QCD transition as an Anderson transition

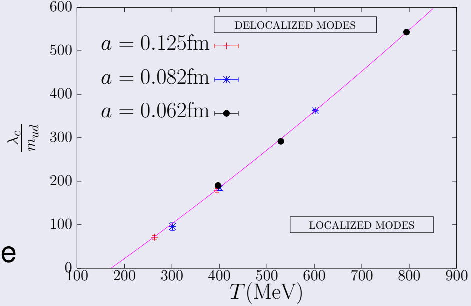
M. Giordano, S.D. Katz, T. Kovács and F. Pittler

June 25, 2014

Preliminaries

Anderson transition in the high T QCD Dirac spectrum

- Appearance of localized modes
- Mobility edge: λ_c boundary of localized modes.
- Real second order phase transition.



In the present talk:

- Apparently no thermodynamic consequences
- How the appearance of this transition correlates with the QCD chiral crossover?

Practical Motivation

QCD Chiral ”transition”

- There is no real order parameter
- $\langle \bar{\psi}\psi \rangle$
  - small in the quark-gluon plasma ”phase”
  - large in the hadronic ”phase”
- $\langle \bar{\psi}\psi \rangle$ has to be renormalized
- Aim: Looking for quantities which can distinguish between the two ”phases” and easy to compute

Simulation setup

- In *QCD* it is hard to find real chiral phase transition [Talk: Tuesday, B. Toth]

$N_t = 4$ staggered quarks

- $N_f = 3$ unimproved staggered quarks with $ma = 0.01$
- Real first order phase transition in the thermodynamic limit
- Ideal to study the relation between this phase transition and the Anderson one

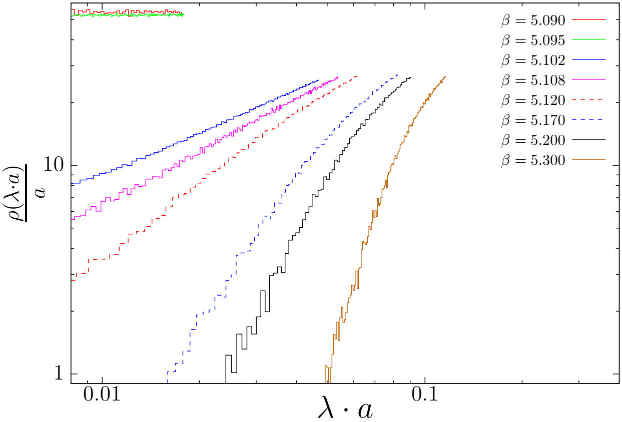
Banks-Casher relation

$$\langle \bar{\psi}\psi(m)\rangle = \int \mathrm{d}\lambda \, \frac{2m}{\lambda^2 + m^2} \rho(\lambda)$$

$\rho(\lambda)$ spectral density of the massless Dirac operator

- Low modes dominate
- At high temperature the lowest modes are localized (Previous two talks)
- At low temperature they are delocalized
- How the form of $\rho(\lambda \sim 0)$ changes across the transition?

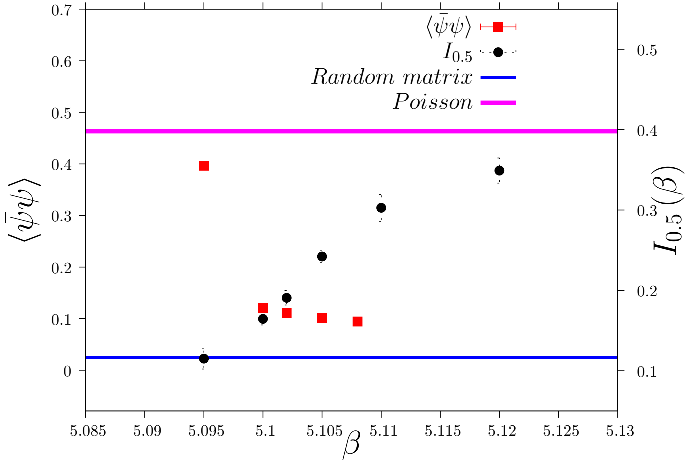
Spectral density,Staggered $N_t = 4$
First order phase transition



- $\frac{\mathrm{d}\rho(\lambda\sim 0)}{\mathrm{d}\lambda} = 0 \leftrightarrow$ the system is below T_c
- $\frac{\mathrm{d}\rho(\lambda\sim 0)}{\mathrm{d}\lambda} = \alpha \leftrightarrow$ the system is above T_c
- Connection to spectral statistics?

