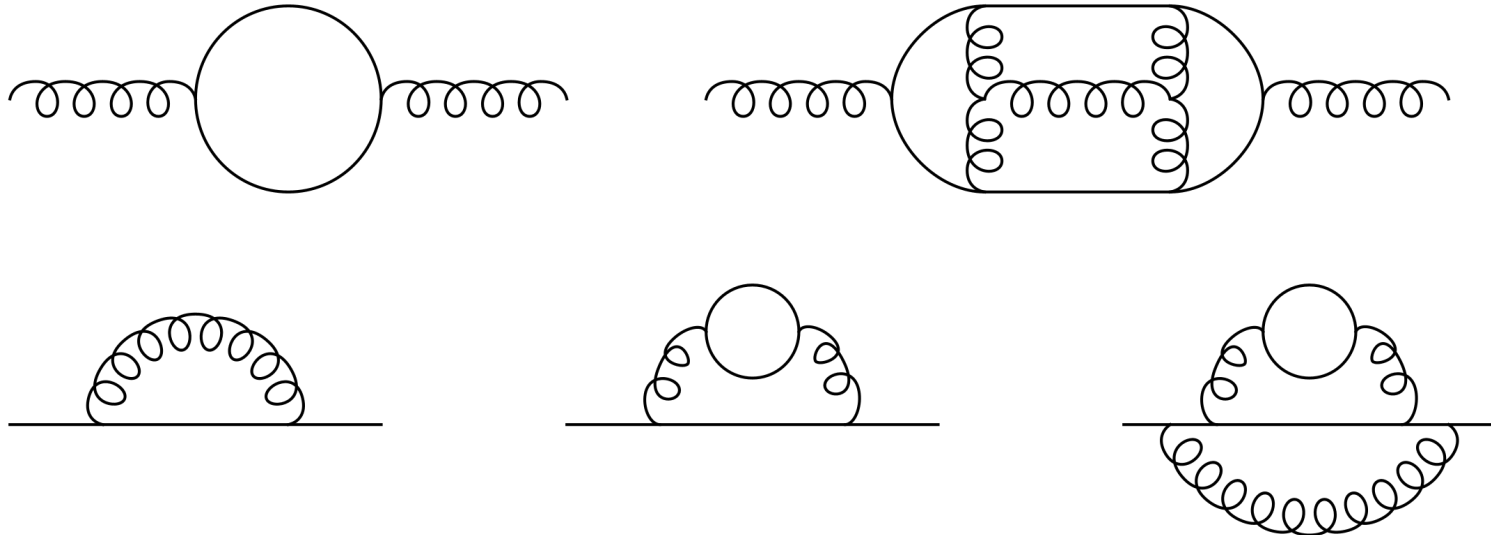


(C)RunDec: A package for running and decoupling of the strong coupling and quark mass

