PROBING THE INTER GALACTIC MAGNETIC FIELD BY MEANS OF HIGH ENERGY PAIR HALOS AROUND EXTREME BLAZARS

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MAGIC

INFN

OUTLINE

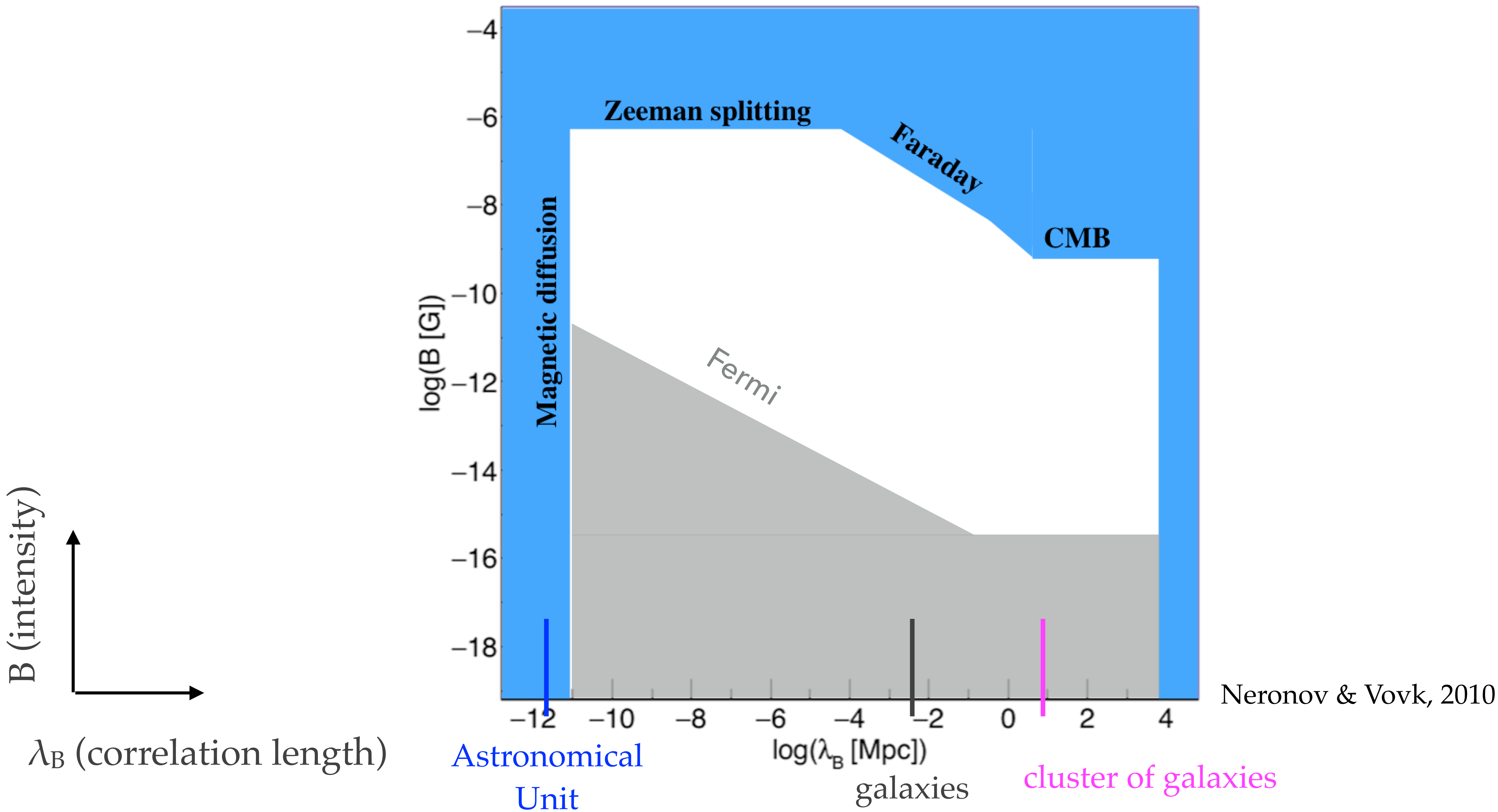
- Standard techniques to measure the Magnetic fields in the Universe
- Constraints of Inter Galactic Magnetic Fields (IGMF) with gamma-ray observations of Active Galactic Nuclei
- Search for extended gamma-ray emission around TeV AGN with MAGIC telescopes
- Upper limits on halo emission
- Conclusions

ON THE NATURE OF THE INTER GALACTIC MAGNETIC FIELDS

- The magnetic fields in the galaxies and cluster of galaxies are often explained through amplification mechanisms of pre-existing magnetic fields
- The nature of these weak fields is largely unknown. Two main hypothesis:
    - *the astrophysical origin*
    - *the cosmological origin*
- **Observationally we need the measurements of magnetic fields in the Intergalactic medium**

THE INTER GALACTIC MAGNETIC FIELDS

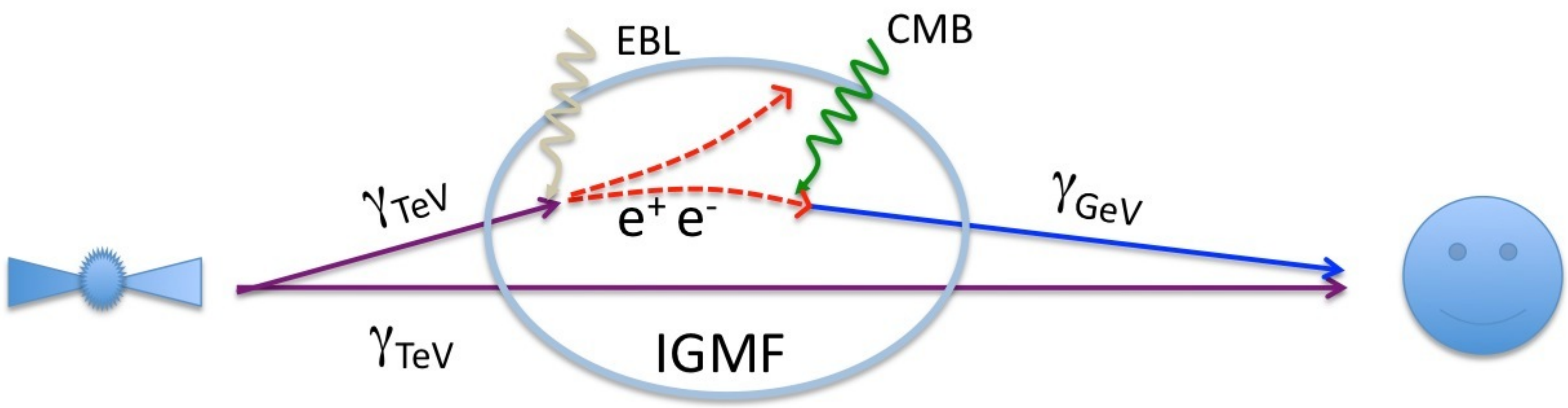
- The IGMF is characterised by the field strength B and the correlation length λ_B



