

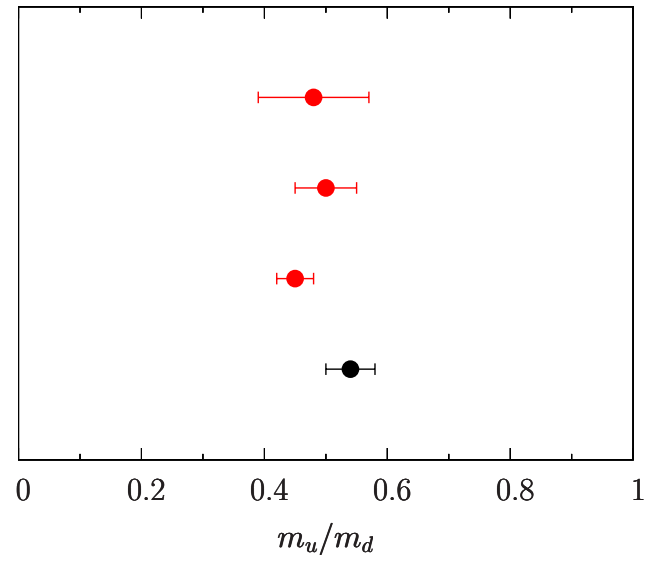
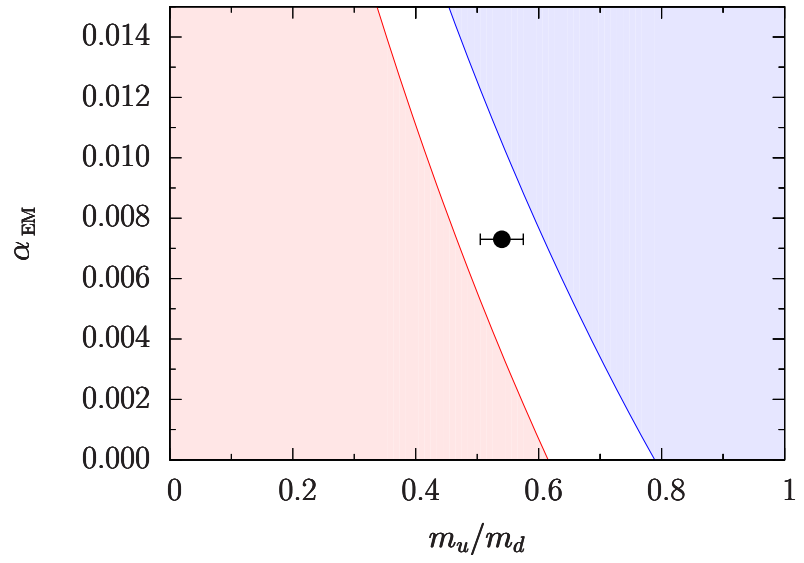
Light quark masses from infrared fixed point

