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some discussion points for precision muon physics

1) proton radius puzzle

2) muon capture and neutrino cross sections

3) some interesting η decays

- muons a great tool

  - new physics sensitivity:

$$\frac{\delta a_\mu}{\delta a_e} \sim \frac{(m_\mu^2/M^2)}{(m_e^2/M^2)} \sim 10^4$$

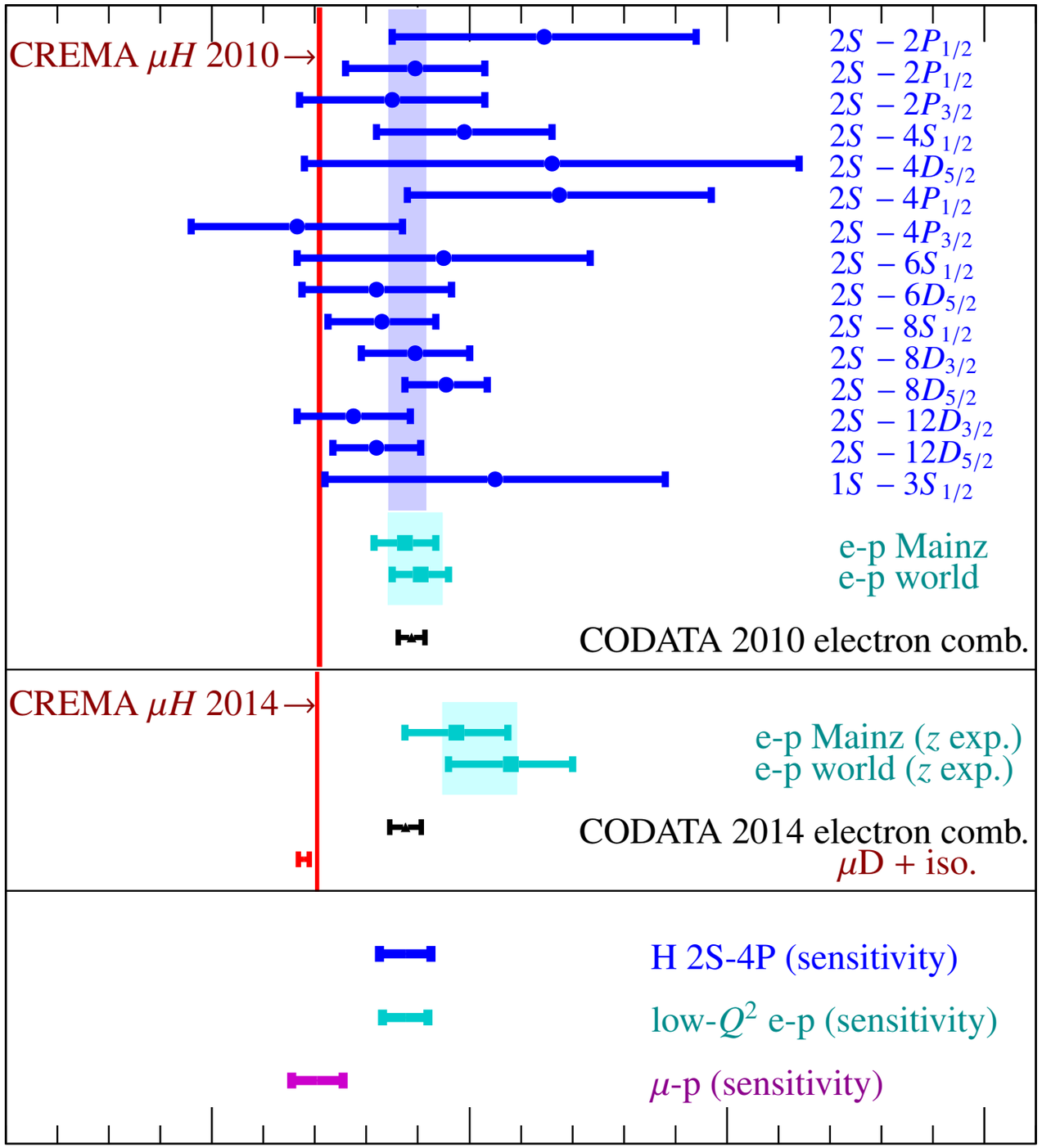
  - nuclear size from spectroscopy:

$$\frac{|\psi(0)_{\mu H}|^2}{|\psi(0)_{eH}|^2} \sim \frac{m_\mu^3}{m_e^3} \sim 10^6$$

- nuclear structure from capture:

$$m_\mu + m_p > m_n \; (> m_e + m_p)$$

I) the proton radius puzzle



1702.01189

Implications:

1) new window on fundamental constants

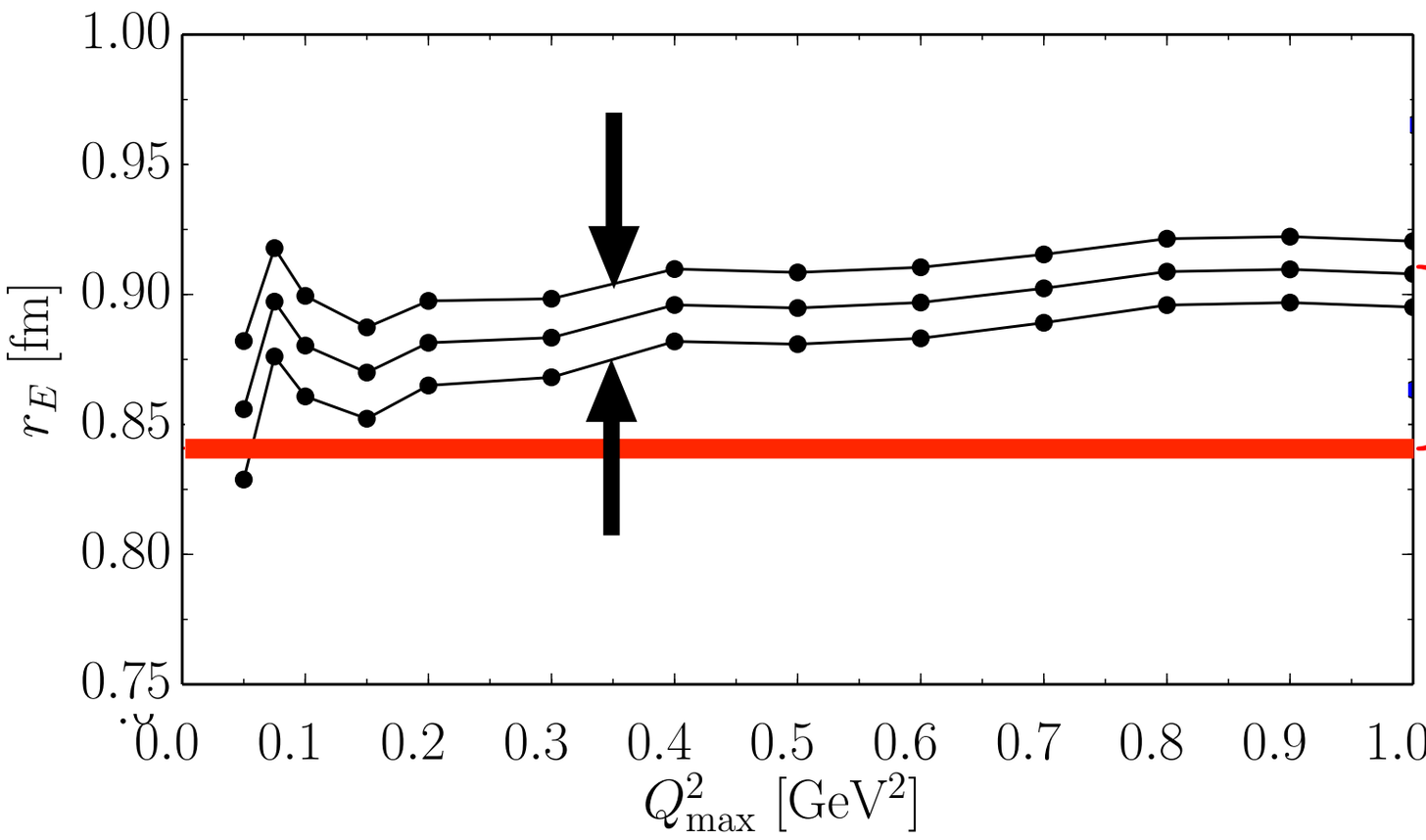
- 6.9 sigma shift in Rydberg

2) canary in the gold mine for lepton-nucleon interactions, critical for neutrino program

- form factor nonlinearities

- radiative corrections

3) something else?