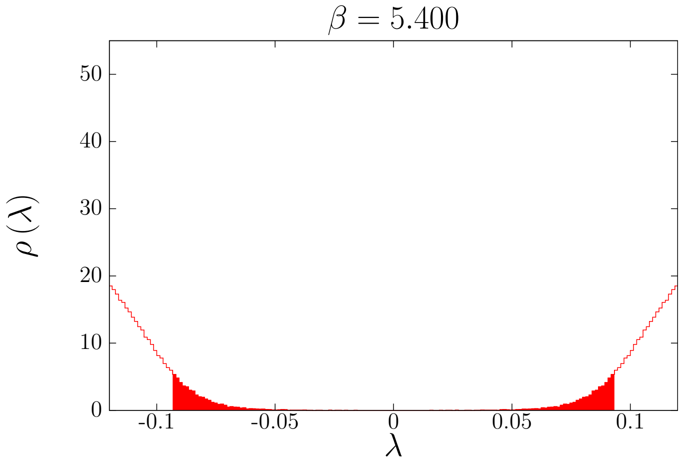
Spectral statistics: Staggered $N_t = 4$

- Integral of the unfolded level spacing distribution: $I_{0.5} = \int_0^{0.5} \mathrm{d}s P(s)\,; s = \frac{\lambda_{i+1}-\lambda_i}{\langle \lambda_{i+1}-\lambda_i \rangle}$



