Status and prospect of the NEWS-G experiment

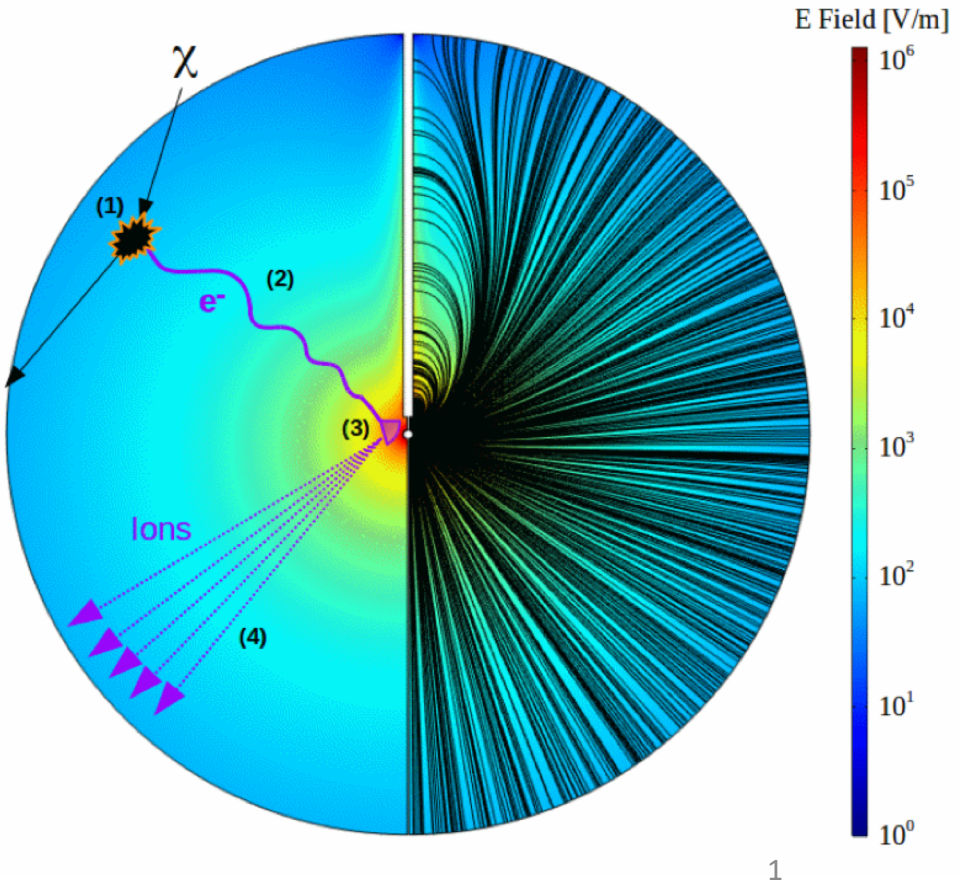
Alexis Brossard, on behalf of the NEWS-G collaboration

New directions in the search for light dark matter particles
Fermilab
June 5th 2019

Detector functioning

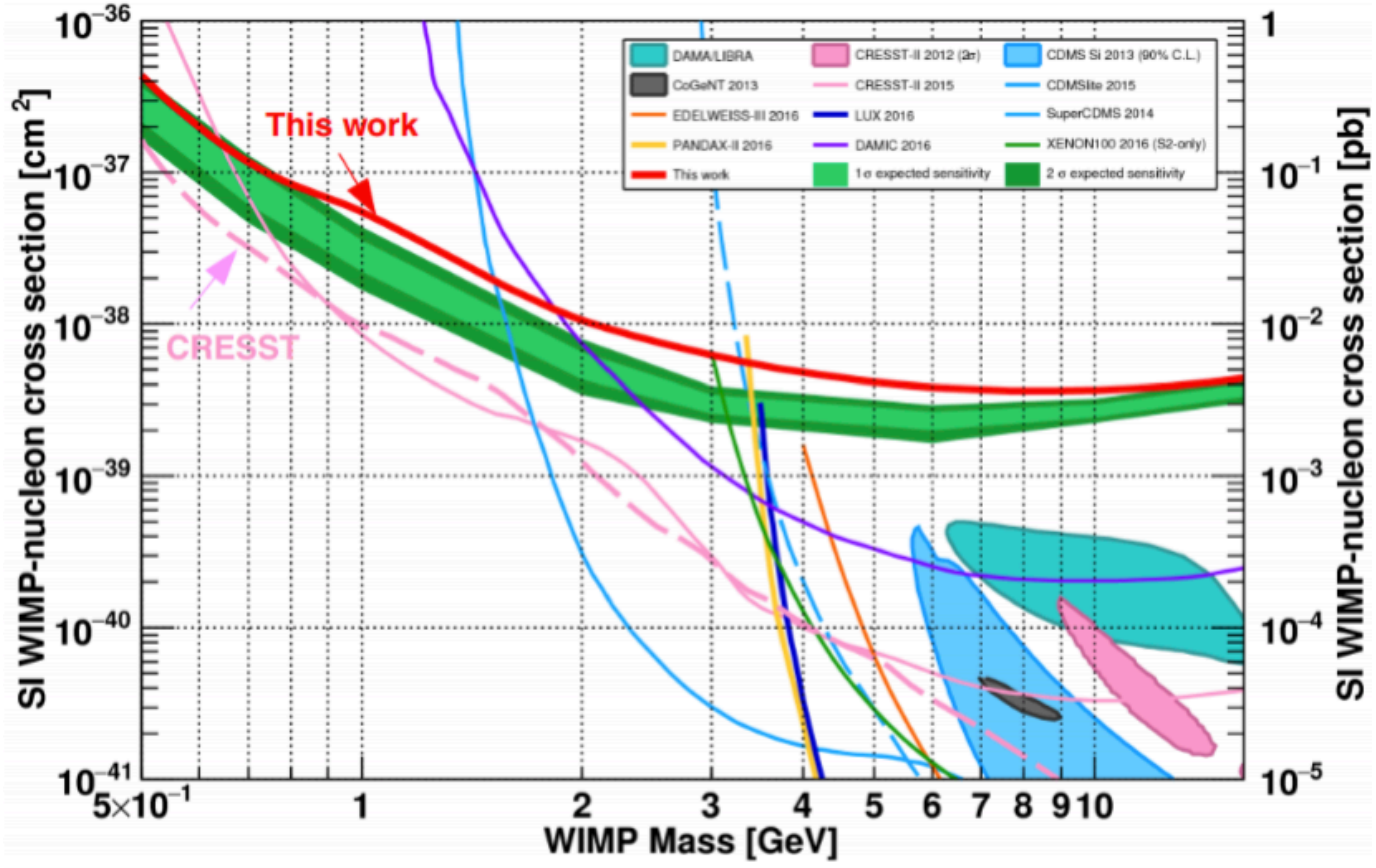
-1 Particle ionizes gas.
-2 Primary electrons drift toward the sensor.
-3 Close to the sensor, secondary ion/electron pairs are produced.
-4 Signal is induced by the motion of secondary ions.
-5 The signal is processed by a pre-amplifier and digitized.

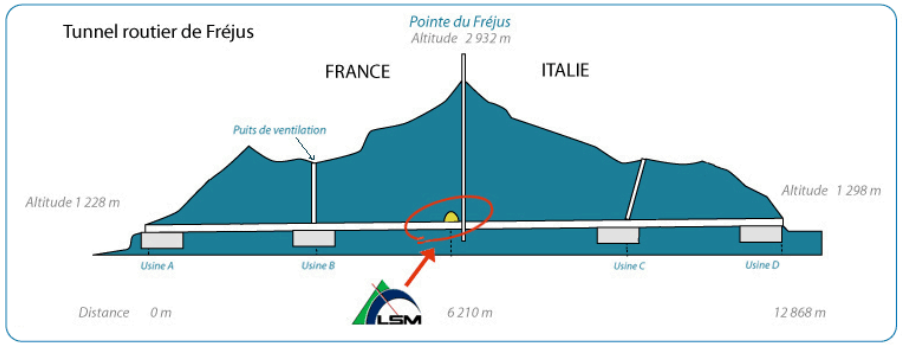
-Possibility to use large range of target mass.
-Sub-keV energy threshold.
-Identification of point like energy deposition by pulse shape.



