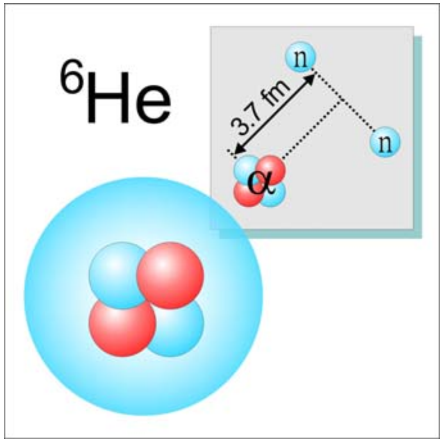
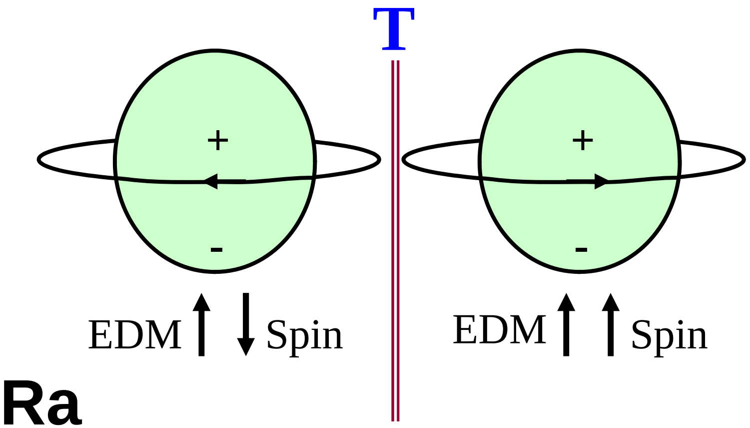
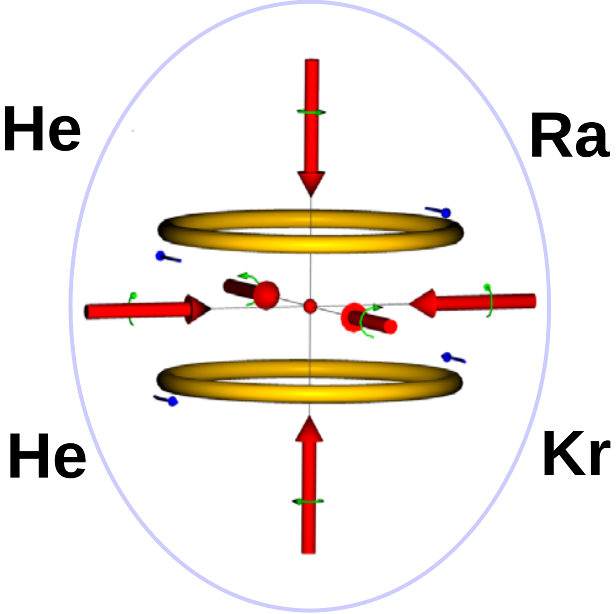
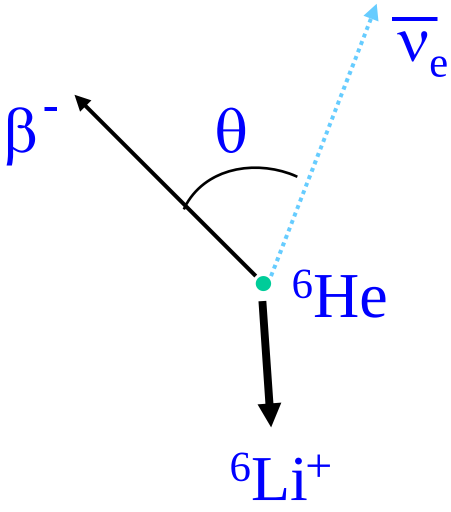
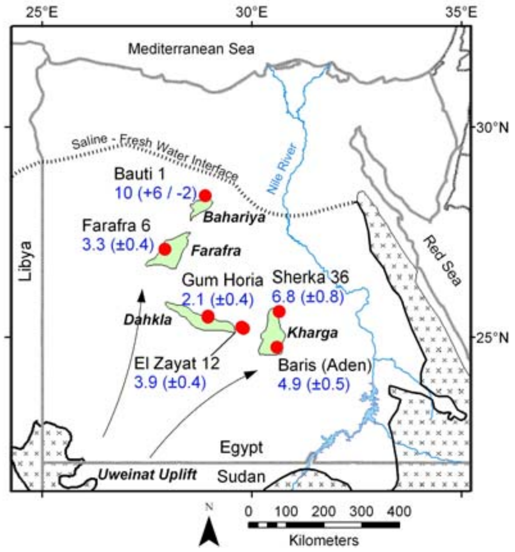




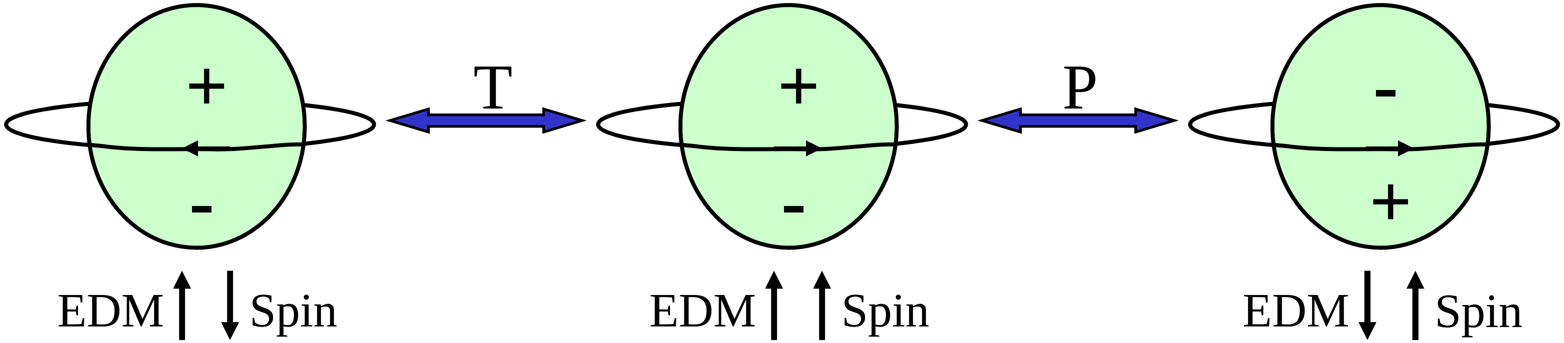






Supported by
DOE, Office of Nuclear Physics

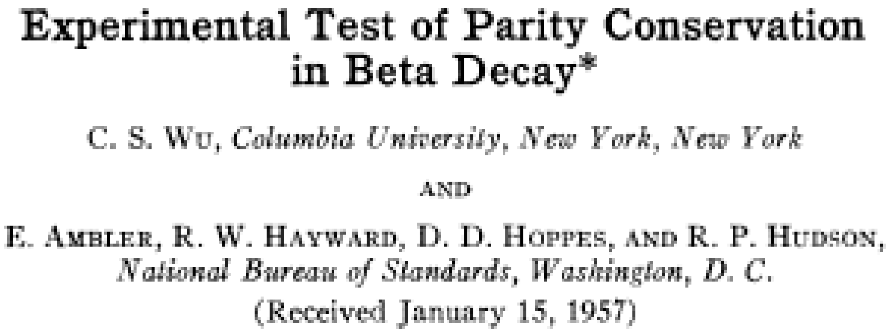
Search for a Permanent Electric Dipole Moment in Ra-225



Pseudo-scalar

$$\vec{\mathbf{s}} \cdot \vec{\mathbf{d}}$$

C. S. Wu
1912-1997



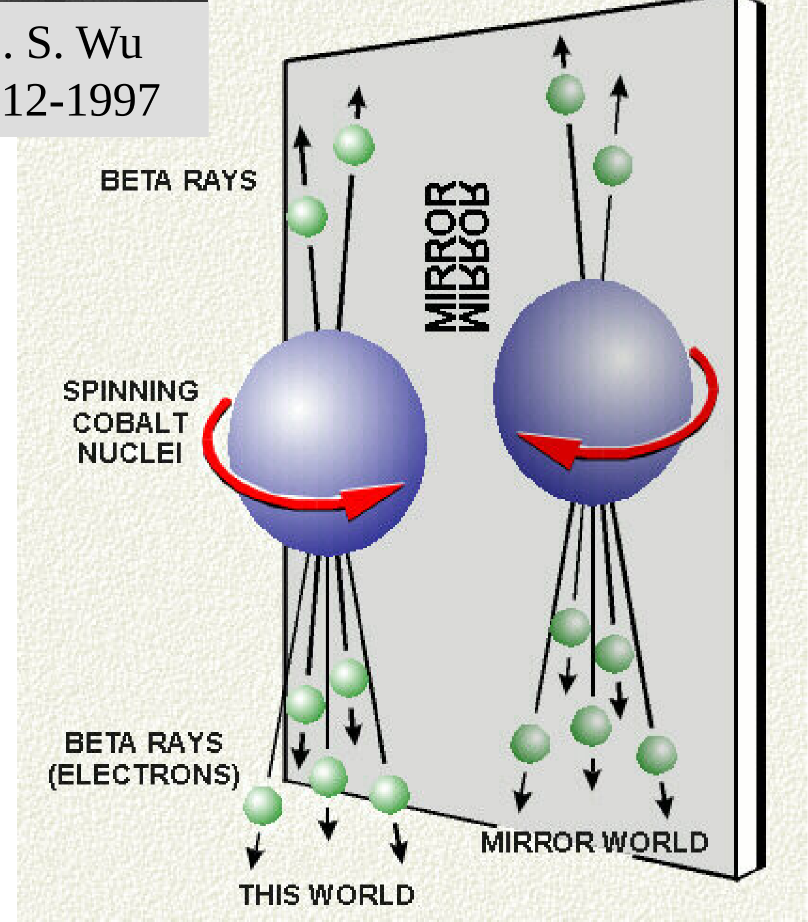
Experimental Test of Parity Conservation in Beta Decay*

