Non-parametric dead time influence estimation of TGF registered by RHESSI

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Main properties of TGF

- TGF are generated in upper atmosphere at atmospheric breakdown on runaway electrons and accompanied by thunderstorm activity (Gurevich+ 1992).

- Short duration (less than millisecond)
- Hard spectrum, up to 100 MeV
- 30% of TGF registered by GBM/Fermi and 10% of TGF registered by RHESSI are identified with lightning
- Lower limit of global TGF frequency is 50/day from RHESSI observations (Smith+ 2005)

Some problems of TGF registration

- Low significance (a few dozens of photons per event)
- Distortion of energetic spectrum and fluence of TGF due to dead time losses and pile-up effect
- Two-thirds of events are not identified with lightning
- Electron and positron beams can be registered from TGF in addition to photons (Briggs+ 2011)

RHESSI experiment

Ramaty High-Energy Solar Spectroscopic Imager (launched in 2002)

- **Primary Mission Objective:**

Explore the basic physics of particle acceleration and energy release in solar flares

- **Orbit:**

Altitude - 600 km

Inclination to the equator – 38°

- **Detectors:**

Nine segmented, hyperpure germanium crystals

Energy range ~3 keV – ~17 MeV

- **Spectral Resolution:**

~1 keV (FWHM) in the front segment up to ~100 keV

~3 keV in the rear segment up to ~1 MeV increasing to ~5 keV at 20 MeV
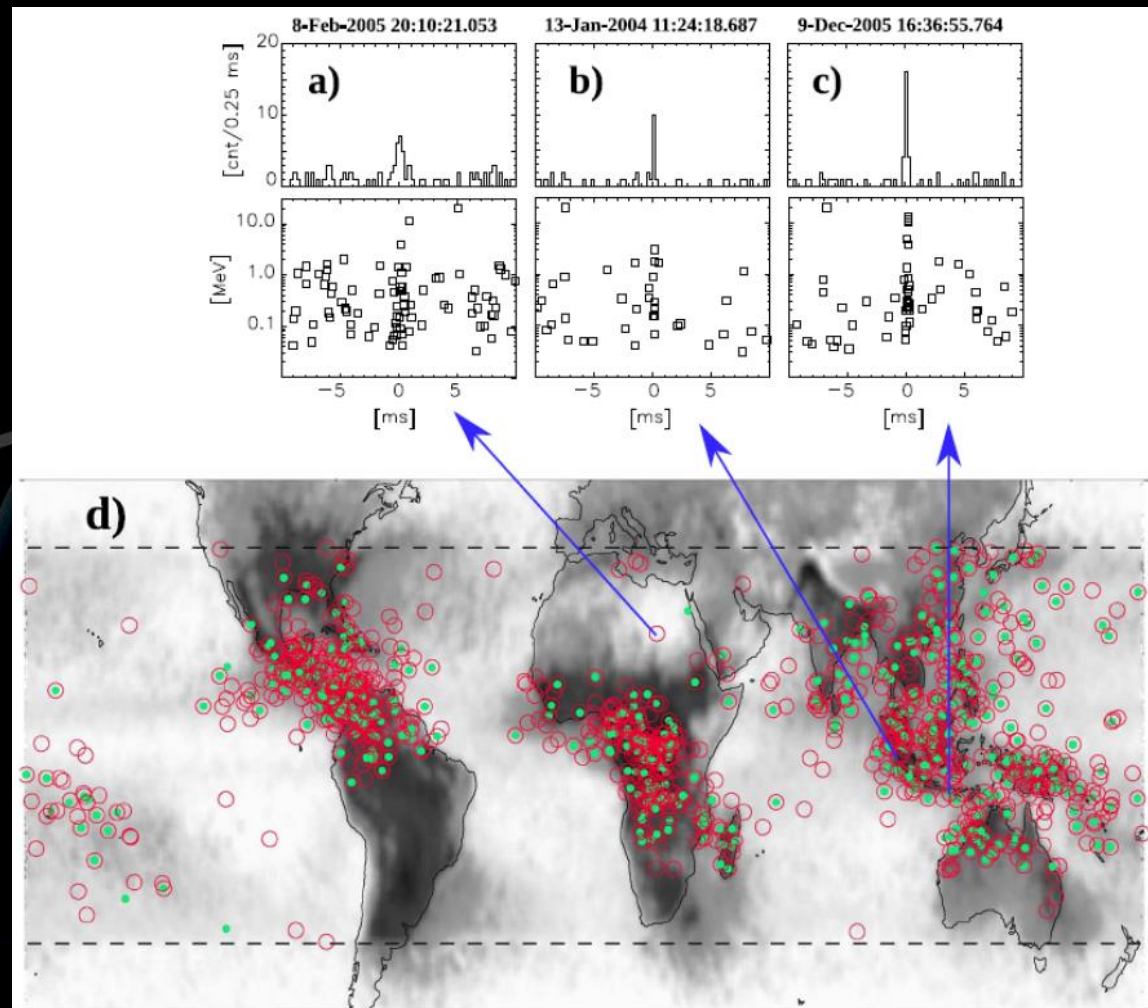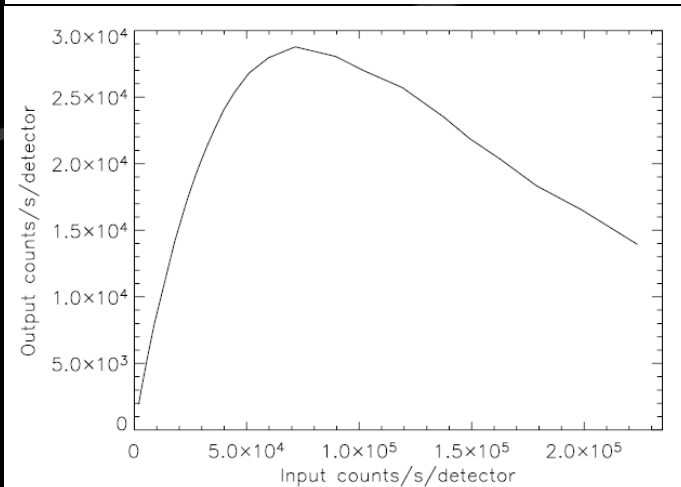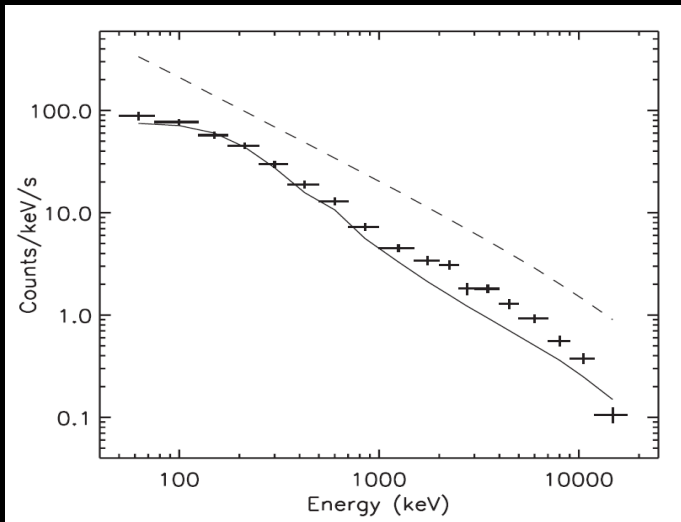
- **Temporal Resolution:**

Photon-by-photon registration with resolution of 10 µs.

RHESSI

Ramaty High-Energy
Solar Spectroscopic Imager

TGFs in RHESSI experiment

- TGF catalog by Grefenstette et al. (2009)
http://scipp.ucsc.edu/~dsmith/tgflib_public/data/

- ~ 1000 TGFs registered in 2002 - 2010

Gjesteland+ 2012

A technique for time profile alignment of TGF (talk by V. Vybornov)

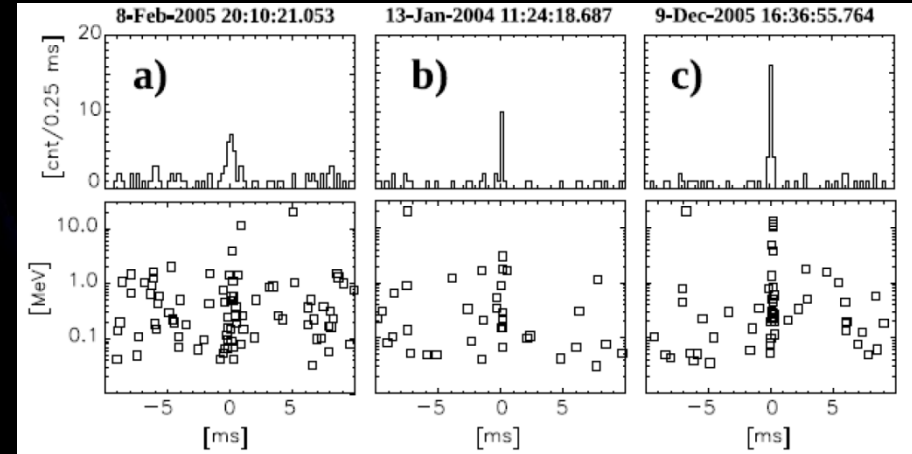- **The problem:**
Low number of counts in single event

