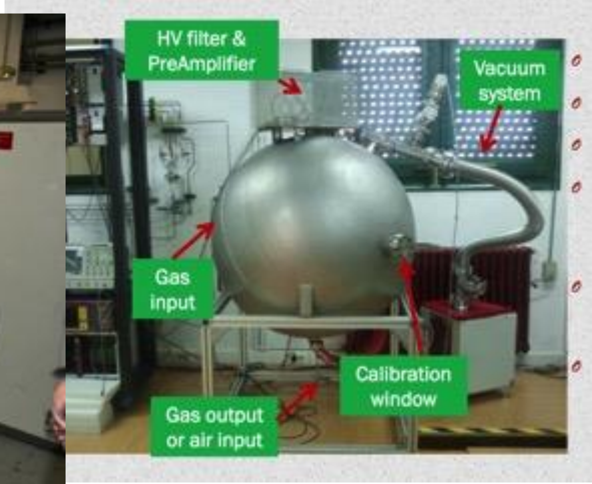
ACHINOS a new amplification structure for the spherical detector

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.

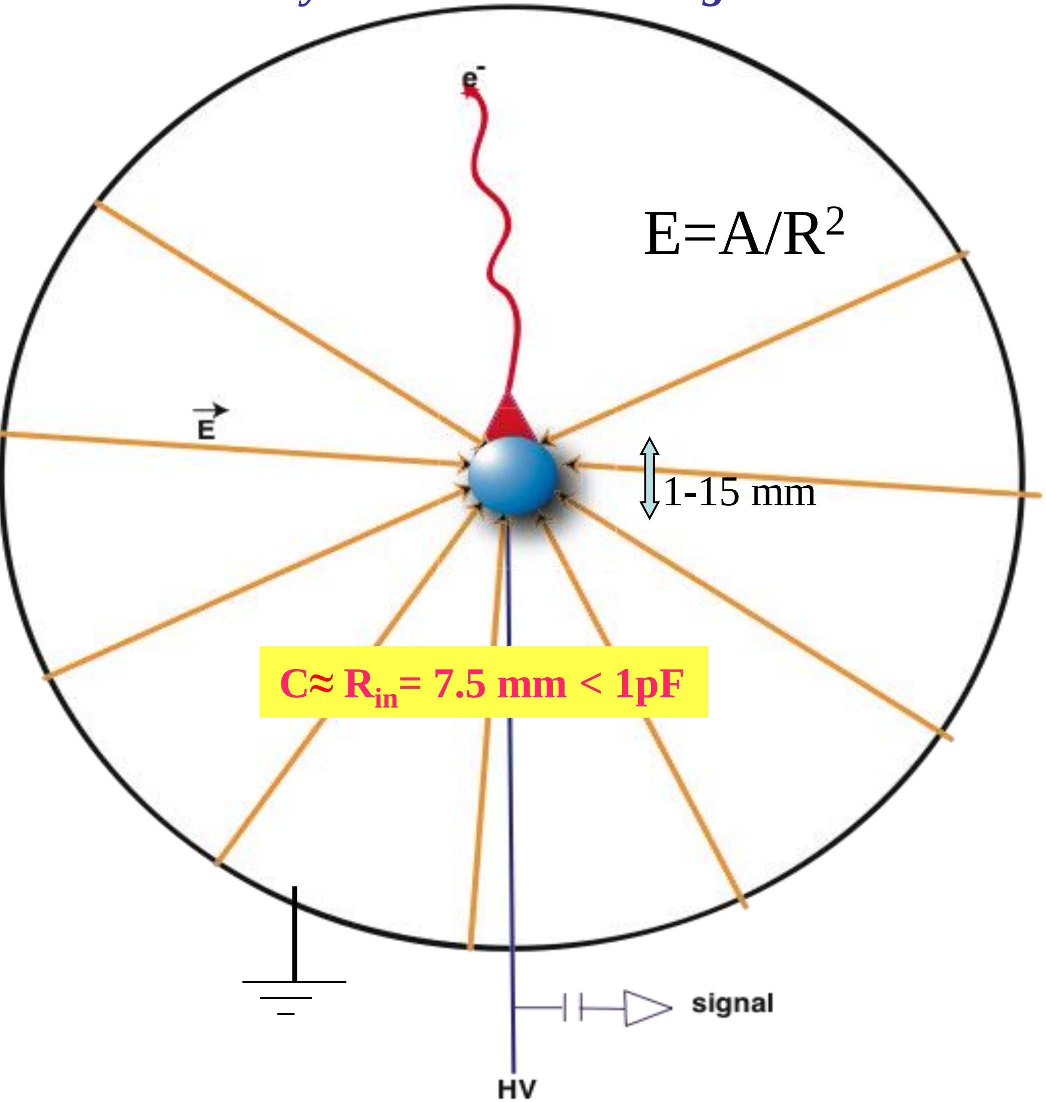
J. D. Vergados et al., Phys.Rev.D79:113001,2009.,

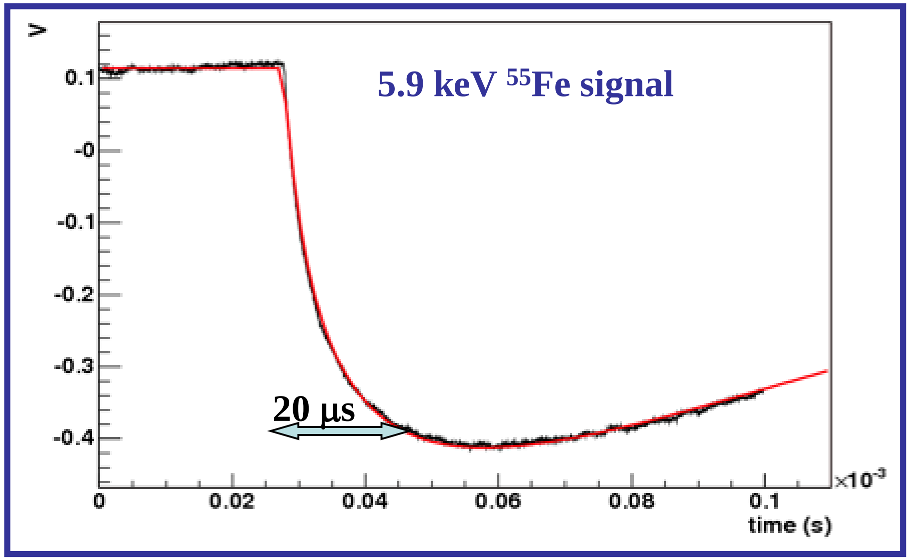
E Bougamont et al. arXiv:1010.4132 [physics.ins-det], 2010

