Correction Methods for Finite-acceptance Effects in Two-particle Correlation Analysis

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Abstract

The present work addresses concern over the validity of the standard mixed-event method for correcting two-particle correlations.[1),2)] New methods for finite-acceptance correction are developed and tested in Monte Carlo simulations.

Introduction

- Two-particle pair-wise correlation analysis is based on the simultaneous measurement of pairs of particles in each event.
- Single and pair densities:

$$\rho_t(\eta_t,\varphi_t)=\frac{d^2N_t}{d\eta_t d\varphi_t}, \quad \rho_a(\eta_a,\varphi_a)=\frac{d^2N_a}{d\eta_a d\varphi_a},$$

$$\rho_{a,t}(\eta_a,\varphi_a;\eta_t,\varphi_t)=\frac{d^4N_{a,t}}{d\eta_a d\varphi_a d\eta_t d\varphi_t}$$

- Current definition of the correlation function:

$$C_{2,R}(\eta_a,\eta_t;\varphi_a,\varphi_t)=\frac{\rho_{a,t}(\eta_a,\varphi_a;\eta_t,\varphi_t)}{\rho_a(\eta_a,\varphi_a)\rho_t(\eta_t,\varphi_t)}-1$$

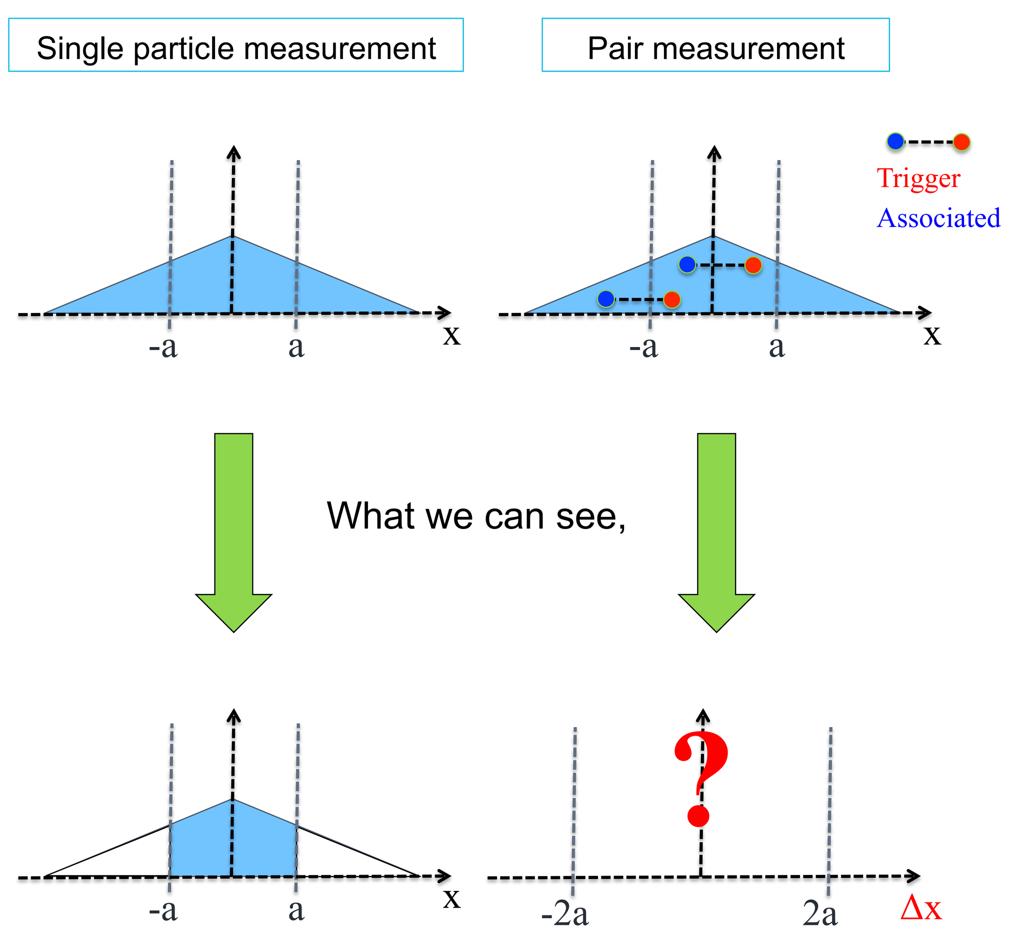
- Experimentally,

$$C_{trig,R}(\Delta\varphi,\Delta\eta)=\frac{1}{N_{trig}}\frac{d^2N^{pair}}{d\Delta\varphi d\Delta\eta}=B(0,0)\frac{S(\Delta\varphi,\Delta\eta)}{B(\Delta\varphi,\Delta\eta)}$$

➔ it is roughly equivalent to the ratio between correlated production and uncorrelated production.

Finite-acceptance Effects

- Finite-acceptance effects in pair measurements are more complicated than the effects in single particle measurements.
- Example in 1D (acceptance [-a, a] in x)



- Finite-acceptance effects in two-particle correlation analysis mean that pairs are not counted depending on the correlated particle positions, and we need to correct for those missing pairs.
- Current per-trigger associated particle yield is divided by normalized mixed-event function for finite-acceptance correction, but this procedure produces a ratio function instead of working as a correction.
