Neutron Calibration System for the MiniCLEAN Experiment

Lu Feng for the MiniCLEAN collaboration
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The MiniCLEAN Experiment

Mini-Cryogenic Low Energy Astrophysics with Noble liquids

Dark matter direct detection using single-phase liquid argon/neon detector.

Located in Cube Hall at SNOLAB, near Sudbury, Ontario, Canada. depth ~2073m

Two-year run with liquid argon, with ~150kg fiducial mass, energy range 50-100keVr (12.5-25keVee), and sensitivity $2 \times 10^{-45} \text{cm}^2$ at 90% C.L. for 100GeV WIMP mass.

Signal Detection

Detect scintillation light resulting from dark-matter induced nuclear recoils with 92 8-inch Hamamatsu R5912 photomultiplier tubes (PMT).

Calibration Goals

- Characterize detector response to nuclear recoils.
- Benchmark neutron simulation physics to understand background.
- Test techniques to tag neutrons.

Neutrons produce the same signal:
1. Background
   e.g. (alpha, n) PMT neutrons
2. External calibration sources

pmt (alpha,n) energy spectrum

1. Deuterium-Deuterium neutron source
   - most of the radiation comes from neutrons
   - monoenergetic ~2.45MeV
   - control: turn (pulsing) on/off, movable source

2. Tagged americium-beryllium source
   - neutrons with energies up to 12MeV

3. “Hot PMT”: similar to PMT glass but with high uranium/thorium content
Neutron Source: “Minitron”

Deuterium-Deuterium neutron source provided by Schlumberger Limited.

D + D → \(^3\)He + n + 3.26 MeV

present housing

200V

(pulsed) “grid”

30-50kV

high voltage

electron source

“cathode”

dehuterium source

“filament”

deuterium target

prototype canister

n

2.45MeV

~10cm

~30cm
Minitron Operation

- **cathode**: ~3A, ~3V
- **filament**: ~20-30 mA, 200V
- **grid**: Serial communication
- **computer**: Rack-mounted

Programmable DC Power Supply
B&K Precision Corporation

Texas Instrument microcontroller
MIT Bates Laboratory

High voltage
~50-100μA, 30-50kV

PCI card

Spellman High Voltage Electronics
Minitron Operation

USB communication

~3A, ~3V

Programmable DC Power Supply
B&K Precision Corporation

cathode

~20-30 mA, 200V

Texas Instrument microcontroller
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filament

grid

serial

computer

rack-mounted

~50-100μA, 30-50kV

high voltage

PCl card

Spellman High Voltage Electronics

>> what affects neutron yield
Minitron Operation

- USB communication
- cathode: ~3A, ~3V
  Programmable DC Power Supply
  B&K Precision Corporation
- filament: ~20-30 mA, 200V
  Texas Instrument microcontroller
  MIT Bates Laboratory
- grid: serial
- computer: rack-mounted
- high voltage: ~50-100μA, 30-50kV
  Spellman High Voltage Electronics

 PCI card

>> what affects neutron yield
>> what controls pulsing

tunable frequency/duty cycle
Minitron Operation

USB communication

USB communication

- cathode
  - Programmable DC Power Supply
  - B&K Precision Corporation

- filament
  - Texas Instrument microcontroller
  - MIT Bates Laboratory

- grid
  - serial
  - computer

- high voltage
  - Spellman High Voltage Electronics

- PCI card

~3A, ~3V

~20-30 mA, 200V

~50-100μA, 30-50kV

>> what affects neutron yield

>> what controls pulsing

>> what measures neutron yield

~10^5 n/sec at 40kV and 50μA
Minitron Measurement

neutron production rate $\propto [\sigma(E) \times n_L \times n_P]$

$\rightarrow$ at 40kV, neutron yield is $\sim 10^3 n/\mu C$, resulting in $\sim 10^5 n/sec$ for 50$\mu$A
Minitron Operation

- cathode: Programmable DC Power Supply, B&K Precision Corporation
- filament: Texas Instrument microcontroller, MIT Bates Laboratory
- grid: Spellman High Voltage Electronics
- high voltage: ~50-100μA, 30-50kV
- serial: USB communication
- computer: PCI card, LabJack
- deployment: rack-mounted

~3A, ~3V
~20-30 mA, 200V

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Minitron Deployment

Canister position measured by yo-yo potentiometer.

We set the frequency at which the position is measured, and currently we require the winch to stop if the canister is within 1/7 cm of its intended location.

Measured velocity of winch:
~1.3 cm/s
“Tall Test”

Mechanical test of the prototype deployment system at roughly the height (~5m) at which it will be positioned relative to the detector.

Yoyo pot: mean = 0.01cm, RMS = 0.05cm
Neutron Calibration System

how everything fits together

Deployment system sits on the deck above the water tank.

Presence of calibration tube and canister do not significantly affect the neutron nuclear recoil spectrum.

by Michael Ronquest
Conclusion

Neutrons produce the same signal as dark matter particles.

External neutron sources will help calibrate and benchmark neutron physics.

Minitron: pulsed deuterium-deuterium source
  \(\rightarrow\) pulsing at tunable frequency and duty cycle
  \(\rightarrow\) yield: \(\sim 10^5\) n/sec
  \(\rightarrow\) variable calibration position
  \(\rightarrow\) material surrounding Minitron does not significantly alter energy spectrum