QCDSF Gauge Ensembles

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Gauge & Fermion Actions

- **Symanzik improved gauge action:**

[R. Horsley et al. *PRD*78 (2008) 054504]

$$S_G^{\rm Sym} = \frac{6}{g^2}\left\{ c_0 \sum_{\rm Plaquette} \frac{1}{3}\,{\rm Re\,Tr}\,(1 - U_{\rm Plaquette}) + c_1 \sum_{\rm Rectangle} \frac{1}{3}\,{\rm Re\,Tr}\,(1 - U_{\rm Rectangle}) \right\}$$

$$c_0 = 5/3, \quad c_1 = -1/12$$

- **Stout Link Non-perturbative Clover (SLiNC) fermion action**

$$\begin{aligned} S_F \;=\; a^4 \sum_x \Big\{ & -\frac{1}{2a}\Big[\bar\psi(x)\widetilde{U}_\mu(x)\,(1-\gamma_\mu)\,\psi(x+a\hat\mu) \\ & + \bar\psi(x)\widetilde{U}^\dagger_\mu(x-a\hat\mu)\,(1+\gamma_\mu)\,\psi(x-a\hat\mu)\Big] \\ & + \frac{1}{a}\,(4 + am_0 + am)\,\bar\psi(x)\psi(x) - c_{SW}\,g\,\frac{a}{4}\,\bar\psi(x)\,\sigma_{\mu\nu}F_{\mu\nu}(x)\,\psi(x)\Big\} \end{aligned}$$

