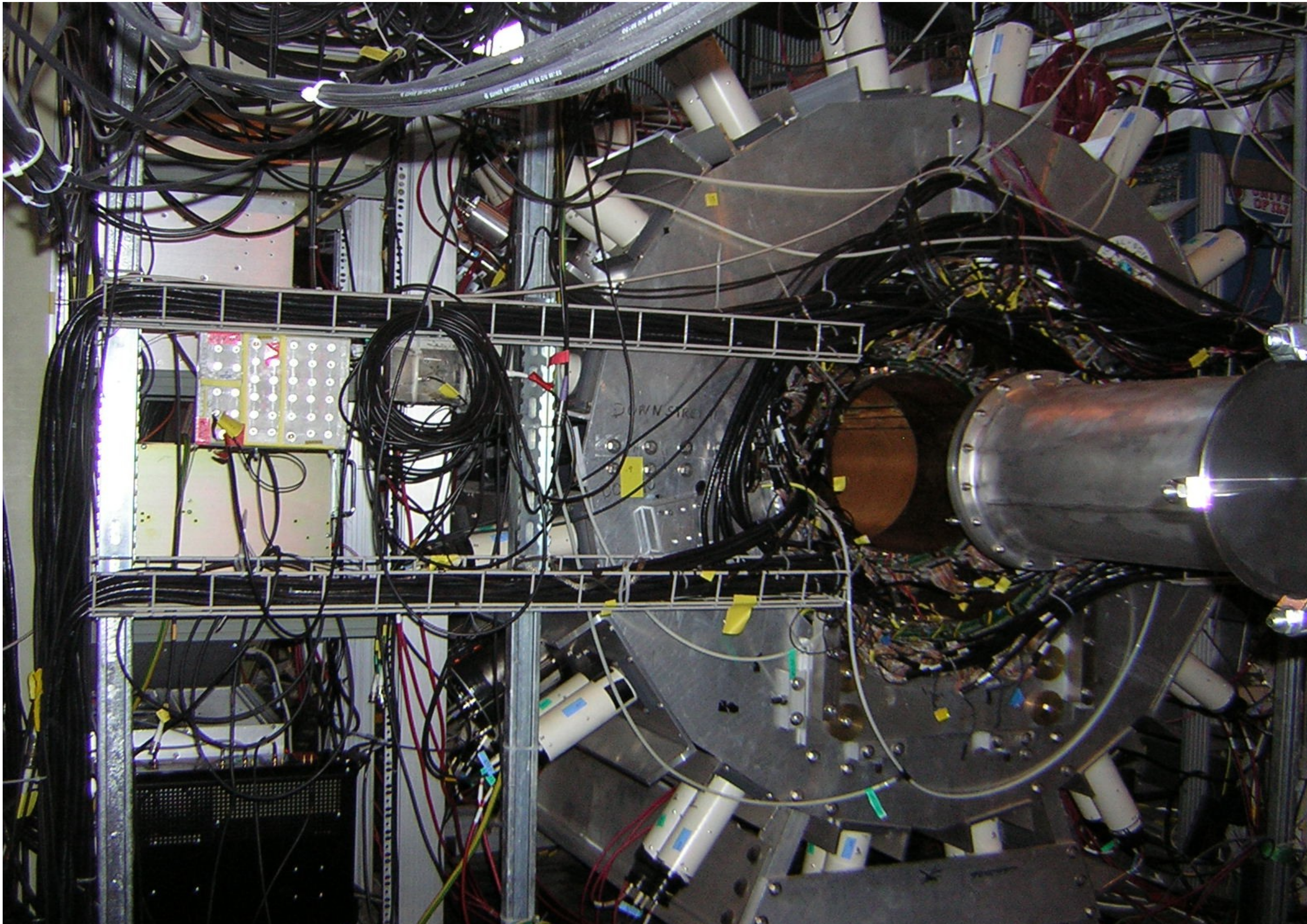
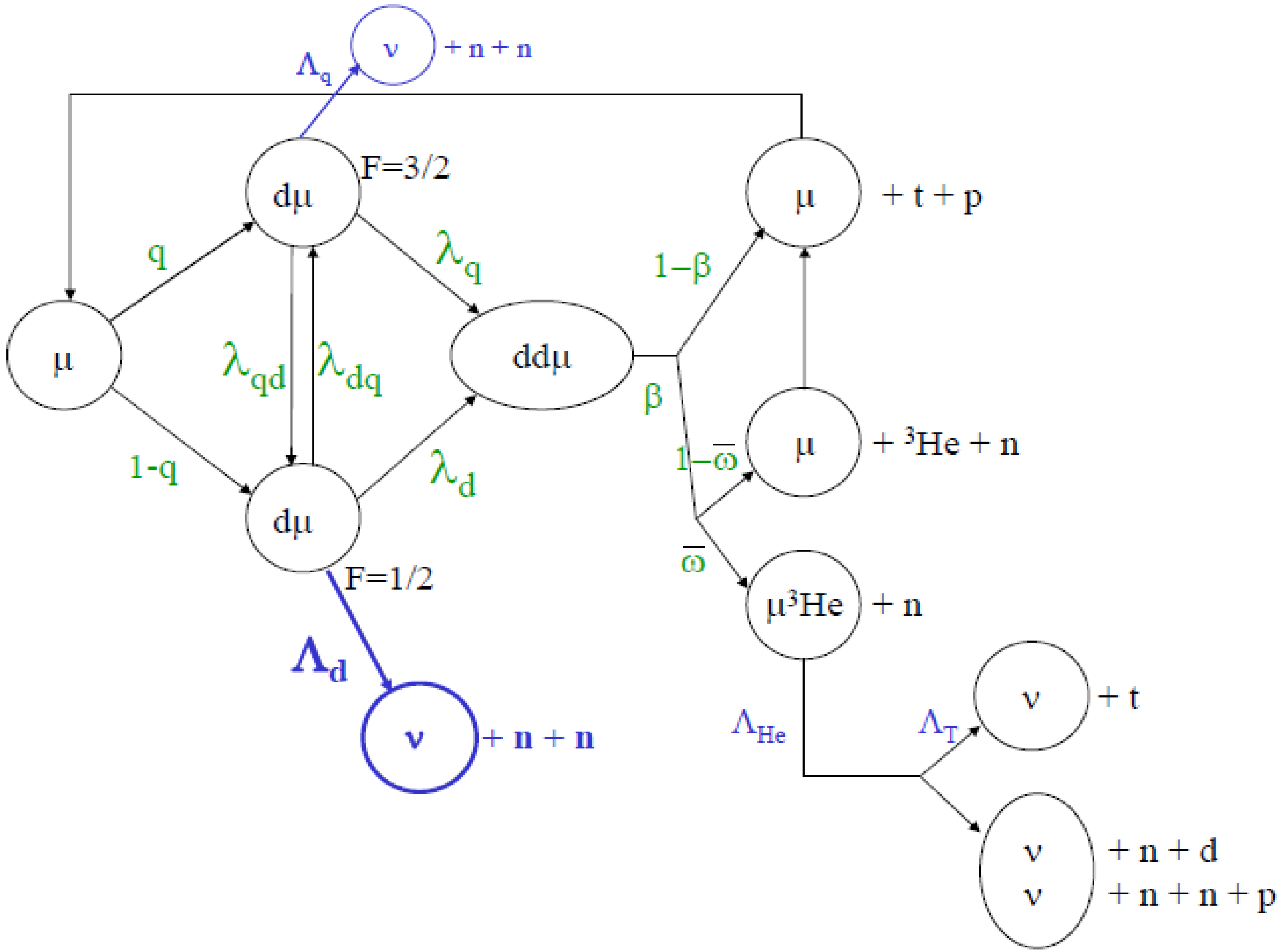
MuSun Experiment
- Neutron Data Analysis



