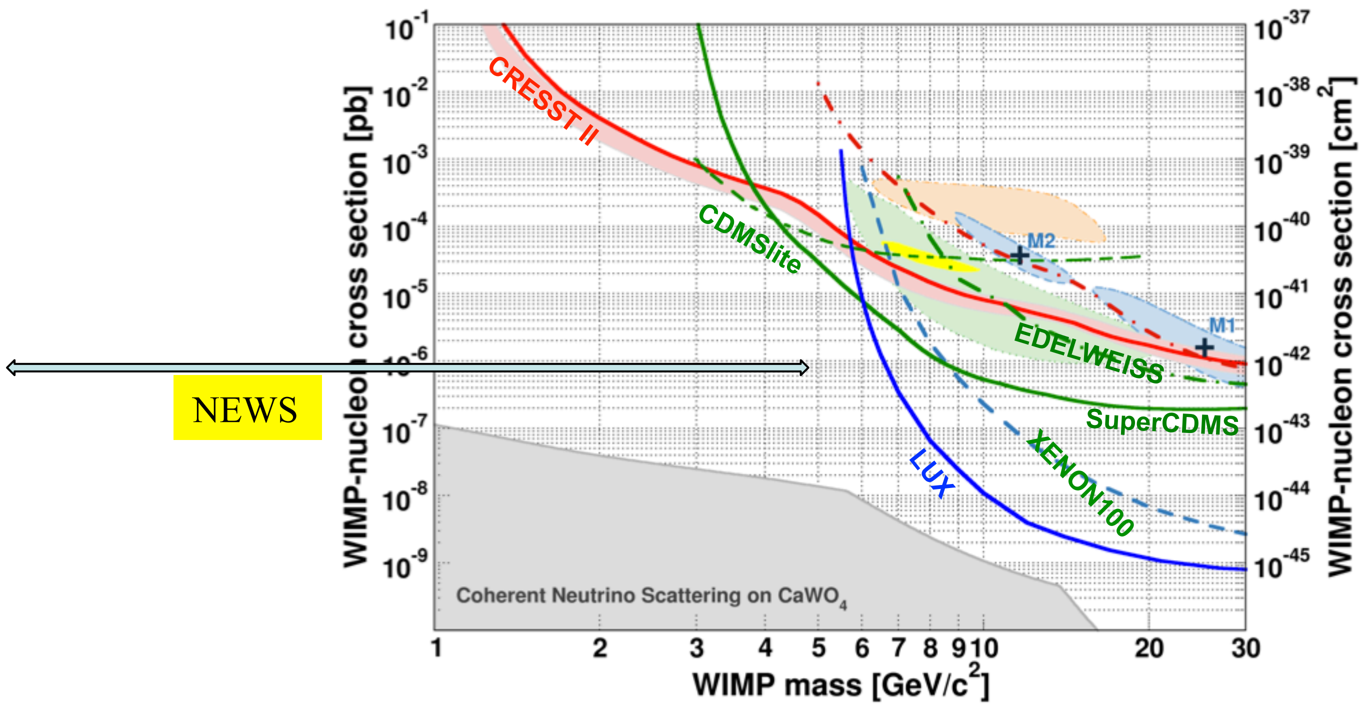
Light dark matter search with a spherical proportional counter

I. Giomataris, CEA-Irfu-France

Dastgeibi Fard Ali, J. Derre, J. Galan, I. Giomataris, G. Gerbier, M. Gros, P. Loiza,P. Magnier, X.F. Navik, F. Piquemal, I. Savvidis, G. Tsiledakis

NEWS (New Experiment for Wimps with Sphere)
Main goal: search for ultra-light WIMP
100 MeV – 10 GeV
Using the novel spherical gaseous detector



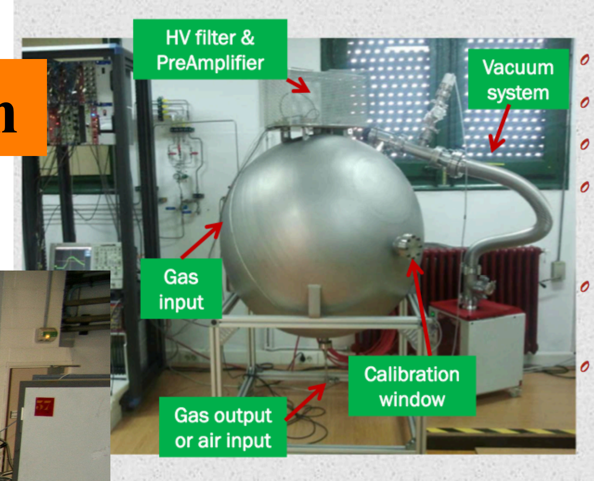
NEWS is a more general network which could search for:
Light dark, neutrino coherent scattering, low energy neutrino oscillations,
Neutrinoless double beta decay, KK axions, ...

Possible collaboration

- Cea/IRFU Saclay — France
- Laboratoire Souterrain de Modane — France
- University of Tessaloniki — Greece
- University of Tsignhua — China
- Institute of High Energy Physics — China
- University of Jiao tong — China
- NCSR Demokritos — Greece
- University of Ioannina — Greece
- Helenic Open university — Greece
- University of Zaragoza — Spain
- Livermore National Lab — US
- University of Princeton — US
- JINR Dubna — Russia
- Cea/DRT — France
- University of Georgia — US
- CNRS/IN2P3/CPPM — France

Low background detector d=60 cm p=10 bar

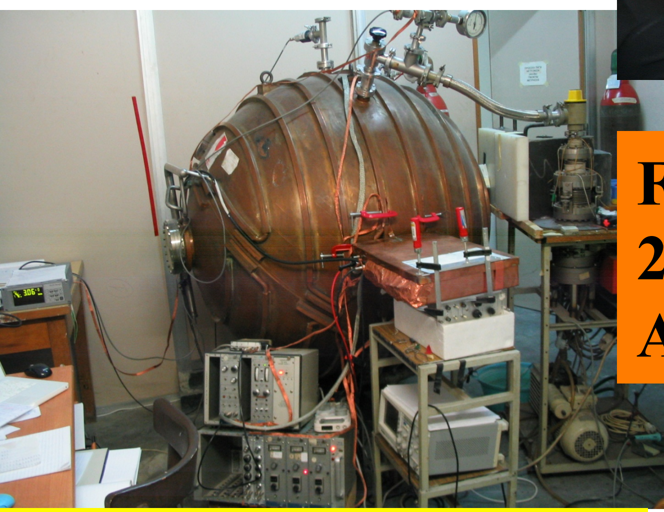
University of Saragoza detector



Spherical detector propagation

Basic R@D detector in Saclay

Future project
2m detector will be developed
At SNOLAB (G. Gerbier et al.)



