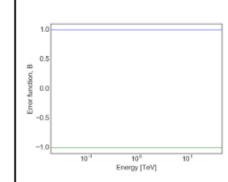
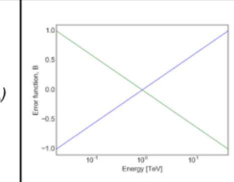
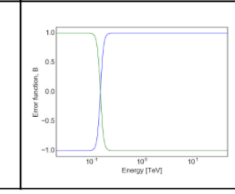
Bracketing IRF

IRF table:

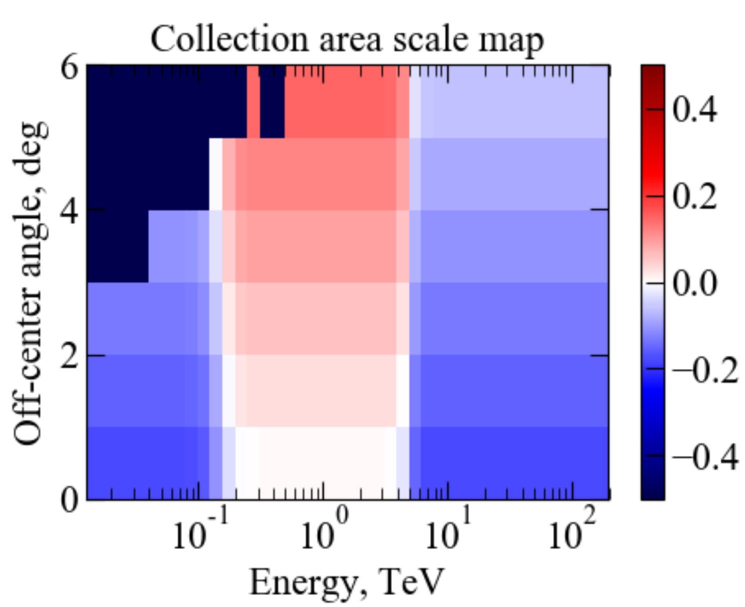
a) The effective area of the array: Aeff
b) The background rate: N
c) The point spread function (PSF)
d) The energy migration matrix

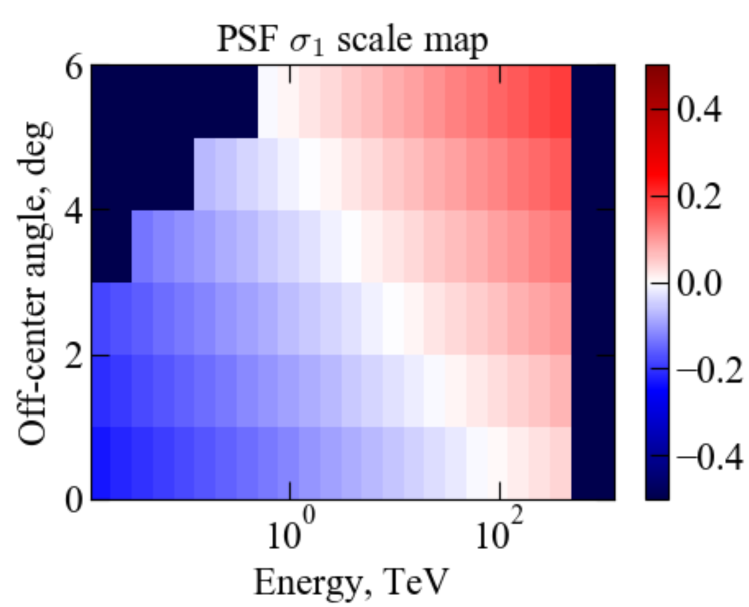
Table 3a: Energy-dependent error functions for CTA North

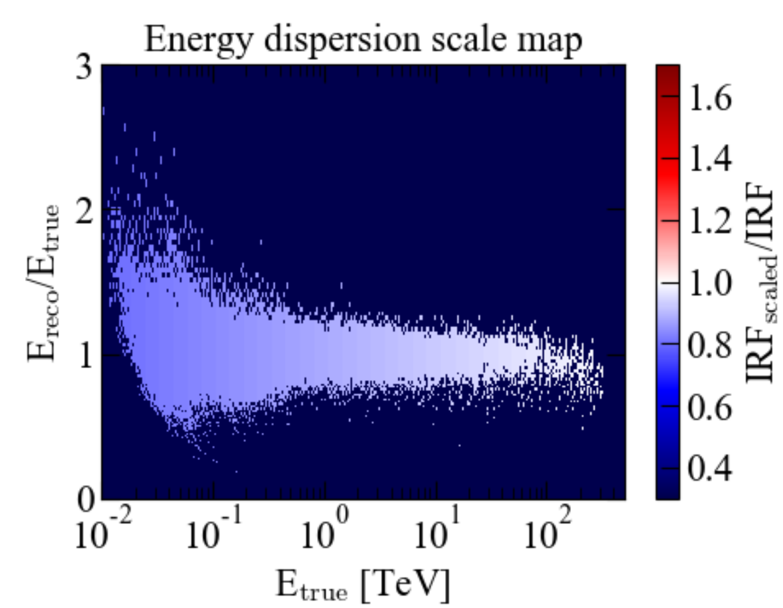
Modification type	Function, B	Graphics	Applicability
Constant	1		. A_{eff}, N: flux normalization . σ_θ: small extension . E_{scale}: spectral cut-off . σ_E: search for lines
Gradient	$[\ln(E/E_{min})+\ln(E/E_{max})]/\ln(E_{max}/E_{min})$		. A_{eff}, N: spectral index, spectral cut-off . E_{scale}: spectral curvature
Step	$\tanh[\ \ln(E/E_t)/(1.31\ \sigma(E_t)/E_t)\ ]$		. A_{eff}, N: spectral index, spectral cut-off . E_{scale}: spectral curvature