Muon Chemistry



Musun - Experimental Goal

• Measure doublet muon capture rate in deuterium

$$\mu^- + d \rightarrow n + n + \nu_\mu$$

Rate from μd (↑↓) atom

Desirable:

(i) Maximum doublet population and

(ii) Minimum background from μ^3He,

Which helps precise determination of Λ_d

Achieved with optimized target conditions –

* High gas density of 5% LH_2 - increases λ_{qd} → doublet population

* Low temp 30 K → smaller rate of λ_d leads to less quartet population via recycling

Neutron Analysis

Sources of Neutrons:

The muons stopped in the TPC produce neutrons due to

(i) **Fusion** of dμd molecule to form ^{3}He+ n + μ :

$$dd\mu \rightarrow {}^3He + n + \mu$$

(ii) **Capture from deuterium**:

$$\mu d \rightarrow n + n + \nu$$

Fusion Neutron Analysis

Fusion neutrons analysis will help in finding

- λ_q, λ_d and λ_{qd} most prominently λ_q(as λ_d is very small at 30K)
- dμd formation rate from quartet state due to recycling of muons

Fusions -

(i) followed by an electron – apply a delayed e- cut to the neutron time spectrum wrt muons stopped in the TPC.

(ii) mono-energetic ~ 2.45 MeV – applied this energy constraint also

Fusion Neutron Analysis

Delayed e-cut:

Applied **only to neutrons** corresponding to **muons stopped** in the TPC –
(I did this applying a mustop definition)

Since fusion neutrons are followed by a **delayed e-** – the e- time spectrum wrt neutrons helped in selecting this delayed electron cut corresponding to a time difference of **200 to 5000 ns** from this spectra => we have fusion neutrons in this time interval

Mono-energetic fusion neutron cut:

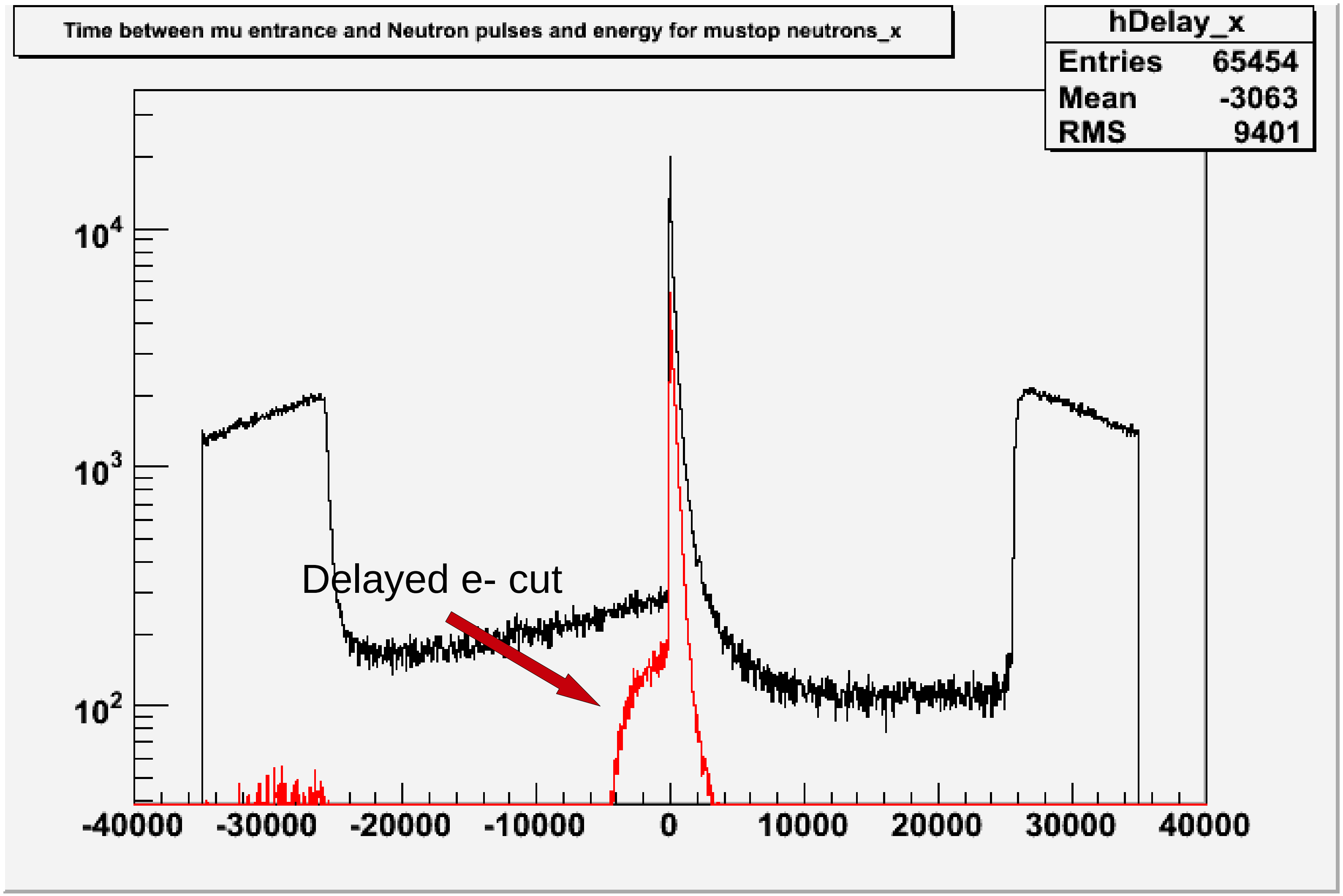
Fusion neutrons are **mono-energetic** (2.45 MeV) and this energy cut (<2.45 MeV) chosen from the energy spectrum of the short lifetime component for different detectors to precisely find fusion neutrons

