Study of Flux and Spectral Variations in the VHE Emission from the Blazar Markarian 501

David Paneque

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submitted to ApJ

OUTLINE

1- Motivation to observe Mrk 501 (again…)

2- Report of the results from the Mrk 501 observations performed with MAGIC (more *details in the paper*)

3- Prospects for GLAST observations on Mrk 501

4- Conclusions and outlook

1- Motivation to observe Mrk 501 (again…)

The physics related to Mrk 501 (and AGNs in general) is not yet understood, despite these guys have been studied for >= 10 years ***(see talks from Padovani, Celotti… in GLAST symposium)***

Culprits

1 - Time evolving broad band spectra

Coordination of instruments covering different energies needed

2 - Poor sensitivity to study high energy part (E>1 GeV)

Large observation times (with EGRET and "old" IACTs) were required to have a decent signal to make physics. Most of our HBL's knowledge relates to the high state

Current experimental data allows for a big inter-model and intra-model degeneracy

More and "higher quality" data required to constrain models

1- Motivation to observe Mrk 501 (again…)

Present and near future:

New Generation of IACTs came online (low Eth, high sensitivity)

GLAST in operation next year (~25 more sensitive than EGRET)

Excellent laboratory for studying High Energy blazar emission

Strong gamma ray source (0.2-0.5 crabs in low state)
z = 0.034; low EBL absorption, we see “almost” intrinsic features

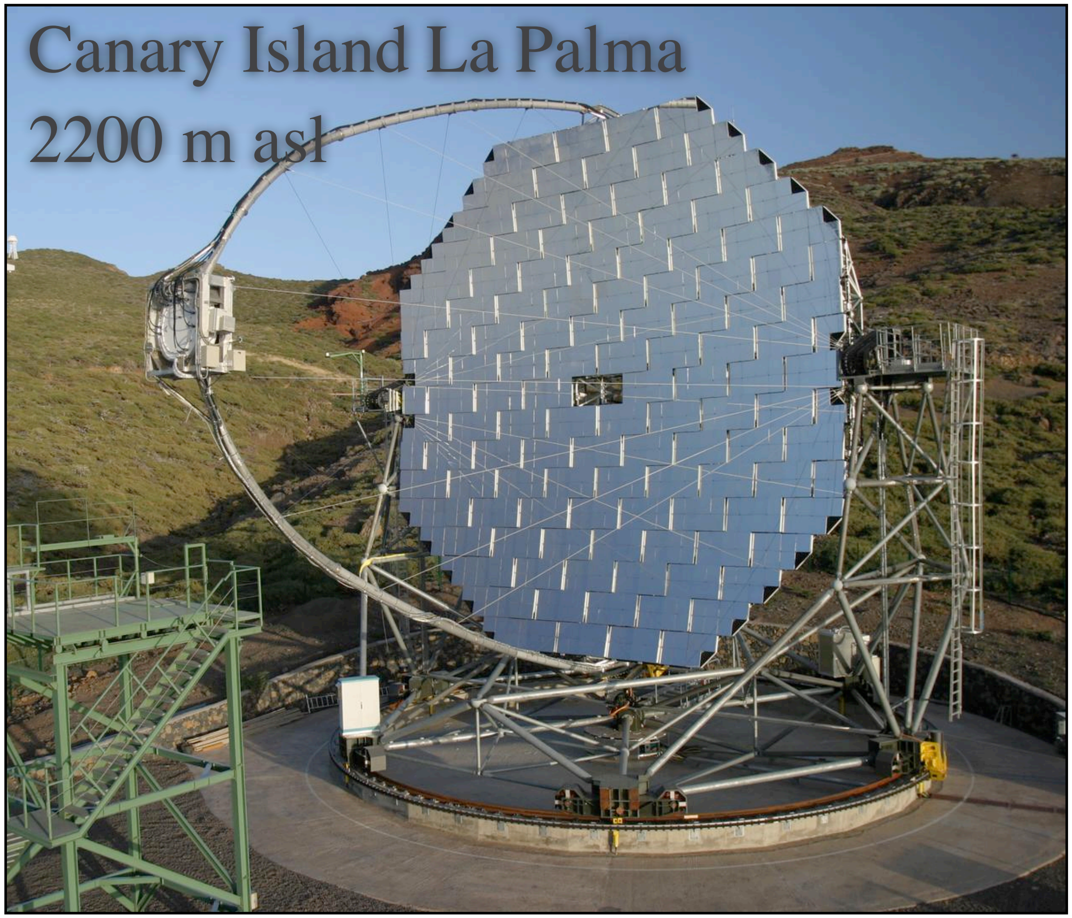
Things we know about Mrk 501 (and HBLs in general)

Dominant gamma-ray emission mechanism is believed to have a leptonic origin (SSC, EC) , at least in high (flaring) state

- **Fast variations (few hours in VHE)**
- **X rays- Gamma-rays correlation (in general)**

2-The used instrument: MAGIC Telescope

Largest Imaging Air Cherenkov Telescope (IACT)
for performing γ-ray astronomy. In operation since Sept. 2004



17 m ∅ mirror dish (**239 m^2**)
3.5^0 Field of View camera with **576 high-QE PMTs**
Fast repositioning **$t_R < 40$ s**

Trigger threshold energy: ~**50 GeV**
Minimum energy for spectral analysis : **100 GeV**
Angular resolution per incoming photon: **0.1^0-0.15^0**
Energy resolution : **20%-30%**
Point source sensitivity:
2.5% Crab / 50 hours

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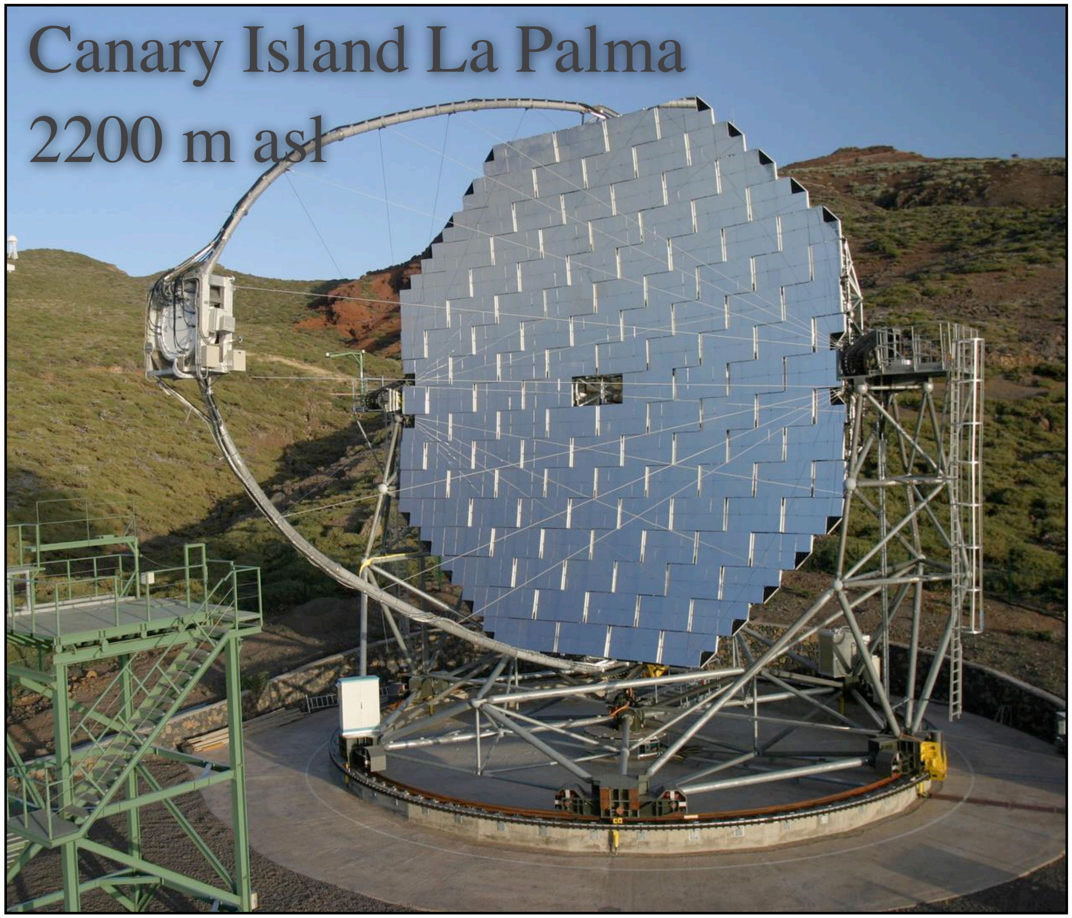


Latest public reports given in the Glast Symposium:

Galactic: Cortina (Torres) et al.

Extragalactic: Mazin et al.

+

Discovery of BLLac as γ-ray emitter; first LBL at VHE

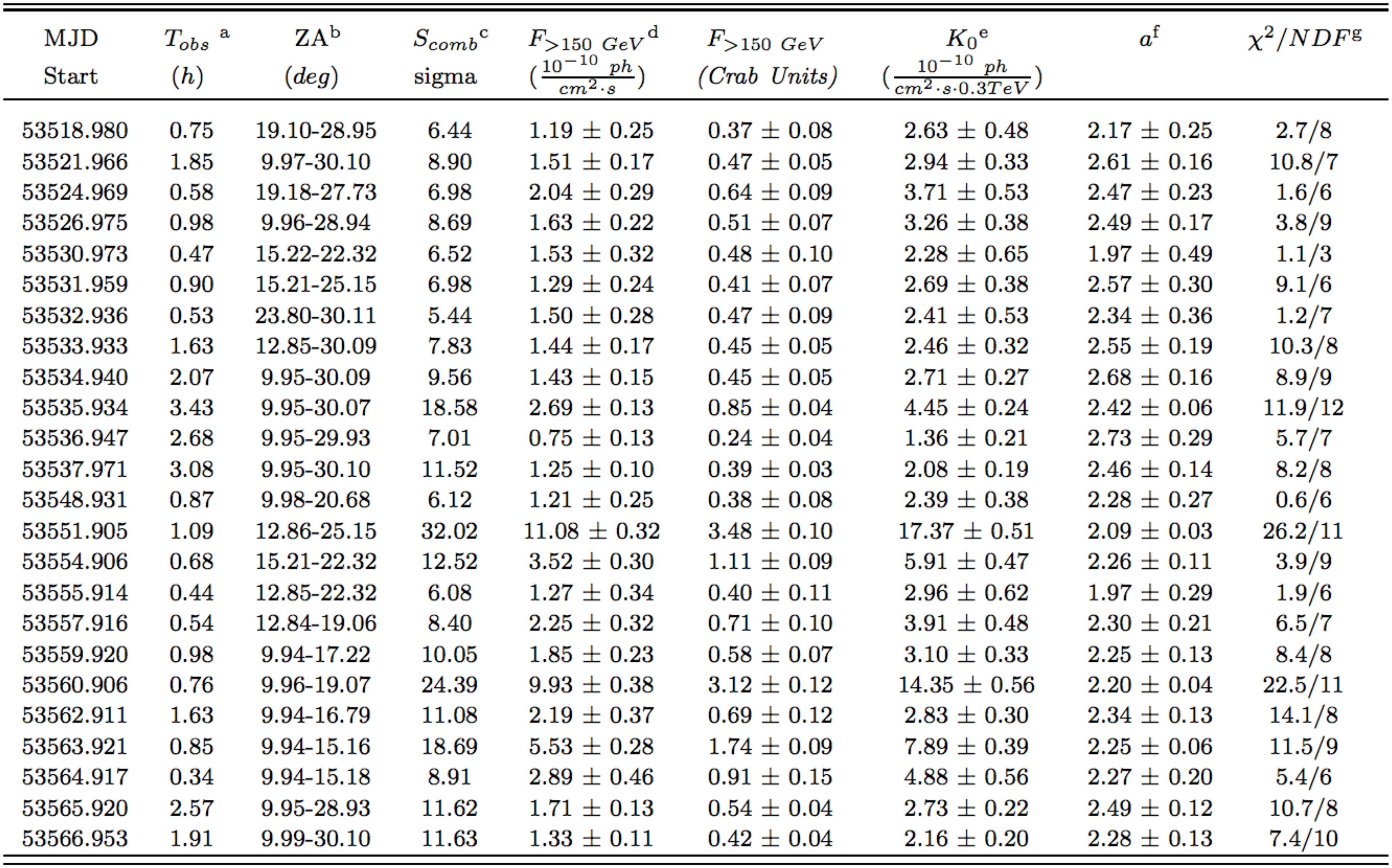
astro-ph/0703084

2- Analysis of the MAGIC data (24 nights, 32 h)

June-July 2005

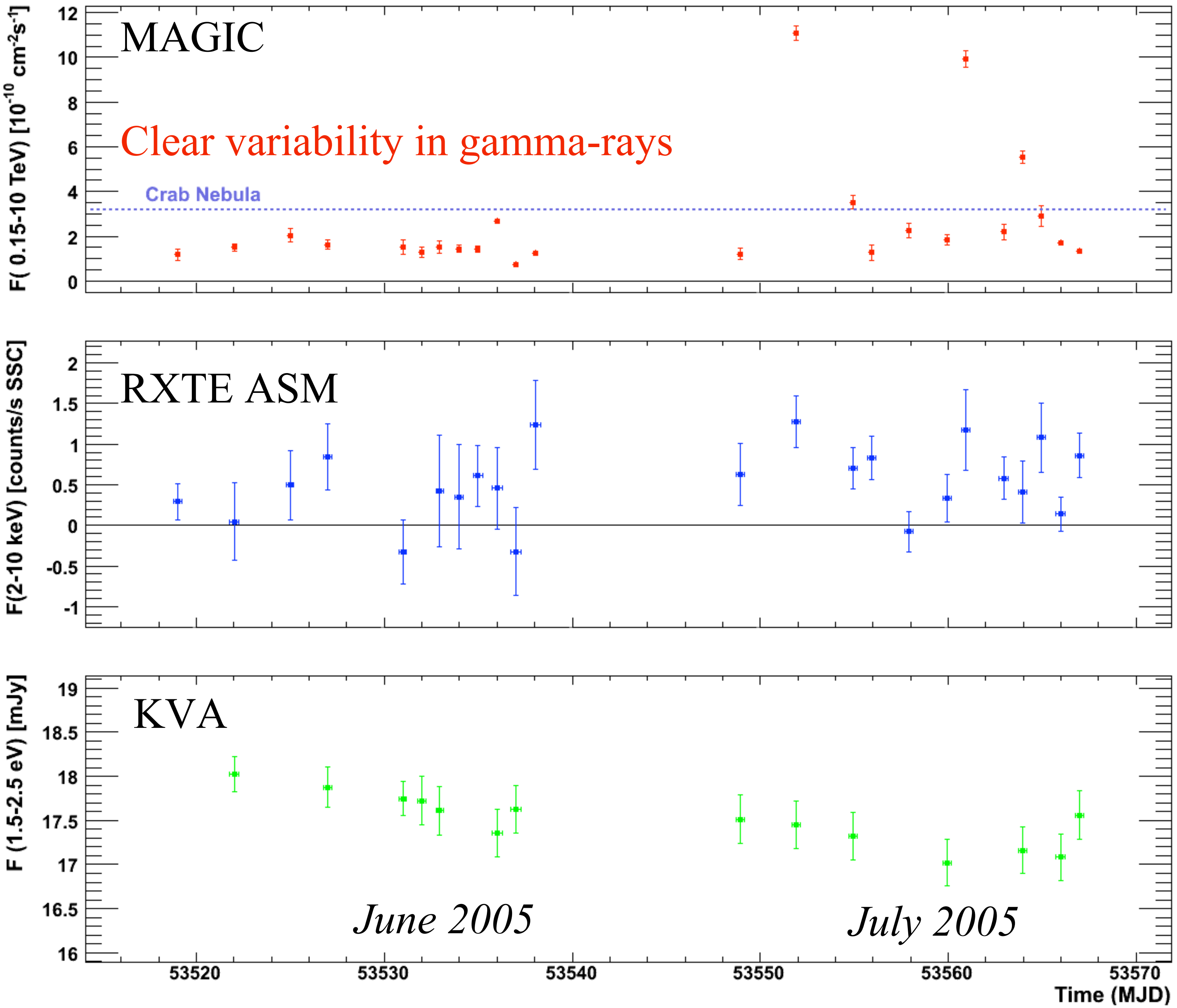
Flux and spectra determined on a night-by-night basis

Obs. Nights ⟷ Gamma-Flux ⟷ Power Law fit to spectra ⟷



MJD Start	T_{obs} [a] (h)	ZA[b] (deg)	S_{comb}[c] sigma	$F_{>150\ GeV}$[d] ($\frac{10^{-10}\ ph}{cm^2 \cdot s}$)	$F_{>150\ GeV}$ ($Crab\ Units$)	K_0[e] ($\frac{10^{-10}\ ph}{cm^2 \cdot s \cdot 0.3 TeV}$)	a[f]	χ^2/NDF[g]	P [h] (%)
53518.980	0.75	19.10-28.95	6.44	1.19 ± 0.25	0.37 ± 0.08	2.63 ± 0.48	2.17 ± 0.25	2.7/8	95.2
53521.966	1.85	9.97-30.10	8.90	1.51 ± 0.17	0.47 ± 0.05	2.94 ± 0.33	2.61 ± 0.16	10.8/7	15.0
53524.969	0.58	19.18-27.73	6.98	2.04 ± 0.29	0.64 ± 0.09	3.71 ± 0.53	2.47 ± 0.23	1.6/6	95.0
53526.975	0.98	9.96-28.94	8.69	1.63 ± 0.22	0.51 ± 0.07	3.26 ± 0.38	2.49 ± 0.17	3.8/9	92.4
53530.973	0.47	15.22-22.32	6.52	1.53 ± 0.32	0.48 ± 0.10	2.28 ± 0.65	1.97 ± 0.49	1.1/3	78.9
53531.959	0.90	15.21-25.15	6.98	1.29 ± 0.24	0.41 ± 0.07	2.69 ± 0.38	2.57 ± 0.30	9.1/6	16.6
53532.936	0.53	23.80-30.11	5.44	1.50 ± 0.28	0.47 ± 0.09	2.41 ± 0.53	2.34 ± 0.36	1.2/7	99.2
53533.933	1.63	12.85-30.09	7.83	1.44 ± 0.17	0.45 ± 0.05	2.46 ± 0.32	2.55 ± 0.19	10.3/8	24.2
53534.940	2.07	9.95-30.09	9.56	1.43 ± 0.15	0.45 ± 0.05	2.71 ± 0.27	2.68 ± 0.16	8.9/9	44.8
53535.934	3.43	9.95-30.07	18.58	2.69 ± 0.13	0.85 ± 0.04	4.45 ± 0.24	2.42 ± 0.06	11.9/12	45.3
53536.947	2.68	9.95-29.93	7.01	0.75 ± 0.13	0.24 ± 0.04	1.36 ± 0.21	2.73 ± 0.29	5.7/7	57.1
53537.971	3.08	9.95-30.10	11.52	1.25 ± 0.10	0.39 ± 0.03	2.08 ± 0.19	2.46 ± 0.14	8.2/8	41.4
53548.931	0.87	9.98-20.68	6.12	1.21 ± 0.25	0.38 ± 0.08	2.39 ± 0.38	2.28 ± 0.27	0.6/6	99.6
53551.905	1.09	12.86-25.15	32.02	11.08 ± 0.32	3.48 ± 0.10	17.37 ± 0.51	2.09 ± 0.03	26.2/11	0.6
53554.906	0.68	15.21-22.32	12.52	3.52 ± 0.30	1.11 ± 0.09	5.91 ± 0.47	2.26 ± 0.11	3.9/9	92.1
53555.914	0.44	12.85-22.32	6.08	1.27 ± 0.34	0.40 ± 0.11	2.96 ± 0.62	1.97 ± 0.29	1.9/6	92.5
53557.916	0.54	12.84-19.06	8.40	2.25 ± 0.32	0.71 ± 0.10	3.91 ± 0.48	2.30 ± 0.21	6.5/7	48.5
53559.920	0.98	9.94-17.22	10.05	1.85 ± 0.23	0.58 ± 0.07	3.10 ± 0.33	2.25 ± 0.13	8.4/8	39.9
53560.906	0.76	9.96-19.07	24.39	9.93 ± 0.38	3.12 ± 0.12	14.35 ± 0.56	2.20 ± 0.04	22.5/11	2.1
53562.911	1.63	9.94-16.79	11.08	2.19 ± 0.37	0.69 ± 0.12	2.83 ± 0.30	2.34 ± 0.13	14.1/8	8.2
53563.921	0.85	9.94-15.16	18.69	5.53 ± 0.28	1.74 ± 0.09	7.89 ± 0.39	2.25 ± 0.06	11.5/9	24.3
53564.917	0.34	9.94-15.18	8.91	2.89 ± 0.46	0.91 ± 0.15	4.88 ± 0.56	2.27 ± 0.20	5.4/6	49.7
53565.920	2.57	9.95-28.93	11.62	1.71 ± 0.13	0.54 ± 0.04	2.73 ± 0.22	2.49 ± 0.12	10.7/8	21.6
53566.953	1.91	9.99-30.10	11.63	1.33 ± 0.11	0.42 ± 0.04	2.16 ± 0.20	2.28 ± 0.13	7.4/10	69.0