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

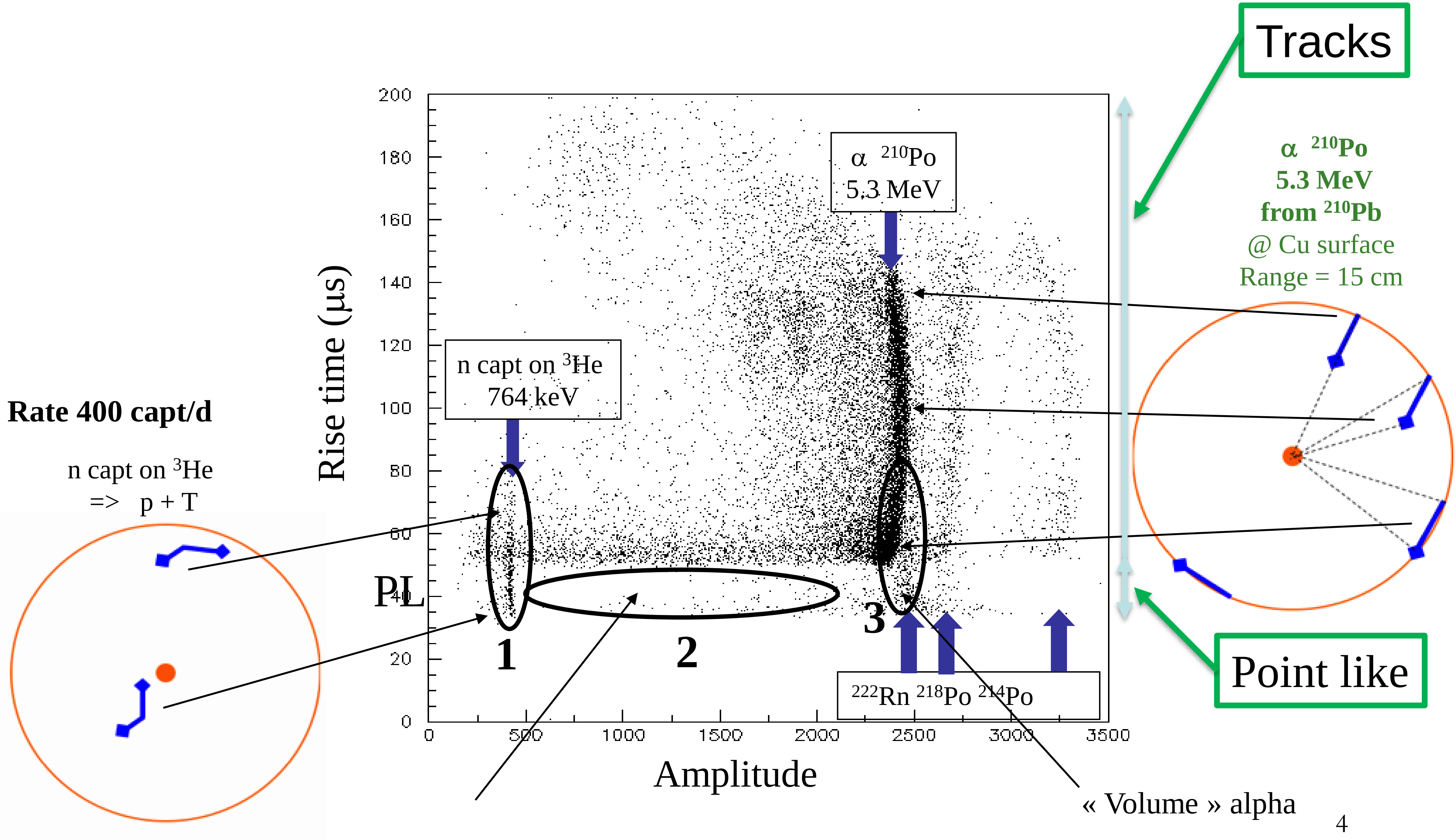




- Simple and cheap
- Large volume
- single read-out
- Robustness
- Good energy resolution
- Low energy threshold
- Efficient fiducial cut
- Low background capability

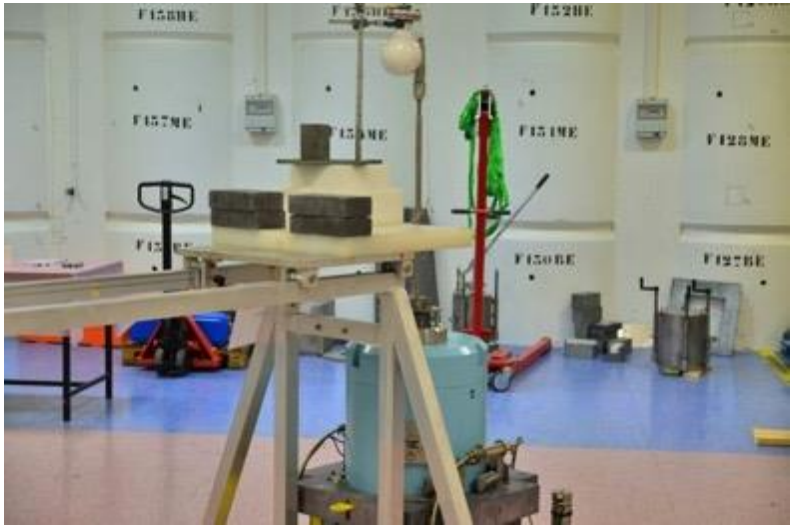
Particle identification capability at MeV energy

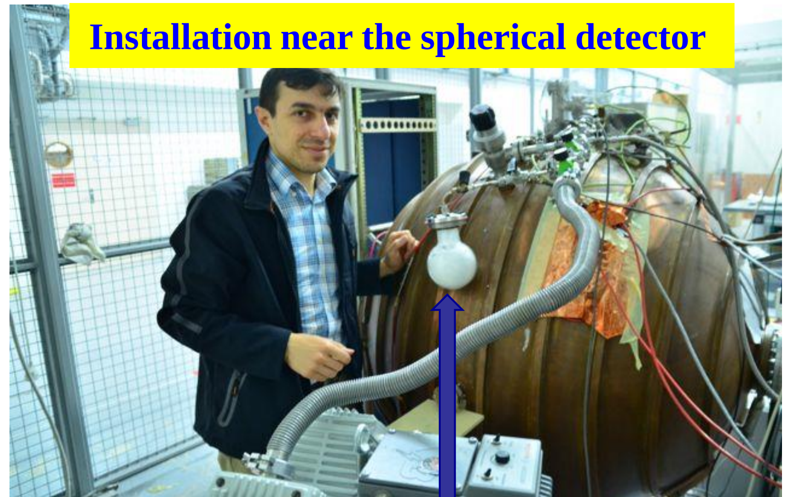
Ar/CH_4 + 3g ^{3}He @ 200 mb SPC 130cm Ø @ LSM



