Multiwaveband Observations of the TeV Blazar PKS 2155-304 with HESS, Fermi, RXTE, Swift and ATOM

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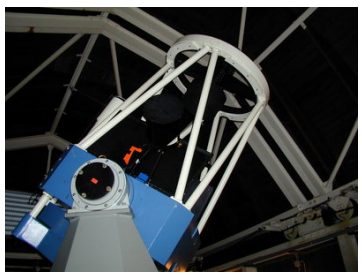
Thanks to Lucie Gérard for the HESS data.

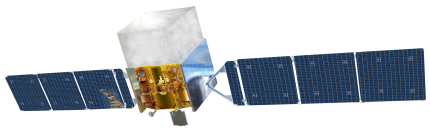
First Fermi-HESS MWL campaign

4 instruments to cover the broad band spectrum
12 days of observation

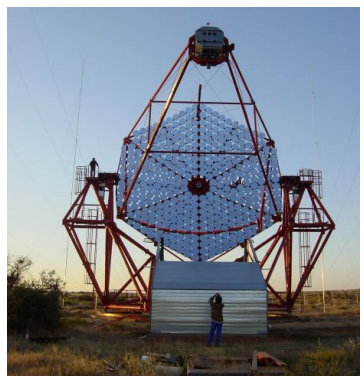


ATOM
(BRV)
106
observations
(60-200 s each)

RXTE + Swift
(0.5 - 10 keV)
75 ks + 6.4 ks



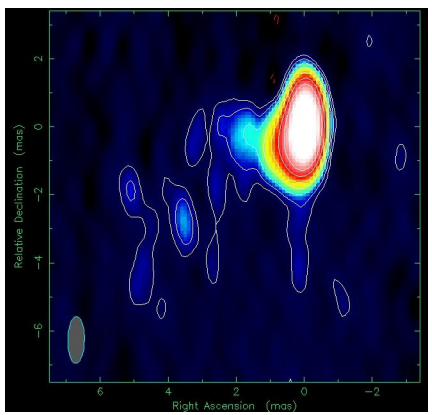
Fermi
(0.2-300 GeV)
$7.7 \times 10^8 \mathrm{cm}^2\mathrm{s}$



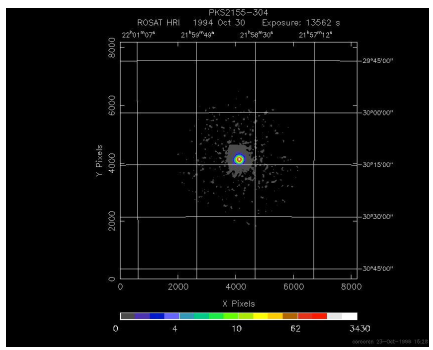
HESS
(0.2-10 TeV)
32.9 hours

First simultaneous observation in optical, X-ray and HE γ-ray

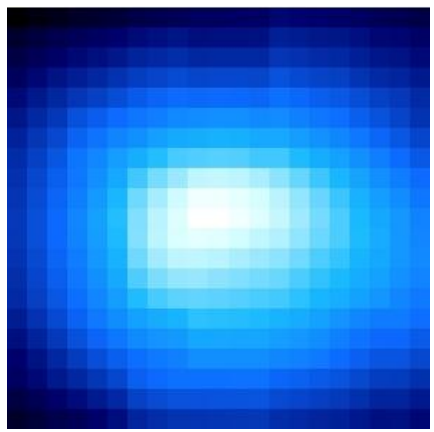
- Blazar : jet toward the observer
- PKS 2155-304 : very bright VHE source
- but faint EGRET source (3EG : 5.9σ)
- variable in all wavelengths, fast variability



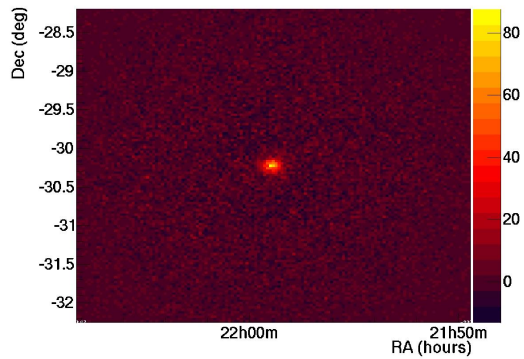
Radio



X-ray



GeV



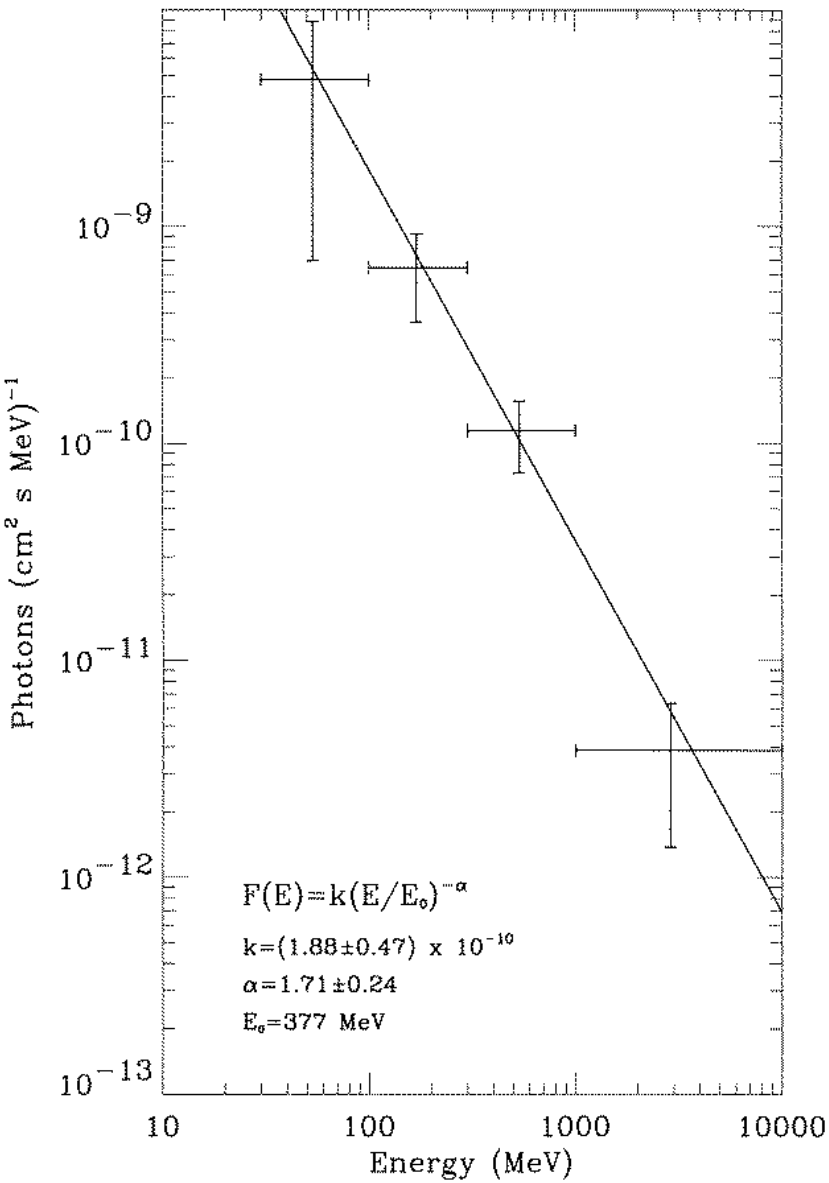
TeV

EGRET measurements:

- Similar fluxes ($\approx$ factor 2)
- but very different spectral state
  $\Gamma_{\rm 3EG} = 2.34 \pm 0.20$
  $\Gamma_{\rm HS} = 1.71 \pm 0.24$

$\Delta\Gamma = 0.6$

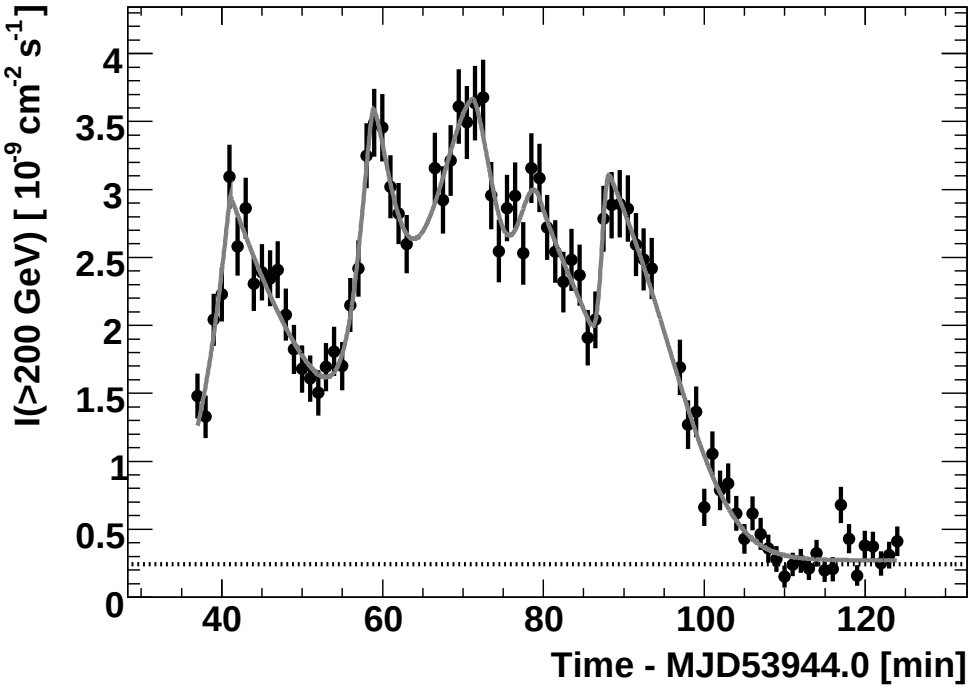
What is the spectral index?

