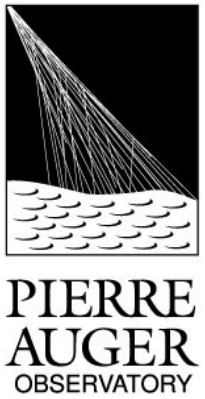


Declination dependency of the Auger spectrum

Diego Ravignani for the Pierre Auger Collaboration

ITeDA (CNEA/CONICET/UNSAM), Argentina

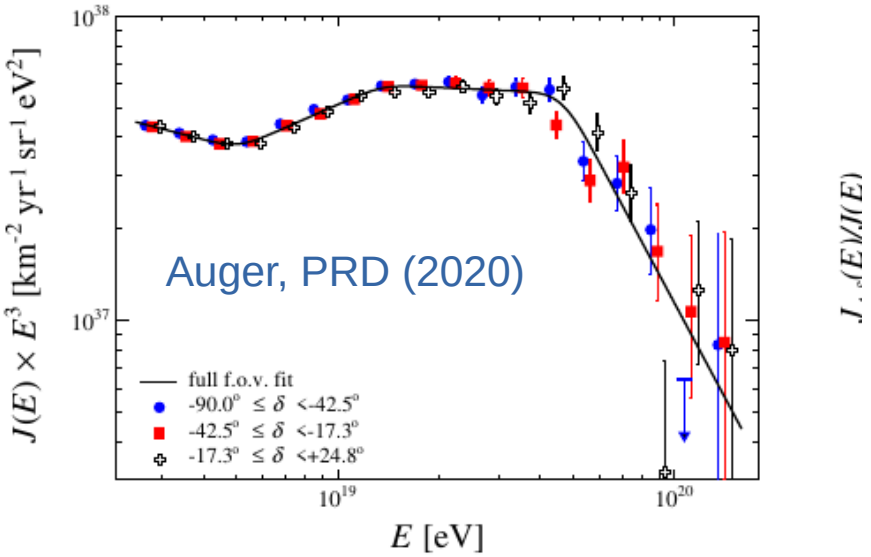
ITeDA

UHECR 2024

Malargüe, Nov. 17-21 2024

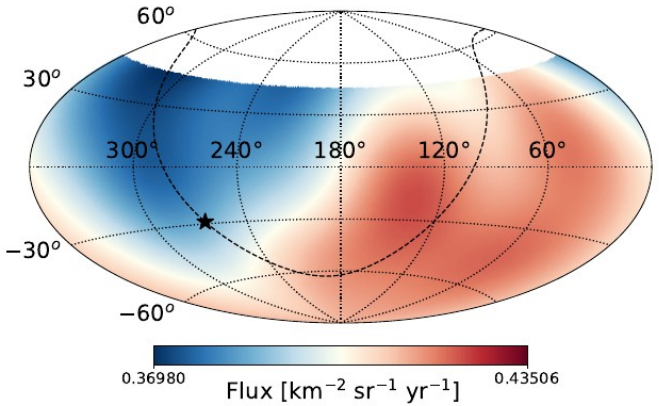
Motivation

Spectra in declination bands



Auger, PRD (2020)

Arrival directions dipole

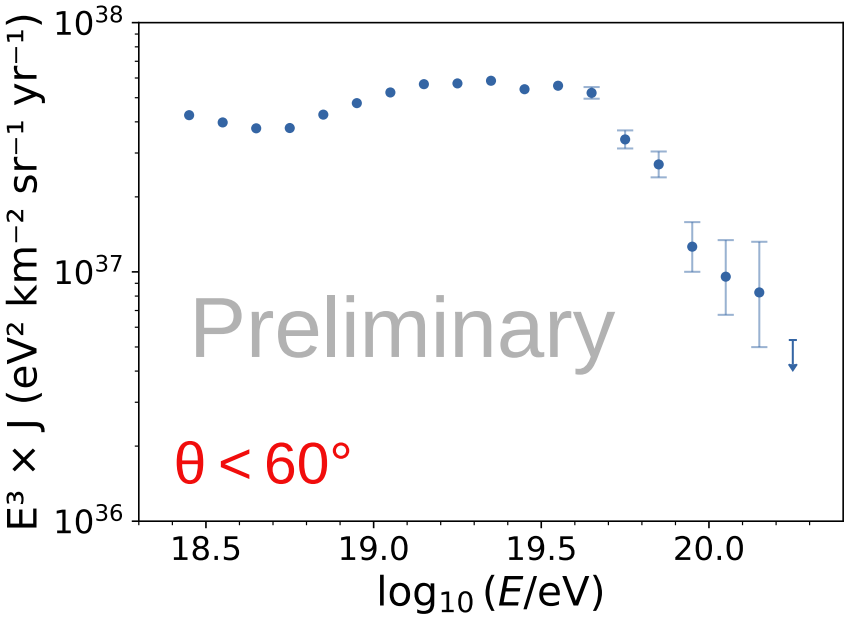


Auger, ApJ (2024)

Spectrum consistent with declination-independent flux?

