UNIVERSITY OF ALBERTA

June 6th 2019

CAP, Vancouver, Canada

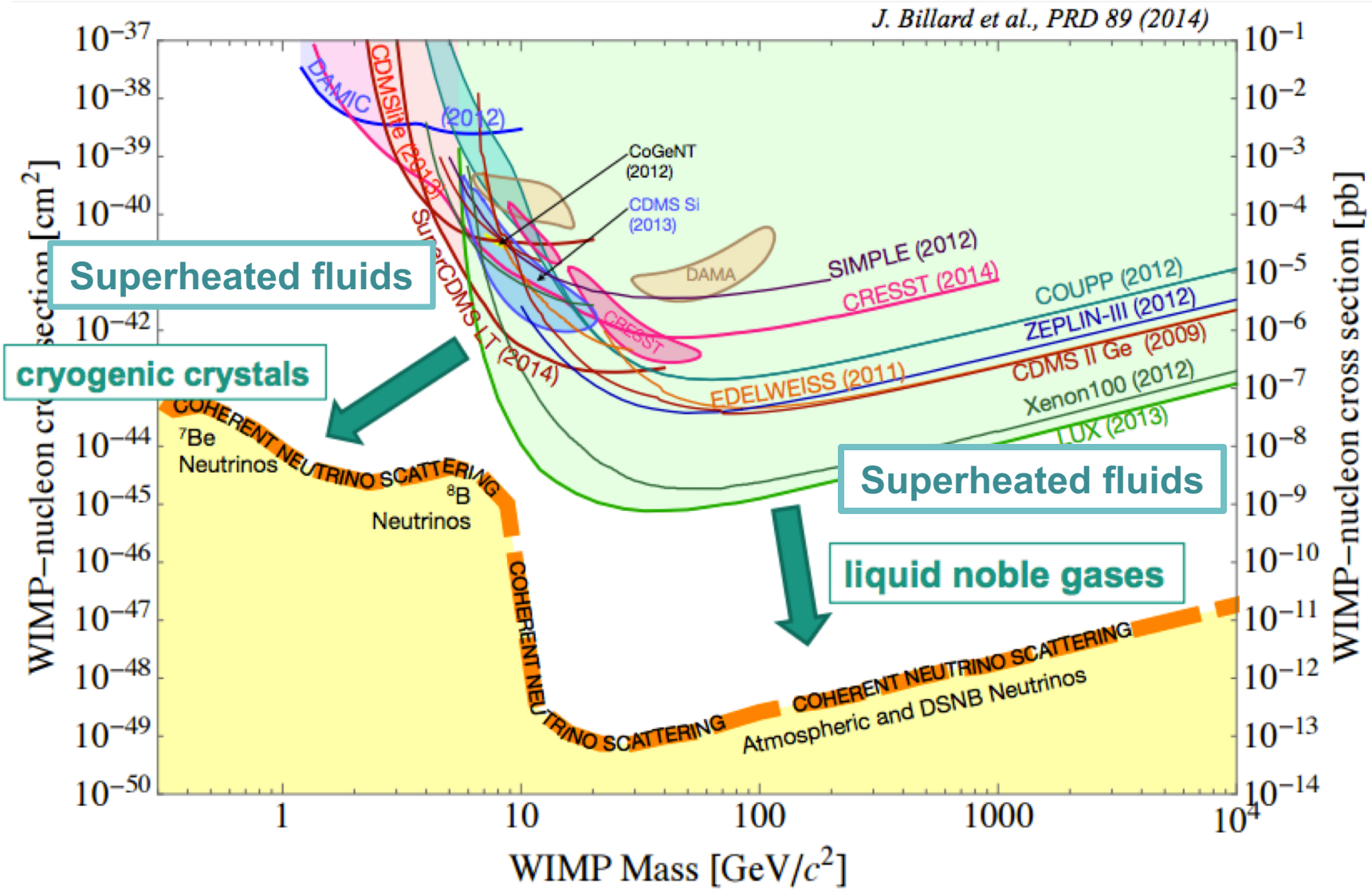
Search for Dark Matter with NEWS-G experiment

Marie-Cécile Piro

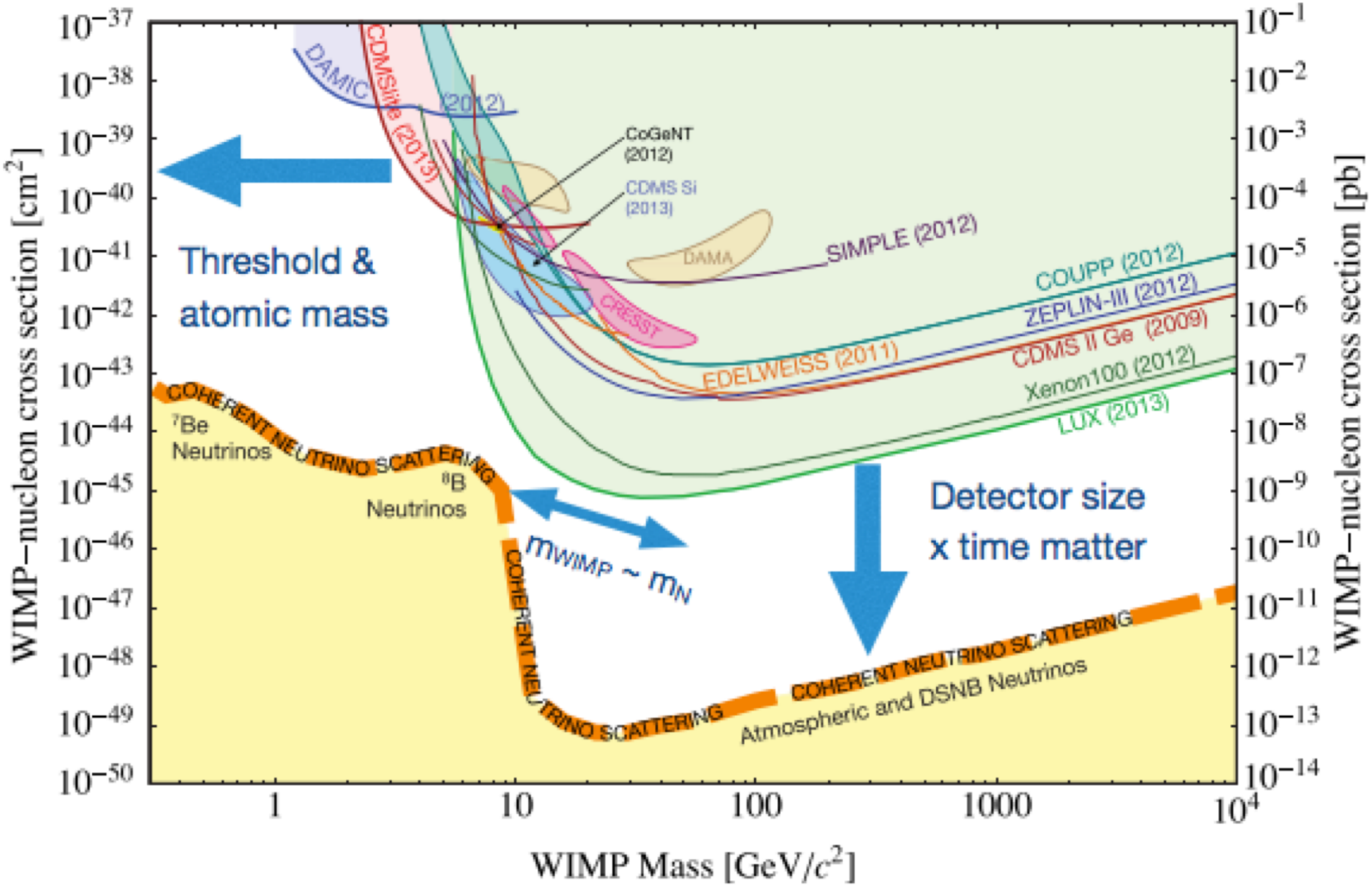
University of Alberta

We are at the beginning of a new era of particle physics!

The race is open !!



Direct detection strategies



Outlines

In recent decades, several detector technologies have been developed with the quest to directly detect dark matter and test one of the most important unsolved questions in modern physics.

NEWS-G experiment focusses on low-WIMP mass searches. Extremely low threshold and very competitive!

What is NEWS-G experiment?

Where we are? Where we are going?

NEWS-G Collaboration

Queen's University

LPSC Grenoble

Aristotle University of Thessaloniki

Irfu

cea

Royal Military College of Canada

Pacific Northwest National Laboratory

University of Birmingham

SNOLAB

University of Alberta

TRIUMF

LSM

Spherical Proportional Counters: SPC

NEWS-G EXPERIMENT:

- Detector:

  Metallic vessel filled with a noble gas mixture, with a high voltage sensor.

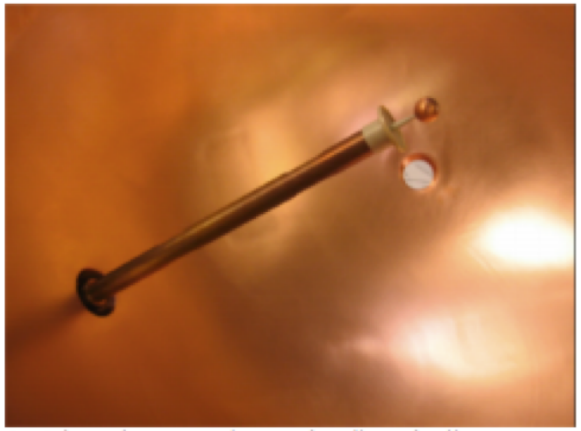
- Active target:

  Gas of Neon, Helium, Hydrogen
  → Low-A target atoms increase sensitivity to low-mass WIMPs

- Read-out:

  Single readout channel (pre-amplifier).