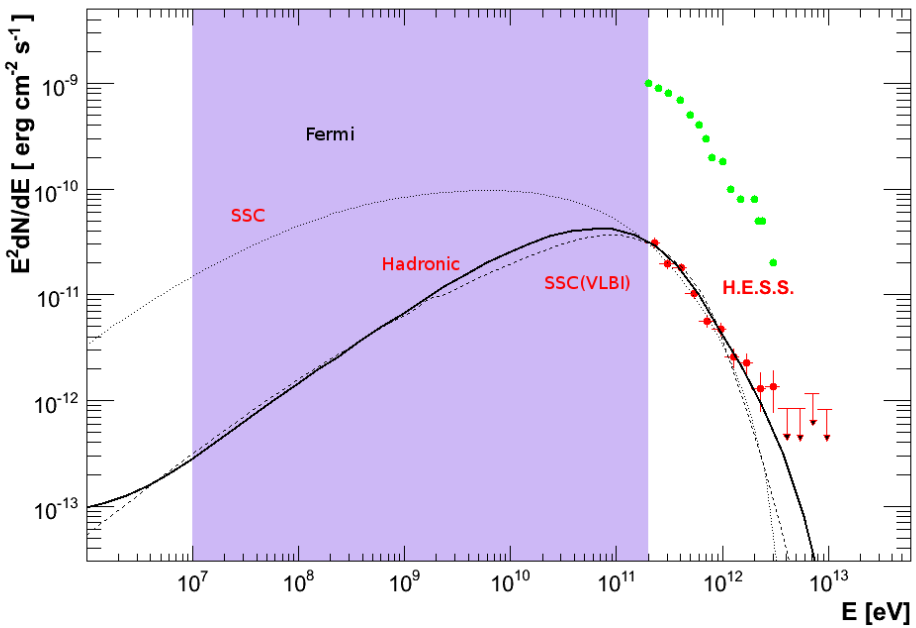


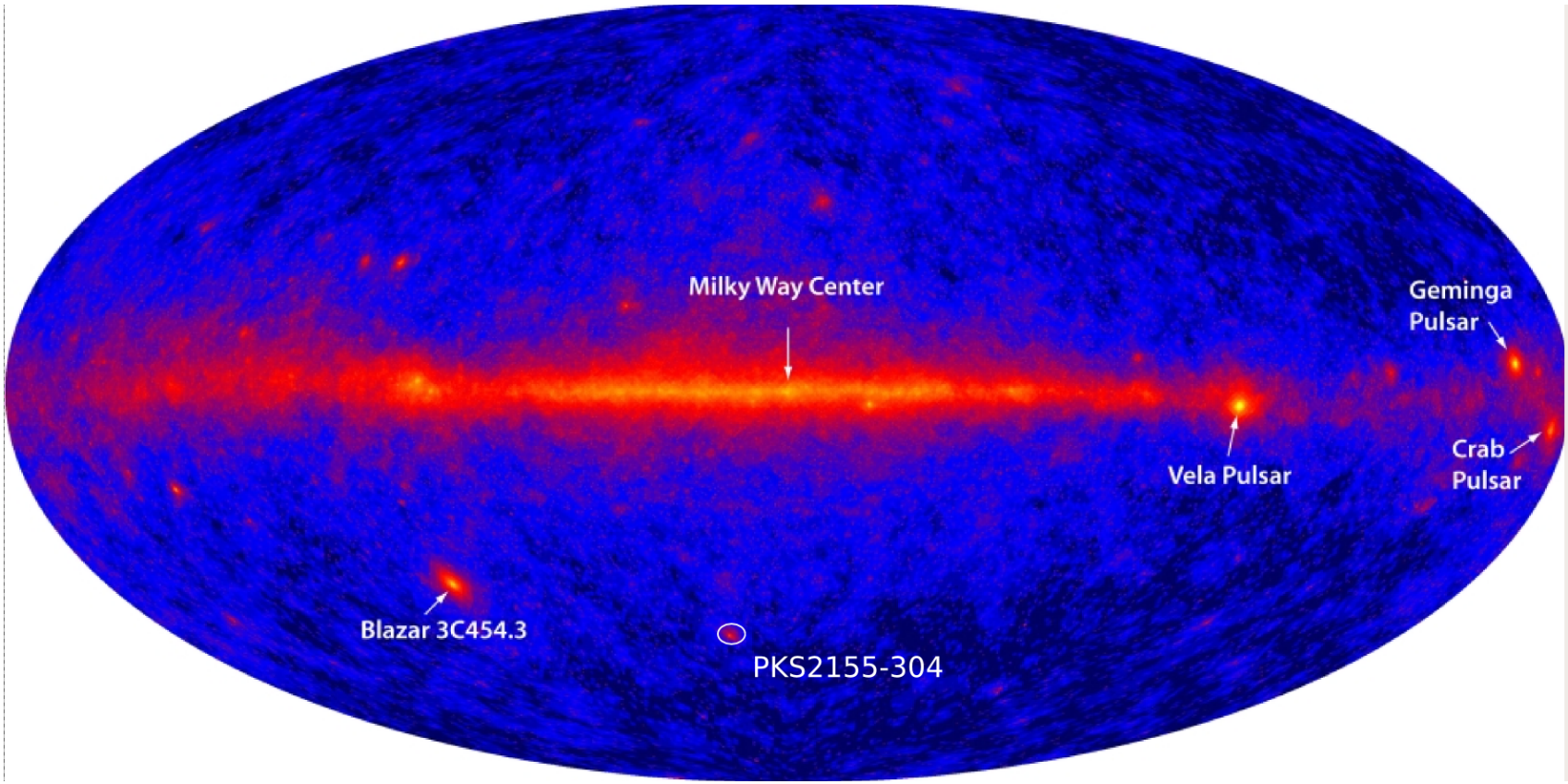
VHE range The flux can be 50 times higher (2006) than the low state flux (2003)

- Soft index $\Gamma = 3.3$: break ($\approx$ GeV)
- different models give different predictions

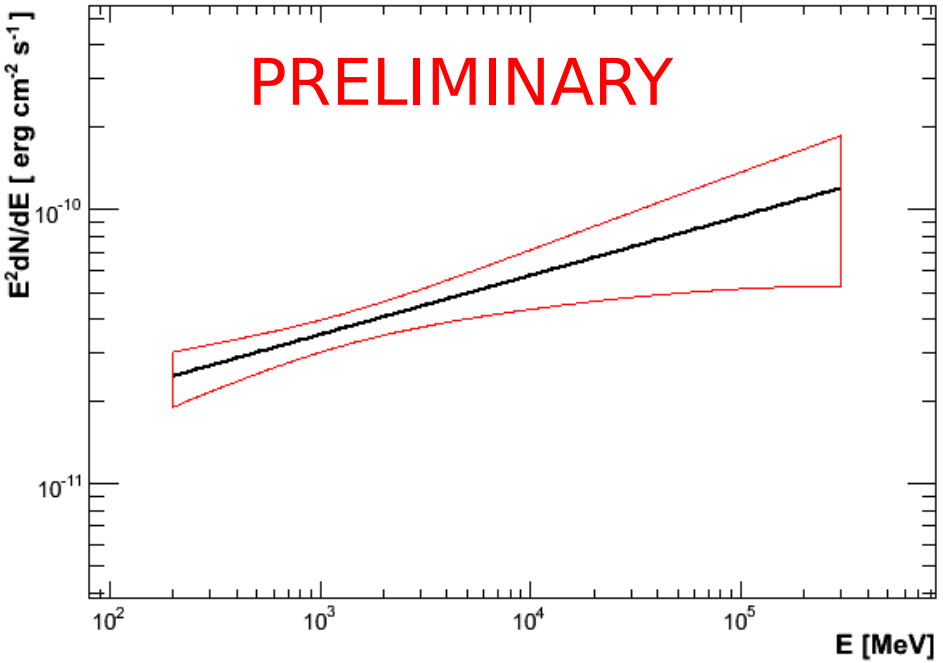
What is the simultaneous shape of the IC bump?
Flux state?





