Measurement of the α Energy Spectrum from 8B and Determination of the Shape of the ν Spectrum

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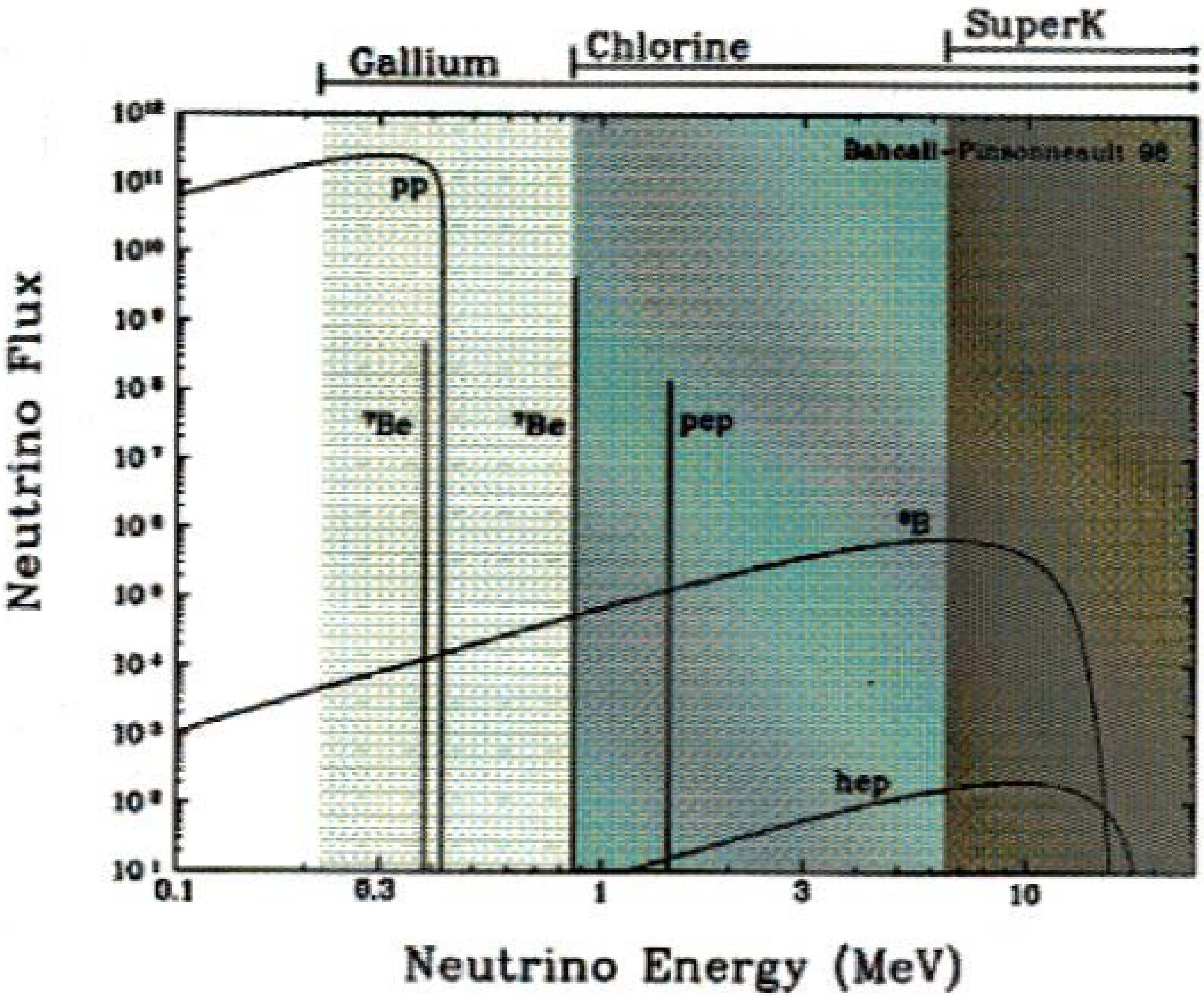
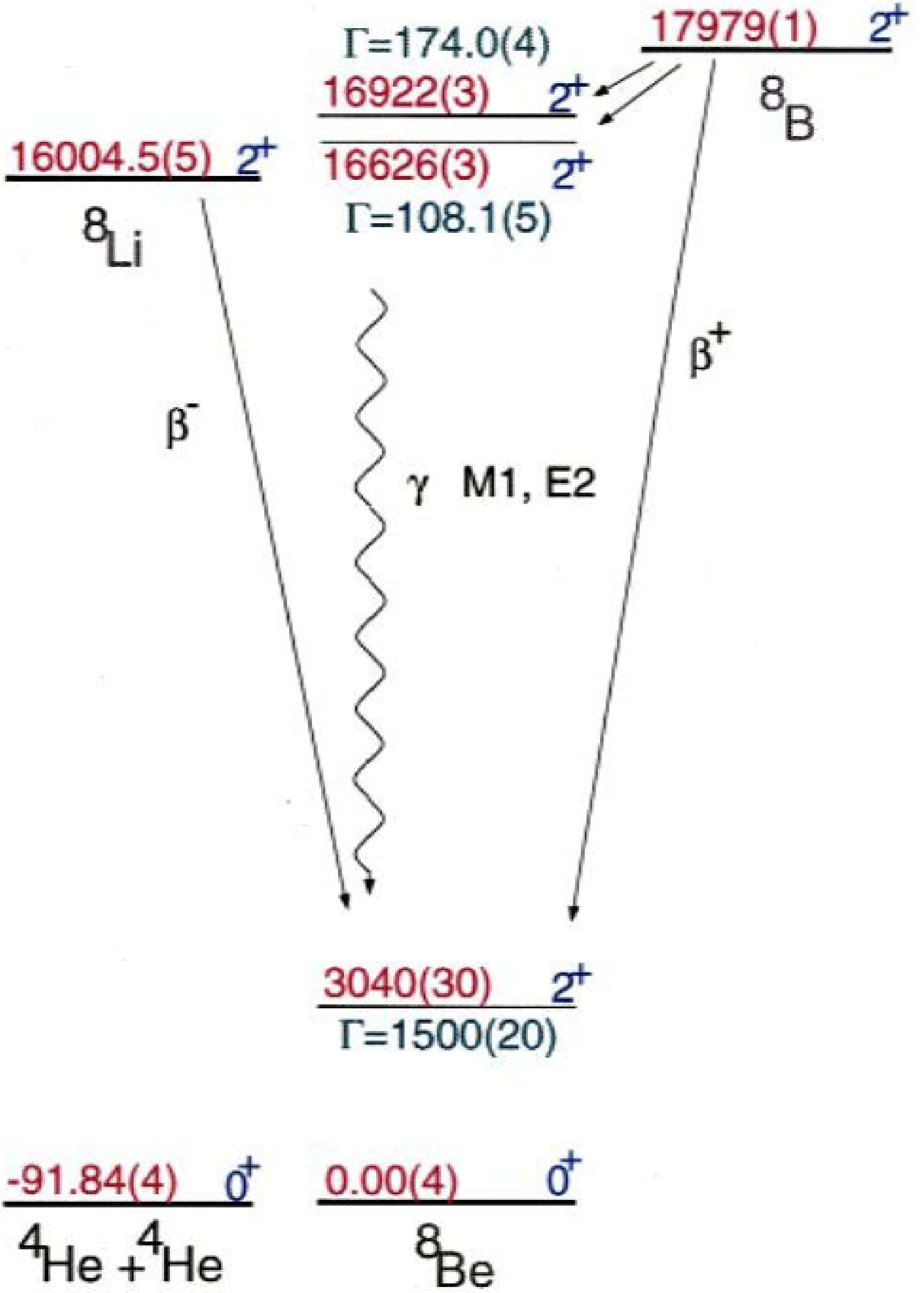
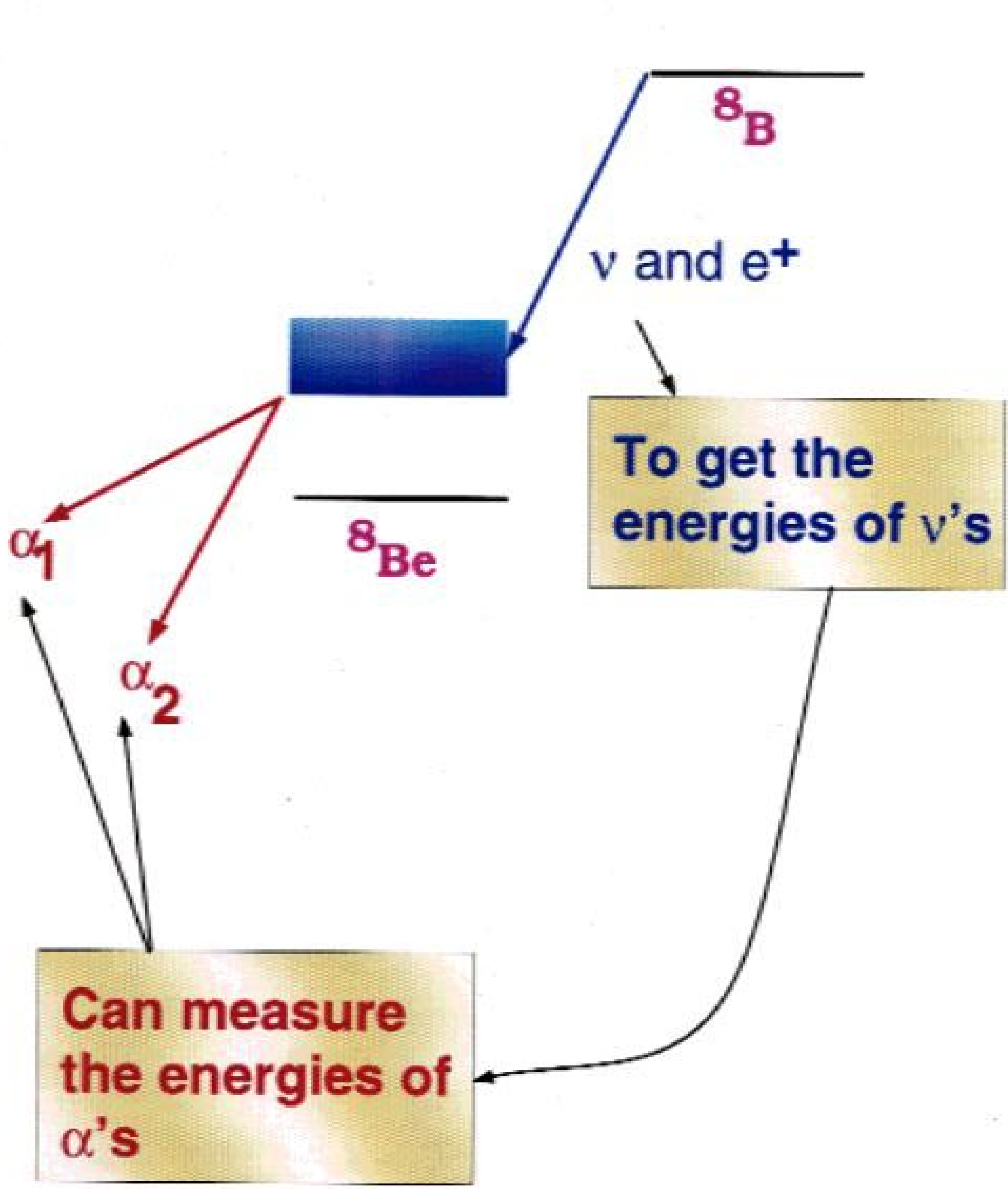
SuperK, SNO, ICARUS... will look at distortions of the 8B ν spectrum