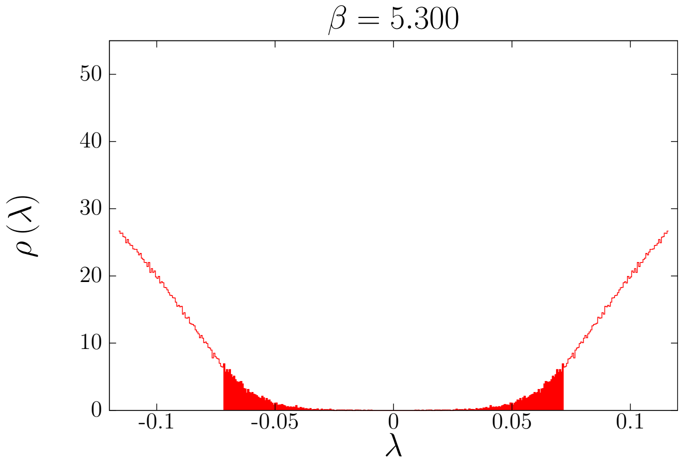
- Localized modes appear at β_c

Motion of the mobility edges



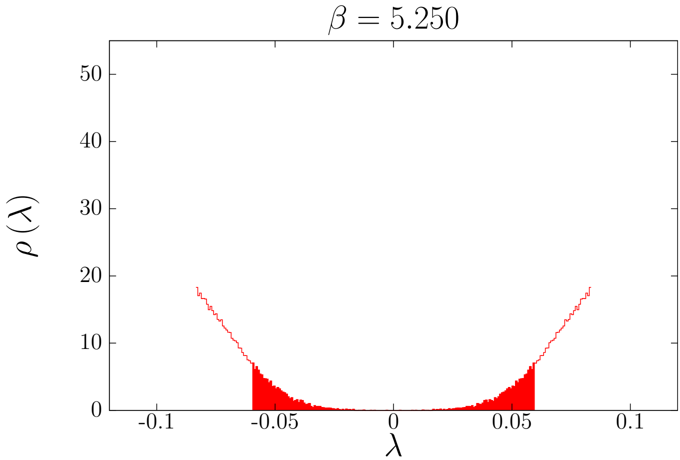
- Mobility edge goes to zero at β_c

Motion of the mobility edges



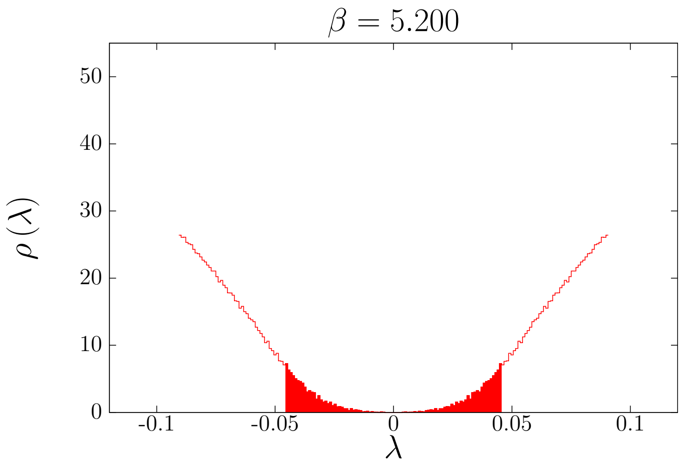
- Mobility edge goes to zero at β_c

Motion of the mobility edges



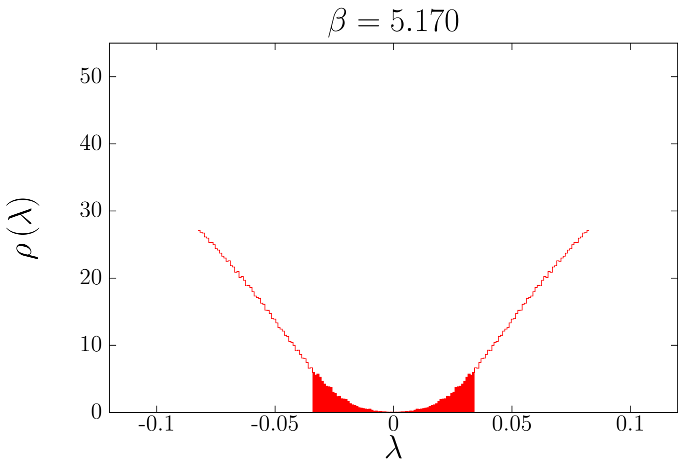
- Mobility edge goes to zero at β_c

Motion of the mobility edges



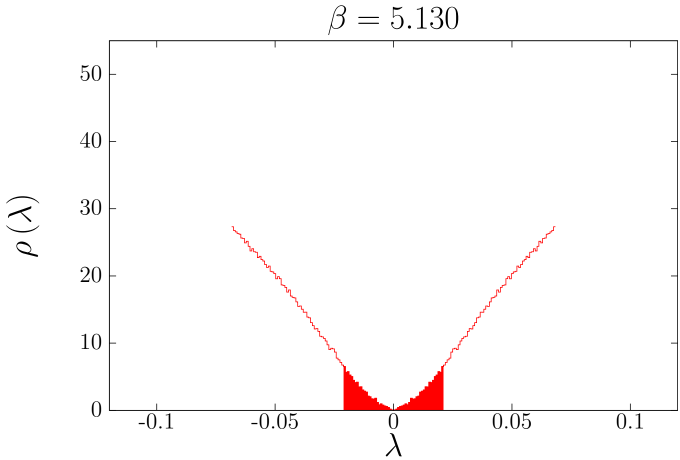
- Mobility edge goes to zero at β_c

Motion of the mobility edges



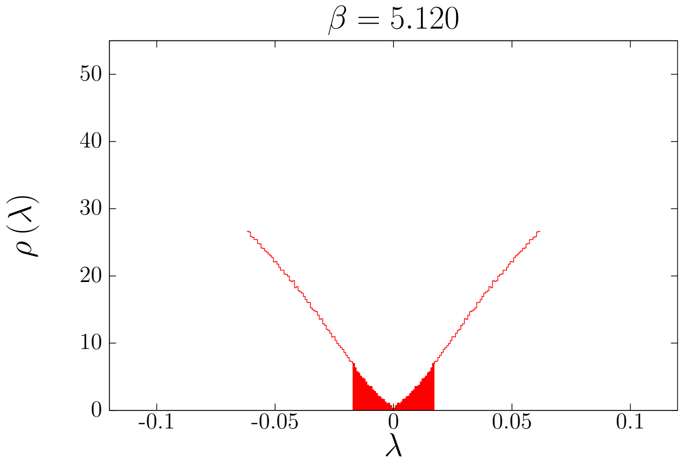
- Mobility edge goes to zero at β_c

Motion of the mobility edges



