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Preliminary Results of a
Rossa-Alpha Experiment
in the IPEN/MB-01 Research Reactor

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PRELIMINARY RESULTS OF A ROSSI-ALPHA EXPERIMENT IN THE IPEN/MB-01 RESEARCH REACTOR

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I. Background

A preliminary set of Rossi-alpha measurements were performed on the IPEN MB-01 research reactor. The intent of the measurements was to determine if the efficiency of the BF_3 detectors placed in the central region of the core was sufficiently high enough to allow an accurate measurement of the effective delayed neutron fraction, β_{eff} , and the alpha at delayed critical. In addition, a preliminary measurement of the intrinsic source strength was performed to determine the optimum external/intrinsic source strength that would allow the obtainment of sufficient counting statistics in a reasonable length of time without degrading the signal-to-noise ratio.

II. Alpha at Delayed Critical

A set of Rossi- α measurements were performed using three different source configurations. In addition, the two BF_3 detectors used to perform the measurements were a) cross correlated with each other and b) electronically summed together and then autocorrelated as a single input signal. The results of these measurements are shown in Figs. 1 through 14.

From these preliminary results, the alpha at delayed critical was determined by plotting the measured alpha as a function of the inverse of the total count rate of the two detectors and then extrapolated via a least-squares fit back to zero inverse count rate (i.e., the point of delayed critical). Fig. 15 shows the results for the source configuration in which the Am-Be source was positioned in the middle of the active core region. Fig. 16 shows the results for the source configuration in which the Am-Be source was removed from the core and the start-up source was positioned just below its normal full in position. Fig. 17 shows the results for the source configuration in which only the intrinsic source was in the core. Table I gives a summary of the alpha at delayed critical as estimated from a least-squares fit of the individual data sets.

The most accurate estimate of the alpha at delayed critical is the one corresponding to the intrinsic source configuration since the signal-to-noise ratio was the greatest for this configuration (i.e., 17%). The signal-to-noise ratio for the other two source configurations was 0.75% for the Am-Be source in the center of the assembly and 10% for the start-up source in its almost full in position.

Using the -232.9 value as the correct value, the neutron generation time at delayed critical

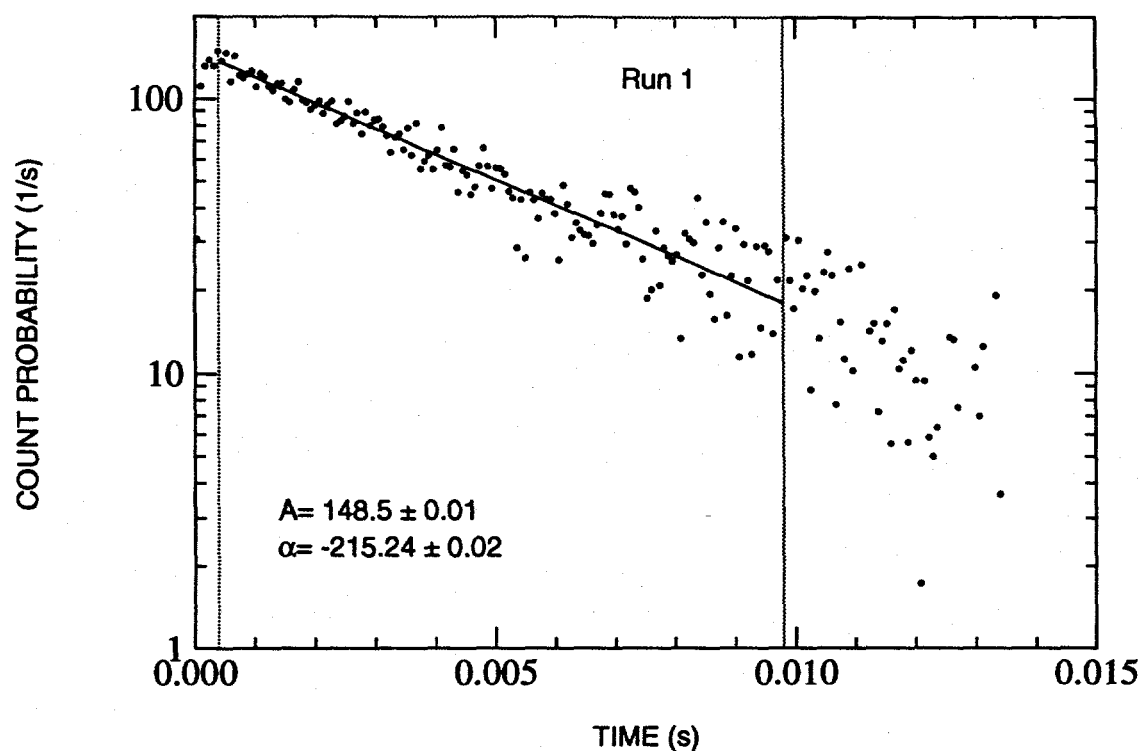


Figure 1.

RUN NUMBER= 1
 Sept. 9, 1997
 Am-Be source in center of assembly
 AUTO CORRELATE
 Number of blocks = 3
 Last 16 ch opt = IN
 Number data pts = 192
 • Time/ch (s) = 7.00000E-05
 Run Time (minutes) = 8.2878
 Det. Resol. time (s) = 1.10000E-06
 Count Rate (cps) =
 raw = 58771.
 corrected = 62833.
 % = 6.9116
 Inverse Count Rate = 1.59152E-05
 Theoretical bkgd = 58779.
 Observed bkgd = 58774.

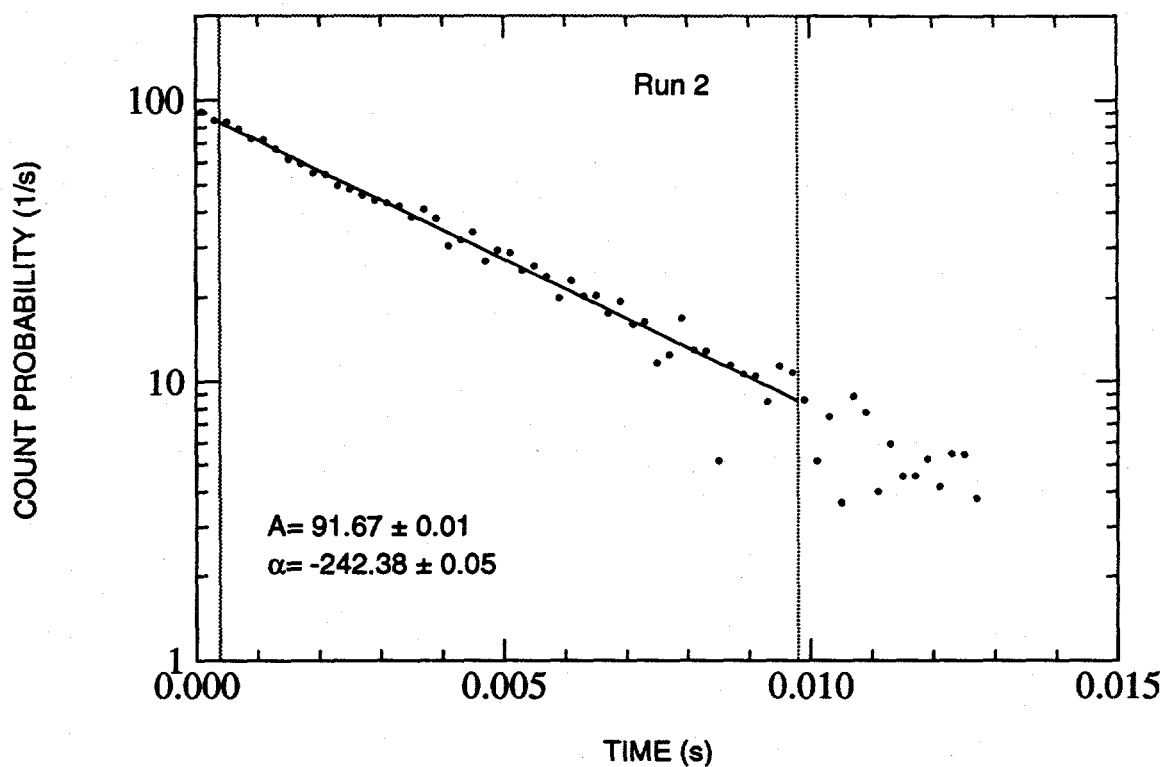


Figure 2.

