A calibration using $^{35}Cl(n,\gamma)$ for measuring the excitation energy of the T=2 state in ^{32}S via $^{31}P(p,\gamma)$

REU Presentation

August 19, 2003

Outline

- Background on isospin and the IMME (Isospin Mass Multiplet Equation)
- Description of the $^{31}P(p,\gamma)$ experiment
- Description of an experiment to check for Doppler shifts in a ^{35}Cl gamma ray source
- Monte Carlo simulation of gamma ray source
- Results of ^{35}Cl gamma ray source experiment

Isospin in protons and neutrons

- The strong interaction (almost) cannot distinguish between neutrons and protons
- Neutrons and protons are states of another particle, the nucleon
- Similar to spin up and down electrons
- Give proton $T_z=1/2$, neutron $T_z=-1/2$
- $Q=e(½+T_z)$

Isospin in nuclei

- Isospin is angular momentum-type-thing so $T_{z,tot}=T_{z,1}+T_{z,2}$
- $T_{z,tot} = ½(Z-N)$
- IMME: It can be shown that the mass of nuclei within an isospin multiplet are related by $M(T,T_z)=a+bT_z+cT_z^2$

$$H = H_0 + \sum_{i<j} \hat{q}_i \hat{q}_j f(r_{ij})$$

where

$$\hat{q}_i = e\left(\frac{1}{2} + \hat{T}^i_{z,tot}\right)$$

Motivation

- Test the IMME
- Use the IMME to determine precisely the mass of ^{32}Ar and hence the endpoint energy in the T=2 Multiplet

$$M(T_3)=a+bT_3+cT_3^2$$

- Improve limits on scalar contributions to the weak interaction.
- Check for isospin mixing corrections to explain the apparent non-unitarity of the CKM matrix

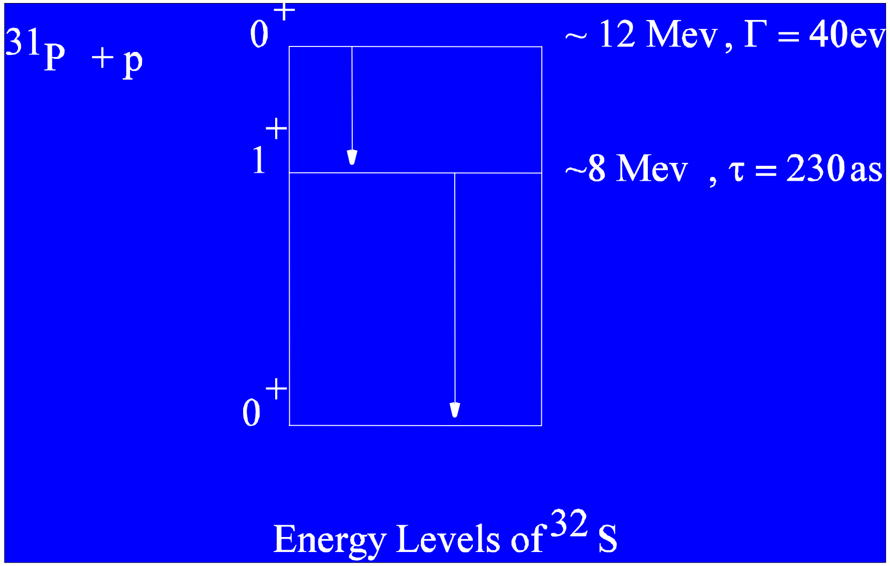
$^{31}P(p,\gamma)$

Measure excitation energy since mass of ground state is well known

Resonance at:

E_p = 3.289 MeV

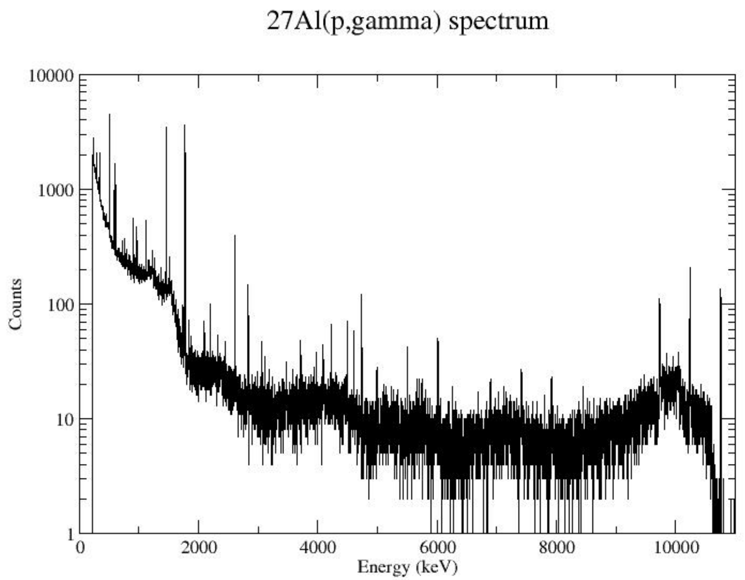
Target: Implanted ^{31}P on a Ta backing with an incident dose ~55μAh and beam energy at 90 keV



