Cf-252 source investigation.

A. General things.

Neutrons emitted in the process of spontaneous fission have the following TOF properties (Fig. 1).

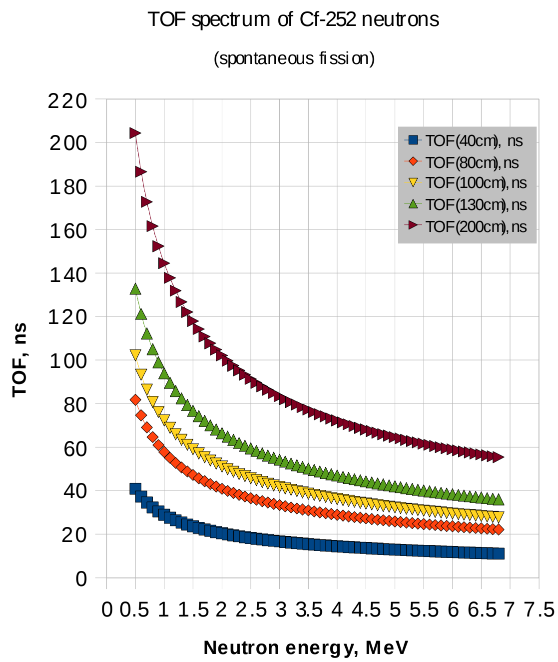

Fig. 1. Neutron TOF as a function of neutron energy and a distance from the Cf-252 source.

In order to obtain the neutron TOF spectrum in units of time the TDC was calibrated with the help of a passive delay line and the calibration is pictured in Fig. 2.

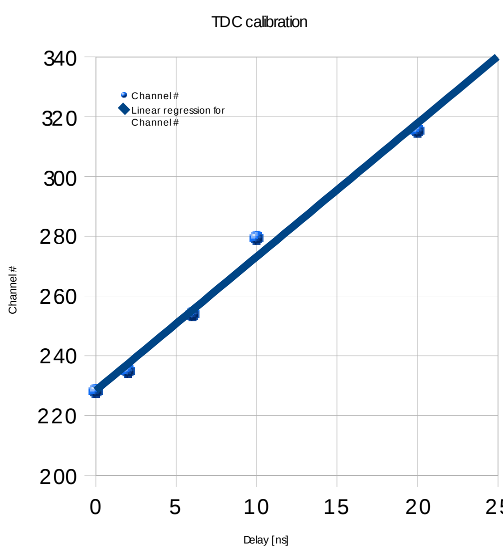

Fig. 2. TDC calibration curve.

The data were fitted with linear regression: Channel#=4.471*Delay(ns)+228.4 . The calibration is 0.22366 ns/ch.

B. Zero time calibration.

Below all the TDC were calibrated in ns. X-axis should be labled TDC ns instead of TDC ch.

In order to define the zero time (photon peak) in neutron TOF spectrum, Na-22 source was used. NaI trigger threshold was reduced to -14 mV on CFD to be able to detect 0.511 MeV photons, U(NaI) = -1050 V and 50 Ohm splitter was removed from the signal channel. Since the CFD was used, the change from the setup set for the neutron TOF spectrum collection to zero time calibration setup may affect the TDC spectra. We will see that it is not the case.

BKG run 3405. NaI is in the shielding. Trigger rate = 7.0345 Hz, U(NaI) = -1050 V, Thresh(NaI) = -14 mV. No veto detector in use. Thresh(neutron det) = -5 mV.

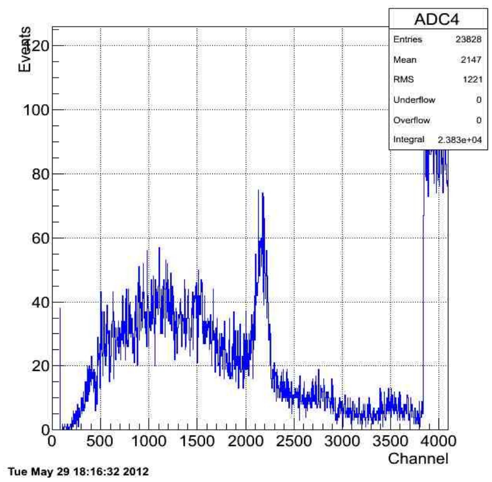

Fig. 3. Background spectrum taken with NaI(Tl). There is a BKG peak in ~2200 channel.

