

New physics with a novel ultra-low energy detector

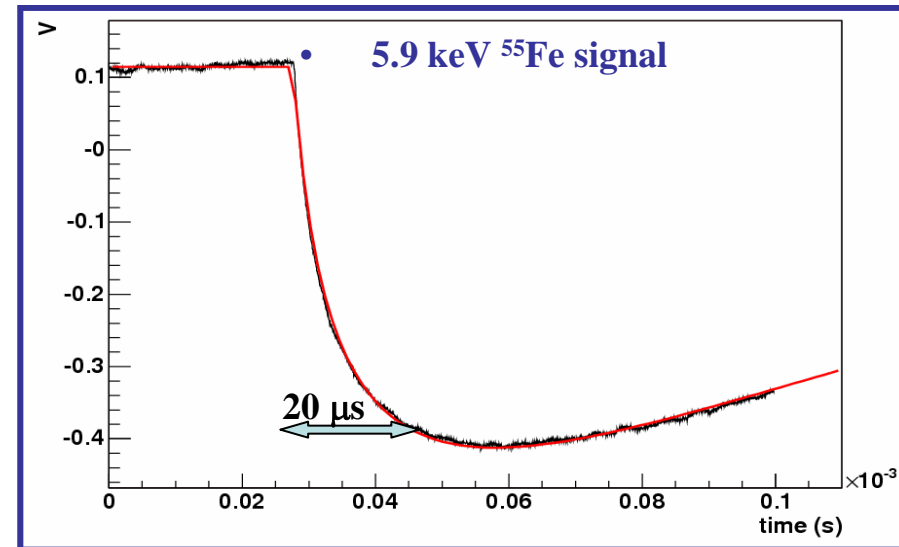
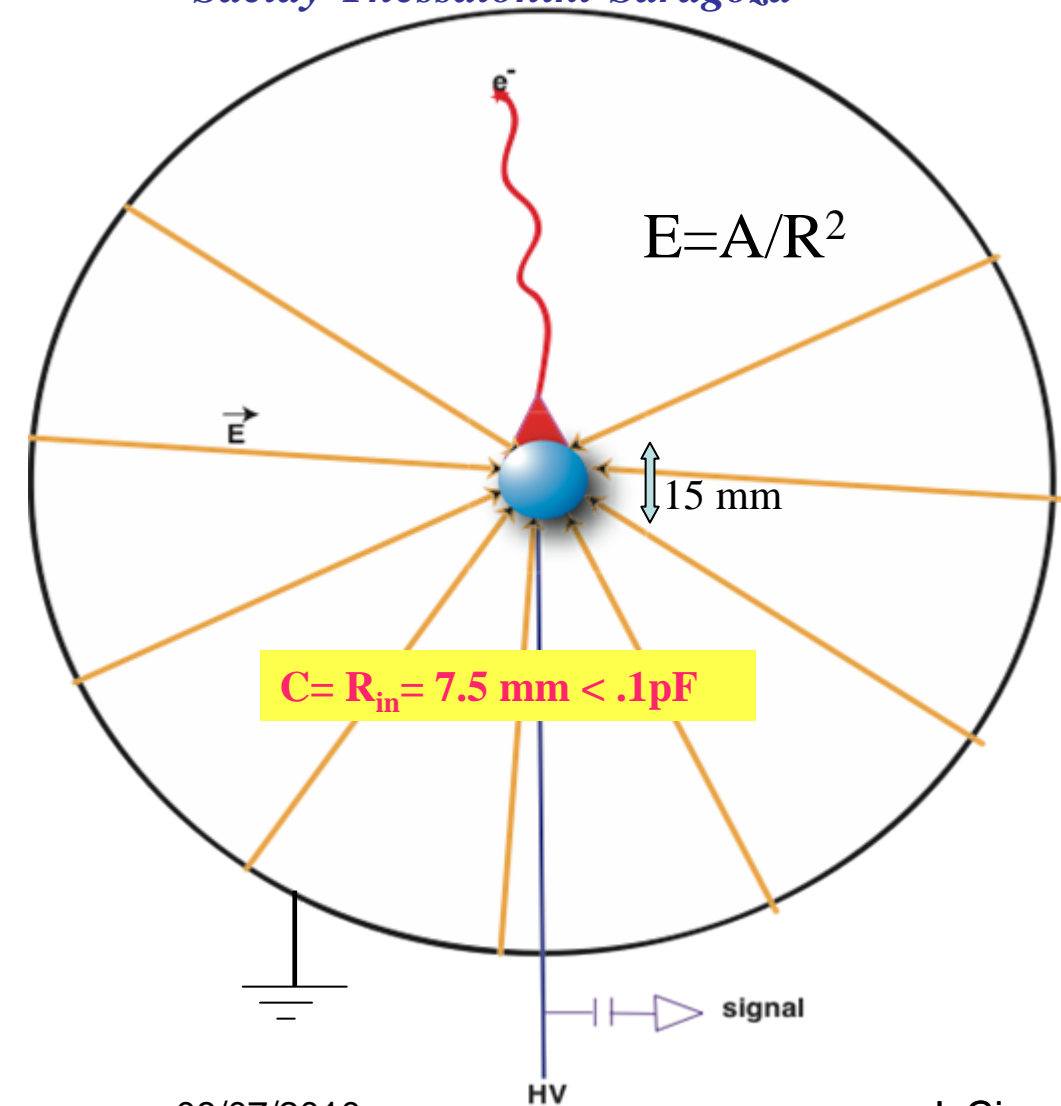
I. Giomataris, CEA-Saclay



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



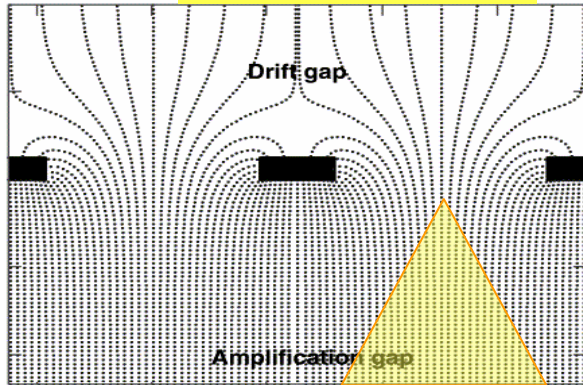
- Simple and cheap
- single read-out
- Robustness
- Good energy resolution
- Low energy threshold
- Efficient fiducial cut

08/07/2010

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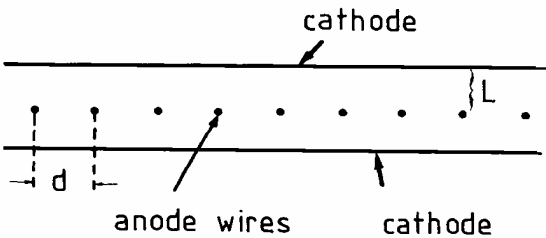
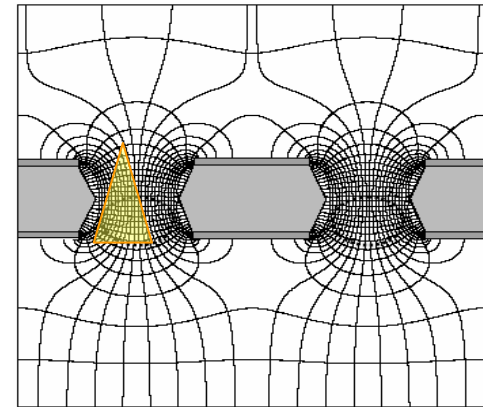
Parallel Plate Detector

Micromegas



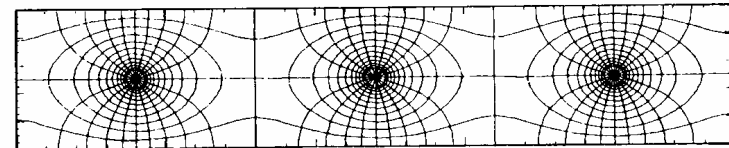
$E = \text{constant}$
 $C \approx S > 1 \text{ nF}$