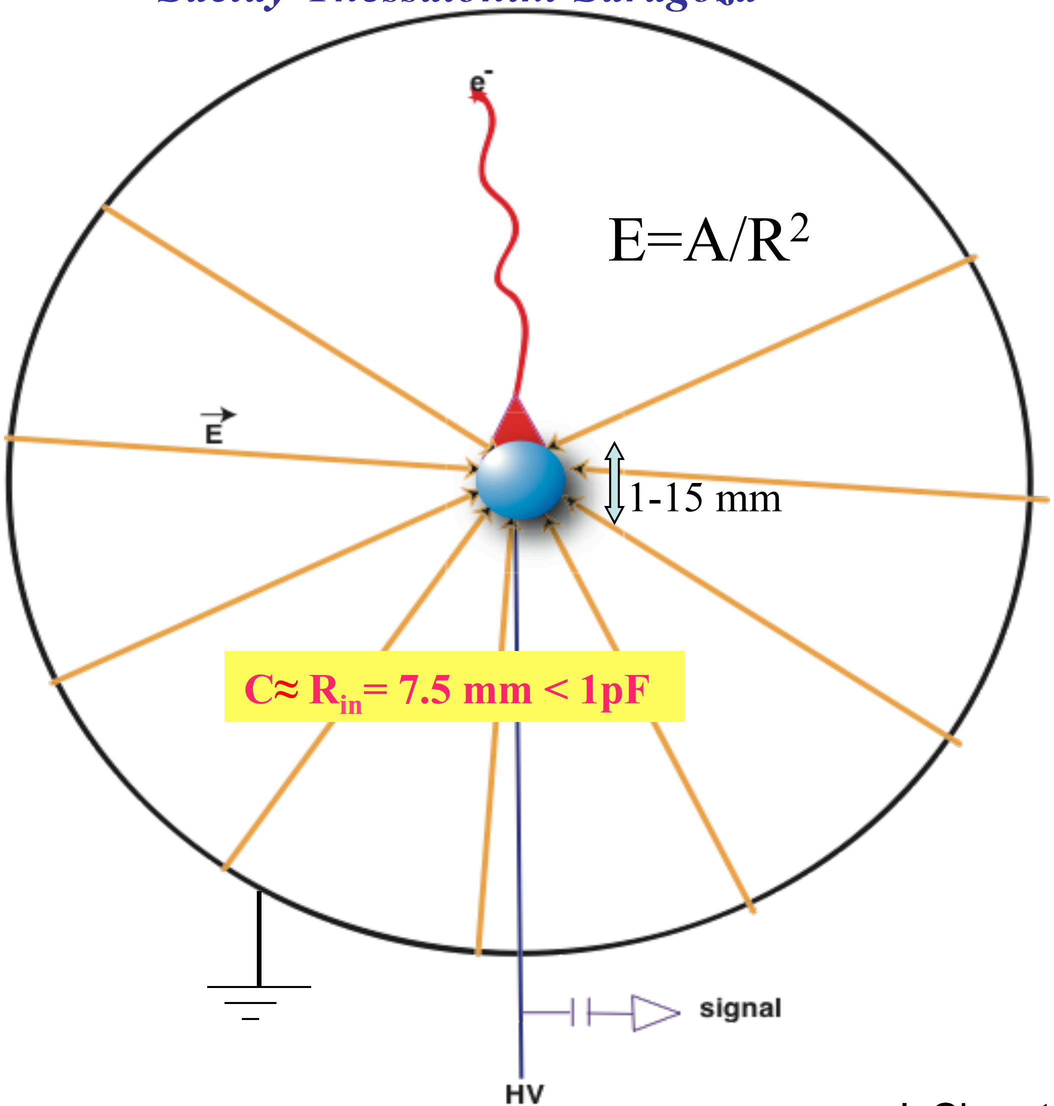
University of Thessaloniki detector

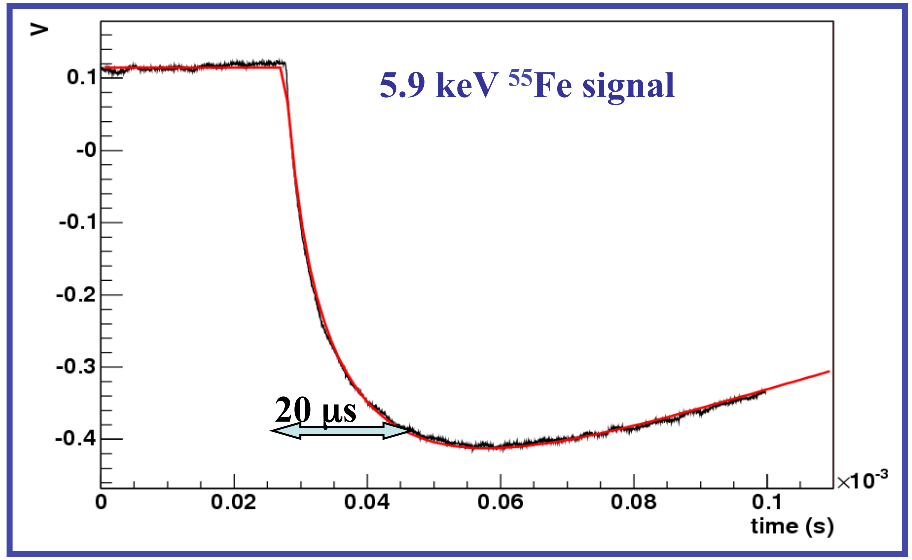
University of Tsinghua - HEP detector

Radial TPC with spherical proportional counter read-out

Saclay-Thessaloniki-Saragoza

A Novel large-volume Spherical Detector with Proportional Amplification read-out, I. Giomataris *et al.*, JINST 3:P09007,2008



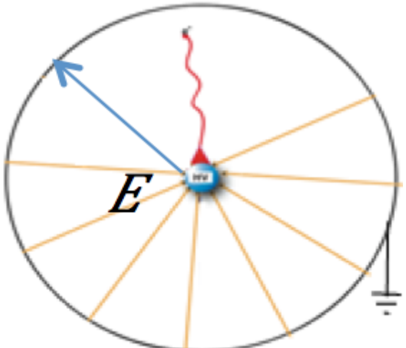


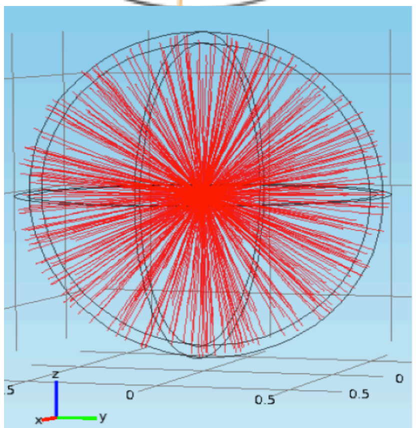
I. Giomataris

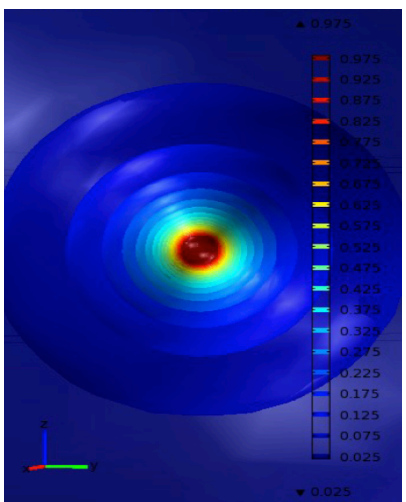
- **Simple and cheap**
- **Large volume**
- **single read-out**
- **Robustness**
- **Good energy resolution**
- **Low energy threshold**
- **Efficient fiducial cut**

