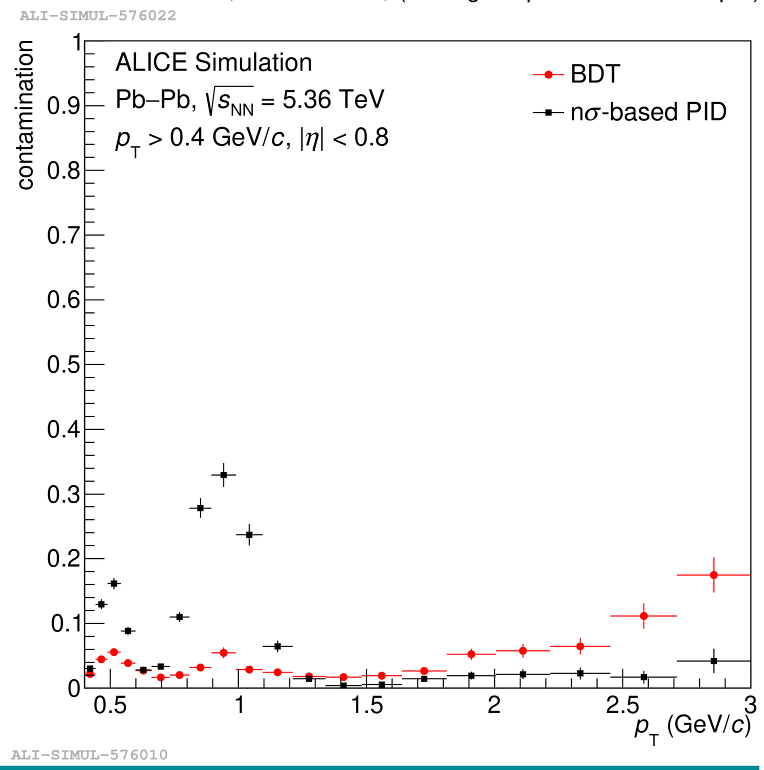


- Machine learning (ML) approach to PID: train boosted decision trees (BDT) to identify electrons on simulated general purpose Monte Carlo (MC) data
- Use information from TPC, TOF, Inner Tracking System (ITS), momentum and topolological variables

► PID using BDTs can significantly reduce hadron contamination while giving higher overall efficiency