LIMITS ON IGMF WITH GAMMA RAY TELESCOPES

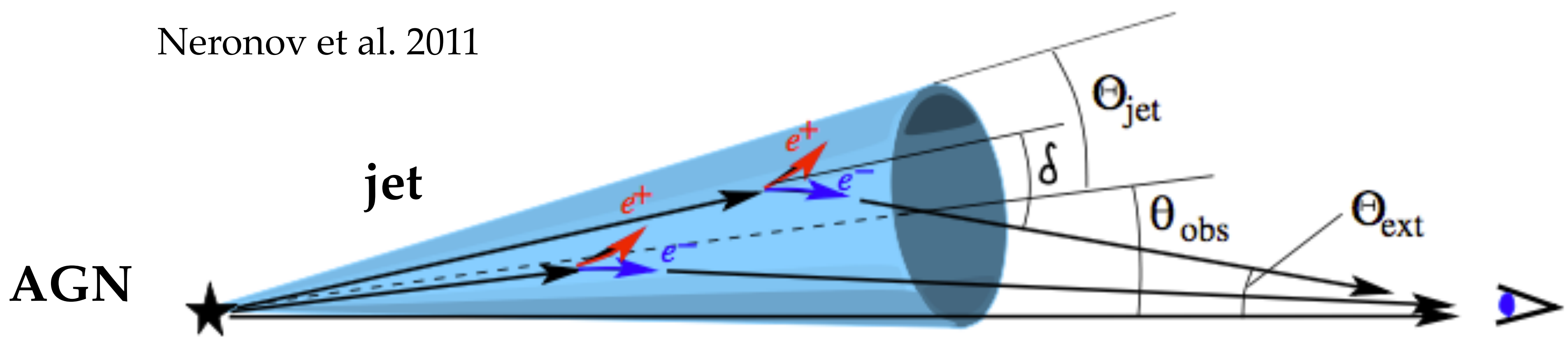
- Physical process: reprocessing of TeV photons in the GeV band
- Measurable effects:
  - *spectral features*
  - *extended emission*

$$E_\gamma \simeq 70 \left[\frac{E'_{\gamma 0}}{10\ TeV}\right]^2\ GeV$$



EXTENDED EMISSION

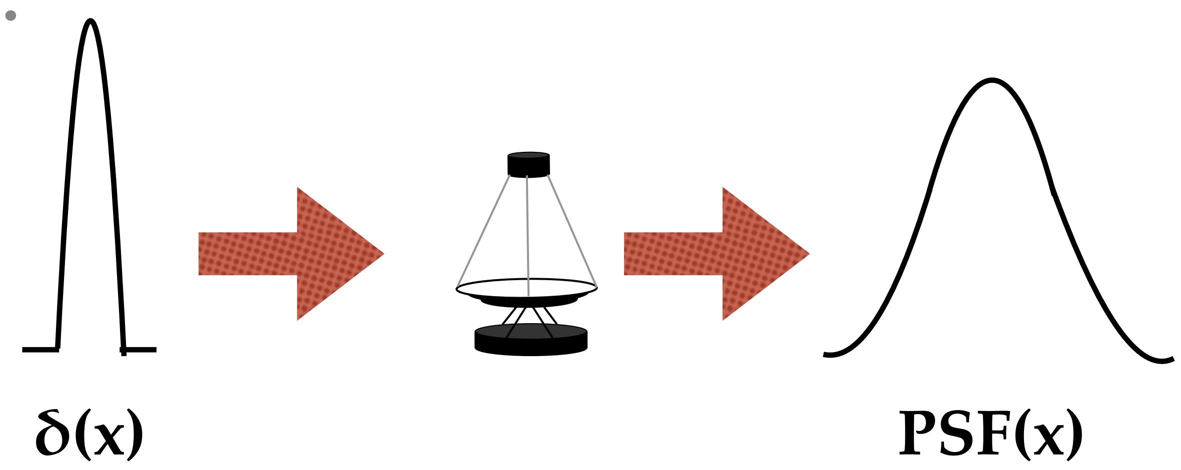
- Observable effect: extended emission around he point source The angular extension grows with increasing IGMF.



- Two regimes:
  - $\lambda_B \gg D_e$ $$\Theta_{ext} \simeq 0.5^\circ (1+z)^{-2} \left[\frac{\tau}{10}\right]^{-1} \left[\frac{E_\gamma}{0.1\ TeV}\right]^{-1} \left[\frac{B_0}{10^{-14}\ G}\right]$$
  - $\lambda_B \ll D_e$ $$\Theta_{ext} \simeq 0.07^\circ (1+z)^{-1/2} \left[\frac{\tau}{10}\right]^{-1} \left[\frac{E_\gamma}{0.1\ TeV}\right]^{-3/4} \left[\frac{B_0}{10^{-14}\ G}\right] \left[\frac{\lambda_{B0}}{1\ kpc}\right]^{1/2}$$

