Calibration and monitoring of a Spherical Proportional Counter

TIPP 2021-05-25

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for the NEWS-G collaboration

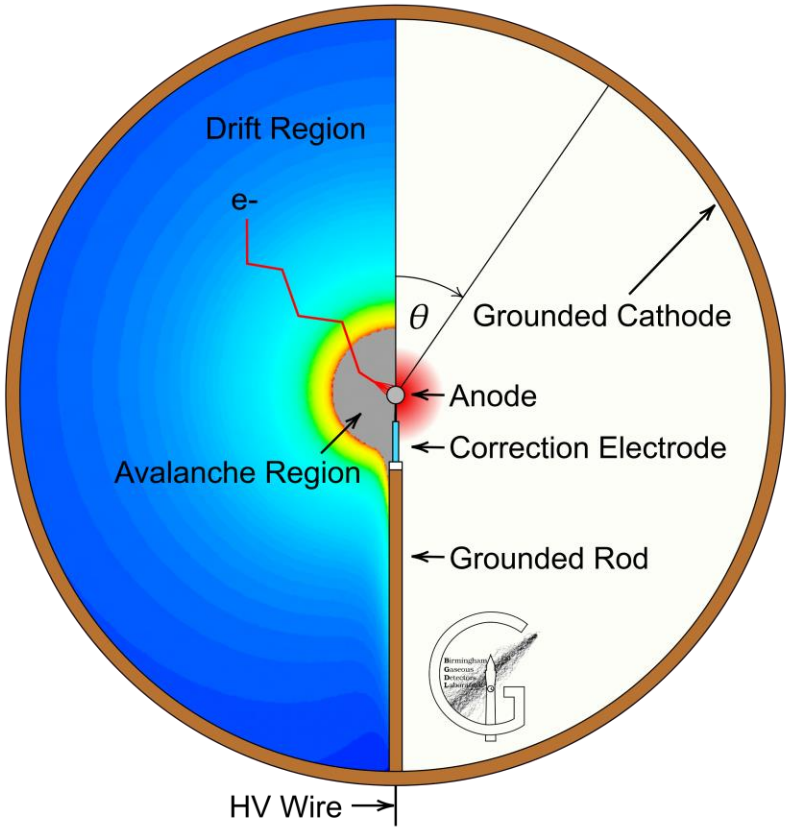
Outline

- The NEWS-G Spherical Proportional Counter
- Calibration tools: laser and sources
- Calibration measurements
  - Ionisation yield (W-value)
  - Drift velocity and diffusion
  - Fiducial volume
  - Quenching factor

NEWS-G

- Direct dark matter detection at SNOLAB (Ontario)
- Gaseous detector:
  - light target nuclei (neon, helium, hydrogen)
  - Light WIMP sensitivity (<1GeV)
- 140cm detector built
  - Full scale test at LSM (France) in 2019 with neon and methane
  - Installation nearly complete at SNOLAB (start expected 2021, depending on Covid restrictions)

NEWS-G Spherical Proportional Counter (SPC)



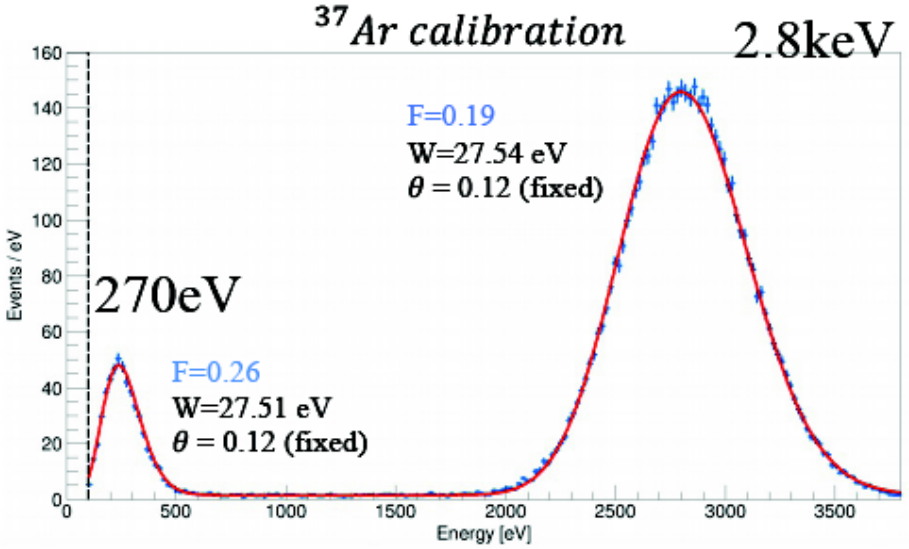
- Grounded sphere with sensor anode
- Low capacitance, high gain

