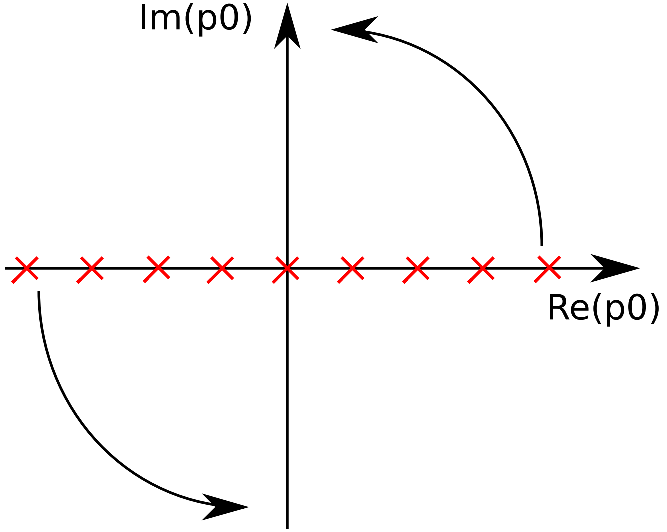
Real time correlation functions at finite temperature



Nicolas Wink

In collaboration with

N. Strodthoff

J. M. Pawlowski

Based on

Formalism + Vacuum

Pawlowski, Strodthoff, PhysRevD.92.094009

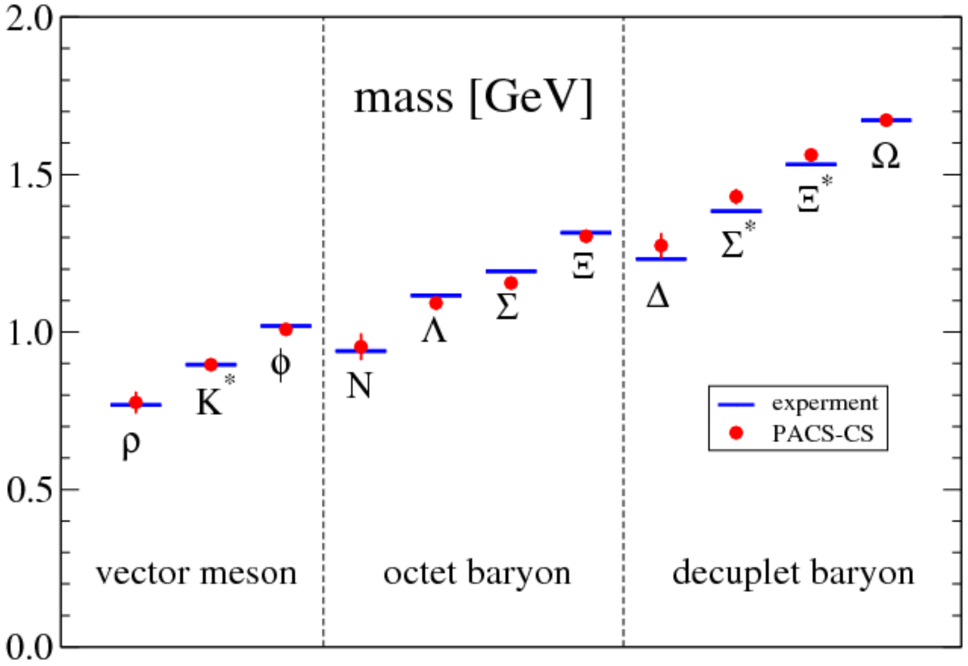
Self-consistent Vacuum

Strodthoff, arXiv:1611.05036

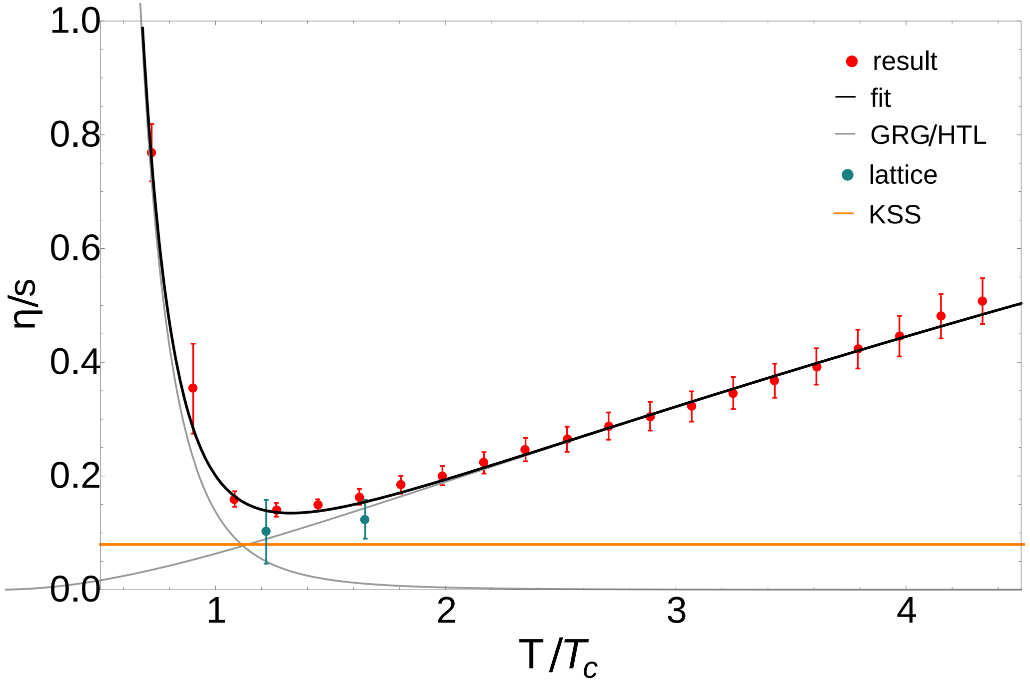
Finite temperature

Pawlowski, Strodthoff, NW, in prep

Why real time correlation functions?