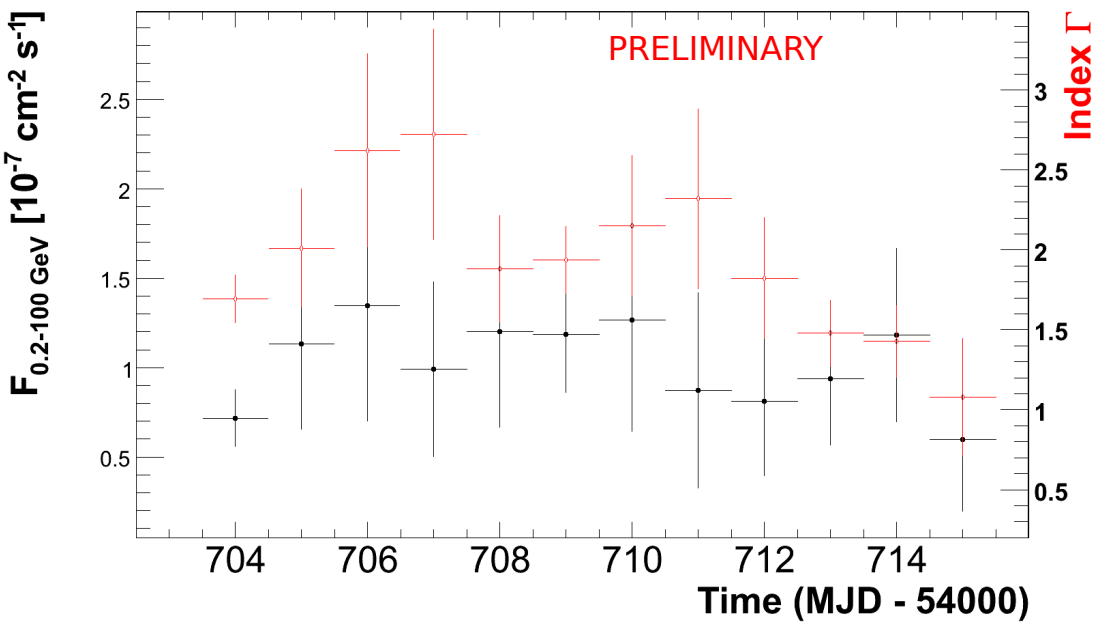


4 days of first light observation : PKS 2155-304 is seen

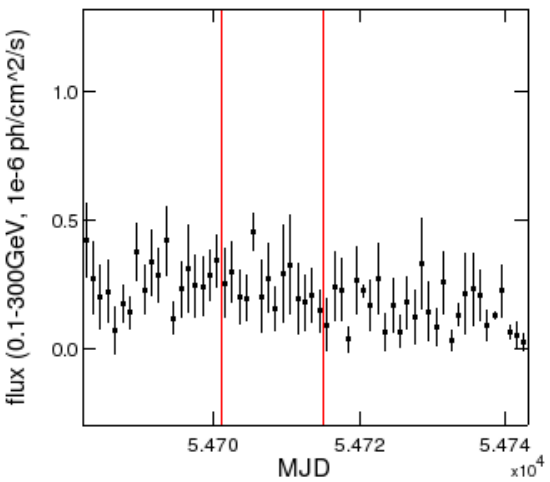


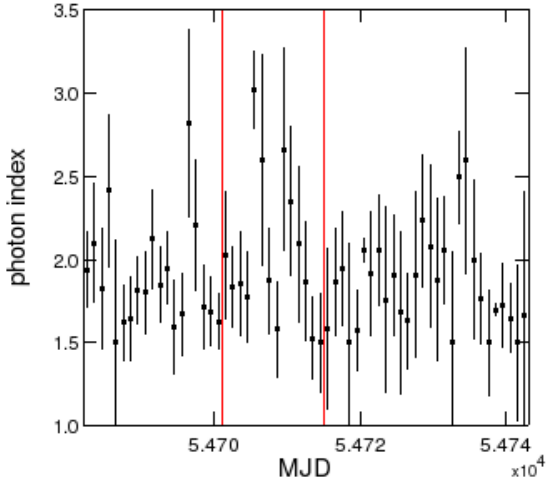
PKS 2155-304 was detected during the campaign

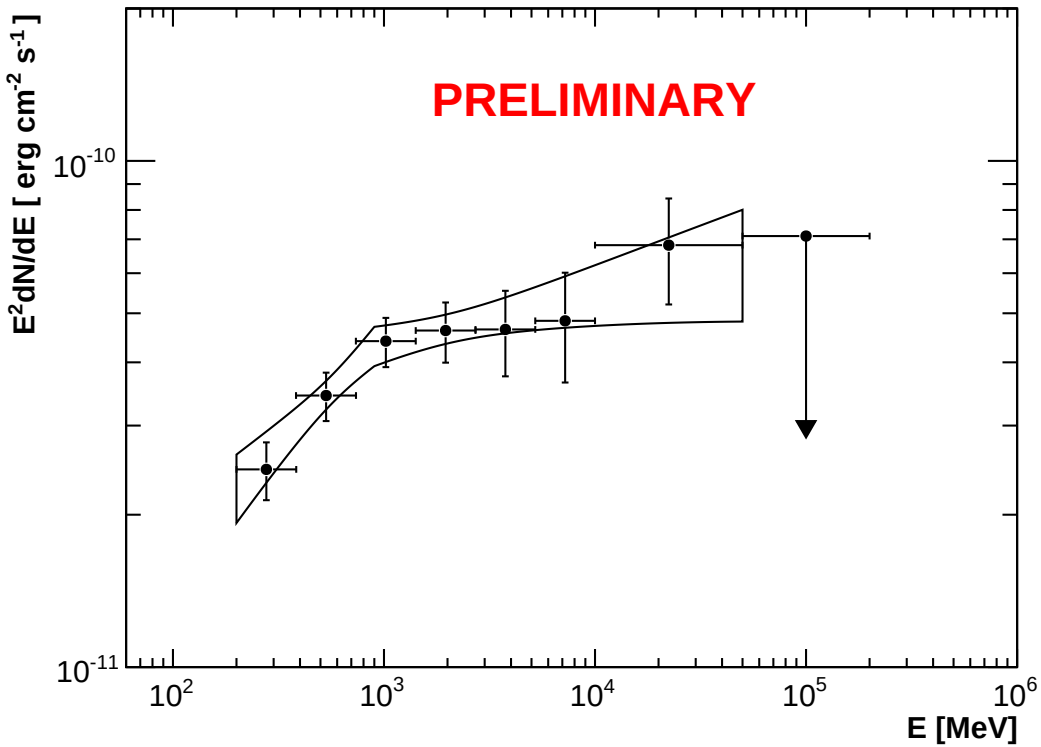
- bright Fermi source
- hard index : $\Gamma = 1.81 \pm 0.11$