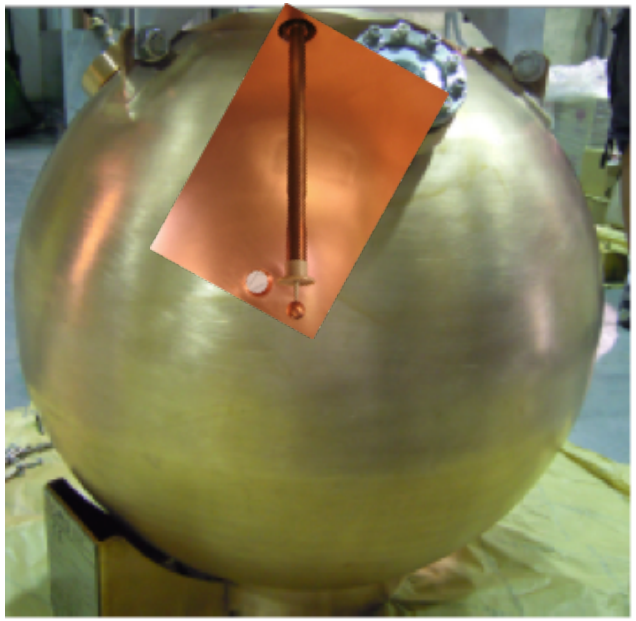
Sub-GeV WIMP limit

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



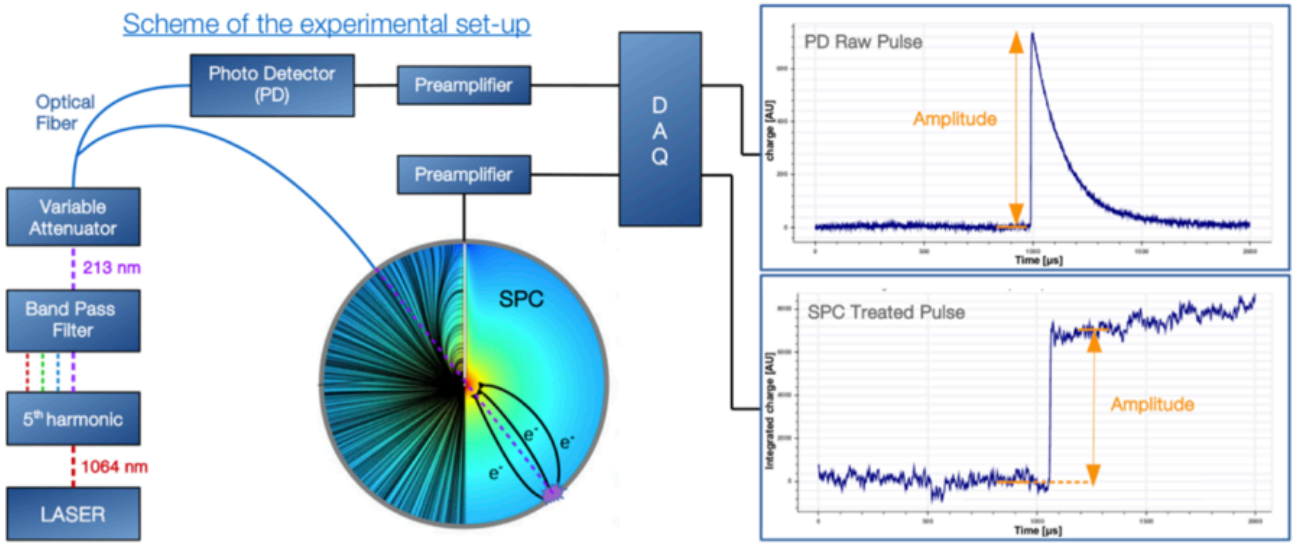


60 cm SPC

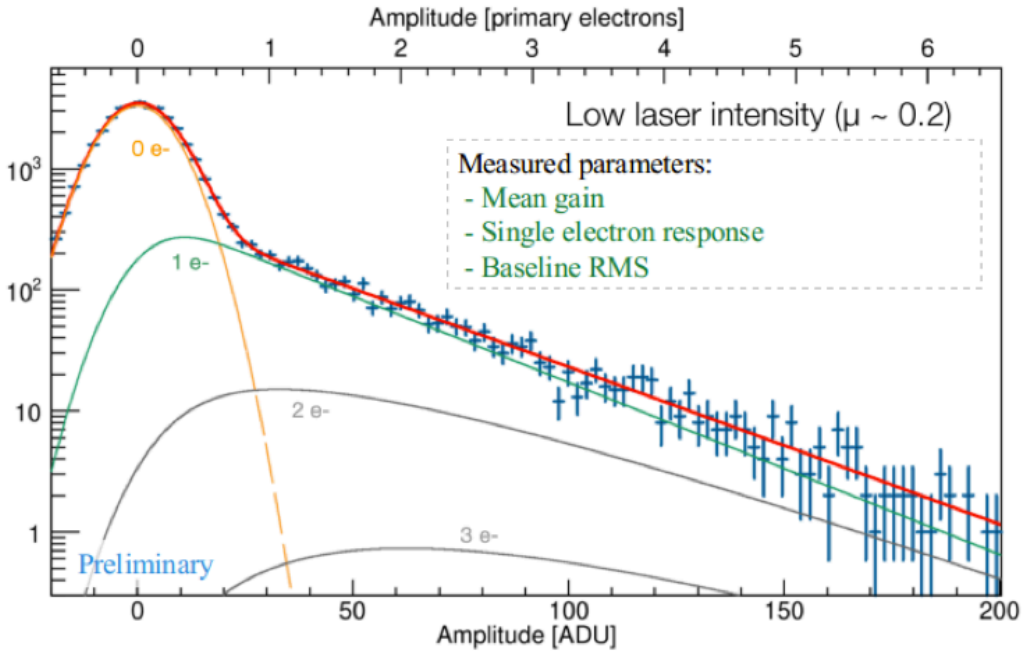


Q. Arnaud et al. (NEWS-G), Astropart. Phys. 97, 54 (2018).

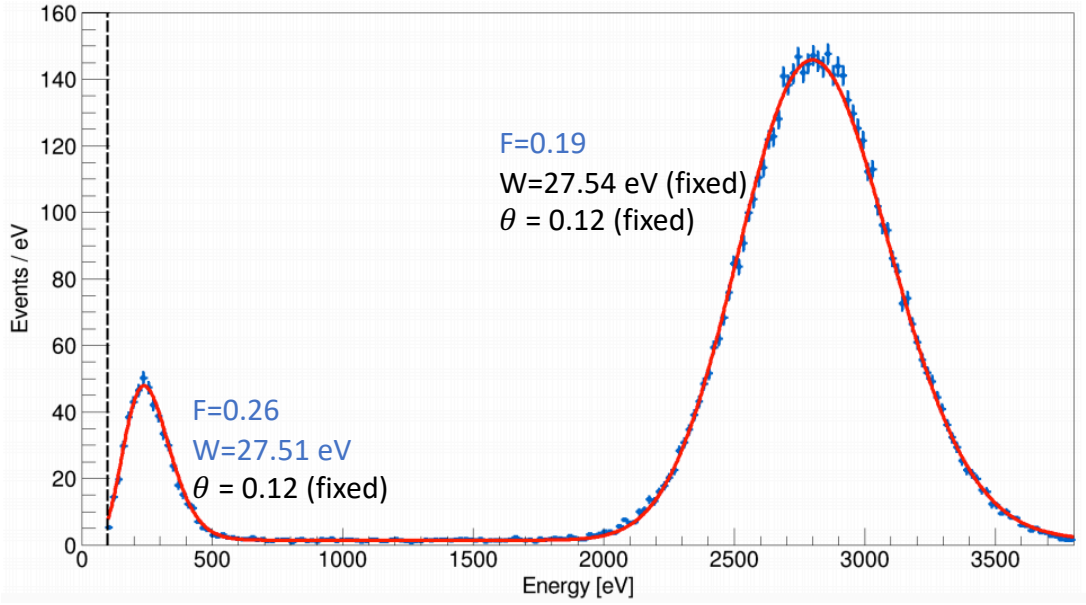
SINGLE ELECTRON CALIBRATION



- 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

