A dedicated SuperNova neutrino detector system

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

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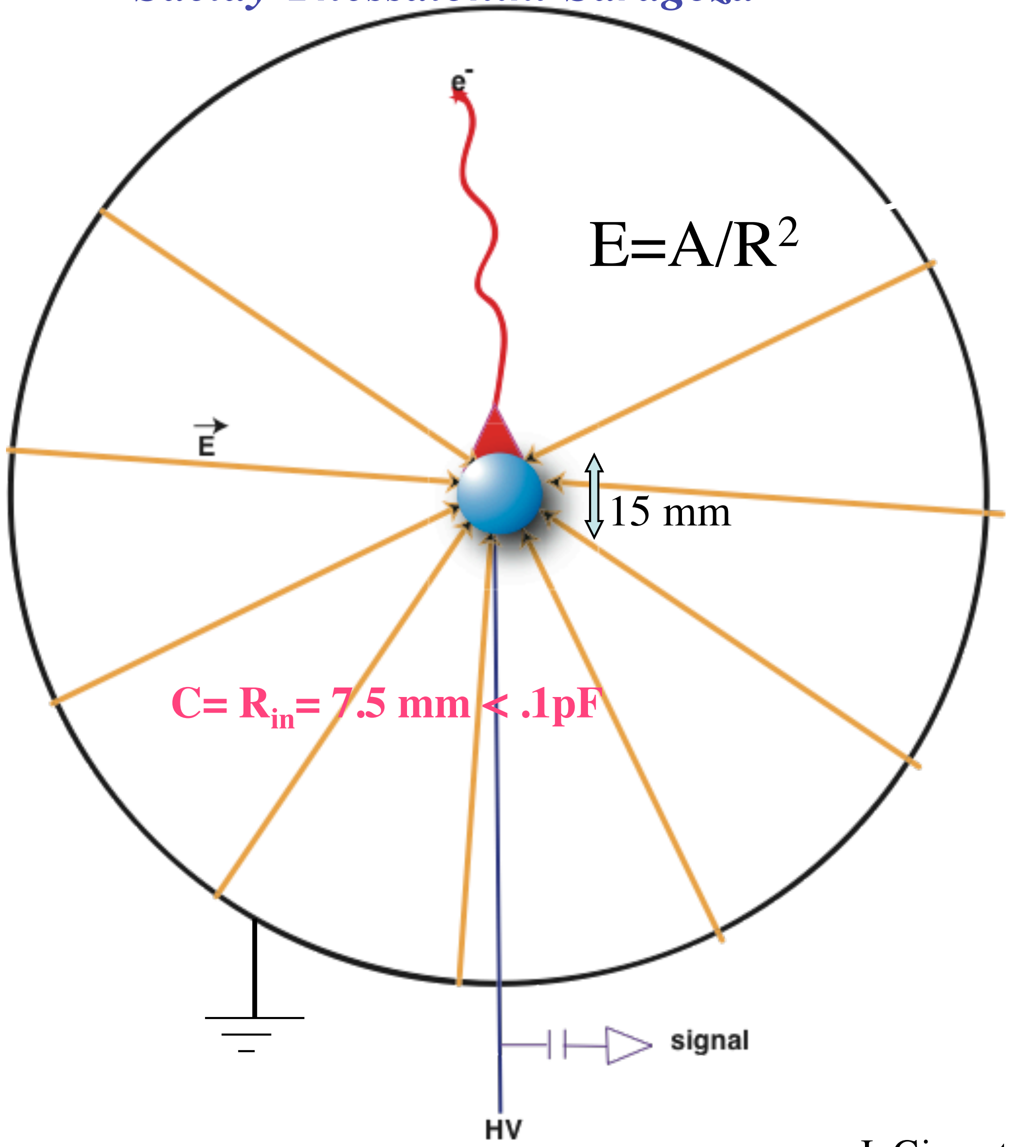
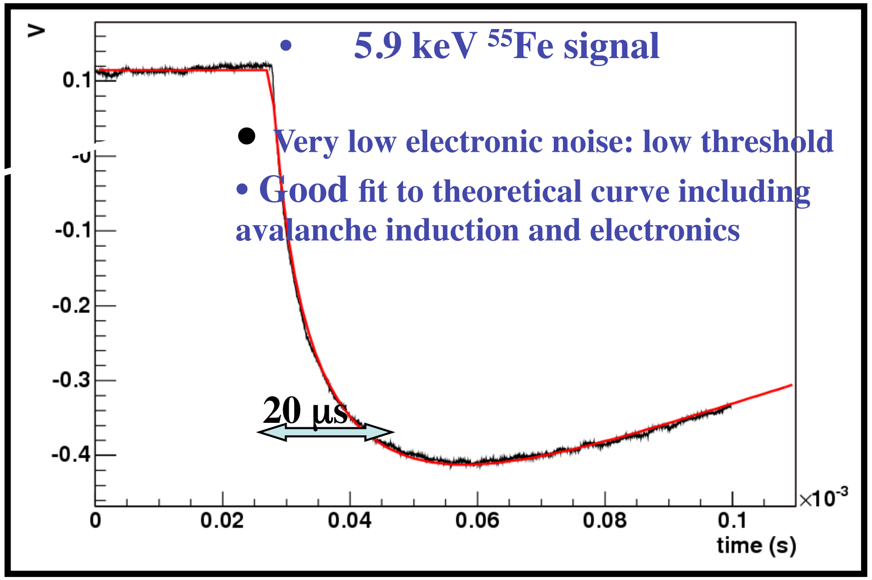
- Principle of the detector and results
- Neutral current neutrino Supernova demonstrator
- Worldwide Network

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. Jul 2008. 12pp, e-Print: arXiv:0807.2802 [physics.ins-det]*





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

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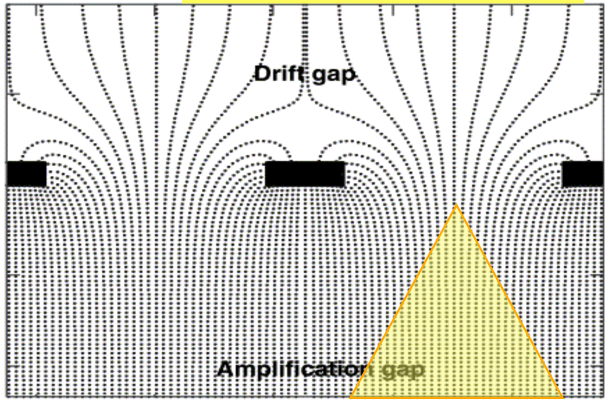
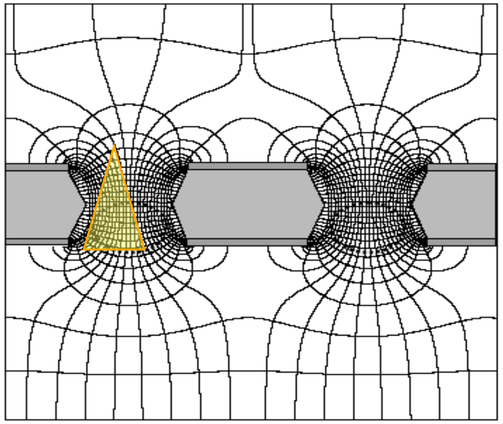
Parallel Plate Detector

