High Velocity Particles From Nuclear Fusion

Domitian Popescu

Laboratoire de Physique Théorique Fondamentale de Paris
31 rue de l'Évêque, F-06140 Coursegoules (France)
E-mail: lab.phys.theo@club-internet.fr
fax / phone: 33 (0)4 93 59 14 46

Abstract

The Heavy Ion collision give in final many different products. Recent experimental data (which confirm older ones) suggests the existence in the reaction of particles emitted with energy close to kinematics limit (Particles Near Kinematics Limit **PNKL**). We are able to interpret this "strange " part of the spectra in terms of new fusion mechanism for heavy ion fusion reactions. The probability of emission of **PNLK** is related to the first stage of the reaction. The properties of first moments of the live of the new fused object are inferred from the general principles.

1 Introduction

The experimental investigation of the energy spectra of protons and alpha particles emitted in heavy ion induced reactions, carried out as earlier as 1961 by Britt and Quinton /1/, showed the presence in the these spectra of, besides the evaporation component, a more intensive and energetic one. The formation of highly energetic protons and alpha particles emitted predominantly in the direction of the incident beam and having a velocity spectrum of the type:

$$p(v) \sim v^2 \exp(-v^2 / v_0^2) \qquad (1)$$

was explained in terms of the separation of an alpha particle from the projectile (or in the case of the ^{12}C - induced reactions, in terms of projectile break-up in the field of the target nucleus).

Further investigations of energetic light particles indicate the possible existence of other emission mechanisms.

Ho et al. /2/ measured the alpha particles spectrum in coincidence with transfer reaction products. An interpretation was proposed that the emission of highly energetic alpha particles proceeded from a strongly located spot at the point of contact of the incident ion with the target nucleus. A different approach of the problem was used by Yamamda et al. /3/ who suggested the mechanism of "massive transfer" during the

International Journal of Computing Anticipatory Systems, Volume 11, 2002
Edited by D. M. Dubois, CHAOS, Liège, Belgium, ISSN 1373-5411 ISBN 2-9600262-5-X

interaction. This representation was developed by Sievek-Wilczynska et al. /4/, who tried to connect such a process with the input angular momentum.

R. K. Bhomick et al /5/, presents results of angular distribution measurements of alpha particles in coincidence with the light transfer products and concluded that the processes of this type are the fast ones. The sequential emission of the alpha particles was regarded as uniquely and a supposition was made that the energetic alpha particles are emitted in the early stage of the reaction. E. Gierlik et al /6/, drown also such a conclusion on the basis of the alpha particles spectra measured in coincidence with binary fission fragments. *The lack of dependence of the alpha particles spectrum shape and the yield on the angle between the fission axis and the beam direction indicated the emission of the alpha particles before the fission of the residual nucleus.*

Because of the strongly forward-peaked angular distribution of energetic alpha particles, it is of great interest to measure their energy spectra at 0°. In /7/, measured the energy spectra at 0° in the reaction $^{22}Ne + ^{197}Au$. These measurements showed that in the given reaction alpha particles were observed with an energy only slightly lower than the maximum possible value calculated on the basis of the conservation laws of a two body process.

As seen in the figure 1 from /7/ the maxim of the energy spectra of the alpha particle measured at 0° in the bombardment of a Ta target by Ne 20 and 22 slightly depends on the projectile energy, whereas the position of the maxim, as follows from the simple calculations, is close to the exit Coulomb barrier for an alpha particle.

In fig 2 of the same article are shows alpha particle energy spectra measured at 0° in the bombardment of a Au target by Ne 22 in comparison with the calculated evaporation spectrum. The cross section at the maximum is predominantly due to evaporation. However, the high energy portion of the experimental spectrum, strongly differ from the one expected on the basis of the evaporation model. For this high energy part of the energy spectra a strong dependence on the projectile energy is observed. It should be pointed out that in the studied reactions alpha particles ca be emitted with velocities significantly greater than the velocity of incident ions. All experimental alpha particle spectra are characterised by well pronounced end point energies E_α^{max} (indicated by arrows in the figures). These energies are estimated on the basis of the conservation laws under the assumption of a two body exit channel, alpha particle emission accompanied by the fusion of the remaining nucleons.. The maximum alpha particle energy spectra is determined by the simple expression:

$$E_\alpha^{max} = E_0 + Q - V \qquad (2)$$

where E_0 is the projectile energy in the centre of mass , Q is the total energy realised in the reaction, and V is the potential energy, which in the case of a two body process, is equal to 0. It can be shown that the maximum value of the alpha particles energy corresponds to a two body process. Thus, in the case of a three body exit channel in the reaction on the Au the break up of the projectile, the alpha particle energy cannot exceed 70 MeV.

The new nucleus formed like the result of the complete fusion of the interacting nuclei would have an excitation energy $E^* = E_{cm} + Q_{CN}$. In contrast with the Nils Bohr Compound Nucleus, the above mentioned system can be found in states of different excitation energy depending on the emitted alpha particles energy. In the extreme case, the system will be in a low excited state (cold nucleus). These nuclei either decay to the ground state by the emission of nucleons and gamma rays, or fission to two fragments. If the small difference between E_α^{max} and the alpha particle spectrum end point energy is presumably of rotational nature, then this may be an indication of the high angular momentum left in the residual nucleus or system.