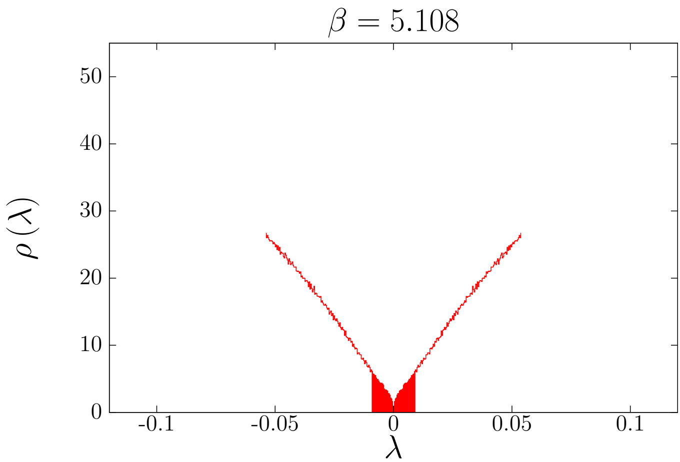
- Mobility edge goes to zero at β_c

Motion of the mobility edges



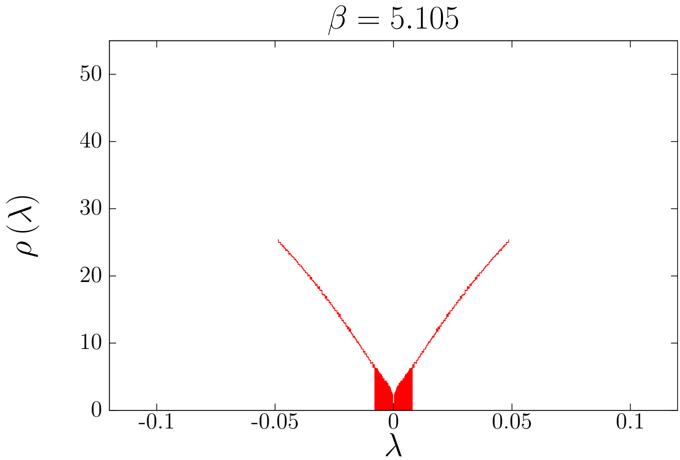
- Mobility edge goes to zero at β_c

Motion of the mobility edges



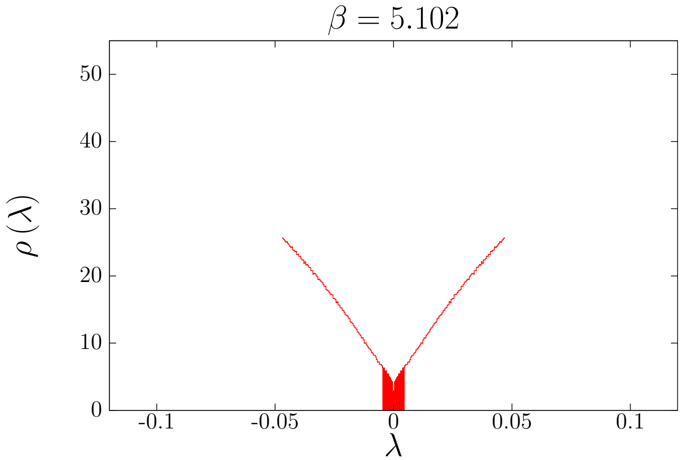
- Mobility edge goes to zero at β_c

Motion of the mobility edges



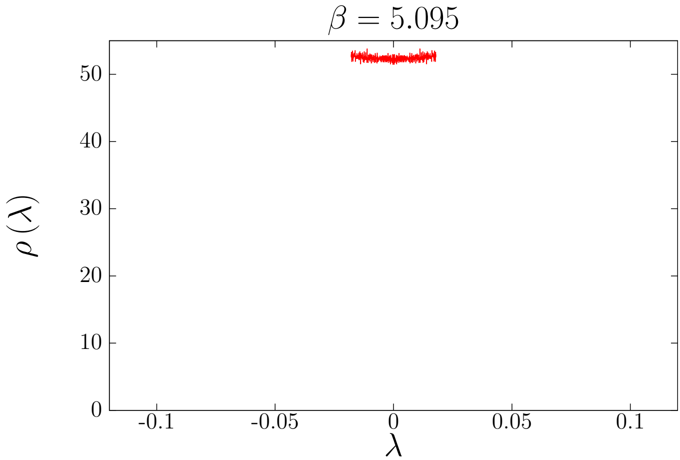
- Mobility edge goes to zero at β_c

Motion of the mobility edges



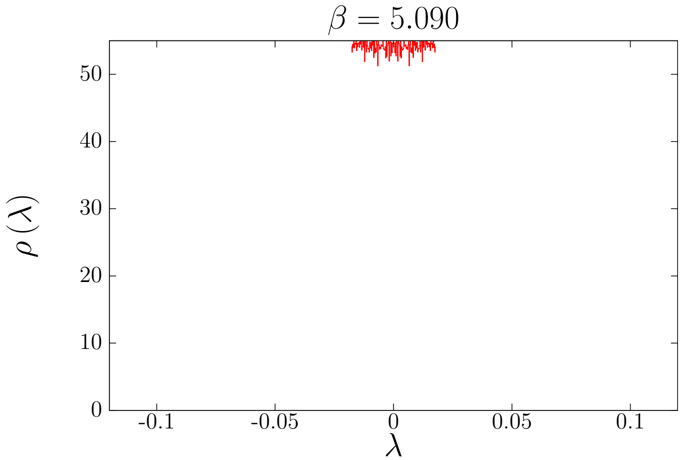
- Mobility edge goes to zero at β_c

Motion of the mobility edges



- Mobility edge goes to zero at β_c

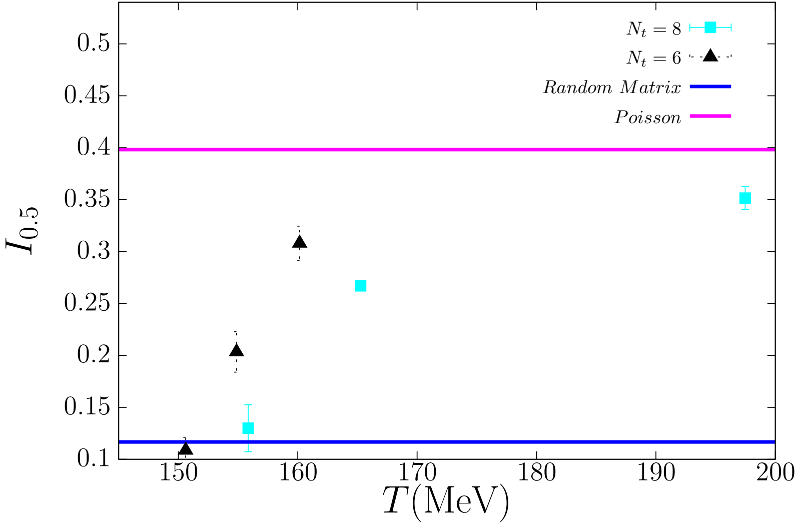
Motion of the mobility edges



- Mobility edge goes to zero at β_c

Spectral statistics:QCD Chiral crossover, $N_t = 6, 8$

Integral of the unfolded level spacing distribution: $I_{0.5} = \int_0^{0.5} \mathrm{d}s P(s)\,; s = \frac{\lambda_{i+1} - \lambda_i}{\langle \lambda_{i+1} - \lambda_i \rangle}$



Conclusion, outlook

- Chiral transition $\Longleftrightarrow$ localized modes (dis)appear
- Spectral statistics may quantitatively characterize the transition
- Still to be done:
  - First eigenvalue distribution
  - Extrapolating spectral statistics to $\lambda \to 0$
  - Taking the thermodynamic limit
  - Taking the continuum limit

Thank you for your attention!