Atom trapping at (TRIμP) KVI

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TRIμP Facility

Towards cooling of Heavy Alkaline Earth Elements (Ba, Ra)

Barium Spectroscopy

Next steps

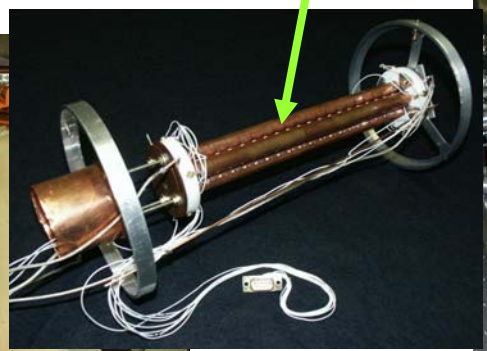
TRIμP - Trapped Radioactive Isotopes: μ-laboratories for fundamental Physics

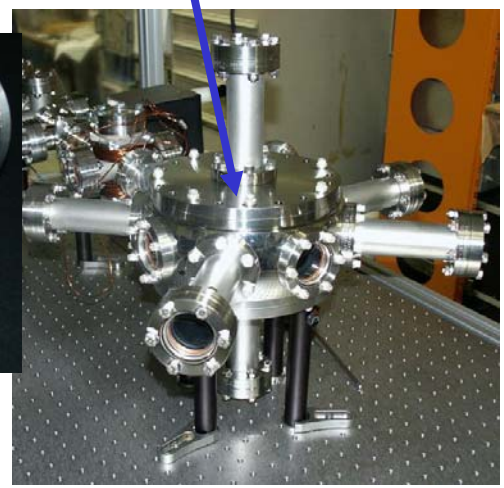
AGOR cyclotron

Production Target → Magnetic Separator → Ion Catcher → RFQ Cooler → Atom Trap → Particle Physics

MeV keV eV meV neV

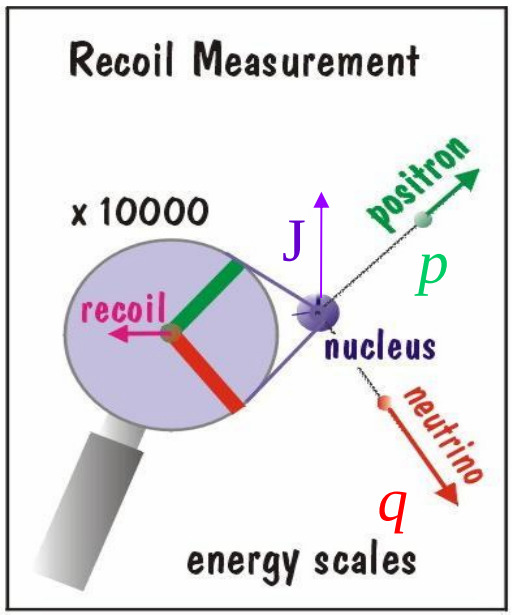
Beyond the Standard Model
TeV Physics
EDM/β-decay





http://www.kvi.nl/~trimp/web/html/trimp.html

β-decay



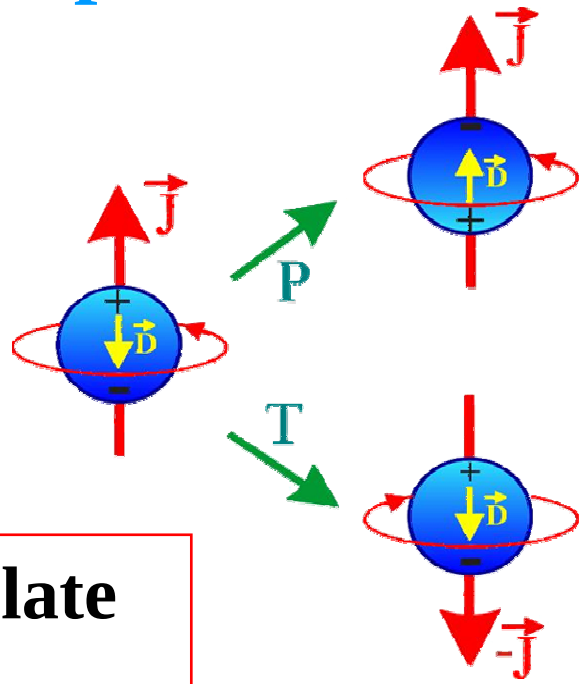
$p, q \approx 1\text{MeV/c} \approx 260$ a.u.

$E_{recoil} = (p + q)^2/2M_{recoil}$

< 100 eV ≈ 3.6 a.u.