RUN NUMBER= 2
 Sept. 9, 1997
 Am-Be source in center of assembly
 CROSS CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 Time/ch (s) = 2.00000E-04
 Run Time (minutes) = 20.049
 Det. Resol. time (s) = 2.20000E-06
 Count Rate (cps) =
 raw = 14607.
 corrected = 15091.
 % = 3.3201
 Inverse Count Rate = 6.62626E-05
 Theoretical bkgd = 15725.
 Observed bkgd = 15727.

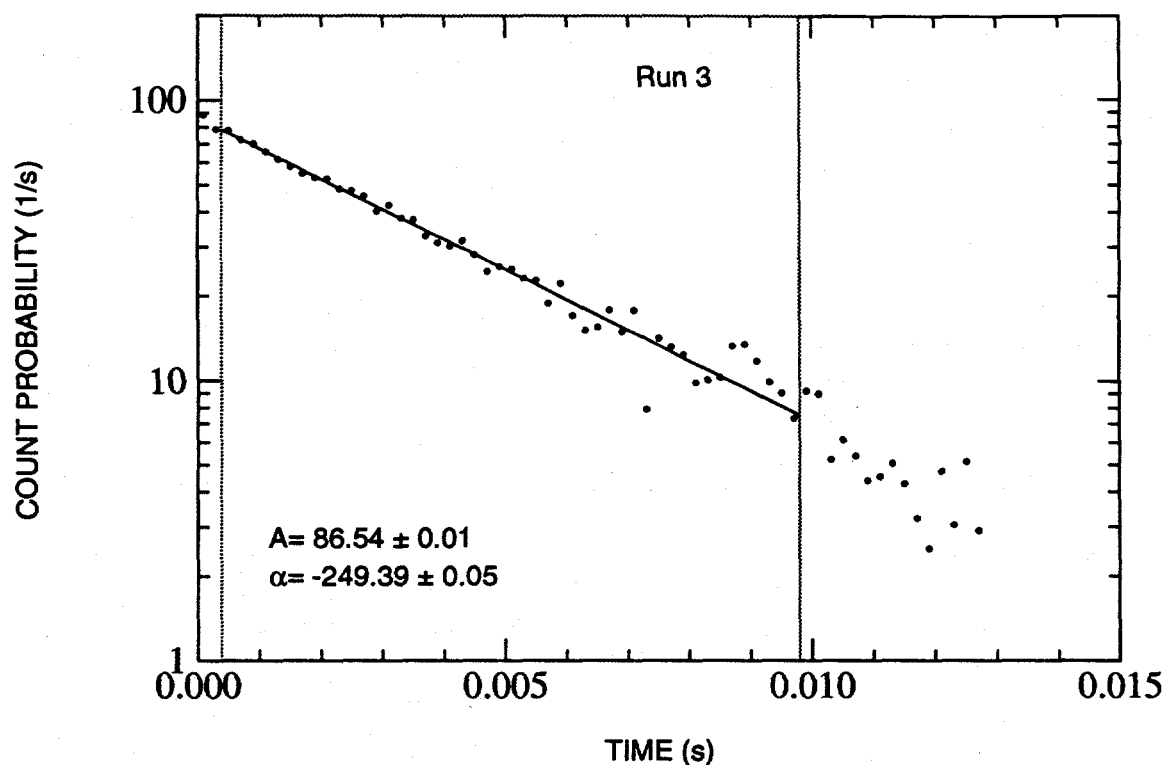


Figure 3.

RUN NUMBER= 3
 Sept 9, 1997
 Am-Be source in center of assembly
 CROSS CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 • Time/ch (s) = 2.00000E-04
 Run Time (minutes) = 24.560
 Det. Resol. time (s) = 2.20000E-06
 Count Rate (cps) =
 raw = 13691.
 corrected = 14116.
 % = 3.1055
 Inverse Count Rate = 7.08431E-05
 Theoretical bkgd = 14780.
 Observed bkgd = 14782.

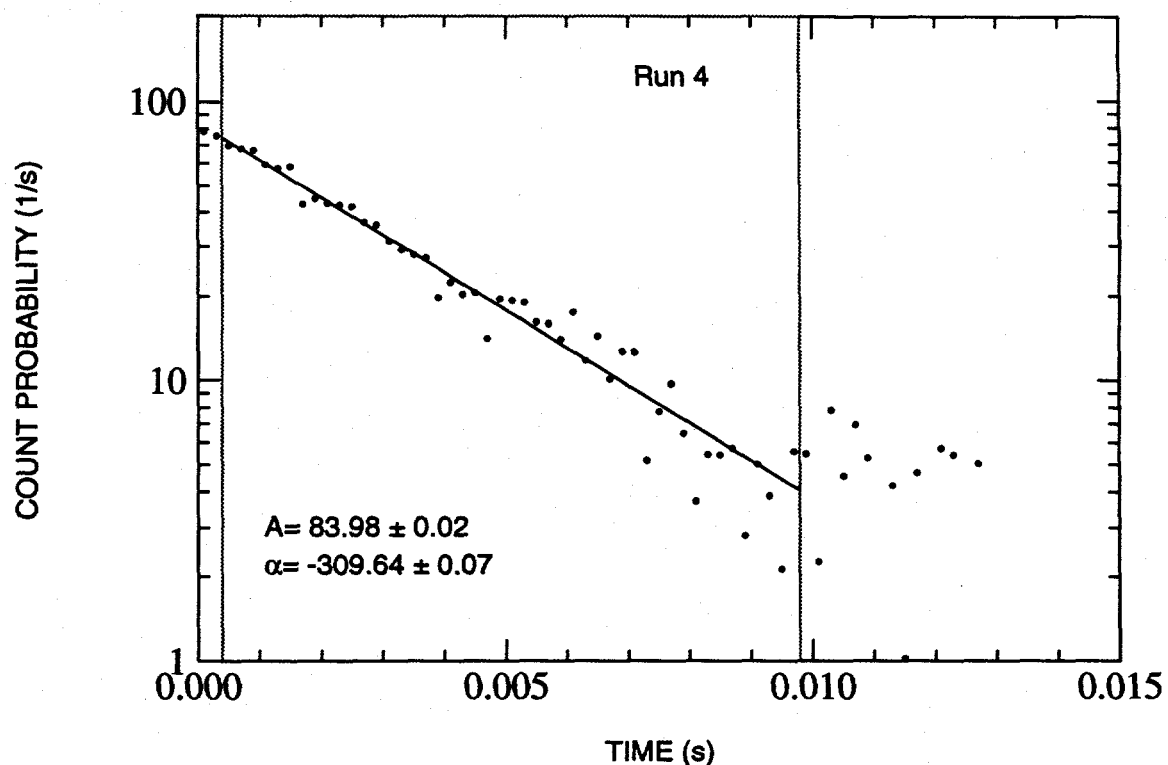


Figure 4.

RUN NUMBER= 4
 Sept 10, 1997, 11:11
 Am-Be source in center of assembly
 CROSS CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 • Time/ch (s) = 2.00000E-04
 Run Time (minutes) = 17.902
 Det. Resol. time (s) = 2.20000E-06
 Count Rate (cps) =
 raw = 3116.7
 corrected = 3138.2
 % = .69040
 Inverse Count Rate = 3.18657E-04
 Theoretical bkgd = 3326.1
 Observed bkgd = 3325.6

