LATTICE QCD FOR HEAVY ION EXPERIMENTS

Z. Fodor

• University of Wuppertal, Germany: hardware prototype, performing the runs and carrying out the analyses

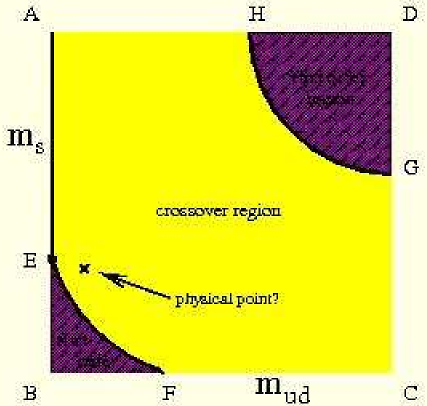
• Eotvos University, Budapest, Hungary: development of the codes (confined boundary condition and chemical potential derivative)

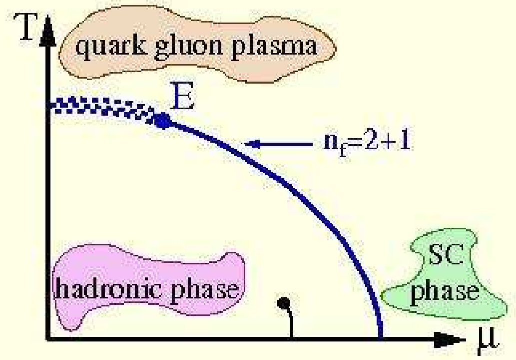
• Swietokrzyska Academy, Kielce, Poland: determination of the necessary geometries relevant for heavy ion collisions, heavy-ion phenomenology

$\Longrightarrow$ Hardware: Graphics Processor Units for lattice QCD

$\Longrightarrow$ Physics goals: curvature at μ=0 & finite volume geometries

Standard picture of the phase diagram and its uncertainties





physical quark masses: important for the nature of the transition

n_f=2+1 theory with m_q=0 or ∞ gives a first order transition

for intermediate quark masses we have an analytic cross over (no χPT)

F. Karsch et al., Nucl. Phys. Proc. 129 (2004) 614; Lattice'07 G. Endrodi, O. Philipsen

continuum limit is important for the order of the transition:

n_f=3 case (standard action, N_t=4): critical $m_{ps}\approx$300 MeV

with different discretization error (p4 action, N_t=4): critical $m_{ps}\approx$70 MeV

the physical pseudoscalar mass is just between these two values

what happens for physical quark masses, in the continuum, at what T_c?

N_t=4,6,8,10 lattices correspond to $a\approx$ 0.3 fm, 0.2 fm, 0.15 fm, 0.12 fm

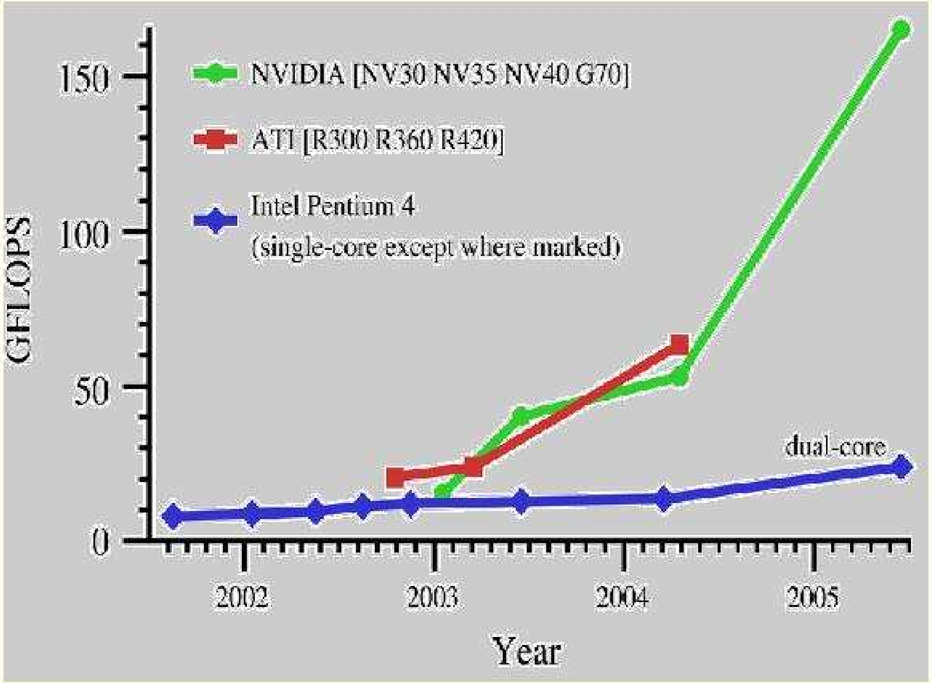
CPU: $\approx N_t^{12}$ (thermodynamics): N_t=10 needs 50-times more than N_t=6


IBM


nVIDIA
DC-12V 0.13A
MEC9
MEC7

Why use Graphical Processing Units?

