G E Mitchell

SYMMETRY BREAKING, RMT AND NUCLEI

A -- USE NUCLEUS AS TEST LABORATORY FOR RMT PREDICTIONS

B -- ASSUME RMT TO INTERPRET NUCLEAR PHENOMENA

A – ISOSPIN SYMMETRY BREAKING

EFFECT ON LEVEL STATISTICS

EFFECT ON TRANSITIONS

B – PARITY VIOLATION

ENHANCEMENT IN COMPOUND NUCLEUS

EFFECT OF SYMMETRY BREAKING ON LEVEL STATISTICS

ISOSPIN

REQUIREMENTS

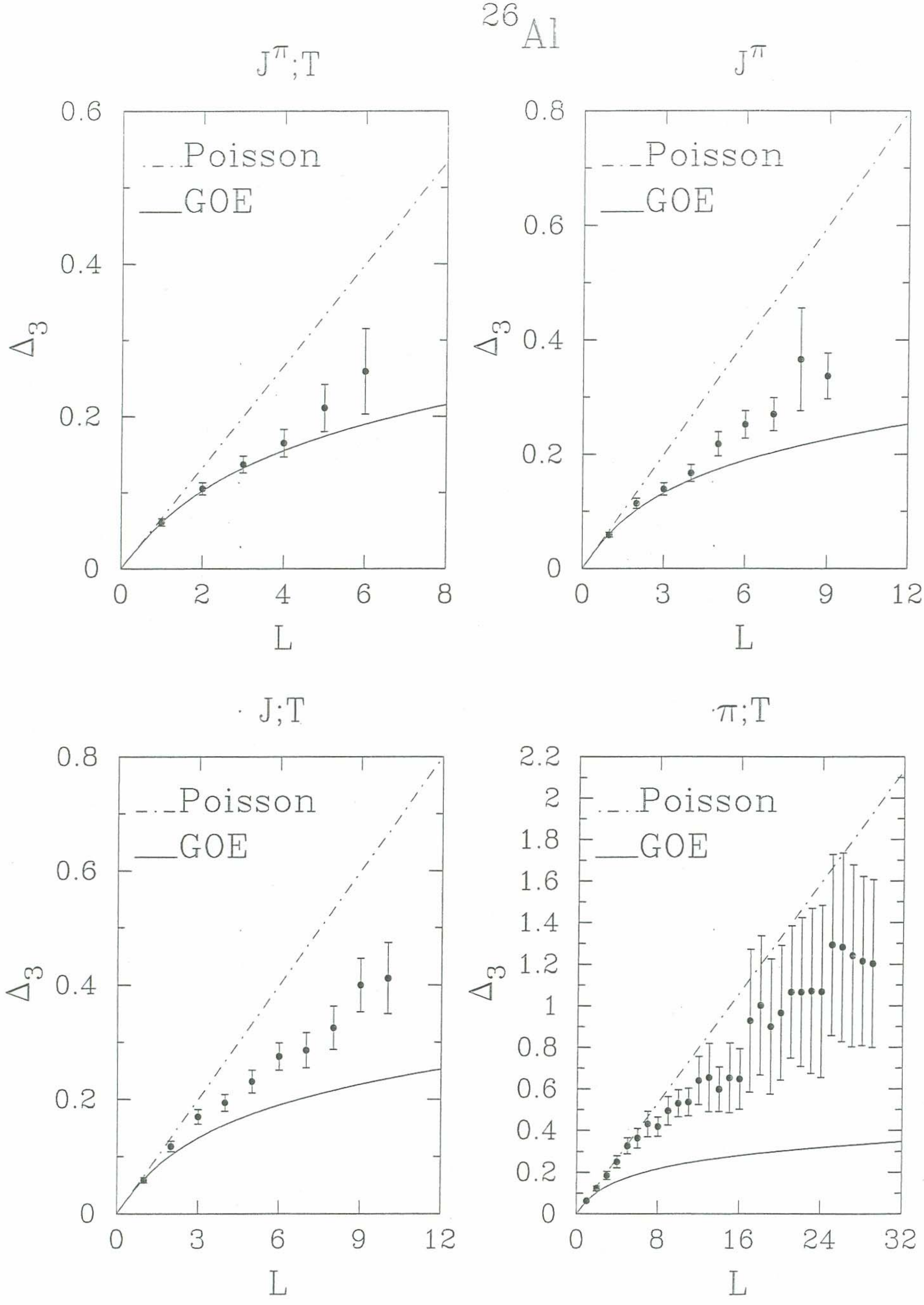
LEVELS WITH KNOWN QUANTUM NUMBERS

COEXISTENCE OF LEVELS WITH DIFFERENT ISOSPIN

FROM GROUND STATE COEXISTENCE
ONLY FOR N = Z = ODD

SUCH NUCLEI ACCESSIBLE
WITH SUFFICIENT # OF LEVELS
IN S-D SHELL

26AL AND 30P



26Al
J^π;T
J^π
J;T
π;T
Poisson
GOE
Δ3
L

GEM

$$H = H_{sc} + \alpha H_{sb}$$

$$H = \begin{bmatrix} T=0 & 0 \\ 0 & T=1 \end{bmatrix} + \alpha \begin{bmatrix} 0 & V \\ V & 0 \end{bmatrix}$$

REDIAGONALIZE, EIGENVALUES CHANGE

EFFECT ON STATISTICAL OBSERVABLES

DEPENDS ON $\lambda = \alpha / D$, NOT JUST α

SMALL SYMMETRY BREAKING CAN LEAD TO LARGE EFFECT

^{30}P LEVEL STATISTICS

LEVELS	BRODY PARAMETER ω
ALL STATES (T IGNORED)	0.54 ± 0.17
ALL STATES (T SEPARATED)	0.60 ± 0.22

^{26}Al LEVEL STATISTICS

LEVELS	BRODY PARAMETER ω
ALL STATES (T IGNORED)	0.54 ± 0.11
ALL STATES (T SEPARATED	0.54 ± 0.14

IN 26Al AND 30P
EIGENVALUE DISTRIBUTIONS
STRONGLY AFFECTED
BY ISOSPIN SYMMETRY BREAKING

PREDICTED BY DYSON, PANDEY
EXPLAINED BY
GUHR AND WEIDENMUELLER
(HEIDELBERG)
HUSSEIN AND PATO
(SAO PAULO)

CONFIRMED IN
COUPLED MICROWAVE CAVITIES
A. RICHTER
(DARMSTADT)

CONFIRMED IN
QUARTZ BLOCKS
C. ELLEGAARD
(COPENHAGEN)

