Nuclear ionization yield measurements in Neon for NEWS-G

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NEWS-G

- Spherical metallic vessel filled with noble gas and central anode with HV: Spherical Proportional Counter

- *Main goal:* search for low mass Dark Matter

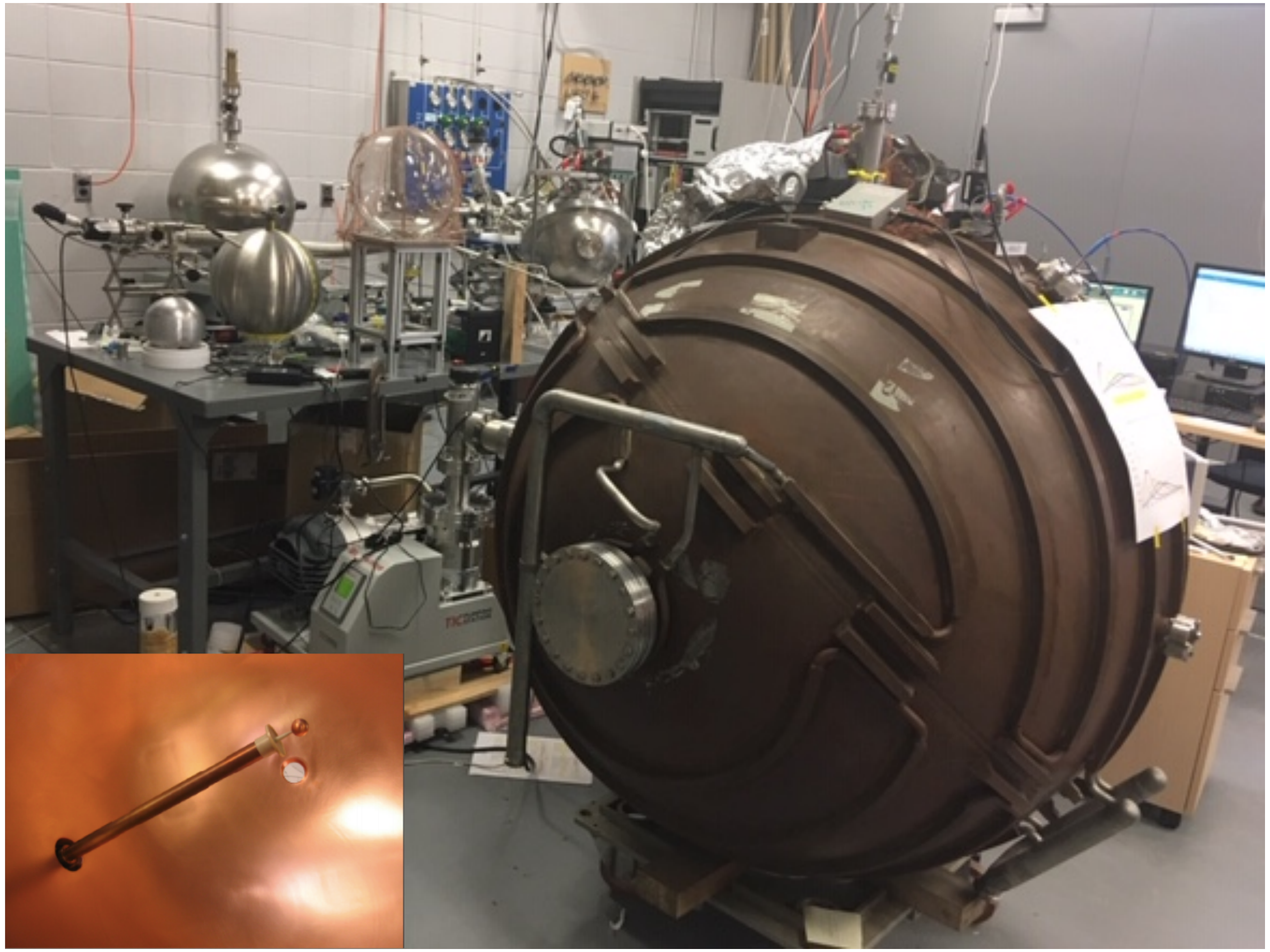
- *Other applications:* CEνNS detection, $0\nu\beta\beta$ search

- *Priority:* ionization yield measurements for gas mixture (Neon) - interpretation of data for (ν, χ) interactions.

Sedine: Laboratoire souterrain de Modane

Detectors

- Diameter: 15, 30, 60, 140 cm
- Sphere: stainless steel, copper, glass, aluminum
- Diameter sensor: 1 – 16 mm
- Gas: Neon, Argon, Helium
- High voltage on sensor: $\vec{E} \sim 1/r^2$
- Large gain
- Low energy threshold



SPC: principle

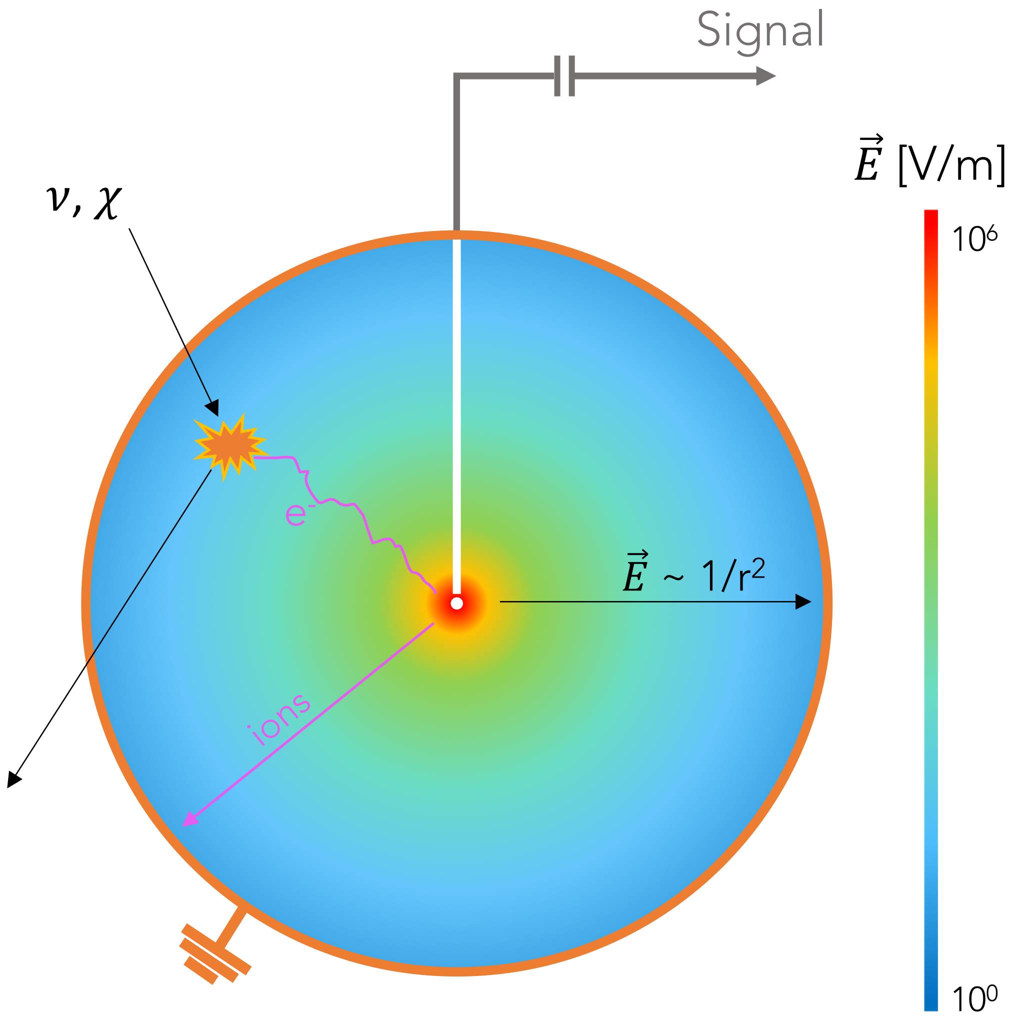
1. Primary ionization
   Mean energy necessary to generate 1 e^-/ion pair: ~30eV in Neon