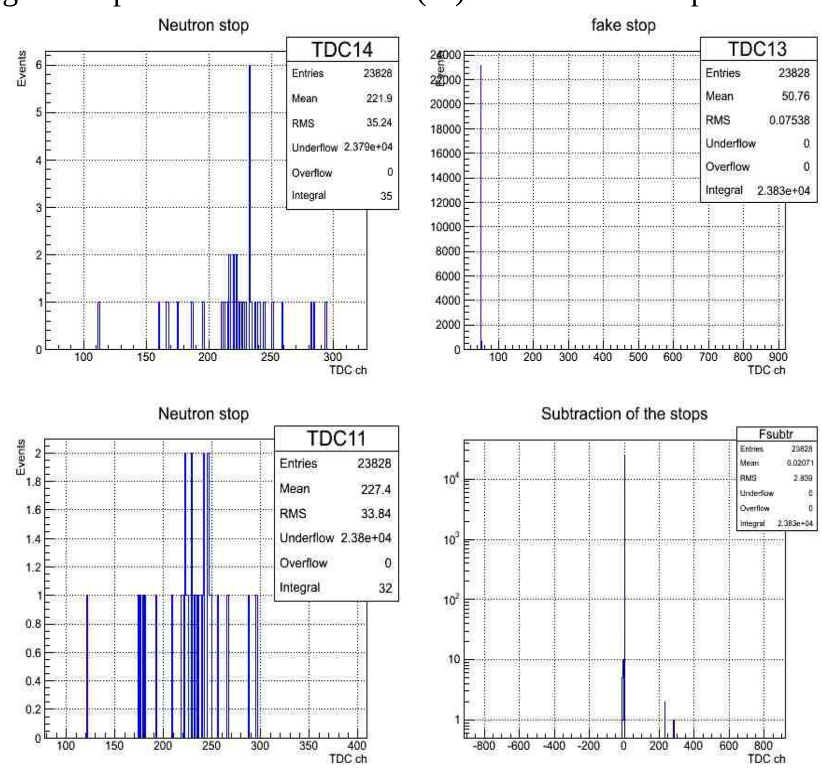

Fig. 4. Background TDC spectrum taken by big plastic scintillator.

It can be seen from Fig. 4 that there is a correlation between the NaI(Tl) common start and plastic scintillator stops at ~230 ns in TDC14 and 240 ns in TDC11. Not a great statistics though.

Run 3404. Na-22 placed inside the shielding upon the NaI(Tl). Rate = 2190 Hz. Detectors are 87 cm away from each other. U(NaI) = -1050 V, Thresh(NaI) = -14 mV. Thresh(neutron det) = -5 mV. No veto detector in use.

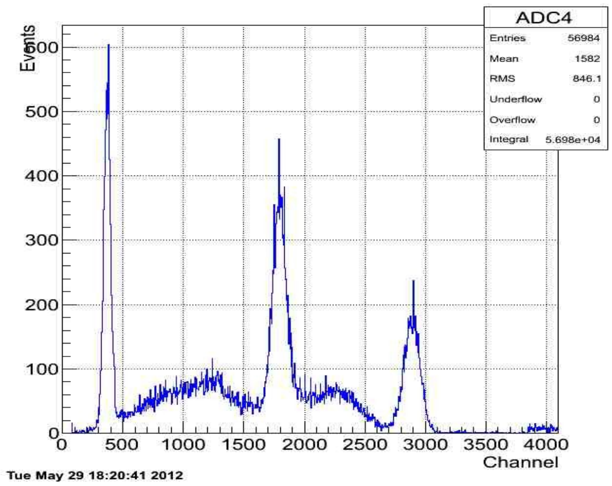

Fig. 5. Na-22 spectrum taken by NaI(Tl).

An example of the spectrum of Na-22 obtained by http://www.amptek.com/gamma8k.html is presented below in Fig. 6.

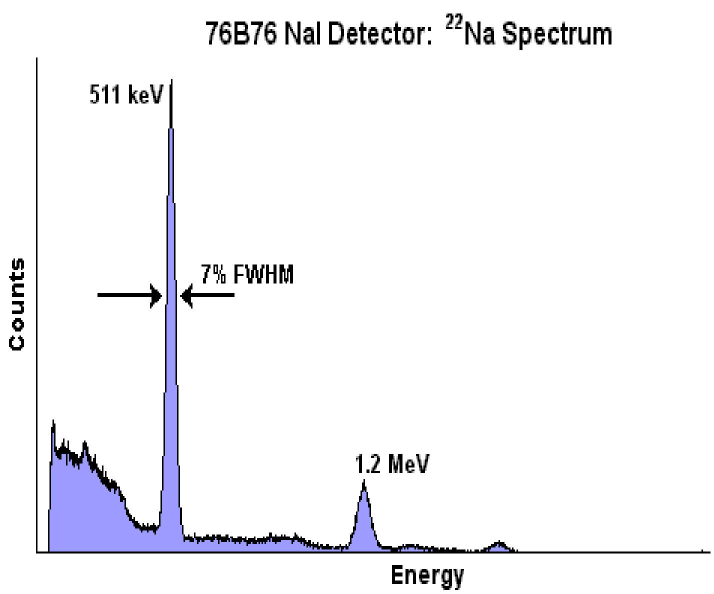

Fig. 6. Na-22 spectrum taken by AmpTek GAMMA-8000.