C. S. Wu, *Columbia University, New York, New York*

AND

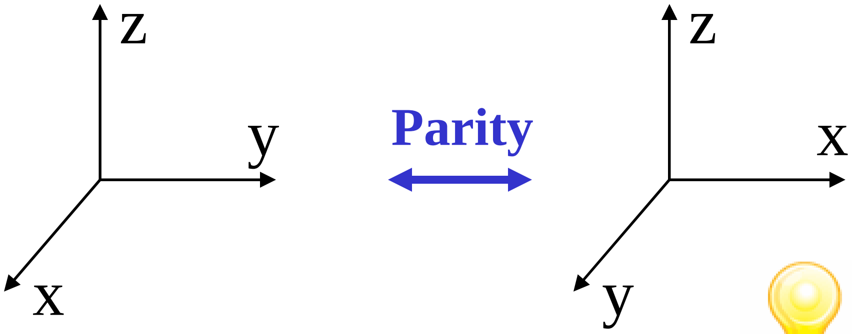
E. Ambler, R. W. Hayward, D. D. Hoppes, and R. P. Hudson,
National Bureau of Standards, Washington, D. C.

(Received January 15, 1957)



Parity (space reversal)

x, y, z → -x, -y, -z



Parity

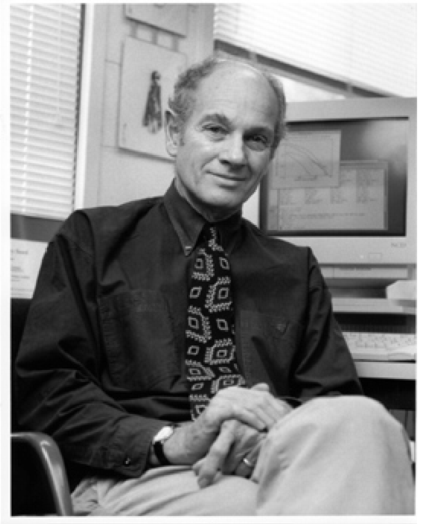
Pseudo-scalar

$$(\vec{x} \times \vec{y}) \cdot \vec{z}$$

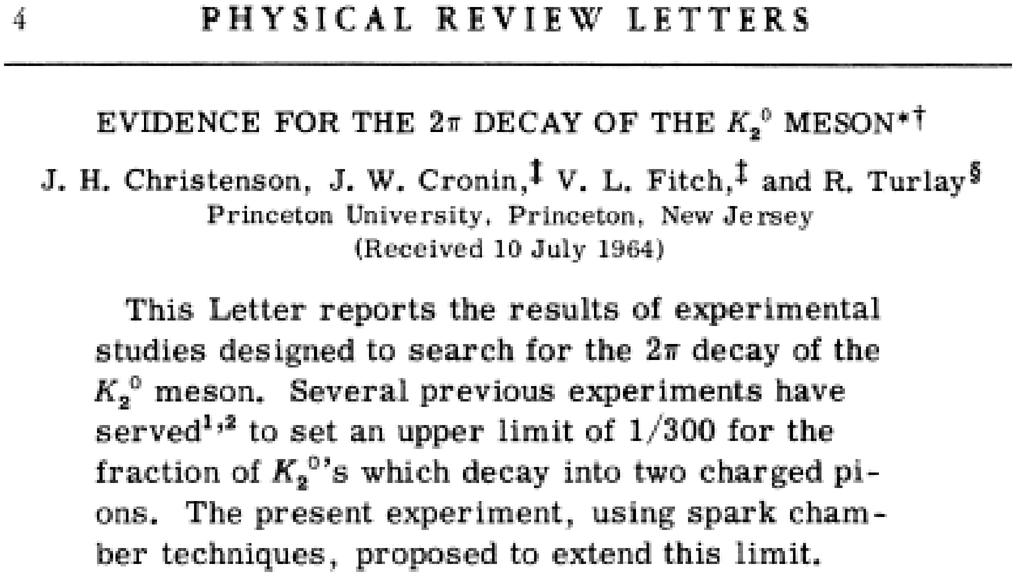
$$\vec{s} \cdot \vec{p}$$

Discrete Fundamental Symmetries

$\cancel{P}$	Parity, or Spatial Inversion
$\cancel{C}$	Charge conjugation, or particle – antiparticle symmetry
T	Time reversal
CP	
CPT	Exact symmetry in quantum field theory with Lorentz invariance



James W. Cronin



4 PHYSICAL REVIEW LETTERS

EVIDENCE FOR THE 2π DECAY OF THE K_2^0 MESON*†

J. H. Christenson, J. W. Cronin,[‡] V. L. Fitch,[‡] and R. Turlay[§]
Princeton University, Princeton, New Jersey
(Received 10 July 1964)

This Letter reports the results of experimental studies designed to search for the 2π decay of the K_2^0 meson. Several previous experiments have served[1,2] to set an upper limit of 1/300 for the fraction of K_2^0's which decay into two charged pions. The present experiment, using spark chamber techniques, proposed to extend this limit.

Neutral K mesons $K^0 = \bar{s}d \qquad \overline{K}^0 = \bar{d}s$

Particles of definite CP $K_{even} = \dfrac{K^0 + \overline{K}^0}{\sqrt{2}} \qquad K_{odd} = \dfrac{K^0 - \overline{K}^0}{\sqrt{2}}$

Allowed decay mode $K_{even} \rightarrow \pi\pi \qquad K_{odd} \rightarrow \pi\pi\pi$

$K_{odd} \rightarrow \pi\pi$ at the level of 0.2% !!!

Discrete Fundamental Symmetries

$\cancel{P}$	Parity, or Spatial Inversion
$\cancel{C}$	Charge conjugation, or particle – antiparticle symmetry
$\cancel{T}$	Time reversal
$\cancel{CP}$	
CPT	Exact symmetry in quantum field theory with Lorentz invariance

P violation and CP violation in the Standard Model

Parity Violation

Weak interaction coupling via (Vector – Axial Vector)

CP Violation

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Cabbibo-Kobayashi-Maskawa Matrix

$$= \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

More CP-Violation Mechanisms?

Strong CP problem

CP-violating phase in Quantum Chromodynamics

$$\mathcal{L}_{\mathrm{mass}} \to -m(\bar{\psi}_{\mathrm{L}}\psi_{\mathrm{R}} + \bar{\psi}_{\mathrm{R}}\psi_{\mathrm{L}}) + \frac{\theta g^2}{32\pi^2} F_a^{\mu\nu}\tilde{F}_{a\mu\nu}$$

Supersymmetry

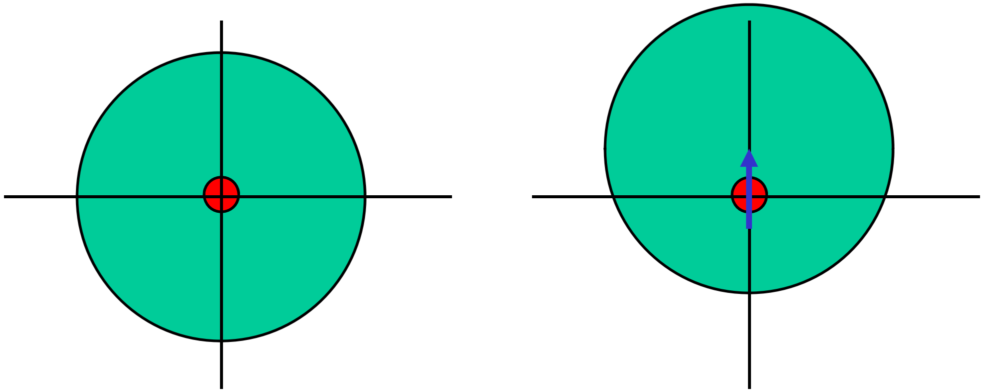
More particles → More CP-violating phases

Matter-antimatter asymmetry

Require additional CP-violation mechanism(s)

Measurability of Nuclear EDM

L.I. Schiff, Phys. Rev. (1963)



Schiff shielding

$$\tilde{d}_{atom} = -d_{nucleus}$$

$$d_{atom} = \tilde{d}_{atom} + d_{nucleus} = 0$$

Incomplete cancellation

$$d_{atom} = \tilde{d}_{atom} + d_{nucleus} \neq 0$$

1) nucleus has finite size;
2) charge distribution ≠ EDM distribution.

Nuclear Schiff moment is lowest order, P,T-odd, measurable electric moment.

