Rubidium g-Factors and Electron e/m by Optical Pumping

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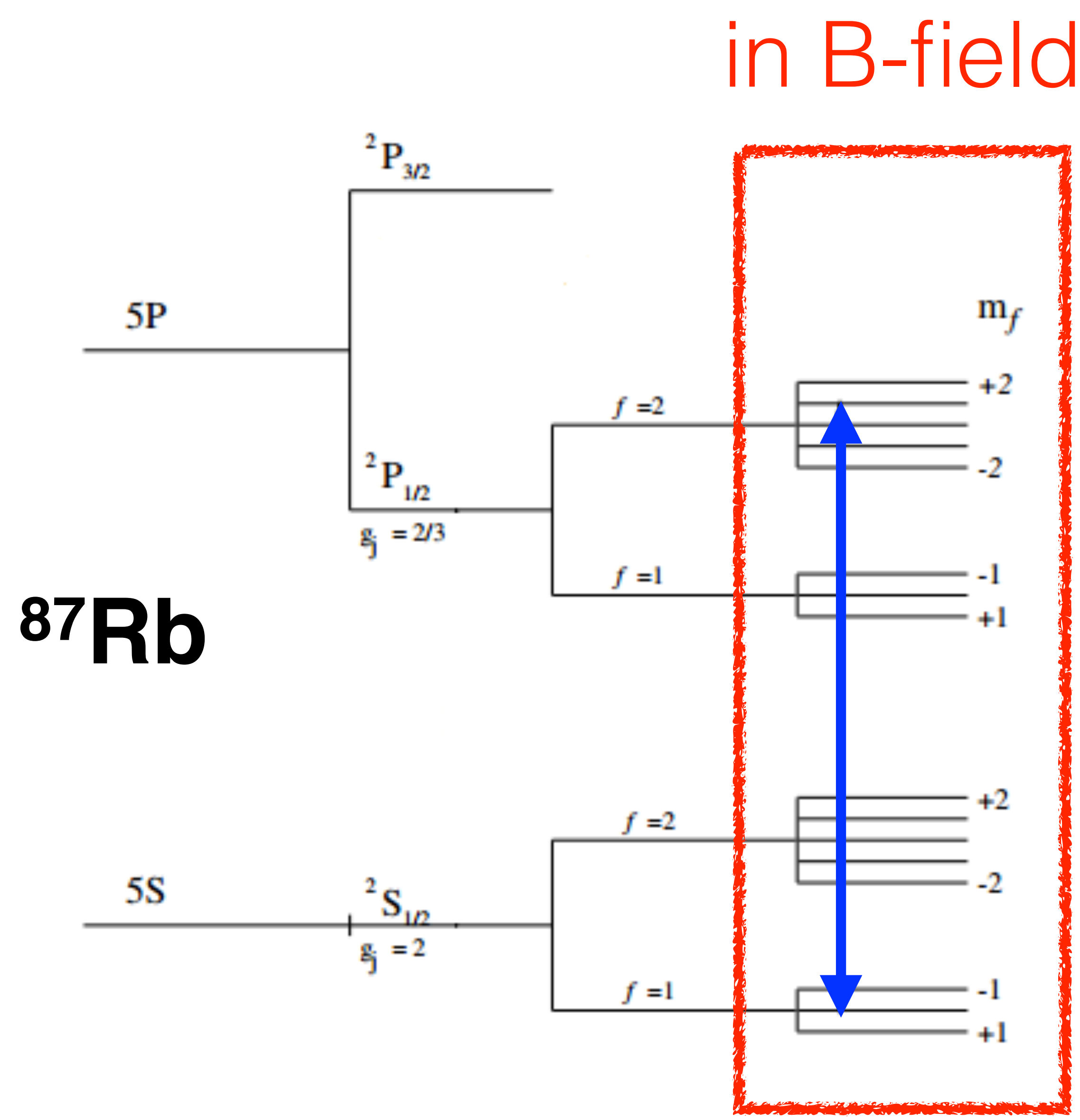
Rubidium

- ^{87}Rb (I=5/2), ^{85}Rb (I=3/2) naturally occurring isotopes
- Zeeman splitting:

$$\Delta E = g_f \mu_B B$$

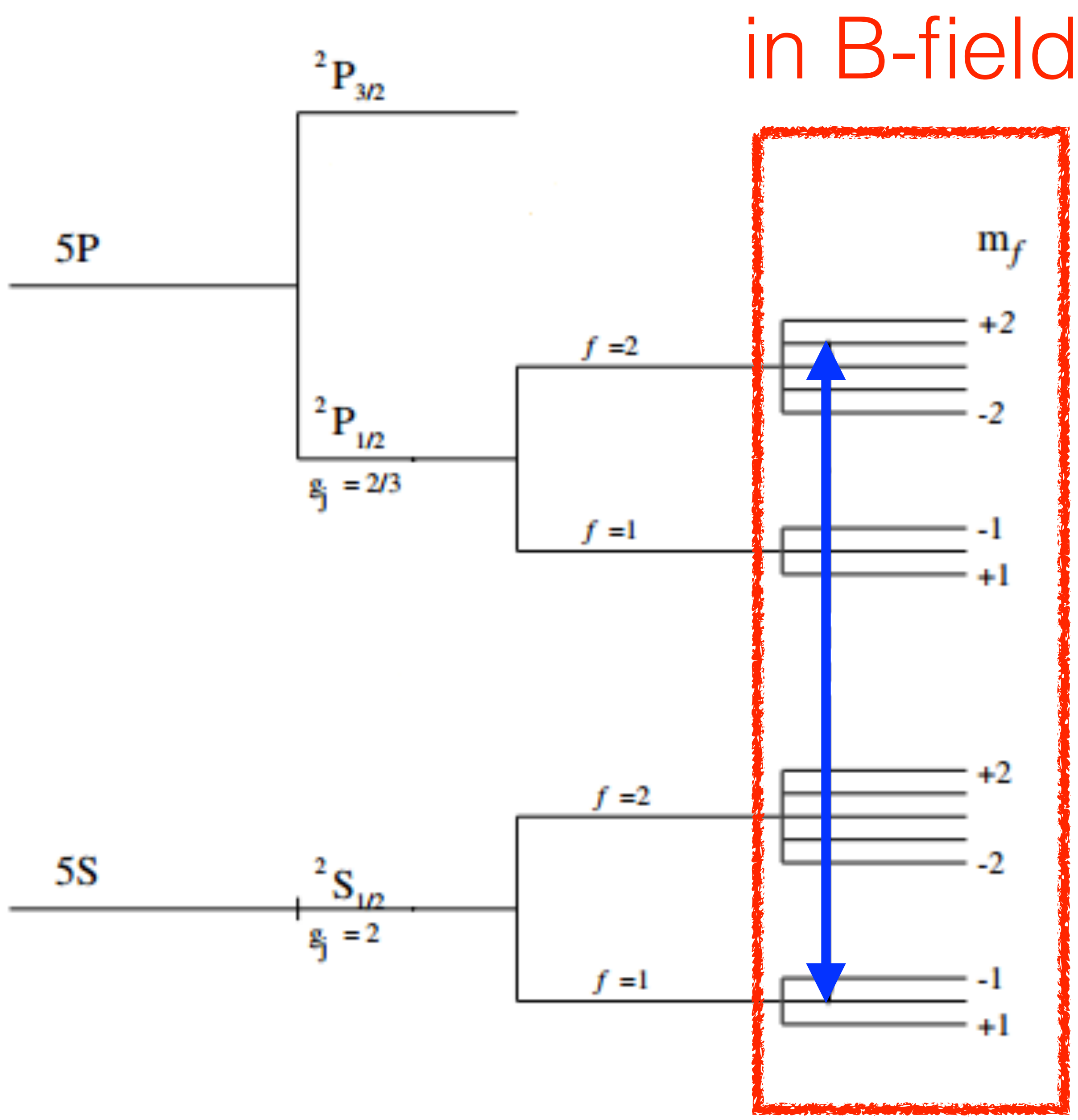
g_f Lande g-Factor,
μ_B Bohr magneton



Zeeman Parameters

- Lande g-factor (electronic only, J=±1/2):
  - $g_f \approx 2\frac{F(F+1)-I(I+1)-J(J+1)}{2F(F+1)},\ F = J + I$
  - ^{87}Rb: I=3/2, g_f = 1/2
  - ^{85}Rb: I=5/2, g_f = 1/3
- Bohr magneton:
  - $\mu_B = \frac{h}{4\pi c}\frac{e}{m_e} \Rightarrow \frac{f}{B_z} = \frac{g_f}{4\pi c}\frac{e}{m_e}$

Optical Pumping



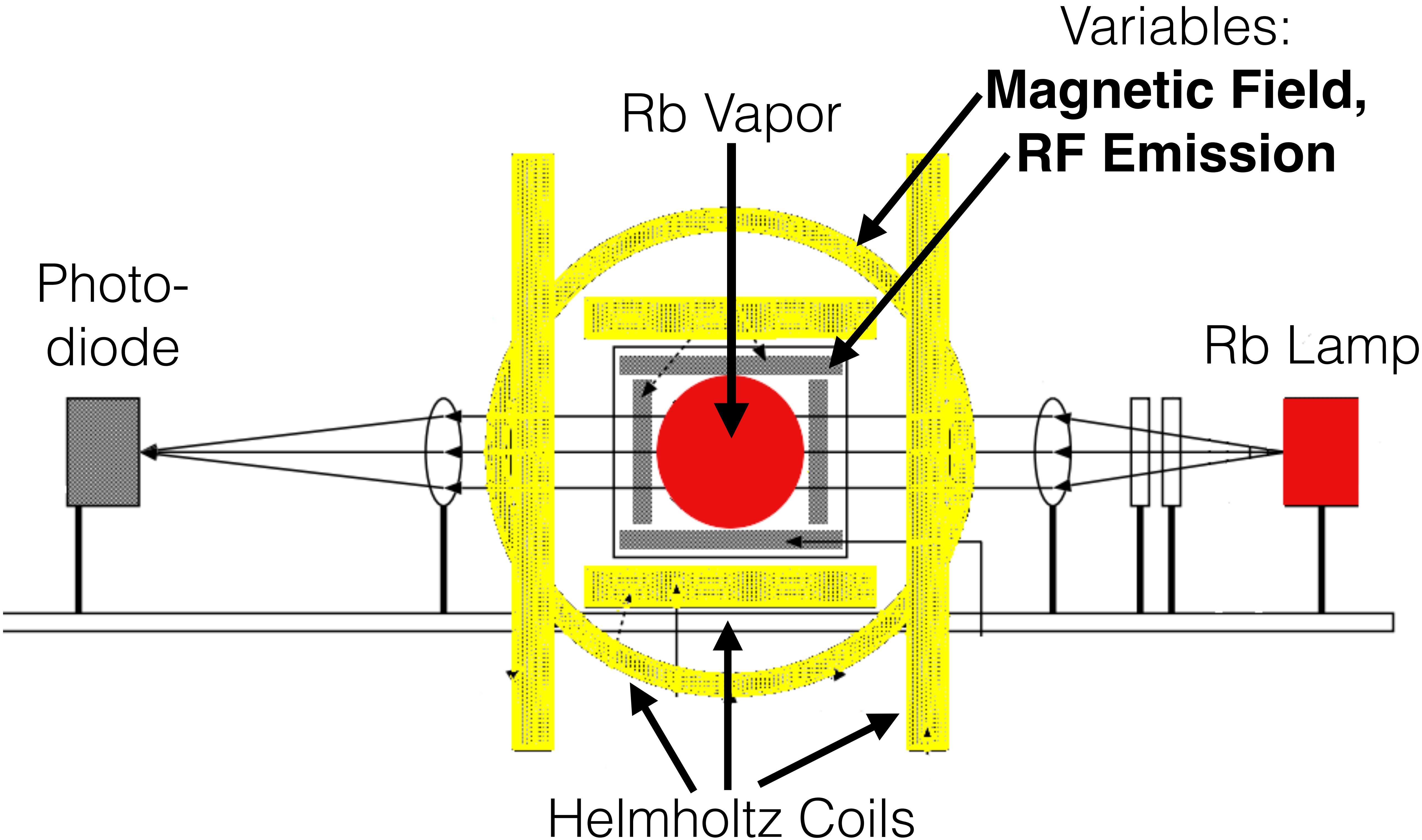
- Circularly polarized light:

$$\Delta m_f = +1$$

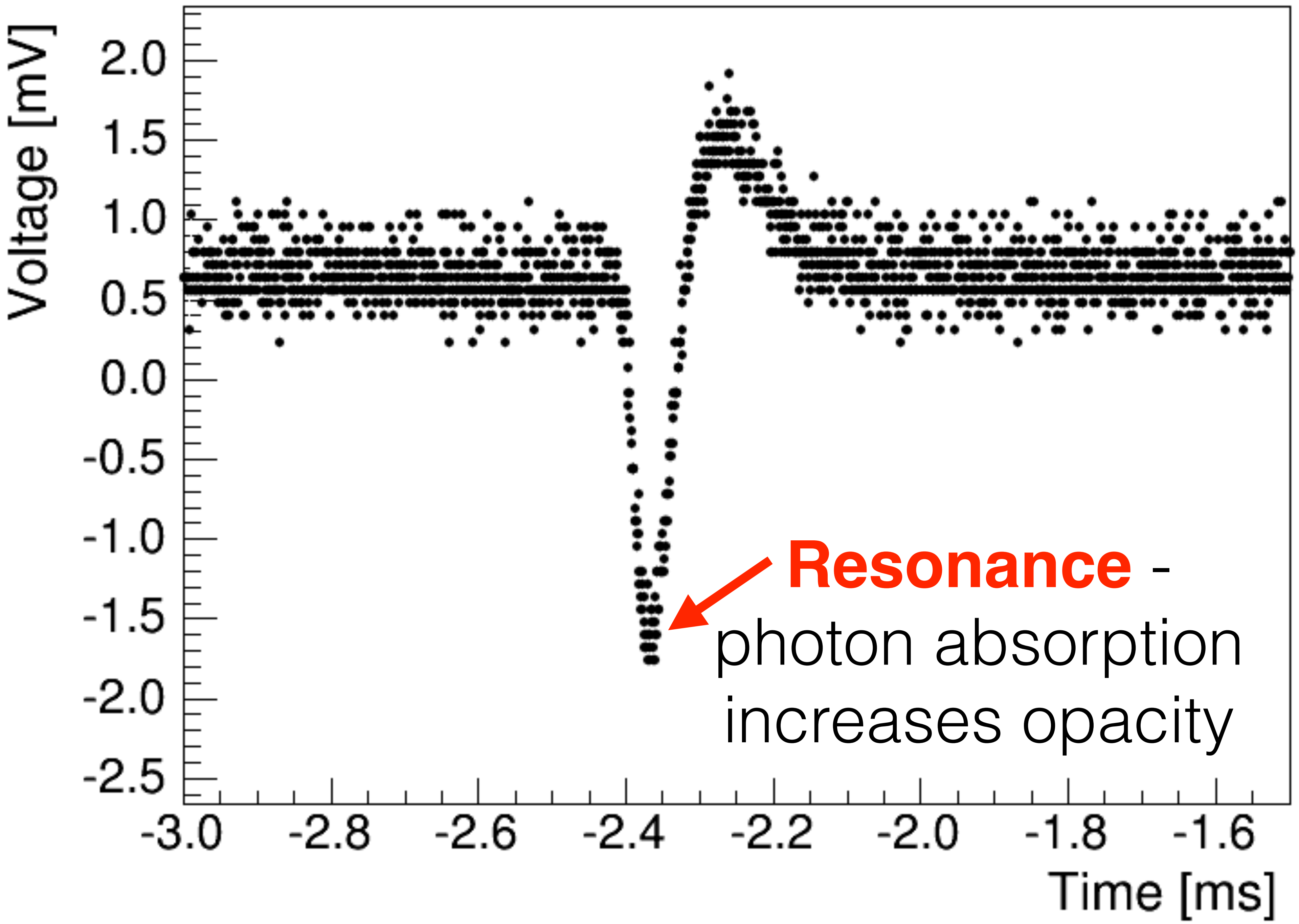
- Spontaneous transitions (RF):