The S/N ratio in our case is 2190 Hz/7.034 Hz = 311.34 . BKG peak can not be seen in the spectrum.

The timing spectrum taken during spectrum measurement is shown in Fig. 7.

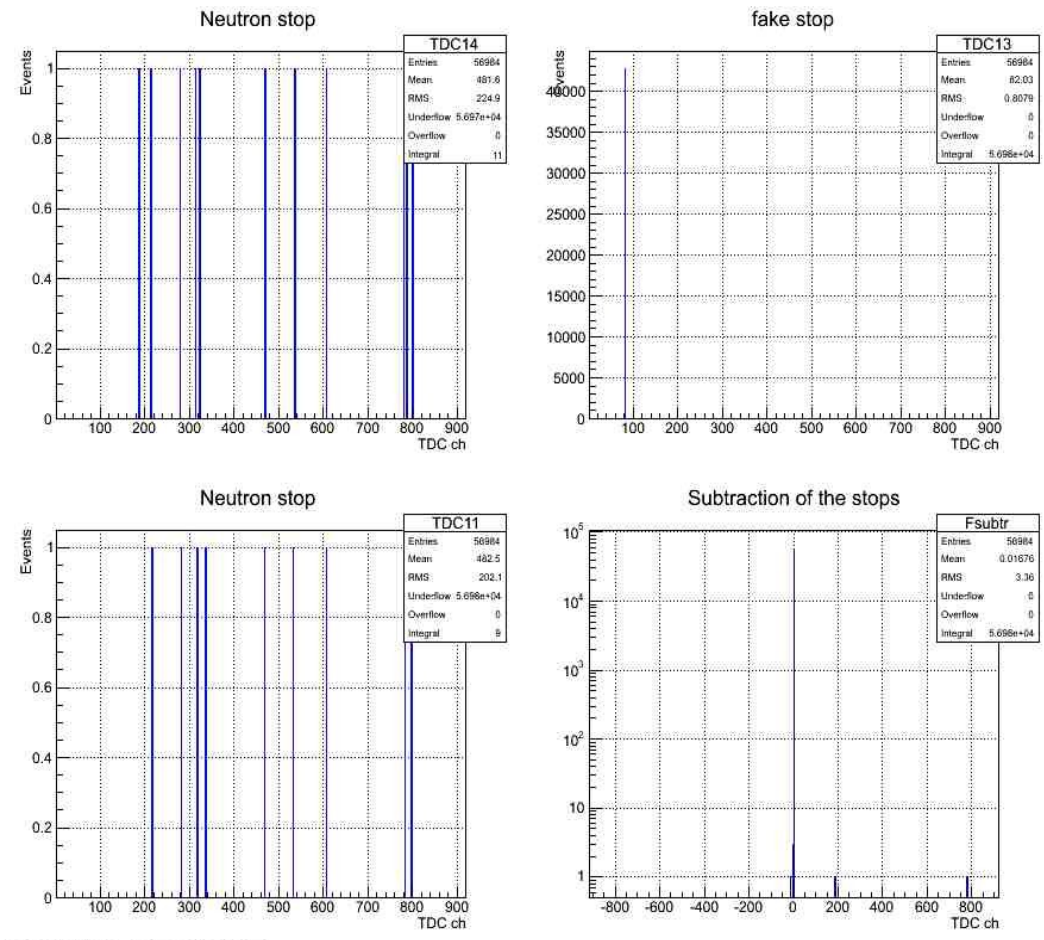

Fig. 7. TOF spectrum.

There is no any correlation between Na-22 start and signals in both channels of the plastic scintillator. The stops are randomly distributed (low statistics). There is no correlation between the signals going all the way through the NaI(Tl) trigger channel and stop channels of the plastic scintillator even at that high trigger counting rate (2190 Hz).

<u>Run 3403.</u> Time zero measurement using Na-22 source. Rate = 50.5 Hz. NaI was outside of the shielding, next to the big plastic scintillator (~ 15 cm away from each other with Na-22 in between). U(NaI) = -1050 V, Thresh(NaI) = -14 mV. Thresh(neutron det) = -5 mV.