EFFECT OF SYMMETRY BREAKING
ON EIGENVALUES
UNDERSTOOD

GOE

AMPLITUDES GAUSSIAN DISTRIBUTED

DISTRIBUTION OF STRENGTHS
(AMPLITUDES SQUARED)

CHI--SQUARED OF ONE DEGREE OF FREEDOM

PORTER THOMAS

REDUCED MATRIX ELEMENTS B(XL)

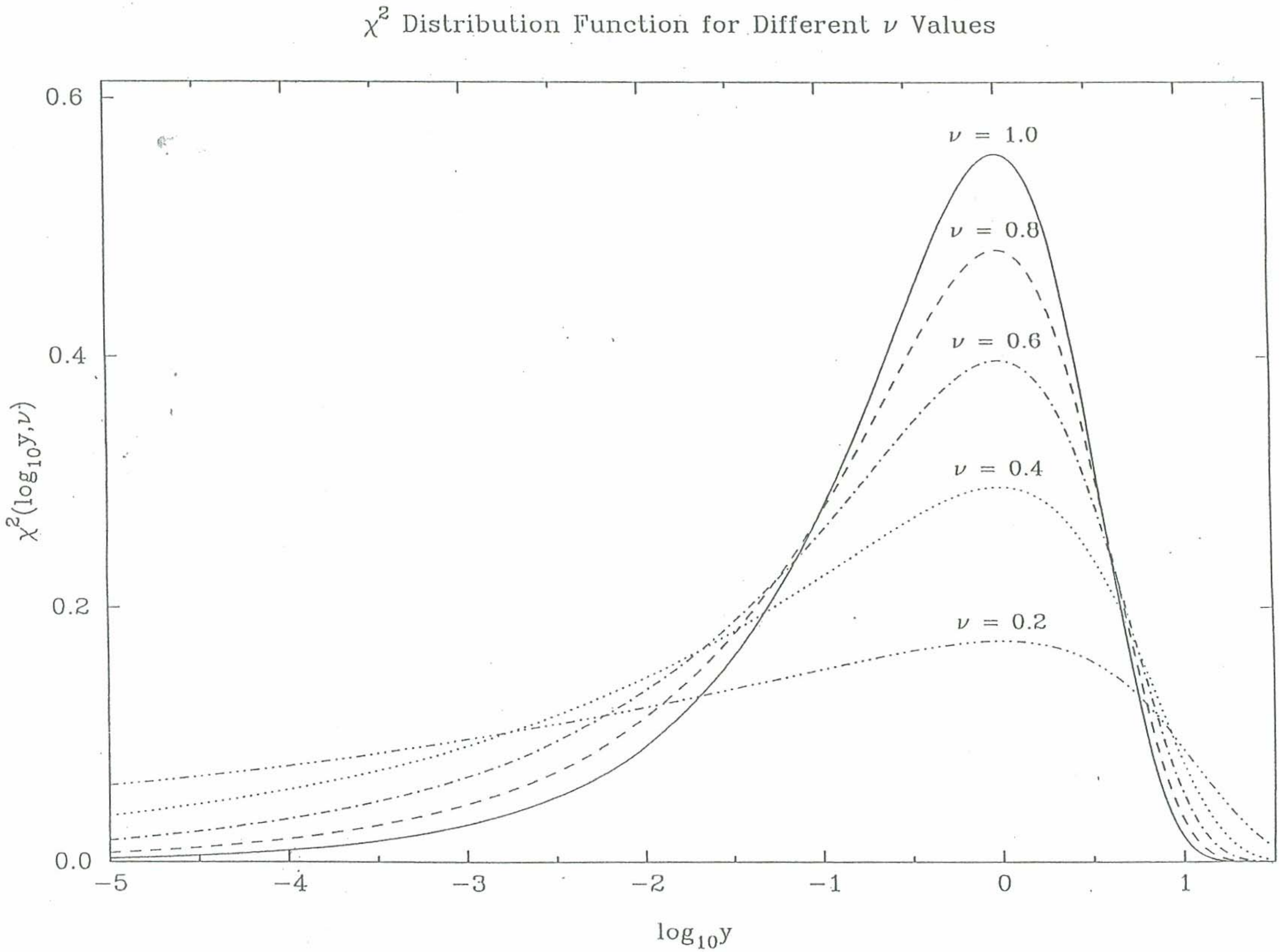
NORMALIZED TO LOCAL AVERAGE B(XL)