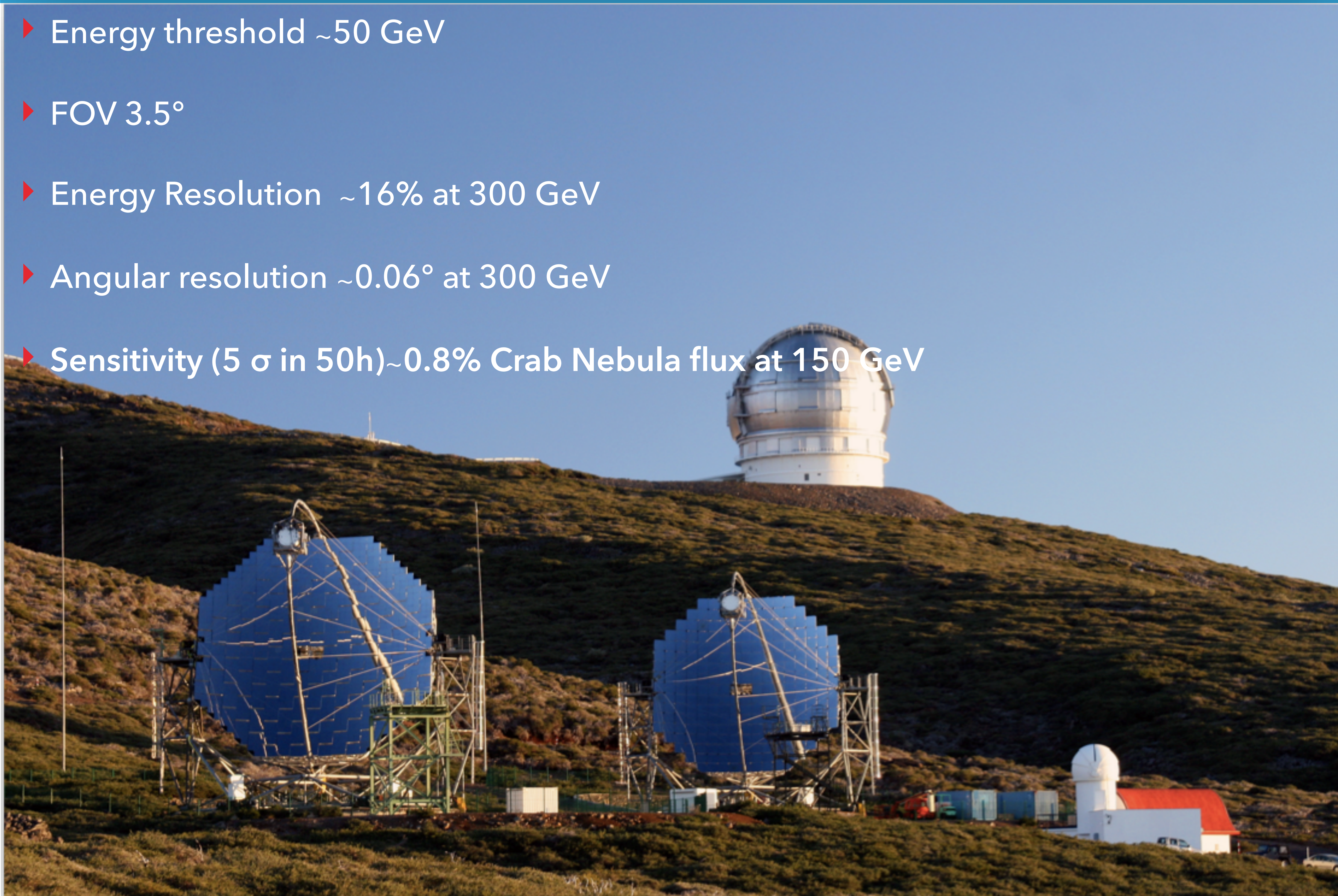
OUR PROJECT TO SEARCH FOR EXTENDED GAMMA RAY EMISSION

- Through the study of the emission profiles of TeV AGN we looked for halo emission around 100 GeV
- We used the VHE data of MAGIC telescopes to derive an analytical description of the Point Spread Function (PSF)
- Three steps have been considered:
  - the background
  - model of PSF
  - comparison of PSF with profiles of AGN



THE MAGIC TELESCOPES

- Energy threshold ~50 GeV
- FOV 3.5°
- Energy Resolution ~16% at 300 GeV
- Angular resolution ~0.06° at 300 GeV
- Sensitivity (5 σ in 50h)~0.8% Crab Nebula flux at 150 GeV



THE MAGIC PSF

- In order to study the MAGIC PSF we selected a data sample of Crab Nebula (about 17 hours).
- We studied the off axis response of the instrument considering sources without signal.
- Finally we built the emission profile of Crab corrected for the off axis response performing the so called θ^2 plot.
- The next step was to derive an analytical description of MAGIC PSF

