Probing sub-eV particles with polarized ³He at the Institut Laue-Langevin

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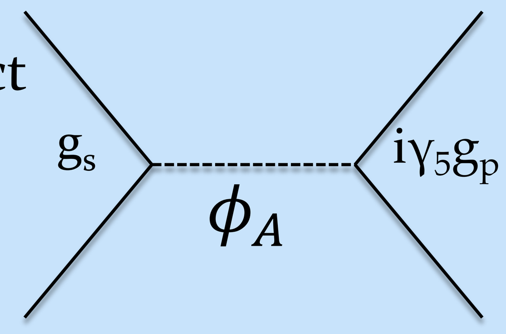
Theoretical motivations

• Theories beyond the Standard Model predict new light scalar bosons
→Axions and Axion-like particles
→WISP: candidate to Dark Matter
→New short range monopole-dipole interaction potential V which occurs as a pseudo-magnetic field



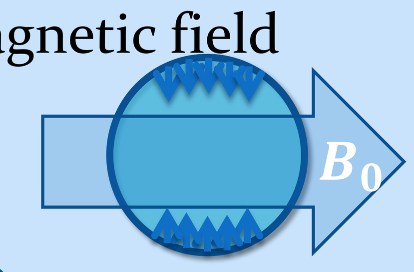
$$\lambda = \frac{\hbar}{m_\phi c}$$

$$V = g_s^N g_p^N \frac{\hbar \vec{\sigma}.\vec{r}}{8\pi M_{NC}}\left(\frac{1}{\lambda r}+\frac{1}{r^2}\right)\exp\left(-\frac{r}{\lambda}\right)$$

Principle of the measurement

• Measure a polarized Helium 3 cell longitudinal relaxation rate Γ_1 dependence with the holding magnetic field B_0
•Search for an exotic contribution due to pseudo-magnetic field

$$\Gamma_1 = \Gamma_{1w} + \Gamma_{1dd} + \Gamma_{me} + \Gamma_{mi} + \Gamma_{NF}$$



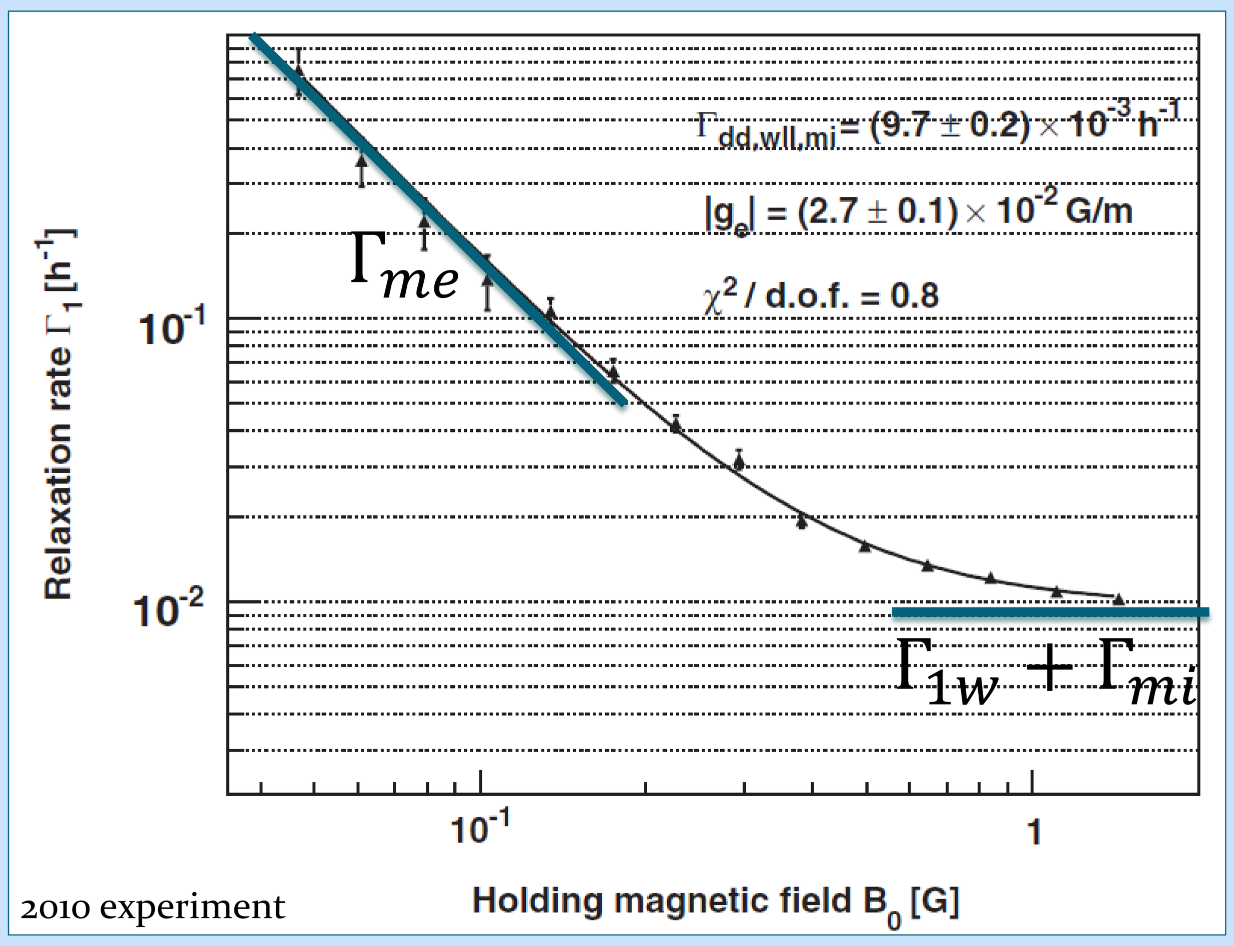
Collisions with walls; Collisions with dipoles; External magnetic field inhomogeneities; Holding field inhomogeneities; Exotic contribution