https://docs.google.com/document/d/1oBOwOOgMcL8Shww6oLjiQoQVbOwl0HGuBTV1YGHTc_k/edit

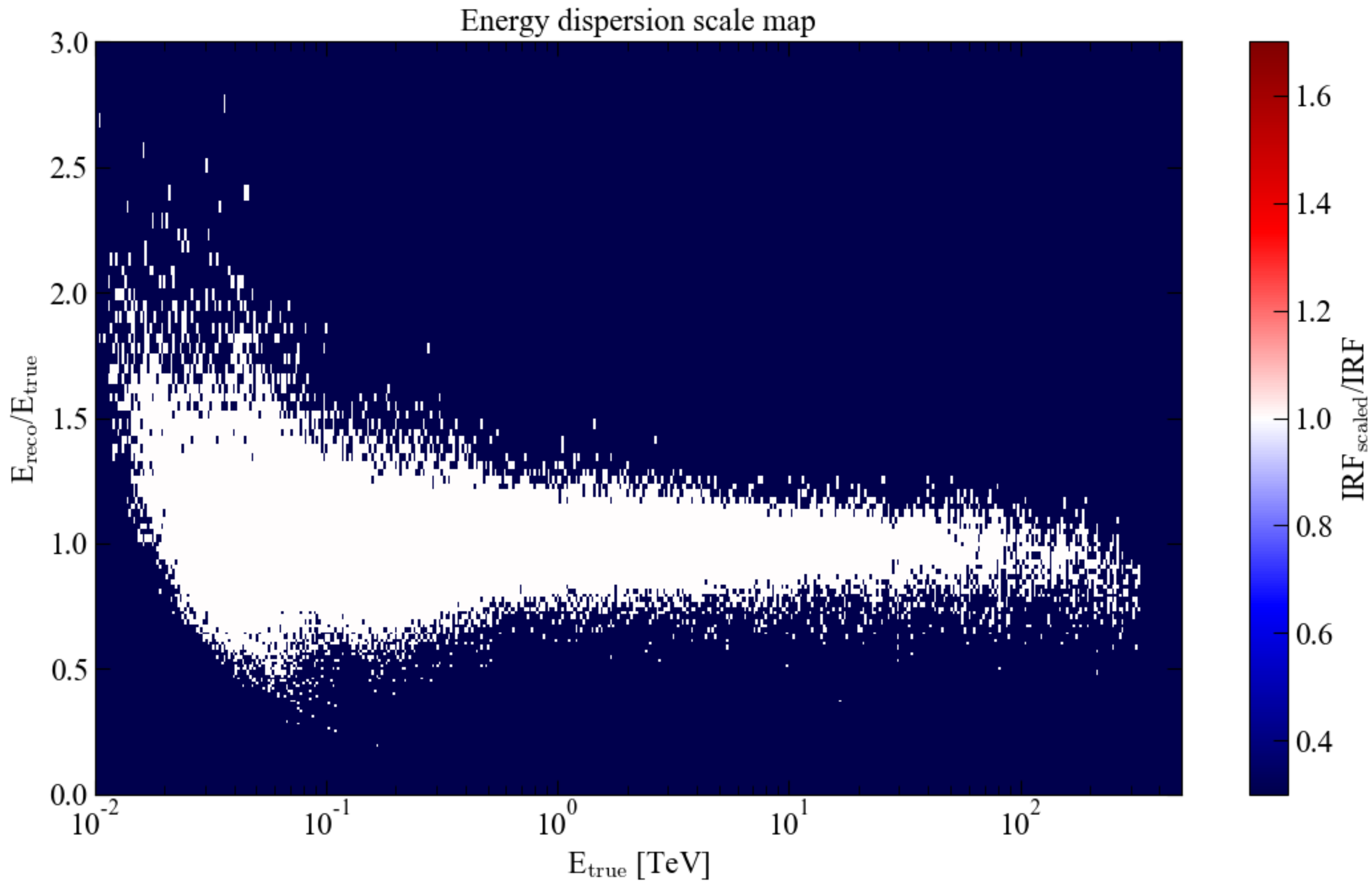
Bracketing IRFs can be modified in a straightforward manner using the script: https://github.com/cta-observatory/cta-irf-scaling







Bracketing IRF



Function	Constant	Gradient	Step
Scale (E)	1	0	0
Scale (θ)	1	0	0

http://www.cta-observatory.org/wp-content/uploads/2017/12/CTA-Performance-prod3b-v1-FITS1.tar.gz

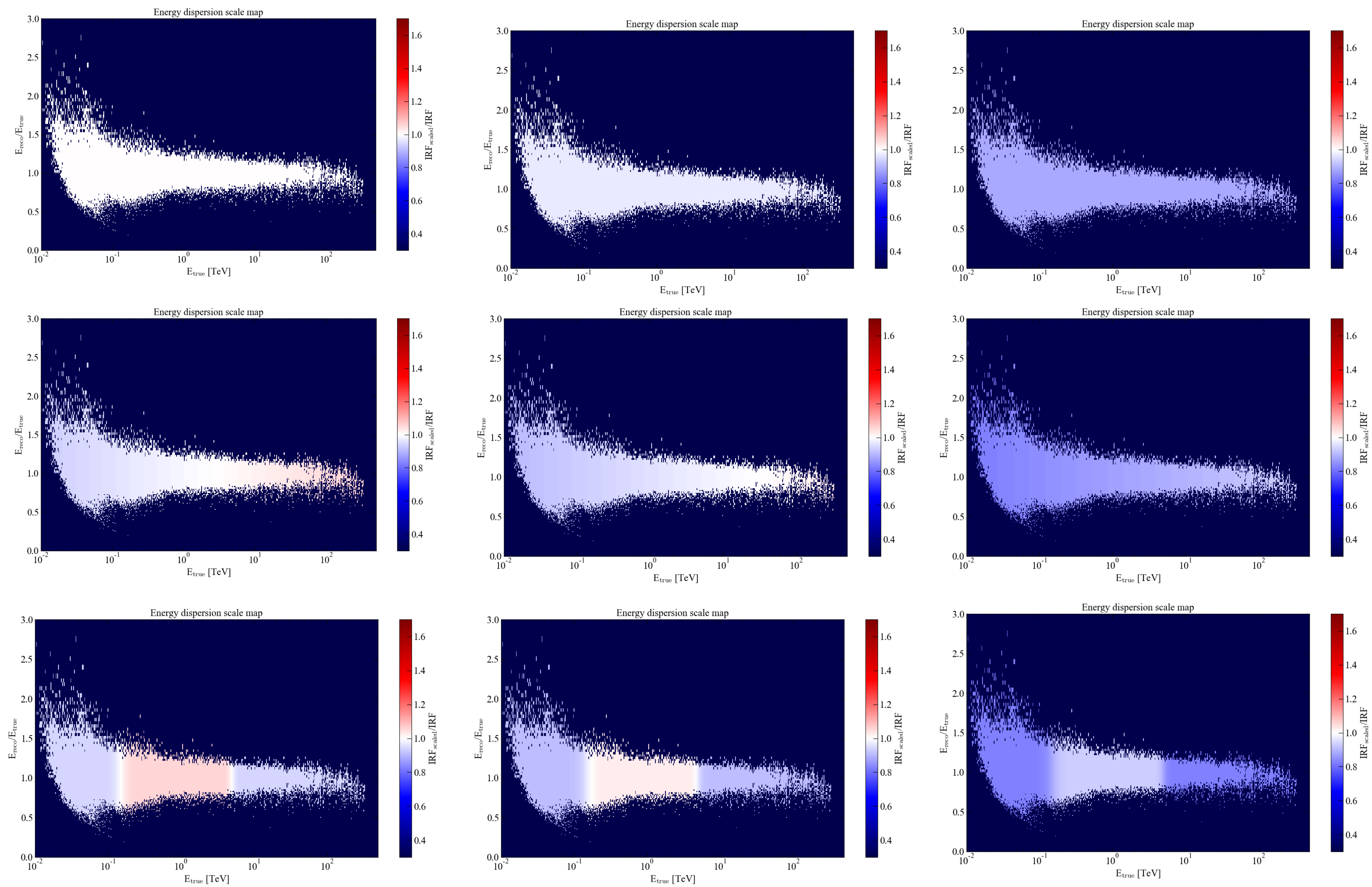
Bracketing IRF

