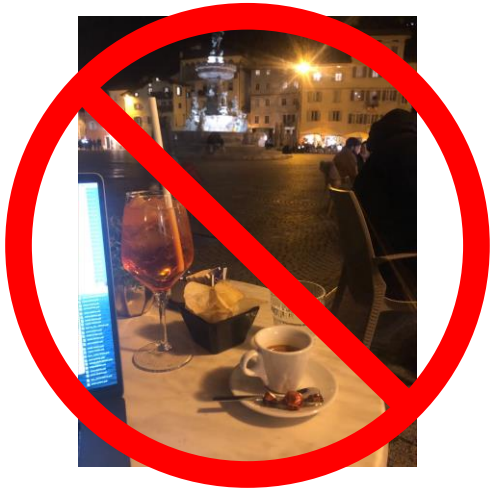
Some Remarks

Skyler Degenkolb *(degenkolb@physi.uni-heidelberg.de)*
Low-Energy Precision Physics
Physikalisches Institut, Universität Heidelberg

ECT*, Trento, 4 March 2024

Some Remarks



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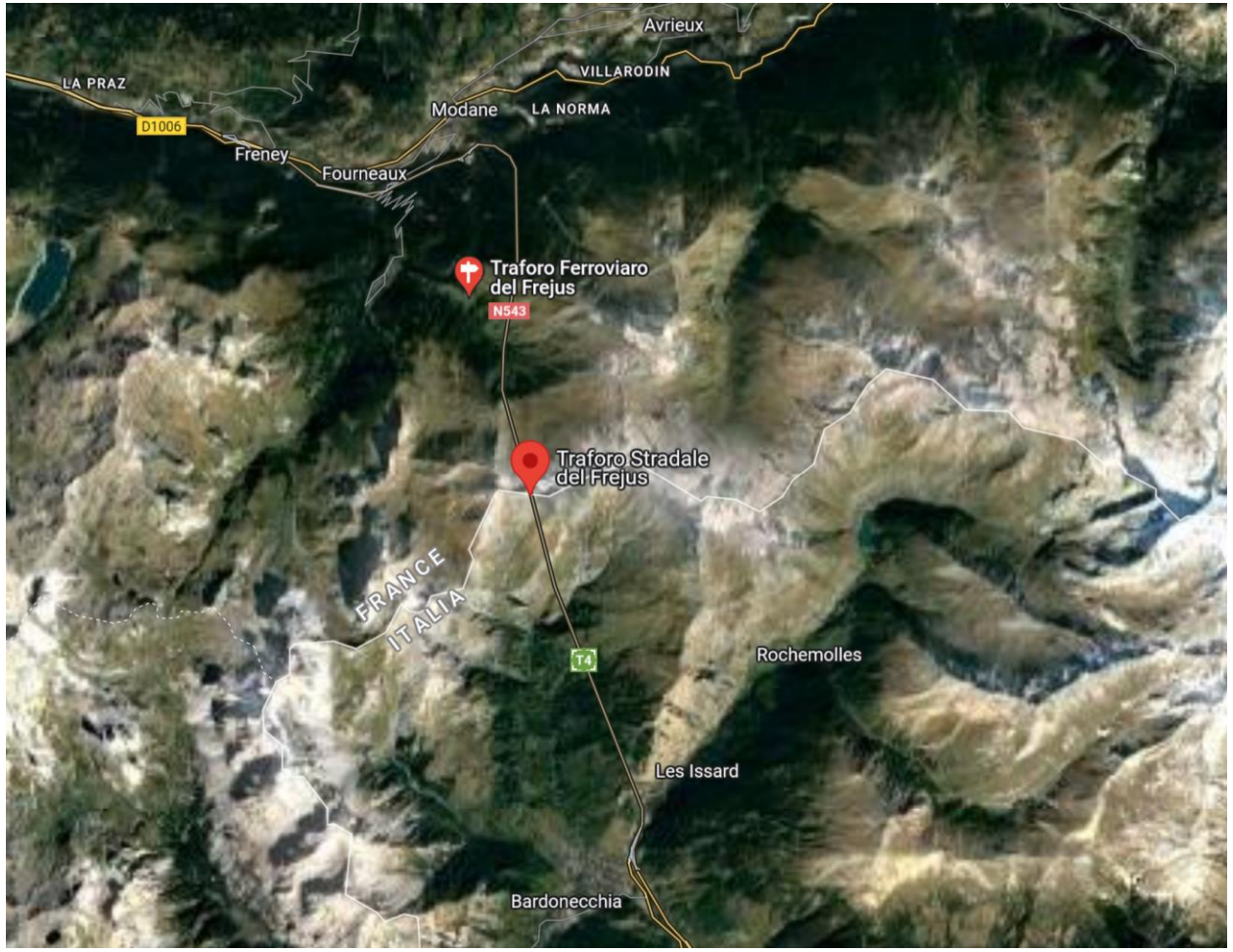
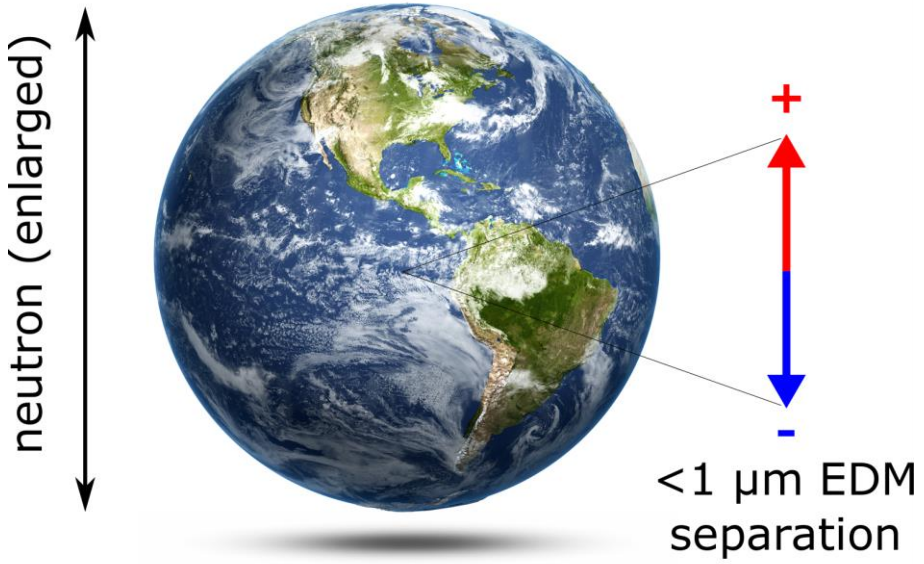
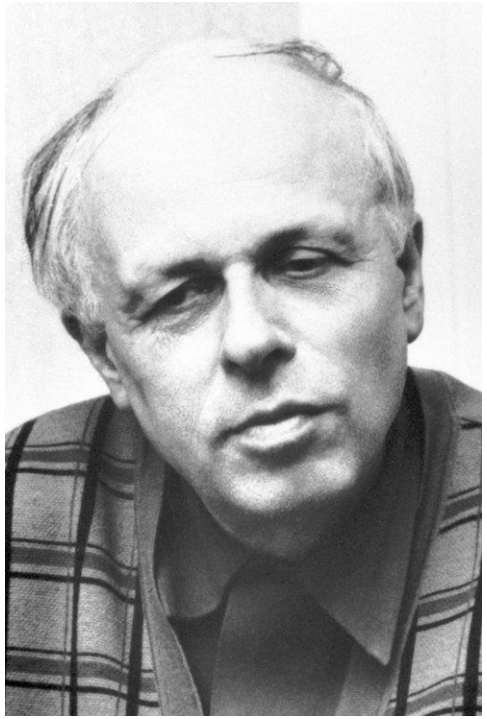
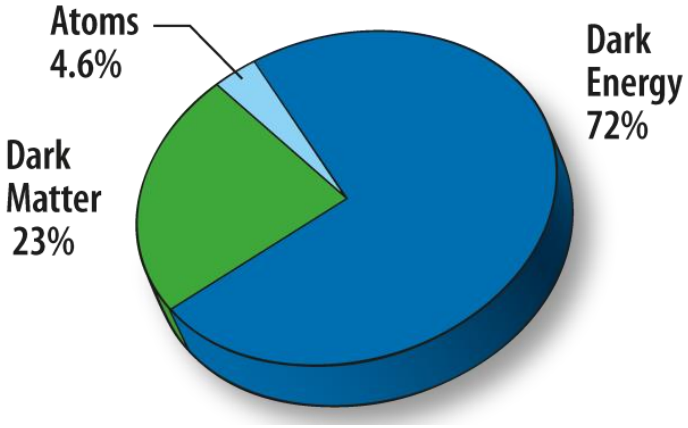
Precision