• ***Behaviour of contributions:***
- Constant with B_0: Γ_{1w}, Γ_{1dd}, Γ_{mi}
- Behave as B_0^{-2}: Γ_{me}
- Γ_{NF} behaviour is very different from the other contributions [1] :

$$\Gamma_{NF} = \frac{\hbar^2 N^2}{8 m_n^2 D R}\frac{\lambda^5 (g_s g_p)^2 \left(1-e^{-d/\lambda}\right)^2}{\left(1+\phi_\lambda^2\right)^2}\left(\sqrt{\frac{2}{\phi_\lambda}}\left(1-\phi_\lambda(2-\phi_\lambda)\right)+\left(\phi_\lambda^2-3\right)\right)$$

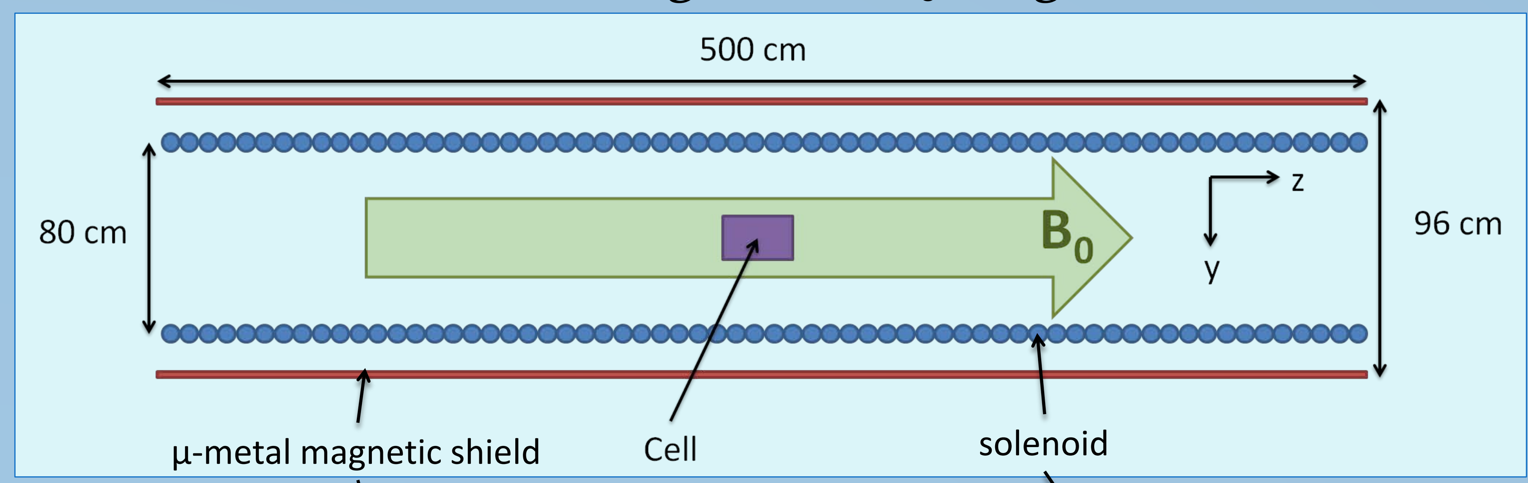
- $\phi_\lambda = \frac{\gamma B_0 \lambda^2}{D}$
- γ is the gyromagnetic ratio of ³He
- D is the diffusion coefficient
- N is the nucleon density of the cell walls and d their thickness
- m_n is the mass of a nucleon
- R is the radius of the cell