All these cut was applied the neutron time spectrum (i.e. neutron time wrt to muons) to finally determine fusion neutrons

Fusion Neutron Analysis

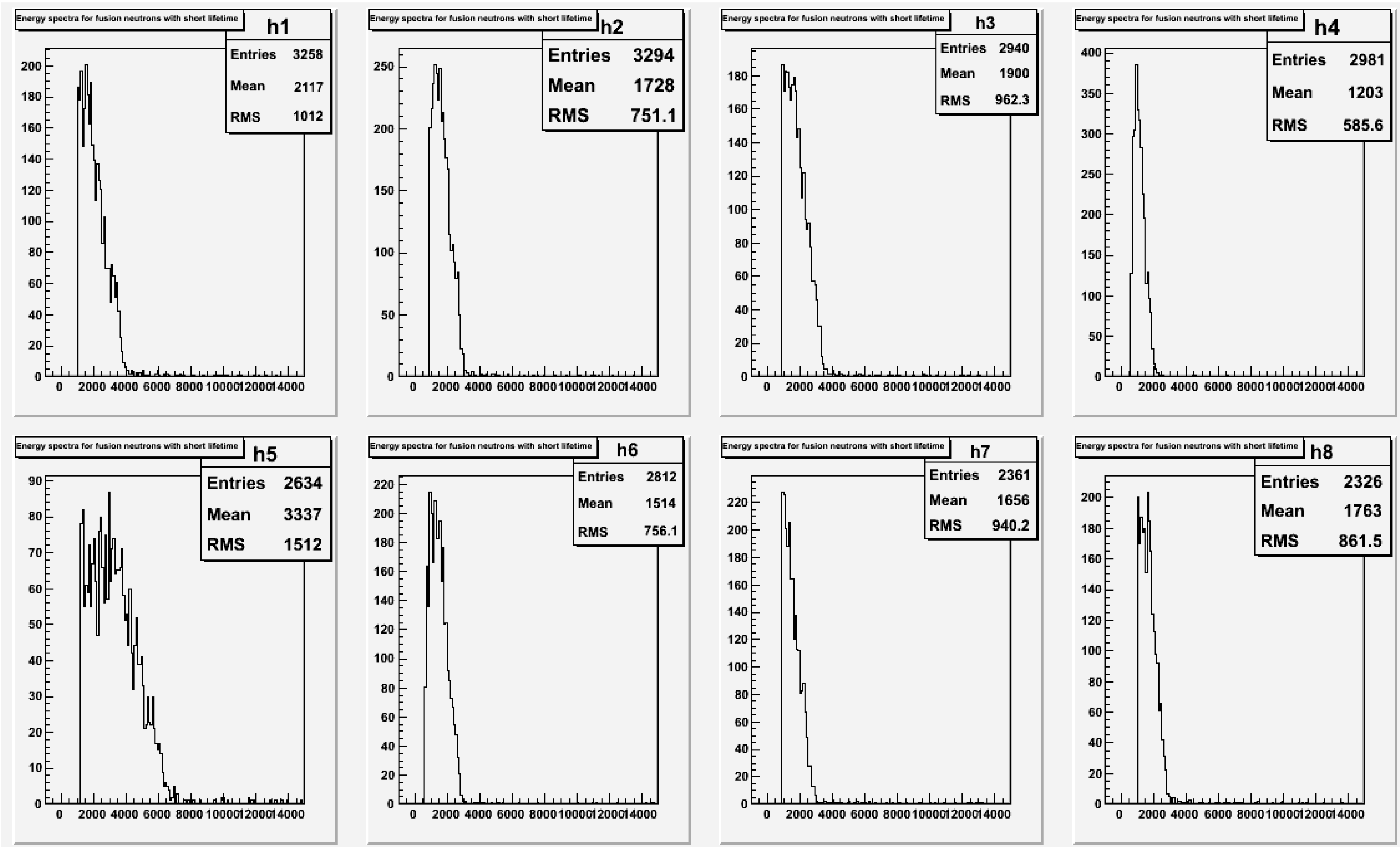
Delayed e-cut: The histogram below shows the delayed e- cut applied to the time spectrum for neutrons corresponding pile up free muons stopped in the tpc.