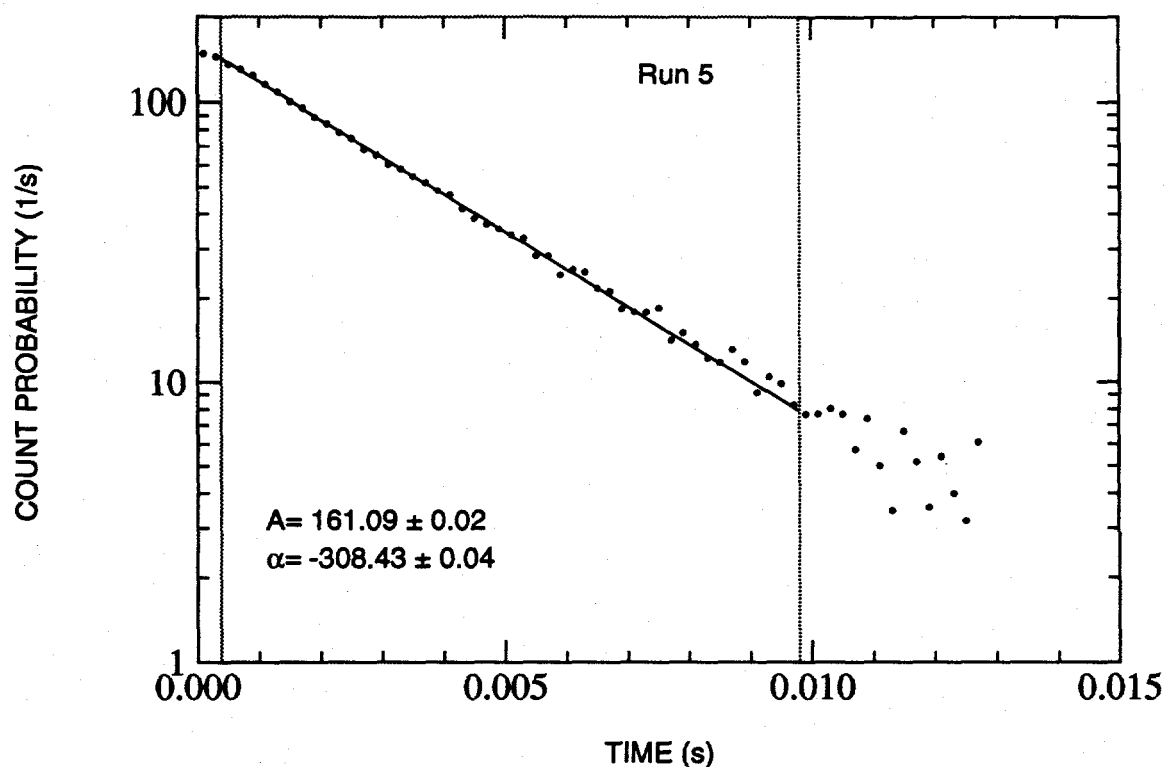


Figure 5.

RUN NUMBER= 5
 Sept. 10, 1997, 11:40
 Am-Be source in center of assembly
 AUTO CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 • Time/ch (s) = 2.00000E-04
 Run Time (minutes) = 64.928
 Det. Resol. time (s) = 1.10000E-06
 Count Rate (cps) =
 raw = 6476.7
 corrected = 6523.2
 % = .71755
 Inverse Count Rate = 1.53299E-04
 Theoretical bkgd = 6476.8
 Observed bkgd = 6477.2

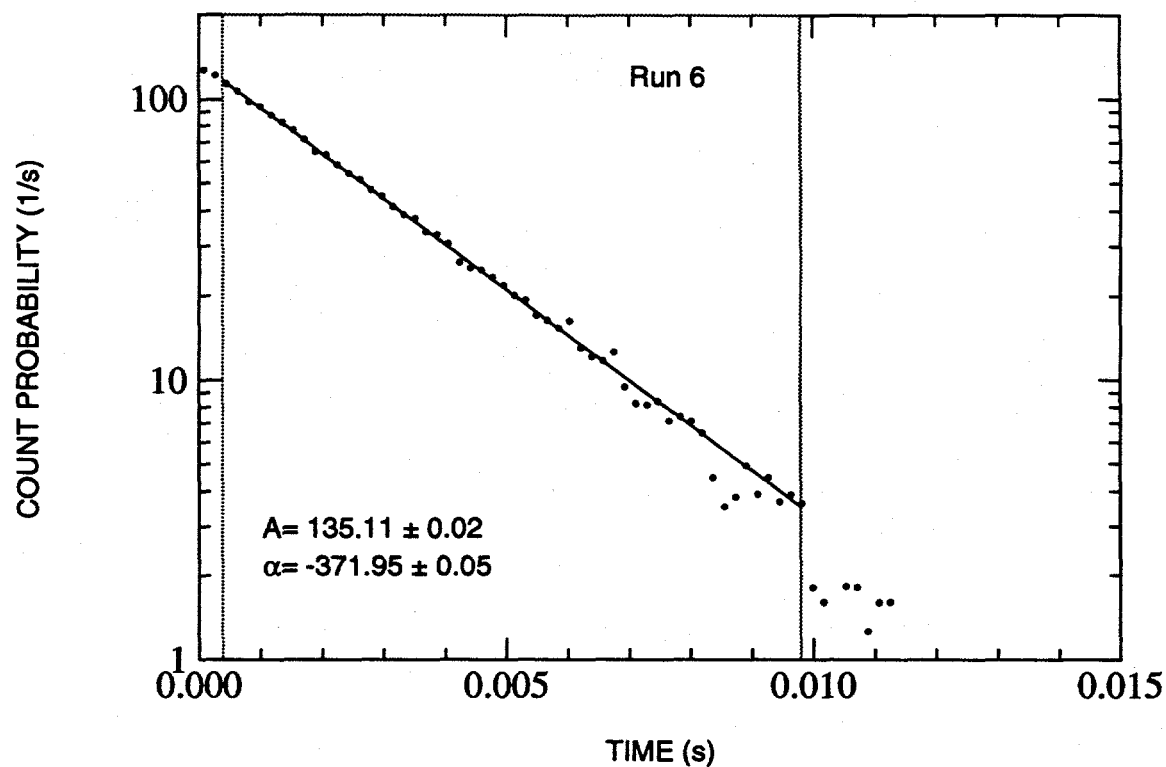


Figure 6.

RUN NUMBER= 6
 Sept. 10, 1997, 1400
 Am-Be source in center of assembly
 AUTO CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 Time/ch (s) = 1.80000E-04
 Run Time (minutes) = 84.429
 Det. Resol. time (s) = 1.10000E-06
 Count Rate (cps) =
 raw = 3344.5
 corrected = 3356.9
 % = .36926
 Inverse Count Rate = 2.97896E-04
 Theoretical bkgd = 3344.6
 Observed bkgd = 3344.9

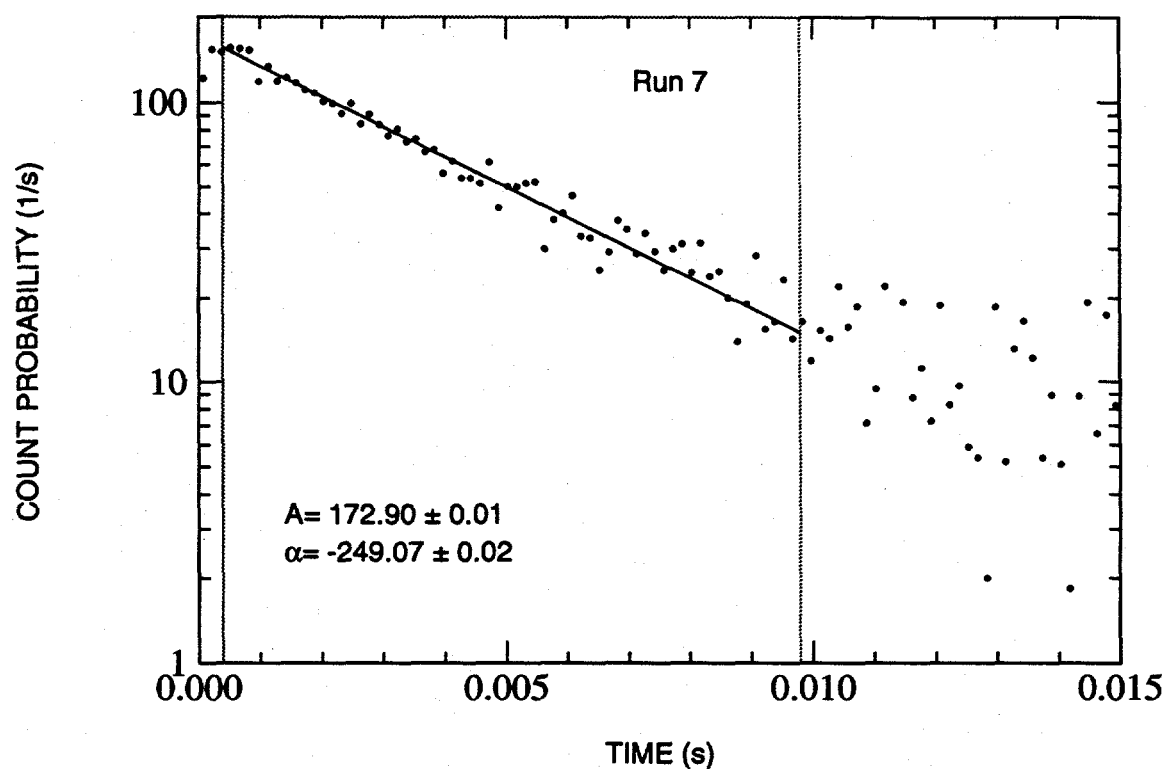


Figure 7.

