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March 1994

XXXII INTERNATIONAL WINTER MEETING
ON NUCLEAR PHYSICS - BORMIO 1994

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Particle correlations in the search for multifragmentation

D.Benchekroun, B. Chambon, B. Cheynis, A.Demeyer, D. Drain, E. Gerlic, D. Guinet, P. Lautesse, L. Lebreton, C.Pastor, M. Stern and L. Vagneron
Institut de Physique Nucléaire de Lyon, Villeurbanne F-69622

A. Chabane, A.J. Cole, P. Désesquelles, A. Giorni, D. Heuer, A. Lleres and J.B. Viano
Institut des Sciences Nucléaires de Grenoble, Grenoble F-38026

M.T. Magda
State University of New York at Stony Brook, Stony Brook, New York 11794-3400

Abstract :

Intermediate mass fragment (IMF : $3 \leq Z \leq 16$) emission from $^{32}S +^{nat}Ag$, ^{58}Ni at 37.5 MeV/nucleon reactions has been studied with the multidetector AMPHORA. The evolution of fragment emission from peripheral to central collisions has been explored, using charged particle multiplicity gates as a selection criterion of various classes of reactions. The fragment-fragment (Li-Li, B-B and C-C) correlation analysis shows that IMF are emitted from an equilibrated source with angular momentum less than 120 $\hbar$ and lifetime of 300 - 450 fm/c.

Introduction

Highly excited nuclear matter can be produced in intermediate energy nucleus-nucleus collisions. As excitation energy is raised from 1 MeV/u to 5-7 MeV/u, intermediate mass fragment emission becomes a significant decay mode [1,2]. Theoretical and experimental work has been performed for understanding the mechanism of multifragment emission processes. A major objective of all experimental works on multifragment emission remains the search of a clear experimental distinction between instantaneous multifragment emission [3] and sequential emission of fragments [4,5].

Fragment-fragment correlation study provides a good method to search for the needed distinction, and large detection devices are valuable tools to perform these correlations. It has been already shown [6,7] that the AMPHORA multidetector array [8] is well suited for the measurement of azimuthal correlations between particles and/or fragments.

In this work, we investigate the mechanism of multifragment emission in $^{32}S +^{nat}Ag$, ^{58}Ni reactions through fragment-fragment azimuthal correlation study.

I- Experimental setup and reaction characteristics

The experiment was carried out using the multidetector AMPHORA (figure 1) with a 37.5 MeV/nucleon ^{32}S beam delivered by the SARA facility. AMPHORA consists of 140 CsI(Tl) detectors covering $\approx$ 82% of 4π solid angle. 78 detectors were set at angles less than 38° and covered by fast plastic detectors thus allowing unambiguous identification of charge up to Z = 16 (within ± 1 charge unit). In case of detectors situated in the ball at more backward angles (38° - 165°), identification was limited to charges Z = 3, heavier fragments being detected but not identified.

A qualitative perspective of the reaction is depicted by the multiplicity distribution of the charged particles as shown for the Ag target in figure 2. It is well known that the charged-particle multiplicity is a gauge of the energy deposition. We used it too as a criterion of the "violence" of the reaction, by correlating charged particle multiplicity to the impact parameter within a simple geometric picture of the collision [9]. We associate the higher multiplicity events to the more central collisions.

