# Polarized bolometer, a new  tool essential to neutrino physics?

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# Why a polarized bolometer?

- Neutrinos are intrinsically polarized in their direction of propagation .They are sensitive to vectorial and axial interaction. The latter depends on the relative direction of the polarization versus the direction of the neutrino beam.
- By changing the polarization of the nuclei of the bolometer, one will change/control the axial interaction, an unexpected situation in the physic of neutrino

# Origin of the proposal

- In a recent paper Tarso Franarin and Malcolm Fairbairn {1} show that a polarized target, in fact gaseous $He^3$, (100kg !!!) permit to change the interaction between the neutrinos and the target, in best **case to suppress it** gaining the possibility to search dark matter, even with a floor of solar neutrinos
- .On contrary, we take advantage of the polarisation to modify the interaction, modifying at hand the part coming from the axial interaction.
- In this presentation we recall an old but well known procedure to polarized nuclei embedded in a dielectric solid and indicate interesting paths for differents nuclei which appears as promising targets for scattering studies.
- (1) Tarso Franarin and Malcolm Fairbairn ArXiv1605.08
- 4sep 2016 and Physical Review D 94,053004 (2016)
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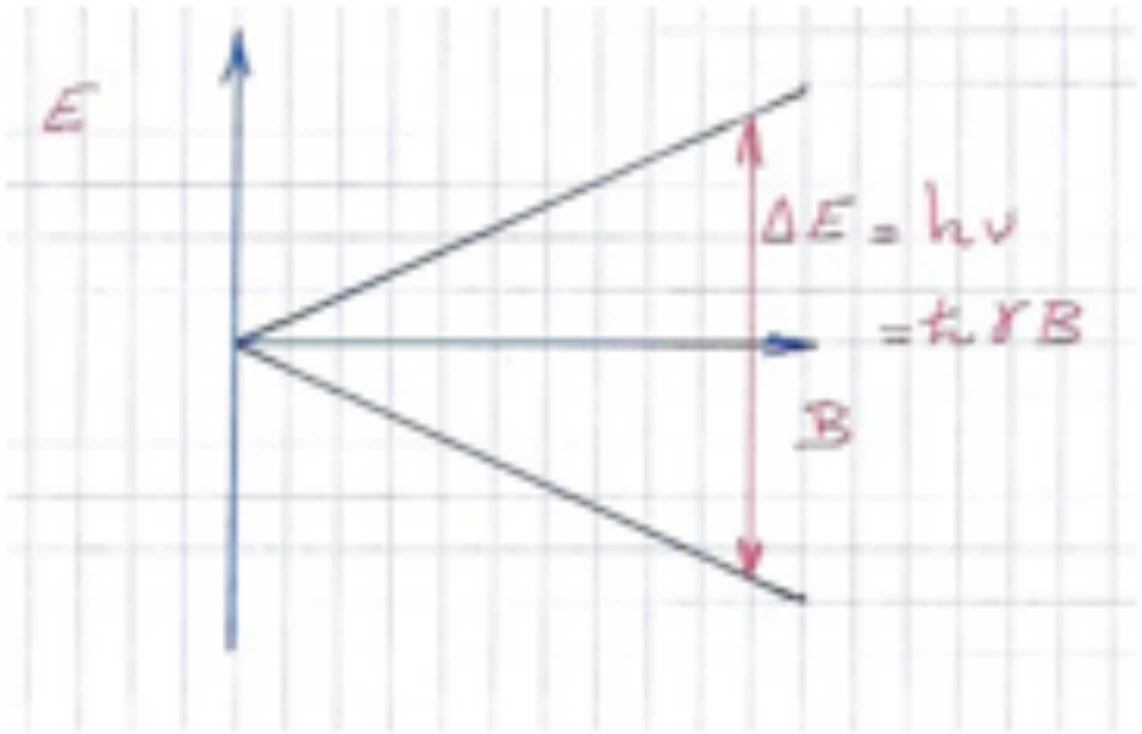
# A spin in a magnetic field




$$\frac{p_1}{p_2} = \exp\left(-\frac{E}{kT}\right)$$

A simple calculation give P= $\langle I_z \rangle / I = \mathrm{th}\frac{E}{2kT}$

