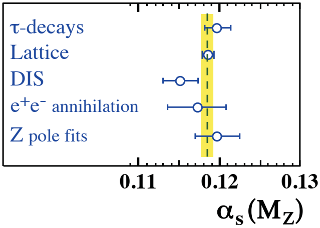
Before I came to CERN . . .
(see Prezi)

Fundamental parameters of QCD from non-perturbative methods

N_f	$\Lambda_{\overline{\mathrm{MS}}}$	Experiment	Theory
0	238(19)	m_K, $K \to \mu\nu_\mu$, ; $K \to \pi\mu\nu_\mu$	LGT, ALPHA Collaboration
2	310(20)	m_K, $K \to \mu\nu_\mu$, ; $K \to \pi\mu\nu_\mu$	LGT, ALPHA Collaboration
5	160(11)	DIS, HERA, ...	NNLO PT, fits to PDFs [Alekhin'12]
5	198(16)	DIS, HERA, ...	NNLO PT, fits to PDFs [Martin'09]
5	275(57)	$e^+e^- \to$ hadrons, LEP	4-loop PT at M_Z

- Error coming from the theory is dominating



- Lattice QCD: *ab initio* determination of QCD parameters
- full control over systematics
  - non-perturbative renormalization
  - chiral extrapolation
  - continuum extrapolation

- **See Alberto's talk...**

RBC-UKQCD Collaboration members

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Together with: J.Hudspith, R. Lewis, K. Maltman (York University)

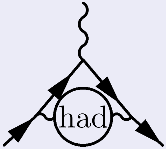
a_μ as a stringent test of the SM

- $a_\mu^{exp} = 11659208.9(6.3) \times 10^{-10}$
- Current theoretical and experimental estimates: $3 - 4\sigma$ discrepancy
  - HVP (unceirt. $O(10^{-10})$)
  - HLbL (unceirt. $O(10^{-10})$)
  - other contributions (unceirt. $O(10^{-11})$ or less)
- New experiments (J-PARC, Fermilab) expected to perform $4\times$ more precise measurement
- Improved precision of the theoretical estimates with dominating uncertainty required

Hadronic vacuum polarisation from the lattice

Can be computed in Euclidean space-time [Blum '02, Lautrup-de Rafael 69]

$$a_\mu^{HLO} = (\tfrac{\alpha}{\pi})^2 \int_0^\infty dQ^2 f(Q^2) \times \hat{\Pi}(Q^2)$$



- $\Pi_{\mu\nu} = a^4 \sum_x e^{iQx} \langle J_\mu^{em}(x) J_\nu^{em}(0) \rangle$
- $\Pi_{\mu\nu}(Q) = (Q^2 \delta_{\mu\nu} - Q_\mu Q_\nu)\Pi(Q^2)$
- $\hat{\Pi}(Q^2) = \Pi(Q^2) - \Pi(0)$

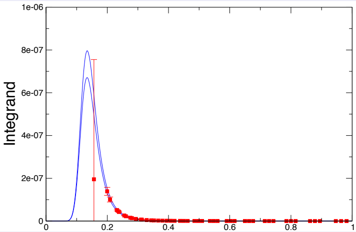
Systematic uncertainties to be controlled - general

1. Simulations at physical m_π
2. Controlled continuum limit, FV effects
3. Disconnected diagrams [Della Morte et al. '10]
4. Obtaining a real world result: charm quark, isospin effects ...

Systematic uncertainties to be controlled - HVP related

- Conventional simulations do not allow access to sufficiently low Fourier momenta
- Integral is dominated in the region where relative errors are enhanced
- Structure of HVP tensor is such that $\Pi(0)$ is not directly accessible
- Systematic uncertainty introduced by extrapolation

Conventional procedure

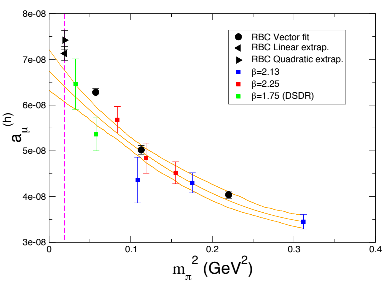


- $\Pi(Q^2) = \frac{\Pi_{\mu\nu}(Q^2)}{Q_\mu Q_\nu - \delta_{\mu\nu} Q^2}$
- Transverse projection: $Q_\mu = 0$
- Take only diagonal components $\Pi_{\mu\mu}$
- $a_\mu^{HLO} = (\frac{\alpha}{\pi})^2 \int_0^\infty dQ^2 f(Q^2) \times \hat{\Pi}(Q^2)$

Previous RBC-UKQCD computation of a_μ^{HLO} [Boyle et al'11]

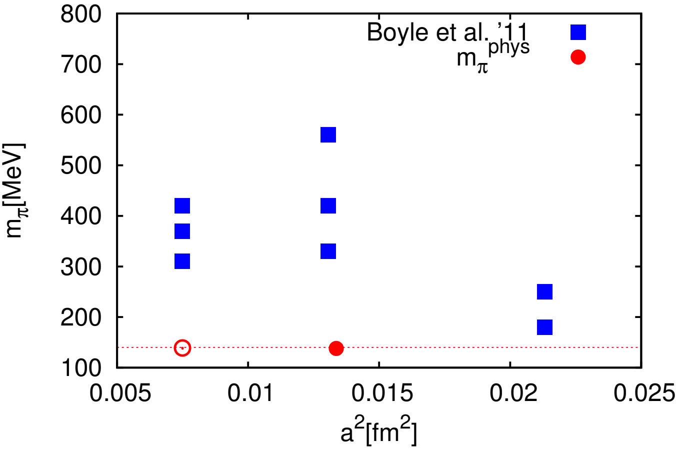
Non physical m_π, $a^{-1} \approx 1.3, 1.7, 2.3$ GeV

- Domain Wall Fermion, Iwasaki/DSDR gauge action
- Fitting Q^2- dependence of $\Pi(Q^2)$ up to $Q_C^2 \approx 2.5 - 9$ GeV^2



- Strong m_π dependence
- Eliminate the systematics of chiral extrapolation: computing HVP at m_π^{phys}

RBC-UKQCD $N_f = 2 + 1$ Domain Wall ensembles



- a_μ^{HLO} from DWF for non-physical m_π [Boyle et al '11]
- physical point HVP (●,○) recently measured

Symmary and outlook

- $\Lambda_{Nf=2,4}$, m_s
- Heavy quark physics (exploratory study - colab. with Southampton-KEK, f_B, f_Ds, ...)
- Algorithmic developement

- a_μ^{HLO} with full control over syst. and stat. uncertainties ($< 1\%$)
- QCD+QED at finite volume
- Precise determination of α_s (gradient flow coupling, changing BC's ...)
- ...(some other non-perturbative problem you are intersted in? [4-2-040])