Lab Book

notes from discussion on Photon attenuation

1) how many we lose $\propto$ how many we have

2) loss $\propto$ thickness (small thicknesses)

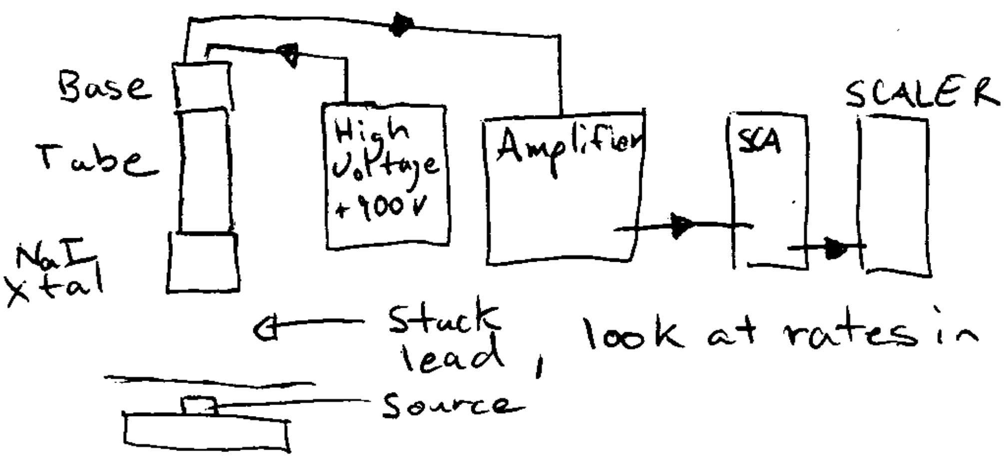
Expect $\Delta N \propto -N \Delta x$

or $\frac{dN}{N} = -\mu dx$

$N(x) = N_0 e^{-\mu x}$ ⇐ test!

3) Some kind of energy dependence

→ use a Single Channel analyzer to pick out dominant energy from a source.

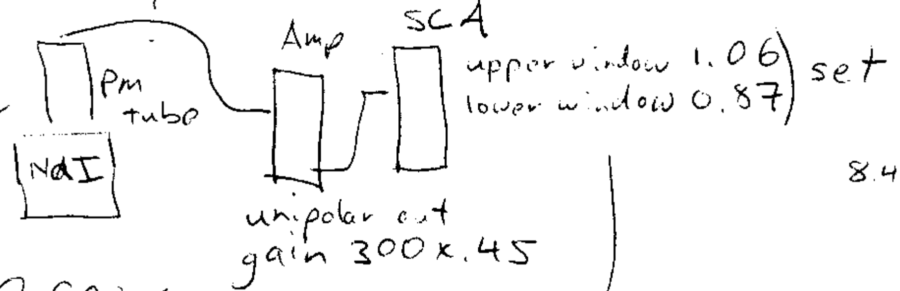


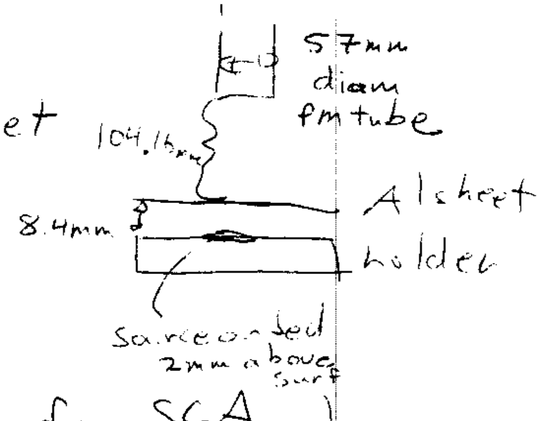

look at rates in Scaler

Data From Sessions on following 3 pages

 Attenuation of photons with matter (high energy) 

