$E_{p,i}$ - E_{iso} correlation and the new criterion for the blind GRB classification

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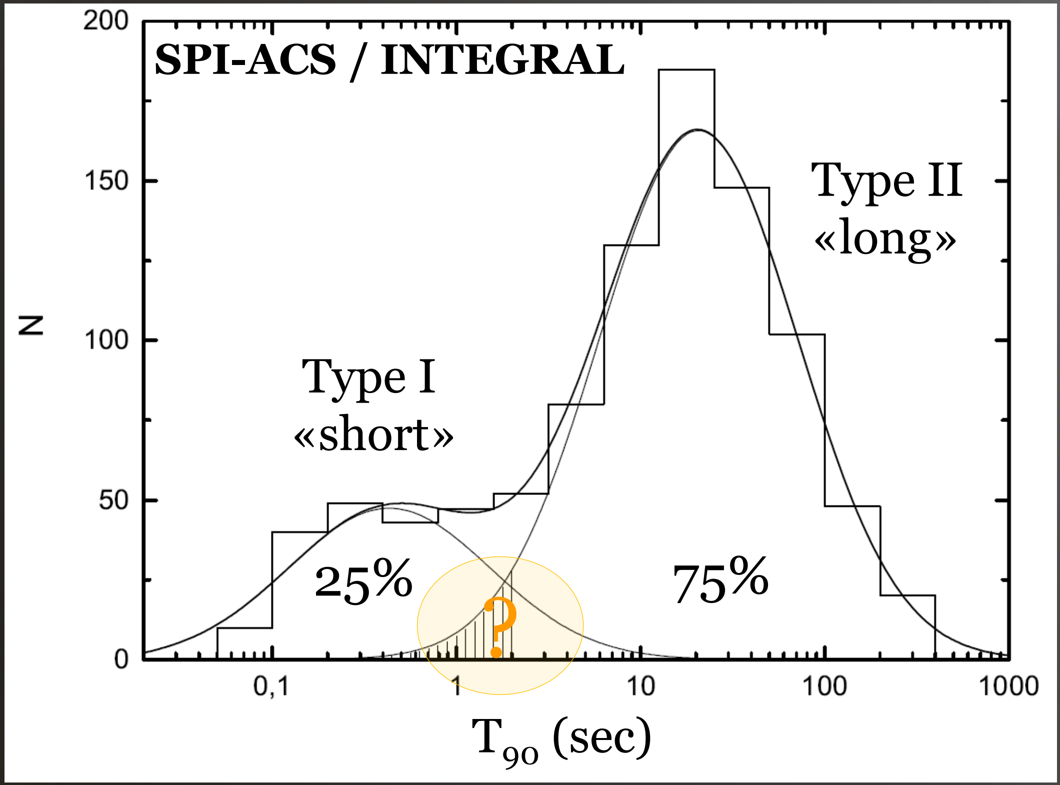
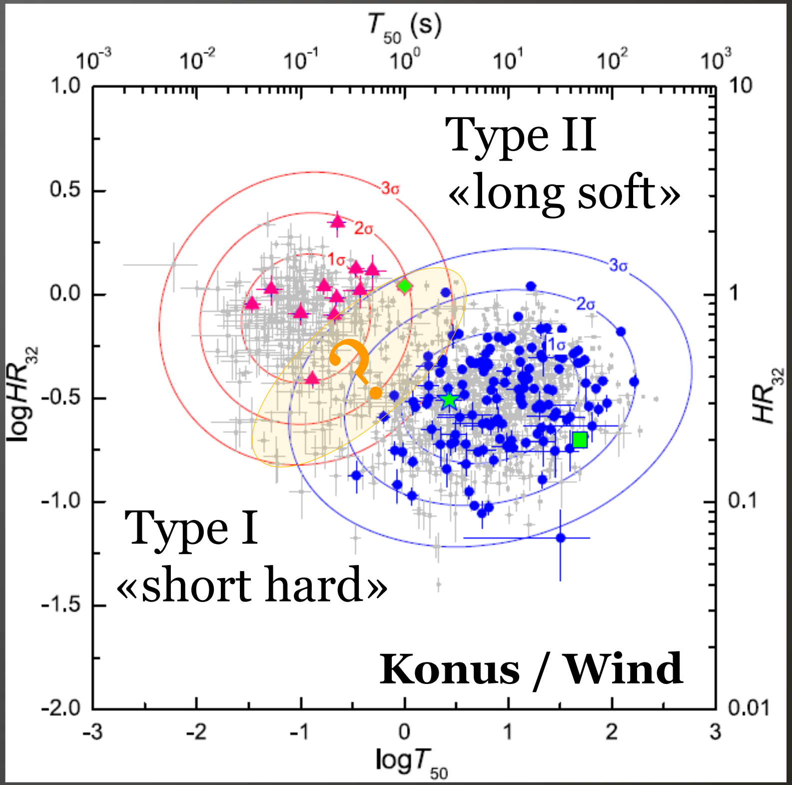
GRB classification

- Type I (short hard) – a merger of compact components in a binary system (NS + NS or NS + BH) + kilonova