- Correlation functions or per-trigger associated particle yields have two dimensions, (Δφ, Δη), but we assume full azimuthal acceptance for the detector in this study ➔ Dimension of finite acceptance correction is 1, only in Δη.
- If yields or Δφ-projections are considered in the analysis, ratio function might produce different results from the intended per-trigger associated particle yields.

New Method Derivation

- Modeling particle correlations in a jet which correspond to near-side jet structure,

If we have an infinite acceptance

$$C_{ideal}(\Delta x)=\frac{1}{N_{trig,ideal}}\int dX\int dx\left(g(X)f_a(x-X)f_t(x-X+\Delta x)\right),$$

$$N_{trig,ideal}=\int dX\int dx\left(g(X)f_t(x-X)\right)$$

✓ X : Common reference point of trigger and associated particle distributions in each event (=jet-axis)

✓ $f_t(x-X)$: Trigger-particle distribution in a single event with respect to $x=X$

✓ $f_a(x-X)$: Associated particle distribution in a single event, with respect to $x=X$

✓ $g(X)$: Each event has X value, and $g(X)$ represents the distribution of X over all events

If we have a finite acceptance

$$C(\Delta x)=\frac{1}{N_{trig}}\int dX\int dx\left(g(X)f_a(x-X)f_t(x-X+\Delta x)A(x)A(x+\Delta x)\right)$$

$$N_{trig}=\int dX\int dx\left(g(X)f_t(x-X)A(x)\right)$$

✓ $A(x)=1$ if $-a<x<a$ and $A(x)=0$ if others

- We can find analytic formulas in certain cases.

➔ $C_{ideal}(\Delta x)=\alpha(\Delta x)C(\Delta x)$

➢ If $g(X)$ is constant,

$$\alpha(\Delta x)=\frac{1}{2a}\int A(x)A(x+\Delta x)dx \qquad \textbf{Method 1}$$

➢ If $f_t(x-X)$ is a delta-function, (=jet-shape for asso. particles)

$$\alpha(\Delta x)=\frac{1}{N_{trig}}\int A(x)n_{trig}(x+\Delta x)A(x+\Delta x)dx \qquad \textbf{Method 2}$$

- Modeling away-side structure in di-jet events,

If we have an infinite acceptance

$$C_{ideal}(\Delta x)=\frac{1}{N_{trig,ideal}}\int dX\int dY\int dx\left(g(X,Y)f_a(x-X)f_t(x-Y+\Delta x)\right)$$

$$+\frac{1}{N_{trig,ideal}}\int dX\int dY\int dx\left(g(X,Y)f_t(x-X+\Delta x)f_a(x-Y)\right)$$

➢ If $g(X,Y)=g(X-Y)$, (pair density depends only on the distance between two jets)