2. Drift of primary e^- towards sensor
   Typical drift times:
   ~ 100 μs

3. Avalanche in the vicinity of the anode
   Generation of thousands of secondary e^-/ion pairs

4. Signal formation
   Current induced by ions → sphere surface

5. Read out: preamplifier



Motivation for ionization yield measurements

- Energy calibration of gaseous detector: gamma sources
  γ rays interact with electrons → electronic recoils
- (ν, χ) interact with nuclei → nuclear recoil

- The ionization yield, or quenching factor, is the ratio of the number of charges produced by an electron and a nuclear recoil of the same energy.

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

- QF measurements priority for NEWS-G (interpretation of data): low energies
  → 1st QF measurement in Neon gas

Quenching factor measurements

- Source of known nuclear recoil energies (E_{nr}): neutrons scatter off nuclei

→ Monoenergetic neutron beam

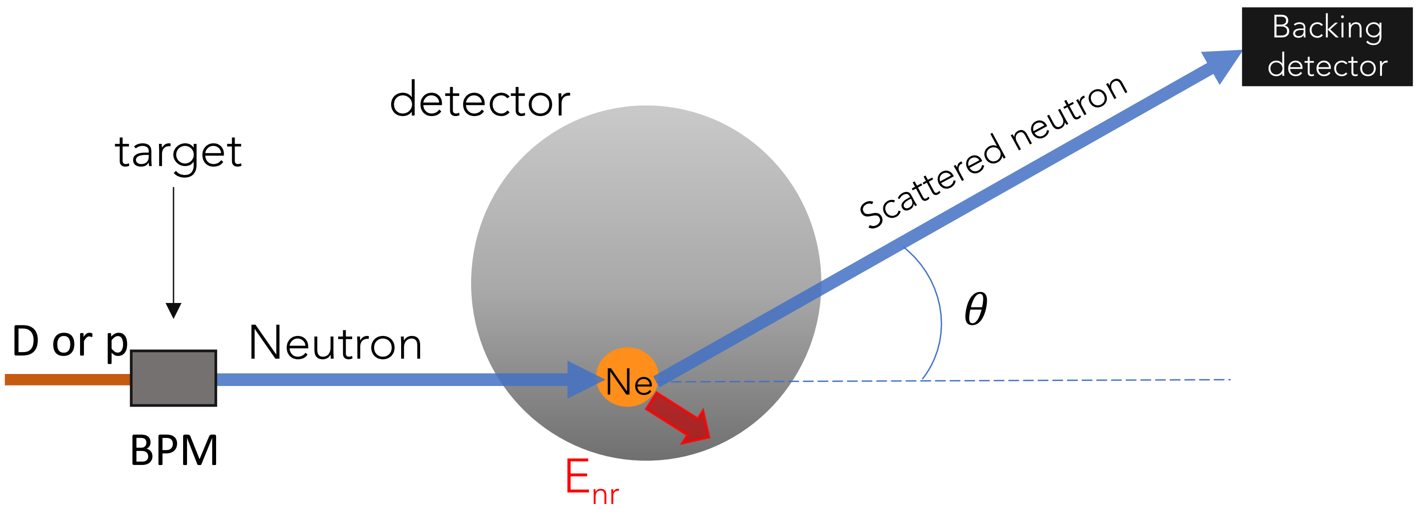
- Energy calibration: γ source

→Measured recoil energy deposited in the gas (E_{ee}) associated with electronic recoils

- The TUNL (Triangle University National Laboratory) facility has a tandem 10MV accelerator

→ Organization of 2 measurements campaigns

Experiment summary



- E_n: known
- θ: chosen
- E_{nr}: calculated $E_{nr}(E_n, \theta)$
- E_{ee}: extracted energy mean from energy spectrum

- Backing detectors (BD)
- Beam Pick-off Monitor (BPM)

Experiment summary

- 2018 spring campaign: D+D→ n+^{3}He+γ: Neutron beam 3.68 MeV
  4 energy points investigated: 4.95-28 keV_{nr}

