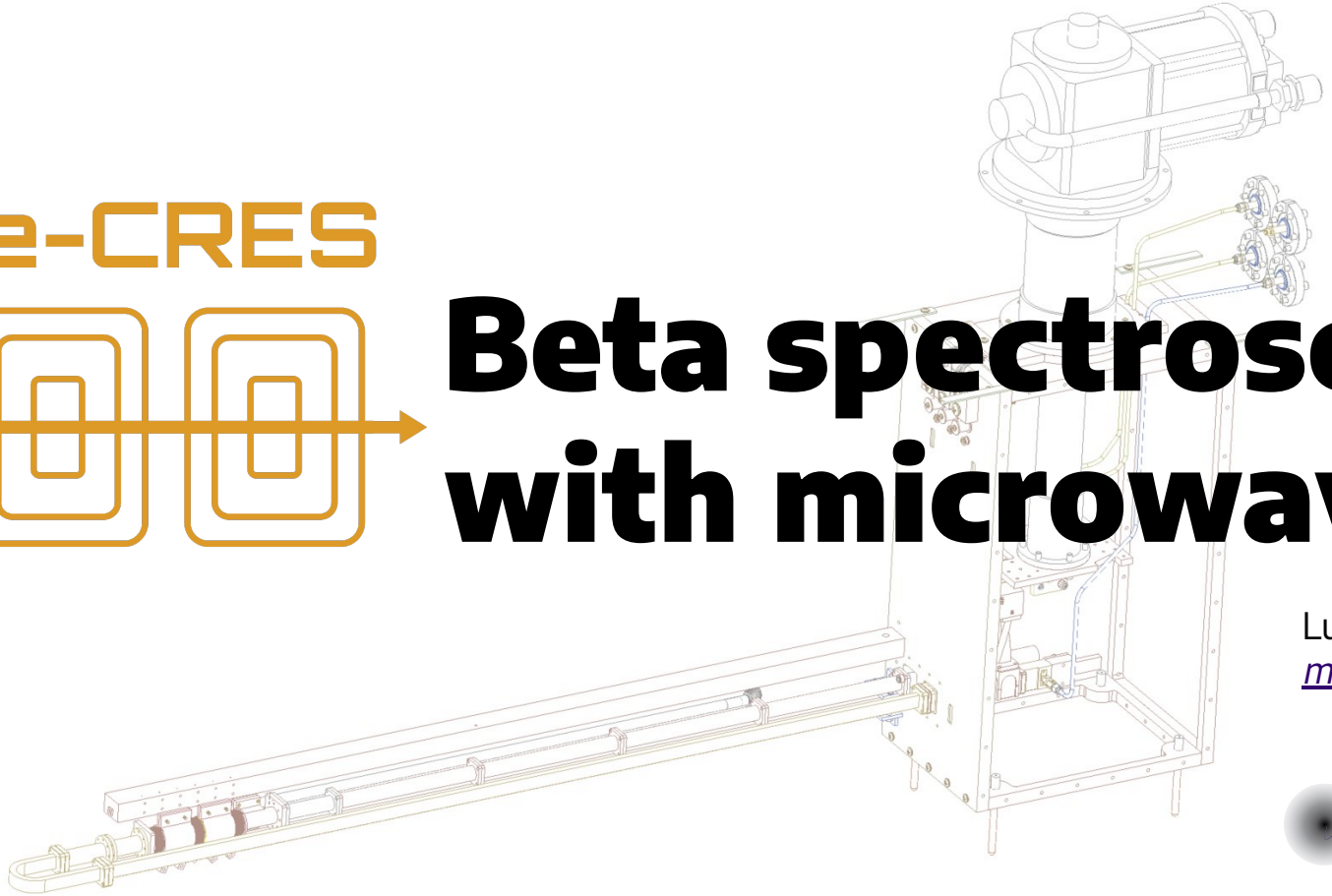
^{6}He-CRES



Beta spectroscopy with microwaves

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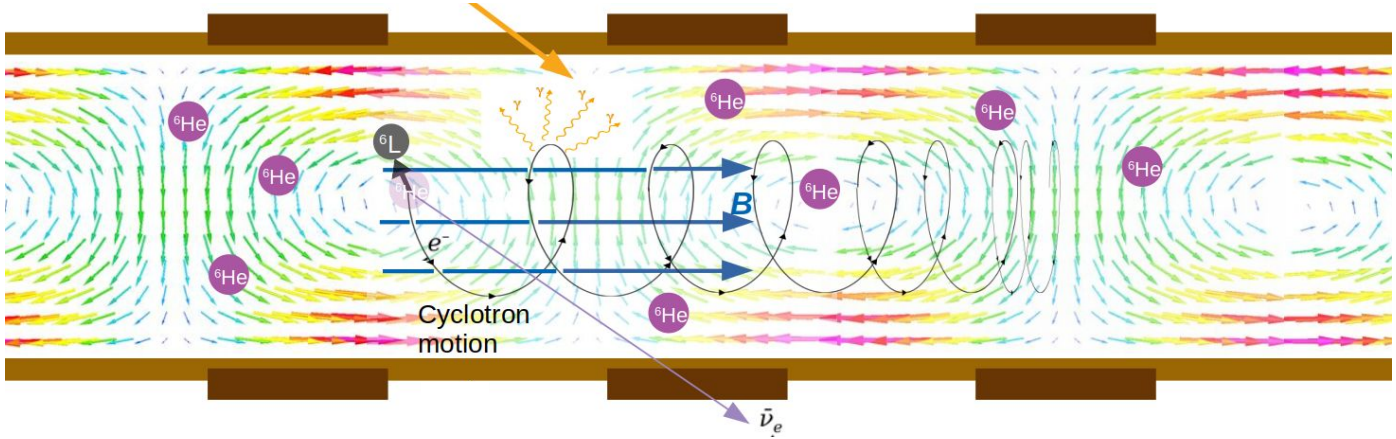
CENPA
Center for Experimental
