The spherical detector

September 2008 Glascow

- Spherical TPC project and motivation
- Second innovation: a spherical proportional counter
- Electric field and transport
- Laboratory results
- Neutron measurements at ground and underground
- Applications

I. Giomataris

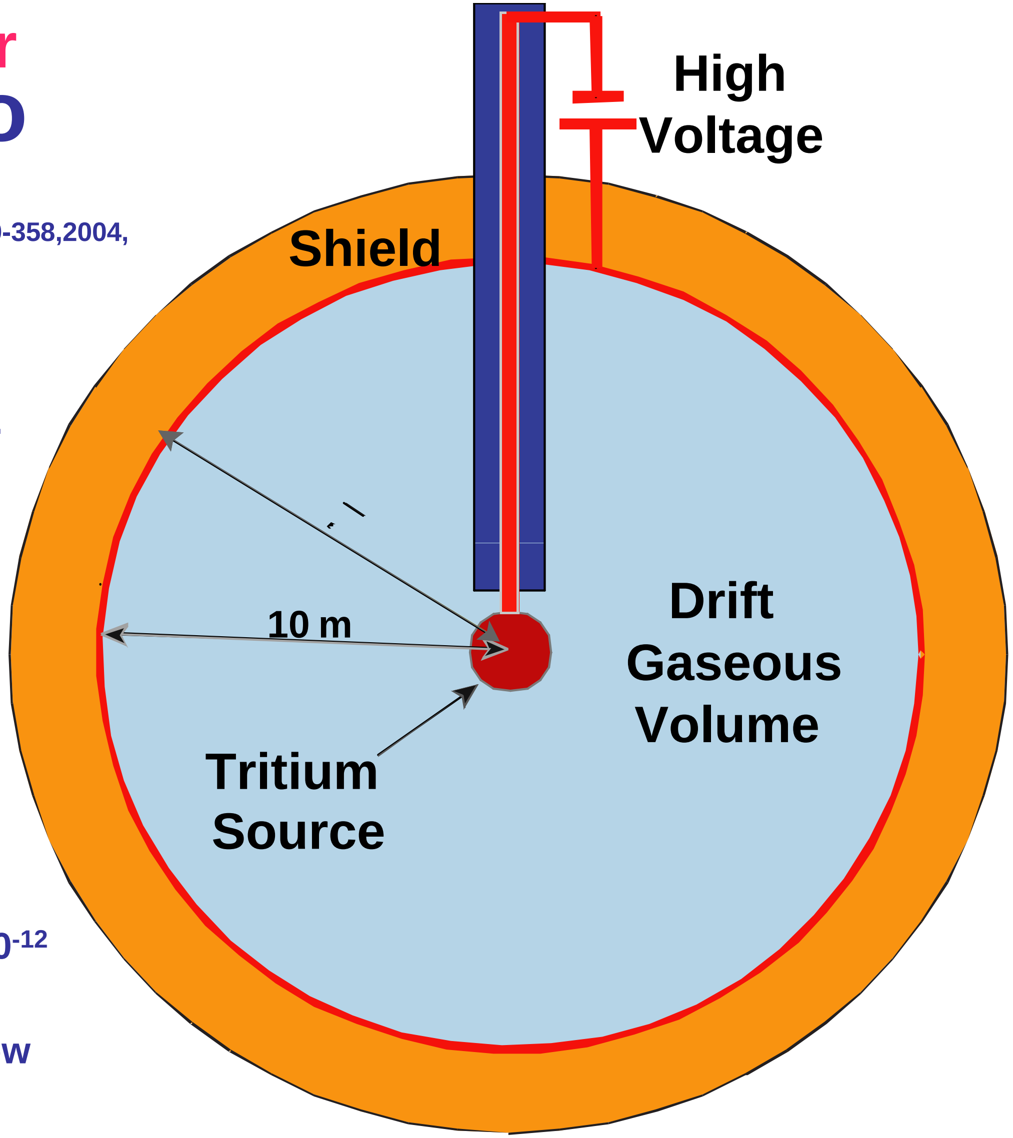
Idea of a spherical detector

Low energy neutrino search

I. Giomataris, J.D. Vergados, Nucl.Instrum.Meth.A530:330-358,2004,

- Large Spherical TPC 10 m radius
- 200 MCi tritium source in the center
- Neutrinos oscillate inside detector volume L_{23}=13 m

$$P(\nu_e \rightarrow \nu_{\mu,\tau}) = \sin^2 2\theta_{13} \sin^2 \pi \frac{L}{L_{23}}$$



Objectives

- Measure θ_{13} (systematic free)
- Neutrino magnetic moment studies << 10^{-12} μ_B
- Measurement of the Weinberg angle at low energy

Challenge : detect electron recoils down to T=100 eV (T_{max}=1.27 eV)
Low background level (to be measured and subtracted)
Measure the radial depth of the interaction