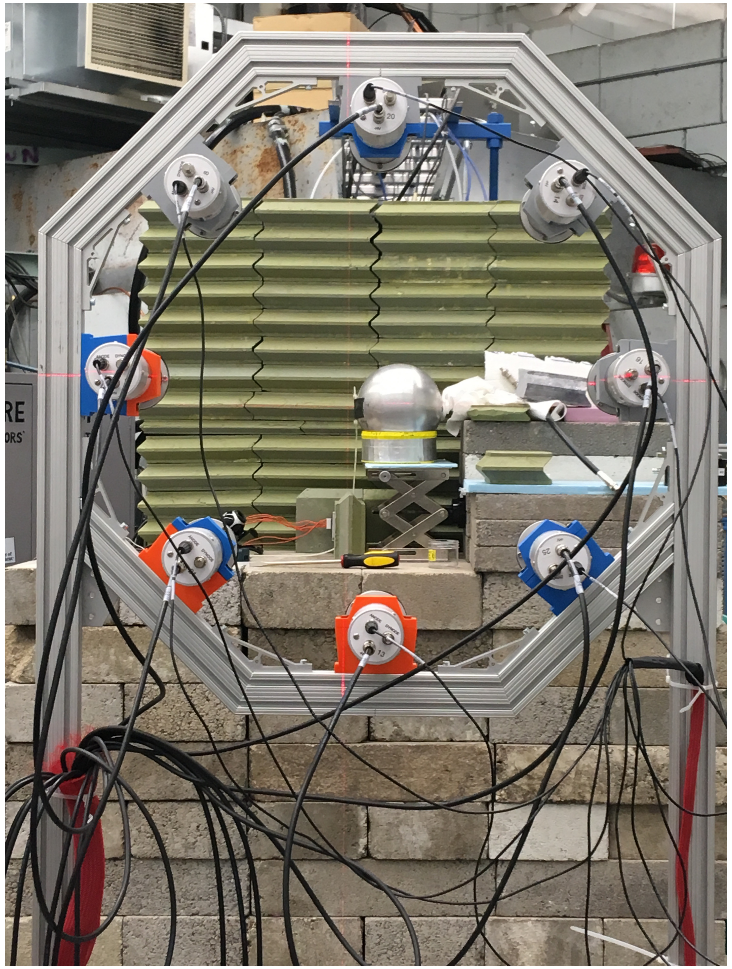
- 2019 winter campaign: p + ^{7}Li → n + ^{7}Be+ γ: Neutron beam 545keV
  8 energy points investigated: 0.33-6.5 keV_{nr}

- Gas: Neon:CH_4 (97:3)

