ANR NEWS (LDM) - R&D R2D2 (2β)

(and the SPC)

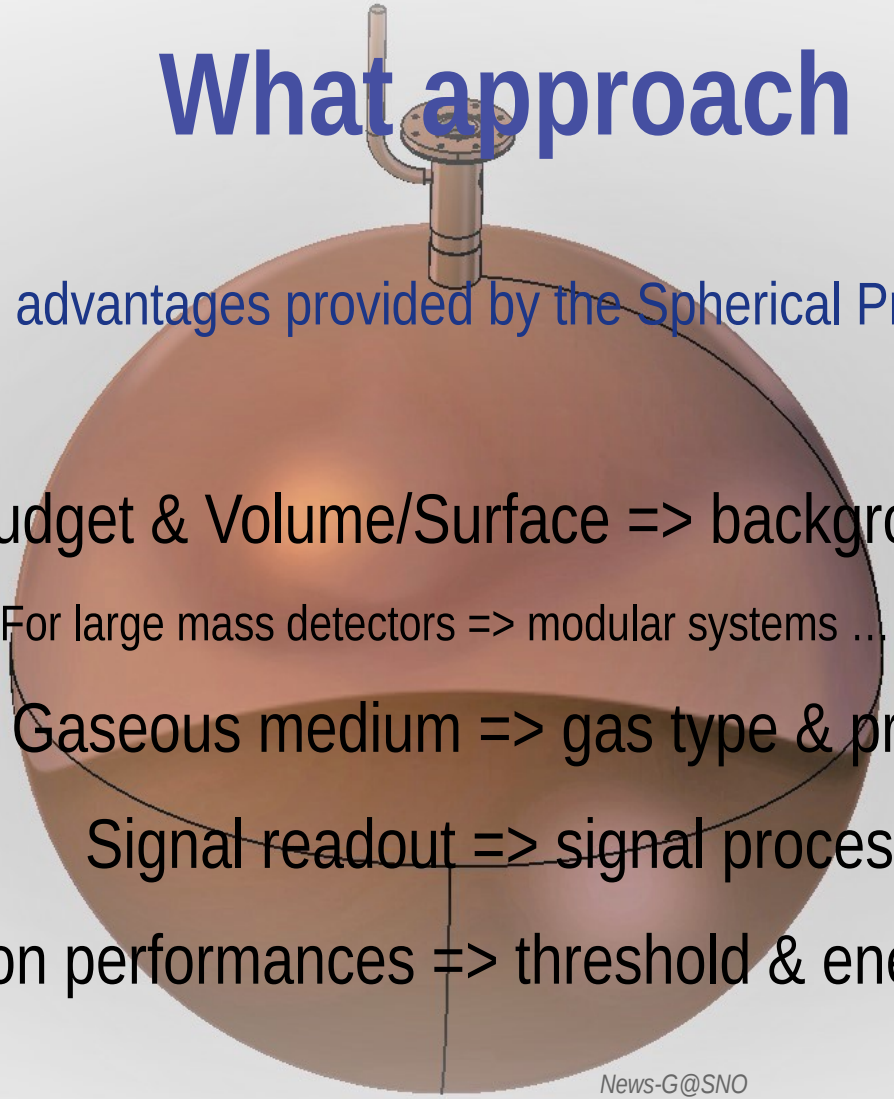
Conseil Scientifique IN2P3 - Octobre 2018

Pascal Lautridou pour les groupes IN2P3 de R2D2 & NEWS

Sedine@LSM

What approach

It is based on the advantages provided by the Spherical Proportional Counter (SPC)



Material budget & Volume/Surface => background radioactivity

For large mass detectors => modular systems … but cheap

Gaseous medium => gas type & pressure

Signal readout => signal processing

Detection performances => threshold & energy resolution

Principle of the SPC

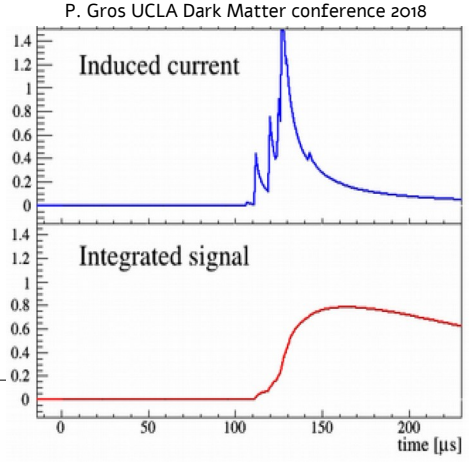
I. Giomataris JINST 2008

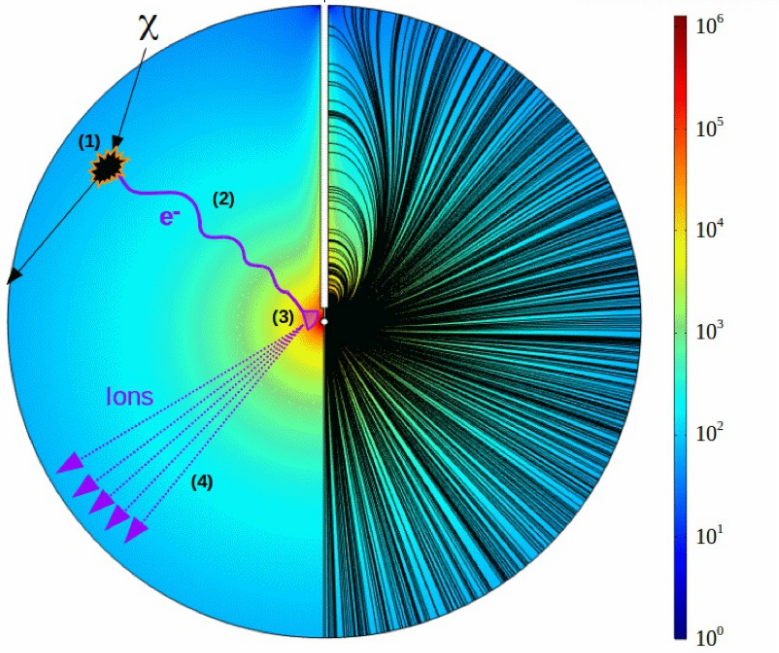
$C = 4\pi\varepsilon\rho < 1$ pF

$1/\rho = 1/r_a - 1/r_c$

$\rho \approx r_a$

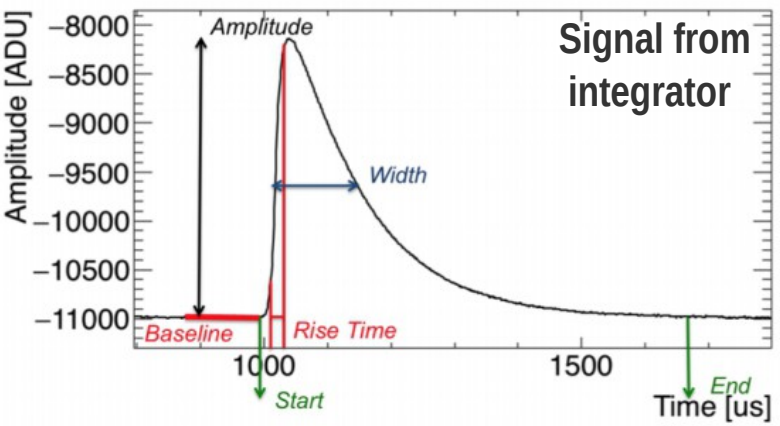
$E(r) = V_0\, r_a / r^2$



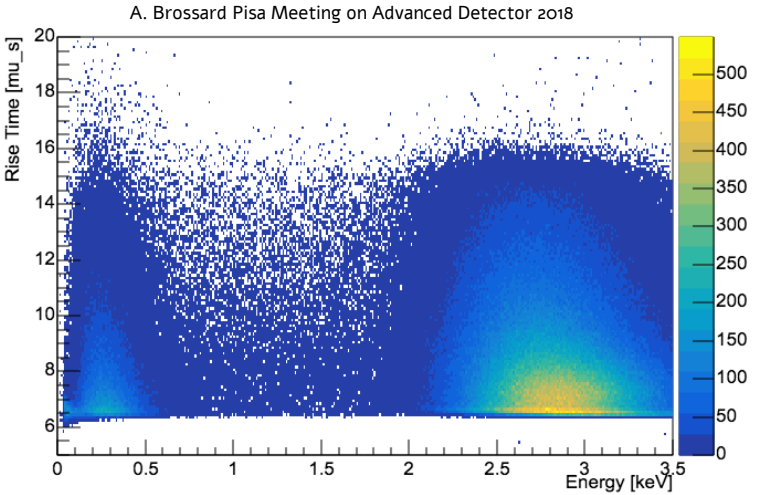


- Simple mechanical structure
- Easy adjustment of parameters
- Sensor: ϕ > 1 mm
- Gain: < 10^4
- Single channel FEE + MHz BWD integrator => allows signal processing
-Threshold down to single electron
-Identification of point like energy deposition via time dispersion: $\sigma(r) \approx (r/r_c)^3$

