CBM calorimeter located at 1.5 meters from the target

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We investigated the possibility to use the innermost section of the standard ECAL for photon reconstruction and electron identification with a very first CBM setup at SIS-100. The smaller momenta and multiplicity of produced particles permits the reconstruction in a calorimeter located at only 1.5 m from the target. The total acceptance of the calorimeter was chosen to coincide with the acceptance of the magnet. The size of the calorimeter wall is 2.0×2.5 m^2 with a module size of 12.5×12.5 cm^2. Each module is divided into 25 (5×5) light-isolated cells. A module stack consists of 70 layers of 1.5 mm thick scintillator plates interlaid by 1.0 mm thick tungsten plates. The total thickness of a calorimeter module is 17.5 cm ($\sim$ 20 radiation lengths). The number of readout channels (taking into account a hole for the beam pipe) is 7900.

This calorimeter design differs significantly from the one used in the standard CBM setup – it has a constant transverse segmentation and covers a wider angular acceptance. The reconstruction algorithms for such a calorimeter required considerable developments. Cluster finding, calibration and fitting with shower shape library procedures were revisited and improved.

A calorimeter cluster should be large enough to maximize the measured photon (electron) energy fraction; on the other hand, it should be small enough to minimize the energy contamination from neighbour tracks. The new cluster finding procedure consists of the determination of local maxima (hottest calorimeter cell); the determination of the 2×2 cell array (including the hottest cell) with maximum energy deposit; the calculation of its centre of gravity, the construction of an ellipse with centre located at distance r from this centre of gravity and major semi-axis coinciding with the direction from the center of gravity to the calorimeter center, the ellipse semi-axes (a and b) and the distance r being parameters of the algorithm; the computation of the intersection area of the ellipse with all related calorimeter cells; the construction of a pre-cluster consisting of n cells with maximum intersection area; and the definition of a cluster as a set of neighbouring pre-clusters.

The parameters a, b and r were determined by minimization of the signal width for 16 GeV photons entering the ECAL at 25° and 35° impact angles. The best pre-cluster size n depends on the photon impact angle and varies from 4 to 9.

Calibration is necessary for a precise matching of the measured energy deposition to the incoming particle energy. The calorimeter response to photons in a wide range of energies and impact angles was simulated to determine the calibration constants. The dependence of the incoming particle energy on the energy deposition in the scintillators was fitted with $c_0 \log x + c_1$ and $c_0 \log x + c_1 + c_2 x$ for all incoming angles. The dependence of parameters c_0, c_1 and c_2 on impact angle was then fitted with a parabola.

The reconstruction algorithms should be able to unfold two neighbour photons hitting the calorimeter in close proximity, which requires the precise knowledge of the shape of the photon energy deposition. There are two different approaches for the shower shape calculation: a shower library or an analytical function [1, 2]. While a shower library has a huge size (> 50 Mb), an analytical formula does not provide enough precision. We united the two methods by fitting the shower library shapes with a neural network (multilayer perceptron). A similar approach can be used not only for the determination of the average cell response but also for calculation of dispersion and correlation coefficients for the energy deposition in neighbouring calorimeter cells. The latter would allow us to use a more precise χ^2 formula for the cluster fitting procedure.

An implementation of the detector layout and the reconstruction algorithms outline above was used to study the feasibility of a measurement of J/$\psi \rightarrow e^+e^-$ in p+C collisions at 30 GeV beam energy. A background of 10^6 UrQMD events for p+C and J/ψ generated by HSD were transported through the STS and calorimeter setup. Tracks with transverse momentum larger than 1.2 GeV/c were selected as J/ψ daughter candidates. The background was determined by the mixed-event method [3]. Figure 1 shows the resulting invariant-mass spectrum of electron pairs. At an assumed J/ψ multiplicity of $5.12 \cdot 10^{-8}$, about 3,000 signals are reconstructed with a signal-to-background ratio of 0.99 and an efficiency of 15%.

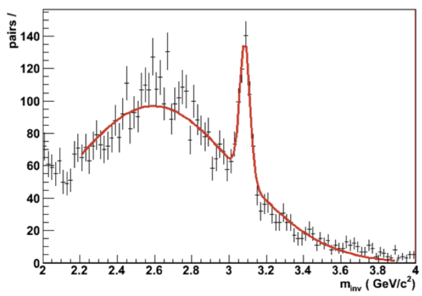

Figure 1: Invariant-mass spectrum of electron pairs after a p_t cut at 1.2 GeV/c on the electrons

References

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