Micromegas

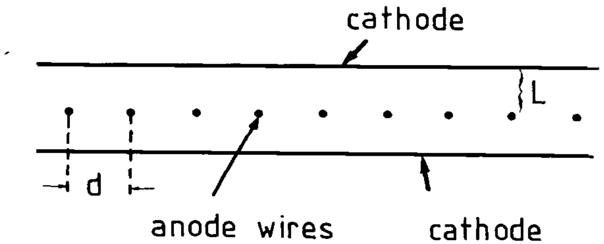


GEM

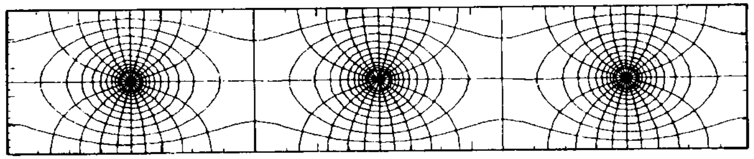


E= constant
C ≈ S > 1nF

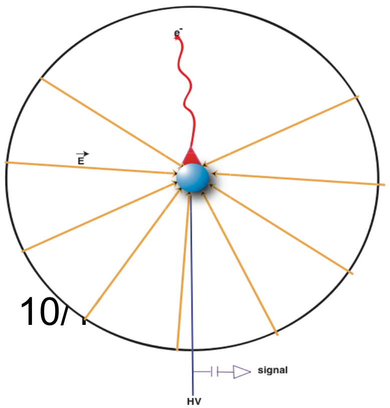
MPWC



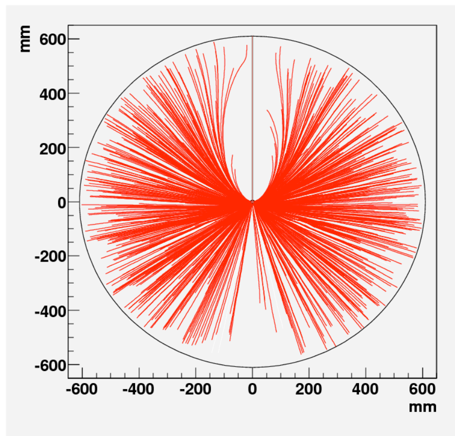
E=1/r
C ≈ **L>10 pF**



Spherical Proportional Counter



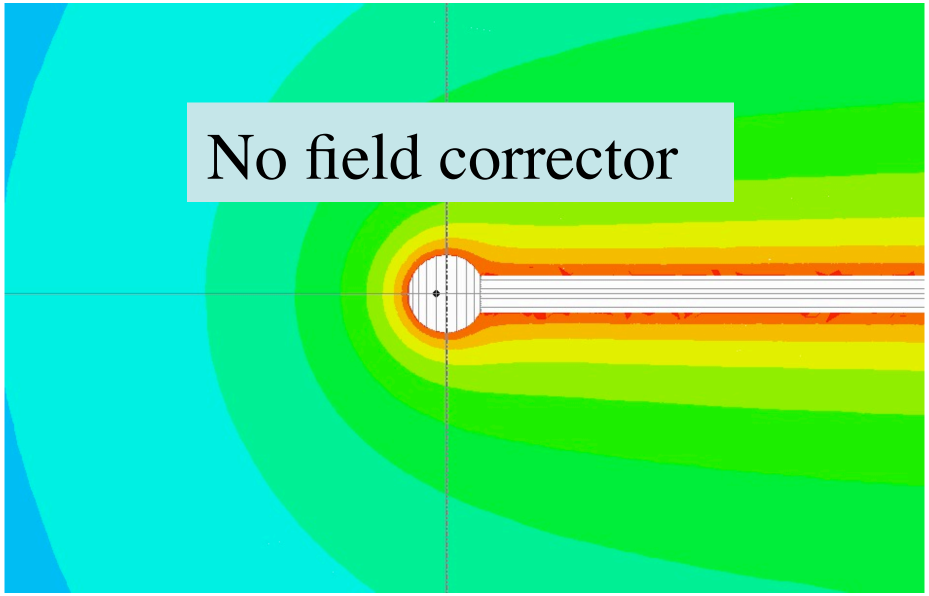
E=1/r²
C ≈ R_{in}< .1pF

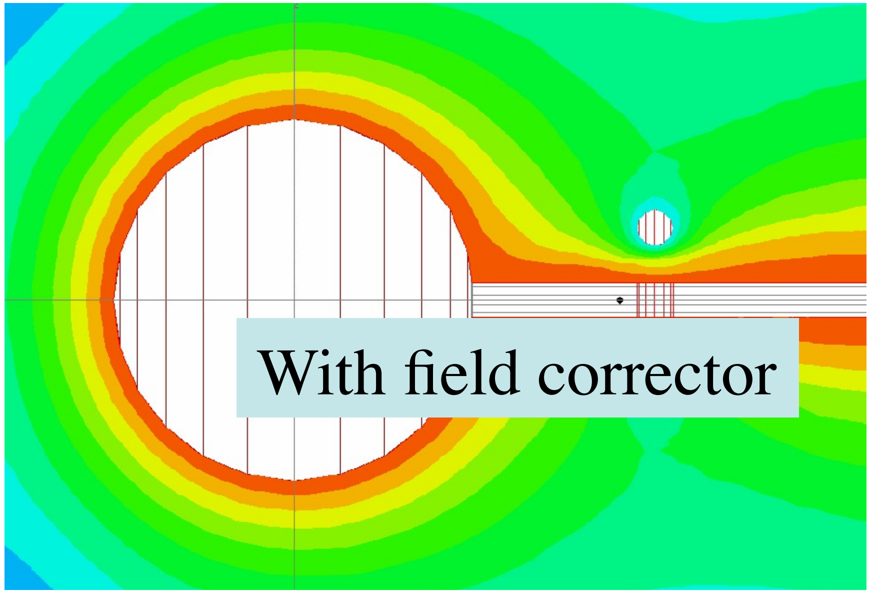


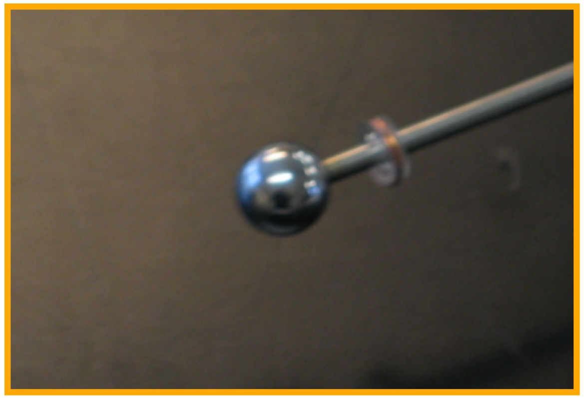
Electrostatics deal

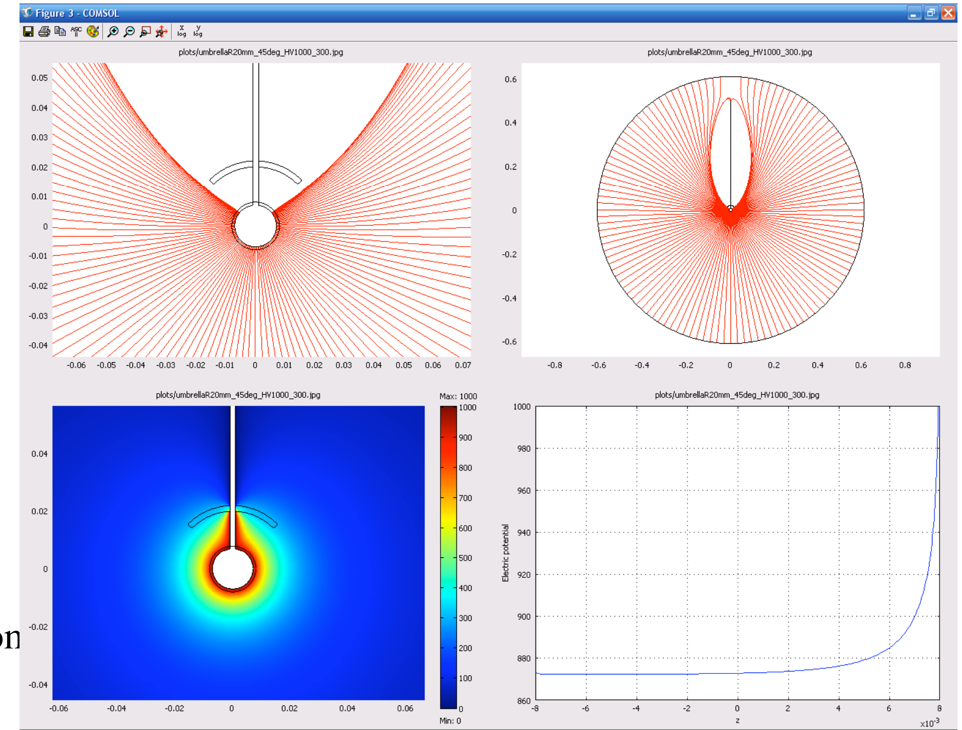
How to keep radial field

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





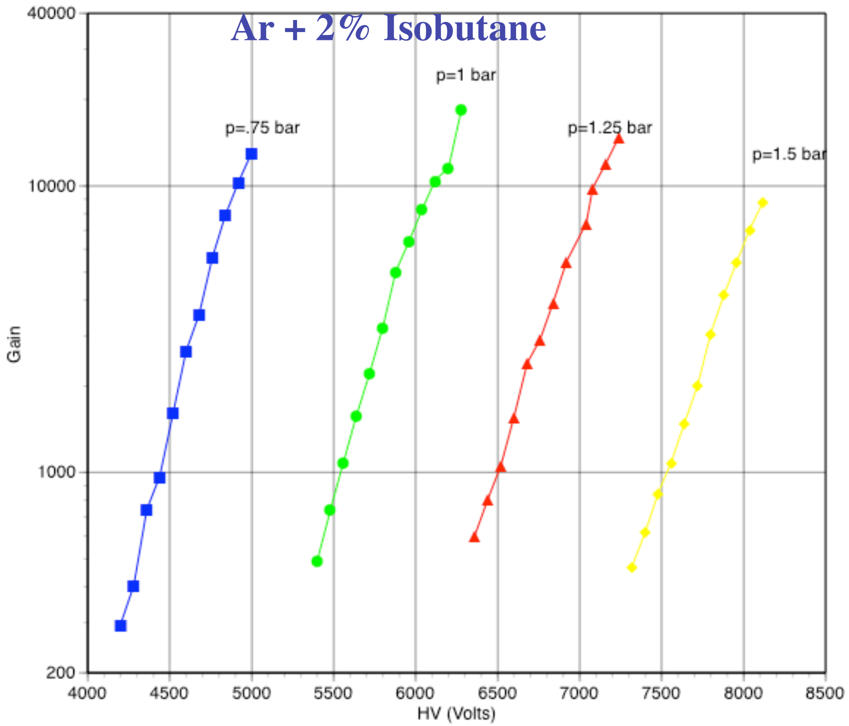