- **The solution:**
Stacking of individual events

- **Advantages:**
- Spectral analysis with better statistics
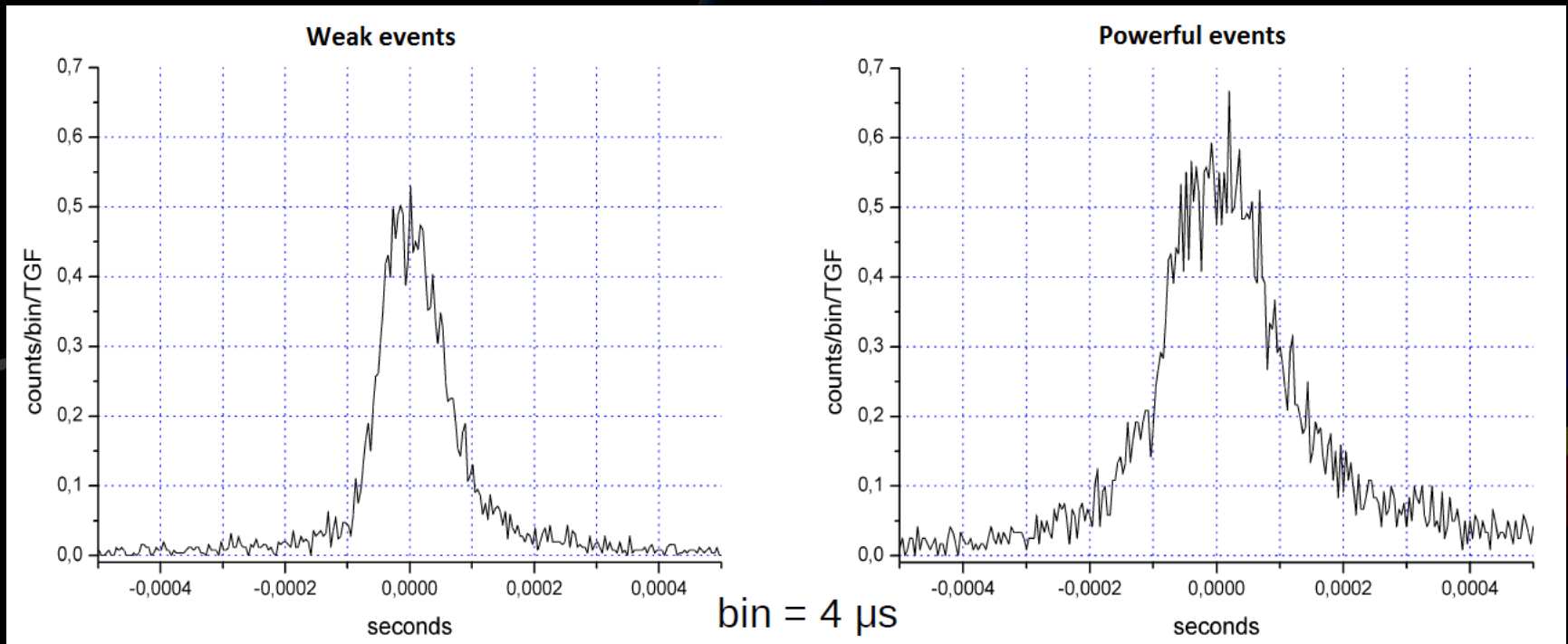- Light curve analysis (shape, components, asymmetry)
- Dead time analysis

- **Disadvantages:**
Investigation of "averaged" TGF - losing information about individual events

