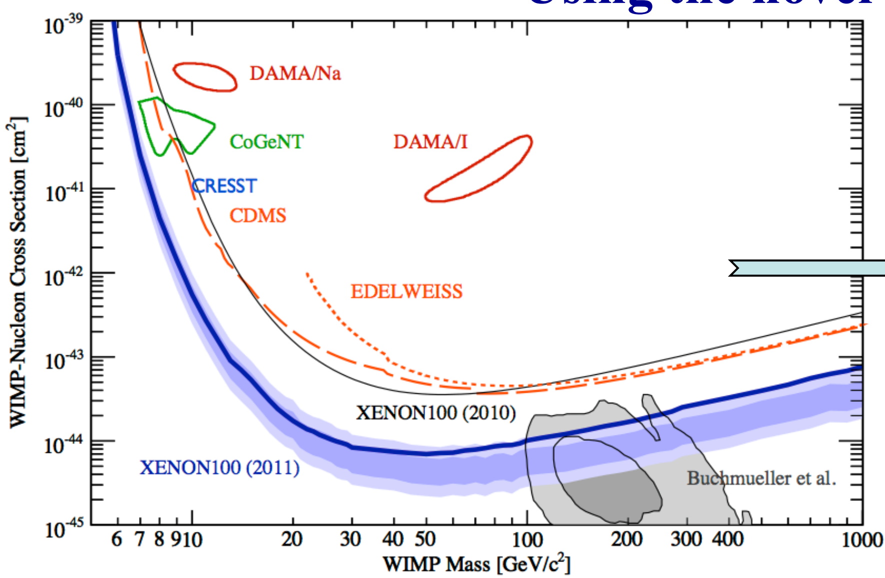
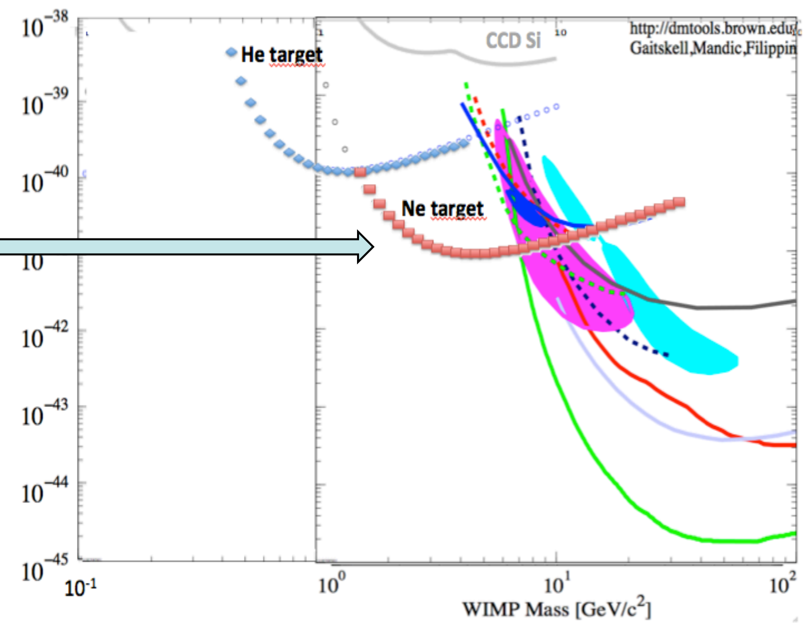
Light dark matter search with a spherical proportional counter

I. Giomataris, CEA-Irfu-France

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, ...

