Catalog of Long-Term Transient Sources in the First 10 Years of Fermi-LAT Data

1FLT Catalog

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Analysis

- 10 yrs of data (|b|>10°)
- IRFs: P8R3
- 120 months + 120 15-day shifted months: 240 different skies (from 4 August 2008 to 5 August 2018 + from 19 August 2008 to 20 August 2018)
- Seeds search: wavelet-based source detection algorithm
- Sources selection > 50 arcmin apart from 4FGL-DR2
- Maximum likelihood for localization and definition of gamma-ray parameters

Results

1FLT

- **142 different 1FLT sources** (TS>25 and not associable to any 4FGL DR2 source): 64 in the nominal 120 months and 78 in the shifted ones (different 1FLT JHHMM+DDMM name and different SRCNUM)
- **108 sources** with a single monthly detection
- **34 sources** with multiple monthly detections

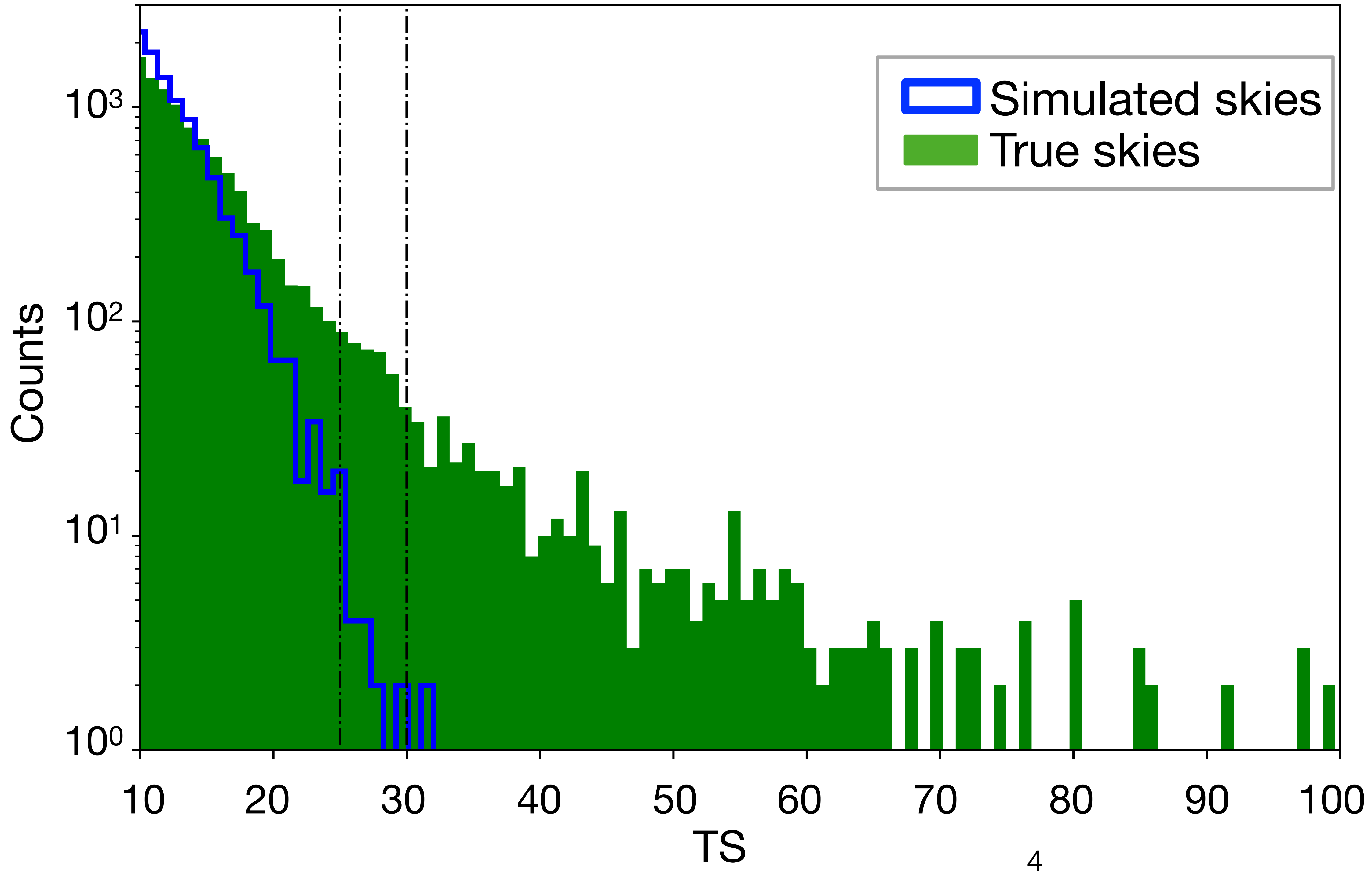
186 detections

Other

- **63 Sun** detections
- **14 GRBs** detected on monthly time scale (**27** detections)

Simulations

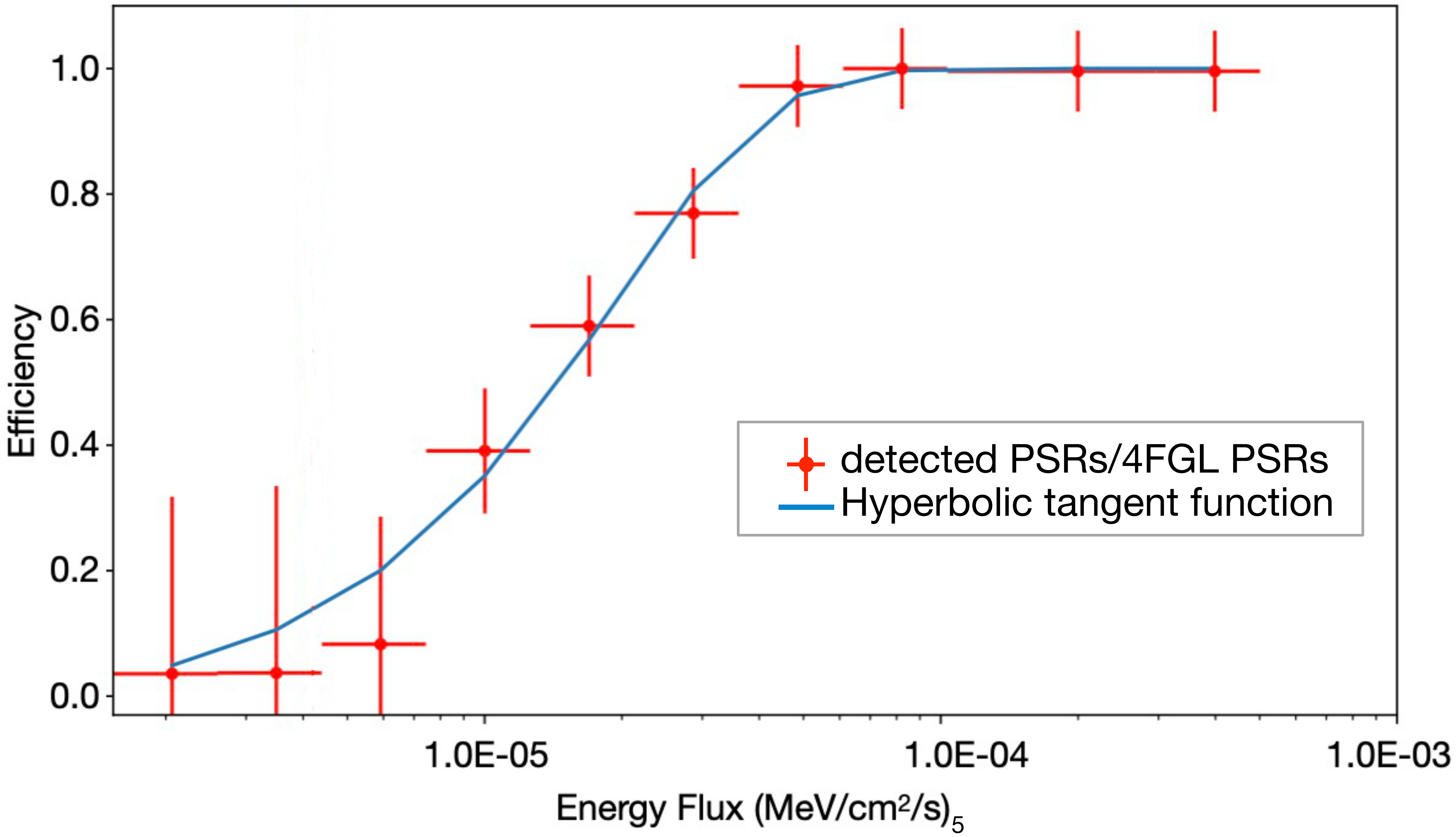
- Simulated 120 month-long datasets, model includes only the Galactic and the extragalactic diffuse emissions.
- Applied same procedure as for the true skies
- 12 spurious detections with TS > 25 and 1 spurious detection with TS > 30 —> flagged sources with single monthly detection and with TS < 30 as low confidence (72 sources) and TS > 30 as high confidence (70 sources)



Histograms of TS evaluation of all extracted seeds from simulated skies, the blue line (the extracted numbers are multiplied by two), and true skies, the green distribution. The two vertical lines show the TS range of low confidence sources (25 < TS < 30).

