# Determining Natural Line-Width, Quadropole and Zeeman Effects in Iron Compounds using Mössbauer Spectroscopy

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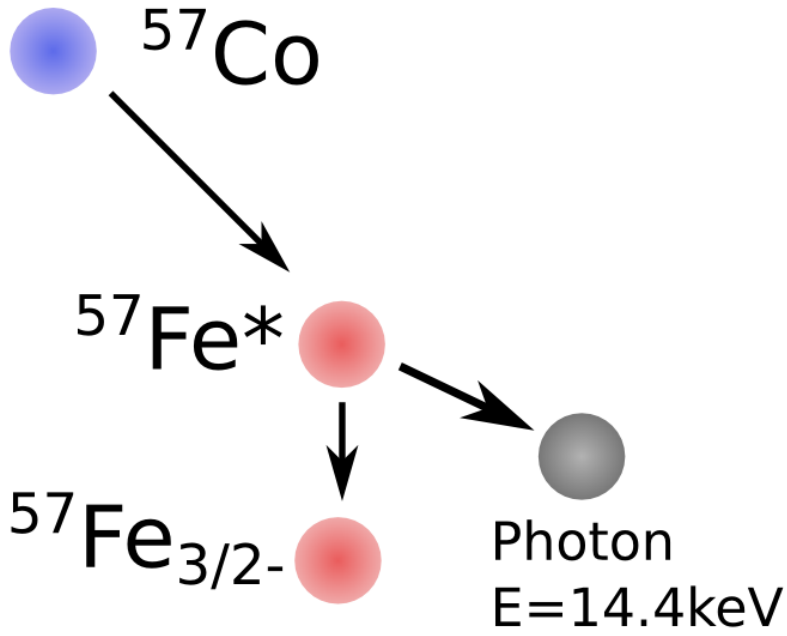
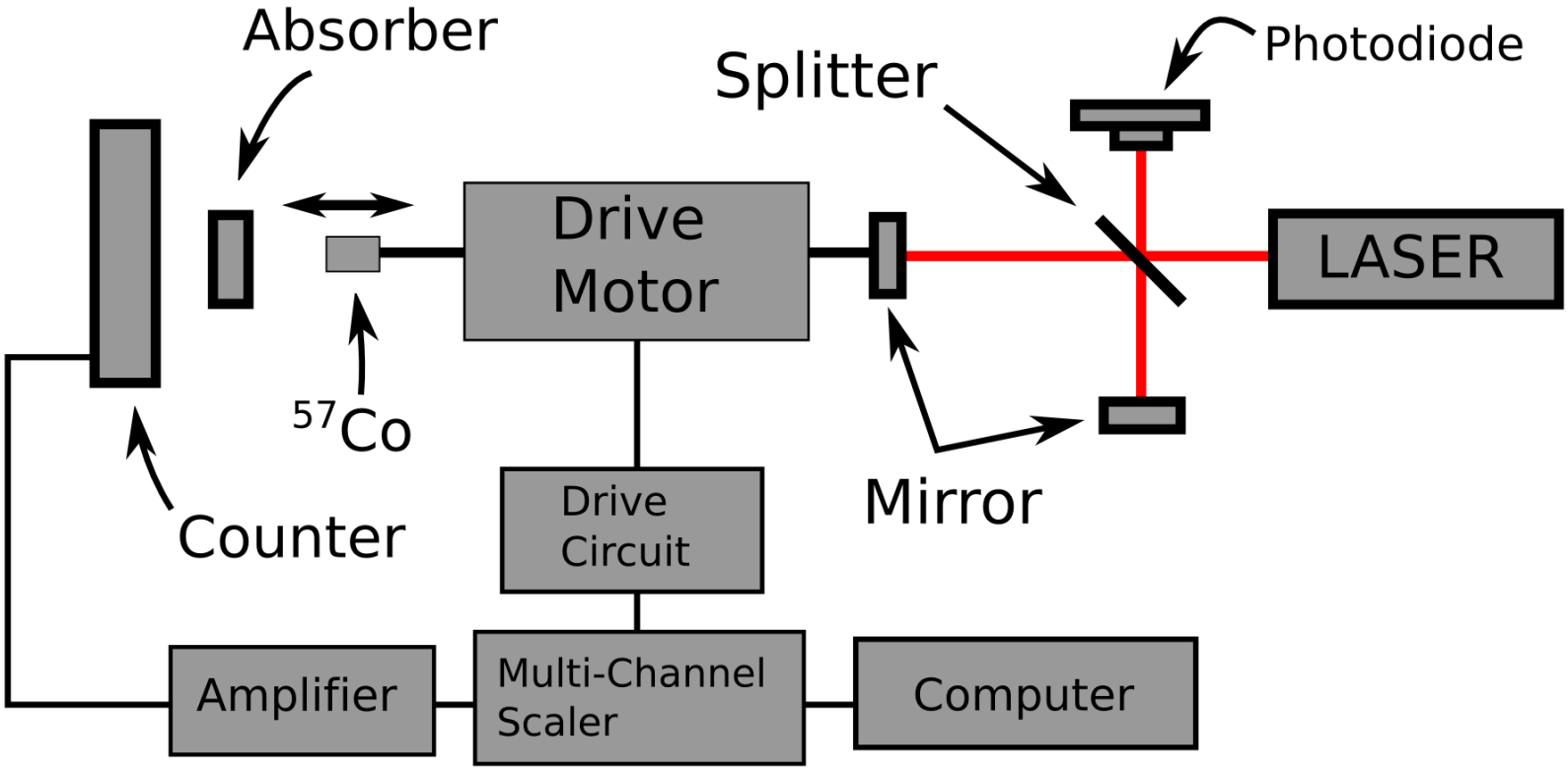
# Principle Behind Mössbauer Spectroscopy