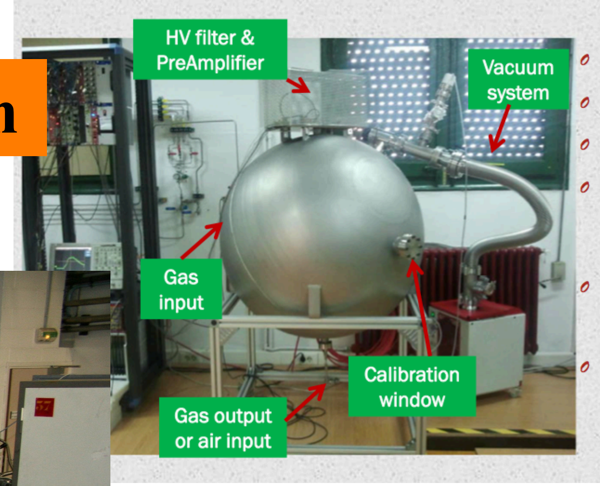
Possible collaboration

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

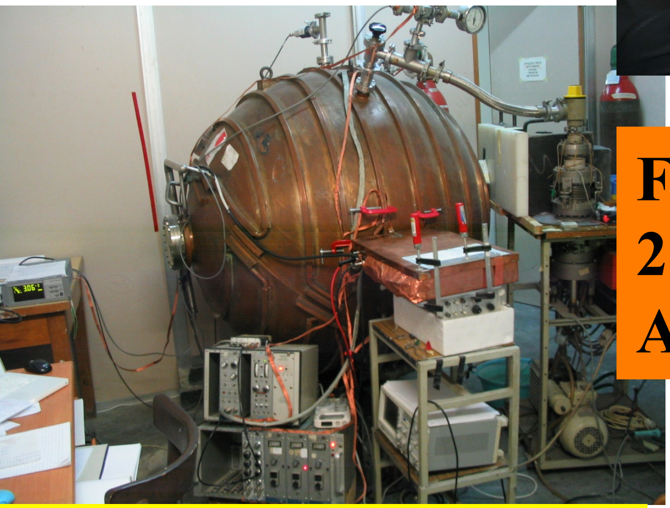
Spherical detector propagation

University of Saragoza detector



Basic R@D detector in Saclay

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



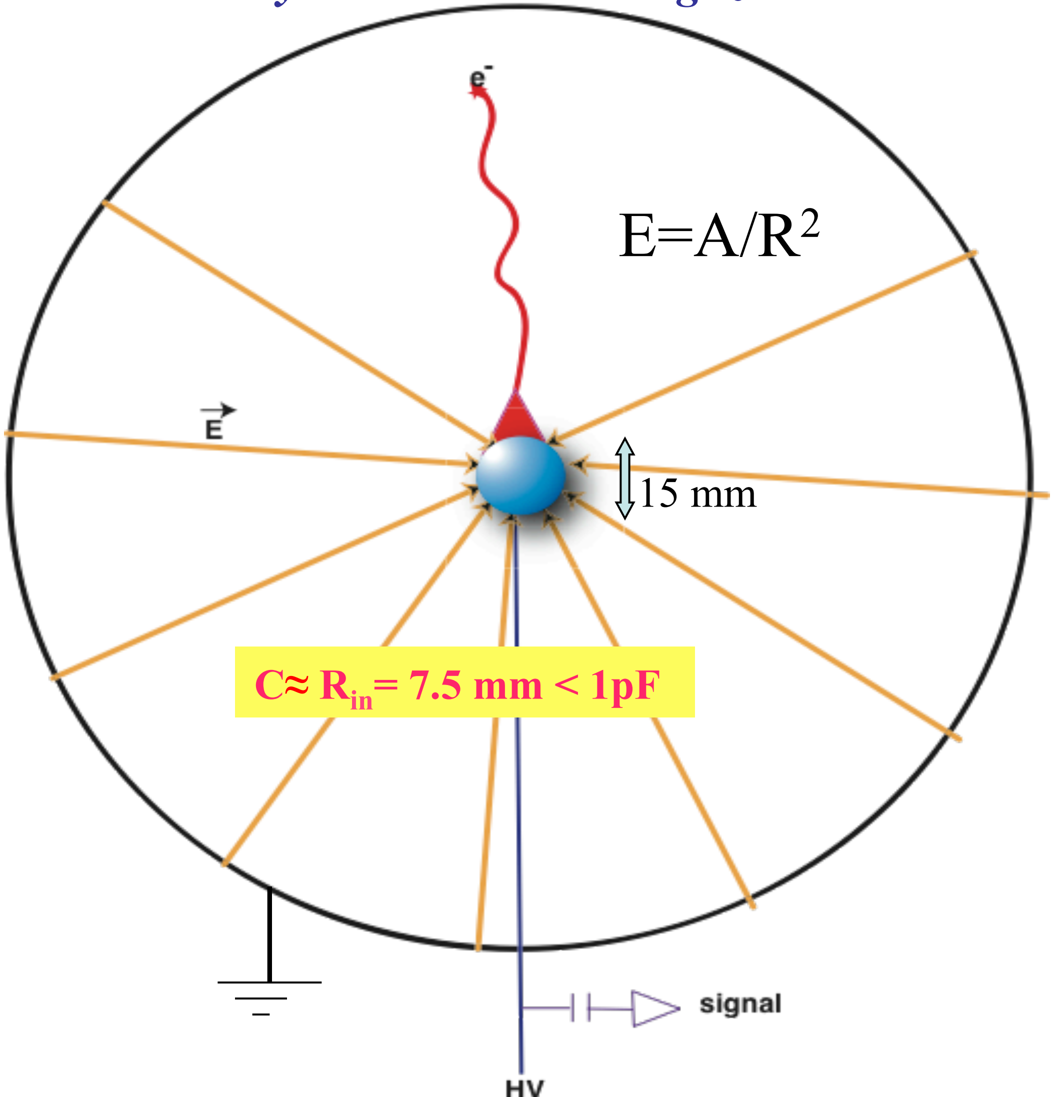
University of Thessaloniki detector

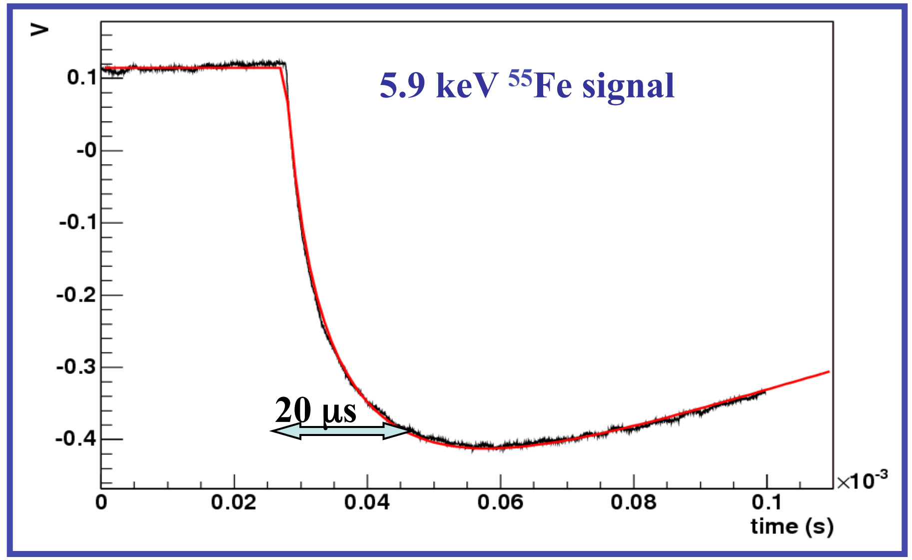
University of Tsinghua - HEP detector

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

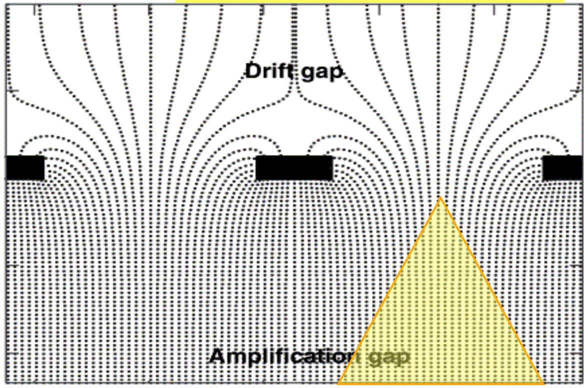




- Simple and cheap
- Large volume
- single read-out
- Robustness
- Good energy resolution
- Low energy threshold
- Efficient fiducial cut

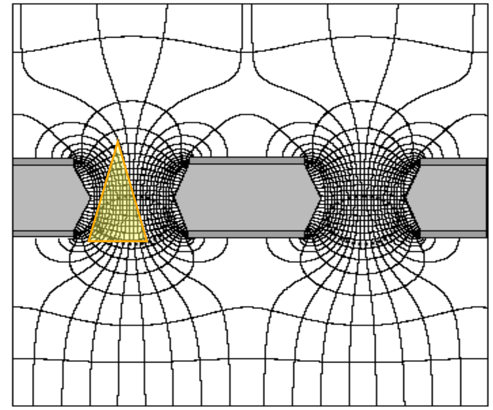
Parallel Plate Detector

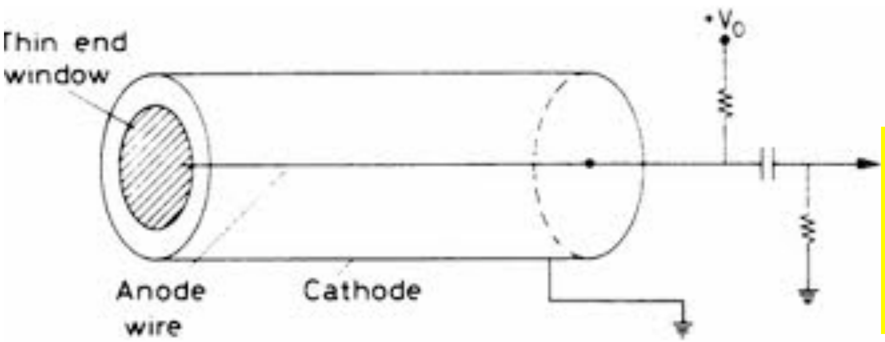
Micromegas



E= constant
$C \approx S > 1nF$

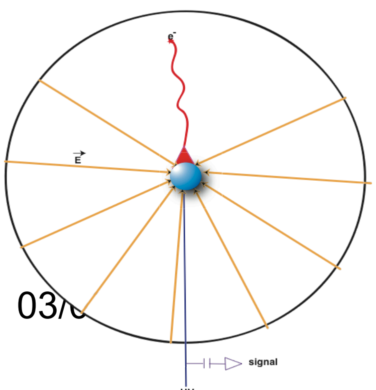
GEM





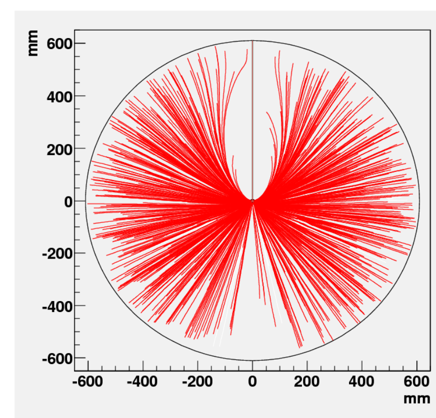
Cylindrical Proportional Counter

$E=V/\ln(b/a)r$ **L** = length and **a**=radius of the wire, **b** = tube radius
$C = 2\pi L/\ln(b/a) >> 10$ pF



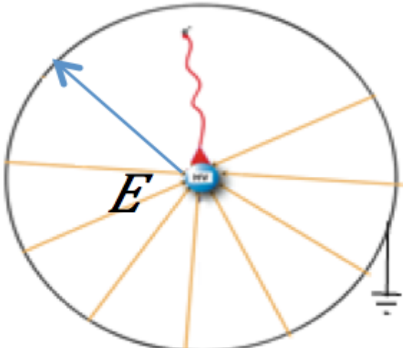
Spherical Proportional Counter

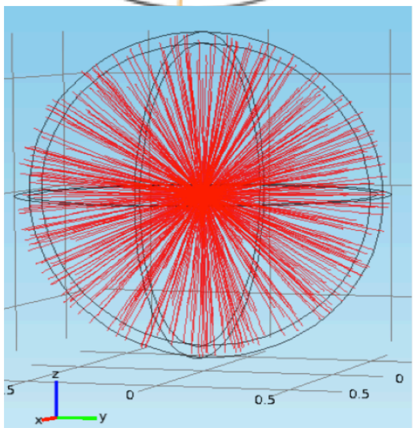
$E=1/r^2$
$\approx V/R_i$ close to the ball
$C \approx R_{in} < 1$pF

