Identification of e^+/e^- Induced Rings in the HADES-RICH ◇

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The Ring Imaging Cherenkov detector (RICH) [1] of the HADES dilepton spectrometer set up at GSI, Darmstadt is the central lepton-ID device for the recognition of e^+/e^- trajectories from nuclear reactions at incident energies of 1-2 Gev per nucleon. The leptons reaching the detector stem from meson $(\pi_0, \eta, \rho, \omega)$ decays and from photon-conversion processes in the detector material. To extract the rare physics signals of interest, i.e. lepton pairs from vector-meson decays, it is vital to provide reliable identification of lepton induced ring patterns in the RICH and efficient discrimination of background signals. Moreover, e^+e^- pairs with small opening angle are not easily resolved and constitute the most prominent source of combinatorial background. Investigations of single and double ring properties [2] obtained from experiment and simulations showed that - when taken individually - none of the recorded ring variables (pad multiplicity, pulse height etc.) is suitable for reliable signal/background discrimination .

In this study we report about the application of the *Principal Component Analysis* (PCA) to extract lepton ID information from the combined analysis of 5 relevant RICH observables: **1:** pad multiplicity, **2:** ring excentricity, **3:** average pad pulse height, **4:** number of local pulse height maxima in ring, and **5:** a pattern quality parameter in ring finder. The goal is to provide for each ring pattern the conditional probability for lepton origin or noise induced fake recognition. Starting with an observable-vector $\vec{x}$ containing these ring parameters $x_1, x_2, ..., x_p$ one can compute the conditional probability $P(l|\vec{x})$ for having found a lepton-induced pattern with the help of the Bayes theorem:

$$P(l|\vec{x}) = \frac{P(l) \times P(\vec{x}|l)}{\sum_{allspeciess} P(s) \times P(\vec{x}|s)} \quad (1)$$

Here $P(\vec{x}|s)$ is the normalized *Probability Density Function* (PDF) of the observables for each species s and $P(s)$ is the relative abundancy of s.

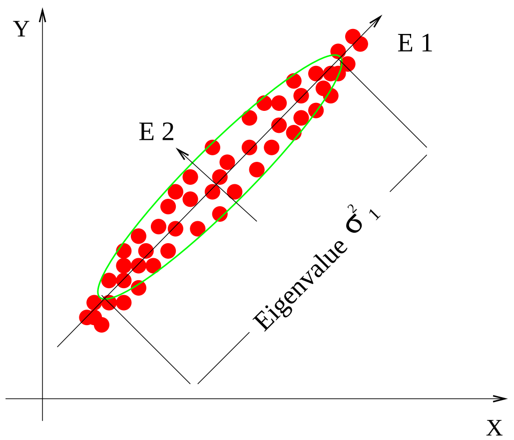

Fig. 1: The originial pattern observables X and Y are strongly correlated. After the transformation most information about the patterns is contained in E_1.

Since correlations are difficult to visualize in more than 2 dimensions we have used PCA to reduce the number of dimensions to only two. The PCA method is illustrated in Figure 1 for two dimensional data. The distribution of points exhibits a strong correlation in its two components x, y. A rotation transforms all patterns into a new coordinate system E_1, E_2 with new components $\hat{x}, \hat{y}$ such that only little information is contained in coordinate E_2. For data of any dimension the PCA method computes and diagonalizes the Covariance-Matrix $\mathcal{C}$ of the pattern-distribution, where $\mathcal{C} =< \vec{x} \times \vec{x}^T >$.

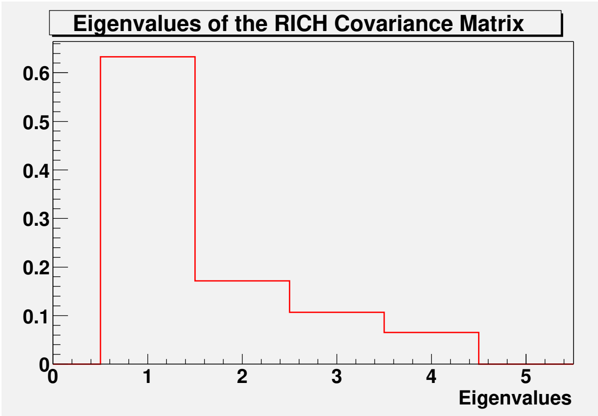

Fig. 2: The Eigenvalue spectrum of the RICH covariance matrix decays exponentially. The first and second Eigenvector are chosen to describe the patterns after the PCA has been performed.

It can be shown [3] that the error in the description of the patterns in less than the original number p of dimensions is minimized if one chooses a space spanned by a subset of the Eigenvectors E_i. The Eigenvalues that are computed in the diagonalization are the corresponding variances σ_1^2, σ_2^2 of the data along these Eigenvectors. Their size offers a measure for the amount of information contained in the respective components. Figure 2 shows for the RICH observables the resulting Eigenvalue spectrum of the 5-dimensional covariance matrix. The first two Eigencomponents are sufficient to describe the ring patterns and are used to build the PDFs for the probability computation.

Full scale simulations show that the method allows already for a clear identification of lepton induced ring patterns and good background suppression without the help of any other HADES detector information. For a conditional probability threshold of 50%, the contamination of the selected ring sample with fake rings was only 8.7%, while only 6.7% of true lepton rings were lost. Applying the PCA also to correlations with observables from other HADES detectors promises to improve these numbers, in particular for close pair identification from π_0-Dalitz decays and γ conversion.

References

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