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MVA based Background Rejection in the Analysis of Low-Mass Dielectrons in Pb-Pb Collisions with ALICE

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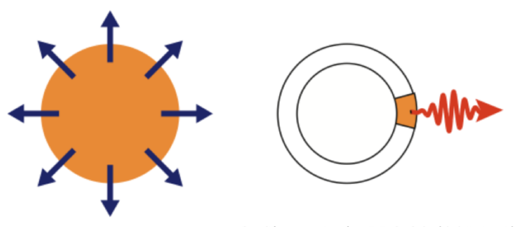
The measurement of e^+e^- **pair production** in ultra-relativistic heavy-ion collisions offers a way to investigate the **temperature** of the quark-gluon plasma (QGP) created in such collisions and to search for signatures of **chiral symmetry restoration** in the line shape of the ρ^0. The dominant background in the analysis originates from photon conversions in the detector material. Numerous observables allow for discrimination of this background which motivates a multivariate approach in the classification of dielectron pairs. The latest results of the low-mass dielectron analysis obtained with **machine learning** methods in Pb-Pb collisions at $\sqrt{s_{NN}}$ =5.02 TeV are presented.

The results show that machine learning has potential to increase the statistical significance of the measured invariant mass spectrum.

1. Physics of Low-Mass Dielectrons

Virtual Thermal Photons:



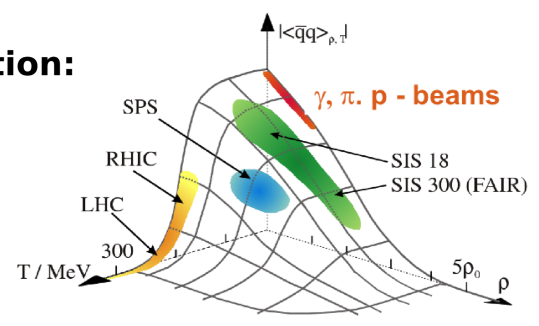
C. Shen et al., PRC 89 (2014, 4)

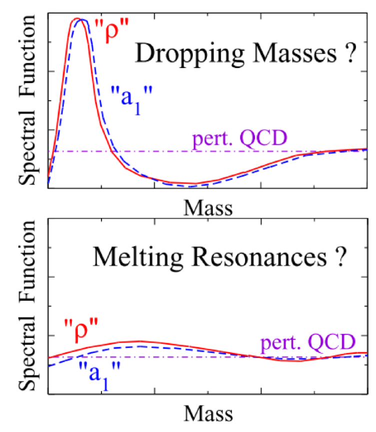
- Thermal radiation from the hadronic gas and QGP
- Photons are blue shifted due to radial expansion of the medium
- Lorentz invariant thermometer based on mass:

$$\frac{dN_{ee}}{dm_{ee}} \propto exp(-m_{ee}/T)$$

Chiral Symmetry Restoration:

Disappearance of chiral condensate in QGP may modify the ρ^0 mass shape

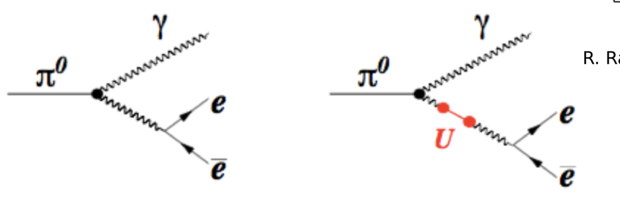




R. Rapp et al., arXiv:0901.3289 [hep-ph]

Dark Photons:

Would show up as peak in continuum of π^0 Dalitz decay



2. Signal & Background Dielectrons

Signal (S): Unlike sign (US) pair from same hadron (h)
Background (BG): all other pairs

Like sign (LS) subtraction:
LS pairs are combinatorial
BG1 & BG2 can be subtracted with LS