2.1- Light curves (LCs): Gamma, X-rays, Optical



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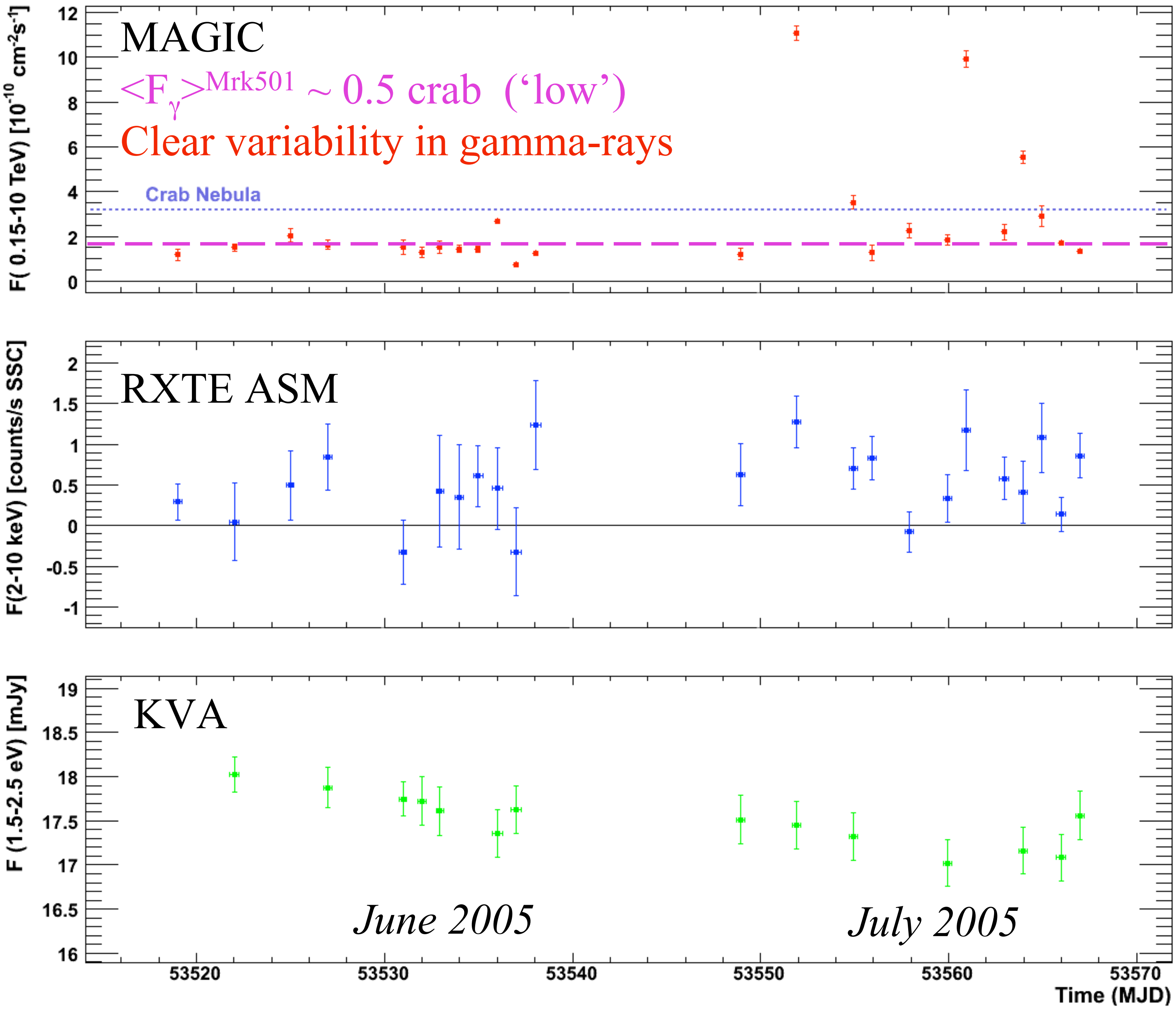


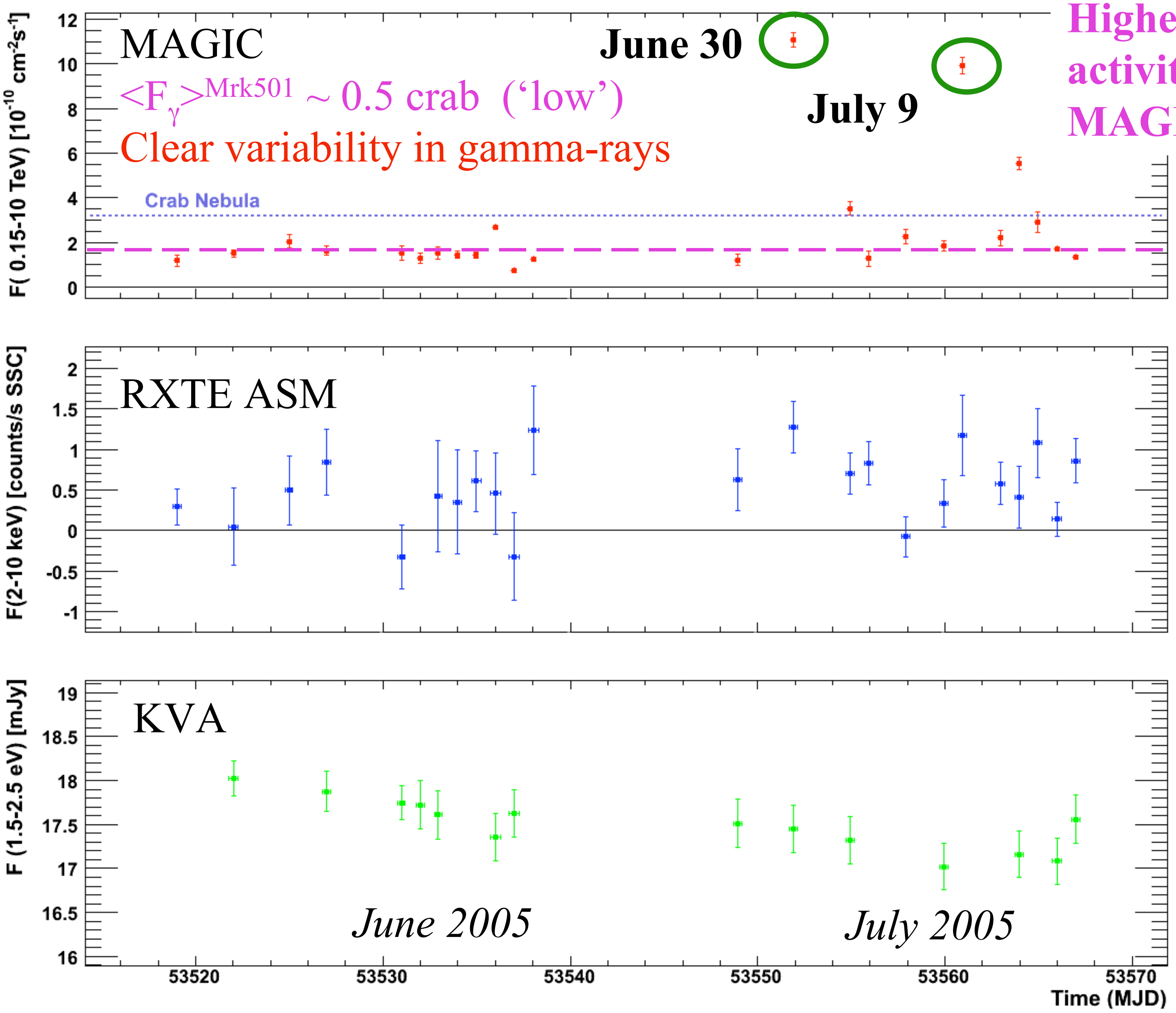
$\langle F_{\gamma}\rangle^{\mathrm{Mrk501}} \sim 0.5$ crab ('low')

Clear variability in gamma-rays

June 2005

July 2005

2.1- Light curves (LCs): Gamma, X-rays, Optical



$\langle F_\gamma \rangle^{\mathrm{Mrk501}} \sim 0.5$ crab (‘low’)

Clear variability in gamma-rays

June 30

July 9

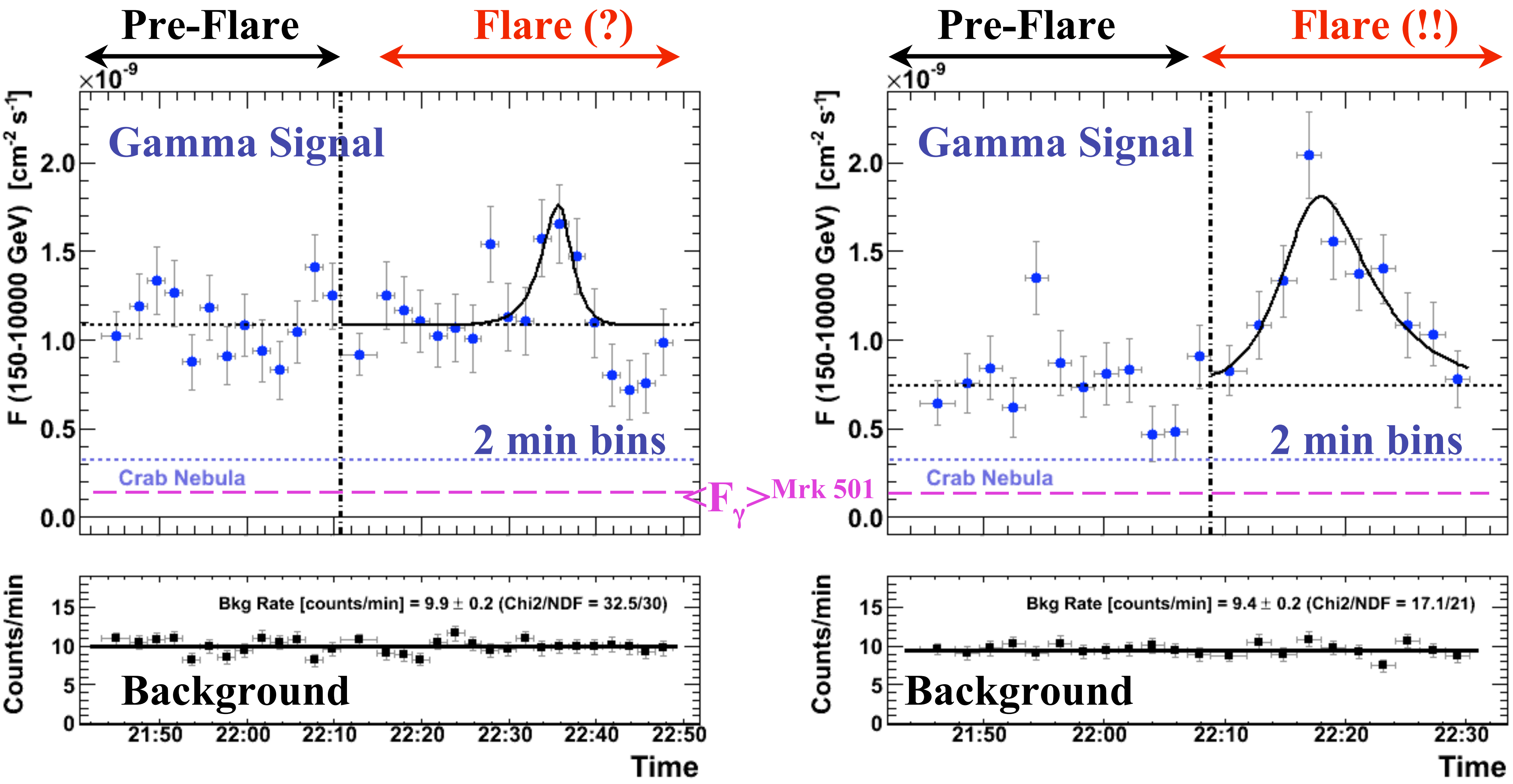
Highest VHE activity during MAGIC obs.

June 2005

July 2005

2.2- Intra-night flux variations (E > 150 GeV)

June 30th ← **Highest VHE activity** → July 9th



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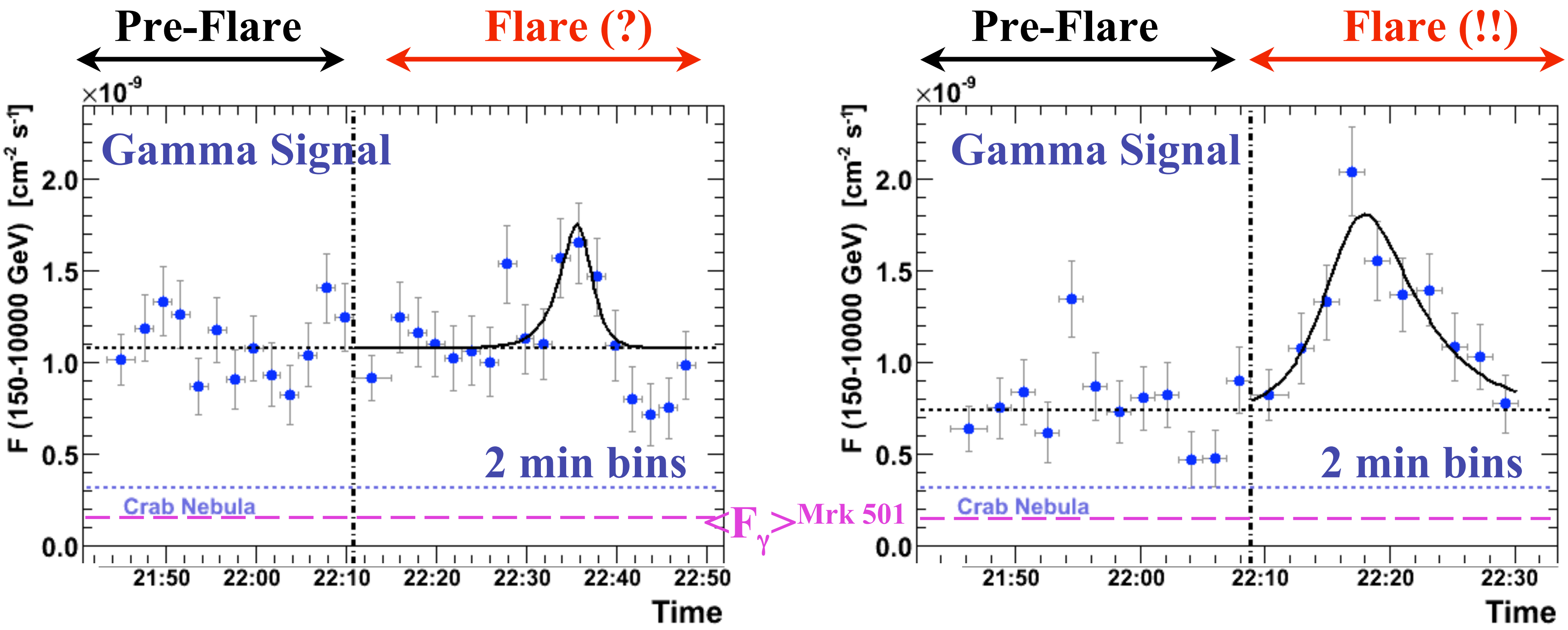
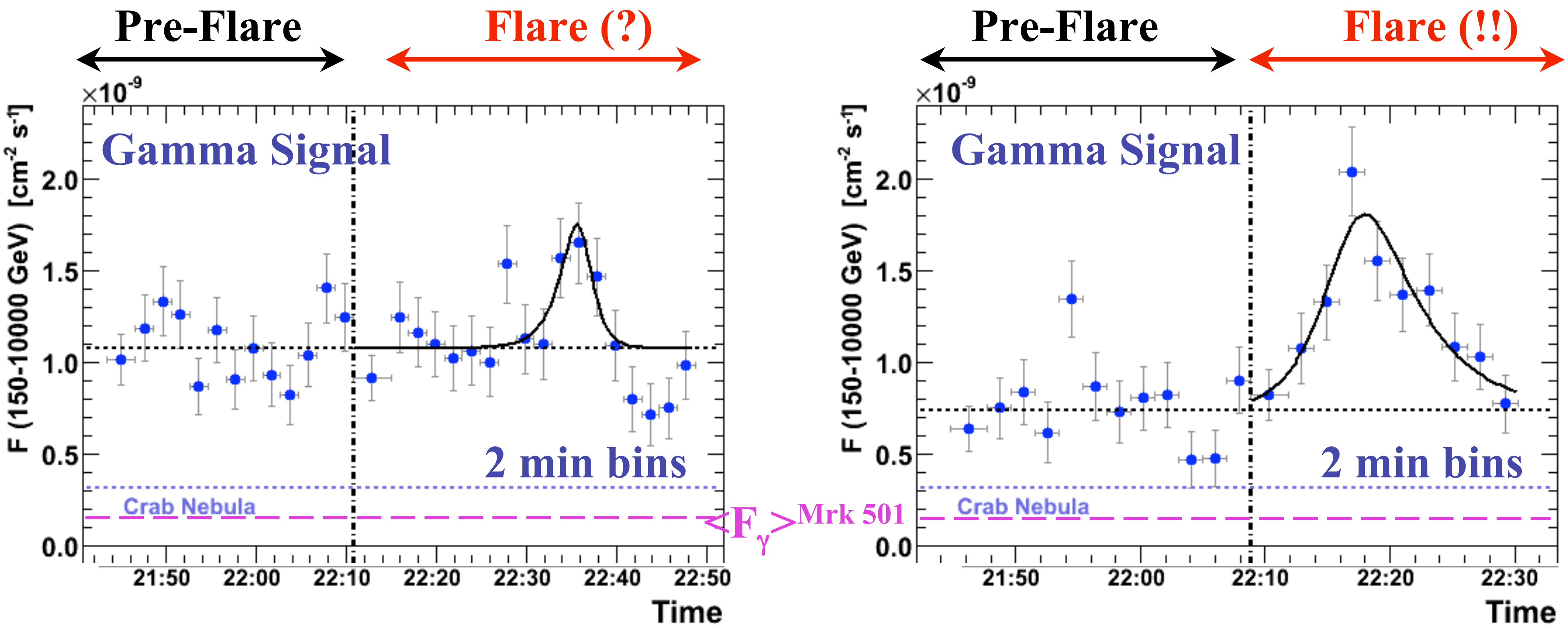


Flaring and *Flickering* (see talk S.Wagner on GLAST Symposium)

2.2- Intra-night flux variations (E > 150 GeV)

June 30th ← Highest VHE activity → July 9th



Assumption: **Flux variation (flare) on the top of a stable emission**

$$F(t) = a + \frac{b}{2^{-\frac{t-t_0}{c}} + 2^{\frac{t-t_0}{d}}}$$

a: pedestal (not fit)

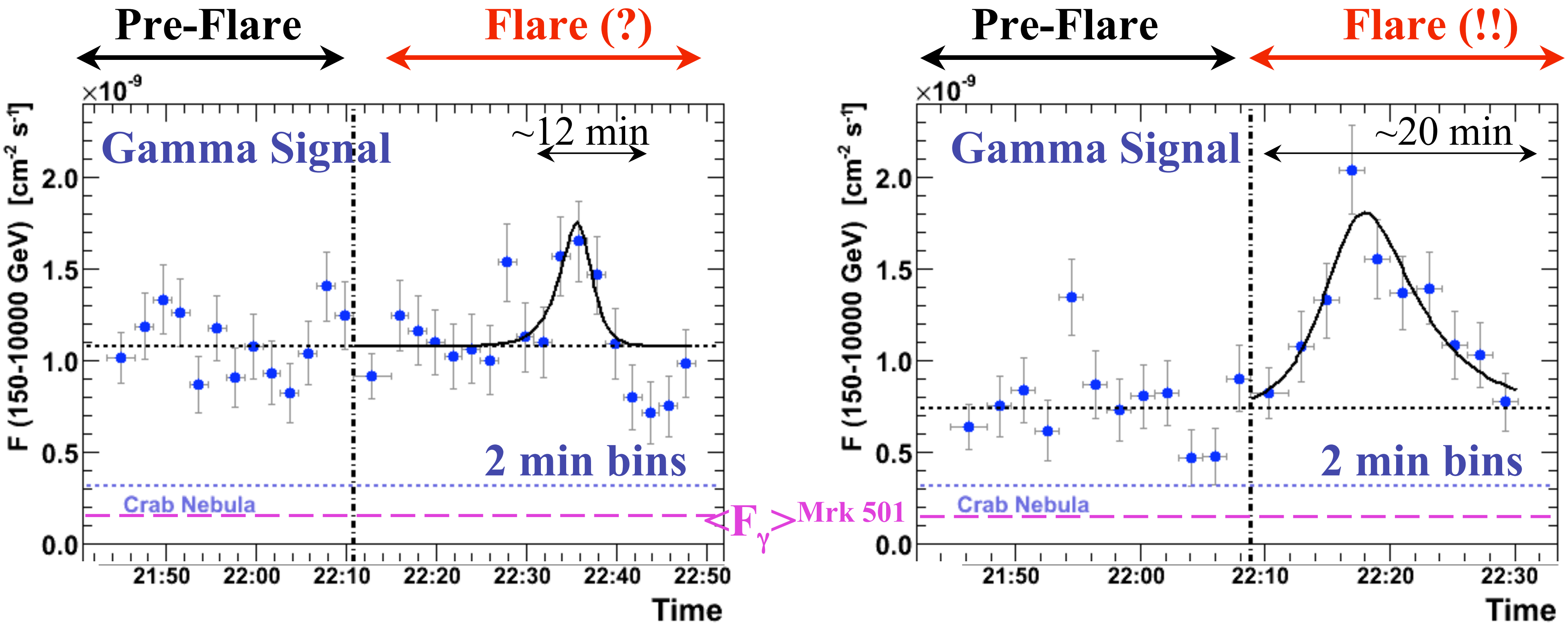
b: amplitude of flux variation

t_0: ~ peak position (not fit)

c, d: flux-doubling times

2.2- Intra-night flux variations (E > 150 GeV)