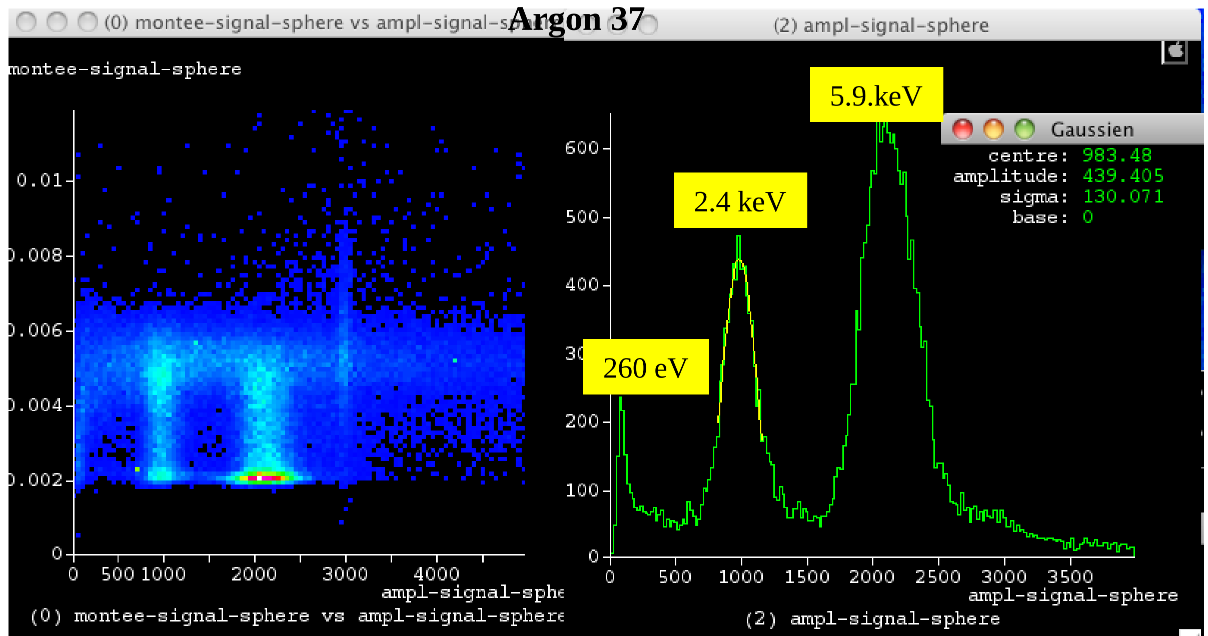
Low-energy calibration source *Argon-37*

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)





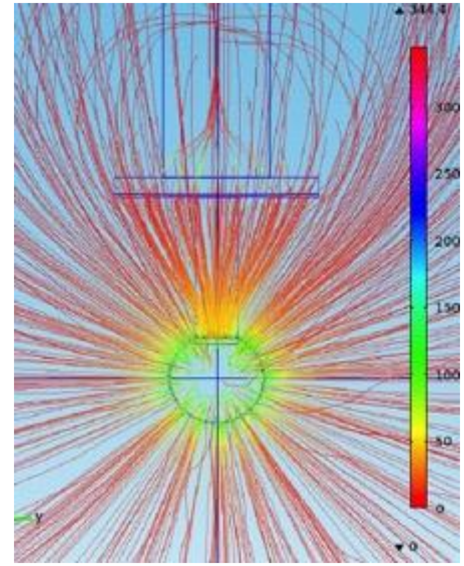
First measurement
with Ar-37 source
Total rate 40 hz
in 250 mbar gas, 8 mm ball
240 eV peak clearly seen
A key result for light dark matter search

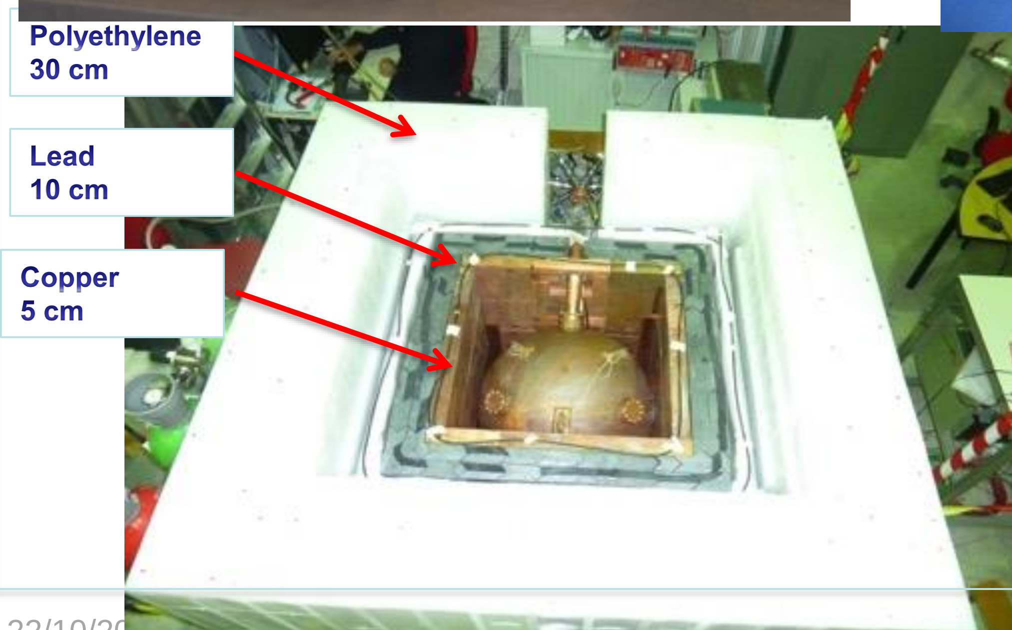


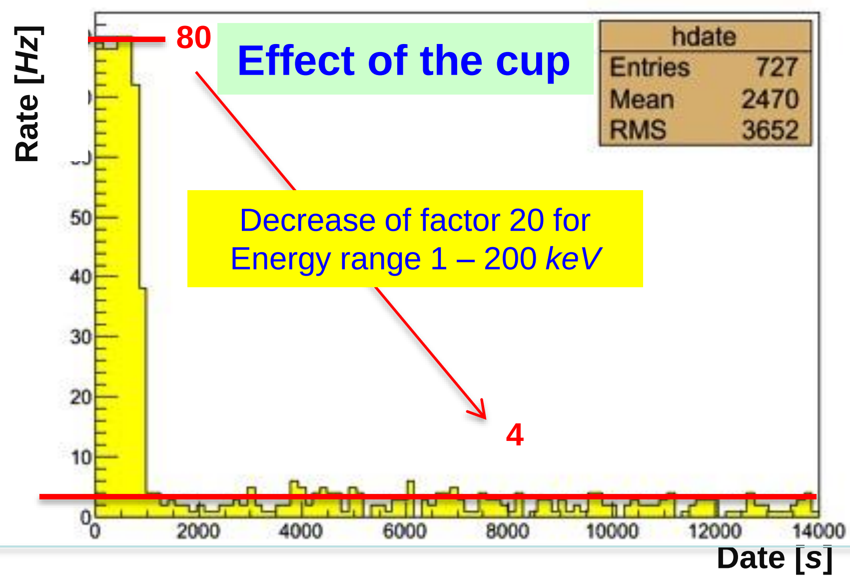
NEWS-LSM: Exploration of light dark matter search at LSM