SEDINE: LSM

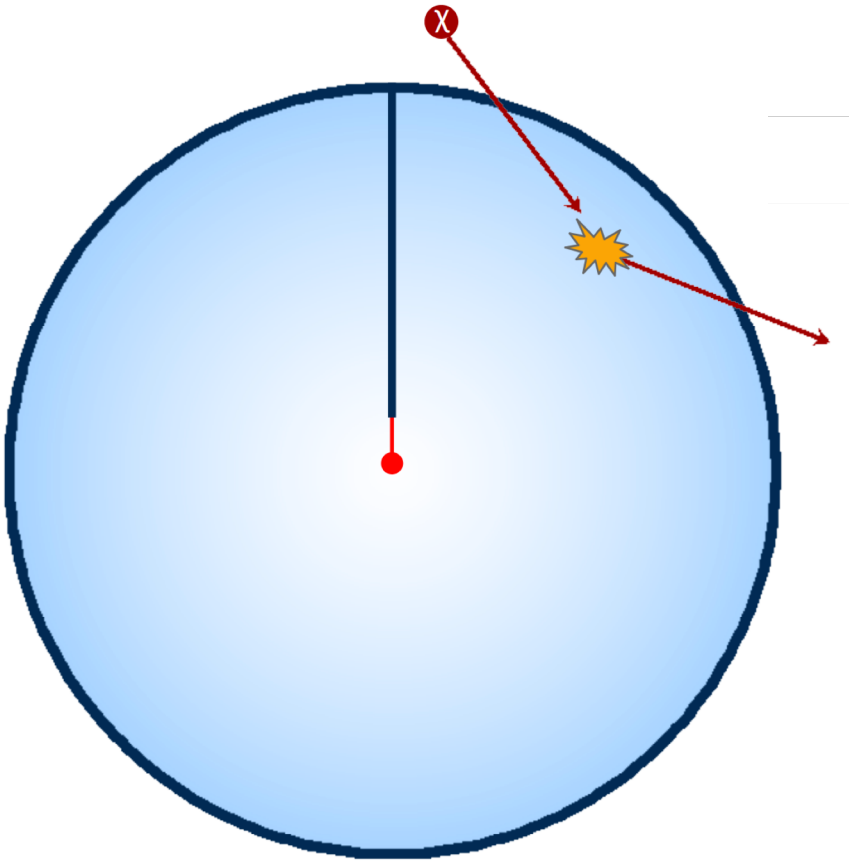


Inside sphere: rod + umbrella + ball = sensor

NEWS-G: Detector principle

NEWS-G EXPERIMENT:

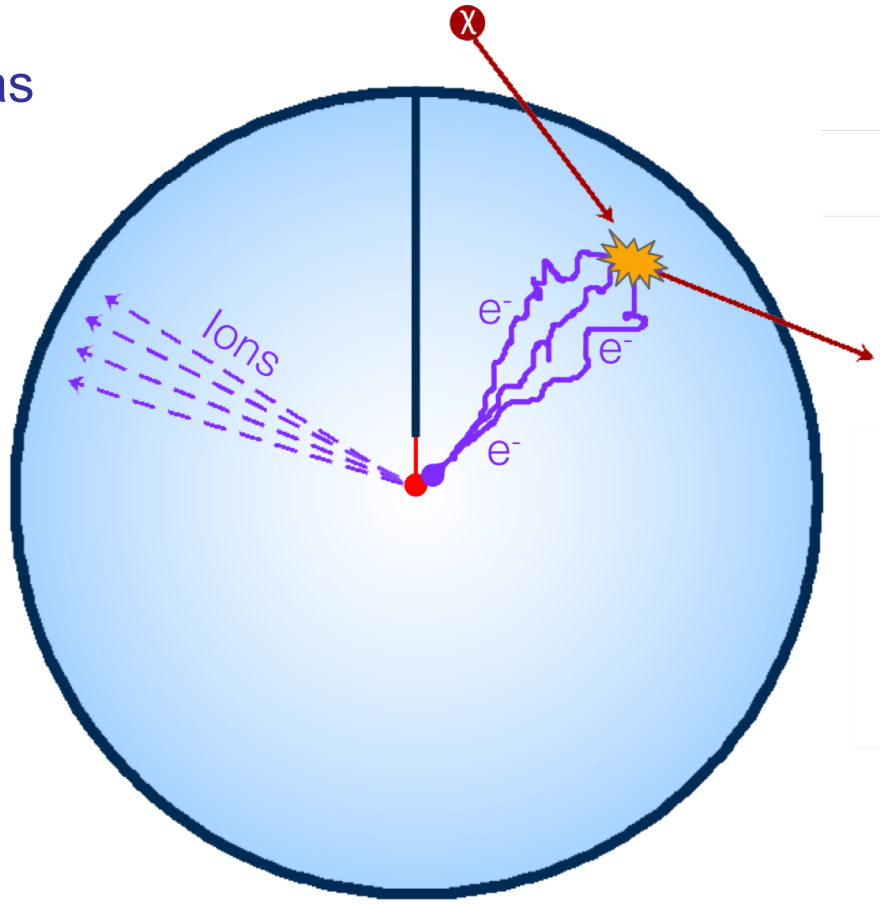
- Incident particle scatters on target gas
  → Primary ionization



NEWS-G: Detector principle

NEWS-G EXPERIMENT:

- Incident particle scatters on target gas
  → Primary ionization
- Drift of primary e^- towards sensor
  → Typical drift time ~ 100μs



NEWS-G: Detector principle

NEWS-G EXPERIMENT:

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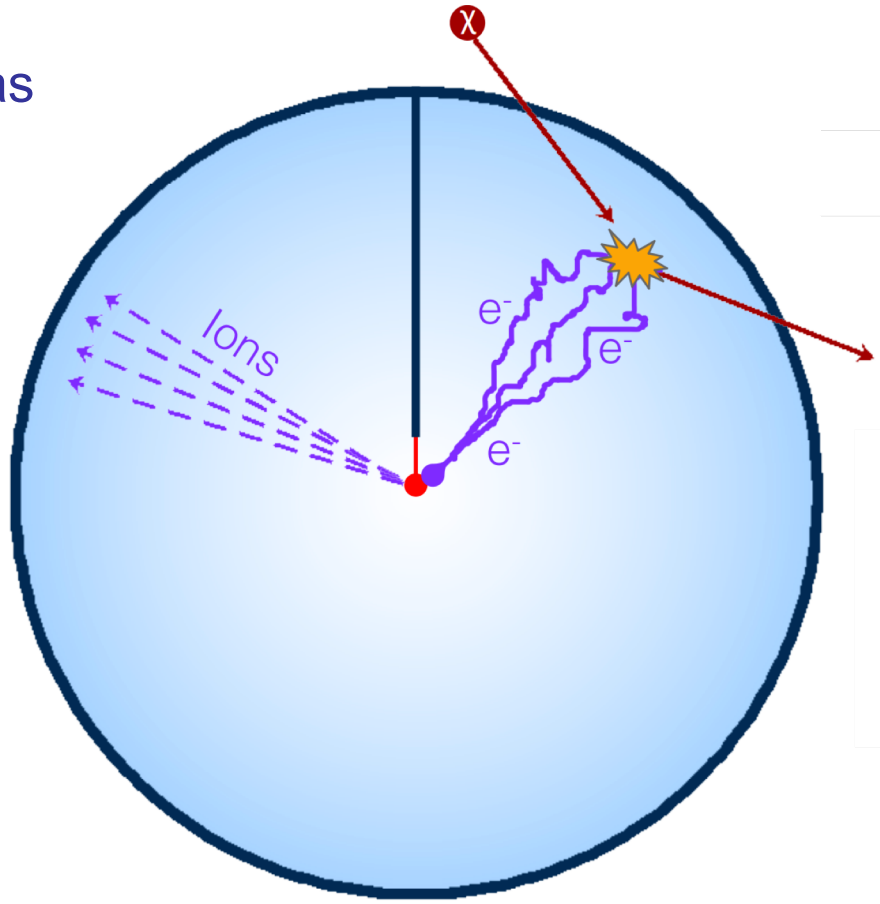
- Avalanche of secondary e-/ion pairs
  → Amplification of signal through Townsend avalanche.



