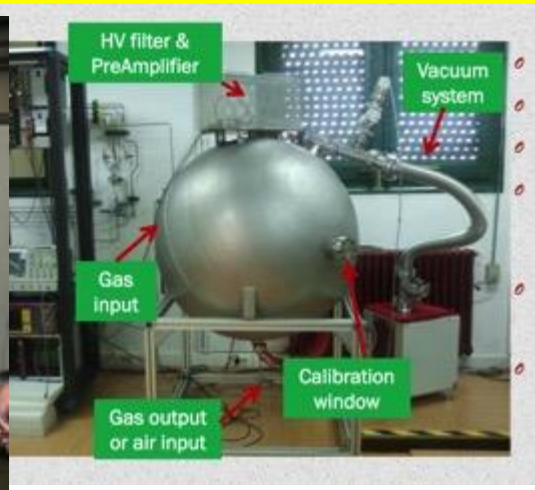
ACHINOS a new amplification structure for the spherical detector

Ioannis Giomataris, CEA-University Paris-Saclay

Low background detector d=60 cm p=10 bar

Basic R@D detector in Saclay

University of Saragoza detector



University of Thessaloniki detector

Queens University test sphere

R2D2 Sphere CNBG Bordeaux

Grenoble Sphere

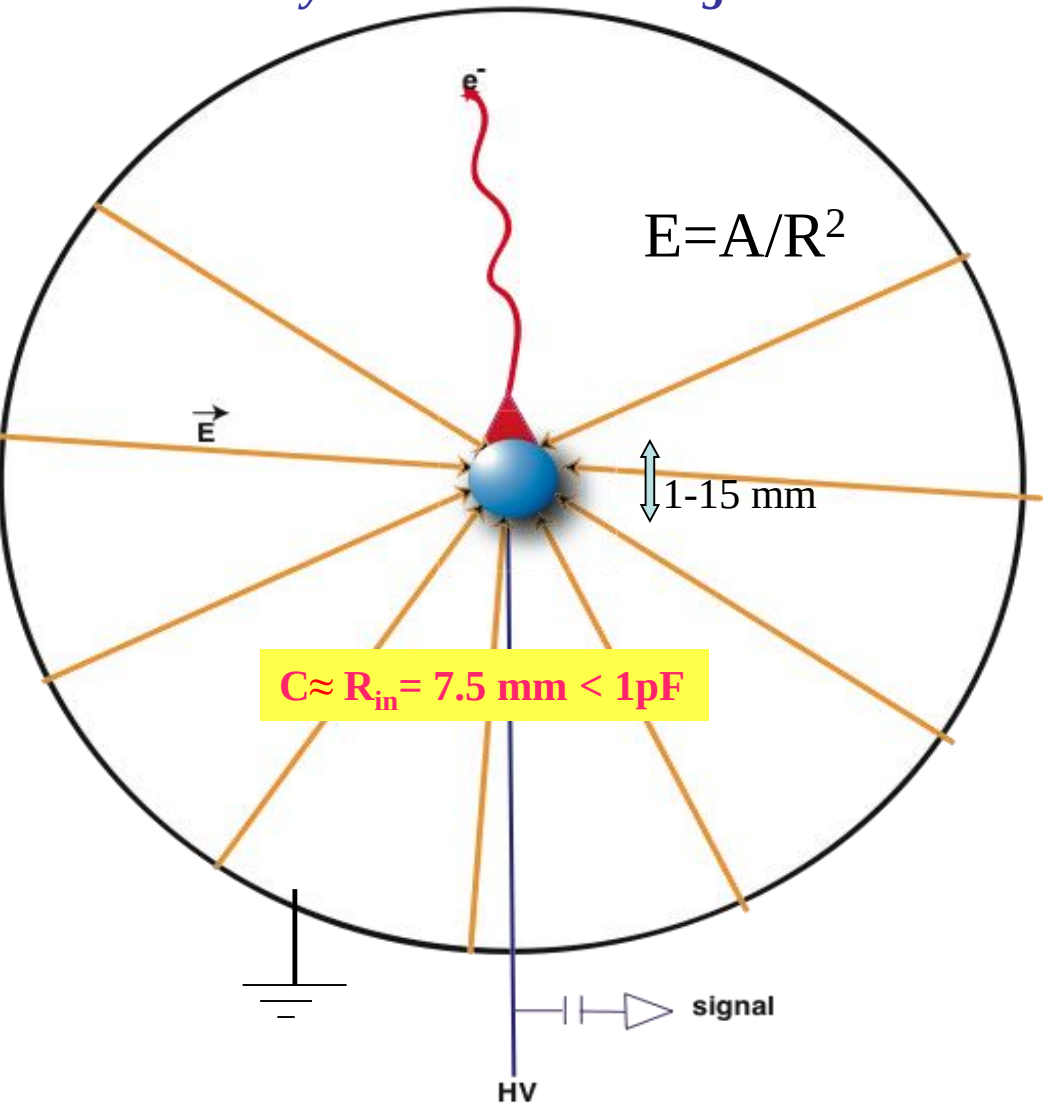
Bibliography

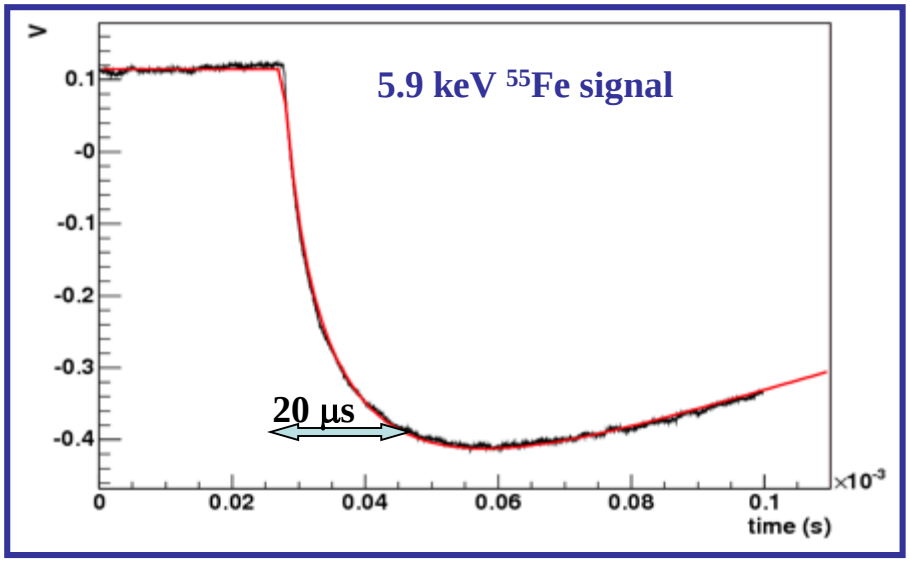
I Giomataris et al., JINST 3:P09007,2008.,
I Giomataris and J.D. Vergados, NIMA530:330-358,2004,
I. Giomataris and J.D. Vergados, Phys.Lett.B634:23-29,2006.
I. Giomataris et al. Nucl.Phys.Proc.Suppl.150:208-213,2006.,
S. Aune et al., AIP Conf.Proc.785:110-118,2005.
J. D. Vergados et al., Phys.Rev.D79:113001,2009.,
E Bougamont et al. arXiv:1010.4132 [physics.ins-det], 2010