  -> low threshold
- Simple design

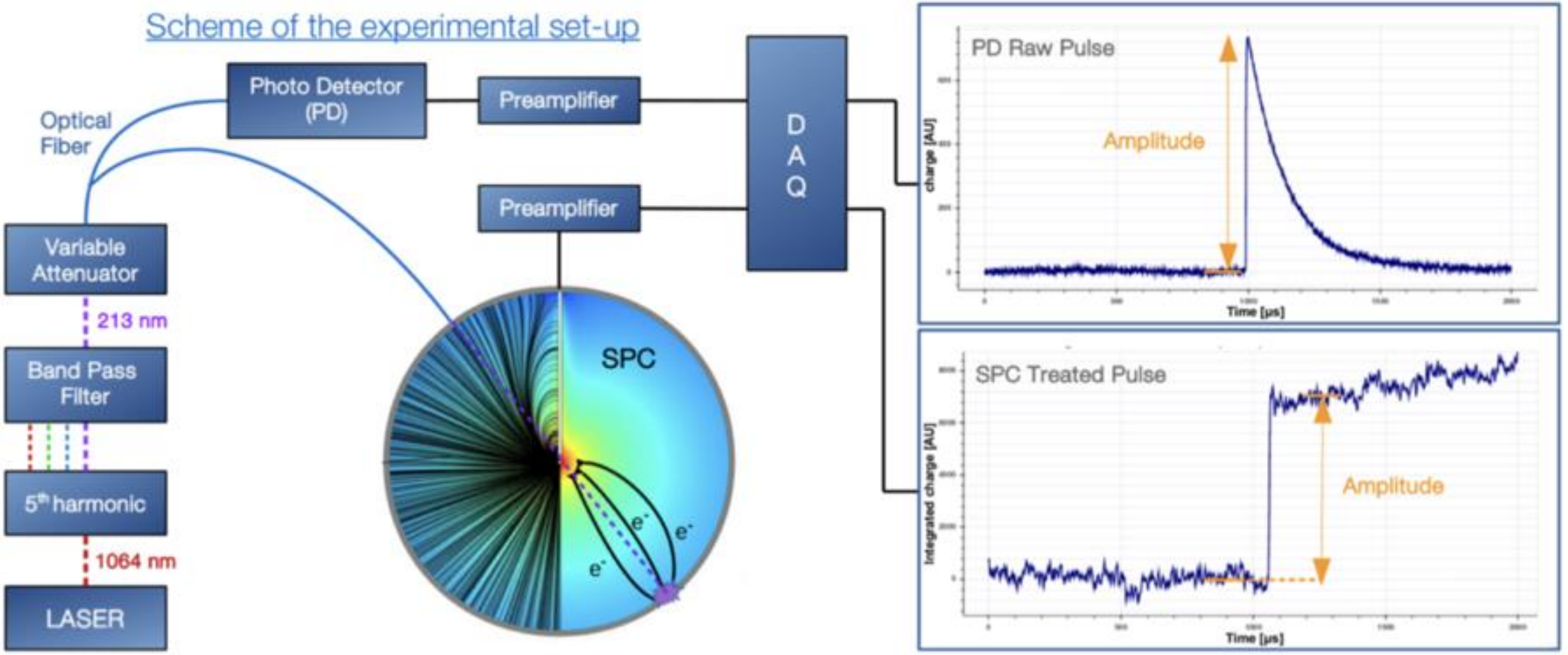
  -> pure materials, low background

Calibration tools

- 213nm UV laser
  - Single photon photoelectric from copper or steel surface
  - 10Hz repetition, 0.5mJ/pulse, adjustable: single electron to few keV equivalent (depends on gas and E field)
  - Pulse by pulse monitoring and tagging with photodetector
- Radio active sources
  - ^{37}Ar: 2.9keV, 0.27keV + 0.26keV escape peak. Uniform volume distribution (gas). Not available during physics runs
  - ^{55}Fe (5.9keV) external through Al window (R&D prototypes only)
  - Al 1.5keV fluorescence from alpha source (R&D prototypes only)