- Detected each 1-2 days
- $F \approx$ cst



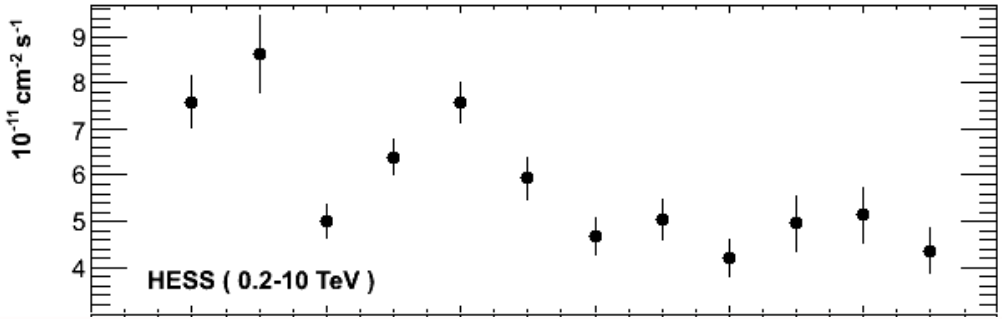




- 2 months LC
- same flux state

2 months of data taking

- broken power law
- $\Gamma_L = 1.61 \pm 0.16$
- $\Gamma_H = 1.96 \pm 0.08$

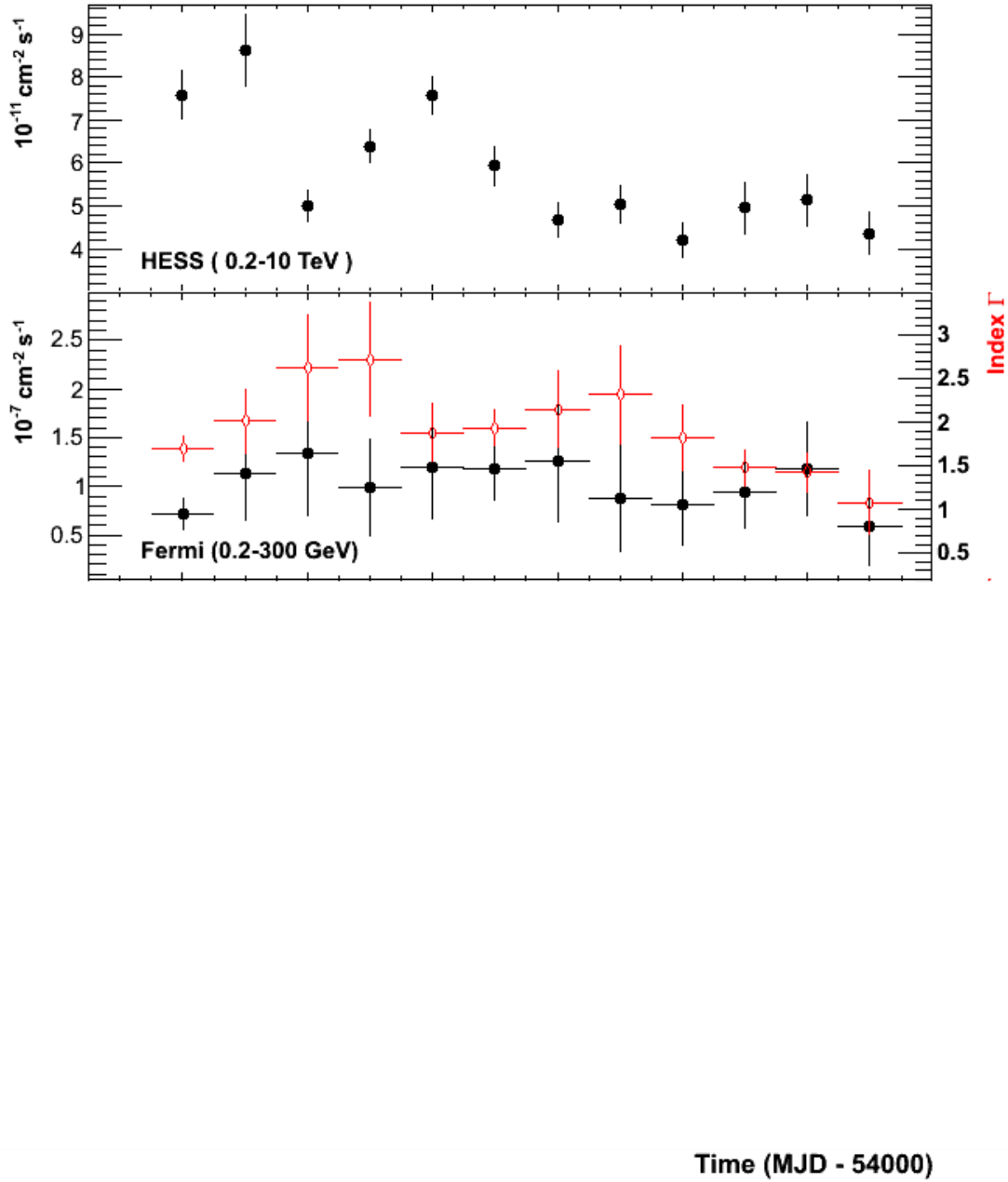


LC of 12 days

- VHE, 23%
-
-
-

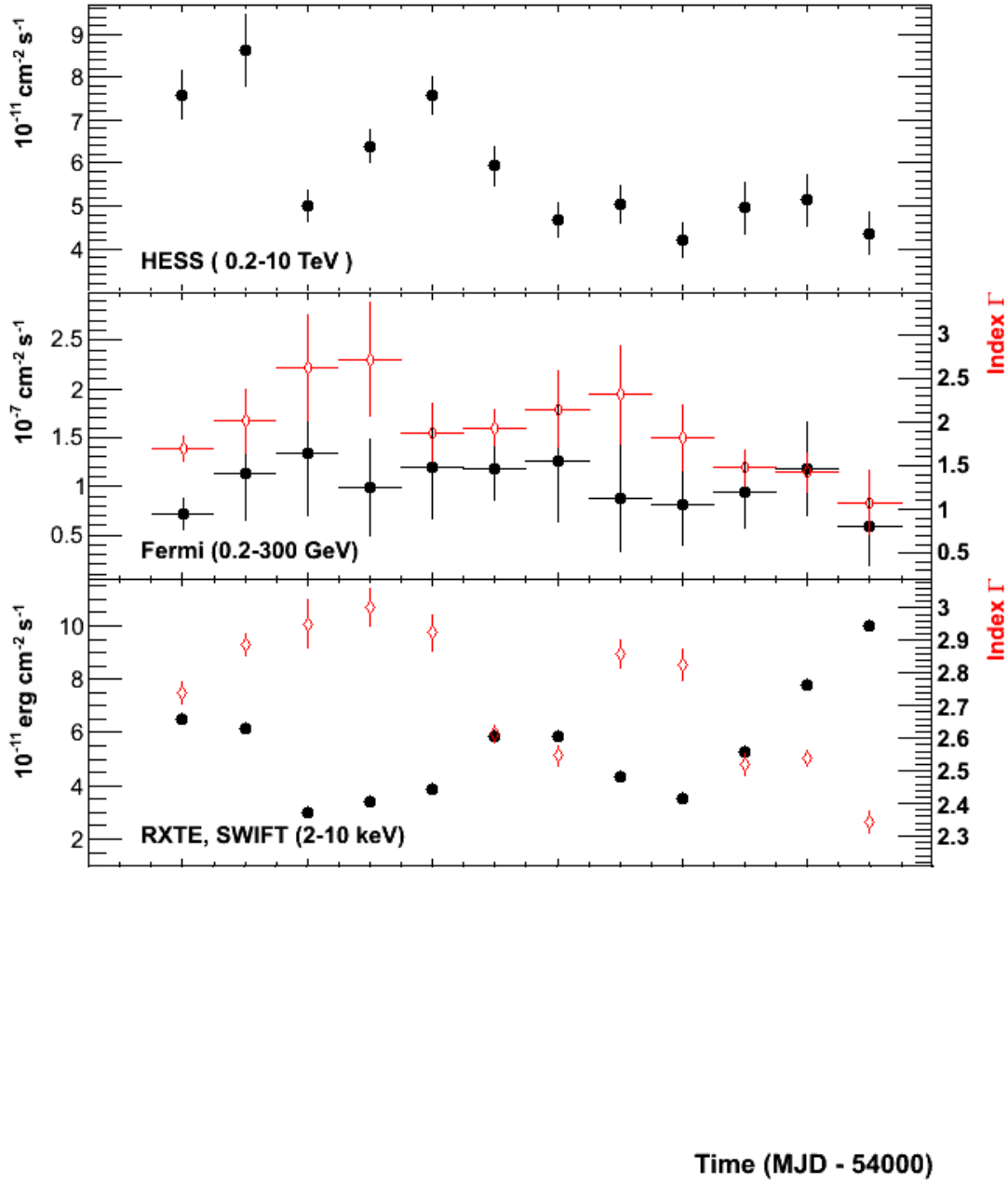
LC of 12 days

- VHE, 23%
- HE, <20%
-