Electrostatics deal - how to maintain a radial field

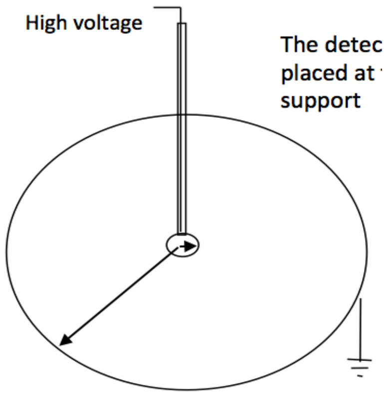
Ideal case: ball non wire

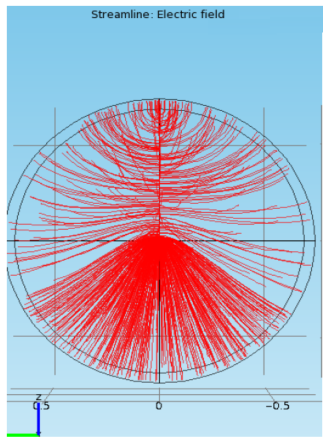


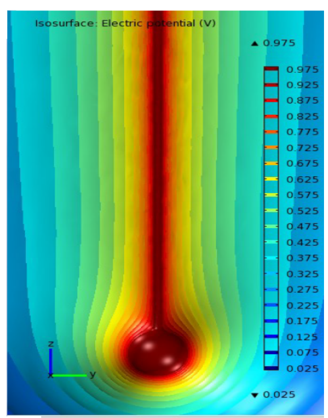




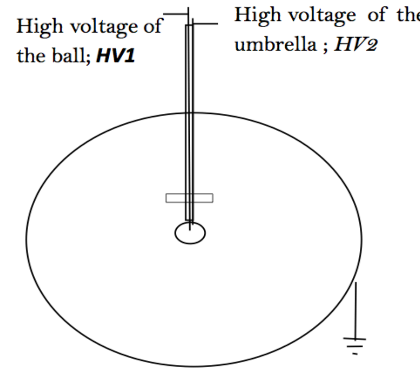
Ball with wire

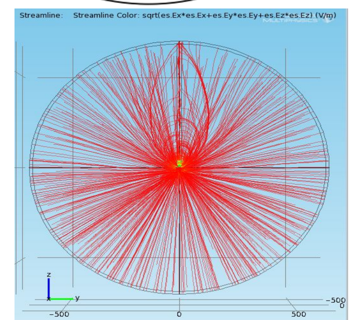


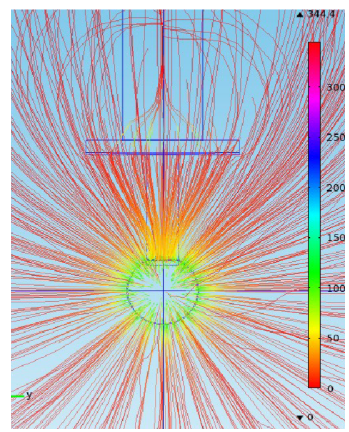


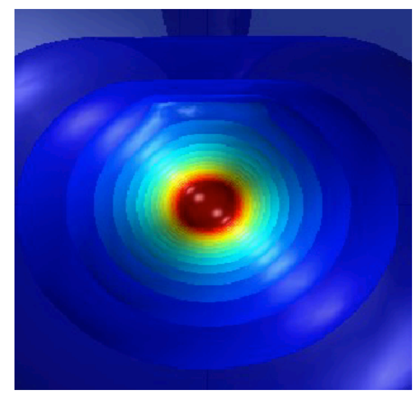


The Ball with umbrella corrector





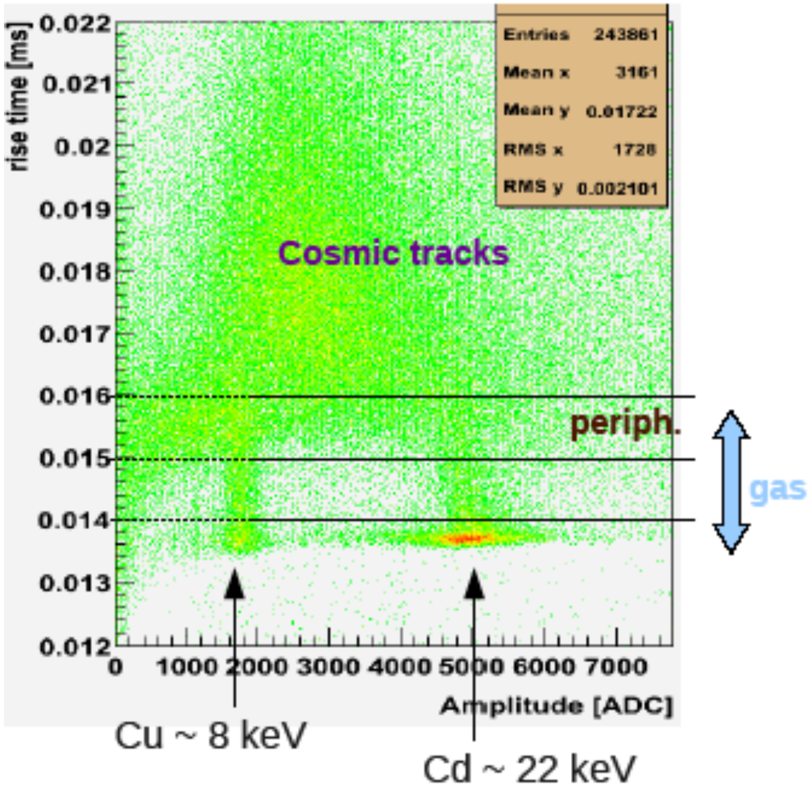


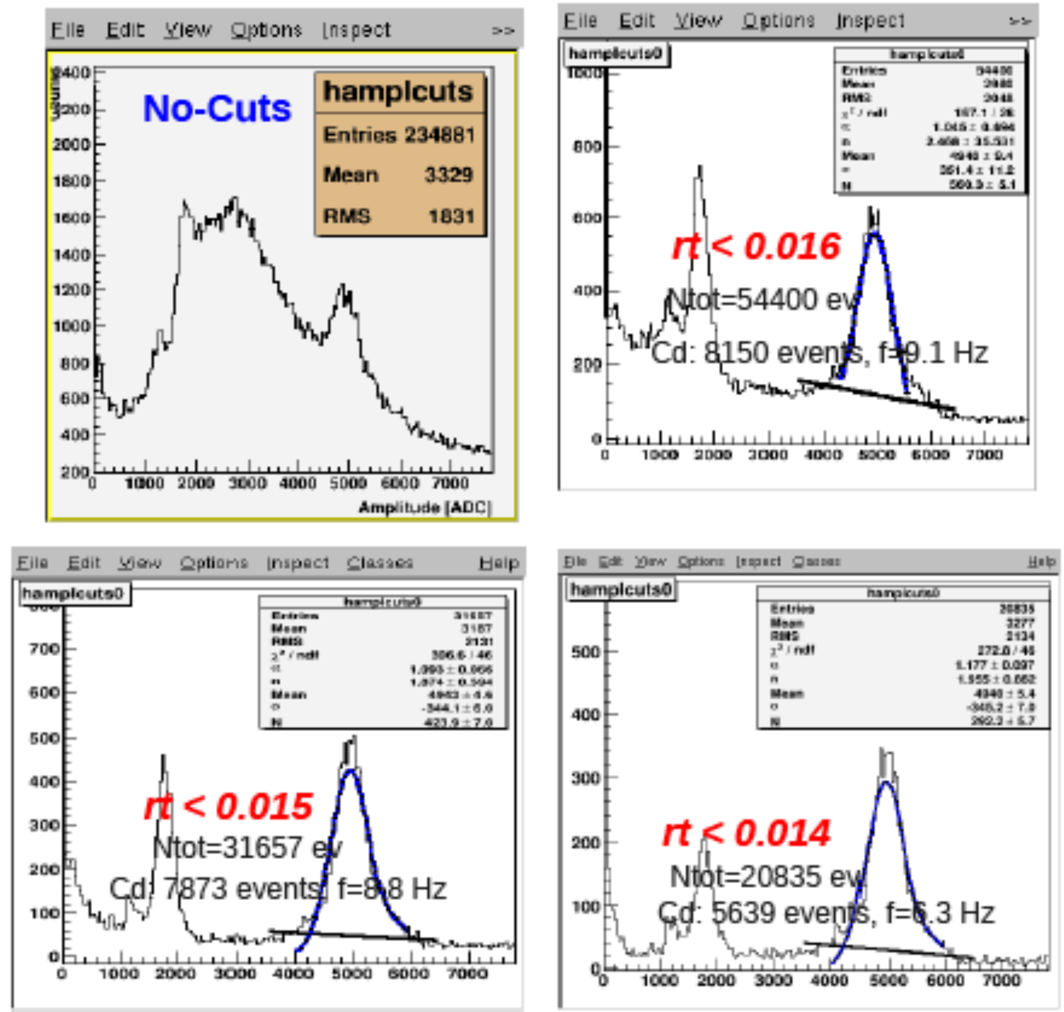


Rejection power

Rise time cut

Using Cd-109 source – December 2009
Irradiate gas through 200µm Al window
P = 100 mb, Ar-CH_4 (2%)





If rt ~ 0.0155 ms ==> R = 65 cm
0.014 ms ==> ~70% of signal

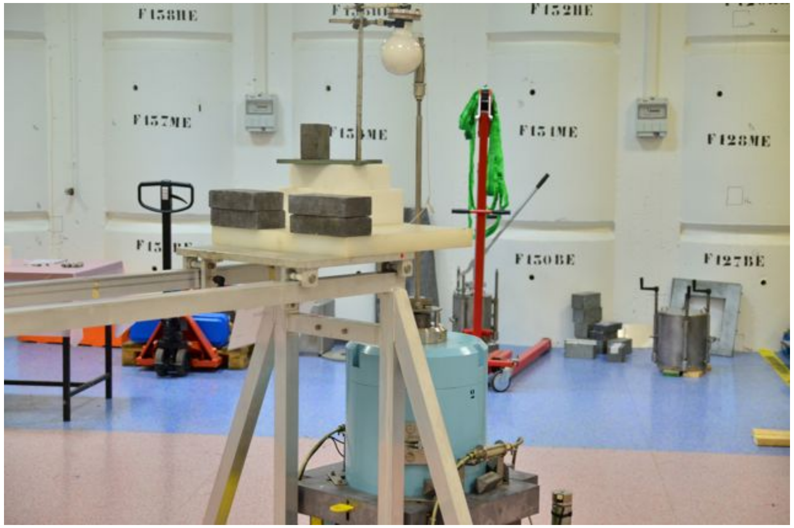
Efficiency of the cut in rt ==> ~ 70% signal (Cd peak)