- Type II (long soft) – a core collapse of a supermassive star + supernova Ib/c



Minaev+ 2017



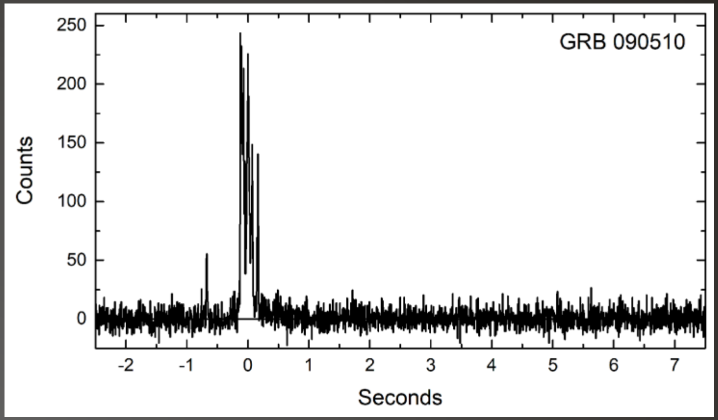
Tsvetkova+ 2017

The sample – type I GRBs

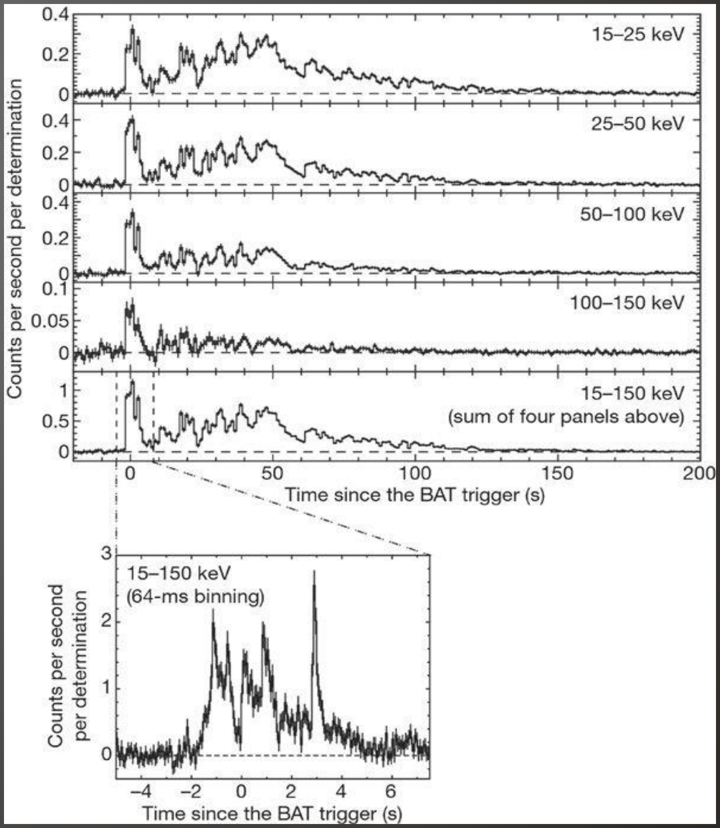
- **37 type I bursts, N(z_{ph}) = 3**

- **26** «regular» bursts

- **11** bursts with an extended emission

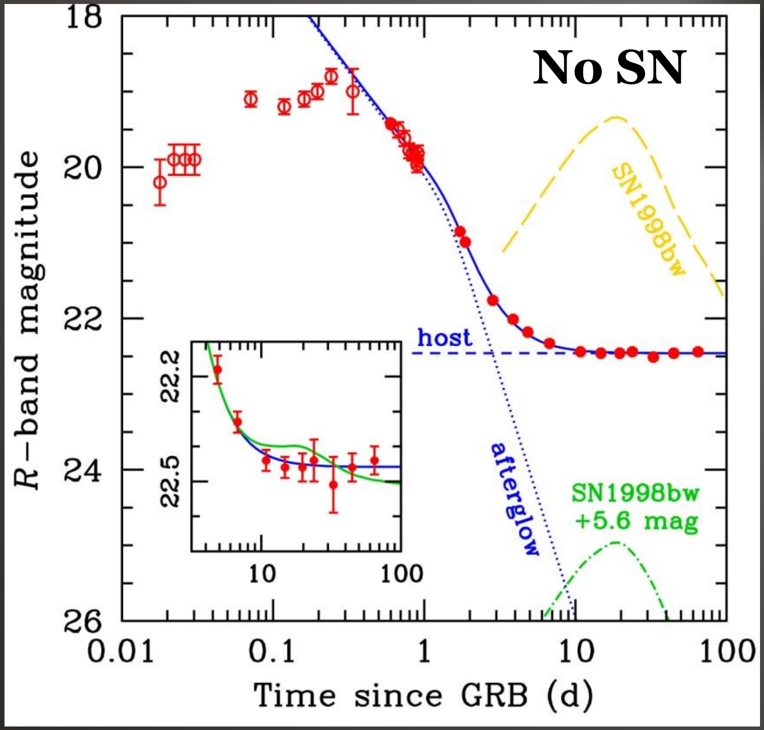


GRB 060614



Gehrels+ 2006

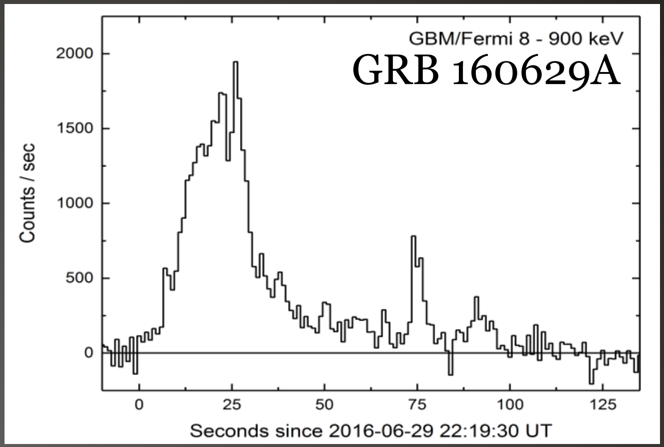
GRB 060614



The sample – type II GRBs

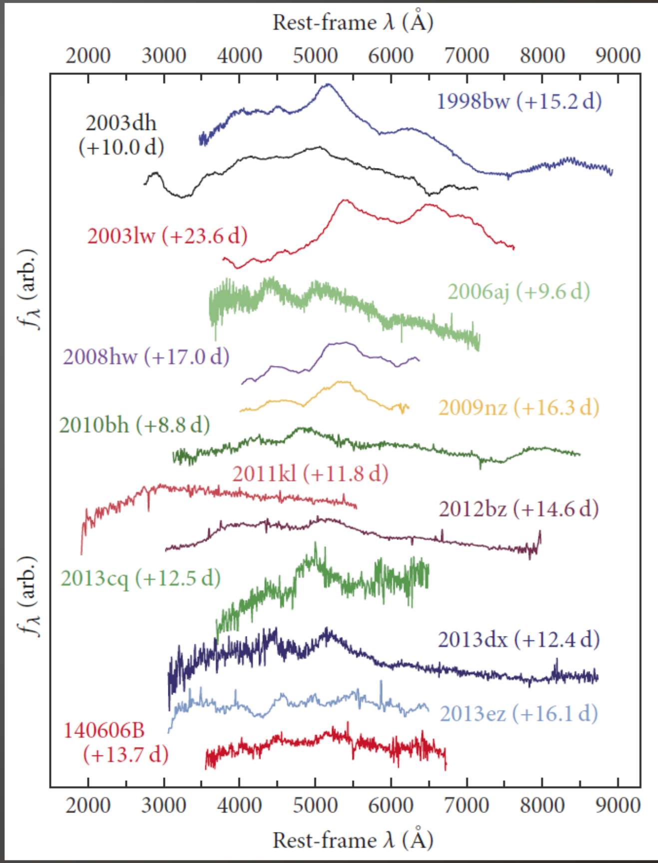
- **275 type II bursts, N(z_{ph}) = 13**

