The spherical detector and neutrinos from Supenova

30 Juin 2008 Aussois, Savoie, France

- **Spherical TPC project and motivation**
- **Second innovation: a spherical proportional counter**
- **Laboratory results and neutron detection**
- **Supernova detection**

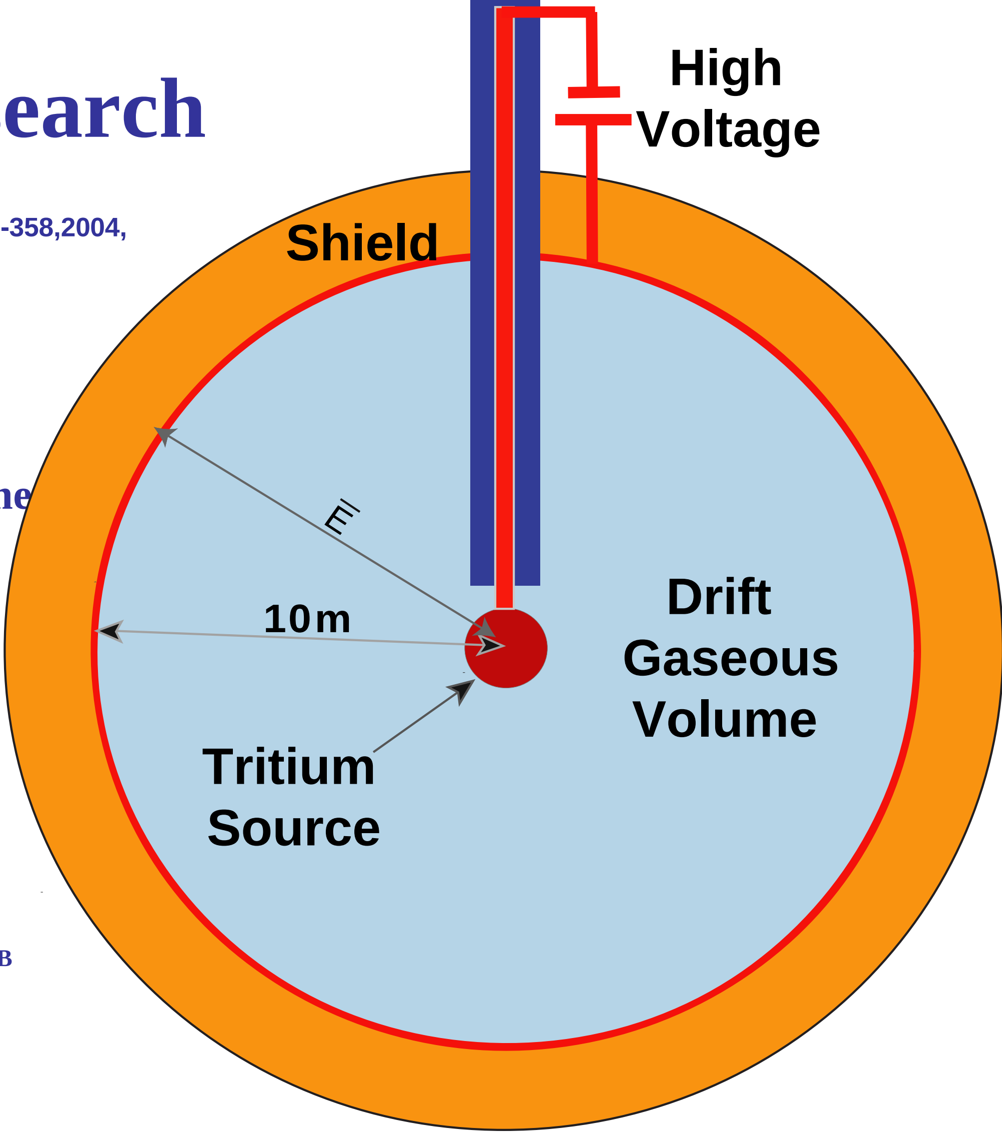
I. Giomataris

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

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



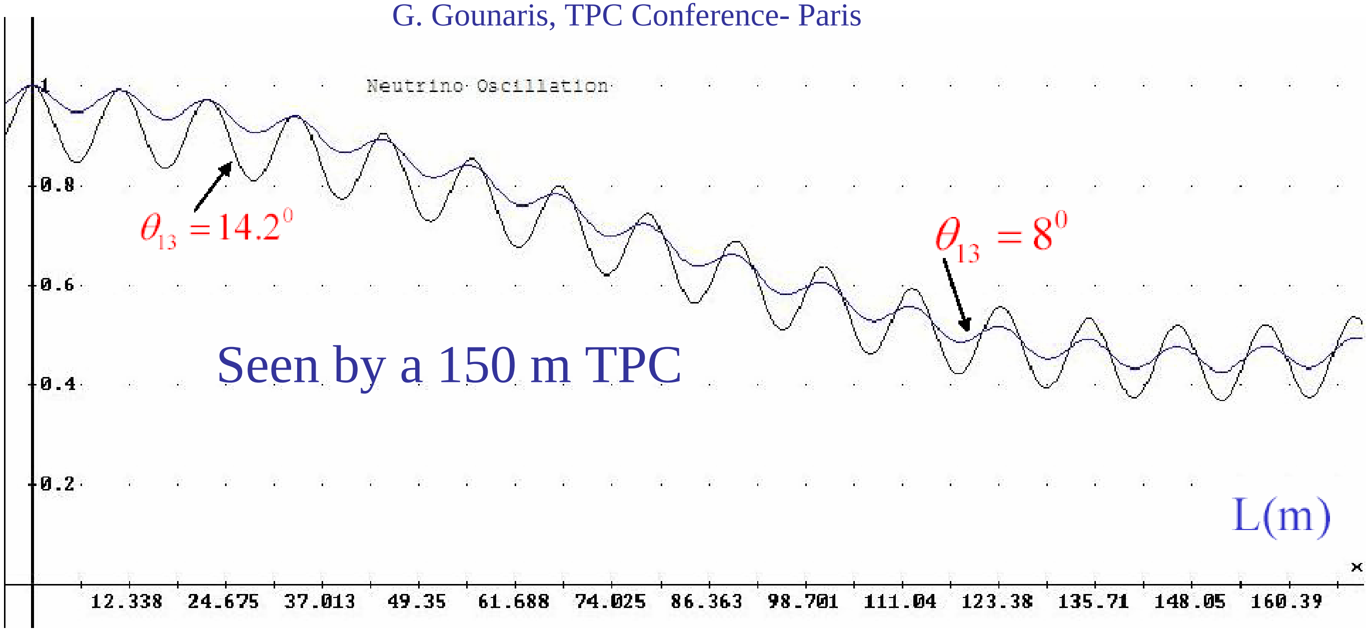
Objectives

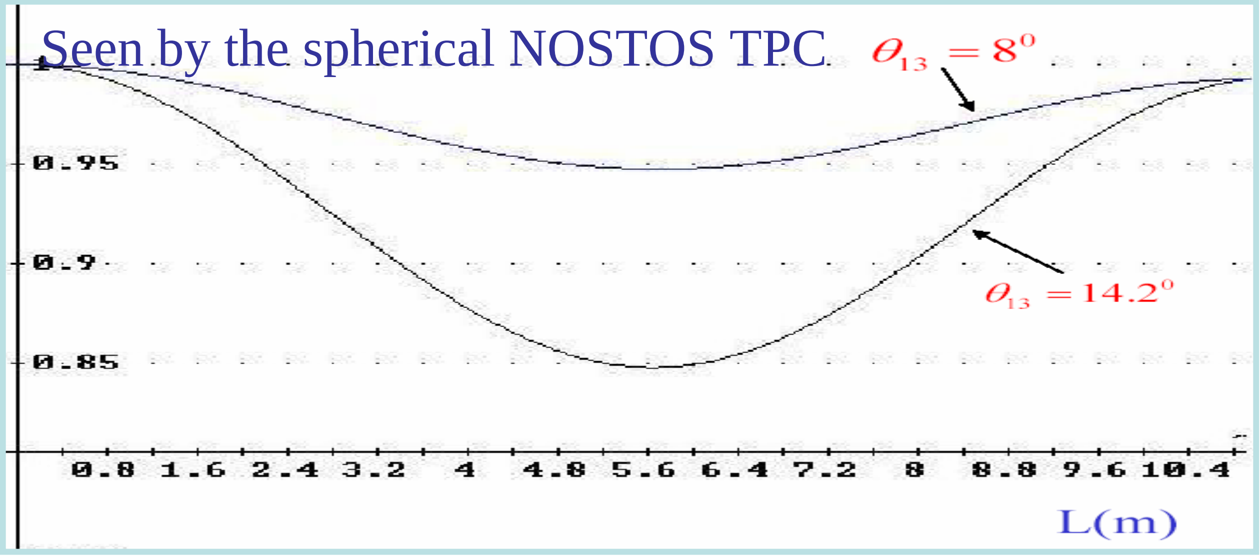
- Measure θ_{13} (systematic free)
- Neutrino magnetic moment studies << $10^{-12}\ \mu_B$
- Measurement of the Weinberg angle at low energy

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

Room size oscillations

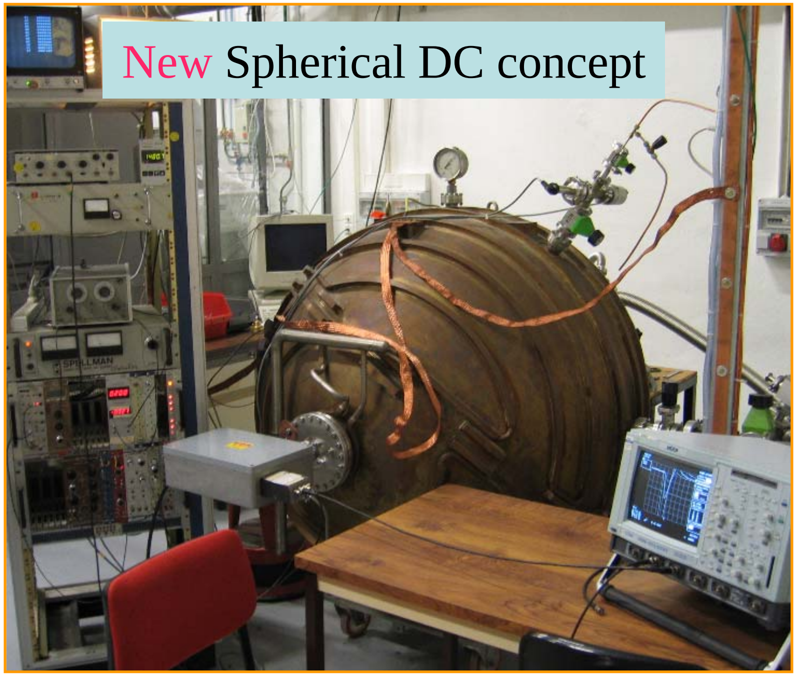
G. Gounaris, TPC Conference- Paris

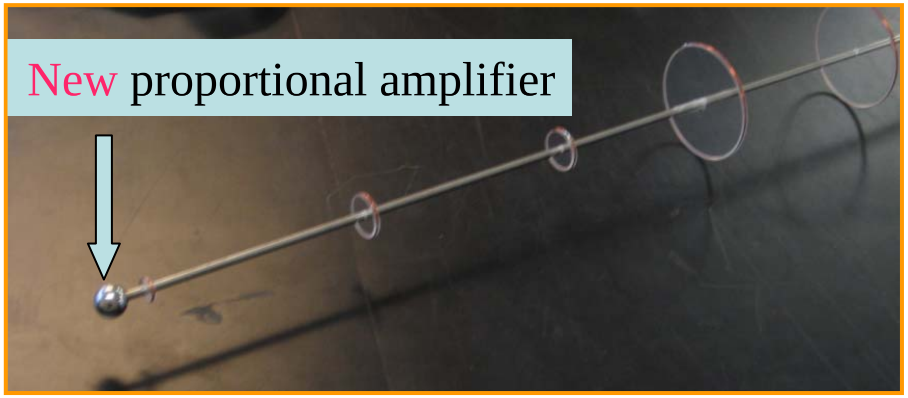


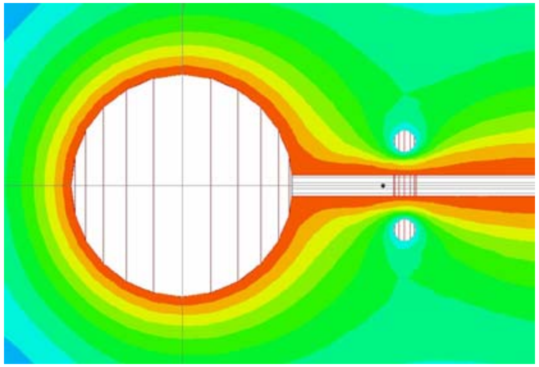


First prototype:
Getting a large detector out of a LEP cavity

- 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

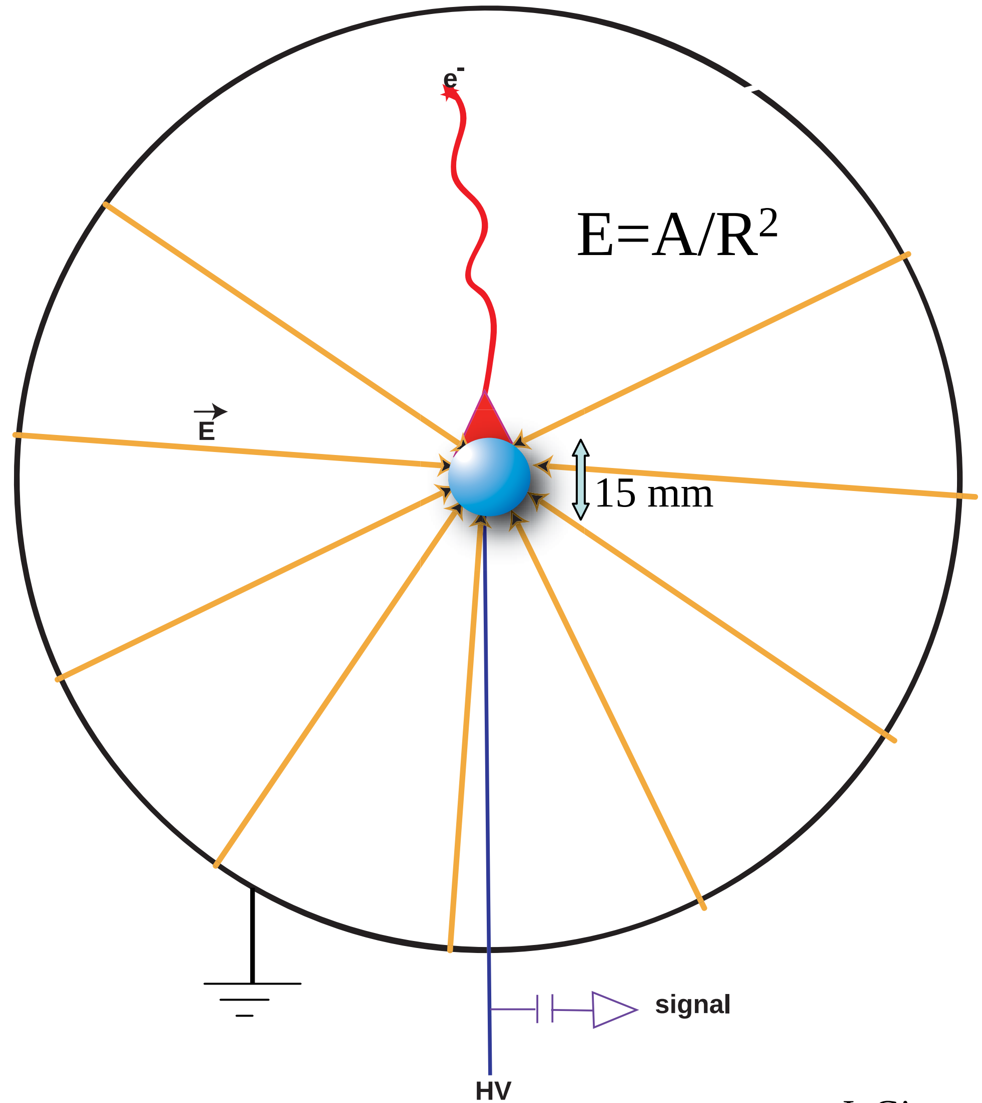


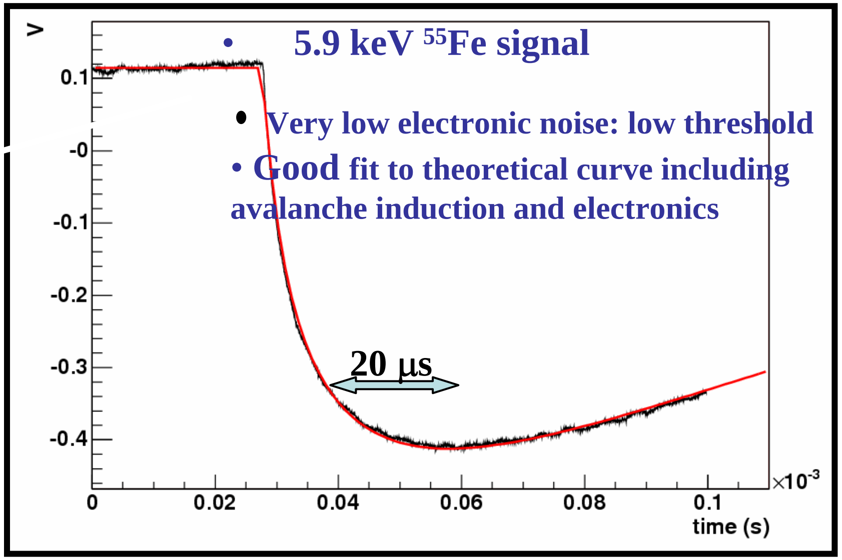




I. Giomataris

Radial TPC with spherical proportional counter read-out





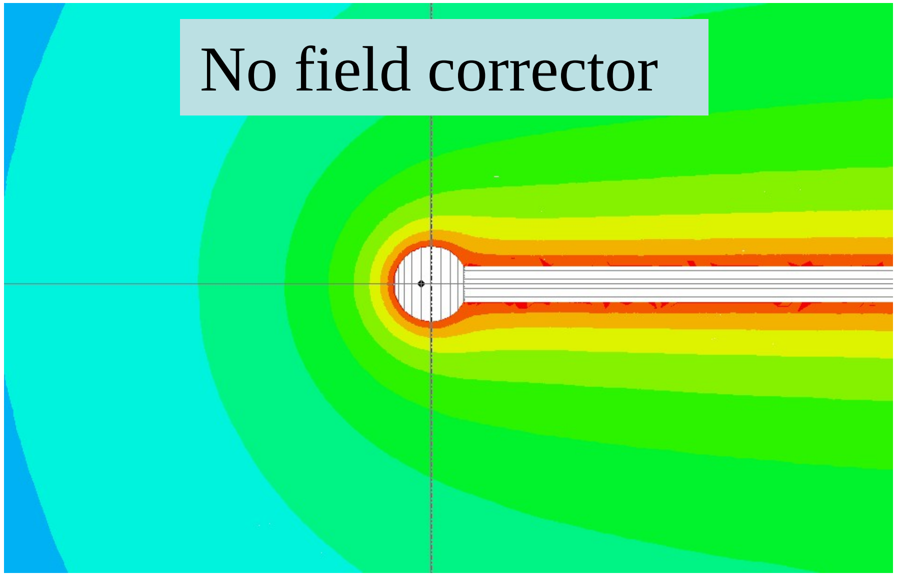
- Simple and cheap
- single read-out
- Robustness
- Good energy resolution
- Low energy threshold

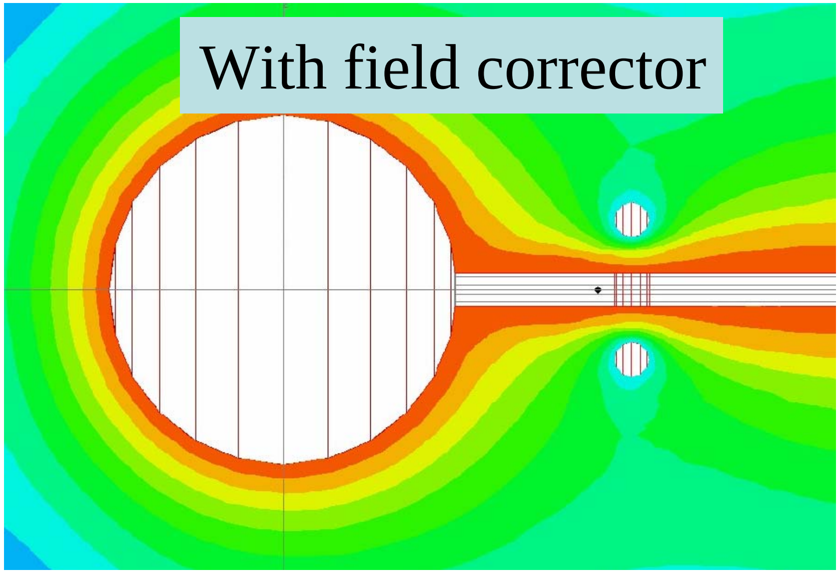
I. Giomataris

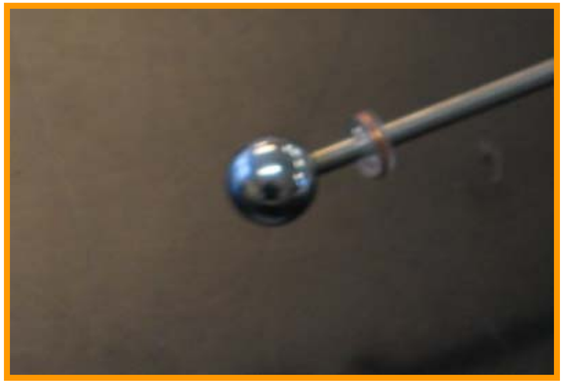
Electrostatics deal

How to keep radial field

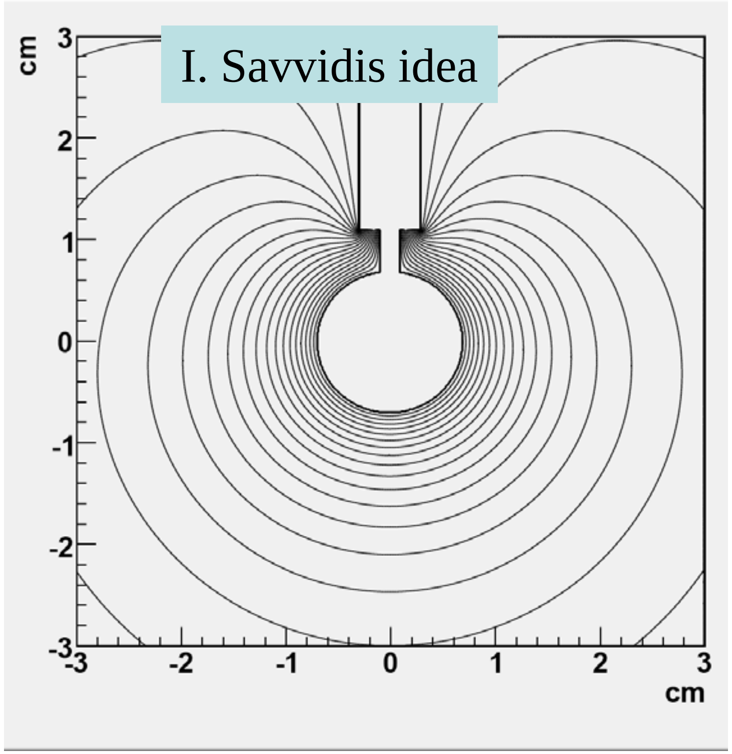
Ideal solution: field $1/R^2$ degrador around the wire

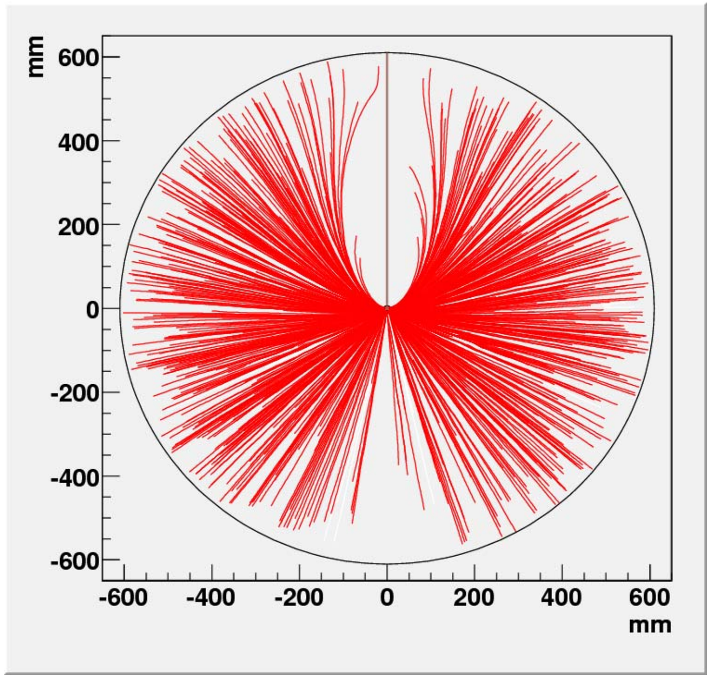






A simple electrostatic solution

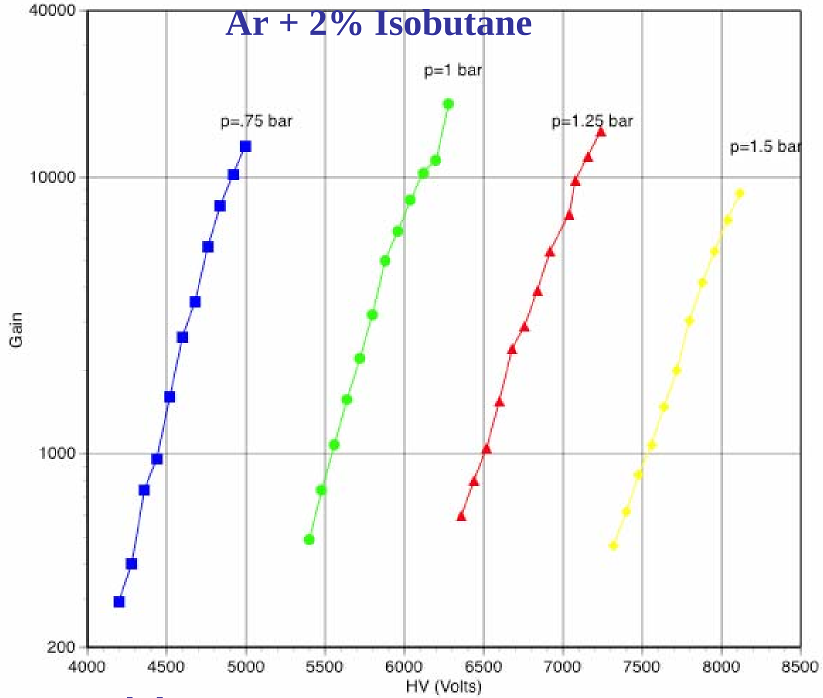


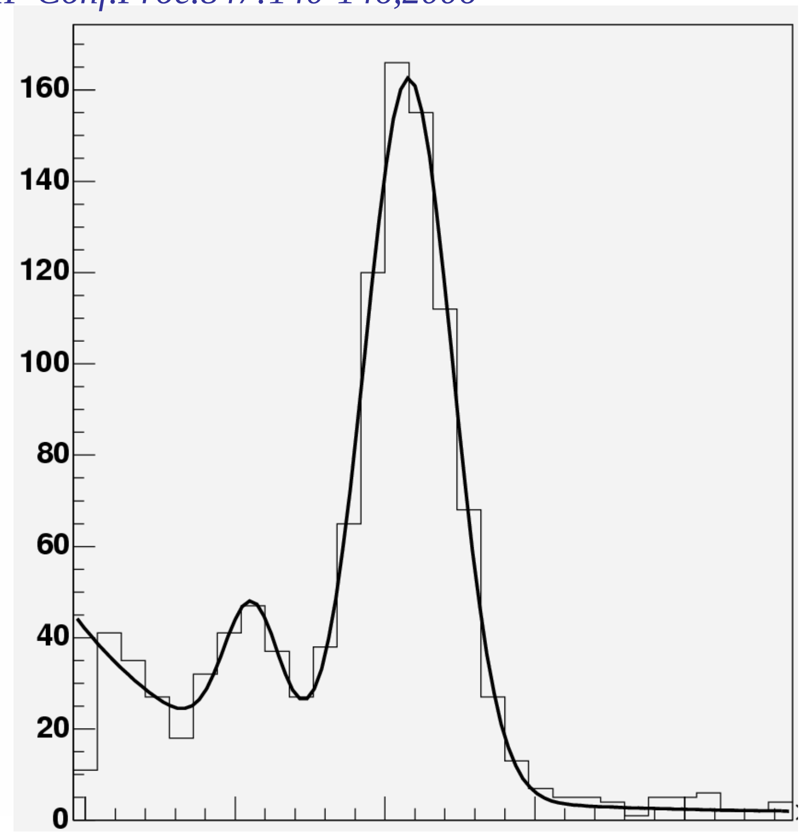


New idea by I. Giomataris and I. Irastorza
Combines also second voltage corrector:
“umbrella field corrector”
Big improvement in stability

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



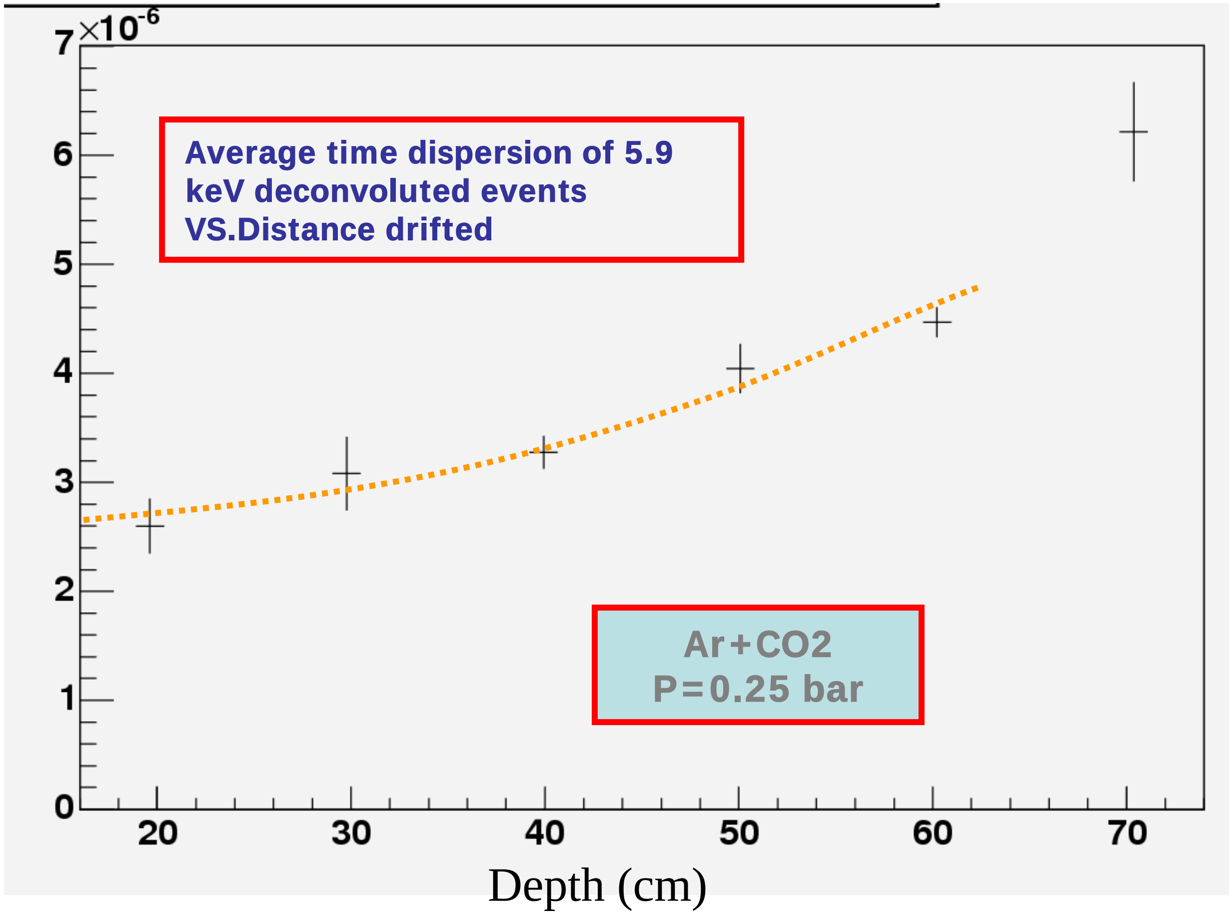


- Stability:
  - –tested up to ~3 months.
  - –No circulation of gas. Detector working in sealed mode. (1 pass through an oxysorb filter)
- No absorption observed
  - –Signal integrity preserved after 60 cm drift.
  - –Not high E needed to achieve high gain.

Signal dipersion with depth

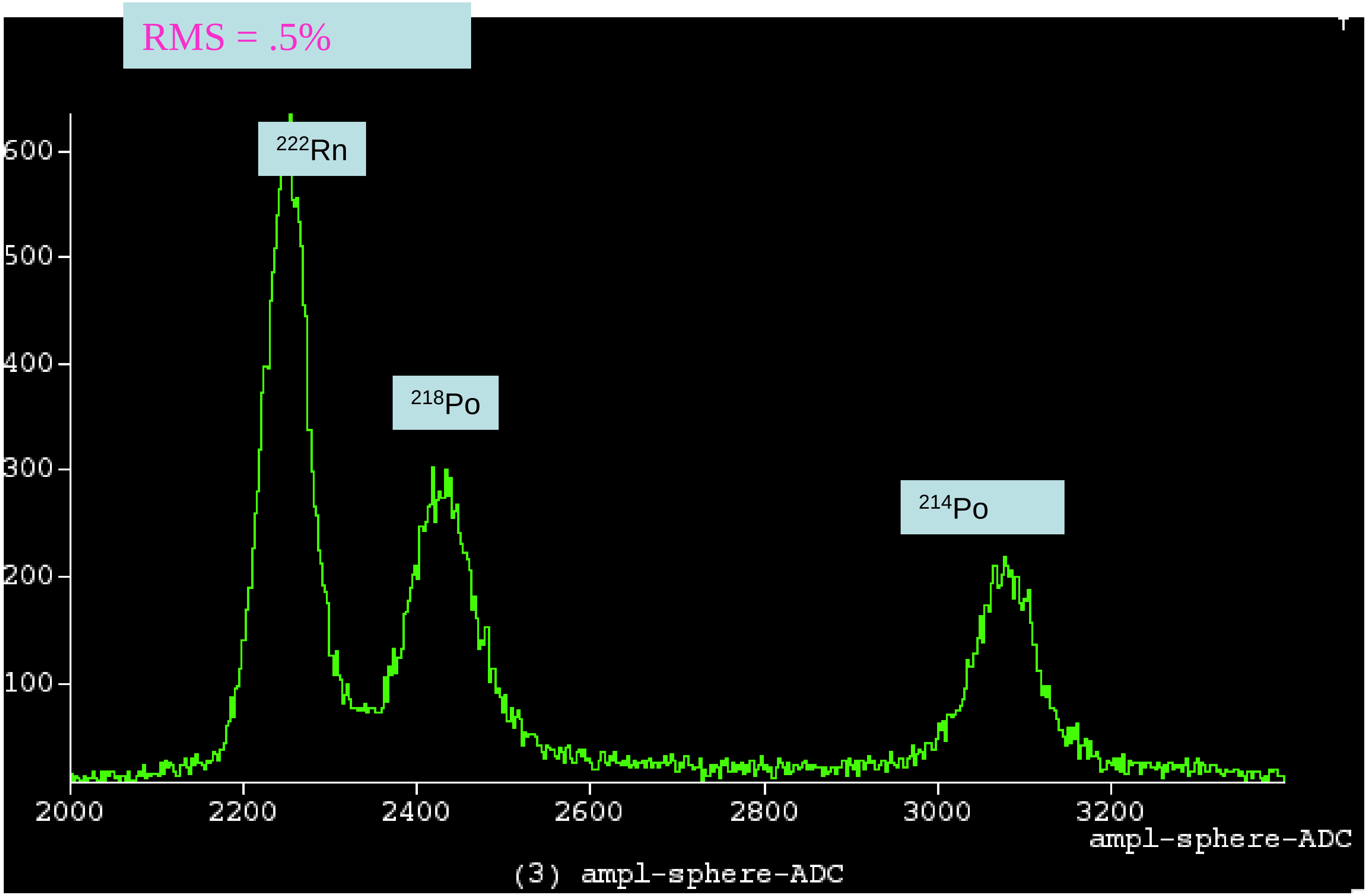
to estimate distance of interaction

- 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)



NEW Excellent energy resolution

Measured Radon gas emission spectrum with spherical detector



Energy resolution under amplification: a world record !!

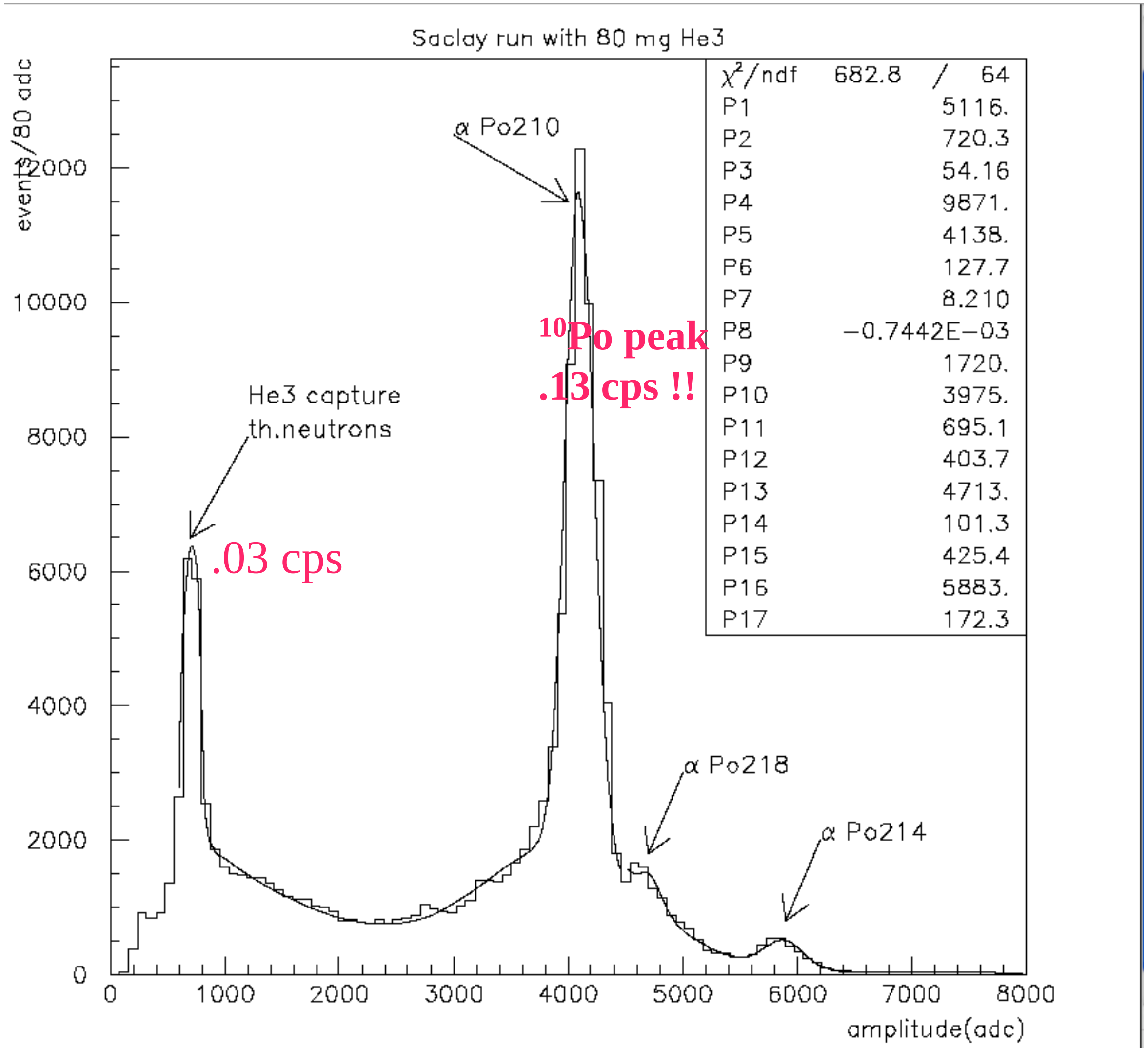
I. Giomataris

Neutron energy and flux measurement

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

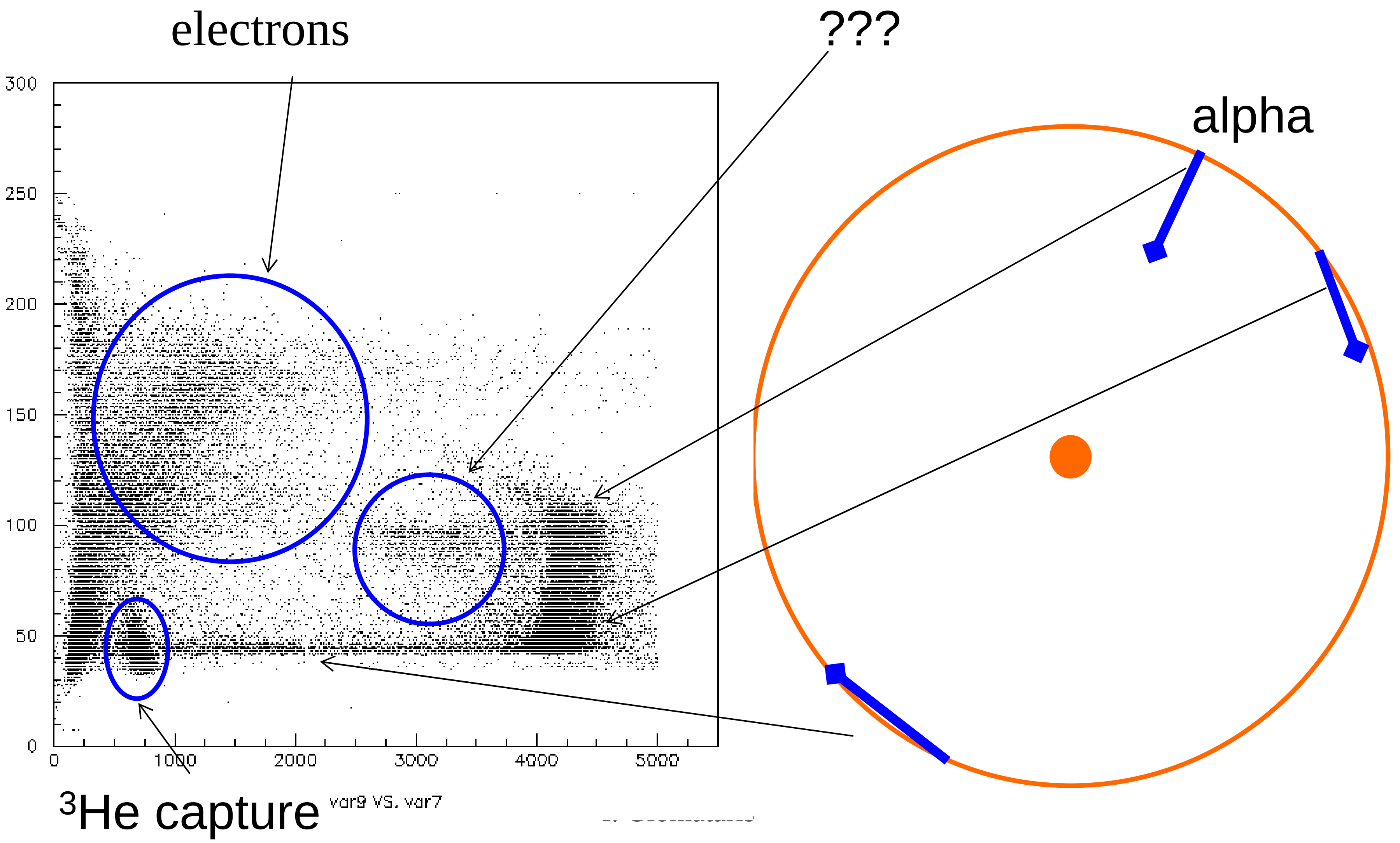
Results at ground

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



Rise time versus amplitude study

by G. Gerbier

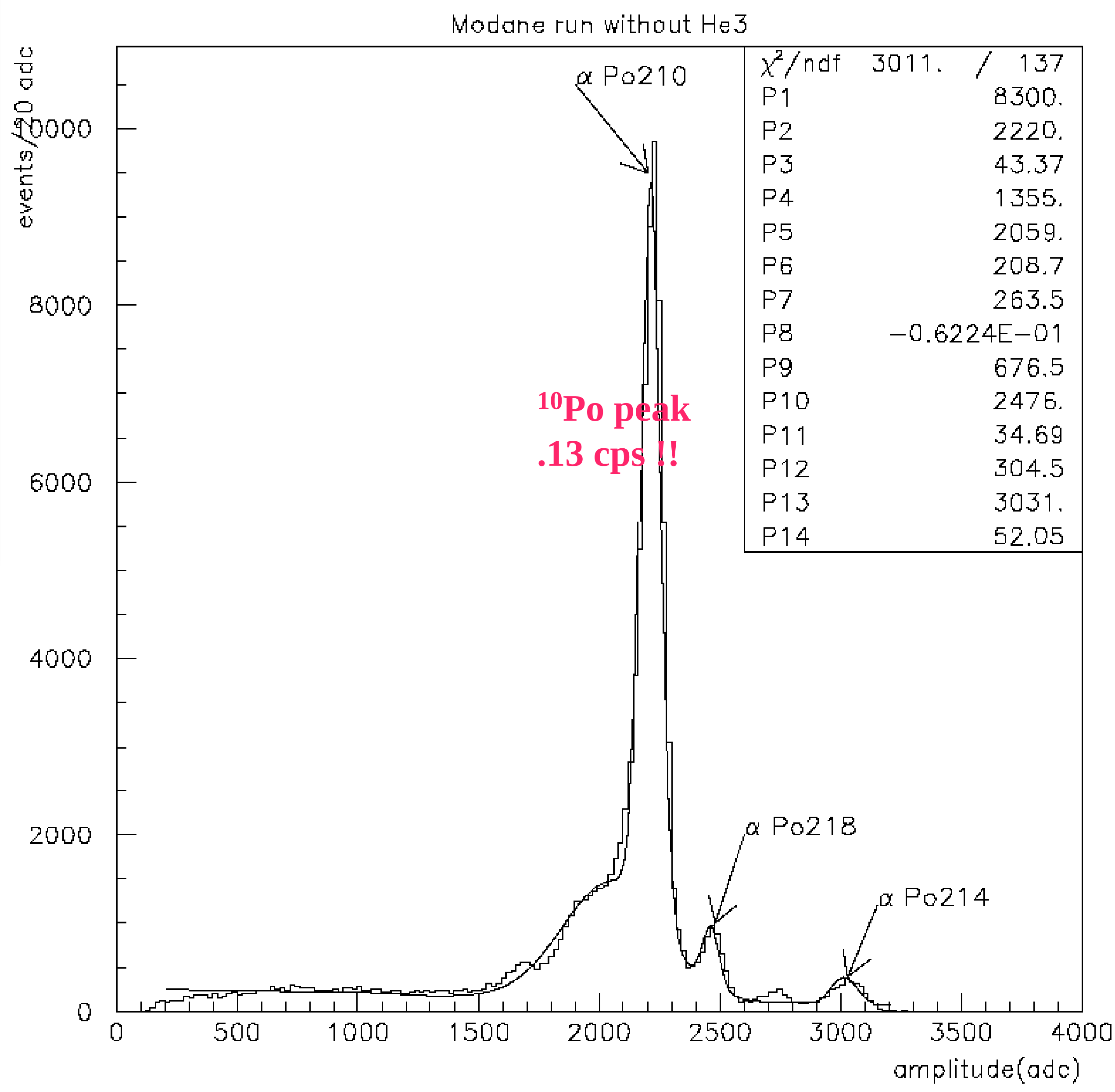


In 2008
Detector installed in LSM laboratory

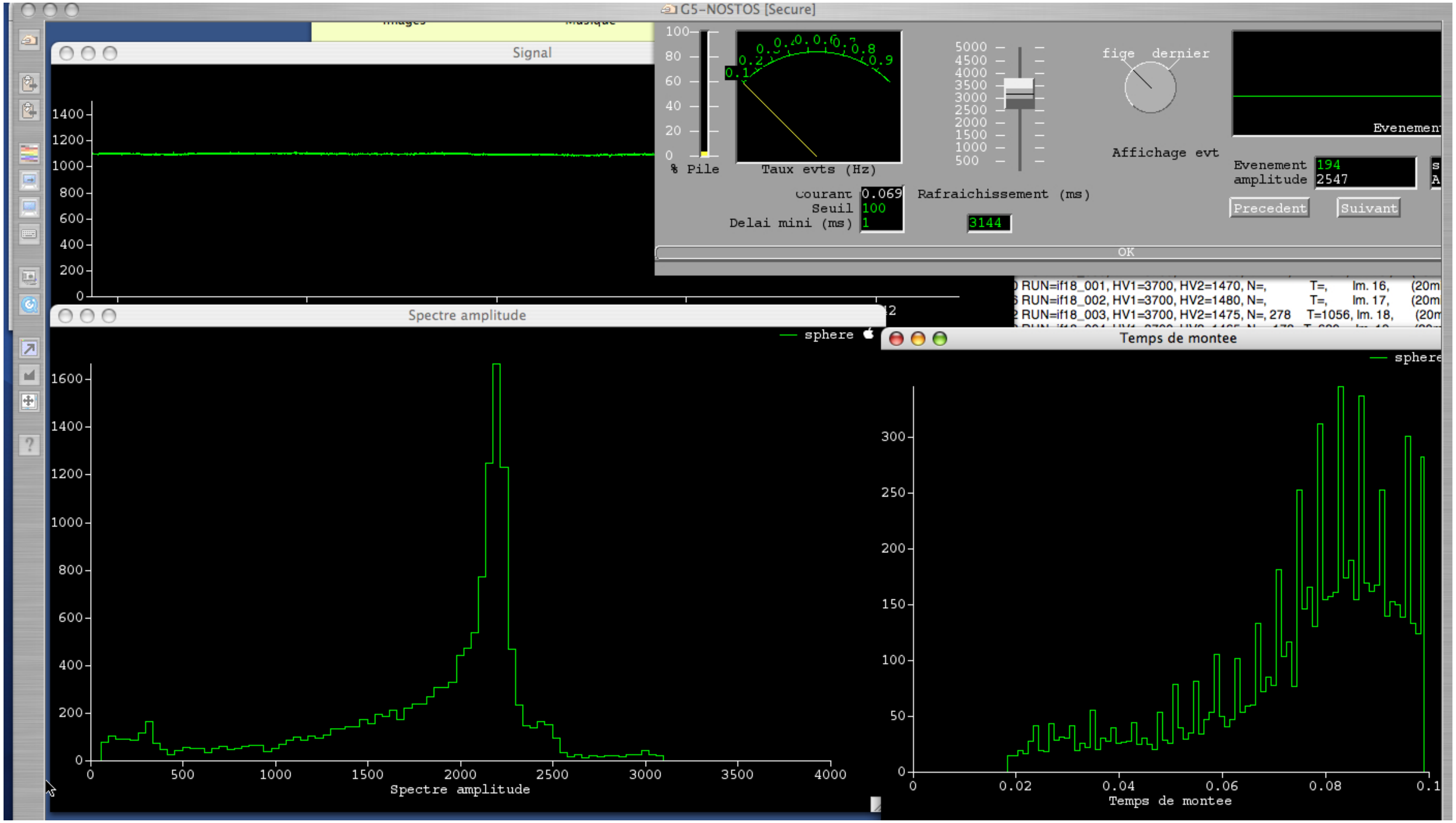
goal: measure thermal neutron background
and estimate fast neutron flux

with 10 gr ^{3}He

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



4 g of ^{3}He have been introduced yesterday at 19H
This morning we clearly see on-line the 760 keV peak



The spherical TPC concept: advantages

- Natural focusing:
  - large volumes can be instrumented with a small readout surface and few (or even one) readout lines
- 4π coverage: better signal
- Still some spatial information achievable:
  - Signal time dispersion

- Other practical advantages:
  - Low capacity, low-noise and threshold
  - No field cage
- Simplicity: few materials. They can be optimized for low radioactivity.
- Low cost

The way to obtain large detector volumes keeping low background and threshold

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 (2×10^7s), assuming full detector efficiency:

- Xe ($\sigma \approx 2.16\times10^{-40}$ cm^2), 2.2×10^6 neutrinos detected, E_{max}=146 eV
- Ar ($\sigma \approx 1.7\times10^{-41}$ cm^2), 9×10^4 neutrinos detected, E_{max}=480 eV
- Ne ($\sigma \approx 7.8\times10^{-42}$ cm^2), 1.87×10^4 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

Neutron spallation source measurement

F. Avignone, Yu Efremenko, Phys. G: Nucl. Part. Phys. 29 (2003) 2665–2675

Oak Ridge project

Total flux about $6x10^8/cm^2/s$ at 5 m

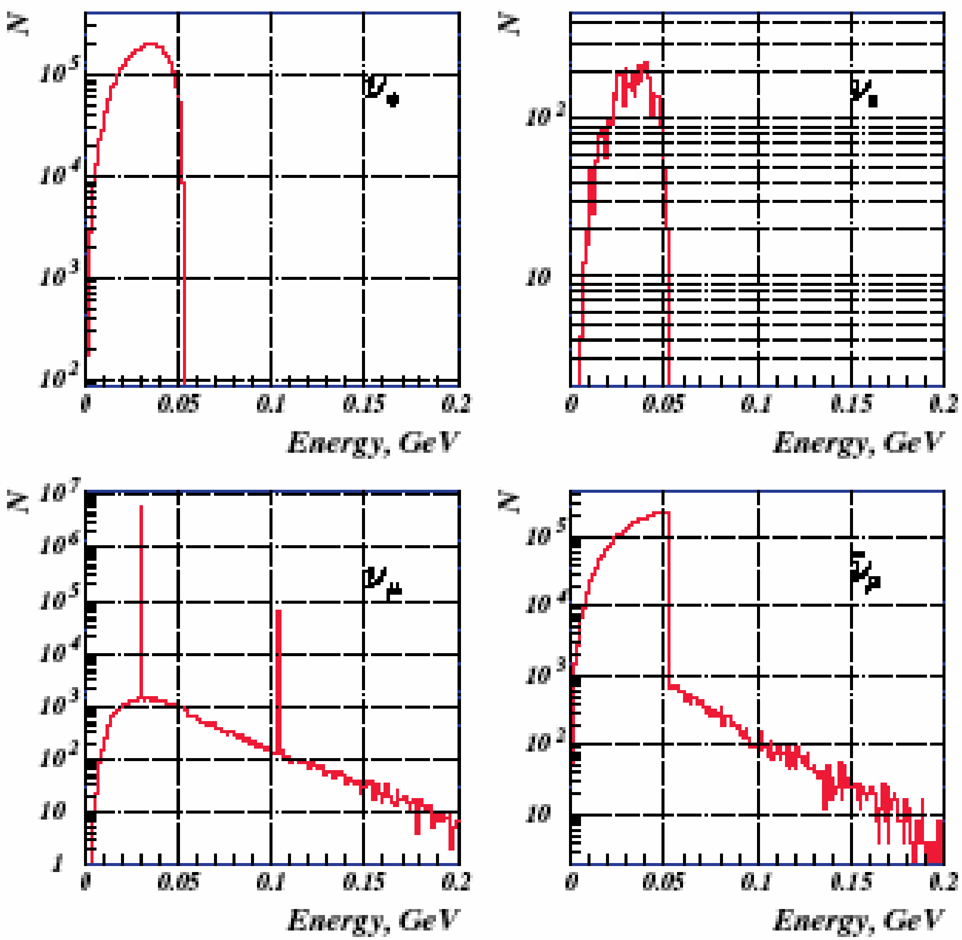


Figure 1. Energy spectra of the four neutrino flavours from a spallation source similar to the SNS.

Advantages

- Higher neutrino energies
- Reasonable nuclear recoil energy
- Pulsed beam

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

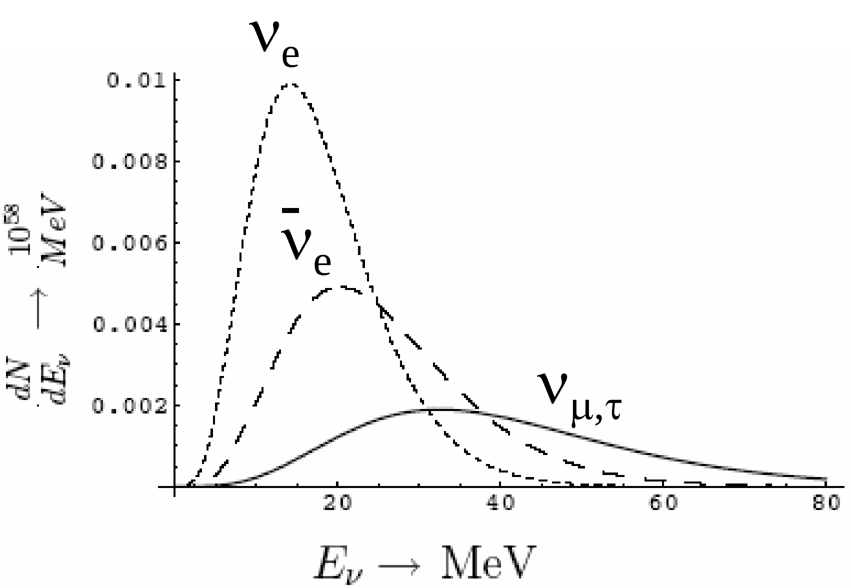
For E_ν = 10 MeV $\sigma \approx N^2E^{\,2} \approx 2.5\text{x}10^{-39}$ cm^2, T_{max} = 1.500 keV

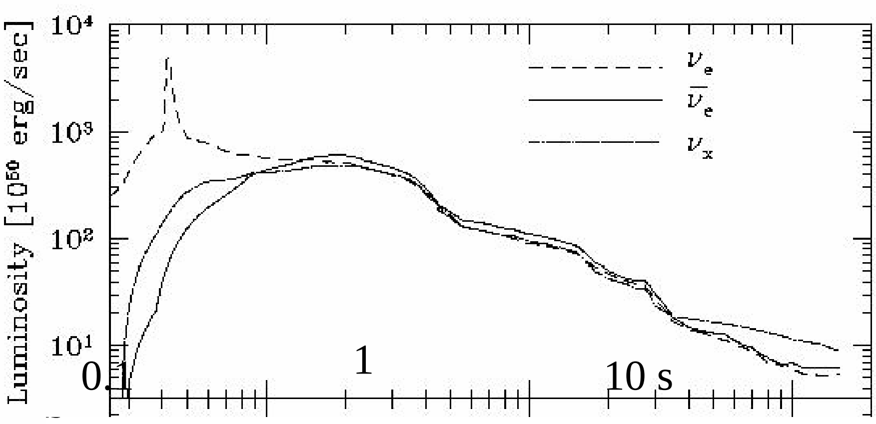
For E_ν = 25 MeV $\sigma \approx 1.5\text{x}10^{-38}$ cm^2, T_{max} = 9 keV

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**