$$\Delta m_f = \pm 1, 0$$

Apparatus

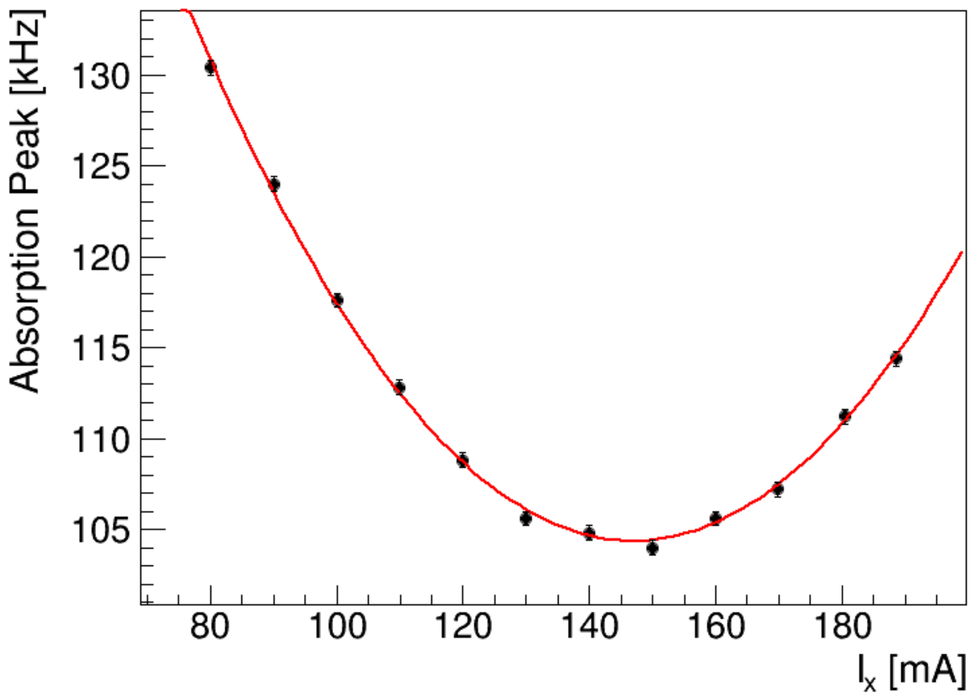

Variables:
Magnetic Field,
RF Emission
Rb Vapor
Photo-
diode
Rb Lamp
Helmholtz Coils

Example Data



Geo-Magnetic Field

- Vary **RF frequency** in time at constant B-field
- Measure peak location on oscilloscope
- Dominant uncertainty from magnetometer comparison
- **Minimal peak frequency indicates minimal B-field:** $f = \frac{g_f \mu_B |B|}{h}$