- **235** «regular» bursts

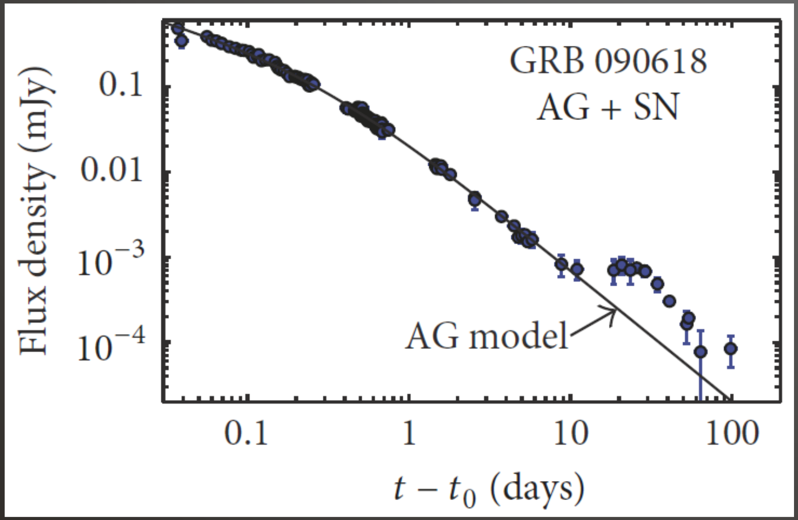


- **40** bursts associated with Ib/c supernovae

  - **21** spectroscopic associations

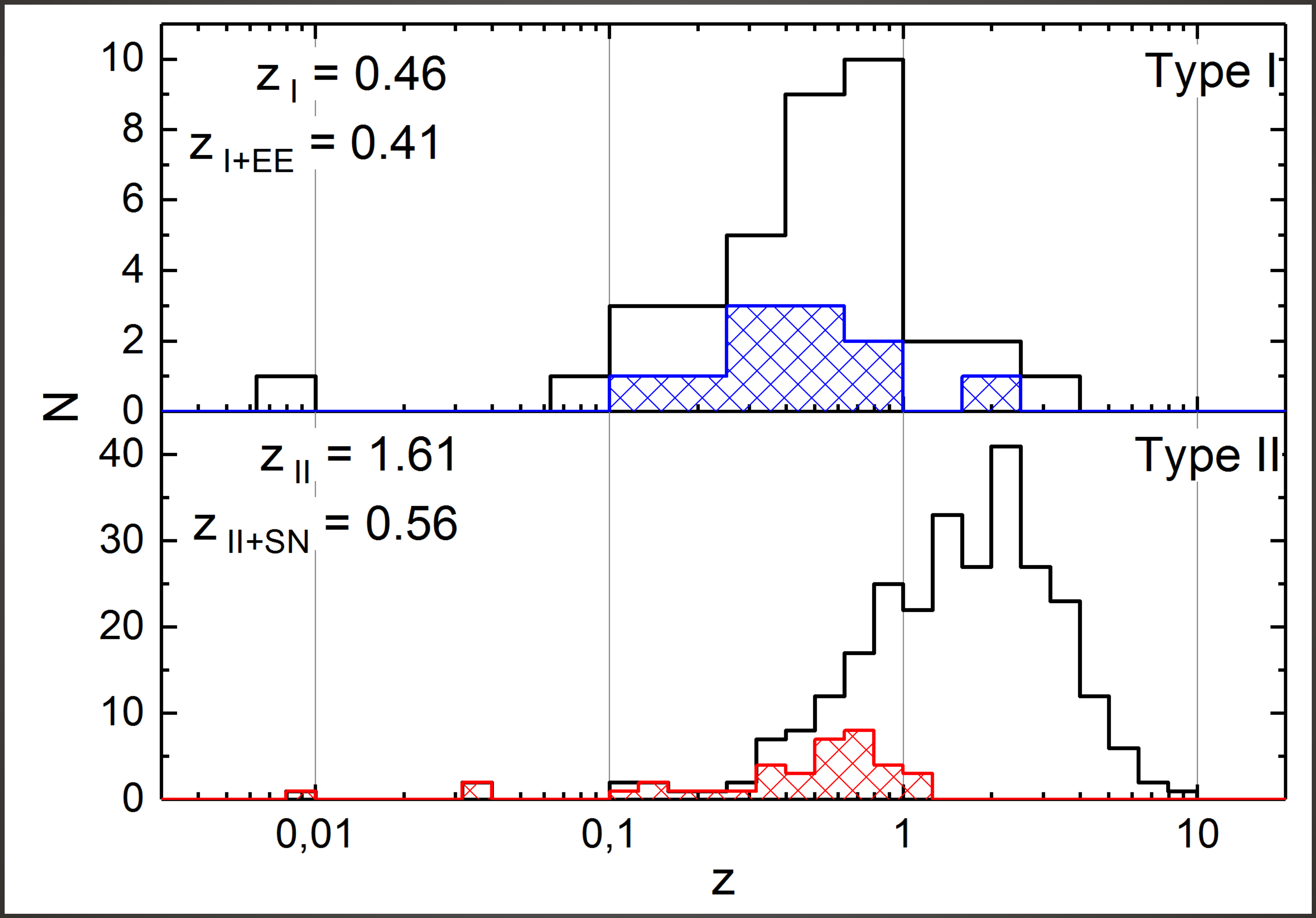


  - **19** photometric associations



Cano+ 2017

The sample statistics



$T_{90,i}$, $E_{p,i}$ and E_{iso} parameters

- $T_{90,i}$ (s) – the duration in the rest frame

$T_{90,i} = T_{90}/(1+z)$

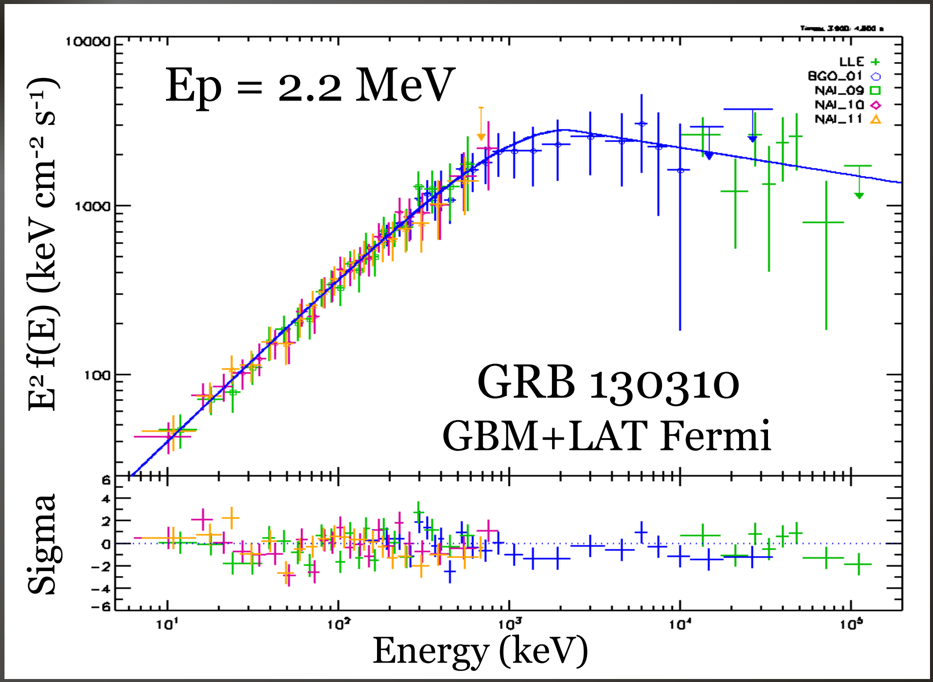
$$f(E) \propto E^{\alpha} \exp\left(-\frac{E(2+\alpha)}{E_p}\right)$$