Nuclear Physics and Astrophysics
UNIVERSITY of WASHINGTON

Cyclotron Radiation Emission Spectroscopy

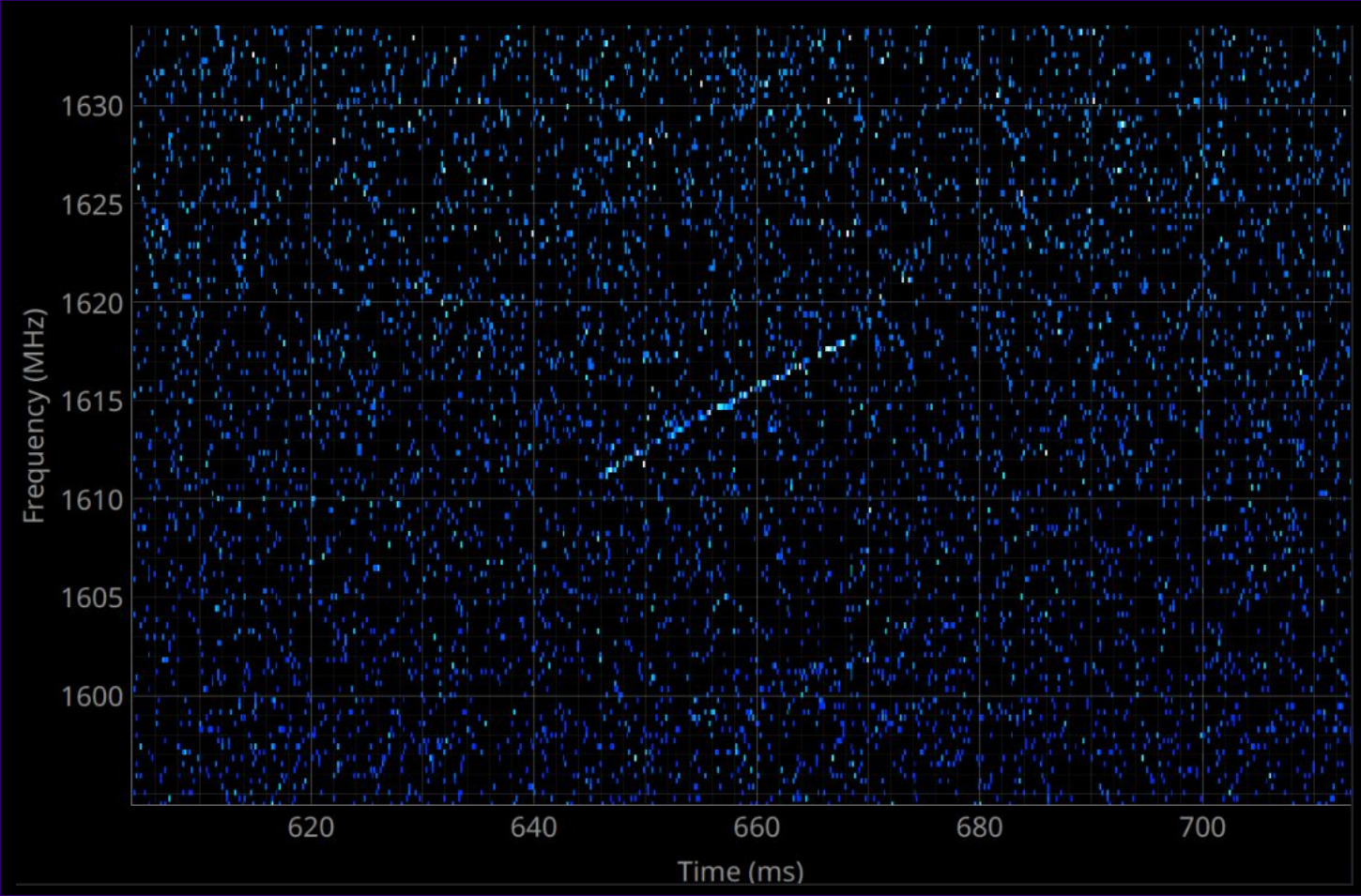
$$\omega_c = \frac{|q|B}{m\gamma} = \frac{|q|Bc^2}{E}$$

