IL NUOVO CIMENTO Vol. 34 C, N. 2 Marzo-Aprile 2011
DOI 10.1393/ncc/i2011-10828-7

Colloquia: WISH2010

Di-hadron correlations at RHIC

C. Nattrass
University of Tennessee at Knoxville - Knoxville, TN, USA

(ricevuto il 16 Novembre 2010; approvato il 26 Dicembre 2010; pubblicato online il 16 Marzo 2011)

Summary. — Di-hadron correlations have been used to study jets at RHIC and have yielded rich insight into the properties of the medium. Studies show that the near-side peak of high-p_T triggered correlations can be decomposed into two parts, a jet-like correlation and the ridge. The jet-like correlation is narrow in both azimuth and pseudorapidity and has properties consistent with vacuum fragmentation, while the ridge is narrow in azimuth but broad in pseudorapidity and roughly independent of pseudorapidity. The energy, system, and particle composition of the jet-like correlation and the ridge are discussed. Data indicate that the jet-like correlation is dominantly produced by vacuum fragmentation. Attempts have been made to explain the production of the ridge component as coming from recombination, momentum kicks, and QCD magnetic fields. However, few models have attempted to quantitatively calculate the characteristics of the ridge. The wealth of data should help distinguish models for the production mechanism of the ridge. Implications for studies of the jet-like correlation and the ridge at the LHC are discussed.

PACS `25.75.-q` – Relativistic heavy-ion collisions.
PACS `21.65.Qr` – Quark matter.
PACS `24.85.+p` – Quarks, gluons, and QCD in nuclear reactions.
PACS `25.75.Bh` – Hard scattering in relativistic heavy-ion collisions.

Measurements of the suppression of high-p_T hadrons in $A+A$ relative to $p+p$ at the Relativistic Heavy-Ion Collider (RHIC) demonstrate that there is strong suppression of high-p_T hadrons in the presence of a hot, dense medium [1, 2]. Di-hadron correlations have been used at RHIC as another way of measuring jet suppression.

In a standard di-hadron correlation analysis, a high-p_T trigger particle is selected and the distribution of associated particles relative to this trigger particle is determined. The correlation on the same side as the trigger particle is called the near-side and the correlation 180° from the trigger particle is called the away-side. Several features have been observed in di-hadron correlations, all of which are highly dependent on the kinematic region studied. At intermediate p_T (2–6 GeV/c) baryon enhancement is observed in the inclusive particle ratios [2,3]. At higher momenta, baryon to meson ratios in $A+A$ collisions are comparable to those observed in $p+p$ collisions [2] and the inclusive R_{AA} shows a strong suppression of high-p_T hadrons [1,2]. On the away-side at low $p_T^{associated}$, there is

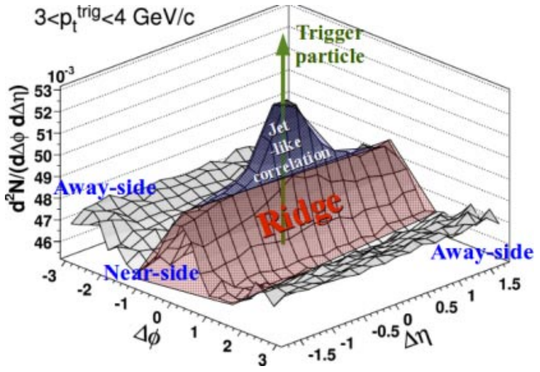

Fig. 1. – (Colour on-line) Data from 0–12% central $\mathrm{Au}+\mathrm{Au}$ collisions at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$ from [11] with $3 < p_T^{trigger} < 4\,\mathrm{GeV}/c$ and $2 < p_T^{associated} < p_T^{trigger}\,\mathrm{GeV}/c$ with the ridge, the jet-like correlation, the away-side and the location of the trigger particle labeled.