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

Gas targets: Ne, He, CH4



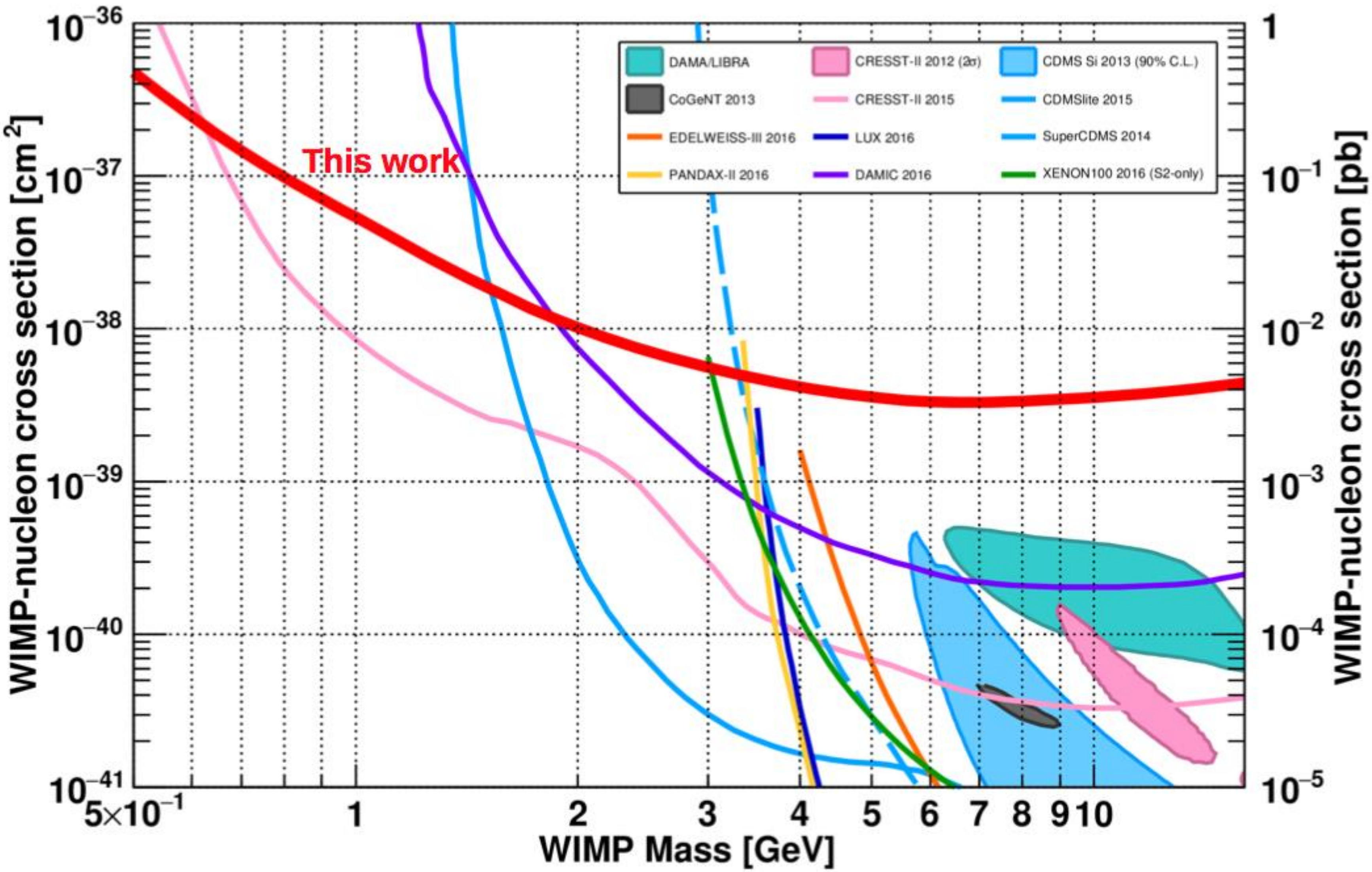




Current sensitivity with Neon at 3 bar

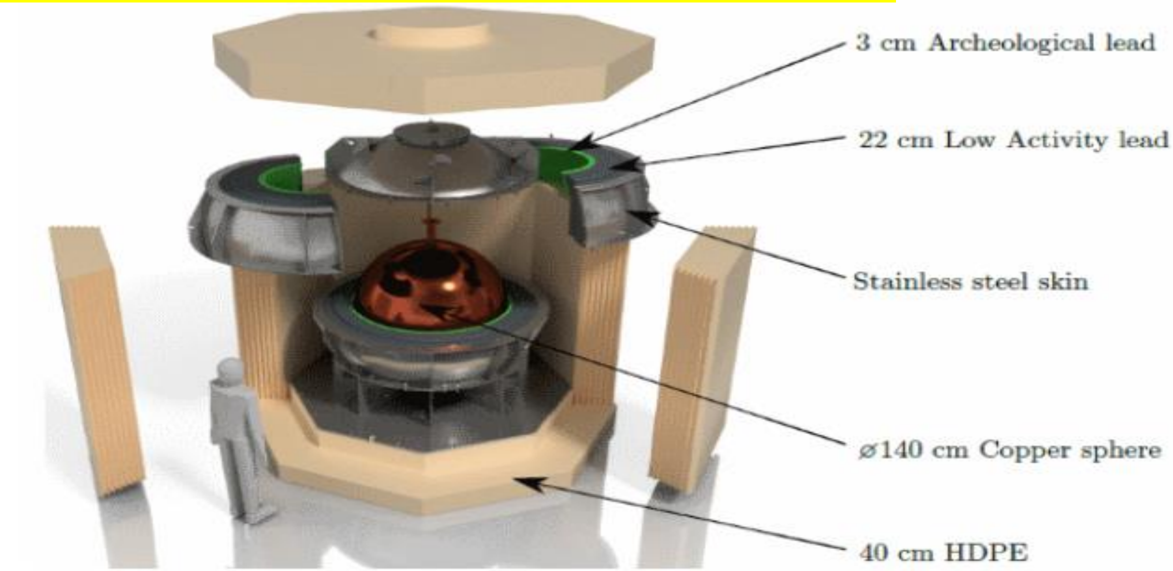
Data 40.5 days, threshold 30 eV

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)