- $E_{p,i}$ (keV) – the position of the maximum (for $\beta < -2$) in the $E^2 f(E)$ spectrum in the rest frame $E_{p,i} = E_p(1+z)$

$$f(E) \propto \begin{cases} E^{\alpha} \exp\left(-\frac{E(2+\alpha)}{E_p}\right), & E < (\alpha-\beta)\frac{E_p}{2+\alpha} \\ E^{\beta}\left[(\alpha-\beta)\frac{E_p}{(2+\alpha)}\right]^{(\alpha-\beta)} \exp(\beta-\alpha), & E \geqslant (\alpha-\beta)\frac{E_p}{2+\alpha}, \end{cases}$$

- E_{iso} (erg) – the equivalent isotropic energy, emitted in 1 – 10000 keV range

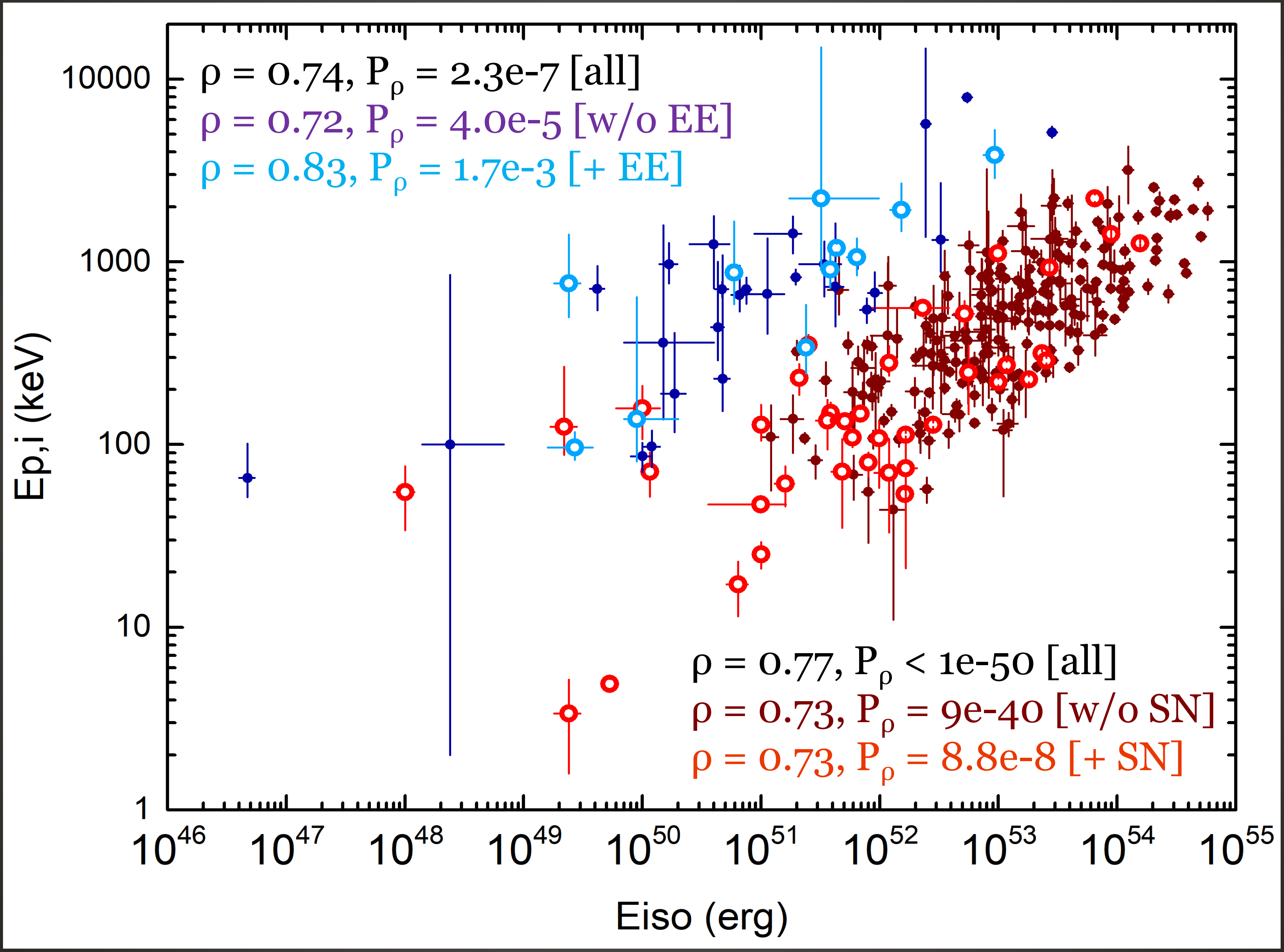
$$E_{\rm iso} = \frac{4\pi D_L^2}{1+z} \times F$$