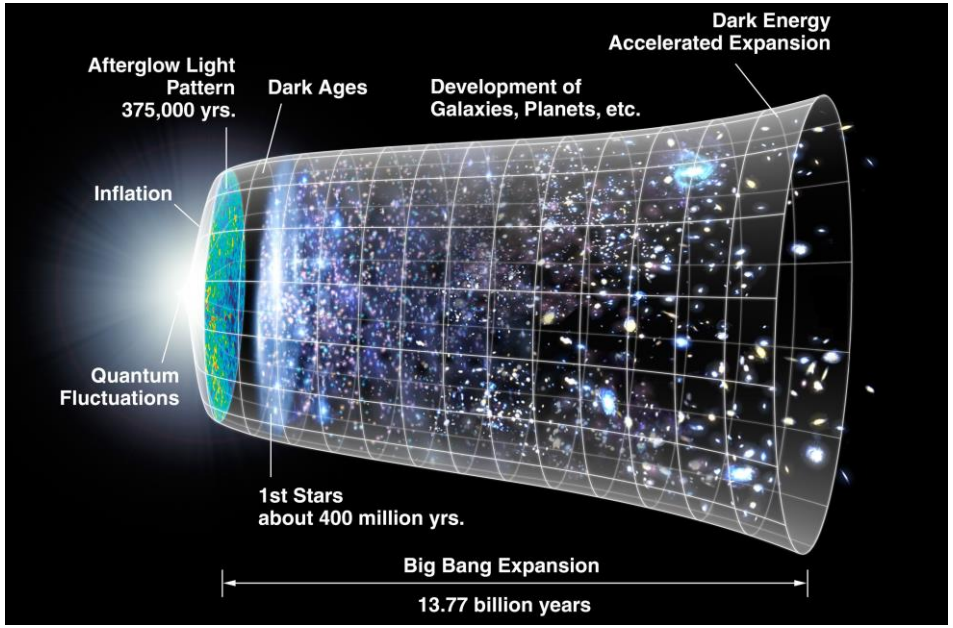

Avrieux
VILLARODIN
LA PRAZ
Modane
LA NORMA
D1006
Freney
Fourneaux
Traforo Ferroviaro del Frejus
N543
Traforo Stradale del Frejus
FRANCE
ITALIA
T4
Rochemolles
Les Issard
Bardonecchia


