Compact QED : the photon propagator, confinement and positivity violation for the pure gauge theory

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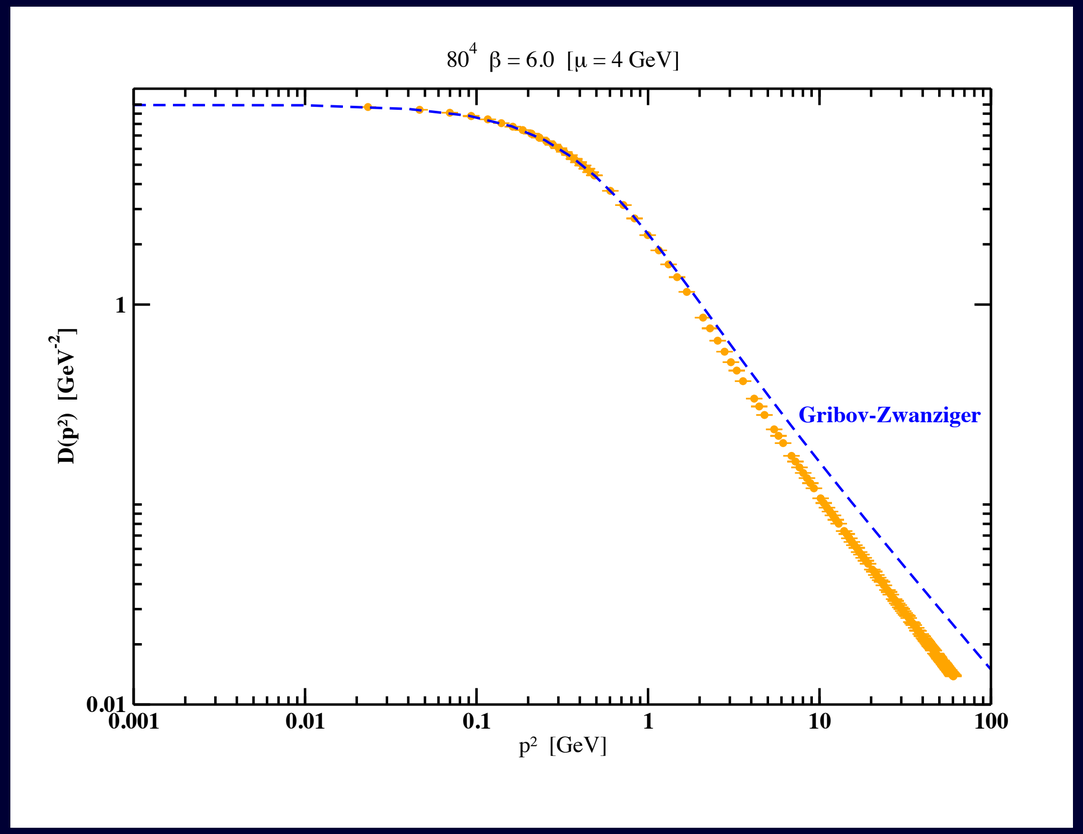
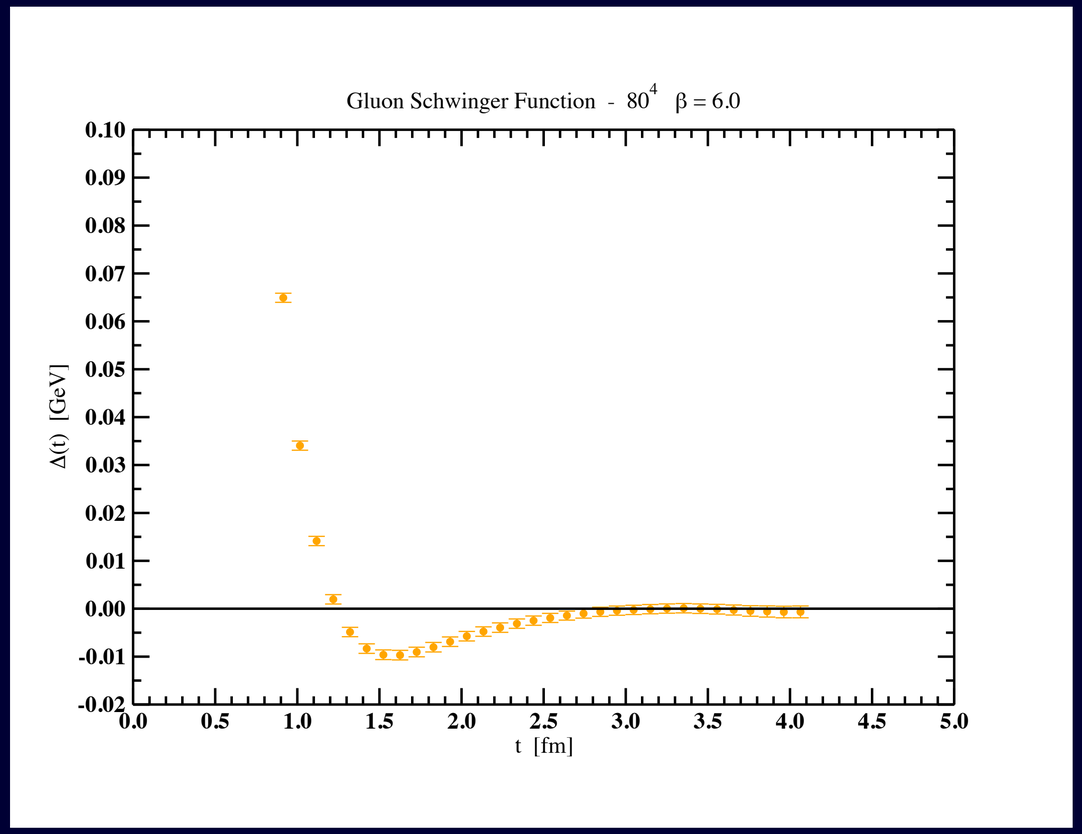
XVTH QUARK CONFINEMENT AND THE HADRON SPECTRUM, STAVANGER

