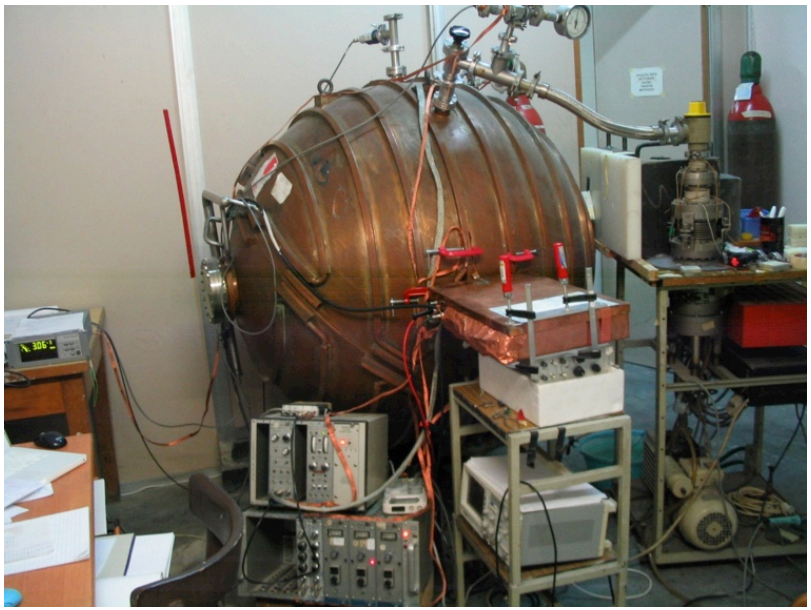
Ultra-light dark matter search in NEWS-G with a gaseous spherical detector

I. Giomataris CEA-Saclay



NEWS collaboration

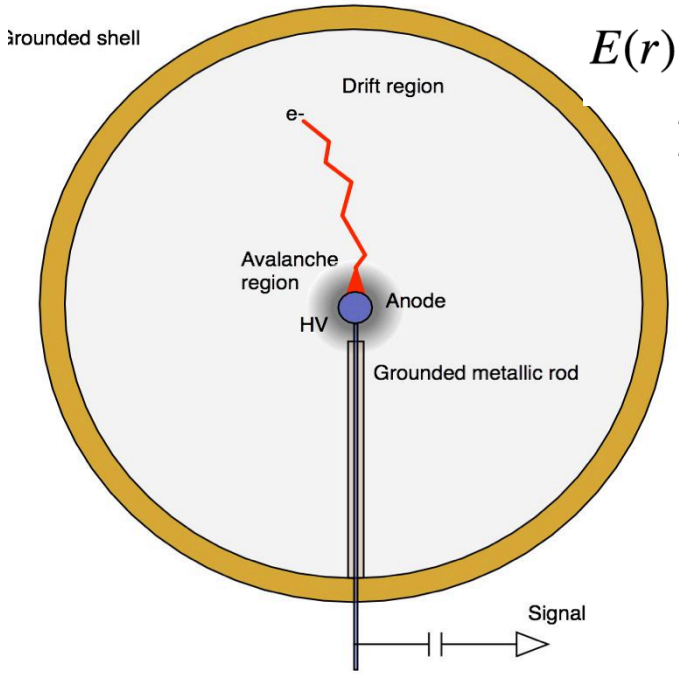
Queen's University Kingston, IRFU/Saclay , LSM, Thessaloniki University, LPSC Grenoble, TU Munich, PNNL,TRIUMPH, Birmigham University

PHYSICS GOAL

- **NEWS-LSM: First exploration of light dark matter search at LSM using SEDINE a small 60cm detector installed at LSM**
- **NEWS-G SNOLAB: Much higher sensitivity and larger detector to be installed at SNOLAB**

The Spherical Proportional Detector

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



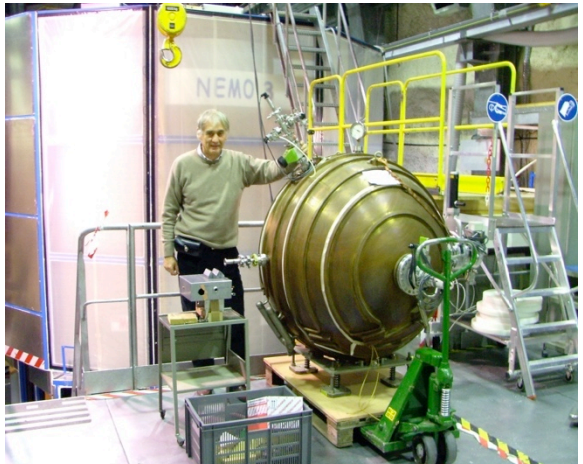
$$E(r) = \frac{V_0}{r^2}\frac{r_A r_C}{r_C - r_A} \approx \frac{V_0}{r^2} r_A$$

r_A = anode ball radius
r_C = cathode radius

C≈ r_a= 1 mm < 1pF

Built by radiopure materials

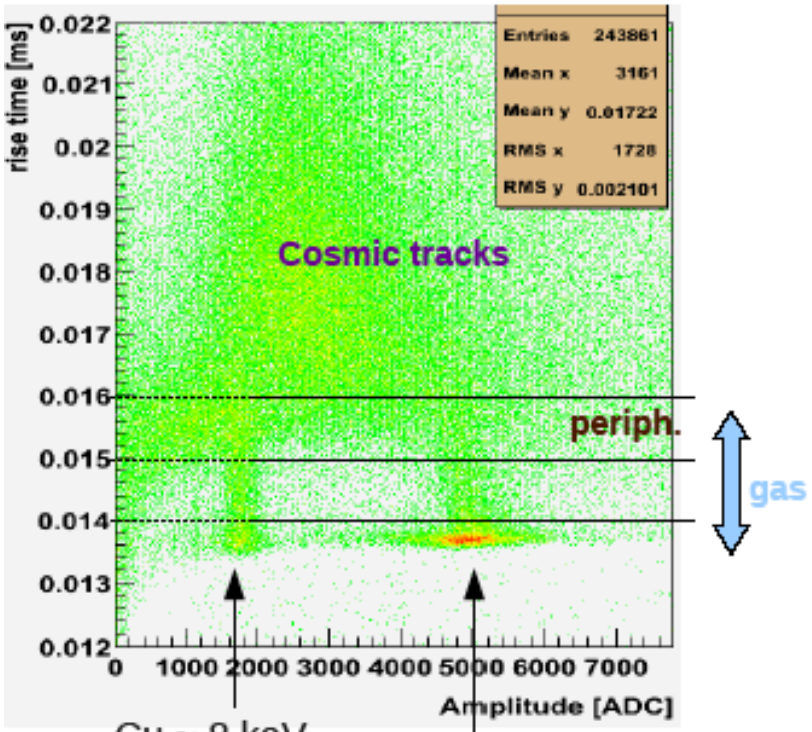
- Vessel made of Cu (~tens of kg)
- Rod made of Cu (~hundreds of gr)
- **All the rest less than < 1 g**



