Reaction plane fit method for jet-hadron and di-hadron correlations

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Jet-hadron and di-hadron correlations are used to study jet production in relativistic heavy ion collisions. In principle, these studies are sensitive to the low momentum and large angle modifications induced by interactions with the medium and allow higher precision measurements than jet-by-jet measurements because the background can be determined by averaging over several jets. In practice, the background due to flow has limited the precision of these measurements. The standard background subtraction method, the Zero Yield At Minimum method, has limitations, particularly at low momenta where modifications may broaden the jet. Since typically the vn are taken from independent measurements, the standard method is also not robust to effects which lead to different v_n in jet-like correlations than the v_n due to flow. This includes the impact of different vn due to flow and due to jet quenching at high momenta. We present an alternate method, the Reaction Plane Fit (RPF) method, which uses the reaction plane dependence of the v_n [1] to constrain the shape and level of the background in the background dominated region at large $\Delta\eta$. We demonstrate the efficacy of this method using a toy model. We then apply the RPF method to di-hadron correlations relative to the reaction plane measured by STAR. Using this method, the shape of the correlation functions show little shape dependence relative to the reaction plane, an increasing IAA with decreasing momentum. This is consistent with the broadening and softening of jets seen in measurements of full jets at the LHC, rather than the "Mach cone" structure observed in earlier studies.

1. Toy model

When the trigger is restricted to a range of angles relative to the reconstructed reaction plane, the effective even v_n^{t} are given by

$$\tilde{v}_n^{R,t} = \frac{v_n + \cos(n\phi_S)\frac{\sin(nc)}{nc}R_n + \sum_{k=2,4,6...}(v_{k+n} + v_{|k-n|})\cos(k\phi_S)\frac{\sin(kc)}{kc}R_n}{1 + \sum_{k=2,4,6...}2v_k\cos(k\phi_S)\frac{\sin(kc)}{kc}R_n} \qquad (1)$$

and the effective background level is given by

$$\tilde{\beta}^R = 1 + \sum_{k=2,4,6...} 2v_k\cos(k\phi_S)\frac{\sin(kc)}{kc}R_n \qquad (2)$$

where ϕ_S is the center of range and $2c$ is the width of the range [1]. The background is then given by:

$$\frac{dN}{\pi d\Delta\phi} = \tilde{\beta}^R\Big(1 + \sum_{n=1}^{\infty} 2\tilde{v}_n^{R,\mathrm{t}}\tilde{v}_n^{\mathrm{a}}\cos(n\Delta\phi)\Big). \qquad (3)$$