- β-ν angular correlations in nuclear β-decay
- Suitable isotope ^{21}Na

Electric Dipole Moment

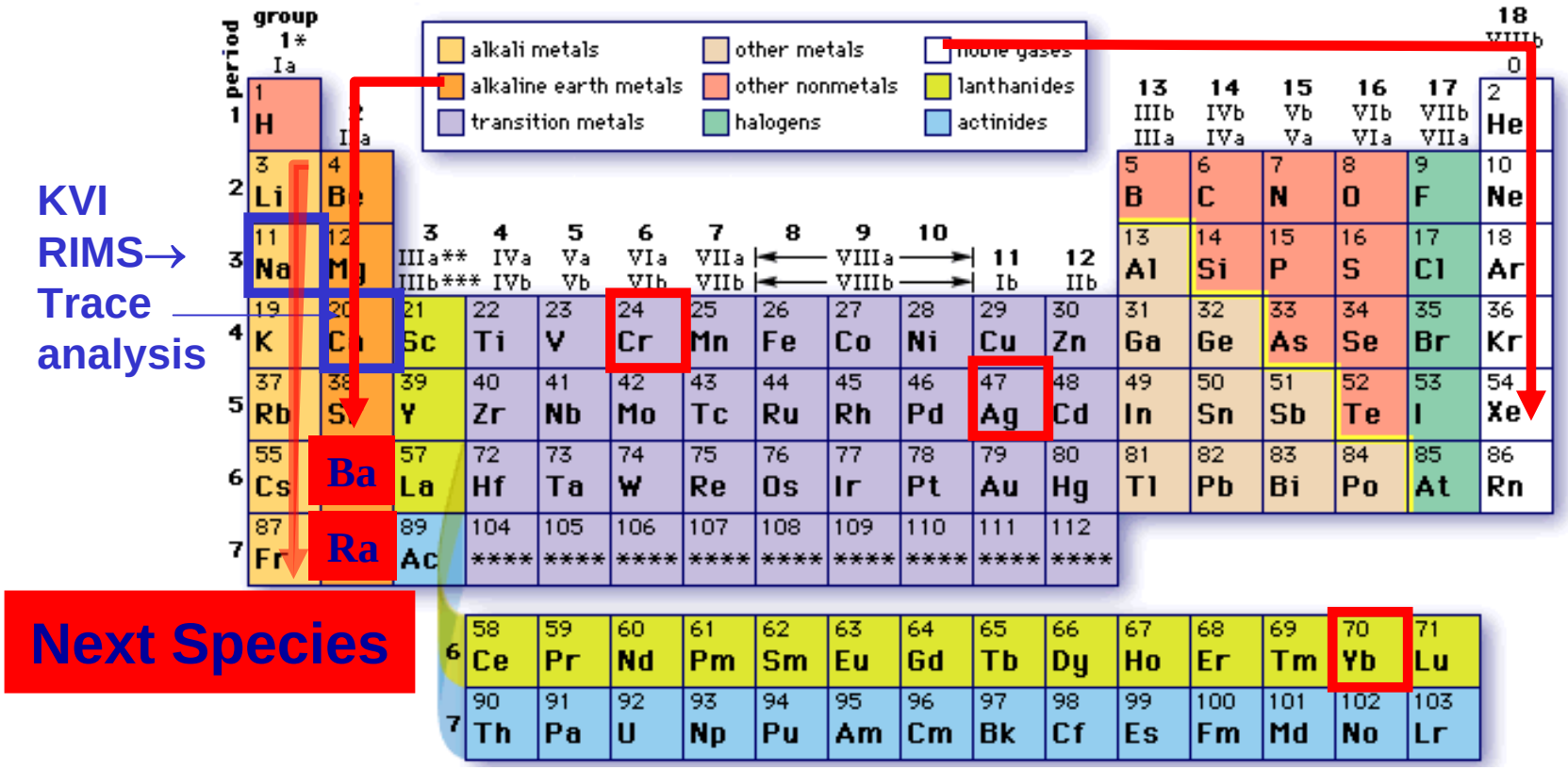


EDMs violate
- **P**arity
- **T**ime Reversal

Radium: Excellent candidate

V. A. Dzuba et al. Phys. Rev.A61 062509(2000)

Laser Cooling Chart



Efficient production of cold atoms:
Magneto Optical Trap

Other Possibilities: Buffer Gas loading into magnetic trap