RUN NUMBER= 7
 Sept. 10, 1997
 Am-Be Source in center of assembly
 AUTO CORRELATE
 Number of blocks = 2
 Last 16 ch opt = IN
 Number data pts = 128
 Time/ch (s) = 1.50000E-04
 Run Time (minutes) = 6.3587
 Det. Resol. time (s) = 1.10000E-06
 Count Rate (cps) =
 raw = 22946.
 corrected = 23540.
 % = 2.5894
 Inverse Count Rate = 4.24801E-05
 Theoretical bkgd = 22948.
 Observed bkgd = 22946.

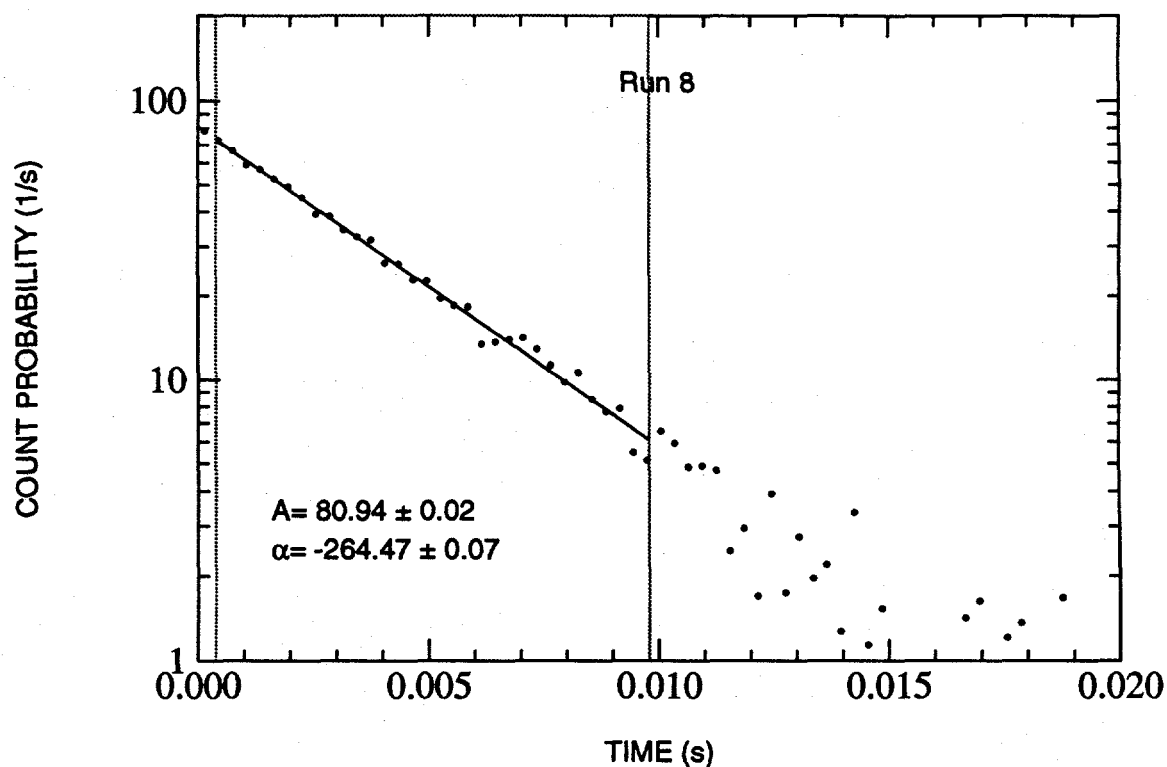


Figure 8.

RUN NUMBER= 8
 Sept 10, 1997, 15:20
 Am-Be source in center of assembly
 CROSS CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 • Time/ch (s) = 3.00000E-04
 Run Time (minutes) = 48.510
 Det. Resol. time (s) = 2.20000E-06
 Count Rate (cps) =
 raw = 11924.
 corrected = 12245.
 % = 2.6939
 Inverse Count Rate = 8.16650E-05
 Theoretical bkgd = 11071.
 Observed bkgd = 11072.

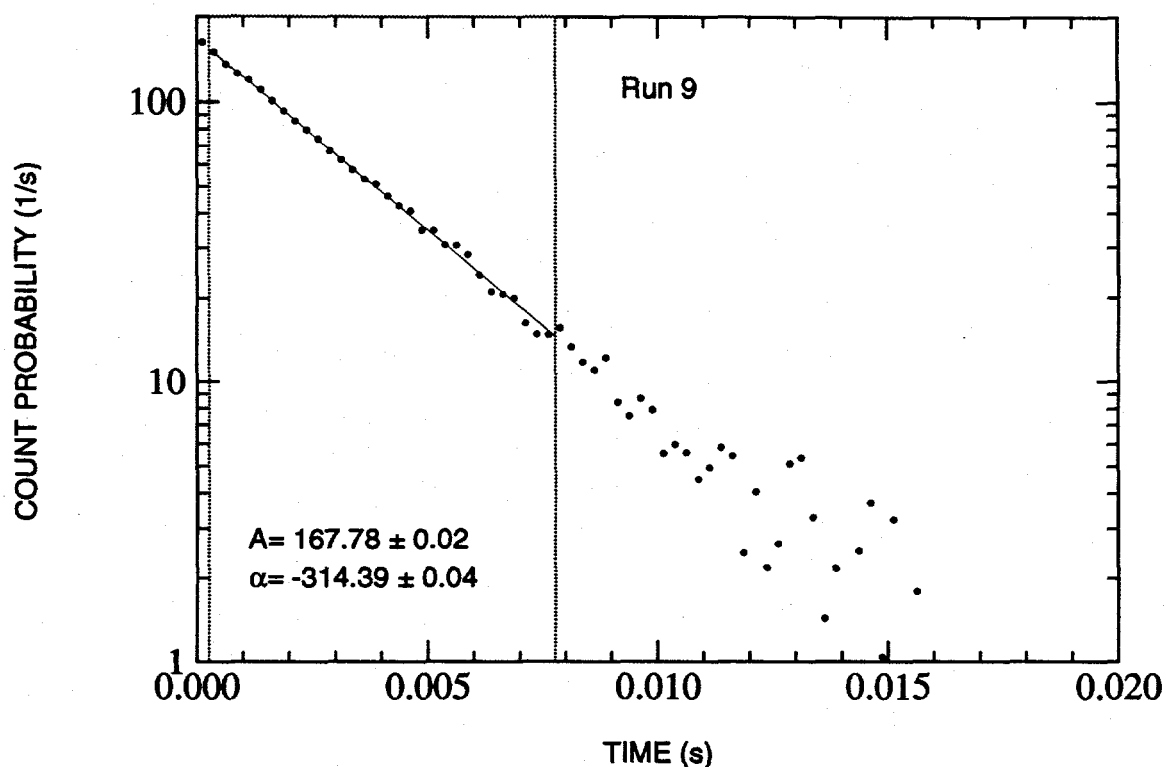


Figure 9.