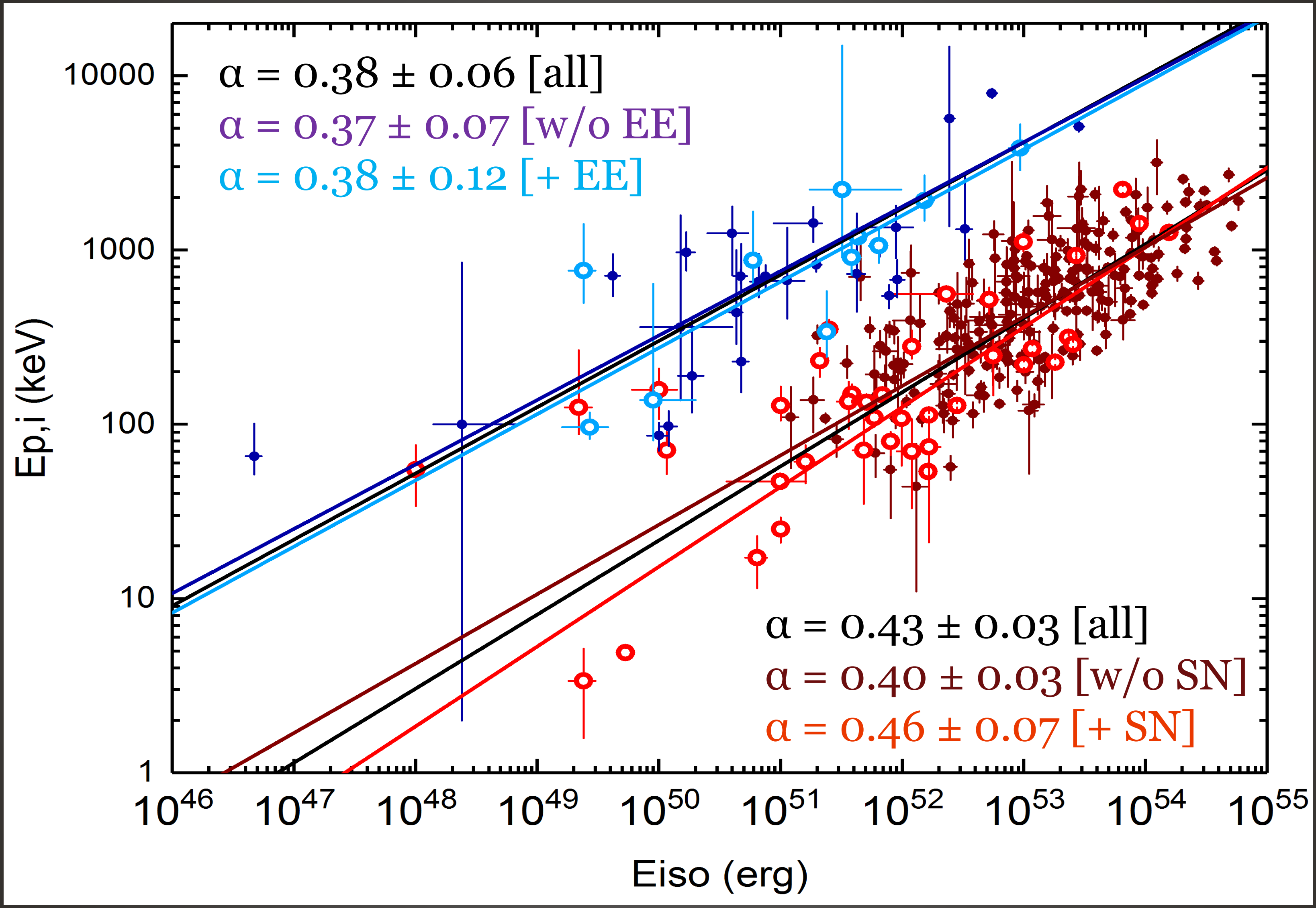
Minaev+ 2017

For I+EE bursts, IPC is considered only

The $E_{p,i} - E_{iso}$ correlation

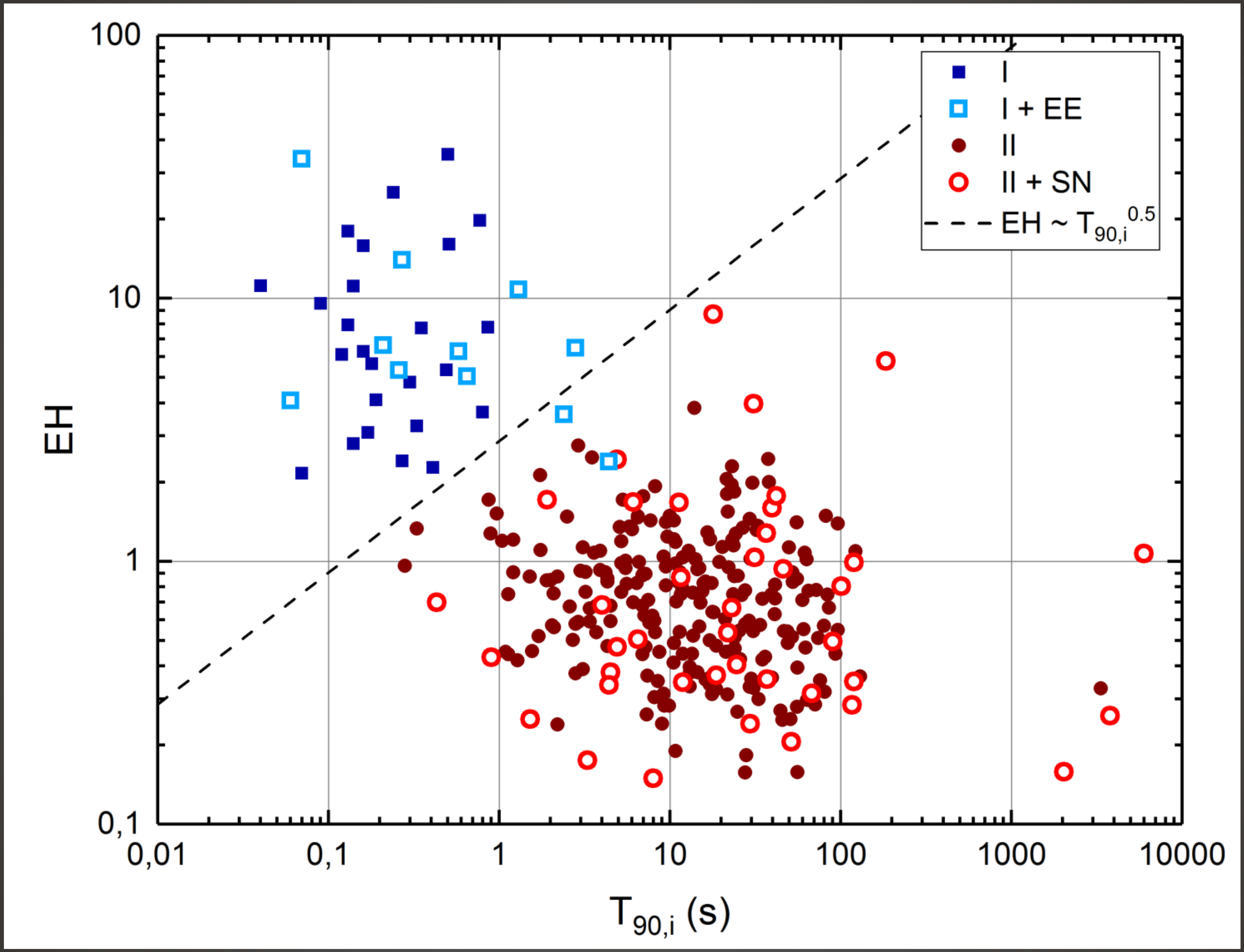


The $E_{p,i} - E_{iso}$ correlation fits, EH parameter



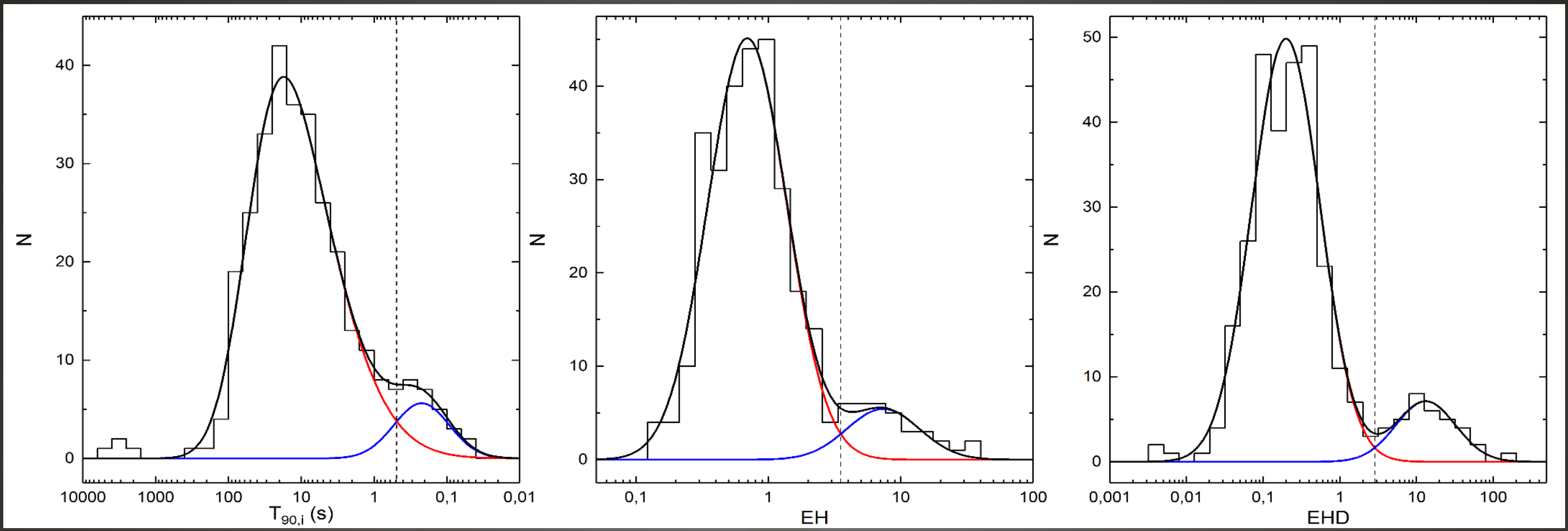
$$EH = \frac{(E_{\mathrm{p,i}}/100\ \mathrm{keV})}{(E_{\mathrm{iso}}/10^{51}\ \mathrm{erg})^{0.4}}$$

EH – $T_{90,i}$ diagram, EHD parameter



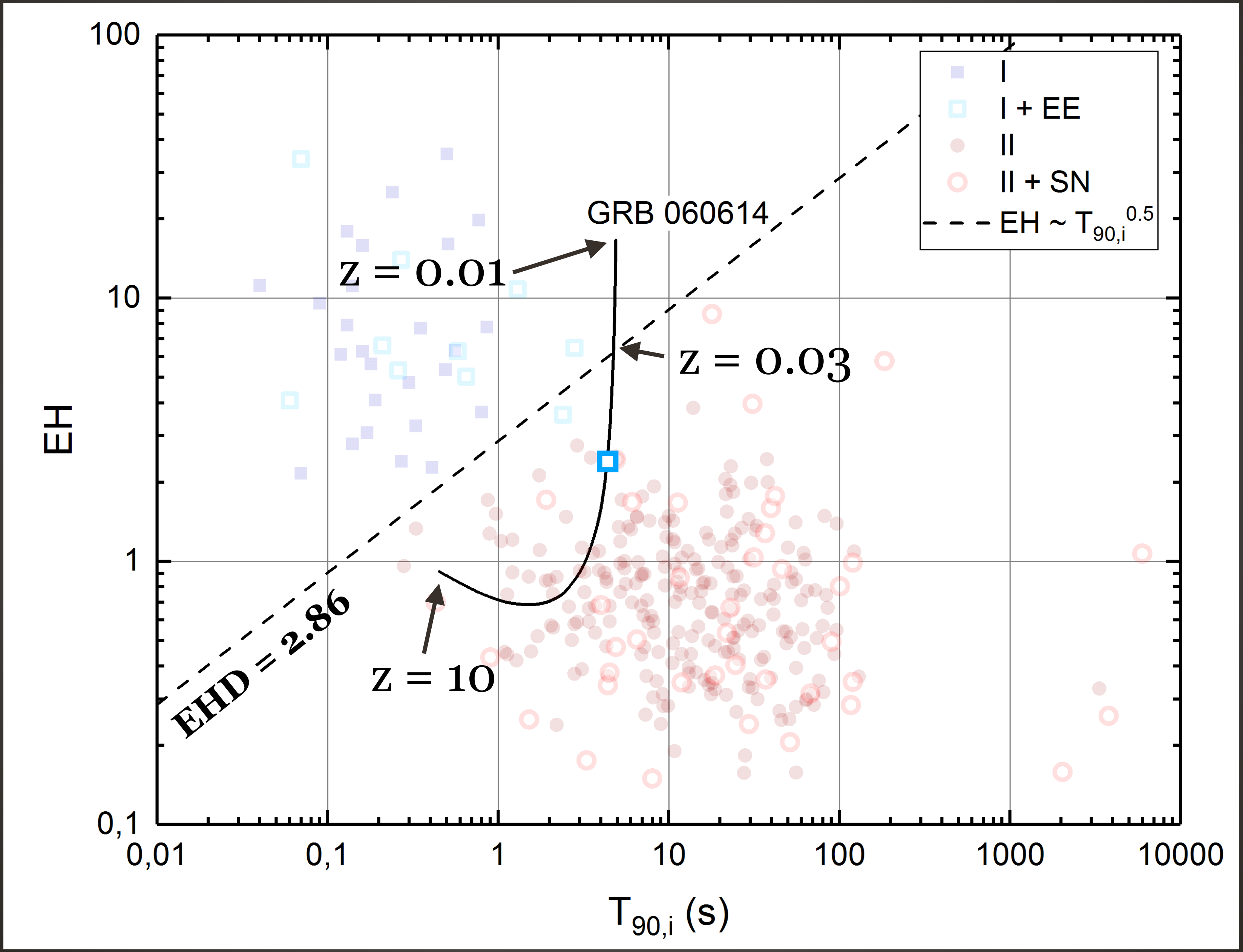
$$EHD = \frac{(E_{\mathrm{p,i}}/100\ \mathrm{keV})}{(E_{\mathrm{iso}}/10^{51}\ \mathrm{erg})^{0.4} \times (T_{90,\mathrm{i}}/1\mathrm{s})^{0.5}}$$

