Corrections of fluctuation observables with the Unfolding techniques at NA61/SHINE

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Motivation

The data analysis requires corrections of the experimental results for the detector inefficiencies. Simple multiplication by a constant factor or bin-by-bin weighing does not account for event migration or event losses and gains. In the study of fluctuations the **deconvolution of distributions is essential** and can be done with the Unfolding by RooUnfold [1]. Namely, all the information about detector biases is contained in Response matrix (RM) whose elements are probabilities to measure X_rec in event with X_sim produced. Inverted RM applied to the measured distribution gives us the true unsmeared one.

Unfolding test: what to do

1) Divide full Monte-Carlo dataset into two parts: to construct RM and to form pseudo-data (pure and biased). 2) Fill RM with sim and rec event/track info. 3) Fill the list of «missed» entities with sim whose rec was lost by selection/trigger. 4) Fill the list of «fake» entities with rec that doesn't have corresponding sim (or that comes from trigger mis-labeling). 5) Choose RooUnfold method.

Quantities of interest

Strongly intensive quantities (SIQs) are widely used in the search for the critical point of strongly interacting matter [2,3]. Being independent of the volume and event-by-event volume fluctuations*, they are defined for extensive event quantities, e.g.: N - charged particles multiplicity, PT - scalar sum of the event transverse momentum, pt - single particle spectra; NF and NB - charged particle multiplicities in Forward and Backward pseudo-rapidity intervals [4].

Due to complexity and time consumption we avoid 3D Unfolding, and, providing that SIQs are centrality independent, we do:

- 2D Unfolding of PT-N and NF-NB joint distributions
- 1D Unfolding of N distribution and one-particle pT spectra

$$\omega[N] = \frac{\langle N^2\rangle - \langle N\rangle^2}{\langle N\rangle}, \qquad \omega[P_T] = \frac{\langle P_T^2\rangle - \langle P_T\rangle^2}{\langle P_T\rangle}$$

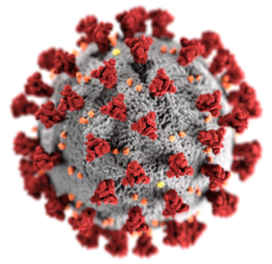
$$\Delta[P_T, N] = \frac{1}{C_\Delta}\left[\langle N\rangle\omega[P_T] - \langle P_T\rangle\omega[N]\right]$$

$$\Sigma[P_T, N] = \frac{1}{C_\Sigma}\left[\langle N\rangle\omega[P_T] + \langle P_T\rangle\omega[N] - 2(\langle P_T \cdot N\rangle - \langle P_T\rangle\langle N\rangle)\right]$$

$$C_\Delta = C_\Sigma = \langle N\rangle\omega(pt), \qquad \omega(pt) = \frac{\overline{pt^2} - \overline{pt}^2}{\overline{pt}}$$

$$\Sigma[N_F, N_B] = \frac{1}{\langle N_B\rangle + \langle N_F\rangle}\left[\langle N_B\rangle\omega[N_F] + \langle N_F\rangle\omega[N_B] - 2(\langle N_F N_B\rangle - \langle N_F\rangle\langle N_B\rangle)\right]$$

* under some conditions [2]



Analysis results for all charged particles

Fluctuation measure	true	biased	unfolded
<N> from 1D distr.	2.92 +- 0.05	3.47 +- 0.05	2.92 +- 0.06
<N> from 2D PT-N distr.	2.92 +- 0.07	3.41 +- 0.09	2.89 +- 0.08
ω[N] from 1D distr.	1.99 +- 0.04	1.73 +- 0.03	2.04 +- 0.06
ω[N] from 2D PT-N distr.	1.99 +- 0.09	1.72 +- 0.07	2.01 +- 0.09
Σ[NF, NB]	1.09 +- 0.06	0.90 +- 0.09	1.05 +- 0.05
<PT>	0.96 +- 0.09	1.12 +- 0.05	0.95 +- 0.03
ω[PT]	0.78 +- 0.07	0.66 +- 0.04	0.77 +- 0.05
<pT>*	0.327 +- 0.004	0.329 +- 0.003	0.328 +- 0.003
ω(pT)*	0.134 +- 0.002	0.132 +- 0.004	0.135 +- 0.005
Σ[PT,N]	1.03 +- 0.03	1.07 +- 0.09	0.97 +- 0.11
Δ[PT,N]	0.99 +- 0.06	0.79 +- 0.08	0.83 +- 0.09

#iterations in RooUnfoldBayes	10	50	100	200	300
<pT>* unfolded/true	1.00808	1.00749	1.00695	1.00637	1.00612

Table 1. Top: Preliminary results of the unfolding of fluctuation measures in EPOS1.99 pseudo-data in NA61/SHINE experimental acceptance. True - pure generator data, biased - reconstructed one, unfolded - unsmeared distribution by RooUnfoldBayes. **Bottom**: Ratio of the unfolded value of the mean particle transverse momentum to the true one as function of the number of iterations. <..>* - the averaging over all particles in all events, <..> - the averaging over events.

