

fQCD: QCD with the Functional RG

1PI-Correlators, Running Couplings and Chiral Symmetry Breaking

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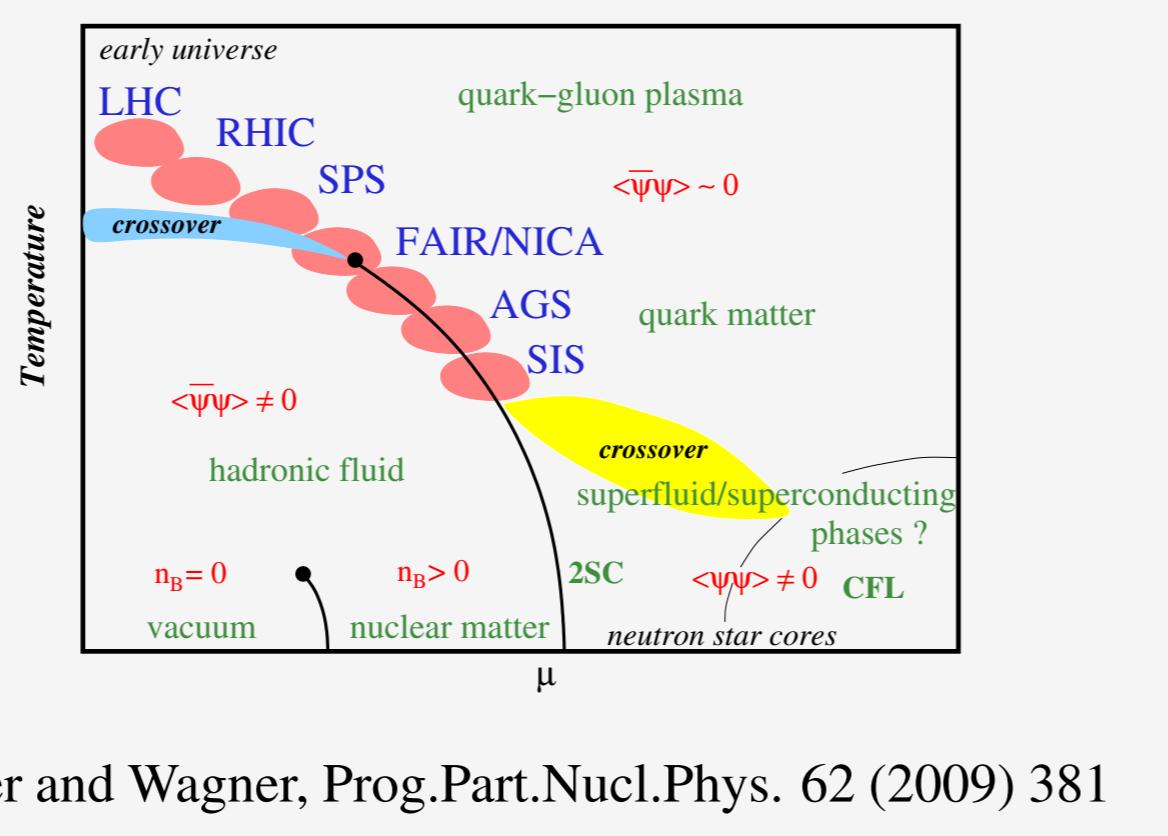