- β decay in a strong B field (0.75-3.6 T) ⇒ observe cyclotron radiation frequency
- f_c ~ 18-20 GHz, P ~ 10 fW signals traveling in a waveguide to be amplified, digitized
- Detecting electromagnetic radiation from individual beta particles



PROJECT 8

^{6}He-CRES



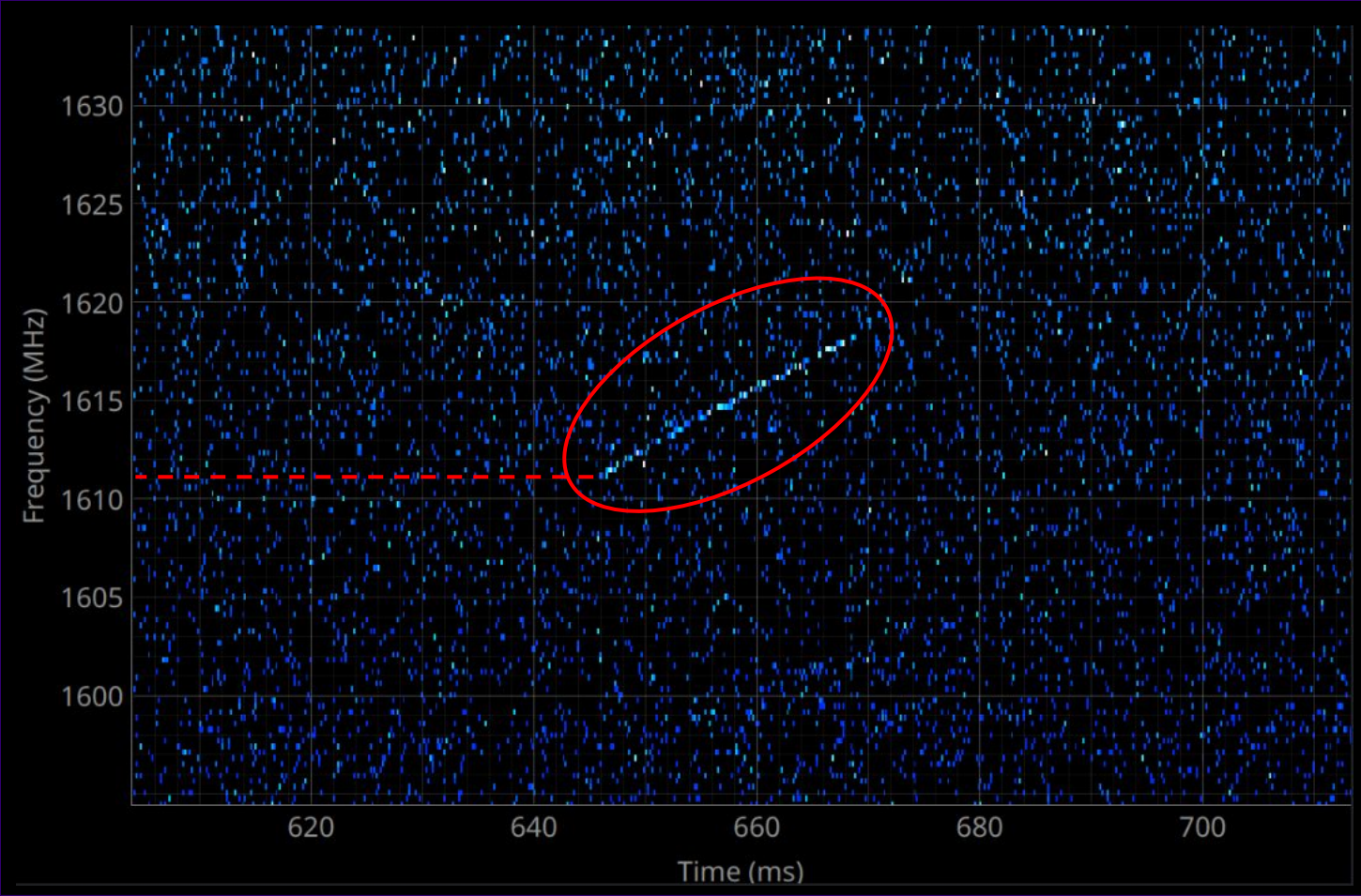
CRES data

"Tracks" with positive slope

Start frequency of the track

=

Initial beta energy



CRES data