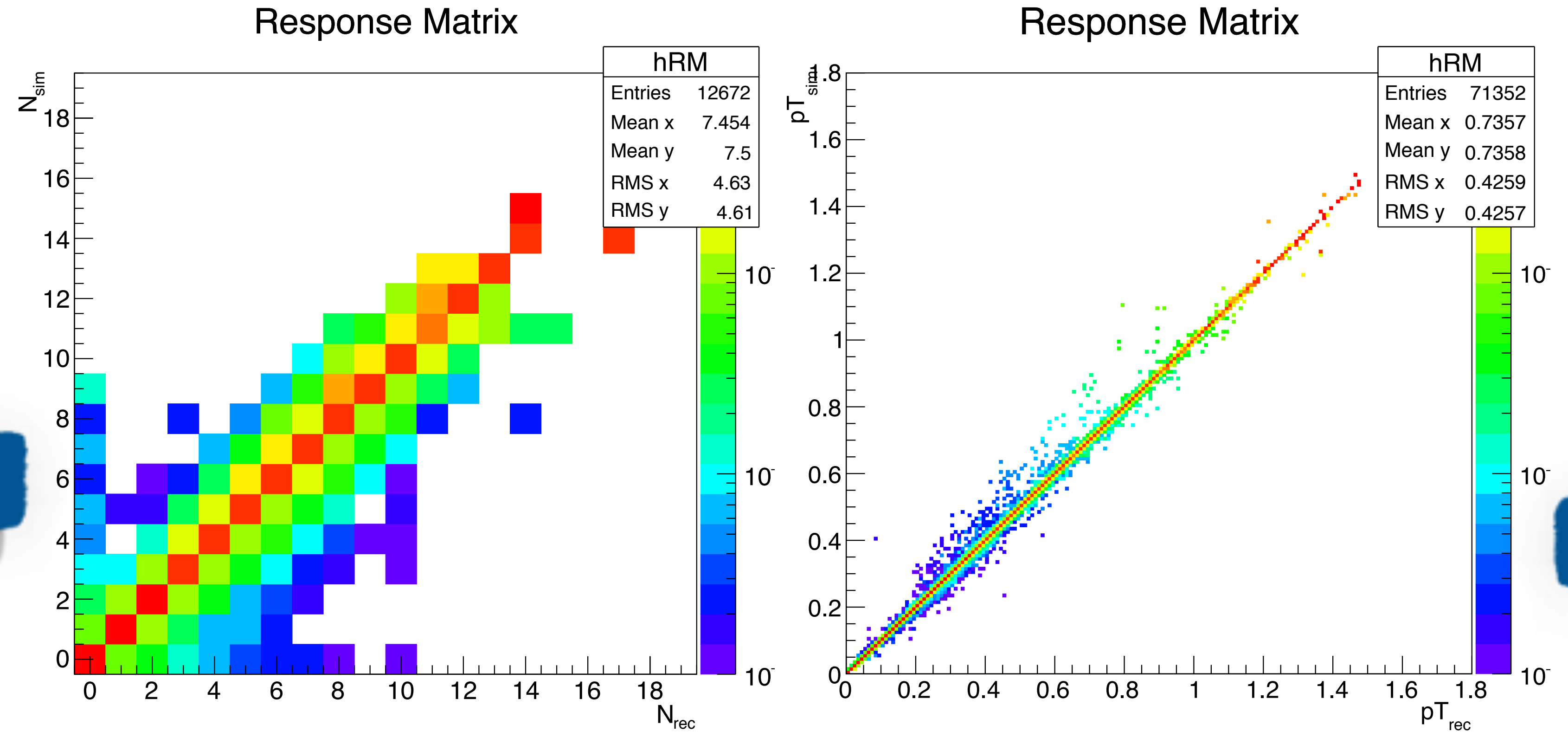


Fig.1 Response matrix of the detector biasing a) charged particle multiplicity: Nrec vs Nsim, b) particle transverse momentum: pTrec vs pTsim (with matching)

Details

The analysis was performed for p+p@158GeV/c Monte-Carlo data by EPOS1.99 generator [5] in the NA61/SHINE acceptance [6]. Events and track selection criteria were chosen as in [7]. Results for <N>, ω[N], Σ[PT,N] and Δ[PT,N] are obtained in η region [2.9, 5.8] in lab frame. Forward window for Σ[NF, NB] is in pseudorapidity range [2.9, 5.8], Backward - [0, 2.9] in lab frame. Response matrix (RM) - 85% of MC statistics, pseudo data - 15%: true - pure generator, biased - the reconstructed as data. Statistical uncertainties were obtained using sub-sample method: the same RM was applied to sampled biased pseudo-data to obtain sampled unfolded distributions to be compared with the sampled true pseudo-data ones (Table 1, Top). The results depend on the number of iterations of RooUnfoldBayes (Table 1, Bottom).

Summary

This poster shows preliminary tests of the Unfolding procedure applied to 1D and 2D distributions in order to correct fluctuation observables. Response matrix (Fig.1) is not diagonal, which excludes the use of bin-by-bin method of corrections. Table 1 reveals that the unfolded results are close to the true values. However, the difference between line#1 and line#2 (#3 and #4 as well) indicates the influence of the switch to 2D unfolding: it spoils the accuracy of Unfolding. This discrepancy mainly comes from the PT unfolding which implies the need of finer binning.

Future plans

- Increase of the MC statistics to build RM
- Study the dependence on the bin sizes for non-integer quantities
- Cross-validation on the second Monte-Carlo with the simulation of trigger

References

[1] https://gitlab.cern.ch/RooUnfold/RooUnfold
[2] Gorenstein M I, Gazdzicki M 2011 *Phys. Rev.* C: Nucl. Phys. **84** 014904
[3] Gazdzicki M, Gorenstein M, Mackowiak-Pawlowska M 2013 *Phys. Rev. C* **88** 024907
[4] Andronov E V 2015 *Theor. Math. Phys.* **185** 1 1383
[5] Werner K, Pierog T 2006 *Phys. Rev.* C **74** 044902
[6] Czopowicz T https://edms.cern.ch/document/1549298/1
[7] Aduszkiewicz A et al [NA61/SHINE Collab.] 2016 *Eur. Phys. J.* C **76** 635

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