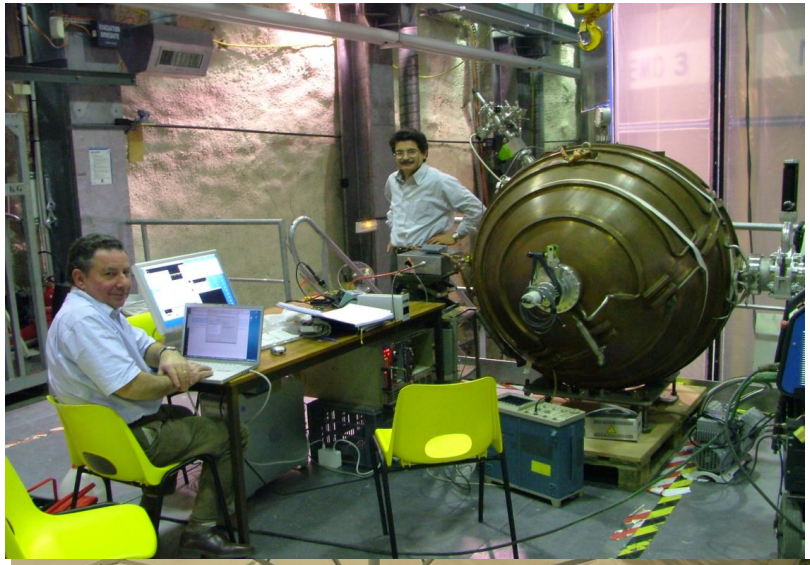
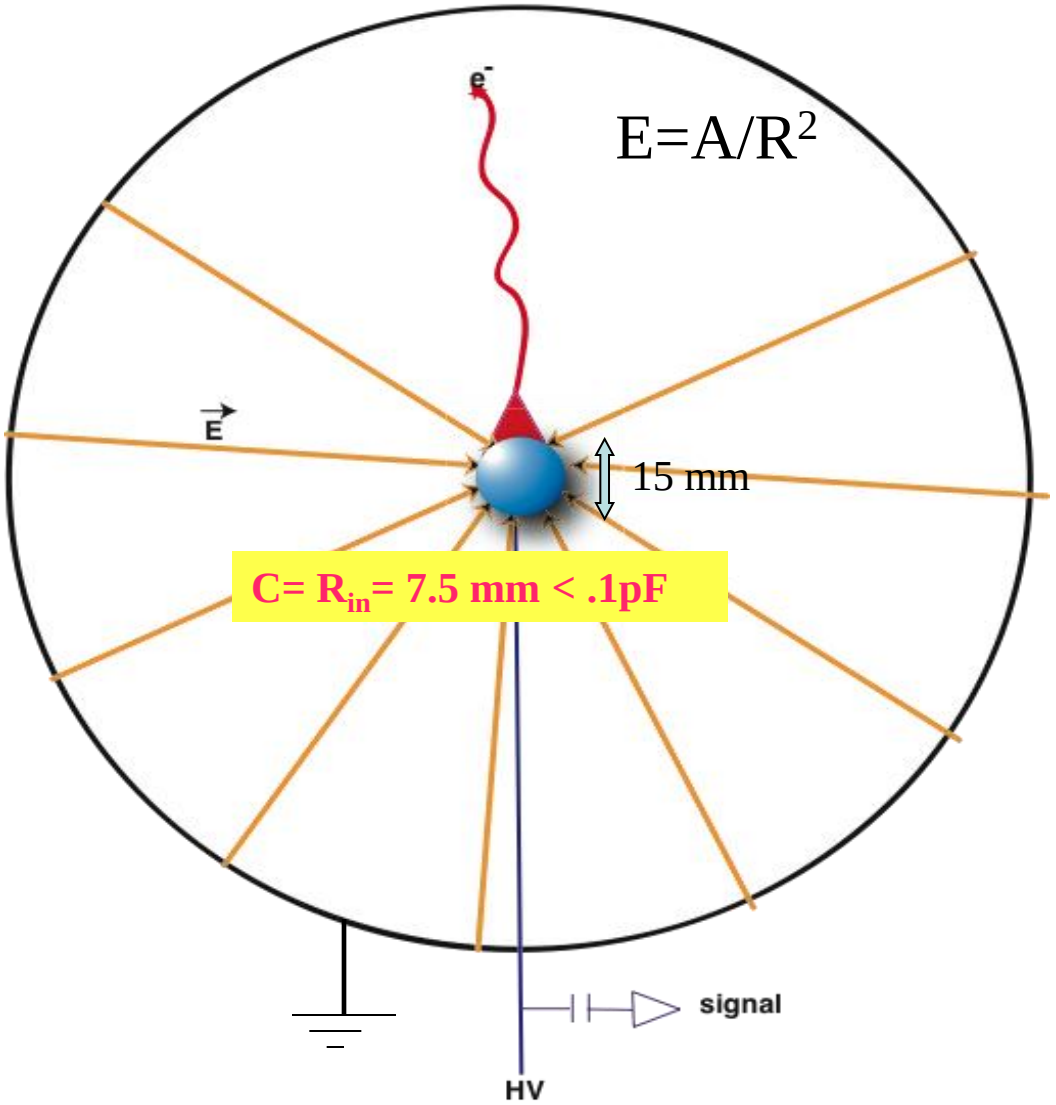
Large Volume Spherical Detector and its Applications

I. Giomataris, CEA-Saclay



Radial TPC with spherical proportional counter read-out

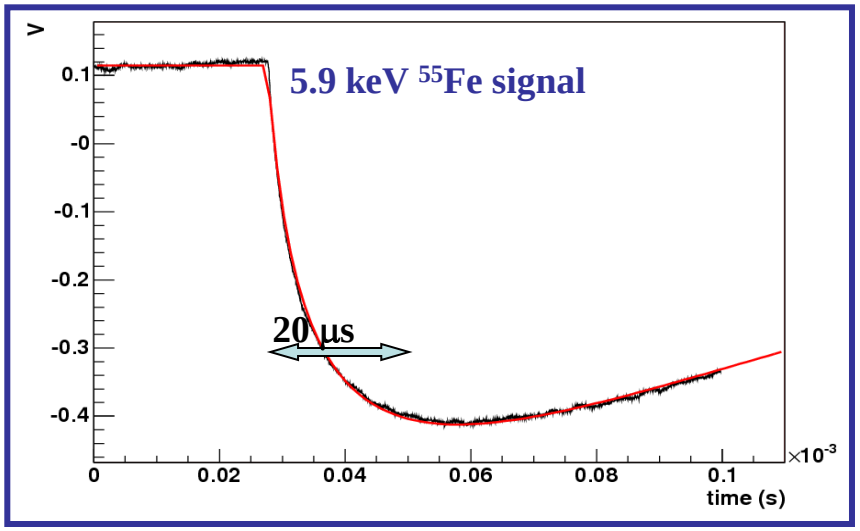
A Novel large-volume Spherical Detector with Proportional Amplification read-out, I. Giomataris *et al.*, JINST 3:P09007,2008



Two innovations

1.Radial TPC ⟹ Single read-out

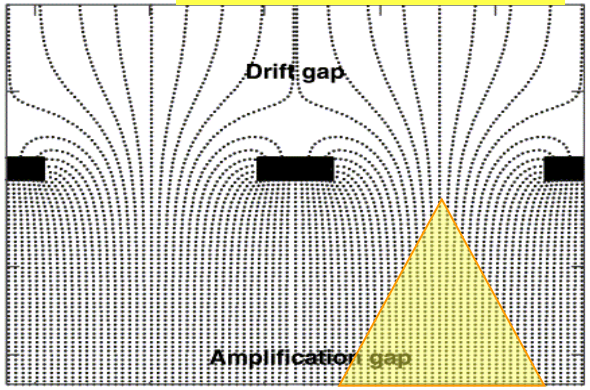
2.Spherical proportional counter



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

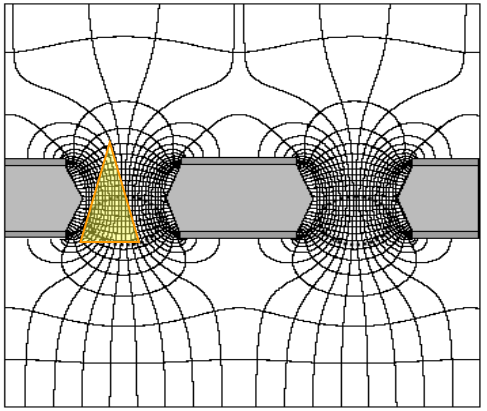
Parallel Plate Detector

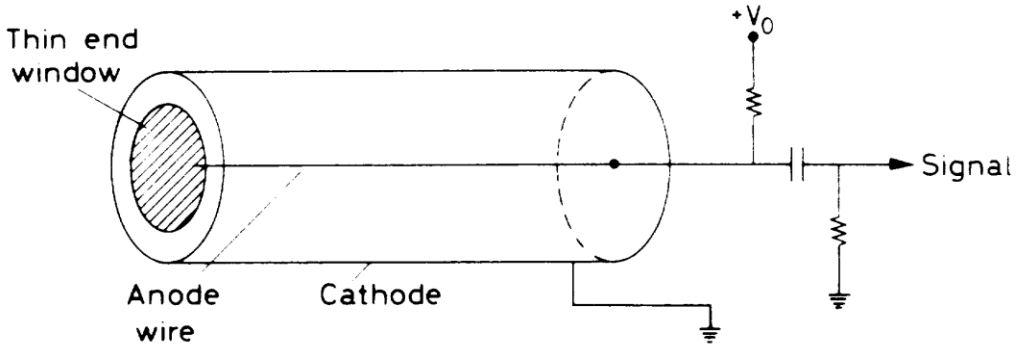
Micromegas



E= constant
C ≈ S > 1nF

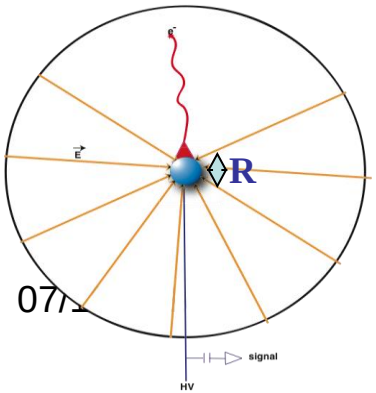
GEM



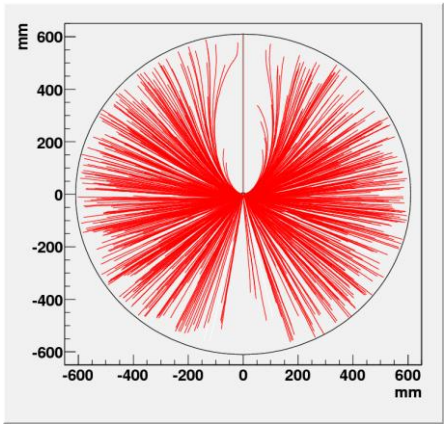


$$E(r) = \frac{CV_0}{2\pi\varepsilon L}\frac{1}{r} \qquad C = \frac{2\pi\varepsilon L}{\ln(b/a)}$$

