Unfolding method for obtaining the photon multiplicity distribution at forward pseudorapidity in high energy p + p collisions

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Introduction

The measurements of multiplicity and the pseudorapidity distributions of produced particles are important to understand the particle production mechanism, the scaling laws and the limiting fragmentation behavior. A Photon Multiplicity Detector (PMD) is built and installed at forward pseudorapidity ($2.3< \eta < 3.9$) in A Large Ion Collider Experiment (ALICE) at the Large Hadron Collider (LHC) to measure the photon multiplicity and its spatial distribution. In such an experiment, the measured raw distributions of quantities like photon multiplicity include several detector related effects [e.g., efficiency, contamination, acceptance in nontrivial way, etc.]. One therefore needs methods to recover the true distribution from the measured distribution, specially in the low multiplicity environment. In this work, we report the results of unfolding photon multiplicity distribution, measured at forward rapidity in *pp* collisions at $\sqrt{s} = 7$ TeV using simulation.

Unfolding by χ^2-minimization

Given a measured distribution M, the true distribution T can be calculated as

$$T = R^{-1}M, \qquad (1)$$

where the matrix R describes the detector response. The matrix element R_{mt} gives the conditional probability that a collision with true multiplicity t is measured as an event with the multiplicity m. An approach to unfold the measured multiplicity distribution is the minimization of the χ^2-function [1–3]. The χ^2-function is given as

$$\hat{\chi}^2(U) = \sum_m \left(\frac{M_m - \sum_t R_{mt}U_t}{e_m} \right)^2, \qquad (2)$$

where U is the guess distribution and e is the error on the measurement M. During the process of unfolding an oscillation is seen in the results. This is minimized by adding a regularization term to the χ^2-function that favors a certain shape of the unfolded spectrum:

$$\chi^2(U) = \hat{\chi}^2(U) + \beta P(U), \qquad (3)$$

where $P(U)$ is the regularization term and β is the weight factor.

Results

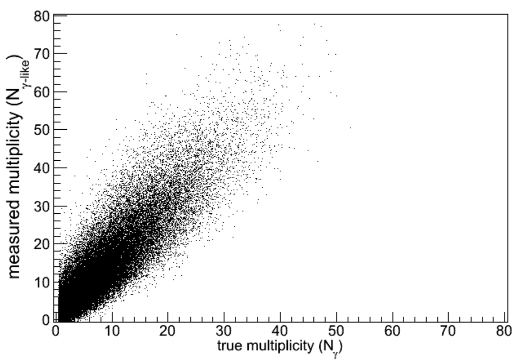

FIG. 1: True photon multiplicity vs. measured photon-like multiplicity for p + p collisions at $\sqrt{s}$ = 7 TeV with $2.3 < \eta < 3.9$.

The analysis is performed in a realistic simulation framework using the event generators

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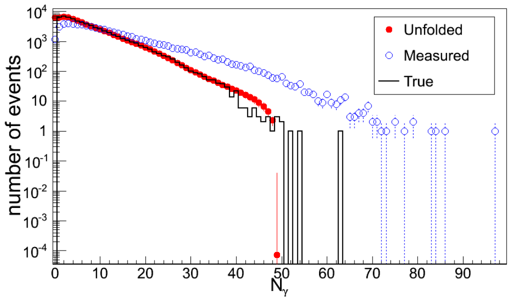

FIG. 2: The measured (open circle), true (solid line) and the unfolded (filled circles) multiplicity distributions of photons for p + p collisions at $\sqrt{s}$ = 7 TeV. The pseudorapidity region is $2.3 < \eta < 3.9$.

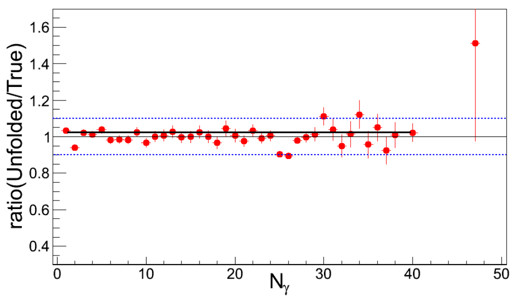

FIG. 3: The ratio between the unfolded multiplicity and the true multiplicity as given in Fig. 2.

$PYTHIA$, $PHOJET$, and $HERWIG$. The response matrix is constructed using a two dimensional histogram as shown in Fig. 1. Different types of regularization functions [e.g., Polynomial of order 0 and 1, and logarithmic function] are used in our study and the values of β are optimized for each regularization type. Figs. 2 and 3 show the comparison between the true, measured and the unfolded multiplicity distribution and the ratio between the unfolded and the true multiplicity, respectively, using $PYTHIA(PYTHIA6D6T)$ event generator. Details of the unfolding procedure and the results from other event generators will be discussed.

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