Radial TPC with spherical proportional counter read-out

Saclay-Thessaloniki-Saragoza

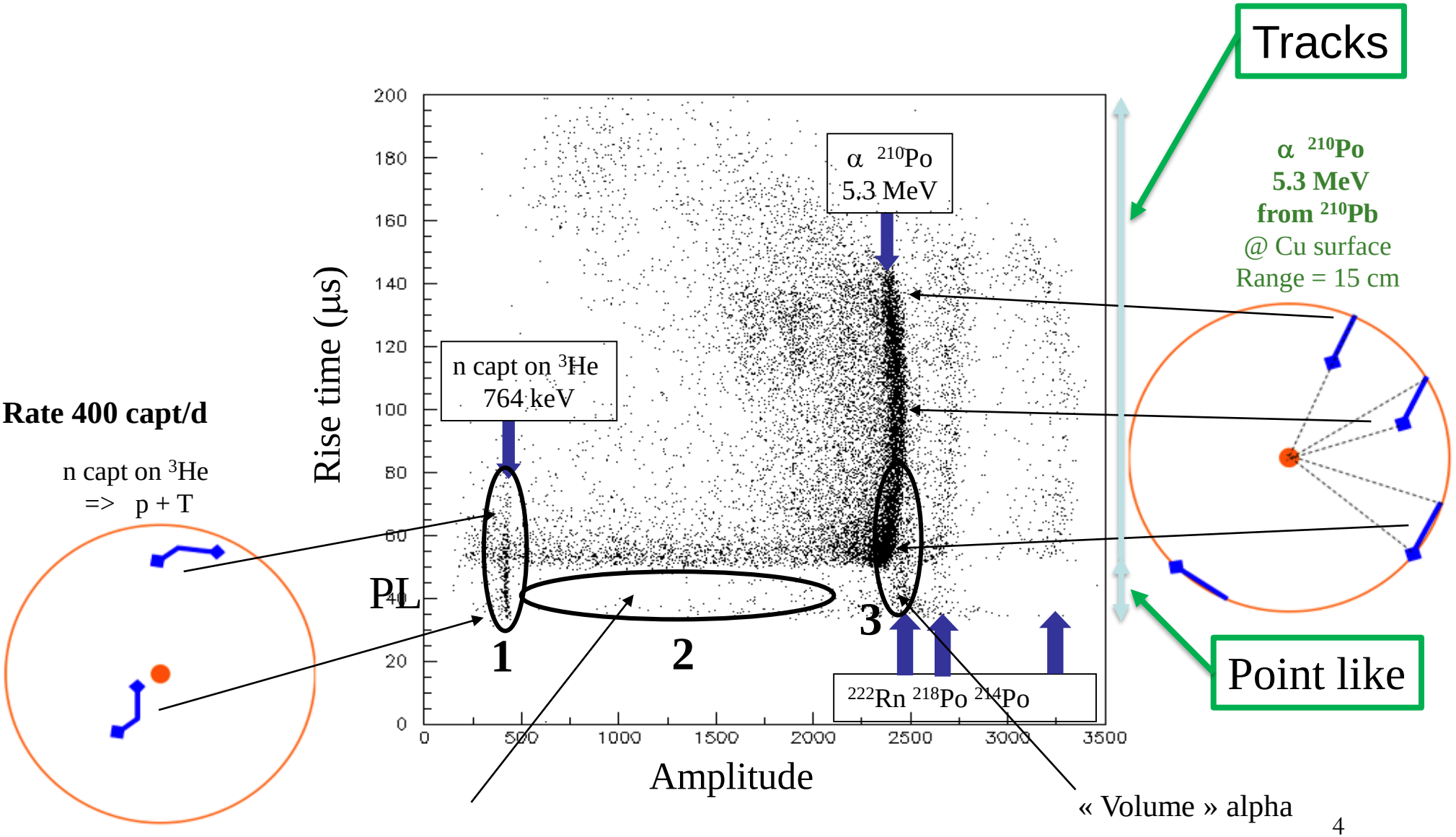
A Novel large-volume Spherical Detector with Proportional Amplification read-out, I. Giomataris *et al.*, JINST 3:P09007,2008





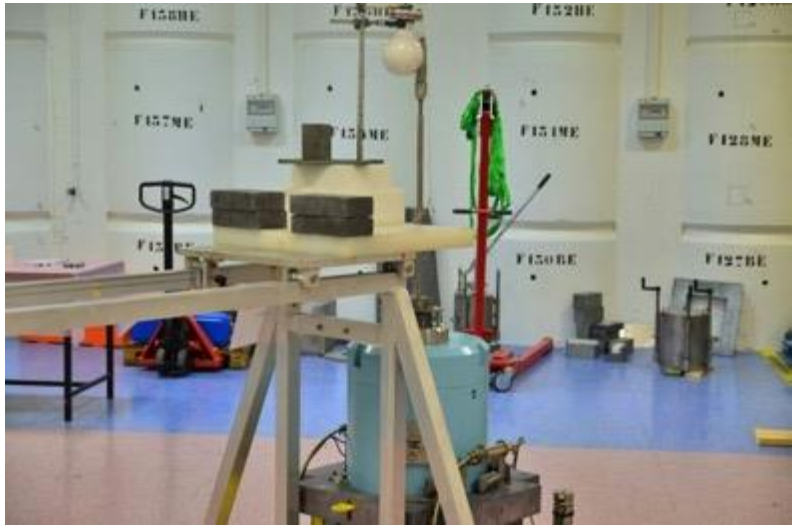
- Simple and cheap
- Large volume
- single read-out
- Robustness
- Good energy resolution
- Low energy threshold
- Efficient fiducial cut
- Low background capability

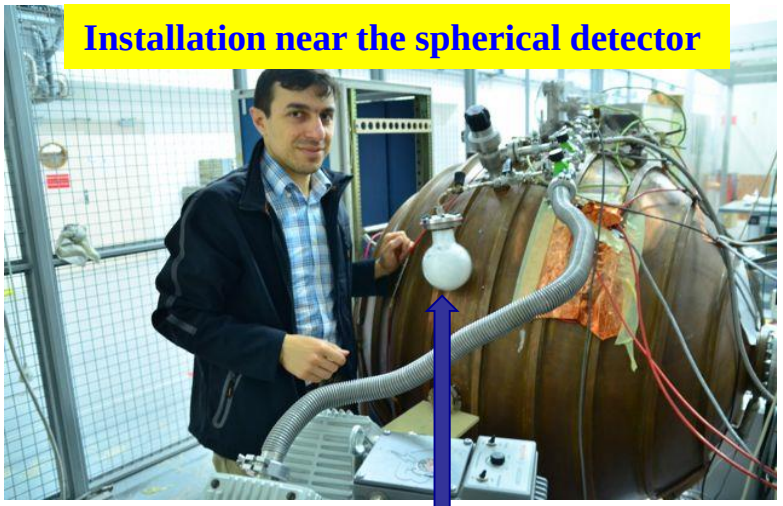
Particle identification capability at MeV energy
Ar/CH_4 + 3g ^{3}He @ 200 mb SPC 130cm Ø @ LSM