17979(1) 2+
8B
Γ=174.0(4)
16922(3) 2+
16626(3) 2+
Γ=108.1(5)
16004.5(5) 2+
8Li
β-
β+
γ M1, E2
3040(30) 2+
Γ=1500(20)
-91.84(4) 0+
4He + 4He
0.00(4) 0+
8Be

High-energy ν's come from ^8B



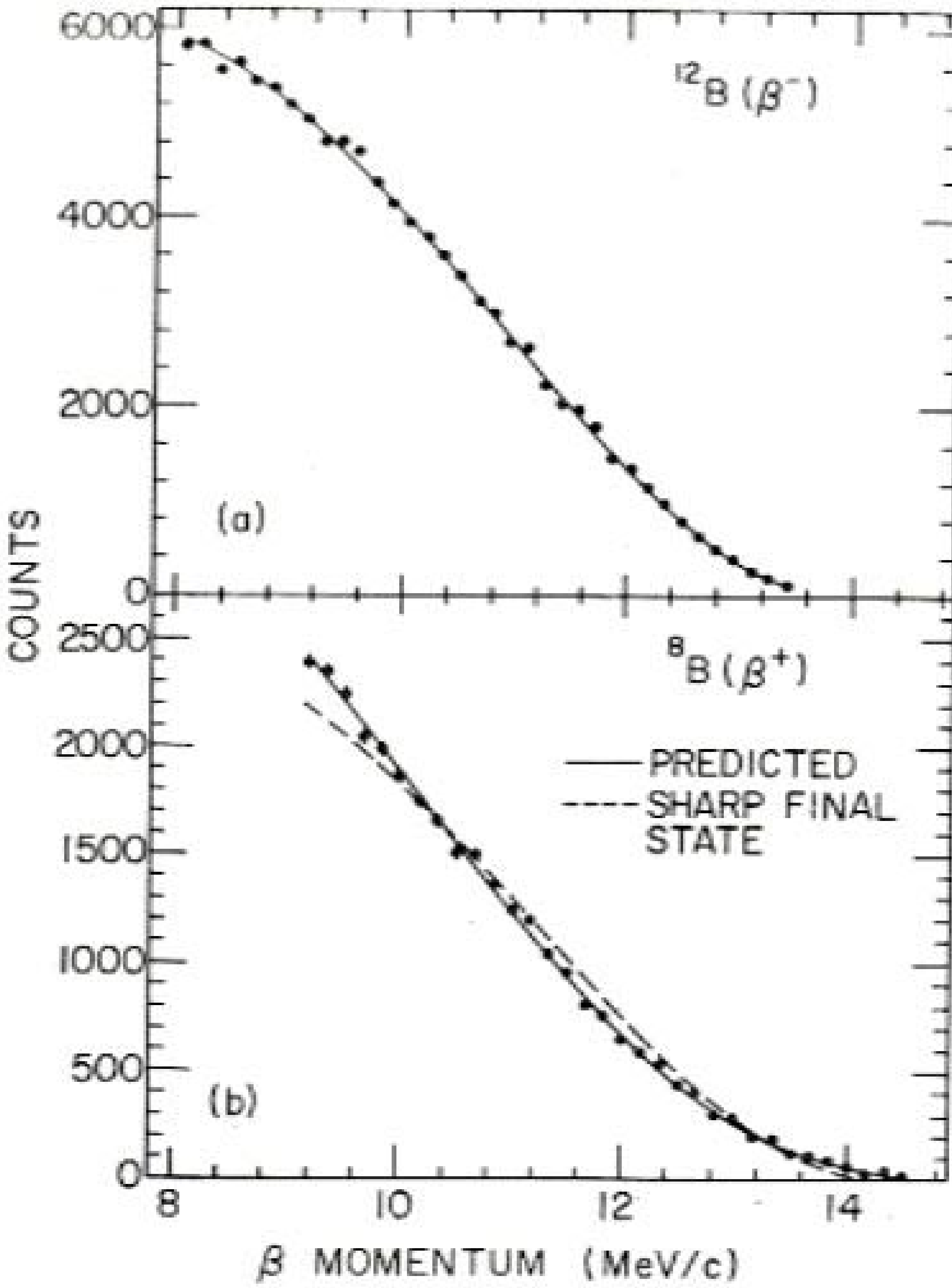


FIG. 2. Measured β momentum spectra. The error bars, where not shown, are smaller than the size of the points. (a) The β^- spectrum of ^{12}B used to calibrate the spectrometer. A fit is performed to obtain the calibration parameter R_0 (see Ref. 15). (b) The β^+ spectrum of ^{8}B. The solid line is the predicted spectrum which gives the best agreement (see Table I). The dashed line shows a normal allowed spectrum for a hypothetical sharp final state at $E_x \approx 3$ MeV in ^{8}Be.

when both recoil order terms and radiative corrections are

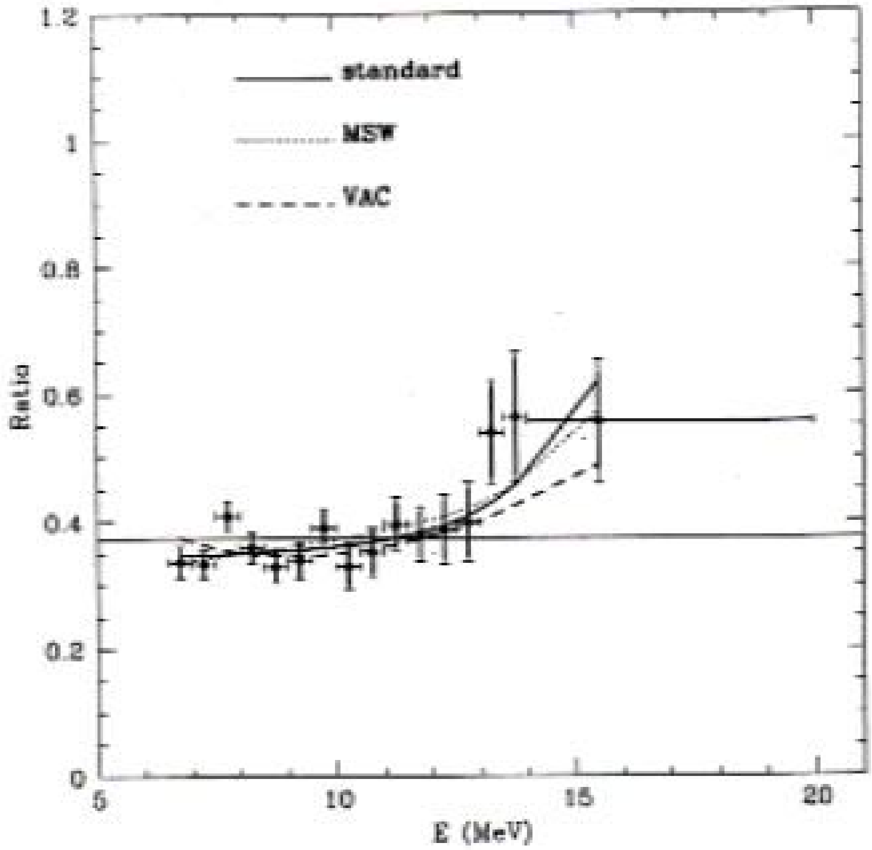


Fig. 1. Combined ^{8}B plus *hep* energy spectrum. The total flux of *hep* neutrinos was varied to obtain the best-fit for each scenario. The figure shows the Ratio of the measured [1] to the calculated number of events with electron recoil energy, E. The measured points were reported by the SuperKamiokande collaboration at Neutrino 98[1]. The calculated curves are global fits to all of the data, the chlorine [20], GALLEX [21], SAGE [22], and SuperKamiokande [1] total event rates, the Superkamiokande [1] energy spectrum, and the SuperKamiokande [1] Day-Night asymmetry. The calculations follow the precepts of BKS98 [23] for the best-fit global solutions for a standard 'no-oscillation' energy spectrum, as well as MSW and vacuum neutrino oscillation solutions. The horizontal line at Ratio = 0.37 represents the ratio of the total event rate measured by SuperKamiokande to the predicted event rate[9] with no oscillations and only ^{8}B neutrinos.

For vacuum oscillations, the value of α corresponding to the global χ^2_{min} does not depend strongly on Δm^2 and $\sin^2 2\theta$ within the acceptable region. The improvement in the C.L. for acceptance increases from 6% to 15% when an arbitrary *hep* flux is considered.

The best-fit global MSW solution with an arbitrary *hep* flux has neutrino parameters given by $\Delta m^2 = 5.4 \times 10^{-6}\mathrm{eV}^2$ and $\sin^2 2\theta = 5.0 \times 10^{-3}$, which

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hep-ph/9904463

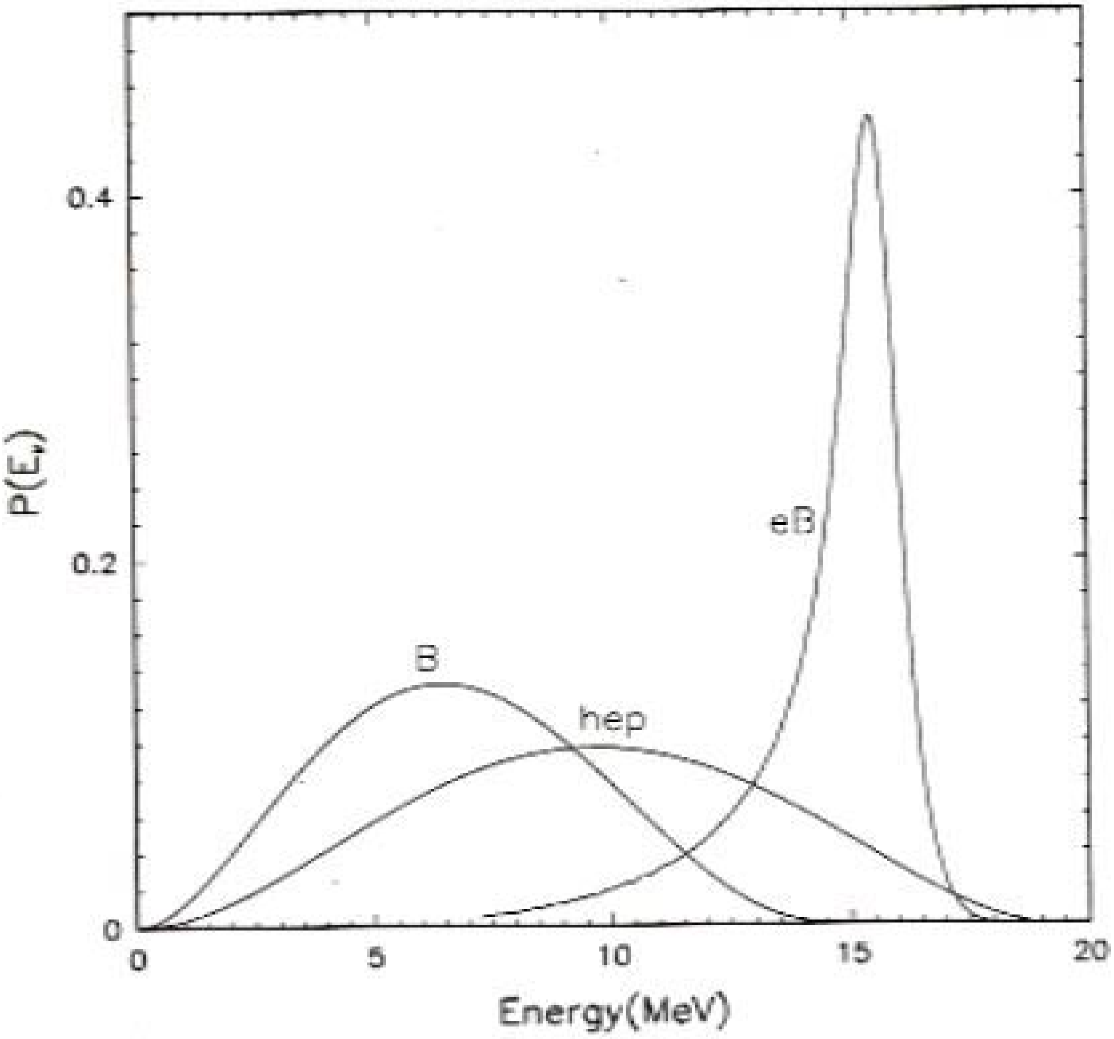

Figure 1: Normalized energy spectra of ^8B, hep and eB neutrinos.

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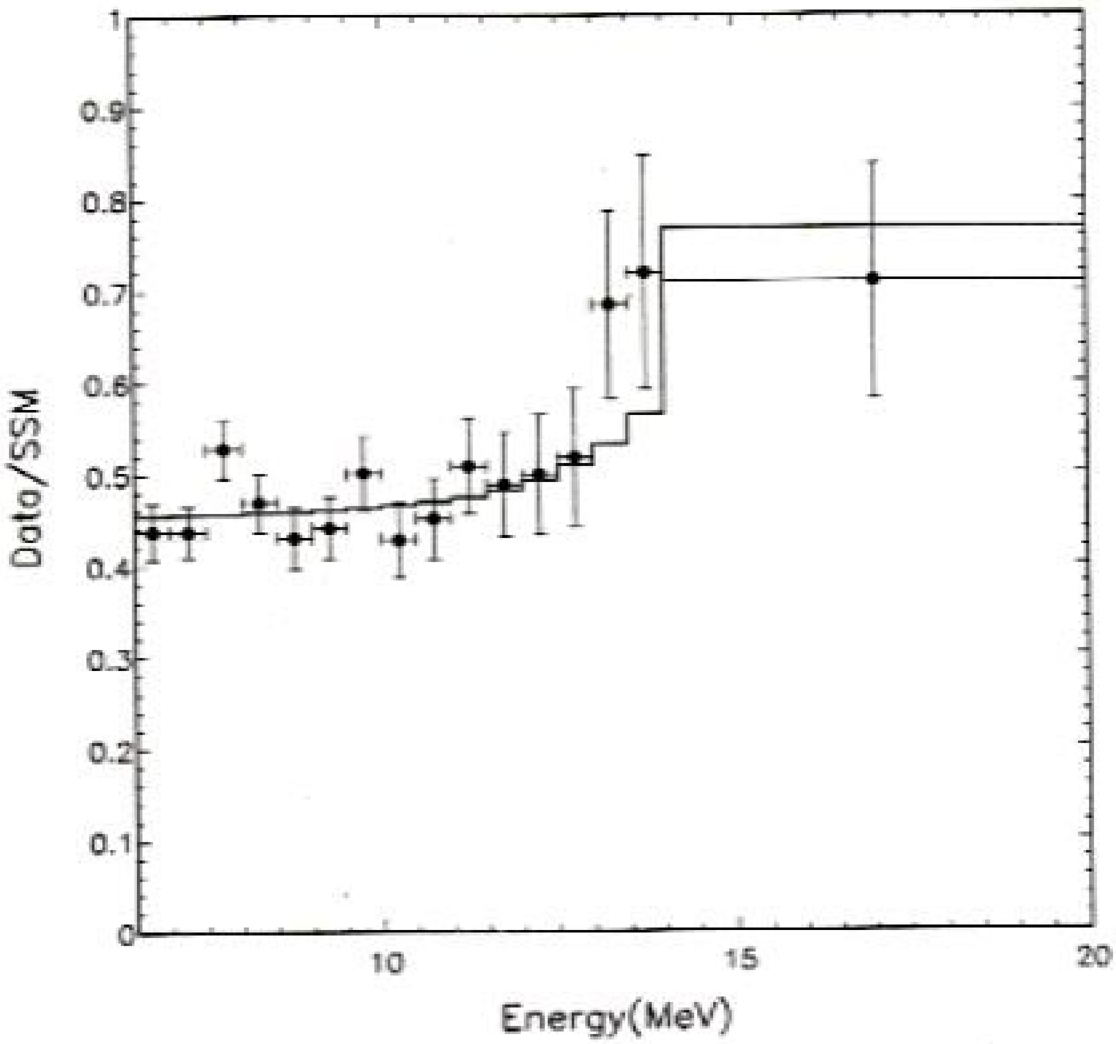


Figure 3: Observed electron energy spectrum normalized to SSM expectations (dots). The solid line is the prediction for $\Phi_{hep} = 1.1 \times 10^4\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$.

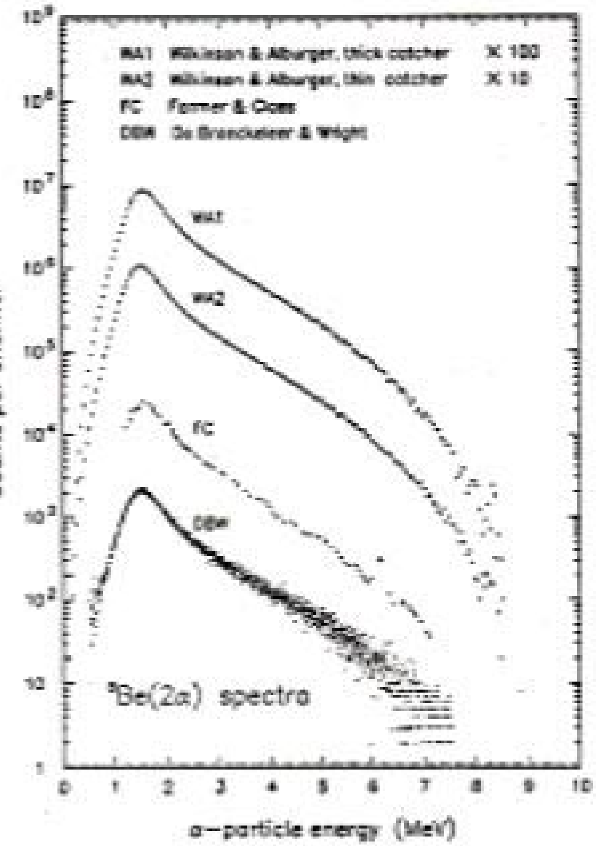


FIG. 2. Compilation of ^{8}Be(2α) decay data. The bin widths are different for different experiments. The data WA1 and WA2 are shifted on the vertical axis.

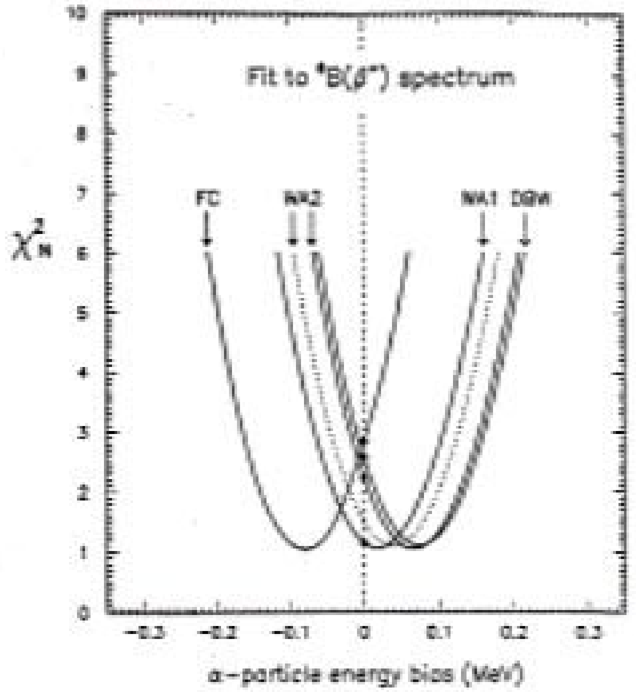


FIG. 3. Values of the normalized chi square in a fit to the experimental positron spectrum, using the input alpha decay data of Fig. 2, with an allowance for a possible bias, b, in the detected α particle energy. The curves are remarkably similar, modulo a constant bias.

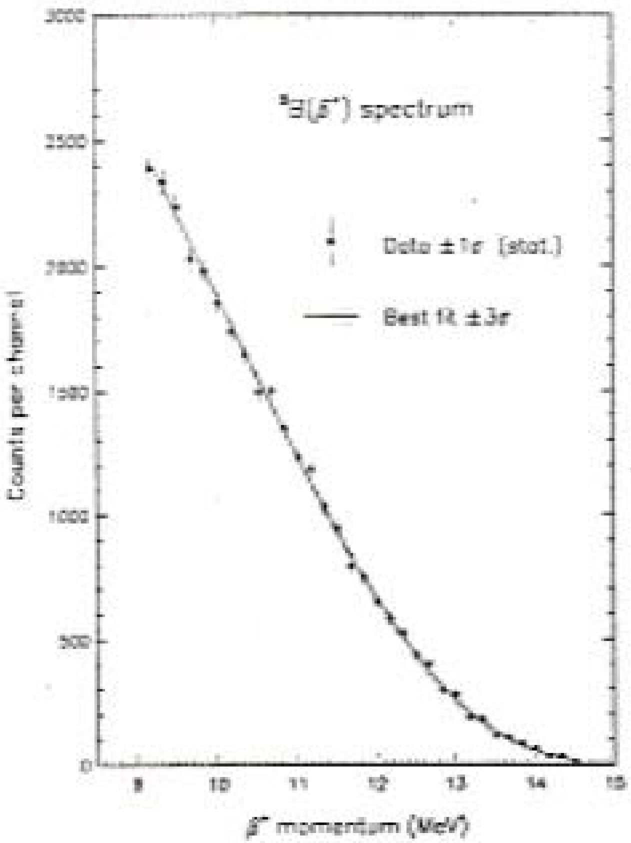


FIG. 4. Experimental data on the positron spectrum, together with the best fit and the $\pm 3\sigma$ fits, corresponding to WA1 alpha decay data within the bias range $b = 0.025 \pm 0.056$ MeV.