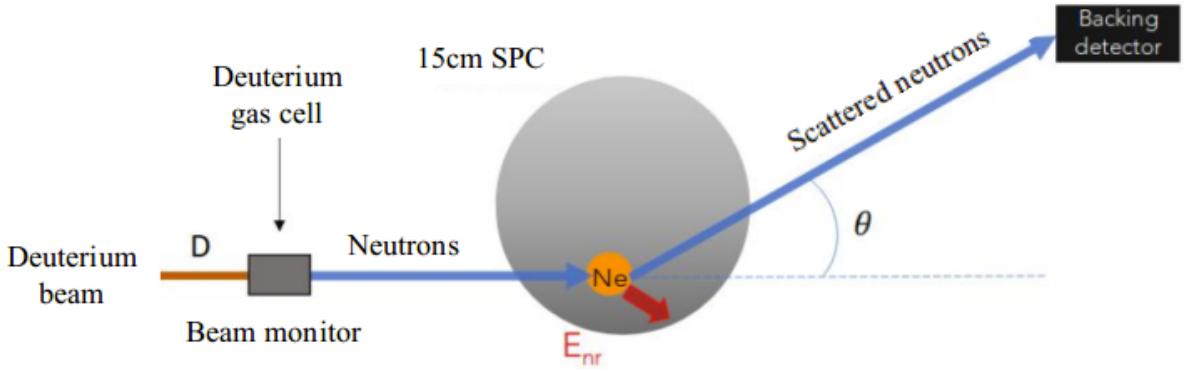


^{37}Ar calibration

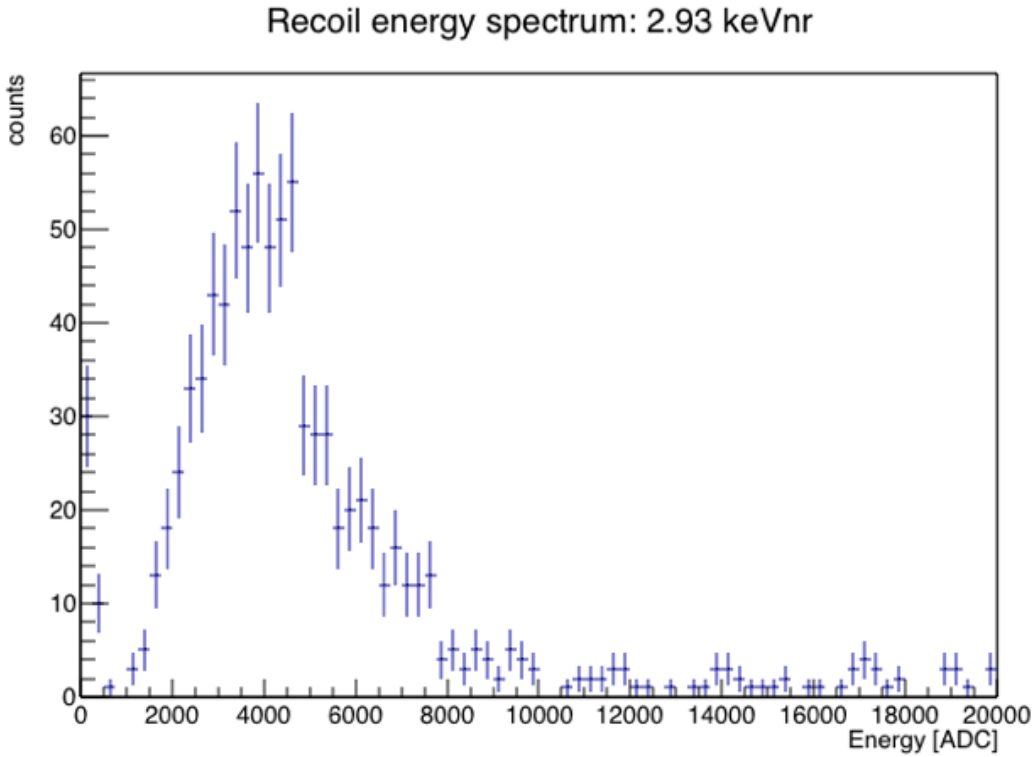


Q. Arnaud et al. (NEWS-G), arXiv:1902.08960, accepted by PRD

QUENCHING FACTOR MEASUREMENT



- E_{eVee}=QF . E_{nr}
- Deuterium from TANDEM accelerator used to produce neutrons:
  D+D -> n (3.68 MeV) + ^{3}He + γ
  p+Li -> 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)