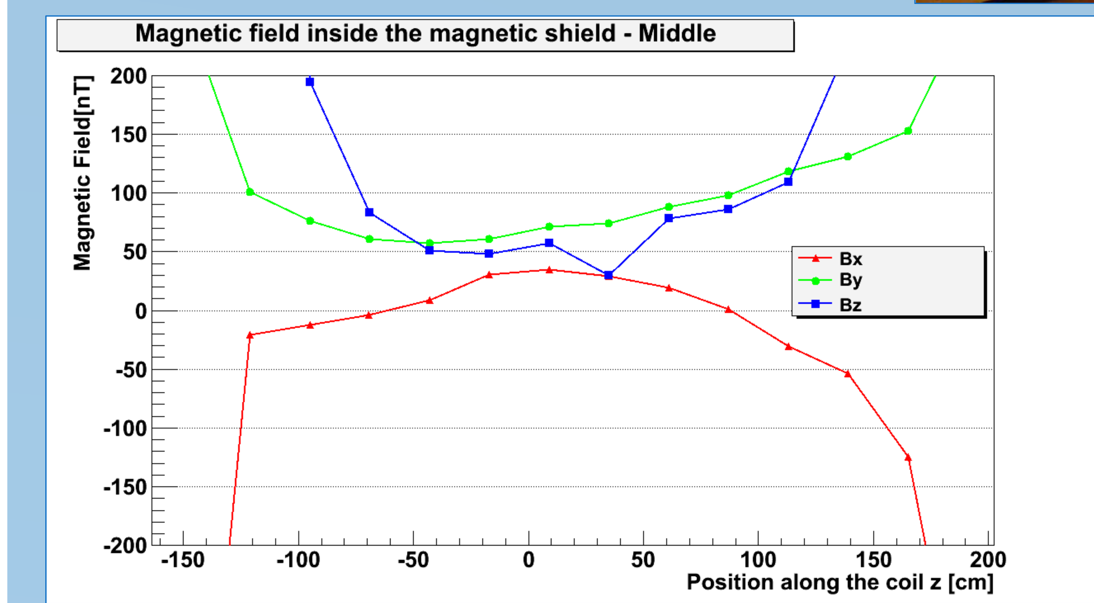
• In 2010 experiment [2], the limiting factors were:
•Environmental magnetic inhomogeneities
•Depolarization due to the walls
•Holding magnetic field B_0 inhomogeneities

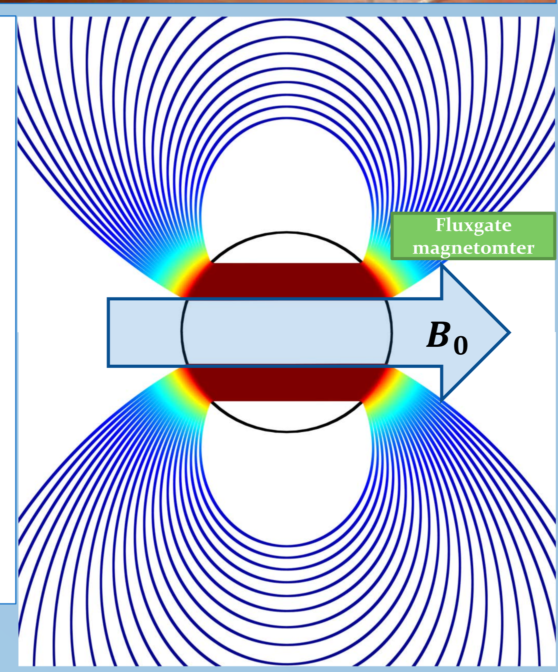


The apparatus

• ***Improvements:***
- Magnetic shield: gradients decreased by factor 30
- Solenoid: a more homogeneous B_0 magnetic field