Idea. measure rate vs thickness of material between detector & source




set @ 900V

Base 2712

→ used trigger on scope from SCA output to set window

Source ~ 4.3mm thick

sheets thickess 0.85mm ± 0.04mm

{ estimate time accurate to 0.5s }

| | #sheets | condition | counts | time |
|---|---|---|---|---|
| beginning of → data | 0 | no source | 400 | 2min 46sec |
| check @ end → | 0 | no source | 400 | 2min 53sec |
| | 0 | source | 10,000 | 24 sec |
| | 0 | " | 25,582 | 60 sec |
| check, ~~next~~ 2nd to last → | 0 | " | 25,577 | 60 sec |
| | 1 | " | 22,975 | " |
| | 2 | ↓ | 21,334 | ↓ |
| | 3 | | 19,431 | |
| | 4 | | 17,767 | |
| | 5 | | 16,309 | |
| | 6 | | 14,876 | |
| | 7 | | 13,834 | |
| next to last check | ~~8~~ 7 | | 13,722 | |
| | 8 | | 12,525 | |
| | 9 | | 11,516 | |
| | 10 | | 10,453 | |
| | 11 | | 9,591 | |
| | 12 | | 8,718 | |
| | 13 | | 7,839 | |

Hypothesis

$$dN \propto N\,dx$$

$$\int \frac{dN}{N} \propto \int -dx$$

$$\ln N = -ax + b$$

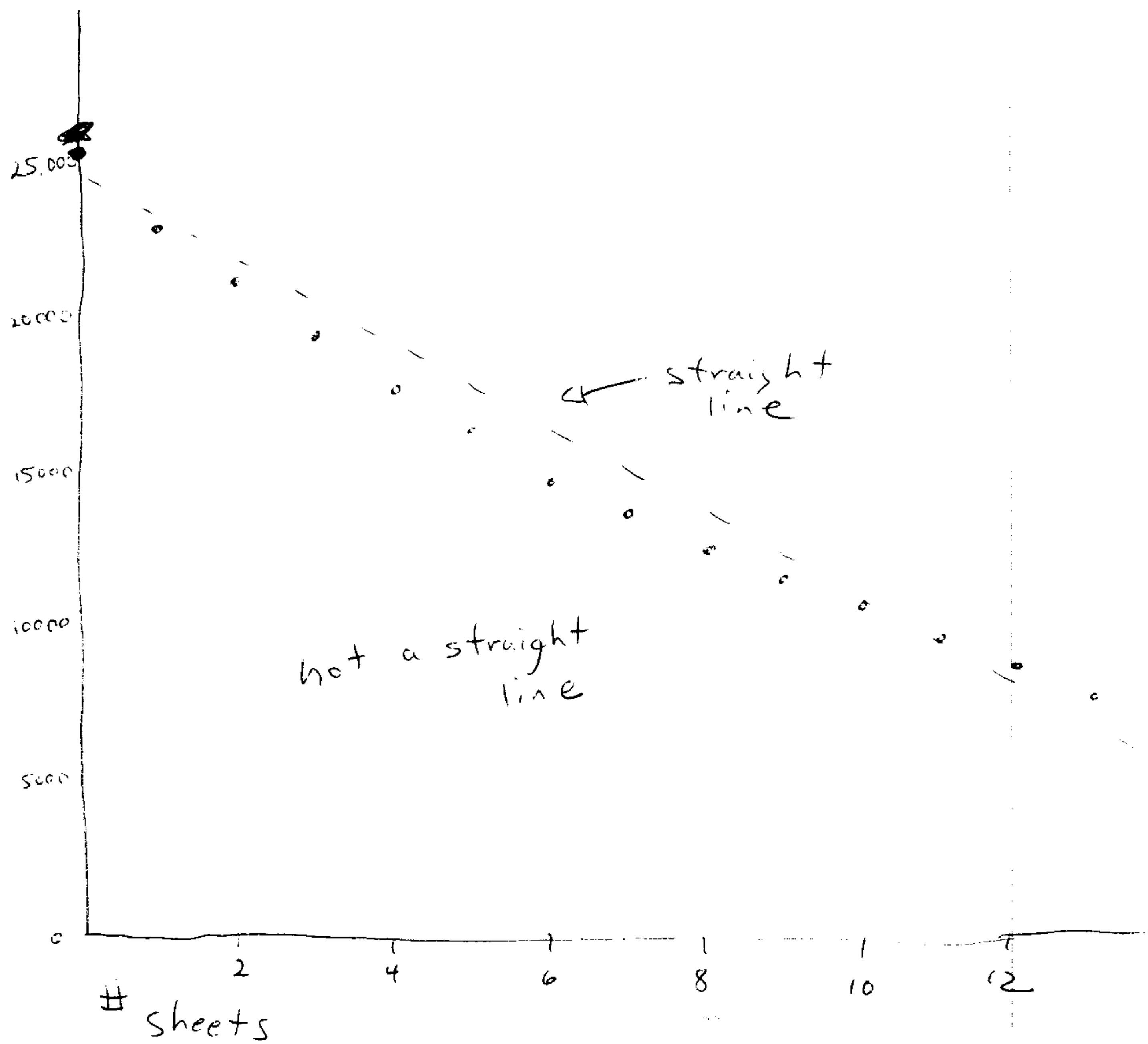
$$N(x) = be^{-ax} \qquad b = N_0$$

$$N(x) = N_0 e^{-ax}$$

( given energy for Cs-137 661.65 )

1.0573 ± 0.000?

rough plot (1st Period)



| Counts | Src Cnt/in | Shots | Δt |
|---|---|---|---|
| 250 | 0 | 0 | 32.52 |
| 250 | 0 | 0 | 44.53 |
| 13762 | 1 | 0 | 30.. |
| 13068 | 1 | 1 | |
| 12167 | 1 | 2 | |
| 10964 | 1 | 3 | |
| 10104 | 1 | 4 | |
| 9571 | 1 | [illegible] | |
| 8798 | 1 | 6 | |
| 8086 | 1 | 7 | |
| 7436 | 1 | 8 | |
| 7117 | 1 | 9 | |
| 6254 | 1 | 10 | |
| 5849 | 1 | 11 | |
| 5318 | 1 | 12 | |
| 4970 | 1 | 13 | |
| 14291 | 1 | 0 | |
| 8274 | 1 | 7 | |
| 250 | 0 | 0 | 32.21 |
| 250 | 0 | 0 | 30.79 |

## Analysis

- Could try straight forward fit to ln(data - background) ⇐ straight line as done in the muon experiment or described in http://www.hep.vanderbilt.edu/~wjohns/classes/225b/

+ This case though is abit more interesting! there is error in both dimensions