G. Schierholz

Deutsches Elektronen-Synchrotron DESY

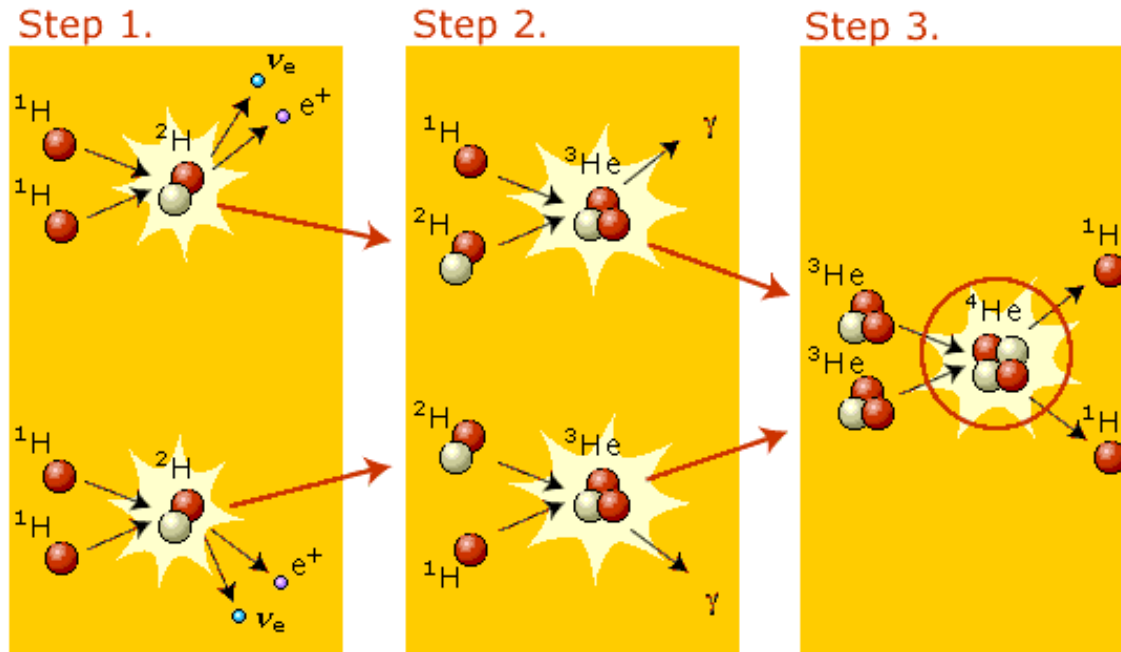


Challenge



RBC-UKQCD
RM123
MILC
QCDSF

QCDSF



$$\epsilon_D > M_n - M_p$$

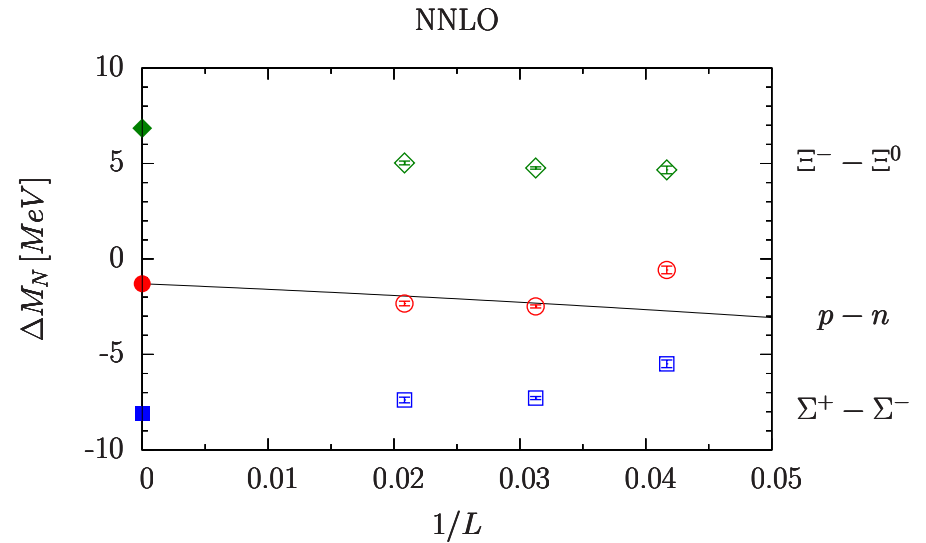
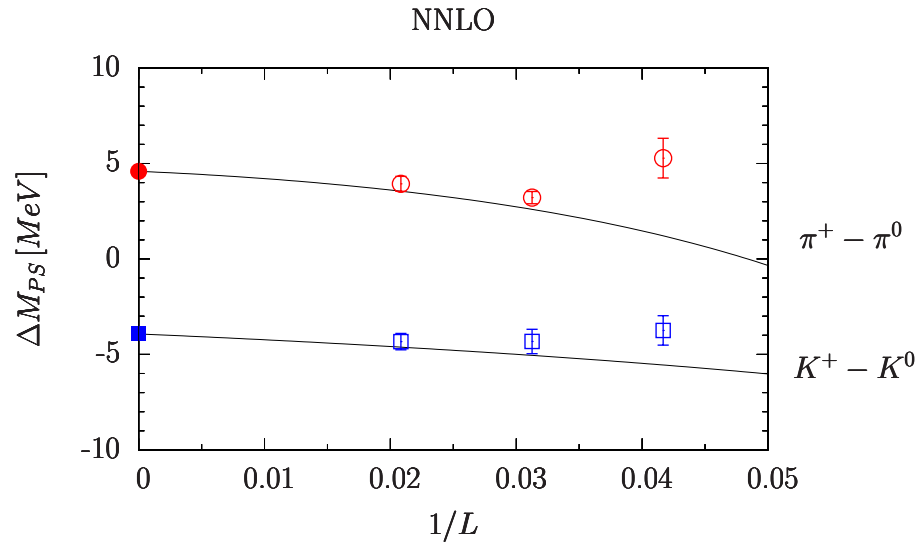
$M_n = M_p$: all hydrogen would be burned