Classification schemes and their reliability

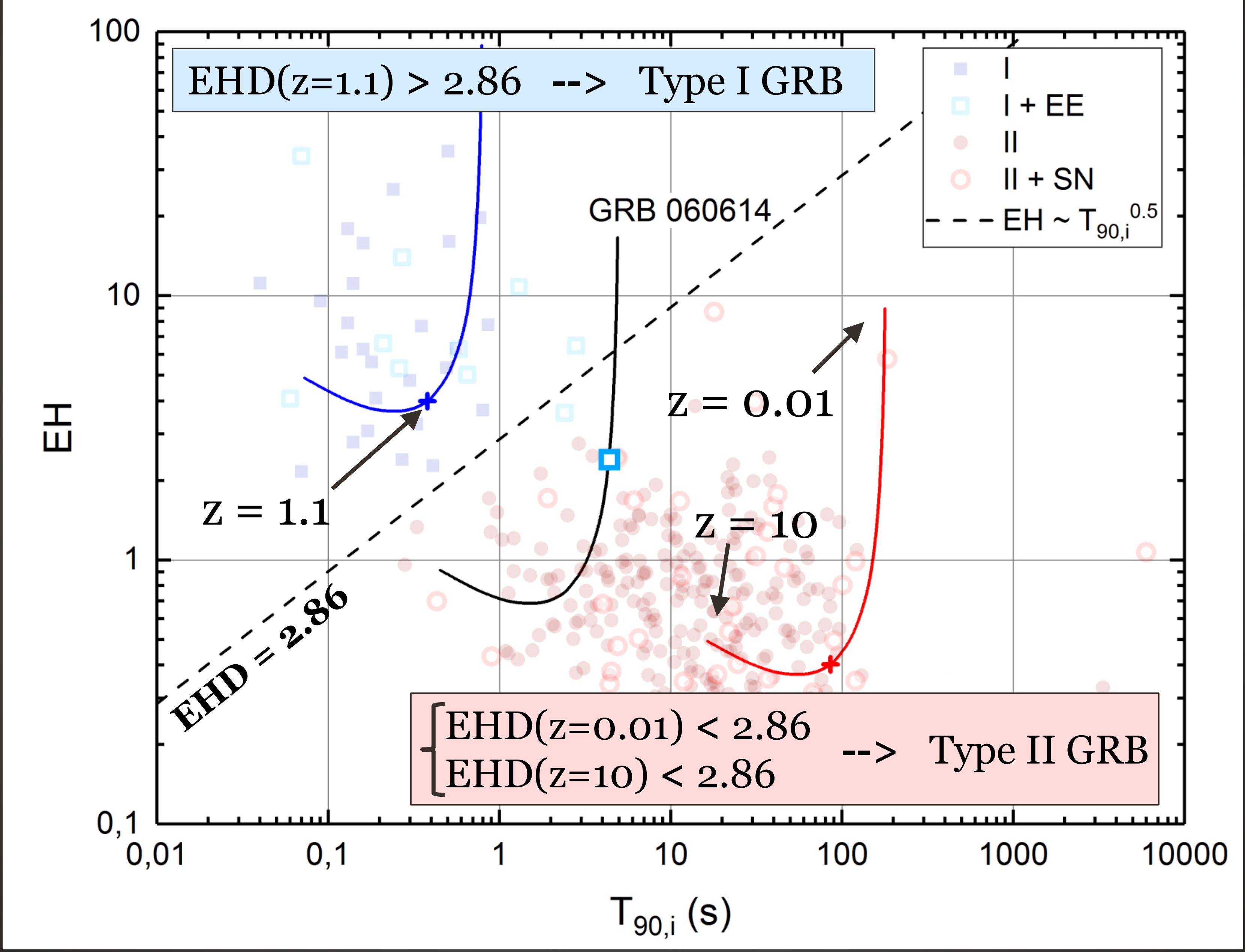


	$T_{90,i}$	EH	EHD
Separation point	0.5 s	3.52	2.86
Type I GRBs beyond the separation	22.2%	12.1%	4.4%
Type II GRBs beyond the separation	1.7%	0.9%	0.5%
Type I GRBs false blind classification	11	7	2
Type II GRBs false blind classification	3	4	0

EH – $T_{90,i}$ diagram, outliers and dependence on z



EH – $T_{90,i}$ diagram, classification without z



Conclusions

- We confirm the strong $E_{p,i}$ - E_{iso} correlation for 37 type I and 275 type II bursts
- The power-law index of the $E_{p,i}$ - E_{iso} correlation is found to be the same for both types of bursts, $E_{p,i} \sim E_{iso}^{\,0.4}$
- Type I bursts with an extended emission and regular type I bursts follow the same correlation. The same behavior is obtained for type II bursts with associated Ib/c supernovae and regular type II bursts
- The $E_{p,i}$ - E_{iso} correlation can be used to classify GRBs. We introduce parameters EH and EHD and show EHD parameter to be the most reliable for the blind classification
- EHD parameter can be used to classify GRBs without redshift

THANK YOU FOR YOUR ATTENTION!

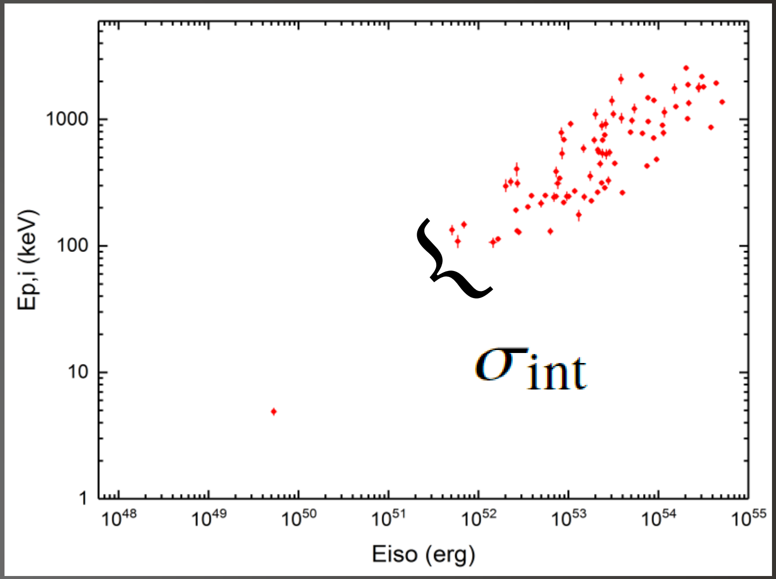
Fitting the correlation

- **«Nukers»** fit (Tremaine+ 2002)

$$\chi^2 = \sum_{i=1}^{N} \frac{(y_i - a x_i - b)^2}{a^2\sigma_{xi}^2 + \sigma_{yi}^2 + \sigma_{\rm int}^2}$$

gives the same results as fitting without errors (equalizes weights).