"Tracks" with positive slope

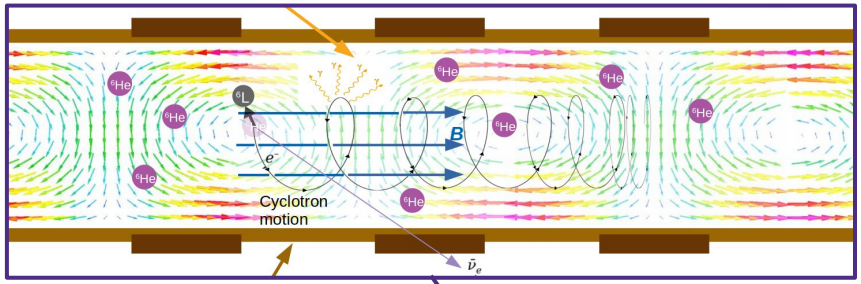
Start frequency of the track

=

Initial beta energy

He6-CRES apparatus

(MRI magnet around waveguide hidden)



Isotope production @ CENPA

Isotopes are produced at CENPA at our FN-Tandem linear accelerator

^{7}Li (d, ^{3}He) ^{6}He

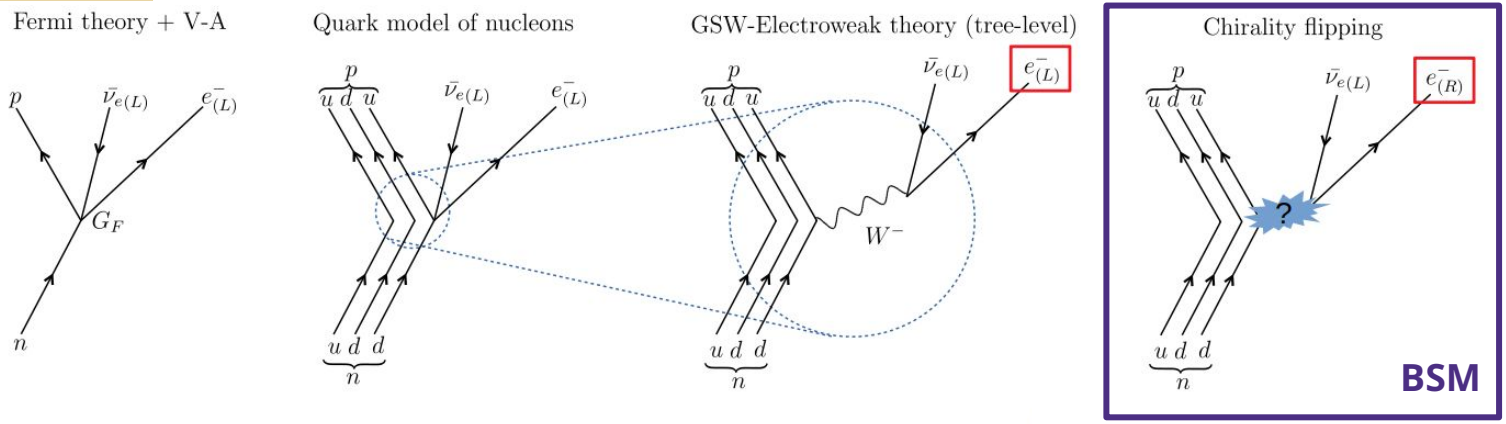
- 17.8 MeV deuteron beam on Li target
- $t_{1/2}$ = 0.806 s

