FERMILAB-POSTER-23-078-PPD

# The (*Z*,*A*) Dependence of $\mu \rightarrow e$ Conversion

Léo Borrel, David G. Hitlin and Sophie Middleton
California Institute of Technology, Pasadena CA 91125 USA

## Introduction:

When $\boldsymbol{\mu \rightarrow e}$ conversion is found, the question of the Lorentz structure of the new CLFV (Charged Lepton Flavor Violation) coupling will come to the fore. The different types of CLFV couplings (dipole, vector, scalar) produce a different (*Z*,*A*) dependence of the conversion rate. Previous studies of the (*Z*,*A*) dependence are extended by:

1. Inclusion of muonic X-ray data on nuclear charge distribution
2. Treatment of the effect of permanent quadrupole deformations
3. Inclusion of neutron distributions using a Hartree-Bogoliubov model

## Motivations:

The study of *Z,A* dependence of $\mu \rightarrow e$ conversion by Cirigliano *et al.*[1] (has recently been updated by Heeck *et al.*[2]

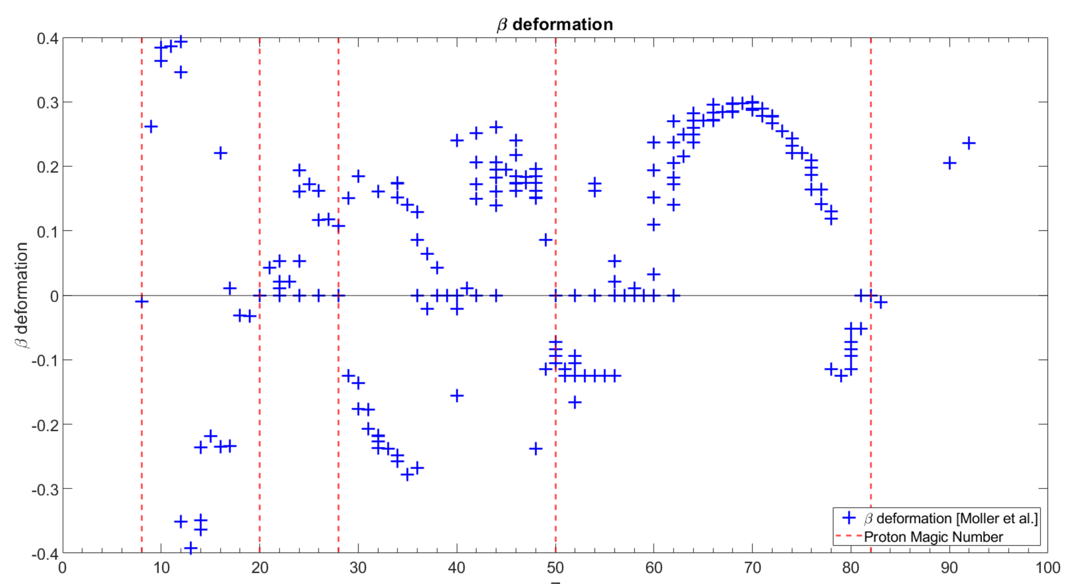
These studies used electron scattering determinations of the nuclear charge distribution, assuming spherical symmetry, and charge distributions scaled by *N/Z* for the neutron distributions.

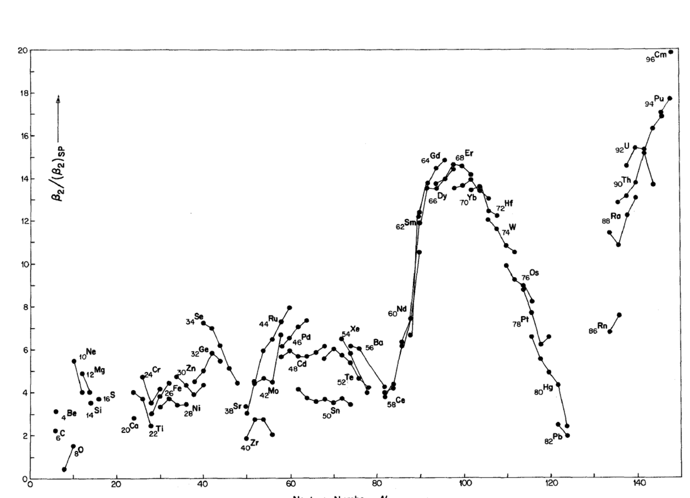
We have built upon this:
1. included muonic X-ray determinations of the nuclear charge distributions.
2. explicitly accounted for permanent quadrupole moments.
3. used a collective model for neutron distributions.

## Observations:

$^{27}Al$, the target used in Mu2e has large quadrupole deformations[3,4] due to the shell model structure for protons and neutrons.

