LIV with H.E.S.S. : Mkn 501 spectrum

M.Lorentz, P.Brun, J-F. Glicenstein,
for the H.E.S.S. collaboration

IRFU
CEA and Université Paris-Saclay

Probing quantum spacetime with astrophysical sources

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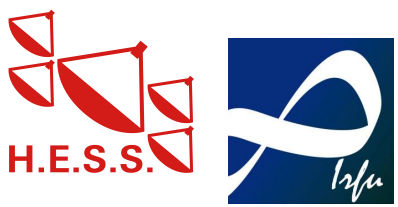
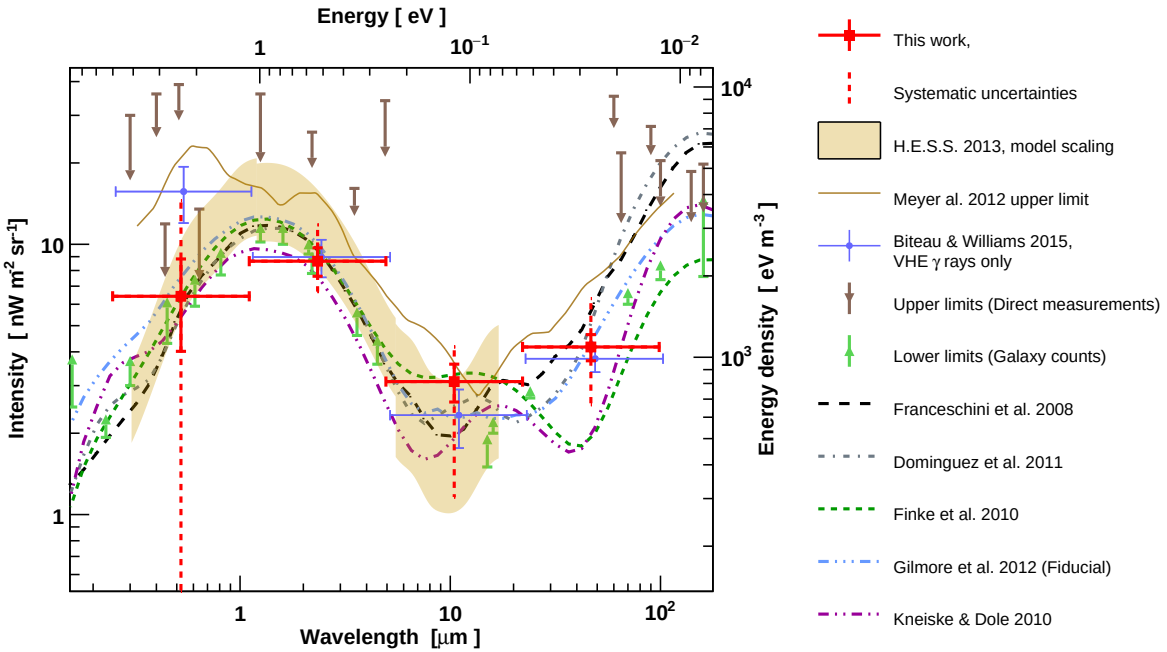


Absorption optical depth

- Photon flux from source at redshift z_s absorbed by Extragalactic Background light (EBL) through $\gamma\gamma \rightarrow e^+e^-$
- Optical depth: $\Phi_{\text{obs}}(E_\gamma) = \Phi_{\text{int}}(E_\gamma)\ \mathrm{e}^{-\tau(E_\gamma, z_s)}$
- Background photon of energy $\epsilon \implies$ threshold energy for pair creation $\epsilon_{thr} = \frac{2m_e^2c^4}{E_\gamma(z+1)}$
- $$\tau(E_\gamma, z_s) = \frac{m^4c^9}{E_\gamma^2}\int_0^{z_s} dz \frac{dt}{dz}\frac{1}{(z+1)^2}\int_{\epsilon_{thr}}^{\infty} d\epsilon \frac{dn(\epsilon, z)}{\epsilon^2 d\epsilon}\int_1^{s_{max}} ds \frac{s}{2}\sigma_{\gamma\gamma}(s, z)$$

  (Gould and Schréder (1967))

Spectral energy distribution of background light



- H.E.S.S. observations of the SED of background light (*H.Abdalla et al (H.E.S.S. collaboration), A & A (2017), M.Lorentz PhD thesis (2017)*) in agreement with models
- This analysis uses the Franceschini et al (2008) model for background light density.