Schiff moment (toy model)

$$d_{atom} \square d_{nucleus} \cdot \frac{|r_c - r_d|}{r_{atom}} \square 10^{-5} d_{nucleus}$$

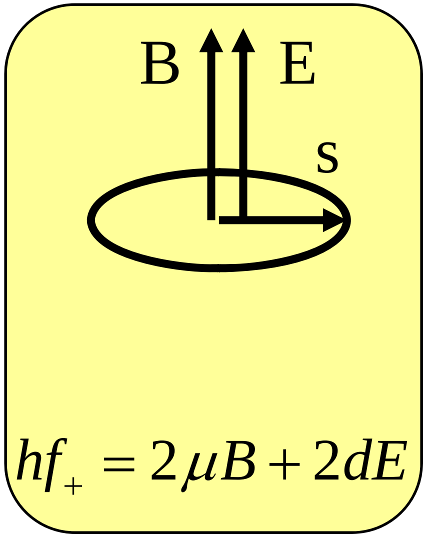
$$S \square d_{nucleus} \cdot \left(r_d^2 - r_c^2 \right)$$

$$d_{atom} \square S \cdot r_{atom}^{-1} \cdot r_c^{-1}$$

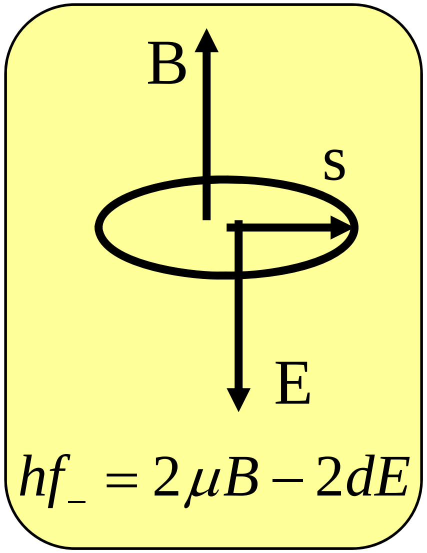
$$\langle \vec{S} \rangle = \left\langle \frac{e}{10} \sum_p \left(r_p^2 - \tfrac{5}{3} \overline{r_{ch}^2} \right) \vec{r}_p \right\rangle$$

a 'radially-weighted dipole moment'

EDM Measurement



$$hf_+ = 2\mu B + 2dE$$



$$hf_- = 2\mu B - 2dE$$

Parameters

B = 10 mGauss

f = 11 Hz

E = 100 kV/cm

$f_+ - f_-$ = 10 nHz

$d = 1 \times 10^{-28}$ e cm

2001 Hg EDM search

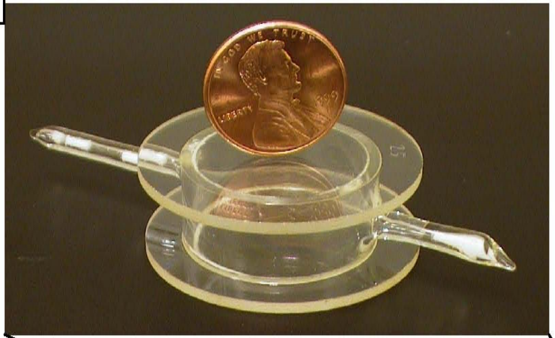
Result:

$[-10.6 \pm 4.9_{\text{stat.}} \pm 4.0_{\text{syst.}}] \times 10^{-29}$ *e* cm

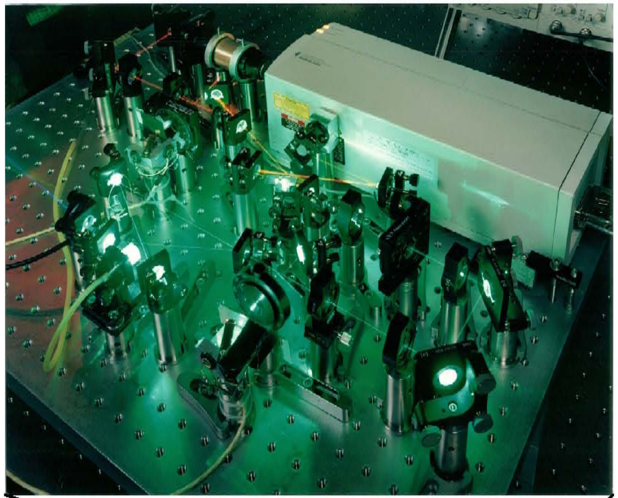
d(^{199}Hg) < 2.1 x 10^{-28} *e* cm

Romalis, Griffith, Jacobs, Fortson

Vapor cells:
10^{14} Hg atoms
Coherence time 200 sec
Wall resistance > 10^{16} Ω



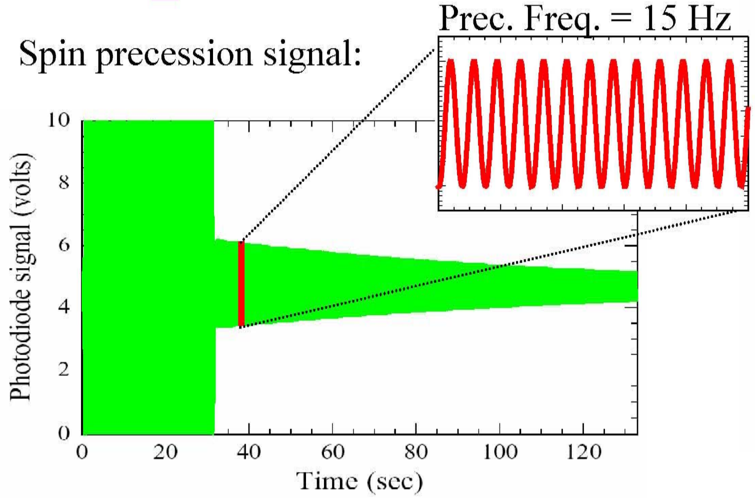
6mW, 254 nm laser from
quadrupled 1016 diode:

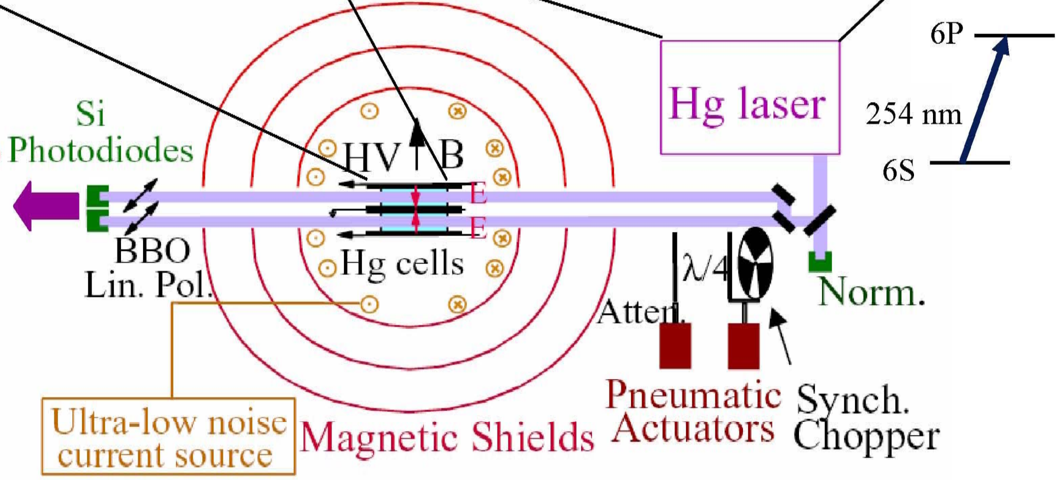


Frequency uncertainty = 1 nHz

~ 80 days data

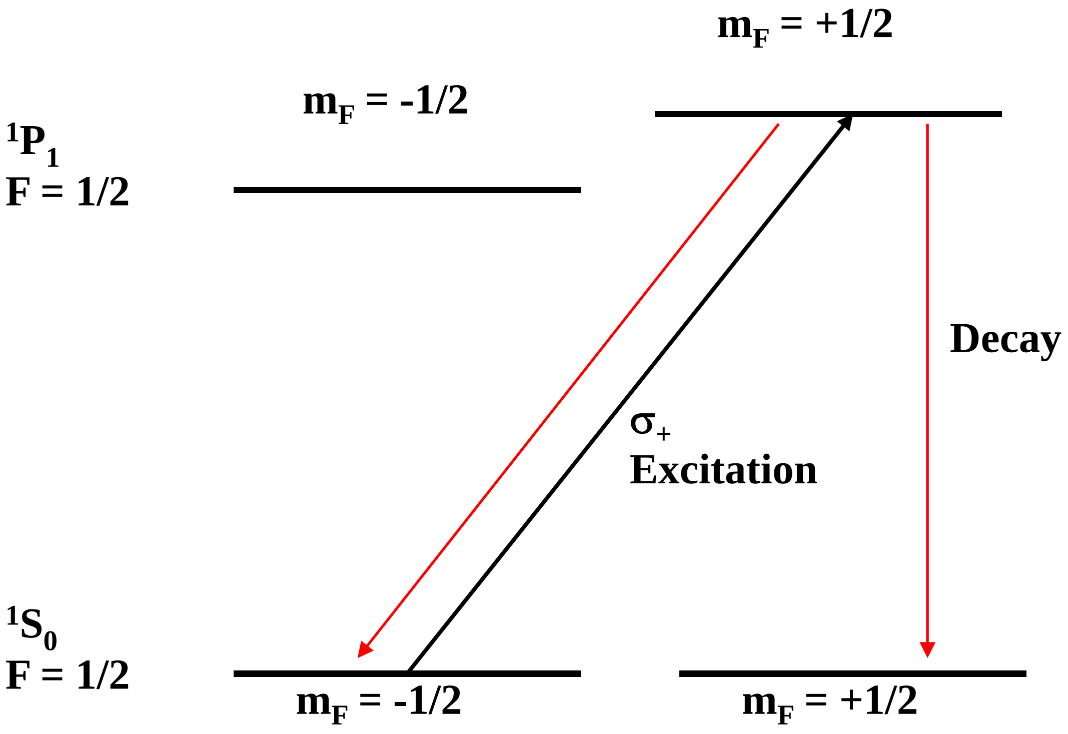
Spin precession signal:





Courtesy of Mike Romalis

Optical Pumping

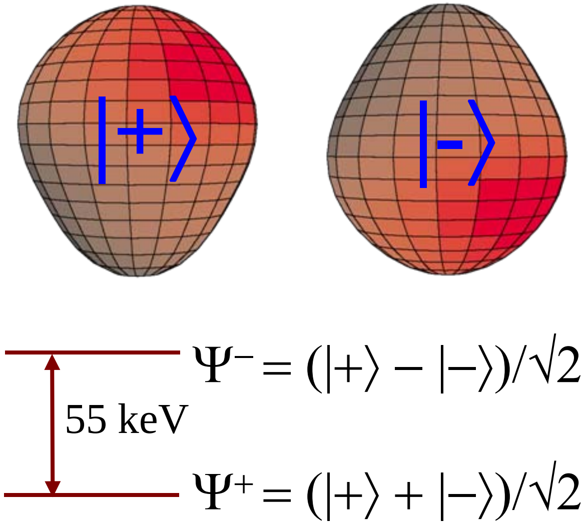


EDM of ^{225}Ra enhanced

EDM of ^{225}Ra enhanced:

- Large intrinsic Schiff moment due to octupole deformation;
- Closely spaced parity doublet;
- Relativistic atomic structure.

Haxton & Henley (1983)
Auerbach, Flambaum & Spevak (1996)
Engel, Friar & Hayes (2000)



$$\Psi^- = (|+\rangle - |-\rangle)/\sqrt{2}$$

$$\Psi^+ = (|+\rangle + |-\rangle)/\sqrt{2}$$

Enhancement Factor: EDM (^{225}Ra) / EDM (^{199}Hg)

Skyrme Model	Isoscalar	Isovector	Isotensor
SkM*	1500	900	1500
SkO'	450	240	600

Schiff moment of ^{199}Hg, de Jesus & Engel, PRC72 (2005)
Schiff moment of ^{225}Ra, Dobaczewski & Engel, PRL94 (2005)

^{225}Ra Source

229Th 7300 yr $\xrightarrow{\alpha}$ 225Ra 15 days $\xrightarrow{\beta}$ 225Ac 10 days $\xrightarrow{\alpha}$ Fr, At, Rn… ~ 4 hours $\xrightarrow{\alpha,\beta}$ 209Bi stable

- 1 mCi ^{229}Th source produces 4 × 10^7 s^{-1} ^{225}Ra
- Chemical extraction of Ra from Th
- Reduction of $Ra(NO_3)_2$ with Ba, Al, Ti…

RIA ~ 1 Ci ^{229}Th

Expected yield for ^{225}Ra: 2.6 × 10^{10} s^{-1}

Search for Electric Dipole Moment of ^{225}Ra

Advantages of an EDM measurement on ^{225}Ra atoms in a trap

- EDM enhanced by ~ 10^2-10^3 due to nuclear octupole deformation.
- Trap allows the efficient use of the rare and radioactive ^{225}Ra atoms.
- Long coherence time (~ 100 s), negligible "v x E" systematics, high electric field (100 kV/cm).

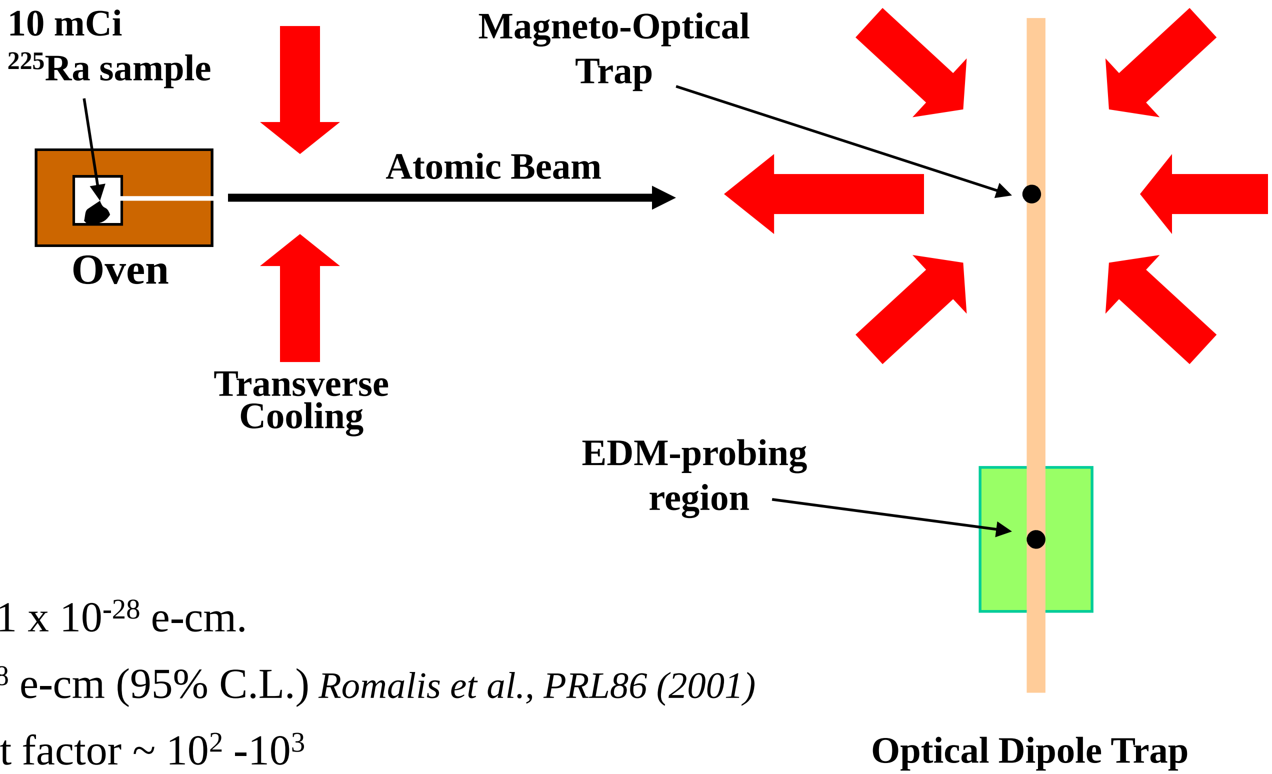
Proposed setup

^{225}Ra

Nuclear Spin = ½

Electronic Spin = 0

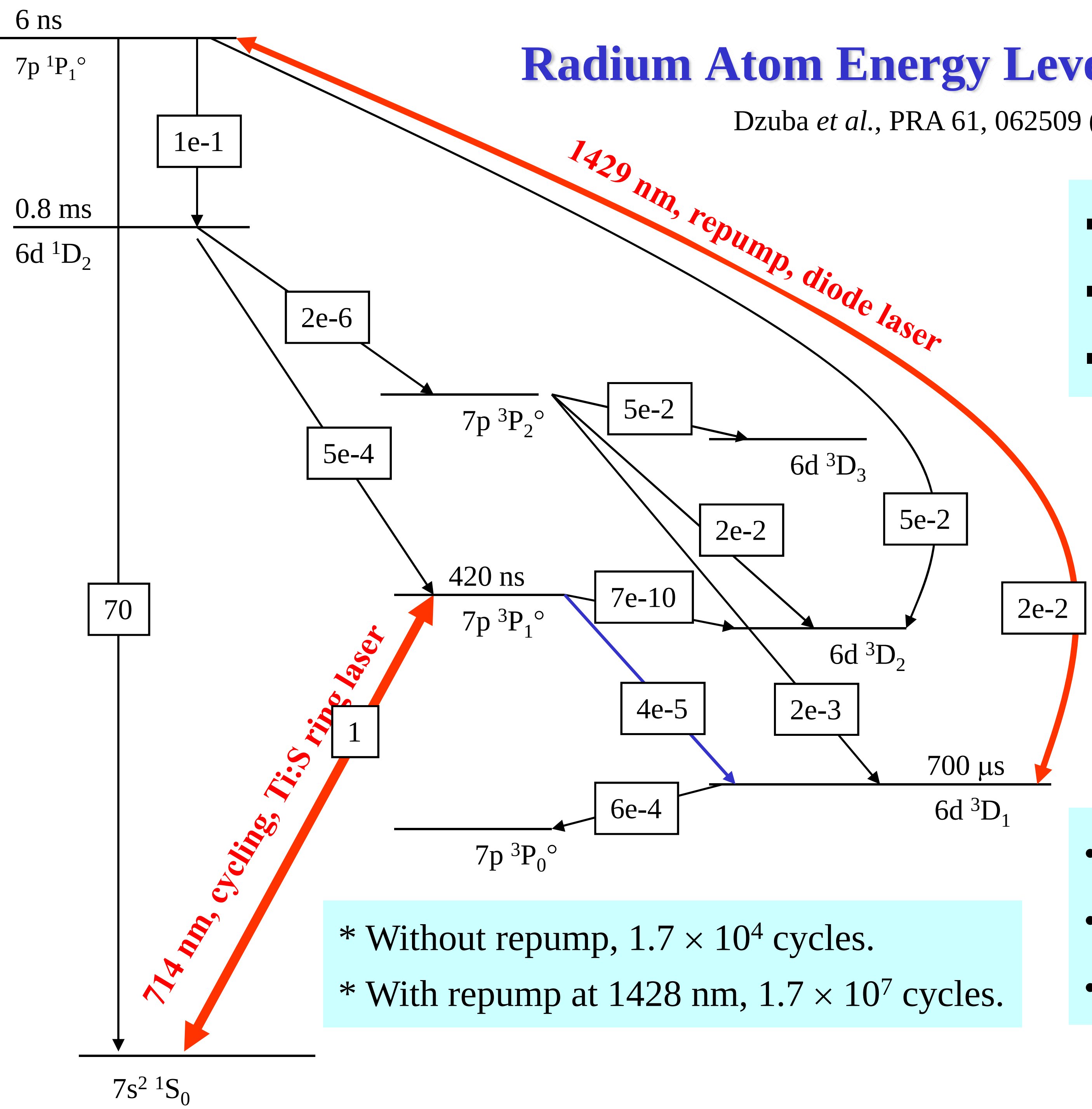
$t_{1/2}$ = 15 days



- Our sensitivity goal: 1 x 10^{-28} e-cm.
- | d(^{199}Hg) | < 2 x 10^{-28} e-cm (95% C.L.) *Romalis et al., PRL86 (2001)*
- Ra / Hg Enhancement factor ~ 10^2 -10^3

