The G2 QCD Phase Diagram

Axel Maas

20th of March 2013
Quarks, Gluons, and Hadronic Matter under Extreme Conditions II
St. Goar
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Mini-review: Maas & Wellegehausen

Lattice'12 proceedings, 1211.5301

DFG

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- Conceptual – Quenched G2 QCD

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- Practical – G2 QCD
  - Fundamental representation real
    - No sign problem
  - Full phase diagram accessible
    - Test of methods and models
    - Qualitative insights

QCD as a gauge theory

- QCD is a gauge theory

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$$L = -\frac{1}{4} F^a_{\mu\nu} F^{\mu\nu}_a$$

$$F^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu$$

g

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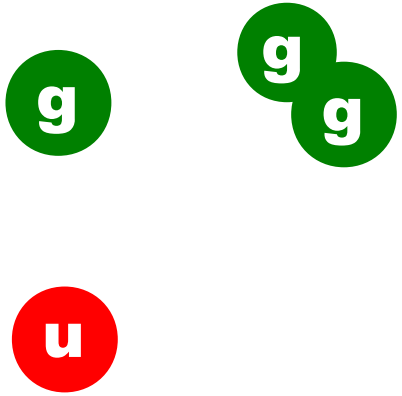

- Gluons A^{a}_{μ}
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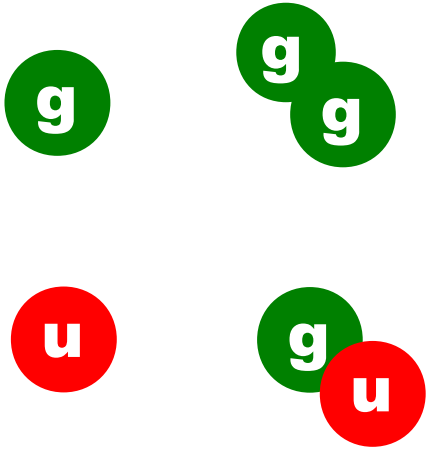

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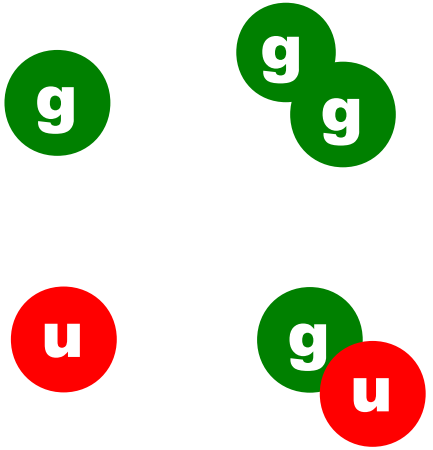

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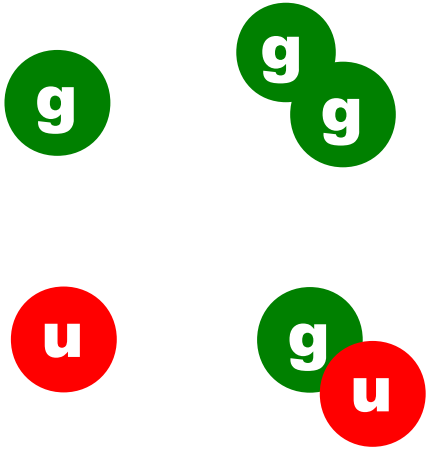

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- Here: G2

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- Asymptotically free, infrared strongly interacting

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Chiral symmetry in G2

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    - (Unbroken) U(1) subgroup of chiral symmetry
- Non-anomalous chiral symmetry breaking for 1 flavor possible

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[Holland et al. NPA 03, Pepe et al. NPA 07]

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[Wellegehausen, Maas, Wipf, von Smekal unpublished]

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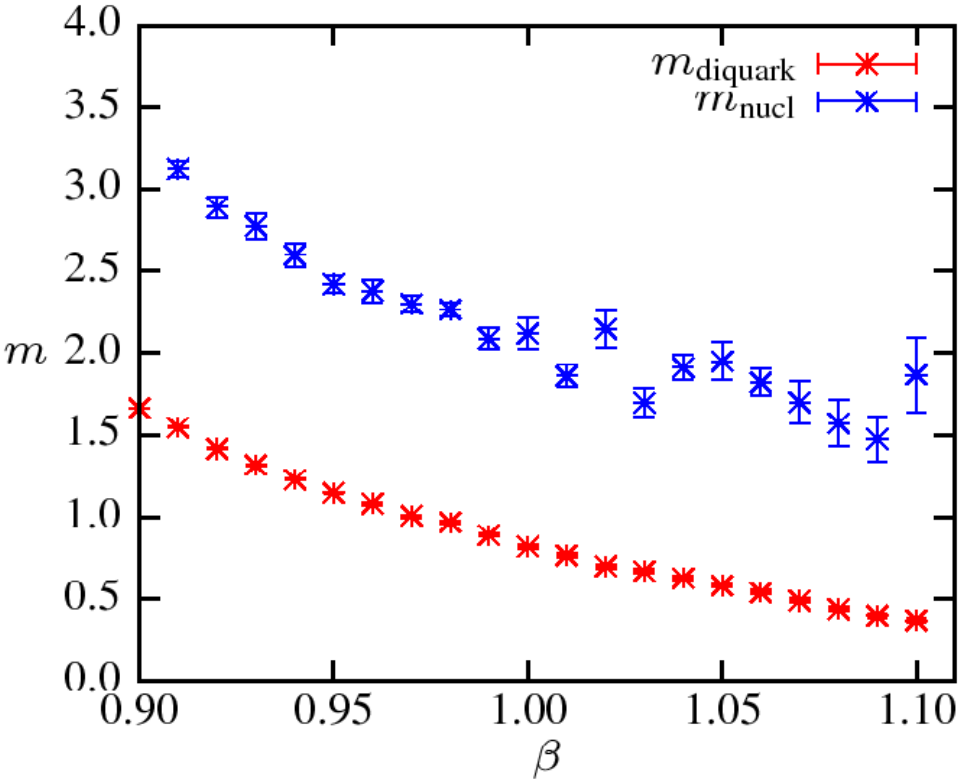

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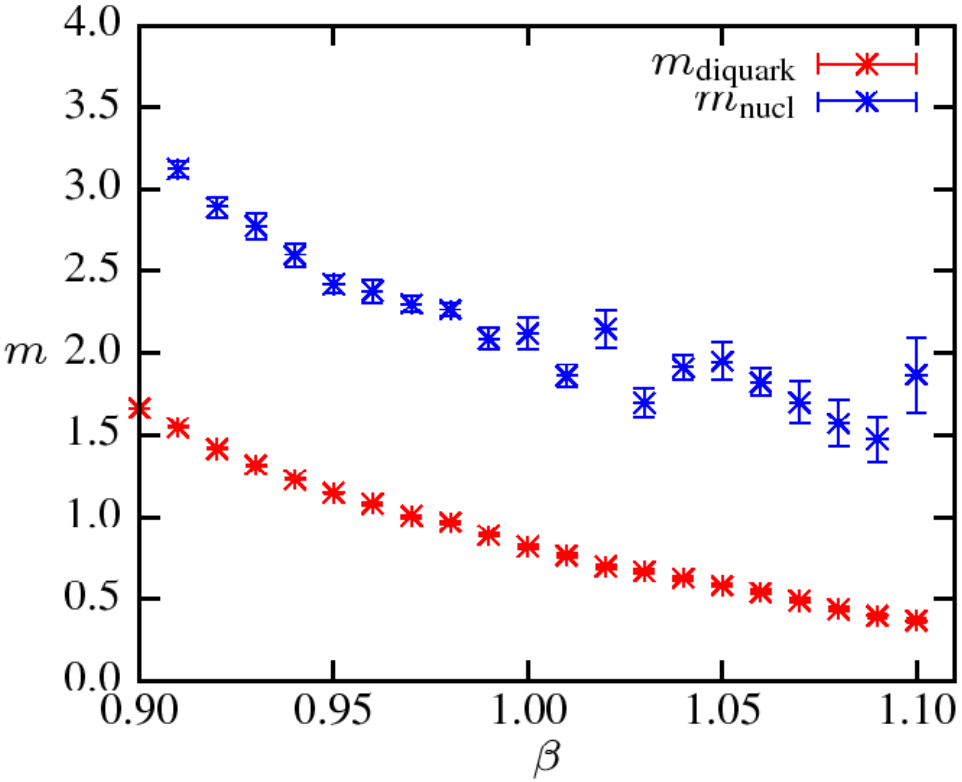

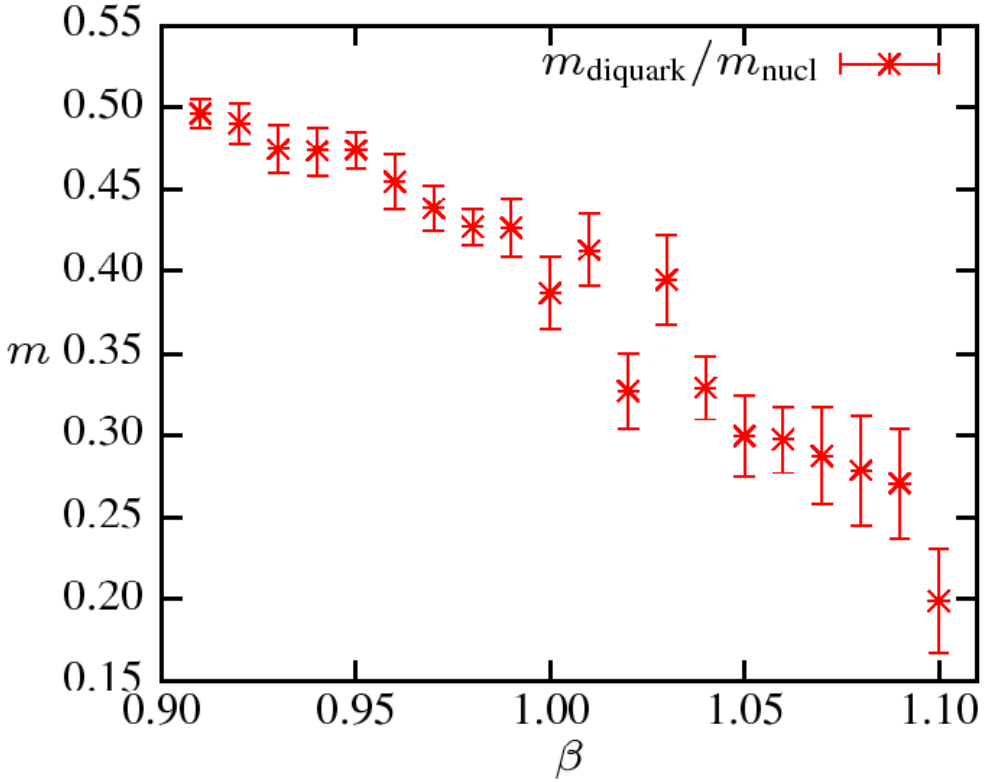

- Nucleons
  - Fermionic baryon with three constituent quarks
  - Chiral limit different to QCD

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  - E.g. pions – not Goldstones
- Baryons (non-zero baryon number)
  - Diquarks - Goldstones
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Quenched G2 QCD

[Danzer, Gattringer, Maas, JHEP09]

