Ultra-light dark matter search in NEWS-G with a gaseous spherical detector

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NEWS collaboration
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PHYSICS GOAL

- **NEWS-LSM:** First exploration of light dark matter search at LSM using SEDINE a small 60cm detector installed at LSM
- **NEWS-G SNOLAB:** Much higher sensitivity and larger detector to be installed at SNOLAB
The Spherical Proportional Detector


- Simple and cheap
- Large volume
- Single read-out
- Robustness
- Good energy resolution
- Low energy threshold
- Efficient fiducial cut
- Low background capability

\[ E(r) = \frac{V_0}{r^2} \frac{r_A r_C}{r_C - r_A} \approx \frac{V_0}{r^2} r_A \]

- \( r_a \) = anode ball radius
- \( r_c \) = cathode radius

Built by radiopure materials
- Vessel made of Cu (~tens of kg)
- Rod made of Cu (~hundreds of gr)
- All the rest less than < 1 g

C\( \approx r_a = 1 \) mm < 1pF
Irradiate gas through 200μm Al window
P = 100 mb, Ar-CH₄ (2%)

Rejection power
Rise time cut

Efficiency of the cut in rt => ~ 70% signal (Cd peak)
Severe background reduction
Energy resolution ~ 6 % and 9 % for Cu and Cd
Low-energy calibration source *Argon-37*

Home made Ar-37 source: irradiating Ca-40 powder with fast neutrons $7 \times 10^6$ neutrons/s
Irradiation time 14 days. Ar-37 emits K(2.6 keV) and L(260 eV) X-rays (35 d decay time)

First measurement with Ar-37 source
Total rate 40 hz
in 250 mbar gas, 8 mm ball
240 eV peak clearly seen
A key result for light dark matter search
Direct detection of ultra-light dark matter
Mass range: 0.1GeV/c^2 - few GeV/c

To reach low-mass sensitivity goal:
- low threshold <100 eV
- low A targets: Ne, He, H

Much larger energy recoils in He

QF much more favorable in He and H
NEWS-LSM: Exploration of light dark matter search at LSM
SEDINE detector installed at LSM end 2012: 60 cm, Pressure = up to 10 bar
Gas targets: Ne, He, CH4

Polyethylene
30 cm

Lead
10 cm

Copper
5 cm

Effect of the cup
Decrease of factor 20 for Energy range 1 – 200 keV
First results of NEWS-G with LSM SEDINE detector


Neon at 3 bar
Data 40.5 days, threshold 30 eV

Next run in Helium sensitivity down to 100 MeV

August physics run in Helium
Goal: get sensitivity down to 100 MeV WIMP mass
Spinned hemispheres stored at LSM
Waiting for electro polishing-plating
By PNNL (E. Hope)
Process tested in a small sphere
Welding using e-beam expected after summer

SNOLAB detector:
140 cm Ø detector, 2 bars, Ne, He, CH₄
Low activity copper, 3 cm archeological lead, 22 cm low activity lead, 40 cm polyethylene+Bo
NEWS-SNOLAB project sensitivity

The graph shows the sensitivity of various dark matter detection experiments over a range of WIMP masses and cross sections. The experiments include NEWS-G @ LSM, DAMIC, CRESST-II, CDMS Lite, H, He, Ne, CoGenT, DAMA/LIBRA, CDMS Si, SuperCDMS, CRESST, EDELWEISS-III, EDELWEISS-II, XENON-100, DarkSide-50, LUX, and PANDAX-II. The graph plots WIMP-nucleon cross sections against WIMP mass.
Sensor Development

Necessary to maximise the usable volume in the detector:
Add a field corrector to rod (umbrella)

1) Case of conductor
   - Discharges are a limiting factor
2) Case of insulator
   - Charging up and unstable operation
3) Best solution resistive material
   Resistivity range $10^9 - 10^{12} \, \Omega \cdot \text{cm}$
   - Allow application of a voltage
   - Suppress discharges
From single to multi-ball ‘ACHINOS’ structure

Advantages
- Amplification tuned by the ball size: 1mm diameter for high pressure
- Volume electric field tuned by the size of the ACHINOS structure
- Detector segmentation: 3D TPC like

Using 3D printer

This year we should be able to use ACHINOS structure at LSM
With small balls 1-2mm to reach high-pressure (10 bar) operation
THANK YOU