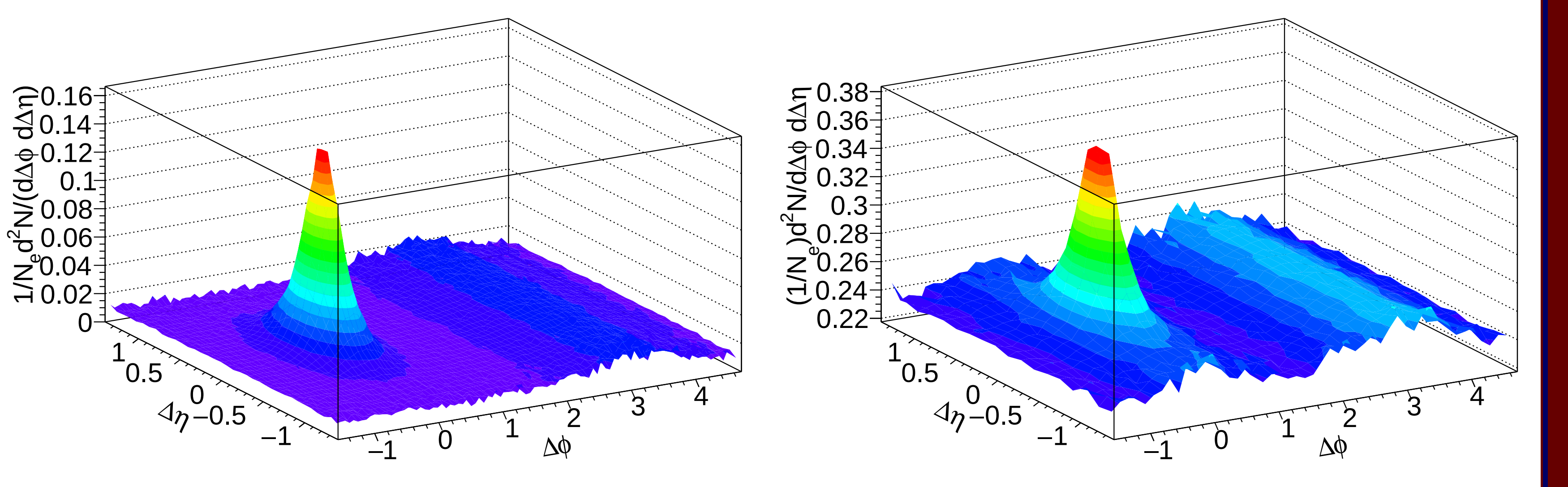

Figure 1: *Signal di-hadron correlations for trigger momenta $8 < p_T^{\mathrm{t}} < 10$ GeV/c within pseudorapidities $|\eta| < 0.5$ and associated particles within $|\eta| < 0.9$ with momentum $1.0 < p_T^{\mathrm{a}} < 2.0$ GeV/c in p+p collisions at $\sqrt{s}$ = 2.76 TeV in PYTHIA [2] (left) and PYTHIA signal added to a thrown flow modulated background (right).*

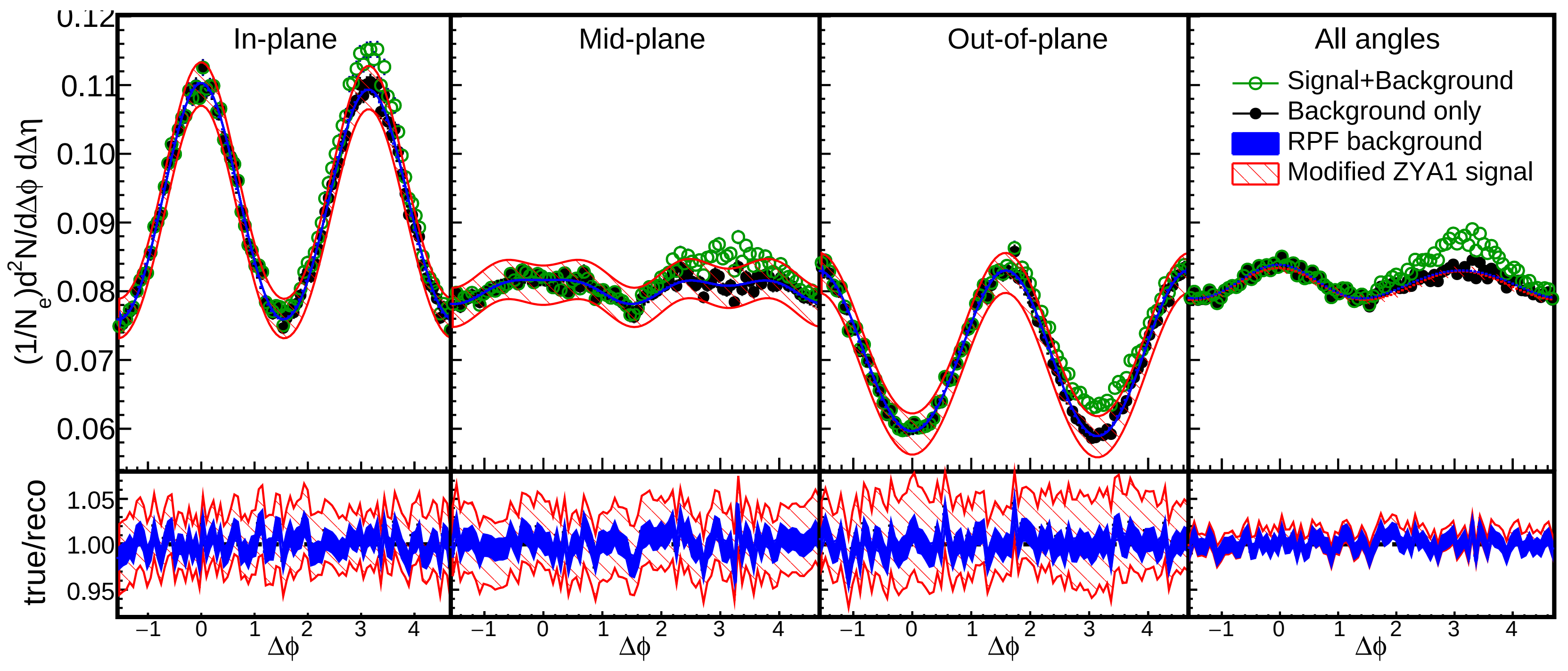

Figure 2: *Top: Top: Signal+background for in-plane, mid-plane, and out-of-plane triggers and for all triggers combined. The data for all angles relative to the reaction plane have been scaled by 1/3 in the top panel. Bottom: Ratios of the background from the RPF and ZYA1 methods to the true background.*