Effect of LIV on absorption optical depth

- Photon dispersion relation: $E_\gamma^2 = p_\gamma^2 - E_\gamma^2 \left(\frac{E_\gamma}{E_{\rm LIV}}\right)^n$ (n=1,2)
- Assumes subluminal motion
- Background photon of energy $\epsilon \implies$ threshold energy
  $\epsilon_{thr} = \frac{2m_e^2c^4}{E_\gamma(z+1)} + \frac{1}{4}\frac{(E_\gamma(z+1)^{n+1})}{E_{\rm LIV}^n}$
- Optical depth $\tau(E_\gamma, z_s) =$

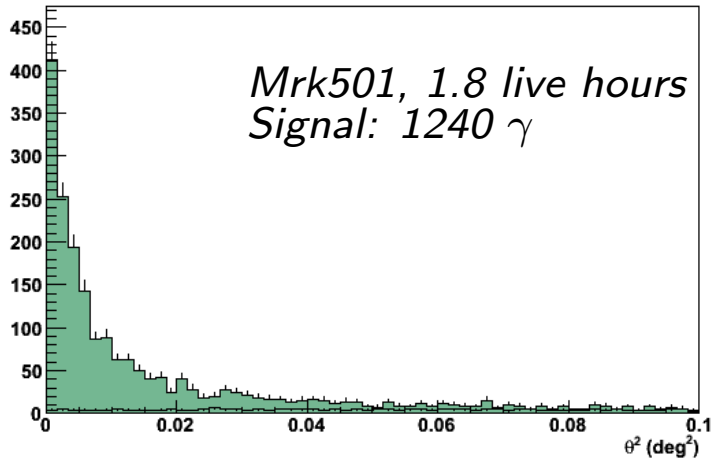
  $\frac{m^4c^9}{E_\gamma^2}\int_0^{z_s} dz \frac{dt}{dz}\frac{1}{(z+1)^2}\int_{\epsilon_{thr}}^{\infty} d\epsilon \frac{dn(\epsilon,z)}{\epsilon^2 d\epsilon}\int_1^{s_{max}} ds \frac{(s-\frac{((z+1)E_\gamma)^{n+2}}{E_{\rm LIV}^n})}{2}\sigma_{\gamma\gamma}(s,z)$

  (Jacob and Piran (2008), Fairbairn et al (2014), Tavecchio and Bonnoli (2015))

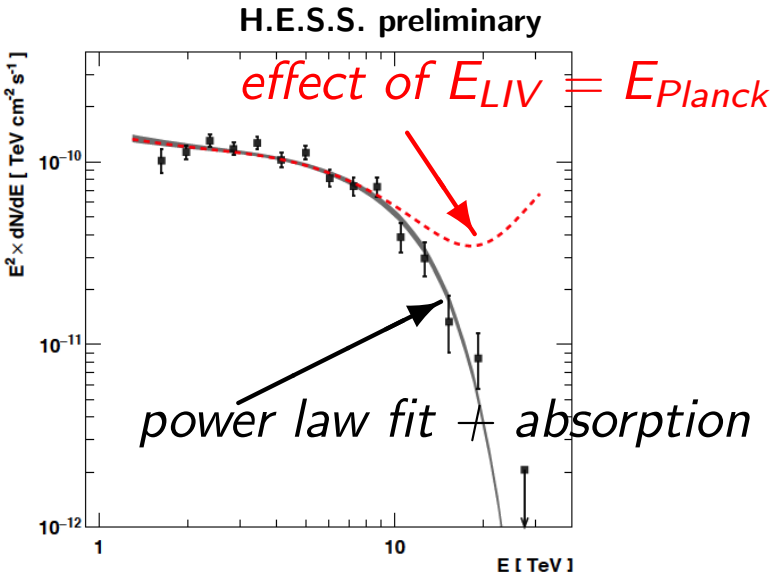
H.E.S.S. observations of Mrk 501 during the 2014 flare