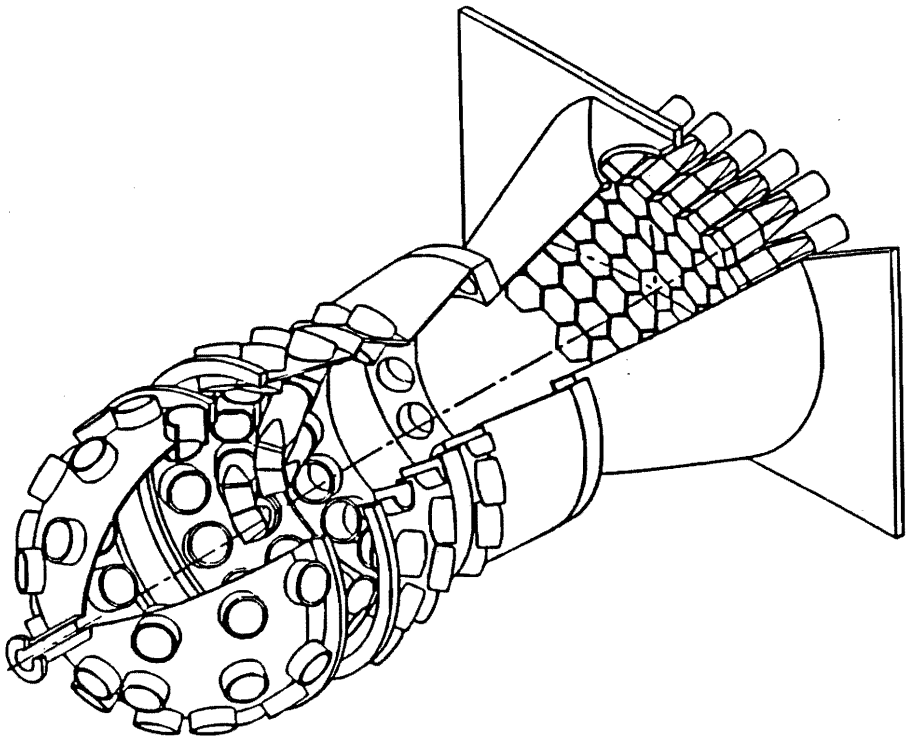

Figure 1 : Schematic view of the 4π detection array

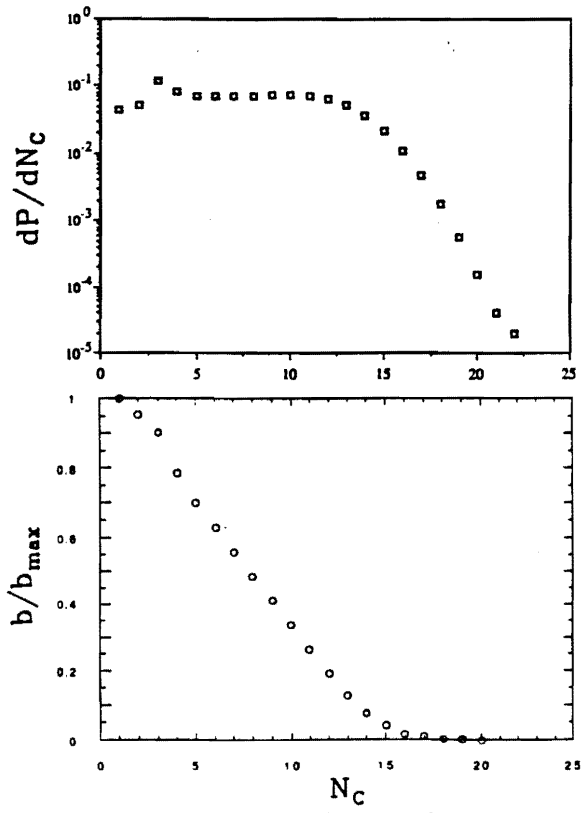

Figure 2 : Multiplicity distribution of charged particles connected with the impact parameter

The relationship between impact parameter and charged-particle multiplicity must not be overinterpreted since fluctuations of the charged-particle multiplicity may be expected even for collisions of well-defined impact parameter. Therefore we related various multiplicity windows namely $N_c \geq 14$ (PM3) to "central" collisions, $8 \leq N_c \leq 13$ (PM2) to "midcentral" collisions and $N_c \leq 7$ (PM1) to "peripheral" collisions.