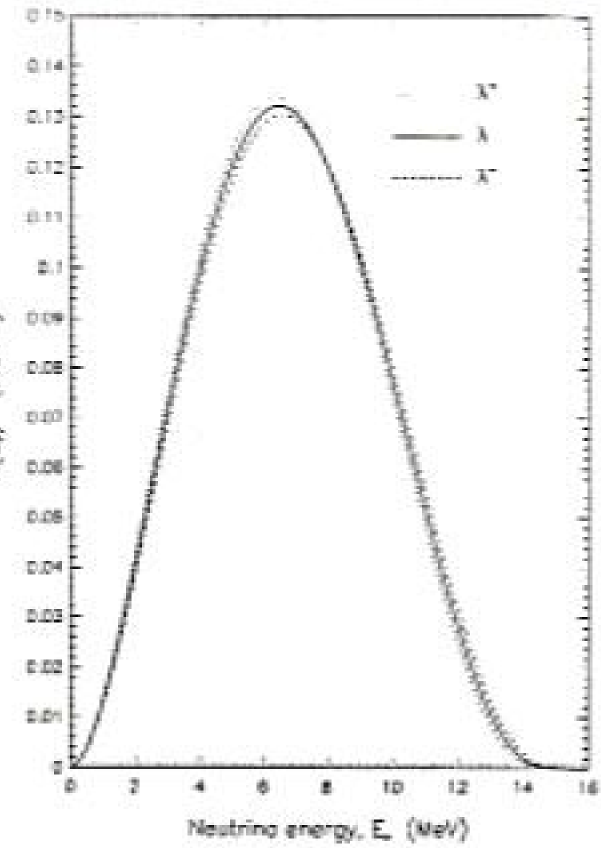
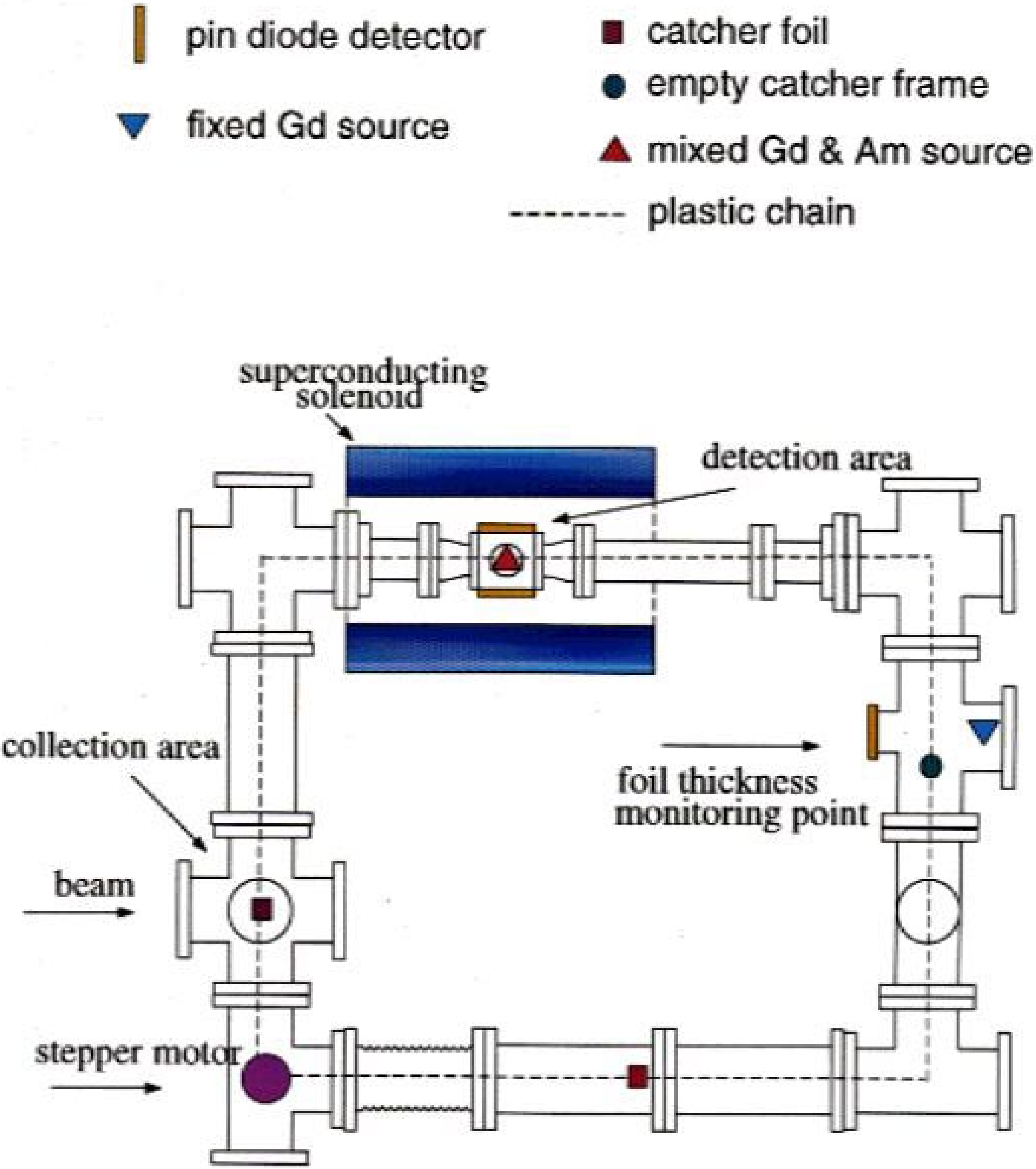
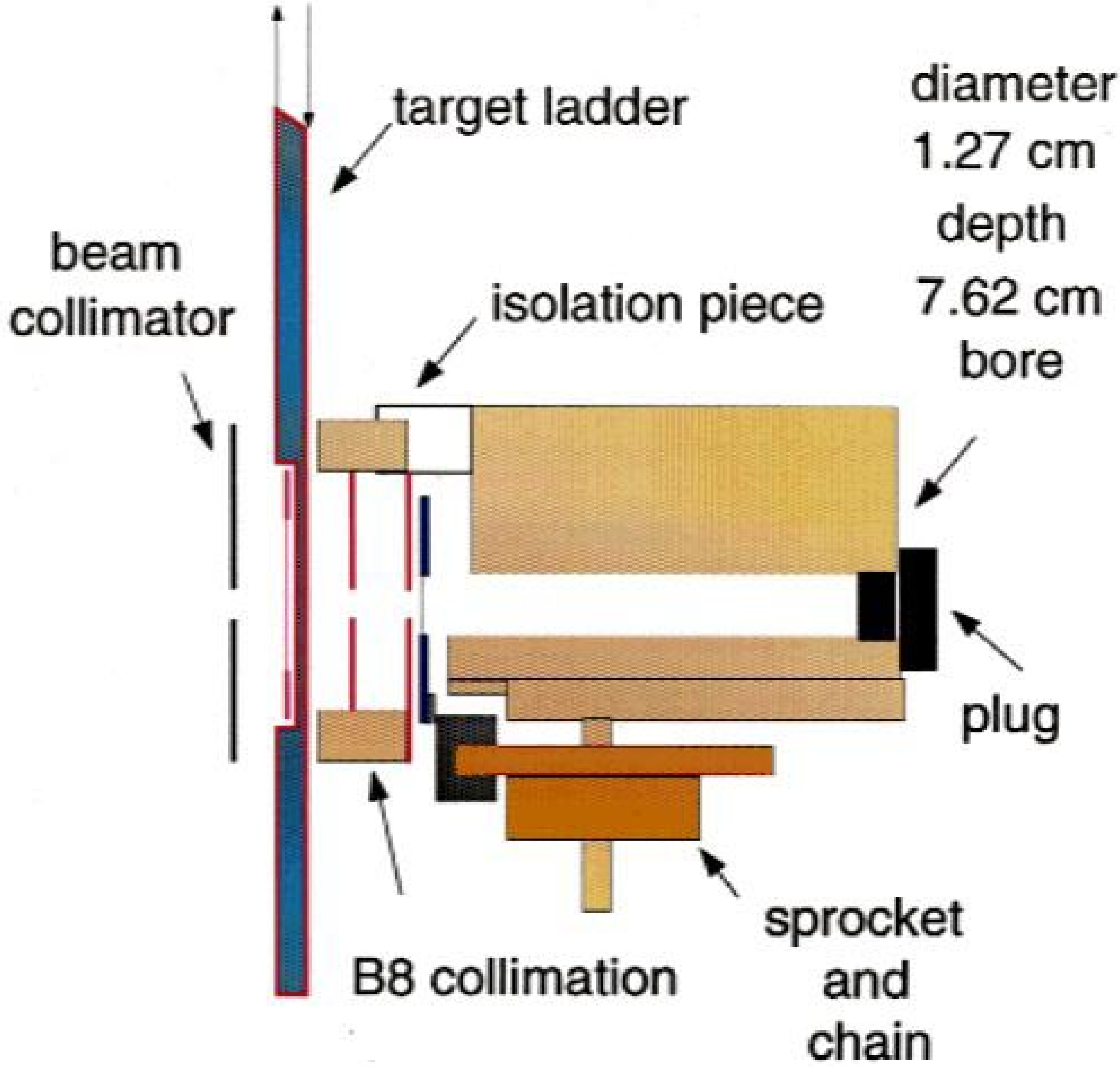
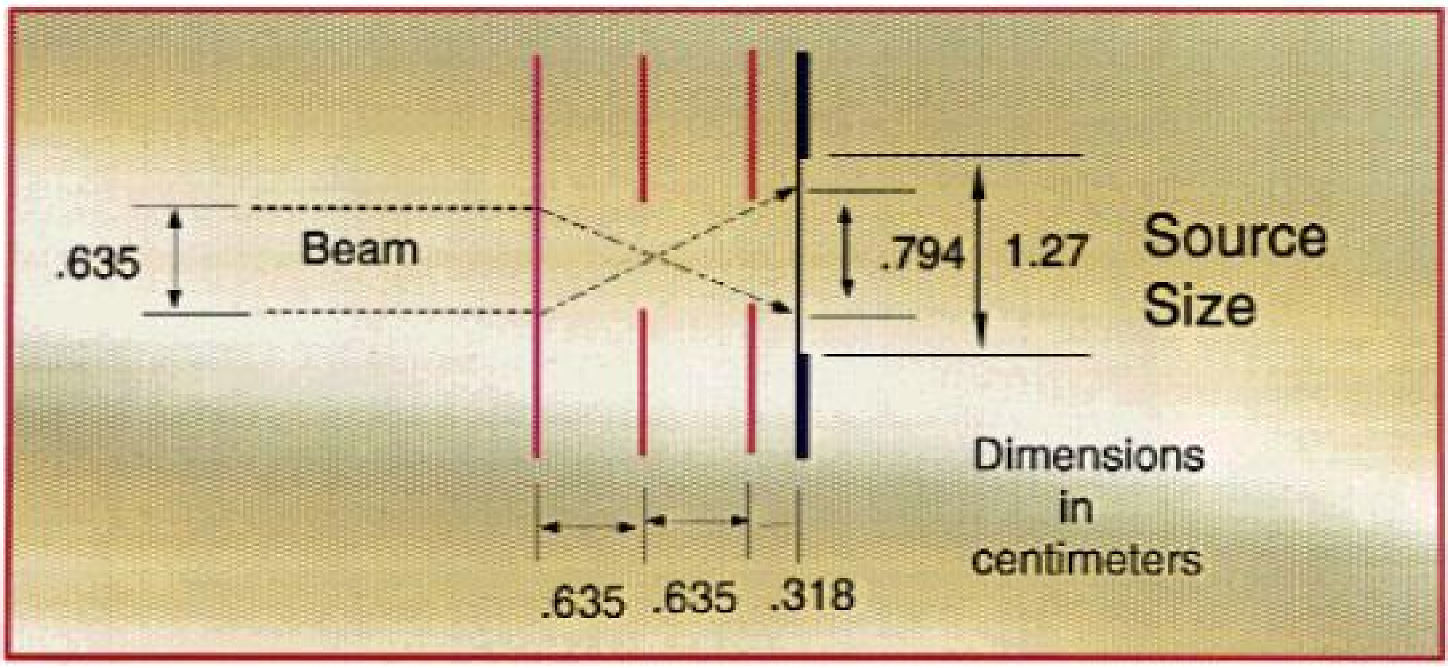