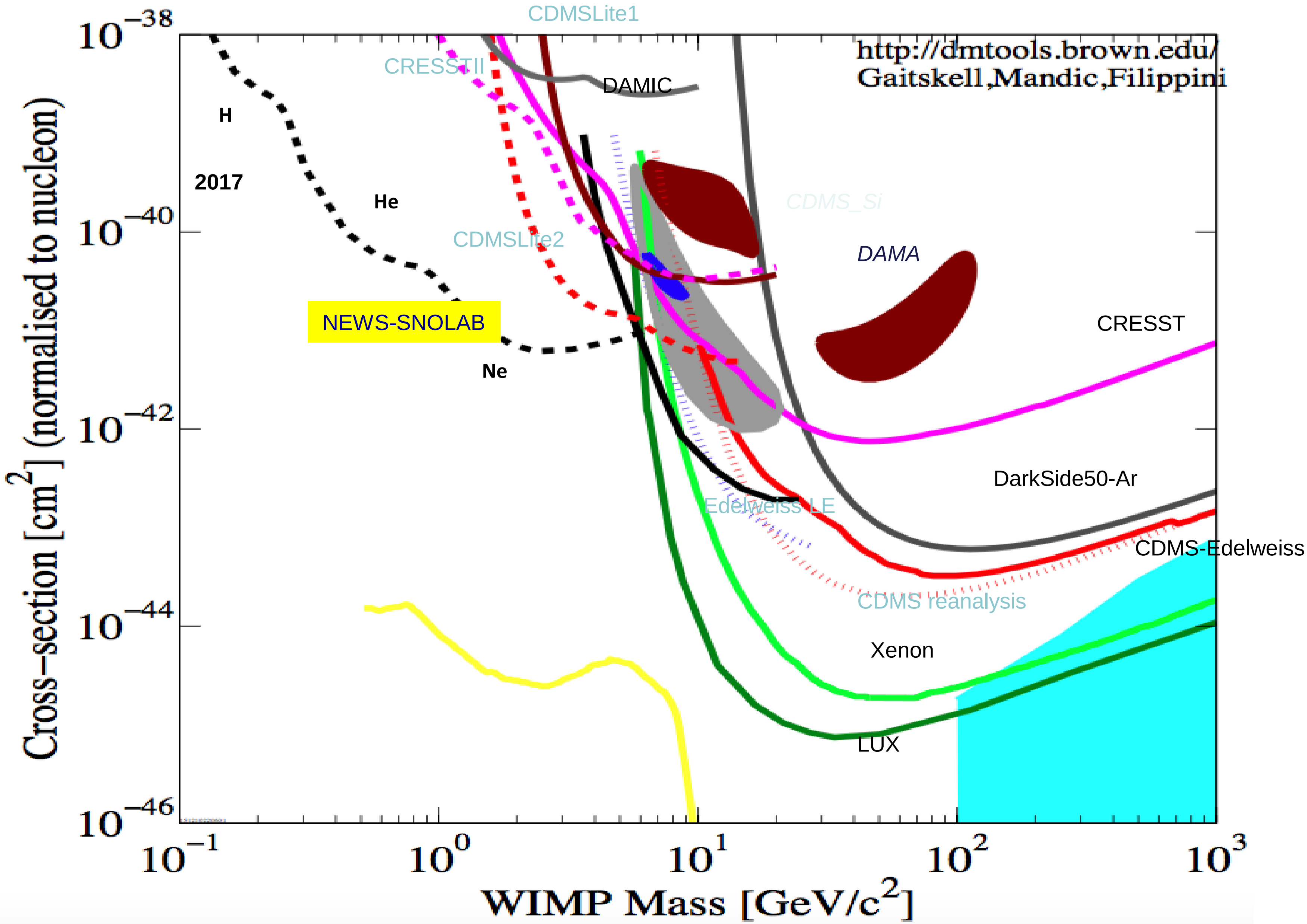


Electropolishing-Electroplating

Spinned hemispheres stored at LSM

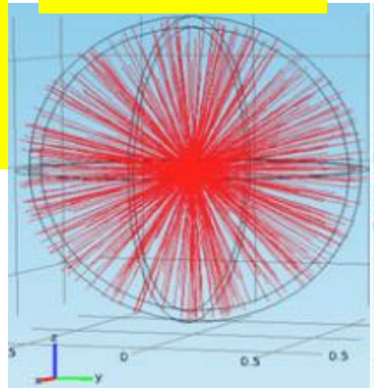
Installed at LSM

NEWS-SNOLAB project sensitivity

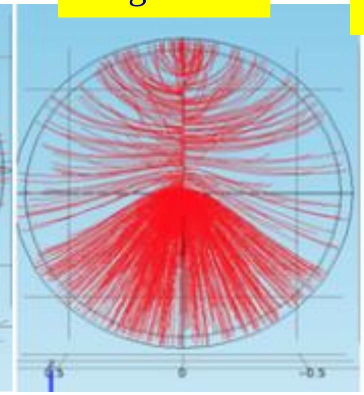


Sensor Development

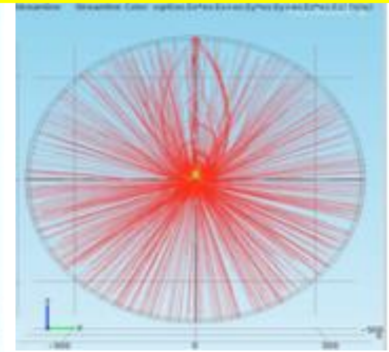
Ideal radial field



Single wire



With umbrella corrector



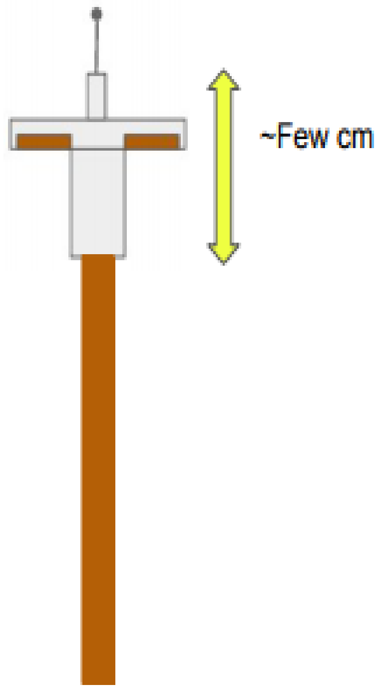
To maximize the usable volume in the detector:
Add a field corrector close to ball (umbrella)

Umbrella materials

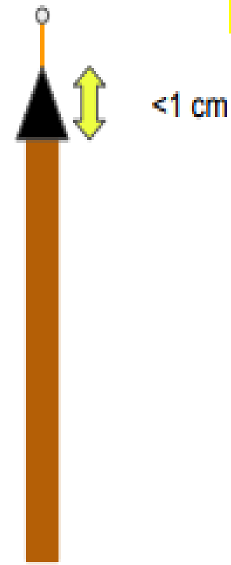
- Pure conductor:
  Sparks from the anode ball

- Pure insulator:
  Charging up and unstable operation

- Resistive materials
  - Resistivity range 10^9 -10^{12} $\Omega\cdot$cm
  - Allow application of a voltage
  - Spark suppression