Radium Atom Energy Level Diagram

Dzuba *et al.*, PRA 61, 062509 (2000)



- $\delta v / \gamma$ = 2.5 mm/s
- Cycling rate ~ 1 MHz
- MOT lifetime ~ 20 s

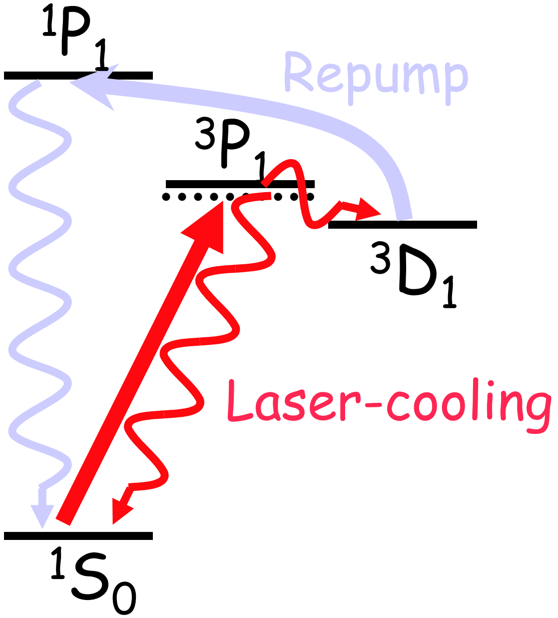
* Without repump, 1.7 × 10^4 cycles.

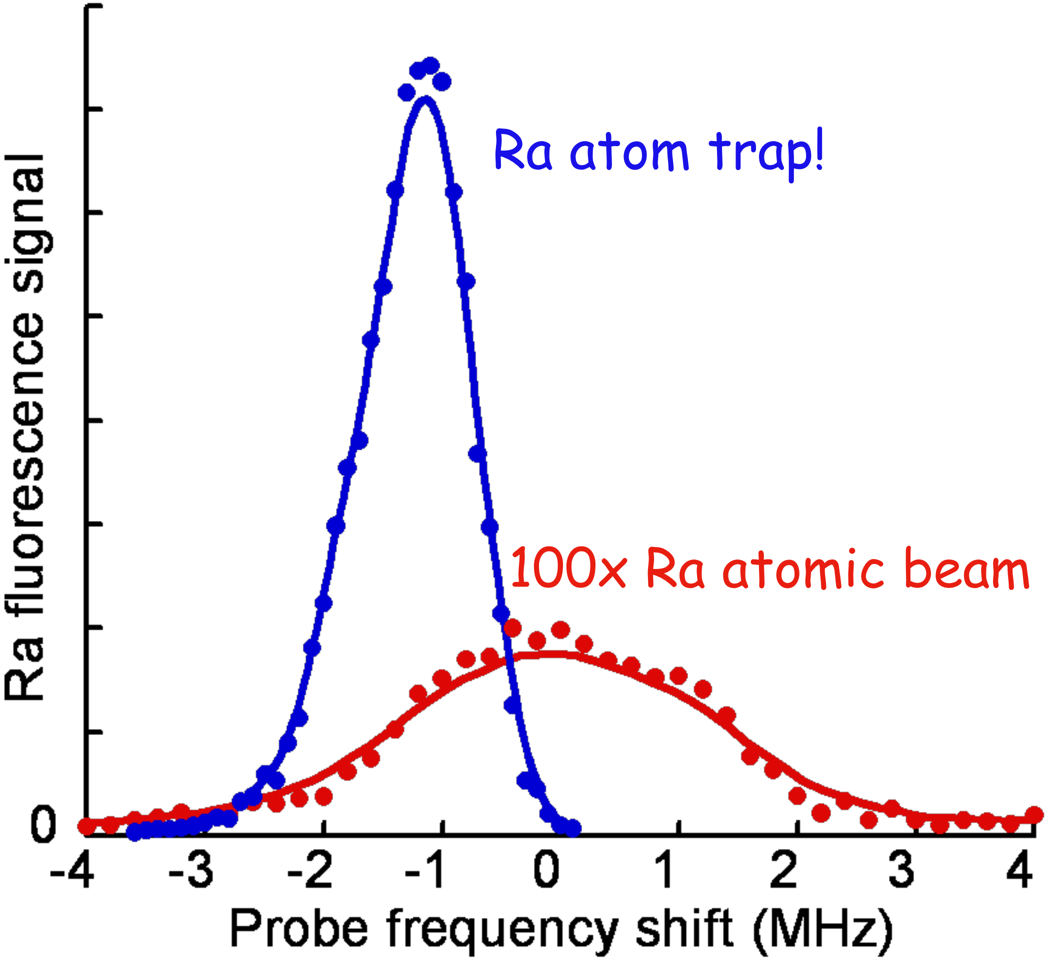
* With repump at 1428 nm, 1.7 × 10^7 cycles.

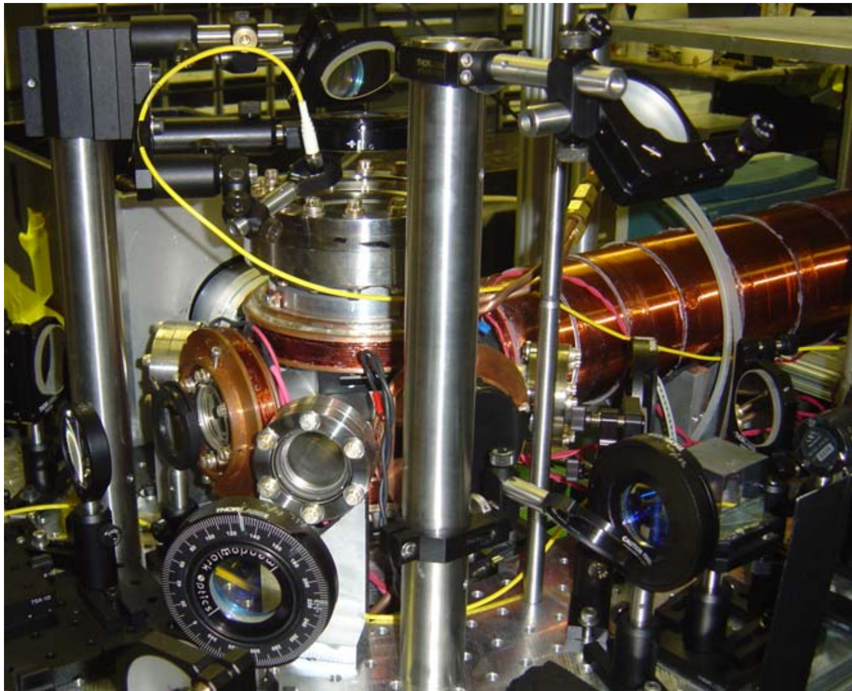
- Linewidth ~ 400 kHz
- Cooling 7 μK, 14 mm/s
- B gradient ~ 1 G / cm

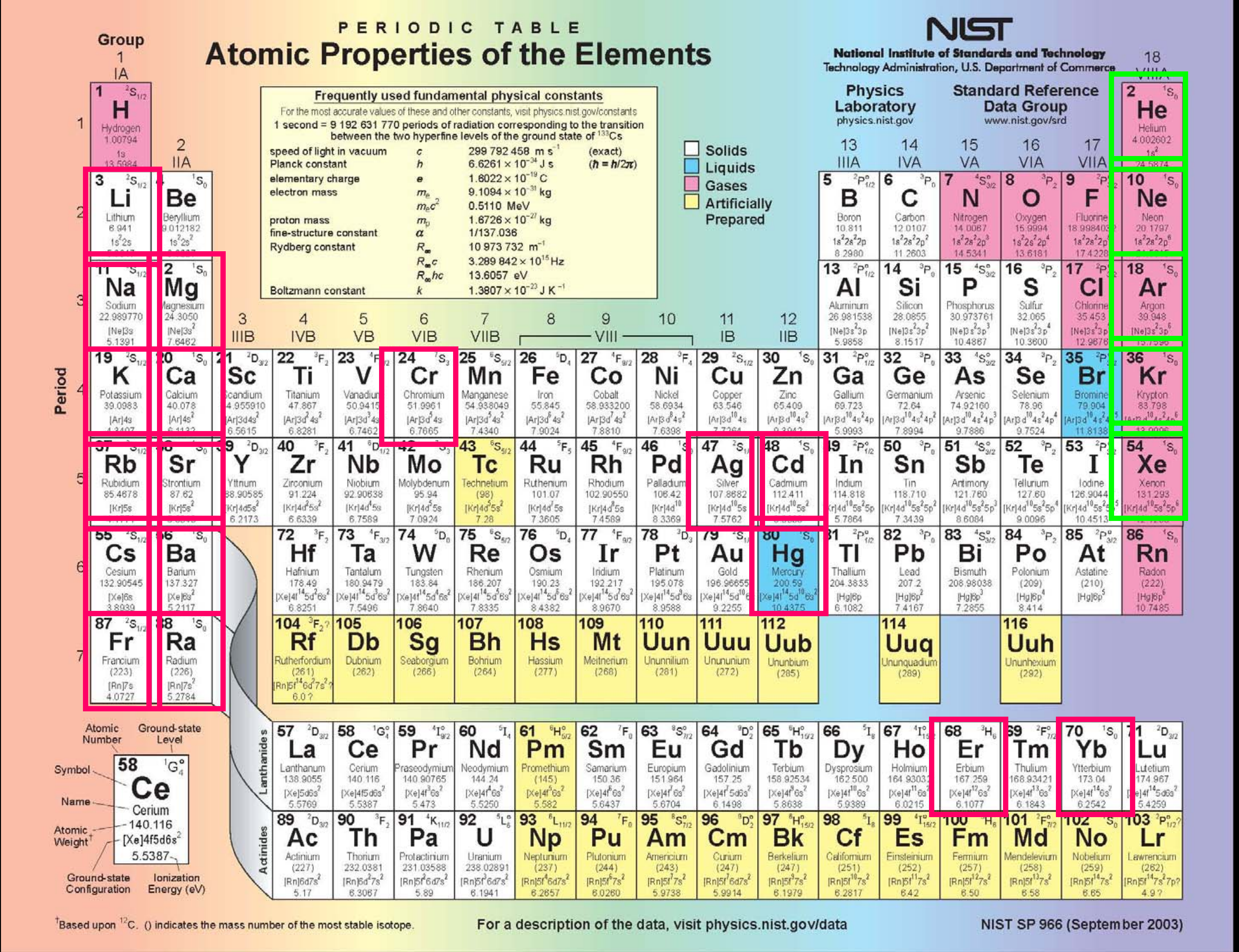
Laser-Trapping of ^{225}Ra and ^{226}Ra Atoms

- **Key ^{225}Ra frequencies, lifetimes measured**
  Scielzo et al. PRA (2006)
- **^{225}Ra laser cooled and trapped!**
  Guest et al. PRL (2007)









PERIODIC TABLE

Atomic Properties of the Elements

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Physics Laboratory
physics.nist.gov

Standard Reference Data Group
www.nist.gov/srd

Frequently used fundamental physical constants

For the most accurate values of these and other constants, visit physics.nist.gov/constants

1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of ^{133}Cs

speed of light in vacuum	c	299 792 458 m s^{-1}	(exact)
Planck constant	h	6.6261×10^{-34} J s	($\hbar = h/2\pi$)
elementary charge	e	1.6022×10^{-19} C	
electron mass	m_e	9.1094×10^{-31} kg	
	$m_e c^2$	0.5110 MeV	
proton mass	m_p	1.6726×10^{-27} kg	
fine-structure constant	α	1/137.036	
Rydberg constant	R_∞	10 973 732 m^{-1}	
	$R_\infty c$	$3.289\,842 \times 10^{15}$ Hz	
	$R_\infty hc$	13.6057 eV	
Boltzmann constant	k	1.3807×10^{-23} J K^{-1}	

⬜ Solids
🟦 Liquids
🟥 Gases
🟨 Artificially Prepared

Period	Group 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	**1** $^2S_{1/2}$ **H** Hydrogen 1.00794 $1s$ 13.5984																	**2** $^1S_0$ **He** Helium 4.002602 $1s^2$ 24.5874
2	**3** $^2S_{1/2}$ **Li** Lithium 6.941 $1s^2 2s$	**4** $^1S_0$ **Be** Beryllium 9.012182 $1s^2 2s^2$											**5** $^2P^o_{1/2}$ **B** Boron 10.811 $1s^2 2s^2 2p$ 8.2980	**6** $^3P_0$ **C** Carbon 12.0107 $1s^2 2s^2 2p^2$ 11.2603	**7** $^4S^o_{3/2}$ **N** Nitrogen 14.0067 $1s^2 2s^2 2p^3$ 14.5341	**8** $^3P_2$ **O** Oxygen 15.9994 $1s^2 2s^2 2p^4$ 13.6181	**9** $^2P^o_{3/2}$ **F** Fluorine 18.9984032 $1s^2 2s^2 2p^5$ 17.4228	**10** $^1S_0$ **Ne** Neon 20.1797 $1s^2 2s^2 2p^6$
3	**11** $^2S_{1/2}$ **Na** Sodium 22.989770 $[Ne]3s$ 5.1391	**12** $^1S_0$ **Mg** Magnesium 24.3050 $[Ne]3s^2$ 7.6462											**13** $^2P^o_{1/2}$ **Al** Aluminum 26.981538 $[Ne]3s^2 3p$ 5.9858	**14** $^3P_0$ **Si** Silicon 28.0855 $[Ne]3s^2 3p^2$ 8.1517	**15** $^4S^o_{3/2}$ **P** Phosphorus 30.973761 $[Ne]3s^2 3p^3$ 10.4867	**16** $^3P_2$ **S** Sulfur 32.065 $[Ne]3s^2 3p^4$ 10.3600	**17** $^2P^o_{3/2}$ **Cl** Chlorine 35.453 $[Ne]3s^2 3p^5$ 12.9676	**18** $^1S_0$ **Ar** Argon 39.948 $[Ne]3s^2 3p^6$ 15.7596
4	**19** $^2S_{1/2}$ **K** Potassium 39.0983 $[Ar]4s$ 4.3407	**20** $^1S_0$ **Ca** Calcium 40.078 $[Ar]4s^2$ 6.1132	**21** $^2D_{3/2}$ **Sc** Scandium 44.955910 $[Ar]3d4s^2$ 6.5615	**22** $^3F_2$ **Ti** Titanium 47.867 $[Ar]3d^2 4s^2$ 6.8281	**23** $^4F_{3/2}$ **V** Vanadium 50.9415 $[Ar]3d^3 4s^2$ 6.7462	**24** $^7S_3$ **Cr** Chromium 51.9961 $[Ar]3d^5 4s$ 6.7665	**25** $^6S_{5/2}$ **Mn** Manganese 54.938049 $[Ar]3d^5 4s^2$ 7.4340	**26** $^5D_4$ **Fe** Iron 55.845 $[Ar]3d^6 4s^2$ 7.9024	**27** $^4F_{9/2}$ **Co** Cobalt 58.933200 $[Ar]3d^7 4s^2$ 7.8810	**28** $^3F_4$ **Ni** Nickel 58.6934 $[Ar]3d^8 4s^2$ 7.6398	**29** $^2S_{1/2}$ **Cu** Copper 63.546 $[Ar]3d^{10}4s$ 7.7264	**30** $^1S_0$ **Zn** Zinc 65.409 $[Ar]3d^{10}4s^2$ 9.3942	**31** $^2P^o_{1/2}$ **Ga** Gallium 69.723 $[Ar]3d^{10}4s^2 4p$ 5.9993	**32** $^3P_0$ **Ge** Germanium 72.64 $[Ar]3d^{10}4s^2 4p^2$ 7.8994	**33** $^4S^o_{3/2}$ **As** Arsenic 74.92160 $[Ar]3d^{10}4s^2 4p^3$ 9.7886	**34** $^3P_2$ **Se** Selenium 78.96 $[Ar]3d^{10}4s^2 4p^4$ 9.7524	**35** $^2P^o_{3/2}$ **Br** Bromine 79.904 $[Ar]3d^{10}4s^2 4p^5$ 11.8138	**36** $^1S_0$ **Kr** Krypton 83.798 $[Ar]3d^{10}4s^2 4p^6$
5	**37** $^2S_{1/2}$ **Rb** Rubidium 85.4678 $[Kr]5s$	**38** $^1S_0$ **Sr** Strontium 87.62 $[Kr]5s^2$	**39** $^2D_{3/2}$ **Y** Yttrium 88.90585 $[Kr]4d5s^2$ 6.2173	**40** $^3F_2$ **Zr** Zirconium 91.224 $[Kr]4d^2 5s^2$ 6.6339	**41** $^6D_{1/2}$ **Nb** Niobium 92.90638 $[Kr]4d^4 5s$ 6.7589	**42** $^7S_3$ **Mo** Molybdenum 95.94 $[Kr]4d^5 5s$ 7.0924	**43** $^6S_{5/2}$ **Tc** Technetium (98) $[Kr]4d^5 5s^2$ 7.28	**44** $^5F_5$ **Ru** Ruthenium 101.07 $[Kr]4d^7 5s$ 7.3605	**45** $^4F_{9/2}$ **Rh** Rhodium 102.90550 $[Kr]4d^8 5s$ 7.4589	**46** $^1S_0$ **Pd** Palladium 106.42 $[Kr]4d^{10}$ 8.3369	**47** $^2S_{1/2}$ **Ag** Silver 107.8682 $[Kr]4d^{10}5s$ 7.5762	**48** $^1S_0$ **Cd** Cadmium 112.411 $[Kr]4d^{10}5s^2$	**49** $^2P^o_{1/2}$ **In** Indium 114.818 $[Kr]4d^{10}5s^2 5p$ 5.7864	**50** $^3P_0$ **Sn** Tin 118.710 $[Kr]4d^{10}5s^2 5p^2$ 7.3439	**51** $^4S^o_{3/2}$ **Sb** Antimony 121.760 $[Kr]4d^{10}5s^2 5p^3$ 8.6084	**52** $^3P_2$ **Te** Tellurium 127.60 $[Kr]4d^{10}5s^2 5p^4$ 9.0096	**53** $^2P^o_{3/2}$ **I** Iodine 126.9044 $[Kr]4d^{10}5s^2 5p^5$ 10.4513	**54** $^1S_0$ **Xe** Xenon 131.293 $[Kr]4d^{10}5s^2 5p^6$
6	**55** $^2S_{1/2}$ **Cs** Cesium 132.90545 $[Xe]6s$ 3.8939	**56** $^1S_0$ **Ba** Barium 137.327 $[Xe]6s^2$ 5.2117		**72** $^3F_2$ **Hf** Hafnium 178.49 $[Xe]4f^{14}5d^2 6s^2$ 6.8251	**73** $^4F_{3/2}$ **Ta** Tantalum 180.9479 $[Xe]4f^{14}5d^3 6s^2$ 7.5496	**74** $^5D_0$ **W** Tungsten 183.84 $[Xe]4f^{14}5d^4 6s^2$ 7.8640	**75** $^6S_{5/2}$ **Re** Rhenium 186.207 $[Xe]4f^{14}5d^5 6s^2$ 7.8335	**76** $^5D_4$ **Os** Osmium 190.23 $[Xe]4f^{14}5d^6 6s^2$ 8.4382	**77** $^4F_{9/2}$ **Ir** Iridium 192.217 $[Xe]4f^{14}5d^7 6s^2$ 8.9670	**78** $^3D_3$ **Pt** Platinum 195.078 $[Xe]4f^{14}5d^9 6s$ 8.9588	**79** $^2S_{1/2}$ **Au** Gold 196.96655 $[Xe]4f^{14}5d^{10}6s$ 9.2255	**80** $^1S_0$ **Hg** Mercury 200.59 $[Xe]4f^{14}5d^{10}6s^2$ 10.4375	**81** $^2P^o_{1/2}$ **Tl** Thallium 204.3833 $[Hg]6p$ 6.1082	**82** $^3P_0$ **Pb** Lead 207.2 $[Hg]6p^2$ 7.4167	**83** $^4S^o_{3/2}$ **Bi** Bismuth 208.98038 $[Hg]6p^3$ 7.2855	**84** $^3P_2$ **Po** Polonium (209) $[Hg]6p^4$ 8.414	**85** $^2P^o_{3/2}$ **At** Astatine (210) $[Hg]6p^5$	**86** $^1S_0$ **Rn** Radon (222) $[Hg]6p^6$ 10.7485
7	**87** $^2S_{1/2}$ **Fr** Francium (223) $[Rn]7s$ 4.0727	**88** $^1S_0$ **Ra** Radium (226) $[Rn]7s^2$ 5.2784		**104** $^3F_2$? **Rf** Rutherfordium (261) $[Rn]5f^{14}6d^2 7s^2$? 6.0 ?	**105** **Db** Dubnium (262)	**106** **Sg** Seaborgium (266)	**107** **Bh** Bohrium (264)	**108** **Hs** Hassium (277)	**109** **Mt** Meitnerium (268)	**110** **Uun** Ununnilium (281)	**111** **Uuu** Unununium (272)	**112** **Uub** Ununbium (285)		**114** **Uuq** Ununquadium (289)		**116** **Uuh** Ununhexium (292)		

Lanthanides	**57** $^2D_{3/2}$ **La** Lanthanum 138.9055 $[Xe]5d6s^2$ 5.5769	**58** $^1G^o_4$ **Ce** Cerium 140.116 $[Xe]4f5d6s^2$ 5.5387	**59** $^4I^o_{9/2}$ **Pr** Praseodymium 140.90765 $[Xe]4f^3 6s^2$ 5.473	**60** $^5I_4$ **Nd** Neodymium 144.24 $[Xe]4f^4 6s^2$ 5.5250	**61** $^6H^o_{5/2}$ **Pm** Promethium (145) $[Xe]4f^5 6s^2$ 5.582	**62** $^7F_0$ **Sm** Samarium 150.36 $[Xe]4f^6 6s^2$ 5.6437	**63** $^8S^o_{7/2}$ **Eu** Europium 151.964 $[Xe]4f^7 6s^2$ 5.6704	**64** $^9D^o_2$ **Gd** Gadolinium 157.25 $[Xe]4f^7 5d6s^2$ 6.1498	**65** $^6H^o_{15/2}$ **Tb** Terbium 158.92534 $[Xe]4f^9 6s^2$ 5.8638	**66** $^5I_8$ **Dy** Dysprosium 162.500 $[Xe]4f^{10}6s^2$ 5.9389	**67** $^4I^o_{15/2}$ **Ho** Holmium 164.93032 $[Xe]4f^{11}6s^2$ 6.0215	**68** $^3H_6$ **Er** Erbium 167.259 $[Xe]4f^{12}6s^2$ 6.1077	**69** $^2F^o_{7/2}$ **Tm** Thulium 168.93421 $[Xe]4f^{13}6s^2$ 6.1843	**70** $^1S_0$ **Yb** Ytterbium 173.04 $[Xe]4f^{14}6s^2$ 6.2542	**71** $^2D_{3/2}$ **Lu** Lutetium 174.967 $[Xe]4f^{14}5d6s^2$ 5.4259
Actinides	**89** $^2D_{3/2}$ **Ac** Actinium (227) $[Rn]6d7s^2$ 5.17	**90** $^3F_2$ **Th** Thorium 232.0381 $[Rn]6d^2 7s^2$ 6.3067	**91** $^4K_{11/2}$ **Pa** Protactinium 231.03588 $[Rn]5f^2 6d7s^2$ 5.89	**92** $^5L^o_6$ **U** Uranium 238.02891 $[Rn]5f^3 6d7s^2$ 6.1941	**93** $^6L_{11/2}$ **Np** Neptunium (237) $[Rn]5f^4 6d7s^2$ 6.2657	**94** $^7F_0$ **Pu** Plutonium (244) $[Rn]5f^6 7s^2$ 6.0260	**95** $^8S^o_{7/2}$ **Am** Americium (243) $[Rn]5f^7 7s^2$ 5.9738	**96** $^9D^o_2$ **Cm** Curium (247) $[Rn]5f^7 6d7s^2$ 5.9914	**97** $^6H^o_{15/2}$ **Bk** Berkelium (247) $[Rn]5f^9 7s^2$ 6.1979	**98** $^5I_8$ **Cf** Californium (251) $[Rn]5f^{10}7s^2$ 6.2817	**99** $^4I^o_{15/2}$ **Es** Einsteinium (252) $[Rn]5f^{11}7s^2$ 6.42	**100** $^3H_6$ **Fm** Fermium (257) $[Rn]5f^{12}7s^2$ 6.50	**101** $^2F^o_{7/2}$ **Md** Mendelevium (258) $[Rn]5f^{13}7s^2$ 6.58	**102** $^1S_0$ **No** Nobelium (259) $[Rn]5f^{14}7s^2$ 6.65	**103** $^2P^o_{1/2}$? **Lr** Lawrencium (262) $[Rn]5f^{14}7s^2 7p$? 4.9 ?

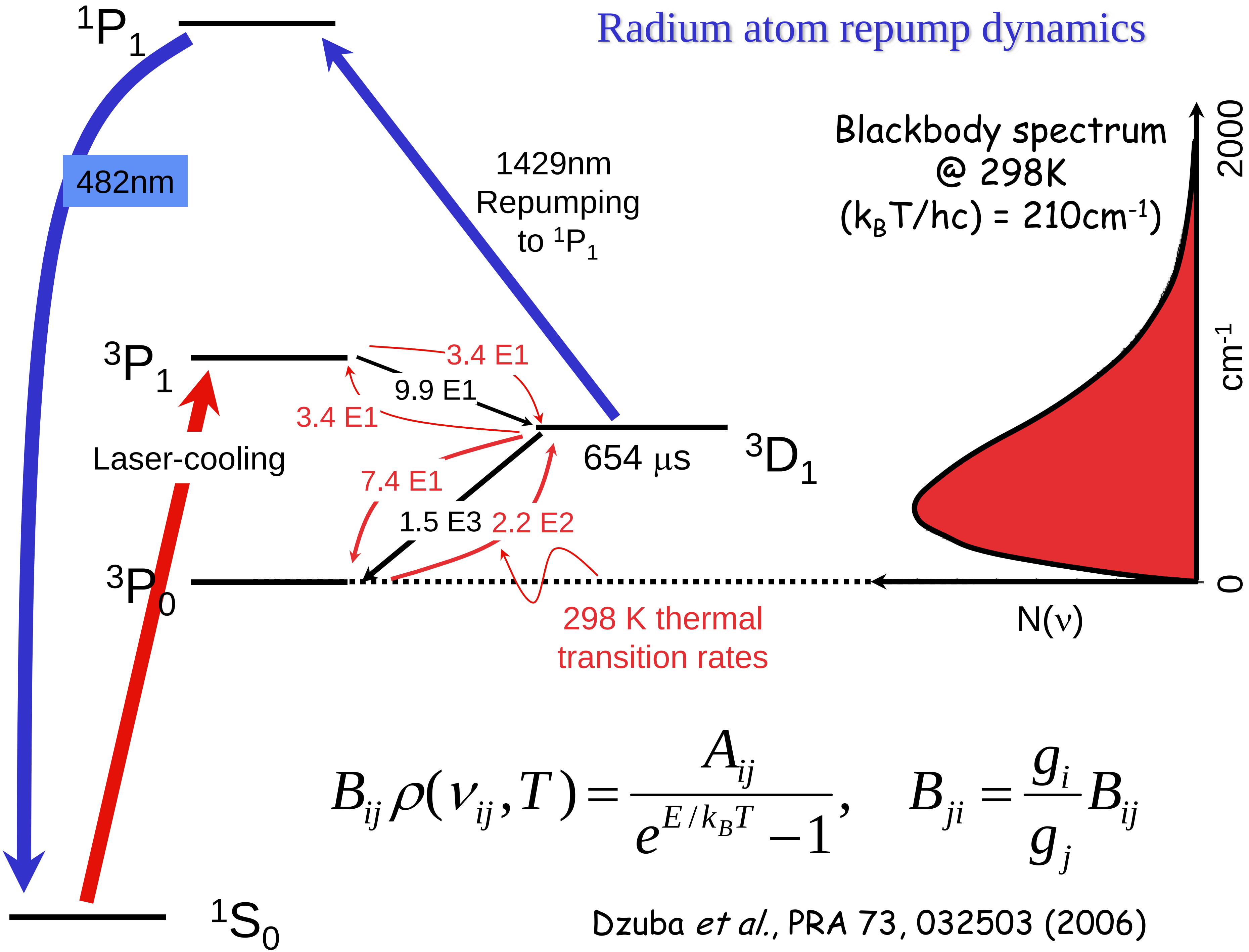
Atomic Number — 58
Ground-state Level — $^1G^o_4$
Symbol — **Ce**
Name — Cerium
Atomic Weight† — 140.116
Ground-state Configuration — $[Xe]4f5d6s^2$
Ionization Energy (eV) — 5.5387

†Based upon ^{12}C. () indicates the mass number of the most stable isotope.