E/θ | Constant | Gradient | Step

Constant

Gradient

Step



$$\mathrm{Scale}_E = 6\,\%$$

$$\mathrm{Scale}_\theta = 12\,\%$$

humbertomh@ifsc.usp.br

Bracketing IRF

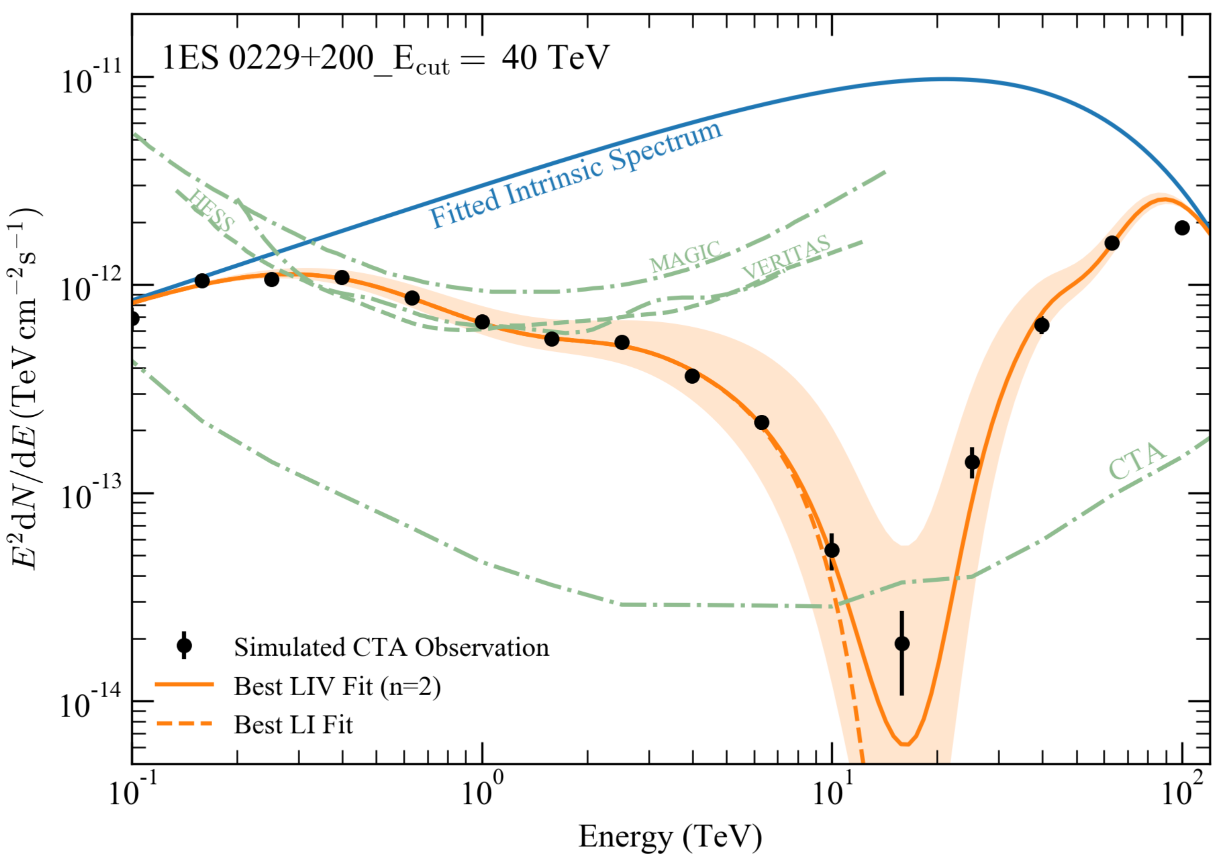
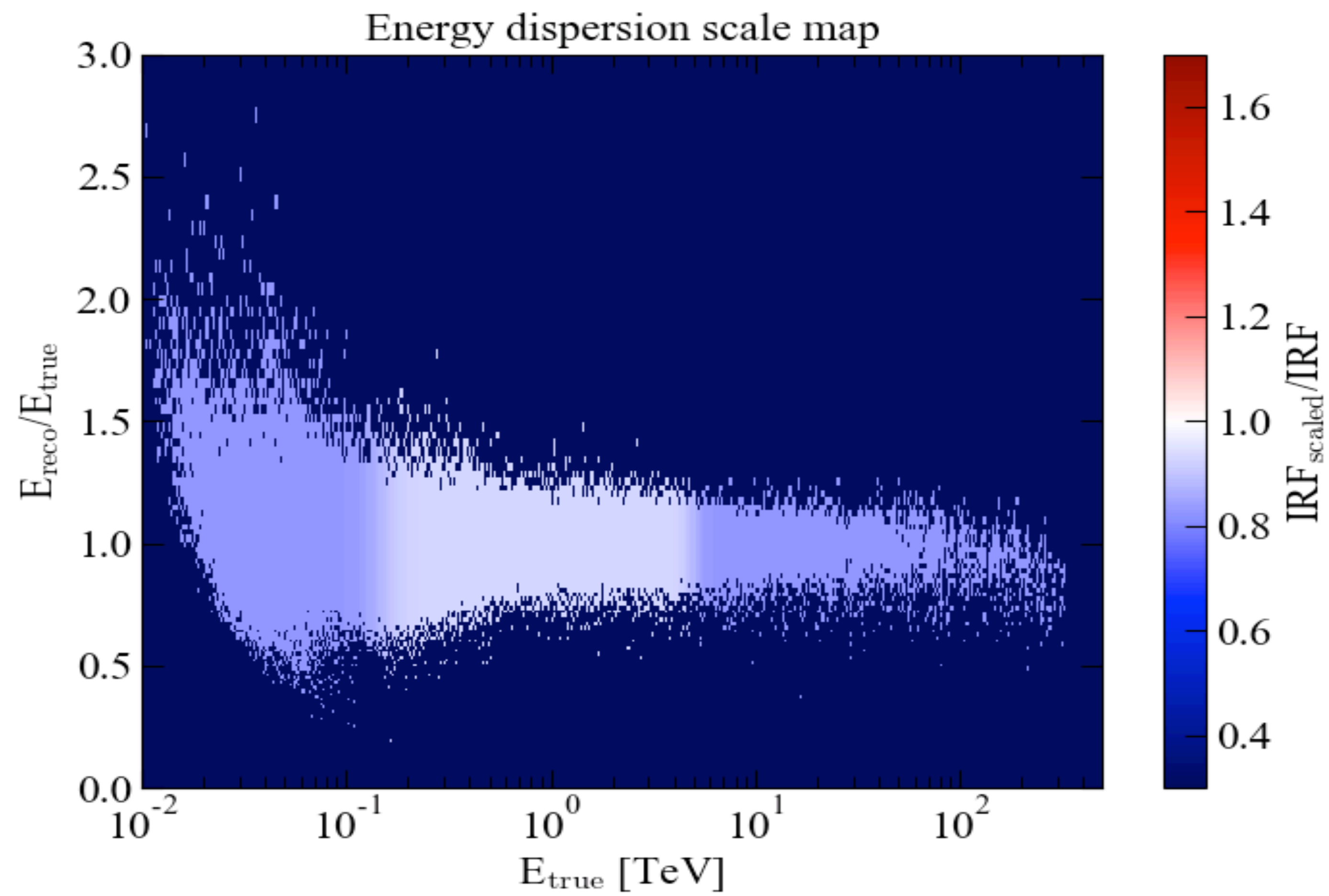