GEM

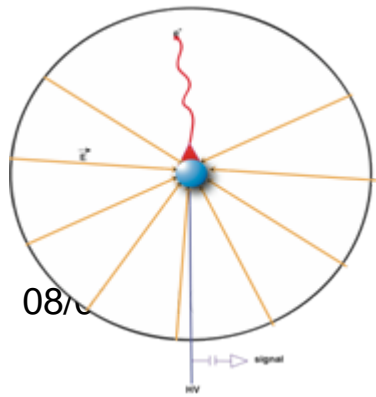


MPWC

$E = 1/r$
 $C \approx L > 10 \text{ pF}$

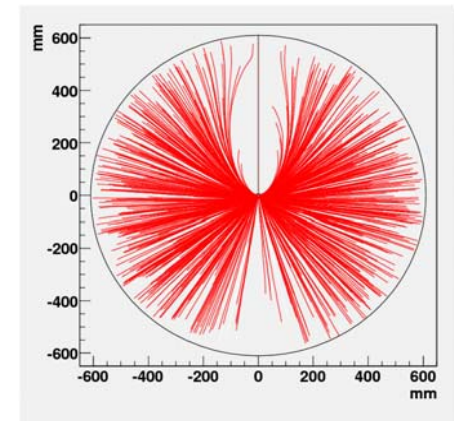


Spherical Proportional Counter

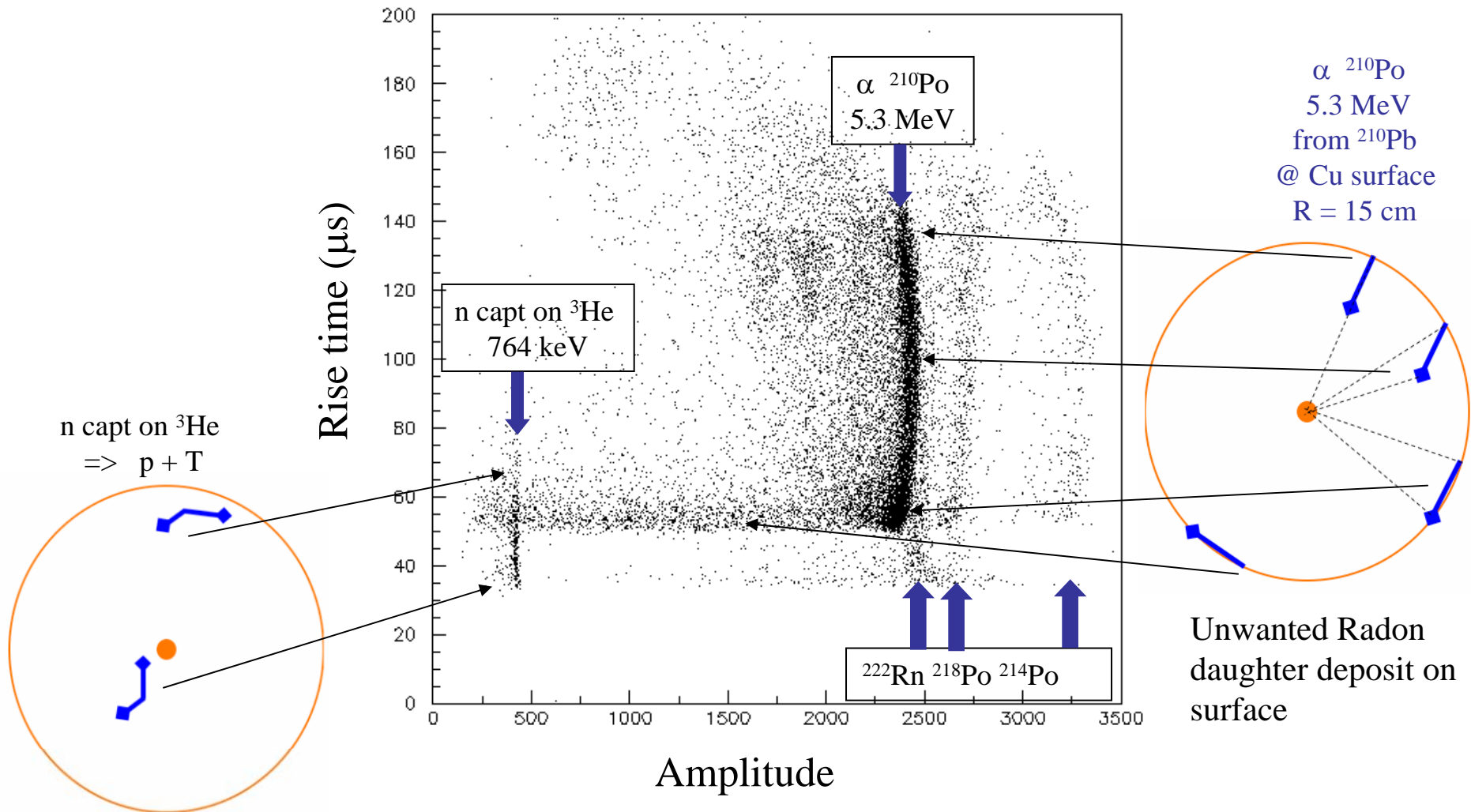


$E = 1/r^2$
 $C \approx R_{in} < .1 \text{ pF}$

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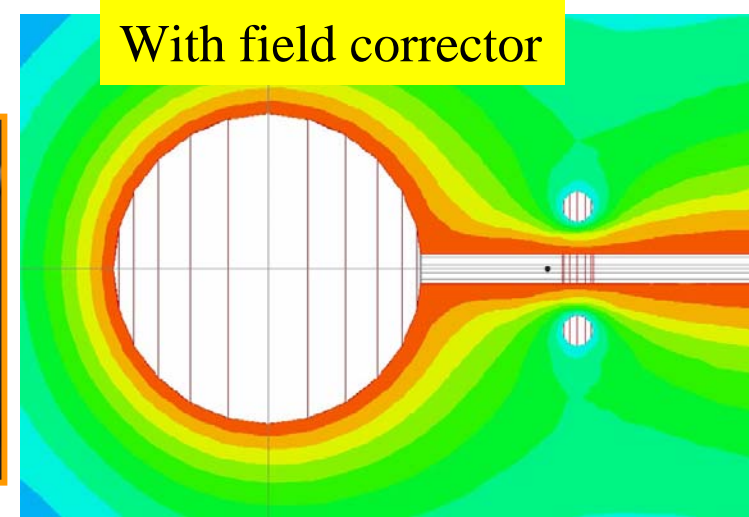
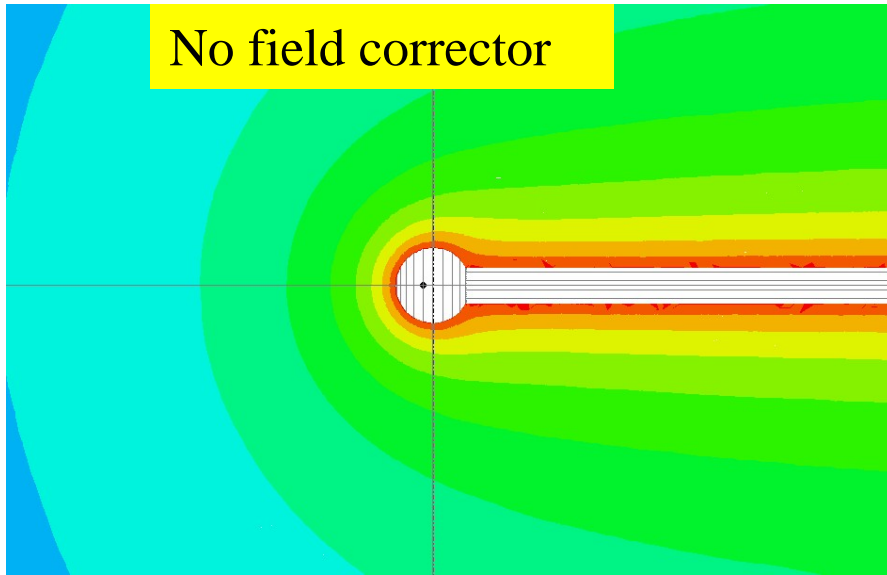
Run at LSM - Ar/CH₄ + 3g ³He 200 mb



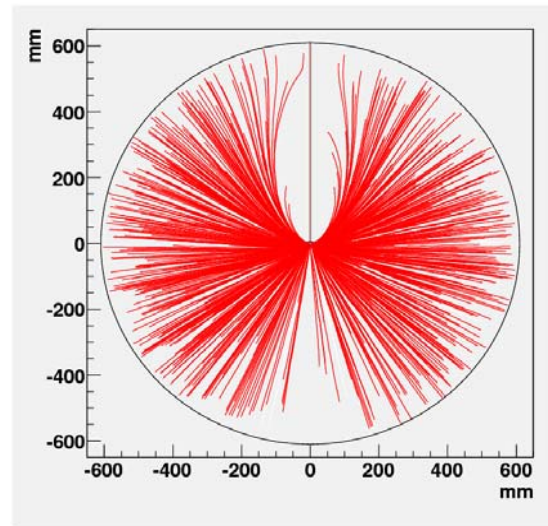
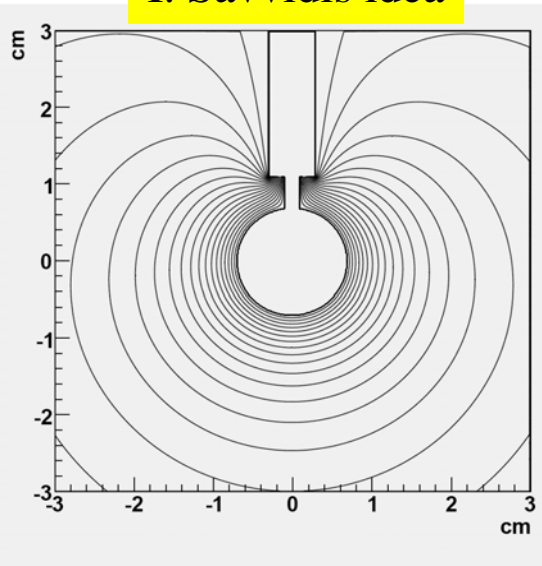
=> dependance of rise time on length of track and radius position

Electrostatics deal, How to keep radial field

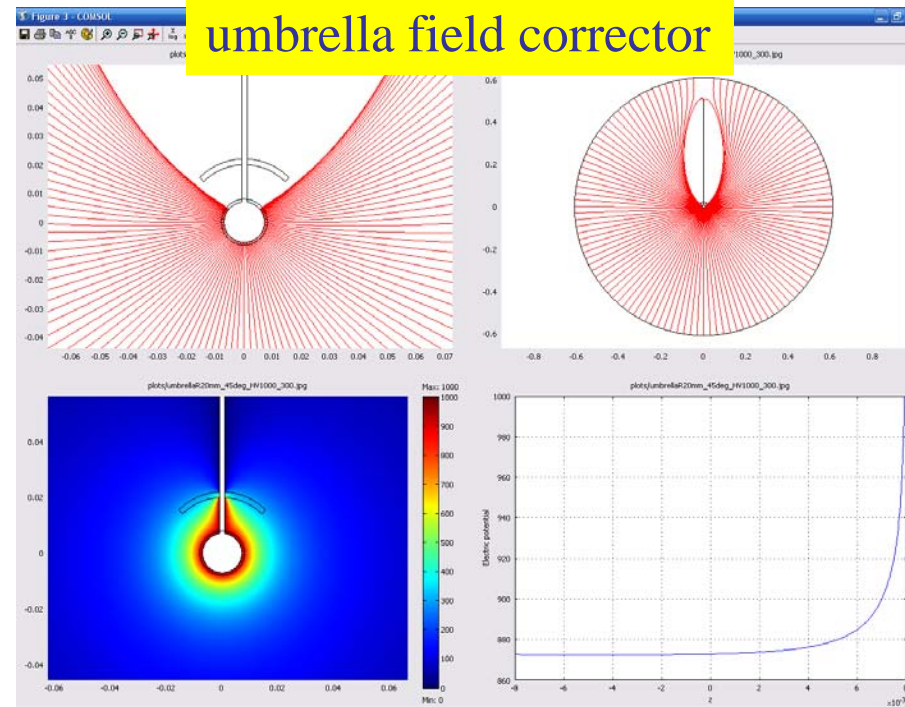
Ideal solution: field $1/R^2$ degrador around the wire



I. Savvidis idea

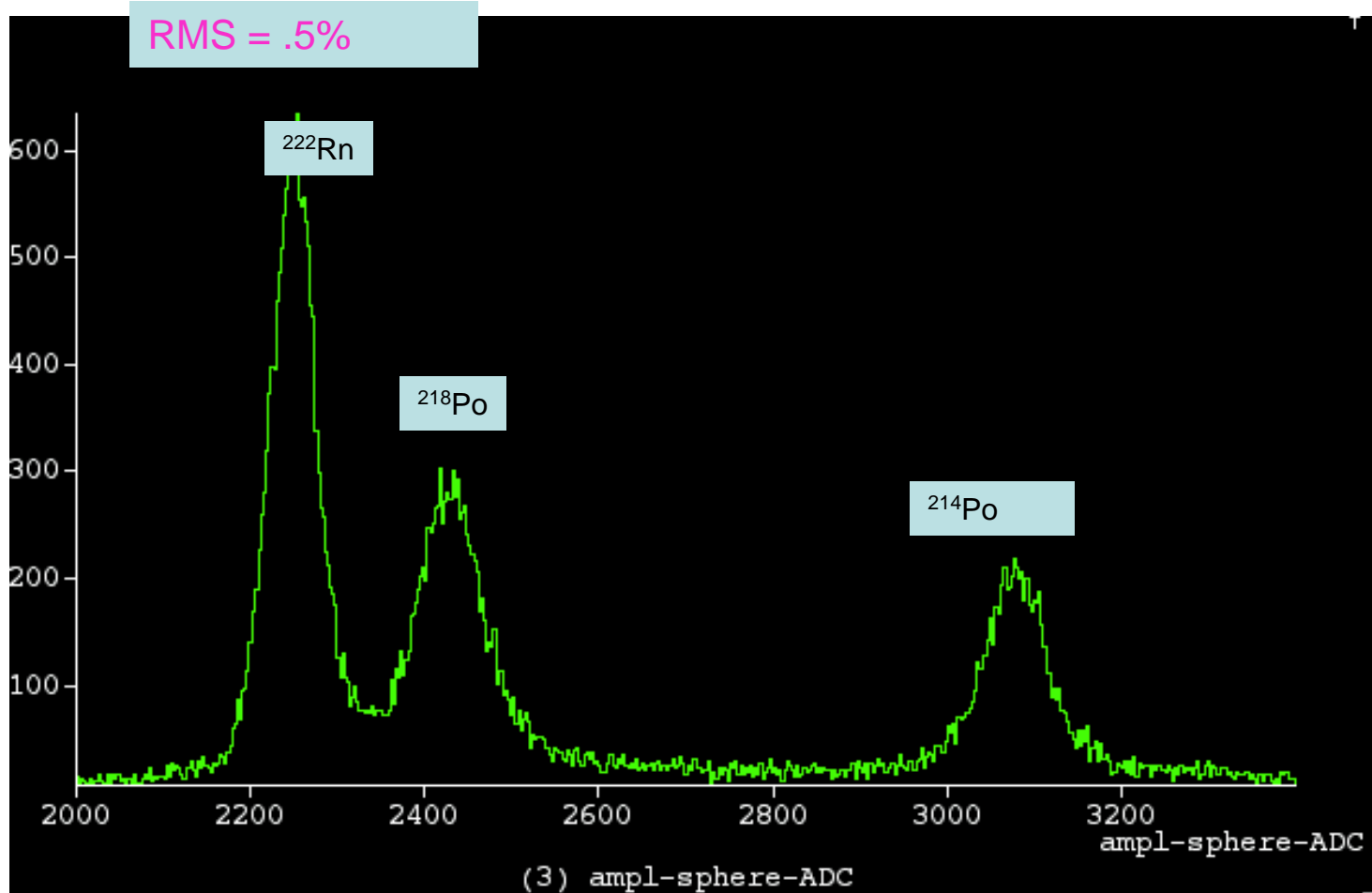


umbrella field corrector



NEW Excellent energy resolution

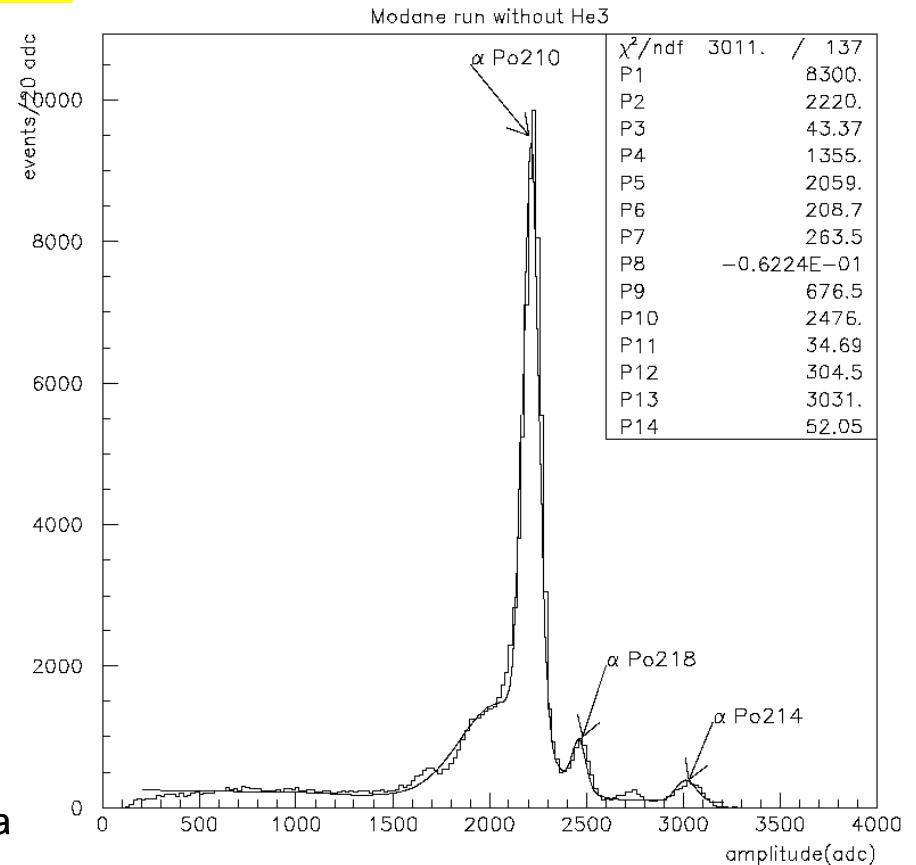
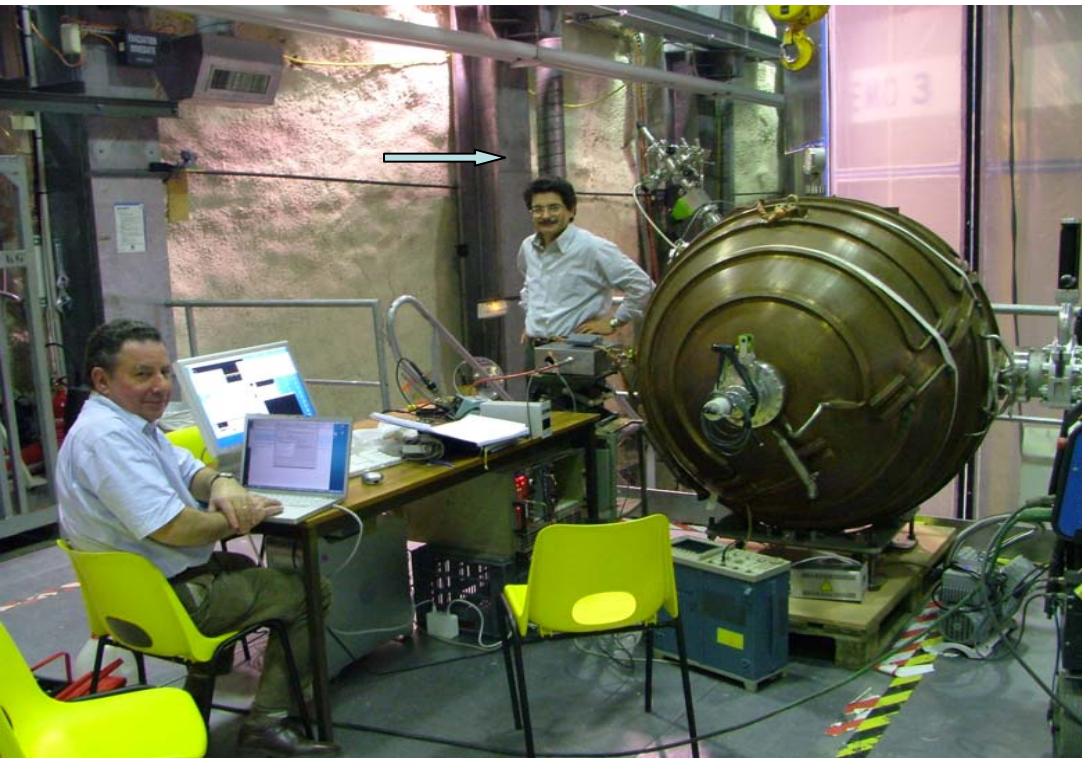
Measured Radon gas emission spectrum with spherical detector