Severe background reduction

Energy resolution ~ 6 % and 9 % for Cu and Cd

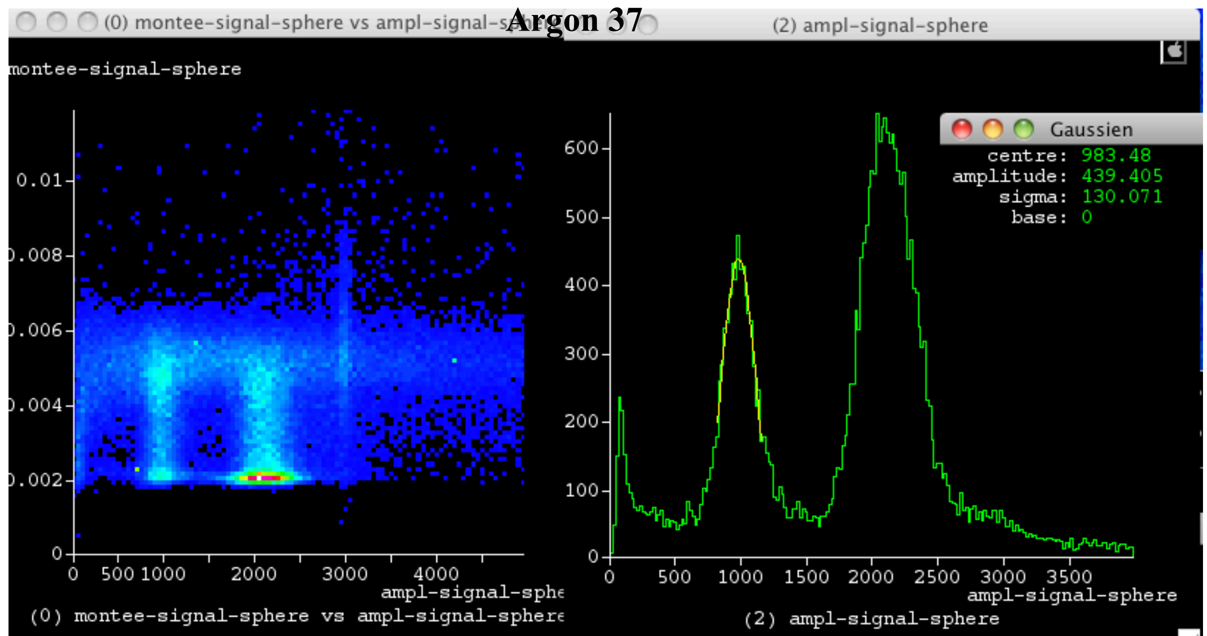
New low-energy calibration source *Argon-37*

Home made Ar-37 source: irradiating Ca-40 powder with fast neutrons $7x10^{6}$neutrons/s
Irradiation time 14 days. Ar-37 emits K(2.6 keV) and L(260 eV) X-rays (35 d decay time)



Argon 37

First measurement
with Ar-37 source
Total rate 40 hz
in 250 mbar gas, 8 mm ball
260 eV peak clearly seen
A key result for light dark matter search

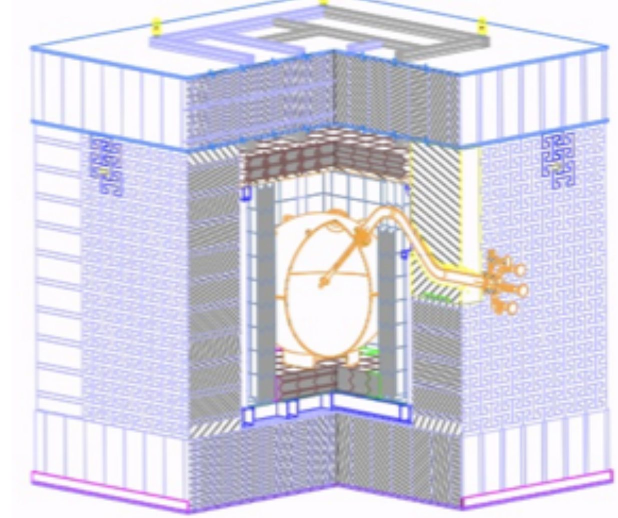


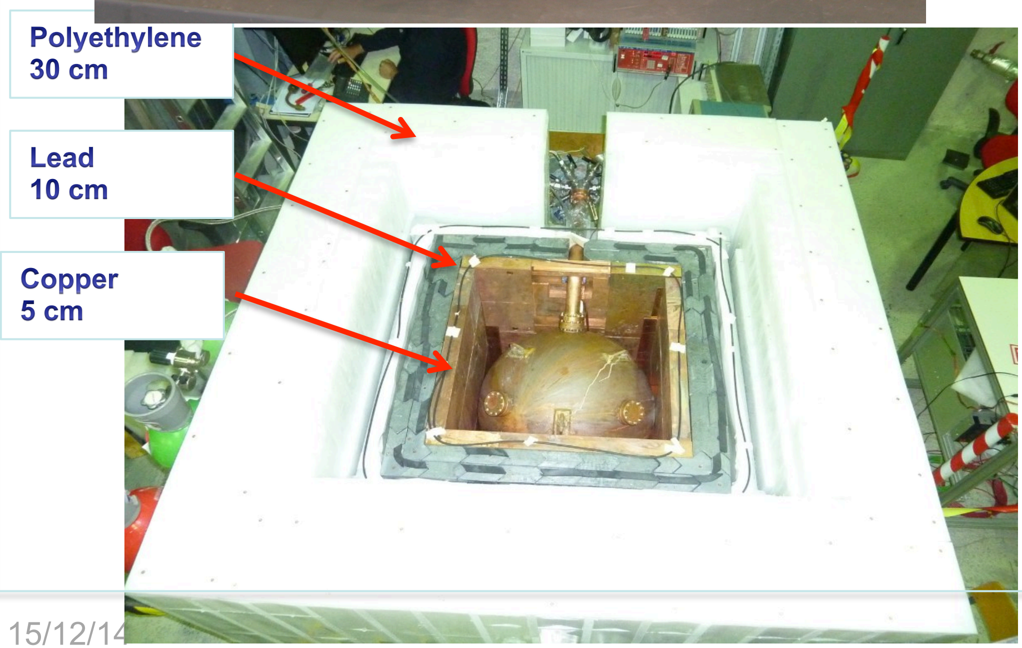
Search for light dark matter

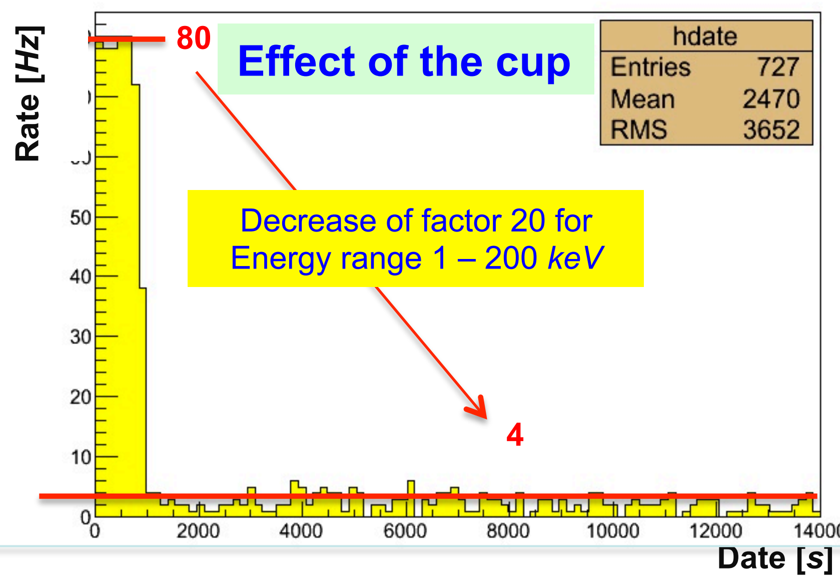
Detector installed at LSM end 2012: 60 cm, Pressure = up to 10 bar

