

***Gammapy* meeting**
- Time dependent Li&Ma -

Time dependent Li&Ma

- Methods
- Create new IRFs
- Simulate DL3 with new IRFs
- Perform Li&Ma time dependent and compare with classic Li&Ma method

Methods

Li&Ma (likelihood ratio method)

$$L = P(N_{ON} | \langle N_{ON} \rangle) P(N_{OFF} | \langle N_{OFF} \rangle) = \frac{e^{-(\bar{s} + \bar{b})T_{ON}} ((\bar{s} + \bar{b})T_{ON})^{N_{ON}}}{N_{ON}!} \frac{e^{-\bar{b}T_{OFF}} (\bar{b}T_{OFF})^{N_{OFF}}}{N_{OFF}!}$$

$$L_0 = P(N_{ON} | \langle N_{ON} \rangle) P(N_{OFF} | \langle N_{OFF} \rangle) = \frac{e^{-\bar{b}_0 T_{ON}} (\bar{b}_0 T_{ON})^{N_{ON}}}{N_{ON}!} \frac{e^{-\bar{b}_0 T_{OFF}} (\bar{b}_0 T_{OFF})^{N_{OFF}}}{N_{OFF}!}$$

Likelihood functions maximized for : $\bar{b}_0 = \frac{N_{ON} + N_{OFF}}{T_{ON} + T_{OFF}}$ $\bar{b} = \frac{N_{OFF}}{T_{OFF}}$ $\bar{s} = \frac{N_{ON}}{T_{ON}} - \frac{N_{OFF}}{T_{OFF}}$

$$\text{Significance : } \sqrt{TS} = \sqrt{-2 \log \left(\frac{L_0}{L} \right)}$$

Methods

Li&Ma time dependent

→ divide the ON source time observation T_{ON} into time N bins of equal length Δt

→ arrival time of ON source counts : $\{t_{\text{ON}}\}$

→ likelihood :

$$L = \underbrace{\left(\prod_{t_i = (\Delta t, \dots, N \Delta t)} \frac{(\Delta t (b + s(t_i)))^{\{0,1\}}}{\{0,1\}!} e^{-\Delta t (b + s(t_i))} \right)}_{\text{product of the probability mass function for each } T_{\text{ON}} \text{ bin (0 or 1 event, for a large N)}} \underbrace{\left(\frac{(b T_{\text{OFF}})^{N_{\text{OFF}}}}{N_{\text{OFF}}!} e^{-b T_{\text{OFF}}} \right)}_{\text{probability mass function for OFF observations}}$$

Methods

Li&Ma time dependent

→ for the null hypothesis : $s(t) = 0$ and $b = b_0$

- likelihood function :
$$L_0 = \Delta t^{N_{ON}} b_0^{N_{ON}} \frac{(b T_{OFF})^{N_{OFF}}}{N_{OFF}!} e^{-(N_{ON} + N_{OFF})}$$

- background rate maximized by :
$$b_0 = \frac{N_{ON} + N_{OFF}}{T_{ON} + T_{OFF}}$$

Methods

Li&Ma time dependent

→ signal time profile (1 free parameter) : $s(t) = \theta f(t)$

→ assumption for the type profile of the burst $f(t) \sim 1/t$

- likelihood function :
$$L = \Delta t^{N_{ON}} \left(\prod_{t_i \in t_{ON}} (b + s(t_i)) \right) \frac{(b T_{OFF})^{N_{OFF}}}{N_{OFF}!} e^{-b(T_{ON} + T_{OFF}) - \int_{t_{ON}(0)}^{T_{ON}} dt s(t)}$$

- background rate maximized by :
$$b = \frac{N_{ON} + N_{OFF} - \int_0^{T_{ON}} dt s(t)}{T_{ON} + T_{OFF}}$$