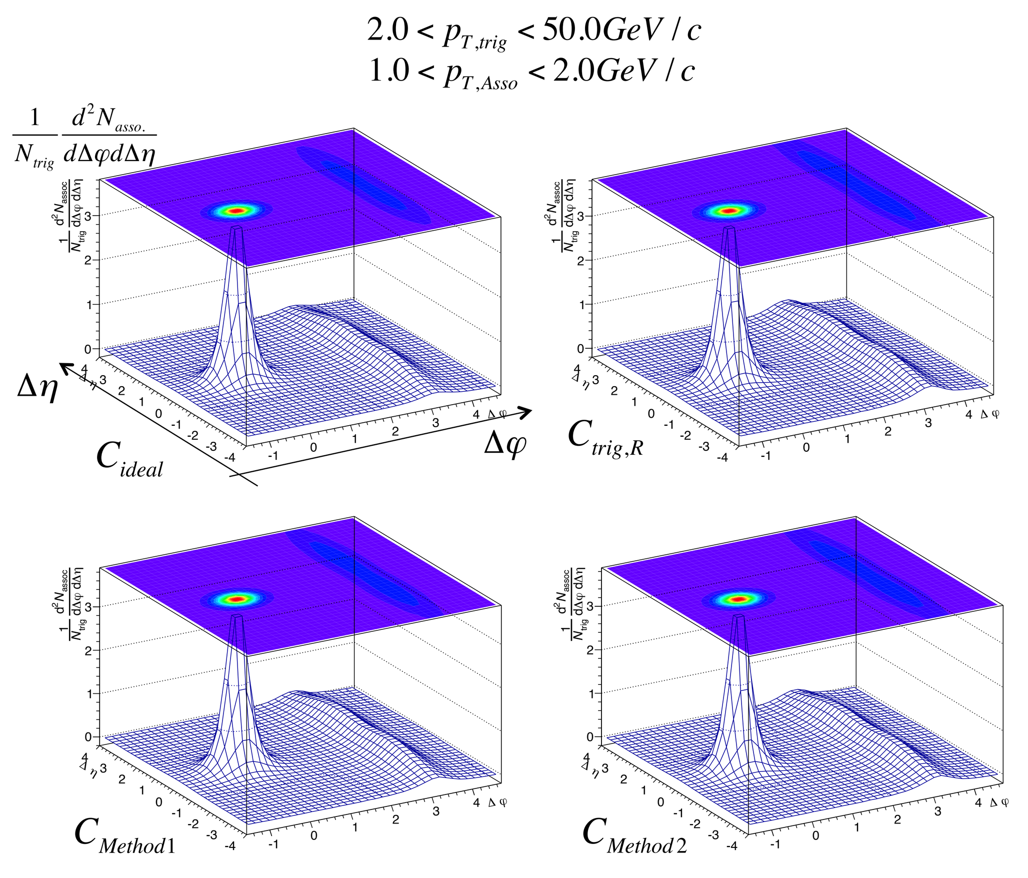
$$\alpha(\Delta x)=\frac{1}{2a}\int A(x)A(x+\Delta x)dx \qquad \textbf{Same as Method 1}$$

