NEWS-G, a spherical TPC with low-A target to search for sub-GeV mass WI(M)Ps

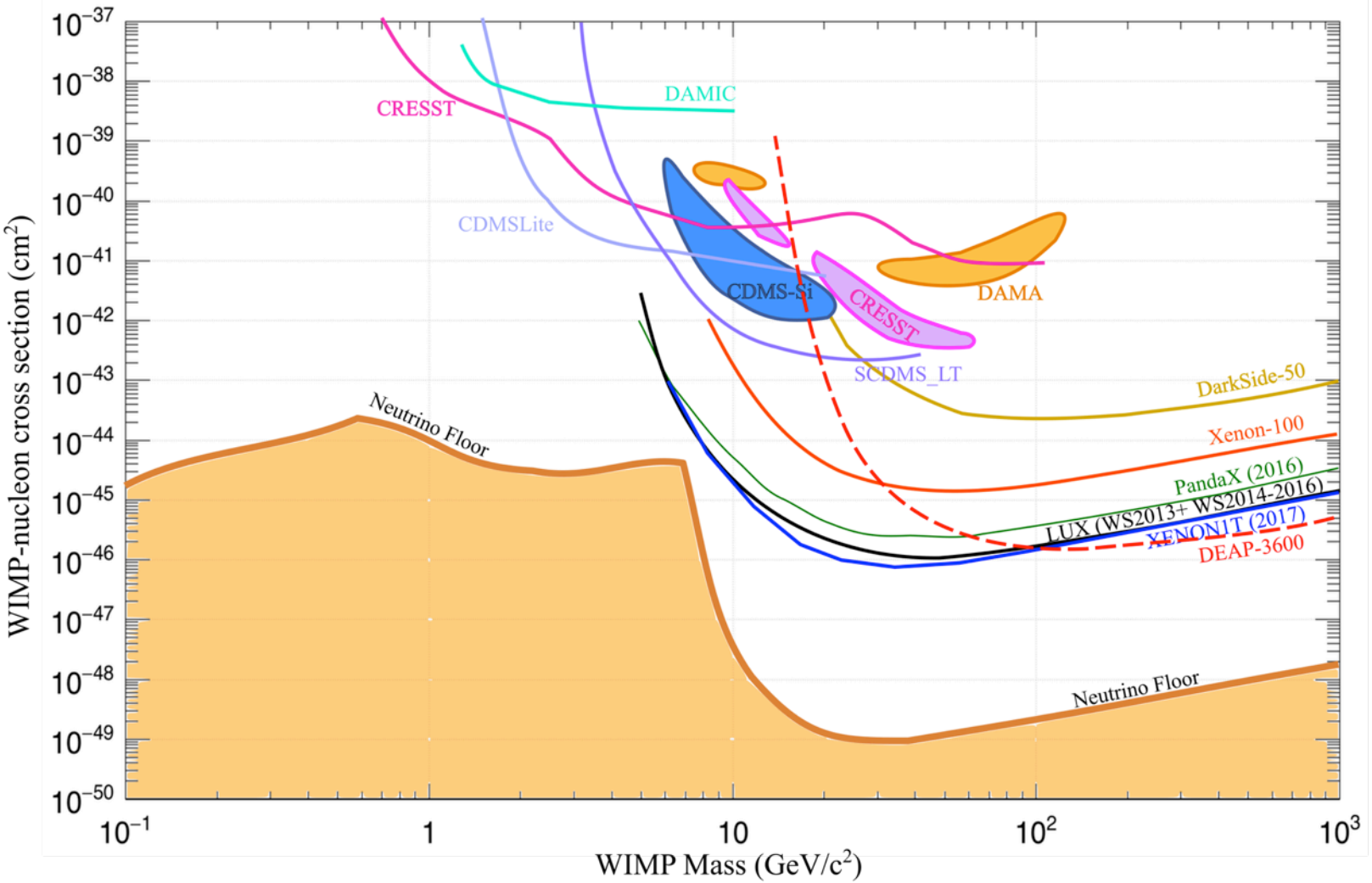
Pierre Gorel, SNOLAB future projects 2017

Collaboration

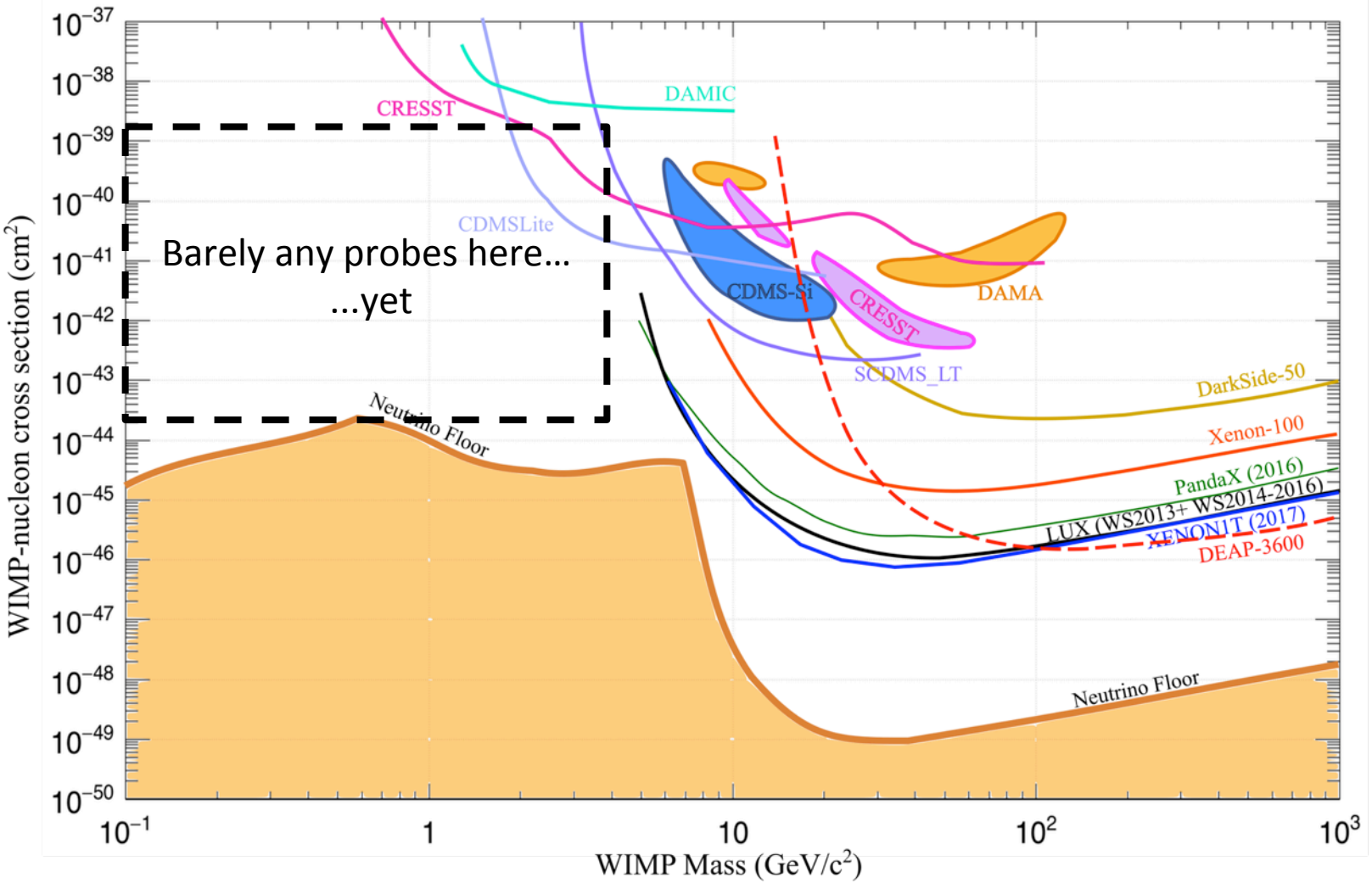
- **Queen's University** – G Gerbier, P di Stefano, R Martin, T Noble, G, Giroux, A Brossard, P Vasquez dS, Q Arnaud, K Dering, J Mc Donald, M Clark, M Chapellier
  - Copper vessel and gas set-up specifications, calibration, project management
  - Gas characterization, laser calibration, on smaller scale prototype
  - Simulations/Data analysis
- **University of Birmingham** – K. Nikolopoulos, P Knight
  - Simulation and R&D
- **Institut de Recherches sur les Lois Fondamentales de l'Univers** – I Giomataris, M Gros, C Nones, I Katsioulas, T Papaevangelou, JP Bard, JP Mols, XF Navick,
  - Sensor/rod (low activity, optimization with 2 electrodes)
  - Electronics (low noise preamps, digitization, stream mode)
  - DAQ/soft
- **Laboratoire Souterrain de Modane/Université de Chambéry** – F Piquemal, M Zampaolo, A Dastgheibi-Fard
  - Low activity archeological lead
  - 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
- **Laboratoire de physique Subatomique et Cosmologie** – D Santos, JF Muraz, O Guillaudin
  - Quenching factor measurements at low energy with ion beams
- **Technical University Munich** – A Ulrich, T Dandl
  - Gas properties, ionization and scintillation process in gas
- **Pacific Northwest National Laboratory** – E Hoppe, D Asner, R Bunker
  - Low activity measurements, Copper electroforming
- **Royal Military College Canada** – D Kelly, E Corcoran
  - 37 Ar source production, sample analysis
- **SNOLAB** – P Gorel
  - Calibration system/slow control
- **Associated lab : TRIUMF** - F Retiere
  - Future R&D on light detection, sensor

