# Investigations and applications with the spherical TPC

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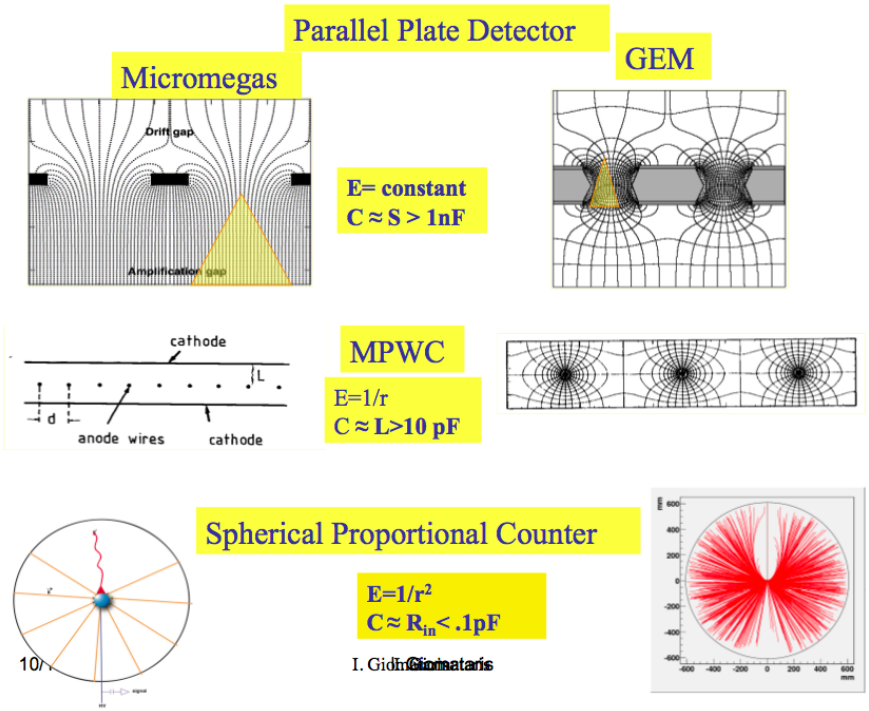
Andes 1st workshop
Buenos Aires, 11-14 april 2011



# Outline

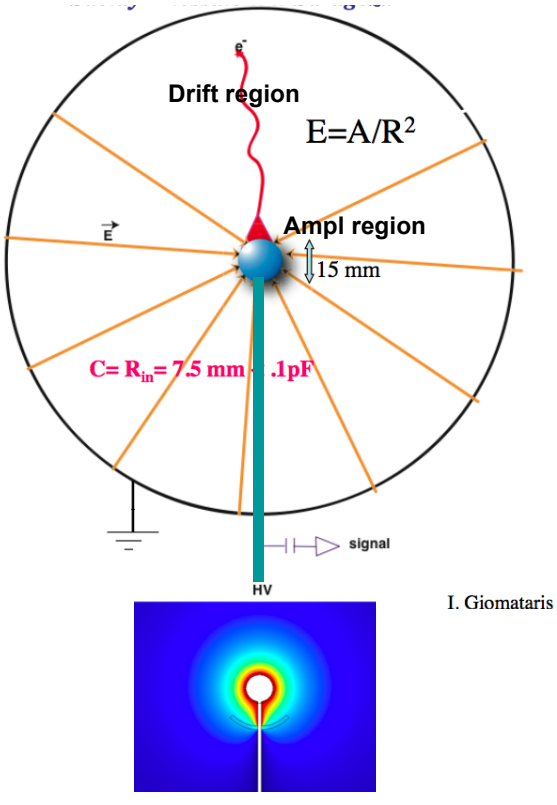
- What is it ?
- High (5 MeV) and low energy (< keV) measurements
- Applications
  - Low neutron flux (thermal & fast) (~ $10^{-6}$ /cm$^2$/s) : prototype
  - Low radioactive contaminant gaz measurements
  - Neutrino coherent scattering
  - SN detectors network
  - Dark matter detection ?

# Principle : comparison with classical configurations

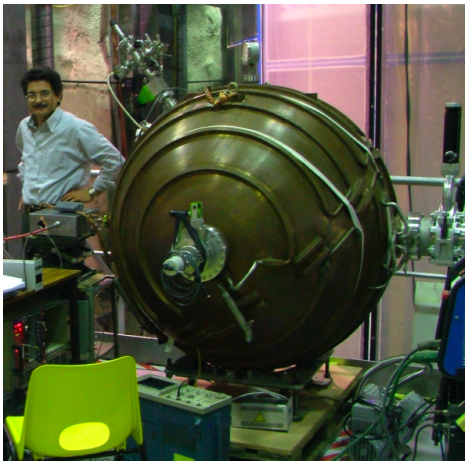



=>Low threshold expected for large mass

# Spherical Proportional Counter

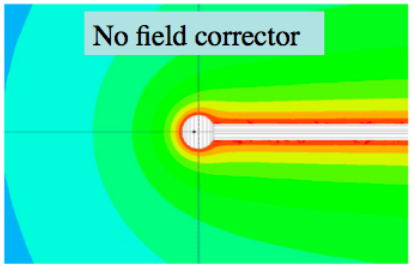


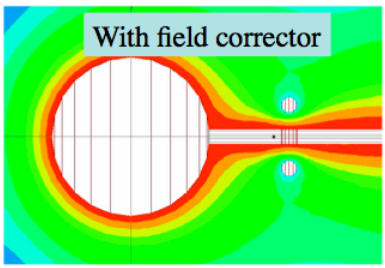

- Low threshold (low C)
- Fiducial selection (risetime)
- Flexible (P, gaz)
- Robust
- Simple/cheap
- 2 LEP cavity tested 1.3 m Ø

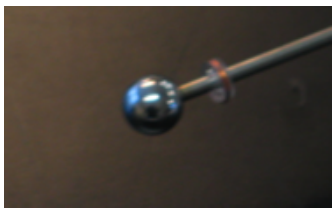


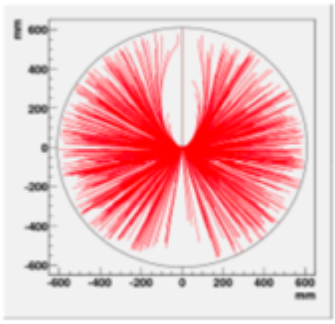
# Recent progress

- New electrode geometry insuring homogenous field(bille + parapluie)





- Calibrations with Ar/CH4 (98/2) mix and Ar/CH4/He3 (90/2/8)
  - Radon => alphas in volume
  - Runs with $^{3}$He à Saclay and LSM
  - Low energy investigation (<1 keV)
- Cleaning of internal surface

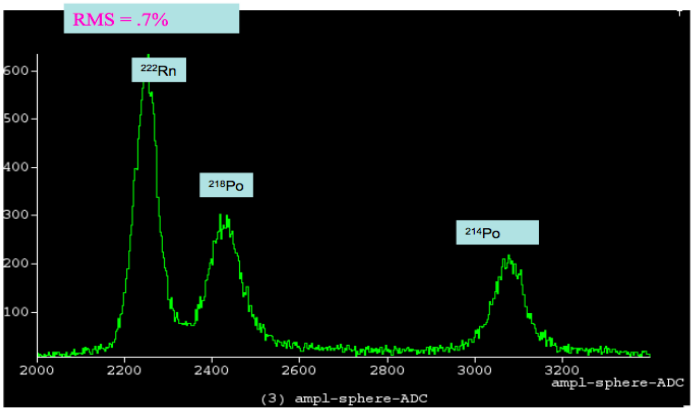


# « High energy » ie 5 to 10 MeV

- Run with Radon gaz in Ar/$CH_{4\ mix}$ at Saclay
  - 5-10 MeV alpha's
  - Excellent energy resolution RMS 0.7 % @ 6 MeV
  - Homogeneity of response (symmetric peak)

**At high energy : Excellent energy resolution**

Measured Radon gas emission spectrum with spherical detector

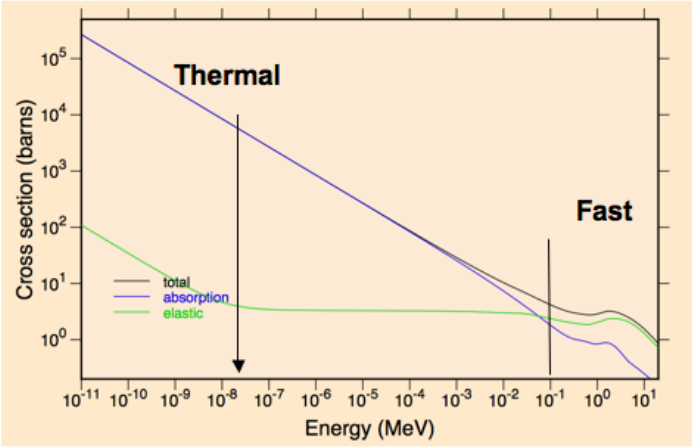





**Energy resolution under amplification: a world record !!**

# Application to detection of thermal and fast neutrons

- Detection of neutron through absorption on $^3$He :
  - n + $^3$He => p + $^3$H + 764 keV
- Thermal and fast (5000 b => 1-2 b)
- « Calorimetric » measurement, low threshold

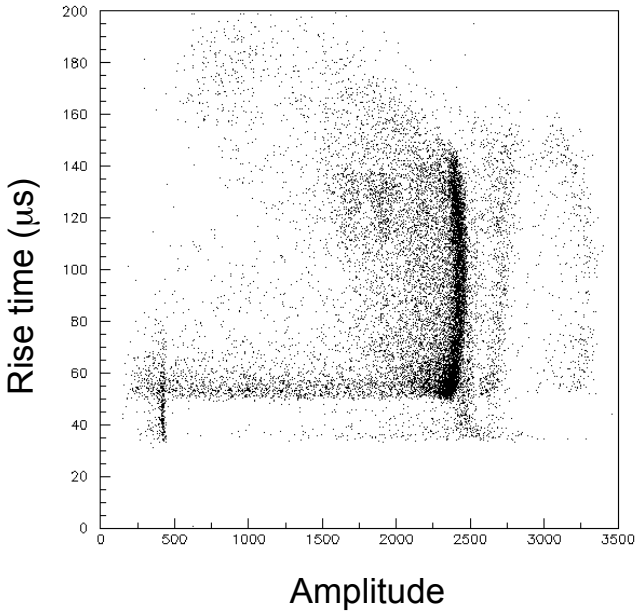



- 2 b à 100 keV
- 1 b à 1-2 MeV

# Run at LSM - Ar/$CH_4$ + 3g $^3$He 200 mb

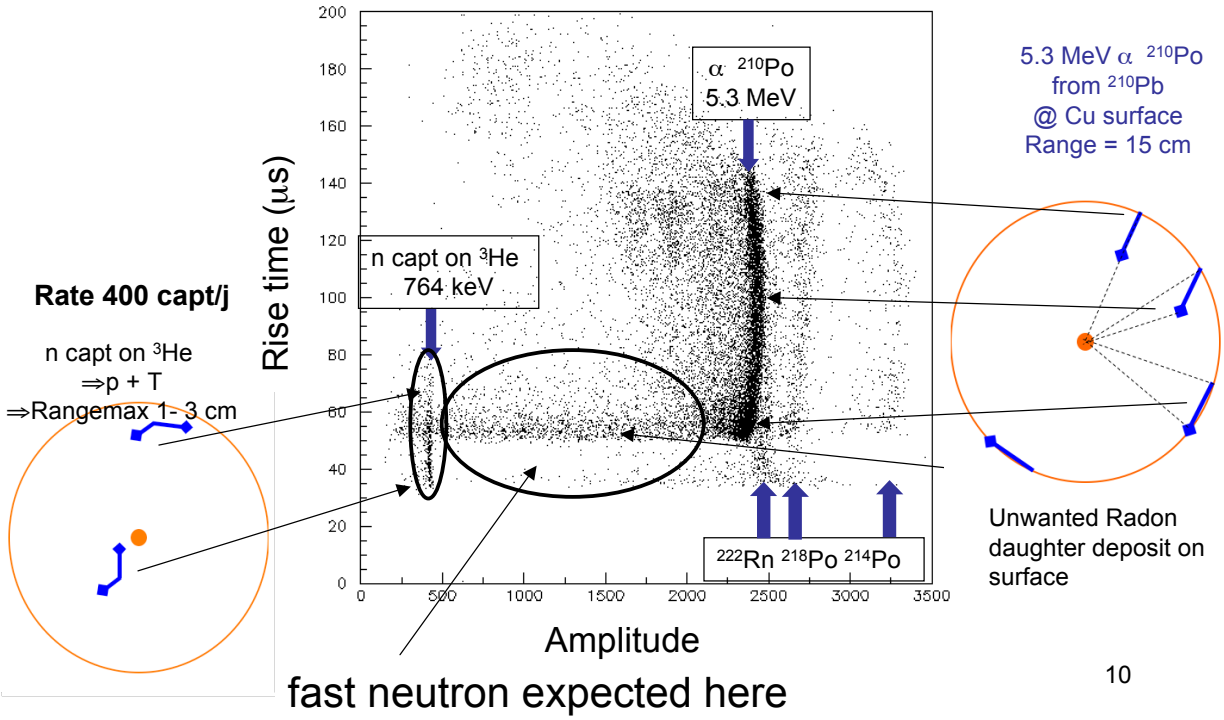
# Run at LSM - $Ar/CH_4$ + 3g $^3He$ 200 mb

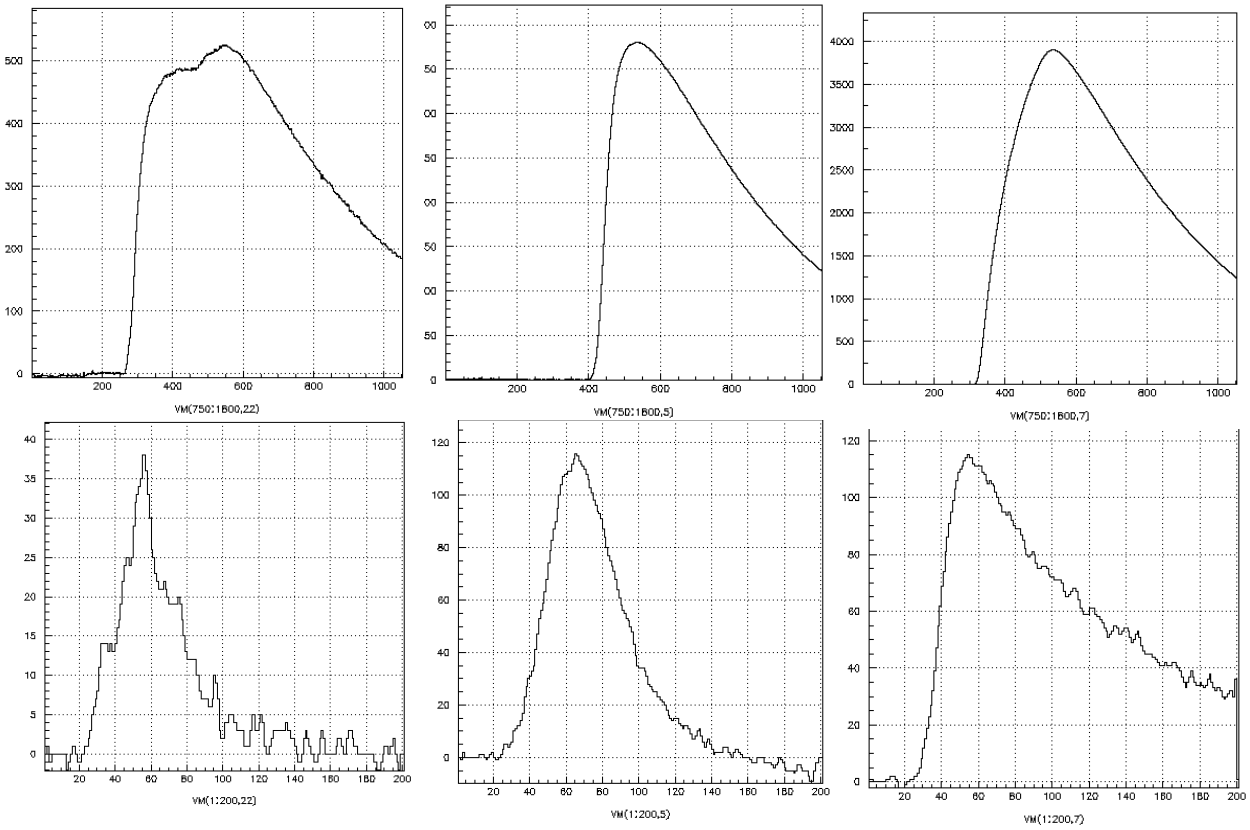
1 MhZ digitisation, shaping time of 1 ms
Study of rise time vs energy :
2 contributions to rise time (10-90)
- dispersion due to diffusion, depends on radius of interaction
- length of track, depends on drift velocity






# Run at LSM - $Ar/CH_4$ + 3g $^3He$ 200 mb



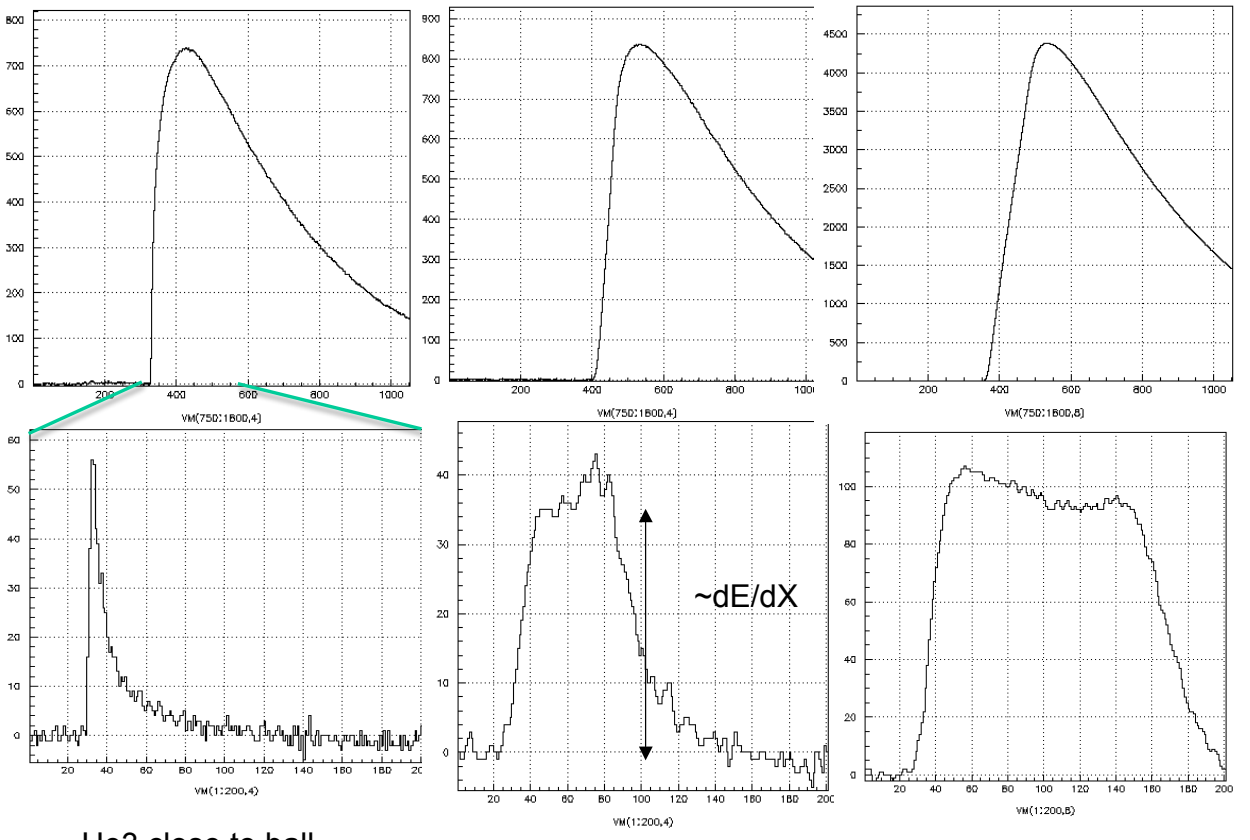



Electron

Alpha surface tangent

Alpha surface radial



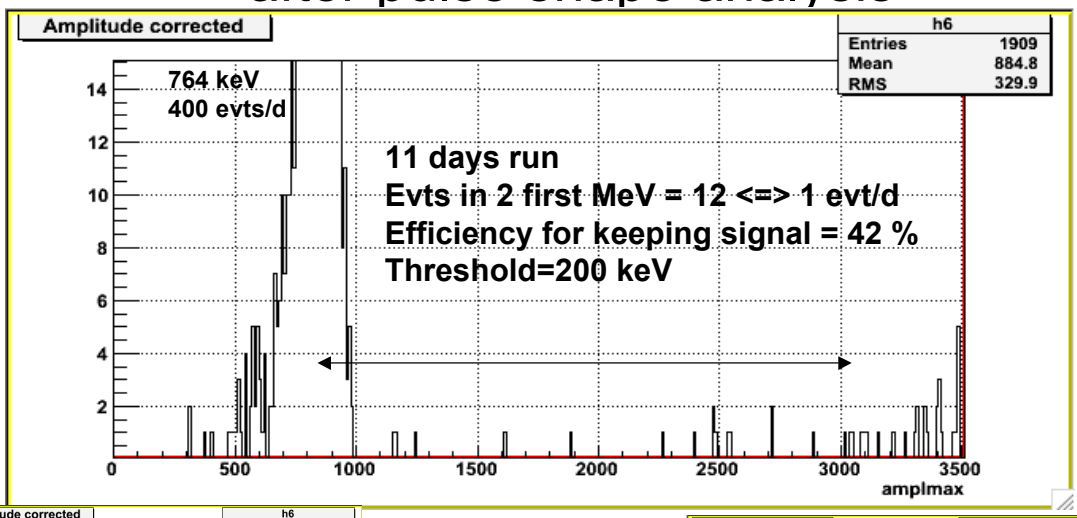


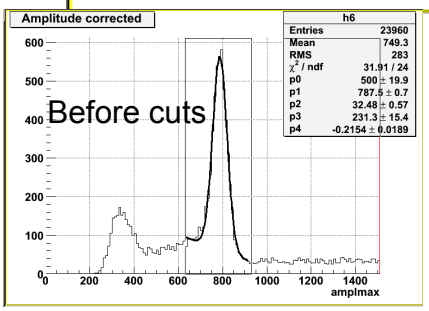

He3 close to ball

He3 in volume

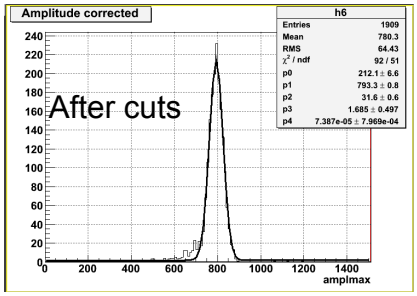
Alpha in volume

# Measured spectrum/rates after pulse shape analysis



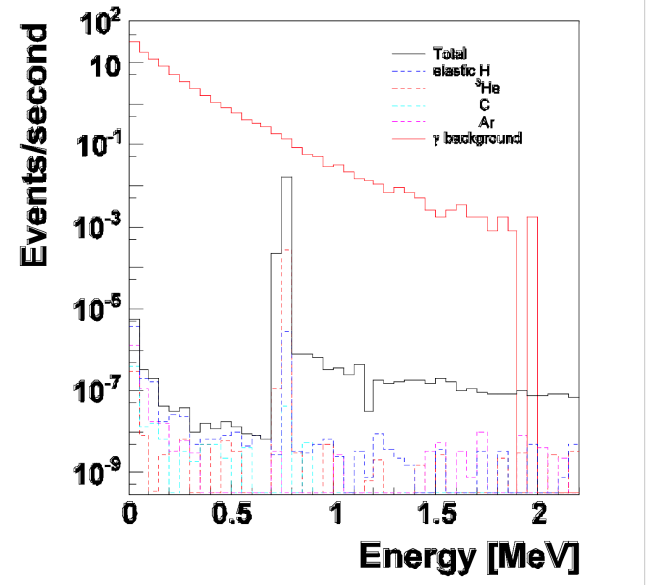



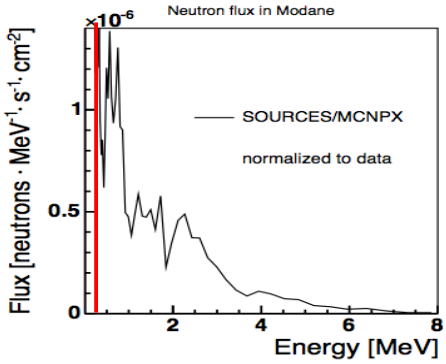

RMS = 3.5 %




# Simulation of expected neutrons in sphere @ LSM

Total $n_{th}$count : 390/d <=> 2 $10^{-6}$ $n_{th}/cm^2/s$
Expected flux from $n_{fast}$ >200 keV ~ * 2
⇒Expect 0.7 event in 11 days !
⇒Most of observed evts is backg



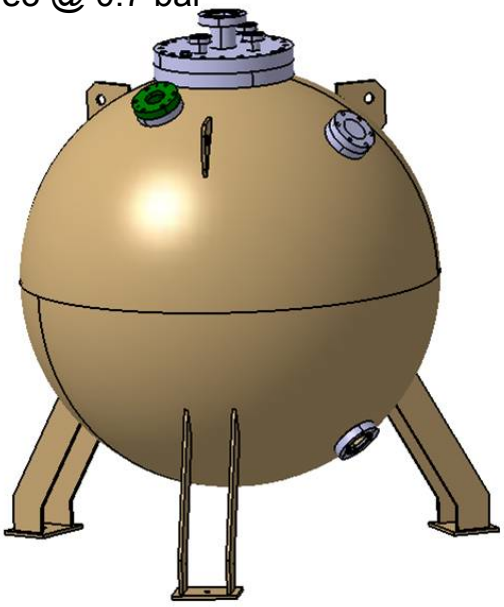

Sphere : - 1.3 m diam - 6 mm Cu thick
Gas : 1 bar
Ar + 2% $C_4H_{10}$
10 g $He_3$
-> 15.9 % H
6.3 % C
72.2% Ar
5.6% He
FWMH: dE= 0.2*sqrt(0.0059*E) MeV
1 $n_{th}/cm^2/s$ and 1.2 $n_{f>500\ keV}$

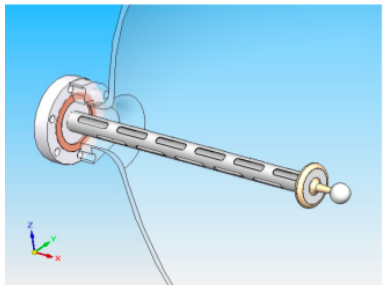
⇒ **Expect 0.2 evt/day after cuts with 10g He3 (150 k€ 2010)**

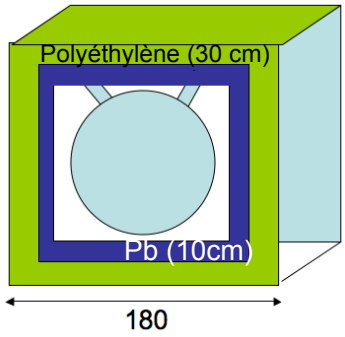
# Low activity project : SEDINE

- Sphere of 60 cm  diameter in low activity Cu and steel
- Low activity material + low Rn emanation

-2 kg Ar @ 10 bar
-10 g He3 @ 0.7 bar



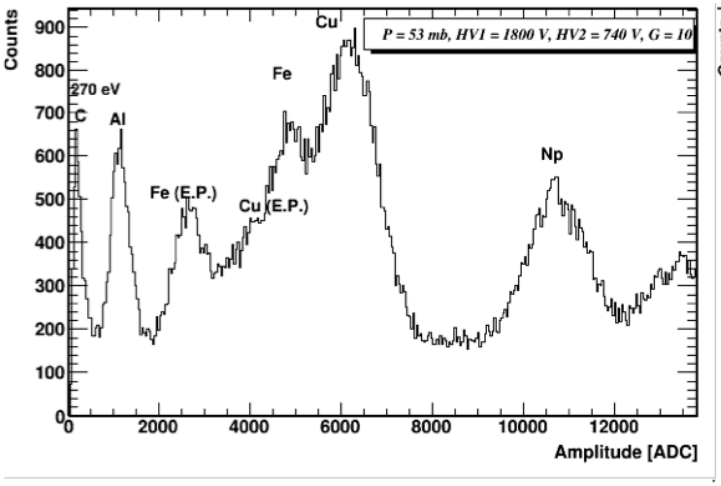


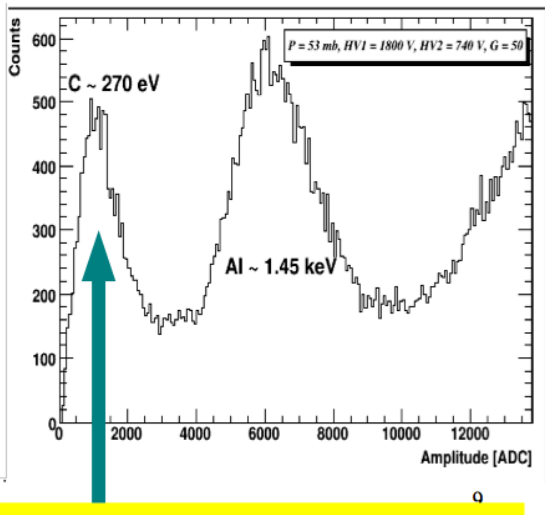





## Sub-keV calibration sources (ii)

- **Am-241 source**
- **10µm Al foil + 20µm polypropylene ≈ α range**
- α crosses Al and absorbed at polypropylene
- ==>Induced Al and C fluorescence



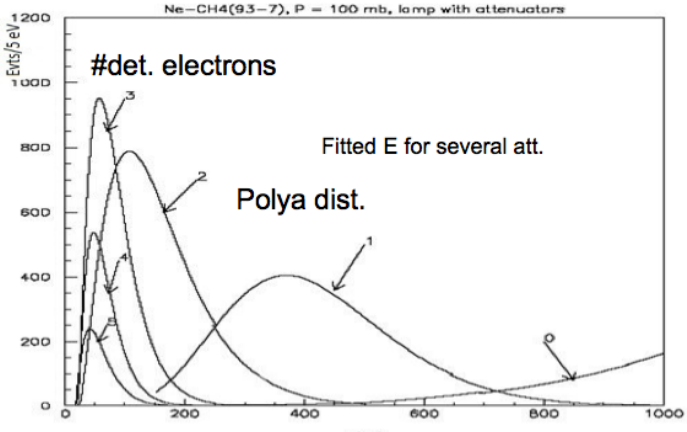



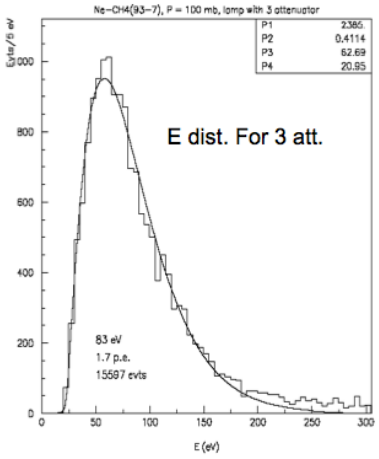

*arXiv:1010.4132 [physics.ins-det], 2010*

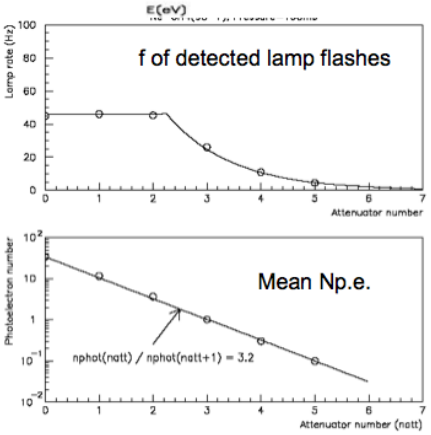
→ **Carbon peak at 270 eV ==> WORLD RECORD**

# Using a UV flash lamp for sub-keV calibration (ii)

- 5 attenuators
- < 3 attenuators ==> Nev ~ stable
- > 3 ==> P for 0 p.e. / flash ↑
- Reduction factor ~ 3
- Natt >3 ==> Emean ~ const
  - Single e- level
  - **Thr < 30 eV**



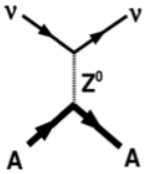




Jacques Derré *arXiv:1010.4132 [physics.ins-det], 2010*

2

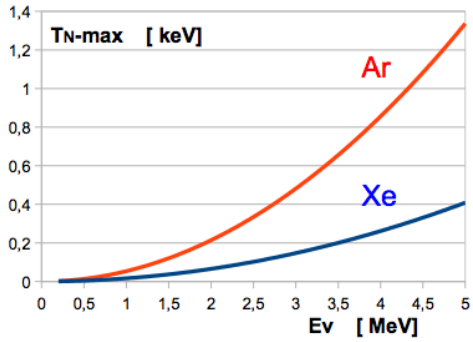
# Coherent Elastic Neutrino – Nucleus Scattering

- **ν + A → ν + A**
- Neutral current
- Coherent up to ~100 MeV
- reactor, solar, spallation source, SN ν
- $\sigma \sim 0.4 \times 10^{-44}\ N^2 (E\nu/MeV)^2 cm^2$




*D. Z. Freedman, Phys. Rev.D,9(1389)1974*

- **Large σ** ↑as Eν↑and scales as $N^2$
- Never be observed before...
- $T_N = 2\, m_N (E_\nu \cos\theta)^2 / \{(m_N + E_\nu)^2 - (E_\nu \cos\theta)^2\}$




- **Recoil energies are tiny!**

## Sensitivity for reactor neutrino detection

**The number of events in one day for the present spherical TPC detector:**

**P=5 Atm, R=.65 m, T=300°K, anti-neutrino flux= $10^{13}$/cm²/s**

| target | anti $\nu_e$ (QF, no Thr) | anti $\nu_e$ (QF) Thr = 1 electron | anti $\nu_e$ (QF) Thr = 2 electron |
|---|---|---|---|
| Xe | 2325 | 825 | 275 |
| Ar | 430 | 292 | 210 |

**40 in small sphere what is backg ?**

# 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*

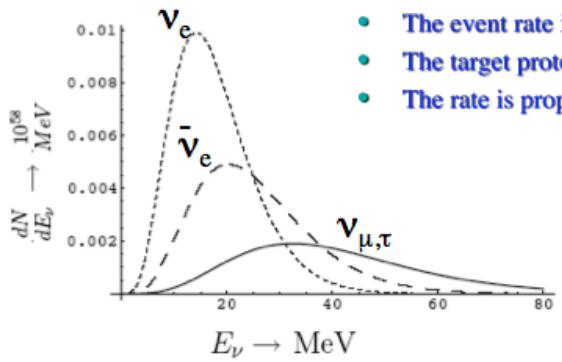
For $E_\nu = 10$ MeV $\sigma \approx N^2 E^2 \approx 2.5 \times 10^{-39}$ cm$^2$, $T_{max} = 1.500$ keV

For $E_\nu = 25$ MeV $\sigma \approx 1.5 \times 10^{-38}$ 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 $N^2$





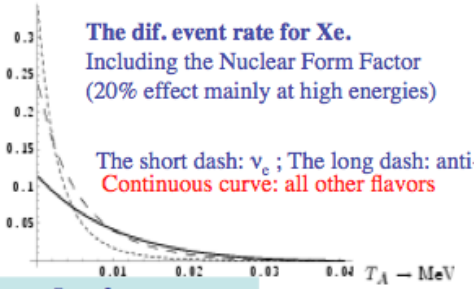

## Supernova detection sensitivity

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: $\nu_e$ ; The long dash: anti- $\nu_e$ ;
Continuous curve: all other flavors

### Sensitivity for galactic explosion

**For p=10 Atm, R=2m, D=10 kpc, $U_\nu$=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** |

## 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



## 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

# Low mass WIMPS' : chaos ?



MPP-2011-
TUM-HEP-806/

**Light Neutralino in the MSSM: a playground for dark matter, flavor physics and collider experiments**

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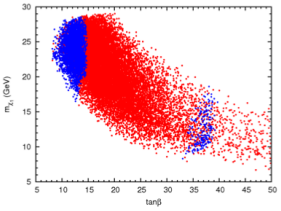
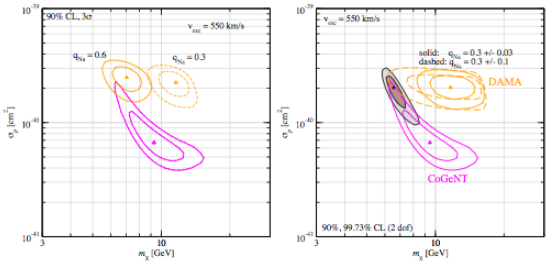
[1] *Max-Planck-Institute für Physik (Werner-Heisenberg-Institute), D-80805 München, Germany*

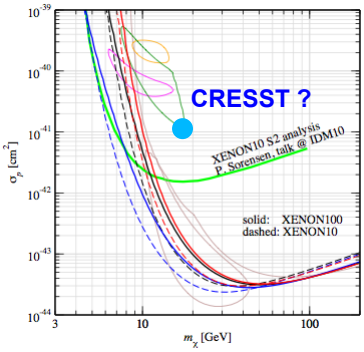
[2] *Physik-Department, Technische Universität München, D-85748 Garching, Germany*

(Dated: April 7, 2011)

We investigate the constraints to the light neutralino dark matter scenario in the minimal supersymmetric standard model from available experimental observations such as decays of $B$ and $K$ meson, relic dark matter abundance, and the search for neutralino and Higgs production at colliders. We find that two regions of the MSSM parameter space fulfill all the constraints: a fine-tuned strip with large $\tan\beta$ where the lightest neutralino can be as light as 8 GeV, and a low $\tan\beta$ region providing a neutralino mass larger than 16 GeV. The large $\tan\beta$ strip, which can be compatible with recently reported signals from direct detection experiments, can be fully tested by means of low-energy observables and, in particular, by $B_s \to \mu\mu$ and Higgs bosons searches at the LHC within the upcoming months.



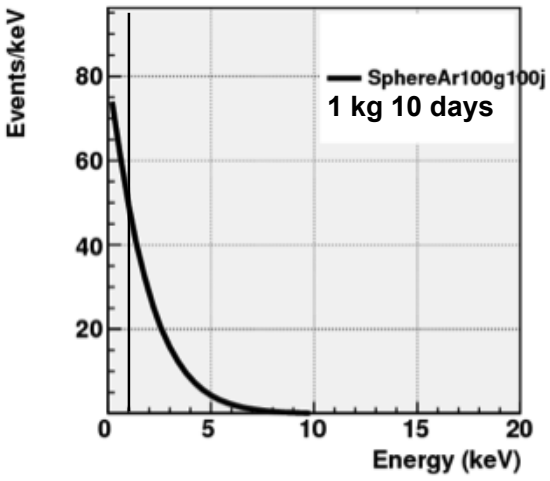




Schwetz 1011.5432

# Low mass WIMP's

Expected spectrum from 7 GeV $10^{-40}$pb in Ar



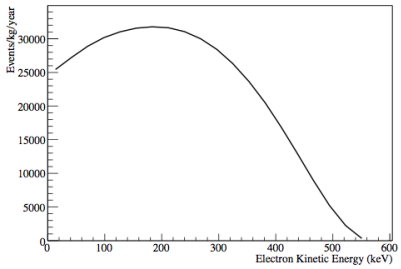




**Figure 2.2: Beta spectrum of argon-39 (calculated by [39])**

Example : beta decay of Ar39
⇒160 evts/kg.d.keV @ 1 keV
⇒ Depleted argon ?

10 evts/d @ 5 atm in small sphere with E> 1 KeV-recoill
-Quench Factor ? To be measured soon
-Background ? PSD effective at which E ?

# Summary-prospects

- Sherical Propotional Counter = promising detector
- SPC out of the shelf (almost) adapted to (fast) **neutron flux** measurements **without shield**
  - Rn and holder seem to be source of background : probably solvable with actual spheres
  - Lot of information in pulse shape : simulation and multivariable analysis to be performed
  - But, $^{3}$He cost is prohibitive for better sensitivities
- Low activity prototype will allow
  - To confirm the interest for neutron measurement
  - To adress the low energy investigation -discrimination nuc/electron recoils, threshold- with acquired knowledge of track behaviour
- Coherent neutrino scattering at hand, but
  - what is backgound ?
  - tuning P, gaz for the best ratio S/B
- R&D for scintillation detection (coating of internal of sphere)…
- Overall a good way of trans-regional collaboration