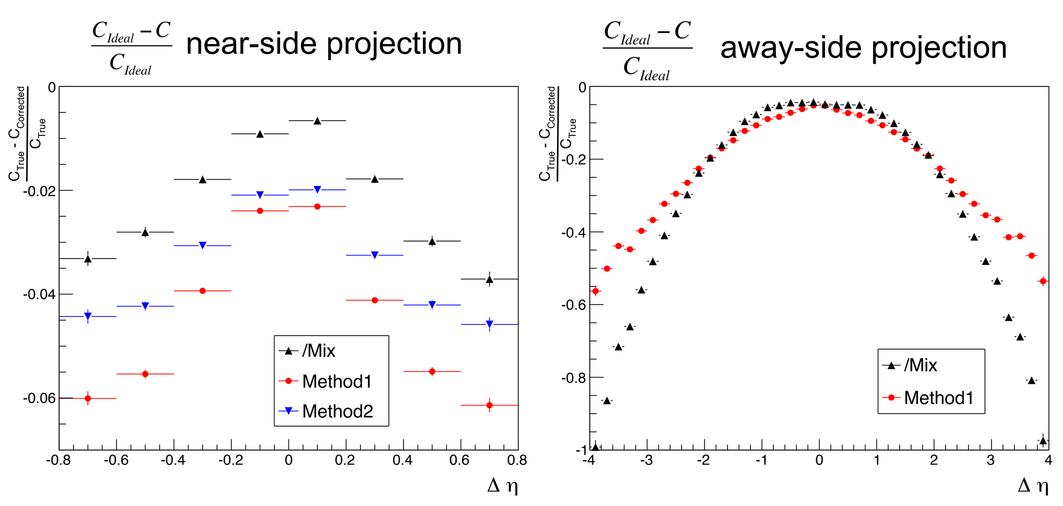
- There is no general formula which can always connect $C_{ideal}(\Delta x)$ and $C(\Delta x)$. But above methods can work as approximate formulas and their validities depend on the signal type.

We apply the new methods onto the Monte Carlo (MC) simulations to check their validity. In the MC simulations, we could detect every η of emitted particles, and control the acceptance range freely.

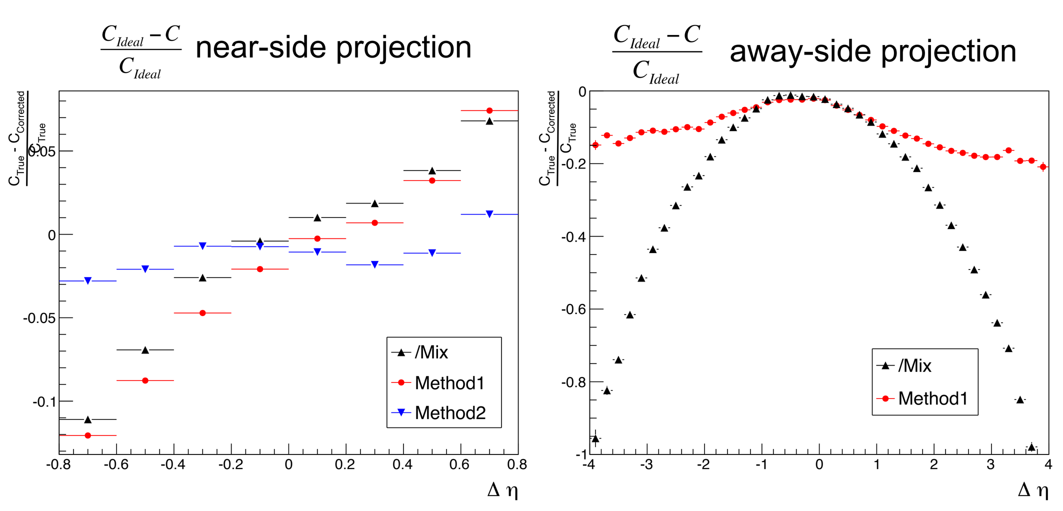
PYTHIA Simulation

- Correlation function shapes from p-p collisions are generally dominated by di-jet signals.
- If η-acceptance is [-2, 2],