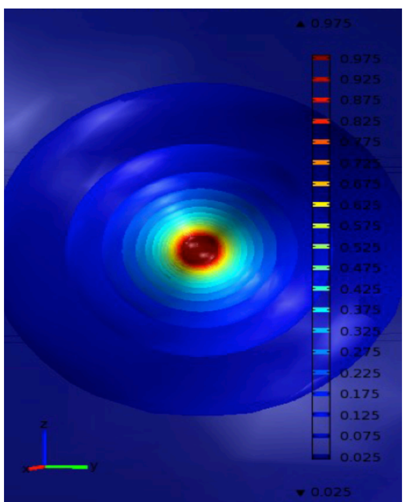


Electrostatics deal - how to maintain a radial field

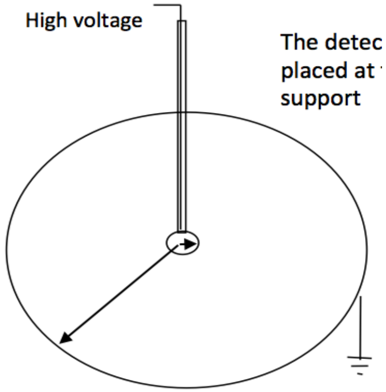
Ideal case: ball non wire

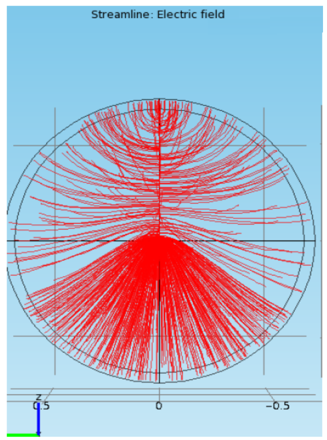


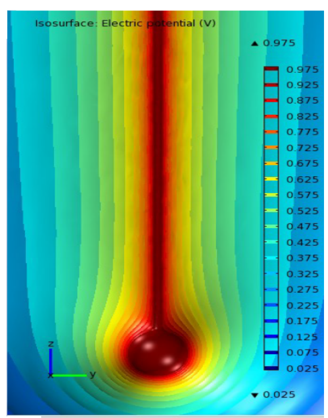




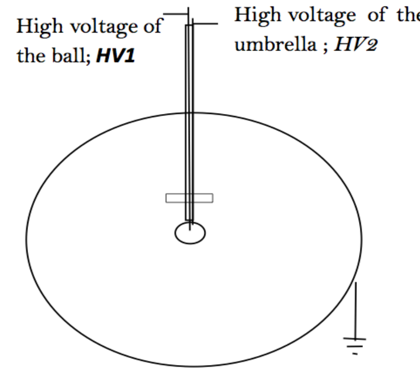
Ball with wire

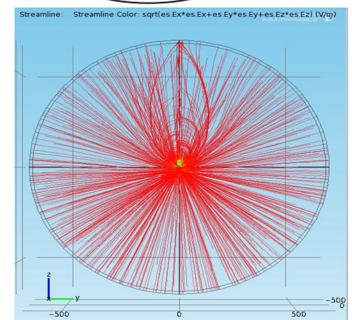


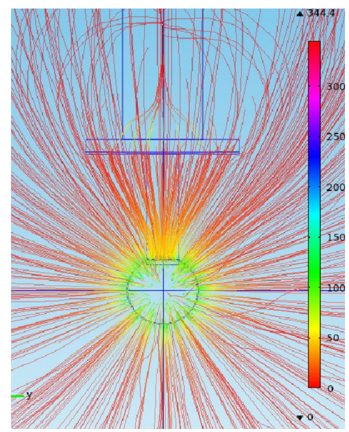


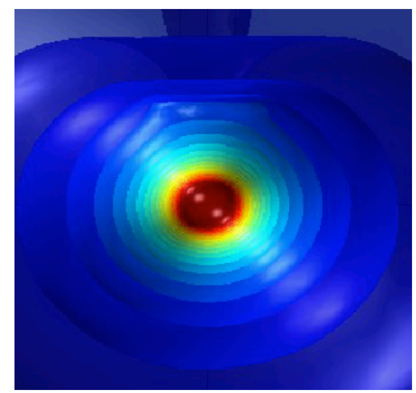


The Ball with umbrella corrector





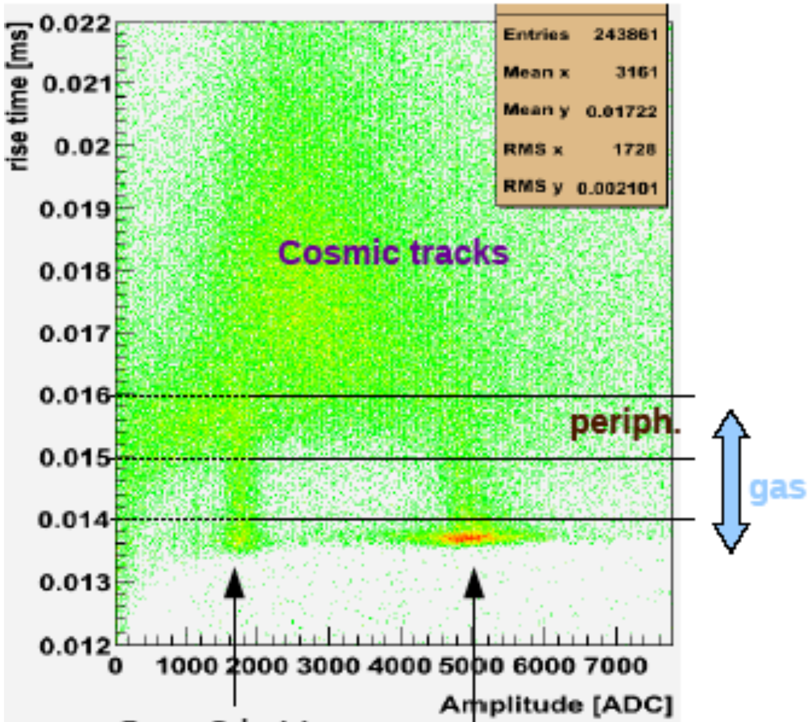




Rejection power

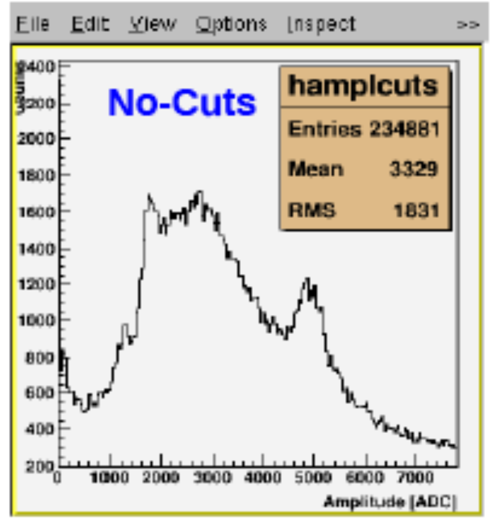
Rise time cut

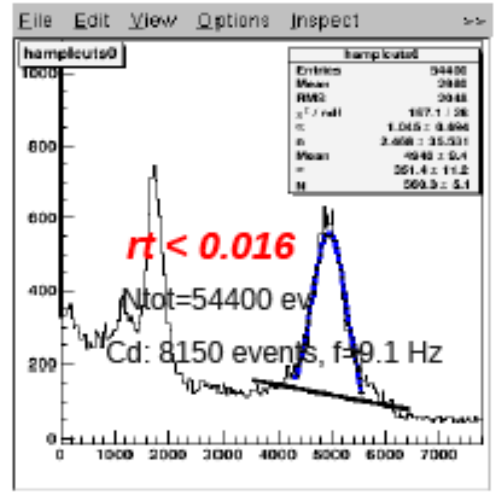
Using Cd-109 source – December 2009
Irradiate gas through 200µm Al window
P = 100 mb, Ar-CH_4 (2%)

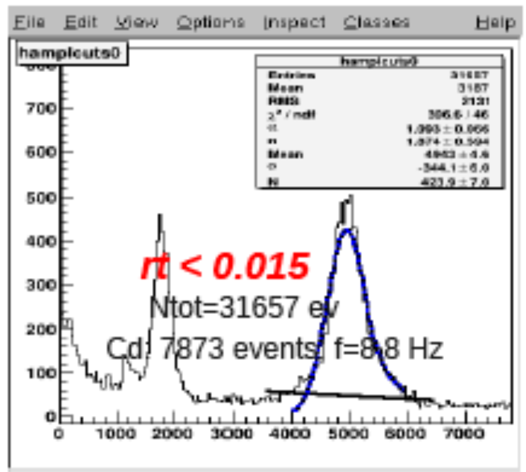


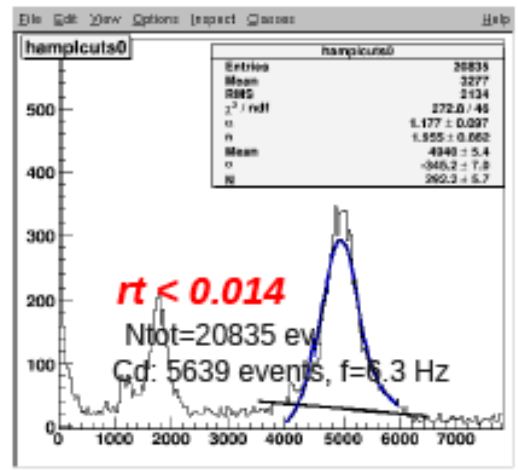
Cu ~ 8 keV

Cd ~ 22 keV









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

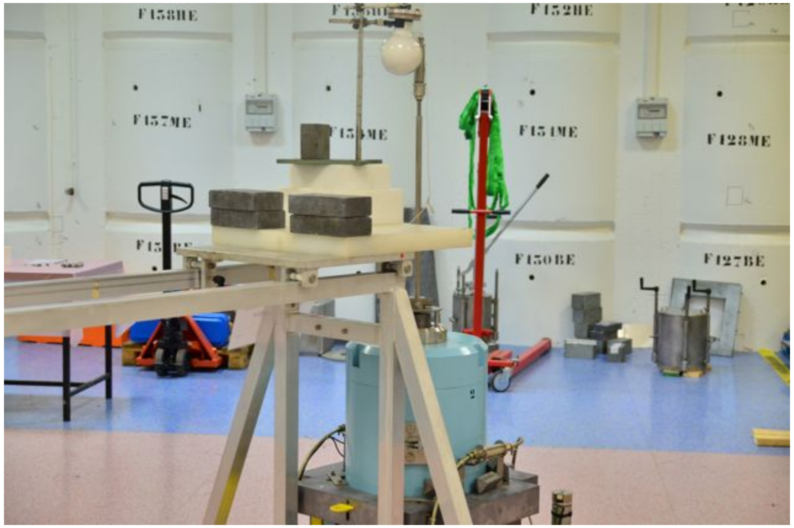
Efficiency of the cut in rt ==> ~ 70% signal (Cd peak)

