Matter-Gluon interaction

Axel Maas

4th of November 2010
The Many Faces of QCD
Ghent
Belgium

(Scalar) Matter-Gluon interaction

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PRELIMINARY

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Why scalar-gluon interactions?

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- **Use a combination of lattice and functional methods**
  - **Lattice provides (comparatively) good reliability**
  - **Functional methods can go where lattice cannot**
    - **Density, massless fermions, real time, disparate energy scales**

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  - Structure less complicated for scalars
    - But also much progress for fermions

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  - **Wilson loops blind to the Lorentz structure**
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- Scalars could play a role in, or beyond, the standard model
  - Higgs and generalizations, sfermions,...
- Field theoretically important
  - Higgs mechanism and Higgs vs. confinement
  - Triviality in complex theories

Interesting systems

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- Unquenched fundamental scalars
  - Is the the Higgs mechanism and confinement different?

Quenched scalars

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    - Mass is quadratic divergent – necessary also in lower dimensions
    - Renormalize to tree-level at 2 GeV [Maas, 2010]

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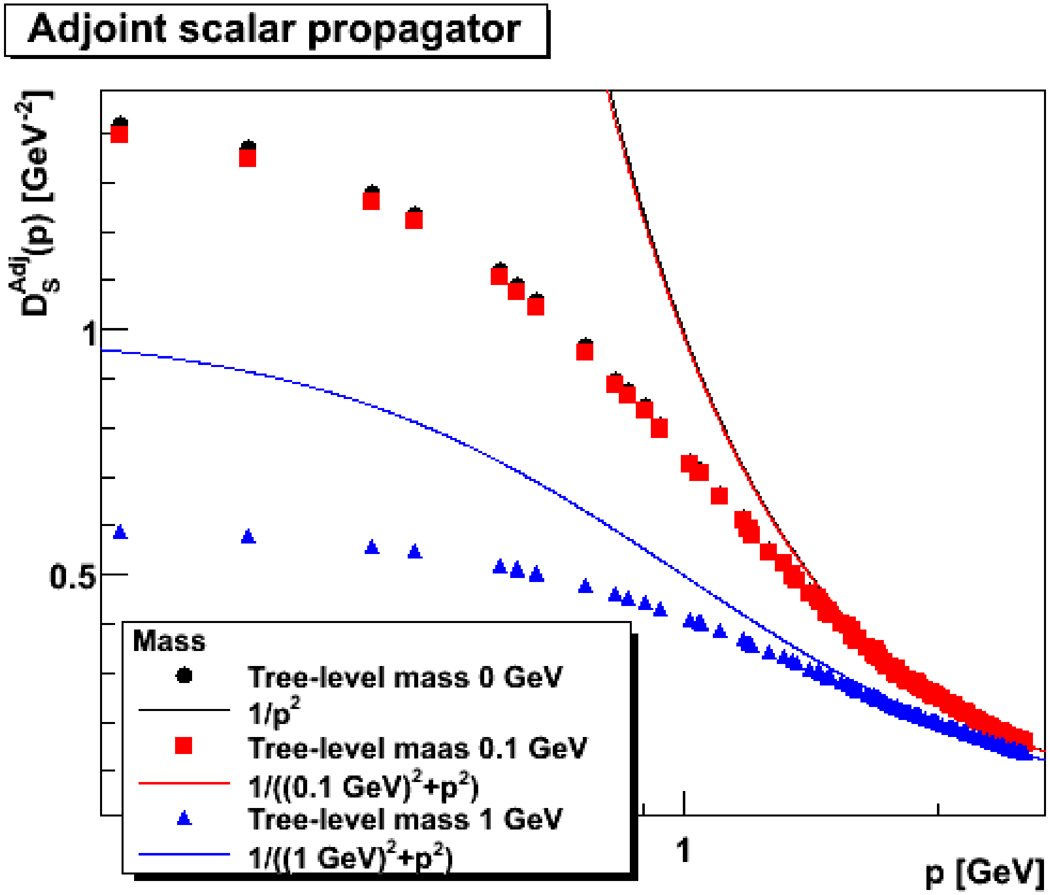
- Compare two, three, and four dimensions
  - Two scaling-like, four decoupling-like

2d: Adjoint vs. Fundamental

2d, L=5.7 fm, a=0.22 fm
[Maas unpublished]



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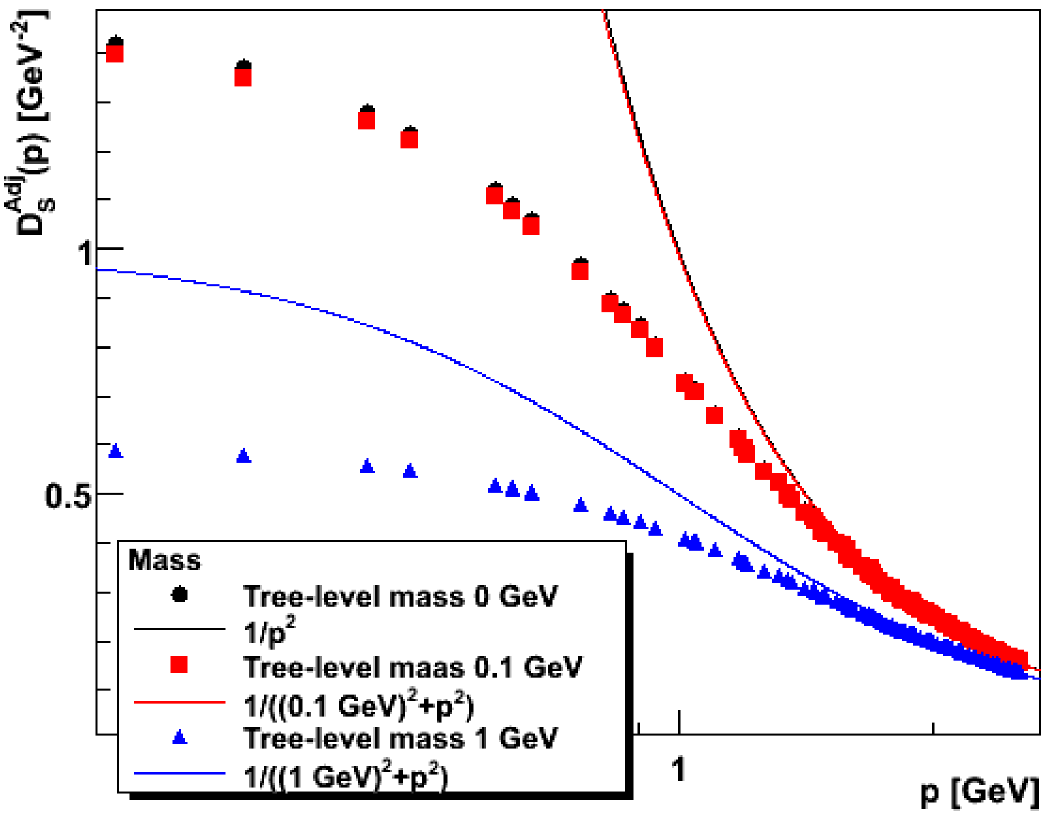
Adjoint scalar propagator



- **Screening-mass unequal renormalized mass**
  - **Mass-dependent screening mass generation**

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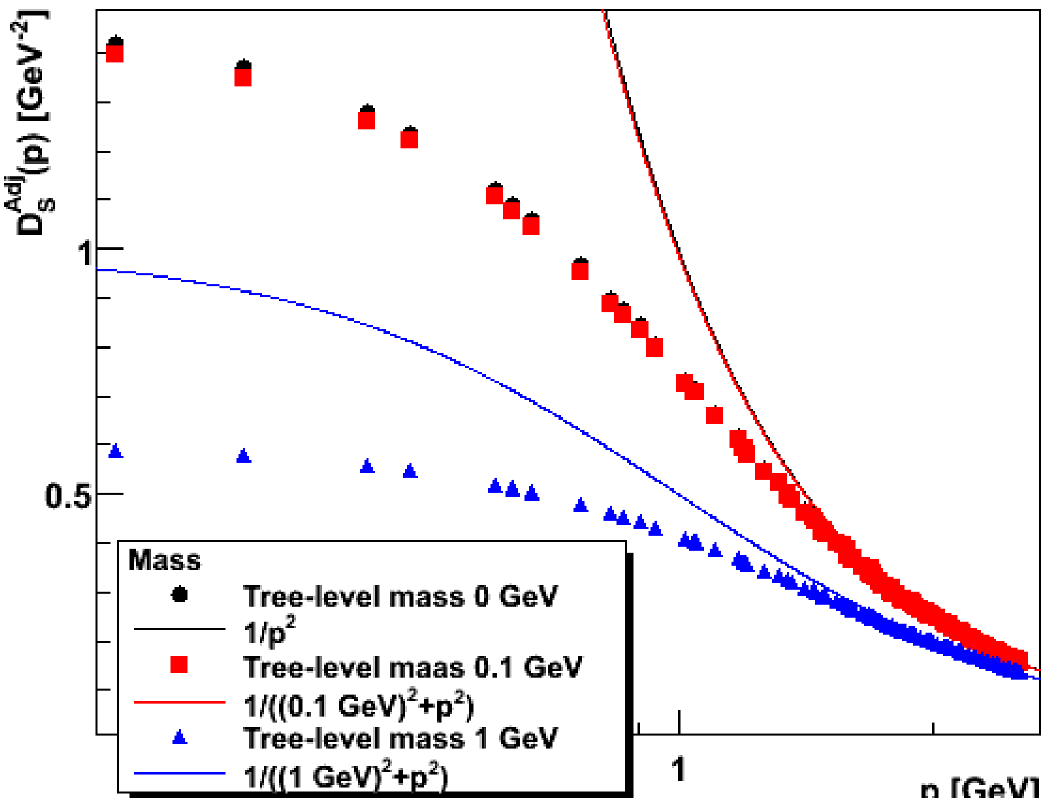
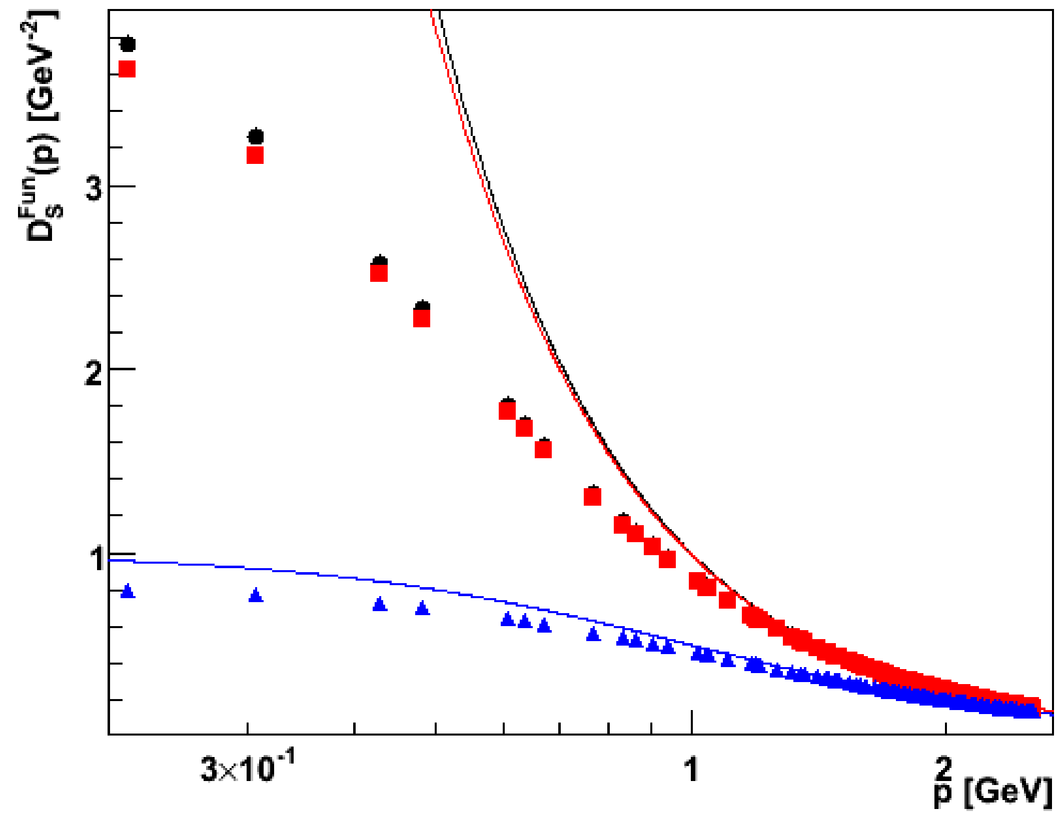