Motivation: understand QCD and gluon confinement





A G Duarte, O. Oliveira, P. Silva PRD 94 (2016) 1, 014502

Complex Conjugate Poles:
D. Dudal, O. Oliveira, N. Vandersikel, PRD 81 (2010) 074505
A. Cucchieri, D. Dudal, T Mendes, N Vandersickel, PRD 85 (2012) 094513
A F Falcão, O. Oliveira, P J Silva, PRD 102 (2020) 11, 114518

$$\Delta(t) = \int_0^{+\infty} \frac{dy}{2\sqrt{y}}\, \rho(y^2)\, e^{-y\,t}$$

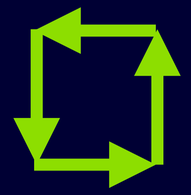
Spectral Density

Compact QED

$$U_\mu(x) = \exp\left\{ i\, e \oint_C A_\mu(z) dz_\mu \right\} = \exp\left\{ i\, a\, e\, A_\mu\left(x + \frac{a}{2}\widehat{e}_\mu\right)\right\}$$

$$S_W = \beta \sum_x \sum_{\mu,\nu} \left(1 - \Re\left[U_{\mu\nu}(x)\right]\right)$$

$$U_{\mu\nu}(x) \equiv$$



$$\equiv \exp\left\{ i\, a\, e\, \Delta A_\mu(x)\right\}$$

$$\beta = 1/e^2$$

$$A_\mu(x) = \sum_{\{sign\}} A_\mu + \frac{2\,\pi\, m_{\mu\nu}(x)}{a\, e}$$

Number of Dirac strings crossing the plaquette

$$m = \frac{1}{6\,V} \sum_{x,\, \mu<\nu} \left| m_{\mu\nu}(x) \right|$$

Compact QED: Landau gauge

Copy the procedure used in non-Abelian gauge theories

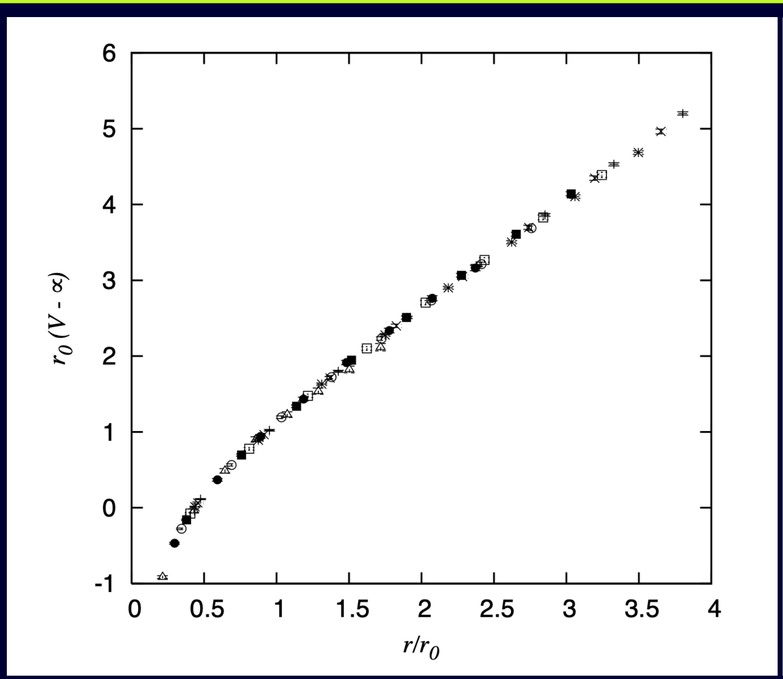
Take into account the log definition of the photon field