RUN NUMBER= 9
 Sept 11, 1997
 Am-Be removed, startup source not quite full in
 AUTO CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 • Time/ch (s) = 2.50000E-04
 Run Time (minutes) = 49.093
 Det. Resol. time (s) = 1.10000E-06
 Count Rate (cps) =
 raw = 510.02
 corrected = 510.31
 % = 5.61342E-02
 Inverse Count Rate = 1.95959E-03
 Theoretical bkgd = 510.03
 Observed bkgd = 510.30

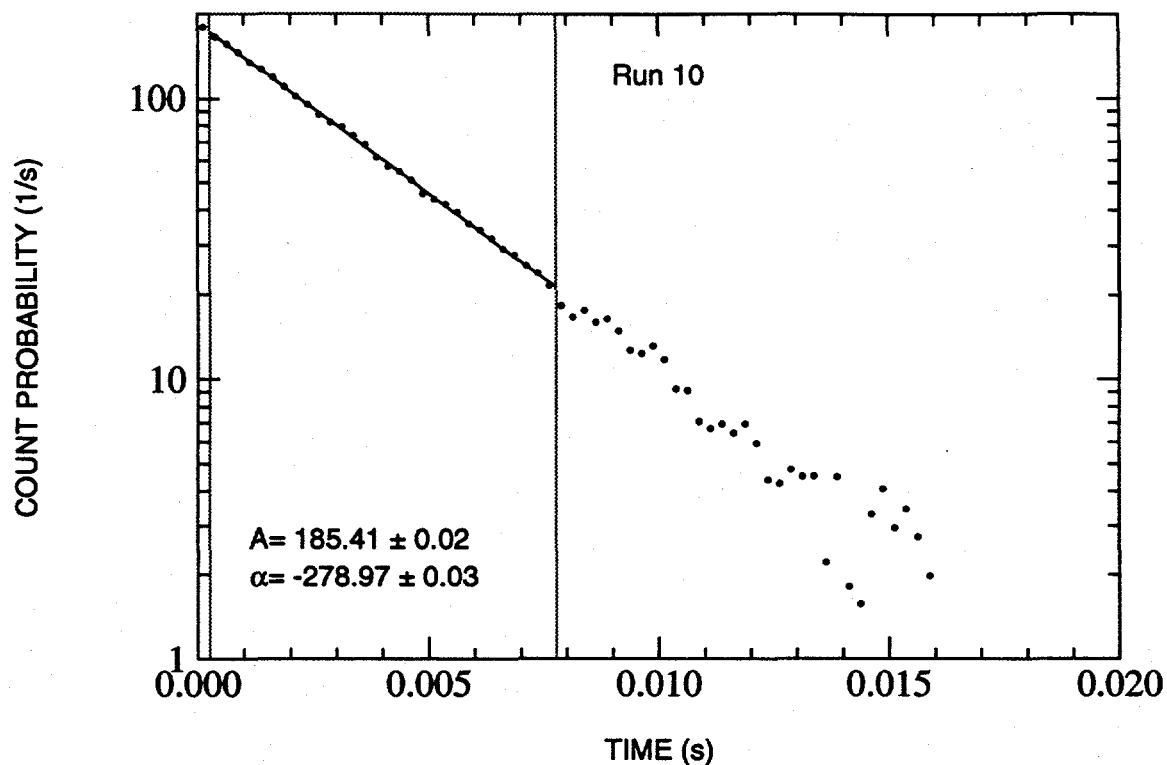


Figure 10.

RUN NUMBER= 10

Sept 11, 1997

Am-Be source removed, startup source not quite full in

AUTO CORRELATE

Number of blocks = 1

Last 16 ch opt = IN

Number data pts = 64

Time/ch (s) = 2.50000E-04

Run Time (minutes) = 100.99

Det. Resol. time (s) = 1.10000E-06

Count Rate (cps) =

raw = 1006.3

corrected = 1007.4

% = .11081

Inverse Count Rate = 9.92661E-04

Theoretical bkgd = 1006.3

Observed bkgd = 1007.4

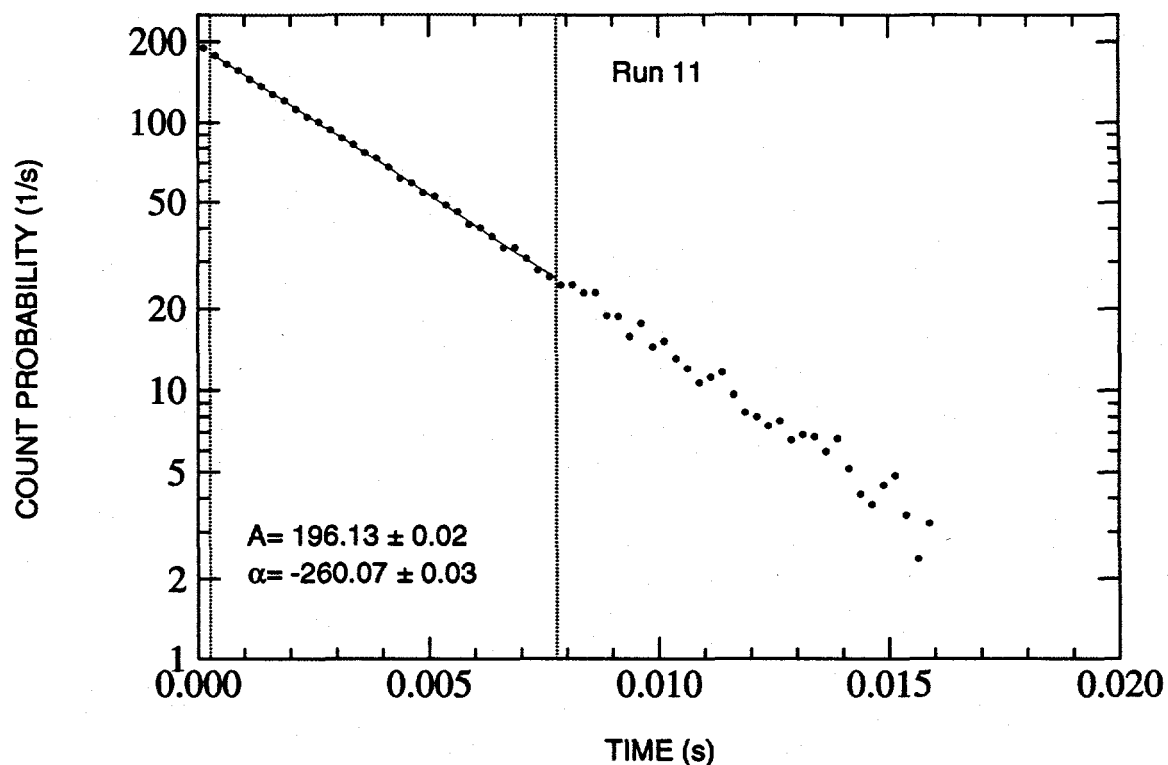


Figure 11.

RUN NUMBER= 11

Sept 11, 1997

Am-Be source removed, startup source not quite full in

AUTO CORRELATE

Number of blocks = 1

Last 16 ch opt = IN

Number data pts = 64

Time/ch (s) = 2.50000E-04

Run Time (minutes) = 107.45

Det. Resol. time (s) = 1.10000E-06

Count Rate (cps) =

raw = 1912.0

corrected = 1916.1

% = .21077

Inverse Count Rate = 5.21899E-04

Theoretical bkgd = 1912.1

Observed bkgd = 1918.1

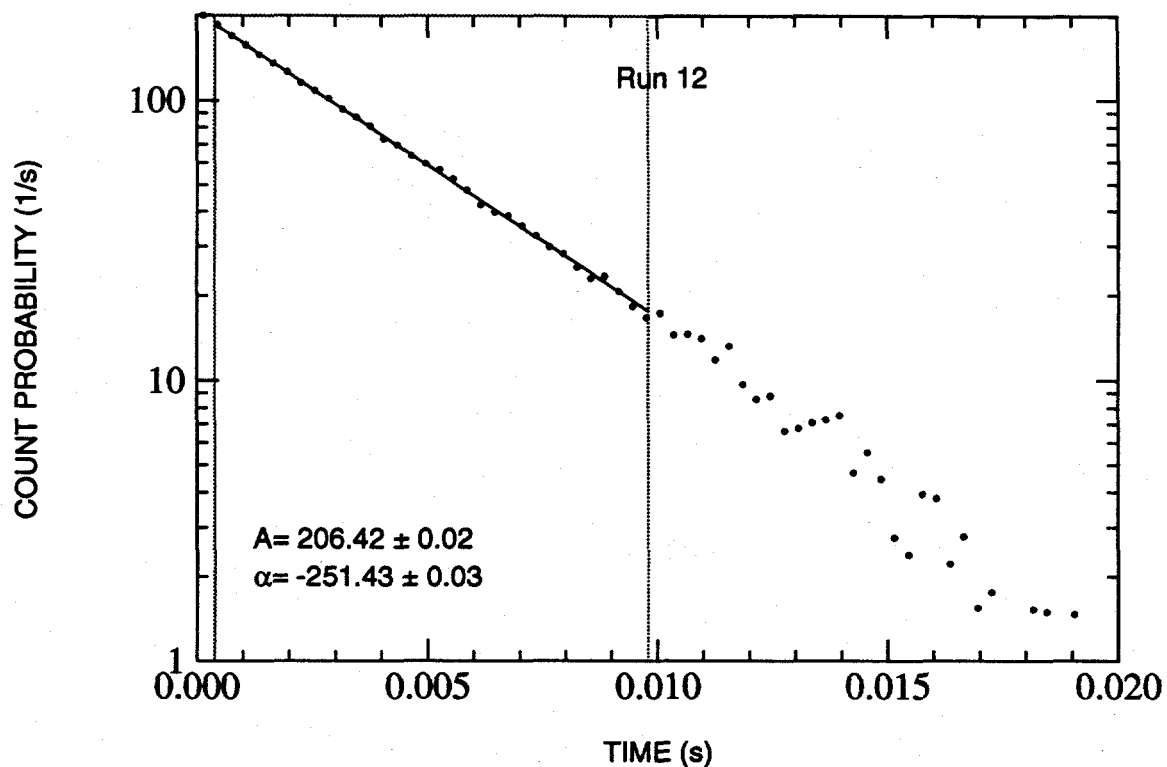


Figure 12.