Fundamental scalar propagator

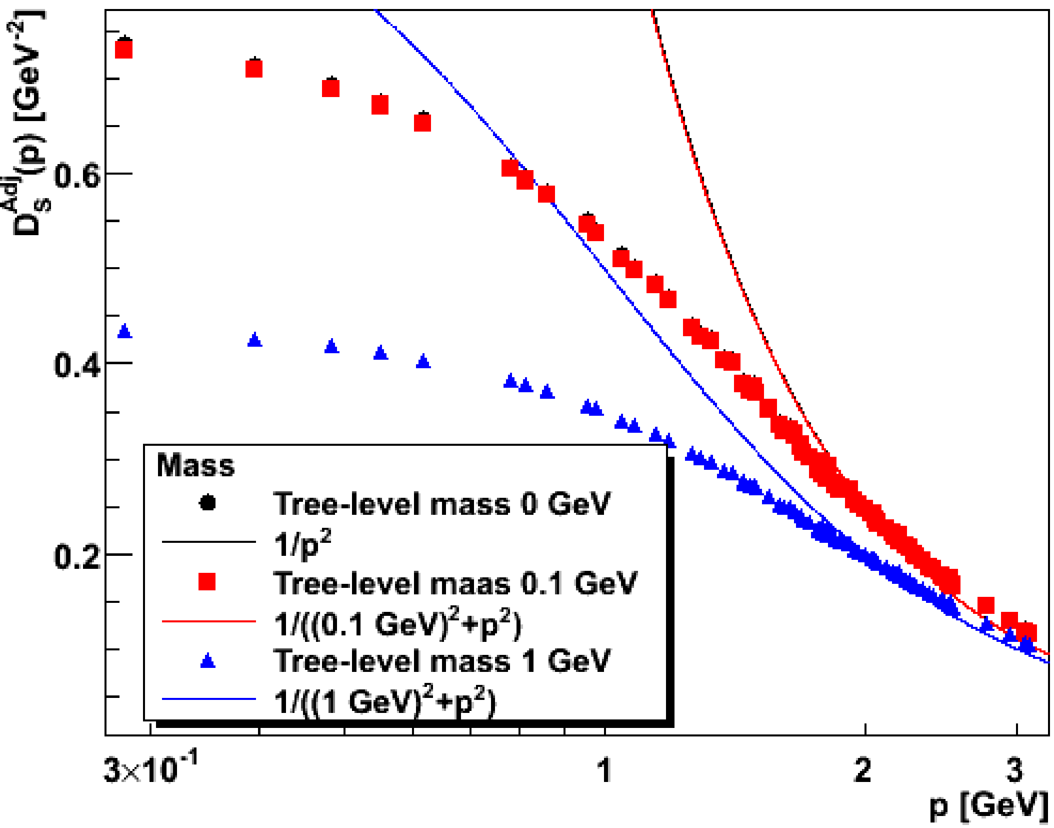


- **Screening-mass unequal renormalized mass**
  - **Mass-dependent screening mass generation**
- **Fundamental similar, but possibly different IR slope**

3d: Adjoint vs. Fundamental

3d, L=4.4 fm, a=0.22 fm
[Maas unpublished]

Adjoint scalar propagator



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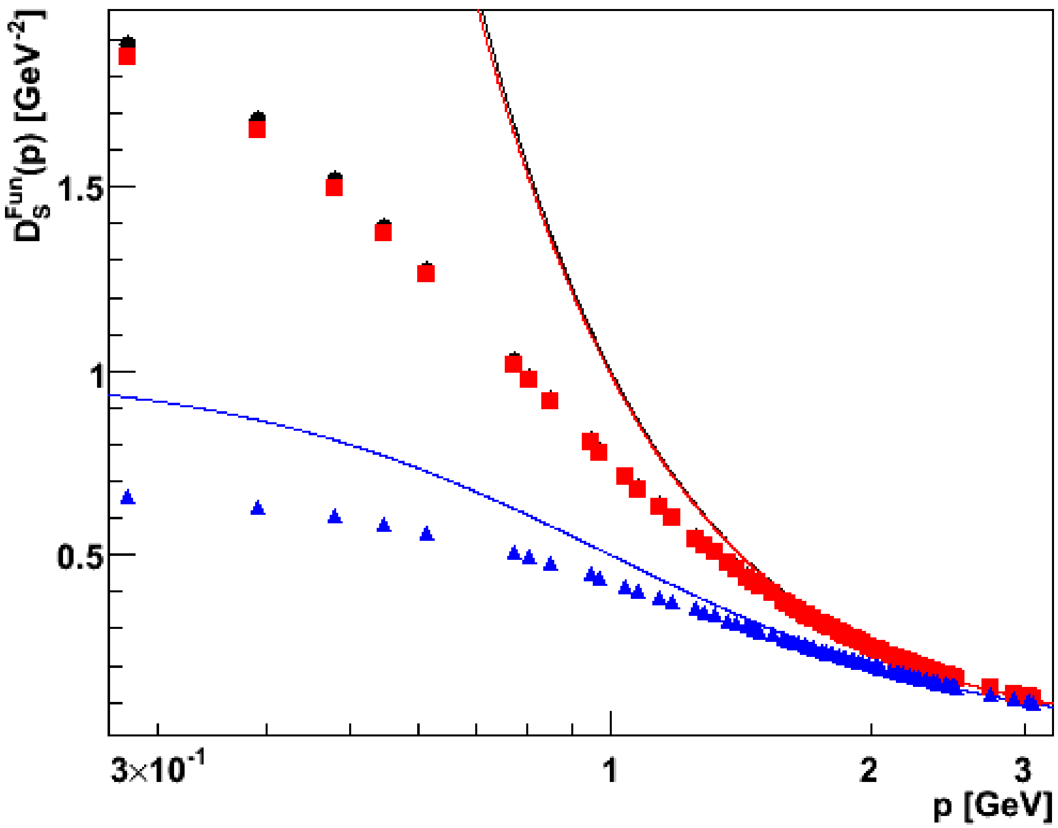

- Screening masses larger
- Slope difference less pronounced
- More UV modifications

4d: Adjoint vs. Fundamental

4d, L=3.1 fm, a=0.22 fm
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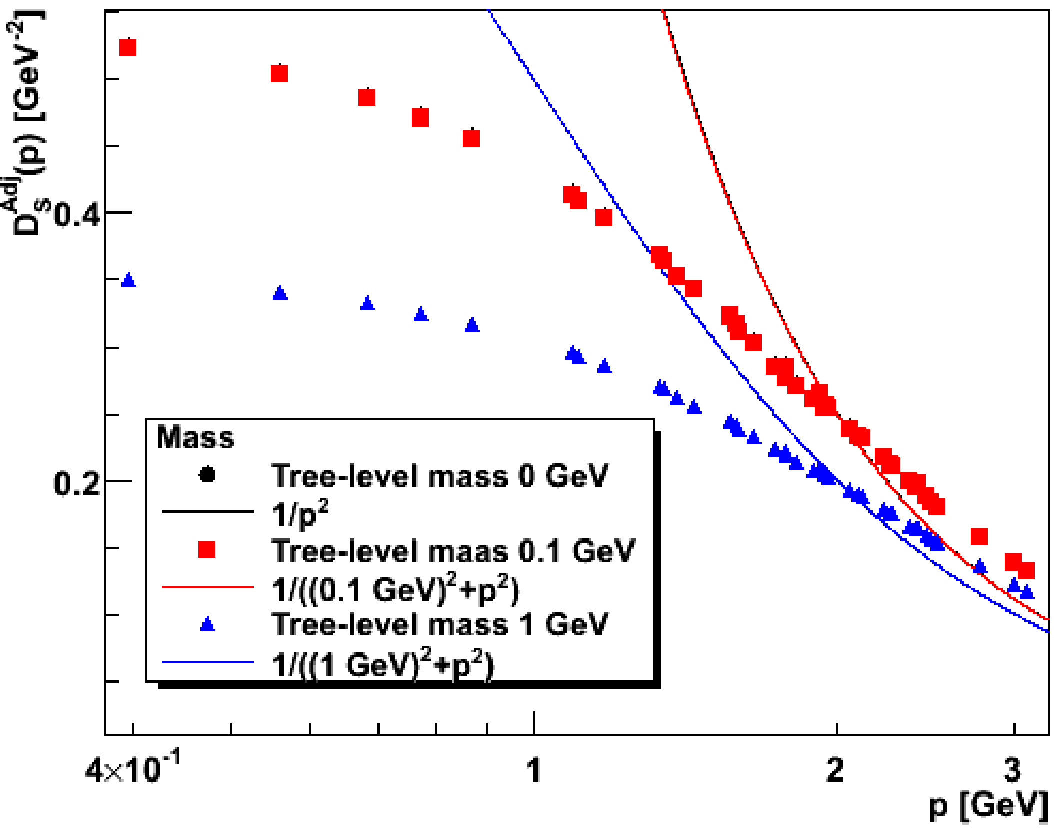
Adjoint scalar propagator