neutron (enlarged)
+
-
<1 μm EDM separation

Forbidden topics*

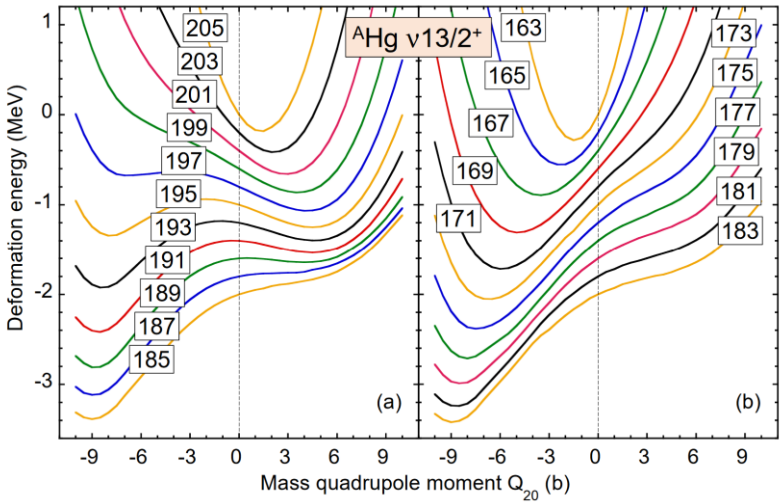


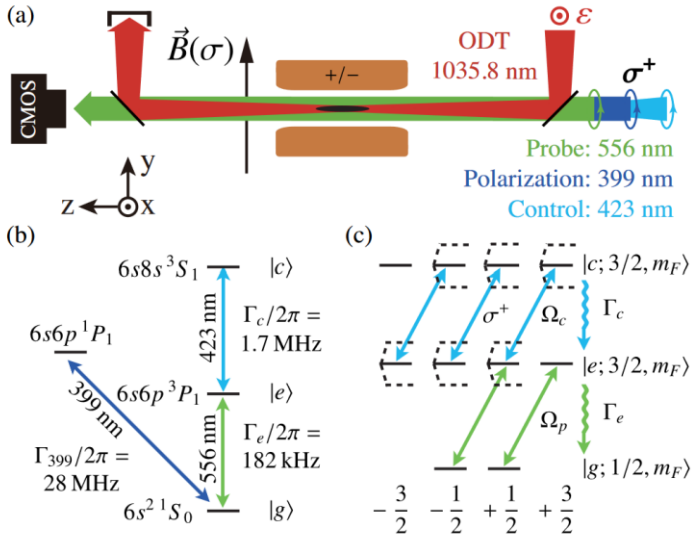


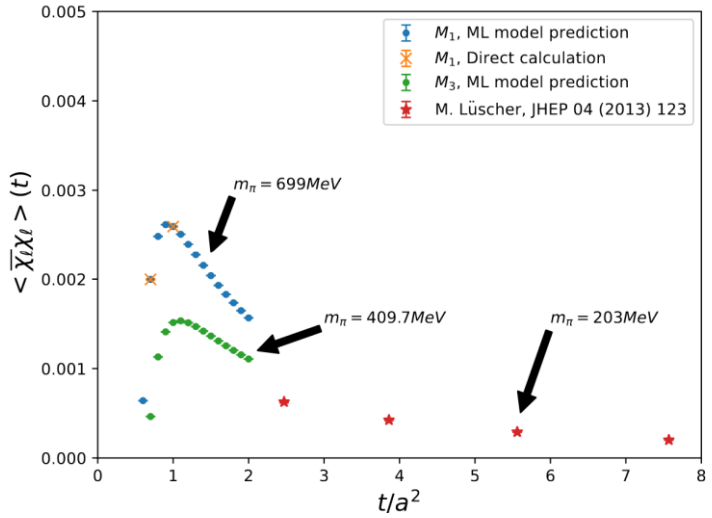


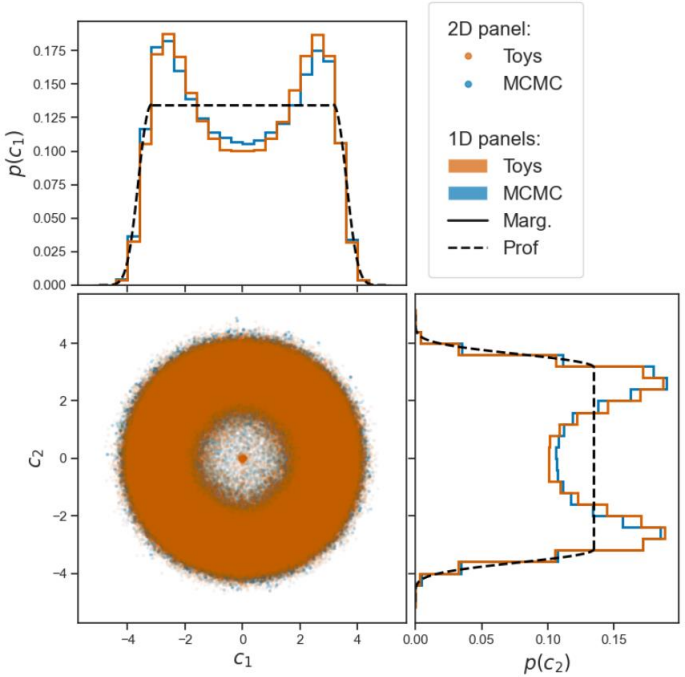
*if used superficially as motivation/intro

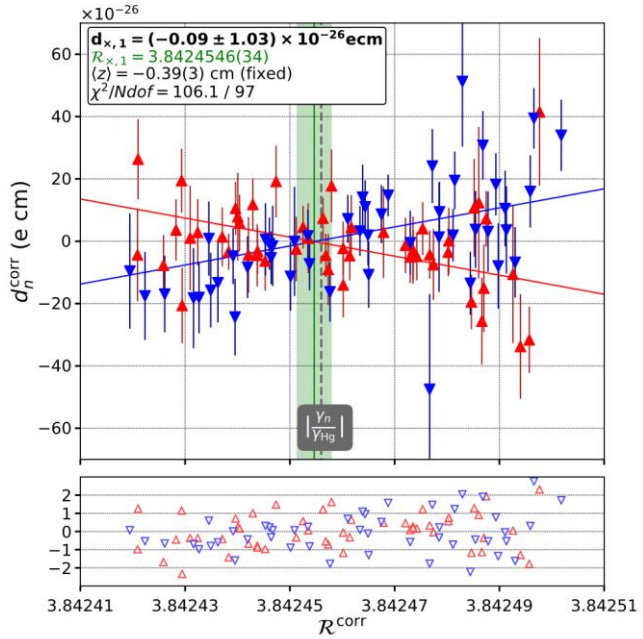
Reminder

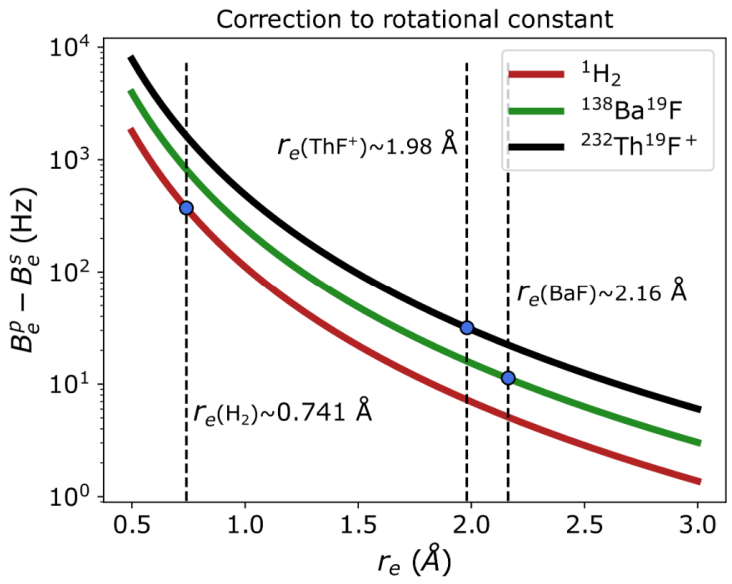

^{A}Hg ν13/2⁺
Deformation energy (MeV)
Mass quadrupole moment Q_{20} (b)
(a)
(b)


(a)
CMOS
ODT
1035.8 nm
Probe: 556 nm
Polarization: 399 nm
Control: 423 nm
(b)
(c)
423 nm
399 nm
556 nm

