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Title: Progress Towards a Measurement of the Neutrino Asymmetry in UCN Beta Decay at LANSCE

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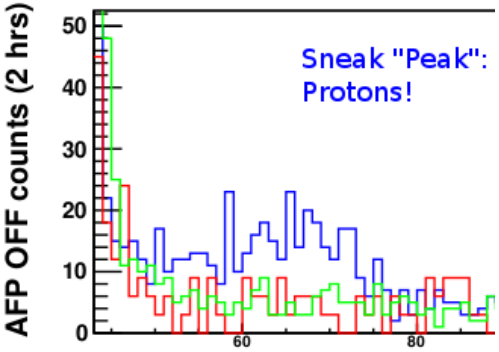
Progress Towards a Measurement of the Neutrino Asymmetry in UCN Beta Decay at LANSCE

Leah Broussard for the UCNB Collaboration

Los Alamos National Laboratory

October 25, 2013



Motivation[1]

Neutron Decay Distribution

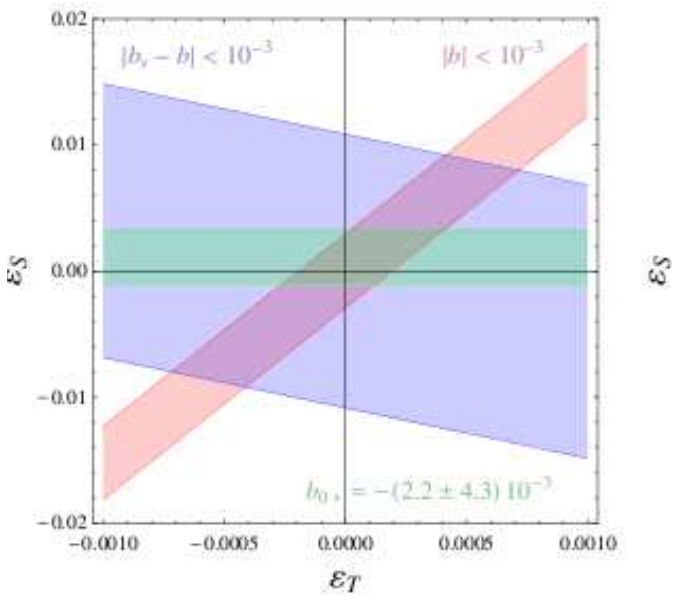
- Observables: effective correlations coefficients

$$\frac{d\Gamma}{dE_e d\Omega_e d\Omega_\nu} \propto w(E_e)(1 + \frac{m_e}{E_e}\overline{b} + \overline{a}(E_e)\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + \overline{A}(E_e)\frac{\vec{\sigma}_n \cdot \vec{p}_e}{E_e} + \overline{B}(E_e)\frac{\vec{\sigma}_n \cdot \vec{p}_\nu}{E_\nu} + \cdots)$$

Testing the Standard Model

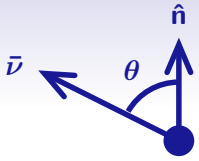
- **A**, **a** $+ \tau_n \rightarrow$ V, A interactions (V_{ud}, RL symmetry, ...)
- **B**, **b** $\rightarrow$ S, T interactions (BSM interactions, MSSM, ...)
- Presence of S, T interactions at 10^{-3} indicate BSM physics
- Green = superallowed $0^+ \rightarrow 0^+$ decays, red = **b** , blue = **B**

10^{-3} level precision:

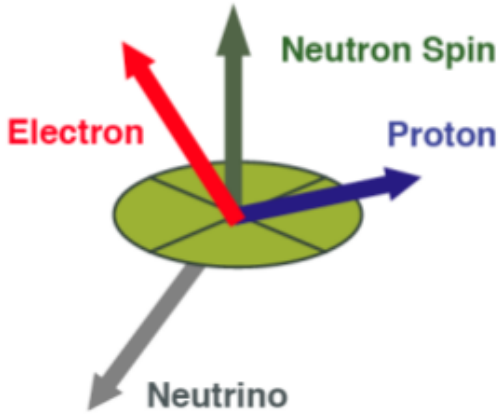


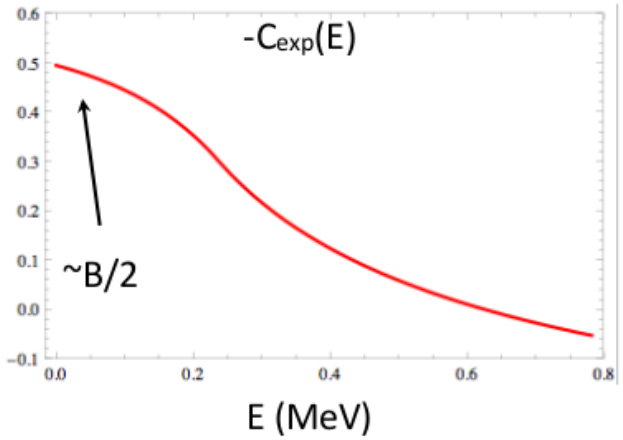
[1] Phys.Rev.D **85**, 054512 (2012)

UCNB: Antineutrino Asymmetry B



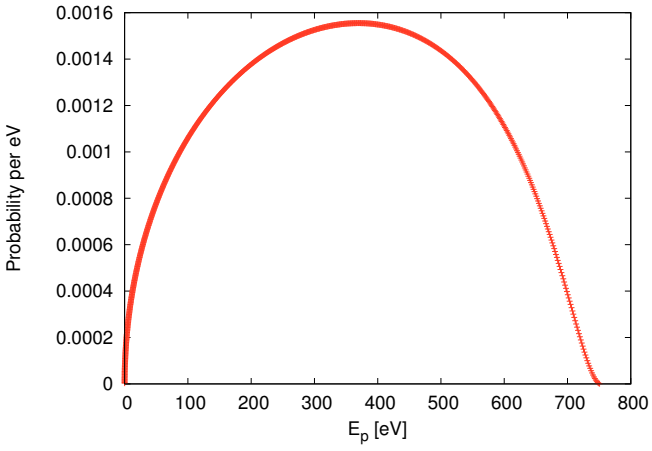
- Cold neutron beam experiments: $B = 0.9807 \pm 0.0030(0.3\%)$
- 3-body decay: Detect proton & beta in coincidence
- Count $N^{\beta p} = N^{\pm\pm}$ = aligned vs. antialigned with σ_n
- $B_{exp}(E) = \frac{N^{--}(E) - N^{++}(E)}{N^{--}(E) + N^{++}(E)}$
- $C_{exp}(E) = \frac{(N^{++}(E) - N^{-+}(E)) - (N^{+-}(E) - N^{--}(E))}{(N^{++}(E) - N^{-+}(E)) + (N^{+-}(E) - N^{--}(E))}$
- Statistical sensitivity $\frac{\delta B}{B} = \frac{2.9}{\sqrt{N}}$: 1 month to reach 0.1% at 10Hz decay rate





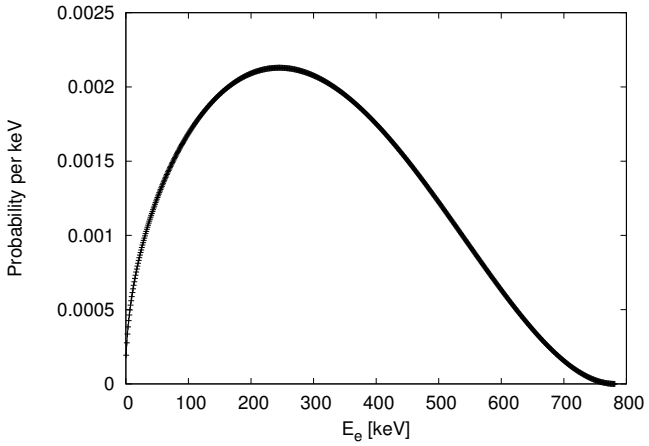
CHALLENGE: Detecting protons and betas

Proton Energy Spectrum



- max E $<$ 800 eV
- slow timing: 10 μs to 1 ms after decay
- Very low energy: detector deadlayer important