Fastest variability observed in Mrk 501



Assumption: **Flux variation (flare) on the top of a stable emission**

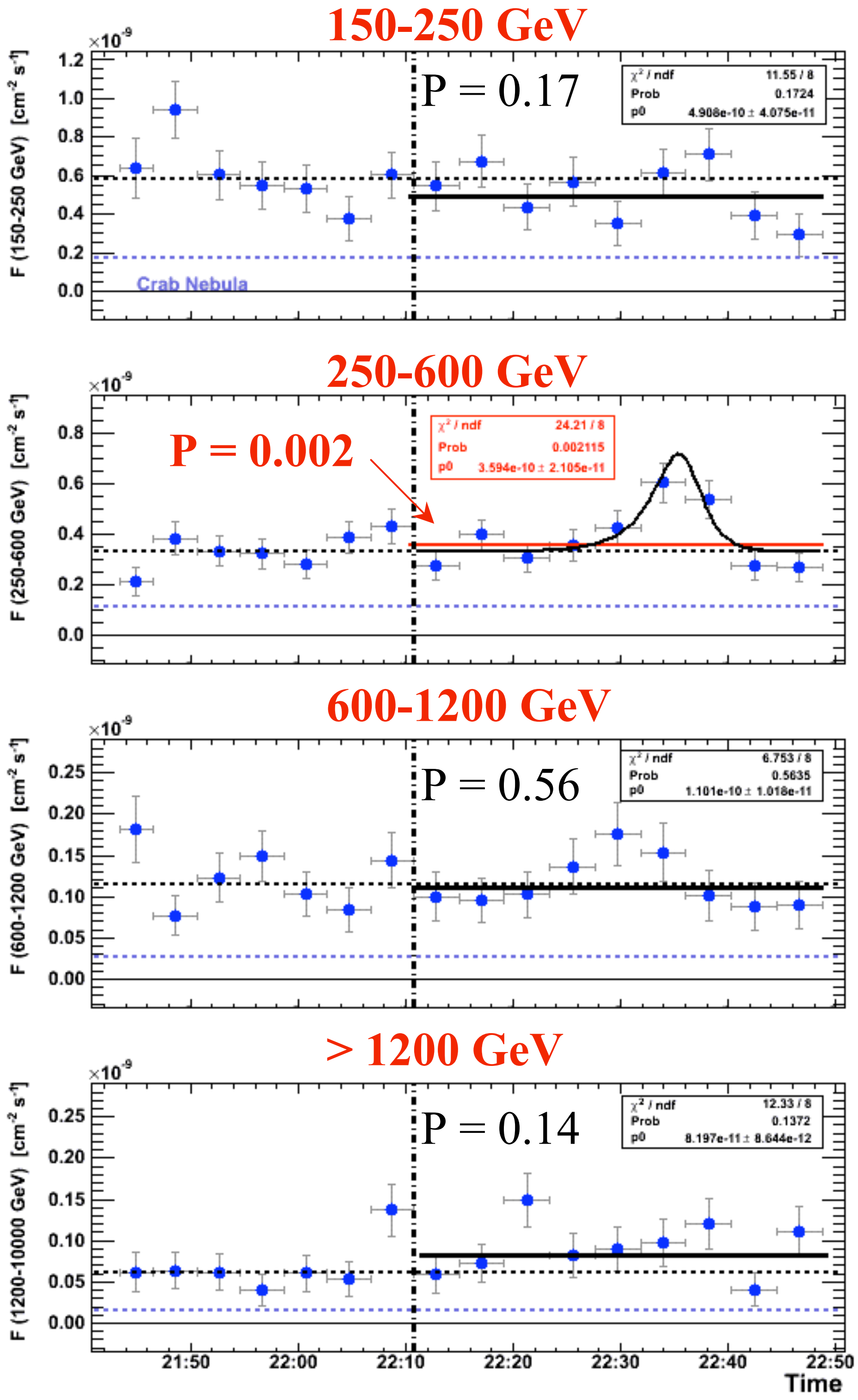
	b $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	c (s)	d (s)	χ^2/NDF[d]	P[e] (%)
Jun30	13.2±4.7	81±41	50±23	20.0/15	17.3[f]
Jul09	20.3±3.3	95±24	185±40	4.2/7	75.8

a: pedestal (not fit)

b: amplitude of flux variation

t_0: ~ peak position (not fit)

c, d: flux-doubling times


150-250 GeV

P = 0.17

250-600 GeV

P = 0.002

600-1200 GeV

P = 0.56

> 1200 GeV

P = 0.14

LCs for different energy ranges (4 min bins)

Active night: June 30

Flare is NOT seen in all energies

All energies are compatible with a constant flux emission, except for the range 250-600 GeV, where a constant emission is highly improbable

Results from fit with the idealistic flare function

$$F(t) = a + \frac{b}{2^{-\frac{t-t_0}{c}} + 2^{\frac{t-t_0}{d}}}$$

a: pedestal (not fit)

b: amplitude of flux variation

t_0: ~ peak position

c, d: flux-doubling times

E > 150 GeV

	b $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	c (s)	d (s)	χ^2/NDF[d]	P [e] (%)
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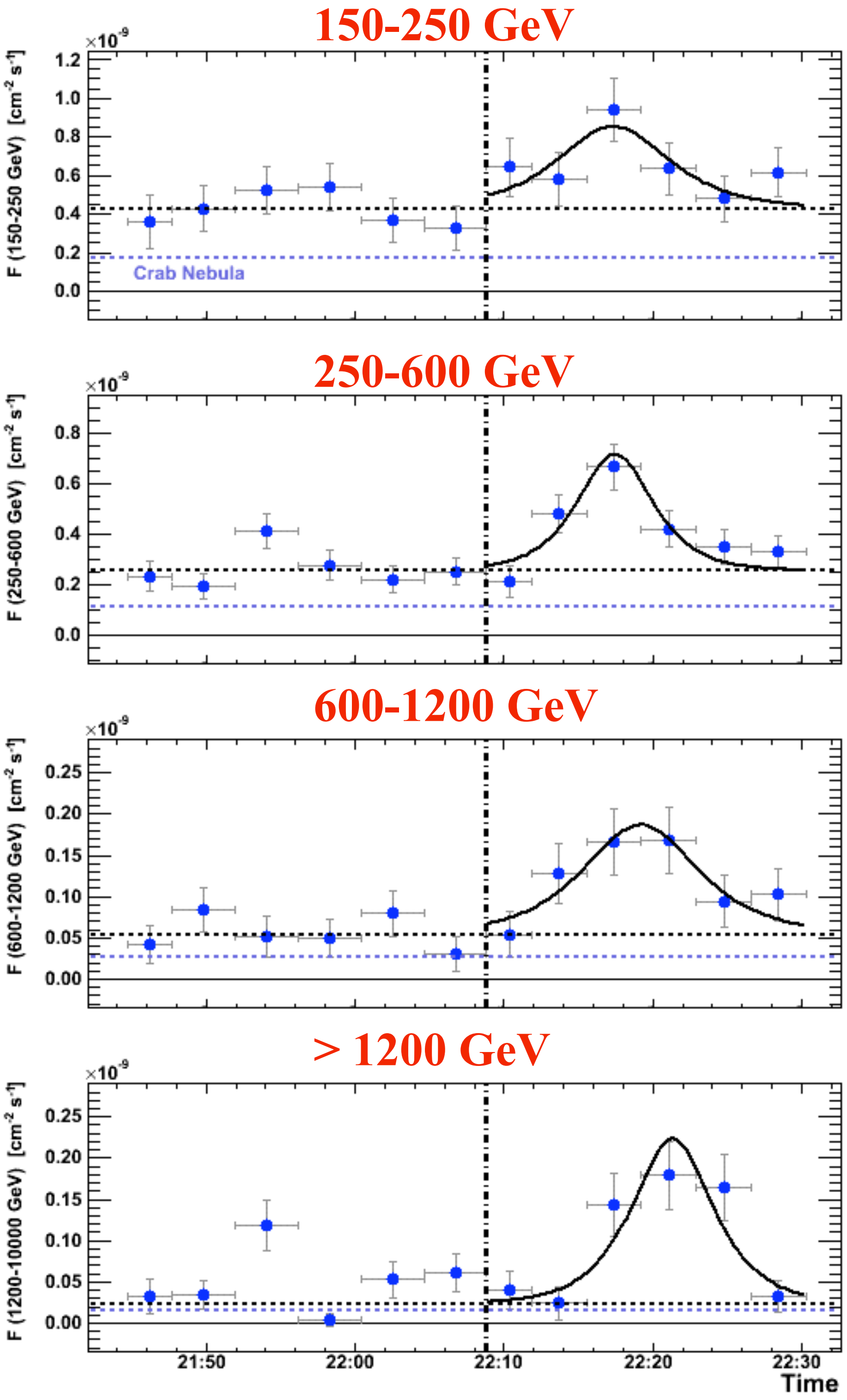
Jul09	20.3±3.3	95±24	185±40	4.2/7	75.8

Fit gives rather compatible numbers for these 2 energy ranges

June 30th (250 GeV<E < 600 GeV)

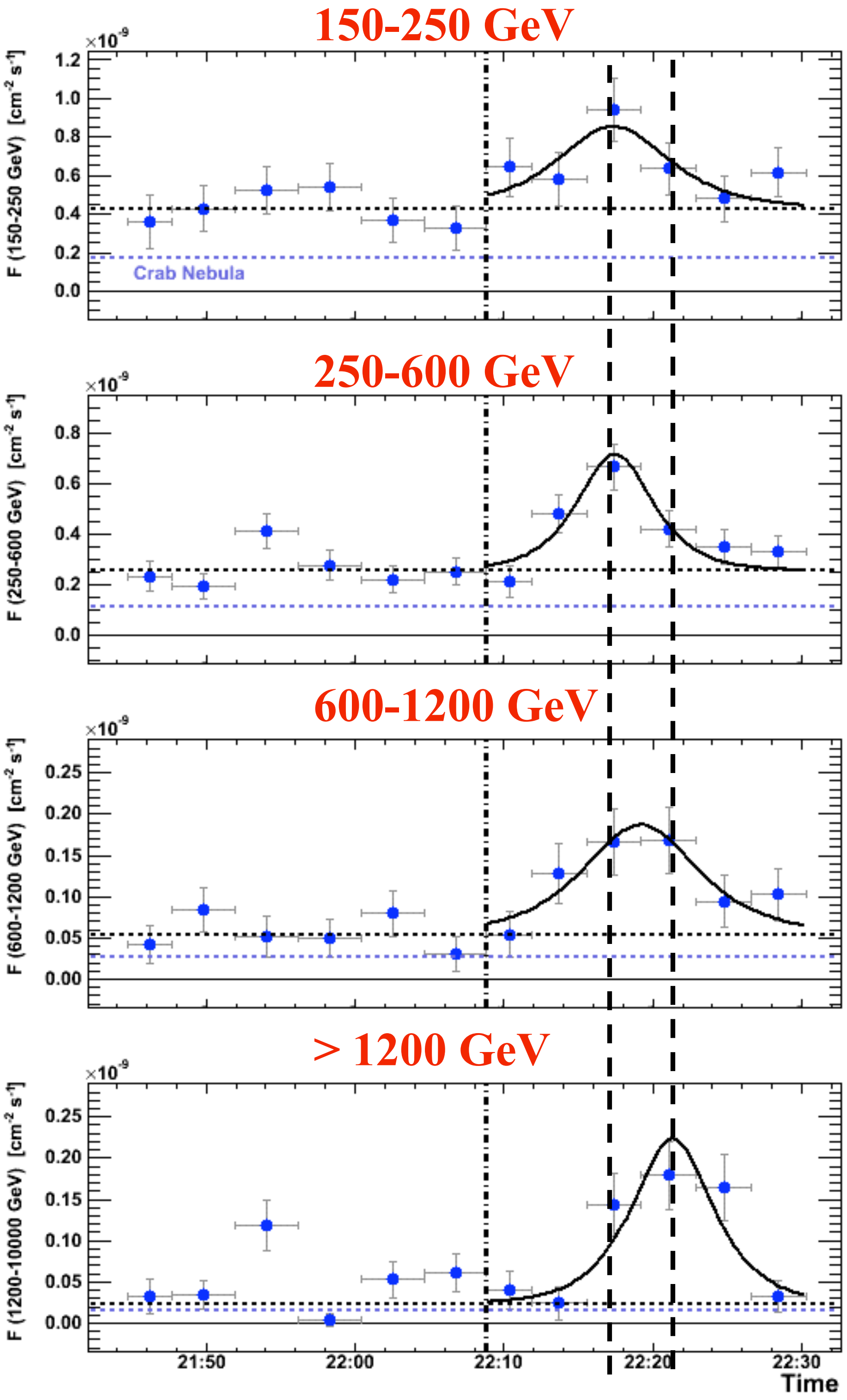
a[c] $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	a $(Crab\ Units)$	b $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	c (s)	d (s)	χ^2/NDF[d]	P [e] (%)
3.30±0.23	3.0±0.2	7.5±2.8	110±57	61±26	5.2/6	51.8



LCs for different energy ranges (4 min bins)

Active night: July 9

Flare is seen in all energy ranges



LCs for different energy ranges (4 min bins)

Active night: July 9

Flare is seen in all energy ranges

Time delay of 4 ± 1 minute between highest and lowest energy ranges

First time in VHE !!

Results from fit with the idealistic flare function

$$F(t) = a + \frac{b}{2^{-\frac{t-t_0}{c}} + 2^{\frac{t-t_0}{d}}}$$

a: pedestal (not fit)

b: amplitude of flux variation

t_0: ~ peak position

c, d: flux-doubling times

E > 150 GeV

	b $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	c (s)	d (s)	χ^2/NDF[d]	P [e] $(\%)$
Jun30	13.2±4.7	81±41	50±23	20.0/15	17.3[f]
Jul09	20.3±3.3	95±24	185±40	4.2/7	75.8

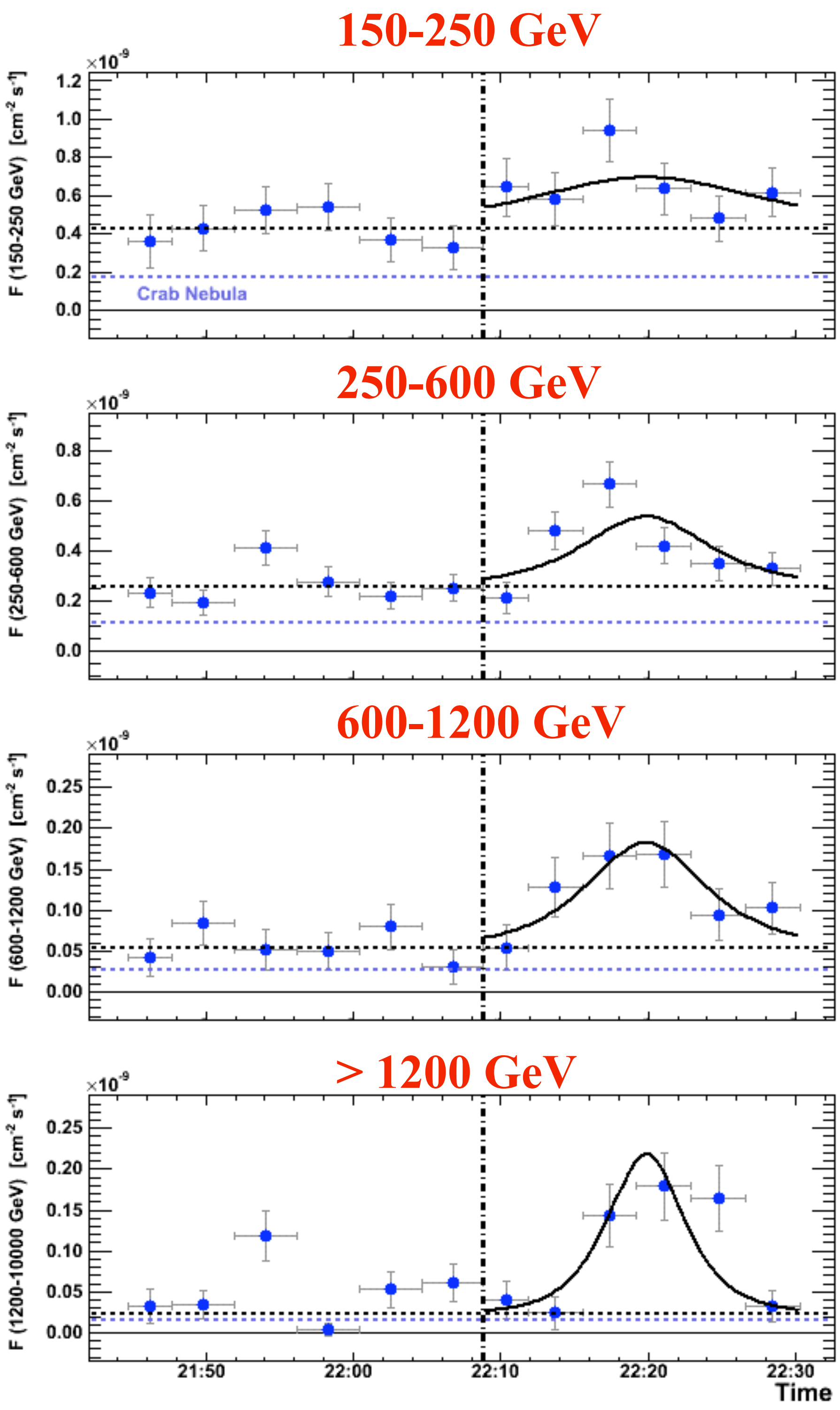
Fit gives rather compatible numbers for these 2 energy ranges

July 9th: Combined fit to all LCs with symmetric flare (c=d); Chi2/NDF =14/12

P = 0.3

Energy Range (TeV)	a[a] $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	a $(Crab\ Units)$	b $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	c (s)	$t_0 - t_0^{LC\ \ E\ 0.15-0.25TeV}$ [b] (s)
0.15-0.25	4.23±0.49	2.48±0.28	8.6±3.7	143±92	0 ± 68
0.25-0.6	2.55±0.24	2.32±0.09	9.3±2.5	95±28	7 ± 36
0.6-1.2	0.53±0.10	1.96±0.37	2.7±0.9	146±56	111 ± 91
1.2-10	0.23±0.06	1.51 ±0.39	4.0±0.9	103±19	239 ± 40

LCs for different energy ranges (4 min bins)



Active night: July 9

Flare is seen in all energy ranges

Combined fit with flare location common for all energy ranges is less probable

Chi2/NDF =25.6/15 (P =0.04)

If flare position is the same, then the shape of the flare should change with energy