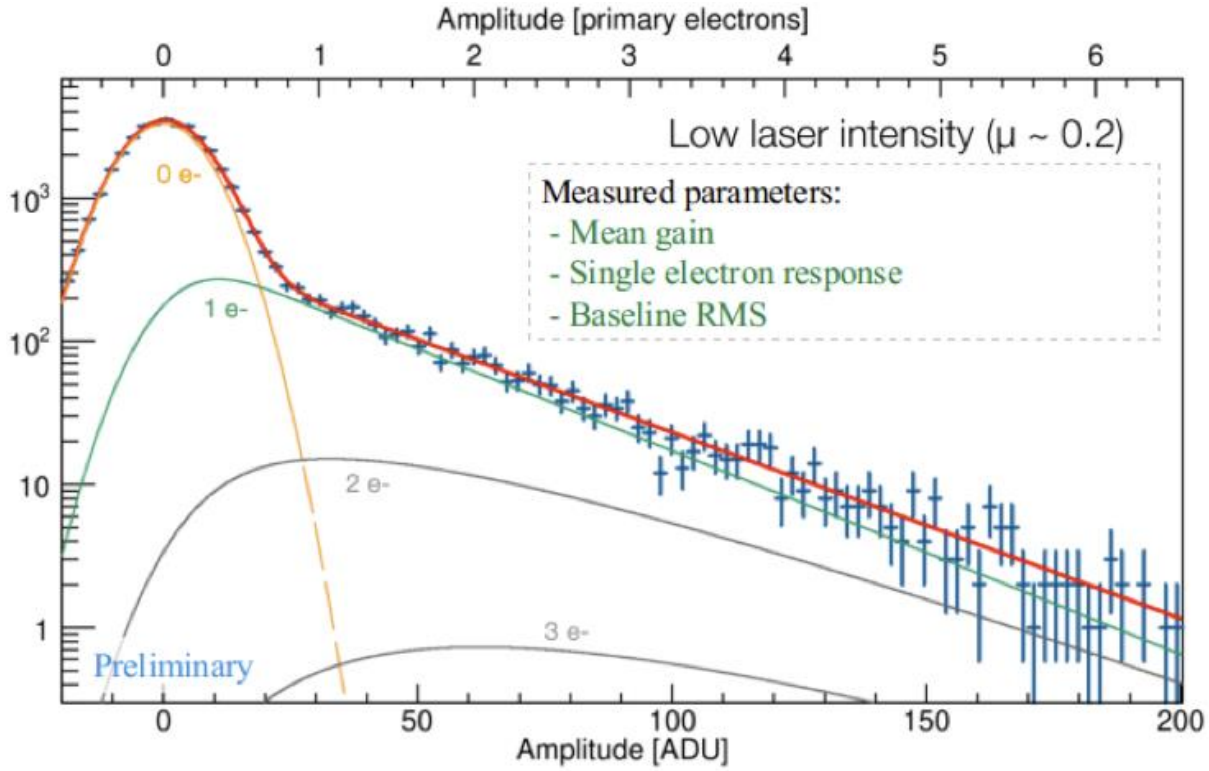


Calibration laser



Laser calibration: single electrons

- Low laser power:
  - mostly 0 or 1 primary electrons
- Trigger on photodetector
  - 0 electron background included
- Fitting Poisson distribution
  - Polya for gain fluctuation
  - Includes contribution of 2 or 3 electrons
  - mean number of electrons μ can be adjusted by with photodetector amplitude cuts

