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

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

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**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 $\sim 30$) 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 $\lambda_{test}$ are, however, still too short as compared to the N-N mean free path $\lambda_{NN} \sim 2fm$ at $\varrho_0$. A timestep of $\Delta t \sim 4fm/c$ would be needed to simulate roughly the nonequlibrium effects $\sim \lambda/R$ but such a $\Delta t$ 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 $\sigma_{NN}$ values and point-like testparticles in VUU, which is not relevant in the argument here.) The number of testparticle collisions versus the timestep $\Delta t$ 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 $\Delta t$ 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 $\Delta t$ 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 $\lambda_{Test}$ is decreased.

We would like to conclude by noting that we have found similar effects of $\Delta t$ 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 $\Delta t$ 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 $\Delta t$ 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 $\Delta t = 2.5$)

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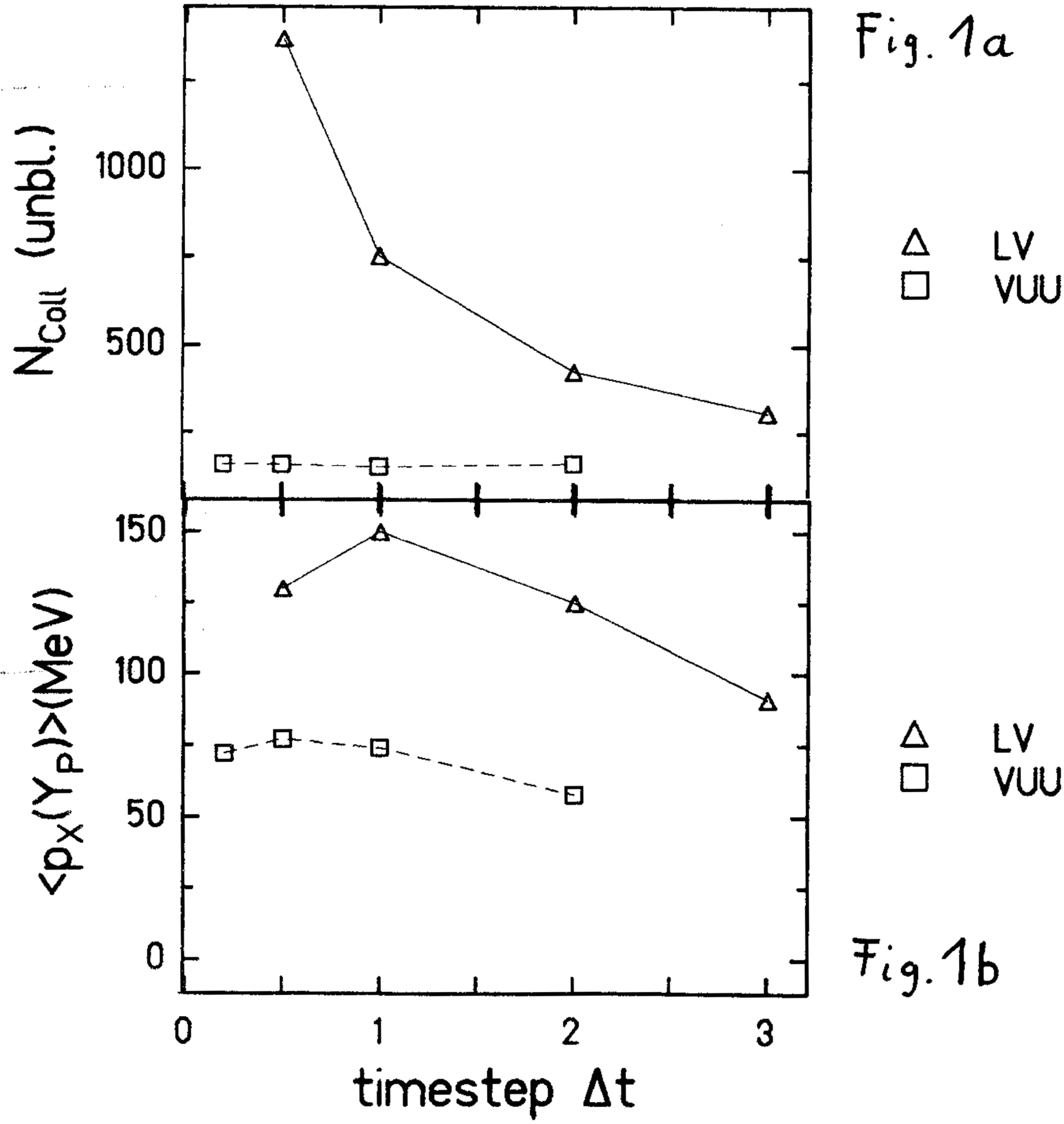


Fig. 1a

Fig. 1b

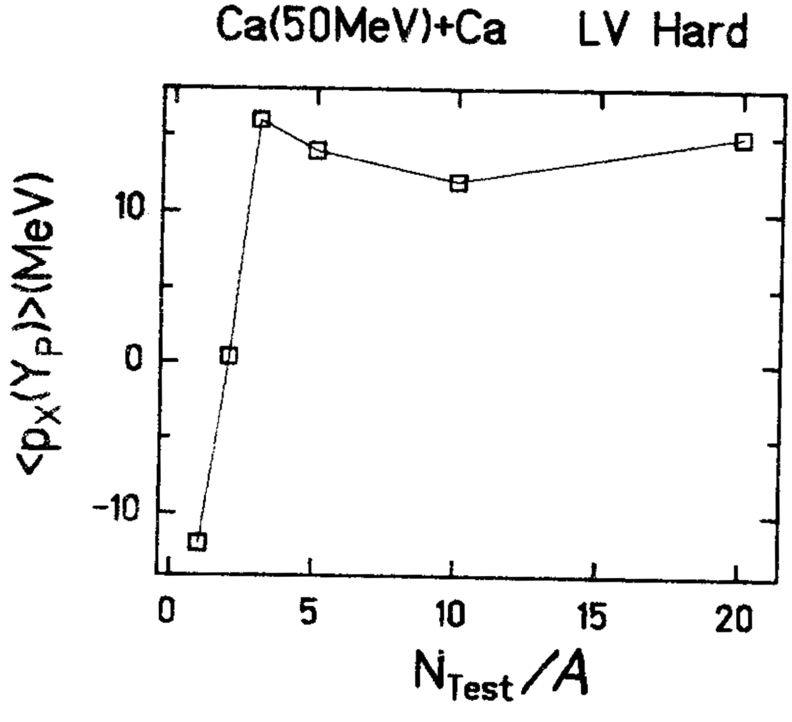


Fig. 2