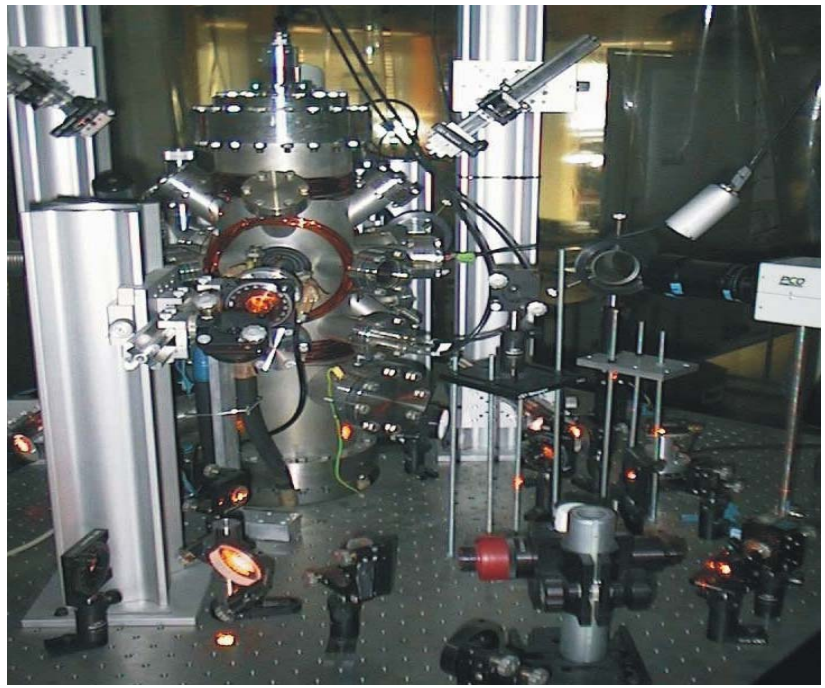
J. Doyle, Harvard; A. Richter, Konstanz

Neutral Atom Traps at KVI

Calcium(Ca) MOT

ALCATRAZ: Ultra sensitive isotope trap analysis of Calcium

Sodium(Na) MOT

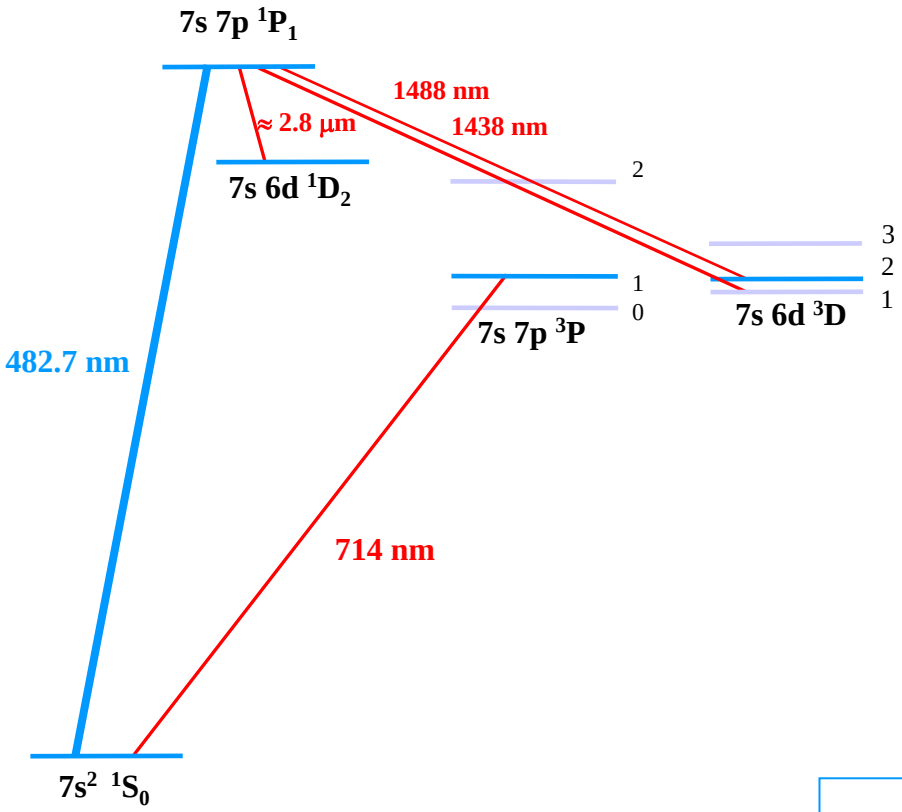


MOTRIMS: Recoil Ion Momentum Spectroscopy

TRIμP

KVI

Radium Atomic Structure



Energy level data:
E. Rasmussen, Z. Phys. 86, 24 (1933) and 87, 607 (1934); H.N. Russel, Phys. Rev. 46, 989 (1934)