NEWS-G: Detector principle

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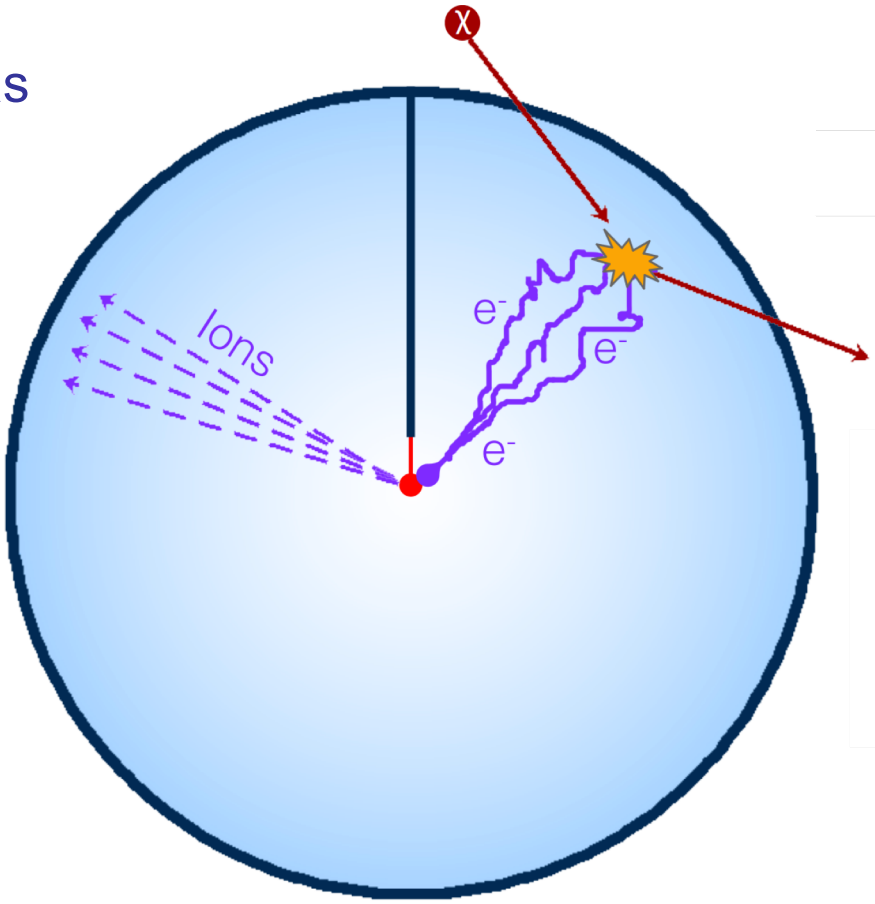
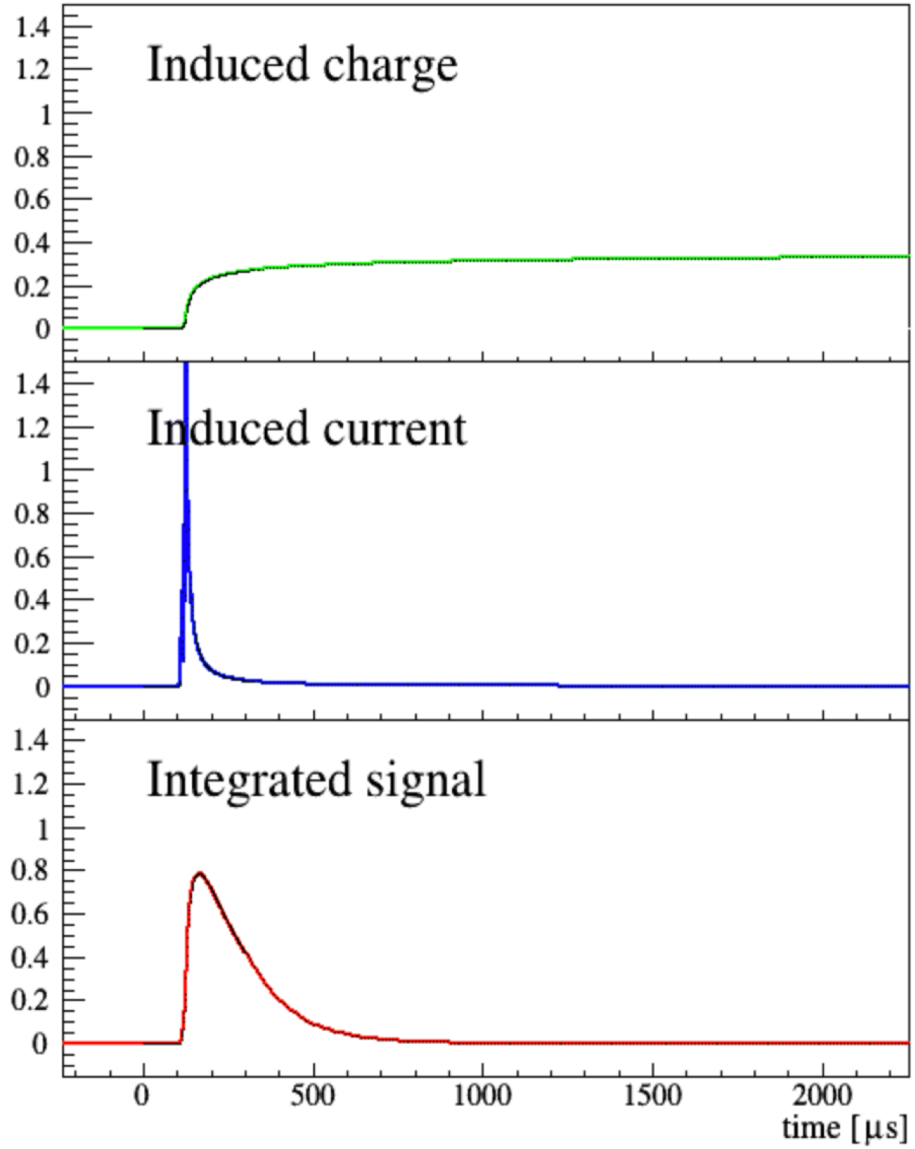
  → Primary ionization
- Drift of primary e^- towards sensor
  → Typical drift time ~ 100μs
- Avalanche of secondary e-/ion pairs
  → Amplification of signal through Townsend avalanche.
- Signal formation
  → Current induced by the secondary ions drifting away from anode



NEWS-G: Detector principle

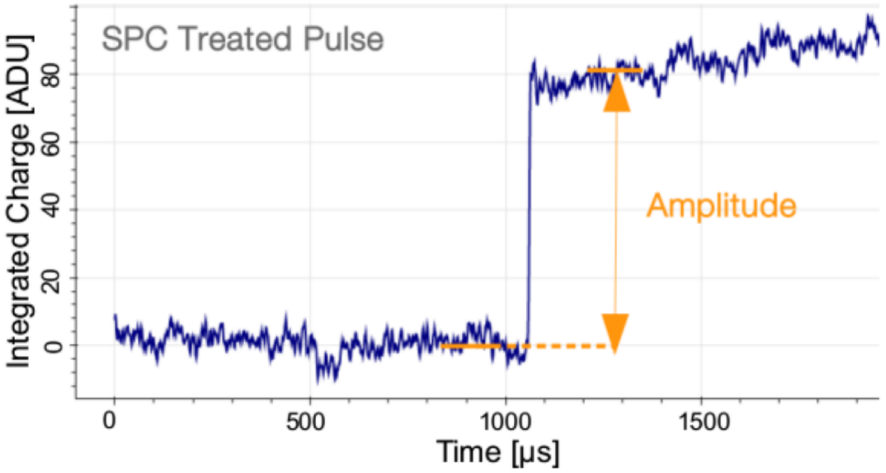


NEWS-G EXPERIMENT:

- Signal readout:

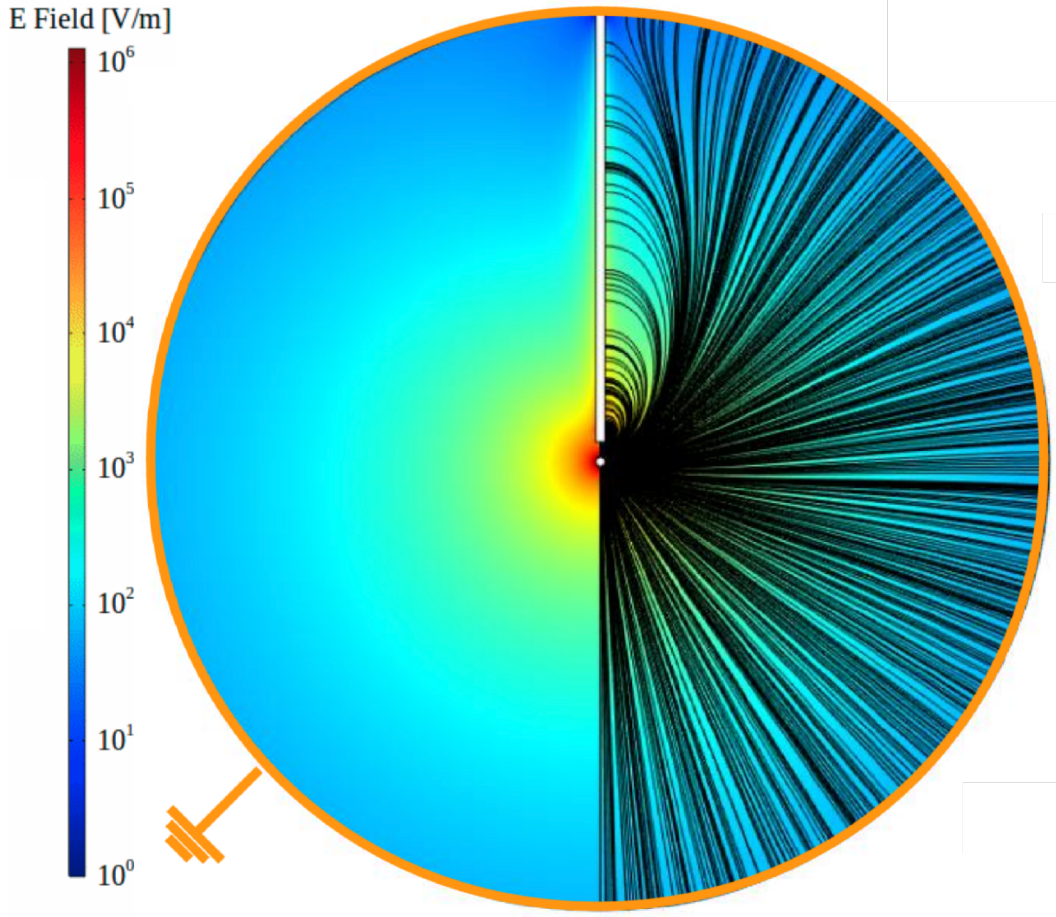
  → Induced current integrated by a charge sensitive pre-amplifier and digitized.