dip at roughly 180° in azimuth away from the trigger particle [4,5]. This is often referred to as the Mach Cone after one of the models for the formation of this structure where a hard parton moving faster than the speed of sound in the medium creates a shock wave [6], although there are other models for this structure [7-10]. For $p_T^{associated} \gtrapprox 2\,\mathrm{GeV}/c$, the away-side is suppressed. There are two structures which have comparable amplitudes for $1 < p_T^{associated} < 3\,\mathrm{GeV}/c$, shown in fig. 1 for $2 < p_T^{associated} < p_T^{trigger}\,\mathrm{GeV}/c$. The jet-like correlation is narrow in both pseudorapidity ($\Delta\eta$) and azimuth ($\Delta\phi$) and is present in d+Au, $\mathrm{Cu}+\mathrm{Cu}$ and $\mathrm{Au}+\mathrm{Au}$ collisions. The ridge is a novel feature first observed in $\mathrm{Au}+\mathrm{Au}$ collisions [11, 12]. For roughly $1 < p_T^{associated} < 3\,\mathrm{GeV}/c$, the ridge is the dominant structure [11], in the same kinematic region where we see baryon enhancement in the inclusive particle spectra. The ridge is also present at lower momenta [13] and extends to at least $p_T^{associated} \approx 8\,\mathrm{GeV}/c$ [11] and at least $\Delta\eta = 4$ [13]. Above $p_T^{associated} \approx 3\,\mathrm{GeV}/c$ the jet-like correlation is the dominant structure on the near-side [14]. On the away-side, for higher $p_T^{trigger}$ and $p_T^{associated}$ the away-side peak reappears [15], in the same kinematic region where the inclusive particle ratios approach the values seen in $p+p$ collisions.

1. – Experimental measurements

The primary criterion used to determine trigger and associated particles is their momenta. High-p_T triggered di-hadron correlations typically method neglect any correlations between high-p_T particles not caused by jets or anisotropic flow. The momenta of the trigger and associated particles are restricted to high-p_T to increase the probability that the particles come from a jet and therefore decrease the combinatorial background. The STAR Collaboration presents correlations normalized per trigger particle [16-18]. With this normalization, results from different systems ($p+p$, d+Au, $\mathrm{Cu}+\mathrm{Cu}$, and $\mathrm{Au}+\mathrm{Au}$) would be identical if there were no modification of the jet. The PHENIX Collaboration uses both this normalization and a normalization where the amplitude of the correlation is interpreted as the probability for an associated particle to be correlated with the jet [5, 19, 20]. In addition to triggered di-hadron correlation measurements, some studies are untriggered and use the minimum p_T within the acceptance of the detector [13, 21, 22]. These analyses are typically normalized such that the amplitude scales with the probability that a random pair of particles with a separation $(\Delta\phi, \Delta\eta)$ are correlated, although the exact details of the normalization vary with the measurement.

1·1. *Background subtraction.* – There is a combinatorial background in this method from trigger and associated particles whose production is not correlated. In $A + A$ collisions, this background is modulated by anisotropic flow of particles in the medium, giving a background of the form [23, 24]

$$b_{\Delta\phi}\left(1 + 2\langle v_2^{trig} v_2^{assoc}\rangle \cos 2\Delta\phi + 2\langle v_4^{trig} v_4^{assoc}\rangle \cos 4\Delta\phi + \dots\right). \tag{1}$$

Odd order terms $(v_1, v_3, \dots)$ are assumed to cancel out because these terms are asymmetric with respect to the reaction plane. Di-hadron correlation analyses are averaged over several events and the sign of v_n is as likely to be positive as negative in each event for odd n so the average is roughly zero. For most analyses, only the v_2 terms are considered and v_2 is determined from independent analyses. These independent analyses have large systematic errors because they may be affected by azimuthal anisotropies from sources other than hydrodynamical flow, such as jet production [25]. The fact that flow leads to a background for studies of jets and jets lead to a background for studies of flow makes separating these effects complicated. There also may be event-by-event fluctuations in v_2, meaning that the average v_2 in all events may not be the average v_2 in the events used for the di-hadron correlation analysis. STAR and PHENIX assumed that v_2 is independent of η, which is valid in their acceptances [26, 27], and PHOBOS takes the η dependence of v_2 into account for their background subtraction. v_2 is on the order of 0.1 and $0.75v_2^2 < v_4 < 1.5v_2^2$ [28] so v_4 terms are negligible in most analyses.