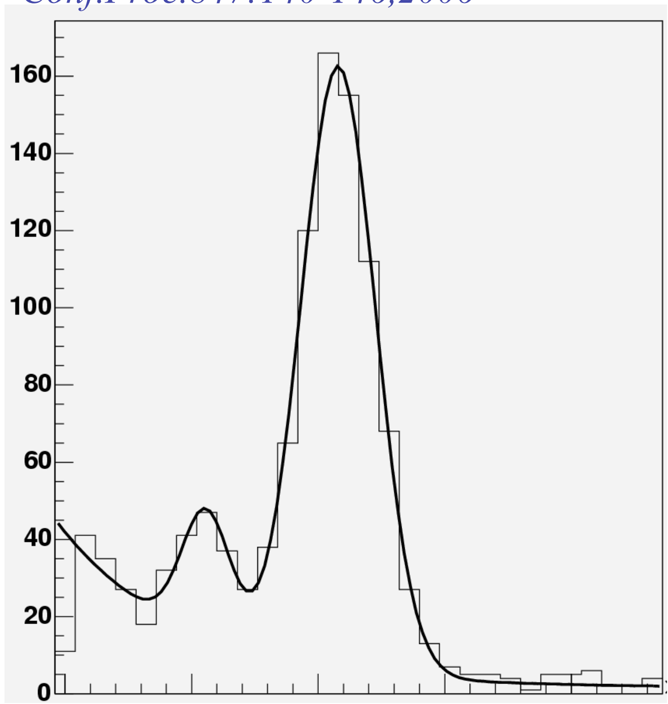


I. Gion

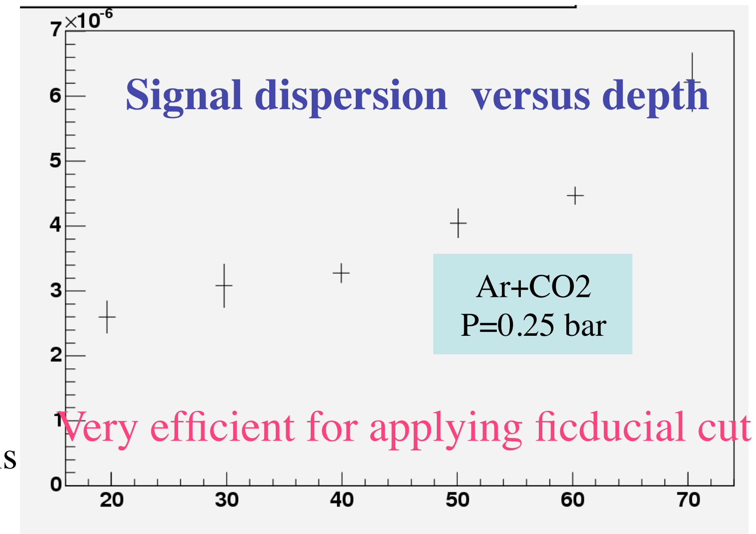
Early experimental results

S. Aune et al., AIP Conf.Proc.785:110-118,2005.
I. Giomataris et al.,Nucl.Phys.Proc.Suppl.150:208-213,2006.
I. Giomataris and J. D . Vergados, AIP Conf.Proc.847:140-146,2006





- Good stability.
- Detector working in sealed mode
- No absorption observed
- Signal integrity preserved after 60 cm drift.
- Not high E needed to achieve high gain.



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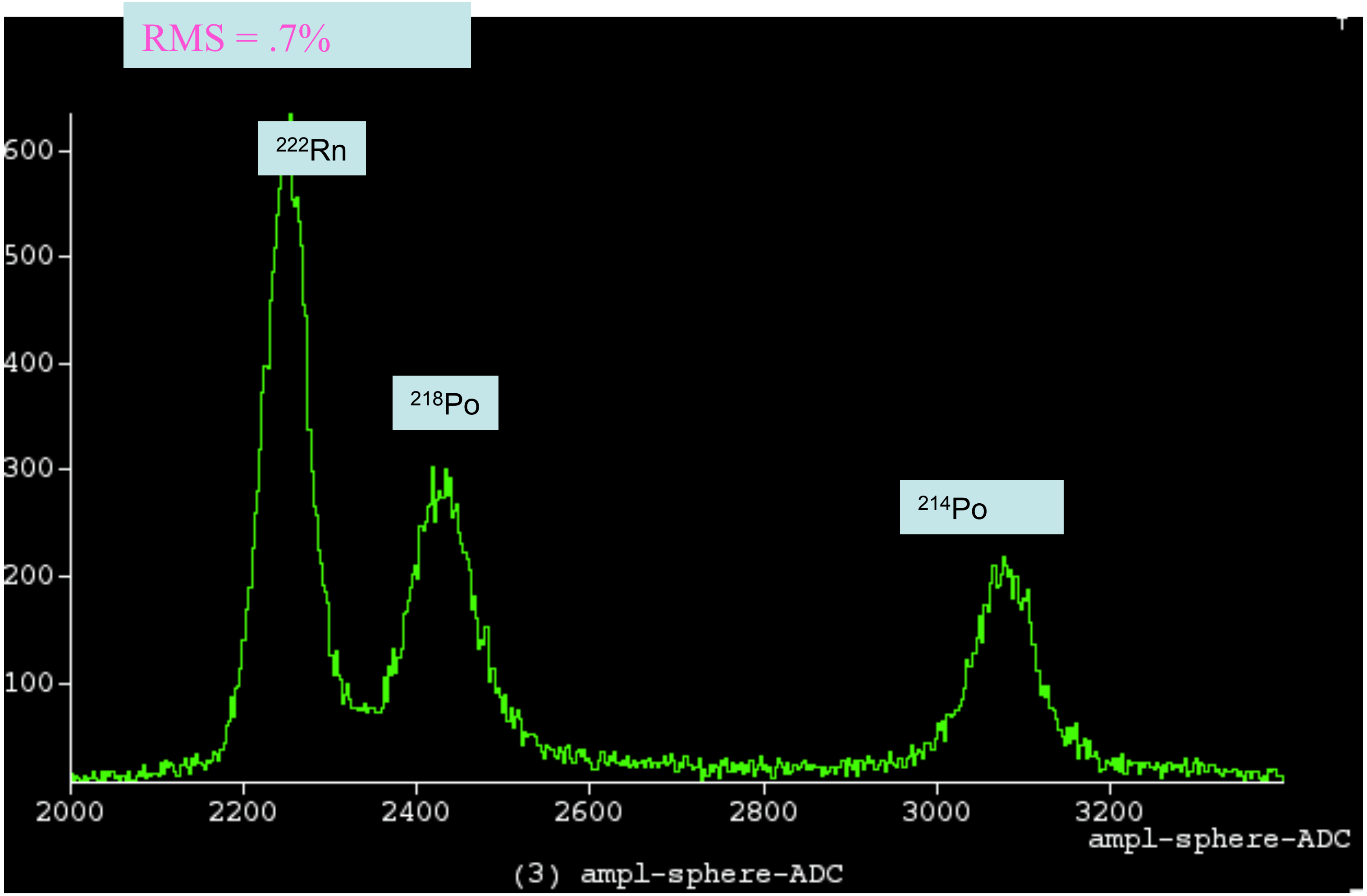
At high energy : Excellent energy resolution