- If the function is fairly linear, we can estimate how this error feeds in

$$\sigma_{tot}^2 = \sigma_{counts}^2 + \left(\frac{dN}{dx}\sigma_x\right)^2$$

this is our ±0.04 mm From given (0.85±0.04) mm thickness for each sheet

- We have a background estimate, but we should be able in principle to include the background as a fit parameter. But! we want to use our estimate too! Can include this as an extra term in our $\chi^2$.

Progression of $\chi^2$ given on next page

1) Straight forward

$$\chi_1^2 = \sum_{\text{points}}^{i} \left( \frac{\left(\#\text{Counts}_i - \underset{\text{Background}}{\text{Estimate of}} - N_0 e^{-\mu x_i}\right)^2}{\left(\sqrt{\#\text{Counts}}\right)^2} \right)$$

2) Including thickness error, $\sigma_x$

$$\chi_2^2 = \sum_{\text{points}}^{i} \left( \frac{\left(\#\text{Counts}_i - \underset{\text{Background}}{\text{Estimate of}} - N_0 e^{-\mu x_i}\right)^2}{\left(\sqrt{\#\text{Counts}_i}\right)^2 + \left(\left(-\mu N_0 e^{-\mu x_i} \sigma_x\right)\right)^2} \right)$$

In both case 1) & 2) I would have to vary the "Estimate of background" myself to see how it played into the ~~f~~ fit parameters

3) Everything, take $\chi_2^2$ & make the "Estimate of Background" a fit parameter, B

$$\chi_3^2 = \sum_{\text{points}}^{i} \left( \frac{\left(\#\text{Counts}_i - B - N_0 e^{-\mu x_i}\right)^2}{\left(\sqrt{\#\text{Counts}_i}\right)^2 + \left(-\mu N_0 e^{-\mu x_i} \sigma_x\right)^2} \right) + \frac{\left(B - \text{Estimate of Background}\right)^2}{\left(\sqrt{\text{Estimate of Background}}\right)^2}$$

i) Techniques 2) & 3) will require some fairly sophisticated software package (like minuit).

ii) Another option is to simulate the process to map out the error space as describe in the second half of the muon lifetime.

iii) I didn't even worry about our time error!