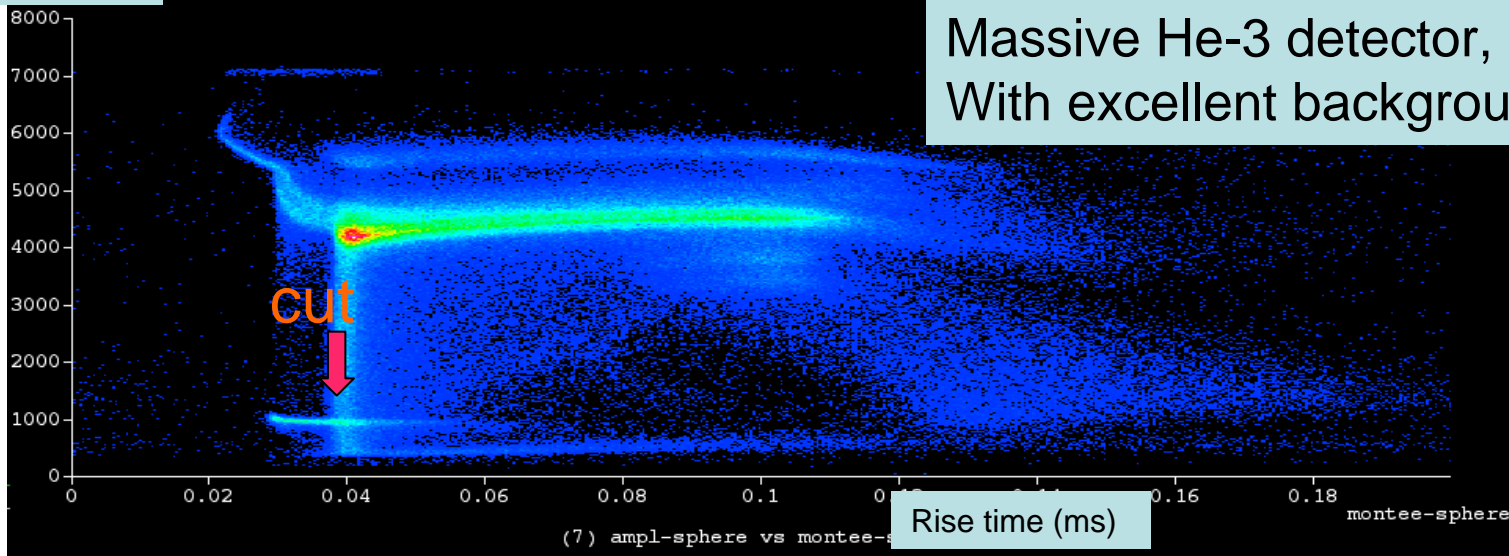
In 2008: Detector installed in LSM laboratory
*Goal: measure thermal neutron background
 and estimate fast neutron flux*

Neutron energy and flux measurement
 ${}^3\text{He} + n \longrightarrow {}^1\text{H} + {}^3\text{H} \text{ (} Q= 765 \text{ keV)}$

LSM-Modane before filling with He-3

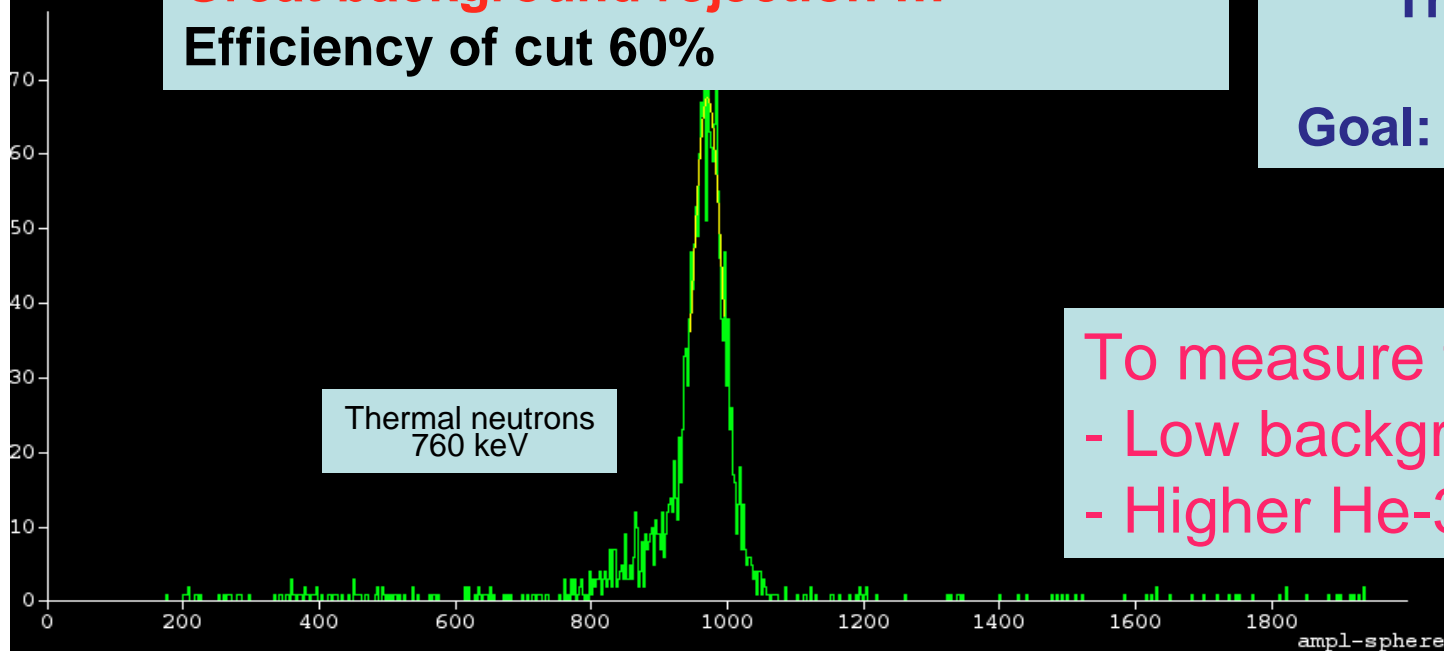


Amplitude



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

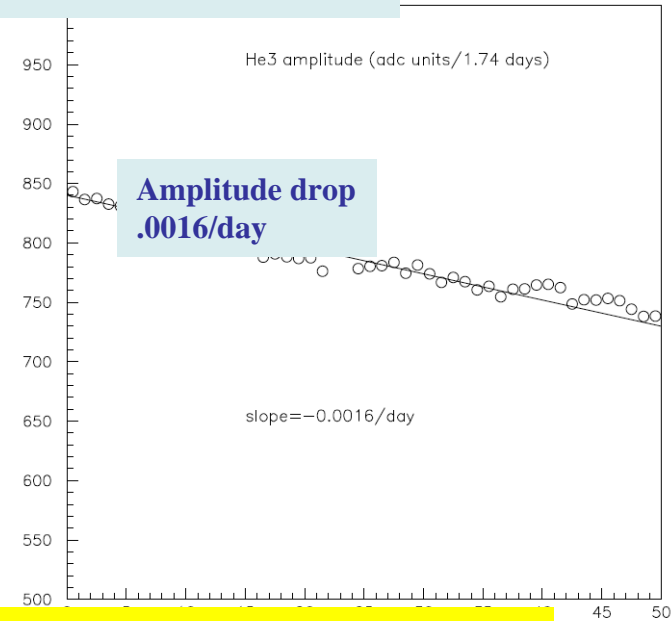
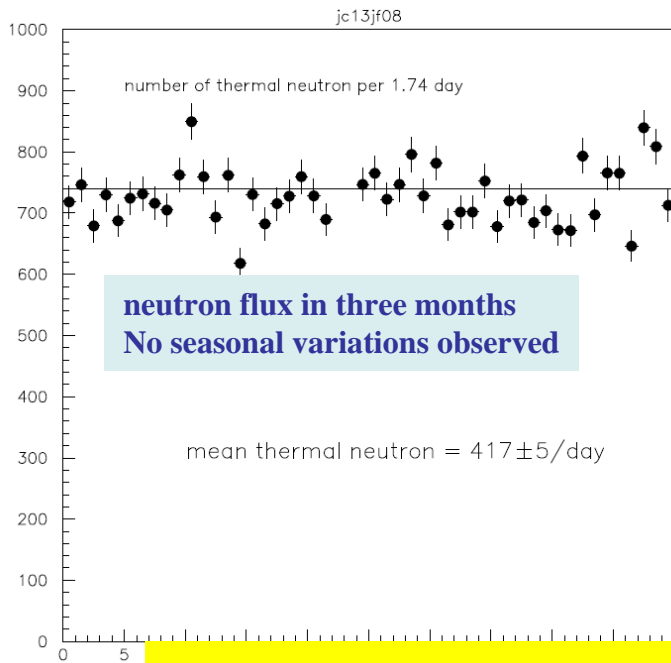
Thermal neutron peak after rise time cut
Great background rejection !!!
Efficiency of cut 60%



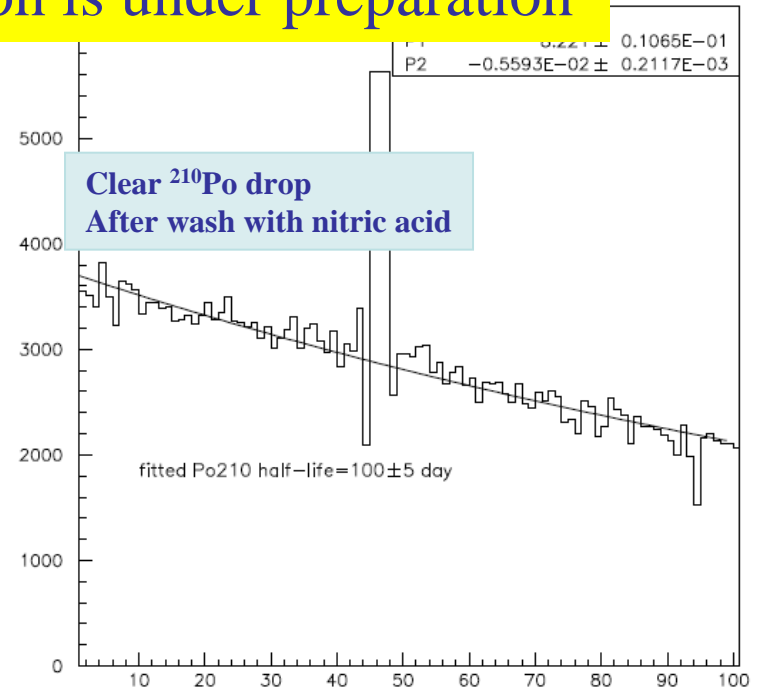
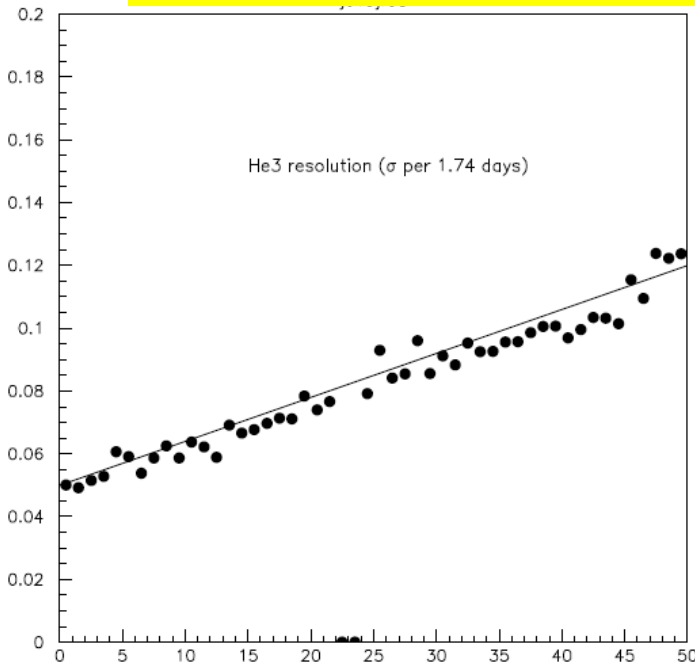
Results in LSM
Thermal neutron flux
 $2.2 \times 10^{-6} / \text{cm}^2 / \text{s}$
Goal: measure fast neutrons