Single electron pulse:



Spherical Proportional Counters

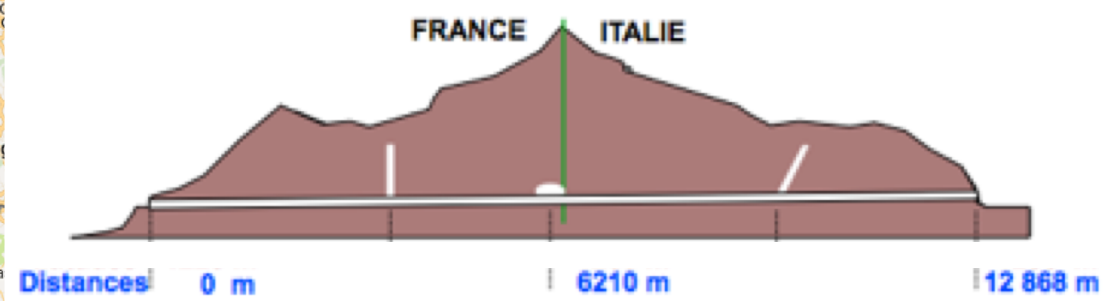
Advantages of NEWS-G experiment:

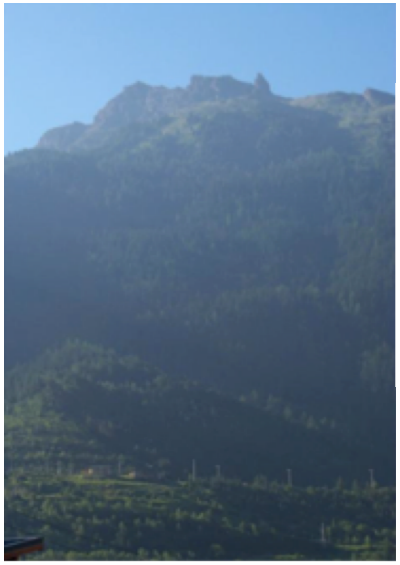


- Low intrinsic capacitance:
  C ≈ 0.3 pF
  → low electronic noise
- Choice of the target, pressure
- High amplification gain from Townsend avalanche
- Volume fidualisation
- **Energy thresholds of ~10 eV!**

First results of NEWS-G AT LSM

- **SEDINE (First prototype) was located at Laboratoire Souterrain de Modane.**
- **Rock coverage from the mountain of 2.9km (4800 m w.e.)**



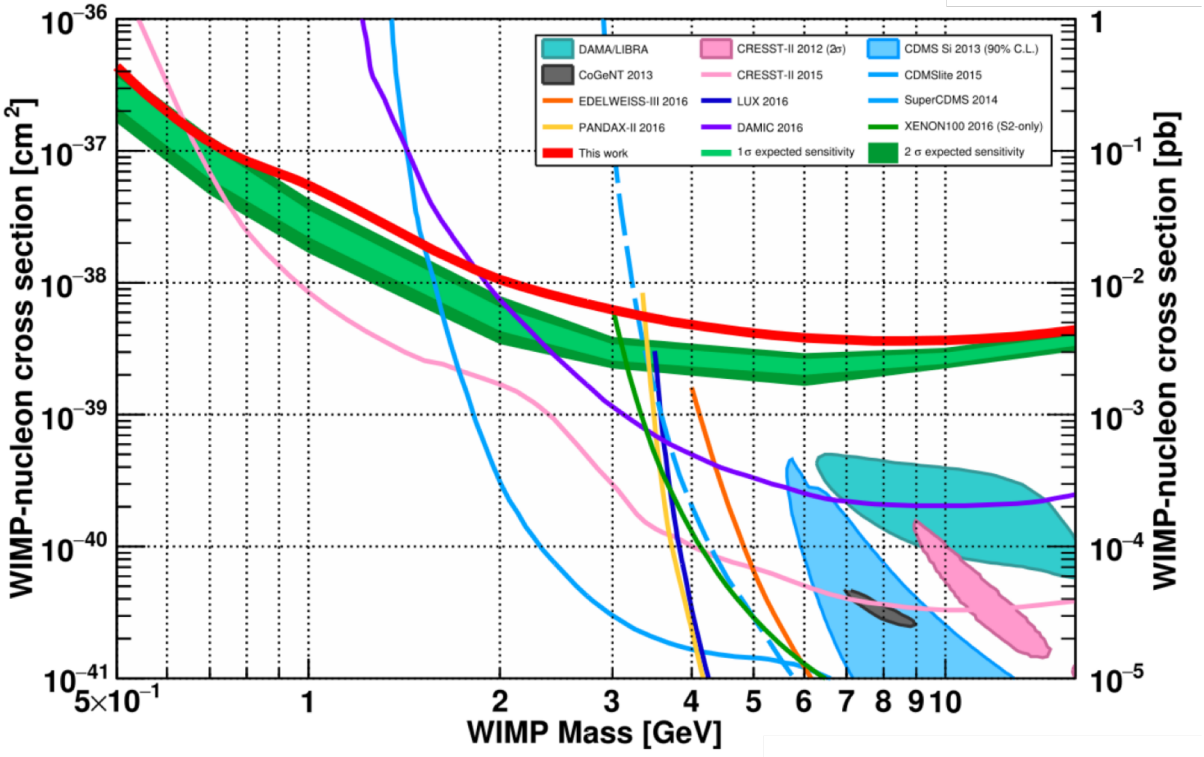


LSM
LABORATOIRE SOUTERRAIN DE MODANE

First results @ LSM

SEDINE:

- 60 cm diameter vessel filled with Neon (+0.7% CH4) at 3.1bar
- 42-day long run, total exposure of 9.7 kg.day
- Very competitive results at low-mass range

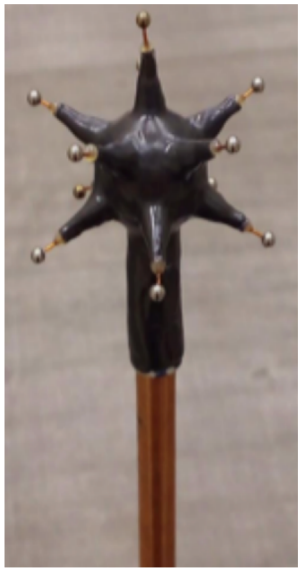


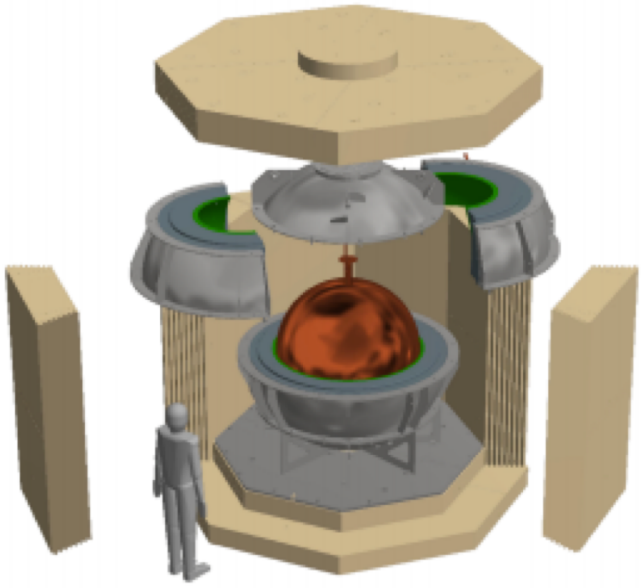
Q. Arnaud et al. (NEWS-G), Astropart. Phys. 97, 54 (2018)

NEWS-G: the next phase!

NEWS-G EXPERIMENT:

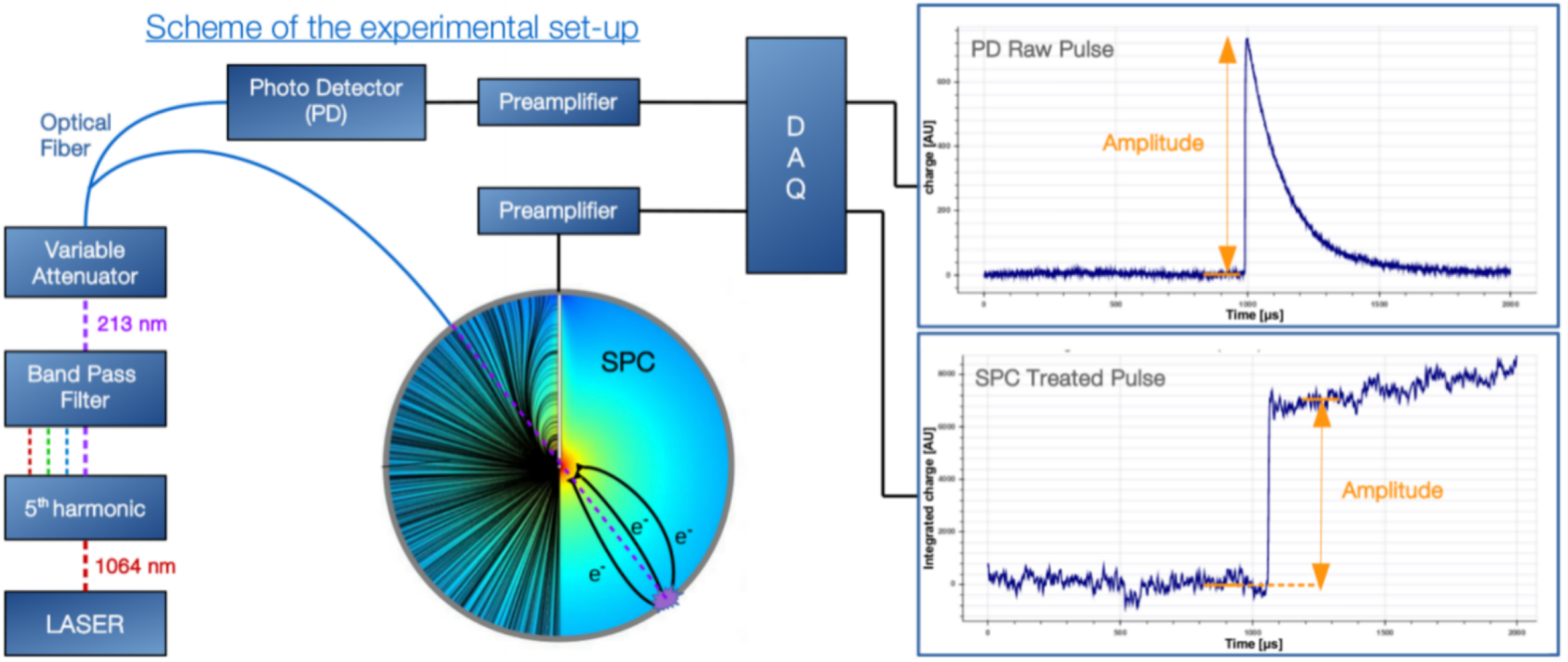
- **Bigger sphere with a lot of improvements and R&D!**





