Reconstruction of the moments of particle multiplicity distributions with Identity Method with MPD

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Identity Method

Collisions of relativistic nuclei can produce matter at extremely high temperatures and densities. Studies of the transition between the hadronic and partonic phases of this matter are being performed, in particular, with such observables as particle yield fluctuations (e.g. net-proton) and other combinations of multiplicity moments, for instance, forward-backward correlations. This requires identification of different particle species (e.g., pions, kaons, protons). Precise determination of the multiplicity of a certain particle type can be difficult due to the misidentification in detectors. The so-called Identity Method (IM) [1,2,3] allows one to solve this problem. For example, if a signal distribution *ρ(dE/dx)* in the Time-Projection Chamber (TPC) is known, one can use the probabilities for a given particle of being of a given type:

$$\omega_j(dE/dx) = \frac{\rho_j(dE/dx)}{\sum_i \rho_i(dE/dx)}; \quad W_j = \sum_i^N \omega_j(dE/dx_i), \text{ where d}E/dx \text{ is defined for each of } N \text{ particles.}$$

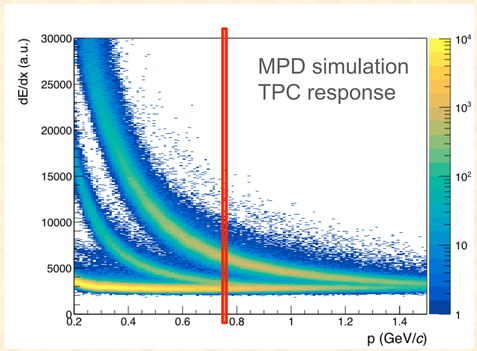
$\langle W_p W_q \ldots \rangle$ – linear combination of moments $\langle N_i N_j \ldots \rangle$ and integrals $\frac{1}{\langle N_i \rangle}\int dm\,\omega_p(m)\omega_q(m)..\rho_i(m)$.

Using linear algebra, one can extract the second [1], mixed and higher moments [2,3]. The basic code for the Identity Method is available on github [4]. The method was successfully used in ALICE, for instance, for studies of π, K, p [5] and net-proton [6] fluctuations.

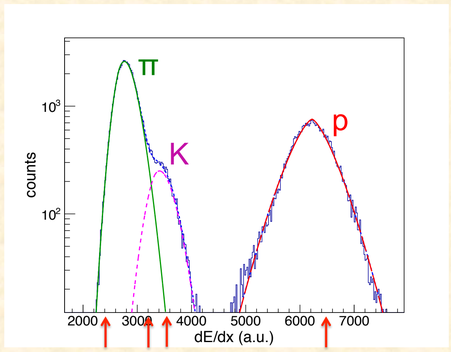
Application to MPD simulated data

The IM was applied to a dataset of Bi–Bi @ 9.46 GeV collisions simulated in SMASH event generator [7], with GEANT3 response of the MPD detector, digitization and full reconstruction. Centrality class 0-20%, 204*k* events were analyzed.

Example momentum bin: 0.75-0.76 GeV/*c*



Fits: by Generalized Gauss for each species:



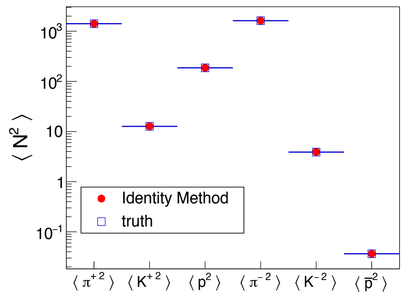
Caveat: simultaneous fitting for all particle species in a momentum slice is a challenging task, if significant signal overlap is present. With real data, it could be done with the so-called clean samples of particles with known PID using products of V0 decays, TOF, etc. [8].

- Fits in all momentum slices are obtained.
  → Plug this information into the machinery of the Identity Method…

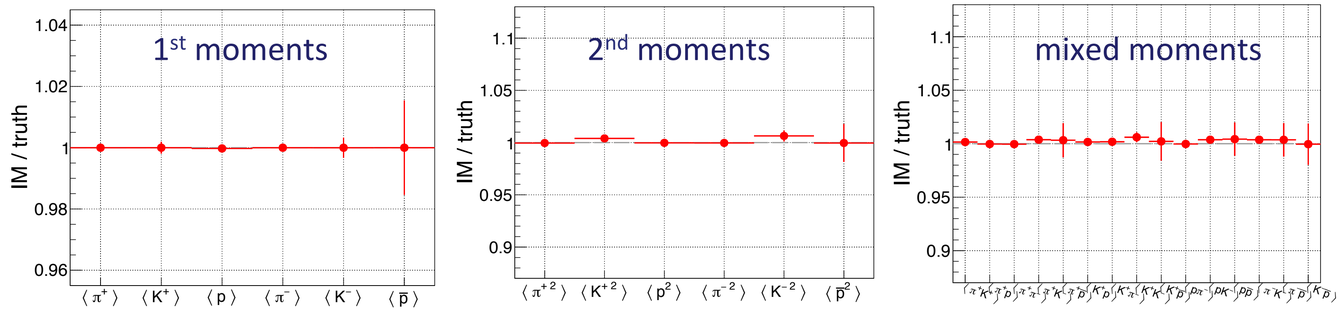
Performance: reconstructed moments in a given *η* range

Kinematic acceptance: **|η|<0.5**, momentum *p* in **(0.3, 1.5)** GeV/*c*.
Species: **π, K, p** and their antiparticles (no electrons in SMASH).
Stat. uncertainties: by subsampling method.

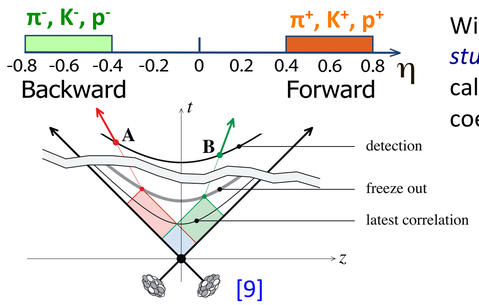
Example: values of the second moments *reconstructed* with the IM, and the *truth* values.



Ratios of the moments *reconstructed* with the IM to the *truth* values are given below. Excellent correspondence is achieved.



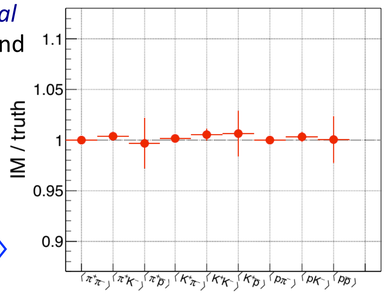
Performance: forward-backward rapidity correlations with PID



With the IM we can also perform *more differential studies*, namely, we can select two regions in ***η*** and calculate the Forward-Backward correlation coefficient between them:

$$b_{\text{corr}} = \frac{\langle FB \rangle - \langle F \rangle \langle B \rangle}{\langle F^2 \rangle - \langle F \rangle^2}$$

Example: cross moments between the F and B windows.



Conclusions

- Identity Method is used in experiments to extract moments of particle distributions.
- Performance of the method was tested with realistic GEANT simulation and reconstruction in the MPD detector using Bi–Bi @ 9.46 GeV collisions generated in SMASH. First tests showed reasonable quality in the reconstructed moments.
- Along with the full-*η* analysis, the Identity Method could be used also for studies of Forward-Backward correlations.

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