Y = B(XL) / <B(XL)>

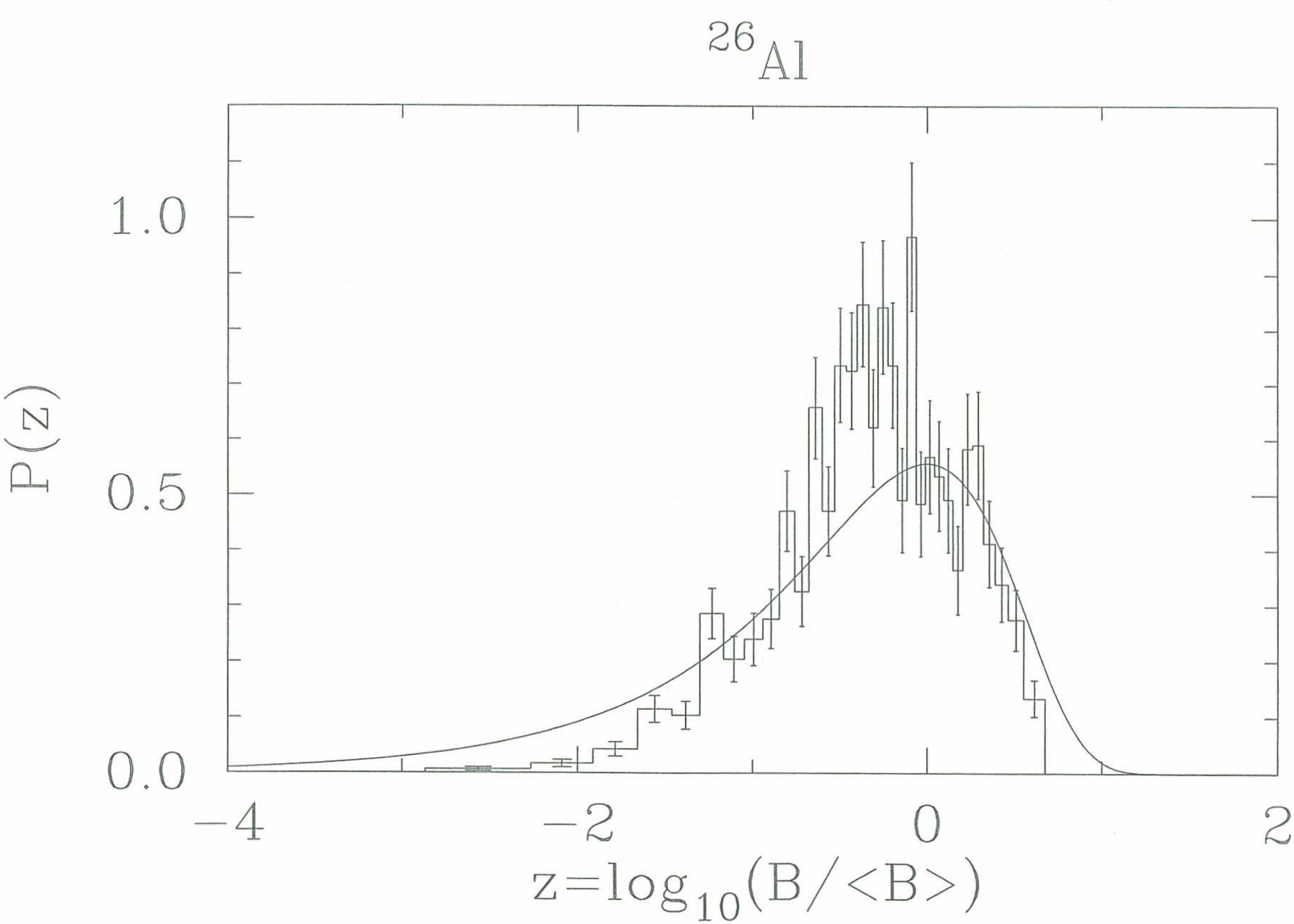
LARGE RANGE OF B (AND Y) VALUES

INTRODUCE NEW VARIABLE

Z = LN(BASE10) Y



χ^2 Distribution Function for Different ν Values
$\chi^2(\log_{10}y,\nu)$
0.6
0.4
0.2
0.0
ν = 1.0
ν = 0.8
ν = 0.6
ν = 0.4
ν = 0.2
−5
−4
−3
−2
−1
0
1
$\log_{10}y$



26Al
P(z)
1.0
0.5
0.0
−4
−2
0
2
z=log10(B/<B>)

$$H = H_{sc} + \alpha H_{sb}$$

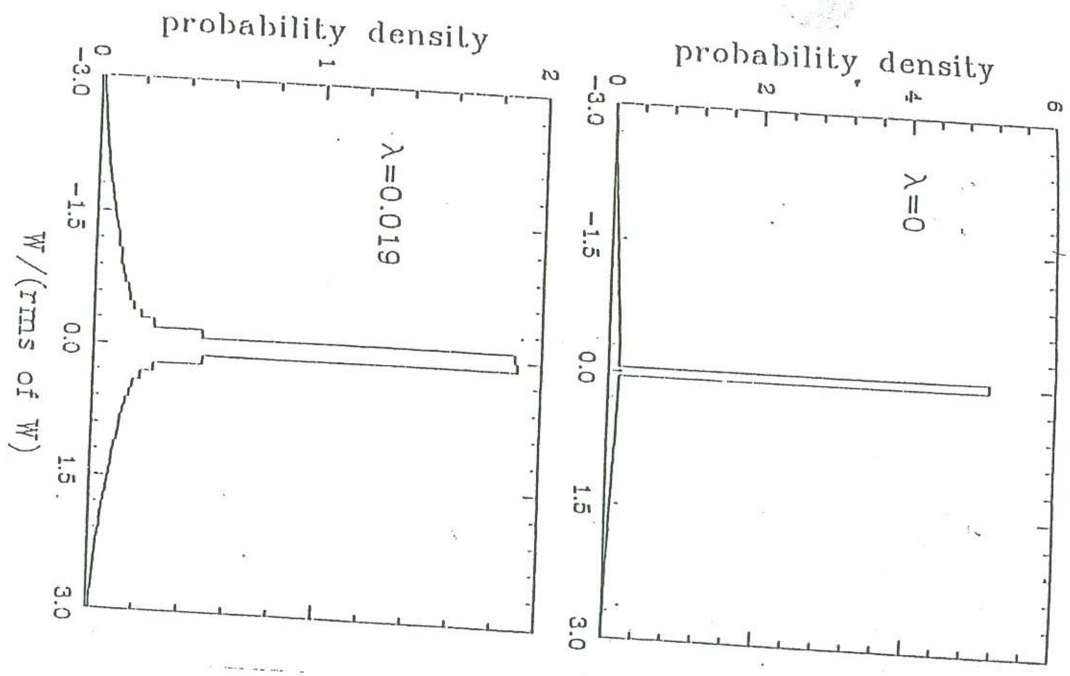
$$H = \begin{bmatrix} T=0 & 0 \\ 0 & T=1 \end{bmatrix} + \alpha \begin{bmatrix} 0 & V \\ V & 0 \end{bmatrix}$$