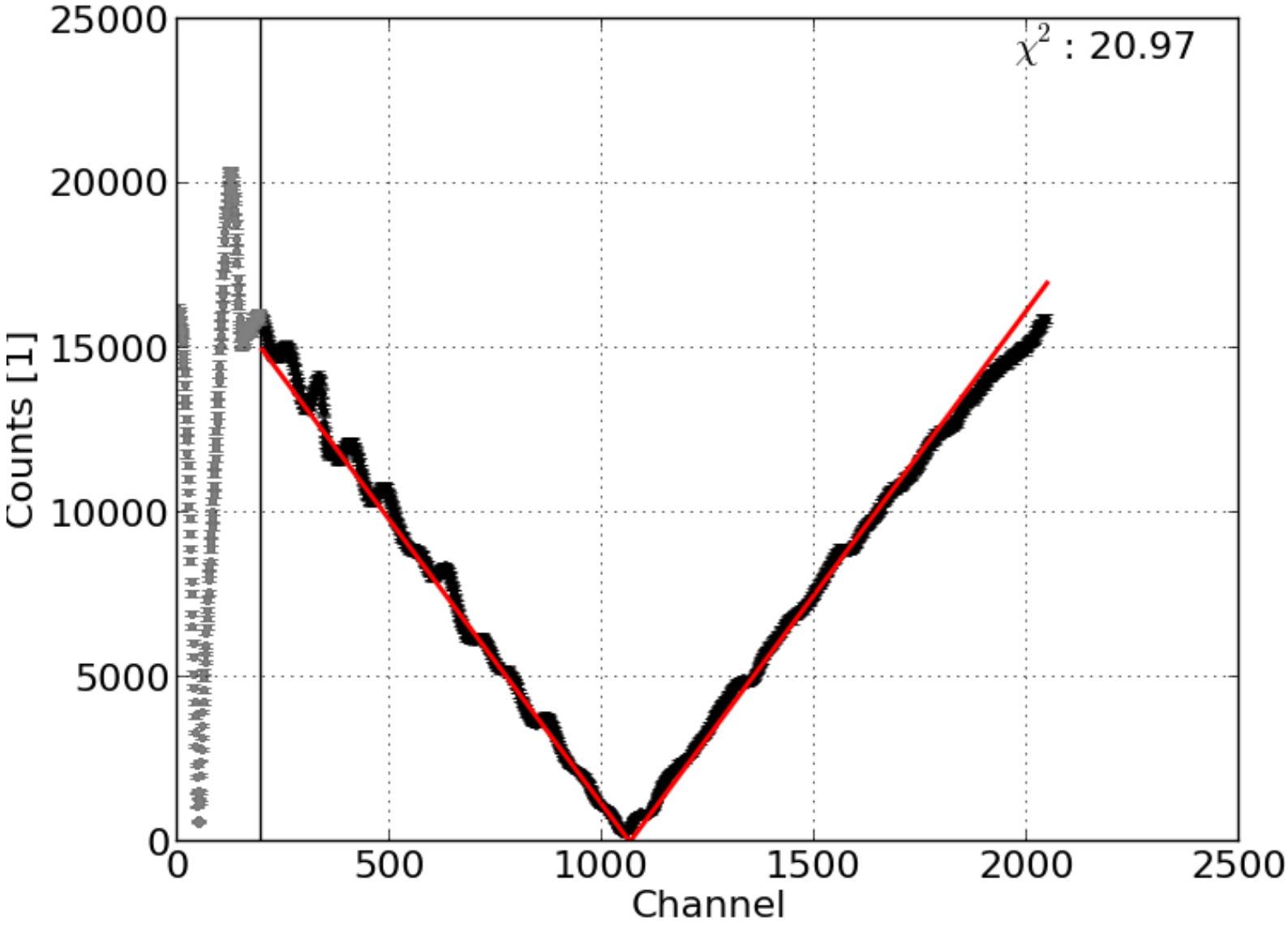



$$E' = E\,(1 + v/c)$$

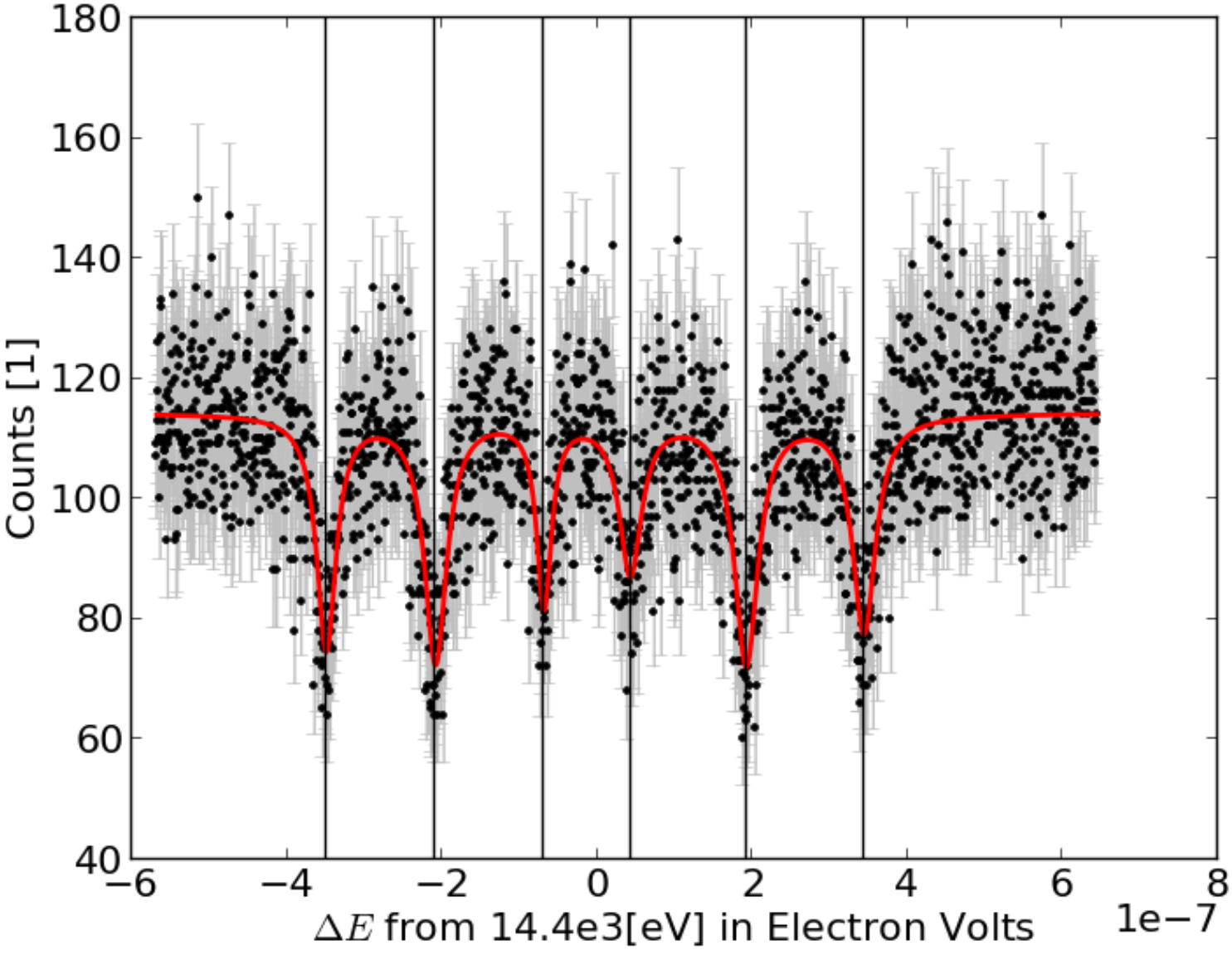
# Equipment Setup



# Absolute Velocity Calibration



# $^{57}Fe$ Absorption Spectrum



# Absorption Line Width and Sample Thickness

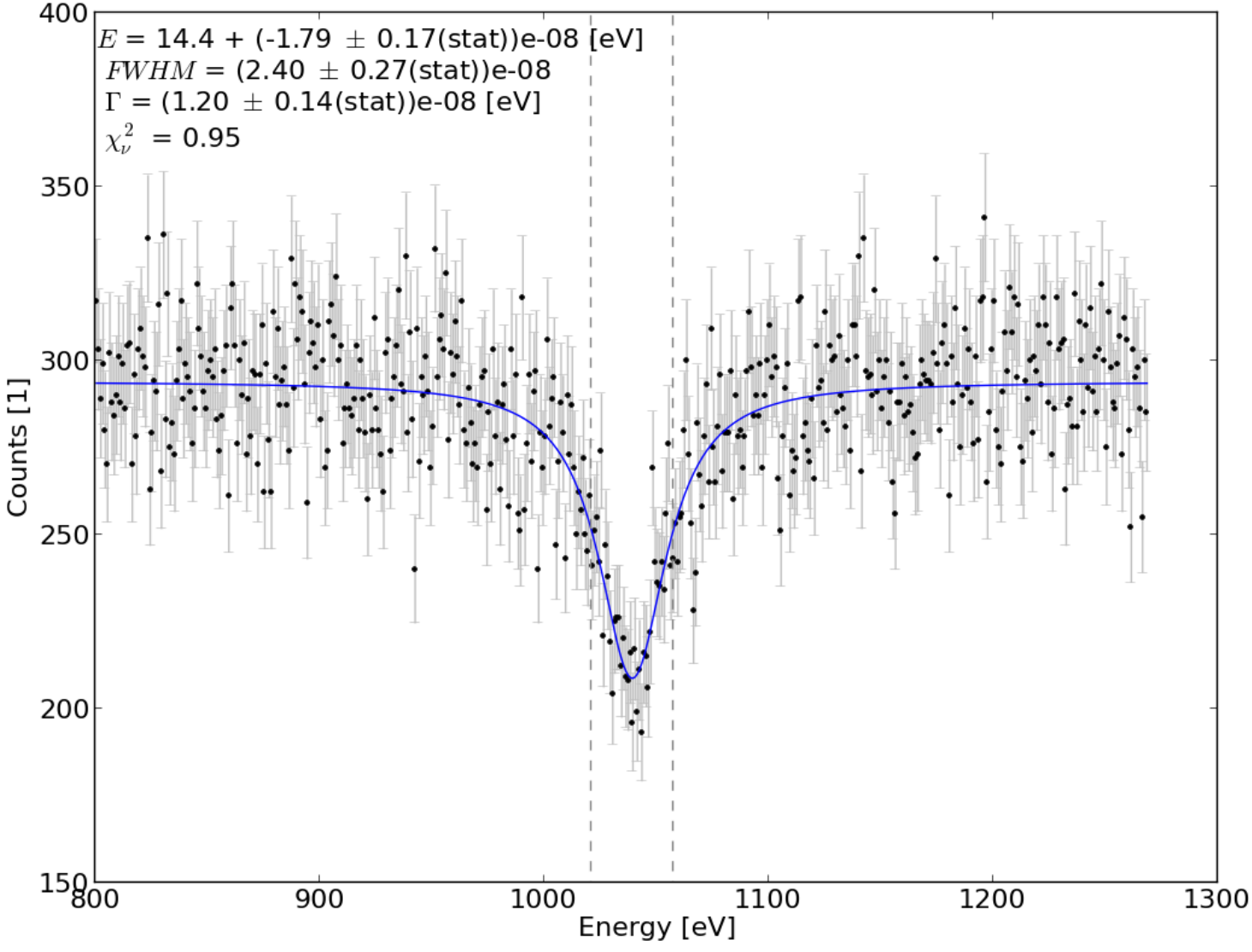
Absorption Profile,

$$I(E) = \frac{I_0(\Gamma)^2}{(E - E_0)^2 + (\Gamma)^2}$$

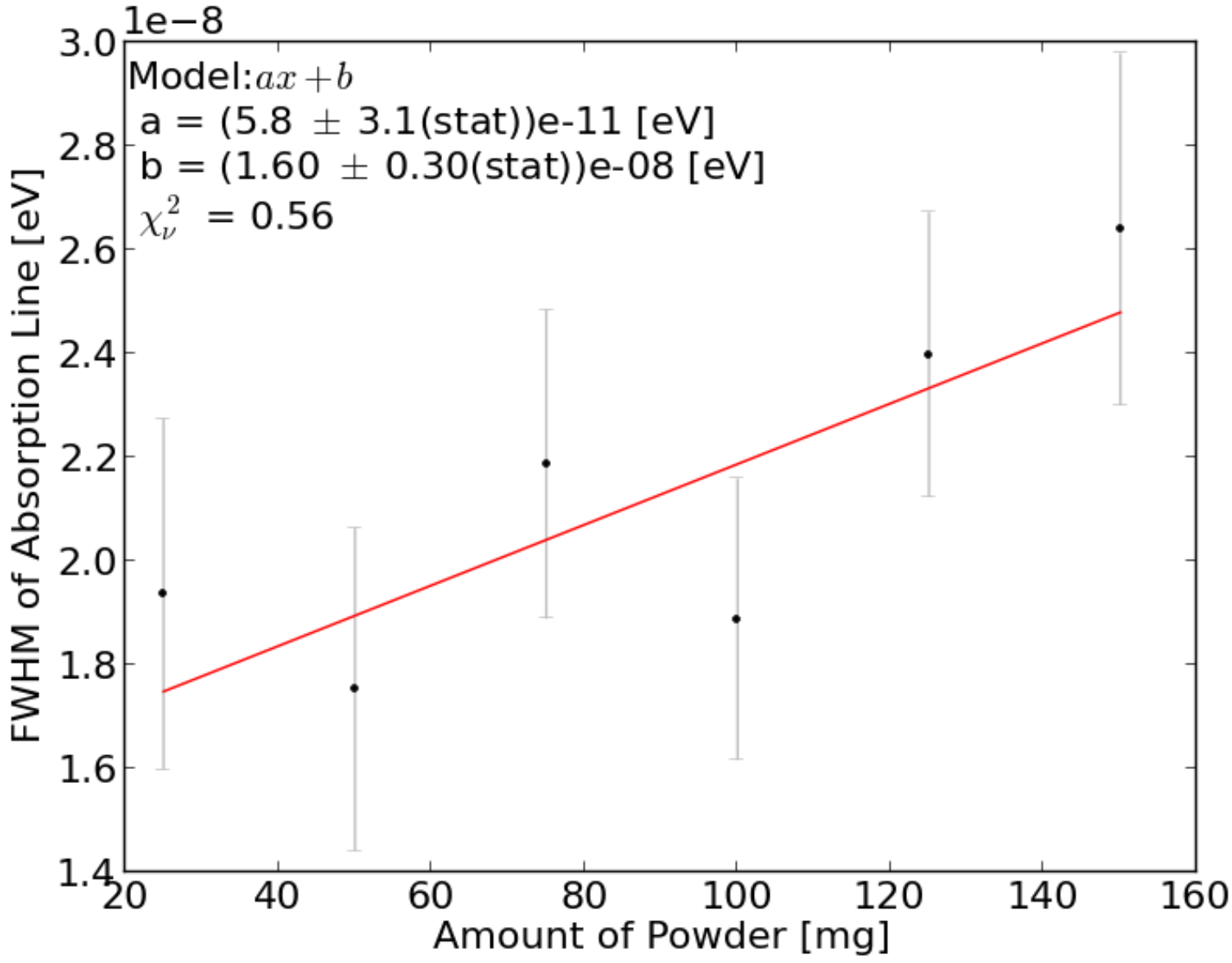