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

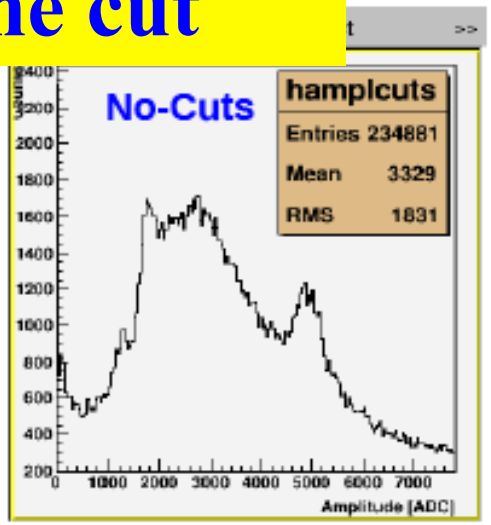
Rejection power
Rise time cut

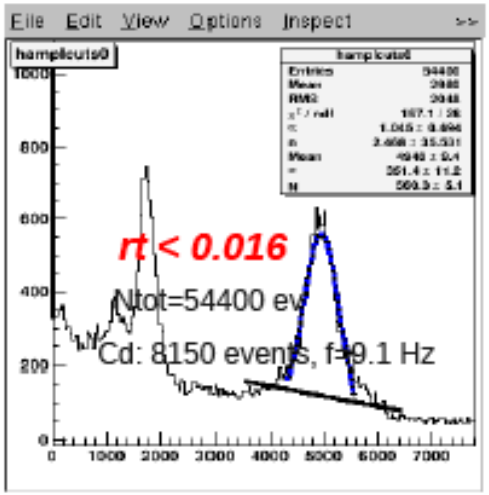
Using Cd-109 source – December 2009
Irradiate gas through 200µm Al window
P = 100 mb, Ar-CH_4 (2%)

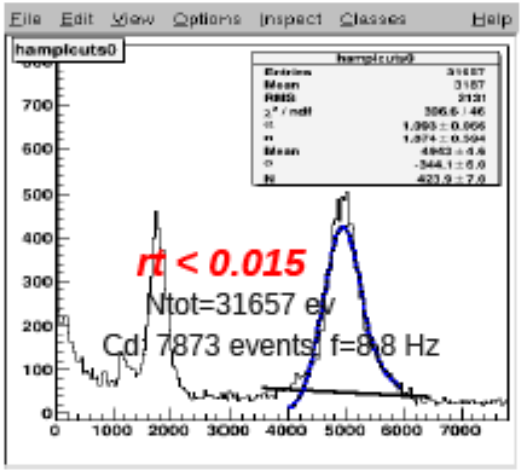


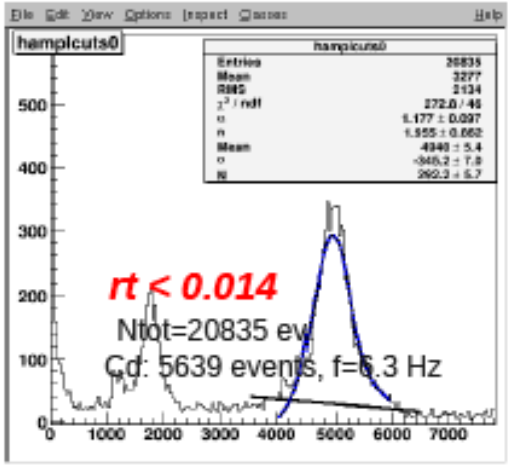
Cu ~ 8 keV

Cd ~ 22 keV









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

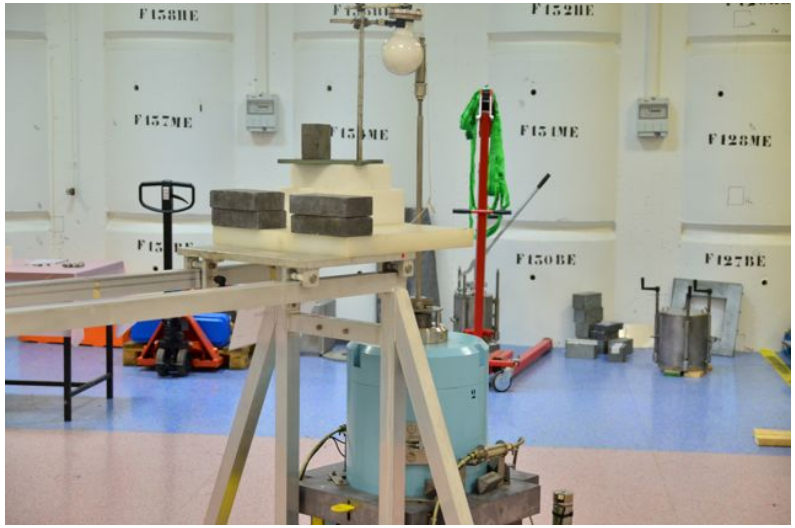
Efficiency of the cut in rt ==> ~ 70% signal (Cd peak)

