ANALYZING TIME-DELAY HISTOGRAMS FROM 2018-2020 CHANGVAN LATITUDE SURVEY

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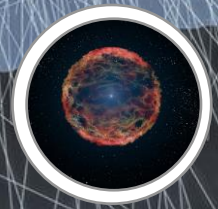
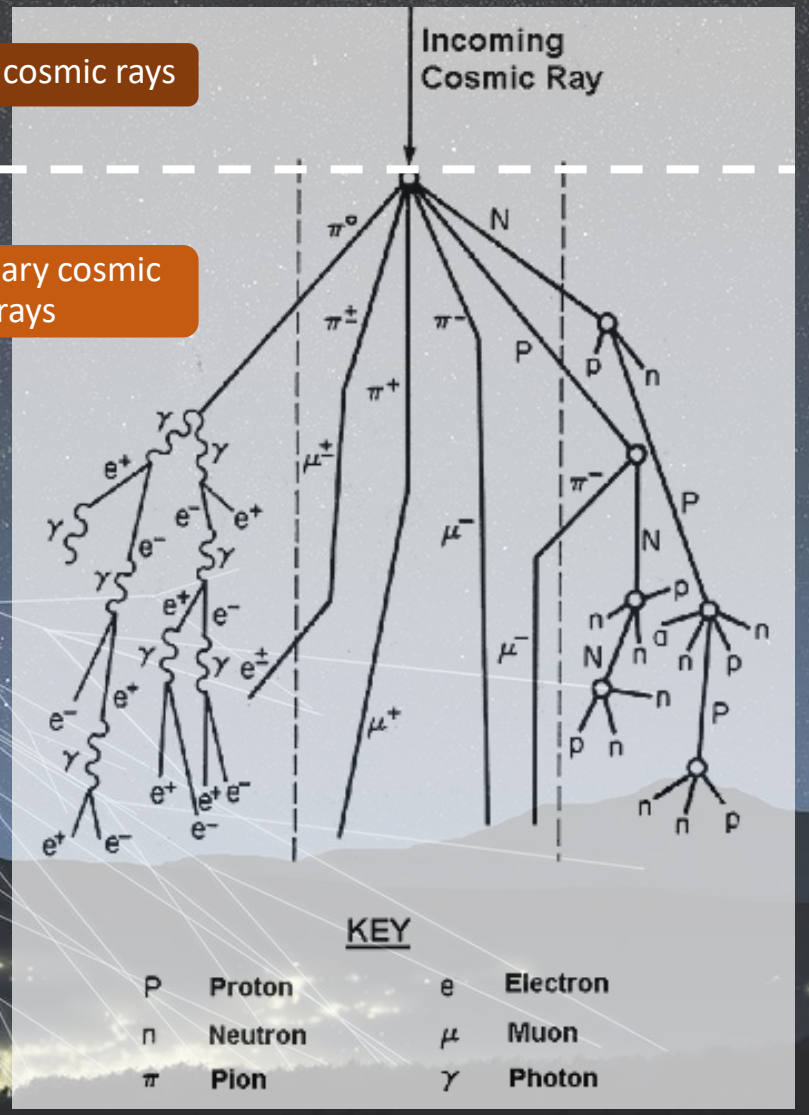
Cosmic rays

The sun

Active galactic nuclei



Supernova

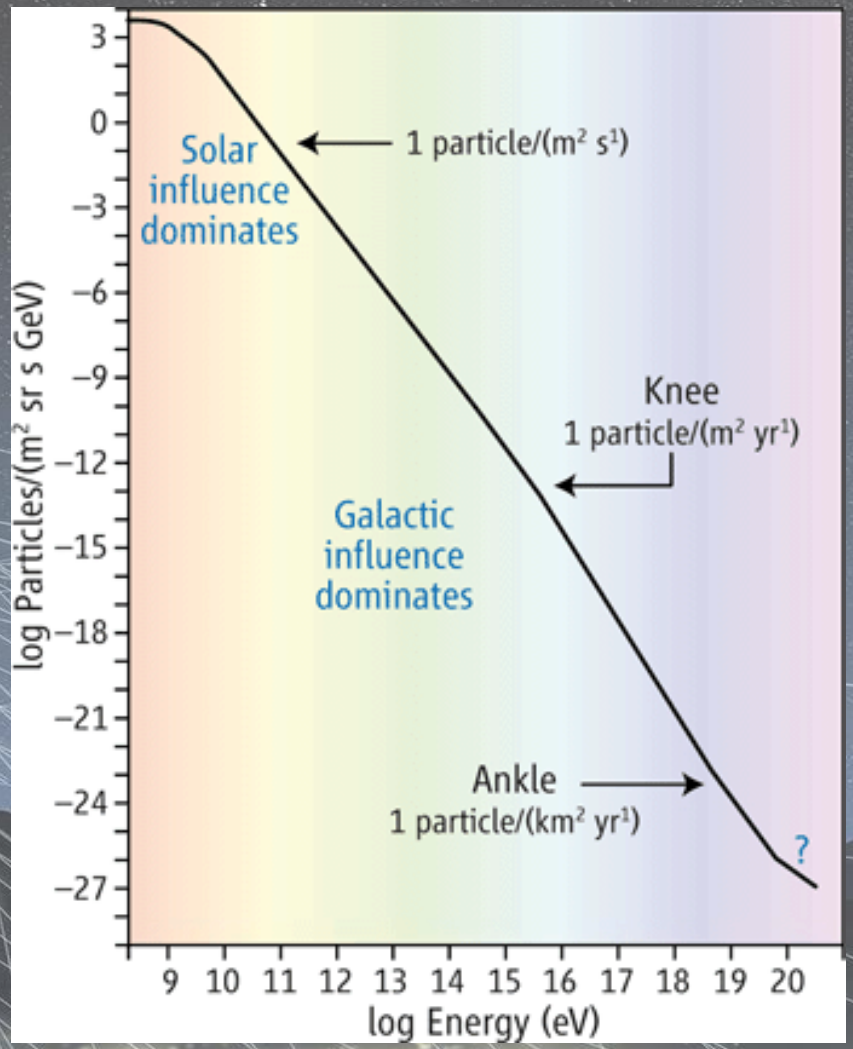


Cosmic ray spectrum

The sun

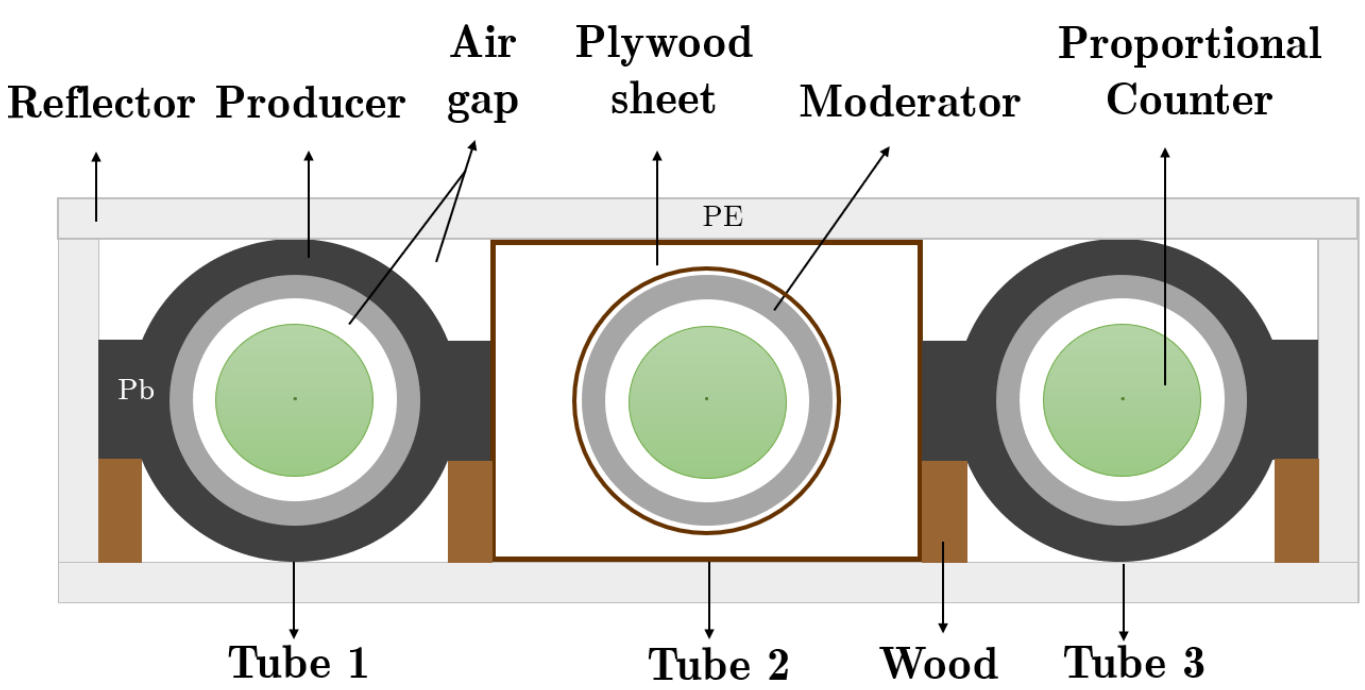
Active galactic nuclei

Supernova



Picture from: https://science.sciencemag.org/content/314/5798/429/F1

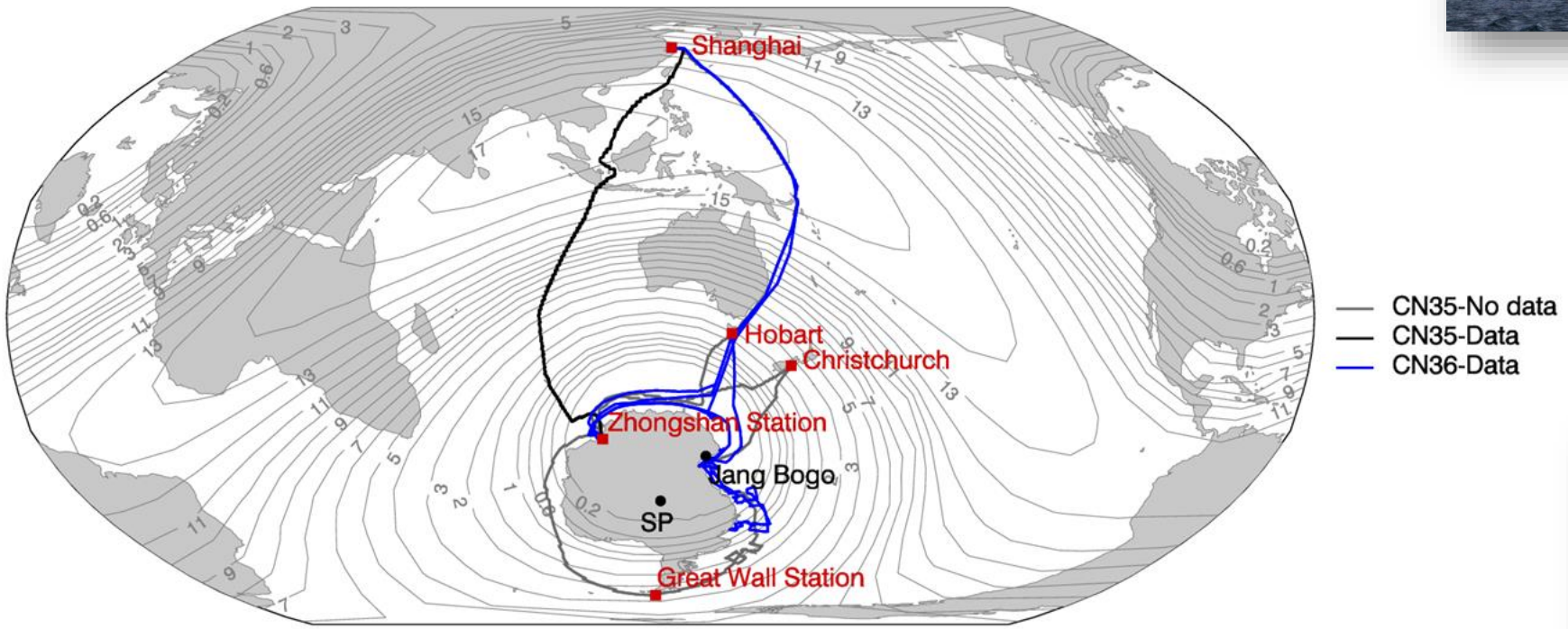
Changvan neutron detectors



Drawing of the Changvan monitor. Tube 1 and Tube 3 are leaded detectors. Tube 2 is unleaded neutron counter hold onto three supported wooden plates.