Measured Radon gas emission spectrum with spherical detector



Energy resolution under amplification: a world record !!

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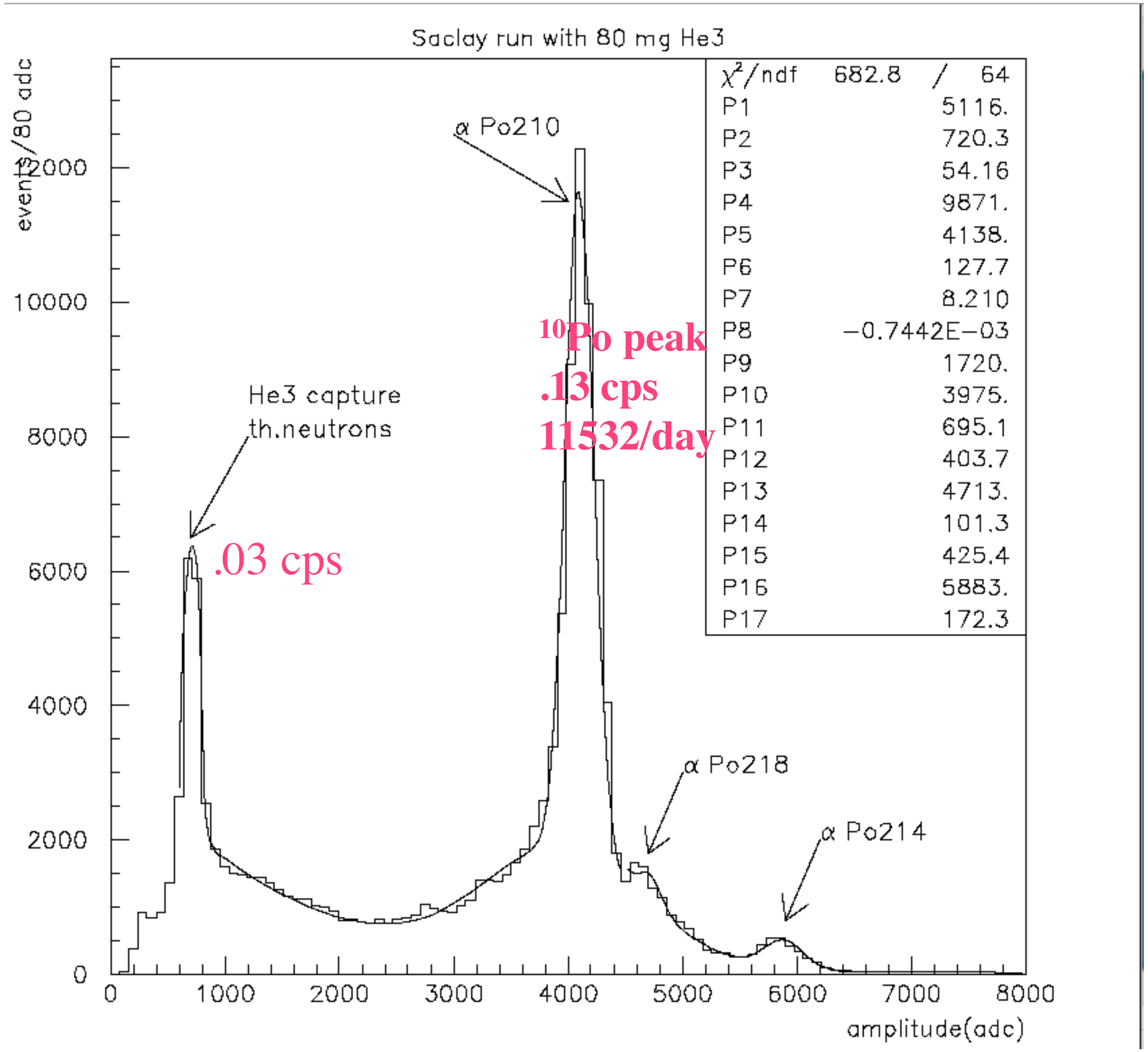
Neutron energy and flux measurement