Fig 6. (a)
CTA sensitivity to the detection of a LIV signature.



Function	Constant	Gradient	Step
Scale (E)	0	0	0.06
Scale (θ)	0	0	0.12

Finding LIV signal

n=1

[eV]	Markarian 501 (Ec = 40 TeV)				Markarian 501 (Ec = 40 TeV)			
	Standard	EBL_upp	EBL_low	B_IRF	Standard	EBL_upp	EBL_low	B_IRF
E_{LIV}:	**9.49E+27**	9.01E+27	9.49E+27	**9.49E+27**	**8.55E+27**	9.01E+27	9.01E+27	**9.49E+27**
σ (CL)	**51.8**	51.3	54.5	**52.3**	**35.1**	34.7	36.2	**34.2**

[eV]	1ES 0229+200 (Ec =40 TeV)				1ES 0229+200 (Ec =20 TeV)			
	Standard	EBL_upp	EBL_low	B_IRF	Standard	EBL_upp	EBL_low	B_IRF
E_{LIV}:	**1.05E+28**	1E+28	1E+28	1.05E+28	**9.01E+27**	1.11E+28	1E+28	**9.01E+27**
σ (CL)	**25.5**	19.5	35.0	26.5	**9.6**	6.6	18.5	**9.3**

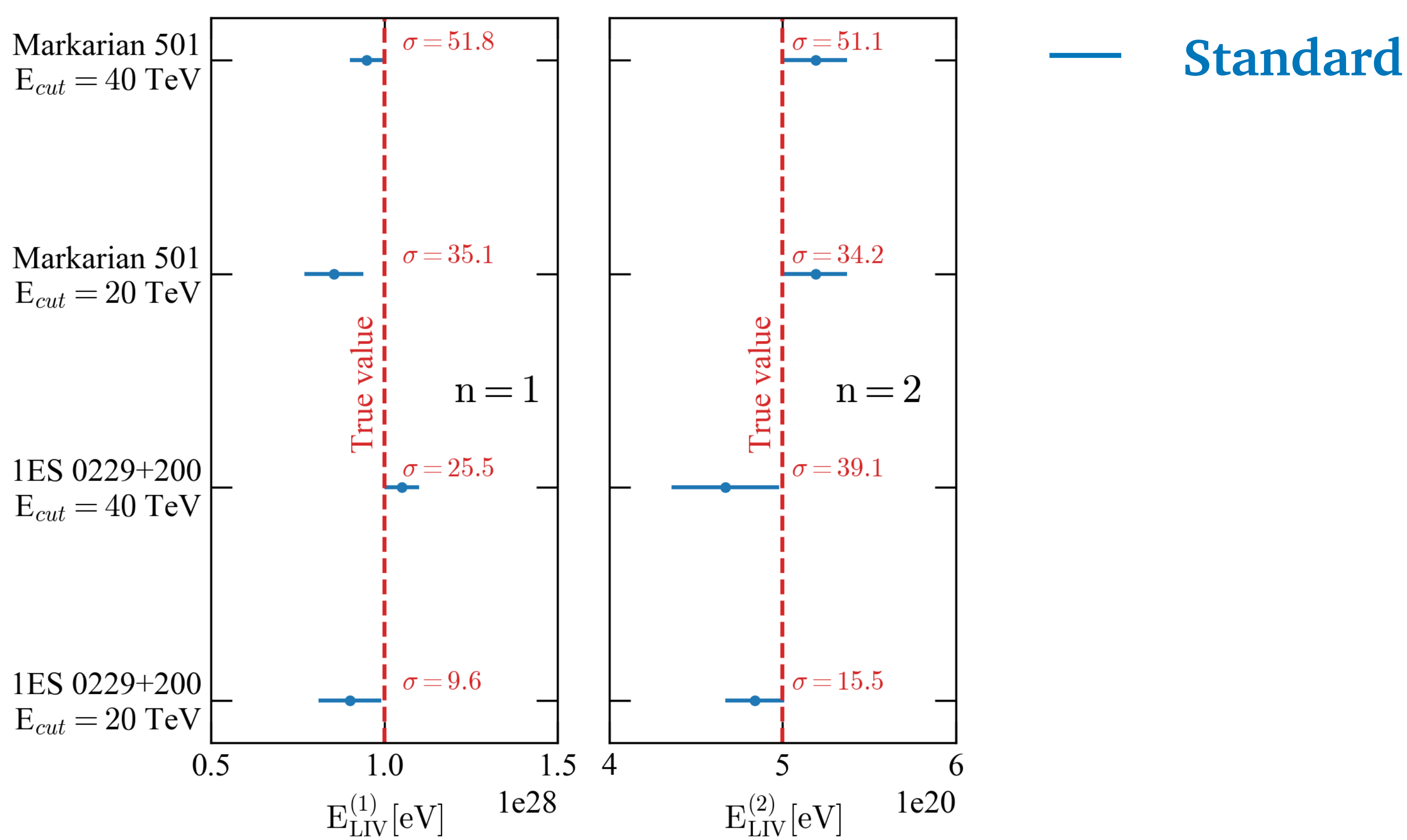


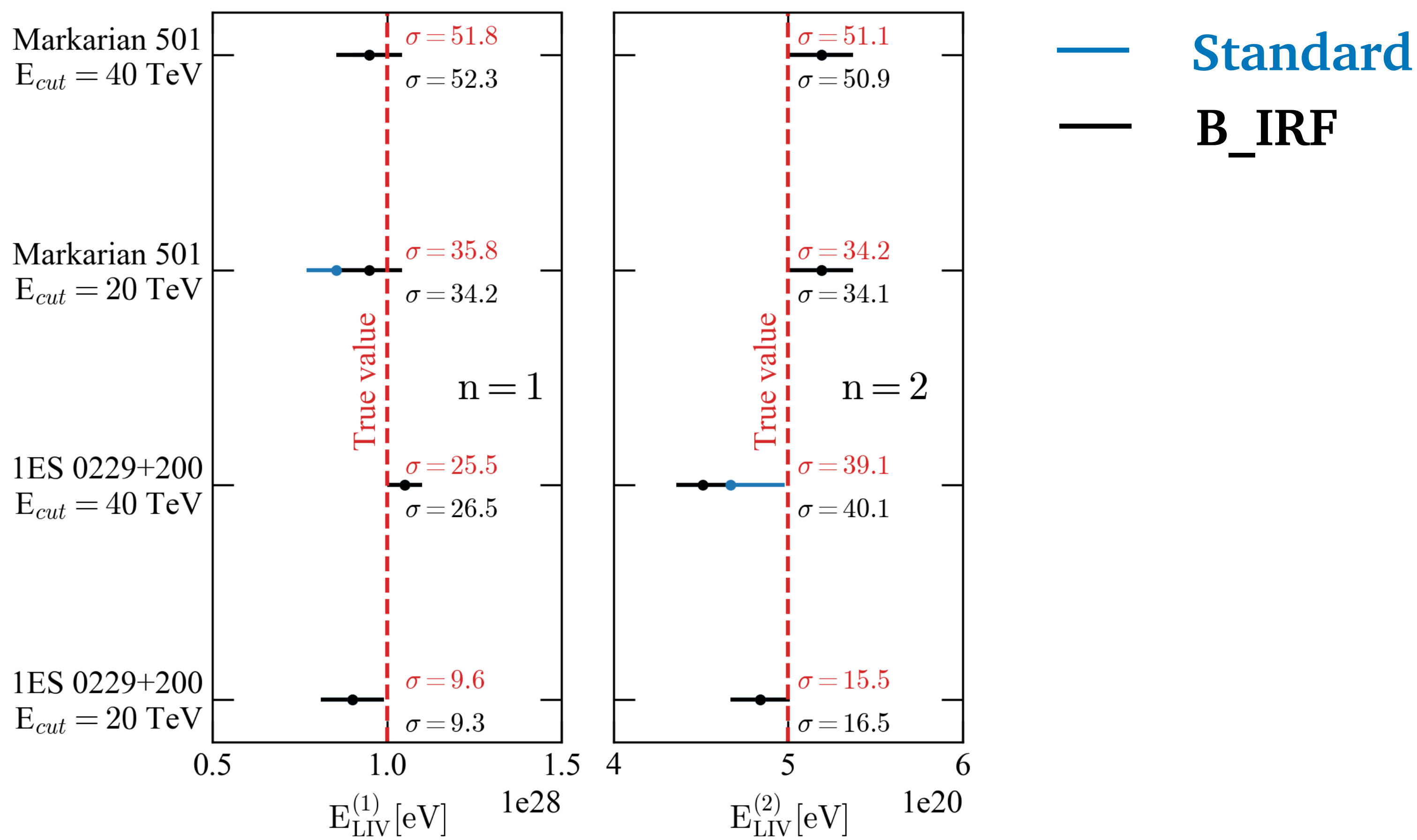
Fig. 6b
Agreement between best-fit parameters and the simulated true values.

