実験企画調整室

UFTP preprint 216/1988

受入
88-9-94
高工研図書室

Institut für Theoretische Physik
Johann Wolfgang Goethe Universität
Frankfurt am Main

Landau-Vlasov model versus Vlasov-Uehling-Uhlenbeck- approach Different flow effects from the same theory?*

C. Hartnack, H. Stöcker and W. Greiner
Institut für Theoretische Physik, Universität Frankfurt, Germany

*This work has been funded in part by the German Federal Minister for Research and Technology (BMFT) under the contract numbers 06 OF 772, 06 HD 776 and by the Gesellschaft für Schwerionenforschung (GSI).

Institut für Theoretische Physik der Universität Frankfurt
Robert-Mayer-Str. 8-10, D-6000 Frankfurt am Main

Landau-Vlasov model versus Vlasov-Uehling-Uhlenbeck- approach Different flow effects from the same theory?

C. Hartnack, H. Stöcker and W. Greiner
Institut für Theoretische Physik, Universität Frankfurt, Germany

Abstract: *Differences between the Nantes-Ganil-Grenoble (NGG) LV-model and the original VUU approach are analysed. It is found that the LV code tends to simulate - for small timesteps - a non viscous testparticle fluid.*

The Nantes-Ganil-Grenoble (NGG) collaboration has recently applied [1] the Landau-Vlasov (LV) transport code [2] to study collective flow effects in heavy ion collisions. It was found [1] that "the LV model provides large flow even with a soft nuclear equation of state (eos), in strong contrast to the earlier work [4] based on the microscopic VUU calculations which shows evidence for a stiff eos." It was concluded that "these discrepancies between models based on similar approaches have certainly to be traced back to the treatment of two body collisions, which requires a closer study of the Uehling Uhlenbeck collision term."[1]

In the present note we take up this task - the origin of the large differences between the LV and VUU predictions are explored. In the LV code nucleons are represented by a large collection (typically ~ 30) gaussian testparticles.[1-3] Collisions between the testparticles occur if the centroids of two gaussians approach each other with a distance of closest approach $d_{Test} < (\sigma_{Test}/\pi)^{1/2}$. The NGG collaboration chooses $\sigma_{Test} = \sigma_{NN}$. [3] This has drastic consequences: the resulting classical * mean free path of such testparticles would be very short, $\lambda_{Test} = (\sigma_{Test} \cdot \varrho_{Test})^{-1} \sim 1/20 fm$ for $\varrho_{Test} = 30\varrho_0$ and thus the testparticles would behave like a perfect, i.e. nonviscous, fluid. In order to re-introduce a longer mean free path into the model, the NGG collaboration decided to introduce the constraint that a given testparticle cannot undergo more than one collision per timestep. Consequently, the mean free path of the testparticle increases to $\lambda_{Test} \sim v_{ion} \cdot \Delta t$ which yields $\lambda_{Test} \sim 0.5 fm$ for the timesteps $\Delta t \sim 1 fm/c$ employed in the LV calculation. (These values of λ_{test} are, however, still too short as compared to the N-N mean free path $\lambda_{NN} \sim 2fm$ at ϱ_0. A timestep of $\Delta t \sim 4fm/c$ would be needed to simulate roughly the nonequlibrium effects $\sim \lambda/R$ but such a Δt is too long to ensure a reasonable accuracy in the numerical integration of the classical equations of motion.)

* for the sake of simplicity let us neglect the Pauli blocking in the qualitative discussion

Thus, the prescription chosen in ref. 1-3 introduces an explicit timestep dependence of the collision frequency and, therefore, of other physical observables. To obtain a quantitative feeling for this effect, we implemented these conditions [1-3] into our VUU code [4,5], i.e. the following results are obtained with Pauli blocking included. (Note that we employ [4] nonreduced σ_{NN} values and point-like testparticles in VUU, which is not relevant in the argument here.) The number of testparticle collisions versus the timestep Δt is shown for Ca (400 MeV/n, b=2fm) + Ca in fig. 1a. Note the $\sim 1/\Delta t$ dependence of N_{Coll} for the simulated LV case (triangles) as compared to the negligible dependence of N_{Coll} on Δt in the original VUU code (squares). Also note the factor of 3 - 6 times larger absolute value of N_{Coll} in the LV case. This means that the LV code approximates a nearly ideal testparticle "fluid" with a quite short mean free path $\lambda_{Test}/R \ll 1$ and therefore with a very small effective viscosity $\eta \rightarrow 0$. However, we know that the actual nuclear viscosity is substantial, $\eta \approx 50 MeV/fm^2c$. [6,7] In fact, viscous fluid dynamical calculations[6] have exhibited the strong dependence of the transverse flow on the viscosity: The ideal fluid ($\eta = 0$) predictions for the transverse momentum transfer $p_X(Y)$ exceed the viscous fluid results (with $\eta = 60 MeV/fm^2c$) by about a factor of two. [6] It is therefore not surprising that this factor of two difference is indeed also observed in fig. 1b, which compares the values of the simulated LV code with our original VUU calculation.[4,5] Note that the LV values approach the VUU result for $\Delta t \approx 4fm/c$ i.e. $\lambda \approx 2fm$. For the LV case with $\Delta t \leq 2fm/c$ we indeed find - as it should be for a perfect, i.e. nonviscous, fluid - that the p_X values are nearly independent (within about 20 percent) of the rapidly changing value of $N_{Coll}(\Delta t)$ (The VUU approach gives per construction Δt independent results.)