Results from fit with the idealistic flare function

$$F(t) = a + \frac{b}{2^{-\frac{t-t_0}{c}} + 2^{\frac{t-t_0}{d}}}$$

a: pedestal (not fit)

b: amplitude of flux variation

t_0: ~ peak position

c, d: flux-doubling times

E > 150 GeV

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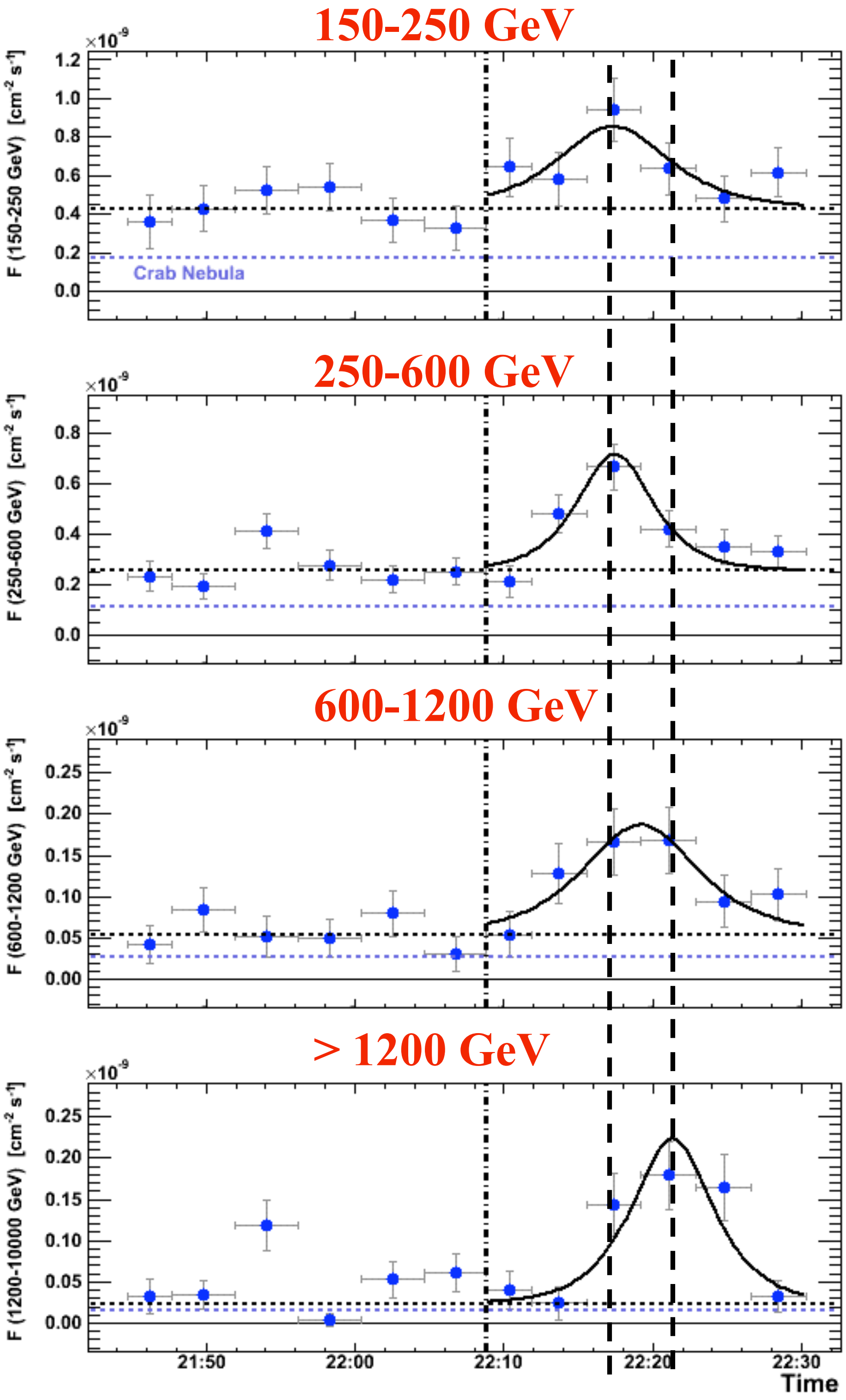
Jun30	13.2±4.7	81±41	50±23	20.0/15	17.3[f]
Jul09	20.3±3.3	95±24	185±40	4.2/7	75.8

July 9th: Combined fit to all LCs with symmetric flare (c=d); *Chi2/NDF =25.6/15*

Common flare location for all energy ranges

P = 0.04

Energy Range (TeV)	a[a] $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	a $(Crab\ Units)$	b $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	c (s)	$t_0 - t_0^{LC\ E\ 0.15-0.25TeV}$ [b] (s)
0.15-0.25	4.23±0.49	2.48±0.28	5.4±2.2	301±210	0 ± 42
0.25-0.6	2.55±0.24	2.32±0.09	5.7±1.5	162±63	0 ± 42
0.6-1.2	0.53±0.10	1.96±0.37	2.6±0.8	153±56	0 ± 42
1.2-10	0.23±0.06	1.51 ±0.39	3.9±1.0	97±22	0 ± 42



LCs for different energy ranges (4 min bins)

Active night: July 9

Flare is seen in all energy ranges

Time delay of 4 ± 1 minute between highest and lowest energy ranges

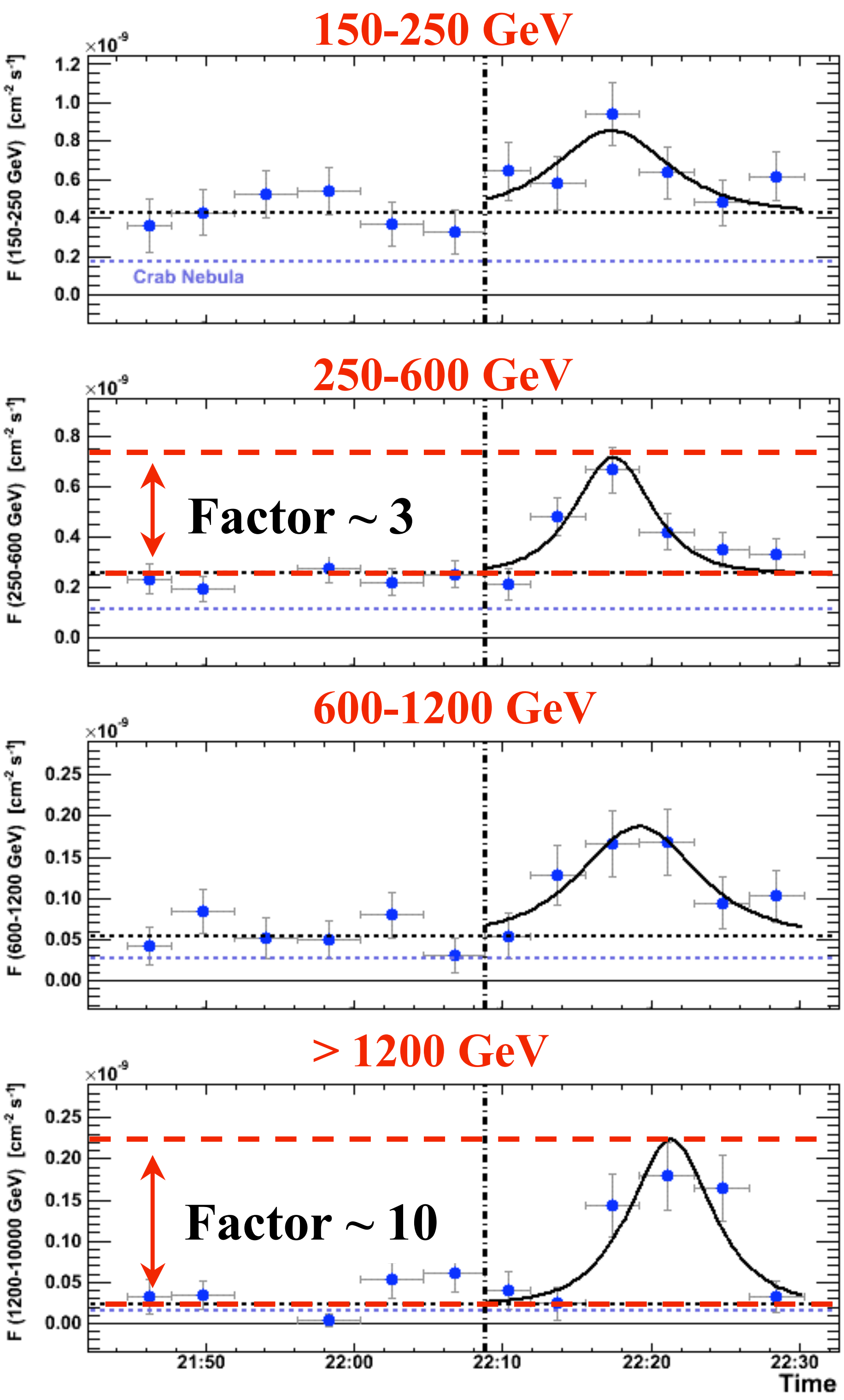
First time in VHE !!

IF

Photons at different energies were emitted simultaneously

$$\Delta T = 4 \pm 1\ min;\ \Delta E \sim 1\ TeV$$

$$E_{QG} = \frac{L}{c} \cdot \frac{\Delta E}{\Delta t} = (0.6 \pm 0.2) \cdot 10^{17}\, GeV$$



LCs for different energy ranges (4 min bins)

Active night: July 9

Flare is seen in all energy ranges

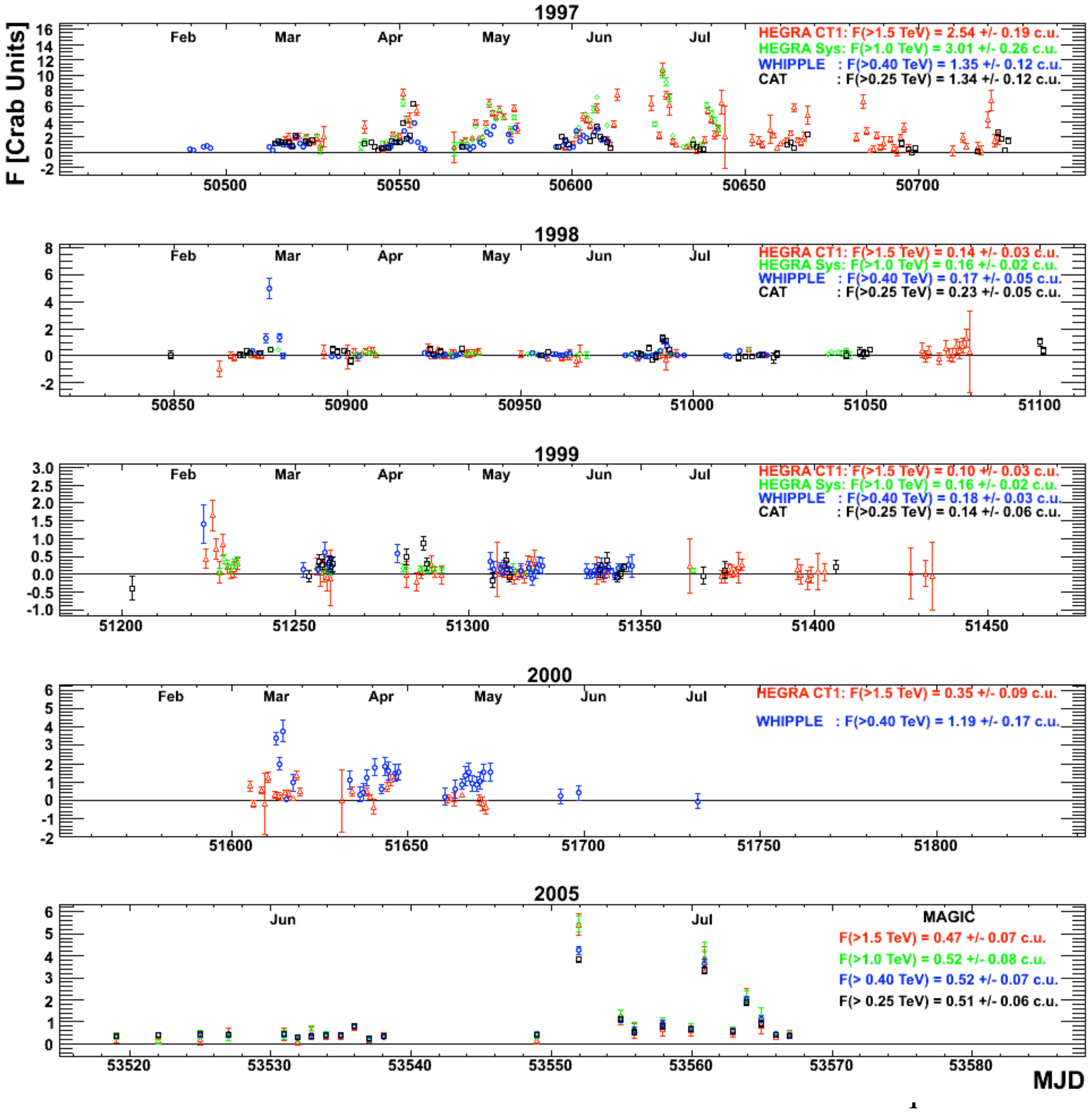
Time delay of 4 ± 1 minute between highest and lowest energy ranges

First time in VHE !!

Flux variations are larger at the largest energies

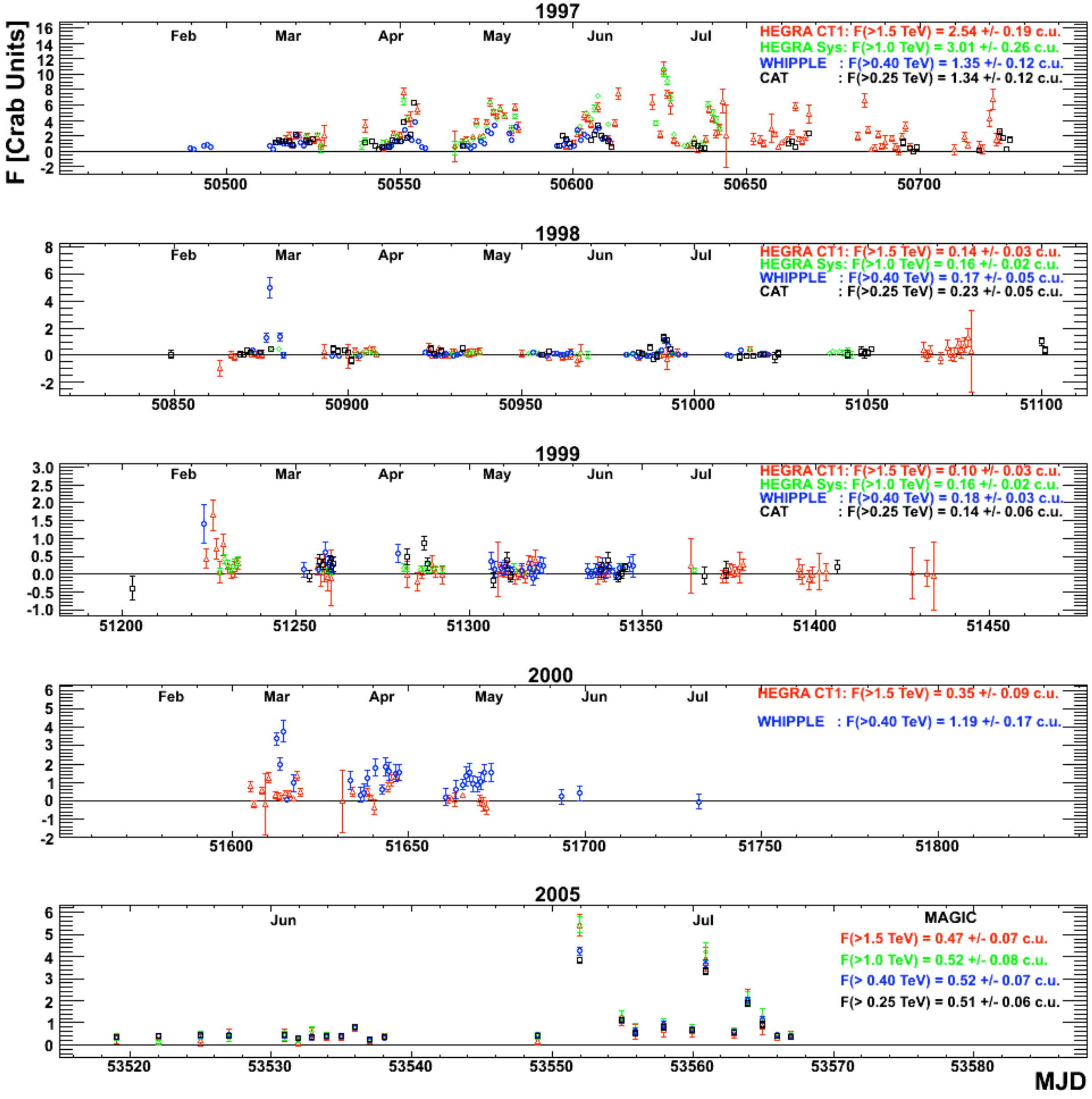
First time in VHE !!

2.3 historical light curves (@ VHE) from Mrk501



In 2005 campaign, lower flux than in 1997 and 2004, but larger than in 1998-1999

2.3 historical light curves (@ VHE) from Mrk501



23 days periodicity observed by HEGRA CT 1 data in 1997

Kranich 2000 (PhD thesis)

Osone 2006 (Astropart. Phys. 26), also in RXTE data

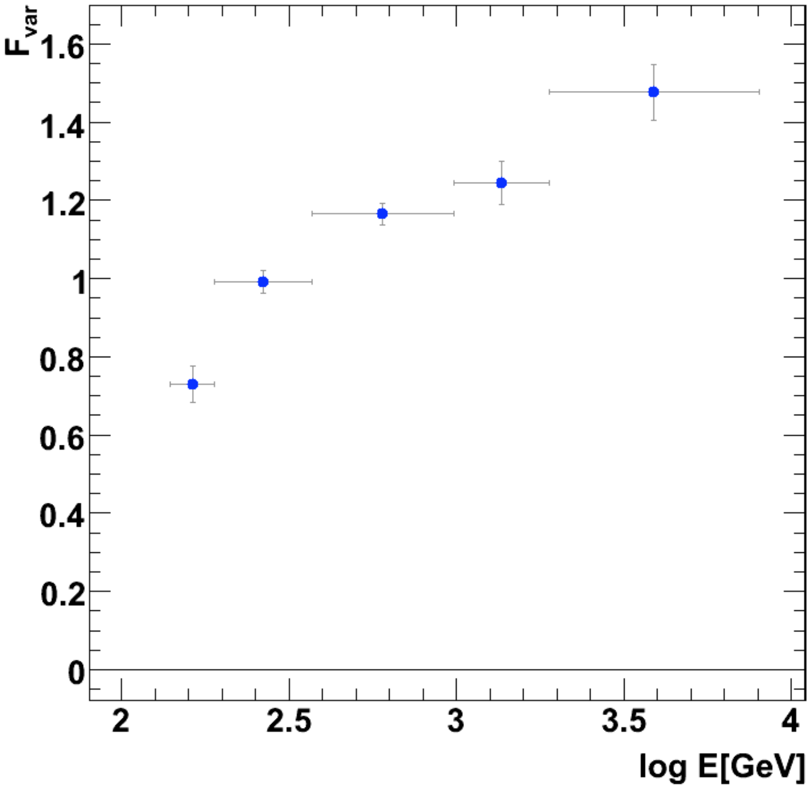
In 2005 campaign, lower flux than in 1997 and 2004, but larger than in 1998-1999

2.3 - Flux variability vs Energy

Quantification following prescription given in *Vaughan et al. 2003*

$$F_{var} = \sqrt{\frac{S^2 - <\sigma^2_{err}>}{<F_\gamma>^2}}$$

All the observing nights (low and high state) included

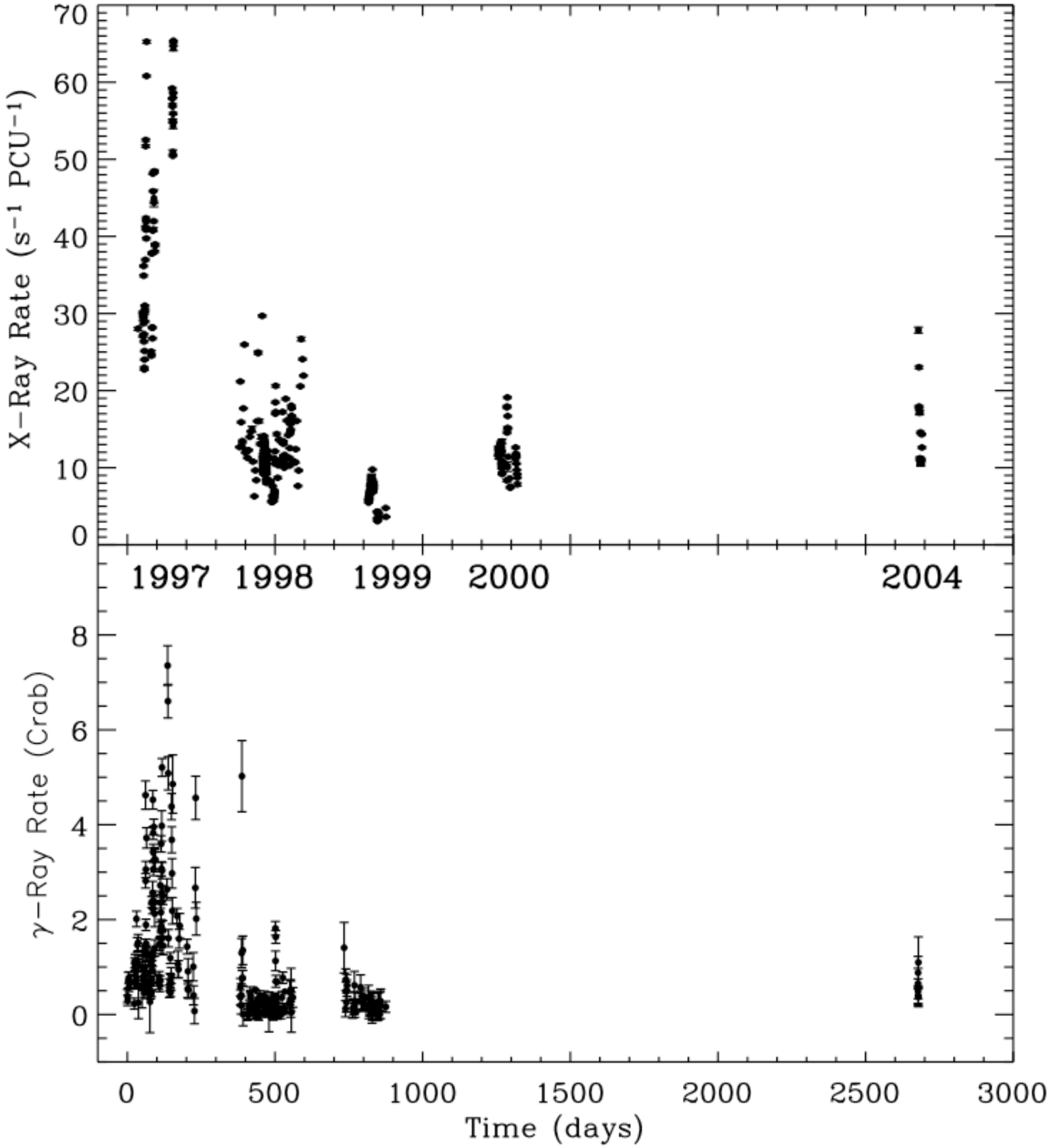


F_{var}^{Mrk501}*(VHE)* increases with energy

Agreement iwht X-ray data (see next slide)