To determine the background for di-hadron correlation analyses, two additional assumptions are usually made. The first assumption is that the raw signal comprises only two components, the combinatorial background as given by eq. (1) and the signal. This is generally called the Two-Component Model. The raw signal (S) is assumed to come from particles from a fragmenting hard parton (J) and from the combinatorial background (B):

$$S = J_1J_2 + J_1B_2 + J_2B_1 + B_1B_2. \tag{2}$$

In $A + A$ the signal is much smaller than the background. The cross terms are typically neglected. If jet production is not correlated with the reaction plane, the cross terms $J_1B_2 + J_2B_1$ would add a constant background. This corresponds to having a lower effective $\langle v_2^{trig} v_2^{assoc}\rangle$ [29]. Jet quenching could also lead to an azimuthal anisotropy of high-p_T hadrons that would cause the cross terms to have the same form as eq. (1), but the azimuthal anisotropy would have a different magnitude and a different physical origin than the v_2 from anisotropic flow. The B_1B_2 term is described by eq. (1). These assumptions alone are not sufficient to determine the background because the level of the background needs to be fixed.

The most common assumption used to determine the level of the background is that there is a region in azimuth $(\Delta\phi \approx 1)$ where there is no contribution from the signal. A background of the form in eq. (1) is fixed in this region, assuming that there are no other relevant terms. This method is called the Zero-Yield-At-1 (ZYA1) [16] or Zero-Yield-At-Minimum (ZYAM) [29] method. Alternative methods have been proposed [30], however,

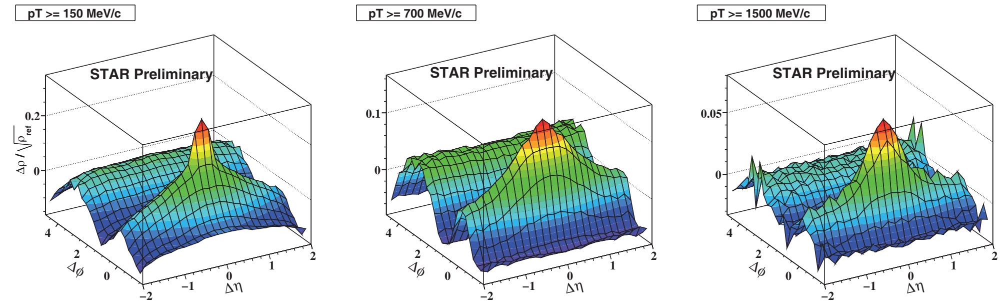

Fig. 2. – (Colour on-line) Data from Cu + Cu collisions at $\sqrt{s_{NN}} = 200\,\text{GeV}$ [31] with p_T cuts gradually applied to an untriggered analysis. In this analysis both the trigger and the associated particles have the same kinematic cuts applied.

these still require an assumption about the amount of combinatorial background in the raw signal.

Most analyses therefore have several inherent assumptions: 1) The only combinatorial background is from particles correlated with the reaction plane due to hydrodynamical flow in the medium. 2) The v_2 term of the azimuthal anisotropy is the only relevant contribution from flow. 3) Jet fragmentation is not correlated with the reaction plane. 4) The minimum in the di-hadron correlation has no contributions from the signal. In addition, studies generally consider the near- and away-side separately. These assumptions are generally a reasonable approximation when the background is small and the near- and away-side peaks are well separated, corresponding to higher $p_T^{trigger}$ and $p_T^{associated}$, but they are more ambiguous in the intermediate p_T (2–4 GeV/c) range.

Untriggered di-hadron correlations are generally analysed by fitting the signal, including the background term in eq. (1). There is an added term at small $(\Delta\phi, \Delta\eta)$ from conversion electrons and HBT correlations which is fit to a 2D Gaussian and in most analyses the away-side is fit as a $\cos(\Delta\phi)$ term. The ridge is parameterized as a 2D Gaussian in untriggered analyses, generally called the "Soft Ridge". While the ridge observed in high-p_T triggered correlations, sometimes called the "Hard Ridge", is independent of $\Delta\eta$ within errors, the Soft Ridge clearly has a dependence on $\Delta\eta$ [21]. Figure 2 shows that the Soft Ridge evolves into the Hard Ridge when a momentum threshold is introduced [31]. This method is sensitive to whether or not the functional form used in the analysis is a valid description of the data. The same shape is assumed for the background as in the ZYAM method, making it as sensitive to the validity of the shape of the background as other analyses. It is less sensitive to event-by-event fluctuations in v_2, non-flow contributions to v_2, and any correlation of jets with the reaction plane because the fit determines an average effective v_2 and uses the information that v_2 is roughly independent of $\Delta\eta$ in the region studied. The $\cos(\Delta\phi)$ term assumed to describe the away-side in these studies leads to a dip on the near-side. Since the Mach Cone structure on the away-side is present in some kinematic regions before background subtraction [32], the assumption that the away-side can be described by a $\cos(\Delta\phi)$ cannot be valid for all kinematic cuts. In addition, the away-side is clearly not described by a $\cos(\Delta\phi)$ in d+Au, PYTHIA, or at high-p_T.