HMC for the simulations

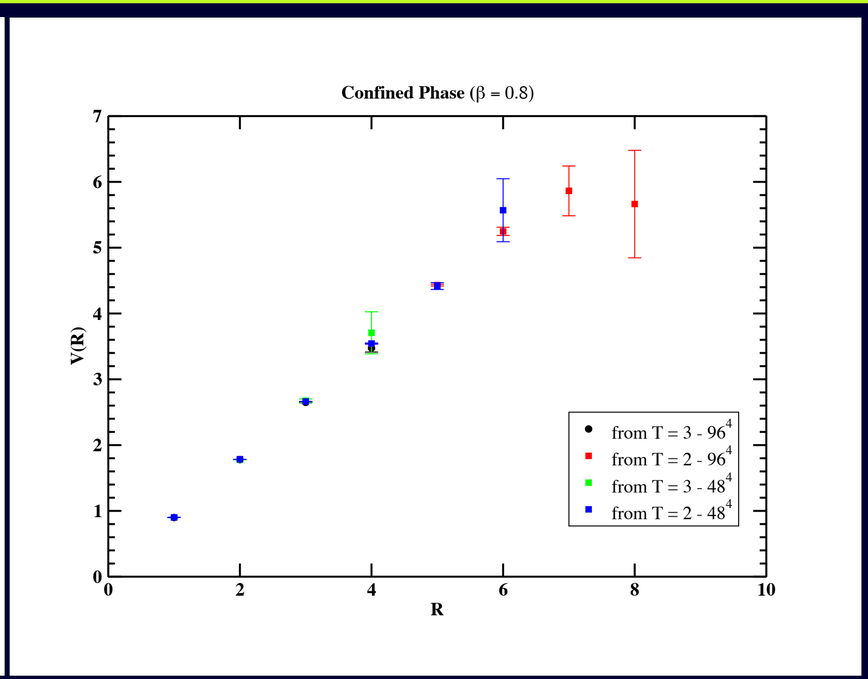
Details can be found in

Lee C Loveridge, O. Oliveira, P. J. Silva

PRD 103 (2021) 9, 094519; PRD 104 (2021) 11, 114511; PRD 106 (2022) 1, L011502

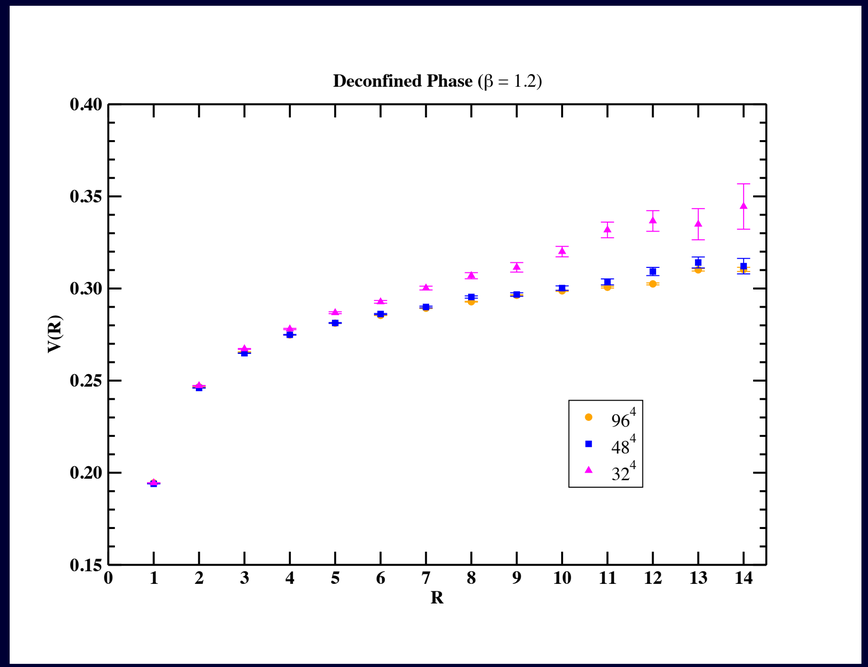


M Panero, *JHEP* 05 (2005) 066



$\beta \lesssim 1$(Confined Phase)

$\beta \gtrsim 1$(Deconfined Phase)



