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Study of leading hadron correlations in the ALICE central barrel in PbPb

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Abstract:

Leading hadron azimuthal angular correlations in the ALICE central barrel are studied with the HIJING event generator employing scenarios with and without in-medium jet quenching. We present investigations of signal to background ratio, significance and leading-hadron fragmentation function of the near- and away-side. In addition, transverse momentum distribution of associated particles with respect to the direction of the trigger is presented.

For the first time in heavy-ion collisions, *exclusive* jet reconstruction will be possible at LHC. This will allow for a detailed study of medium-induced modifications of the jet fragmentation, providing a sensitive probe to investigate the properties of the QGP produced at LHC.

On the other hand, most of our present knowledge about jet modification in heavy-ion collisions at SPS and RHIC [1] is based on *statistical* methods. These methods employ azimuthal correlations between a high-p_t leading hadron (the *trigger* particle) and other particles from the same event, selected in a lower p_t range (the *associated* particles). In p-p and d-Au collisions, a clear di-jet pattern emerges, manifested by a positive correlation around $\Delta\phi \approx 0$ (the *near side*) and $\Delta\phi \approx \pi$ (the *away side*). In contrast to these findings, a significant suppression of moderate p_t associated particles on the away-side has been observed in central Au-Au collisions, interpreted as a consequence of medium-induced energy loss of the leading parton in the dense partonic matter at RHIC. In this note, we investigate the potential of leading hadron correlation studies in the high multiplicity environment of a Pb-Pb collision at $\sqrt{s_{NN}} = 5.5$ TeV in the central barrel of the ALICE detector.

While exclusive jet reconstruction at LHC will be feasible for jet energies $E_T > 40$ GeV and jet fragments of $p_t > 2$ GeV/c, leading hadron correlation studies are in principle possible down to very low transverse momenta, in particular of associated particles, allowing to investigate the transfer of radiated energy to the bulk medium. Such studies have been performed at RHIC, demonstrating that significant away-side correlations with a leading hadron persist at transverse momenta as low as 150 MeV/c [2].

Leading hadron correlation studies at medium and low p_t are generally hampered by a huge background of uncorrelated soft particles and eventually limited by the signal-to-background ratio. At LHC, the situation is very different from lower beam energies: The larger cross-section for large-q^2 processes enhances the yield of leading hadrons at a given trigger p_t, thereby increasing the signal. For the same reason, the amount of uncorrelated particles in the range of associated p_t will also increase compared to lower beam energies, giving rise to an increased combinatorial background. Additional complications due to the asymmetry of the combinatorial background imposed by elliptic flow in non-central events are neglected because we focus on rather central events only.

For the present investigation, central Pb-Pb HIJING events ($\sigma/\sigma_{geo} < 10\%$) at $\sqrt{s_{NN}} = 5.5$ TeV have been studied. The HIJING events have been processed by a fast simulation, applying the acceptance filter of the ALICE central barrel $|\eta| < 0.9$ and a parametrized momentum resolution. We compare the results of HIJING event samples in quenched and unquenched mode. For each sample, $4 \cdot 10^5$ events have been generated.

Charged trigger particles with transverse momentum $8 < p_t^{trig} < 15$ GeV/c have been selected in the acceptance of the ALICE central barrel $|\eta| < 0.9$. Pairs are created with associated particles in the same acceptance and in a lower p_t-range and plotted as a function of their azimuthal separation $\Delta\phi$. In this range of p_t^{trig}, we detected a trigger particle in about 30% of the quenched events and in about 70% of the unquenched events. The choice of this range of p_t^{trig} allows a comparison to recent results from RHIC for which the same p_t^{trig} had been chosen [3].

Fig. 1 shows examples of leading hadron azimuthal correlations in unquenched events for $8 < p_t^{trig} < 15$ GeV/c and different ranges of p_t^{assoc}. The number of associated tracks is normalized to the number of triggers N_{trig} (the *conditional yield*). A clear near-side jet topology can be observed in all cases, while only a shallow indication of an away-side structure is visible within the present statistics. This is consistent with the expectation that only a small fraction of the jets belongs to di-jet events in the acceptance. Similar distributions for quenched events are shown in Fig. 2.