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

Summary of 2009 results at LSM



He-3 recovery system and recirculation is under preparation



Under study

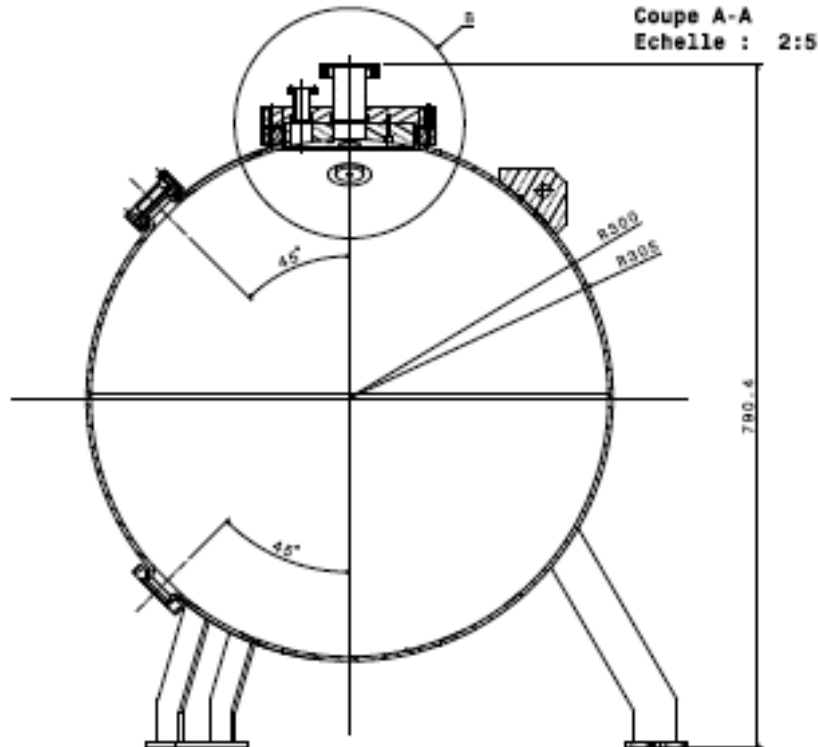
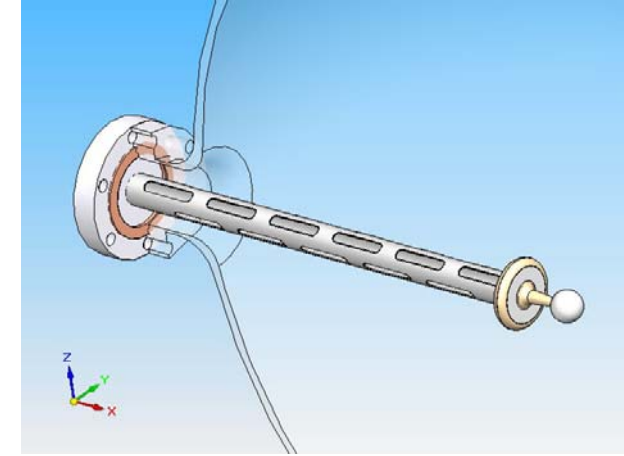
New detector made out of radiopure Cu vessel

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

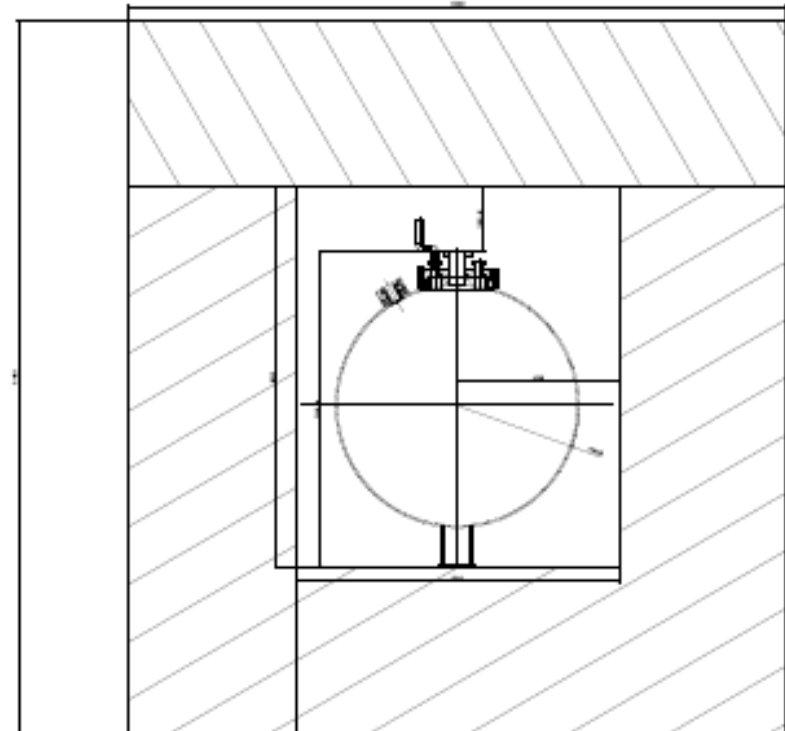
Appropriate shield will be provided by LSM

Goal

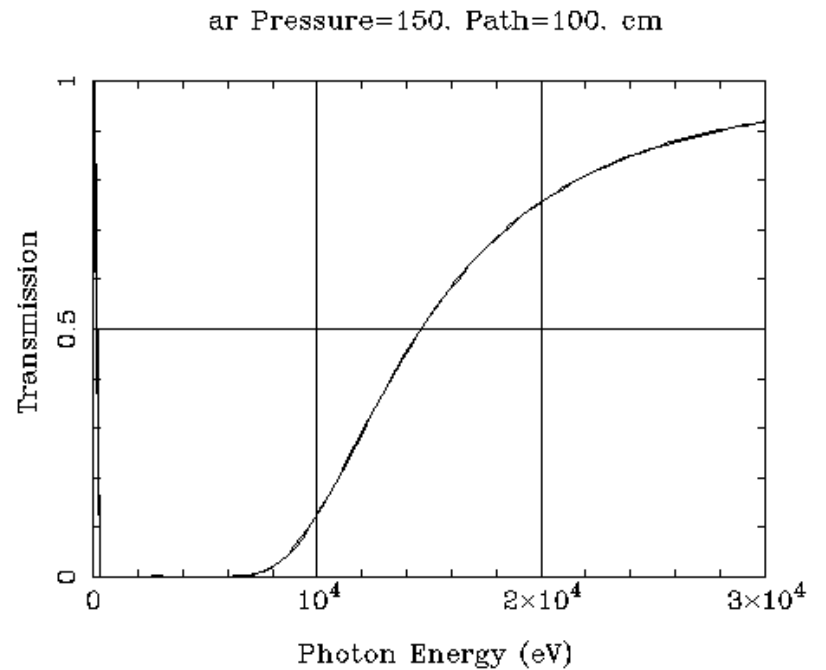
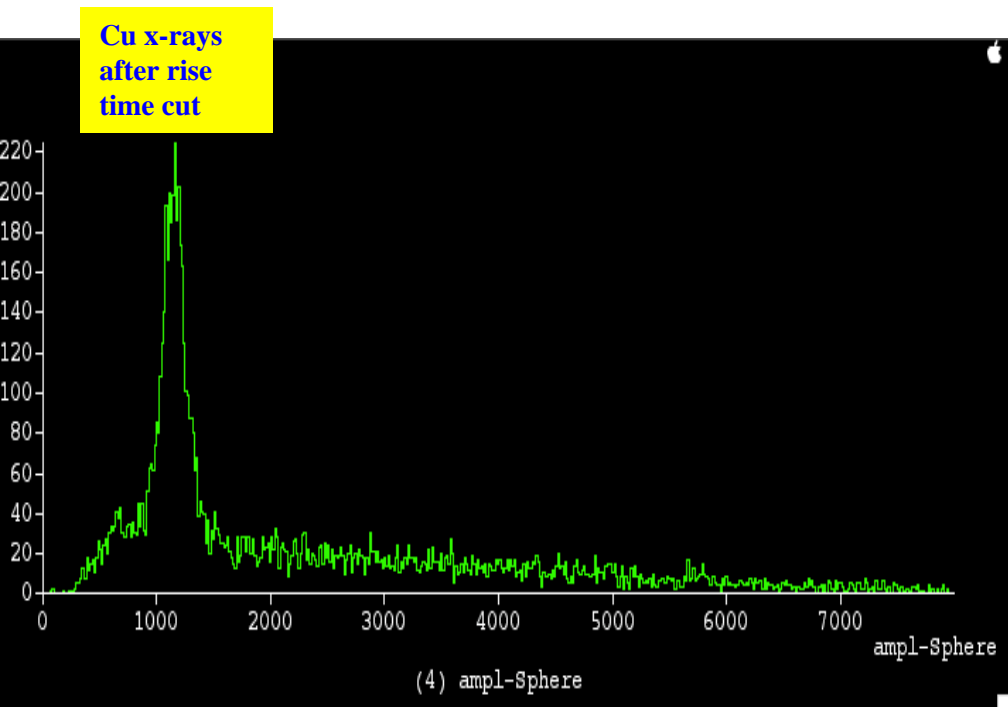
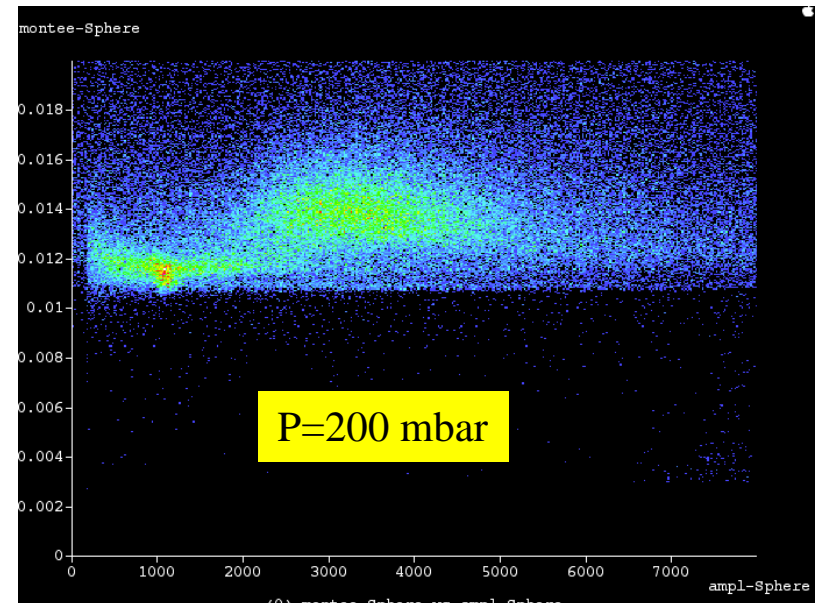
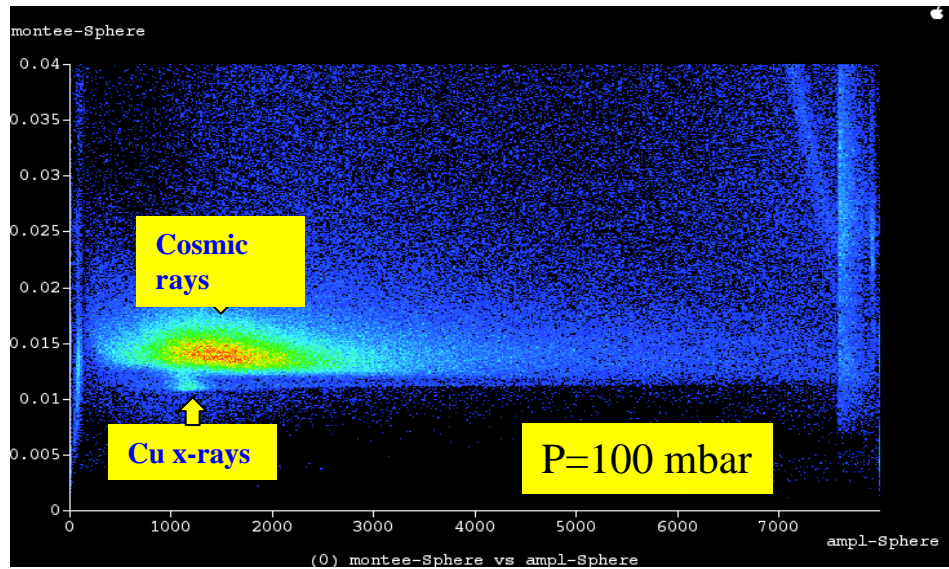
- Measure fast neutron energy distribution at LSM
- Explore ultra low energy with low background detector