CHANGVAN LATITUDE SURVEY

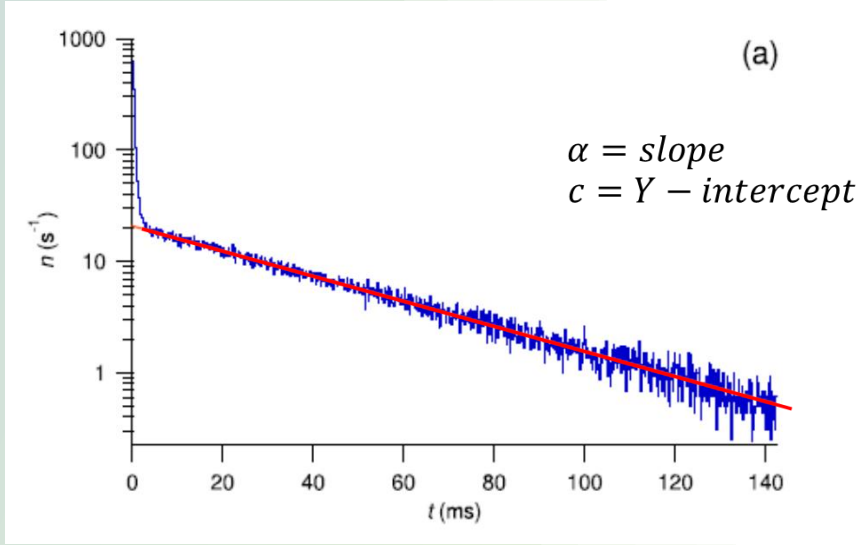
The latitude surveys in 2018-2019 and 2019-2020.



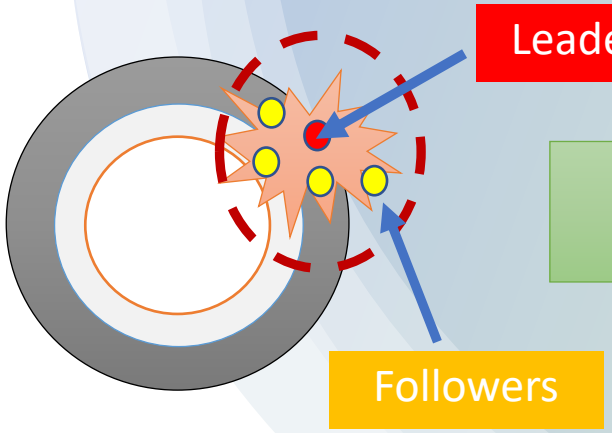
Tracks of the latitude surveys in 2019 and 2020, superimposed on contours of the vertical cutoff rigidity in GV.
Figure from : Yakum et al. 2021

We developed an analysis technique to statistically remove the effect of chance coincidences and measured the leader fraction (L) of neutrons that do not follow a previous neutron from the same primary cosmic ray.

- Leader fraction (L) refers to neutron counts that do not follow a preceding neutron count in the same counter from the same atmospheric secondary particle
- We statistically calculate the leader fraction (L) from histograms of time delay that related to cosmic ray spectral index.
- Amplitude of exponential tail (red) indicates rate of "leaders" arriving by chance, not "following" in temporal association with preceding count.



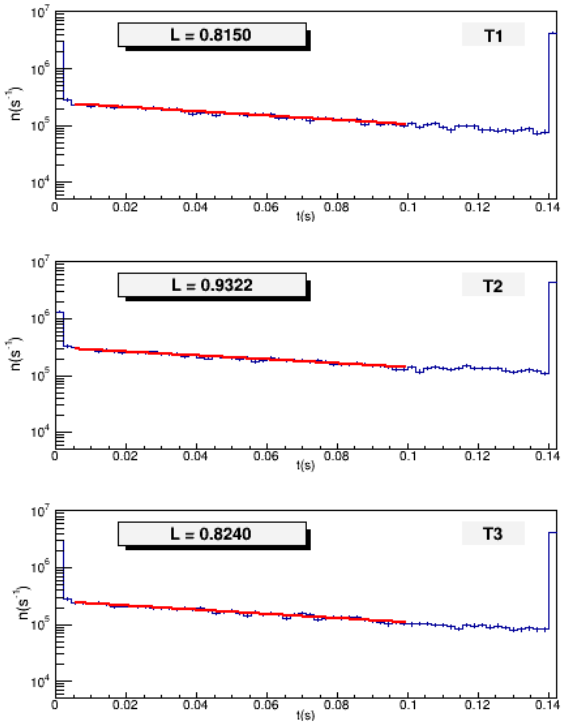
Ruffolo et al., 2016



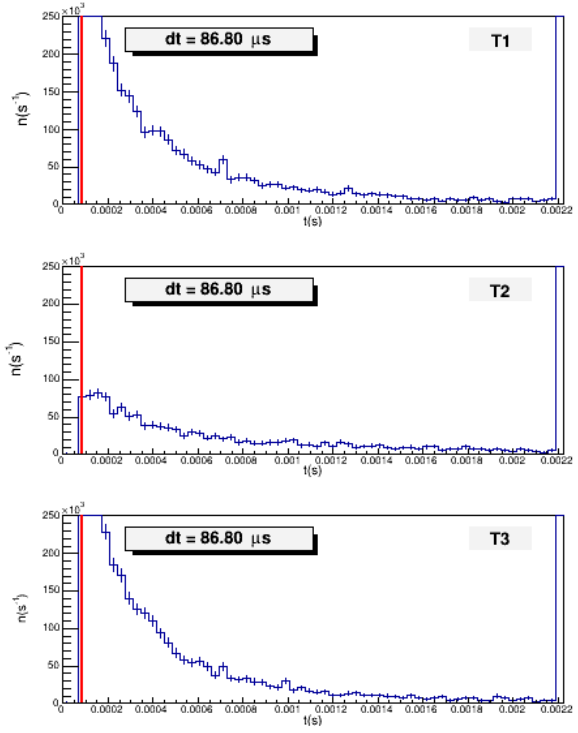
$$\text{Leader Fraction} = \frac{First\ count\ (Leader)}{All\ pulse\ (Leader + Followers)}$$

Example of Single tube time-delay histogram (CN35) the 23rd hour of 11/02/2019

Long-time delay histogram



Short-time delay histogram



Determination of leader fraction

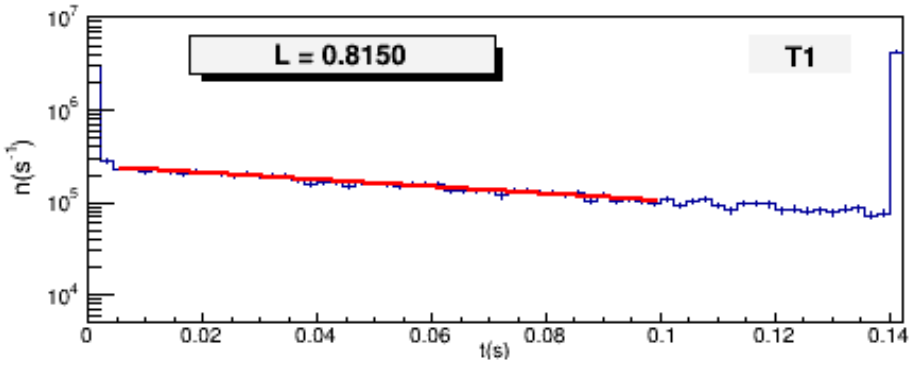
We derived L from the method suggested by [Rufflolo et al., 2016], normalizing each histogram to account for missing values at $t > t_0$:

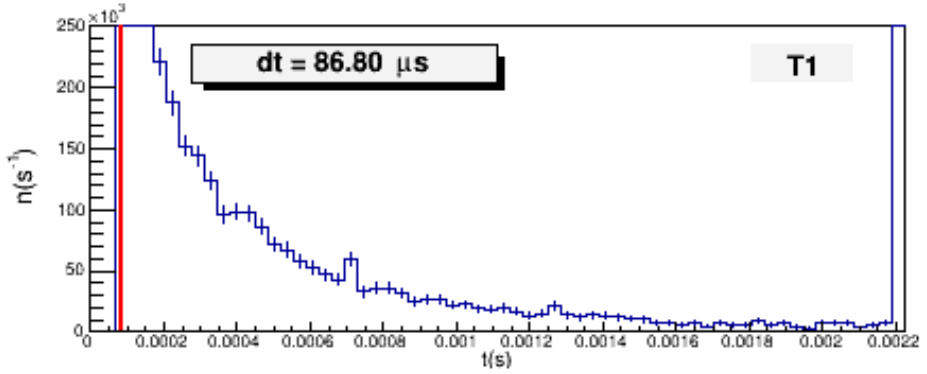
$$L = \frac{\frac{A_0}{\alpha} e^{-\alpha t_d}}{\sum_{t=t_d}^{t_0} N_t + \frac{A_0}{\alpha} e^{-\alpha t_0}}$$

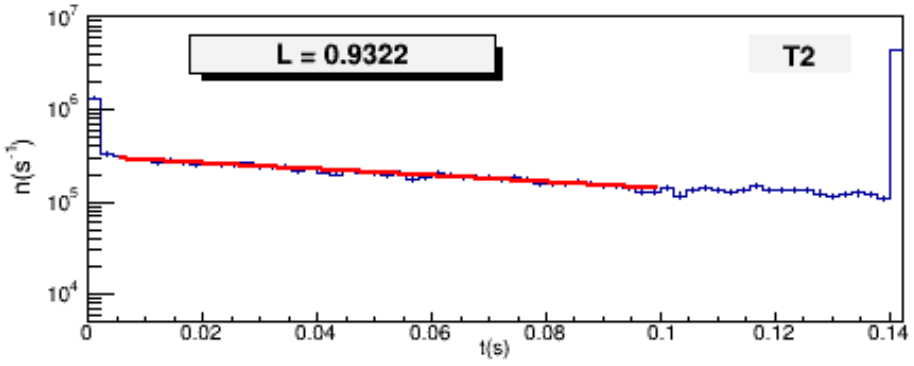
Where α and A_0 are the parameters from the hourly long-time histogram fit. As said earlier, $t_0 = 0.142\ s$ is the overflow time in the electronic system, and dead time $t_d = 87\mu s$. The term $\sum_{t=t_d}^{t_0} N_t$ is the sum of the neutron pulses for all time bins from t_d to t_0 from the recorded histogram files.