Low-energy calibration source *Argon-37*

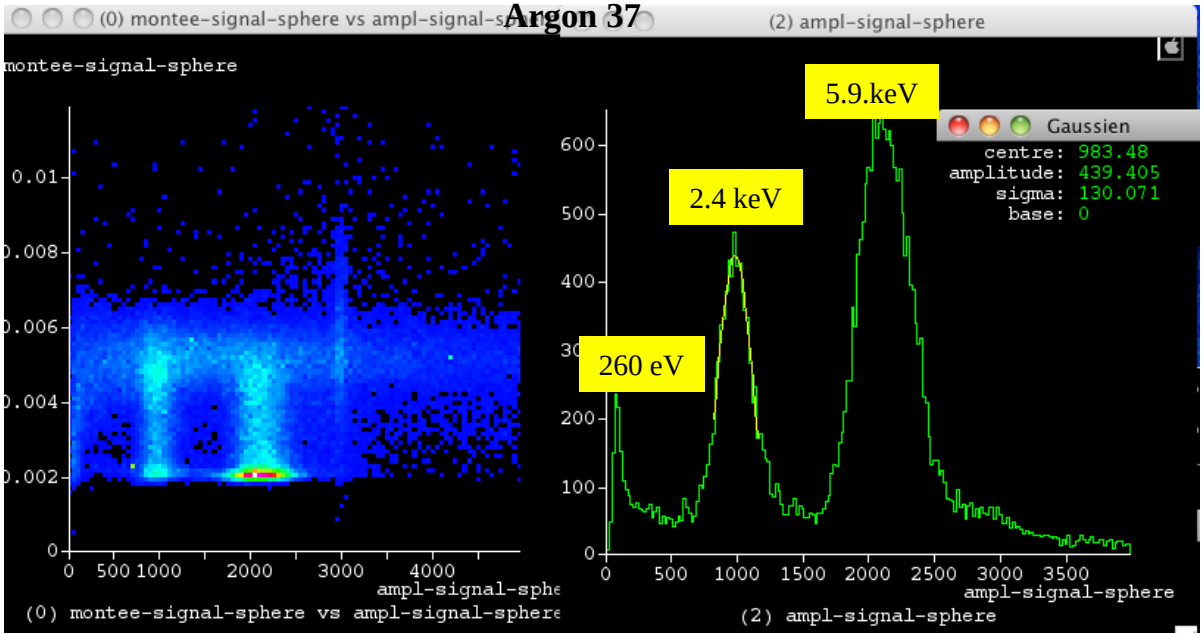
Home made Ar-37 source: irradiating Ca-40 powder with fast neutrons 7×10^6 neutrons/s
Irradiation time 14 days. Ar-37 emits K(2.6 keV) and L(260 eV) X-rays (35 d decay time)





Argon 37

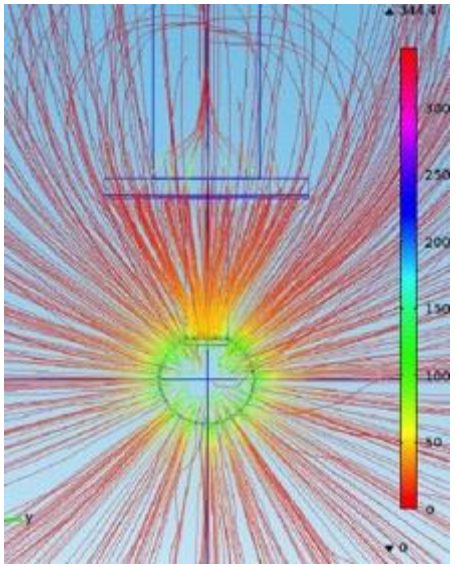
First measurement
with Ar-37 source
Total rate 40 hz
in 250 mbar gas, 8 mm ball
240 eV peak clearly seen
A key result for light dark matter search

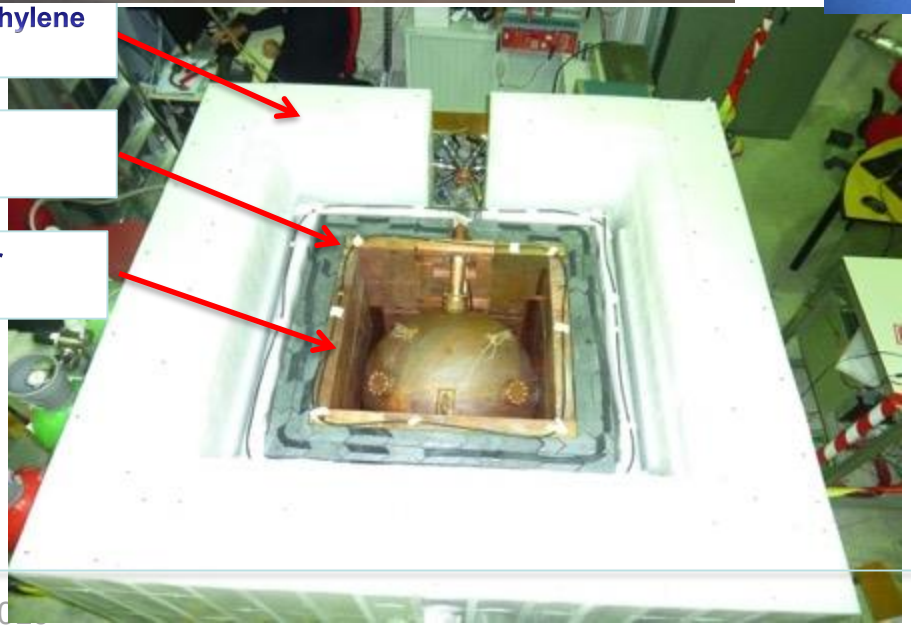


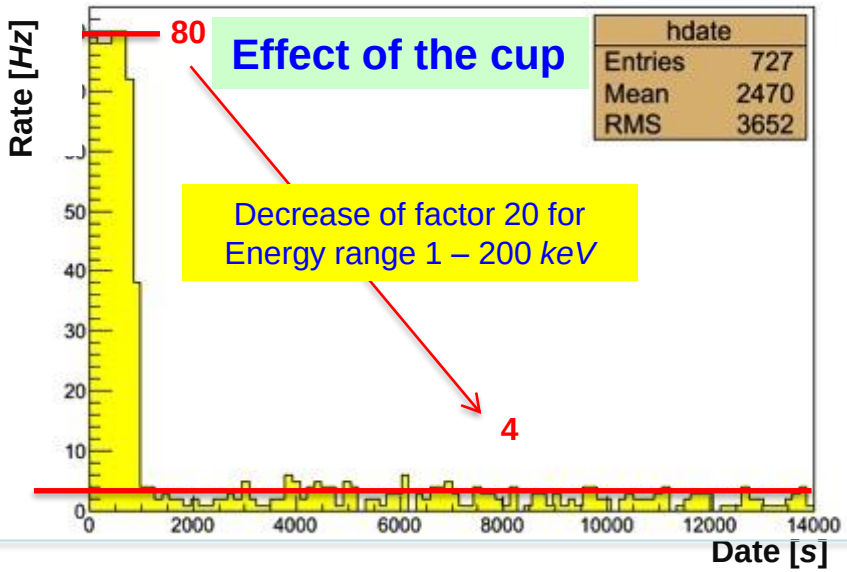
NEWS-LSM: Exploration of light dark matter search at LSM