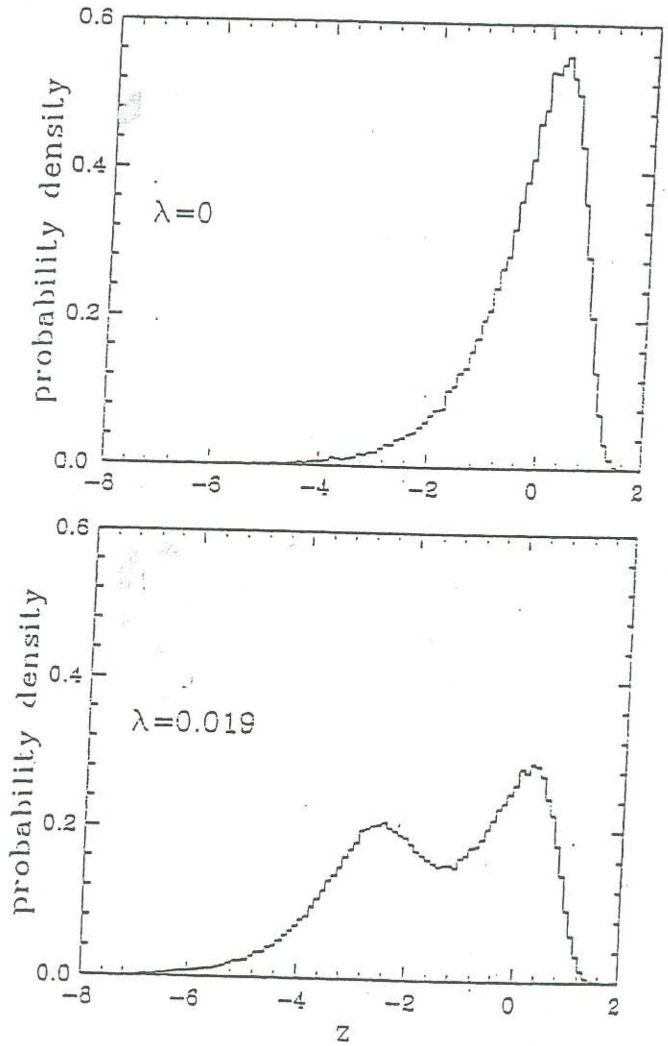
EFFECT ON
STATISTICAL OBSERVABLES

DEPENDS ON $\lambda = \alpha / D$

REDIAGONALIZE,
EIGENVALUES CHANGE
WAVEFUNCTIONS CHANGE

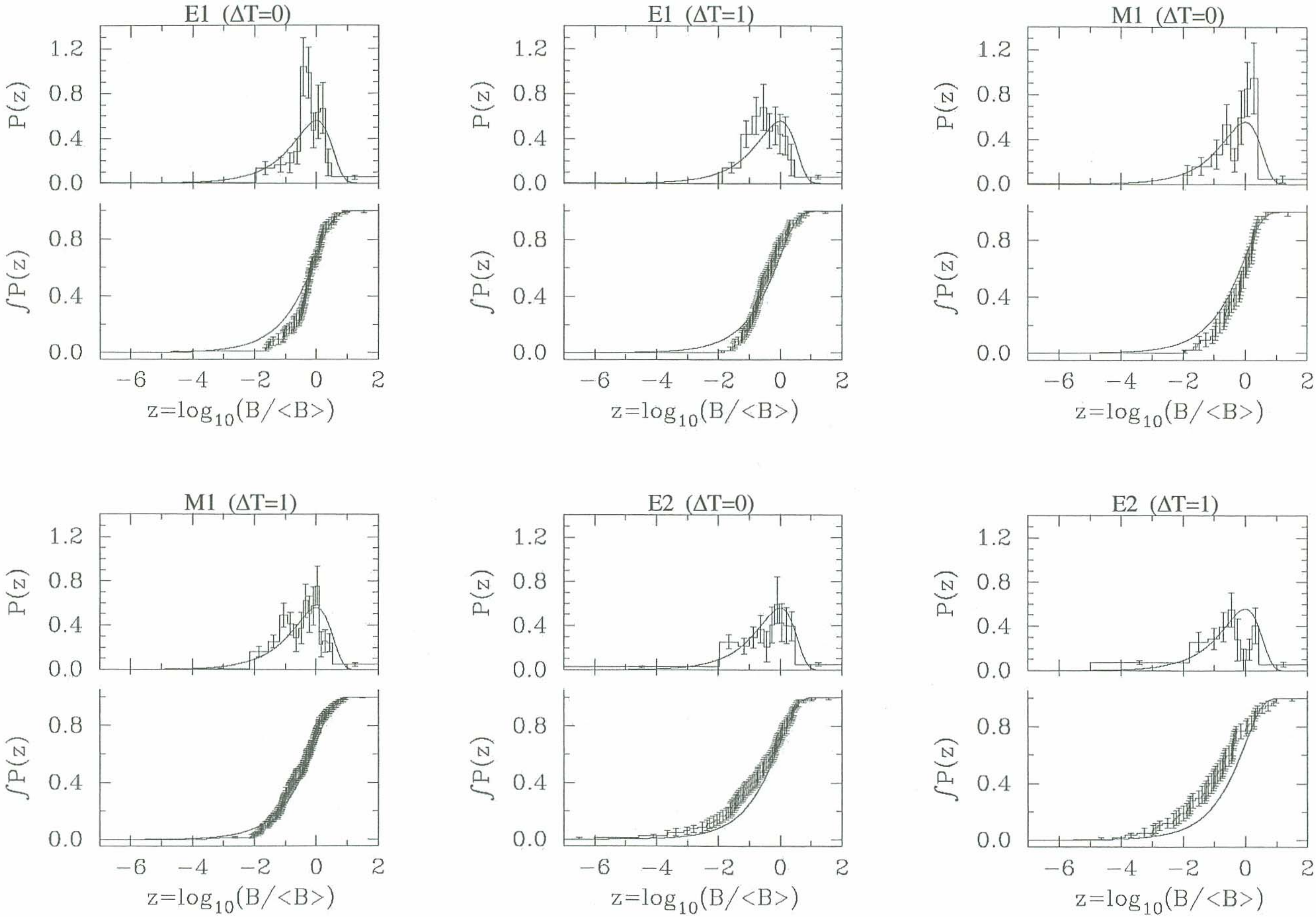
TRANSITIONS $< \Psi_f^n | O | \Psi_i^n >$


probability density
λ=0.019
W/(rms of W)
probability density
λ=0
0
1
2
4
6
−3.0
−1.5
0.0
1.5
3.0