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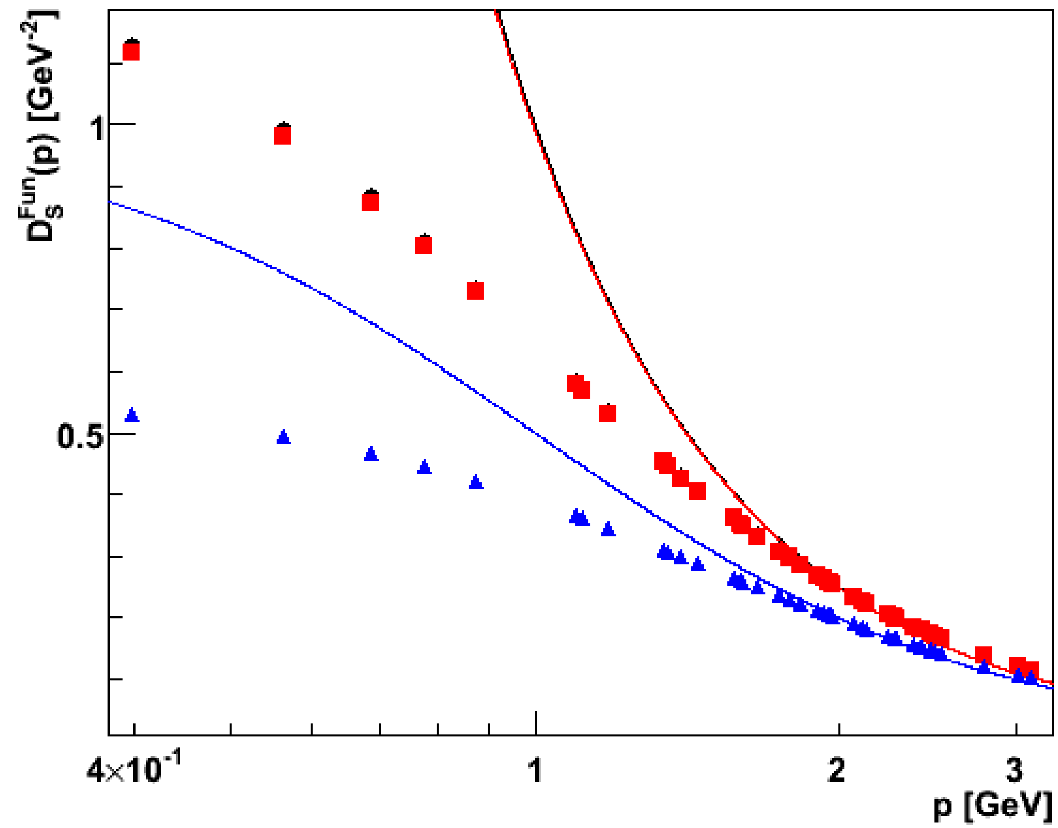


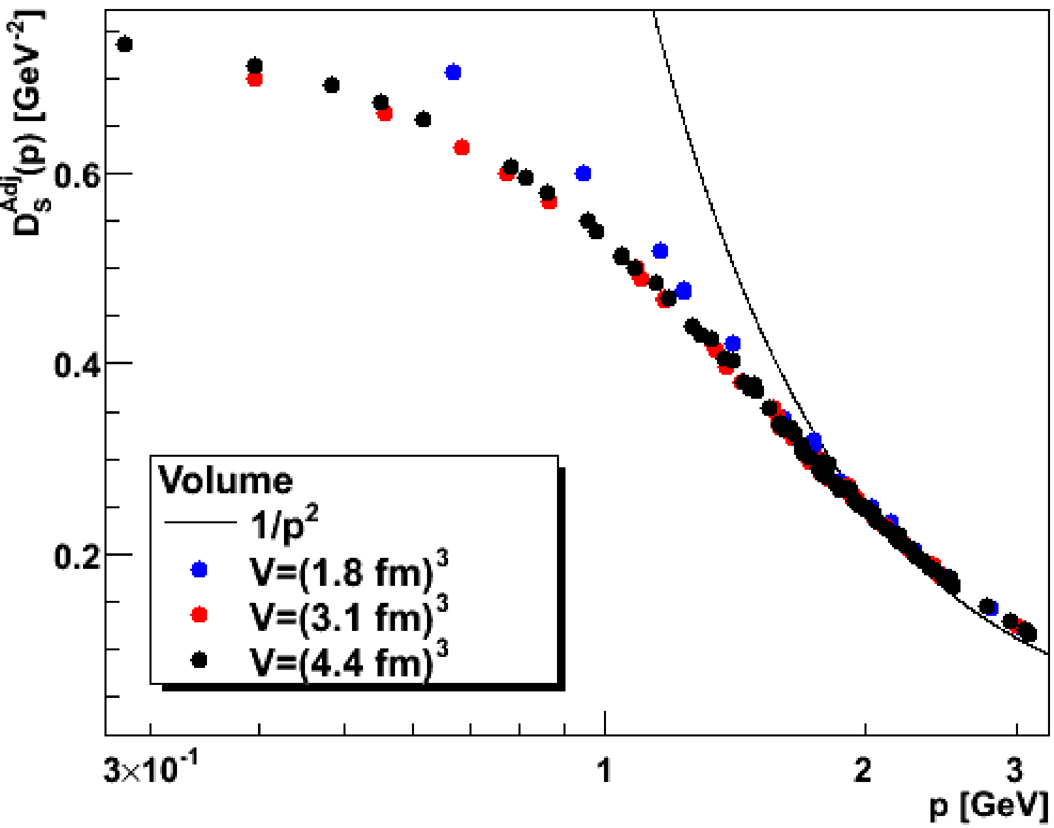
- **Screening masses even larger**
- **Significant ultraviolet modifications**
- **Slope difference less pronounced**

UNI GRAZ

Volume dependence mass zero

3d, a=0.22 fm
[Maas unpublished]

Adjoint scalar propagator



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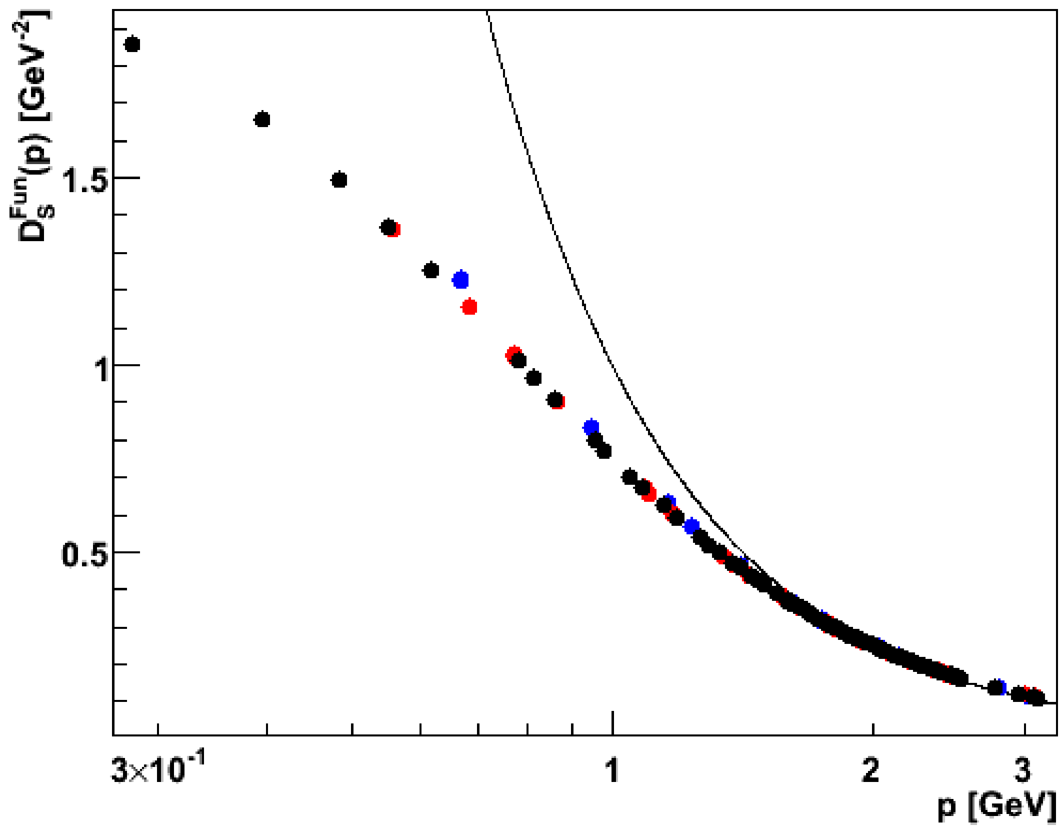
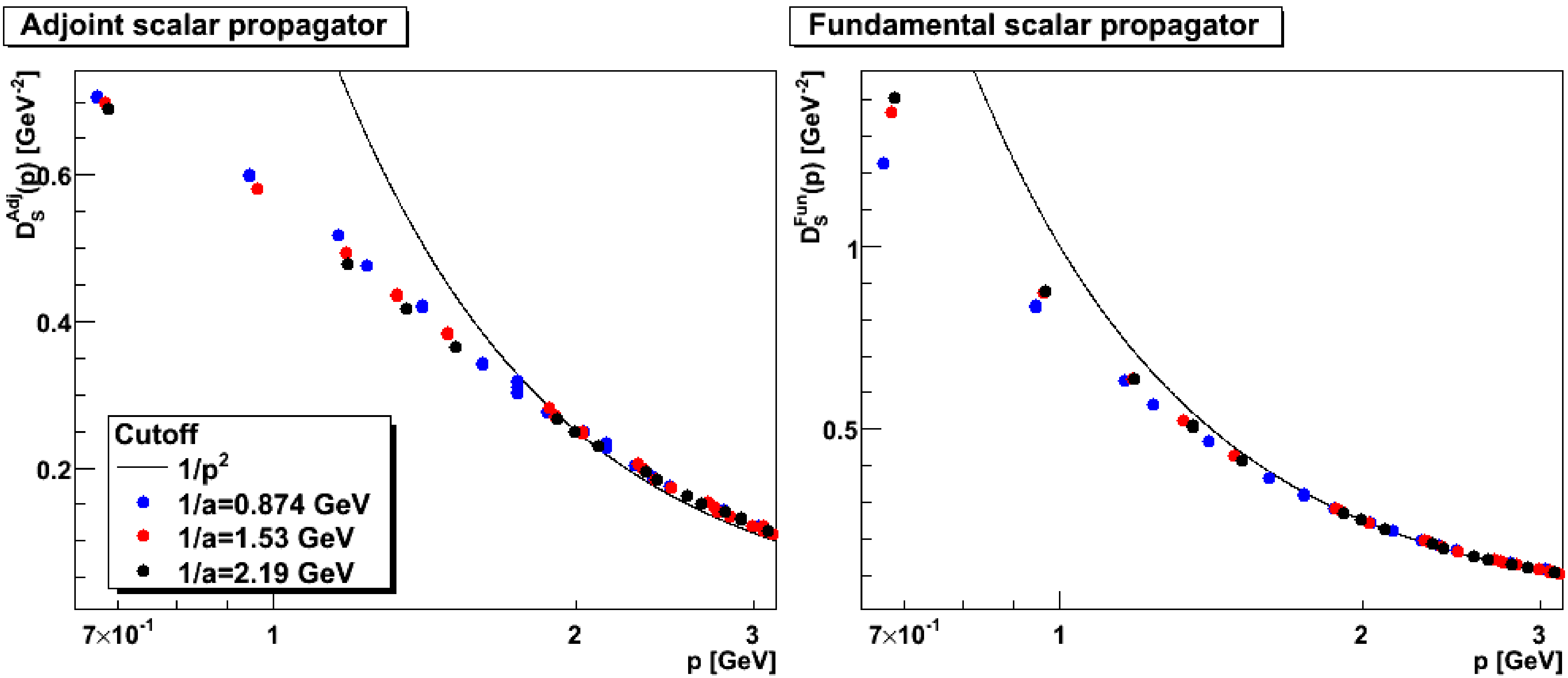