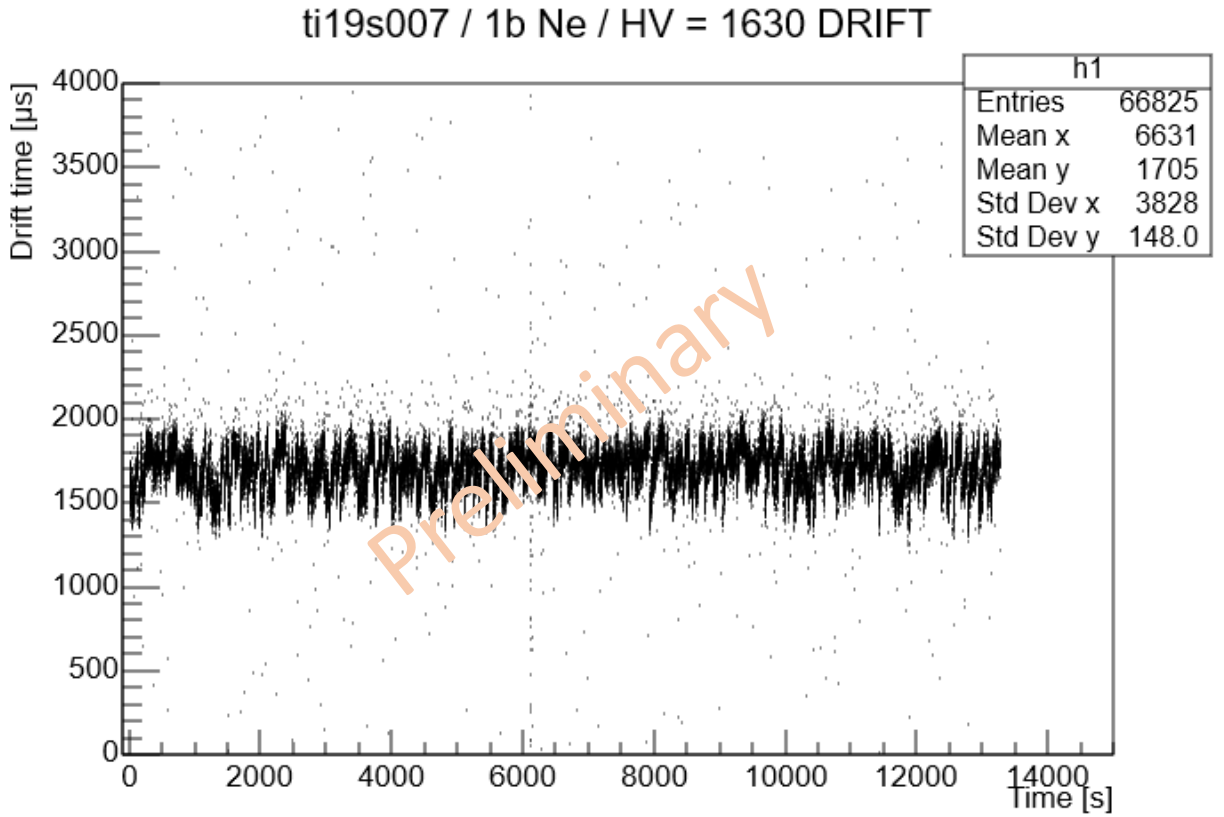


W value calibration

- Single electron response measurement
  - On underground detector
  - Regularly during physics measurement
- Electron recoil measurement from X-ray sources
  - ^{37}Ar (270eV, 2.9keV) on underground detector
  - Al (1.49keV) and ^{55}Fe (5.9keV) in smaller lab detectors
- Measurement of W-value in range 0.26 - 5.9keV
  - Measurement compatible with published values (within 10%) for CH4 gas
  - Extending to all gas mixtures used in NEWS-G