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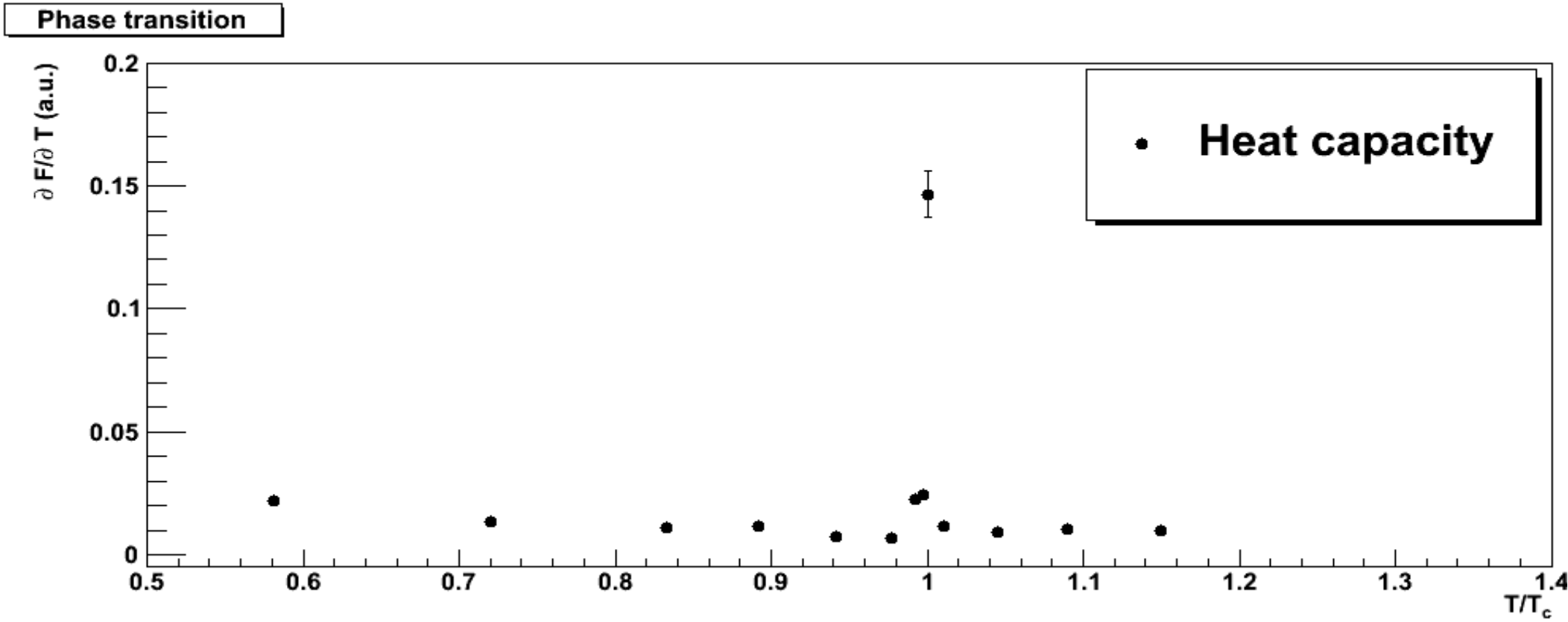

- First order transition [Pepe et al. NPA07, Greensite et la. PRD07, Cossu et al. JHEP07]
  - Observed in free energy
- Complicated by a bulk transition
  - Requires fine lattice [Cossu et al. JHEP 07]

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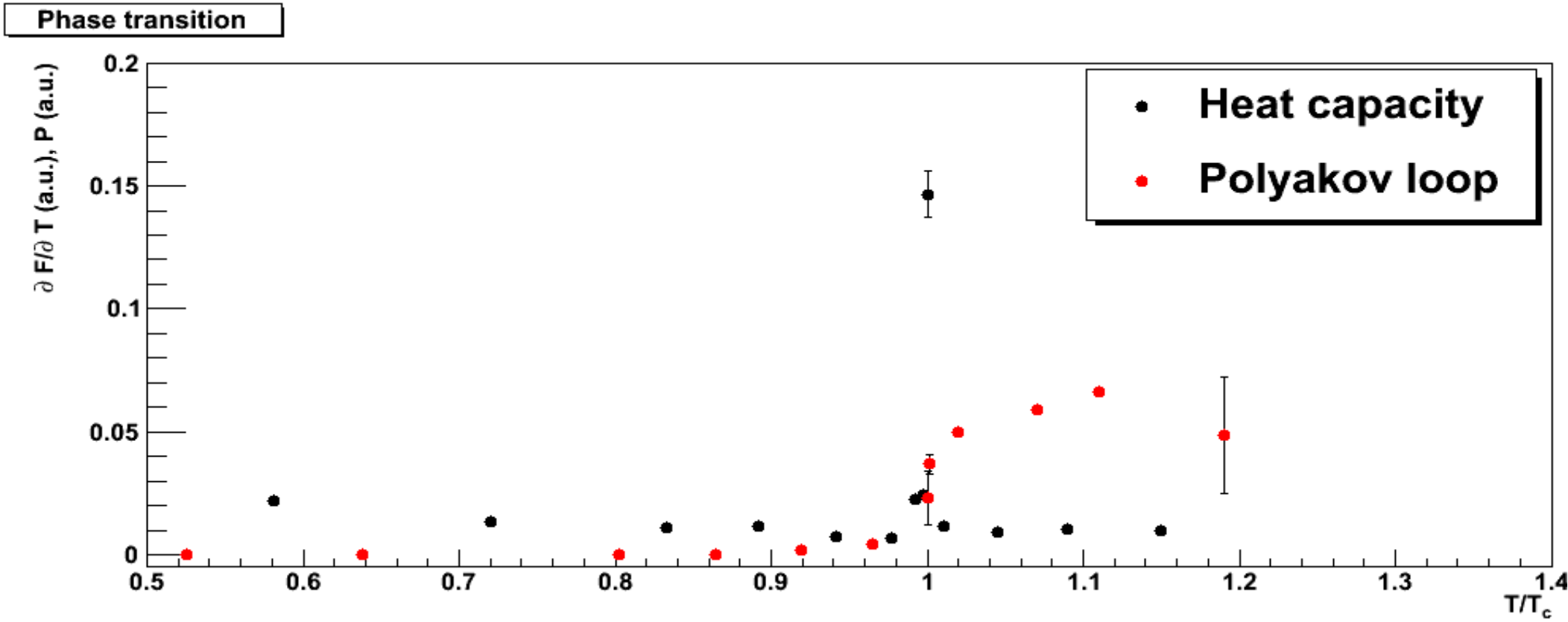

- Polyakov loop transition

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  - Coincident with free energy

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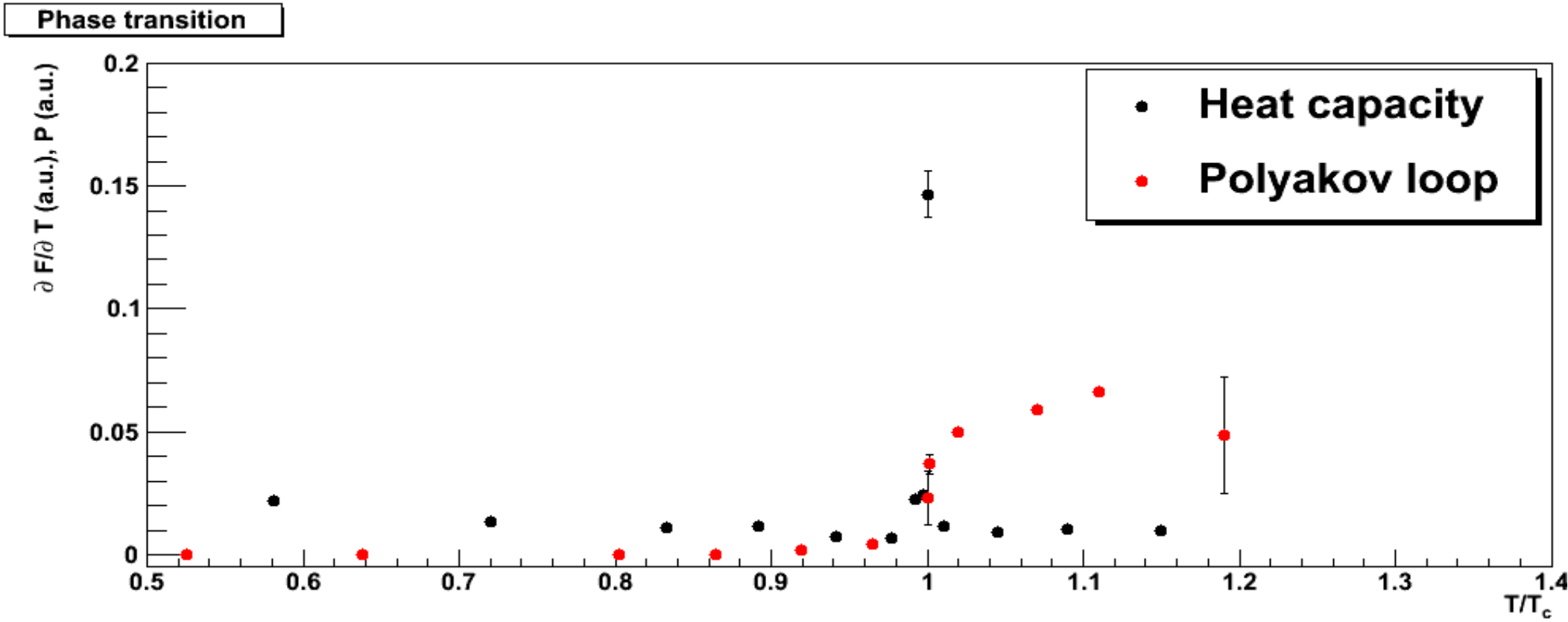

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  [Pepe et al. NPA07, Greensite et la. PRD07, Cossu et al. JHEP07]
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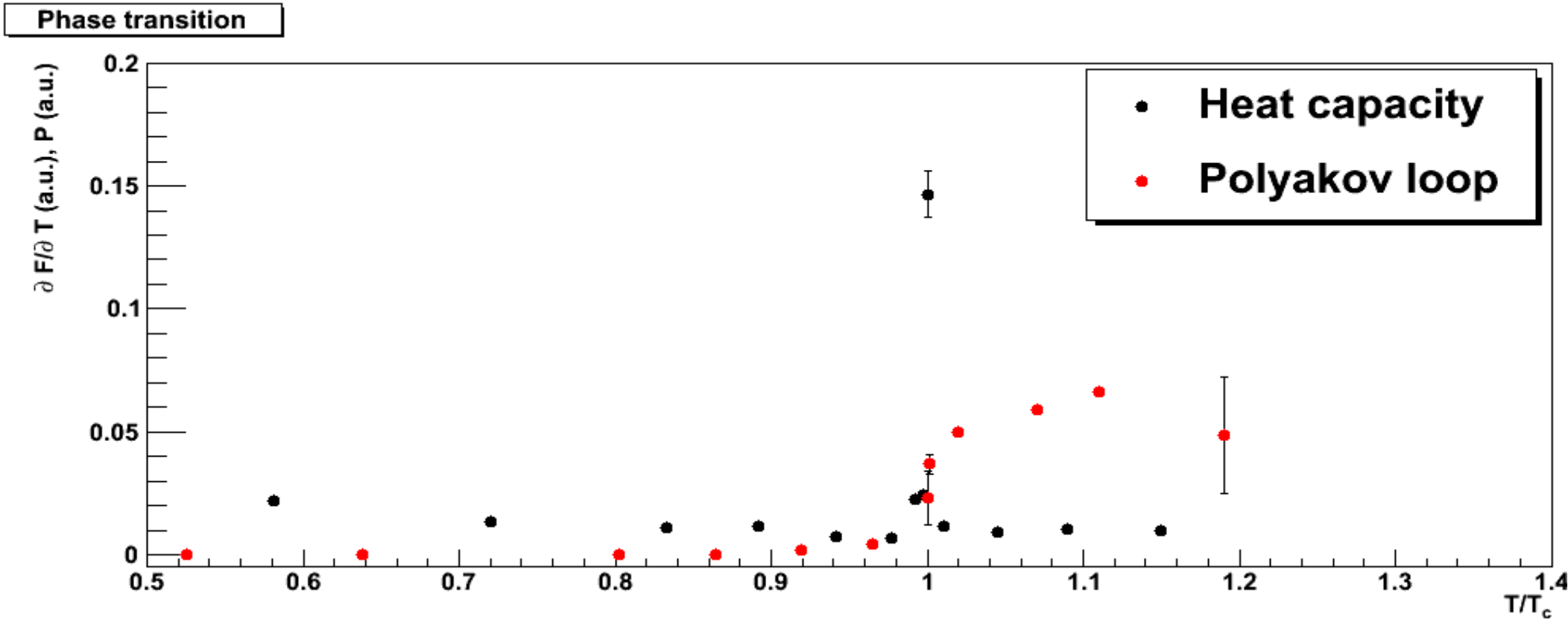

