Neutron Spectroscopy
With the Spherical Proportional Counter

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Collaboration:

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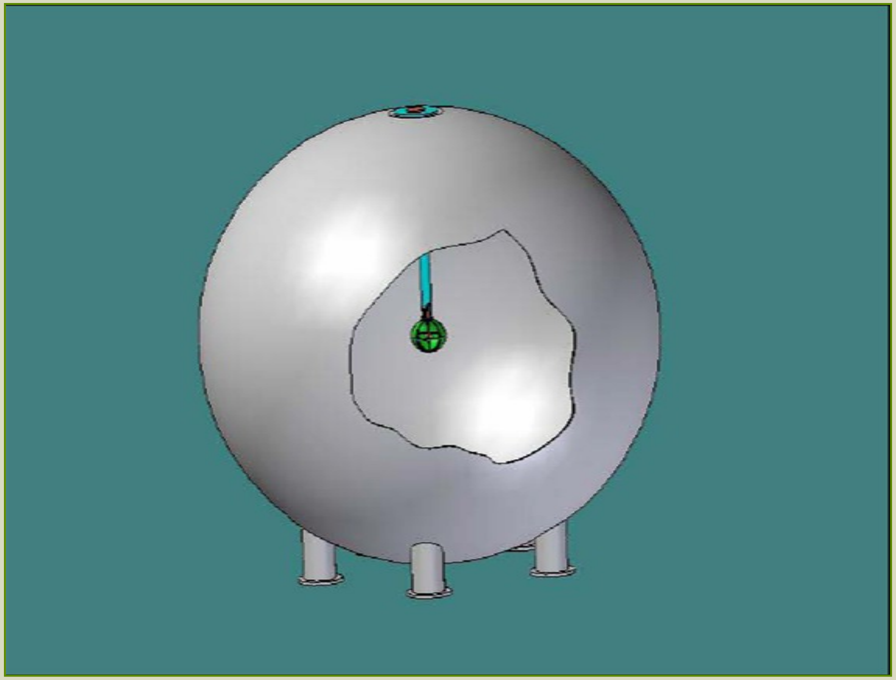
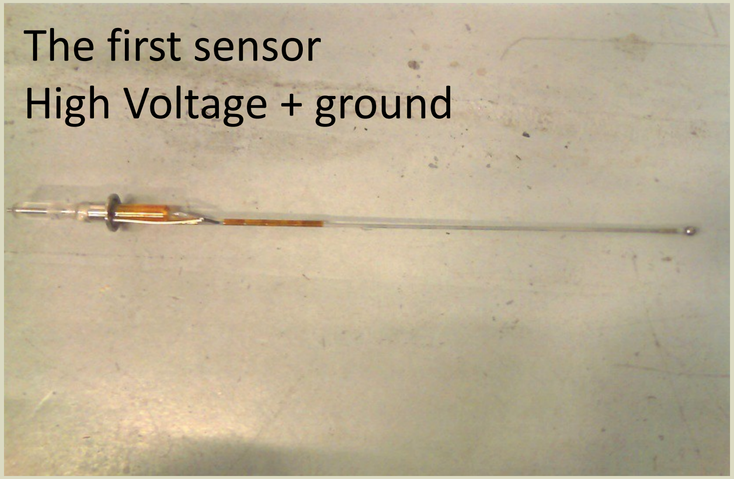
The detectors



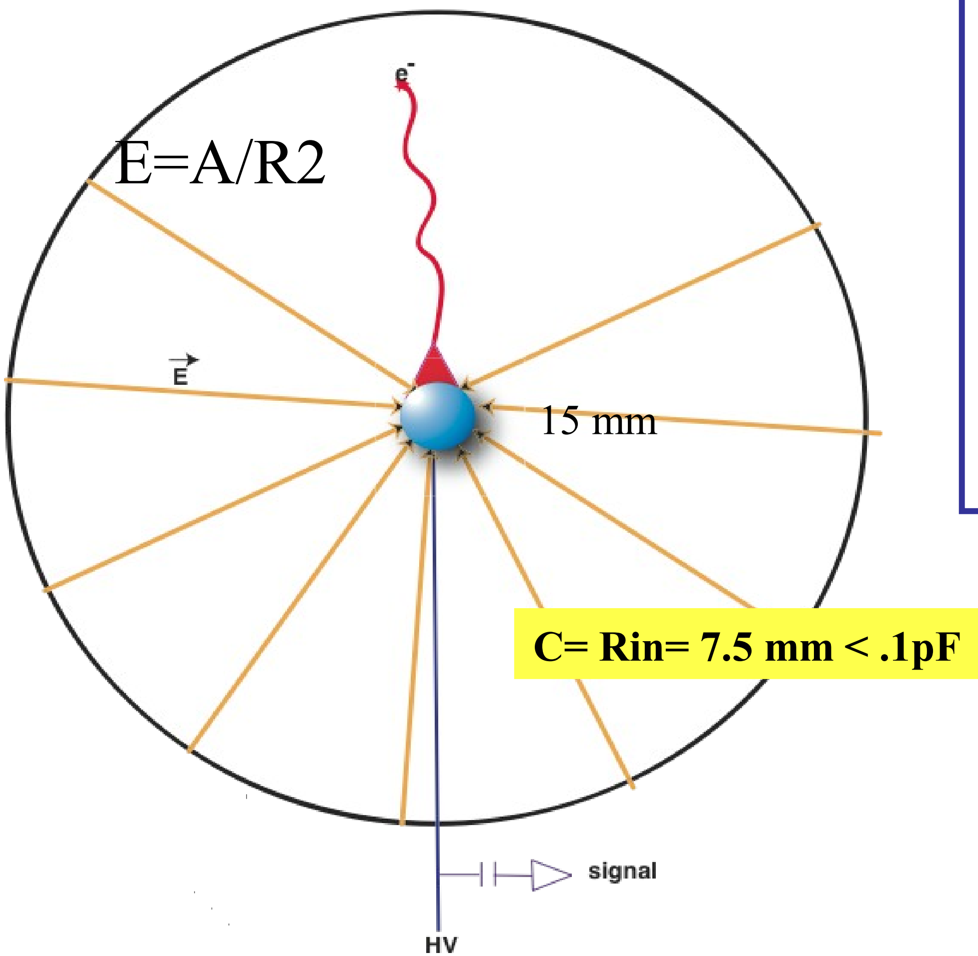
Volume = 1 m3, Cu 6 mm
Gas leak < 5x10-9mbar/s.
Gas mixture Argon + 2%CH4
.Pressure up to 5 bar
Internal electrode at high voltage.
Read-out of the internal electrode 15 mm



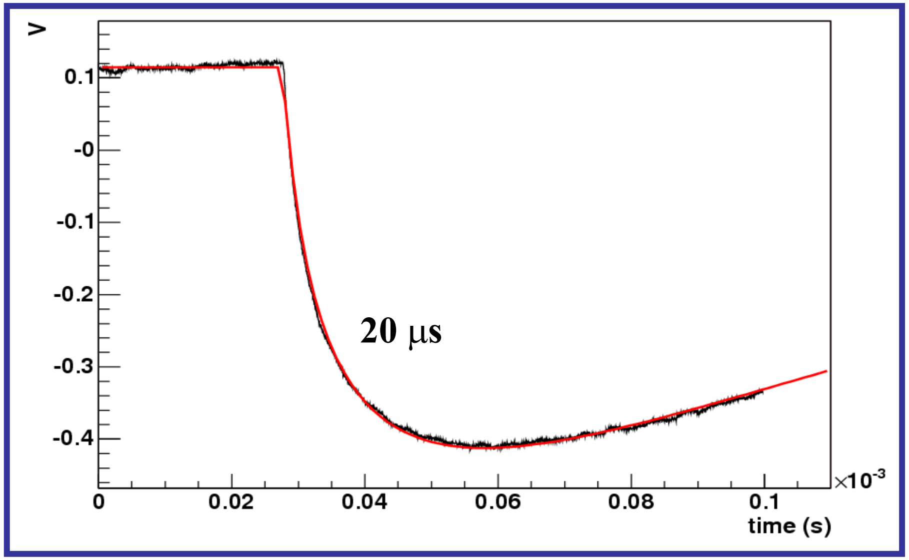
Radial TPC with spherical proportional counter read-out