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

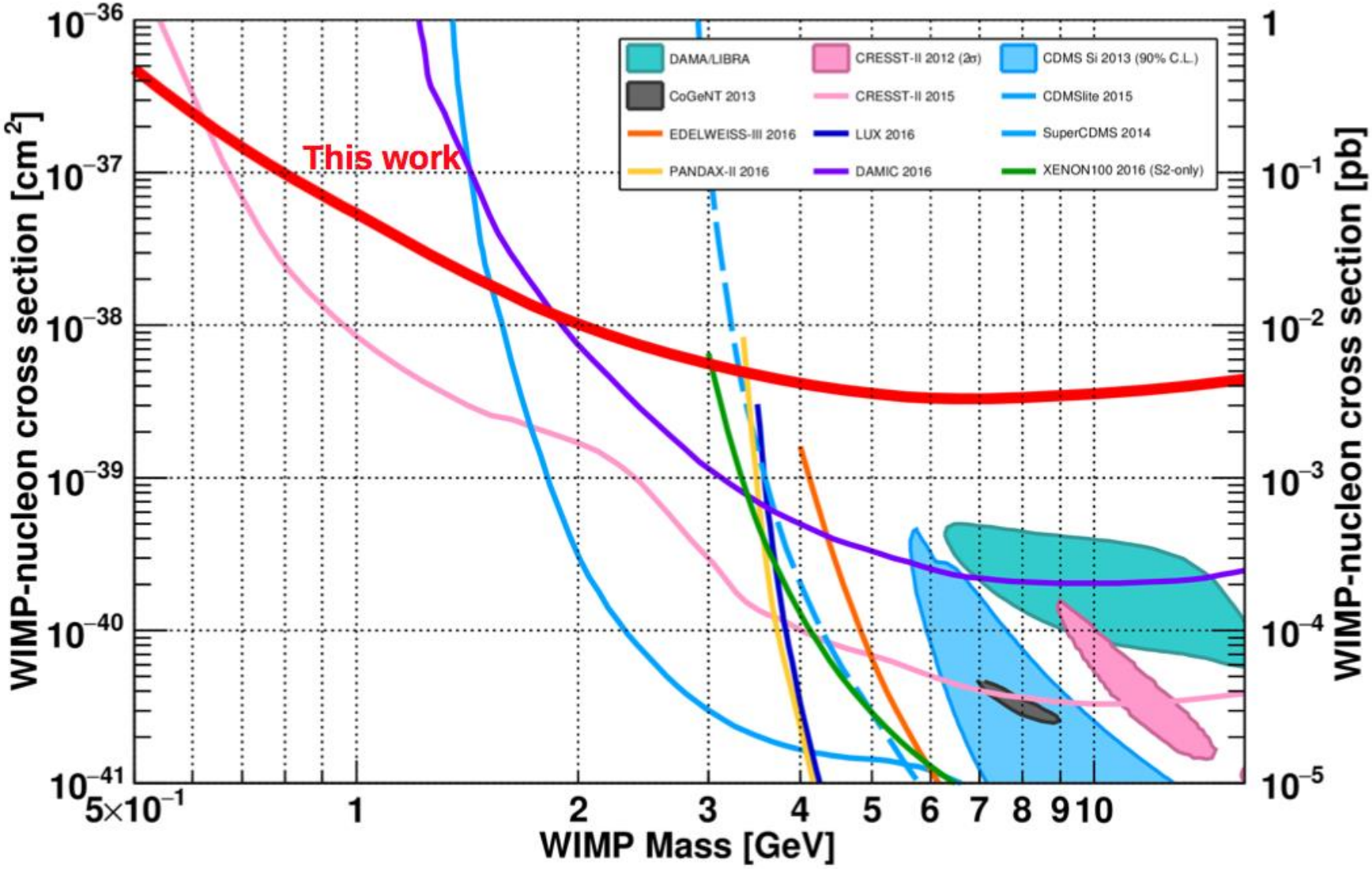
Gas targets: Ne, He, CH4





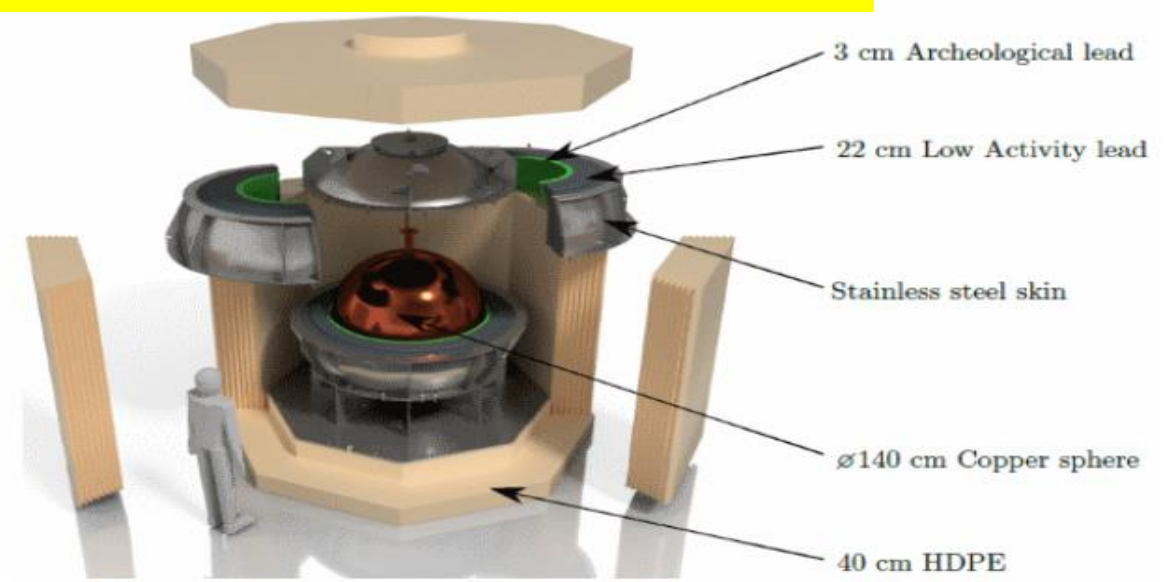


Current sensitivity with Neon at 3 bar
Data 40.5 days, threshold 30 eV
Arnaud and al, Astropart. Phys. 97 (2018) 54–62



NEWS-SNO with compact shield : implementation at SNOLAB by fall 2017
Funded mainly by Canadian grant of excellence and ANR-France

Copper vessel (140 cm Ø, 12 mm thick
Low activity copper (C10100)

