Lattice QCD at Fermilab: Celebrating the Career of Paul Mackenzie

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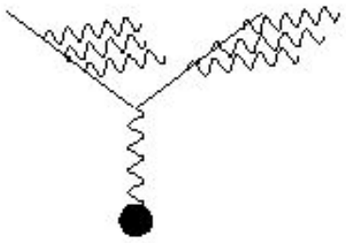
Welcome!

- Paul Mackenzie's academic family tree:

Hideki Yukawa

Yukawa couplings



Donald Yennie

IR gauge bosons

Stan Brodsky

hadrons & QCD

Peter Lepage

perturbative &
lattice QCD

Paul Mackenzie

lattice QCD for
Yukawa couplings

Highlights: Paul Mackenzie

- Perturbative QCD:
  - properties of quarkonia
  - scale setting in the perturbative series

- Lattice QCD:
  - early calculations of hadronic couplings
  - early calculation of the mass of the H dibaryon

- Computing:
  - ACPMAPS computer and its Canopy software
  - clusters of PCs with fast interconnects = lattice QCD supercomputers

- Service:
  - charter member of the USQCD Executive Committee (Chair & spokesman, 2009–2018)
  - principal investigator of the Exascale Computing Project "LatticeQCD" (2016–2018)

Highlights: Lattice QCD at Fermilab — A History of Leadership

- New theoretical tools and insights
  - lattice HQET
  - renormalized lattice perturbation theory
  - improved lattice QCD actions
  - lattice Gauge Theory with C-periodic boundary conditions
  - relativistic heavy quarks, aka the “Fermilab action”
  - improved relativistic heavy quark action (Oktay-Kronfeld)
  - minimal renormalon subtracted mass scheme

- New numerical methods
  - Fourier acceleration
  - lattice QCD + QED (Duncan, Eichten, Thacker)
  - Bayesian statistics for lattice data

Highlights: Lattice QCD at Fermilab — A History of Leadership

- Numerical results
  - *H* Dibaryon
  - glueball spectra
  - first phenomenologically relevant determination of α_s
  - $B \to D^*$ form factor at zero recoil
  - HQET parameters $(\bar{\Lambda}, \lambda_1)$
  - **Predictions:**
    - B_c masses (confirmed by CDF)
    - D, D_s-meson decay constants (confirmed by BaBar, CLEO-c)
    - semileptonic D-meson form factors (confirmed by CLEO-c)
  - Quarkonium splittings
  - **First** LQCD results with commensurate to experiment precision
    - Semileptonic $B \to \pi$ form factors ➠ $|V_{ub}|$
    - Semileptonic $B \to D^*$ form factors ➠ $|V_{cb}|$
    - Semileptonic $K \to \pi$ form factor ➠ $|V_{us}|$
  - **Definitive** lattice-QCD results:
    - B, D-meson decay constants and heavy-quark masses with sub-percent precision

Future: Lattice QCD at Fermilab — meeting new challenges

- Ongoing programs:
  - hadronic corrections for the muon g-2 with ~0.5% level precision
  - semileptonic B, D-meson form factors ($B \to \pi \ell \nu$, $B_s \to K \ell \nu$, $B \to K(\pi) \ell \ell$, $B \to D \ell \nu$) with percent-level precision
  - nucleon matrix elements

- New programs: towards multi-hadron systems and non-local operators
  - two-pion contributions to hadronic vacuum polarization correction
  - hadron-tensor of the pion

- Possible future directions: resonances, two-nucleon systems

- Lattice field theory and quantum information
  - optimizing simulations on NISQ hardware
  - understanding error propagation
  - interfaces between classical and quantum computation