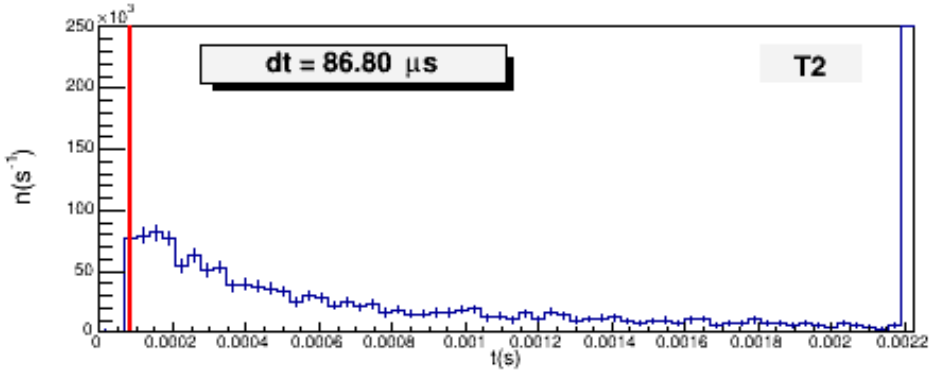
For Single tube time delay histogram, we fitted histogram from 5 - 100 ms.

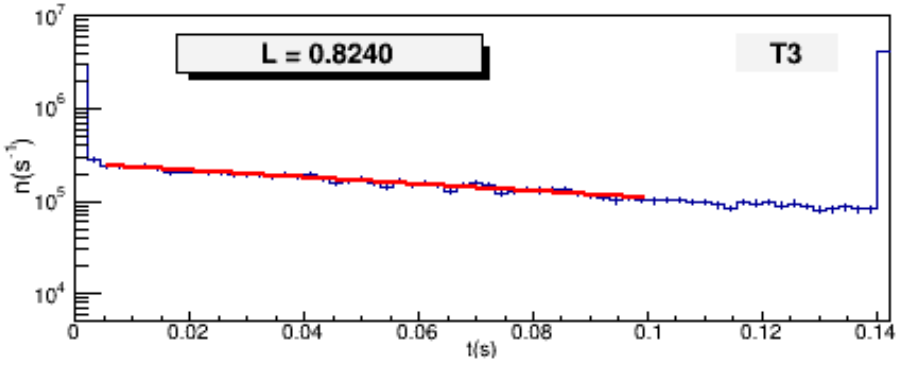
Example of Single time-delay histogram (CN35) the 23rd hour of 11/02/2019

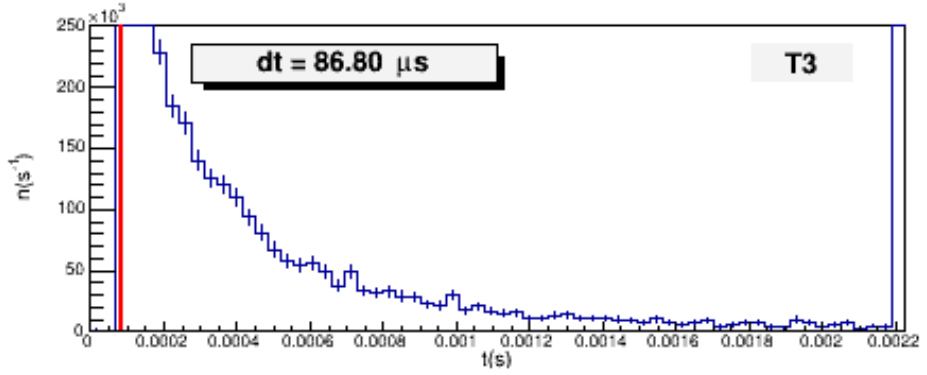






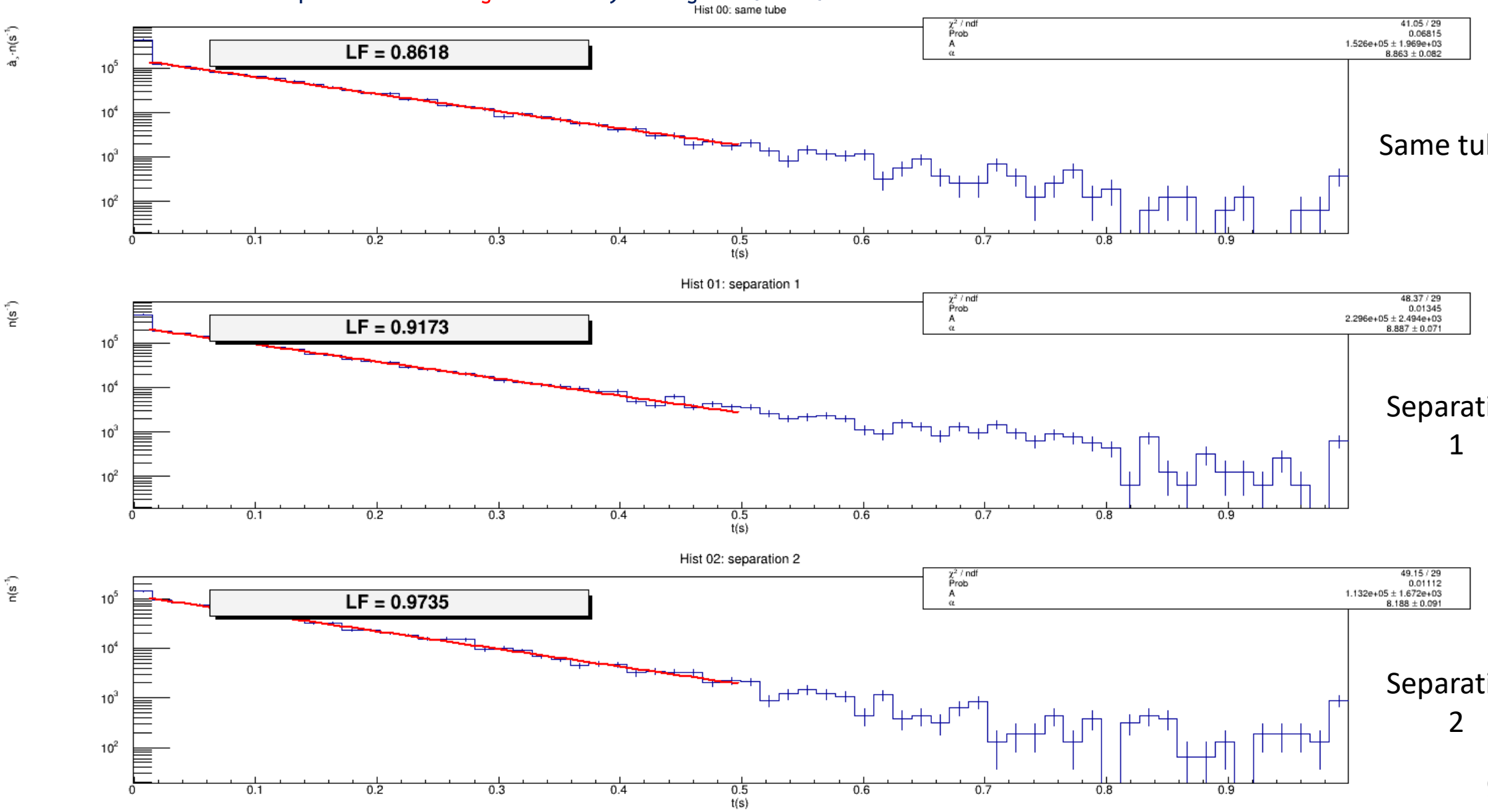




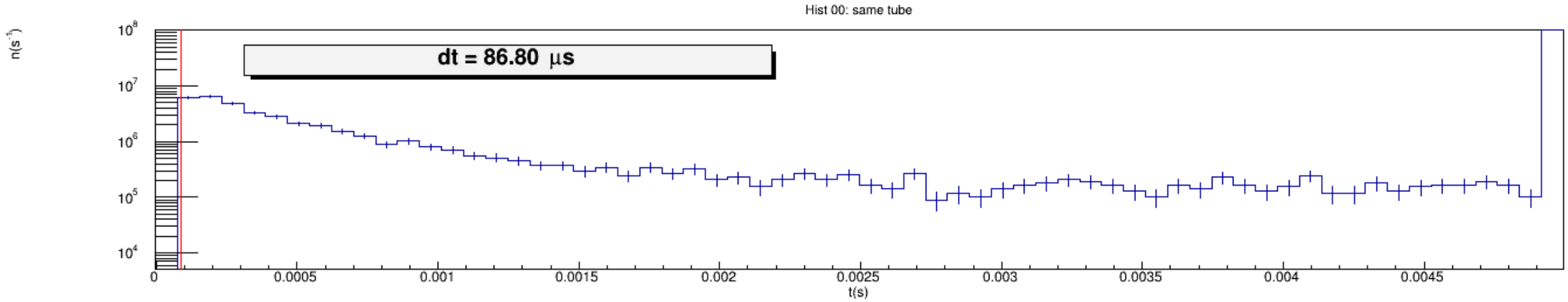


For Cross tube time delay histogram, we fitted histogram from 10 - 500 ms.

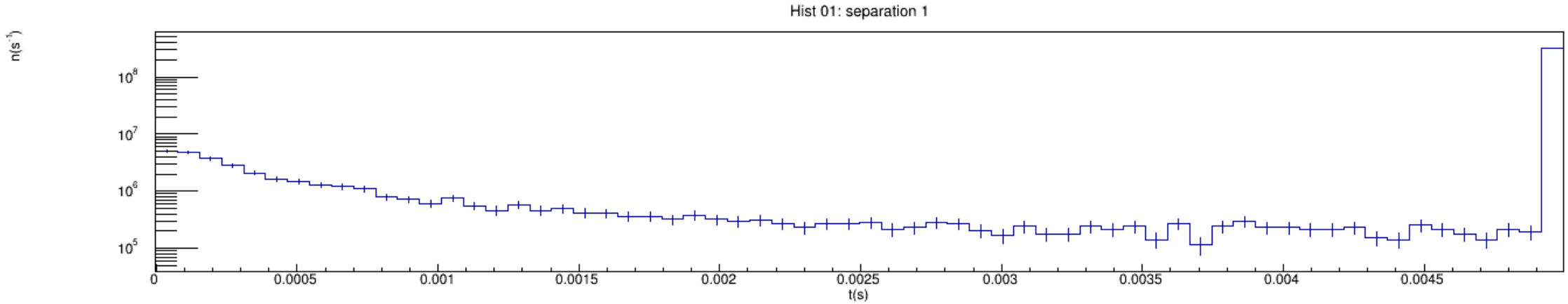
Example of Cross long-time delay histogram (CN35) the 17th hr of 11/02/2019



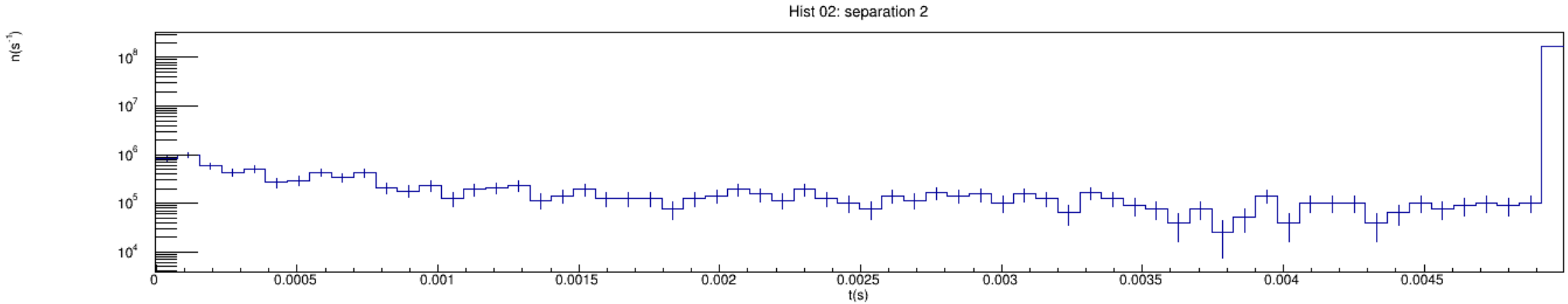
Example of Cross short-time delay histogram (CN35) the 17th hr of 11/02/2019