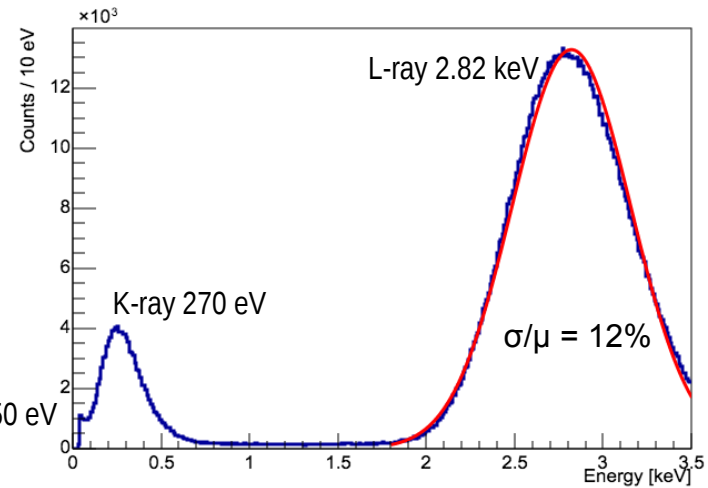
Energy Resolution & Energy Threshold



Rise Time ~longitudinal diffusion
~ radius of energy deposition



0.5 bar Ar/CH4 (2 %) + Ar 37 source



Threshold < 50 eV

@ 1 MeV
$\Delta E/E < 1\ \%$
FWHM
expected

scaling suggests
0.3 -0.7 %

ANR NEWS (New Experiments With Spheres) @ LSM
Dark Matter search in 0.1 - 10 GeV

A. Dastgheibi-Fard, I. Giomataris*, M. Gros, O. Guillaudin, I. Katsioulas, J.-F. Muraz, J.-P. Mols, X.-F. Navick, T. Papaevangelou, F. Piquemal, D. Santos, M. Zampaolo

*LSM, LPSC, IRFU + Queen's University, Canada (13 Members)**

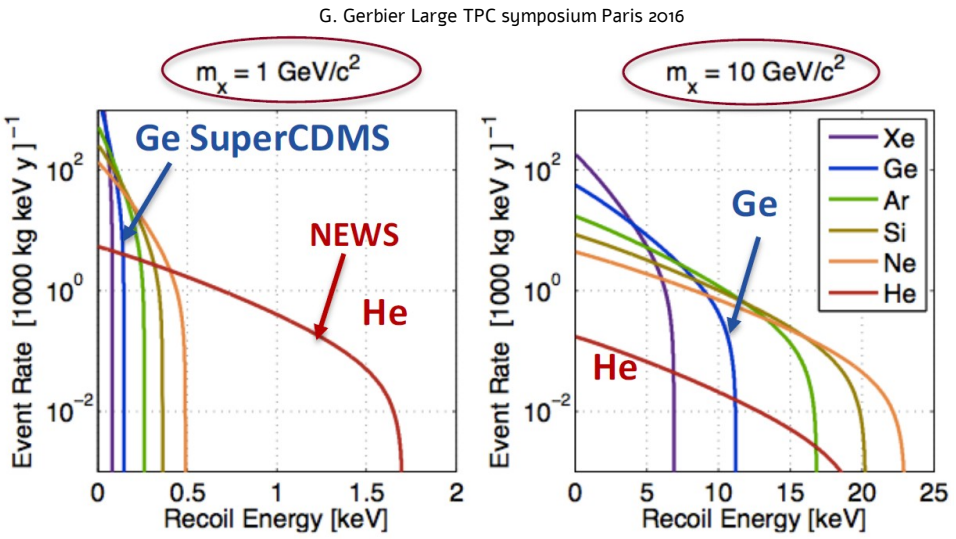
ANR Goal (2015-2019): development of the methodology

As part of NEWS-G (New Experiments With Spheres-Gas)

+ Pacific Northwest National Laboratory, USA, (2 Members) + Royal Military College of Canada, Canada, (2 Members) + University Műnchen, Germany, (1 Member) + SNOLAB, Canada, (1 Member) + Aristotle University of Thessaloniki, Greece, (1 Member) + University of Birmingham, UK, (1 Member) + University of Alberta, USA, (1 Member) + TRIUMF laboratory, Canada, (1 Member) + SUBATECH, (1 Member)

Light nuclei (H, He, Ne) to detect light WIMPs

Recoil distributions with various targets



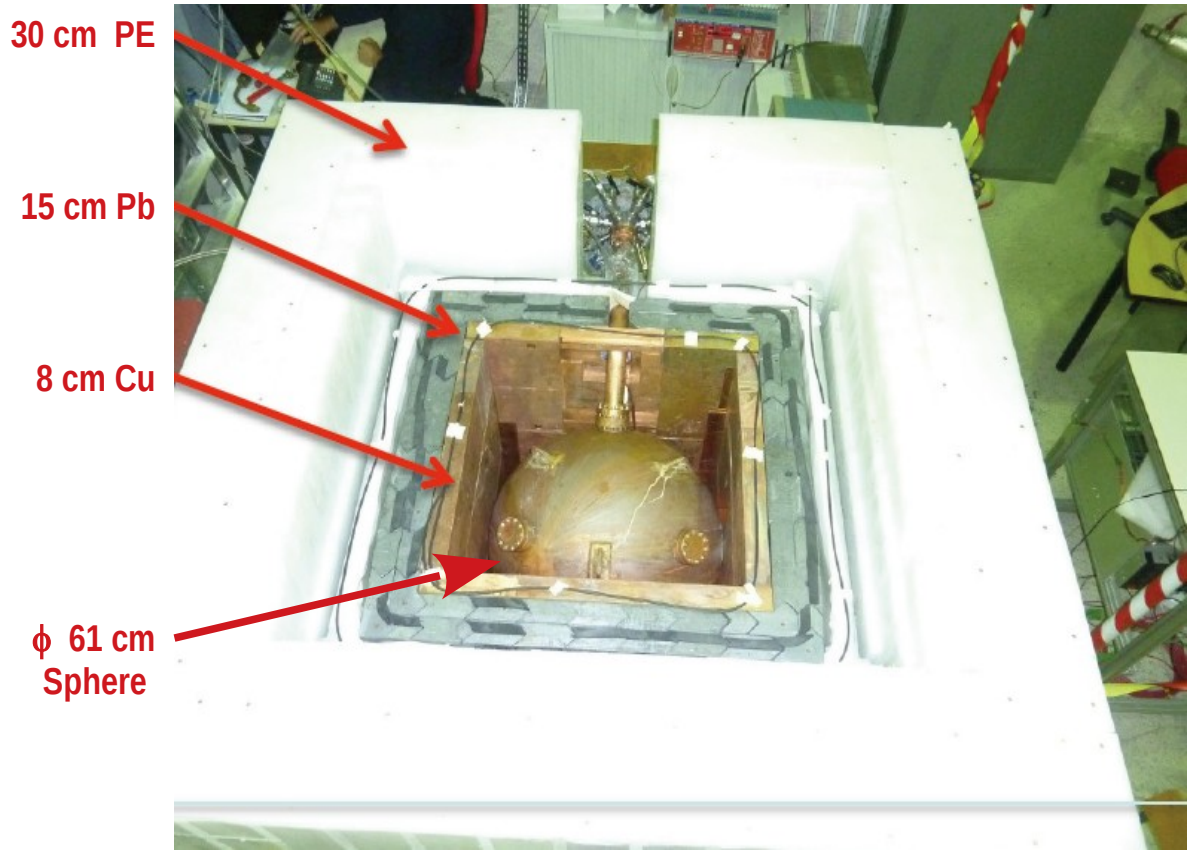
First phase: use SEDINE @ LSM as prototype for detection with He, Ne @ 3 bars