probability density
λ=0
probability density
λ=0.019
z

^{30}P



FOLLOWING

WU—AMBLER, GARWIN—LEDERMAN

MANY STUDIES OF PARITY VIOLATION IN
STRONG INTERACTION PROCESSES

CONFLICTING RESULTS (MAINLY RUSSIAN)
IN
NEUTRON-INDUCED REACTIONS
LOOKING AT GAMMA RAYS

FINALLY AT ILL
VERY LARGE NEUTRON SPIN ROTATION

CONFUSION
EXTREME EXAMPLE
RESORT TO FIFTH FORCE

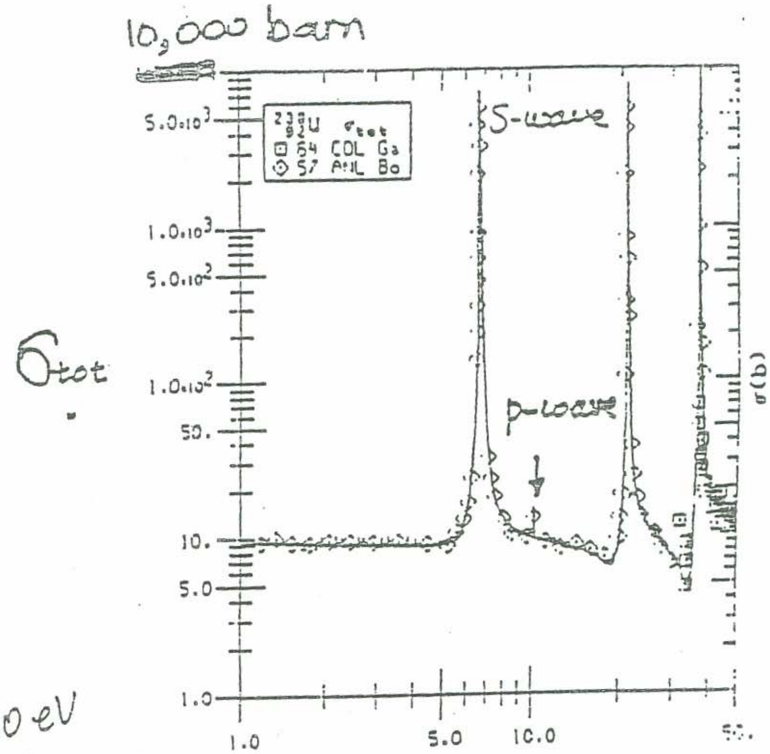
EXPLANATION
SUSHKOV—FLAMBAUM

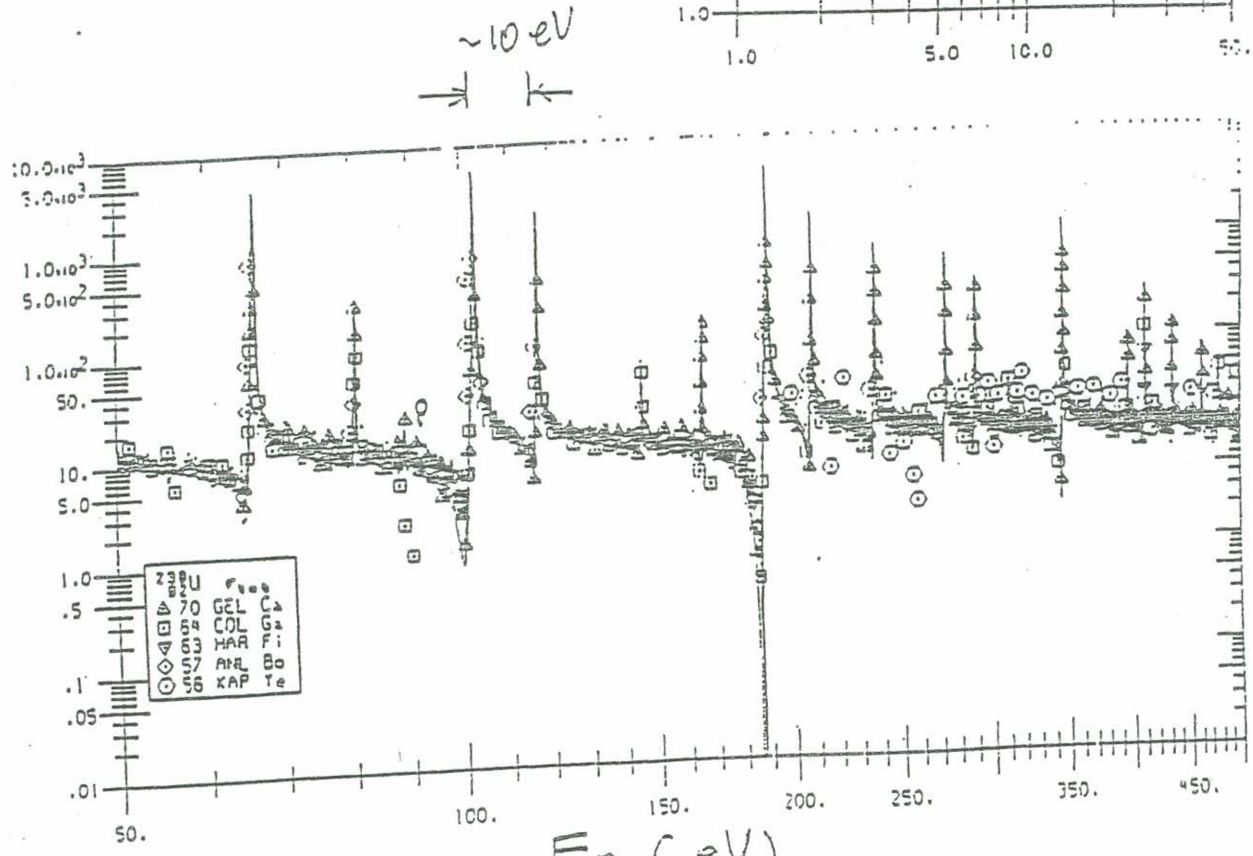
OBSERVATION OF LARGE PARITY VIOLATION
IN NEUTRON RESONANCES IN 139LA
FRANK LABORATORY, DUBNA