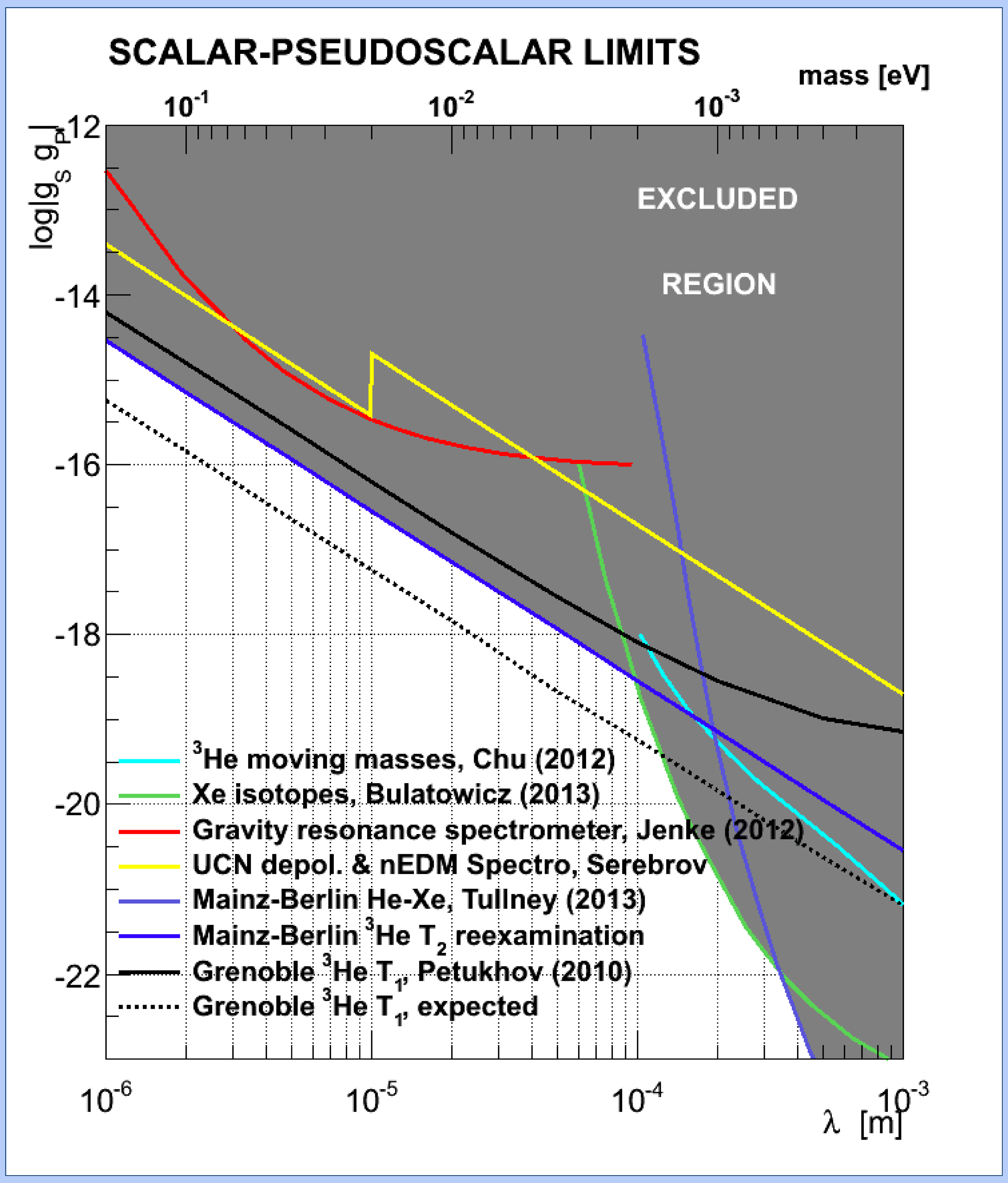






•***Measurement of Γ_1 :***
Due to high polarization, the ³He cell generates a magnetic field B_s (proportional to polarization) which can be measured with a three-axis fluxgate magnetometer.
→ Evaluation of Γ_1 with magnetic field exponential decrease with time: $B_s \propto \exp -\Gamma_1 t$

Expected constraints



1. M. Guigue, G. Pignol, Article in preparation
2. A. K. Petukhov, G. Pignol, D. Jullien, and K. H. Andersen, Physical Review Letters **105**, 170401 (2010)