- **No systematic volume effects (yet?)**
- **Adjoint scalars stronger affected**
- **Larger masses show less effect**

Cutoff dependence mass zero

3d, L=1.8 fm
[Maas unpublished]



- **Little effect for the adjoint**
- **Some systematic effect for fundamental**
- **Requires detailed investigations**

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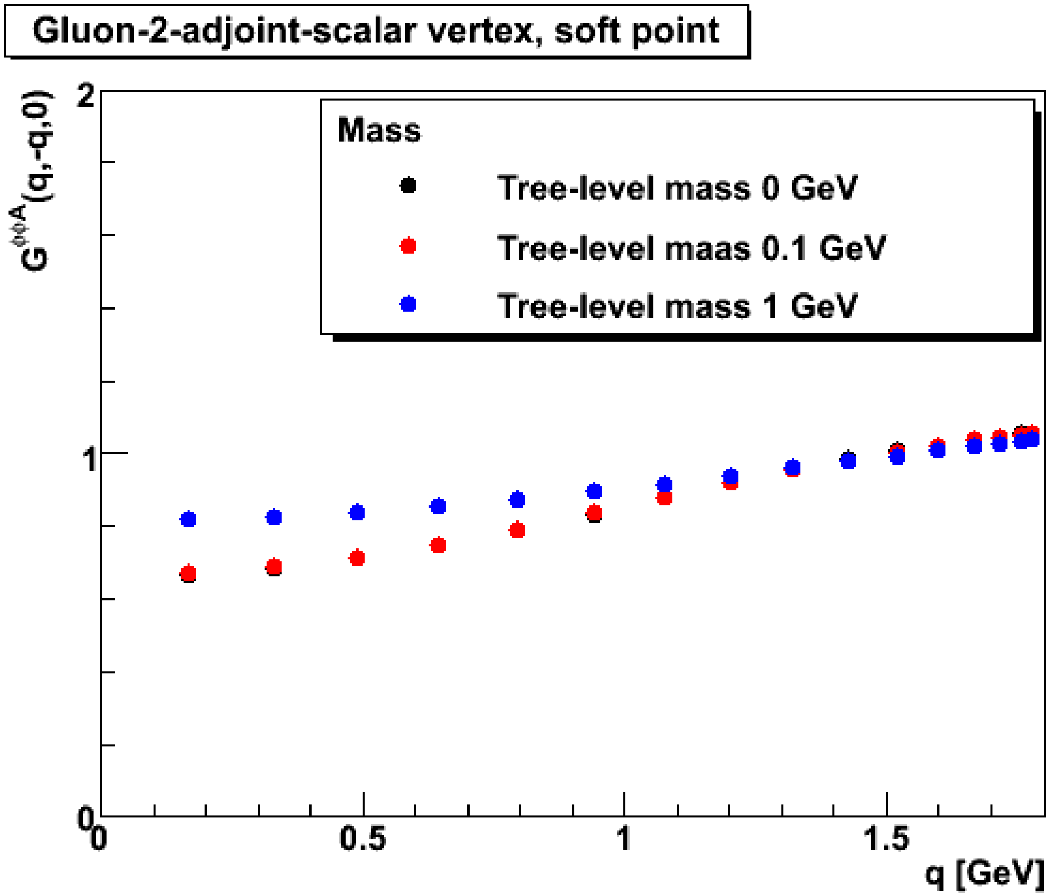
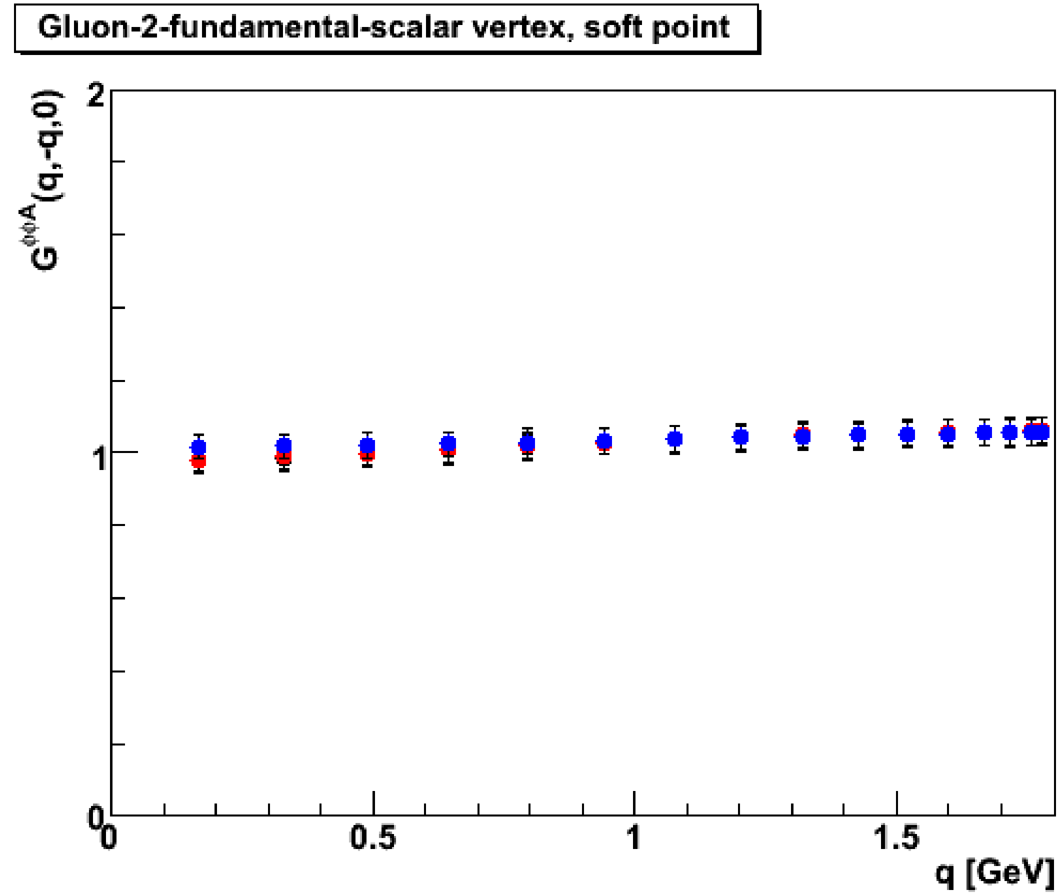
  - Configuration with zero gluon momentum
    - Symmetric and orthogonal similar

2d: Gluon-2-scalar vertex

2d, L=7.5 fm, a=0.22 fm

[Maas unpublished]