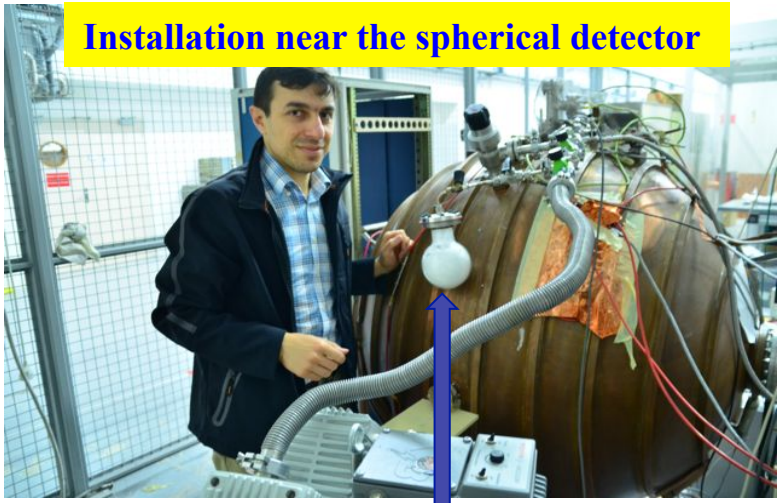
Severe background reduction

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

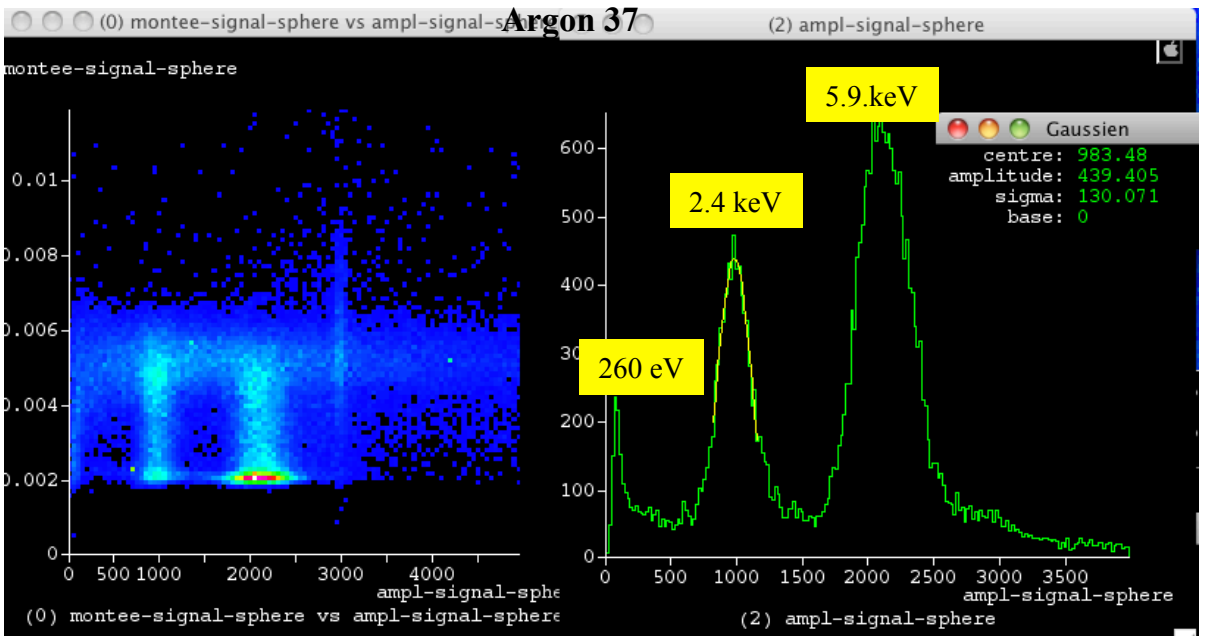
Low-energy calibration source *Argon-37*

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

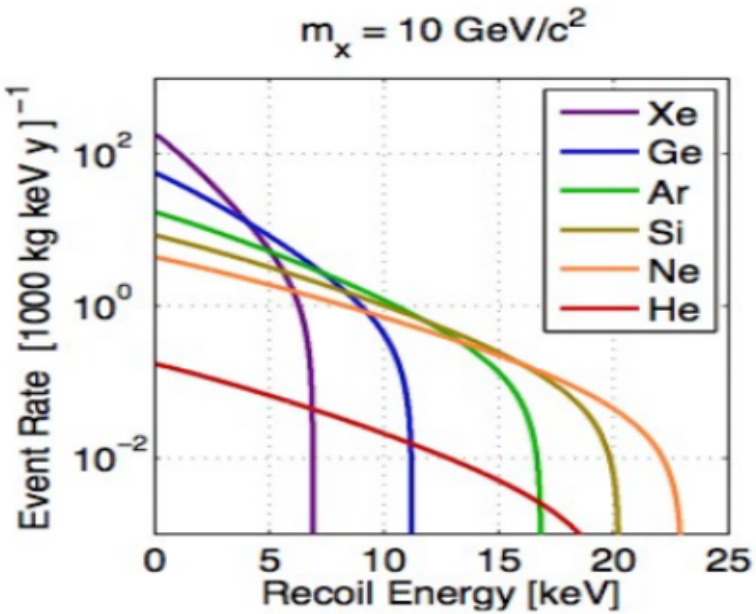


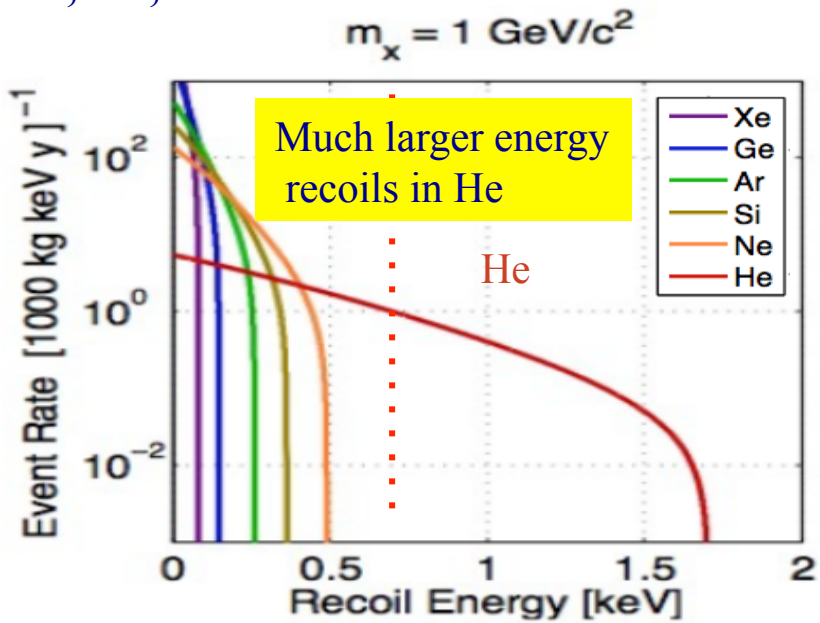
Direct detection of ultra-light dark matter