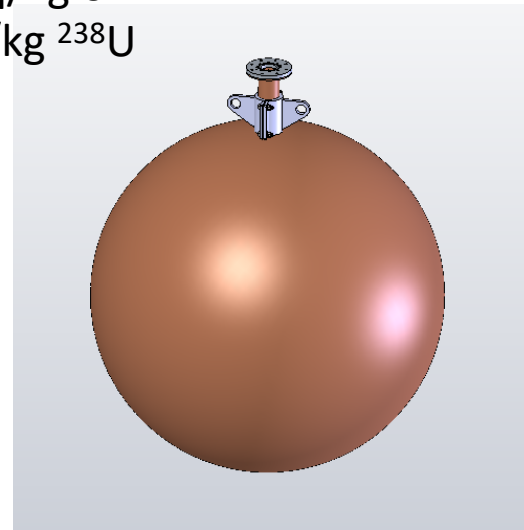


Marie Vidal

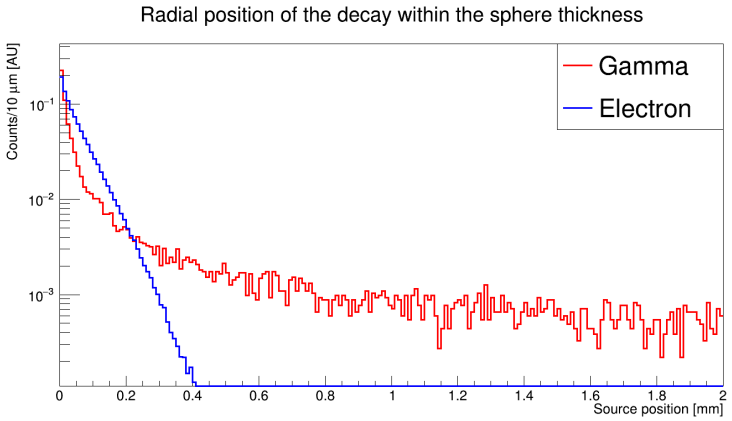
NEW DETECTOR – COPPER SPHERE BACKGROUND

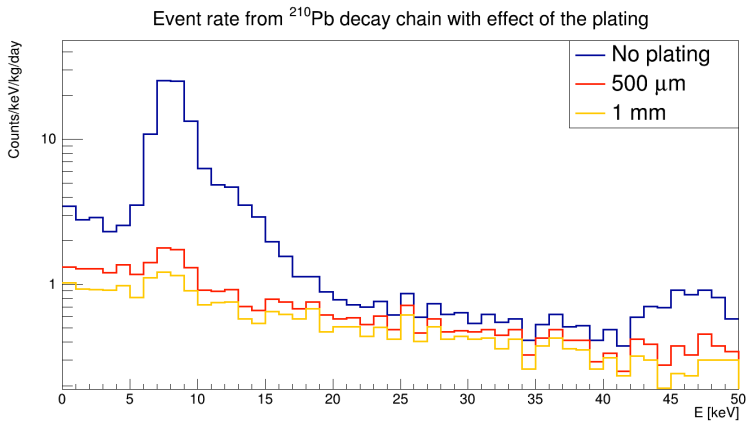
Pacific Northwest NATIONAL LABORATORY

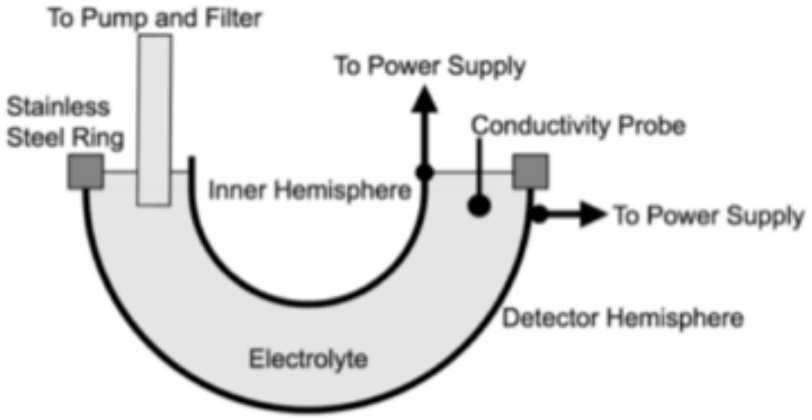
140 cm diameter vessel
from low activity copper (C10100)
28.5 mBq/kg of ^{210}Pb (Preliminary)
7 - 25 µBq/kg of ^{232}Th
1 - 5 µBq/kg ^{238}U



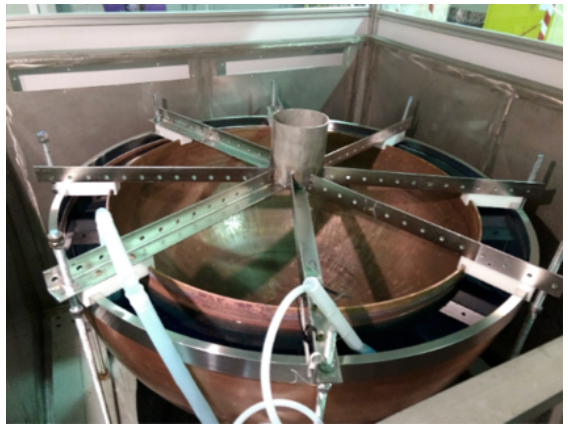
The large amount of ^{210}Pb in the copper is the main source of background.
The inner surface of the sphere was electropolished and electroplated.
500 µm of pure copper plated on the inner surface reduce by 70% the sub-keV event event rate from ^{210}Pb and ^{210}Bi.







Patrick Knights

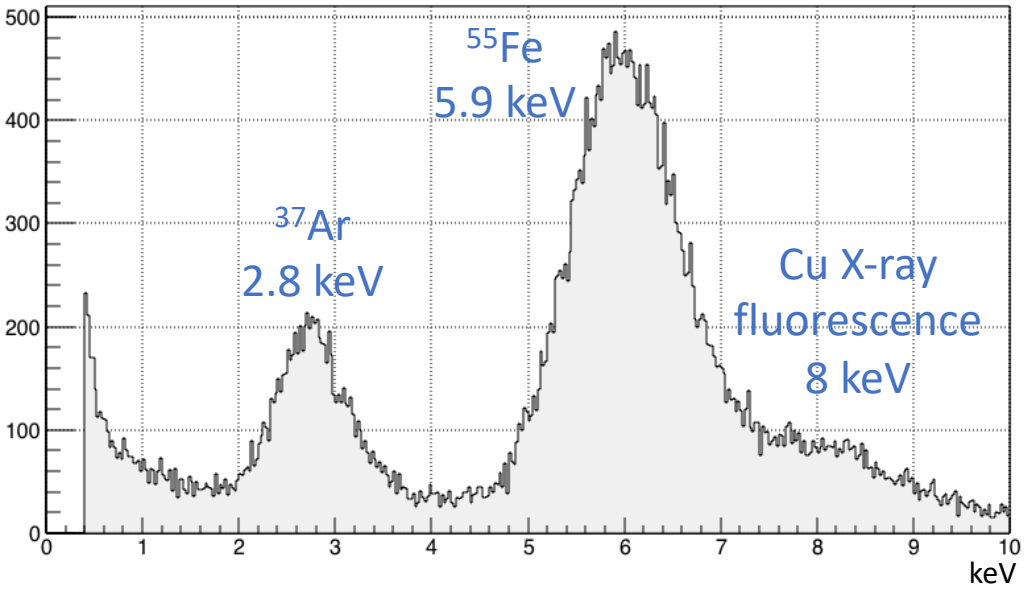


NEW DETECTOR – SENSOR DEVELOPMENT

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



Bakelite

Glass

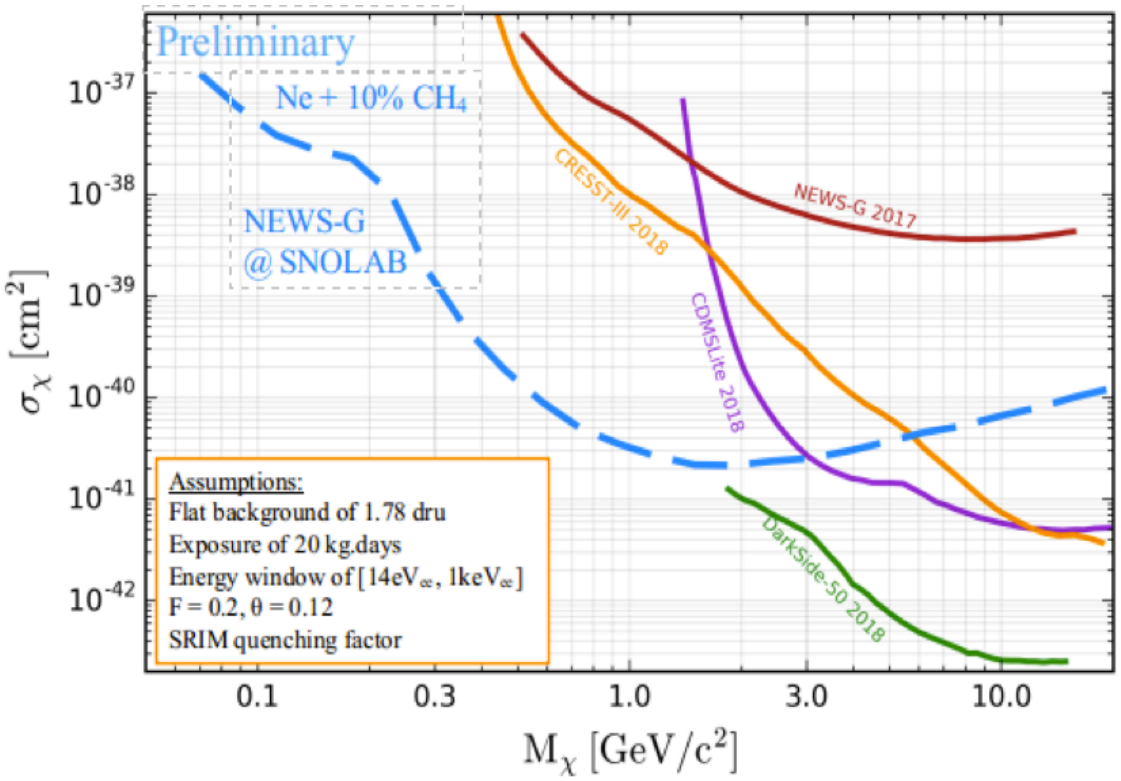
Achinos (sea urchin)