I. Gion

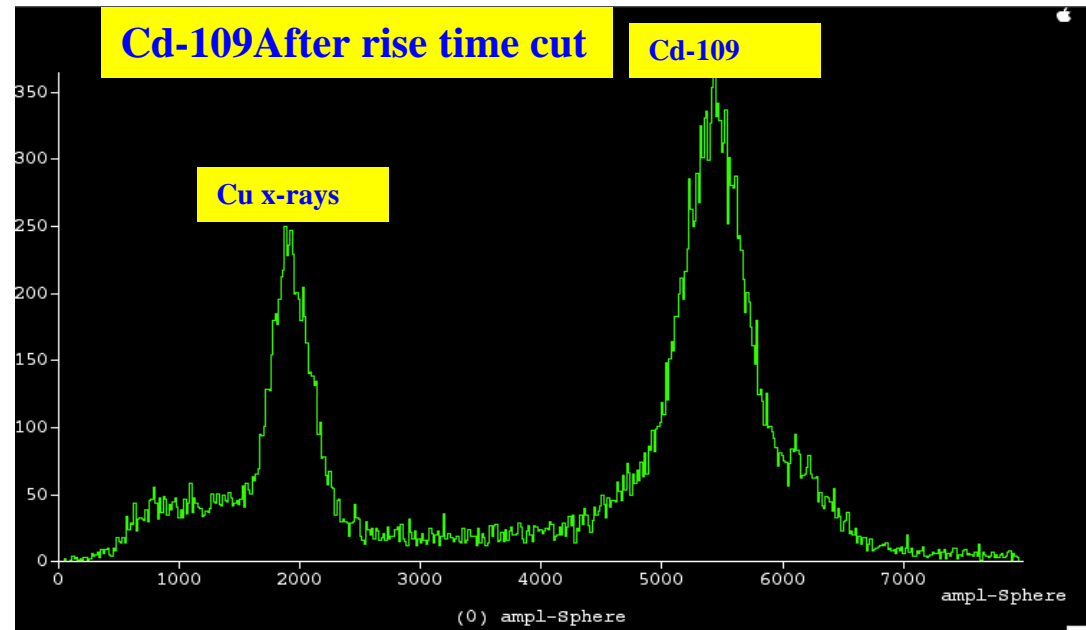
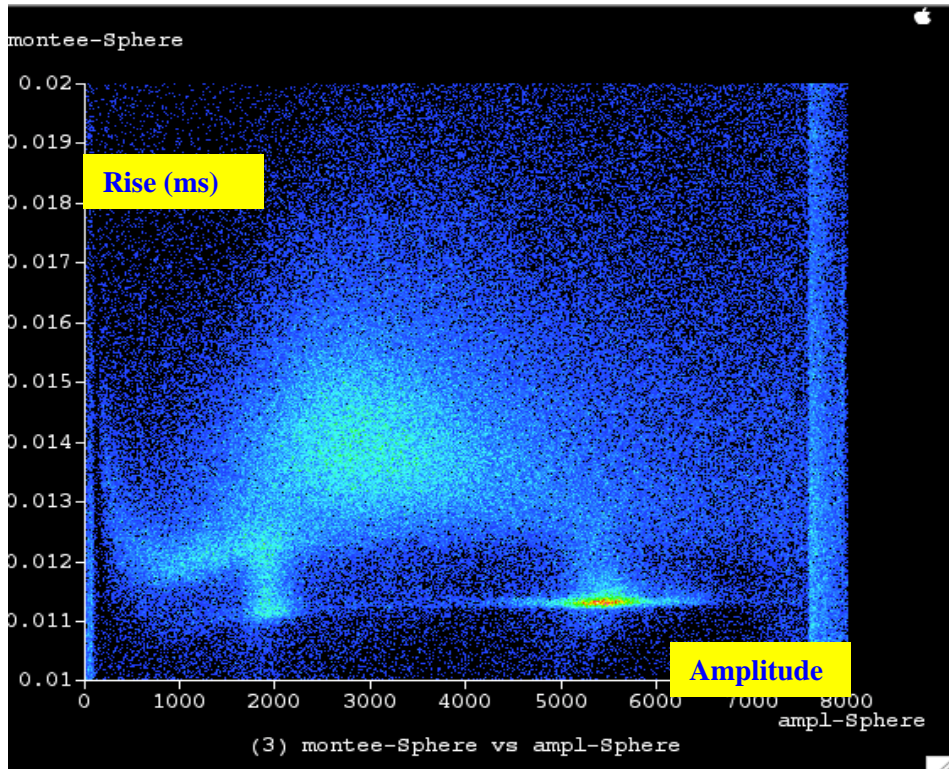
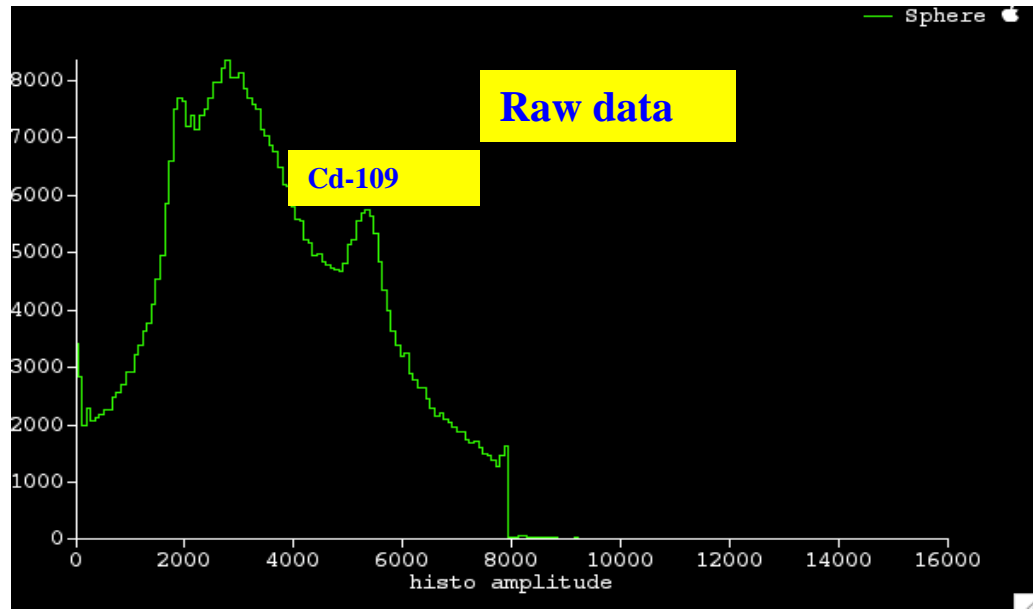


Back to Saclay - Low energy investigations

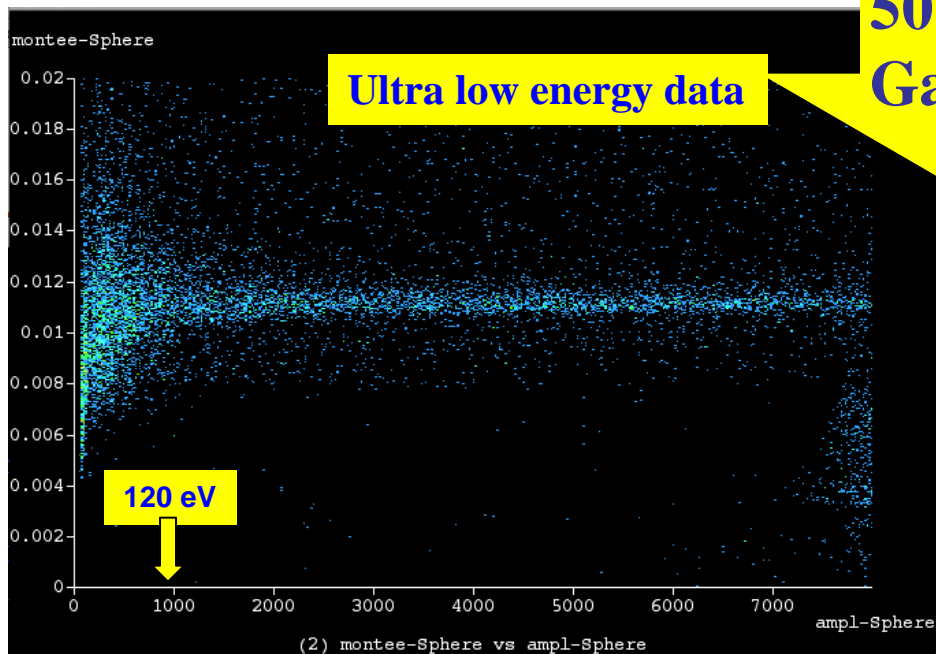
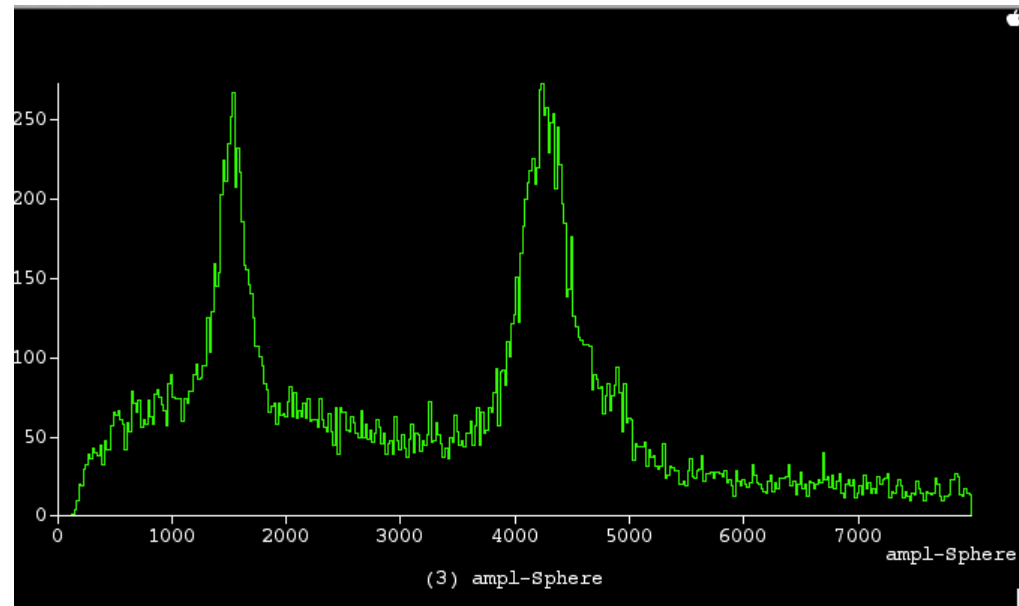
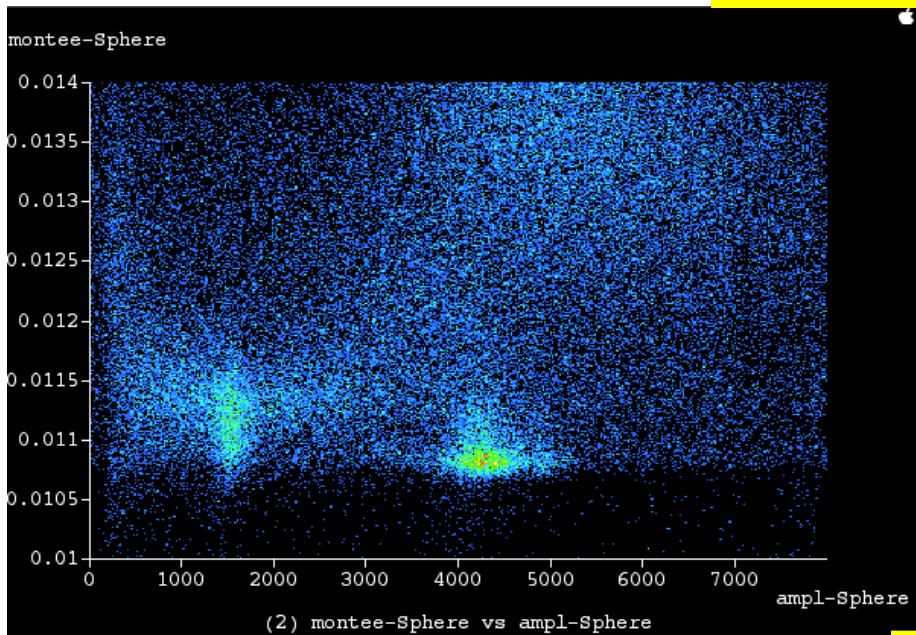


