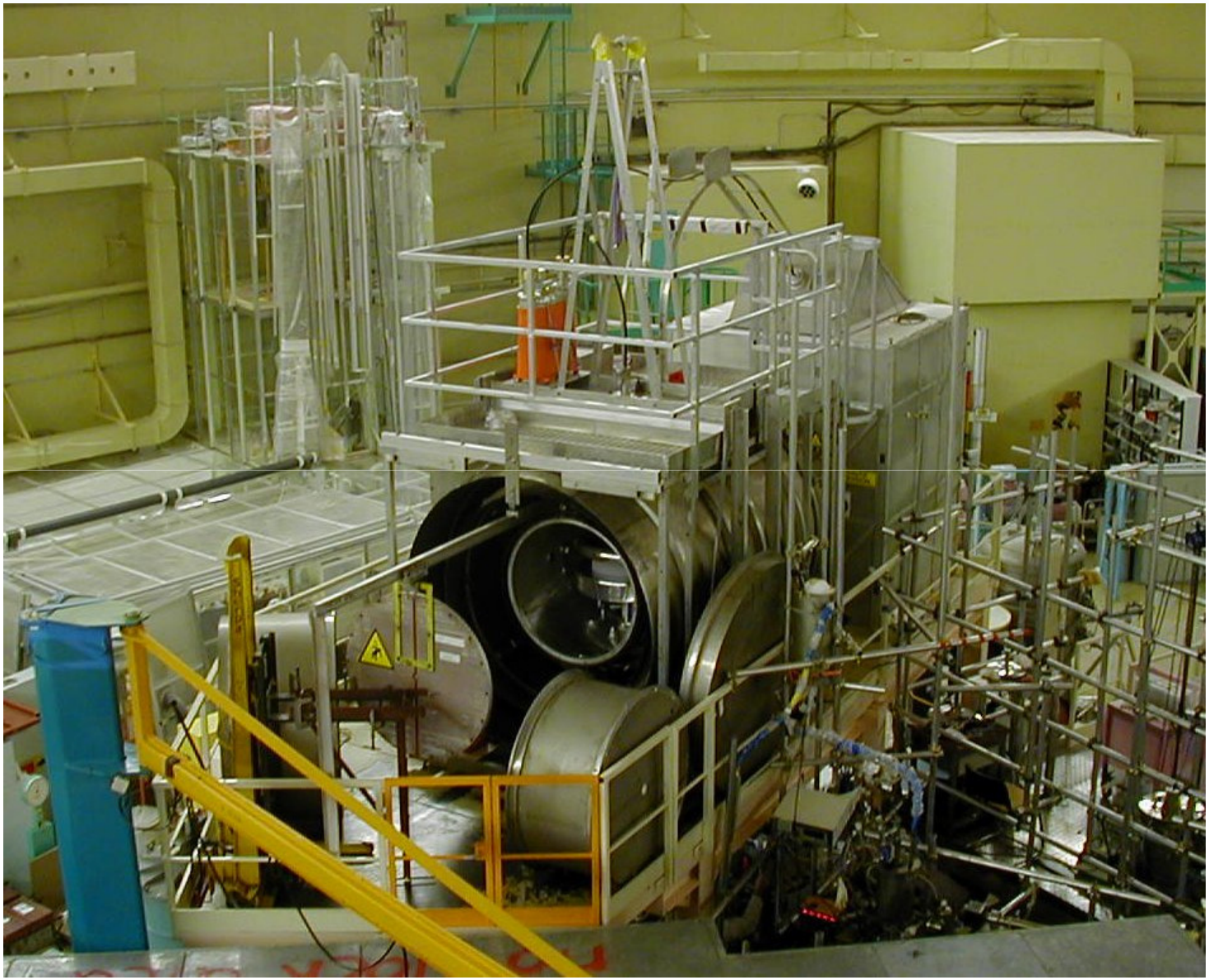
Search for spin-dependent forces using neutron electric dipole moment spectrometers

Les Houches, Febuary XX 2009

OILL nEDM spectrometer



On its way to PSI

The Neutron EDM Collaboration

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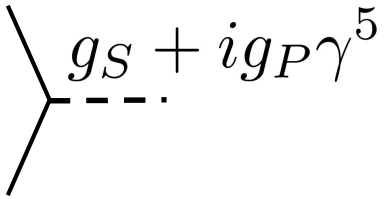
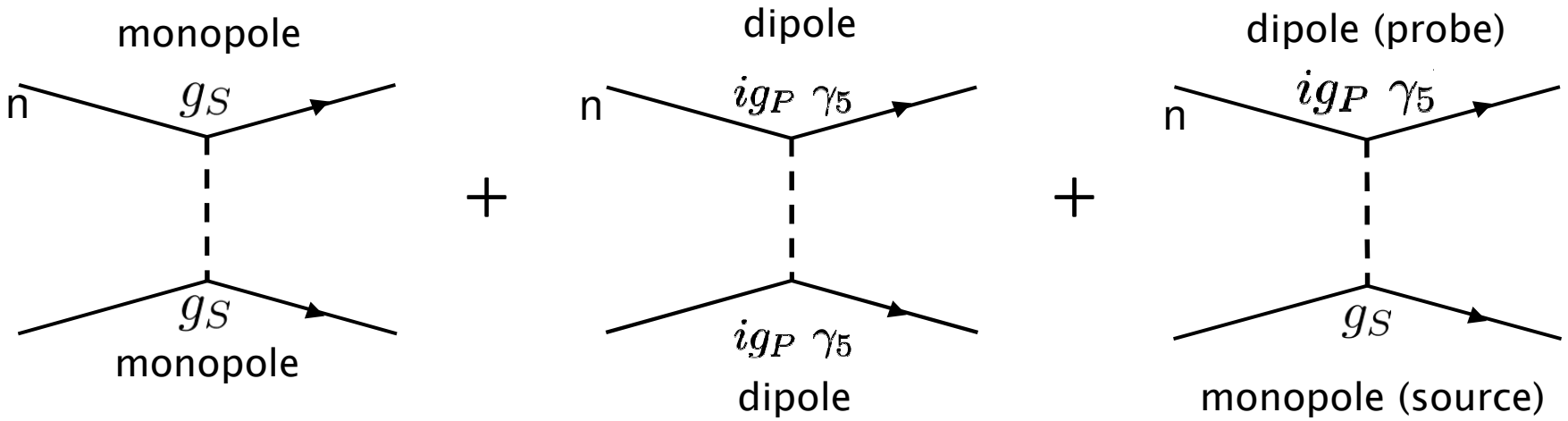
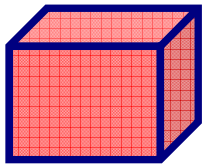
Short-range spin-dependent forces



