

Overview

- Set-up and problems

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- Describing elementary particles

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 - Correlation functions

[Maas 1106.3942]

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- Gauge bosons in minimal walking technicolor

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- Gauge bosons in minimal walking technicolor
 - Propagators
 - Vertices
 - Zero mass limit
- Summary

[Maas 1106.3942]

[Maas JHEP '11]

The basic task

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 - QCD, technicolor, ...
 - In general non-factorizable

The task at hand

[Andersen et al. EPJ+ 2011]

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 - **Strongly interacting chiral gauge theory when coupled to the standard model**

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- Gauge-invariant bound states of tops, Ws, Higgses... may be rather unstable

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- Non-perturbative extension
 - Correlation functions central element

Describing a theory

[Maas 1106.3942
Fischer JPG 2006]

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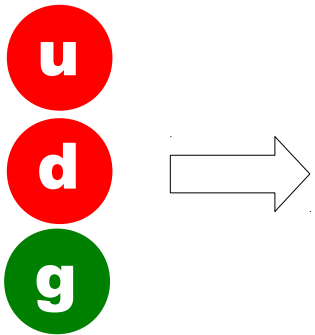
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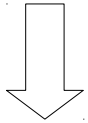
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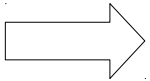
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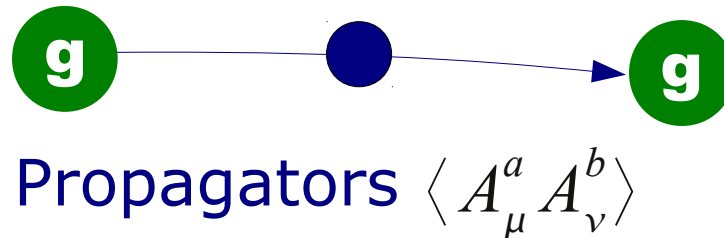


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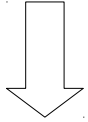
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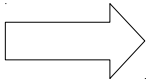


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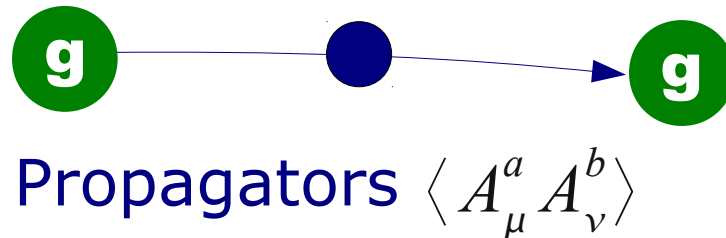


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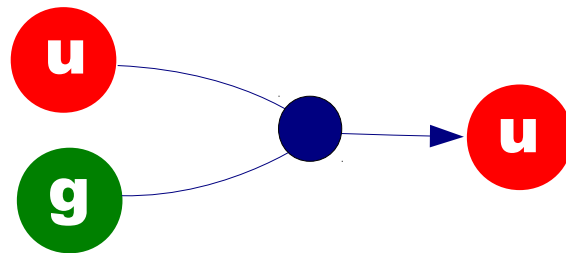
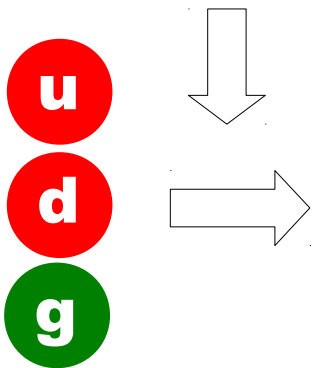
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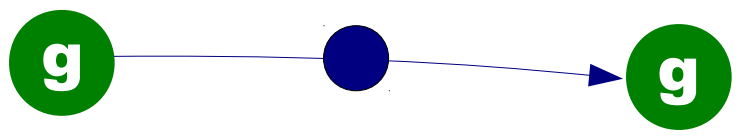
Quantization



Interaction vertices $\langle \bar{\Psi}_i A_\mu^a t_a^{ij} \Psi_j \rangle$

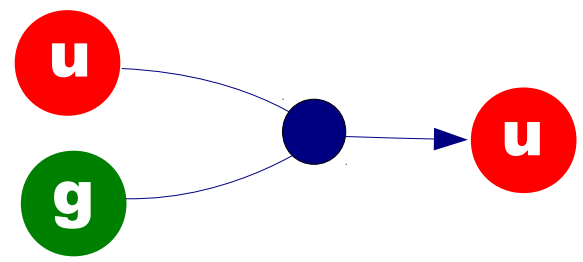
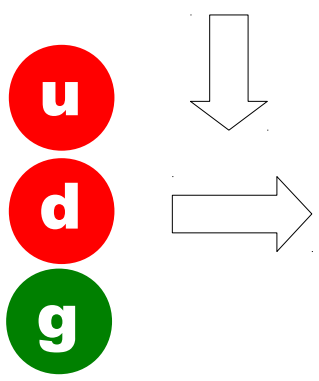
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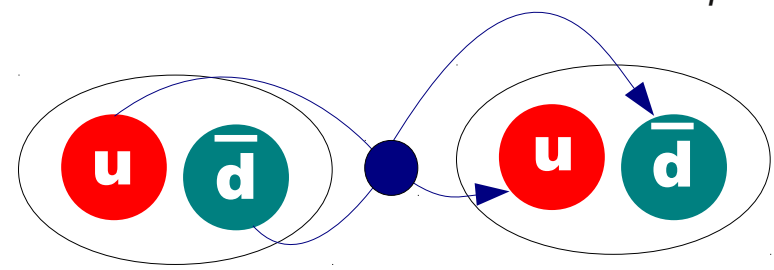


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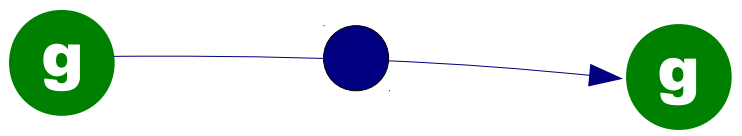


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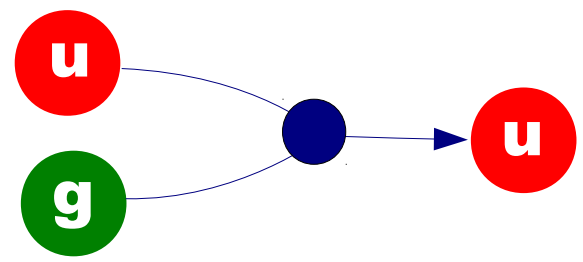
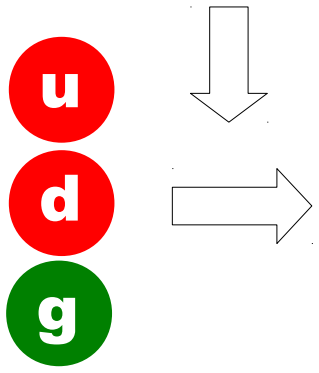
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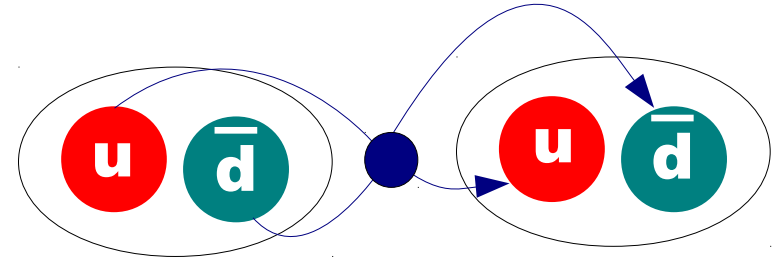


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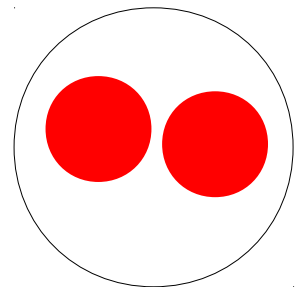
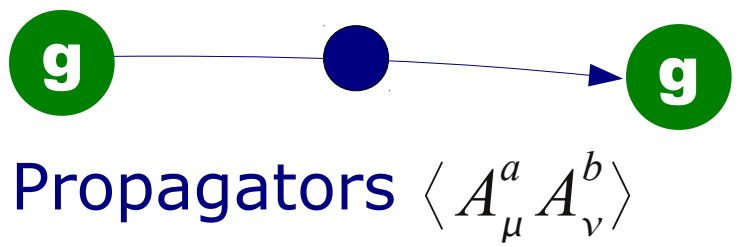


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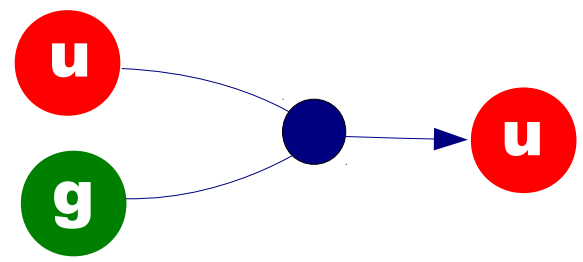
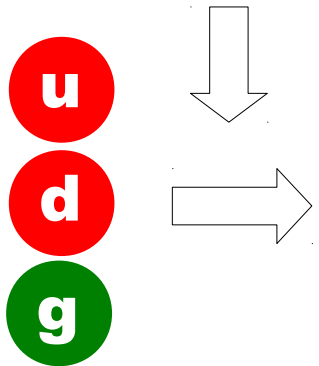
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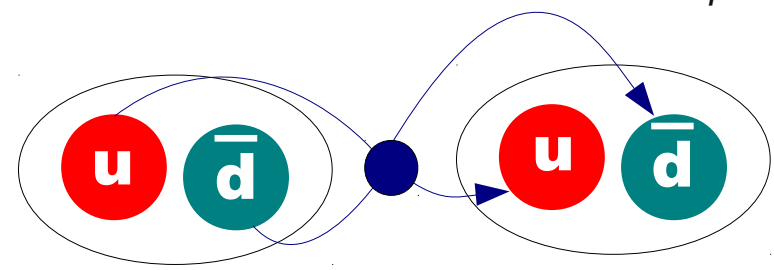
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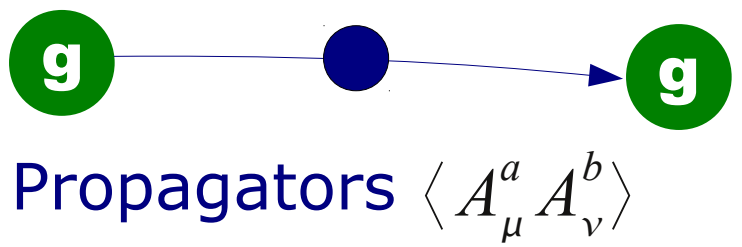


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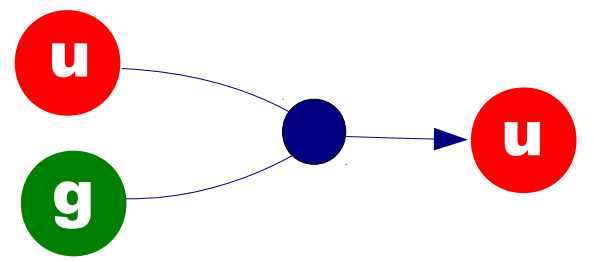
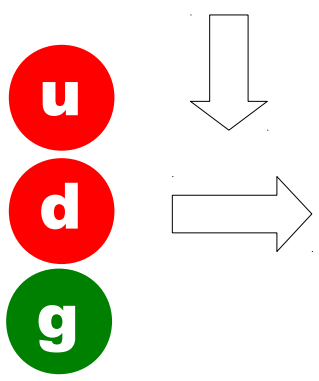
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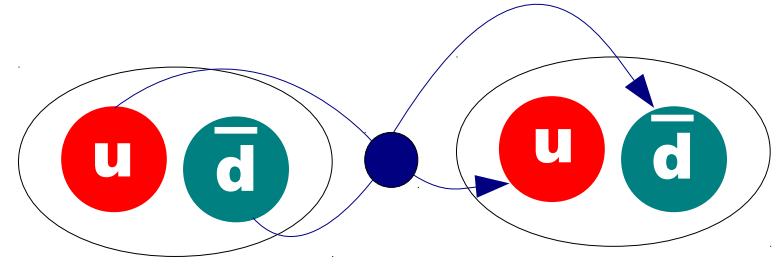
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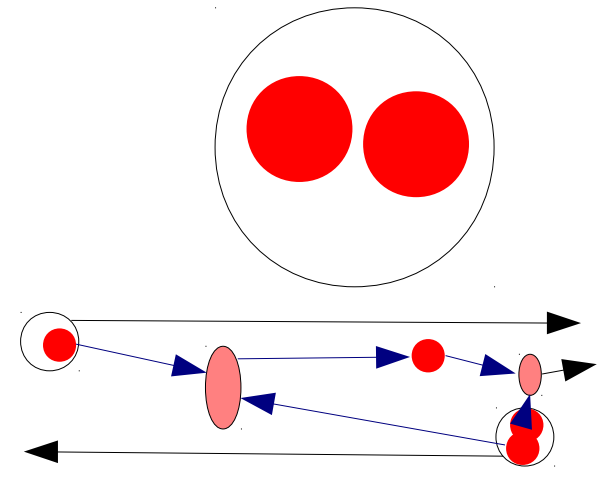
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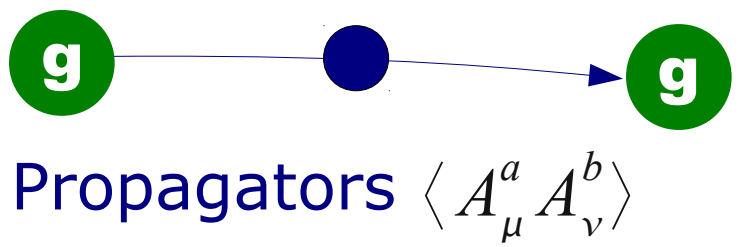
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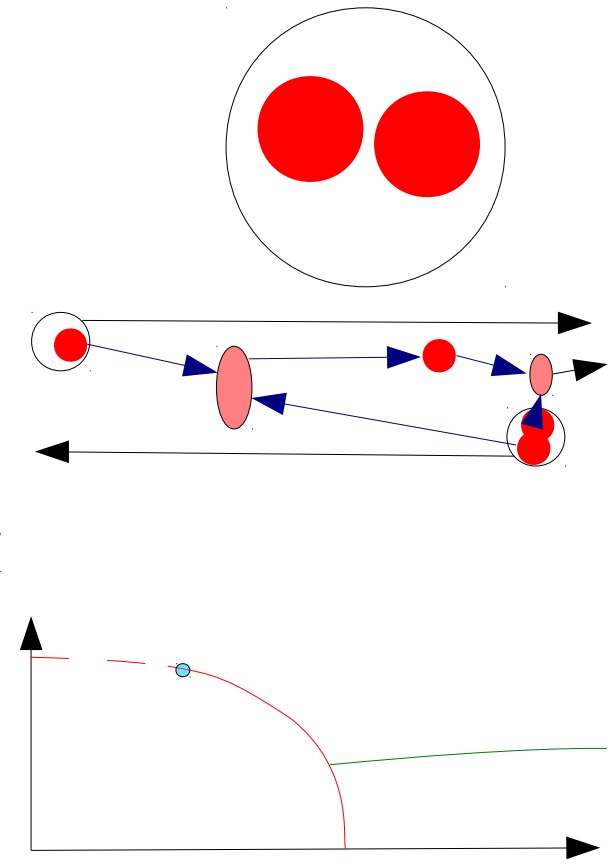
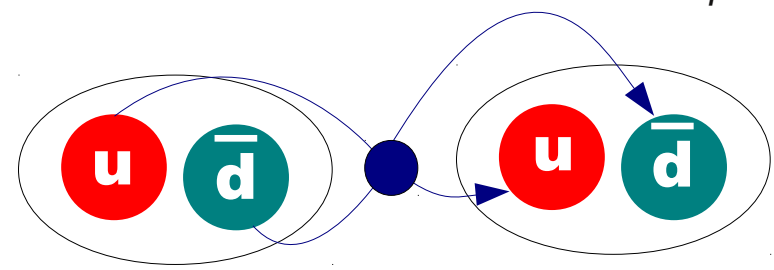
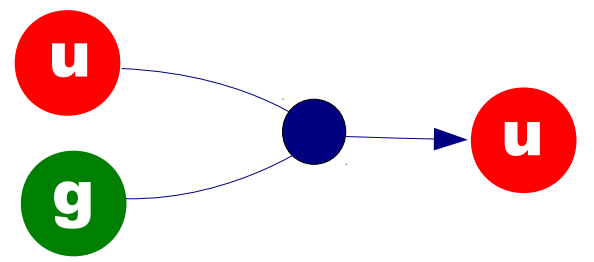
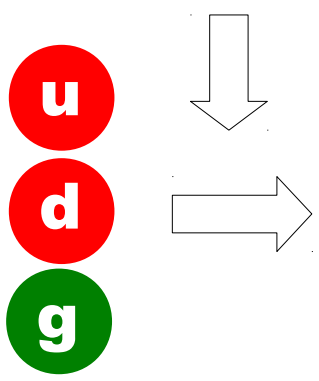
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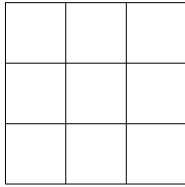
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- Perturbation theory covered in lattice and functional equations

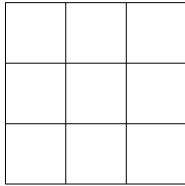
Methods to calculate correlation functions

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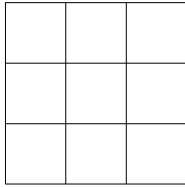
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- Discretize space-time in a box and calculate the path-integral and expectation values explicitly
- ✓ Full non-perturbative dynamics correctly implemented
- ✗ Finite volume artifacts, disparate scales most severe obstacles