With Cd-209 source
December 2009

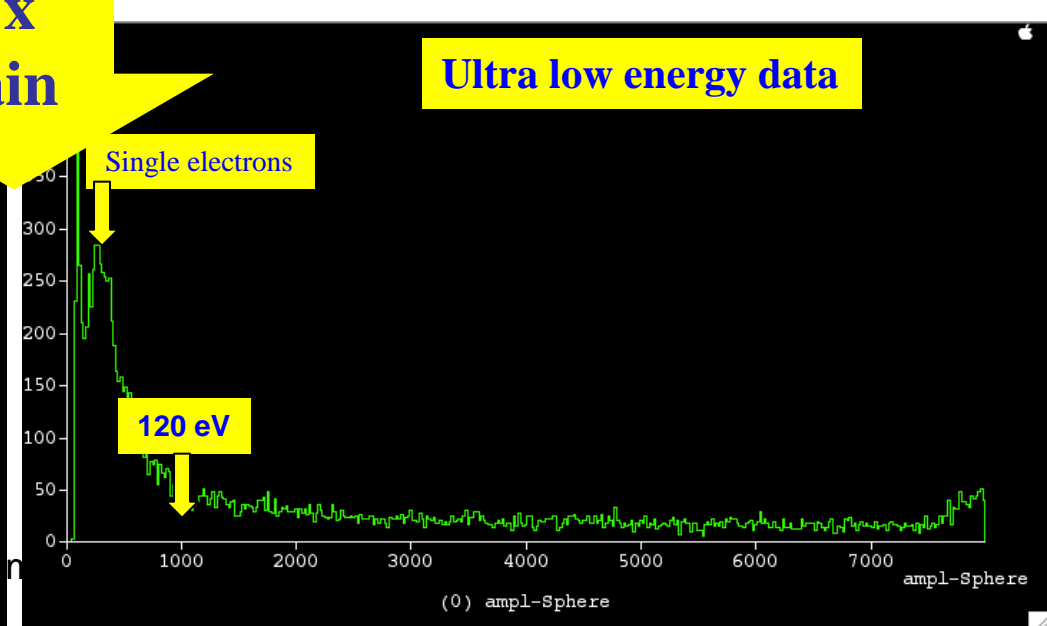
P=100 mbar Ar+2% CH₄



P=200 mbar Ar+2% CH₄

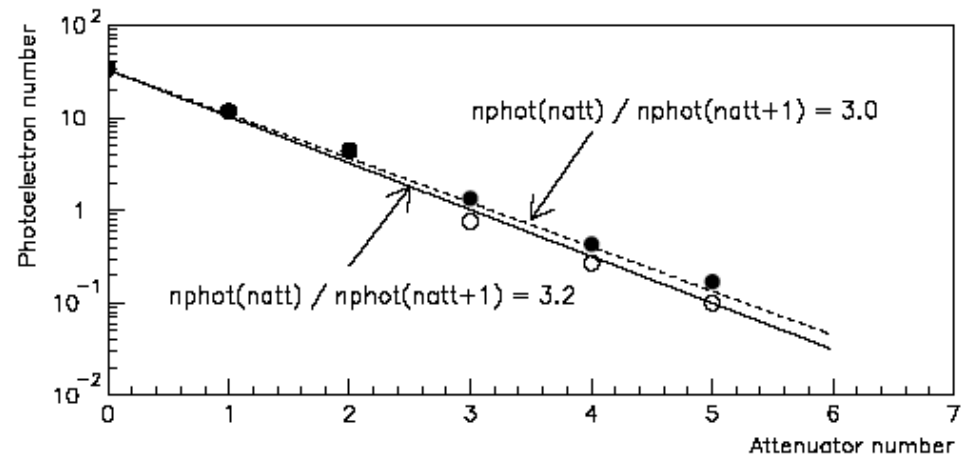
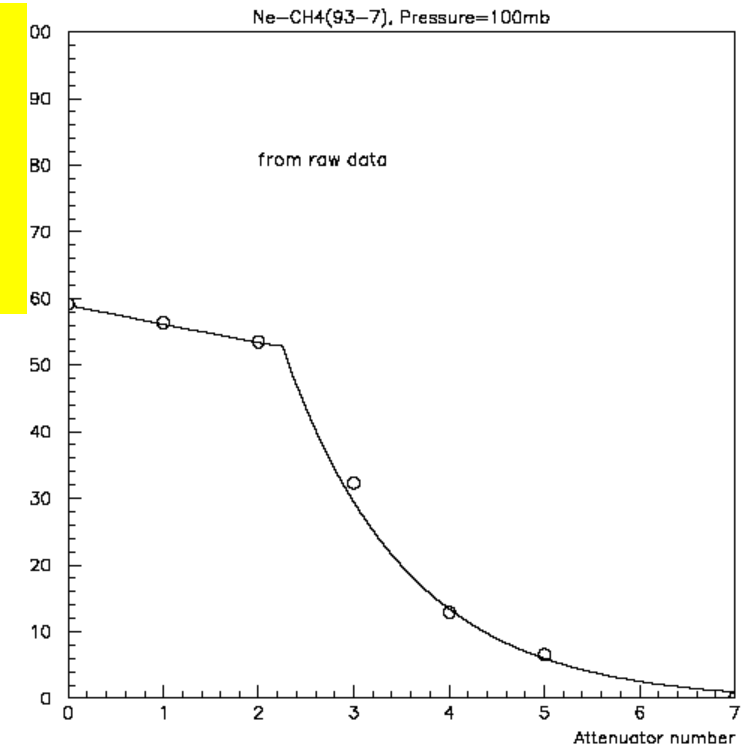
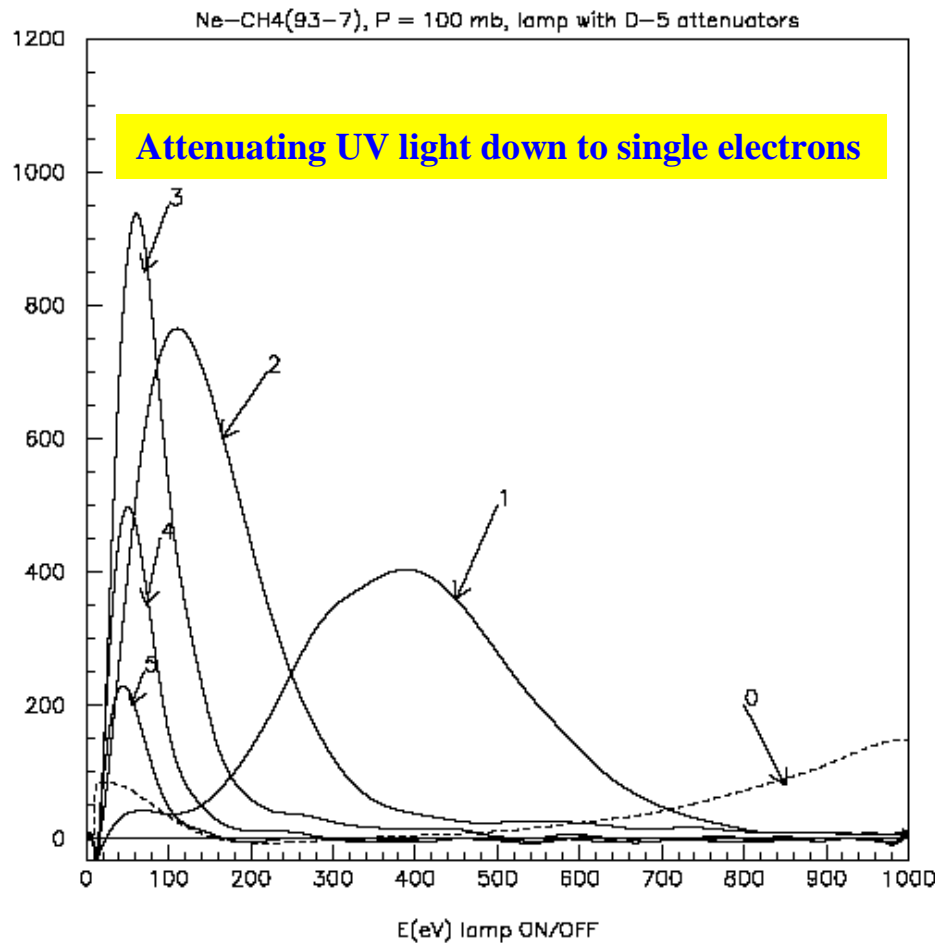


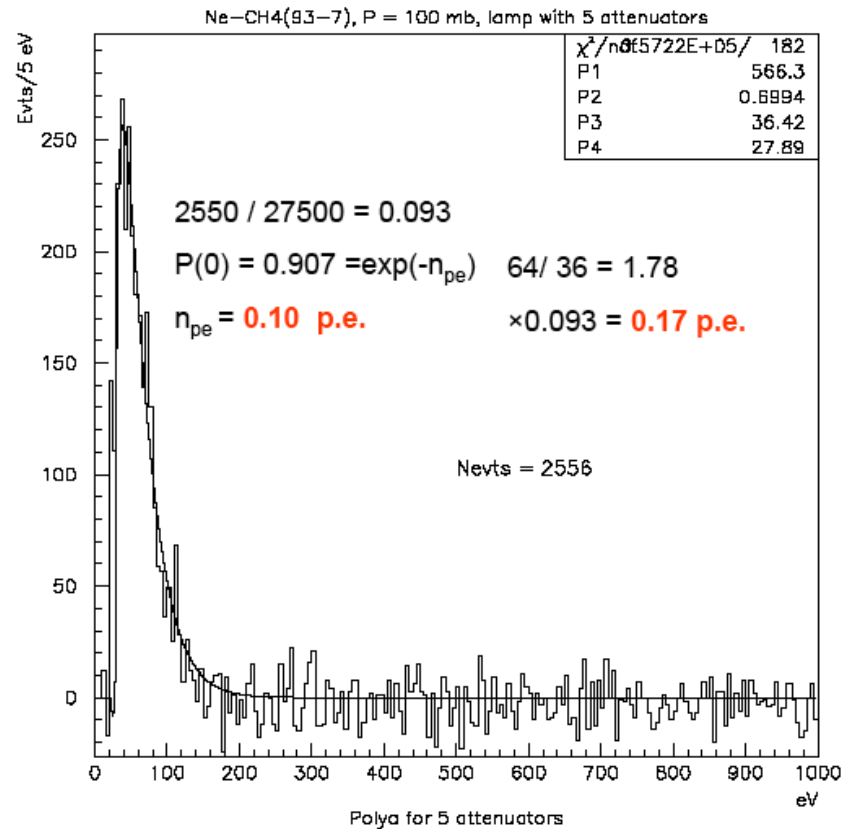
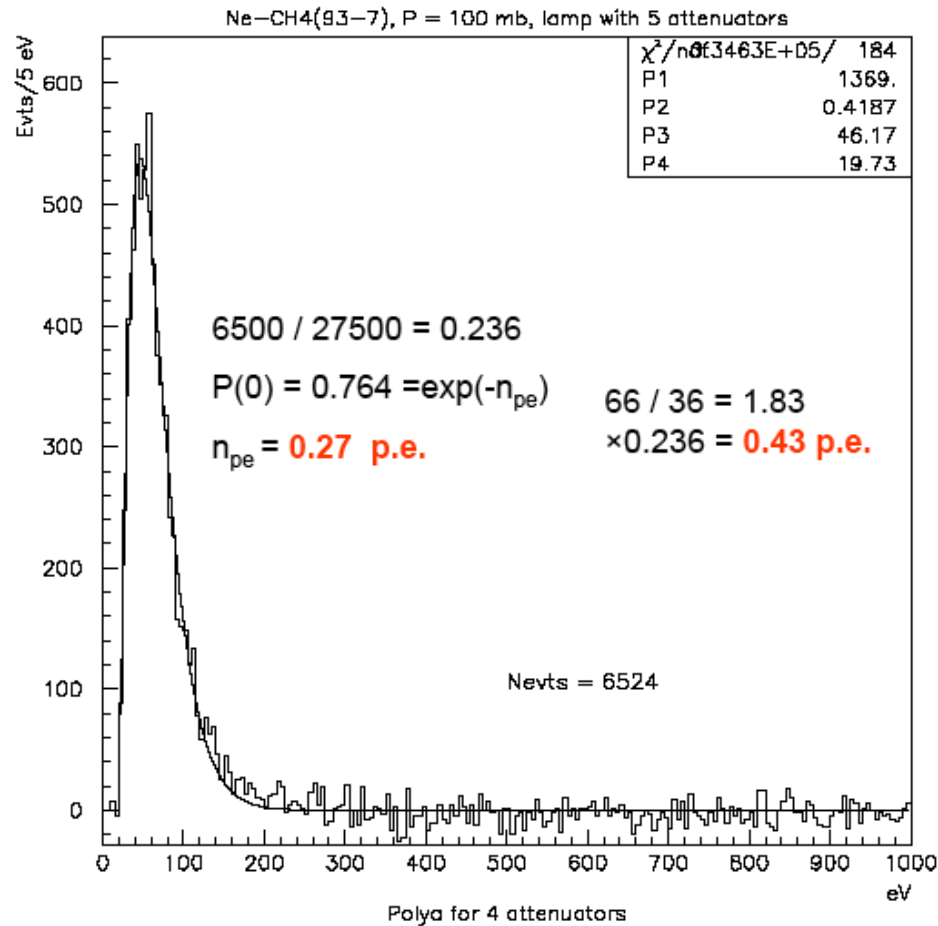
50 x
Gain