Gas targets: Ar, Ne, He, CH4

Detector inside shield





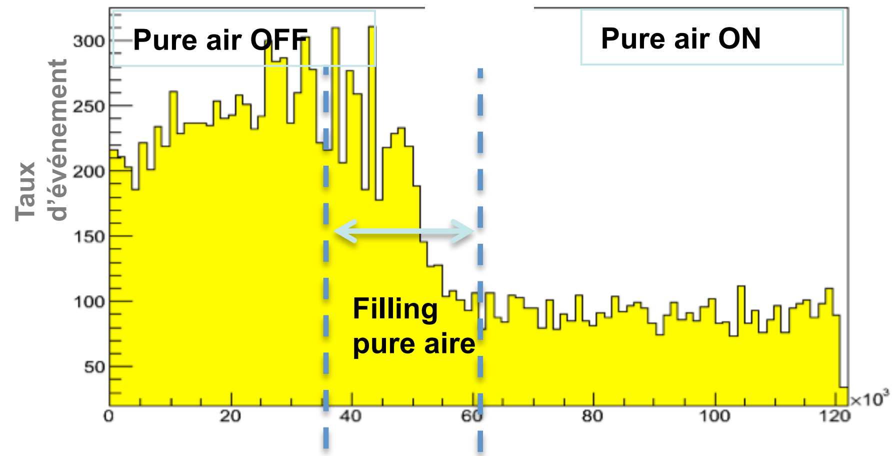


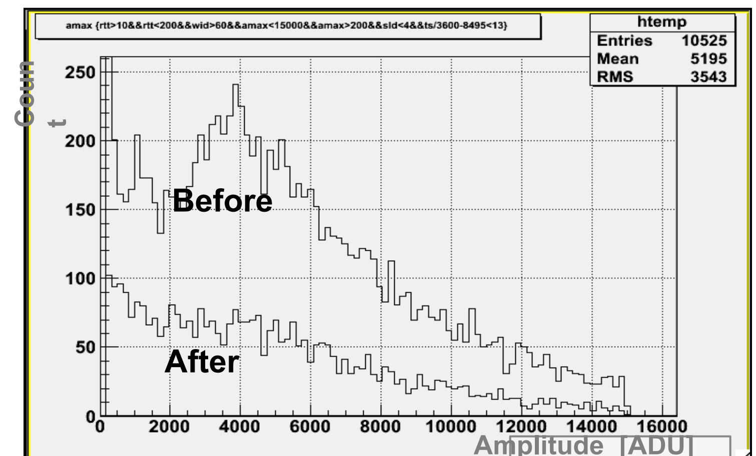
External Radon contamination

Radon rate

- @LSM ≈ 15 Bq/m^3
- After anti-radon factory ≈ 20 mBq/m^3

Ne (2 bar) + He (1 bar) + CH_4 (2%)





Internal contamination cleaning
Goal: remove Po-210,Pb-210

1st chemical cleaning of sphere

Conditions :

- Nitric acid (17 %)
- Temperature 10° *C*
- Cleaning by filling the spherical cavity
- Washing by pure water
- Drying by hot nitrogen

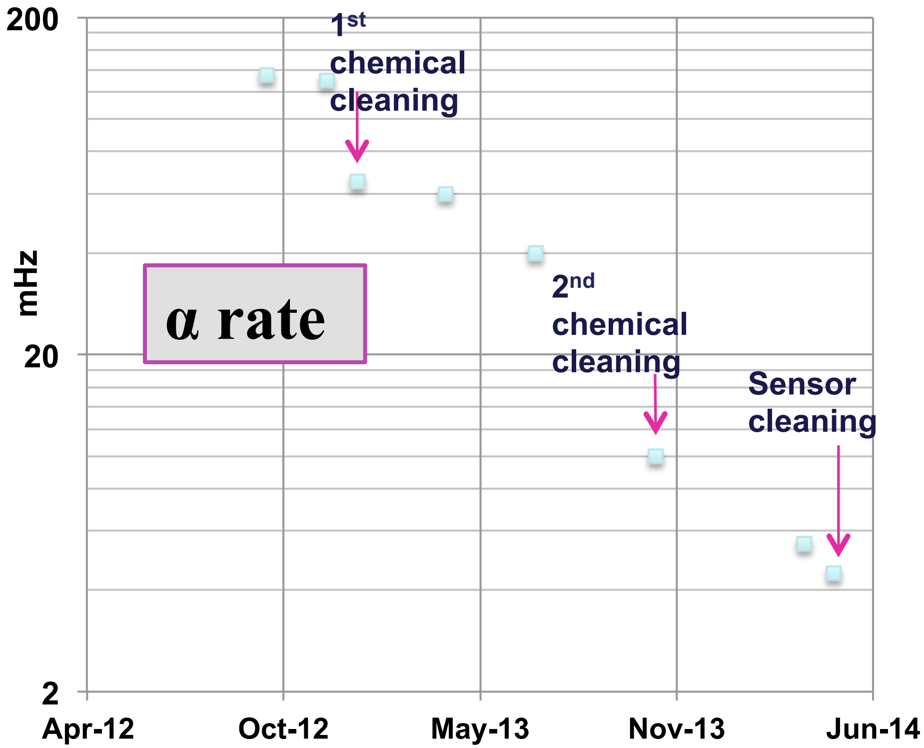
2nd chemical cleaning of sphere

Conditions :

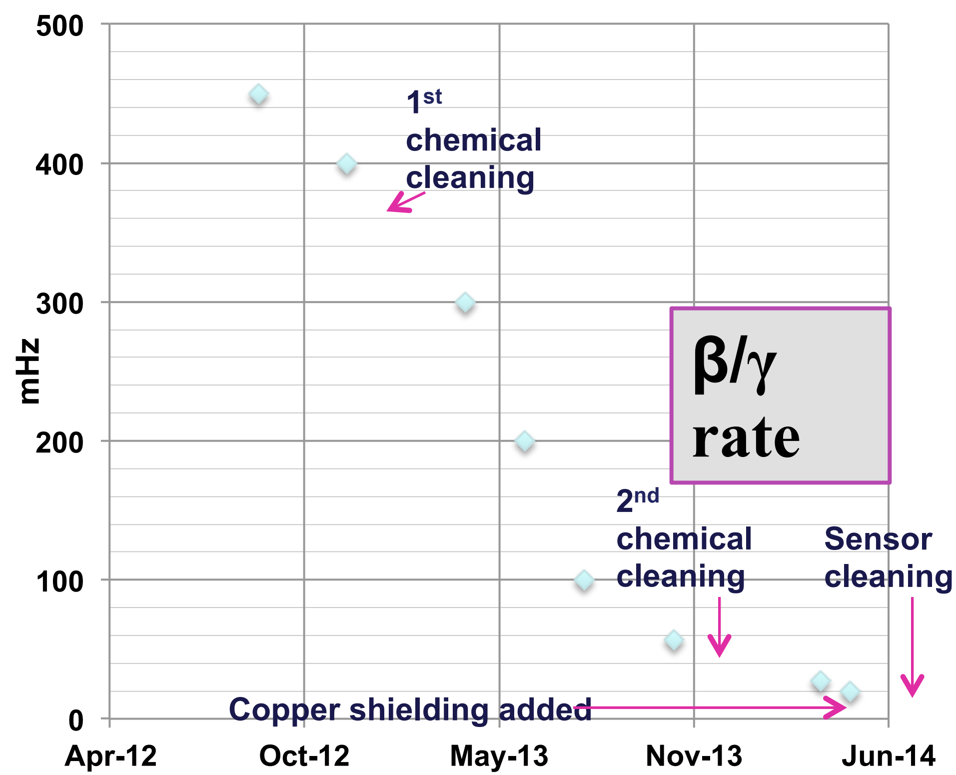
- Nitric acid (30 %)
- Temperature 30° *C*
- Cleaning by spray
- Washing by pure water
- Drying by hot nitrogen

Backround evolution of the detector

Alpha rate evolution



β/γ rate evolution



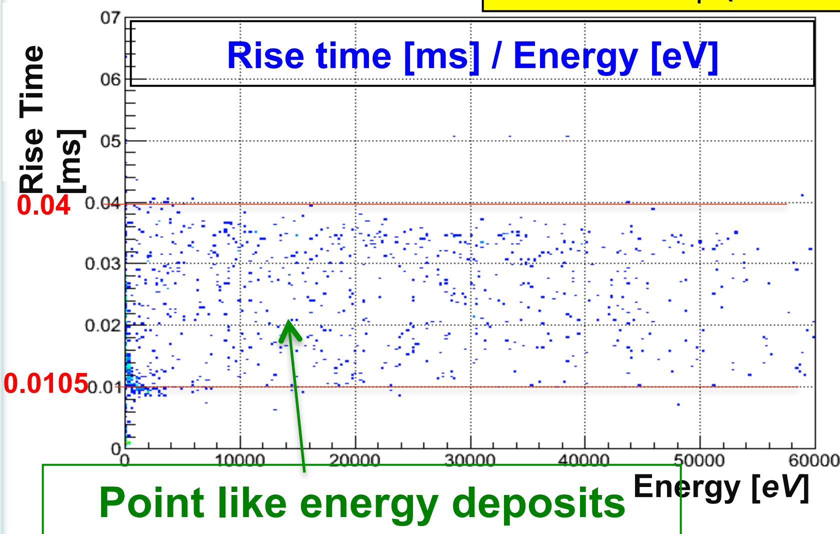
Decreasing factor = 45
180 *mHz* => 4 *mHz*