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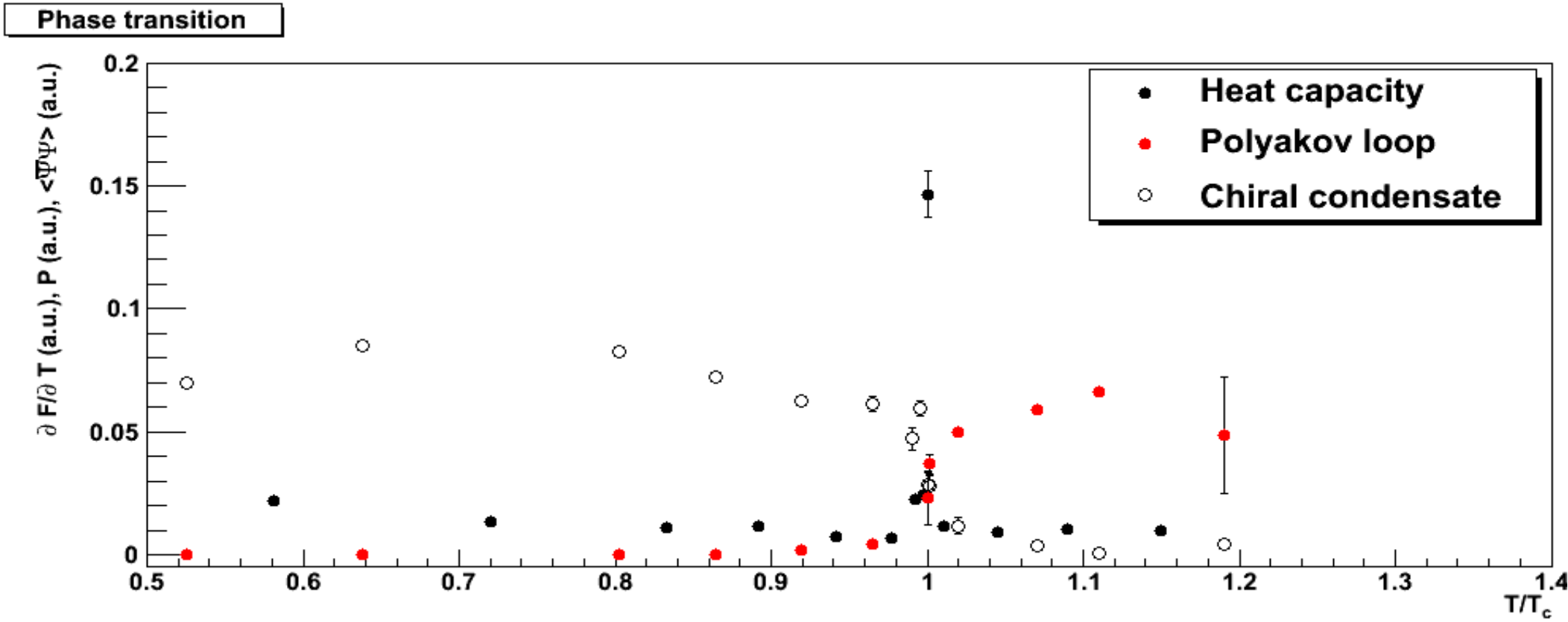

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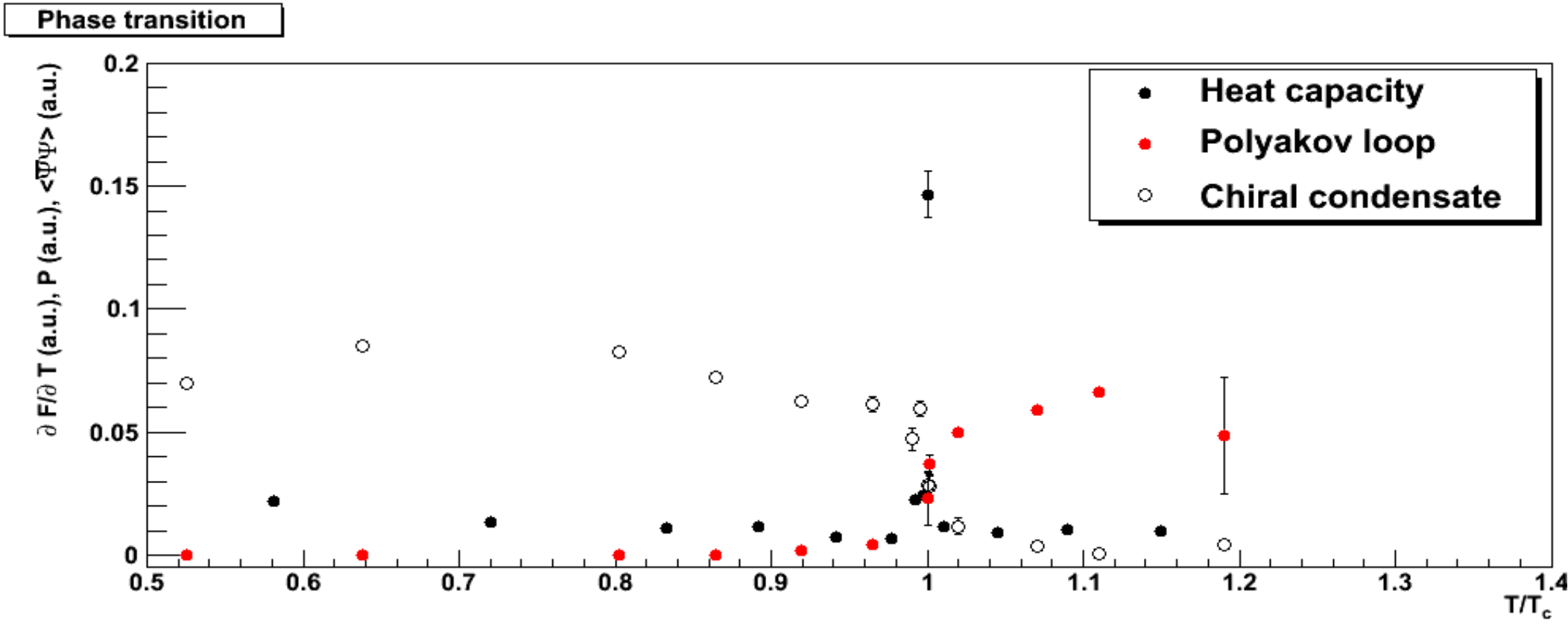
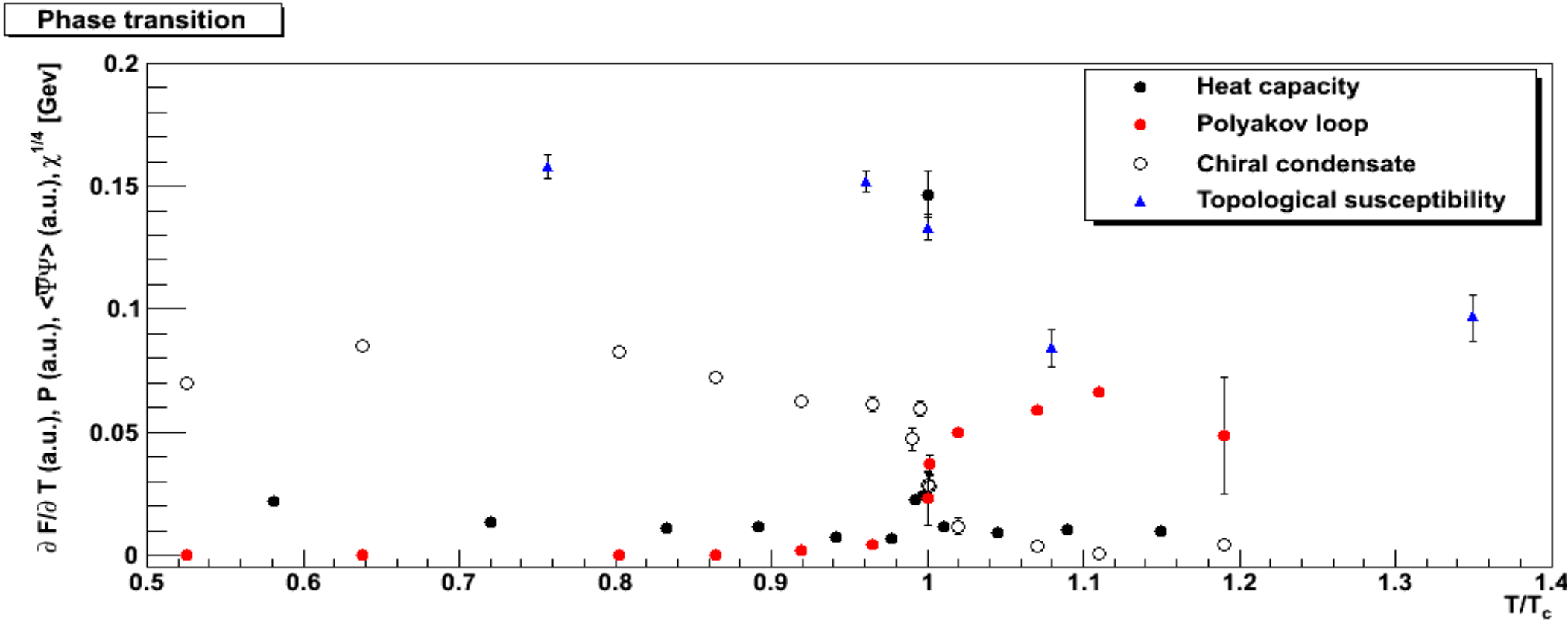


- Chiral symmetry 'broken' in quenched G2 QCD
- 'Restoration' at the phase transition
  - Like in QCD
  - Unlike adjoint QCD [Bilgici, Ilgenfritz, Gattringer, Maas JHEP 09]

Topological susceptibility

[Ilgenfritz & Maas PRD'12]



- Topological structure similar
  - Topology reflects phase transition
  - Fewer topological lumps the higher the temperature

Finite density

[Maas, von Smekal, Wellegehausen, Wipf '12]

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    - No sign problem for odd number of flavors
  - Full phase diagram accessible

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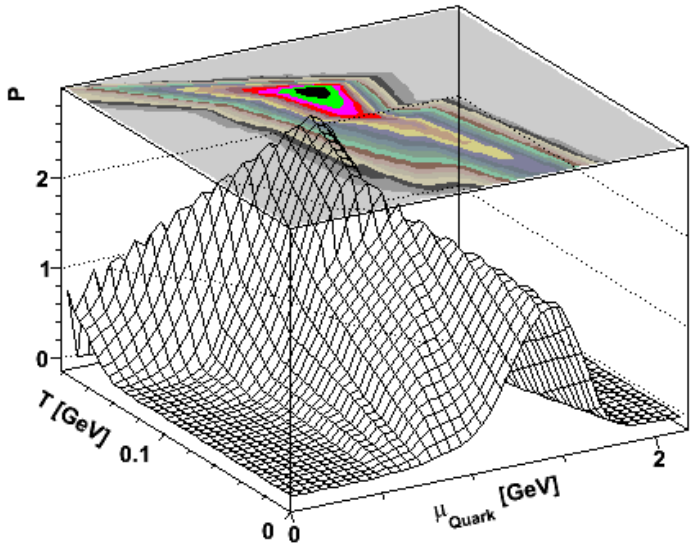
  - Preliminary: Not very different for 2 flavors

Phase diagram

[Maas, von Smekal, Wellegehausen, Wipf PRD'12]

Polyakov loop



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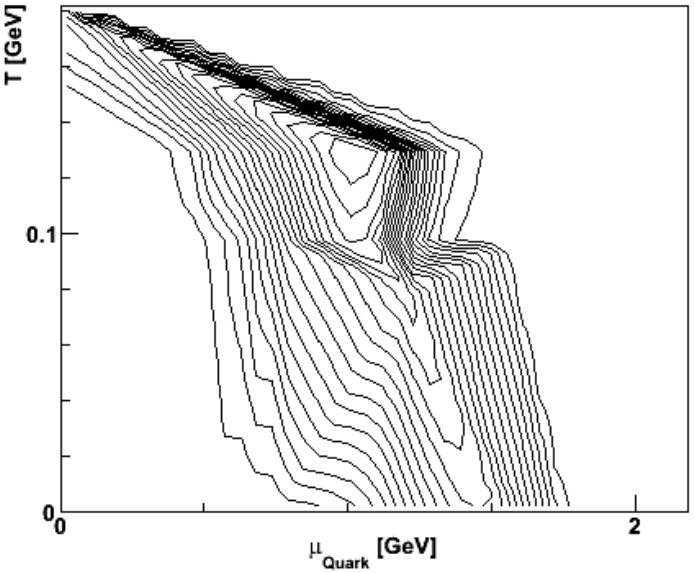
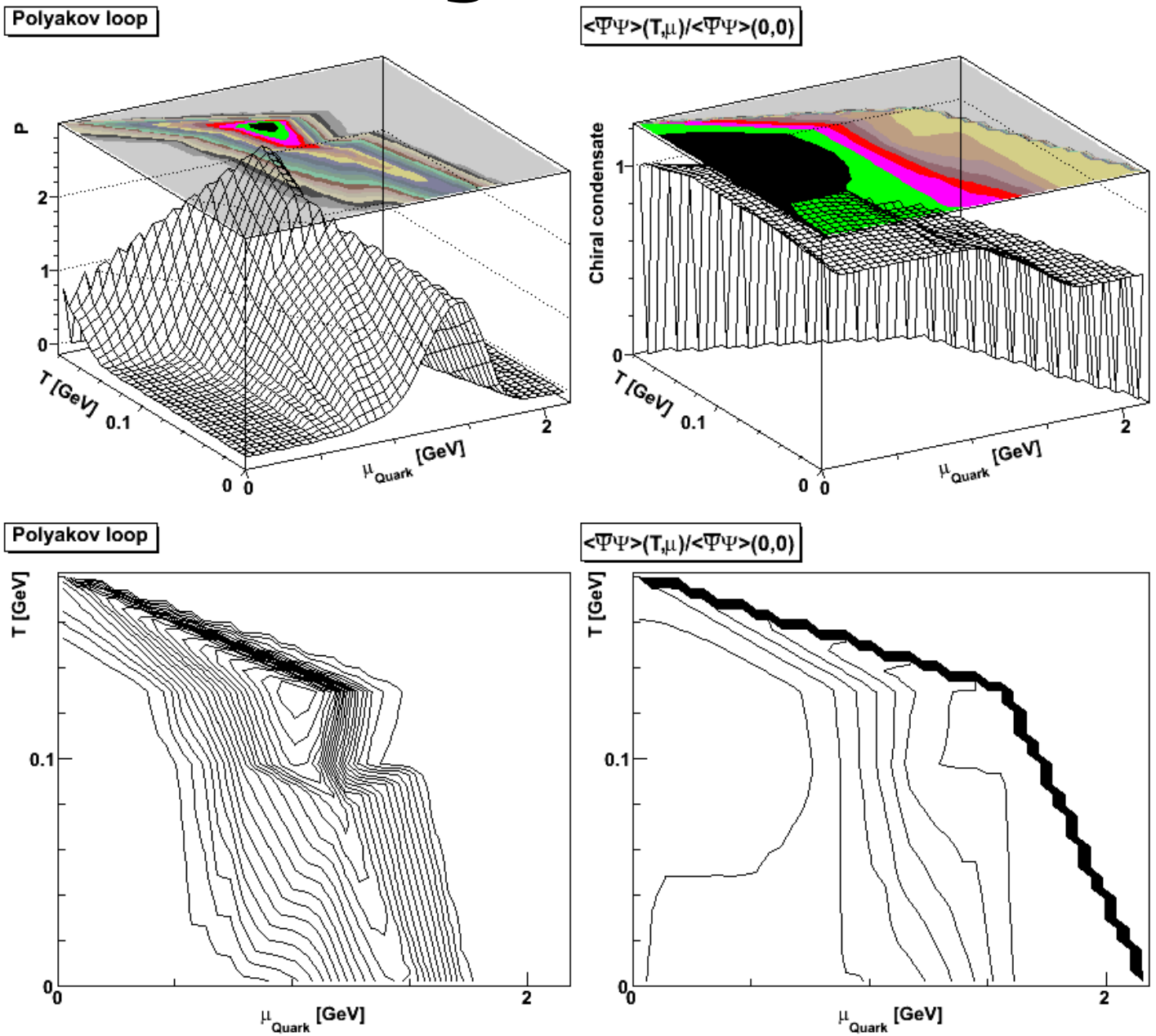