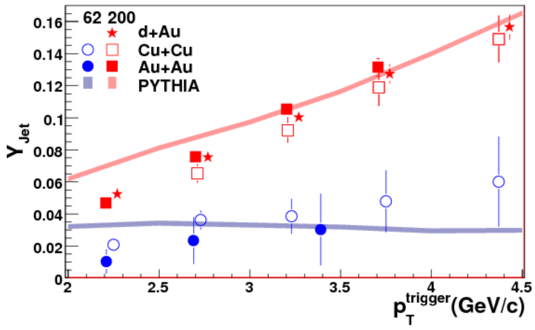

Fig. 3. – (Colour on-line) The $p_T^{trigger}$ dependence of the jet-like yield per trigger particle for $3.0 < p_T^{trigger} < 6.0\,\mathrm{GeV}/c$ and $1.5\,\mathrm{GeV}/c < p_T^{associated} < p_T^{trigger}$ for minimum bias d+Au, 0–60% central Cu + Cu, and 40–80% central Au + Au collisions at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$ and 0–60% central Cu + Cu and 0–80% central Au + Au collisions at $\sqrt{s_{NN}} = 62\,\mathrm{GeV}$ [40] with comparisons to PYTHIA version 6.4.10 [33] tune A [34] at $\sqrt{s_{NN}} = 62\,\mathrm{GeV}$ (blue) and $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$ (red) [39].

1˙2. *Results*. – The jet-like correlation is separated from the ridge and the background by using the observation that both the ridge and the v_2 modulated background are independent of $\Delta\eta$ at high p_T, while the jet-like correlation is dependent on both $\Delta\eta$ and $\Delta\phi$. This means that the jet-like yield is not sensitive to the assumptions made in the ZYAM method. Figure 3 shows the dependence of the jet-like yield, the number of particles associated with a trigger particle, as a function of $p_T^{trigger}$ compared to PYTHIA version 6.4.10 [33] tune A [34]. No dependence on the collision system is observed in the data, consistent with the expectation that the jet-like correlation is produced dominantly by fragmentation. While PYTHIA overestimates the yield at lower $p_T^{trigger}$, the agreement is still remarkable given that comparisons are made to $A + A$ data.

The ridge has been measured at RHIC by STAR [11, 21, 35-37], PHOBOS [13], and PHENIX [38] experiments. Measurements indicate that the jet-like correlation is dominantly produced by the fragmentation of hard partons, while the ridge is comparable to the bulk. The spectra of particles in the jet-like correlation and in the ridge are shown in fig. 4. The spectra of particles in the jet-like correlation is harder for higher $p_T^{trigger}$, consistent with expectations if the jet-like correlation is dominatly produced by fragmentation. By comparison the spectra of particles in the ridge has a slope comparable to the inclusive particle spectra.

Raw correlations clearly show different behavior for both baryons and mesons [19]. Figure 5 shows the $\frac{\Lambda+\bar{\Lambda}}{2K_S^0}$ and $\frac{p+\bar{p}}{\pi^++\pi^-}$ for the inclusive particle spectra, the jet-like correlation and the ridge. The composition of the jet-like correlation is comparable to the inclusive p+p ratios, which are expected to be dominated by jet fragmentation at high-p_T. The composition of the ridge is comparable to the inclusive spectra for both $\frac{\Lambda+\bar{\Lambda}}{2K_S^0}$ and $\frac{p+\bar{p}}{\pi^++\pi^-}$.