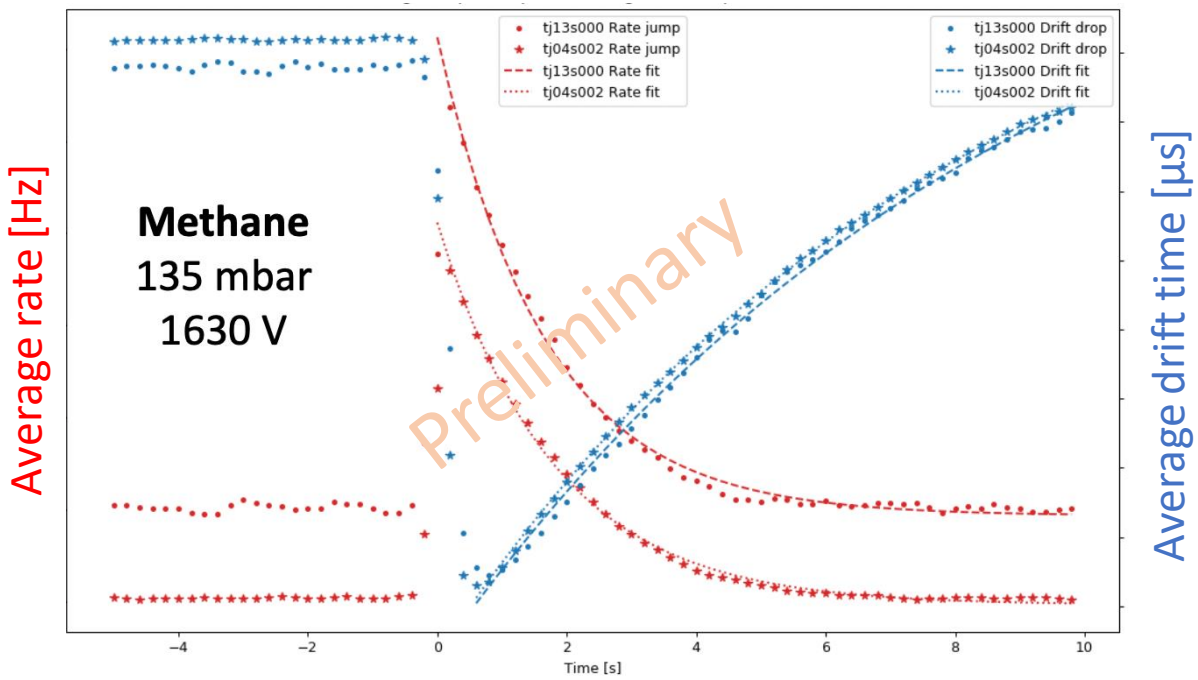
Detector monitoring

- High intensity laser (100s of electrons): low fluctuations
- Tagging from photodetector
- 10Hz during physics run
- Drift velocity measurement
  - t_{sphere}-$t_{photodetector}$



