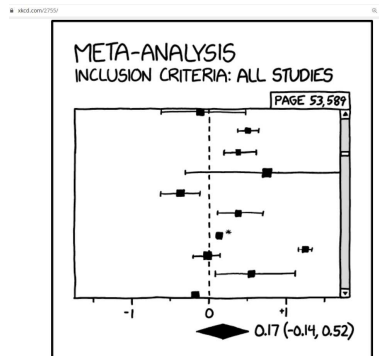
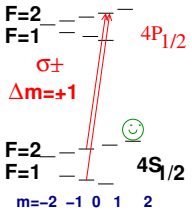
“Truth loves its limits, for there it meets the beautiful”

Rabindrinath Tagore, “Fireflies”

- **TRINAT and CIPI: it’s hard to publish in Phys Rev A**
- **Entanglement-enabled microscopic $\not{T}$**
- **U. College London, Jyväskylä effort to make a BEC of ^{135m}Cs to make coherent γ radiation**
  Could be done in TRINAT with 81mRb
- **charge radii for V_{ud}: optical and μ^-**
- **TRINAT and detector development techniques**
- **TRINAT and eng phys continuity**

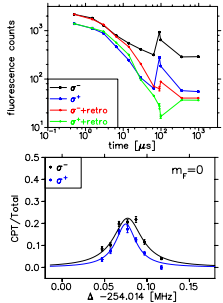


After TRINAT's 3 yrs in Canadian Institute for Photonics Innovations:



• **Atoms trapped in the coherent dark state have poor nuclear polarization: we learned to create and destroy 'Coherent Population Trapping'**

$\rho_{ij} = \psi_i^* \psi_j$ 'coherences' i.e. 'God throws dice where I can't observe them'



CPT $\Rightarrow$ B_{TRINAT}=2.19(2) G

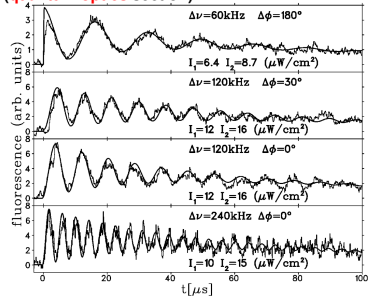
Phys Rev referee:

'Unpublishable anywhere' 6 collegial paragraphs on existing techniques e.g. a commercial atomic clock. ☹

S. Gu, JB, Groves, Dhat, Opt. Comm. 2003

Gu worked 6 mnths, lasers off the hyperfine resonance: (1-parameter fit)

BRIEF REPORTS **S. Gu and JB Phys Rev A 2003 (quantum optics section)**



'it's been done... yet a nice textbook example' ☺

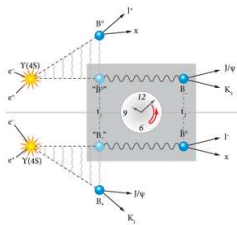
"ORRO can be used for quantum information"

'Please provide detail or remove the phrase' ☹

$\exists$ 900 CPT papers. Quantum physics is hard. Lots of smart people do it. I use it when I should

Entanglement in decays

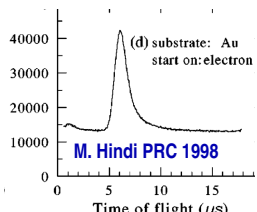
$\exists$ microscopic $\not{T}$ in nature! independent of assumptions about QFT, CPT theorem

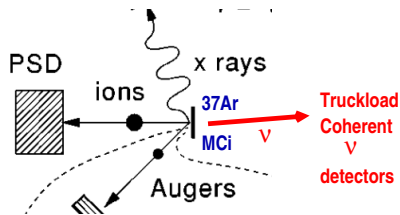


- BABAR PRL 2012: Entanglement of B meson pairs enables $\psi_i \leftrightarrow \psi_f$
- $\not{T}$ in K's KLOE-2 PLB 2023 (A. Olin, P. Amaudruz worked on KLOE...)

Delayed-choice experiment to measure θ_{12}, θ_{13}?