Phase diagram

[Maas, von Smekal, Wellegehausen, Wipf PRD'12]



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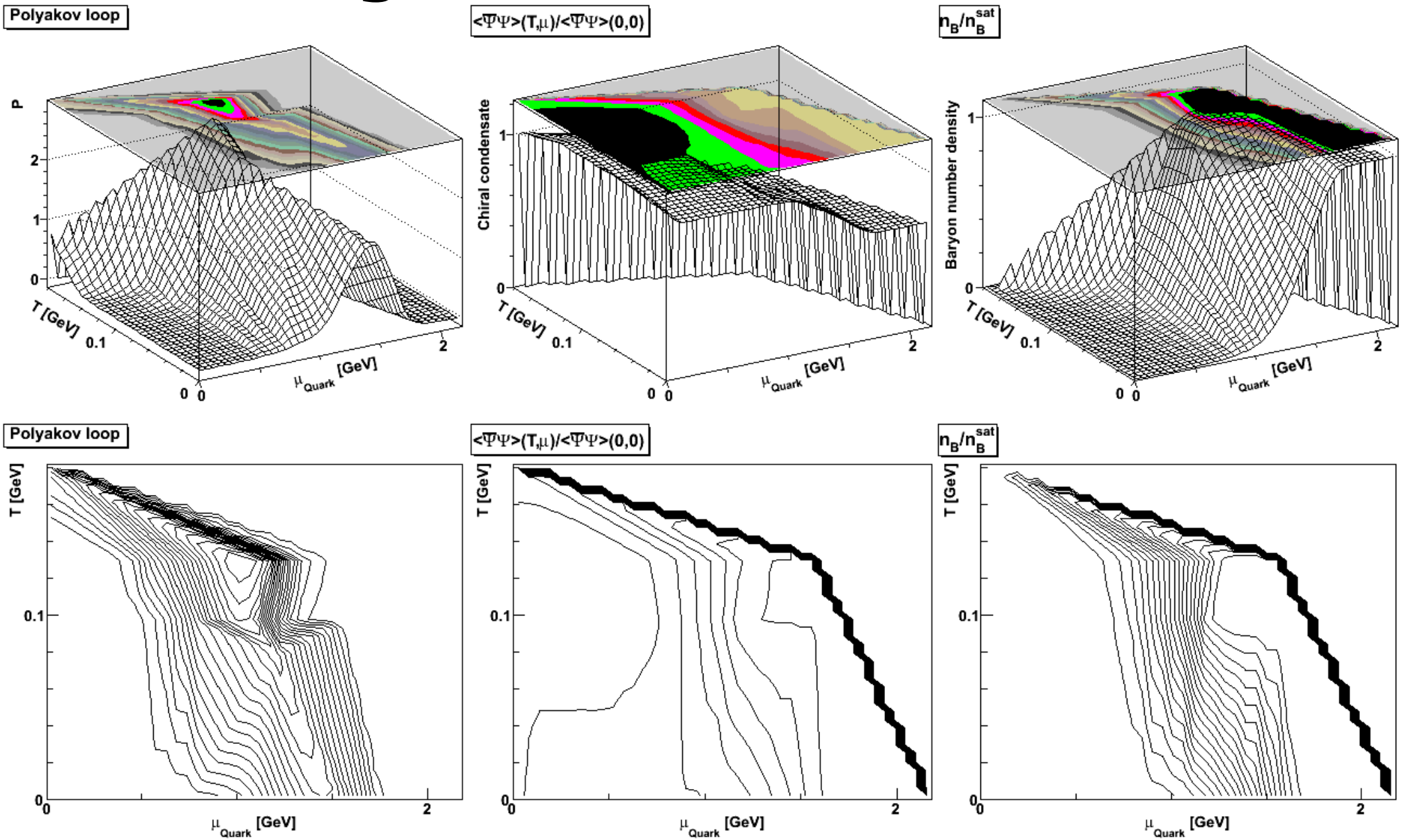

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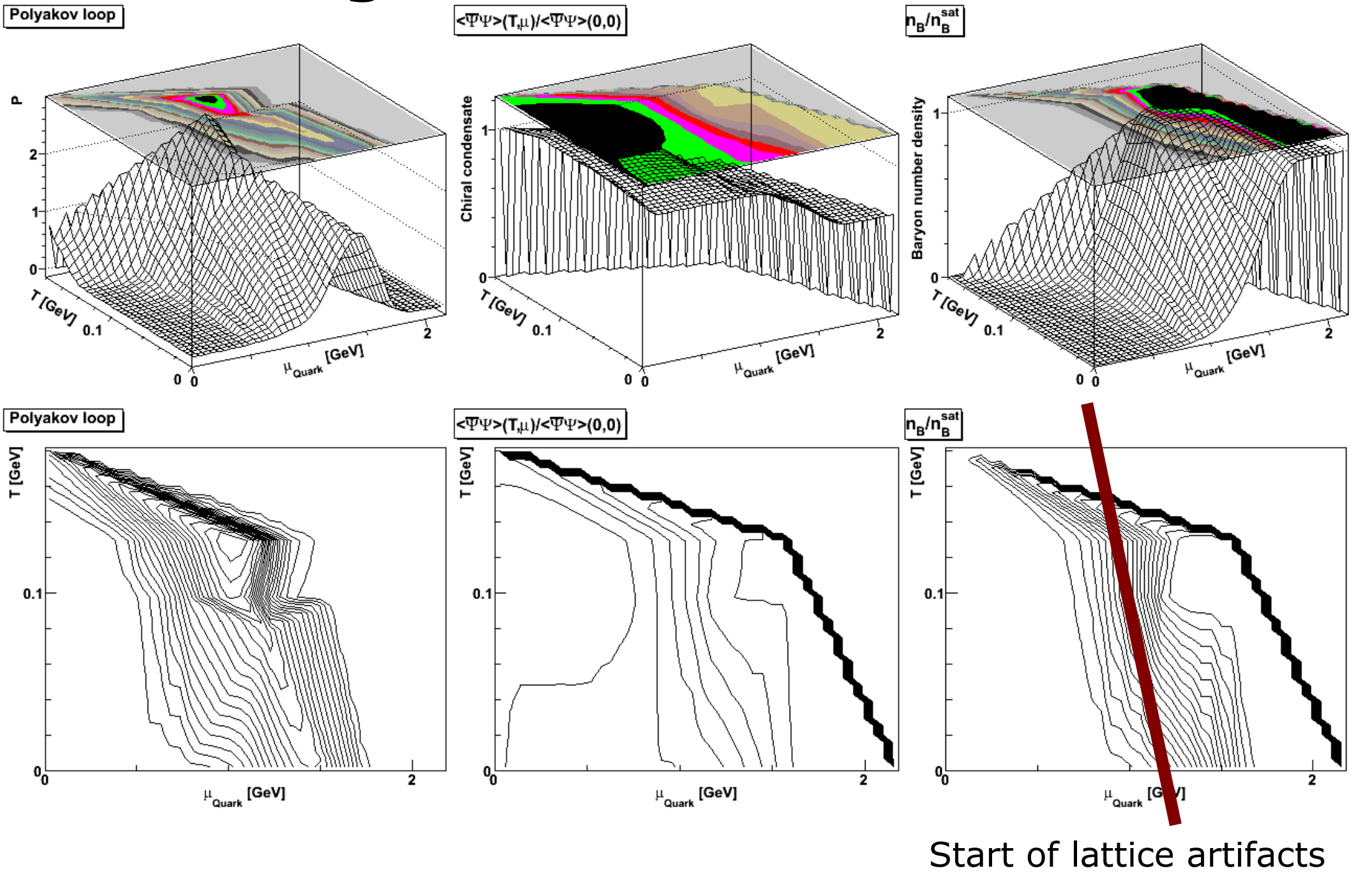

Equation of state

[Maas, von Smekal, Wellegehausen, Wipf unpublished]

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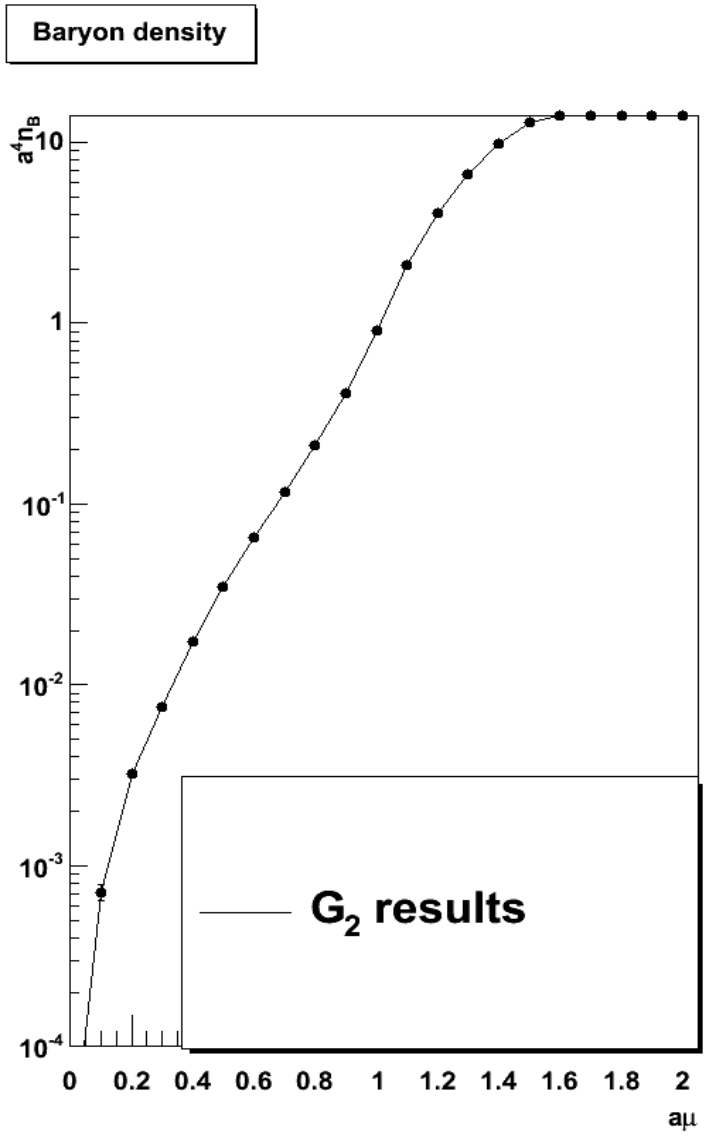