For the 1st period data, I converted everything to #counts/60 sec

I used both background measurements since the repeat measurements @ 0 sheets & 7 sheets showed no variation statistically:

0 sheets

difference

$$\frac{|25{,}582 - 25577|}{\sqrt{25{,}582 + 25{,}587}} = \frac{5}{226.2}$$

$\sqrt{\#counts}^2$

expected error

Almost unbelievable agreement

same for 7 sheets

$$\frac{13834 - 13722}{\sqrt{13834 + 13722}} = \frac{112}{166}$$

still good agreement

So Average Background

counts/min

measurement 1) $400 \pm 20$ counts in 166 sec $\Rightarrow 144.6 \pm 7.2$

2) $400 \pm 20$ counts in 173 sec $\Rightarrow 138.7 \pm 6.9$

Weighted Average Background $= \dfrac{(144.6/(7.2)^2) + (138.7/6.9^2)}{(1/7.2)^2 + (1/6.9)^2} = 141.5$

Error on Avg. $= \sqrt{1/((1/7.2)^2 + (1/6.9)^2} = 4.98$

Note: the uncertainty on this number is <u>much</u> less than the uncertainty in any measurement I.e. $\sqrt{7839} = 88.5$, so we can ignore it & check our assumption

(note: error on thickness is 4.7% of thickness)

Since I want to do this as simply as possible, I'll fit this in [redacted] Exeel using the method from http://www.hep.vanderbilt.edu/~wjohns/classes/225b/lecture2/page.pdf

page.pdf

i) my 1st check is to increase background to 146.5 & redo fit

ii) 2nd check is to add in error in thickness using initial answer & seeing how result changes (see page 6)

result = $y = a + bx$

$$y = \ln(\text{counts})$$

$$e^{a} e^{bx} = N_0 e^{-\mu x}$$

$$N_0 = e^{a} \quad b = -\mu$$

straight fit $\mu = -b = 1.05\cancel{8}68 \pm 0.0067$

$\chi^2/DOF = 12.85/12 = 1.07$ close to 1 is good

(second period data $\mu = 0.955 \pm 0.009$, $\chi^2/DOF = 2.3$!)

~~1.0568~~

i) 1st check $\mu = -b =$ ~~1.0574~~ ~~±0.0067~~

$1.0572 \pm 0.0067$

$\chi^2/DOF = 12.85/12 = 1.07$

ii) 2nd check $\mu = -b = 1.05738 \pm 0.00749$

$\chi^2/DOF = 10.196/12 = 0.85$

now, we want to compare our $\mu$ with energy to see how it compares to what we expect for Cs-137 $E = 662$ keV

$\mu = \frac{1.2}{cm}$ (Melissinos, "Experiments in MODERN PHYSICS" 1966, Academic Press Limited)

Our values differ from the accepted

$$\mu_{period1} = 1.0568 \pm 0.0067$$

$$\mu_{accepted} = \frac{1.2}{cm} \qquad \mu_{period2} = 0.953 \pm 0.009$$

In the descriptions in Melissinos*, there is an extended discussion about taking care that
1) the sheets are a separated (nope, didn't do it)
2) the source is collimated (nope, didn't do it)
3) the detector prefered is a scintillator (this we did)

1) & 2) minimize (are supposed to anyway) photons scattered back into the detector that would otherwise escape detection. (Find this a lot of places on the web).

Does our data support this?

I didn't write down the SCA window for the second period, but we can look at the noise rate to judge. The hypothesis to test is: A bigger window lets in more scattered photons, and our results will differ more for a bigger window.

| Period 1 noise (60 sec) | Period 2 noise (60 sec) |
| --- | --- |
| $141.5 \pm 4.98$ | avg of $(250 \pm 15.8)\left(\frac{60}{32.52}\right)$ & $(250 \pm 15.8)\left(\frac{60}{44.53}\right)$ |
| | $418 \pm 17$ ! |

Some evidence that this is an effect.