Electron Energy Spectrum



- max E $\approx$ 800 keV
- fast timing: 10 ns
- problem: backscattering $\rightarrow$ partial energy signal

System Requirements

Detect Protons

- Bias detector to $\sim$30 kV: accelerate protons
- Thin deadlayer to minimize energy loss
- Very low noise required: cool to LN_2 temperatures

Detect Electrons

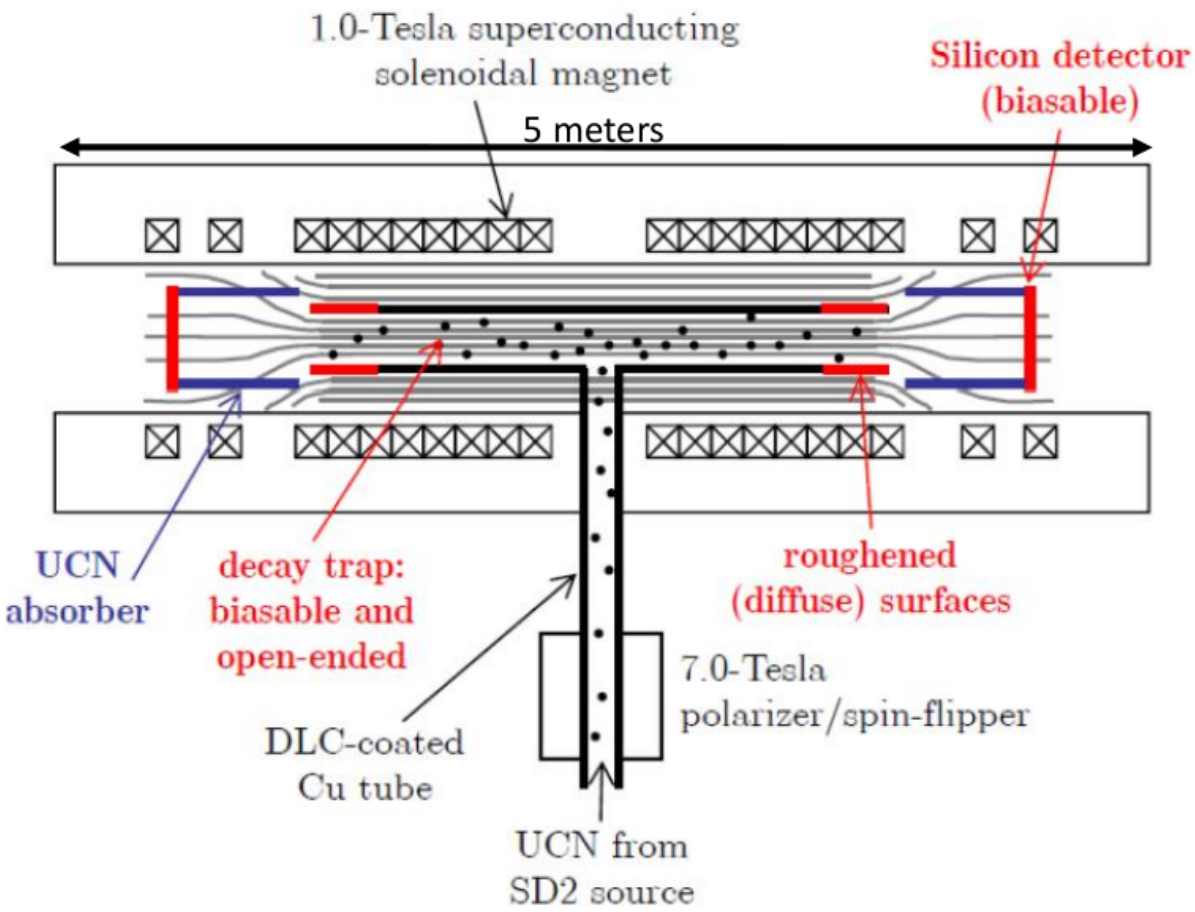
- Backscattering probability on silicon very high
- Fast timing to resolve backscattered events