-



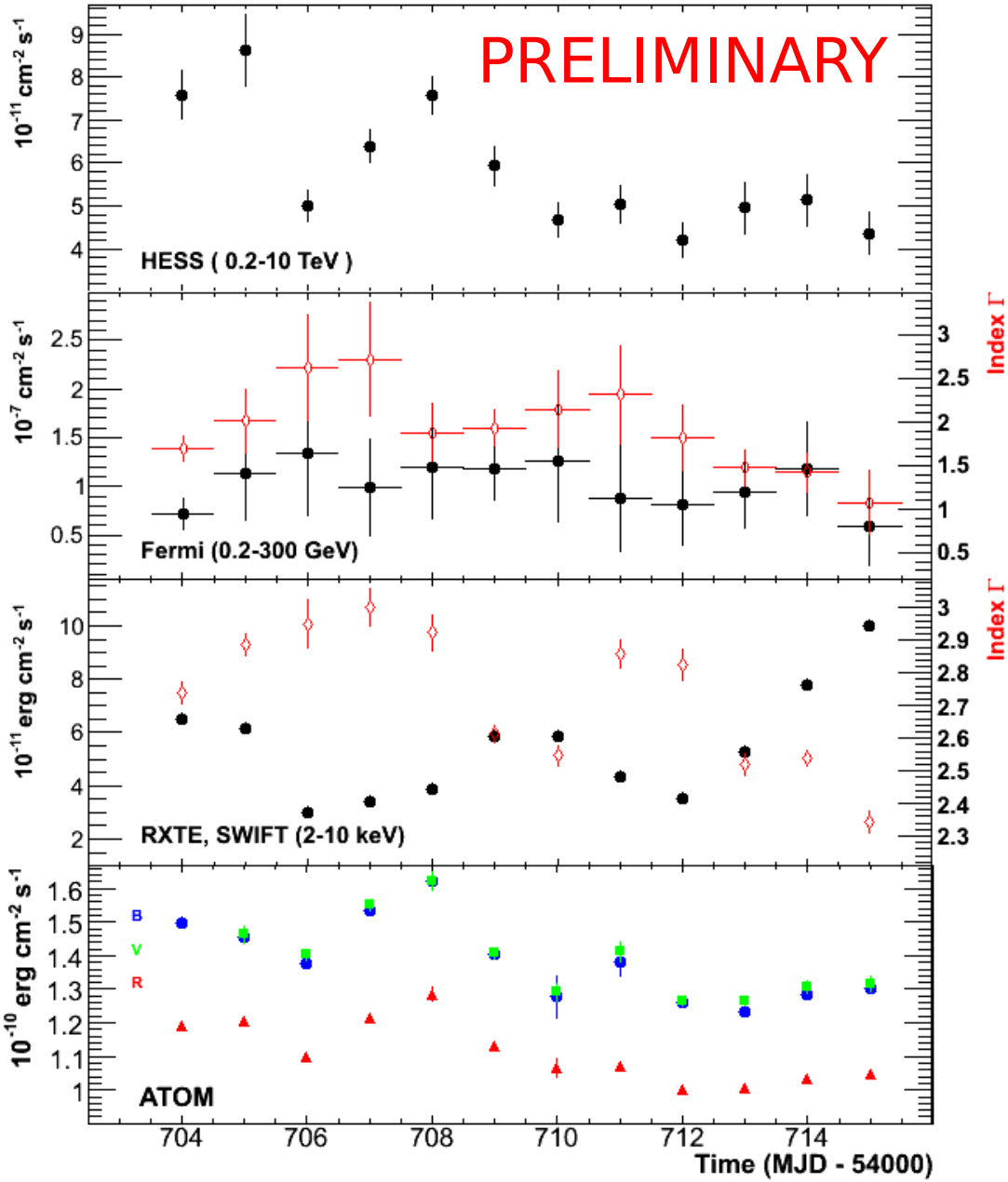
LC of 12 days

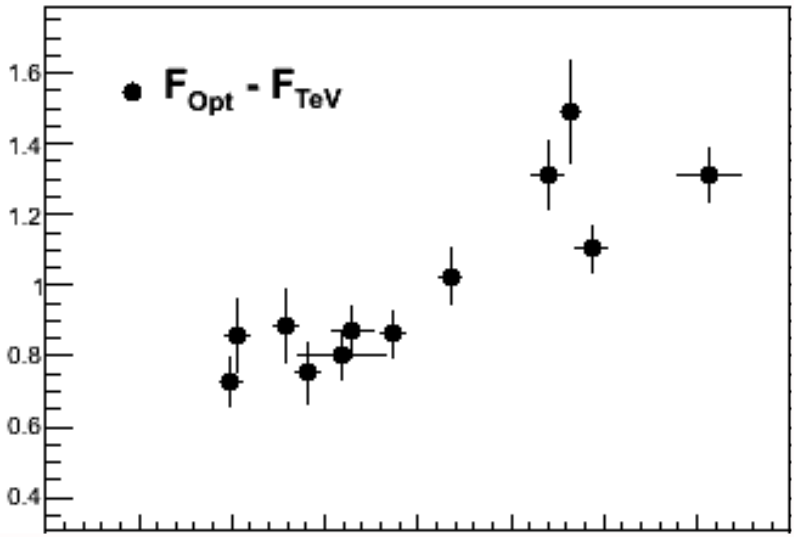
- VHE, 23%
- HE, <20%
- X, 35%
-



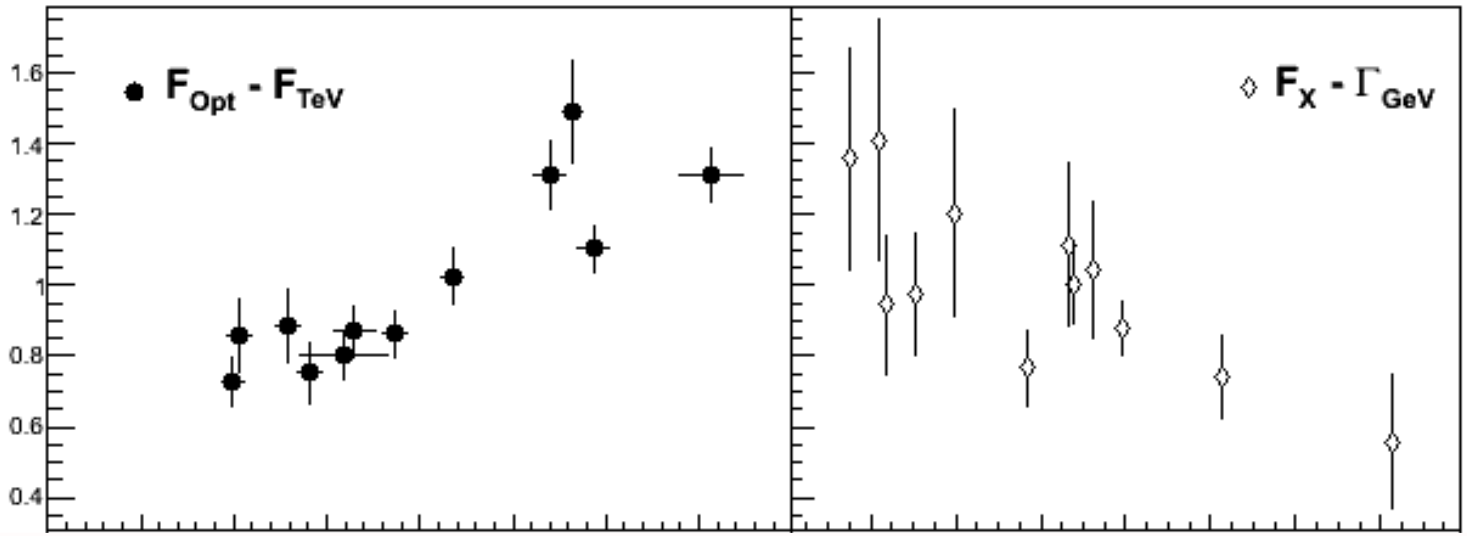
LC of 12 days

- VHE, 23%
- HE, <20%
- X, 35%
- Optical, 8%

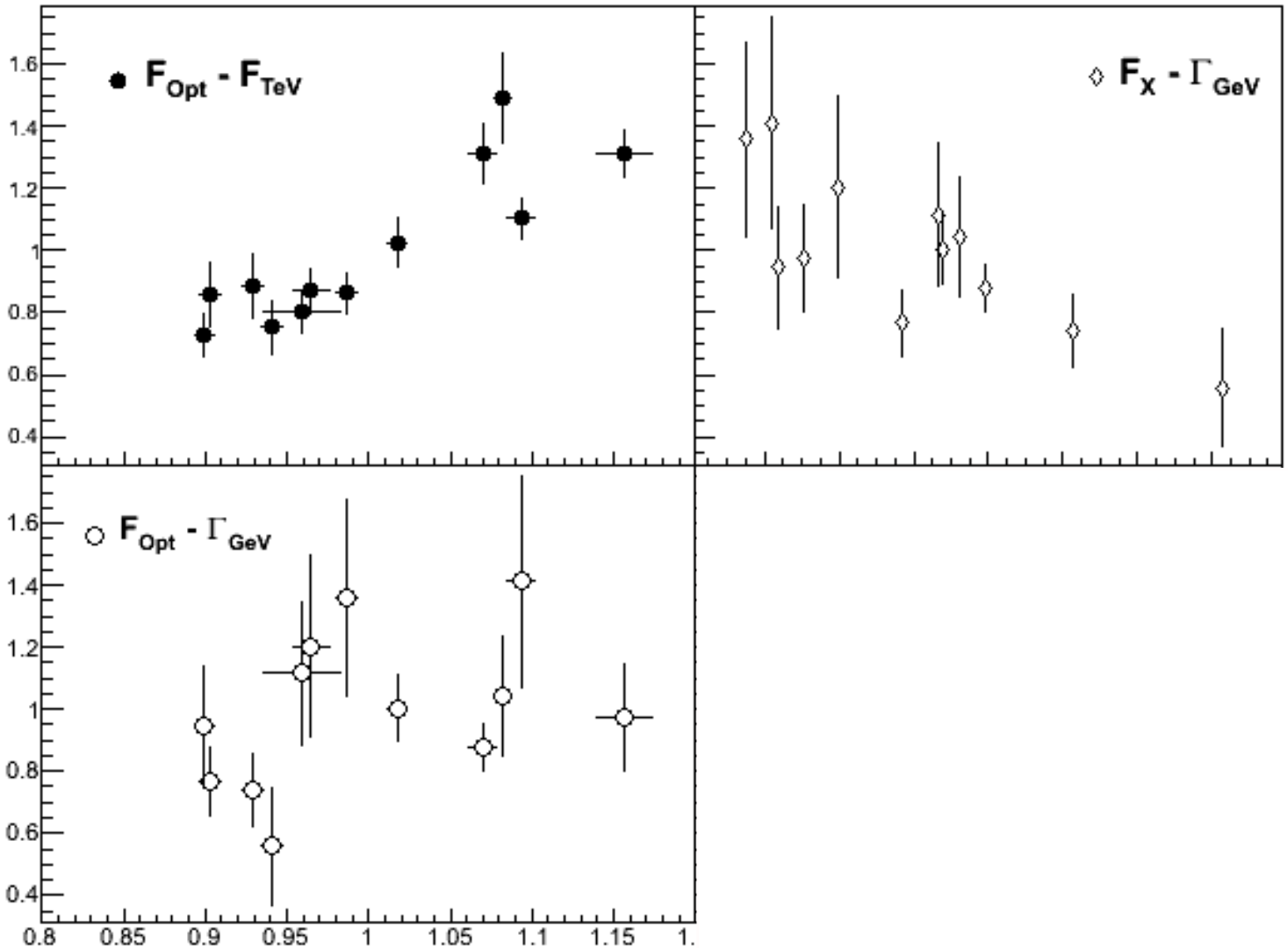




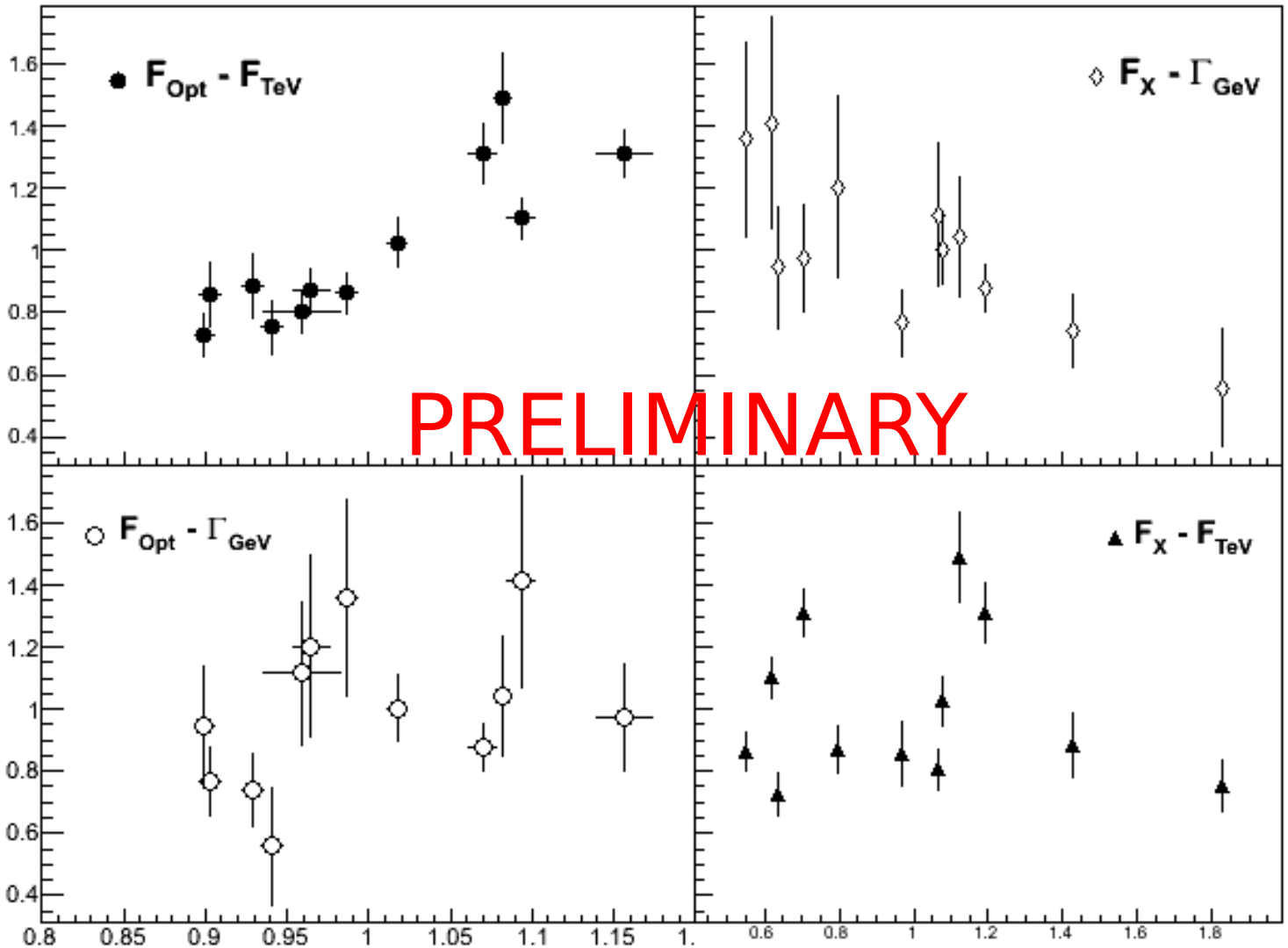
Optical and VHE fluxes : $r = (0.77 - 0.86) \pm 0.09$