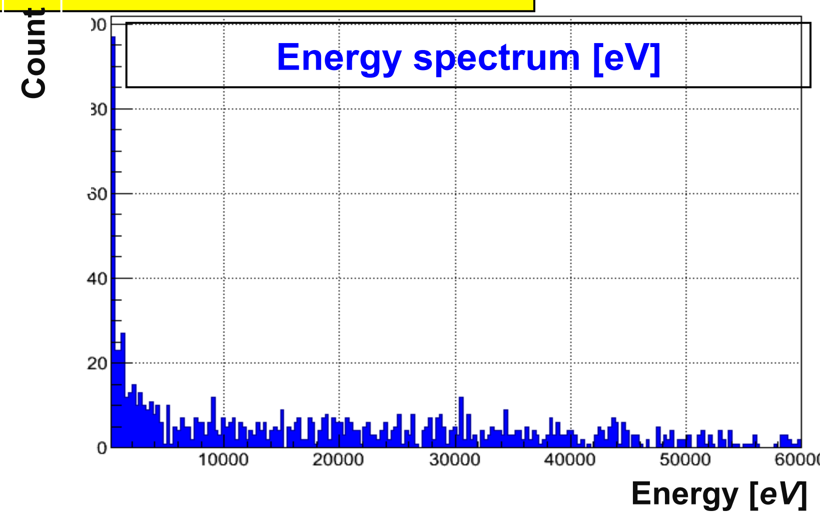
Decreasing factor = 20
400 *mHz* => 20 *mHz*

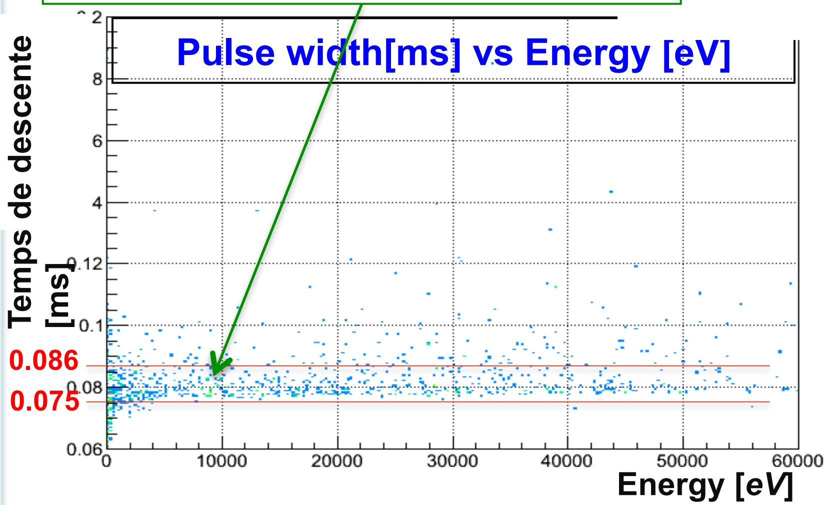
Analysis – optimization of cuts

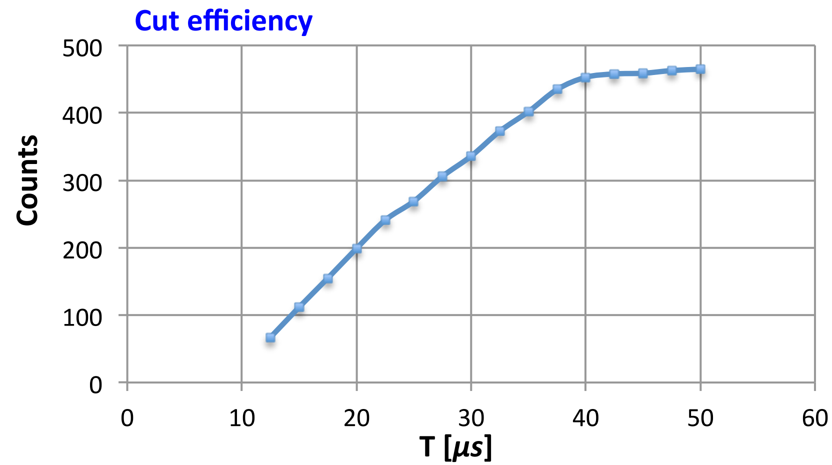
Calibration with neutrons (^{241}Am-Be) source