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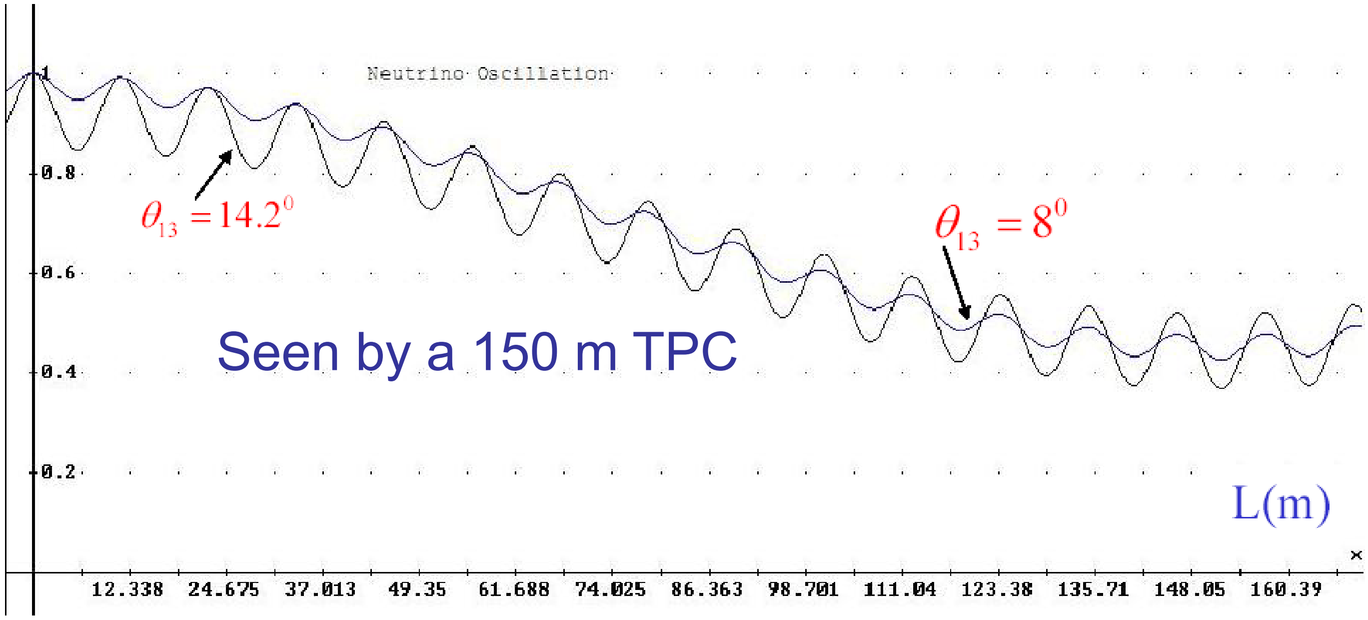
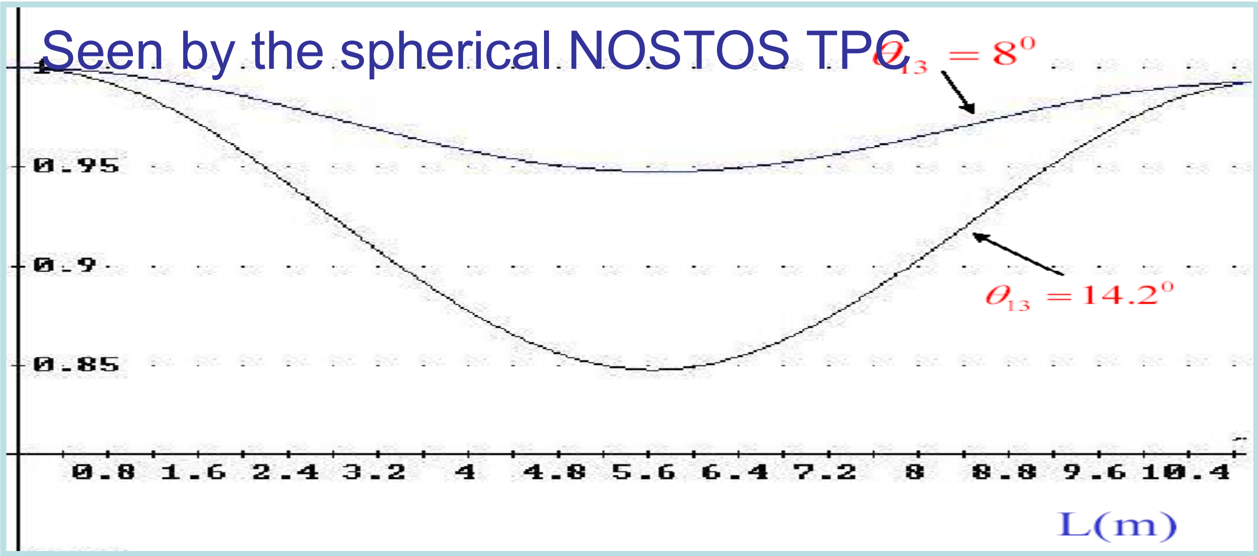
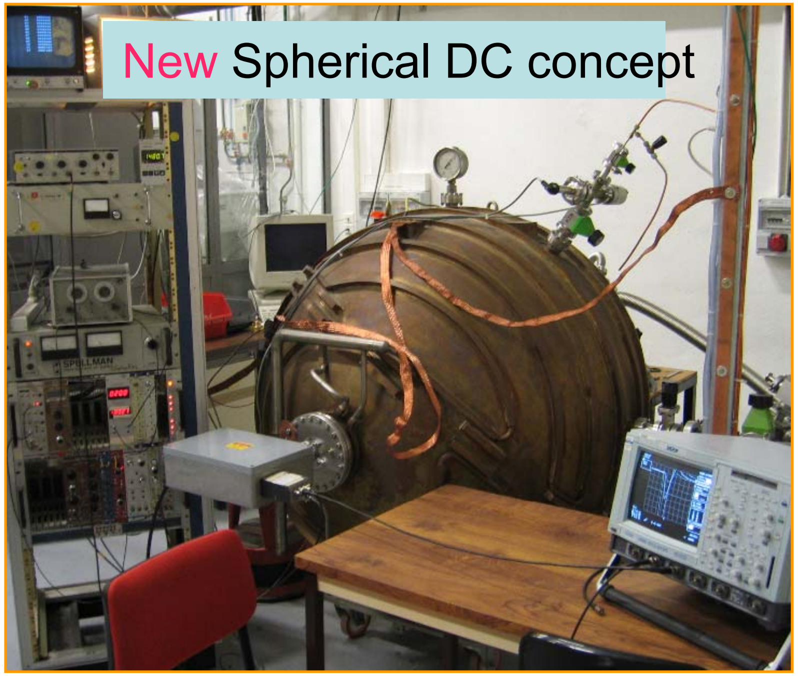
Room size oscillations

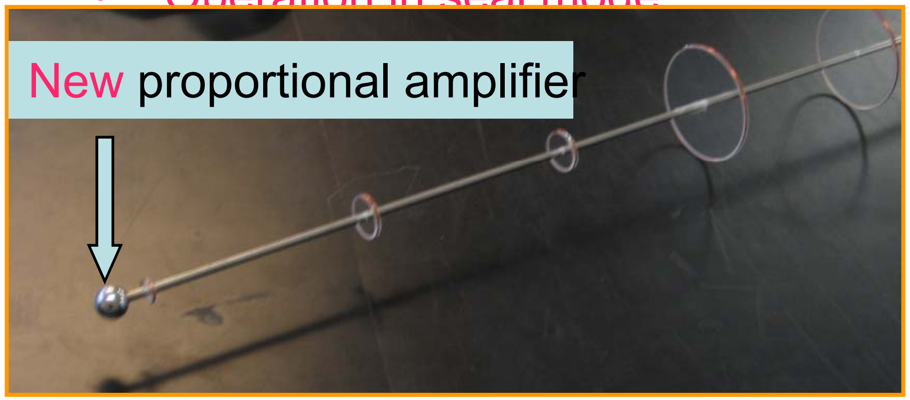


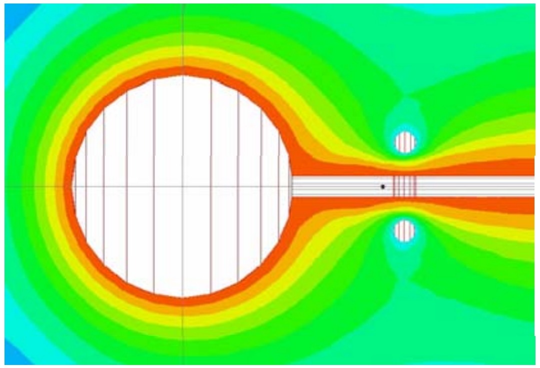


First prototype:
Getting a large detector out of a LEP cavity

- D=1.3 m
- V=1 m^3
- Spherical vessel made of Cu (6 mm thick)
- P up to 5 bar possible (up to 1.5 tested up to now)
- Vacuum tight: ~10^{-7} mbar (outgassing: ~10^{-9} mbar/s)
- Operation in seal mode







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Radial TPC with spherical proportional counter read-out