- Mrk 501
  - Well known blazar at redshift z = 0.034
  - In list of interesting targets from Fairbarn et al (2014) and Tavecchio and Bonnoli (2015)
  - Very bright and strongly variable at all energies
  - June 2014 flare, reported at ICRC 2015
- H.E.S.S. observations

- Observations triggered as ToO from a FACT alert, mean zenith angle $\sim 63^o$
- Very significant detection $\sim 67\ \sigma$ in $< 2h$ (H.E.S.S. phase I analysis)
- Highest fluxes ever recorded by H.E.S.S. on Mrk 501



Mrk 501, 2014 flare spectrum

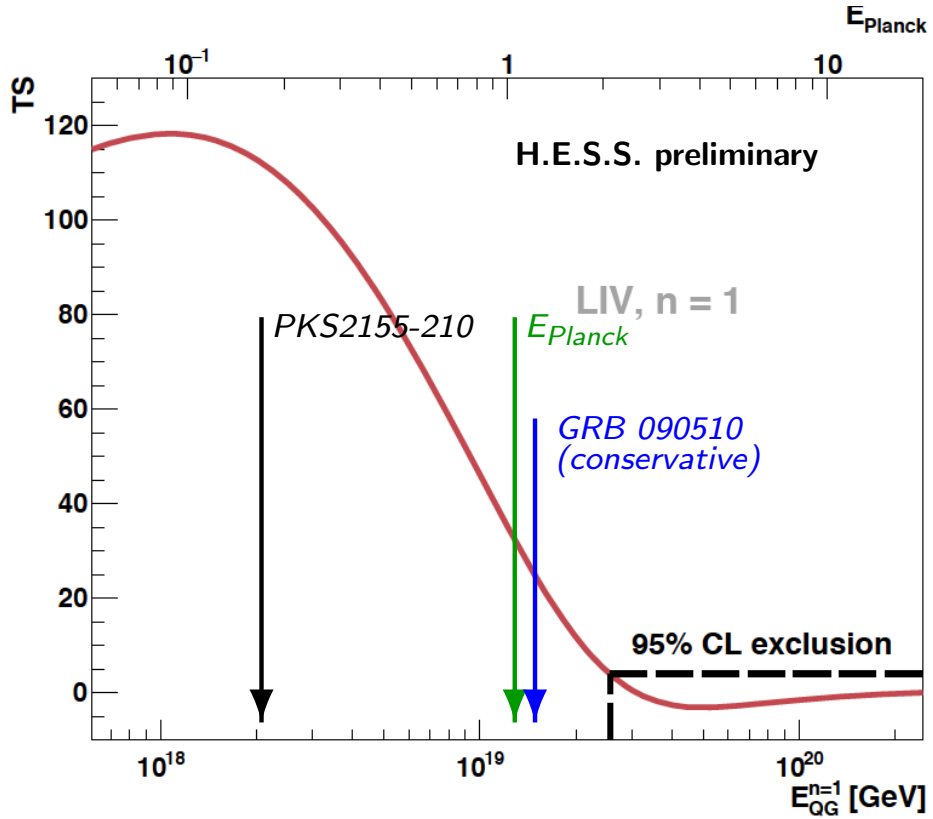


- Fits well to an EBL-absorbed power-law
- Intrinsic photon index:

$$\alpha = 2.03 \pm 0.04_{stat} \pm 0.2_{sys}$$

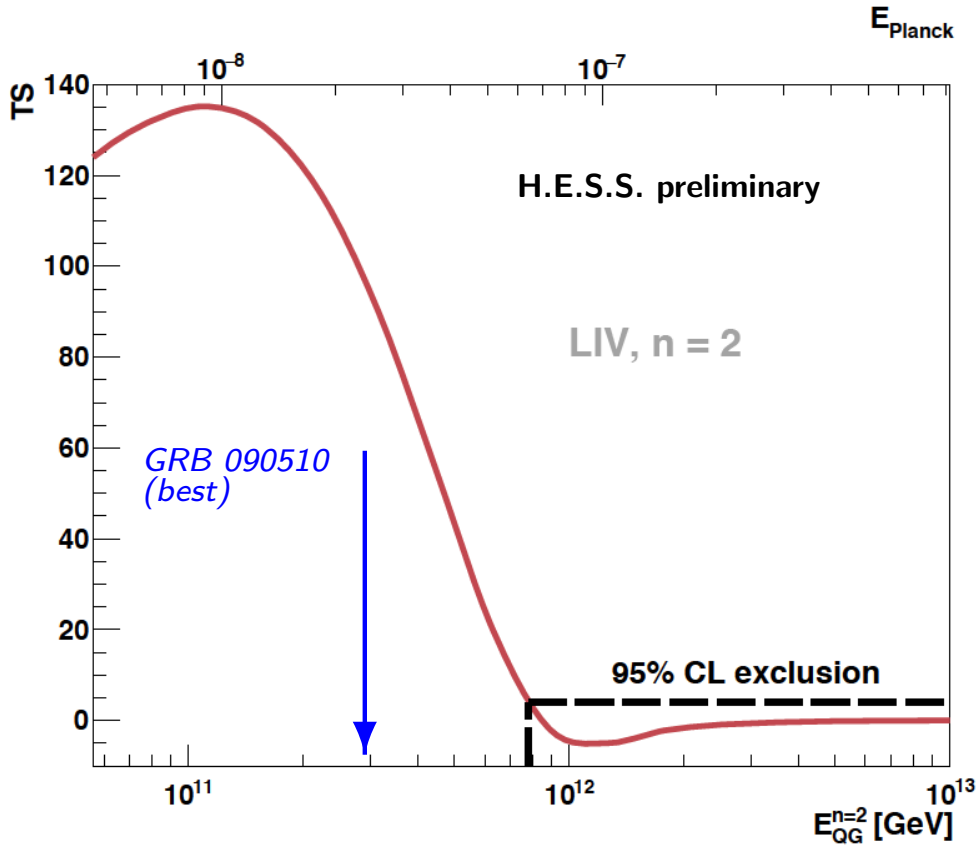
- Spectrum crosschecked by independent methods: direct unfolding, different data sets.
- General agreement of reconstructed spectra at high energy. Spectrum extends up to 20 TeV
  $\Longrightarrow$ spectral constraints on LIV.

LIV exclusion limits:linear case



- The spectrum is fitted with a modified EBL contribution with E_{LIV} and free spectral parameters.
- Lower limit at 95 % CL: $\boxed{E_{LIV}^{n=1} > 2.1\ E_{\mathrm{Planck}}}$
- E_{Planck} excluded at 5.8 σ

LIV exclusion limits:quadratic case



- Fit with modified EBL as in the linear case
- Lower limit at 95 % CL : $E_{LIV}^{n=2} > 7.81\ 10^{11}\mathrm{GeV} = 6.4\ 10^{-8}\ E_{\mathrm{Planck}}$
- Best current limit in the $n = 2$ case.

Conclusion

- Preliminary results:

	Linear case	Quadratic case
limit on E_{LIV} (95 % CL)	2.56 10^{19} GeV	7.81 10^{11} GeV

- Best LIV energy scale limits obtained with AGNs.
- In the linear case, limit obtained comparable to limit from GRB 090510.
- In the quadratic case, current best lower limit on E_{LIV}.