New results from Vibrating Wire measurements in superfluid ^{3}He: *From particle detection to topological defects*

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Particle detection with superfluid ^{3}He-B

Superfluid ^{3}He at ultra-low temperatures presents promising features as a sensitive medium for the bolometric detection, in particular for the search of non-baryonic Dark Matter [1,2].
Within the MACHE3 collaboration, using a detector prototype of 3 adjacent cells, we were able to detect cosmic muons at an energy of about 65 keV, as expected from calculations (fig. 1) [3].
The even more remarkable result was further on the detection of internal conversion electrons of 7.3 and 13.6 keV released by a small amount of radioactive ^{57}Co in one of the cells. A threshold of 1 keV is currently achieved by the detector.

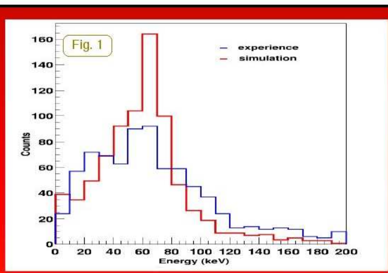


Fig. 1: Cosmic muon detection by the Dark matter detector prototype in good agreement with numerical simulations. The energy of the cosmic muon spectrum is centered around 65 keV.

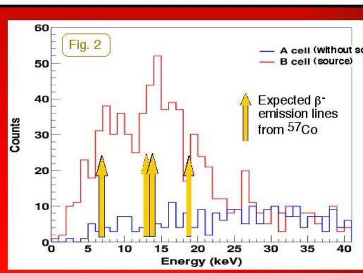


Fig. 2: Energy spectrum of low energy electrons released by a 57Co source inside one bolometric cell (B). For comparision, the other cell (A, without source) shows the background, mainly due to γ-rays and muons.

Neutrons again

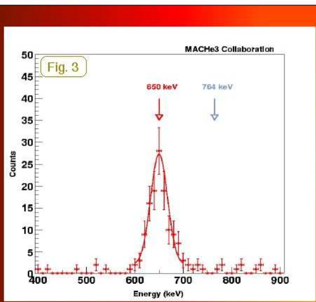
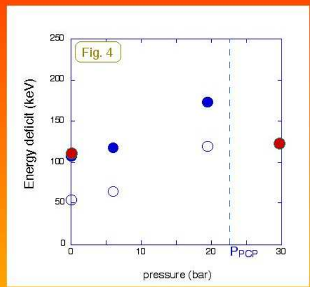


Fig. 3: Neutron detection spectrum in superfluid 3He at 0 bar. The energy shift with respect to 764 keV is attributed partly to UV scintillation, and to the creation of metastable vortices

Fig. 4: Pressure dependence of the rough energy deficit (●) and after substraction of pressure independent UV scintillation losses (○) from [4].
New measurements (●) are in good agreement at zero pressure and indicate a strong decrease of the energy deficit at high pressure.



The nuclear neutron capture reaction

$$n + {}^3He \longrightarrow {}^3H + p$$

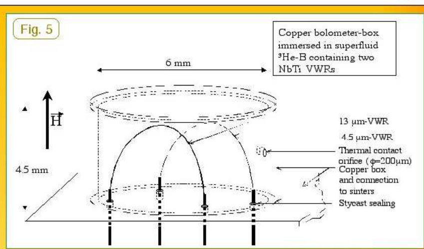
releases an energy of 764 keV, producing a hot spot in the superfluid. Previous measurements showed that even after substraction of UV scintillation (7%), not all the released energy was detected bolometrically [4]. It was concluded that 7 to 15 % of the total energy remained trapped in topological defects created by the fast cooling through the superfluid transition, according to the Kibble-Zurek (KZ) theory.
We repeated these measurements at pressures above the polycritical point (A-B-N) and found a pronounced reduction of the energy deficit. This non-trivial pressure dependence gives further support to KZ type theories.

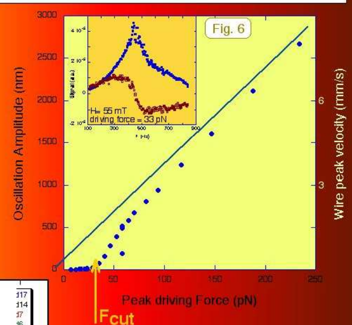
Probing topological defects in superfluid ^{3}He with a Vibrating Wire Resonator ?

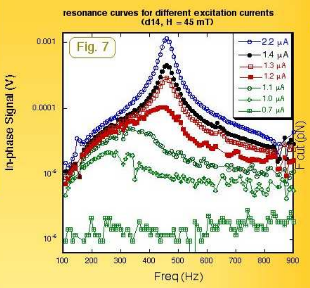
In some experimental runs (demagnetizations) we observed the 4.5 µm diameter wire in one cell (fig. 5) to display anomalously high damping, in contradiction with the extremely low temperatures indicated by a second 13 µm diameter wire.

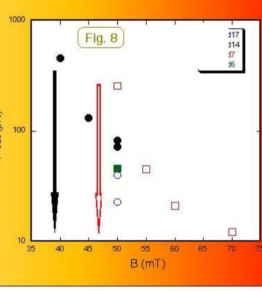
At magnetic fields around 100 mT, this extra damping term was found to be independent of the excitation drive. For lower fields (H < 70 mT), we observed the Vibrating Wire resonance to collapse rapidly on decreasing the excitation current until the VWR does not respond at all, as if it were trapped fig. 6 and 7).
This trapping force strongly increases as the field is lowered (fig. 8), until the VWR gets eventually completely blocked. Upon further lowering of the field, the trapping of the wire suddenly disappears (arrows in fig. 8). No anomalous behavior was observed to reappear in the same experimental run after such an 'unblocking'.

Finally, we succeeded to remove the defect by applying pulses with the heater wire, reaching temperatures close to Tc.









Conclusion

1. **Superfluid ^{3}He detectors are suitable for dark matter search [5]**

2. **Vortex formation after a fast cooling of ^{3}He through the phase transition is sensitive to the A-B transition. Therefore, ultraviolet radiation can not explain the missing energy and the process of vortex formation is more likely to be described by the "Aurore de Venise" scenario. [6]**

3. **The interaction of the vibrating wire with a topological defect is a very new subject of investigations. The order of magnitude of the force and energy involved, indicates that the defect is likely to be the "cosmological" soliton. [7]**

References

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