Aug 2017

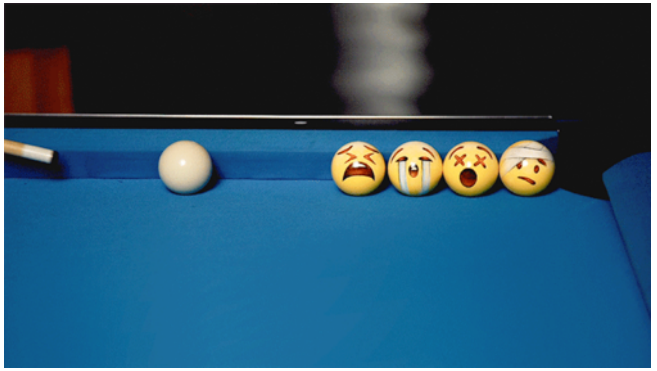
State of the art of WIMP search



Nothing seen at high mass? Let's look for lighter WIMPs



Detection of low mass particle

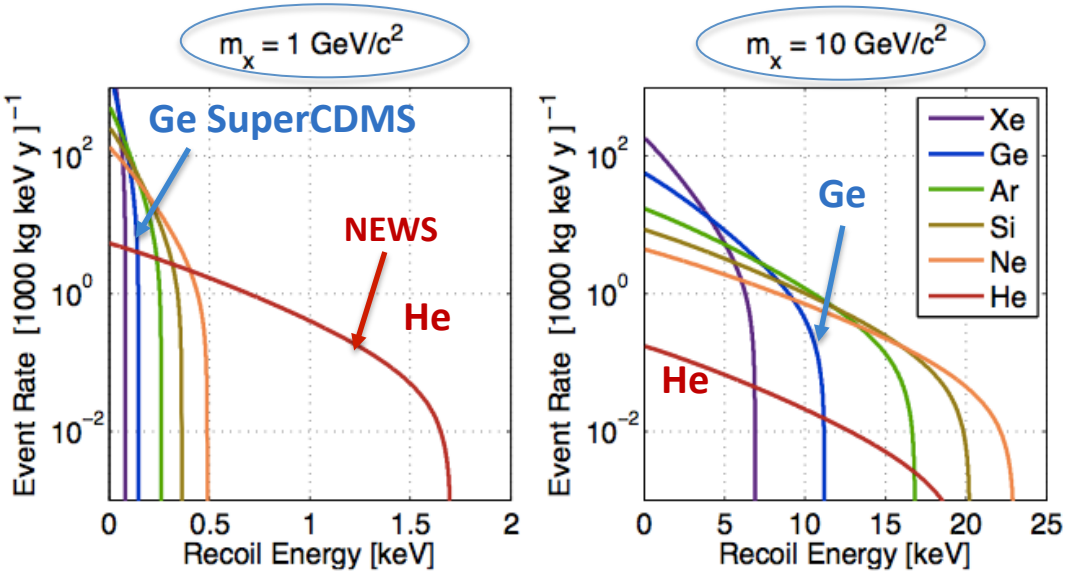


- Maximize momentum transfer

=> use light nuclei to detect light particle

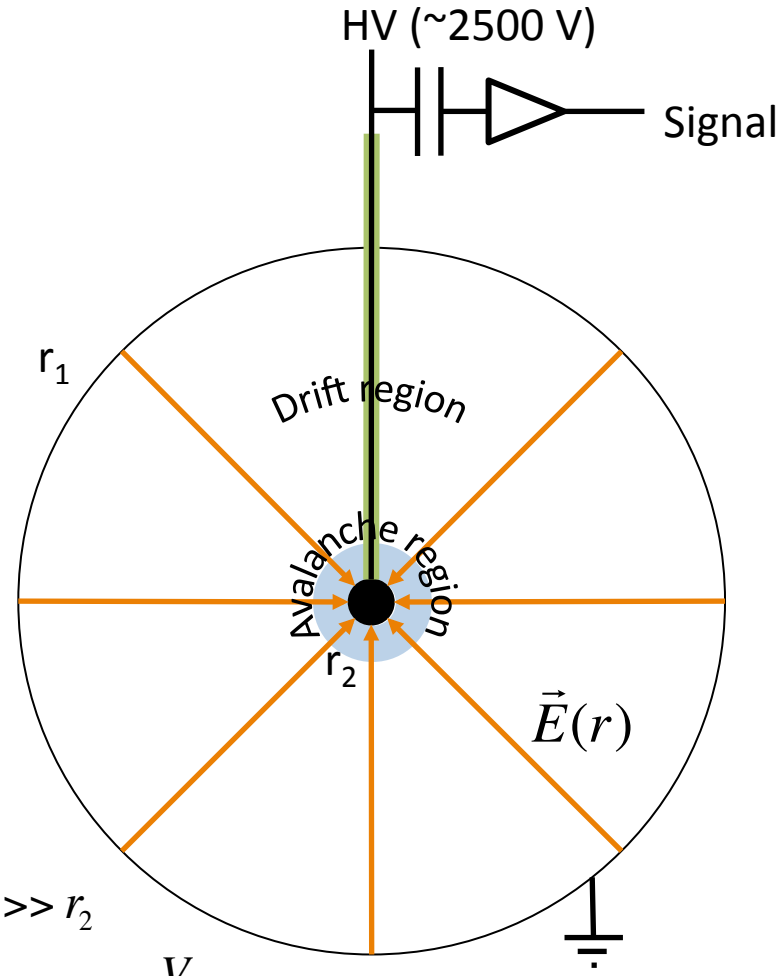
(proton mass: 0.938 GeV)

- H, He, Ne lightest among noble gas



Recoil distributions with various targets material

New Experiments With Spheres (Gas)



$r_1 >> r_2$

$$\Rightarrow E(r) \approx \frac{V_0}{r^2} \times r_2$$

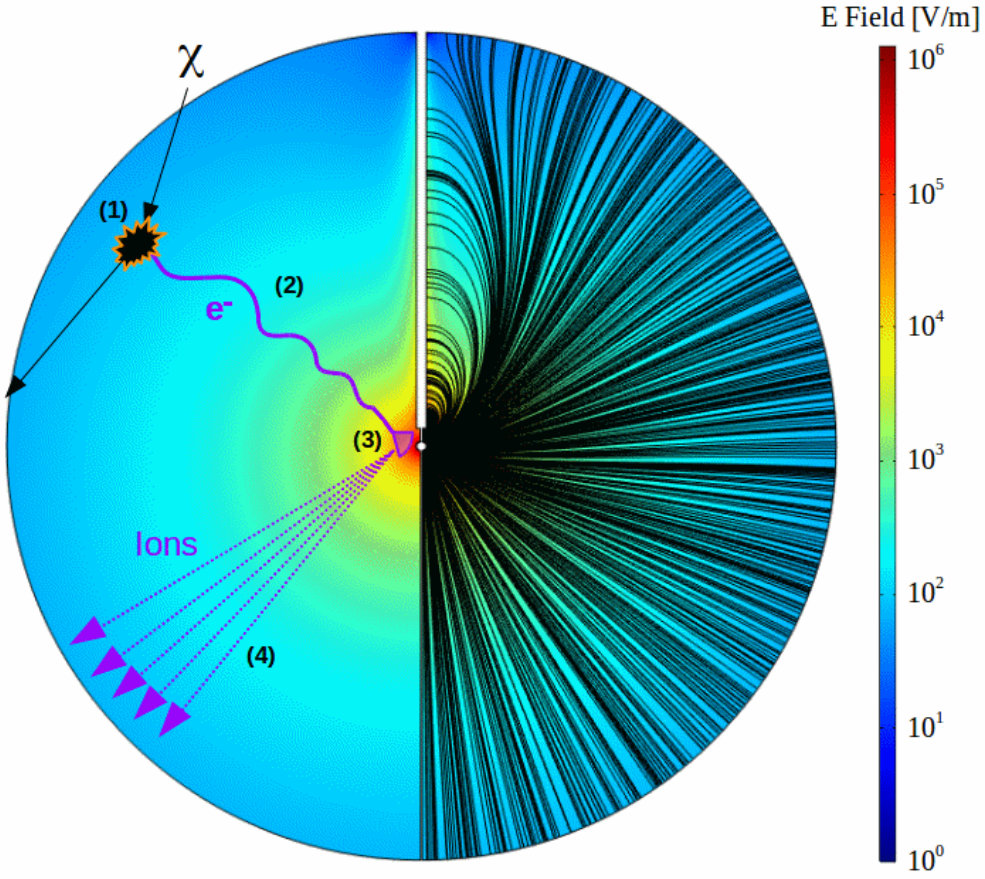
$$\Rightarrow C \approx 4\pi\varepsilon r_2 \sim 0.1pF$$

- Spherical detector
- Single electrode
- Spherical proportional counter/ TPC
- **Flexible (Pressure, gas)**

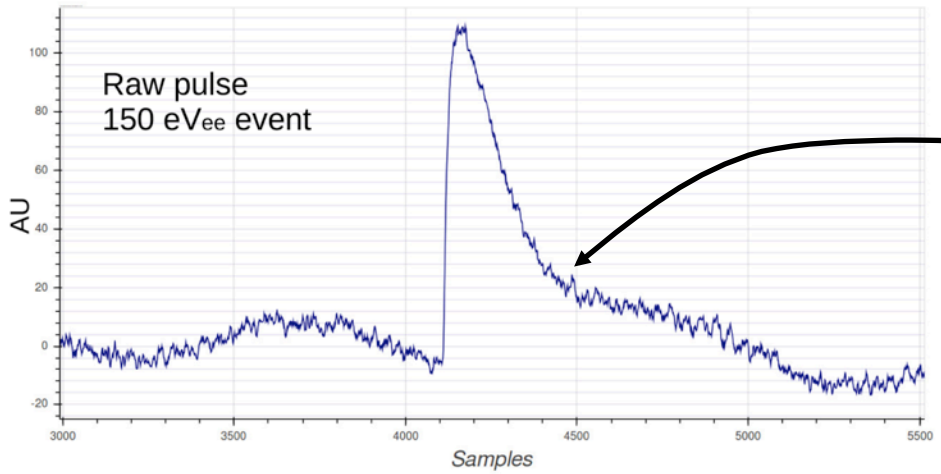
➢ Low threshold ~50 eV_{ee} <u>independent on sphere radius</u>

