Understanding results of box calculation Hw2: nucleon evolution in a mean -field potential

TRANSPORT 2017

March 27-30, 2017 **FRIB-MSU, East Lansing, Michigan, USA**

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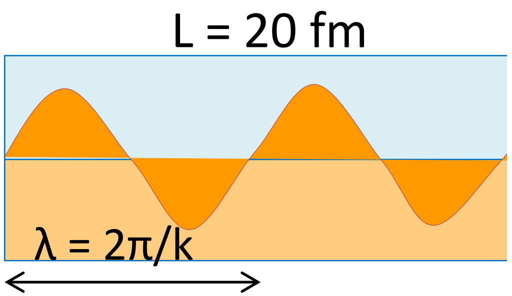
HW 2

Box simulations: test of m.f. dynamics

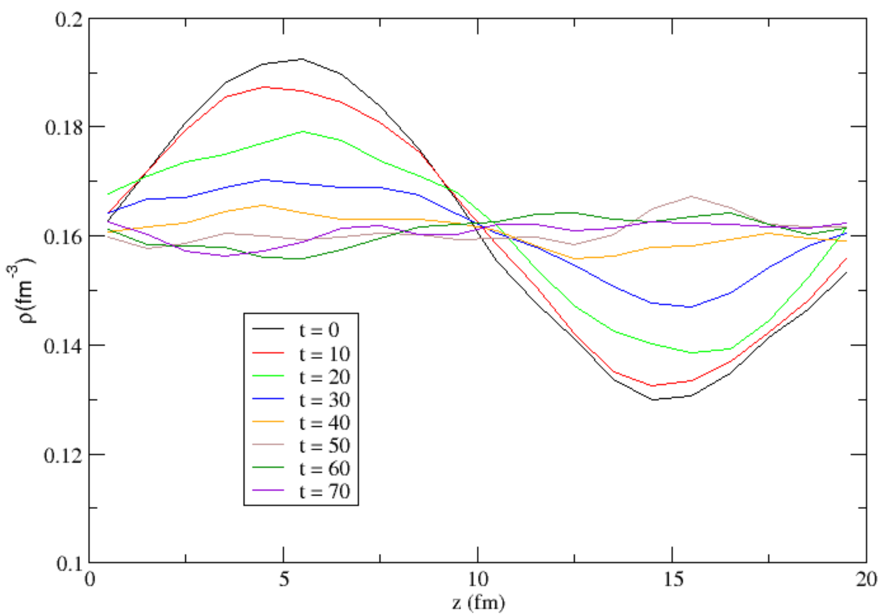


$$\rho(z,t=t_0)= \rho_0 + a_\rho \sin(k_i z)$$

$k_i = n_i\, 2\pi/L$ $\quad a_\rho = 0.2\, \rho_0$

Fermi sphere defined as a function of the local density

- Study the time evolution of ρ(z)



-- Symmetric matter --

- Only mean-field potential
- No surface terms
- Compressibility K = 240 MeV

An example: SMF results

	BUU-type		QMD-type
1	BUU-Swagato	1	IQMD-BNU
2	IBUU	2	IQMD-IMP
3	GiBUU	3	ImQMD-CIAE
4	pBUU	4	TuQMD
5	SMF	5	UrQMD
6	RVUU		
7	SMASH		

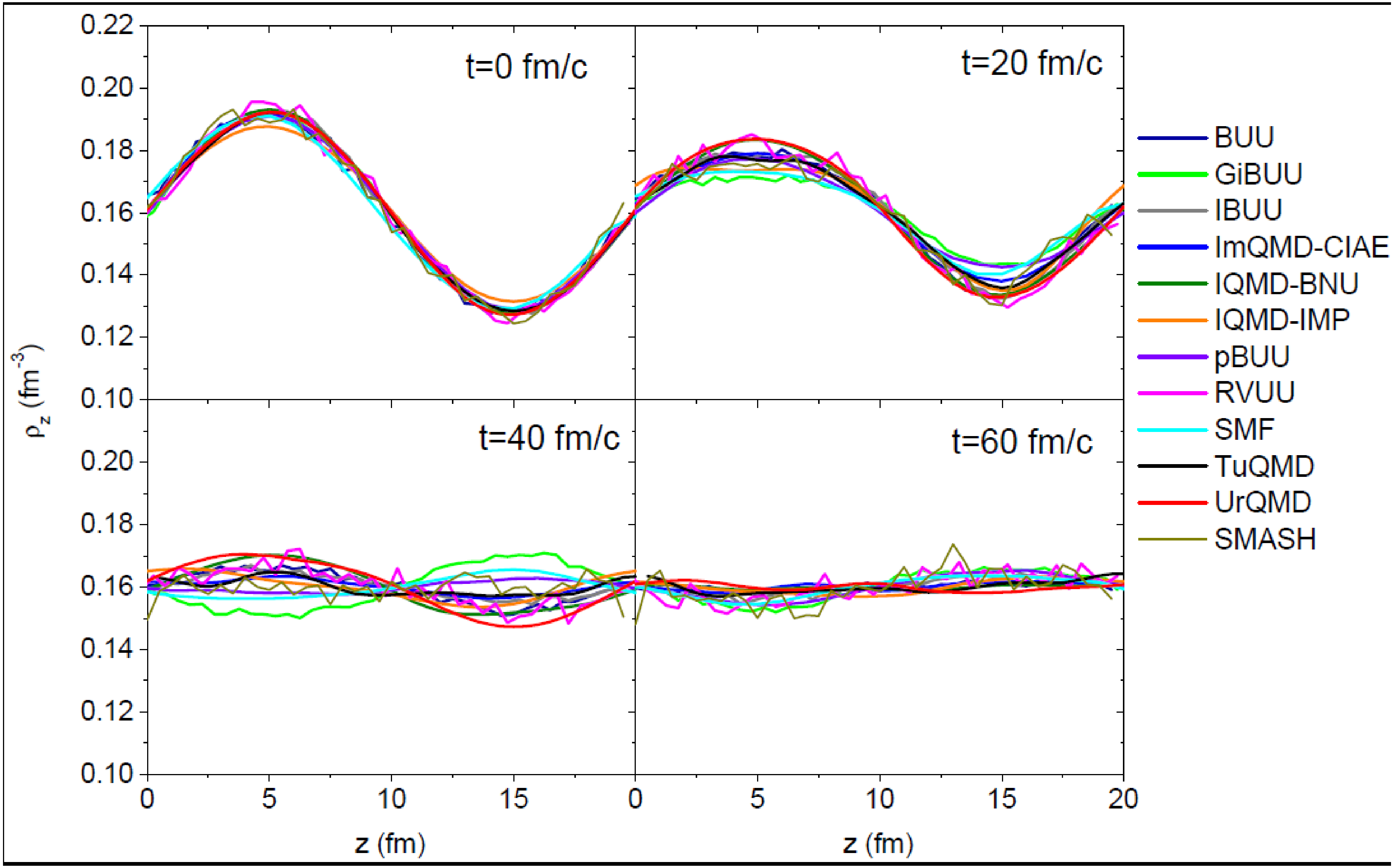
Analysis of the results performed by
Yingxun Zhang *and* Yongjia Wang