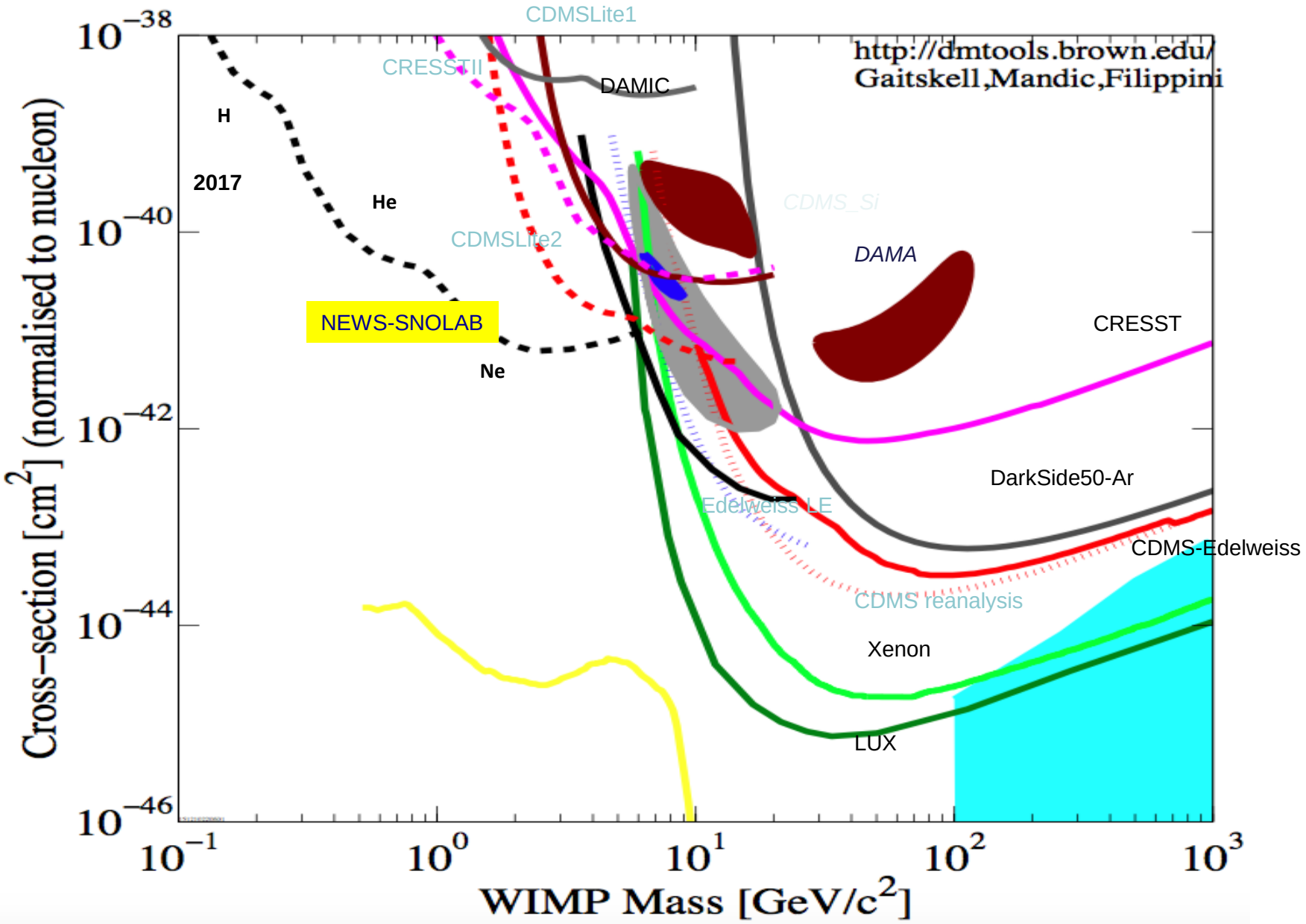


Electropolishing-Electroplating

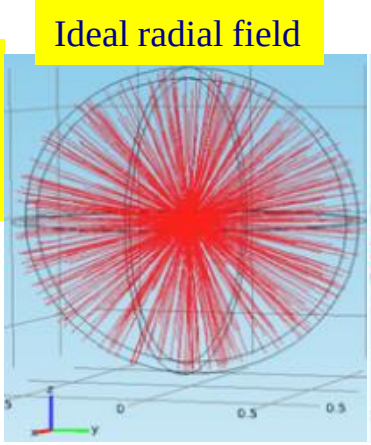
Spinned hemispheres stored at LSM

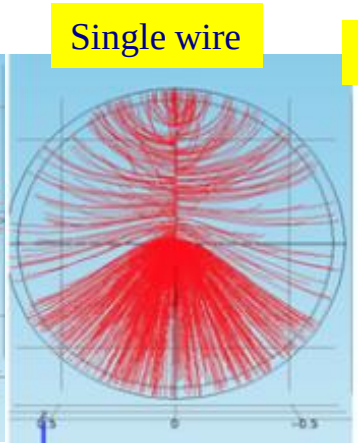
Installed at LSM

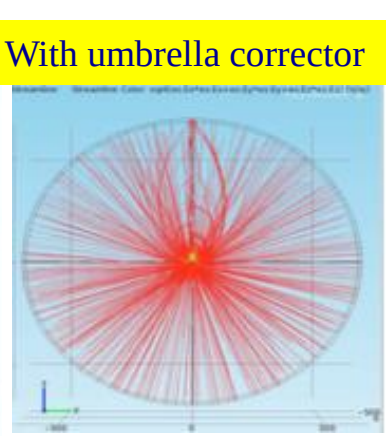
NEWS-SNOLAB project sensitivity



Sensor Development







To maximize the usable volume in the detector:

Add a field corrector close to ball (umbrella)

Umbrella materials

- Pure conductor:

Sparks from the anode ball

- Pure insulator:

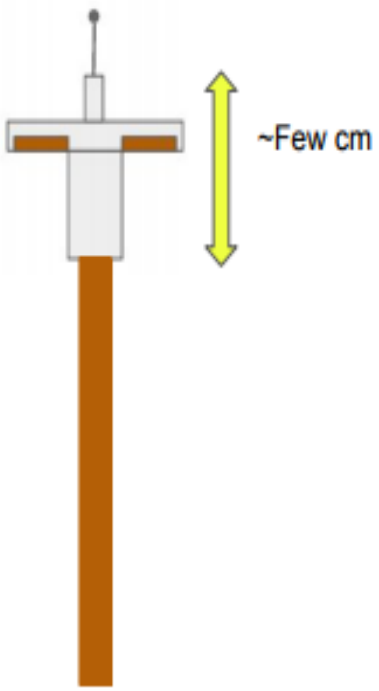
Charging up and unstable operation

- Resistive materials

  Resistivity range 10^9 -10^{12} Ω·cm

  Allow application of a voltage

  Spark suppression



Classic "umbrella"

< 2016

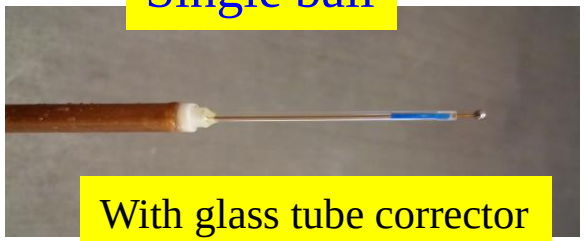
Bakelite Version 2

2017 second half

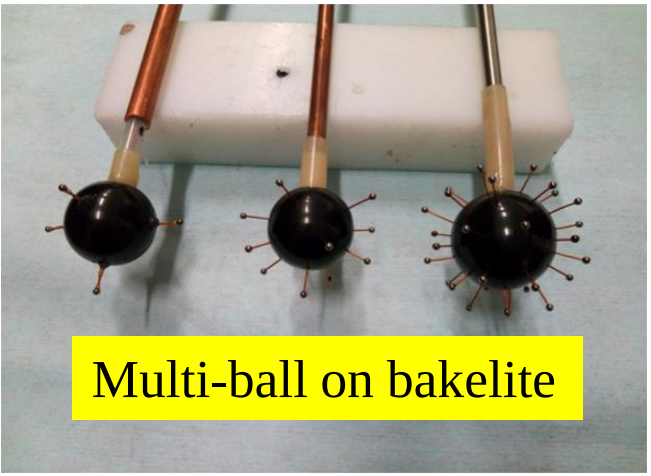
2018
Thin glass tube

From single to multi-ball ‘ACHINOS’ structure

Single ball



With glass tube corrector



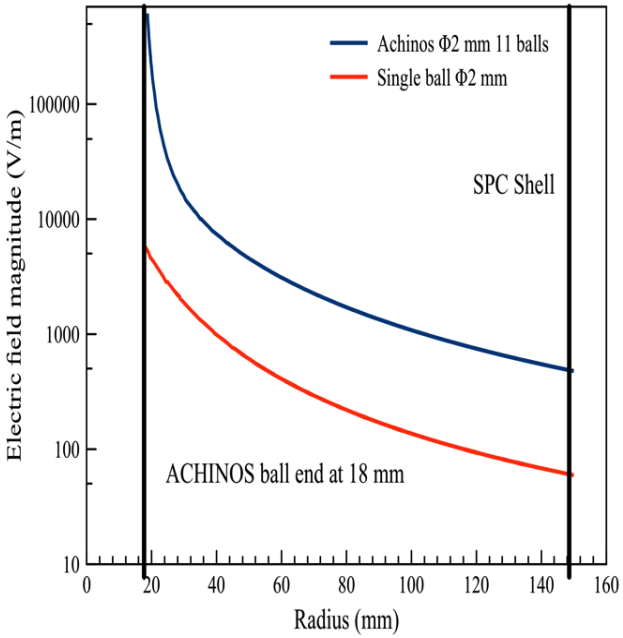
Multi-ball on bakelite

Advantages

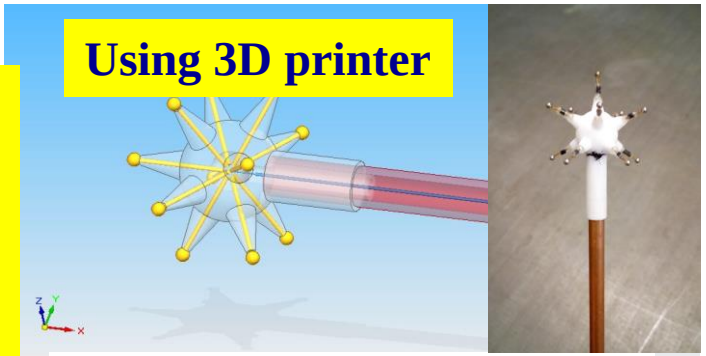
- Amplification tuned by the ball size: 1mm diameter for high pressure