➢ Large mass / large volume (~30 kg) with single channel

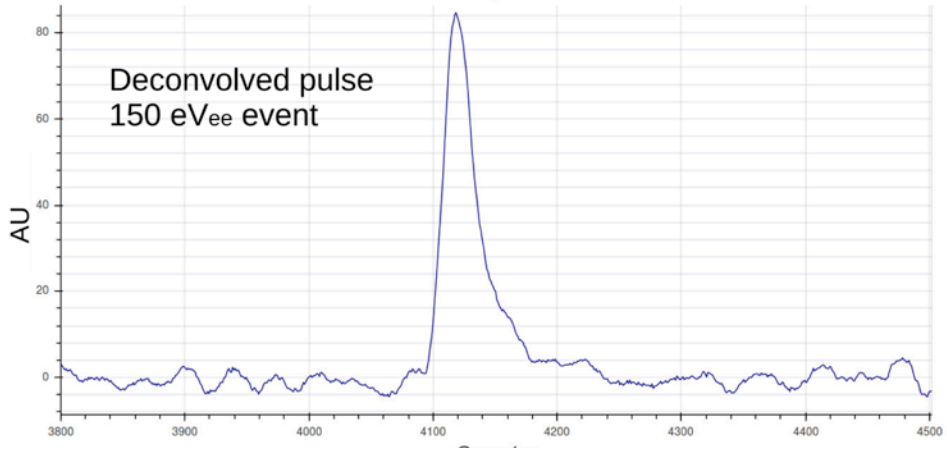
Signal generation



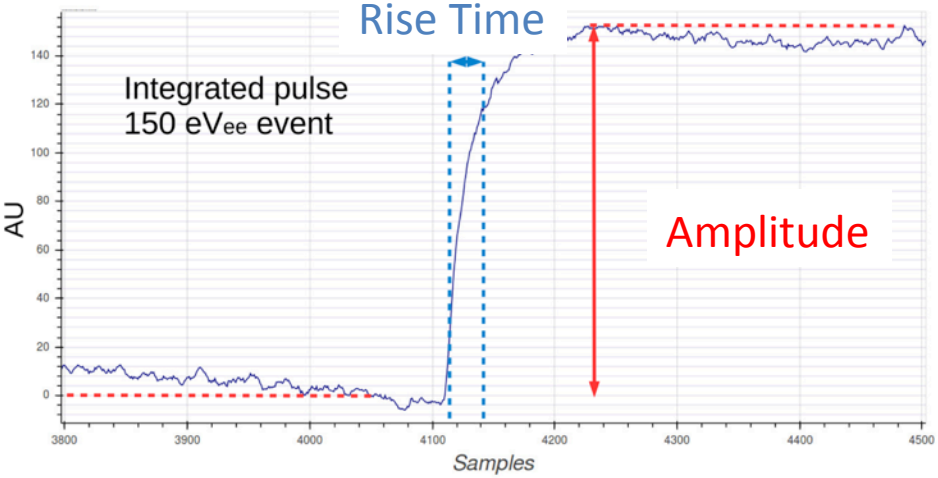
1. Primary electron(s)
2. Electrons drift
3. Avalanche
4. Secondary Ions drift



Charge sensitive pre-amplifier
→50μs time constant



1) Deconvolution by exponential decay



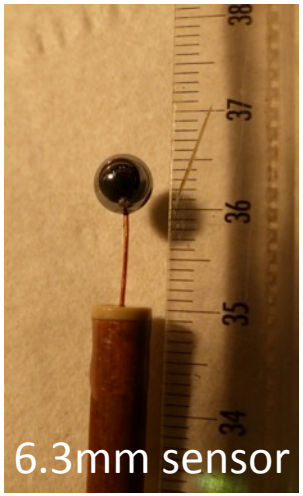
2) Low-pass filter+ integration
Amplitude → Energy
Rise Time → Radius (fiducialization)

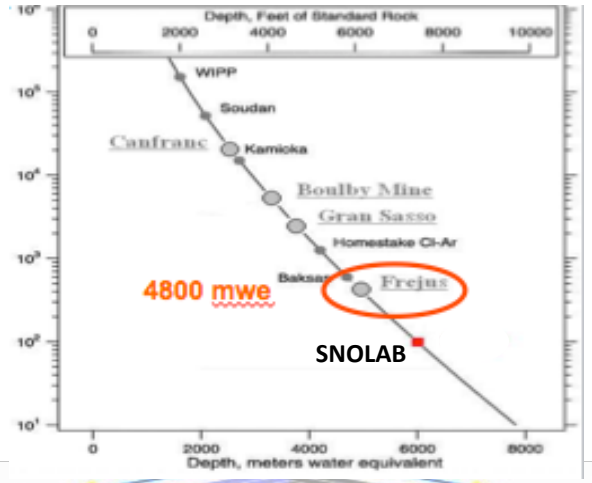
Low activity 60 cm Ø prototype @ **LSM : SeDiNe**

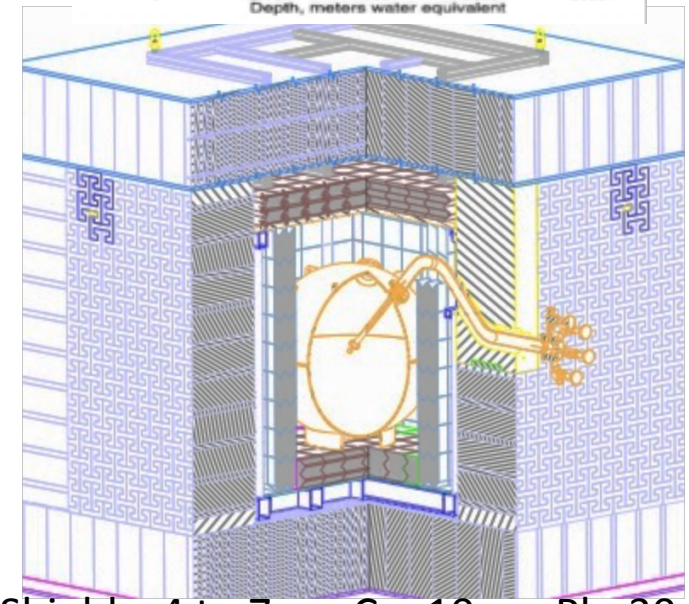
Laboratoire **S**outerrain de **M**odane

- Copper vessel equipped with 6 mm Ø sensor
- Runs with **Neon**+0.7%CH_4 @ 3.1 bars
  => 310 g sensitive mass
- Several internal cleanings for radon deposit removal
- 42 days run for WIMP search


60 cm NOSV Cu vessel


6.3mm sensor

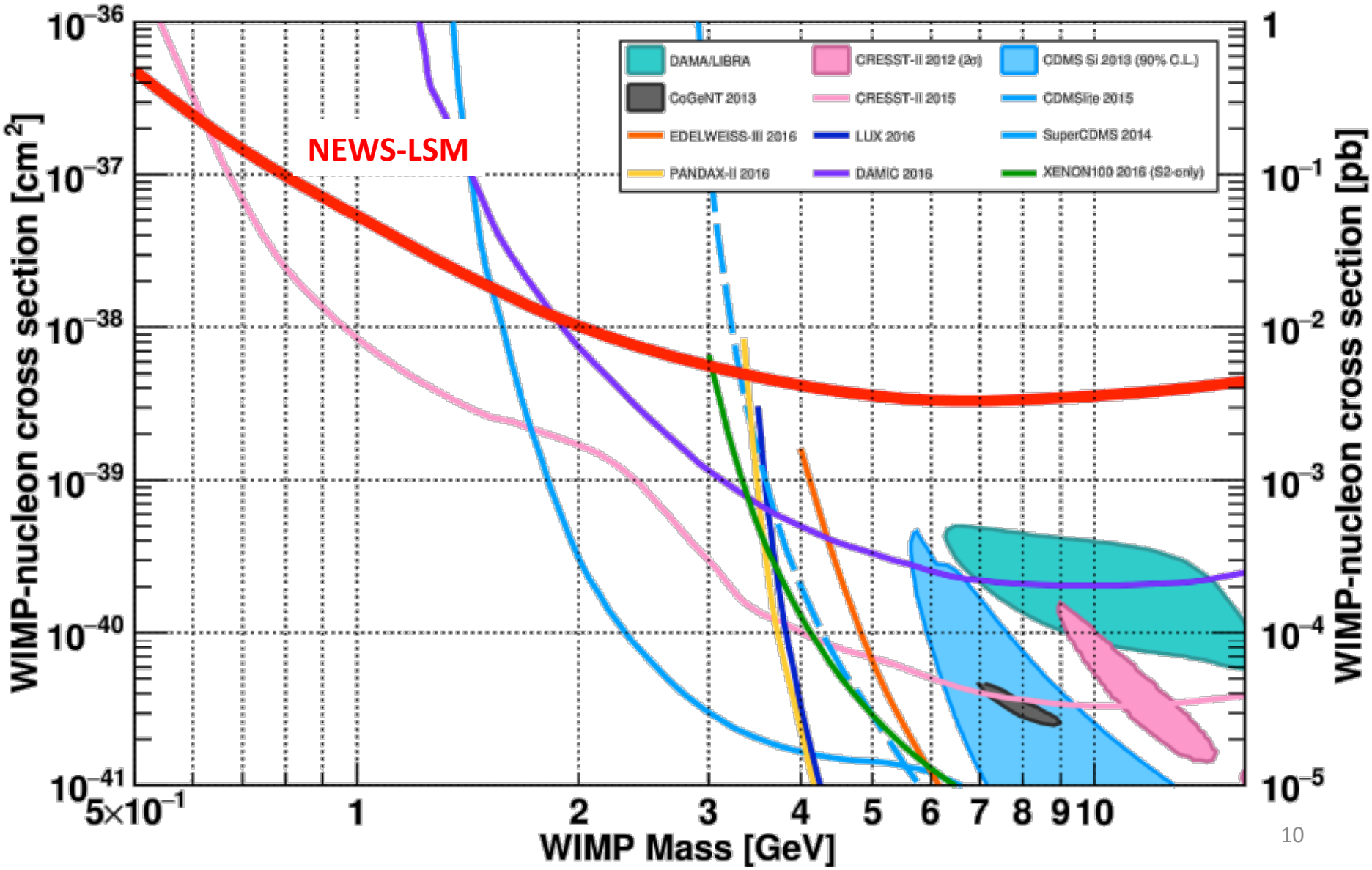




Shields: 4 to 7 cm Cu, 10 cm Pb, 30 cm PE

9.7kg.day with Ne

Arxiv: 1706.04934 (Submitted to Astroparticle Physics)