Classic "umbrella"
< 2016

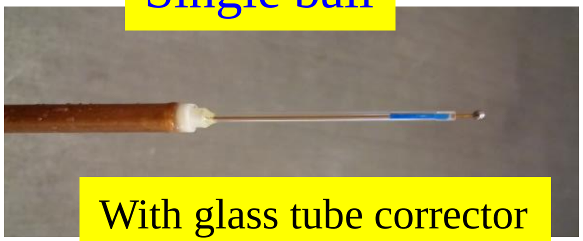


Bakelite Version 2
2017 second half

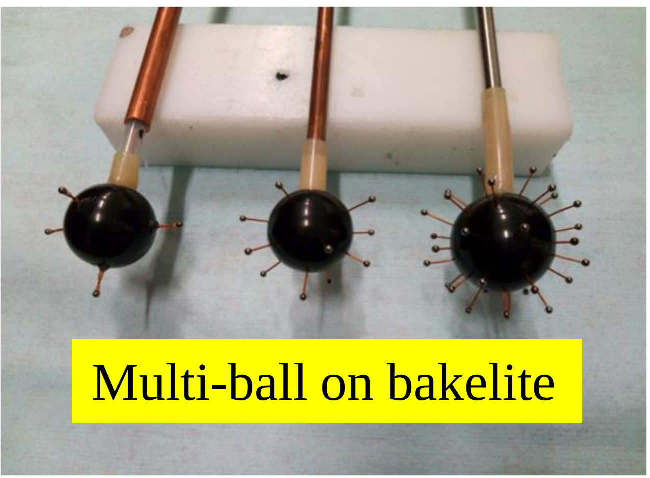
2018
Thin glass tube

From single to multi-ball 'ACHINOS' structure

Single ball



With glass tube corrector



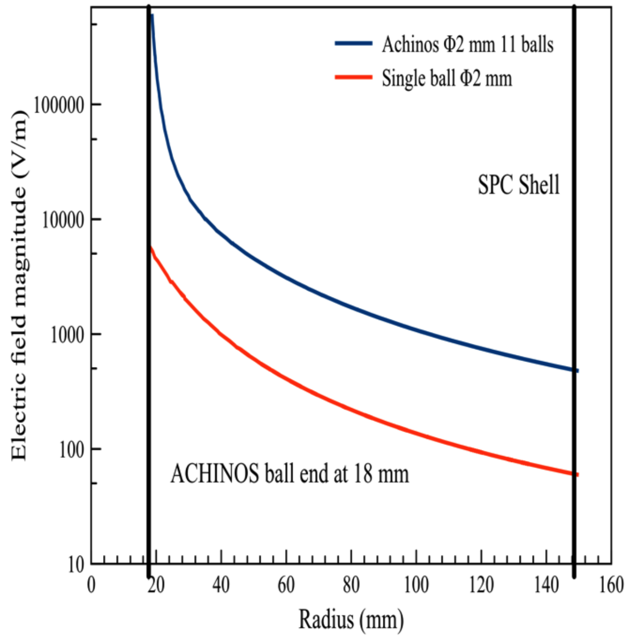
Multi-ball on bakelite

Advantages

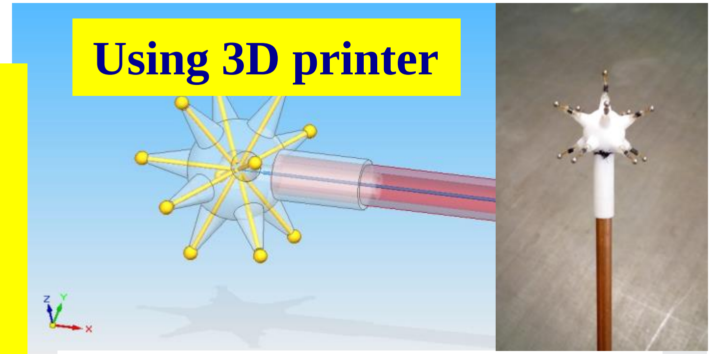
- Amplification tuned by the ball size: 1mm diameter for high pressure

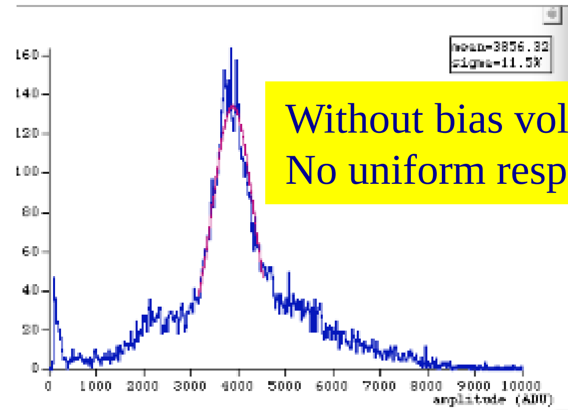
-Volume electric field tuned by the size of the ACHINOS structure

- Detector segmentation: 3D TPC like

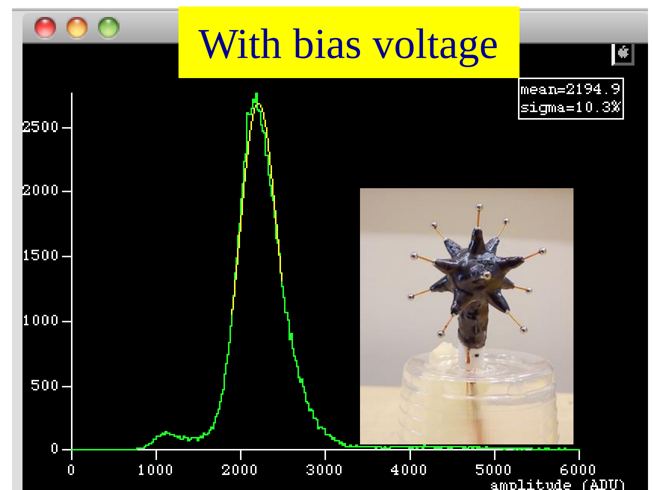


Using 3D printer





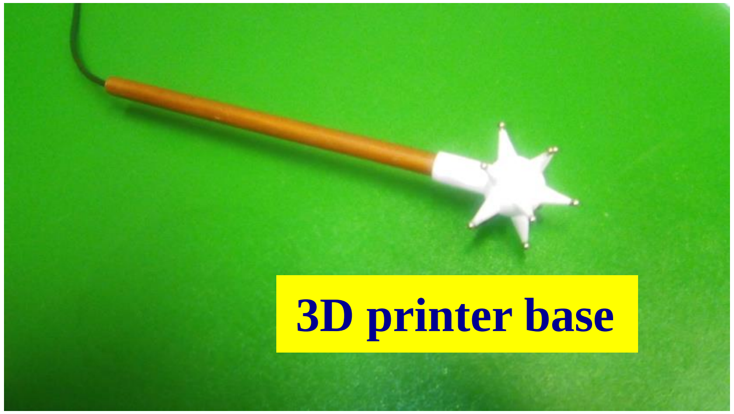
Without bias voltage
No uniform response

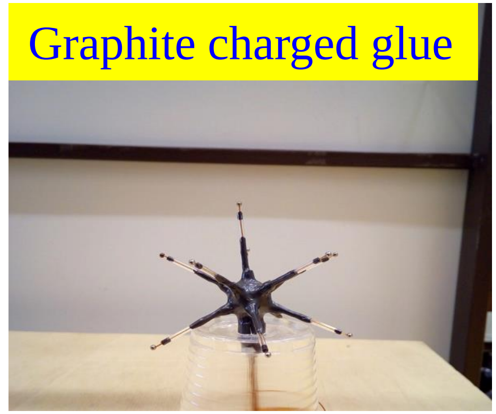


With bias voltage

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

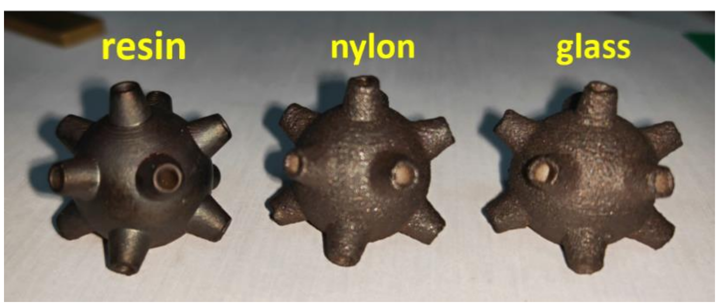
Multi-ball 'ACHINOS' structure
Developed in Saclay in collaboration with University of Thessaloniki

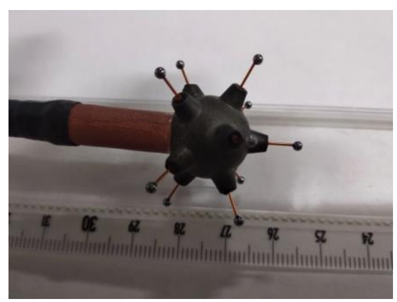


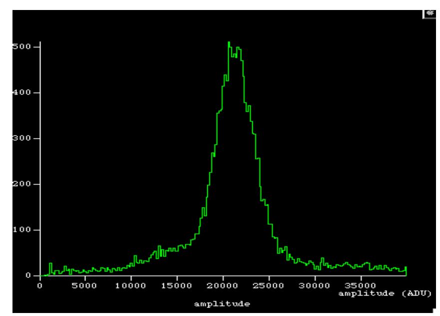


Problem of robustness of charged glue:
At high voltages because of discharges in the bulk it becomes conductor!!!