Sub-keV calibration: UV lamp

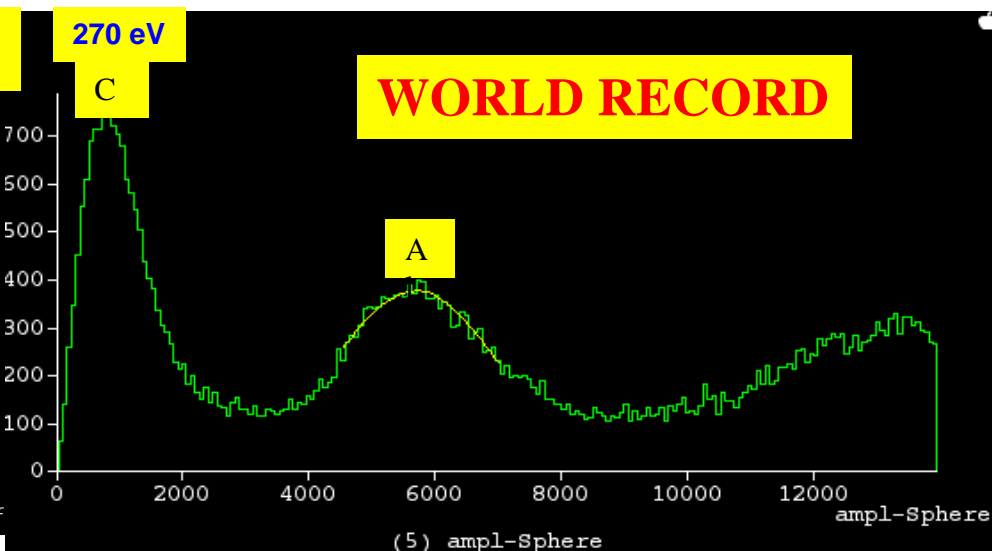
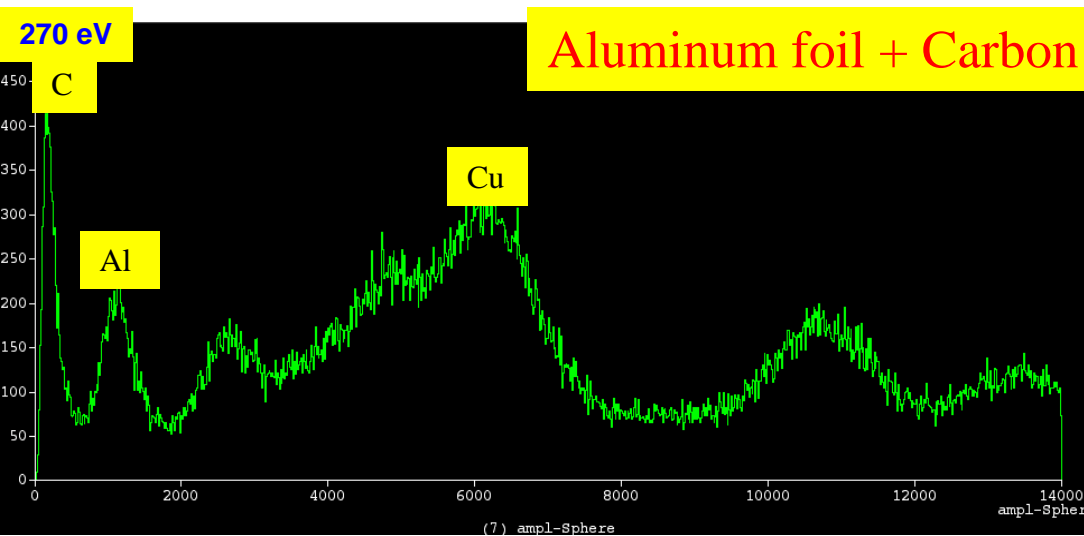
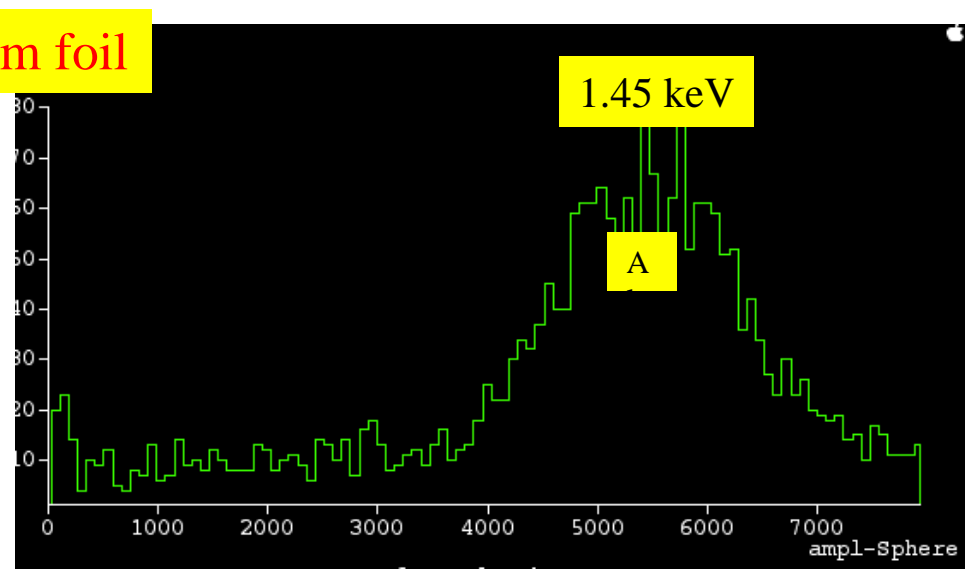
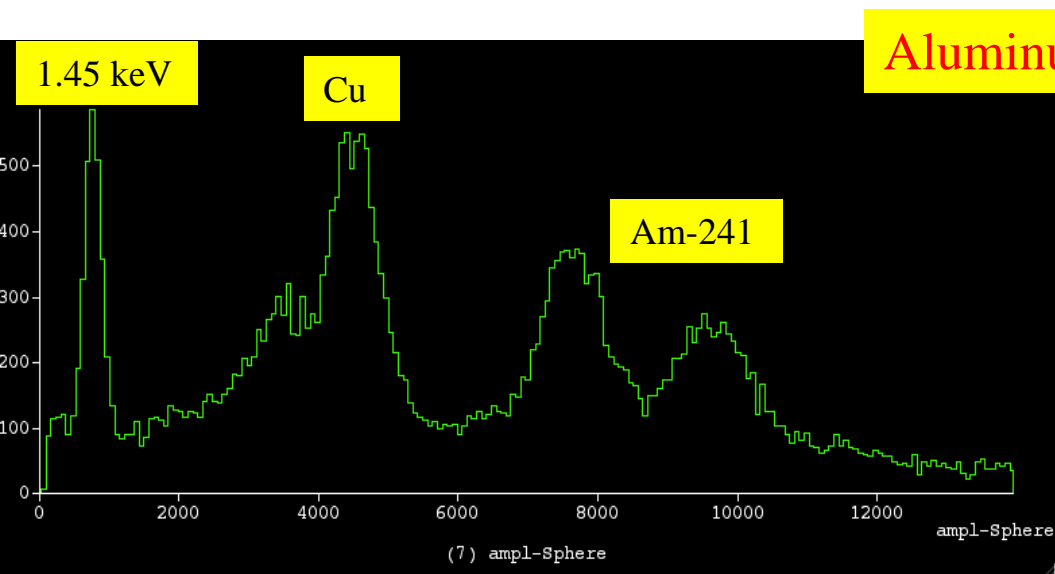
- We are using a pulsed hydrogen lamp
- MgF_2 entrance window
- Electrons are extracted by the internal spherical vessel
- UV attenuators: 38% transparent mesh



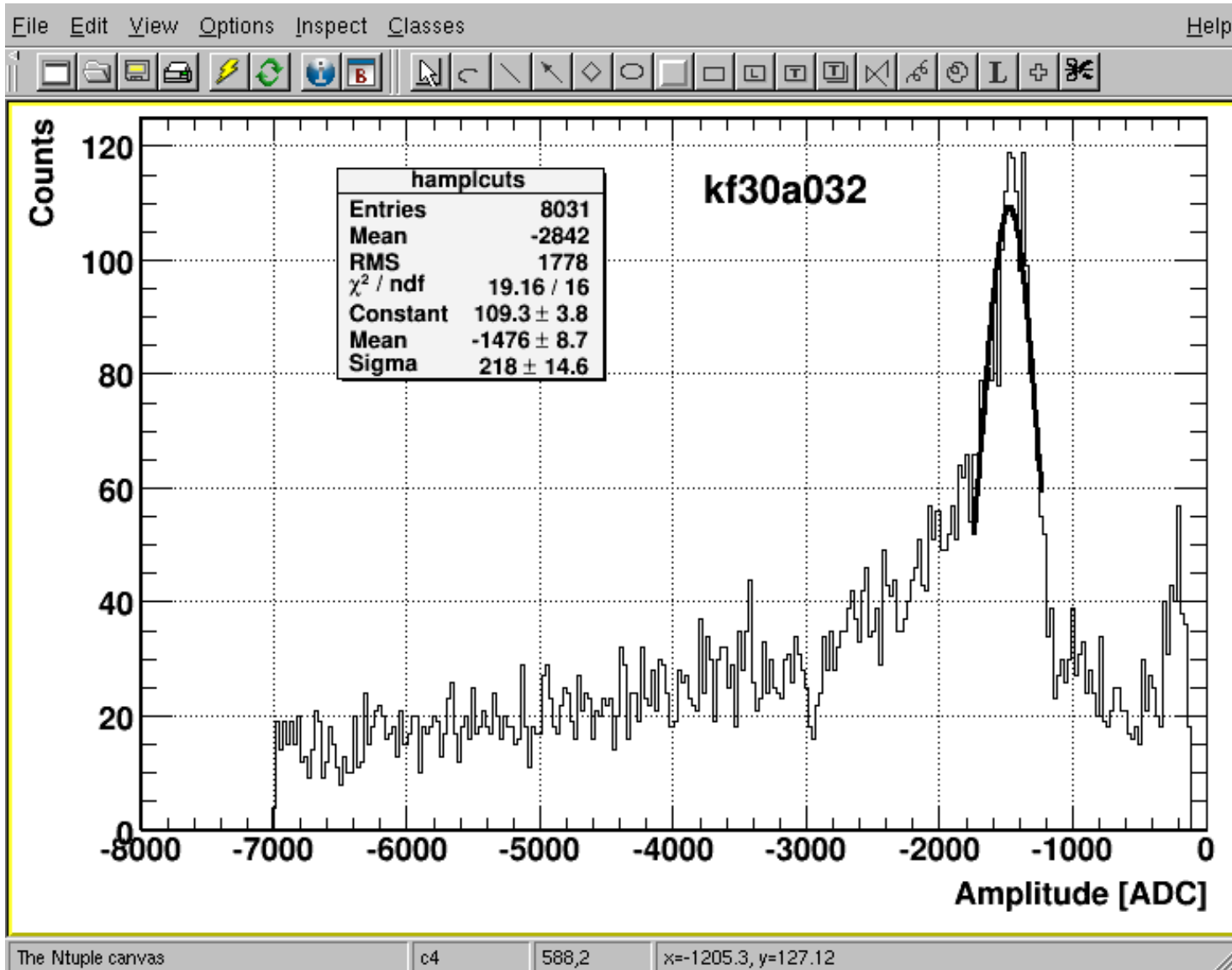


Ultra low energy calibration results

X-rays from Am-241 fluorescence



July 2010 LSM first results

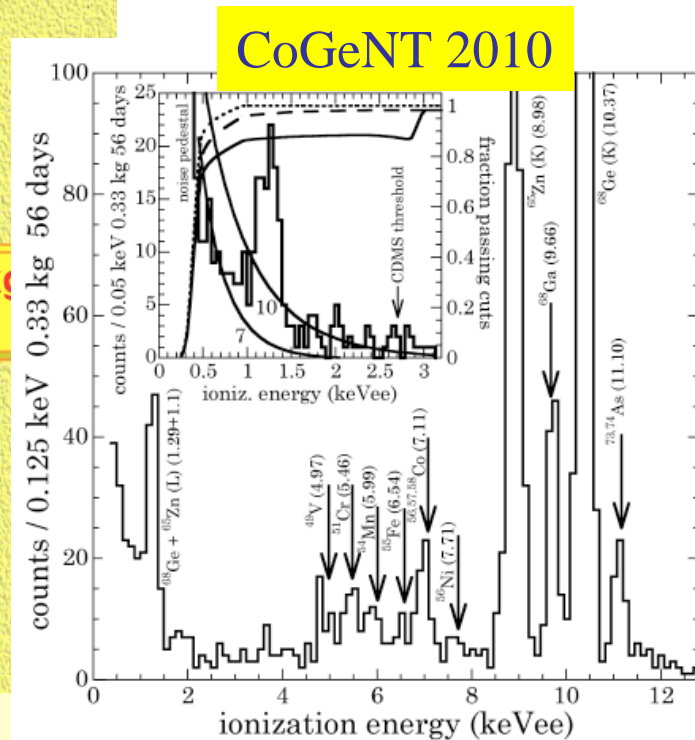
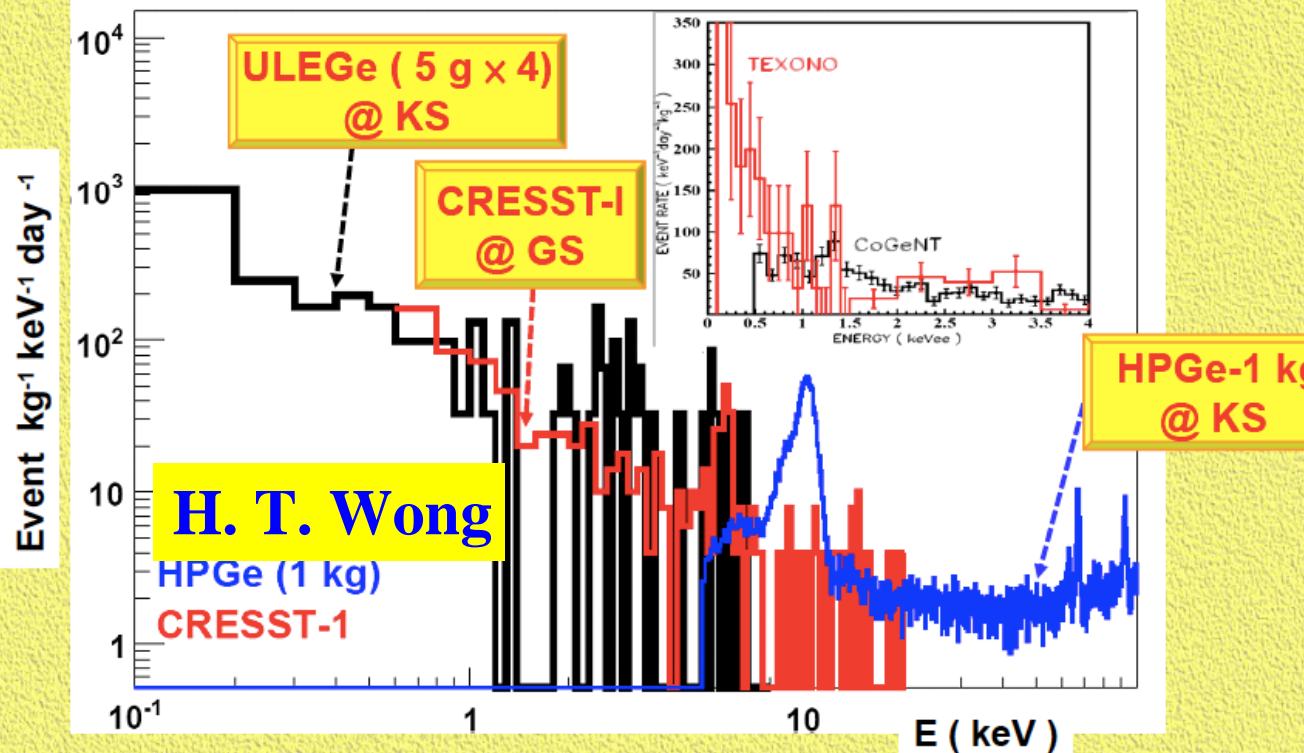


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Dark matter search through very low energy threshold < 100 eV