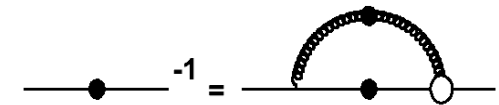
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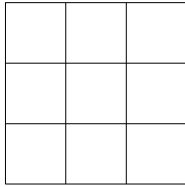
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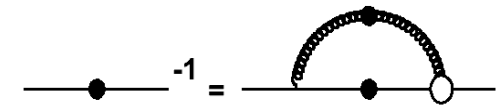
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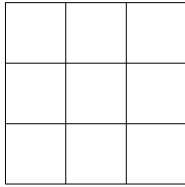
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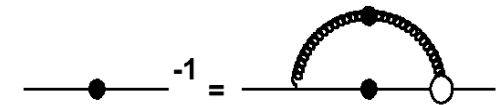
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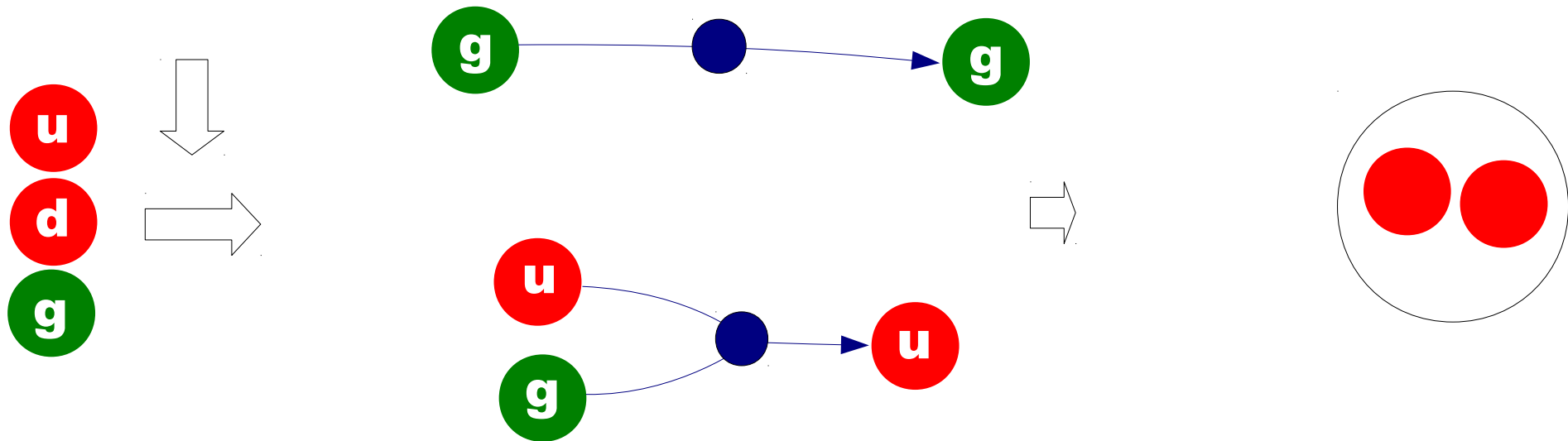
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- **Perturbation theory** included

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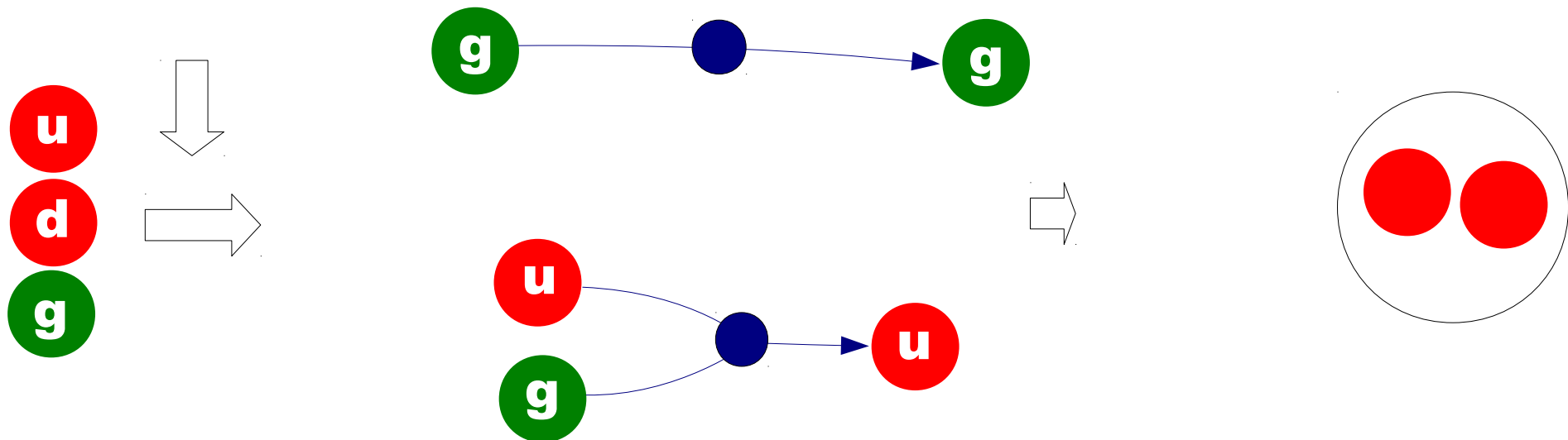
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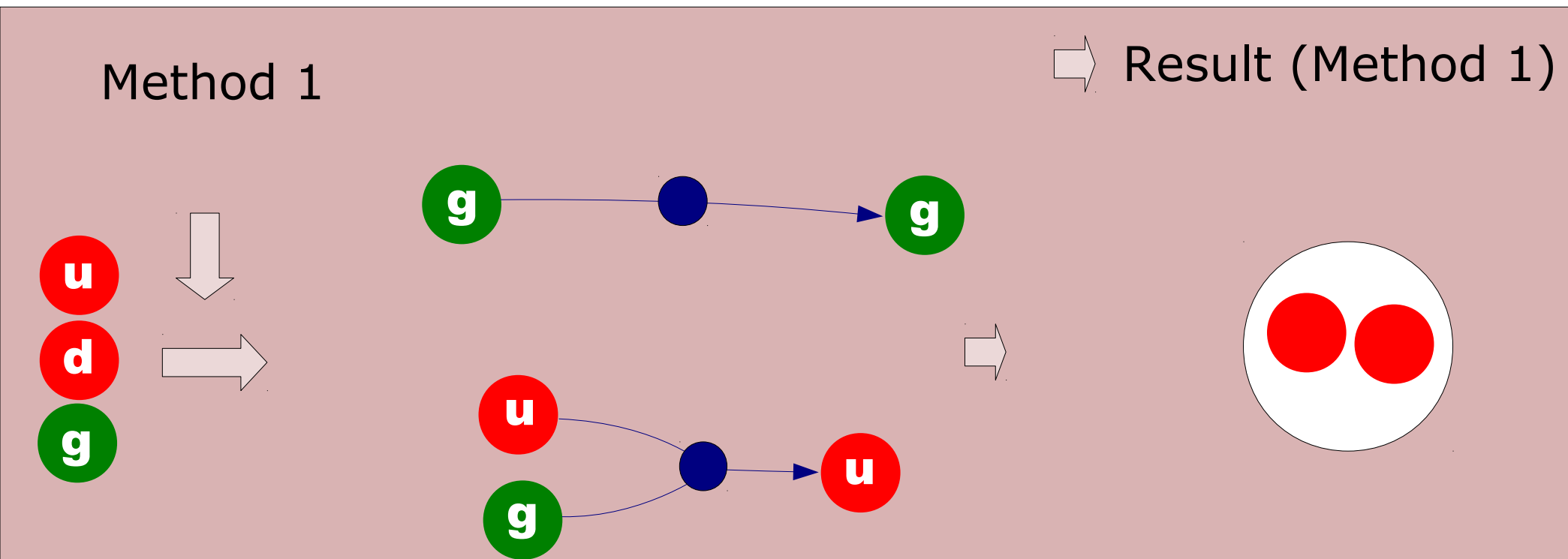
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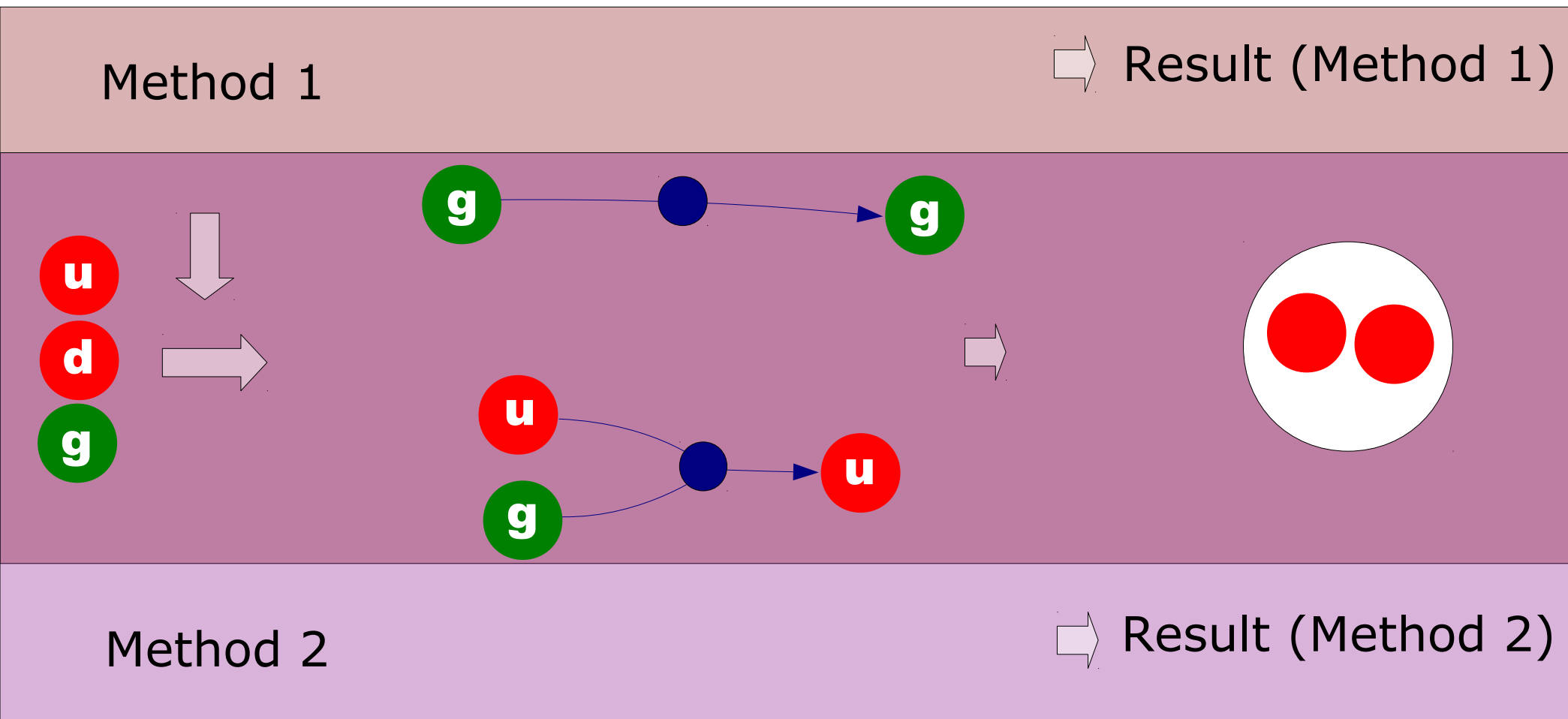
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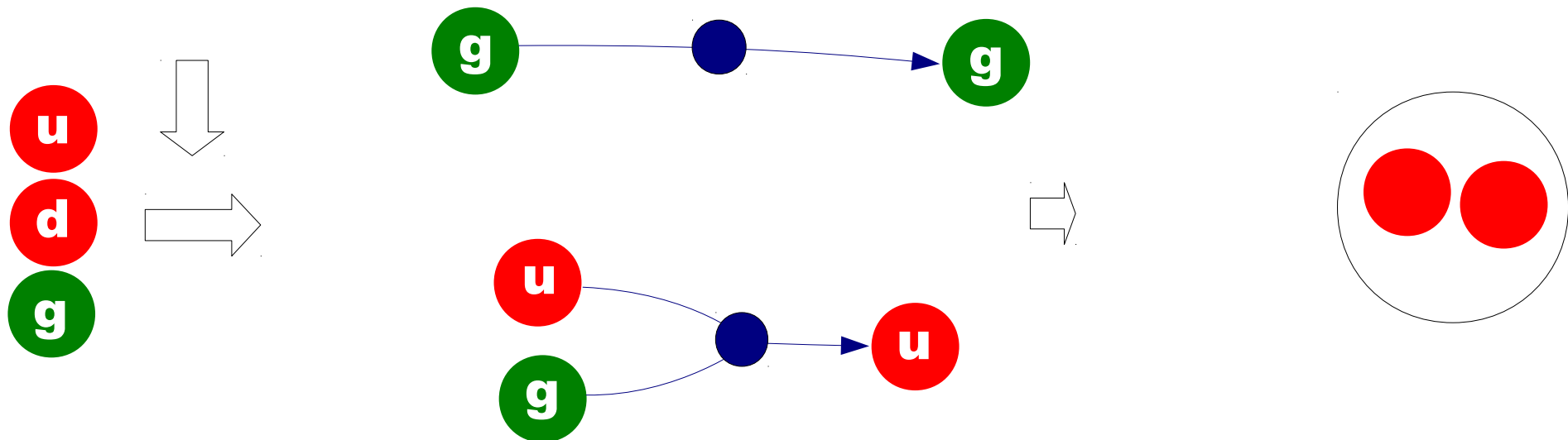
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Lattice calculations