PACS-CS collaboration



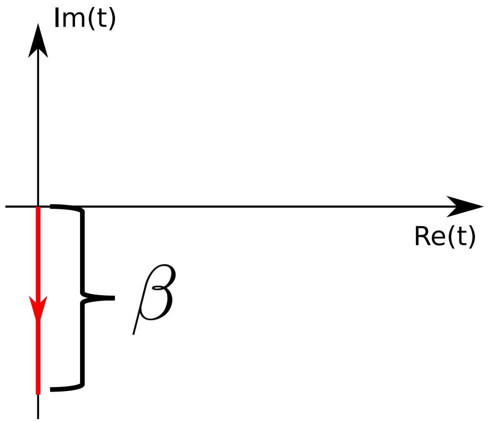
PRL, 115 (2015) no.11, 112002

Christiansen, Haas, Pawlowski, Strodthoff

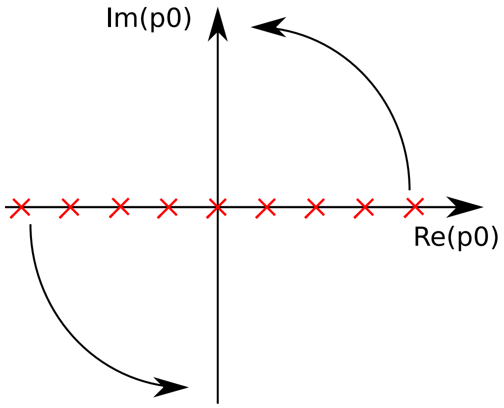
Bound state spectrum

Transport coefficients

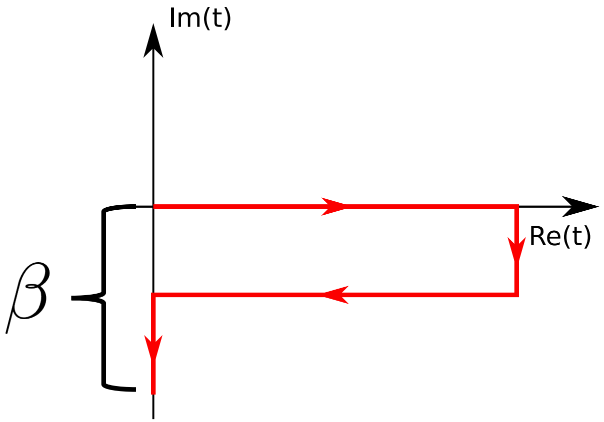
From imaginary to real times



Matsubara contour



Continuation from Matsubara frequencies



Schwinger-Keldysh contour

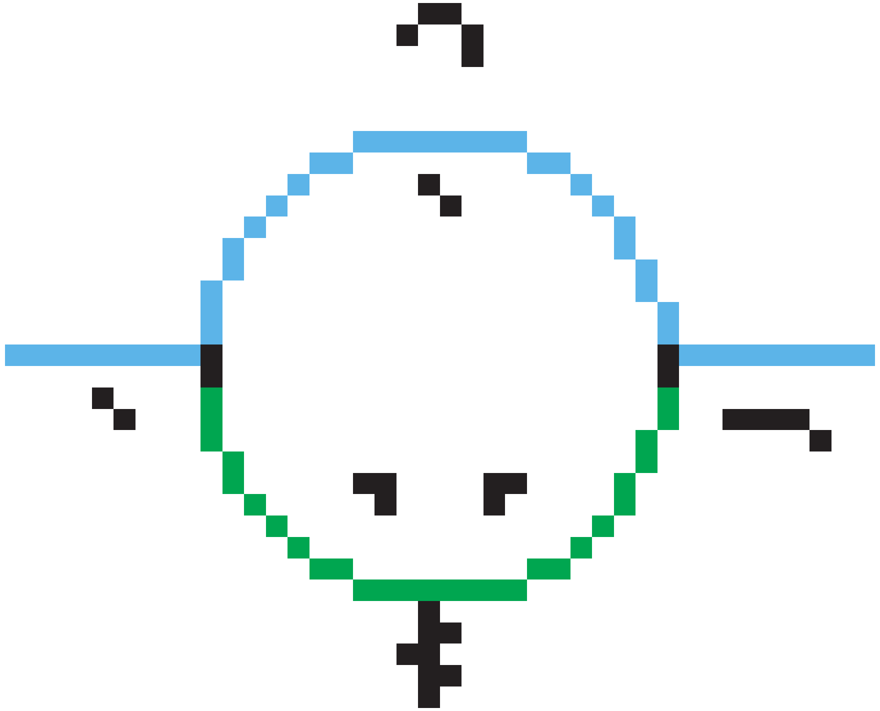