Figure 6 shows the jet-like yield, the ridge yield, and the ratio of the jet-like yield to the ridge yield as a function of N_{part}. The jet-like yield shows litte dependence on the system size over two orders of magnitude in N_{part} while the ridge yield increases by a factor of three in the same range. Both the jet-like yield and the ridge yield are

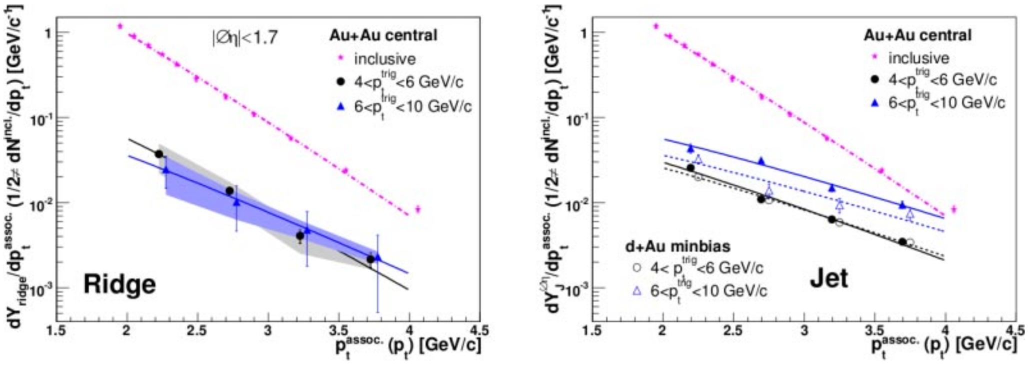

Fig. 4. – (Colour on-line) Spectra of particles in the ridge (left) and particles in the jet-like correlation (right) compared to inclusive particle spectra for $2 < p_T^{associated} < p_T^{trigger}$ GeV/c. Figure from [11].

considerably smaller in $\sqrt{s_{NN}} = 62$ GeV than in $\sqrt{s_{NN}} = 200$ GeV, and the ratio of the jet-like yield to the ridge yield is the same for both energies. From these data we anticipate the presence of the ridge in $A+A$ collisions both at lower energies in the RHIC beam energy scan and at higher energies in Pb + Pb collisions at the LHC. Figure 7 shows the dependence of the ridge yield and the jet-like yield on the angle relative to the reaction plane. The ridge is clearly dominantly in the reaction plane.

Three particle correlations on the near-side have been studied to determine whether the particles in the ridge are correlated with each other [36]. These results should be interpreted carefully because of the kinematic limits, however, they indicate that particles in the ridge are not correlated with each other. These studies also indicated that while the jet-like correlation is dominantly from charged hadrons with opposite signs, the ridge is present for charged hadrons with the same sign.

There are sufficient experimental observations from $A+A$ collisions to significantly constrain models for the production of the ridge in $A+A$. The recent observation of a

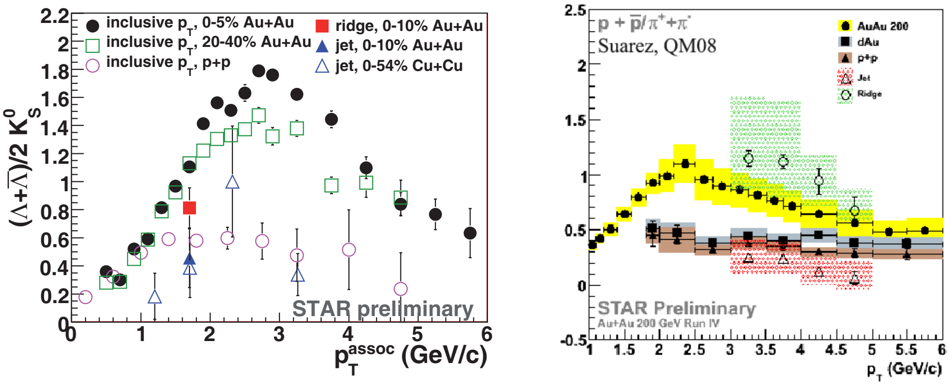

Fig. 5. – (Colour on-line) Comparison of particle ratios in the jet-like correlation and in the ridge for $\frac{\Lambda+\bar{\Lambda}}{2K_S^0}$ [40] (left) and for $\frac{p+\bar{p}}{\pi^{+}+\pi^{-}}$ [41] (right).