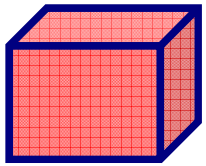
interactions of range λ
mediated by new light boson of mass M

$$\lambda = \frac{\hbar}{Mc}$$

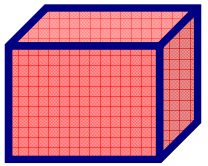




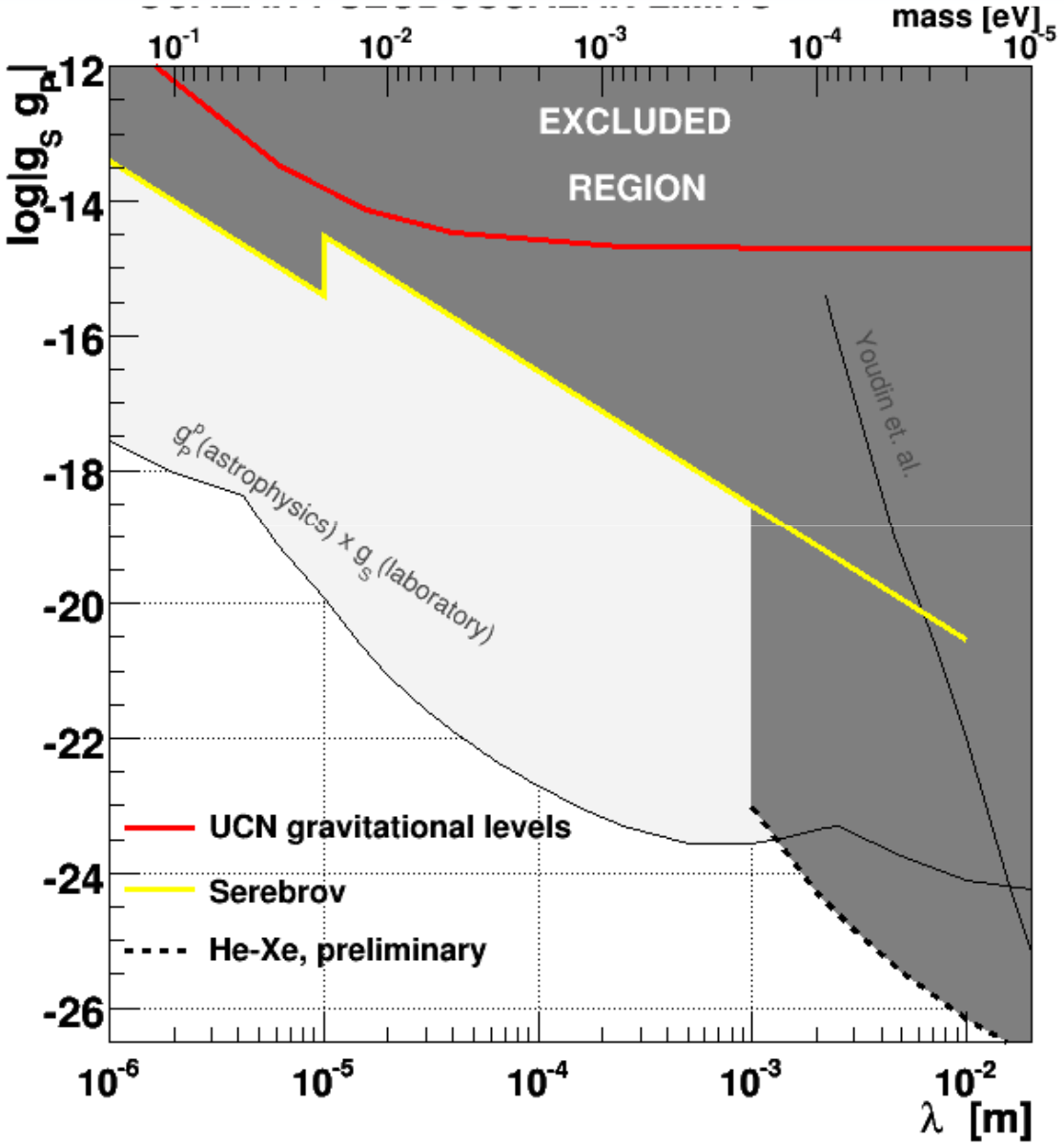
Macroscopic body



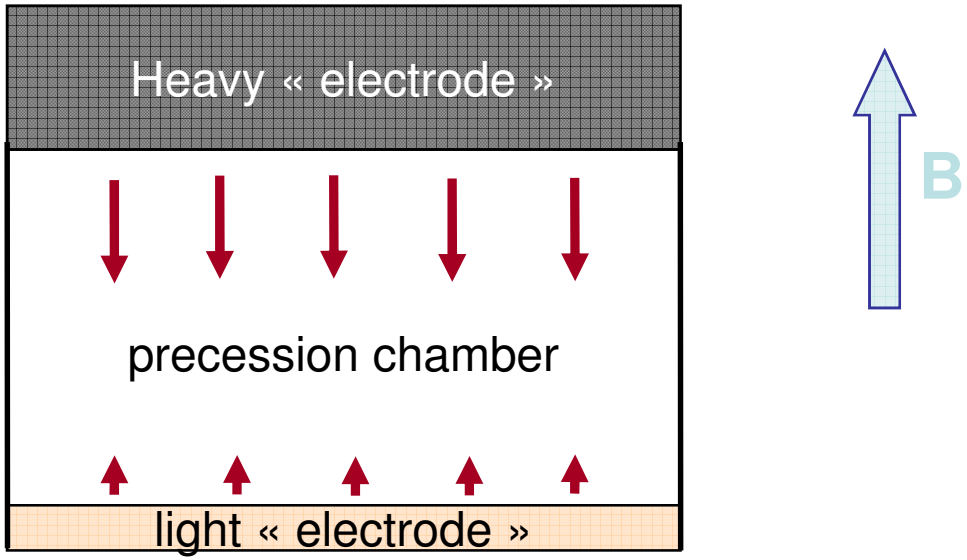
Spinning particle



Existing constraints

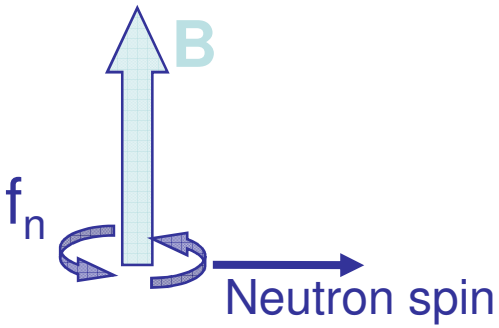


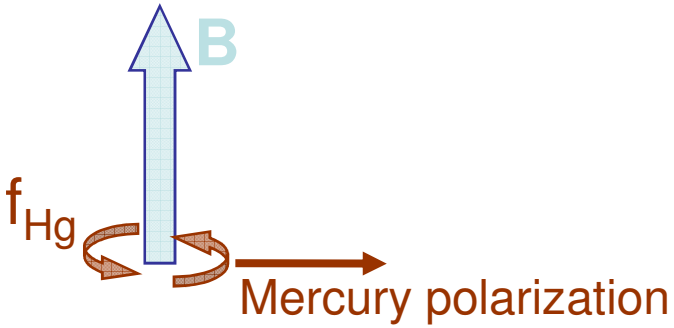
Principle of the experiment



We compare the neutron precession frequency
when the magnetic field is up and down.