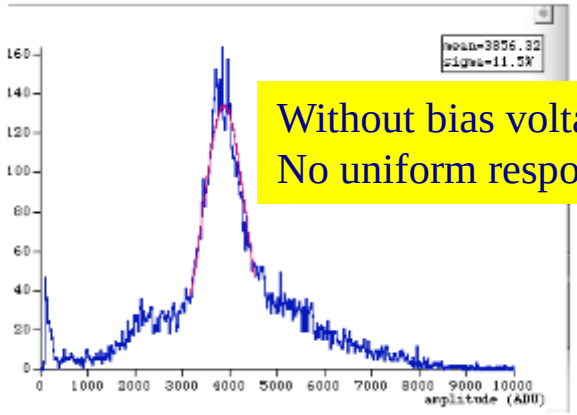
-Volume electric field tuned by the size of the ACHINOS structure

- Detector segmentation: 3D TPC like



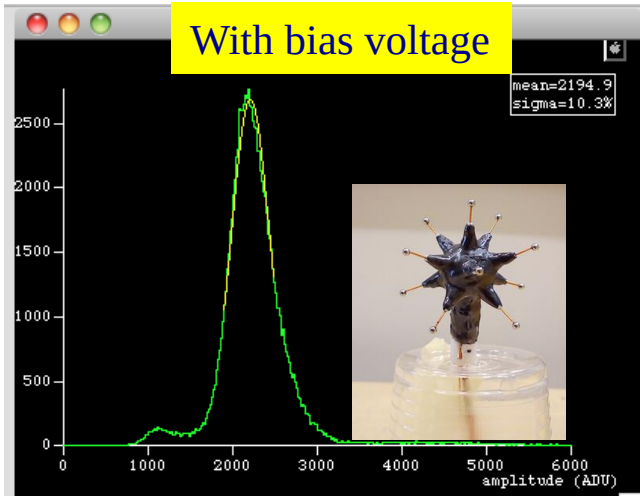
Using 3D printer





Without bias voltage
No uniform response

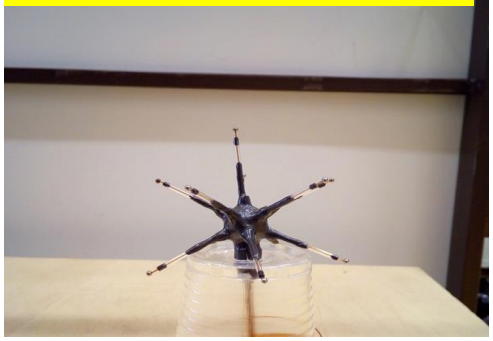
With bias voltage



This year we should be able to use ACHINOS structure at LSM
With small balls 1-2mm to reach high-pressure (10 bar) operation

Multi-ball 'ACHINOS' structure
Developed in Saclay in collaboration with University of Thessaloniki

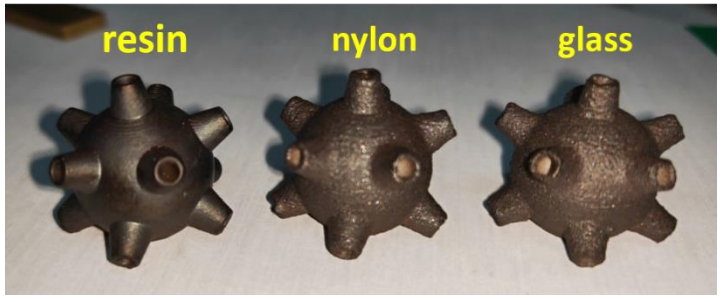
Graphite charged glue

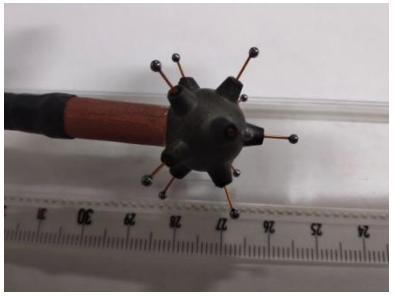


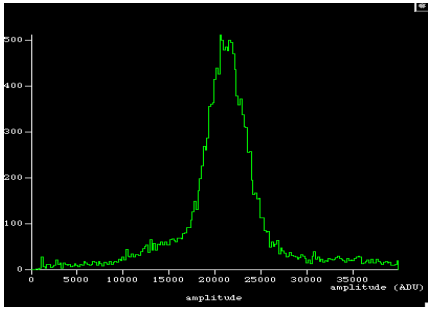
copper charged glue

Problem of robustness of charged glue:
At high voltages because of discharges in the bulk it becomes conductor!!!

DLC layer (collaboration with USTC)
It is a fantastic technical solution:
Robust, stable, precise

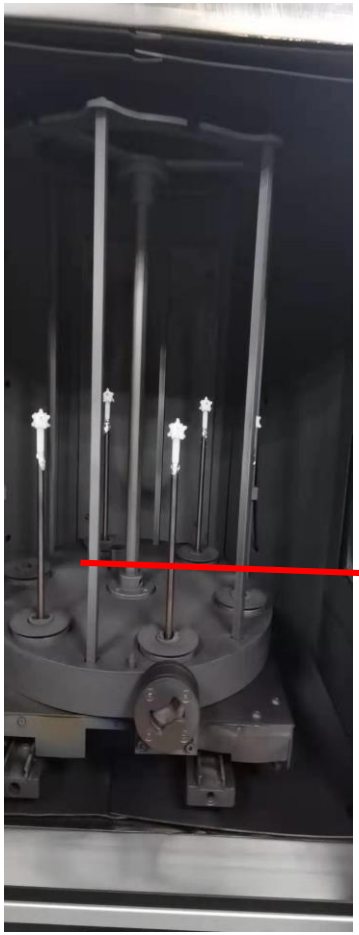


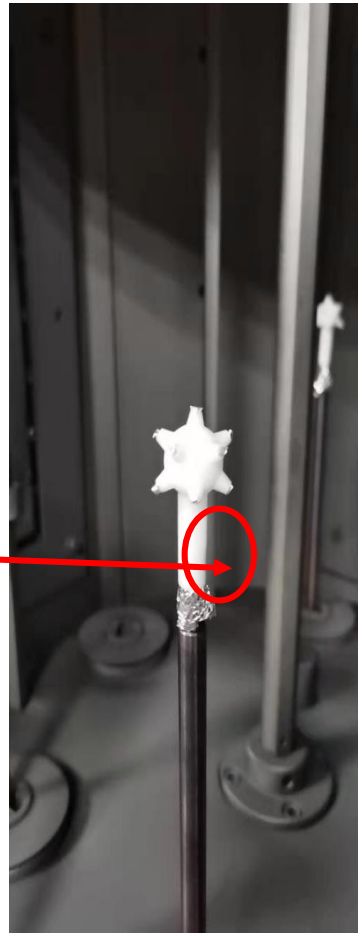




DLC coating on balls and tubes done at USTC

by Zhou Yi et al.