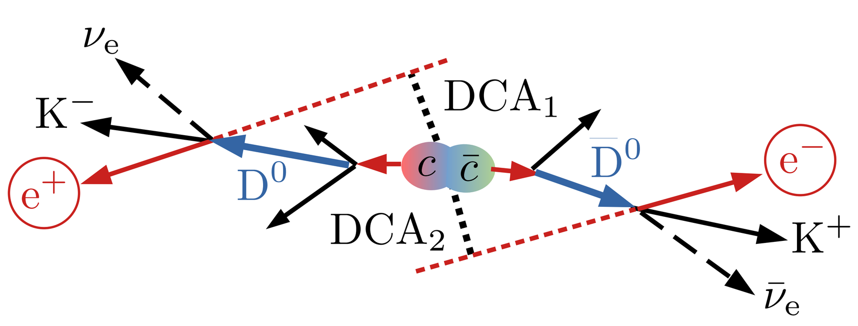




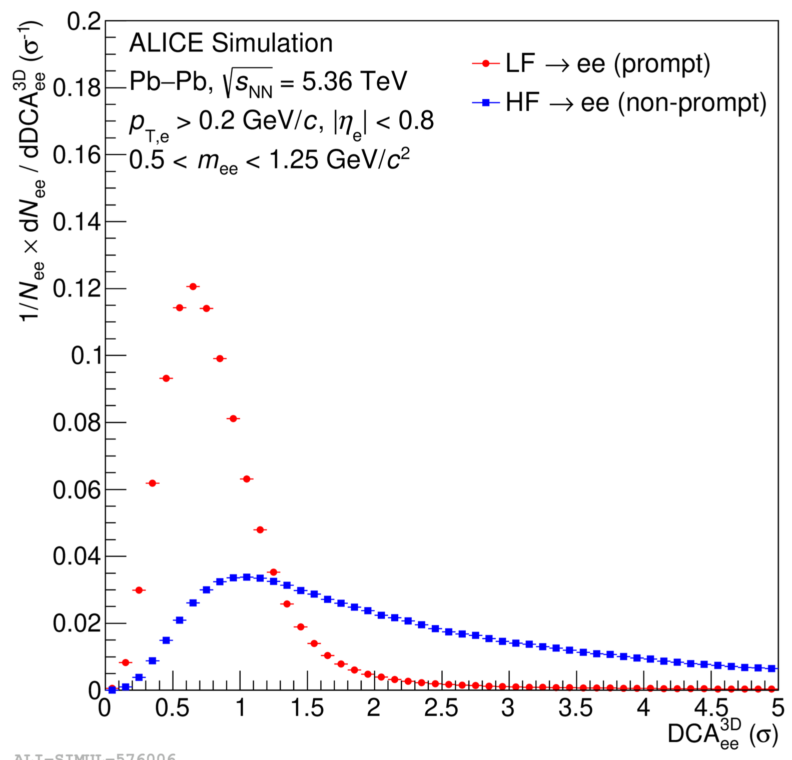


Separation of prompt vs. non-prompt dielectrons

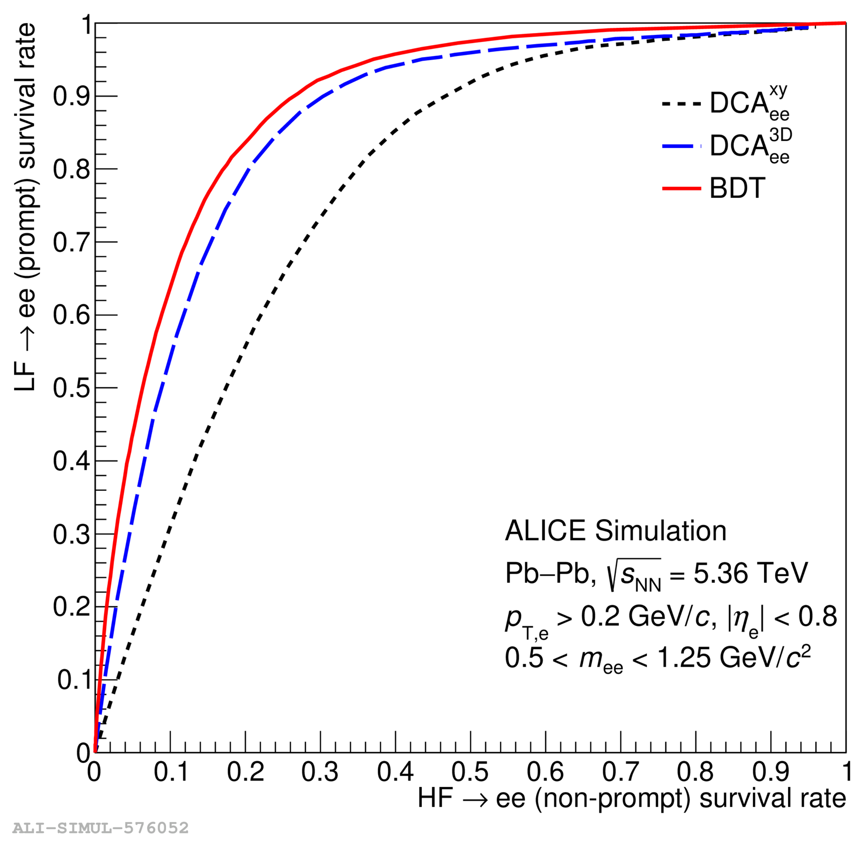
- Electrons from semileptonic decays of correlated HF hadrons are main background to thermal electrons from QGP in the intermediate mass region $1.1\,\mathrm{GeV}/c^2 < m_{ee} < 2.7\,\mathrm{GeV}/c^2$
- In Run 1&2 it was shown that distance of closest approach (DCA) to vertex in transverse plane can be used to discriminate prompt electrons from pairs originating from HF hadron decays [1,2] $$\mathrm{DCA}_{ee} = \sqrt{[(\mathrm{DCA}_1)^2 + (\mathrm{DCA}_2)^2]/2}$$