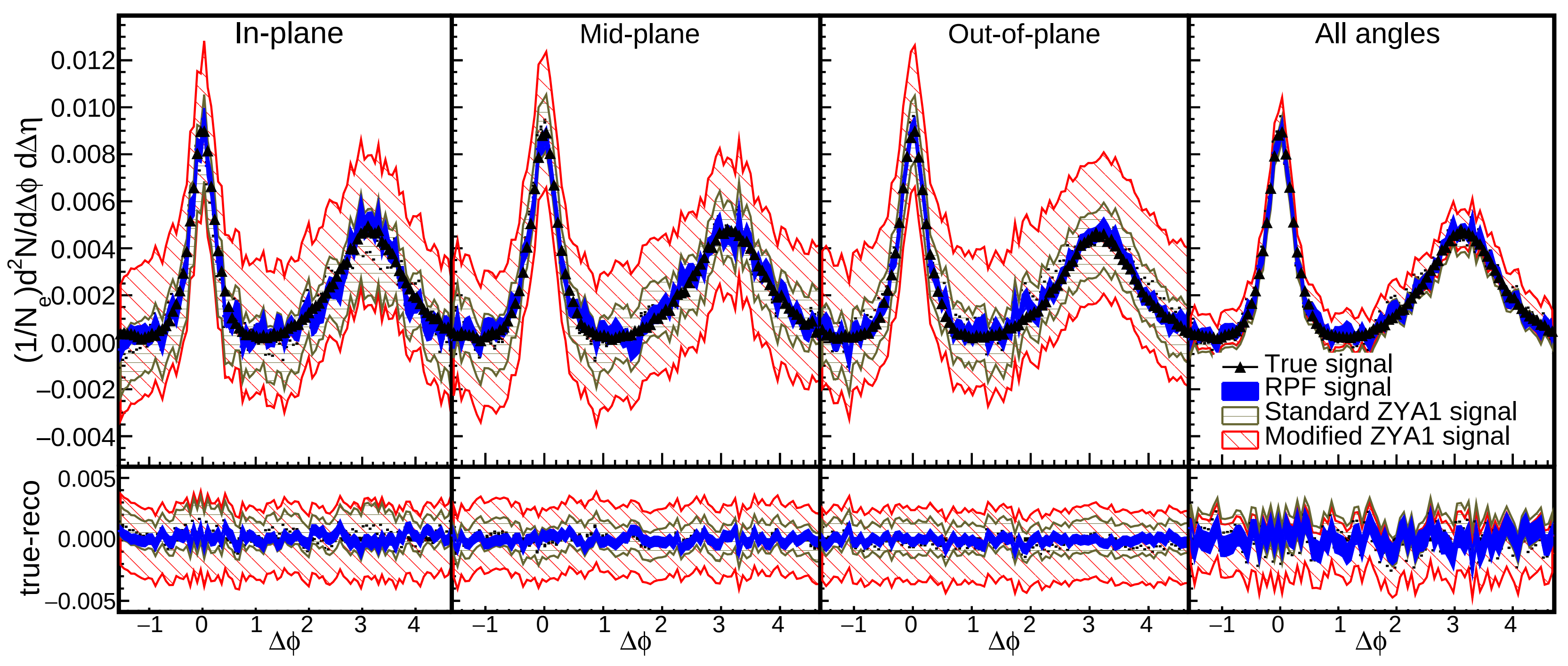

Figure 3: *Top: The true signal for for in-plane, mid-plane, and out-of-plane triggers and for all triggers combined. The data for all angles relative to the reaction plane have been scaled by 1/3 in the top panel in order to fit on the same scale. Bottom: Differences between the true signal and the signal extracted using the background from the ZYA1 method, modified ZYA1 method, and the background from the RPF method.*