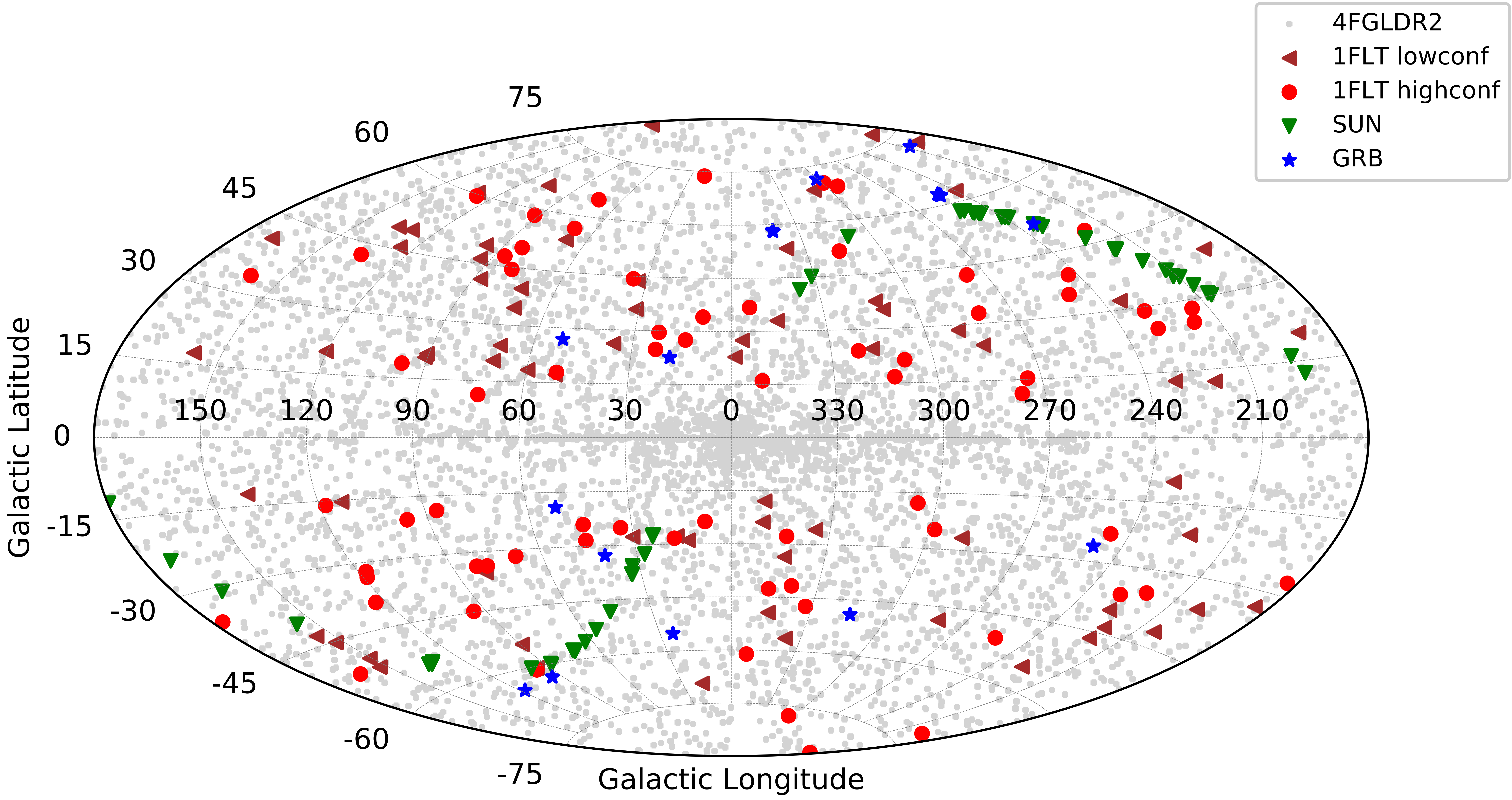
Efficiency

Detection rate as a function of the energy flux of high-latitude PSRs. Each point represents the ratio of detected sources over 240 overlapping months with respect to the number of true 4FGL PSRs with |b| > 10 binned by flux. The error bars correspond to the statistical uncertainty estimated using the binomial statistic. The blue curve is the hyperbolic tangent function *tanhλ(f - f₀)*.



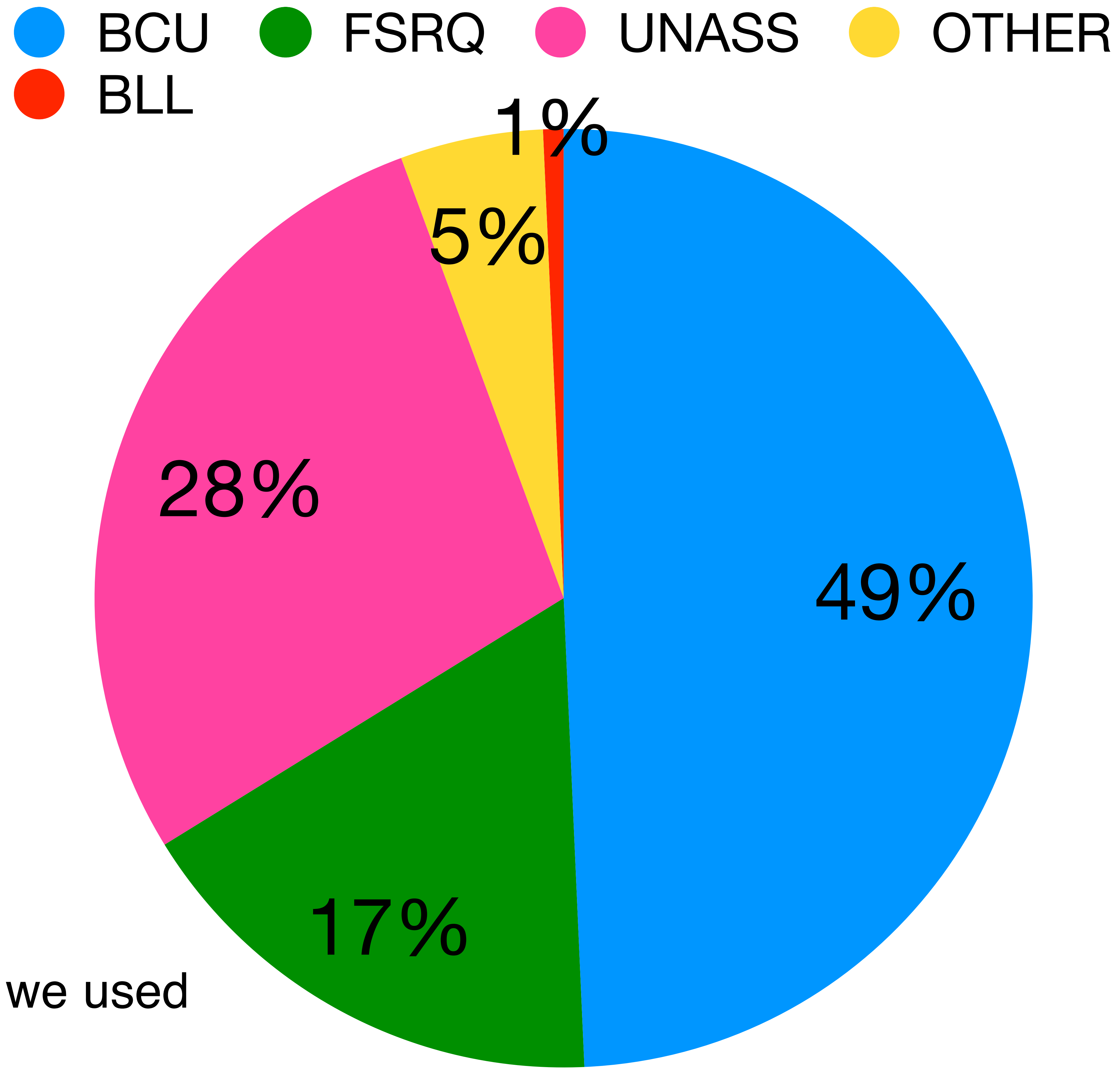
Efficiency > 80% with energy flux > 3E-5 MeV/cm2/s and ~100% for energy flux > 5E-5 MeV/cm2/s