Use analyticity constrains and KMS condition to obtain real time correlation functions form Matsubara formalism

Illustrative example

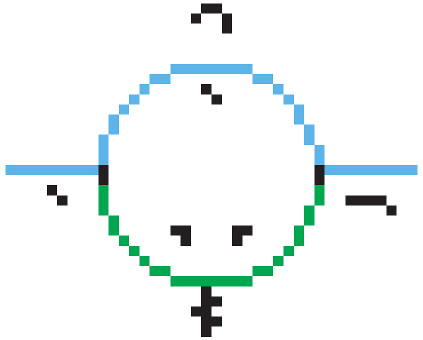
Two bosonic fields with $\sim\ \Phi\Phi\varphi$

Calculate $\Gamma^{(2)}(p)$ for $p^0 \in \mathbb{C}$

Calculate Matsubara sum $\displaystyle\sum\!\!\!\!\!\!\!\int_{T,q} G_1(q+p)G_2(q)$



Illustrative example

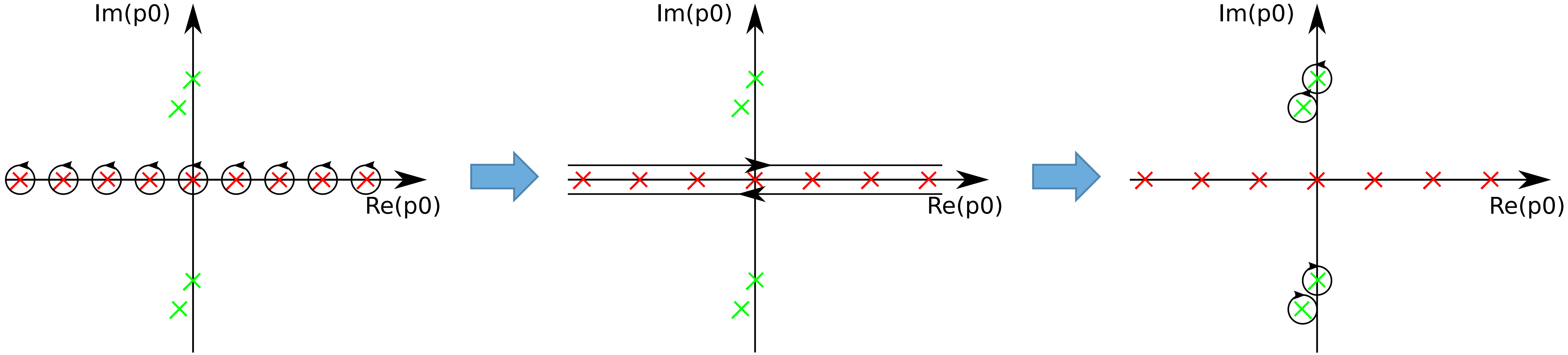


Replace sum by contour integral:

Bosonic occupation number

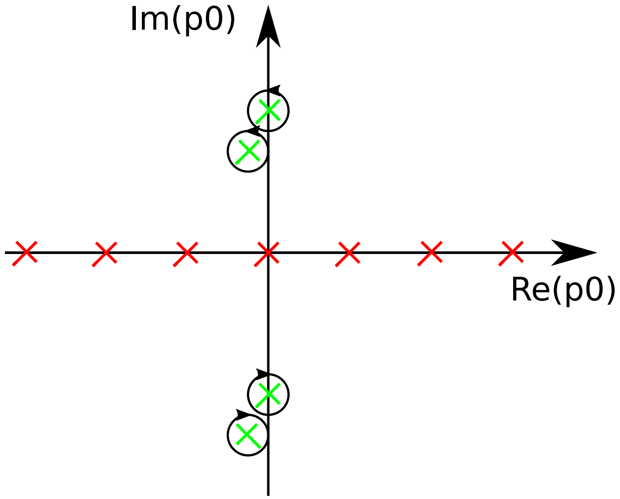
$$T\sum_n f(2\pi nT) = -\frac{1}{2}\int_C \mathrm{d}z \quad f(z)[1+2n_B(iz)]$$

$$\sum_T \frac{1}{(q_0+p_0)^2+(\epsilon^1_{q+p})^2}\,\frac{1}{(q_0)^2+(\epsilon^2_q)^2}$$



Illustrative example

$$\frac{1}{i}\sum_{\pm}\left(\mathrm{Res}_1^{\pm}\cdot[1+2n_B(-\not{i}p_0+\epsilon^1_{q+p})]+\mathrm{Res}_2^{\pm}\cdot[1+2n_B(\epsilon^2_q)]\right)$$



$$p_0 = 2\pi m T \quad m\in\mathbb{Z}$$

Identify ambiguity of the analytic continuation

$$n_B(ip_0) = 1$$

Mathematically rigorous

Baym and Mermin, Journal of Mathematical Physics 2, 232 (1961)

Analytic off the imaginary axis

Correct decay behaviour at infinity

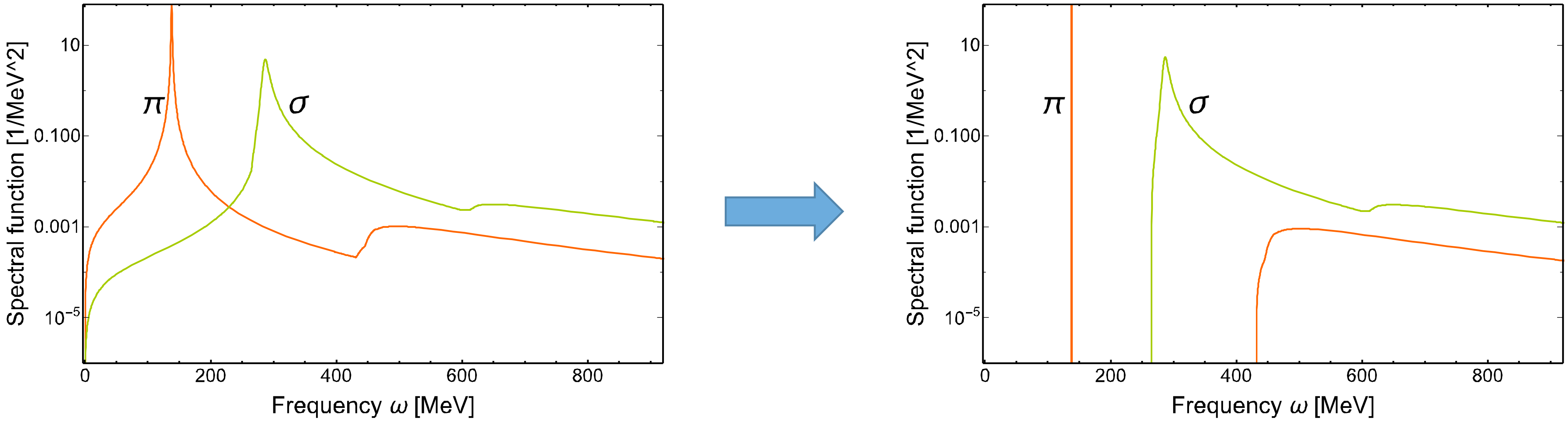
Unique physical analytic continuation identified by setting $n_B(ip_0) = 1$ everywhere

