The Spectral Properties and Variability of MRK 501 and MRK 421 as observed with the Stereoscopic IACT System of the HEGRA–Collaboration

presented by

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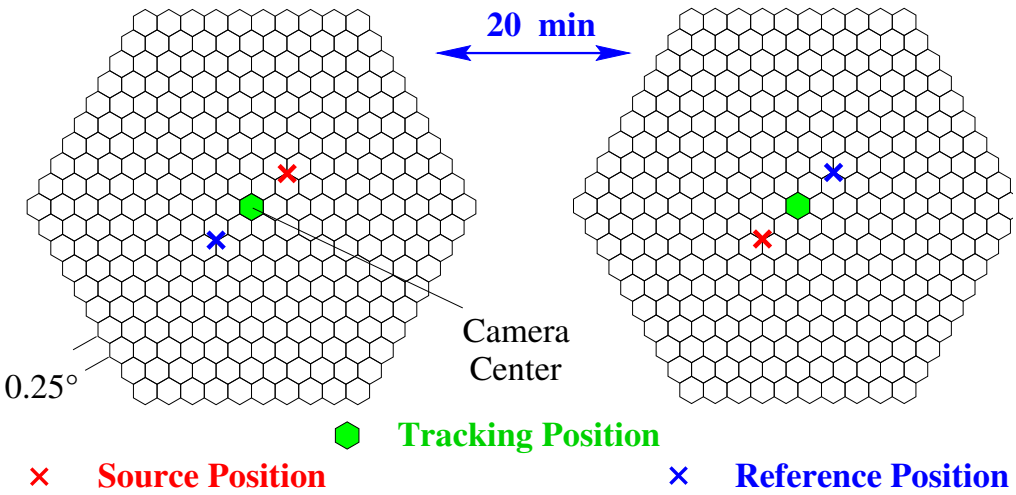
The Kruger Workshop on TeV Gamma–Ray Astrophysis
Towards a Major Atmospheric Cherenoov Detector – V
South Africa, 1997

Observation Mode and Period

System : 4 CTs stereoscopically



"Wobble Mode": 0.5° Displacement

Mrk 501 March 1997 – July 1997

> 100 h at $\Theta < 50°$
> 67 h at $\Theta < 30°$ (f.c.)
> 84 h at $\Theta < 45°$ (f.c.)

Mrk 421 Jan 1997 – June 1997

> 100 h at $\Theta < 50°$ (few ON/OFF)
> 63 h at $\Theta < 30°$ (f.c.)
> 70 h at $\Theta < 45°$ (f.c.)

Gamma–Hadron Separation

width = *width* (Amp, dtc, Θ)

→ **Stereoscopy:**

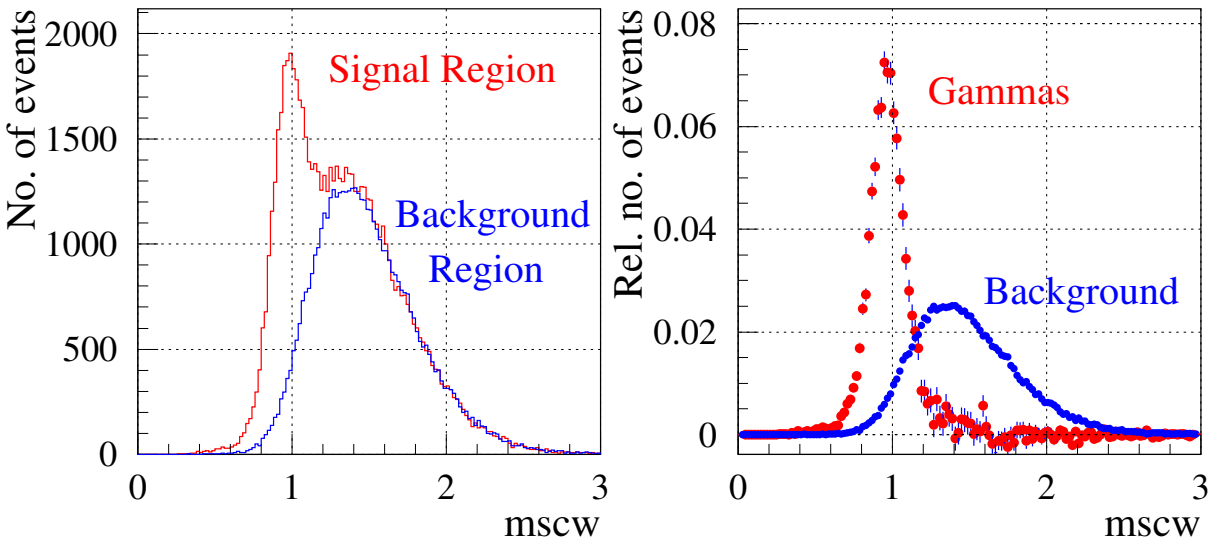
Core Position within 15 m and $\mathrm{Amp}_{CTi}(r)$

