Multiparticle correlations in pp-collisions at $\sqrt{s} = 13$ TeV

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This work is devoted to the analysis of multiparticle correlations in events with the Drell-Yan process in proton-proton collisions with the factorial moment method. This method consists in study of the dependence of factorial moments of multiplicity distribution in the intervals of dynamical variable on the size of these intervals and allows one to exclude statistical effects related to finite particle multiplicity in events, thus exctracting genuine dynamical correlations. The dataset collected by the CMS detector in 2017 corresponds to an integrated luminosity of 41.55 fb^{-1} at a center-of-mass energy of 13 TeV. Monte-Carlo datasets are used for comparison with experimental data. We present the calculated numerical values of normalized one-dimensional factorial moments of multiplicity distribution in a selected pseudorapidity interval and demonstrate the dependencies of these values on the parameters of theoretical calculations.

Normalized factorial moments

Let $\Delta\eta$ be the pseudorapidity interval which is divided into M bins of the size $\delta\eta = \Delta\eta/M$. Let n_i be the particle multiplicity in the i-th bin and let N be the total particle multiplicity in the whole $\Delta\eta$ interval. Then the normalized factorial moment of multiplicity distribution of the q-th order is defined as follows:

$$F_q^h(\delta\eta) = M^{q-1} \left\langle \sum_{i=1}^{M} \frac{n_i(n_i-1)(n_i-2)...(n_i-q+1)}{N(N-1)(N-2)...(N-q+1)} \right\rangle_{events}.$$

In case of independent particle production on the $\Delta\eta$ interval the factorial moments of multiplicity distribution of any order are constant and equal to 1. Otherwise the values of factorial moments change with decreasing bin size.

Mathematical model

For simplicity we consider a mathematical model which can be related to the clan model of multiparticle production proposed by Giovannini and Van Hove. This mathematical model is based on the following assumptions:

- particles in events are produced in groups
- each group contains at least one particle
- the number of groups cannot be greater than the number of particles
- number of groups follows the Poisson distribution
- number of particles in a group follows the Geometric distribution.

Let m be the number of groups produced in event and α be the probability that a particle is produced in a group. Thus the multiplicity probability density to produce k particles on the $\Delta\eta$ interval is given by the next equation:

$$P(k) = \sum_{m=0}^{k} \frac{e^{-\lambda}\lambda^m}{m!} \binom{k-1}{m-1} \alpha^{k-m}(1-\alpha)^m.$$

Generated particles selection

- particle is charged
- $p_T > 0.5$ GeV
- $|\eta| \leq 1$

Reconstructed tracks selection

- $p_T > 0.5$ GeV
- $|\eta| \leq 1$
- $|\rho_{track} - \rho_{vertex}| \leq 2$ mm,
- $|z_{track} - z_{vertex}| \leq 2$ mm

Event selection

- dimuon trigger "Mu17" and "Mu8"
- ≥ 2 muons
- ≥ 2 tight muons
- ≥ 2 isolated muons
- $p_T(\mu_1) > 25$ GeV and $p_T(\mu_2) > 10$ GeV
- ≥ 1 dimuon $\mu^+\mu^-$ with $70 \leq m_{\mu\mu} \leq 110$ GeV

The unfolding procedure algorithm

1. $F_q^{rec}(M) \times$ purity $= F_q^{recMatched}(M)$
2. Response matrix $\longrightarrow$ RooUnfold framework + SVD algorithm $\longrightarrow F_q^{genMatched}(M)$
3. $F_q^{genMatched}(M)$/acceptance $= F_q^{gen}(M)$
4. $F_q^h(M) = \langle F_q(M) \rangle_{events}$