Retarded/Advanced Greens function

Retarded Greens function $\lim_{\varepsilon \to 0} G(-i(\omega + i\varepsilon))$

→ Take limit analytically

→ Numerical extrapolation



Generalisation to the FRG

<u>No new conceptual problems</u>

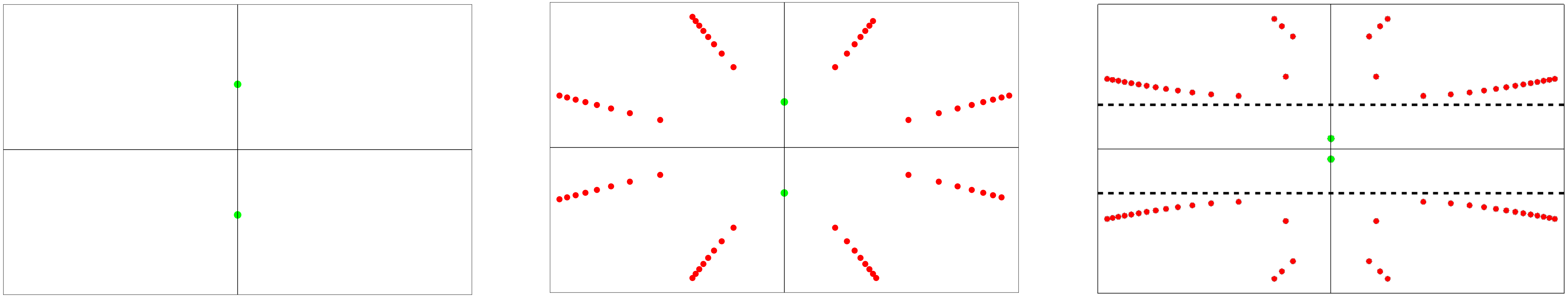
Kamikado, Strodthoff, von Smekal, Wambach, Eur.Phys.J. C74, 2806 (2014)

Tripolt, Strodthoff , von Smekal, Wambach, Phys.Rev. D89, 034010 (2014)

Regulator poles

$R_k(\vec{q}^{\,2})$ → No changes

$R_k(q^2)$ → Additional poles



$$\frac{1}{q^2+m^2} \qquad \frac{1}{q^2+m^2+R_k(q^2)} \qquad \frac{1}{q^2+m^2+R_k(q^2+m_r)}$$