First formulation of Homework #2

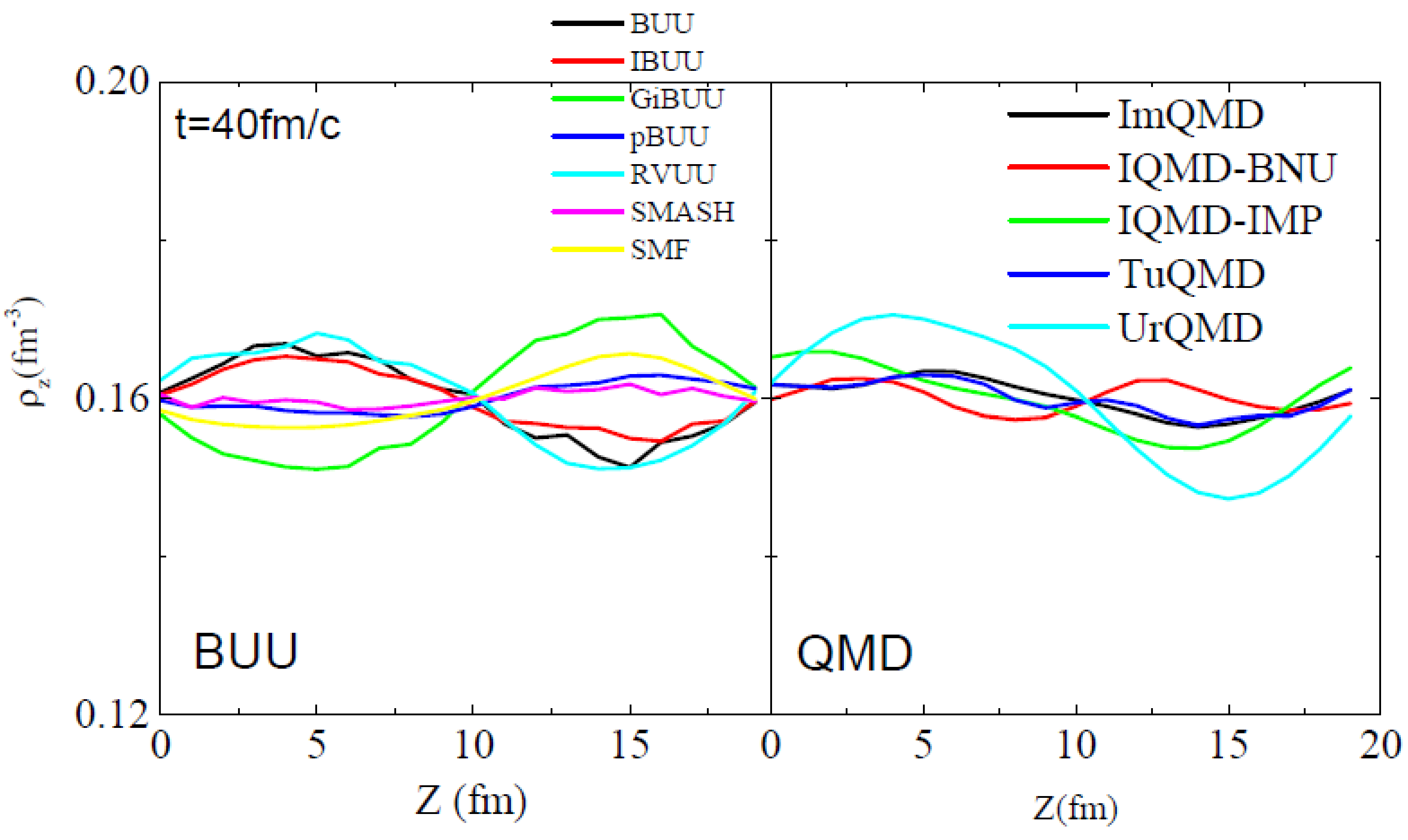
BUU-like: 10 runs with 100 test particles
MD-like: 200 runs

Average ρ(z,t)