Tasks: sphere construction, low-radioactivity material, cleaning methods, sensor & FEE optimization, DAQ set-up, calibration procedures, quenching factor

2015-2019: SEDINE @ LSM

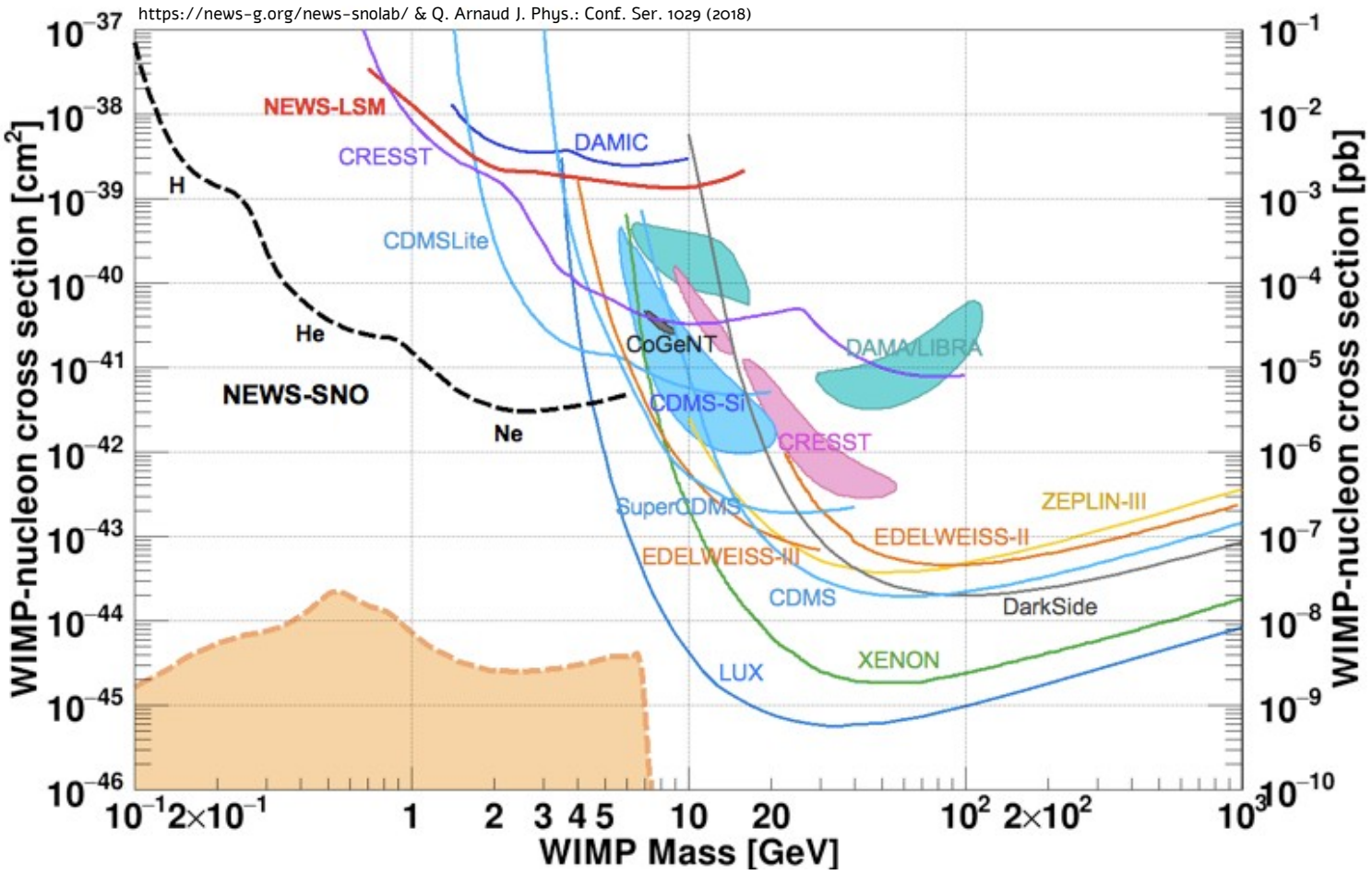
2016: 3.1 bar Ne/CH4 (0.7 %) in sealed mode

- Ionization energy w = 36 eV
- HV: 2520 V, no sparks, Gain: 3000
- FEE: Canberra 2006 (50 µs RC), Sampling: 2 MS/s
- Acquisition threshold @ 50 eV (~30 ADU)
- Data taking continuously during 42 days
- Loss of gain 3 % along 42 days monitored with
- 210 Po line + variation on days scale of ± 4 %
- Calibrations: 37Ar & 8 keV line from Cu fluorescence + simulation Am-Be neutron source



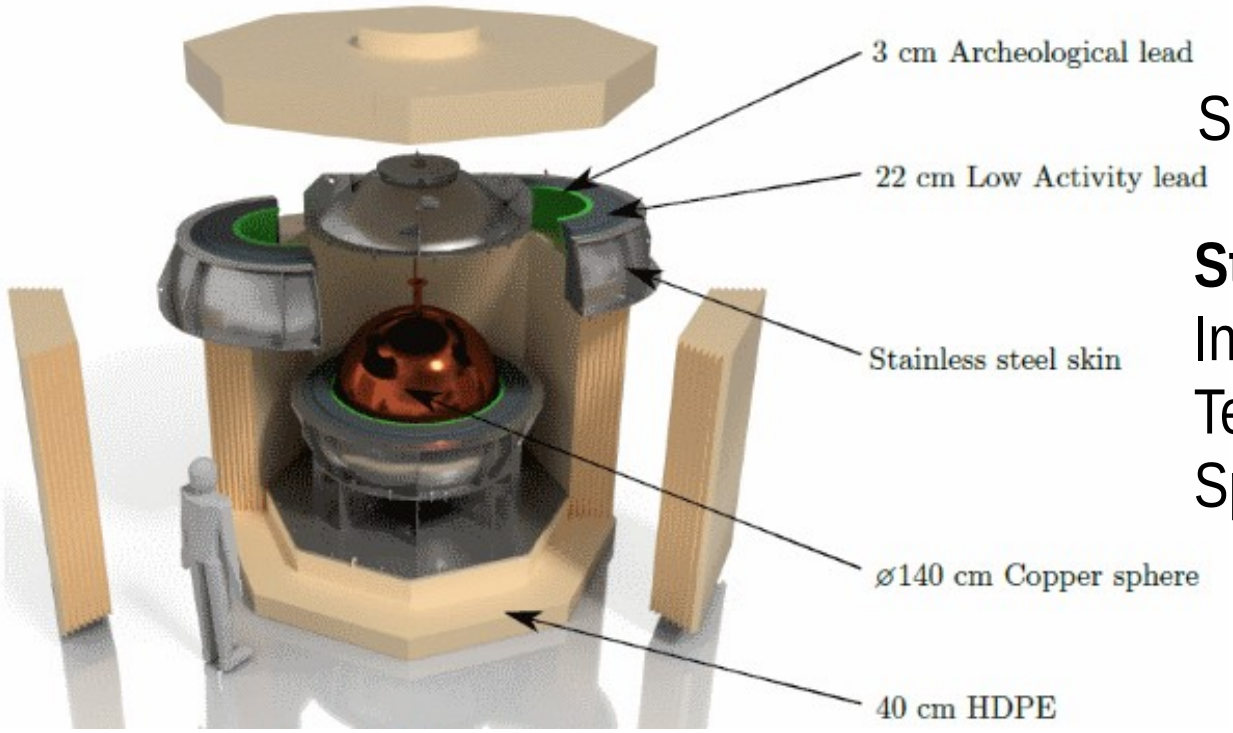
2017-2019: 3 bar He/CH4

Sensitivity curve



From 2020: NEWS-G @ SNO

https://news-g.org/news-snolab/



Goal:

Gas H, He with P <= 10 bar

Sentitivity to cross section of 10^{-41} cm^2

Status:

In construction

Technical design ongoing

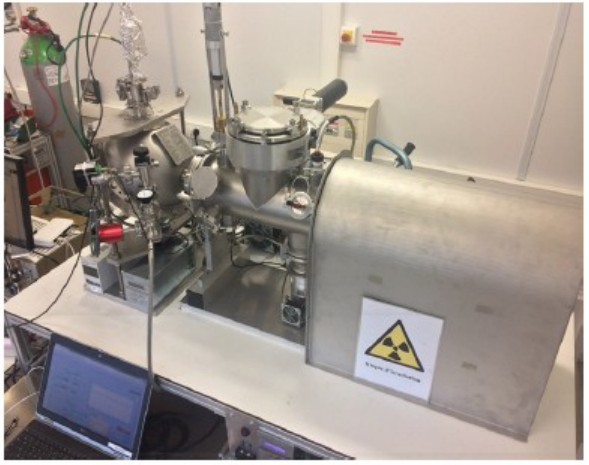
Space at SNO assigned

IN2P3 contributions:

Same as ANR +

Signal processing (since June 2018)

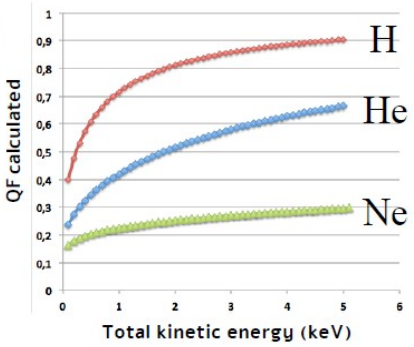
Quenching factor measurements



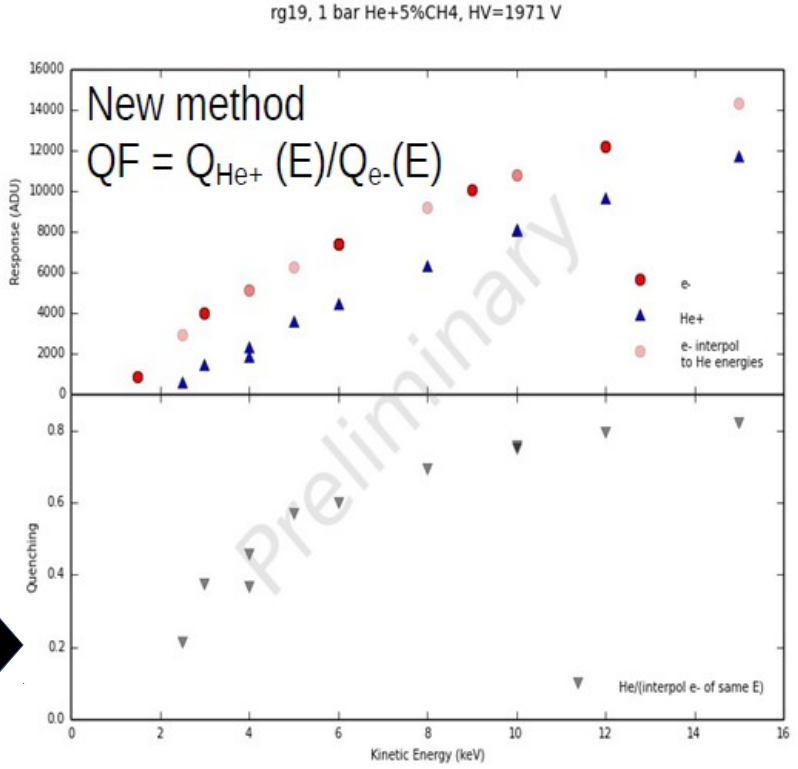
Goal: measure QF down to 500 eV ion energy using the Grenoble MIMAC facility for H, He, Ne, CF4, Ar, Xe at various pressures

Saclay, Grenoble, Thessaloniki, Queen's-Kingston

QF depends on
- ion type
- gas mix
- gas pressure
=> need 1 dedicated measure per detection setup



Range of interest for Dark Matter

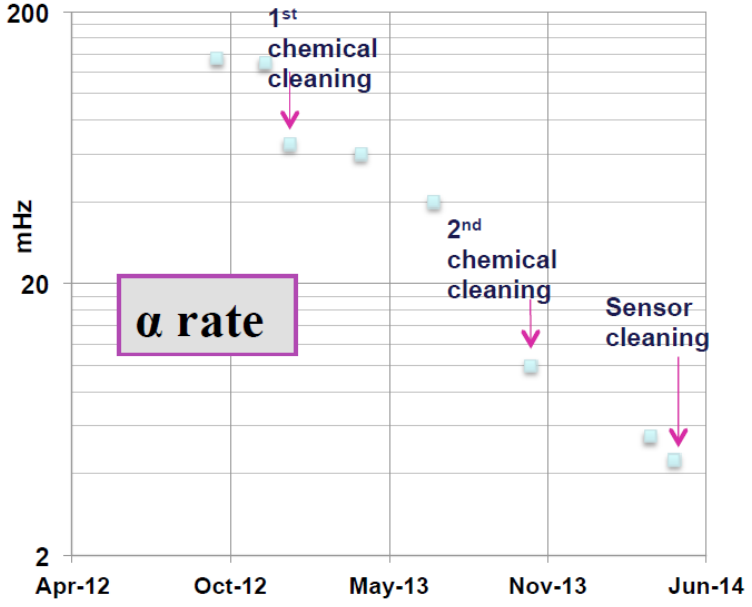


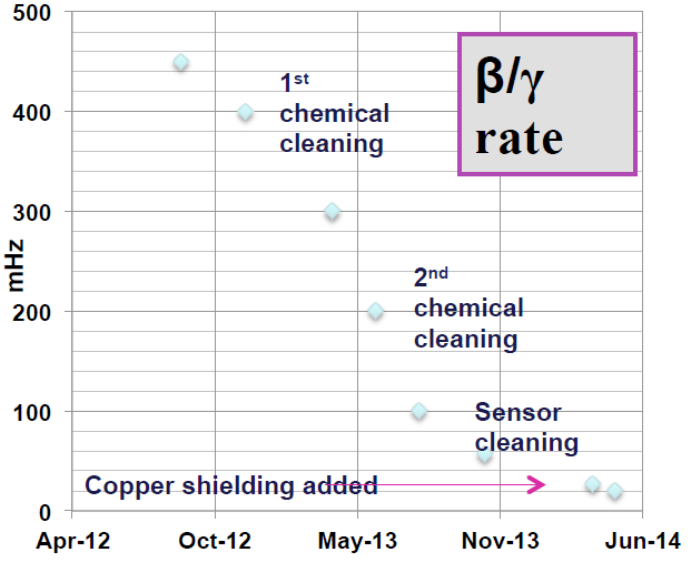
Earlier measurements D. Santos et al., ArXiv:0810.1137: Differences between measurements and calculations