QCDSF

R. Horsley, Y. Nakamura, D. Pleiter,
H. Perlt, P. Rakow, G. S., A. Schiller,
H. Stüben, R. Young, J. Zanotti

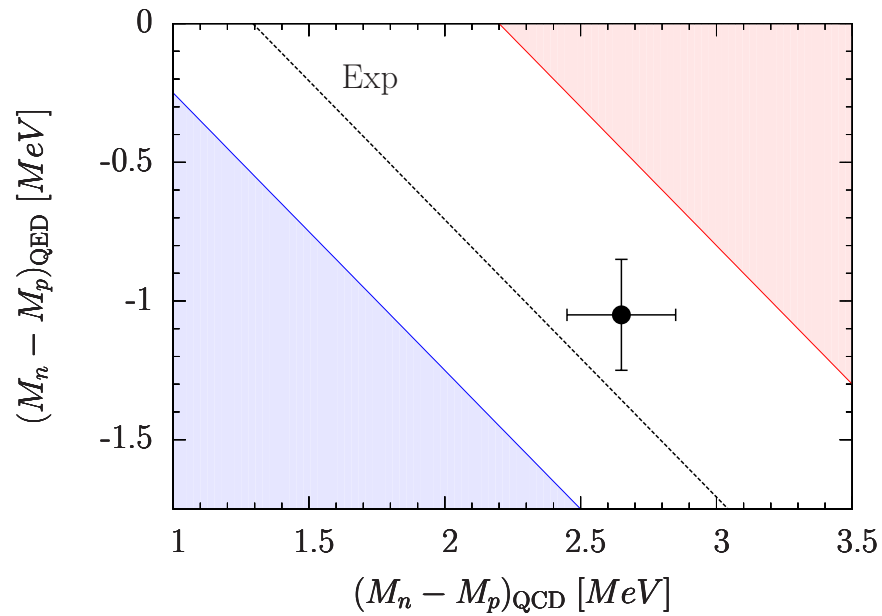
$$\begin{aligned}
 M^2(aab) &= M_0^2 + \alpha_1 (2\delta m_a + \delta m_b) + \alpha_2 (\delta m_a - \delta m_b) \\
 &+ \beta_0^{\text{EM}} (e_u^2 + e_d^2 + e_s^2) + \beta_1^{\text{EM}} (2e_a^2 + e_b^2) \\
 &+ \beta_2^{\text{EM}} (e_a - e_b)^2 + \beta_3^{\text{EM}} (e_a^2 - e_b^2)
 \end{aligned}$$

$$\delta m_q = m_q - m_0$$



Isospin splittings

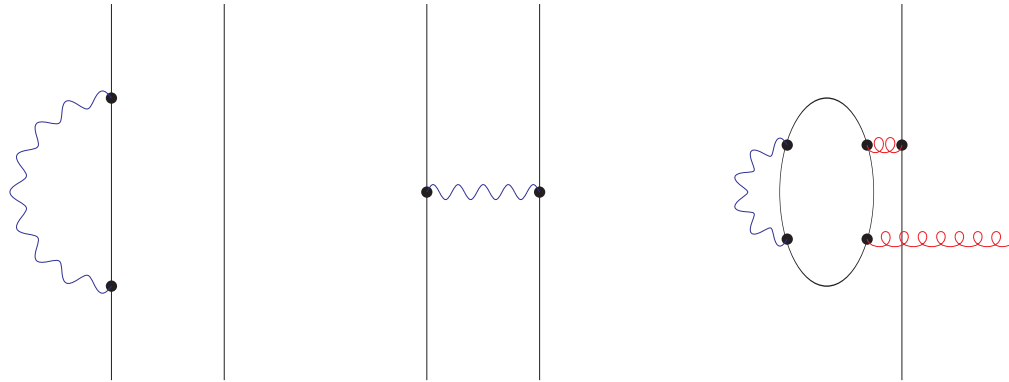
$$M_p^2 - M_n^2 = (\alpha_1 + 2\alpha_2)(m_u - m_d) + (\beta_1^{\text{EM}} + 2\beta_3^{\text{EM}})(e_u^2 - e_d^2)$$