Florian Herren - Institute for Theoretical Particle Physics

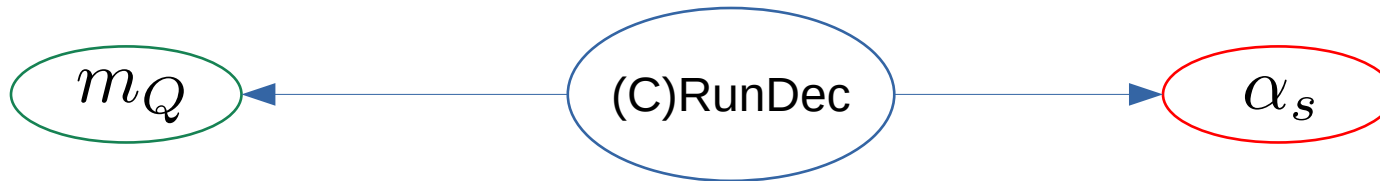


Overview

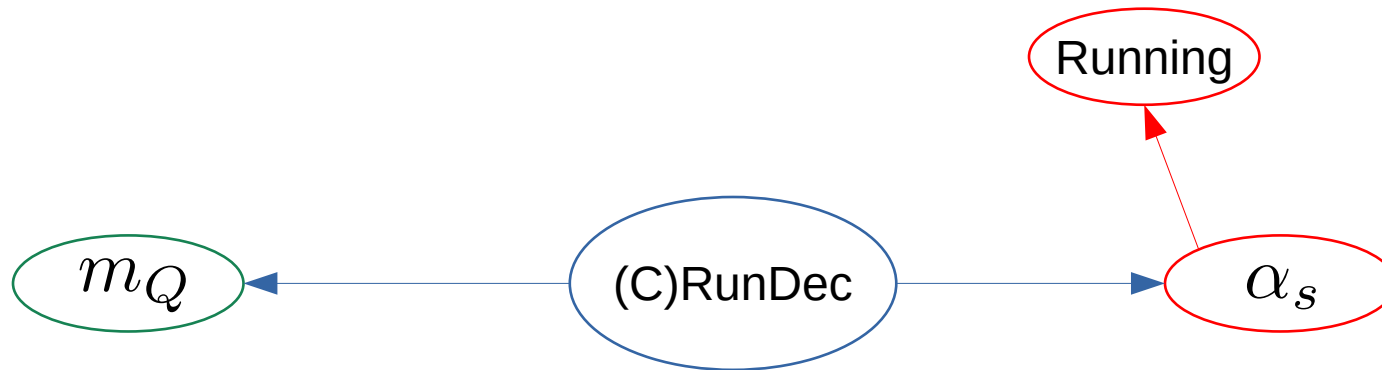
- Mathematica package RunDec published in 2000 [Chetyrkin, Kühn, Steinhauser 2000]
- C++ package CRunDec in 2012 [Schmidt, Steinhauser 2012]
- Implement routines for running and decoupling, as well as quark mass relations
- Many new results since then: 5-loop beta-function, 4-loop MS-OS relation...

—▶ (C)RunDec v3.0 in 2017 [Herren, Steinhauser 2017]

Overview



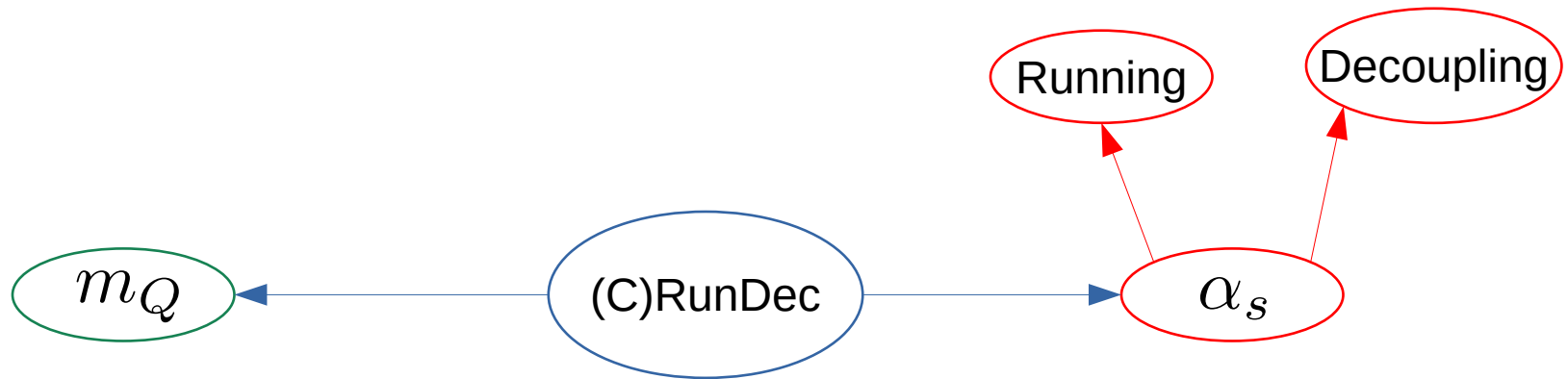
Overview



$$\mu^2 \frac{d}{d\mu^2} \frac{\alpha_s^{(n_f)}}{\pi} = \beta_{\alpha_s}^{(n_f)} \quad \leftarrow \text{At five loops}$$