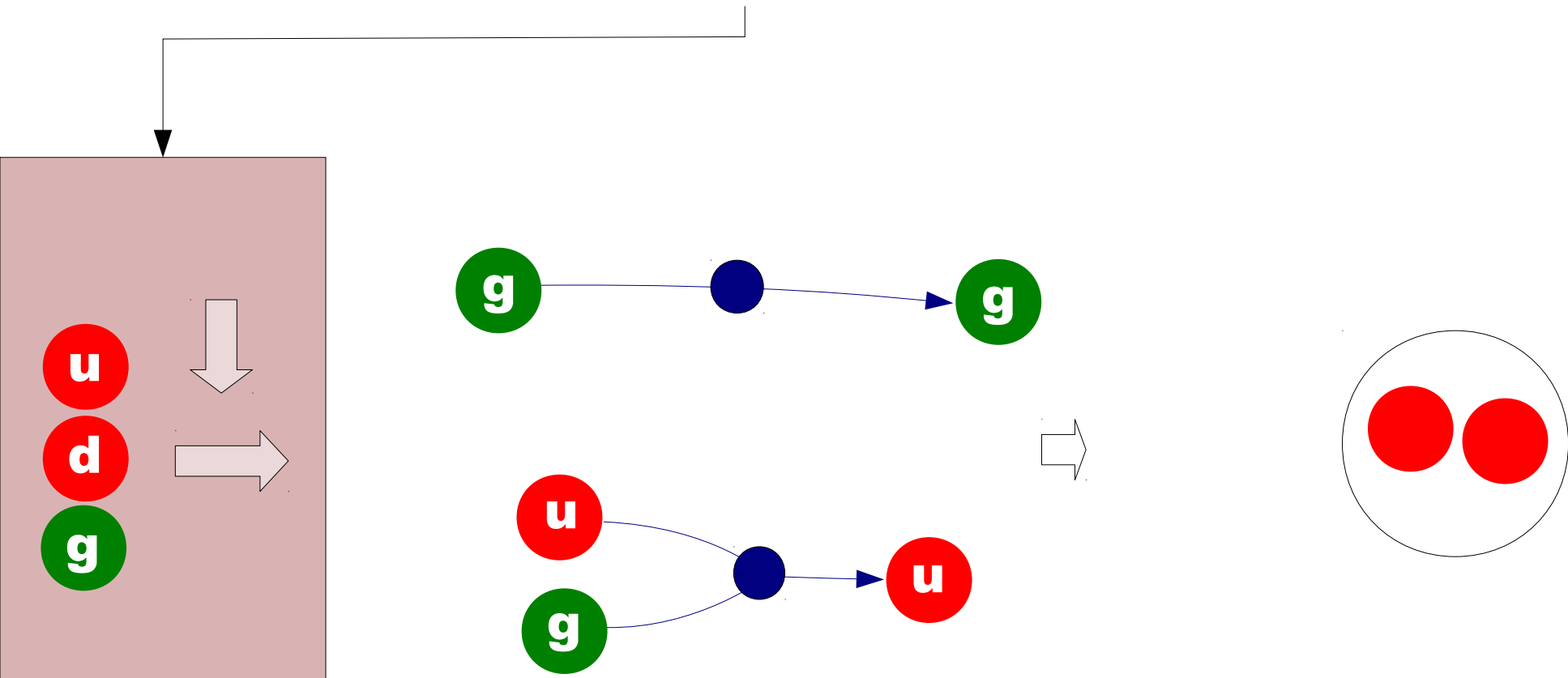


Functional calculations

Methods to calculate correlation functions

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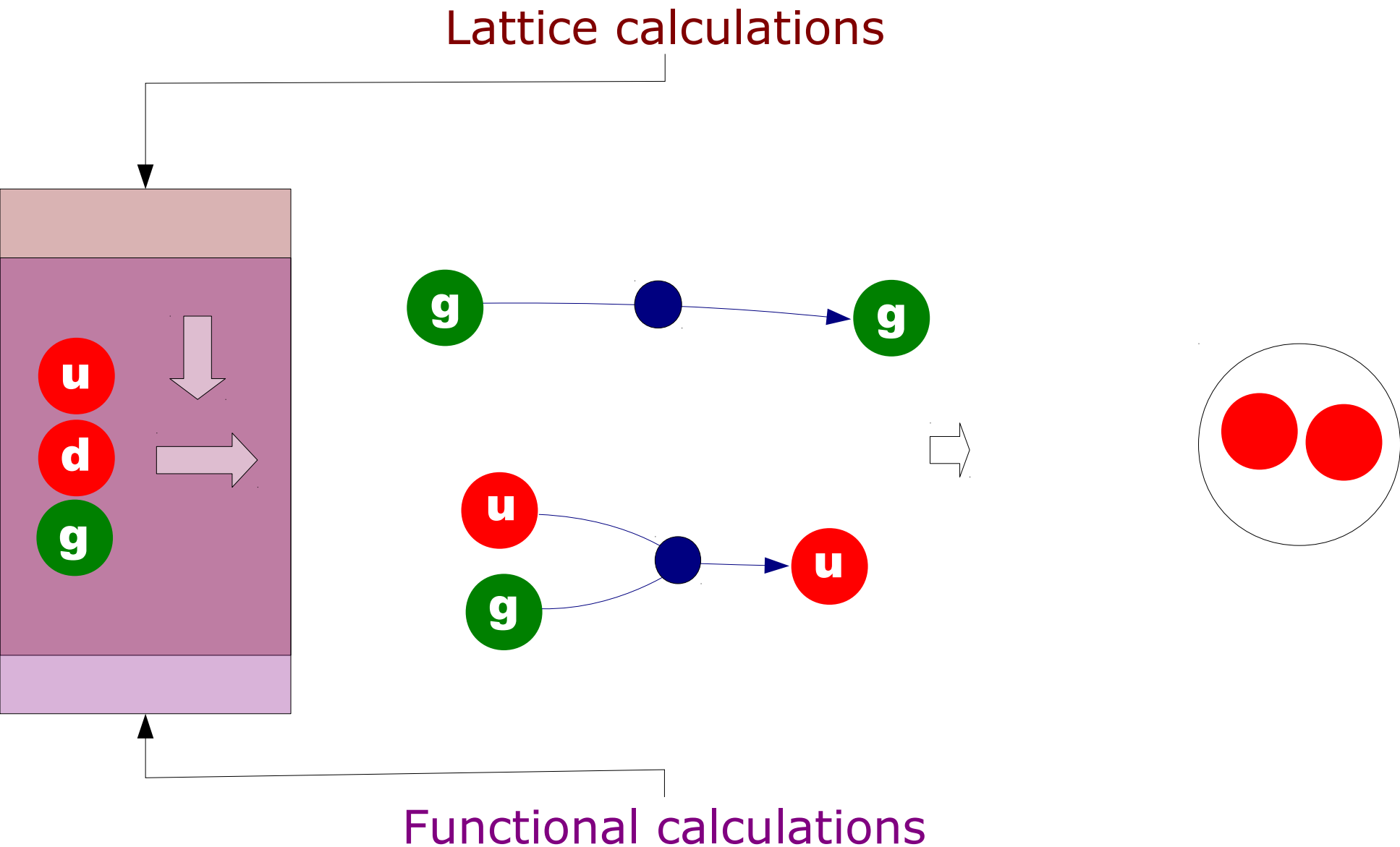
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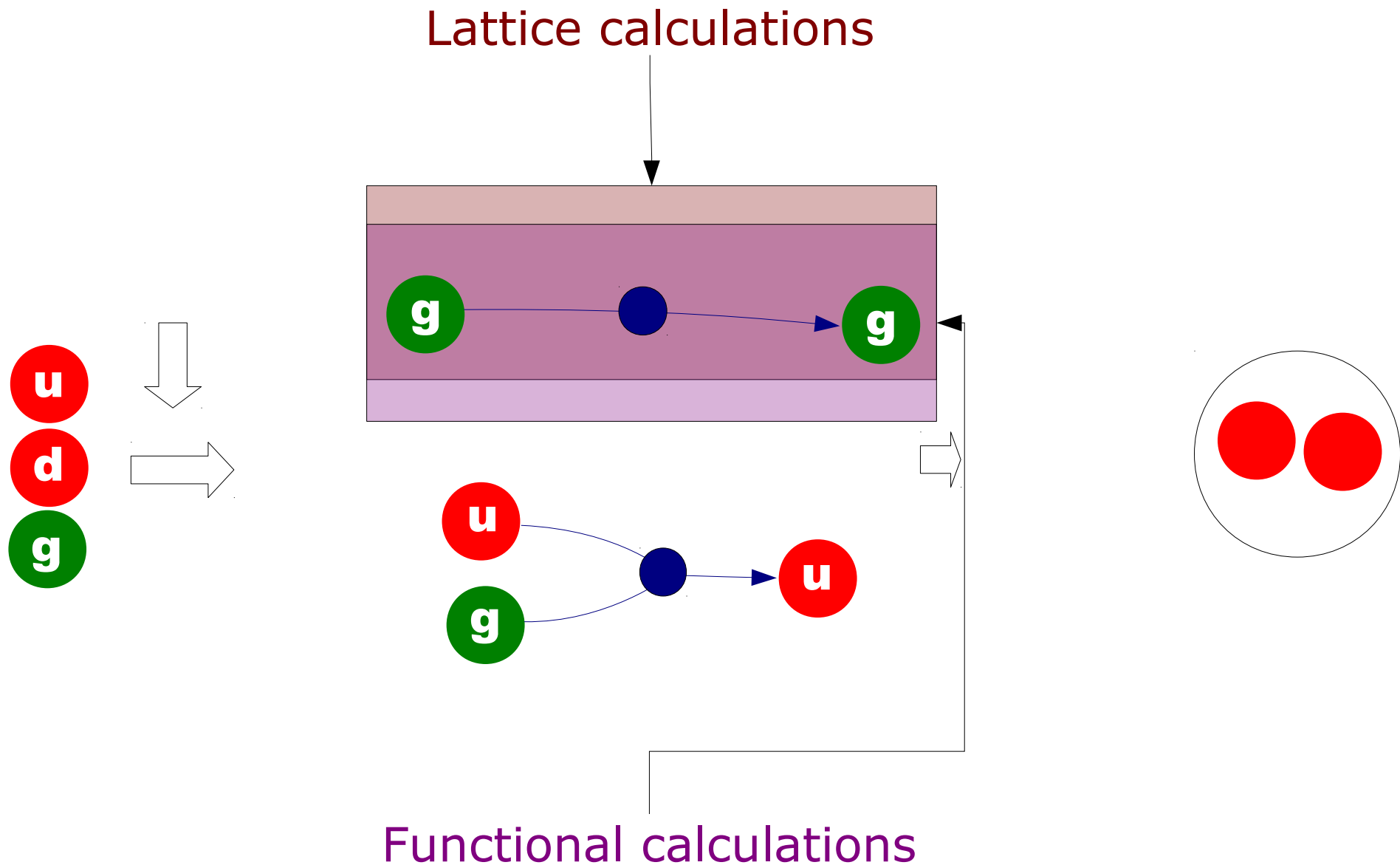
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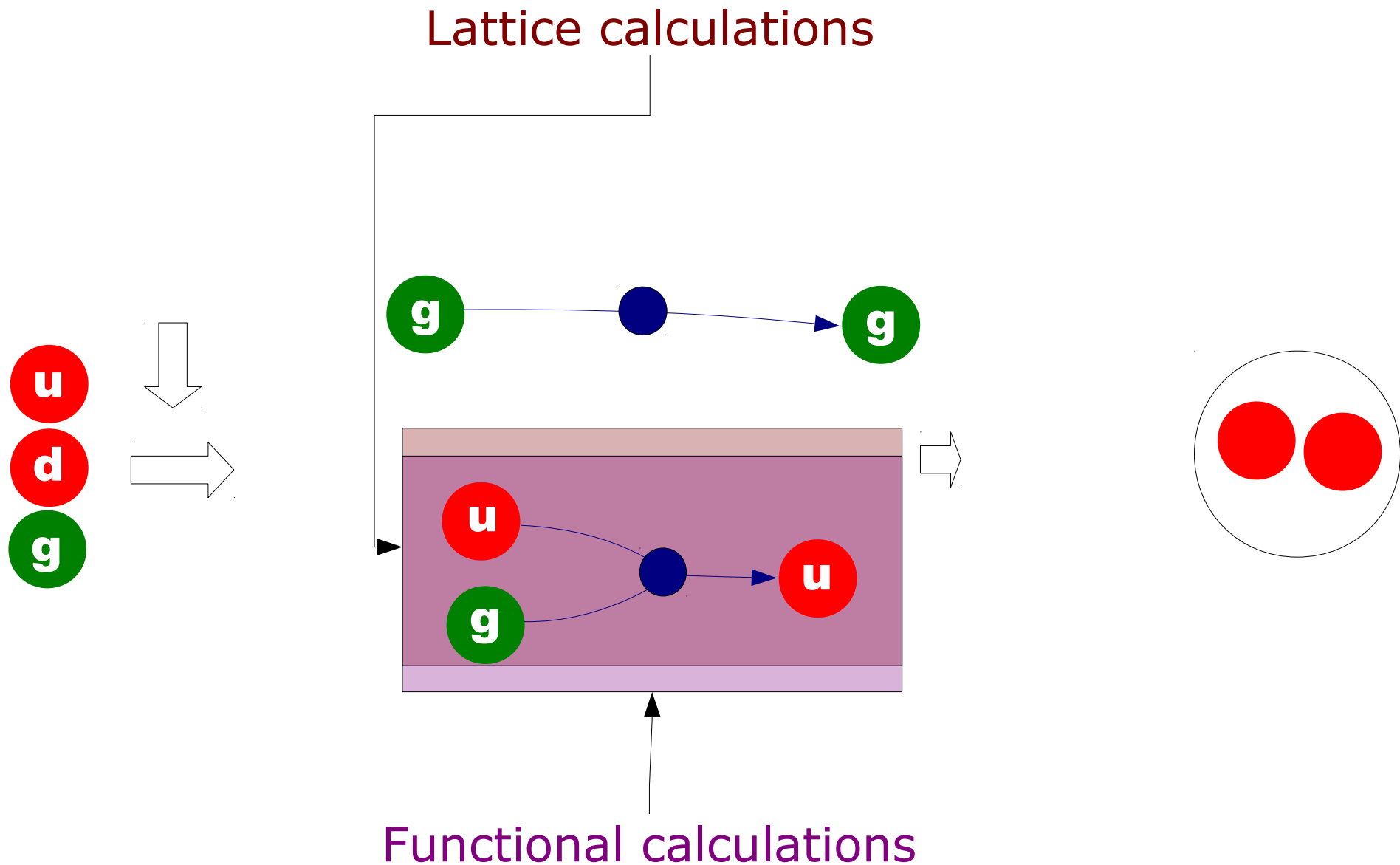
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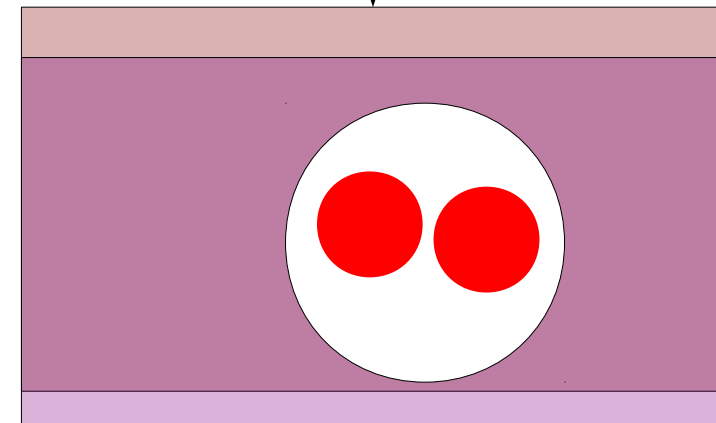
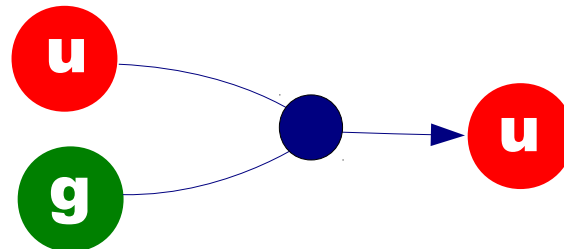
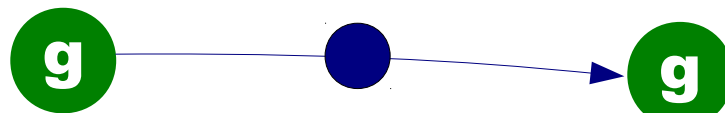
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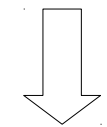


Functional calculations

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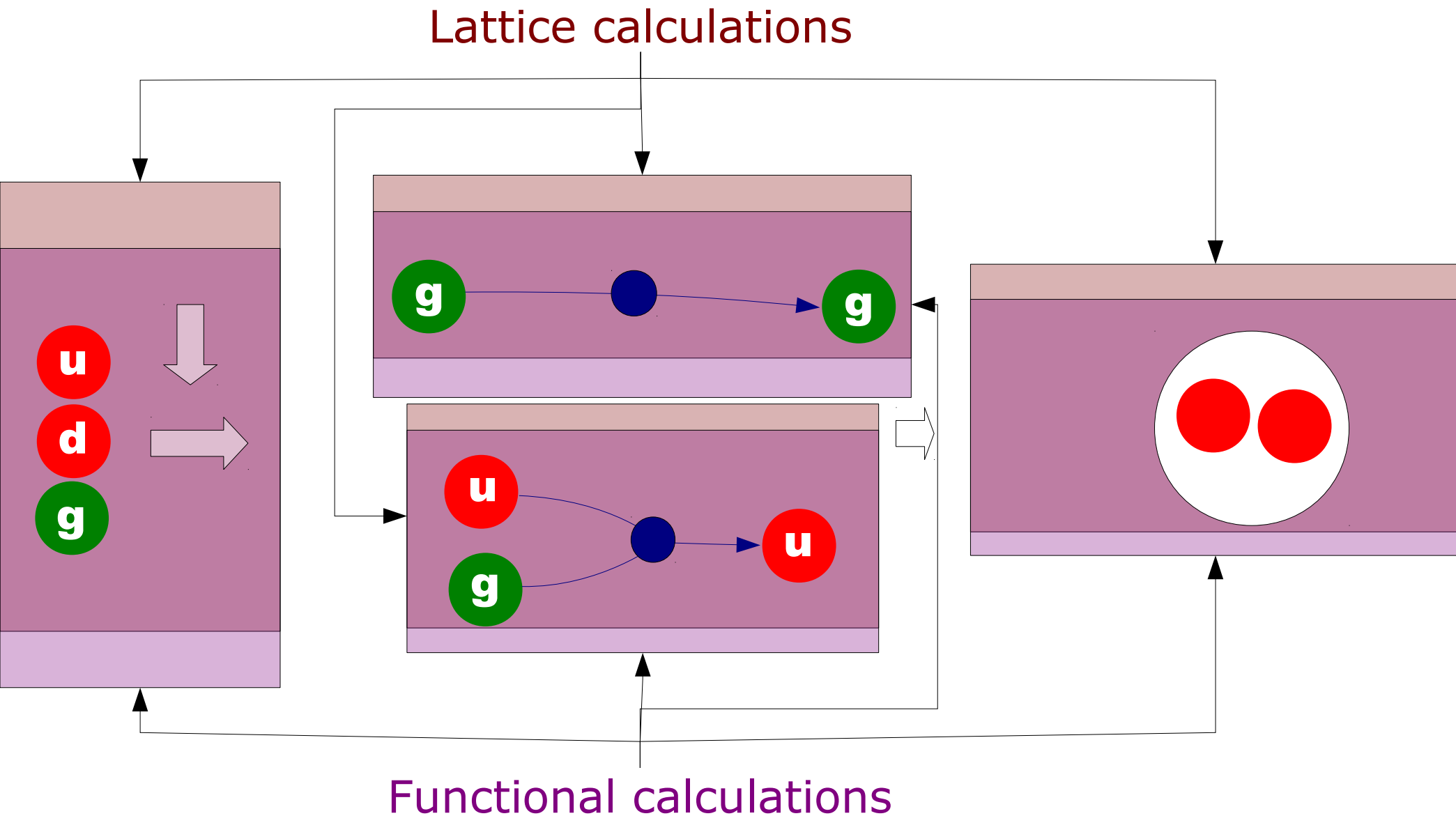
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Methods to calculate correlation functions

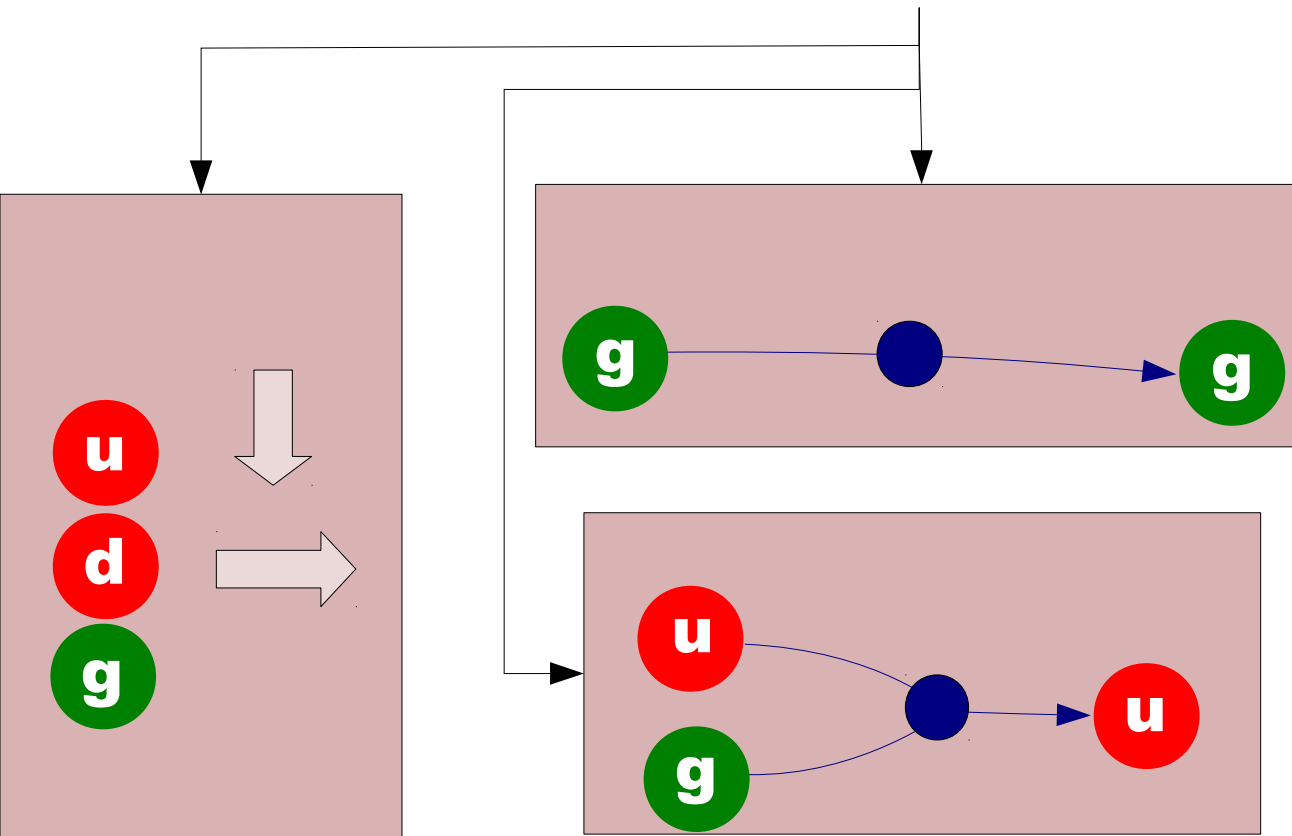
[Maas 1106.3942
Fischer JPG 2006]