Aitoff Projection



Census

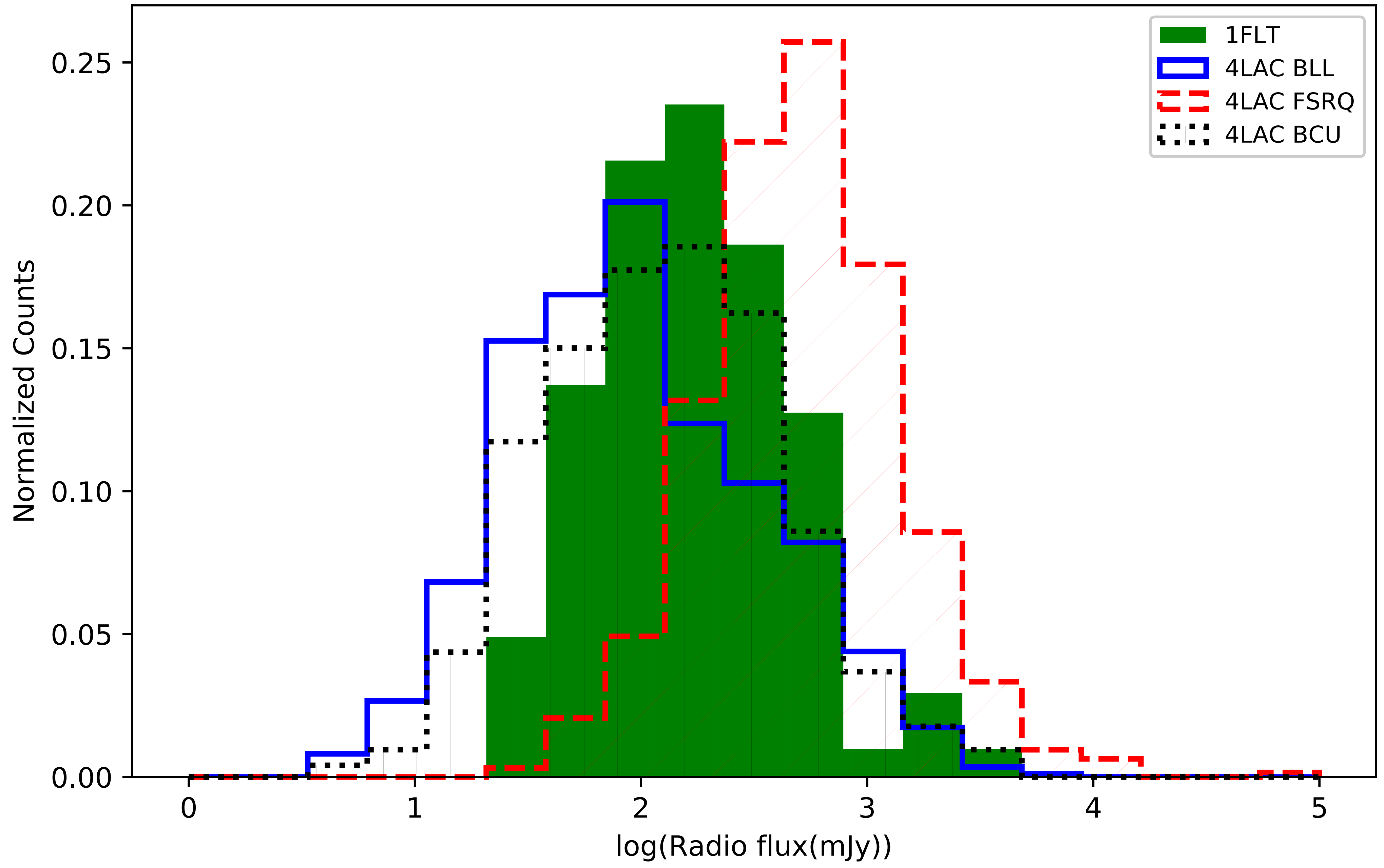
BCU	70
FSRQ	24
AGN	2
CSS	1
RG	3
SSRQ	1
BLL	1
UNASS	40



To identify candidate counterparts of the 1FLT sources we used two approaches:

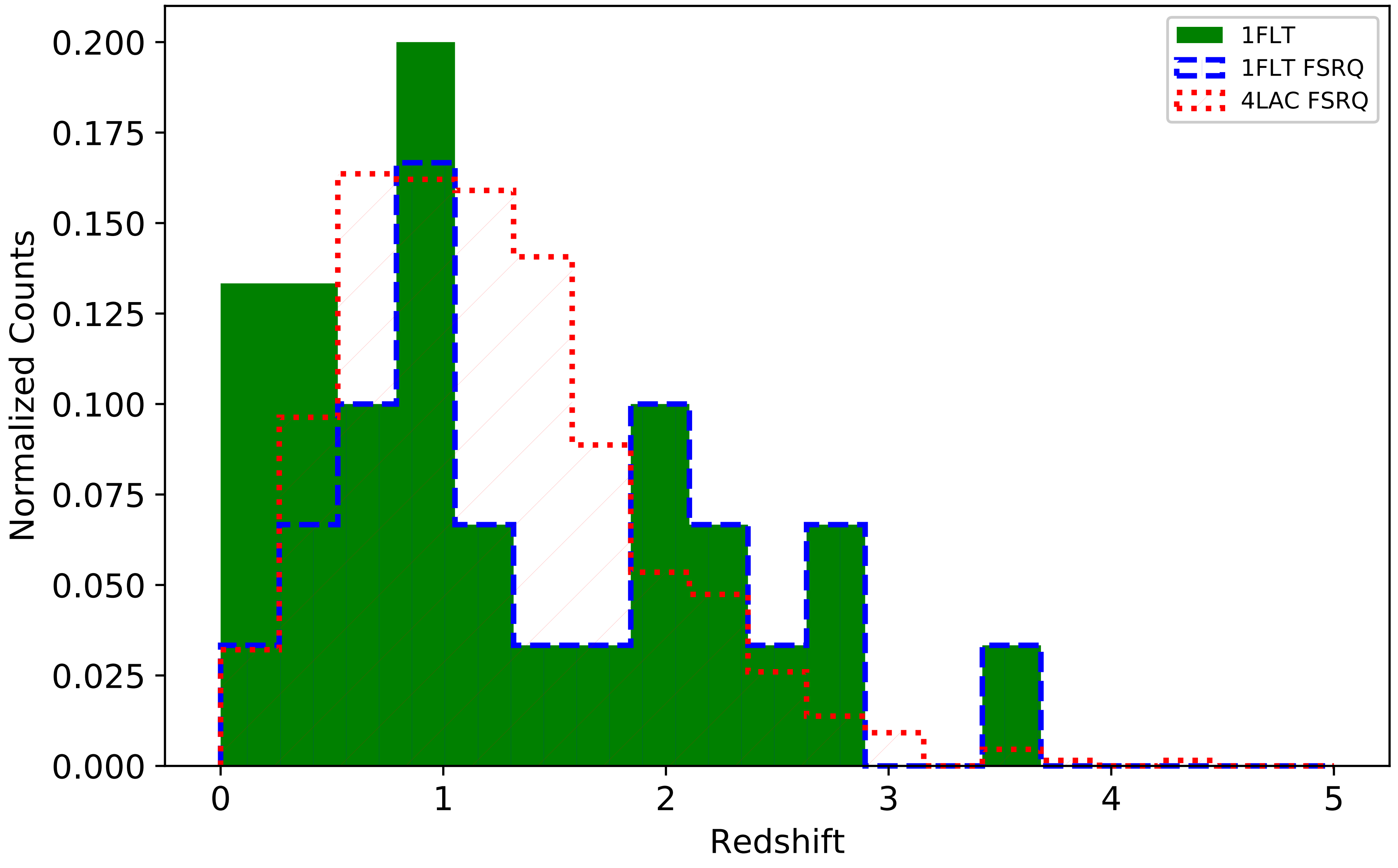
- **the Bayesian method**, used in the general catalogs
- **the positional method,** which searches for the counterpart inside the error ellipse.