# How to polarize nuclei in a solid?

If you try to apply a high magnetic field and a very low temperature to enhance **P= <Iz>/I** (so call brute force) in a dielectric, you will fail because :

*You need a very large magnetic field and a very low temperature. A numerical example for protons, the biggest nuclear moment

2.5T and 1,4K result only in P=0,18%

*the spin of a nuclei have no interaction with the phonons of the solid !! So P will never reach its thermodynamic equilibrium

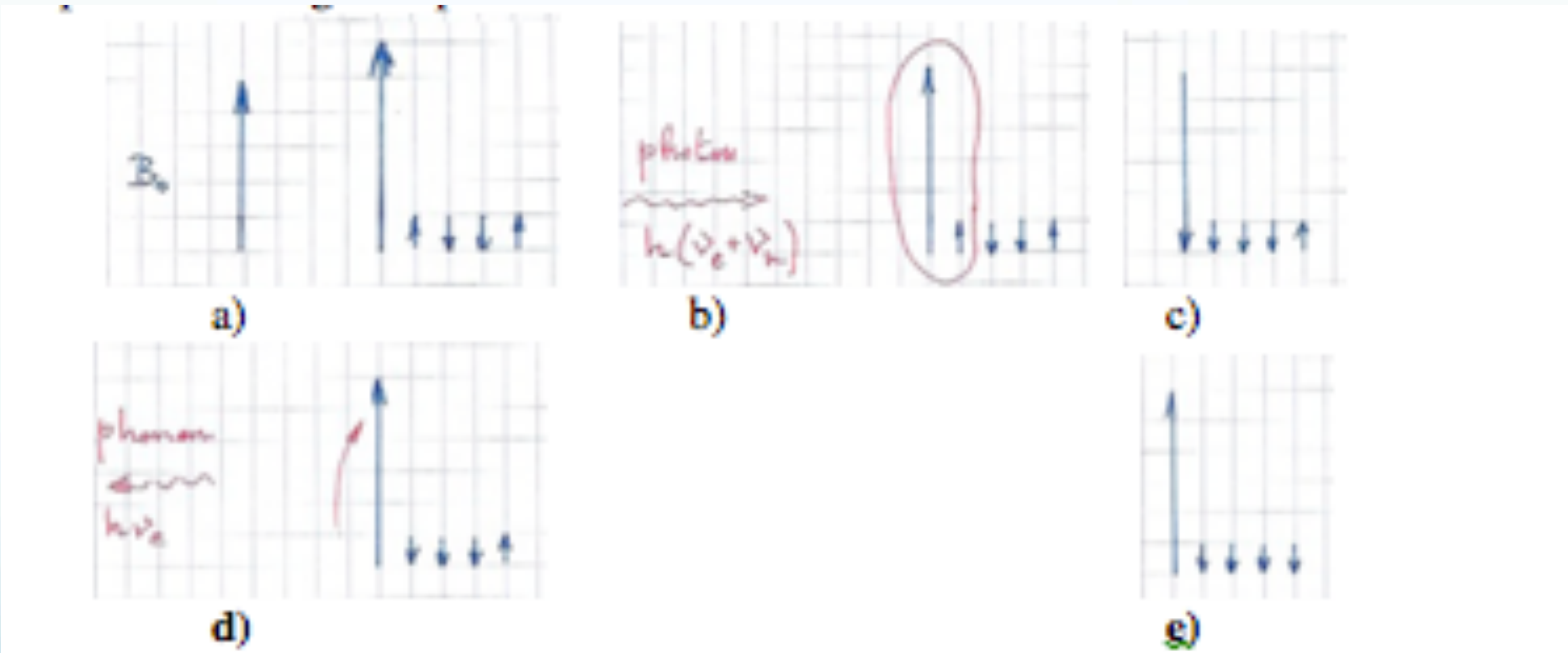
# Transfer of the electronic polarization to the nuclei. Dynamic polarization.