Spherical Proportional Counter

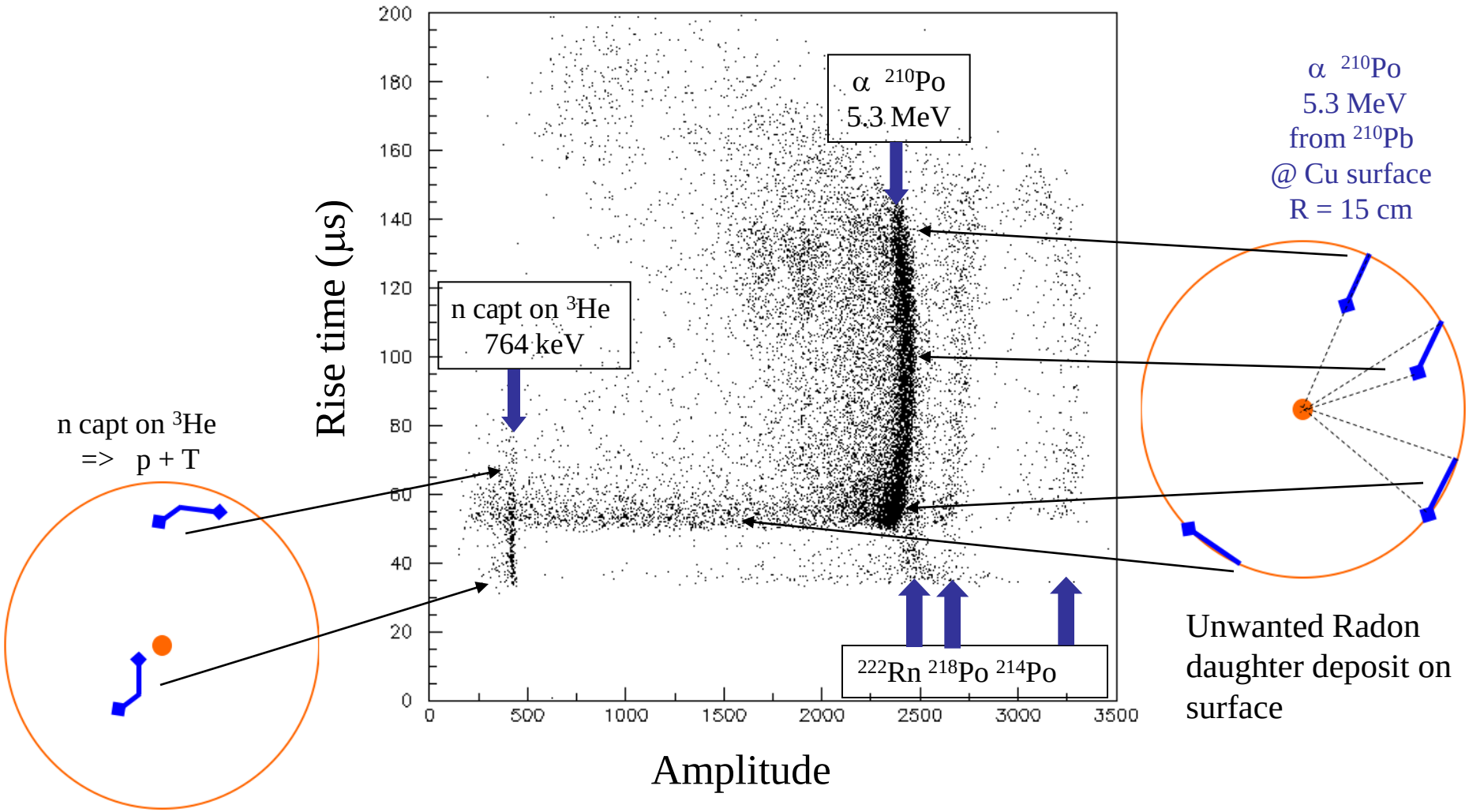


E=1/r²
C ≈ R_{in} < .1pF



I. Giomataris

Run at LSM - Ar/CH_4 + 3g ^3He 200 mb

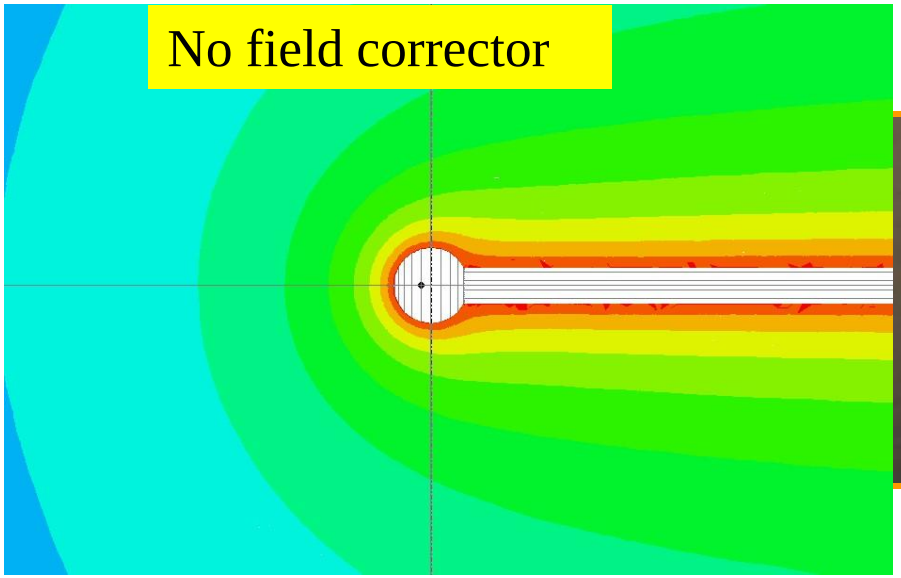


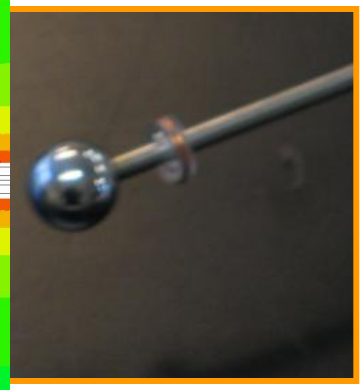
= > dependance of rise time on length of track and radius position

Electrostatics deal, How to keep radial field

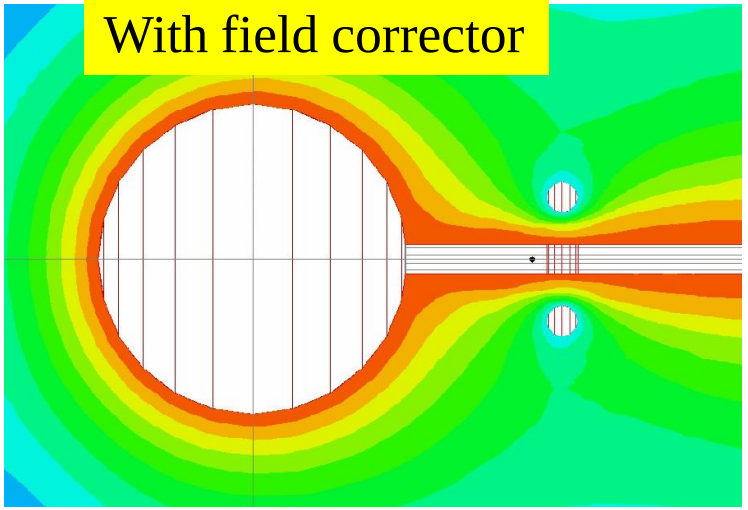
Ideal solution: field $1/R^2$ degrador around the wire

No field corrector

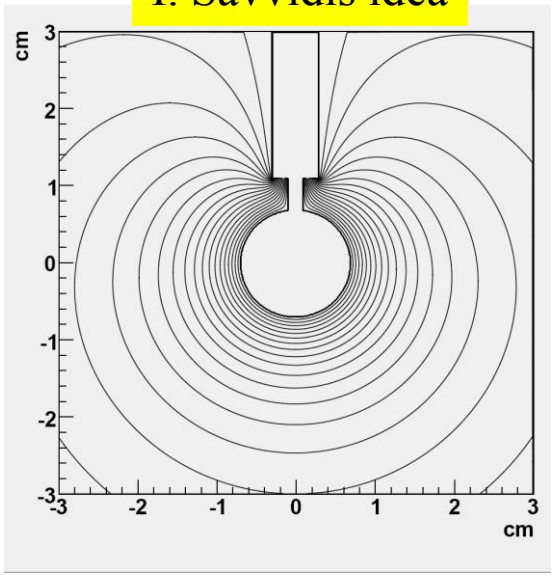


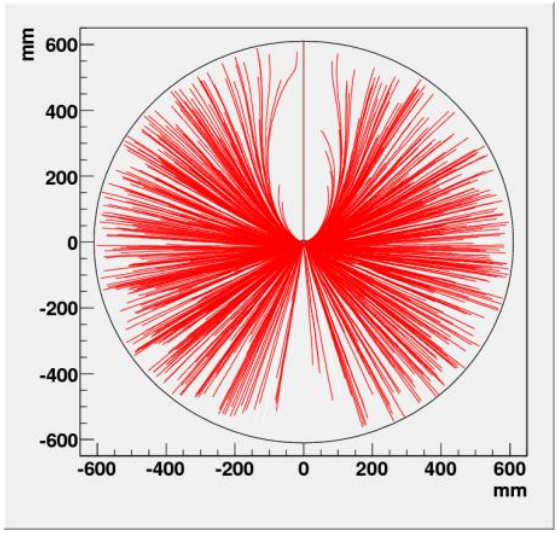


With field corrector

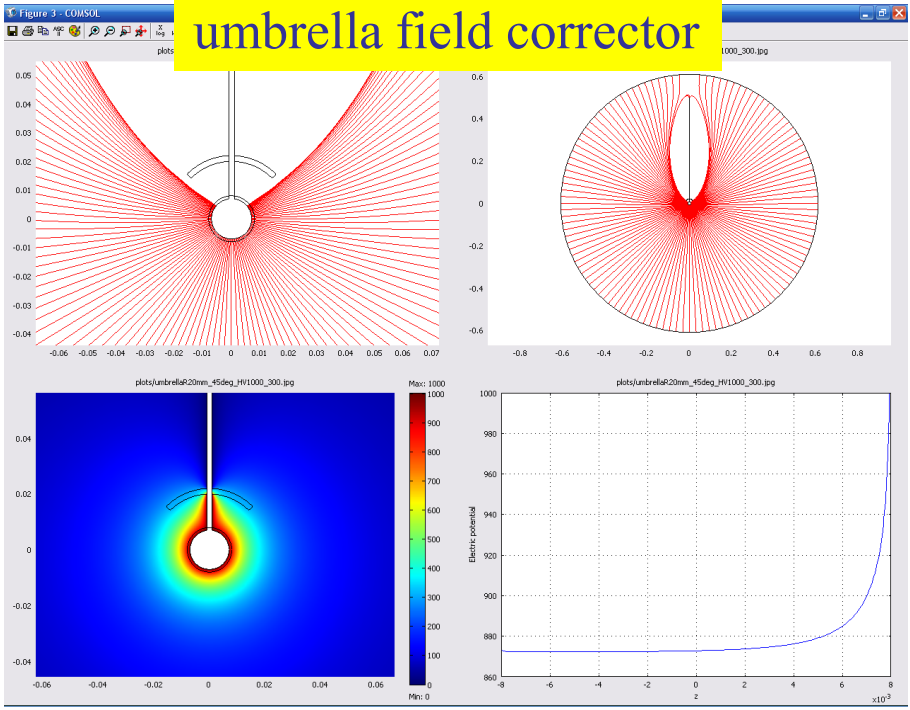


I. Savvidis idea



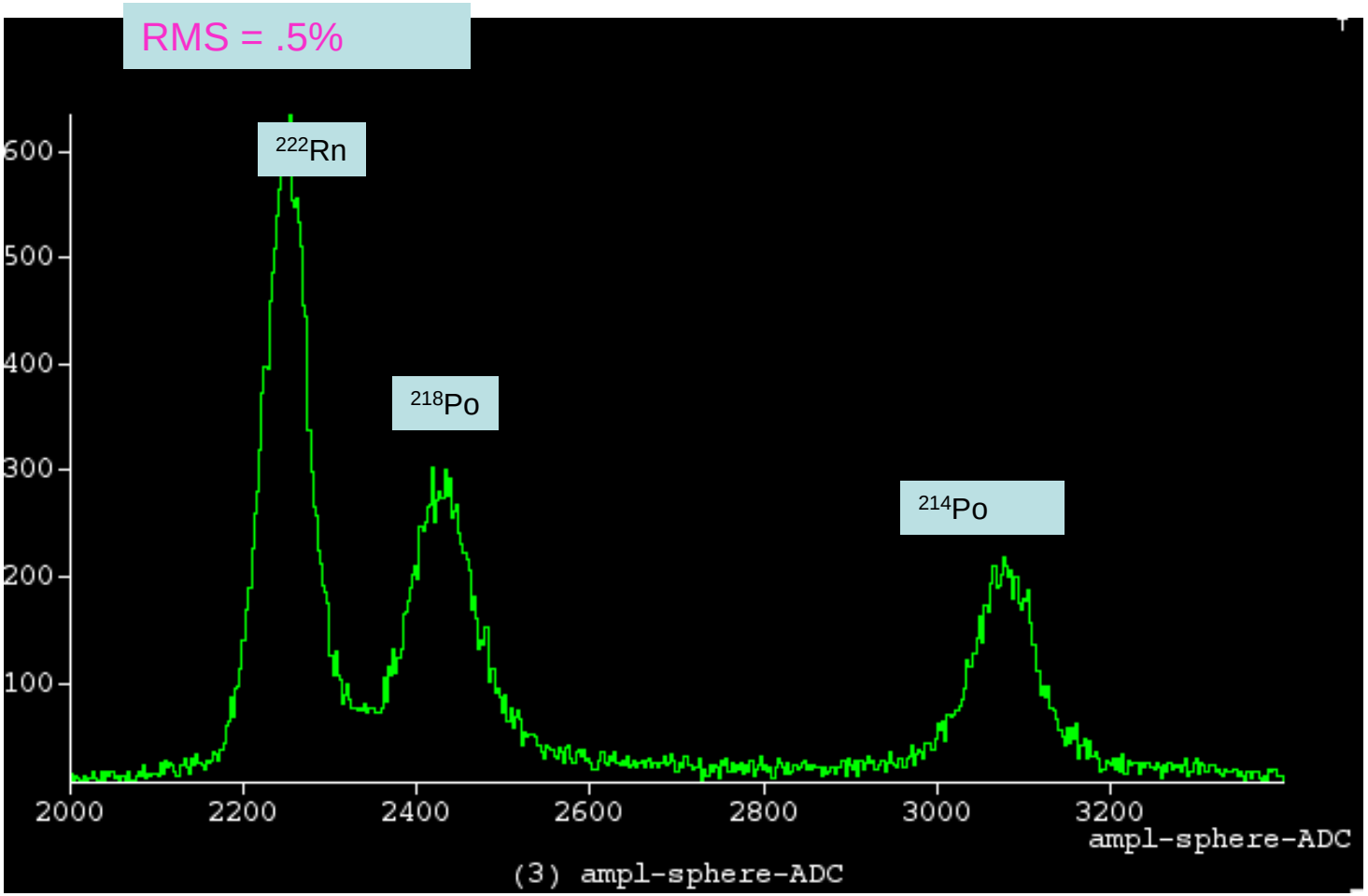


umbrella field corrector



NEW Excellent energy resolution

Measured Radon gas emission spectrum with spherical detector



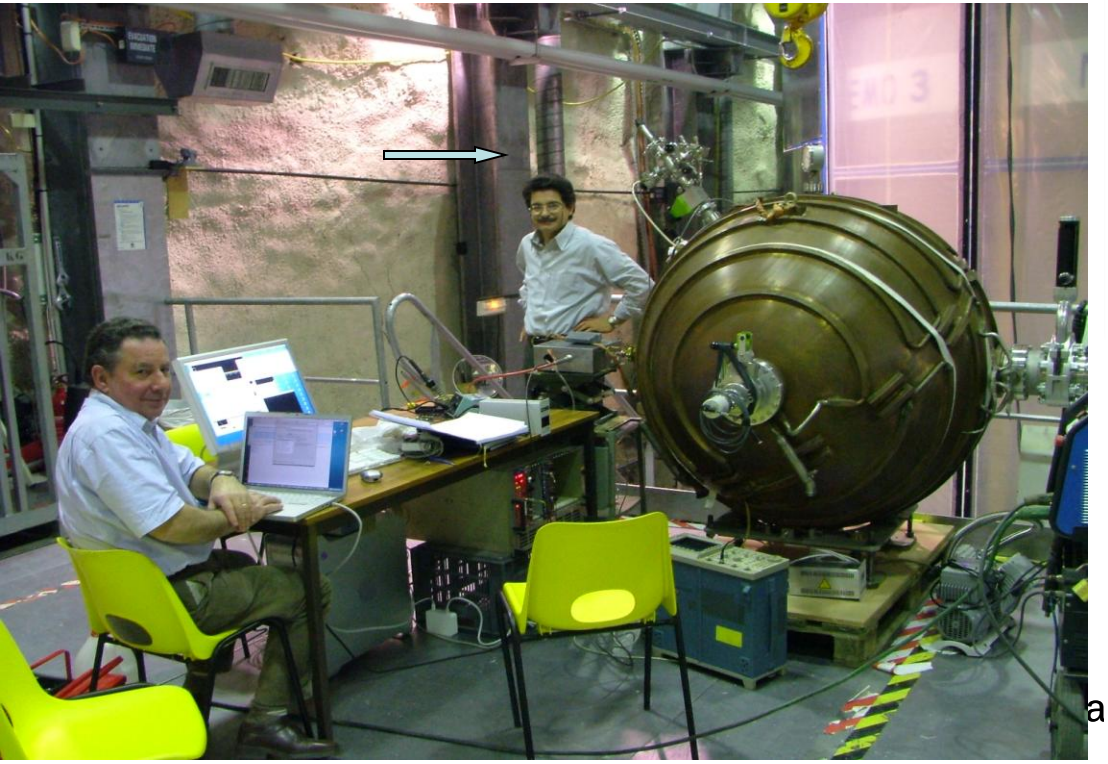
In 2008: Detector installed in LSM laboratory

