Neutral particles identification at LHCb

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Introduction

The ability to identify the nature of particles is one of the major requirements in a flavor physics experiment. At LHCb [1], one challenging feature is the identification of neutrals. Important analyses of the core LHCb physics program rely on calorimetry to identify photons, high-energy neutral pions and electrons.

The LHCb calorimeter system is composed of a scintillating pad plane (SPD), a preshower detector (PS), an electromagnetic calorimeter (ECAL – lead shashlik technology) and a hadronic calorimeter (HCAL – iron Tile-Cal technology). The interaction of a given particle in these detectors leaves a specific signature.

The signatures of photons and high momenta π0 are quite similar since neutral pions mainly decay into two photons. The energy deposited in the ECAL cells can either be reconstructed as a single cluster (a photon) or two subclusters (a π0).

Neutral PID

Particle identification (PID) algorithms are based on multivariate classifiers. They combine information from different sub-detectors into a discriminant output, and are trained to separate photons from hadrons, electrons and high-energy π0.

Input variables: 14 variables describing the energy deposits in each of the sub-detectors of the calorimeter system (e.g.: number of hits in the SPD and the PS in front of the ECAL cluster, distribution of the energy deposit in the ECAL cluster, etc. ...).

Three different Neural Networks (MultiLayer Perceptrons - MLP) are trained on Monte Carlo simulated data to separate photon signatures from three other objects:

- Photon/hadron separation – “IsNotH”
- Photon/electron separation – “IsNotE”
- Photon/π0 separation – “IsPhoton”

Output distributions for signal (γ) and backgrounds (h/e/π0):

IsNotH
IsNotE
IsPhoton [2]

MC/Data discrepancies:

The simulation does not reproduce the real data with full accuracy. Discrepancies in the IsPhoton performance between data and MC are expected:

- Photon identification efficiency as a function of π0 rejection efficiency, for MC and signal data

Solution: use calibration data to correct the simulated samples

Calibration samples

The decay modes used for calibration are chosen to be abundant, pure and together cover a large kinematic region:

<table>
<thead>
<tr>
<th>γ calibration modes</th>
<th>π0 calibration modes</th>
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<tbody>
<tr>
<td>D∗+(→(η′→π0π0)γ)ττ</td>
<td>D∗+(→(D0→Kππππ+π−)γ)ττ (π0 resolved)</td>
</tr>
<tr>
<td>B−→Kγ</td>
<td>B−→ωγ</td>
</tr>
<tr>
<td>D*(2010→D*(→Kππππ+π−)γ)ττ (π0 merged)</td>
<td></td>
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</tbody>
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TurCal stream:

In Run 2, thanks to the real-time detector alignment and calibration, selected exclusive decays with both online (Turbo) and offline (Full) informations are available directly at the second High Level Trigger (HLT2) with the TurCal (Turbo-Calibration) [3] stream.

Mass Fits:

Invariant mass fits to the TurCal data are performed in order to get a background subtracted PID distribution using the SpPlot technique [4]:

- γ sample example: B −→ (κ∗+ → κ+κ−) γ
- π0 sample example: D∗+( → D(0−→ Kππππ+π−)πττ

The efficiency for a given cut is computed in each bins of variables that are correlated with the PID (e.g. Eγ, pseudo-rapidity). The MC samples can then either be reweighted to match the PID selected data, or resampled to correct the distribution of the PID variable.

Implementation and perspectives:

- The development of invariant mass fits on Run 2 data (TurCal) is ongoing.
- A calibration tool is available to analysts to correct the simulated IsPhoton distribution. Developments are ongoing to propose a similar procedure for IsNotH and IsNotE PID variables.

References: