Torsion Balance Search for Lorentz-invariance, Dark Energy and Dark Matter

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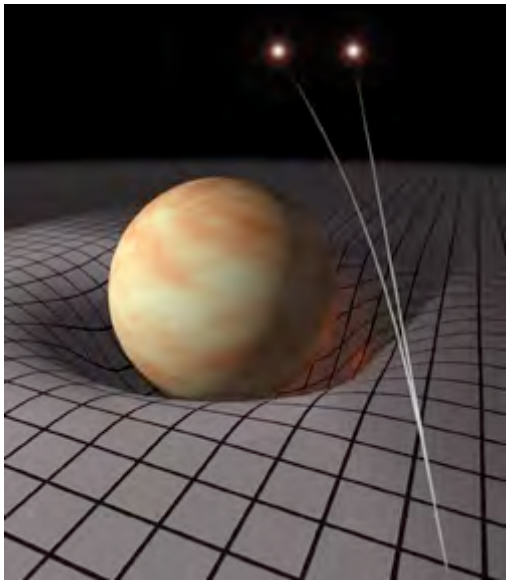
AAPT Meeting

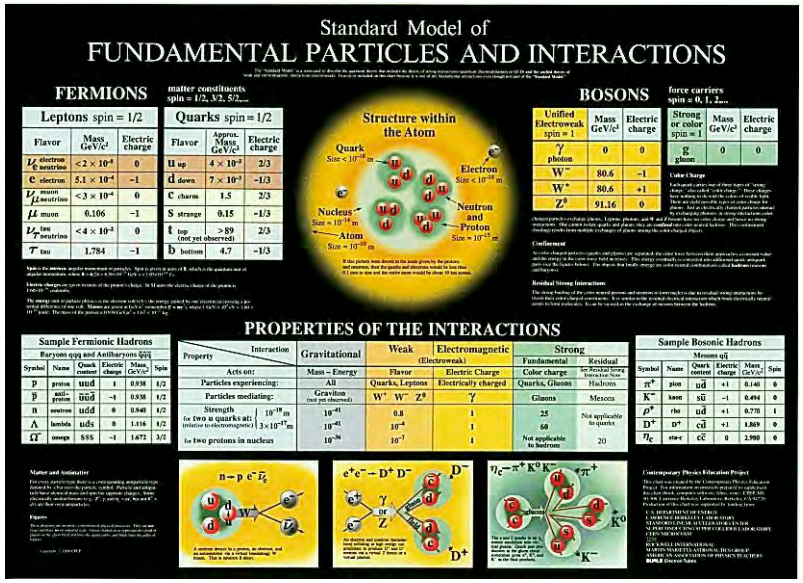
5 January, 2007

Why search for violations of Lorentz-invariance?

General Relativity



the Standard Model



GR + SM = Lorentz-symmetry breaking???

What about Dark Energy and Dark Matter?

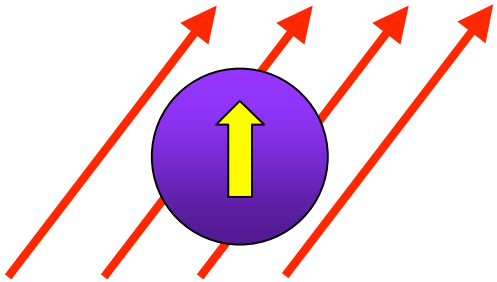
We're also not sure what the universe is made of:

96% new particles and fields that mediate forces we may be able to measure in the laboratory

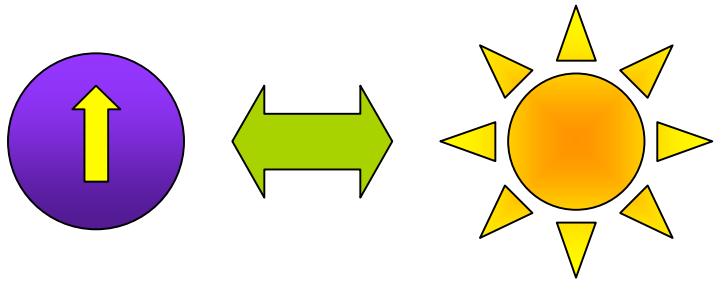
Spin-dependent forces

spin is a property of all fundamental particles

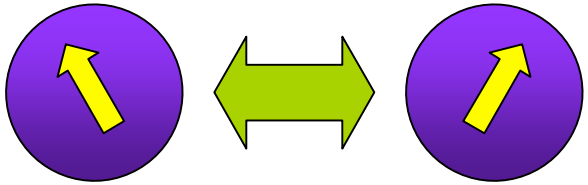
theories of quantum gravity, dark energy and dark matter predict forces between a particle's spin and:



a background field fixed in space



sources of unpolarized matter



another particle's spin

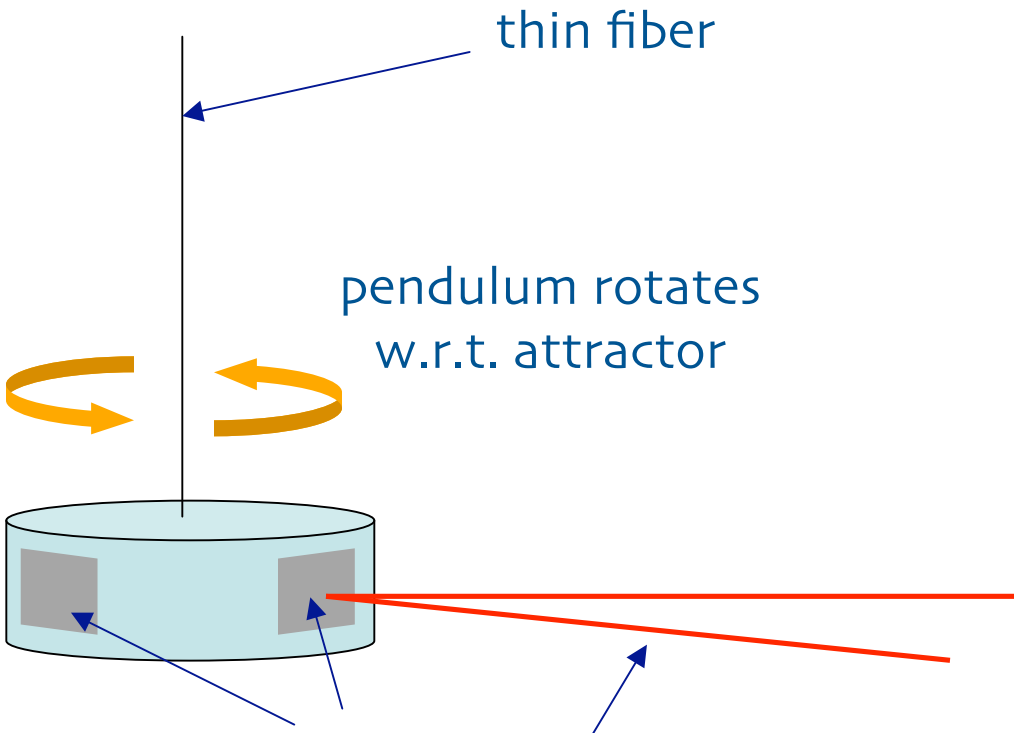
Torsion balances

Coulomb's torsion balance:

A high precision measurement of forces coupled to electrons in 1871

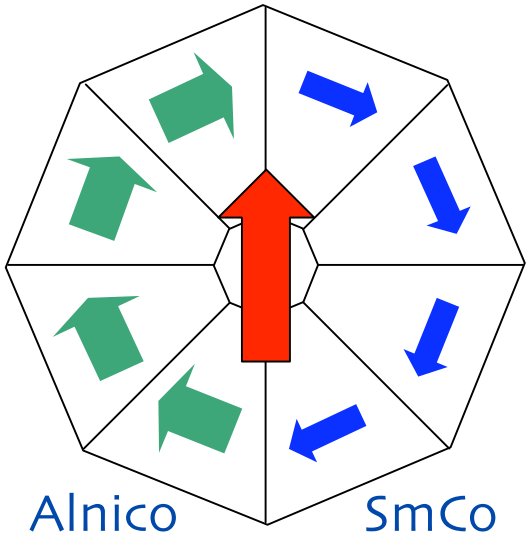
How they work:

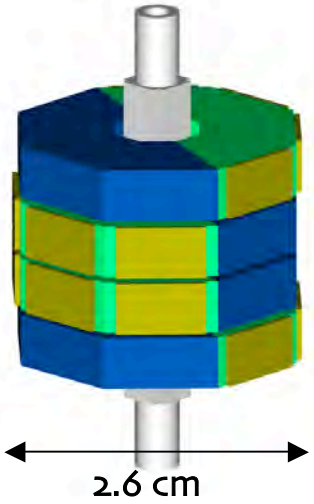
attractor:
a background field, a distant mass, something we made . . .



The spin pendulum

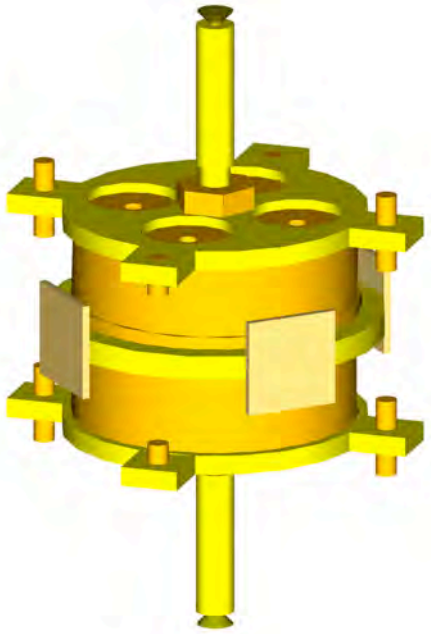
- large net electron spin
- negligible external magnetic field

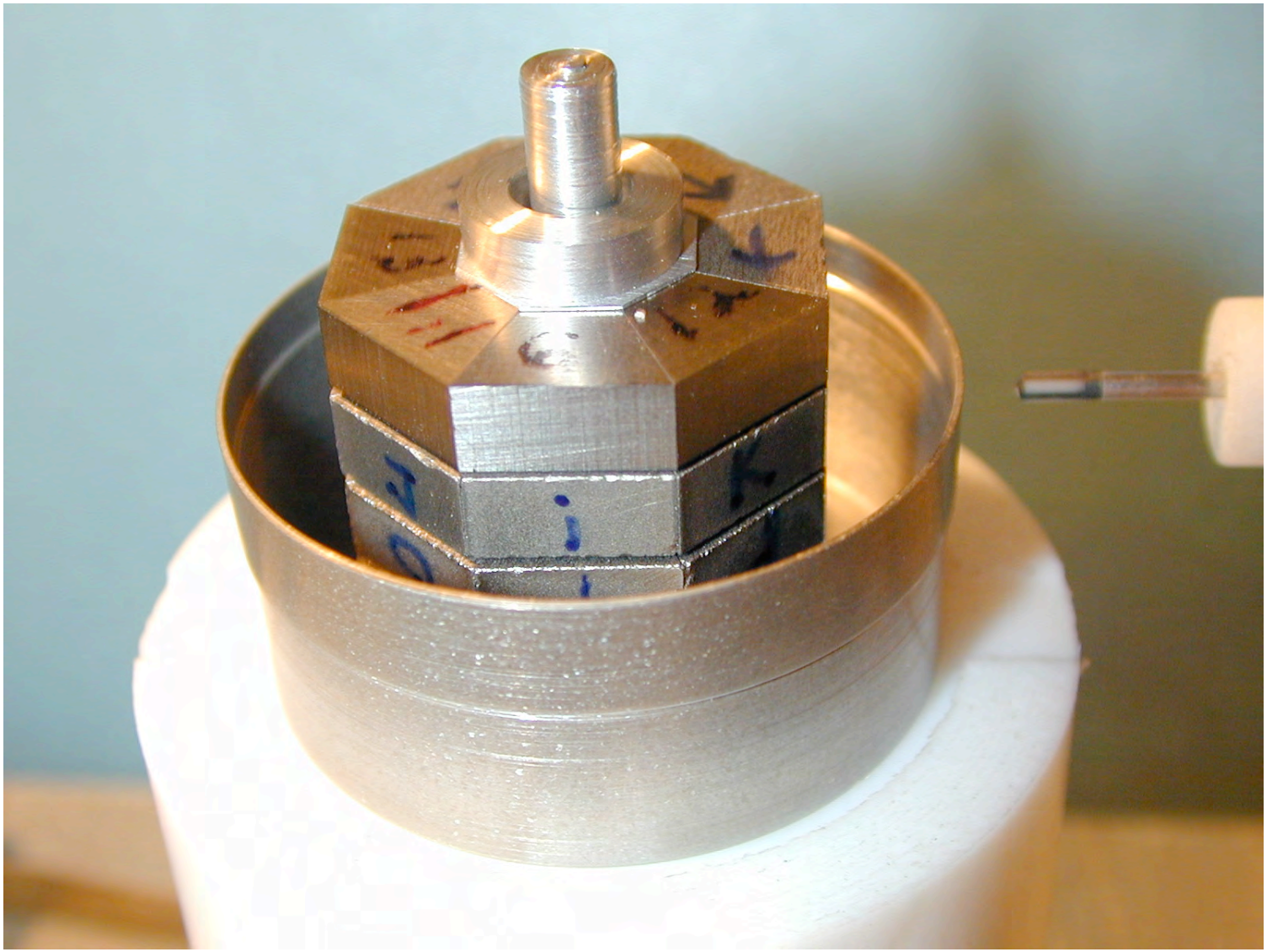




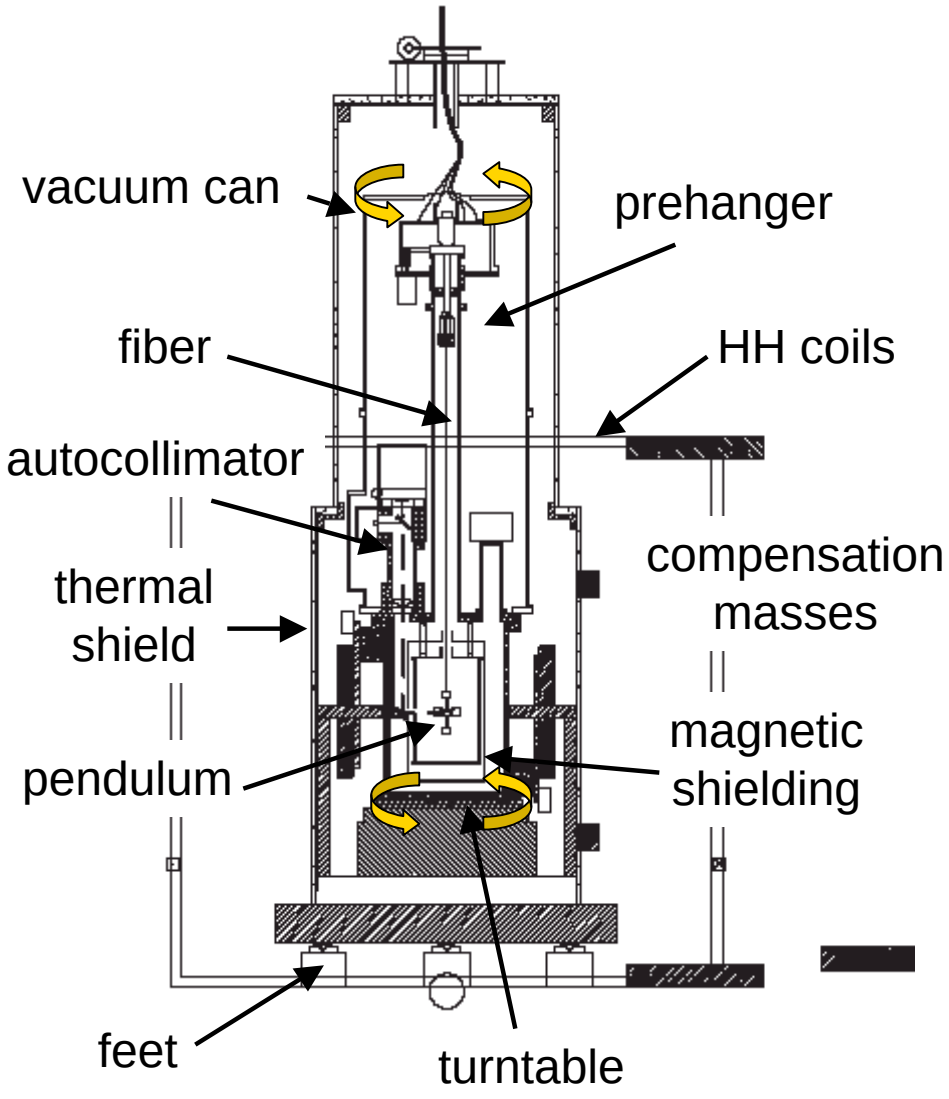
- more spins
- greater symmetry

- gold-plated
- magnetically shielded
- 4 mirrors

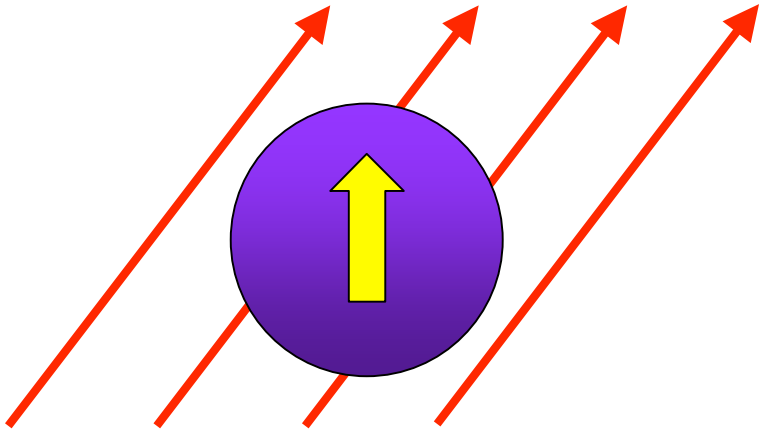




The torsion balance apparatus



Recent Results: limits on a background field



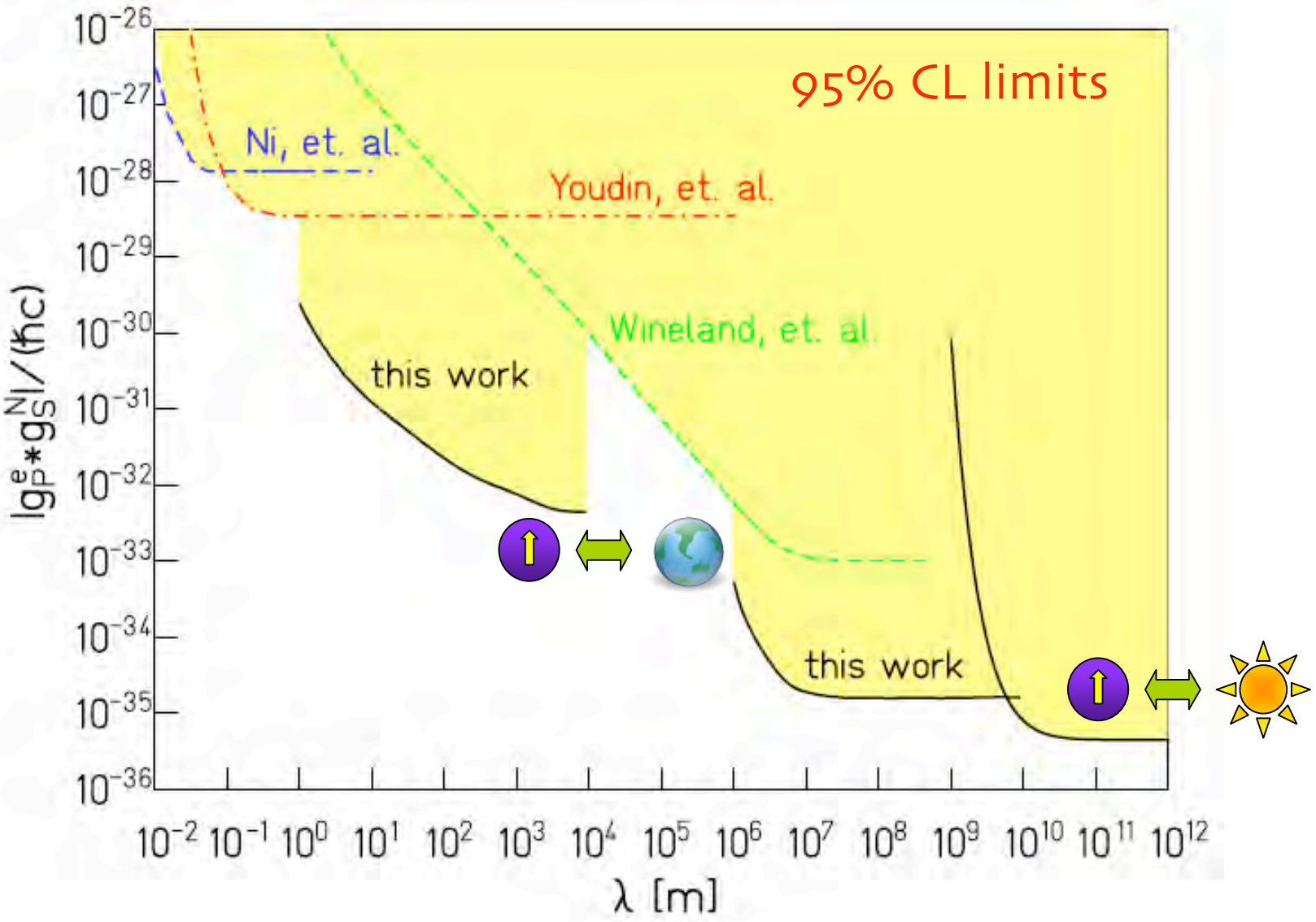
$|b_\perp| = (1.8 \pm 2.5) \times 10^{-22}$ eV

$b_z = (-29 \pm 39) \times 10^{-22}$ eV

expect to see effects of new physics at:

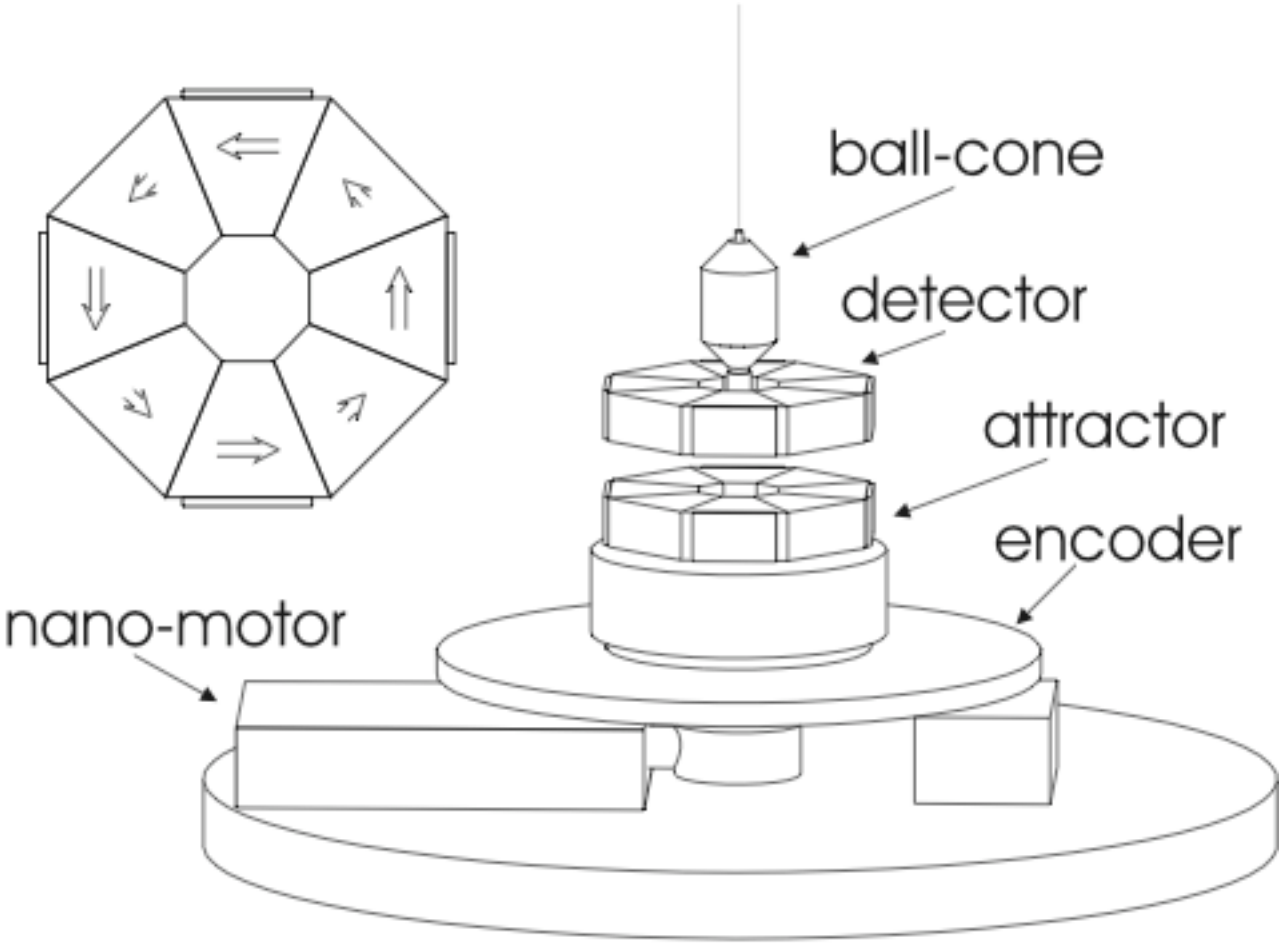
$(m_e/m_{Pl})m_e \sim 10^{-17}$ eV

More Recent Results:

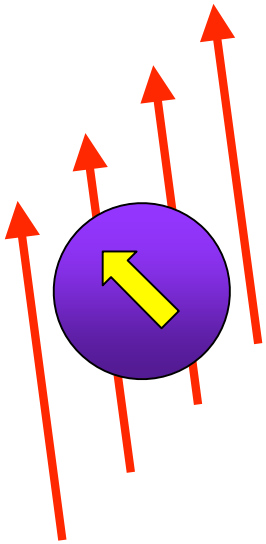


Torsion balance + spin sources

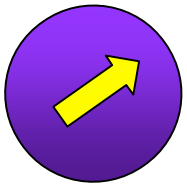
New torsion pendulum



Thanks to . . .