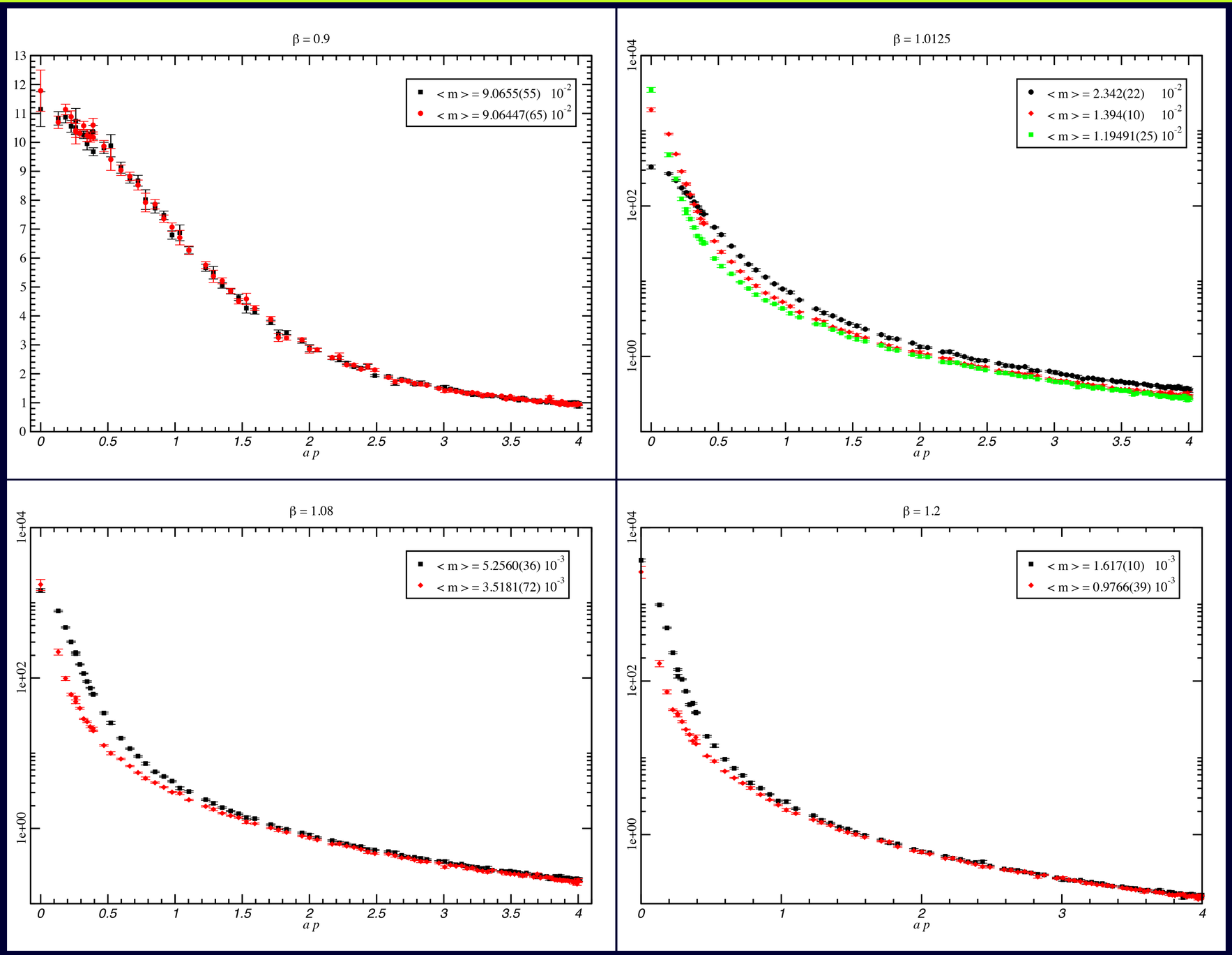
Confined Phase