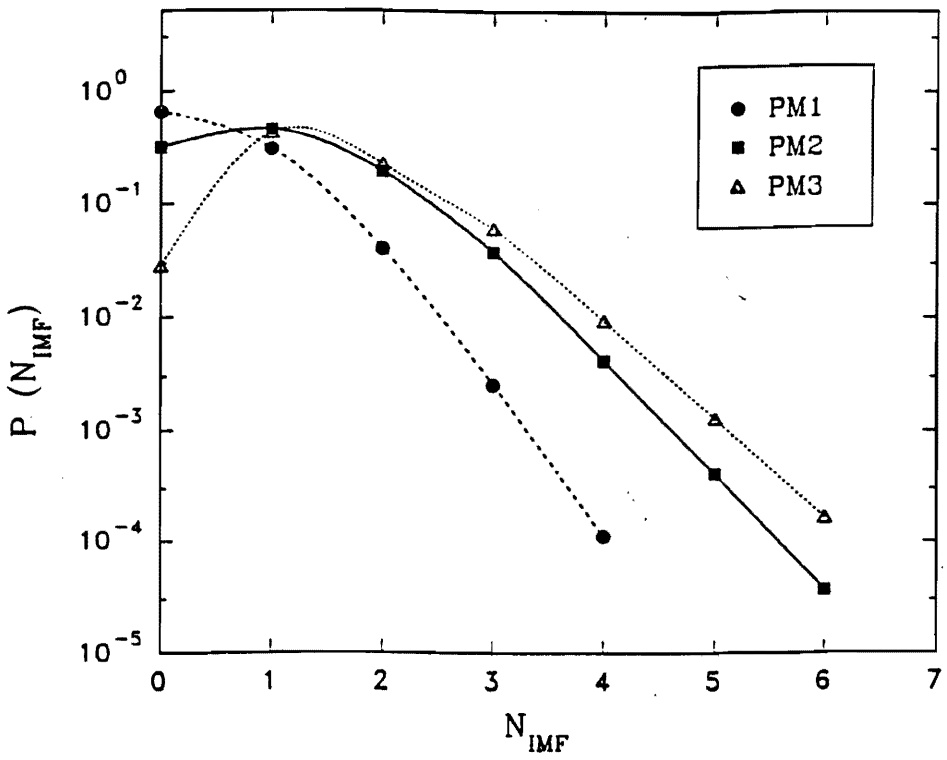

Figure 3 : Normalized probability distributions of IMF when triggered with different charged particle multiplicity windows ($^{32}S + ^{nat}Ag$)

Experimental multiplicity distribution for intermediate mass fragments ($3 \leq Z \leq 16$) detected in peripheral, midcentral and central collisions are shown in figure 3. In case of peripheral collisions the IMF multiplicity distribution is peaked at $N_{IMF} = 0$ indicating that IMF emission is a less probable outcome. The distributions for midcentral and central collisions are peaked at $N_{IMF} = 1$ with a broad distribution extending up to 5-6 fragments. The values of the average number of IMF ($\langle N_{IMF} \rangle$) related to the last two windows are higher in case of the Ni target suggesting higher energy deposition. This result has been checked by selecting the "complete events" acquired in the $^{32}S + ^{58}Ni$ reaction, i.e. events characterized by a total charge larger than 80% of the charge available in the reaction. Charged particle multiplicity gate on central collisions leads to multiplicity distributions with an average number of IMF as large as 2.5, confirming the central character of this class of reactions.