SD-1500 spectra

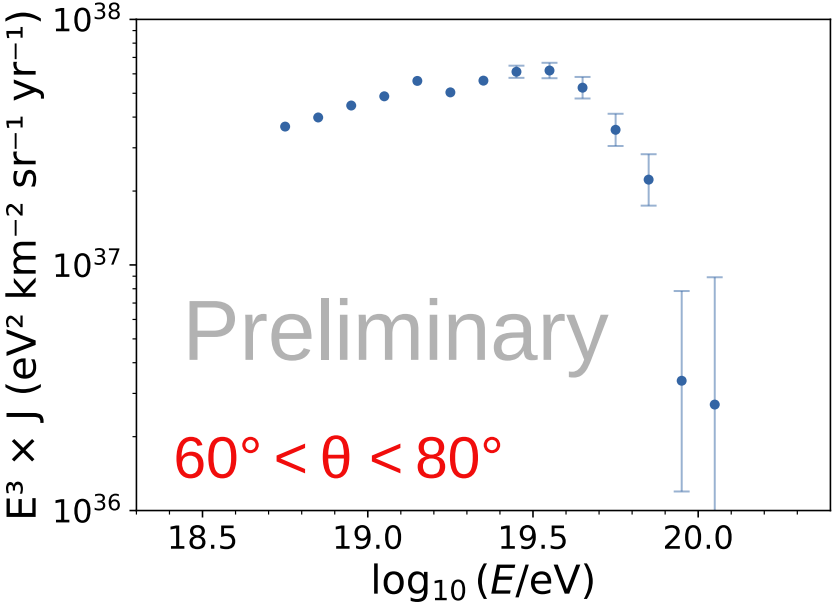
Vertical



ε = 60 430 km² sr yr

Jan 2004 - Aug 2018

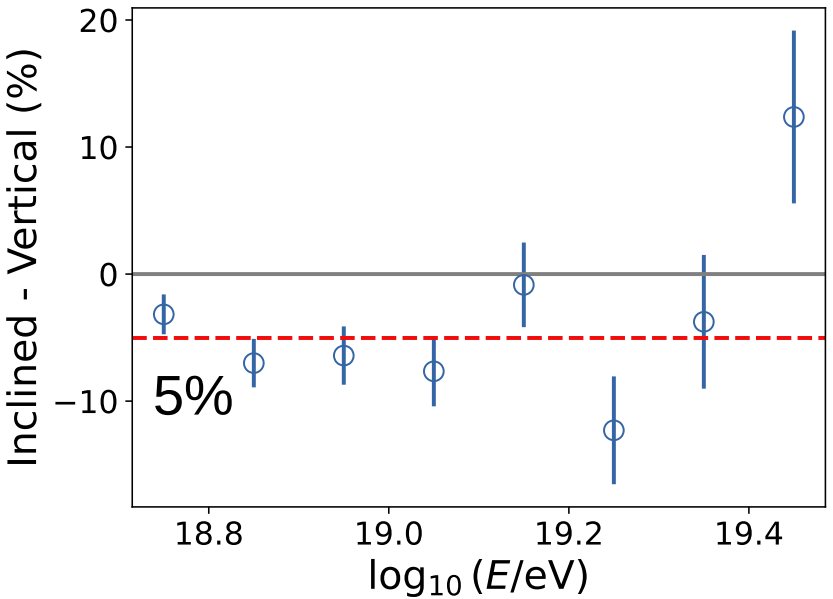
Inclined

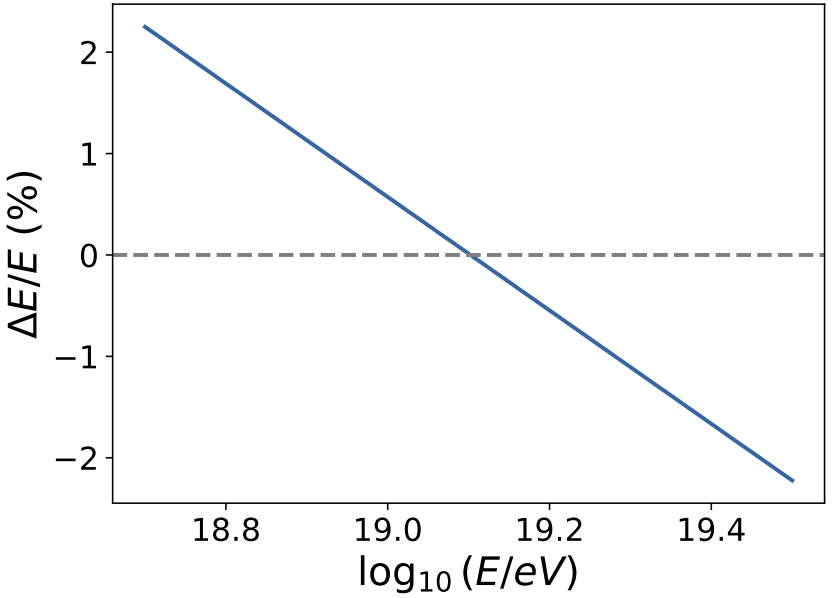


ε = 17 850 km² sr yr

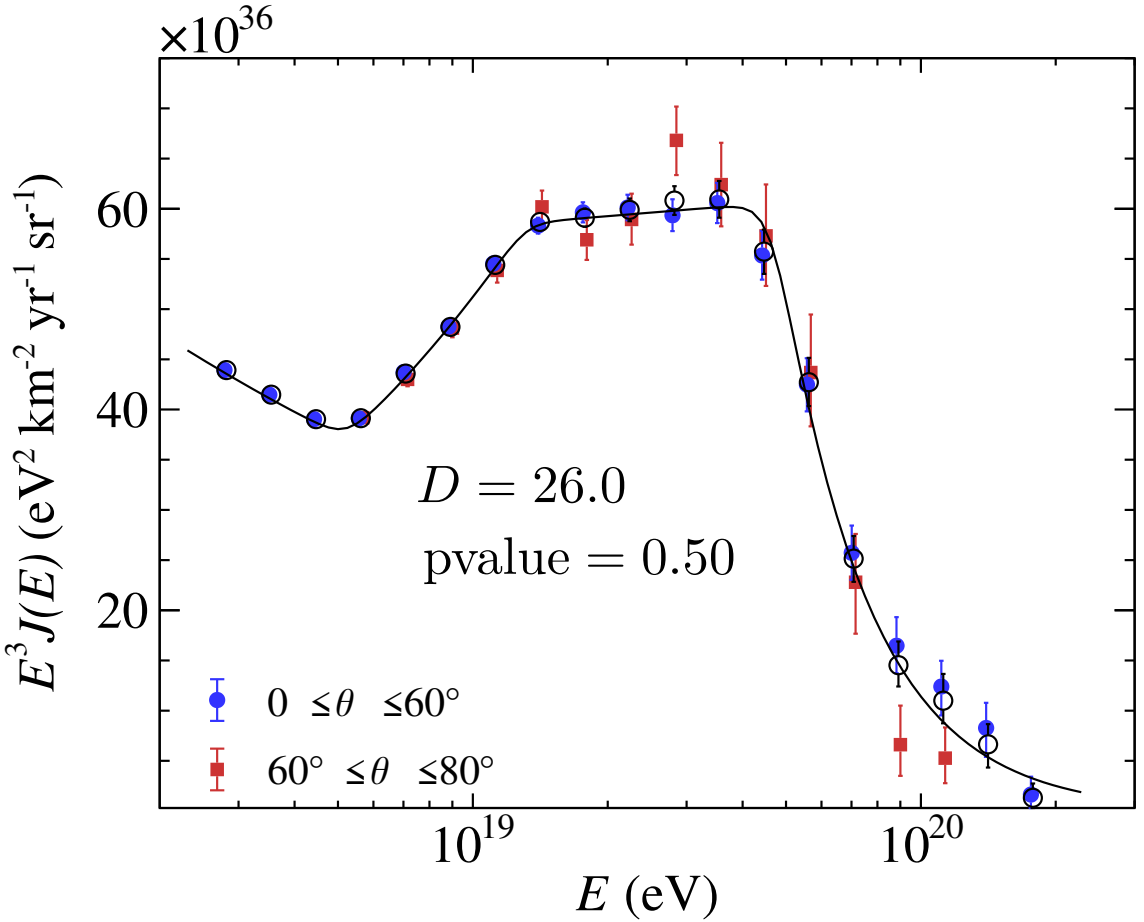
Jan 2004 - Aug 2021

Vertical / inclined consistency