Severe background reduction

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

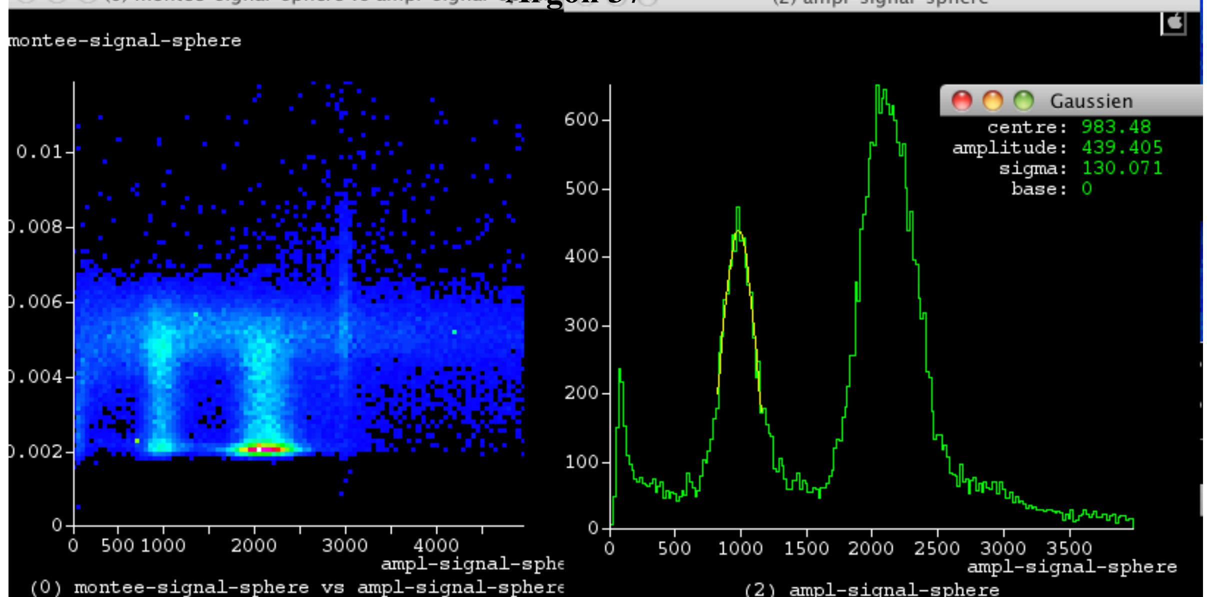
New low-energy calibration source *Argon-37*

Home made Ar-37 source: irradiating Ca-40 powder with fast neutrons 7×10^6 neutrons/s
Irradiation time 14 days. Ar-37 emits K(2.6 keV) and L(260 eV) X-rays (35 d decay time)

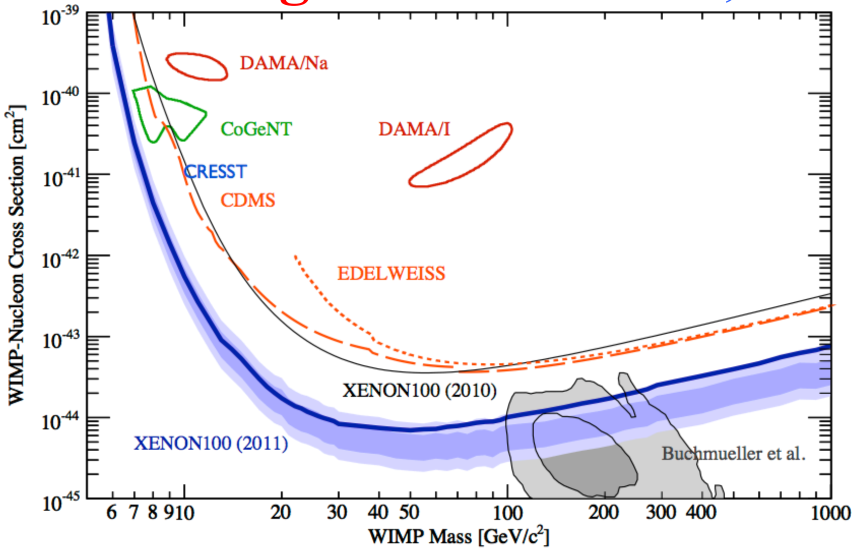


Argon 37

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



Cuurent light DM: DAMA, COGENT, claim rejected?

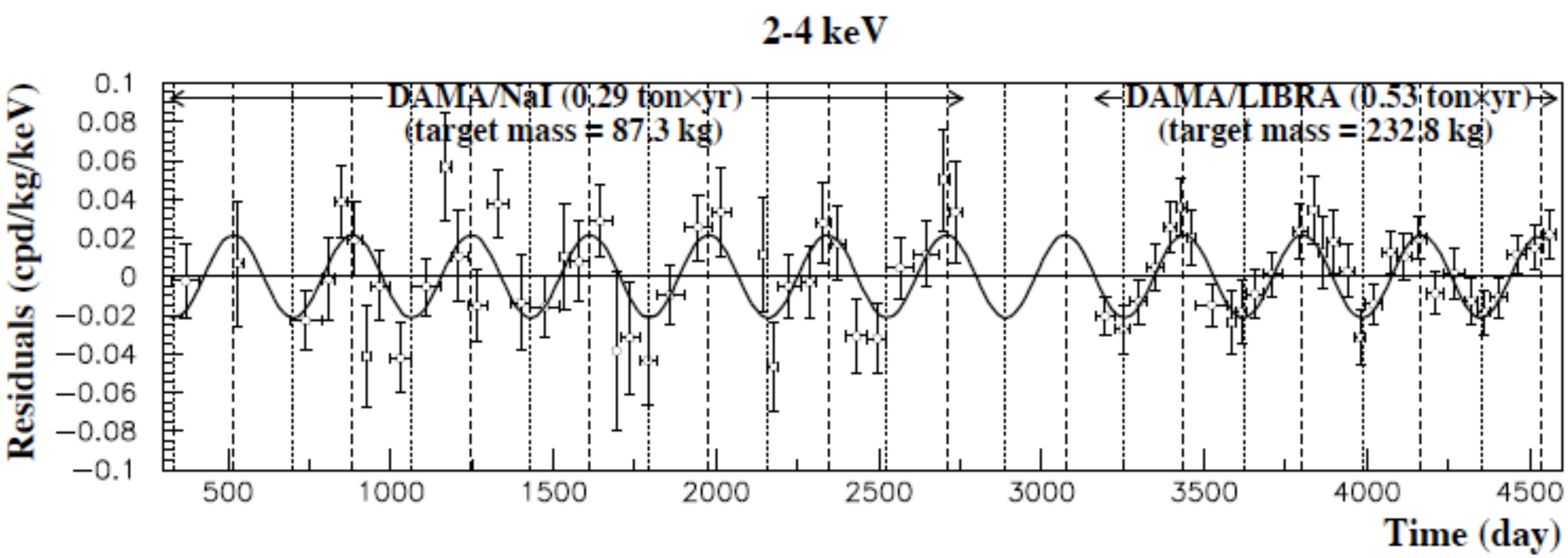


Light Dark Matter candidates < 10 GeV

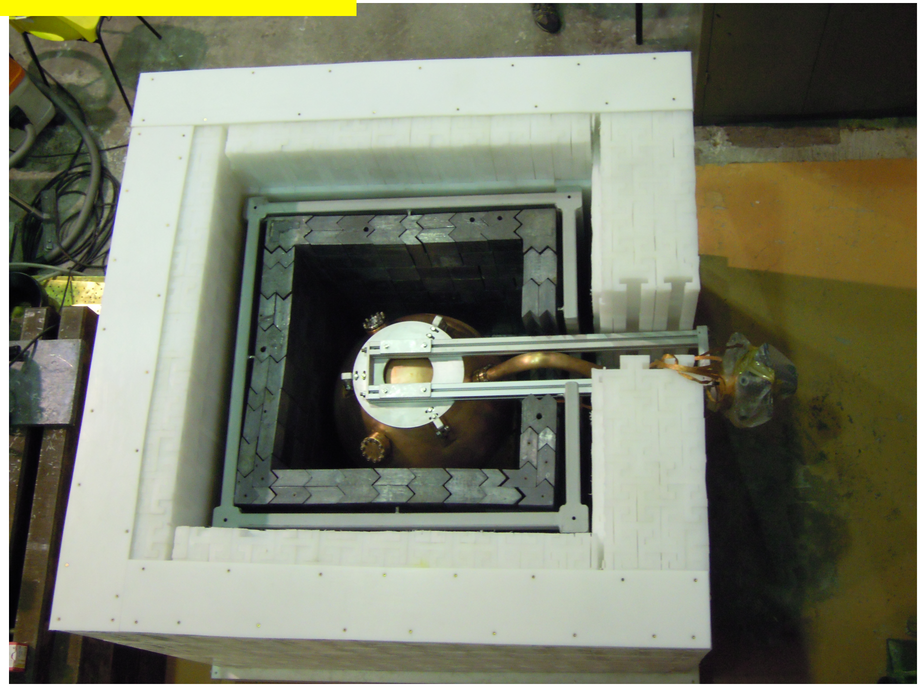
- Light U boson(Fayet, Boehm&Fayet)
- Secluded WIMP dark matter (Arkani-Hamed, Pospelov, Ritz, Voloshin)
- Kaluza-Klein Axion like Particle
- Assymetric Dark Matter
- Electron-Interacting dark matter

→ **SEARCH FOR LIGHTER MASSES**

DAMA+LIBRA 11 years, 0.83 ton × year, 8.2σ modulation signal.