- Pressure (2018/2019): 500mbar/2bar

- Energy calibration: Fe55 peak at 5.9keV

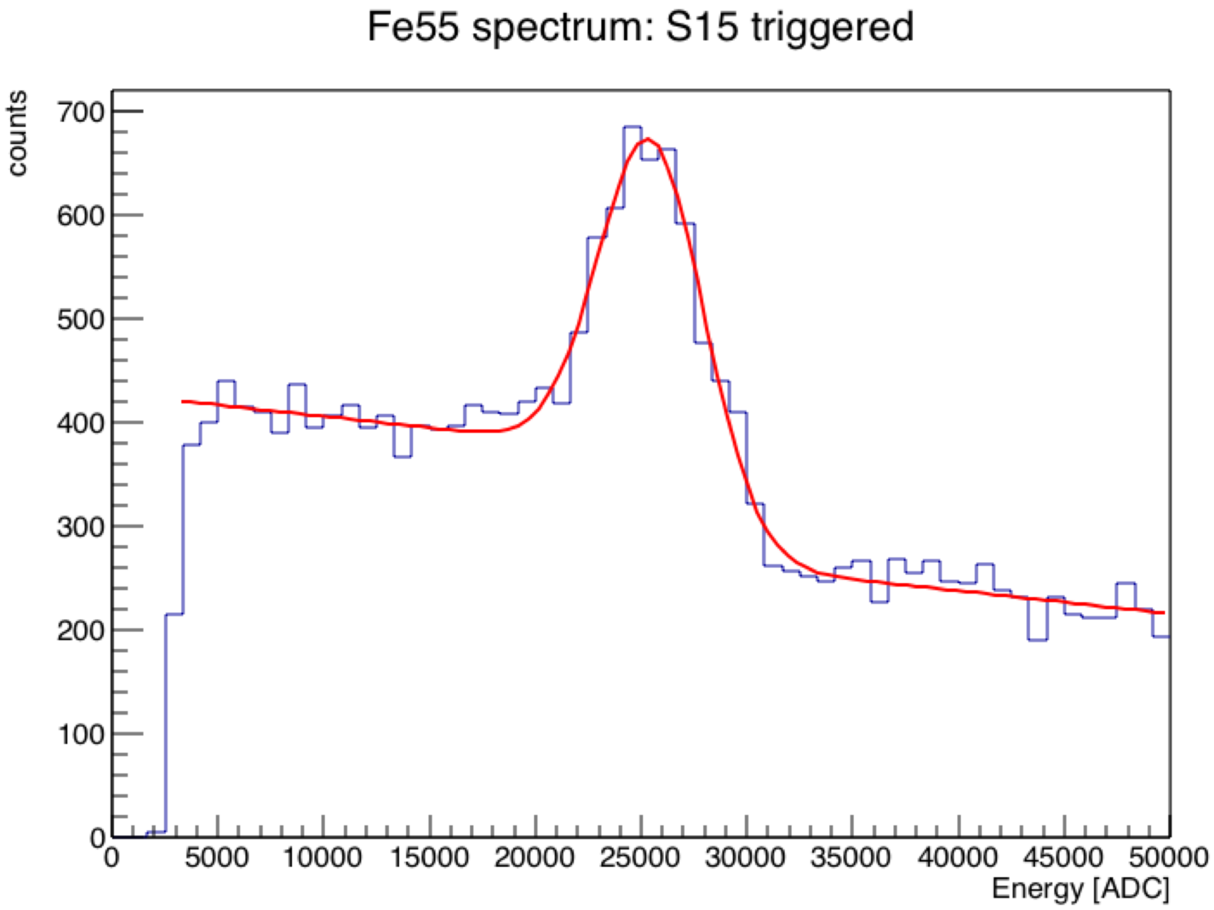
Quenching factor: experimental set up

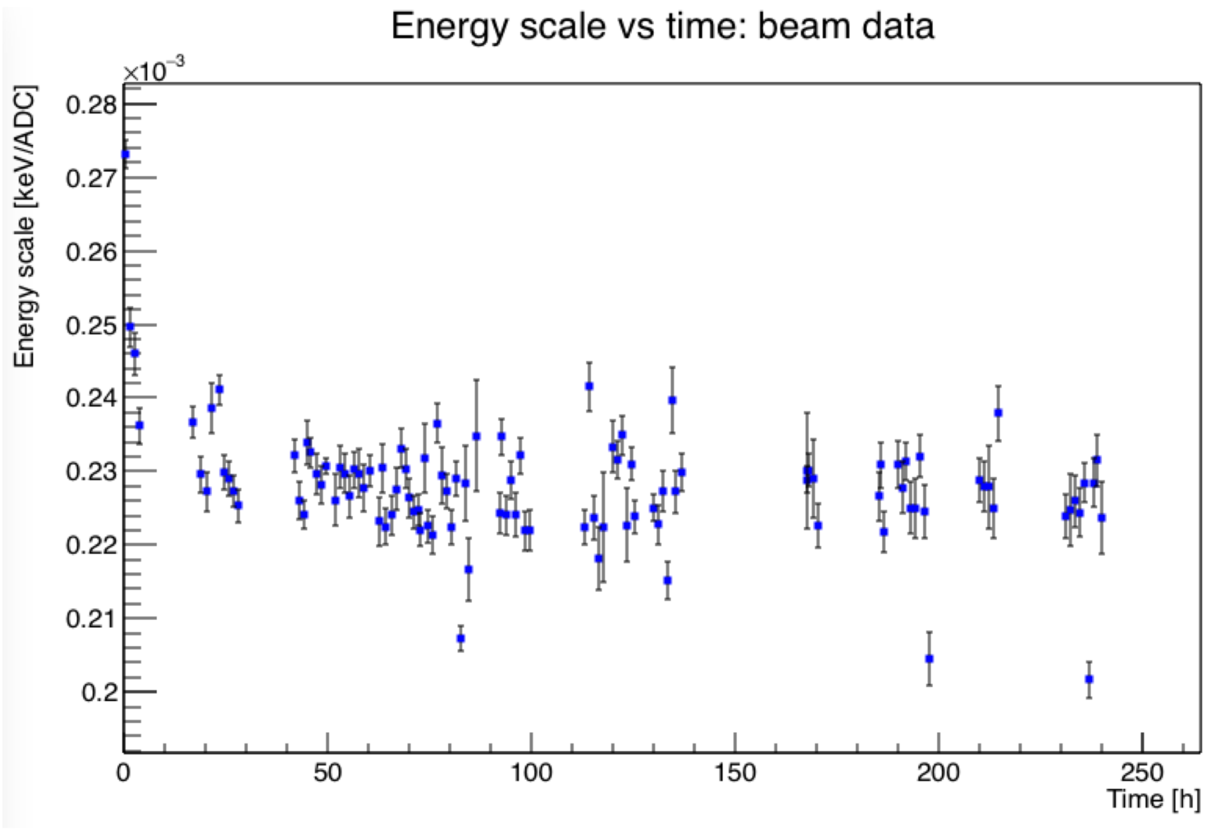


Annulus configuration

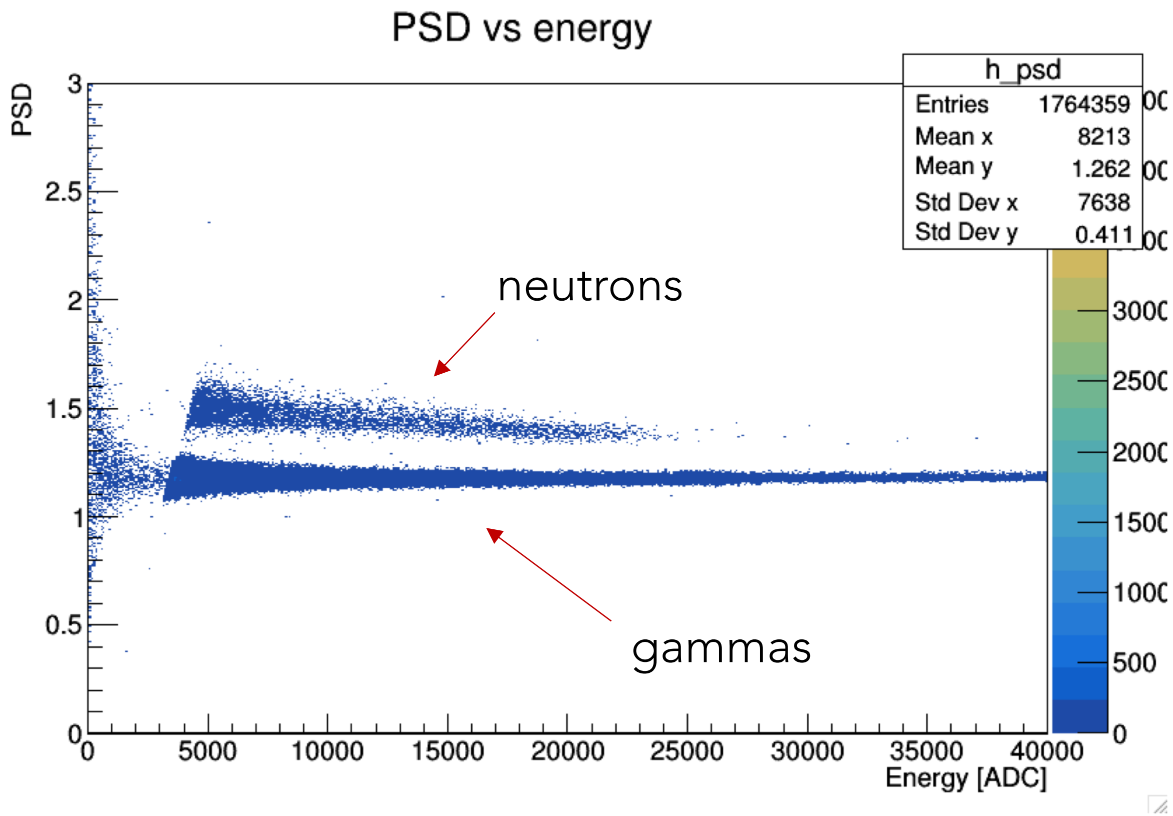