Method

Li&Ma time dependent

→ maximize θ with Brent method

→ ratio likelihood test $TS = -2 \log\left(\frac{L_0}{L}\right)$

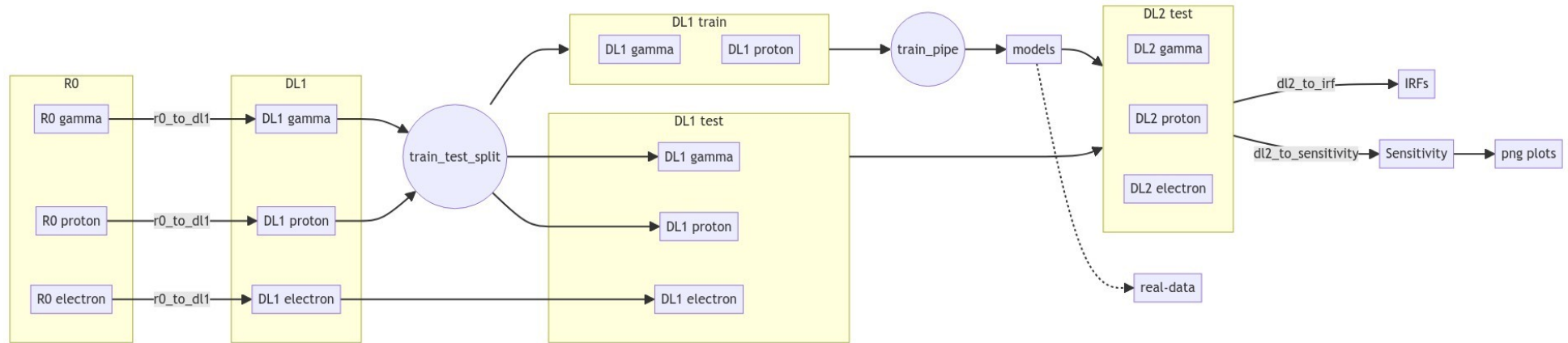
→ Li&Ma time dependent significance $\sigma = \sqrt{TS}$

Create new IRFs

Production : 20200629_prod5_trans80 (old MC !)

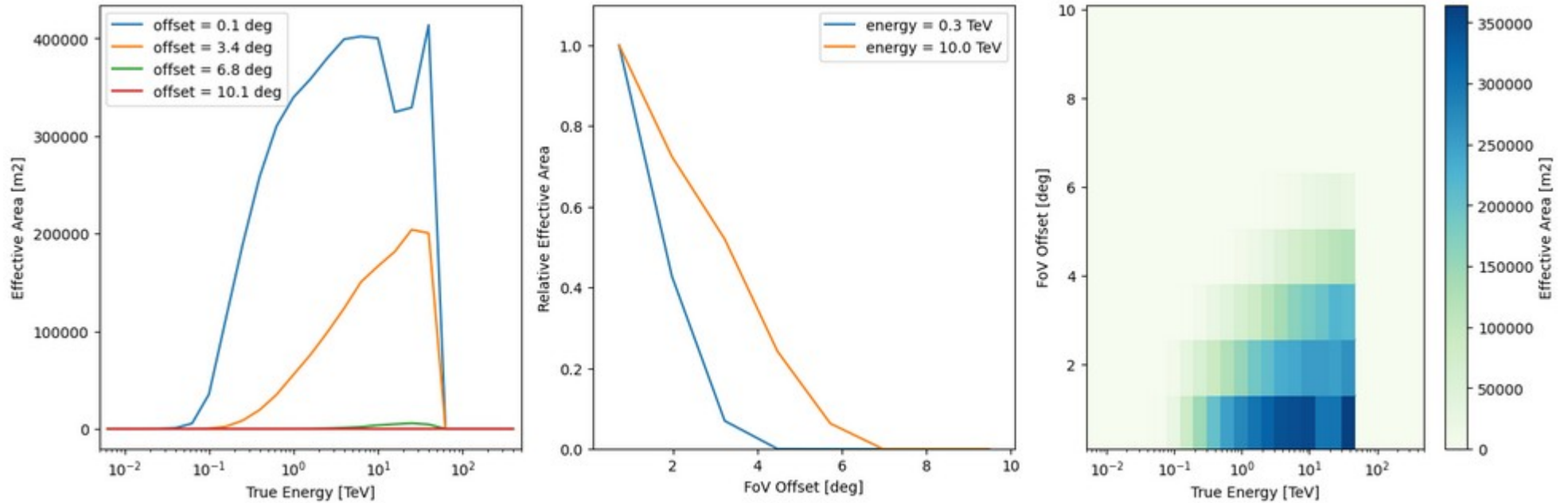
- gamma diffuse
 - background with protons and electrons
- } Full enclosure