Improvement of Cu induced background

For Radon cleaning inside gas => huge expertise of the global community

Goal: to remove 210 Po -210 Pb from Cu => chemical cleaning => - 10 μm

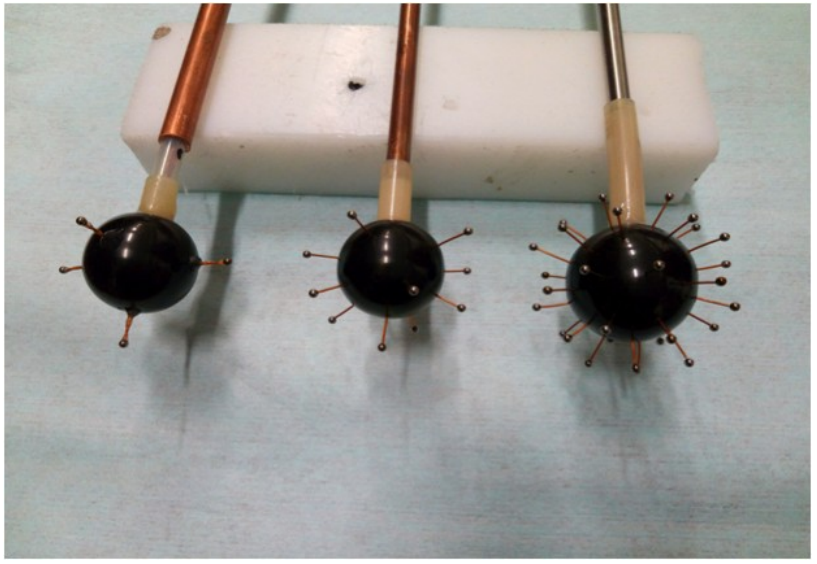




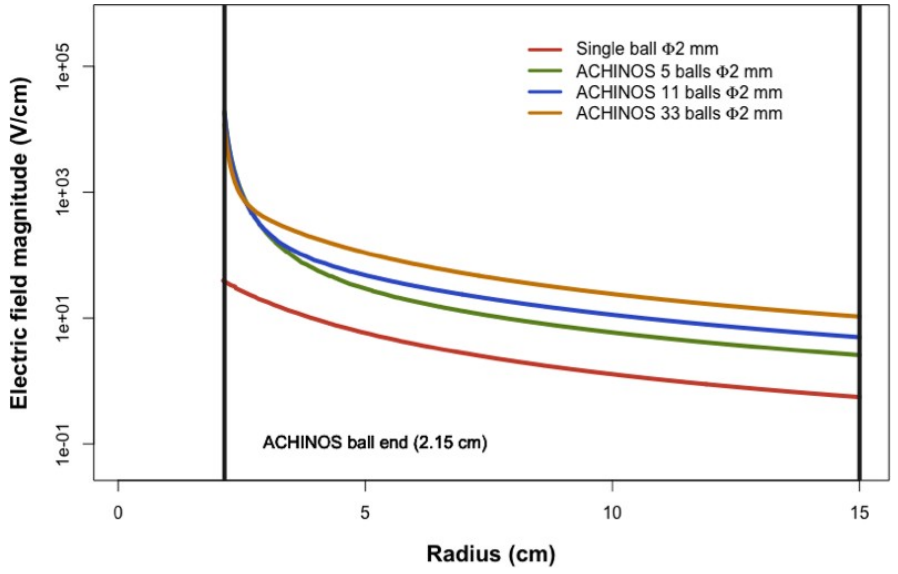
I. Giomataris Journée Matière Sombre Paris 2016

2017 => New method: electrolysis of Cu => - 10 μm + 500 μm (possibly up to +1 cm …)

=> Radio-purity of electro-deposition at the level of 10 nBq/kg



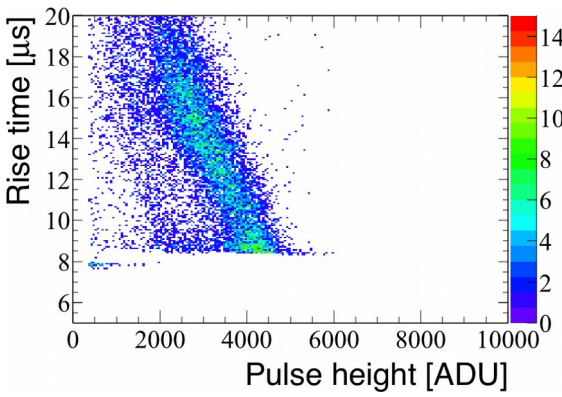
A. Giganon arXiv:1707.09254



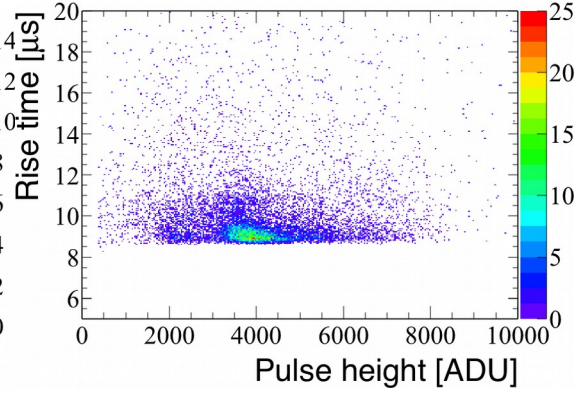
Improvement of drifting
=> Multi-anode “Achinos”
=> E(r) ↗ => Drift Time ↘

He:Ar:CH4 (80:11:9) - 640 mbar - ^{55}Fe - 2-mm anode ball

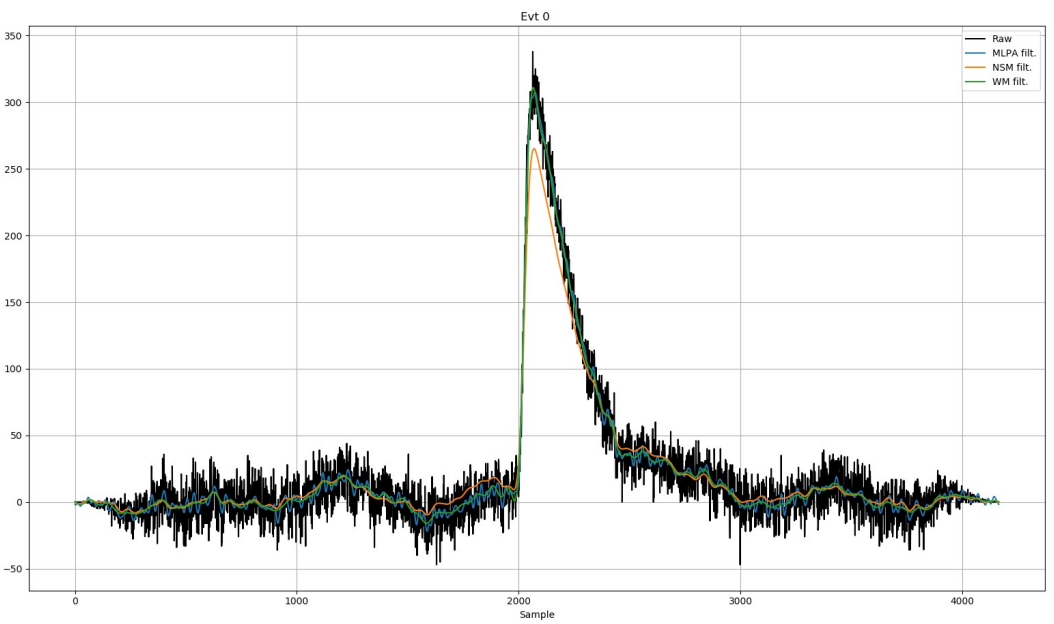
1 ball



11 balls



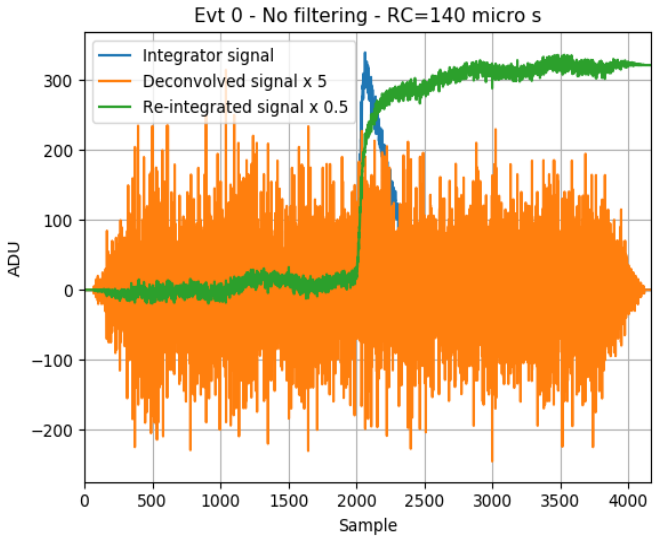
+ Track recognition (spatial coverage of each individual anode ball)