→ **Monte Carlo:**

Parametrize $width_{exp}$(Amp, dtc, Θ) of γ–showers

→ **Data:**

Def: mscw = $\frac{1}{N_{CT}} \sum \frac{width(A,dtc,\Theta)}{width_{exp}(A,dtc,\Theta)}$



Cut at mscw = 1.3

⇒ Minimize systematic uncertainties

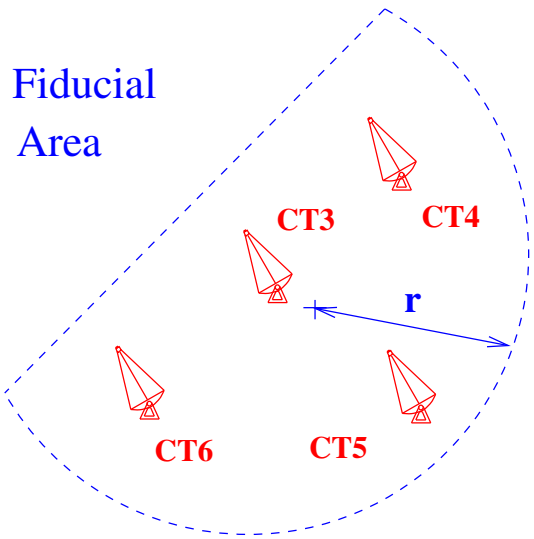
⇒ Maximize γ–statistics

⇒ NOT for maximum sensitivity

Energy Reconstruction

→ Stereoscopy:

Core Position within 15 m (unambiguous)

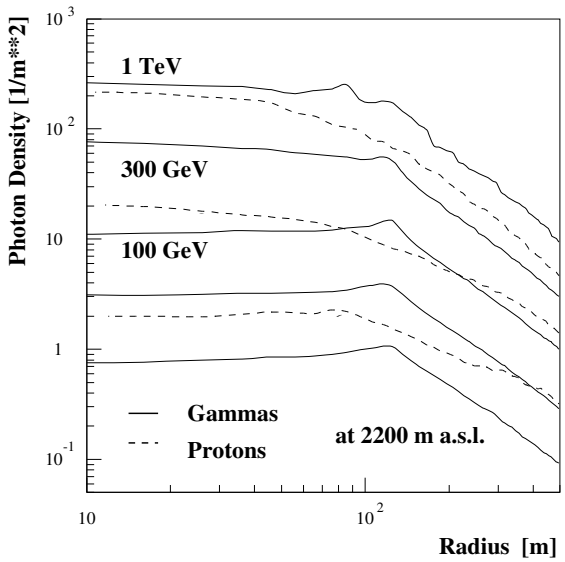


Fiducial Area:

r_{max} = r(E) such that

$$\eta_{trg}(E) = \int_0^{r_{max}} \eta_{trg}(r, E)\, dr > 80\,\%$$

r_{max} from Monte Carlo



Photon Density:

$\Phi_{p.e.} = \Phi_{p.e.}(r, E)$

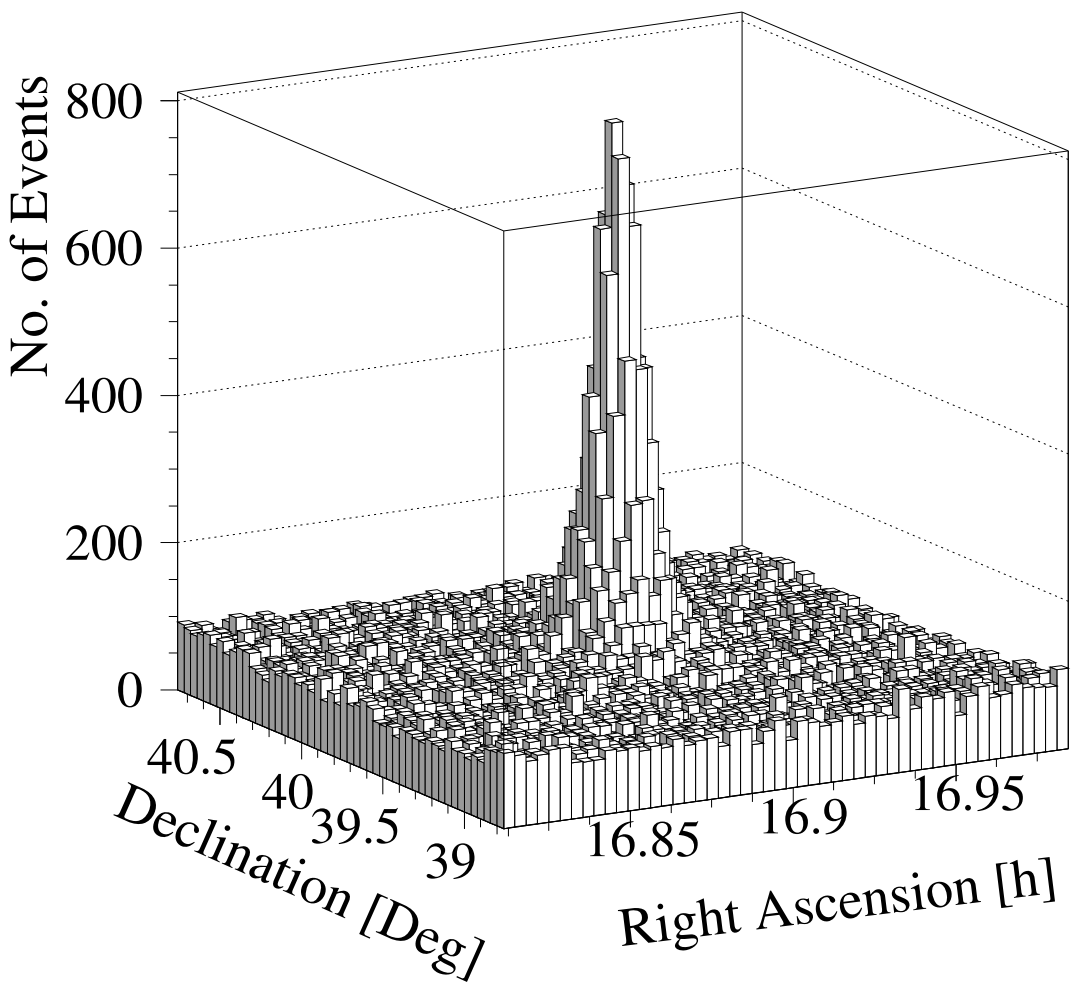
$\Rightarrow$ E = E(Amp, r)