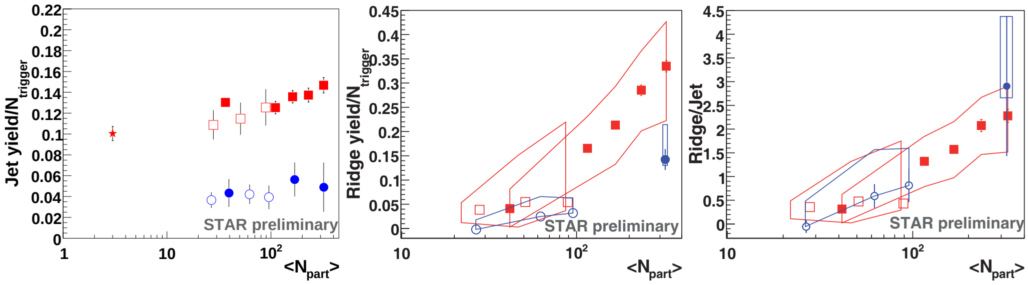

Fig. 6. – (Colour on-line) Dependence of the jet-like yield (left), ridge yield (middle), and jet-like yield to ridge yield ratio (right) per trigger particle for $3.0 < p_T^{trigger} < 6.0\,\mathrm{GeV}/c$ and $1.5\,\mathrm{GeV}/c < p_T^{associated} < p_T^{trigger}$. Stars show data from d+Au collisions at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$, closed (open) squares show data from Au + Au (Cu + Cu) collisions at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$, and closed (open) circles show data from Au + Au (Cu + Cu) collisions at $\sqrt{s_{NN}} = 62\,\mathrm{GeV}$. Data are from [40].

ridge in high-multiplicity $p + p$ collisions by CMS [13] also constrains models, provided the structure observed by CMS and in $A + A$ at RHIC arise from the same mechanism.

2. – Models for the ridge

There are multiple models for the production of the ridge. It is useful to break these models down into different classes:

- Causal models—the ridge is created by the interaction of a hard parton with the medium.
- Hydrodynamical models—the ridge is actually a background from hydrodynamical flow.
- Initial conditions—the ridge arises from initial conditions in the incoming nuclei.

Causal models include the momentum kick model [42], gluon brehmsstrahlung [43] and recombination [44]. In the momentum kick model, the ridge is formed by collisional energy loss of the hard parton with particles in the medium [42]. The momentum kick model is consistent with the data, but predicts a sharp drop in the amplitude of the ridge just outside of the acceptance of the range of the measurements available so far [42]. It has also been proposed that the ridge is formed by gluon brehmsstrahlung in the medium dispersed by flow [43], or through medium heating in combination with recombination of quarks and gluons on the medium [44]. In the gluon brehmsstrahlung model the ridge would come from fragmentation and therefore would have a similar composition to the jet-like correlation, but this is not observed in the data. In both the momentum kick model and the recombination model, the ridge arises from medium partons, leading to a composition similar to the bulk. However, generally causal models have difficulty producing a ridge large enough in $\Delta\eta$ to be consistent with the data and these models may not be consistent with the data from 3-particle correlations [36]. These models would also imply the existence of a medium in $p + p$ collisions and therefore would be a rather speculative explanation for the CMS data.

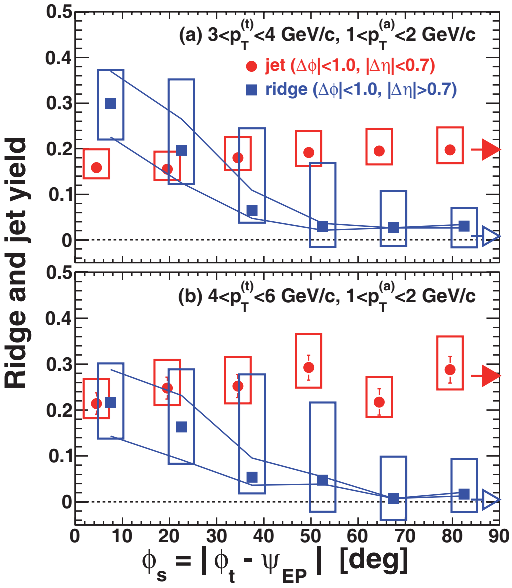

Fig. 7. – (Colour on-line) The jet-like yield and the ridge yield as a function of the angle of the trigger particle relative to the reaction plane $1 < p_T^{associated} < 2\,\mathrm{GeV}/c$ for (a) $3 < p_T^{trigger} < 4\,\mathrm{GeV}/c$ and (b) $4 < p_T^{trigger} < 6\,\mathrm{GeV}/c$. Error bars are statistical and boxes show systematic error bars. Data are from [35].