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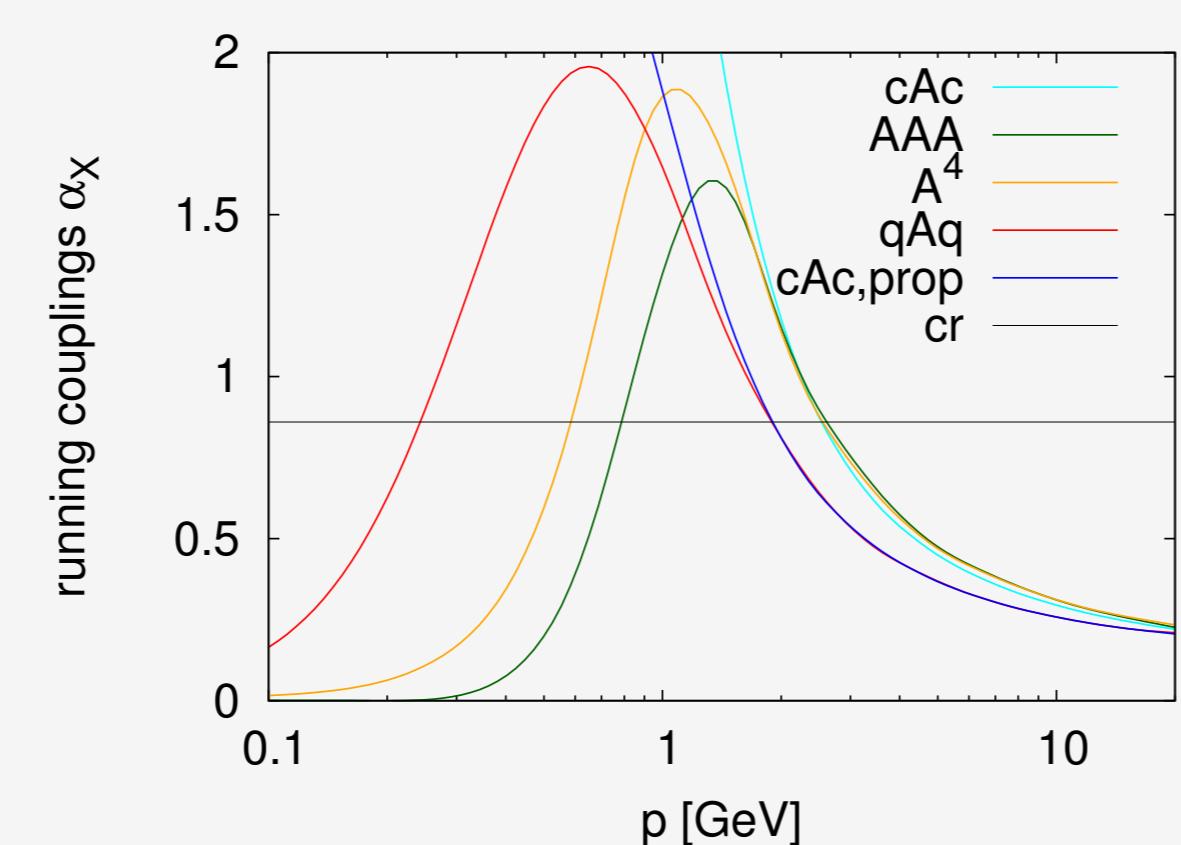
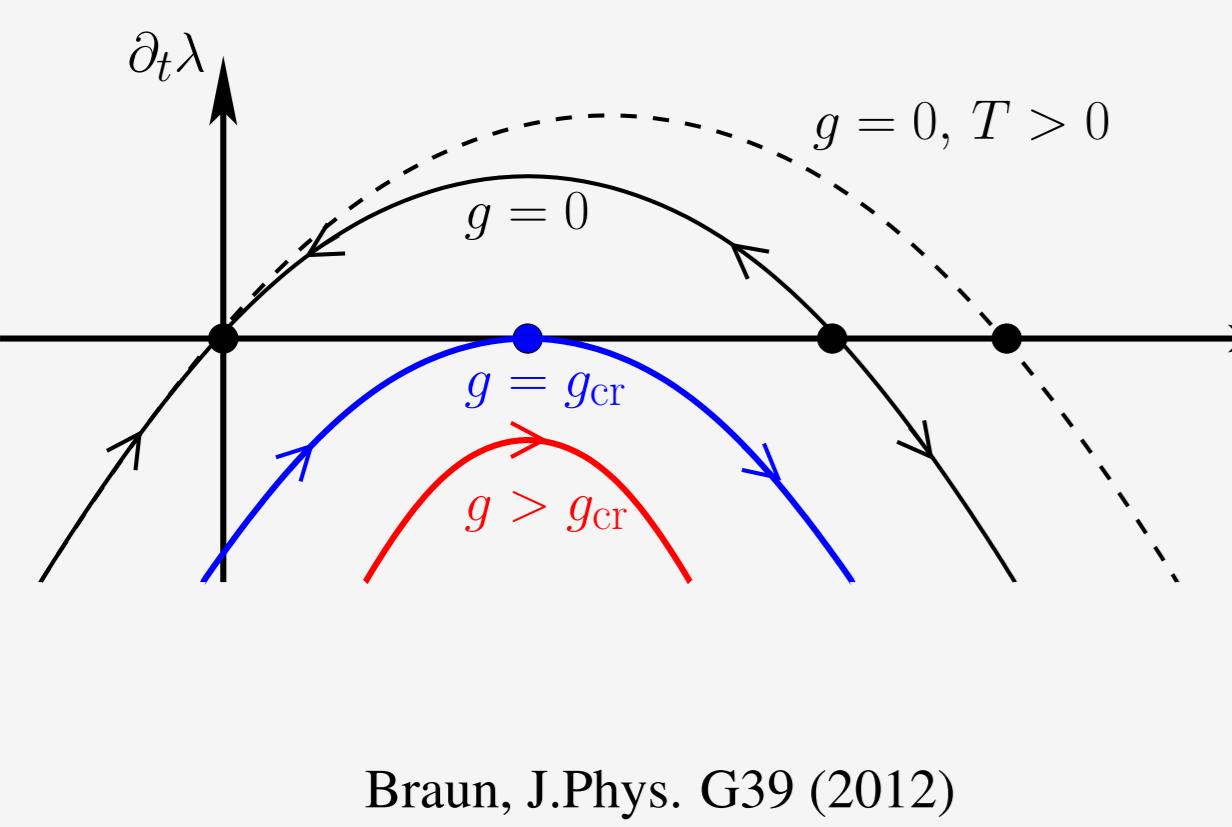
Motivation: Phase Diagram and Hadron Properties