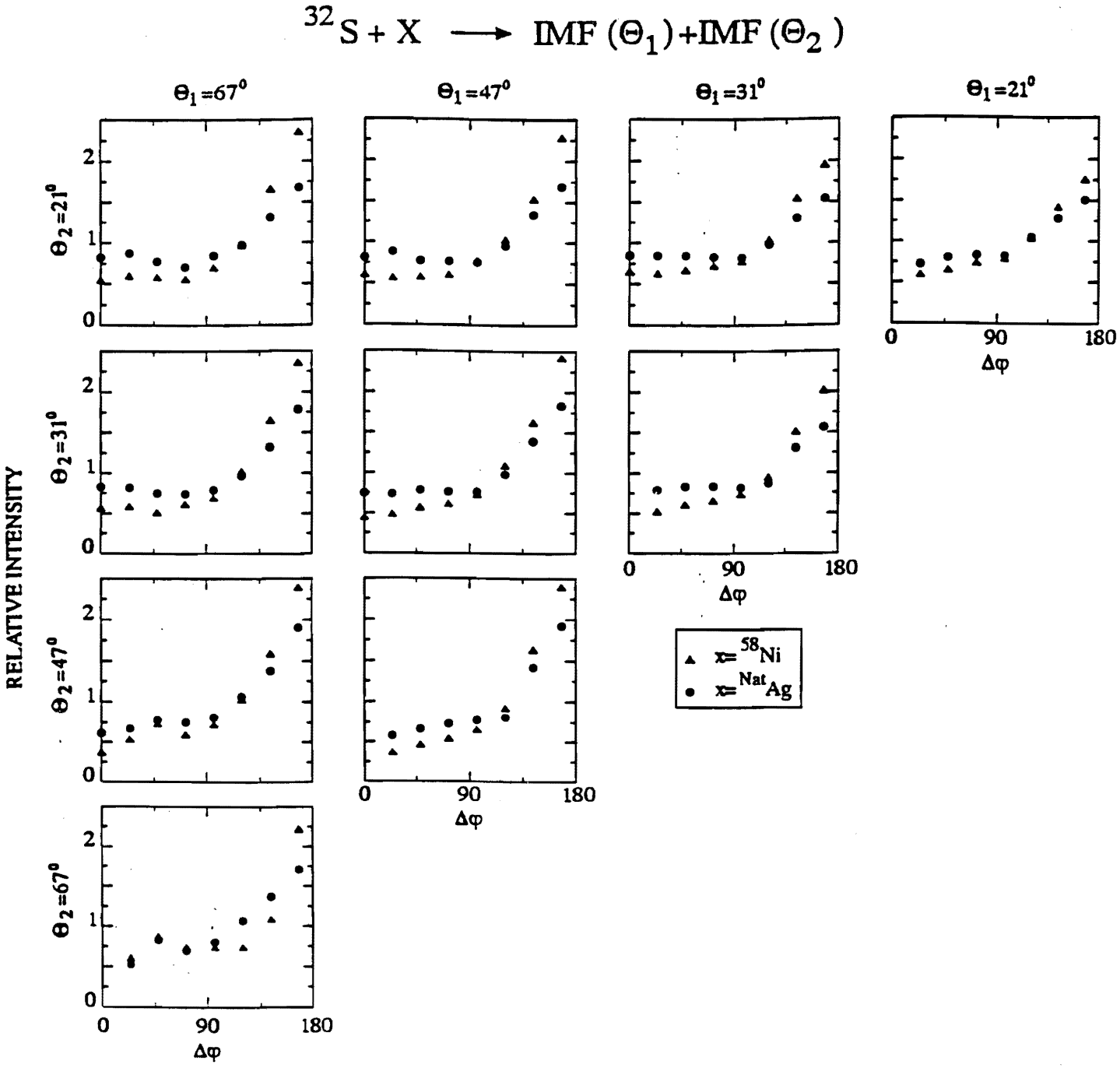

Figure 4 : IMF-IMF azimuthal correlation functions obtained in $^{32}S + ^{nat}Ag$, ^{58}Ni reactions

These results show that multiple fragment emission occurs at a significant rate; in order to better characterize the mechanism and distinguish between possible scenarios, knowledge of the impact parameter and the lifetime of the emitting source is necessary. This is the reason why we undertook the study of two fragment azimuthal correlations.

II- Particle-particle azimuthal correlations

In this study we focus on IMF-IMF pairs in the particulary advantageous geometry with cylindrical symmetry around the beam direction of rings 4, 5, 6 and 7 located on the average at polar angles $\theta = 67°$, $47°$, $31°$ and $21°$. Each of these rings consists of 15 identical detectors evenly spaced in azimuthal angle φ. Since all polar angles are the same for a given ring and the detectors have equivalent solid angles and comparable efficiencies, the relative yields of uncorrelated fragment pairs are identical for detector pairs with the same θ_1,θ_2 and $\Delta\varphi$. After a proper normalization, the $\Delta\varphi$ correlations are equivalent to a two-fragment azimuthal angle correlation functions.

In figure 4, correlation functions for IMF pairs are shown for the two targets and ten polar angle combinations. Two effects are supported by these data : first the anisotropy (ratio of the relative intensities (I(0°)-I(90°))/I(90°)) which stresses the importance of the spin driven emission from a rotating source; secondly the ratio I(0°)/I(180°) must be associated with the final state interaction through the coulomb repulsion and momentum conservation effects. As an example of the spin effect, the correlation function gated by the various multiplicity windows stresses a larger anisotropy for the more peripheral collisions in agreement with a larger related impact parameter.