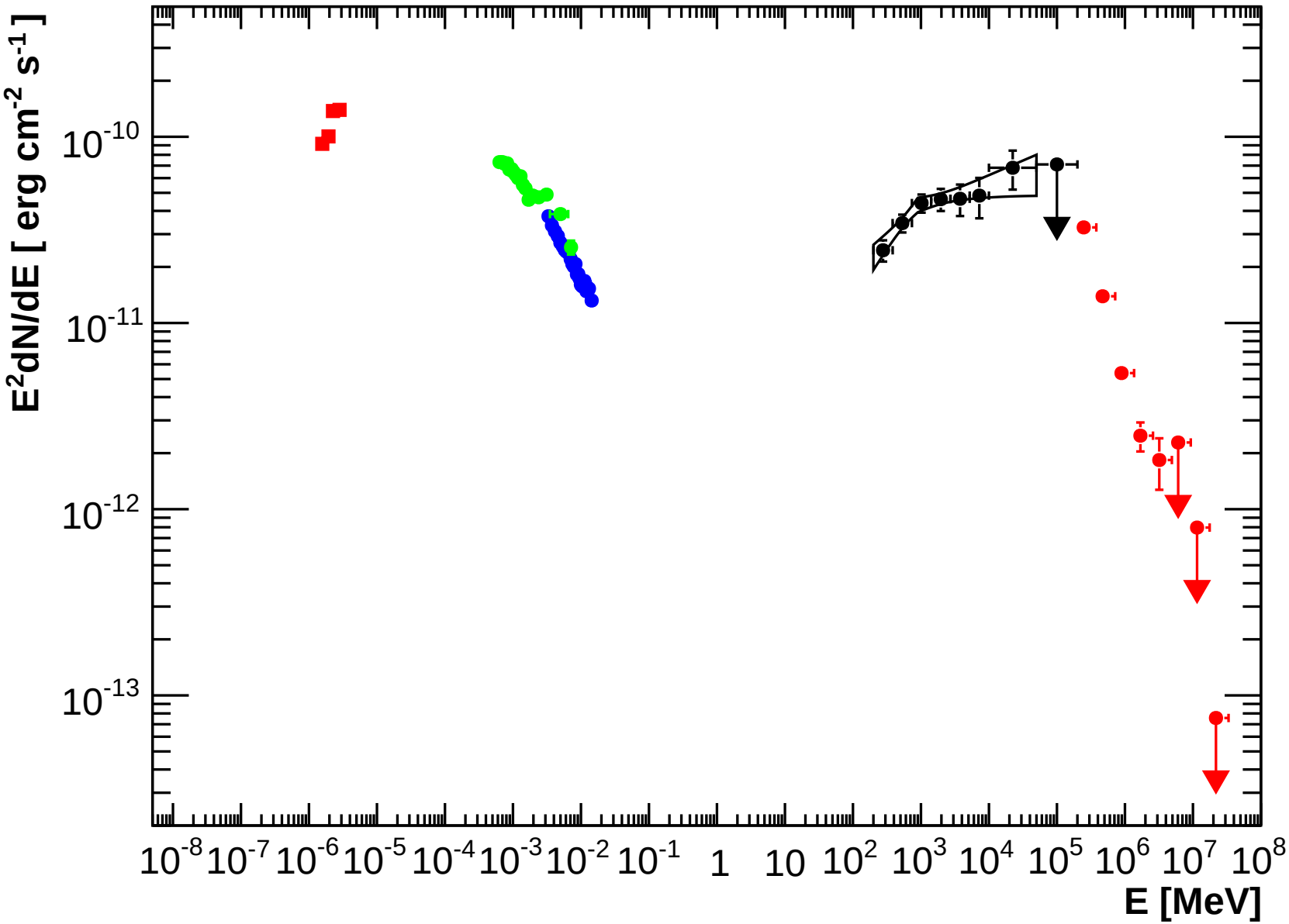
X-ray flux and Fermi photon index : $r = -0.80 \pm 0.15$

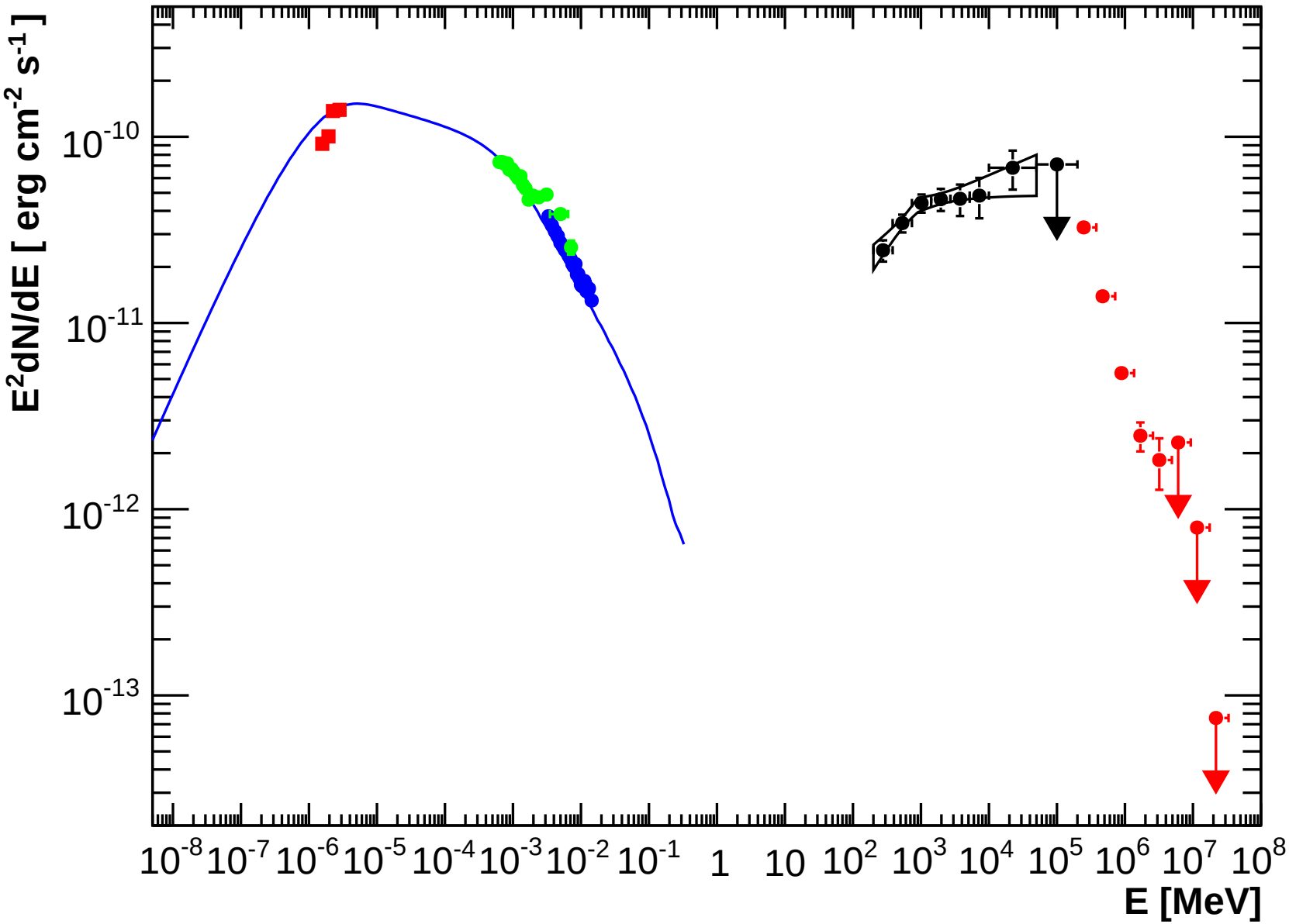


Optical flux and Fermi photon index : $r = 0.10 \pm 0.28$



X-ray and VHE fluxes : $r = 0.12 \pm 0.10$


E²dN/dE [erg cm⁻² s⁻¹]
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸
E [MeV]