Multiple energies configuration

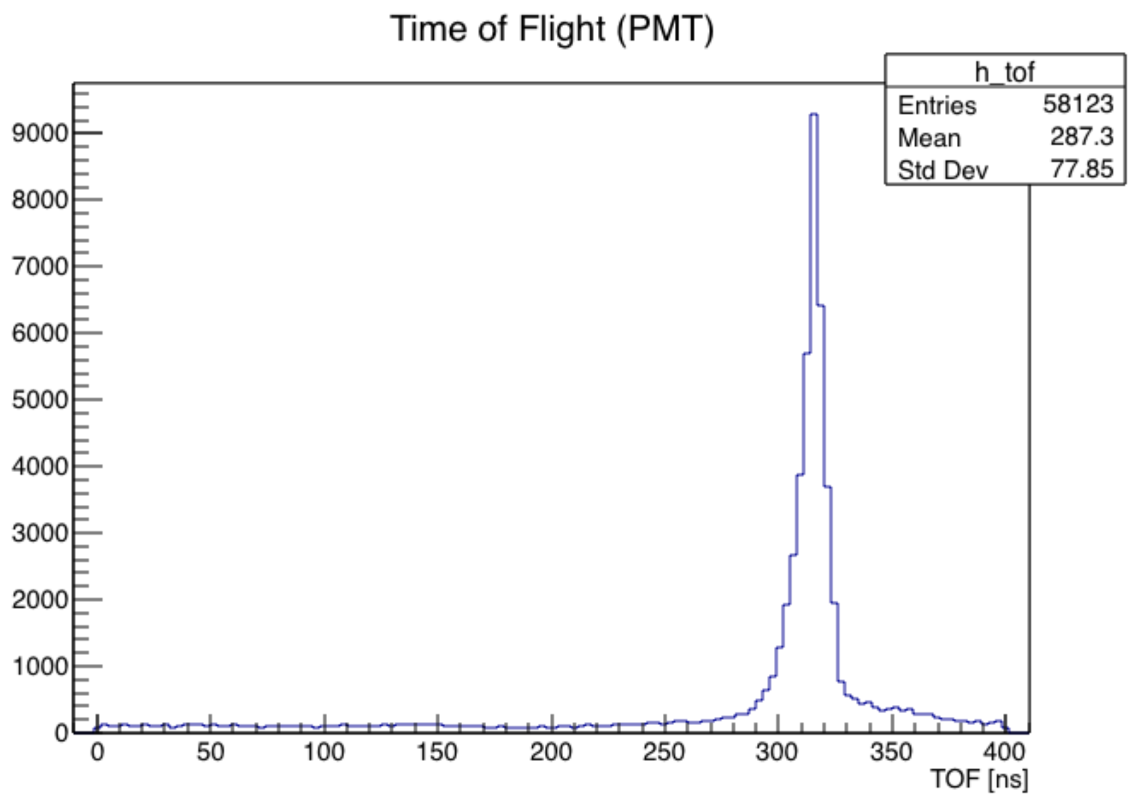
Calibration: Fe55 peak at 5.9 keV





Quenching factor measurements
Analysis

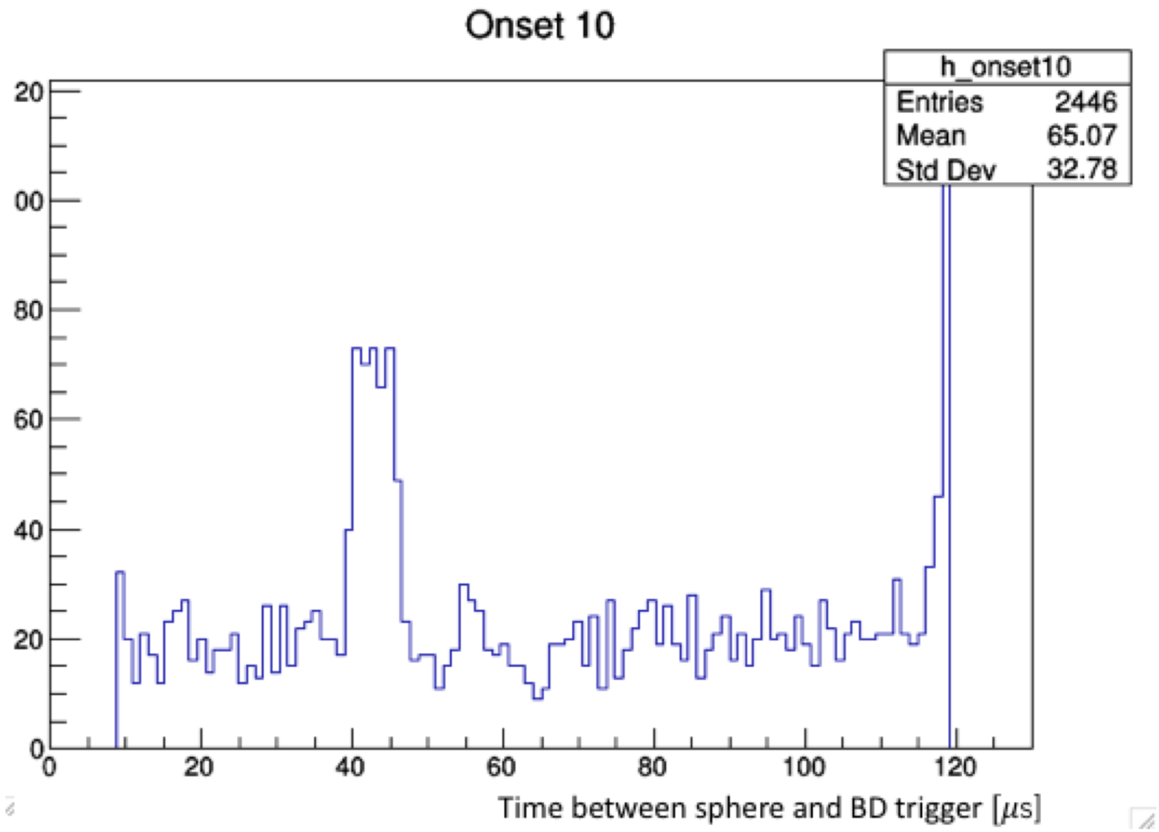




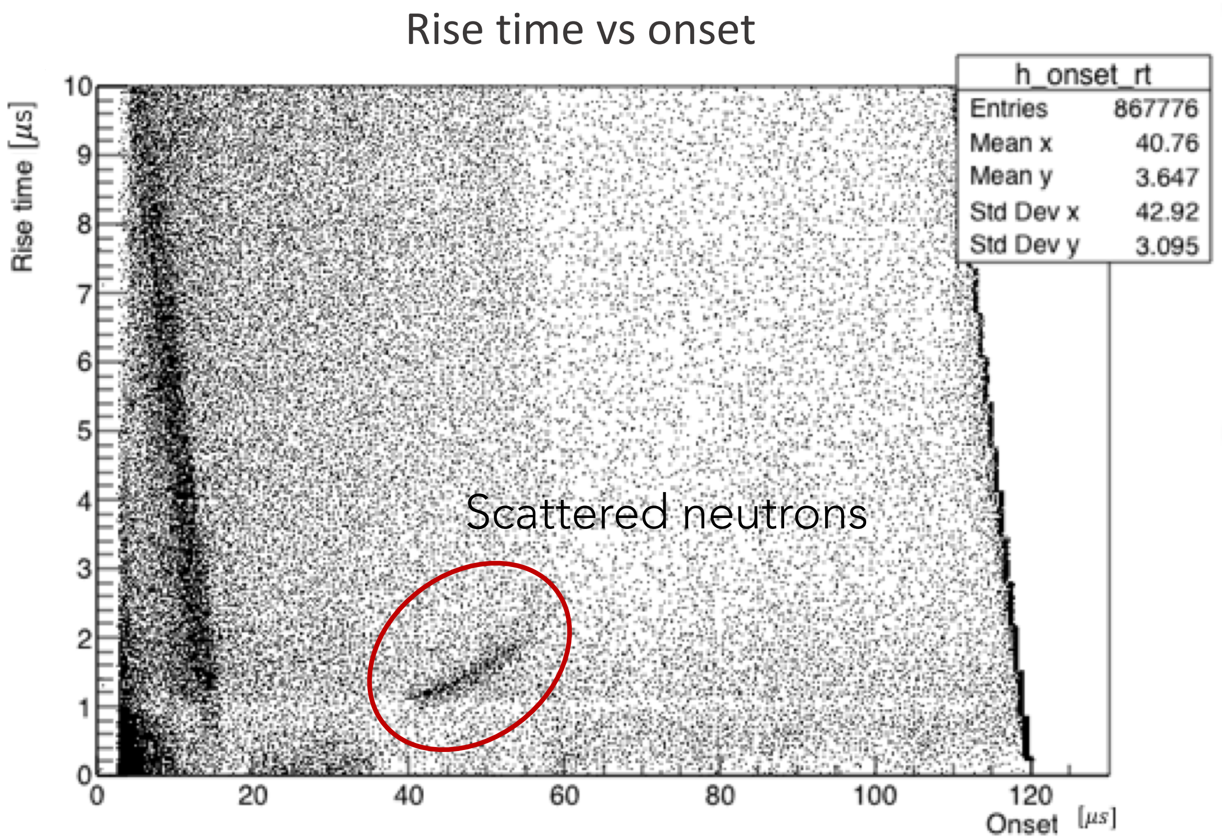