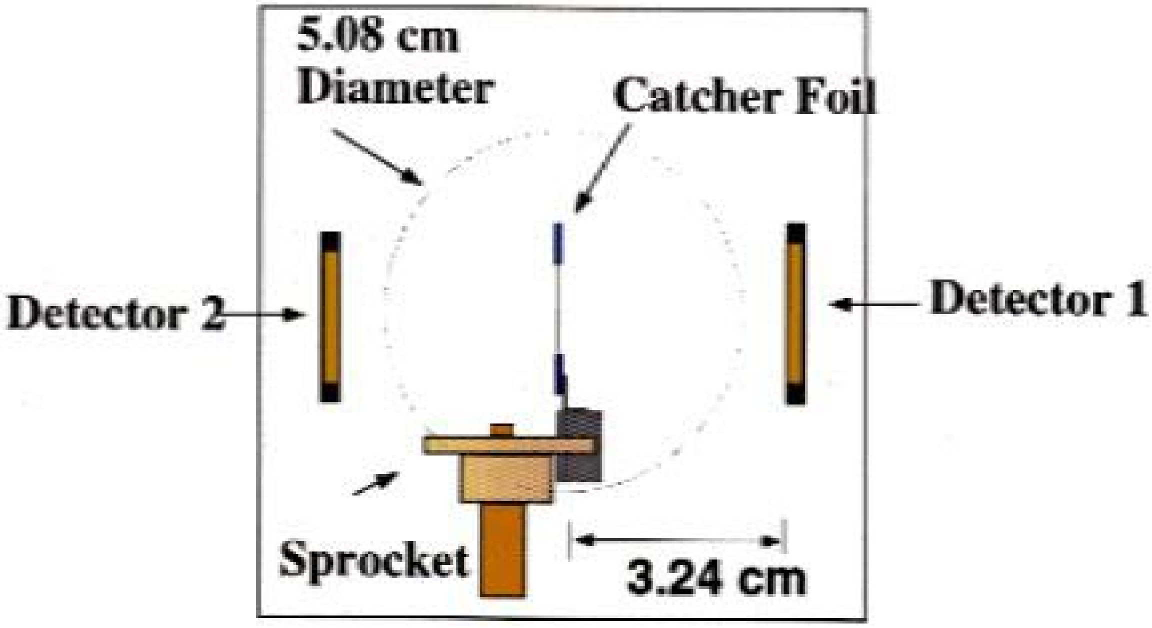
FIG. 5. The best-estimate (standard) ^{8}B neutrino spectrum λ, together with the spectra $\lambda^{\pm}$ allowed by the maximum ($\pm 3\sigma$) theoretical and experimental uncertainties.



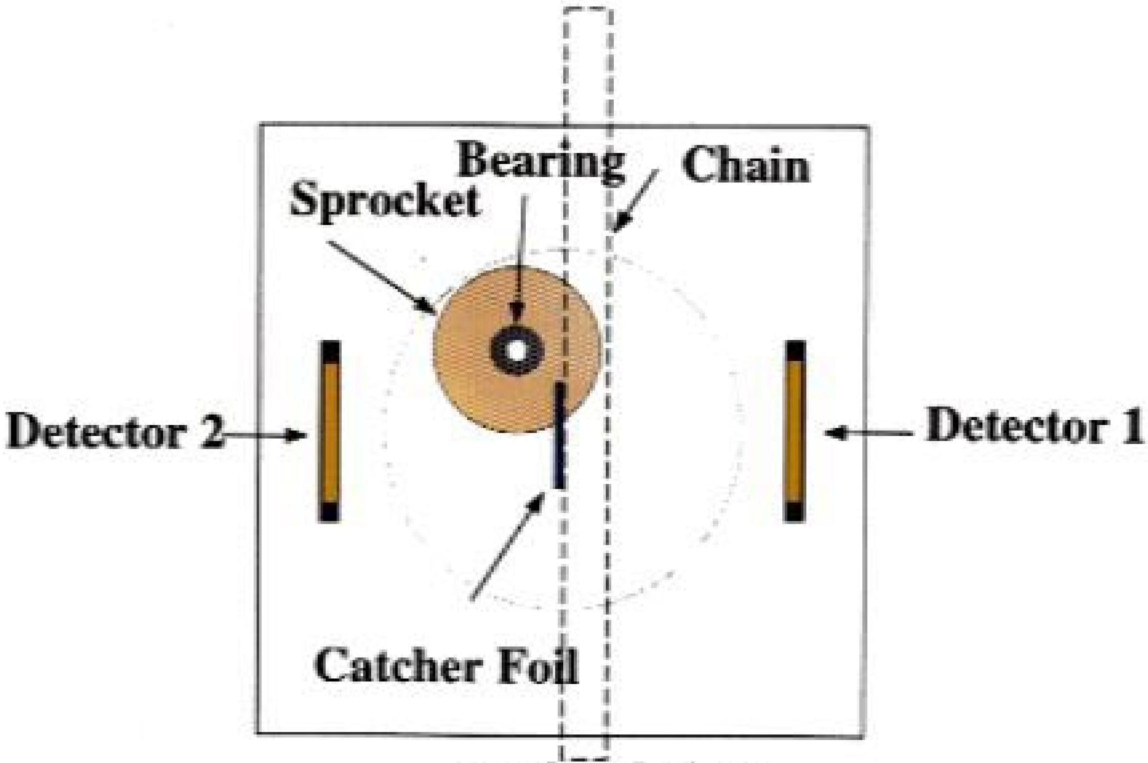
pin diode detector
fixed Gd source
catcher foil
empty catcher frame
mixed Gd & Am source
plastic chain
superconducting solenoid
detection area
collection area
foil thickness monitoring point
beam
stepper motor


target ladder
diameter
1.27 cm
depth
7.62 cm
bore
beam
collimator
isolation piece
plug
sprocket
and
chain
B8 collimation

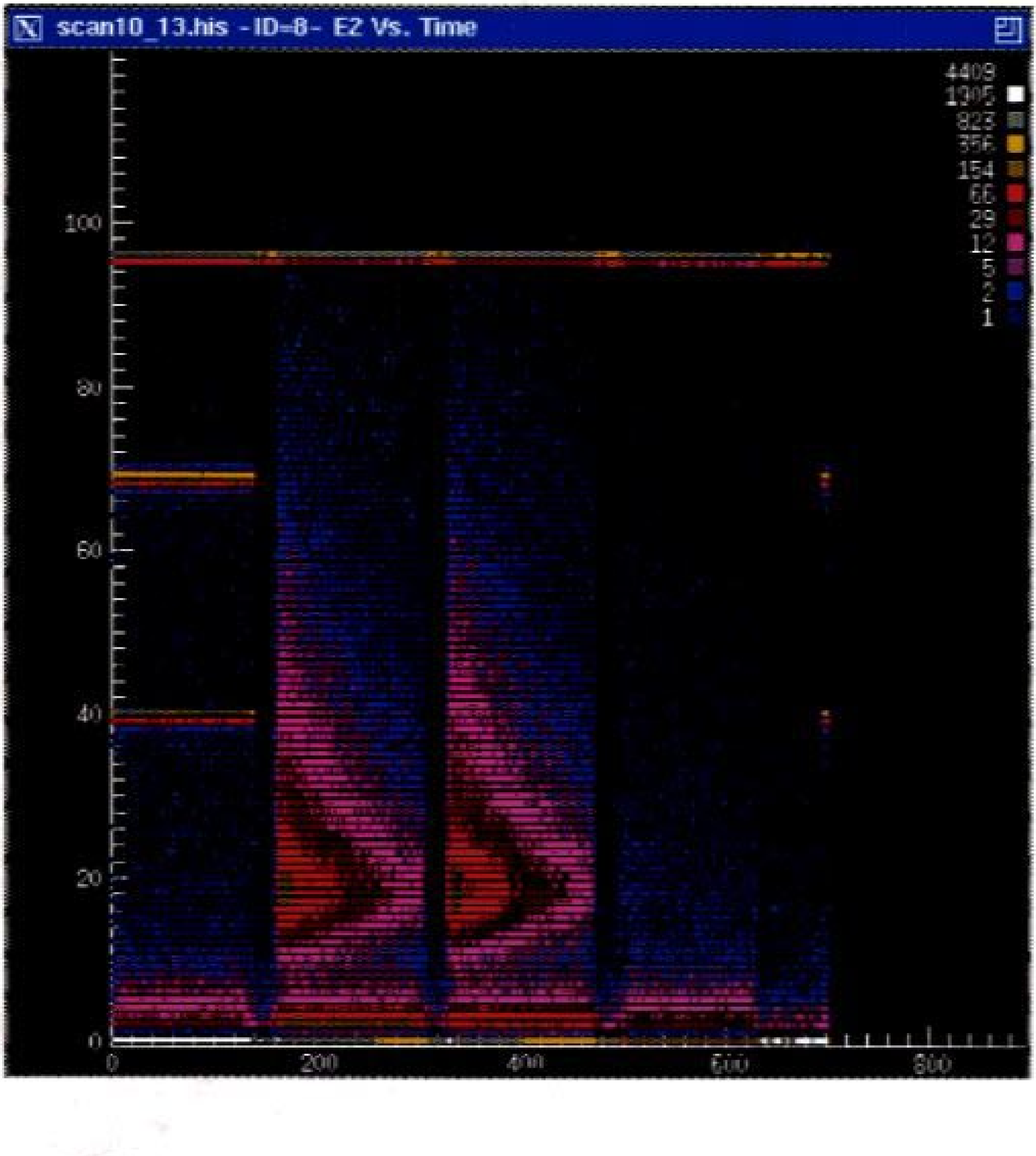

.635
Beam
.794
1.27
Source
Size
Dimensions
in
centimeters
.635
.635
.318



side view



overhead view


scan10_13.his - ID=8- E2 Vs. Time
4409
1305
823
356
154
66
29
12
5
2
1
100
80
60
40
20
0
0
200
400
600
800