$Ne + CH_4$ (0.7 %) P = 3 bar T = 4455 s



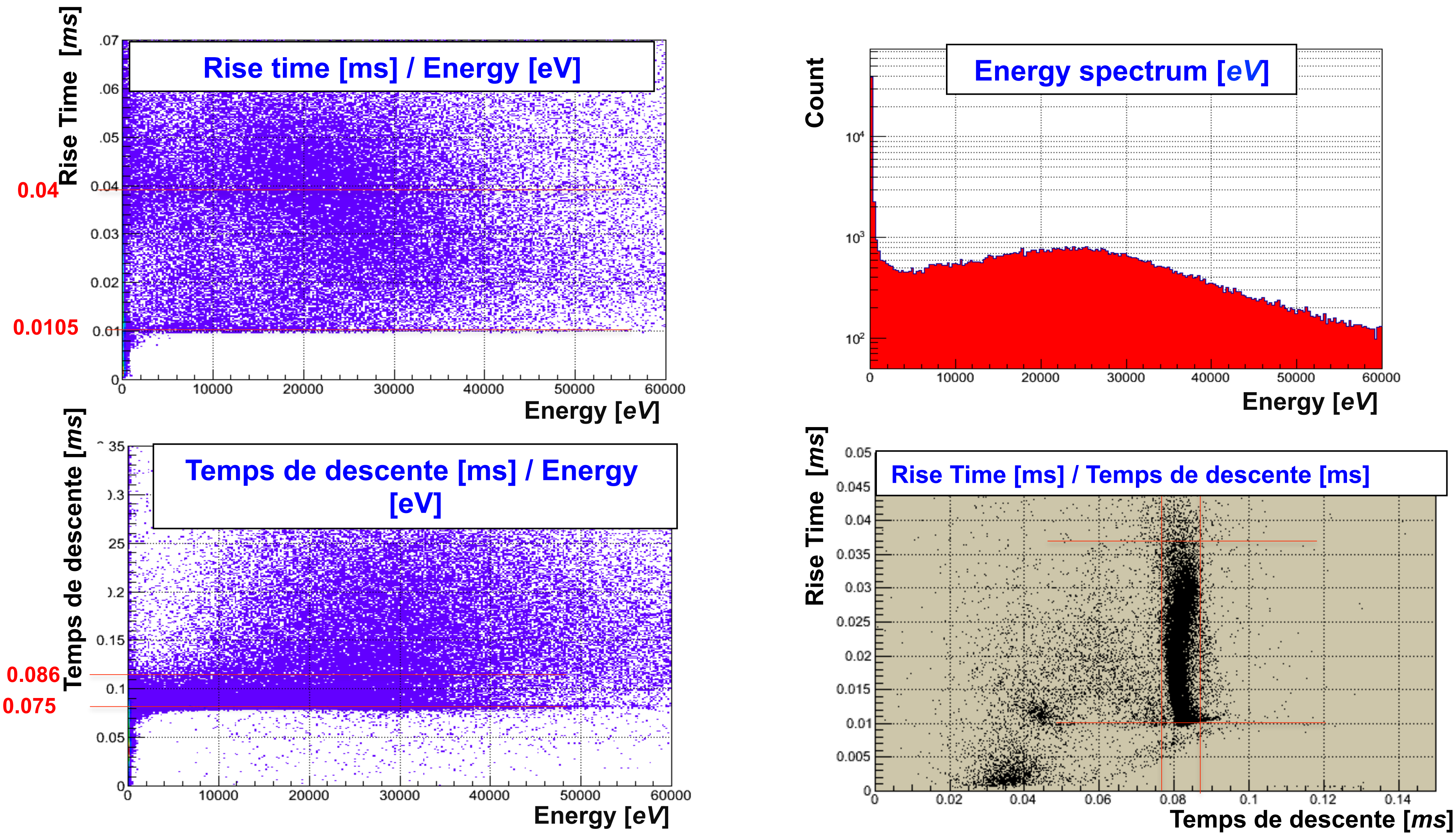




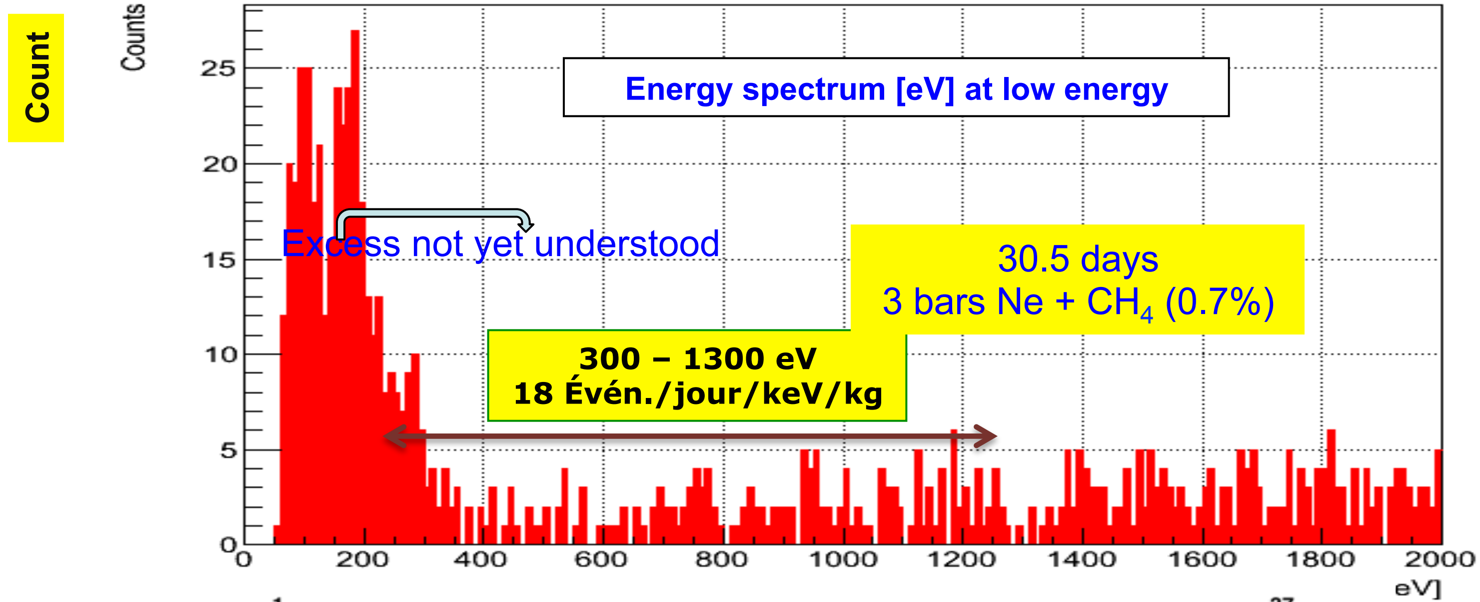


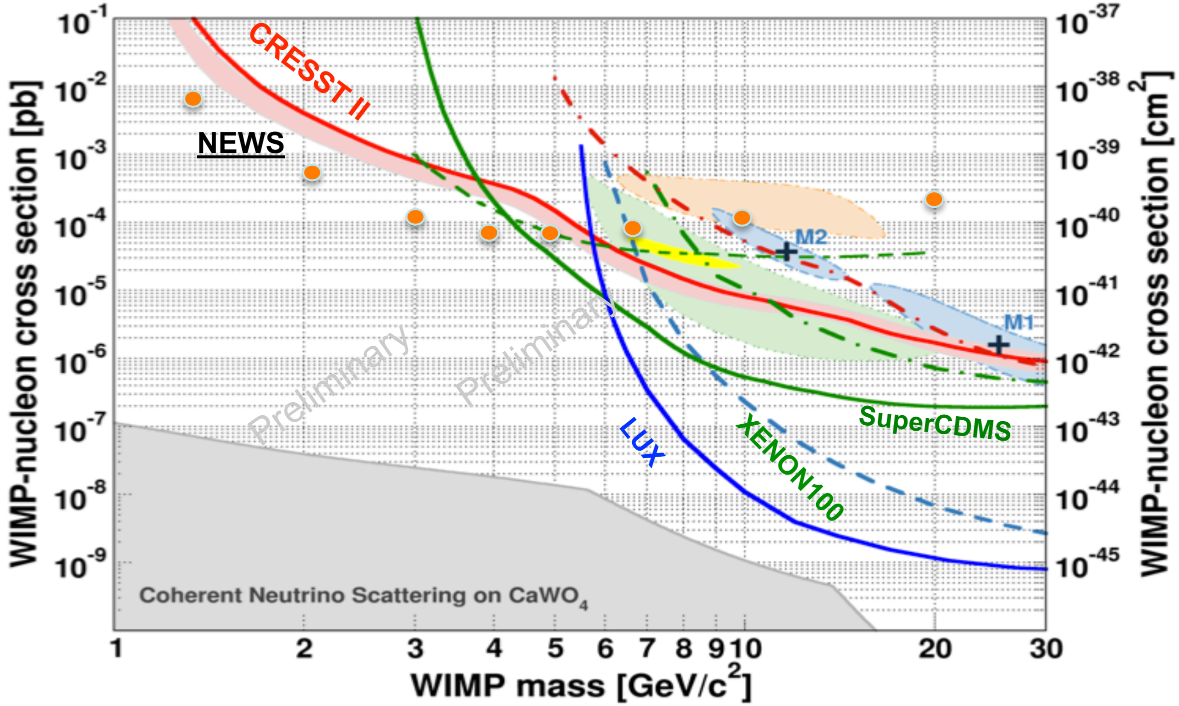
Physic run (light-WIMPs research)

Ne + CH_4 (0.7 %) P = 3 bar T = 30.5 jours

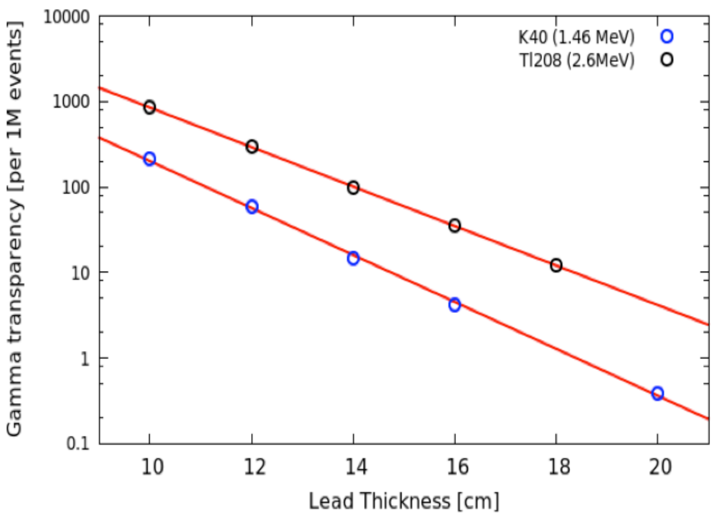


Light WIMP search results





Future improvements: simulation and measurements show that present background level is limited by the shield thickness (Pb 10 cm, Cu 5 cm)

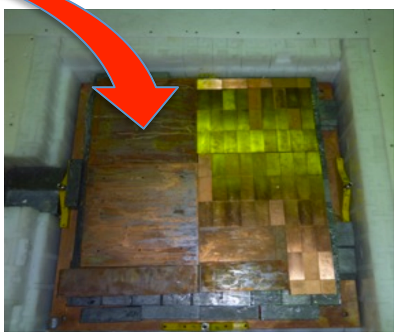


Simulation

lead shield more than 10 [cm]	^{40}K (1.4 MeV)	^{208}Tl (2.6 MeV)
12	↘ x 3.7	↘ x 2.9
14	↘ x 14.8	↘ x 8.5
16	↘ x 52.2	↘ x 24.4
20	↘ x 1095	↘ x70