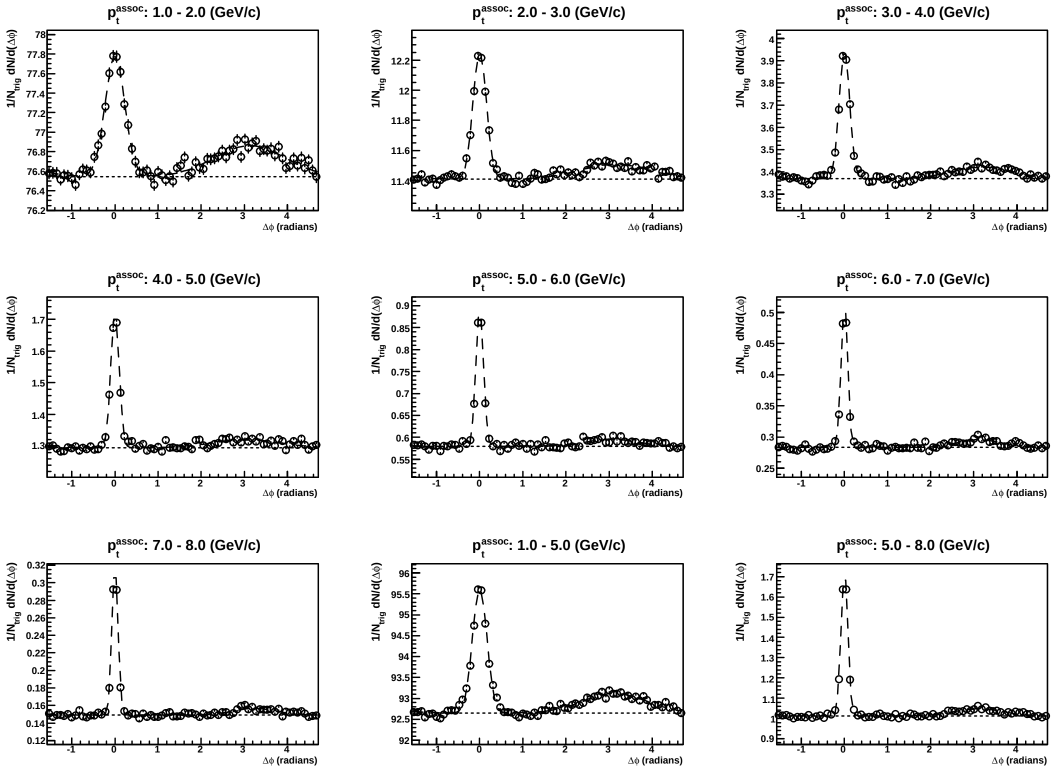

Fig.1: Leading hadron azimuthal correlations in unquenched central Pb-Pb HIJING events at $\sqrt{s_{NN}} = 5.5$ TeV. For $8 < p_t^{trig} < 15$ GeV/c, different ranges of p_t^{assoc} are shown.

The azimuthal correlations have been fitted by a constant plus two Gaussians at $\Delta\phi = 0$ and $\Delta\phi = \pi$, respectively. In general, this leads to a very good description of the measured distributions. In a few cases, however, a successful fit of the away-side structure could not be performed within the present statistics.

With increasing p_t^{assoc}, the width of the near-side peak is significantly reduced, as demonstrated in Fig. 3. The away-side peak is substantially broader and shows only a little p_t^{assoc} dependence. We note that this finding is in contrast to preliminary results from central Au-Au collisions at RHIC, where a significant narrowing of the away-side peak at high p_t^{assoc} was observed [3].

In all cases, a considerable amount of combinatorial background is observed, even at the highest selection of p_t^{assoc}. The signal-to-background ratio S/B has been determined in $\pm 2\sigma$ windows around the peaks, using the fit results for σ and the integral. The dependence on p_t^{assoc} of S/B at the near- and away-side is shown in Fig. 4.

As expected, S/B improves with increasing p_t^{assoc}. In the quenched scenario, this improvement is much more pronounced than in the unquenched events, reflecting the softer p_t

spectrum of the background in the quenched events.

