Status and prospect of the NEWS-G experiment

Alexis Brossard, on behalf of the NEWS-G collaboration

New directions in the search for light dark matter particles
Fermilab
June 5th 2019
-1 Particle ionizes gas.
-2 Primary electrons drift toward the sensor.
-3 Close to the sensor, secondary ion/electron pairs are produced.
-4 Signal is induced by the motion of secondary ions.
-5 The signal is processed by a pre-amplifier and digitized.

-Possibility to use large range of target mass.
-Sub-keV energy threshold.
-Identification of point like energy deposition by pulse shape.
Competitive sub-GeV limit with neon target at the Laboratoire Souterrain de Modane
3.1 bars of Ne + 0.7% CH$_4$ 42 days of data

Sub-GeV WIMP limit

SINGLE ELECTRON CALIBRATION

- Measure mean gain to 1% precision
- Measure drift and diffusion time
- Monitor stability of detector within 1%
- Measure trigger threshold efficiency
- Measure of W-value to 1% precision and constraint on the Fano factor

$^{37}$Ar calibration

$F=0.19$
$W=27.54 \text{ eV (fixed)}$
$\theta = 0.12 \text{ (fixed)}$

$F=0.26$
$W=27.51 \text{ eV}$
$\theta = 0.12 \text{ (fixed)}$

Q. Arnaud et al. (NEWS-G), arXiv:1902.08960, accepted by PRD
QUENCHING FACTOR MEASUREMENT

- $E_{eVee} = QF \cdot E_{nr}$

- Deuterium from TANDEM accelerator used to produce neutrons:
  - D+D $\rightarrow$ n (3.68 MeV) + $^3$He + γ
  - p+Li $\rightarrow$ n (545 keV)+ $^3$H + γ
  Scattering angle gives the expected nuclear recoil energy.
  $E_{nr}(E_{neut}, \theta)$

- Two measurement campaigns performed for 12 energy points:
  - 5 - 28 keV$_{nr}$ (spring 2018)
  - 0.3 - 6.5 keV$_{nr}$ (winter 2019)
NEW DETECTOR – COPPER SPHERE BACKGROUND

The large amount of $^{210}\text{Pb}$ in the copper is the main source of background. The inner surface of the sphere was electropolished and electroplated. 500 µm of pure copper plated on the inner surface reduce by 70% the sub-keV event event rate from $^{210}\text{Pb}$ and $^{210}\text{Bi}$.
NEW DETECTOR – SENSOR DEVELOPMENT

Studies of new sensors for:

- Improve isotropy of the field / gain
- Improve the time stability of the detector
- Ensure a strong enough electric field in the whole volume

S130 calibration with a grid sensor, Ar + 2% CH$_4$ at 200 mbar

$^{55}$Fe $5.9$ keV
$^{37}$Ar $2.8$ keV
Cu X-ray fluorescence $8$ keV

I. Katisoulas et al. (NEWS-G), arXiv:1809.03270
<table>
<thead>
<tr>
<th>Source</th>
<th>Contamination / flux</th>
<th>Counts / keV / kg / day &lt; 1 keV</th>
<th>Counts / keV / kg / day in [1 ; 5] keV</th>
<th>Rate [mHz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper sphere</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>210Pb</td>
<td>28.5 mBq/kg</td>
<td>1.1</td>
<td>0.95</td>
<td>0.9</td>
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<td>60Co</td>
<td>38 μBq/kg</td>
<td>0.12</td>
<td>0.09</td>
<td>0.37</td>
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<tr>
<td>238U</td>
<td>3 μBq/kg</td>
<td>0.012</td>
<td>0.011</td>
<td>0.027</td>
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<tr>
<td>232Th</td>
<td>13 μBq/kg</td>
<td>0.074</td>
<td>0.063</td>
<td>0.15</td>
</tr>
<tr>
<td>40K</td>
<td>0.1 mBq/kg</td>
<td>0.03</td>
<td>0.13</td>
<td>0.61</td>
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<tr>
<td>Archeological lead</td>
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<td></td>
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<tr>
<td>210Bi</td>
<td>&lt;25 mBq/kg</td>
<td>&lt;0.27</td>
<td>0.23</td>
<td>0.46</td>
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<tr>
<td>238U</td>
<td>62 μBq/kg</td>
<td>0.18</td>
<td>0.12</td>
<td>0.37</td>
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<tr>
<td>232Th</td>
<td>9 μBq/kg</td>
<td>0.026</td>
<td>0.014</td>
<td>0.052</td>
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<tr>
<td>40K</td>
<td>&lt;1 mBq/kg</td>
<td>&lt;0.22</td>
<td>0.16</td>
<td>0.62</td>
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<tr>
<td>VLA Lead</td>
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<tr>
<td>238U</td>
<td>62 μBq/kg</td>
<td>0.13</td>
<td>0.094</td>
<td>0.37</td>
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<tr>
<td>232Th</td>
<td>9 μBq/kg</td>
<td>0.022</td>
<td>0.017</td>
<td>0.063</td>
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<tr>
<td>40K</td>
<td>&lt;1 mBq/kg</td>
<td>&lt;0.24</td>
<td>0.16</td>
<td>0.64</td>
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<tr>
<td>Cavern</td>
<td>208Tl 2.6 MeV γ</td>
<td>0.06 γ cm²/s</td>
<td>0.088</td>
<td>0.069</td>
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<tr>
<td>TOTAL</td>
<td></td>
<td>1.752</td>
<td>1.428</td>
<td>2.562</td>
</tr>
</tbody>
</table>