UV Laser calibration system

- 213 nm laser used to extract primary electrons from wall of SPC
- Photo detector in parallel tags events and monitors laser power
- Laser intensity can be tuned to extract 1 to 100 photo electrons



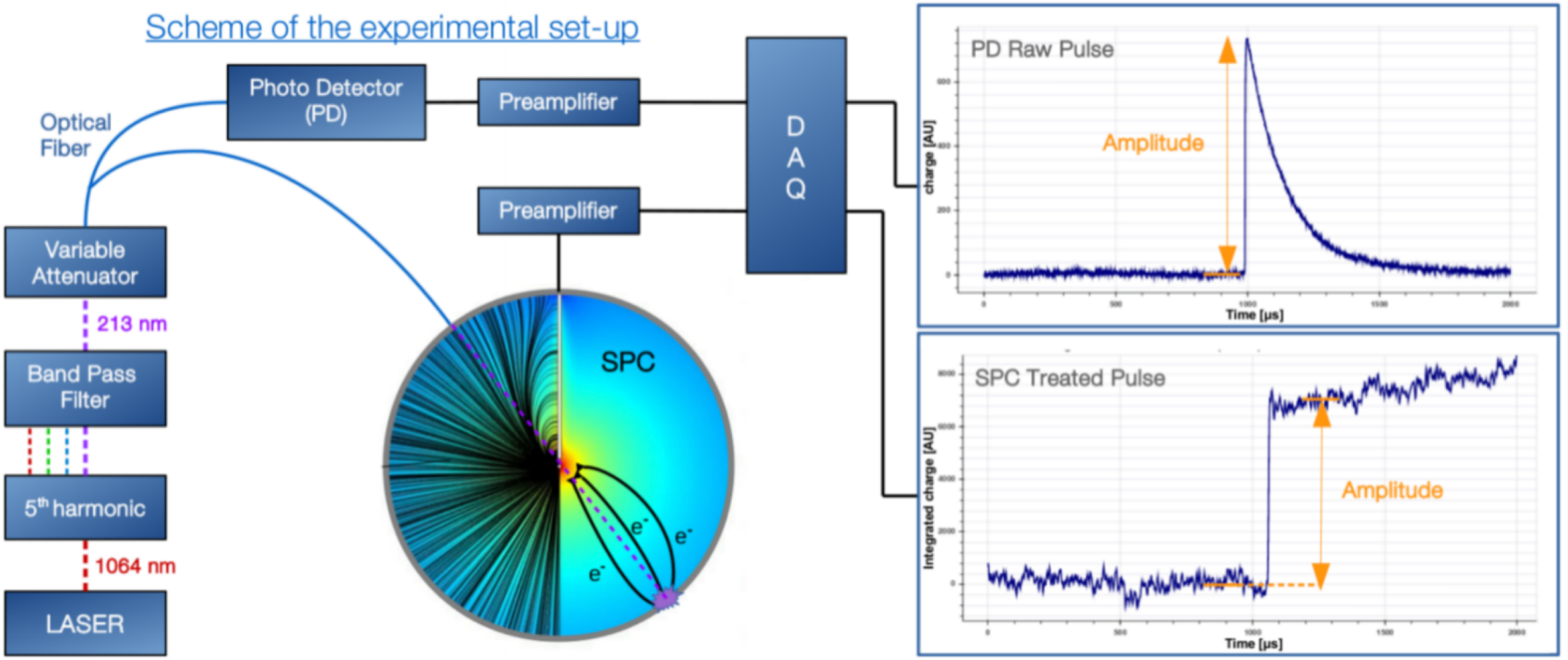
Q. Arnaud et al. (NEWS-G), arXiv:1902.08960, accepted by PRD

→***Daniel Durnford : Wednesday 1:45PM***

UV Laser calibration system

Laser calibrations used to:

- Measure mean gain to 1% precision
- Measure drift and diffusion time
- Monitor stability of detector to within 1% (to be used for new detector)
- Measure trigger threshold efficiency



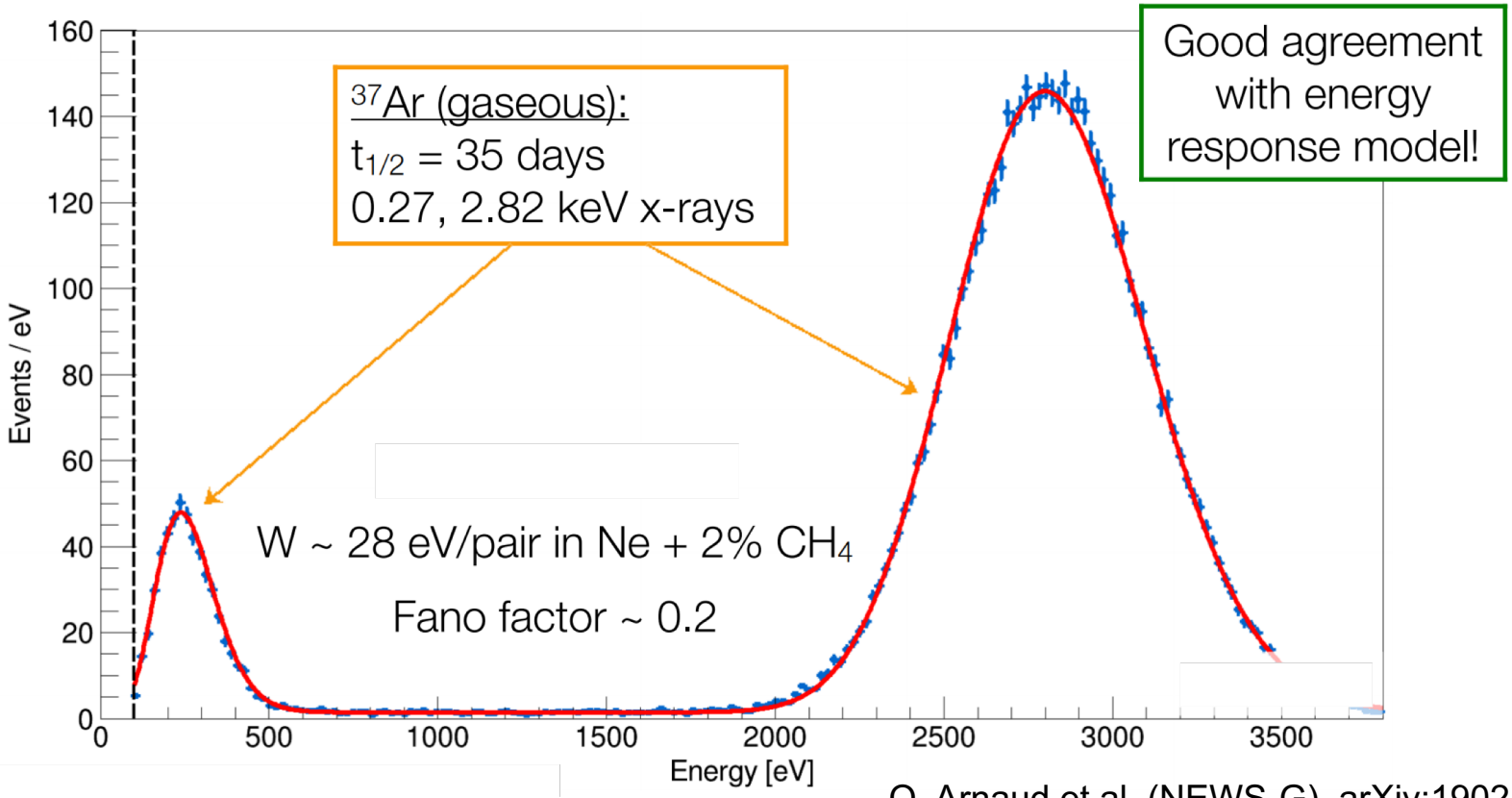
Q. Arnaud et al. (NEWS-G), arXiv:1902.08960, accepted by PRD

→ ***Daniel Durnford : Wednesday 1:45PM***

^{37}Ar measurements

Low energy, detector volume calibration with ^{37}Ar:
D.G. Kelly et al. Journal of Radioanalytical and Nuclear Chemistry 318(1), 279 (2018).

Can also be used to measure the gas properties (W-value, Fano factor)