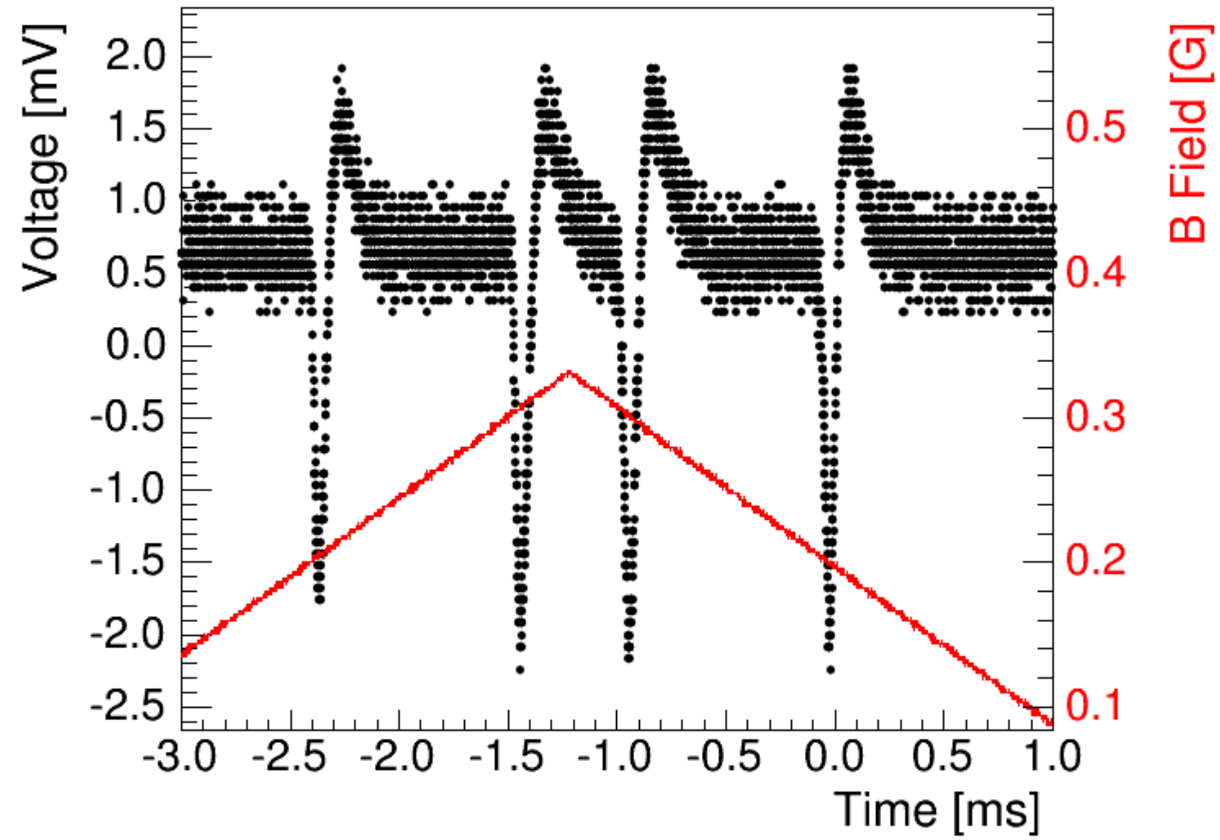


B_x = 367±14 mG
B_y = 57±16 mG
B_z = 198±14 mG
|B| = 421±14 mG

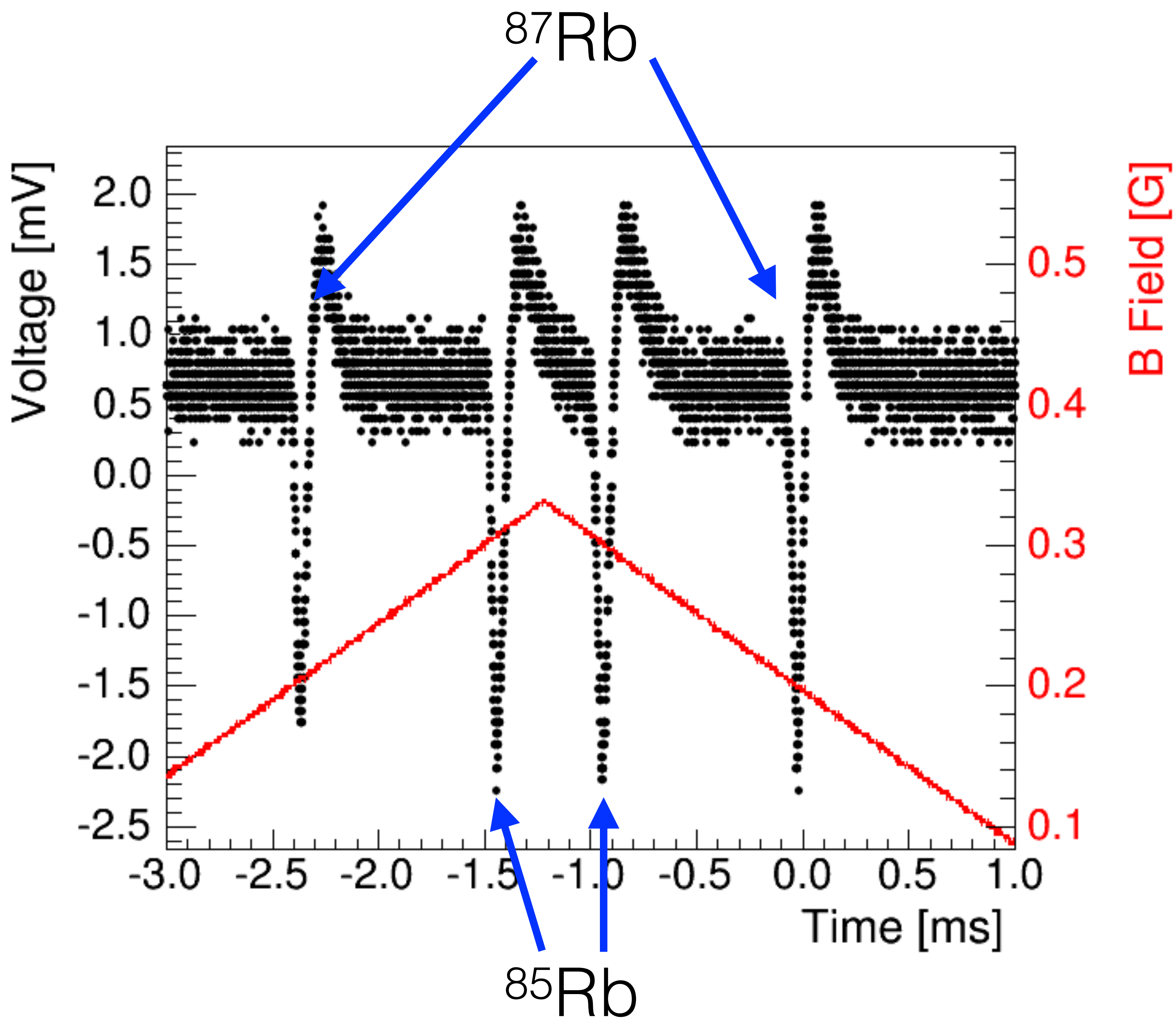
Variable Magnetic Field

- Zero B_x and B_y fields
- Vary $\mathbf{B_z}$ as sawtooth function of time with constant RF frequency
- ID absorption peaks for both isotopes of Rb,
- Calculate:

$$\frac{|B|}{f} = \frac{h}{g_f \mu_B}$$

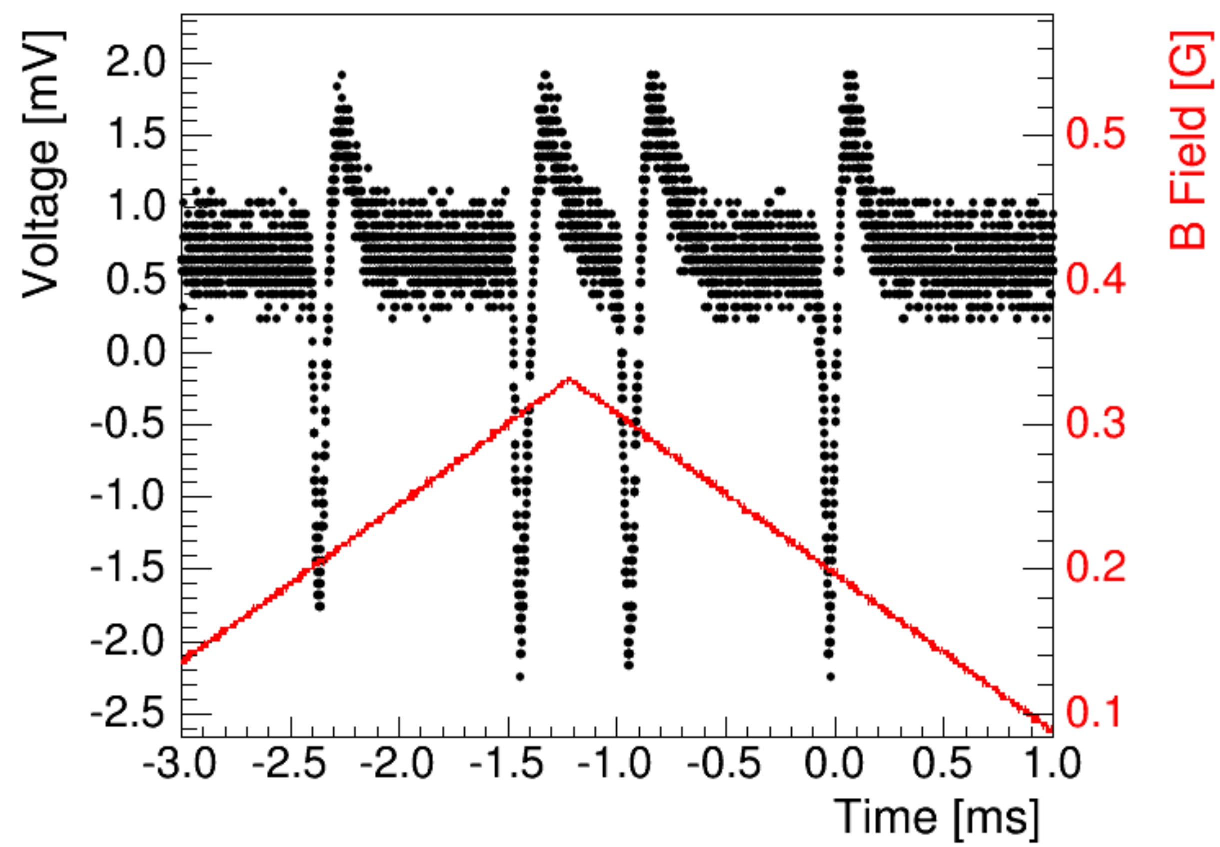


Resonant Absorption



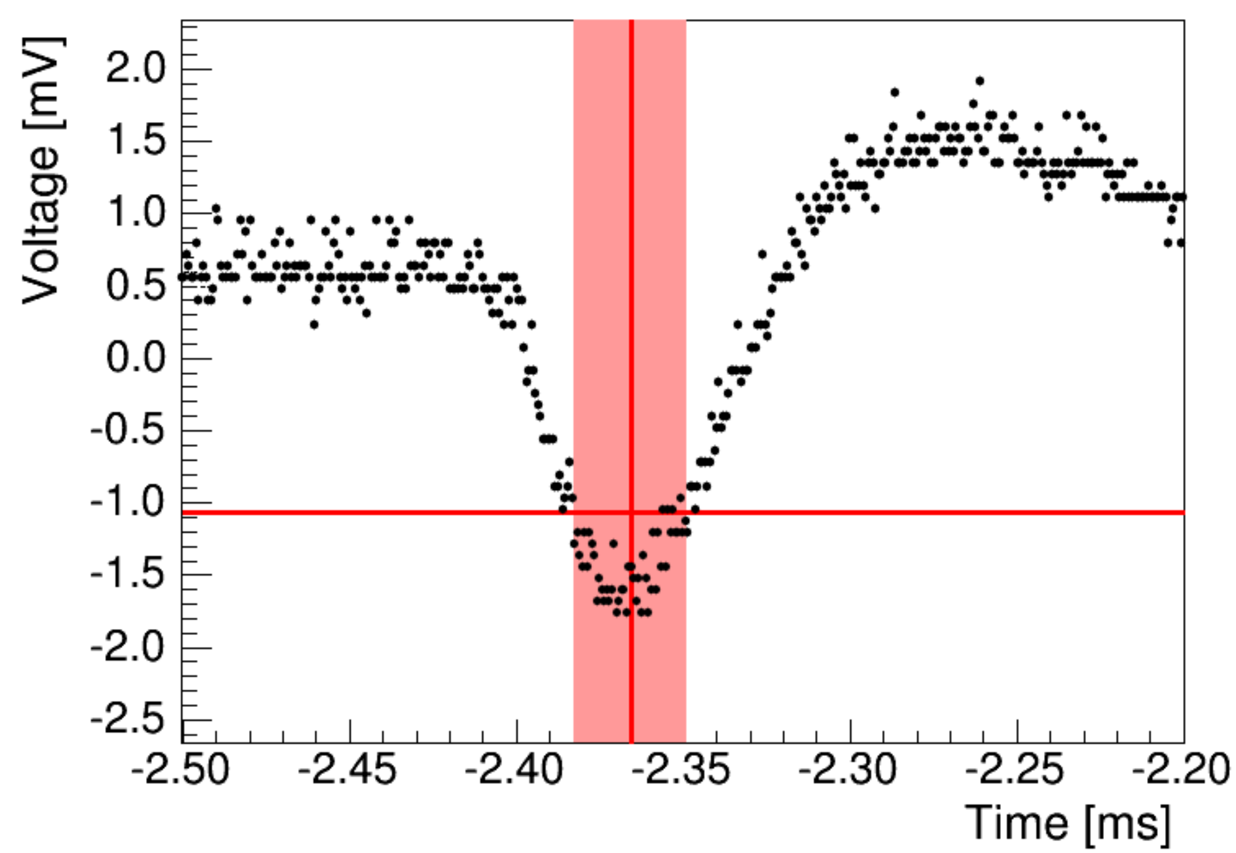
Variable Magnetic Field

- Take data at six fixed RF frequencies from 100 - 150 kHz