$\Delta(E)/E \approx 20\,\%$

event by event

Reconstructed Shower Directions

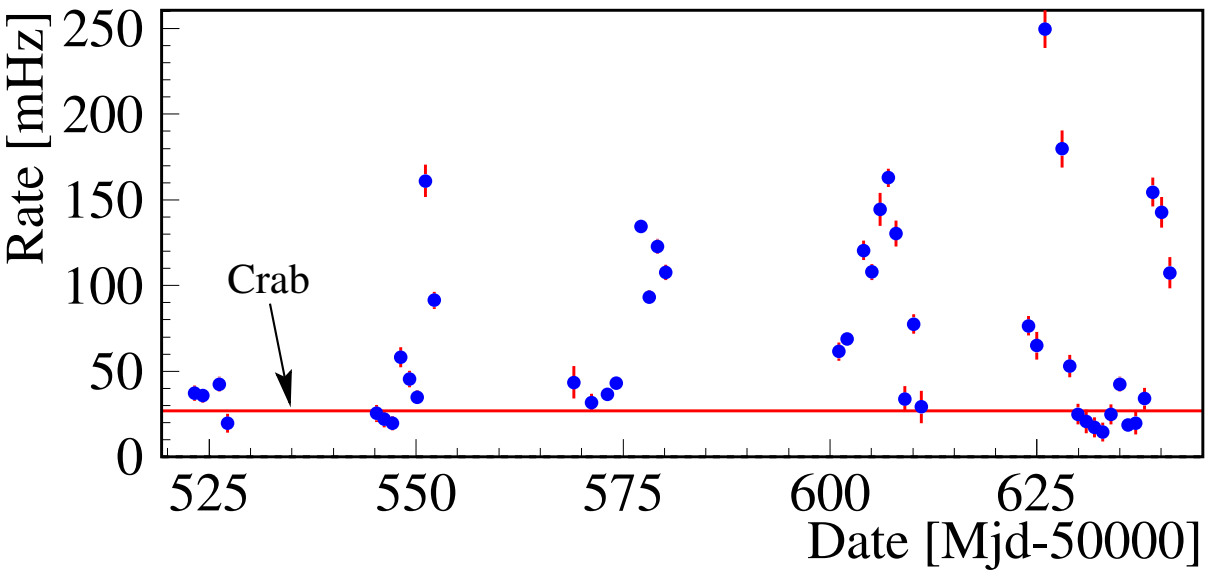
Mrk 501 Signal after mscw $<$ 1.3 Cut



Time Variability of Markarian 501

Count Rate on a Night by Night Basis

$\Theta_z < 30°$, $\theta^2 < 0.1$ deg^2



Maximal count rate : ~ 9.3 Crab
Minimal count rate : ~ 0.5 Crab

Maximal rapidity of rate changes

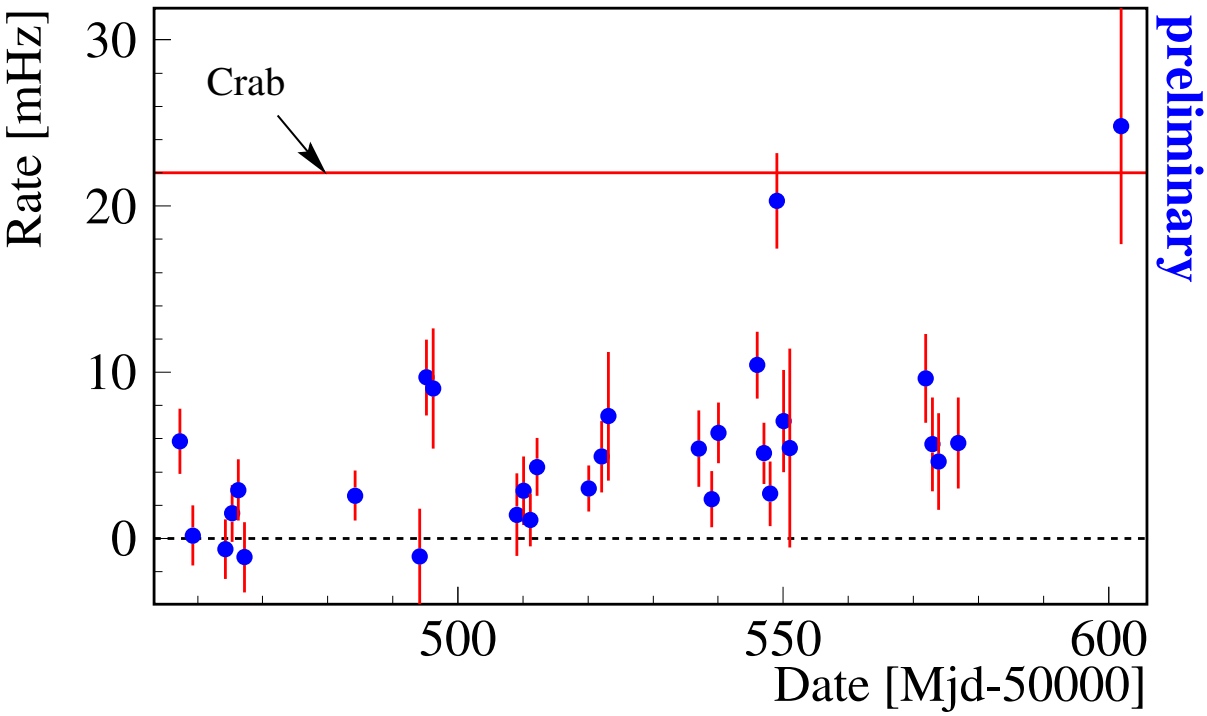
Increase : $\times\ 4.69 \pm 0.61$ / day at Mjd: 50551
Decrease : $\times\ 3.86 \pm 0.06$ / day at Mjd: 50609