2 Predictions from Qgg Extension

If we suppose that the systematic Qgg /8/ is a good guide for the evaluation and interpretation of the general trends of the cross section of the projectile like particles (up to the proton) we can concluded that the same kind of the phenomena will be seen in the spectra of the alpha and the proton particles.

Indeed, the recent measurements of the R. Coniglione et al. /9,10,11/ report on the measurements of the energetic protons in exclusive experiments. Their data support the hypothesis that in heavy ion collisions at intermediate energy the energetic protons are emitted.

In the reported experiment the protons with energy close to 200 MeV, even for the angles higher than 90° with cross section only 100 lower than the cross sections of the protons at forward angles like 42°.

For the bombarding energies of 10A MeV the cross section of the PNKL particles was found of the order of 0.1μb/MeVsr, it means six order of magnitude lower than the maximum. If we extrapolate to the intermediate energies used by Coniglione et al. we have to found protons with energies of 1000 with the cross sections of the same values 0.1nb/MeVsr.

The kinematics limit calculate for the intermediate velocity source close to half of the beam velocity and Fermi movements $v_{max} = 1/2\ v_{beam} + v_{Fermi}$ and was calculate at 93 MeV. The data are far from that limit , farther than 200 MeV supporting our prediction that near 1000 MeV the spectra will be present with cross section of the order of 0.1nb/MeVsr.

3 Interpretation

The origin of this kind of particles PNKL is yet not clear. Like we mentioned in the introduction

---Ho et al./2/ suggested a strong heated spot at the pint of contact of the incident ion with the target nucleus,

---Yamada et al./3/ suggested the mechanism of massive transfer ,
--- K. Sievek-Wilczynska et al./4/ tried to connect such particles with the angular momentum,
--- R. Sham and J. Knoll,/12/ suggested mechanism of nucleon interaction with « virtual cluster »
--- B. Ghosh and R. Shyam, /13/multiple scattering and the high momentum tails in the nucleon Fermi momentum distribution

Our interpretation is in the frame of the new model of nuclear reaction/14/ where the fusion of the nucleus is at large distance (10 or more, may by 60 fm); this kind of particles appears in the first instant of the fusion. The virtual pion which transport the information between nuclei will produce an huge perturbation in one of the nucleus such that a very energetically piece of nuclear matter is ejected from the nucleus. If the direction is not in the shadow cone of the partner nucleus, this piece of nuclear matter will escape and registered as PNKL. We have to explicate what we understand by piece of nuclear matter. A piece of nuclear matter its a assembly of neutrons and protons related by nuclear forces or any kind of cluster as ^{14}C etc.

If the piece of matter go inside the intermediate zone, the process of thermalisation will start and a very hot spot will appear. With other words the mini compound matter will be formed. In this time the two nuclei partners of the reaction will remains cold and will change to the Double Nuclear System, which will change to the final one nucleus, which will decay specially by gamma transitions. In all the stages evaporation of particles and gamma is permitted.

4 Conclusions

1. We have been able to understand the production of the PNKL particles in the frame of the new mechanism of nuclear reaction/14/.

2. We suggest using the heavy ion reaction at very high energies 100GeVA to obtain protons or other particles with energies of 10TeV or more. This can be done in few world laboratory even now in 2001 and not to wait up to 2010 when LHC will produce a good beam of 10TeV.

3. We can study the PNKL particles in the reaction near or under Coulomb barrier. In that cases it will be easier to detect the light particles for their low energies lower than 50 MeV.

4. The PNKL will furnish direct information about the partner nuclei since only few degree of liberty are involved.

5. We are able to explain the quadratic dependence of the proton multiplicity in the figure 2 (c) from /11/ in the sense that the high energy proton will encounter less and less particles in the way, and will have very low probability to collide an other proton.

References

/1/ H. C. Britt and A. R. Quinton Phys.Rev. 124 (1961)887
/2/ H. Ho et al. Z. Phys A283(1977) 235
/3/ H. Yamada et al. Phys. Rev. Lett.43 (1979)605
/4/ K. Sievek-Wilczynska et al. Nucl. Phys. A330(1979) 150
/5/ R. K. Bhomick et al Phys. Rev. 80B (1978)41, Phys. Rev. Lett.43 (1979)619
/6/ E. Gierlik et al preprint JINR P7-12839, Dubna 1979
/7/ E. Gierlik et al preprint JINR E7-12922, Dubna 1979
/8/. V.V. Volkov, A.G. Artukh, G.F. Gridnev, A.N. Mezentsev, V.L. Mikheev, A. Popescu, D.G. Popescu, A.M. Sukhov, L.F. Chelnokov, Izv. AKad. Nauk SSSR, Ser. Fiz. 42 (1978) 2234.
/9/ R. Coniglione et al. Phys. Lett B322 (1994) 38-42
/10/ R. Coniglione et al. Phys. Lett B471 (2000) 399-345
/11/ R. Coniglione et al. Report LNS(Catania,Italy) 20-02-2001
/12/ R. Shyam and J. Knoll, Nucl. Phys. A448 (1986) 322
/13/ B. Ghosh and R. Shyam, Phys. Lett. B A234 (1990) 248
/14/ D. G. Popescu, International Journal of Computing Anticipatory Systems, 2002.