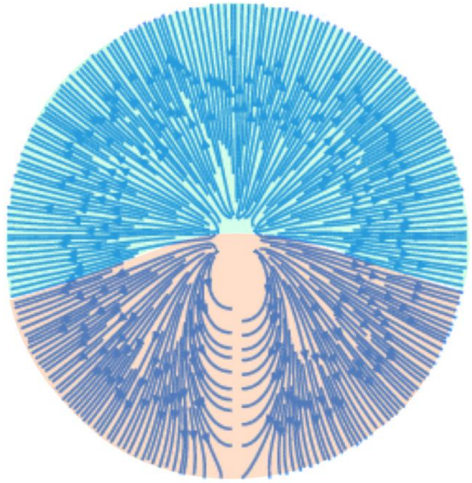
Space charge effect

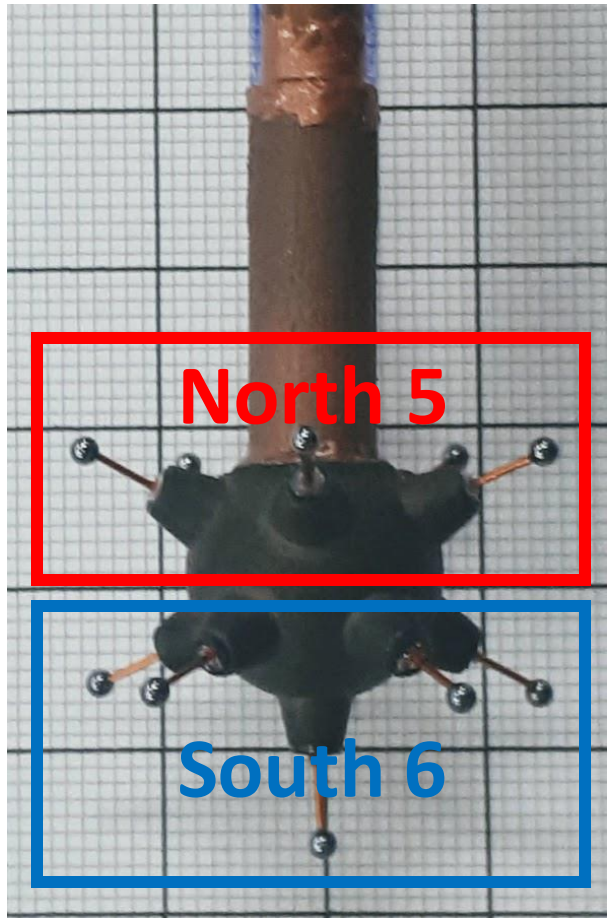
- Very low field at large radius
  - <1V/cm
  - Very sensitive to field created by drifting ions
- Charges created by alpha events
  - Ions drifts over several seconds
  - Drift velocity increased
- Laser measurement sensitive
  - Drift velocity
  - Electron extraction efficiency
- Background associated to alpha events
  - Increased rate for few seconds
  - Process unknown (recombination?)



Fiducialisation

- Multianode sensor, 2 channels
  - "North" (5 balls), "South" (6 balls)
- Test of fiducial volume
  - ^{37}Ar unifomly distributed
  - Compare North/South ratio to simulation
  - Tests with different voltages
- Possible surface background information
  - bottom of sphere
  - Equator welding





Nuclear recoil quenching factor

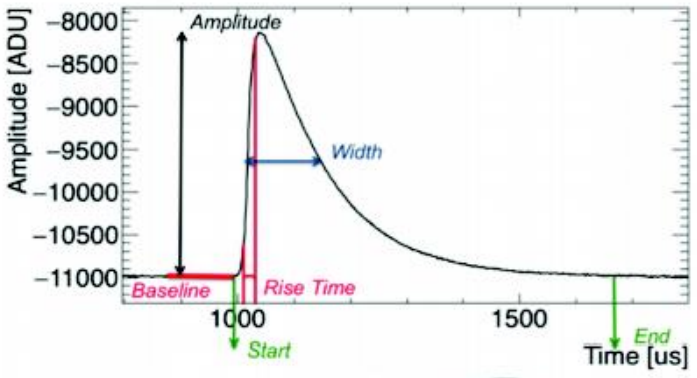
- Ionisation yield from nuclear recoil
- Calibration with
  - Monoenergetic neutron beam
  - Ion beam
- Neutron scattering in neon measured down to ~300eVnr
- Proton recoil in methane down to ~1keV