- $\mu = 0$: crossover known from lattice
- $\mu \neq 0$: sign problem in lattice QCD
- Functional methods:
 - nonperturbative
 - no sign problem
 - access to realtime observables



Dynamical Chiral Symmetry Breaking

- β -function of four-quark interaction $\partial_t \lambda = a \lambda^2 + b \lambda \alpha + c \alpha^2$, $b > 0$; $a, c \leq 0$
- area of $\alpha_{A\bar{q}q} > \alpha_{cr}$ determines chiral symmetry breaking
- area very sensitive to semiperturbative running couplings



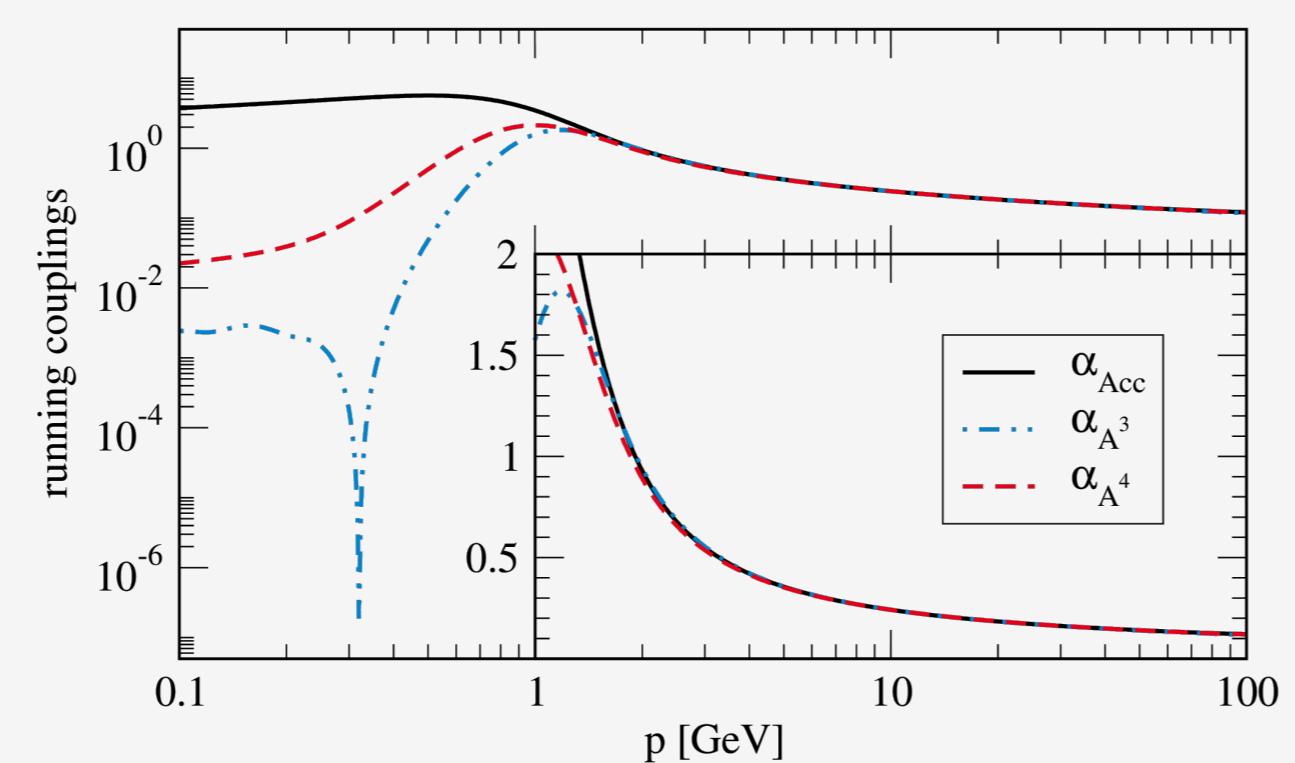
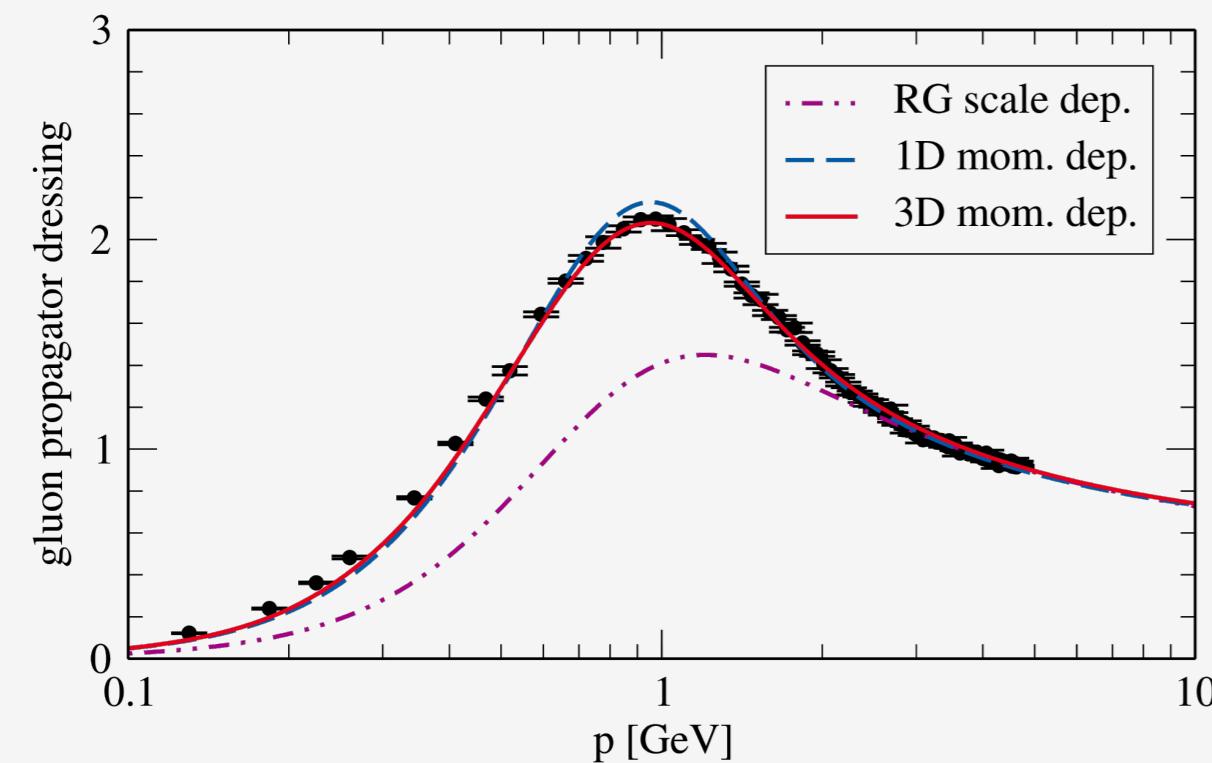
Yang-Mills Theory

A. K. Cyrol, L. Fister, M. Mitter, J. M. Pawłowski, N. Strodthoff, arXiv:1605.01856 [hep-ph]

- prerequisite for QCD
- self-consistent calculation of propagators and classical vertex structures
- indications for apparent convergence
- STI-consistent treatment of quadratic divergencies

$$\begin{aligned}\alpha_{A\bar{c}c}(p) &= \frac{1}{4\pi} \frac{Z_{A\bar{c}c,\perp}^2(p)}{Z_A(p) Z_c^2(p)} \\ \alpha_{A^3}(p) &= \frac{1}{4\pi} \frac{Z_{A^3,\perp}^2(p)}{Z_A^3(p)} \\ \alpha_{A^4}(p) &= \frac{1}{4\pi} \frac{Z_{A^4,\perp}^2(p)}{Z_A^2(p)}\end{aligned}$$