2. STAR data

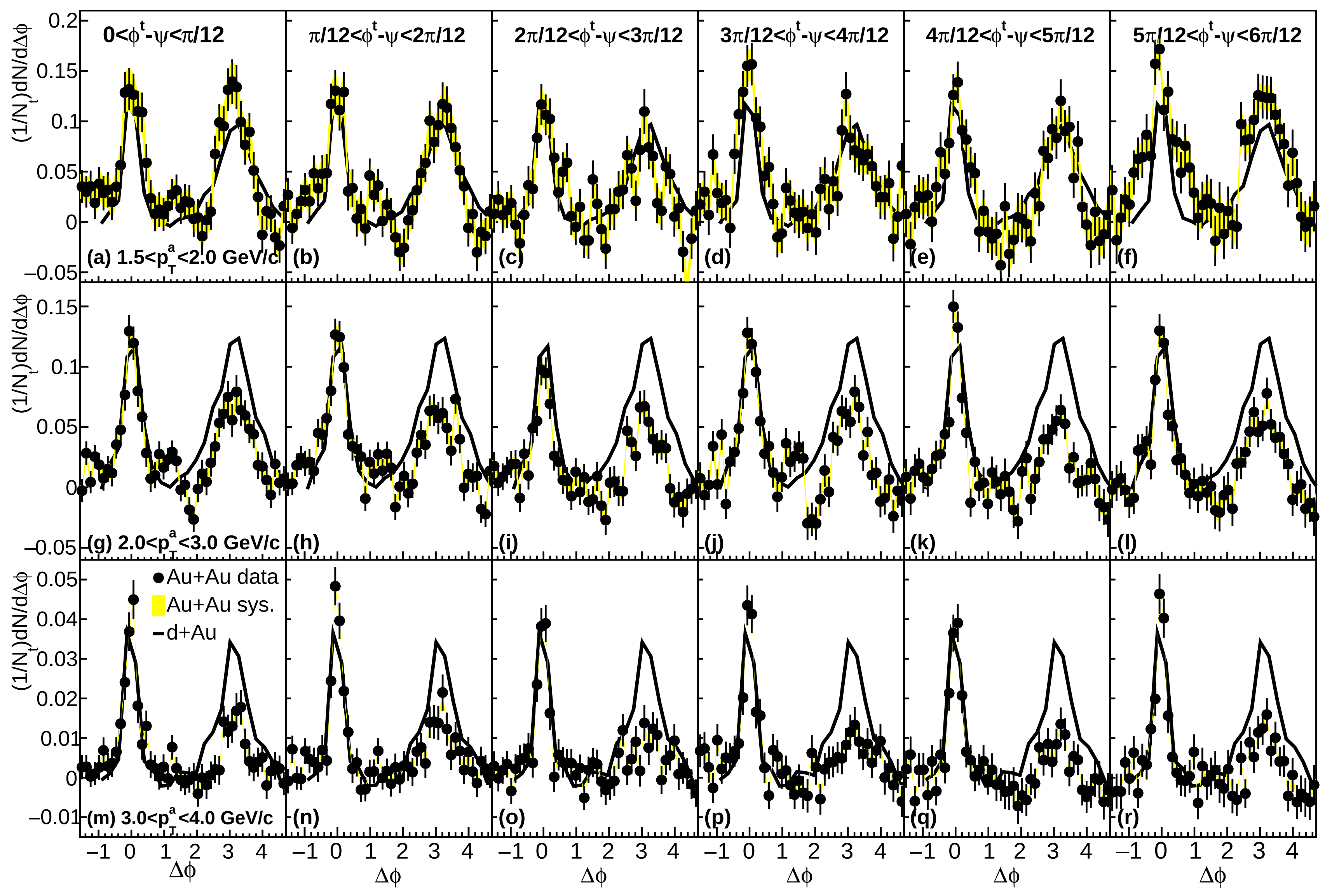

Figure 4: *In [3] the RPF method was applied to STAR data [4, 5]. Background subtracted di-hadron correlations with 4.0 $< p_T^{\mathrm{t}} <$ 6.0 GeV/c for 1.5 $< p_T^{\mathrm{a}} <$ 2.0 GeV/c (a-f), 2.0 $< p_T^{\mathrm{a}} <$ 3.0 GeV/c (g-l), 3.0 $< p_T^{\mathrm{a}} <$ 4.0 GeV/c (m-r) in $d + Au$ and $Au + Au$ collisions at $\sqrt{s_{\mathrm{NN}}}$= 200 GeV for trigger particles from 0 $< \phi_s < \pi/12$ (a,g,m), $\pi/12 < \phi_s < 2\pi/12$ (b,h,n), $2\pi/12 < \phi_s < 3\pi/12$ (c,i,o), $3\pi/12 < \phi_s < 4\pi/12$ (d,j,p), $4\pi/12 < \phi_s < 5\pi/12$ (e,k,q), and $5\pi/12 < \phi_s < 6\pi/12$ (f,l,r).*