Nearly 1000 runs are added below:



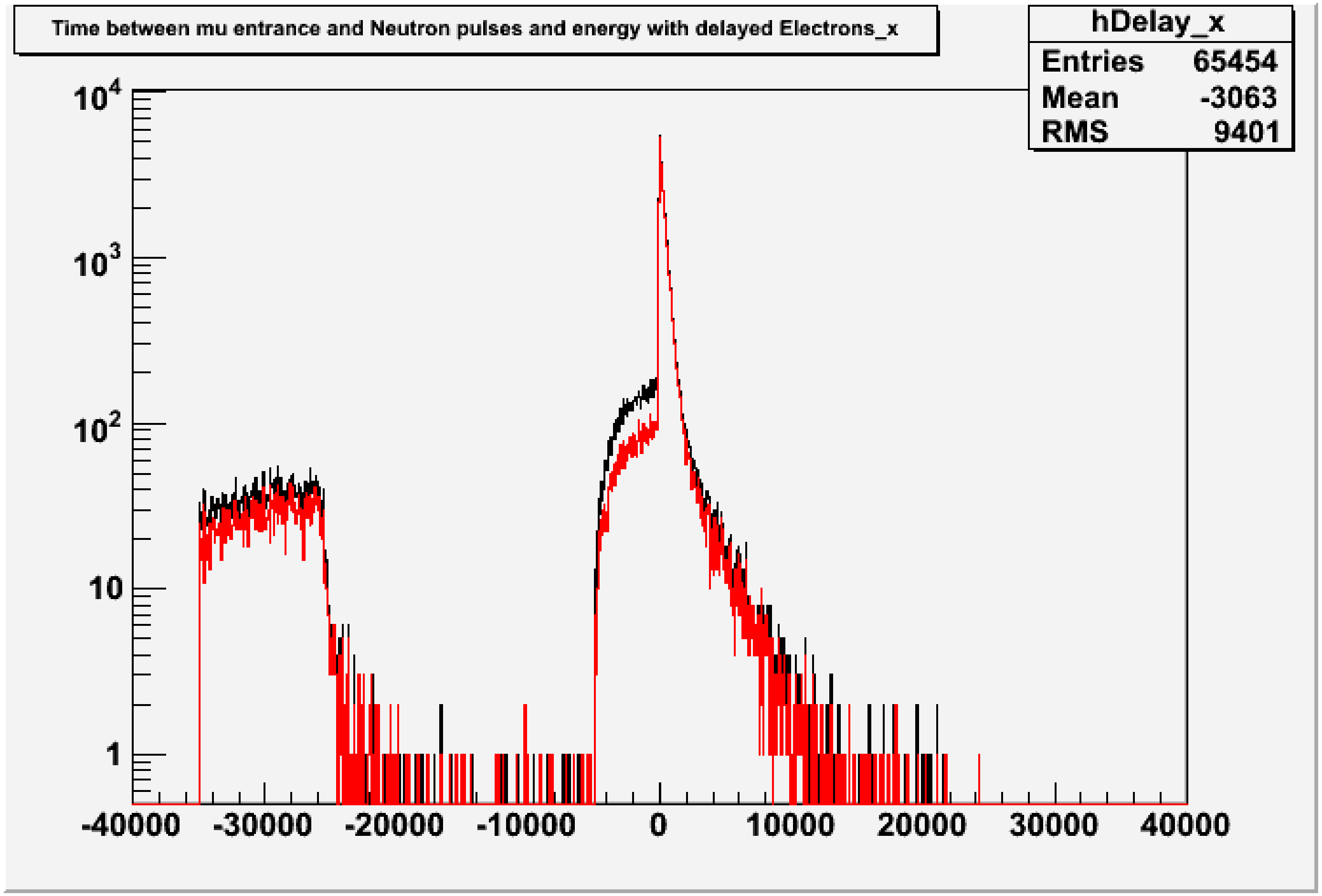
Fusion Neutron Analysis

I applied the short lifetime compts. cut (time difference b/w n and mu ~ 1000 ns)on the neutron energy spectrum to find the energy of fusion neutrons which is close to 2.45 MeV for all channels, as shown below



Fusion Neutron Analysis

For the 1000 runs black – time spectrum for neutrons with delayed e- cut
Red - time spectrum for neutrons with additional energy cut i.e. E<2.45 MeV
The red histogram thus shows the fusion neutrons