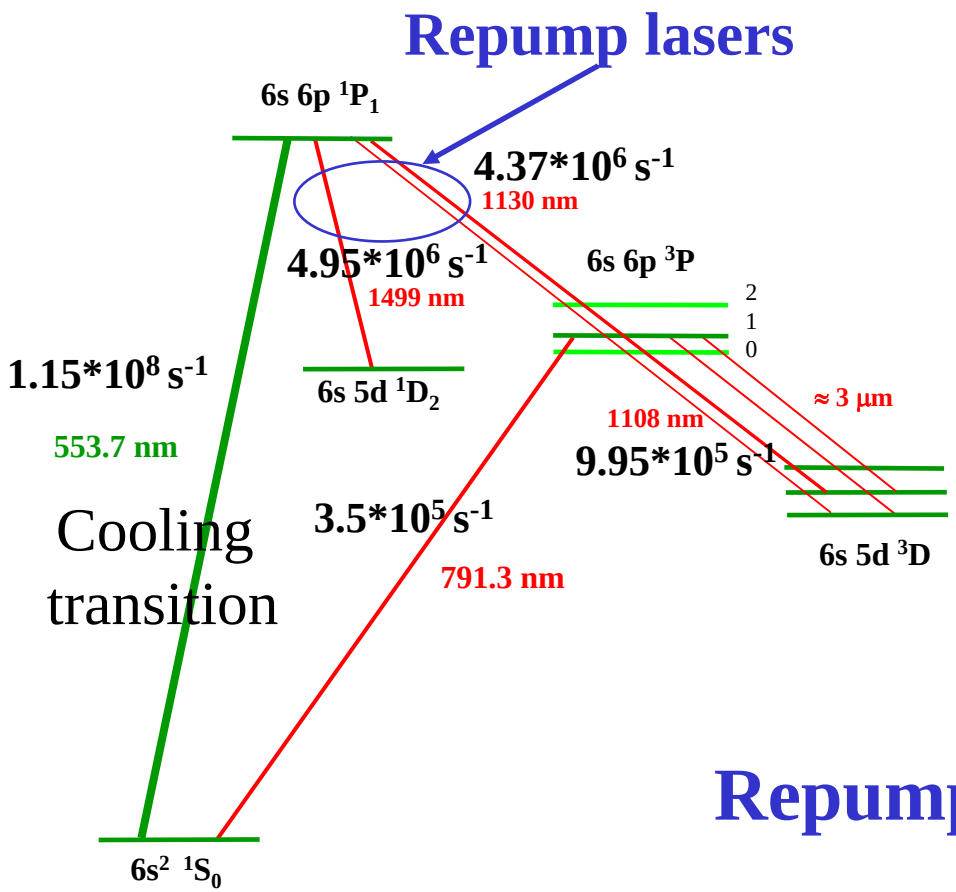
Spectroscopy of P and D states

- Lifetime measurement
- Energy level spacing
- Hyperfine structure
- Needed for atomic structure calculations

Calculations done by K Pachuki and Flaumbam, Dzuba et al.

But what about laser cooling of Radium?

Barium - Testing ground for laser cooling and trapping of Radium

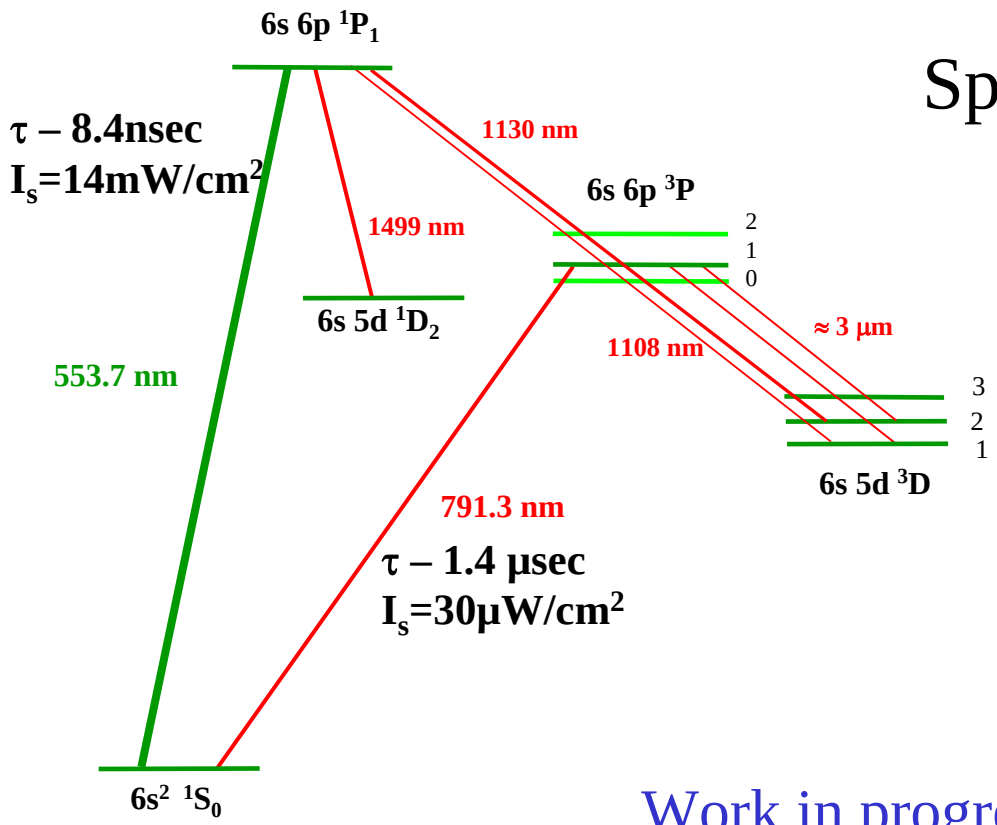


Constraints

- Low lying meta-stable D states
- Leakage to D-states after interacting with ~340 photons
- 3 Repumping lasers needed