No existing IRFs with Istchain v0.10.5



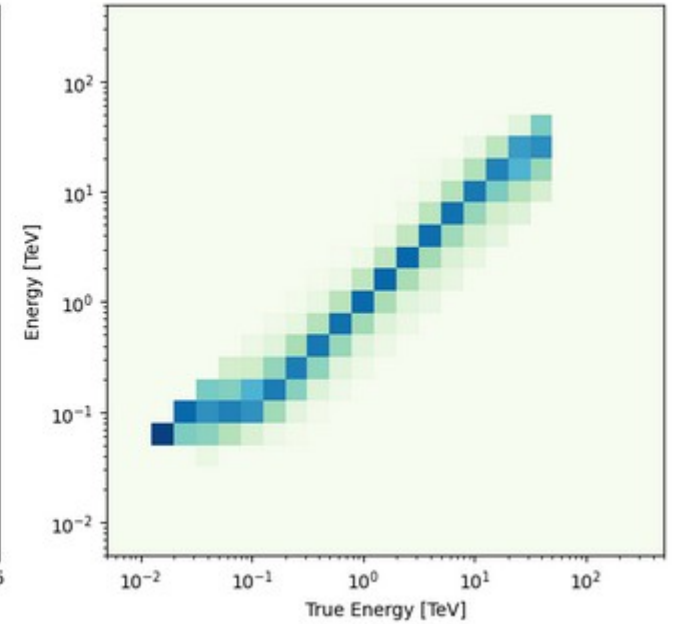
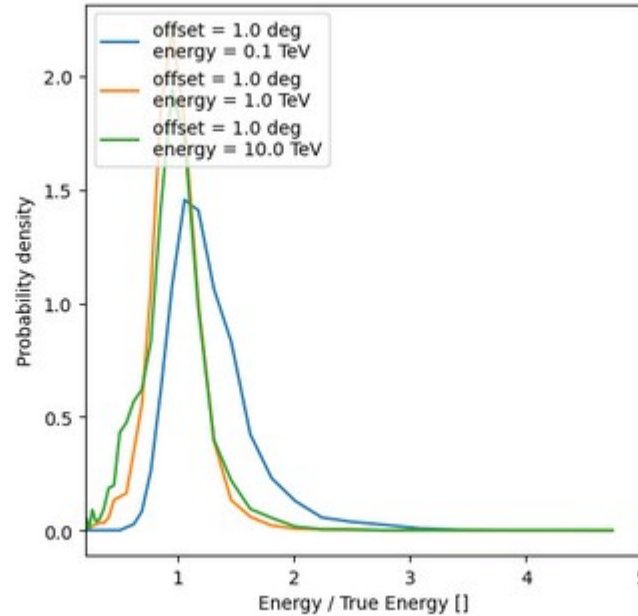
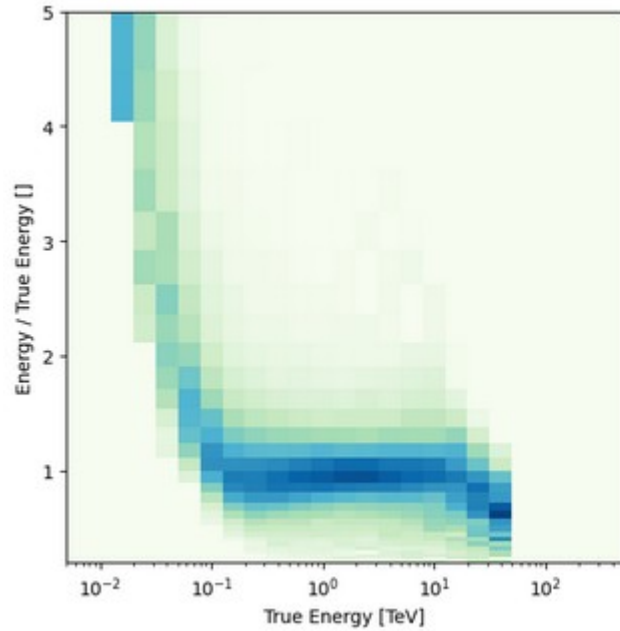
Create new IRFs