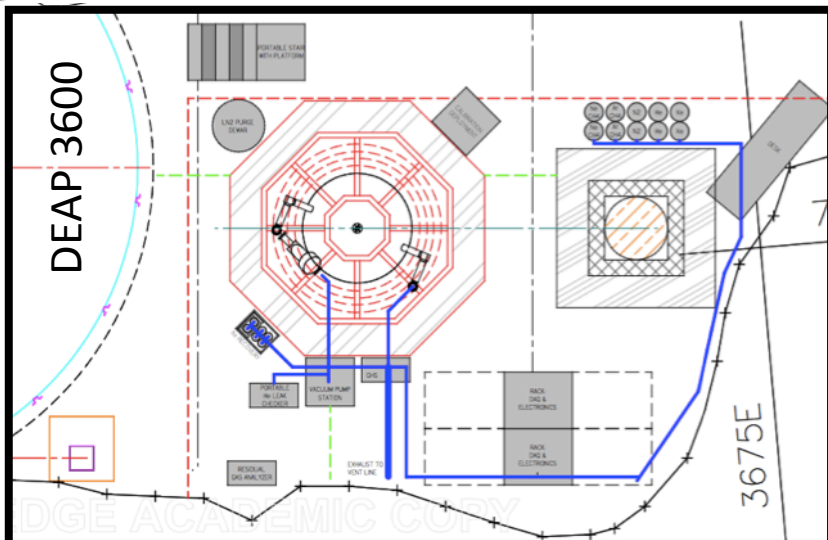
Experiment
Support
Logistic/utilities
Available
Access

SNOLAB

NEWS-G (in CubeHall)

6000 mwe

0.27 muon/m²/d

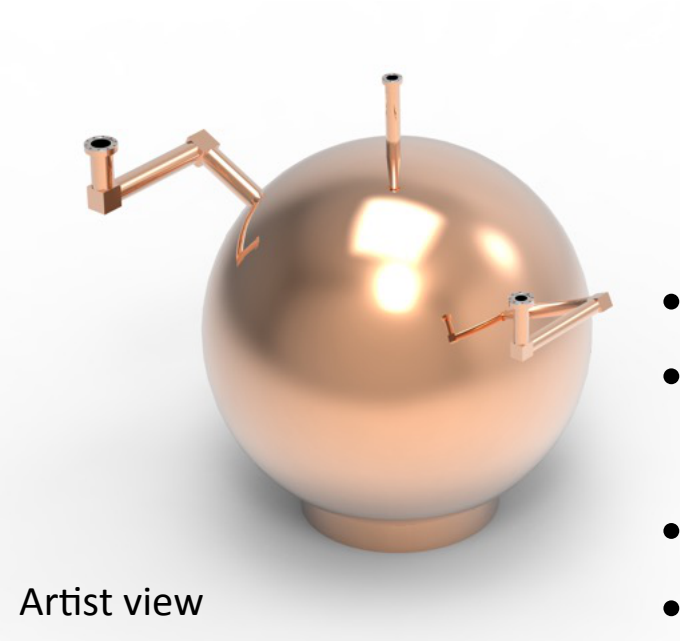


Background budget (simulation)

12mm thick, Ø140cm copper sphere. Ne+CH4(1%), 11.43kg of gas
Hypothesis for WIMP sensitivity limit calculation : 100 kg.d, 1 electron threshold

Source Position	Qty	Source	Contamination	Units	Evt/kg/day <1keV
Copper	627.83 kg	^{60}Co	30	µBq/kg	0.054
Copper	627.83 kg	^{238}U	3	µBq/kg	0.011
Copper	627.83 kg	^{232}Th	12.9	µBq/kg	0.063
Inner surface	57255 cm^2	^{210}Pb	1	nBq/cm^2	0.012
Arch Lead	2108.95 kg	^{238}U	61.8	µBq/kg	0.062
Arch Lead	2108.95 kg	^{232}Th	9.13	µBq/kg	0.010
Rod	0.0932 kg	^{60}Co	30	µBq/kg	0.000
Rod	0.0932 kg	^{238}U	3	µBq/kg	0.000
Rod	0.0932 kg	^{232}Th	12.9	µBq/kg	0.000
Wire	2.66x10^{-5} kg	^{60}Co	31000	µBq/kg	0.000
Wire	2.66x10^{-5} kg	^{238}U	3x10^5	µBq/kg	0.001
Wire	2.66x10^{-5} kg	^{232}U	5x10^4	µBq/kg	0.000
Wire	2.66x10^{-5} kg	^{40}K	166x10^4	µBq/kg	0.001
Lab		^{208}Tl/^{40}K			0.076

Total: 0.289 evts/kg/day < 1keV


Artist view

Copper sphere

- Ø140 cm, 12mm thick
- 10 bars: Ne, He, CH_4

- Sphere fabrication: spinning
- Low activity copper (C10100) located
  - Activity measured @PNNL

    ⇒7 to 25 μBq/kg of Th

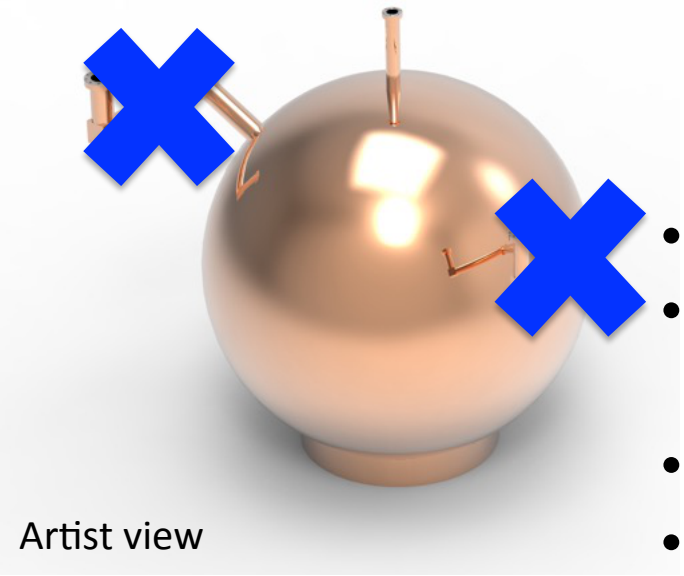
    ⇒1 to 5 μBq/kg of U

    } Within specs

- Initial project of water jet cleaning non-practical
  - ➢ Acid etching @LSM
  - ➢ R&D for copper electroplating (PNNL)


Copper spinning test (July 2016)