- Suppose a dielectric solid in which, among the nucleis, is added a small concentration of electronic spins. Contrary to the nuclei the electronic spin are well coupled to the lattice and by all means they could return to equilibrium by a self emission of a phonon

- ,their moment is much bigger than the nucleus one by three order of magnitude which means that for example an unpaired electron (with g=2) in the condition seen before (field of2.5T and a temperature of 1.4K) the polarisation is 49% !

- How to transfer this polarisation to the surrounding spins?

- Remember that if a radiofrequency is applied at the resonant frequency to the spin system, it flip spins , passing them from the lower level to the upper. The electronic spins return to their equilibrium with a strong rate $1/T_1$. In fig 3 a) the electronic spin is fully polarised and the nuclei are not, there is equal nuclear spin up and down .If now we applied a frequency sum of the resonant frequencies of the electron and the nuclei the transition is forbidden to first order but strong enough to second order. (fig 3 b). It will flip a nuclei from up to down leaving the system as in fig(3 c) . The electronic spin will return to equilibrium emitting a phonon fig(3 d). The process will continue with also a diffusion of polarisation among the nuclear spin. At the end the polarisation of the nuclei will be negative and equal in size to the electronic spin fig(3 e)


B₀
photon
h(νe+νn)
phonon
hνe
a)
b)
c)
d)
g)

# Examples of dynamic polarization

CaF2 doped with Thulium ions

The experiment lead in the past with very high field (H= 2.7 T ) and medium low temperature (T= .4K ) a **polarization of the F nuclei near 90%** . It was used , after adiabatic demagnetization of the nuclei to the discovery of nuclear antiferromagnetism [5]

**LiF and LiH doped with F centers**

Irradiation either with neutrons or with fast electrons of LiF lead to so call F centers. An ion is ejected and leave an empty space with an electron , usually with g=2 . These centers were used as polarization center for both F and Li nuclei at H = 2.5T and T= .4K

LiH was later on polarized, at a lower temperature (around 100mK) a rather high field (5,5T) but it need special surrounding without any humidity which react very strongly with the surface of the crystal [6],

La2Mg3 (NO3)6 24H2O doped with Nd

In this salt, first used as a polarized target for nuclear and high energy physics one was able to polarized all the nuclei of this salt H, La, N. The experiments were

done at 2.5 T and 1.4K with a microwave frequency around 70Ghz (lambda=4mm)
H was used as polarized nuclei for nuclear physics [2],
and also at CERN for (unpublished) the study of the parity of the Ksi

Al2O3 doped with Fe or Cr
This was intensively studied (7) at very low temperature (down to 6mK) to observe the different coupling between Al, Fe, phonons and finally the Kapitza resistance of the crystal in a dilute solution of He3/He4. The transfer of polarization was this time done without radiofrequency but by adiabatic demagnetization of the Fe at zero field, mixing with the Al nuclei and repolarization of the Al. It is a good candidate as a polarized bolometer, with moderate magnetic field. An other doping is with Cr ions in ruby which was studied also by the same group .With this Cr ion a possible scheme at low field is possible since Cr ion have zero degenerate levels.

**4) Issues**

We should test how dynamic polarization is working at very low temperature.In a high initial magnetic field it should produce very high polarization, even on a nuclei with a small magnetic moment.

We will need very moderated magnetic fields to insure a simple thermometry suited to bolometry. It would be then possible to polarized the bolometer in a high field and then reduce it slowly to a suitable but probably non zero field.

**5) Conclusion**. A new path is proposed to get a tool to detect and modifie at hand the interaction between neutrino and nuclei through axial interaction. One then should choose a light nuclei to have the strongest effect du to the polarization and in the the same time a large nuclear recoil . As calculated in [1], $^{19}F$ still offer a large polarisation effect. LiF appears to be a good test candidate but later on LiH and LiD are very appealing.The final experiment should be done on a neutrino beam, with the possibility of on off situation and a large beam energy, the interaction following a $E^2$ cross section.

# Conclusions

- Very ambitious project….need a team, a neutrino beam, probably high energy 50MeV to get enough events
- Needs clarifications on the feasibility, first how well a polarized bolometer is working.
- Please read the proposed LTD paper with more details. Give me your email and I will send the paper!

- Merci pour votre attention