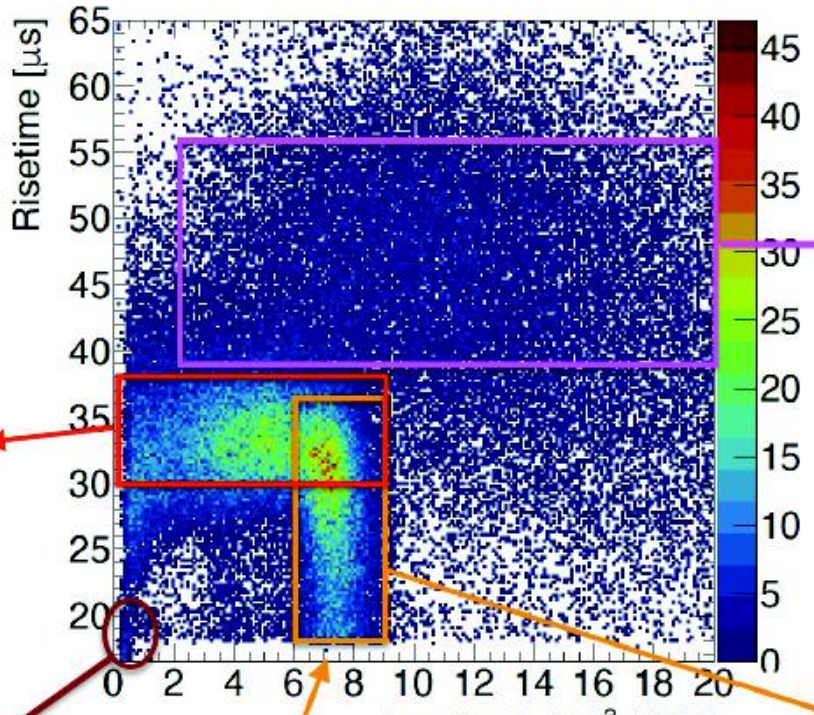
Conclusions

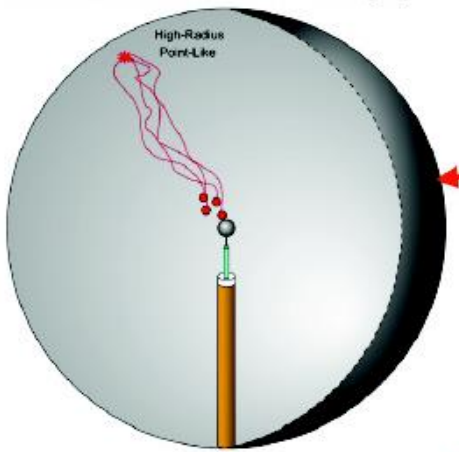
- Dark matter experiments like NEWS-G need continuous calibration and monitoring
- UV laser is a powerful tool
  - Calibration of single electron gain
  - Monitoring of drift field
- Used in physics run at LSM 2019
  - Evidence of space charge effect from high energy (alpha) events
- Experience to improve monitoring scheme at SNOLAB 2021
  - Alternate low intensity (single electron) and high intensity
  - Study space charge from laser