Same tube

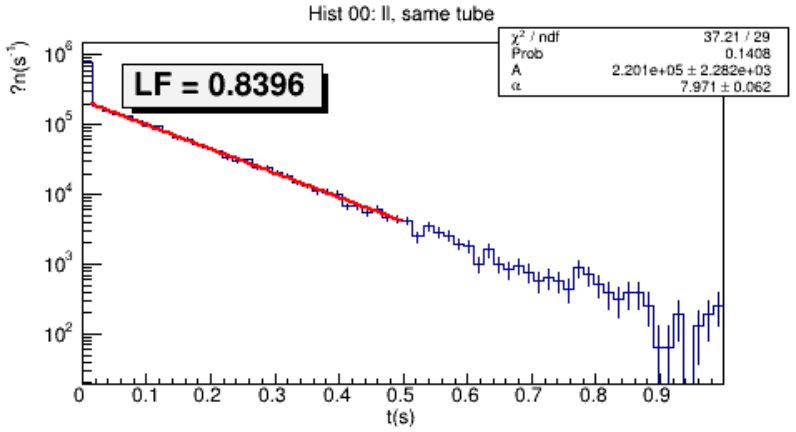


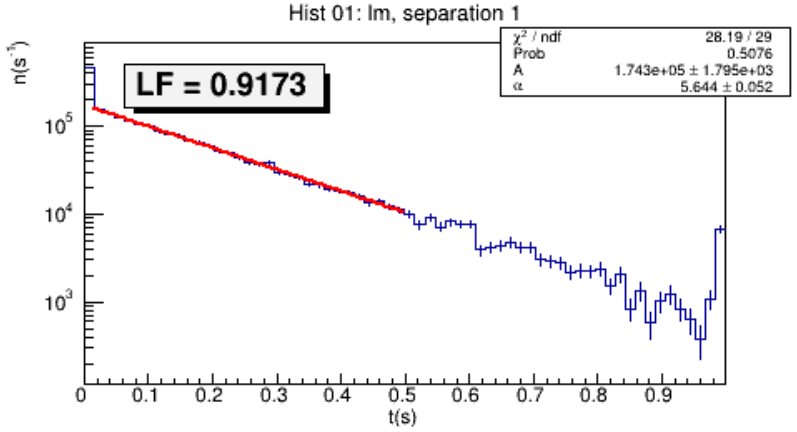
Separation 1

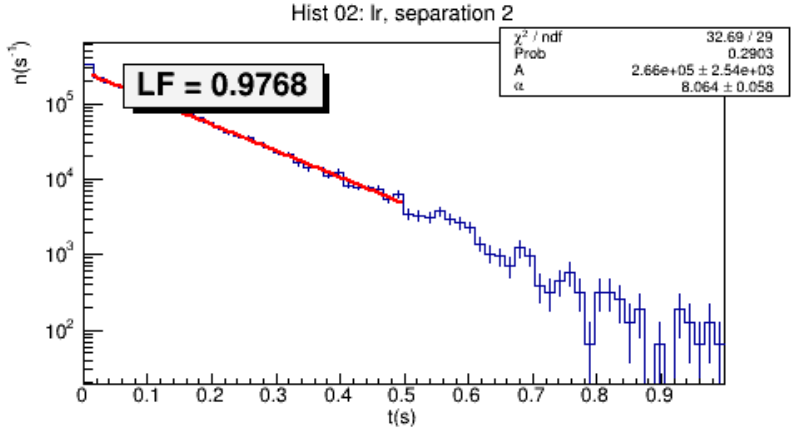


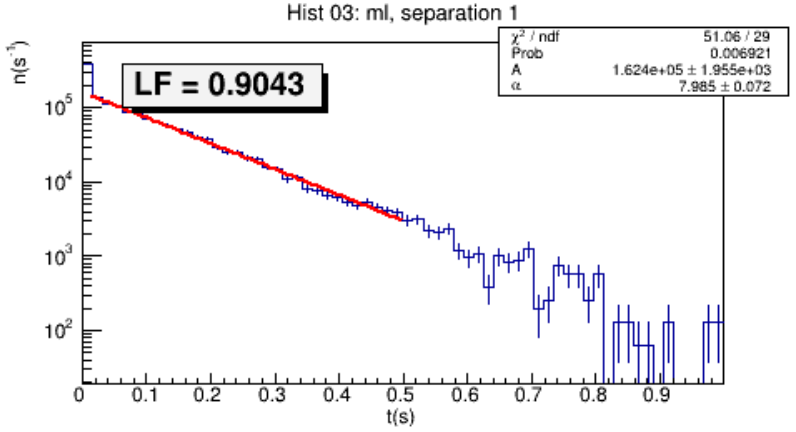
Separation 2

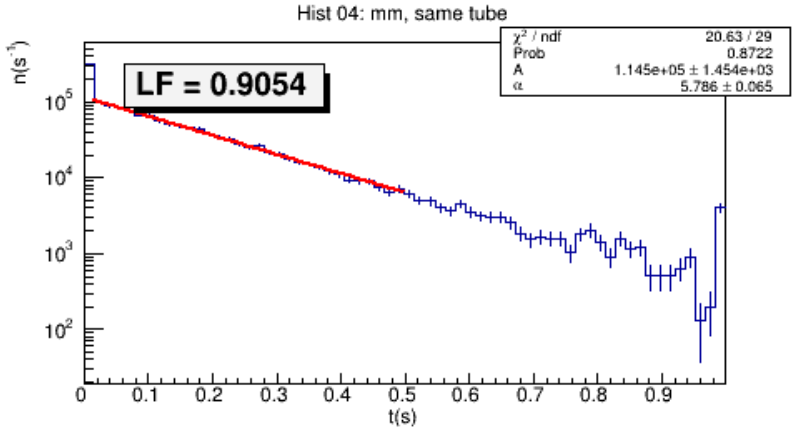
Example of Cross long-time delay histogram (CN36) the 6th hr of 3/04/2020

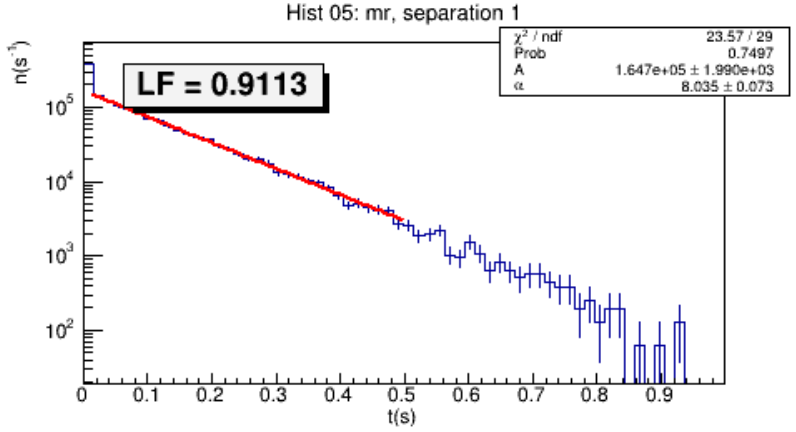


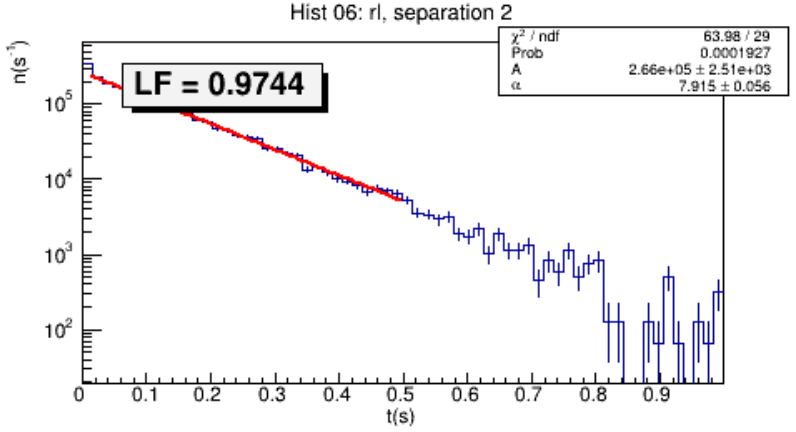


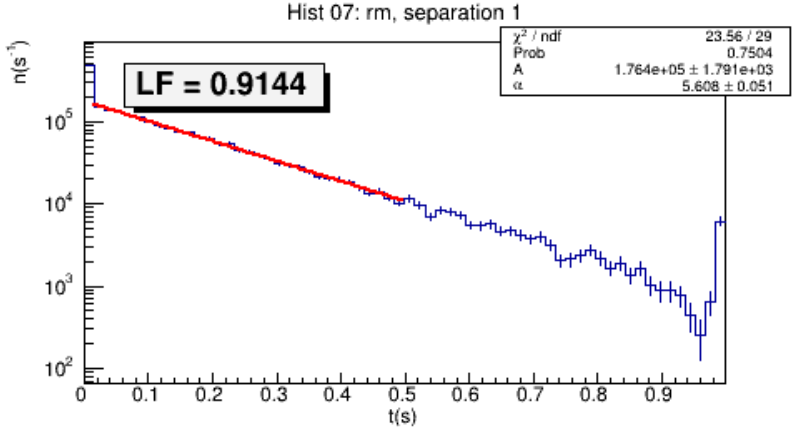


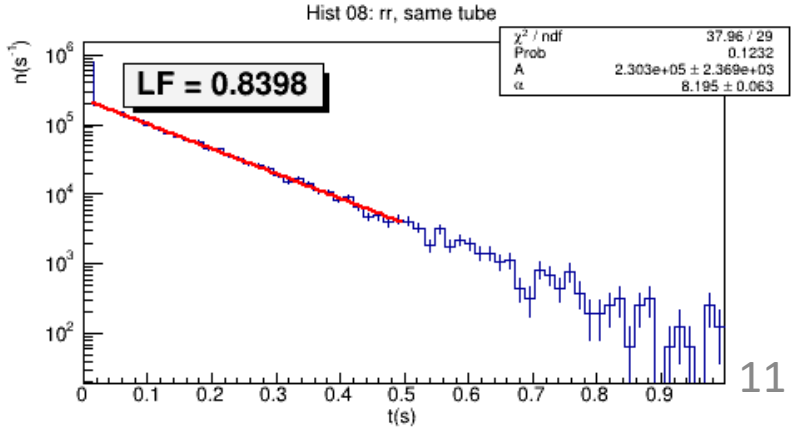




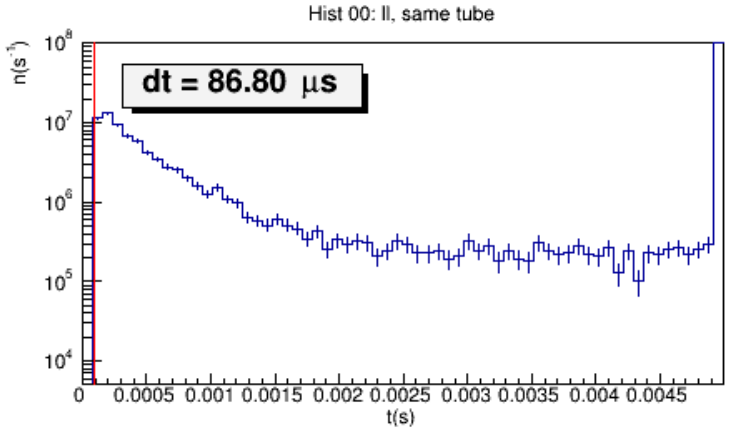


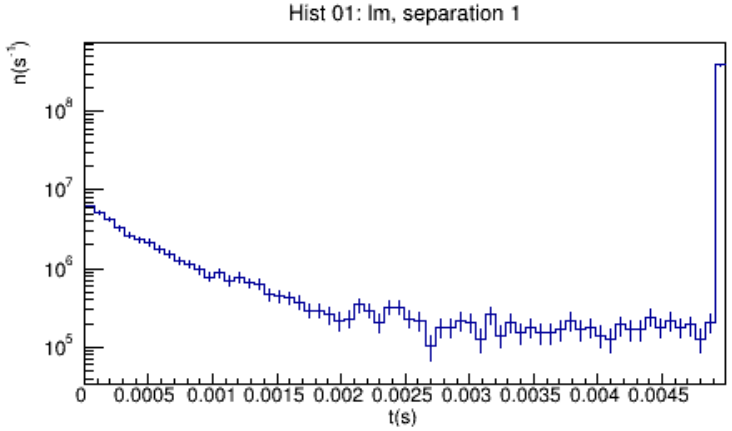


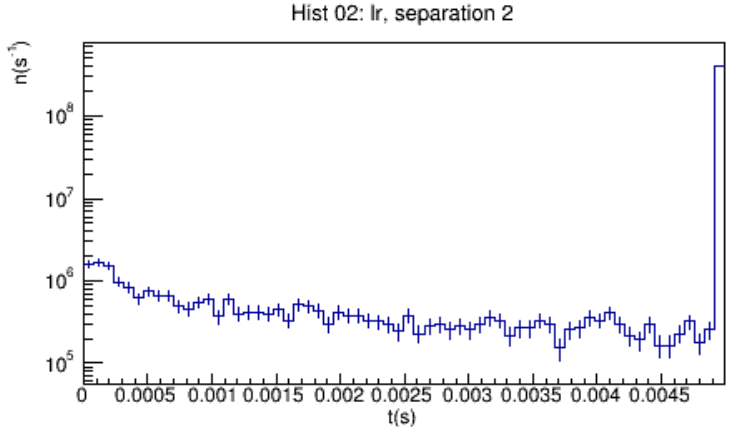


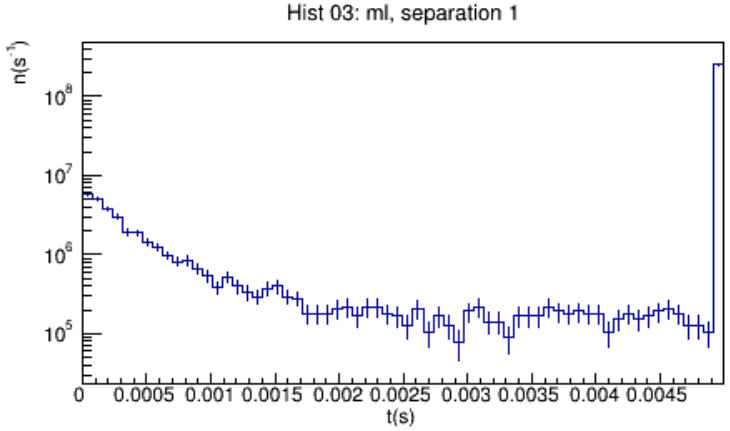


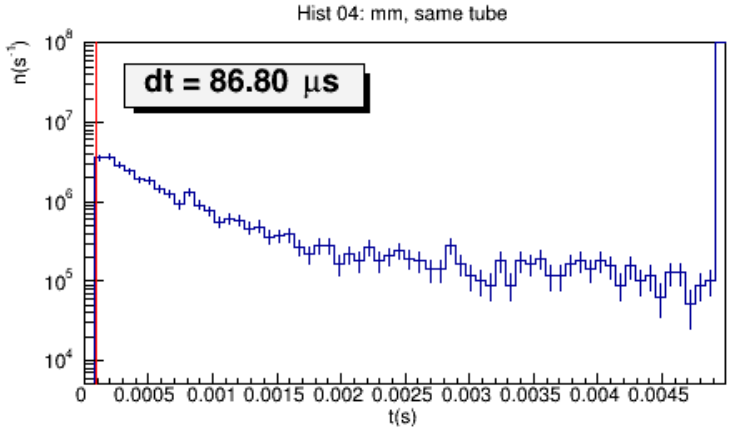
Example of Cross short-time delay histogram (CN36) the 6th hr of 3/04/2020

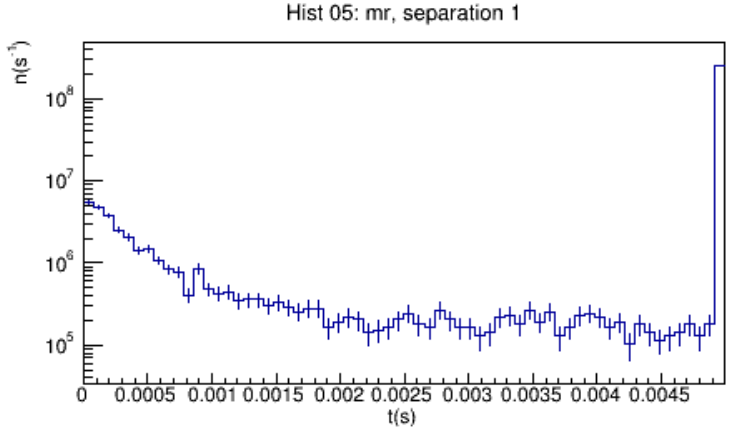


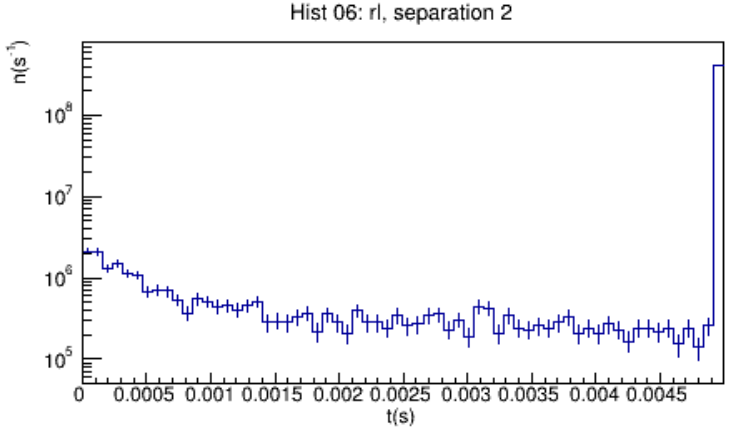


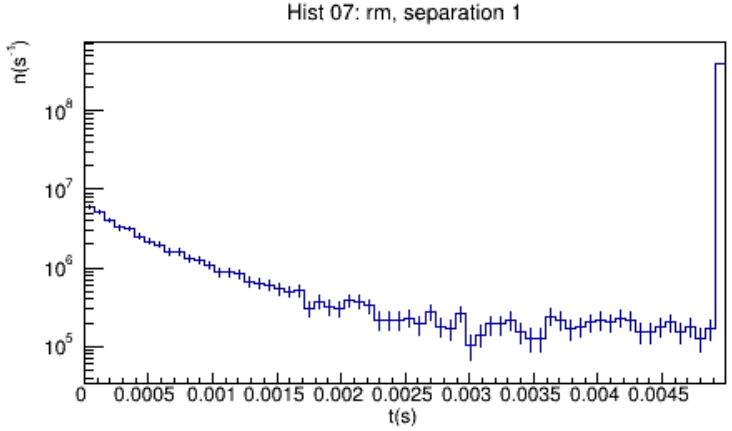


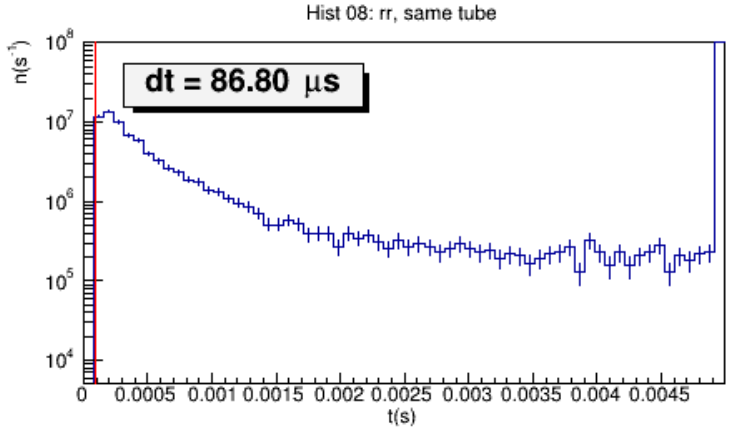




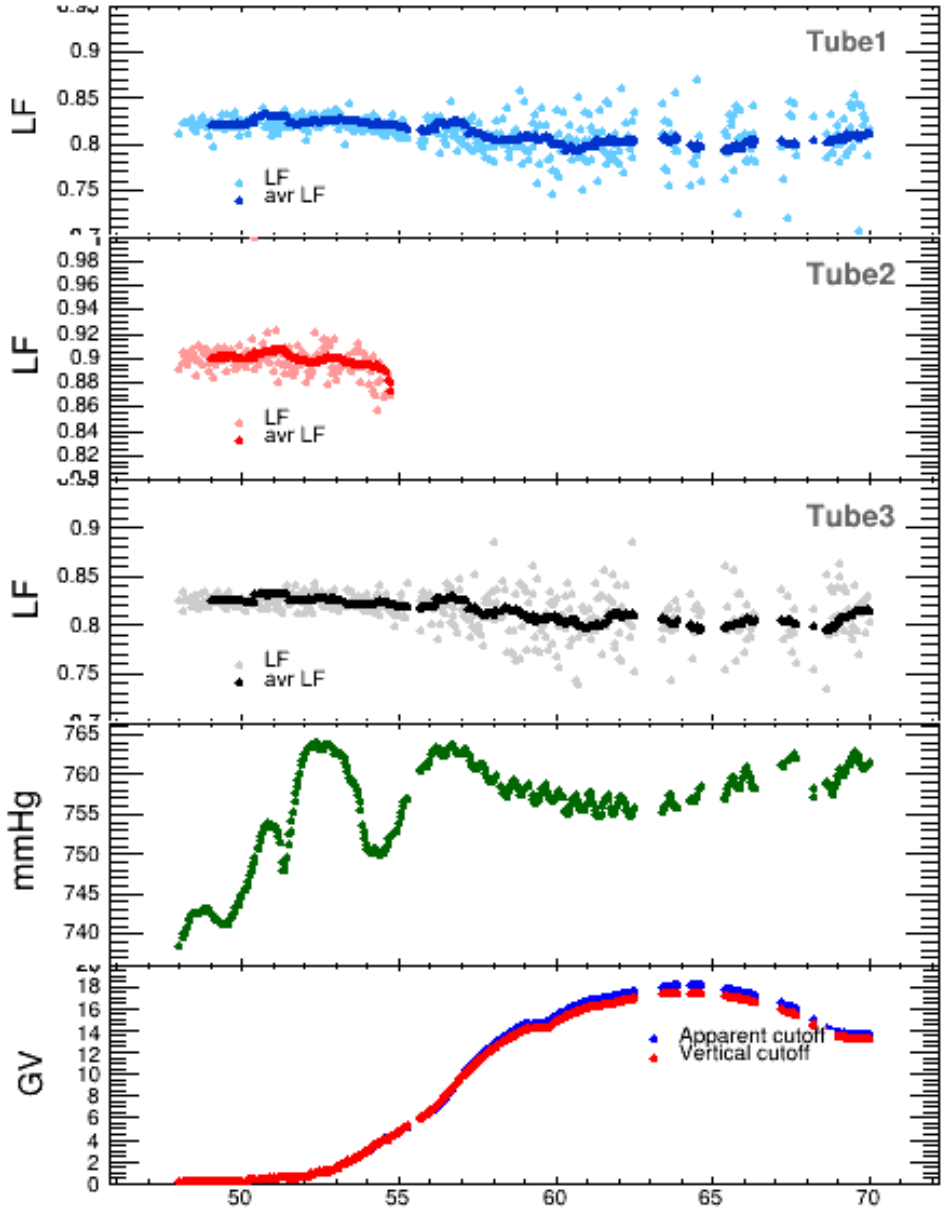


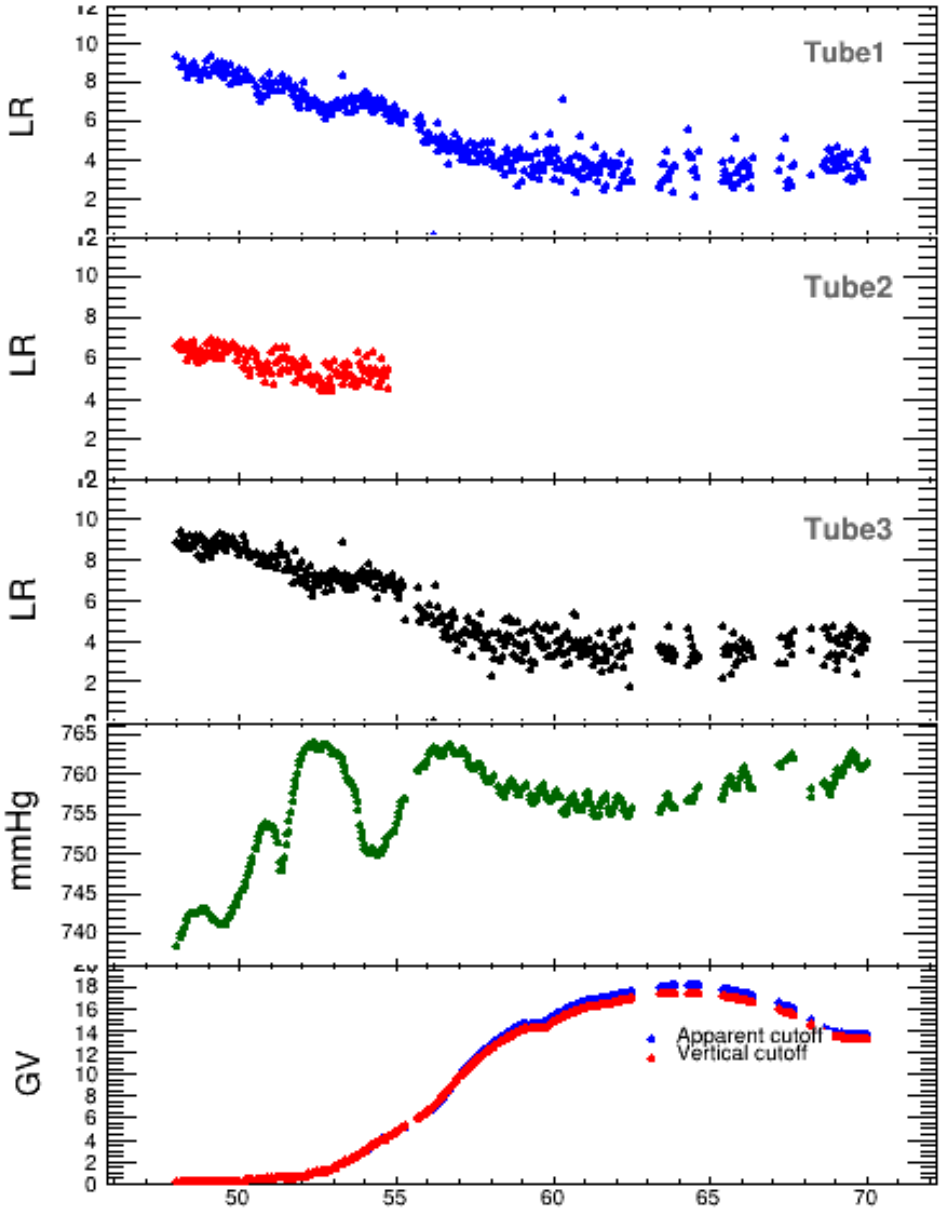




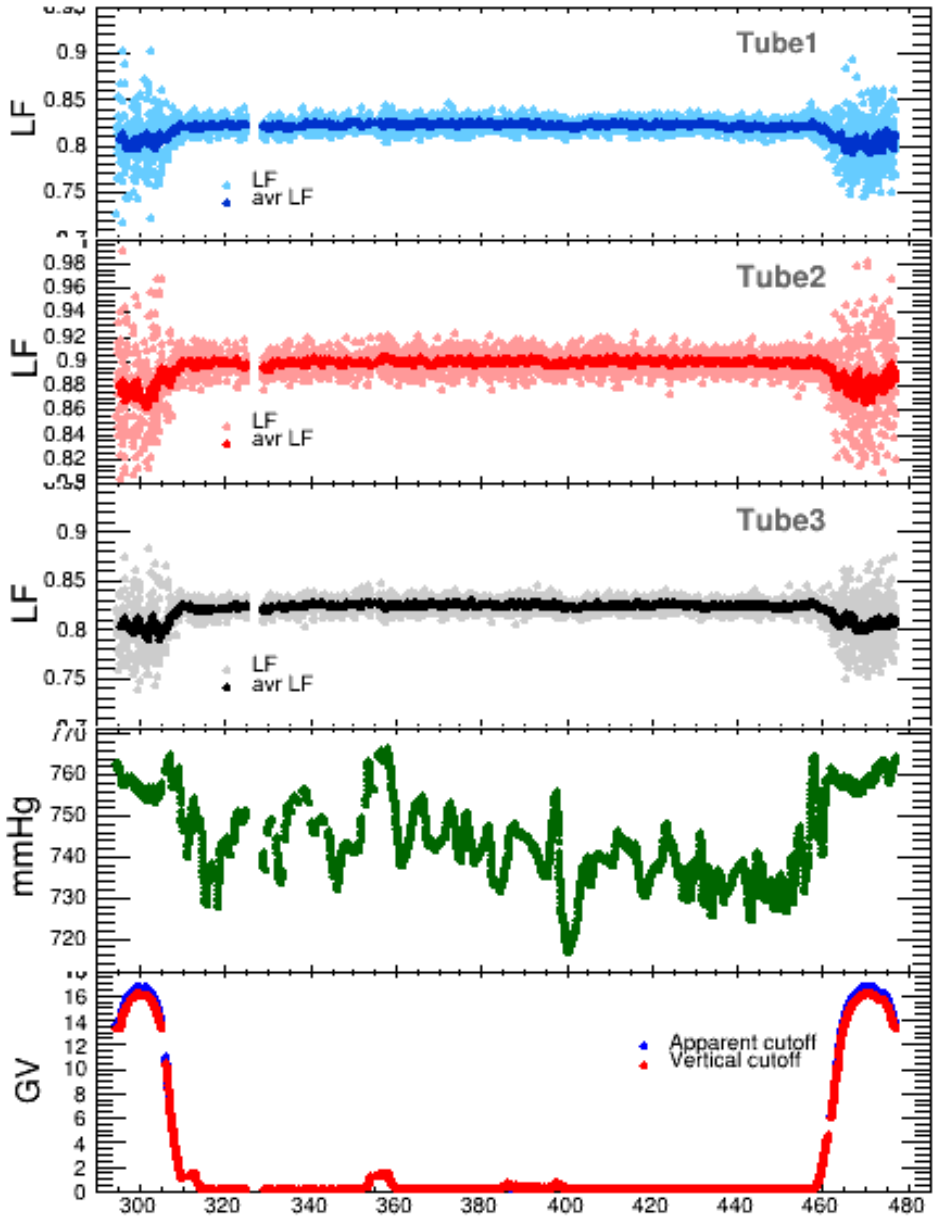


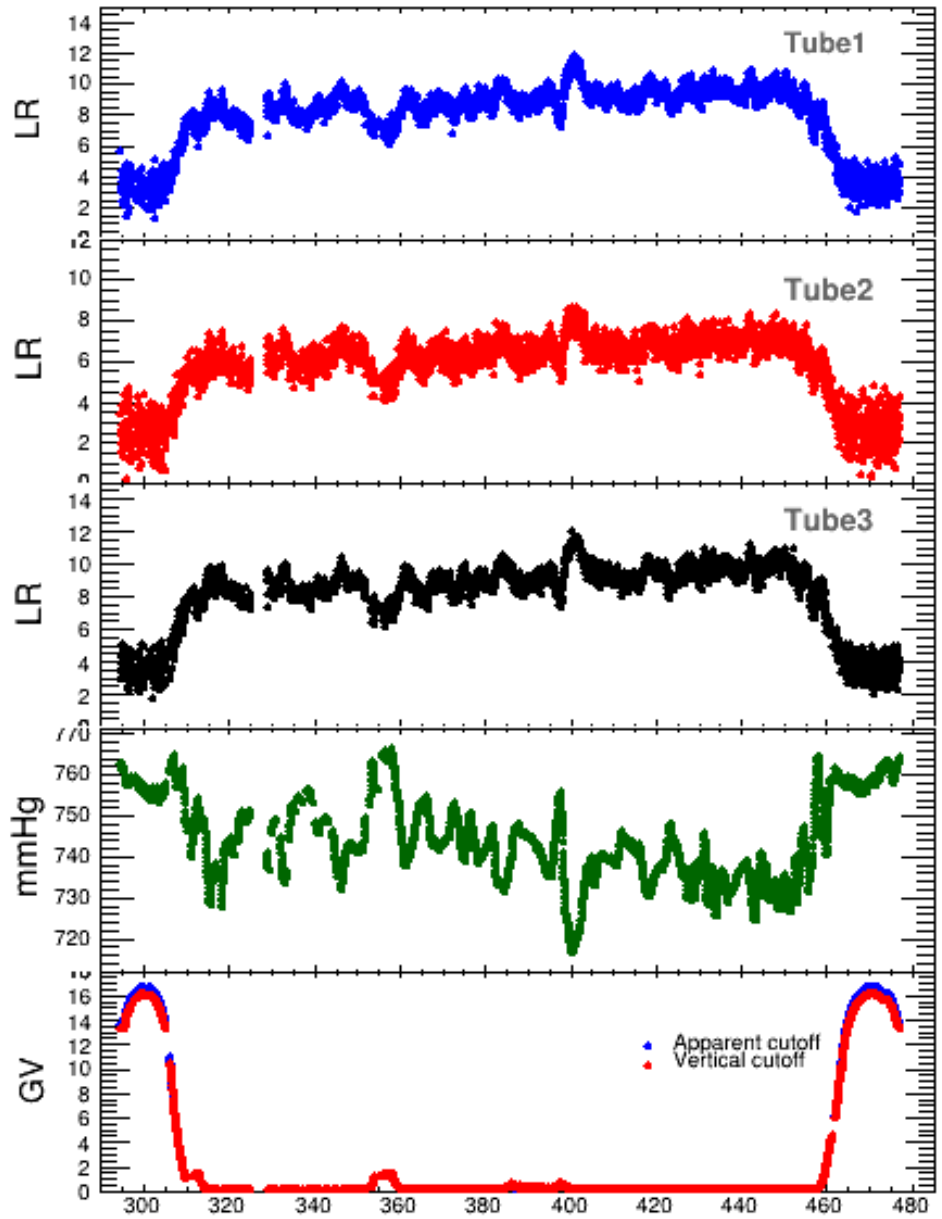
Single time delay histogram (CN35) shows Leader fraction (LF) and Leader rate (LR) of Changvan latitude survey year 2018-2019



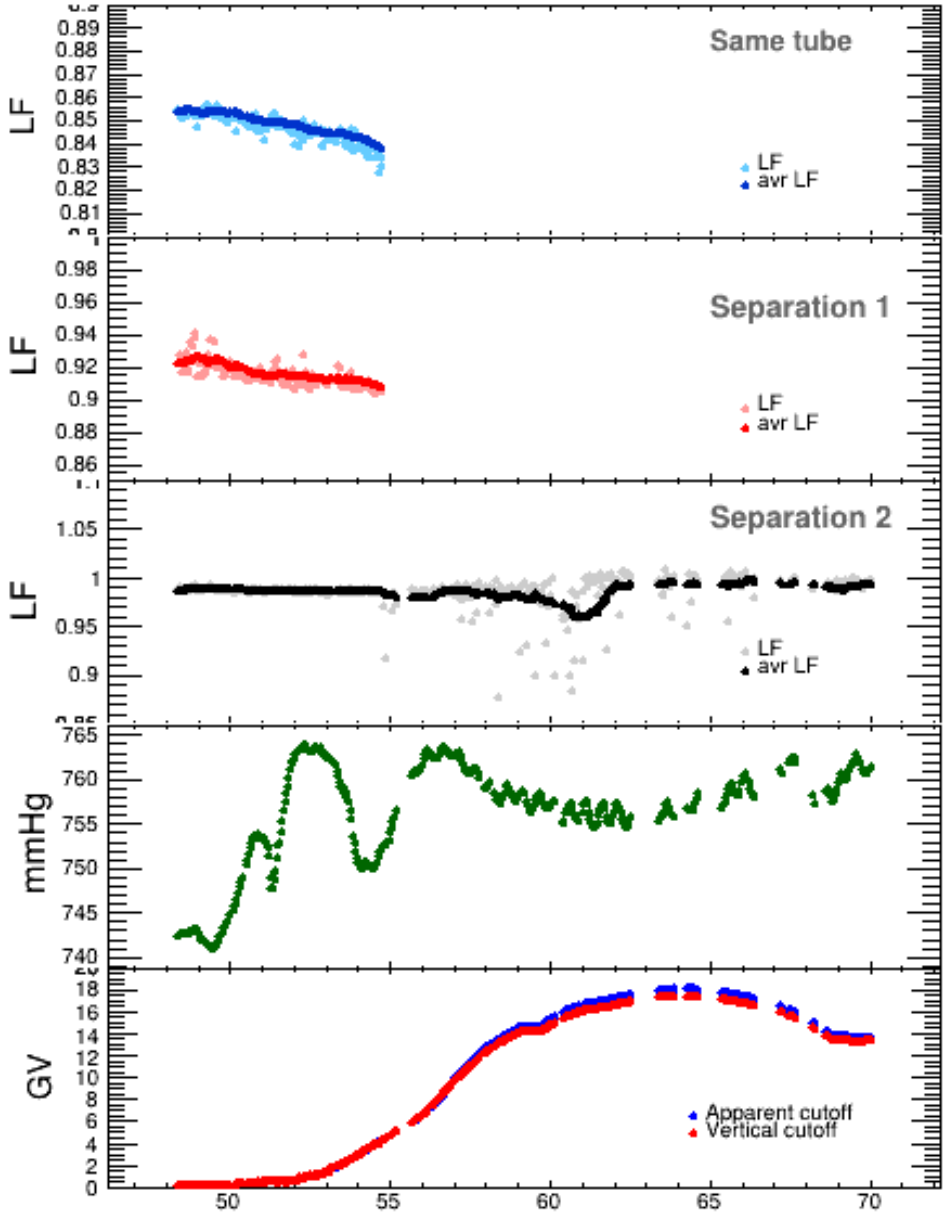


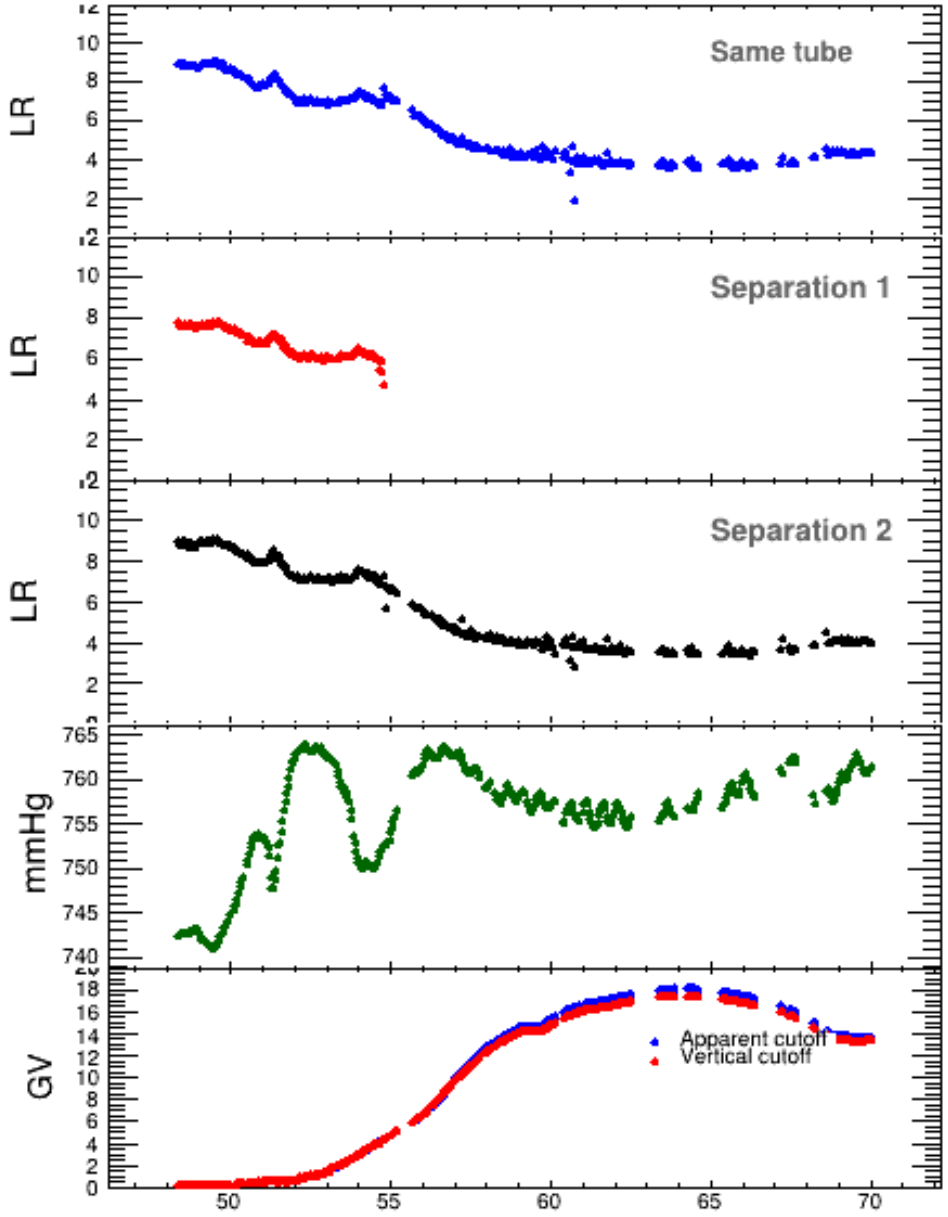
Single time delay histogram (CN36) shows Leader fraction (LF) and Leader rate (LR) of Changvan latitude survey year 2019-2020



