Experiment: Preliminary results from a 60cm prototype run with Neon for dark matter search
Overview of the prototype SEDINE

- **Operation & data taking conditions**
  - NOSV Cu sphere vessel (60 cm Ø) + sensor (6 mm Ø) +HV
  - Fill gas Ne (6N:99.3%) + quencher CH4 (5.5N:0.7%) @3.1 bar
    - 310 g sensitive mass
  - HV set to 2520 V
    - no sparks & gain~ 3000
  - Seal mode, no recirculation
  - DAQ sampling frequency 2 MHZ + soft trigger
  - Data taking continuously for 42 days for WIMP search
  - Calibration : 5000 ADU@ 8.1 keV
  - Threshold @30ADU 50 eV
    - No noise in sable conditions
  - Loss of gain 4 % along 42 days monitored with $^{210}$Po line + variation on days scale of +4%
  - Mode of operation: Point like energy deposition

- **Shielding:**
  - Located @Laboratoire Souterrain de Modane(4800mwe)
  - Cu(4-7cm) + Pb(10cm) +PE(30cm) shielding
Pulse modeling/simulation: ionisation

- Energy deposited produces e-/ions pairs in Neon gas (36eV/pairs)
Pulse modeling/simulation: diffusion

- Primary e- drift to sensor while ions drift to ground
- Due to diffusion, each e- arrives at distinct times at the sensor

max diffusion time: 20us
Total drift time (max): 500us
Pulse modeling/simulation: avalanche

- Primary e- arrive at the avalanche region near the sensor & get multiplied
- Gain modelled by a polya distribution.

\[ P \left( \frac{G}{\bar{G}} \right) = \frac{(1 + \theta)^{1+\theta}}{\Gamma(1 + \theta)} \left( \frac{G}{\bar{G}} \right)^{\theta} \exp\left(- \left(1 + \theta \frac{G}{\bar{G}} \right) \right) \]

\[ \text{Polya distribution: } \theta = 0.1 \text{ & } \bar{G} \]

\[ \sim 3000 \text{ e-/ions pairs in average} \]
Primary e- arrive at the avalanche region near the sensor, get multiplied and induce a signal on the sensor.
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\( r_1 \) at which occur avalanche

\( r_2 + \lambda \)

Distribution of charge over time: pulse

Cumulative pulse

RT(10-90%)
Simulated pulses

• Risetime calibration

**Volume events**
Neutron/WIMP/Compton

**Surface events**
$^{210}$Po decay products($\alpha$, $^{206}$Pb)
Energy calibration

- 2 methods
  - Volume calibration with $^{37}\text{Ar}$ source (after end of run), obtained from $^{40}\text{Ca}(n,\alpha)^{37}\text{Ar}$
  - Internal calibration with 8 keV peak from Cu fluorescence

- Match of both calibrations within 15 %

L capture, Auger e$^-$/X 0.27 keV
K capture, Auger e$^-$/X 2.82 keV

8 keV peak from Cu fluorescence

$^{37}\text{Ar}$ X rays calibration

WIMP search data
Comparison of simulation with neutron calibration (AmBe) data

- Good agreement noticeable
Comparison of simulation with bckg events (surface & Compton) from WIMP search data

1) Ongoing work to fully understanding the detector response to optimize simulation

2) Apply a Boosted Decision Tree (BDT) analysis to provide conservative limits.

- Fair agreement close to the ROI
- Long risetime tail in data not reproduced by simulation

\[ E_{\text{thresh}} = 150 \, eV \, \text{ (eff >85 %)} \]
Improvement in simulation & background modeling

- Field map & simulation of e-/ions transport in real detector set up shows inhomogeneity of E field lines near rod leading to higher RT & lower gain
- Studies under way to simulate expected tails of long diffusion time and drop in gain due to inhomogeneous field
- About 25% of volume expected to be affected

⇒ Inhomogeneity of field lines near rod

⇒ Diffusion in (r, θ) plane

⇒ anisotropic diffusion/RT

⇒ anisotropic gain
- Set of linear cuts in the multidimensional space (Risetime and Energy) in order to optimize the signal / background discrimination

- BDT trained to classify events using simulated events from our signal and background models

- Reduces the parameters space to only one variable : the BDT score

- Poisson limit derived with the remaining events above the BDT optimal cut

PDF of a 7GeV WIMP

- WIMP spectrum using standard assumption on WIMP velocities, escape velocity and with quenching factor (QF) of Neon nuclear recoils in neon calculated from SRIM simulation

➤ QF measurement below 1keV scheduled to start in Grenoble in the next month.

PDF of the signal for a WIMP of 7GeV

Contour at X % of the total signal, X from 10 to 90 %
Boosted Decision Tree (BDT) analysis

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PDF of a 7GeV WIMP +background events

- PDF of the signal for a WIMP of 7GeV
  - Surface event
  - Compton event
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PDF of a 7GeV WIMP + background events

Distribution of simulated signal / background events in BDT Score

Background like: low BDT Score  Signal like: high BDT Score
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PDF of a 7GeV WIMP +background events

Distribution of simulated **signal** / **background** events in BDT Score
Preliminary: Expected sensitivity of SEDINE assuming events in ROI are pure background and behave in ROI as expected from sidebands

- Limit set on spin independent coupling.
Conclusion

- 12.6 kgd of data using a 60cm prototype currently being analyzed and finalized
- Good pulse treatment and understanding
- Pulse modeling/simulation using ideal homogeneous E field reproduce reasonably well the data (Calibration + WIMP search)
  - Fine tuning of pulse simulation to account for E field and charge transport in real detector set up is underway
- Preliminary analysis results for WIMP sensitivity (using conservative BDT analysis) are promising and pave a way to the larger scale detector to be installed at SNOLAB
Queen’s University Kingston – GG, P di Stefano, R Martin, T Noble, B Cai, A Brossard, A Kamaha, P Vasquez dS, Q Arnaud, K Derig, J Mc Donald, 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) - F Piquemal, M Zampaolo, A DastgheibiFard
– Low activity archeological lead for close electronics/valve shield
– 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 Grenoble - D Santos, JF Muraz, O Guillaudin
– Quenching factor measurements < 1 KeV with ion beams

TU Munich – A Ulrich
– Gas properties and ionisation process for Pening mixtures

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

Associated lab: TRIUMF – Fabrice Retiere
– light detection, sensor

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Discussion on trigger efficiency at threshold

Trigger efficiency (~100%)

Example of 150eV raw pulse