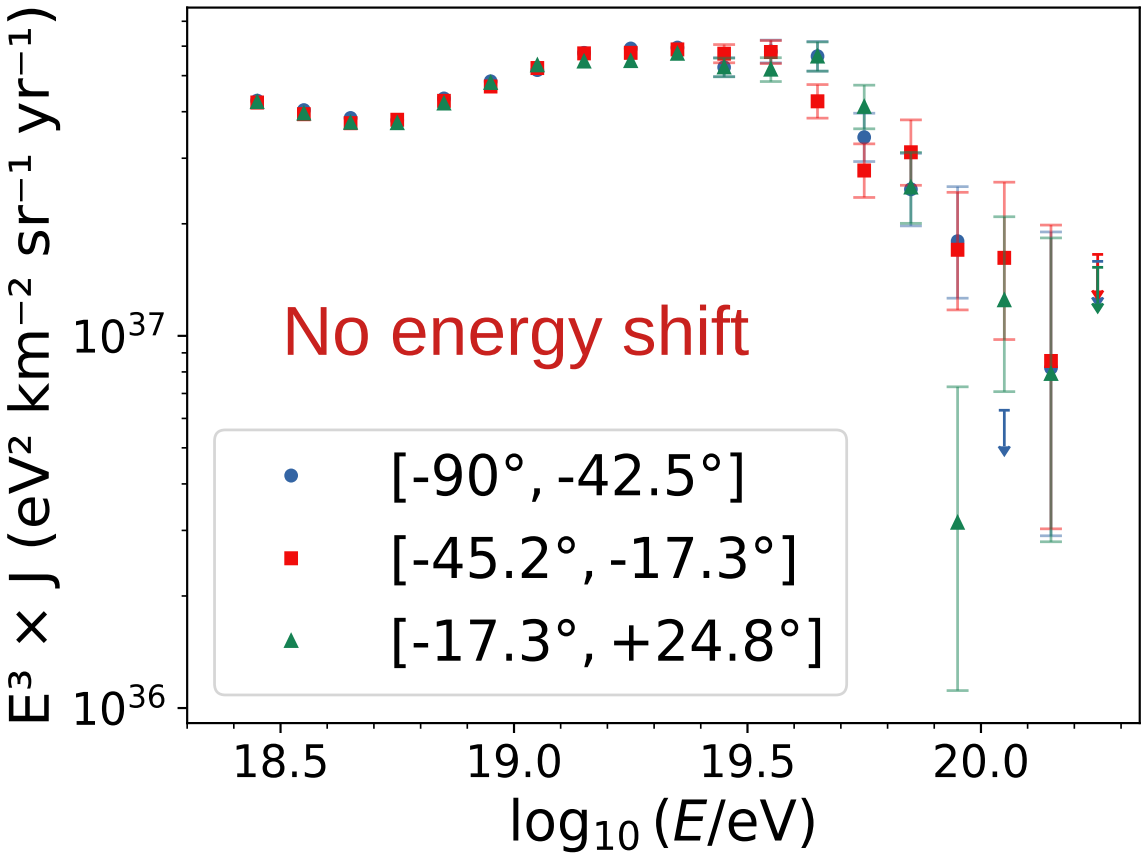


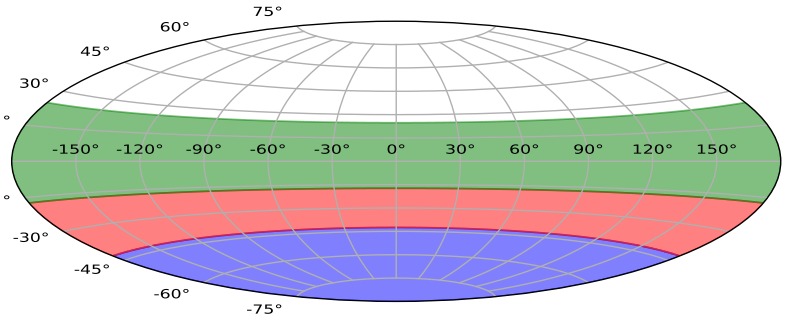


Vertical / inclined consistency



Vertical spectrum bands

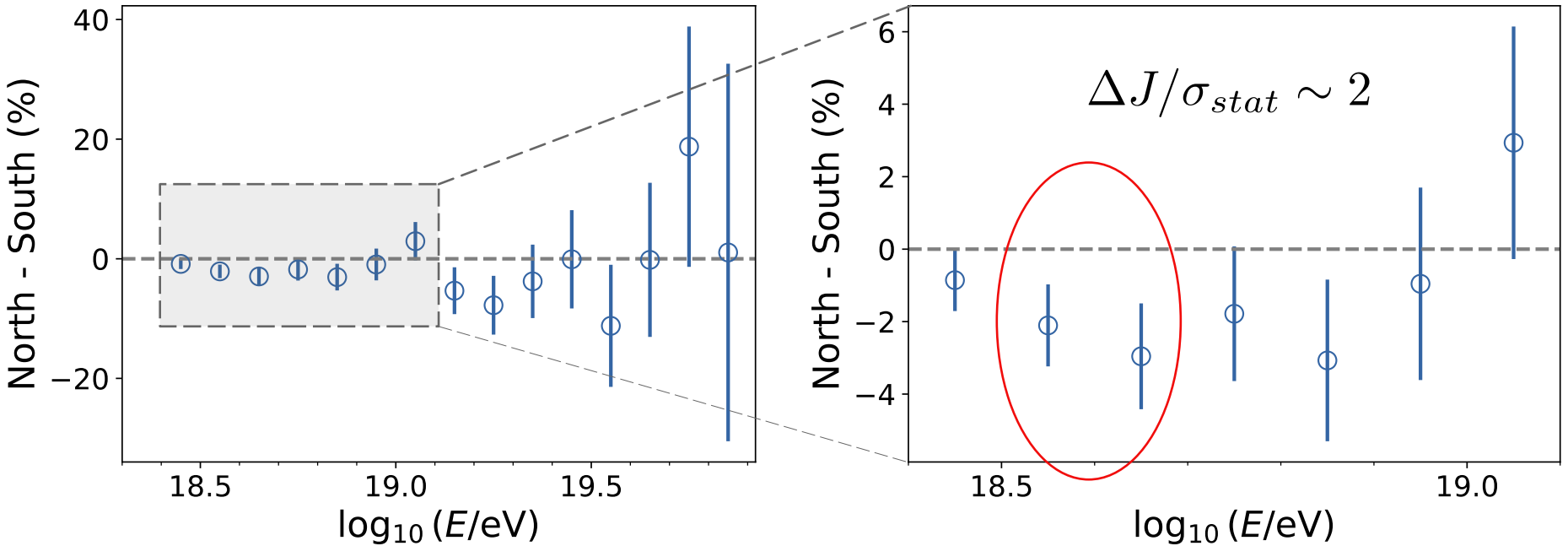




ε ~ 20000 km² sr yr

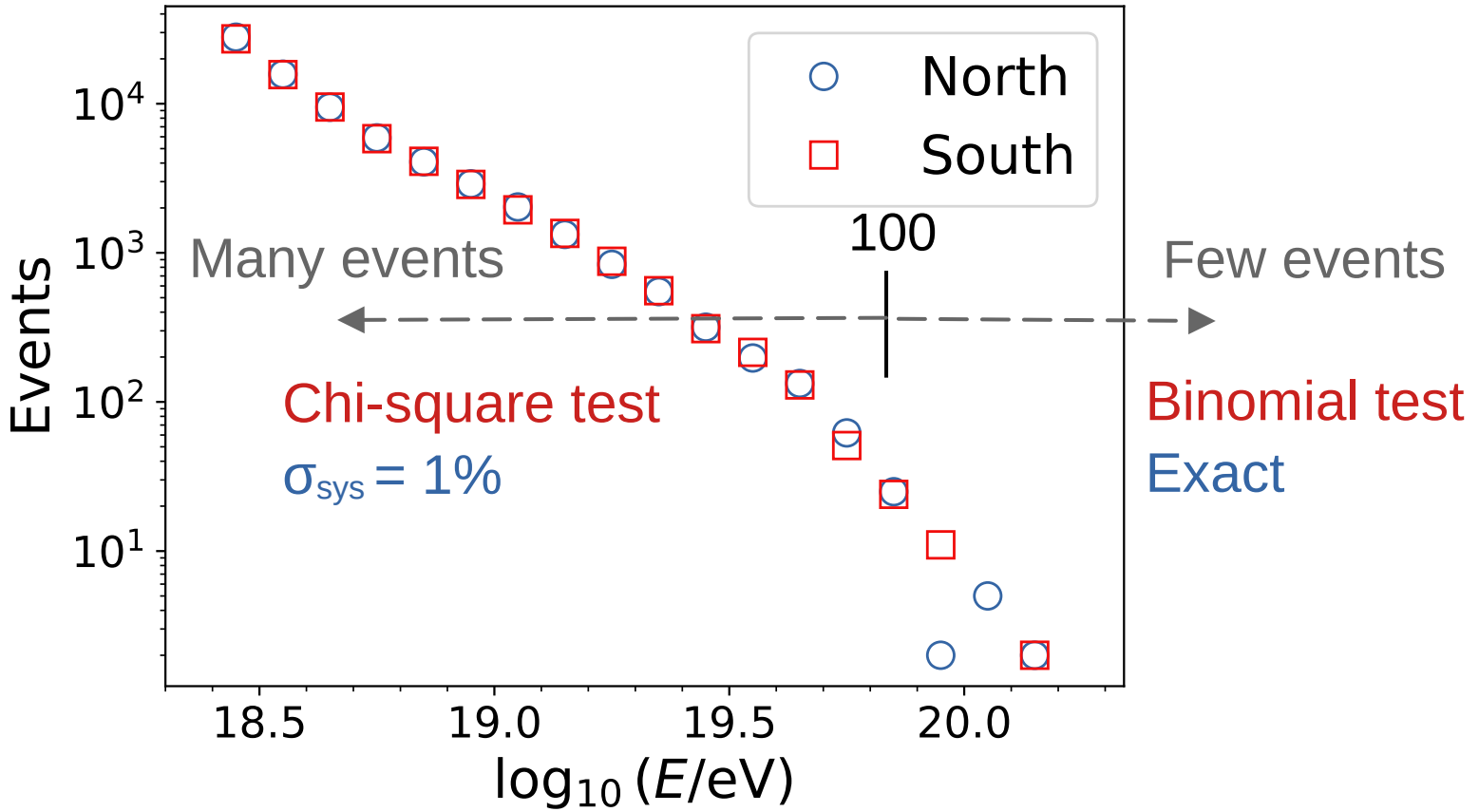
3-way comparison

Systematic uncertainty

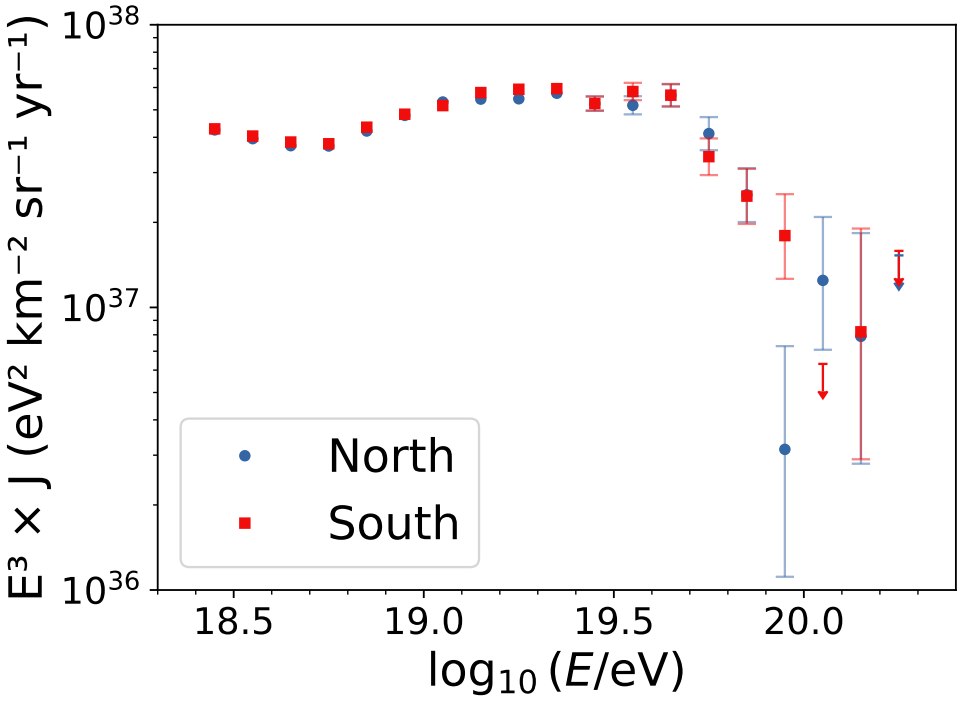