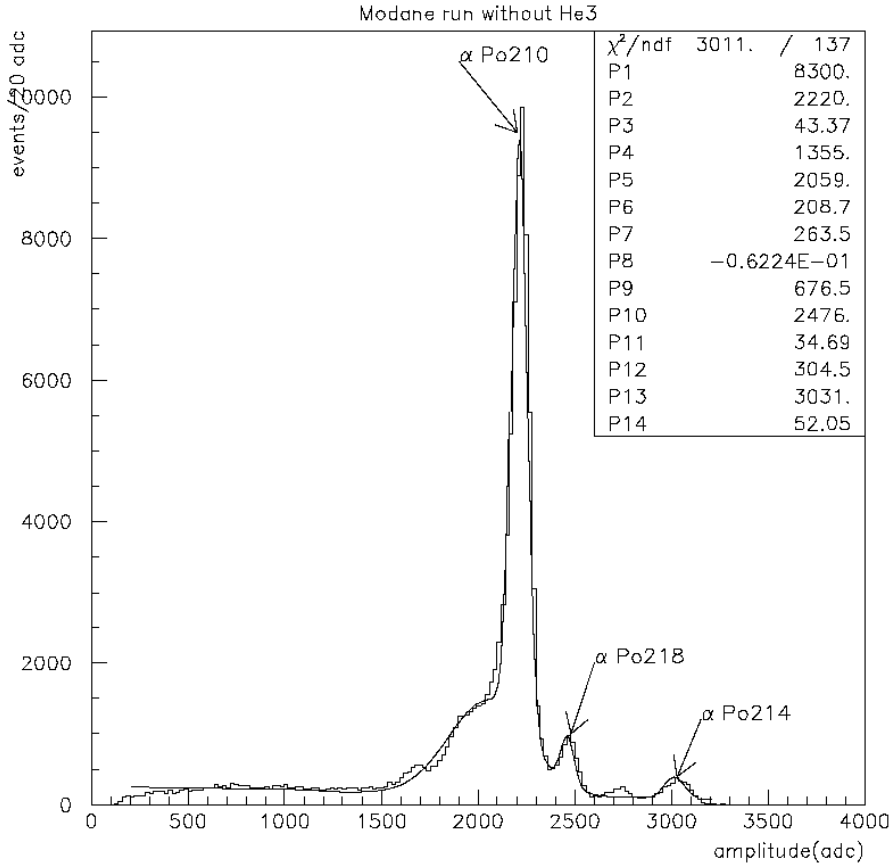
Goal: measure thermal neutron background and estimate fast neutron flux

Neutron energy and flux measurement

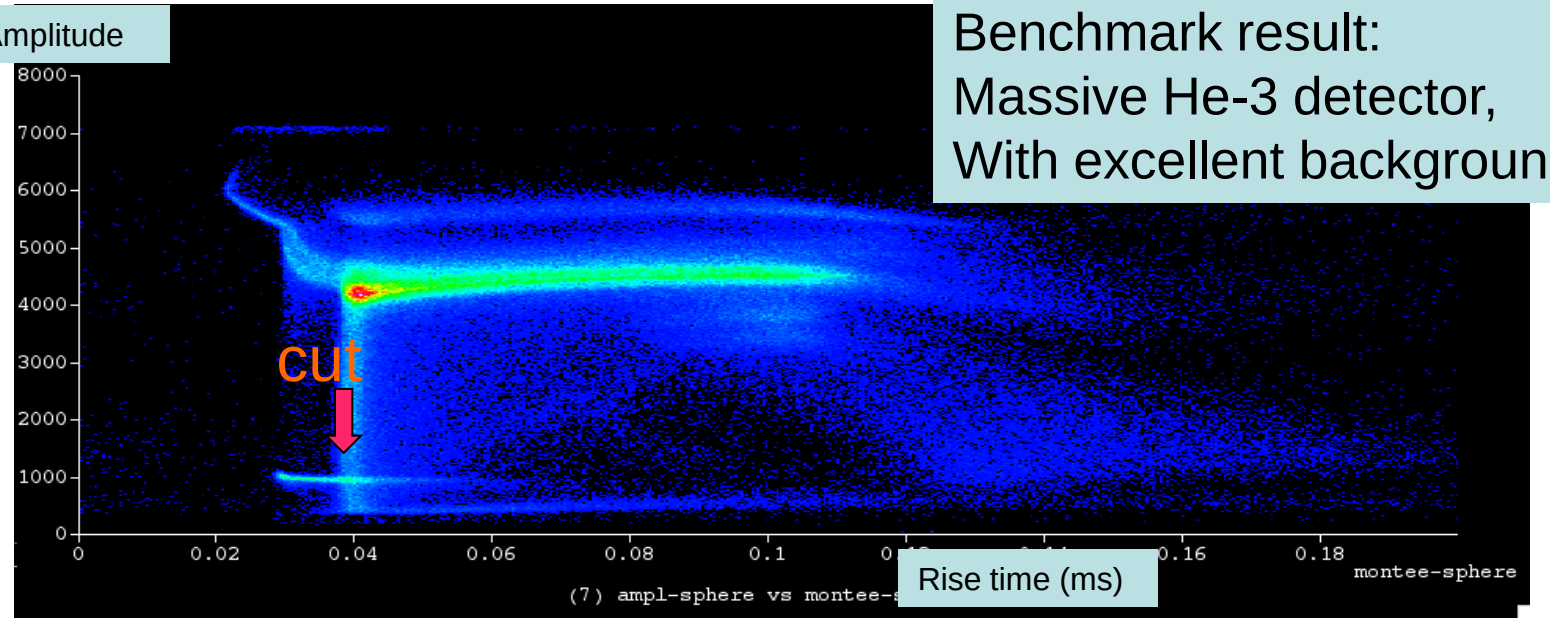
$^{3}He + n \longrightarrow {}^{1}H + {}^{3}H$ (Q= 765 keV)

LSM-Modane before filling with He-3

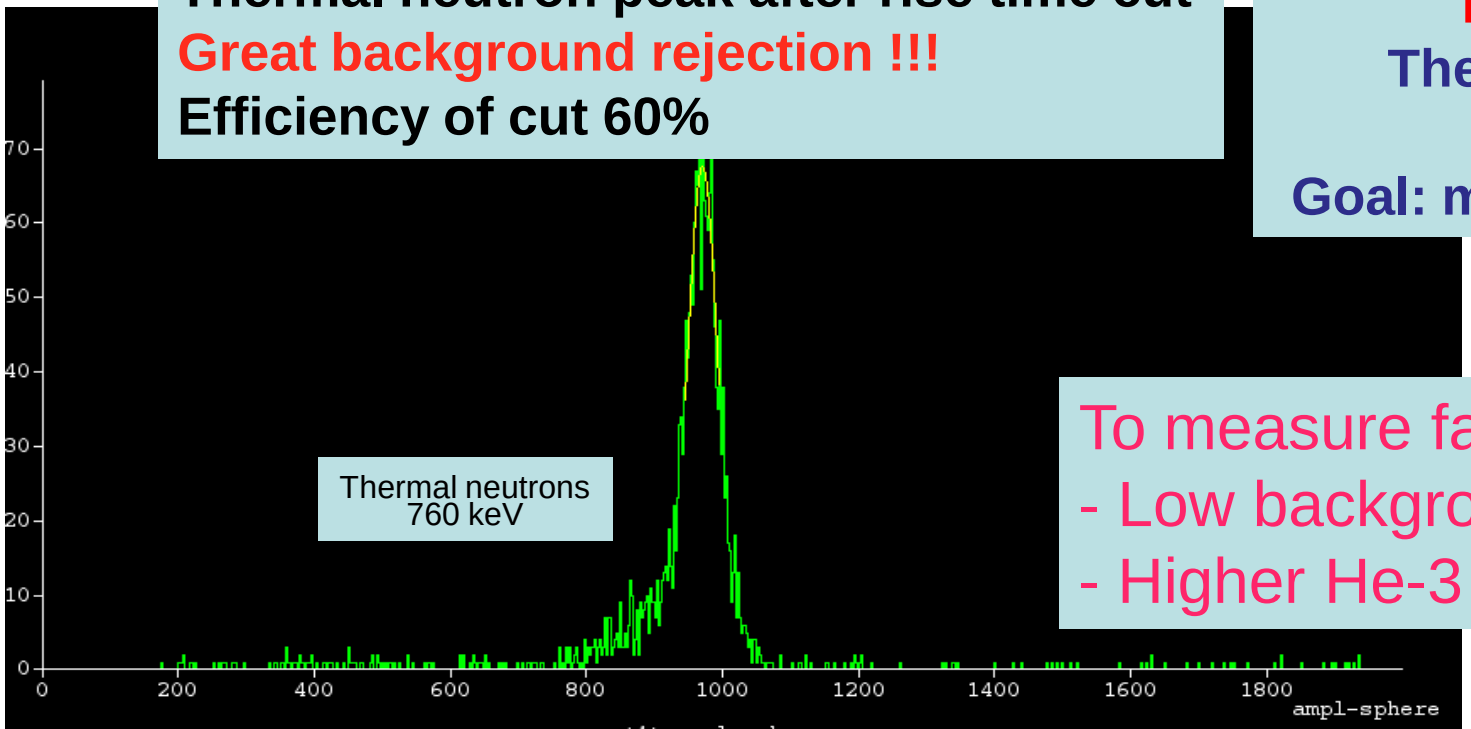




Benchmark result:
Massive He-3 detector,
With excellent background level



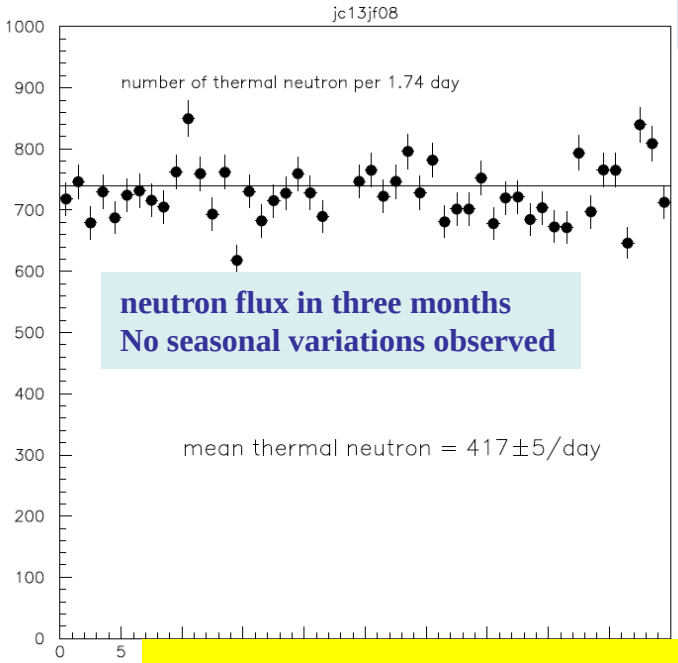
Thermal neutron peak after rise time cut
Great background rejection !!!
Efficiency of cut 60%



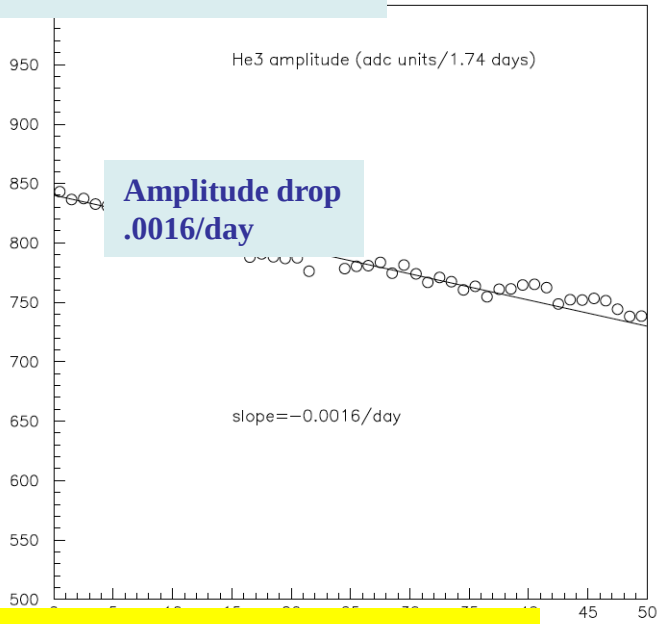
Results in LSM
Thermal neutron flux
$2.2 \times 10^{-6}/cm^2/s$
Goal: measure fast neutrons

To measure fast neutrons we need
- Low background detector
- Higher He-3 mass

Summary of 2009 results at LSM

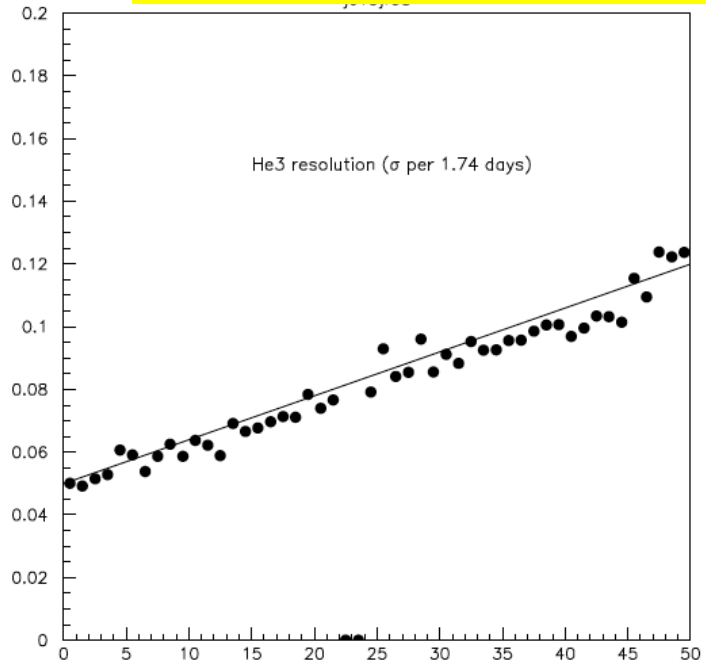


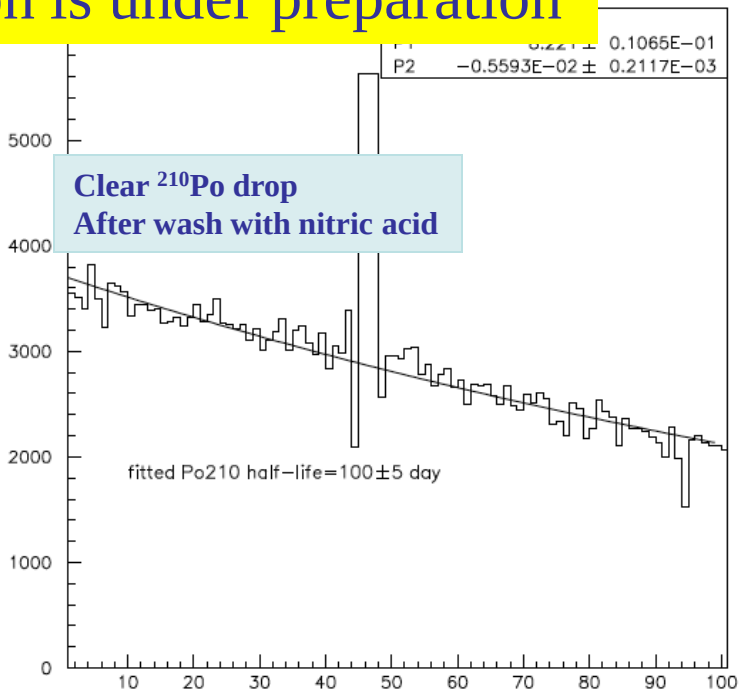
neutron flux in three months
No seasonal variations observed