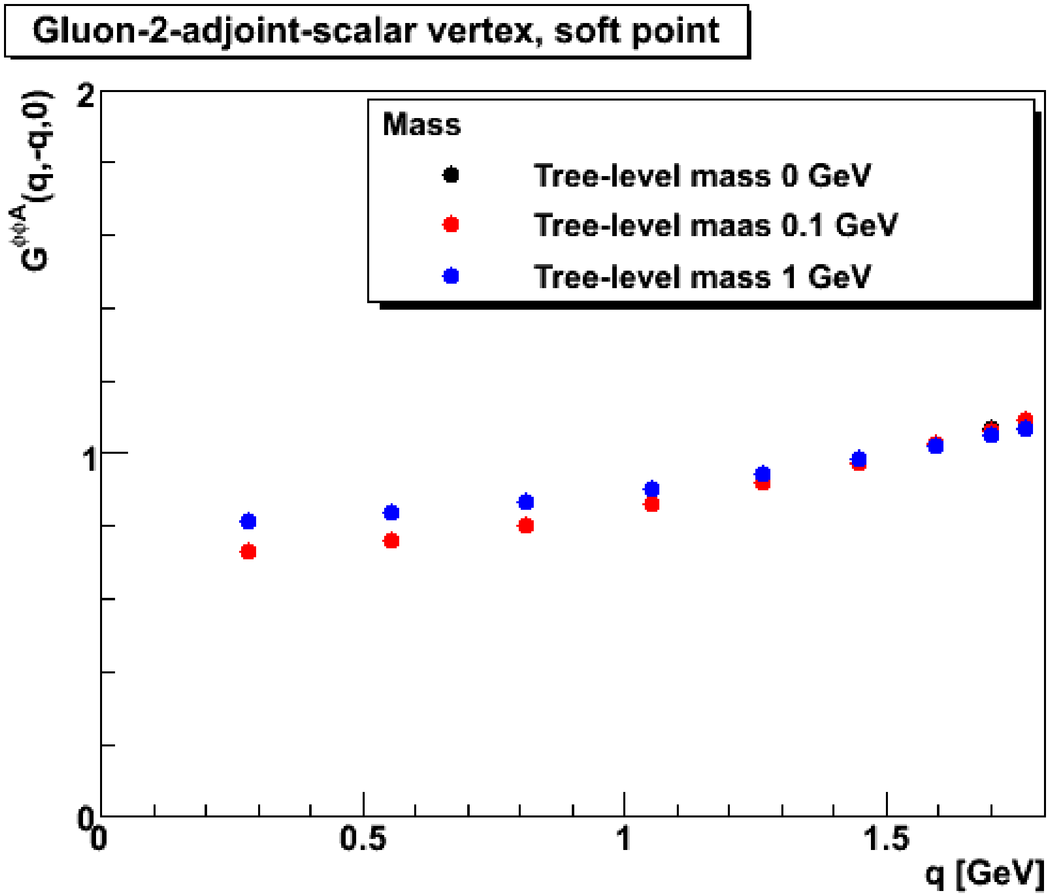


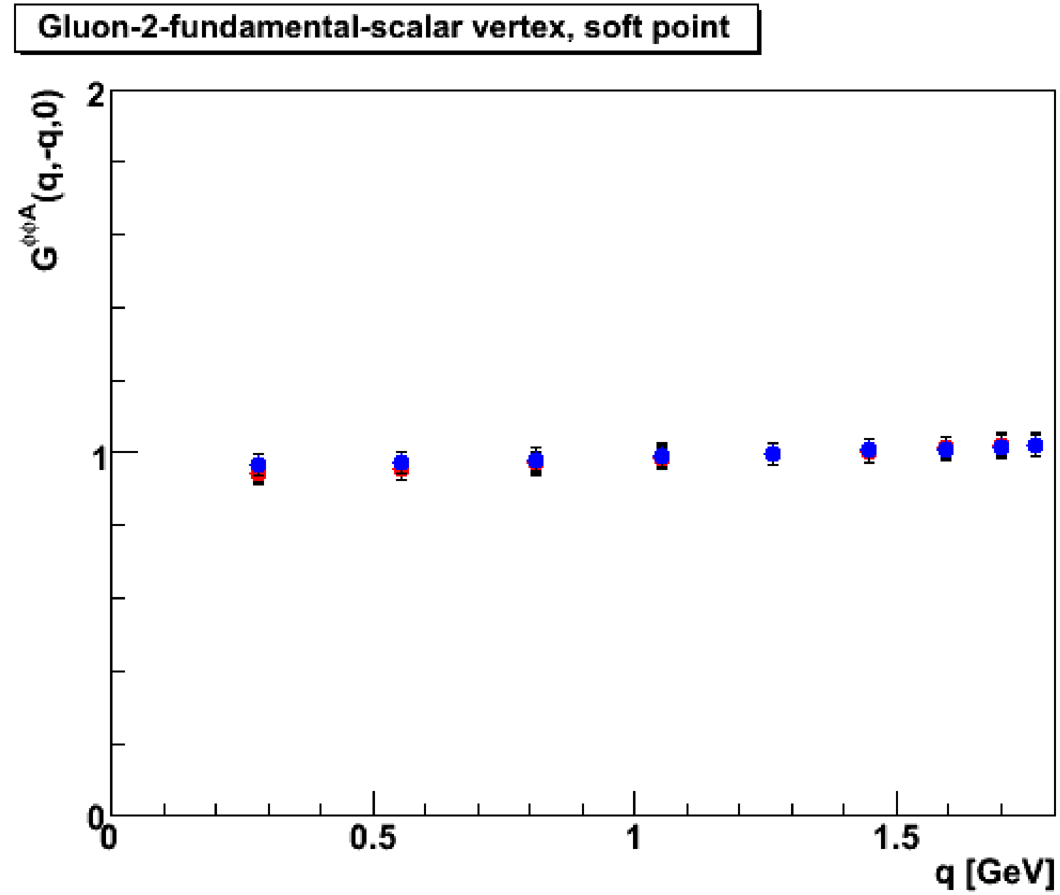
- **Almost no difference to tree-level (=1)**
  - **Same for vanishing gluon/orthogonal scalar momenta**
- **No divergences**

3d: Gluon-2-scalar vertex

3d, L=4.4 fm, a=0.22 fm

[Maas unpublished]





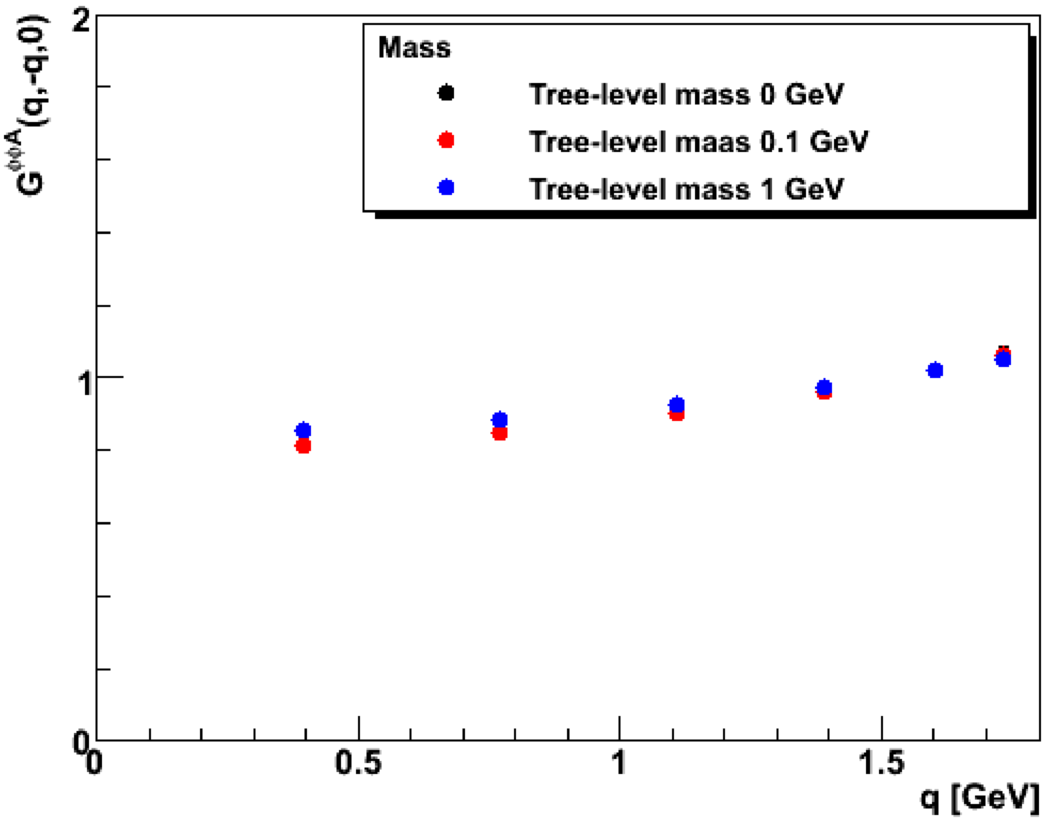
- **Very similar to two dimensions**
- **Some infrared suppression in the adjoint case**
- **Largely independent on tree-level mass**

4d: Gluon-2-scalar vertex

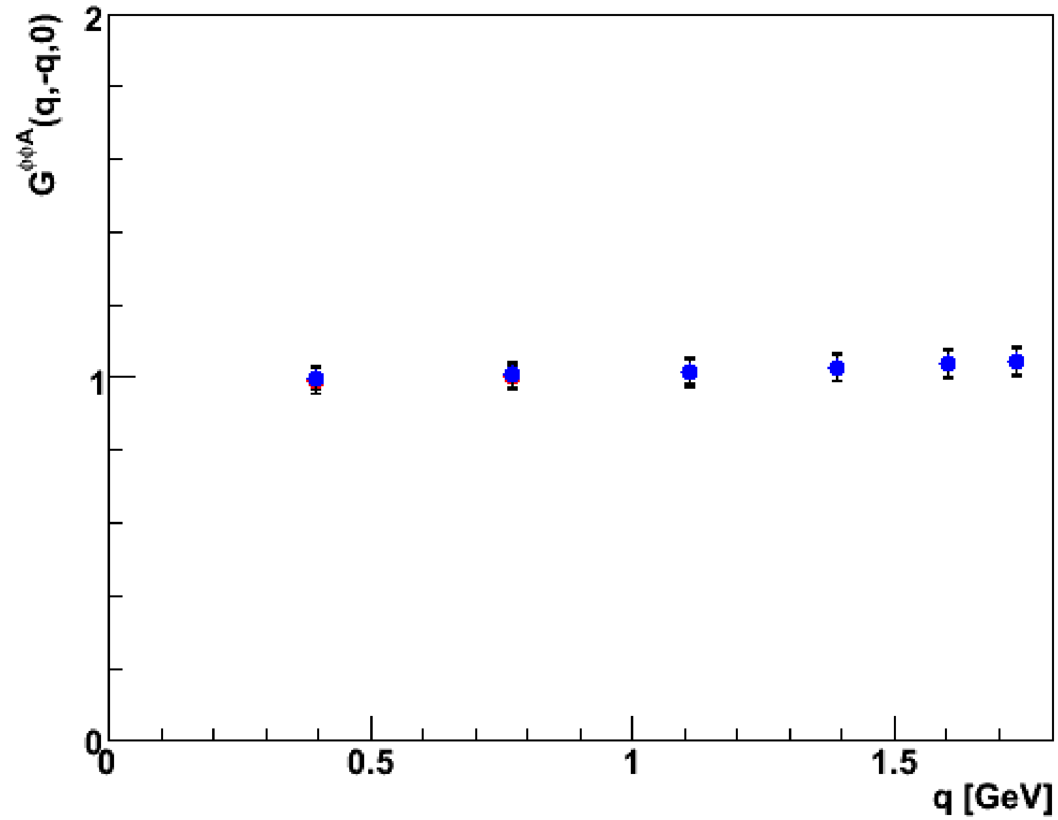
4d, L=3.1 fm, a=0.22 fm

[Maas unpublished]