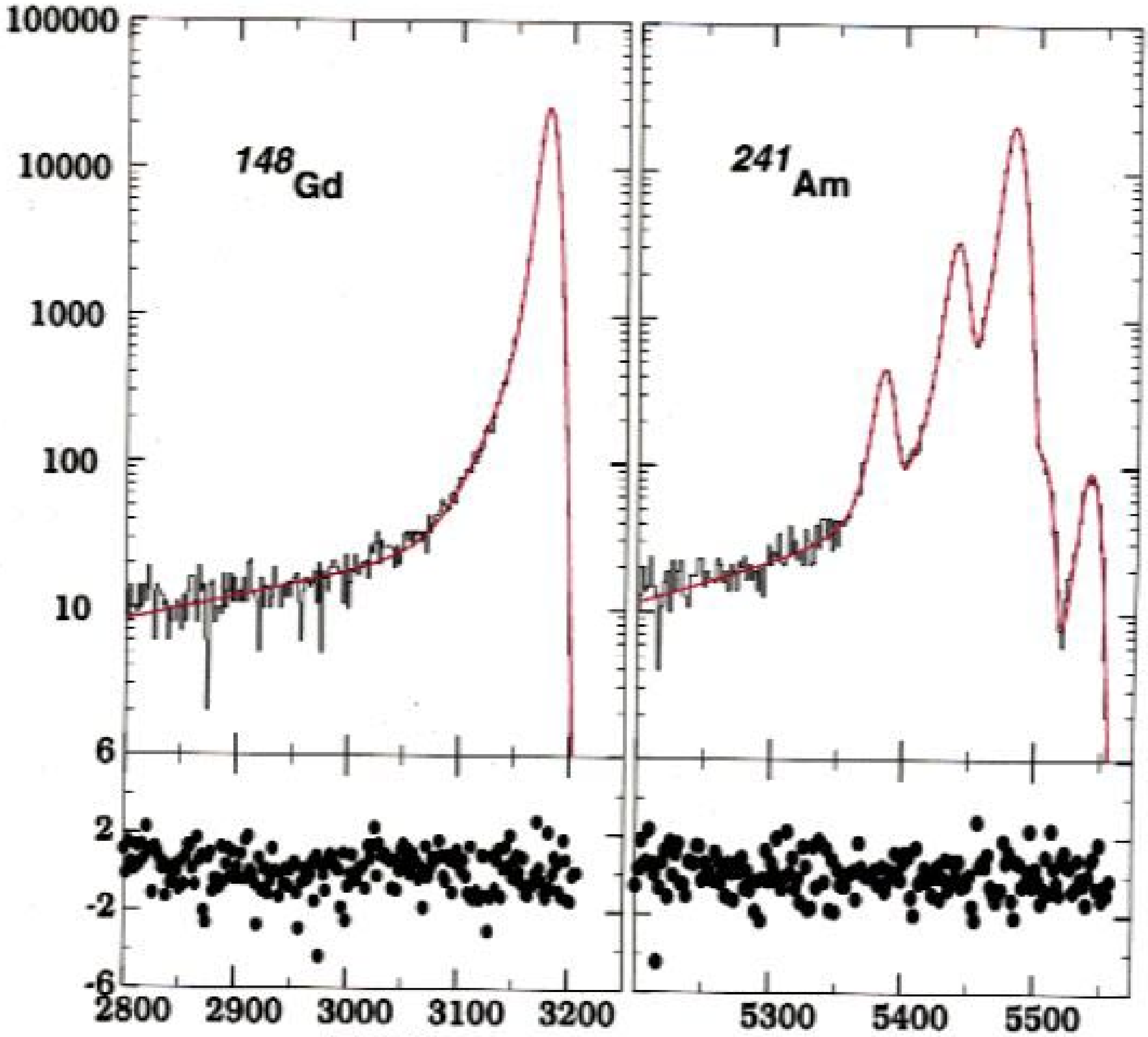
Advantages of our Setup:

1) Detectors completely blind to β's
   - a) allowed us to count α-α coincidences without β's.
   - b) cleared low-energy β backgrounds.
   - c) avoided β summing.

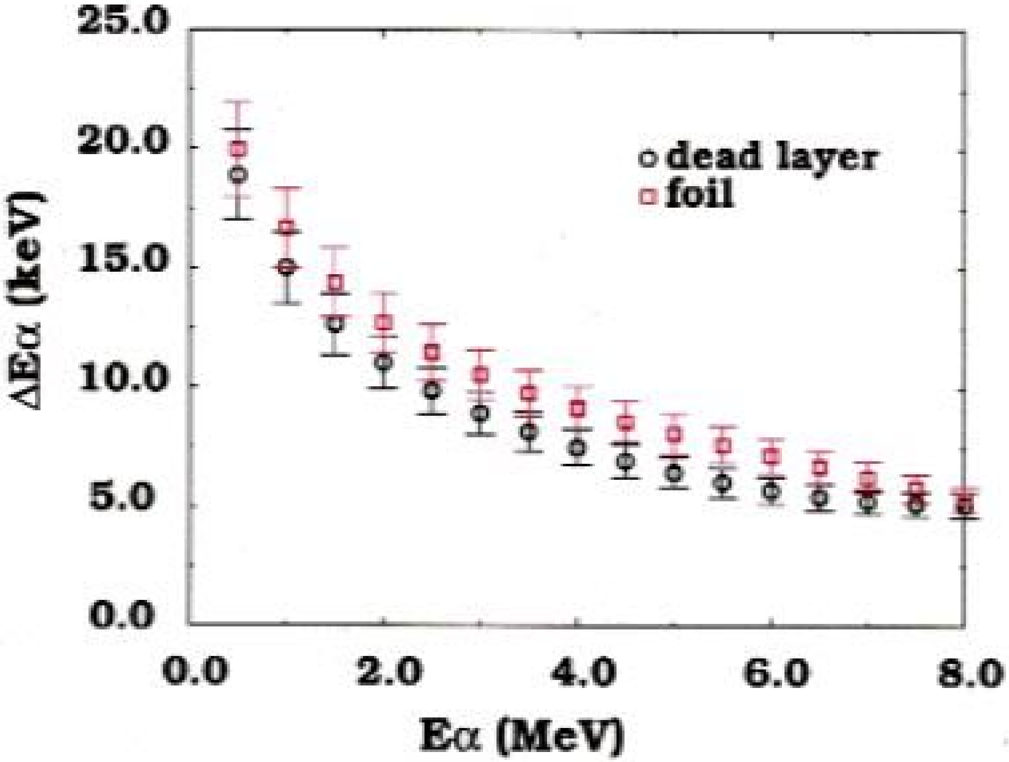
2) Continuous α-energy calibration.

3) Continuous foil-thickness monitoring.

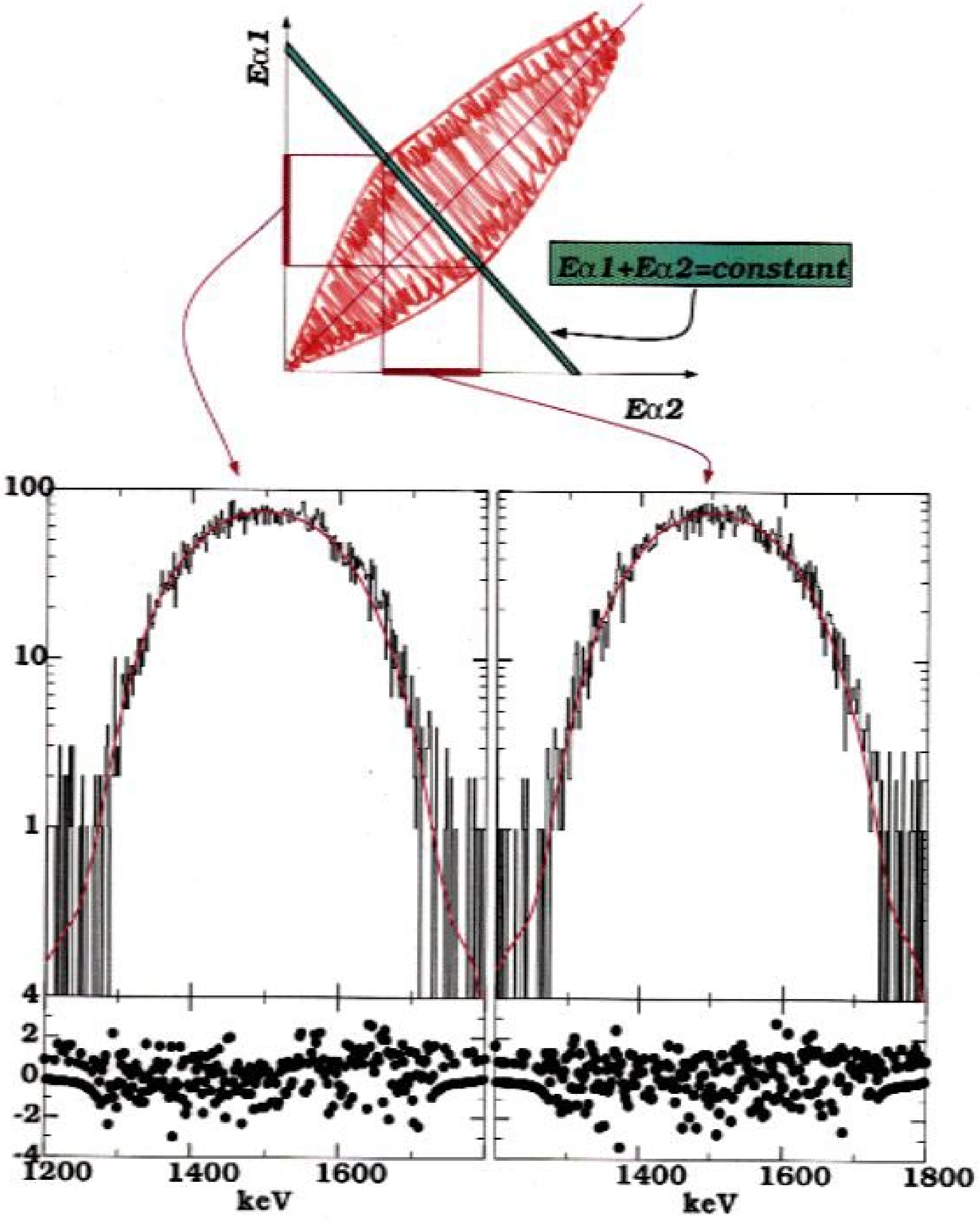
Energy calibrations are taken within each cycle in both detectors with mixed (148Gd+241Am) sources