Amplitude drop
.0016/day

He-3 recovery system and recirculation is under preparation



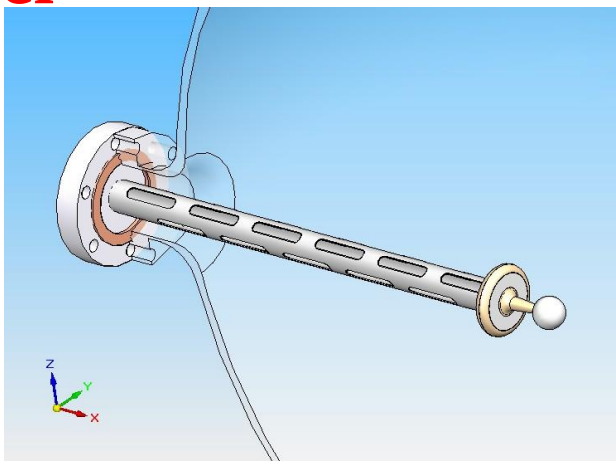


Clear ^{210}Po drop
After wash with nitric acid

Under study

New detector made out of radiopure Cu vessel

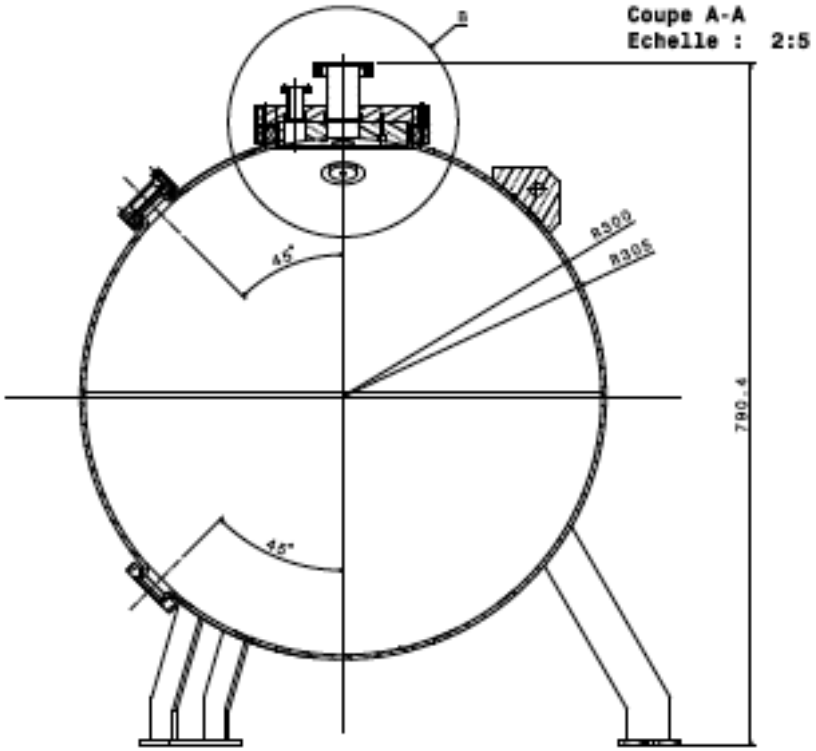
- Diameter = 70 cm
- Pressure = up to 10 bar

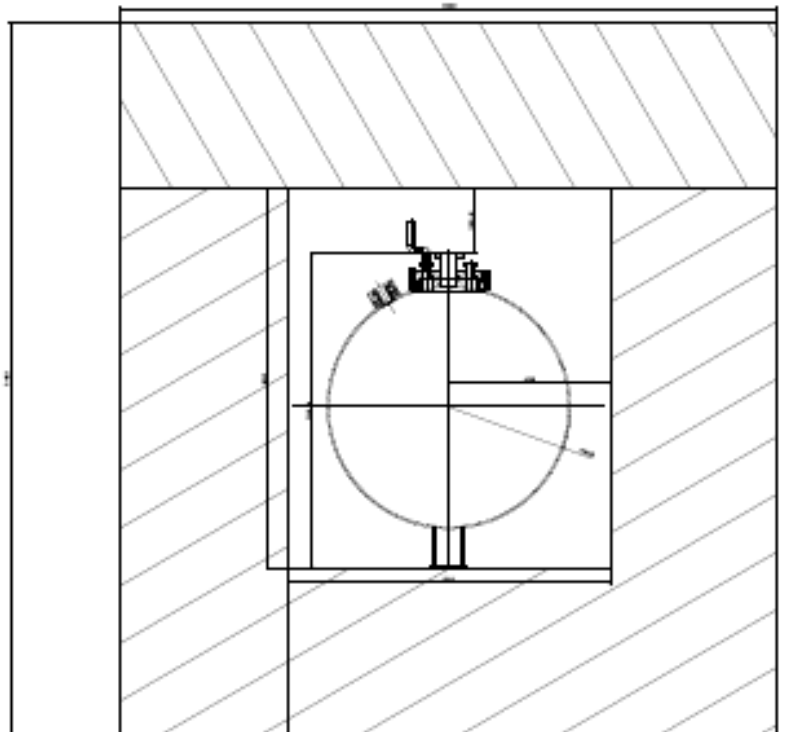


Appropriate shield will be provided by LSM

Goal

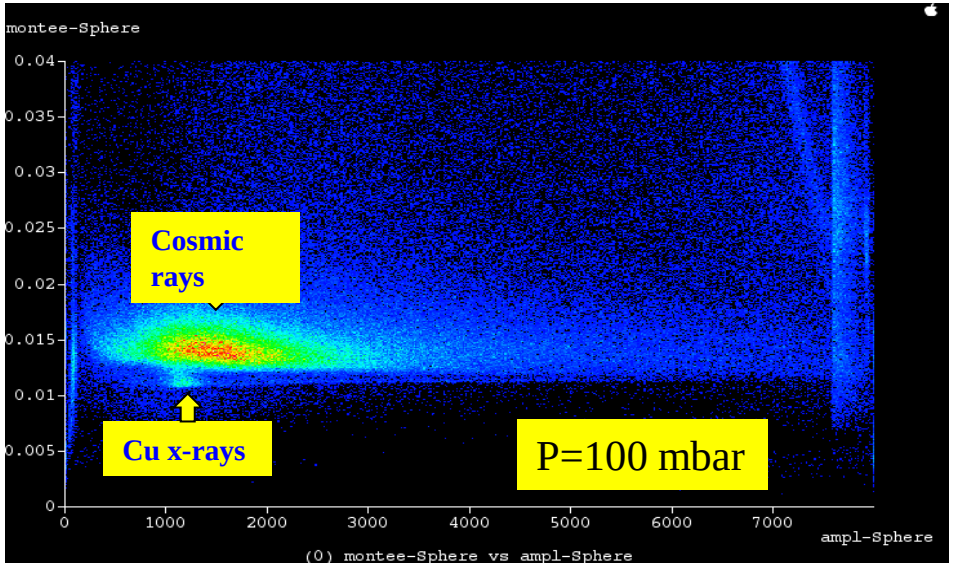
- Measure fast neutron energy distribution at LSM
- Explore ultra low energy with low background detector