$$\Delta M_{\text{QCD}} \approx \Delta M_{\text{QED}}$$

$$M_{K^+}^2 - M_{K^0}^2 = \alpha (m_u - m_d) + \beta_2^{\text{EM}} (e_u - e_s)^2 + \dots$$

$$M_{\pi^+}^2 - M_{\pi^0}^2 = \beta_2^{\text{EM}} (e_u - e_d)^2 + \dots$$



Solution from QCD + QED

$$m_u/m_d$$

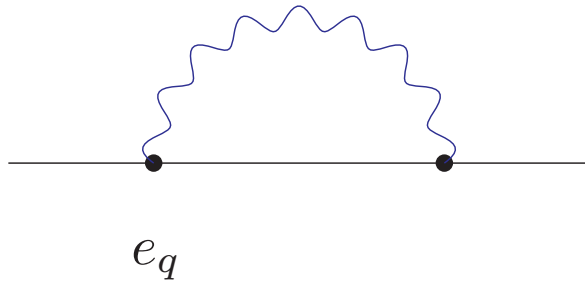
QCD

$$\frac{m_u}{m_d} = \frac{M_{K^+}^2 - M_{K^0}^2 + (2 + \epsilon_\gamma)M_{\pi^0}^2 - (1 + \epsilon_\gamma)M_{\pi^+}^2}{M_{K^0}^2 - M_{K^+}^2 - \epsilon_\gamma M_{\pi^0}^2 + (1 + \epsilon_\gamma)M_{\pi^+}^2}$$

ϵ_γ known

QED

m_q



RG

$$\frac{\partial \ln m_u/m_d}{\partial \ln \mu} = 0 - \frac{e^2}{8\pi^2} + \frac{e^2}{12\pi^2} \left(4 \frac{m_u^2}{\mu^2} - \frac{m_d^2}{\mu^2} \right)$$

QCD

QED

↑

$$\gamma_q^{\text{EM}} = -\frac{3e_q^2}{8\pi^2} \left(1 - 2 \frac{m_q^2}{\mu^2} \right) + \text{HOTs}$$

Solution

$$\frac{m_u}{m_d} = \frac{1}{2} \mu^{-\frac{e^2}{8\pi^2}} = \boxed{\frac{1}{2}} - \frac{e^2}{16\pi^2} \ln \mu + O(e^4)$$

Strange quark?

$$\frac{\partial \ln m_s/m_c}{\partial \ln \mu} = 0 + \frac{e^2}{8\pi^2} + \frac{e^2}{12\pi^2} \left(\frac{m_s^2}{\mu^2} - 4 \frac{m_c^2}{\mu^2} \right) + \text{Yukawa couplings (CKM)}$$