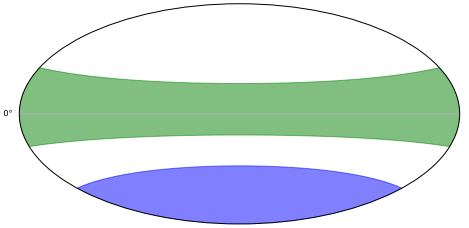
σ_{sys} = 1%

Spectra comparison



North vs. South





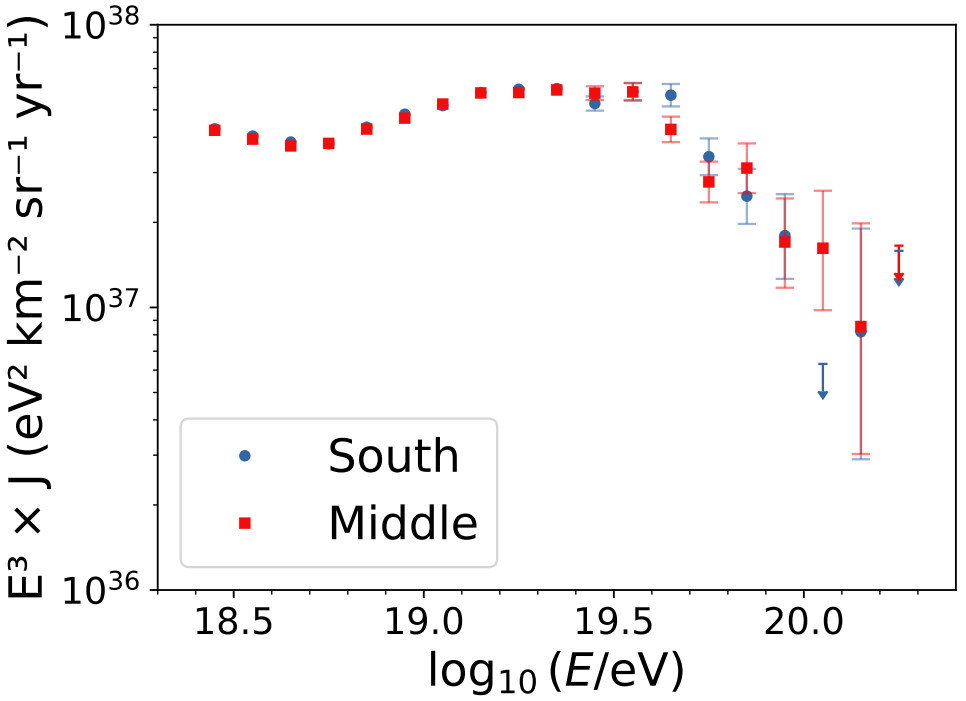
$t_{obs} = 42.8$

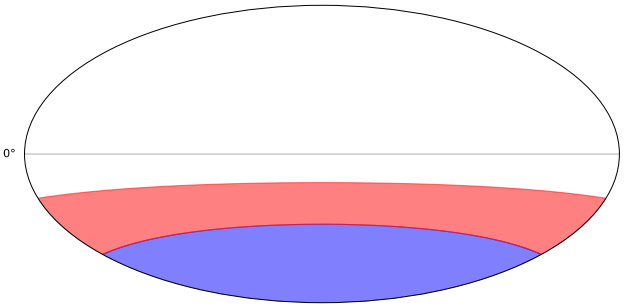
$\mathrm{ndof} = 36$

$\mathrm{pvalue} = 14.8\%$

1.4σ significance

South vs. Middle





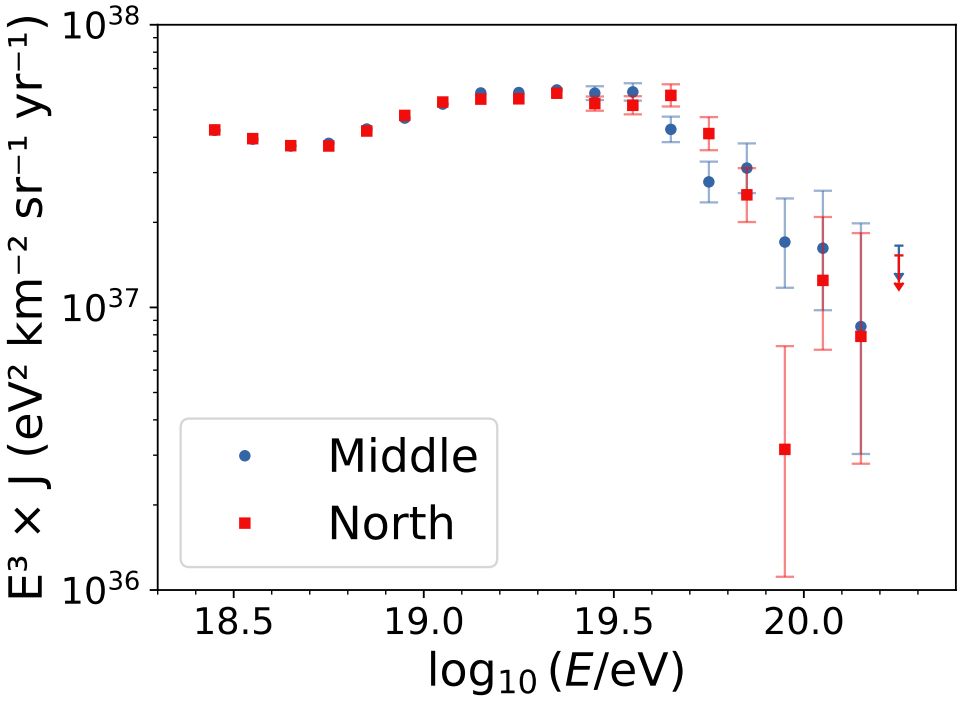