Methods to calculate correlation functions

[Maas 1106.3942
Fischer JPG 2006]

Lattice calculations



Applications of this framework

- Yang-Mills theory and QCD [Maas 1106.3942, Fischer JPG 2006]

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Describing a theory

[Maas 1106.3942
Fischer JPG 2006]

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Scale

[Maas JHEP 2011]

- Pure technicolor sector
 - $SU(2)+2$ adjoint flavors of techniquarks

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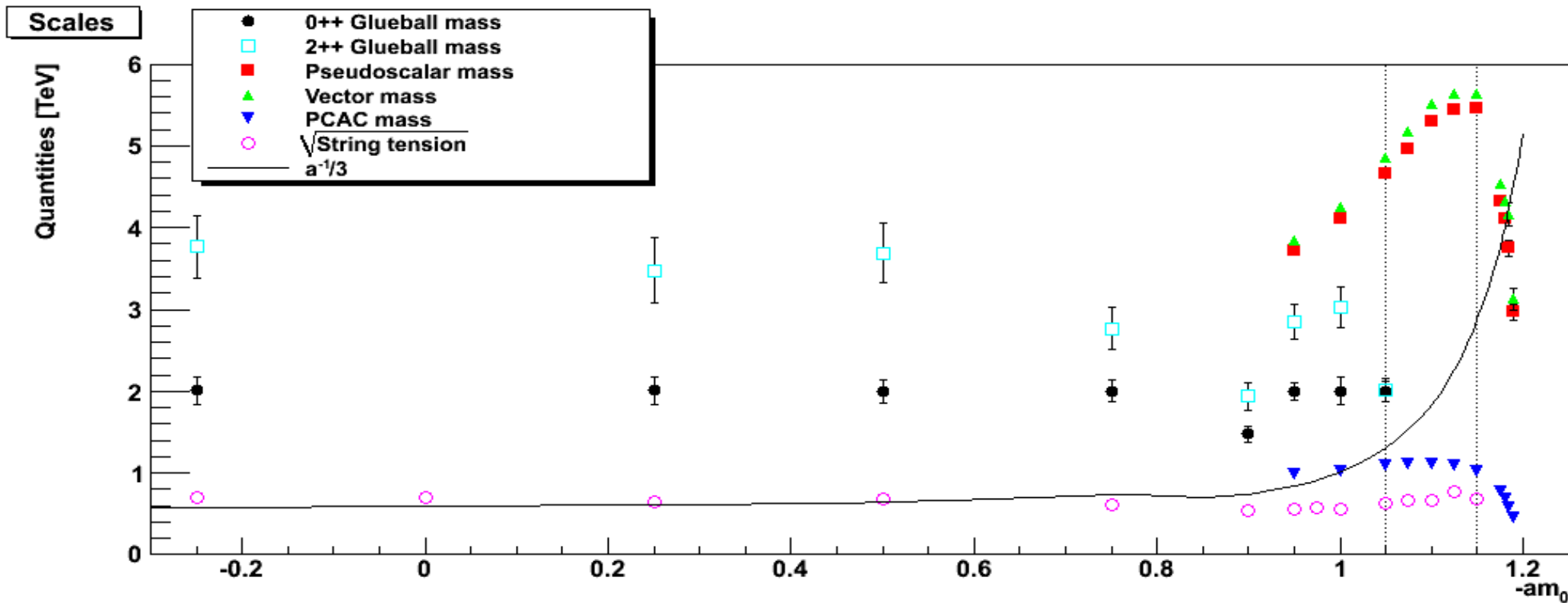
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- Other possibilities exist
 - Lattice scale, mesons, fixed scale,...

Scale

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Scale

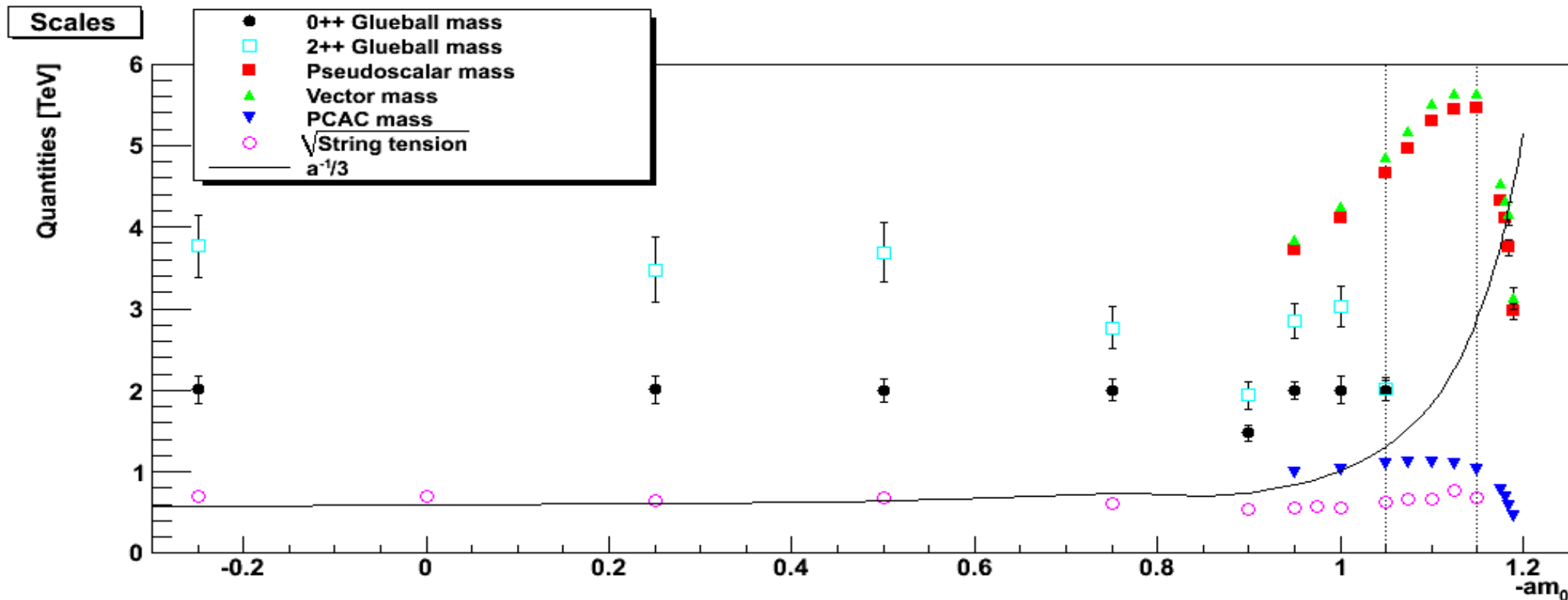
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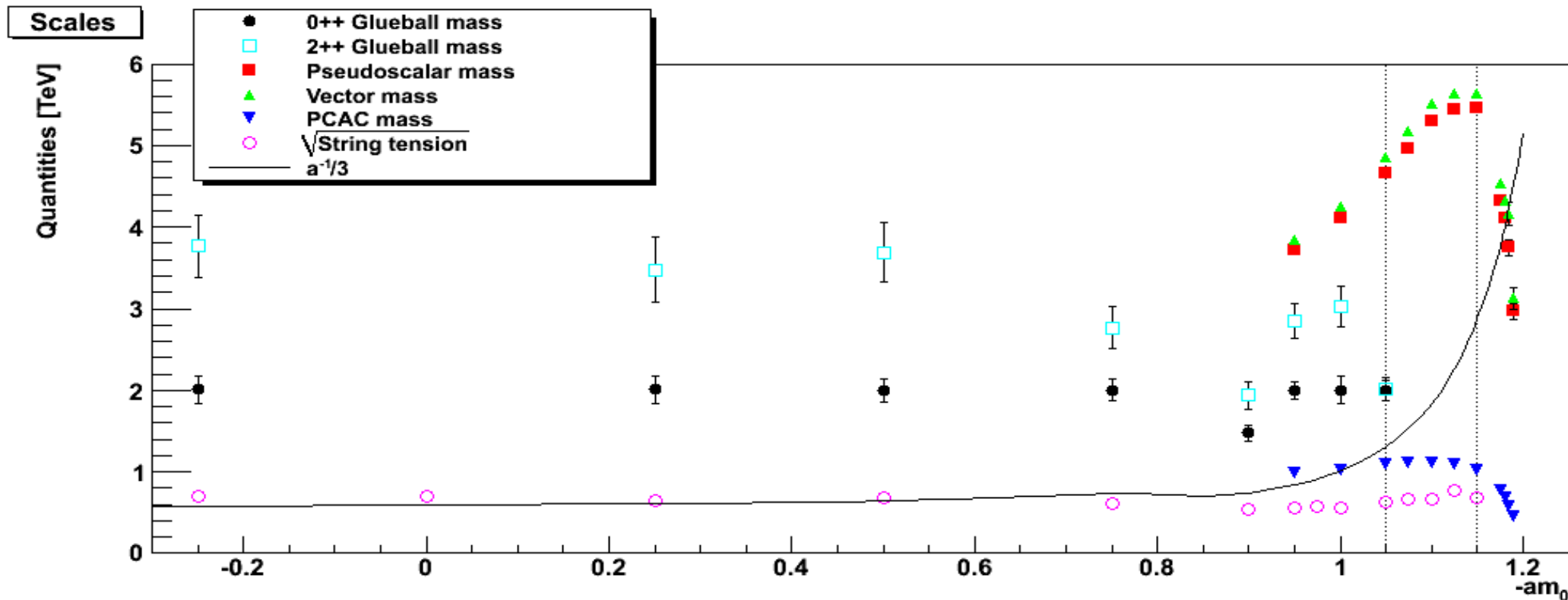
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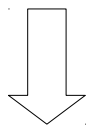
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Describing a theory

[Maas 1106.3942
Fischer JPG 2006]

Quantization

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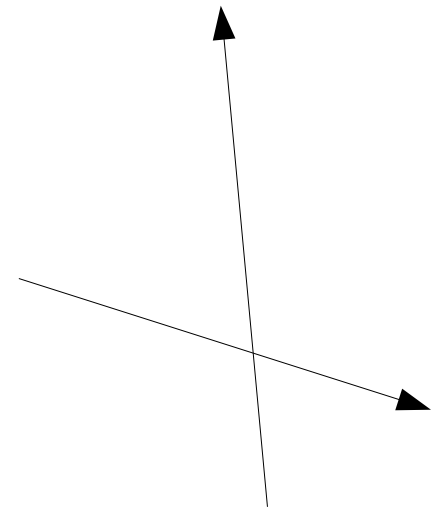
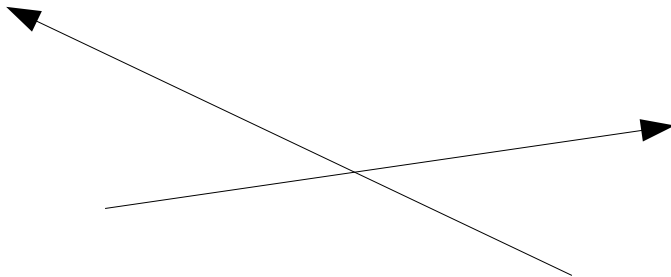


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Quantization and gauge fixing

[Maas 1106.3942]

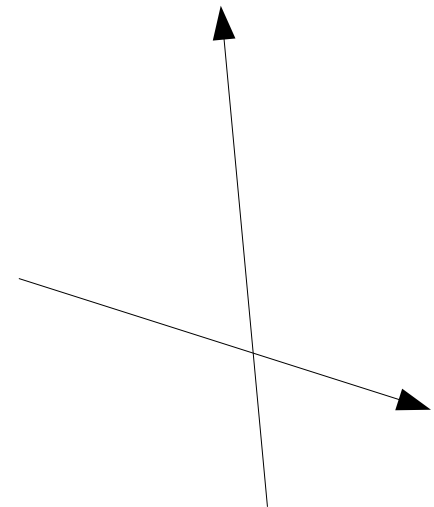
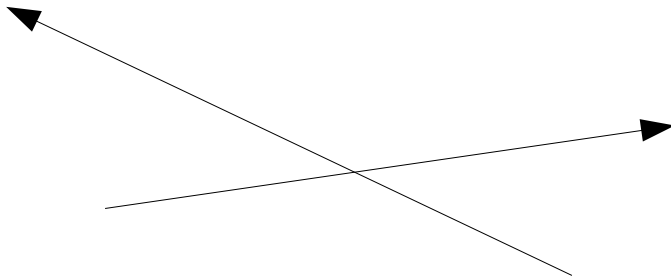
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Quantization and gauge fixing

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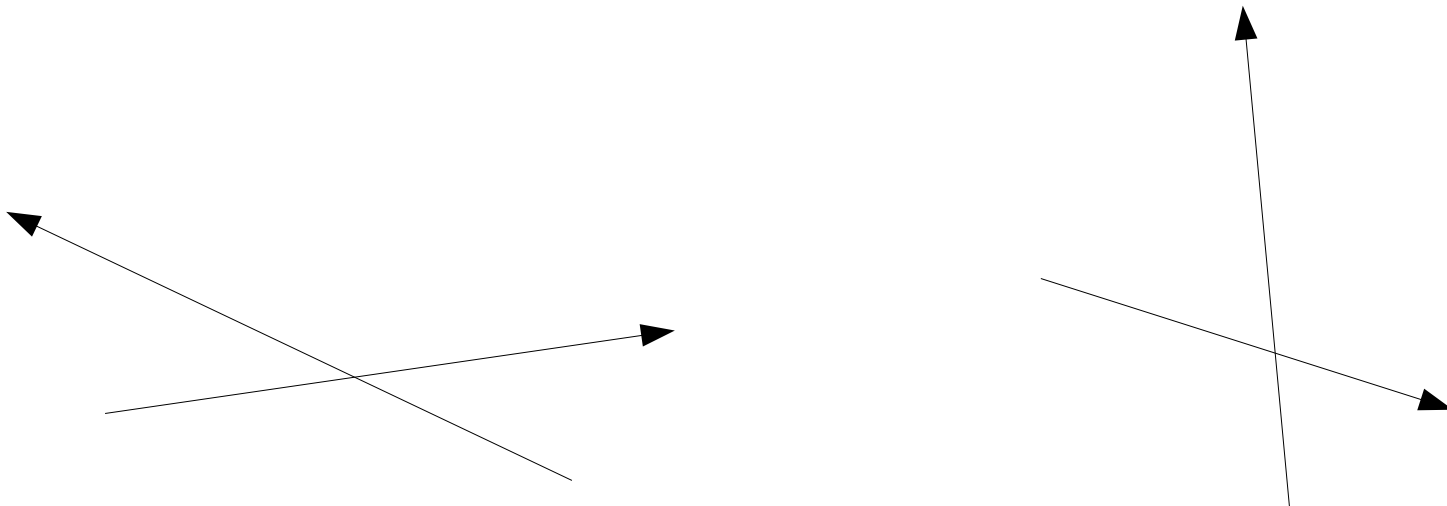
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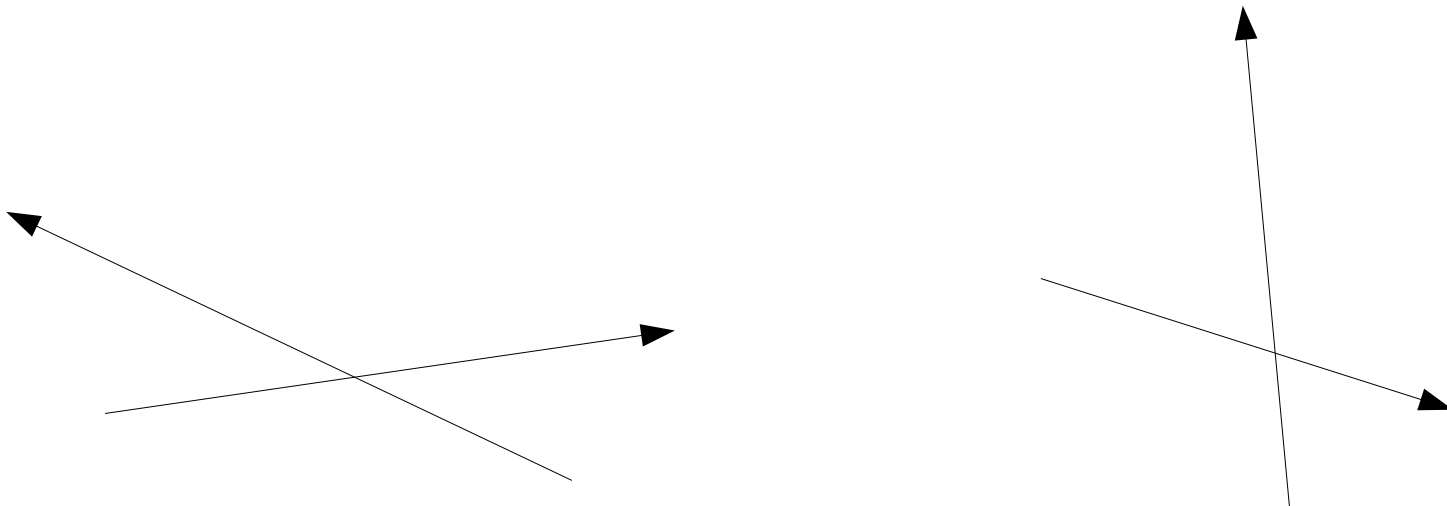
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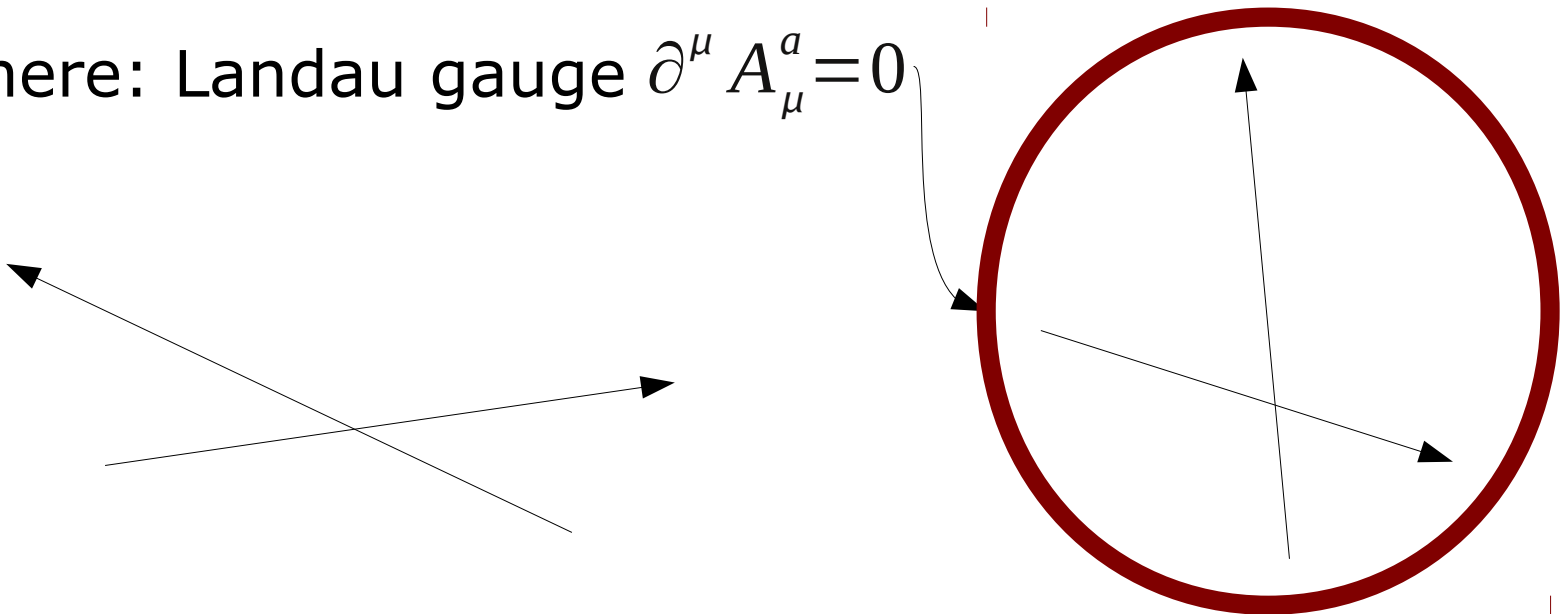
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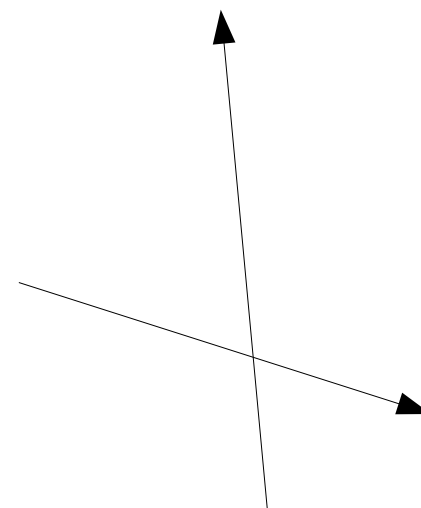
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Quantization and gauge fixing