- Tune input current to Helmholtz coil such that four peaks are visible
- Take three measurements for each configuration



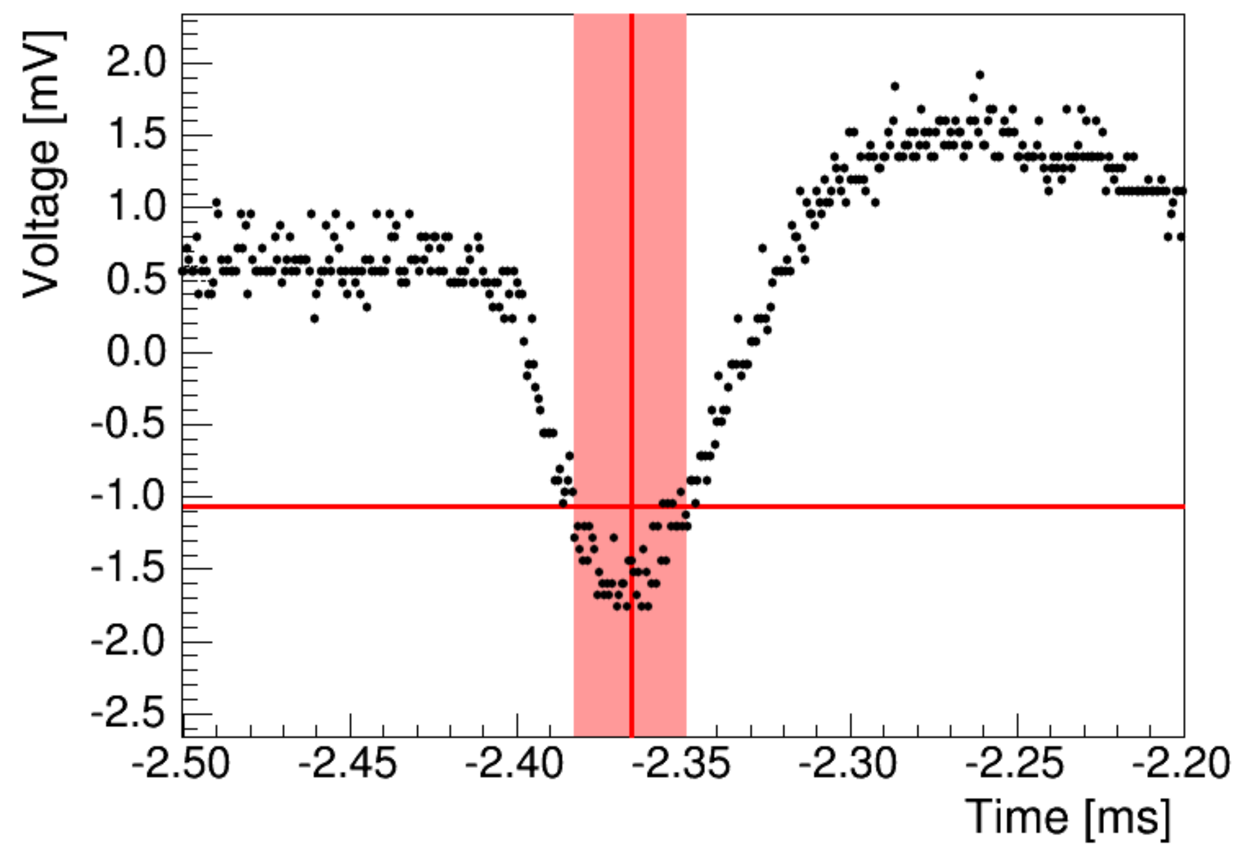
Peak Location

- For each peak, find first and last point curve takes minimum value
- Average to find nominal peak location