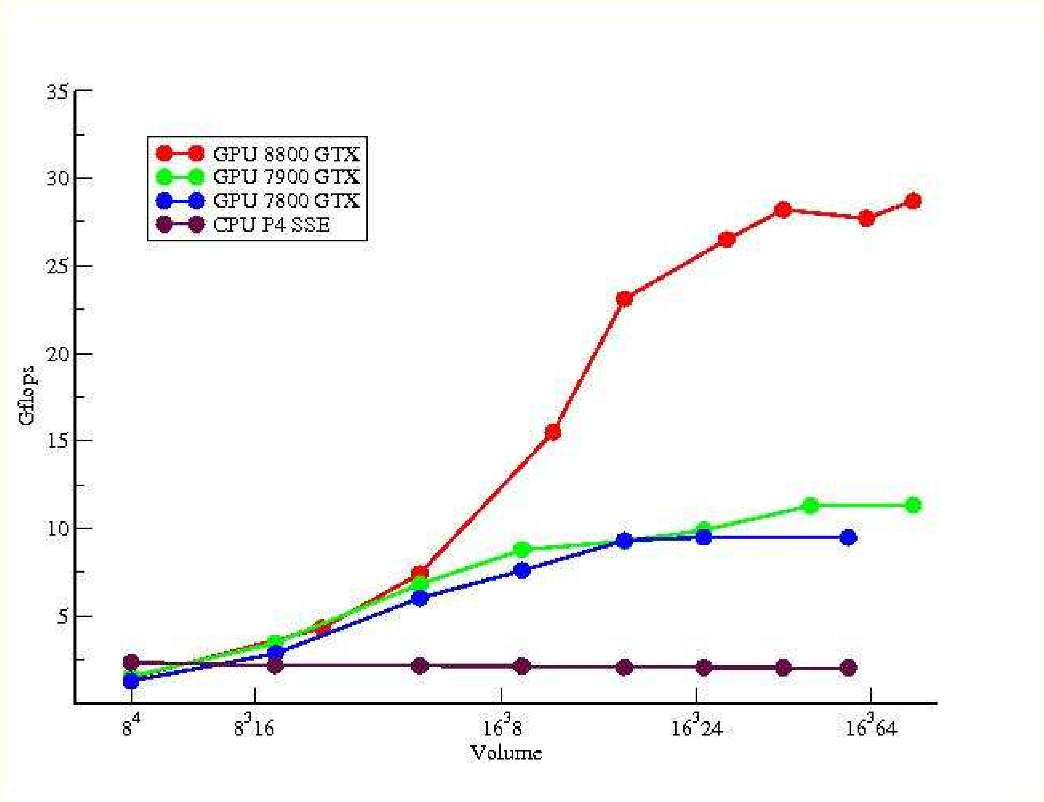
G.I.Egri, Z.Fodor, C.Holbling, S.D.Katz, D.Nogradi, K.K.Szabo, Comput. Phys. Commun. 177 (2007) 631



Ian Buck, Stanford

Gamerz market is big huge: top model costs ~ $500

How much power can be utilized for the lattice?



Conjugate gradient: 90% of Dirac matrix multiplication $\sim$ 30 GFlops

How is this possible?

- CPU: lot of transistors do non-computational tasks
- GPU: transistors (almost) only calculate

GPU architecture

- Native data: 2D arrays, textures (for games its content ends up on the screen).
- Each pixel (or fragment): 4 floating point numbers: RGBA color channels.
- Each pixel computation: incoming textures $\rightarrow$ outgoing textures: same operation on each pixel $\rightarrow$ massively parallel.
- Like a stream: pipeline should be full $\rightarrow$ performance is better for large textures (lattices).

Software environment

Bad news:

GPU hardware is undocumented

Only possibility to program it is through graphics drivers

Direct3D or OpenGL environments

OpenGL also under Linux

Main steps:

- allocate textures
- upload textures to video memory
- upload fragment program
- set target texture(s)
- run fragment program
- download output texture to main memory