Ramsey method with Hg comagnetometer





f_n changes whith B

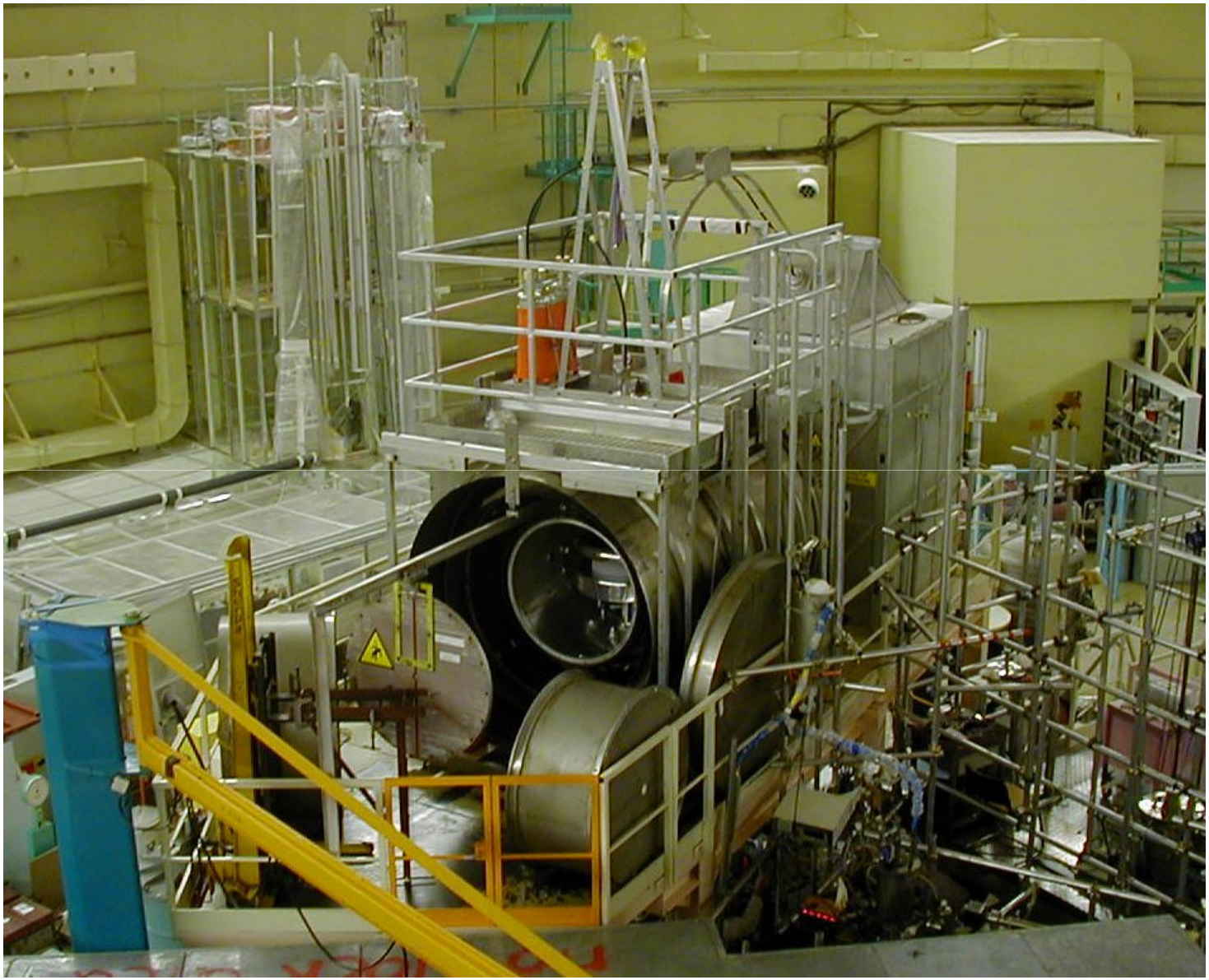
$$R = \frac{f_n}{f_{Hg}}$$

Free from magnetic field fluctuations

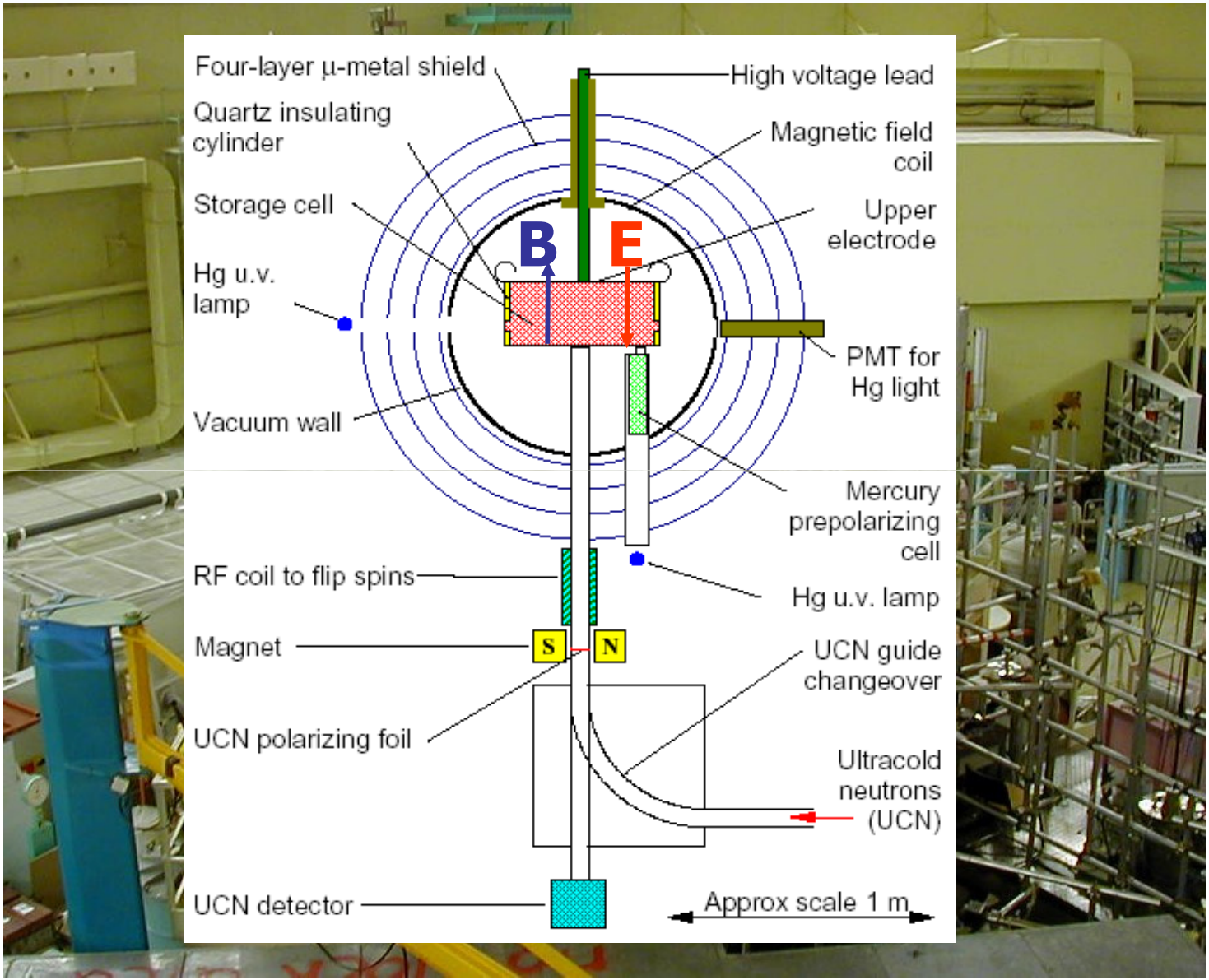
EDM searches: Compare R with $E\downarrow$ and $E\uparrow$