$t_{obs} = 31.2$

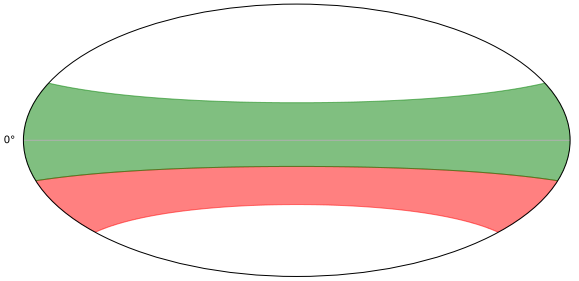
$\mathrm{ndof} = 36$

$\mathrm{pvalue} = 34.1\%$

0.9σ significance

Middle vs. North





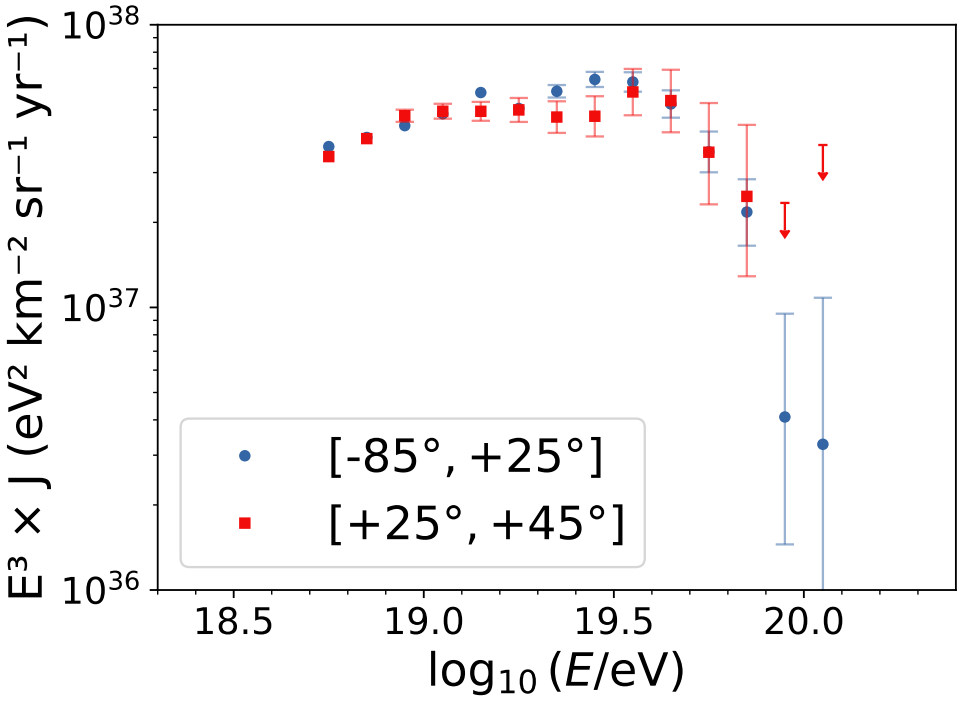
$t_{obs} = 40.6$

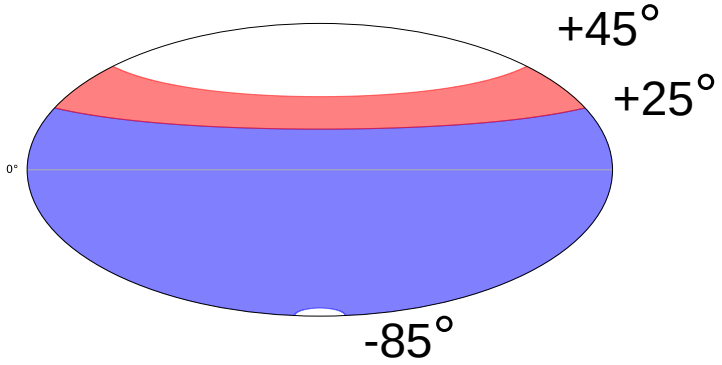
$\mathrm{ndof} = 36$

$\mathrm{pvalue} = 21.5\%$

1.2σ significance

