Correcting for detector effects in high-multiplicity events with the HBOM method

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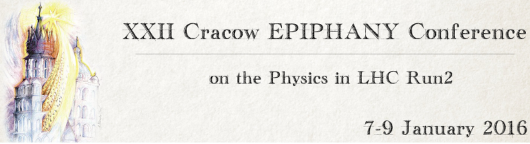


Detector effects

Measurements of particle multiplicities in high energy collisions may be affected by following detector effects:

- inefficiency in the detection of particles,
- incorrectly reconstructed tracks (called fakes),
- secondary particles created in decays of primary particles or due to their interactions with the detector material.

In general measurements with a detector can be expressed by:

$$g(y) = \int A(y,x)f(x)dx,$$

where:

$g(y)$ - measured distribution
$f(x)$ - truth distribution
$A(y,x)$ - response function

Discrete form with n bins for x and m bins for y:

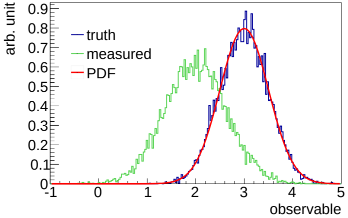
$$\mathbf{y} = \mathbf{A}\mathbf{x}$$

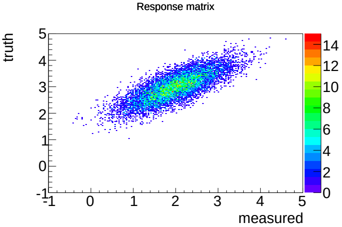
$\mathbf{y}$ - measured histogram
$\mathbf{x}$ - truth histogram
$\mathbf{A}$ - response matrix

General idea of unfolding

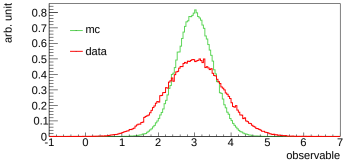
To correct for detector effects an unfolding method is used which needs to invert the response matrix:

$$\mathbf{x} = \mathbf{A}^{-1}\mathbf{y}$$





However unfolding does not work when real data has a wider distribution than simulation used to obtain the response matrix.



HBOM (Hit Backspace Once More) method

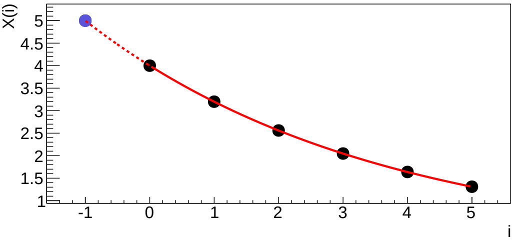
First proposed: J. Monk, C. Oropeza-Barrera, Nucl. Instrum. Meth. A 701 (2013) 17-24
Let us consider a detector response described by operator A, then:

$$X^{obs} = X(0) = AX^{true} = AX(-1)$$

Operator A can be applied i times:

$$X(i) = A^{i+1}X^{true}$$

Repetition of the above procedure will result in a sequence of values of the observable $X(i)$.



Observables

To study performance of the HBOM method factorial moments will be used which are defined as:

$$F_{i_1,\dots,i_B} \equiv \left\langle \prod_{j=1}^{B} \frac{n_j!}{(n_j - i_j)!} \right\rangle ,$$

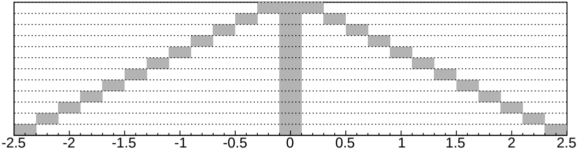
where B denotes number of pseudorapidity bins and n_j is the number of charged particles emitted into a given pseudorapidity interval. For three pseudorapidity bins, the above equation can be expressed as:

$$F_{i_L,i_C,i_R} \equiv \left\langle \frac{n_L!}{(n_L - i_L)!} \frac{n_C!}{(n_C - i_C)!} \frac{n_R!}{(n_R - i_R)!} \right\rangle$$

In the following we will focus on the four factorial moments:

$$F_{100}, F_{101}, F_{120}, F_{111}$$

Factorial moments are extracted in 3 pseudorapidity bins with varying distance between forward and backward bin.



Correction of the factorial moments I

To correct for track reconstruction inefficiency the following procedure is applied:

- measurement of an observable (in this case: factorial moments) using all reconstructed tracks satisfying the analysis cuts – 0th iteration,
- removal of tracks from the sample according to the detector inefficiencies (discussed in the next slide),
- repeated measurement of the observable – 1st iteration,
- removal of further tracks from the sample and measurement of the observable – 2nd iteration, etc.,
- fitting (with exponential or polynomial) the distribution of the observable as a function of the iteration number,
- extrapolation to the iteration -1 should give an estimate of the true value of the observable.

Secondaries and fakes can be also corrected for.