[Baikov, Chetyrkin, Kühn 2016]
[Herzog, Ruijl, Ueda, Vermaseren, Vogt 2017]
[Luthe, Maier, Marquard, Schröder 2017]

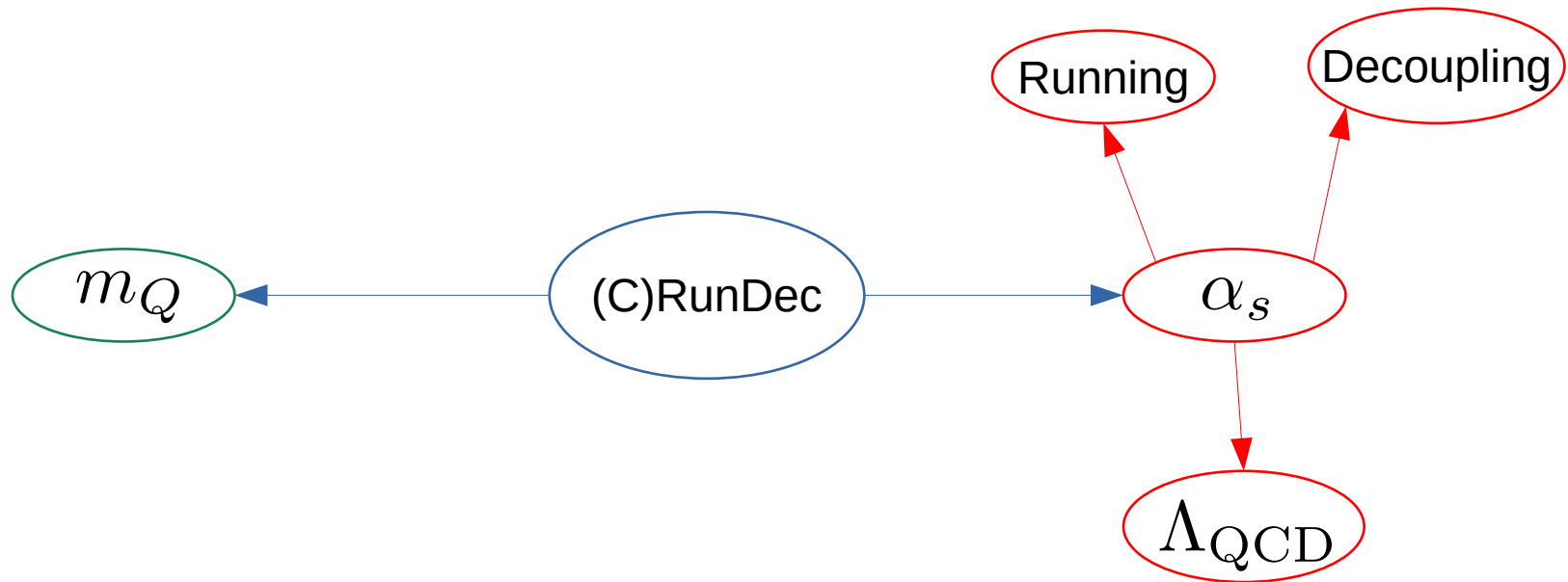
Overview



$$\alpha_s^{(n_f-1)} = \zeta_{\alpha_s} \alpha_s^{(n_f)}$$