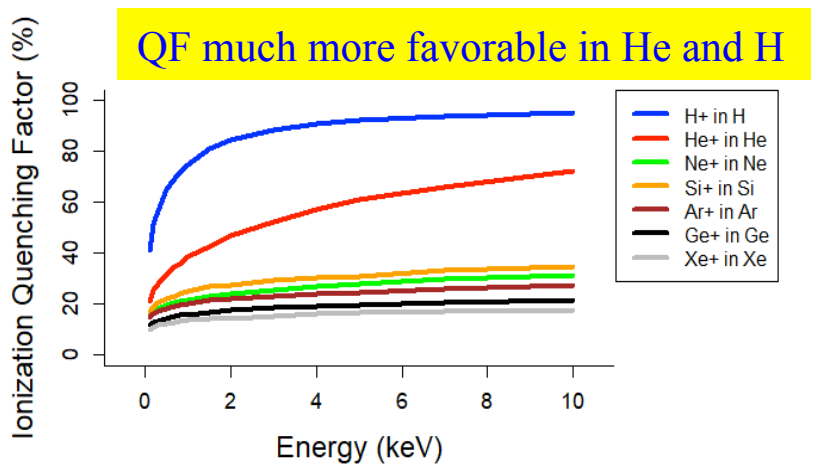
Mass range: 0.1GeV/c²- few GeV/c

To reach low-mass sensitivity goal:

- **low threshold <100 eV**
- **low A targets: Ne, He, H**



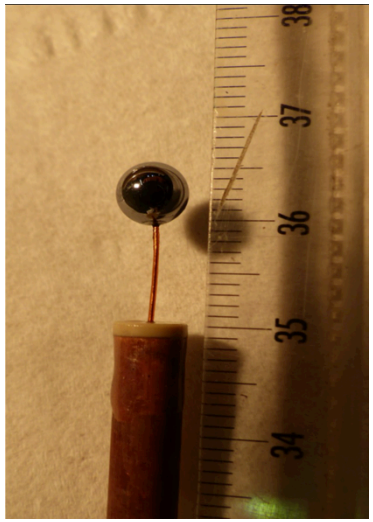


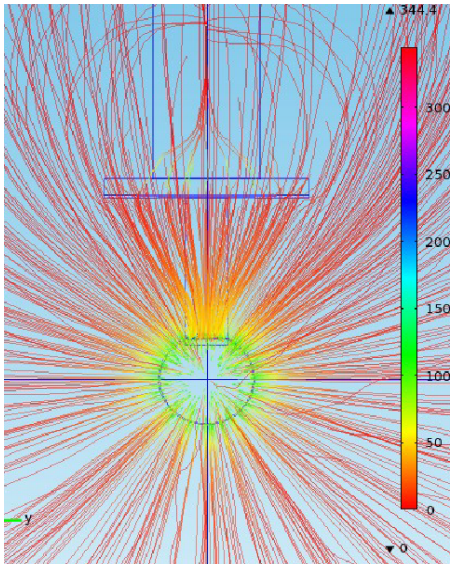


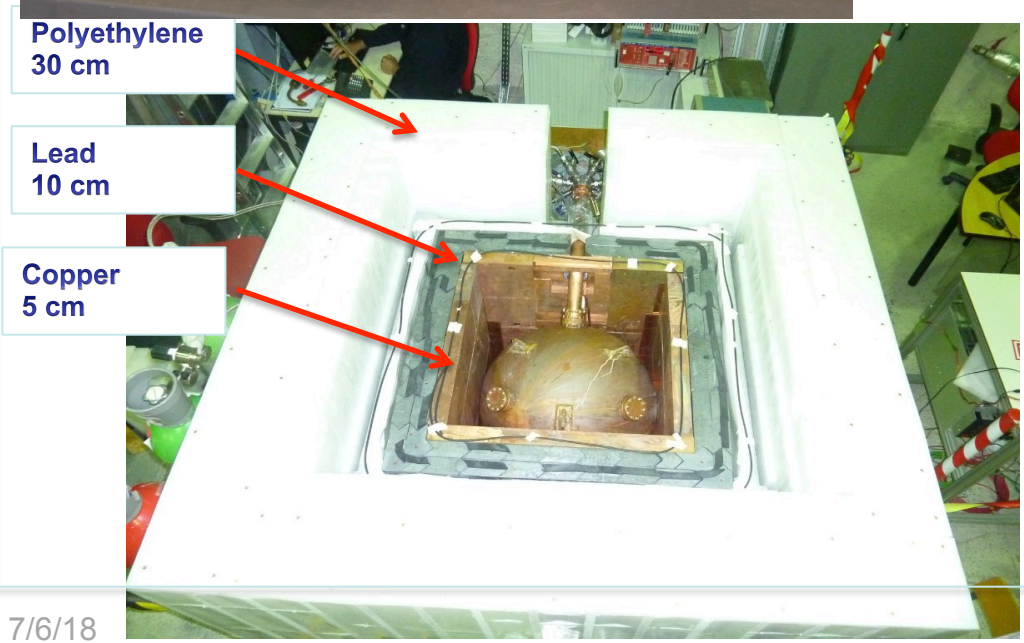
NEWS-LSM: Exploration of light dark matter search at LSM