Photons Transmitted (Assuming Thin Sample)

$$C(E) = C_0 \left(1 - \frac{B}{(E - E_0)^2 + \Gamma^2}\right)$$

# Example FWHM Fit of Absorption Line - 125[$mg$] Sample



# Determining Natural Line Width



# Measured Values for $^{57}Fe$ Natural Line Width

## Accepted Values

$$\tau_{1/2} = 9.8 \times 10^{-8}\ [sec]$$

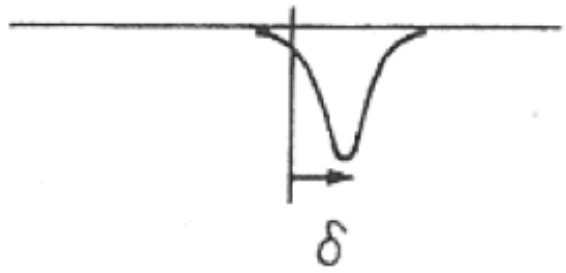
$$\Gamma = \frac{h \ln 2}{2\pi\tau_{1/2}} = 4.7 \times 10^{-9}\ [eV]$$

## Measured Values

$\Gamma$: $(8.0 \pm 1.5(stat)) \times 10^{-9}$ [eV]
Factor of $\sigma$ Off Accepted $\Gamma$: 2.19
$\tau_{1/2}$: $(5.7 \pm 1.1(stat))e - 08$ [sec]

FWHM $\Delta E$: $(1.60 \pm 0.3(stat)) \times 10^{-8}\ [eV]$
E: $(1.43999999998364 \pm 0.000000000000072(stat)) \times 10^{4}$ [eV]
Fractional Width: $(1.11 \pm 0.21(stat)) \times 10^{-12}$