Finding LIV signal

n=1

[eV]	Markarian 501 (Ec = 40 TeV)				Markarian 501 (Ec = 40 TeV)			
	Standard	EBL_upp	EBL_low	B_IRF	Standard	EBL_upp	EBL_low	B_IRF
E_{LIV}:	**9.49E+27**	9.01E+27	9.49E+27	**9.49E+27**	**8.55E+27**	9.01E+27	9.01E+27	**9.49E+27**
σ (CL)	**51.8**	51.3	54.5	**52.3**	**35.1**	34.7	36.2	**34.2**

[eV]	1ES 0229+200 (Ec =40 TeV)				1ES 0229+200 (Ec =20 TeV)			
	Standard	EBL_upp	EBL_low	B_IRF	Standard	EBL_upp	EBL_low	B_IRF
E_{LIV}:	**1.05E+28**	1E+28	1E+28	1.05E+28	**9.01E+27**	1.11E+28	1E+28	**9.01E+27**
σ (CL)	**25.5**	19.5	35.0	26.5	**9.6**	6.6	18.5	**9.3**



Excluding LIV signal

n=1

	Markarian 501 (Ec = 40 TeV)				
CL	**E_{LIV} limit [eV]**	Δ (EBL) [eV]	Δ (Soft) [eV]	Δ (B_IRF) [eV]	**Δ [eV]**
2σ	**1.23E+29**	1.40E+28			**1.40E+28**
		-6.06E+28	-3.20E+28	-2.81E+28	**-7.41E+28**
3σ	**1E+29**	3.00E+28			**3.00E+28**
		-4.38E+28	-1.80E+28	-1.45E+28	**-4.95E+28**
5σ	**7.7E+28**	2.80E+28			**2.80E+28**
		-2.89E+28	-1.46E+28	-7.70E+27	**-3.33E+28**
	Markarian 501 (Ec = 20 TeV)				
CL	**E_{LIV} limit [eV]**	Δ (EBL) [eV]	Δ (Soft) [eV]	Δ (B_IRF) [eV]	**Δ [eV]**
2σ	**7.31E+28**	2.69E+28	2.25E+28	2.18E+28	**4.13E+28**
		-1.97E+28			**-1.97E+28**
3σ	**6.58E+28**	2.43E+28	1.46E+28	1.12E+28	**3.05E+28**
		-2.02E+28			**-2.02E+28**
5σ	**5.06E+28**	1.87E+28	1.00E+28	8.70E+27	**2.29E+28**
		-1.55E+28			**-1.55E+28**

Source:	Markarian 501		1ES 0229+200		Mkr501		1ES 0229+200	
E_{cut}:	40 TeV	20 TeV	40 TeV	20 TeV	40 TeV	20 TeV	40 TeV	20 TeV
Limits	$E^{(1)}_{LIV} \times 10^{28}$eV				$E^{(2)}_{LIV} \times 10^{21}$eV			
2σ	$12.3^{+1.4}_{-7.41}$	$7.31^{+4.13}_{-1.97}$	$1.37^{+4.88}_{-5.59}$	$1.23^{+2.51}_{-4.23}$	$2.33^{+2.51}_{-0.73}$	$1.64^{+0.36}_{-0.56}$	$0.58^{+1.83}_{-0.18}$	$0.54^{+1.18}_{-0.17}$
3σ	$10^{+3.00}_{-4.95}$	$6.58^{+3.05}_{-2.02}$	$1.11^{+0.26}_{-0.05}$	$0.95^{+1.34}_{-0.36}$	$2.1^{+1.79}_{-0.61}$	$1.53^{+0.31}_{-0.52}$	$0.54^{+1.17}_{-0.2}$	$0.48^{+0.74}_{-0.17}$
5σ	$7.7^{+2.8}_{-3.3}$	$5.06^{+2.29}_{-1.55}$	$0.77^{+0.92}_{-0.36}$	$0.59^{+0.67}_{-0.22}$	$1.7^{+1.15}_{-0.33}$	$1.33^{+0.27}_{-0.70}$	$0.44^{+0.46}_{-0.17}$	$0.37^{+0.29}_{-0.12}$

Table. CTA upper limits for LIV scenarios with n=1 and 2. Systematic errors due to the EBL model, software selection and energy dispersion, are shown in all cases.