Correction of the factorial moments II

Condition for removing tracks takes the form:

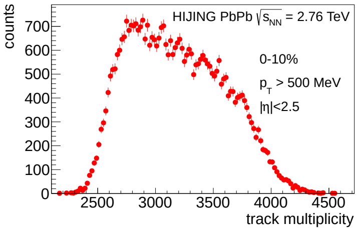
$$eff > r,$$

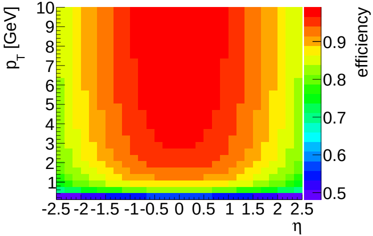
where eff is the efficiency for a given track and r is a random number from the uniform distribution in the interval [0,1].
Non-integer iterations can be introduced. In general, the rejecting procedure of the n-th iteration can be done from the 0th iteration with the following condition:

$$eff^n > r$$

For performance studies PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV were generated using the HIJING generator. As a track reconstruction efficiency function was taken:

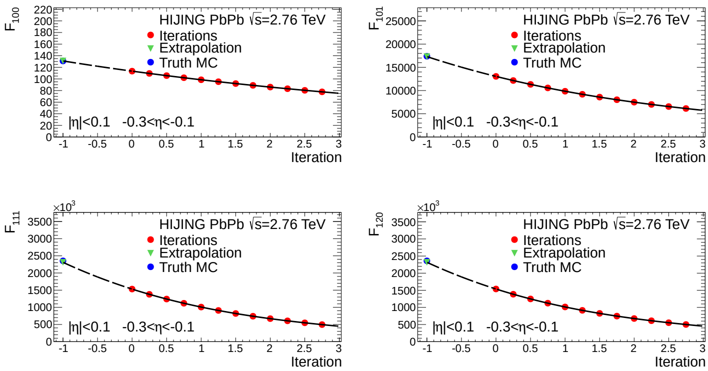
$$eff(p_T, \eta) = \frac{2}{\pi}\,\mathrm{tg}^{-1}\left(\frac{p_T - 80\text{ MeV}}{150\text{ MeV}}\right)\exp\left(-\frac{\eta^2}{36}\right)$$





Closure test I

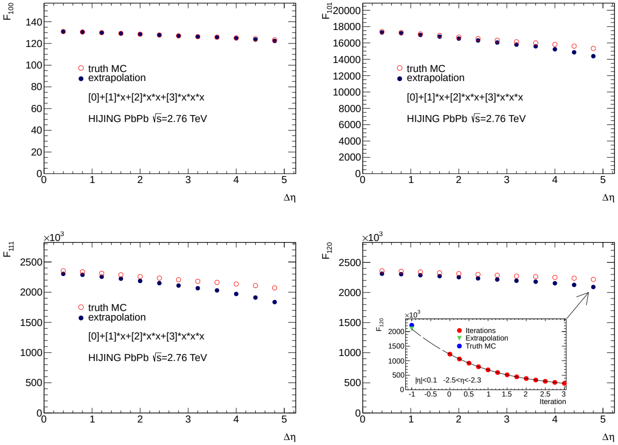
To correct factorial moments for detector inefficiencies the HBOM method was used. For the fitting function $ax^3 + bx^2 + cx + d$ was chosen.



In the central rapidity bins the HBOM method reproduces truth value very well.

Closure test II

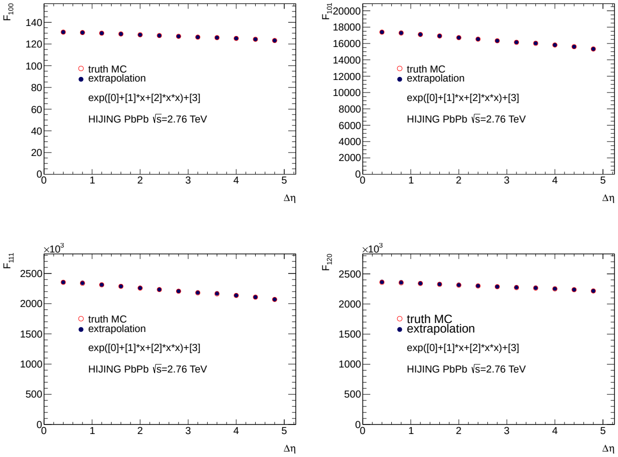
Factorial moments as a function of distance between bin centers corrected with $\boldsymbol{ax^3 + bx^2 + cx + d}$.



Factorial moments of rank 2 and 3 are significantly shifted with respect to the truth value.

Closure test III

Factorial moments as a function of distance between bin centers corrected with $\exp(ax^2 + bx + c) + d$.



Exponential function reproduces truth value very well in the whole pseudorapidity range.

Summary

- The general problem of correcting for detector effects in HEP measurements was discussed.
- The HBOM method was studied on high track multiplicity events generated with HIJING.
- Factorial moments were choosen as an example observable.
- Presented method gives promising results.
- More studies of the fitted function are needed.