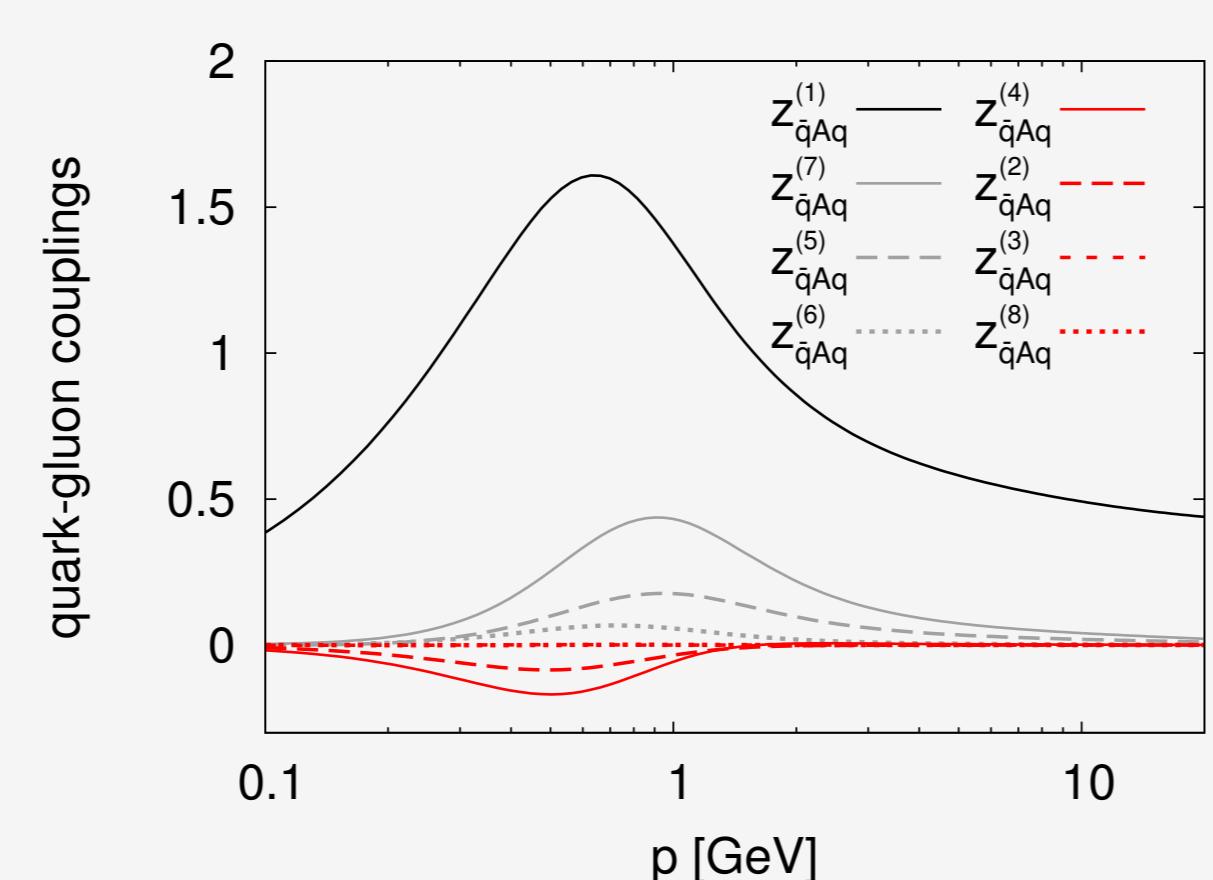
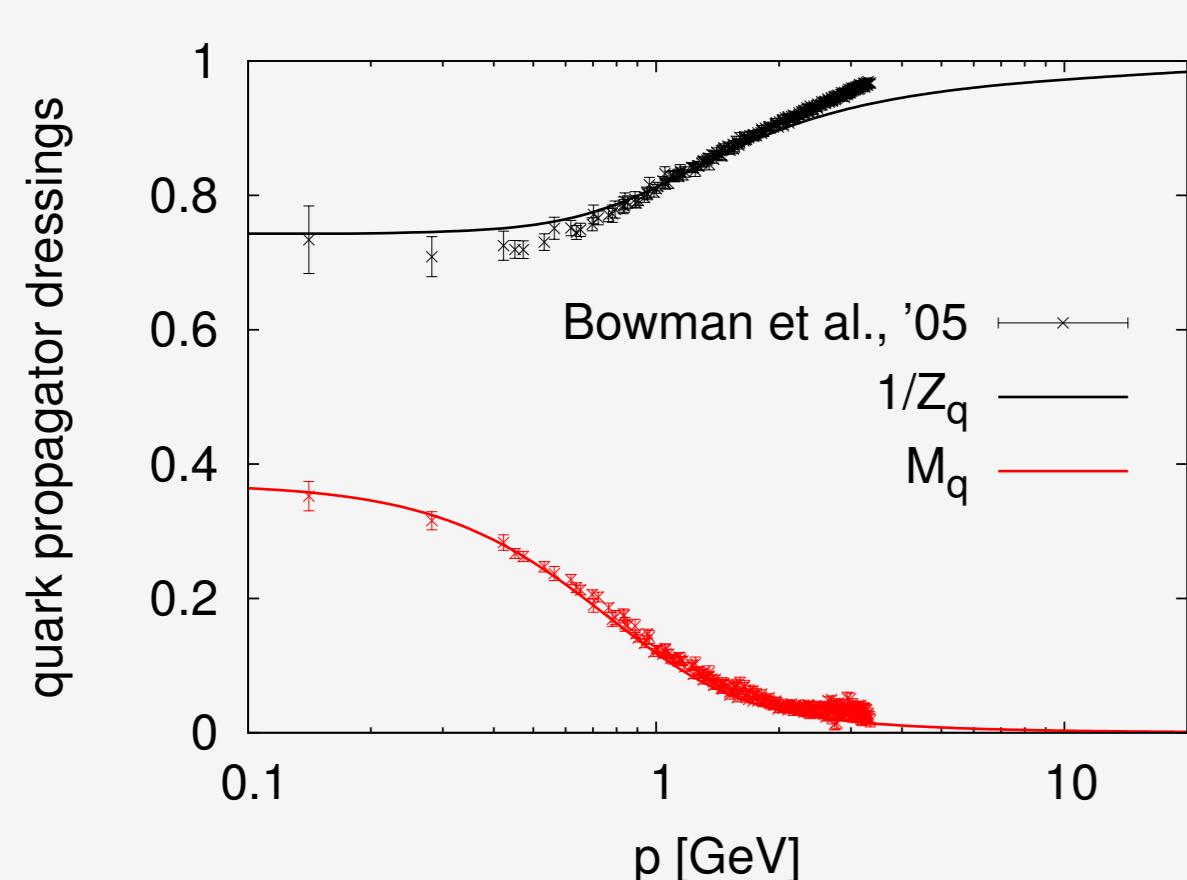
$$[\Gamma_{AA}]^{ab}_{\mu\nu}(p) = Z_A(p) p^2 \delta^{ab} \Pi_{\mu\nu}^\perp(p)$$



