Characterization of the NEWS spherical gas detectors

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NEWS: New Experiments With Spheres

CAP congress in Ottawa

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Spherical gas detector working principle

- Large metallic sphere grounded
- Small sensor (1-16 mm) in the center of detector on positive high voltage
- Filled with gas mixture
- Particle interaction creates electron-ion pairs in the gas
- Electrons drift and create avalanches toward center of detector
- Ions drift toward the ground and induce current/charge on the electrode
- Measured signal is proportional to particle energy

\[ E \approx \frac{V}{r^2} \cdot r_s \]

for \( r_c \gg r_s \)
Spherical gas detector

- Simple detector design
- Low radioactivity
- Very low energy threshold, sensitive to low-mass WIMPs
- Low mass targets (Ne, He, H)
- Flexible gas pressure and interchangeable sensor size
- Single signal readout channel
- Good energy resolution

\[ E \approx V/r^2 \cdot r_s \]

for \( r_c \gg r_s \)
Gas mixture

- Noble gases, hydrogen and nitrogen have low electron attachment coefficients. Electrons continuously migrate.
- Quench gas is necessary
  - Avalanche is based on secondary ionization. However, gas molecule may be raised to an excited state but not ionized. This excited state decays by photon emission. These photons interact with gas molecule and produce secondary electrons, which distort proportionality of the gas detector.
  - Quench gas is added to absorb these photons. Often this quench gas is methane (CH$_4$)
NEWS detectors

• NEWS-SNO dark matter detector (1.4 meter diameter copper sphere)
  – G. Gerbier talk on Tuesday

• SEDINE detector at Modane Underground Laboratory (60 cm diameter copper sphere)
  – F. Vasquez de Sola talk on Tuesday
  – A. Kamaha talk next

• Prototype detectors at Queen’s University
  15 cm, 30 cm high pressure, and 50 cm diameter stainless steel spheres
Inside a sound-proof room

15 cm stainless steel sphere (S15)

Pressure transducer

To vacuum pumps

Gas line
Detector sensor design

- Central electrode (ball)
- Ball/Umbrella support
- Umbrella (Field corrector)
- Pipe, ball support
- Pipe/Sphere point fixing
- High voltage cable
Data taking

• Gases tested at Queen’s
  – Ne+2%CH$_4$ up to 1 bar
  – Ar+2%CH$_4$ up to 1 bar
  – Ne+1%CH$_4$, 200 mbar only so far

• Calibration
  – Fe-55 X-ray calibration
  – Nitrogen gas laser calibration
Gain/stability studies with Fe-55 X-rays

Ne+2%CH\textsubscript{4}
500 mbar
HV1 (ball) = 650 V
HV2 (umbrella) = 72 V
Optimization of operating voltages

Ne+2%CH$_4$

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Alphas in S15

Po-210 alpha rate < 3 mHz

Ar+2%CH₄, 1 bar
HV1=1 kV, HV2=167 V

2% energy resolution@5.3MeV

Integral of pulse
Laser calibration

• Nitrogen gas laser produces UV photons
• Photons extract surface atomic electrons from stainless steel sphere
• Electron drift time and diffusion time measurements – to be compared with simulations with Magboltz
• Single electron measurement
• Looking into solid state laser to study stability of detector gain
Laser calibration

Ne+2%CH4
200 mbar
HV1 = 550 V
HV2 = 69 V

N₂ laser (60 electrons)  Fe-55 6-keV X-rays

![Graph showing laser calibration data]

| htm       | Entries | Mean    | Std Dev | \( \chi^2 \) / ndf | p0     | \( \chi^2 \) / ndf | p1                  | p2        | p3        | p4        | p5        | p6        | p7        |
|-----------|---------|---------|---------|---------------------|--------|---------------------|----------------------|----------|----------|----------|----------|----------|----------|--------|
|           | 166054  | 3999   | 2338    | 400.7 / 292         | 76.91 ± 7.93 | 0.004858 ± 0.000734 | 909.0 ± 5.2           | 5676 ± 6  | 1187 ± 8  | 1079 ± 9  | 1993 ± 9  | 704.6 ± 8.5 |
Electron drift/diffusion time study

- Timing difference between laser trigger pulse and gas detector signal → electron drift time
- Width of the distribution → electron diffusion

Ne+2%CH$_4$
1 bar
HV1 = 1050 V
HV2 = 170 V

Peak @ 15 µs
Sigma is 1 µs
Baseline noise improvements

Noise in the signal baseline has been greatly reduced by
- Improvements on electronics grounding
- Sitting the detector inside a sound-proof room
- Adding glass break between signal and other electrical devices

Ne+2%CH₄
200 mbar
HV1 = 480 V
HV2 = 60 V
Summary

• Characterization of various gases at different pressures for a spherical gas dark matter detector, NEWS-SNO, is ongoing
• Detector is capable of providing stable gain at optimized high voltages on the electrodes
• Nitrogen gas laser calibration provides essential information on electron drift/diffusion time
• Single electron studies with laser are feasible
**NEWS Collaboration**

- **Queen’s University Kingston** – GG, P di Stefano, R Martin, T Noble, B Cai, A Brossard, A Akamaha, P Vasquez dS, Q Arnaud, K Dering, J McDonald, M Clark, and summer students
  - 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** - F Piquemal, M Zampaolo, A DastgheibiFard
  - 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

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

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

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

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

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