$$am_0 = \frac{1}{2\kappa_c} - 4$$

$$\widetilde{U}_\mu(x) = e^{i\,Q_\mu(x)}\,U_\mu(x)$$

QCDSF ensemble landscape

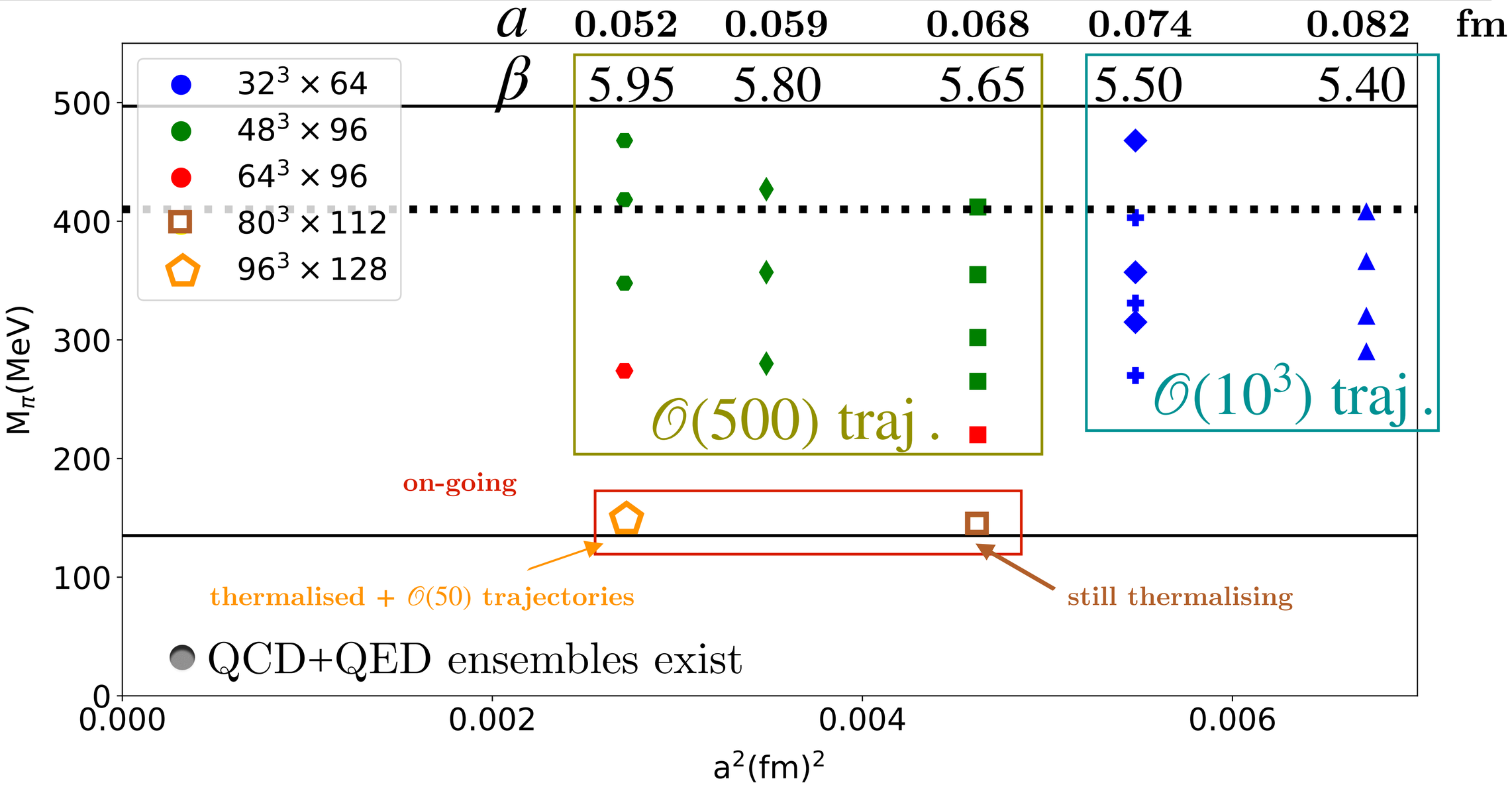
Physics

- All ensembles are utilised mostly for hadron physics, e.g. spectrum and structure

Generation

- Algorithm: HMC (2) + Rational HMC (1)
- Code: BQCD [EPJ Web Conf. 175 (2018) 14011]
- Running on:
  - JUWELS (Jülich, Germany)
  - CSD3 (Cambridge, UK)
  - Tursa (Edinburgh, UK)
  - NHR@ZIB and NHR-NORD@Göttingen (Germany)

QCDSF ensemble landscape



Data management & Sharing

Management

- Data project on Jülich houses some configurations