Background Studies

The background of the fusion time spectra may include a number of factors like:

* Neutrons from muon decay

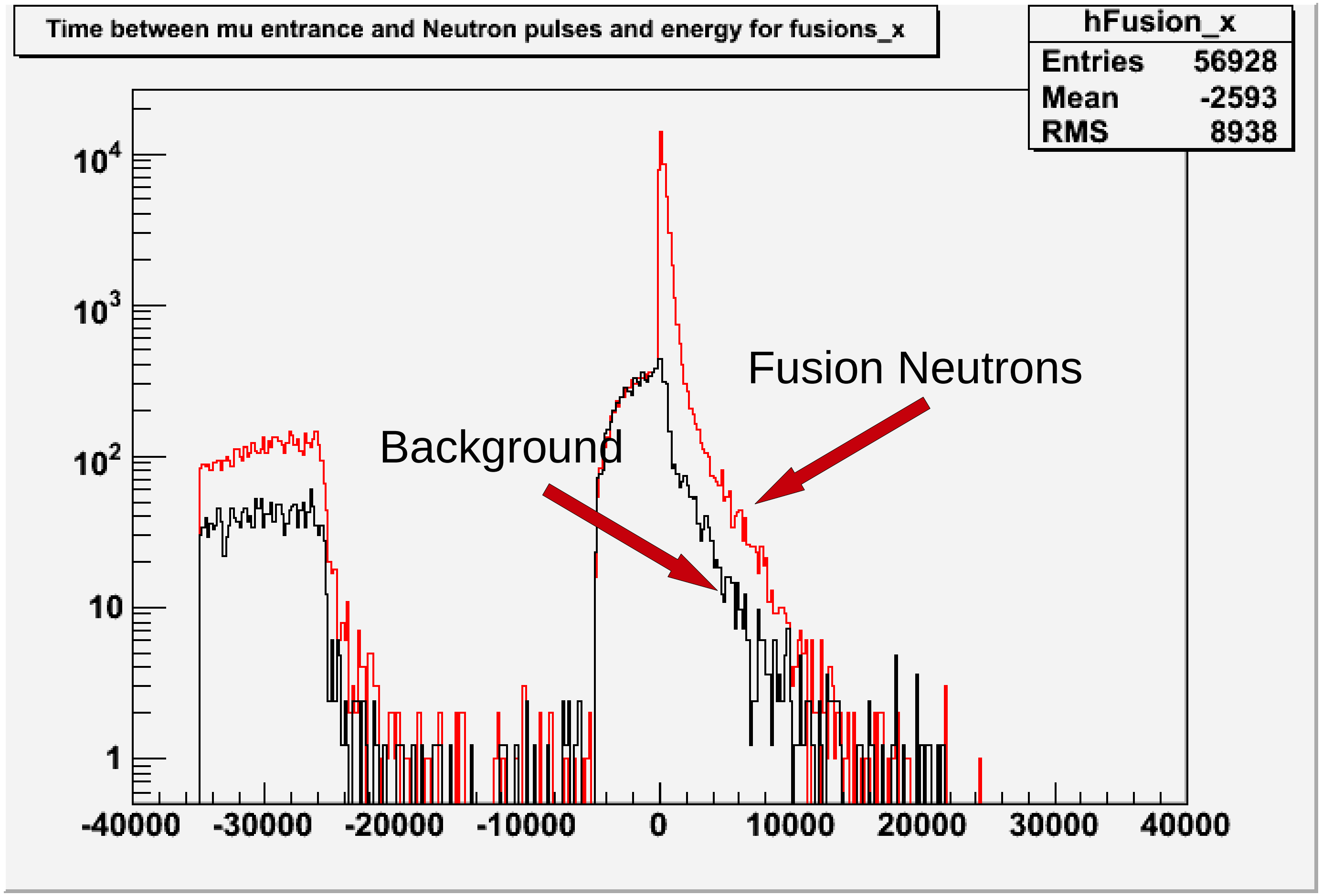
* Neutrons due to muons stopped in walls of the tpc, impurities, deuterium etc. - this was avoided using mustop condition

* Neutrons from room backgrounds / cosmics etc.

* Neutrons from muons that do not reach the tpc or muSC.

