SuperCDMS-SNOLAB: an active neutron veto shield design

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SuperCDMS collaboration
Dark Matter Search
Goal: direct detection of WIMP elastic scattering off nuclei few WIMPS/year/ton
Signature: nuclear recoil with E<100 KeV

Shielding (Pb, polyethylene, Cu)
Reduce backgrounds from radioactivity

Active Background Rejection
Distinguish between nuclear recoils (WIMPS, neutrons) and electron recoils (backgrounds) -> by recording both ionization and heat (phonon) signals
Surface events tag -> interdigitized electrode scheme – phonon sensor

Deep Underground (SNOLAB)
Fewer cosmic rays to produce neutrons
Neutrons produce nuclear recoils

SuperCDMS

DETECTOR

SHIELDING

α, β, γ, n

U/Th/K

μ

μ

n

ROCK

ROCK
Depth is Important!

Moving from Soudan to SNOLab:

Reduce muon flux by $500\times$

Reduce high-energy neutron flux by $100\times$

Worry about neutrons from residual radioactivity only
Which Neutrons?

- **Cosmogenic** muon-induced: expect <0.1 in 100kg- years @SNOLab

- **External radiogenics** (Fission and \((\alpha, n)\) from U,Th in cavern rock): expected to be negligible with passive shielding

- **Internal radiogenics** (Fission and \((\alpha, n)\) from U,Th in Cu cans and supports): expect order of 1 in 100 kg – depending on screening and material cleanliness

- Identification background events especially neutrons that can produce nuclear recoils similar to WIMPS.
- The veto will indirectly act as a diagnostic device.
Neutron veto - how to

- n capture in the veto
- fast scatters in the veto
- gamma from captures outside the veto

WIMP search strategy

Any WIMP candidate in coincidence with a veto energy deposited of the n-capture process will be rejected
Physics Requirements

- Total unvetoed background in Ge <<1 counts in 100kg SNOlab phase

- Total background rate (neutron & gamma) must be the same: neutron veto must not generate excessive backgrounds in the zips
  \[\Rightarrow\] Implies radioclean construction

- Negligible contribution to dead-time
  \[\Rightarrow\] Implies low (<kHz) non-coincident trigger rate

- High (~90% or better) efficiency
  (a modest efficiency of ~80% would reduce neutron background to <1 event)
Neutron Flux Monitor

Additional requirement:
good ability to discriminate neutrons from the gamma background

- *In situ* measurement of radiogenic neutron rates – better precision than the multiple scattering measurement

- Evaluation of Monte Carlo systematics

- Monitoring/tuning of Ge nuclear recoil acceptance using tagged neutrons
Dimensions:
13 feet diameter
14 feet height

Current Design

Dimensions: 13 feet diameter 14 feet height

DILUTION FRIDGE

CRYOCOOLER

EBOX

WATER Shielding closing LIQUID SCINTILLATOR TANK

7/24/12
Silvia Scorza - IDM 2012
LEAD

LEAD

WATER/POLY SHIELDING

LIQUID SCINTILLATOR MODULES

PMTs

POLY planks

WATER/POLY SHIELDING
Neutron veto modules filled with Linear Alkylbenzene (LAB), read out by PMTs

Doped with high cross-section isotopes (B, Gd, Li)
- decreases capture time/distance (ex. 5% Boron doping reduces capture time from 250 \( \mu \text{s} \) to 3 \( \mu \text{s} \))
- affects design due to need to contain+detect capture products
**LAB Doping**

**Boron**

- $\rightarrow$ **ALPHA** (~3 MeV) + **GAMMA** (500keV)
- $\rightarrow$ observed light may be as low as 50keVee

**Challenges:**
- ✓ minimize environmental radioactivity by:
  - constructing the detector out of radiopure materials,
  - developing a clean boron-loaded scintillator,
  - utilizing adequate shielding for the neutron veto.
- ✓ energy threshold

**Gadolinium**

- $\rightarrow$ **GAMMA** cascade 8MeV
  - ($>^{208}\text{Ti}$ line ~2.7MeV)

- Reduction outer shielding
- It has been demonstrated by Daya Bay experiment

**BUT**
- decreased efficiency for detecting internal neutrons
- possible introduction of radio contaminant (Gd is less pure than B)
Efficiency

Veto efficiency vs threshold for 100μs veto times for recoil events.

Recoil events: passing the energy deposition criteria (10 -100keV) and >10% of the deposited energy must have come via recoils.

LAB Gd doped shows higher efficiency than LAB B doped.
- Scintillator and optical test starting soon
- Final design by 2014
- SuperCDMS SNOLab construction 2014
CDMS/SuperCDMS Collaborations

Caltech
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