- $32^3 \times 64$, and $48^3 \times 64$ are already on the ILDG, although accessing them is non-trivial
- $80^3 \times 112$ configs are 11 GB each, goal: $\mathcal{O}(500)$ trajectories
- $96^3 \times 128$ configs are 22 GB each, goal: $\mathcal{O}(500)$ trajectories
- Configs are in ILDG format
- Metadata compliant with ILDG scheme

Sharing

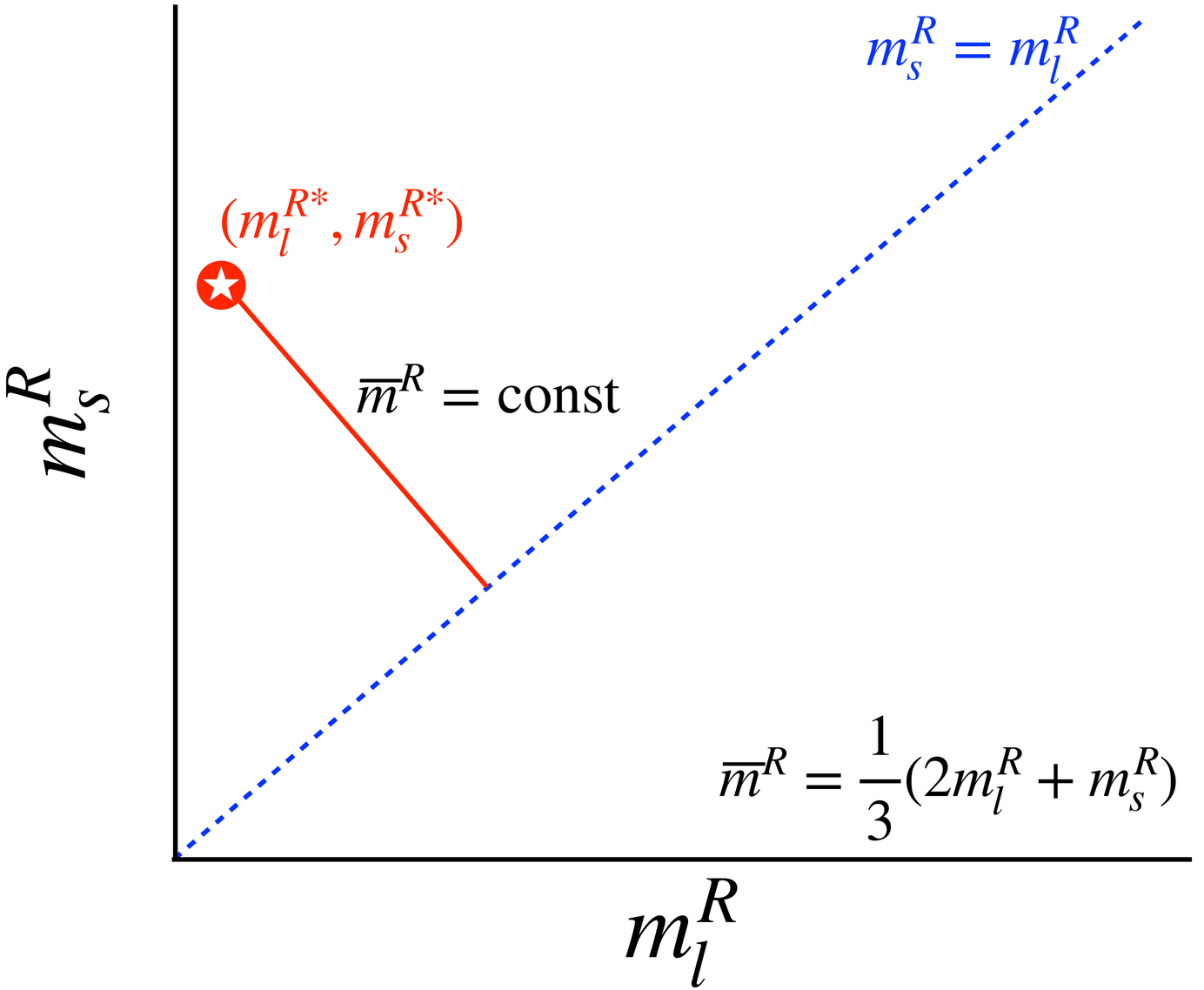
- Please contact the collaboration before using available the configurations
- Generated configurations will be made available upon request pending collaboration's confirmation
- New collaborative projects welcome