Results



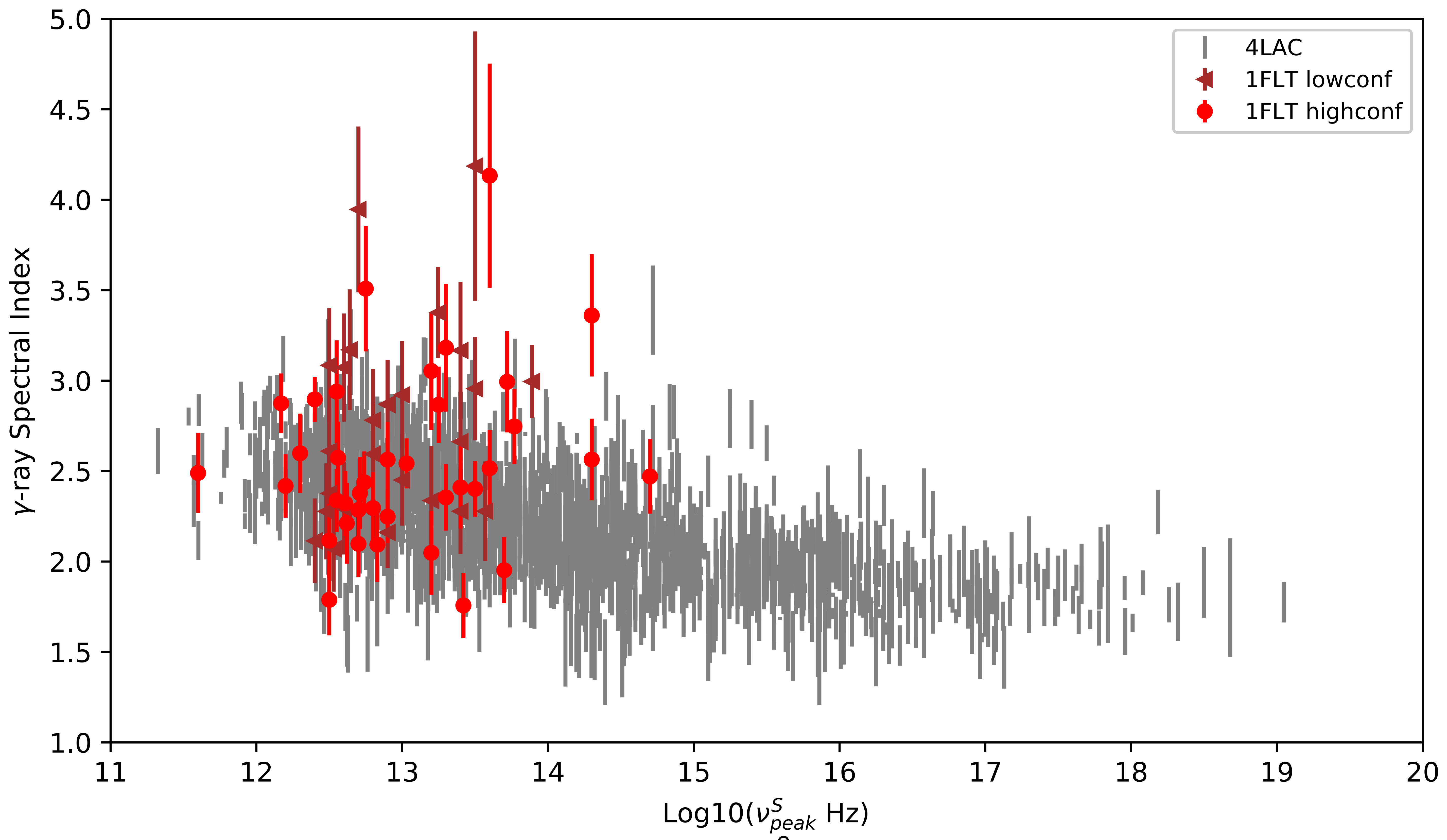
1FLT sources show a fainter radio flux than the 4LAC FSRQs but comparable to those of the 4LAC BCUs

The redshift is available for all FSRQs, for 1 BCU, 1 BLL, 3 RG and 1 non-blazar object. About 50% of 1FLT FSRQs are detected at $z > 1$.