Effective area



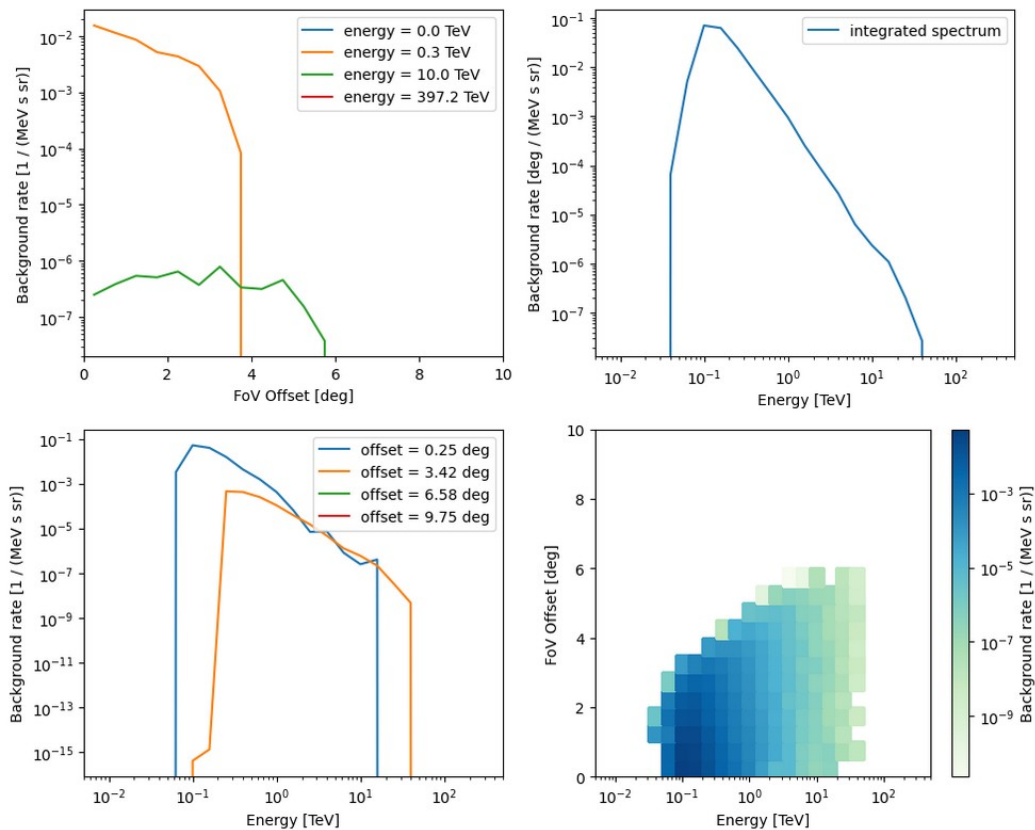
Create new IRFs

Energy dispersion



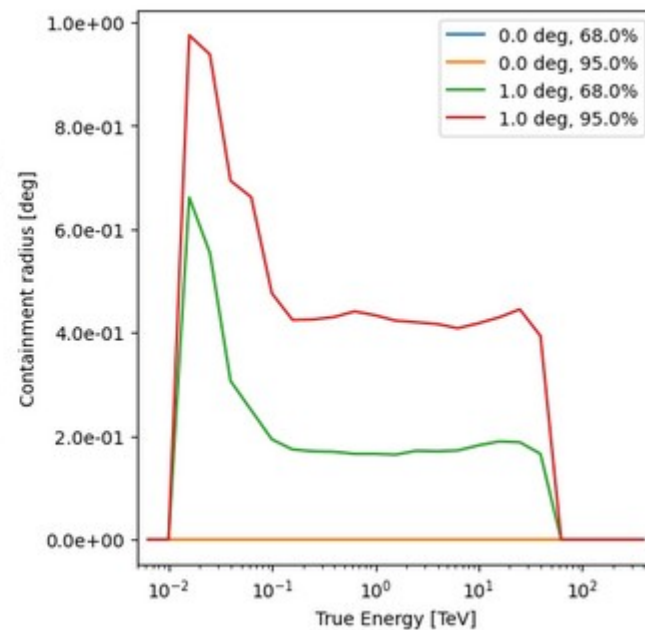
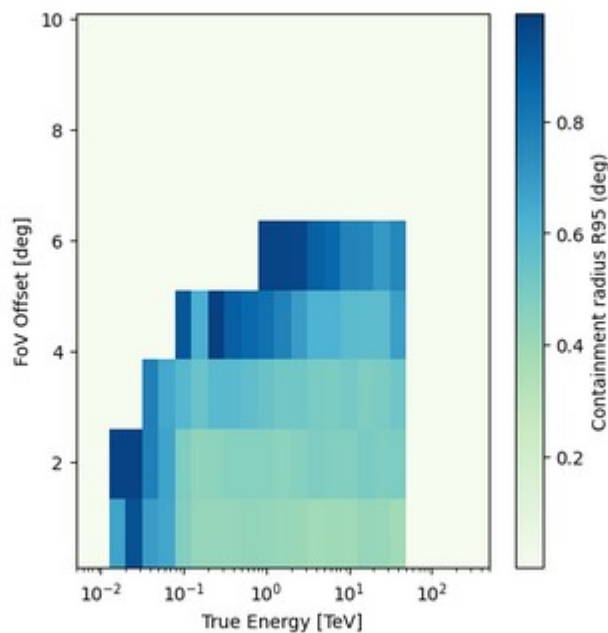
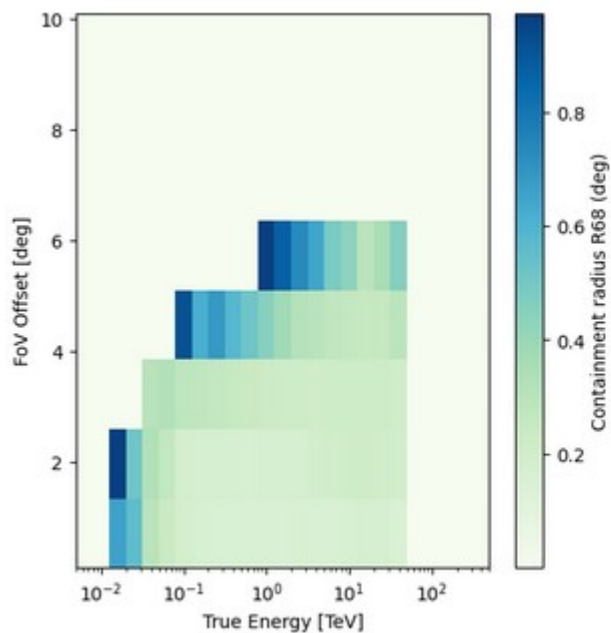
Create new IRFs

Background



Create new IRFs

Point spread function



Simulate DL3

Generate observation table

	time_reference	livetime	delay	temporal_index	time_scale	normalization	spectral_index	energy_reference	redshift
id									
0	2000-01-01	4800.0	364.481709	-2.72453	30.0	2.105078e-07	4.41179	30.0	NaN