Time of flight: time of the neutron event at backing detector – time of the neutron event at BPM

Quenching factor measurements

Analysis

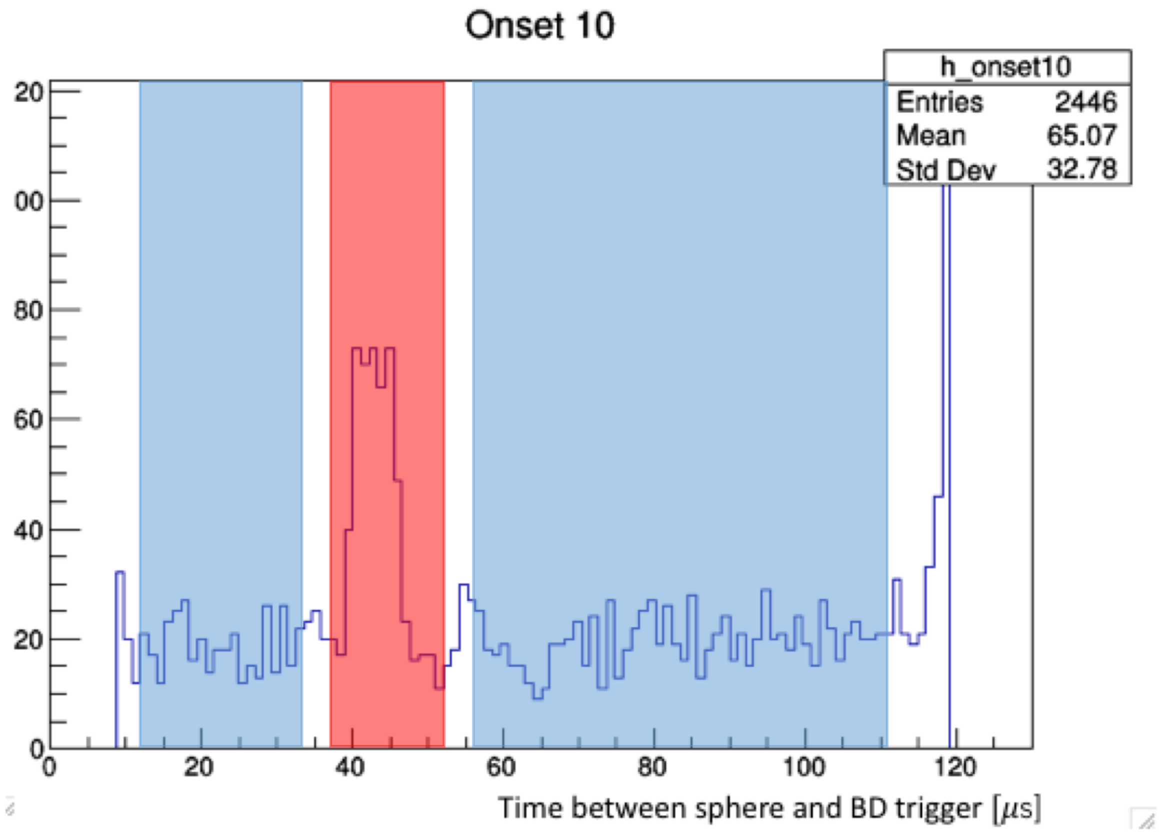


Location of SPC events in time relative to the DAQ trigger (/BD trigger)
→ Excess ~ 40 μs
→ Signal of interest!