Grid

I. Katisoulas et al. (NEWS-G), arXiv:1809.03270

BACKGROUND SUMMARY / SENSITIVITY PROJECTION

		Contamination / flux	Counts / keV / kg / day < 1 keV	Counts / keV / kg / day in [1 ; 5] keV	Rate [mHz]
Copper sphere (500 µm electrolyte inside)	^{210}Pb	28.5 mBq/kg	1.1	0.95	0.9
	^{60}Co	38 µBq/kg	0.12	0.09	0.37
	^{238}U	3 µBq/kg	0.012	0.011	0.027
	^{232}Th	13 µBq/kg	0.074	0.063	0.15
	^{40}K	0.1 mBq/kg	0.03	0.13	0.61
Archeological lead	^{210}Bi	<25 mBq/kg	<0.27	0.23	0.46
	^{238}U	62 µBq/kg	0.18	0.12	0.37
	^{232}Th	9 µBq/kg	0.026	0.014	0.052
	^{40}K	<1 mBq/kg	<0.22	0.16	0.62
VLA Lead	^{238}U	62 µBq/kg	0.13	0.094	0.37
	^{232}Th	9 µBq/kg	0.022	0.017	0.063
	^{40}K	<1 mBq/kg	<0.24	0.16	0.64
Cavern	^{208}Tl 2.6 MeV γ	0.06 γ cm^2/s	0.088	0.069	0.26
TOTAL			1.752	1.428	2.562



^{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

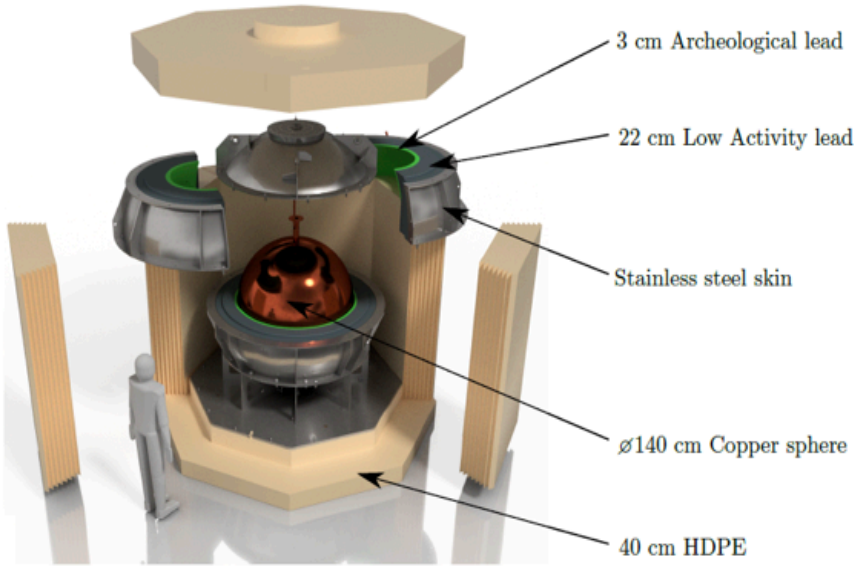
^{40}K activity in C10100 copper measured by NEXT-100

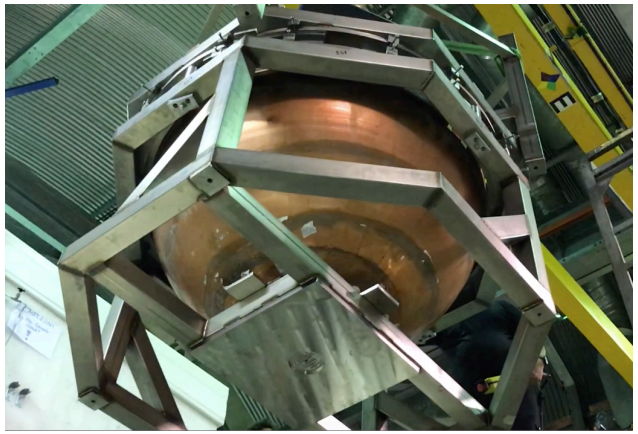
The upper limits in the lead are not counted in the total

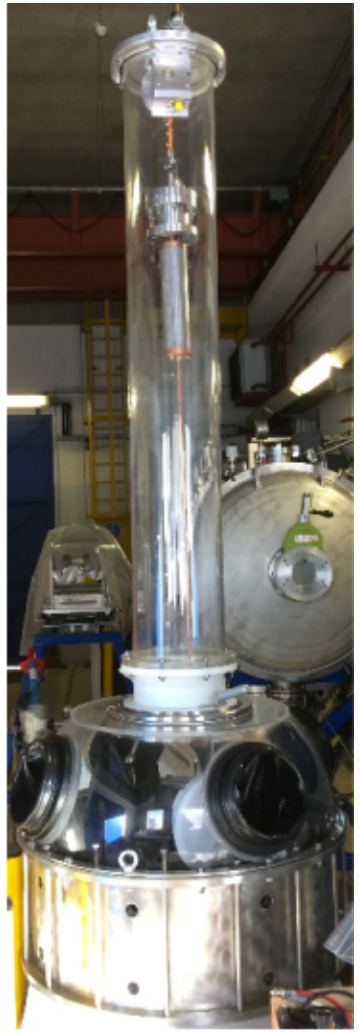
Daniel Durnford

NEW DETECTOR – FABRICATION PROGRESS

Compact lead and PE shield flushed with N_2 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).

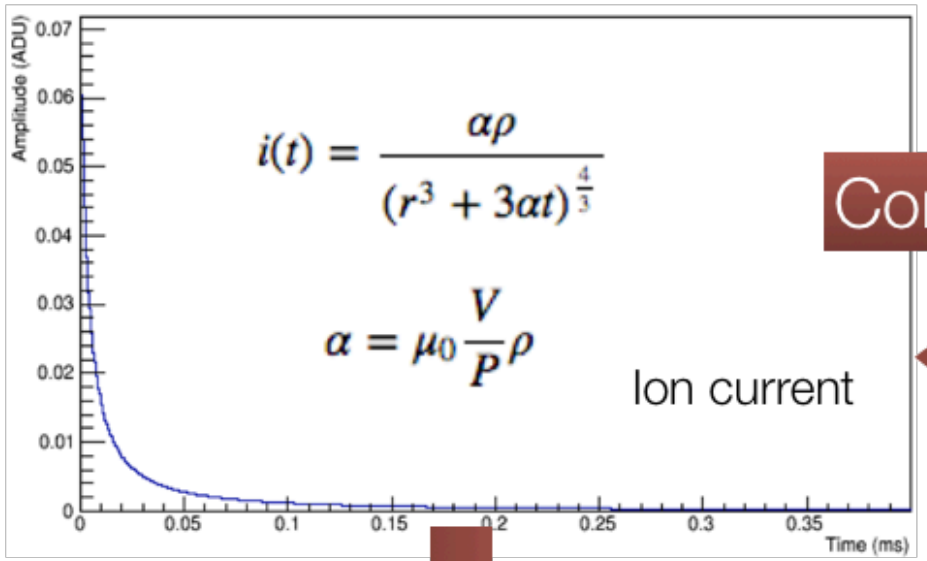
NEWS-G collaboration

- **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, M Chapellier, 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
- **IRFU** (Institut de Recherches sur les Lois fondamentales de l'Univers)**/CEA Saclay** -**I Giomataris**, M Gros,, T Papaevangelou, JP Bard, JP Mols
  - 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