Generate run table

	id_obs	file_obs	file_model	livetime	delay	offset	offset_direction
id							
0	0	/home/lemoine/gammapy/gammapy-notebooks/Simul...	/home/lemoine/gammapy/gammapy-notebooks/Simul...	1200.0	364.481709	0.4	0.0
1	0	/home/lemoine/gammapy/gammapy-notebooks/Simul...	/home/lemoine/gammapy/gammapy-notebooks/Simul...	1200.0	1564.481709	0.4	90.0
2	0	/home/lemoine/gammapy/gammapy-notebooks/Simul...	/home/lemoine/gammapy/gammapy-notebooks/Simul...	1200.0	2764.481709	0.4	180.0
3	0	/home/lemoine/gammapy/gammapy-notebooks/Simul...	/home/lemoine/gammapy/gammapy-notebooks/Simul...	1200.0	3964.481709	0.4	270.0

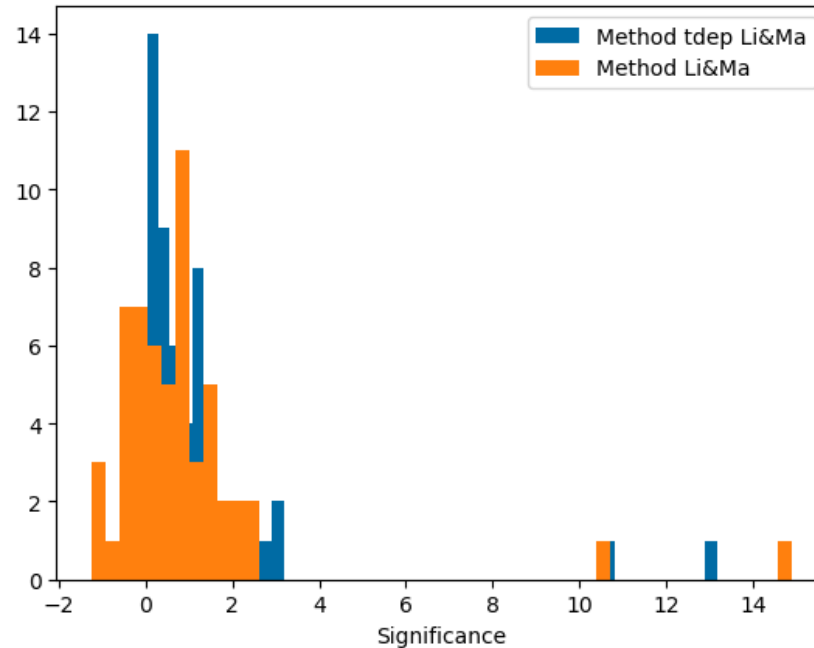
Simulate DL3

Make simulations

	id_obs	integration_time	significance	optimized_amplitude	tdep_significance	excess	background	livetime	mc_source_counts	mc_source_counts_on_region	mc_background_counts_on_region	run_time
id												
0	0	10.0	0.943202	7227.574428	0.857085	15.0	162.0	600.0	0	0	177	0.695145
1	0	20.0	-0.692925	4838.441060	0.650122	-15.5	340.5	1200.0	0	0	325	0.799172
2	0	40.0	-1.130287	4919.087312	0.712939	-35.5	673.5	2400.0	0	0	638	1.164876
3	0	60.0	-0.491923	3777.910962	0.562439	-19.0	1003.0	3600.0	0	0	984	1.650263
4	0	80.0	-0.470224	3375.279296	0.510201	-21.0	1339.0	4800.0	0	0	1318	2.212151

Perform Li&Ma methods

for 100 source simulations,



tdep significance always positive => take the sign of the excess ?

Distribution of the significance for the 100 simulated events

Capharnaüm

$$b = \frac{N_{ON} + N_{OFF} - \int_0^{T_{ON}} dt s(t)}{T_{ON} + T_{OFF}}$$

$$\log(L) = N_{OFF} \log b + \sum_{t_i \in \{t_{ON}\}} \log(b + s(t_i))$$