Striving for precision in lattice QCD

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"Confinement of quarks"

Phys. Rev. D10 (1974) 2445

Kenneth G. Wilson

"Continuum limit and improved action in lattice theories"

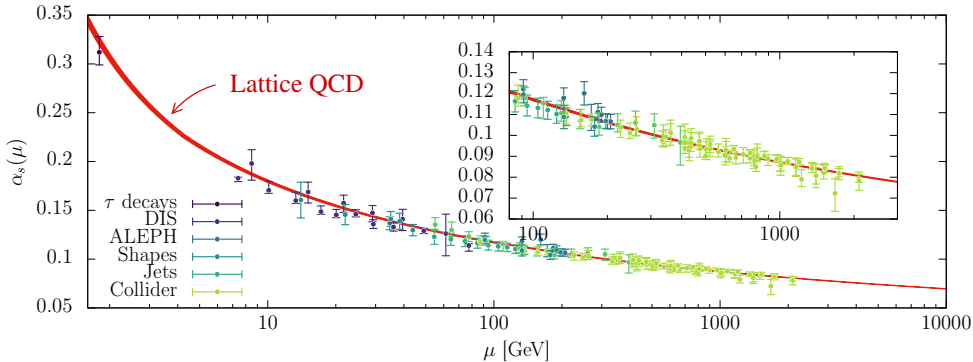
Nucl. Phys. B226 (1983) 187 & 205

$\Rightarrow$ Understanding of how the continuum limit is reached

Kurt Symanzik

First step towards controlling the errors in lattice QCD computations

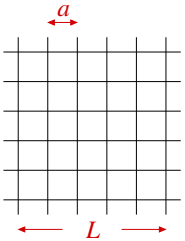
Dalla Brida et al. (ALPHA Collaboration), arXiv:2501.06633



$\underbrace{\frac{1}{3}(2f_K + f_\pi),\ M_\pi,\ M_K,\ M_D,\ M_B}_{\text{physics input}}$ $\longrightarrow$ $\alpha_s(M_Z) = 0.11873(56)$

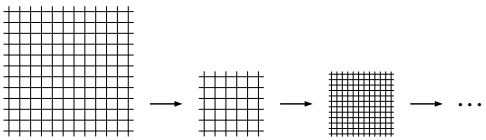
"A numerical method to compute the running coupling in asymptotically free theories"

M. Lüscher, P. Weisz & U. Wolff, Nucl. Phys. B359 (1991) 221



1. Choose $a\,[\mathrm{fm}]$ and find $g(a), m_u(a), m_d(a), \ldots$ where $f_\pi, M_\pi, \ldots$ assume their physical values

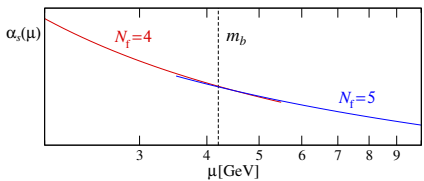
2. Compute the evolution of a non-perturbatively defined $\alpha(\mu)$ from $\mu \sim 0.4\,\mathrm{GeV} \to M_Z$



3. At $\mu = M_Z$ compute $\alpha_s = \alpha + c_1\alpha^2 + c_2\alpha^3 + \ldots$

Achieving high precision required ...

- *Efficient simulation algorithms* — 1987, 2001–05, ...
  HMC algorithm, quark determinant factorisation, ...
- *Understanding & estimating lattice-spacing effects* — 1983–85, 1996, ...
  Symanzik continuum-limit improvement, ...
- *Developing new ways to probe QCD* — 1992, 2010
  Schrödinger functional, Yang–Mills gradient flow
- *Control over the heavy-quark thresholds* — 2019–22



Thanks again for the prize and thanks for your attention!