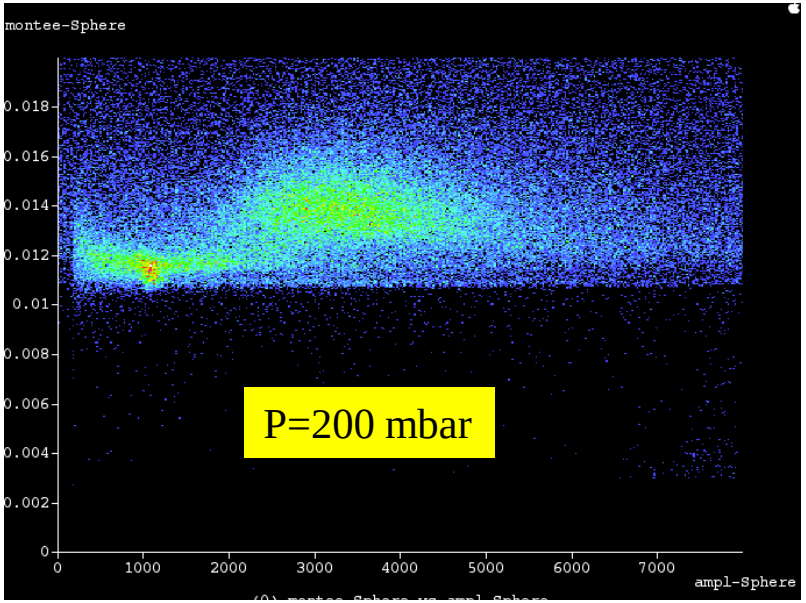


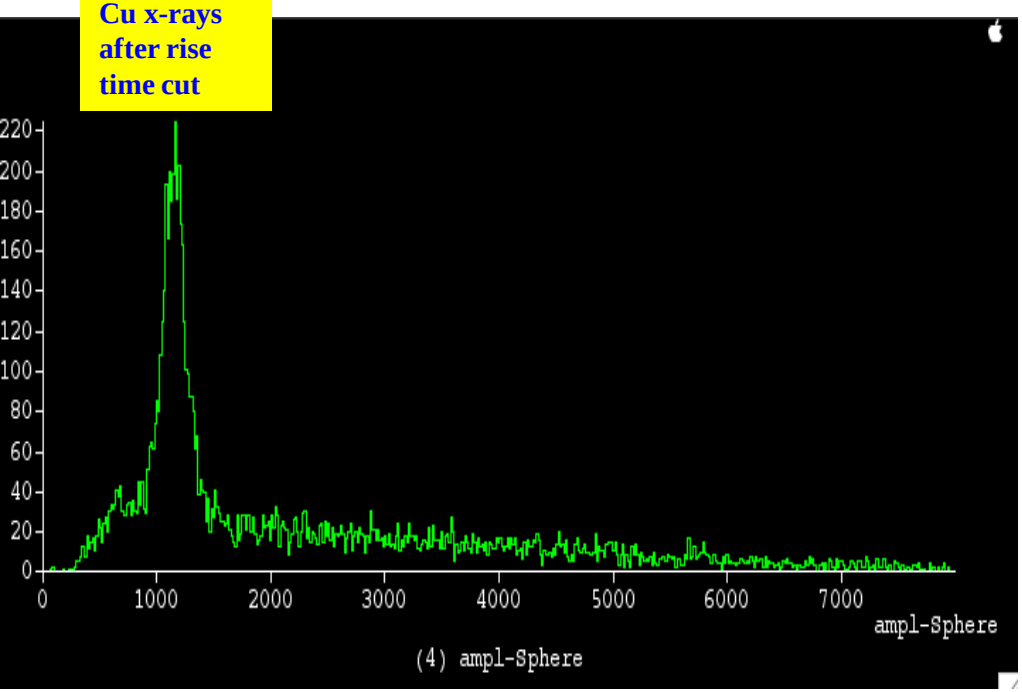


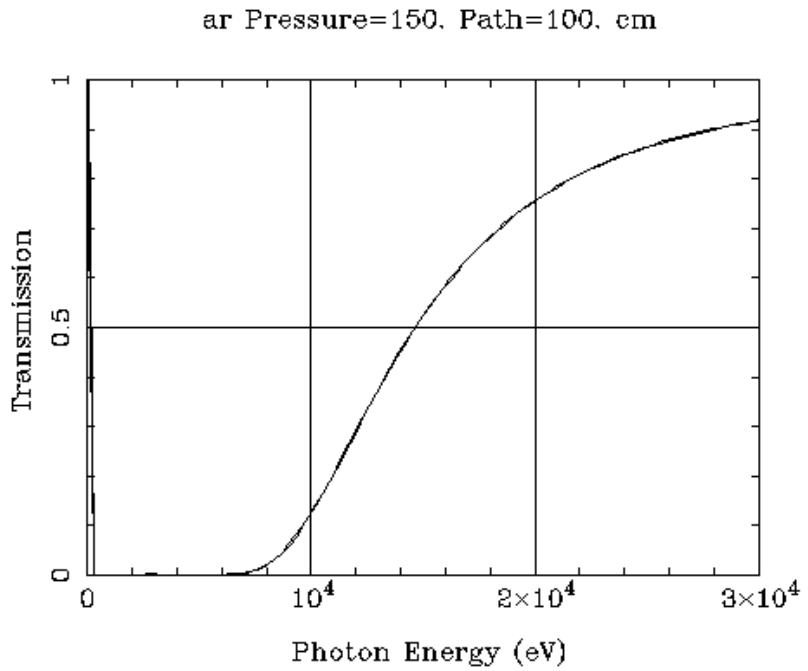
I. Gion

Back to Saclay - Low energy investigations



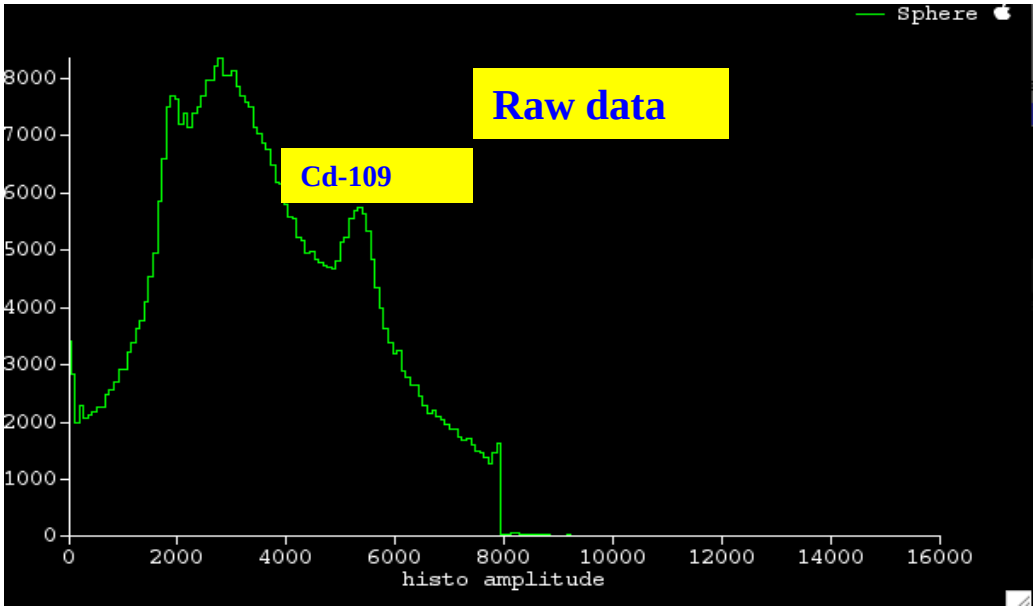


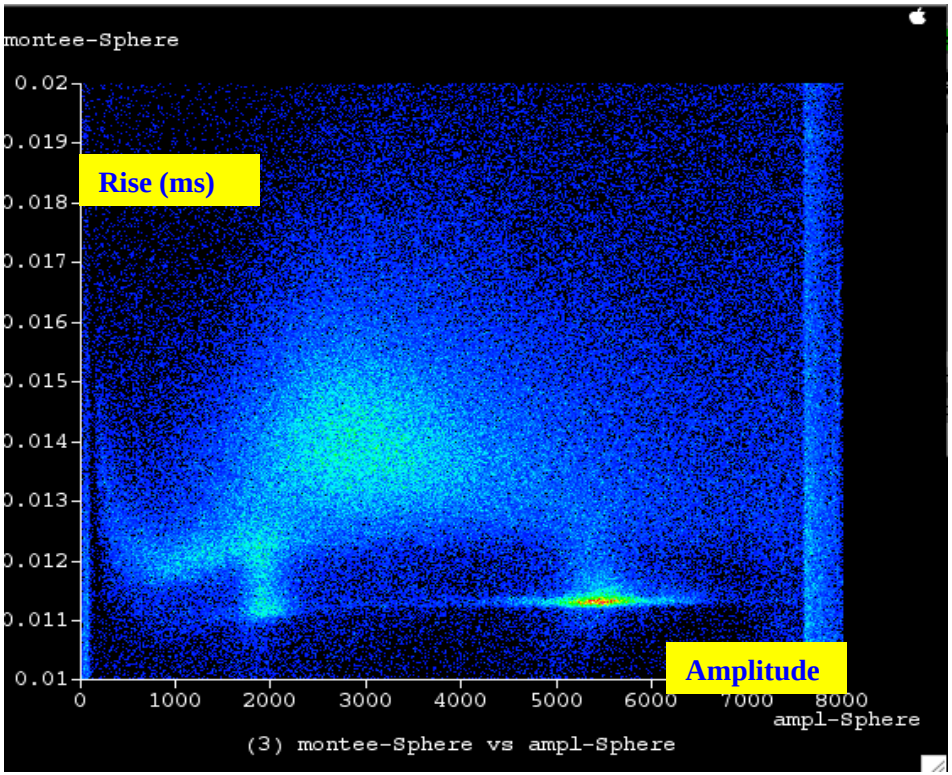


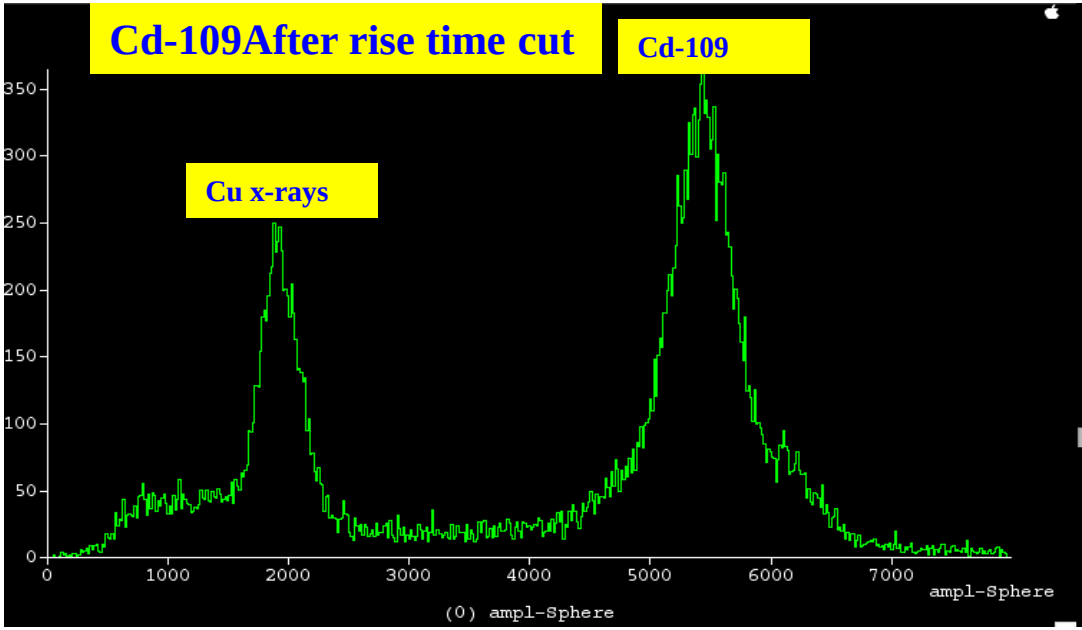


With Cd-209 source
December 2009

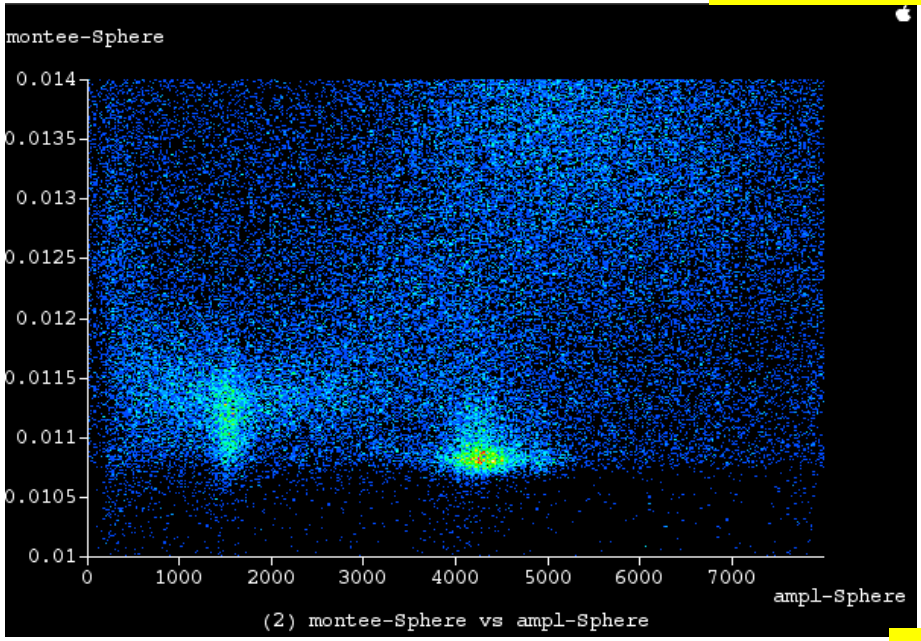
P=100 mbar Ar+2% CH_4

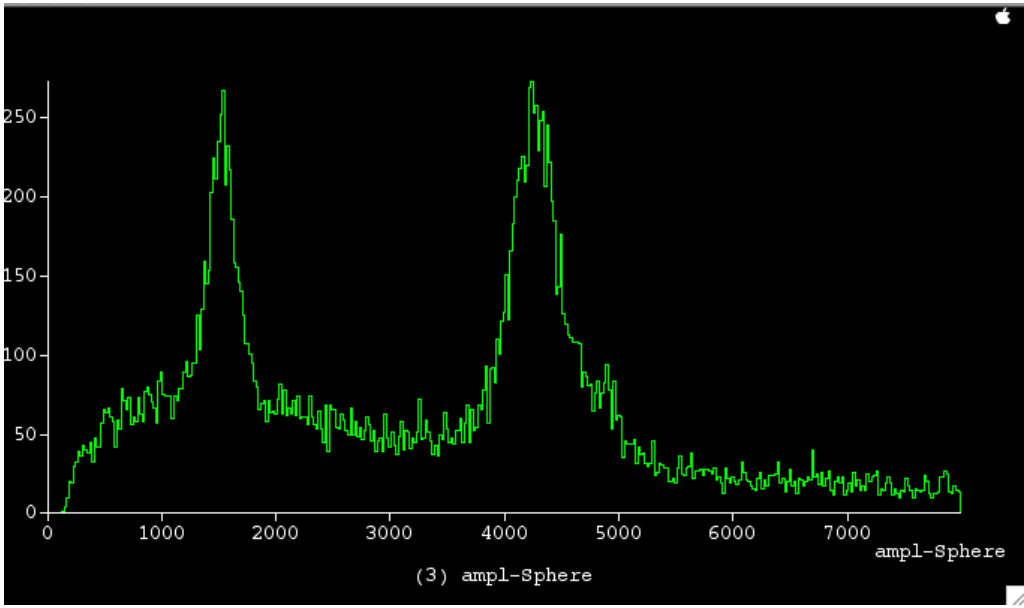




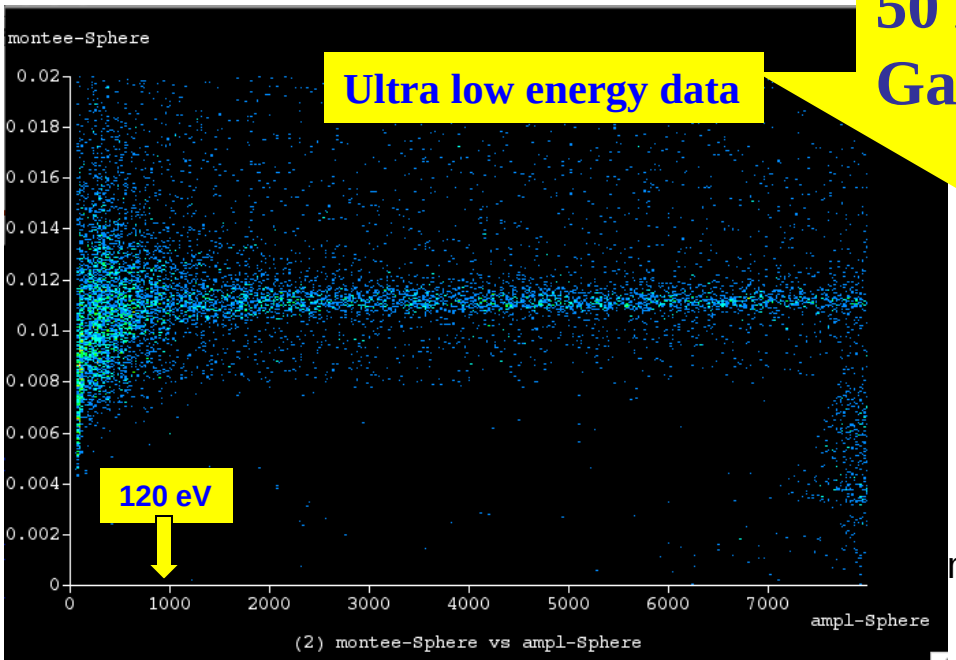


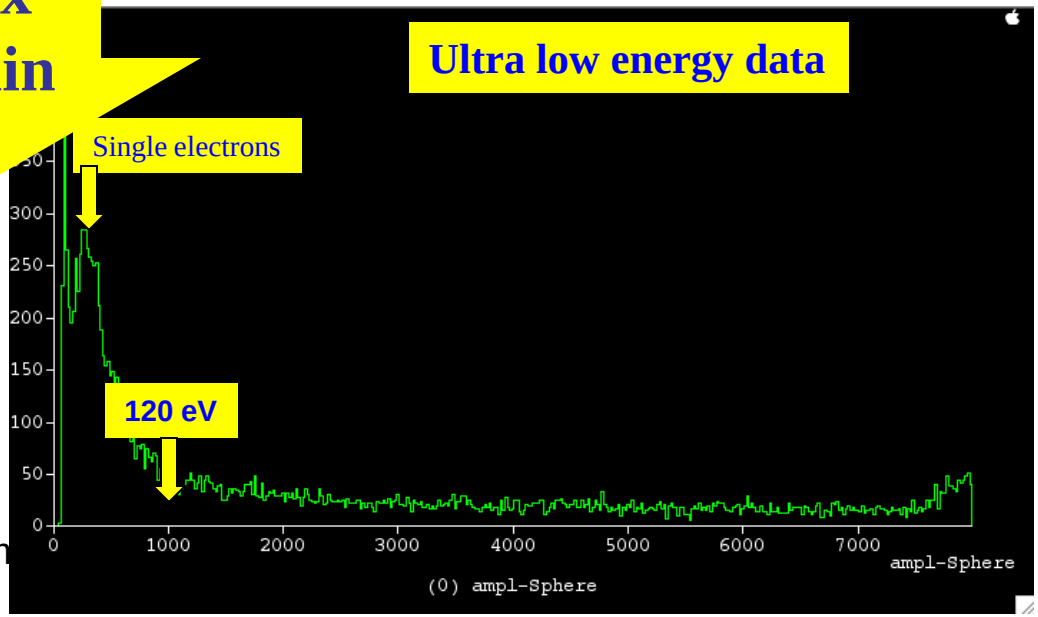