We have also studied the dependence of the observables on the number of testparticles used in the LV code. Since $\lambda_{Test} \sim (N_{Test}/A)^{-1}$ we expect again that e.g. p_X should approach the asymptotic "ideal fluid" value for N_{Test} large enough to ensure $\lambda_{Test} \ll R$. Fig. 2 shows that this is indeed the case: The p_X value at 50 MeV even changes sign when λ_{Test} is decreased.

We would like to conclude by noting that we have found similar effects of Δt and N_{Coll} also at lower energies where the LV code has been employed extensively before [2] (see fig. 2). The effects are also observed for a cascade version (i.e. no potential, no Pauli blocking) of the simulated LV code. G. Peilert has observed analogous results in a modified QMD program.

Stimulating discussion with C. Gregoire, P. Schuck and A. Bonasera on the LV code and with B. Schürmann on the "testparticle fluid" are gratefully acknowledged.

Figures

Fig.1: Comparison of the dependence of the number of unblocked collisions (divided by N_{Test}/A) from the timestep Δt for VUU and LV (with $N_{Test}/A = 25$)

Fig.2: Comparison of the dependence of the flow p_X at projectile rapidity from the timestep Δt for VUU and LV (with $N_{Test}/A = 25$)

Fig.3: Dependence of the flow p_X at projectile rapidity from the number of Testparticles N_{Test}/A for LV at low energies (with $\Delta t = 2.5$)

References

[1] F.Sebille, G.Royer, C.Gregoire, B.Remaud, P.Schuck, Nuclear dynamics with the (finite range) Gogny force: flow effects, GANIL preprint 1988

[2] C. Gregoire, B.Remaud, F.Sebille and L.Vinet, Phys. Lett. B **186** (1987) 14
C. Gregoire, B.Remaud, F.Sebille and L.Vinet, Nucl.Phys **A465** (1987) 317
B. Remaud, C. Gregoire, F.Sebille and L.Vinet, Phys. Lett. B **180** (1986) 198
B. Remaud, C. Gregoire, F.Sebille L.Vinet and Y.Raffray, Nucl.Phys **A447** (1985) 555C
A. Bonasera, C. Gregoire, Ambinguities in the estimate of hard photon production in intermediate energy nucleus-nucleus collisions, GANIL preprint 1988
C. Gregoire, D. Jaquet, M. Pi, B. Remaud, F. Sebille, E. Surrand, P. Schuck, L. Vinet, GANIL preprint P 87-15
L. Vinet, C. Gregoire, P. Schuck, GANIL preprint P 86-28

[3] C. Gregoire, private communications

[4] H. Kruse, B.V.Jacak, H. Stöcker, Phys.Rev.Lett. **54** (1985) 289
J.J. Molitoris and H. Stöcker, Phys.Rev. **C32** (1985) 47
J.J. Molitoris, D. Hahn and H. Stöcker, Nucl.Phys. **A447** (1985) 13C
H. Stöcker and W.Greiner, Phys.Rep. **137** (1986) 277

[5] G. Peilert, A. Rosenhauer, H. Stöcker, W. Greiner, J. Aichelin, Mod.Phys.Lett. **A3** (1988) 459

[6] T.Rentzsch, W.Schmidt, J.A.Maruhn, H.Stöcker, W.Greiner, Hirschegg Proc. Jan. 1988 and to be published
H.Stöcker, Proc. High Energy Heavy Ion Study LBL Nov.1987 Berkely
G.Buchwald, L.P.Csernai, J.A.Maruhn, W.Greiner, H.Stöcker, Phys.Rev. **C24** (1981) 2848

[7] A.R. Bodmer, Microscopic and hydrodynamic descriptions of high energy heavy ion collisions, Argonne preprint 1979, unpublished
B.Schürmann, W.Zwermann, Phys.Rev.Lett. **59** (1987)
B.Schürmann, Mod.Phys.Lett in print