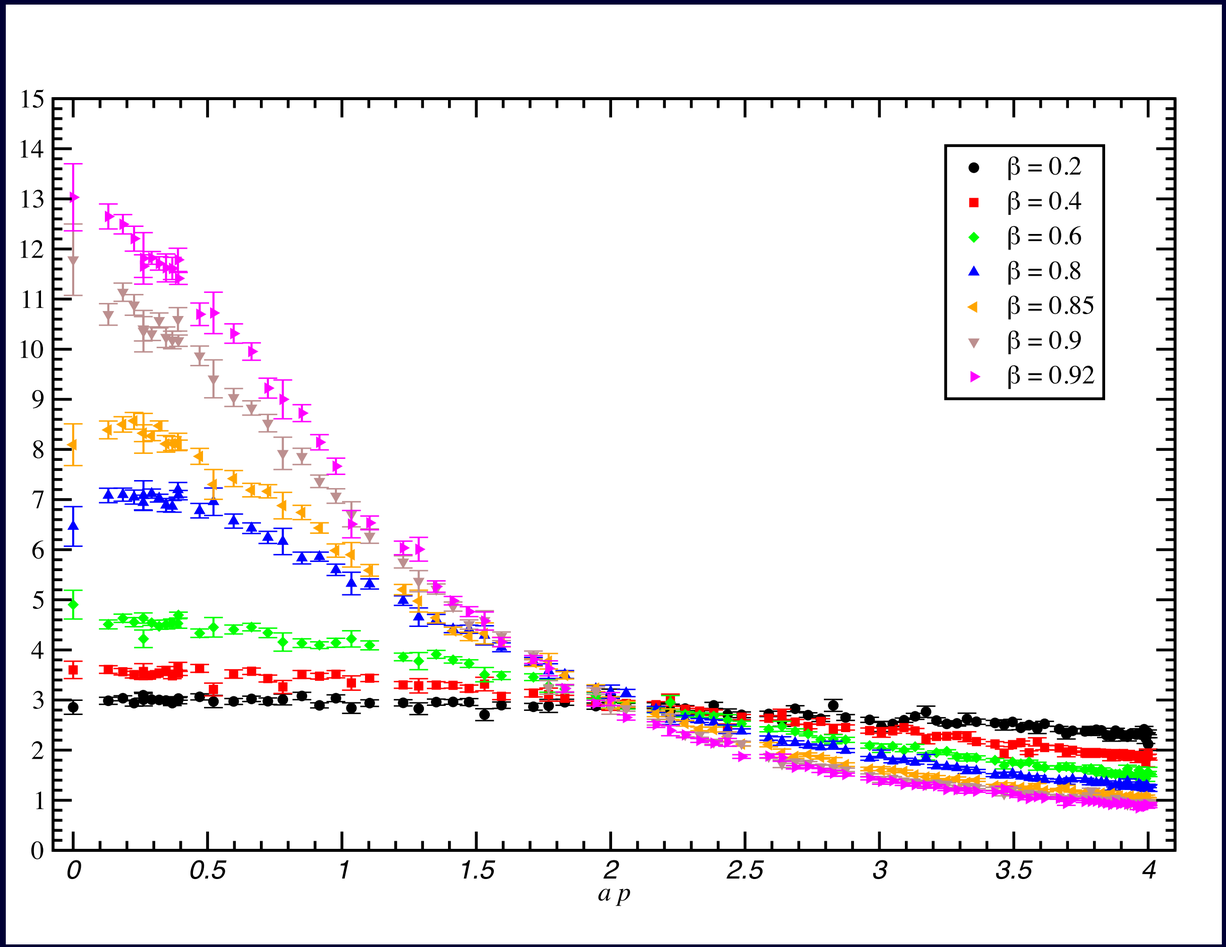
A. M. Polyakov, Nucl. Phys. B120, 429 (1977)