Number of samples: 6*4=24

Batch Number	Number of balls and tubes	Resistance of Ball (Mohm)	Resistance of Tube (Mohm)
8-31-2	6	300M	30M
8-31-3	6	4.5G	120M
8-31-4	6	1G	170M
8-31-5	6	4G	270

In summary

ACHINOS multi-ball sensor is major breakthrough for the read-out of the spherical detector:

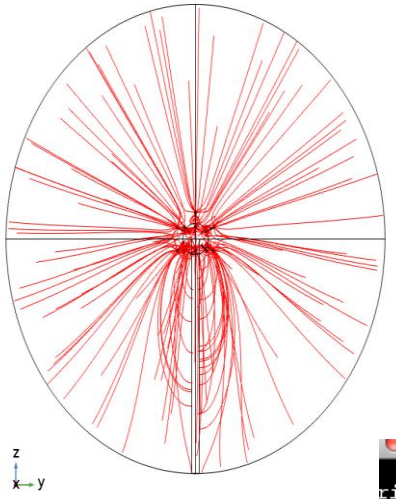
It tunes the volume electric field at will by tuning distance and number of balls.

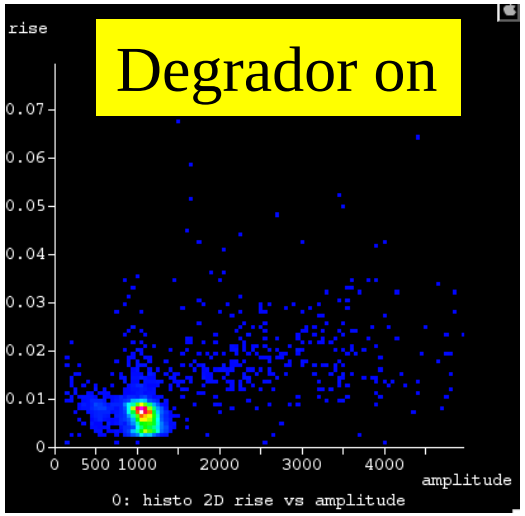
It could be used for any sphere size and any gas pressure

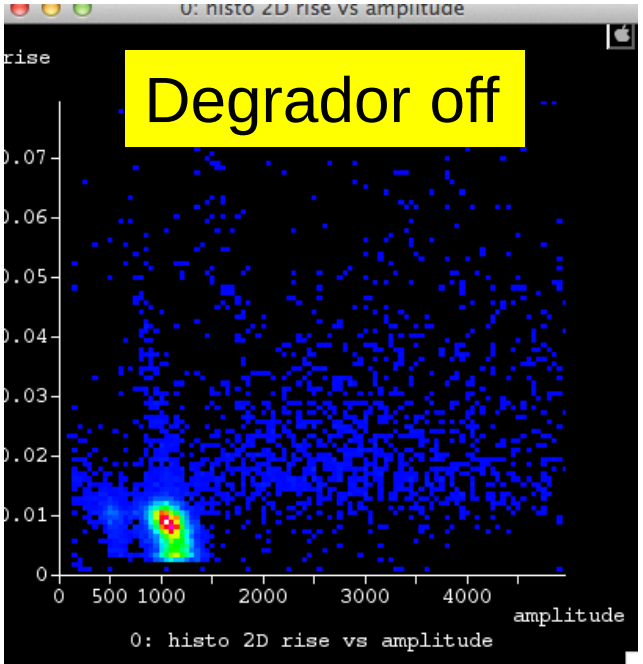
The DLC resistive layer is a robust and efficient protection electrode well adapted to the sensor

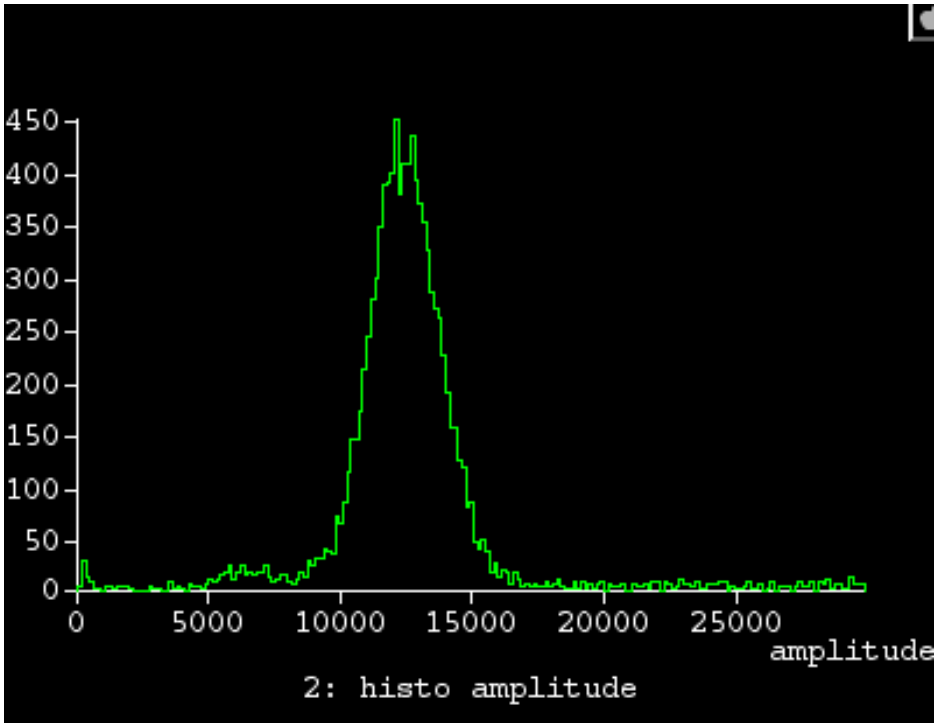
Towards a complete radial field degrador

Very recent development in collaboration with I. Savvidis







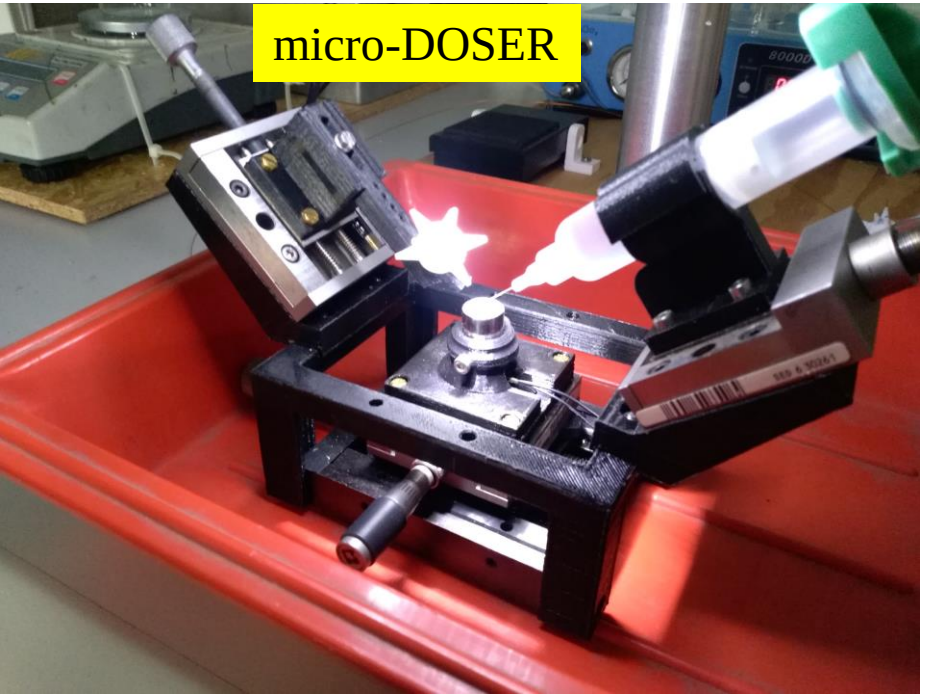


Future developments

- **Optimize ACHINOS structure (higher precision)**

New set-up using micro-doser is now ready (with J.Ph. Mols)