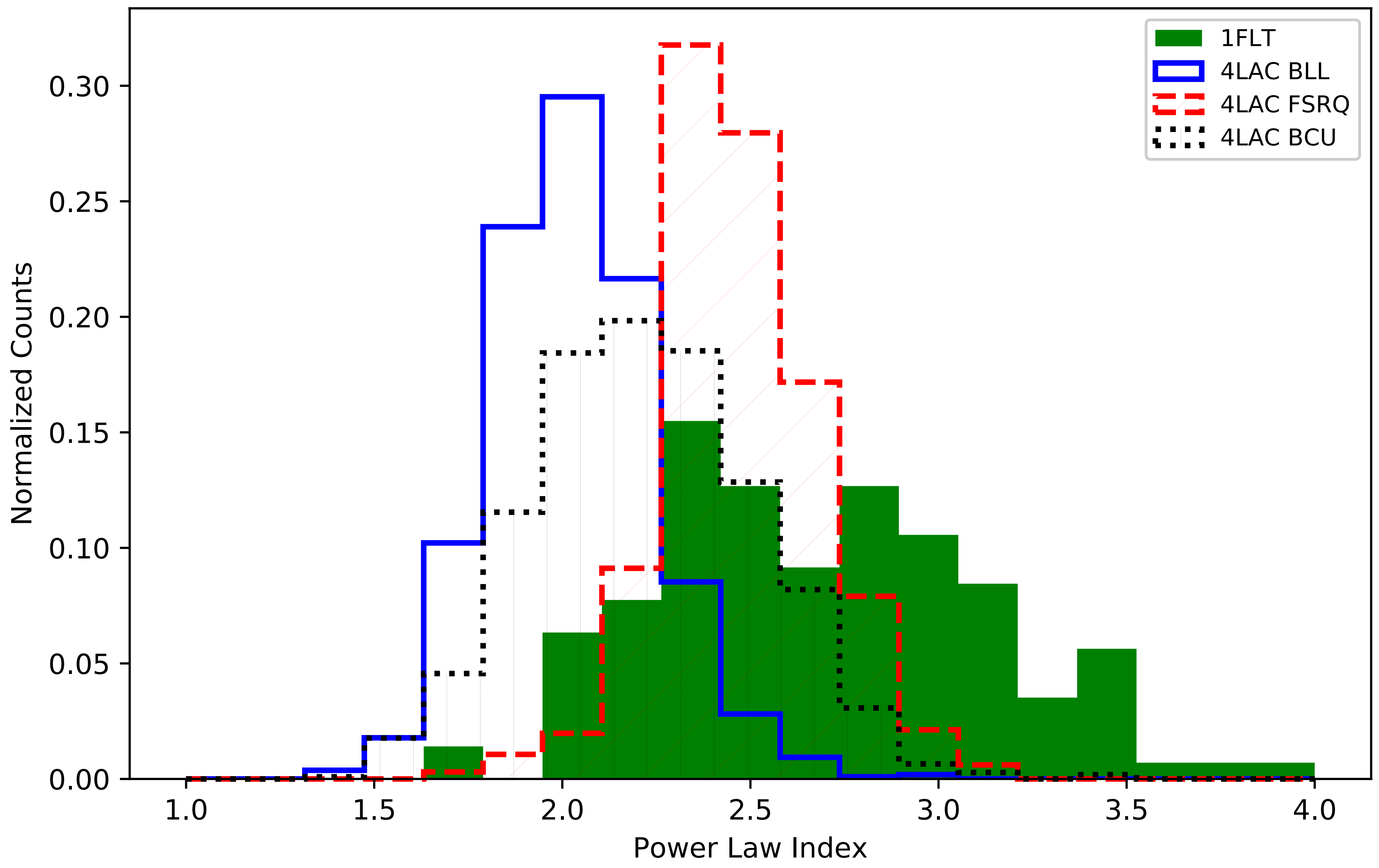


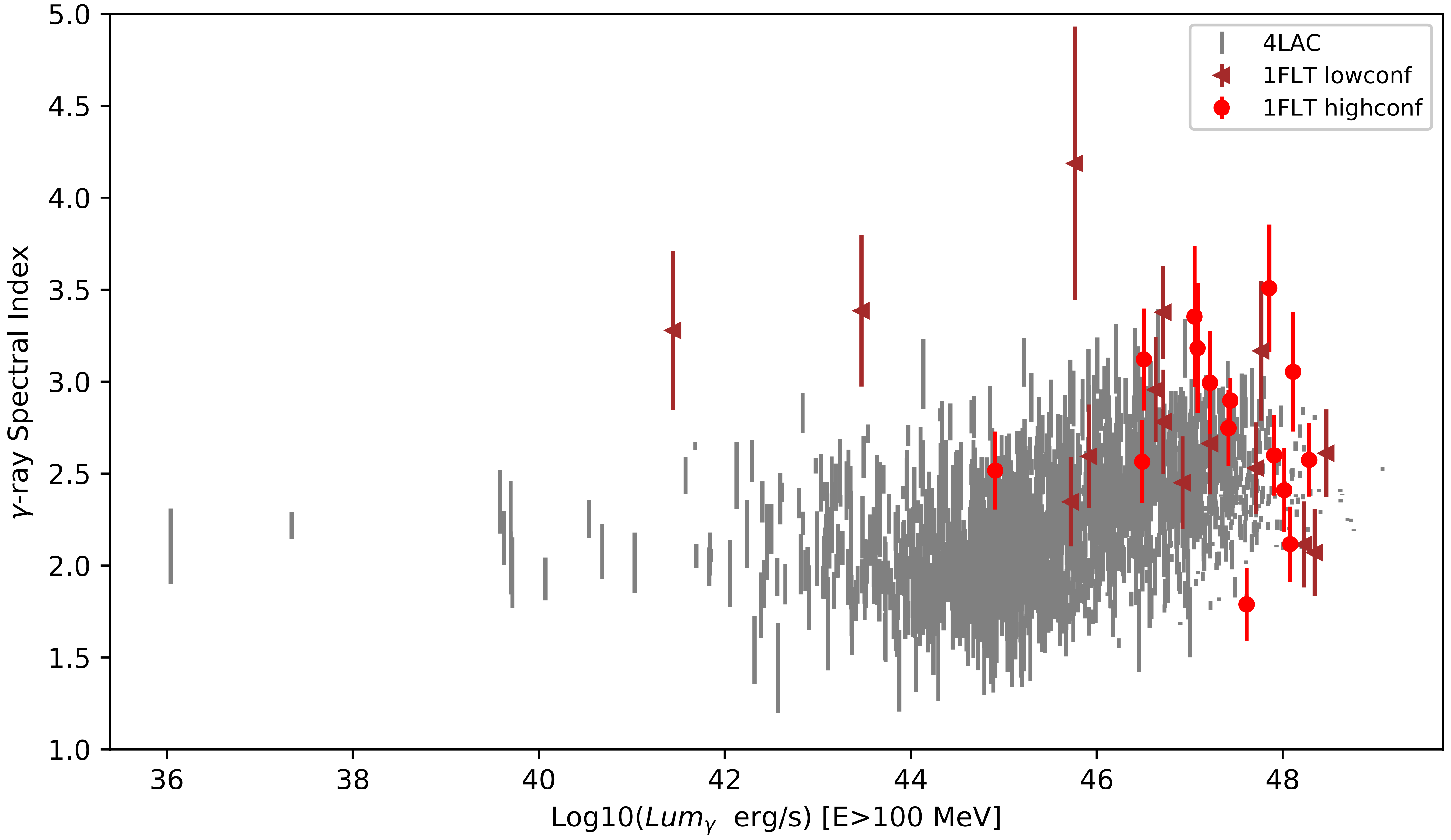
Results

Evaluation of Synchrotron Peak of the low-energy hump of the SED fitting with a 3rd degree polynomial (same procedure as 4LAC): 1FLT sources are mainly Low Synchrotron Peaked Blazars



Results

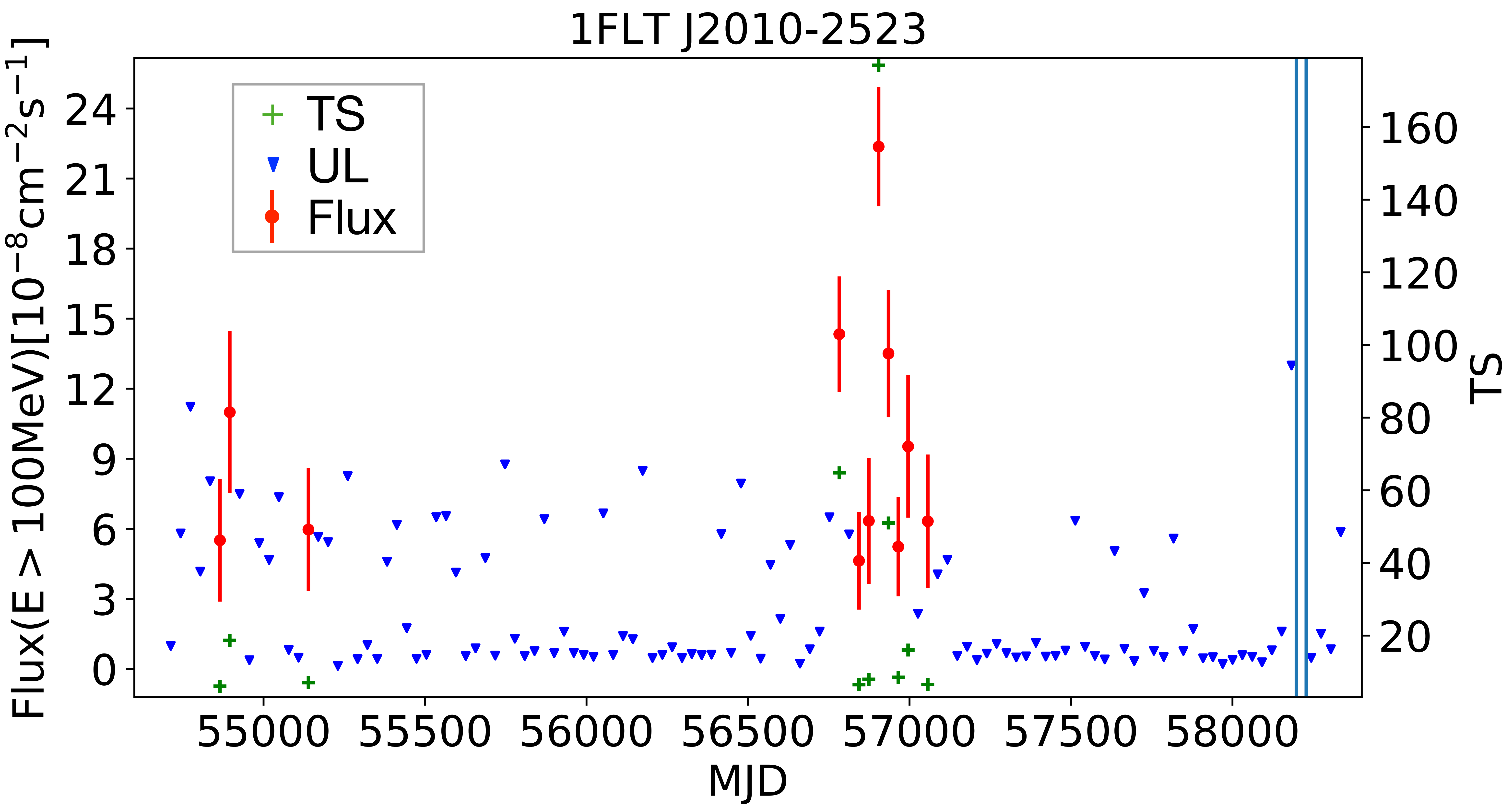




The 1FLT distribution extends to softer Γ values compared to 4LAC, with a median value of 2.7 compared to 2.2 of 4LAC (2.5 if we consider only 4LAC FSRQs.)

The 1FLT sources show a higher gamma-ray luminosity, possibly since they are detected during a flaring state, and softer gamma-ray spectrum than the sources detected integrating over years of data.