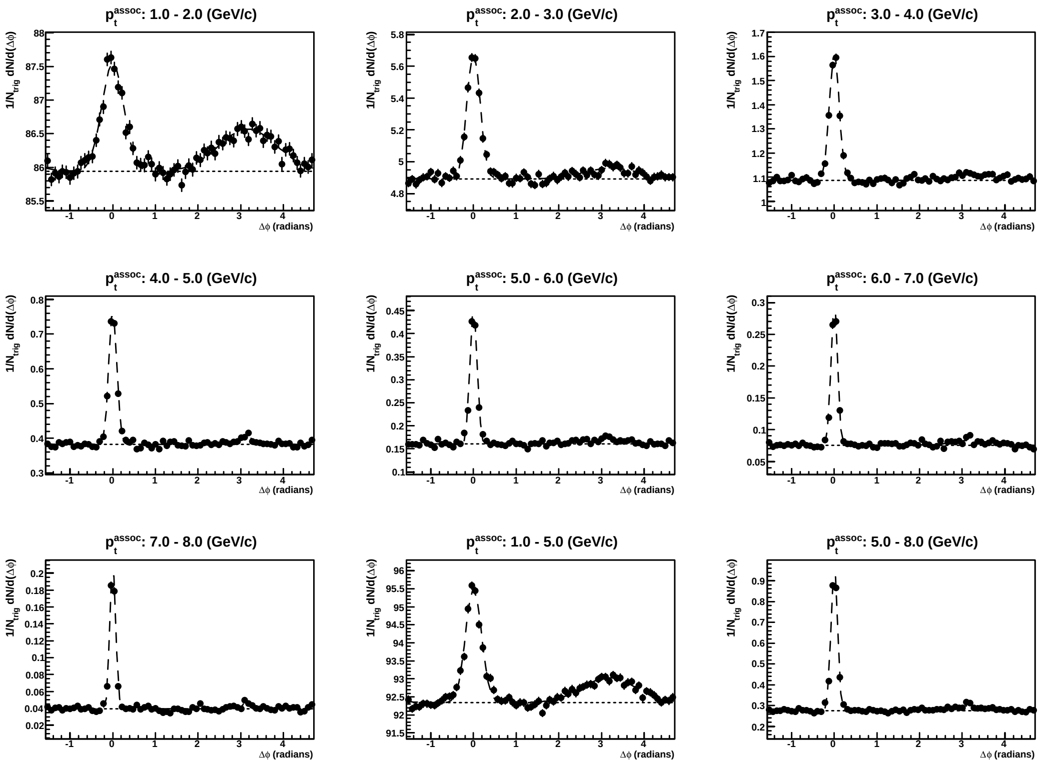

Fig. 2: Leading hadron azimuthal correlations in quenched central Pb-Pb HIJING events at $\sqrt{s_{NN}} = 5.5$ TeV. For $8 < p_t^{trig} < 15$ GeV/c, different ranges of p_t^{assoc} are shown.

The observed signal-to-background ratios are in contrast to preliminary results from central Au-Au collisions at RHIC, presented by STAR. At these energies and for the same choice of p_t^{trig}, the signal-to-background ratio at the near-side is close to unity for $3 < p_t^{assoc} < 4$ GeV/c. At $p_t^{assoc} > 6$ GeV/c, the STAR measurement is essentially free of combinatorial background [3]. This is expected from the much softer background spectrum at RHIC energies.

The significance $S/\sqrt{S+B}$ of the present study has been extrapolated to 10^7 events, corresponding to one year of ALICE running (Fig. 5). The p_t^{assoc} dependence of $S/\sqrt{S+B}$ reflects the interplay between S/B and the fragmentation function. On the near-side, highest significance can be achieved at intermediate p_t^{assoc}, while the significance on the away-side shows a monotonic decrease with p_t^{assoc}. We note, however, that the results of the present study rely strongly on the details of final-state interactions implemented in HIJING.

The measurement of the associated yield at fixed p_t^{trig} and in bins of p_t^{assoc} allows the determination of the hadron-triggered fragmentation function dN/dz_t, with $z_t = p_t^{assoc}/p_t^{trig}$. This quantity is related to the parton fragmentation function, however, without exact knowledge of the energy of the scattered parton. For a given range of z_t, the number of associated particles per trigger has been determined from the $\Delta\phi$ distributions. The integrals of the Gaussian peaks at $\Delta\phi = 0$ and $\Delta\phi = \pi$ in a $\pm 2\sigma$ have been extracted from the fit results. The combinatorial background in the same window was subtracted using the result for the constant term in the fit function. The near and away-side hadron-triggered fragmentation functions for the quenched and unquenched scenario are shown in Fig. 6. Despite the rather high level of combinatorial background, a significant measurement of dN/dz_t for this range of p_t^{trig} can be performed down to $p_t^{assoc} \approx 1$ GeV/c. On the near-side, this constitutes a dramatic improvement compared to the situation at RHIC which is due to the much larger cross-section for trigger particles at LHC. For a similar measurement on the away-side, 10^7 events will be sufficient, however, again strongly depending on the underlying physical scenario.