^{19}F (p, n) ^{19}Ne

- 12 MeV proton beam on SF_6 target
- $t_{1/2}$ = 17.22 s

Overhead view of the CENPA accelerator hall

Non-(V-A) chirality flipping interactions



$$\mathcal{L}_{CC} = -\sqrt{2}G_F^0 V_{ud}\left[\bar{e}^L\gamma_\mu\nu_e^L \cdot \bar{u}\gamma^\mu(1-\gamma^5)d\right] \quad \text{SM (V-A)}$$

$$+\epsilon_S\,\bar{e}^R\nu_e^L \cdot \bar{u}d \quad \text{Scalar}$$

$$+\epsilon_T\,\bar{e}^R\sigma_{\mu\nu}\nu_e^L \cdot \bar{u}\sigma^{\mu\nu}(1-\gamma^5)d\Big] \quad \text{Tensor}$$

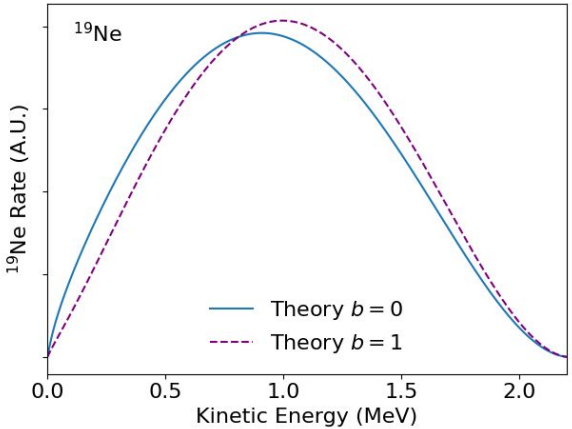
Effective S, T currents parametrized by Fierz interference term b_{Fierz}

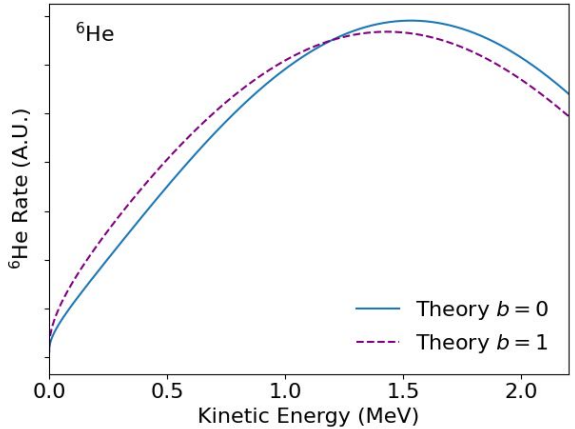
Figure by H. Harrington

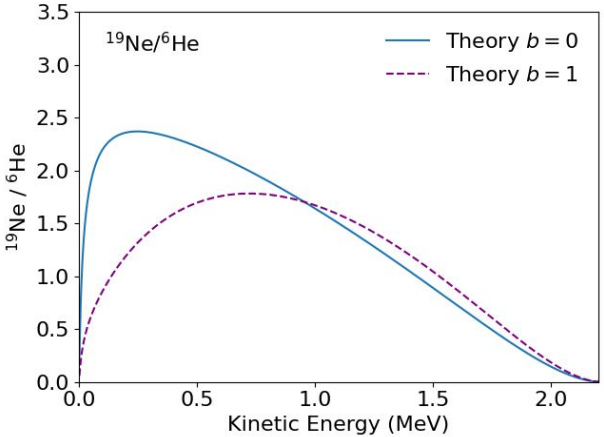
Jackson, Treiman, and Wyld, Phys. Rev. 106, 517 (1957).