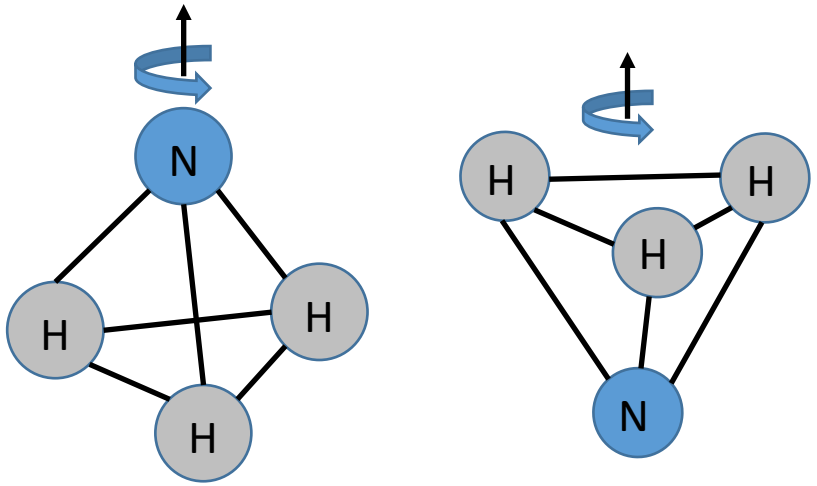

M_1, ML model prediction
M_1, Direct calculation
M_3, ML model prediction
M. Lüscher, JHEP 04 (2013) 123
$m_\pi = 699MeV$
$m_\pi = 409.7MeV$
$m_\pi = 203MeV$
t/a^2


2D panel:
Toys
MCMC
1D panels:
Toys
MCMC
Marg.
Prof
c_1
c_2
$p(c_1)$
$p(c_2)$


$d_{x,1} = (-0.09 \pm 1.03) \times 10^{-26}$ecm
$\mathcal{R}_{x,1} = 3.8424546(34)$
$\langle z \rangle = -0.39(3)$ cm (fixed)
$\chi^2/Ndof = 106.1 / 97$
d_n^{corr} (e cm)
$\mathcal{R}^{corr}$


Correction to rotational constant
$^{1}H_2$
$^{138}Ba^{19}F$
$^{232}Th^{19}F^+$
$r_e(ThF^+)$~1.98 Å
$r_e(BaF)$~2.16 Å
$r_e(H_2)$~0.741 Å
$B_e^p - B_e^s$ (Hz)
r_e (Å)

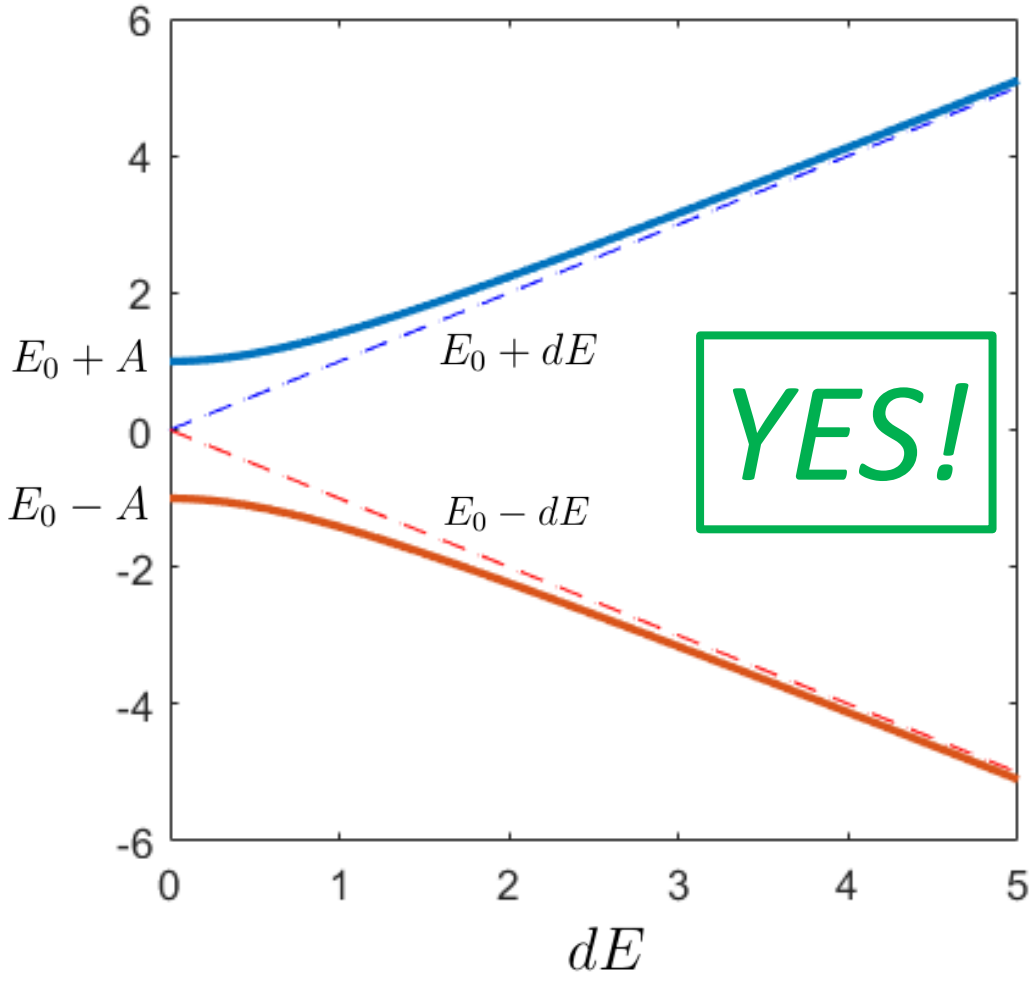
Is it different from a molecular dipole?