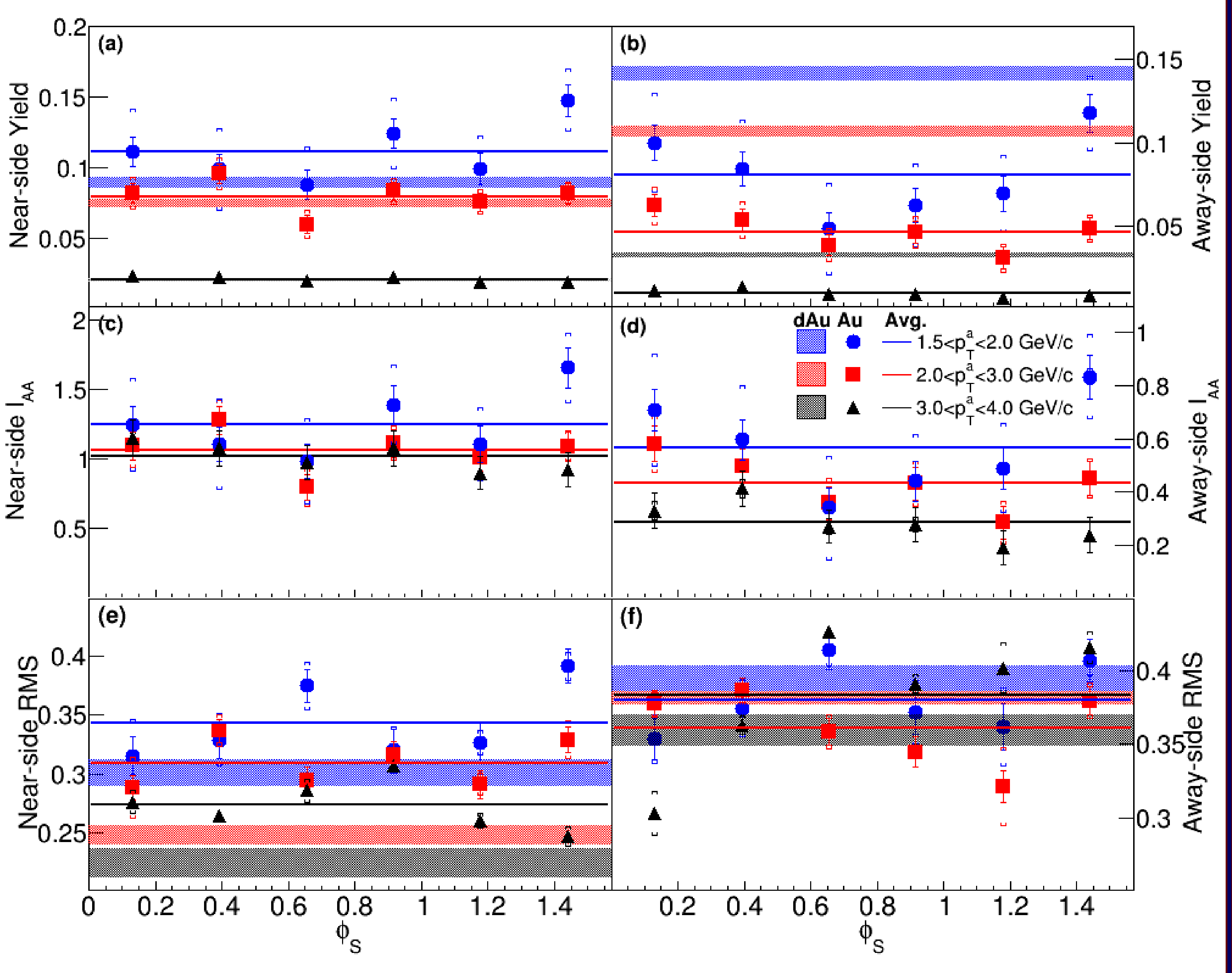

Figure 5: *Yields (a,b), truncated RMS (c,d), and I_{AA} (e,f) for the near-side (a,c,e) and away-side (b,d,f). Systematic uncertainties are 100% correlated point to point. Statistical uncertainties are non-trivially correlated point to point for a fixed p_T^{a} but are uncorrelated for different p_T^{a}.*