Dependence in rise time and onset time

Quenching factor measurements
Analysis



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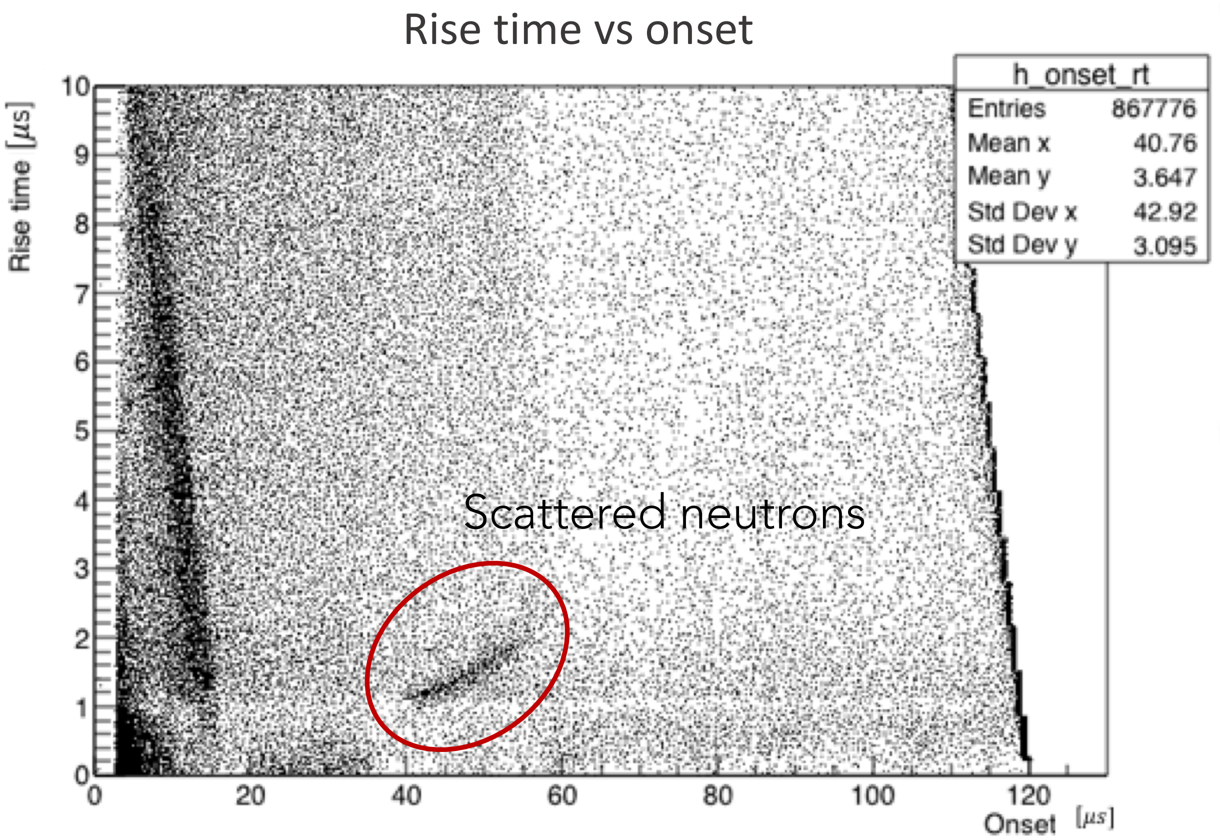
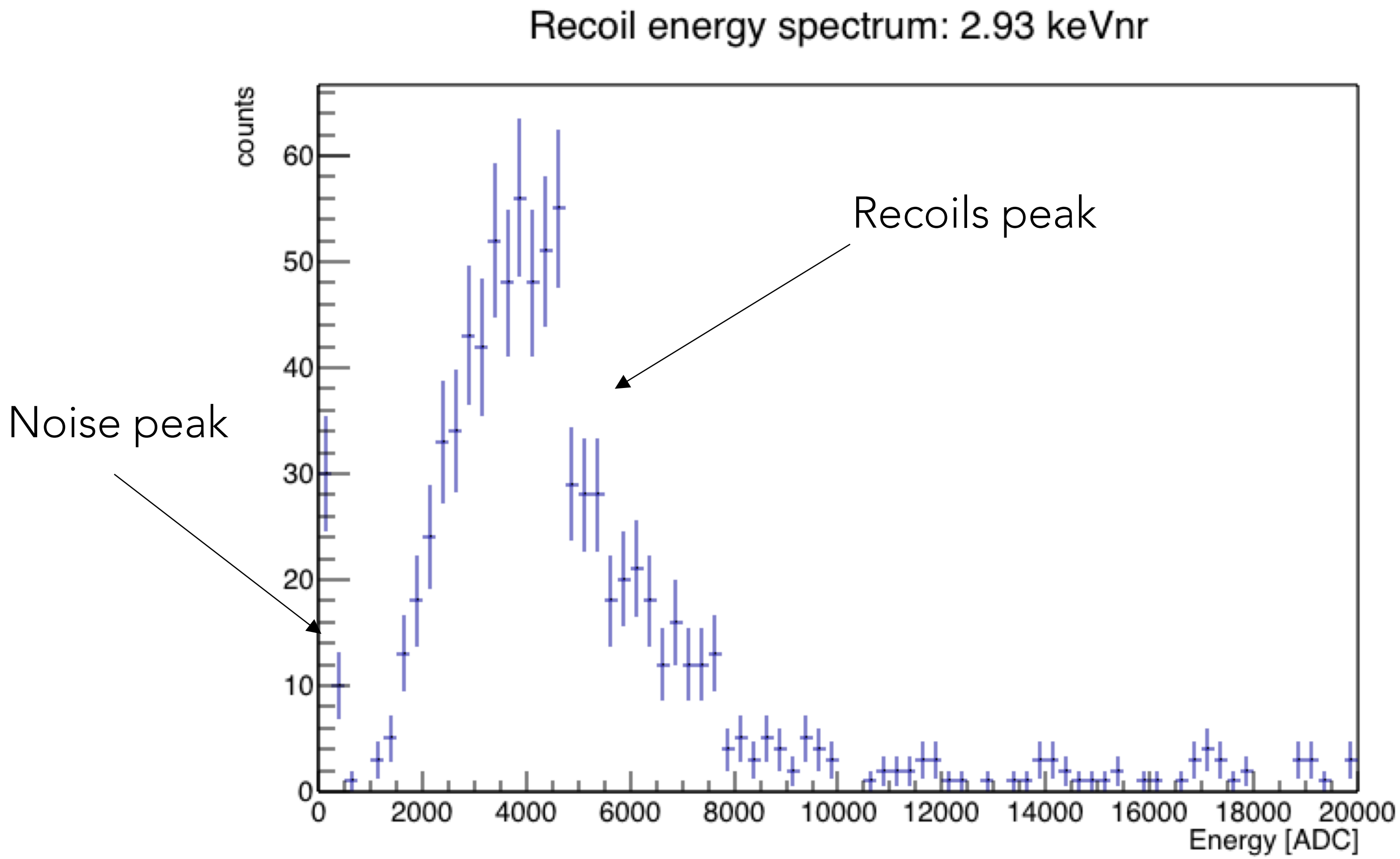
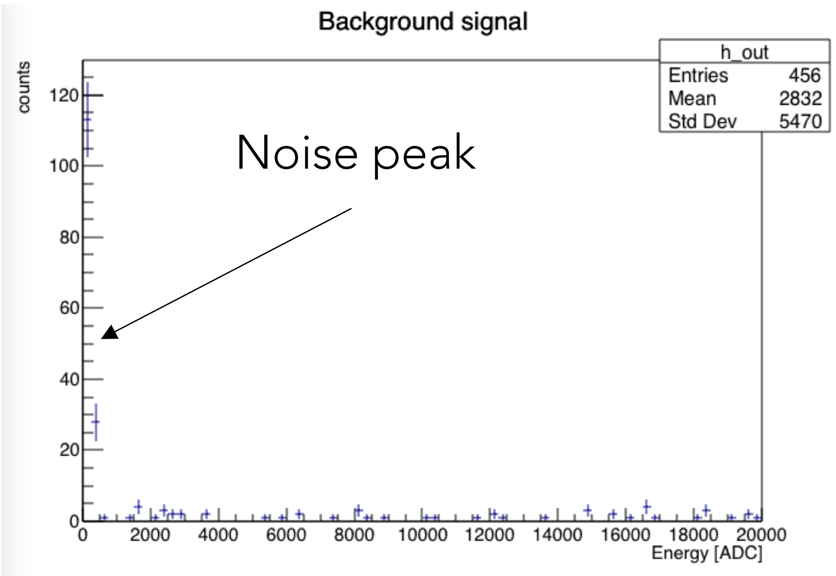


