Lattice Studies of QCD Thermodynamics on QCDOC (LDRD project 06-001)

(August 16, 2007, LDRD midterm review: Ch. Schmidt for F. Karsch)

Research goals:

- studies of the QCD phase diagram and the equation of state; determination of critical parameters for the transition to the high temperature phase of QCD
- studies of in-medium properties of hadrons, the temperature dependence of their masses and widths, the survival of resonances at high temperature

LDRD funds cover:

- 2 Post Docs
- travel support

Exploiting the possibilities new research tools at BNL (and in Europe) offer

US – QCDOC – RBRC

BI – apeNEXT

$\sim$ 6 TFlops for QCD-Thermodynamics
$\sim$ 50 times more CPU-time than for previous studies of the EoS

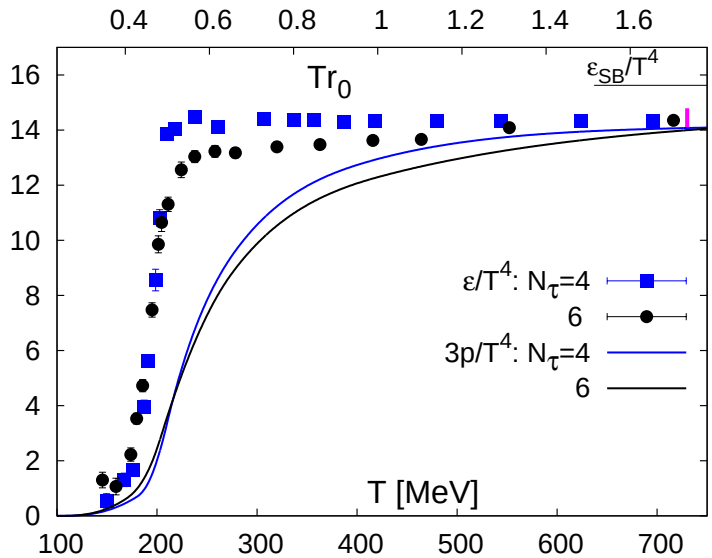
calculations with an (almost) realistic quark mass spectrum $\Rightarrow$ provide direct input to RHIC phenomenology

Project Status

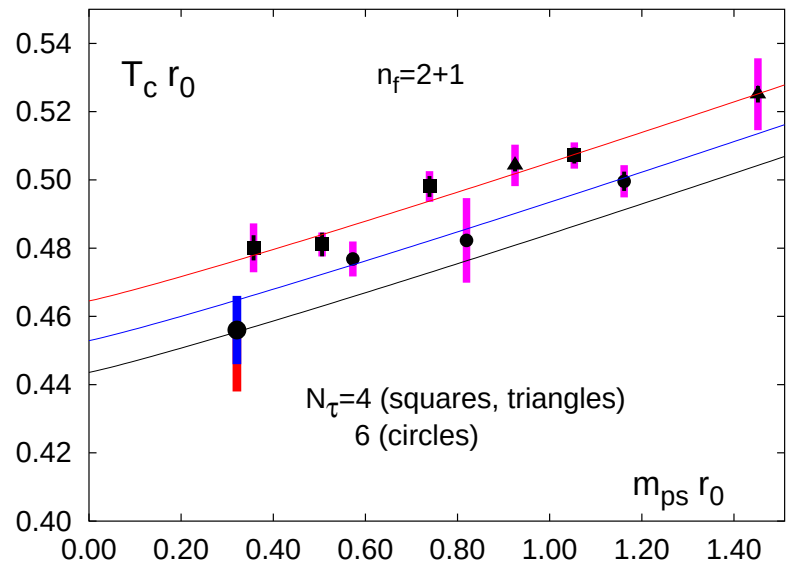
- since spring 2005 the group uses $\sim$ 5 Teraflops on the RIKEN-BNL and DOE QCDOC maschines;
  - implementation and test of a new, exact simulation algorithm for QCD with light quarks (RHMC);
  - development of simulation software for studies of the QCD equation of state at non-zero baryon and strangeness chemical potential up to 8th order in a Taylor expansion
- first high precision study of the QCD transition temperature which allowed a controlled extrapolation to physical light quark mass values
  - $T_c = 192(7)(4)$ MeV
- study of the QCD equation of state with almost physical quark masses
  - first high statistics analysis with light quarks ($m_\pi \simeq 220$ MeV) in a wide temperature range