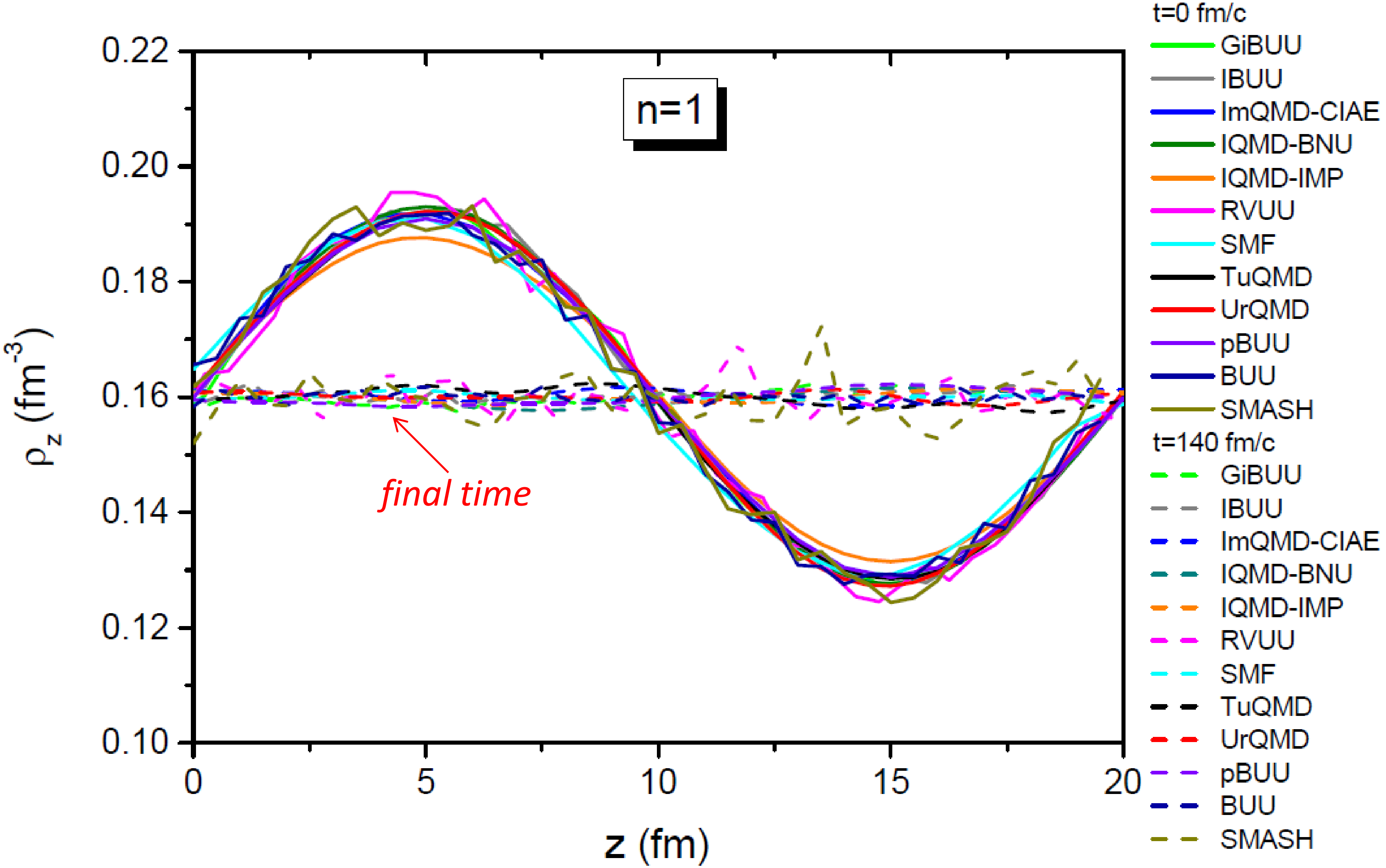
n = 1



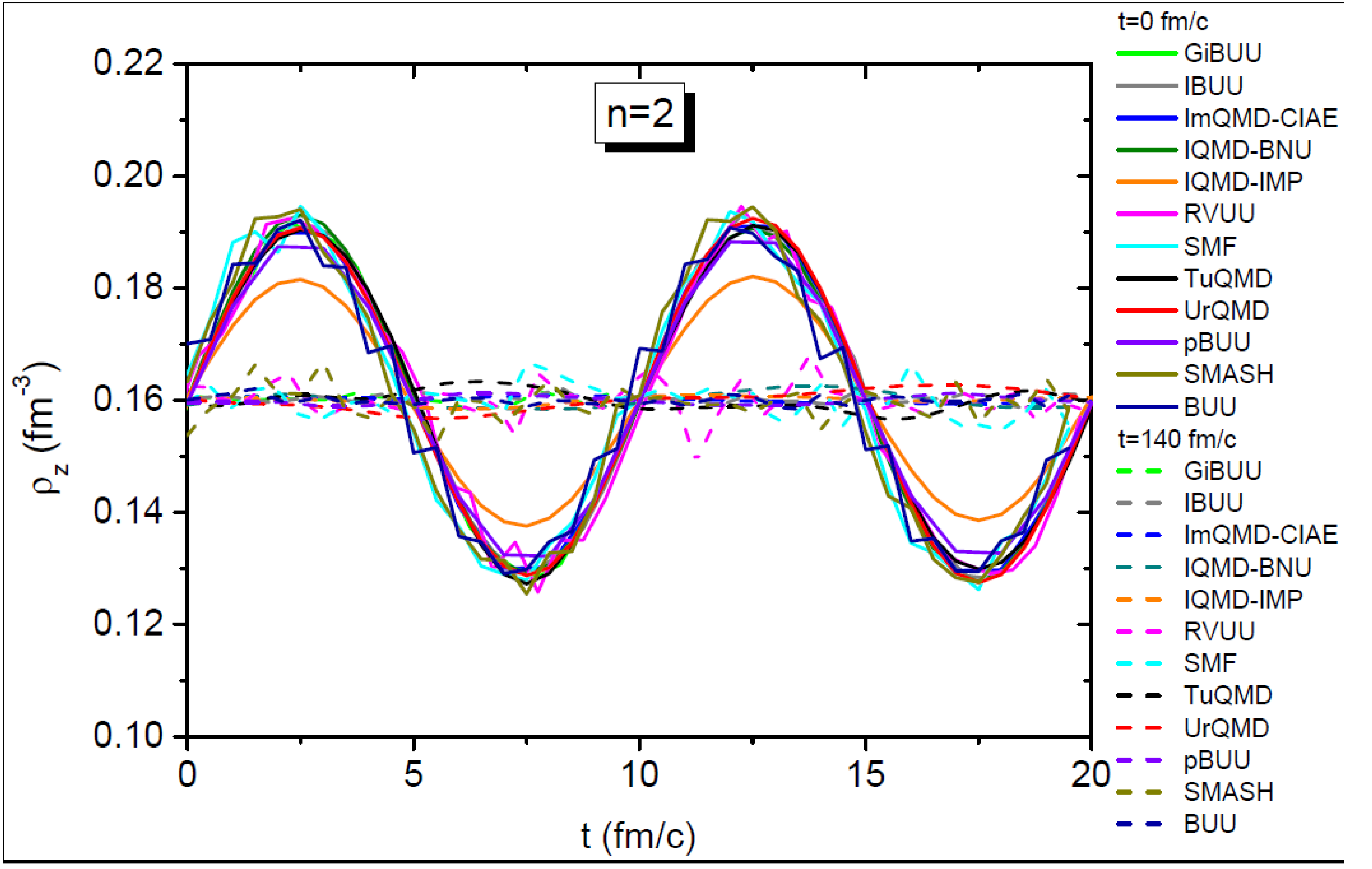
Zoom at 40 fm/c :
Different oscillation frequency in the different models



First formulation of Homework #2

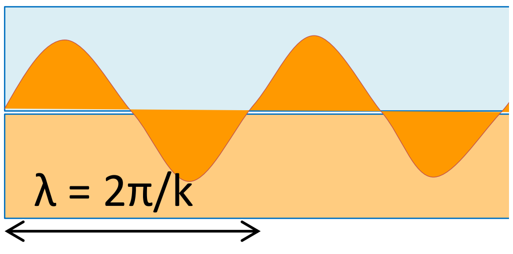


First formulation of Homework #2



2.1 Box simulations: test of m.f. dynamics: space Fourier transform

Second formulation of Homework #2:
Longer final time and results given each 0.5-1 fm/c



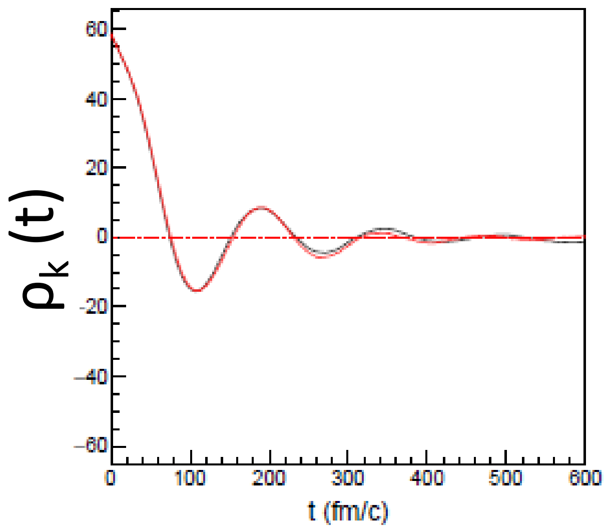
$$\rho(z,t=t_0)= \rho_0 + a_\rho \sin(k_i z)$$

$k_i = n_i\, 2\pi/L$ $\qquad$ $a_\rho = 0.2\, \rho_0$

- Study the time evolution of $\rho(z)$ on a longer time interval
- Extract the Fourier transform in space