Calibration using $^{27}Al(p, \gamma)$

Calibration: $^{27}Al(p, \gamma)$ at E_p= 992 keV

- Peaks not at proper energy: Around 10 MeV instead of 8 MeV
- Overlapping peaks



Gammas from $^{35}Cl(n, \gamma)$

- Use a 10 MeV neutron source
- Moderate neutrons so that they will capture
- Capture cross section: $\sigma=\sigma_0 \, v_T/v$
- When neutrons capture on Cl, gammas of various energies are emitted
- Doppler shifts?

$E\gamma' = E\gamma(1+v/c \cos\theta)$

Monte Carlo for Doppler Shifts in $^{35}Cl(n, \gamma)$

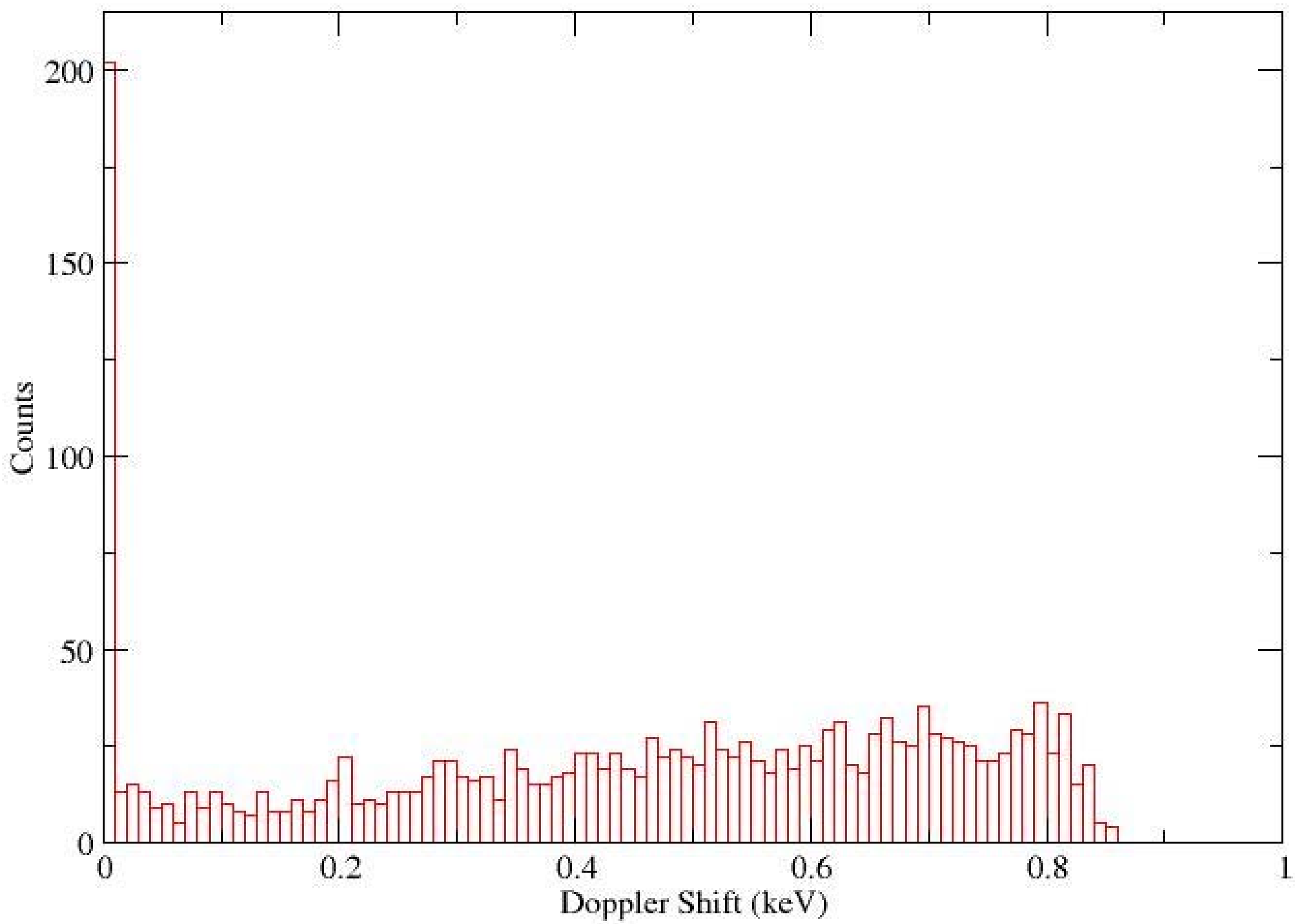
1. Simulate events according to probability distributions
2. Start with a neutron moving in random direction
3. Calculate distance to next interaction according to probability distributions involving the mean free path of the neutron in material

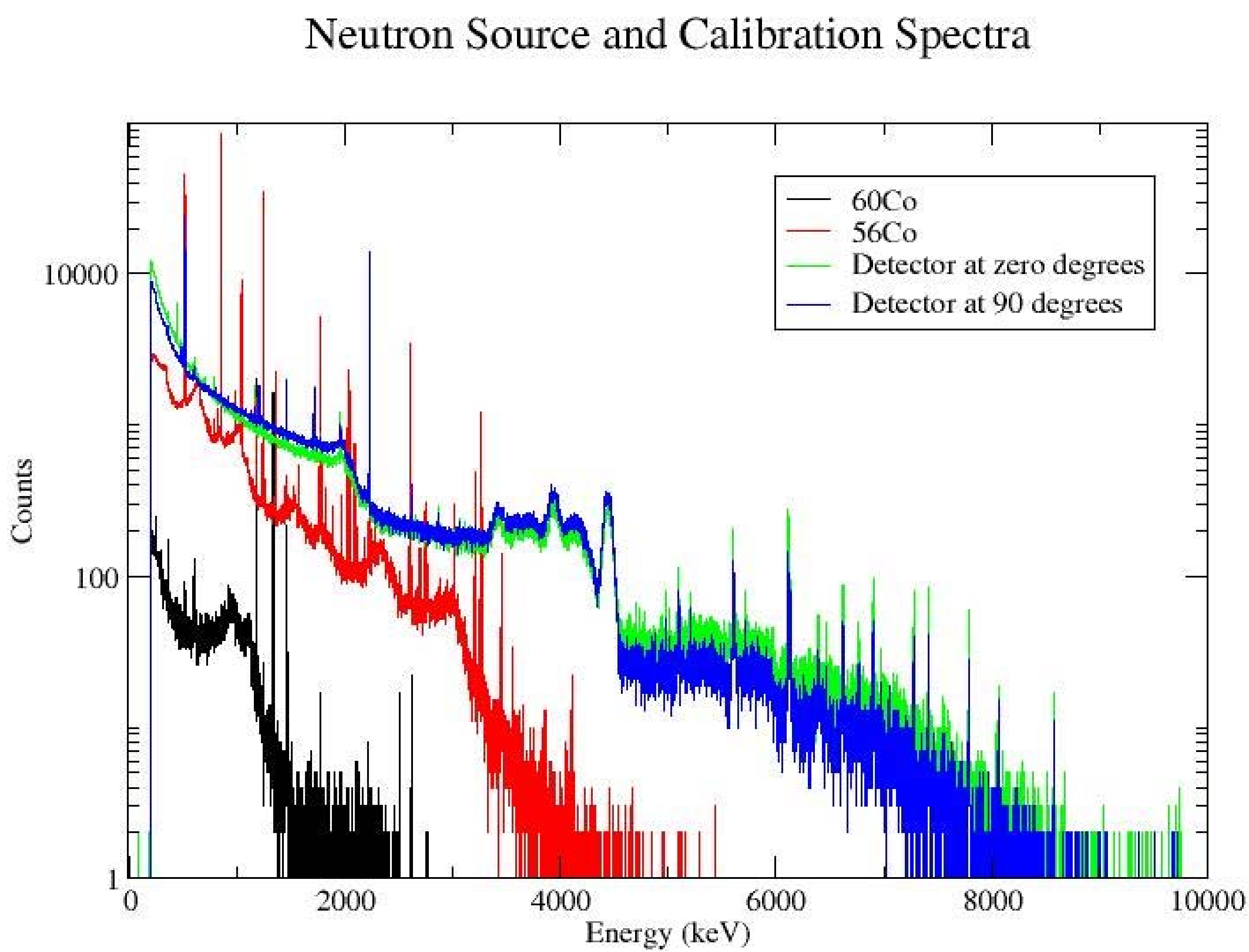
Monte Carlo (cont.)