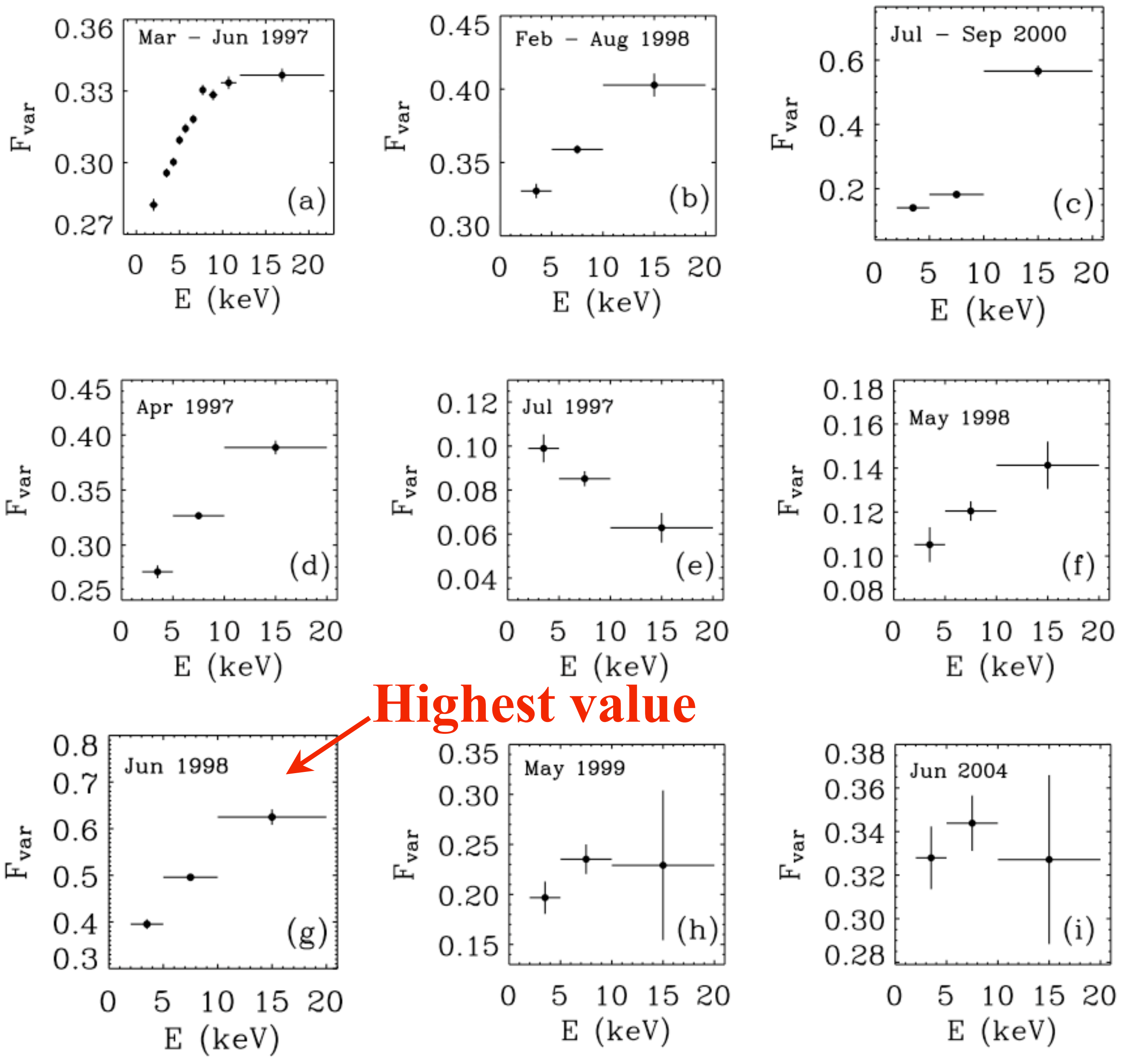
Variability might be caused by injection of higher energy particles (shorter cooling times)

Comparison with Fvar at X-rays (Gliozzi et al. 2006, ApJ, 646)



Collection of X-ray and gamma-ray data over years 1997-2000 and 2004

Comparison with Fvar at X-rays (Gliozzi et al. 2006, ApJ, 646)



Highest value

In general, F_{var} increases with energy

Highest F_{var} value was not obtained in 2007, when X-ray (and gamma) flux was highest

2.3 - Flux variability vs Energy

Quantification following prescription given in *Vaughan et al. 2003*

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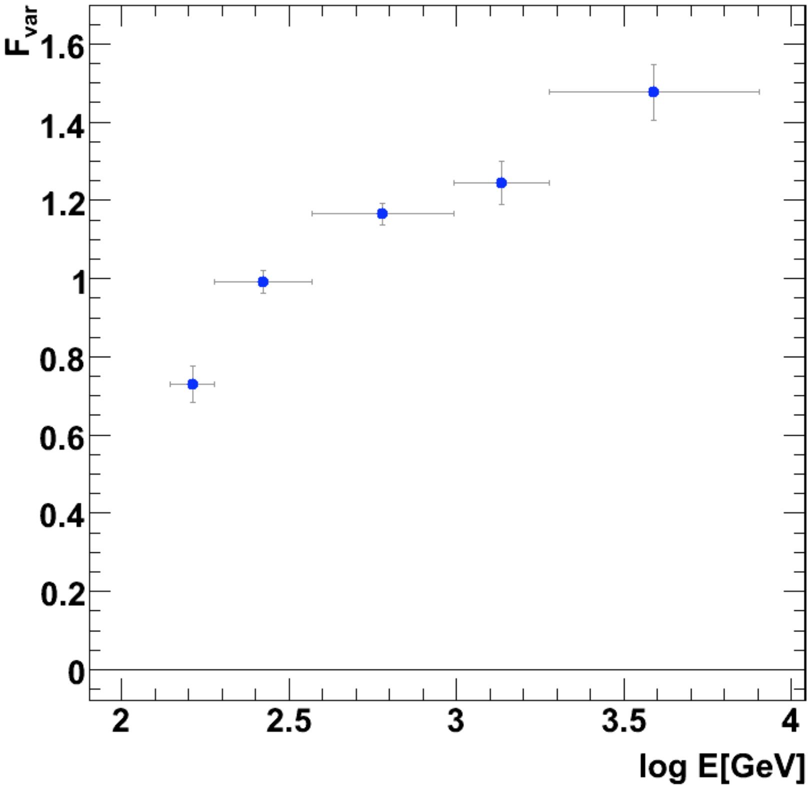
All the observing nights (low and high state) included



F_{var}^{Mrk501}(VHE) increases with energy

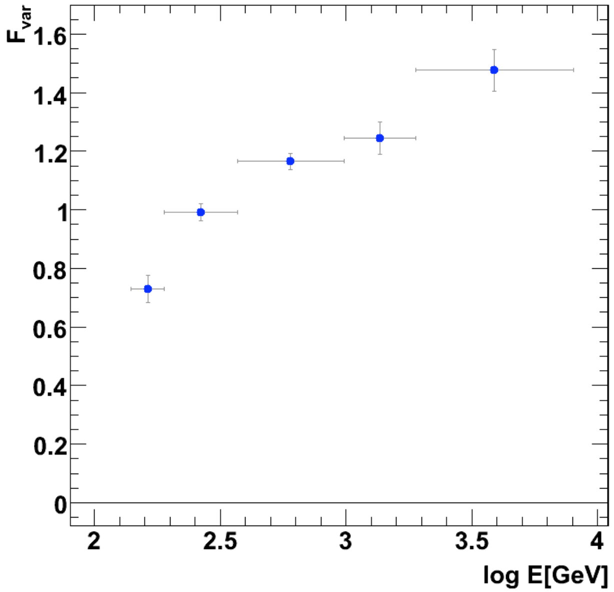
F_{var}^{Mrk501} increases with energy aslo at X-rays (see Gliozzi et al. 2006)

F_{var}^{Mrk501}(VHE) > F_{var}^{Mrk501}(X-rays)

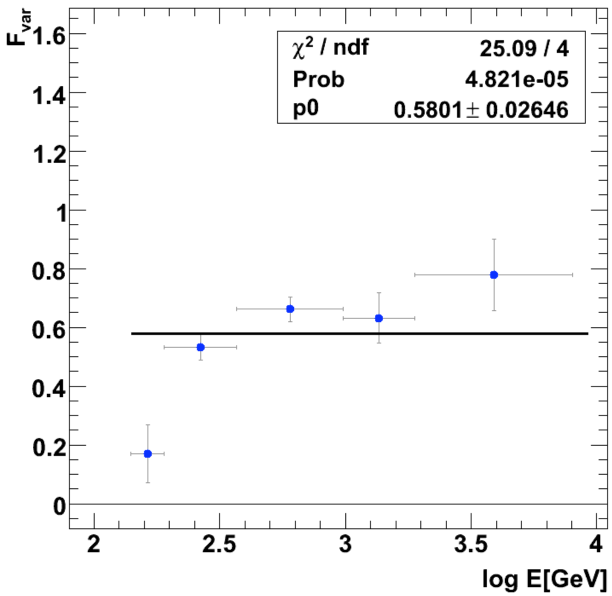
The highest ***F_{var}^{Mrk501}(X-rays)*** is ~0.6 (in 1998). In 1997, year with very high activity, the highest ***F_{var}^{Mrk501}(X-rays)*** was ~0.4. ***Perhaps flux variability is highest when activity is not largest***

Fractional variability vs energy

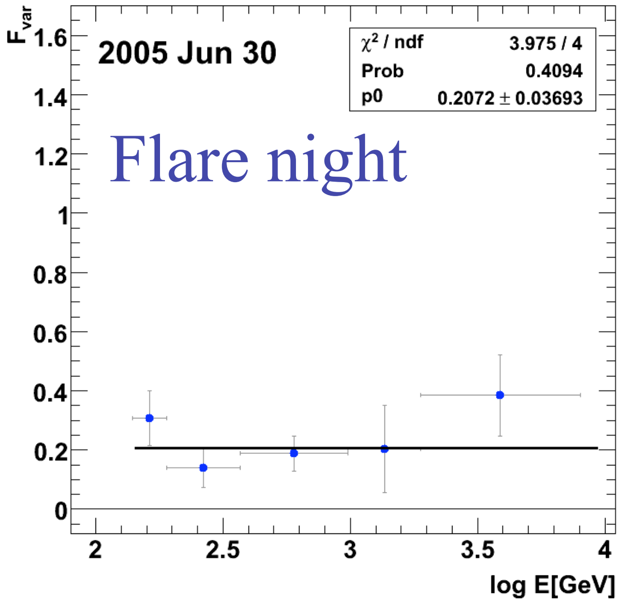
All nights included

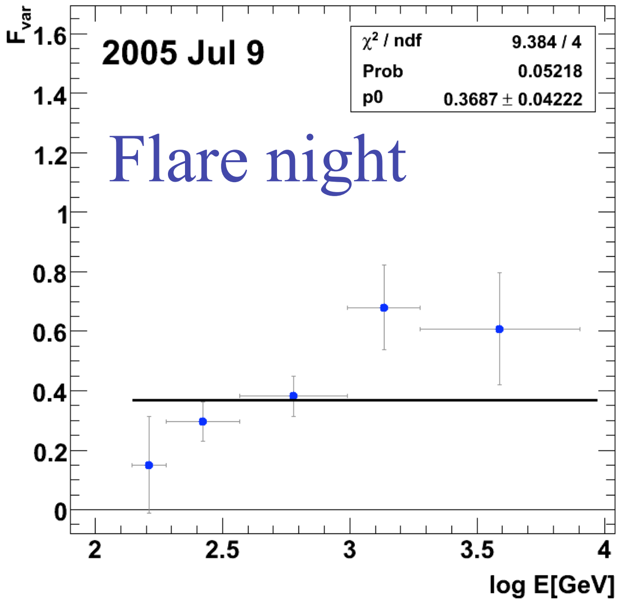


Flare nights excluded



F_{var} increases with energy





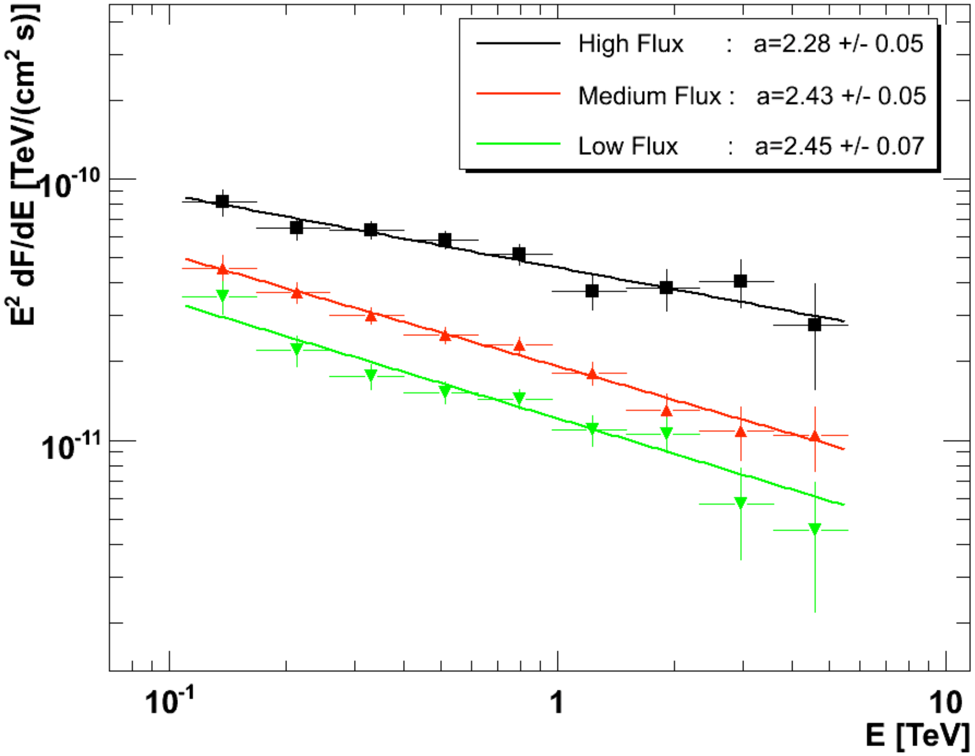
F_{var} seems to increase with energy for Jul 9 flare

2.4 - Overall flux levels

Low : Flux (E>150 GeV) < 0.5 Crab 12 days

Medium : Flux > 0.5 Crab && Flux < 1.0 Crab 8 days

High : Flux > 1.0 Crab (Flare nights excluded) 2 days



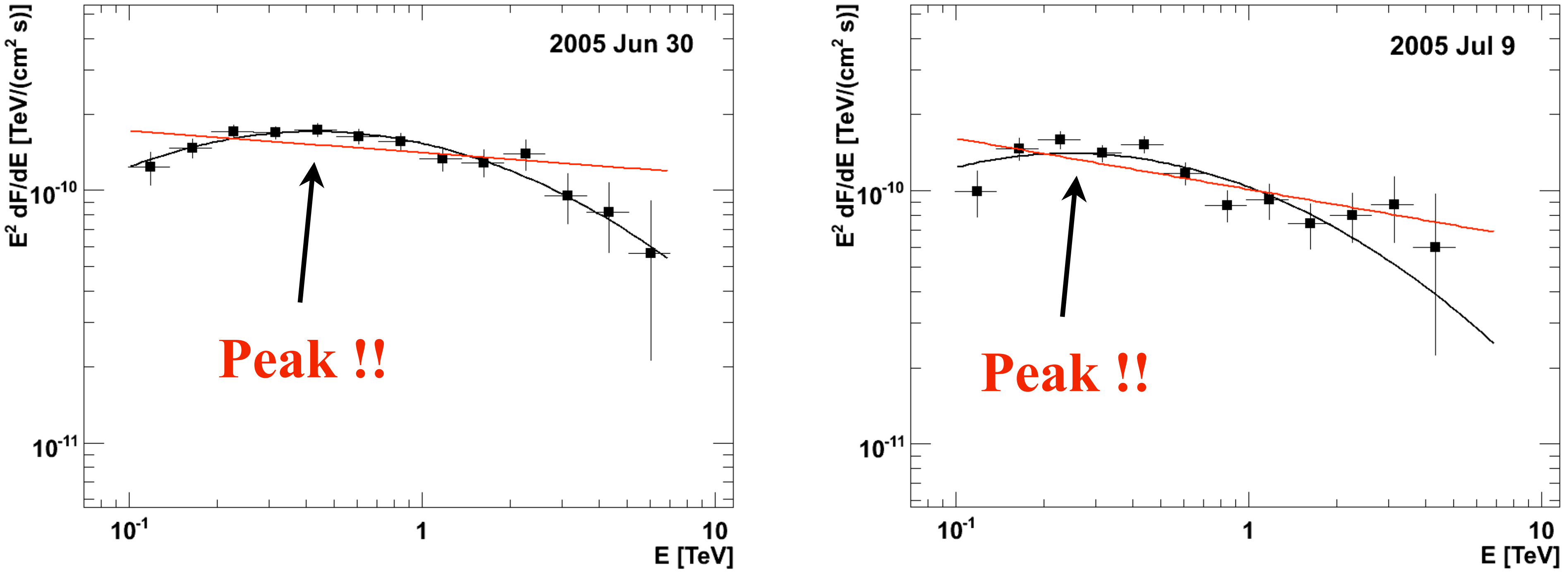
Evidence of hardening of spectra with flux level

Agreement with previous evidences (Pian et al 1998, Tavecchio et al. 2001…) which used the VERY BIG flare of 1997

Flux Level^m	T_{obs} ^{a} (h)	ZA^b (deg)	S_{comb} ^{c} sigma	$F_{>150\ GeV}$ ^{d} $(\frac{10^{-10}\ ph}{cm^2 \cdot s})$	$F_{>150\ GeV}$ (Crab Units)	K_0 ^{e} $(\frac{10^{-10}\ ph}{cm^2 \cdot s \cdot 0.3TeV})$	a^f	χ^2/NDF^g	P^h (%)
Low	17.2	9.96-30.1	16.7	1.24± 0.08	0.39 ± 0.02	2.31±0.13	2.45 ± 0.07	7.8/7	34.6
Medium	11.0	9.95-30.0	22.8	2.11± 0.09	0.66 ± 0.03	3.57±0.15	2.43 ± 0.05	2.9/7	89.4
High	1.52	9.95-22.3	21.7	4.62± 0.21	1.45 ± 0.07	7.13±0.32	2.28 ± 0.05	4.8/7	68.7