$\Rightarrow$ Investigations on sub-day and sub-hour variability in progress

Time Variability of Markarian 421

Count Rate on a Night by Night Basis

$\Theta_z < 30°$, $\theta^2 < 0.05$ deg^2



Max. count rate : $\sim$ 1.1 Crab at Mjd: 50549

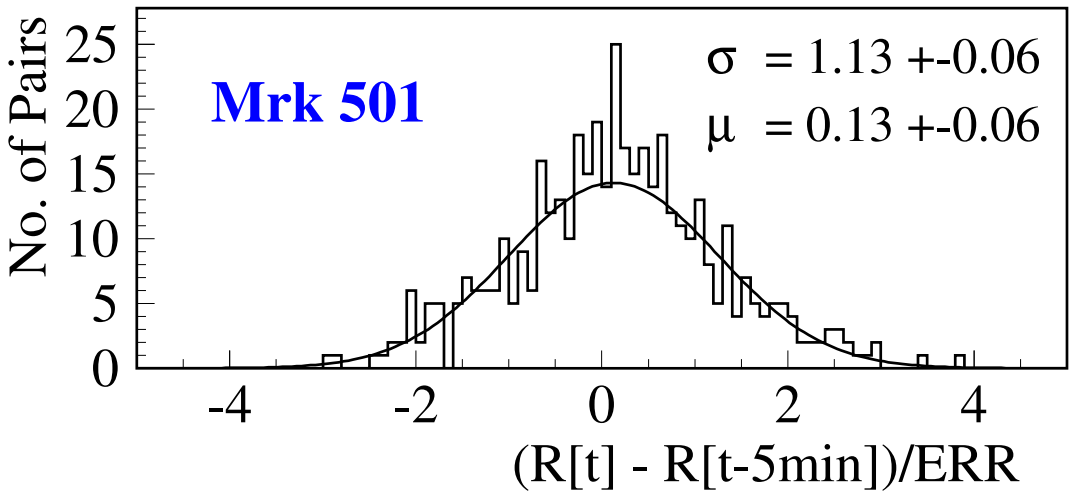
Min. count rate : $\sim$ 0.

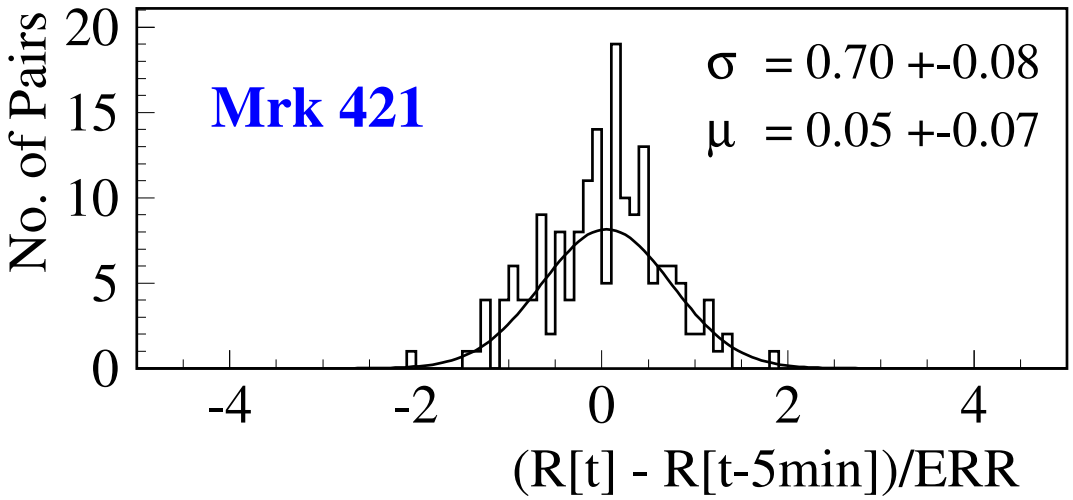
Short Term Variability of Markarian 501 and Markarian 421