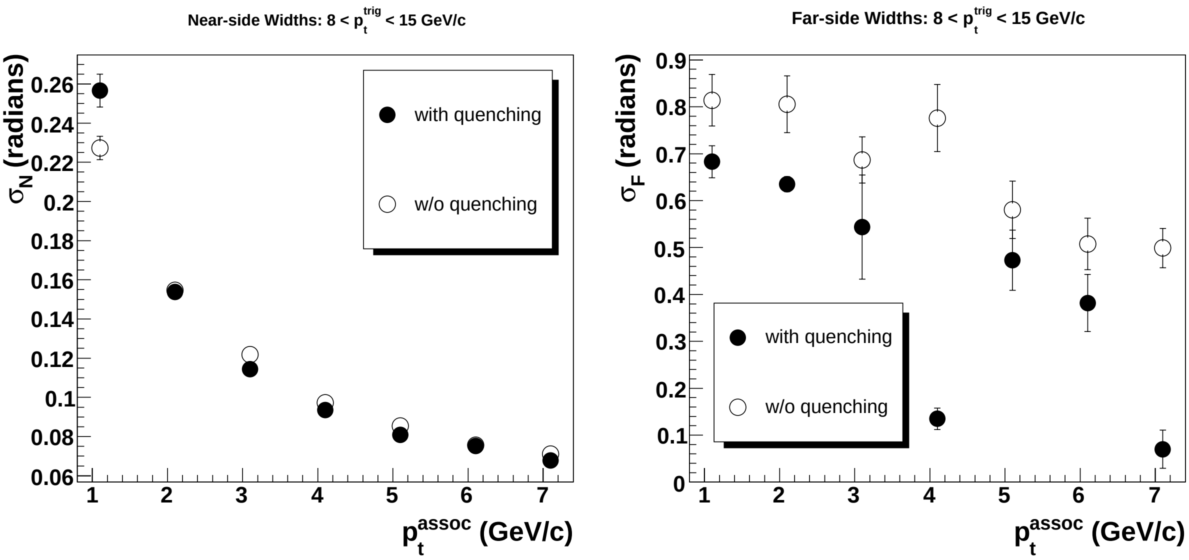

Fig. 3: Gaussian width of near- and away-side peak in quenched and unquenched HIJING events as function of p_t^{assoc} for $8 < p_t^{trig} < 15$ GeV/c.