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

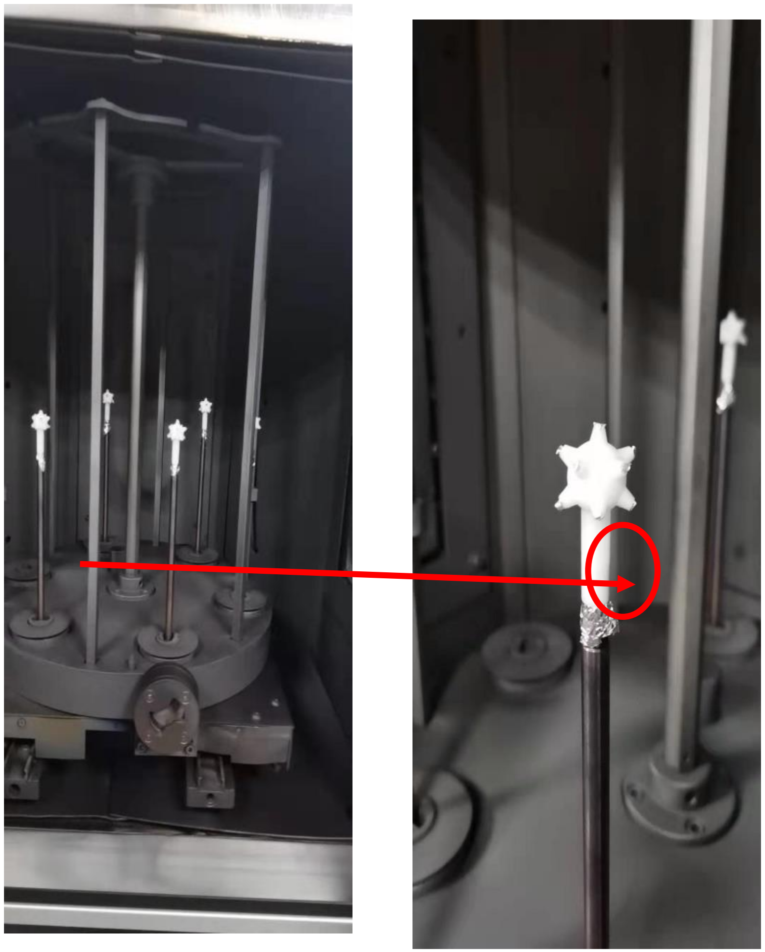






DLC coating on balls and tubes done at USTC

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 thje spherical detector:

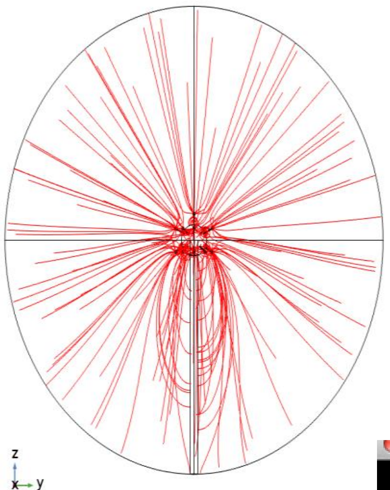
It tunes the volume electric field at will

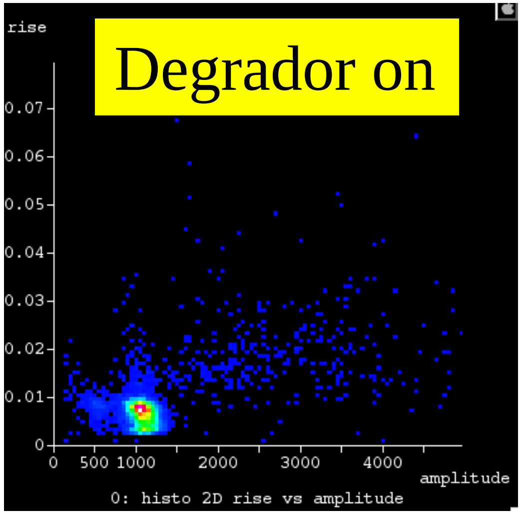
It could be used for any size and any gas pressure

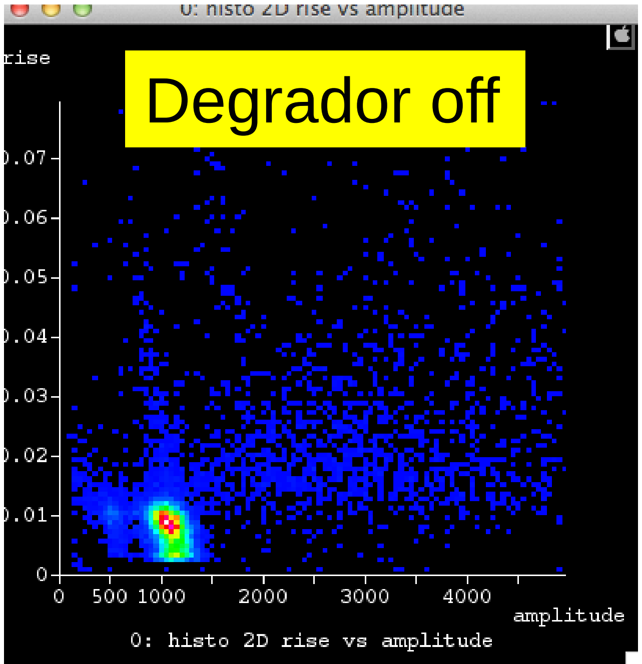
The DLC resistive layer is a robust and efficient protection electrode well adapted to the sensor

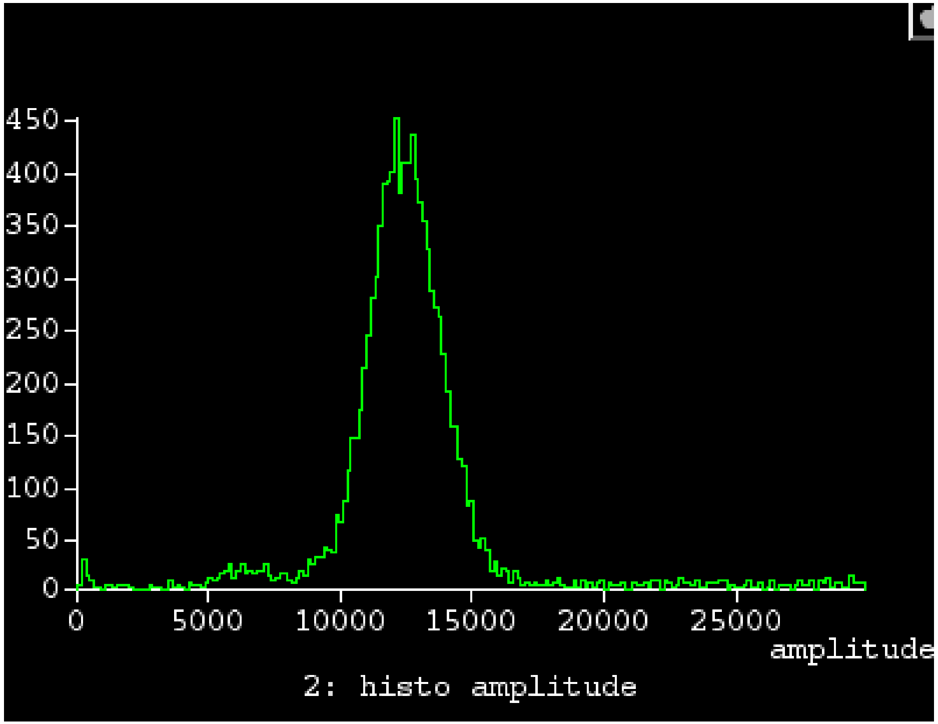
Towards a complete radial field degrador