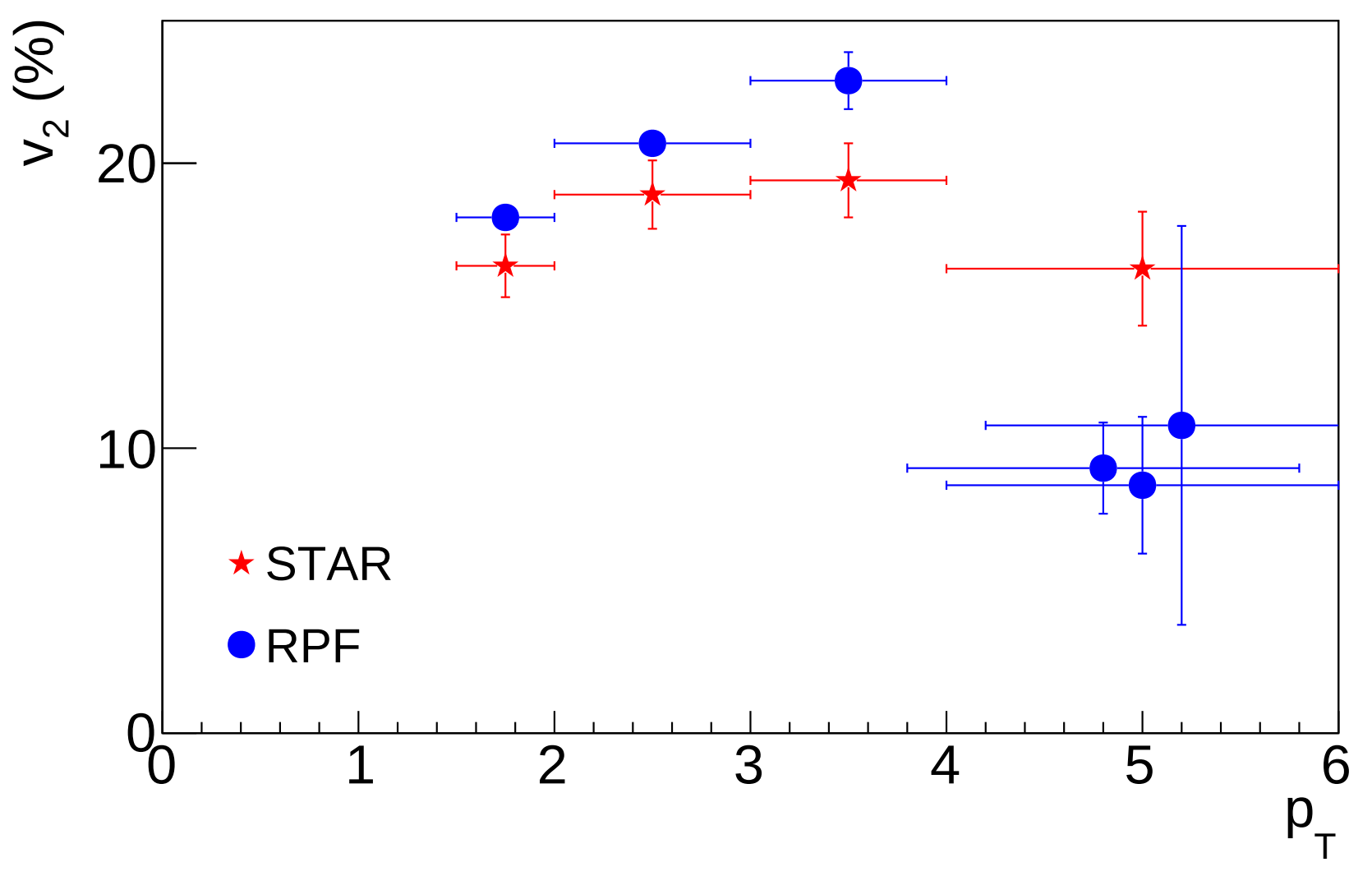

Figure 6: *A comparison of the v_n from [4, 5] to those extracted from the RPF method.*

References

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