Count Rate on a 5 minute binning

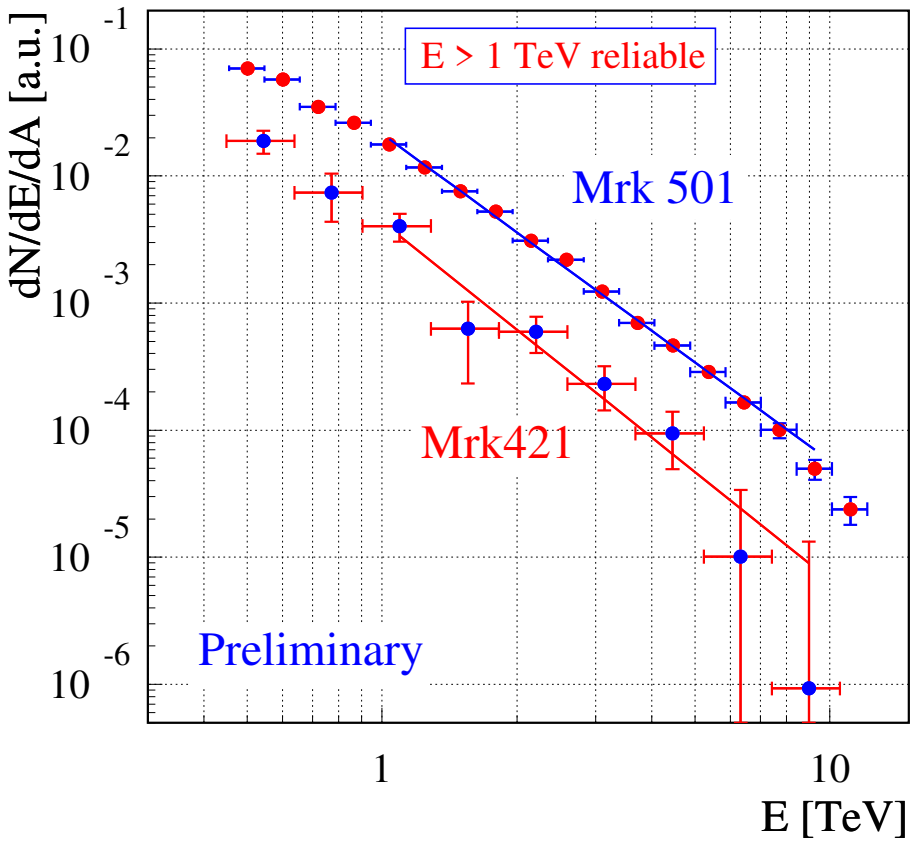
Mrk501: $\Theta_z < 30°$, $\theta^2 < 0.10$ deg^2