Despite the conversion process occurring largely from the 1*S* state of the muonic atom, the deformation effects the radial nucleon distribution, particularly at the edge of the nucleus.



- We use a deformed Fermi model to represent the *p* and *n* distributions:

$$\rho(r) = \frac{1}{1+exp\left[\frac{r\left(1+\frac{\beta}{4}\sqrt{\frac{5}{\pi}}(3cos^2\theta-1)\right)-c}{t}\right]}$$

The weighted quadrupole deformation $\beta$ peaks at the edge of the nucleus, effectively modifying the skin thickness *t.*

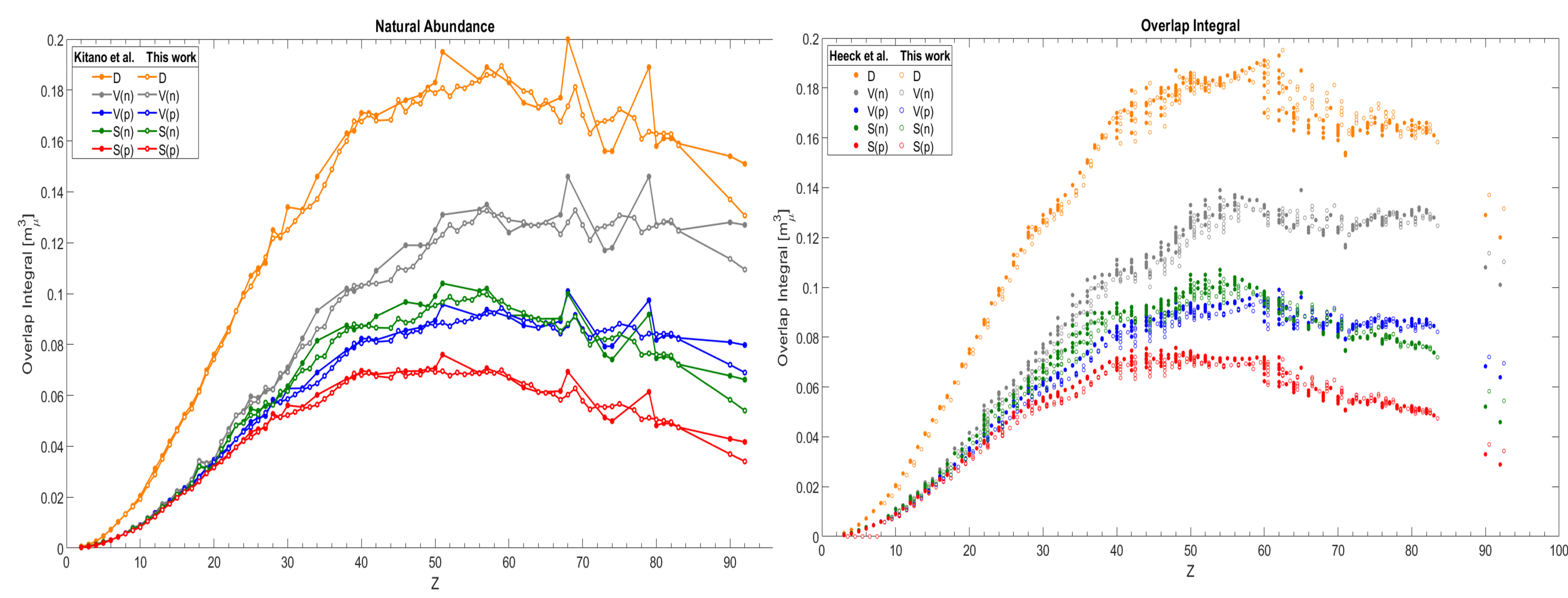
- We include muonic X-ray data, particularly for nuclei with large nuclei with quadrupole deformations, and for many individual isotopes.
- Electron scattering[5] and muonic X-ray[6] data can be combined using model-independent Barrett Moments[7]

$$\left\langle r^k e^{-\alpha r}\right\rangle = \frac{4\pi}{Ze}\int_0^\infty \rho_N r^k e^{-\alpha r} r^2 dr$$

where the value of *k* and *α* are determined by fitting $2P_{3/2}$ - $1S$ transition energies over a wide range of nuclei.

- The error in the Barrett radii deduced from muonic atom measurements is typically smaller than the error on the same quantity calculated from electron scattering experiments.
- We employ the Zhang *et al.*[8] calculation that uses a relativistic Hartree-Bogoliubov model for even-even nuclei to account for neutron distribution.