- **Small size balls << 1mm (with X. Coppolani)**
- **Read-out individually each ball**
- **Improve energy resolution (<< 1%)**



Additional physics

Neutrinoless double beta decay experiment with Xe-136 at 50bar

In collaboration with CNBG (F. Piquemal et al.,), CPPM (J. Busto et al.,)

The goal is to reach a record low background level << 10^{-4}/keV/Kg/y and an energy resolution of .3%

Simulation results are encouraging:

Expected background rate in the region of Q_{bb} (2.46 MeV)

$8.x10^{-5}$/keV/Kg/ year Arubis copper

$1.54x10^{-5}$/keV/Kg/ year PNNL copper

(compared to $2x10^{-3}$/keV/Kg/ year of running experiments)

A dedicated Supernova detector

Simple and cost effective - Life time >> 1 century

Through neutrino-nucleus coherent elastic scattering

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

Sensitivity for galactic explosion

For p=10 Atm, R=2m, D=10 kpc, $U_\nu = 0.5x10^{53}$ ergs

Number of events (after quenching, E_{th} =0.25 keV)

He	Ne	Ar	Kr	Xe	Xe (with Nuc. F.F)
0.08	1.5	6.7	23.8	68.1	51.8

Idea : A world wide network of several of such dedicated Supernova detectors

To be managed by an international scientific consortium and operated by students

THANK YOU

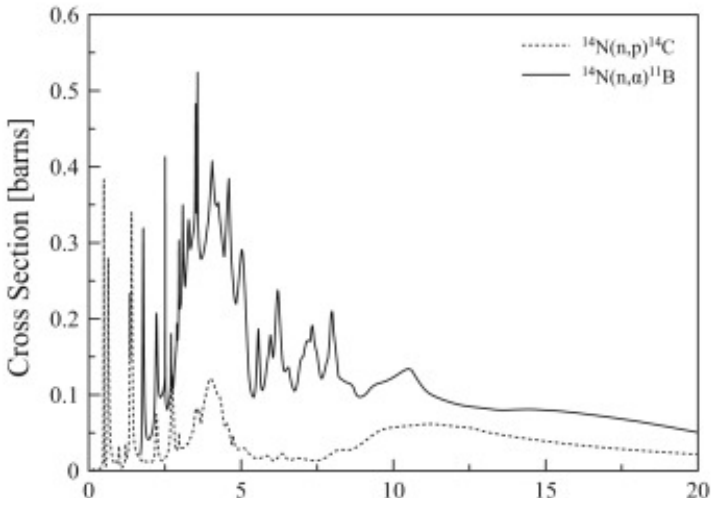
Back up slides

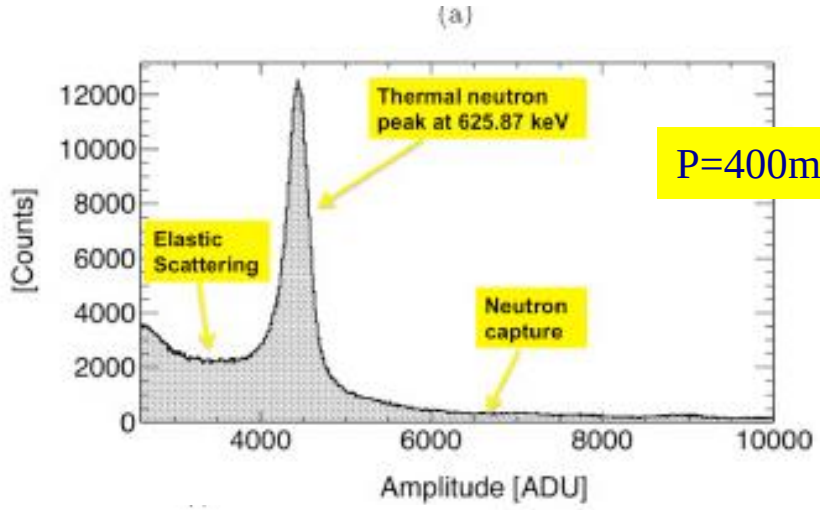
Neutron spectroscopy with N_2 target

E. Bougamont al, NIM847 (2017) 10-14.

$^{14}N + n \rightarrow {}^{14}C + p + 625.87\ \text{keV}$

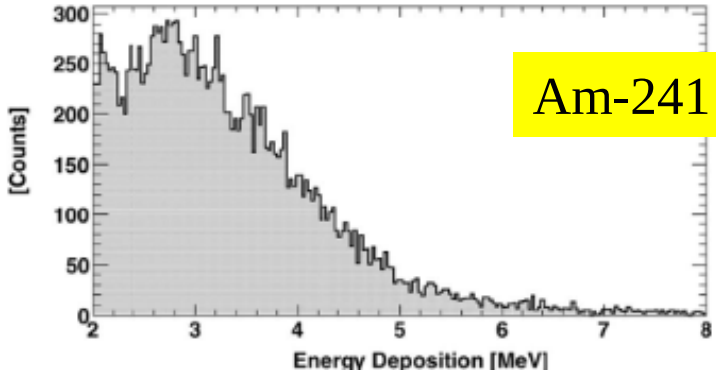
$^{14}N + n \rightarrow {}^{11}B + \alpha - 158\ \text{keV}$

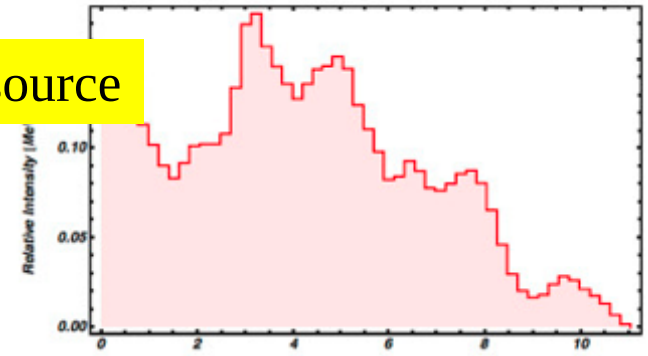


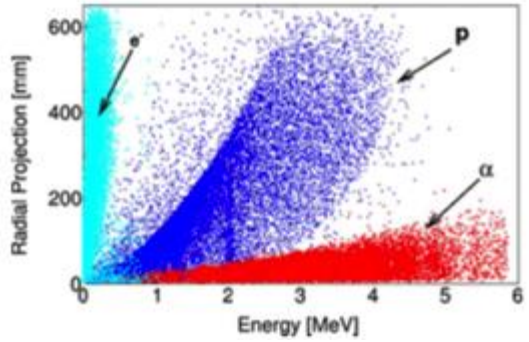


P=400mbar

Am-241 source







Future great improvement: Use the ACHINOS sensor (1mm ball)

- **Gas pressure > 2bar will reduce the wall loss effect**
- **Multi-ball tread-out will highly improve dE/dX: particle ID**