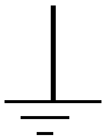
Saclay-Thessaloniki-Saragoza

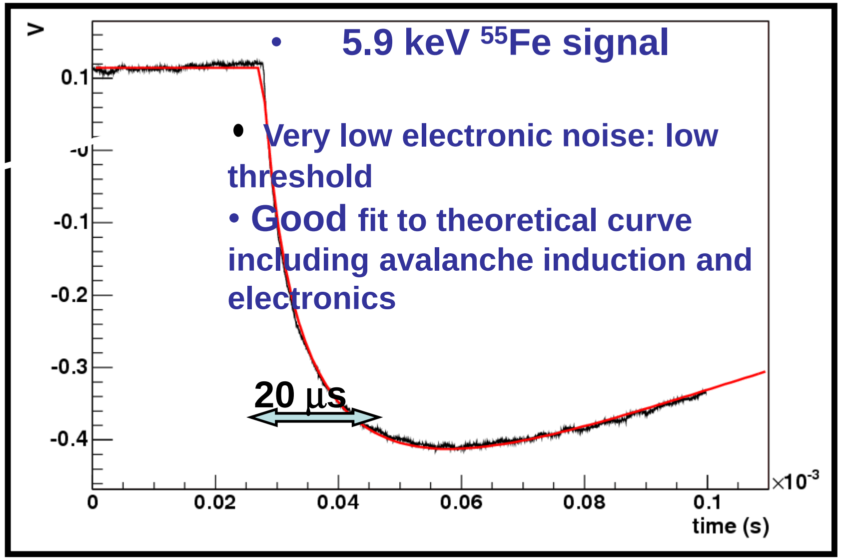
A Novel large-volume Spherical Detector with Proportional Amplification read-out, I. Giomataris *et al. Jul 2008. 12pp, e-Print: arXiv:0807.2802 [physics.ins-det]*

$E = A/R^2$

QuickTime™ and
decompressor
are needed to see this picture.

15 mm





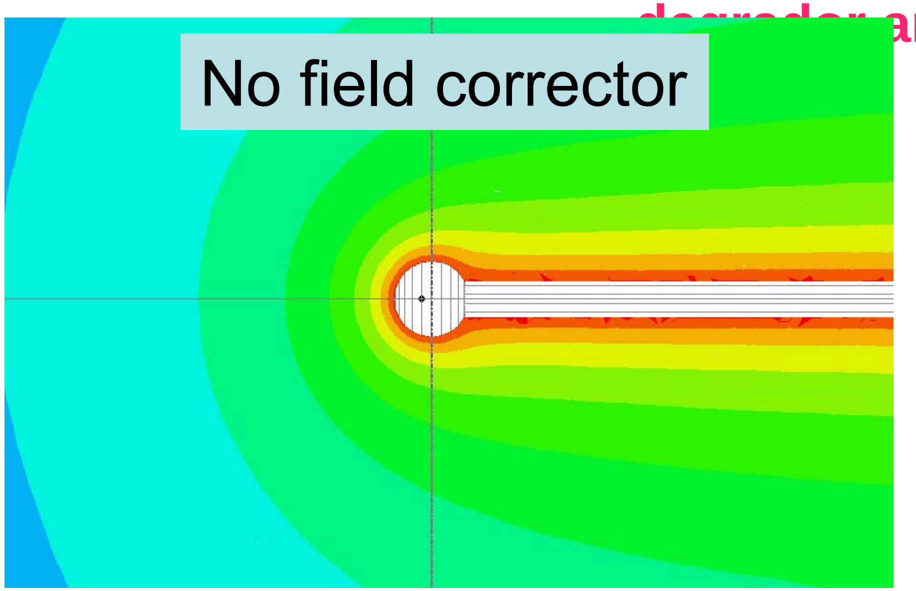
- **Simple and cheap**
- **single read-out**
- **Robustness**
- **Good energy resolution**
- **Low energy threshold**