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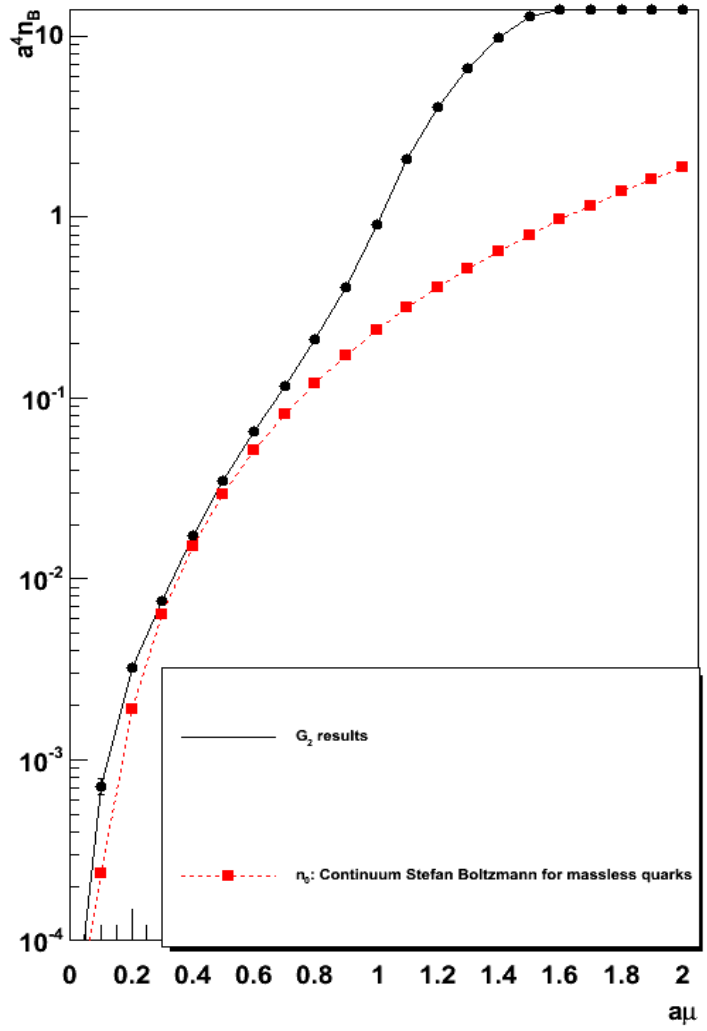

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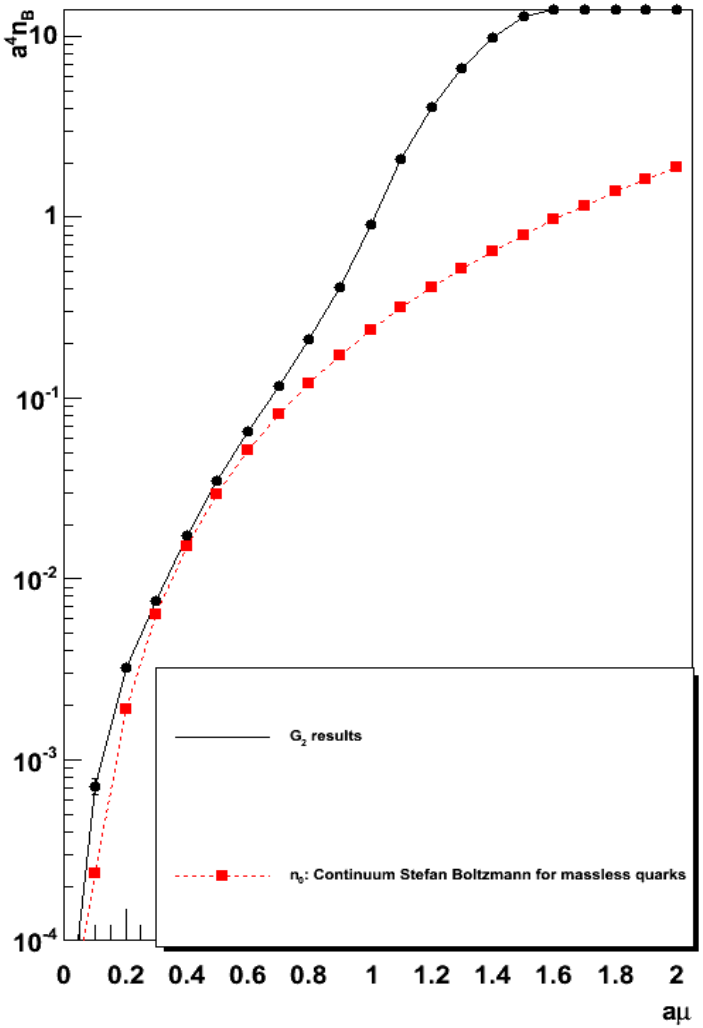
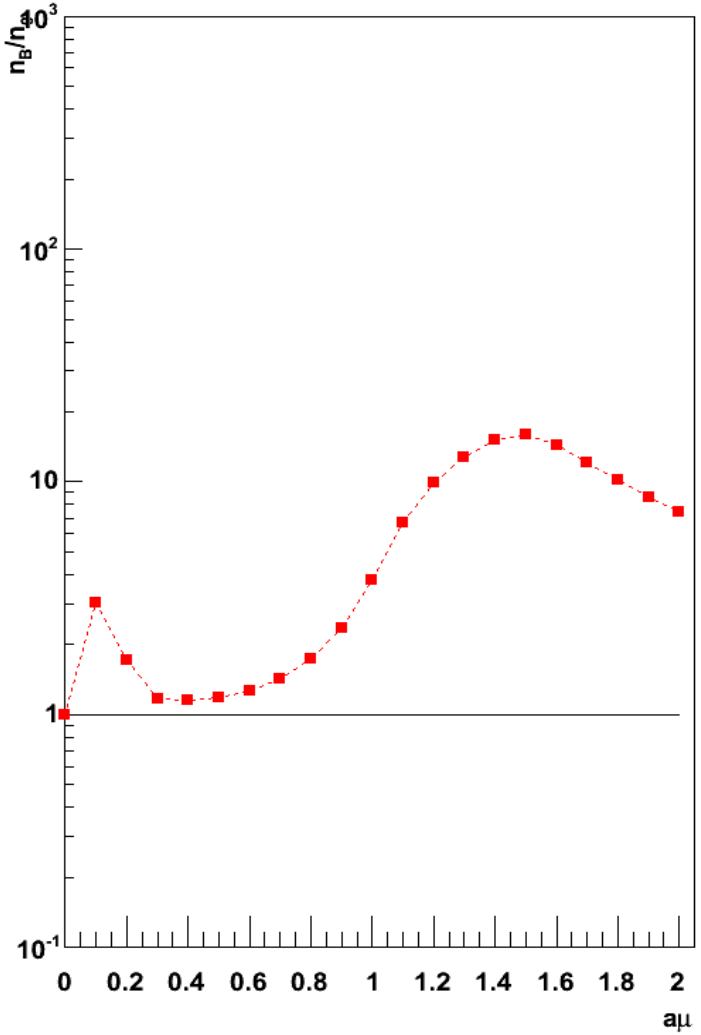


Relative baryon density



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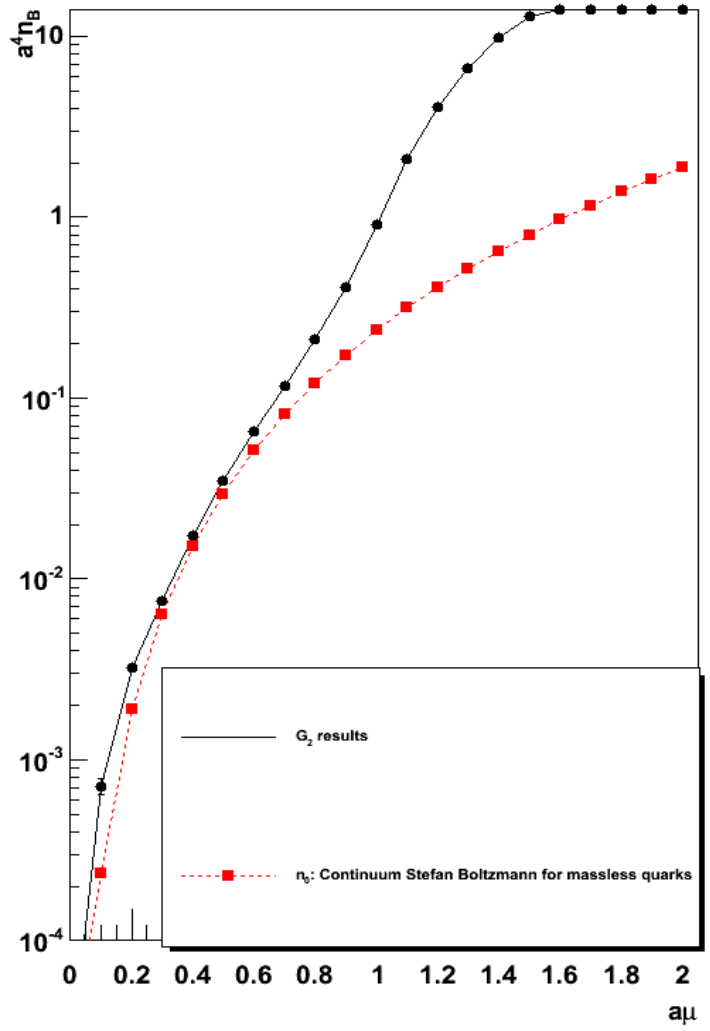

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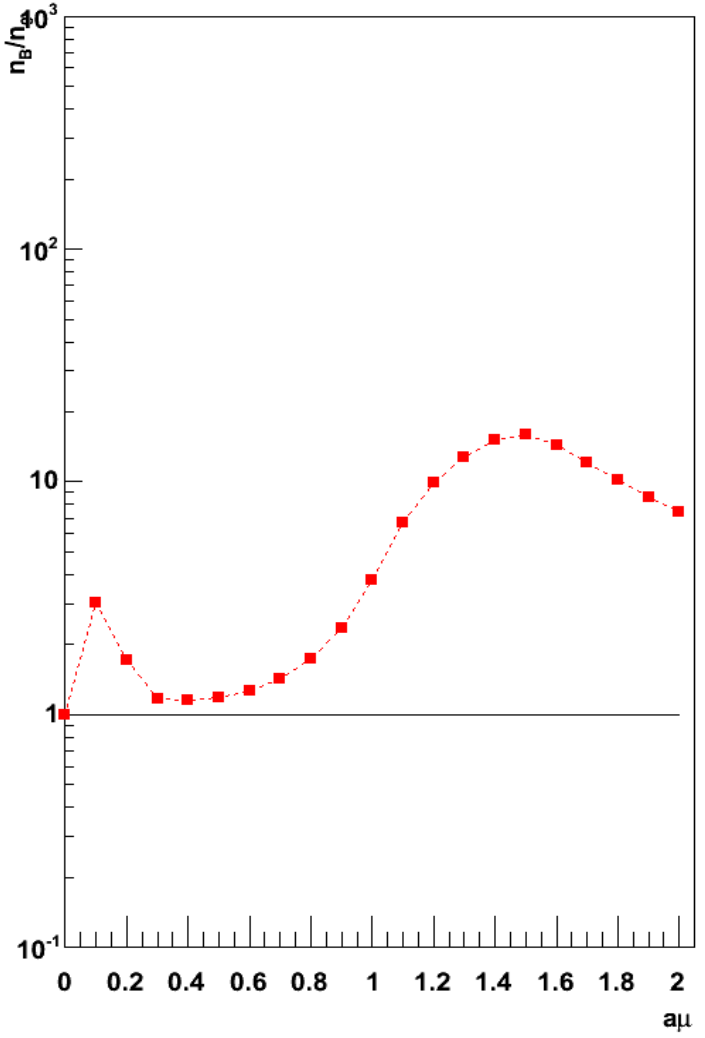

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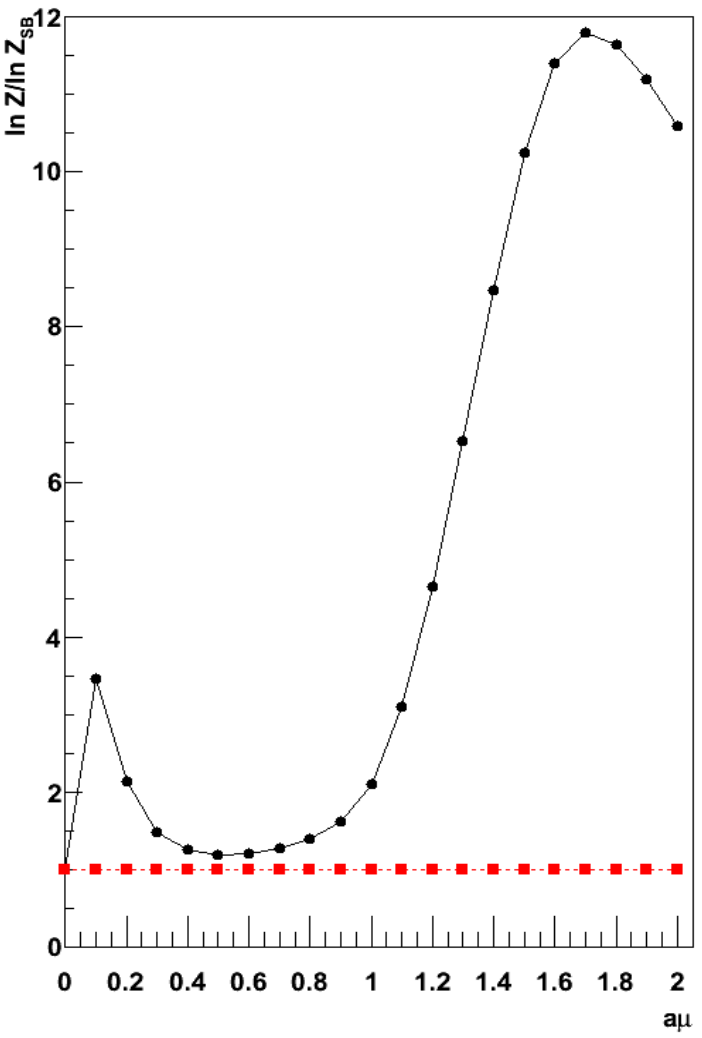

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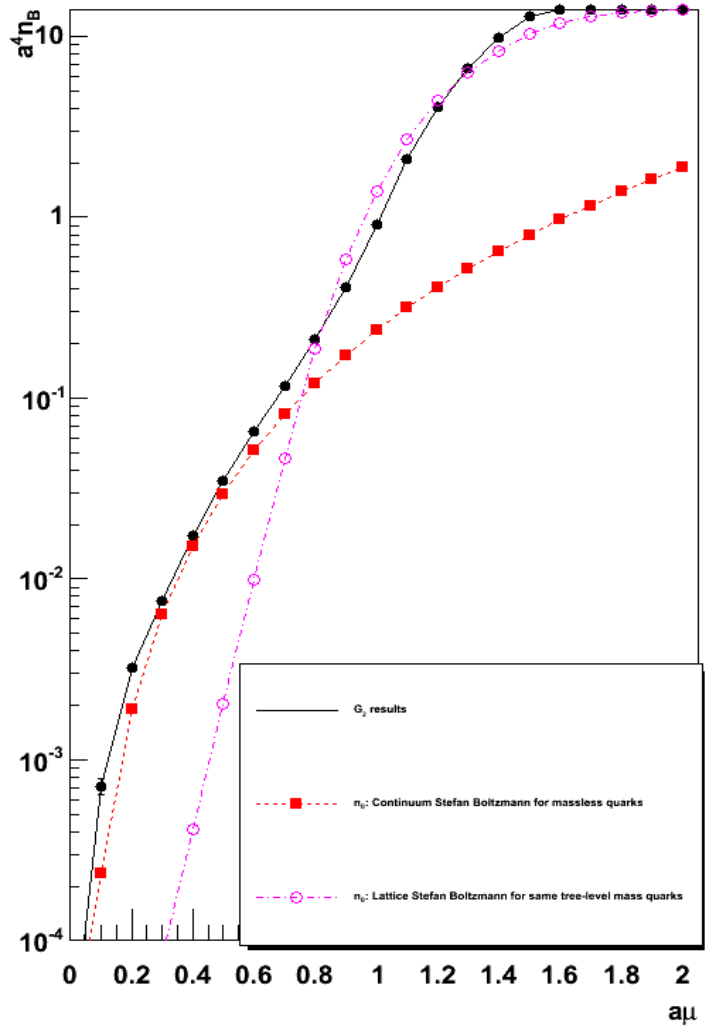

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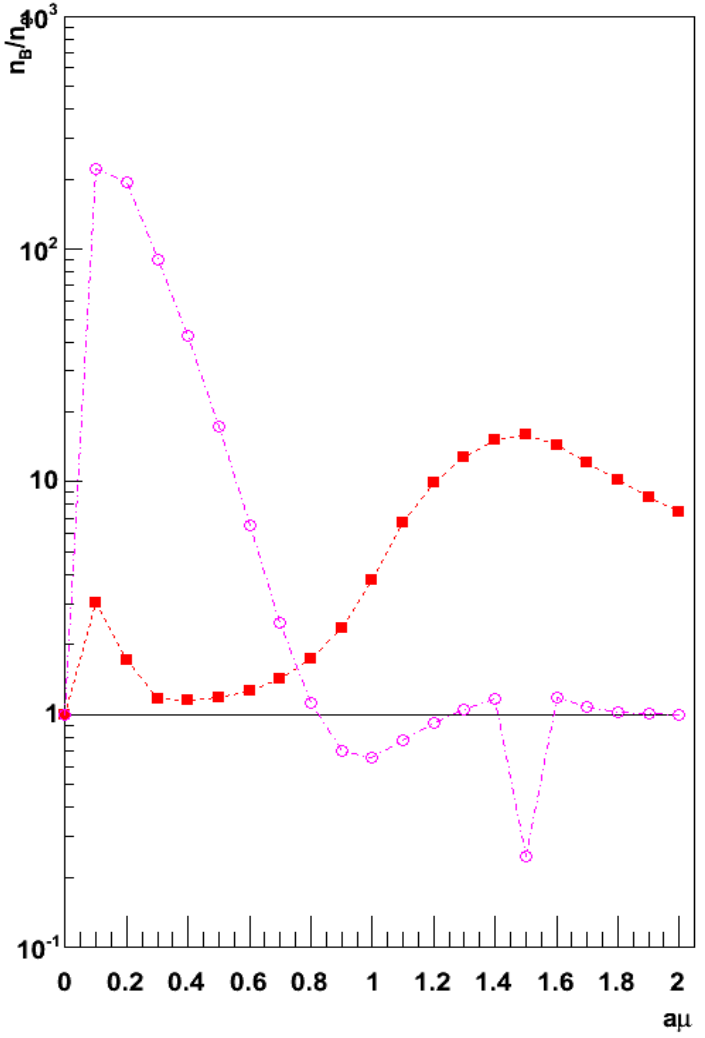

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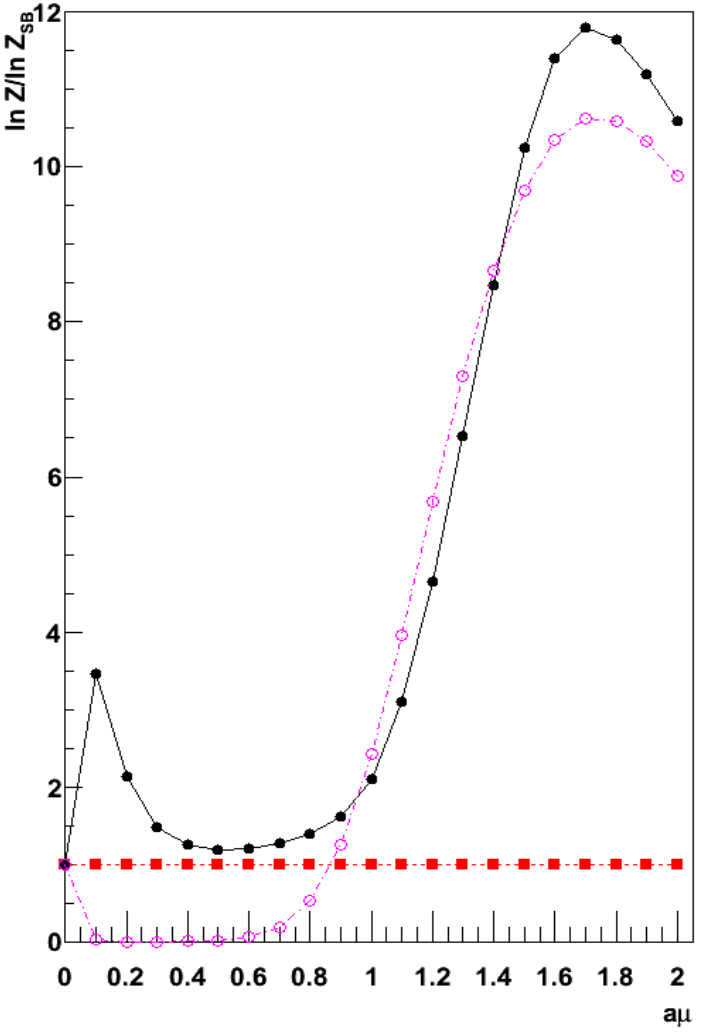

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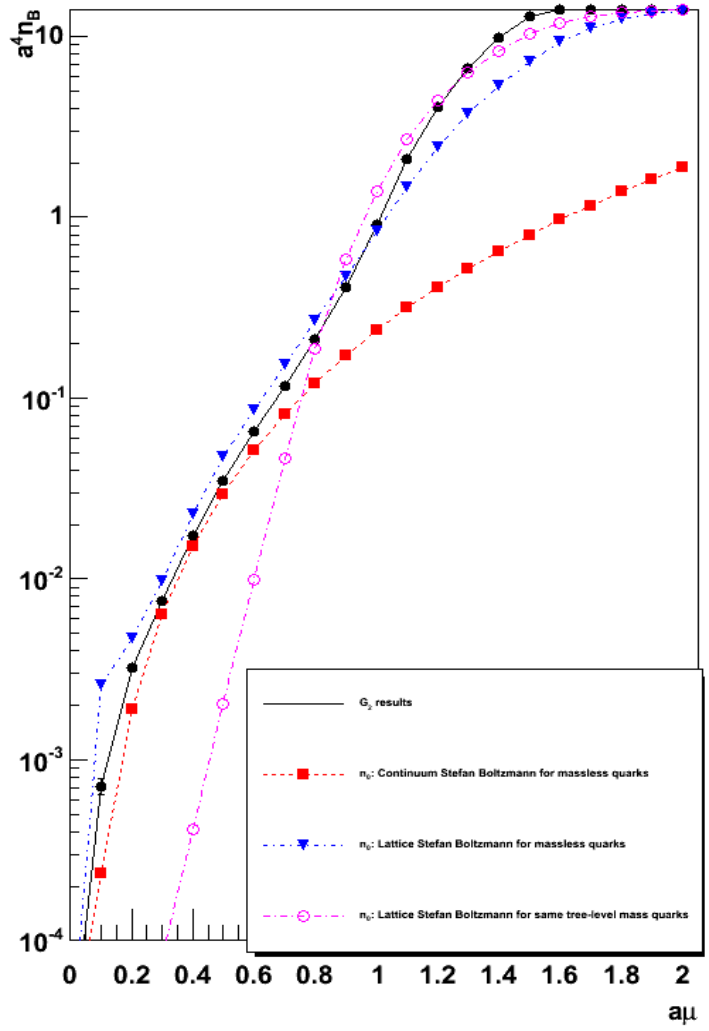

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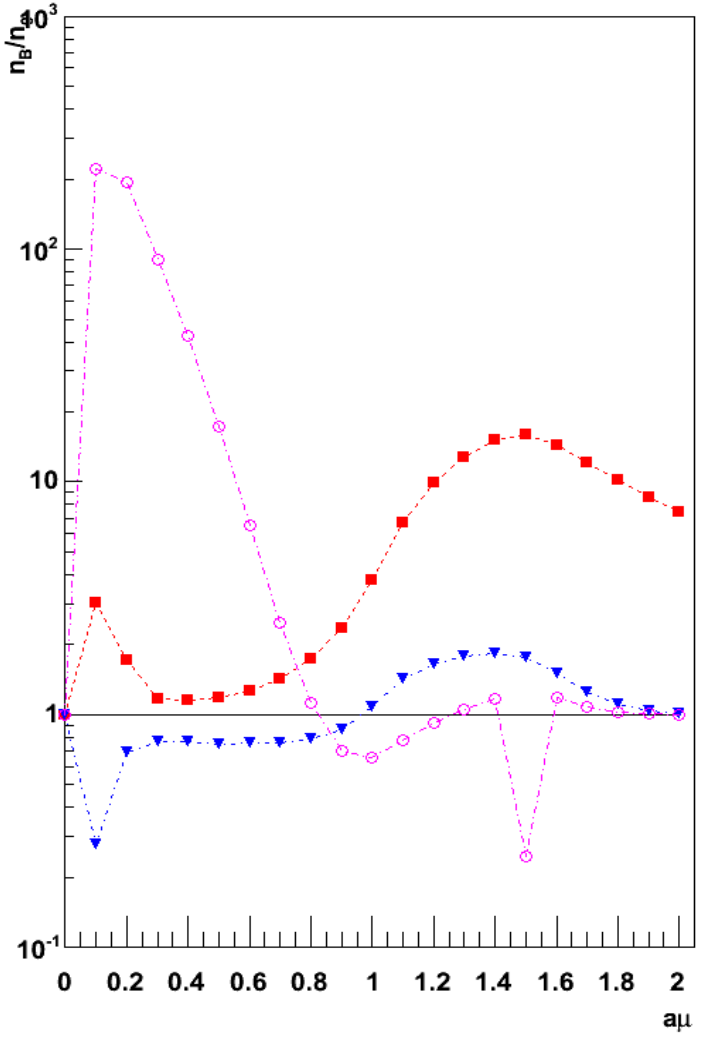