Backup

Quark mass tuning

[W. Bietenholz et al. *PRD*84, 054509 (2011)]

- Start from
  $m_l^R = m_s^R \equiv m_0^R \approx m_0^{R*}/3$
- Approach the physical point (m_l^{R*}, m_s^{R*}) along $\overline{m}^R = \text{const}$
- u/d (π) gets lighter, s (K, η) gets heavier



Scale setting

[W. Bietenholz et al. *PRD*84, 054509 (2011)]

- Consider the flavour singlet quantities,

  e.g., $X_\pi^2 = \frac{1}{3}\left(2M_K^2 + m_\pi^2\right)$, and $X_N = \frac{1}{3}\left(M_N + M_\Sigma + M_\Xi\right)$

- In the SU(3) flavour symmetry breaking expansion,

$$X_S(\overline{m}^{R(0)} + \delta m_l^R, \overline{m}^{R(0)} + \delta m_l^R, \overline{m}^{R(0)} + \delta m_s^R) = X_{S\,sym}^{(0)} + O((\delta m_q^R)^2)$$

  the approach to the physical point along the $\overline{m}^R = \text{const.}$ line is constant up to quadratic effects

Scale setting

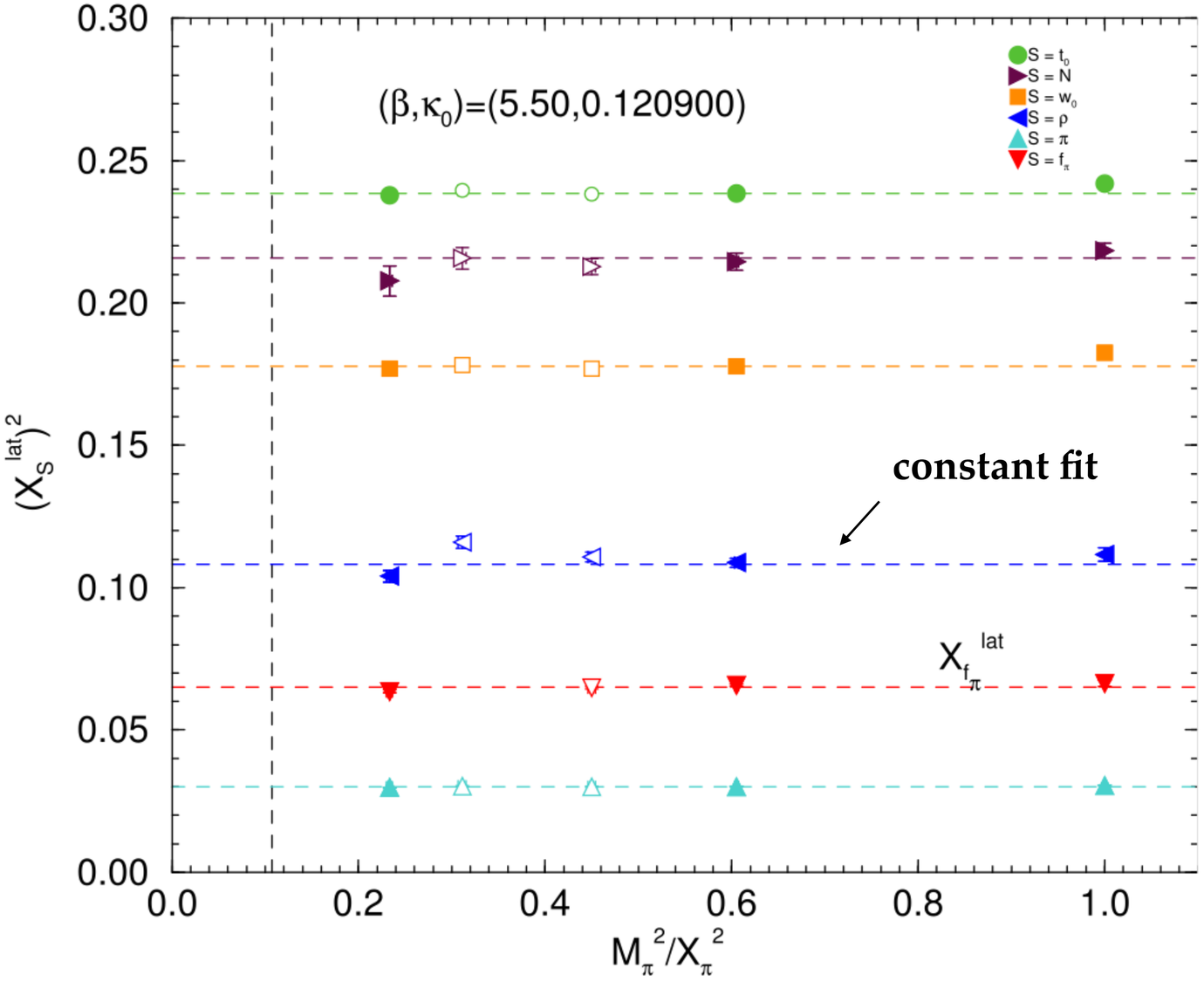
[V.G. Bornyakov et al. (QCDSF–UKQCD Collaboration) *PLB* 767 (2017) 366-373]

- Determine the scale by,

$$X_S^{\text{lat}} = a_S X_S^{\text{exp}}$$

where the quantity S may be hadronic or flow scales

$$S = \pi, \rho, N, \Delta, t_0, w_0$$



Lattice QCD+QED setup

- $\mathrm{SU(3)_f}$ symmetric point?
  - QCD: trivial — input $am_u = am_d = am_s$ → $m_u^R = m_d^R = m_s^R$
  - +QED: with $Q_u = +\frac{2}{3},\ Q_d = Q_s = -\frac{1}{3}$

$$am_u = am_d = am_s \rightarrow m_u^R \neq m_d^R = m_s^R$$

- Define the *"Dashen Scheme"*
  - Tune quark masses to $\mathrm{SU(3)_{sym}}$ point via $m_\pi^{u\bar{u}} = m_\pi^{d\bar{d}} = m_\pi^{s\bar{s}}$
    - n : 0 $m_\pi^{n\bar{n}} = 408(3)$ MeV
    - d : -1/3 $m_\pi^{d\bar{d}} = 409(1)$ MeV
    - u : +2/3 $m_\pi^{u\bar{u}} = 407(3)$ MeV

$V=32^3x64$, $a=0.068$fm

- $\mathrm{N_f}$ =1+1+1 *O(a)*-improved Clover ("SLiNC")
- Tree-level Symanzik gluon action
- Non-compact QED with $\alpha_{QED} = 0.1$

gauge-fixing of Uno & Hayakawa (2008) — on valence quarks