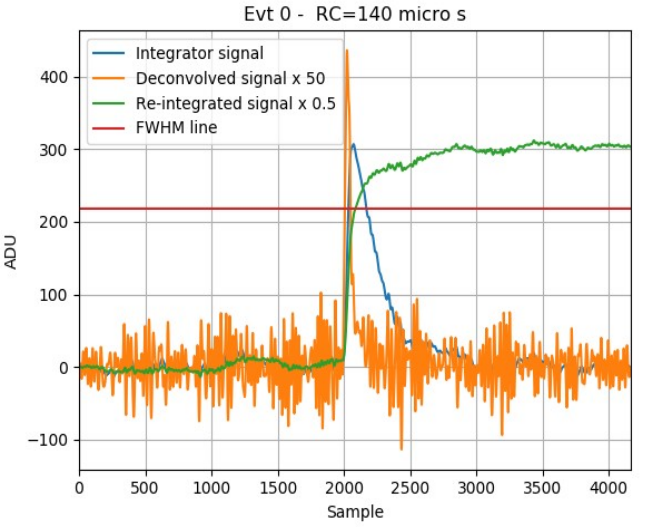


Improvement of S/N through signal processing

SUBATECH since June 2018

Filtering
+ Regularization
+ Deconvolution





- Reveals the distribution of charges
- Corrects the ballistic deficit

R&D R2D2
(Rare Decays with Radial Detector)
SPC development for 2ββ0ν search

J. Busto, C. Cerna, F. Druillole, A. Dastgheibi-Fard, C. Jollet, I. Katsioulas, I. Giomataris, M. Gros, P. Lautridou, A. Meregaglia*, X. F. Navick, F. Perrot, F. Piquemal, A. Rebii, M. Roche, B. Thomas, M. Zampaolo

CPPM, CENBG, LSM, IRFU, SUBATECH

Master-project initiated in 2017

2 objectives: to improve energy resolution & radioactive background compared to last experiments

Use of ^{136}Xe at high pressure

Avantages

- High density is desirable to contain event
- Moderate density helps to reject Compton backgrounds

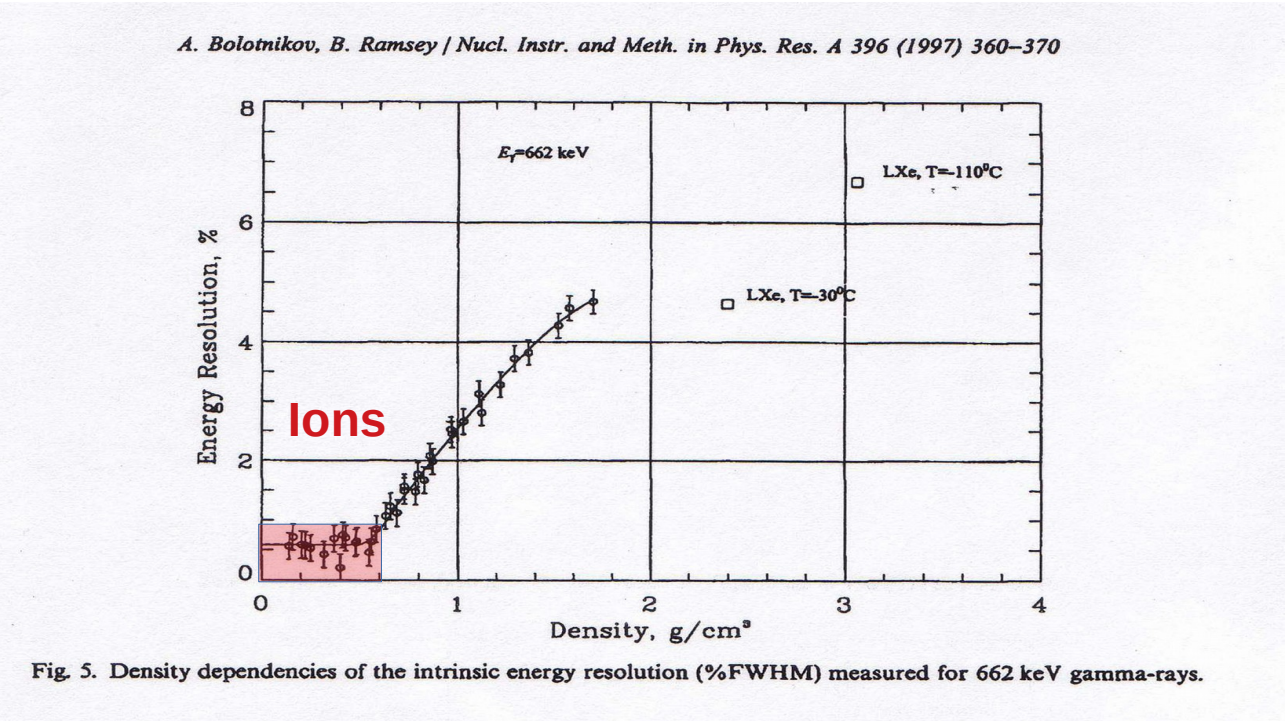


Fig. 5. Density dependencies of the intrinsic energy resolution (%FWHM) measured for 662 keV gamma-rays.

EXO-200 ~3-4 % FWHM
NEXT: 1% FWHM (20 bar + light detection)
KamLAND-Zen: 8% FWHM
XENON ~ 3% FWHM

R2D2 objective

Reach < 1% FWHM @ 40 Bar
(Impact on ROI width)

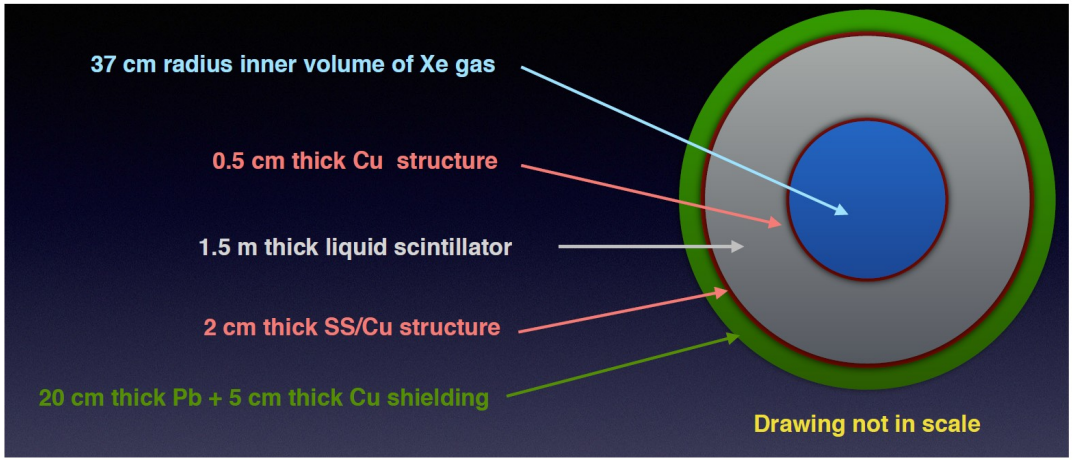
Issue: $\Delta E/E$ after avalanche ?