E²dN/dE [erg cm⁻² s⁻¹]
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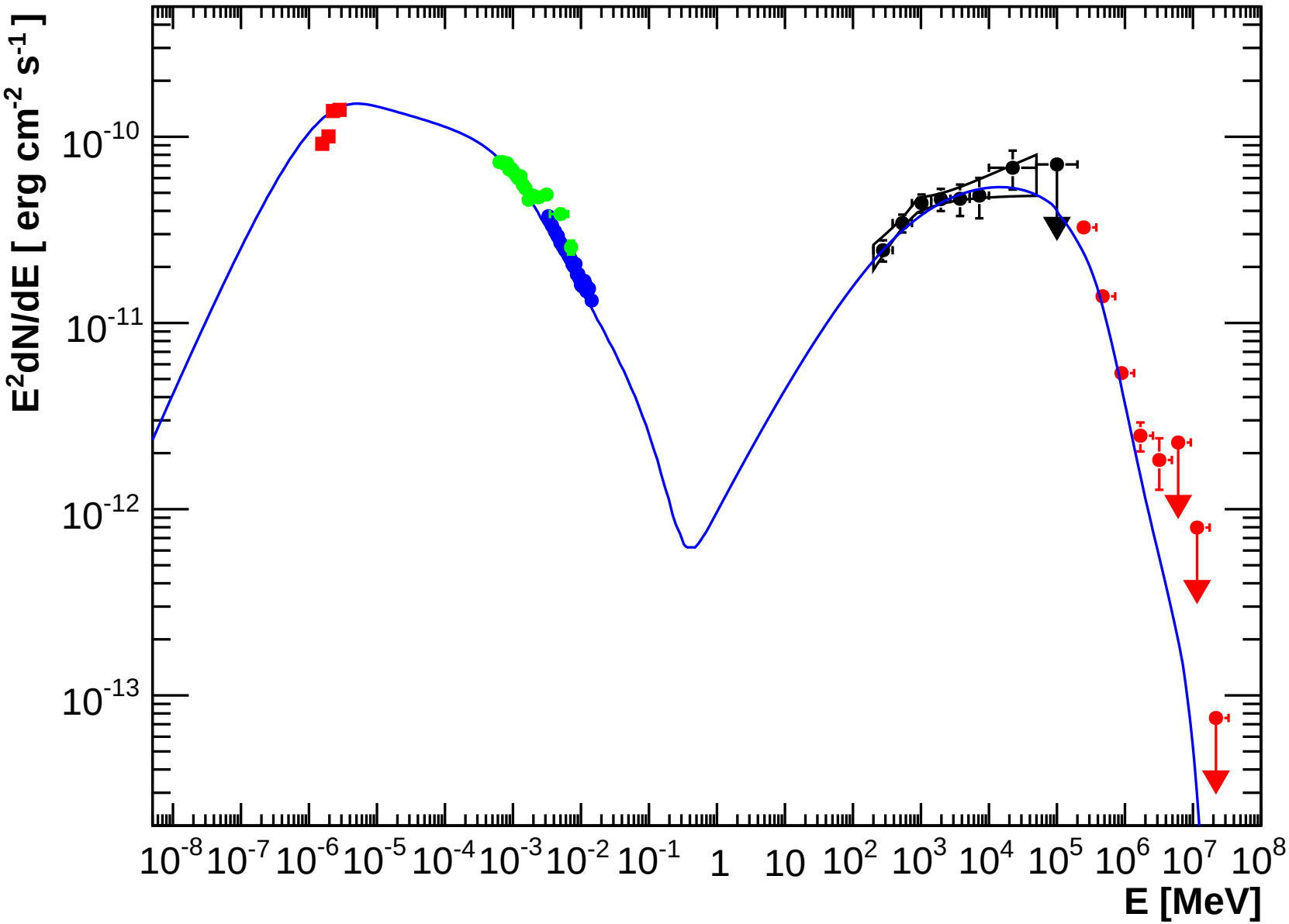
10⁻¹³
10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸
E [MeV]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10⁻¹¹
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10⁻¹³
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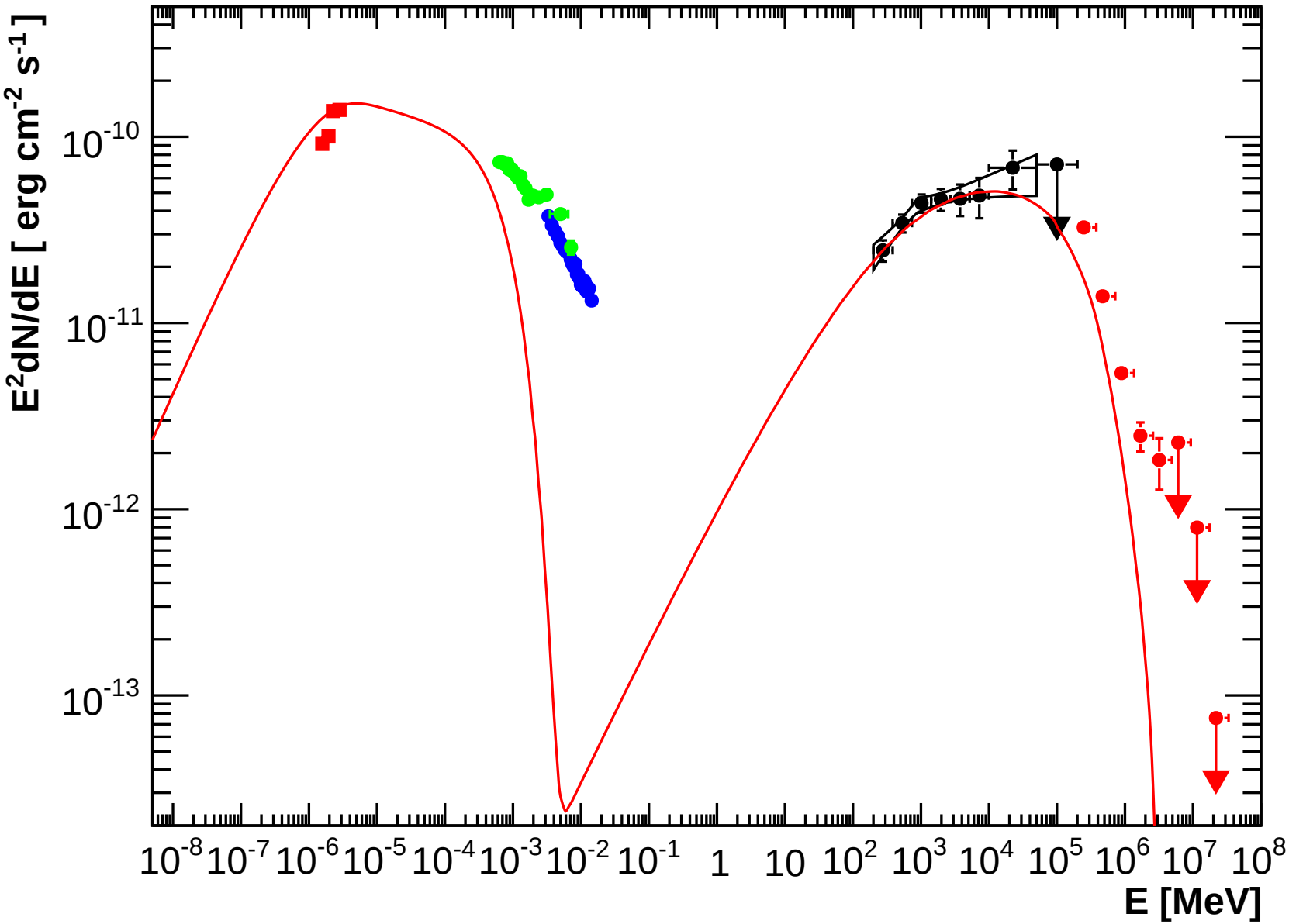
E [MeV]


E²dN/dE [erg cm⁻² s⁻¹]
10⁻¹⁰
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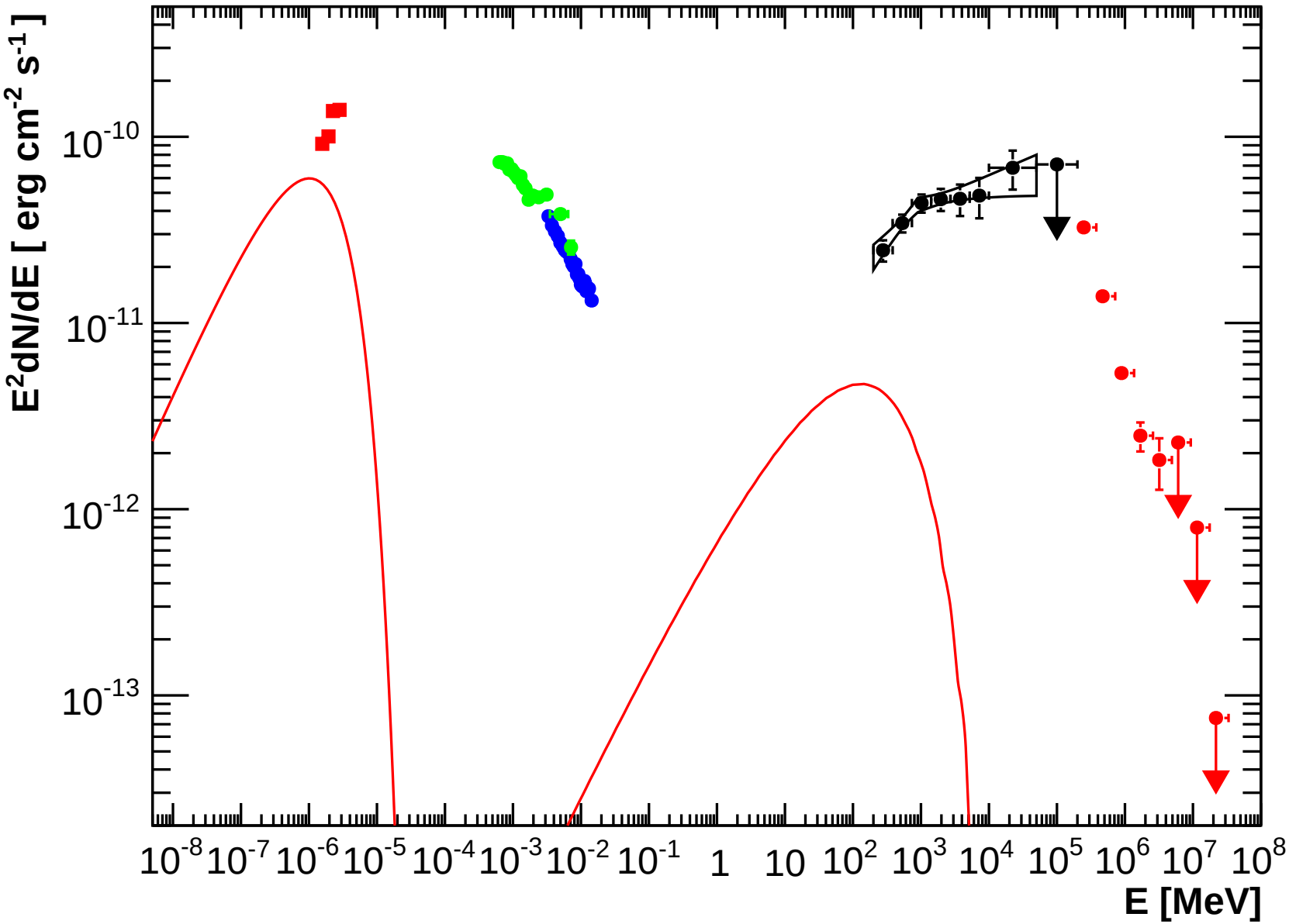
10⁻¹³
10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸
E [MeV]


E²dN/dE [erg cm⁻² s⁻¹]
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸
E [MeV]

Conclusions

First simultaneous Fermi-HESS campaign

- PKS 2155-304 was detected by Fermi in a low and hard state
- a spectral softening was found at $\approx 1\mathrm{GeV}$
- No X ray - TeV correlation
- Optical - TeV correlation
- X ray - Fermi photon index correlation
- SSC model : Klein-Nishina effect
- Can't explain all correlations
- Need multi-zone model to explain correlations