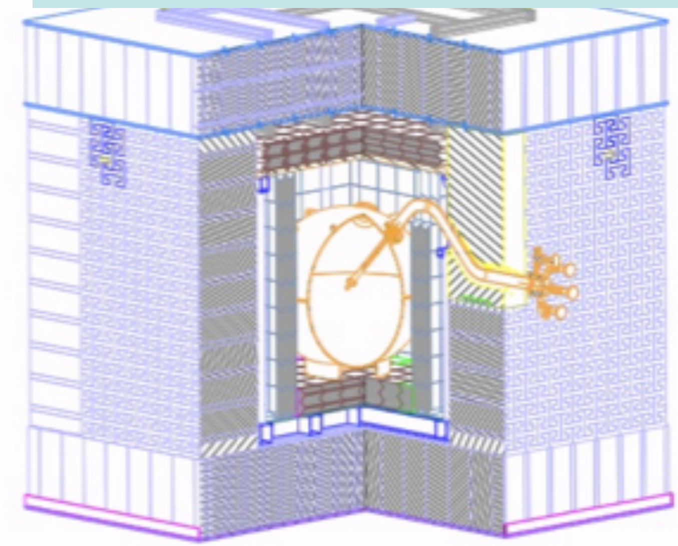


Search for light dark matter
Detector installed at LSM end 2012

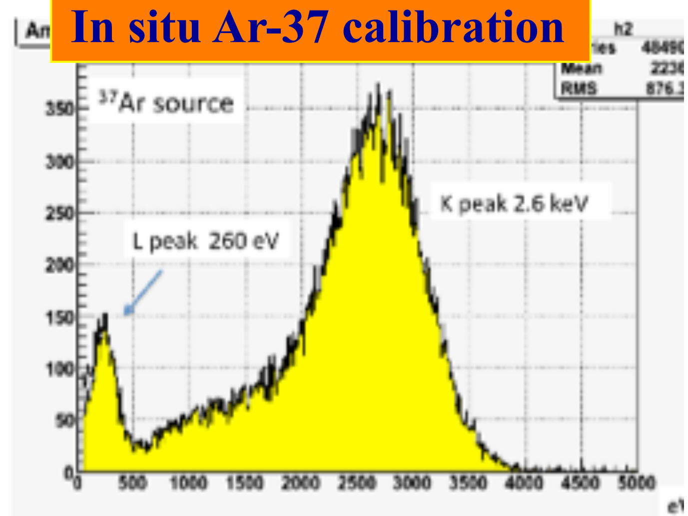


SEDINE detector made out of radiopure Cu
Diameter = 60 cm, Pressure = up to 10 bar