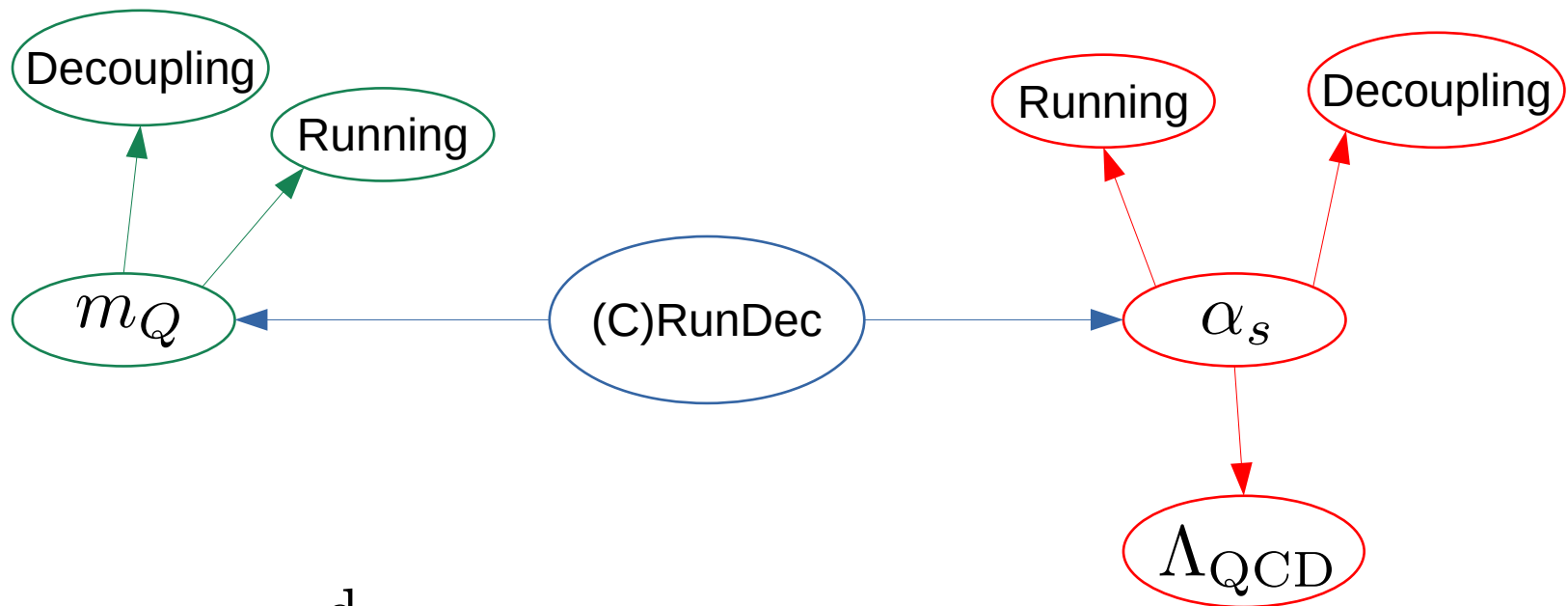
At four loops [Schröder, Steinhauser 2006]
[Chetyrkin, Kühn, Sturm 2006]

Overview



$$\ln \frac{\mu^2}{\Lambda^2} = \frac{1}{\pi} \int \frac{d\alpha_s}{\beta_{\alpha_s}}$$