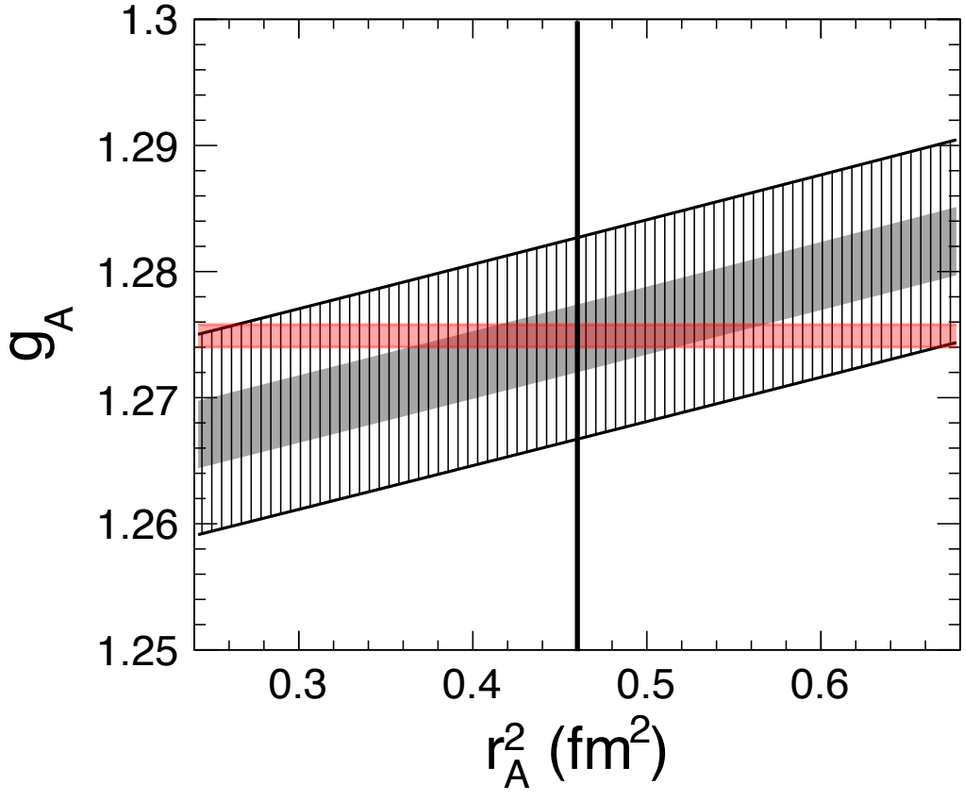
1505.01489

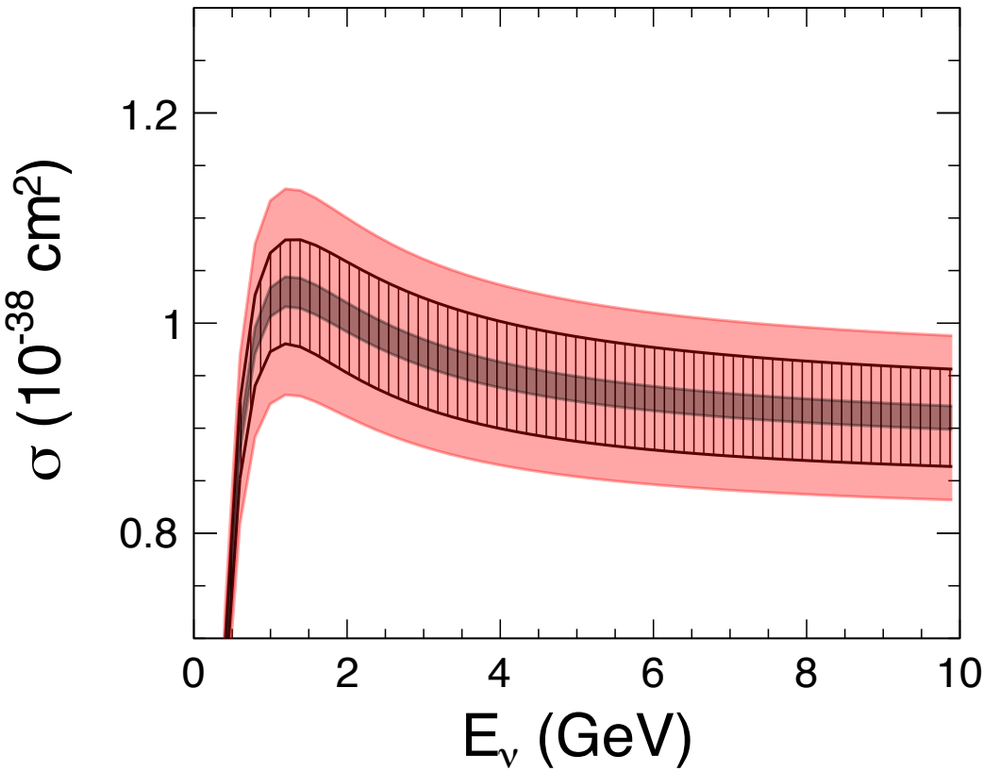
discrepancy with muonic hydrogen

$$-\frac{e^2}{Q^2}F(Q^2) \to -\frac{e^2}{Q^2}F(Q^2) \mp \frac{g^2}{Q^2+m_V^2}$$

new force?

2) muonic hydrogen and the nucleon axial radius





w/ P. Kammel, W. Marciano, A. Sirlin

- there is a surprisingly large uncertainty on the (CCQE) signal cross section for neutrino experiments *1603.03048*

- cross section uncertainty traced to axial-vector nucleon form factor

- form factor uncertainty dominated by nucleon axial radius

- new constraints from capture rate in μH (currently: *competitive with neutrino-deuteron scattering*. future: *better*)

3) η decays and new light particles

• new physics models for proton radius puzzle have large isospin violation, enhanced muon couplings

e.g. $\mathcal{L} = \left[c_u \bar{u} u + c_d \bar{d} d\right] \bar{\mu} \mu$

• consider the rare process:

$$\frac{\Gamma(\eta \to \pi^0 \mu^+ \mu^-)_{\rm BSM}}{\Gamma_{\rm tot}} \approx 3 \times 10^{-3} \times \left(\frac{\Delta R_p^2 - \Delta R_n^2}{-0.054 {\rm fm}^2} \right)^2$$

electron-muon radius differences for proton, neutron (from μH, μD)

• η decays very constraining: present experimental limit, Br < 5 x 10^{-6}, disfavors scalar contact interaction model

• light scalar mediator extensions a potential target for future experiments

• light vector models, η→γV (V→ee, …) another potential target