$|1\rangle$ $|2\rangle$

The *energy* eigenstates are:

$$\frac{1}{\sqrt{2}}\left(|1\rangle \pm |2\rangle\right)$$



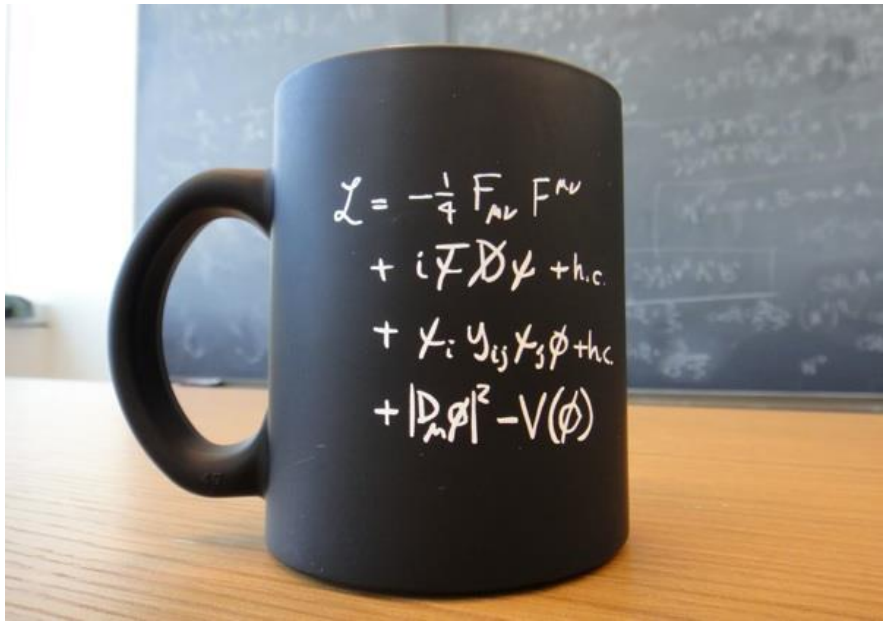
New Physics, but in Familiar Terms

$$\mathscr{L}_{\text{fermion}} = -\frac{\mu}{2}\bar{\psi}\sigma^{\mu\nu}F_{\mu\nu}\psi - i\frac{d}{2}\bar{\psi}\sigma^{\mu\nu}\gamma^5 F_{\mu\nu}\psi$$