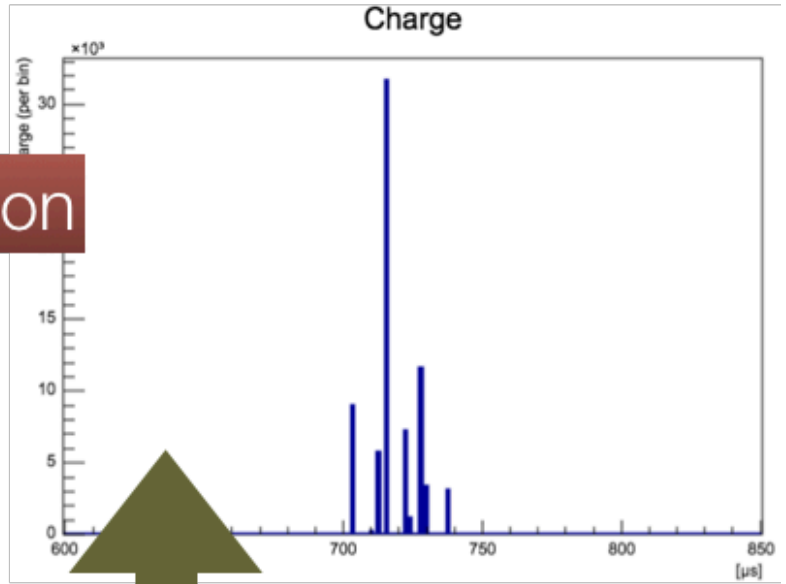
April 2019

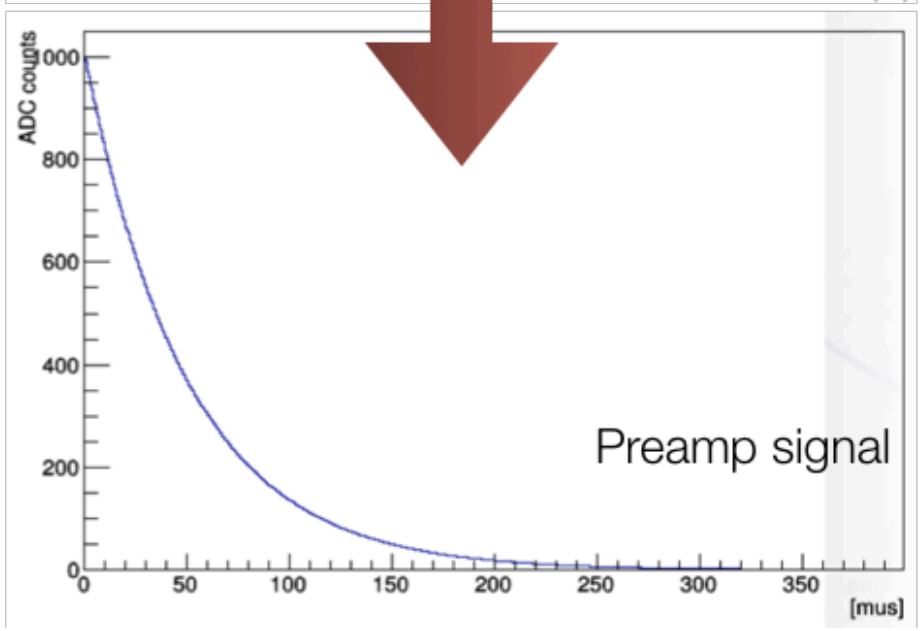
Backup Slides

Signal Formation / Signal Processing

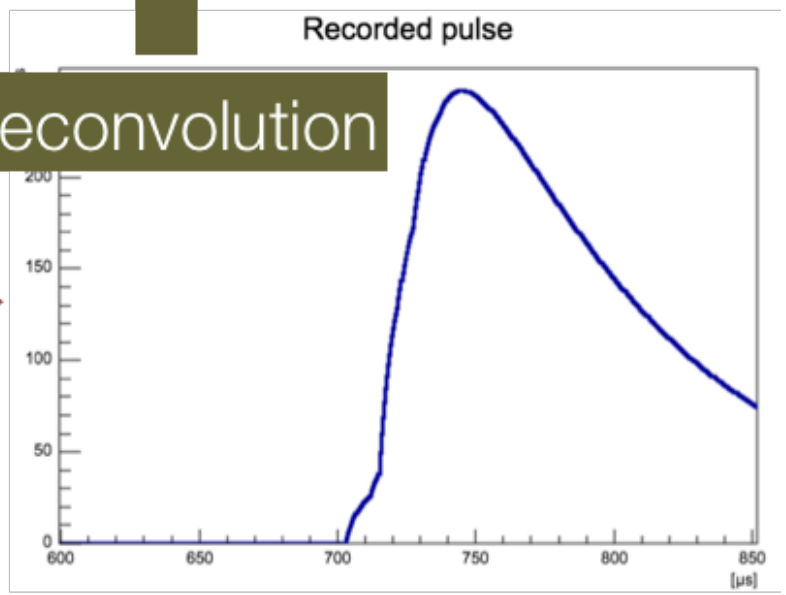


Convolution





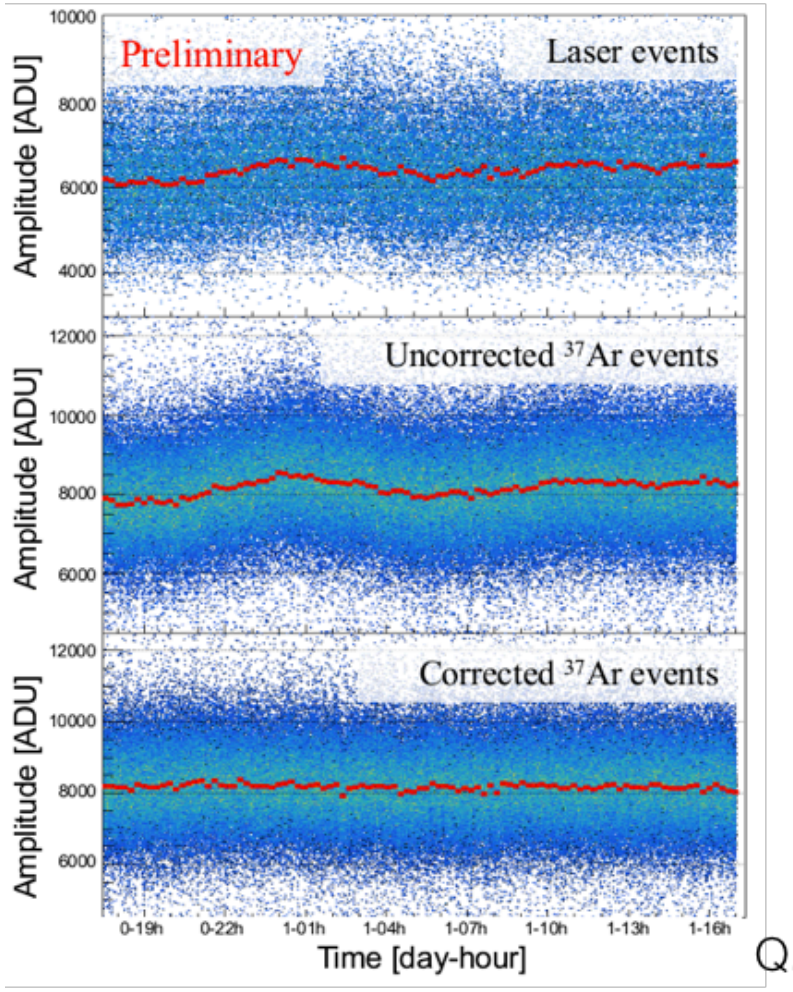
Deconvolution



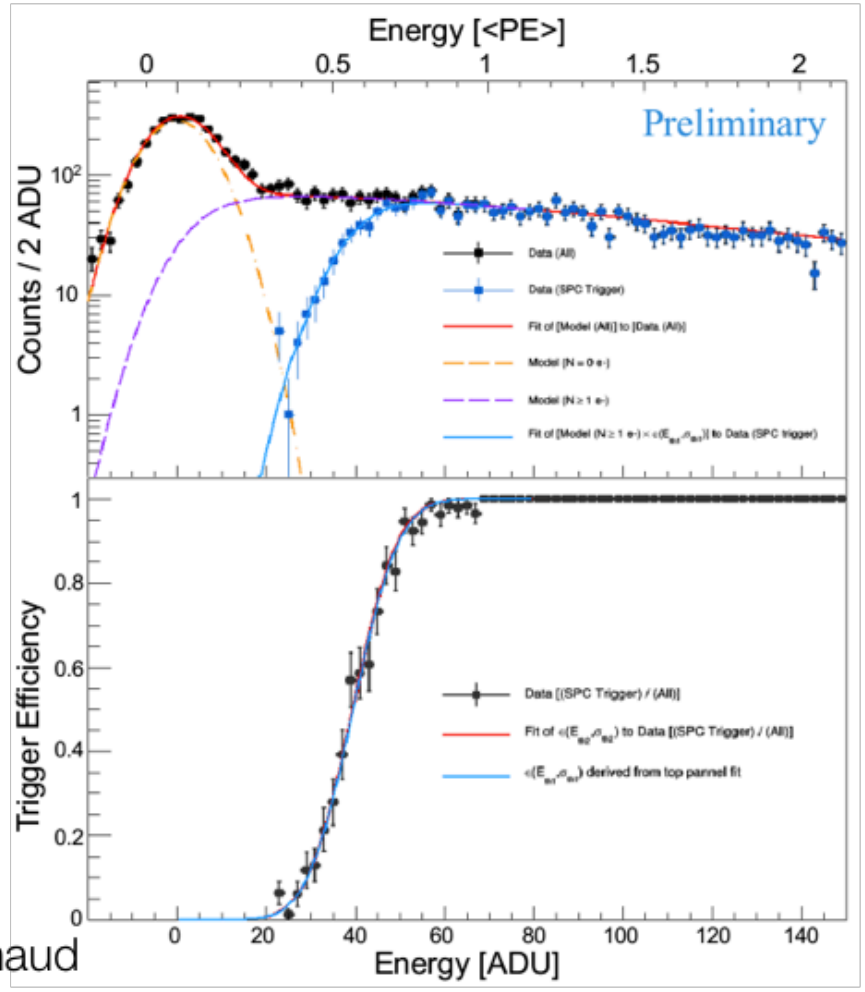
Francisco Vazquez

Laser monitoring / trigger efficiency

Gain monitoring



Trigger efficiency