Overview



$$\mu^2 \frac{d}{d\mu^2} m^{(n_f)} = m^{(n_f)} \gamma_m^{(n_f)}$$

$$m^{(n_f-1)} = \zeta_m m^{(n_f)}$$

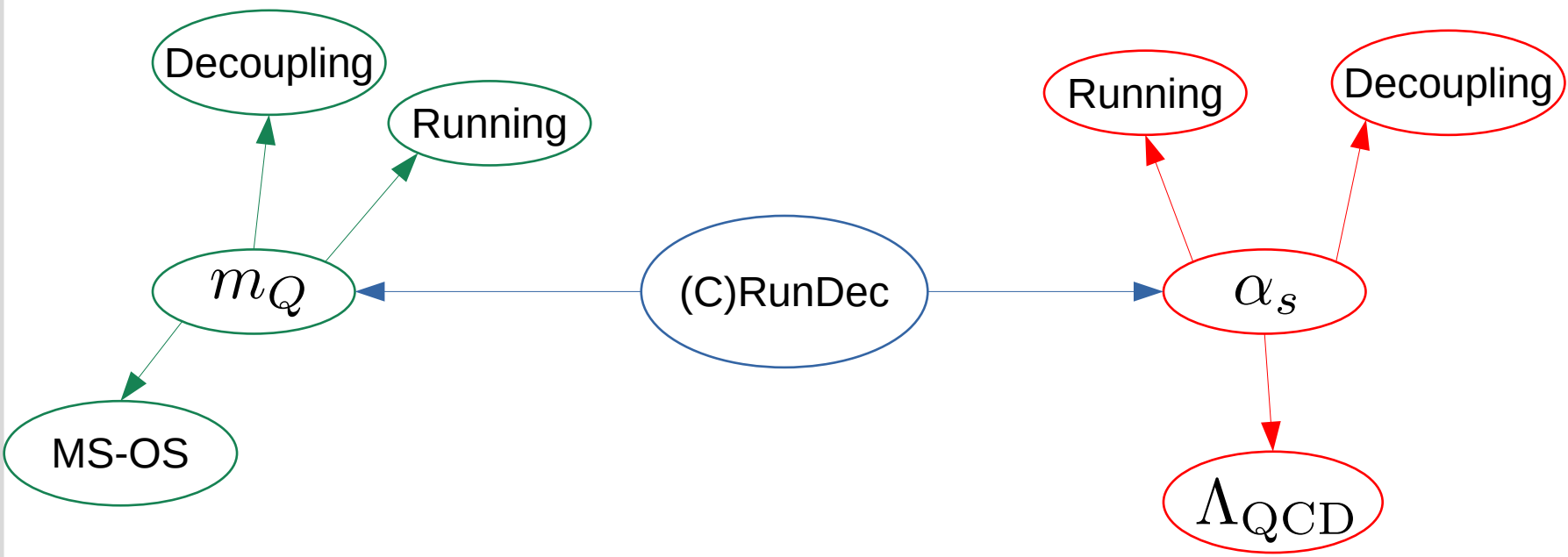
Four loops

[Liu, Steinhauser 2015]
 [Gerlach, Herren, Steinhauser 2018]

Five loops

[Baikov, Chetyrkin, Kühn 2014]
 [Luthe, Maier, Marquard, Schröder 2016]
 [Baikov, Chetyrkin, Kühn 2017]