Last revision: gas exchange through neck



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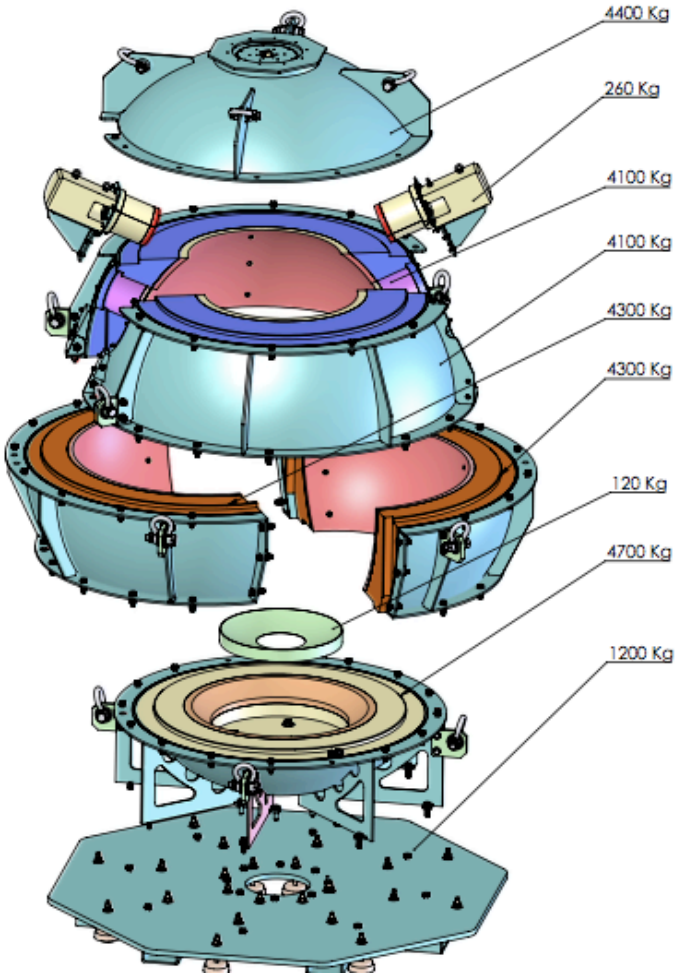
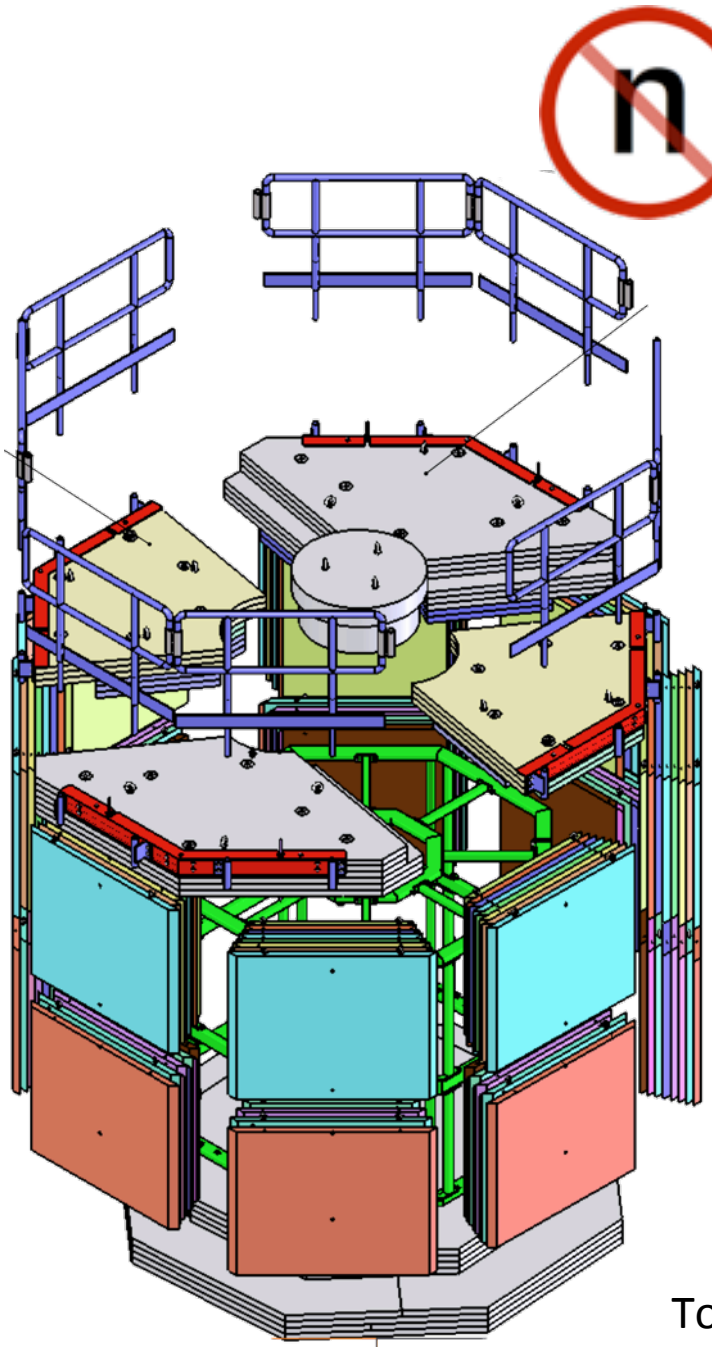
Copper spinning test (July 2016)

Compact lead shield



- Thickness : min 25cm
  - Inner layer : 3cm archeological lead (LSM)/
  - Outer layer: low activity lead.
- Design: Fonderies de Gentilly
  - Oversight by LSM & Queen's (+SNOLAB feedback)

Total weight : ~27 tons



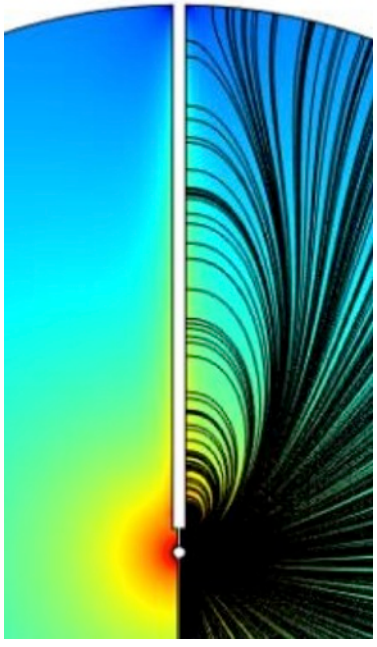
Polyethylene shield

- HD Polyethylene Slabs
- Stainless steel support

- Design: Fonderies de Gentilly
  - Oversight by LSM & Queen's (+SNOLAB feedback)

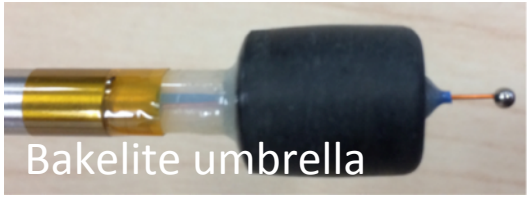
Total weight : ~14 tons

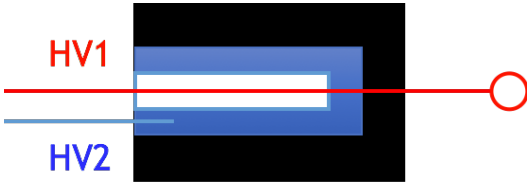
Sensors R&D



- Sensor support disturbs the field

➔ “umbrella” to counter the effect.





Effect of HV2, geometry…

- Single channels “achinos” for optimization amplification & drift field ➔ First tests promising
- Multi channels sensors (segmentation)

- Different materials: Si, Bakelite, Cu powder…

Calibration program

- ^{37}Ar: Low energy, “volume” events
  - Injection through gas system

- Laser : Low Energy, “surface” events
  - Fibre going down the neck

- External sources:
  - AmBe (Nuclear recoil & neutron capture)
  - ^{22}Na (High energy gammas)
  - Insertion tube through the shields

^{37}Ar

Production: $^{40}Ca + n \rightarrow {}^{37}Ar + \alpha$

Half-life: 35 days

Electron capture ➔ X-rays: 270 eV & 2.82 keV

Unique challenges:

- Clean production/extraction
- Material activation
- Assay of the production

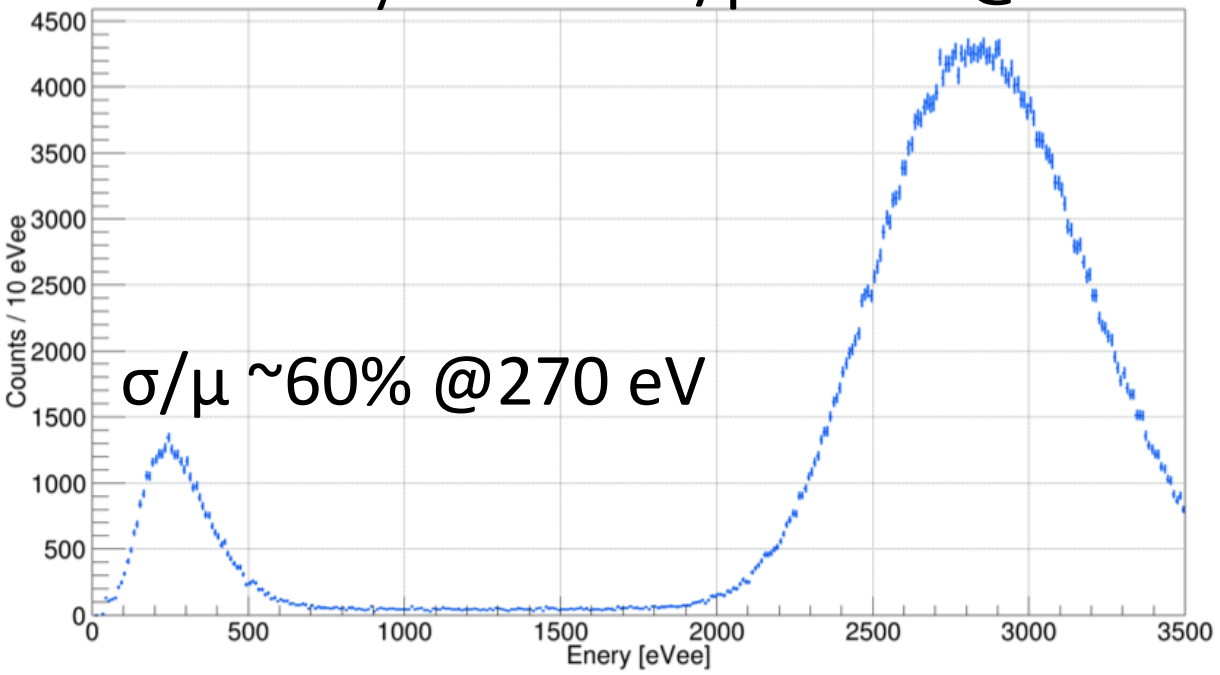
First delivery, May 2017 !

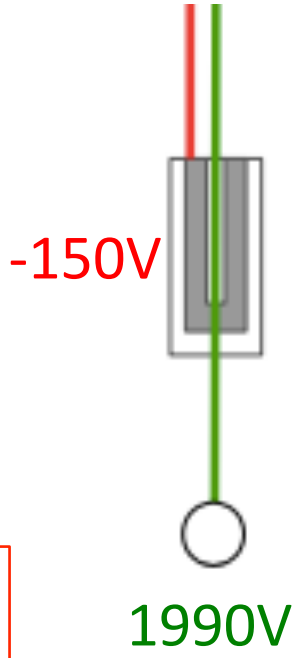
Clean transportation canister

^{37}Ar on prototype 30cm sphere

Preliminary !