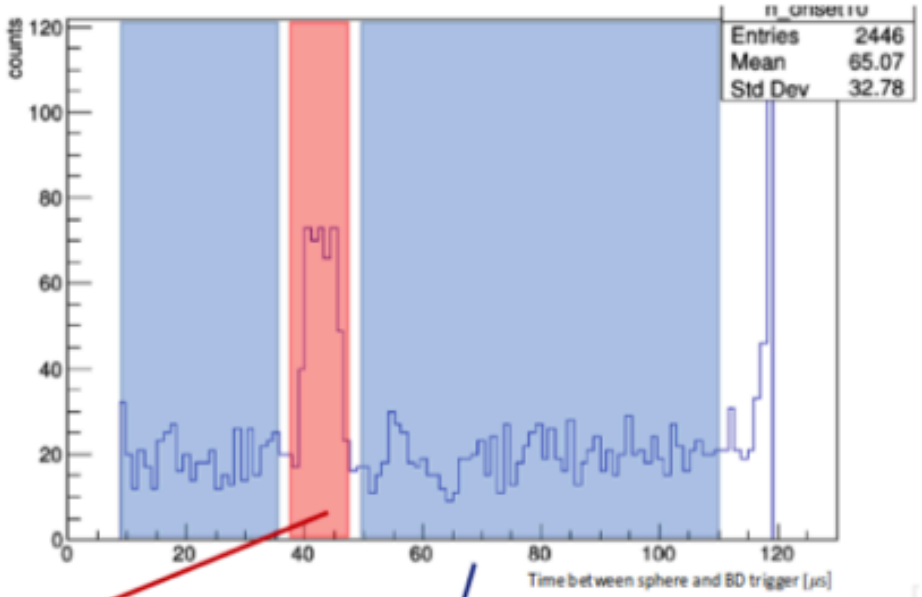


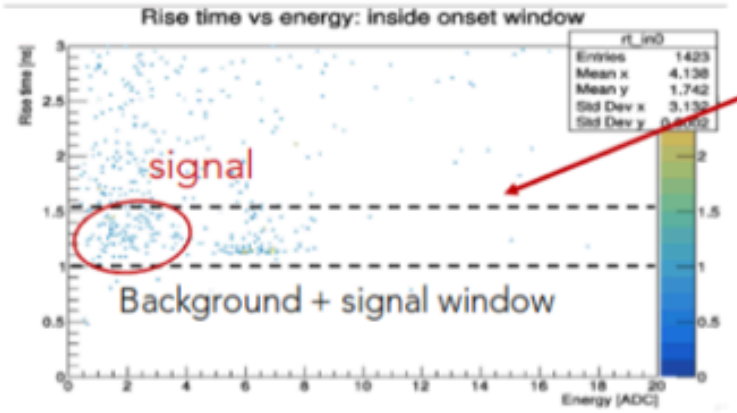
Q. Arnaud

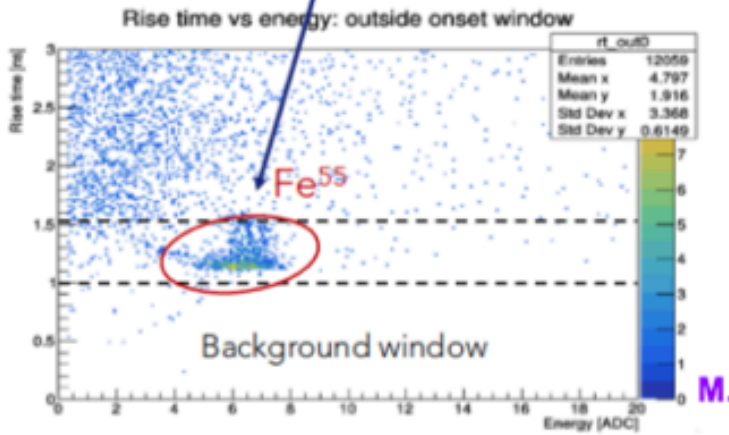
x

Quenching factor measurement cut

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

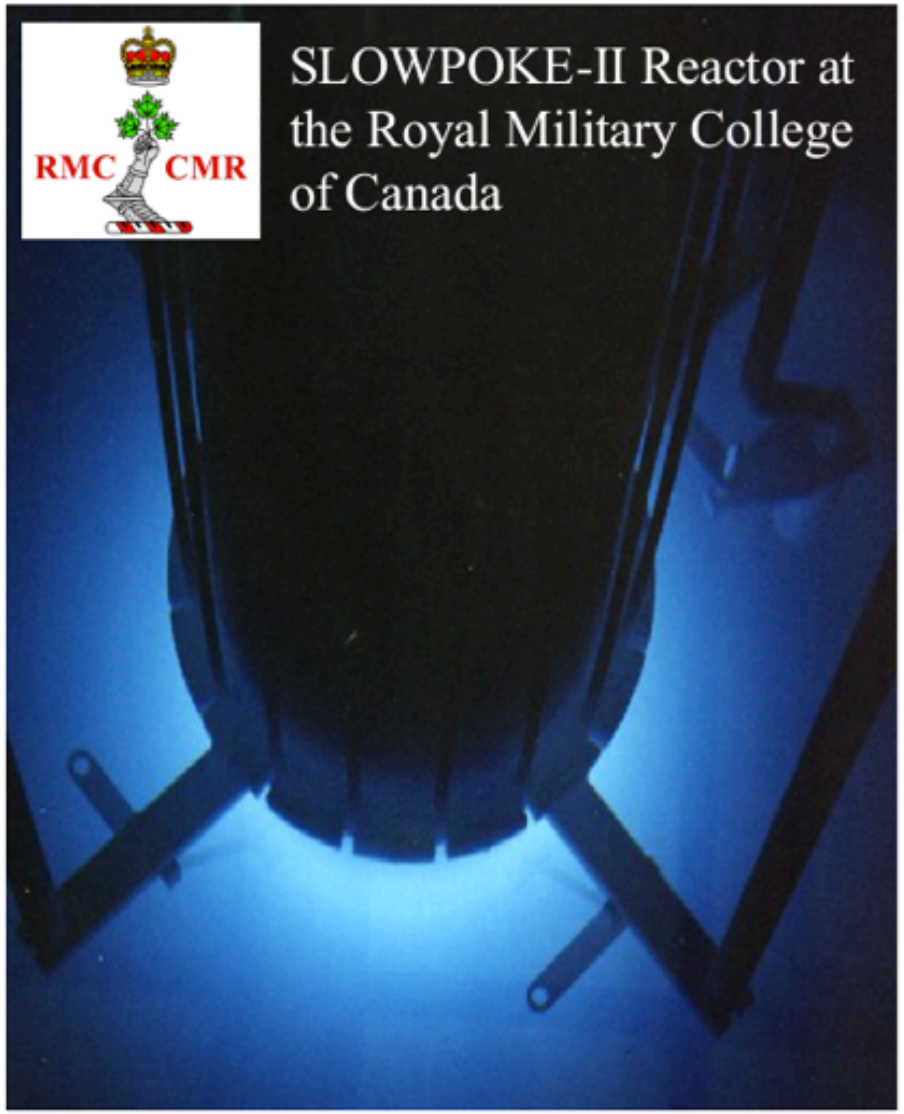






M. Vidal, Queen's

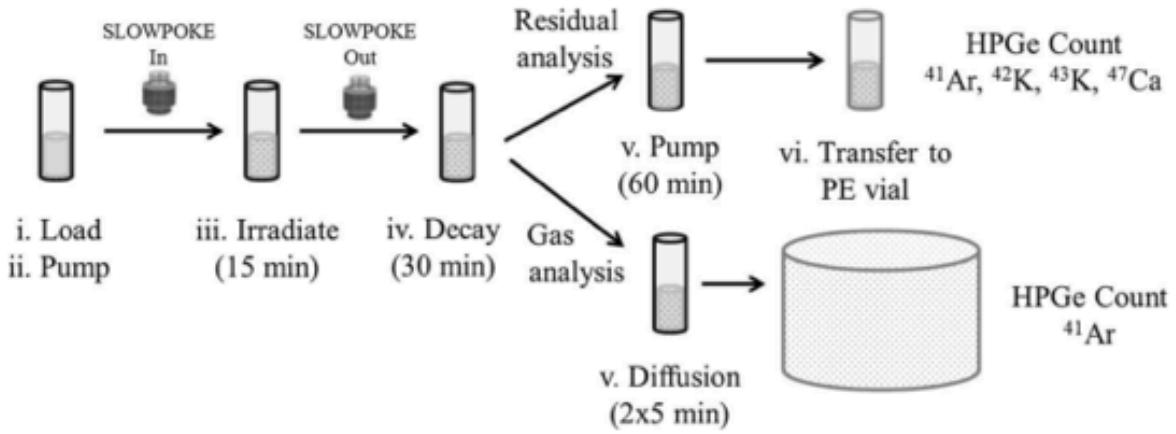
^{37}Ar production



$^{40}Ca(n,\alpha)^{37}Ar$

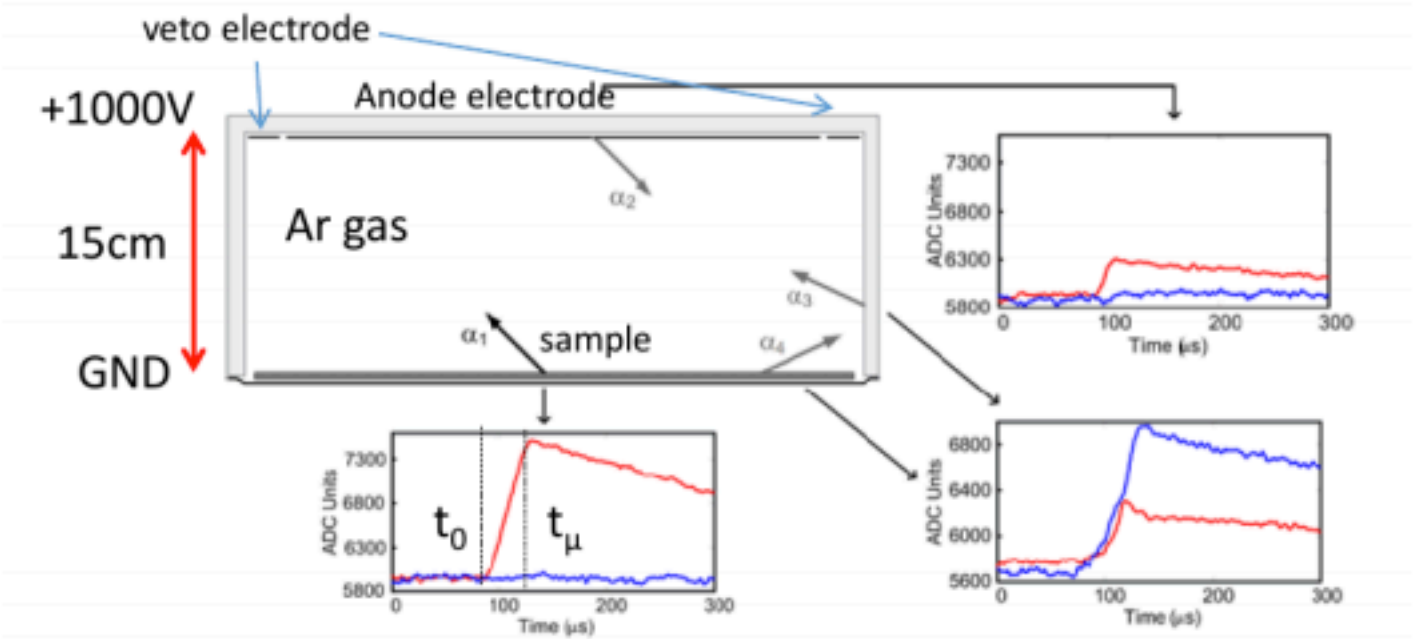