Stacking of RHESSI TGFs
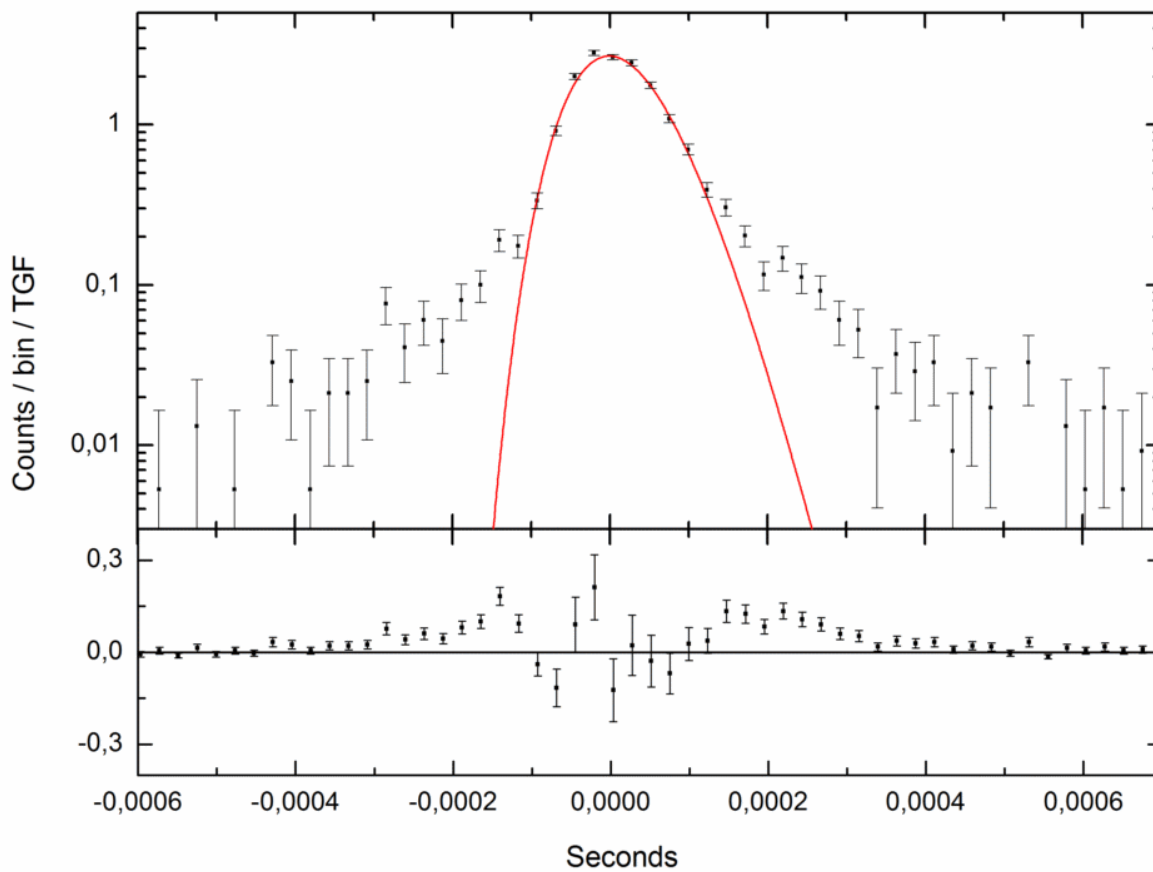
- Five groups of events:

19-36   counts / TGF, 253 TGFs
36-42   counts / TGF, 202 TGFs
42-47   counts / TGF, 177 TGFs
47-55   counts / TGF, 156 TGFs
55-139   counts / TGF, 120 TGFs
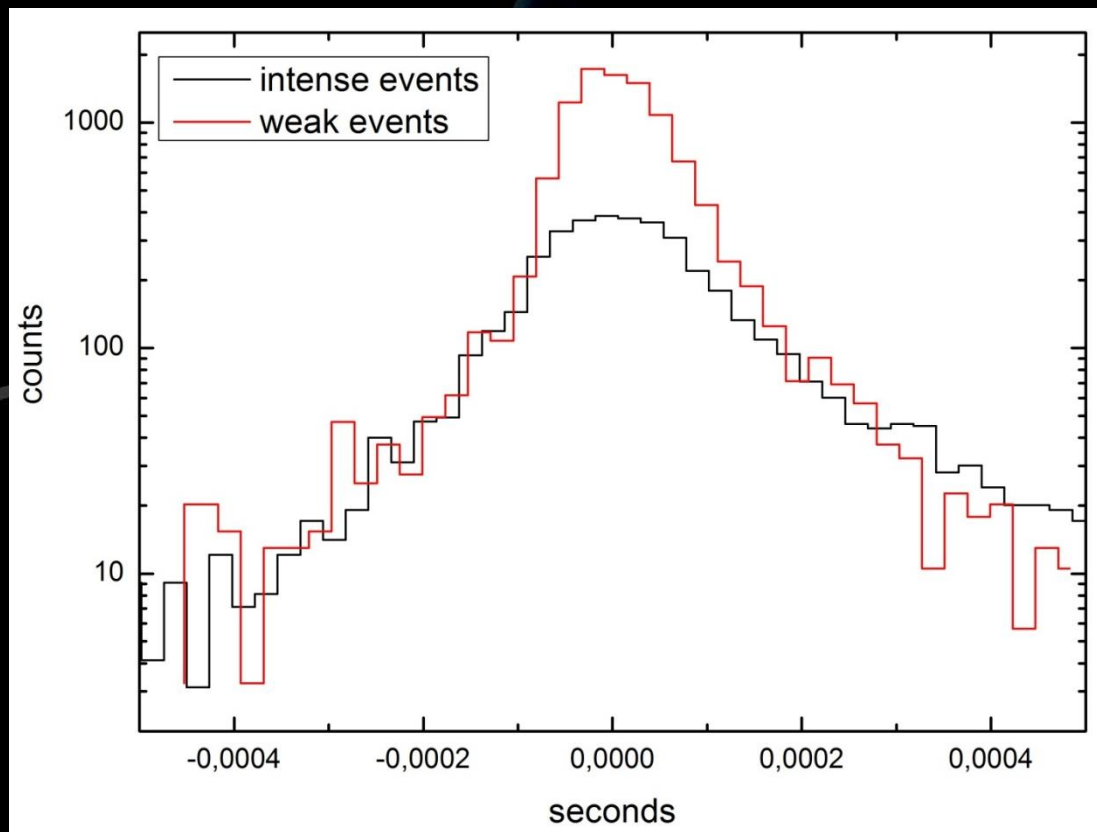

bin = 4 µs

Stacking of RHESSI TGFs

$$I(t) = A\lambda \exp\left(-\frac{\tau_1}{t - t_s} - \frac{t - t_s}{\tau_2}\right),$$