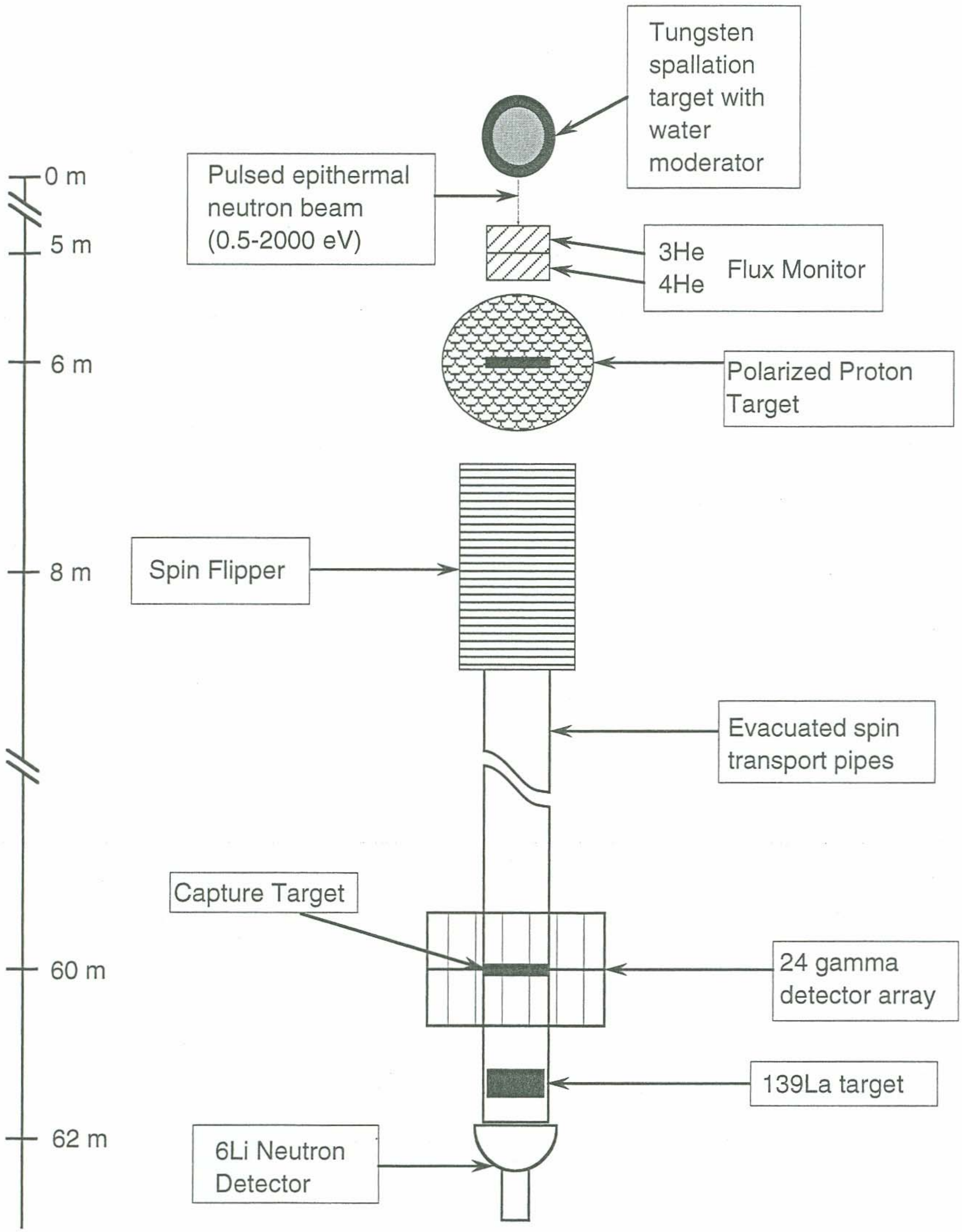
THEN WE STARTED
TRIPLE COLLABORATION

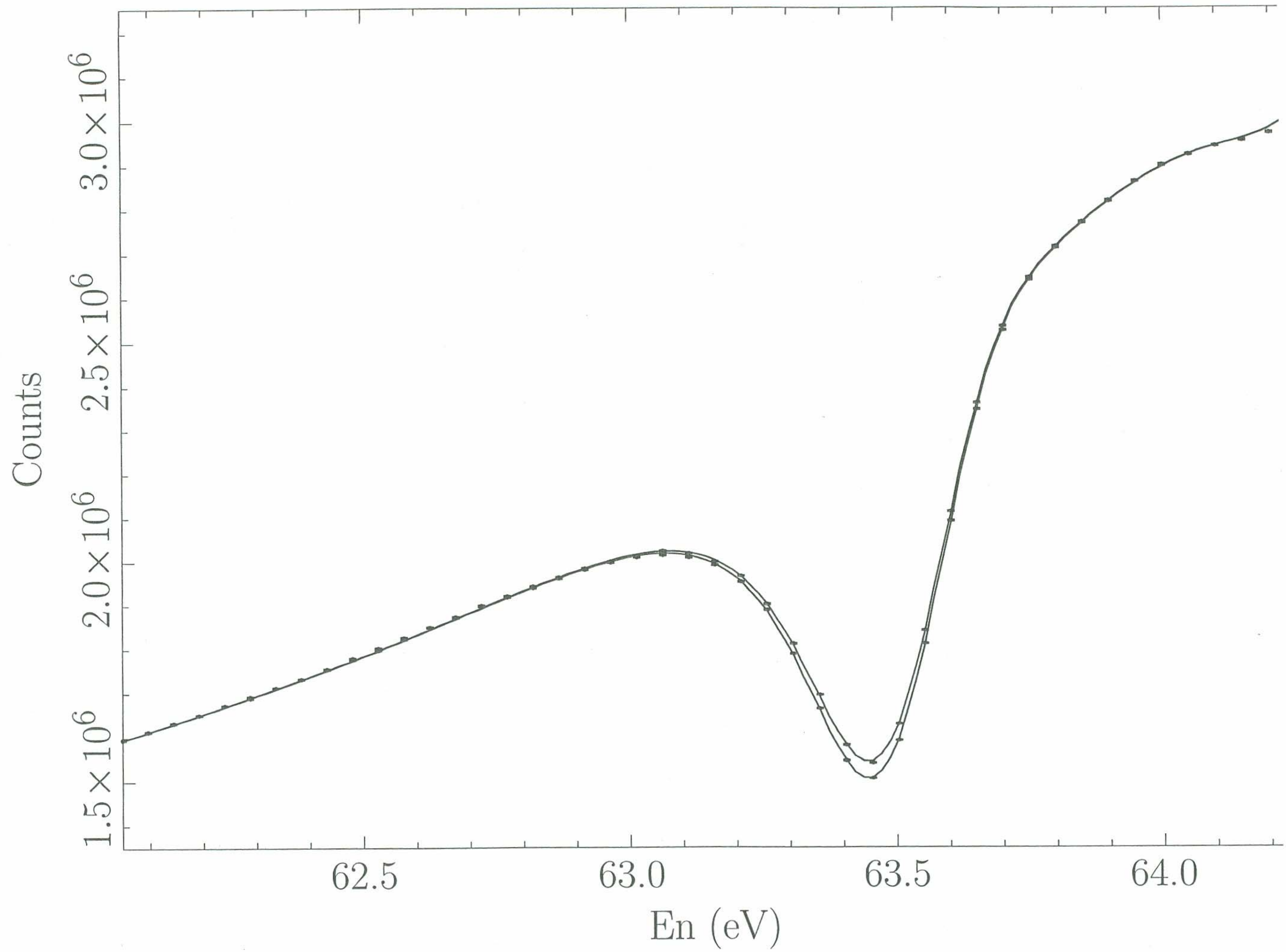
- Epithermal (0.1 – 10^5 eV) Neutron–Nucleus scattering:

$n + {}^{238}U$

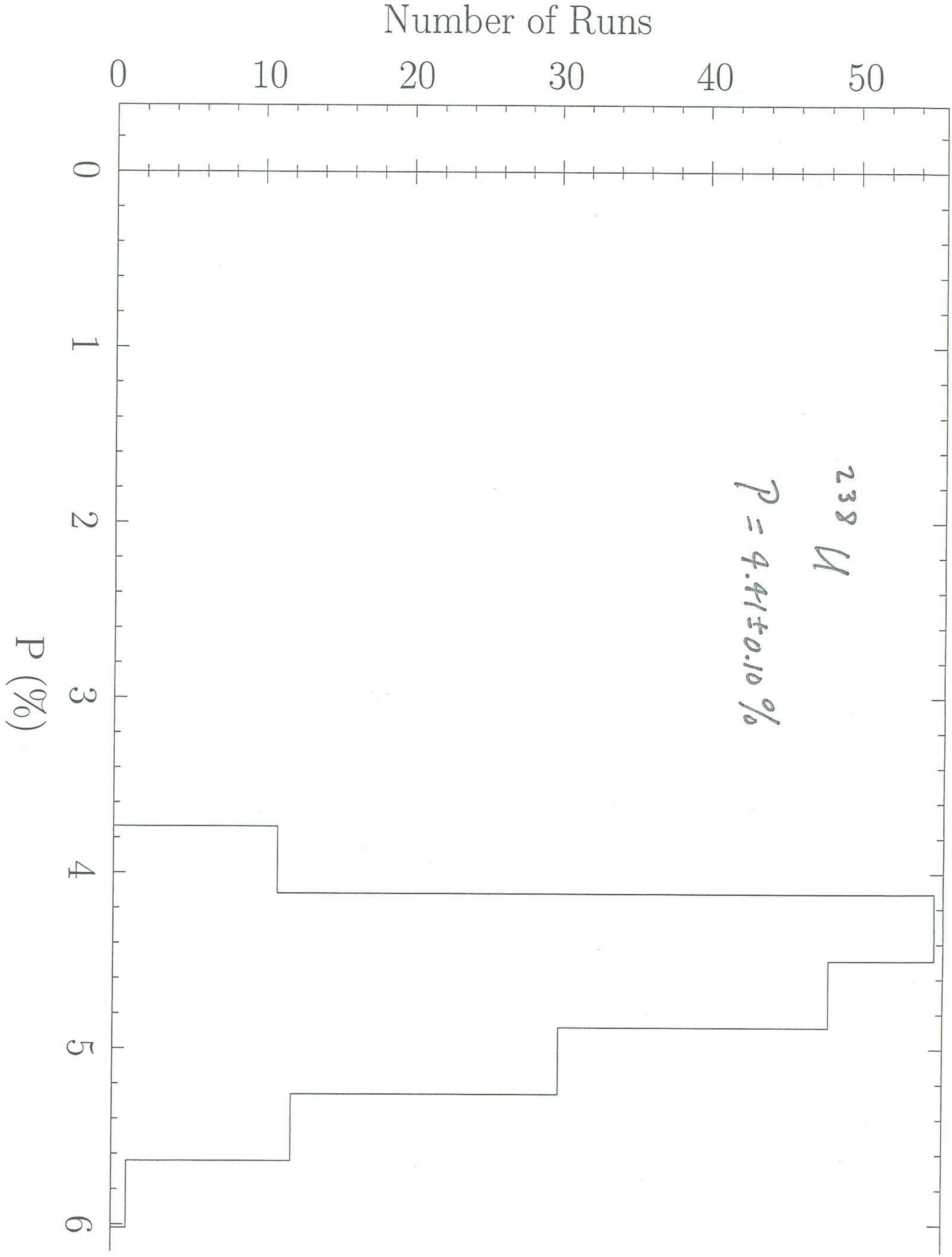





Tungsten spallation target with water moderator
Pulsed epithermal neutron beam (0.5-2000 eV)
0 m
5 m
6 m
8 m
60 m
62 m
3He
4He
Flux Monitor
Polarized Proton Target
Spin Flipper
Evacuated spin transport pipes
Capture Target
24 gamma detector array
139La target
6Li Neutron Detector



Counts
1.5×10^6
2.0×10^6
2.5×10^6
3.0×10^6
62.5
63.0
63.5
64.0
En (eV)



Number of Runs
0
10
20
30
40
50
0
1
2
3
4
5
6
P (%)
238 U
P = 4.41±0.10 %

1. PNC asymmetry for mixing with several s-levels

The observed asymmetry for a given p-wave level μ has contributions from many s-wave levels ν, and the PNC asymmetry is

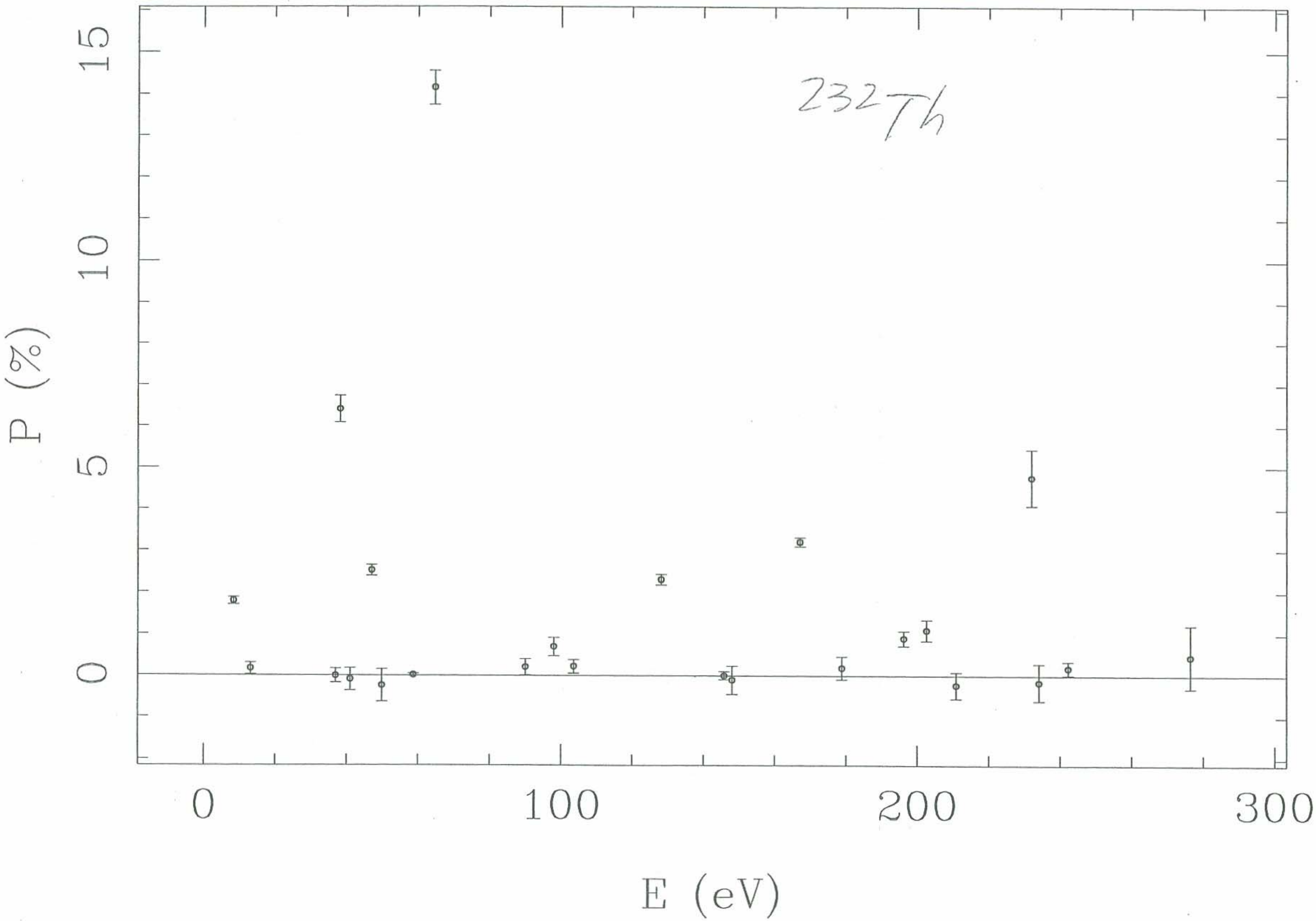
$$p_\mu = 2 \sum_\nu \frac{V_{\nu\mu}}{E_\nu - E_\mu} \frac{\Gamma_{\nu n}^{1/2}}{\Gamma_{\mu n}^{1/2}}, \tag{1}$$