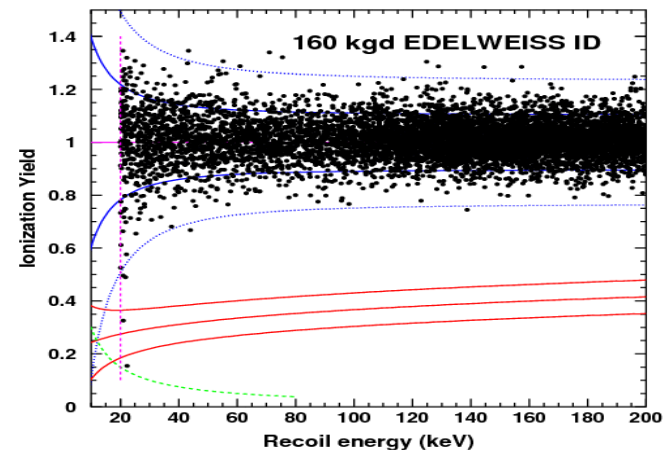
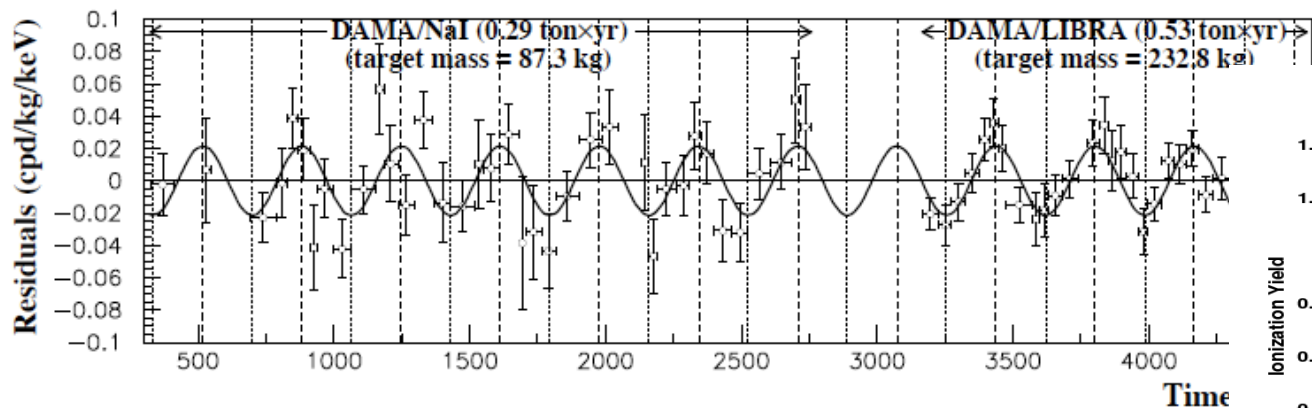
Sub-keV Background Measurements & Comparisons



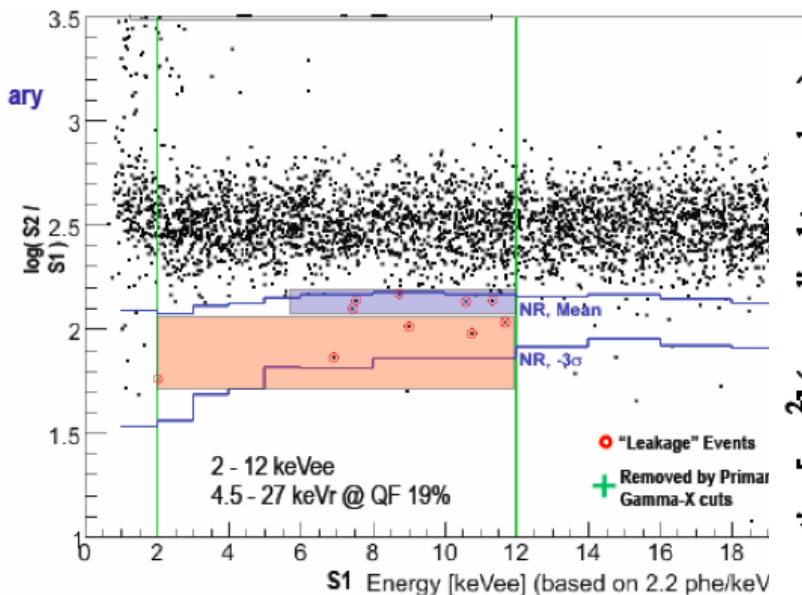
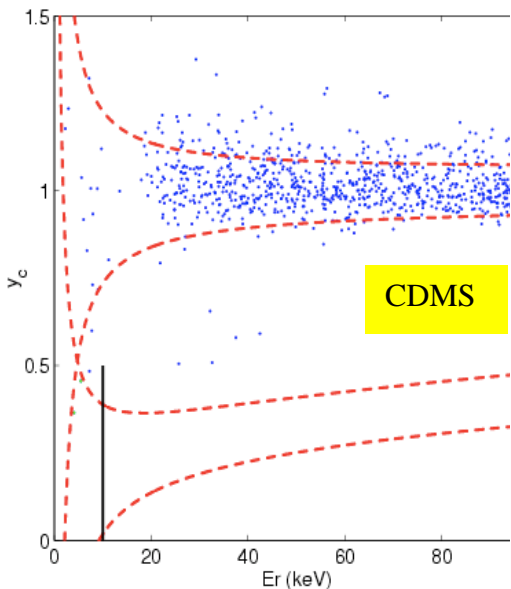
- Bkg $\sim O(1)$ cpd/kg/keV > 10 keV, \sim to underground expts.
- ULEGe bkg @ KS \sim CRESST-1 @ GranSasso
- Intensive studies on sub-keV background understanding

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

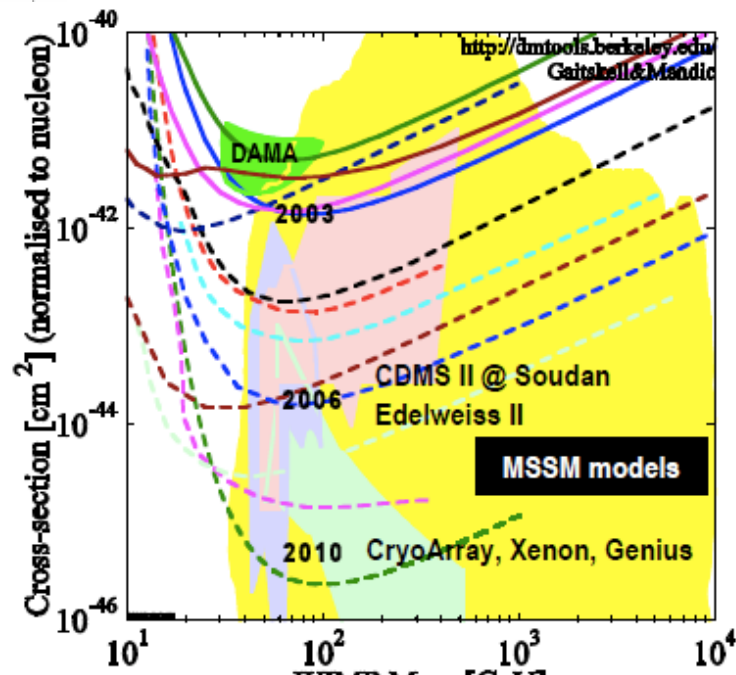
2-4 keV



DAMA disfavoured by other direct searches



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Light Dark Matter particles? < a few GeV

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

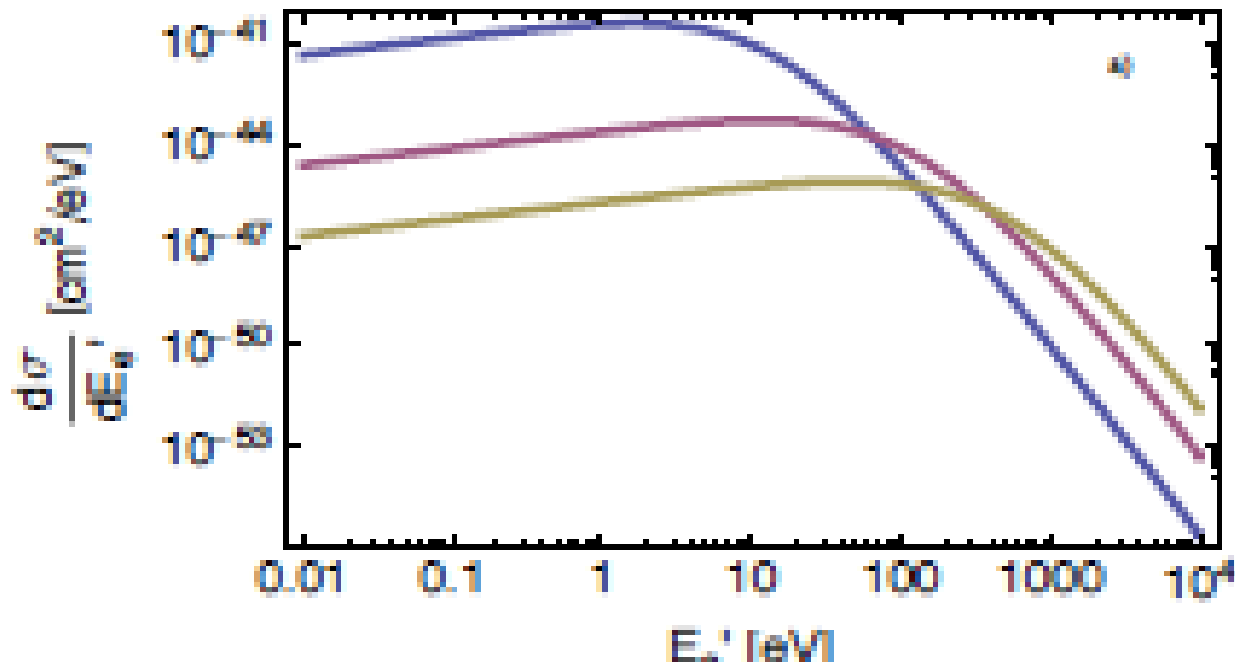
If DM is a fermion and coupled to light particles then it can be lighter than a few GeV.

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



Neutrino-nucleus coherent elastic scattering

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

A. Drukier, L. Stodolsky, *Phys.Rev.D*30:2295,1984, JI Collar, Y Giomataris - *NIMA*471:254-259,2000, H. T. Wong, *arXiv:0803.0033-2008*, PS Barbeau, JI Collar, O Tench - *Arxiv preprint nucl-ex/0701012*, 2007

High cross section but very-low nuclear recoil

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

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

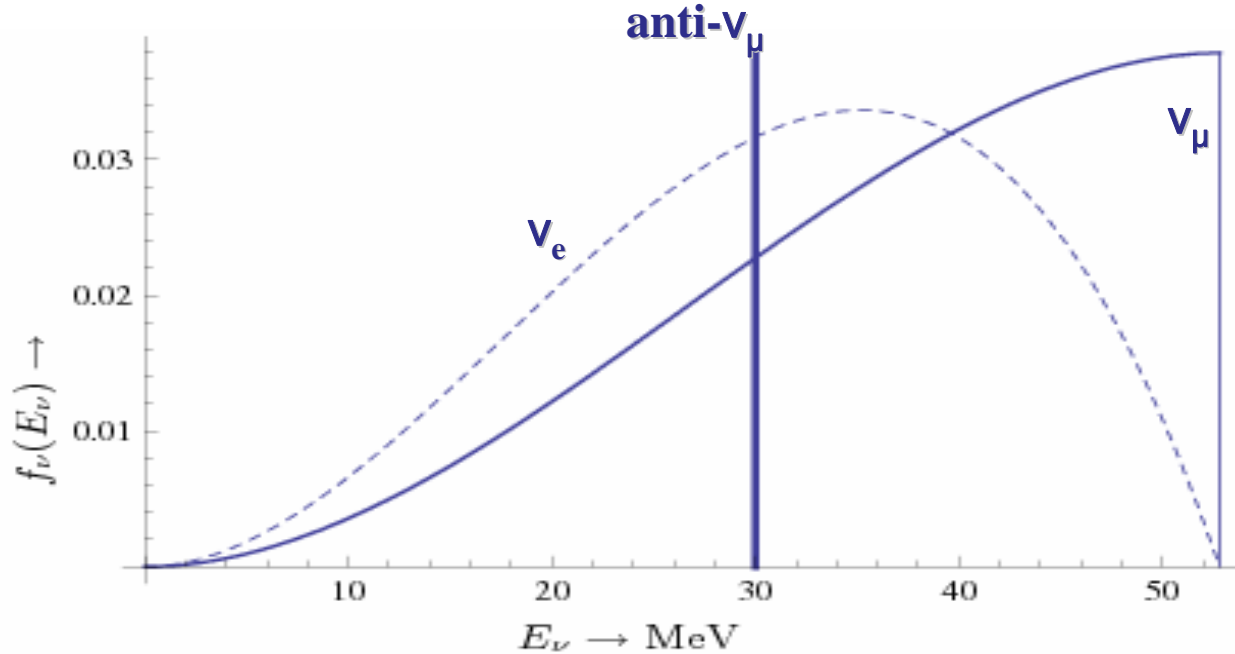
We need to calculate and measure the quenching factor

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=300⁰K, L=10 m**

targe t	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
⁰⁸ 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

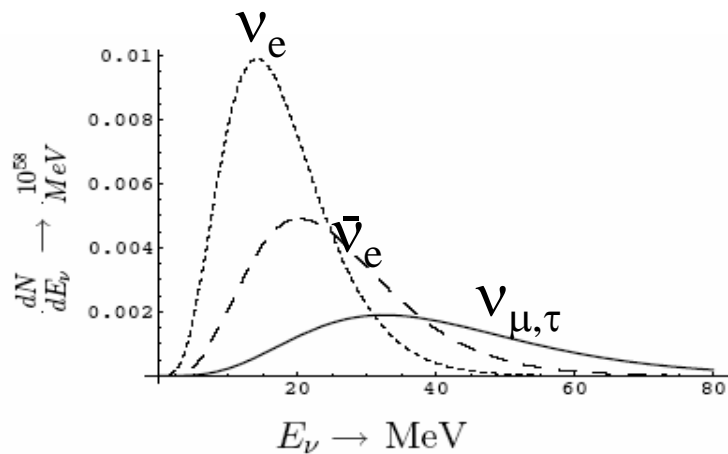
The average nuclear recoil energy is:

	He	Ne	Ar	Kr	Xe
$\langle E_r \rangle$:	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. Aune¹, E. Bougamont¹, M. Chapellier¹, A. Dedes⁵, P. Colas¹, J. Derre¹, G. Fanourakis⁷, E. Ferrer¹, W. Fulgione¹⁰, Th. Geralis⁷, G. Gerbier¹, M. Gros¹, I. Irastorza⁹, P. Kanti⁵, Y. Lemiere¹, X.F. Navick¹, Th. Papaevangelou¹, P. Salin⁴, I. Savvidis³, N. Spooner⁶, S. Tzamarias⁸, J. D. Vergados⁵

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/>