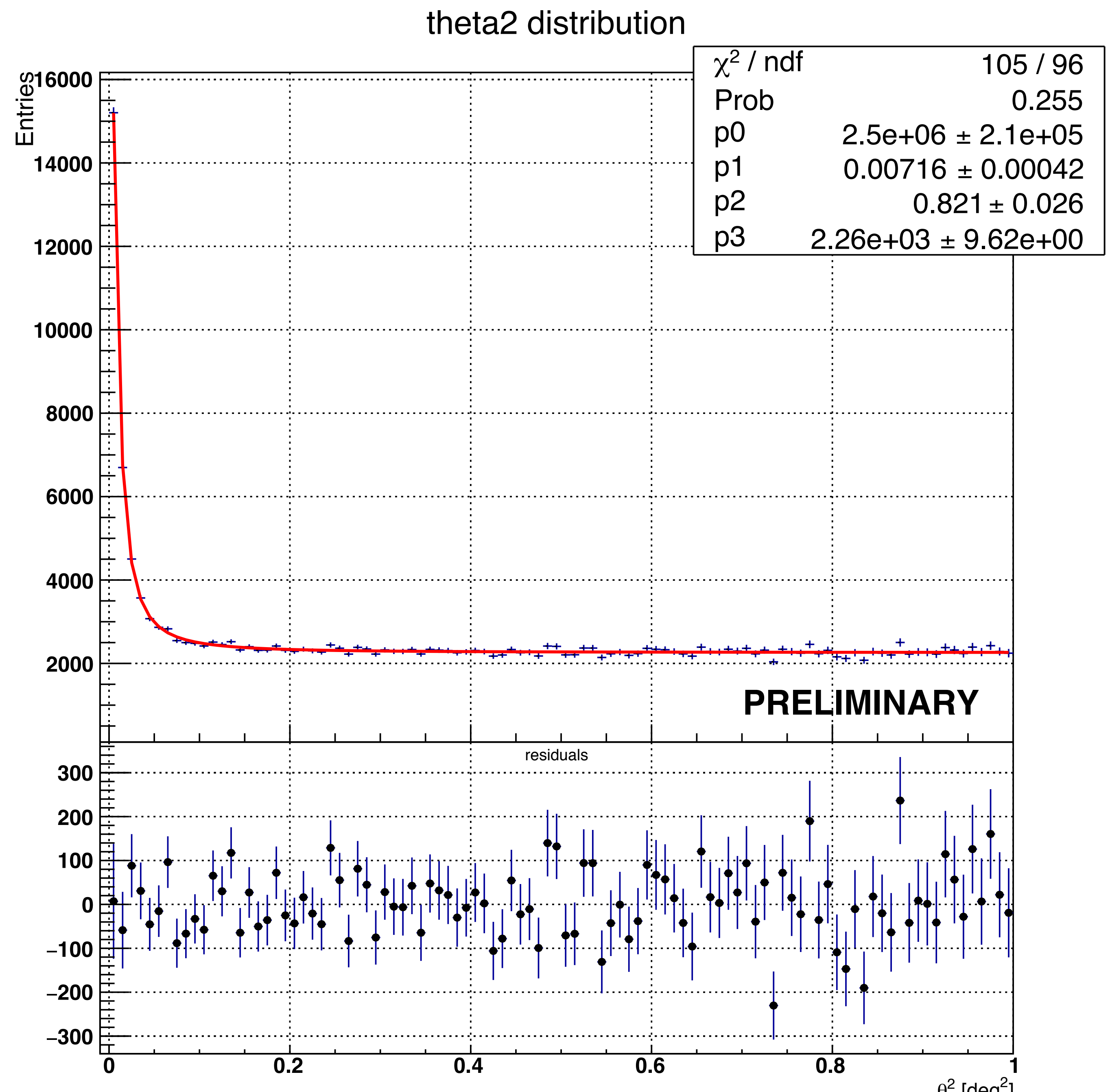
FIT OF MAGIC PSF

- We used the King function to fit the MAGIC PSF

$$f(\theta^2) = p0 * p1 * \left[1 + \left(\frac{\theta^2}{p1}\right)^2\right]^{-p2} + p3$$

King function

corrected background



MAGIC coll., paper in prep.

- This function is able to describe the data also at high values of θ^2

SEARCH FOR EXTENDED GAMMA RAY EMISSION AROUND TEV AGN

- In order to search for extended emission we selected two different AGN:
  - Markarian 421 (10 hours, z=0.03)
  - 1ES 0229+200 (40 hours, z=0.14)
- Since the PSF depends on the spectrum and the zenith range of the point source, to perform the comparison we first rescaled properly the PSF to the test source

COMPARISON BETWEEN PSF AND AGN EMISSION PROFILES

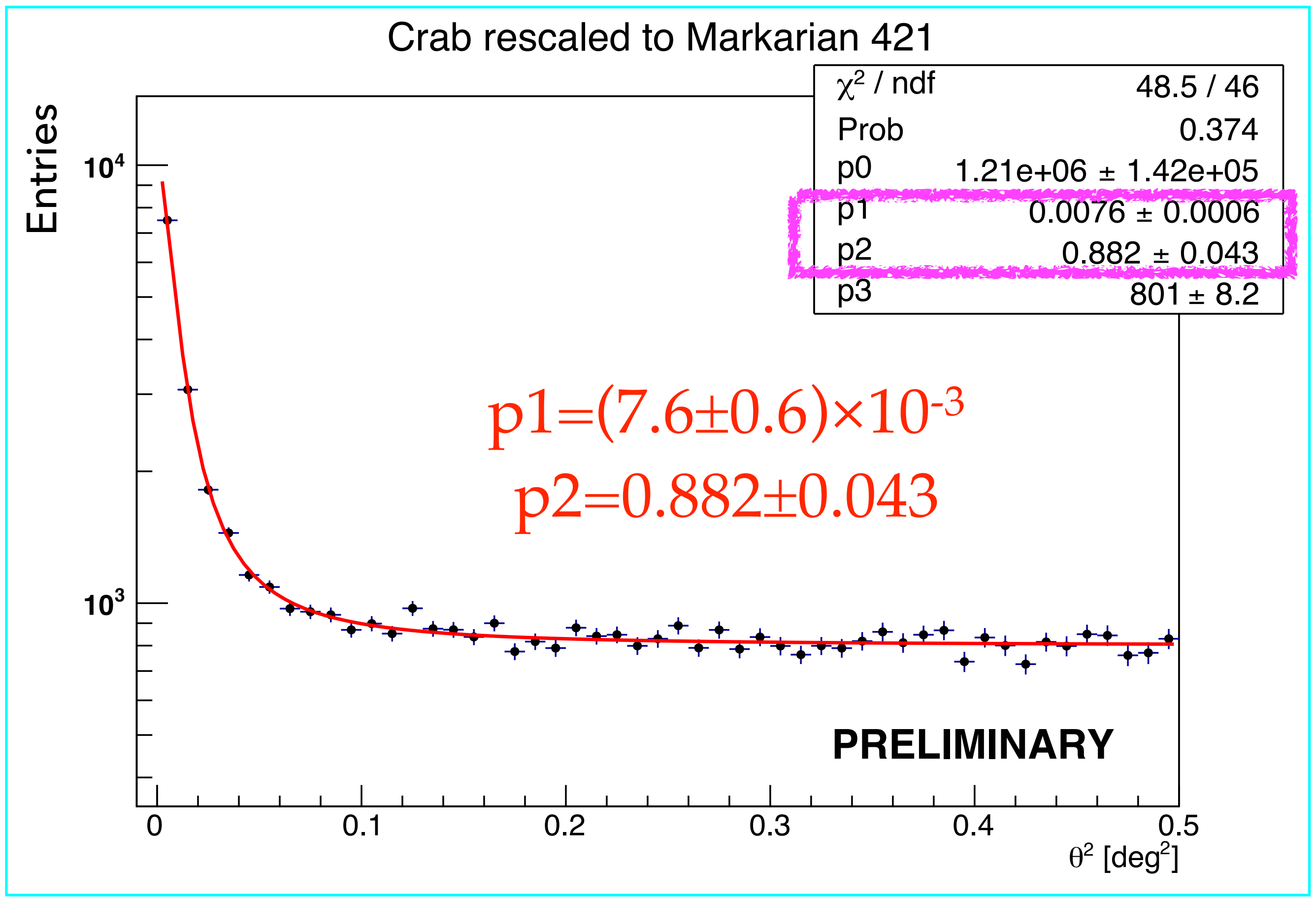
- To compare the PSF reference with the AGN we followed this procedure:

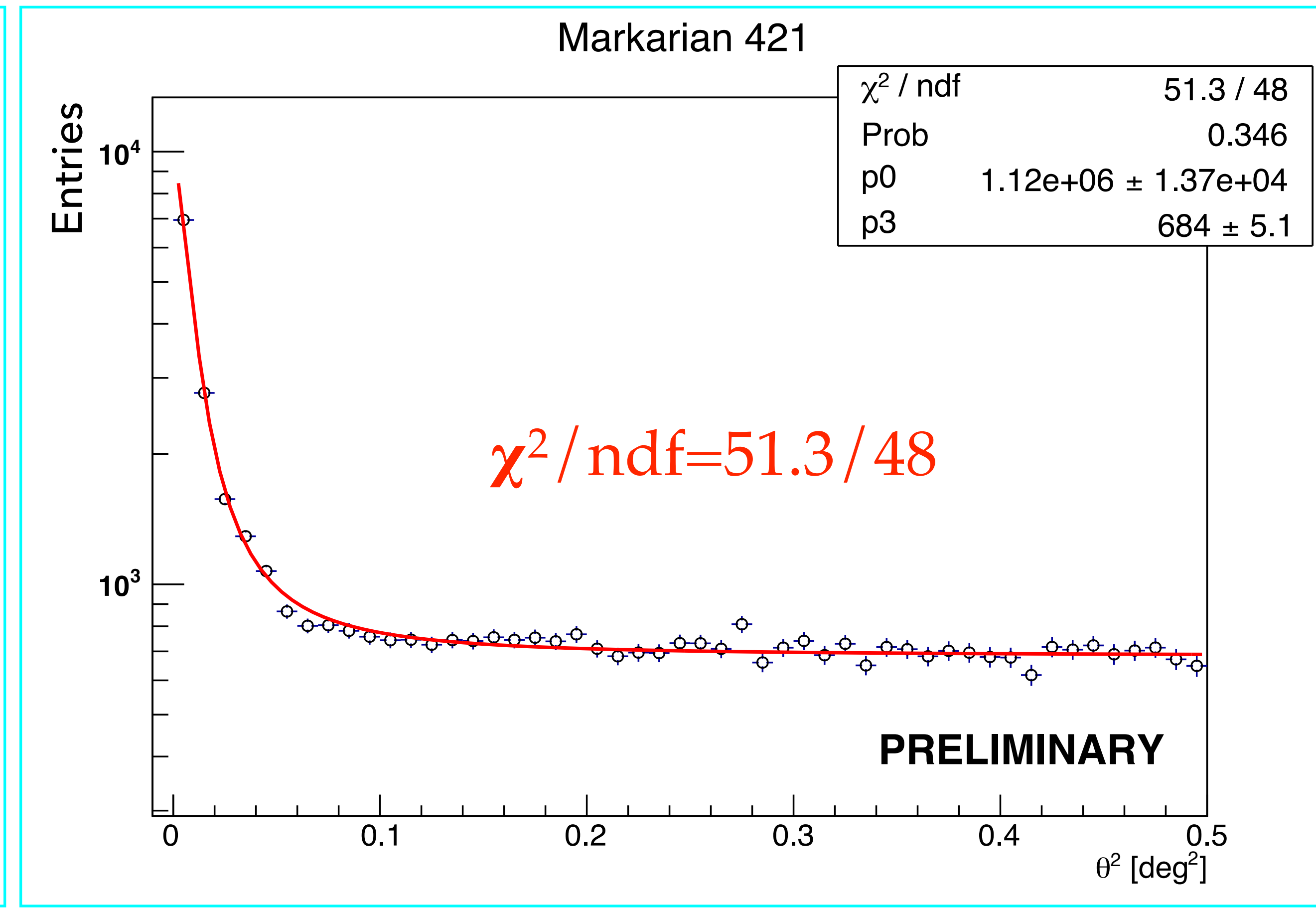
$$\text{PSF model:}\quad f(\theta^2) = p0 * p1 * \left[1 + \left(\frac{\theta^2}{p1}\right)^2\right]^{-p2} + p3$$

- Crab: fit with 4 free parameters
- AGN: p1 and p2 fixed to Crab
- **If the new fit is able to describe the data then no reason to claim difference between PSF profile and AGN**