Search for spin-dependent force: Compare R with $B\downarrow$ and $B\uparrow$

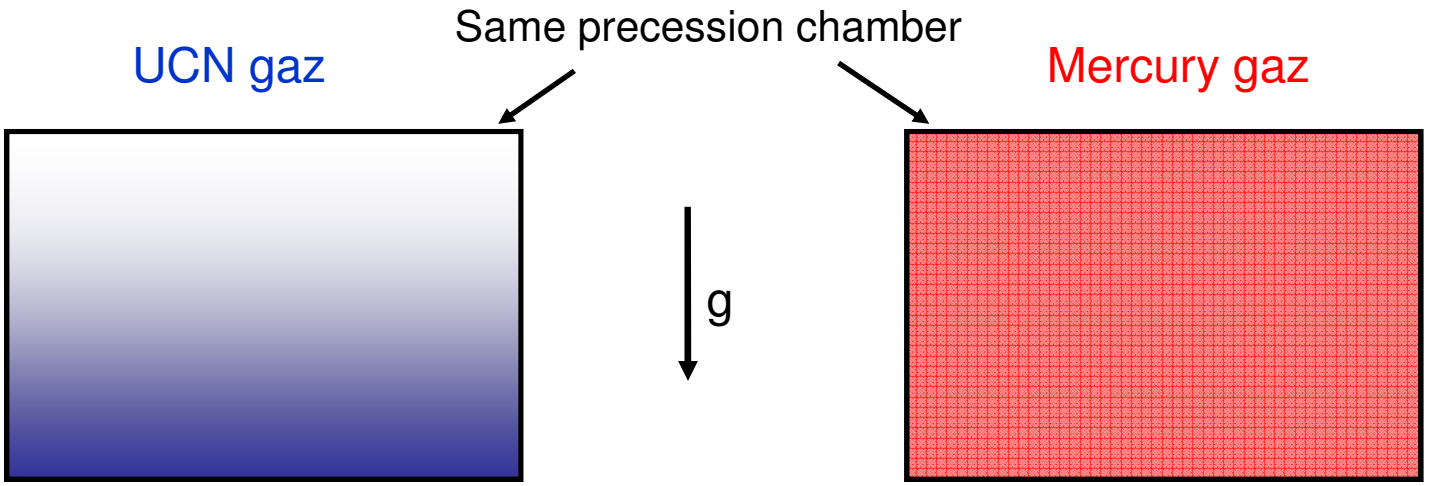
OILL nEDM spectrometer



OILL nEDM spectrometer



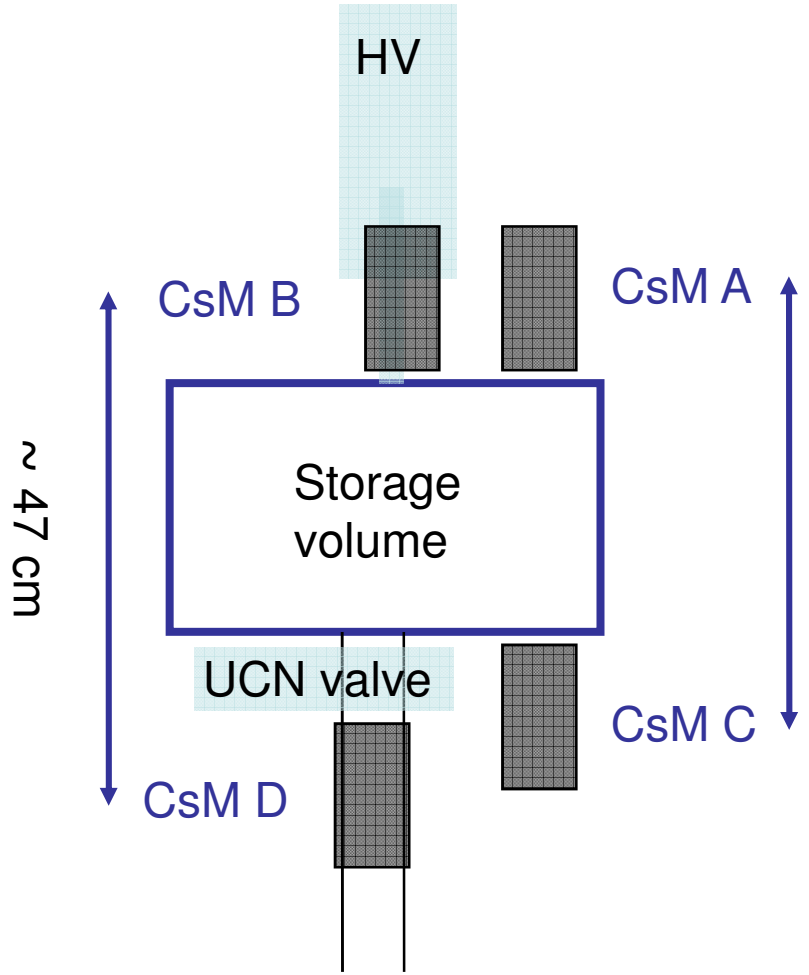
Systematics: gravitational effect

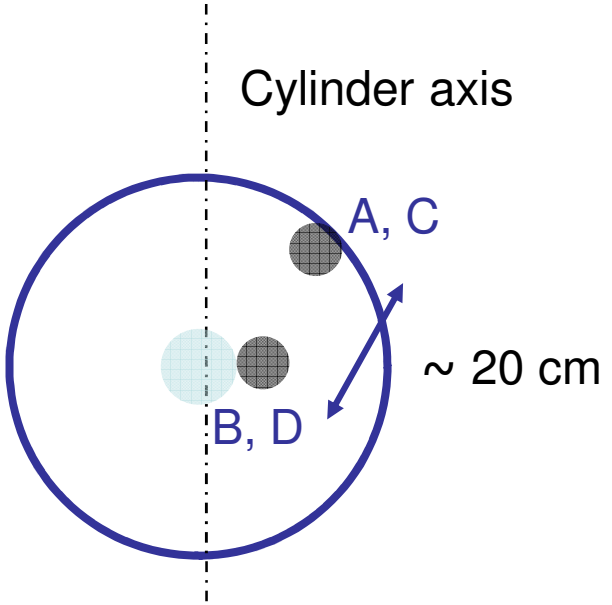


Center of gravity height difference is $h \approx 2 \text{ mm}$

R depends on vertical gradients $$R = \frac{\gamma_n}{\gamma_{\text{Hg}}} \left(1 - \frac{(\partial B/\partial z)h}{B} \right)$$