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

→***Daniel Durnford : Wednesday 1:45PM***

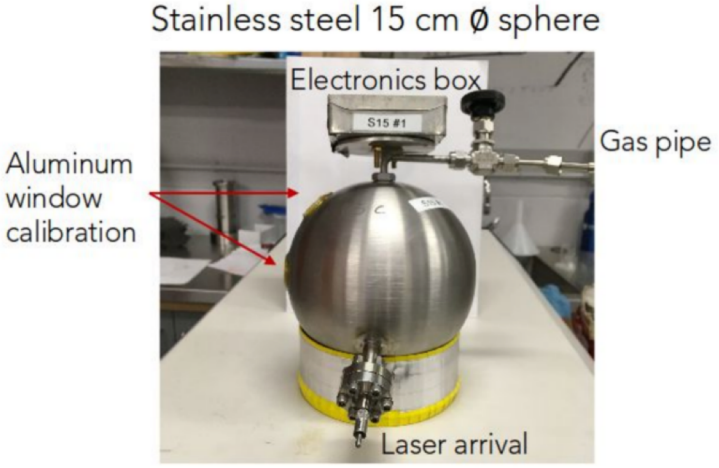
Quenching factor measurements

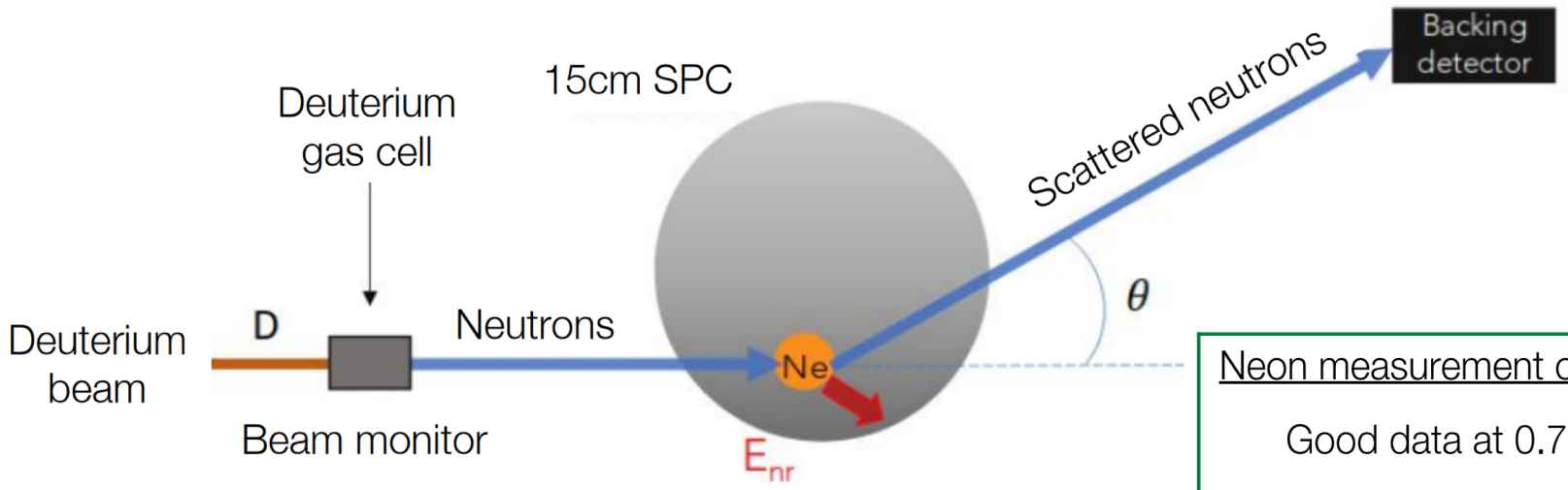
$$W_{\mathrm{nr}} = W_{\gamma}/Q(E)$$

Ongoing measurement campaigns at:

TUNL
TRIANGLE UNIVERSITIES NUCLEAR LABORATORY

Deuterium from a TANDEM accelerator used to produce neutrons: D(D,n)^{3}He





Neon measurement campaign:

Good data at 0.7 keV$_{nr}$

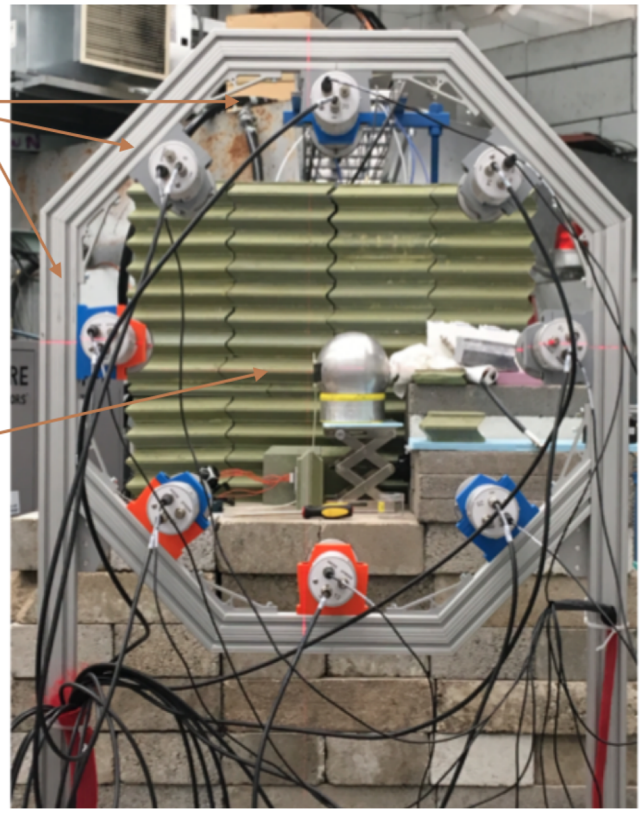
Working on 0.3 keV$_{nr}$!

→ ***Marie Vidal : Wednesday 11:45AM***

Quenching factor measurements

DETECTOR CONDITIONS:

- Neon (+2% CH4) at 500 mbar
- Energy calibration with Fe55 (5.9 keV)
- Use Time of Flight / Onset time cuts and backing Detector PSD cuts to remove background
- Two measurement campaigns performed:
  - 5 - 28 keV_{nr} (analysis ongoing)
  - 0.3 - 6.5 keV_{nr} (analysis ongoing)



Setup at TUNL

→ ***Jean-François Caron:***

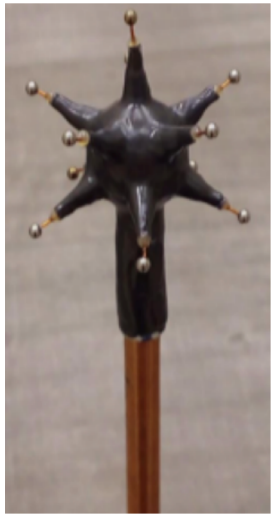
For new setup at Queen's Wednesday Poster

→ ***Marie Vidal : Wednesday 11:45AM***

New generations of sensors

Research done on new sensors to solve various issues:

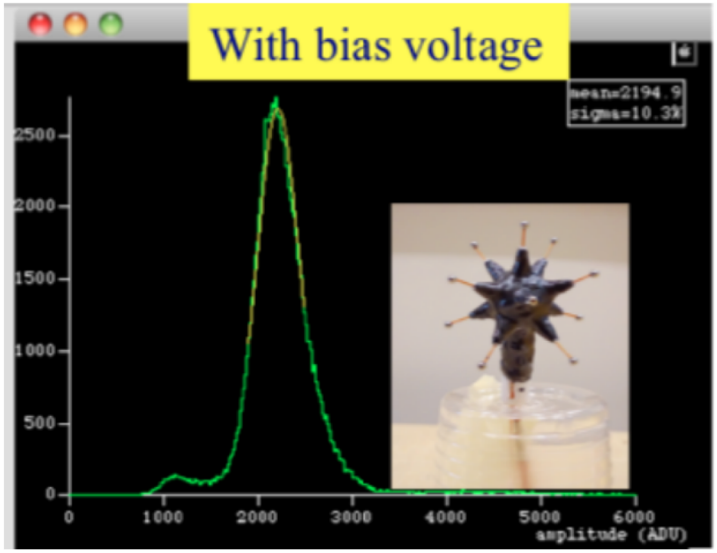
- Improve isotropy of the field / gain
- Improve time stability of detector
- Vary amplification and drift time independently



Solution:

- ACHINOS (Greek for sea urchin) in development: large gain, fast drift time electrode, with potential for directional signal

→ Already shown better resolution than single ball sensor in some setups!

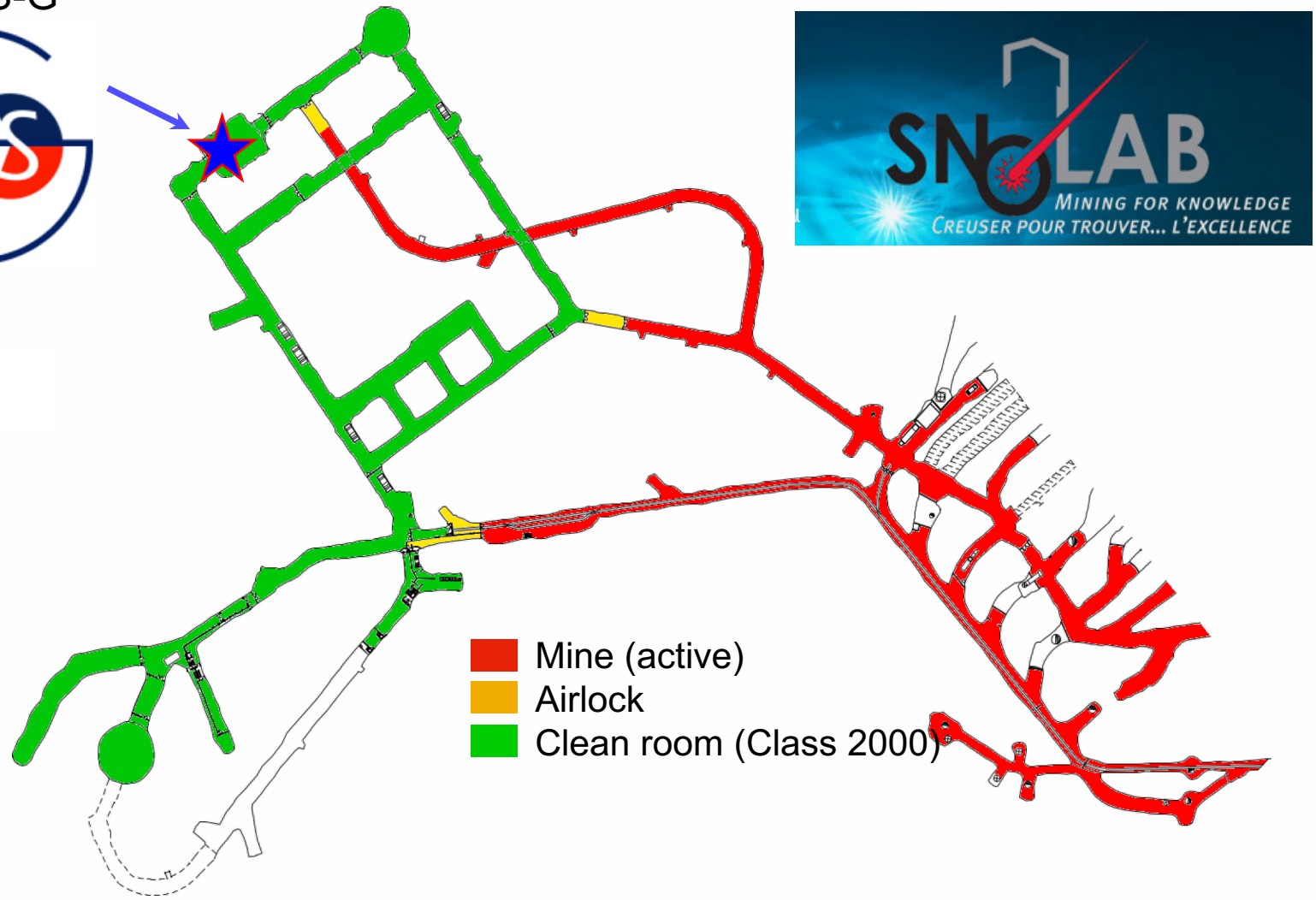


NEWS-G at SNOLAB: Think BIG!