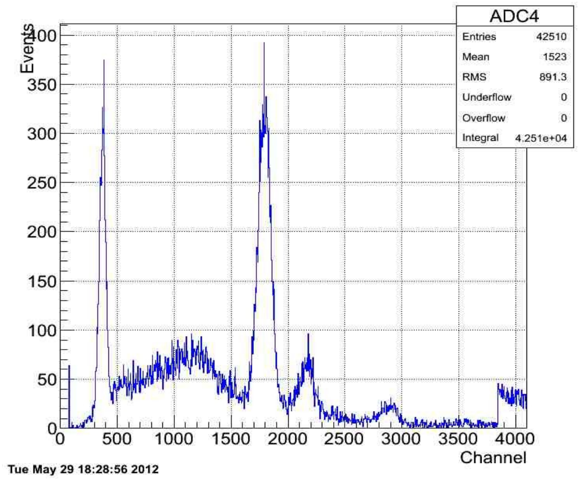

Fig. 8. Na-22 spectrum taken via unshielded NaI(Tl).

In Fig. 8 the spectrum of Na-22 taken using unshielded NaI(Tl) detector is shown. Signal-to-Noise ratio is 50.5 Hz/7.034 Hz = 7.2 and BKG peak can be seen in the channel ~2200.

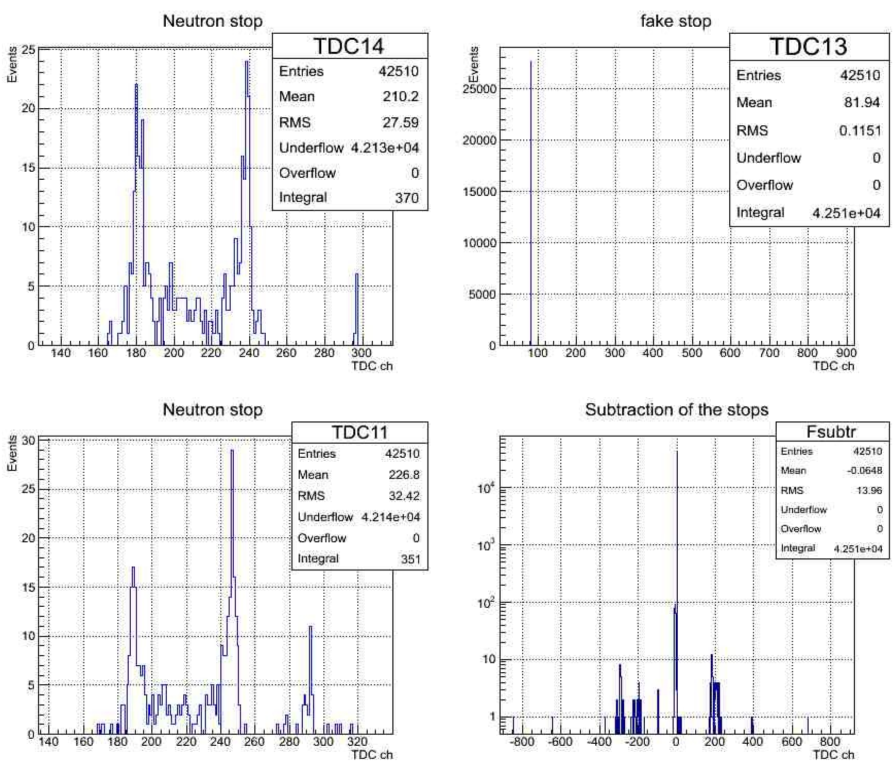

Fig. 9. TOF measured using 0.511 MeV annihilation photons from Na-22.

It can be seen from Fig. 9 that there are two peaks in TOF spectrum. According to Fig. 4 above and Figs. 11, 13 the peaks at later time are due to the cosmic rays and the first two peaks are due to the Na-22 annihilation photons. The reason for that is still unclear to me.

Run 3397. BKG run. No veto, no shielding around NaI. Rate = 1.67 Hz, U(NaI) = -1020 V, Thresh(NaI) = -50 mV. 50 Ohm signal splitter is on NaI signal channel. The setup was configured for the Cf-252 neutron TOF measurement and cutting photons below 1.2 MeV. Thresh(neutron det) = -5 mV.

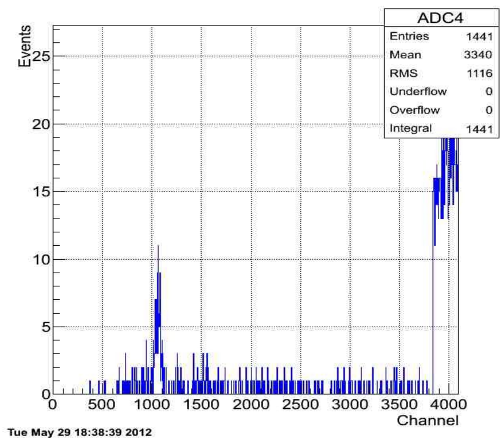

Fig. 10. BKG spectrum taken by unshielded NaI(Tl).