- $^{210}$Pb measured by X-mass
- $^{238}$U and $^{232}$Th measured at PNNL
- $^{60}$Co estimated from 3 months of exposure at sea level
- $^{40}$K activity in C10100 copper measured by NEXT-100
- The upper limits in the lead are not counted in the total

Daniel Durnford
NEW DETECTOR – FABRICATION PROGRESS

Compact lead and PE shield flushed with N₂ for radon mitigation

• Hemispheres electroplated and electron beam welded.
• Glove box to manipulate rod/sensor in radon and oxygen free environment.
• Lead and PE shield to be installed soon.

Koby Dering
NEWS-G detector has promising characteristics for sub-GeV dark matter detection.

New detector currently under construction and run at the LSM to be installed at SNOLAB end of this year.

Performances ensured by new calibrations and monitoring.

The background is dominated by the copper sphere, the future relies on copper purity investigation (6N copper).
NEWS-G collaboration

- Queen’s University Kingston – G Gerbier, P di Stefano, R Martin, G Giroux, S Crawford, M Vidal, G Savvidis, A Brossard, F Vazquez dS, K Dering, J Mc Donald, P Gros, A Rolland, C Neyron
  - Copper vessel and gas set-up specifications, calibration, project management
  - Gas characterization, laser calibration, on smaller scale prototype
  - Simulations/Data analysis

  - Sensor/rod (low activity, optimization with 2 electrodes)
  - Electronics (low noise preamps, digitization, stream mode)
  - DAQ/soft

- LSM (Laboratoire Souterrain de Modane), IN2P3, U of Chambéry – M Zampaolo, A DastgheibiFard
  - Low activity archeological lead
  - Coordination for lead/PE shielding and copper sphere

- Thessaloniki University – I Savvidis, A Leisos, S Tzamarias
  - Simulations, neutron calibration
  - Studies on sensor

- LPSC (Laboratoire de Physique Subatomique et Cosmologie) Grenoble – D Santos, JF Muraz, O Guillaudin
  - Quenching factor measurements at low energy with ion beams

- Pacific National Northwest Lab – E Hoppe, R Bunker
  - Low activity measurements, Copper electroforming

- RMCC (Royal Military College Canada) Kingston – D Kelly, E Corcoran
  - 37 Ar source production, sample analysis

- SNOLAB – Sudbury – P Gorel, S Langrock
  - Calibration system/slow control

- University of Birmingham – K Nikolopoulos, P Knights, I Katsioulas, R Ward
  - Simulations, analysis, R&D

- University of Alberta – MC Piro, D Durnford
  - Gas purification, data analysis

- Associated labs : TRIUMF – F Retiere

April 2019
Backup Slides
Laser monitoring / trigger efficiency

Gain monitoring

Trigger efficiency

Q. Arnaud
Quenching factor measurement cut

- TOF cut and backing detector PSD cut
- Clear nuclear recoil signal found
- Energy scale (gain drift) set by $^{55}\text{Fe}$ calibration

M. Vidal, Queen’s
\[ ^{40}\text{Ca}(n,\alpha)^{37}\text{Ar} \]

Source produced in an oxygen-free environment

Counting of gaseous and solid by-products allows for indirect measurement of \(^{37}\text{Ar}\) production

$^{210}$Pb measurement in copper

By measuring rise time ($t_\mu - t_0$), surface event can be distinguished from event in Ar gas or ceiling.