# Isomer Shift




$$\delta = C \cdot (R_e^2 - R_g^2)|\phi_s^2(0) - \phi_a^2(0)|$$

where,

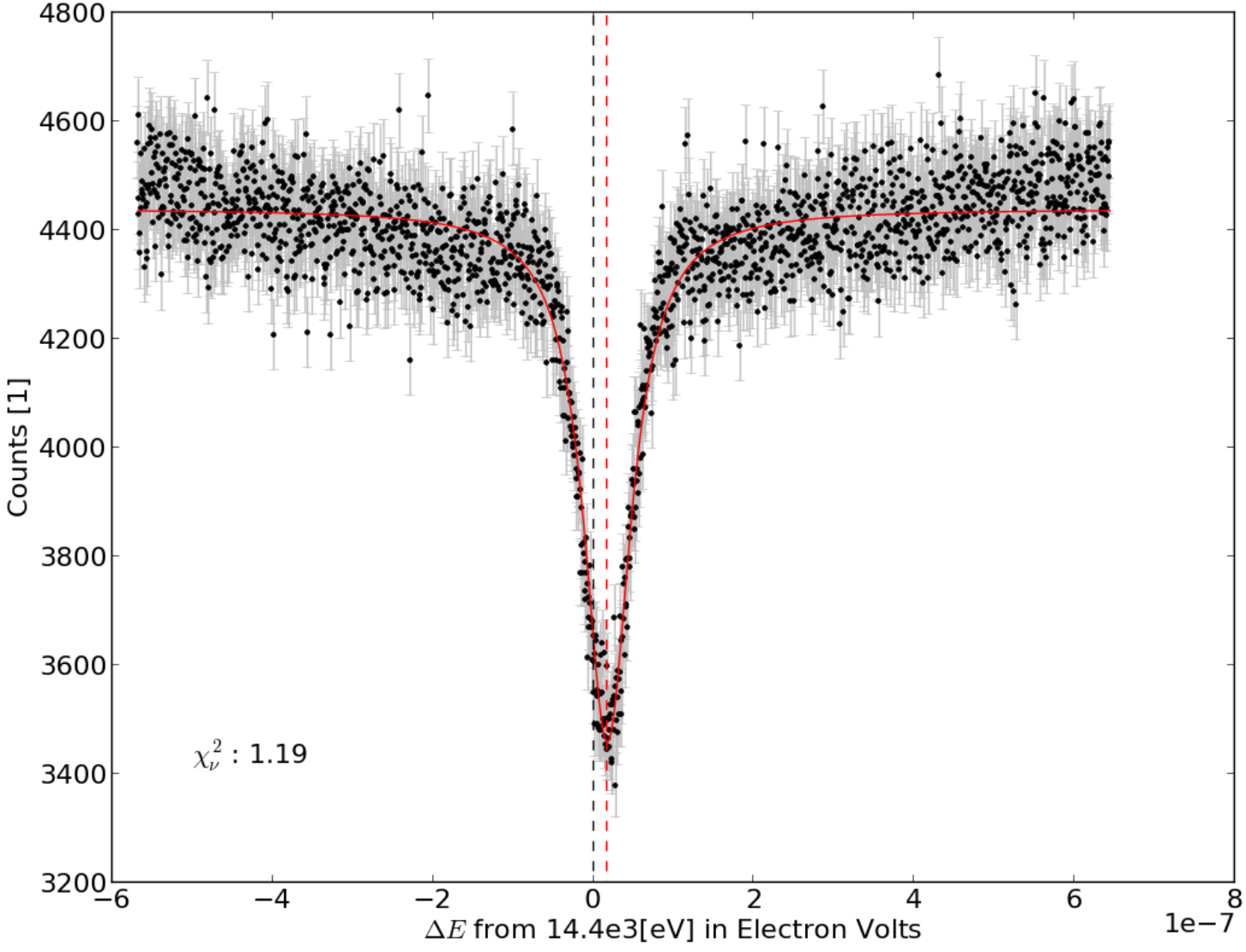
$R_e$ = Absorber nucleus charge radius in excited state