Saclay-Thessaloniki-Saragoza

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

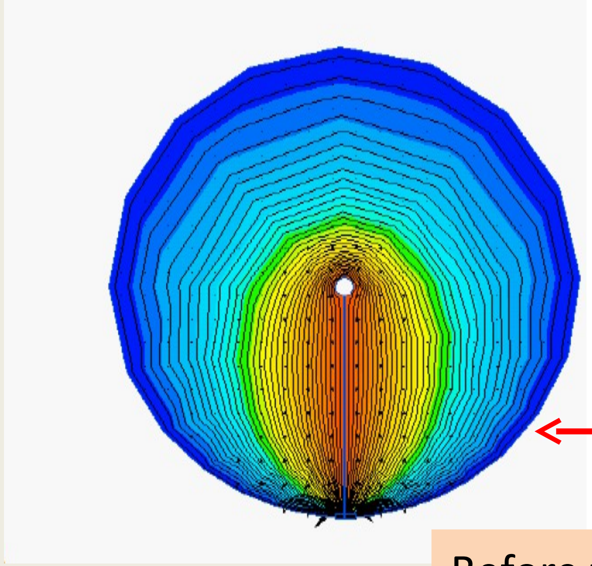


• 5.9 keV 55Fe signal

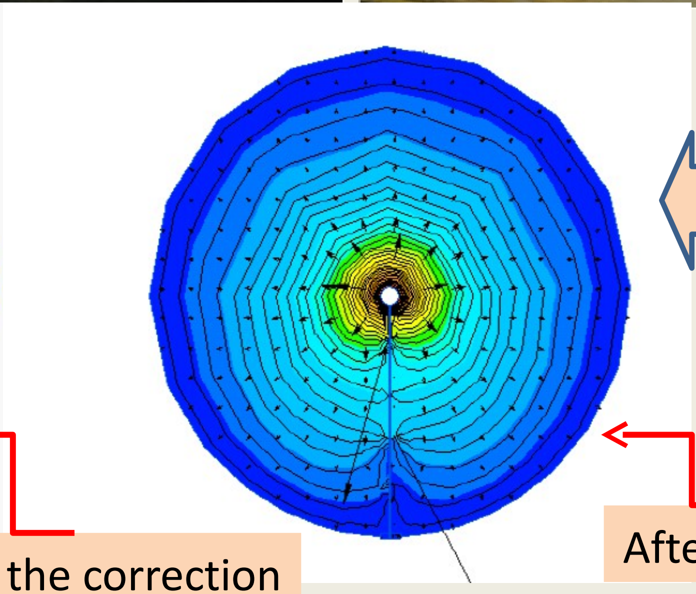


- Simple and cheap
- single read-out
- Robustness
- Good energy resolution
- Low energy threshold
- Efficient fiducial cut

Two of the sensors which have been used
with a second high voltage to improve the electric field in the drift volume



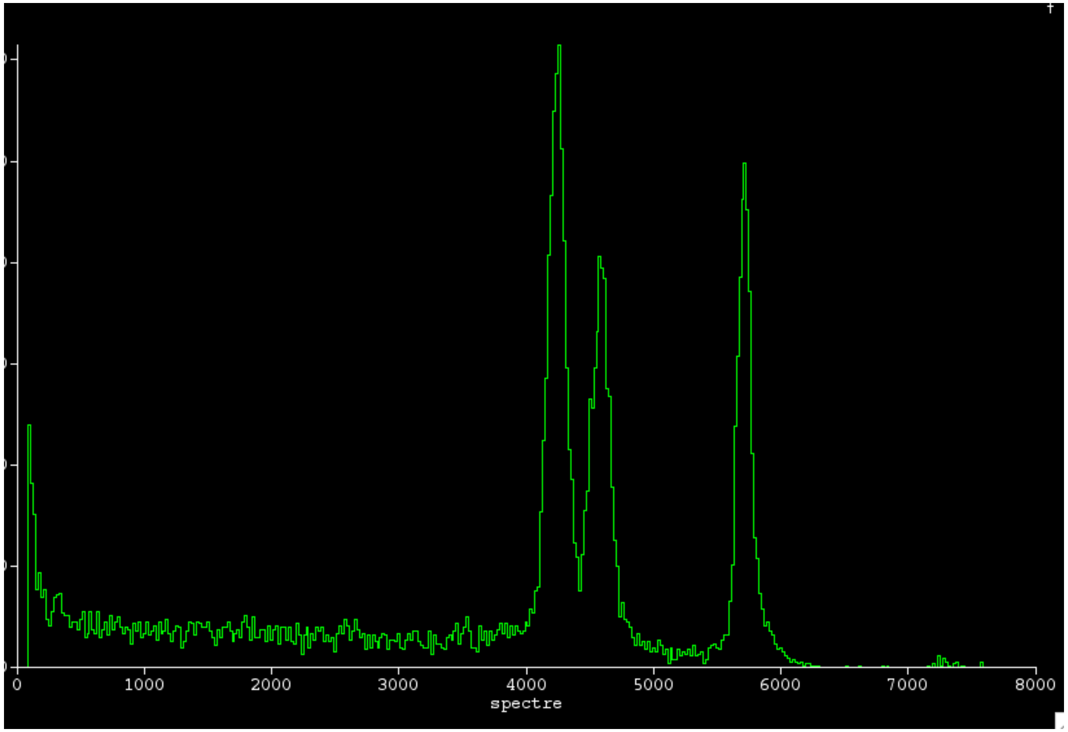
Before the correction



After the correction

The electrostatic field (simulation results)

Calibration using Rn source.



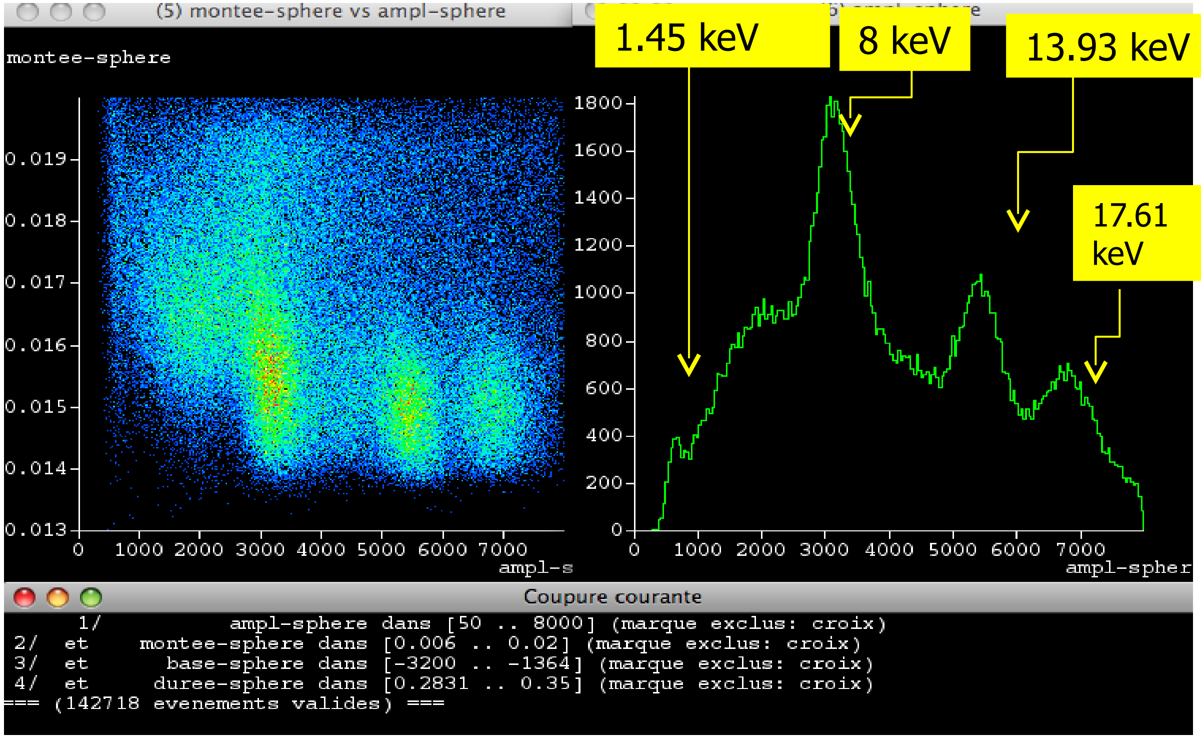
Rn and Rn daughters:

- Rn-222: 5.49 MeV alpha
- Po-218: 6.00 MeV alpha
- Po-214: 7.68 MeV alpha

- Resolution: σ=2%

- Gas: 98% Ar + 2% CH4
- P=200 mbar
- HV=2800 Volt

Calibration using X-rays sources

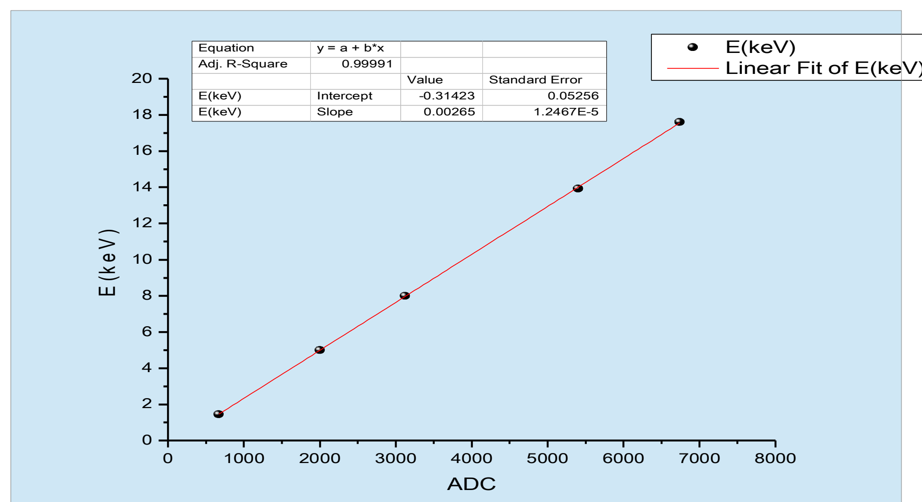


Low energy spectroscopy X-ray peaks

13mm sensor, 50mbar Ar+2%CH_4

Aluminium (1.45 keV)
Copper (8 keV)
Neptunium(Lα) (13.93 keV)
Neptunium(Lβ) (17.61 keV)

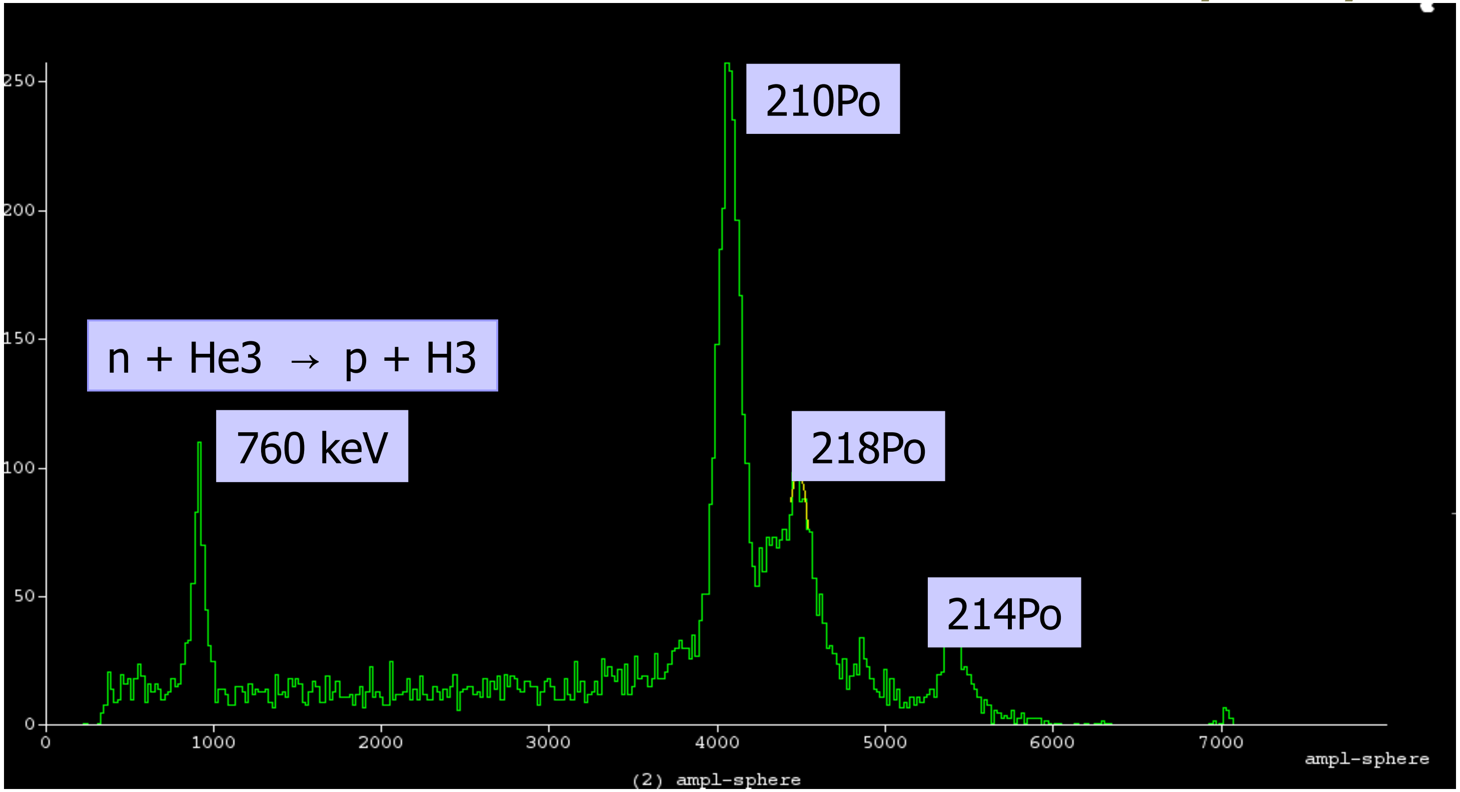
Low gain X-ray linearity



Thermal Neutron detection with He-3
Using the reaction 3He(n,p)H3

Results in LSM(5 weeks): 3 g of 3He
Detector is stable operating in seal mode
Gas Ar +2% CH4 at p=280 mbar

Low thermal neutron flux = 1.9 10-6 n/cm2/s



Why N2 for neutron detection and spectroscopy

Comparison with the commercial neutron counters

Commercial **thermal** neutron counters:

He-3 counters:

3He(n,p)H3: Q=0.76 MeV and σth=5330 barns

BF-3 counters:

10B(n,α)Li7:Q2.79 MeV and σth=3837 barns (6%)

10B(n,α)Li*7:Q=2.31 MeV and σth=3837barns(94%),7Li*→7Li+480 keV

*** Not neutron spectra measurements.

***The cost of the 3He gas is very high and the BF3 is very toxic gas.

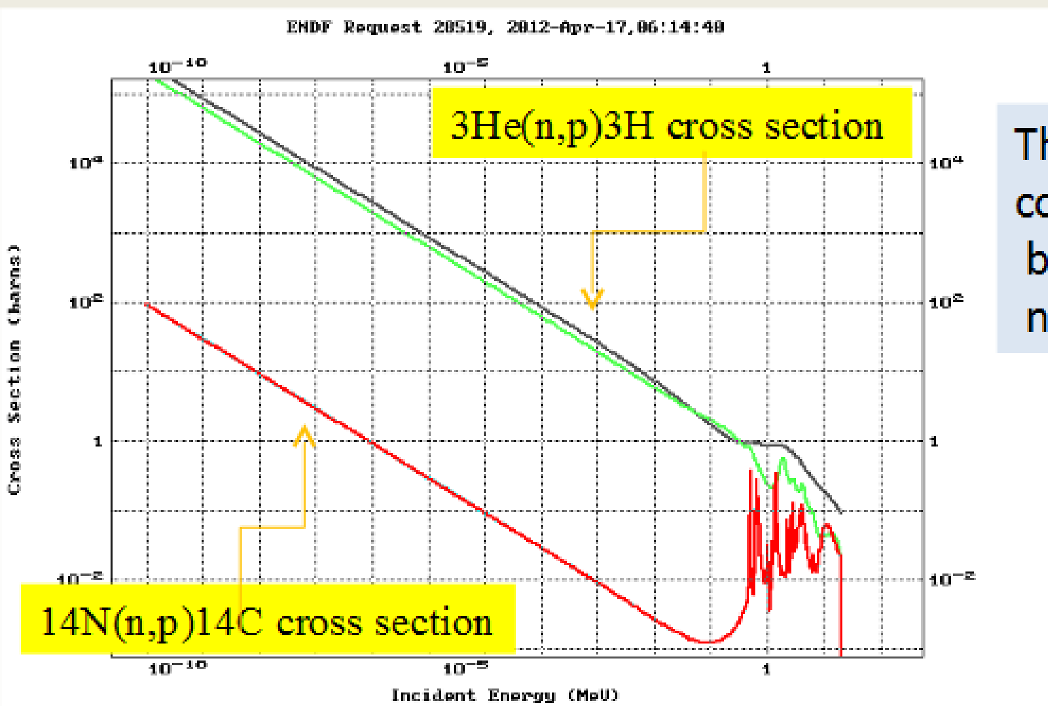
N2 neutron spectrometer:

Can be used successfully as a thermal neutron detector
and as a fast neutron spectrometer
via the 14N(n,p)14C and 14N(n,α)B11 reactions

Thermal neutron detection using the reaction:

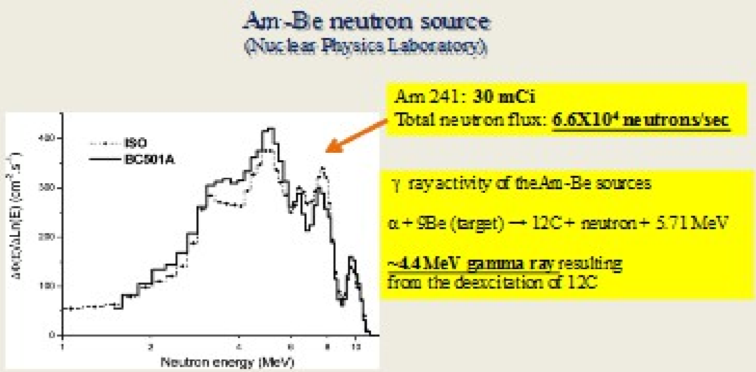
$$^{14}N + n \rightarrow {}^{14}C + p + 625.87\ \text{keV}$$

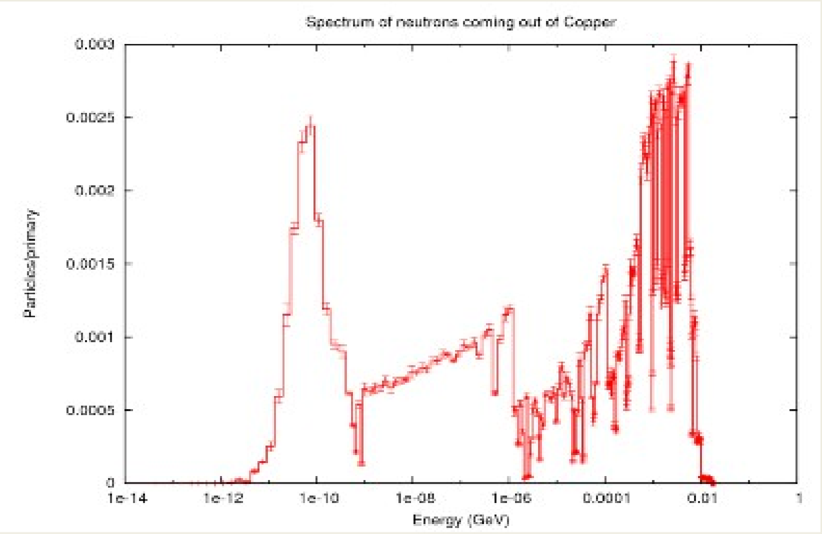
The signals are coming from the protons and the 14C
As an example for a gas mixture of 50% Ne and 50% N2 and 500mbar pressure, the proton range for thermal neutrons is 2.2cm and the wall effect 2%.

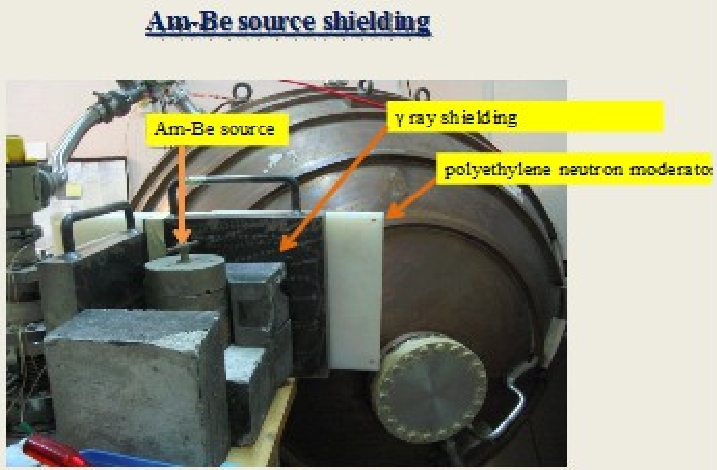


The cross section disadvantage can be covered sufficiently
by the large amount of
nitrogen atoms in the sphere.

Experimental setup in AUTH lab.: Neutron irradiation with Am-Be source

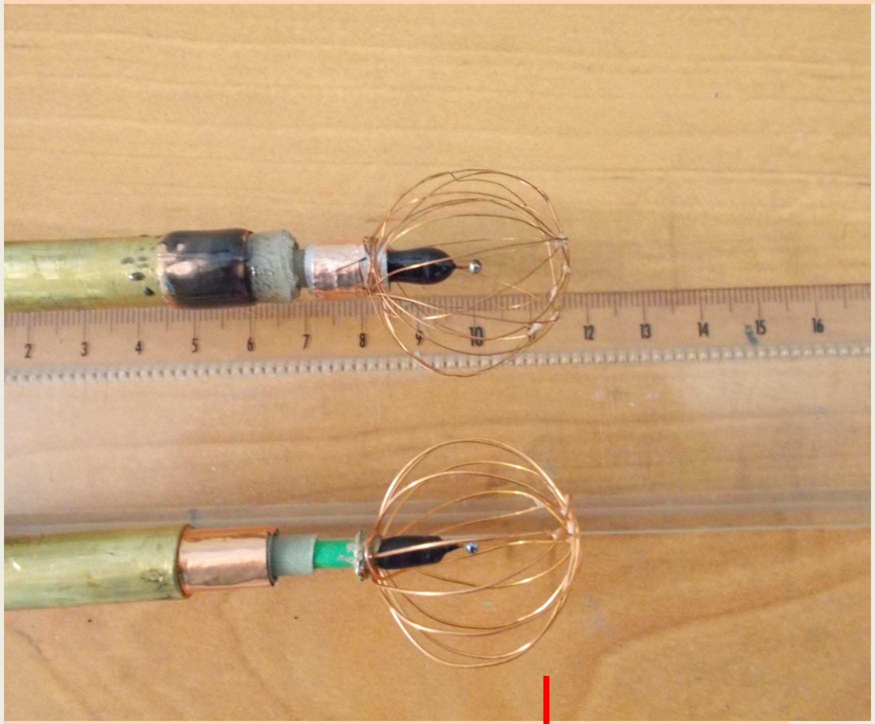




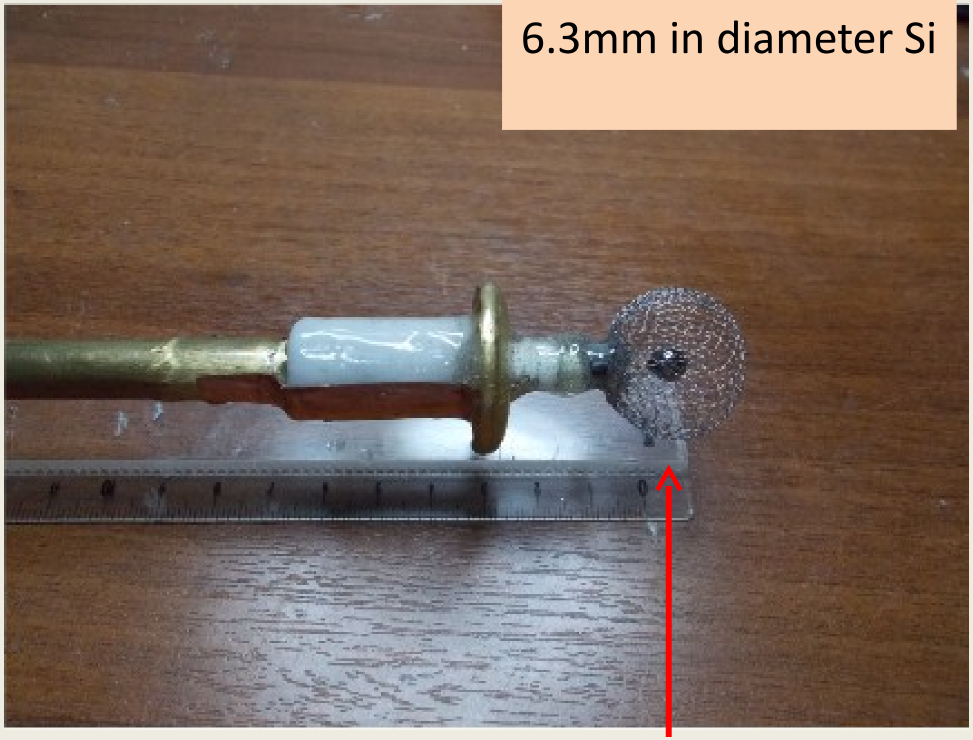


Shielding
Pb= 9cm
Fe= 5cm
PE= 2cm

New sensors developed in AUTH, with grid for high volume and high pressure N2 gas



2mm in diameter metallic
and Si sensors

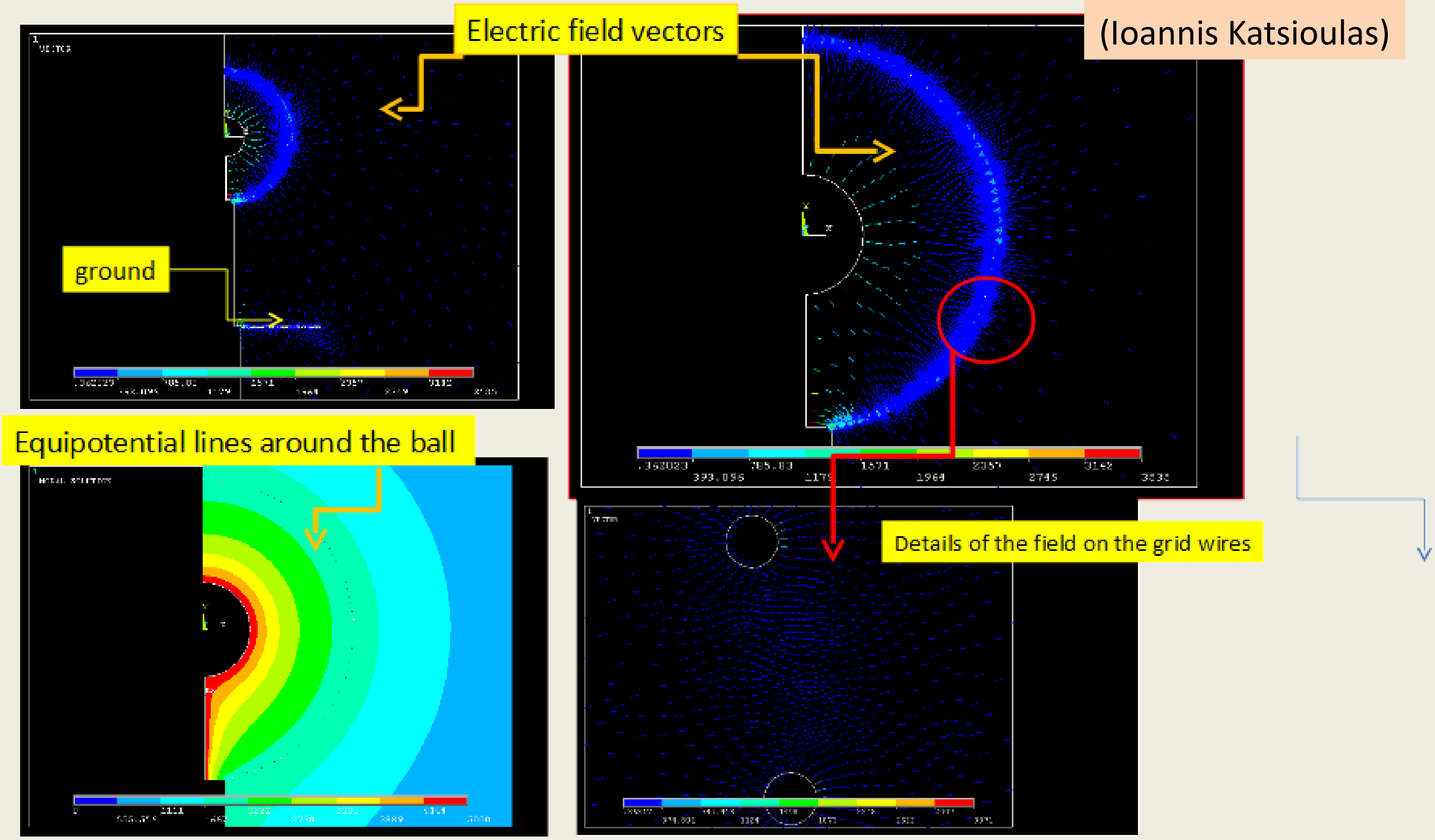


6.3mm in diameter Si

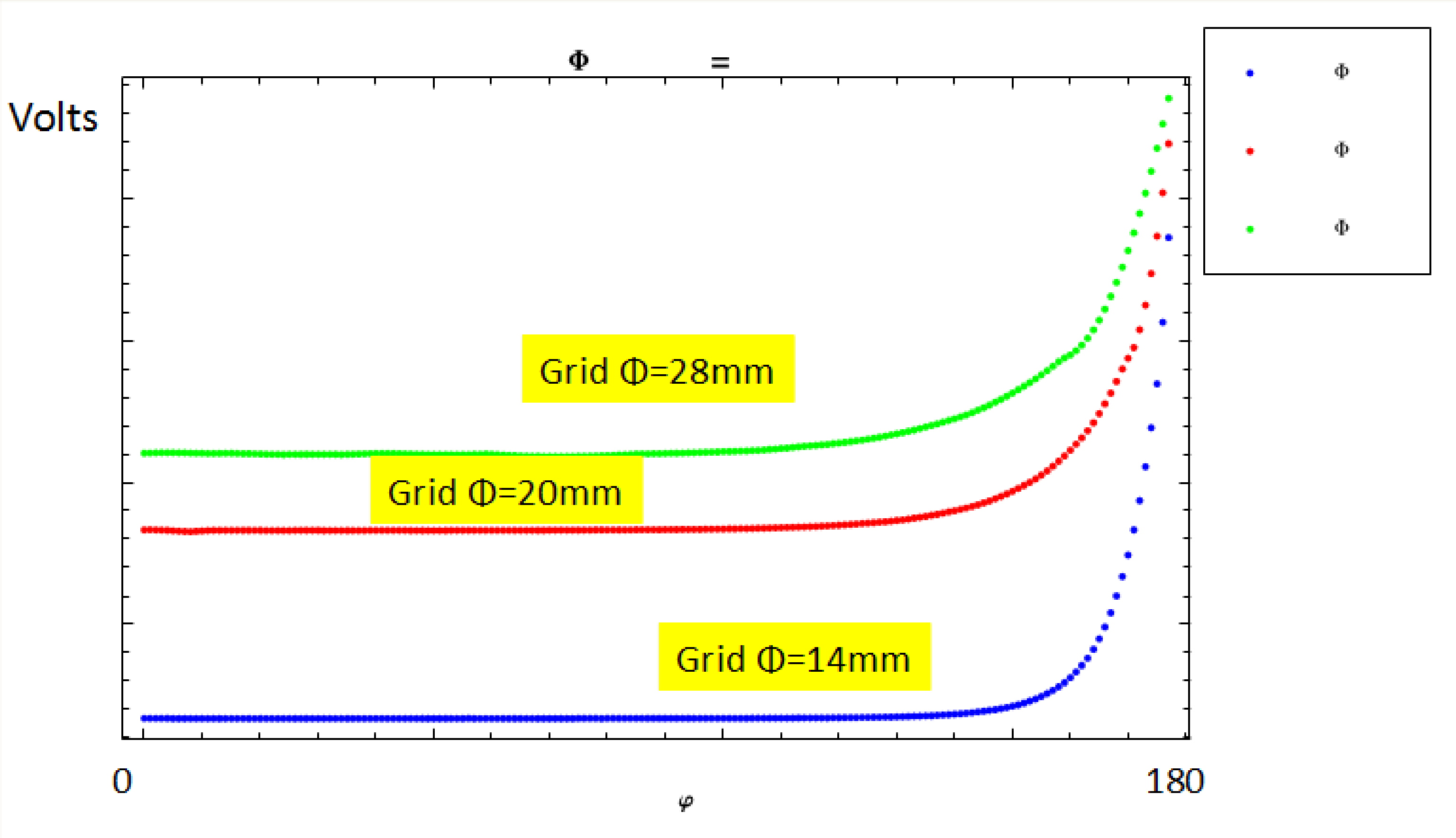
The grid is metallic 25mm in diameter .
The second voltage HV2 is applied on the grid, producing with the HV1 on the ball, an electric field with spherical symmetry.

Simulation results for the sensor with ball Φ=6.3mm + grid Φ=20mm

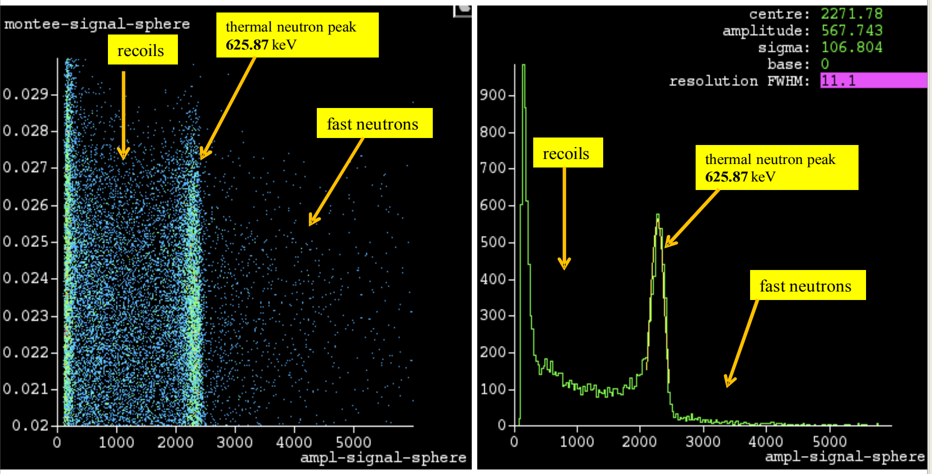
(Ioannis Katsioulas)



Sensor Φ=8 mm +Grid Φ=14, 20, 28 mm
Voltage at a distance d=2.0 mm from small ball

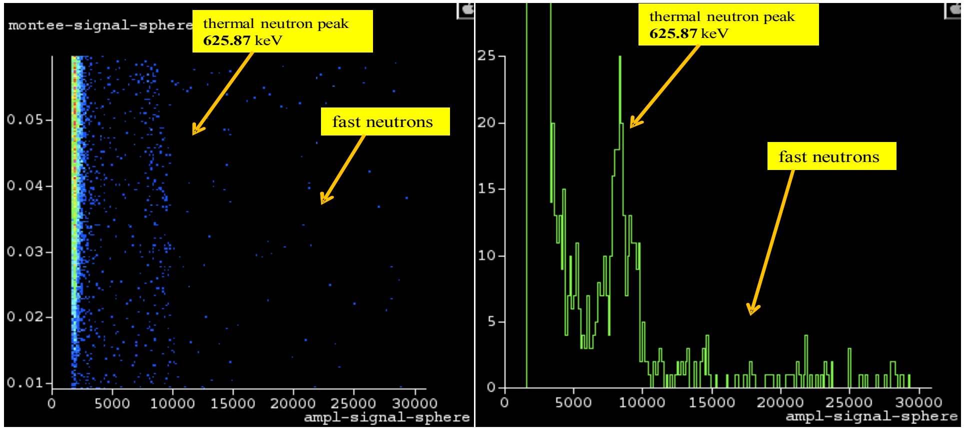


CEA-Saclay data:



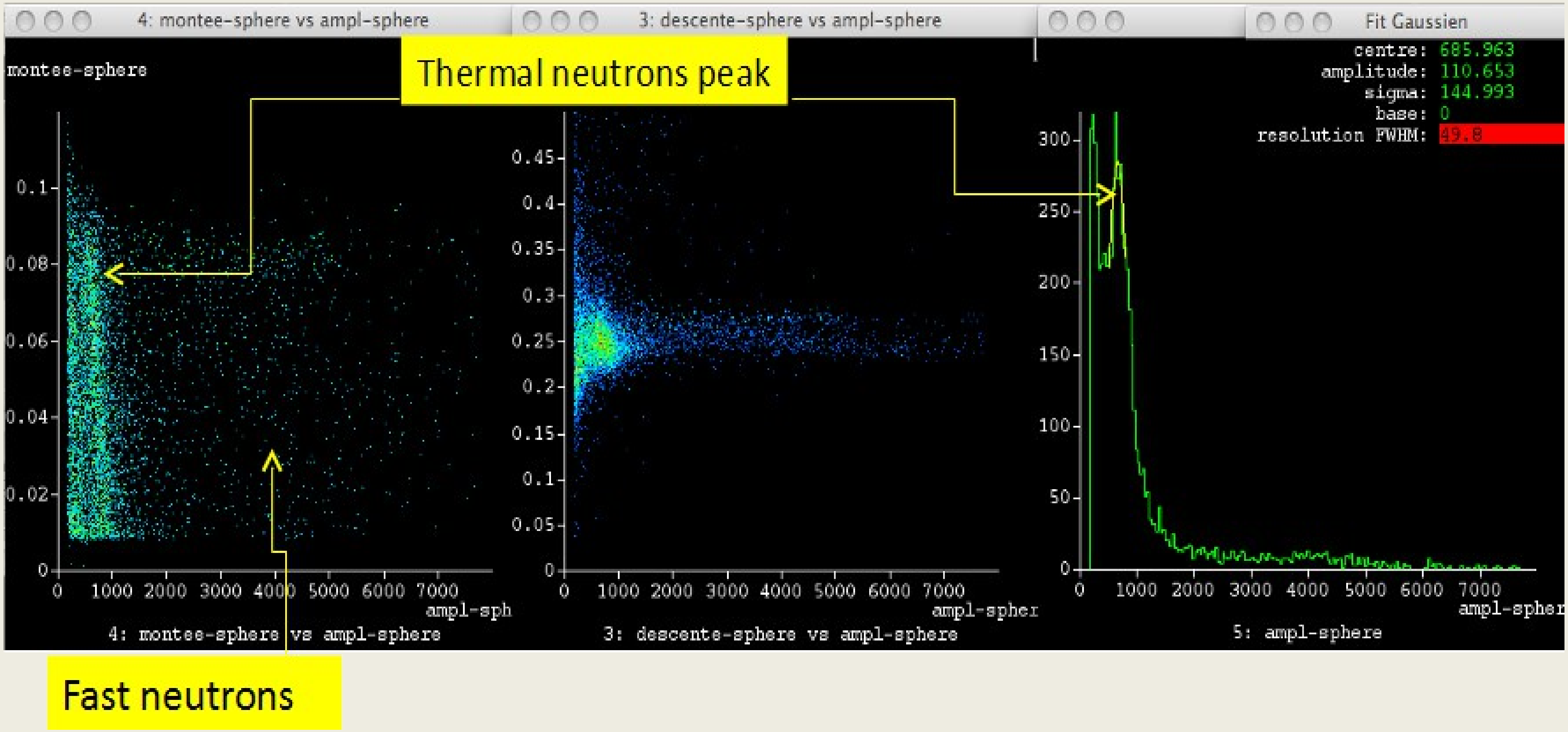
Neutrons from a 252Cf source. In the left picture is the rise time as a function of the amplitude and in the right picture is the amplitude spectrum in ADC units.

Atmospheric neutron detection with 500mbar pure N2



AUTH data

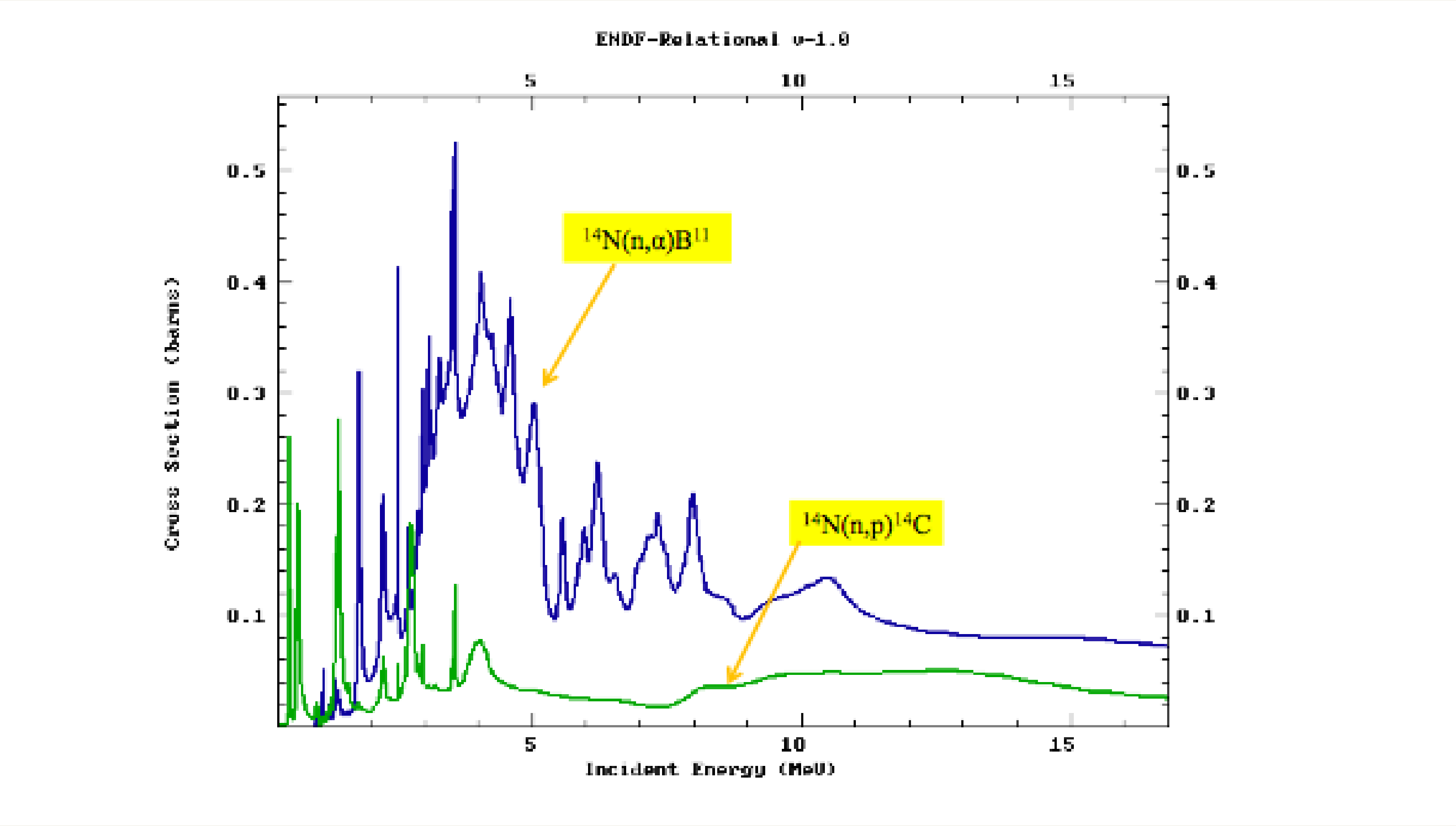
Sensor 8mm, P=200mbar N2, HV1=5586V, HV2=1516V
neutrons from Am-Be source , with PE moderator



Fast neutron detection using the reactions:

$^{14}N + n \rightarrow ^{14}C + p + 625.87$ keV

$^{14}N + n \rightarrow ^{11}B + \alpha$ Q= -158 keV



Experimental data from Am-Be (4cm Pb shielding)
8mm sensor, 140 mbar N_2 + 9mbarAr+1mbarCH_4

Am 241: 30 mCi Total neutron flux: 6.6X10[illegible] neutrons/sec

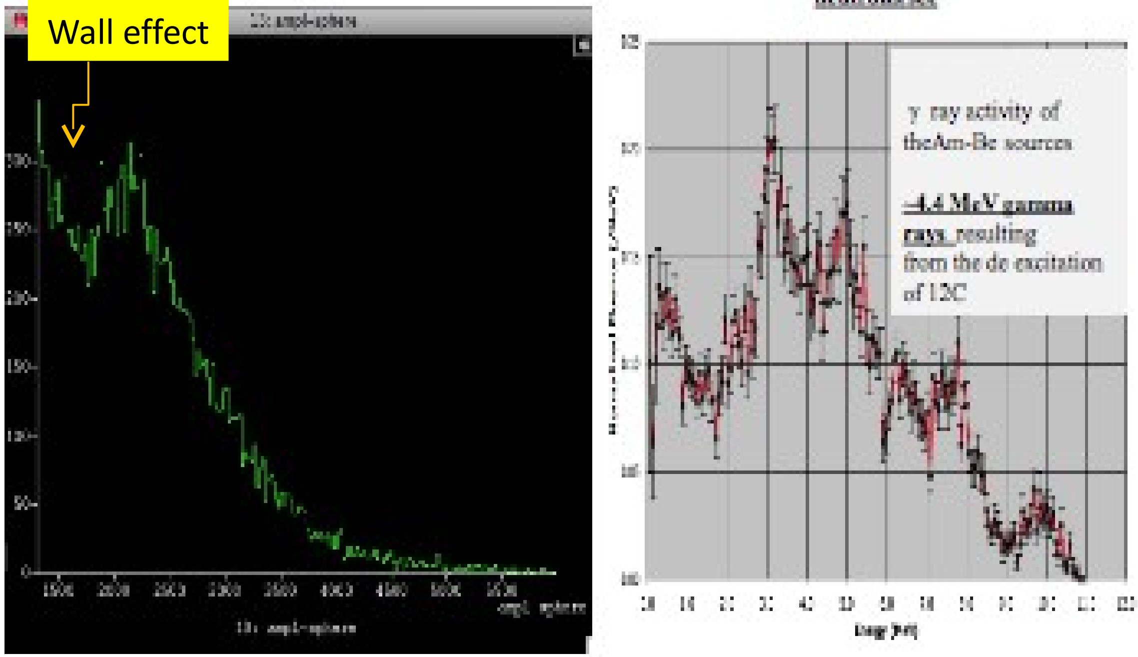


Figure8. *Experimental data after irradiation with Am-Be neutron source. There is movement of the spectrum to the a left coming from the moderated neutrons.*

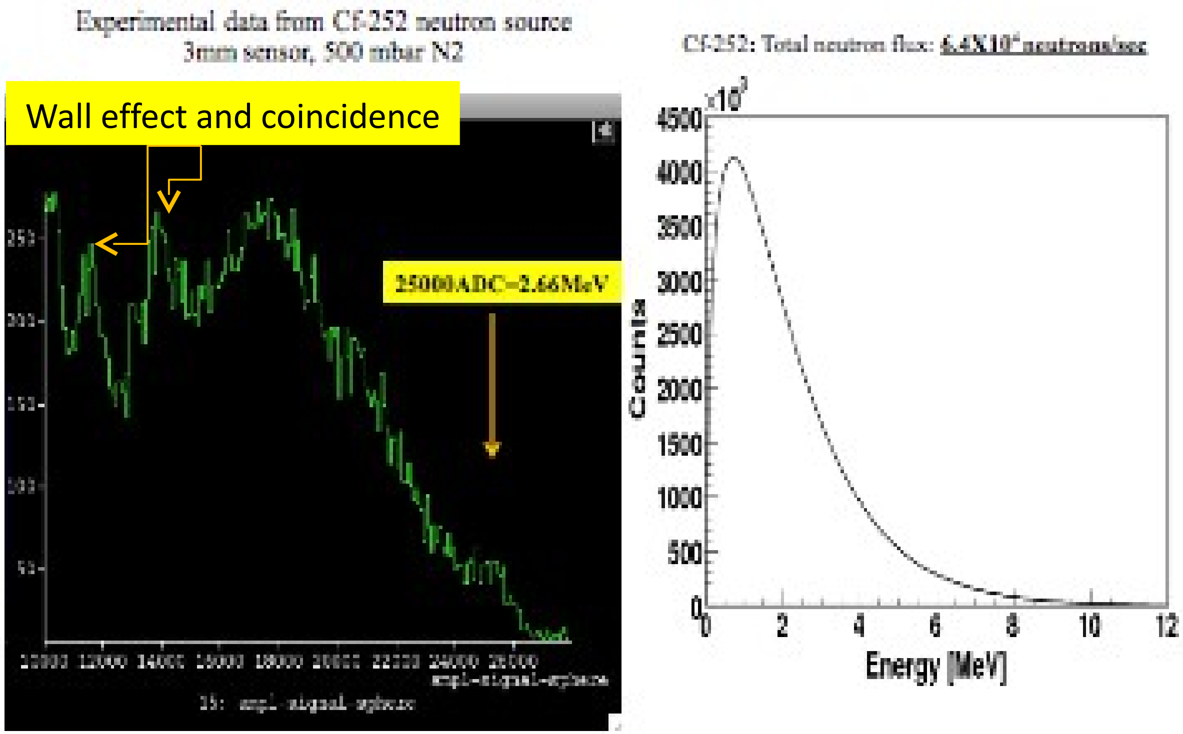


Figure7. *Experimental data after irradiation with Cf neutron source. The (n,p) cross sections coincidence peaks appear at the left picture.*

Applications:

- Neutron spectroscopy
- Fast neutron measurement at underground lab
- Neutron seasonal variations
- Correlations with sunspot activity
- Solar neutron detection

Conclusions and the next step

•The spherical proportional counter can be used successfully as a neutron detector via the 14N(n,p)14C.

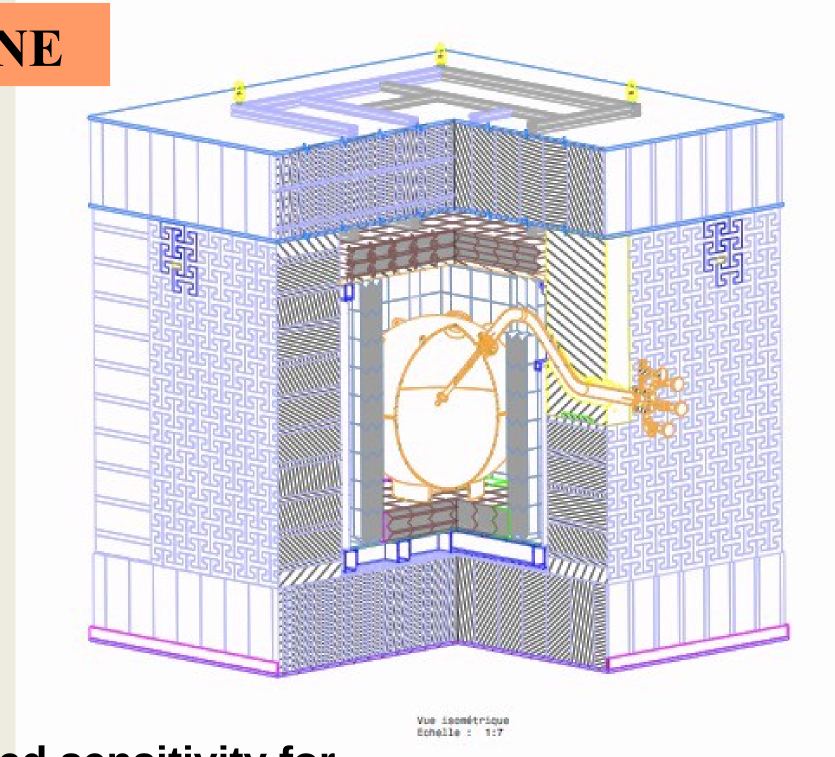
brevet français n° 13 56374 du 01 juillet 2013 (CEA 75%-AUTH 25%)

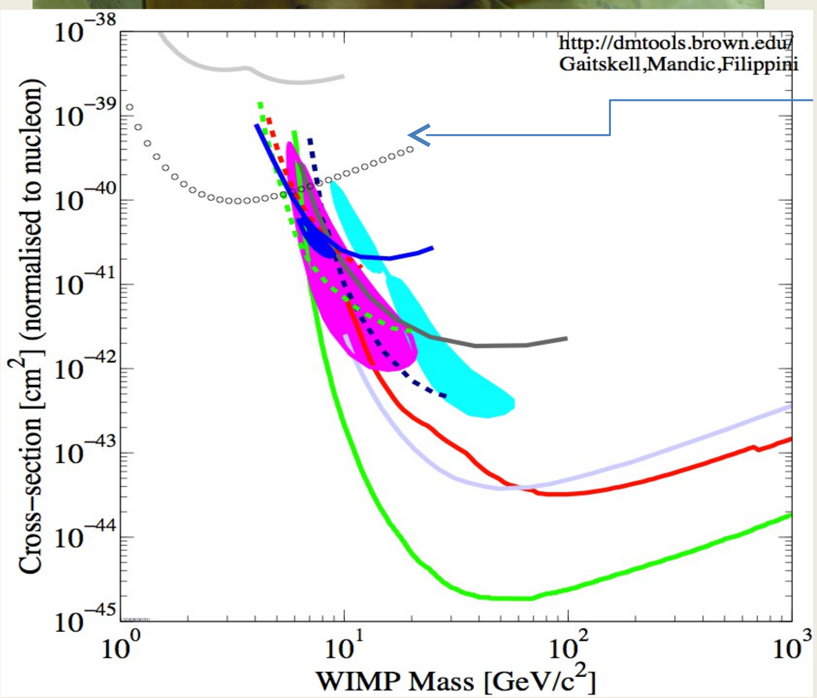
•The large volume with the possibility to operate at high gas pressure is an important advantage of our detector compared to the traditional cylindrical proportional counters.

•Thermal neutron flux has been precisely measured and the detector operates in a stable fashion for many months.

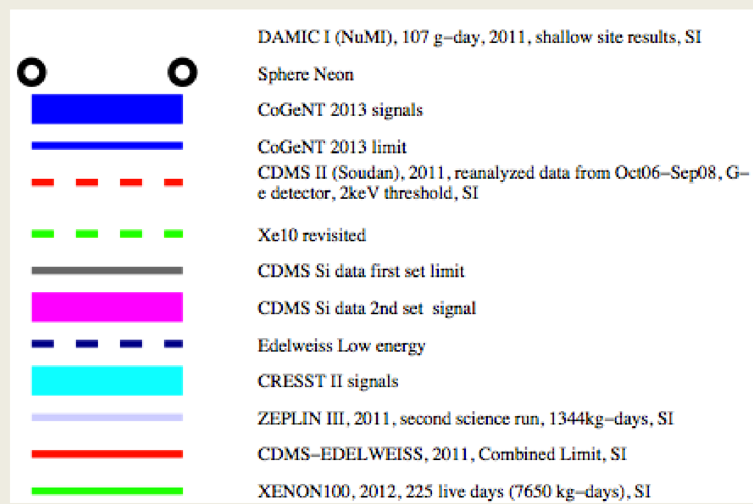
• Fast neutron spectroscopy is possible .

SEDINE





Projected sensitivity for background of 1 evt/kg.keV.d @ 0.3 keV NR, with Neon



The “NEWs” collaboration

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- JD Vergados**, University of Ioannina**
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- Jaime Ruz Armendariz, **Livermore**