Detect Coincidences

- 1 T Magnetic field operation: guide charge particles to detectors
- Proton, electron maximum Larmor radius $\approx$ 4 mm
- Check coincidence in adjacent pixels

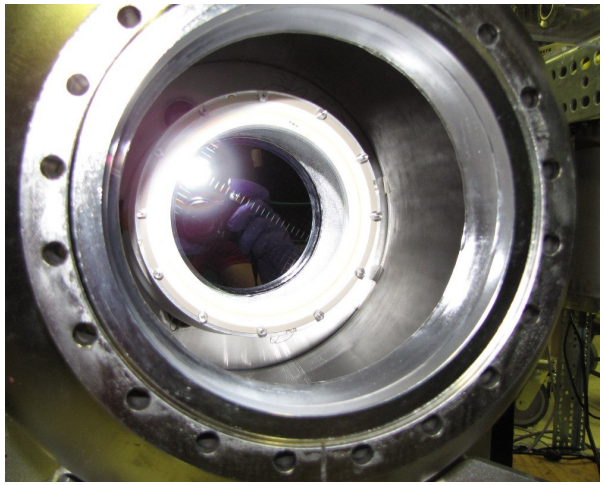
Experimental Approach

- Installed in existing UCNA spectrometer
- Protons/Electrons guided by 1 T field to Detectors
- Detectors biased -30kV to accelerate protons
- Entire DAQ biased with detectors



Large area silicon detectors

Junction Side (charged particle entry)



Ohmic Side (Electronics)

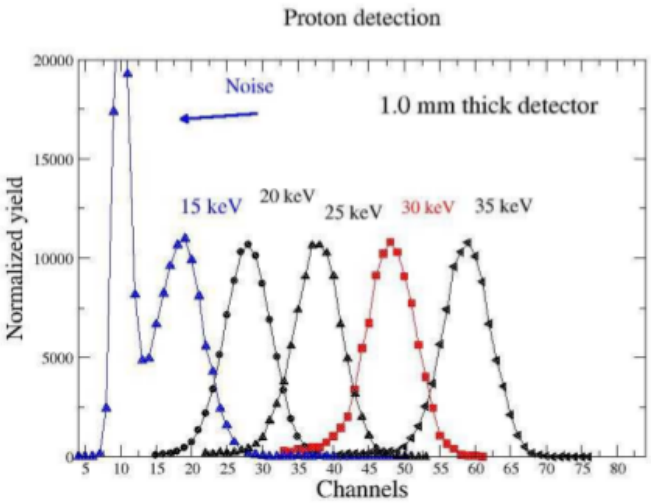
- 12 cm diameter active area, 2 mm thick
- Hexagonal array of 128 pixels, each 0.8 cm^2 area
- p-type implant minimizes "deadlayer"
- Metallized Al mesh $\rightarrow$ improve charge collecting time
- Detect both protons and betas