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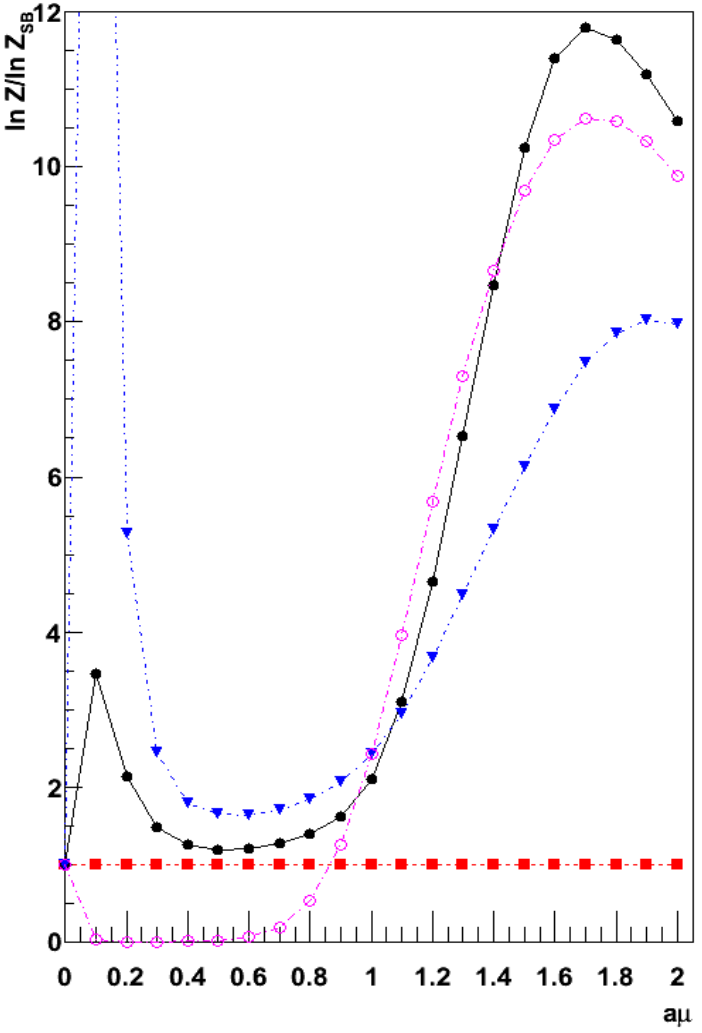

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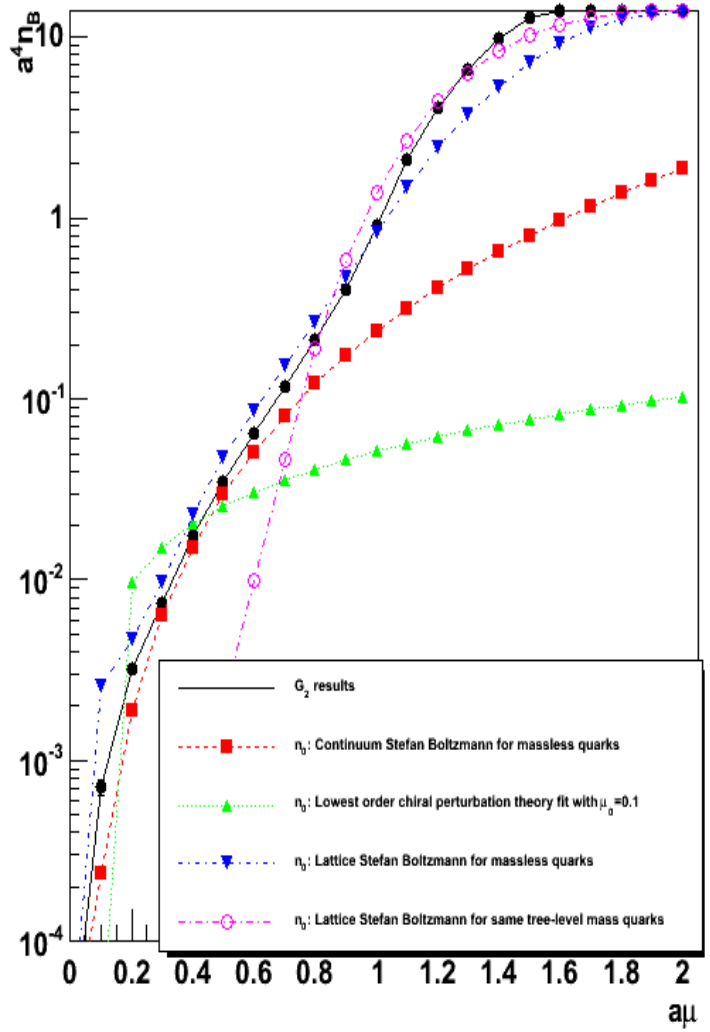

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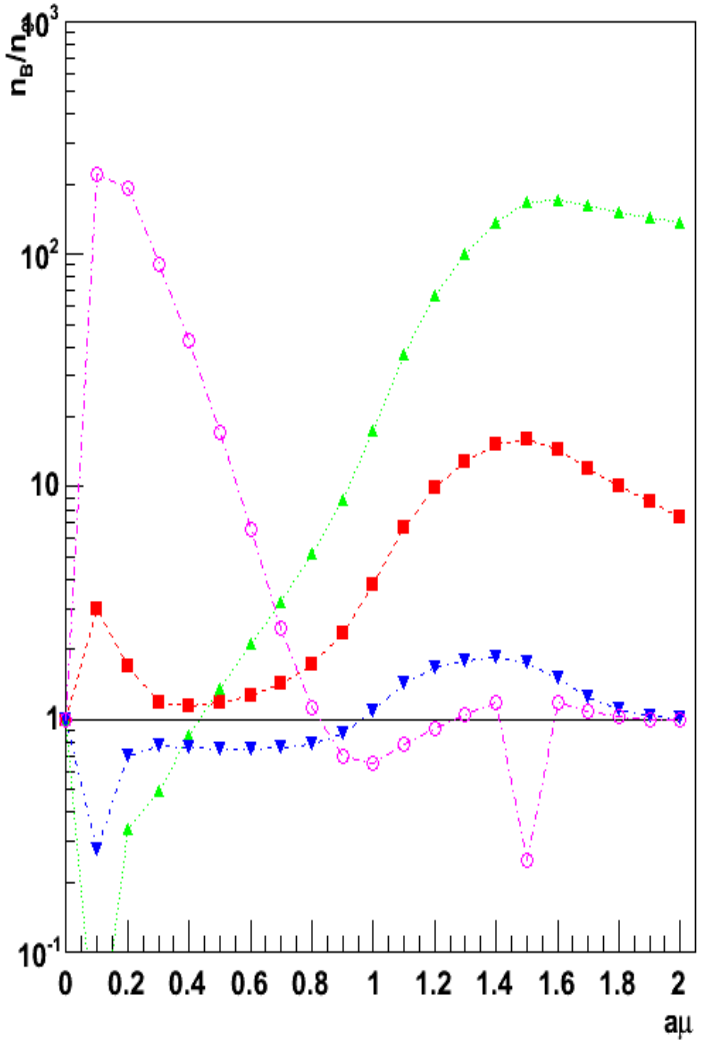

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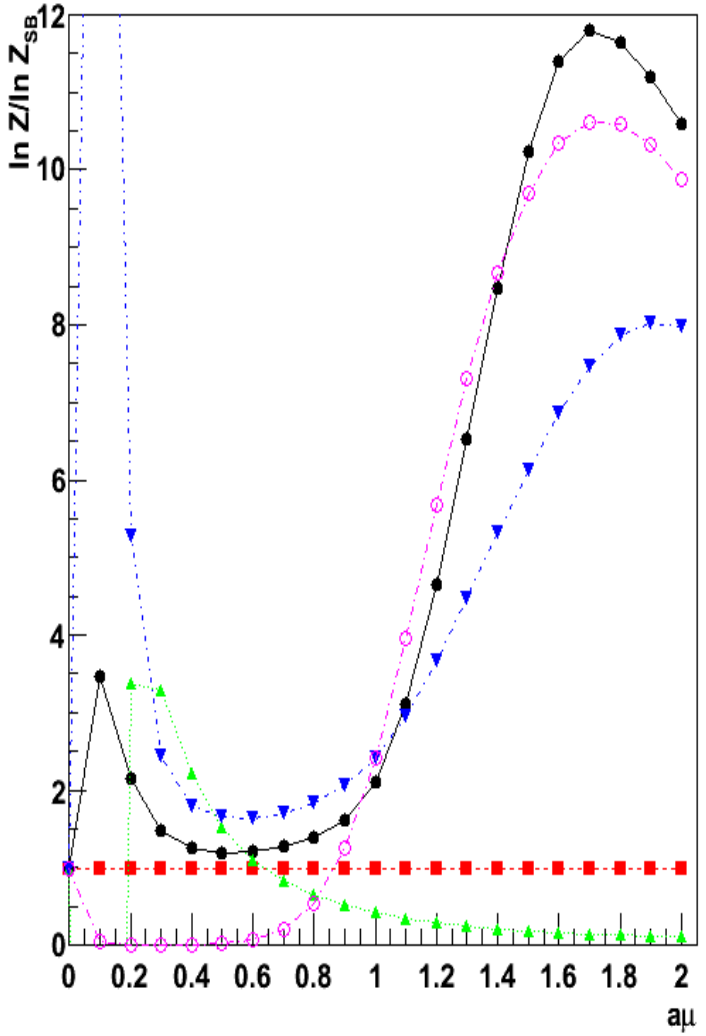

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Low-density regime

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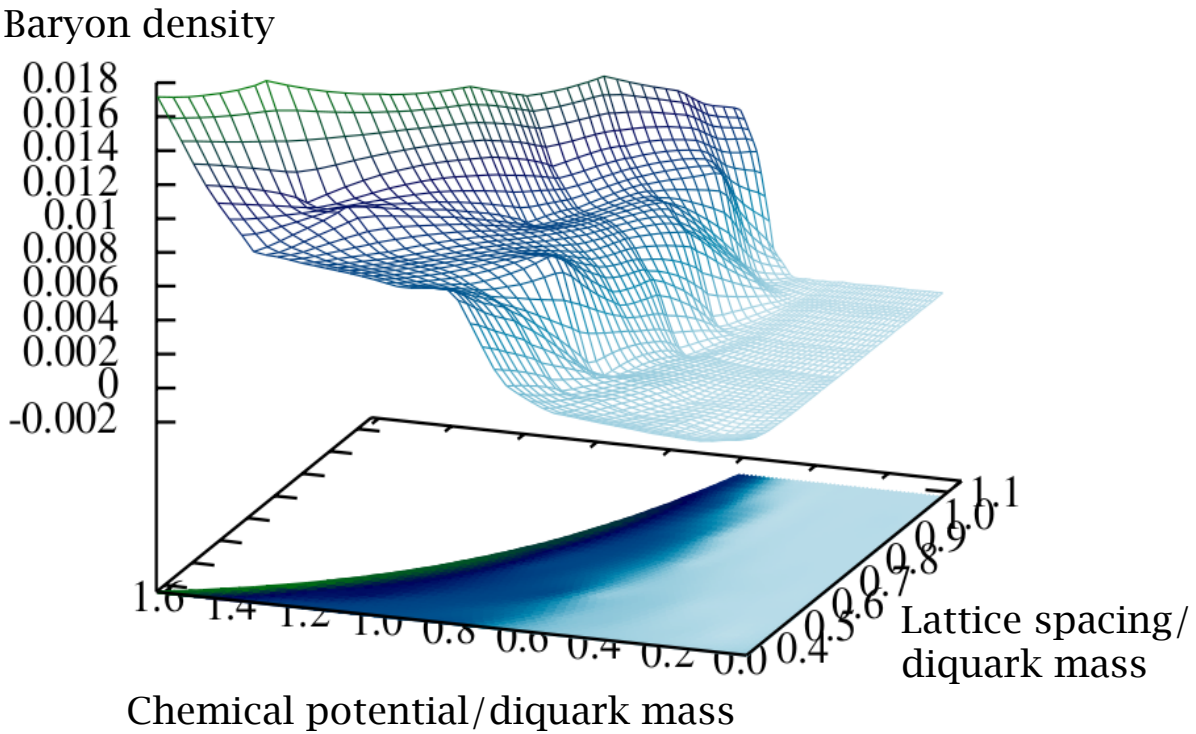