...to be installed in late 2019

2km underground!

NEWS-G

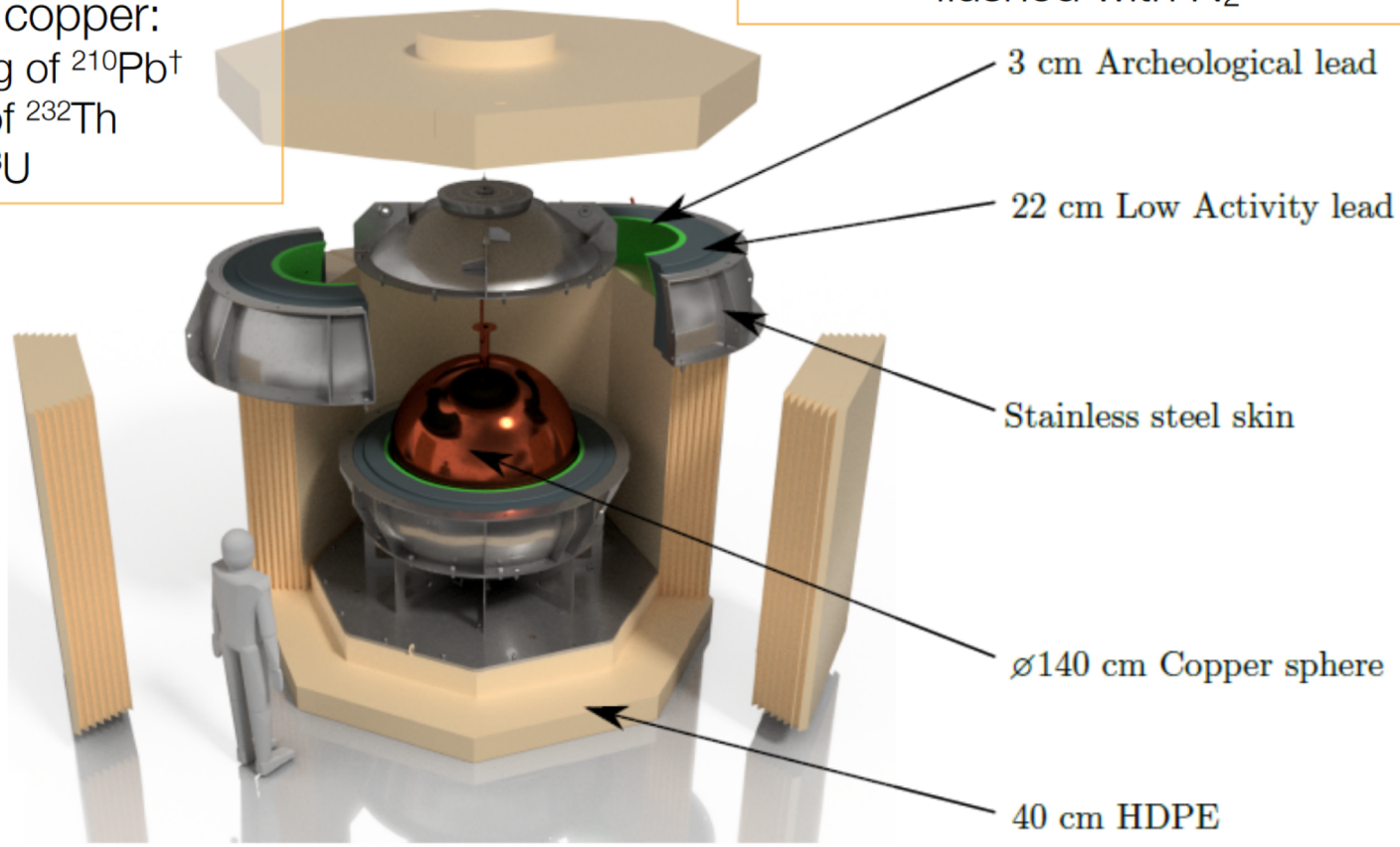


NEWS-G at SNOLAB: Think BIG!

Bigger, better SPC to be installed in SNOLAB!

A 140cm SPC made of low activity C10100 copper:
- »36 ± 13 mBq/kg of ^{210}Pb†
- »7 - 25 μBq/kg of ^{232}Th
- »1 - 5 μBq/kg ^{238}U

Compact Lead and PE shield, flushed with N_2

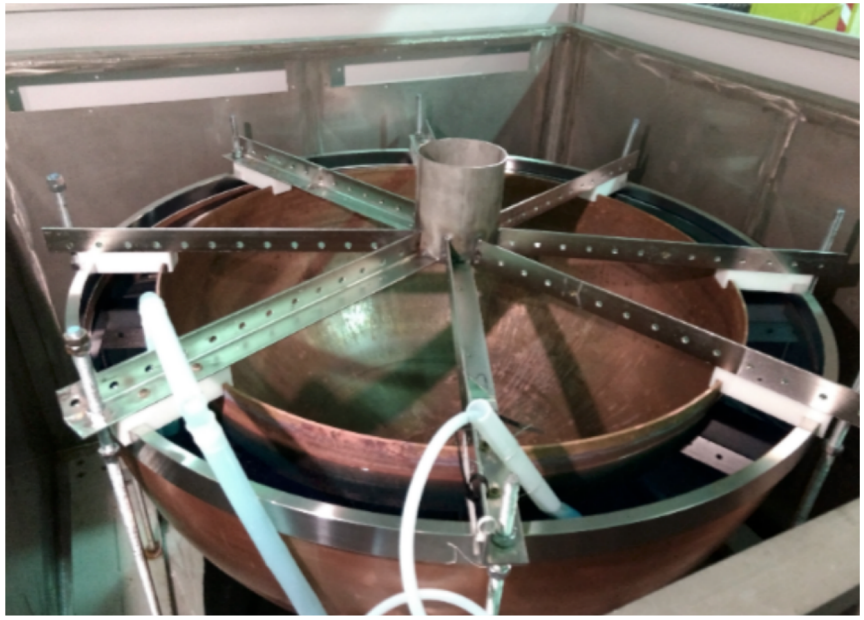


Electropolished and electroplating

- To stop Bremsstrahlung X-rays from ^{210}Pb and ^{210}Bi β-decays in copper, the inner surface of the detector was alternatively electropolished and electroplated

- 0.5 mm pure copper plated on inner surface at LSM in collaboration with PNNL: expected background from ^{210}Pb and ^{210}Bi under 1 keV reduced by 70%

- Detector currently being tested at LSM



NEWS-G: Fabrication progress

The two hemispheres of the SPC are complete

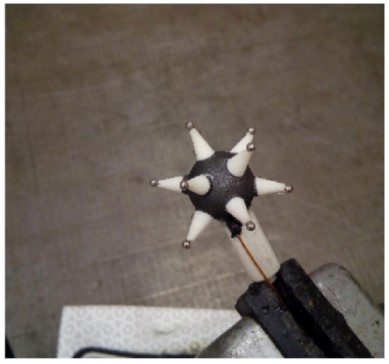
Cleaned, and electron-beam welded

Steel skin of shield, casting of VLA lead nearly complete

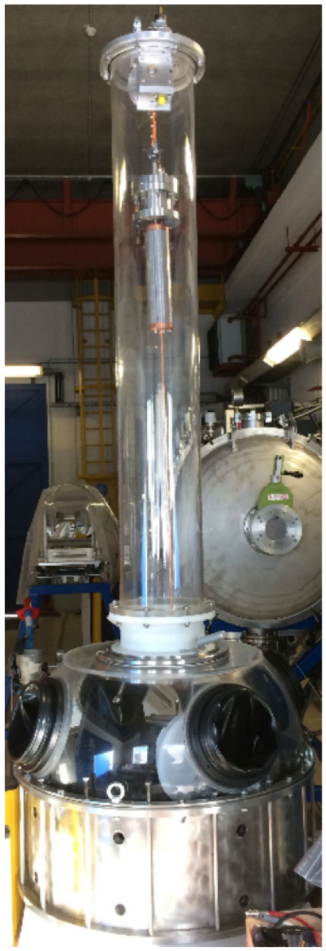
Almost complete: Shield at LSM in June!

Development of multi-electrode sensors

ACHINOS!



Glove-box to store sensor in radon, O_2 free environment: complete!