We measured detectors dead layers and calculated energy loss in the dead layers plus foils

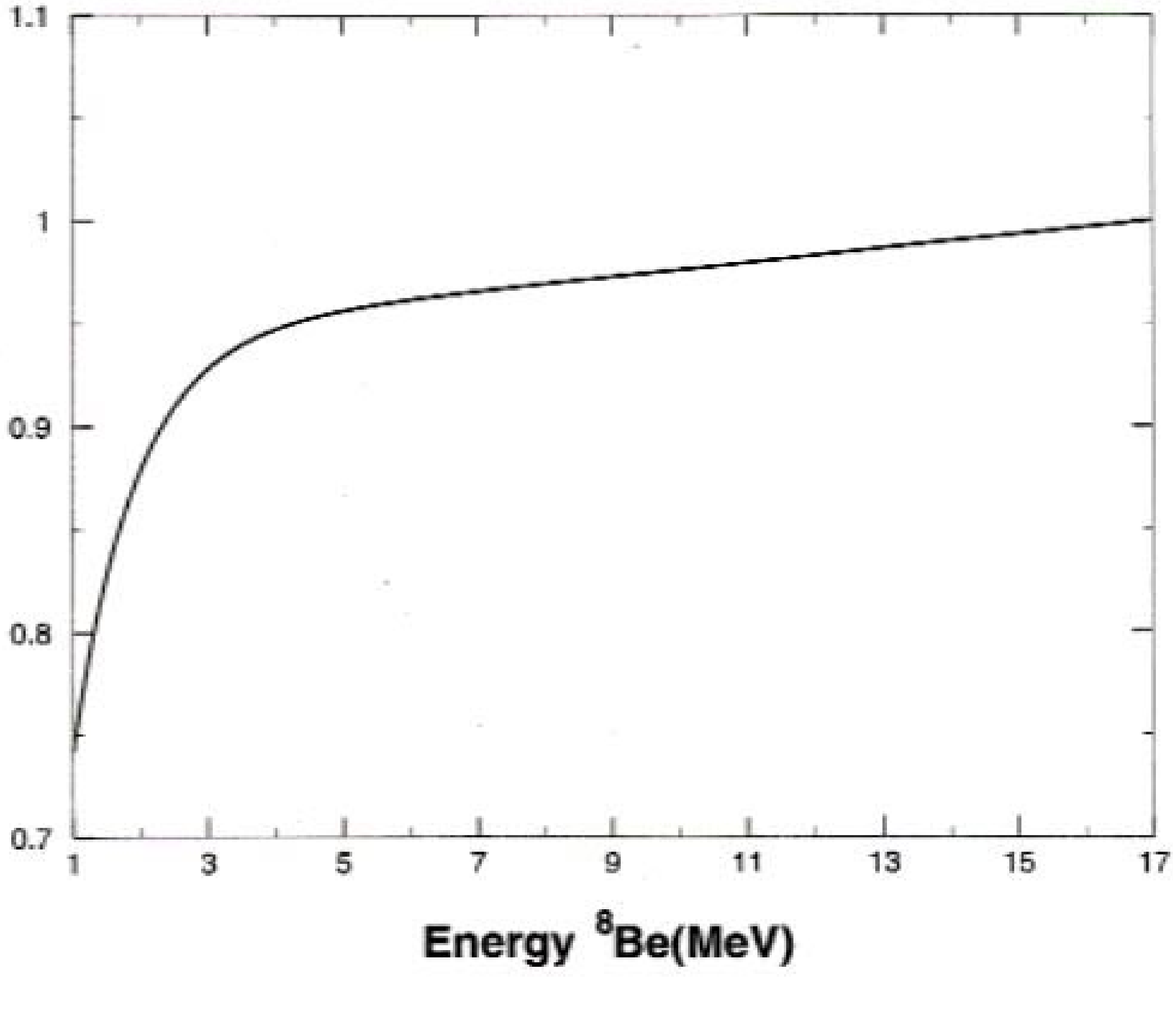


We corrected the 8B spectrum event-by-event for energy loss.



Eα1
Eα1+Eα2=constant
Eα2
100
10
1
4
2
0
-2
-4
1200
1400
1600
keV
1400
1600
1800
keV

Efficiency for ^{8}B



The problem: $\frac{-\hbar^2}{2m}\frac{d^2\phi}{dr^2} + V(r)\,\phi = E\,\phi$ (1)

Instead, we solve: $\frac{-\hbar^2}{2m}\frac{d^2 X_\lambda}{dr^2} + V\,X_\lambda = E_\lambda X_\lambda$ (2)

$$\left(\frac{dX_\lambda}{dr} + b\,X_\lambda\right)_{r=a} = 0$$

The solutions to the real problem can be expanded in terms of the X_λ's :

$$\phi = \sum_\lambda A_\lambda X_\lambda \qquad\qquad A_\lambda = \int_0^a X_\lambda \phi \, dr$$

From (1) and (2) :

$$\frac{\hbar^2}{2m}\left(\phi\frac{dX_\lambda}{dr} - X_\lambda\frac{d\phi}{dr}\right) = \left(E - E_\lambda\right)\, A_\lambda$$

$$\phi(r) = G(r,a)\left\{\phi'(a) + b\,\phi(a)\right\}$$

$$\Downarrow$$

$$\frac{\hbar^2}{2m}\sum_\lambda \frac{X_\lambda(r)\,X_\lambda(a)}{E_\lambda - E}$$

define "reduced width" : $\gamma_\lambda^2 = \frac{\hbar^2}{2m}\left[X_\lambda(a)\right]^2$

"R" : $R = \sum_\lambda \frac{\gamma_\lambda^2}{E_\lambda - E}$

To calculate cross section:

$$\phi_{outside} = I - U\,O \qquad \begin{cases} I = \dfrac{e^{-ikr}}{\sqrt{4\pi v}} \\ O = \dfrac{e^{+ikr}}{\sqrt{4\pi v}} \end{cases}$$

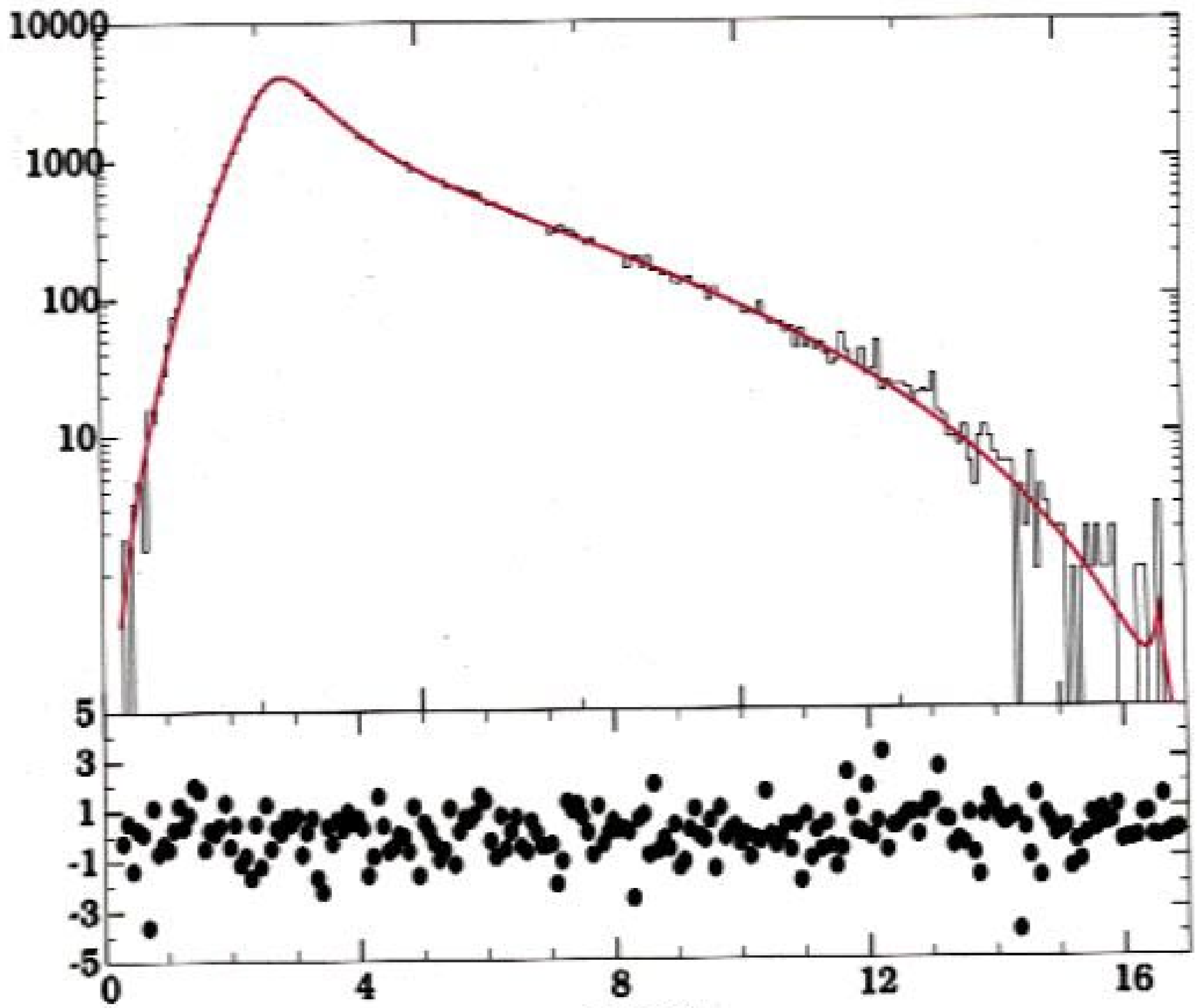
$$\sigma = \frac{\pi}{k^2} \left| 1 - U \right|^2$$