Mrk421: $\Theta_z < 30°$, $\theta^2 < 0.05$ deg^2





Energy Spectrum of Mrk 501 and Mrk 421



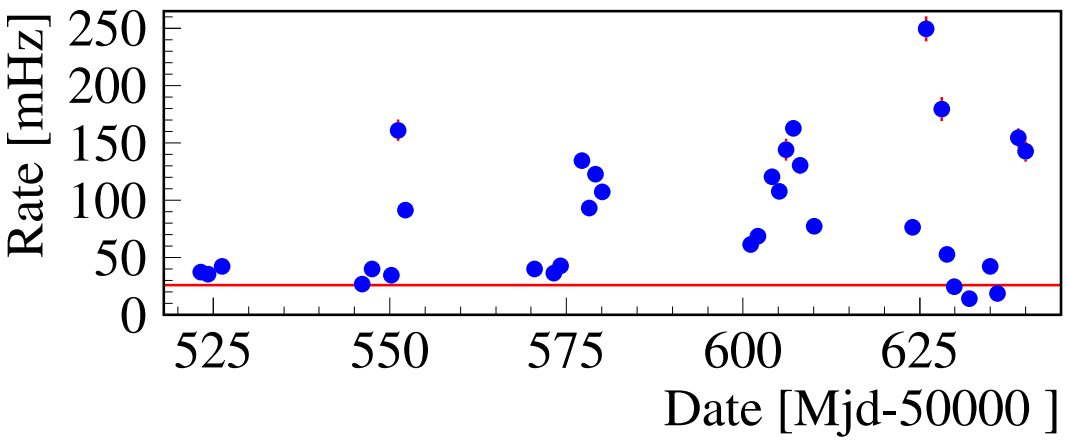
Spectral index

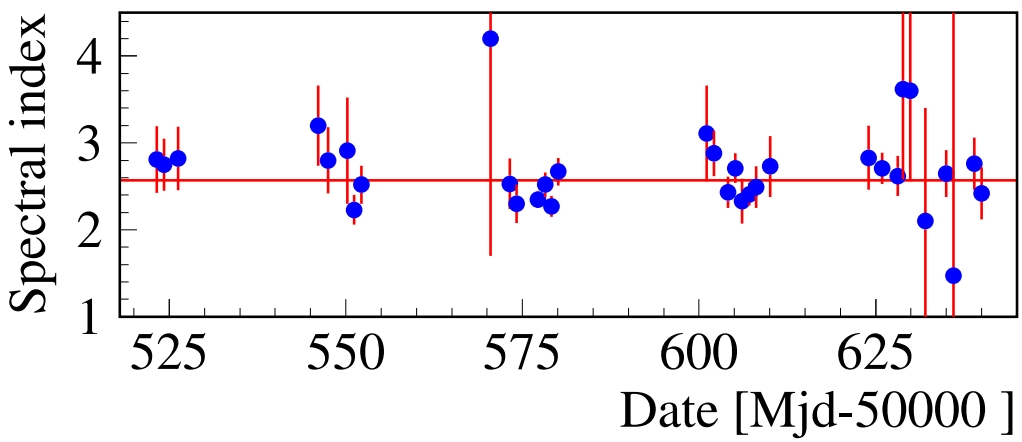
Mrk 501	α = -2.57 $\pm$ (0.03)$_{stat}$ $\pm$ (0.2)$_{sys}$
Mrk 421	α = -2.82 $\pm$ (0.34)$_{stat}$ $\pm$ (0.2)$_{sys}$
Crab	α = -2.60 $\pm$ (0.22)$_{stat}$ $\pm$ (0.2)$_{sys}$

$\rightarrow$ **Further systematic studies**

Spectral Hardness vs Date

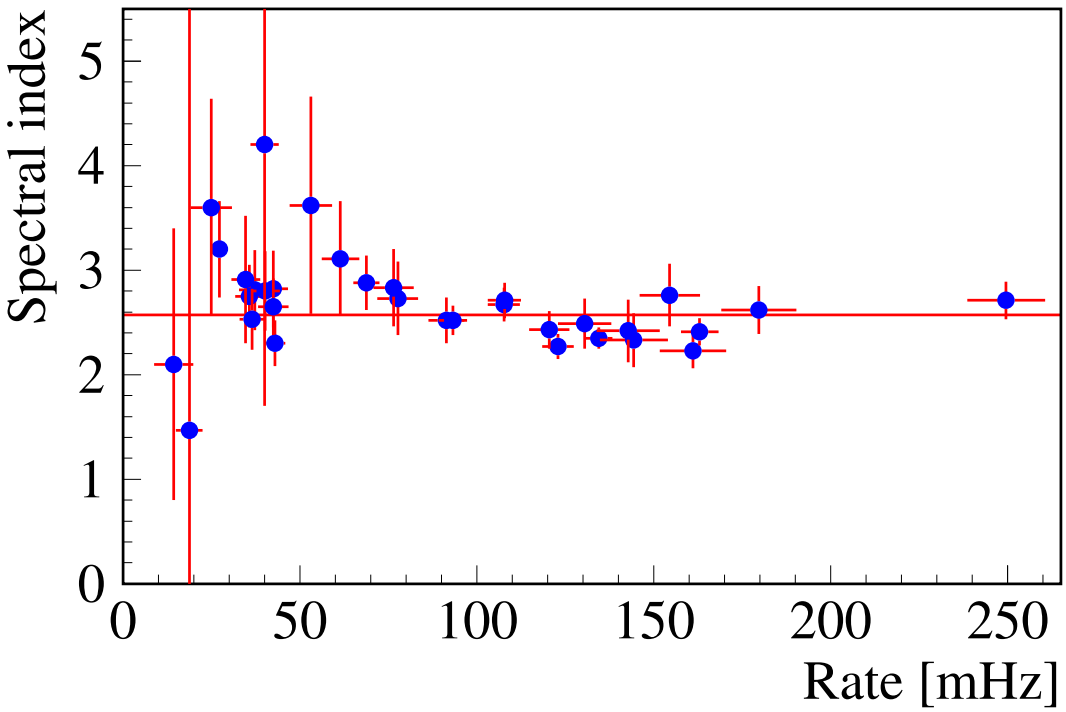
Mrk501: $\Theta_z < 30°$, $\theta^2 < 0.1\ \mathrm{deg}^2$