2.5 - Spectra for the 2 nights with the highest VHE activity

Curved spectra is favoured over simple power law

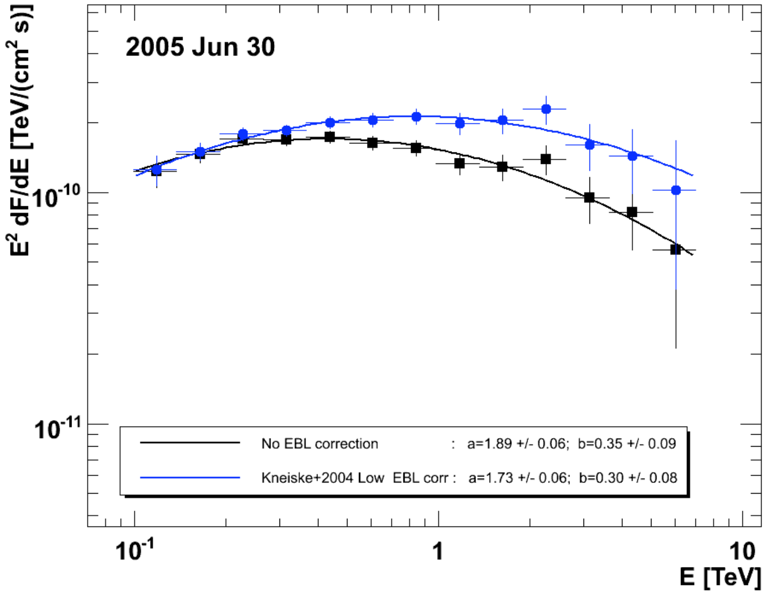


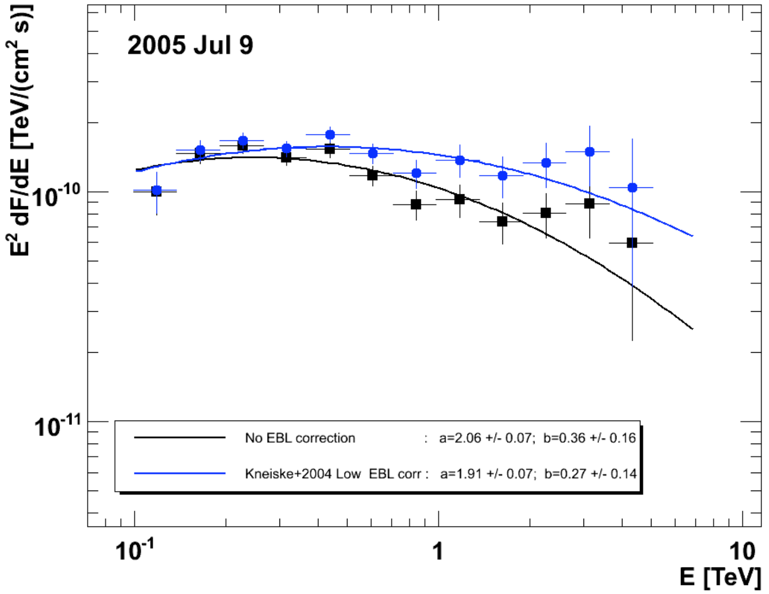
Power law **Log-Parabolic func.**

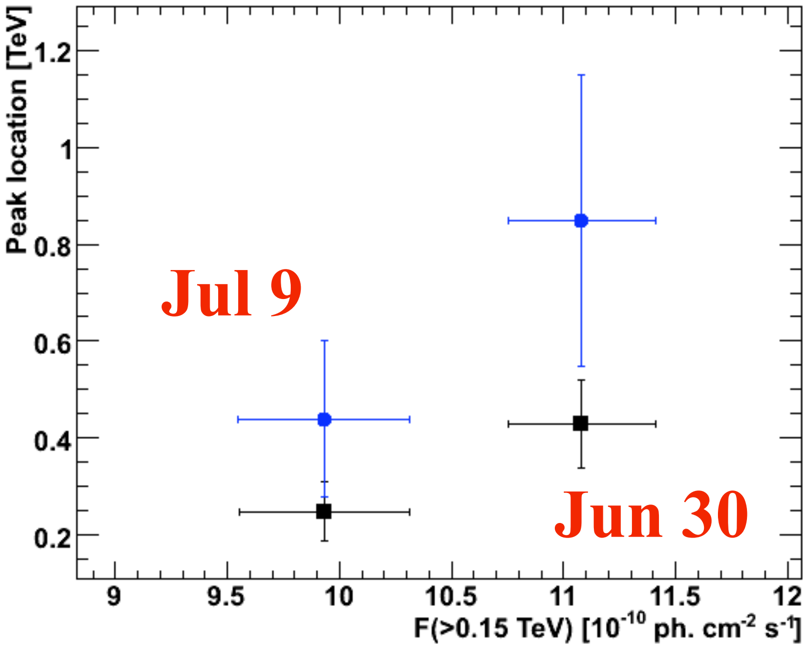
	Fit performed with formula 5				Fit performed with formula 6				
Date	K_0 $\left(\frac{10^{-10}\ ph}{cm^2 \cdot s \cdot 0.3TeV}\right)$	a	χ^2/NDF	P (%)	K_0 $\left(\frac{10^{-10}\ ph}{cm^2 \cdot s \cdot 0.3TeV}\right)$	a	b	χ^2/NDF	P (%)
June 30	17.4±0.05	2.09±0.03	26.1/11	0.6	18.6±0.06	1.89±0.06	0.35±0.09	6.1/10	80.1
July 9	14.3±0.06	2.20±0.04	22.5/11	2.1	15.5±0.07	2.06±0.07	0.36±0.16	15.2/10	12.5

2.6 - Position of spectral peak before and after EBL correction

Model used: 'low' EBL from Kneiske et al 2004







EBL correction moves the spectral peak to higher energies

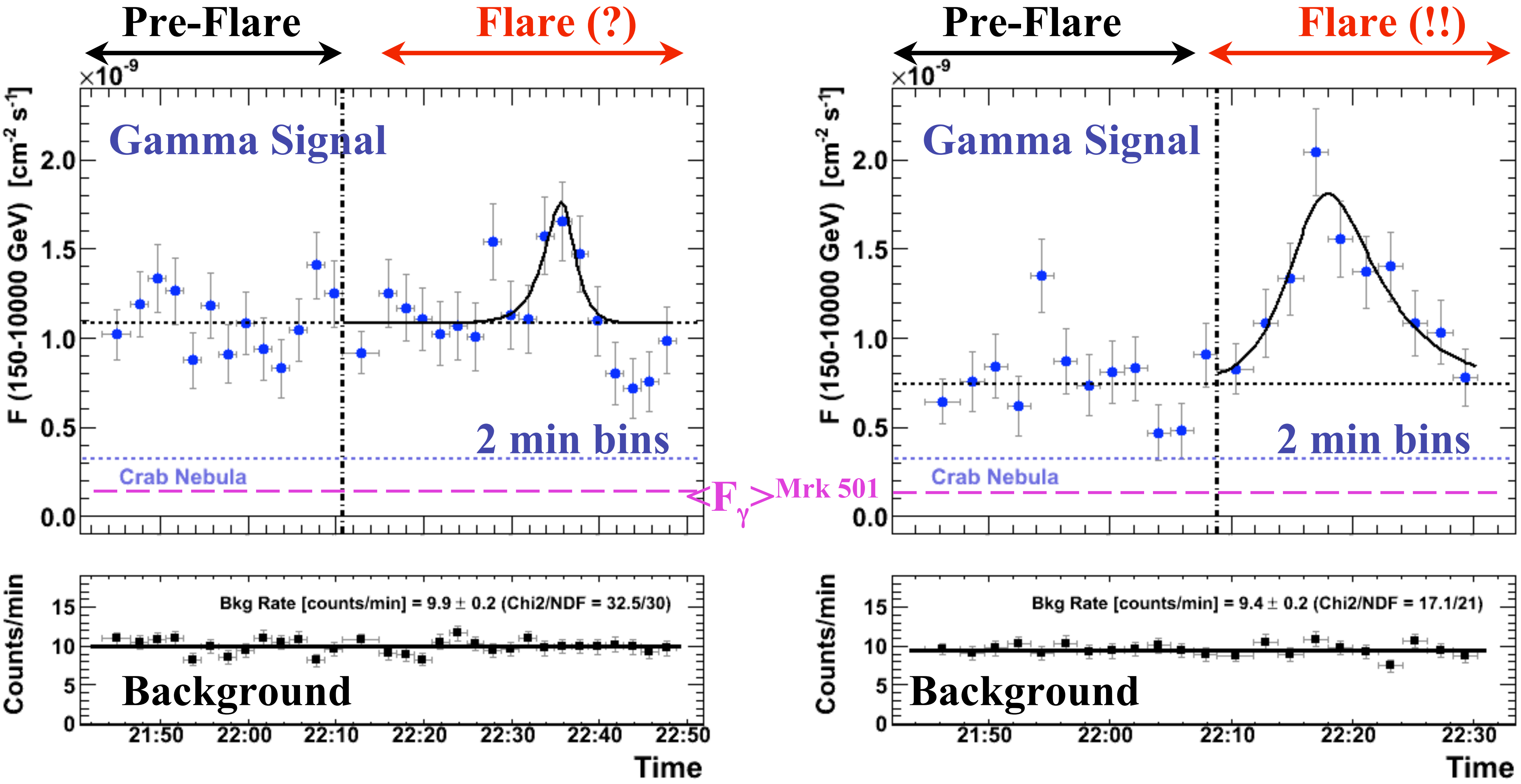
During the nights of low activity, the flare is not seen at E > 100 GeV

Peak location seems to depend on the source luminosity. Flares might be produced by injection of higher energy particles

2.7 Spectra for the flaring nights (pre-flare and flare)

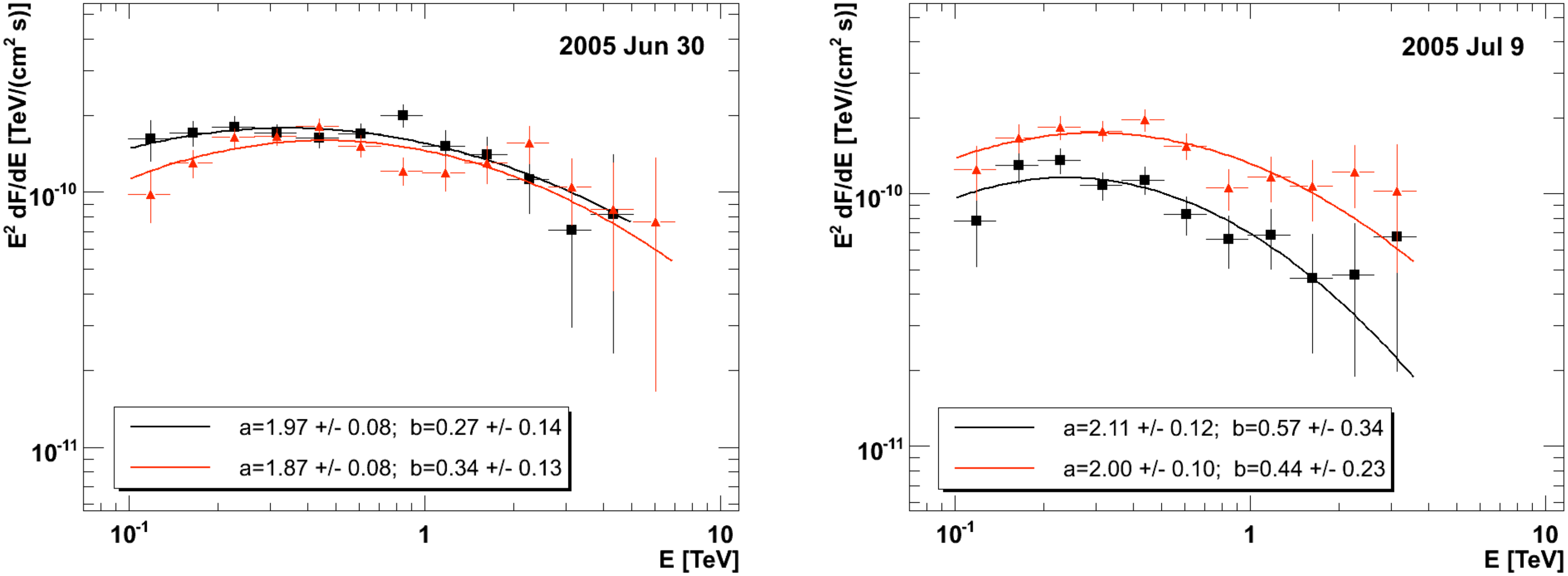
Definition of **pre-flare** and **flare** in the LC

June 30th ⟵ Highest VHE activity ⟶ July 9th



2.7 Spectra for the flaring nights (pre-flare and flare)

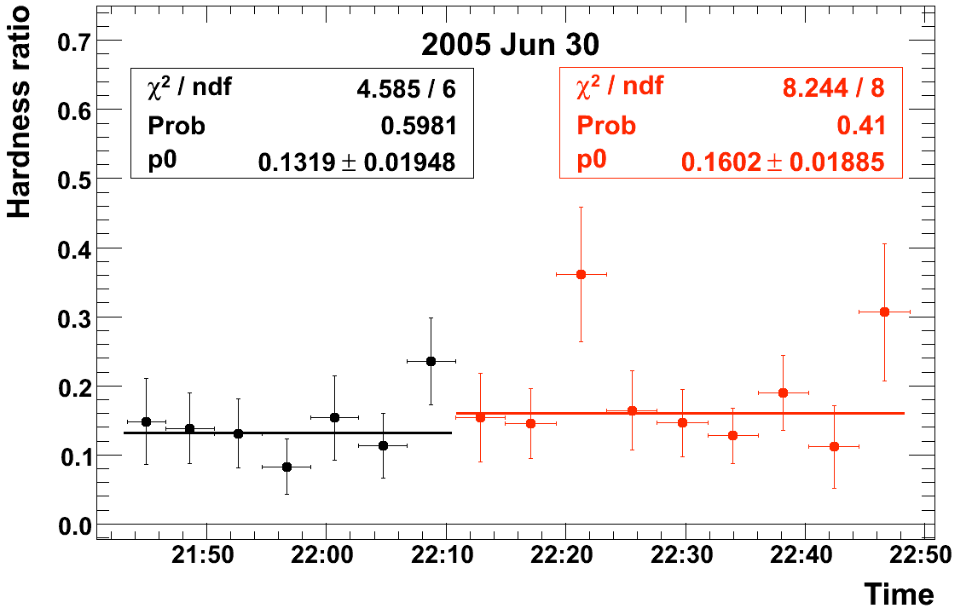
During **flaring part**, the spectra seems a bit harder; yet not significant

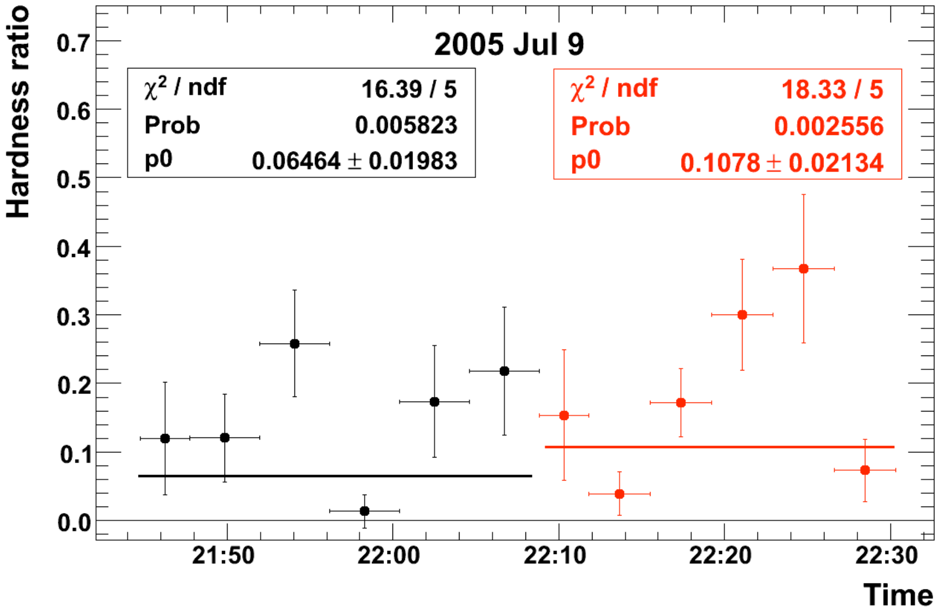


Results of the fit with a log-parabola on the active nights

	MJD Start	T_{obs} [a] (h)	S_{comb} [c] sigma	$F_{>150\ GeV}$ [d] $(\frac{10^{-10}\ ph}{cm^2\cdot s})$	$F_{>150\ GeV}$ (Crab Units)	K_0 $(\frac{10^{-10}\ ph}{cm^2\cdot s\cdot 0.3TeV})$	a	b	χ^2/NDF	P [h] (%)
Jun30	53551.905	0.46	22.3	10.99±0.48	3.46±0.15	19.8±1.0	1.97±0.08	0.27±0.14	8.2/9	51.2
	53551.924	0.63	24.7	11.15±0.43	3.50±0.14	17.2±0.8	1.87±0.08	0.34±0.13	13.8/10	18.1
Jul09	53560.906	0.40	15.2	7.64 ± 0.48	2.40 ± 0.15	12.7±1.1	2.11±0.12	0.57±0.34	6.4/8	59.8
	53560.923	0.36	19.6	12.39 ± 0.60	3.89 ± 0.19	19.3±1.3	2.00±0.10	0.44±0.23	8.9/8	35.2

2.8 - Hardness ratio F(1.2 −10TeV)/F(0.25−1.2TeV) vs time

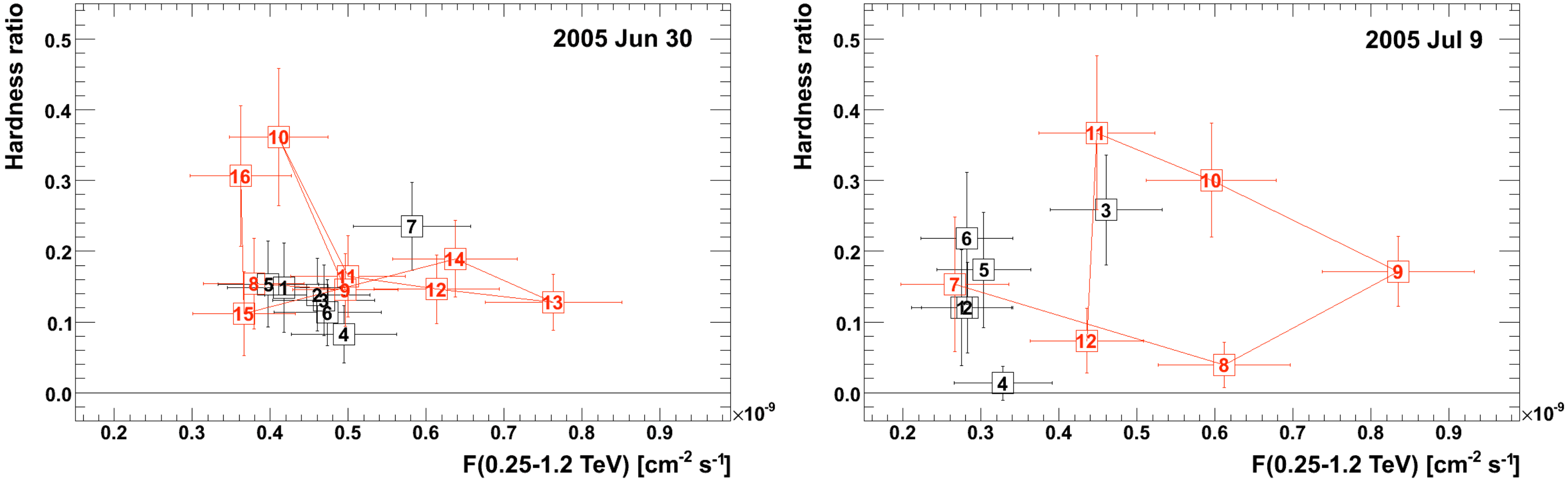




Hardness ratio is a bit higher during the flare for both nights, but not very significant (1-2 sigmas)