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

Results at ground

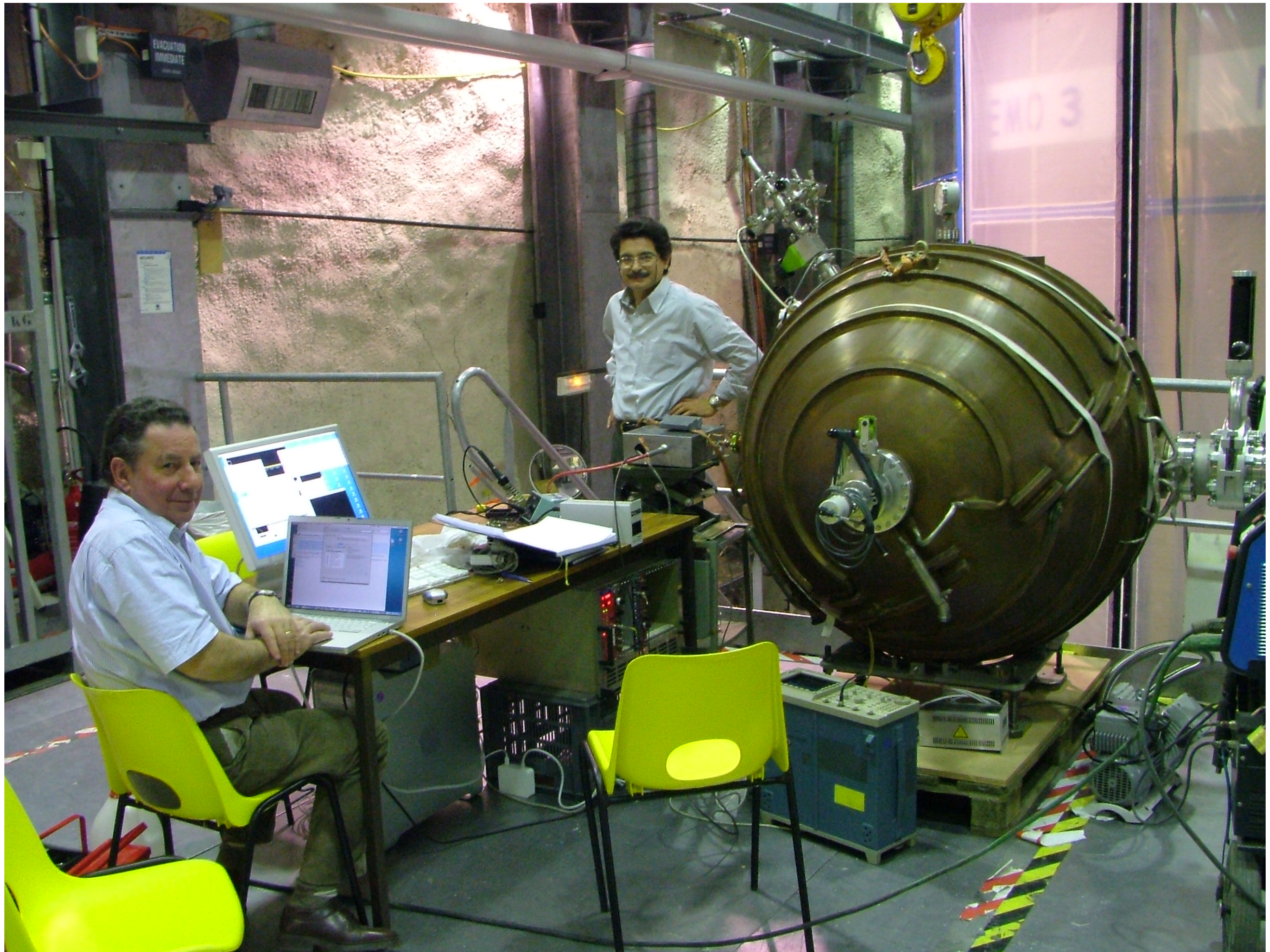
Saclay Ar-CH4(98-2)+80mg He3



In 2008
Detector installed in LSM laboratory

goal: measure thermal neutron background
and estimate fast neutron flux

with 10 gr ^{3}He



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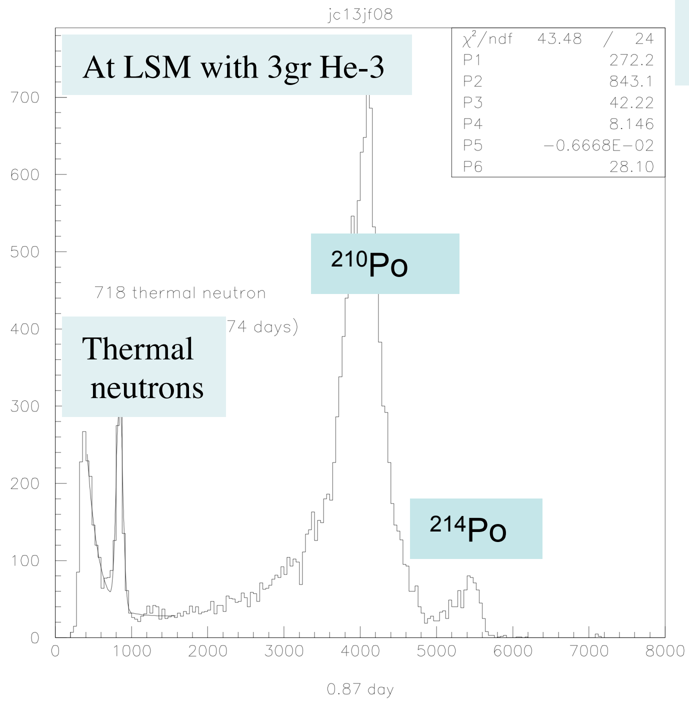
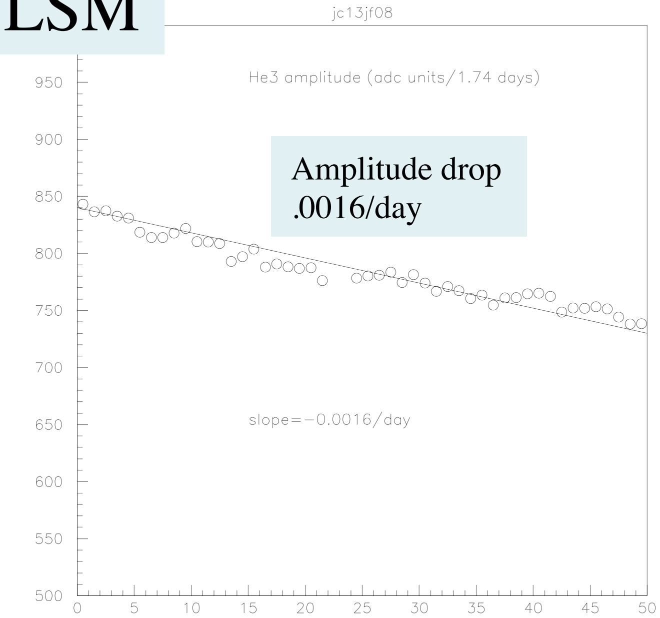
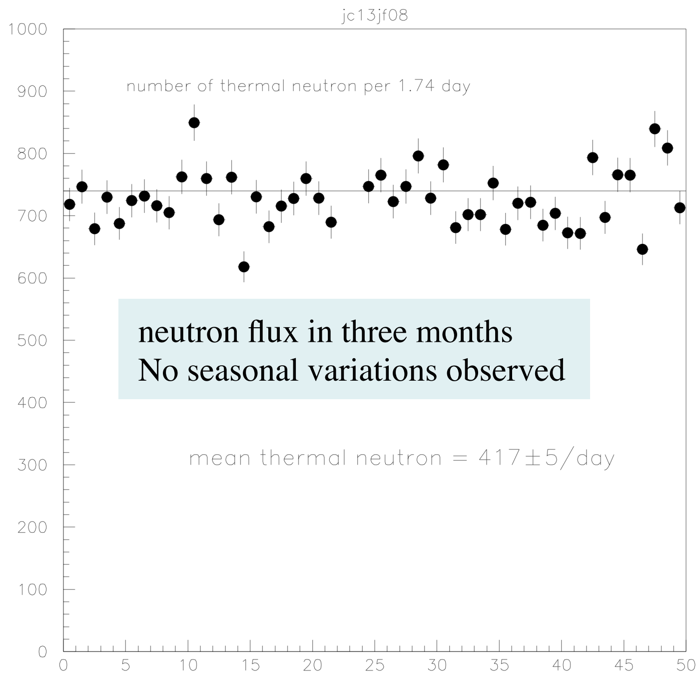
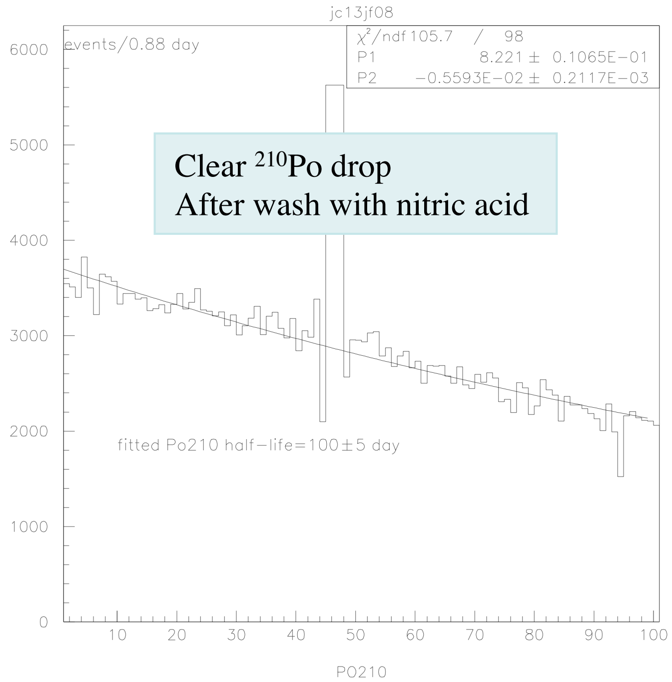
Results at LSM