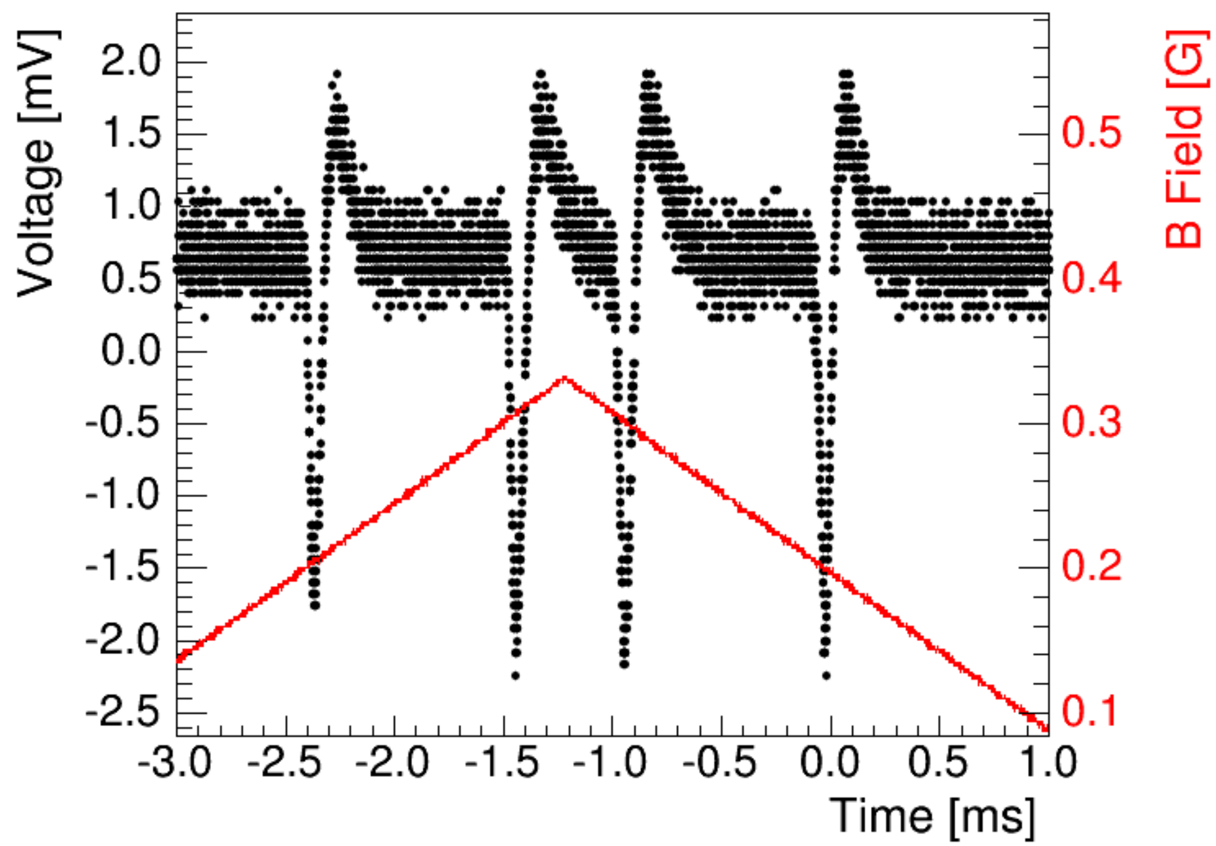
Peak Location Uncertainty

- Estimate background noise as σ(first 100 data points)
- Take first and last point where curve falls below **minima+3*σ** as uncertainty in peak location



Peak Location Analysis

- Extract information from 4 peaks in each dataset, two on either side of B-field peak
- Convert time measurement to magnetic field
- Calculate B/f for each peak



Uncertainties

- Leading uncertainty from magnitude of geo-magnetic field
- Also assess uncertainties from:
    - peak width
    - sampling/step size
    - statistics

Lande g-Factors

- Separate peak information for ^{87}Rb and ^{85}Rb
- Compute

$$g_f = \frac{hf}{\mu_B |B|}$$

- Find

$$^{87}\mathrm{Rb}: \; g_f = 0.527 \pm 0.003$$

$$^{85}\mathrm{Rb}: \; g_f = 0.353 \pm 0.002$$

- Accepted

$$^{87}\mathrm{Rb}: \; g_f = 0.5$$

$$^{85}\mathrm{Rb}: \; g_f = 0.33$$

e/m

- Compute

$$\frac{e}{m} = \frac{4\pi c f}{B_z g_f}$$

using accepted g-factors

- Calculate

$$\frac{e}{m} = (5.47 \pm 0.02) \times 10^{17} \text{ esu/G}$$

- Accepted

$$\frac{e}{m} = 5.27 \times 10^{17} \text{ esu/G}$$

Summary

- Observe resonant absorption peaks in Rubidium optical pumping setup corresponding to ^{85}Rb and ^{87}Rb
- Calculate Rb g-Factors, electron e/m
- g-Factors, e/m systematically high - most likely due to incompletely cancelled geo-magnetic field