MARKARIAN 421 AND 1ES 0229+200: RESULTS

- θ^2 plots produced in the energy range: 100-1389.5 GeV





- **Angular distribution compatible with point source emission**

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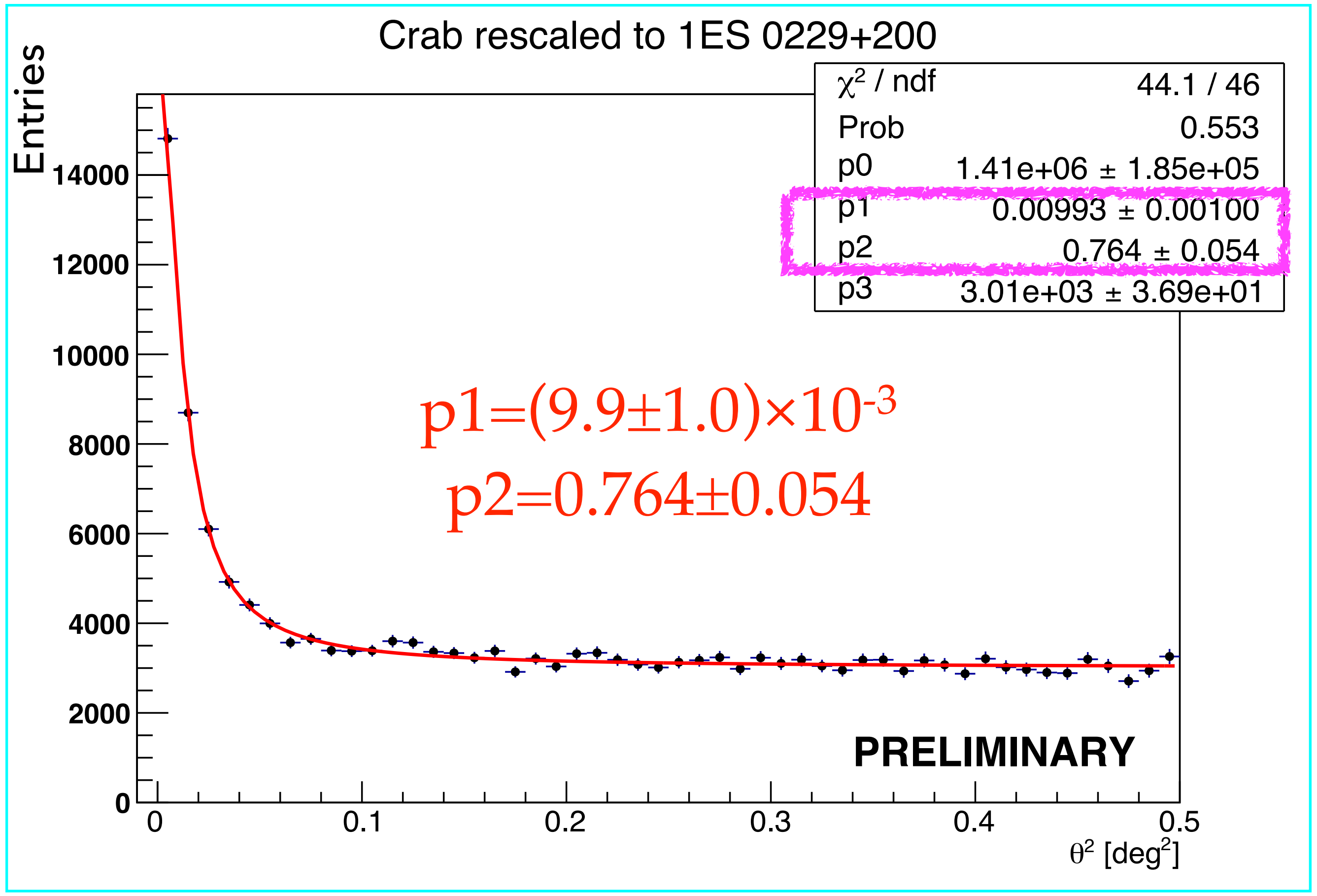
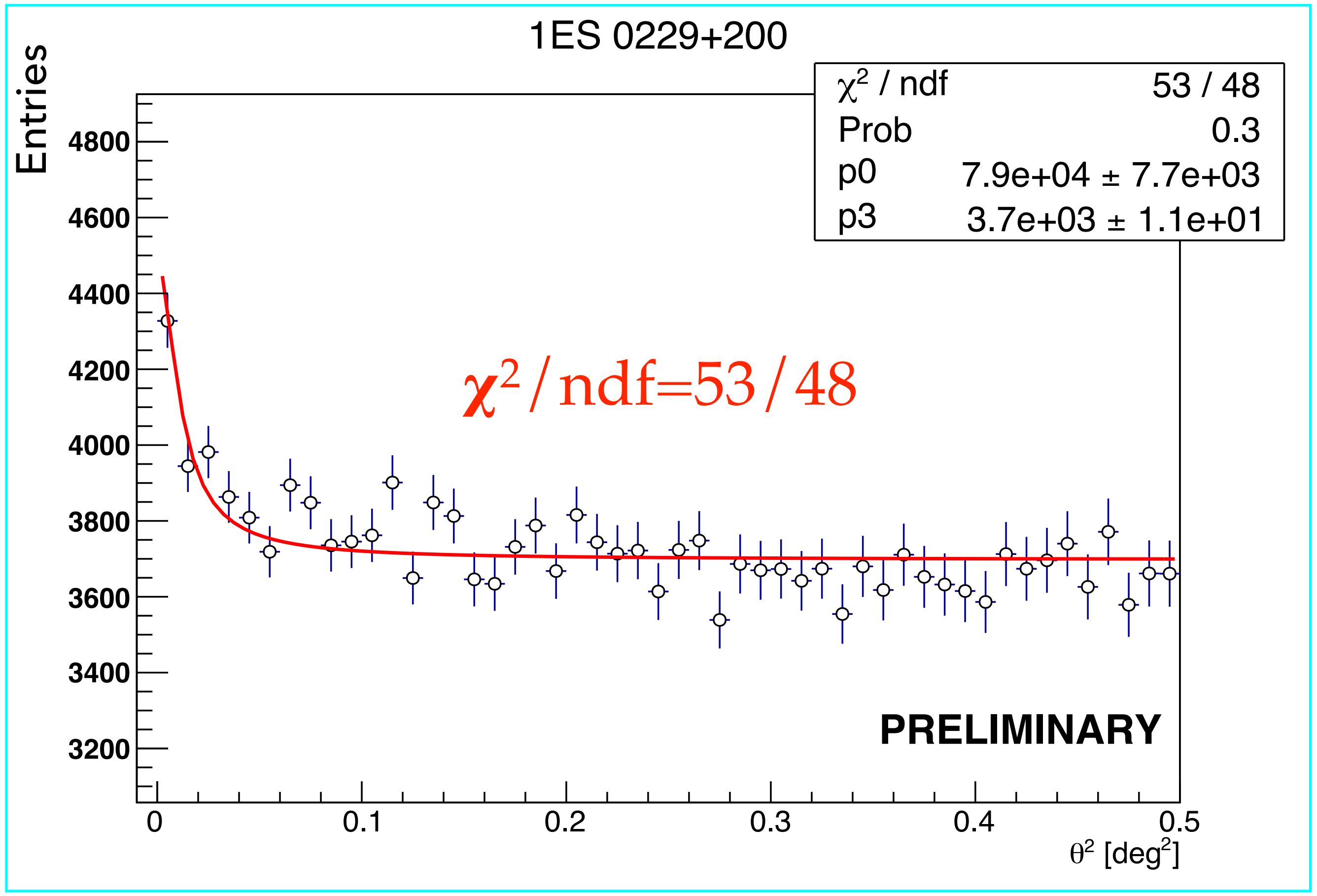




- Angular distribution compatible with point source emission

UPPER LIMITS ON HALO EMISSION (WORK IN PROGRESS)

- Using an analytical description of halo we can compute upper limits on halo emission:

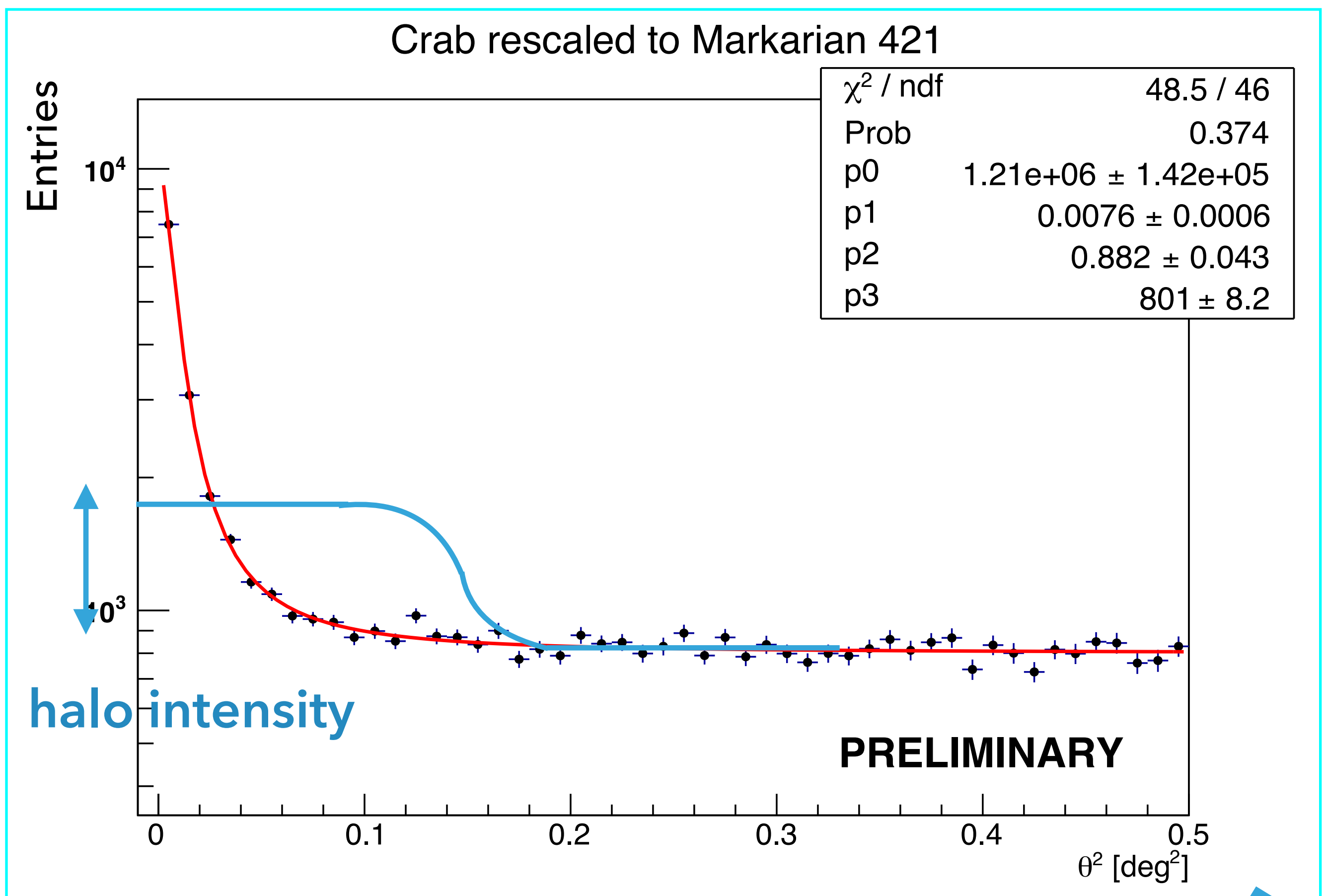
$$f(\theta^2) = halo(N, \theta^2_{ext}; \theta^2) + p0 * p1 * \left[1 + \left(\frac{\theta^2}{p1}\right)^2\right]^{-p2} + p3$$

- For a given extension (θ^2_{ext}) of halo we can determine the maximum level of halo (N) permitted by the data and then compute upper limits on halo in source units:

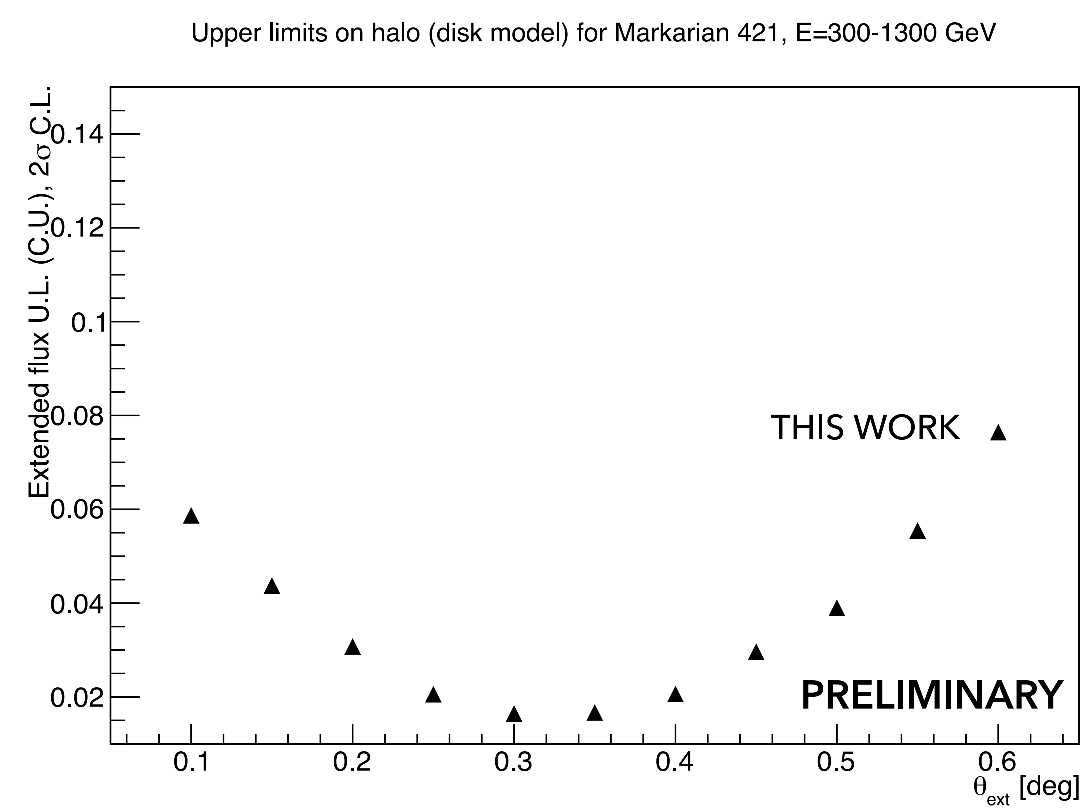
$$U.L.\ (source\ units) = \frac{\int_0^\infty halo(N, \theta^2_{ext}; \theta^2) d\theta^2}{\int_0^\infty p0 * p1 * \left[1 + \left(\frac{\theta^2}{p1}\right)^2\right]^{-p2} d\theta^2}$$

UPPER LIMITS ON HALO EMISSION (WORK IN PROGRESS)

- In the case of Markarian 421 using a disk shape of halo:



- Most Stringent upper limit for θ_{ext}=0.3°. U.L. (C.U.)=1.6%



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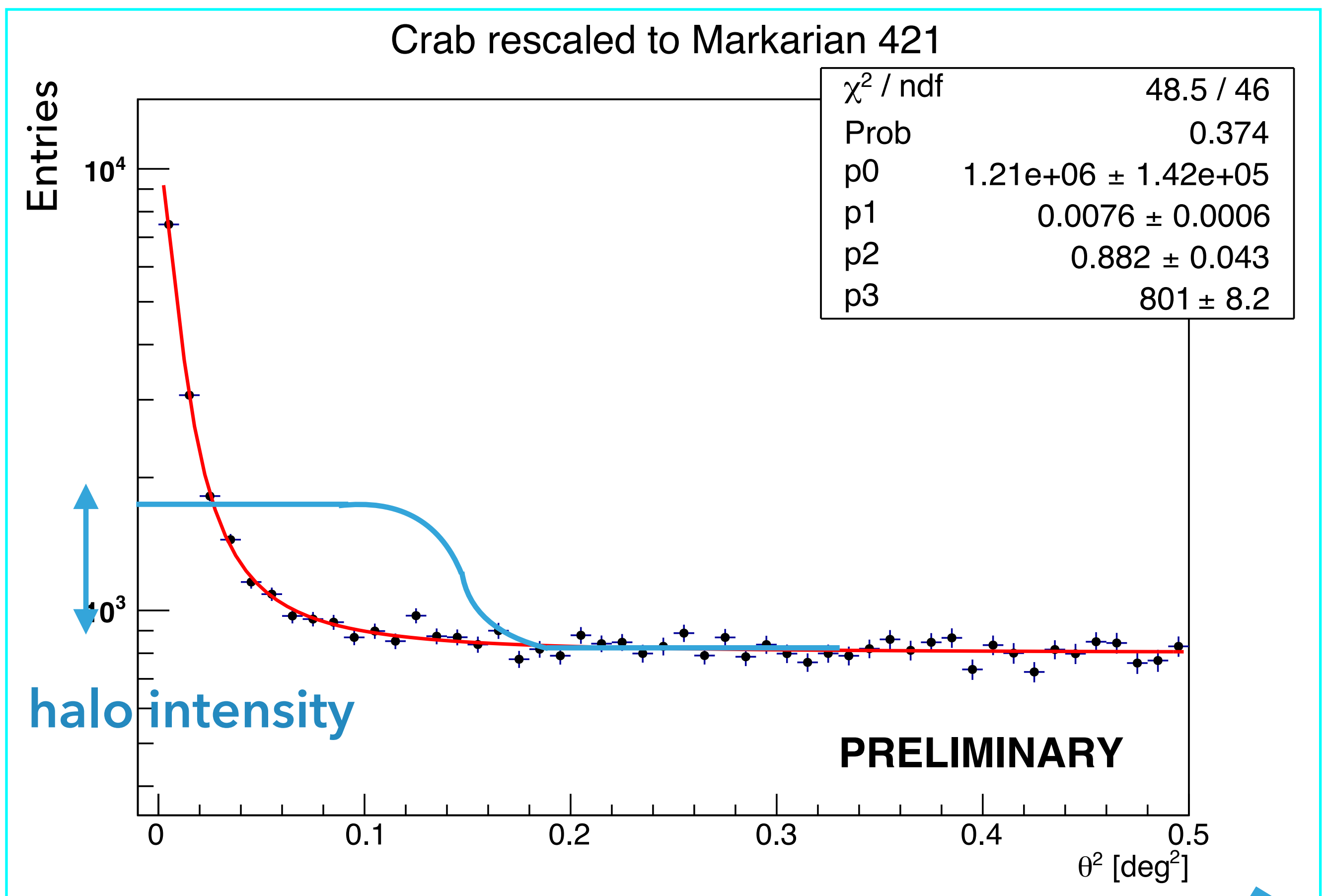
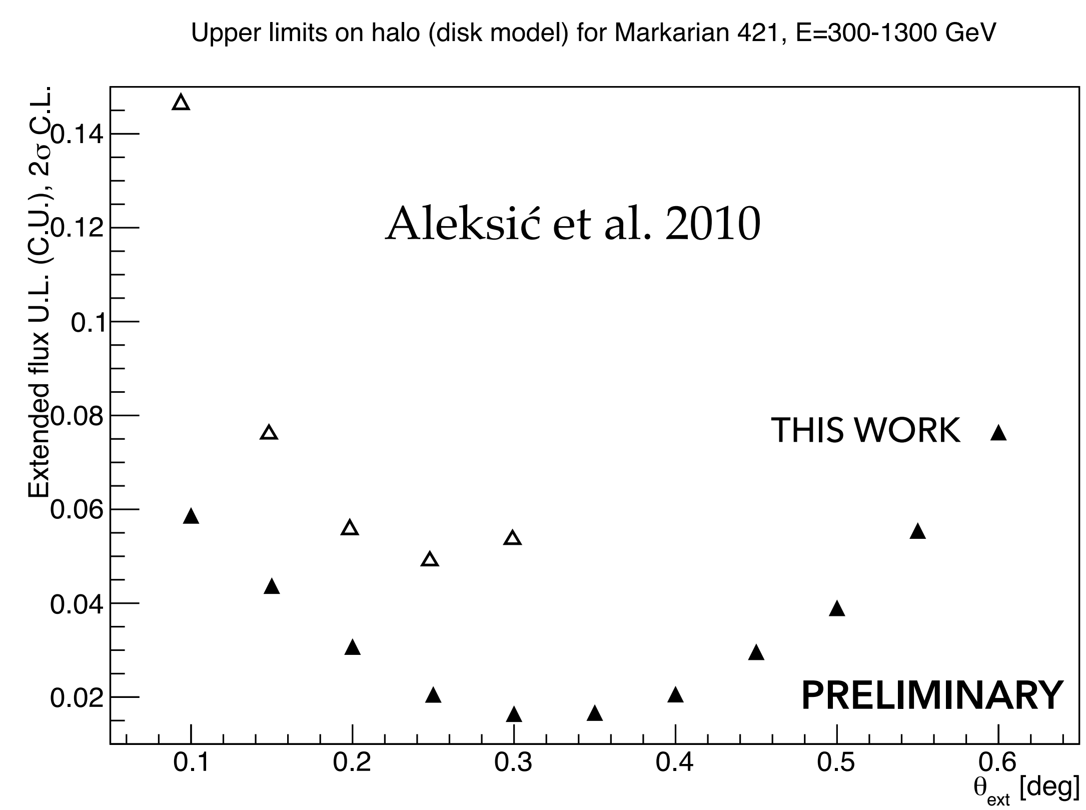


- **Most Stringent upper limit for θ_{ext}=0.3°. U.L. (C.U.)=1.6%**

- **Three times better than previous measurement**



CONCLUSIONS

- We studied the emission profiles of two AGN in order to look for extended emission in VHE domain.
- We characterised the MAGIC PSF and gave a good analytical description (the King function).
- The two tested sources, Markarian 421 and 1ES 0229+200, are compatible with a point source.
- We can now compute upper limits of halo emission assuming different models of halo. The angular extension of the halo emission can provide us informations about the IGMF (work in progress).