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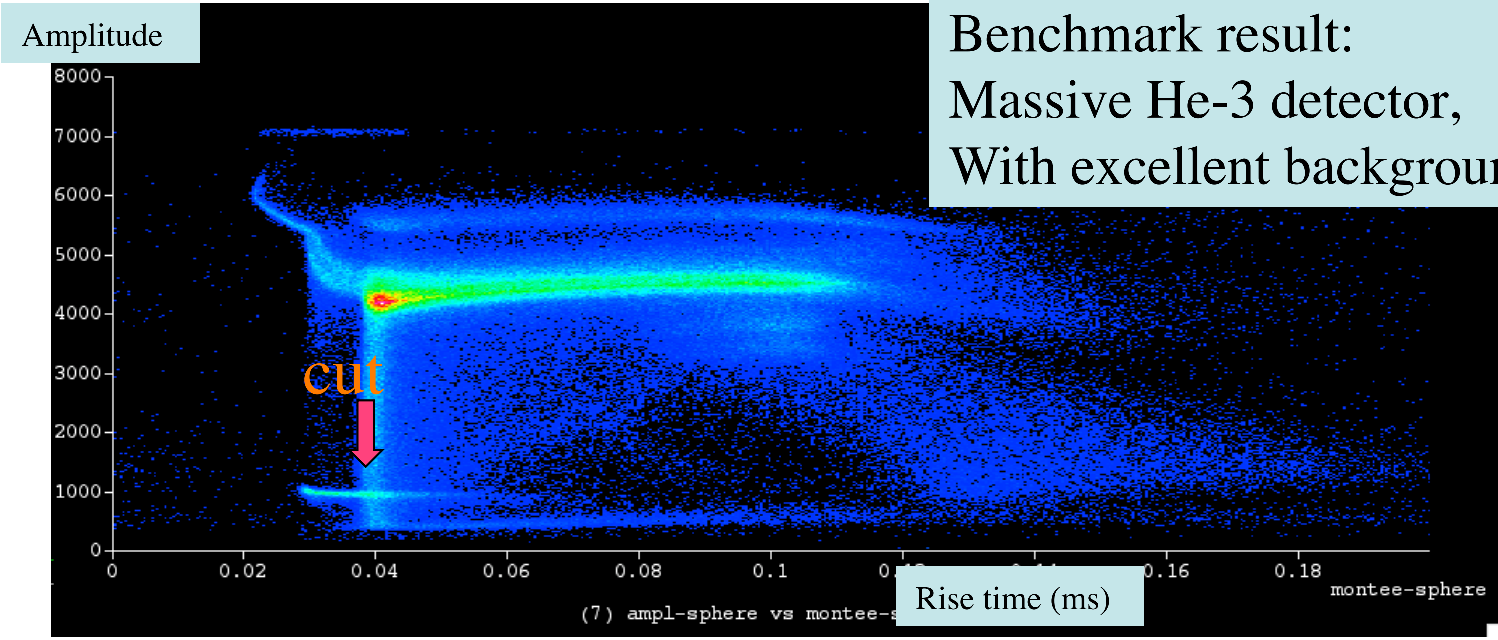
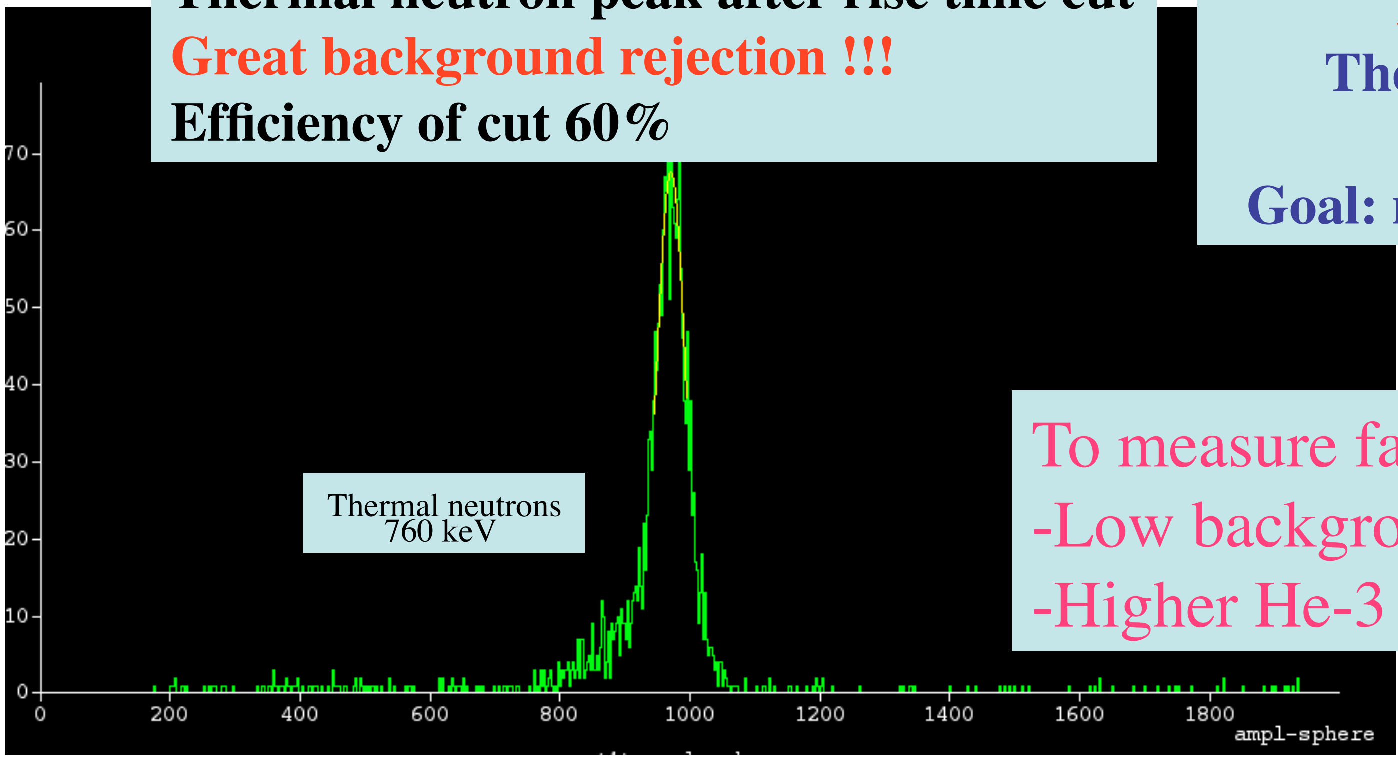
Benchmark result:
Massive He-3 detector,
With excellent background level