# Period 1

| A | | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sheets | | Thickness(cm) | Counts | CountErr | Ln(Counts-BKGND) | CountErr /(Counts-BKGND) | 1/E^2(S) | B*G(Sx) | E*G(Sy) | B*B*G(Sxx) | B*E*G(Sxy) | (E-(a+bB)) | L^2*G |
| | 0 | 0 | 25582 | 159.9437 | 10.1440977 | 0.006287 | 25299.783 | 0 | 256643.5 | 0 | 0 | 0.005425 | 0.744468 |
| | 1 | 0.085 | 22975 | 151.5751 | 10.035984 | 0.0066383 | 22692.871 | 1928.894 | 227745.3 | 163.9559964 | 19358.35015 | -0.01286 | 3.752339 |
| | 2 | 0.17 | 21334 | 146.0616 | 9.96140262 | 0.0068921 | 21051.939 | 3578.83 | 209706.8 | 608.401023 | 35650.16205 | 0.00239 | 0.120222 |
| | 3 | 0.255 | 19431 | 139.3951 | 9.86731619 | 0.0072265 | 19149.03 | 4883.003 | 188949.5 | 1245.165704 | 48182.13216 | -0.00187 | 0.06672 |
| | 4 | 0.34 | 17767 | 133.2929 | 9.777102 | 0.0075625 | 17485.127 | 5944.943 | 170953.9 | 2021.280674 | 58124.31561 | -0.00225 | 0.088574 |
| | 5 | 0.425 | 16309 | 127.7067 | 9.69075833 | 0.007899 | 16027.228 | 6811.572 | 155316 | 2894.918 | 66009.29584 | 0.001236 | 0.024474 |
| | 6 | 0.51 | 14876 | 121.9672 | 9.59794696 | 0.0082777 | 14594.346 | 7443.116 | 140075.8 | 3795.98938 | 71438.63674 | -0.00175 | 0.044467 |
| | 7 | 0.595 | 13834 | 117.618 | 9.52460352 | 0.00859 | 13552.447 | 8063.706 | 129081.7 | 4797.905163 | 76803.60402 | 0.014741 | 2.944957 |
| | 8 | 0.68 | 12525 | 111.9151 | 9.42412022 | 0.0090374 | 12243.599 | 8325.647 | 115385.1 | 5661.439985 | 78461.89858 | 0.004088 | 0.204605 |
| | 9 | 0.765 | 11516 | 107.3126 | 9.33912929 | 0.0094345 | 11234.739 | 8594.575 | 104922.7 | 6574.849924 | 80265.84769 | 0.008927 | 0.895331 |
| | 10 | 0.85 | 10453 | 102.2399 | 9.24101506 | 0.0099151 | 10171.915 | 8646.128 | 93998.82 | 7349.208916 | 79899.00029 | 0.000643 | 0.004205 |
| | 11 | 0.935 | 9591 | 97.93365 | 9.15371711 | 0.0103639 | 9310.0876 | 8704.932 | 85221.91 | 8139.111339 | 79682.48419 | 0.003175 | 0.093859 |
| | 12 | 1.02 | 8718 | 93.37023 | 9.05678118 | 0.0108868 | 8437.2967 | 8606.043 | 76414.75 | 8778.163441 | 77943.04459 | -0.00393 | 0.130359 |
| | 13 | 1.105 | 7839 | 88.53813 | 8.94865088 | 0.0115022 | 7558.5542 | 8352.202 | 67638.86 | 9229.183623 | 74740.94312 | -0.02223 | 3.735534 |
| sums | | | | | | | 208808.96 | 89883.59 | 2022055 | 61259.57317 | 846559.715 | 0 | 12.85012 |
| DET (SSxx-SxSx) | | 4712487960 | | | | | | | | | | | |
| Background = 141.5 | | | | | | | | | | | | | |
| SSxy-SxSy | | -4980273844 | | | | | | | | | | | |
| b = a19/a17 | | -1.056824736 | | | | | | | | | | | |
| b error = sqrt(S/DET) | | 0.006656554 | | | | | | | | | | | |
| y=a+bx | | | | | | | | | | | | | |
| a=(SxxSy-SxSxy)/DET | | 10.13867311 | | | | | | | | | | | |
| ChiSquare | | 12.85011541 | | | | | | | | | | | |
| ChiSquare/DOF (14-2) | | 1.070842951 | | | | | | | | | | | |

