The prospects for 2γ physics with lattice QCD

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A few 2γ observables to compute

Electric & Magnetic polarizabilities of pion

- *ChPT* vs. Experiment:

  One Loop ChPT $\quad \alpha_{\pi^+} = 2.7\,[10^{-4}\,\mathrm{fm}^3]$

  COMPASS $\quad \alpha_{\pi^+} = 1.9(0.7)_{st.}(0.8)_{sy.}\,[10^{-4}\,\mathrm{fm}^3]$

- Contribution to hadronic light-by-light (ingredient in dispersive treatment)

[Engel, *et al*. PRD (2012), Colangelo, *et al*. 1402.7081]

Magnetic polarizability of nucleon

- Experiment: 50% - 100% uncertainty for neutron?
- *ChPT* in single and few nucleon systems

[Talks by **Philips** & **Grießhammer**]

- Dominant error in determining nucleon EM splitting

[Walker-Loud, Carlson, Miller PRL (2012)]

- Help constrain proton structure corrections to *μ-H*

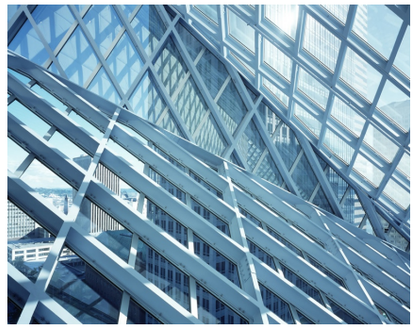
[Hill, Paz PRL (2011)]

HIγS @ TUNL

[Talks by **Howell** & **Ahmed**]