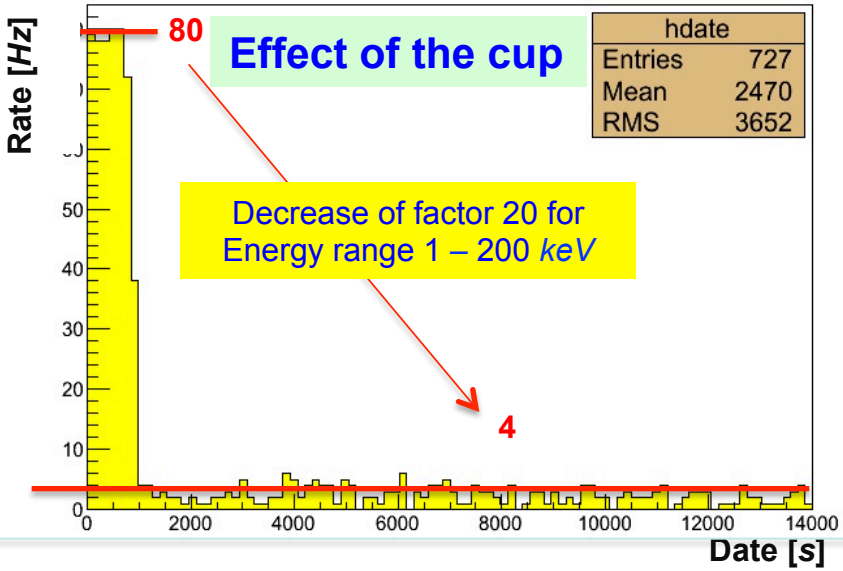
SEDINE detector installed at LSM end 2012: 60 cm, Pressure = up to 10 bar

Gas targets: Ne, He, CH4





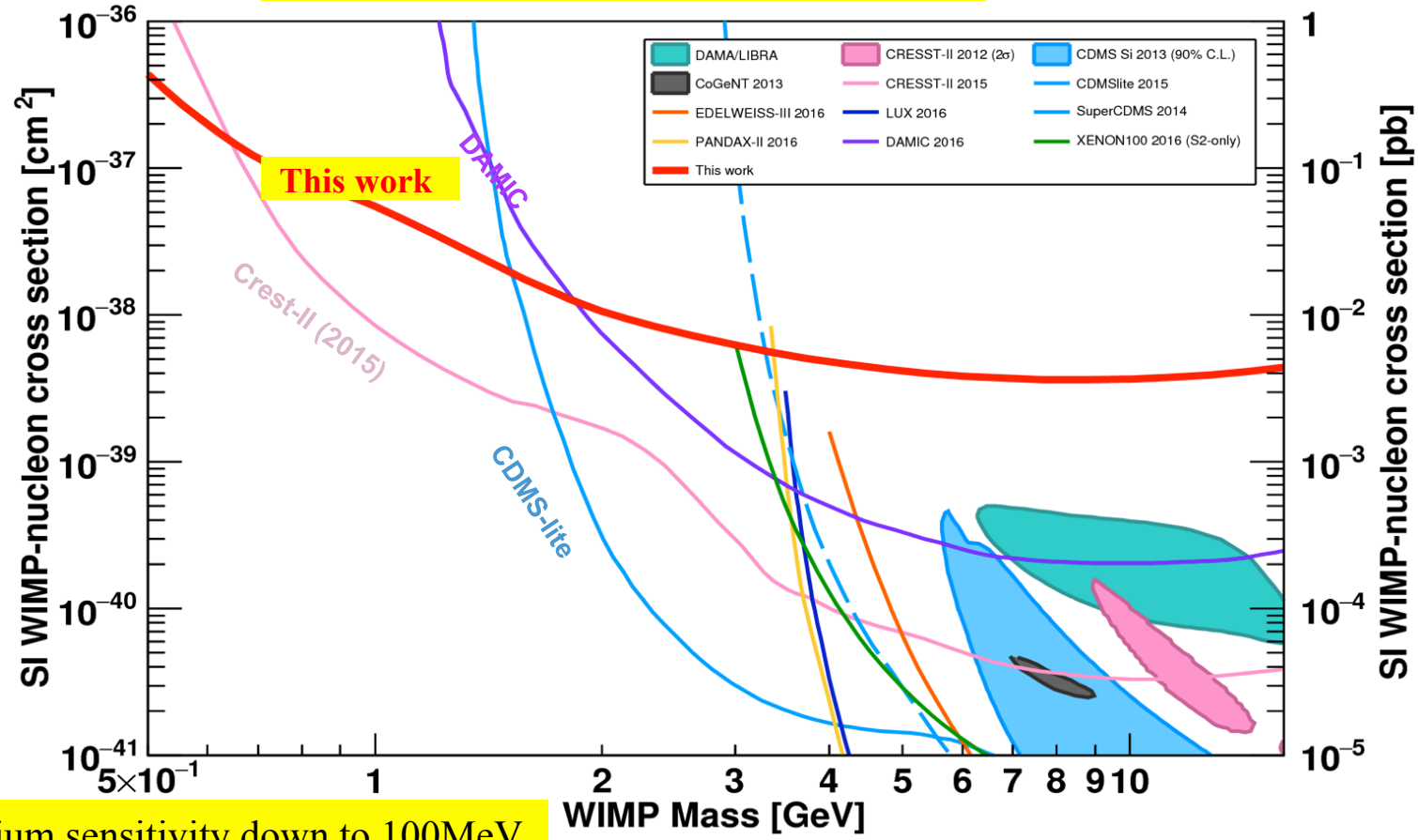




First results of NEWS-G with LSM SEDINE detector

NEWS-G collaboration, Astrop.Phys.97, 54(2018)