Next steps and plan

- Detector is already built
- Shields are coming together (end of June)
- New detector currently being tested at LSM
- Tests will run over the summer from July!
- Next: **@ SNOLAB**

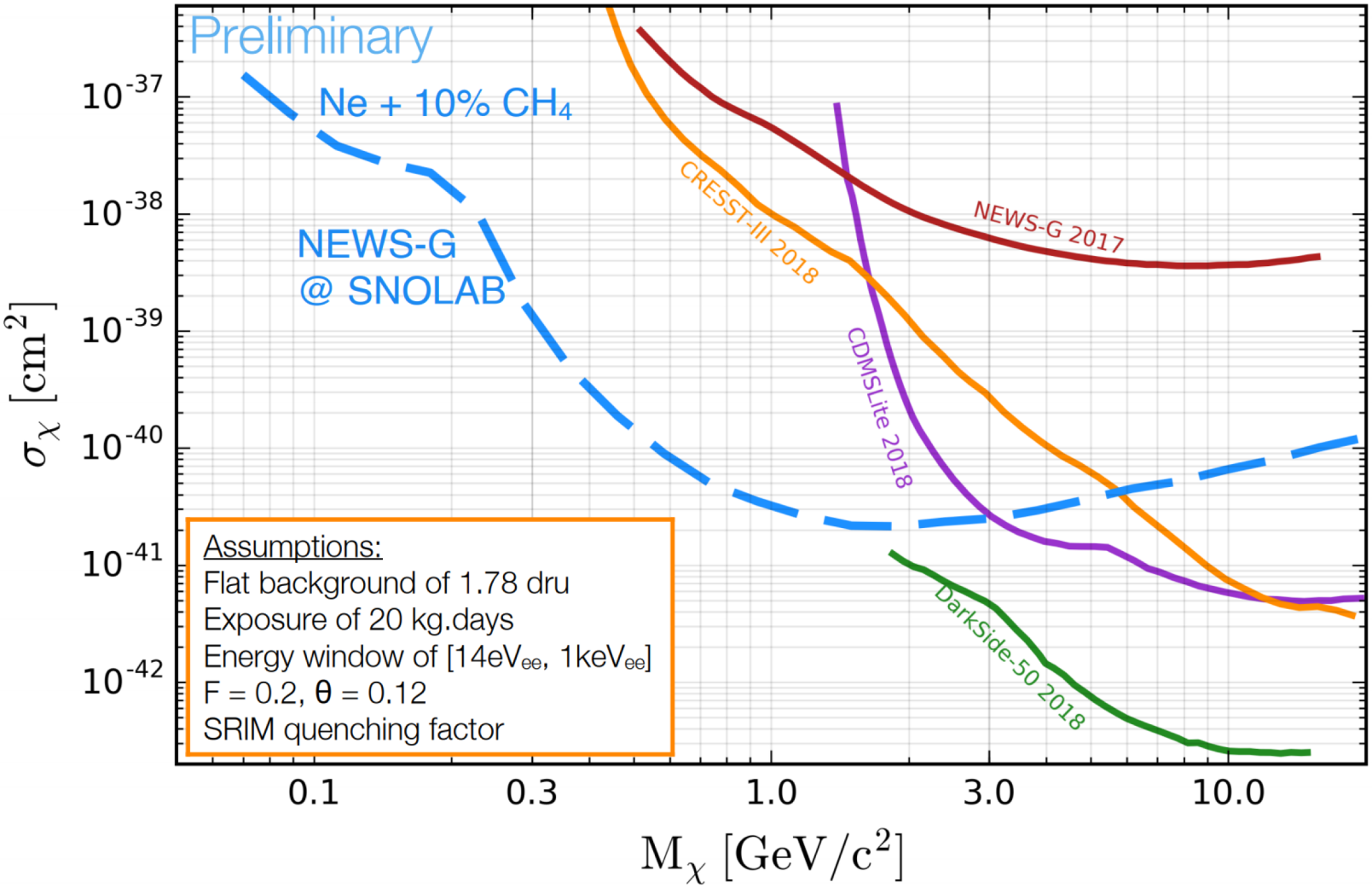
PE Shielding @ UofA

Radon trap @ UofA

Activated charcoal trap
cooled down to -40C,
(design at University of Alberta,
being tested at Queen's University)

Future goal: Projected sensitivity

Installation in SNOLAB to start late 2019



Summary

- SPCs are uniquely adapted for **low-mass Dark Matter detection**.
- The SEDINE detector **has already set competitive** limits under 1 GeV
- R&D in many different exciting directions:
  - → **Laser and ^{37}Ar calibrations** to characterize our detector down to single electron
  - → Quenching measurements **down to 300 eV**
  - → Development of new sensors: **ACHINOS**

- A **new, larger, cleaner** detector is coming to SNOLAB. Detector is already built, shields are coming together
  - → New detector **currently being tested at LSM**, tests will run over the summer
  - → **SNOLAB run by the end of the year!**

NEWS-G Collaboration

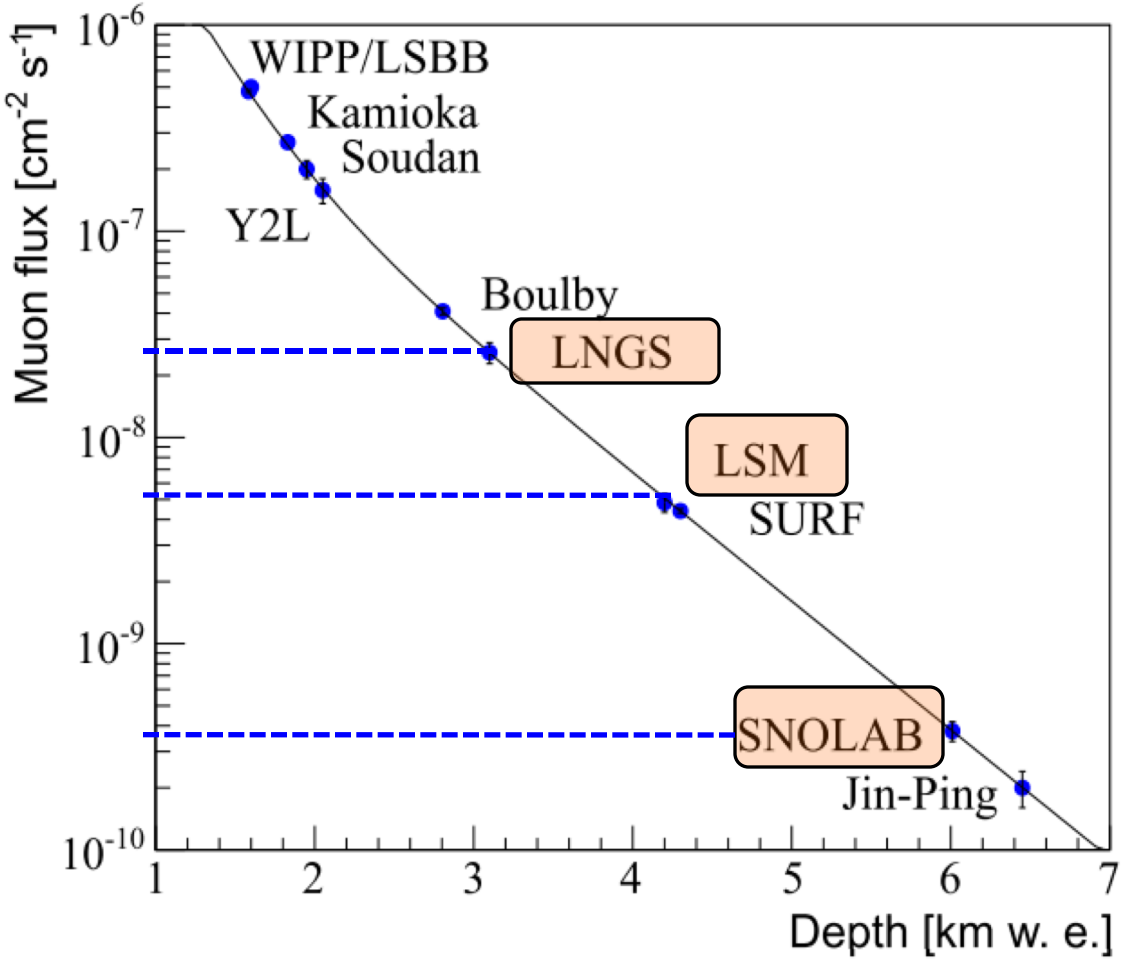
- **Queen's University Kingston – G Gerbier,** P di Stefano, R Martin, G Giroux, S Crawford, M Vidal, G Savvidis, A Brossard, P Vazquez dS, , K Dering, J Mc Donald, M Chapellier, P Gros, A Rolland, C Neyron
  - Copper vessel and gas set-up specifications, calibration, project management
  - Gas characterization, 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

NEWS-G at SNOLAB: Background

		Contamination / flux	Counts / keV / kg / day < 1 keV	Counts / keV / kg / day in [1 ; 5] keV	Rate [mHz]
Copper sphere (500 μm electrolytic inside)	^{210}Pb	36 mBq/kg	1.34	1.2	1.14
	^{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*	*0.013*	*0.061*
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			1.992	1.678	2.802

Underground laboratories

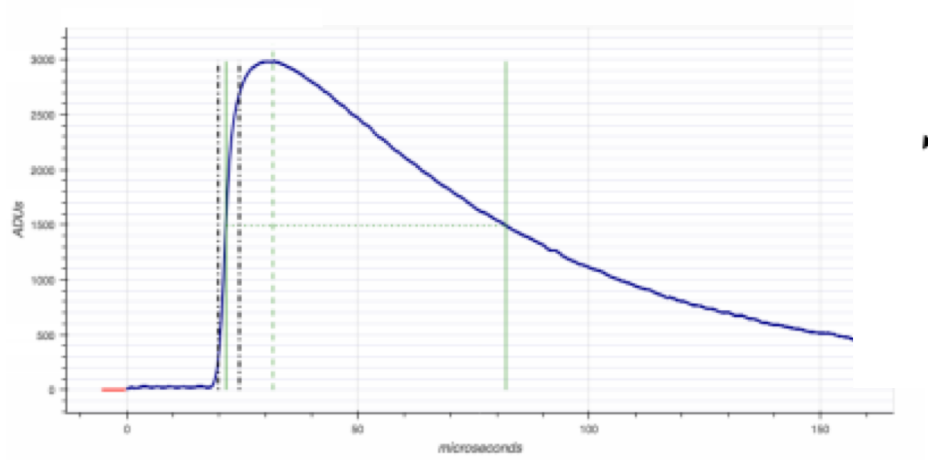
- Cosmic rays & cosmic activation of detector materials



NEWS-G: Detector principle

NEWS-G EXPERIMENT:

- Primary ionization
- Drift of primary e- towards sensor
- Avalanche in the vicinity of the anode
- Signal formation
  → Current induced by the ions



Raw pulse