Period 2

| A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sheets | Thickness(cm) | Counts | CountErr | Ln(Counts-BKGND) | CountErr /(Counts-BKGND) | 1/E^2(S) | B*G(Sx) | E*G(Sy) | B*B*G(Sxx) | B*E*G(Sxy) | (E-(a+bB)) | L^2*G |
| 0 | 0 | 13762 | 117.3116 | 9.5143632 | 0.0086558 | 13347.174 | 0 | 126989.9 | 0 | 0 | -0.0212 | 5.99982 |
| 1 | 0.085 | 13068 | 114.3154 | 9.46179923 | 0.0088768 | 12690.762 | 1078.715 | 120077.4 | 91.69075887 | 10206.58297 | 0.007415 | 0.697837 |
| 2 | 0.17 | 12167 | 110.3041 | 9.38915579 | 0.0092097 | 11789.967 | 2004.294 | 110697.8 | 340.7300475 | 18818.63234 | 0.015953 | 3.000587 |
| 3 | 0.255 | 10969 | 104.733 | 9.28359083 | 0.0097164 | 10592.291 | 2701.034 | 98334.5 | 688.7637283 | 25075.29661 | -0.00843 | 0.75284 |
| 4 | 0.34 | 10104 | 100.5187 | 9.19978486 | 0.0101391 | 9727.5728 | 3307.375 | 89491.58 | 1124.507421 | 30427.1363 | -0.01106 | 1.188902 |
| 5 | 0.425 | 9571 | 97.83149 | 9.14441422 | 0.0104287 | 9194.7718 | 3907.778 | 84080.8 | 1660.805658 | 35734.3409 | 0.014755 | 2.001872 |
| 6 | 0.51 | 8798 | 93.79765 | 9.05823759 | 0.0108966 | 8422.1032 | 4295.273 | 76289.41 | 2190.589044 | 38907.60006 | 0.00976 | 0.802251 |
| 7 | 0.595 | 8086 | 89.92219 | 8.9717024 | 0.0113883 | 7710.4645 | 4587.726 | 69175.99 | 2729.697197 | 41159.71579 | 0.004406 | 0.149677 |
| 8 | 0.68 | 7436 | 86.23224 | 8.88557929 | 0.0119007 | 7060.8548 | 4801.381 | 62739.78 | 3264.939241 | 42663.05369 | -0.00054 | 0.002028 |
| 9 | 0.765 | 7117 | 84.36231 | 8.84043544 | 0.0121788 | 6742.0724 | 5157.685 | 59602.86 | 3945.629298 | 45596.18441 | 0.035501 | 8.49738 |
| 10 | 0.85 | 6254 | 79.08224 | 8.70698676 | 0.0130413 | 5879.7723 | 4997.806 | 51195.1 | 4248.135491 | 43515.83469 | -0.01677 | 1.6528 |
| 11 | 0.935 | 5849 | 76.47876 | 8.63763934 | 0.0135145 | 5475.172 | 5119.286 | 47292.56 | 4786.532238 | 44218.54458 | -0.00493 | 0.133193 |
| 12 | 1.02 | 5318 | 72.92462 | 8.53875897 | 0.0142209 | 4944.7883 | 5043.684 | 42222.36 | 5144.557712 | 43066.80226 | -0.02263 | 2.532612 |
| 13 | 1.105 | 4973 | 70.5195 | 8.46884293 | 0.0147438 | 4600.2592 | 5083.286 | 38958.87 | 5617.031489 | 43049.55422 | -0.01137 | 0.594305 |
| sums | | | | | | 118178.03 | 52085.32 | 1077149 | 35833.60932 | 462439.2788 | 0 | 28.00611 |
| DET (SSxx-SxSx) | 1521864176 | | | | | | | | | | | |
| Background = 209 | | | | | | | | | | | | |
| SSxy-SxSy | -1453491845 | | | | | | | | | | | |
| b = a19/a17 | -0.955073302 | | | | | | | | | | | |
| b error = sqrt(S/DET) | 0.00881212 | | | | | | | | | | | |
| y=a+bx | | | | | | | | | | | | |
| a=(SxxSy-SxSxy)/DET | 9.535565088 | | | | | | | | | | | |
| ChiSquare | 28.00610546 | | | | | | | | | | | |
| ChiSquare/DOF (14-2) | 2.333842121 | | | | | | | | | | | |