Gradient control: Cs magnetometers





(B – D) → central vertical gradient

(A – C) → lateral vertical gradient

(B – A) → top horizontal gradient

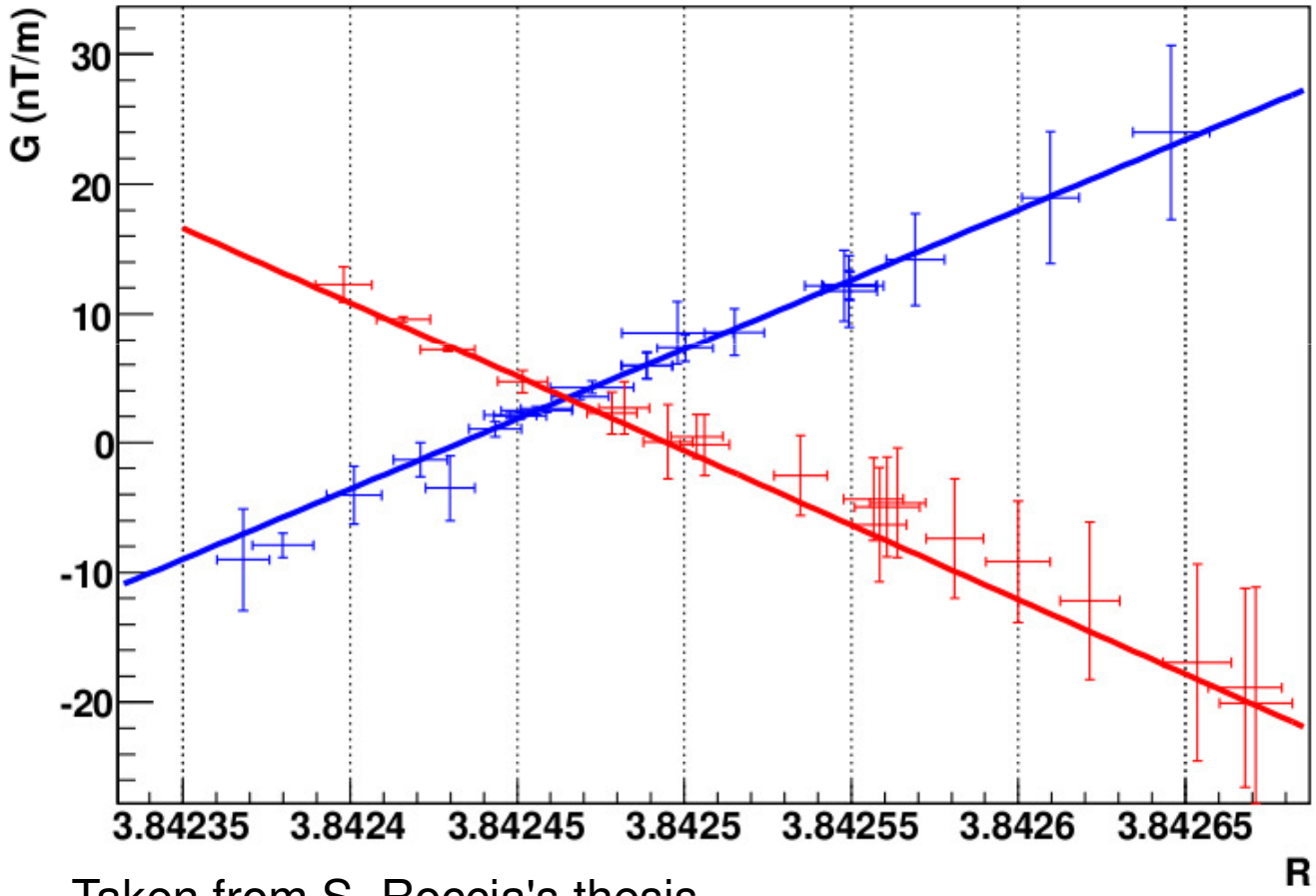
(D – C) → bottom horizontal gradient

$G = \frac{1}{2}\{(B - D)+(A - C)\}$

The result at ILL

R depends on vertical gradients

$$R = \frac{\gamma_n}{\gamma_{\mathrm{Hg}}}\left(1 - \frac{(\partial B/\partial z)h}{B}\right)$$