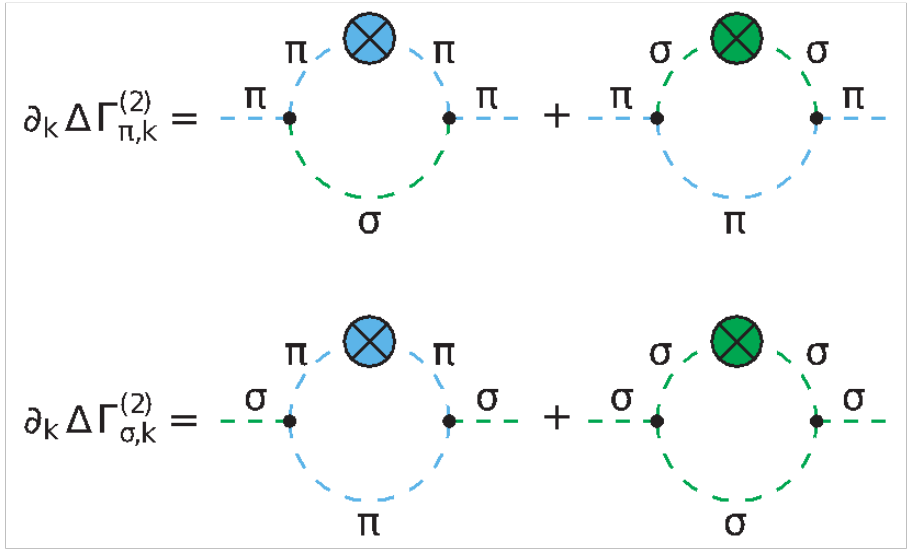
Application to the O(N)-Model

Effective description of the lightest mesons

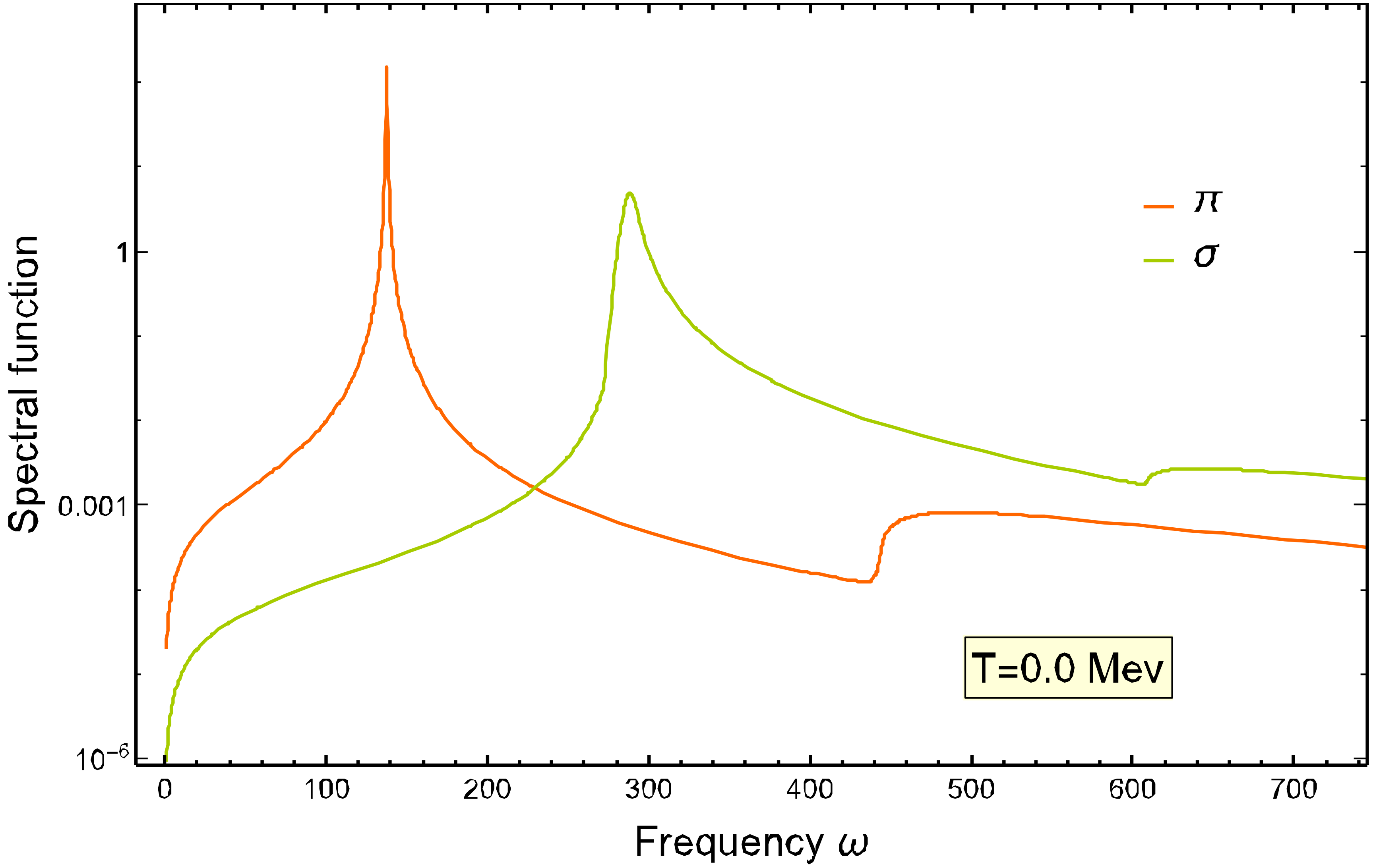
$$\Gamma_k = \sum\!\!\!\!\!\!\!\int_{T,q} \frac{Z_\sigma}{2} q^2 \sigma\sigma + \frac{Z_\pi}{2} q^2 \pi_a \pi^a + V(\sigma)$$