$$\lambda = \exp\left(2\left(\frac{\tau_1}{\tau_2}\right)^{\frac{1}{2}}\right), \quad t - t_s > 0.$$
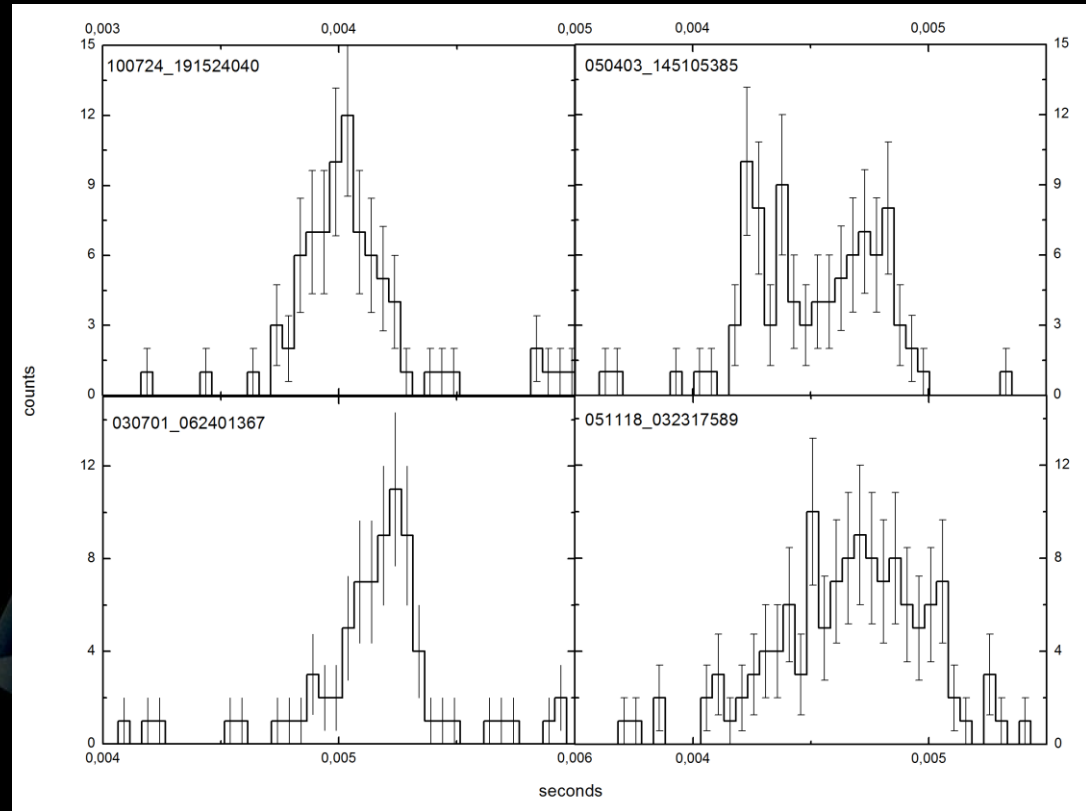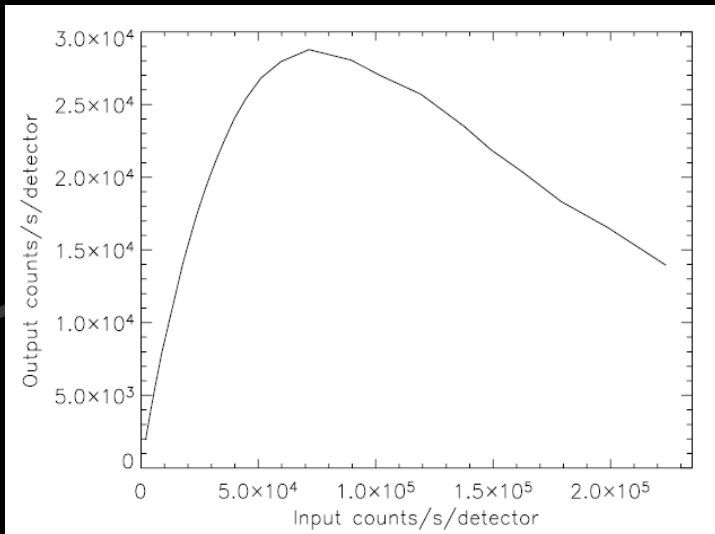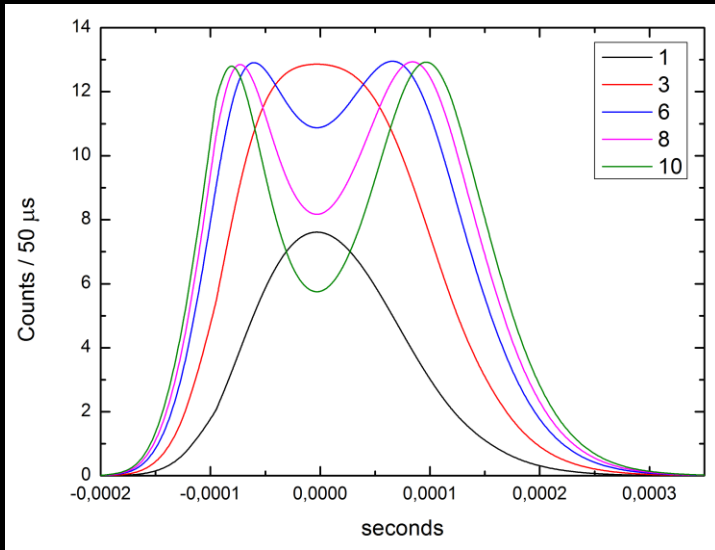
Nonparametric estimation of dead time effects

- **If:**
- **All TGFs have the same shape of light curve and differ only in fluence**
- **Dead-time losses in long component of light curve are negligible**
- **Then:**
- **The lower limit of dead time effects in TGFs in RHESSI experiment is 60%.**

Dead time effects in brightest TGFs

Conclusions

- **TGFs registered by RHESSI were investigated.**

- **Method of event stacking was proposed to analyze light curves of TGFs.**

- **Nonparametric method of dead time influence estimation of TGF registered by RHESSI was proposed.**

- **The lower limit of dead time effects in RHESSI experiment is 60%.**

Thank you for your attention!