Special phenomena should be associated at zero degree with an enhancement of the intensity because of a break-up in flight of particle unstable fragments ($^8Be \rightarrow 2\ ^4He$), or a decrease of the intensity because of a short time delay between the emission of two successive fragments.

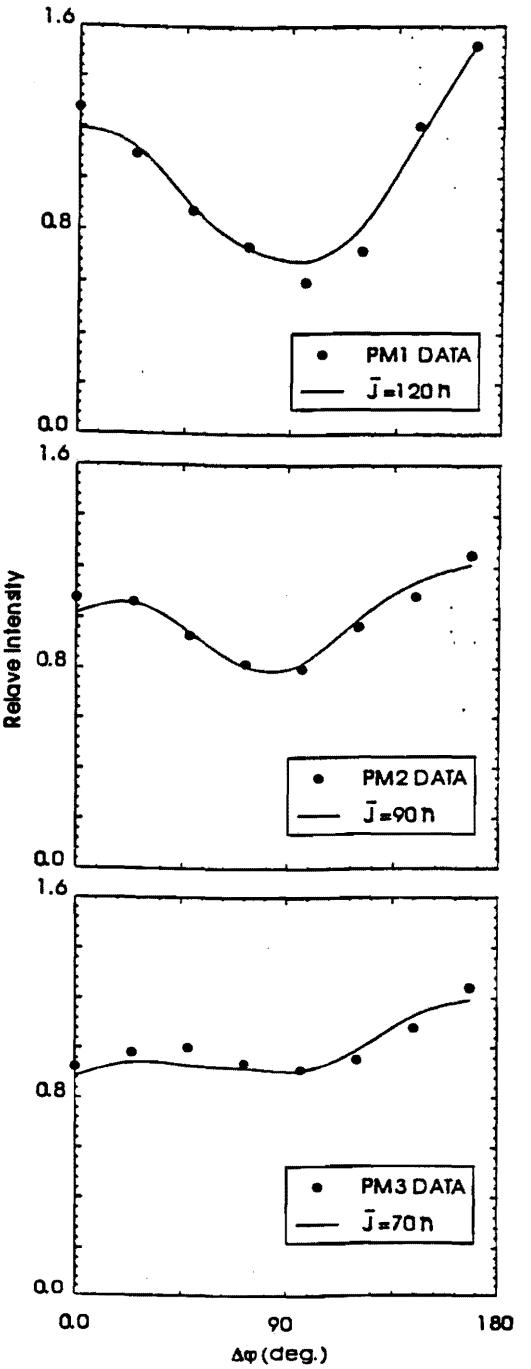

Figure 5 : Analysis of Li(21°)-Li(47°) correlations for $^{32}S + ^{nat}Ag$ system with a model of sequential emission from a rotating source. The mean values of angular momentum used in the simulations are indicated

III- Reaction simulations

A statistical model code (MODGAN [10]) has been used to simulate these correlation functions. It takes care of the emission of particles (H, He and IMF) coming from a rotating excited source with an average angular momentum $\bar{J}$. The choice of the emitter namely $Z_0 = 48$, $A_0 = 112$ and $v_0 = 1.35$ cm/ns has been made accordingly to heavy residue measurements performed with silicon detectors. The code picks up two particles with a time delay chosen from an exponential distribution $e^{-t/\tau}$, where τ is the lifetime of the source.