Calculate spectral functions of the O(N) model

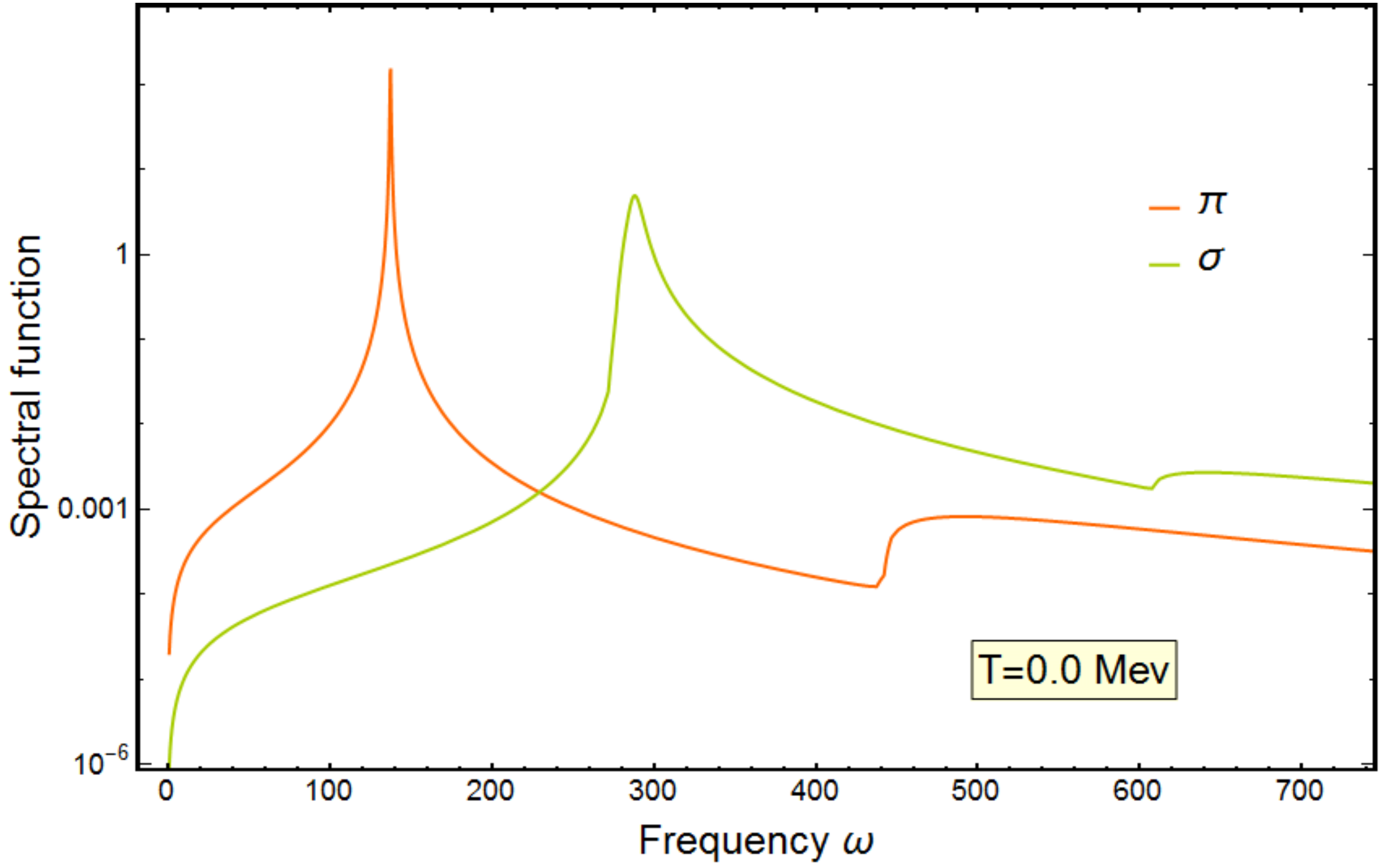
$$\rho(\omega, \vec{p}) = -2 \ \mathrm{Im} \ G_{\mathrm{R}}(\omega, \vec{p})$$



Application to the O(N)-Model



Application to the O(N)-Model



Summary & Outlook

- Perform analytic continuation
- Conceptual easy algorithm
- Finite temperature spectral functions

- Fully self-consistent truncation at finite temperature
- Real time representation of vertices
- Application to different model