P=200 mbar Ar+2% CH_4





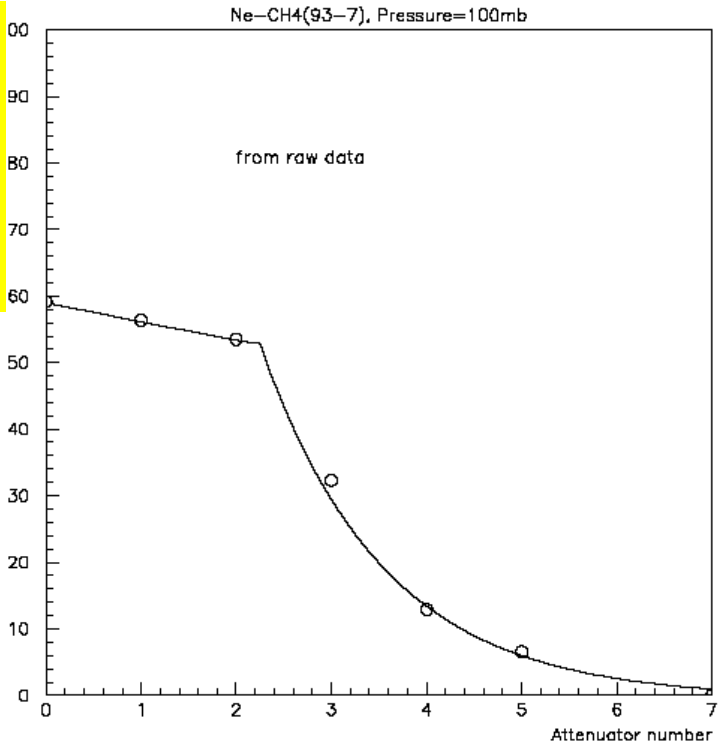
50 x Gain

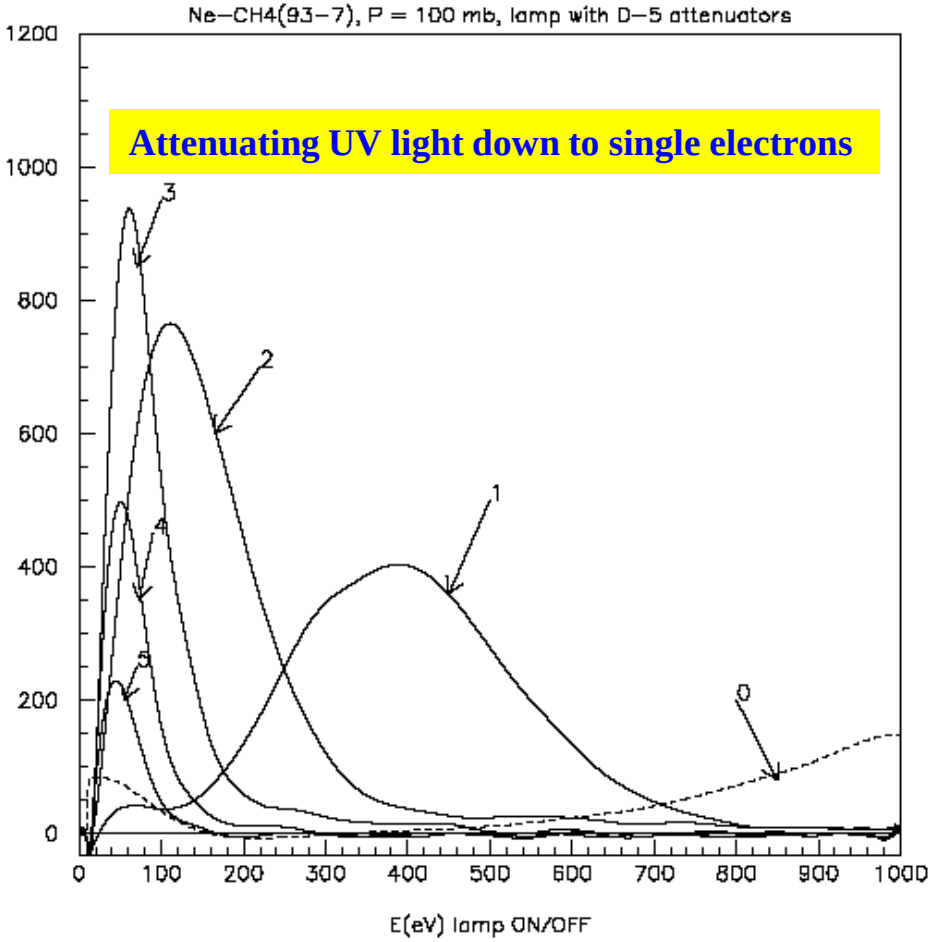


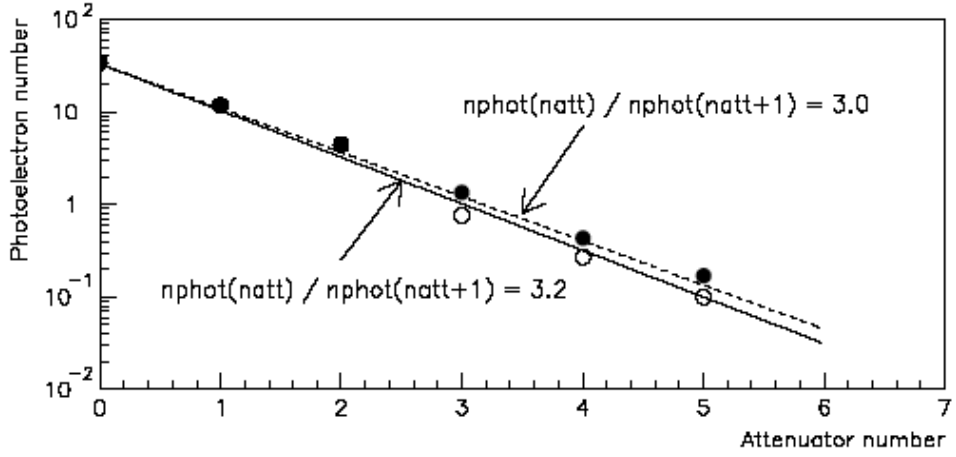


Sub-keV calibration: UV lamp

- We are using a pulsed hydrogen lamp
- MgF_2 entrance window
- Electrons are extracted by the internal spherical vessel
- UV attenuators: 38% transparent mesh







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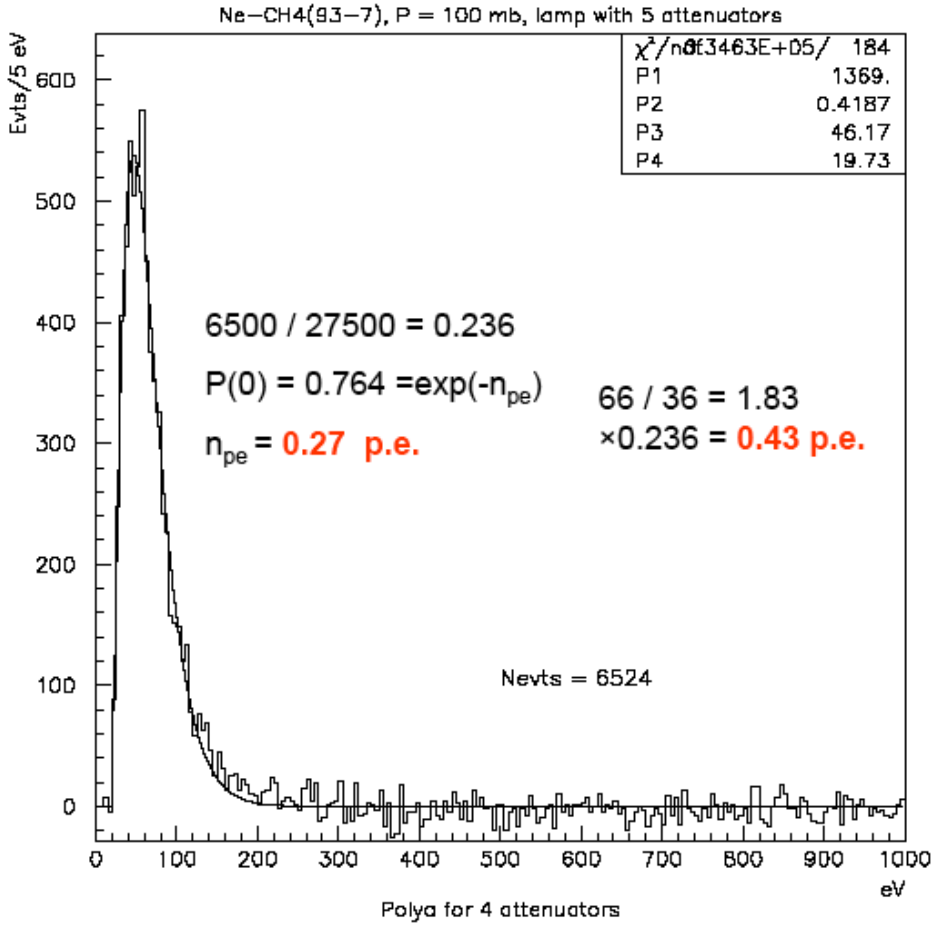
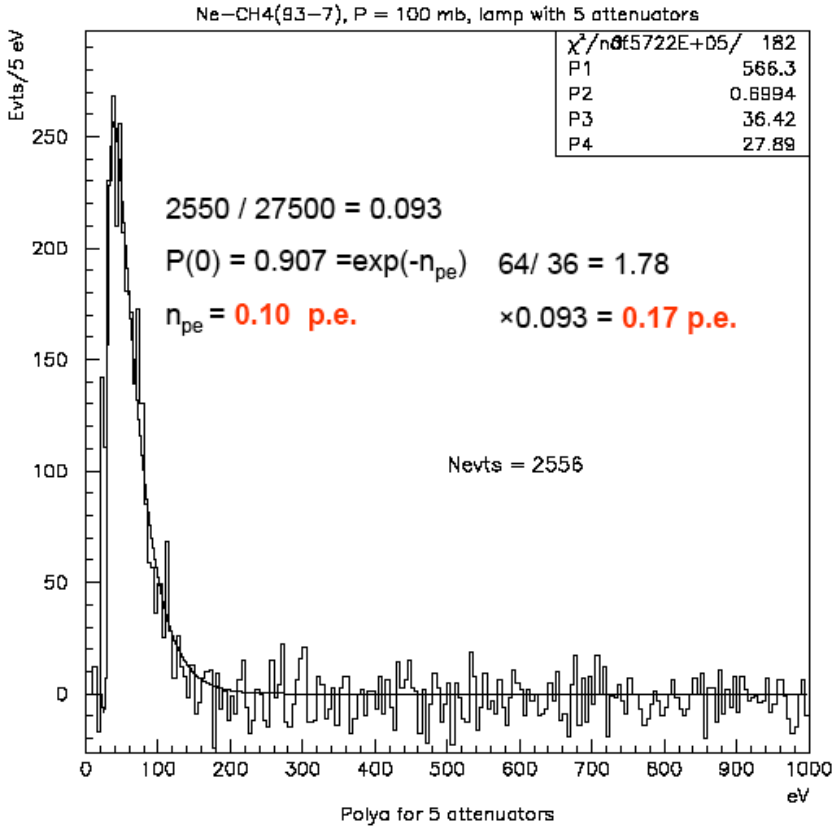