Signal was passed through 50 Ohm splitter and our BKG peak in Fig. 3 moved to ~2200/2=1100 channel.

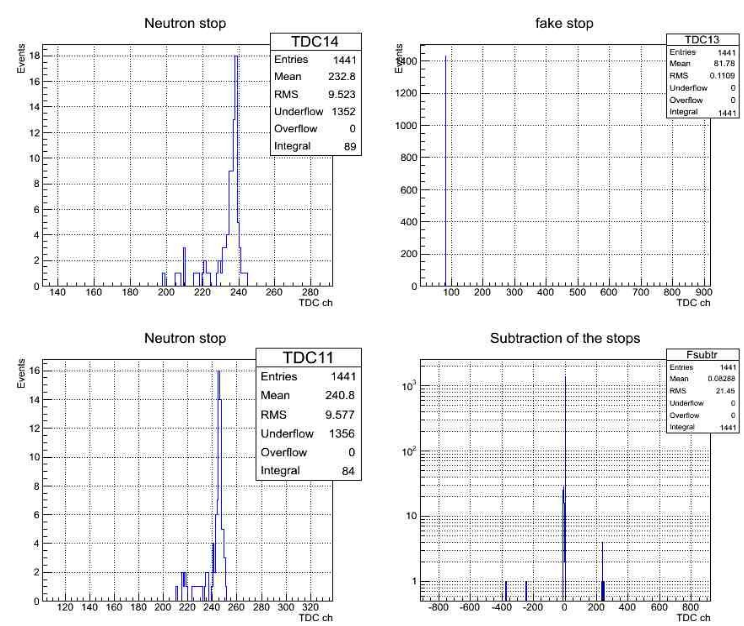

Fig. 11. BKG TOF spectrum.

Fig. 11 shows that the position of the TOF peak for BKG radiation does not depend on the NaI(Tl) CFD threshold and bias voltage.

<u>Run 3385.</u> BKG run, NaI is inside the shielding. There is 2" of borated poly + 2" of lead in front of the plastic scintillator. Rate = 1.03 Hz. Veto detector is inside the shielding right above the NaI(Tl). U(NaI) = -1020 V, Thresh(NaI) = -50 mV. Thresh(neutron det) = -5 mV. 50 Ohm signal splitter is on NaI signal channel.

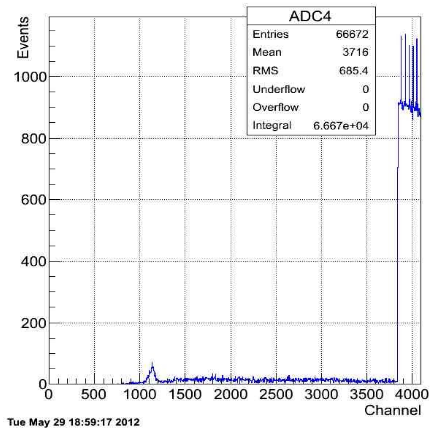

Fig. 12. BKG spectrum taken by shielded and cosmic rays veto'ed NaI(Tl) detector.

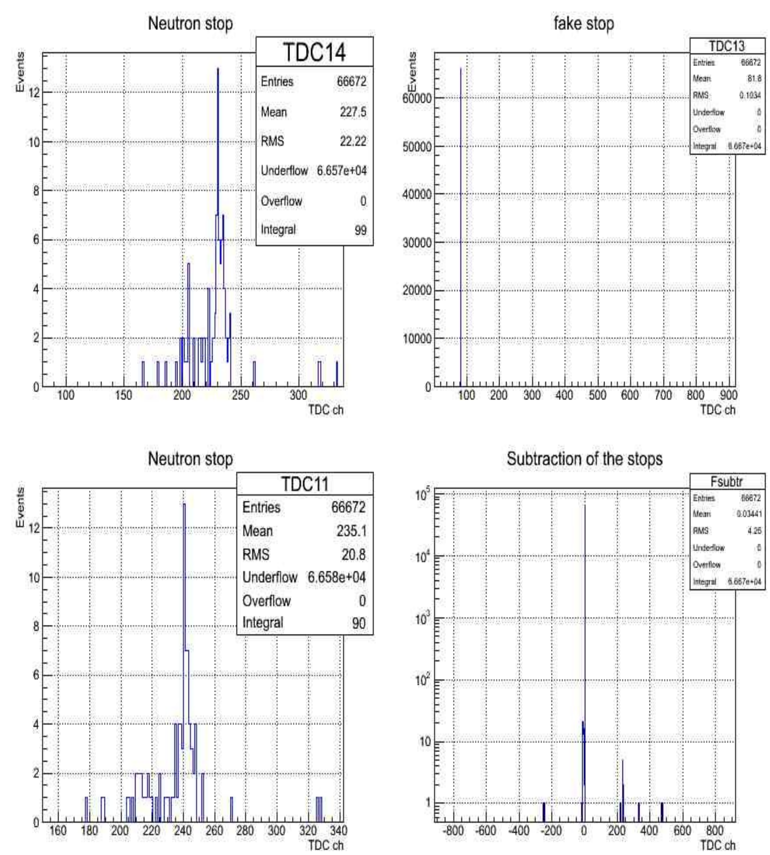

Fig. 13. BKG TOF spectrum.