Source produced in an oxygen-free environment

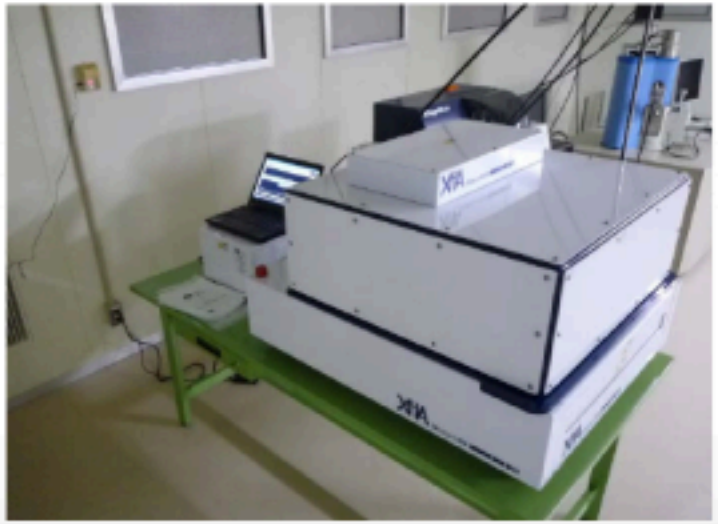
Counting of gaseous and solid by-products allows for indirect measurement of ^{37}Ar production



D.G. Kelly et al. Journal of Radioanalytical and Nuclear Chemistry 318(1), 279 (2018).

^{210}Pb measurement in copper





signal

veto signal

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