Excluding LIV signal

n=1

	Markarian 501 (Ec = 40 TeV)				
CL	E_{LIV} limit [eV]	Δ (EBL) [eV]	Δ (Soft) [eV]	Δ (B_IRF) [eV]	Δ [eV]
2σ	1.23E+29	1.40E+28			1.40E+28
		-6.06E+28	-3.20E+28	-2.81E+28	-7.41E+28
3σ	1E+29	3.00E+28			3.00E+28
		-4.38E+28	-1.80E+28	-1.45E+28	-4.95E+28
5σ	7.7E+28	2.80E+28			2.80E+28
		-2.89E+28	-1.46E+28	-7.70E+27	-3.33E+28
	Markarian 501 (Ec = 20 TeV)				
CL	E_{LIV} limit [eV]	Δ (EBL) [eV]	Δ (Soft) [eV]	Δ (B_IRF) [eV]	Δ [eV]
2σ	7.31E+28	2.69E+28	2.25E+28	2.18E+28	4.13E+28
		-1.97E+28			-1.97E+28
3σ	6.58E+28	2.43E+28	1.46E+28	1.12E+28	3.05E+28
		-2.02E+28			-2.02E+28
5σ	5.06E+28	1.87E+28	1.00E+28	8.70E+27	2.29E+28
		-1.55E+28			-1.55E+28

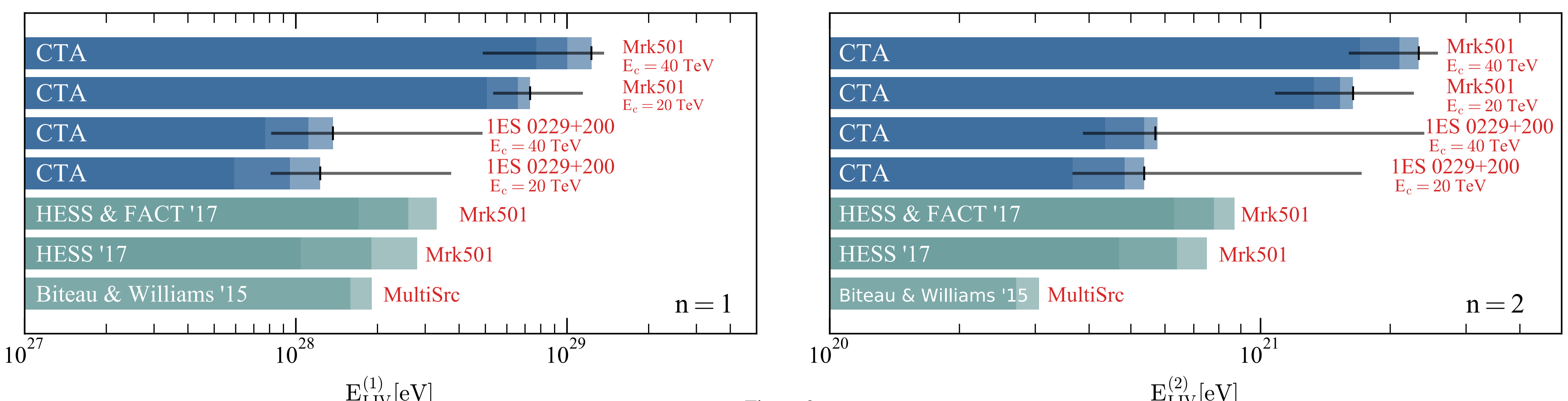


Figure 9:
Excluded LIV energy scales by subluminal searches in the photon sector using a similar analysis technique than the used this work. Better confidence levels are marked with darker colors. Limits from Biteau&Williams'15 are translated to the photon sector and to the quadratic term. CTA potential limits are presented for comparison (in blue) with the systematic errors in black for the 2σ limit.

To do list

- ☑ Done
- ■ Next

- ☑ 1. GammaPy: Fit and Simulation
  - ☑ LI : 4 Cases
  - ☑ LIV: 4 Cases
  - ☑ Ctools cross-check : 8 Cases
- ☑ 2. Work cases
  - ☑ Signal reconstruction case
    - ☑ Mrk501 40/20 TeVECPL
    - ☑ 1ES 0229+200 40/20 TeVECPL
  - ☑ LIV-rejection case (n=1)
    - ☑ Mrk501 40/20 TeVECPL
    - ☑ 1ES 0229+200 40/20 TeVECPL

- ☑ Common plot macro
- ☑ Prod3-IRF
- ☑ Update: ebltable V 1.14
- ☑ Update: New Src's-Input
- ☑ Update: Analysis at source
- ☑ LIV case n=2

- ☑ 3. Systematics
  - ☑ EBL-model
  - ☑ Software: γ-Py/CTools
  - ☑ **Energy**
- ☑ 4. Writing

Thanks!