C. Influence of borated polyethylene on the Cf-252 neutron flux.

Run 3395. No borated polyethylene in front of the plastic scintillator. Just 2" of lead. Cf-252 source in. Rate = 59.67 Hz. Veto detectors in use. U(NaI) = -1020 V, Thresh(NaI) = -50 mV. Thresh(neutron det) = -5 mV. 50 Ohm signal splitter is on NaI signal channel.

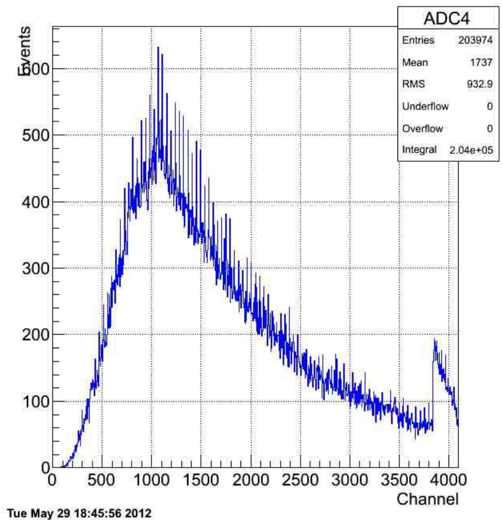

Fig. 14. Cf-252 spectrum taken by NaI(Tl).

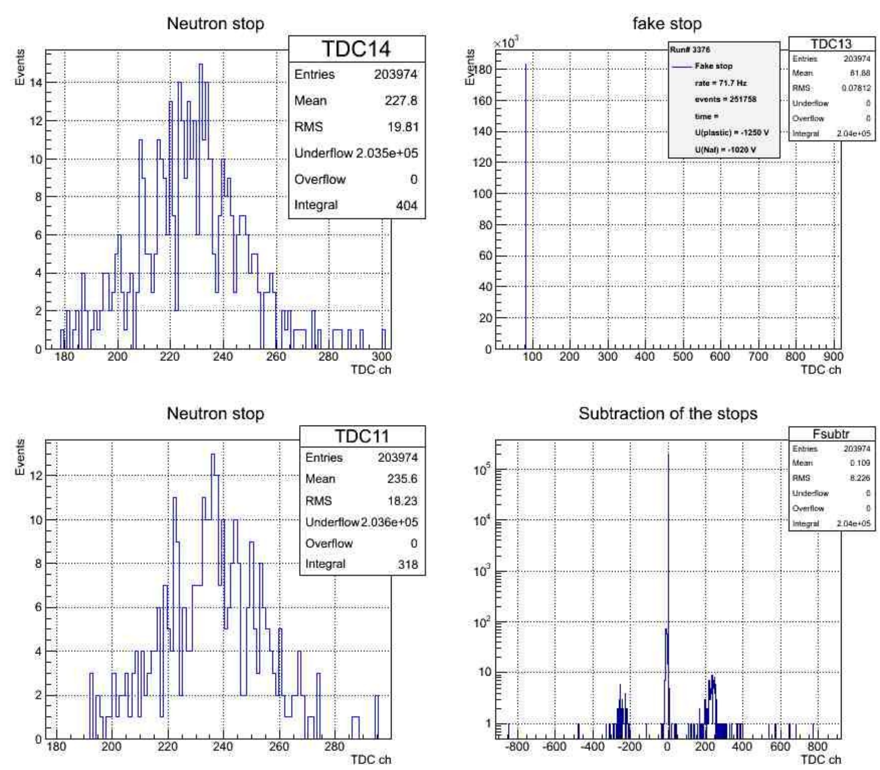

Fig. 15. Neutron ToF spectrum. No borated polyethylene.