Measurement

Adding 10cm copper on top of shield **reduces background by 32%!!!**

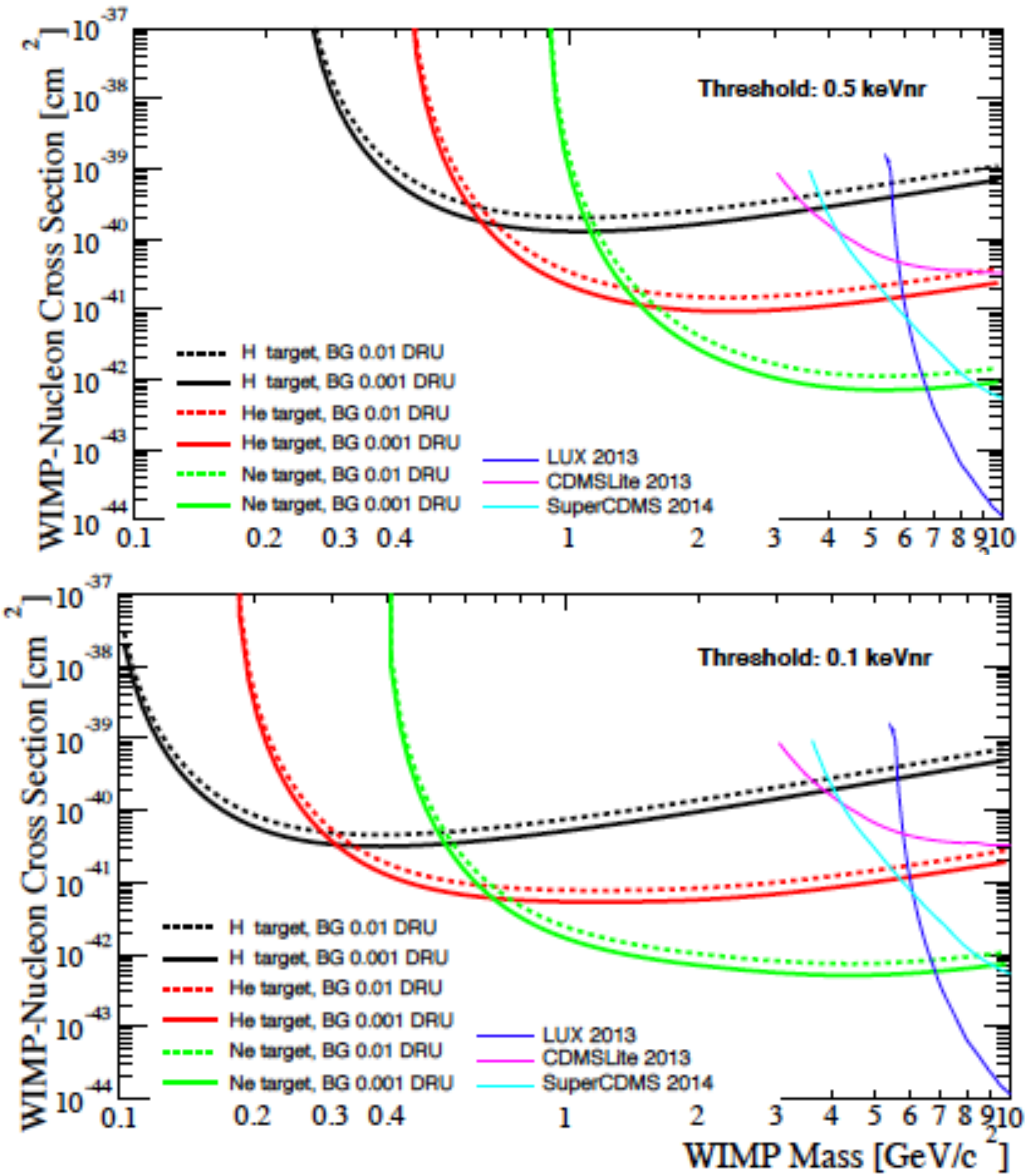


Cut	Amp	Amp
	1000 – 40000	2000 – 40000
5cm of the Cu on the top	↘ 21 %	↘ 21 %
10cm of the Cu on the top	↘ 32.1 %	↘ 32.1 %

Next january we will add 5 cm Pb and 2 cm Cu

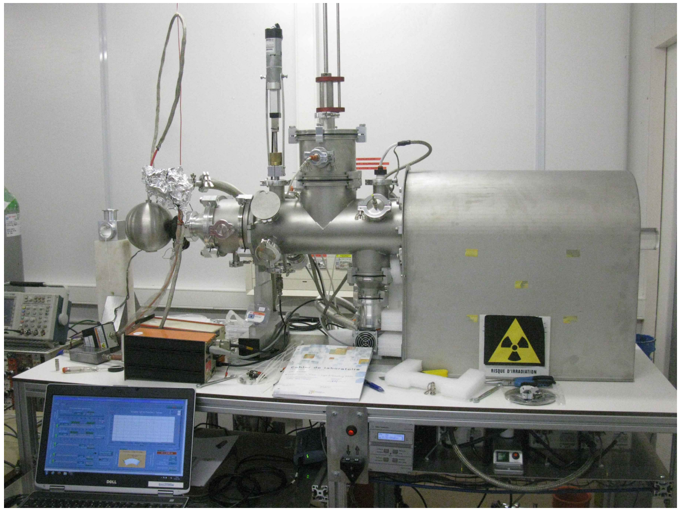
Projected sensitivity with a 2 m detector

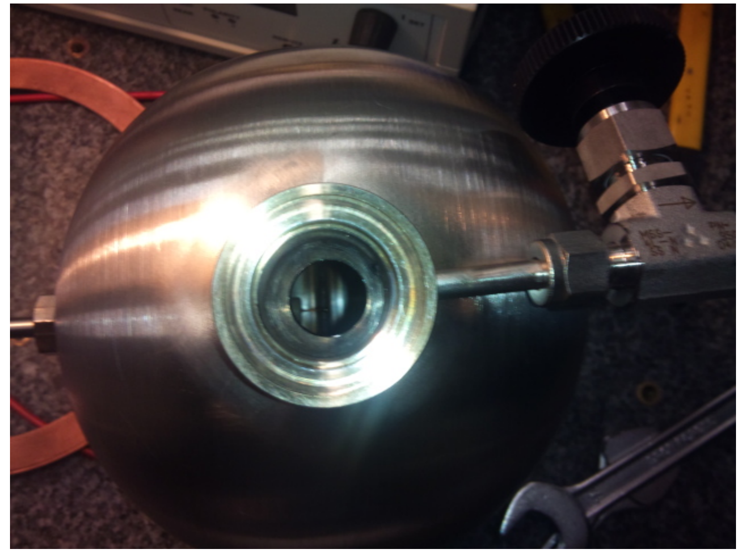
Simulations by Kaxuan Ni et al.,



Quenching factor measurements

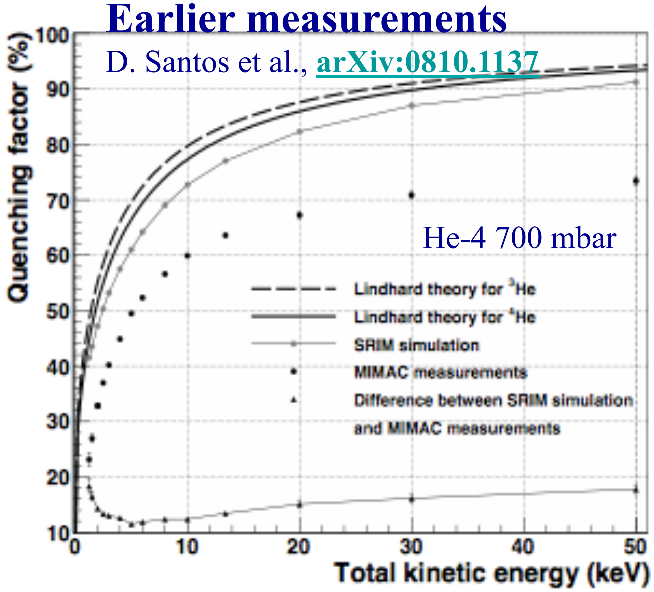
Goal: measure QF down to 500 eV ion energy using the Grenoble MIMAC facility for H, He, Ne, CF4, Ar, Xe at various pressures





Earlier measurements

D. Santos et al., arXiv:0810.1137



Recent investigations with a 15 cm sphere show the capability to measure 500 eV He-4 ions with an estimated QF of about 30%

Saclay, Grenoble, Thessaloniki, Queen's-Kingston

Additional Physics

Motivated by:

- **Sub-keV energy threshold of the detector**
- **Large volume detector (1 m^3 to much larger)**
- **Large mass and sub-keV energy threshold**
- **Good energy resolution**
- **Low background**
- **Versatility of the target (gas and pressure)**

- Neutrino-nucleus coherent elastic scattering near a nuclear reactor
- A dedicated Supernova detector (4 m in diameter)

Y. Giomataris, J. D. Vergados, Phys.Lett.B634:23-29,2006

Idea : A world wide network, at University level, of several (tenths or hundreds) of such dedicated Supernova detectors managed by students

- Gravitationally trapped massive Axion (like) particles decays

L. Di Lella, K. Zioutas, Astropart. Phys. 19 (2003) 145

- Room size Neutrino oscillations using very low energy neutrino sources

I. Giomataris, J.D. Vergados, Nucl.Instrum.Meth.A530:330-358,2004, J.D. Vergados,Y. Giomataris, Y. Novikov, Nucl.Phys. B854 (2012) 54-66 , Phys.Rev. D85 (2012) 033003

- Background free double beta decay experiment, *I. Giomataris, arXiv:1012.4289*

CONCLUSIONS

- Promising results with a novel spherical counter
- Ultra low energy threshold capability down to single electron
- Light dark matter search down to 100 MeV
- Low background records are expected