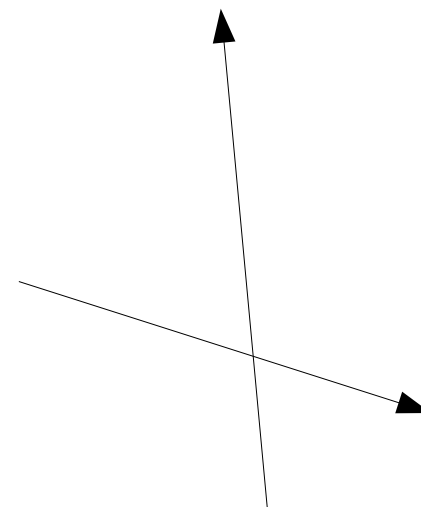
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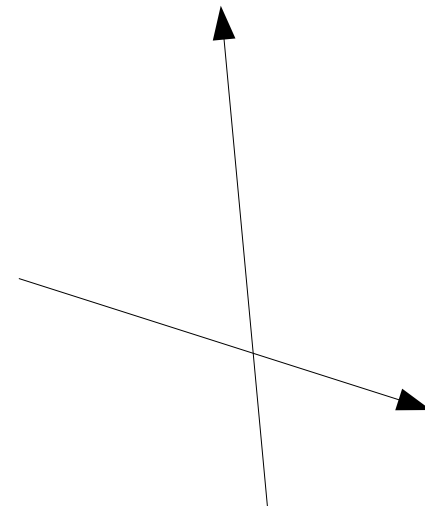
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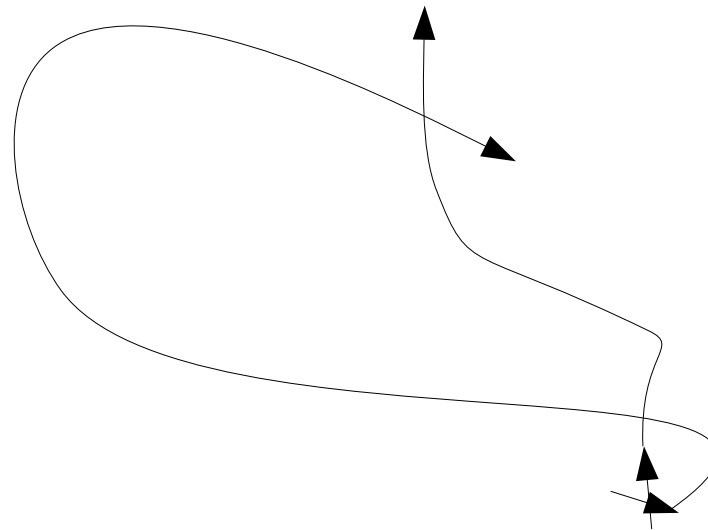
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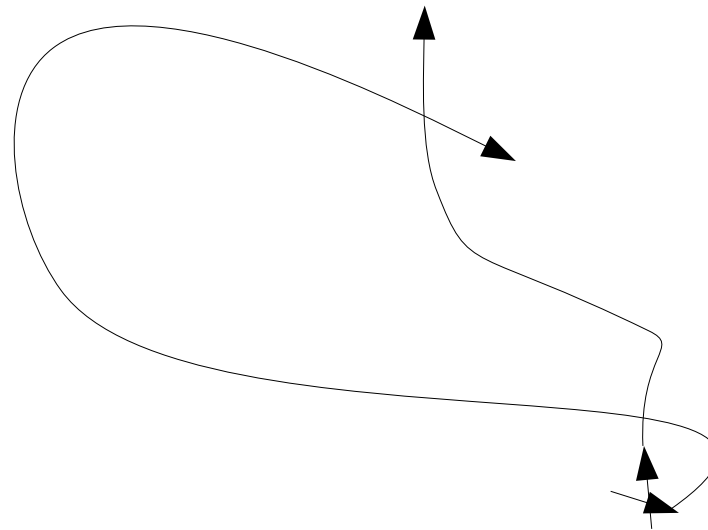
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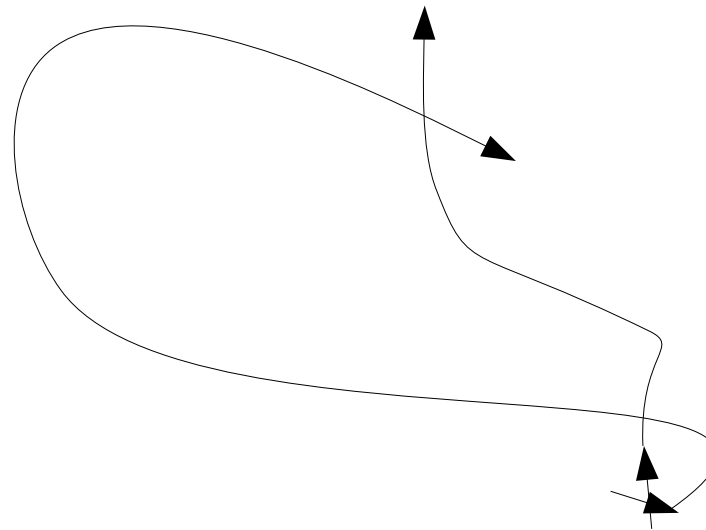
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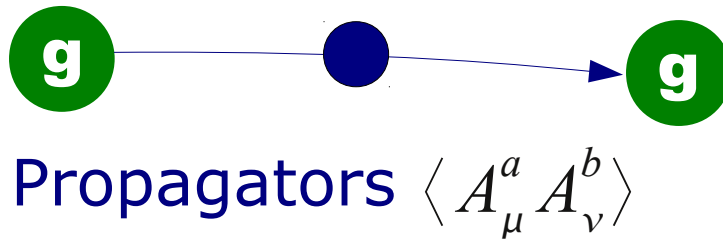
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- Impact of Gribov-Singer ambiguity very similar to Yang-Mills theory at same lattice size/glueball mass [Maas JHEP 2011]
 - Similar to other confining theories [Maas EPJC 2010]

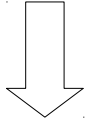
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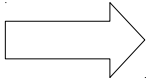


Quantization

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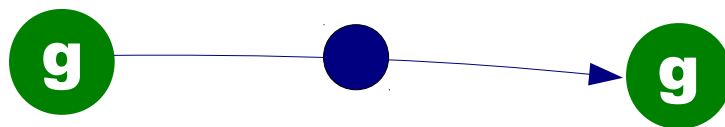
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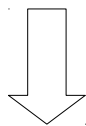


Propagators $\langle A_\mu^a A_\nu^b \rangle$

Quantization

$$D_{\mu\nu}^{ab}(x-y) = \langle A_\mu^a(x) A_\nu^b(y) \rangle$$

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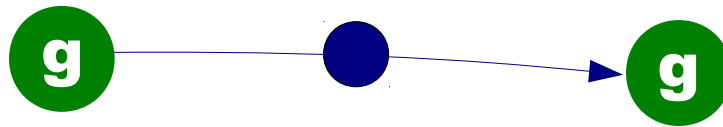
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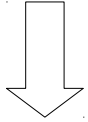
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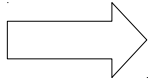
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$$D_{\mu\nu}^{ab}(p) = \delta^{ab} \left(\delta_{\mu\nu} - \frac{p_\mu p_\nu}{p^2} \right) D(p)$$

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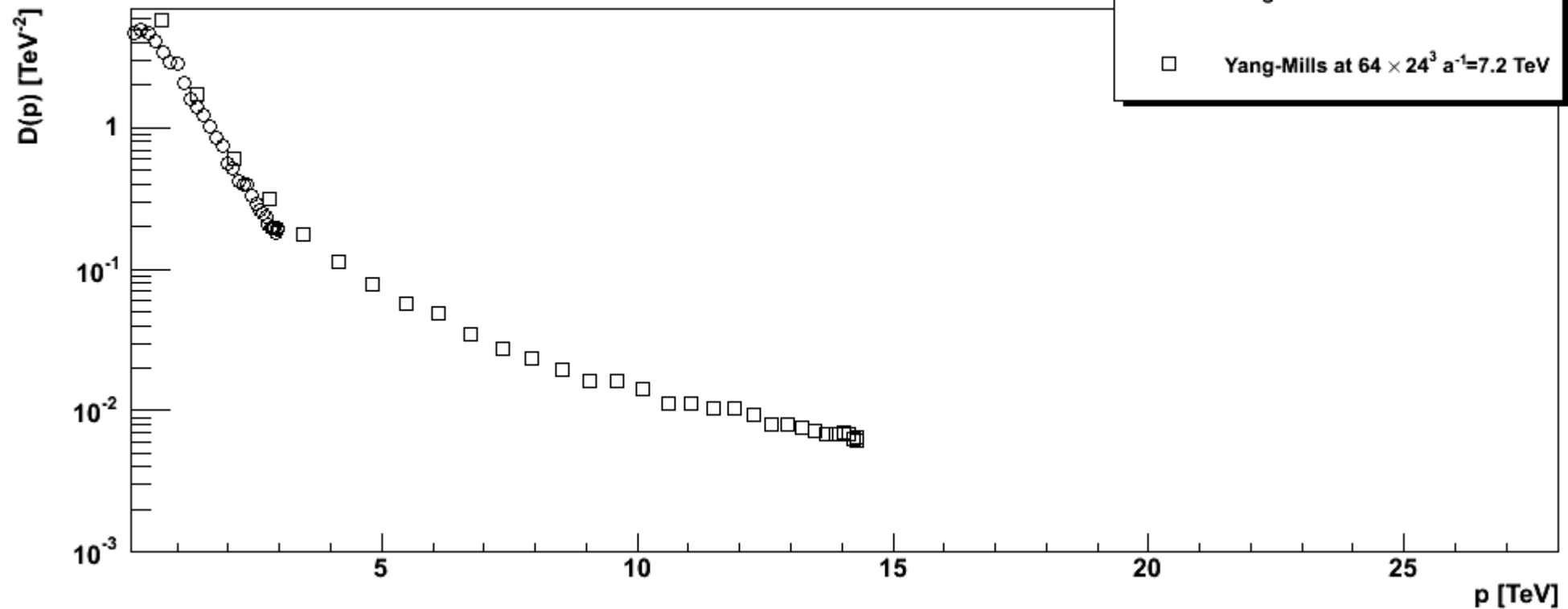


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Technigluon propagator

[Maas JHEP 2011]

Technigluon propagator

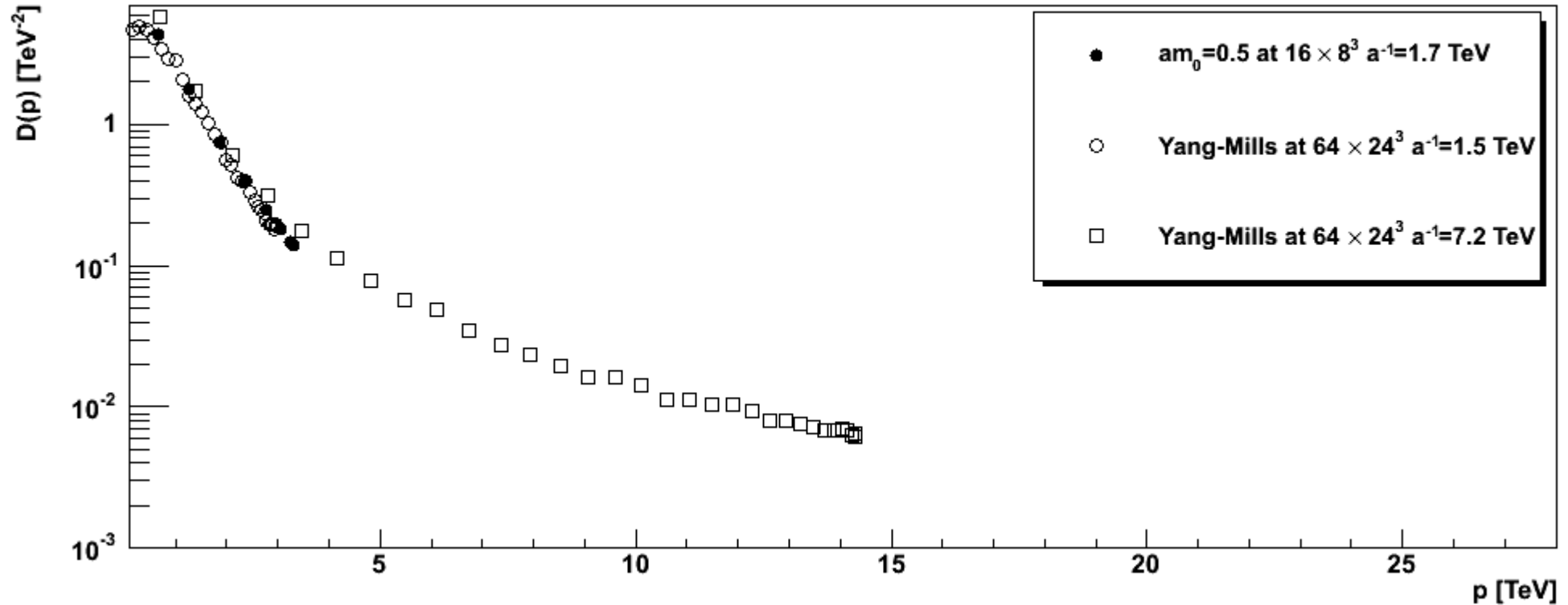


- Rescaled Yang-Mills results for comparison

Technigluon propagator

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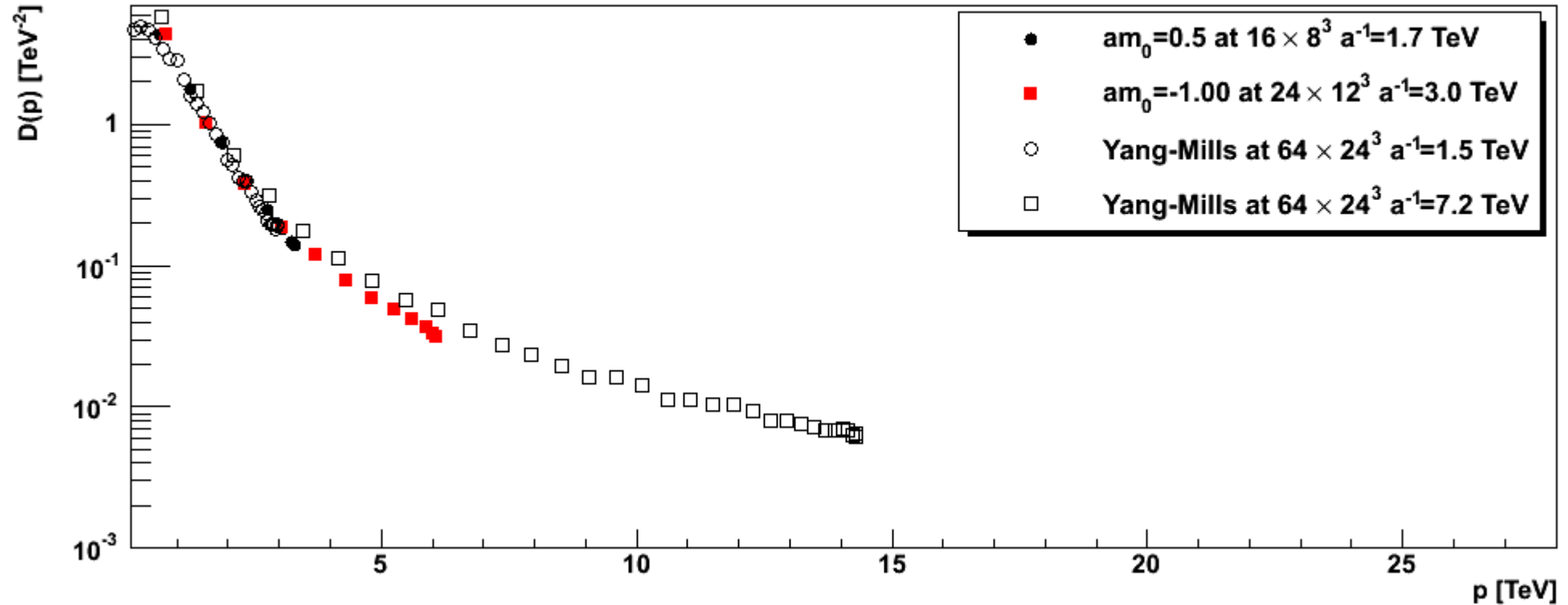