Inclined spectrum





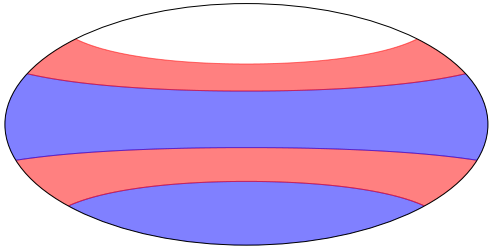
$t_{obs} = 30.3$

$\mathrm{ndof} = 28$

$\mathrm{pvalue} = 22.0\%$

1.2σ significance

Summary



- Declination bands test
- Coverage from -90° to +45°
- 1% uncorrelated systematics

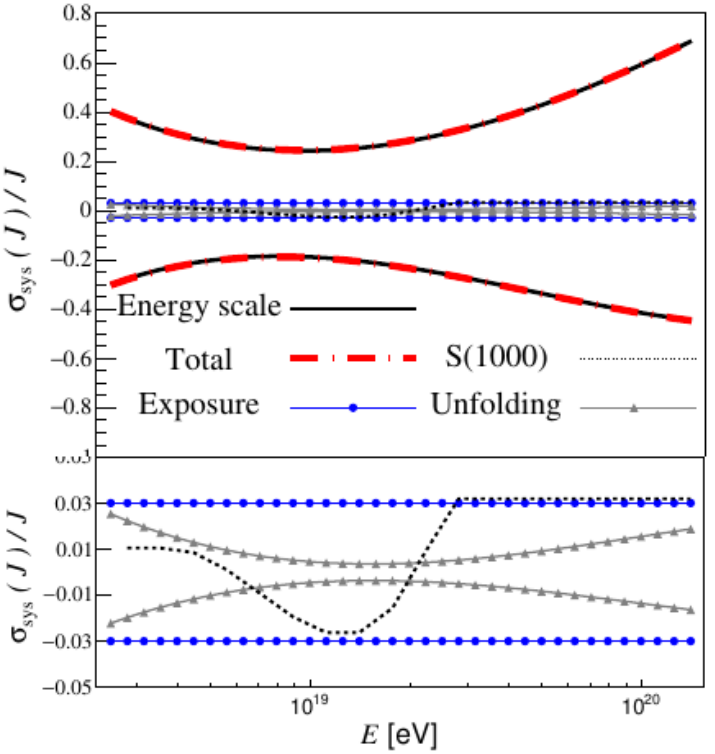
Spectra consistent with declination uniformity