Other gas (MoF6 …) also envisaged in the future

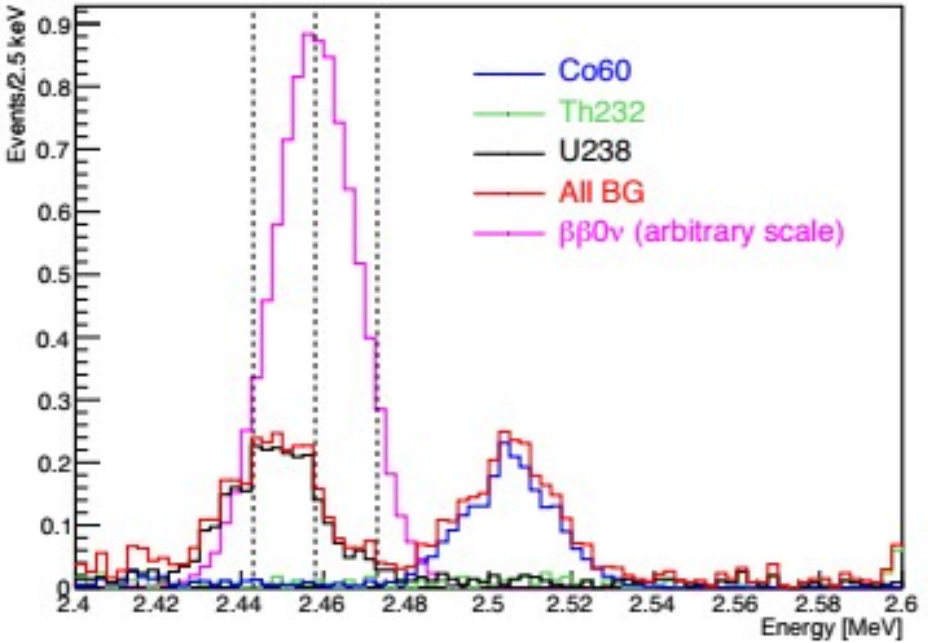
Simulations of Background

Settings

- $\Delta E/E$ = 1% FWHM @ $Q_{\beta\beta}$ of 2.458 MeV
- 50 kg ^{136}Xe @ 40 bar (ϕ = 74 cm)
- 10 μBq/kg Cu activity for all sources of background (< 2 μBq/kg available)



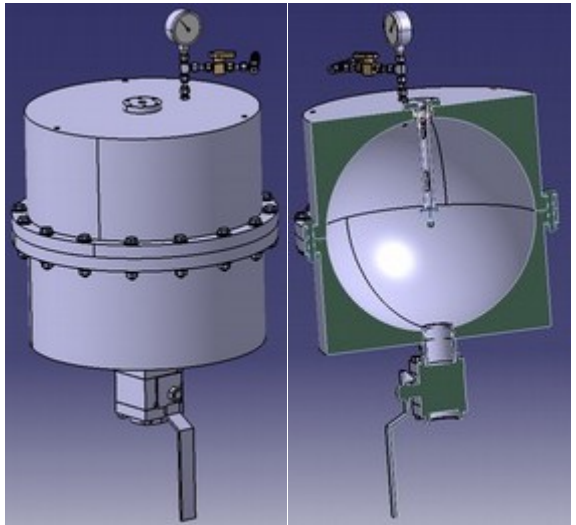
A. Meregaglia JINST 2018

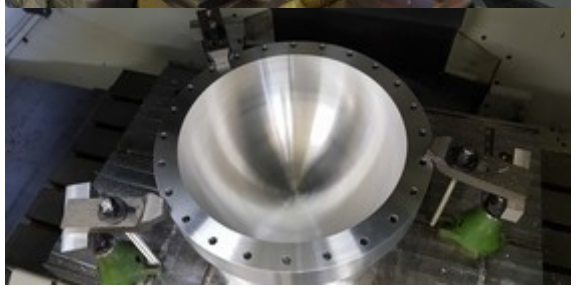


ROI width: $Q_{\beta\beta}$ ± 0.6%

1 year data tacking

=> In ROI: 2 background evt/y => $T^{0\nu}_{1/2}$ = 2.5 10^{25} Y, $\langle m_{\beta\beta} \rangle$ < (160 - 330) meV





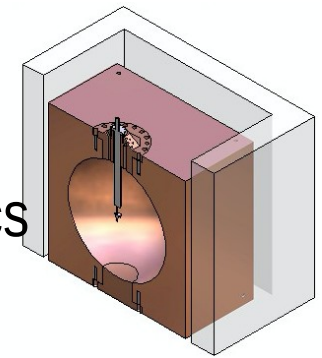
Roadmap

2019: ΔE/E< 1% FWHM @ CENBG

(SPC construction (ϕ = 40 cm) + Gas recovery system + Anode optimization for 6000 V- HV + Long track & 2-blob recognition,…)

- **With ArP2 @ 1-40 bar**
- **With natural Xe @ 1-40 bar** (+ Test of Rn contamination)
- **Search for fundings (ANR, ERC…) in parallel**

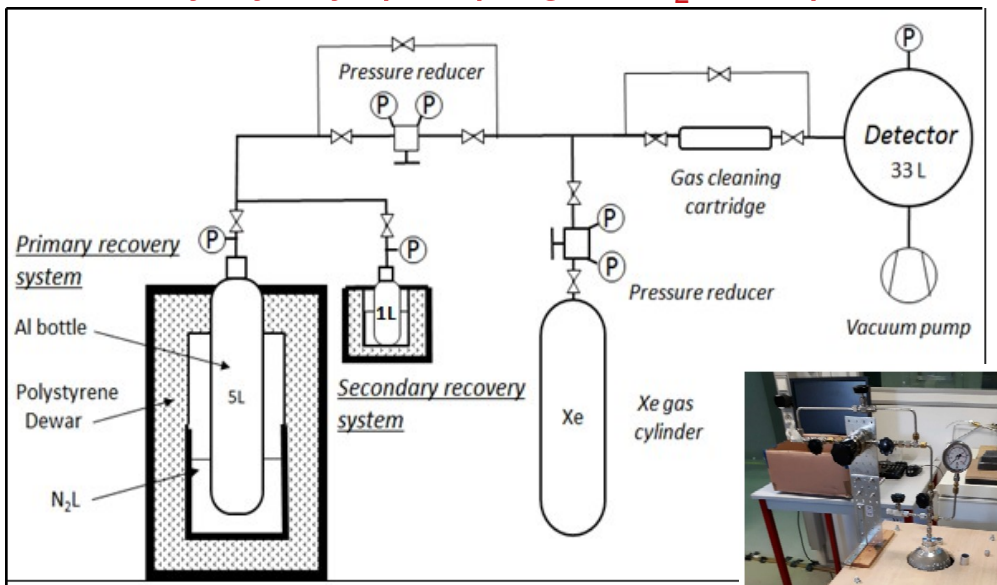
2020: "zero- background" @ LSM with SPC
(ϕ = 60 cm, 27 kg ^{136}Xe) => first results of physics



=> Prospect: A ton-scale detector (possibly modular) with zero-background

Recovery & Cleaning system

Recovery by cryopumping @ N_2L temperature



- Very clean technique (no mechanical pump)
- Simple and low cost

2 recovery tanks

- Primary => 5L Al tank -> 660 L Xe gas
  (15% of Xe remains in the recovery tank)
- Secondary => 1L Al tank
  (3% of Xe remains in the recovery tank)

Cleaning

Hot getter

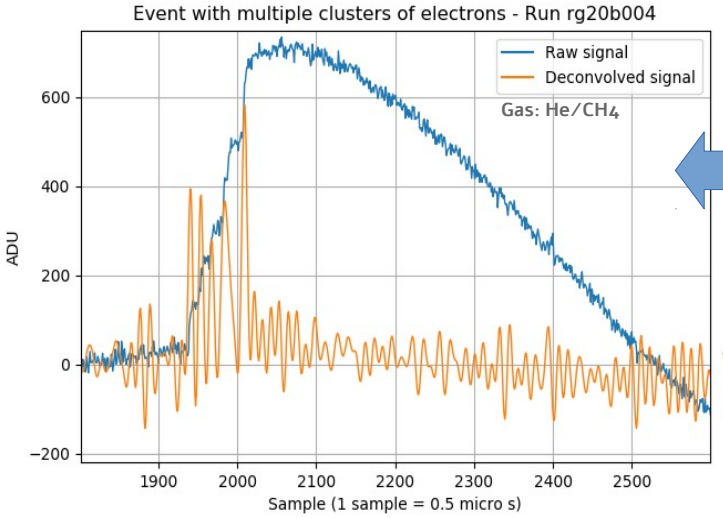
Ambient absorber

- Very high gas purity is require (O_2 and H_2O)
- High purity Xe (Air Liquide, Linde) : 99.999 %
  => *1 ppm O_2*