Repump (Fiber) lasers ordered

Spectroscopy of Barium

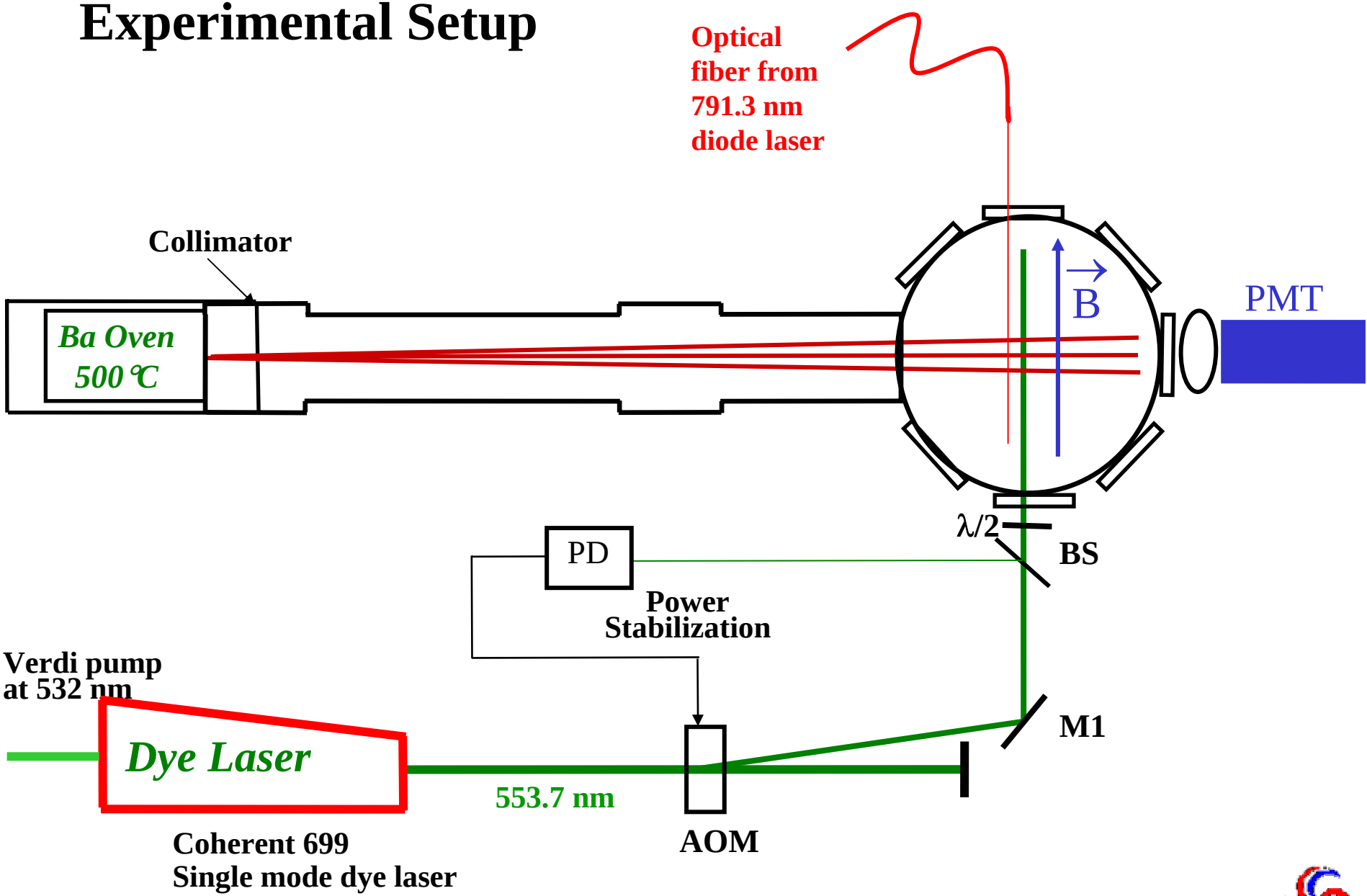


Spectroscopy of P and D states

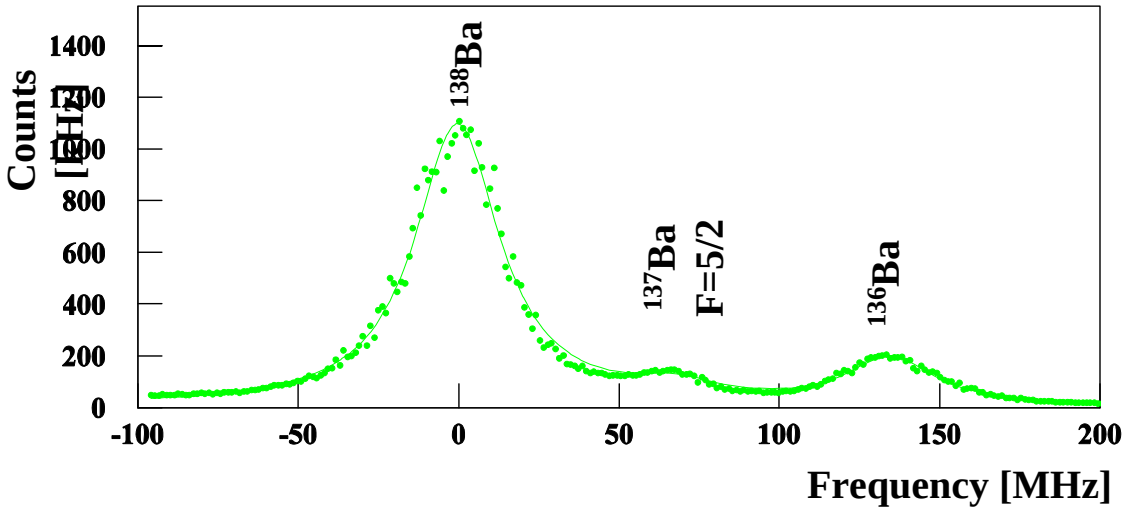
- Life time measurement
- Hyperfine structure

