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«JASPER: a software for quantum chromodynamics Dyson-Schwinger equation numerical calculation»

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JASPER: problem setup

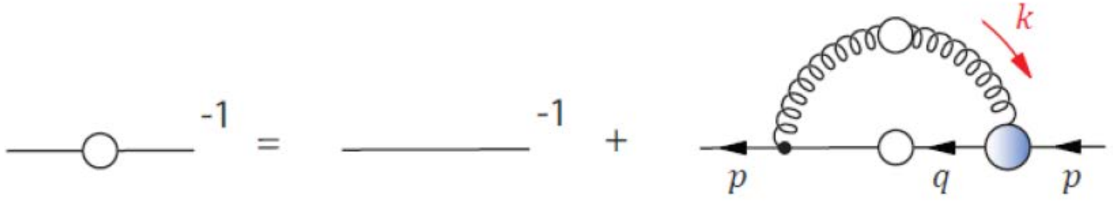
Goal: development of the Dyson-Schwinger equation (DSE) numerical solution program as a part of a HPC information system for estimate some elementary particle properties

Tasks:

- Build a numerical scheme for DSE solution calculating
- Numerical solution scheme implementation development (JASPER code)
- Using the JASPER program to dynamical quark mass obtain

JASPER: problem setup

Dyson-Schwinger equation for inverse quark propagator:



$$S^{-1}(p,\mu) = Z_2(\mu^2,\Lambda^2)\left(-i\gamma^{\rho} p_{\rho} + m(\mu) Z_m(\mu^2,\Lambda^2)\right) + \Sigma(p,\mu,\Lambda)$$

Merge of quark-gluon vertex and gluon propagator:

JASPER: problem setup

Dyson-Schwinger equation for inverse quark propagator:

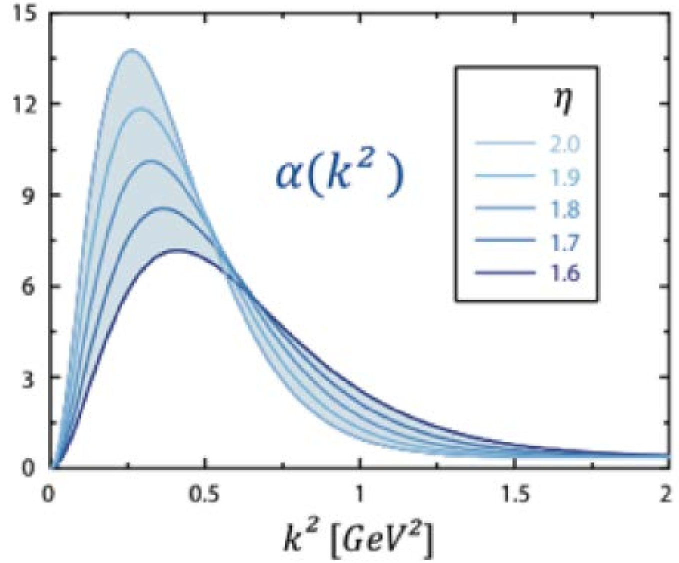
$$S^{-1}(p,\mu) = Z_2(\mu^2,\Lambda^2)\left(-i\gamma^\rho p_\rho + m(\mu) Z_m(\mu^2,\Lambda^2)\right) + \Sigma(p,\mu,\Lambda)$$

Where $Z_2(\mu^2,\Lambda^2) = \left(Z_f(p^2=\Lambda^2,\mu^2)\right)^{-1}$ is the quark field strength renormalization constant with the quark dressing function $Z_f(p^2,\mu^2)$, μ is the renormalization scale, $m(\mu)$ – is the renormalized quark mass, $Z_m(\mu^2,\Lambda^2)$ – is the quark mass renormalization constant, and Λ is the ultraviolet cutoff scale.

JASPER: problem setup

Maris and Tandy Ansatz for the rainbow truncation scheme:

$$\alpha(k^2) = \underbrace{\frac{c\pi}{\omega^7}\left(\frac{k^2}{\Lambda_0^2}\right)^2 \exp\left(\frac{-k^2}{\omega^2\Lambda_0^2}\right)}_{\text{IR-behavior}} + \underbrace{\frac{\pi\gamma_m\left(1-\exp\left(\frac{-k^2}{\Lambda_0^2}\right)\right)}{\left(\log\left(e^2-1+\left(1+\frac{-k^2}{\Lambda_{QCD}^2}\right)\right)\right)^{1/2}}}_{\text{UV-behavior}}$$



where ω and c are adjustable parameters of order unity, $\Lambda_{QCD} = 0.234$ GeV, $\Lambda_0 = 1$ GeV, $\mu \gg \Lambda_{QCD}$ is a large normalization scale, γ_m is the anomalous dimension, $\eta = \dfrac{1}{\omega}$

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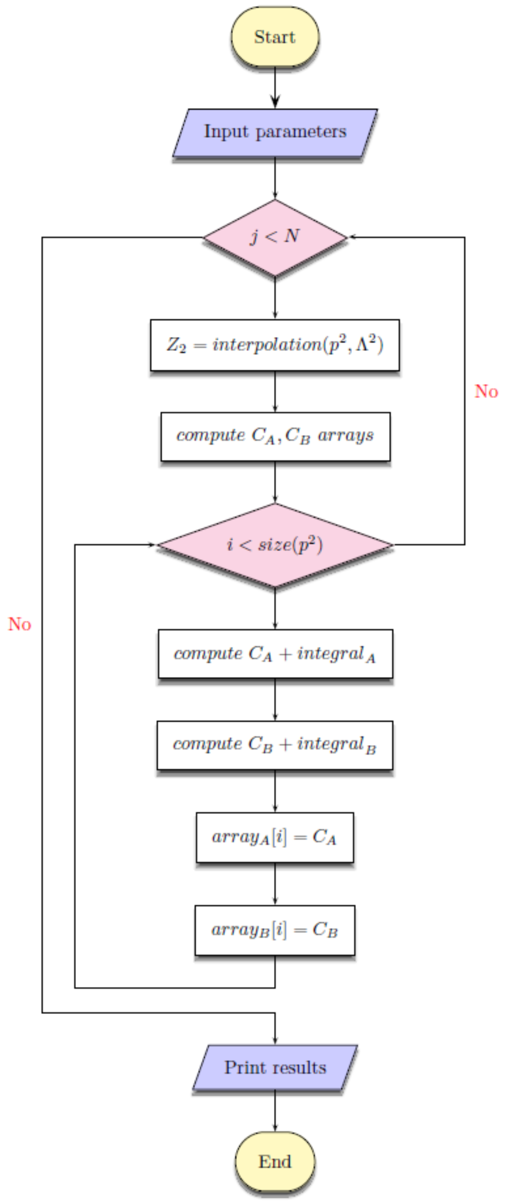
JASPER: code

JASPER program key features:

- Using GNU Scientific Library v2.6
- Double integration by the QAG method
- C++ language
- Iteration scheme



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Conclusions

Calculations using this program were validated by comparing the results of calculating the double integral by the QAG method with the Simpson rule-based calculation of the same integral. The numerical results for dynamical quark mass in complex Euclidean space were obtained. This result will be employed to study the hadron spectrum with the Bethe-Salpeter equation approach.

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