Light Curve



1FLT J2010-2523 (PMN J2010-2524)

7 monthly detections with TS > 25

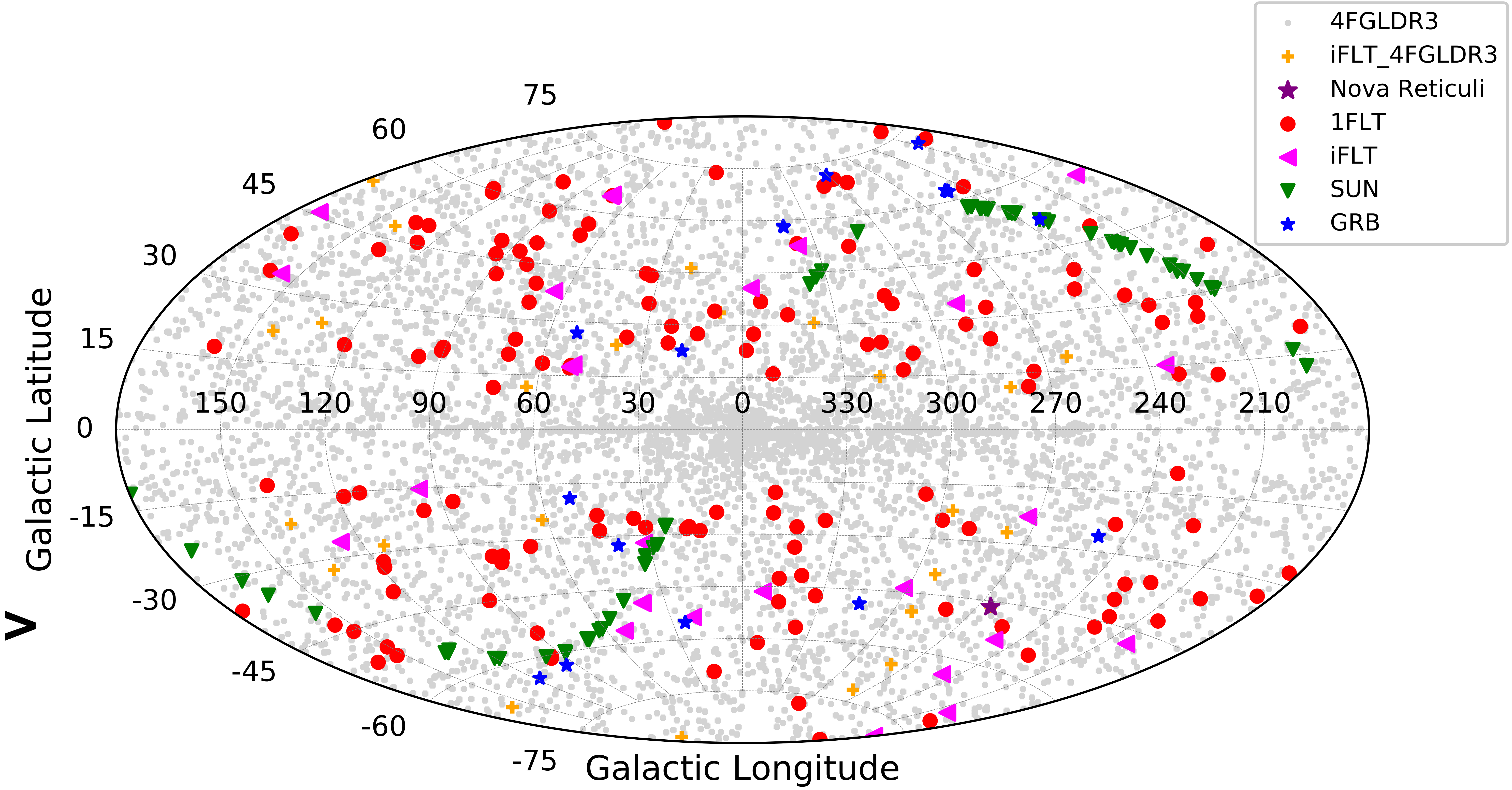
The ROI model included all PGWave seed detections of the TBIN located in a ROI of 10° centered at the 1FLT catalog position of the source of interest. When the target was detected with TS < 4, or the number of its predicted photons was Npred < 3, or the uncertainty on its flux estimate was large (dFlux/Flux > 0.5), upper limits were calculated.

The two light blue lines highlight TBIN 115 which corresponds to a gap in the Fermi-LAT data during the “safe hold” mode in March 2018 when the instrument was powered off.

Incremental FLT (iFLT)

Integration time:
2018-08-05 — 2020-08-04 (nominal)
2018-08-20 — 2020-08-19 (shifted)

- 48 months:
  TBIN 120 to 143 (nominal)
  TBIN 120.5 to 143.5 (shifted)
- 108 gamma-ray detections in monthly time bins (9 detections of the Sun)
- 55 new sources with respect to 4FGL-DR2
- 25 common sources with 4FGL-DR3 **—> 30 new gamma-ray emitters over 2 years**
  —> 15 per year, compatible with 1FLT, 142 over 10 years

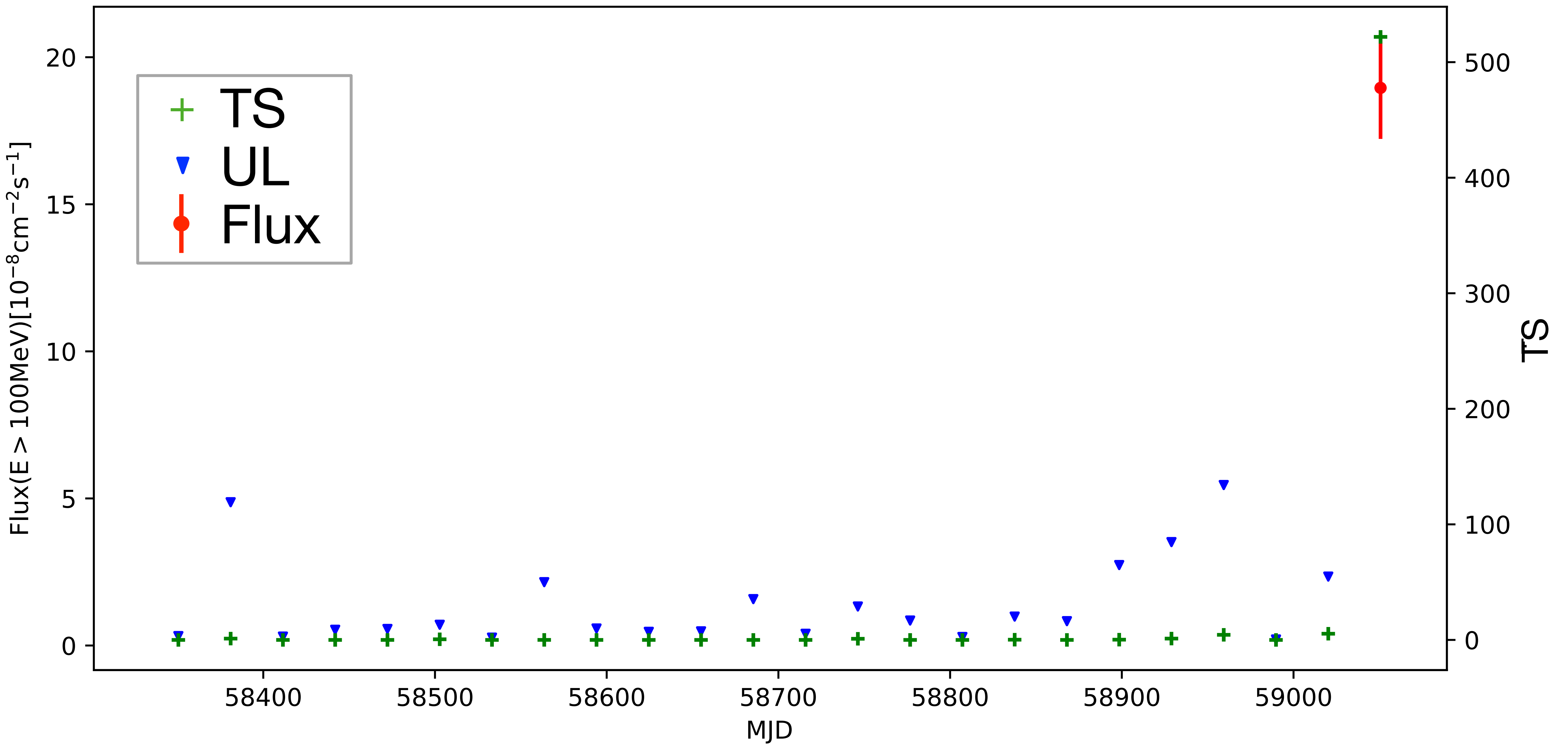


Incremental FLT (iFLT)

Nova Reticuli [ATel #13868]