Work in progress with a thermal atomic beam

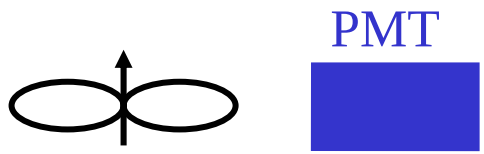
Experimental Setup

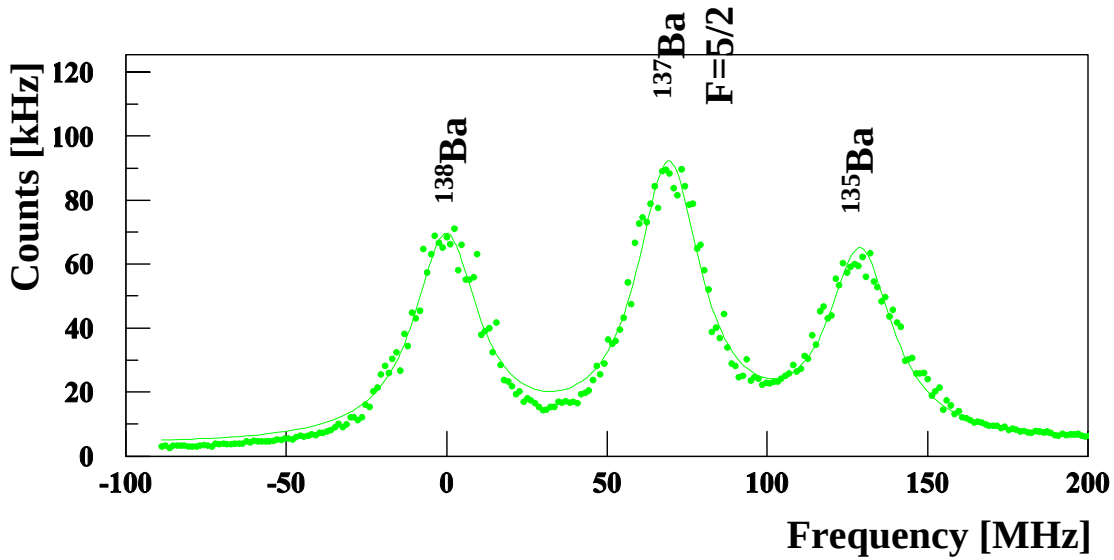


Fluorescence at 553.7 nm from different Ba isotopes

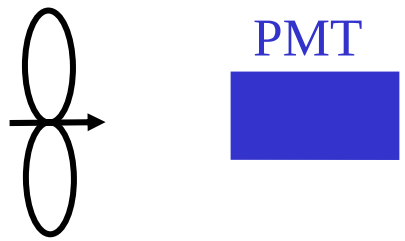


⊥ Polarization plane



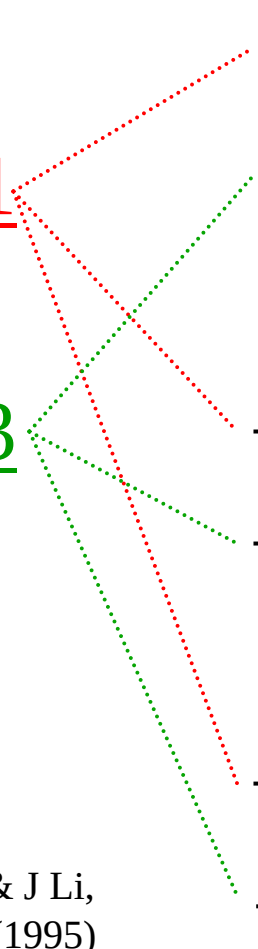


in Polarization plane



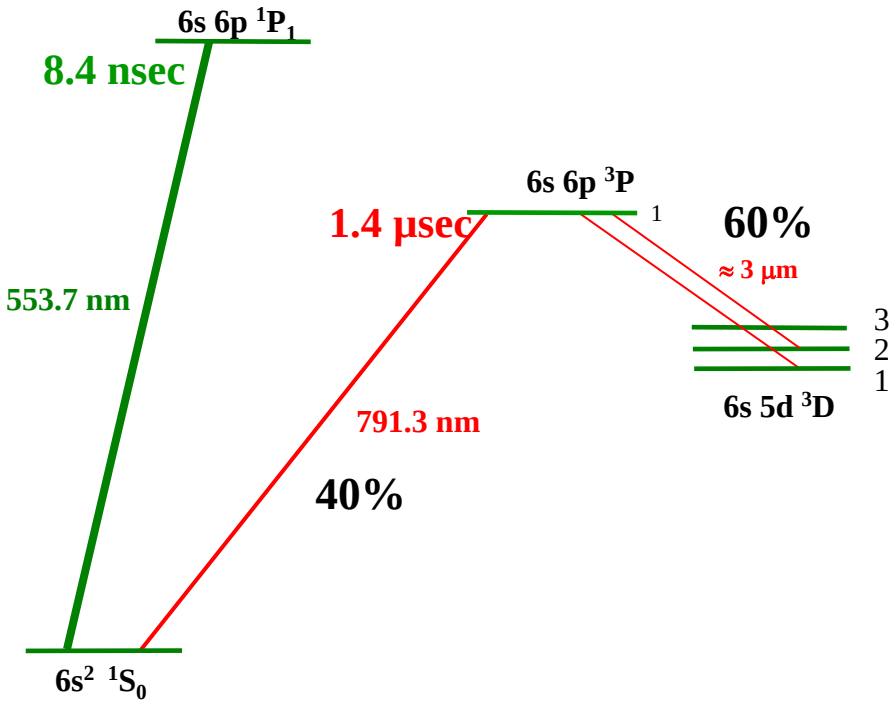
Isotope shifts and Hyperfine Splitting of the $^1S_0$ -$^1P_1$ transition in Barium