Gluon-2-adjoint-scalar vertex, soft point



Gluon-2-fundamental-scalar vertex, soft point



- **Very similar to two and three dimensions**
- **Adjoint and fundamental case renormalize differently**
  - **Increases vs. decreases with cut-off**

Volume dependence mass zero

3d, a=0.22 fm

[Maas unpublished]

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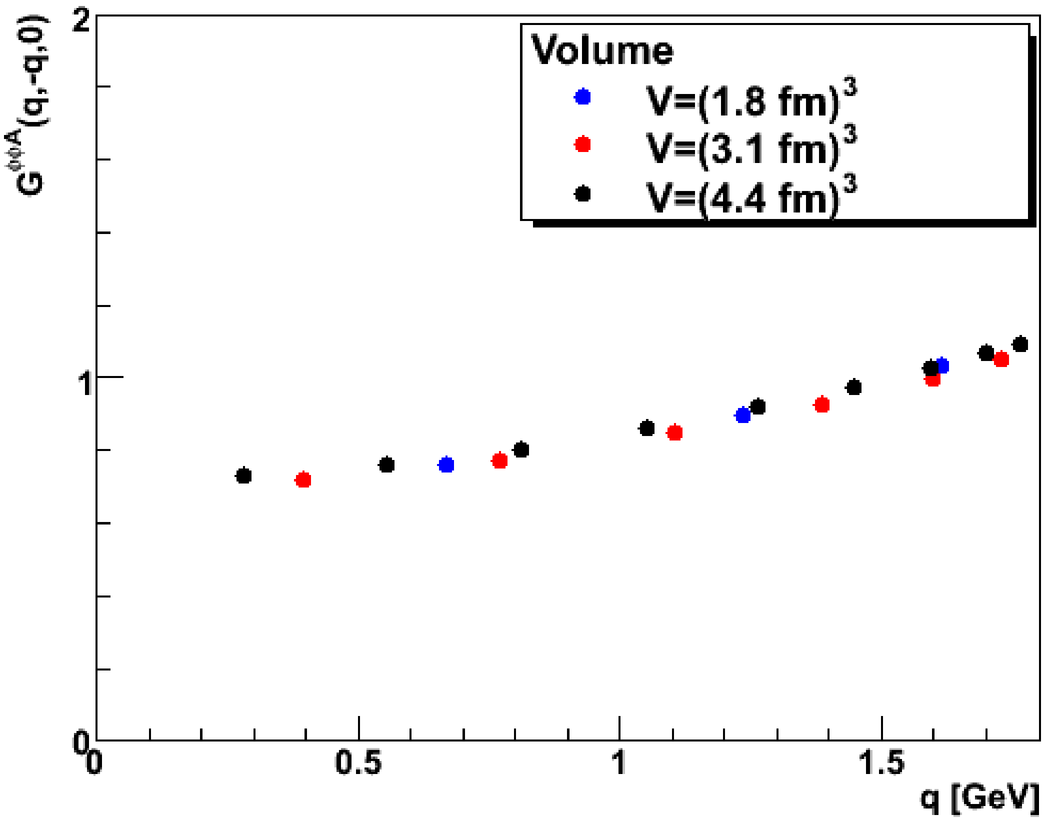

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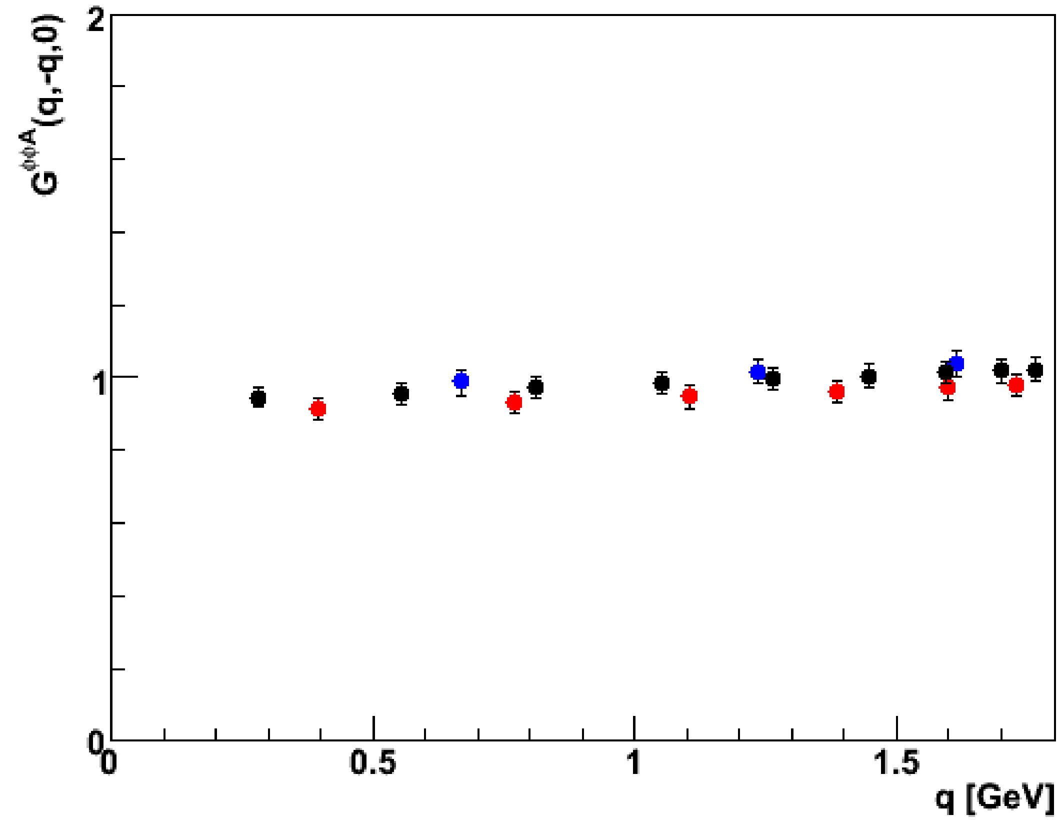

- **Adjoint vertex shows almost no effect**
- **Fundamental vertex shows almost no effect**

Cutoff dependence mass zero

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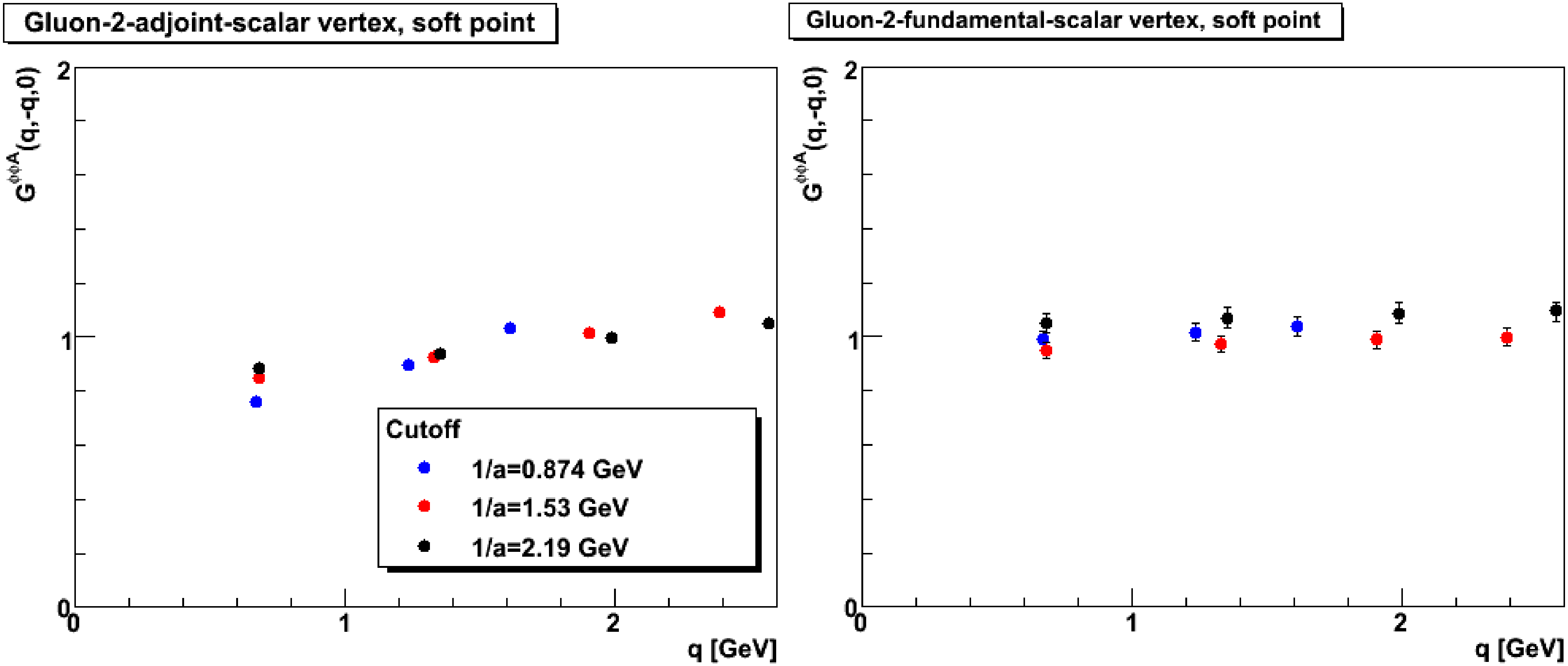