MDM

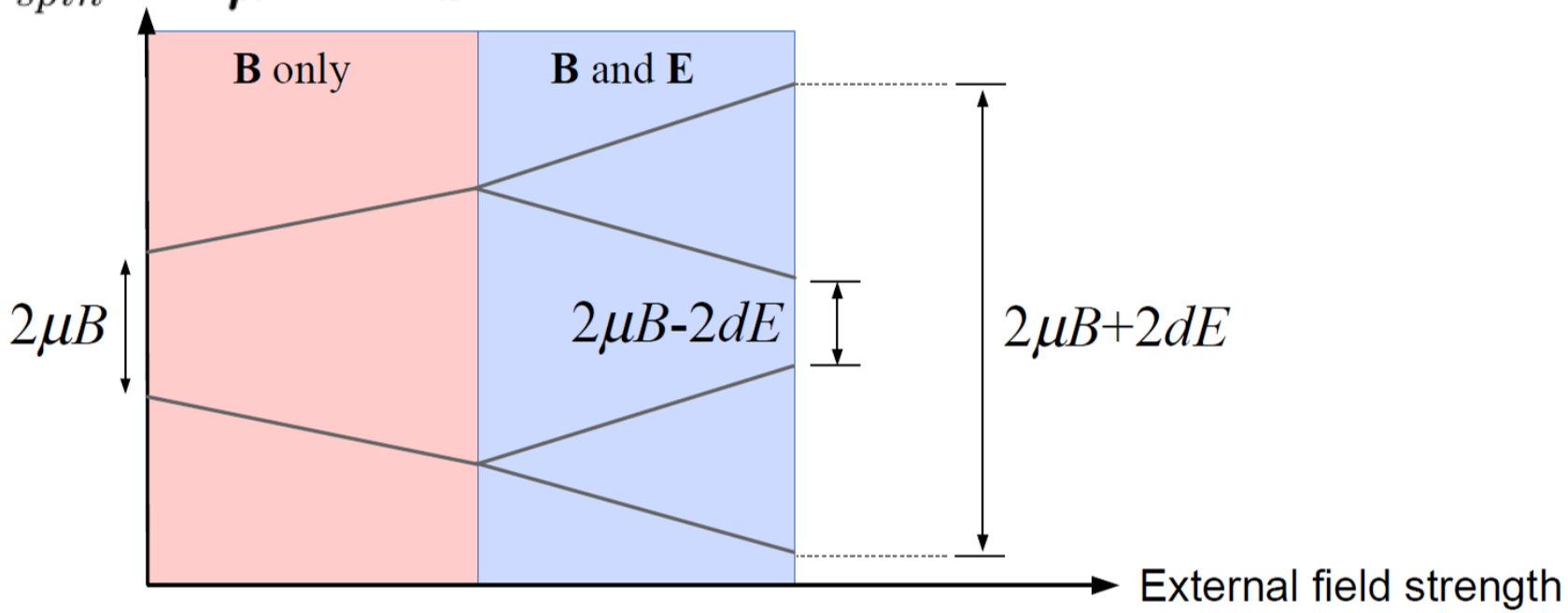
EDM

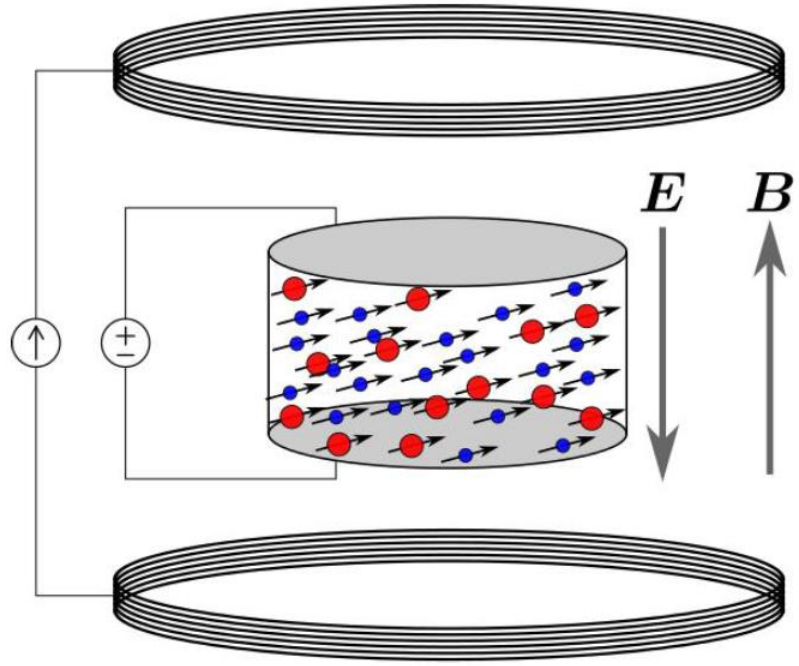
- Non-conservation of *P* and *T* already apparent in EDM term
- Consistency with zero vs. consistency with SM



How could you or I measure an EDM?

$$H_{spin} = -\boldsymbol{\mu} \cdot \mathbf{B} - \mathbf{d} \cdot \mathbf{E}$$





$$\hbar(\omega_+ - \omega_-) = 4dE$$

…up to drift, gradients, etc.

Remember it is “locked” to the spin

Spin-precession based magnetometry:

- $E = -\boldsymbol{\mu} \cdot \boldsymbol{B}$
- $\boldsymbol{\tau} = \boldsymbol{\mu} \times \boldsymbol{B}$
- $\boldsymbol{\mu} = \gamma \boldsymbol{L} \rightarrow \boldsymbol{\omega}_L = -\gamma \boldsymbol{B}$

Time evolution from Bloch equations:

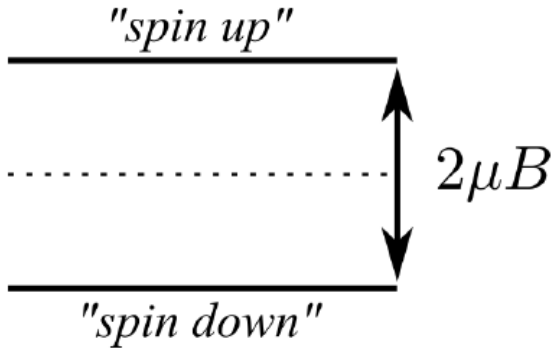
$$\frac{d\boldsymbol{\mu}}{dt} = \gamma \boldsymbol{\mu} \times \boldsymbol{B} - (\textit{relaxation terms})$$