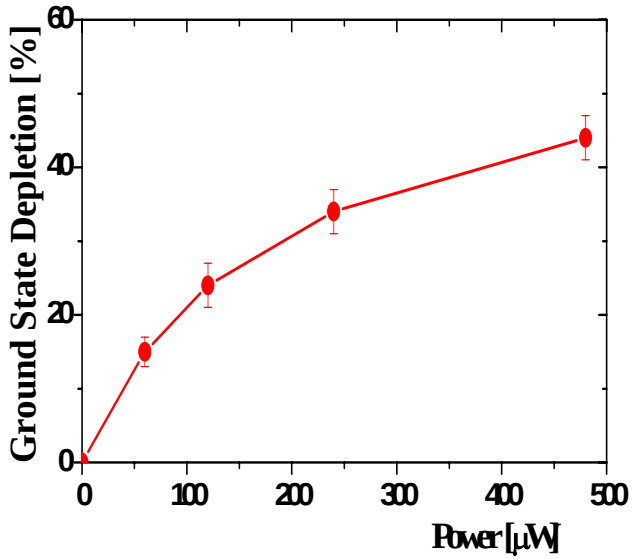
Isotope	IS (MHz)*	HFS (MHz)	F
138	0	—151.67	5/2
137	215.1	—138.75	
136	128		
135	259.3	— -59.46	3/2
134	----	— -64.14	
132	----		
130	----	— -334.37	1/2
		— -219.17	



* W A van Wijngaarden & J Li, Can.J. Phys. **73**, 484-488(1995)