Hardness ratio is probably NOT constant during flare July 9th

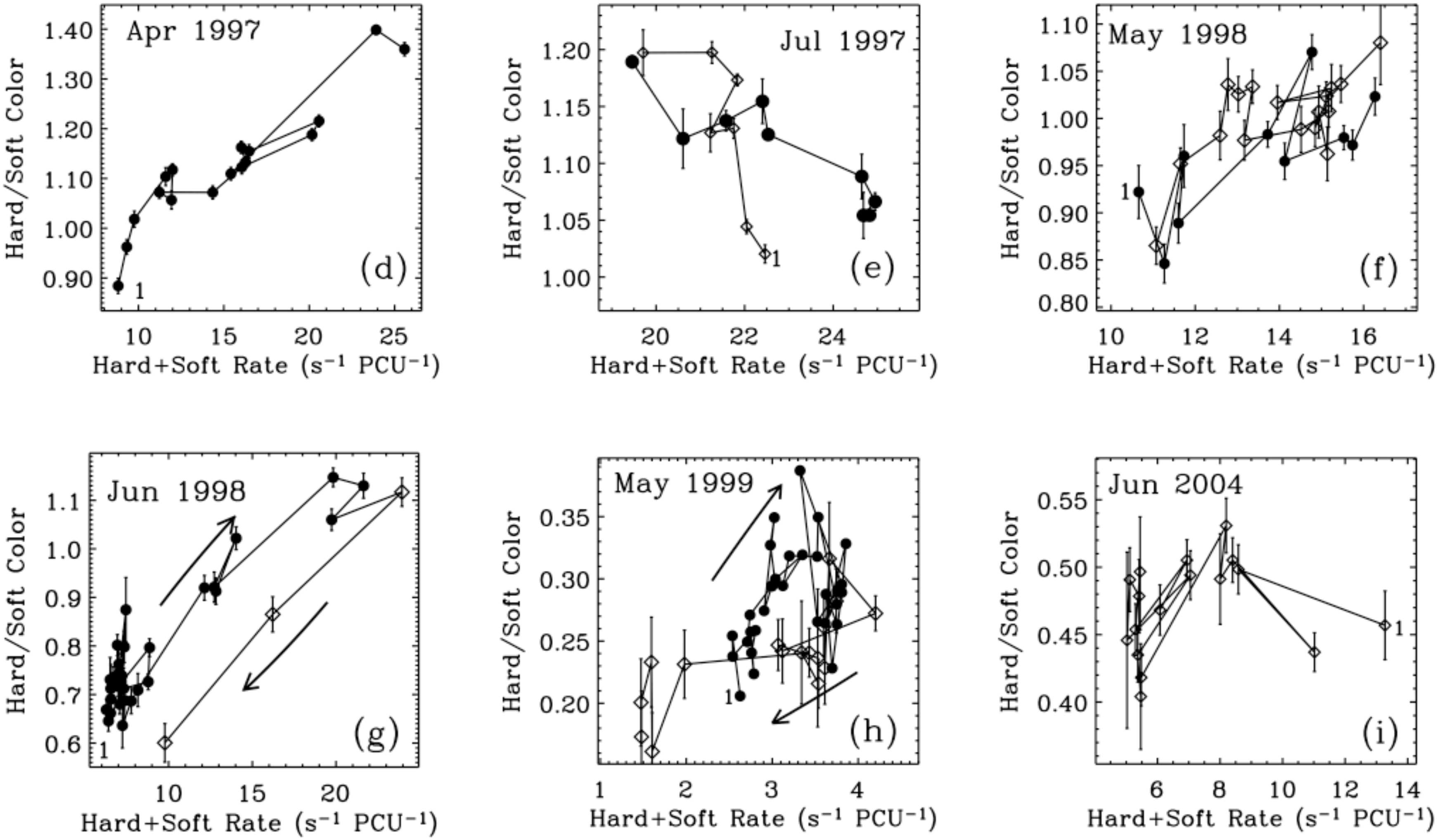
2.9 - Hardness ratio F(1.2 −10TeV)/F(0.25−1.2TeV) vs Flux



Larger spread in points from the flare (with respect to pre-flare)

Evolution of points for flare July 9th shows a clear loop pattern rotating counterclockwise; this might indicate similar variability, cooling, acceleration timescales, as pointed out by Kirk&Mastichiadis (1999)

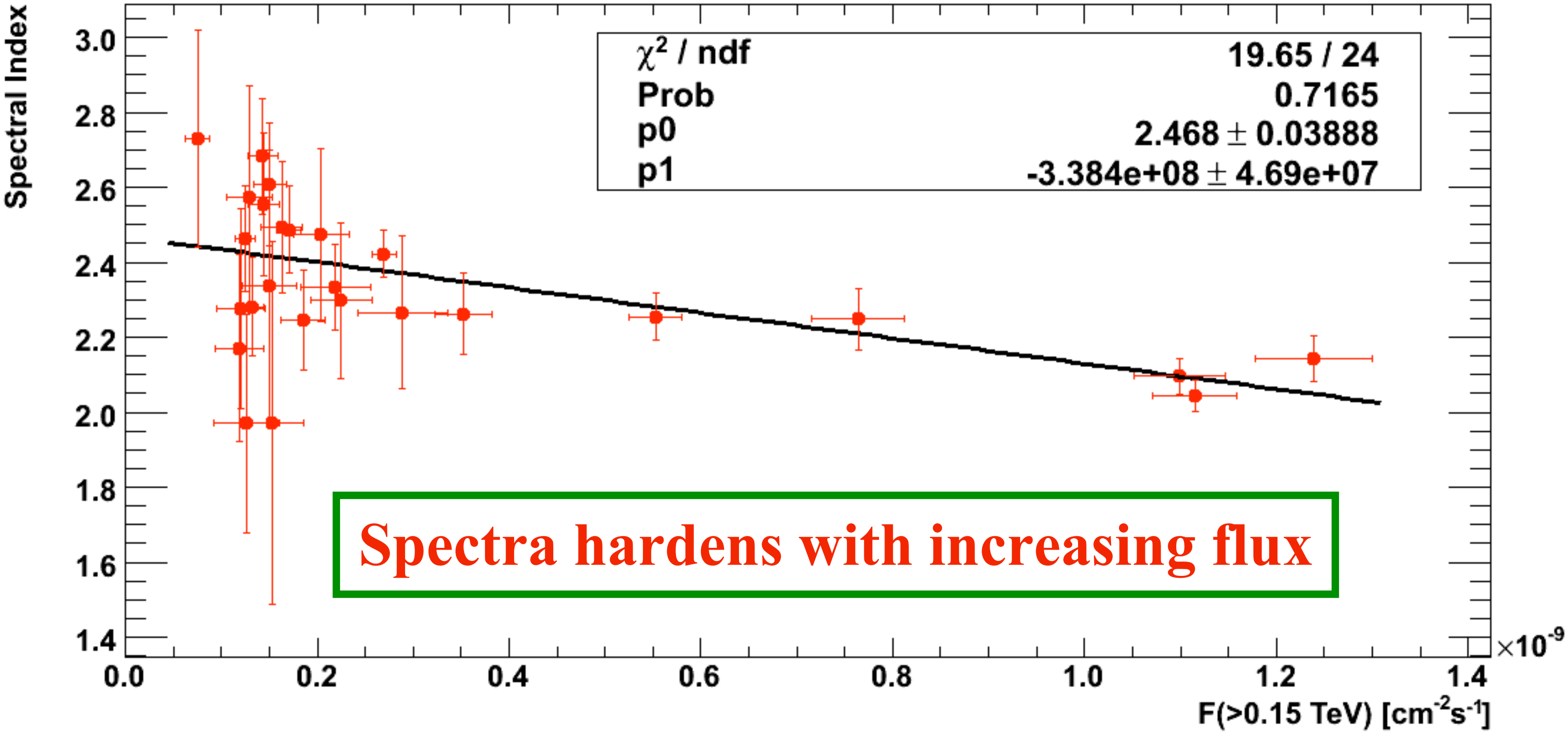
Comparison with Hardness ratio at X-rays (Gliozzi et al. 2006)



When pattern is clear, it is actually rotating clockwise; i.e. *opposite pattern to the gamma-ray flare observed in July 9th*

2.10 - Correlation spectral index - gamma flux (E>150 GeV)

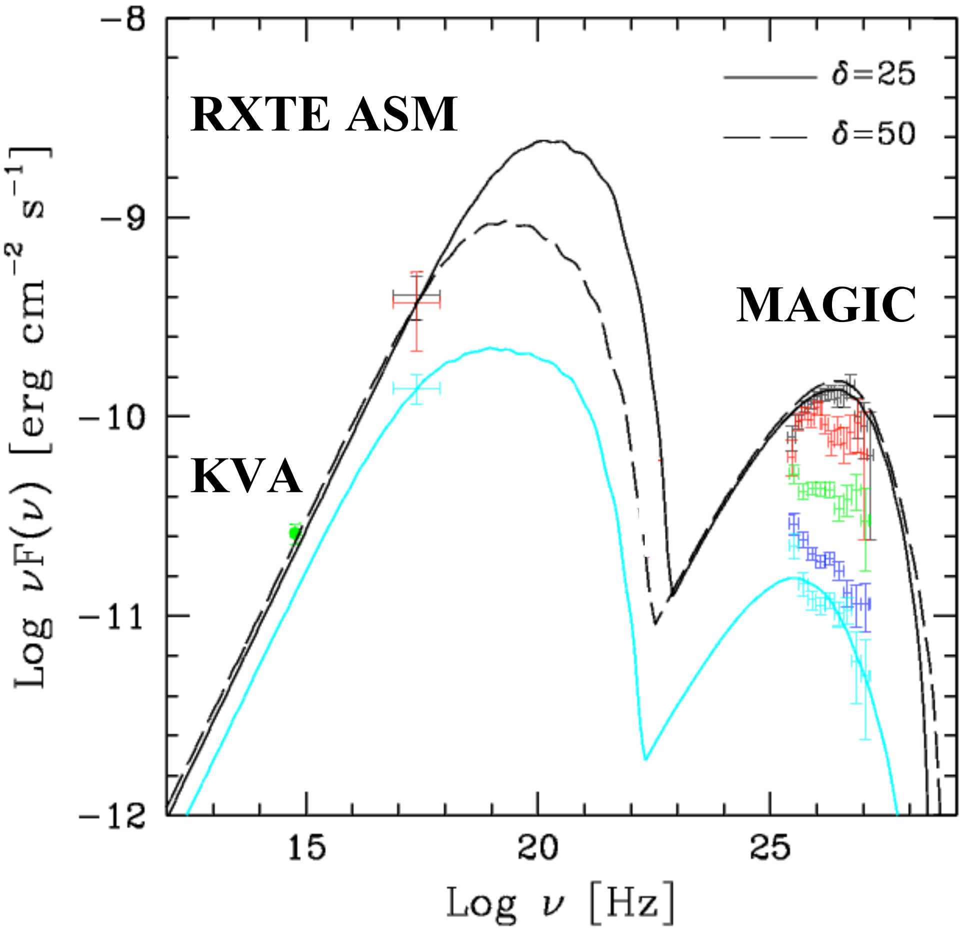
All 24 nights included
Flare nights split into 2 (“pre-flare” and “flare”)



Spectra hardens with increasing flux

Constant fit gives Chi2/NDF = 76.6/25 (Prob 4 e-7)

2.11 - Overall SED during these observations



Very dynamic spectra in VHE: 3 flux levels + 2 active nights = = 5 different spectra

Unluckily, we do not have simultaneous broad band X-rays: big intra-model degeneracy

It is important to organize multiwavelength campaigns

SED fit with one zone SSC model (model from Tavecchio et al. 2001)

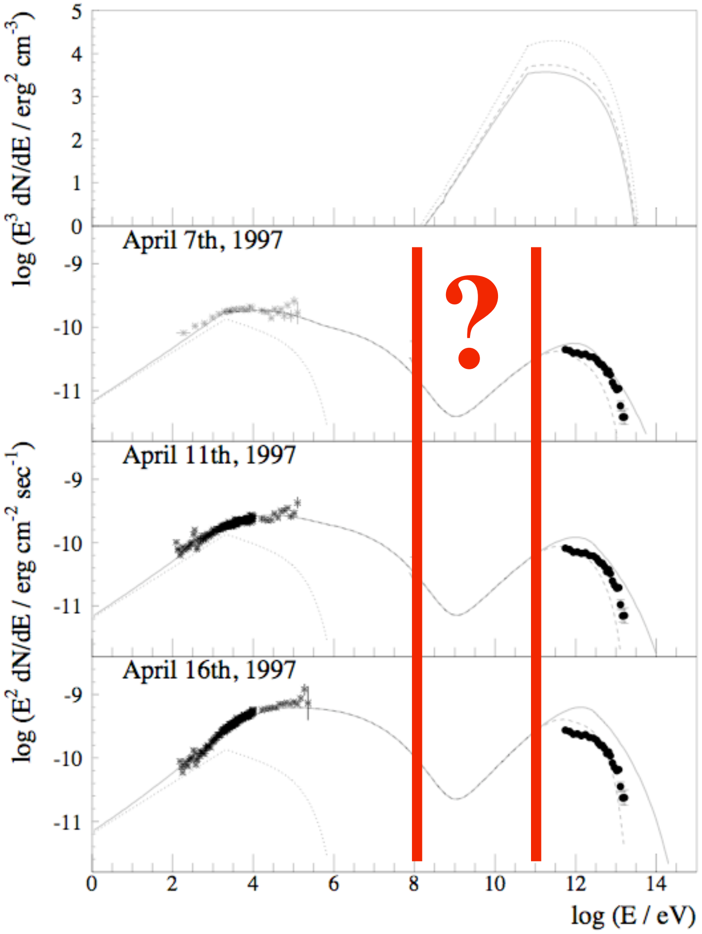
spectrum	γ_{min}	γ_{br}	γ_{max}	n1	n2	B Gauss	K particle/cm^3	R cm	Doppler factor
June 30	1	10^6	10^7	2	3.5	0.52	$2.5 \cdot 10^4$	10^{15}	25
June 30 (bis)	1	$5 \cdot 10^5$	10^7	2	3.5	0.115	$2.5 \cdot 10^4$	10^{15}	50
Low flux	1	10^5	$5 \cdot 10^6$	2	3.2	0.55	$1.6 \cdot 10^4$	10^{15}	25

3 - What GLAST can do with Mrk 501

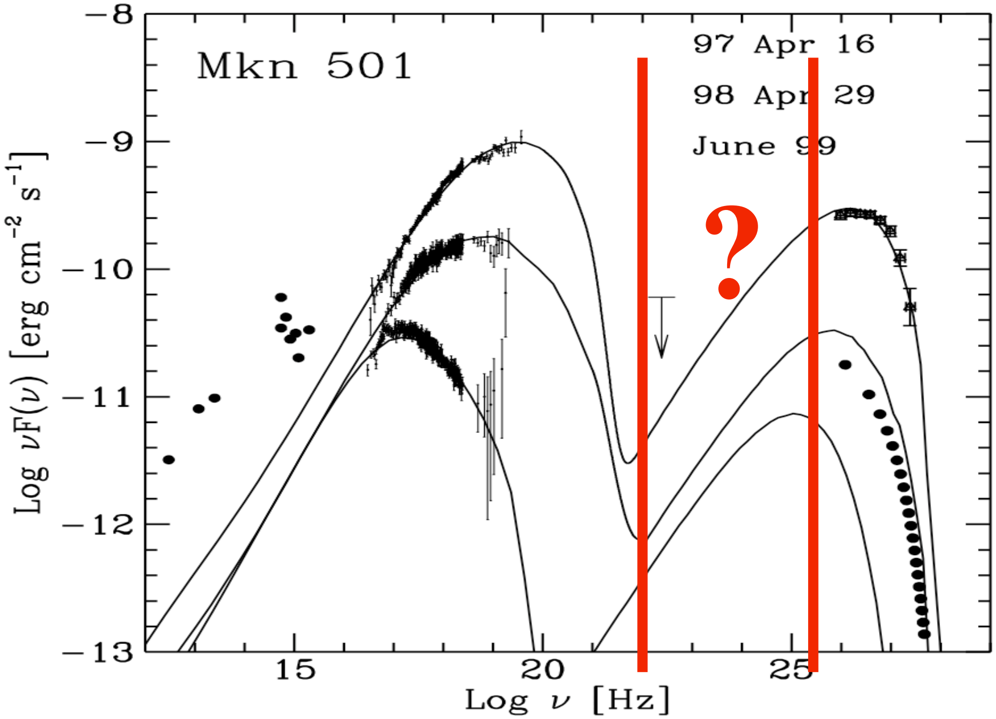
!!!!!!! A LOT !!!!!!!

There are no data points in the very important range 0.1-100 GeV

Krawzcinski 2002, MNRAS



Tavecchio 2001 ApJ 554



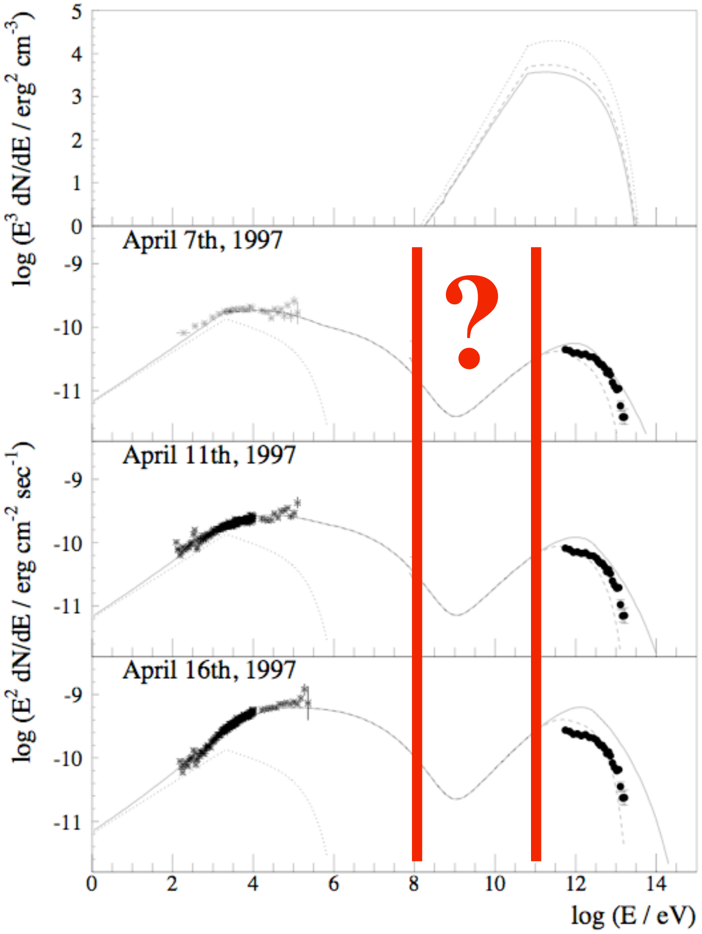
3 - What GLAST can do with Mrk 501

!!!!!!! A LOT !!!!!!!

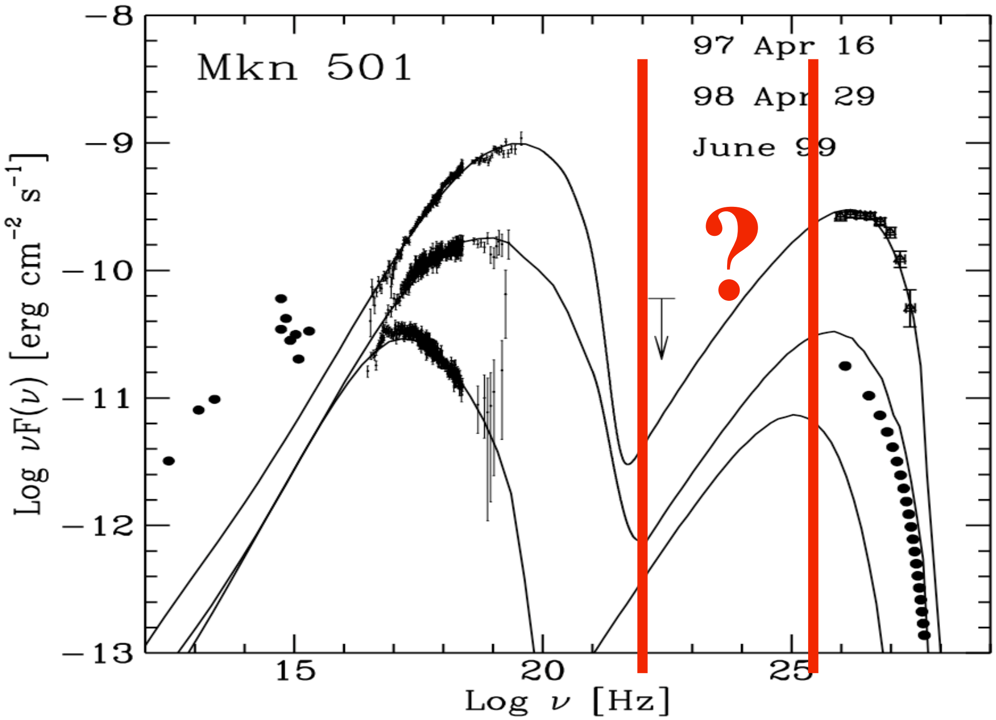
Uniform Time coverage !!

