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UCN A Collaboration

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Russia June 18 - 21, 2001

Outline

• The UCN A Experiment
• Electron Detector Prototyping Status
• Electron Detector Calibration Scheme and Status
• New Measurements of Electron Backscattering
UCN A experiment at LANSCE aims to measure beta asymmetry $A$ to 0.2%.

Multi-wire proportional counter (or Time Projection Chamber) used in conjunction with scintillator to detect betas.

Option to also use silicon multistrip counter in place of these detectors: different systematics (cross-check on corrections), energy dependence of $A$ (increased sensitivity to weak magnetic moment $\mu_a$ and induced tensor $g_T$ terms).

Prototypes of all three detectors are in testing phase at this time.
Gain and efficiency curves as a function of high voltage measured for isobutane and P10 gas near operating pressure. Also: development of thin windows.
Scintillator Detector for UCN (Bent Light Guides)

Version 1: No frame around scintillator

Front View

Features:

1. EJ–204V High vacuum safe scintillator 15 cm radius x 0.35 cm thick
   UVT Acrylic, 3.9 cm wide, 0.635 cm thick strips, bent connected at ring around scintillator
   - Divided into 3 sets of 4 strips connecting to 3 phototubes

- Prototype using straight light-guides tested last year, but will not fit in current spectrometer magnet design.
- Comparison of light guides with adiabatic bend to straight light-guides found to have little effect on photoelectron yield.
- Light guides must transport light over about one meter, to reduce effect of fringe field on phototubes.
- Curved light-guide prototype arrived at Caltech last week.
• Possible ultimate solution: 90° bend at scintillator/light guide interface with clever light-guide design.
- Micron design W(DS)1000
- 5 cm × 5 cm × 1000 μm
- 16 strips per side
- Pigtail connectors allow close-packing

\[ ^{137}\text{Cs} (624, 656 \text{ keV, } \beta) \]

\[ \sigma_E \approx 6 \text{ keV.} \]

\[ ^{59}\text{Fe (}\beta-\gamma\text{) E vs. coinc. time} \]

FWHM in time is about 10 ns at 40 keV.

Solution for ultimate experiment: arrange in 2×2 array.
Electron Detector Systematics

Dominant detector-related contributions to syst. error:

<table>
<thead>
<tr>
<th>Systematic Effect</th>
<th>Size of Correction</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backscattering</td>
<td>$1 \times 10^{-3}$</td>
<td>$2 \times 10^{-4}$</td>
</tr>
<tr>
<td>Detector Response Function</td>
<td>$3 \times 10^{-4}$</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>Detector Linearity</td>
<td>$6 \times 10^{-5}$</td>
<td>$6 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

**Total systematic uncertainty: $4 \times 10^{-4}$**

 Assumes detector linearity and response function known to 0.03%, simulation of missed backscattered fraction good to 20%.

Auxiliary equipment to aid in the characterization of the detectors:

- **Electron Sources:**
  - Kellogg Electron Gun (40-150 keV)
  - JPL Dynamitron (100-1500 keV)
  - Radioactive Beta/CE Sources
- Helmholtz-coil spectrometer for electron source calibration and definition
- Electron Backscattering Chambers
  - New measurements of energy and angular dependence of backscattering and transmission in energy range of neutron $\beta$-decay.
Electron Sources

**Kellogg Electron Gun:** 40 to 150 keV

![Image of Kellogg Electron Gun]

**JPL Dynamitron:** 250 to 1000 keV

![Image of JPL Dynamitron]
See design in J. Yuan et al NIM A (in press)

Features:
- Iron free
- Double focusing
- Laser-alignment system

Results:
- resolution $\Delta p/p = 0.3\%$
- Energy calibration 0.1% absolute
- Dynamitron and Electron gun are calibrated.
Backscattered $\beta$’s

Backscattered betas give false asymmetry

Experiment is designed to minimize backscattering:

- magnetic mirroring of backscattered betas,
- use of low Z materials in electron detectors.

Residual correction is about 0.1% and is largest systematic correction due to electron detection to measured asymmetry.
Existing Data Set

Numerous measurements of normal incidence backscattered fraction $\eta$ over full energy range for elements from Be to Au.

A few measurements of $\frac{d\eta}{dE'd\Omega}$ from Be below 40 keV, only on Si and Al targets.

Models of electron transport (e.g. EGS, Penelope) can model electron backscattering, but have not been tested in energy range relevant to neutron beta decay.