To get U we take the logarithmic derivative and equate it to the value inside:

$$U = e^{-2ika} \frac{1 - bR + ikR}{1 - bR - ikR}$$

$$\Rightarrow \sigma = \frac{\pi}{k^2} \left| 2 \sin ka \; e^{ika} - \frac{2k\gamma_0^2}{(E_0 - E) - (b + ik)\gamma_0^2} \right|^2$$

8B energy spectrum



R-matrix fit to the data

$$N(E) = \left(\frac{Nt}{6166\pi}\right) f_\beta P_1 \left(\frac{\left|\sum_{j=1}^{n} \frac{M_{Fj}\gamma_j}{E_j - E}\right|^2 + \left|\sum_{j=1}^{n} \frac{M_{Gj}\gamma_j}{E_j - E}\right|^2}{\left|1 - (S_2 - B_2 + iP_2)\sum_{j=1}^{n} \frac{\gamma_j^2}{E_j - E}\right|^2} \right) \quad (1)$$

The 16 MeV doublet was assumed to be a near equal mixture of $T = 0$, and $T = 1$. Let ψ_a and ψ_b be two wavefunctions with isospin 0 and 1, respectively:

$$\psi_2 = \alpha\psi_a + \beta\psi_b \quad , \quad \psi_3 = \beta\psi_a - \alpha\psi_b$$

. The values of α and β were extracted from the widths:

$$\alpha^2 = \frac{\Gamma_2}{\Gamma_0} \quad , \quad \beta^2 = \frac{\Gamma_3}{\Gamma_0} \quad , \quad \Gamma_0 = \Gamma_2 + \Gamma_3. \quad (2)$$

The relation between the reduced width γ_i and the width Γ_i for a given level were approximated by the following formulas

$$\gamma_1^2 = \frac{\Gamma_1}{2P_2(E_1) - \Gamma_1 \frac{dS_2(E_1)}{dE}} \quad , \quad \gamma_2^2 = \frac{\alpha^2\Gamma_0}{2P_2(E_2)} \quad , \quad \gamma_3^2 = \frac{\beta^2\Gamma_0}{2P_2(E_3)}. \quad (3)$$

The matrix elements for the 16 MeV doublet can then be expressed in terms of the matrix elements of the functions ψ_a and ψ_b.

$$M_{2F} = \beta M_{bF}$$

$$M_{3F} = -\alpha M_{bF}$$

$$M_{2GT} = \alpha M_{aGT} + \beta M_{bGT}$$

$$M_{3GT} = \beta M_{aGT} - \alpha M_{bGT}$$

$$M_{bF} = \sqrt{2}$$

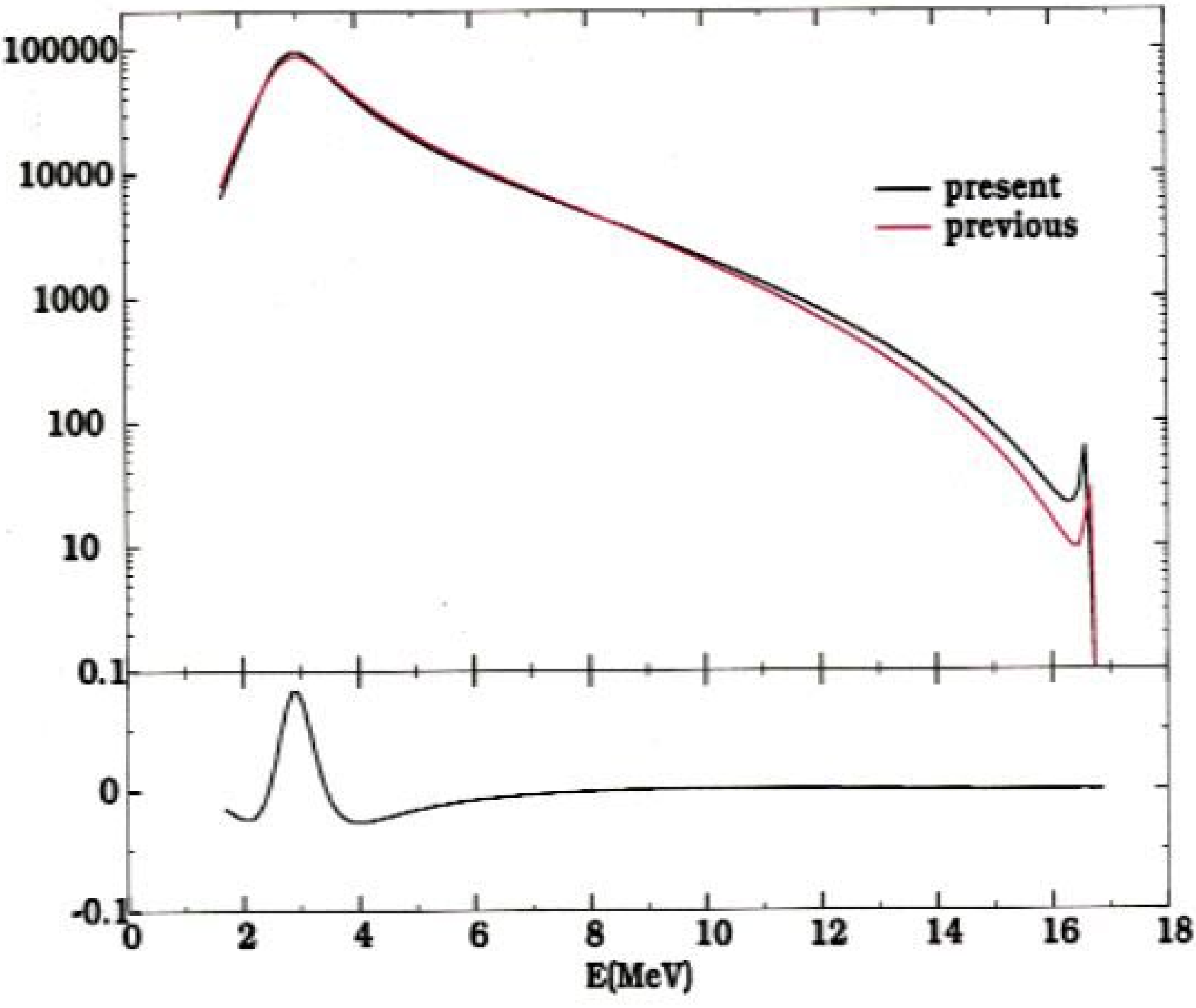
$$M_{aF} = 0$$

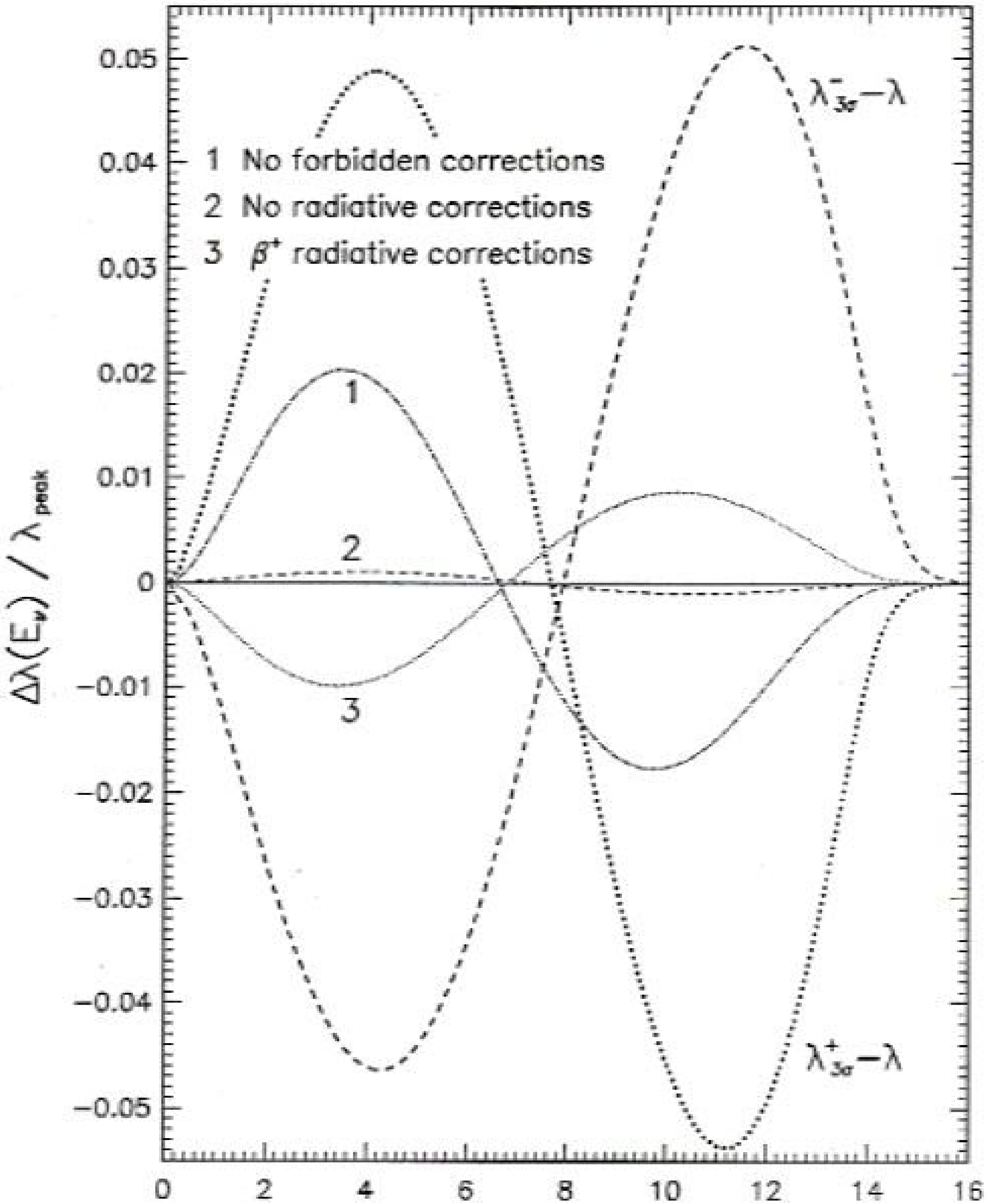
$$M_{bGT} = 0$$

$$M_{aGT} = 2.64$$

The value of M_{aGT} was left as a free variable in the χ^2 fit. It was also assumed that the contribution from M_{bGT} would not be significant and was held fixed at zero.

8Be endpoint distribution
present results vs. previous results





1 No forbidden corrections
2 No radiative corrections
3 β+ radiative corrections
λ−3σ−λ
λ+3σ−λ
1
2
3
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
0
2
4
6
8
10
12
14
16
Δλ(Eν) / λpeak
Neutrino energy, Eν (MeV)

Neutrino energy spectrum