$$\Rightarrow \text{EoS for } 0.8 \lesssim T/T_c \lesssim 4$$

T_c and Equation of State



state-of-the-art EoS



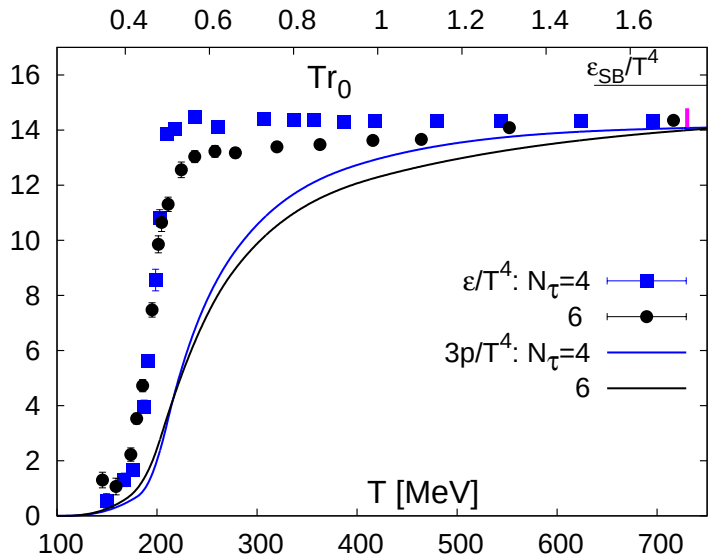
transition temperature

- ϵ/T^4, p/T^4 for $m_\pi \simeq$ 220 MeV; reduced deviations from SB limit;
- $T_c = (192(7)(4)$ MeV

the project generated large sets of data, which currently are used for further studies of

- finite density QCD: Taylor expansion of bulk thermodynamic observables, study of fluctuations and correlations between e.g. baryon number, strangeness and electric charge
- screening in the QGP: heavy quark potentials, Debye screening, thermal hadron correlation functions

T_c and Equation of State



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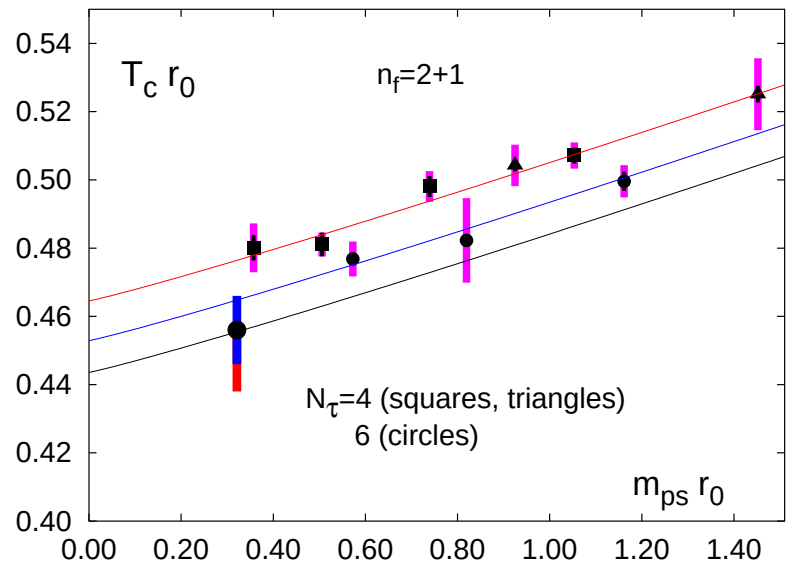

transition temperature

- ϵ/T^4, p/T^4 for $m_\pi \simeq$ 220 MeV; reduced deviations from SB limit;
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the project gained large visibility in a short time:

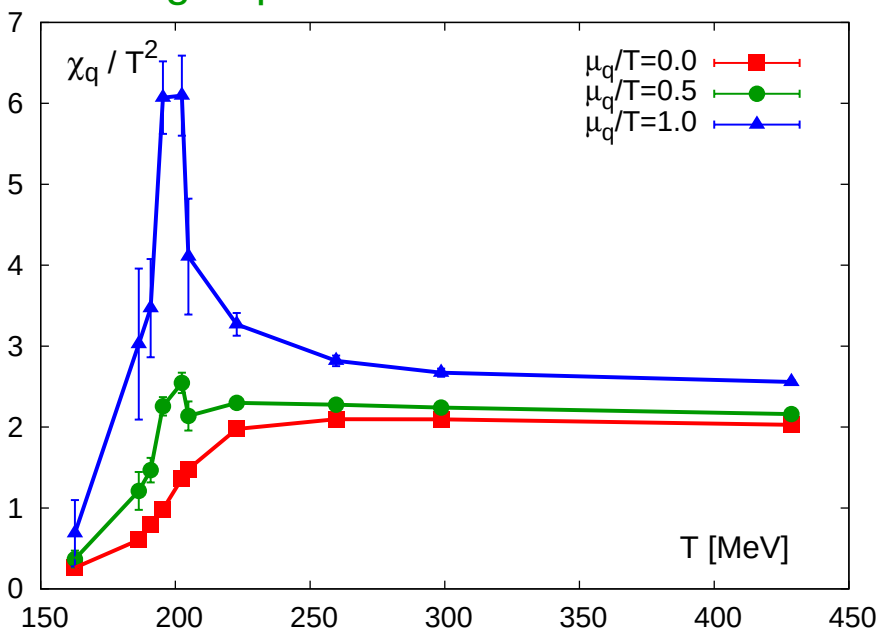
- main publication: Phys. Rev. D74 (2006) 054507, 49 citations
- plenary talks at Lattice 2006 ($\mu > 0$) and 2007 ($\mu = 0$)
  SciDAC '06, Hard Probes '06, CPOD 06&07, SQM 06&07...
- new, US-wide research collaboration: hotQCD