b_{Fierz} distortion to the beta spectrum

(b greatly exaggerated)





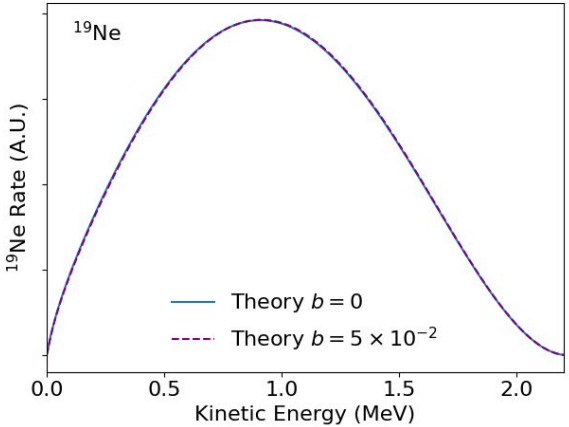


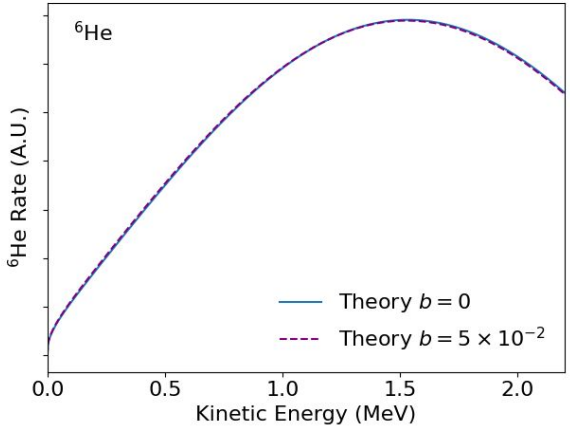
$$\frac{dN}{dE} = \frac{dN_{SM}}{dE}\left(1 + b_{\mathrm{Fierz}}\frac{m}{E}\right)$$

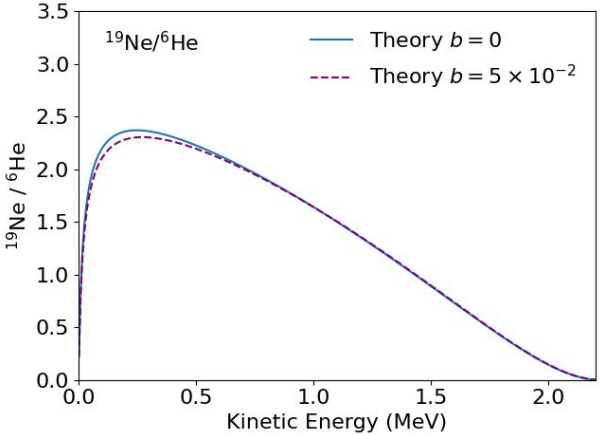
Relative – sign in *b* between electron/positron decays

Spectral ratio ^{19}Ne/^{6}He:
1) enhances b_{Fierz} distortion
2) cancels shared systematics

b_{Fierz} distortion to the beta spectrum







$$\frac{dN}{dE} = \frac{dN_{SM}}{dE}\left(1 + b_{\mathrm{Fierz}}\frac{m}{E}\right)$$

Relative – sign in *b* between electron/positron decays

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“1-minute talk”

He6-CRES measures beta spectra from the cyclotron radiation of individual beta particles

- **C**yclotron **R**adiation **E**mission **S**pectroscopy

CRES is a high-precision, inherently low-background spectroscopy technique

- Broad applicability to other precision beta decay measurements e.g. at FRIB

Exotic currents in the charged current weak interaction cause distortions to beta decay spectra by the Fierz interference term

- Constraining $b_{Fierz} < 10^{-3}$ implies sensitivity to new physics at $\Lambda_{BSM} > 10$ TeV scale