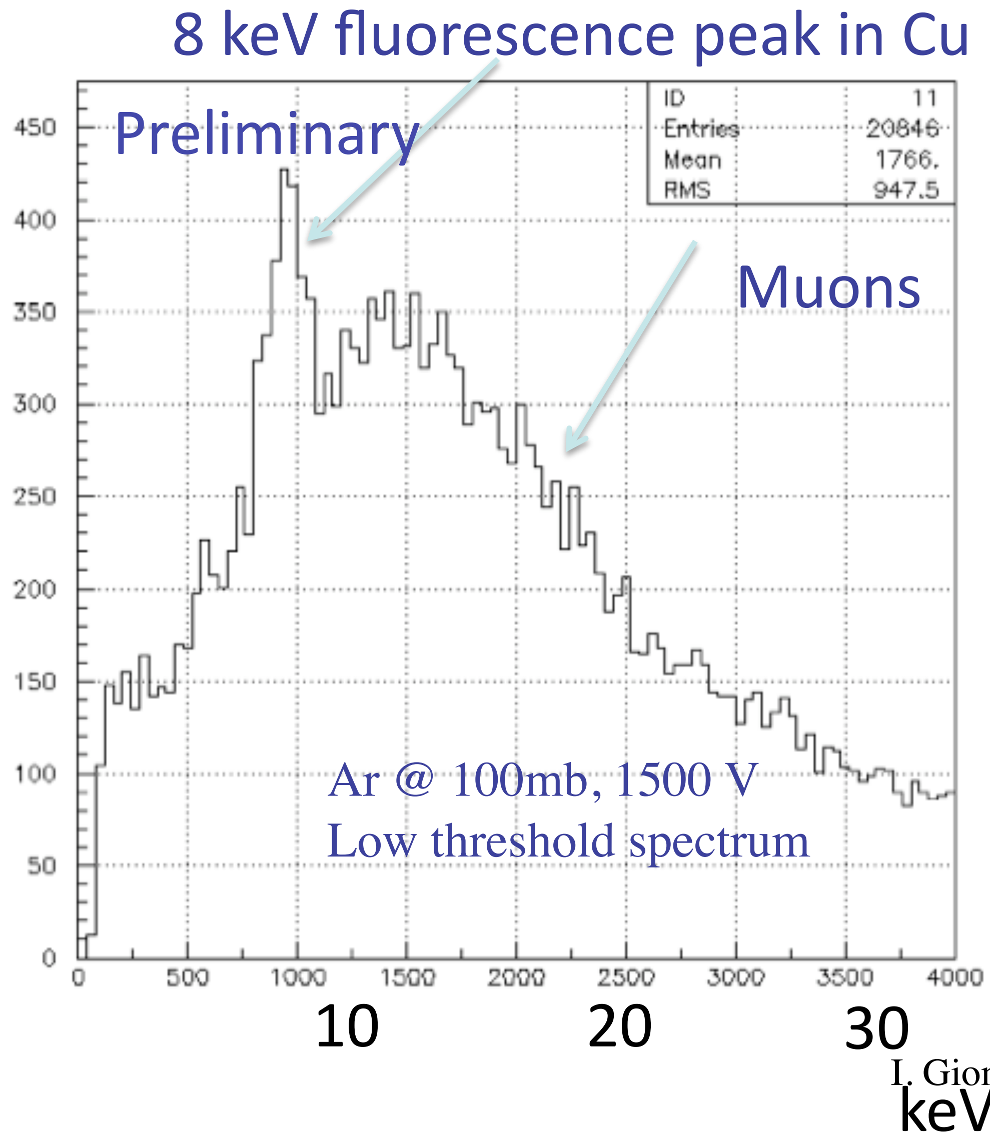
Thermal neutron peak after rise time cut
Great background rejection !!!
Efficiency of cut 60%

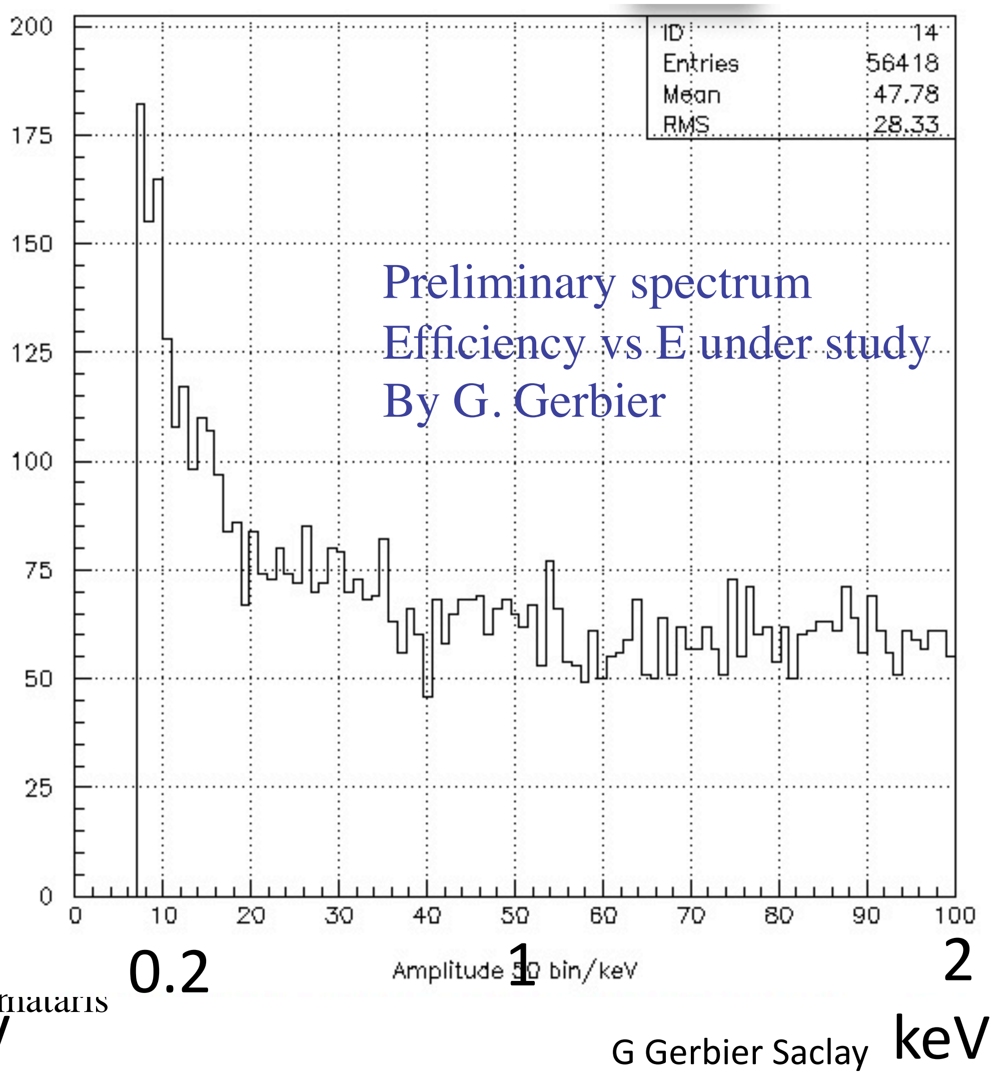


Results in LSM
Thermal neutron flux
$2.2x10^{-6}/cm^2/s$
Goal: measure fast neutrons

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

Run at low threshold with Saclay SPC





Low energy threshold application

Neutrino-nucleus coherent elastic scattering

$\nu + N \dashrightarrow \nu + N$

$\sigma \approx N^2E^2$, *D. Z. Freedman, Phys. Rev.D9(1389)1974*

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

A. Druikier, L. Stodolsky, Phys.Rev.D30:2295,1984

*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

Nuclear reactor measurement with present prototype

At 10 m from the reactor, after 1 year run ($2x10^7$s), assuming full detector efficiency:

- Xe ($\sigma \approx 2.16x10^{-40}$ cm^2), $2.2x10^6$ neutrinos detected, T_{max}=146 eV
- Ar ($\sigma \approx 1.7x10^{-41}$ cm^2), $9x10^4$ neutrinos detected, T_{max}=480 eV
- Ne ($\sigma \approx 7.8x10^{-42}$ cm^2), $1.87x10^4$ neutrinos detected, T_{max}=960 eV