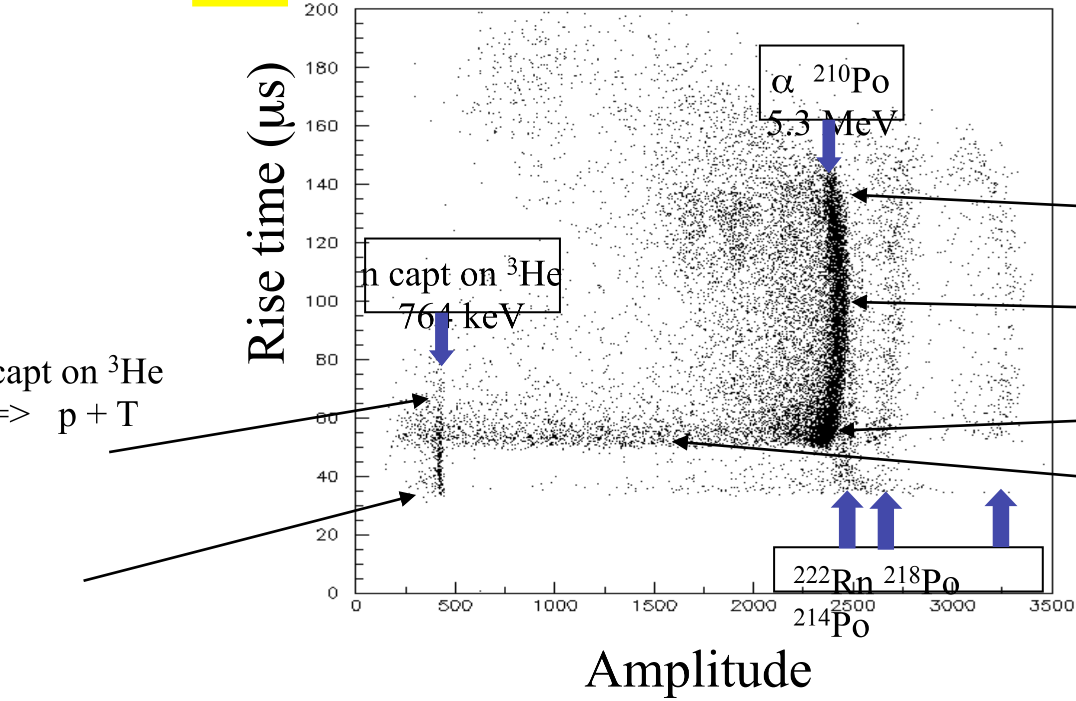
Gas targets: Ar, Ne, He, CH4

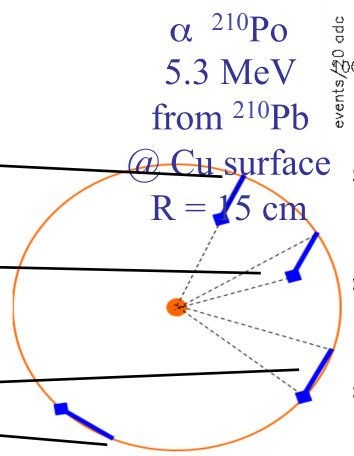


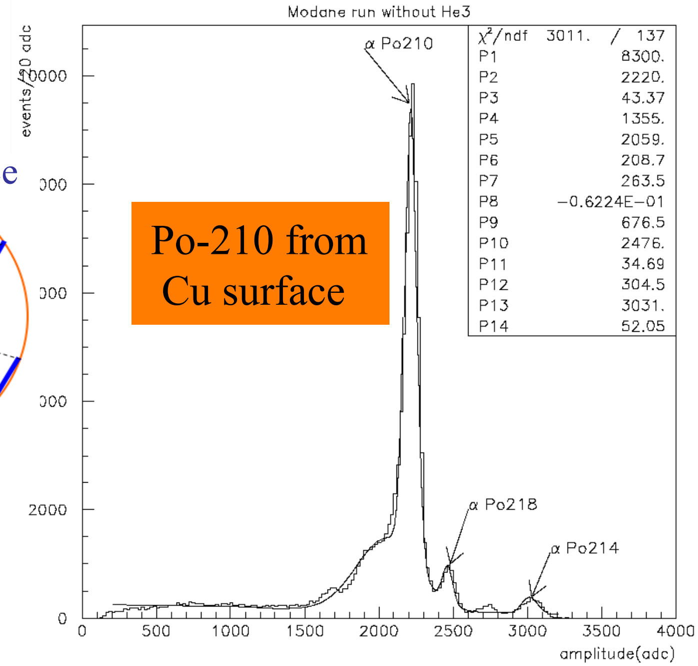
In situ Ar-37 calibration

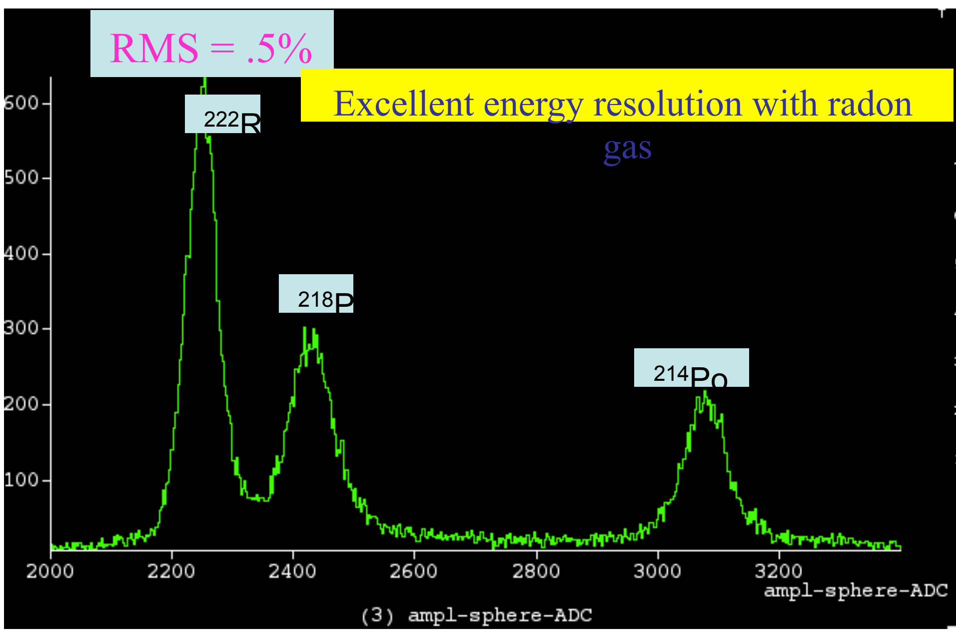


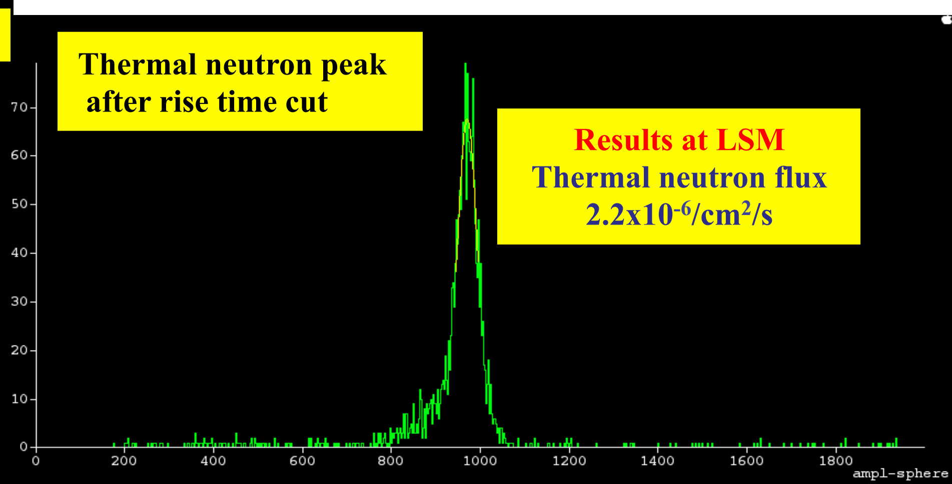
Signing radon and Po-210 contamination with spherical detector











Po-210, Pb-210 contamination deal

1st prototype: after cleaning the internal spherical vessel by spraying nitric acid we observed a decrease of alpha rate (at 5.3 MeV) with a decay time of Po-210

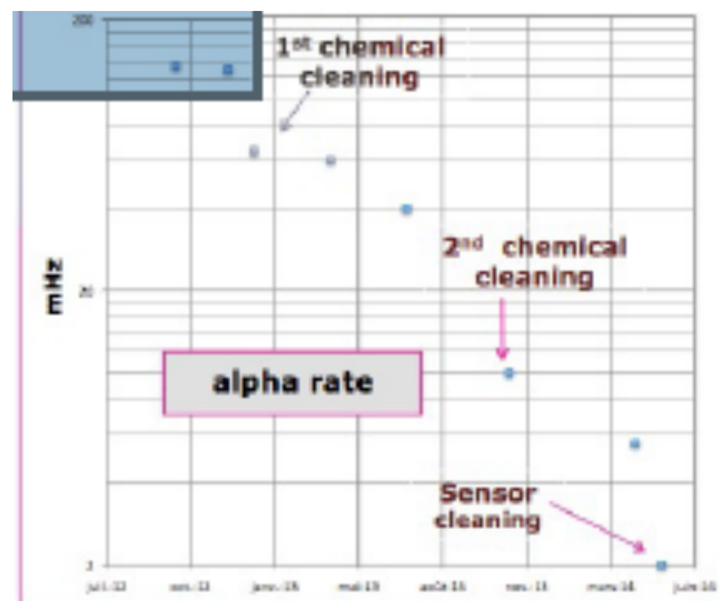
Low background detector:

1st cleaning: after filling the internal spherical vessel (last year) with nitric acid we observed a decrease of alpha rate of about 3 but then a stable rate (.06Hz) (Pb-210 not removed?)

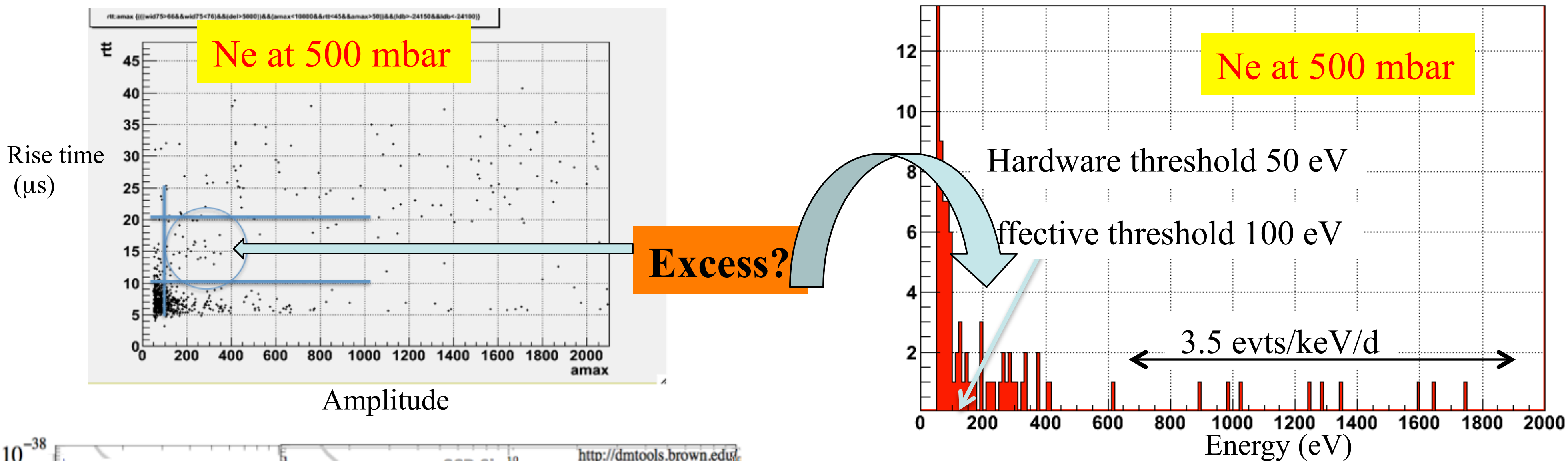
2nd cleaning: Cu vessel was sprayed with nitric acid Similar to the 1st prototype procedure the rate drops to (.004Hz)

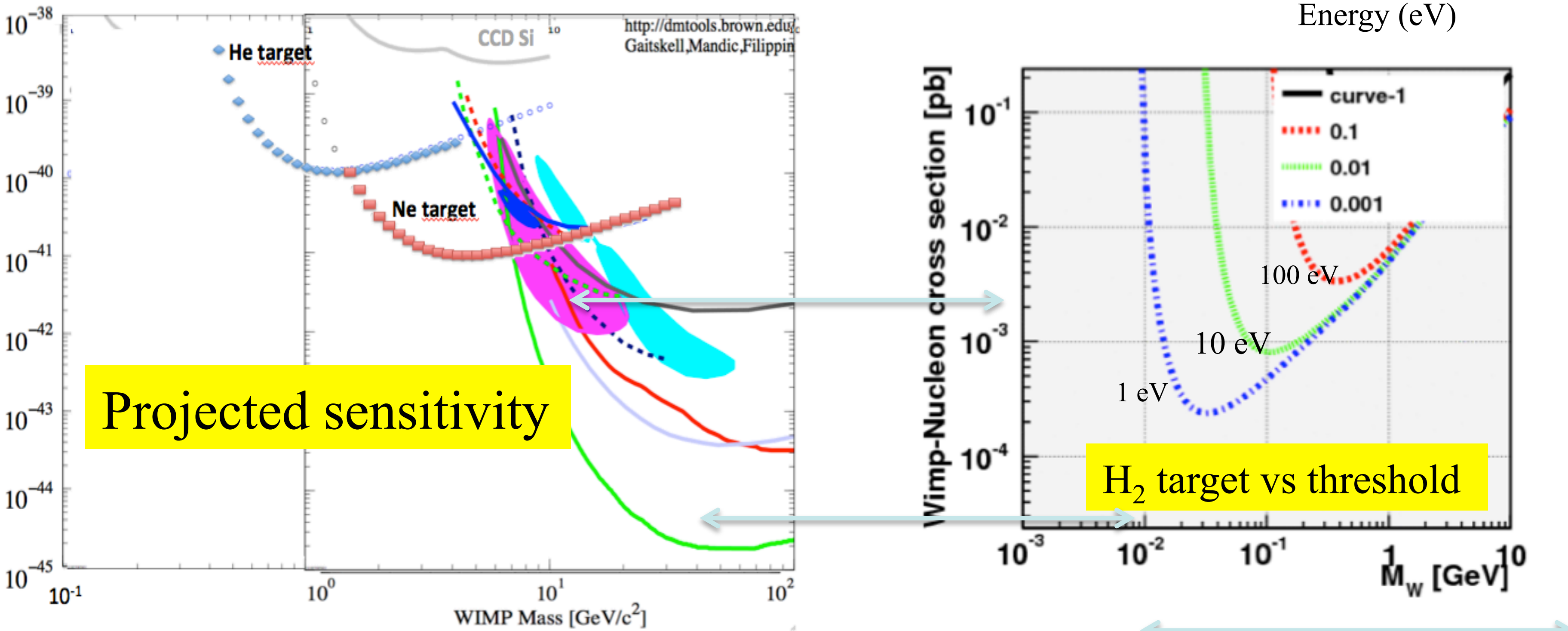
3rd cleaning: the rate drops to (.002Hz)