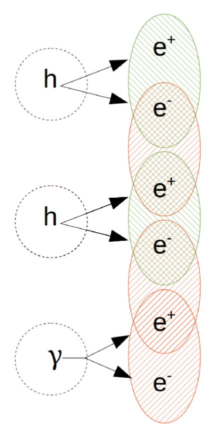
S = US - LS

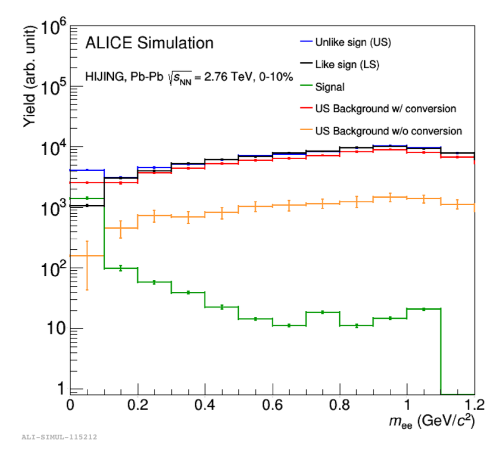
Statistical significance of signal: z = S/$\sigma_{Signal,stat}$ with $\sigma_{Signal,stat}$ ~ $(US+LS)^{1/2}$

Aim: reduce US and LS while keeping S unchanged

Dominant BG: BG2 - Combinatorial with conversions

BG subtraction needs to be more precise than S/BG ~ 10^{-3}





3. Neural Network Training

Neural Network (NN) training on single tracks from Monte Carlo (MC) simulations
Signal: tracks not from conversions
Background: tracks from conversion

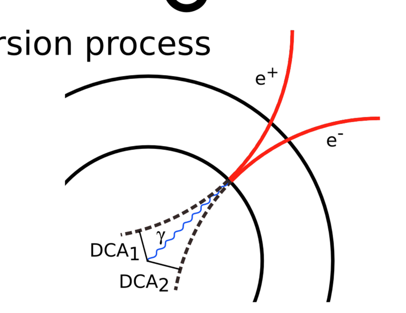
Variables
19 observables are used for BG rejection
e.g. DCA_{xy}, chi², shared clusters, p_T ...

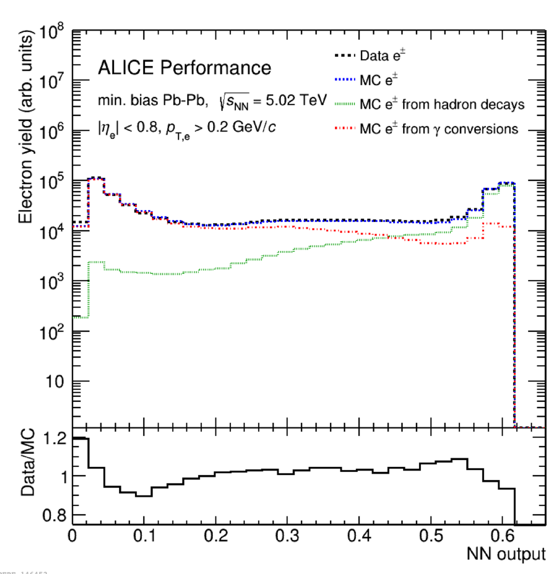
Example: **DCA_{xy}** for rejection of BG2 & BG3:
Distance of closest approach of track to the primary vertex in xy-plane

Discrimination of BG via cut on NN output (MVA cut):
Maximize **Significance** (z) of **S = US - LS** on real data
Optimal MVA cut: NN ouput > 0.35

