NEWS-G, a spherical TPC with low-A target to search for sub-GeV mass WIMPs

Pierre Gorel, TAUP 2017 (Sudbury)
State of the art of WIMP search
Possibilities for a lower mass

Barely any probes here... ...yet
Detection of low mass particle

• Maximize momentum transfer
  => use light nuclei to detect light particle (proton mass: 0.938 GeV)
• H, He, Ne lightest among noble gas

Recoil distributions with various targets material
New Experiments With Spheres (Gas)

- Spherical detector
- Single electrode
- Spherical proportional counter/TPC
- Flexible (Pressure, gas)

- Low threshold $\sim 50 \text{ eV}_{ee}$ independent on sphere radius
- Large mass / large volume ($\sim 30 \text{ kg}$) with single channel

\[ E(r) \approx \frac{V_0}{r^2} \times r_2 \]
\[ C \approx 4\pi \varepsilon r_2 \sim 0.1 \text{pF} \]
Signal generation

1. Primary electron(s)
2. Electrons drift
3. Avalanche
4. Secondary Ions drift
1) Deconvolution by exponential decay

2) Low-pass filter + integration

Amplitude ➔ Energy
Rise Time ➔ Radius
(fiducialization)
Low activity 60 cm Ø prototype @ LSM : SeDiNe

- Copper vessel equipped with 6 mm Ø sensor
- Runs with Neon+0.7%CH₄ @ 3.1 bars
  => 310 g sensitive mass
- Several internal cleanings for radon deposit removal
- 42 days run for WIMP search

60 cm NOSV Cu vessel 6.3mm sensor

Shields: 4 to 7 cm Cu, 10 cm Pb, 30 cm PE
9.7 kg/day with Ne

Arxiv: 1706.04934 (Submitted to Astroparticle Physics)
6000 mwe
0.27 muon/m²/d
NEWS-G @ SNOLAB: early 2018

Copper vessel

- Ø140 cm, 12mm thick
- 10 bars
- Ne, He, CH₄

Glove box for rod change

Lead shield

- 25 cm thick:
  - 3cm inner: archeological
  - 22cm outer: very low activity

40 cm Polyethylene
**Background budget (simulation)**

12mm thick, Ø140cm copper sphere. Ne+CH4(1%), 11.43kg of gas

Hypothesis for WIMP sensitivity limit calculation : 100 kg.d, 1 electron threshold

<table>
<thead>
<tr>
<th>Source Position</th>
<th>Qty</th>
<th>Source</th>
<th>Contamination</th>
<th>Units</th>
<th>Evt/kg/day &lt;1keV</th>
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</thead>
<tbody>
<tr>
<td>Copper</td>
<td>627.83 kg</td>
<td>⁶⁰Co</td>
<td>30</td>
<td>µBq/kg</td>
<td>0.054</td>
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<tr>
<td>Copper</td>
<td>627.83 kg</td>
<td>²³⁸U</td>
<td>3</td>
<td>µBq/kg</td>
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<td>Inner surface</td>
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<td>nBq/cm²</td>
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<tr>
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<tr>
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<td>Rod</td>
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<td>µBq/kg</td>
<td>0.000</td>
</tr>
<tr>
<td>Rod</td>
<td>0.0932 kg</td>
<td>²³⁸U</td>
<td>3</td>
<td>µBq/kg</td>
<td>0.000</td>
</tr>
<tr>
<td>Rod</td>
<td>0.0932 kg</td>
<td>²³²Th</td>
<td>12.9</td>
<td>µBq/kg</td>
<td>0.000</td>
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<tr>
<td>Wire</td>
<td>2.66x10⁻⁵ kg</td>
<td>⁶⁰Co</td>
<td>31000</td>
<td>µBq/kg</td>
<td>0.000</td>
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<tr>
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<tr>
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<td>²⁰⁸Tl/⁴⁰K</td>
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</tbody>
</table>

**Total: 0.279 evts/kg/day < 1keV**
Construction: copper sphere

- Sphere fabrication: spinning
- Low activity copper (C10100) located
  - Activity measured @PNNL
    \(\Rightarrow 7\) to \(25\ \mu\text{Bq/kg of Th}\)
    \(\Rightarrow 1\) to \(5\ \mu\text{Bq/kg of U}\)
  \(\bigg\rfloor\) Within goals

- Initial project of water jet cleaning non-practical
  - Acid etching @LSM
  - R&D for copper electroplating
Sensors R&D

Sensor support disturbs the field ➔ “umbrella” to counter the effect.

- Single channels “achinos” for optimization amplification & drift field
- Multi channels sensors (segmentation)
- Different materials: Si, Bakelite, Cu powder...
Calibration program

• AmBe: Nuclear recoils

• $^{22}$Na: High energy gammas

• 213nm Laser: Low Energy, “surface” events

• $^{37}$Ar: Low energy, “volume” events
{}^{37}\text{Ar}

Production: \(^{40}\text{Ca} + \text{n} \rightarrow ^{37}\text{Ar} + \alpha\)

Half-life: 35 days

Electron capture $\rightarrow$ X-rays: 270 eV & 2.82 keV

First delivery, May 2017!
$^{37}$Ar signal

Preliminary! $\sigma/\mu \sim 20\%$ @2.82 keV

$\sigma/\mu \sim 60\%$ @270 eV

Gas mixture: Ar+CH$_4$ (2\%)

Online trigger: 10 eV ($\sim$ 0.3 primary e$^-$)

Analysis threshold: 50 eV
NEWS-G expected sensitivity
100 kg-day, 1 electron threshold
Collaboration

- **Queen’s University** – G Gerbier, P di Stefano, R Martin, T Noble, G Giroux, A Brossard, P Vasquez dS, Q Arnaud, K Dering, J Mc Donald, M Clark, M Chapellier
  - Copper vessel and gas set-up specifications, calibration, project management
  - Gas characterization, laser calibration, on smaller scale prototype
  - Simulations/Data analysis

- **University of Birmingham** – K. Nikolopoulos, P Knight
  - Simulation and R&D

- **Institut de Recherches sur les Lois Fondamentales de l’Univers** – I Giomataris, M Gros, C Nones, I Katsioulas, T Papaevangelou, JP Bard, JP Mols, XF Navick,
  - Sensor/rod (low activity, optimization with 2 electrodes)
  - Electronics (low noise preamps, digitization, stream mode)
  - DAQ/soft

- **Laboratoire Souterrain de Modane/Université de Chambéry** – F Piquemal, M Zampaolo, A Dastgheibi-Fard
  - Low activity archeological lead
  - Coordination for lead/PE shielding and copper sphere

- **Thessaloniki University** – I Savvidis, A Leisos, S Tzamarias, C Elefteriadis, L Anastasios
  - Simulations, neutron calibration
  - Studies on sensor

- **Laboratoire de physique Subatomique et Cosmologie** – D Santos, JF Muraz, O Guillaudin
  - Quenching factor measurements at low energy with ion beams

- **Technical University Munich** – A Ulrich, T Dandl
  - Gas properties, ionization and scintillation process in gas

- **Pacific Northwest National Laboratory** – E Hoppe, D Asner, R Bunker
  - Low activity measurements, Copper electroforming

- **Royal Military College Canada** – D Kelly, E Corcoran
  - 37 Ar source production, sample analysis

- **SNOLAB** – P Gorel
  - Calibration system/slow control

- **Associated lab : TRIUMF** - F Retiere
  - Future R&D on light detection, sensor

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Aug 2017