Challenge : Very low energy threshold < 100 eV is required

We need to calculate and measure the quenching factor

Application : Remote control of nuclear reactors

Background must be kept as low as possible

Supernova detector

Through neutrino-nucleus coherent elastic scattering

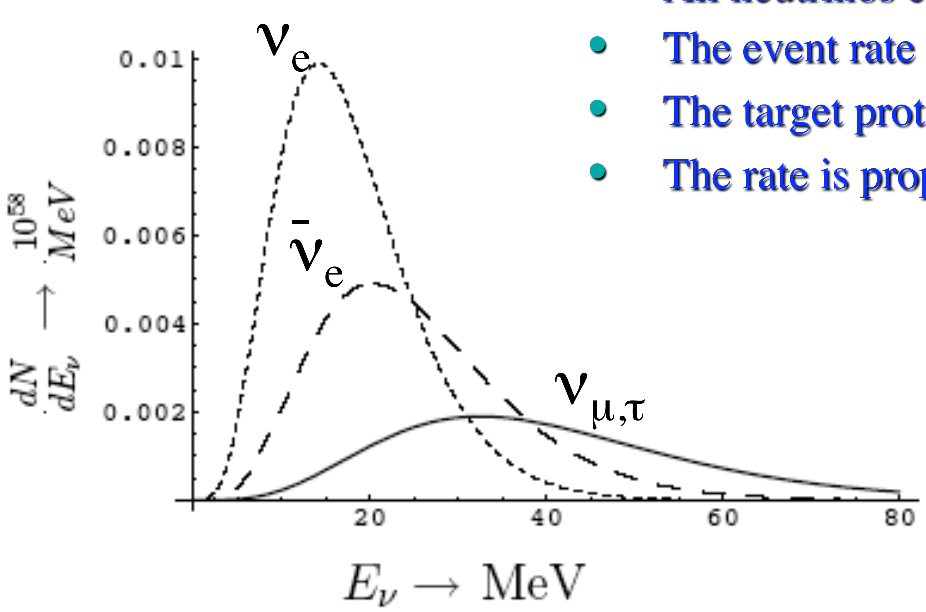
Supernova neutrino detection with a 4 m spherical detector

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

For E_ν = 10 MeV $\sigma \approx N^2E^2 \approx 2.5\text{x}10^{-39}$ cm^2, T_{max} = 1.500 keV

For E_ν = 25 MeV $\sigma \approx 1.5\text{x}10^{-38}$ cm^2, T_{max} = 9 keV

Expected signal : about 100 events (Xenon at p=10 bar) per galactic explosion



Advantages of a Neutral Current Detector

- All neutrinos contribute
- The event rate is not affected by neutrino oscillations
- The target proton contribution is negligible, but all neutrons contribute
- The rate is proportional to N^2

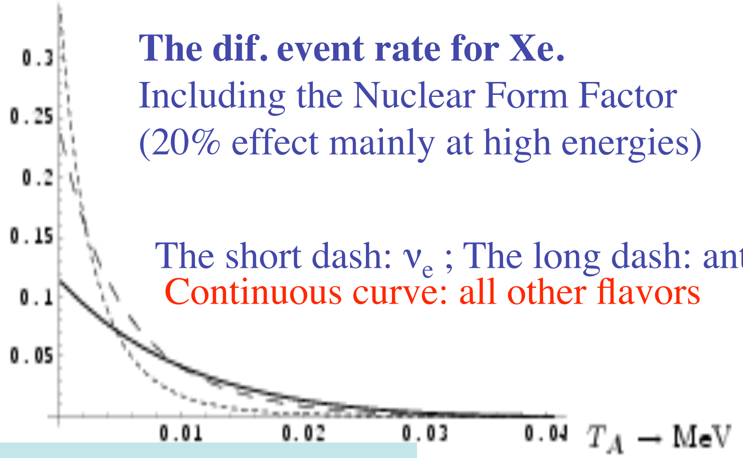
Supernova detection sensitivity

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



The dif. event rate for Xe.
Including the Nuclear Form Factor
(20% effect mainly at high energies)

The short dash: ν_e ; The long dash: anti- ν_e ;
Continuous curve: all other flavors

Sensitivity for galactic explosion

For p=10 Atm, R=2m, D=10 kpc, U_ν =0.5x10^{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

The proposed Supernova demonstrator

- 4 m in diameter
- 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

- Establish stability and robustness of the system at high pressure and low energy threshold < 100 eV
- Improve background level at the sub-keV energy range (first studies with a smaller prototype under study)
- 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

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Pointing?

Neutral current detector has not pointing capability

In the case of a large number of such detectors direction could be provided by triangulation

Synergy with other Supernova detectors?

(super-K, kamLAND, LVD, Borexino, Icarus, Baksan, Mini-BooNe)

(Hyper-K, MEMPHYS, DUSEL,LENA, CLEAN, NOvA, OMNIS, SNO+, HALO, MOON)

Yes,

- Neutral current is sensitive to all neutrino flavors – complementarity
- In coincidence, they would improve extra galactic sensitivity

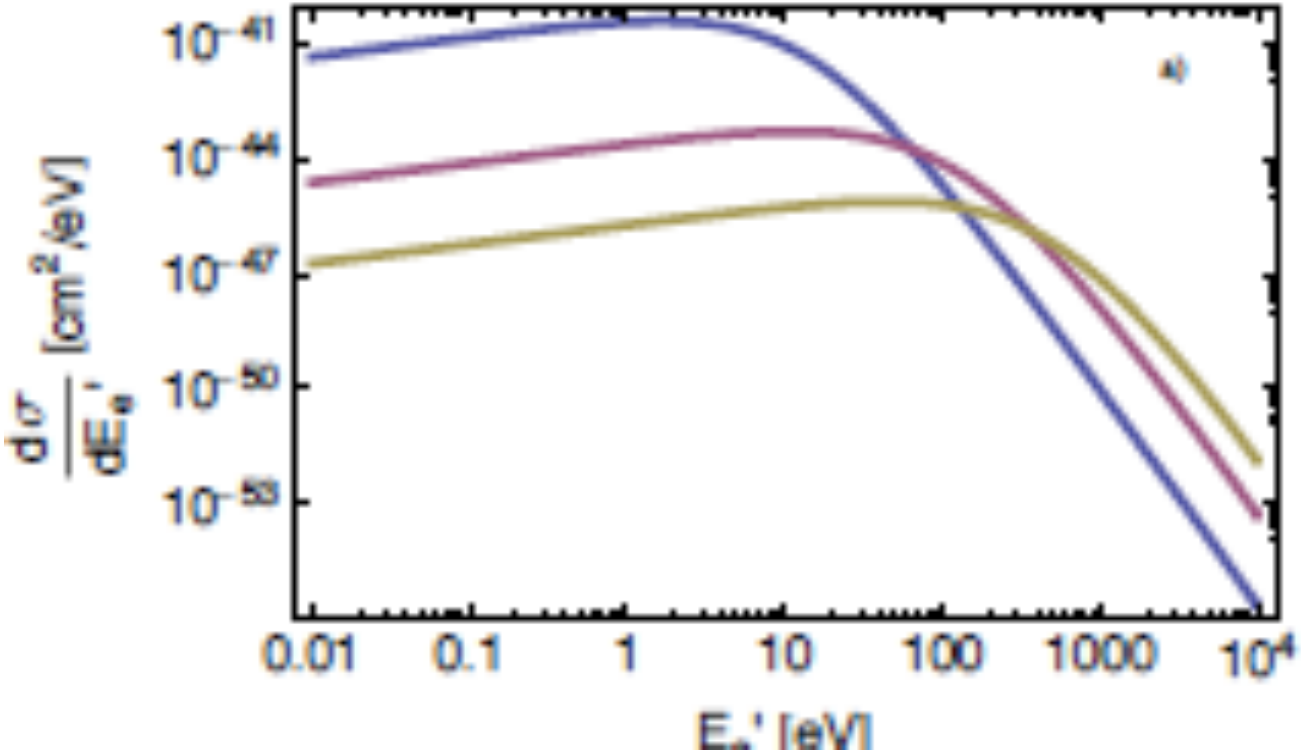
Extragalactic sensitivity ?

To tackle Andromeda neutrino bursts (700 kpc) we need:

- a world wide network of several hundreds such detectors
- background level of a few counts/hour below 1 keV

Additional physics

- Dark matter search through very low energy threshold < 100 eV



A. Dedes et al., arXiv.org/pdf/0907.0758

Summary

- A new spherical detector is born and developed
- Good energy resolution, robust and stable
- A first prototype is operating in LSM
- A low cost Supernova demonstrator is proposed
- A world wide network of several detectors is advetized