Spin polarizabilities, …

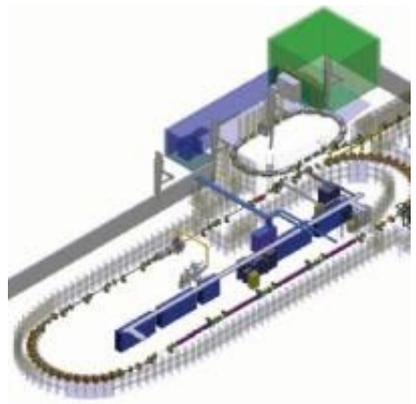
- **JLAB Hall D: PR-13-008**



QCD

EFT

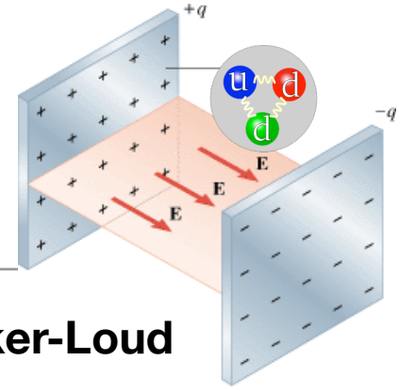
$n \to \pi^- + p \to n$



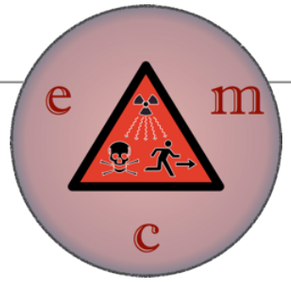
EXP

Lattice QCD Methods for Hadronic Polarizabilities

$\alpha_E \quad \beta_M$



$U_\mu^{\text{e.m.}}(x) = e^{iqA_\mu(x)} \in U(1)$



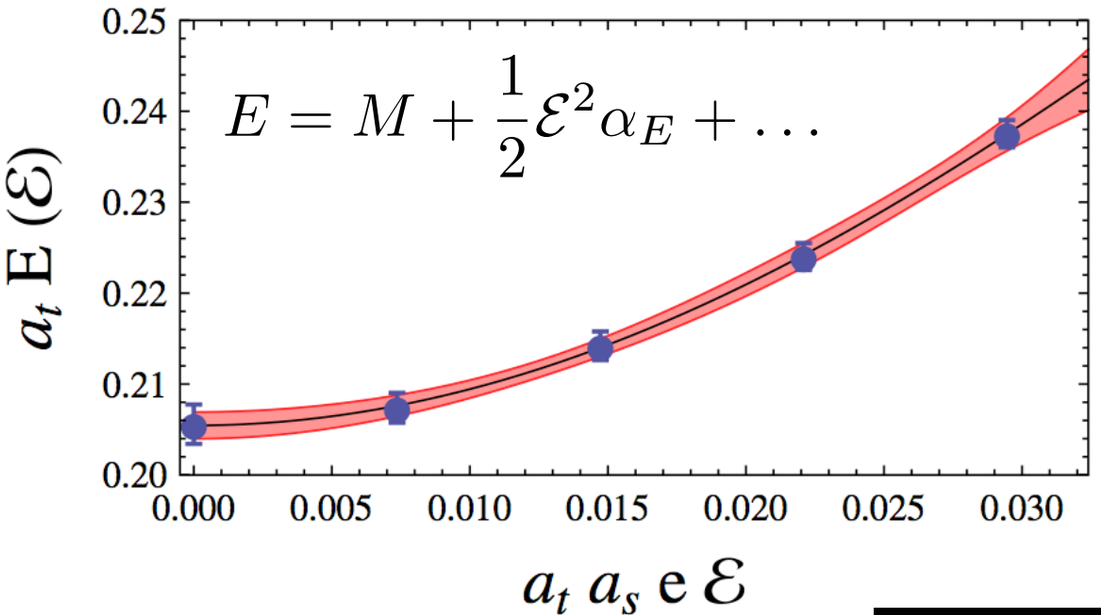
W. Detmold, B. Tiburzi, A. Walker-Loud

PRD 2006, 2009, 2010

- Determine E&M polarizabilities from QCD by: turning on external fields + study external field dependence of hadronic correlation functions

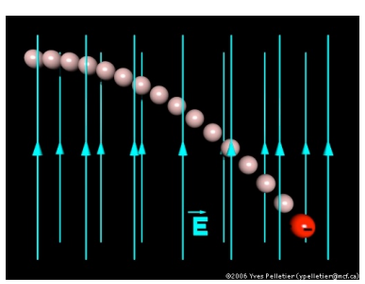
E.g. neutron in electric field

$$E_{\text{eff}} = M + \frac{1}{2}\mathcal{E}^2\left(\alpha_E - \frac{\mu^2}{4M^3}\right) + \ldots$$



Hadrons considered

π^0, K^0, n **and** π^+, K^+, p



Simultaneous fit to boost projected correlators

$$\text{Tr}[\mathcal{P}_\pm G(\tau)] = Z\left(1 \pm \frac{\mu\mathcal{E}}{2M_N^2}\right)\exp(-\tau E_{\text{eff}})$$

Anisotropic clover lattices (**HadSpec**)