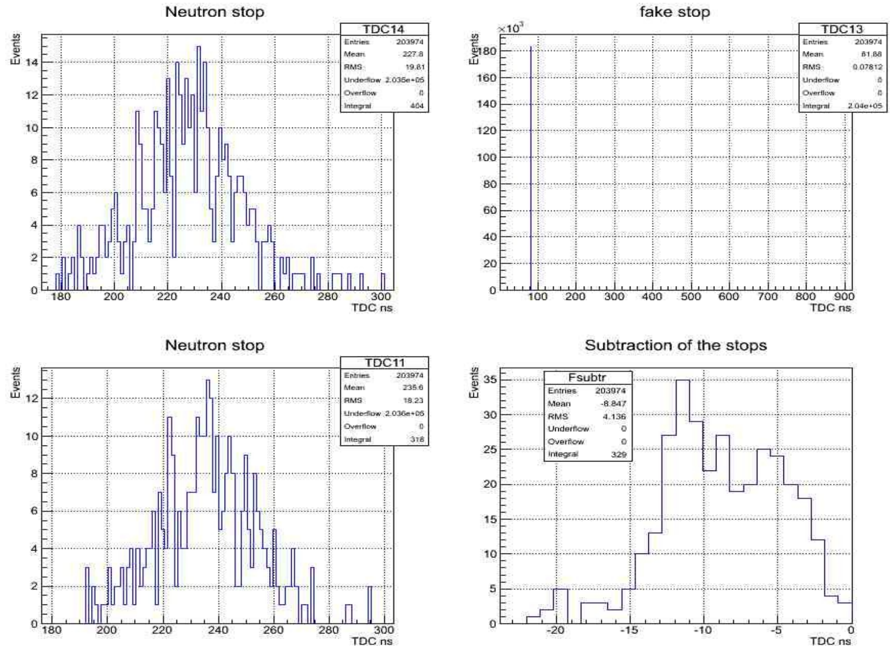

Fig. 15.a. Neutron ToF spectrum w/ zoomed signal subtraction plot. No borated polyethylene.

According to Fig. 9 the photons should come at ~180 ns in TDC14 and at ~190 ns in TDC11. If it is correct then the rest are neutrons. The source was at 70 cm away from the plastic scintillator. Fig. 1 says that neutron ToF for that distance should be ~50 ns for 1 MeV neutron. In channel TDC14 we have 180ns + 50ns = 230 ns which is correct, and in channel TDC11 190ns+50ns=240 ns which is also correct.

Hence we have 404 neutrons in region 180-300 ns in channel TDC14 and 318 neutrons in region 180-300 ns in channel TDC11. The duration of run was 3418.36 sec. Hence the neutron counting rate was 404/ 3418.36 = 0.12 Hz in TDC14 and 318/ 3418.36 = 0.093 Hz in TDC11.

<u>Run 3394.</u> 2" of borated polyethylene in front of the plastic scintillator + 2" of lead. Cf-252 source in. Rate = 63.46 Hz. Veto detectors in use. U(NaI) = -1020 V, Thresh(NaI) = -50 mV. Thresh(neutron det) = -5 mV. 50 Ohm signal splitter is on NaI signal channel.

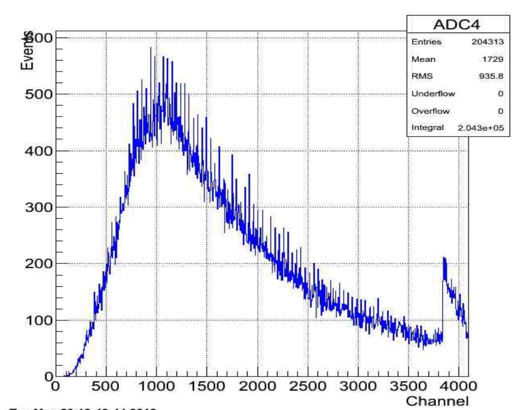

Fig. 16. Cf-252 spectrum taken by NaI(Tl).