There are no data points in the very important range 0.1-100 GeV

Krawzcinski 2002, MNRAS



Tavecchio 2001 ApJ 554



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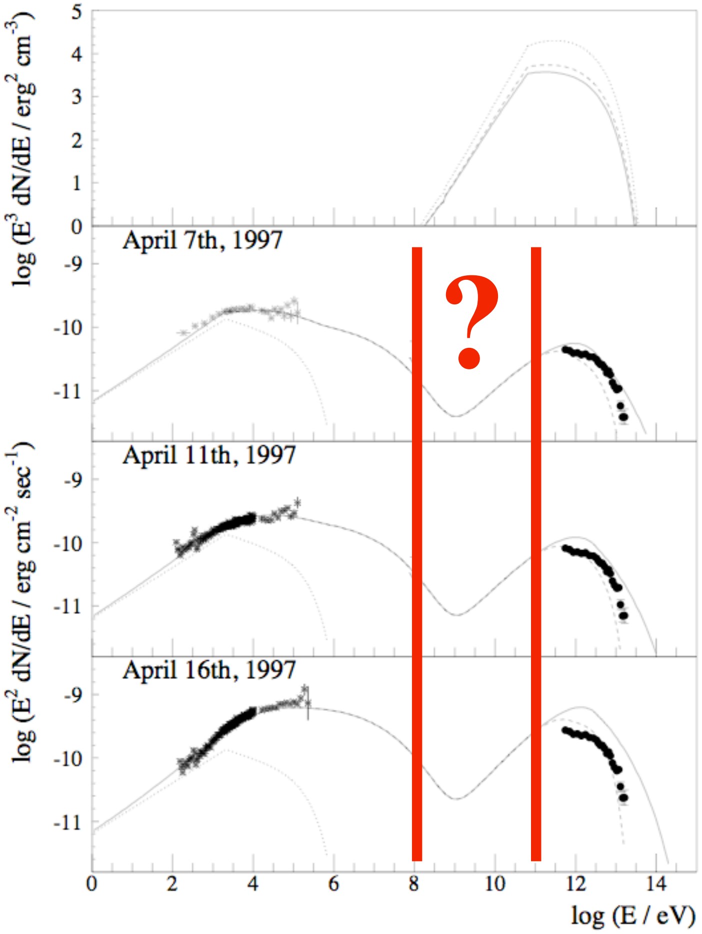
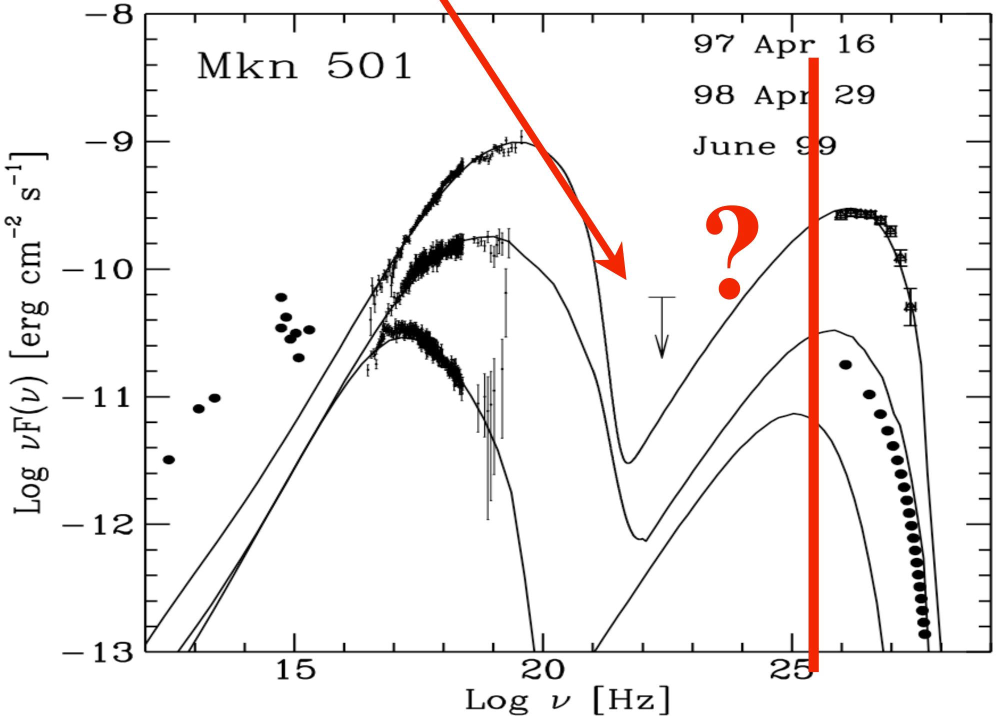
Krawzcinski 2002, MNRAS



EGRET upper limit during obs. 1997; April 9-16

Tavecchio 2001 ApJ 554

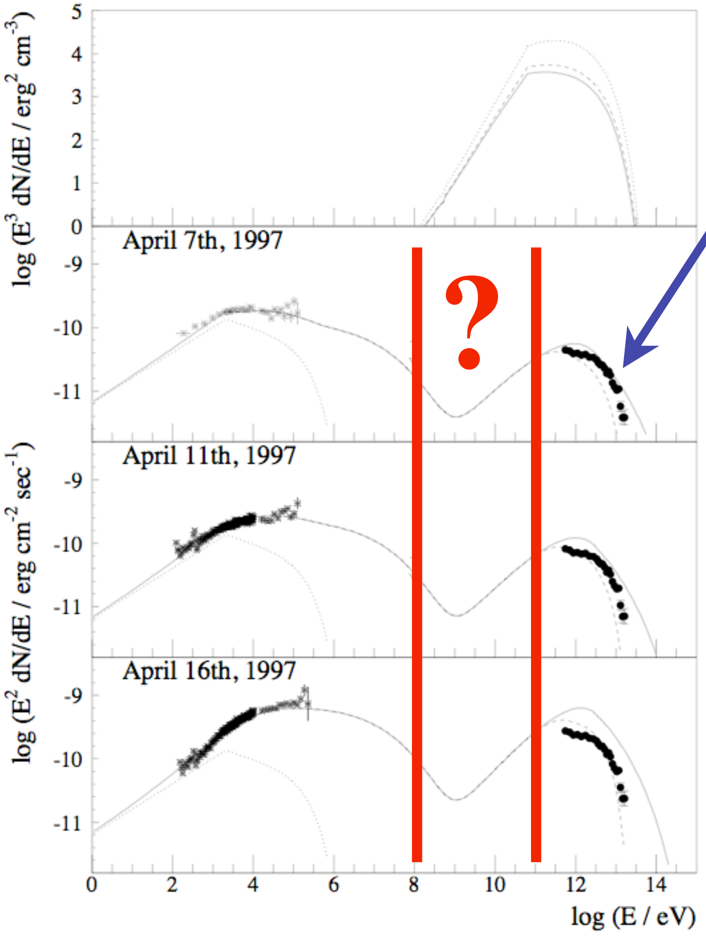


3 - What GLAST can do with Mrk 501

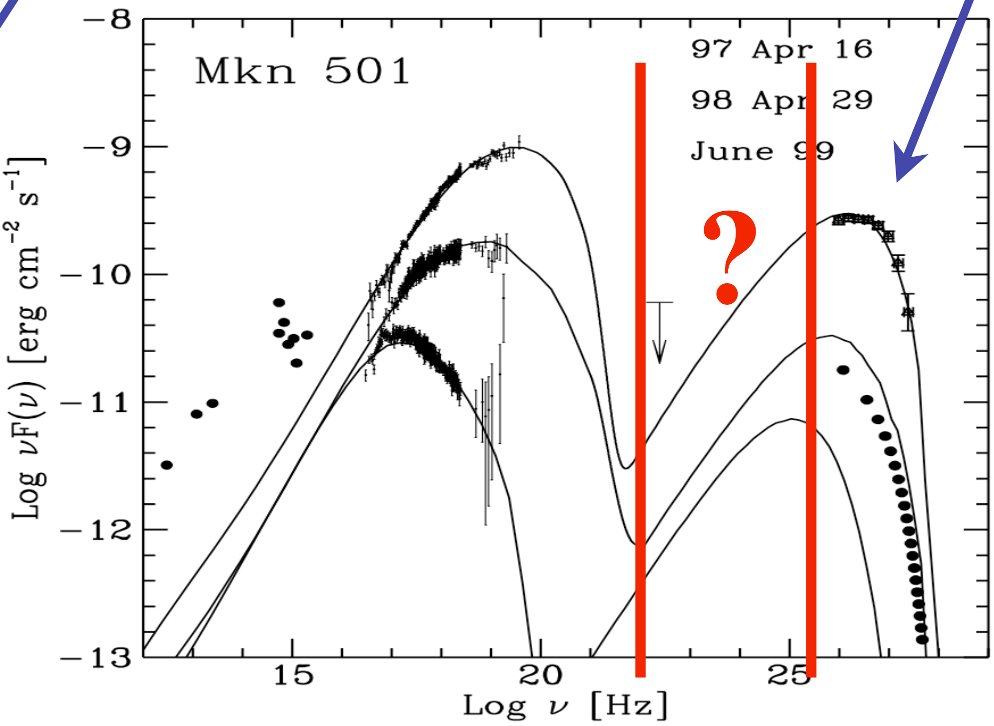
!!!!!!! A LOT !!!!!!!

Spectra is not EBL corrected !!!
Intrinsic curvature is less than the one showed

Krawzcinski 2002, MNRAS



Tavecchio 2001 ApJ 554

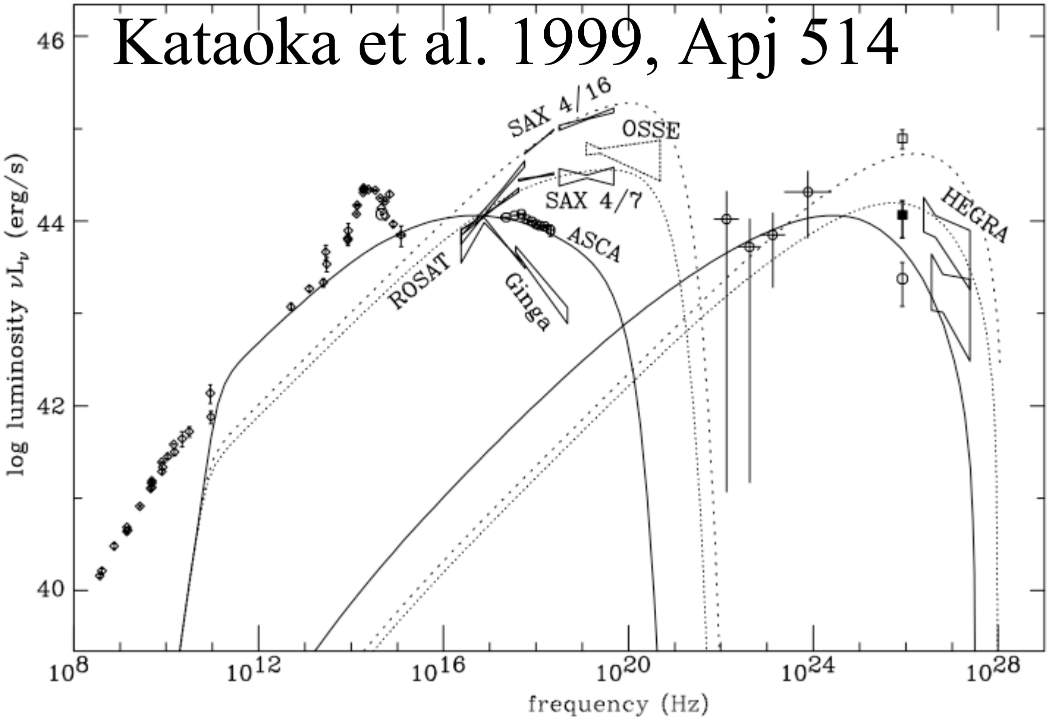


3 - What GLAST can do with Mrk 501

!!!!!!!   A LOT   !!!!!!!

Mrk 501 is NOT in the 3rd EGRET catalogue

EGRET detected Mrk 501 with confidence (5.2 sigma @ E>500 MeV) only once; flare in March 1996


Kataoka et al. 1999, Apj 514

3 - What GLAST can do with Mrk 501

!!!!!!!   A LOT   !!!!!!!

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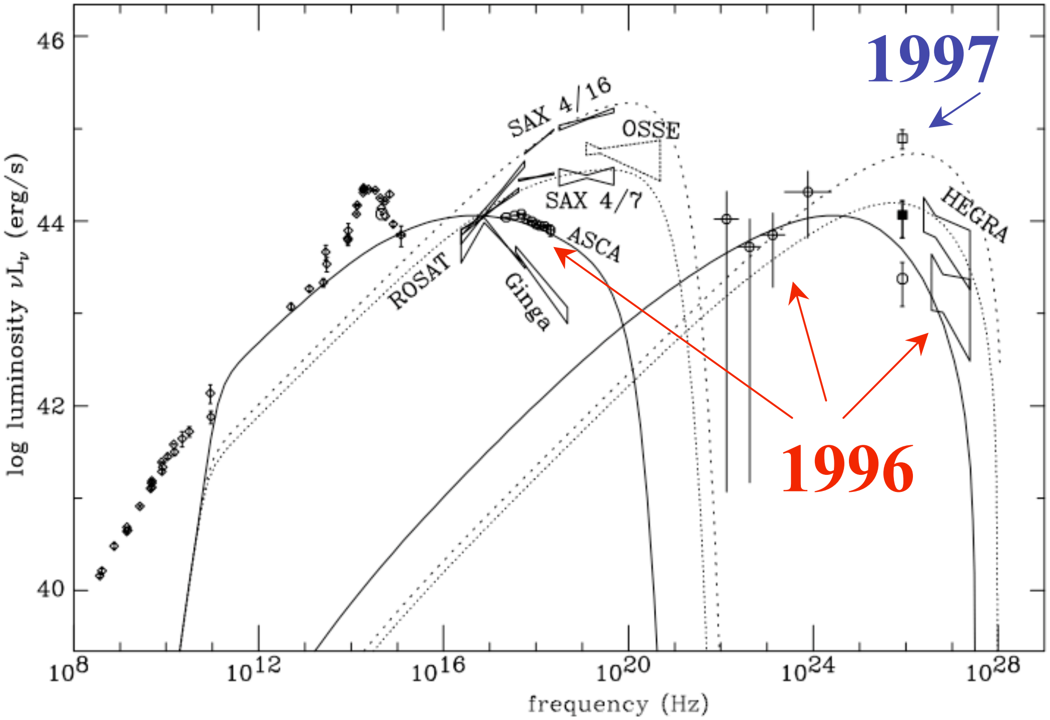
Kataoka et al. 1999, Apj 514



1997

1996

Mrk 501 is at a distance of 5x10{26} cm; teh luminosity of 44 erg/s corresponds to ~4 x 10^{-10} erg cm-2 s-1, in agreement with Tavecchio 2001.

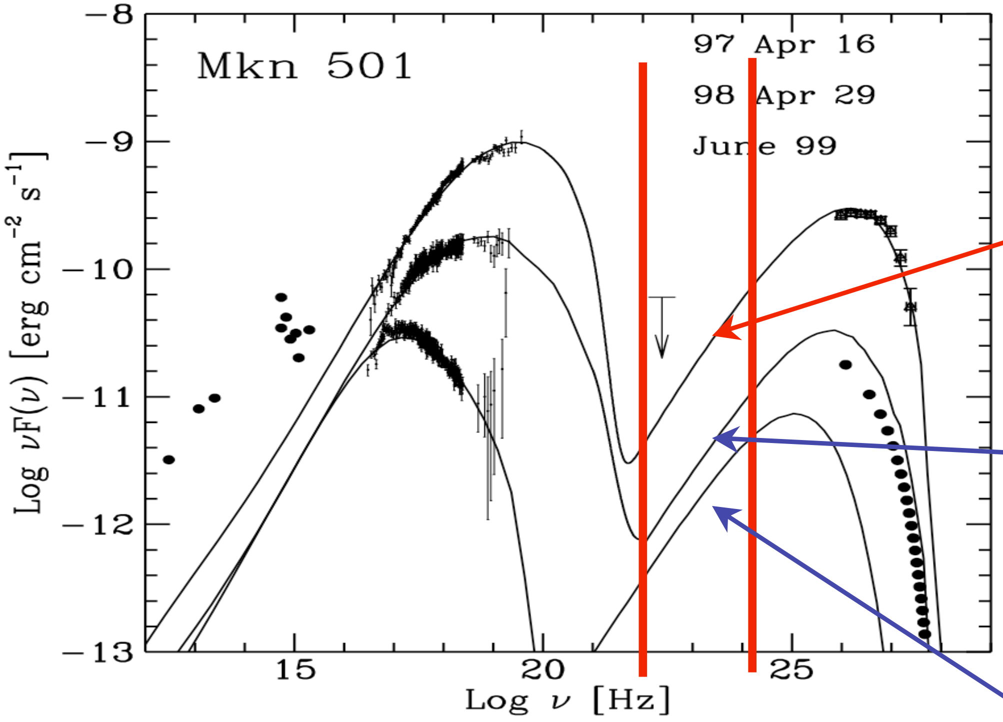
BUT TeV flux in 1996 is a at least a factor 10 lower than in 1997

Simultaneous and good quality measurements are badly needed !!

How much time will GLAST need to detect Mrk 501??

$$\boxed{\frac{dF}{dE} = k \bullet \left(\frac{E}{GeV} \right)^{-a}}$$

Tavecchio 2001 ApJ 554



High
K = 3.67x10^{-8} GeV^{-1}cm^{-2}s^{-1}
a = 1.45
F(>0.1GeV) = 2.30 x10^{-7} cm^{-2} s^{-1}

Low 1
K = 5.8x10^{-9} GeV^{-1}cm^{-2}s^{-1}
a = 1.45
F(>0.1GeV) = 3.64 x10^{-8} cm^{-2} s^{-1}

Low 2
K = 2.3x10^{-9} GeV^{-1}cm^{-2}s^{-1}
a = 1.45
F(>0.1GeV) = 1.45x10^{-8} cm^{-2} s^{-1}

0.1-10 GeV

Simultaneous and good quality measurements are badly needed !!

How much time will GLAST need to detect Mrk 501??

Estimate of required time to achieve 5 sigmas

I used Benoit's macro:

http://confluence.slac.stanford.edu/display/SCIGRPS/Significance+estimator+tool

High
a = 1.45
F(>0.1GeV) = 2.30 x10^{-7} cm^{-2} s^{-1}

Low 1
a = 1.45
F(>0.1GeV) = 3.64 x10^{-8} cm^{-2} s^{-1}

Low 2
a = 1.45
F(>0.1GeV) = 1.45x10^{-8} cm^{-2} s^{-1}

Simultaneous and good quality measurements are badly needed !!

How much time will GLAST need to detect Mrk 501??

Estimate of required time to achieve 5 sigmas

I used Benoit's macro:

http://confluence.slac.stanford.edu/display/SCIGRPS/Significance+estimator+tool

High
a = 1.45
F(>0.1GeV) = 2.30 x10^{-7} cm^{-2} s^{-1} ⟶ **0.25 days**

Low 1
a = 1.45
F(>0.1GeV) = 3.64 x10^{-8} cm^{-2} s^{-1} ⟶ **2.4 days**

Low 2
a = 1.45
F(>0.1GeV) = 1.45x10^{-8} cm^{-2} s^{-1} ⟶ **7.6 days**

Isnt't it impressive ? ; is it too optimistic ??

Benoit's macro has been tested by Vincent Lonjou using the DC2 analysis; **it seems to be working correctly**.

http://www.cesr.fr/~lonjou/files/mkn421_1day/mkn421_1day.html

Although we have to be aware of limited photon statistics;

$$Nphtons = F(>0.1GeV)*Area\ (cm2)*\ Time(s)*FractionSky\ *\ Eff(E) =$$

$$=\underset{\textbf{High flux}}{2.3\text{e-}7} \times 1.\text{e}4 \times \underline{3600. \times 6.}_{\ \textbf{0.25 days}} \times 1./5 \times \mathrm{Eff(E)} = 10 \times \mathrm{Eff(E)} \sim 5\ \mathrm{ph}$$

Therefore, we get 5 sigmas (TS=25) with ~5 photons

statistical uncertainty on flux above 100 MeV: **62.5 %**

statistical uncertainty on index: **13.7 %**

In order to have more photon statistics (and reduce flux error) we have to integrate over somewhat larger times

High flux (Tavecchio 2001), observed during 1 day

TS: 99.93 significance: 10.00

statistical uncertainty on flux above 100 MeV: 31.3

statistical uncertainty on index: 6.9

Low 1 flux (Tavecchio 2001), observed during 1 week

TS: 72.56 significance: 8.52

statistical uncertainty on flux above 100 MeV: 36.0

statistical uncertainty on index: 7.5

Anyhow, they are STILL very impressive numbers !!!

GLAST Blazar group plans Multiwavelength campaigns

We submitted 2 RXTE proposals to observe bright TeV sources.

Sources observable from the Nordern hemisphere:

Mrk 421, Mrk 501, 1es1959+650

MAGIC already agreed in participating

VERITAS very much interested in participating too (private communication from Krawzcynski)

Sources observable from the Soudern hemisphere:

PKS 2155

HESS already agreed in participating

CONCLUSIONS

Observations of Mrk 501 with MAGIC allowed us to study flux and spectra variations down to 100 GeV on a night by night basis

1 - Changes in flux and spectra on several timescales:
months, days, and few minutes

2 - Intra-day variations with flux-doubling times ~2 minutes
Much shorter than previous Mrk 501 and Mrk 421 observations

3 - Flux variability increases with energy

4 - Time delay of ~4 minutes between flare location at E <0.25 TeV and E > 1.2 TeV

5 - Spectra hardens with flux

6 - Detection of the IC peak in the SED for the most active nights

New IACTs increased our capability to study blazars (low/high)

GLAST has excellent capability to study these bright TeV sources

Good times for blazar gamma-ray astronomy !!