Quenched QCD

M. Mitter, J. M. Pawłowski, N. Strodthoff. Phys.Rev., D91:054035, 2015

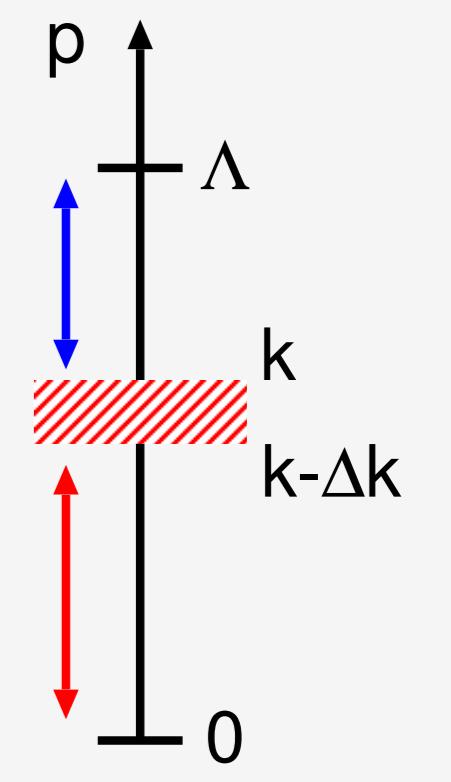
- No matter loops in pure glue sector
- Quark propagator: $\Gamma_{\bar{q}q}(p) \propto Z_q(p) (\not{p} + M_q(p))$
- Spontaneous chiral symmetry breaking very sensitive to quark-gluon interactions
- Full tensor basis of transverse quark-gluon vertex $\Gamma_{A\bar{q}q}^{(3)} = Z_q \sqrt{Z_A} \cdot \sum_i z_i^{A\bar{q}q} \mathcal{T}^i$