- Cohen Glashow Ligeti PLB 678 191 (2009): EC's ψ_f has ν_e mass eigenstates entangled with nuclear recoil to keep E and p conserved
- Formaggio Kaiser Murskyj WeissPRL 117 050402 (2016) ν oscillations show Leggett-Garg inequality
- Kayser Kopp Robertson Vogel PRD 82 093003 (2010): recovered oscillation(L,E_ν, m_ν)





Move the $^{37}Cl^{+}$-capturing E field mm's to cm's: 'delayed-choice' experiment (?), trace out ν mixing angles.

10^{-4} or 10^{-2} $eV^2 \rightarrow 10^4$ or 10^2 m $\rightarrow$ 300 μs or 3 μs

Any uses for a radioactive BEC?

best use of BEC's and atom interferometry for spectroscopy JB knows about:

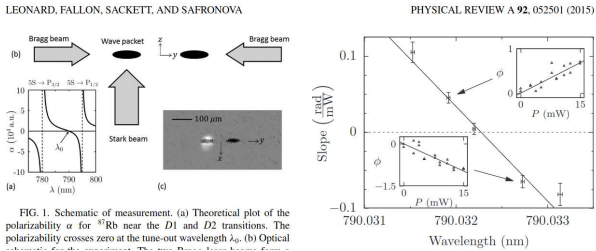


FIG. 1. Schematic of measurement. (a) Theoretical plot of the polarizability α for ^{87}Rb near the $D1$ and $D2$ transitions. The polarizability crosses zero at the tune-out wavelength λ_0. (b) Optical

Sackett's group thinks about parity-violating effects Priv comm Sackett's student

Fr Atomic PNC U. Manitoba/TRIUMF drives a forbidden 7s $\rightarrow$ 8s transition and prepares and probes hyperfine states, but does not need phases or coherence and is not using techniques in the quantum physics sections of Phys Rev

Coherent γ generation with nuclear isomer from a BEC: Marmugi Walker Renzoni PLB 2018

U. College London exp at Jyväskylä ^{135}Cs isomer

BEC of isomer with 10^5 atoms at a certain density $\rightarrow$ all isomer nuclei to decay at once (into 4π).

TRINAT can trap 10^6 ^{81m}Rb now: $\exists$ all-optical BEC creation with 20% efficiency Hu Science 2017

CKM unitarity is off by $\sim 2.8\,\sigma$ at ppt

Corrections to the phase space integral *f* (!)
Include a better 'weak charge radius' from isobaric charge radii.

for Holstein's finite-size correction:

$f \propto 1 + q^2 R^2_{\mathrm{ChargedWeak}} \neq q^2 R^2_{\mathrm{Charge}}$

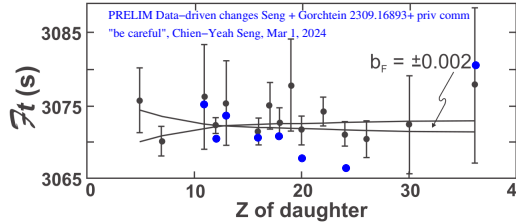
(This is a standard expansion of a pointlike nucleus to include its spatial distribution, related by a Fourier transform to the momentum transfer *q*)

Holstein RMP: One can get $R^2_{\mathrm{ChargedWeak}}$ by comparing isobaric triplets of measured R^2_{Charge}, but no one has done this correctly before.

A related calculation suggests an isospin-breaking test from similar info

(For decays to excited states, δ_{NS} is given by product of GT and M1 matrix elements... driving some M1 experiments, maybe at TRIUMF)

The *F*t values move about this much for the ones that have been measured.

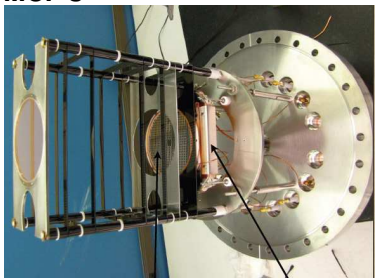


The error on ^{38m}K *ft* also grows by 1.2x.
Seng says if we do ^{38}K isotope shift to 0.3 MHz, (1/20 Γ) he can compare to Ar,Ca and see isospin breaking.
The SMS is likely under control with a benchmarked relativistic CC calculation from Sahoo et al. NJP 2022
We could use $4S \rightarrow 4P$ Γ=6 MHz, or $4S \rightarrow 5P$ Γ= 1.1 MHz. An order better would also need better μonic atom X-rays from the new TRIUMF beamline.