- Rescaled Yang-Mills results for comparison
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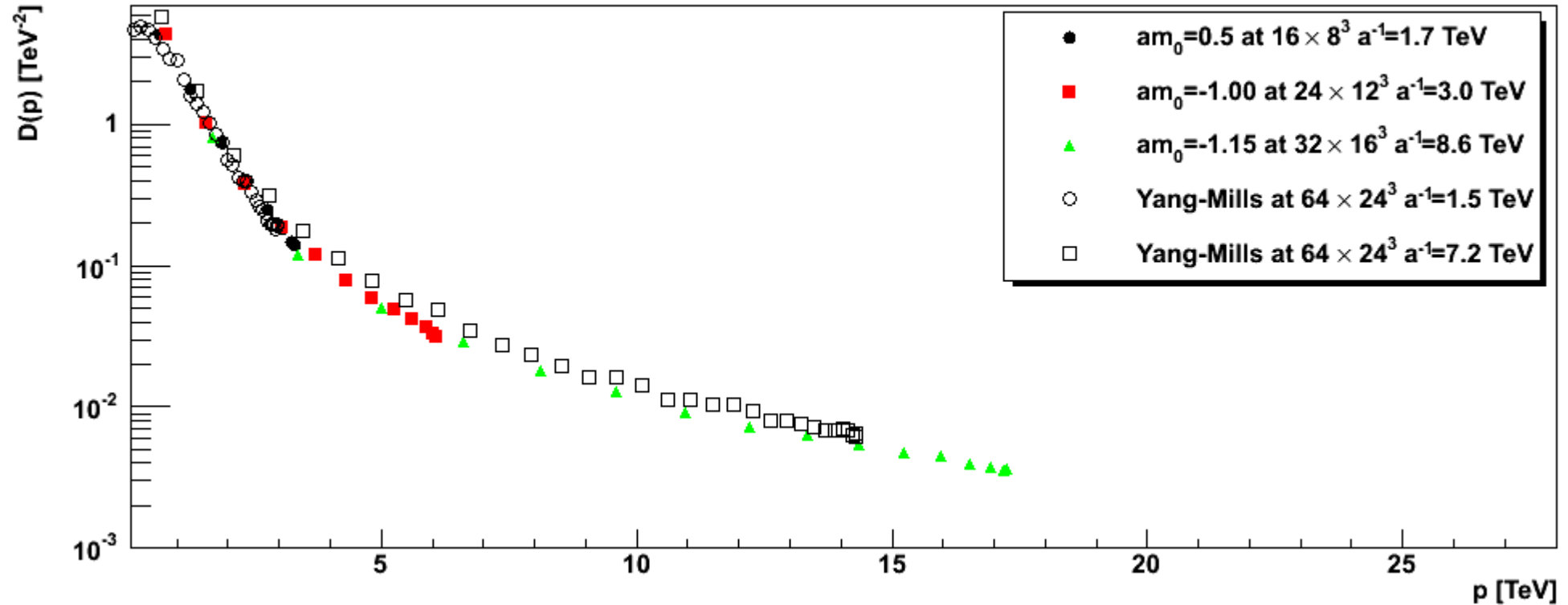


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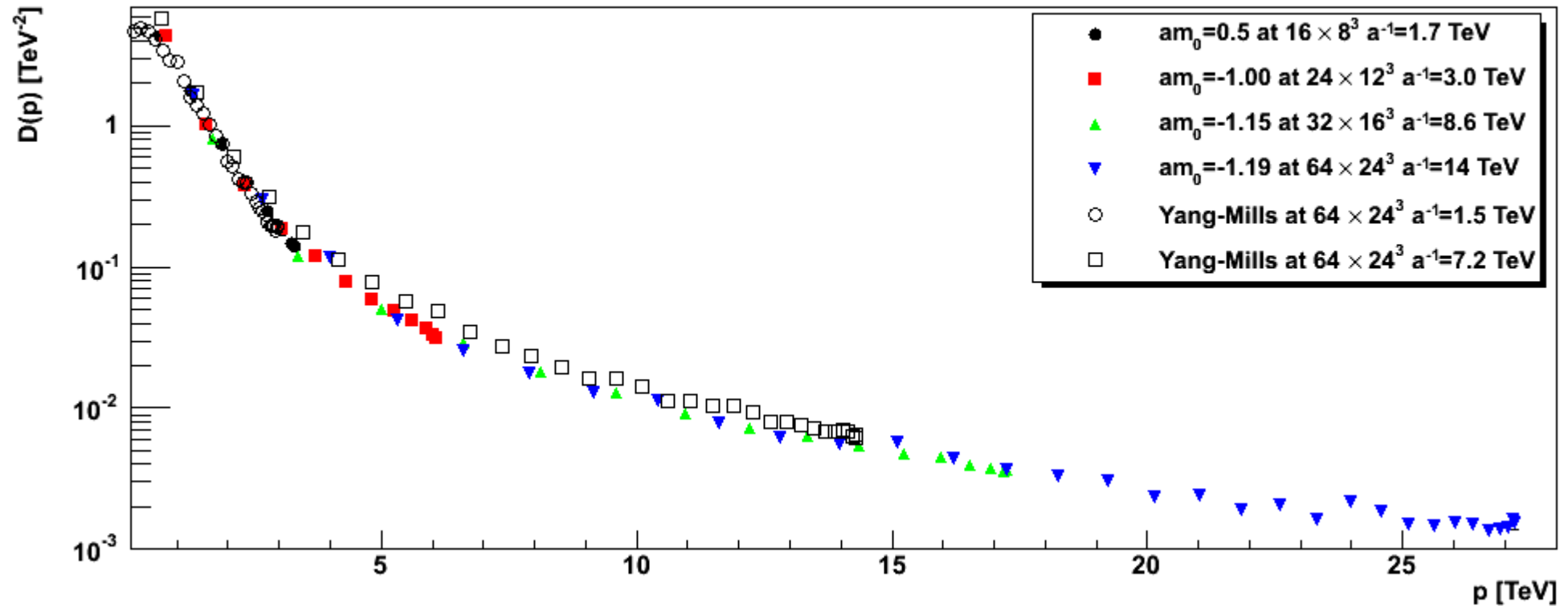


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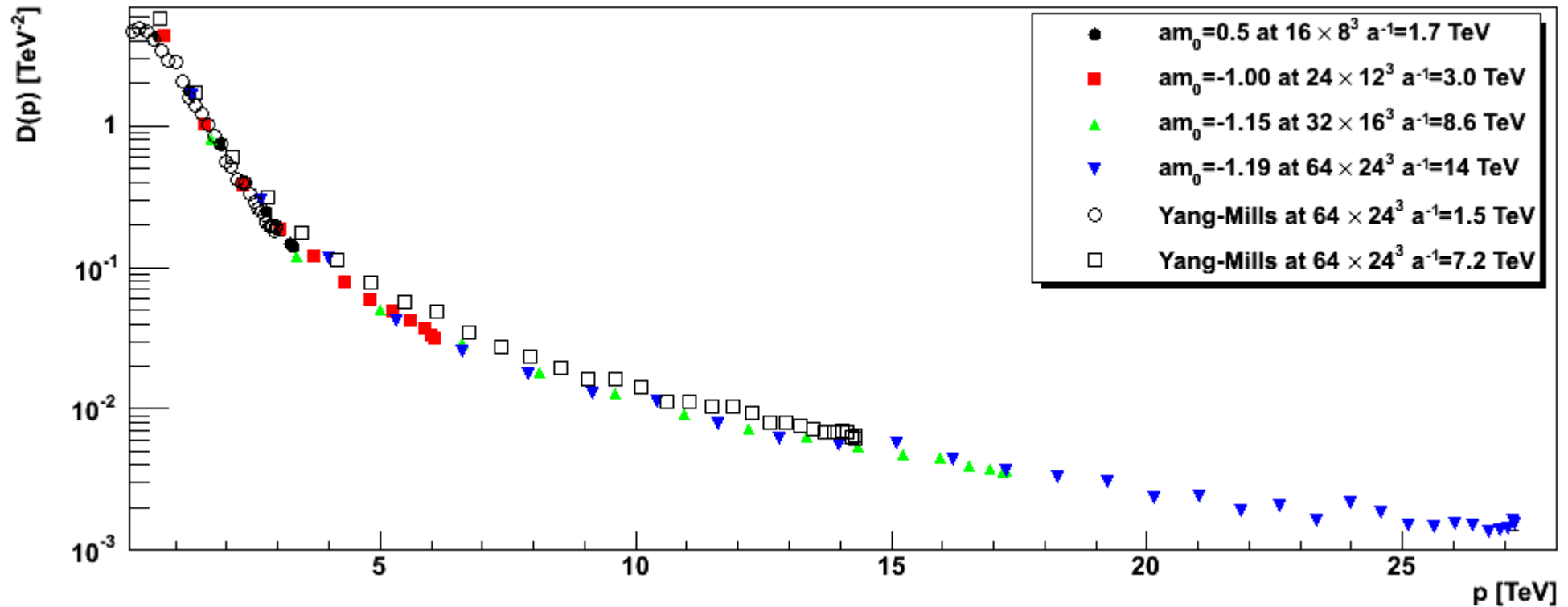


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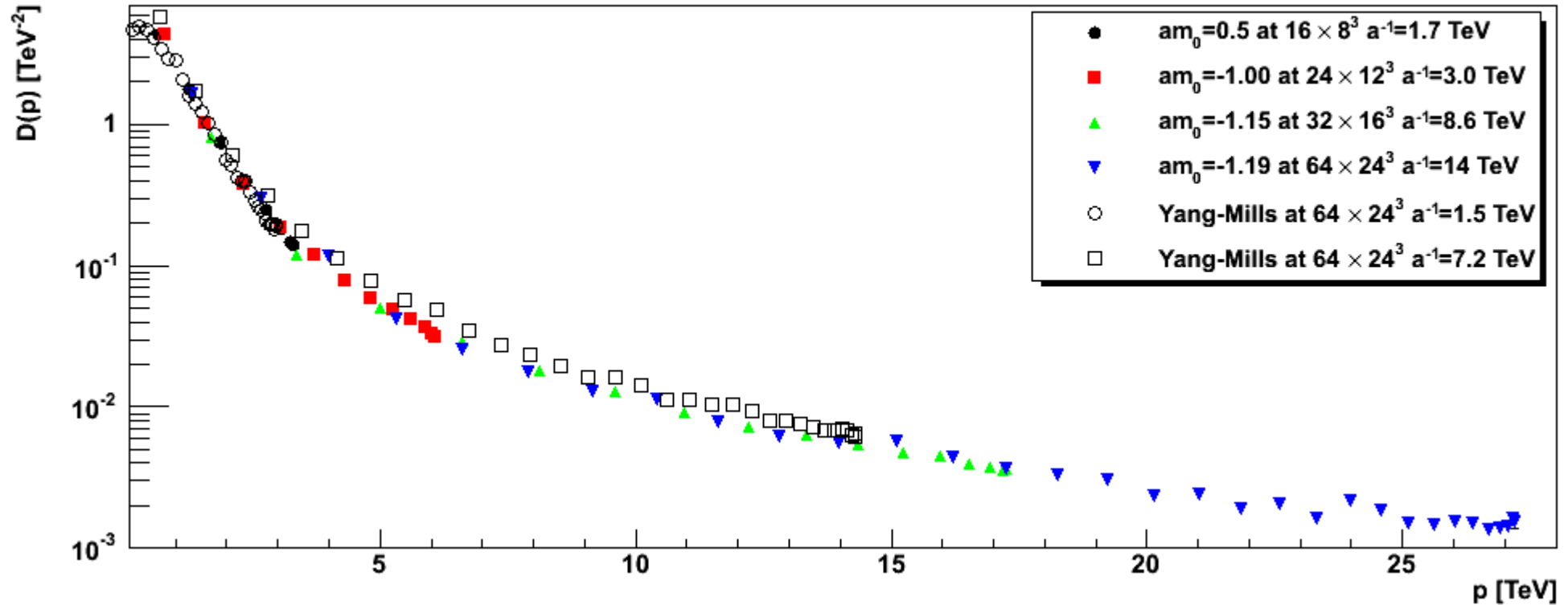


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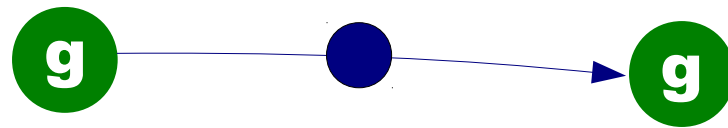
Technigluon propagator



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- Faddeev-Popov ghost propagator similar

Describing a theory

[Maas 1106.3942
Fischer JPG 2006]



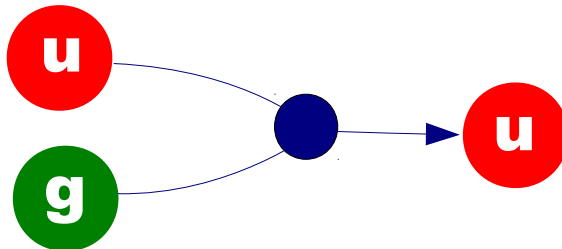
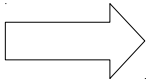
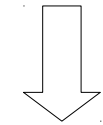
Propagators $\langle A_\mu^a A_\nu^b \rangle$

Quantization

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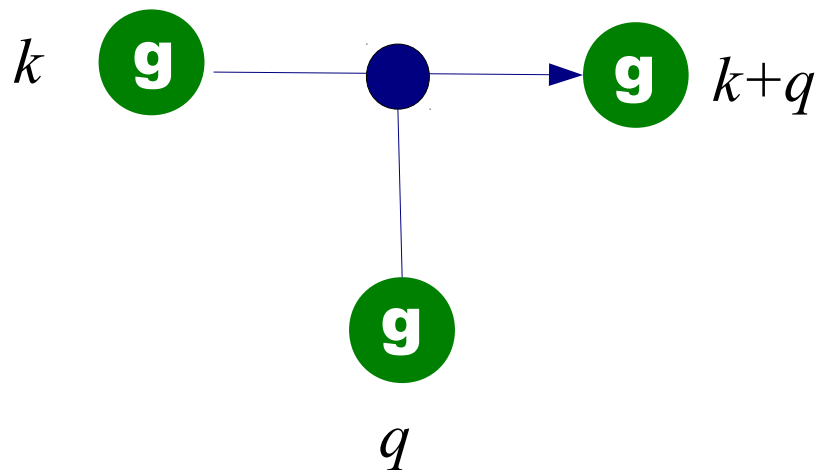
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Interaction vertices $\langle \bar{\Psi}_i A_\mu^a t_a^{ij} \Psi_j \rangle$

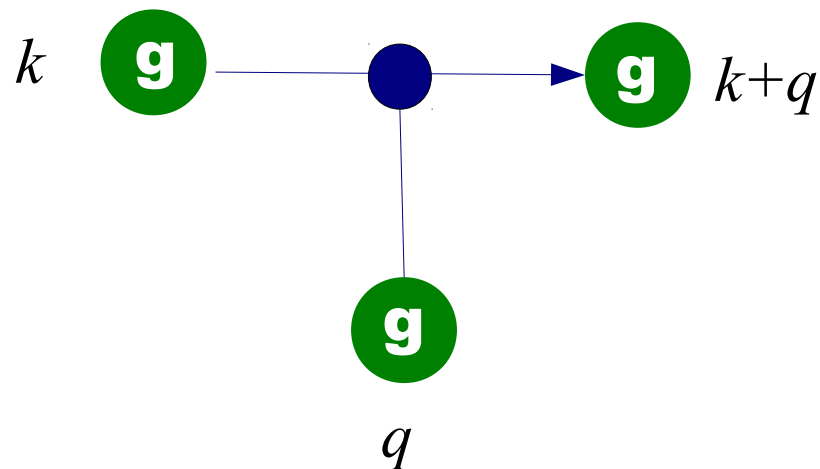
Three-technigluon vertex

[Maas JHEP 2011]



Three-technigluon vertex

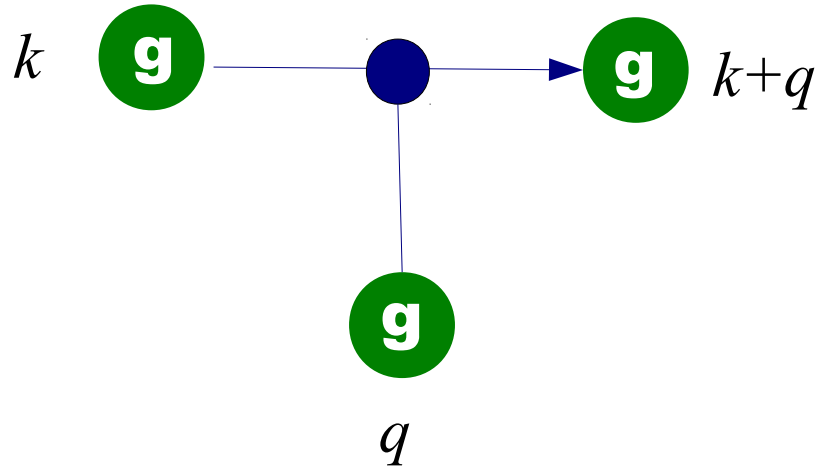
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$$G_{\mu\nu\rho}^{abc}(x, y, z) = \langle A_{\mu}^a(x) A_{\nu}^b(y) A_{\rho}^c(z) \rangle$$