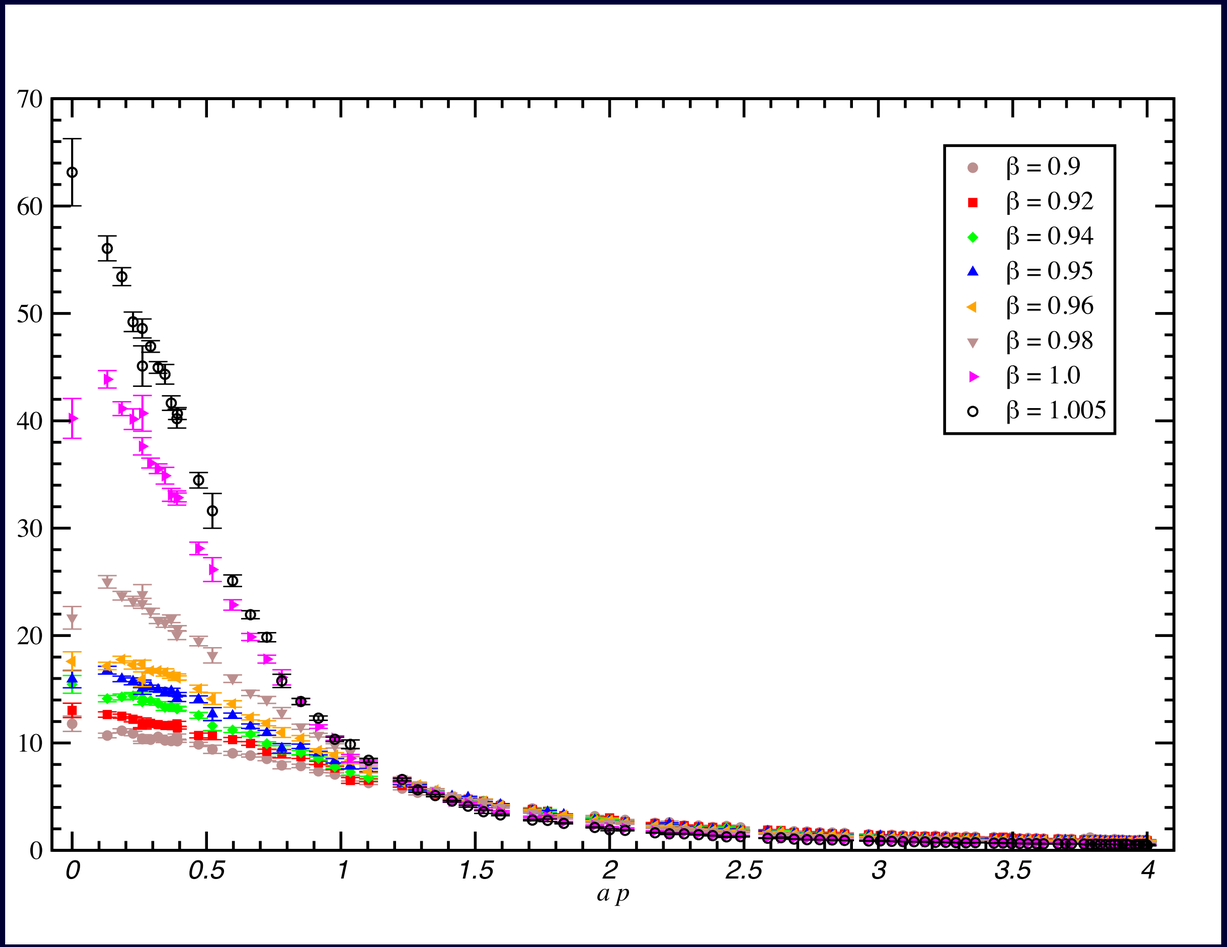
Mass gap —> confinement

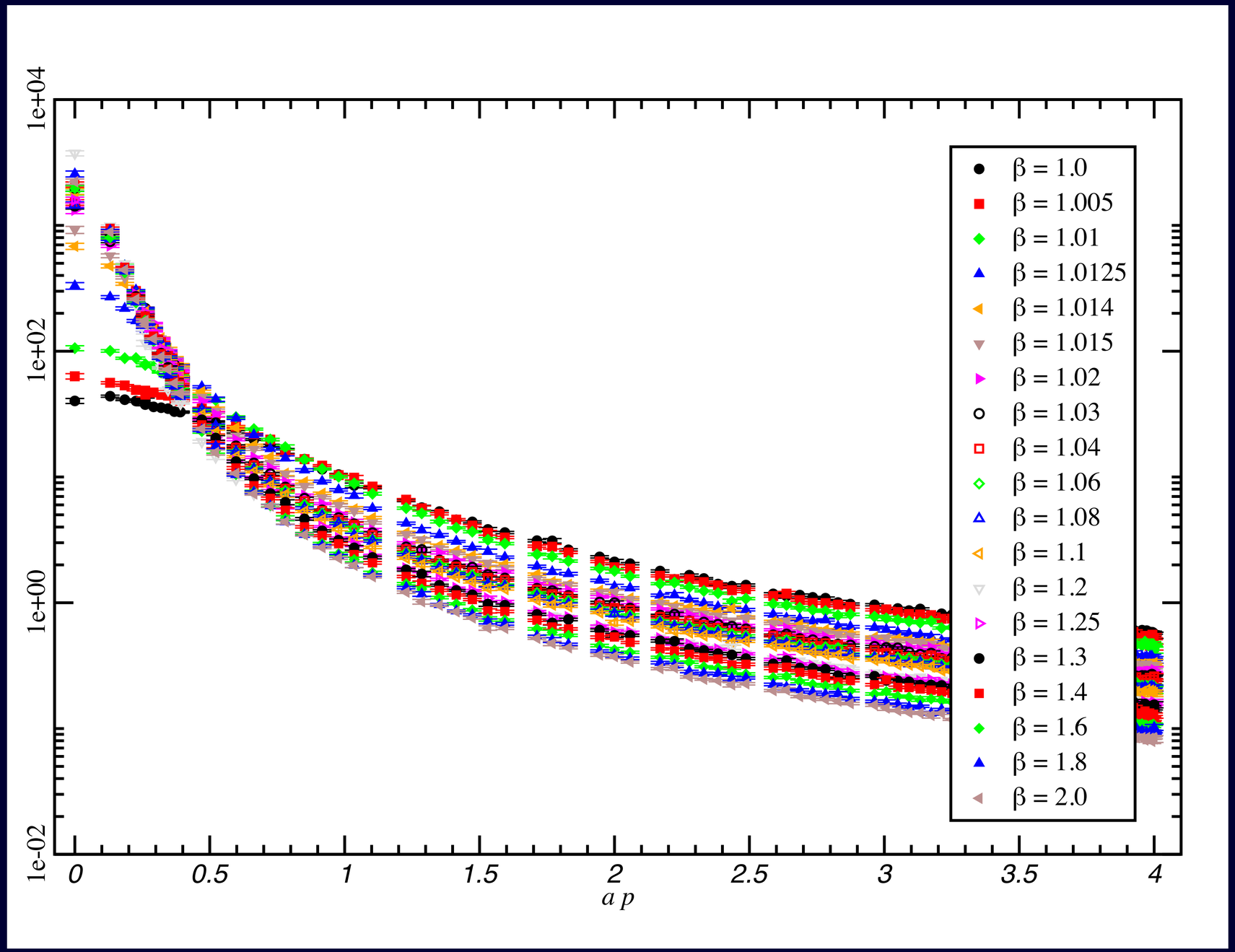
Deconfined Phase

Free field theory


β = 0.9
< m > = 9.0655(55) 10^-2
< m > = 9.06447(65) 10^-2
a p
β = 1.0125
< m > = 2.342(22) 10^-2
< m > = 1.394(10) 10^-2
< m > = 1.19491(25) 10^-2
a p
β = 1.08
< m > = 5.2560(36) 10^-3
< m > = 3.5181(72) 10^-3
a p
β = 1.2
< m > = 1.617(10) 10^-3
< m > = 0.9766(39) 10^-3
a p


β = 0.2
β = 0.4
β = 0.6
β = 0.8
β = 0.85
β = 0.9
β = 0.92
a p


β = 0.9
β = 0.92
β = 0.94
β = 0.95
β = 0.96
β = 0.98
β = 1.0
β = 1.005
a p


1e+04
1e+02
1e+00
1e-02
0
0.5
1
1.5
2
2.5
3
3.5
4
a p
β = 1.0
β = 1.005
β = 1.01
β = 1.0125
β = 1.014
β = 1.015
β = 1.02
β = 1.03
β = 1.04
β = 1.06
β = 1.08
β = 1.1
β = 1.2
β = 1.25
β = 1.3
β = 1.4
β = 1.6
β = 1.8
β = 2.0