$20^3 \times 128 \qquad m_\pi = 390\,\text{MeV}$

$\mu_n = -1.6(1)\,[\mu_N]$

$\alpha_E^n = 3(1) \times 10^{-4}\,\text{fm}^3$

STATISTICAL UNCERTAINTIES ONLY
NOT FOR USE WITH EXPERIMENT

m_π

a

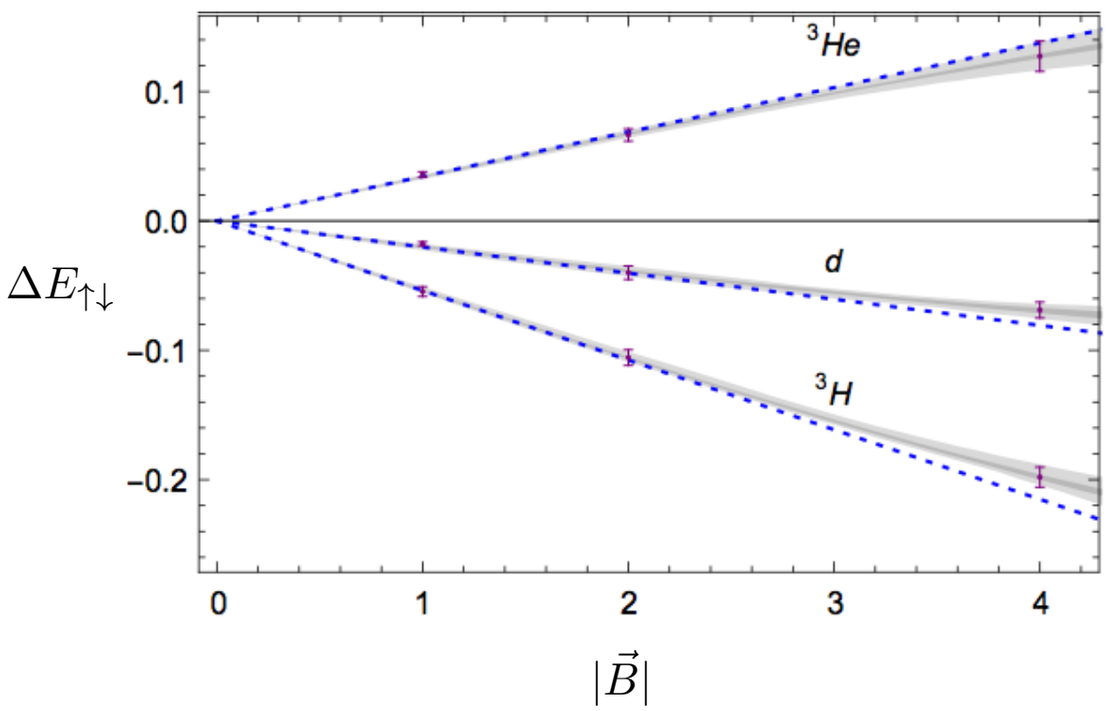
L

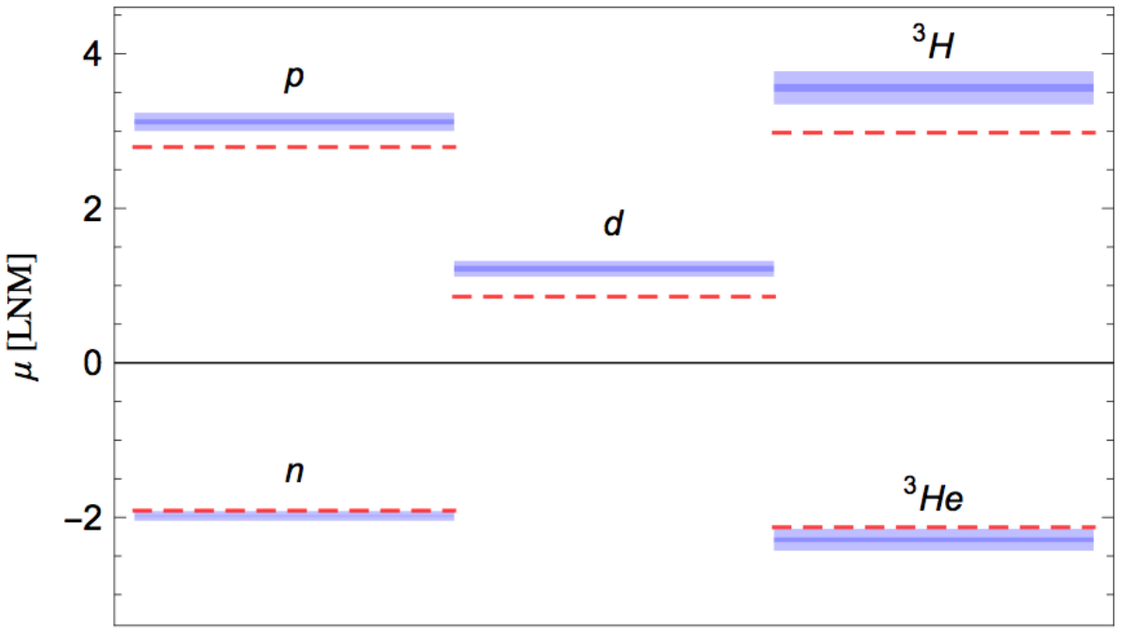
q_{sea}

Magnetic Moments of Light Nuclei

[Beane, *et al*. 1409.3556]

Proof of principle: lattice QCD computation of Zeeman splittings $m_\pi^{\rm latt} = 800\,\mathtt{MeV}$ $M_N^{\rm latt} = 1600\,\mathtt{MeV}$





Remarkable surprise!

$$[\mathrm{LNM}] = \frac{e}{2M_N^{\rm latt}}$$

Lattice presents tremendous opportunity:

- Understand interplay between single and few nucleon dynamics from QCD
- Lower pion mass to expose chiral dynamics
- Ultimately confront experiment