Proton Detection Demonstrated

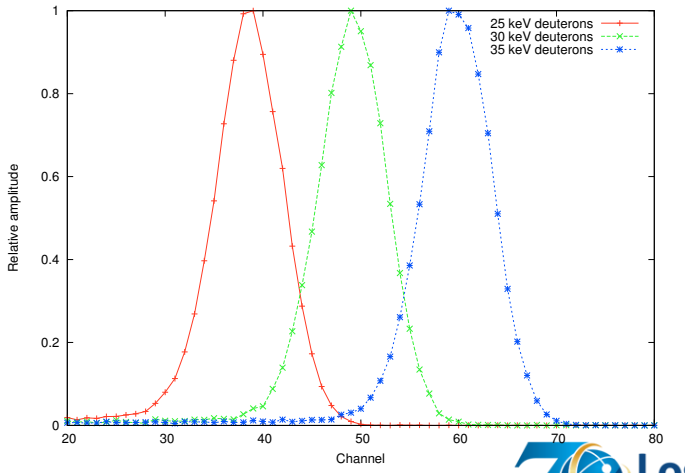
TUNL mini proton beam

- TUNL accelerator: proton energies from 10 keV to 60 keV
- 1 mm Si detector cooled to $\sim$ -15°C
- <20 keV protons resolvable
- $\sim$1.5 keV resolution
- Deadlayer measured using protons: 100.4 $\pm$ 2.3 nm
- Deadlayer measured using deuterons: 93.7 $\pm$ 16.0 nm

Protons



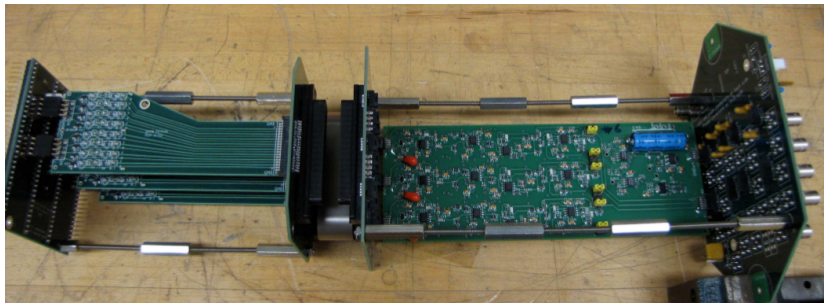
Deuterons



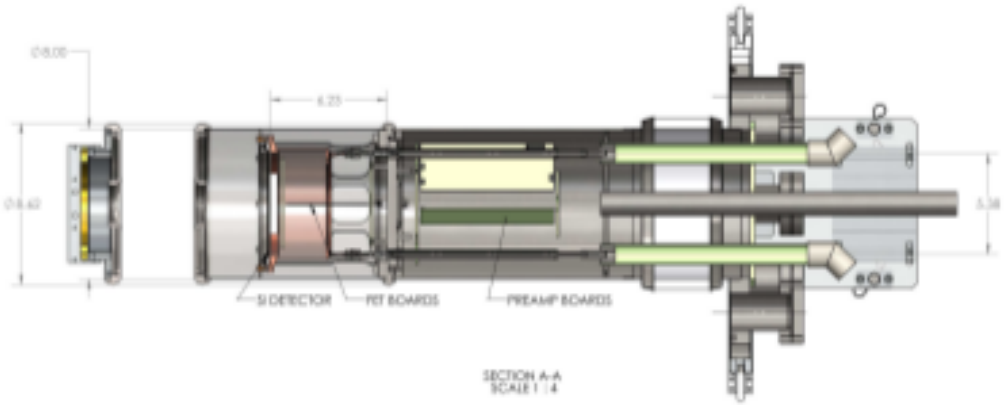
New Amplifier design

Can we achieve required resolution with compact design?

- FET mounted at detector, separated from rest of amplifier
- Cool detector + FET assembly to LN_2 temperatures:
  FET at $\sim$100 K $\rightarrow$ avoid thermal noise
- Minimum rise time $\sim$ 5 ns
- Current setup: 9 ch per detector
- On the test bench: energy resolution $\sim$ 2 keV = 2$\times$ theoretical noise
- Fully installed in system: energy resolution $\sim$ 2.5 keV, noise pedestal $\sim$ 20 keV
- **Upgrade:** 24 ch system ready for testing next week!