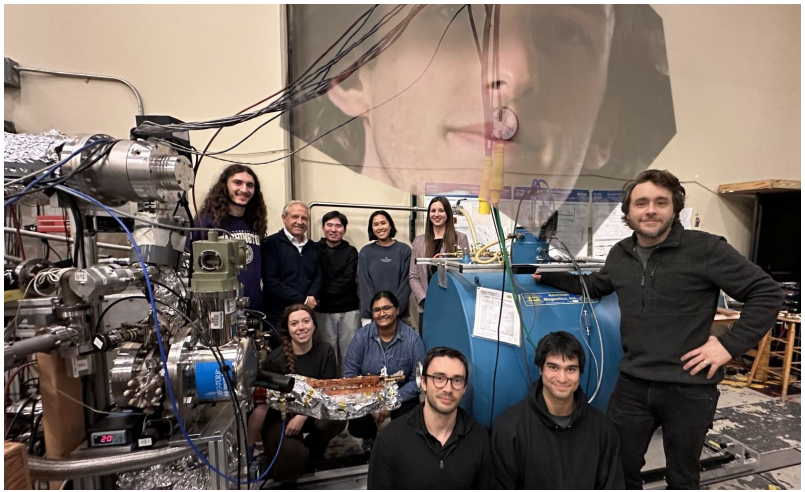
About me

Graduate student researcher at UW CENPA (PI: Alejandro Garcia)

Current research directions:

- FPGA and RF hardware development for data acquisition
- Commissioning upgraded cryopump
- Phase-coherent signal processing for CRES event detection+reconstruction
- Lineshape and spectrum analysis

Thanks!



He6-CRES Collaboration

W. A. Byron, N. Buzinsky, B. Dodson, A. Garcia, A. Goodman, A. Gorman, H. Harrington, L. Hayen[†], M.E. Higgins, N.C. Hoppis, P.T. Kolbeck, B. Maxwell, L. Malavasi, D. McClain[‖], D. Melconian[‖], P. Mueller[**], N. Oaxaca, N. S. Oblath[‡], G. Savard[**], D. Stancil[†], D. W. Storm, H. E. Swanson, R.J. Taylor[†], J. Tedeschi[‡], M.W. Thomas, B. A. VanDevender[‡], C. Wiseman, F. Wietfeldt[††], A. R. Young[†], X. Zhu.

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[‖]Texas A&M, College Station, TX.
[**]Argonne National Laboratory, Lemont, IL.
[‡]Pacific Northwest National Laboratory, WA.
[††]Department of Physics, Tulane University, New Orleans, LA.

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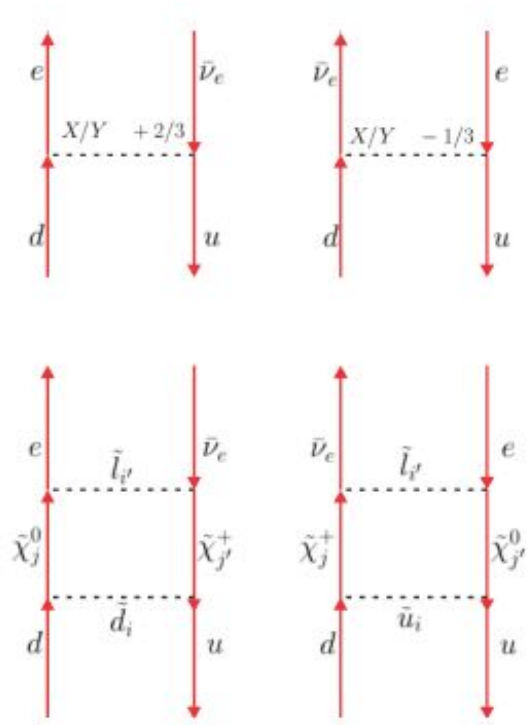
Bonus

Examples of models with chirality flipping interactions

FIG. 1. Example diagrams of effective chirality-flipping interactions in models beyond the SM. Top: leptoquarks suggested by grand-unified models with electric charge of $+2/3$ on the left and $-1/3$ on the right. Bottom: loop diagrams suggested by supersymmetric models: $\tilde{u}, \tilde{d}, \tilde{l}$ represent squarks and sleptons, while the $\tilde{\chi}$ represent charged and neutral supersymmetric particles (from Ref. [5]).



Rewrite quark-lepton bilinears with Fierz identities
e.g. scalar current

$$\psi\bar{\chi} = \frac{1}{4}(c_S 1 + c_V^\mu \gamma_\mu + c_T^{\mu\nu} T_{\mu\nu} + c_A^\mu \gamma_\mu \gamma_5 + c_P \gamma_5).$$