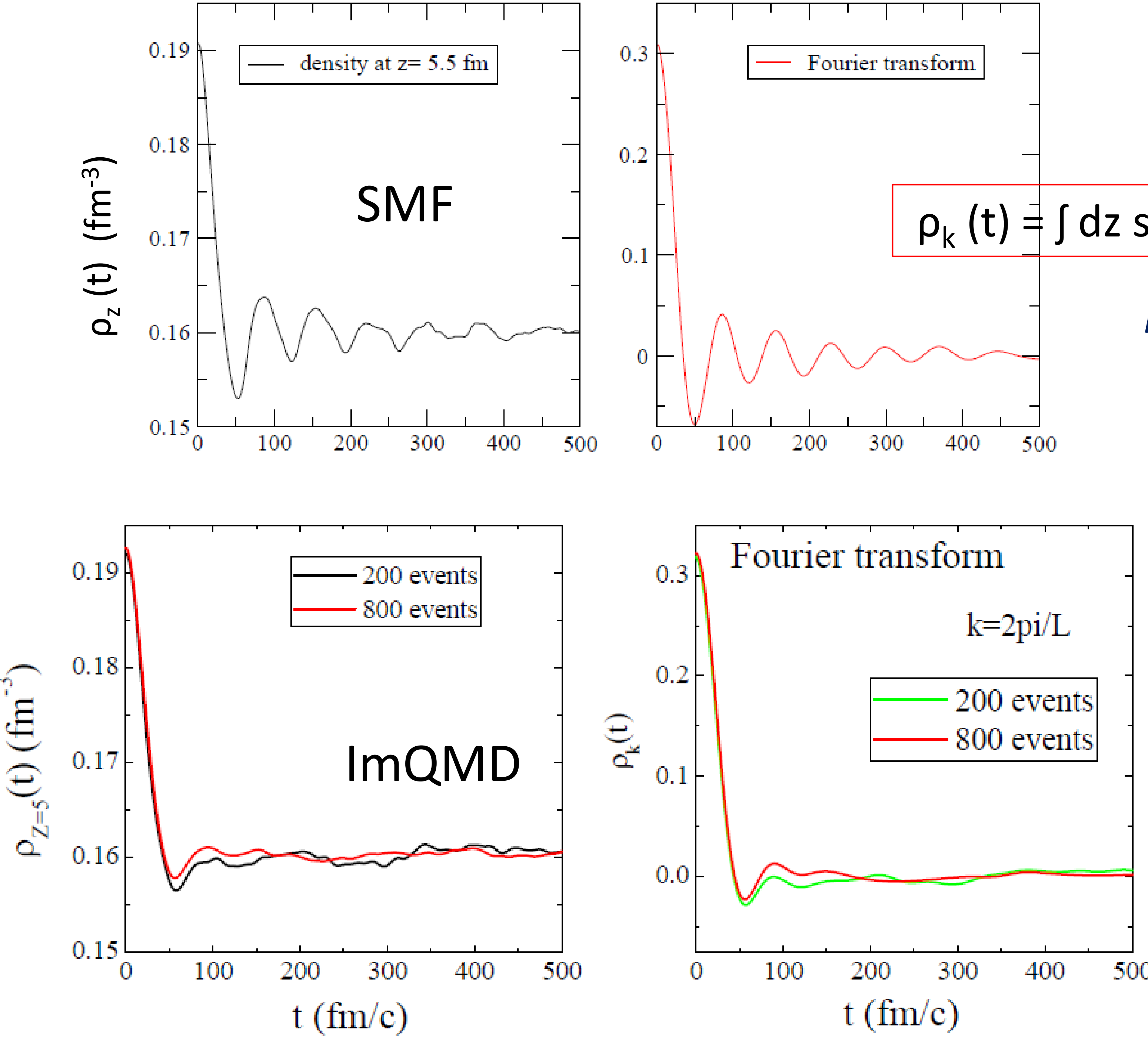
$$\rho_k(t) = \int dz \sin(kz)\, \rho(z,t)$$

➢ significant contribution only for $k = k_i$ (to be checked)