For a description of the data, visit physics.nist.gov/data

NIST SP 966 (September 2003)

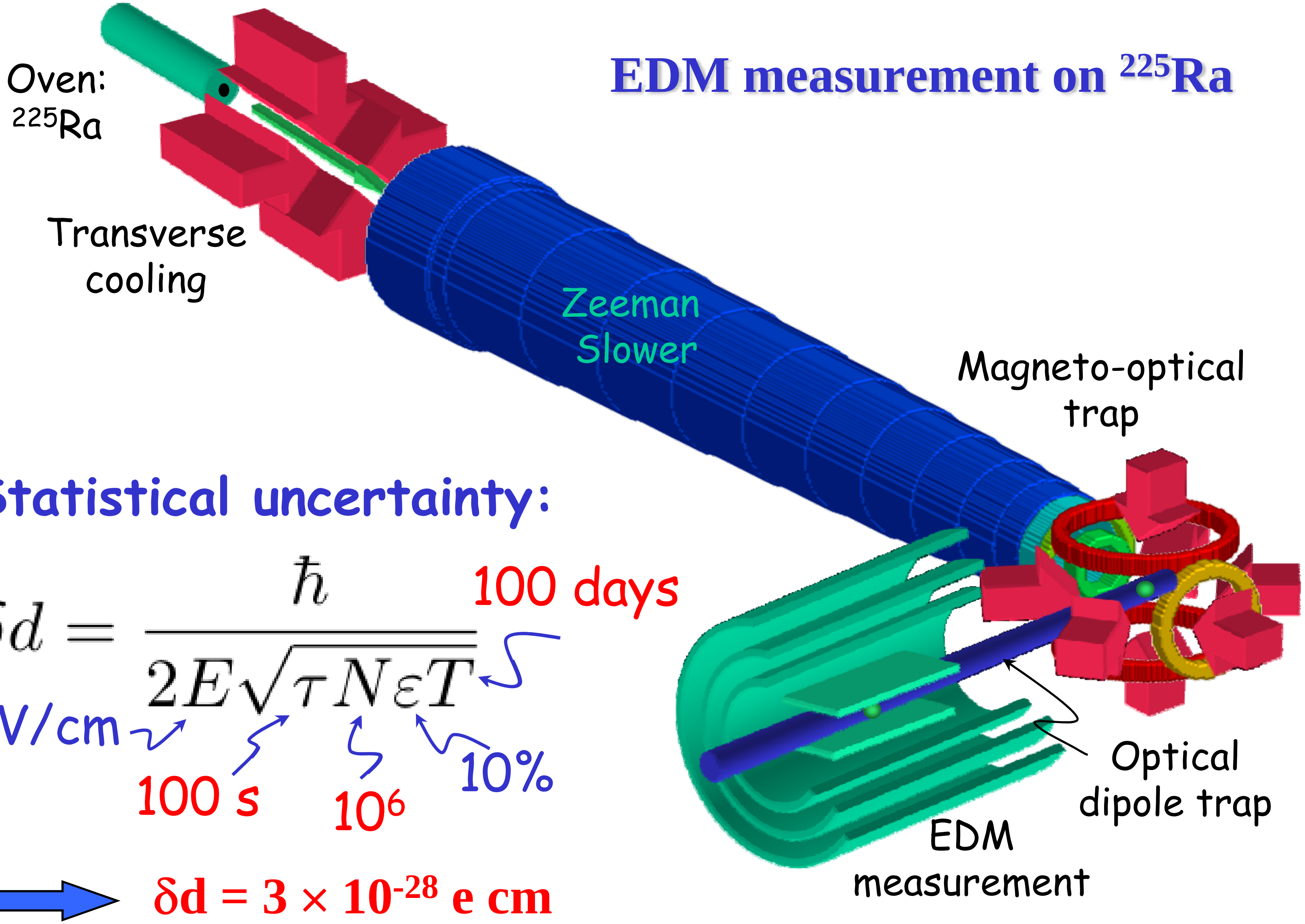
Radium atom repump dynamics



$$B_{ij}\rho(\nu_{ij},T)=\frac{A_{ij}}{e^{E/k_BT}-1},\qquad B_{ji}=\frac{g_i}{g_j}B_{ij}$$

Dzuba *et al.*, PRA 73, 032503 (2006)

EDM measurement on ^{225}Ra



Statistical uncertainty:

$$\delta d = \frac{\hbar}{2E\sqrt{\tau N \varepsilon T}}$$

100 days

100 kV/cm

100 s

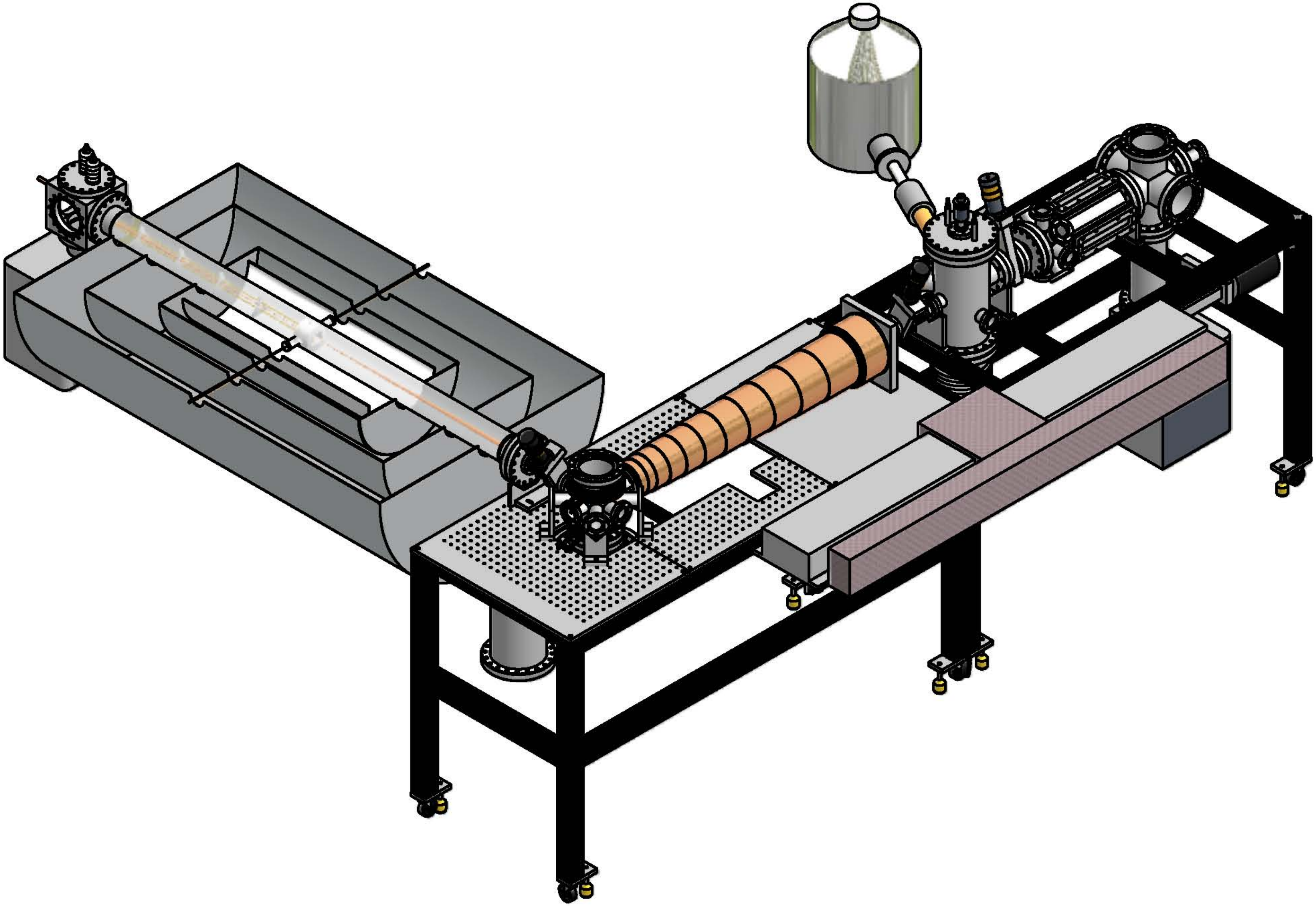
10^6

10%

→ **$\delta d = 3 \times 10^{-28}$ e cm**

Ra / Hg Enhancement factor ~ 10^2 - 10^3

Best experimental limit: d(^{199}Hg) < 2×10^{-28} e cm



Radium EDM Collaboration

Irshad Ahmad
Kevin Bailey
Michael Bishof
Jeff Guest
John Greene
Harvey Gould
Roy Holt
Zheng-Tian Lu
Peter Mueller
Tom O’Connor
Ibrahim Sulai
Will Trimble

Argonne Atom Trappers

Nuclear EDM Searches

Isotope	Current Limit (e cm)	Institution	Technique
Neutron	< 2.9E-26 Grenoble	SNS Grenoble	Superfluid He
^{199}Hg	< 2.1E-28 Washington	Washington	4 cells
^{129}Xe	(0.7 ± 3.3)E-27 Michigan	Princeton	Liquid cell
^{225}Ra	N/A	Argonne KVI	Trap
^{223}Rn	N/A	Michigan & TRIUMF	Cell
^{2}H	N/A	Brookhaven	Storage ring