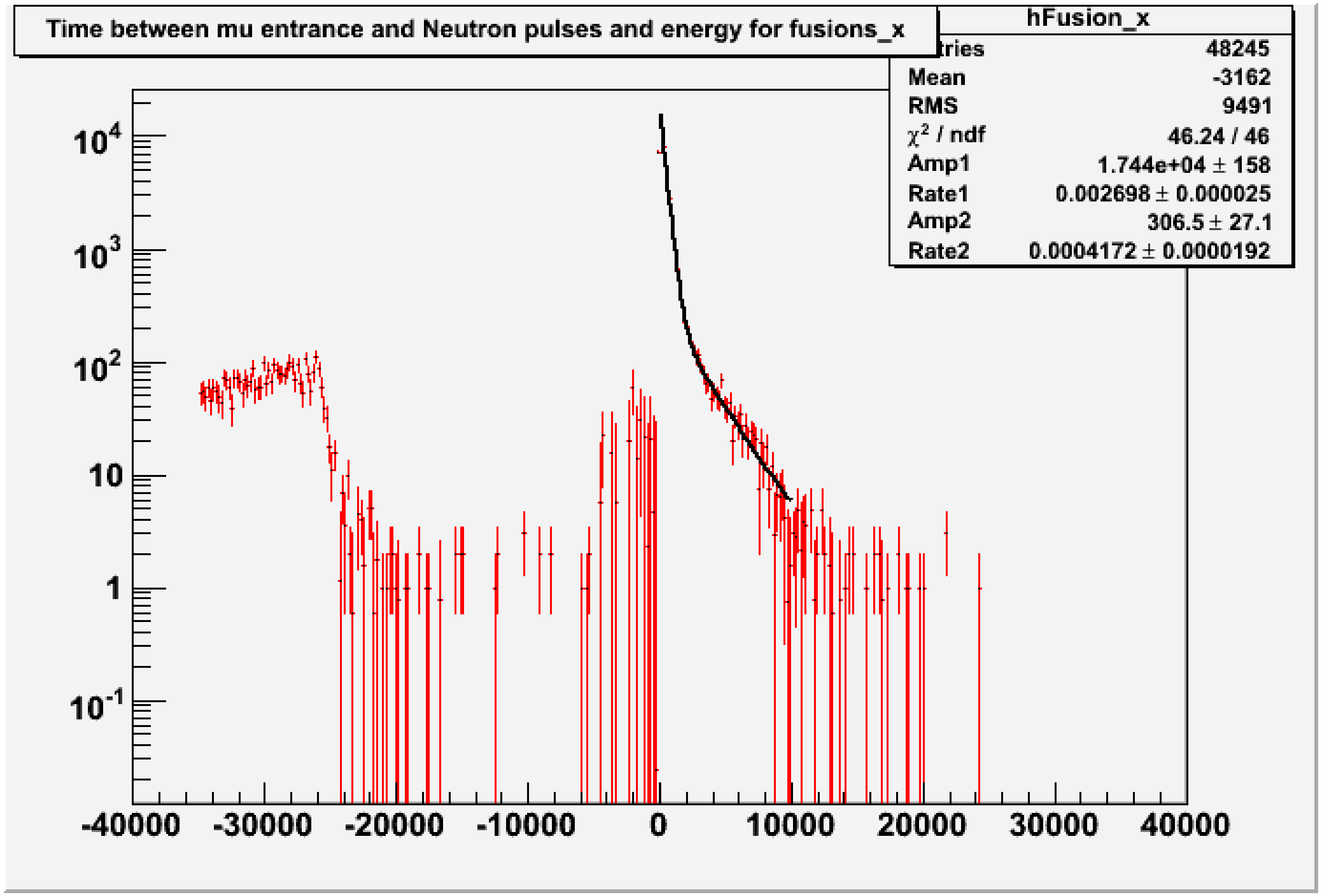
Background Studies

Black - All neutrons with mustop condition, delay e- cut and an additional cut of energy >= 2.45 MeV neutrons for all mu- runs. Helped estimating the background due to neutrons that **appear to be fusion neutrons** but not actually so since they do not fall in that energy region. They could be neutrons due to the muons that do not reach the muSC and yet somehow produce background neutrons from other sources



Time Spectrum – Fit for Fusion Neutrons

I normalized the background and subtracted it from the time spectrum for fusion neutrons and then fitted it to finally get the two lifetimes as shown below:



Fusion Neutrons - Conclusions

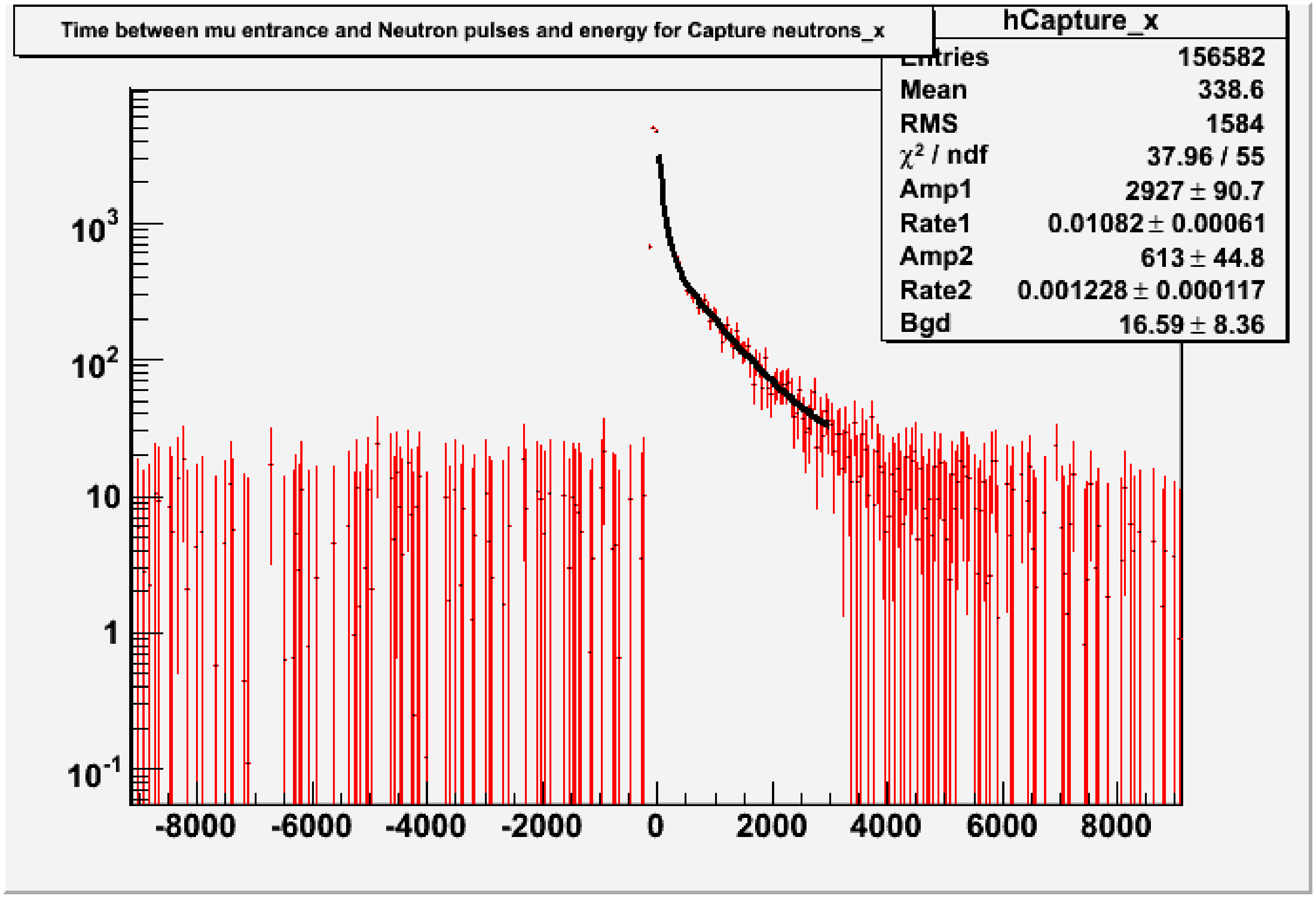
Thus we arrive at the following observations and conclusions:

* Observe a short lifetime component corresponding to the rate 0.00296 ns^{-1} which we can conclude to be the ddμ form. rate from quartet state λ_q (~ 3.98 μs^{-1} at the approx. experimental conditions – which are comparable)

* Observe a long lifetime component corresponding to the rate 0.0041 ns^{-1} which we conclude to be the ddμ form. rate from quartet state via the recycled muons after fusions

Time Spectrum – Fit for Capture Neutrons

Fitted the time spectrum for capture neutrons – cuts applied were no delayed e- and energy > 2.45 MeV, but could not conclude anything substantial as the number is much more than it should be => mustop definition may not be good enough



Thank you!