damped oscillations are expected

n = 1



$$\rho_k(t) = \int dz \sin(kz)\, \rho(z,t)$$

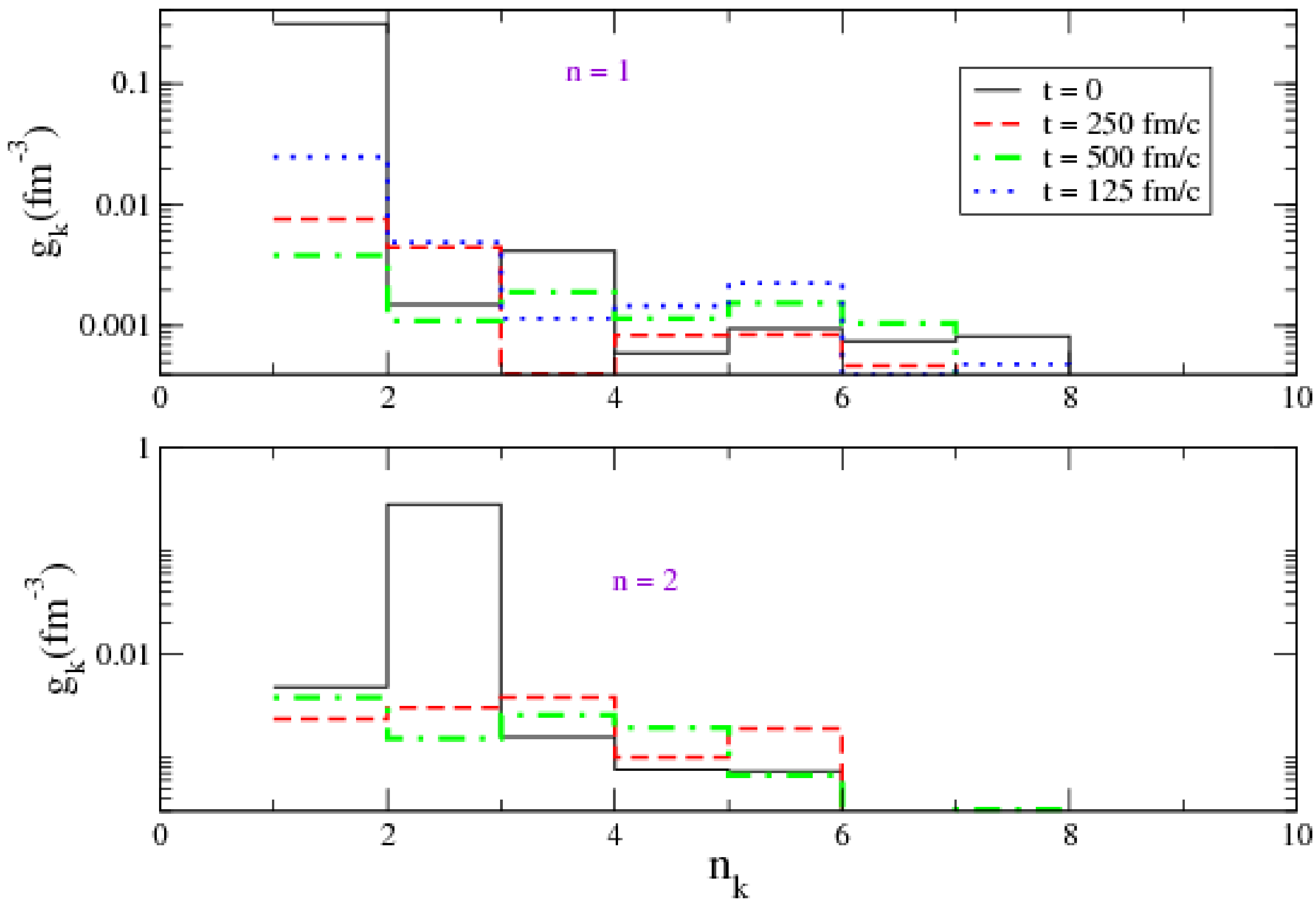
$k = n\, 2\pi/L$

Strong damping

Role of non-excited modes

$\rho_k\ (t) = \int dz\ \sin(kz)\ \rho(z,t)$

$k = n_k\ 2\pi/L$



n = 1

n = 2

SMF simulations

Output rho(z,t) with 1 or 0.5 fm/c

	BUU-type		**QMD-type**
~~1~~	~~BUU-Swagato~~	1	IQMD-BNU
2	IBUU	~~2~~	~~IQMD-IMP~~
3	GiBUU	3	ImQMD-CIAE
4	pBUU	4	TuQMD
5	SMF	~~5~~	~~UrQMD~~
6	RVUU		
7	SMASH		

Time evolution of Fourier transform ρ_k

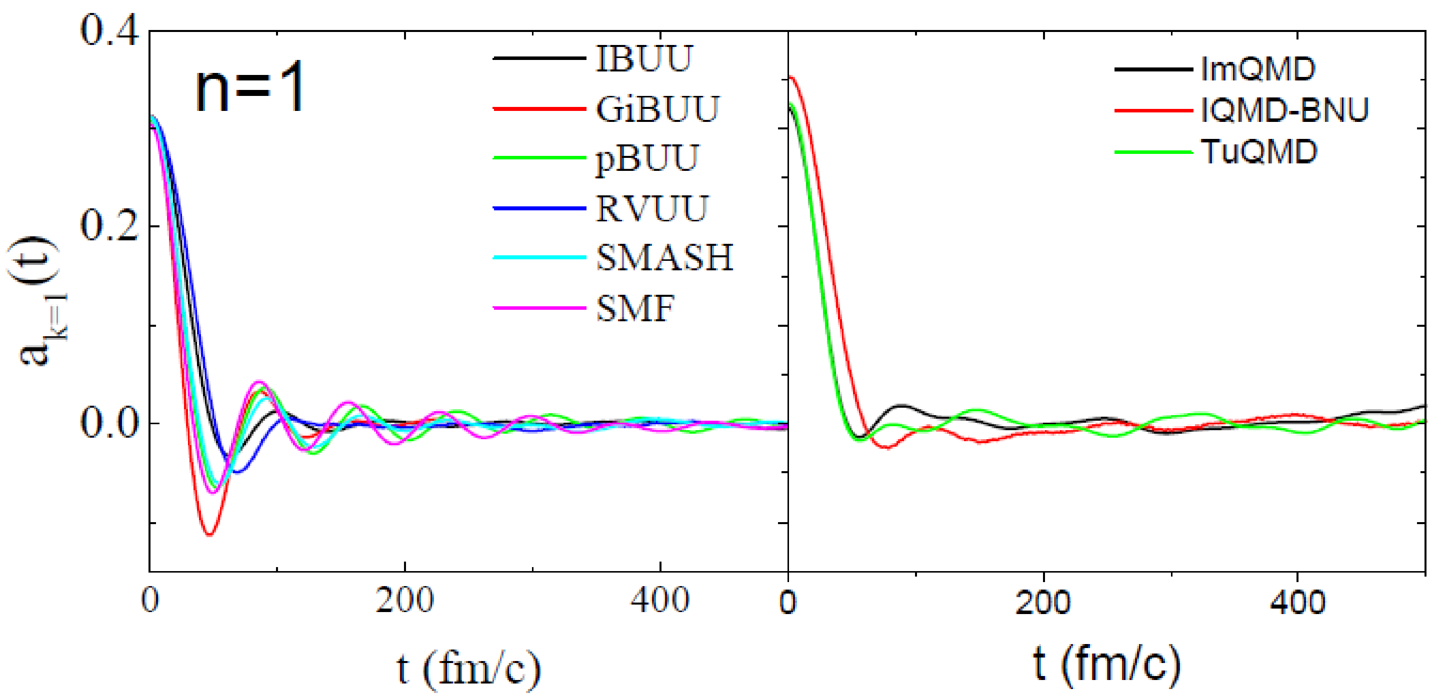
Second formulation of Homework #2:
Longer final time and results given each 0.5-1 fm/c

n = 1

$$\rho_k(t) = \int dz \sin(kz)\, \rho(z,t) \qquad k = n\, 2\pi/L$$

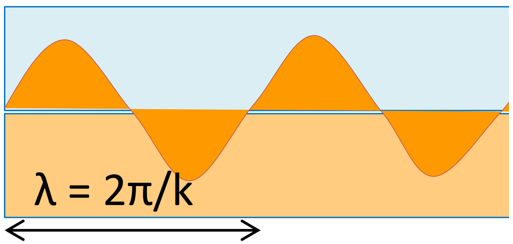
Different oscillation frequency in BUU-like

Larger damping and structureless fluctuations In QMD-like



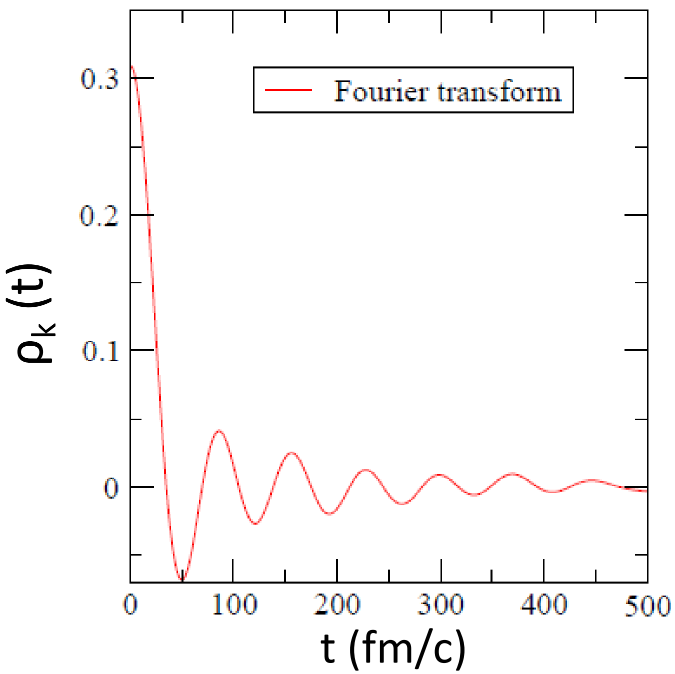
2.2

Box simulations: test of m.f. dynamics: time Fourier transform



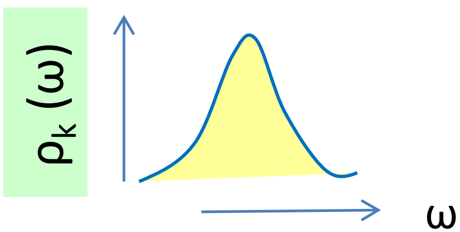
$\rho(z,t=t_0) = \rho_0 + a_\rho \sin(k_i z)$