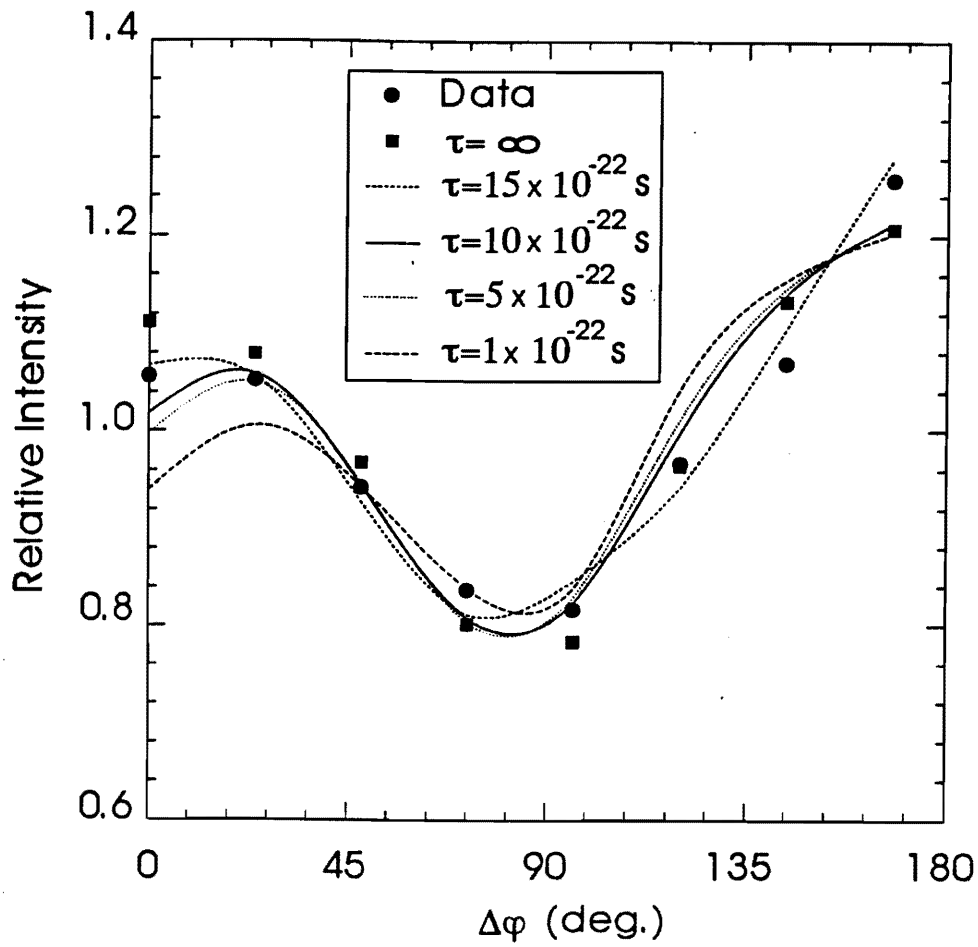

Figure 6 : Li(21°)-Li(47°) azimuthal correlations for the $^{32}S + ^{nat}Ag$ system compared with the model ($\bar{J} = 90\hbar$)

We first tried to analyze the Li-Li correlation functions triggered by the the multiplicity windows PM1, PM2 and PM3 in order to check their dependence on the angular momentum of the rotating source. One can see in figure 5 that the "central" collisions are

associated with an average angular momentum $\bar{J} = 70\hbar$ and "midcentral" collisions with $\bar{J} = 90\hbar$, both in complete agreement with the associated impact parameter as shown in figure 2. The so-called "peripheral" collisions are associated with $\bar{J} = 120\hbar$ and should be interpreted as the less central contribution because Li pairs at these angles select central collisions with a wide multiplicity distribution.