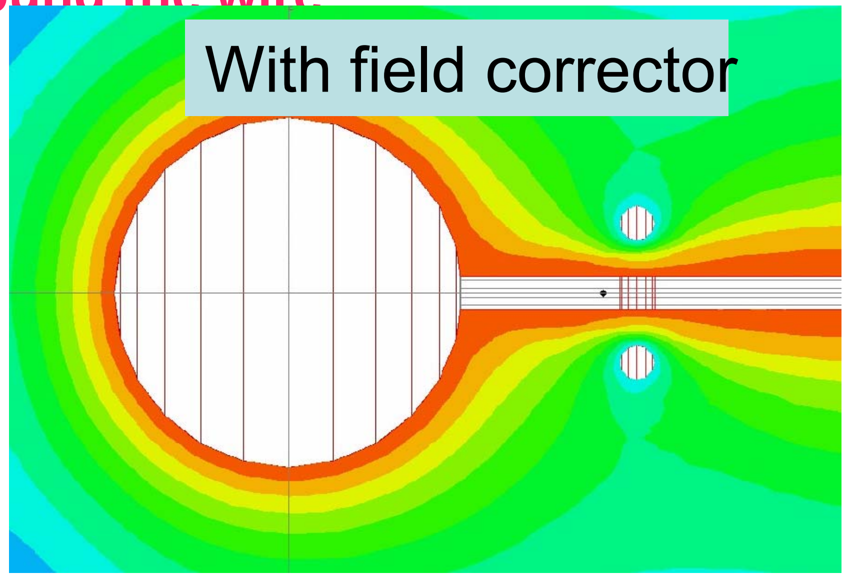
Electrostatics deal

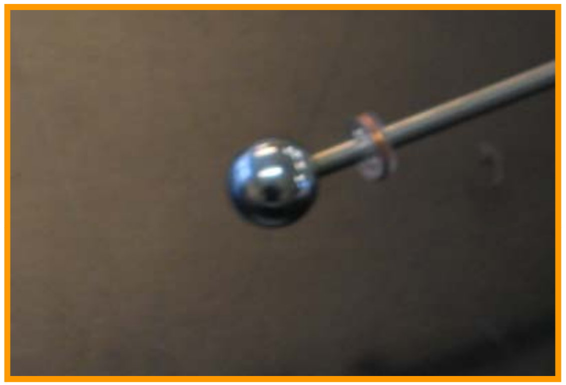
How to keep radial field

Ideal solution: field $1/R^2$

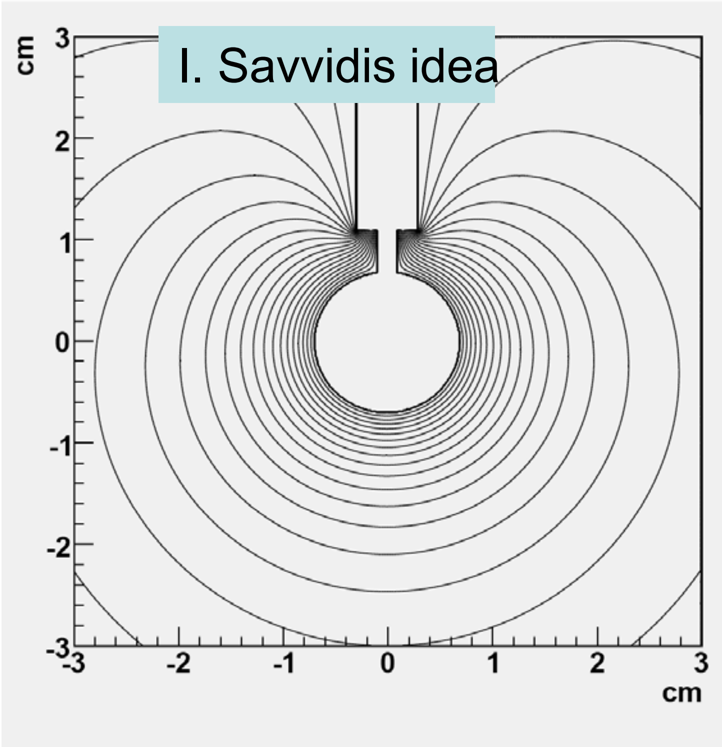
degrader around the wire

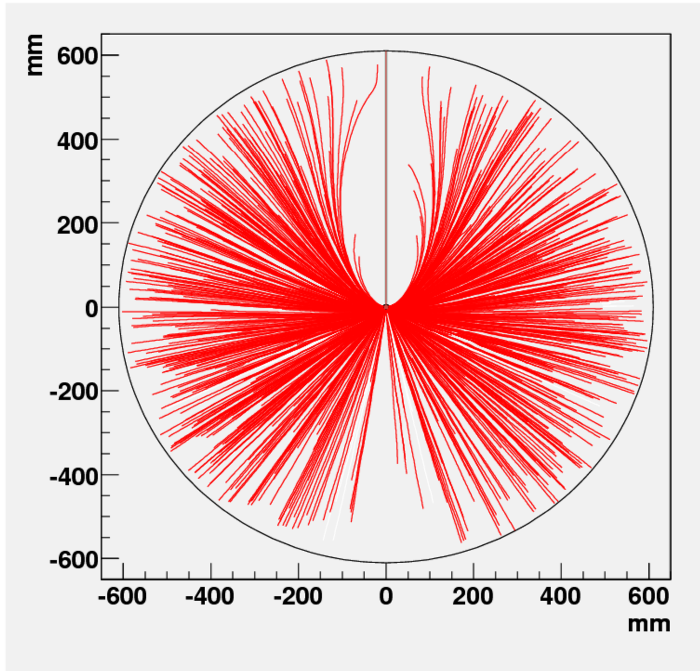






A simple electrostatic solution



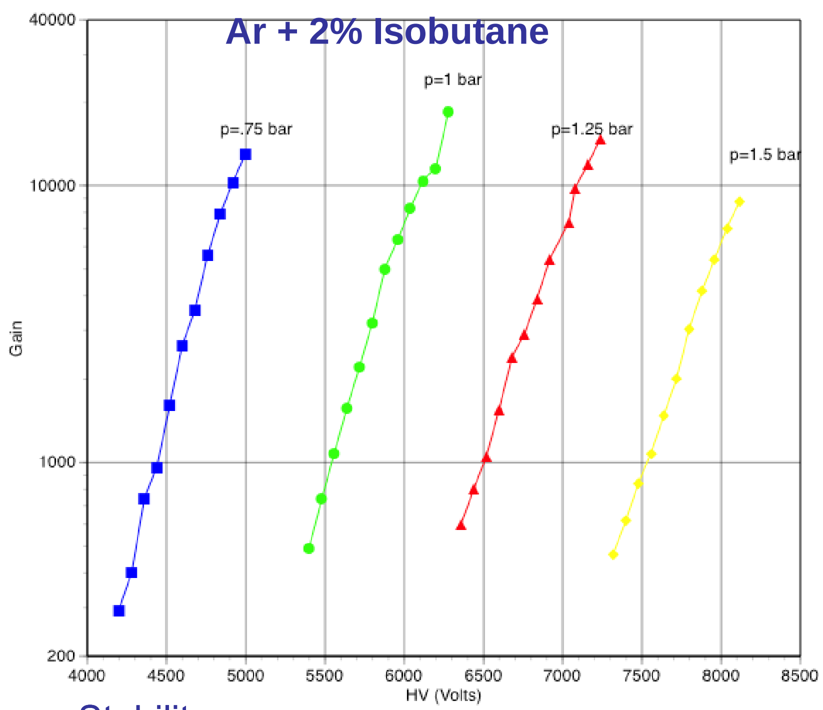


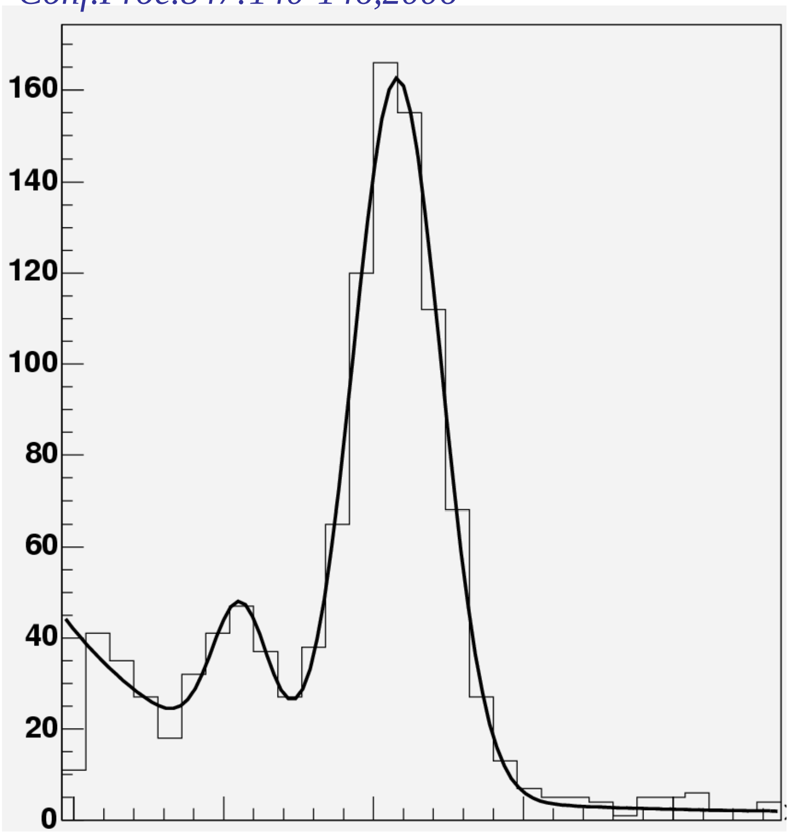
New idea by I. Giomataris and I. Irastorza
Combines also second voltage corrector:
"umbrella field corrector"
Big improvement in stability

I. Giomataris

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





- Stability:
  - –tested up to ~3 months.
  - –No circulation of gas. Detector working in sealed mode. (1 pass through an oxysorb filter)
- No absorption observed
  - –Signal integrity preserved after 60 cm drift.
  - –Not high E needed to achieve high gain.

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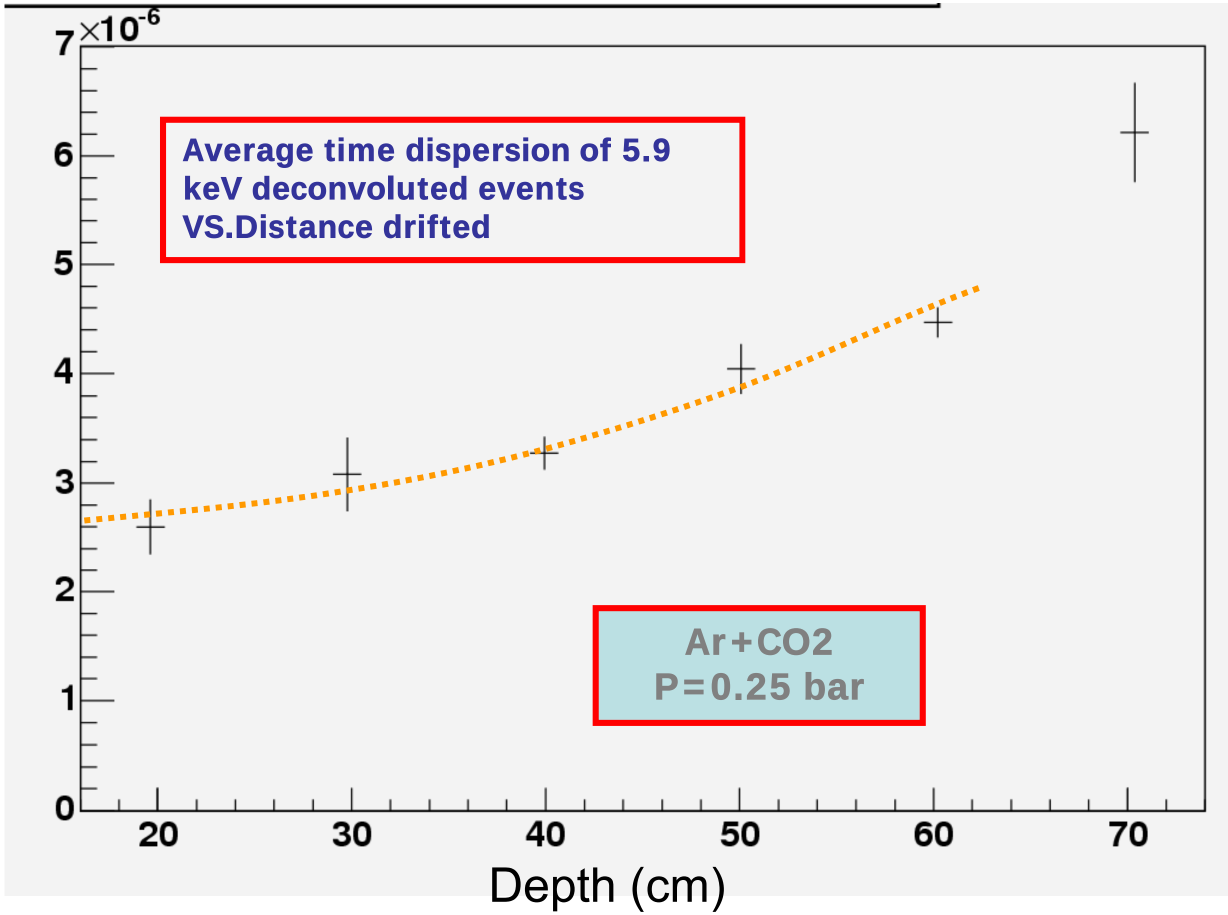
Signal dipersion with depth

to estimate distance of interaction

- Even with a very simple (and slow) readout, we have proved the use of dispersion effects to estimate the position of the interaction (at least at ~10 cm level).
- Further test are under preparation to better calibrate (external trigger from Am source)



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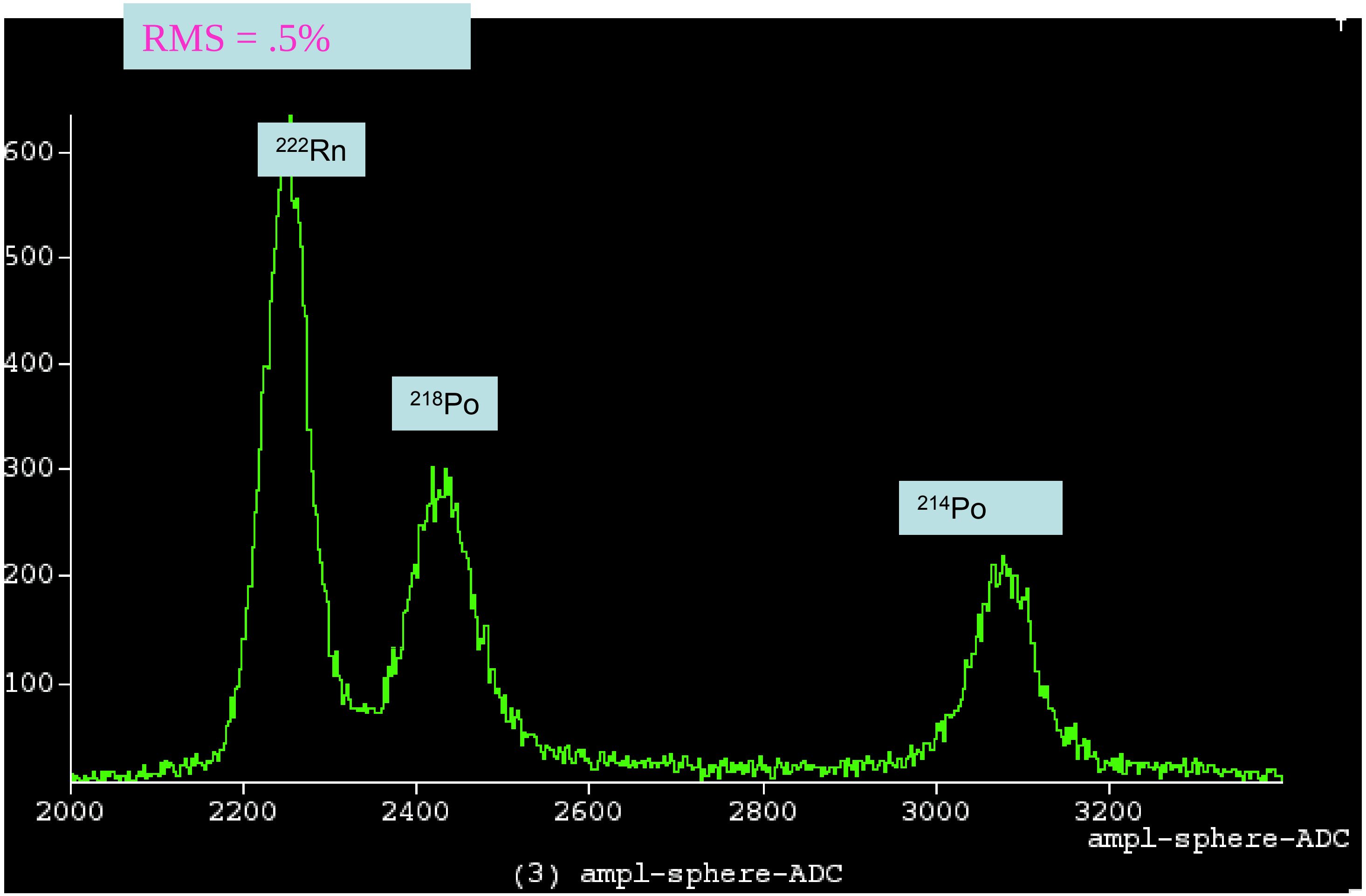
NEW Excellent energy resolution

Measured Radon gas emission spectrum with spherical detector



Energy resolution under amplification: a world record !!

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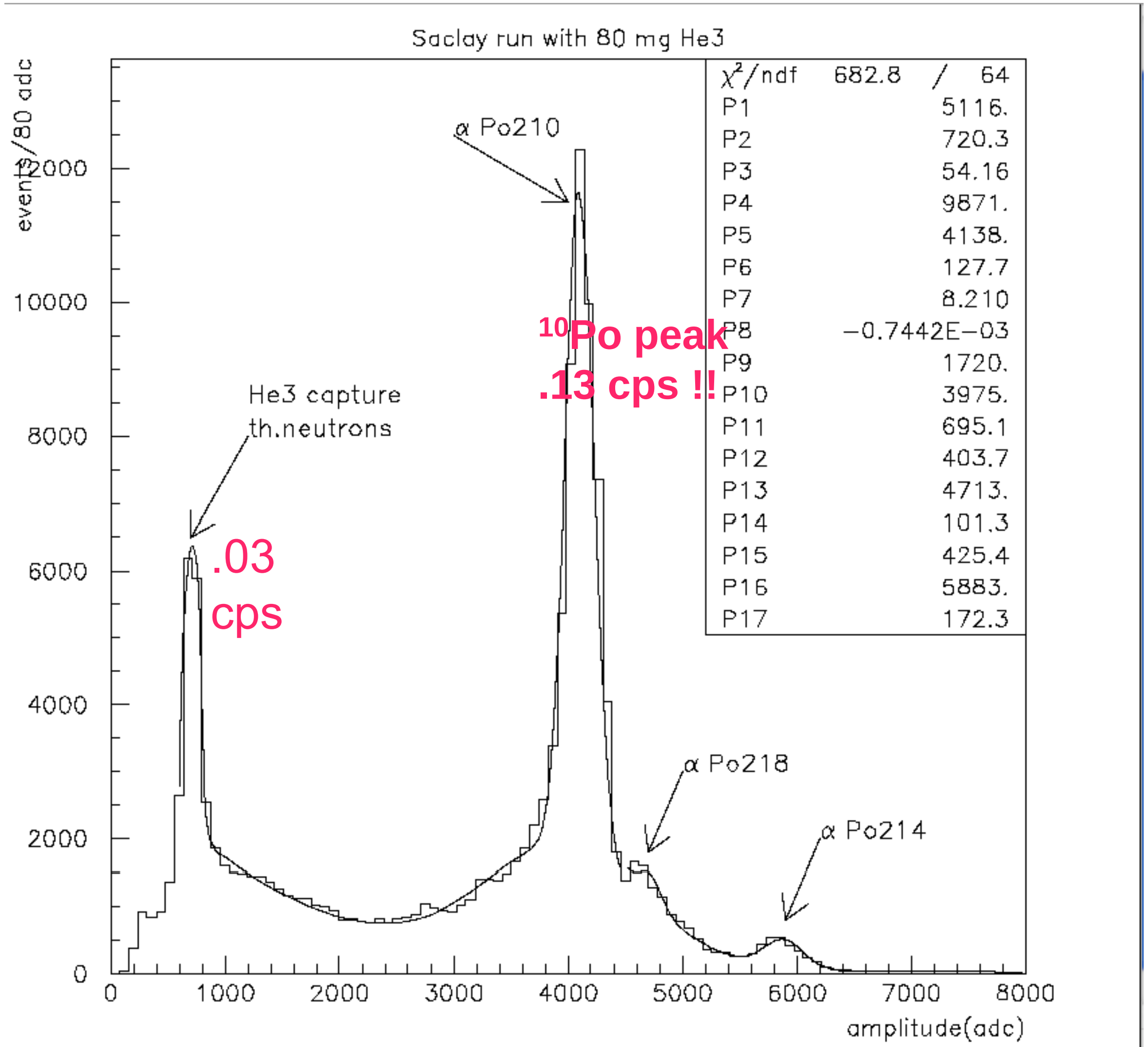
Neutron energy and flux measurement

$^3He + n \longrightarrow$ $^1H + {}^3H$ (Q= 760 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

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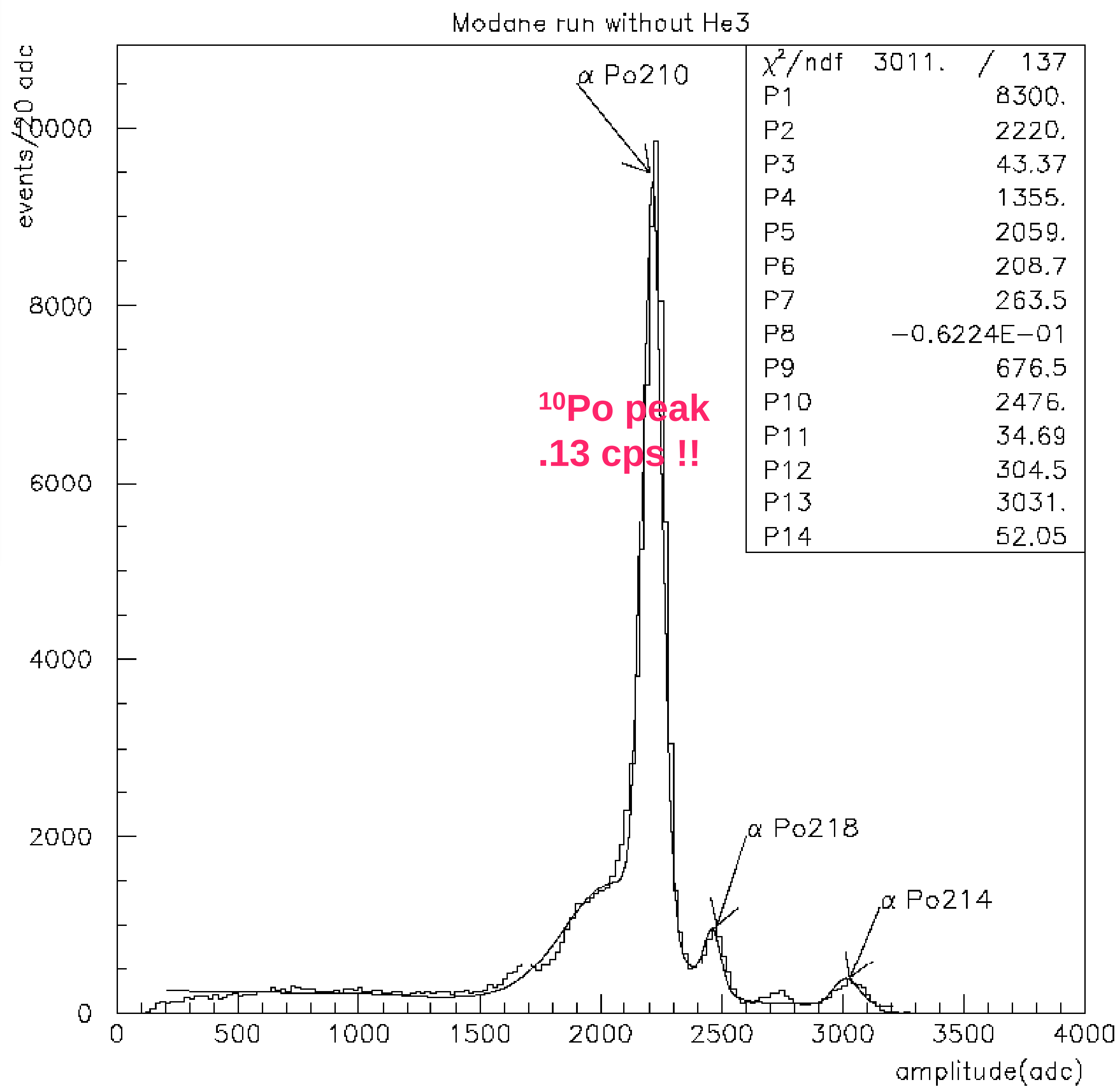
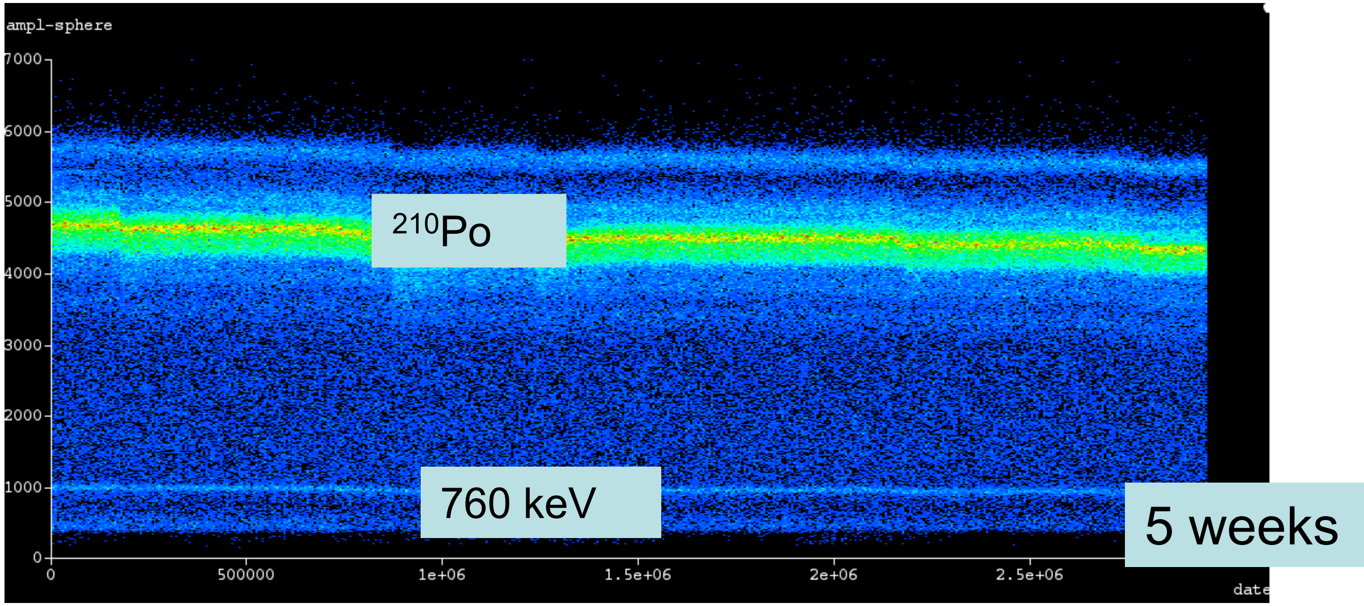
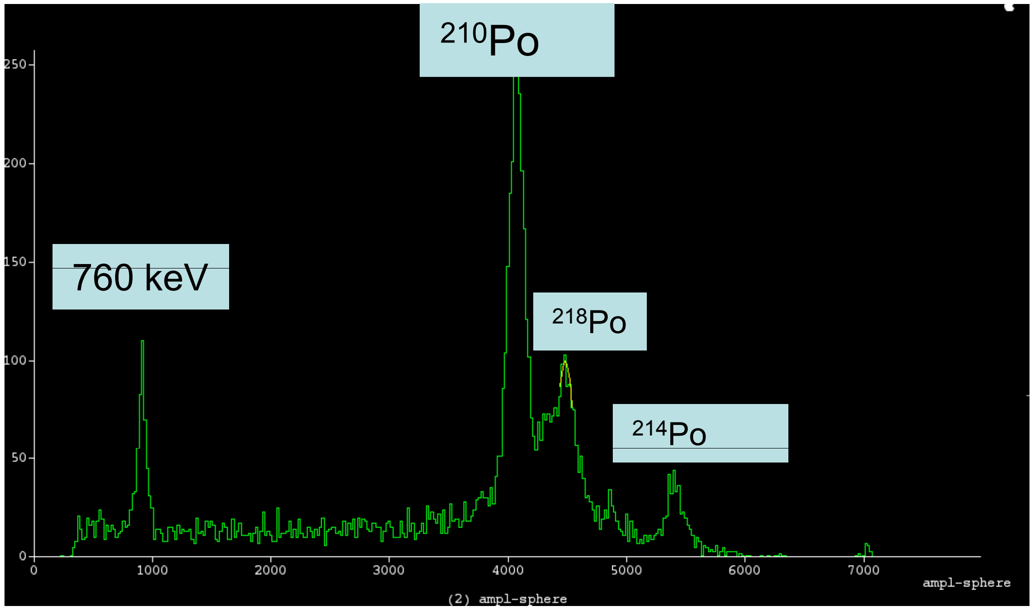
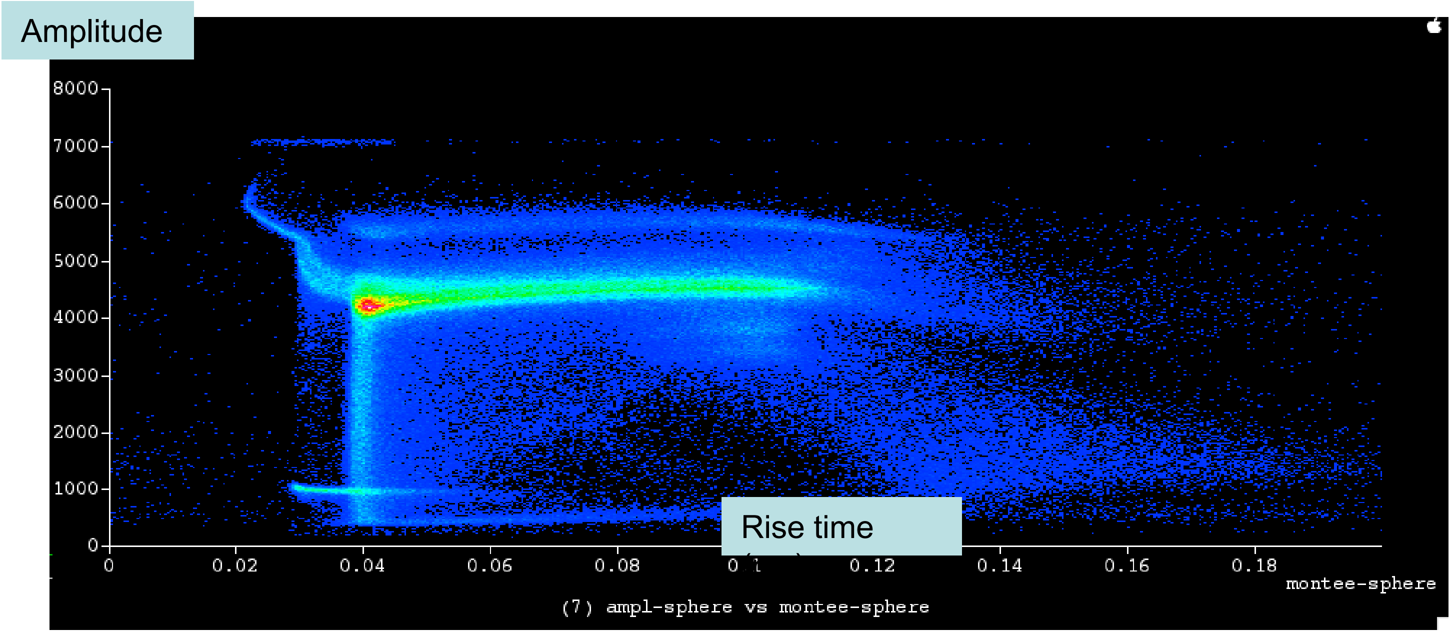
LSM-Modane, same sphere, same gas, without He3

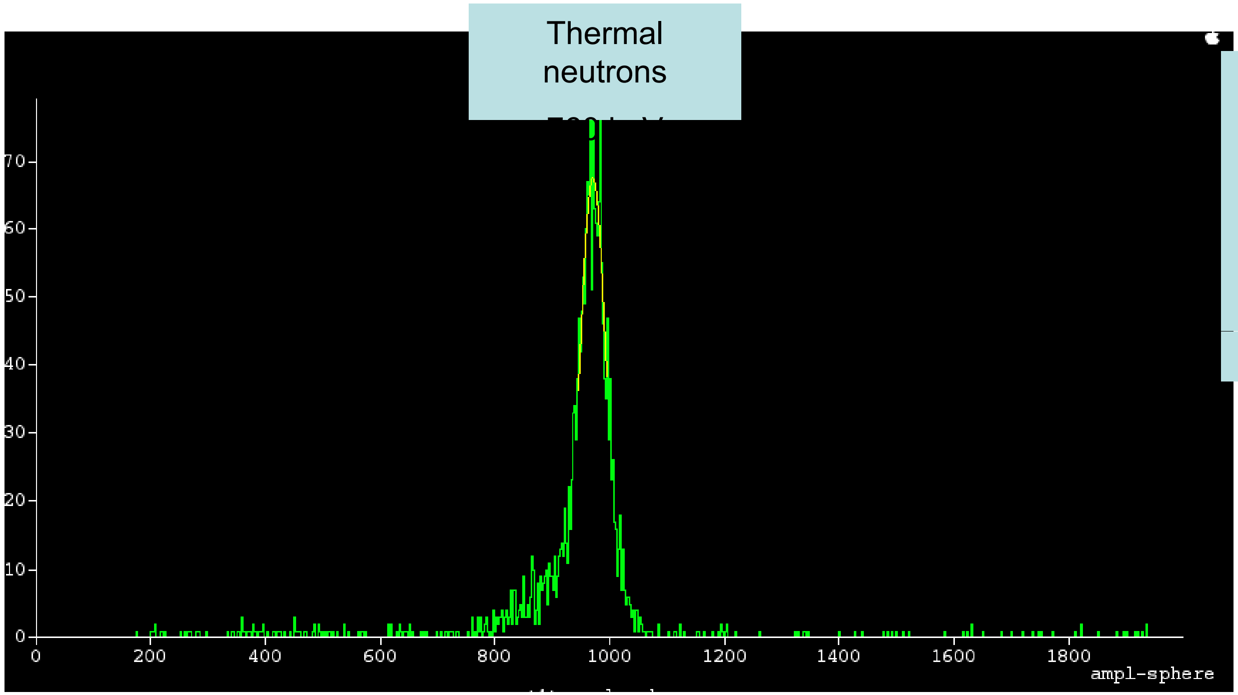


3 g of ^3He have been introduced on June 30









Results in LSM (preliminary)

Thermal neutron flux

$3{,}6 \times 10^{-6}/cm^2/s$

Short term
Develop the spherical detector and study Neutrino-nucleus coherent elastic scattering

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

*JI **Collar**, Y Giomataris - Nuclear Inst. and Methods in Physics Research, A, 2001*

H. T. Wong, arXiv:0803.0033-2008

*PS Barbeau, JI **Collar**, O Tench - Arxiv preprint nucl-ex/0701012, 2007*

Nuclear reactor measurement sensitivity 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, E_{max}=146 eV
- Ar ($\sigma \approx 1.7x10^{-41}$ cm^2), $9x10^4$ neutrinos detected, E_{max}=480 eV
- Ne ($\sigma \approx 7.8x10^{-42}$ cm^2), $1.87x10^4$ neutrinos detected, E_{max}=960 eV

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

How to get simple and cheap Supernova counter

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

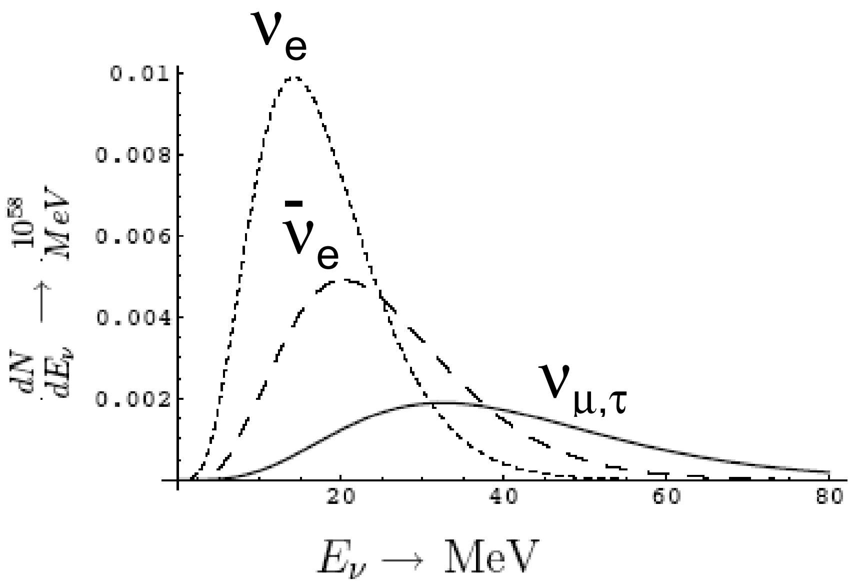
For E_ν = 10 MeV $\sigma \approx N^2E^{\,2} \approx 2.5\text{x}10^{-39}$ cm^2, T_{max} = 1.500 keV

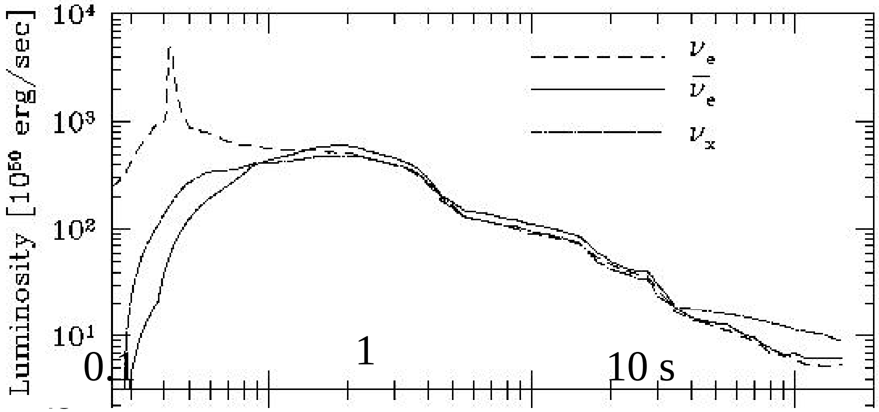
For E_ν = 25 MeV $\sigma \approx 1.5\text{x}10^{-38}$ cm^2, T_{max} = 9 keV

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

Idea : A European or 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





Conclusions

- **A new spherical detector is born and developed**
- **Good energy resolution, robust and stable**
- **Many applications in low energy neutrino physics are open**
- **Massive high-sensitivity neutron detector**
- **It could provide simple and cheap Supernova detection**
- **Neutron flux measurement in LSM is going on**