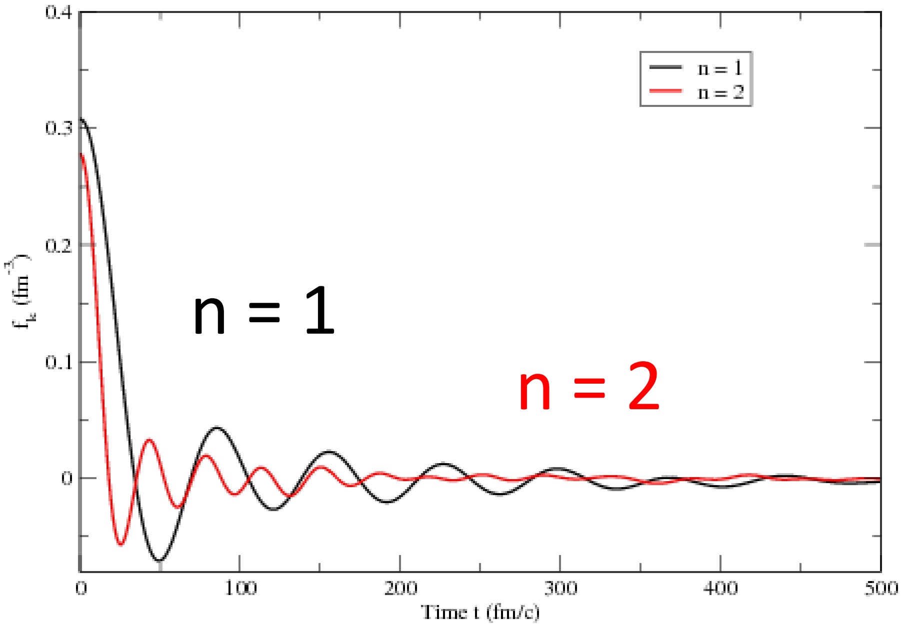
$k_i = n_i\, 2\pi/L \qquad a_\rho = 0.2\, \rho_0$