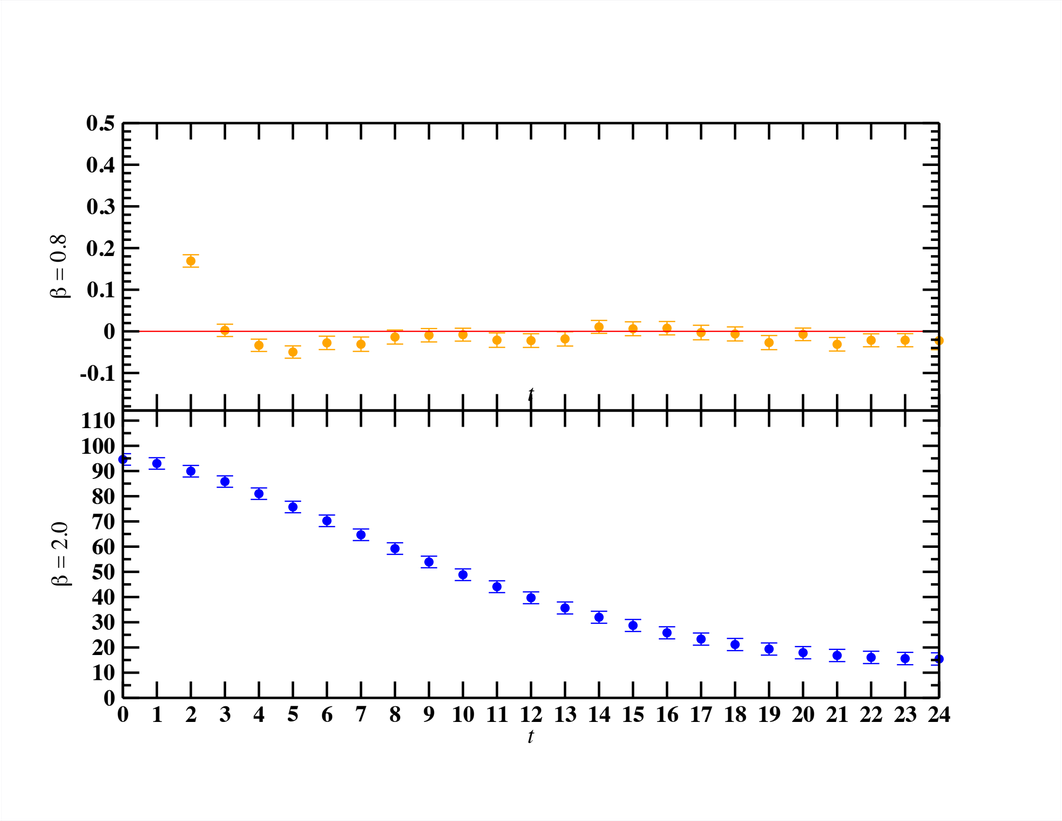
Schwinger Function

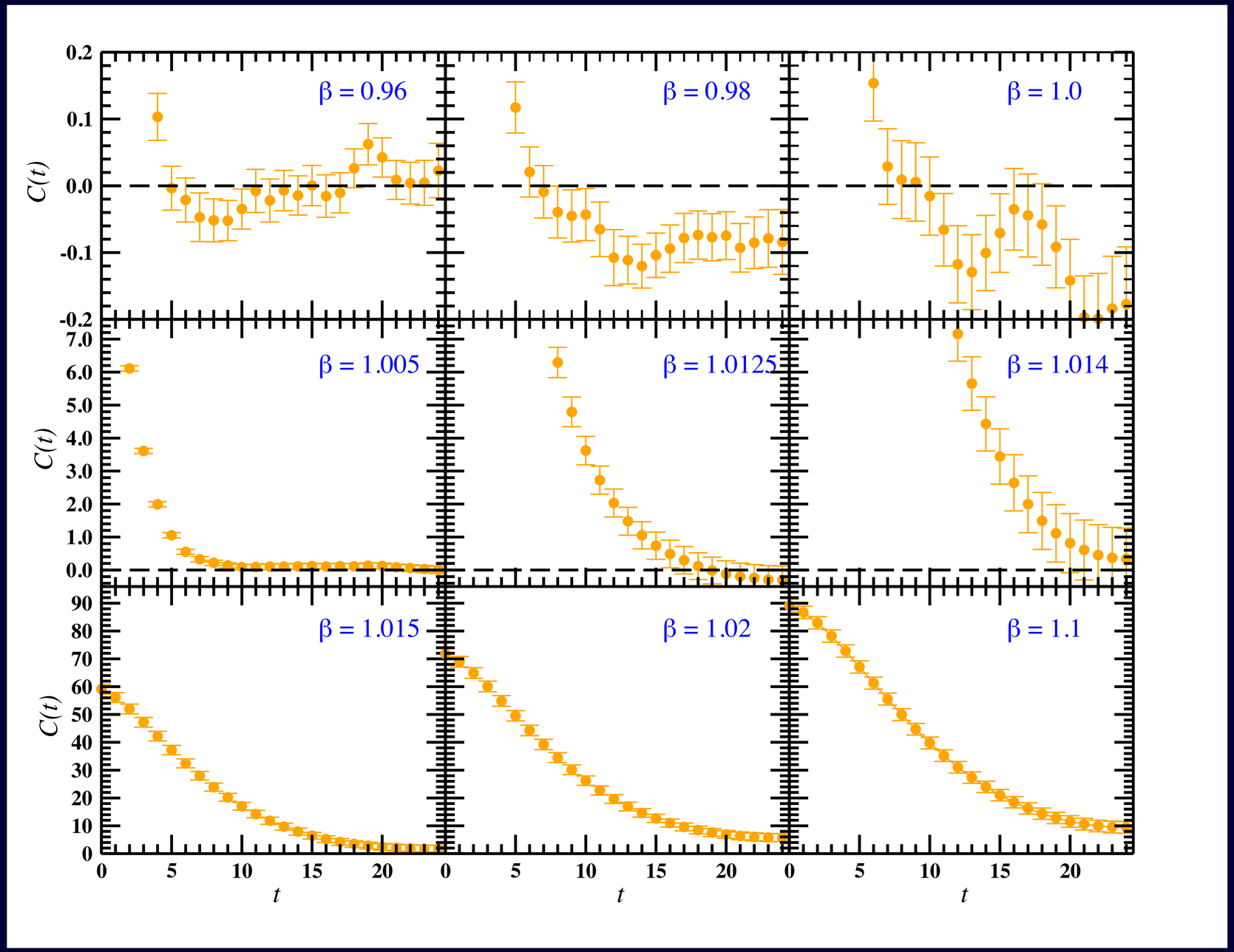
$$C(t) = \int_0^{+\infty} \frac{dy}{2\sqrt{y}}\, \rho(y^2)\, e^{-y\,t}$$

$$D(p^2) = \int_0^{+\infty} d\mu\, \frac{\rho(\mu)}{p^2 + \mu}$$

$$\rho(\mu) = \sum_n \delta(\mu - m_n^2)\, |\langle 0|\mathcal{O}|n\rangle|^2$$

Schwinger Function




β = 0.96
β = 0.98
β = 1.0
β = 1.005
β = 1.0125
β = 1.014
β = 1.015
β = 1.02
β = 1.1
C(t)
t
0.2
0.1
0.0
-0.1
-0.2
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20

Summary, Conclusions and Outlook

QED is a relevant and an interesting theory that needs further studies

understanding of confinement + topology + dynamical chiral symmetry breaking

Good understanding of the photon propagator

Needs a large statistical simulation (finite volume/spacing effects)

Topological freezing and the need for new algorithms for QED

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