4. At each interaction point, decide whether the interaction was scattering or capture
5. If interaction was scattering, give neutron new direction and go to step 3
6. If the neutron captures on a nucleus, compute nuclear recoil and Doppler shift
7. Project shift onto axis of detector
8. $E\gamma' = E\gamma(1+v/c \cos \theta)$

Doppler Shift of 7790 keV peak

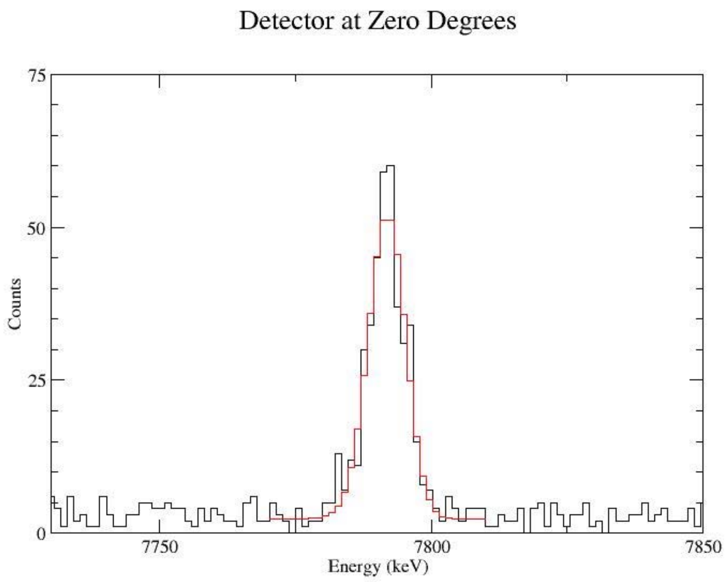
(detector resolution effects removed to make plot more interesting)

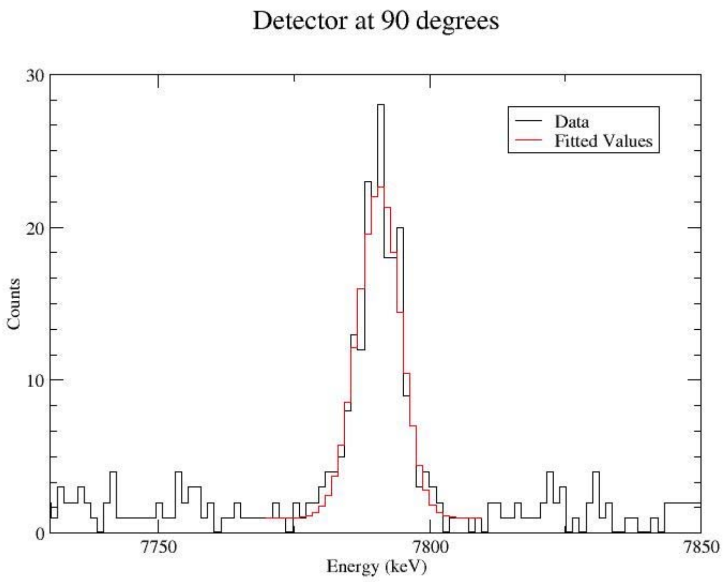




Neutron Source and Calibration Spectra
60Co
56Co
Detector at zero degrees
Detector at 90 degrees
Counts
10000
100
1
0
2000
4000
6000
8000
10000
Energy (keV)

Doppler Shifts at 7790 keV





Doppler Shifts on Various Peaks

Energy (keV)	0 degrees	90 degrees	Difference
7790.33	7791.11±.21	7790.31±.33	.80±.39
7413.97	7414.75±.20	7413.54±.25	1.21±.30
5715.24	5716.20±.42	5714.81±.57	1.39±.71

Conclusions

- $^{35}Cl(n,\gamma)$ works for calibrations
- Monte Carlo calculations agree with data but higher statistics needed
- $^{31}P(p,\gamma)$ data under analysis

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