which can be rewritten as

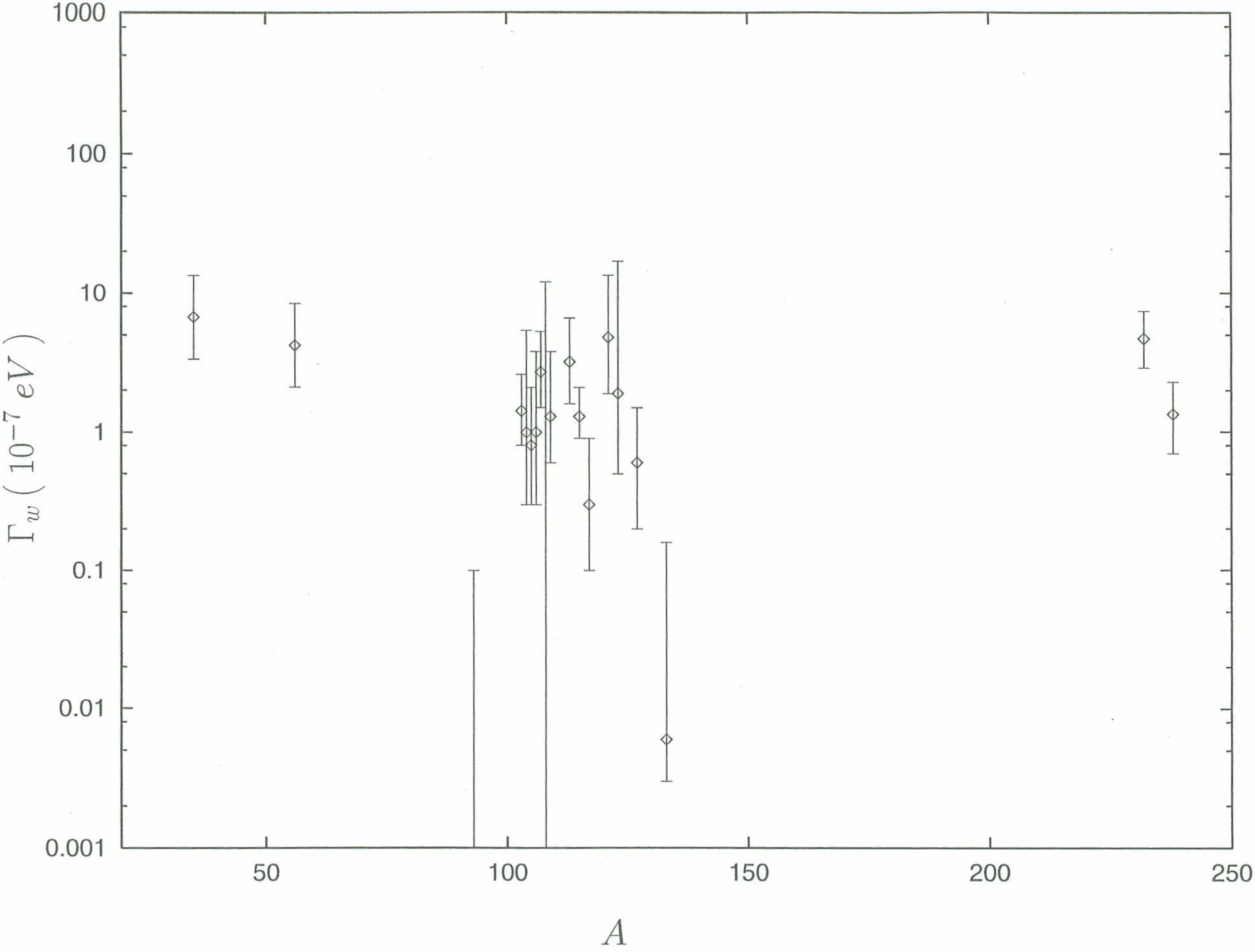
$$p_\mu = \sum_\nu A_{\nu\mu} V_{\nu\mu}, \tag{2}$$

with $A_{\nu\mu} = 2(\Gamma_{\nu n}/\Gamma_{\mu n})^{1/2}/(E_\nu - E_\mu)$, where $(\Gamma_{\mu n})^{1/2} \equiv g_\mu$ and $(\Gamma_{\nu n})^{1/2} \equiv g_\nu$ are the neutron decay amplitudes of levels μ and ν, E_μ and E_ν are the corresponding resonance energies, and $V_{\nu\mu}$ is the matrix element of the PNC interaction between levels μ and ν. The $A_{\nu\mu}$ are known since they are functions of the known neutron widths and the resonance energies. There are many more unknown $V_{\nu\mu}$ than there are equations and therefore the individual mixing matrix elements $V_{\nu\mu}$ cannot be determined.

We assumed that the $V_{\nu\mu}$ were independent Gaussian random variables with mean zero and variance M_J^2. The variance M_J^2 is the weak interaction mean-squared matrix element. Since each p_μ is the sum of the variables $V_{\nu\mu}$ with constant coefficients, each p_μ is a Gaussian random variable with variance $M_J^2 A_\mu^2$, where $A_\mu^2 = \sum_\nu A_{\nu\mu}^2$.



232Th
P (%)
0
5
10
15
0
100
200
300
E (eV)


1000
100
10
1
0.1
0.01
0.001
Γ_w (10^{-7} eV)
50
100
150
200
250
A