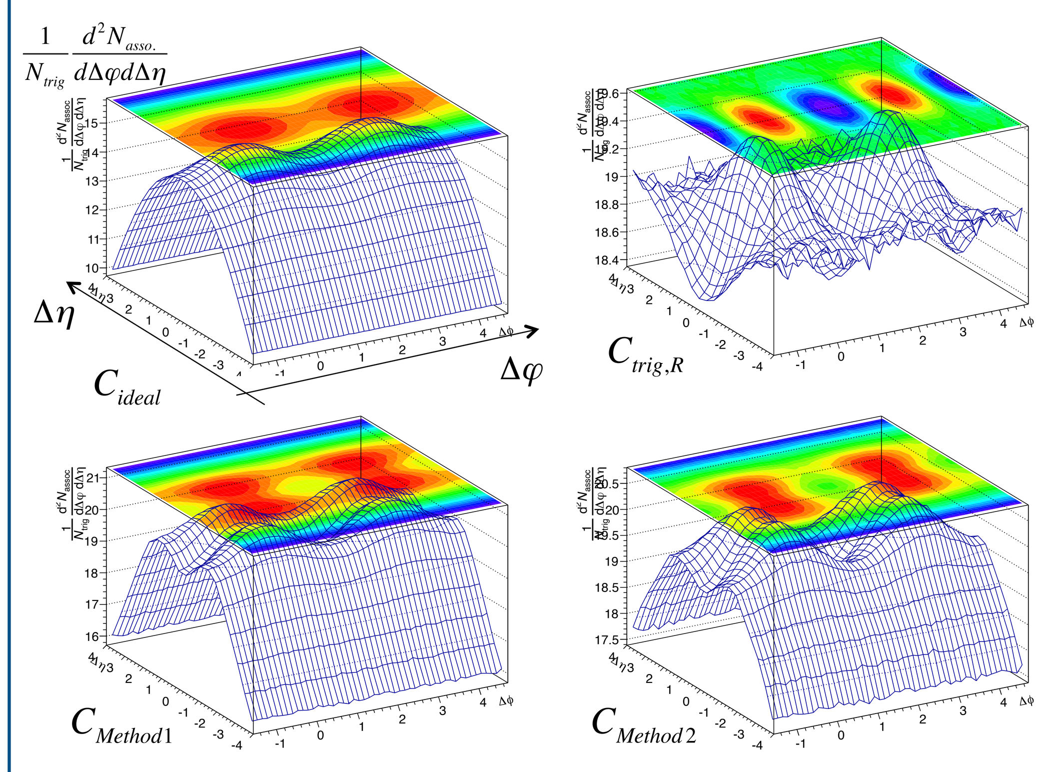


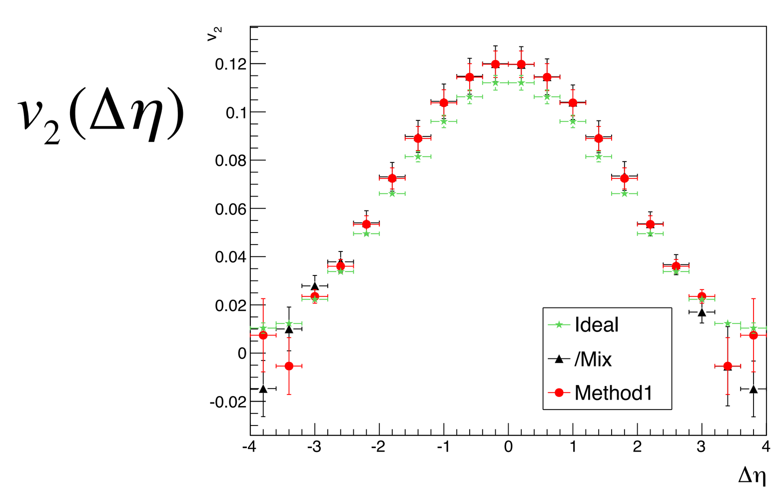
- If η-acceptance is [0, 4],



Collective MC Simulation

- Collective Toy MC simulation with Δη-dependent v_2





- Correlation function's yield at each Δη-bin works as weighting factor in Δφ-projection. Integrated v_2, which is evaluated after Δφ-projection, depends on correlation function yields if v_2 is dependent on Δη.

Conclusion

- The current finite-acceptance correction method produces a ratio function (=correlated/uncorrelated).
- New methods are developed and tested with the MC simulations, and they
  - ✓ analytically work for specific cases, (constant trigger location distribution over all events or delta-function-like trigger distribution …)
  - ✓ work as approximation in other cases.
- Analysis concerning yields or Δφ-projection largely depend on finite-acceptance correction method.

1) L. Xu, C.-H. Chen, and F. Wang, Phys. Rev. C88 (2013) 064907
2) S. Ravan, P. Pujahari, S. Prasad, and C. A. Pruneau, Phys. Rev. C89 (2014) 024906

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