σ/μ ~20% @2.82 keV





Gas mixture: Ar+CH_4 (2%)

Online trigger: 10 eV (~ 0.3 primary e^-)

Analysis threshold: 50 eV

Calibration program

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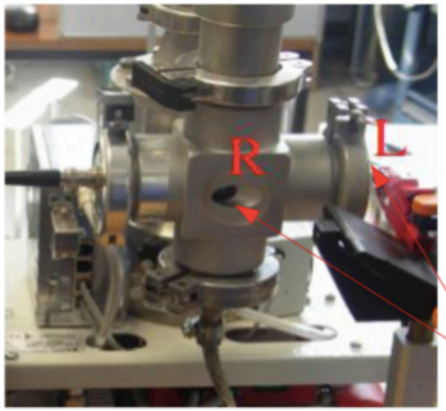
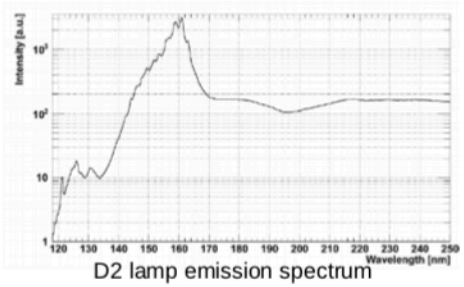
Measurements of work function in Copper/ Steel as function of UV wavelength

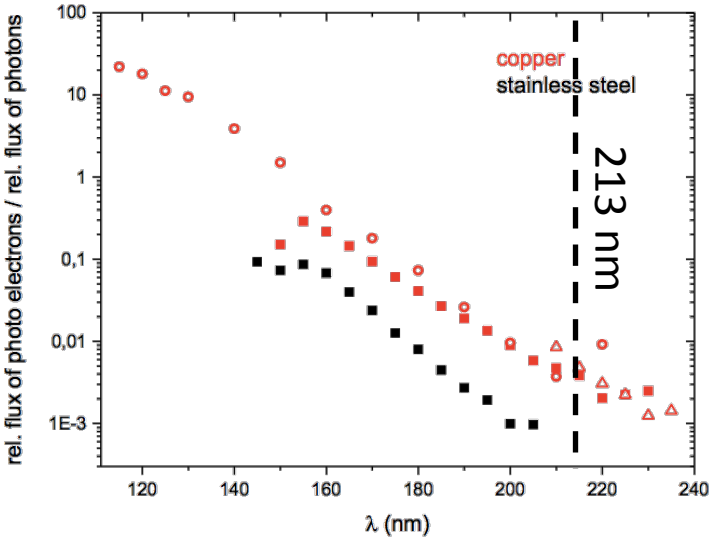


Test cell under vacuum (E-06 Pa)



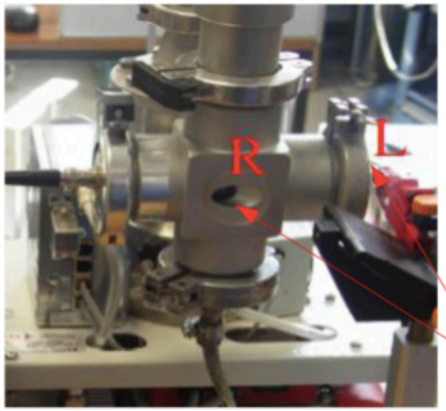
D2 lamp emission spectrum

Optical ports for light injection



- Allowed to size the power and wavelength of laser

Surface events calibration



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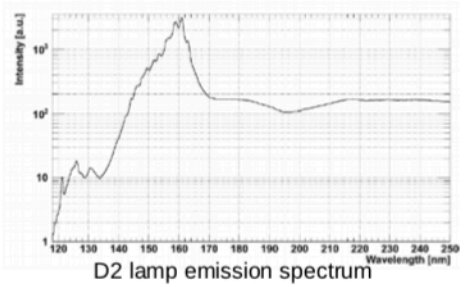
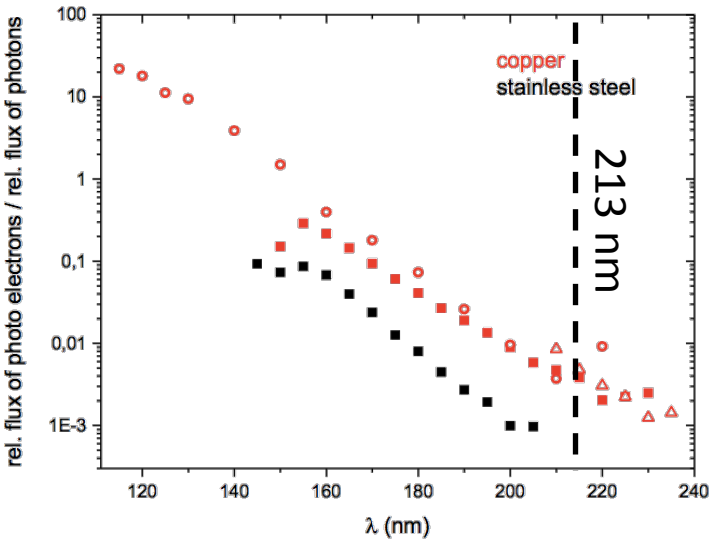


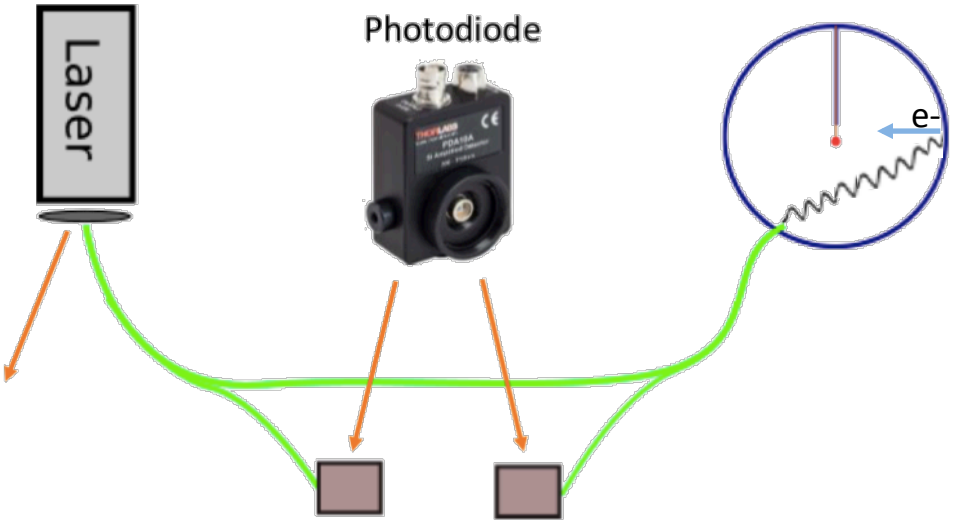
D2 lamp emission spectrum

Optical ports for light injection



0.5 mJ @213 nm

Changeable neutral density filters

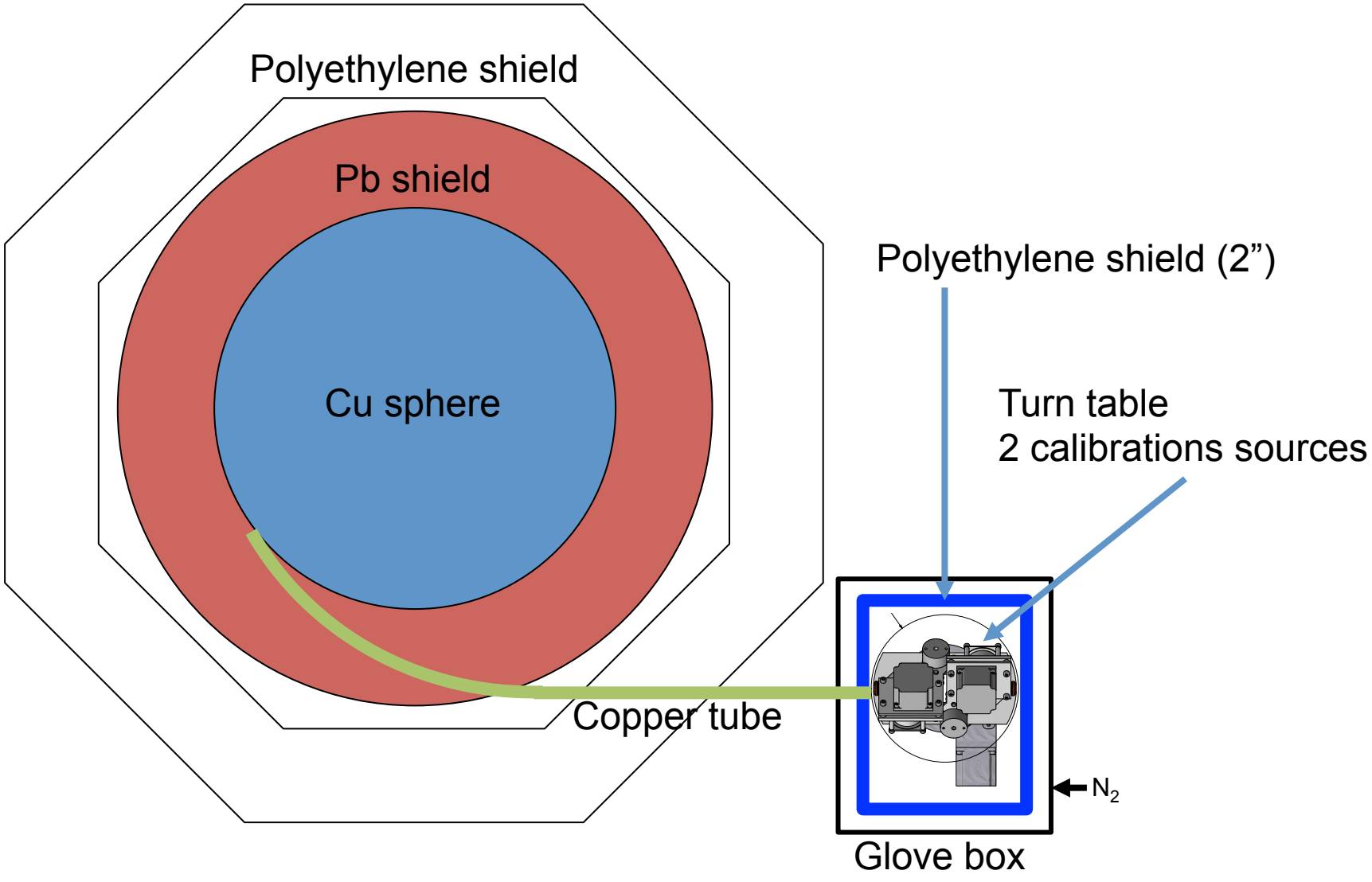


- Allowed to size the power and wavelength of laser
- Principles of control of input light and aging of fibers with photodiodes