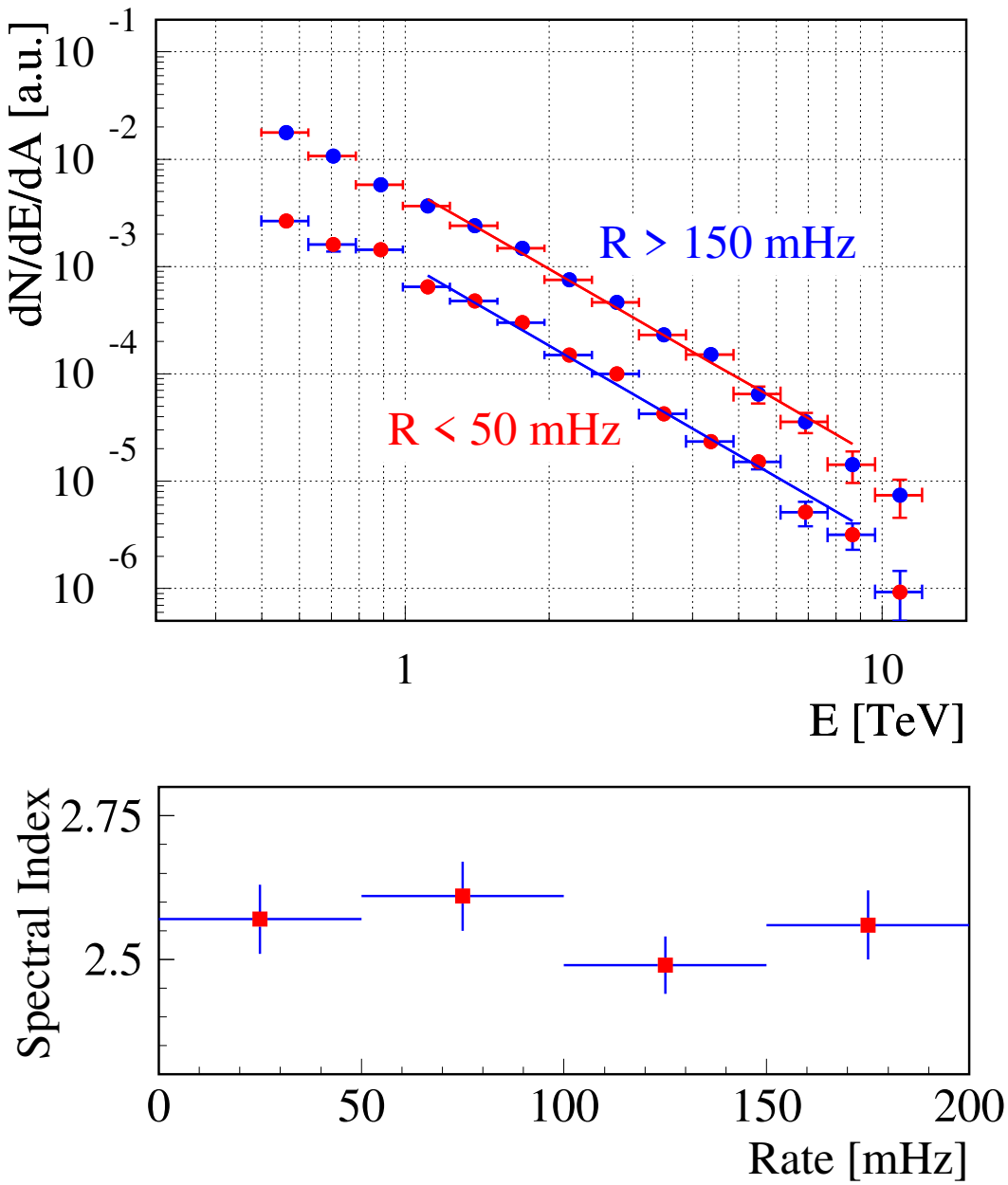
Spectral Hardness vs Flux

Mrk501: $\Theta_z < 30°$, $\theta^2 < 0.1\ \mathrm{deg}^2$



Mrk501: Spectral Hardness vs Flux 2

Mrk501: $\Theta_z < 30°$, $\theta^2 < 0.1\ \mathrm{deg}^2$



Summary and Outlook

Variability Mrk 501

- ⇒ Flux levels up to ~ 9 Crab observed
- ⇒ Flux changes by up to factor ~ 4 within one day
- ⇒ No significant 5 min. variations seen (up to now)
- ⇒ Further studies in progress

Spectra:

- ⇒ No obvious cutoff at E $<$ 10 TeV
- ⇒ Spectrum of Mrk 501 (and Mrk 421) similar to Crab
- ⇒ Shape of the spectrum of Mrk 501 independent of time and flux

Systematic studies:

- ⇒ "Final" spectrum
- ⇒ Spectrum at E $>$ 10 Tev; Data available