better $\langle r^2 \rangle$ of ^{38m}K, ^{37}K, and ^{37}Ar are needed for *f*! and for isospin breaking

TRINAT Detector development needs

MCP's



Commercial delay-line anode

- **large-area SiPM readout**

We use AiT or develop large-area SensL SiPM readout for β and γ energy and timing

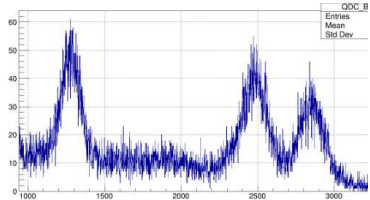
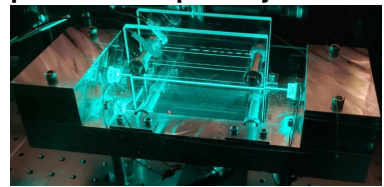


Figure 6: 137Cs and 60Co spectrum with GAGG

- **Gas detector for β δE: TAMU (with some help from TRIUMF)**

Francium UHV power-buildup cavity

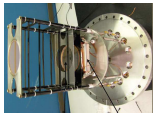


TRINAT and FrPNC Lasers, electrooptic devices, and control electronics and control boards are mostly commercial. Implementation is done with students and postdocs.

TRINAT is grateful for good support from TRIUMF for fast preamps (Leonid et al.) and for DAQ (Konstantin, Pierre et al.). More help would always be welcome.

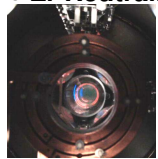
TRINAT/Francium and Eng Phys: precision UHV instrumentation

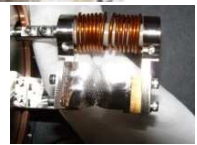
- Two generations of E field

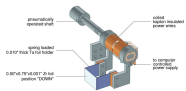


Glassy C and Ti electrodes to minimize eddy currents and β scattering
TRINAT has its own $5K clean hood based on βNMR sample prep

- Zr Neutralizers



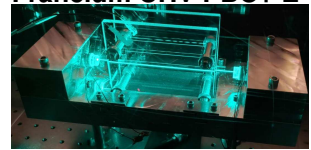




Fr 300,000 cycles 20 $\leftrightarrow$ 750 C

- Precision spot welding

Francium UHV PBC+ E



PEEK for vibration isolation

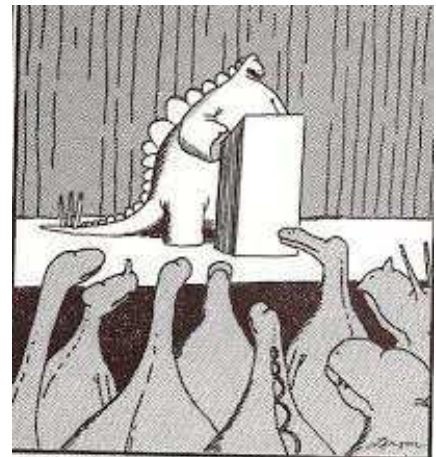
TRINAT UHV PCTFE viewports to minimize birefringence (Warner Behr Gorelov RevSciInst)

TRIUMF Machine (George–Cu-SS weld, Tim–2014 chamber) and Scintillator shops (Chapman) have been critical, but Engineering Physics for precision intrumentation at TRINAT (and some FrPNC) has been led by 1 person on soft money. Continuity and sharing of expertise could be better and more justly done through a precision measurements centre

“Truth loves its limits, for there it meets the beautiful”

Rabindrinath Tagore, “Fireflies”

- **TRINAT and CIPI: I use quantum physics (as defined by Phys Rev) when it’s existential, but without a comparative advantage it’s unwise to compete with people who spend their lives doing it.**
- **Entanglement-enabled microscopic $\not{T}$**
- **U. College London, Jyväskylä effort to make a BEC of ^{135m}Cs to make coherent γ radiation**
  Could be done in TRINAT with 81mRb
- **charge radii for V_{ud}: optical and μ^-**
- **TRINAT and detector development techniques**
- **TRINAT and eng phys continuity**



"The picture's pretty bleak, gentlemen. ... The world's climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut."