Large TPCs for low energy rare event detection

- Highlights from the Paris TPC workshop
- Spherical TPC project and motivation
Gaseous TPCs:

1) Low energy neutrino detection (neutrino oscillations, solar neutrinos, double beta decay, magnetic moment, supernova), I. Vergados, G. Gounaris, I. Irastorza, Ph. Gorodetzky, G. Bonvicini, Z. Daraktchieva, M. Green, M. Zito

2) Axion search, Th. Dafni, B. Beltran

3) WIMP search with recoil direction, B. Sadoulet, N. Spooner, D. Santos

Liquid TPCs,

A. Rubbia, E. Aprile, N-J-T. Smith, Ph. Lightfoot, V. Peskov

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Main motivation: drifting ions instead of electrons reduces the diffusion effect

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Use low pressure gas

Negative ion drift with CS$_2$ idea by Jeff Martoff

DRIFT and Prospects for a Large Scale Directional WIMP TPC

N. Spooner
MIMAC-He3: Micro-tpc Matrix of Chambers of He3 (D. Santos)

$^3$He for axial detection of non-baryonic dark matter

High spatial temporal resolution recoil track projection
⇒ energy threshold < 1 keV
⇒ electron/recoil discrimination

Last refinement: CMOS integrated pixel anodes (H. Van der Graaf)

Idea: Combine micro-pad CMOS with high accuracy MPGD like Micromegas
Spherical TPC with spherical proportional counter read-out

- 5.9 keV $^{55}$Fe signal
- Very low electronic noise: low threshold
- Good fit to theoretical curve including avalanche induction and electronics

$E = A/R^2$

20 μs

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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:**
  - Symmetry: lower noise and threshold
  - Low capacity
  - 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

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First prototype: the Saclay sphere

- D=1.3 m
- V=1 m³
- Spherical vessel made of Cu (6 mm thick)
- P up to 5 bar possible (up to 1.5 tested up to now)
- Vacuum tight: \( \sim 10^{-6} \) mbar (outgassing: \( \sim 10^{-9} \) mbar/s)

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- 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.
First results

• 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 tests are under preparation to better calibrate (external trigger from Am source)

[Graph showing average time dispersion of 5.9 keV deconvoluted events vs. distance drifted]

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First underground tests in LSM 5-4-2004

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Long term program

NOSTOS  I. Giomataris, J. Vergados, hep-ex/0303045

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

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

Objectives
- Measure \( \theta_{13} \) (systematic free)
- Neutrino magnetic moment studies \( \ll 10^{-12} \mu_B \)
- Measurement of the Weinberg angle at low energy
Short term (3 year program)
Neutrino-nucleus coherent elastic scattering

\[ \sigma \approx N^2E^2, \quad D. \ Z. \ Freedman, \ Phys. \ Rev.D,9(1389)1974 \]

1. Nuclear reactor measurement sensitivity with present prototype

after 1 year run (2x10^7 s), assuming full detector efficiency:

- Xe (\(\sigma \approx 2.16 \times 10^{-40} \text{ cm}^2\)), \(2.2 \times 10^6\) neutrinos detected, \(E_{\text{max}} = 146 \text{ eV}\)

- Ar (\(\sigma \approx 1.7 \times 10^{-41} \text{ cm}^2\)), \(9 \times 10^4\) neutrinos detected, \(E_{\text{max}} = 480 \text{ eV}\)

- Ne (\(\sigma \approx 7.8 \times 10^{-42} \text{ cm}^2\)), \(1.87 \times 10^4\) neutrinos detected, \(E_{\text{max}} = 960 \text{ eV}\)

**Challenge : Very low energy threshold**

We need to calculate and measure the quenching factor

2. Spalation source measurement with present prototype

3. Supernova neutrino detection with a 2nd demonstrator (4 m)

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

For \(E_\nu = 25 \text{ MeV}\) \(\sigma \approx 1.5 \times 10^{-38} \text{ cm}^2\), \(T_{\text{max}} = 9 \text{ keV}\)

Expected signal: 100 events (Xenon at p=10 bar) per galactic explosion (including detector threshold and quenching factor)

Idea: A European or world wide network of several (tenths or hundreds) of such simple (one channel), robust and low cost detectors (\(T_{\text{life time}} >> 1 \text{ century}\))
Conclusions

• Large volume TPCs are already used for rare event detection

• Combined with new MPGD precise detector can provide low energy threshold and recoil directionality

• A novel detector based in the spherical geometry with spherical proportional counter read-out has been successfully tested and it is under development.

• Many applications in low energy neutrino physics are open