$R_g$ = Absorber nucleus charge radius in ground state

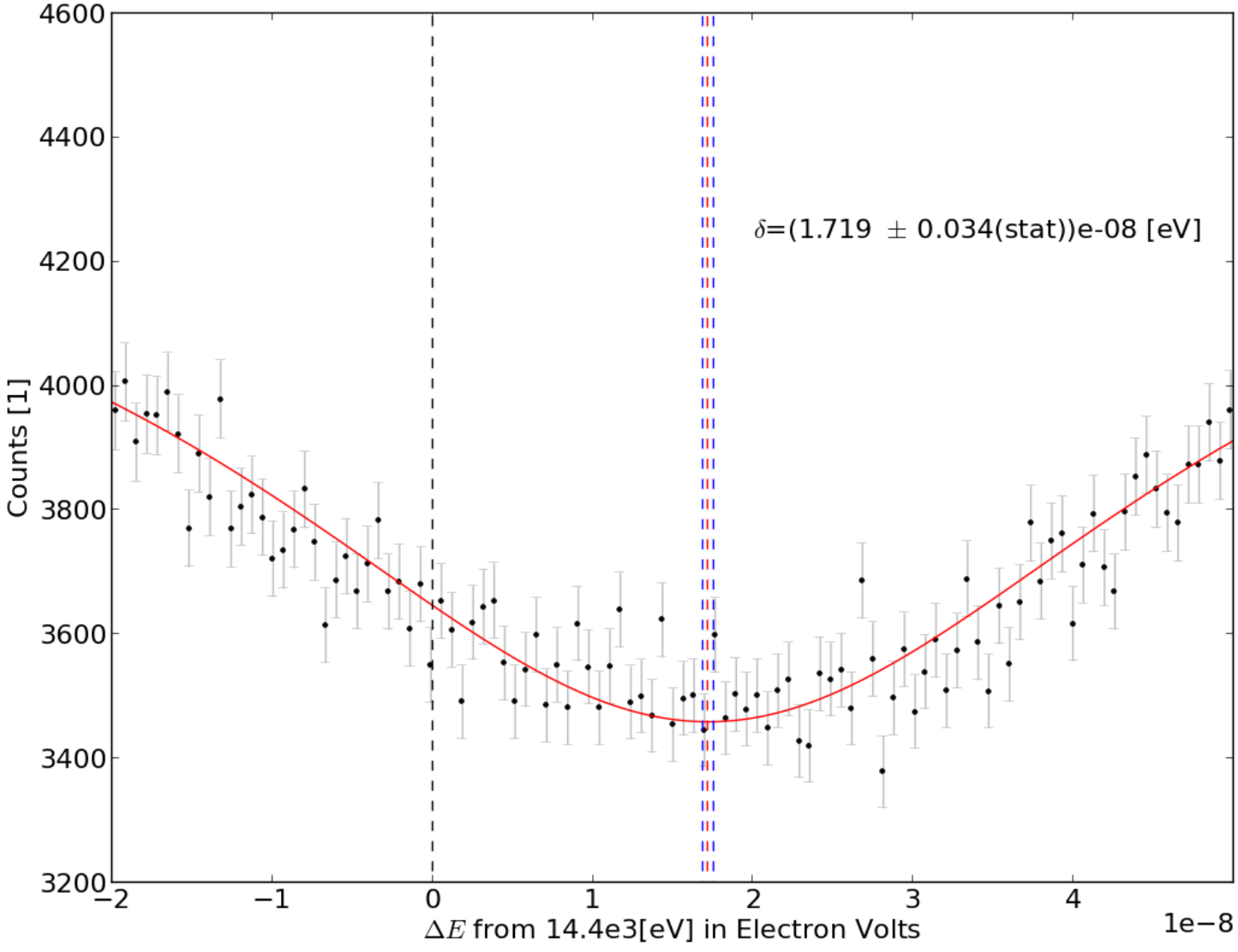
$\phi_s$ = Source Electron Density

$\phi_a$ = Absorber Electron Density

# Absorption Spectrum of $Fe_2(SO_4)_3$

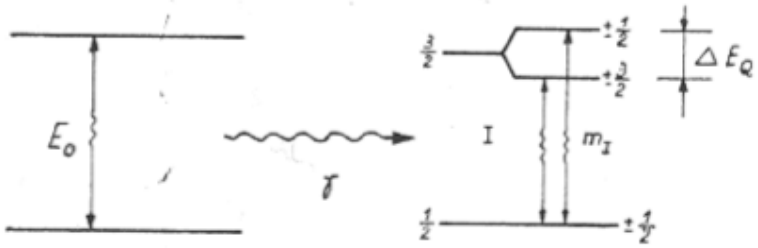


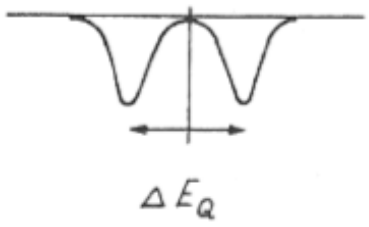