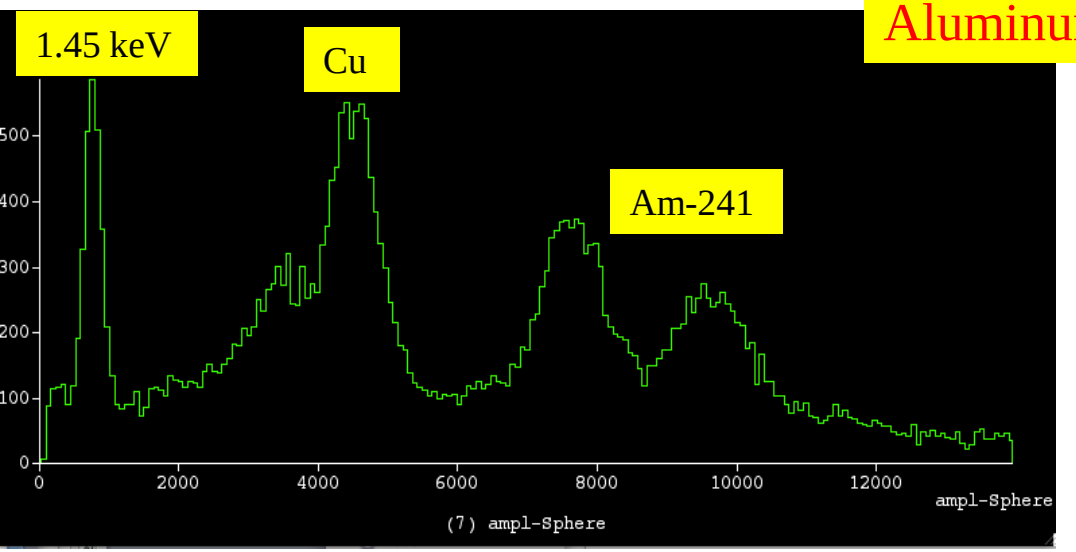


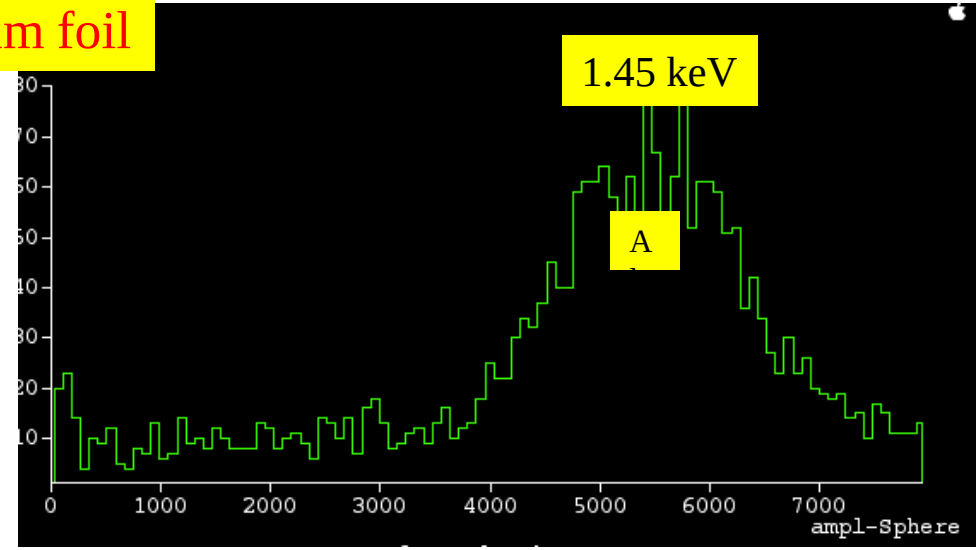
I. Giomataris

Ultra low energy calibration results

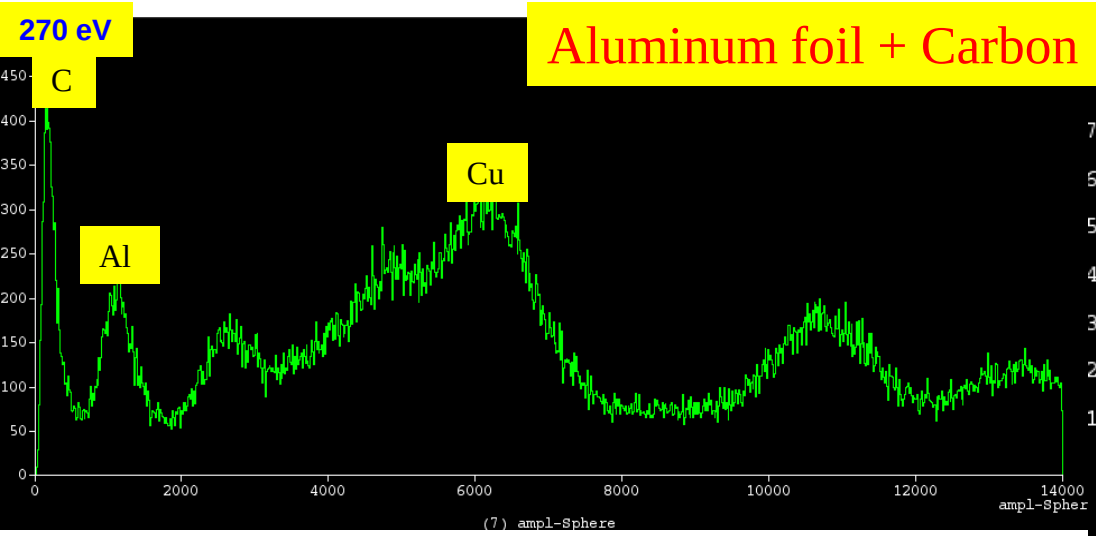
X-rays from Am-241 fluorescence

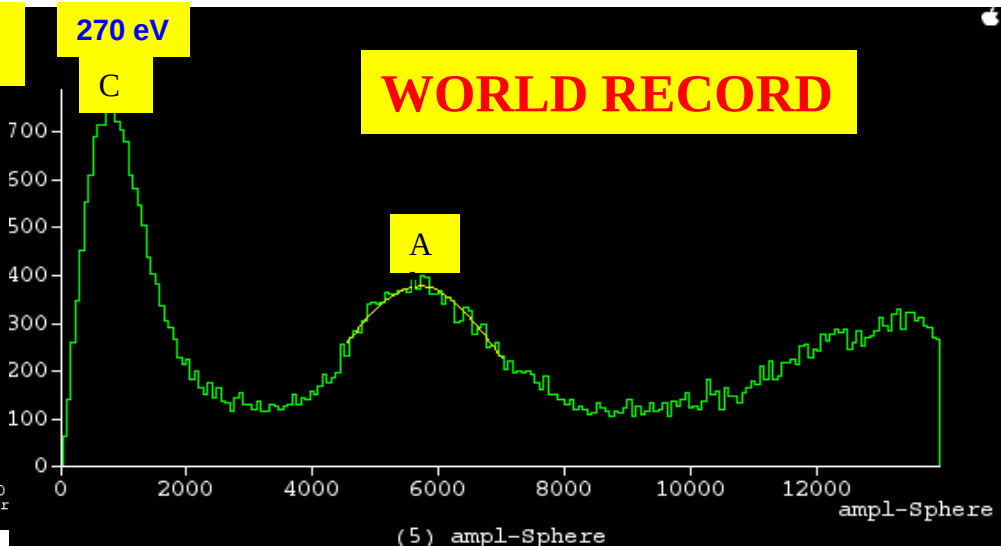
Aluminum foil



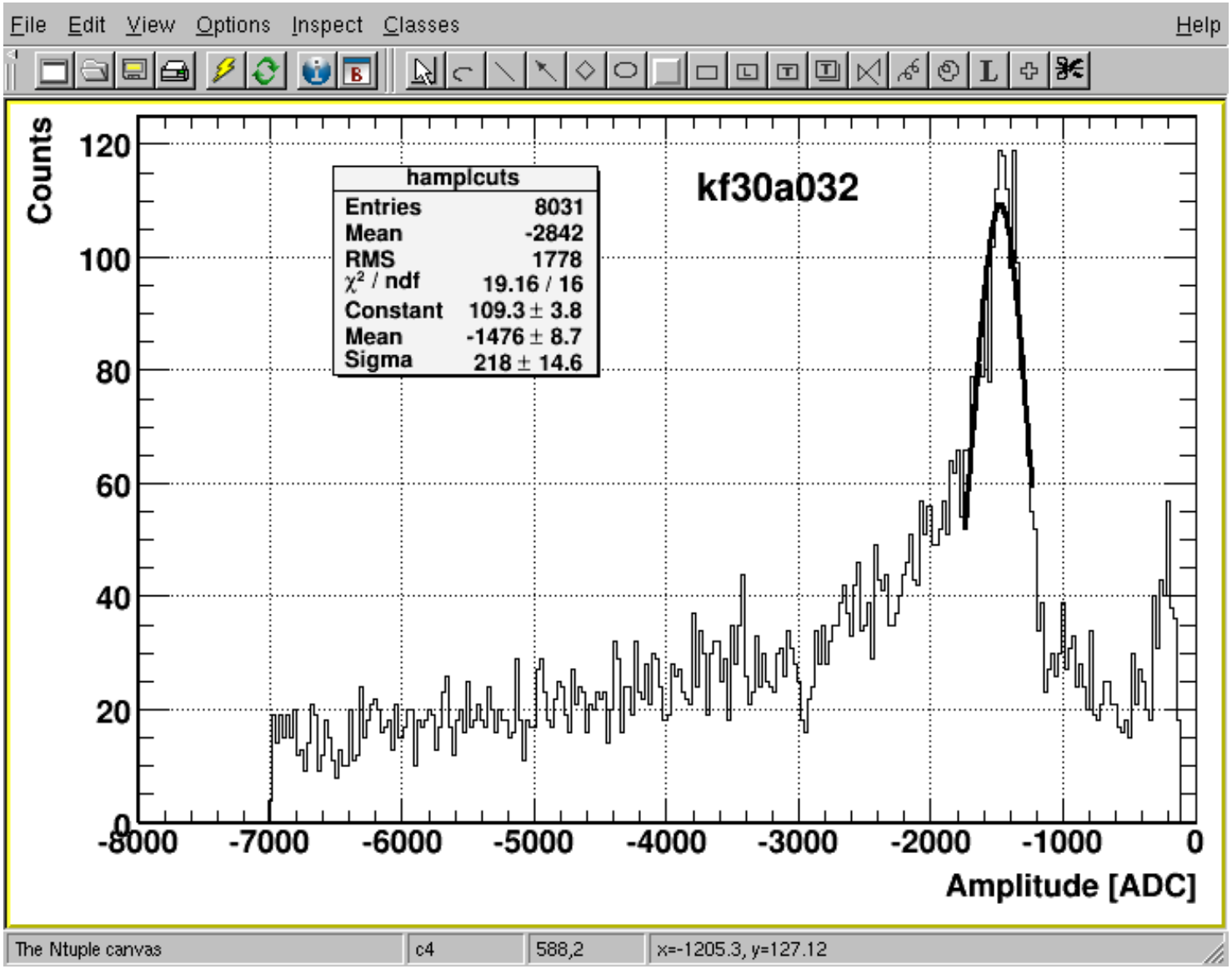


Aluminum foil + Carbon





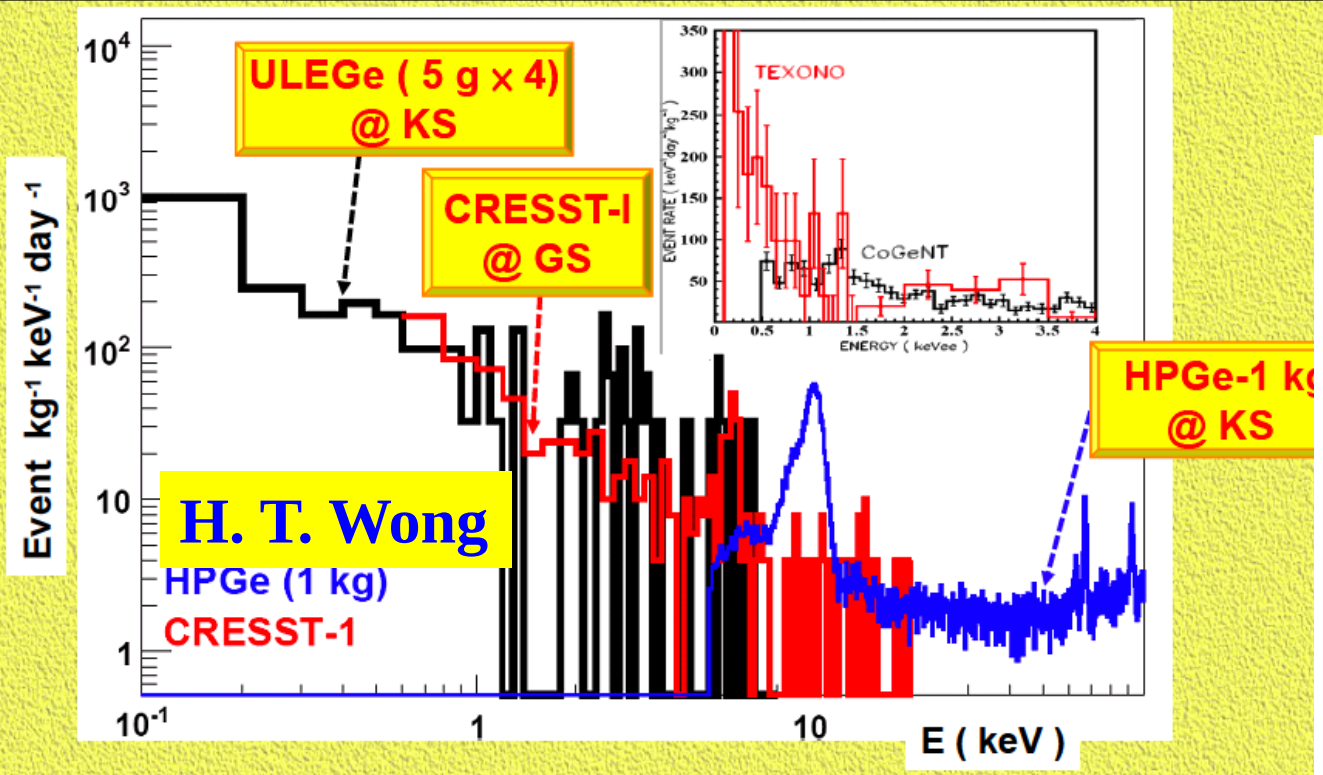
July 2010 LSM first results



I. Giomataris

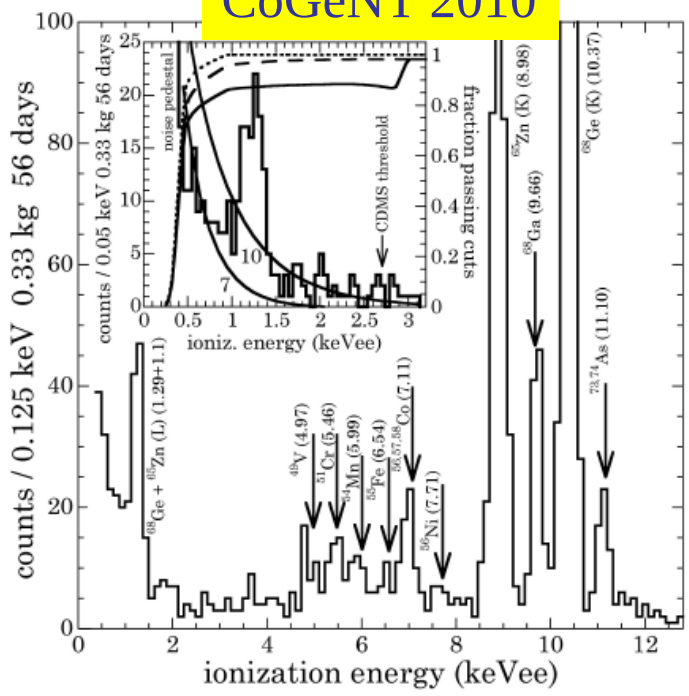
Dark matter search through very low energy threshold < 100 eV

Sub-keV Background Measurements & Comparisons

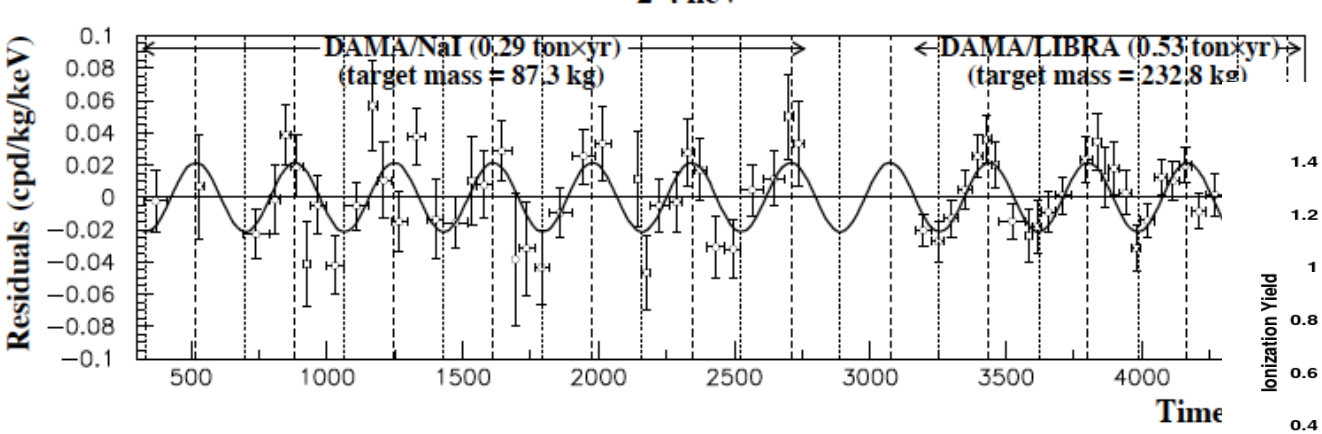


- Bkg ~ O(1) cpd/kg/keV >10 keV, ~ to underground expts.
- ULEGe bkg @ KS ~ CRESST-1 @ GranSasso
- Intensive studies on sub-keV background understanding

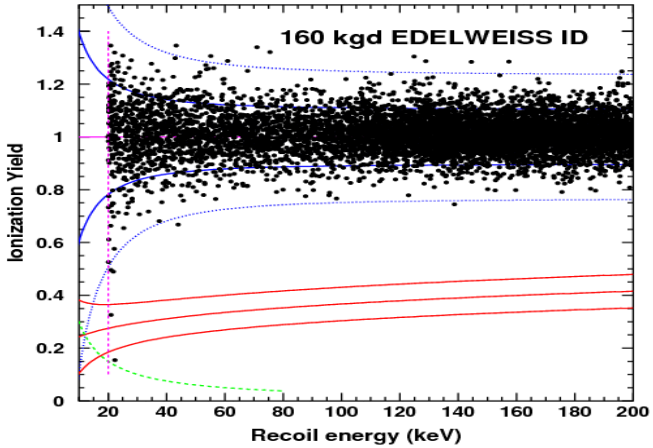
CoGeNT 2010

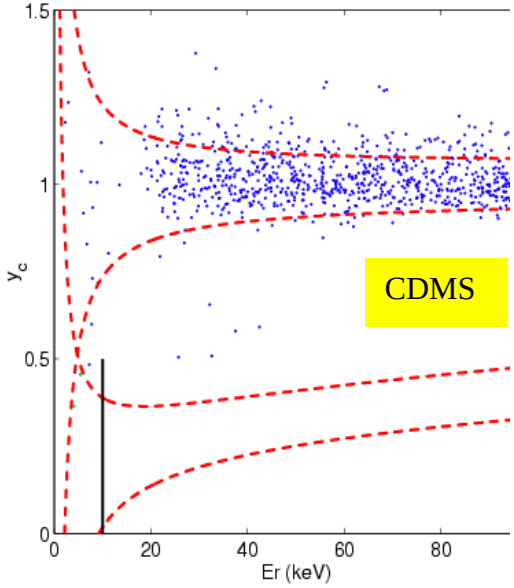


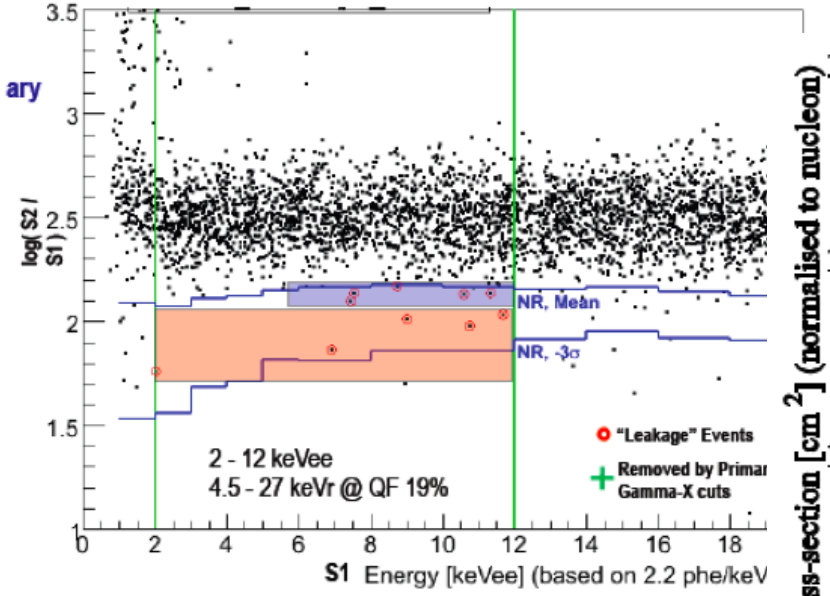
DAMA+LIBRA 11 years, 0.83 ton × year, 8.2σ modulation signal.