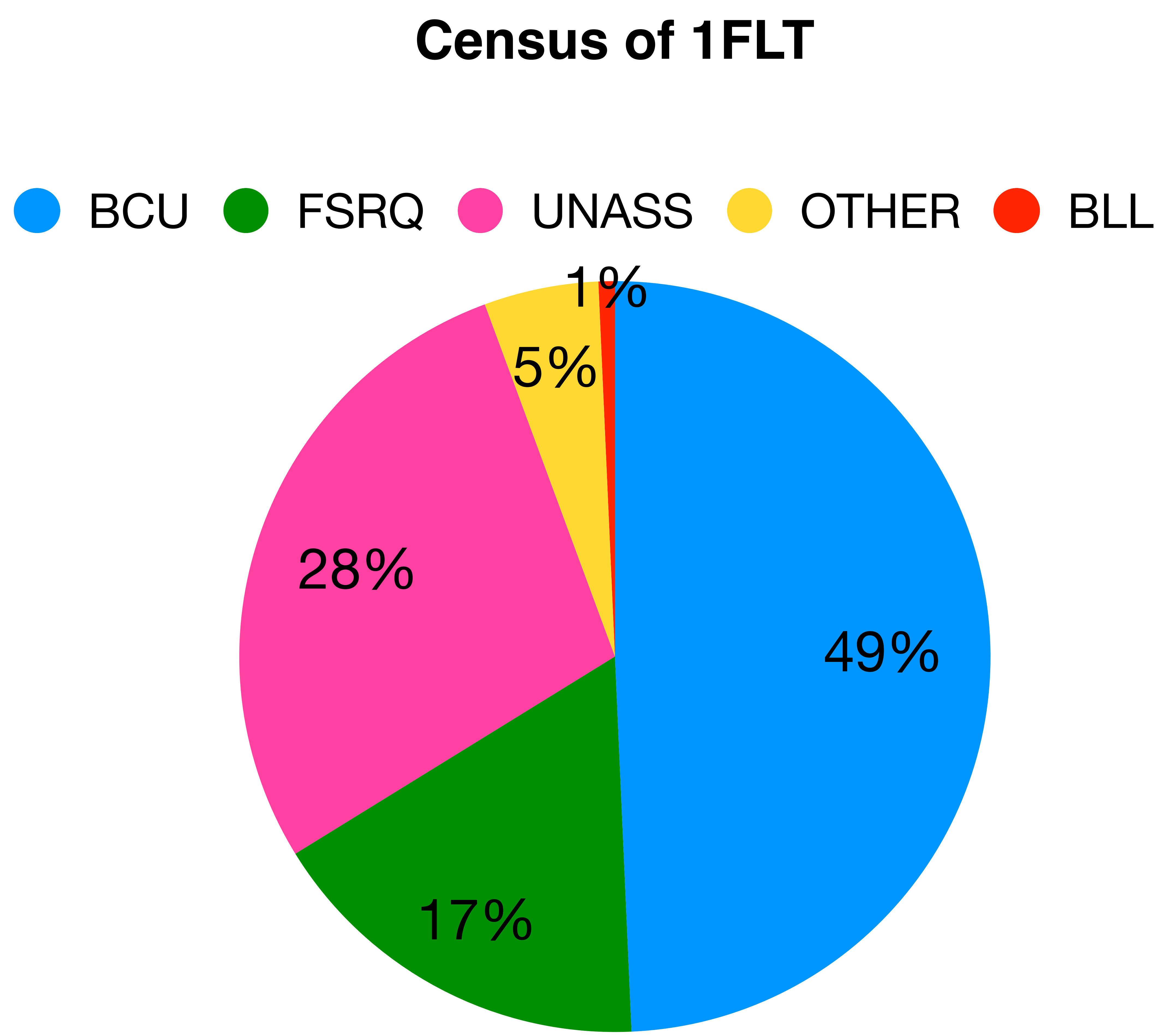
2 detections: TBIN 143 (TS=507) and 143.5 (TS=30)

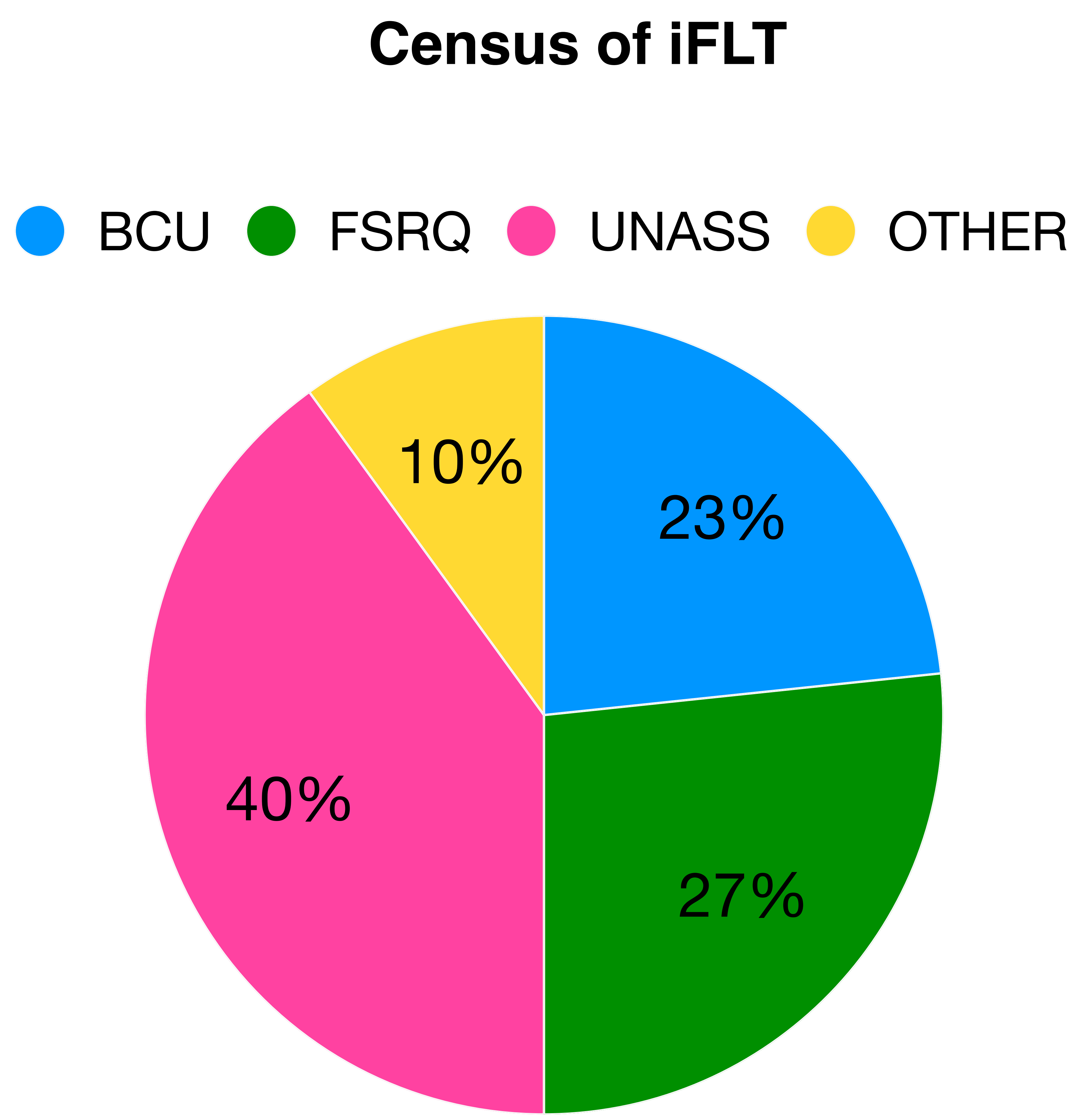
This iFLT target is positionally consistent with 4FGL J0358.5-5432—PMN J0358-5434 (bcu)—> Different time binning permits to distinguish different emitters



The ROI model included all PGWave seed detections of the TBIN located in a ROI of 10° centered at the iFLT position of the source of interest. When the target was detected with TS < 4, or the number of its predicted photons was Npred < 3, or the uncertainty on its flux estimate was large (dFlux/Flux > 0.5), upper limits were calculated