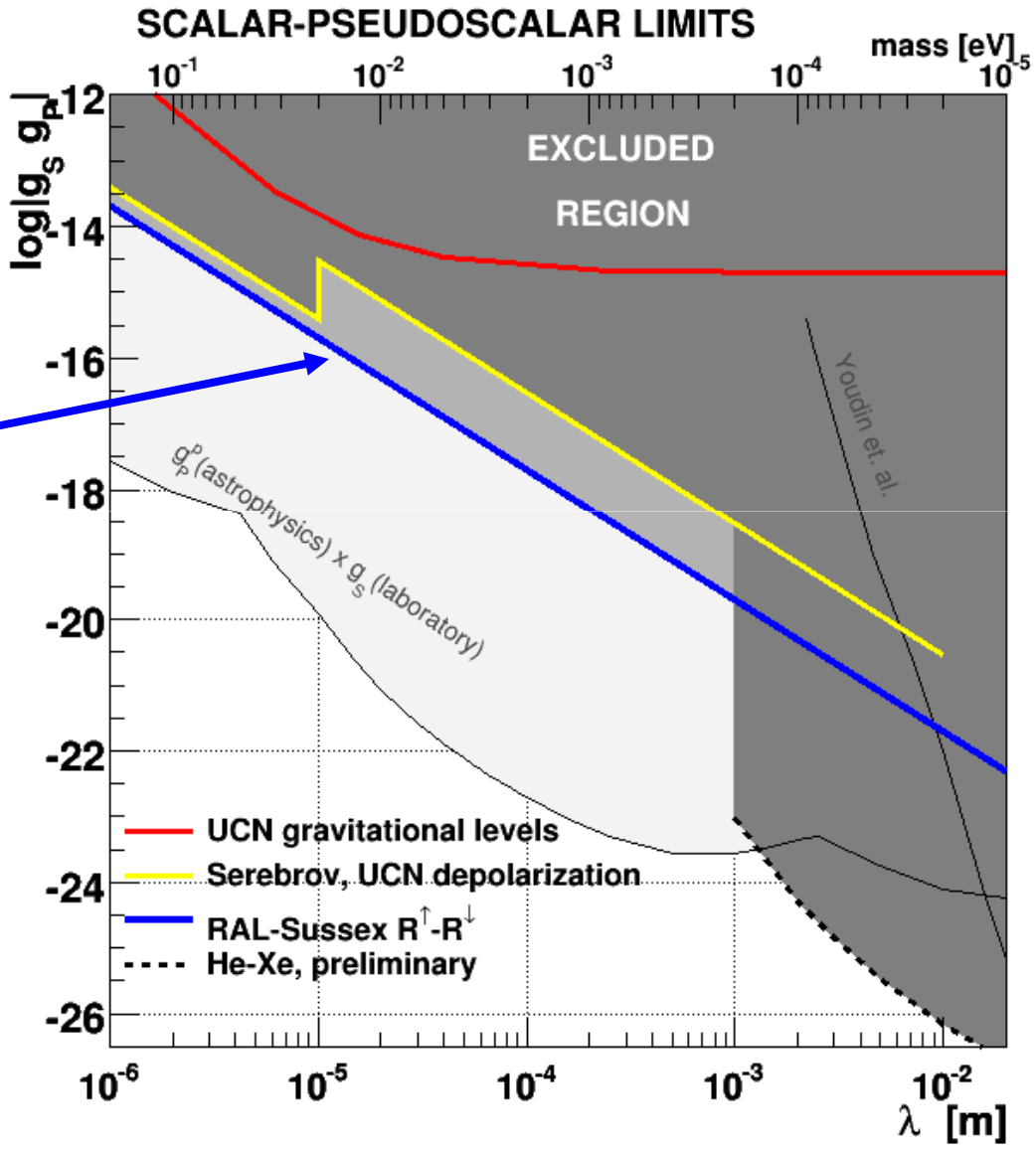
Taken from S. Roccia's thesis

Preliminary result

$$\Delta R = 30 \pm 30 \text{ ppm}$$

+

10% Gravitational asymmetry



Forseen future improvements

$$R = \frac{\gamma_n}{\gamma_{\mathrm{Hg}}}\left(1 + \frac{G\,h}{B_0} + \frac{q^2 D^2}{16 B_0^2}\right) \pm \frac{\Delta R}{2}$$

1 Better control of the vertical gradient **G**

Remove sources of local fluctuations
Smaller (closer) Cs magnetometers
More Cs magnetometers