Fit changes dramatically with x -> y, y -> x

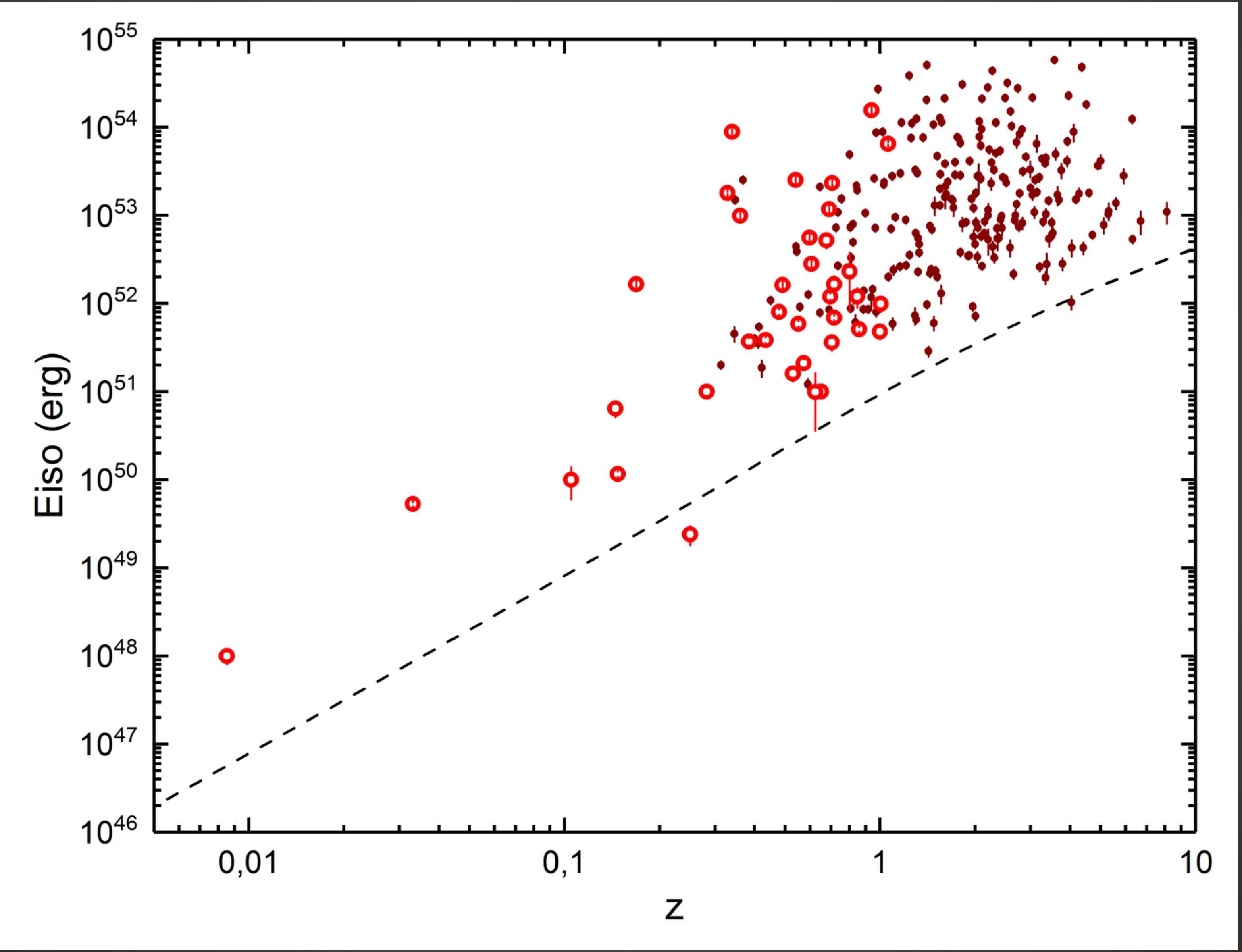


- **York** fit (York+ 2004) – least-squares estimation, no changes with replacing x -> y, y -> x, gives slightly steep slopes

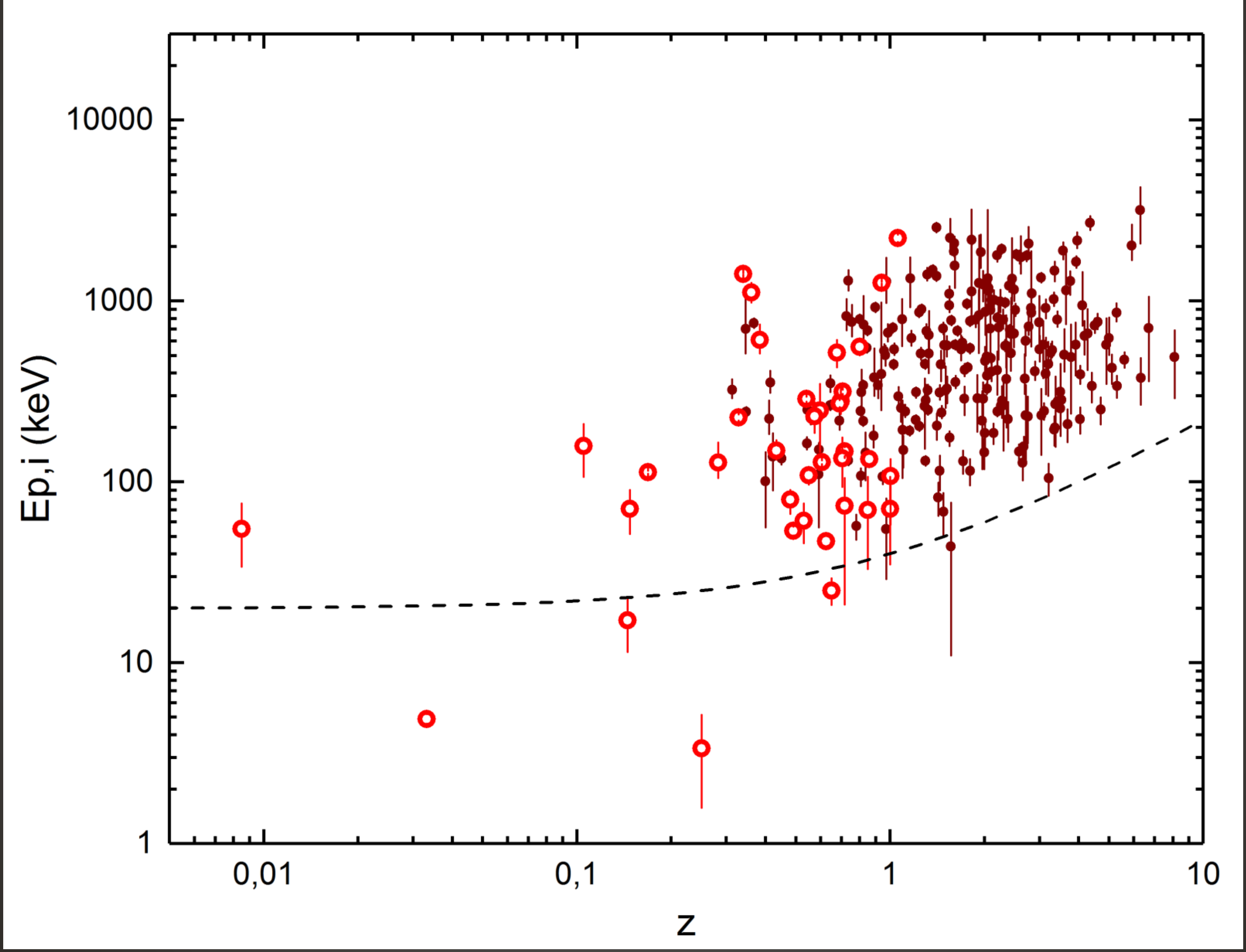
- **Deming** fit (Deming 1943) – maximum likelihood estimation, no changes with replacing x -> y, y -> x, gives slightly gentle slopes

$$a = \text{mean}\,(a_Y, a_D),\ \ \sigma_a = \text{sqrt}\,(\sigma_{aY}^2 + \sigma_{aD}^2)$$
$$b = \text{mean}\,(b_Y, b_D),\ \ \sigma_b = \text{sqrt}\,(\sigma_{bY}^2 + \sigma_{bD}^2)$$

The evolution of E_{iso} with z for type II, selection effects



The evolution of $E_{p,i}$ with z for type II, selection effects



The sample statistics