Significant drop



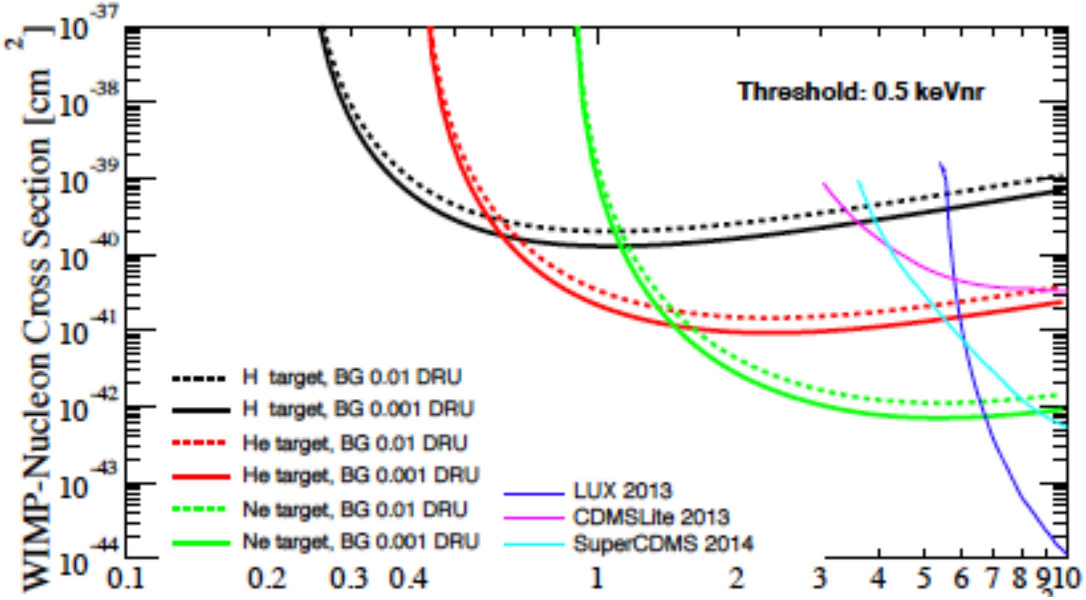
Light WIMP search results

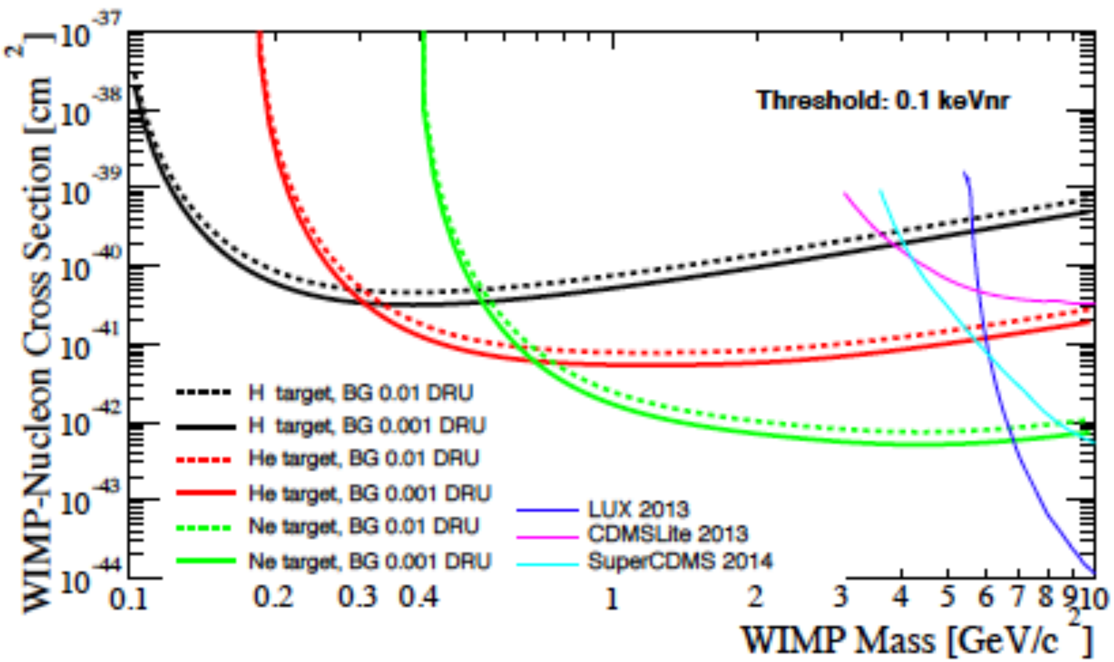




Projected sensitivity with a 2 m detector

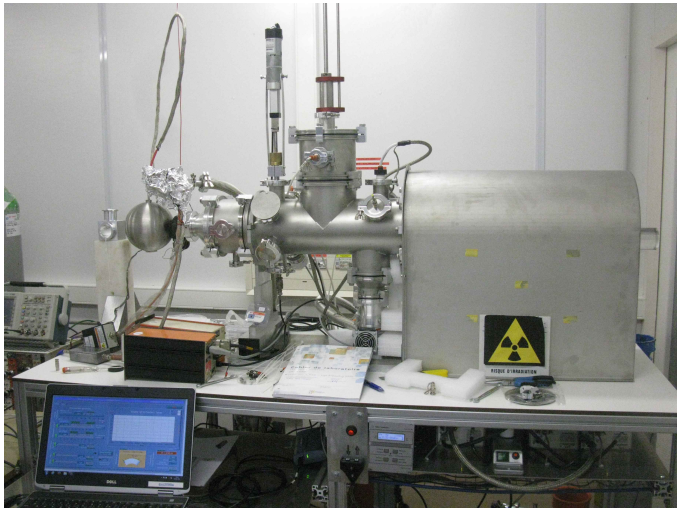
Simulations by Kaxuan Ni et al.,

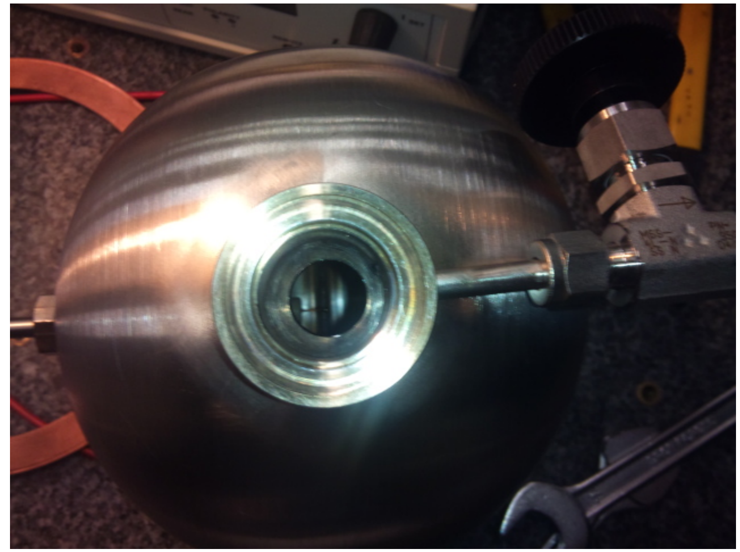




Quenching factor measurements

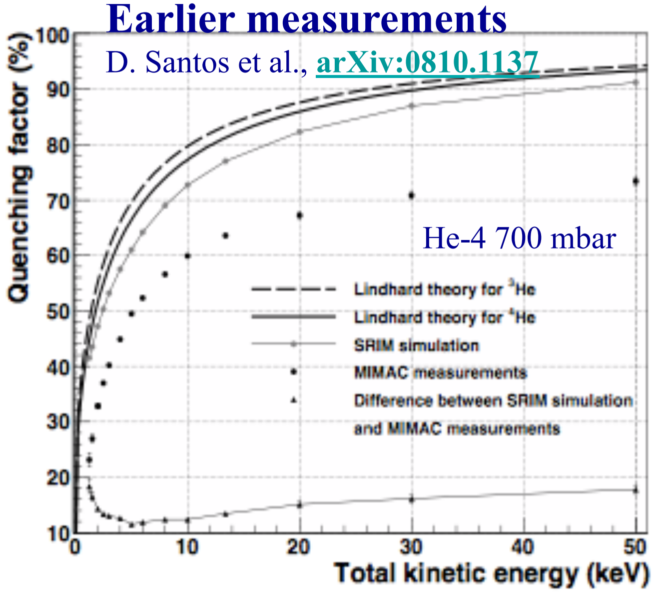
Goal: measure QF down to 500 eV ion energy using the Grenoble MIMAC facility for H, He, Ne, CF4, Ar, Xe at various pressures





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

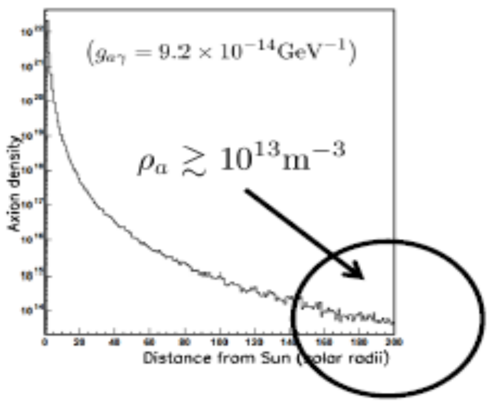
I. Giomataris, J.D. Vergados, Nucl.Instrum.Meth.A530:330-358,2004, J.D. Vergados,Y. Giomataris, Y. Novikov, Nucl.Phys. B854 (2012) 54-66 , Phys.Rev. D85 (2012) 033003