Very recent development in collaboration with I. Savvidis







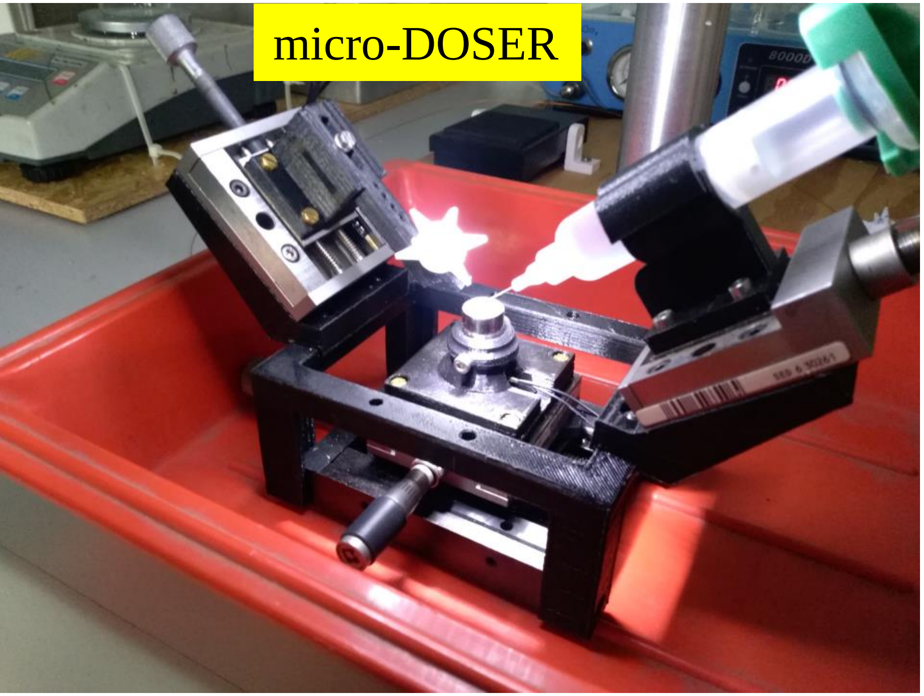


Future developments

- 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_ν =$0.5x10^{53}$ 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

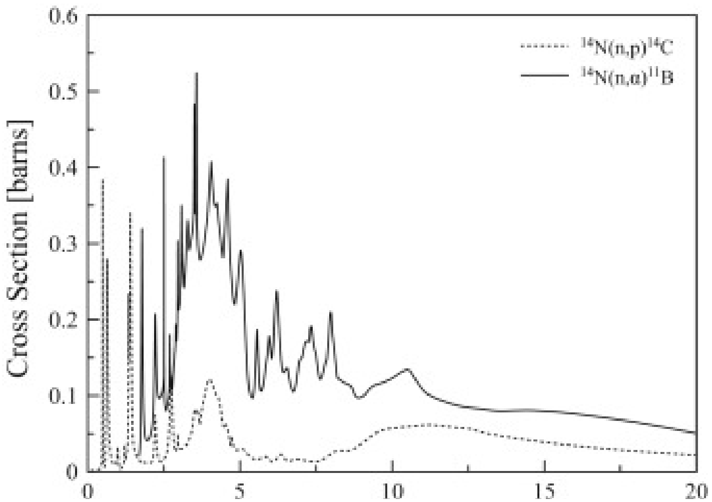
THANK YOU

Back up slides

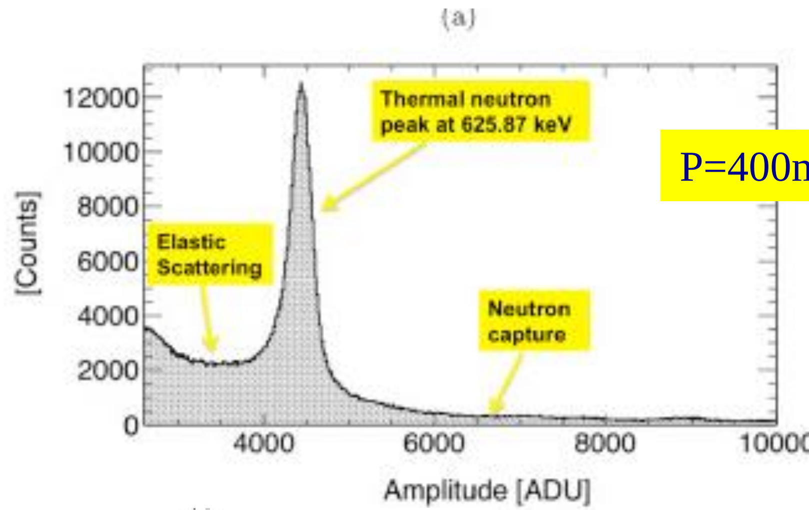
Neutron spectroscopy with N_2 target

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

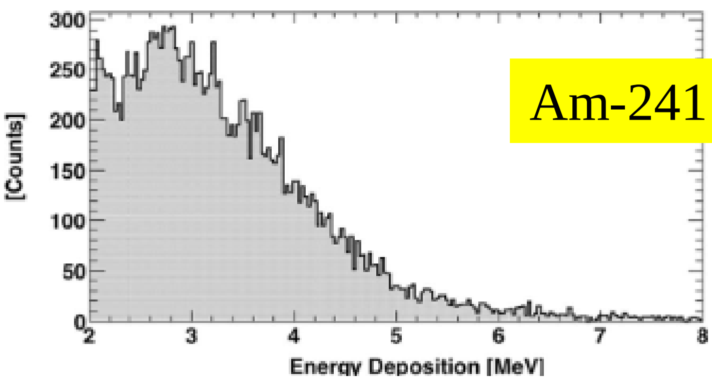
$$^{14}N + n \rightarrow {}^{14}C + p + 625.87\ \mathrm{keV}$$



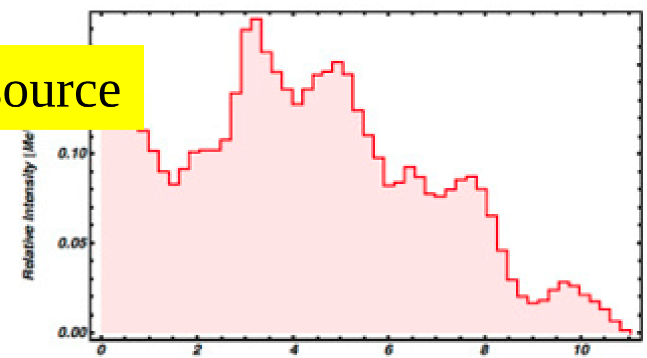
$$^{14}N + n \rightarrow {}^{11}B + \alpha - 158\ \mathrm{keV}$$

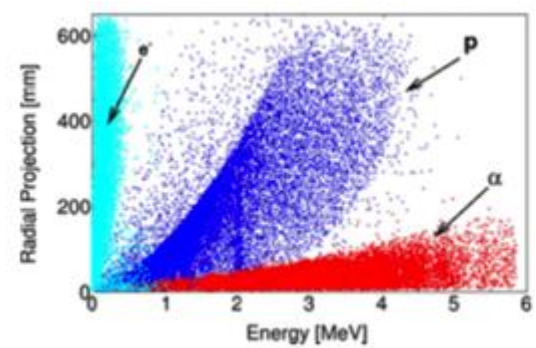


P=400mbar



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**