Backup

Systematic uncertainty

Between bands

$$\begin{cases} \sigma^1_{sys} = \sigma_c \oplus \sigma^1_u \\ \sigma^2_{sys} = \sigma_c \oplus \sigma^2_u \end{cases}$$



Correlated

σ_c ~ 25-60% → $\Delta J = 0$

e.g. FD absolute calibration

Uncorrelated

σ_u ~ 1% → $\Delta J \neq 0$

e.g. CIC zenith dependency

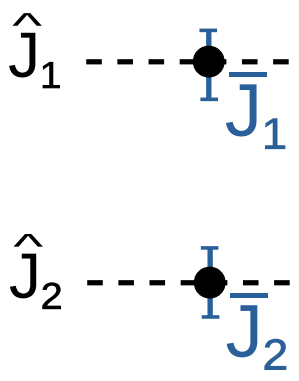
Same spectra → small σ_u

Comparing two data

Measurred flux

$H_0 : \bar{J}_1 = \bar{J}_2$

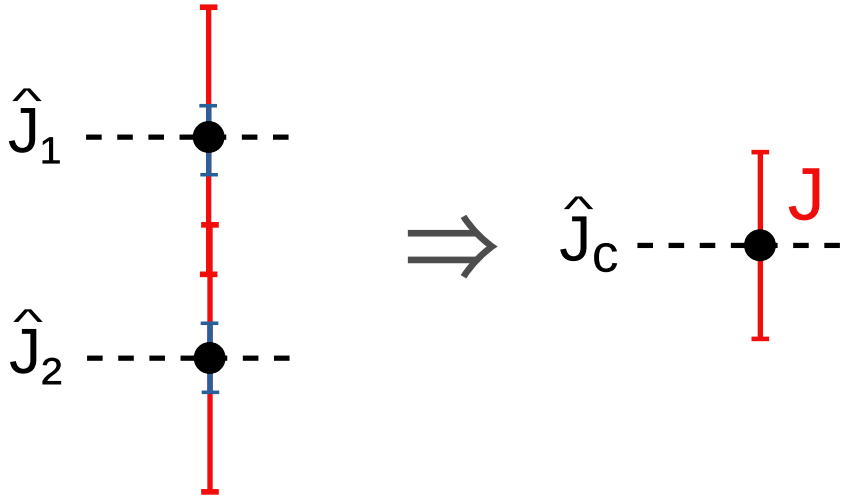
False



H_0 rejected

Physical flux

$H_0 : J_1 = J_2$



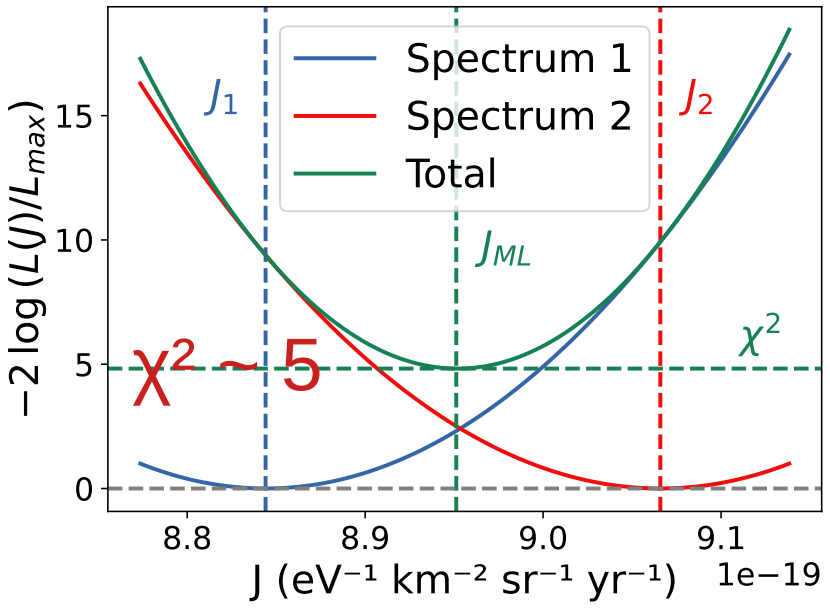
H_0 not rejected

Consider systematics

Chi-square test in one bin

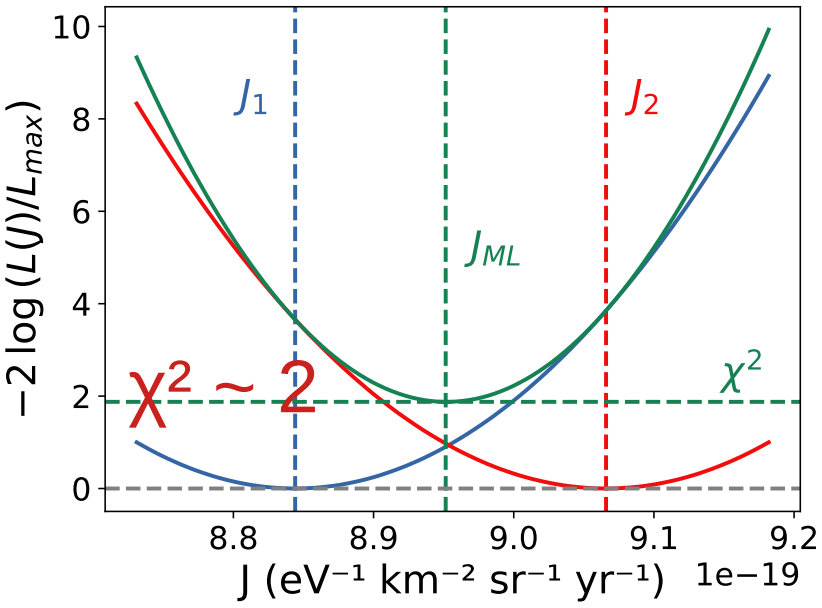
Bin [18.5, 18.6] $k_1 = 15775$ $k_2 = 15677$