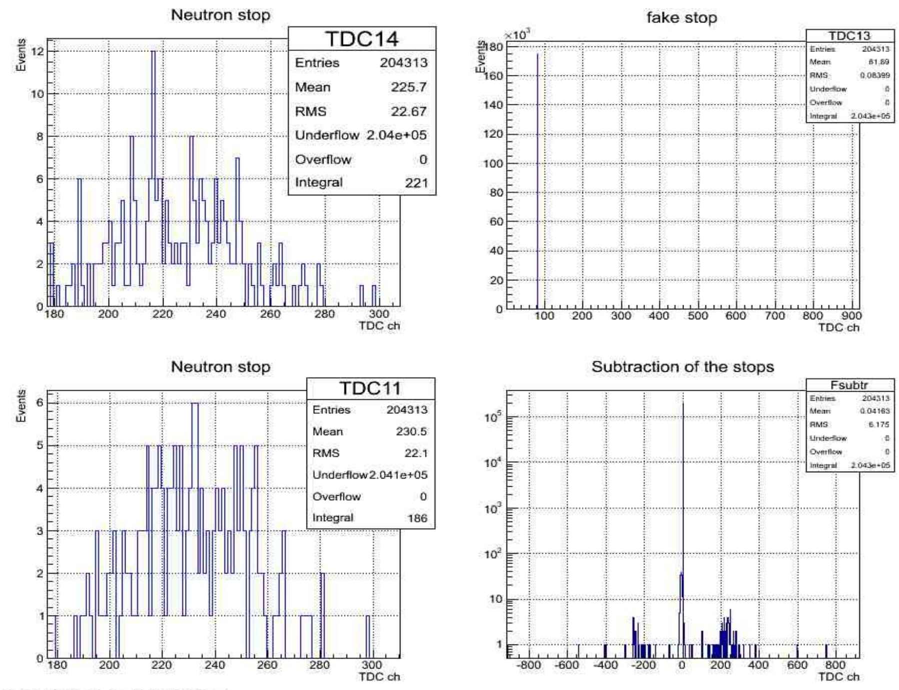

Fig. 17. Neutron ToF spectrum. 2" of borated polyethylene.

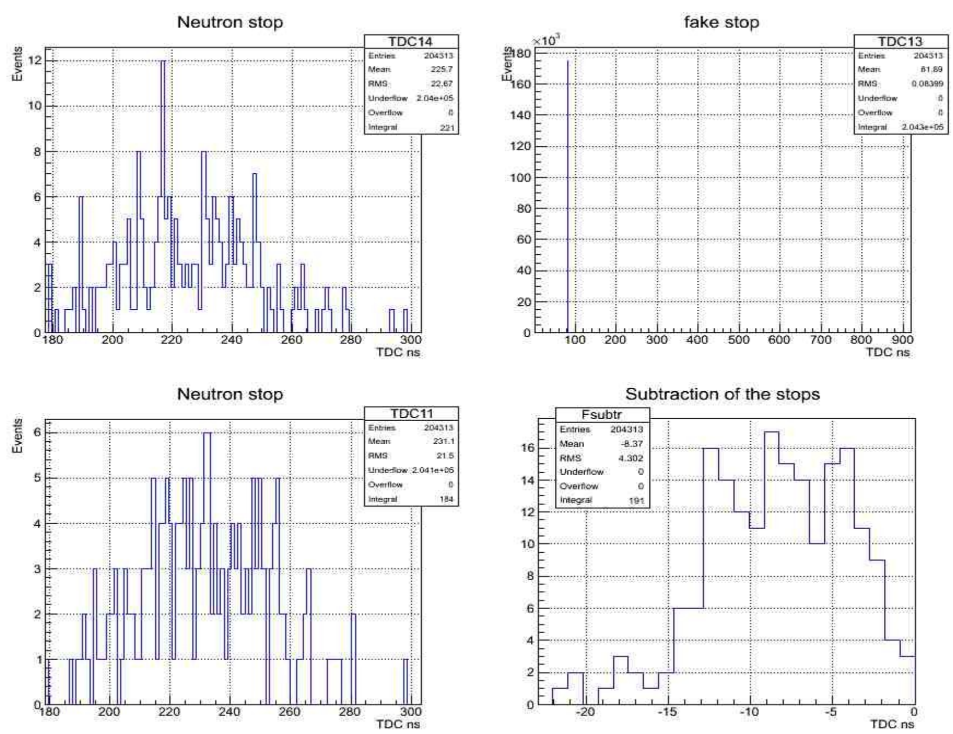

Fig. 17.a. Neutron ToF spectrum w/ zoomed signal subtraction plot. 2" of borated polyethylene.

Same reasoning gives us 221 neutron in region 180-300 ns in channel TDC14 and 186 neutrons in region 180-300 ns in channel TDC11. The duration of run was 3219.55 sec. Hence the neutron counting rate was 221/ 3219.55 = 0.0686Hz in TDC14 and 186/3219.55 = 0.0577 Hz in TDC11.

TDC14:

n-rate change depending on the borated polyethylene (BP): BP_out/BP_in = 0.12/0.0686 = 1.74

TDC11:

n-rate change depending on the borated polyethylene (BP): BP_out/BP_in = 0.093/0.0577 = 1.61

D. Efficiency of the plastic scintillator.

If the data presented in the previous report are correct, then the
neutron detector efficiency defined by TDC14 channel is:

N_n = 404;
N_fission_trig = 203974;
Delta_omega @ 70 cm ~ 0.108 sr;
Nu = 3 neutrons;

Eff(by TDC14) = 404/203974 * 1/3 * 4pi/0.108 * 100%
= 0.00198*0.33*116.3*100% = 7.6%.

Same procedure for TDC11:

N_n = 318;
N_fission_trig = 203974;
Delta_omega @ 70 cm ~ 0.108 sr;
Nu = 3 neutrons;

Eff(by TDC11) = 318/203974 * 1/3 * 4pi/0.108 * 100%
= 0.00156*0.33*116.3*100% = 5.98%.