- **Reduces adjoint vertex suppression**
- **Fundamental vertex little affected**
- **Also some significant effects up to momenta of order 2/a for small 1/a**

Quenched summary

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  - Dynamical mass generation seems to be present

Dynamical fundamental scalars

- **Scalar matter**

$$L=-\frac{1}{4}F_{\mu\nu}F^{\mu\nu}-\phi^{+}\left(\frac{1}{2}D_{\mu}D^{\mu}+m^{2}\right)\phi+\lambda\left(\phi^{+}\phi\right)^{2}-\bar{c}\,\partial^{\mu}D_{\mu}c$$

$$D_{\mu}=\partial_{\mu}-ieA_{\mu}^{a}\tau^{a}$$

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- **Self-interaction not present for quarks**
  - **Dependency not fully explored**
    - **But generically weak at large coupling**
  - **Triviality? Interactions are gauge-dependent!**

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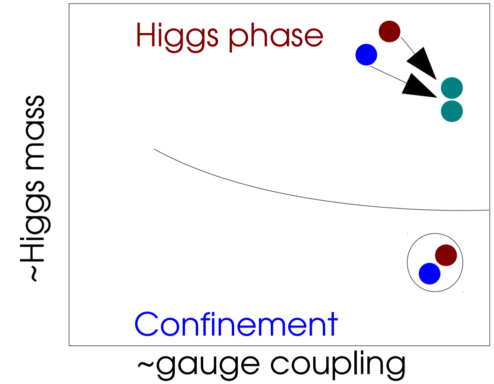
  - **Problem: Higgs mechanism**
    - **No (gauge-invariant) difference of confinement and Higgs phase**
    - **Is this influencing the string breaking compared to QCD?**



[Fradkin & Shenker, 1979]

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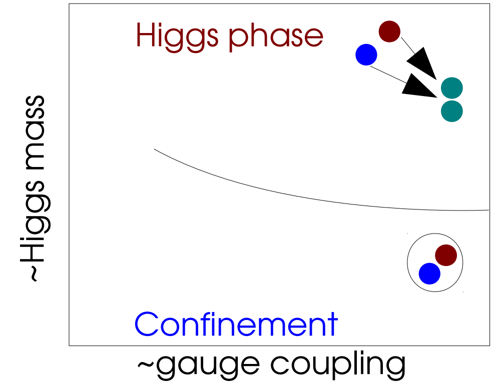


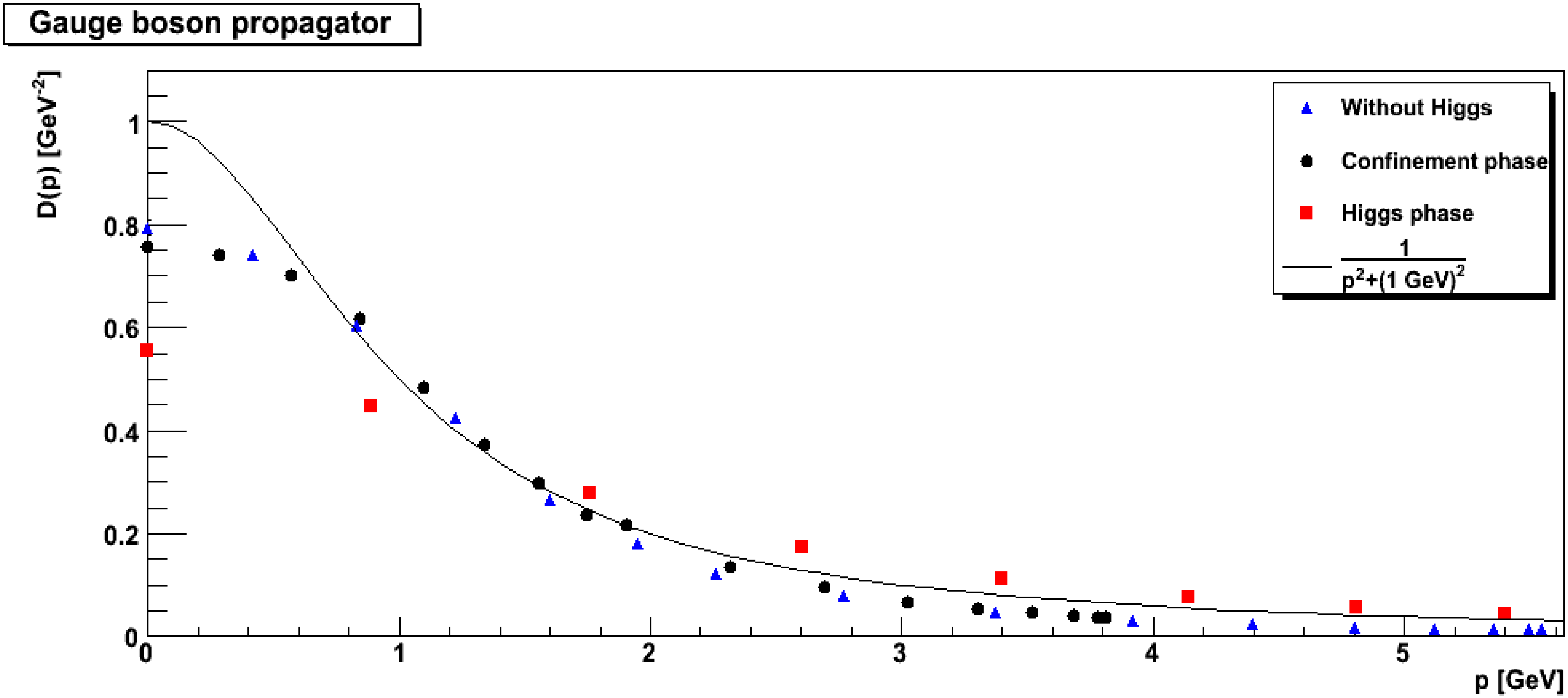
[Fradkin & Shenker, 1979]

- **Propagators in minimal Landau-'t Hooft gauge**

Gauge bosons

4d, unquenched: 24^4 beta=2.0, kappa=0.25, lambda=0.5
4d, Higgs, 24^4 beta=2.3, kappa=0.32, lambda=1.0
4d, quenched: 24^4 beta=2.2

[Maas 2010]



- **Little qualitative difference – impact of matter and 'phase' small**
- **As in QCD** [Fischer, Alkofer PRD03, Kamleh et al. PRD07]

Ghosts

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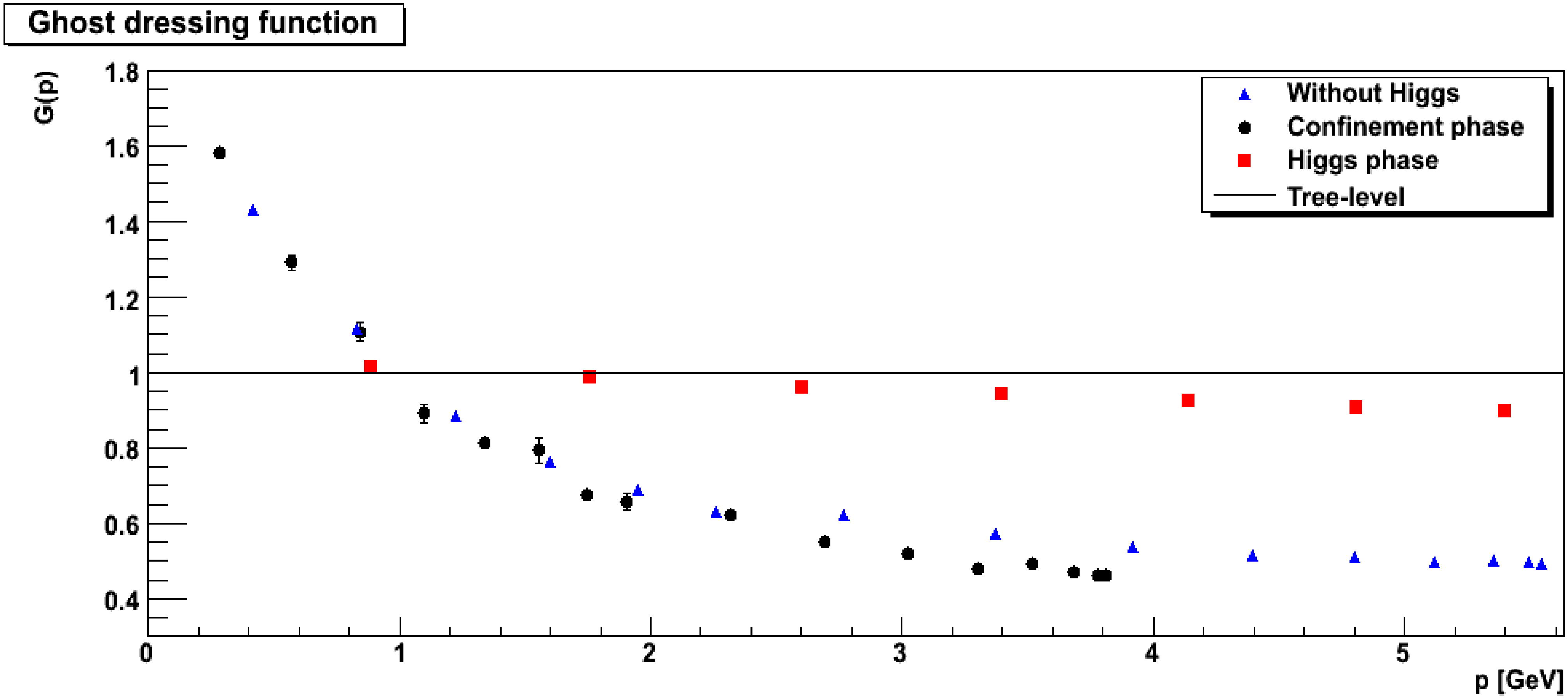

- **Significant impact of 'phase', but not of matter**
- **Much more photon-like in the Higgs 'phase'**
  - **As in Coulomb gauge** [Greensite, Olejnik, Zwanziger 2004]