Neon at 3 bar
Data 40.5 days, threshold 30 eV

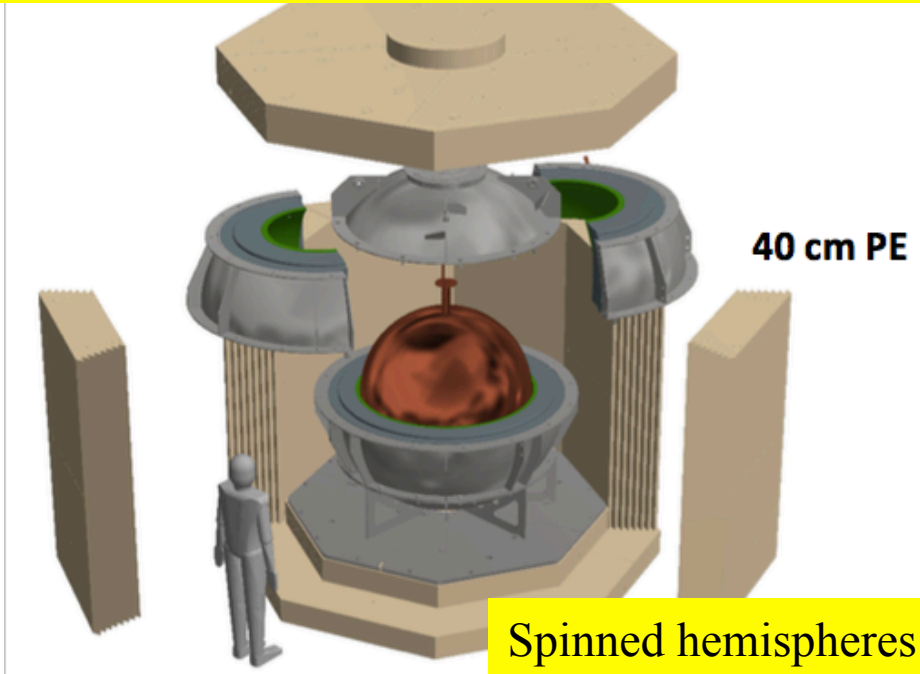


Next run in Helium sensitivity down to 100MeV

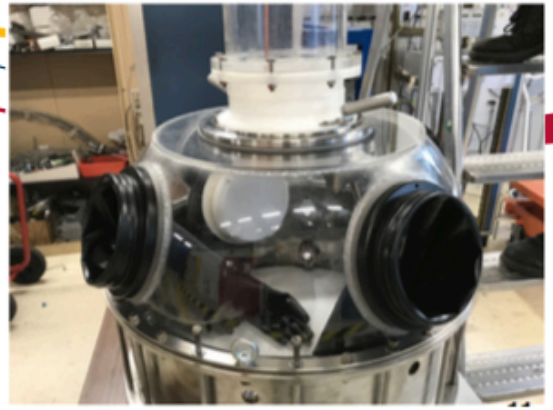
August physics run in Helium
Goal: get sensitivity down to 100 MeV WIMP mass

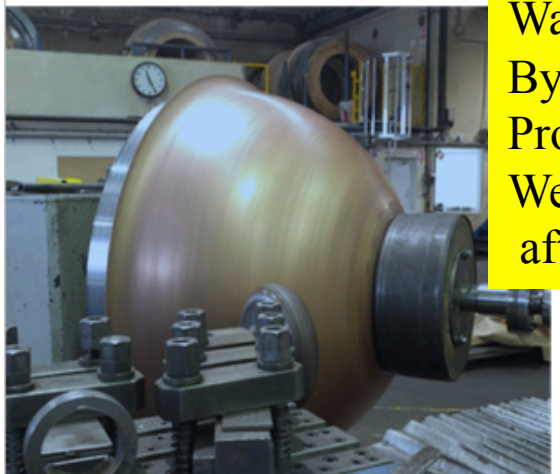
SNOLAB detector:

140 cm Ø detector, 2 bars, Ne, He, CH_4
Low activity copper, 3 cm archeological lead,
22 cm low activity lead, 40 cm polyethylene+Bo