Overview



$$m_Q(\mu) = z_m(\mu) M_Q$$

Light quark mass effects
at three loops

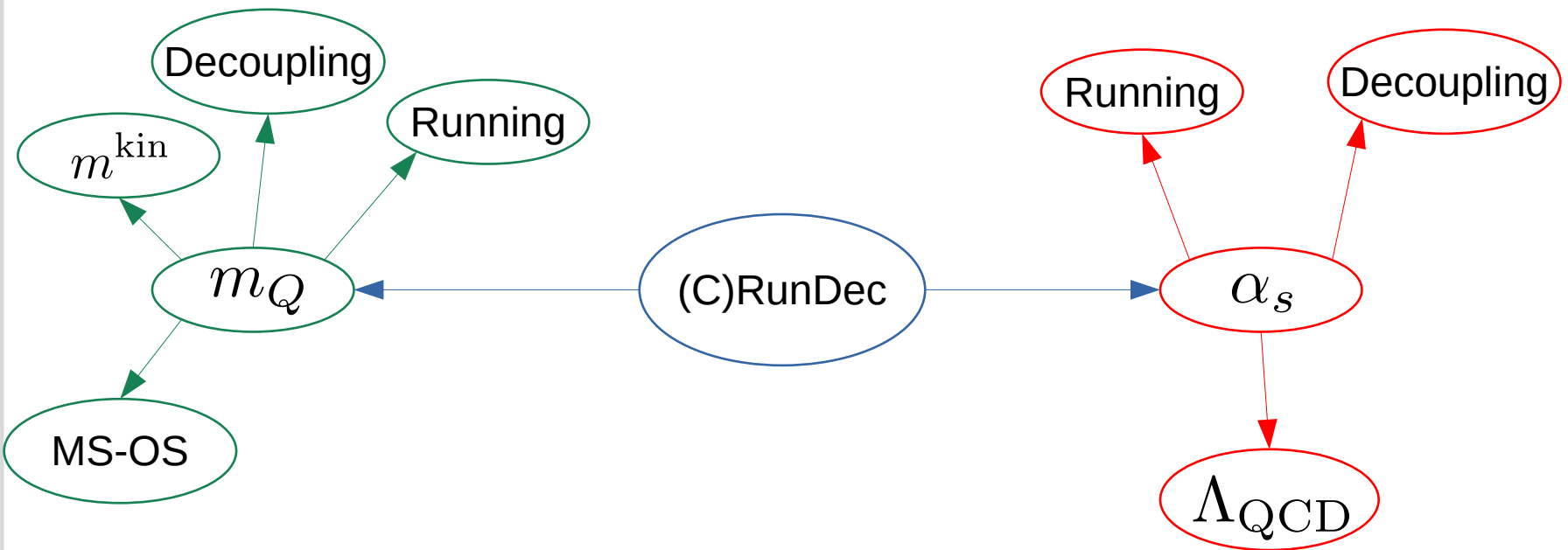
[Bekavac, Grozin, Seidel, Steinhauser 2007]

Four loops

[Marquard, Smirnov, Smirnov, Steinhauser 2015]

[Marquard, Smirnov, Smirnov, Steinhauser, Wellmann 2016]