## Our Results:



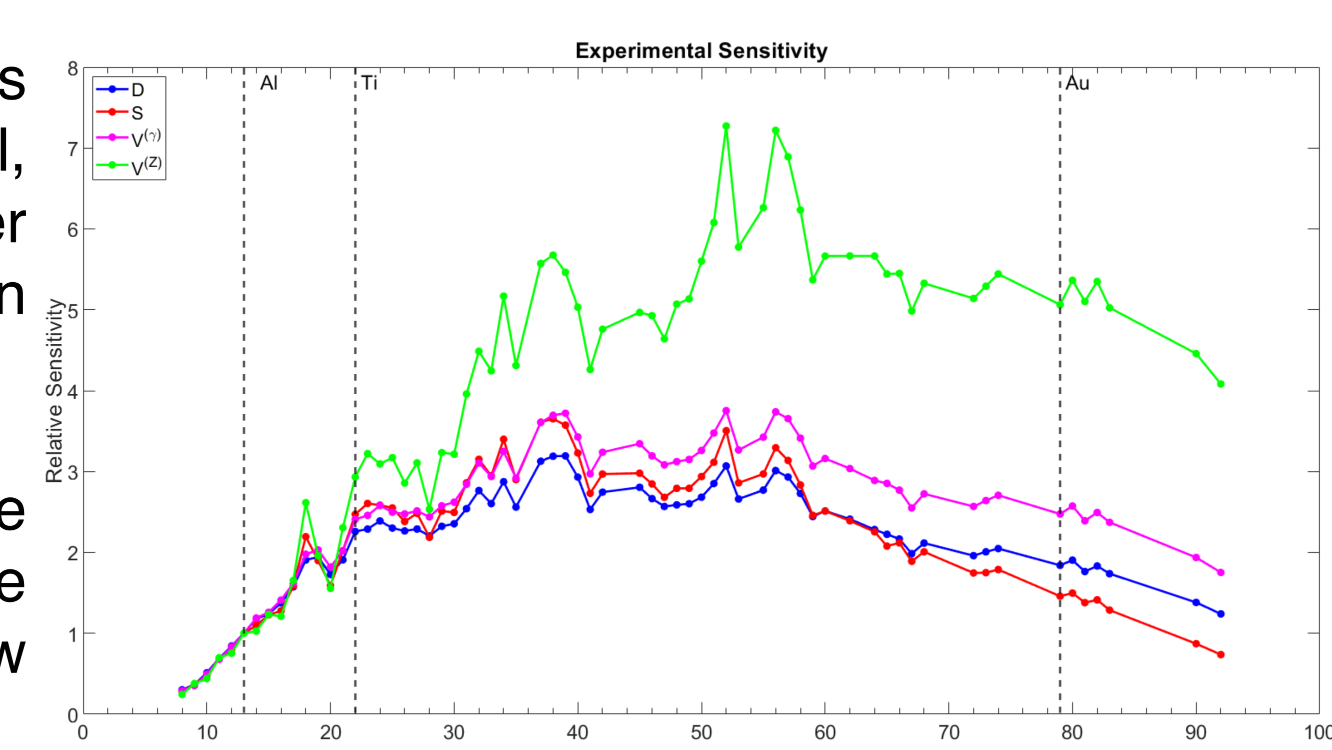

Accounting for permanent quadrupole deformations, using more realistic neutron distributions and the addition of muonic X-ray data through the use of Barrett moments results in changes in the calculated *Z* dependence of the various CLFV couplings, particularly in the region of large quadrupole deformations.

The dip at the onset of large quadrupole deformations is reduced, and the excursions in the natural abundance plot are diminished.

## Relative Sensitivity in Different Nuclei:

If Mu2e measures conversion in Al, we could later measure the rate in another material.

The relative rate can elucidate the type of new physics.




Supported by the US Department of Energy grant SC0011925.
A portion of this work was done at the Aspen Center for Physics.

1) V. Cirigliano *et al.*, *Phys. Rev*. D80, 013002 (2009).
2) J. Heeck *et al.*, *Nucl. Phys.* B980 115833 (2022).
3) P. Möller *et al.*, *Atom. Data Nucl. Data Tabl.* 109-110, 1 (2016).
4) P.H. Stelson and L. Grodzins, *Nucl. Data* A1, 21 (1965).
5) H. De Vries *et al.*, *Atom. Data Nucl. Data Tabl.* 35, 495 (1987).
6) G. Fricke *et al.*, *Atom. Data Nucl. Data Tabl.* 60, 177 (1995).
7) R.C. Barrett, Rep. *Prog. Phys.* 37, 1 (1974).
8) K. Zhang *et al.*, *Atom. Data Nucl. Data Tabl.*, 144, 101488(2022).
9) E. Macagno *et al.*, *Phys. Rev.* C1, 1202 (1970).
10) J.H. Heisenberg *et al.*, *Nucl. Phys.* A164, 340 (1970).
11) S. Weinberg and G. Feinberg, *Phys. Rev. Lett.* 3, 111 (1959).
12) T. Suzuki *et al. Phys. Rev.* C35, 2212 (1986).