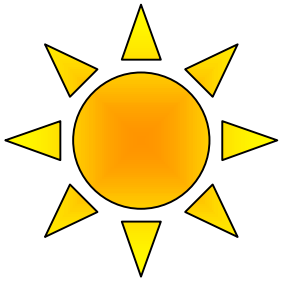


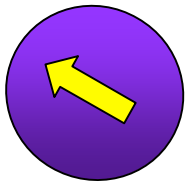
Blayne Heckel
Eric Adelberger
Jens Gundlach



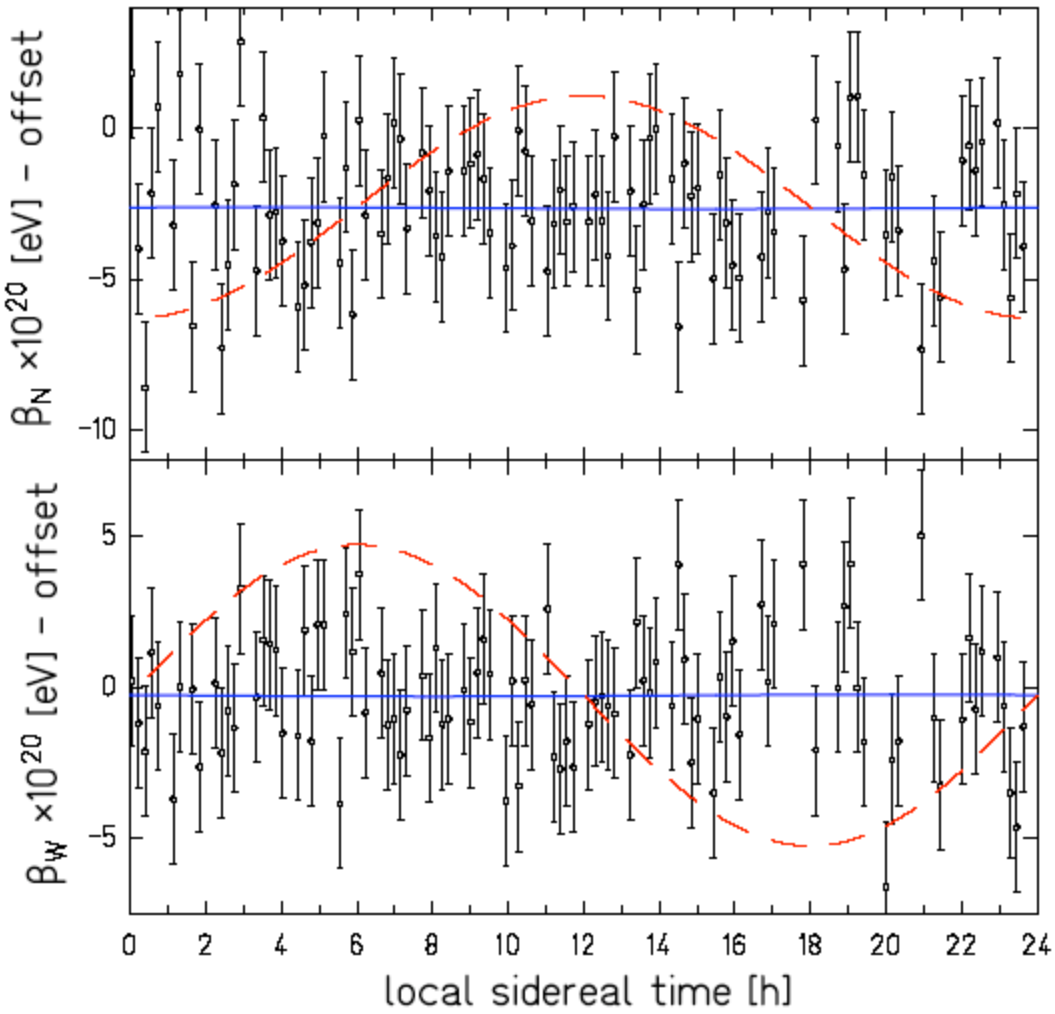
Stephan Schlamminger
Erik Swanson

Ted Cook
William Terrano





Typical Data



hypothetical
$b_x = 5 \times 10^{-20}$ eV
(b_y, b_z = 0)

best sidereal fit:
$b_x = (-0.2 \pm 1.9) \times 10^{-21}$ eV
$b_y = (-0.1 \pm 1.9) \times 10^{-21}$ eV