Functional Renormalization Group

- Bare action at initial scale, $\Gamma_{k=\Lambda} = S$
- Integration of momentum shells via flow equation

$$\partial_t \Gamma_k[\phi] = \frac{1}{2} \left(\text{---} \otimes \text{---} - \text{---} \otimes \text{---} - \text{---} \otimes \text{---} + \frac{1}{2} \text{---} \otimes \text{---} \right)$$

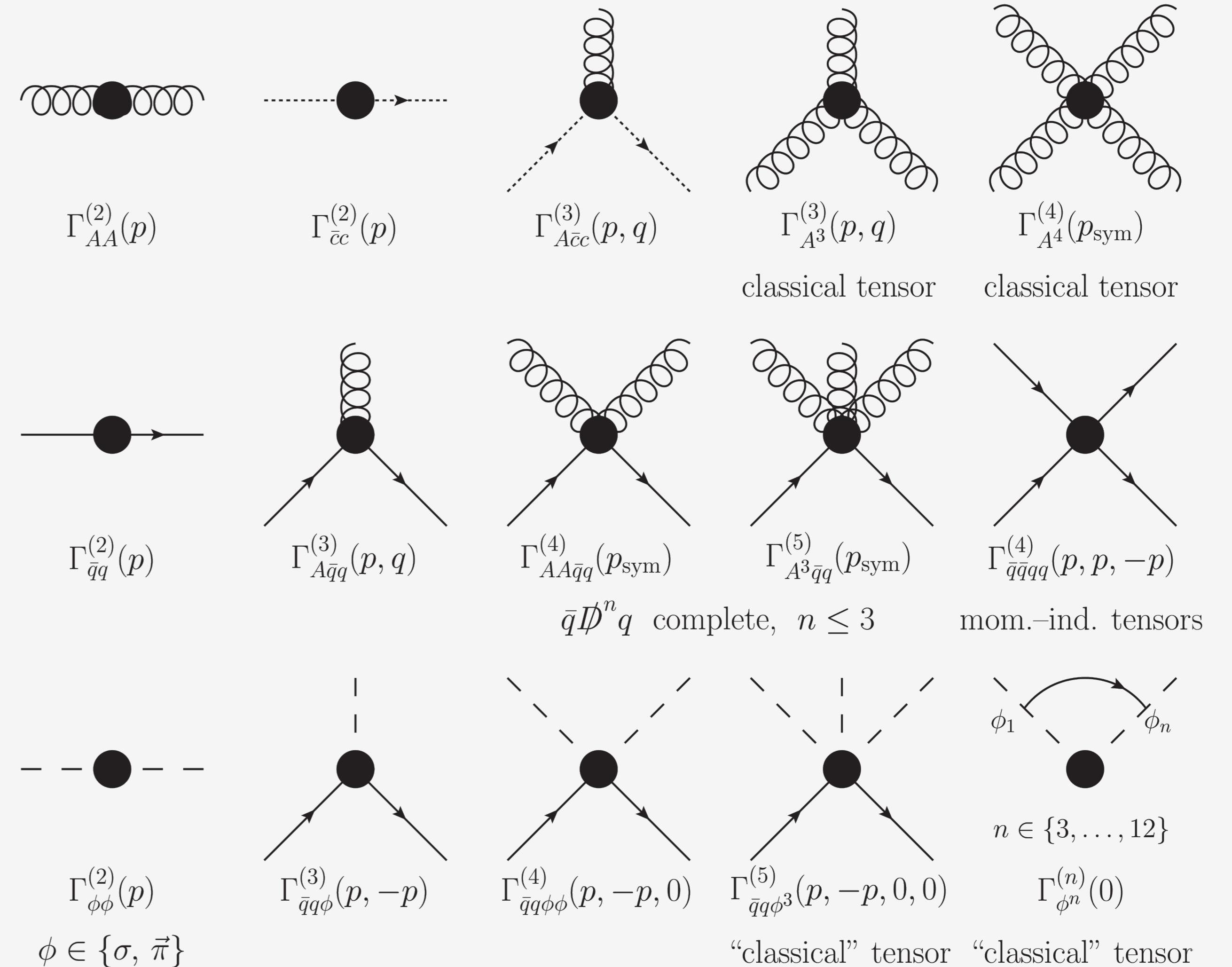


- Full 1PI effective action at vanishing cutoff scale, $\Gamma_{k=0} = \Gamma$

Vertex Expansion of Effective Action

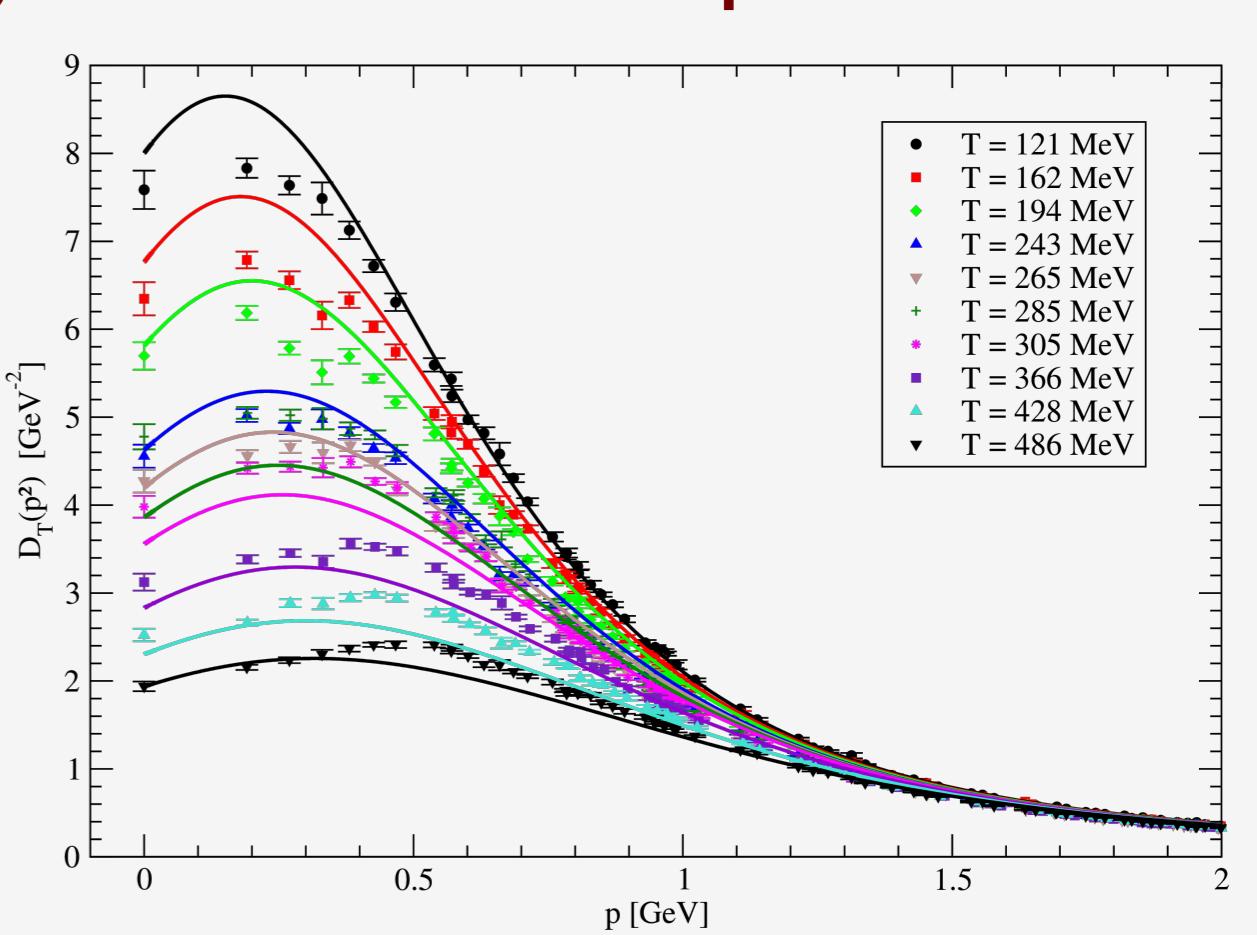
- Systematic approximation by vertex expansion:

$$\Gamma[\Phi] = \sum_n \int_{p_1, \dots, p_{n-1}} \Gamma_{\Phi_1 \dots \Phi_n}^{(n)}(p_1, \dots, p_{n-1}) \Phi^1(p_1) \dots \Phi^n(-p_1 - \dots - p_{n-1})$$



Outlook: Yang-Mills Theory at Finite Temperature

- Finite T: $\int \frac{dp_0}{2\pi} \rightarrow T \sum$
- same truncation as in vacuum YM
- plot: magnetic component from Silva et. al. Phys.Rev. D89 (2014) compared to averaged components from FRG
- upcoming: splitting of magnetic and electric components



Outlook: QCD with N_f = 2

- Fully coupled glue and matter sector
- extended truncation (cf. Vertex Expansion of Effective Action)