RUN NUMBER= 12
 Sept 12, 1997
 intrinsic source only
 AUTO CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 Time/ch (s) = 3.00000E-04
 Run Time (minutes) = 68.087
 Det. Resol. time (s) = 1.10000E-06
 Count Rate (cps) =
 raw = 744.39
 corrected = 745.00
 % = 8.19503E-02
 Inverse Count Rate = 1.34228E-03
 Theoretical bkgd = 744.39
 Observed bkgd = 748.56

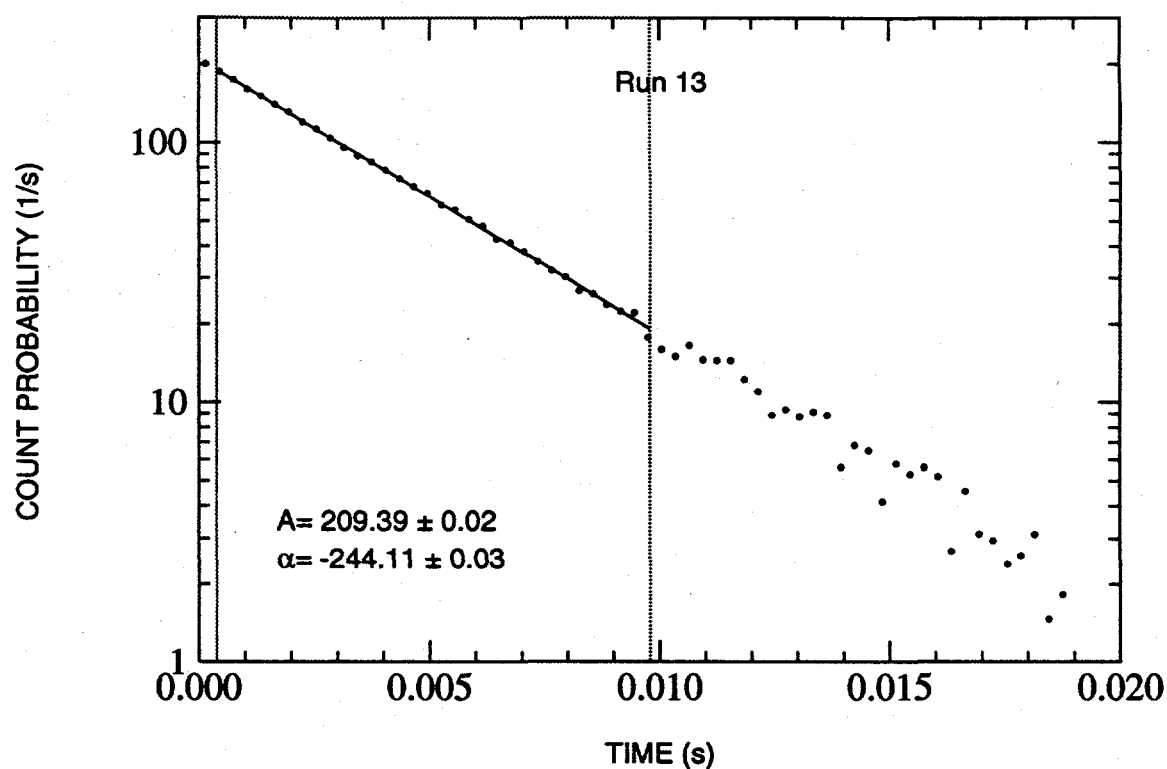


Figure 13.

RUN NUMBER= 13
 Sept 12, 1997
 intrinsic source only
 AUTO CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 Time/ch (s) = 3.00000E-04
 Run Time (minutes) = 70.387
 Det. Resol. time (s) = 1.10000E-06
 Count Rate (cps) =
 raw = 1229.6
 corrected = 1231.3
 % = .13544
 Inverse Count Rate = 8.12170E-04
 Theoretical bkgd = 1229.6
 Observed bkgd = 1235.1

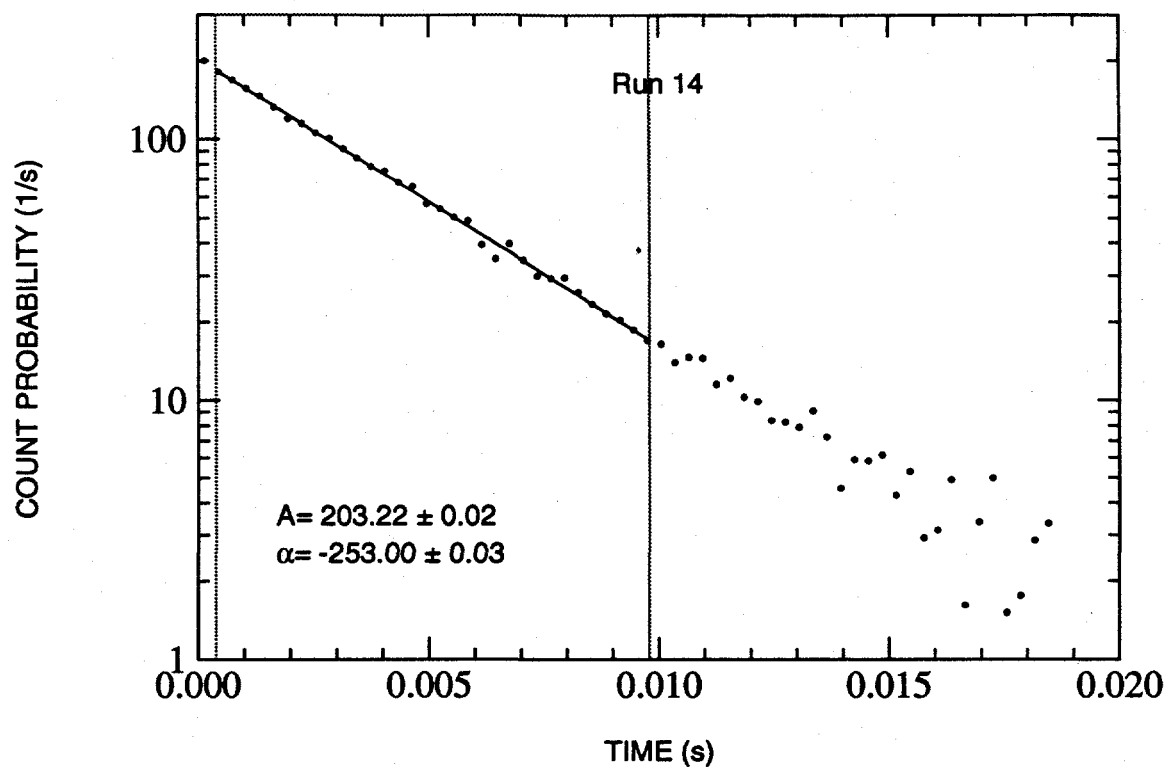


Figure 14.