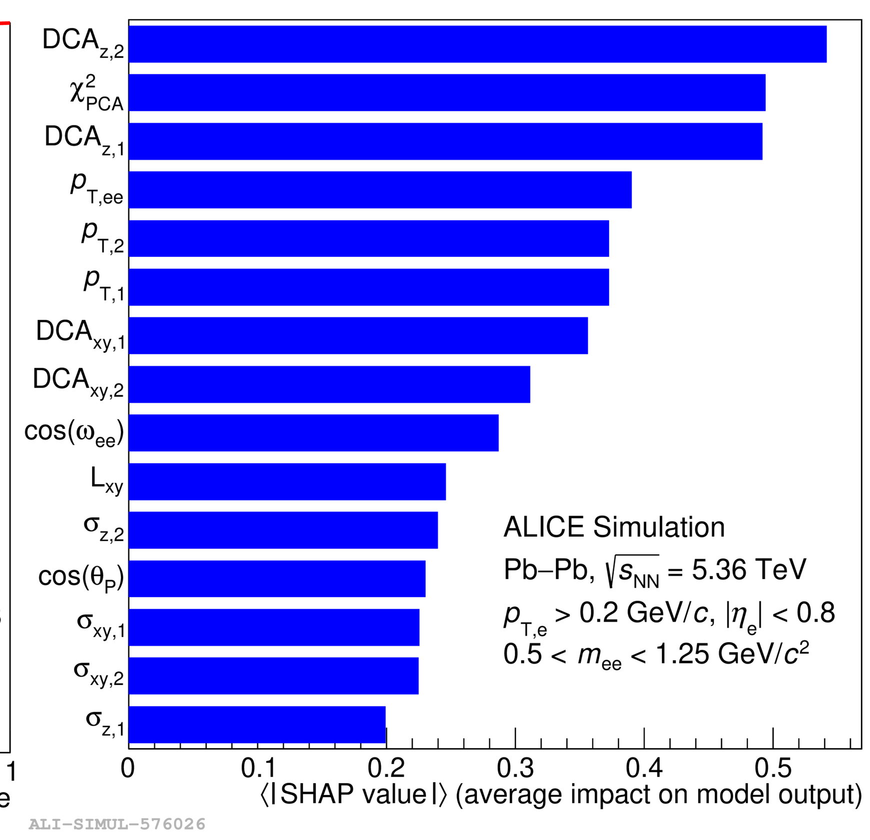


- Dielectrons from HF hadron decays have larger DCA
  - D-mesons: $c\tau \sim 150$–$300\,\mu$m
  - B-mesons: $c\tau \sim 450\,\mu$m
- Upgraded ITS in Run 3 with comparable resolution in z-direction allows use of 3-dimensional DCA



- Train BDT in invariant mass range: $0.5\,\mathrm{GeV}/c^2 < m_{ee} < 1.25\,\mathrm{GeV}/c^2$
  - Prompt: from ρ, ω, ϕ decays
  - Non-prompt: from decays of correlated charm and beauty hadrons
- Do not consider combinatorial background at this stage





➞ Slight improvement with BDTs over DCA-only approach seems possible
➞ Promising starting point for future more involved studies

Summary & outlook

- Measurement of low-mass dielectrons allows to measure temperature of QGP via thermal radiation
- Large background from HF decays makes good signal from background separation mandatory
- Upgraded ALICE detector (3–6 times better vertex pointing resolution) allows better topological separation of dielectrons from prompt and non-prompt sources
- ML techniques show promising improvements in electron identification and non-prompt background rejection

[1] ALICE, *Dielectron production in central Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV*, arXiv: 2308.16704v1
[2] ALICE, *Dielectron production in proton-proton collisions at $\sqrt{s}$ = 7 TeV*, JHEP **09** (2018) 064

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