Three-technigluon vertex

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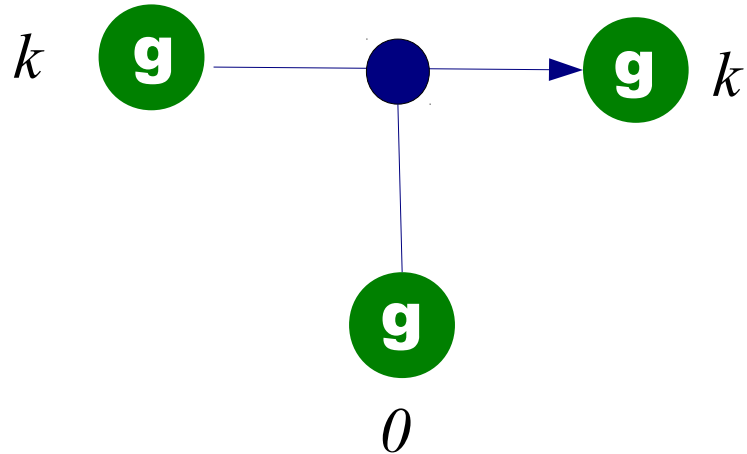


$$G_{\mu\nu\rho}^{abc}(x, y, z) = \langle A_{\mu}^a(x) A_{\nu}^b(y) A_{\rho}^c(z) \rangle$$

$$G^{A^3}(k, q, k+q) = \frac{\Gamma_{\mu\nu\rho}^{0; abc} G_{\mu\nu\rho}^{abc}(k, q, k+q)}{\Gamma_{\alpha\beta\gamma}^{0; deg} D_{\alpha\delta}^{df}(k) D_{\beta\epsilon}^{eh}(q) D_{\gamma\omega}^{gi}(q+k) \Gamma_{\delta\epsilon\omega}^{0; fhi}}$$

Three-technigluon vertex

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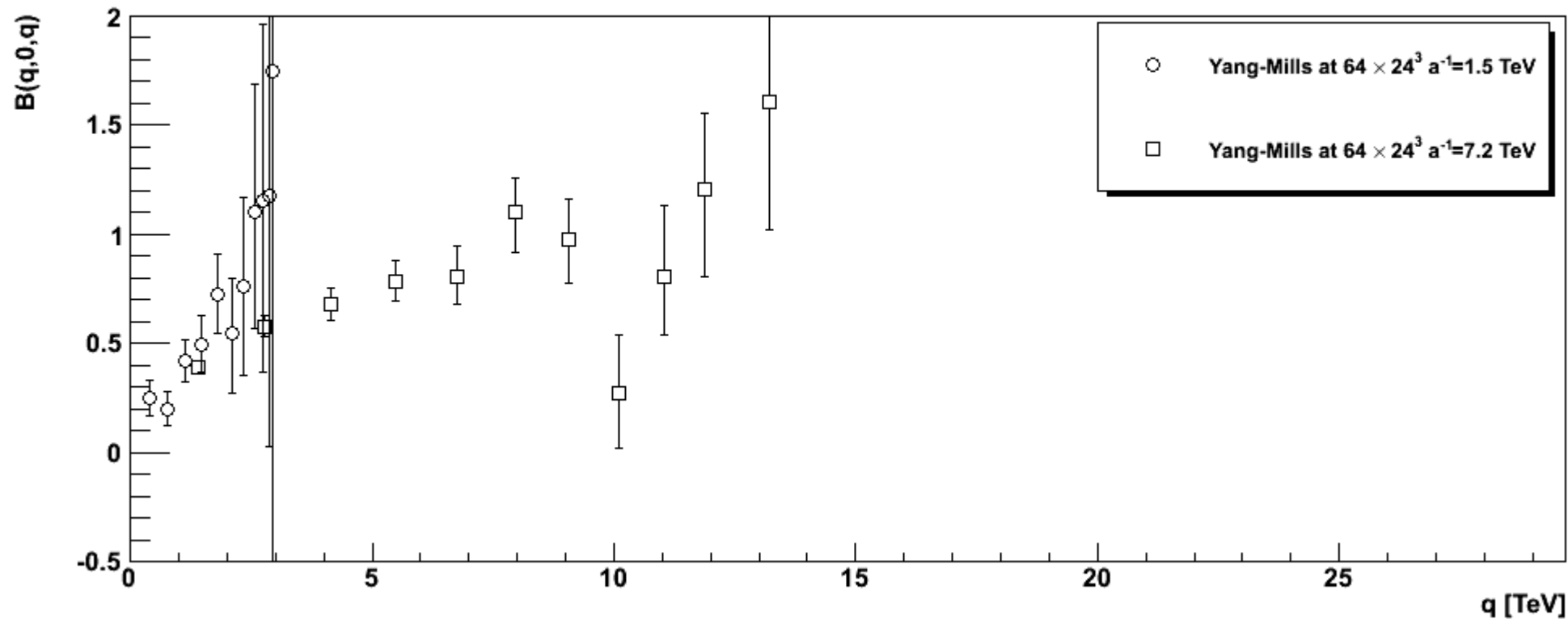
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Three-technigluon vertex

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Three-technigluon vertex

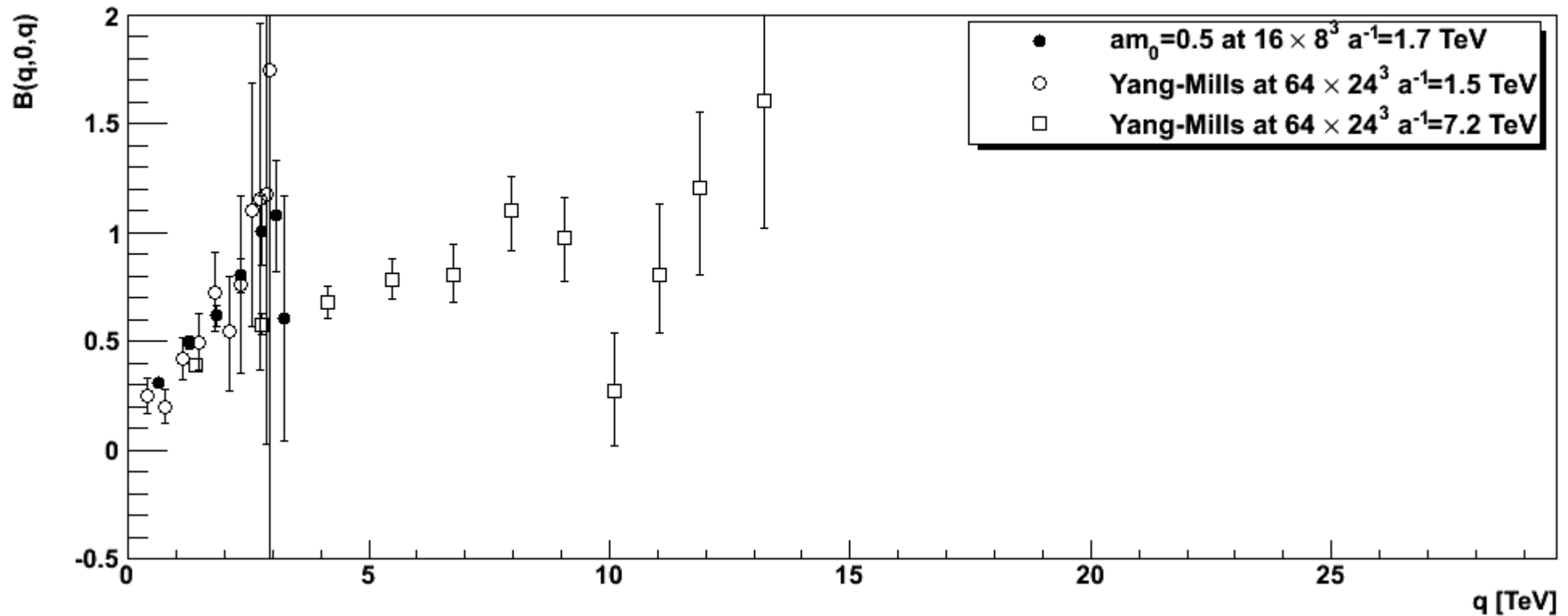


- Significant structure for Yang-Mills theory

Three-technigluon vertex

[Maas JHEP 2011]

Three-technigluon vertex

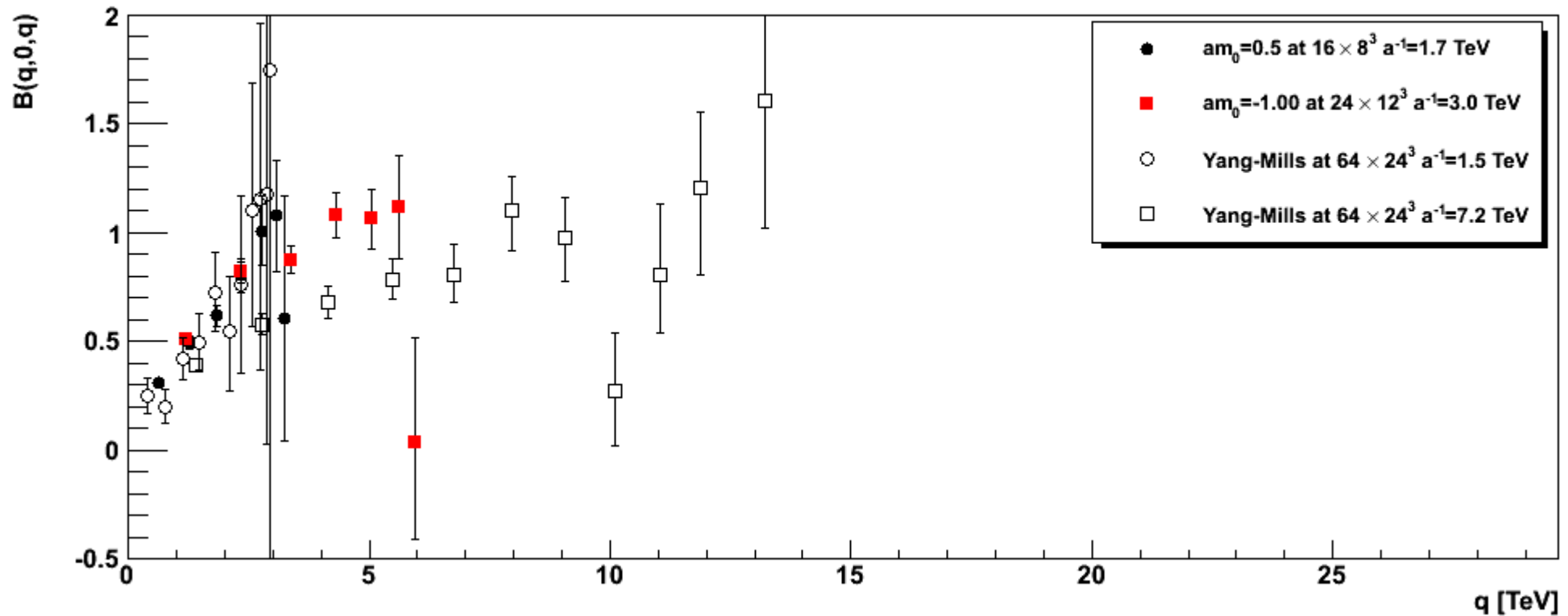


- Significant structure for Yang-Mills theory
- Similar at finite mass

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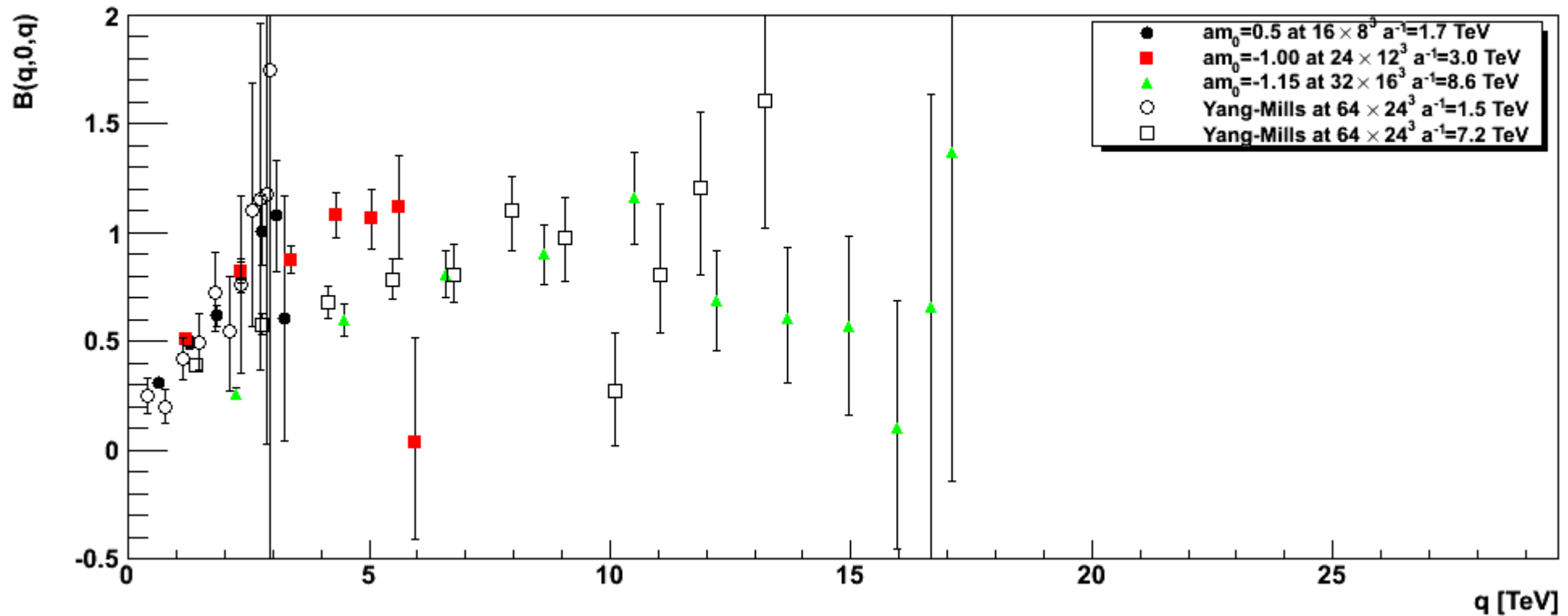


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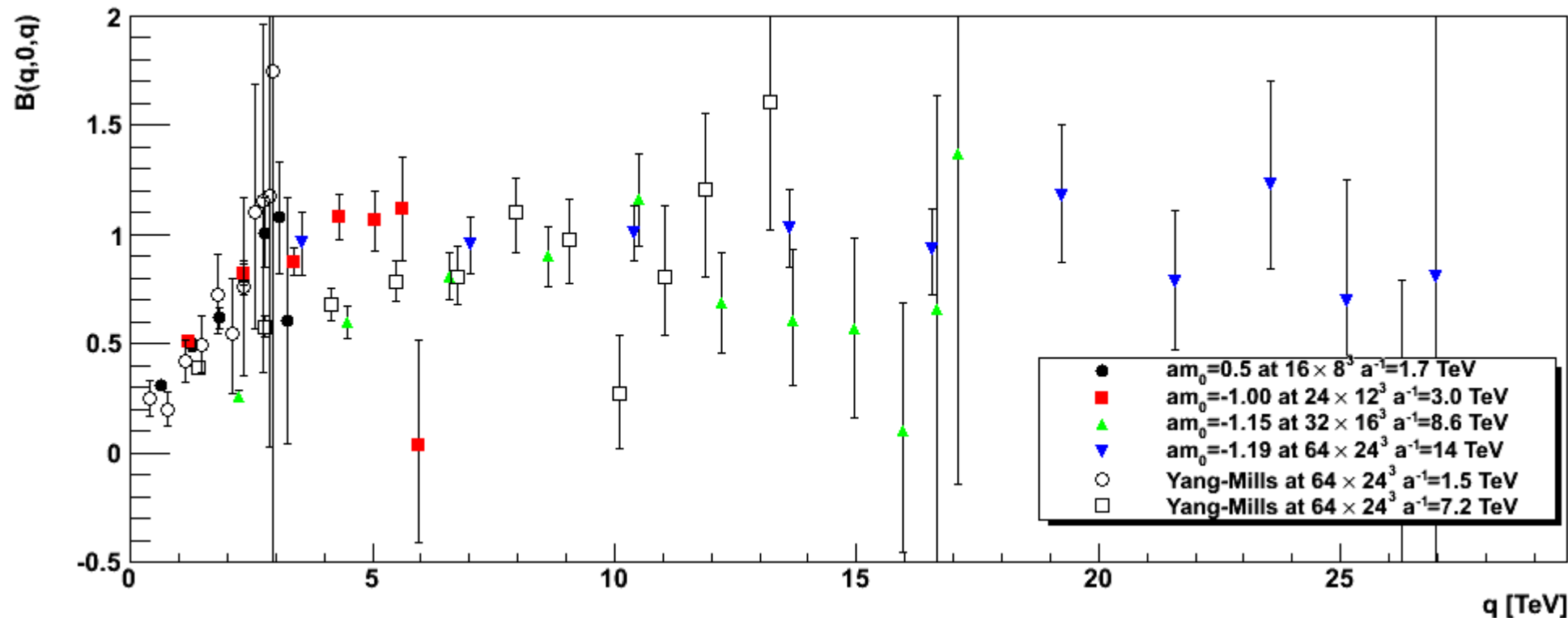