RUN NUMBER= 14
 Sept 12, 1997
 intrinsic source only
 AUTO CORRELATE
 Number of blocks = 1
 Last 16 ch opt = IN
 Number data pts = 64
 Time/ch (s) = 3.00000E-04
 Run Time (minutes) = 23.164
 Det. Resol. time (s) = 1.10000E-06
 Count Rate (cps) =
 raw = 372.52
 corrected = 372.67
 % = 4.09937E-02
 Inverse Count Rate = 2.68334E-03
 Theoretical bkgd = 372.52
 Observed bkgd = 374.33

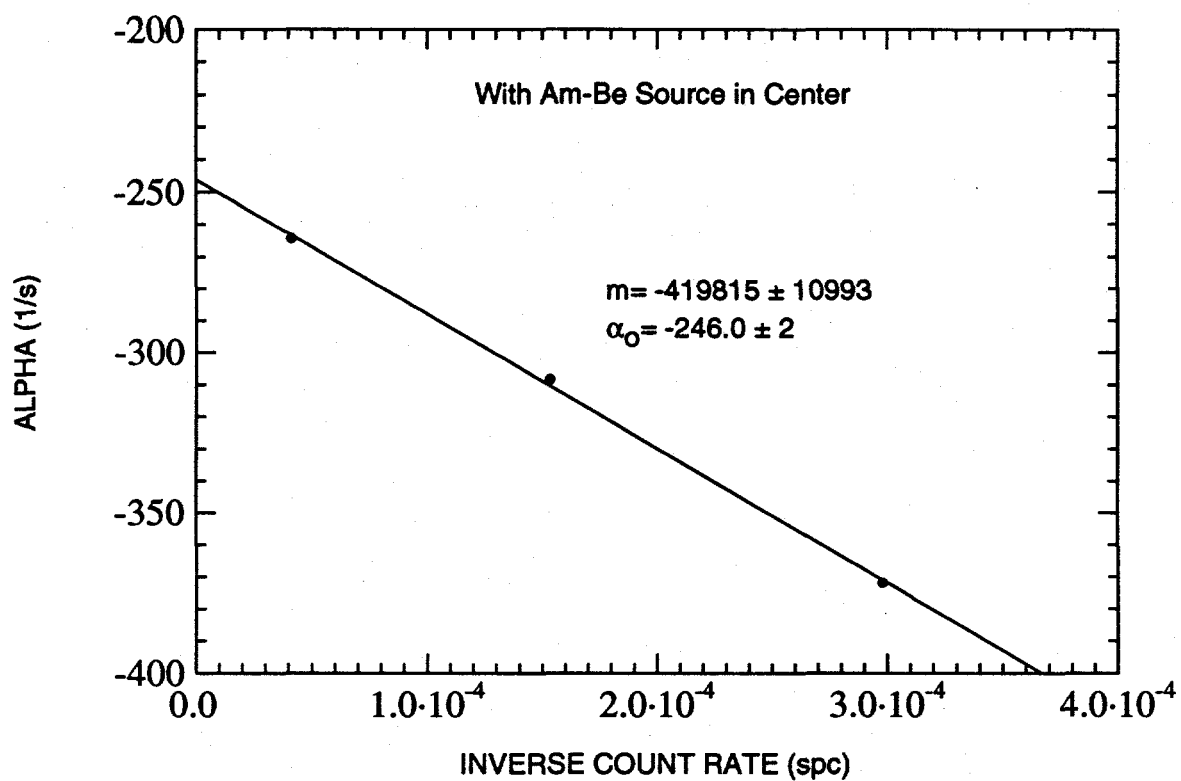


Fig. 15. Alpha vs. inverse count rate for the source configuration in which the Am-Be source was located in the center of the active fuel region.

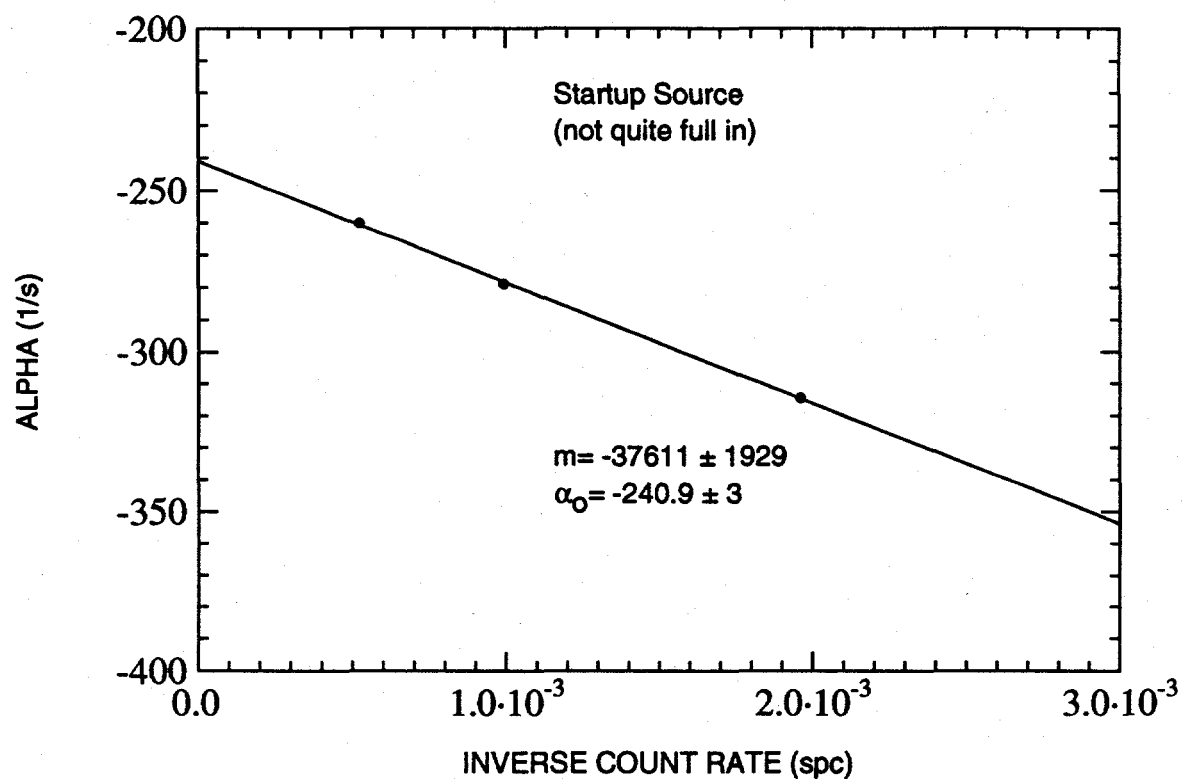


Fig. 16. Alpha vs. inverse count rate for the source configuration in which the Am-Be source was removed from the system and the startup source was located in its almost full in position.

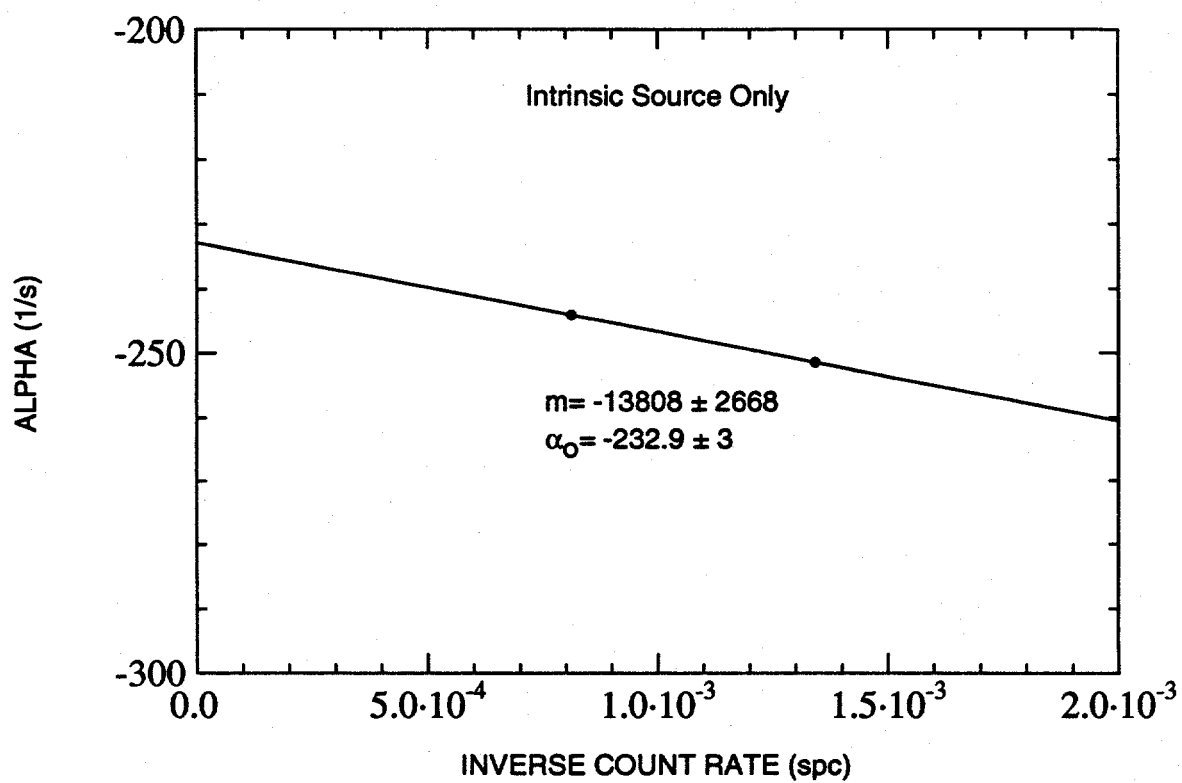


Fig. 17. Alpha vs. inverse count rate for the intrinsic source configuration .