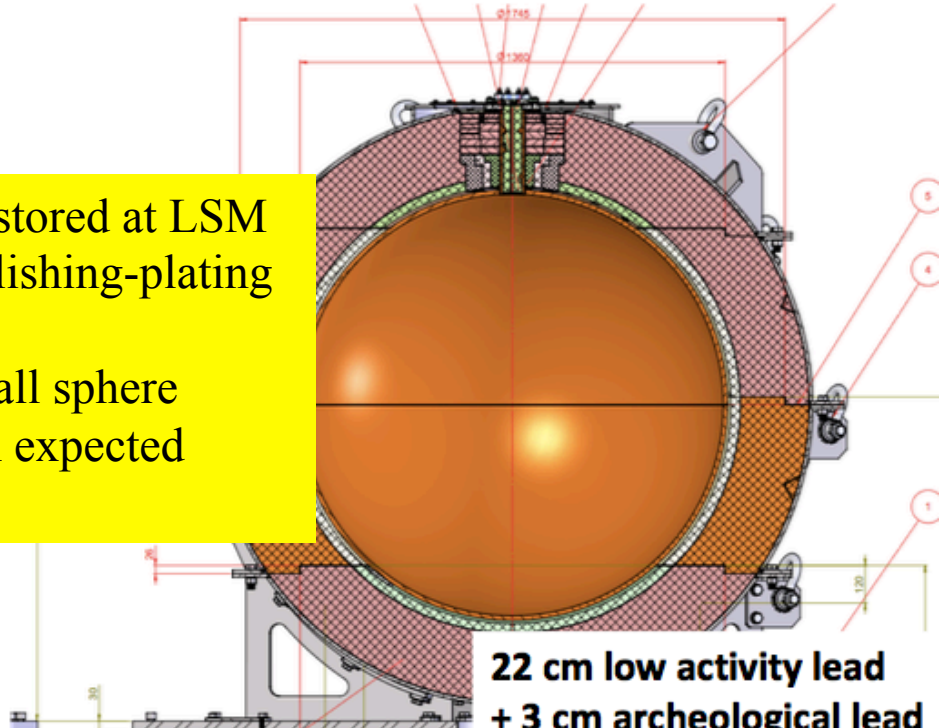


Glove box ready
Change of rod without introducing radon

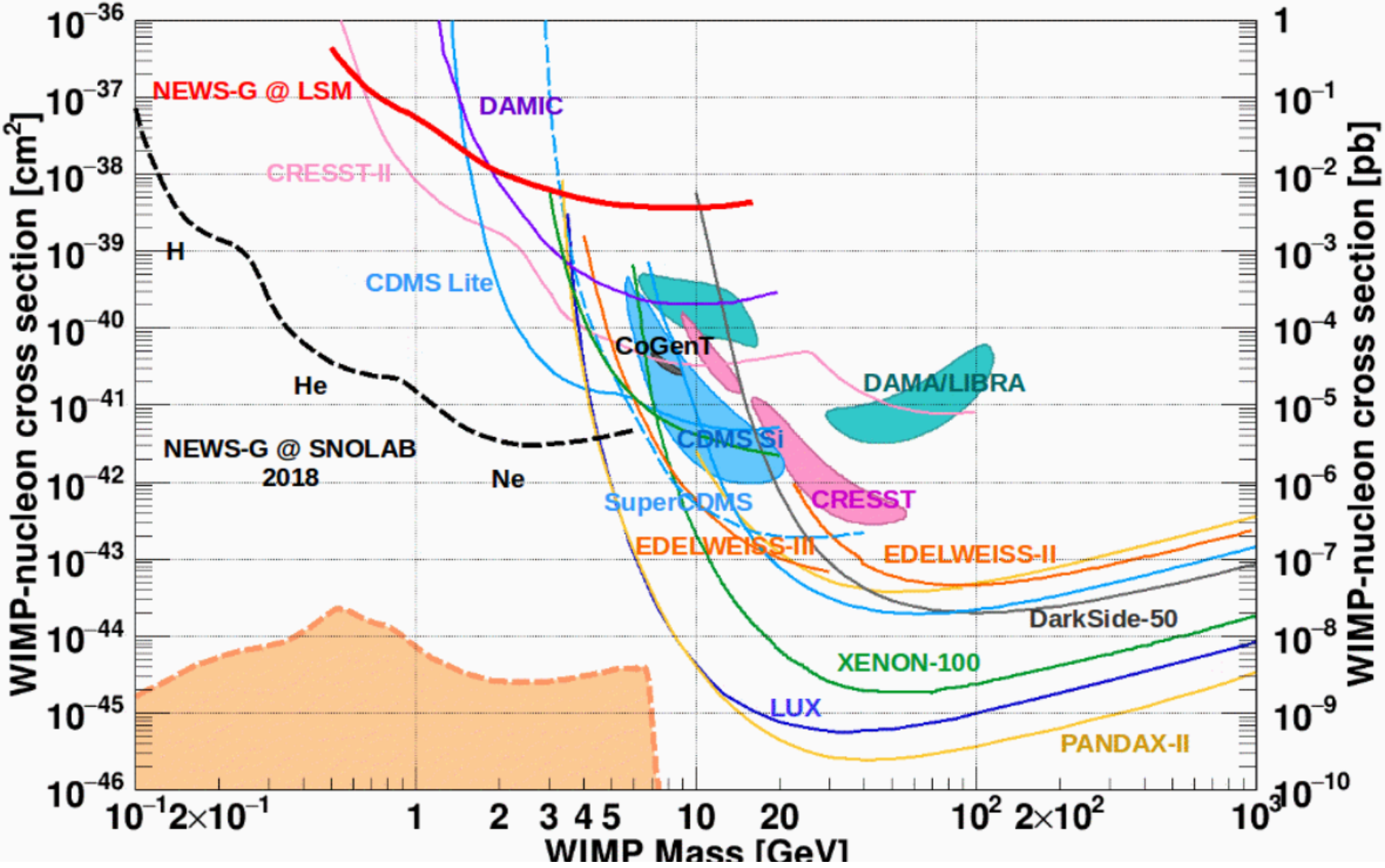




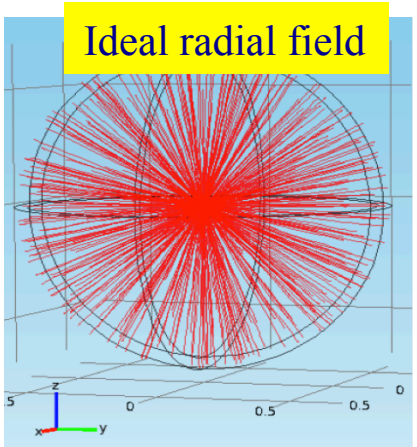
Spinned hemispheres stored at LSM
Waiting for electro polishing-plating
By PNNL (E. Hope)
Process tested in a small sphere
Welding using e-beam expected
after summer

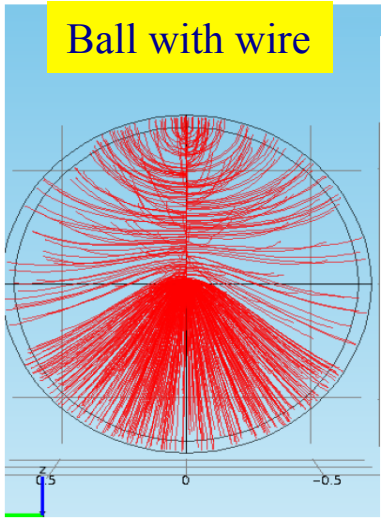


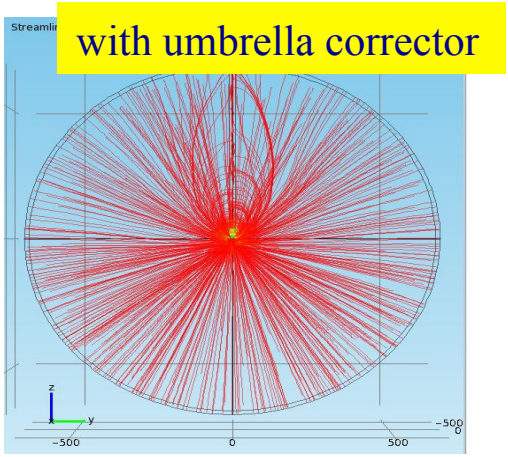
NEWS-SNOLAB project sensitivity



Sensor Development







Necessary to maximise the usable volume in the detector:

Add a field corrector to rod (umbrella)

1) Case of conductor

- Discharges are a limiting factor

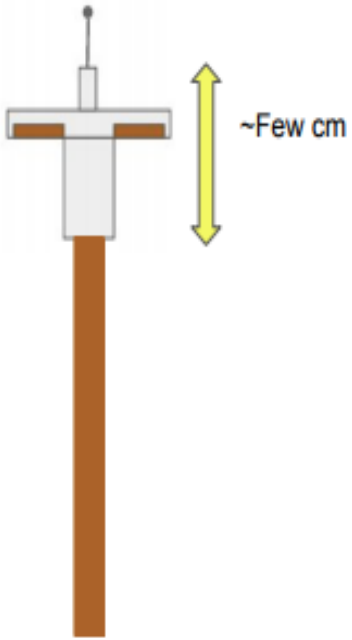
2) Case of insulator

- Charging up and unstable operation

3) Best solution resistive material

Resistivity range 10^9 -10^{12} Ω·cm

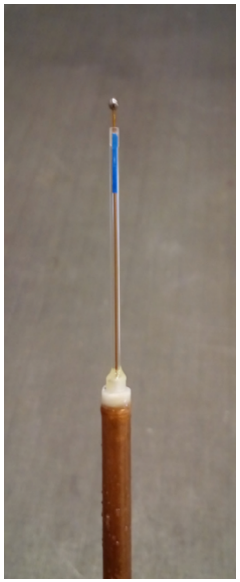
- **Allow application of a voltage**
- **Suppress discharges**