2 Changing **h** h depends on the neutron energy spectrum

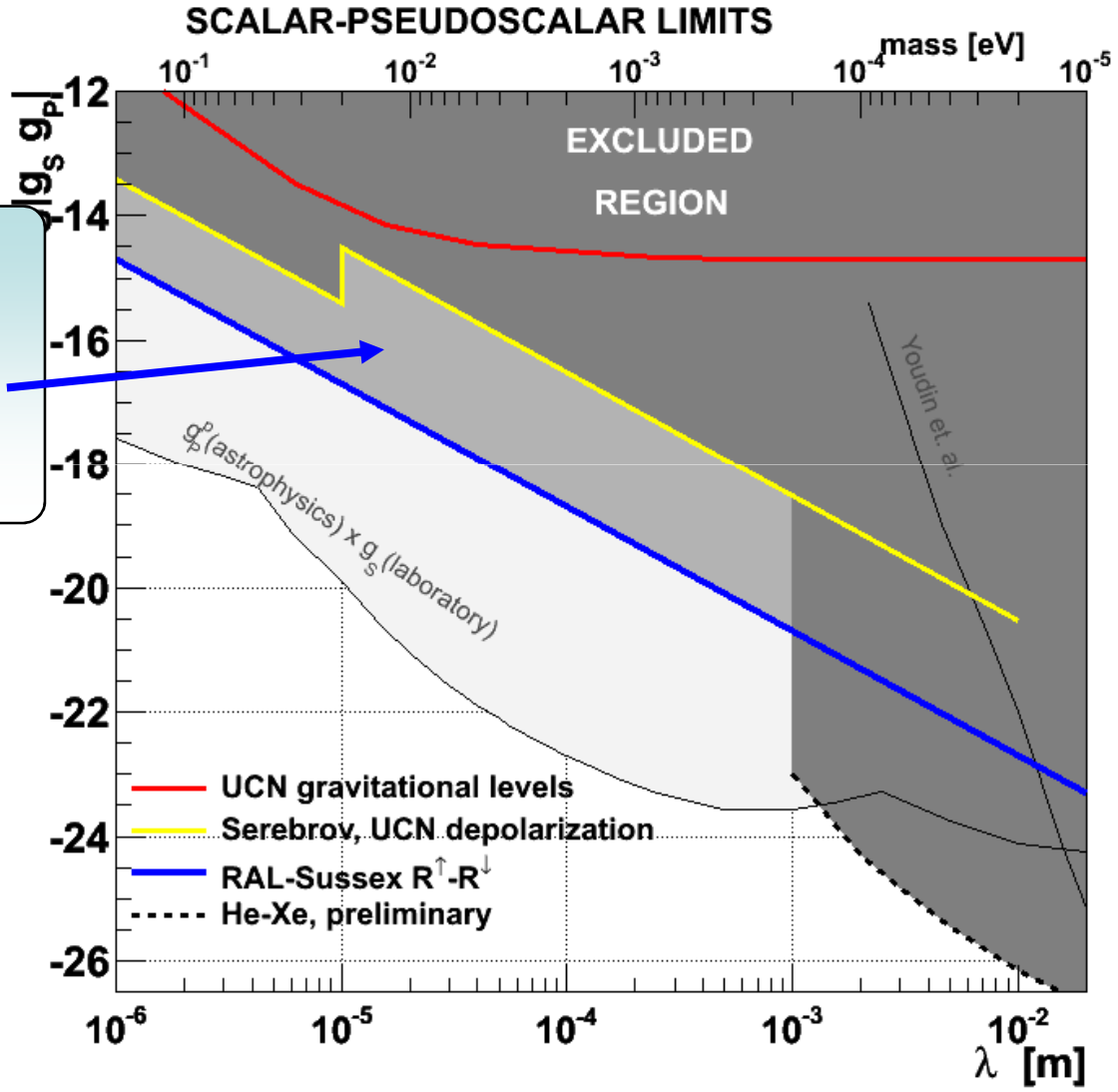
Insert foils with different Fermi potential
Measure as a function of neutron counting time