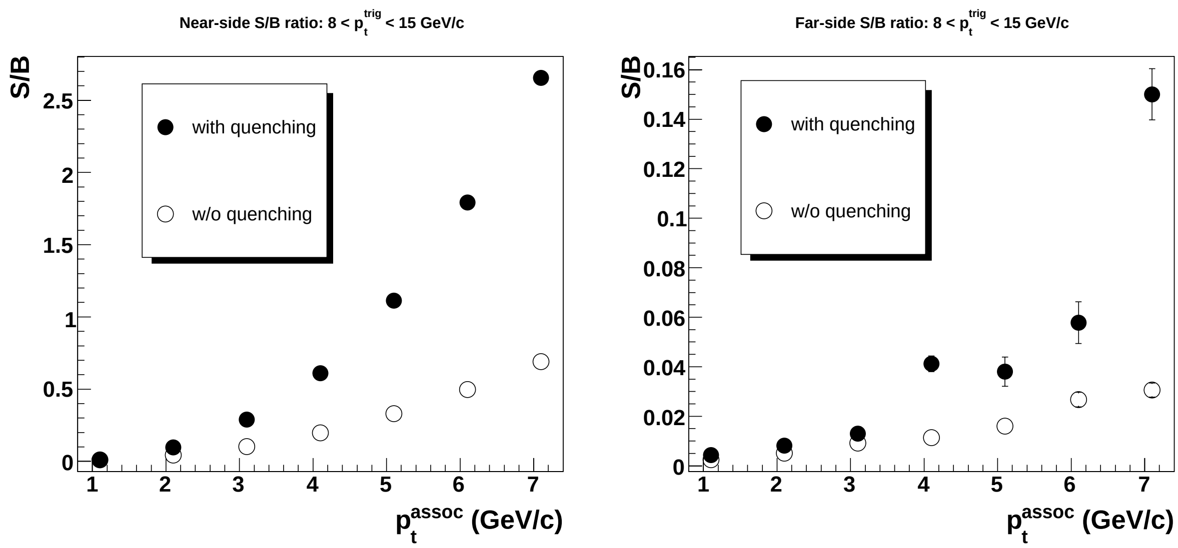

Fig. 4: Near and away-side signal-to-background ratio S/B in quenched and unquenched HIJING events as function of p_t^{assoc} for $8 < p_t^{trig} < 15$ GeV/c.

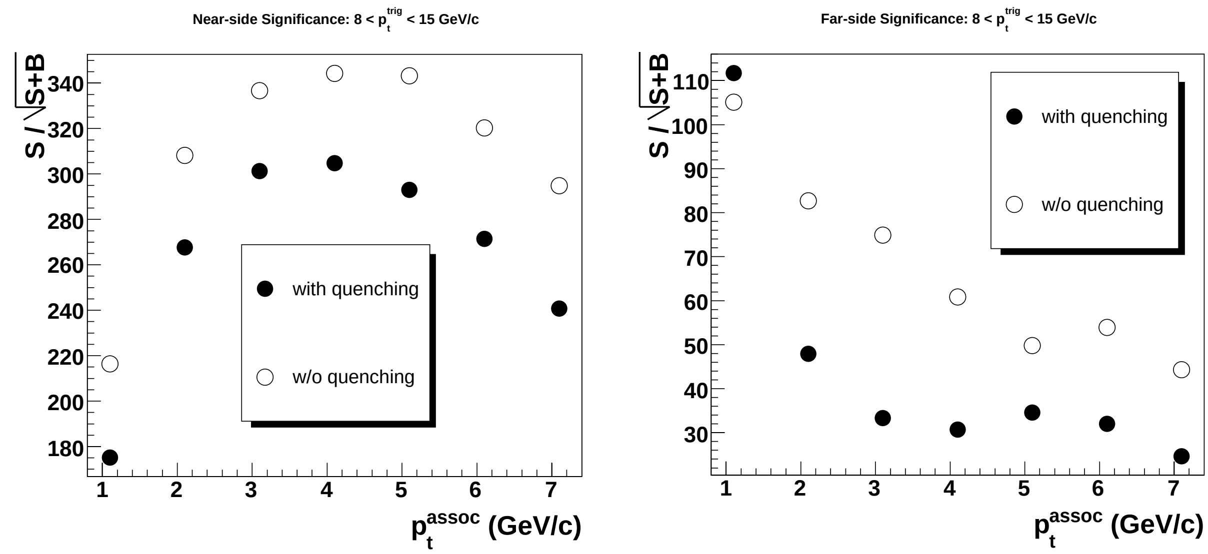

Fig. 5: Near and away-side significance $S/\sqrt{S+B}$ *in quenched and unquenched HIJING events as function of* p_t^{assoc} *for* $8 < p_t^{trig} < 15$ *GeV/c*.

