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Title:	Precision Measurement of Neutron Decay Correlations
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Precision Measurement of Neutron Decay Correlations

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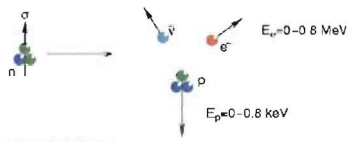
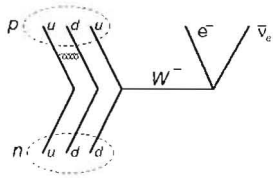
and collaborators from Hamilton College, ORNL, NIST, U. Kentucky, U. Michigan, and UNAM (Mexico)

Project Goals

- Develop new experiments to measure neutron decay parameters with 10^{-4} precision
- Analyze and understand important systematic effects
- Develop precision neutron polarimetry techniques required for these experiments
- Develop a new detector technology based on large-area ion-implanted silicon detectors



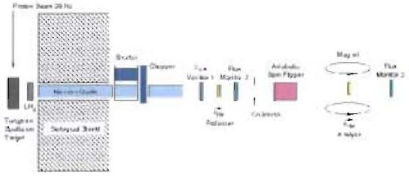
Neutrons beta decay into a three-body final state. Kinematic correlations in the decay are sensitive to physics beyond the Standard Model.

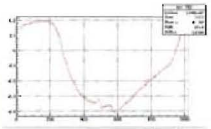


The neutron decays when a down quark changes into an up quark via the weak interaction. In the process, the neutron becomes a proton and an electron and a neutrino are emitted. This is one of the simplest systems to study such quark transitions.

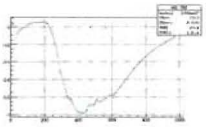
Methods

- Critical properties of prototype detectors will be tested
  - Energy and timing resolution
  - Noise and signal charge-collection time as a function of detector temperature
  - Entrance window thickness
- Neutron polarimetry method will be demonstrated
  - Method depends upon understanding neutron transmission through ^{3}He
  - Method has been proven to work in ideal (impractical) geometry at 3% precision
  - Will use simultaneous measurement with neutron analyzer to verify precision
  - Goal precision is 0.1%
- Systematic effects will be identified, tabulated, and estimated

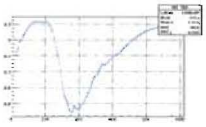




Flux Monitor 1
Incident (unpolarized) neutron spectrum



Flux Monitor 2
Transmitted (polarized) neutron spectrum



Flux Monitor 3
Analyzed neutron spectrum

Background & Significance

- The neutron is an ideal laboratory to search for physics beyond the Standard Model
  - Neutron decay can be calculated very accurately in the SM
  - Precision measurements of neutron decay parameters are possible
  - Sensitive to undiscovered particles and couplings
- New facilities provide intense sources of neutrons
- New techniques are needed to reduce systematics to match the expected statistics
- Previous experiments limited by key systematic uncertainties
  - Knowledge of neutron polarization
  - Backgrounds in detectors
  - Limitations of available detector technologies
- This project aims to improve these limiting systematics
  - Develop a new method for precision neutron polarimetry
  - Develop new detectors
  - Develop techniques to detect decay particles in coincidence

Full-size silicon detector prototype. The detector is made from a single 6" wafer and is segmented into 127 pixels.

Results & Discussion

- Prototype detector testing
  - Basic operation of detector has been verified using alpha and beta sources
  - Preliminary measurement of entrance window thickness is consistent with specifications
  - Cryostat for cryogenic operation has been designed and is being procured
- Precision neutron polarimetry method demonstration
  - First measurement with LANSCE beam yielded 0.7% precision, limited by statistics and systematics
  - Second measurement with improved apparatus completed in June
  - Data analysis in progress
  - Third measurement planned for next FY
- Analysis of systematic uncertainties
  - 20 systematic uncertainties identified and estimated
  - Three result in correction $>10^{-3}$, require careful control
    - Neutron pulse width (2×10^{-3})
    - Magnetic field inhomogeneity (3×10^{-3})
    - Neutron polarization (4×10^{-3})
  - Four identified as requiring further simulation for accurate estimate
    - Misalignment effects
    - Electron backscatter from detectors
    - Proton time-of-flight effects
    - Detector timing resolution
    - Proton scattering from residual gas
  - Results presented in proposal to Spallation Neutron Source (SNS) Fundamental Neutron Beam (FnPB)

Conclusion & Future Plans

- Finish characterization of prototype detector properties
- Complete third precision neutron polarimetry experiment
- Complete analysis of systematic effects
- Propose full experiment (the abBAexperiment) for SNS FnPB

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