Overview

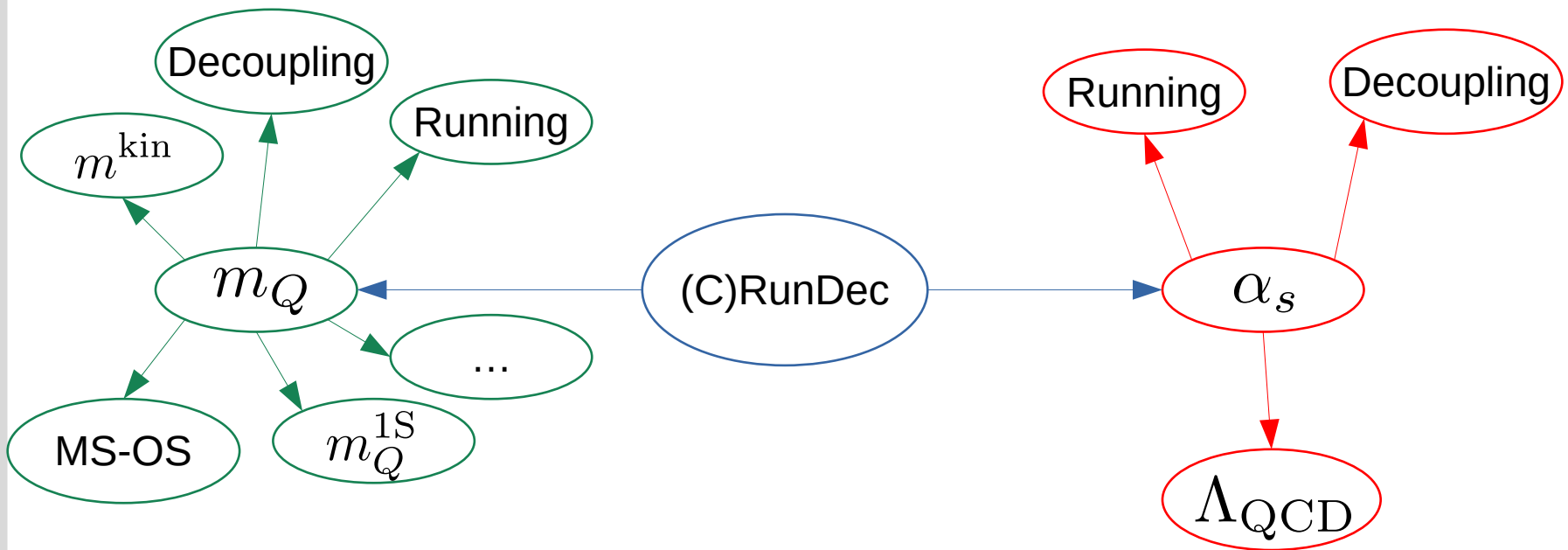


$$m_Q^{\text{kin}}(\mu) = M_Q - \bar{\Lambda}(\mu)|_{\text{pert}} - \frac{\mu_\pi^2(\mu)|_{\text{pert}}}{2m_Q^{\text{kin}}}$$

Three loops [Fael, Schönwald, Steinhauser 2020]

Talk by Matteo

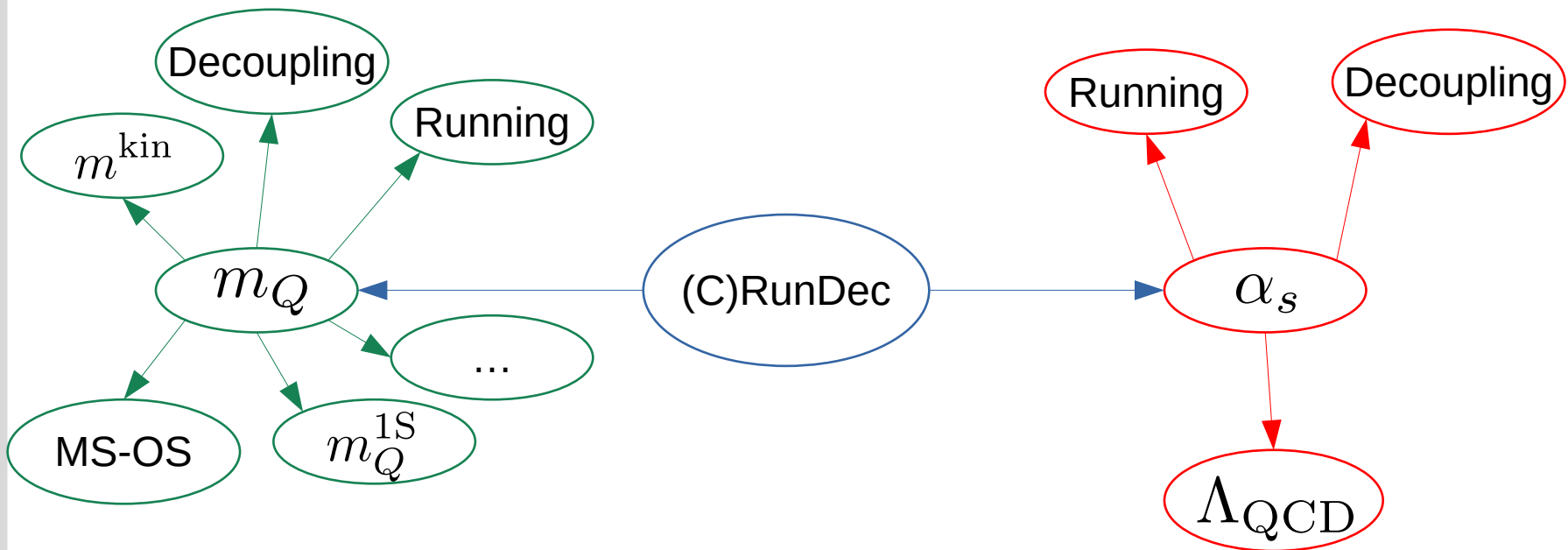
Overview



More quark mass schemes: 1S, PS, RS, RS', RI, RGI

Code examples

Outlook



Add further mass schemes:

- MSR
- ?

Include QED + Electroweak corrections:

- MS-OS relation
- Decoupling?
- Running?