Backup

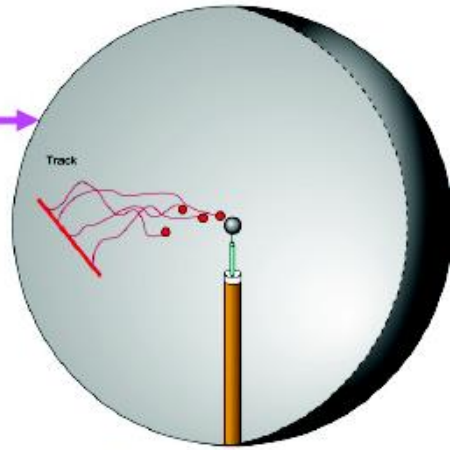
Pulse Shape Discrimination





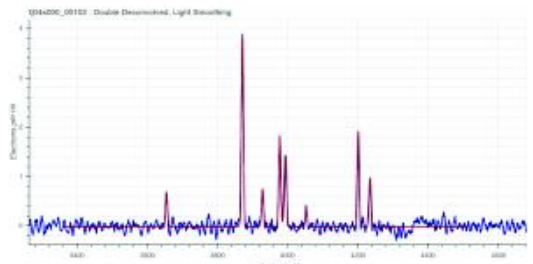


"Surface"-like events

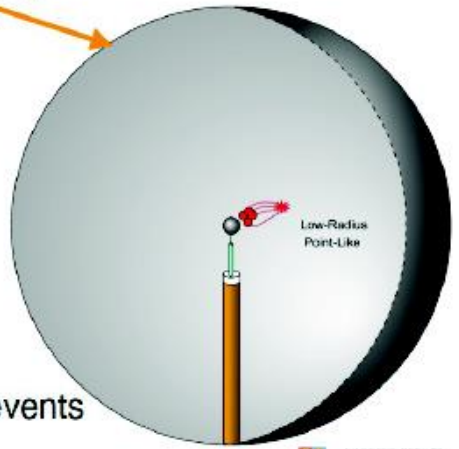


"Muon"-like events

Counting the electrons at very low energies

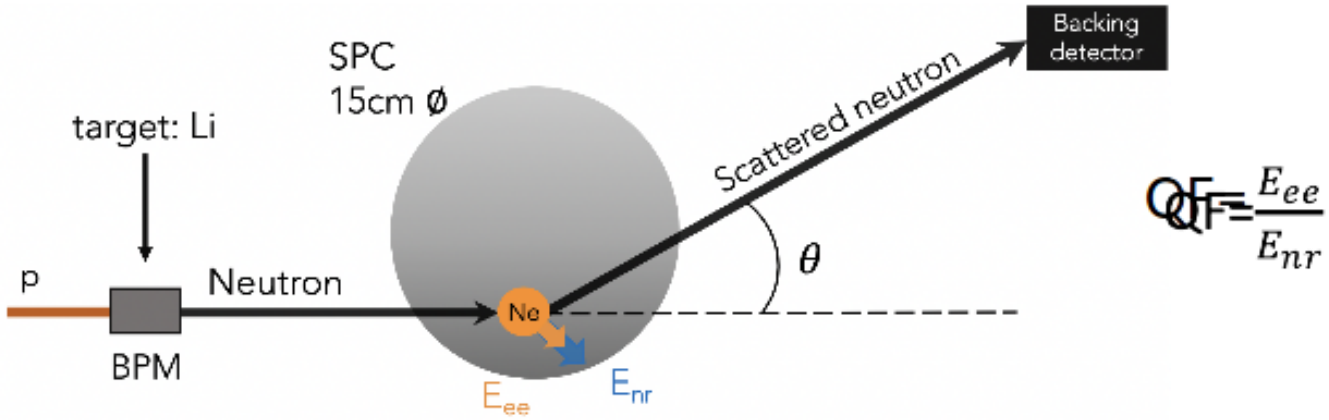


5.9 keV X-rays
from ^{55}Fe decays



"Signal"-like events

Neutron scattering

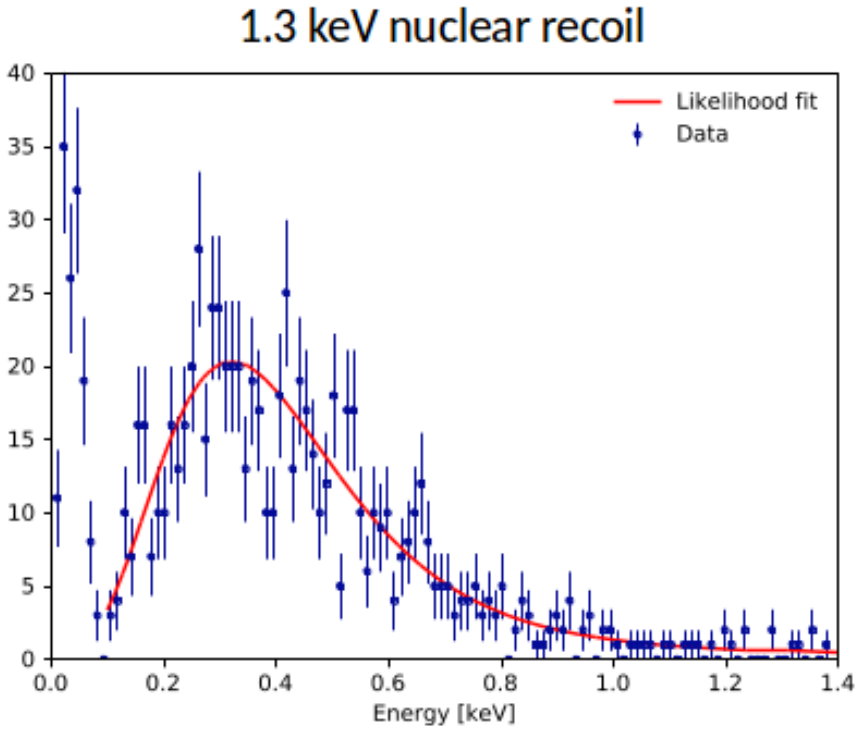


$$QF = \frac{E_{ee}}{E_{nr}}$$

Measurement done at the TUNL facility
Neutron pulsed beam: E_n = 545 ± 20 keV
8 energy points: 0.34 to 6.8 keV_{nr}
Publication under review

TUNL
Triangle Universities Nuclear Laboratory

Same experiment is under development with the tandem accelerator of the Reactor Material Testing Laboratory at Queen's University.



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