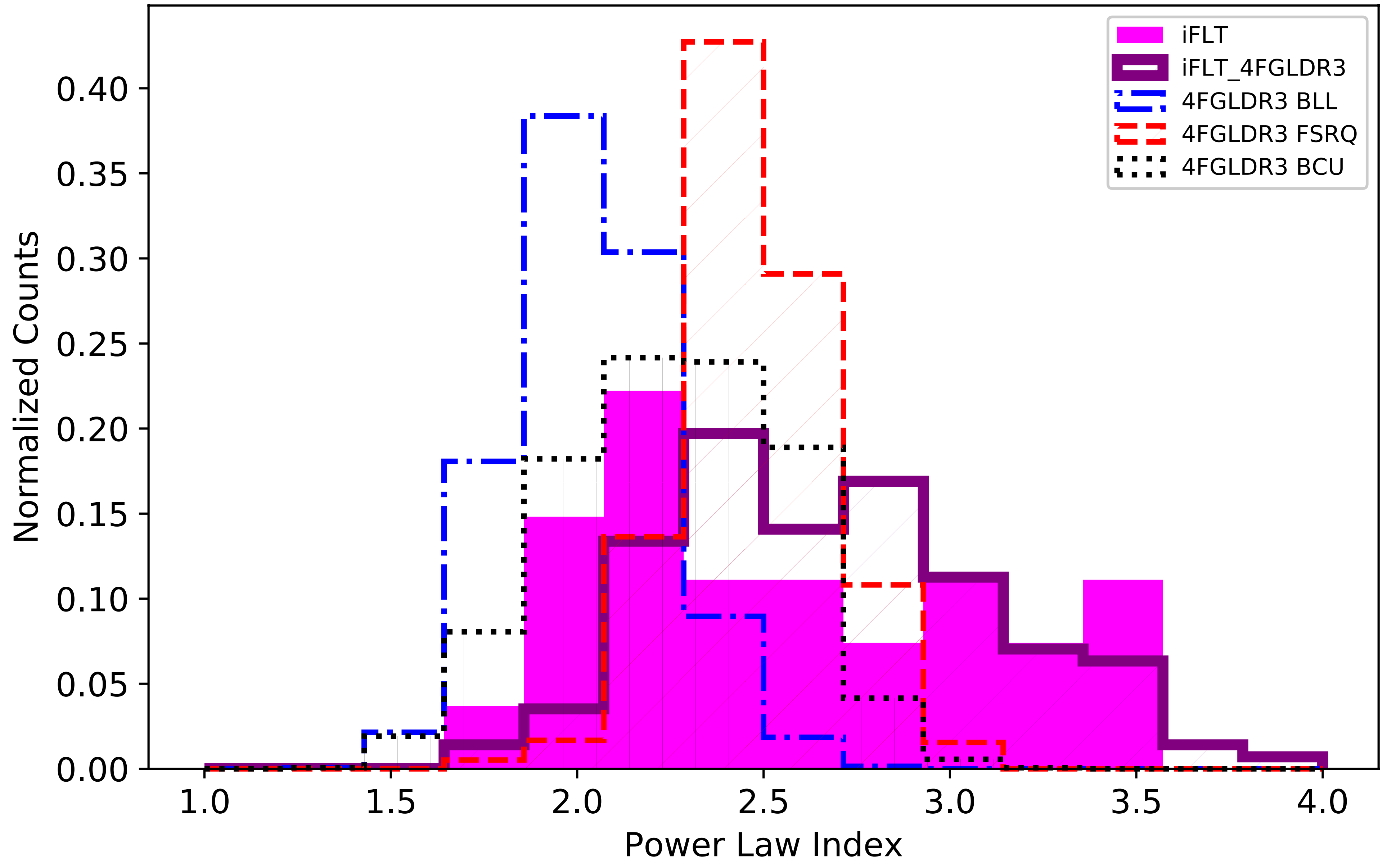
Incremental FLT (iFLT)



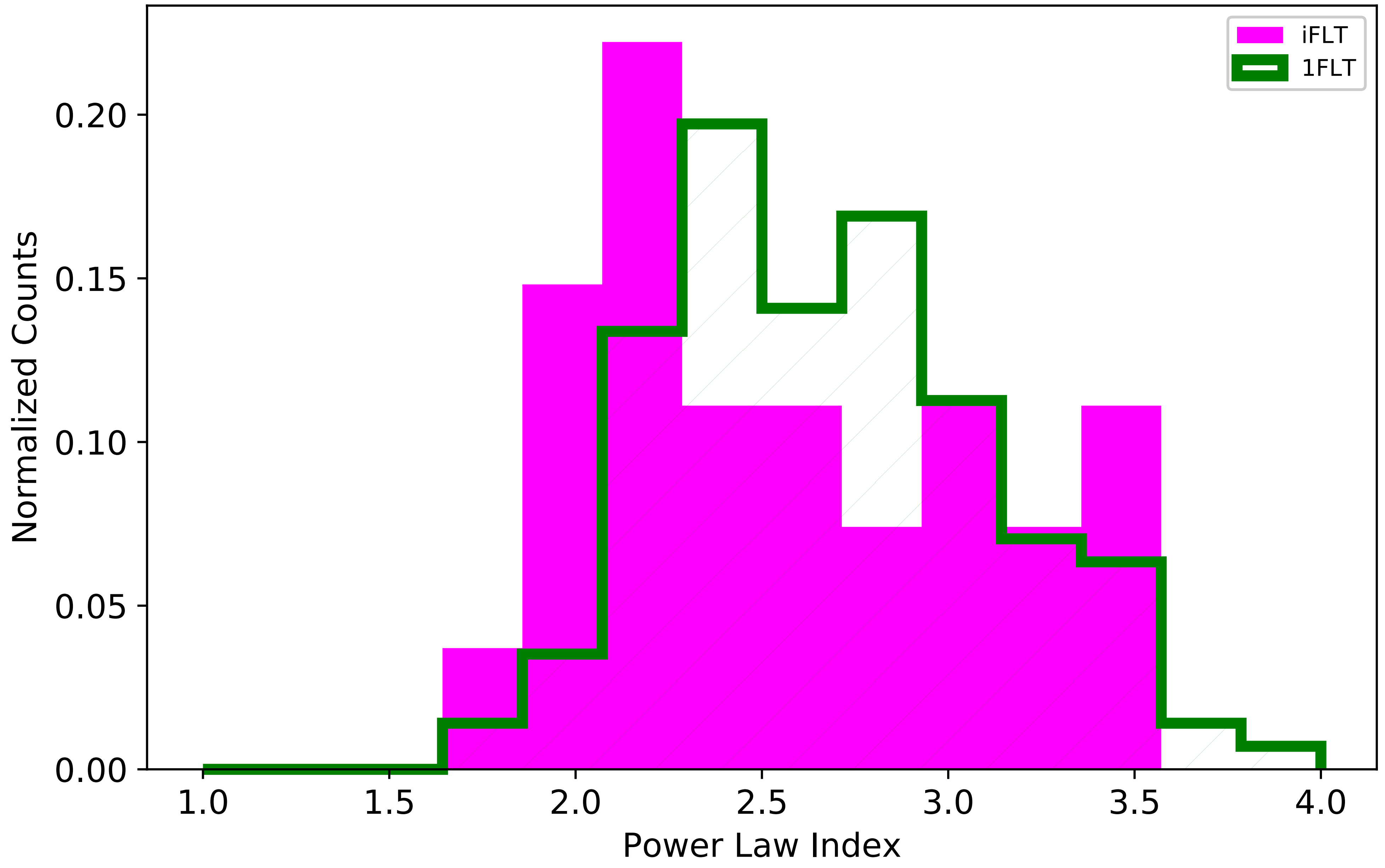


Incremental FLT (iFLT)

iFLT sources power law index softer than 4FGL-DR3 sources



iFLT sources power law index shows a similar distribution range as 1FLT.
The median value for the iFLT sources is 2.7, as for the 1FLT sources.



Summary

- **The 1FLT catalog and the iFLT list are mainly populated by softer sources if compared to the FGL catalogs.** This confirms that these soft sources are not distinguishable from the diffuse gamma-ray background when considered over multi-year integration times.

- **This study found that the fraction of FSRQs is larger when using a monthly binning** compared to catalogs using data averaged over longer intervals. This is due both to BL Lacs that are in general less variable around 1 GeV and to FSRQs whose strong gamma-ray activity is mainly seen only during flaring events. If the flare intensity is fainter than the integrated background over years, we lose the capability to detect these FSRQs in long-time integrated catalogs.

- **In the 1FLT (and in the iFLT) we detected sources only when they were in an active flaring phase.** For this reason they show a high gamma-ray luminosity with respect to the 4LAC sources whose fluxes were calculated over a longer integration time.

Conclusion

- 1FLT paper —>
  Catalog of Long-Term Transient Sources in the First 10 Years of Fermi-LAT Data
  Accepted by ApJS on 24 May 2021
  https://arxiv.org/abs/2106.00100

- The 1FLT catalog is available online for an easy and fast visualization at
  www.ssdc.asi.it/fermi1flt

- The incremental source list iFLT will be updated yearly at link
  www.ssdc.asi.it/fermi_iflt