There are two main mechanisms for the production of the ridge which involve hydrodynamical flow. In the radial flow plus trigger bias model, the ridge arises because both radial flow and jet quenching lead to the emission of particles from the surface of the medium. Since both particles from the fragmenting hard parton and from the medium are emitted from the surface of the medium, these particles are correlated in space [45]. In the v_3 model, fluctations in the initial overlap region lead to a non-zero v_3 on average. This v_3 leads to a $\cos(3\Delta\phi)$ term in the correlation [46, 47]. In these models, the ridge is basically a hydrodynamical background that was not considered. This easily explains why the ridge composition is similar to the bulk. These models are consistent with the reaction plane dependence of the ridge. Since there is already considerable evidence for hydrodynamical flow in $A + A$ collisions [25], these effects would be expected and would be a straightforward explanation for the ridge in $A + A$ collisions. However, these models would also require the existence of a medium in $p + p$ collisions to explain the CMS data.

There are a few different models which explain the ridge through various initial state conditions. In a heavy-ion collision there are large QCD magnetic fields early in the collision and the large fluctuations in these QCD magnetic fields can lead to a ridge [48]. This production mechanism may also be present in $p + p$ collisions and may be able to explain the ridge in $p + p$ without any need for a medium or hydrodynamical flow. However, it is not clear that this mechanism can produce a ridge large enough to explain the $A + A$ data. In addition, it has been proposed that hot spots early in the collision could lead to fluctuations which could explain the ridge [49]. It is not clear what could lead to these hot spots in $p + p$ collisions that may be able to explain the CMS data.

It is not straightforward to distinguish between various production mechanisms for the ridge because some calculations include a combination of initial conditions which may lead to fluctuations and hydrodynamical effects. In a full hydrodynamical calculation, both the radial flow plus trigger bias mechanism and v_3 may lead to a ridge. It is possible for the ridge in $p+p$ and in $A+A$ to arise from different mechanisms, but it would be simpler if the ridge were produced by the same mechanism in both $p+p$ and $A+A$ collisions. A better theoretical understanding of the models for the production mechanism for the ridge is needed in order to understand the effects each model would predict.

3. – Conclusions

There are extensive data on the near-side of di-hadron correlations from $A+A$ collisions. The data indicate that the jet-like correlation arises dominantly from fragmentation of a hard parton, perhaps with some modification. The ridge is well characterized in $A+A$ and sufficient data are available to constrain models. Several additional experimental constraints will be available in the near future. The beam energy scan at RHIC allows studies of the ridge at lower energies [50] and the recent $\mathrm{Pb}+\mathrm{Pb}$ collisions at the LHC will enable studies of the ridge at higher energies. In addition, studies of the ridge in $p+p$ at the LHC could be useful for constraining models. The simplest explanation would be one that could explain both the $p+p$ and the $A+A$ data. Studies of the charge dependence and particle composition of the ridge in $p+p$ collisions may help clarify whether the $p+p$ ridge and the $A+A$ ridge are produced by the same mechanism. Searches for the ridge in high multiplicity collisions at lower energies, particularly those where the ridge was observed in $A+A$ collisions, would be interesting. However, more quantitative comparisons with existing data could also considerably constrain models.

REFERENCES

[1] Adare A. *et al.* (PHENIX Collaboration), *Phys. Rev. Lett.*, **101** (2008) 232301.
[2] Abelev B. I. *et al.* (STAR Collaboration), *Phys. Lett. B*, **655** (2007) 104.
[3] Adler S. *et al.* (PHENIX Collaboration), *Phys. Rev. C*, **69** (2004) 034909.
[4] Aggarwal M. M. *et al.* (STAR Collaboration), *Phys. Rev. C*, **82** (2010) 024912.
[5] Adare A. *et al.* (PHENIX Collaboration), *Phys. Rev. C*, **77** (2008) 011901.
[6] Renk T. and Ruppert J., *Phys. Rev. C*, **73** (2006) 011901.
[7] Vitev I., *Phys. Lett. B*, **630** (2005) 78.
[8] Polosa A. D. and Salgado C. A., *Phys. Rev. C*, **75** (2007) 041901.
[9] Chiu C. B. and Hwa R. C., *Phys. Rev. C*, **74** (2006) 064909.
[10] Dremin I. M., *Nucl. Phys. A*, **767** (2006) 233.
[11] Abelev B. I. *et al.* (STAR Collaboration), *Phys. Rev. C*, **80** (2009) 064912.
[12] Putschke J., *J. Phys. G*, **34** (2007) S679.
[13] Alver B. *et al.*, *Phys. Rev. Lett.*, **104** (2010) 062301.
[14] Abelev B. I. *et al.* (STAR Collaboration), *Phys. Lett. B*, **683** (2010) 123.
[15] Adams J. *et al.* (STAR Collaboration), *Phys. Rev. Lett.*, **97** (2006) 162301.
[16] Adams J. *et al.* (STAR Collaboration), *Phys. Rev. Lett.*, **95** (2005) 152301.
[17] Adams J. *et al.* (STAR Collaboration), *Phys. Rev. Lett.*, **91** (2003) 072304.
[18] Adler C. *et al.* (STAR Collaboration), *Phys. Rev. Lett.*, **90** (2003) 082302.
[19] Afanasiev S. *et al.* (PHENIX Collaboration), *Phys. Rev. Lett.*, **101** (2008) 082301.
[20] Adare A. *et al.* (PHENIX Collaboration), *Phys. Rev. Lett.*, **98** (2007) 232302.
[21] Adams J. *et al.* (STAR Collaboration), *J. Phys. G*, **33** (2007) 451.