Dependence in rise time and onset time

Energy spectrum





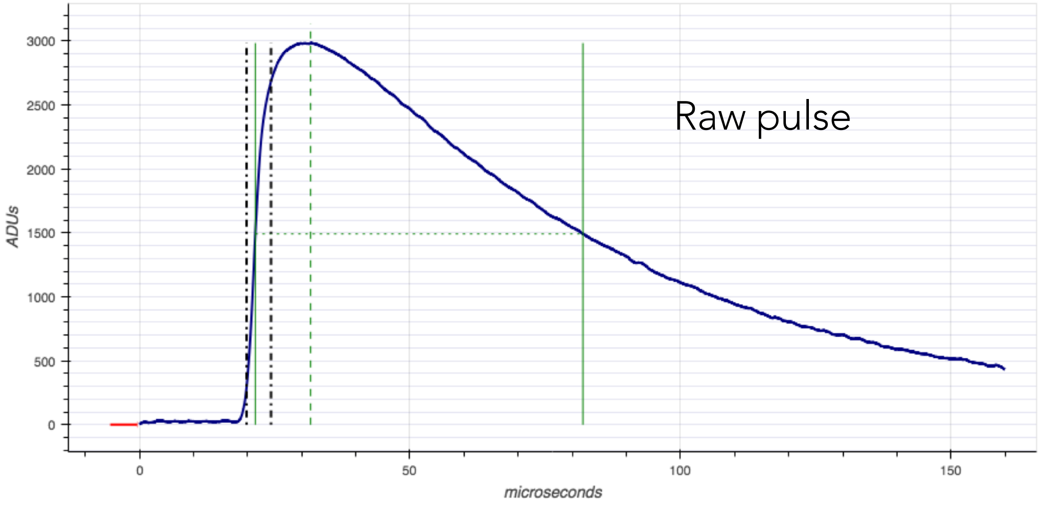
Conclusion

- We demonstrated the feasibility of QF measurements in gases using a SPC and a neutron beam
- We took 12 energy points from 0.3 keV_{nr} up to 28 keV_{nr}
- We reached single electron
- The analysis is on-going

Thank you

TUNL Triangle Universities Nuclear Laboratory
NSERC CRSNG
Canada Excellence Research Chairs
Chaires d'excellence en recherche du Canada
Queen's University

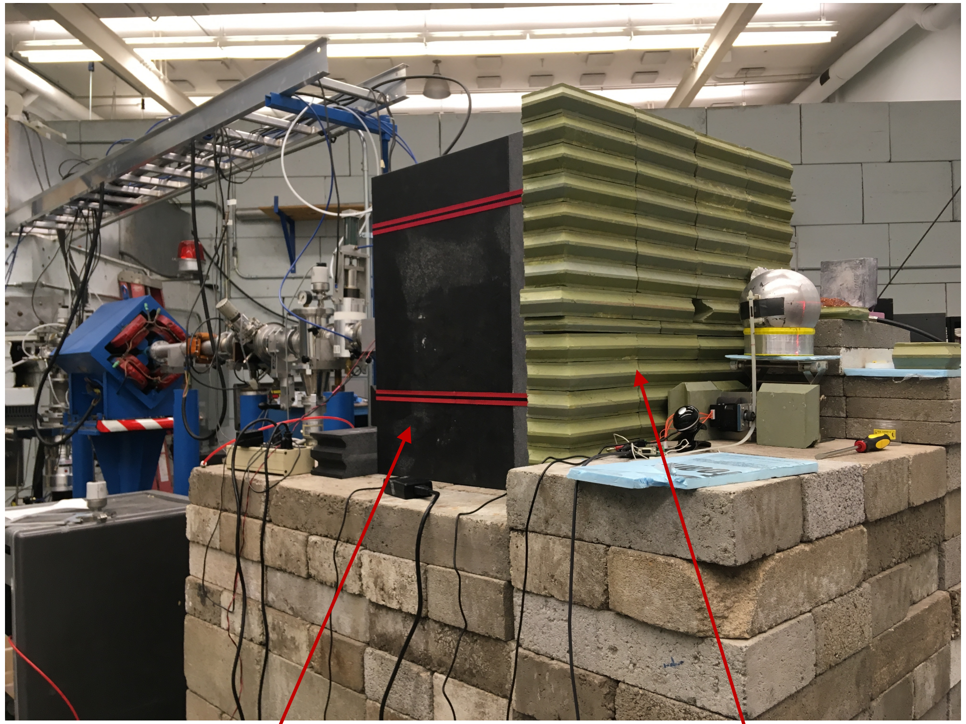
NEWS-G: Example pulse



Amplitude provides estimation of the energy of the event.
Rise time provides an estimation of the radial distance of the event → Rise time linked to diffusion of the electrons along their drift toward anode.

Experiment conditions

Shieldings have been added around the beam line.



Polyethylene doped with B for neutron capture

Lead wall for gammas

Lead shield on backing detectors to improve gammas background

$E_{nr}(E_n, \theta)$

$$E_{nr}(E_n, \theta) = 2E_n \frac{M_n^2}{(M_n + M_T)^2} \left(\frac{M_T}{M_n} + \sin^2\theta - \cos\theta \sqrt{\left(\frac{M_T}{M_n}\right) - \sin^2\theta} \right)$$

Recoils events selection