# Isomer Shift in $Fe_2(SO_4)_3$



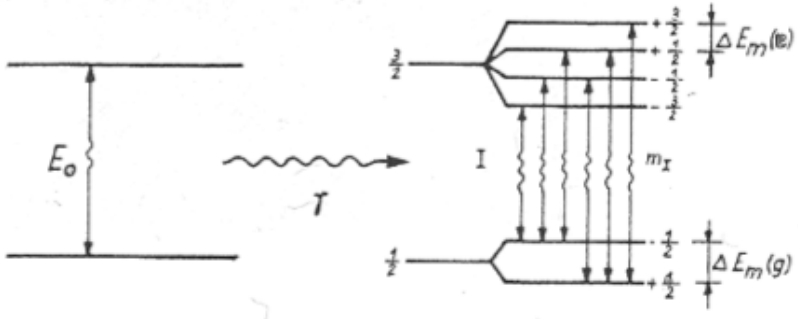
# Quadrupole and Zeeman Effects

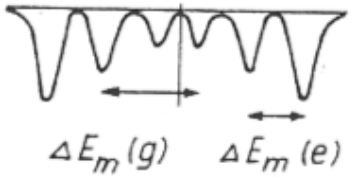
## Quadrupole



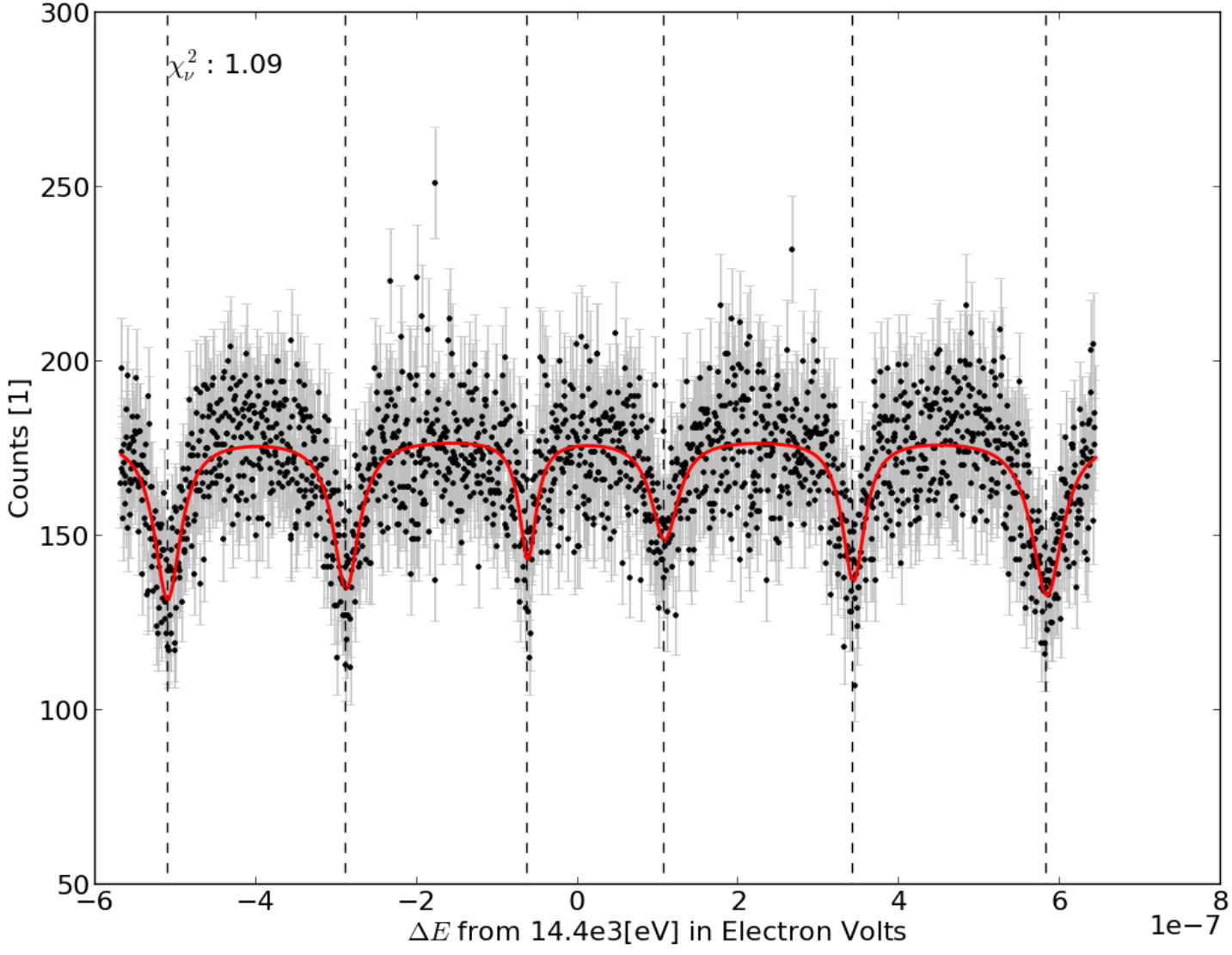




## Zeeman



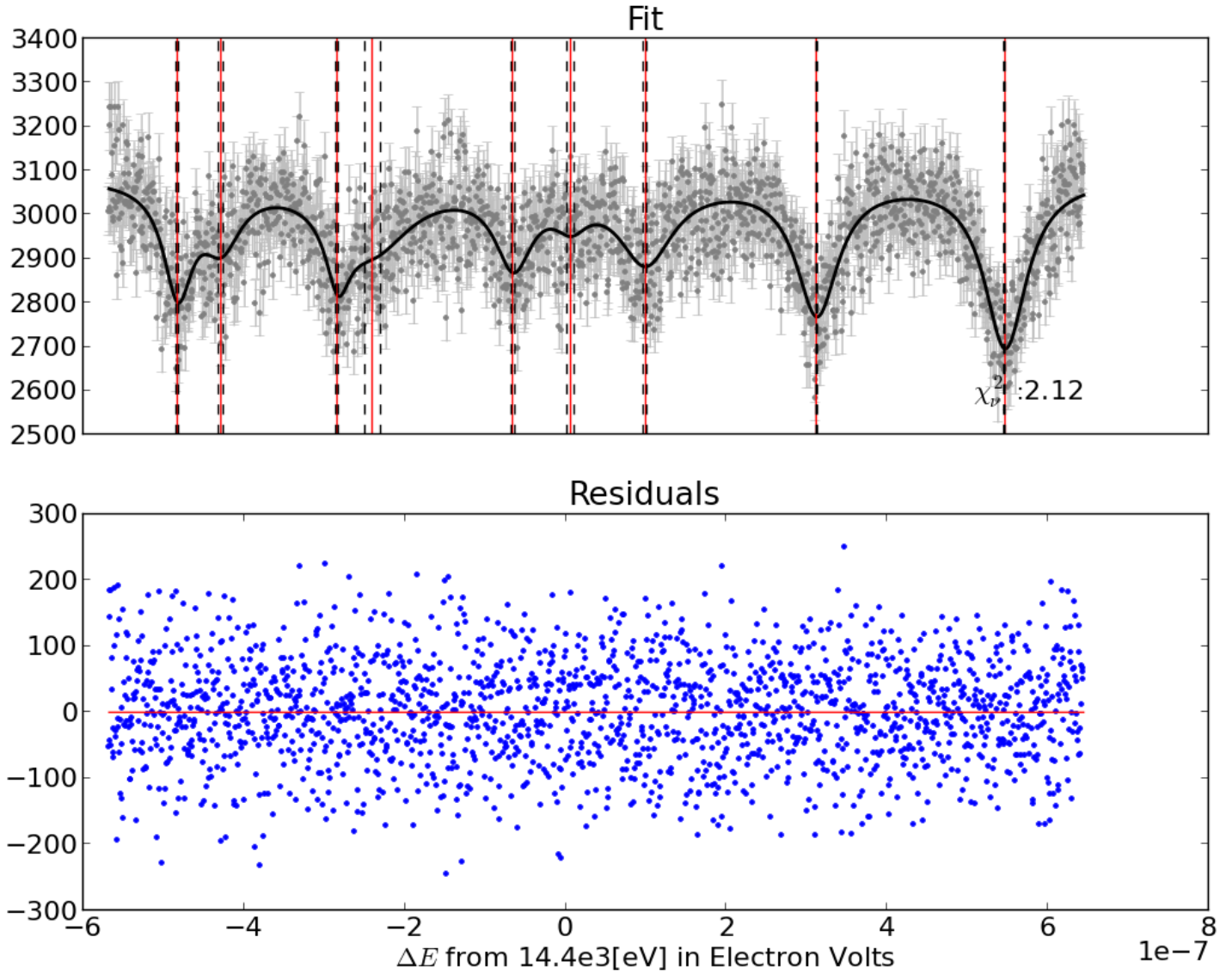
# Peak Fitting Quadrupole and Zeeman Effects in $Fe_2O_3$