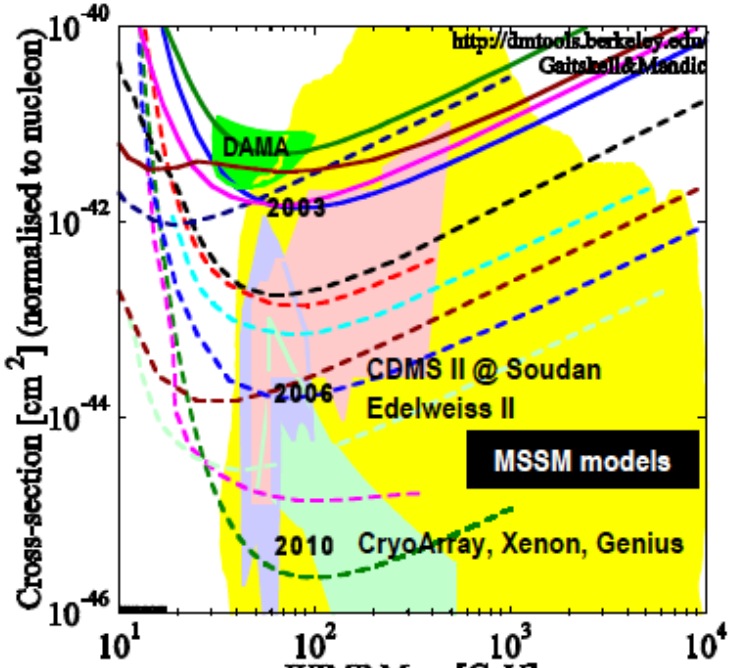


DAMA disfavoured by other direct searches







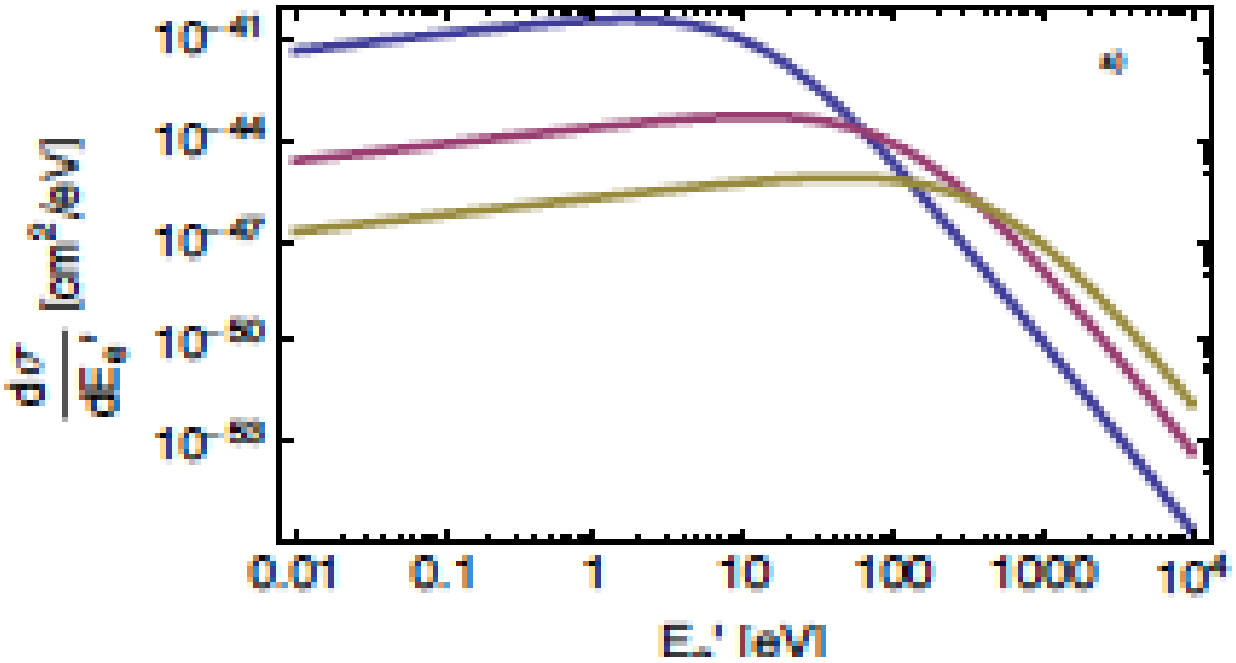


Light Dark Matter particles? < a few GeV

- **Light scalars or fermions (Fayet, Boehm&Fayet):**

  If DM is a fermion and coupled to light particles then it can be lighter than a few GeV.
  If DM is a scalar and coupled to light or heavy particles then it can be lighter than a few GeV.

- **Kaluza-Klein Axion like Particle lighter than a few KeV.**
- **Secluded WIMP dark matter (Pospelov, Ritz, Voloshin '07)**
- **Electron-Interacting dark matter**



A. Dedes, I. Giomataris,, K. Suxho, J.D. Vergados, Nucl.Phys.B826:148-173,2010

Neutrino-nucleus coherent elastic scattering

$\nu + N \rightarrow \nu + N \quad \sigma \approx N^2 E^2$, *D. Z. Freedman, Phys. Rev.D,9(1389)1974*

*A. Druikier, L. Stodolsky, Phys.Rev.D30:2295,1984, JI Collar, Y Giomataris - NIMA471:254-259,2000, H. T. Wong, arXiv:0803.0033-2008, PS Barbeau, JI **Collar**, O Tench - Arxiv preprint nucl-ex/0701012, 2007*

At the Nuclear reactor:

High cross section but very-low nuclear recoil < 200 eV

$$T_N = 2 m_N (E_n \cos\theta)^2 / \{(m_N + E_n)^2 - (E_n \cos\theta)^2\}$$

Illustration: using the present prototype at 10 m from the reactor, after 1 day run

target	anti ν_e (QF, no Thr)	anti ν_e (QF) Thr = 1 electron	anti ν_e (QF) Thr = 2 electron
Xe	2325	**825**	**275**
Ar	430	**292**	**210**

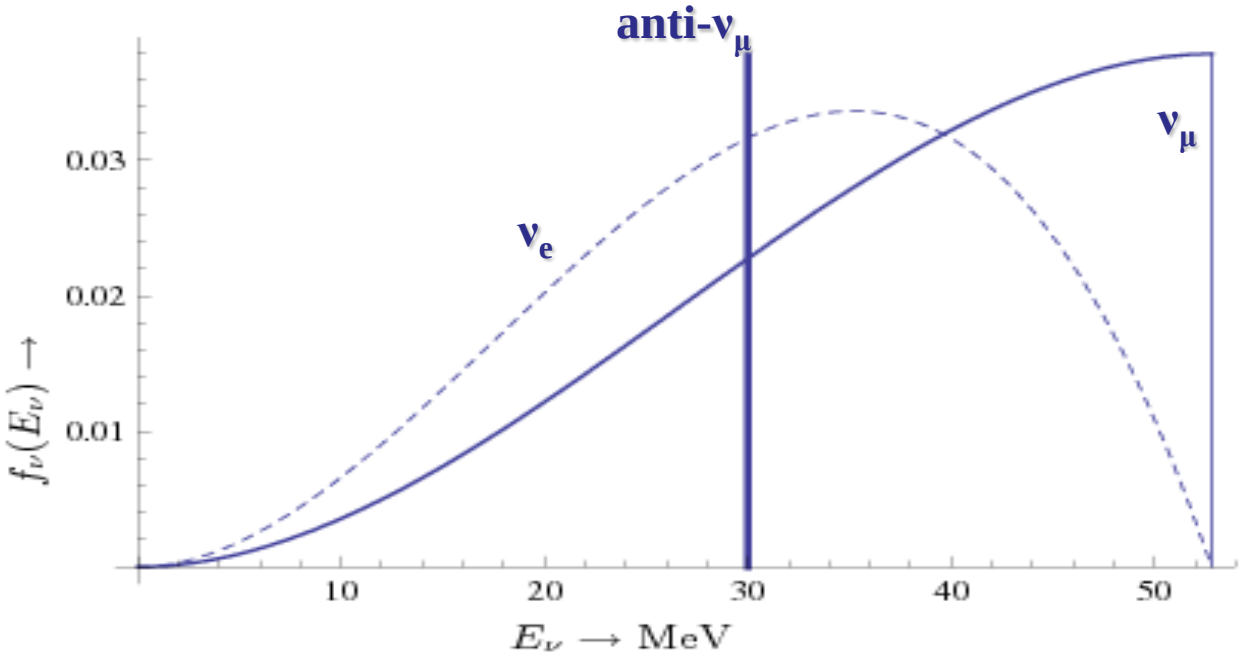
Argon is a good candidate

Challenge : Very low energy threshold
We need to calculate and measure the quenching factor
Application : Remote control of nuclear reactor

Measuring Neutrino-nucleus coherent elastic scattering

At the Oak Ridge **Spallation Neutron Source** (SNS).

J.D. Vergados, F.T. Avignone, I. Giomataris, Phys.Rev.D79:113001,2009, K. Scholberg, AIP Conf.Proc.1182:76-79,2009



SENSITIVITY

Number of events in one year for the spherical TPC detector: P=10 Atm, R=5 m, T=300^{0}K, L=10 m

target	ν_e (no FF)	ν_e (FF)	anti ν_μ (no FF)	anti ν_μ (FF)	ν_μ (no FF)	ν_μ (FF)	all ν (no FF)	all ν (FF)
Xe	5115	3747	6840	4644	4179	3360	16137	**11751**
Ar	417	359	555	459	336	306	1311	**1126**

Supernova detector

Through neutrino-nucleus coherent elastic scattering

Supernova neutrino detection with a 4 m spherical detector

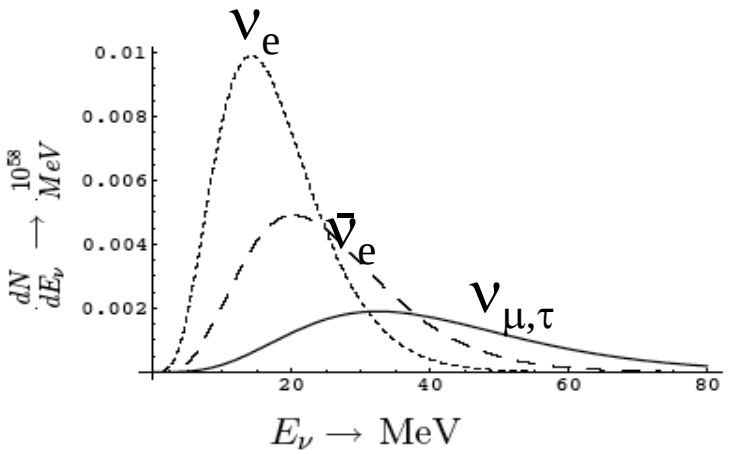
Y. Giomataris, J. D. Vergados, Phys.Lett.B634:23-29,200

The average nuclear recoil energy is:

	He	Ne	Ar	Kr	Xe	
$<E_r>$:	0.576	0.117	0.058	0.029	0.017	MeV

The threshold neutrino energy
(for nuclear recoil energy E_{th}=250 eV) is

	He	Ne	Ar	Kr	Xe	
$(E_\nu)_{th}$	0.70	1.58	2.24	3.16	4.05	MeV



Sensitivity for galactic explosion

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

 # Number of events (no quenching, zero threshold)

He	Ne	Ar	Kr	Xe	Xe (with Nuc. F.F)
.16	3.95	19.1	76.8	235	179

 # 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 (tenths or hundreds) of such dedicated Supernova detectors robust, low cost, simple (one channel)

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

A dedicated SuperNova neutrino detector system

2nd LSM-EXTENSION WORKSHOP - OCTOBER 16th, 2009 - Modane, France

S. Aune[1], E. Bougamont[1], M. Chapellier[1], A. Dedes[5], P. Colas[1], J. Derre[1], G; Fanourakis[7], E. Ferrer[1], W. Fulgione[10], Th. Geralis[7], G. Gerbier[1], M. Gros[1], I. Irastorza[9], P. Kanti[5], Y. Lemiere[1], X.F. Navick[1], Th. Papaevangelou[1], P. Salin[4], I. Savvidis[3], N. Spooner[6], S. Tzamarias[8], J. D. Vergados[5]

The proposed Supernova demonstrator

- 2 m in radius
- Vessel (seal) : radio pure Cu or stainless steel
- P= 10-50 bar
- Gas Xe (10 bar) or Ar (50 bar)

Milestones of R@D phase

•Define the conditions for long term operation

Gas purification, gain stability, maintenance

- Design and build a low cost demonstrator

GOAL : Life Time of such system about 1 century

- Set up a European or worldwide collaboration

Summary

- **A new spherical proportional counter is born and developed**
- **Good energy resolution, robust and stable**
- **A first prototype is running in LSM**
- **Ultra low energy calibration down to 280 eV**
- **Single electrons are seen**
- **Impact on dark matter**
- **Neutrino-nucleus coherent scattering under reach**
- **A low cost Supernova demonstrator is proposed**
- **A world wide network of several detectors is advertized**

Workshop on neutrino SuperNova detectors December 16-17
Paris TPC conference December 14-17 *http://www-tpc-paris.cea.fr/*