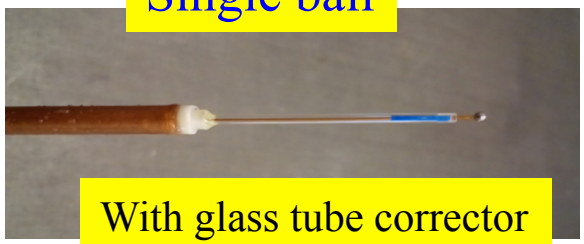
Classic "umbrella"
< 2016

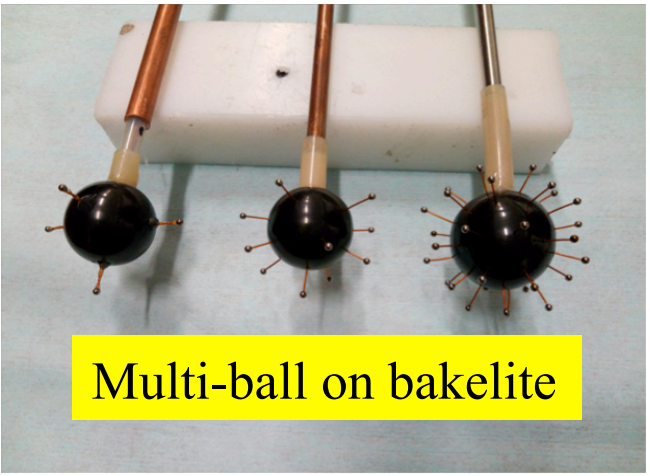
akelite Version 2
17 second half

Glass corrector



From single to multi-ball 'ACHINOS' structure



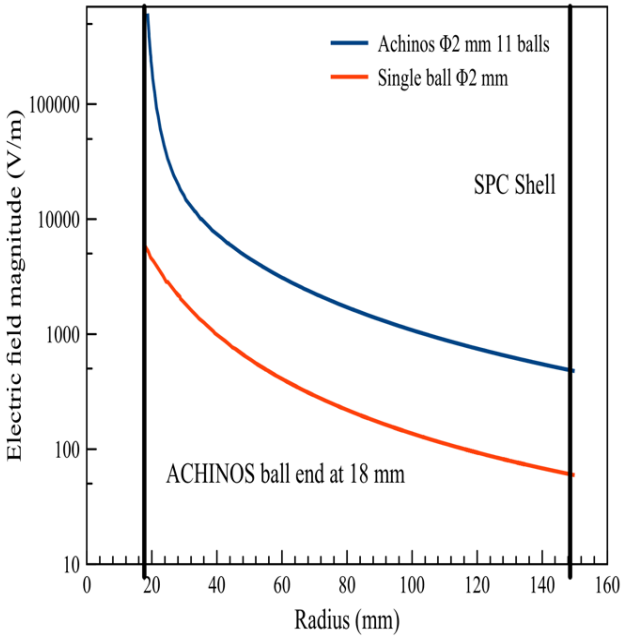


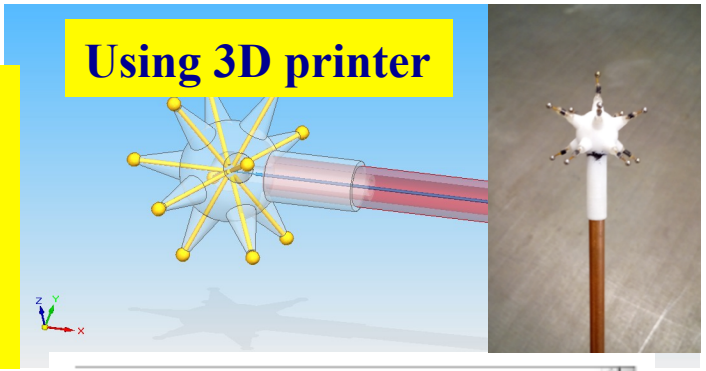
Advantages

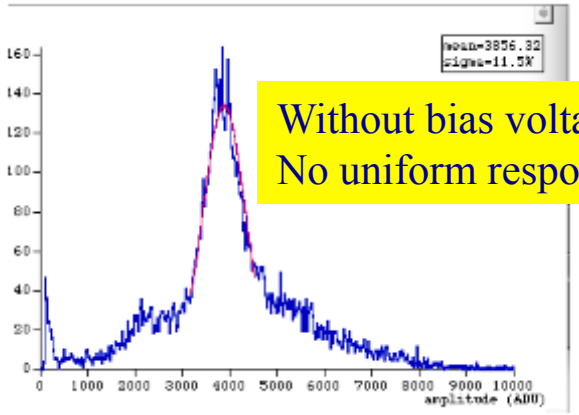
- Amplification tuned by the ball size: 1mm diameter for high pressure

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

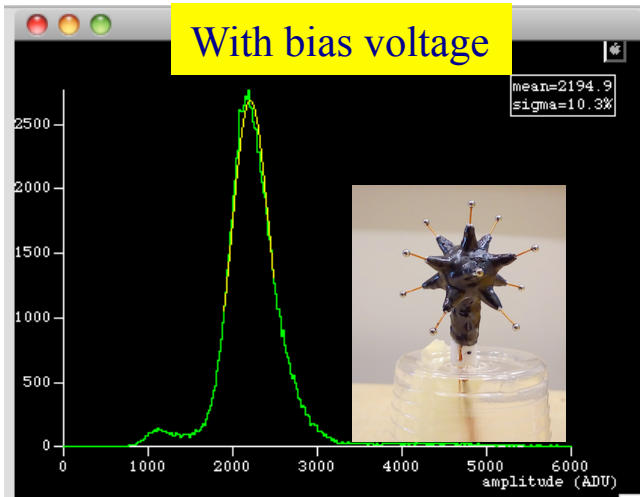
- Detector segmentation: 3D TPC like







Without bias voltage
No uniform response



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

THANK YOU