$\sigma_{sys} = 0$



$\sigma^2 = \sigma^2_{stat}$

$\sigma_{sys} = 1\%$



$\sigma^2 = \sigma^2_{stat} + \sigma^2_{sys}$

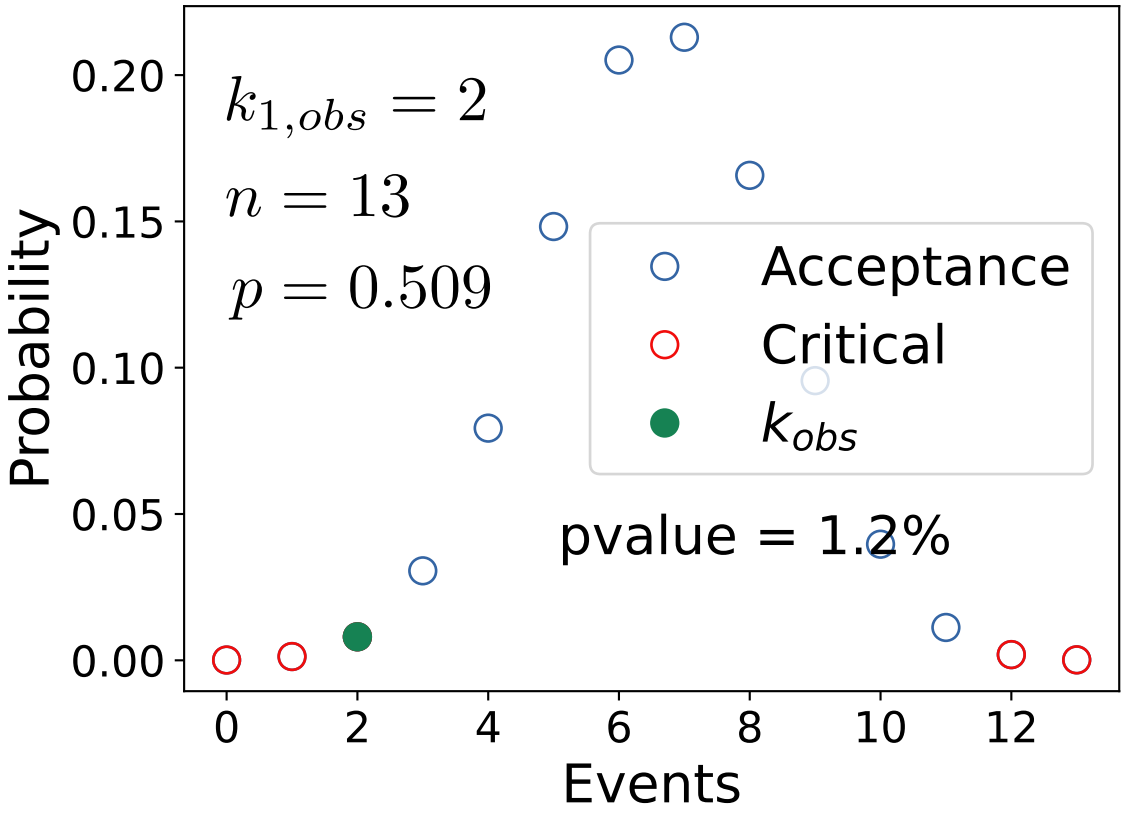
Binomial test in one bin

Bin [19.9, 20.0]

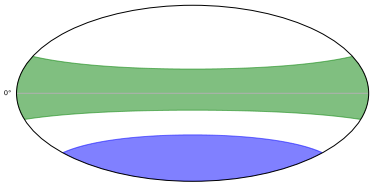
$$H_0 : k_1 \sim \text{Binomial}\,(n, p)$$

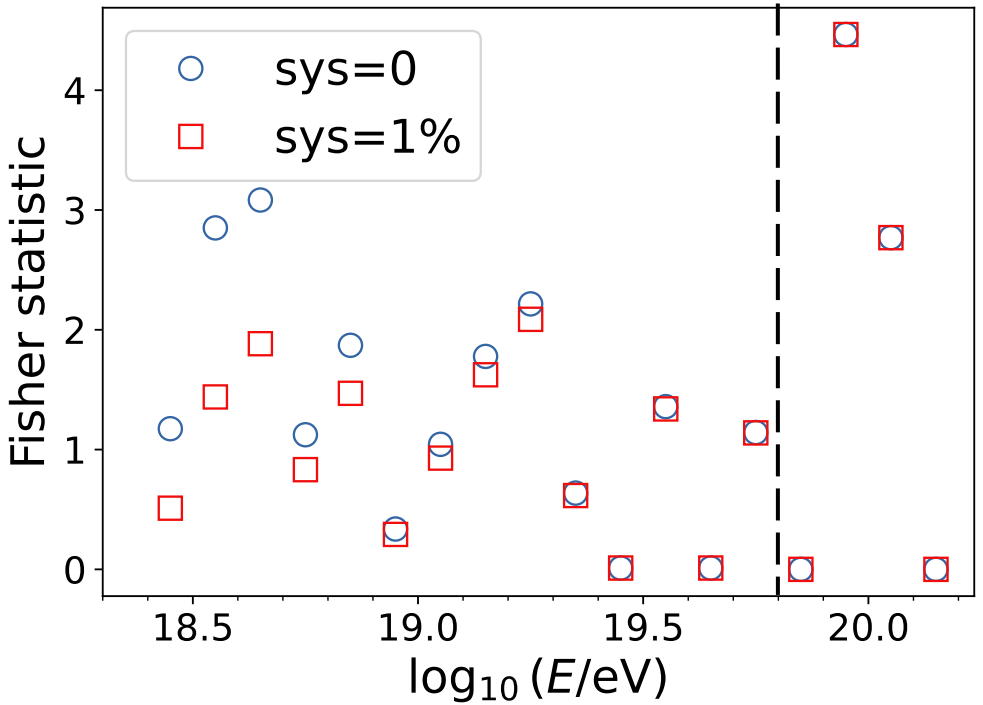
$$n = k_1 + k_2$$

$$p = \frac{\varepsilon'_1}{\varepsilon'_1 + \varepsilon'_2}$$



Combination of all bins





Fisher's method

$$t_i = -\log(\text{pvalue}_i)$$

$$n \geq 100 \Rightarrow t_i \sim \chi^2_2$$

$$n < 100 \Rightarrow t_i \sim \text{Discrete}$$

$$t = \sum t_i \qquad \text{ndof} = 36$$

Simulations

$$\begin{cases} \sigma_{sys} = 0\% & t_{obs} = 51.7 & \text{pvalue} = 2.7\%\,(2.2\sigma) \\ \sigma_{sys} = 1\% & t_{obs} = 42.8 & \text{pvalue} = 14.8\%\,(1.4\sigma) \end{cases}$$