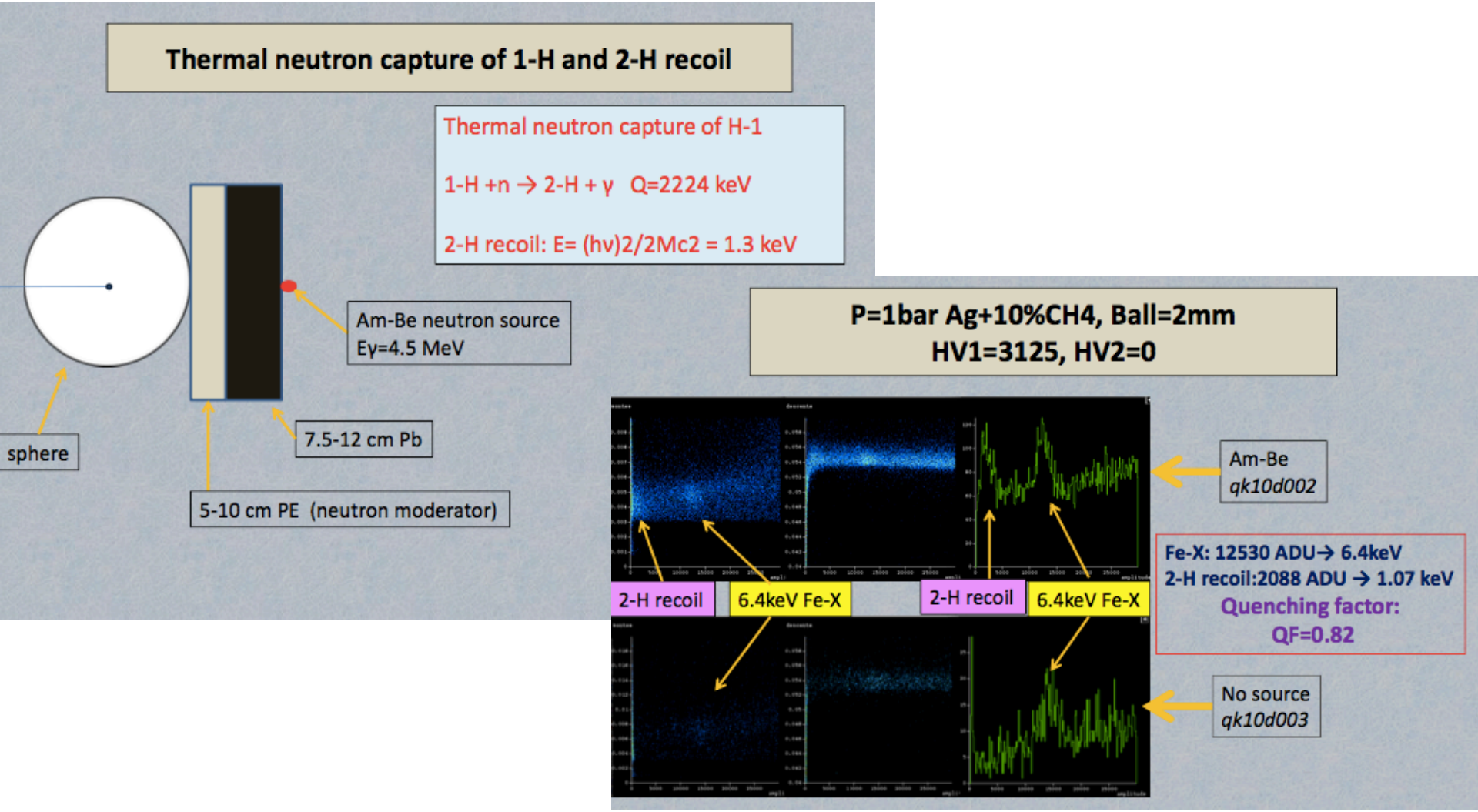
Calibration program

- ^{37}Ar: Low energy, “volume” events
  - Injection through gas system
- Laser : Low Energy, “surface” events
  - Fibre going down the neck
- External sources:
  - AmBe (Nuclear recoil & neutron capture)
  - ^{22}Na (High energy gammas)
  - Insertion tube through the shields