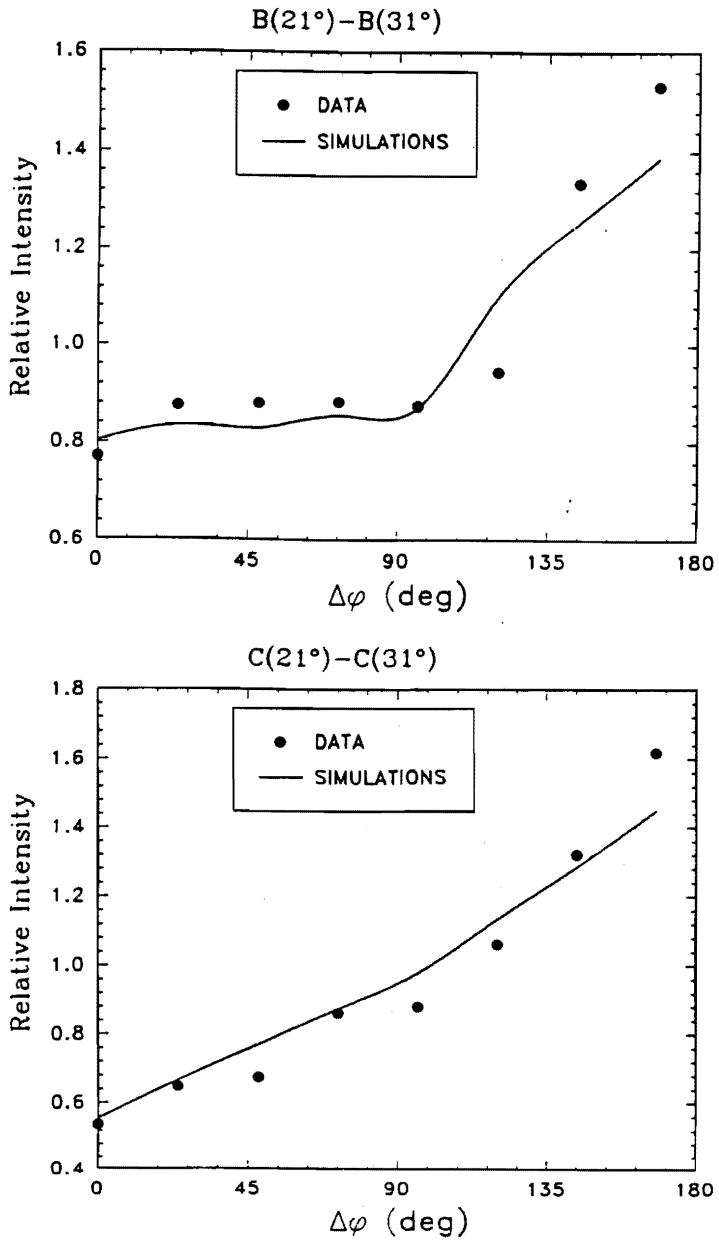

Figure 7 : B-B and C-C azimuthal correlations compared with the simulations ($\bar{J} = 90\hbar$ and $\tau = 10\ 10^{-22}$ s)

We explored the sensitivity of the intensity at $\Delta\varphi$=0° to the time delay between the two fragments which results from the above mentioned exponential distribution. With the choice of angular momenta indicated above, τ values of $\approx$ (10 - 15)10^{-22} s are needed to fit the Li correlation functions (figure 6). Same analysis has been done for Boron and Carbon pairs with a similar quality of the fit and with close out values of $\bar{J}$ and τ parameters (figure 7). This result shows that all considered fragments (Li, B, C) originate from a unique source, characterized by approximatively the same average angular momentum and lifetime.

Conclusions

In conclusion particle azimuthal correlations offer a useful tool to study the time delay between the emission of two heavy fragments. We observed here that most of the violent collisions defined by two IMF produced at angles larger than 21 degrees are related to impact parameters less than 30% b_{max}. On other hand lifetime of the order of 300 to 450 fm/c indicates that the experimental data are well described by a slow sequential emission of fragments from a rotating source with angular momenta up to 120$\hbar$. Further analysis is in progress on the 37.5 A.MeV ^{32}S + ^{58}Ni and 30 A.MeV ^{32}S + ^{nat}Ag in order to study the dependence on incident energy and reaction system.

[1] G. Bertsh and P.J. Siemens, Phys. Lett. 126B, 9 (1983)
[2] E. Suraud, Nucl. Phys. A495, 73 (1989)
[3] D.H.E Gross, Phys. Lett. B203, 26 (1988)
[4] L. Morreto, Nucl. Phys. A247, 211 (1975)
[5] W.A. Friedman and W.G. Lynch, Phys. Rev. C26, 16 (1983)
[6] T. Ethvignot et al. Phys. Rev C46, 637 (1992)
[7] T. Ethvignot et al. Phys. Rev C48, 618 (1993)
[8] D. Drain et al. Nucl. Inst. and Meth. in Phys. Res. A281, 528 (1989)
[9] C. Cavata et al. Phys. Rev. C42, 1760 (1990)
[10] N.N. Ajitanand et al. to be published in Nucl. Inst. and Meth. in Phys. Res.