Results

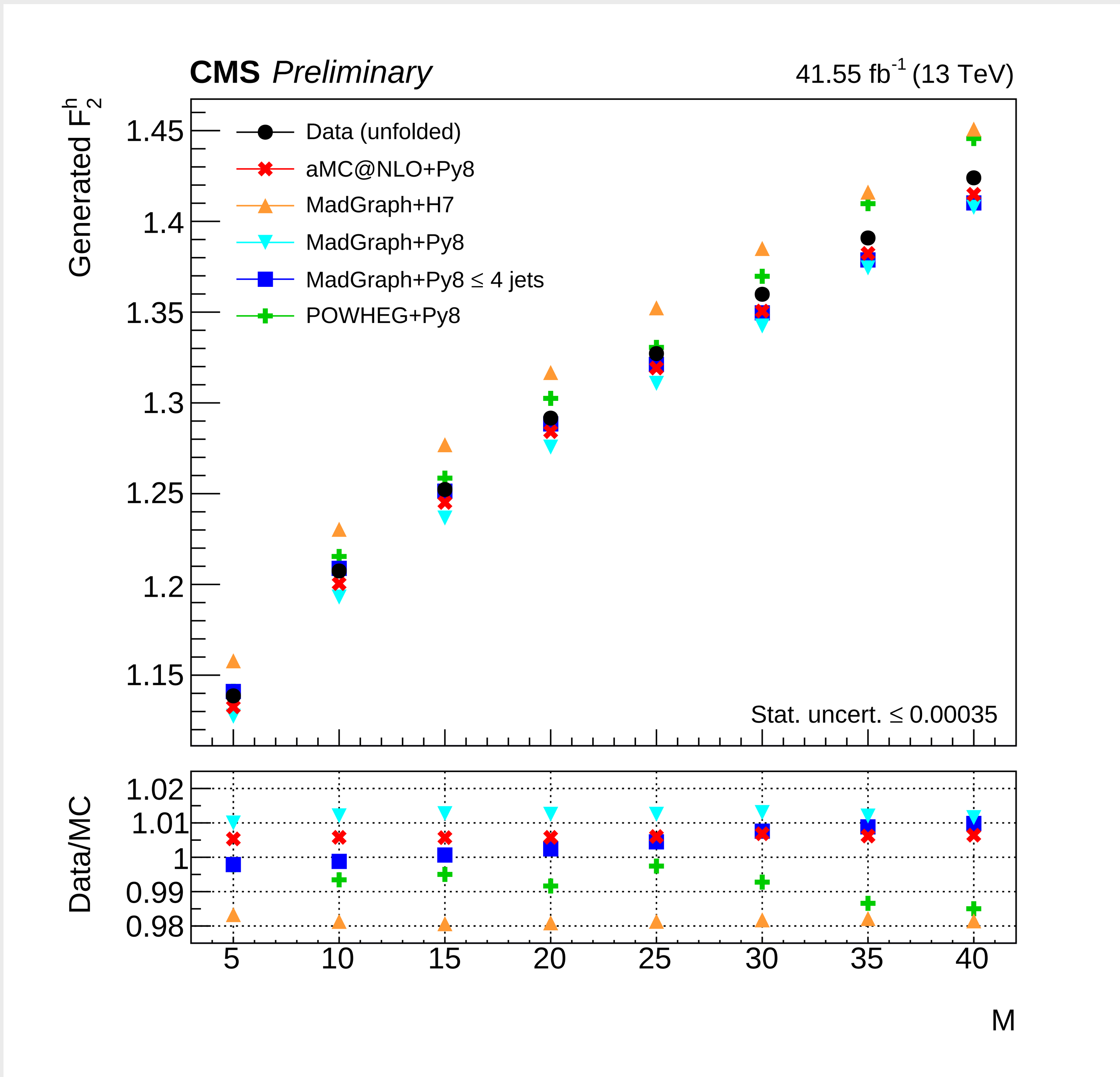

Figure 1: Generator level $F_2^h(M)$ dependencies after event cuts

Conclusions

- We observe dependencies of normalized factorial moments of multiplicity distribution on the details of theoretical calculations:
  1. the small dependence of normalized factorial moments of multiplicity distribution on the strong coupling order,
  2. the strong dependence of normalized factorial moments of multiplicity distribution on the parameters of the hadronization and parton shower models.
- Since the values of normalized factorial moments of multiplicity distribution may be directly related to the numbers of produced particles and produced groups of particles in events, the assumption about differences in clusterization processes in used Monte-Carlo generators makes sense. In particular, group widths and probabilities of particles to be clustered in a group may vary in different theory approaches.

1. *A. Bialas, R. Peschanski.* Moments of rapidity distributions as a measure of short-range fluctuations in high-energy collisions // Nuclear Physics B. 1986. vol. 273, p. 703-718.
2. *A. Giovannini, L. Van Hove.* Negative binomial properties and clan structure in multiplicity distributions // Acta Phys. Pol. B. 1988. vol. 19, p. 495-510.