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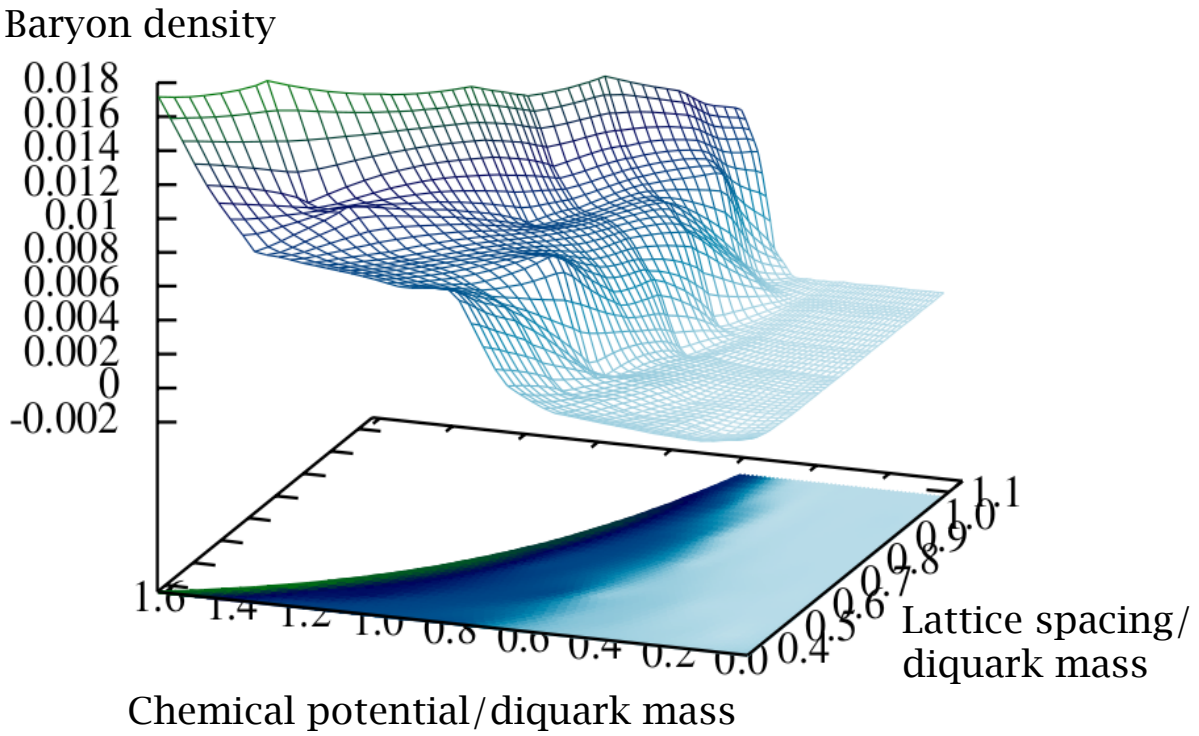

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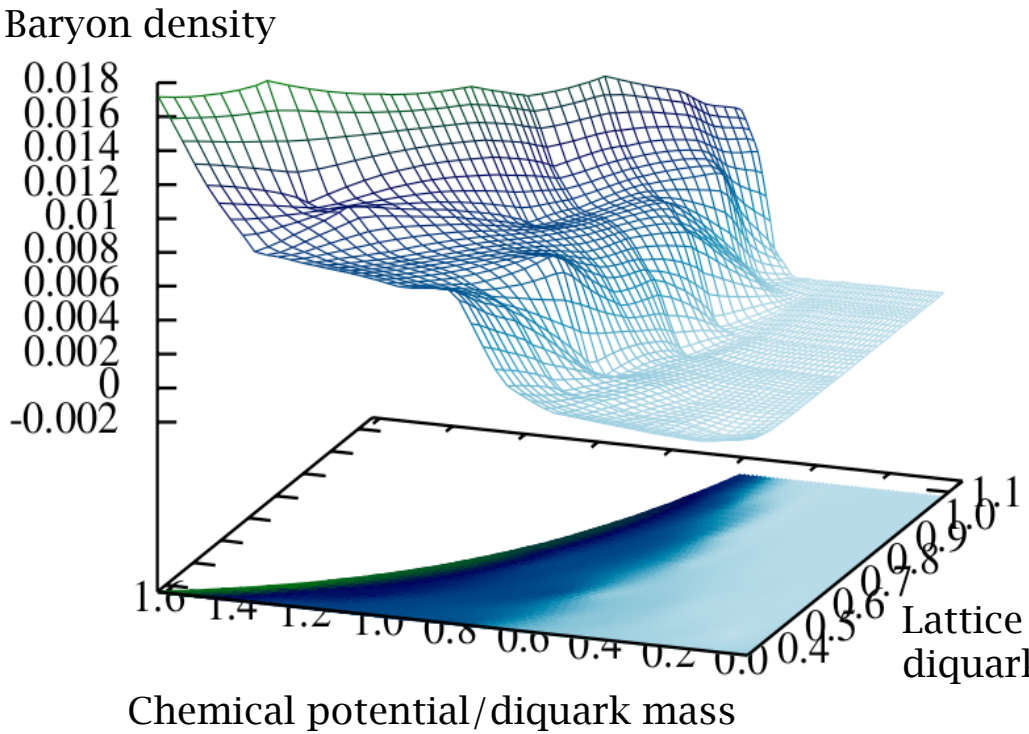

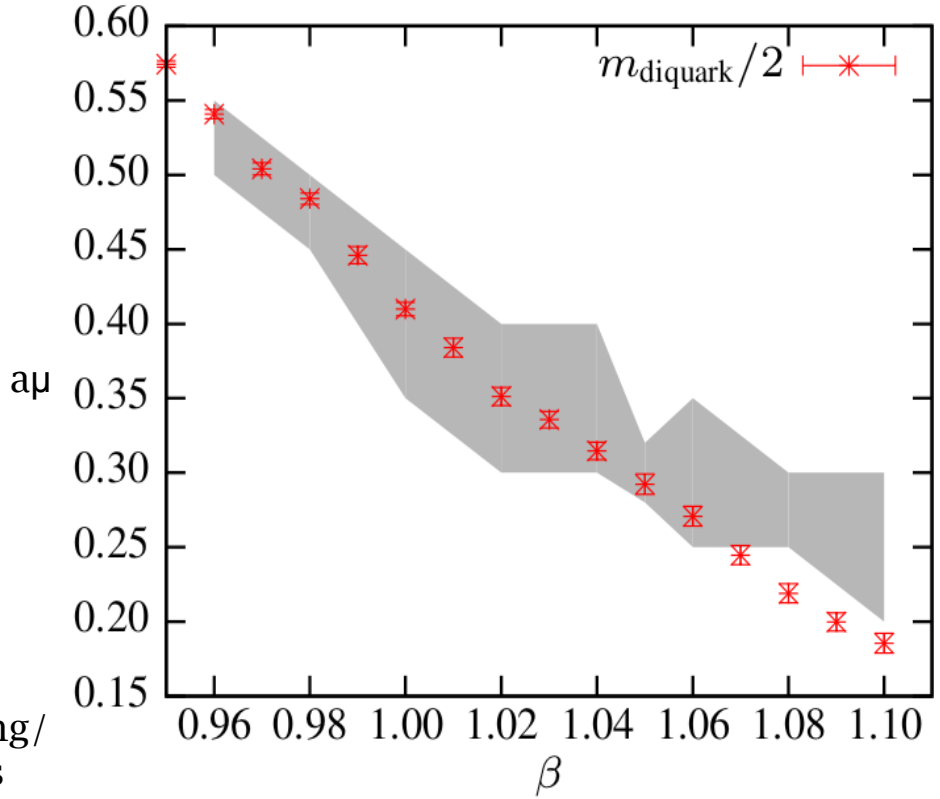

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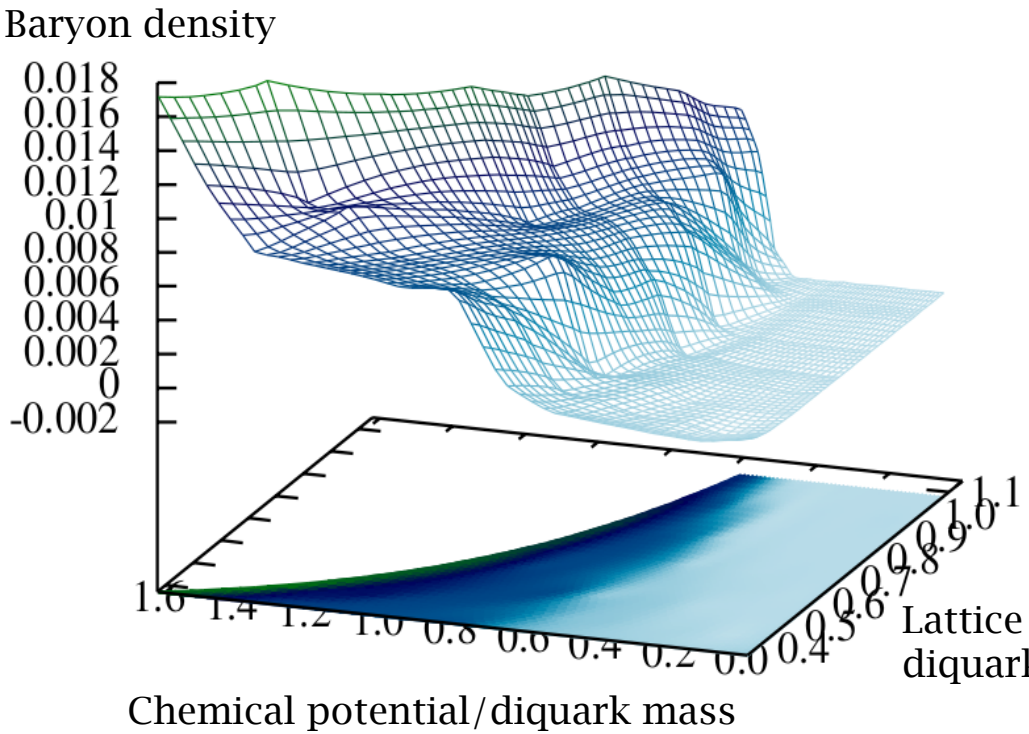

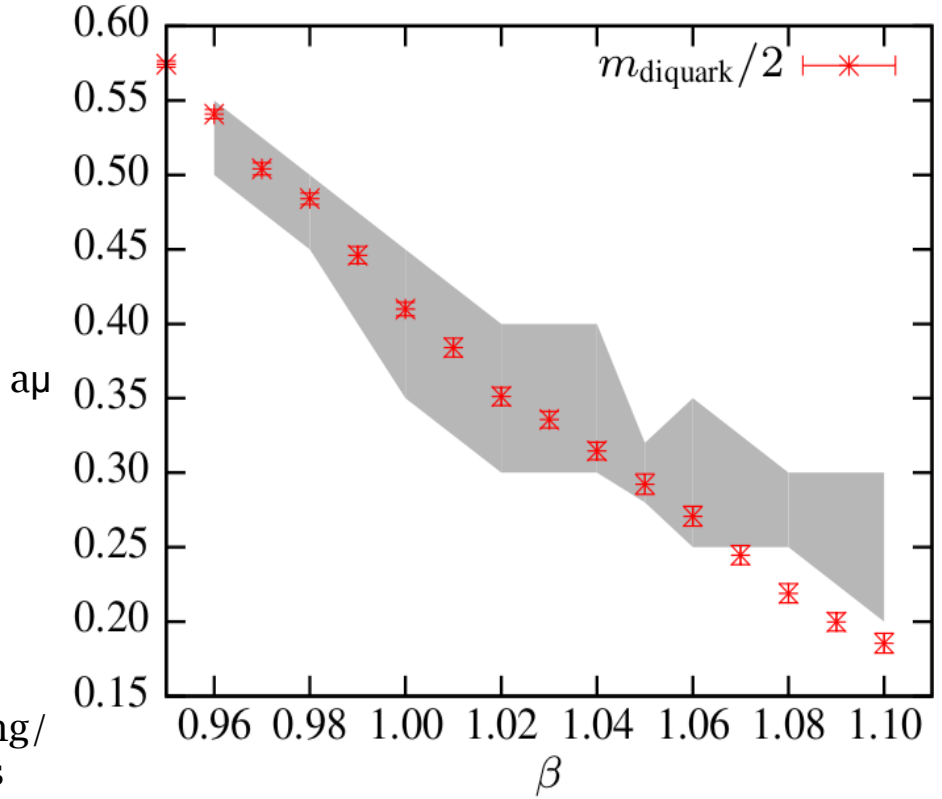

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  - Tests for truncation/approximations in continuum methods
    - E.g. functional methods

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  - Rough shape of the phase diagram of a gauge theory is similar to the expected one