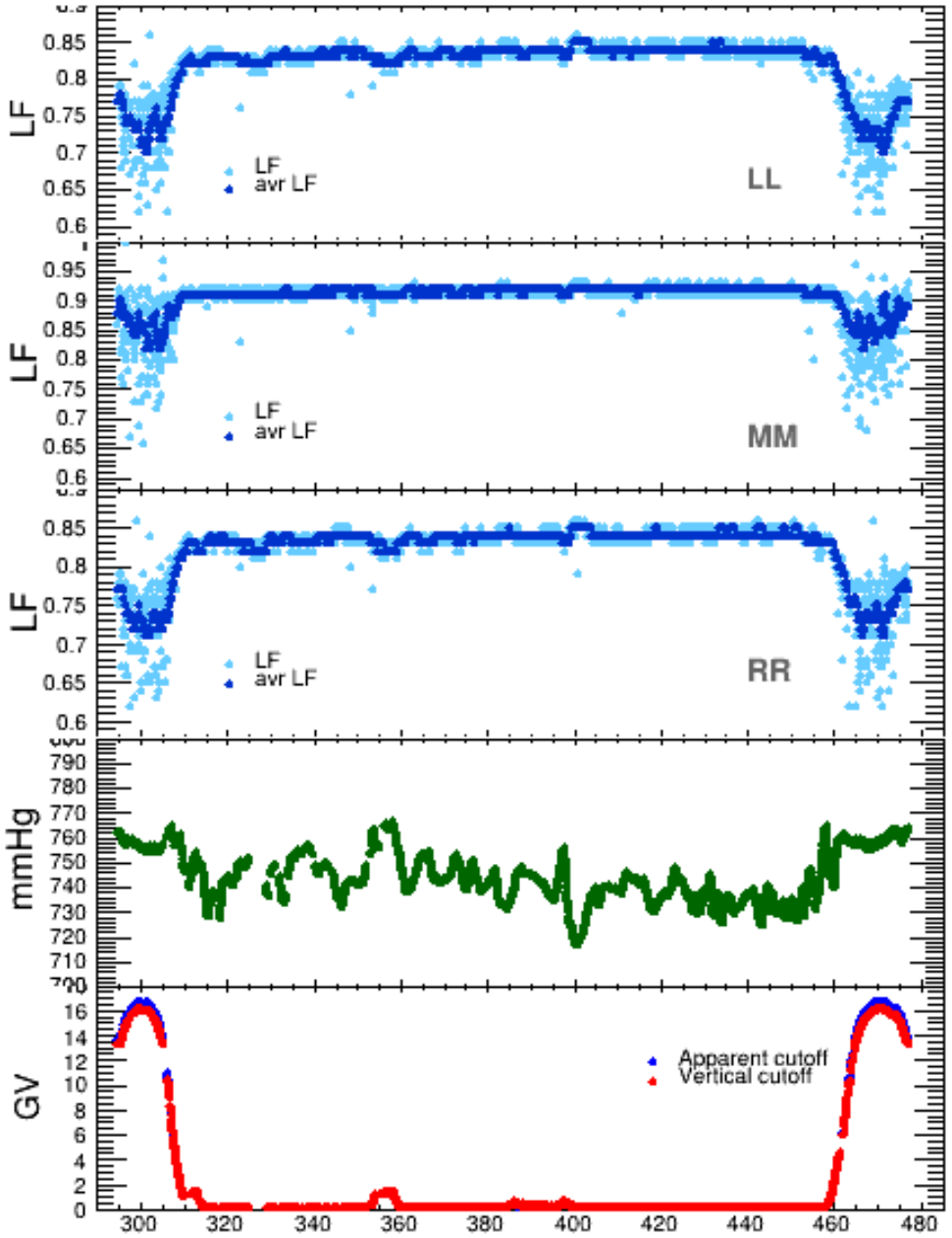


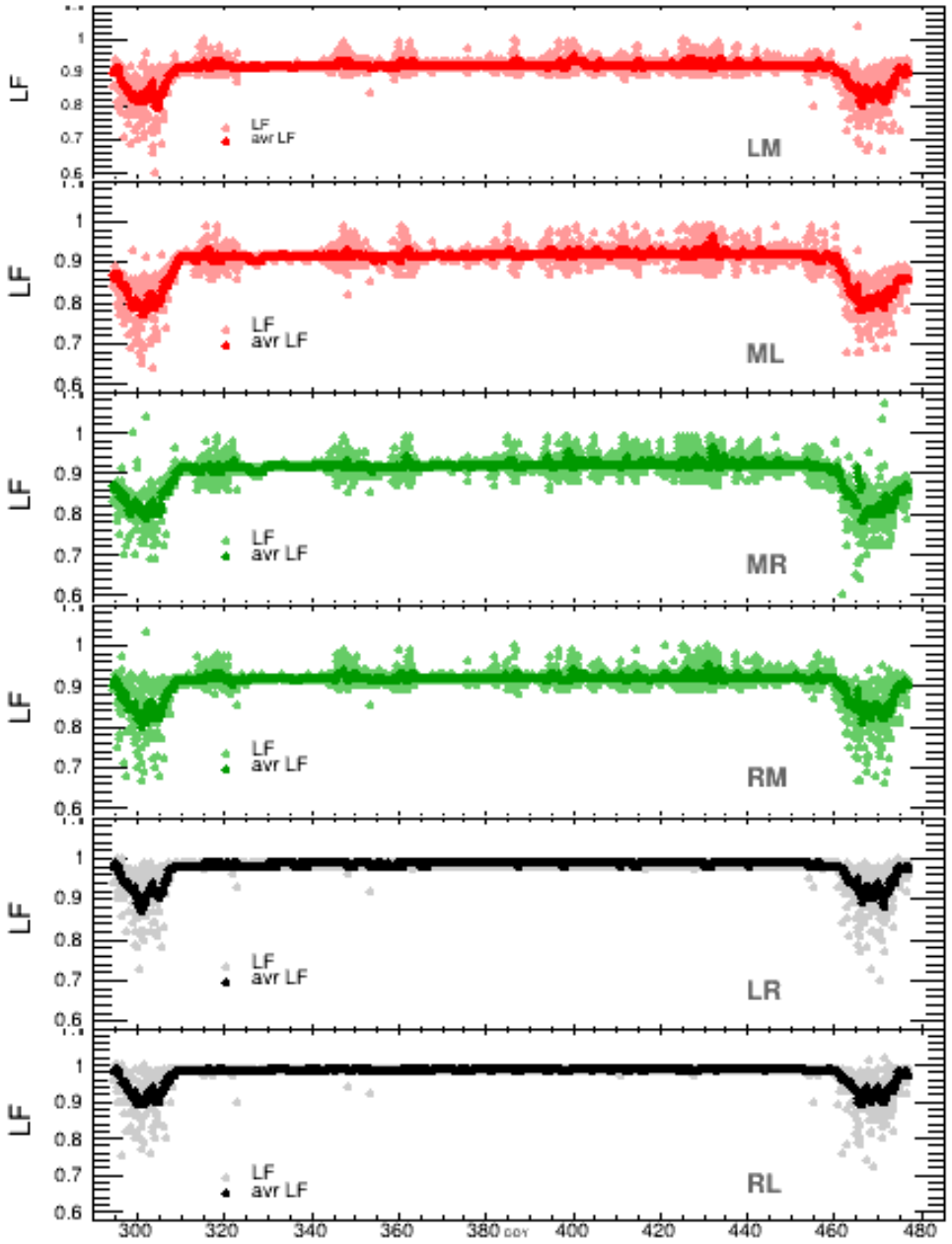
Cross time delay histogram (CN35) shows Leader fraction (LF) and Leader rate (LR) of Changvan latitude survey year 2018-2019



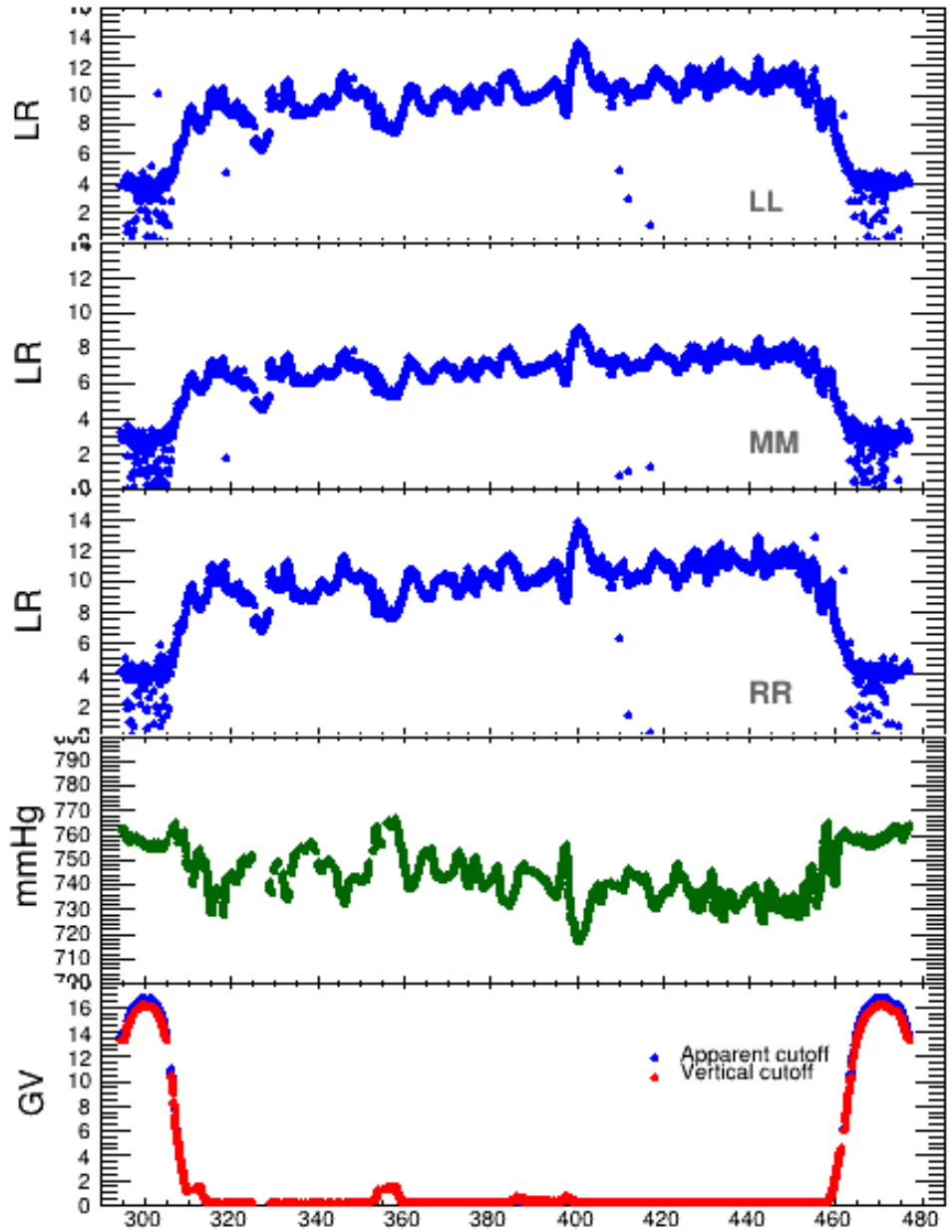


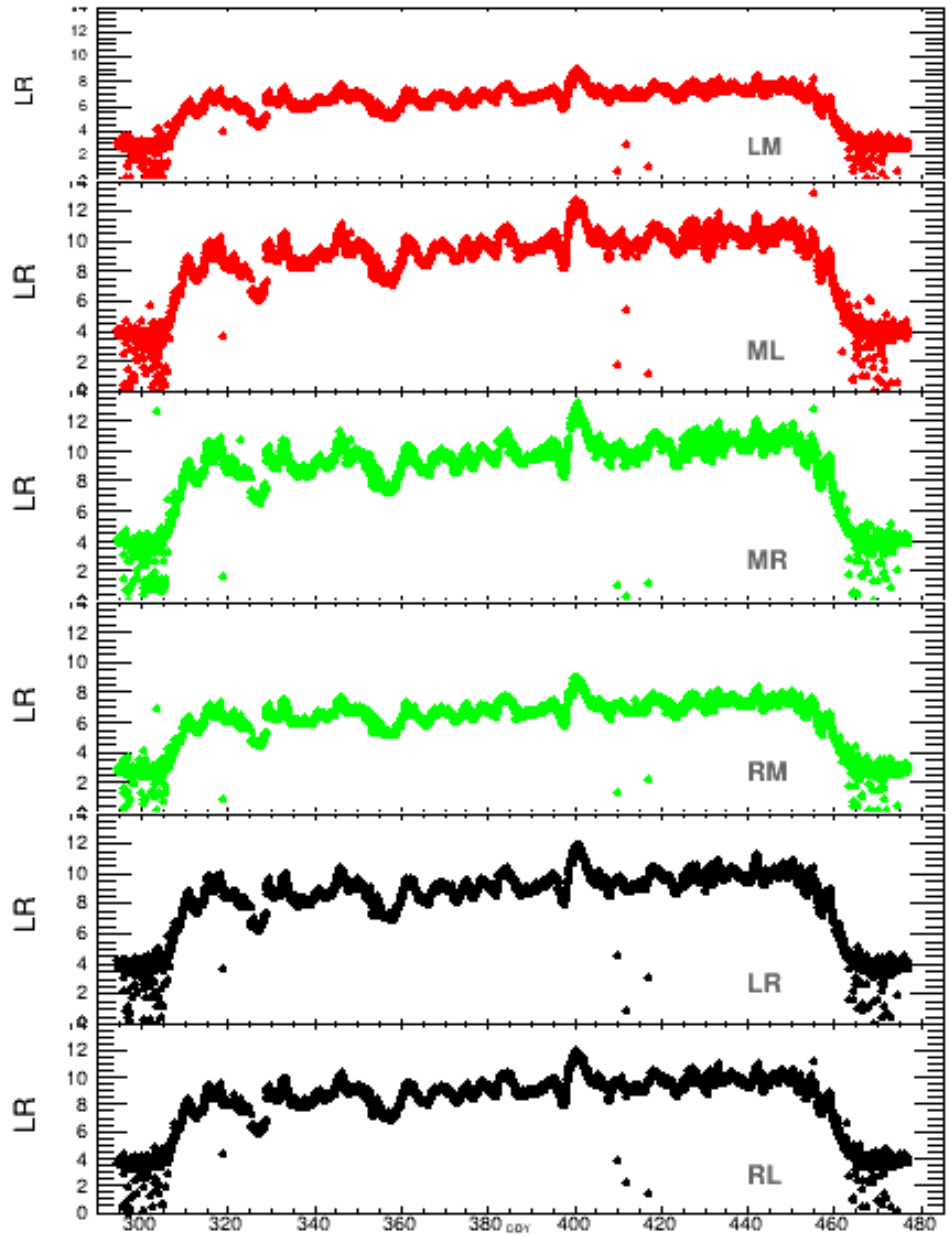
Cross time delay histogram (CN36) shows Leader fraction (LF) of Changvan latitude survey year 2019-2020





Cross time delay histogram (CN36) shows Leader rate (LR) of Changvan latitude survey year 2019-2020





Thank you for your attention