Motivates more measurements from 0 to 782 keV

Measure $\frac{d\eta}{dE'd\Omega}$ and $\eta$.

Focus on light materials: Beryllium, Scintillator, Silicon.
Two modes of operation:

- Integration of target and chamber currents for $\eta$ measurement (use as Faraday cup)

- Measure energy and angular distribution $\frac{d\eta}{dE'd\Omega}$ using moveable Si detector
Acquired Data Set

Kellogg:

- Be, Si, scintillator targets
- 42, 63, 84, 105, 126 keV incident beams
- 20, 30, 40, 50, 60, 70, 80 detector angles
- oblique incidence backscattering

JPL:

- Be, Si, scintillator targets
- 338, 461, 600, 700 keV incident beams
- 20, 30, 40, 50, 60, 70, 80 detector angles

JPL data not finalized, yet.
**Results:**

**Prelim. syst. uncertainty \( \approx 5\%. \)**

### Normal Incidence Backscattered Fraction for Be

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Backscattered Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.045</td>
</tr>
<tr>
<td>100</td>
<td>0.035</td>
</tr>
<tr>
<td>1000</td>
<td>0.015</td>
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</tbody>
</table>

This work - Preliminary

Saldick

Neubert

Massoumi

Previous data fit

### Normal Incidence Backscattered Fraction for Si

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Backscattered Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.2</td>
</tr>
<tr>
<td>100</td>
<td>0.18</td>
</tr>
<tr>
<td>1000</td>
<td>0.12</td>
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</tbody>
</table>

This work - Preliminary

Bishop

Drescher

Dohle

Previous data fit
Useful variable: \( q \equiv \frac{E'}{E_{\text{beam}}} \)

Beryllium target, 126 keV incident electrons

PRELIMINARY
Background-subtracted raw spectrum

\( \theta = 20 \text{ degrees} \)
\( \theta = 30 \text{ degrees} \)
\( \theta = 40 \text{ degrees} \)
\( \theta = 50 \text{ degrees} \)
\( \theta = 60 \text{ degrees} \)
\( \theta = 70 \text{ degrees} \)
\( \theta = 80 \text{ degrees} \)

systematic error < 10 %
Scintillator target, 126 keV incident electrons

PRELIMINARY
Background-subtracted raw spectrum

\( \theta = 20 \text{ degrees} \)
\( \theta = 30 \text{ degrees} \)
\( \theta = 40 \text{ degrees} \)
\( \theta = 50 \text{ degrees} \)
\( \theta = 60 \text{ degrees} \)
\( \theta = 70 \text{ degrees} \)
\( \theta = 80 \text{ degrees} \)

systematic error < 10 %
Silicon target, 126 keV incident electrons

\( q = \frac{E}{E_{\text{beam}}} \)

PRELIMINARY Background-subtracted raw spectrum

\( \theta = 20 \text{ degrees} \)
\( \theta = 30 \text{ degrees} \)
\( \theta = 40 \text{ degrees} \)
\( \theta = 50 \text{ degrees} \)
\( \theta = 60 \text{ degrees} \)
\( \theta = 70 \text{ degrees} \)
\( \theta = 80 \text{ degrees} \)

systematic error < 10 %
\( \frac{d\eta}{dq\,d\Omega}(\theta = 50^\circ) \) for various \( E_{\text{beam}} \)

PRELIMINARY Background-subtracted raw spectrum

\( E_{\text{beam}} = 41 \text{ keV} \)
\( E_{\text{beam}} = 62 \text{ keV} \)
\( E_{\text{beam}} = 83 \text{ keV} \)
\( E_{\text{beam}} = 105 \text{ keV} \)
\( E_{\text{beam}} = 126 \text{ keV} \)

Approximate Scaling Behaviour
Beryllium target, 126 keV incident electrons

\[ \frac{d\eta}{d\Omega} \]

\( \propto e^{-C/\cos(\theta)} \)

PRELIMINARY

syst. err. + extrapol. err. L 15 %
Prototyping of MWPC/TPC, scintillator, and silicon detectors for UCN $A$ is underway.

Electron sources and a Helmholtz-coil spectrometer are ready to be used to characterize these prototypes.

New data set exists for electron backscattering in energy range relevant to neutron beta decay:

- Nicely fills in gap in previous knowledge of electron backscattering from light materials.

- This data will serve as benchmark to test electron transport codes. Such code must be used to assign a systematic error for experiments detecting electrons in neutron decay.