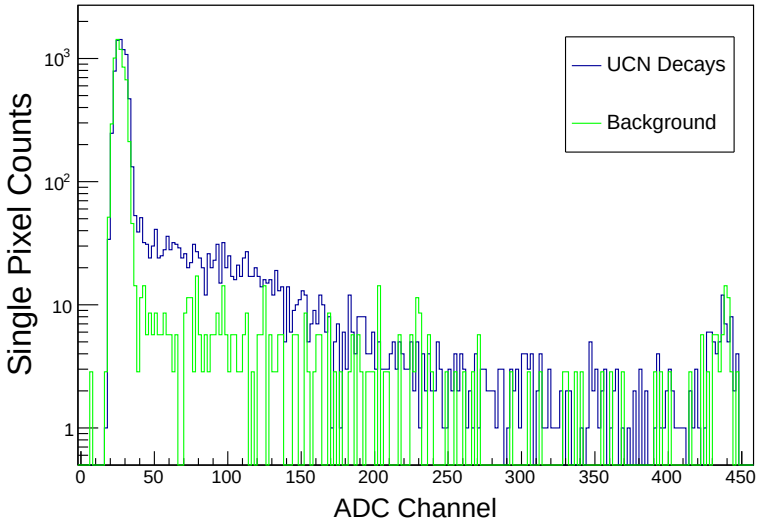


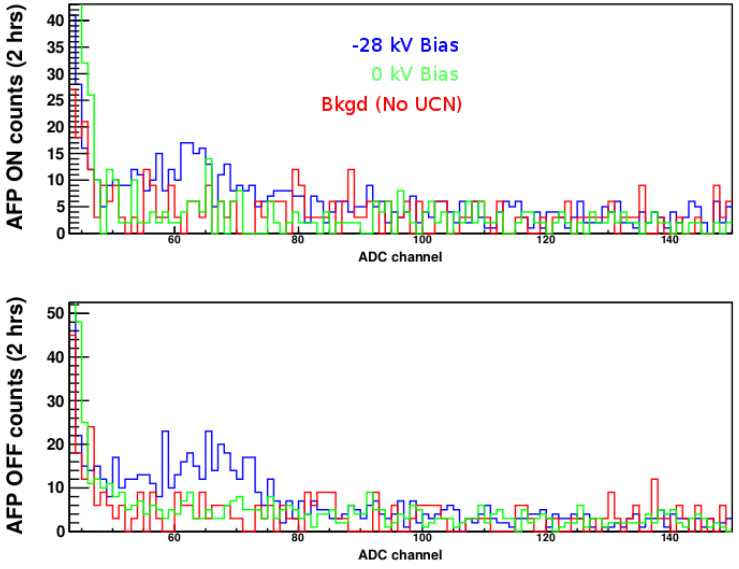
Improved Biased Detector Apparatus



- Full DAQ biased: detector, amps, digitizers
- Fiber from DAQ to computers
- Data taken at up to -30 kV, 1 T field, with working detector

UCN beta decay





- Neutron decay betas already observed ($\sim$ 0.1 Hz/pixel)
- **MILESTONE:** protons from neutron decay!
- Protons clearly resolvable, system biased at -28 kV ($\sim$ 0.05 Hz/pixel)
- Weak evidence of β-p coincidences (expected rate very low)
- Analysis ongoing...

Current Status

Summary

- We have detected protons from neutron beta decay!
- Substantial improvements to reduce noise implemented
  - Next: eliminate microphonics from LN_2 cooling

Coming soon

- Test 24 channels assembly = more rate
- Confirm proton-electron coincidences
- Install East detector: coincidence criteria = significant background reduction
- Study timing, energy, angle-effects using dedicated sources
- Preliminary goal: 0.1% statistical uncertainty
- Evaluate requirements for 0.01% uncertainty measurement

Collaboration List

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