Table I . Alpha at Delayed Critical

Source Configuration	α_o (1/s)
Am-Be in Center	-246.0
Start-up Source	-240.6
Intrinsic Source only	-232.9

is estimated by assuming an effective delayed neutron fraction of 0.00787, which was calculated and measured by IPEN. Hence, the neutron generation time is

$$\Lambda = -\frac{\beta_{eff}}{\alpha} = -\frac{0.00787}{-232.9} = 33.8 \mu s. \quad (1)$$

This corresponds reasonable well with the calculated neutron generation time of 34.5 μs using the 16-group Hansen-Roach cross sections and 32.0 μs as calculated by IPEN.

III. Intrinsic Source Measurement

The equivalent fundamental mode source strength for the intrinsic source and the start-up source in its almost full in position was determined by plotting the count rate of the two detectors (corrected for deadtime) as a function of the inverse reactivity of the system. The reactivity of the system at each subcritical configuration was determined from

$$\rho_s = 1 - \frac{\alpha}{\alpha_o} \quad (2)$$

For each source configuration, the slope of the curve was determined from a least-squares fit of the data. These results are shown in Fig. 18.

The equivalent fundamental mode source of the intrinsic source is given by

$$(g^* S)_i = \frac{(g^* S)_p}{\frac{m_p}{m_i} - 1} \quad (3)$$

Using the values of the slopes shown in Fig. 18, the equivalent fundamental mode source strength of the intrinsic source is a factor of 29.4 less than the equivalent fundamental mode source strength of the Am-Be source when located in the center of the active fuel region.

The start-up source in its almost full in position plus the intrinsic source strength is a factor of 11.72 less than the equivalent fundamental mode source strength of the Am-Be source

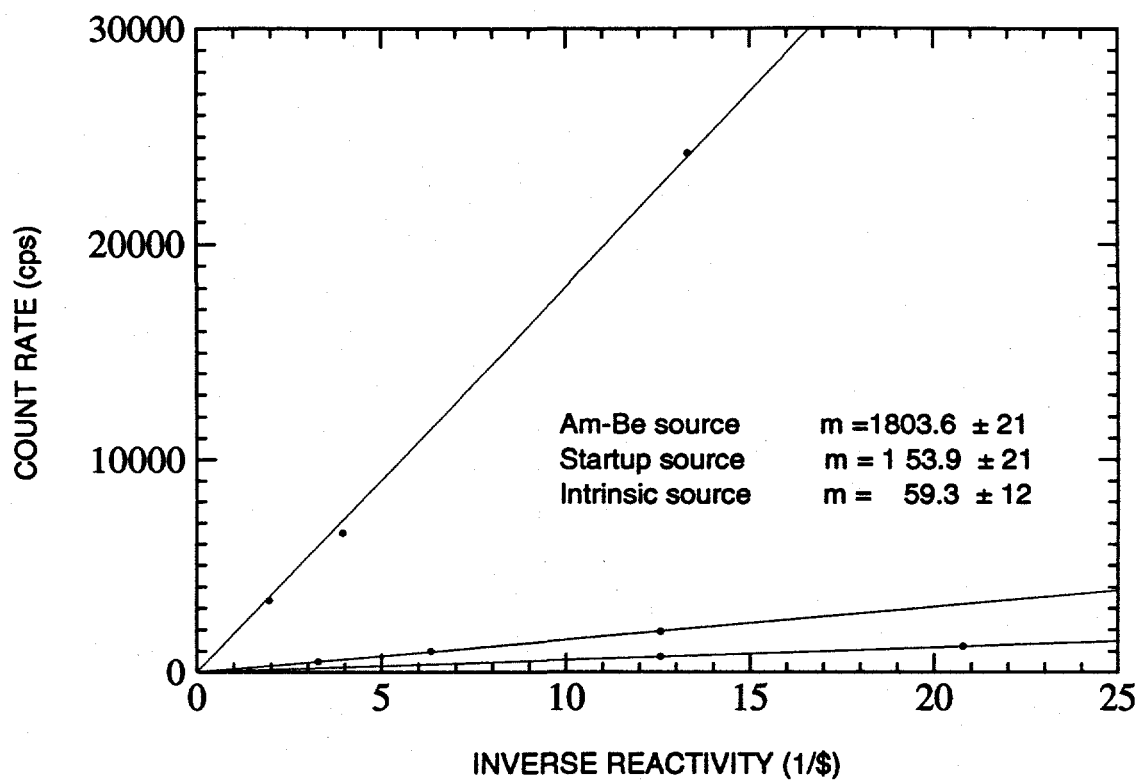


Fig. 18. Plot of detector count rate vs. inverse reactivity. The slope of each curve was determined from a least-squares fit of the data.

when located in the center of the active fuel region.

Using the three-dimensional neutron transport code, THREEDANT, it was determined that the g^* factor for the Am-Be source in the center of the assembly was 1.78. Assuming an absolute source strength of 25,000 neutron/sec, the equivalent fundamental mode intrinsic source strength is estimated to be 1513 neutrons/sec. Based on 190 kg of ^{238}U in the active core region, the total intrinsic source strength is approximately 2584 neutrons/sec. This yields a measured g^* factor for a uniformly distributed ^{238}U spontaneous neutron source of 0.586, which is considerable smaller than the calculated g^* of 0.75 by LANL and 0.84 by IPEN.

IV. Recommendations

As a result of these preliminary Rossi-alpha measurements, there are several recommendations that should be implemented before performing another series of measurements.

- The Rossi- α measurements should be performed with only the intrinsic source present.
- Because of the low-level scram that currently exist on the MB-01 reactor, it is nearly impossible to obtain reactivities lower than about $-\$0.20$ with just the intrinsic source driving the system. In order to perform an accurate effective delayed neutron fraction measurement, it is necessary to go as far subcritical as $-\$1.20$. Hence, the low-level scram must be converted to an interlock so that the system will not scram at low multiplications. This change does not constitute a safety concern since the entire experiment is performed in the subcritical state. The interlock should disallow the operator to add reactivity to the system, but not preclude rod movements in which the system is made more subcritical.
- The BF_3 detectors used in these measurements need to be replaced with more efficient detectors. Rather than an active detection zone of a few centimeters, the active region of the new detectors should be as high as the active core region. This will increase the detector efficiency by an order of magnitude, which will allow a more accurate measure of the effective delayed neutron fraction and the alpha at delayed critical.
- A calibrated Am-Be source of approximate strength of 1000 neutrons/second should be acquired in order to perform a more accurate intrinsic source measurement. The count rates obtained during this measurement were too high; the dead-time correction was, in some cases, as high as 7%, which is too high for a precision measurement.
- And finally, a stronger Am-Be source of approximately 1,000,000 neutrons/second should be acquired in order to perform a more accurate deadtime measurement of

the detector system.

V. Conclusions

With the implementation of the above recommendations, it should be straight forward to perform a precision effective delayed neutron fraction measurement and a measurement of the alpha at delayed critical. The MB-01 reactor is well suited for neutron noise measurements in that the neutron generation time is small enough that the intrinsic source strength will not cause the system to exceed the neutron noise threshold. The information that was obtained during this preliminary set of measurements was invaluable and provides a good indication of what needs to be done in order to perform precision measurements of vital reactor parameters.