Previous RAL-Sussex result

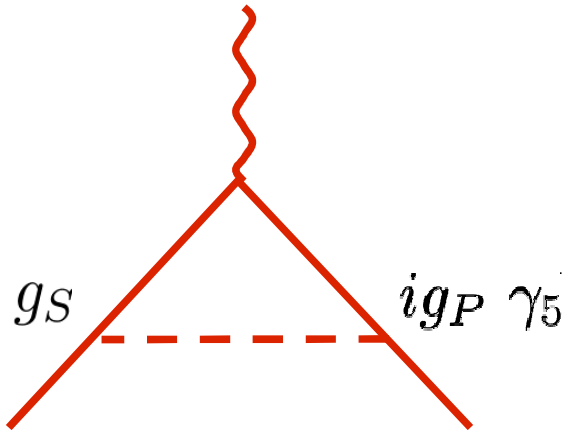
$$\Delta R = 6 \pm 4 \text{ ppm}$$

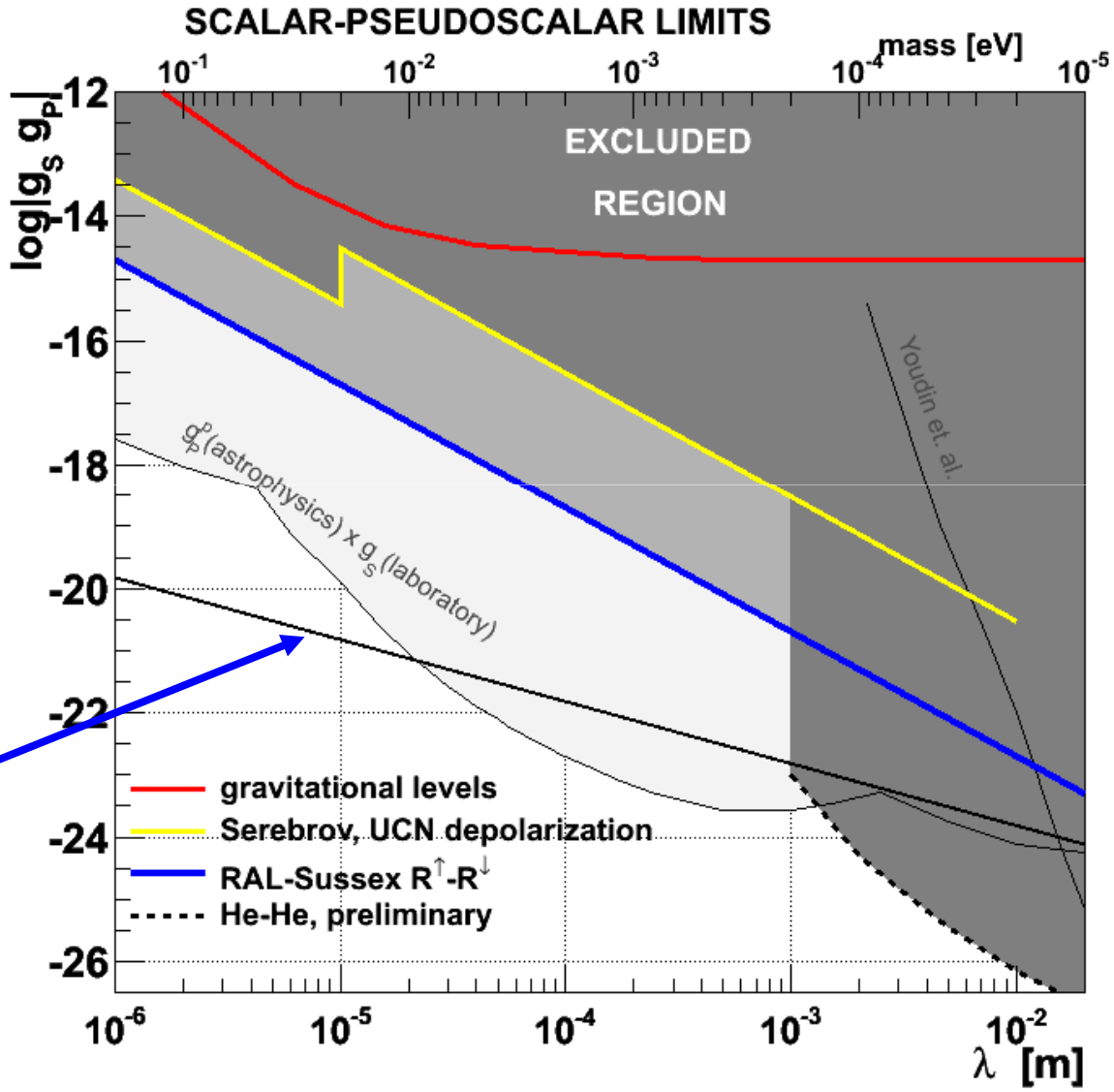
+

10% Gravitational asymmetry



Quark EDM





Current neutron EDM bound

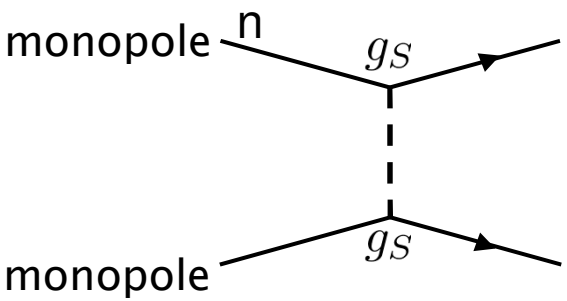
Conclusions and perspectives

Limits from nEDM spectrometers will be improved, with a better control of the gradients. Factor 10 is forseen.

With a dedicated chamber we can improve further

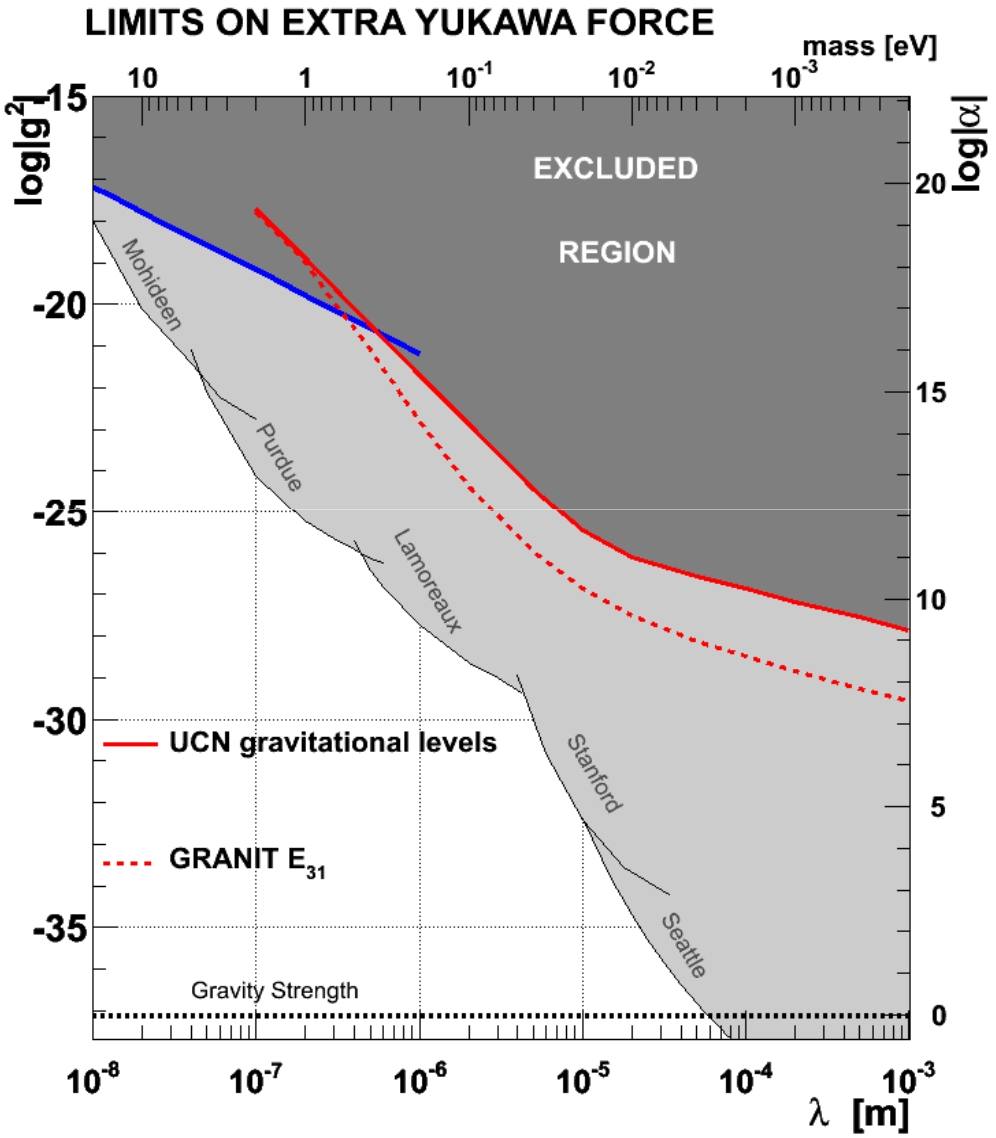
Theoretical input is needed

Monopole-Monopole



Induce a new short-range spin-independent Yukawa force

$$V_Y(r) = Q_1 Q_2 \frac{g^2}{4\pi} \frac{\hbar c}{r} e^{-r/\lambda}$$



Dipole-Dipole, Astrophysics

For $\lambda > 1$ nm

Proton limit, no exotic energy losses in stars

$$|g_P^{(p)}| < 2 \times 10^{-4}.$$

Neutron limit, SN1987A, duration of neutrino pulse

$$3 \times 10^{-10} < |g_P^{(n)}| < 10^{-6}$$

Neutron limit, SN1987A, number of neutrinos

$$9 \times 10^{-7} < |g_P^{(n)}| < 10^{-3}$$