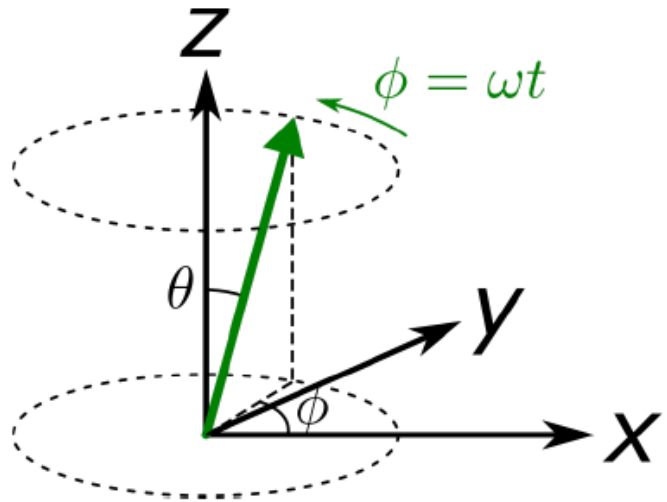
Sensitivity from: $\Delta E \Delta t \geq \hbar/2$

- relaxation limits measurement time
- many particles $\rightarrow$ many measurements

EDM fundamental sensitivity:

$$|\delta\omega| = \frac{|dE|}{\hbar F} \qquad (\Delta m_F = 1)$$





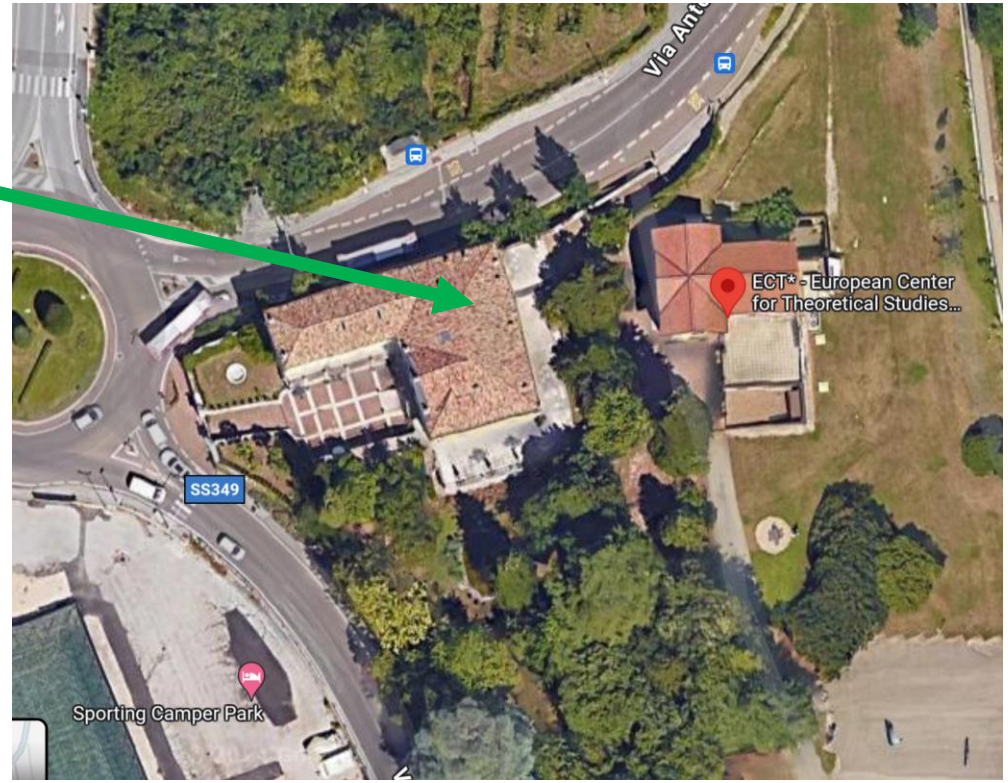
Cornell and Wieman… Nobel 2001, Rev. Mod. Phys. 74, 875 (2002)

vious initial step toward understanding dynamical behavior. Second, in experimental physics a precision measurement is almost always a frequency measurement, and the easiest way to study an effect with precision is to find an observable frequency that is sensitive to that effect. In the case of dilute-gas BEC, the observed fre-

Practical details

- Talks are 30 + 15 min
  - Please upload slides or bring a USB stick if possible
- Coffee and lunches in the Villa
- Posters can stay up all week
  - Set up starting from coffee today
  - Tuesday evening: scheduled session
- Conference dinner today (paid!)
- Informal dinner Thursday (sign up!)

- Strike announced for Friday



Practical details

08:00	**1 - Registration**	*Aula Renzo Leonardi, ECT**	08:00 - 09:00
09:00	**2 - Welcome**	*Aula Renzo Leonardi, ECT**	*Ubirajara van Kolck et al.* 09:00 - 09:30
	3 - Global analysis of CP-violation in atoms, molecules and role of medium-heavy systems	*Aula Renzo Leonardi, ECT**	*Konstantin Gaul*
10:00			09:30 - 10:15
	Coffee	*Aula Renzo Leonardi, ECT**	10:15 - 10:45
	4 - Nonperturbative physics, chiral symmetry and EDM observables	*Aula Renzo Leonardi, ECT**	*Maxim Pospelov*
11:00			10:45 - 11:30
	2 - Discussions: complementarity of experiments and consistent approaches	*Aula Renzo Leonardi, ECT**	
12:00			11:30 - 12:30
	Lunch		