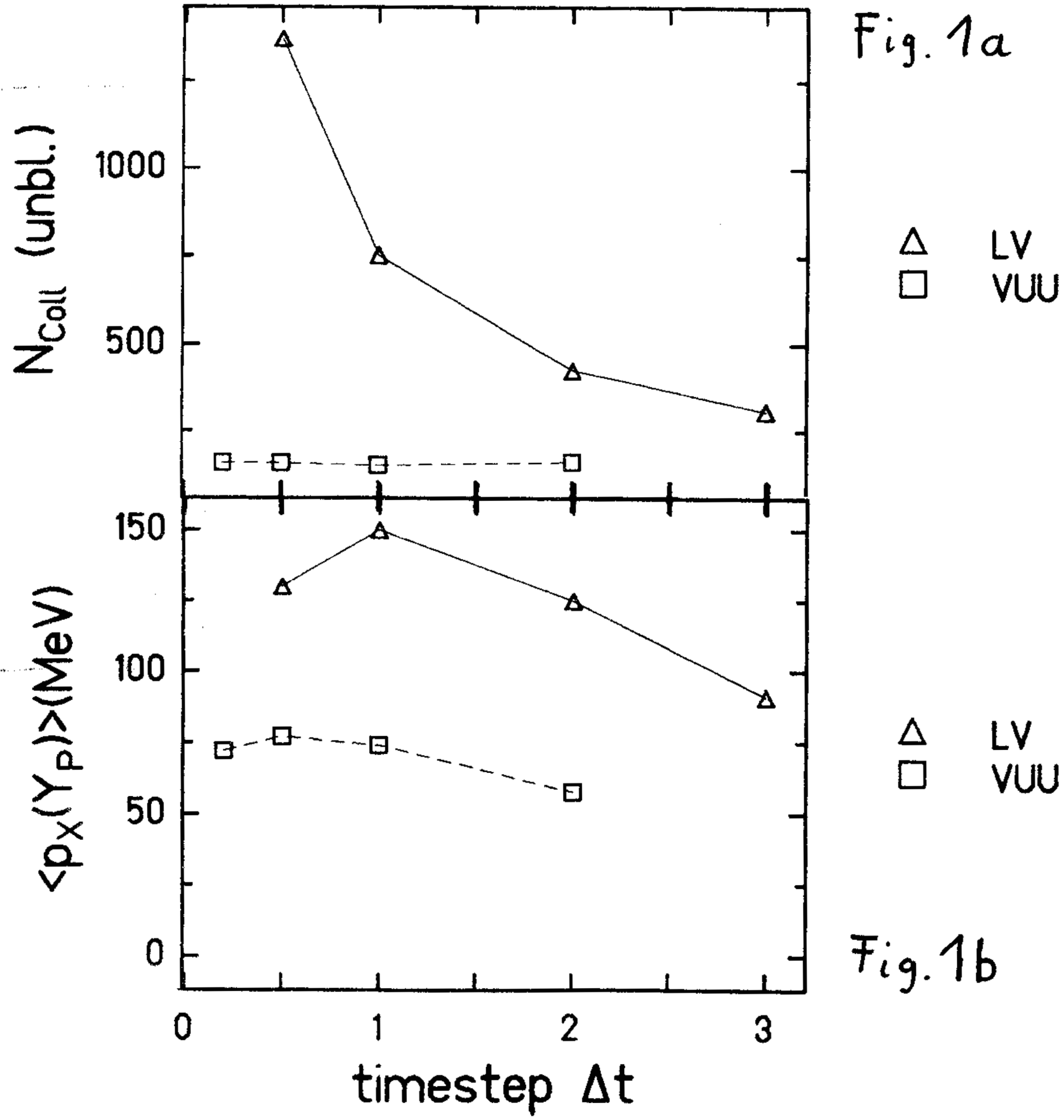

Fig. 1a

Fig. 1b

Ca(50MeV)+Ca LV Hard

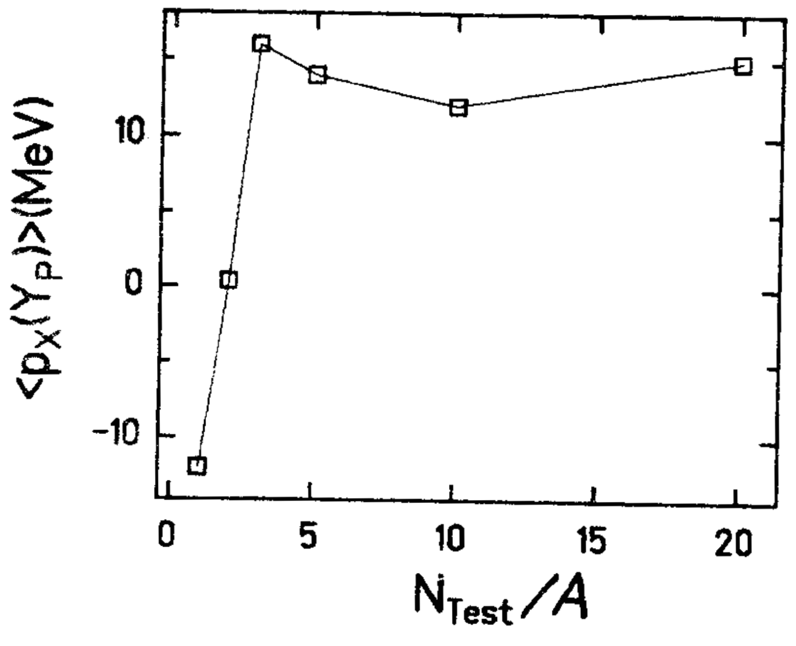

Fig. 2