Scalar

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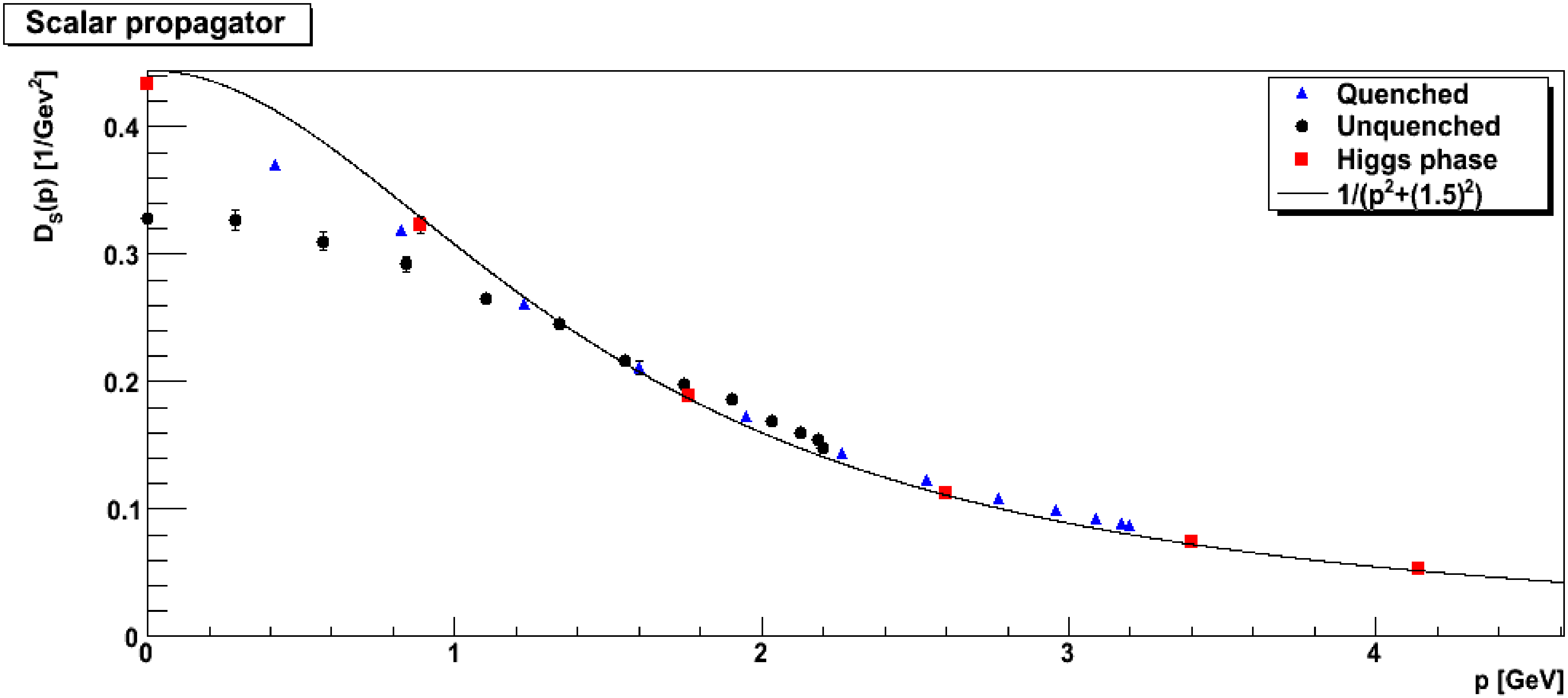

- **Close to tree-level with renormalized mass**
- **Little difference between the 'phases'**
- **Again dynamical mass generation**

Running coupling

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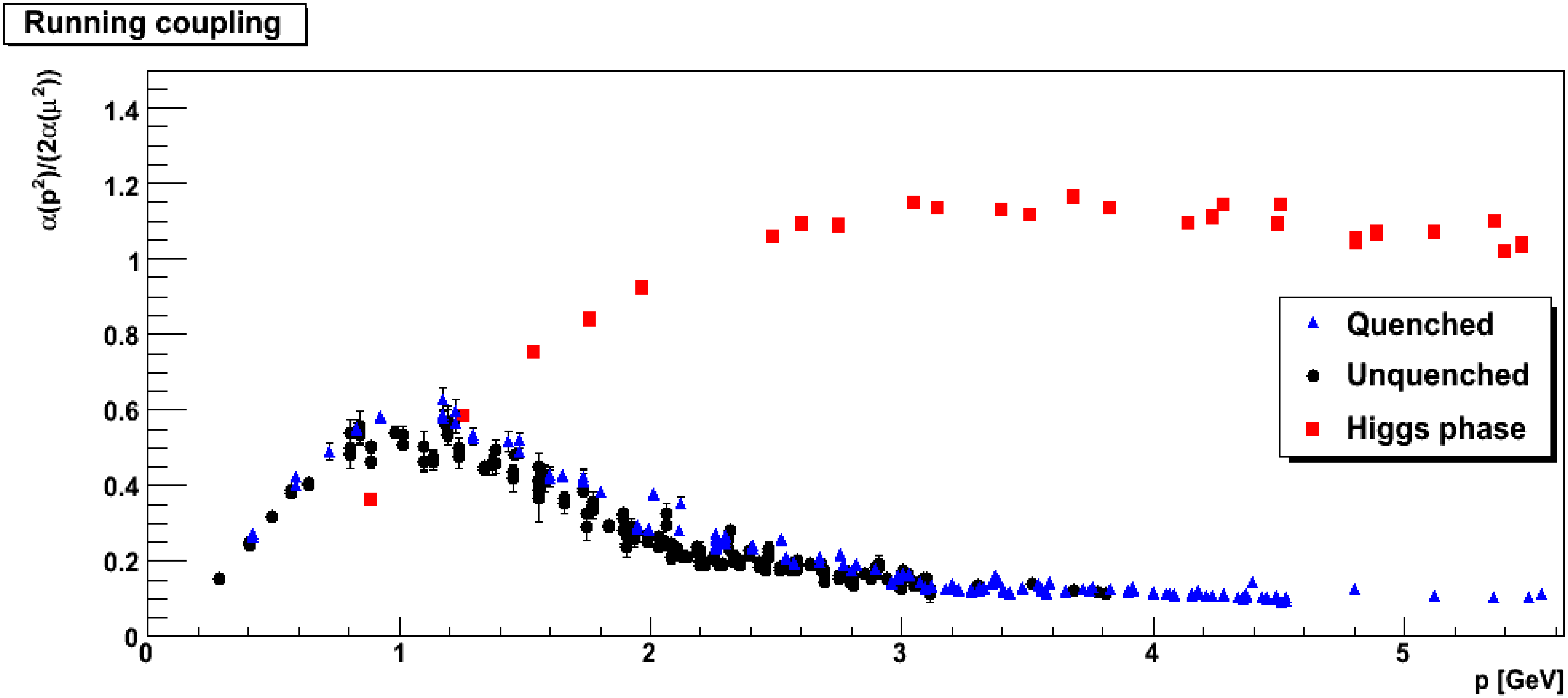

- **No qualitative difference seen**
- **Screening leads to suppression of interactions at small momenta**

Summary

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Modified coupling

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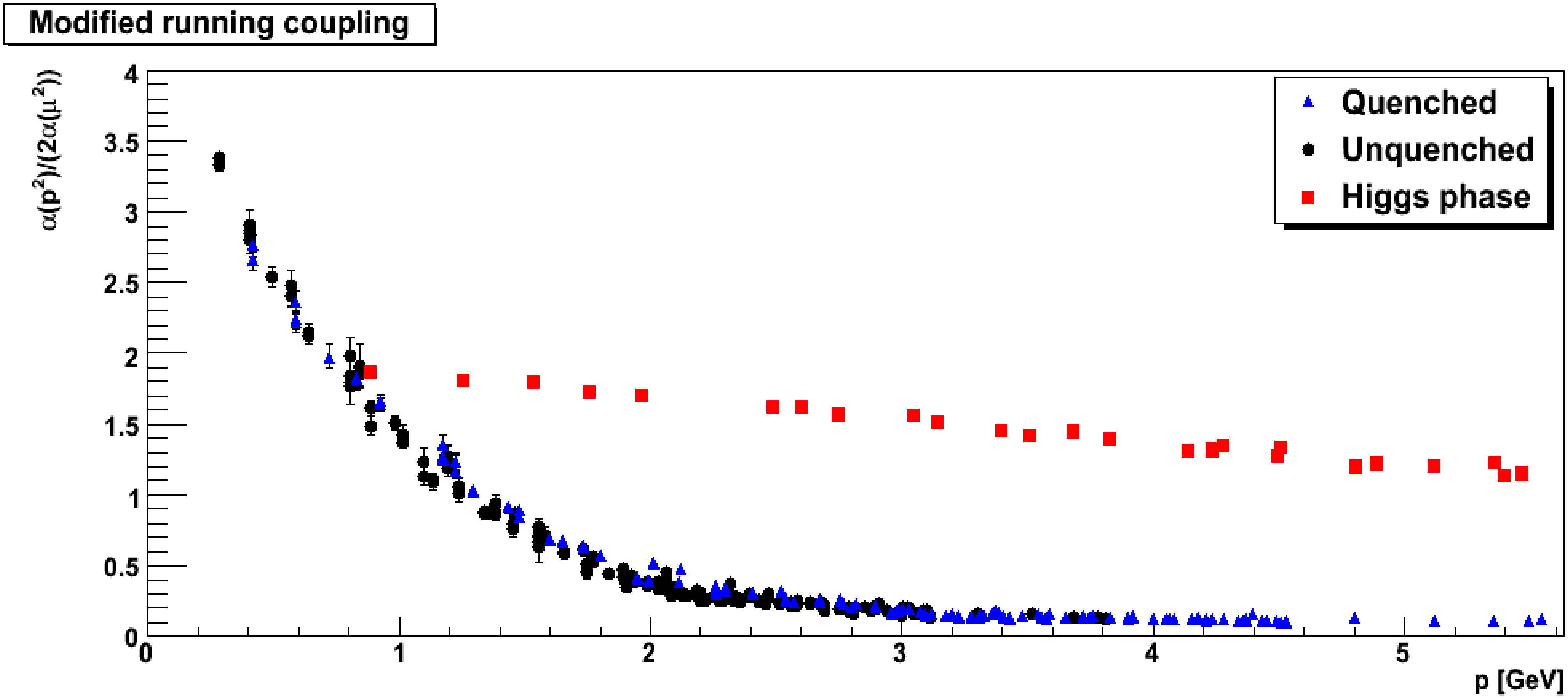

- **Infrared parameter is the screening mass of the gluon**
- **No qualitative difference – both finite**