[22] Daugherity M. (STAR Collaboration), *J. Phys. G*, **35** (2008) 104090.
[23] Adler C. *et al.* (STAR Collaboration), *Phys. Rev. C*, **66** (2002) 034904.
[24] Bielcikova J. *et al.*, *Phys. Rev. C*, **69** (2004) 021901.
[25] Voloshin S. A., Poskanzer A. M. and Snellings R., arXiv.0809.2949v2 (2008).
[26] Back B. B. *et al.* (PHOBOS Collaboration), *Phys. Rev. C*, **72** (2005) 051901.
[27] Back B. B. *et al.* (PHOBOS Collaboration), *Phys. Rev. Lett.*, **94** (2005) 122303.
[28] Adare A. *et al.* (PHENIX Collaboration), *Phys. Rev. Lett.*, **105** (2010) 062301.
[29] Ajitanand N. N. *et al.*, *Phys. Rev. C*, **72** (2005) 011902.
[30] Sickles A., McCumber M. P. and Adare A., *Phys. Rev. C*, **81** (2010) 014908.
[31] De Silva L. C. (STAR Collaboration), arXiv:0910.5938v1 (2009).
[32] Cole B., *High p_T photon and hadron probes of Hot/Dense matter.* Talk given at Quark Matter 2005 (2005).
[33] Sjostrand T., Mrenna S. and Skands P., *JHEP*, **05** (2006) 026.
[34] Field R. D. (CDF Collaboration), *eConf*, **C010630** (2001), hep-ph/021192.
[35] Agakishiev H. *et al.*, arXiv:1010.0690v1 (2010).
[36] Abelev B. I. *et al.* (STAR Collaboration), *Phys. Rev. Lett.*, **105** (2010) 022301.
[37] Adams J. *et al.* (STAR Collaboration), *Phys. Rev. Lett.*, **95** (2005) 152301.
[38] Adare A. *et al.* (PHENIX Collaboration), *Phys. Rev. C*, **78** (2008) 014901.
[39] Nattrass C., *System, energy, and flavor dependence of jets through di-hadron correlations in heavy ion collisions.* Poster given at RHIC/AGS User's Meeting 2010 (2010).
[40] Nattrass C., *J. Phys. G*, **35** (2008) 104110.
[41] Suarez C., *Particle dependence of the Ridge and the Jet.* Poster given at Quark Matter 2008 (2008).
[42] Wong C.-Y., *Phys. Rev. C*, **78** (2008) 064905.
[43] Armesto N., Salgado C. A. and Wiedemann U. A., *Phys. Rev. Lett.*, **93** (2004) 242301.
[44] Chiu C. B. and Hwa R. C., *Phys. Rev. C*, **72** (2005) 034903.
[45] Pruneau C. A., Gavin S. and Voloshin S. A., *Nucl. Phys. A*, **802** (2008) 107.
[46] Sorensen P., *J. Phys. G*, **37** (2010) 094011.
[47] Alver B. and Roland G., *Phys. Rev. C*, **81** (2010) 054905.
[48] Romatschke P., *Phys. Rev. C*, **75** (2007) 014901.
[49] Greiner C., these proceedings.
[50] Aggarwal M. M. *et al.* (STAR Collaboration), arXiv:1007.2613v1 (2010).