Cross-section:

Cross-section calculated by *crosssection.f*, based on [1]. Command line:

$$\boxed{\text{gfortran -o c.exe crosssection.f -lmathlib}}$$

When executed, create file *crosskaml.dat* with:

$$\frac{d^2\sigma(E_\nu, T_{e^+})}{dE_\nu dT_{e^+}}$$

Effective cross-section:

Based on L/E binning (fig.5 in [2]), we calculate an effective cross-section based on that particular energy binning with program *espectrokamland.le.f*:

$$\boxed{\text{gfortran -o e.exe espectrokamland.le.f -lmathlib -lkernlib}}$$

where the following is calculated:

$$\frac{d\sigma(E_\nu)}{dE_\nu} = \int_{\tilde{T}_{e^+}^{min}}^{\tilde{T}_{e^+}^{max}} d\tilde{T}_{e^+} \int dT_{e^+} R(T_{e^+}, \tilde{T}_{e^+}) \frac{d^2\sigma(T_\nu, T_{e^+})}{dT_\nu dT_{e^+}}$$

where

$$R(T_{e^+}, \tilde{T}_{e^+}) = \frac{1}{\sqrt{2\pi\sigma_T^2}} \exp\left[-\left(\frac{\tilde{T}_{e^+} - T_{e^+}}{2\sigma_T}\right)^2\right]$$

with

$$\sigma_T = 0.065\sqrt{T_{e^+}}$$

Statistical Analysis:

The χ^2 analysis is performed with routine *chi2.f* and subroutines *subchi2.f* and *subspec.f*:

$$\boxed{\text{gfortran -o c.exe chi2.f subchi2.f subspec.f -lmathlib}}$$

which calculates the rates and χ^2 of KamLAND. We used the following expression for the χ^2, based on Poisson statystics:

$$\chi^2 = 2\sum_i \left[fR_i^{th} - R_i^{exp} + R_i^{exp} log\left(\frac{R_i^{exp}}{fR_i^{th}}\right)\right] + \left(\frac{1-f}{0.041}\right)^2$$

where the χ^2 is minimized in the total flux normalization factor f.

Flux and Data:

The Flux is calculated through the following parameterization:

$$\phi = \sum_{j=1,4} \phi_j \exp\left(a_{0,j} + a_{1,j}E_\nu + a_{2,j}E_\nu^2\right)$$

where the factors a and ϕ_i are provided by KamLAND, table 1.

Table 1: Neutrino flux parameters

ϕ_i	0.570	0.295	0.078	0.057
a_0	0.870	0.896	0.976	0.793
a_1	-0.160	-0.239	-0.162	-0.080
a_2	-.0910	-0.0981	-0.079	-0.1085

We assume the same flux composition for all reactors. We use 22 reactors with the distances and contributions to total flux in KamLAND given by table 2

The data are presented in table 3, “graphically reduced” from KamLAND paper.

References

[1] P. Vogel and J. F. Beacom, “Angular distribution of neutron inverse beta decay, anti-neutrino(e) + p → e+ + n,” Phys. Rev. D **60**, 053003 (1999) doi:10.1103/PhysRevD.60.053003 [hep-ph/9903554].

Table 2: Reactors

name	contribution (%)	distance (km)
	30.9	160
	13.8	179
	9.0	191
	7.9	88
	7.6	138
	7.5	214
	7.4	146
	3.8	349
	3.5	351
	1.3	141
	1.2	295
	0.9	138
	0.8	401
	0.7	431
	0.6	561
	0.4	754
	0.2	830
	0.2	783
	0.8	712
	0.6	735
	0.5	709
	0.5	986

[2] A. Gando *et al.* [KamLAND Collaboration], "Constraints on θ_{13} from A Three-Flavor Oscillation Analysis of Reactor Antineutrinos at KamLAND," Phys. Rev. D **83**, 052002 (2011) doi:10.1103/PhysRevD.83.052002 [arXiv:1009.4771 [hep-ex]].

Table 3: Reactors

ΔE_ν (MeV)	R_{th}	R_{ex}/R_{th}
15.6597 - 24.6363	59.547829	0.395866
24.6363 - 27.6942	105.21388	0.667727
27.6942 - 29.4698	91.706429	0.629571
29.4698 - 31.3440	119.44465	0.586645
31.3440 - 33.1196	131.14526	0.804452
33.1196 - 35.0925	161.02548	0.785374
35.0925 - 36.7694	145.14534	0.732909
36.7694 - 38.8409	184.27446	0.558029
38.8409 - 41.1097	201.80777	0.558029
41.1097 - 43.9704	245.68504	0.551669
43.9704 - 47.0284	243.55714	0.489666
47.0284 - 50.3822	230.59836	0.387917
50.3822 - 53.9334	200.76579	0.467409
53.9334 - 57.6819	176.71275	0.491256
57.6819 - 61.7263	153.93623	0.585056
61.7263 - 66.1652	131.16353	0.497615
66.1652 - 71.7879	117.47219	0.575517
71.7879 - 78.8903	92.720367	0.658188
78.8903 - 86.6831	57.012432	0.612083
86.6831 - 110.000	30.065214	0.279809