Adsorbent ambient cartridge :

- *Supelco® O (< 0.5 ppm O_2)*
- *GateKeeper® GPU (< 1 ppb O_2)*
- *SAES® (< 0.1 ppt O_2)*

Hot getter : SAES® (< 1 ppb O_2)

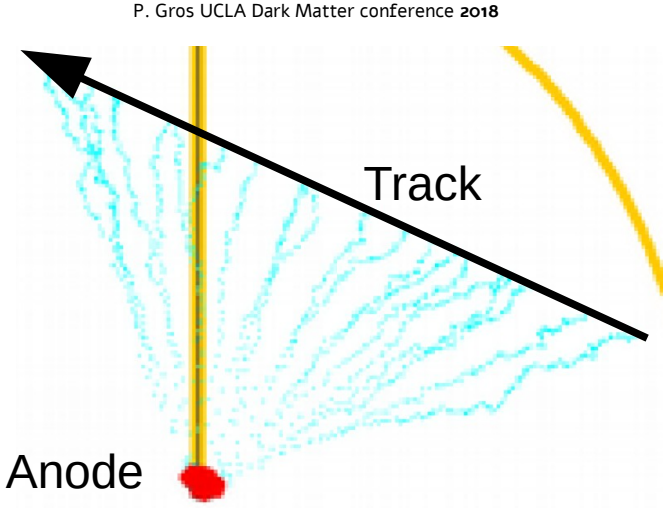


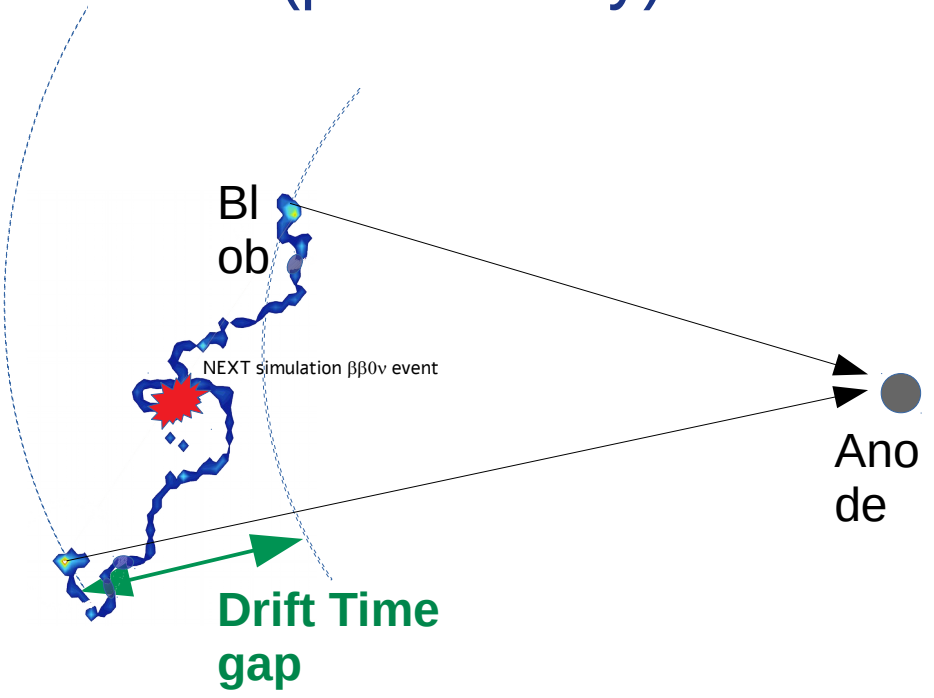
Experimental observations

& After signal processing

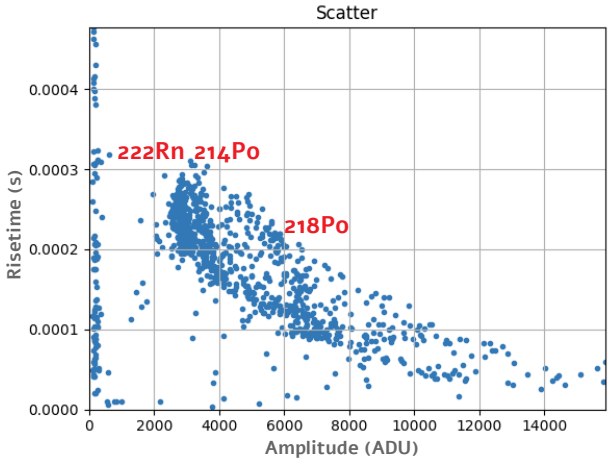
New possibility ? Ability to recognize multi-blob events ? (preliminary)

Interpretation: Long track signal ?



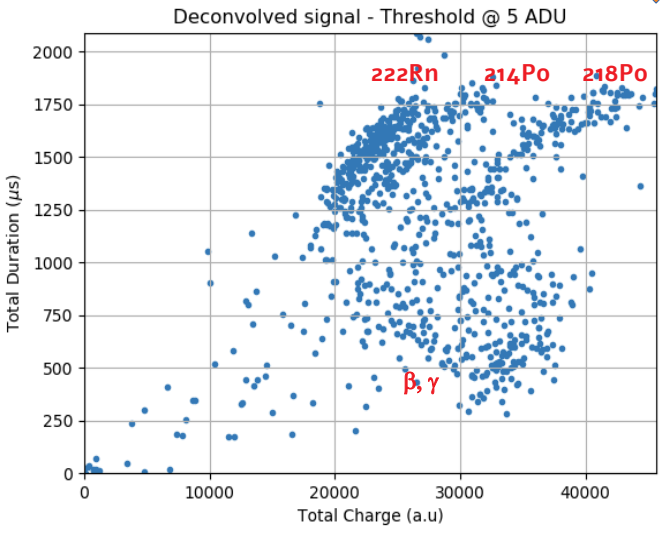


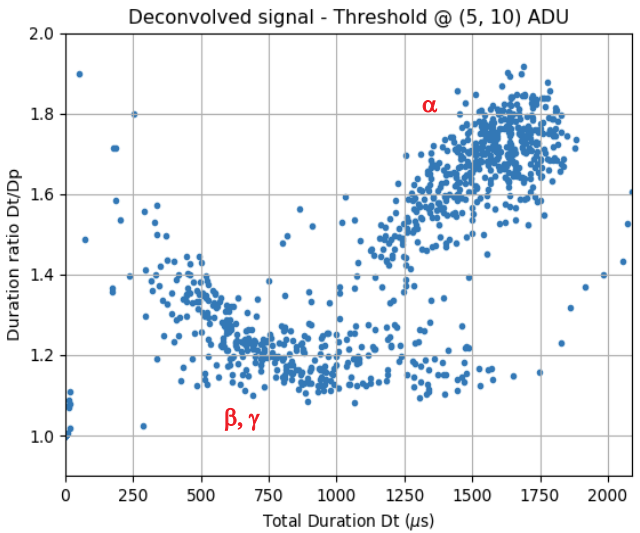
He/CH4 1 Bar + Rn source

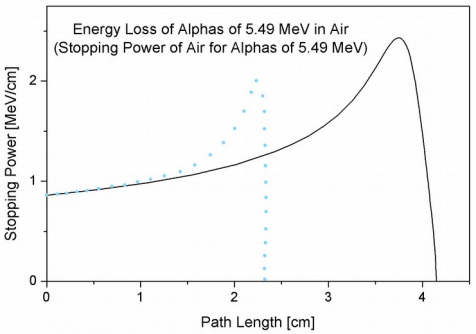


New possibility ?
Ability to recognize the nature of interactions ? (preliminary)

After signal processing
+ PSD method







Signal content linked to the Bragg curve ?

Organization