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

KK-axions as a candidate to low energy decay

Gravitationally trapped massive Axion (like) particles decays

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



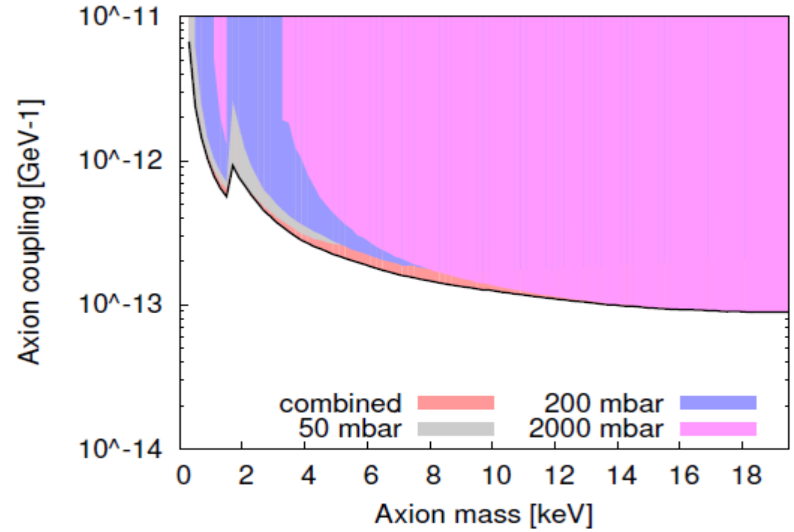
$$T_\odot \ll \tau_a$$

$$\rho_a = 1.18 \times 10^{39} \left(\frac{g_{a\gamma}}{\mathrm{GeV}^{-1}}\right)^2 [\mathrm{m}^{-3}]$$

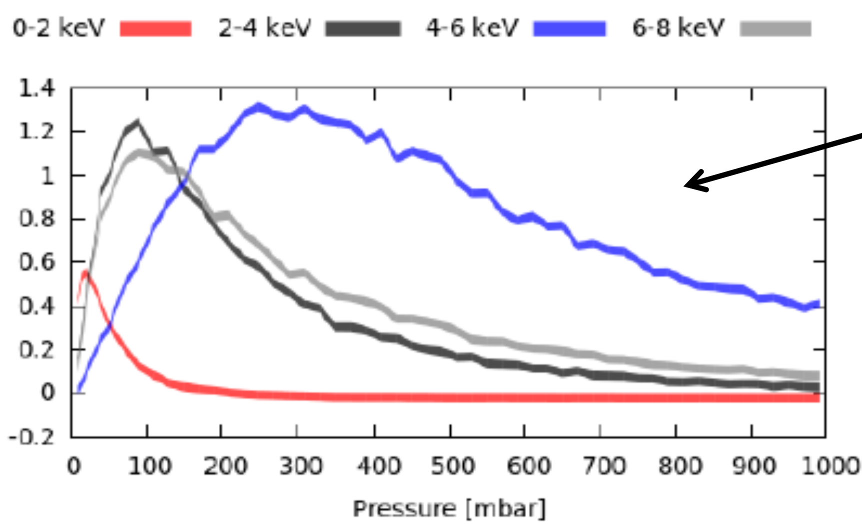
$$\tau_a = 1.35 \times 10^5 \left(\frac{g_{a\gamma}}{\mathrm{GeV}^{-1}}\right)^{-2} \left(\frac{m_a}{\mathrm{eV}}\right)^{-3} \mathrm{s}$$

$$N_\gamma = \tau_a^{-1} \cdot \rho_a \cdot V_{Sph} \cdot T_{exp} \cdot \epsilon_{det}$$

Zero background estimation
SEDINE sensitivity



Ratio 2-prong to 1-prong events coming from a decay signal



Furthermore flexibility on gas mixture and pressure allows to proof the decay hypothesis by modulating the 2-prong and 1-prong efficiency

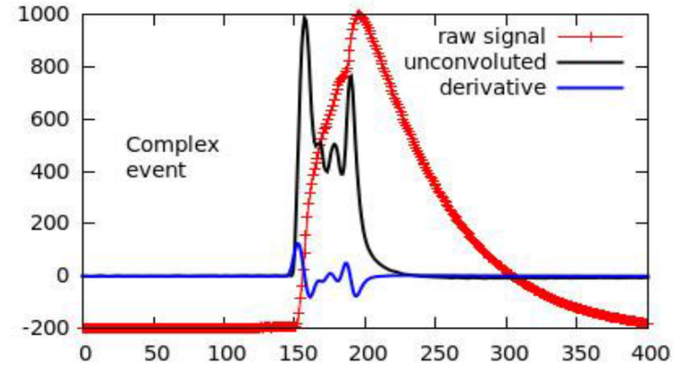
J.Galan, Patras 2013 Slides
http://arxiv.org/abs/1310.4092

Low energy decay detection capability

SPC advantages

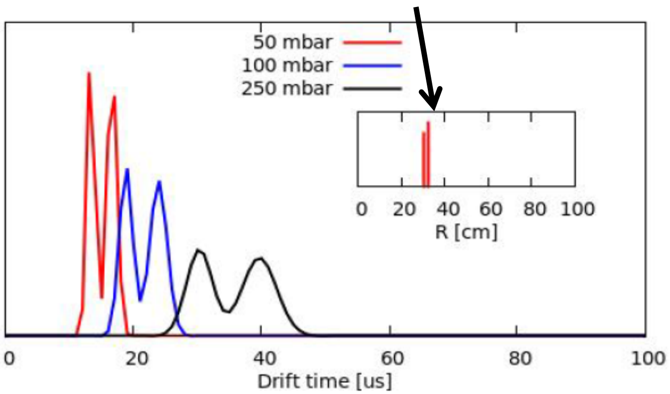
Low energy threshold
Large volume
Low volumetric background levels

Measured event in Argon

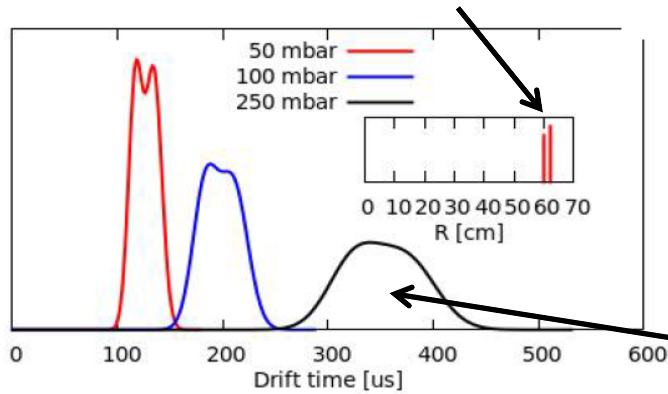


Simulated time signals at different pressures

Event close to sensor



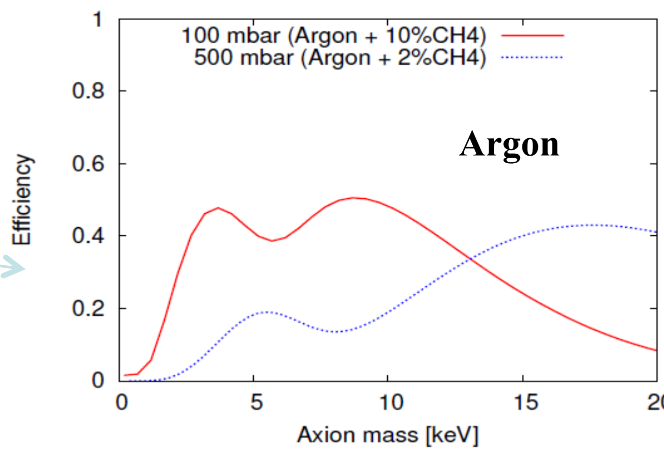
Event near surface

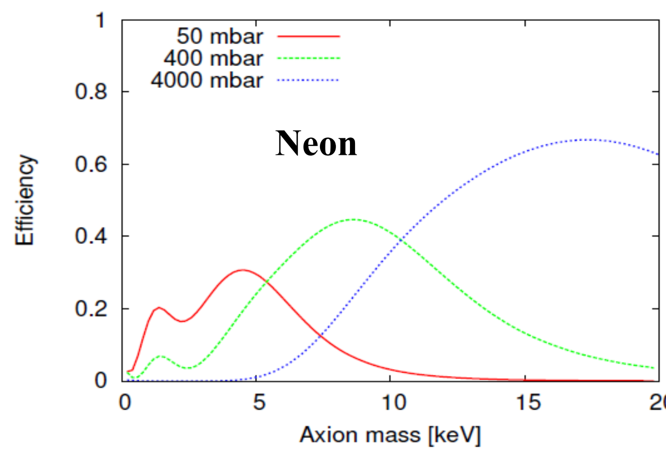


Higher pressure

Detection of 2-prong events depends on pressure

Efficiency to 2-prong events **depends on diffusion and attenuation lenght**





CONCLUSIONS

- **A new promising counter on spherical geometry**
- **Ultra low energy threshold capability down to single electron**
- **Light dark matter search down to 100 MeV**
- **Excess below 400 eV in Neon is under study**