- Fourier transform in time: *extract the oscillation frequency*

$\rho_k(\omega) = \int dt \cos(\omega t)\, \rho_k(t)$

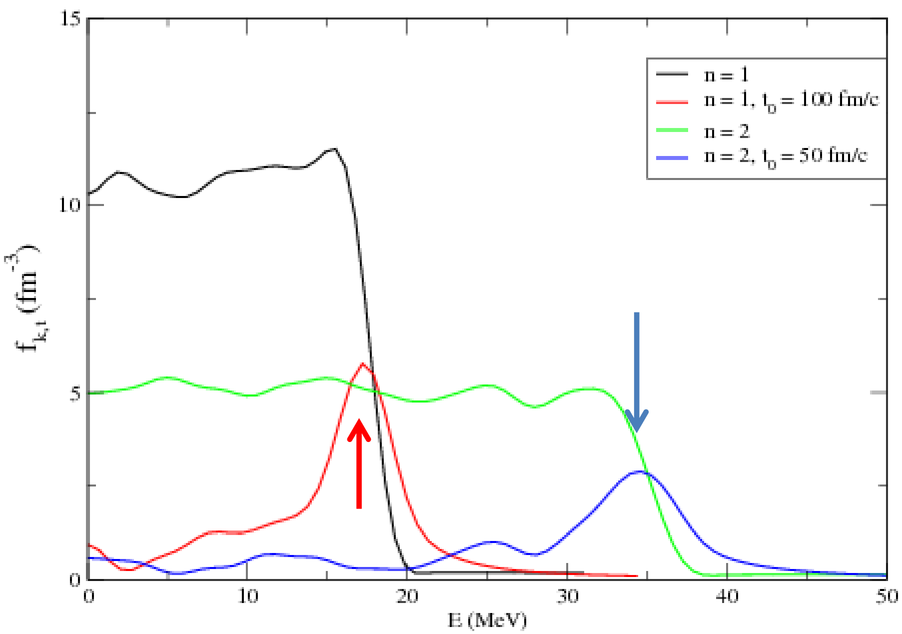




$$\rho_k\,(t) = \int dz\, \sin(kz)\, \rho(z,t)$$

$$k = n\, 2\pi/L$$

SMF simulations

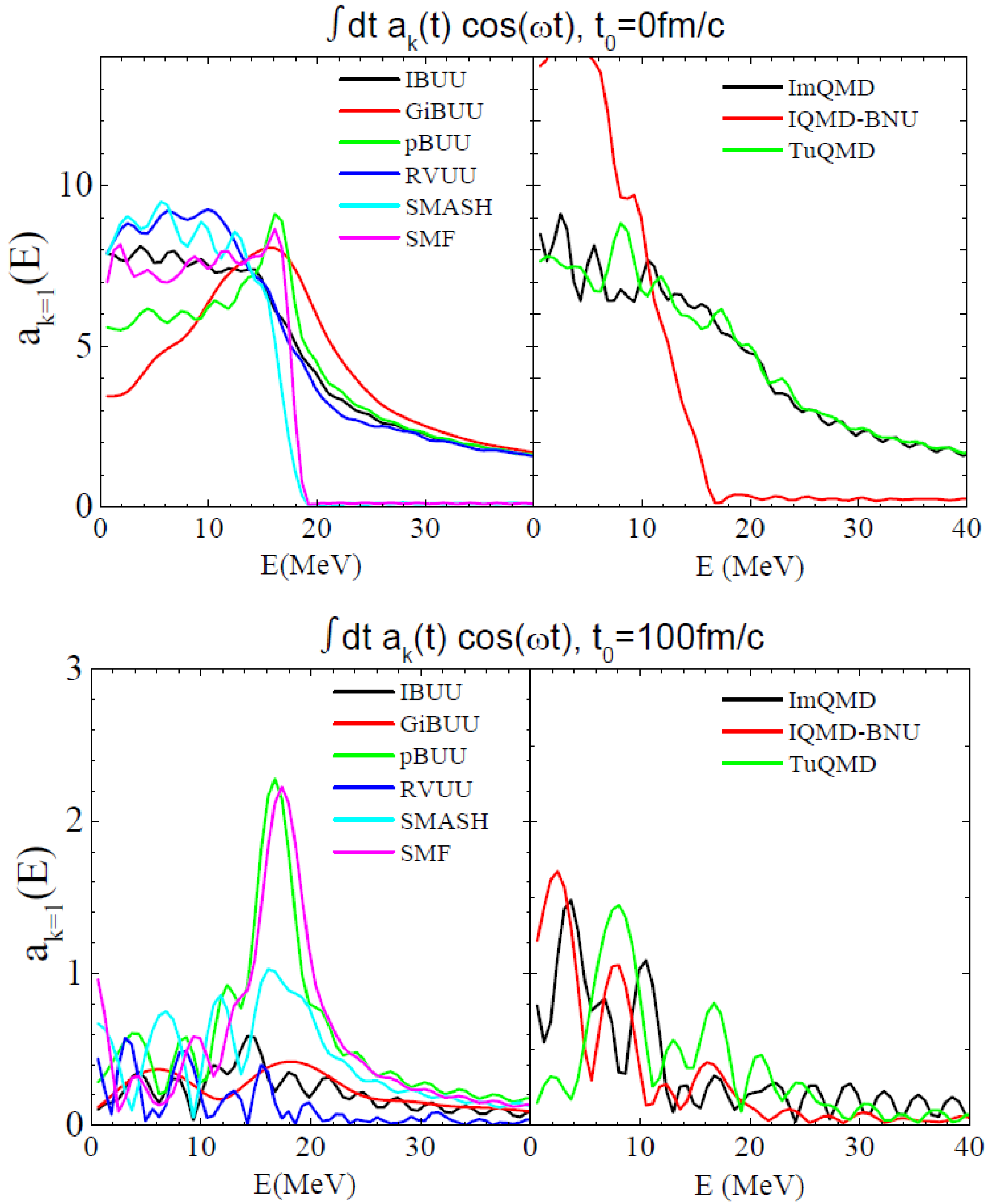


Fourier transform with respect to time

$$\rho_k\,(\omega) = \int dt\, \cos(\omega t)\, \rho_k(t)$$

$$E = \text{hbar}\ \omega$$

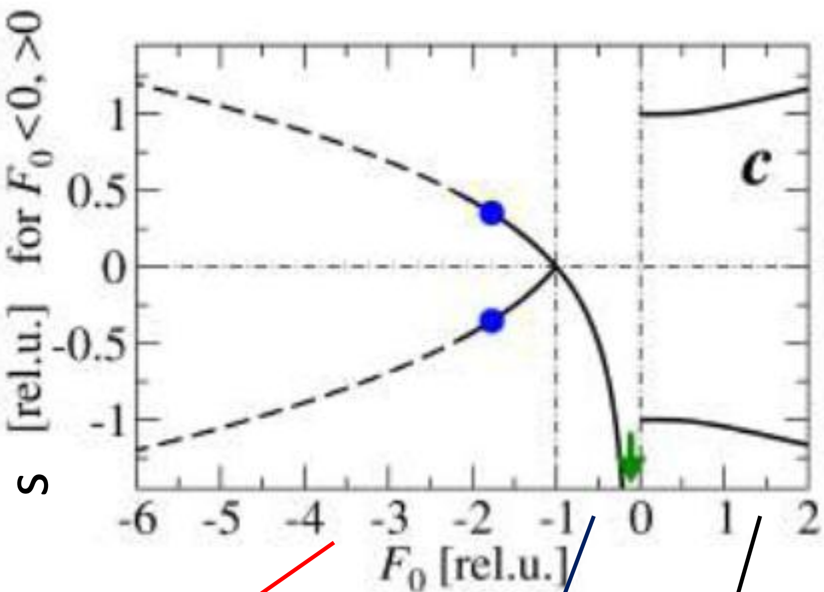
⟹ $\omega\ /\ (k\, v_F\ )\ \sim\ 1$ n = 1, E ~ 18 MeV



Fourier transform with respect to time:

All models

Linearized Vlasov equation → stationary solutions (oscillations) → extract the oscillation frequency



analytical relation between oscillation frequency ad compressibility **K**

$1 + 1/F_0 = s/2 \ln[(s+1)/(s-1)]$

$s = \omega / (k v_F)$

unstable regime

Landau damping

stable regime

Landau parameter $F_0 = K / (6 \varepsilon_F) - 1$

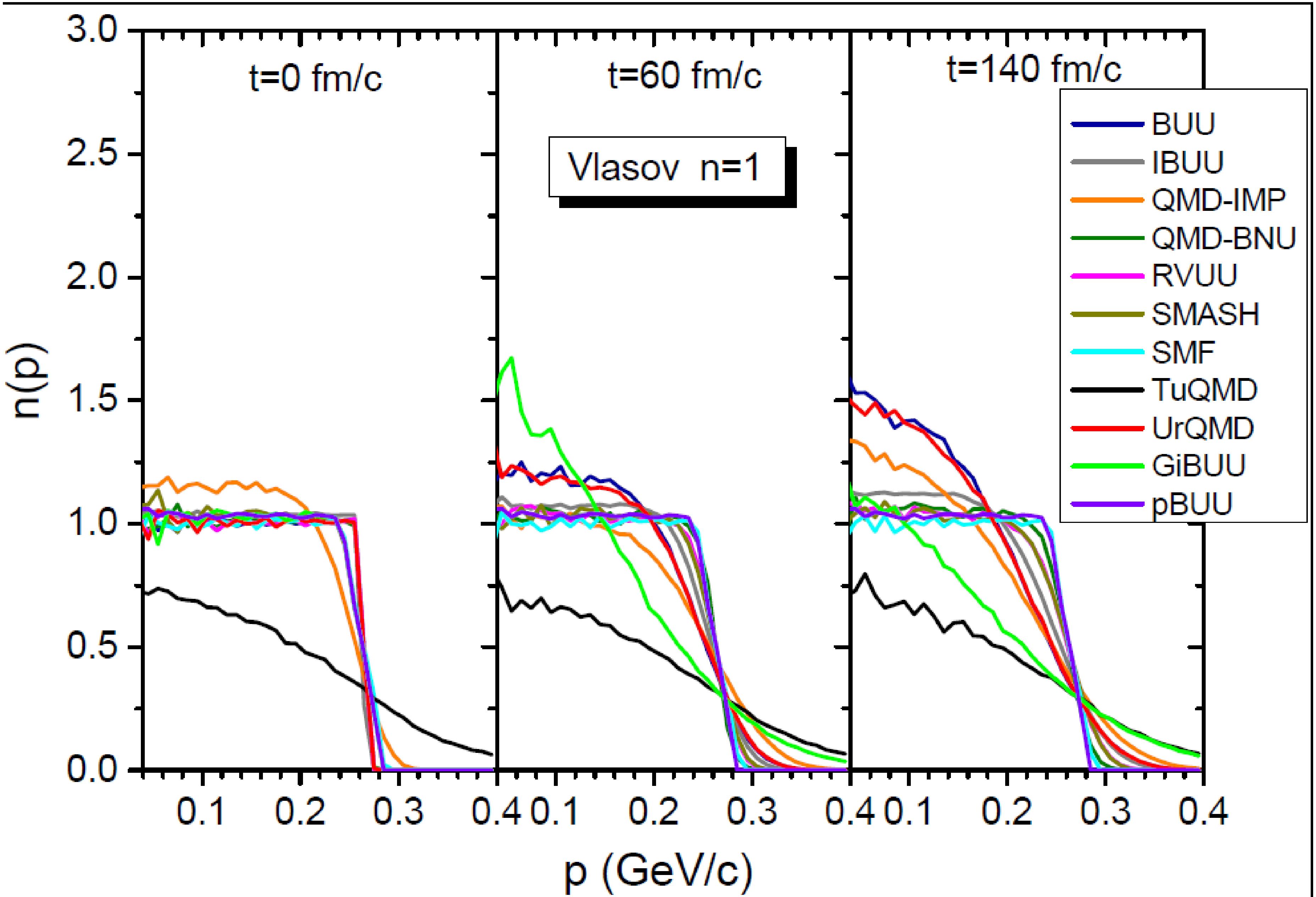
K = 240 MeV → $F_0 = 0.1$

Fluctuations are amplified

→ fragment formation !

s ~ 1 n = 1, E ~ 18 MeV

Evolution of Momentum Distribution



Conclusions

- Model dependence of the oscillation frequency:

Induced surface effects ? $F_0 \rightarrow F_0 g(k)$

Definition of local density and density-dependent
mean-field potential should be checked and compared for all models

- The frequency extracted for BUU-lile models is close to the analytical predictions

- Large damping observed for QMD-like models, probaly caused by larger surface effects and by fluctuations

2

Some points to be discussed for HW 2

- Details about the procedure used to evaluate the density, in each model, should be given : how do induced surface effects impact the oscillation frequency ?