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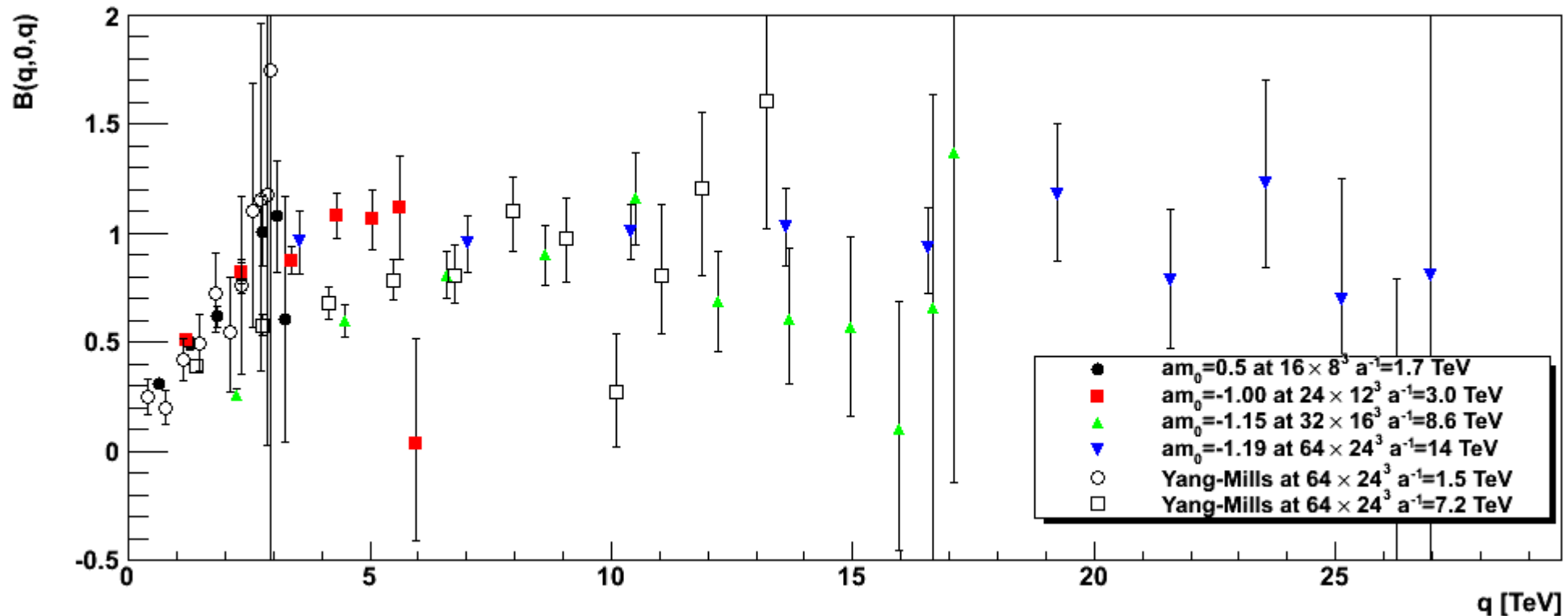


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- Similar at finite mass
- Flattens out towards chiral limit?

Three-technigluon vertex

[Maas JHEP 2011]

Three-technigluon vertex



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- Strongly affected by lattice asymmetry

Running coupling

[Maas JHEP 2011]

- Running coupling computed from correlation functions
[von Smekal et al. AoP 1997]

Running coupling

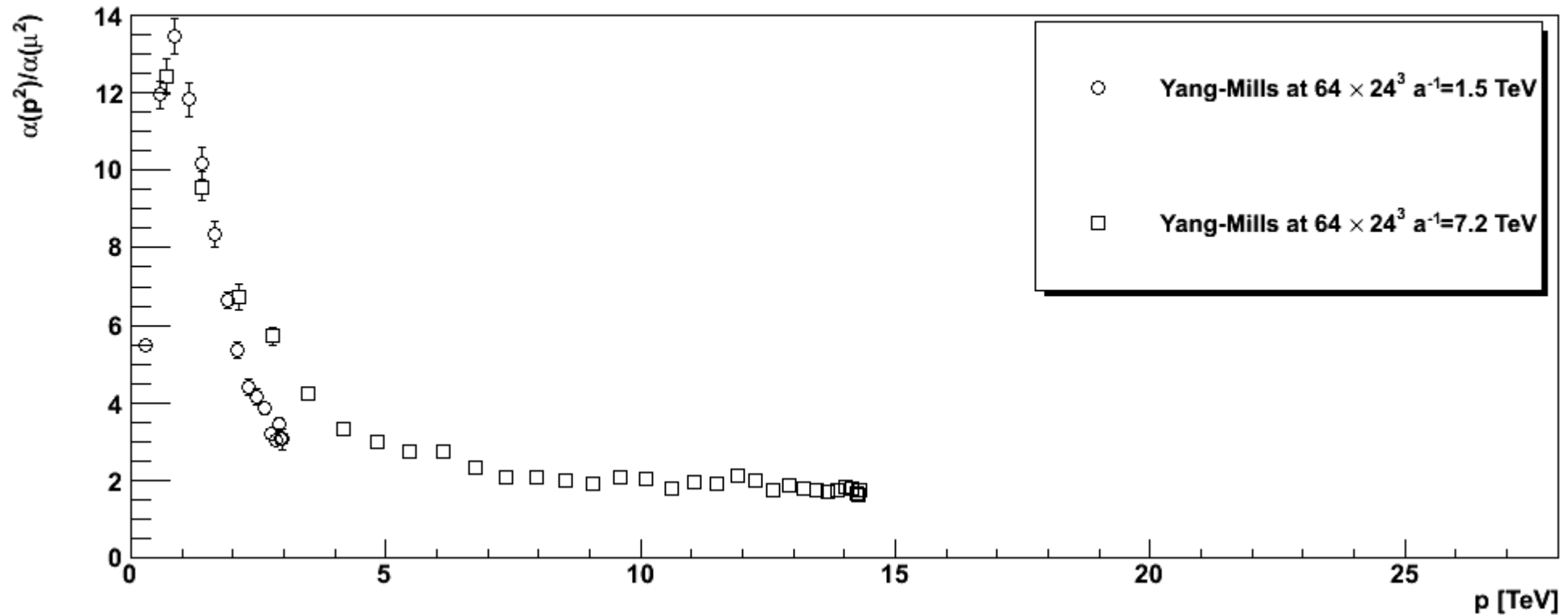
[Maas JHEP 2011]

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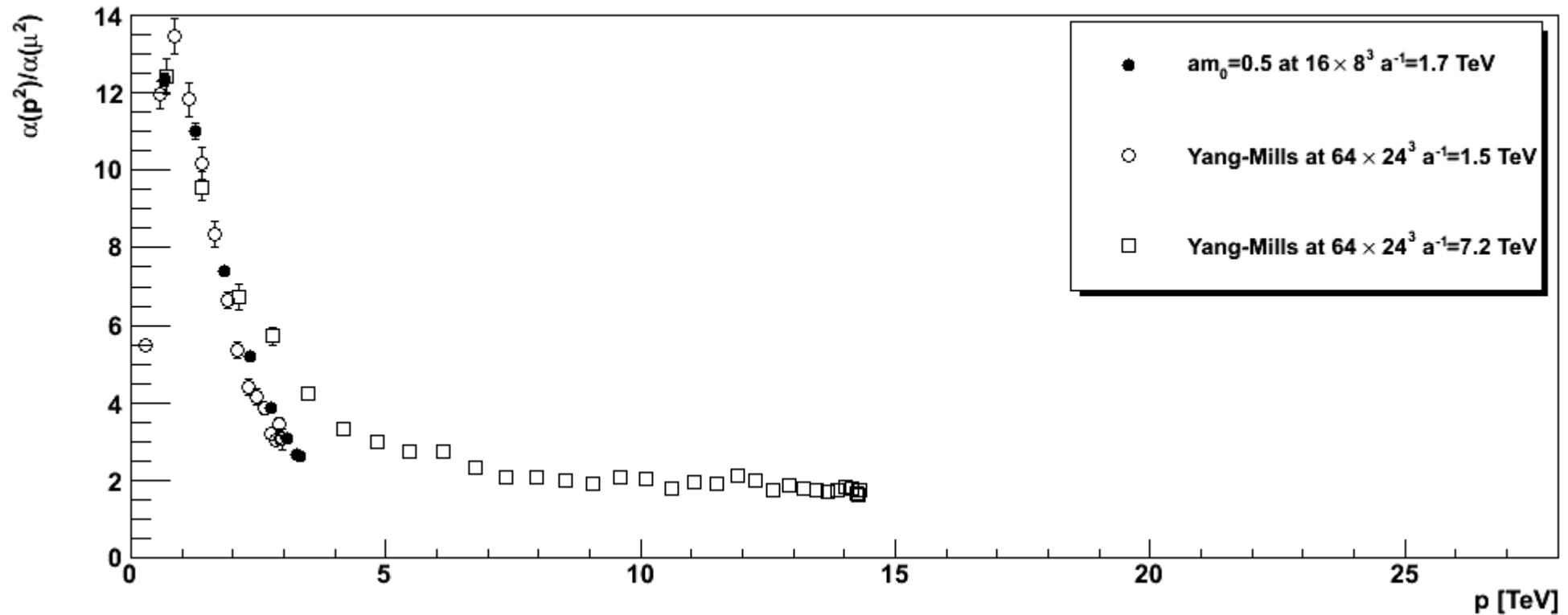


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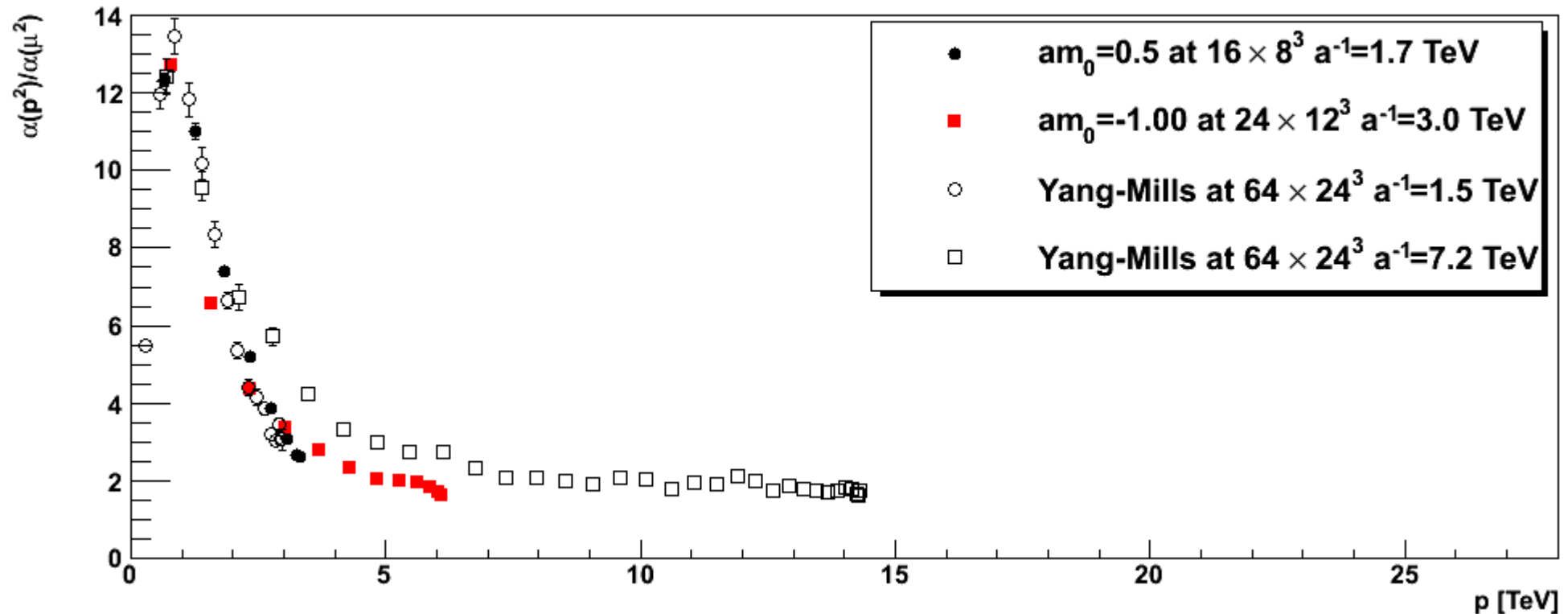


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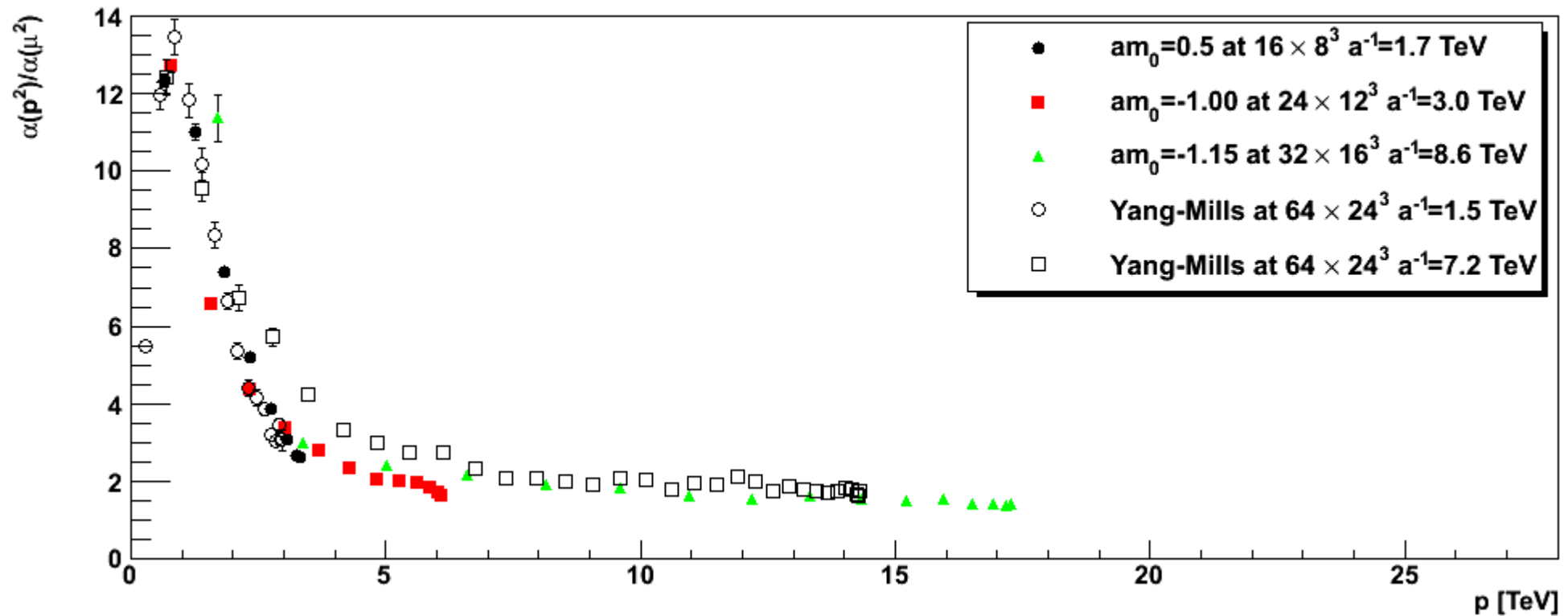


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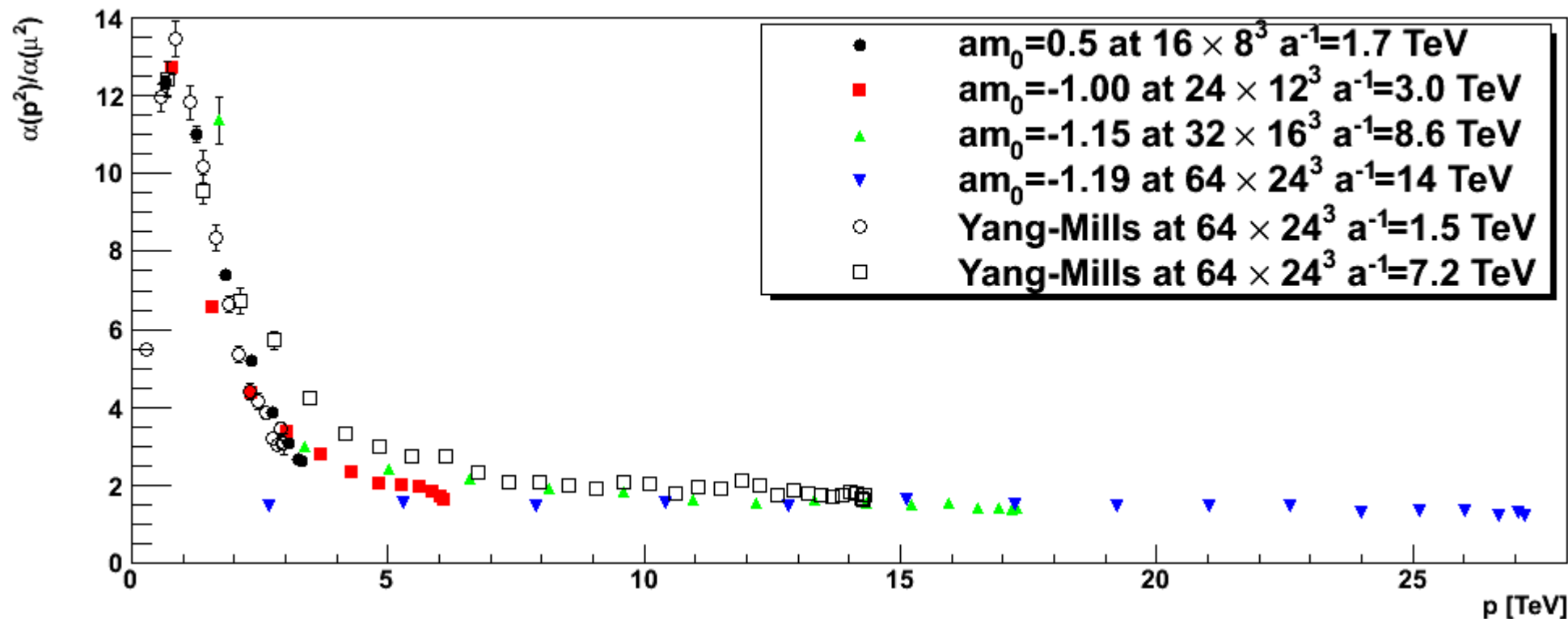


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