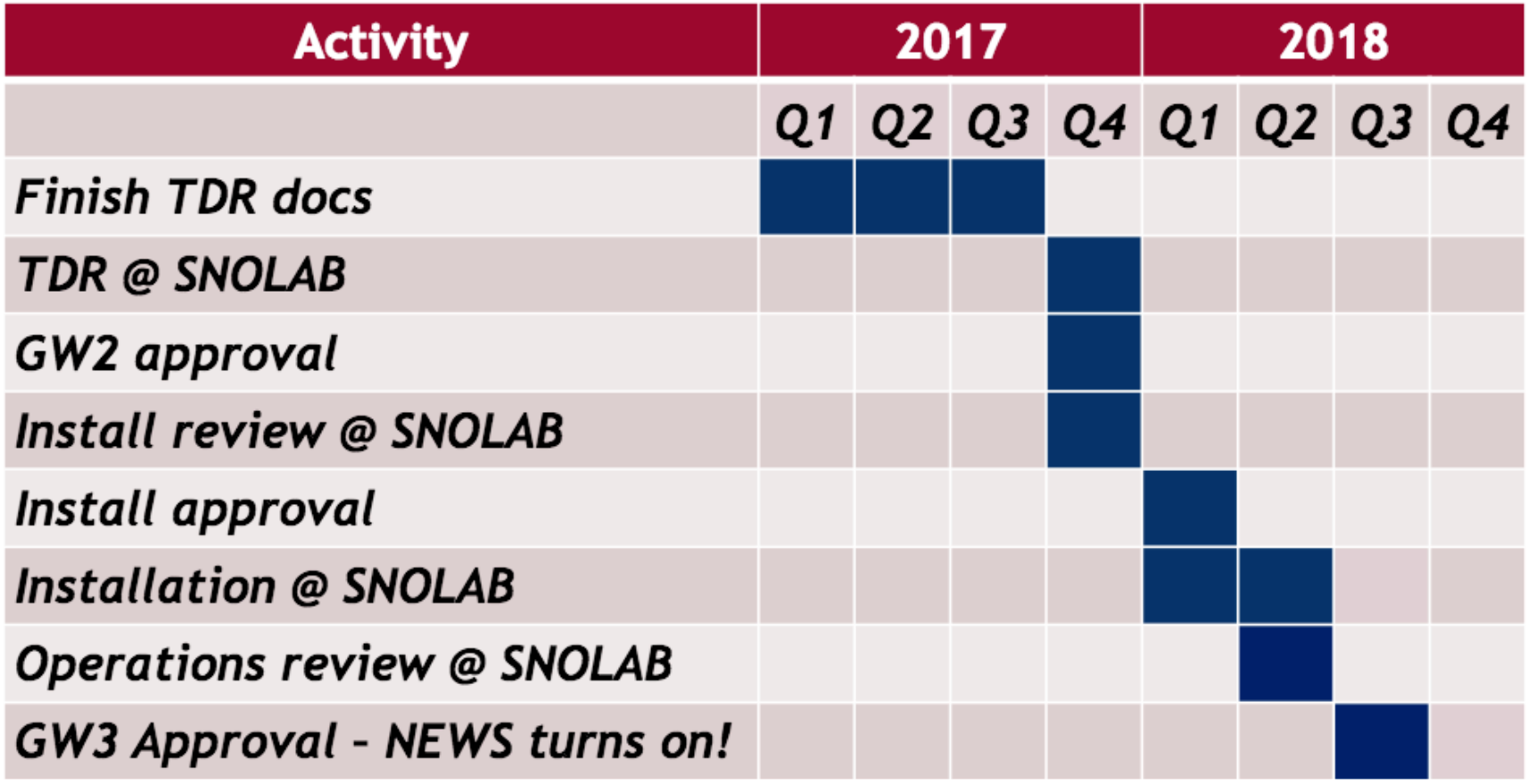
Source deployment through shield



Measurement of quenching of ^{2}H recoil: 1.3 keV in Ar



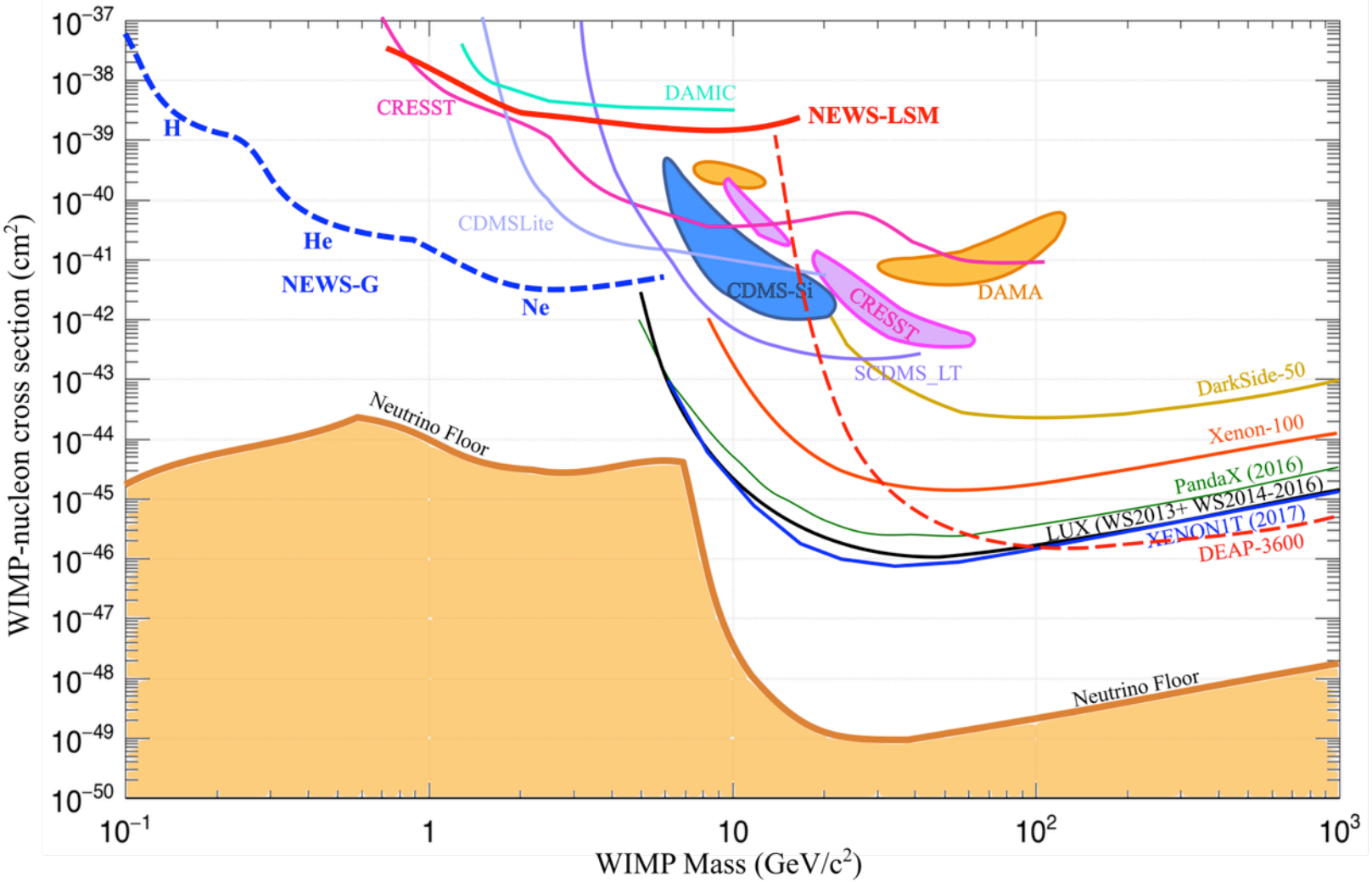
Timeline (as of April 2017)



Update: TDR review requested for 2018, Q1

NEWS-G expected sensitivity

100 kg-day, 1 electron threshold



Longer term evolution of the project

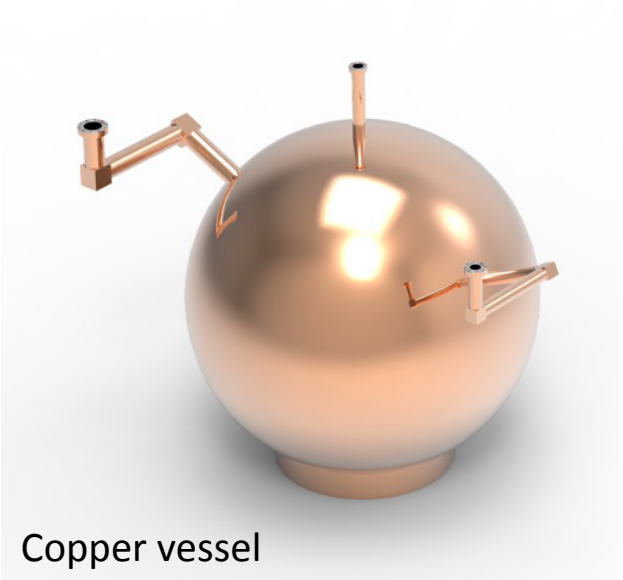
- Electroforming copper (PNNL)
  - Decrease ^{60}Co and U/Th by more than 10
  - Funding for 30cm prototype.
- Directionality
  - Low pressure (longer tracks)
  - Segmented Achinos

BACKUP

Work packages

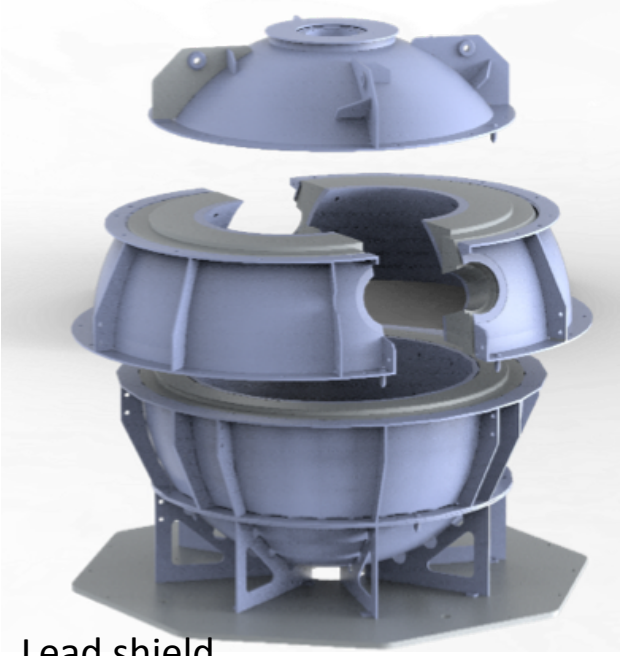
		Leader	Deputy
WP0	Governance: Science Collaboration, Project	G. Gerbier (Queen's)	I. Giomataris (IRFU)
WP1	Copper and Sphere	M. Zampaolo	G. Gerbier (Queen's)
WP2	Rod/Sensor/electronics/DAQ	M. Gros (IRFU)	P. Gorel (SNOLAB)
WP3	Gas handling/pump recirculation	K. Dering (Queen's)	J.F. Muraz (LPSC)
WP4	Compact Shield and ancillaries	M. Zampaolo (LSM)	K. Dering (Queen's)
WP5	Calibration	P. Gorel (SNOLAB)	A. Ulrich (TUM)
WP6	Quenching factor measurements	D. Santos (LPSC)	P. DiStephano (Queen's)
WP7	Material selection/screening	A. Dastgheibi-Fard (LSM)	A. Broussard (Queen's)
WP8	Simulations	A. Broussard (Queen's)	I. Kastiolas (IRFU)
WP9	Data handling/analysis	R. Martin (Queen's)	Q. Arnauld (Queen's)
WP10	SeDiNe measurements	I. Giomataris (IRFU)	A. Dastgheibi-Fard (LSM)
WP11	Documentation	J. McDonald (Queen's)	A. Ronceray (Queen's)
WP12	SNOLAB interface	J. McDonald (Queen's)	K. Dering (Queen's)
WP13	R&D sensors, copper, light	I. Giomataris (IRFU)	I. Savvidis (Thessoniki)

NEWS-G @ SNOLAB: early 2018



Copper vessel

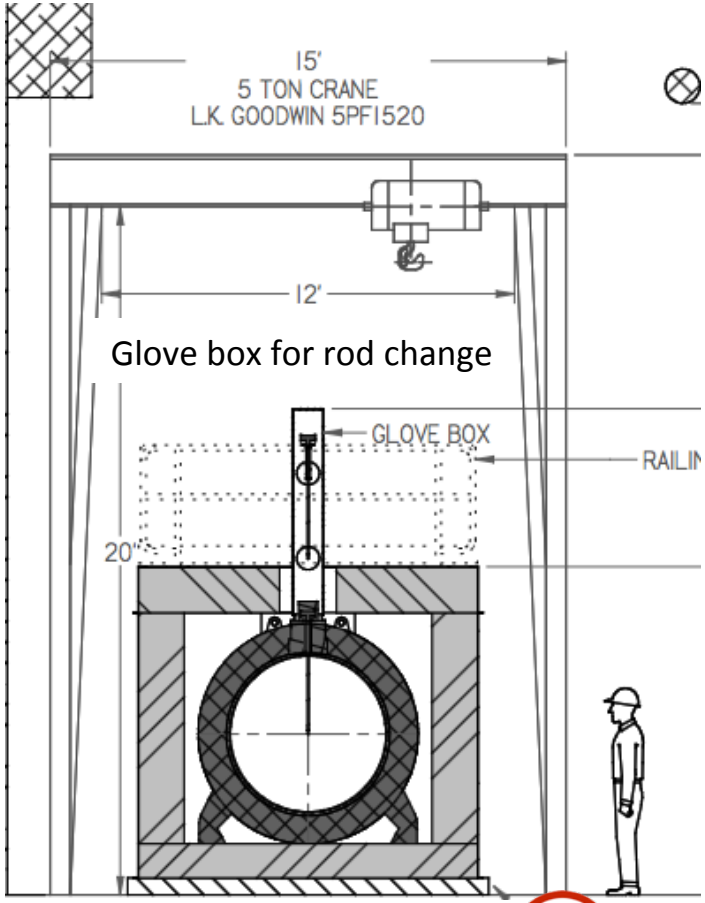
- Ø140 cm, 12mm thick
- 10 bars
- Ne, He, CH_4



Lead shield

25 cm thick:

- 3cm inner: archeological
- 22cm outer: very low activity



40 cm Polyethylene

Construction: copper sphere


Copper spinning test (July 2016)

- Sphere fabrication: spinning
- Low activity copper (C10100) located
  - Activity measured @PNNL

⇒7 to 25 μBq/kg of Th
⇒1 to 5 μBq/kg of U
} Within goals

- Initial project of water jet cleaning non-practical
  - ➢ Acid etching @LSM
  - ➢ R&D for copper electroplating (PNNL)