$\mu_q > 0$: Fluctuations of baryon number and strangeness in (2+1)-flavor QCD

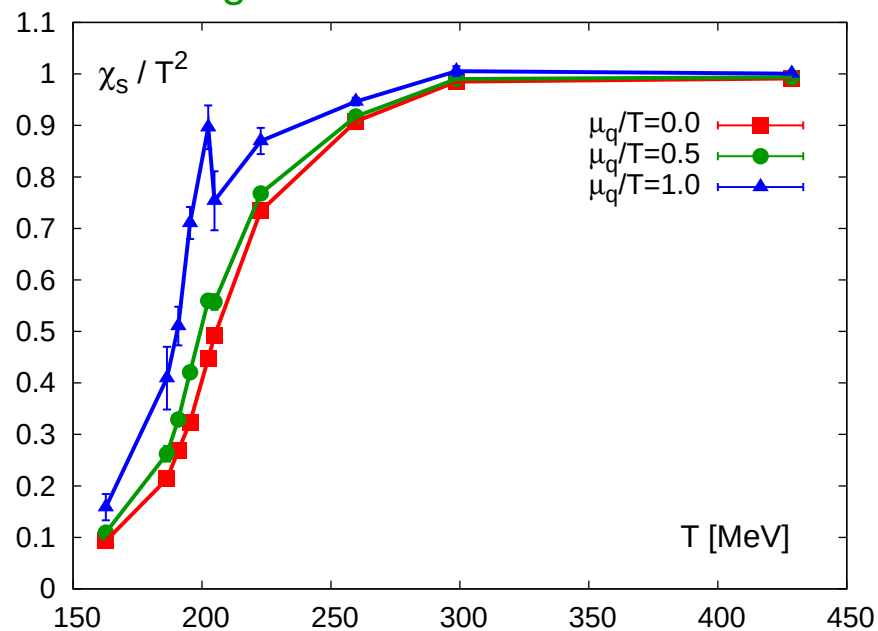
ongoing project of the RBC-Bielefeld collaboration

$\Rightarrow$ input to RHIC low energy program and the search for a critical point

light quark number fluctuation



strangeness fluctuation



$\Rightarrow$ large quark number fluctuations

$\Rightarrow$ enhanced strangeness fluctuations (so far only $\mathcal{O}(\mu^4)$!!)

- $\mathcal{O}(\mu^6)$ and $\mathcal{O}(\mu^8)$ will be main project activity on QCDOC in FY08

Publications

1) S. Ejiri, F. Karsch, E. Laermann and C. Schmidt, The isentropic equation of state of 2-flavor QCD, Phys. Rev. D **73**, 054506 (2006)

2) M. Cheng *et al.*, The transition temperature in QCD, Phys. Rev. D **74**, 054507 (2006)

3) M. Cheng *et al.*, Study of the finite temperature transition in 3-flavor QCD using the R and RHMC algorithms, Phys. Rev. D **75**, 034506 (2007)

4) M. Cheng *et al.*, Flavor Symmetry breaking and scaling for improved staggered fermions, Eur. Phys. J. C, to appear.

5) S. Ejiri, F. Karsch and K. Redlich, Hadronic fluctuations at the QCD phase transition, Phys. Lett. B **633**, 275 (2006)

6) M. Doring, K. Hubner, O. Kaczmarek and F. Karsch, Color screening and quark-quark interactions in finite temperature QCD, Phys. Rev. D **75**, 054504 (2007)

7) Z. Fodor, S. D. Katz and C. Schmidt, The density of states method at non-zero chemical potential, JHEP **0703**, 121 (2007)

8) S. Ejiri, On the existence of the critical point in finite density lattice QCD, arXiv:0706.3549 [hep-lat]

9) A. Jakovac, P. Petreczky, K. Petrov and A. Velytsky, Quarkonium correlators and spectral functions at zero and finite temperature, Phys. Rev. D **75**, 014506 (2007)

Financial Information

- **FY 07 Budget: $161,000**
- **Expenses thru 7/31/07: $121,348**
- **Balance: $39,652**
- **Commitments: $32,533**
- **Available Balance: $7,119**
- **YTD Percentage spent: 75.4%**