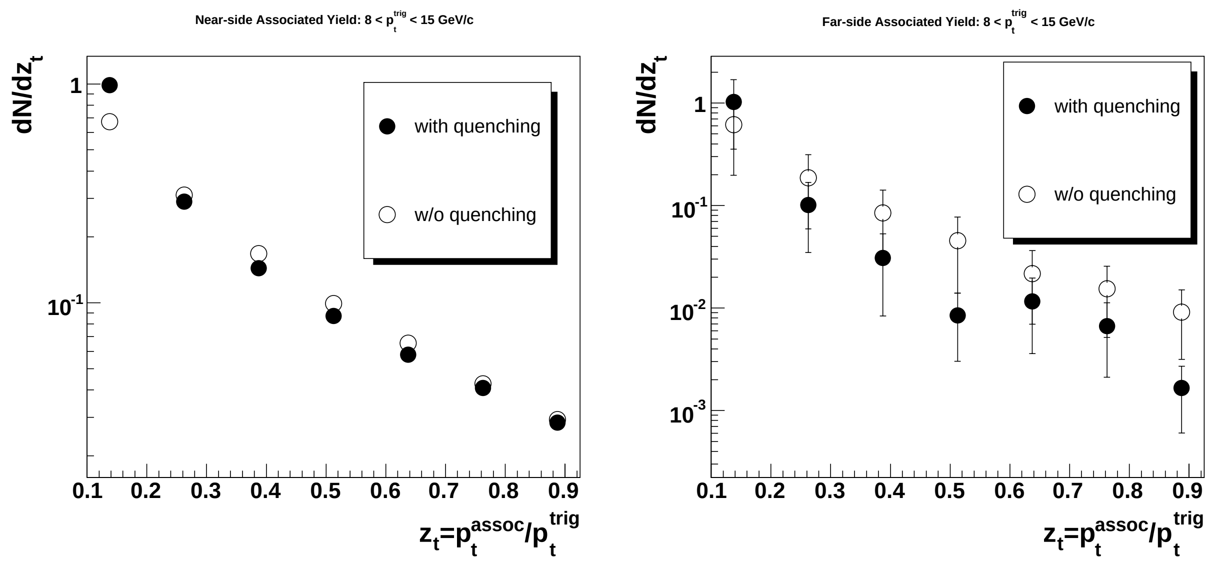

Fig. 6: Near- and away-side leading-hadron fragmentation function $\mathrm{d}N/\mathrm{d}z_t$ *for* $8 < p_t^{trig} < 15$ *GeV/c in quenched and unquenched HIJING events.*

Additional information about jet modification in the dense medium can be achieved by a measurement of the transverse momentum distribution of associated particles with respect to the direction of the trigger. For this study, we employ the measure $j_T = p^{assoc} \cdot \sin(\alpha)$, with α beeing the angle between trigger and associated particle. The resulting distribution $\mathrm{d}N/\mathrm{d}j_T$ is shown in the left panel of Fig. 7. To account for combinatorial background, the same distribution has been accumulated for trigger particles which have been embedded into a different event. Subtraction of the two spectra yields a very significant measurement of $\mathrm{d}N/\mathrm{d}j_T$ within the present statistics, as demonstrated in the right panel of Fig. 7.

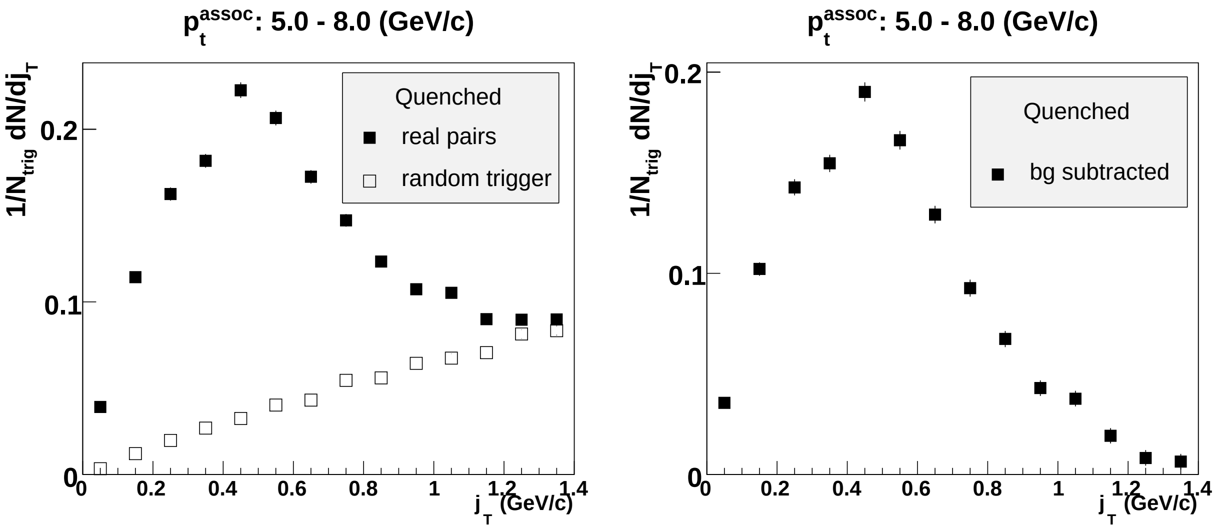

Fig. 7: Transverse momentum distribution $\mathrm{d}N/\mathrm{d}j_T$ *of associated particles with respect to the trigger direction. Left panel: Real-event and mixed-event (random trigger) distributions. Right panel: After mixed-event subtraction.*

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