Data-driven performance evaluation

Conversion process

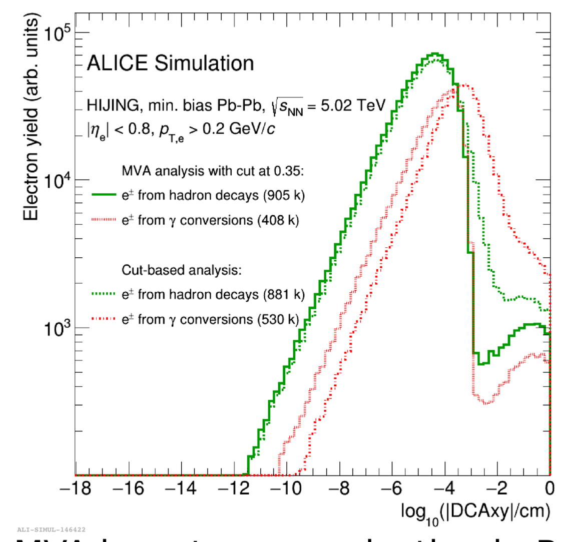




4. Evaluation on MC

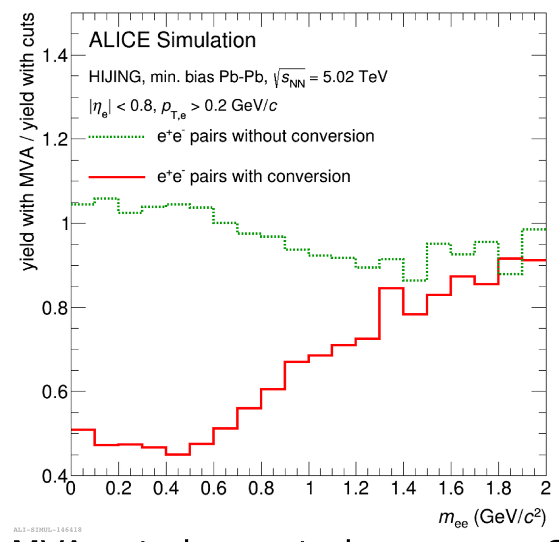
Comparison of MVA cut to traditional cut based analysis
Cut variable example: number of shared clusters in inner tracker

Comparison on **single track** level: DCA_{xy}
Signal: tracks not from conversions
Background: tracks from conversions



MVA has stronger rejection in BG dominated region and vice versa

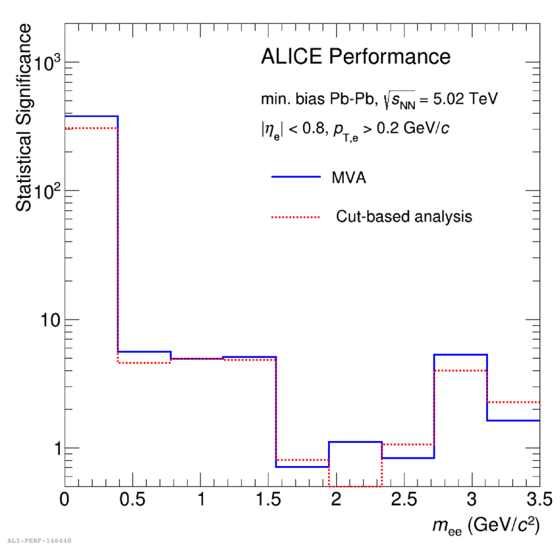
Comparison on **pair** level: m_{ee}
Signal: pairs w/o conversions
Background: pairs w/ conversions



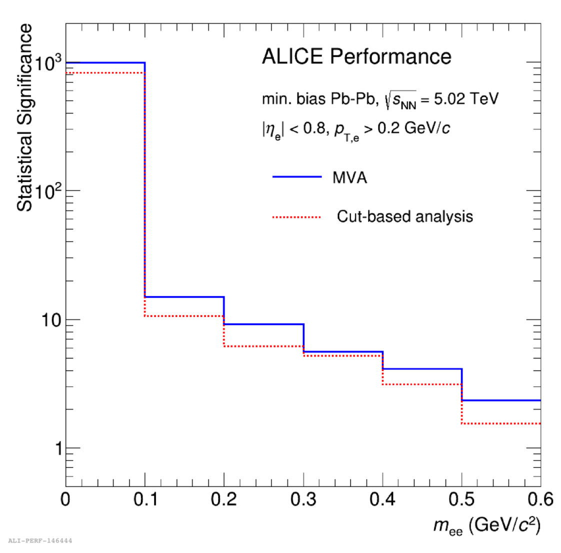
MVA cut chosen to have same S yield as traditional cuts: less BG

5. Evaluation on Data

Comparision of statistical significance on data



Comparable significance in m_{ee} > 0.6 GeV/c²



Higher statistical significance in m_{ee} < 0.6 GeV/c²

6. Summary

Conversion electrons are the dominant background for low-mass dielectrons

Numerous different variables carry relevant information to identify them

Neural network is trained on MC to discriminate conversion electrons

More efficient background rejection on MC with NN than with standard cut-based method

Compatible results with data: NN achieves higher statistical significance for m_{ee} < 0.6 GeV/c²

Outlook

- Apply efficiency correction
- Estimate systematic uncertainty in the dielectron spectrum associated to MVA cut
- Implementation of an independent MVA based electron PID
- Comparison of dielectron mass spectrum to expectation from known hadronic sources

Doktoratskolleg Particles and Interactions

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