QCD

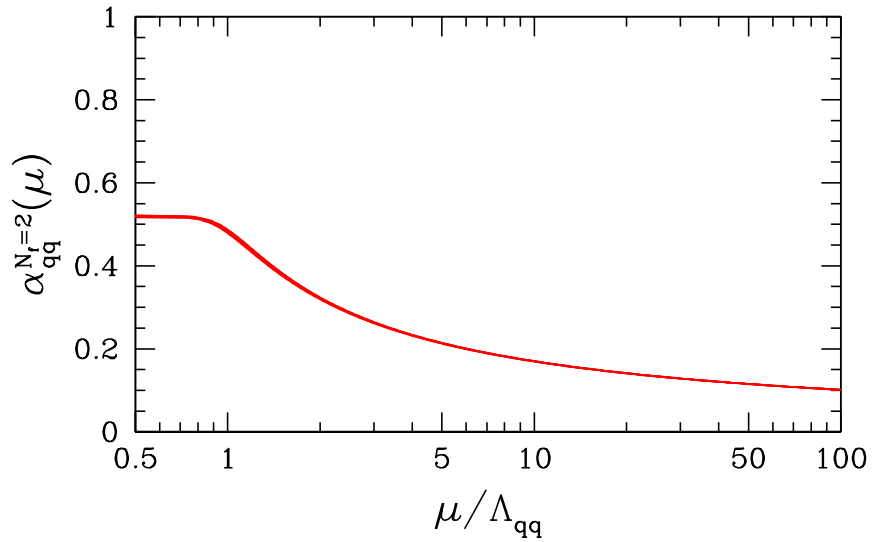
QED

EW

Non-negligible

cf. Pendleton & Ross

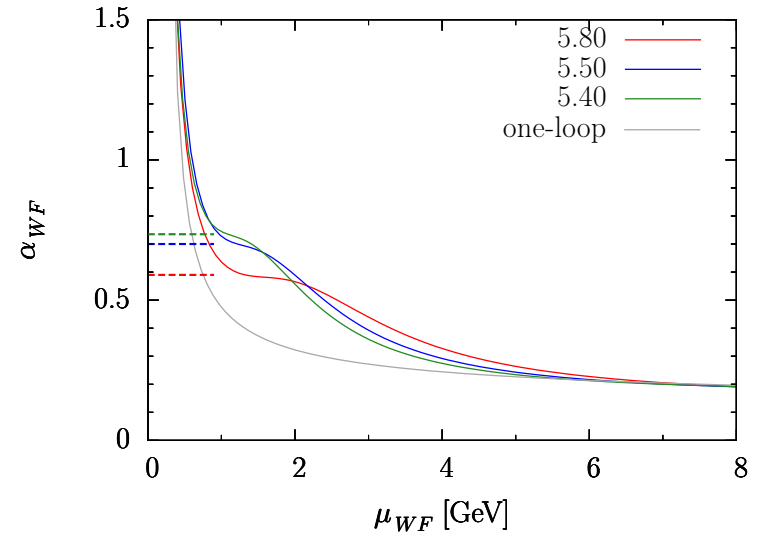
QCD fixed point ?



NSPT 20+4 loops

PLB 728 (2014) 1

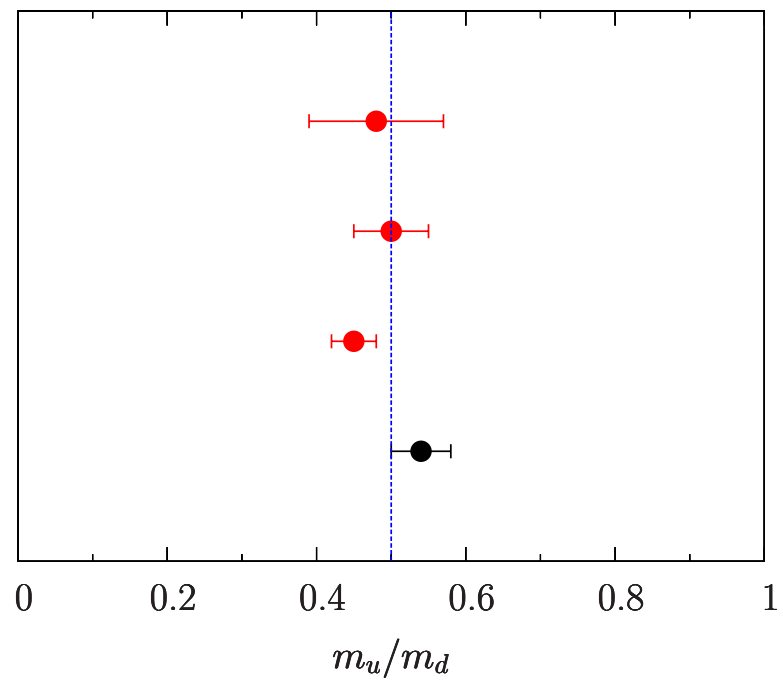
WSC



WF $N_f = 2 + 1$

$C_2 = -0.25, C_4 = 0.047$

Conclusion



RBC-UKQCD

RM123

MILC

QCDSF