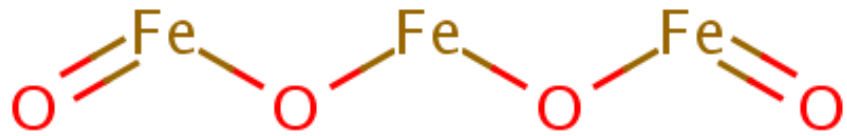
# Measured Values for Quadrupole and Zeeman Effects in $Fe_2O_3$

$$\Delta E_g = (4.018 \pm 0.013(stat))e - 07\ [eV]$$
$$\Delta E_m = (2.294 \pm 0.013(stat))e - 07\ [eV]$$
$$\Delta Q = (9.4 \pm 1.6(stat))e - 09\ [eV]$$

# Measurement of the Absorption Spectrum for $Fe_3O_4$



# Chemical Structure of $Fe_3O_4$




https://www.ebi.ac.uk/chebi/

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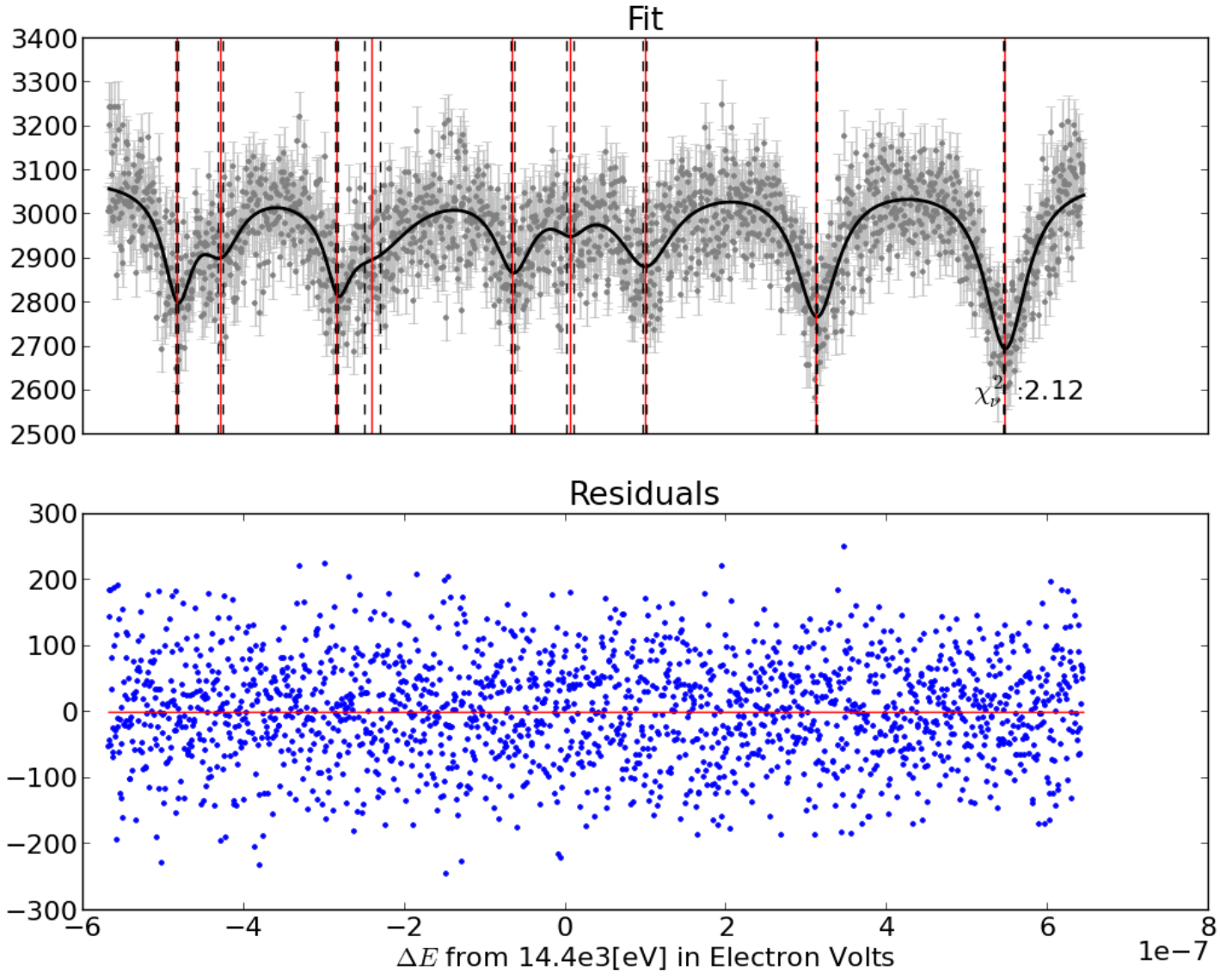

# Final Remarks

- Mössbauer spectroscopy allows for fine measurements of atomic structure.
- We have confirmed accepted measurements for $\tau_{1/2}$ in $^{57}Fe$.
- The technique can be applied to provide information about the chemical structure of a substance as demonstrated by our application to $Fe_3O_4$.