- The evolution of the momentum distribution in some models needs to be understood

- More damping in QMD-like models: why ?
  The finite number of test particles (1 in this case) may act as a spurious collision term, driving the system towards classical behavior (see Reinhard & Suraud, ‘90)

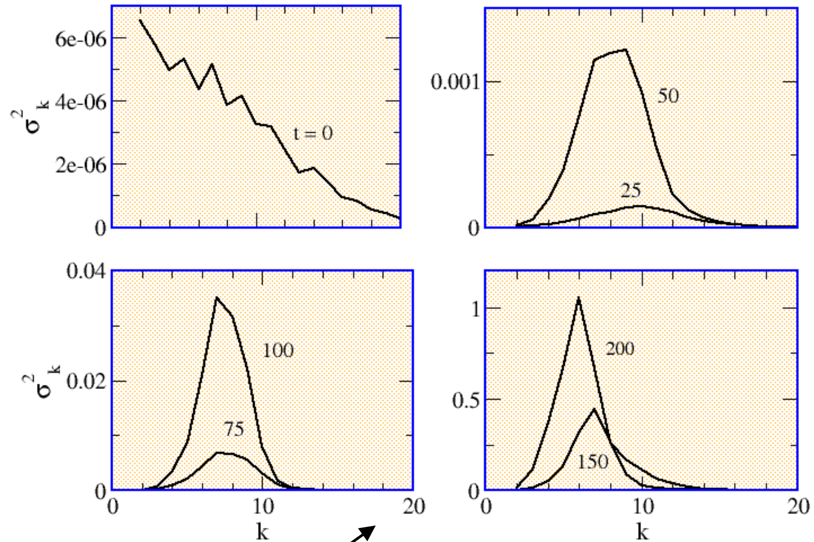
  Surface effects may also be different

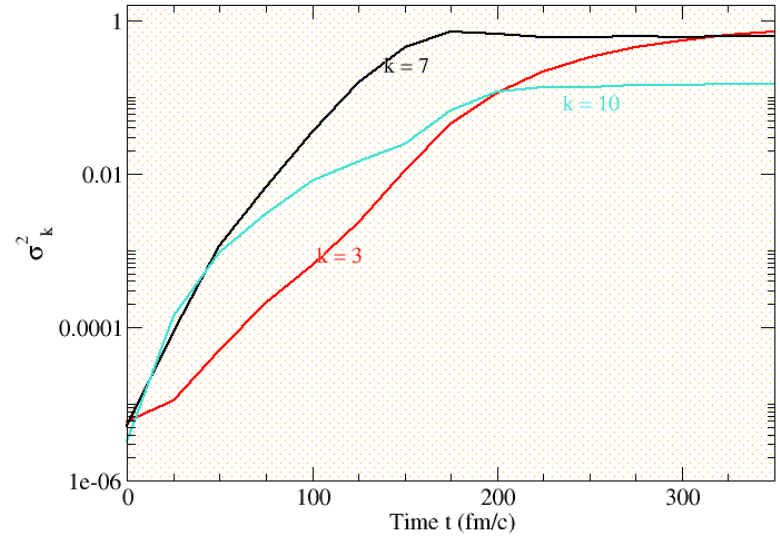
Possible further investigations for HW 2

- In BUU-like approaches, check the sensitivity of results to test particle number
- Increase the compressibility **K**: more robust oscillations
- Investigate the variance of the density fluctuations at equilibrium:
  Ex. Non-interacting Fermi gas at temperature T: $\sigma(V) = \rho / V * (3T) / (2\,\varepsilon_F)$
- Investigate unstable conditions: fluctuations will grow
  → Investigate growth time and fragment formation
- Switch-on symmetry potential and investigate isovector fluctuations
- Combine mean-field and collision integral in the study of density oscillations

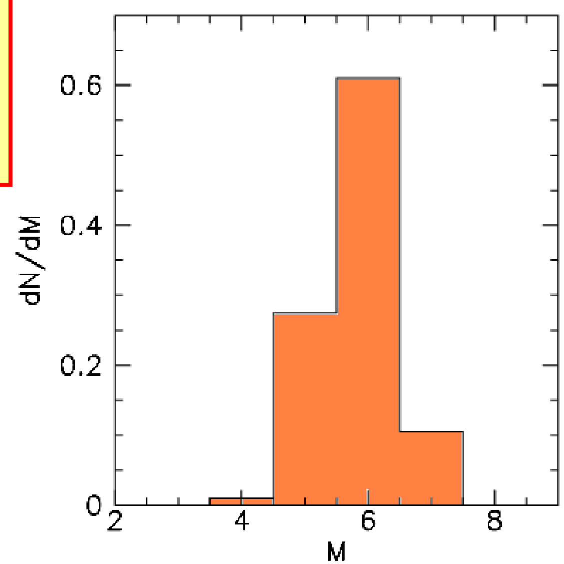
Propagation of fluctuations by the unstable mean-field

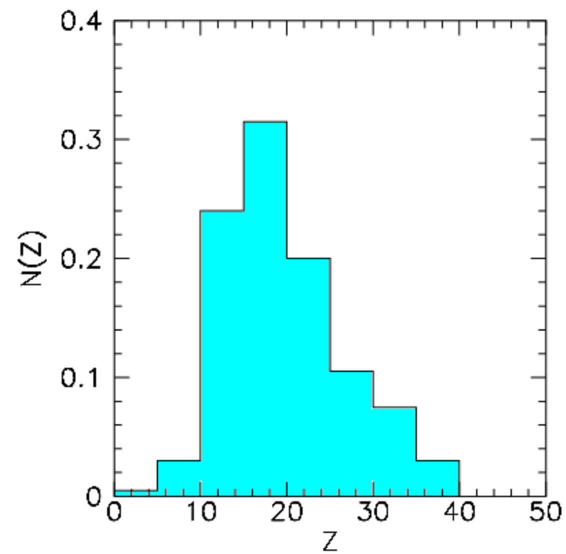
Box calculations : $\rho = 0.05\ fm^{-3}$, $T = 3$ MeV





Fourier analysis of
the density variance <δρδρ> :
rapid growth of density fluctuations





Fragment multiplicity and
charge distributions
(300 nucleons)