Upload/download is slow $\rightarrow$ many runs without download needed

e.g. full Conjugate Gradient on GPU, not only Dirac operator

Overlap improving multi-parameter reweighting

Z. Fodor and S.D. Katz, Phys. Lett. B534 (2002) 87

$$Z(m,\mu,\beta) = \int \mathcal{D}U \exp[-S_g(\beta,U)] \det M(m,\mu,U) =$$
$$\int \mathcal{D}U \exp[-S_g(\beta_0,U)] \det M(m_0,\mu=0,U)$$
$$\left\{\exp[-S_g(\beta,U)+S_g(\beta_0,U)] \frac{\det M(m,\mu,U)}{\det M(m_0,\mu=0,U)}\right\}$$

first line = measure, field configurations of the Monte-Carlo

curly bracket = can be measured on each configuration, weight

simultaneously changing several parameters: better overlap

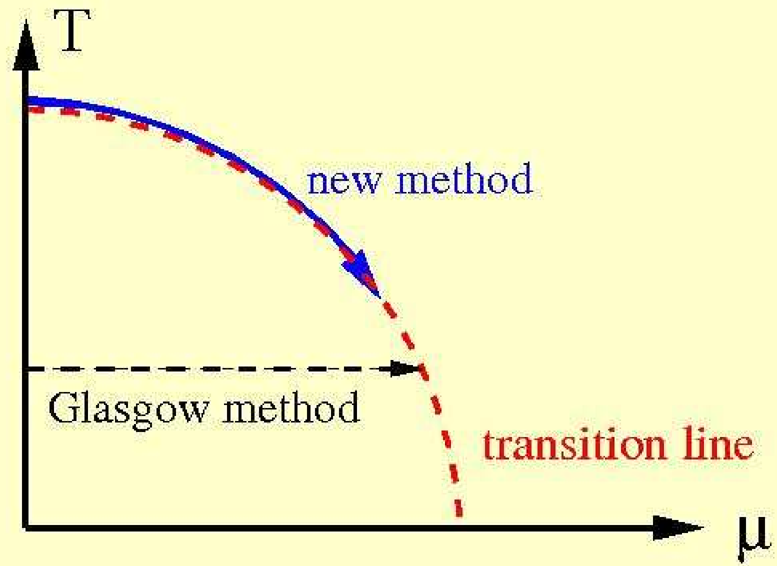
e.g. transition configurations are mapped to transition ones

expectation value of an observable O:

$$\langle 0 \rangle_{\beta,\mu,m} = \frac{\sum w(\beta,\mu,m) O(\mu,m)}{\sum w(\beta,\mu,m)}$$

observables to get the transition points at $\mu \neq 0$ (susceptibilities)

Comparison with the Glasgow method



<table>
<tr><td>one parameter reweighting</td><td>New method</td></tr>
<tr><td>single parameter (μ)</td><td>two parameters (μ and β)</td></tr>
<tr><td>purely hadronic configurations</td><td>transition configurations</td></tr>
</table>

● transition temperature depends on the geometry

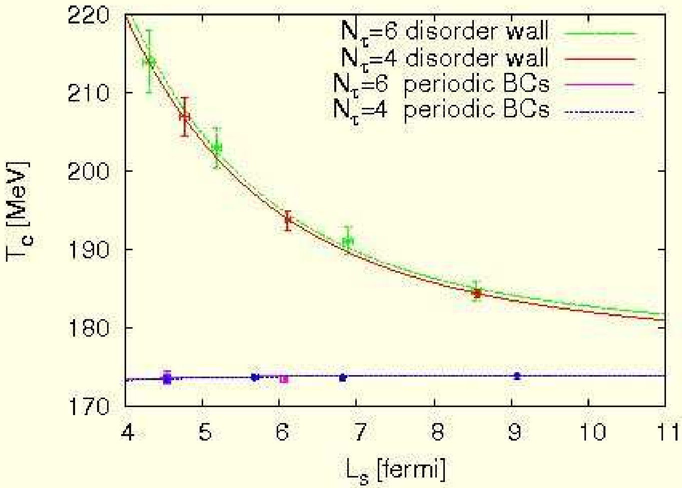
eg. nanotube-water didn't freeze, even at hundreds of degrees below 0^oC

A. Bazavov and B. Berg, Phys.Rev. D76 014502 (2007)

determined the transition temperature pure SU(3), no qarks

with "confined" spatial boundary conditions: more like experiments

instead of periodic one (which we use to reach $V \to \infty$ fast)



large deviation (upto 30 MeV) from the infinite volume limit

$\Longrightarrow$ calculate it in full QCD (cross-over) for different geometries

• Joint Research Activity proposal

Wuppertal, Germany — Budapest, Hungary — Kielce, Poland

$\Longrightarrow$ Hardware: Graphics Processor Units for lattice QCD

$\Longrightarrow$ Physics goals: curvature at μ=0 & finite volume geometries

• expected budget and Community contribution requested

complete cost: 700.000 euros

request: 325.000 euros
travels, workshops: each institution 10.000 euros (together 30.000 euros)
one person/year (University Wuppertal): 55.000 euros
GPU based hardware prototype (University of Wuppertal) 240.000 euros