Backup Slides

definition of $F_{\rm var}$

x a measurement σ_{err} the error.
average :

$$\bar{x} = \frac{1}{N}\Sigma x$$

variance :

$$S^2 = \mathrm{var}(x)$$

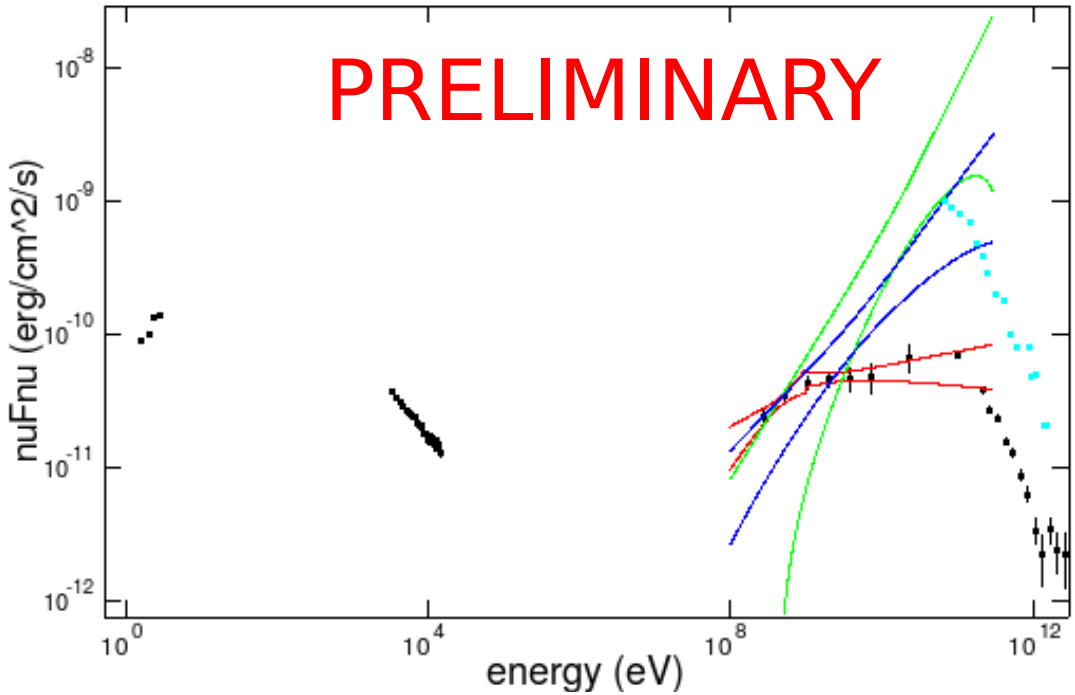
square of errors

$$var_{err} = \frac{1}{N}\Sigma \sigma_{err}^2$$

Normalized excess variance

$$F_{\rm var} = \sqrt{\frac{S^2 - var_{err}}{\bar{x}^2}}$$

S. Vaughan et al, MNRA, 2003



blue curves : 1 sigma contours for the 1.77 day power-law fit

green curves : 1 sigma contours for the 0.22 day fit

Time interval	Integral (100 MeV-300 GeV)	Index
0.22 day	1.90 $\pm$ 1.00 e-7	-0.97 $\pm$ 0.26
1.77 day	1.43 $\pm$ 0.52 e-7	-1.32 $\pm$ 0.16

Flux alone might not indicate an ongoing TeV flare

Optical and VHE fluxes correlation : Is it real?

Possible bias :

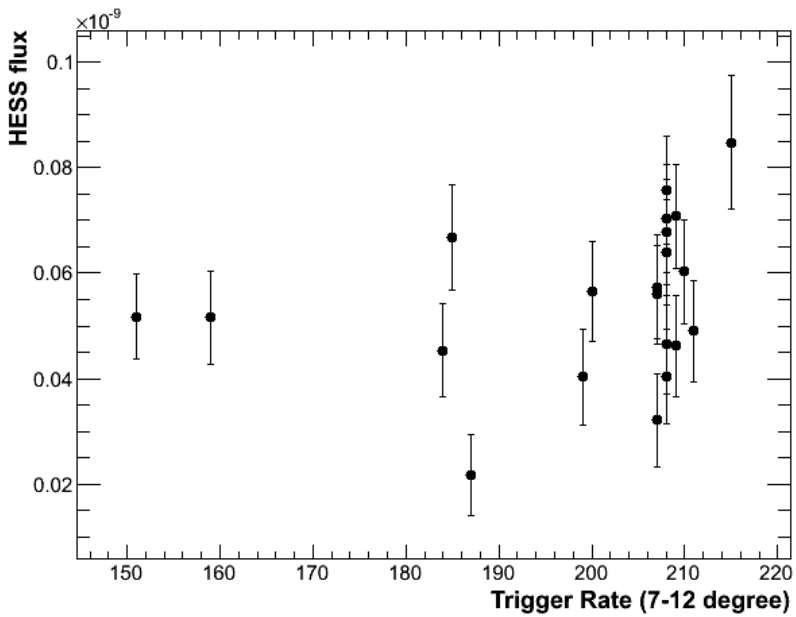
- ATOM and HESS share the same site : atmospheric effects
- Systematic errors are not taken into account

HESS trigger rate

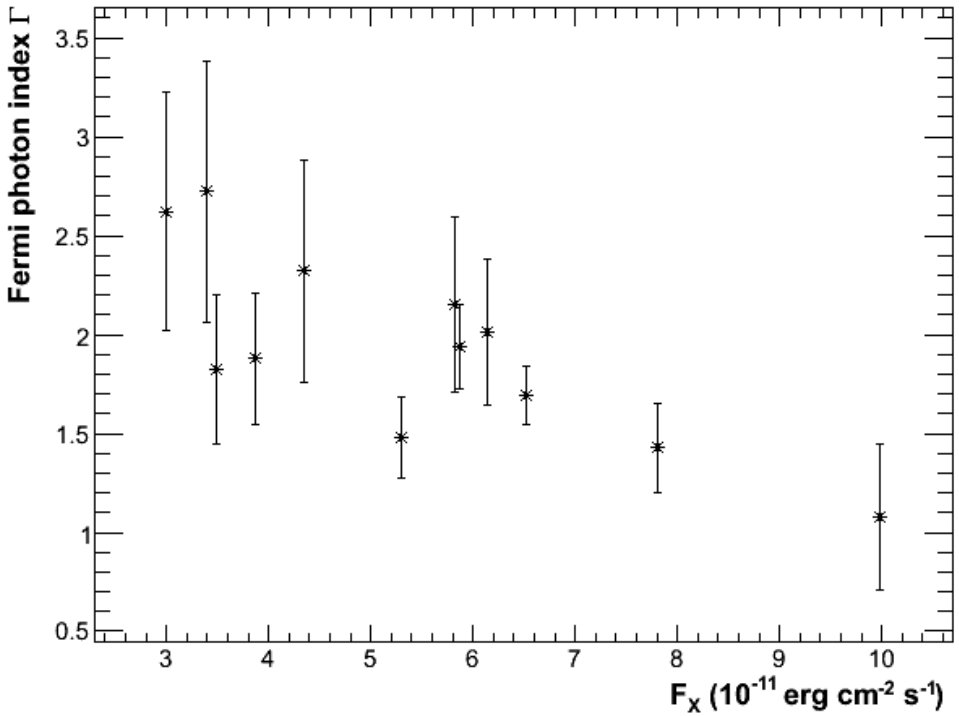
For each night, small zenith angle window (7-12 degree) : clearly no correlation

Reference stars are stable in the ATOM light curve

errors enhanced by 30% : the correlation is still there



$F_X - \Gamma_{HE}$ correlation



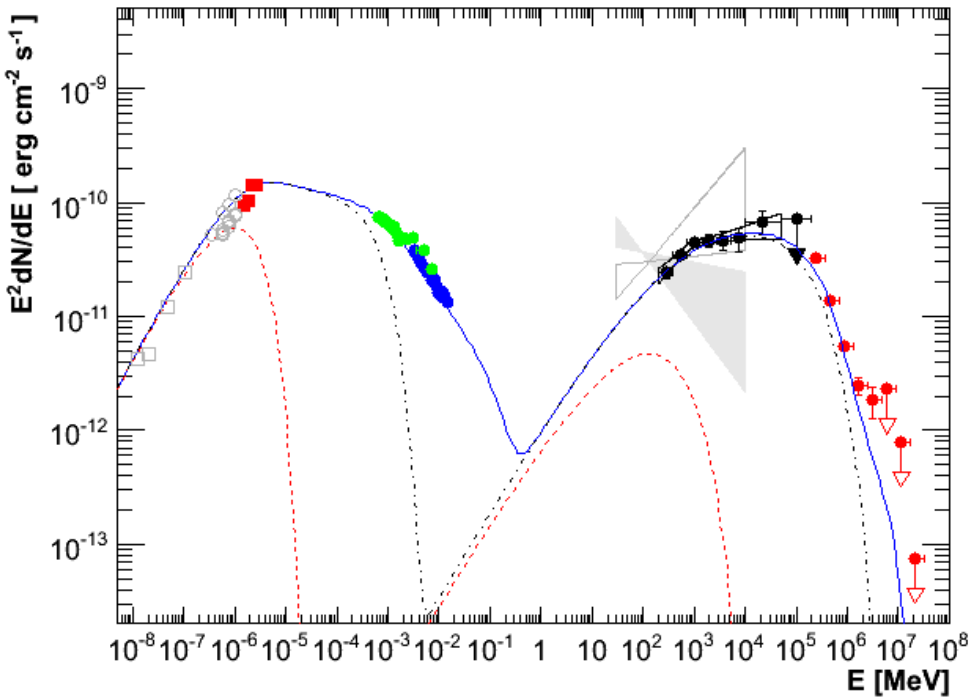
1-degree (p0) and 2-degree (p1) polynomial fit
p0 probability = 19%
p1 probability = 64%
F_{test} : 8.73, probability 1.4%

Time average SSC model : "Straw man" model

LAT : $\Gamma_L = 1.61 \pm 0.16$, $\Gamma_H = 1.96 \pm 0.08$, $E_{br} = 1.0 \pm 0.3$

SSC parameters :

- $N_e \propto E^{-s}$, $s_0 = 1.3$, $s_1 = 3.2$, $s_2 = 4.3$
- $\gamma_1 = 1.4 \times 10^4$, $\gamma_2 = 2.3 \times 10^5$
- $R = 1.5 \times 10^17$, $\delta = 32$, $B = 0.018 G$



Electrons producing X-ray do not produce VHE photons.
HE and VHE photons are produced by electrons $\gamma_1 < \gamma < \gamma_2$