Intercombination line $^1S_0$–$^3P_1$



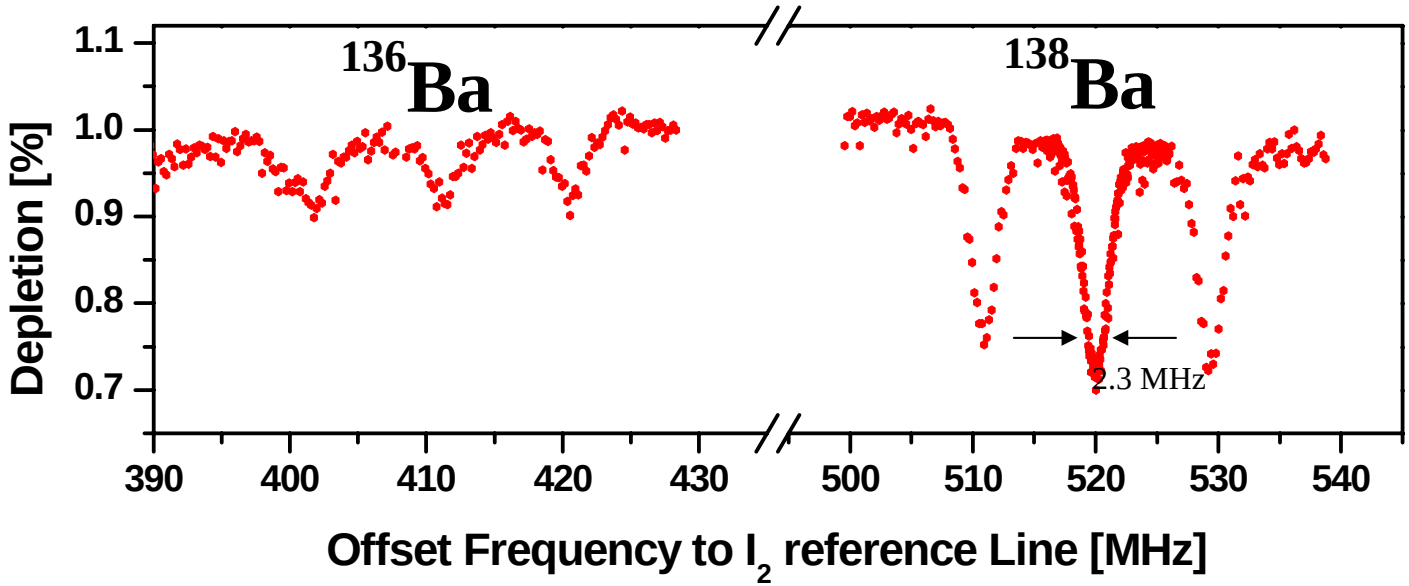


Creation of intense beam of meta-stable D-state atoms

Hyperfine Splitting of $^1S_0$–$^3P_1$ transition in an External Magnetic field

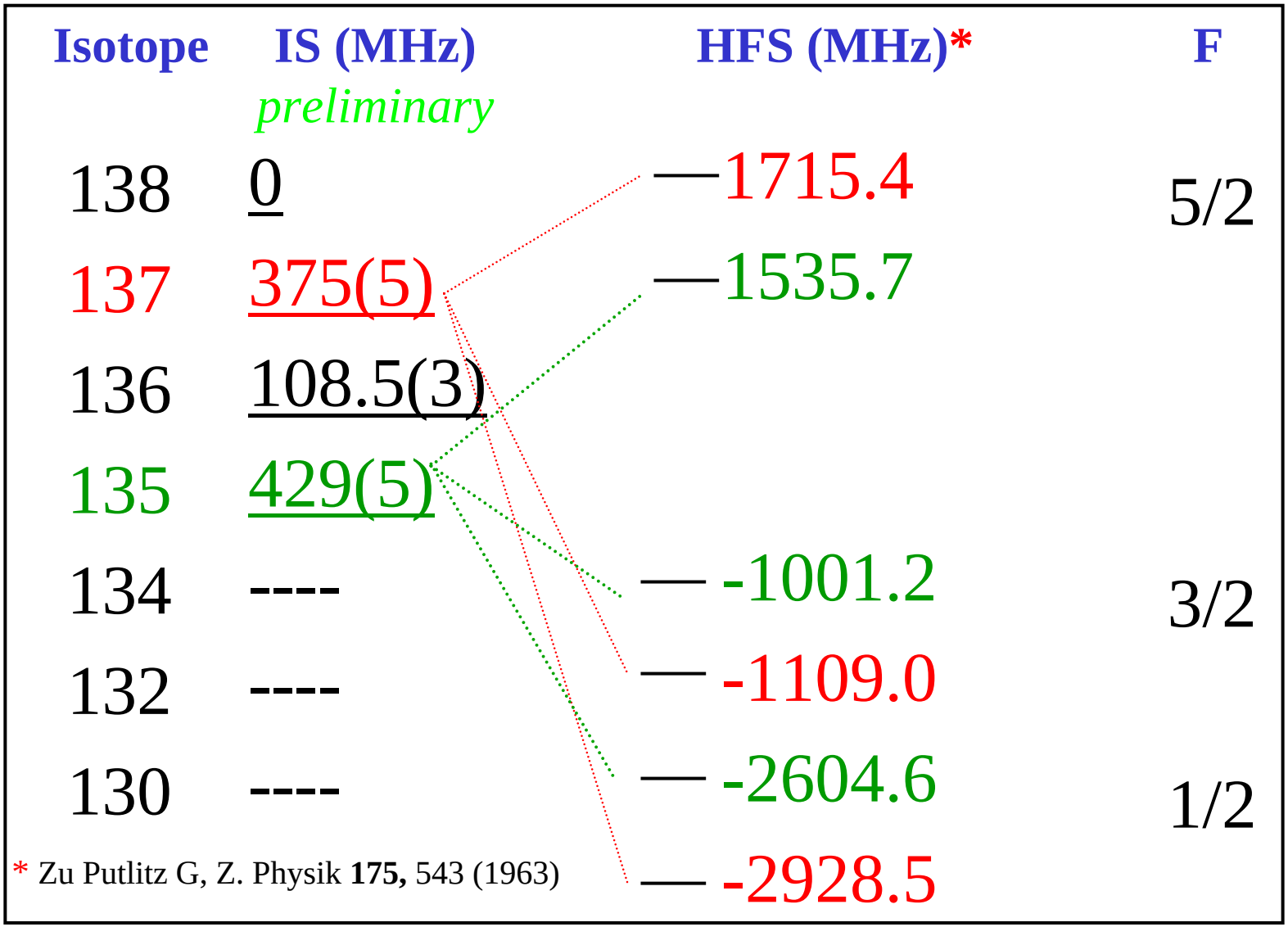
$\Delta\nu = g_J \mu m_J B$

$\Delta\nu_{IS} = {}^{138}Ba–{}^{136}Ba = 108.5\ (3)$ MHz



- Decay rate
- Branching into 3D states

Isotope shifts and Hyperfine Splitting of the $^1S_0$ - $^3P_1$ transition in Barium



* Zu Putlitz G, Z. Physik **175,** 543 (1963)

Next steps

Laser Cooling of Barium

- **Repump Lasers for**
  $^1P_1$–$^1D_2$ transition @ 1500.4 nm
  $^1P_1$–$^3D_2$ transition @ 1130.6 nm and
  $^1P_1$–$^3D_1$ transition @ 1107.8 nm
- Delivery of Fiber lasers – January 2005
- Spectroscopy of meta-stable D-states

Towards Radium

- Laser @482.5nm for $^1S_0$–$^1P_1$ transition by frequency doubling Ti:Sapp Laser
- Production of Radium at TRIμP
- Spectroscopy in a Radium beam

TRIμP Group:

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Hanle effect

Life time of $^1P_1$ state

$P_{laser} \perp B$ field

$\tau_{eff} = h/(2\pi\, g_J\, \mu\, \Delta B_{1/2})$

$\tau_{eff} = 8$ nsec $\pm$ 0.5sec