

Searching for Dark Matter decay signals in the Galactic Halo with the MAGIC telescopes

Daniele Ninci on behalf of the MAGIC collaboration

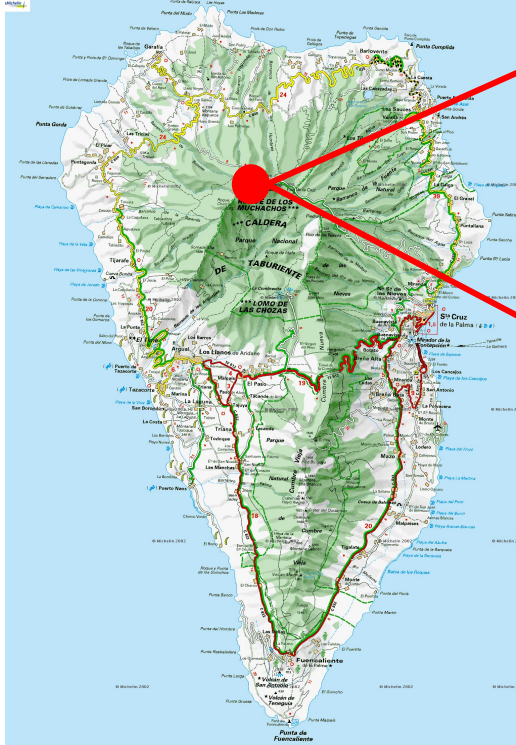
ICRC 2019, Madison



Outline

- MAGIC experiment
- *New method* for the search of Dark Matter (DM) in the Galactic Halo (GH)
- Systematic uncertainty evaluation
- Dark Matter lifetime result
- Conclusions

MAGIC telescopes



ospheric Ch

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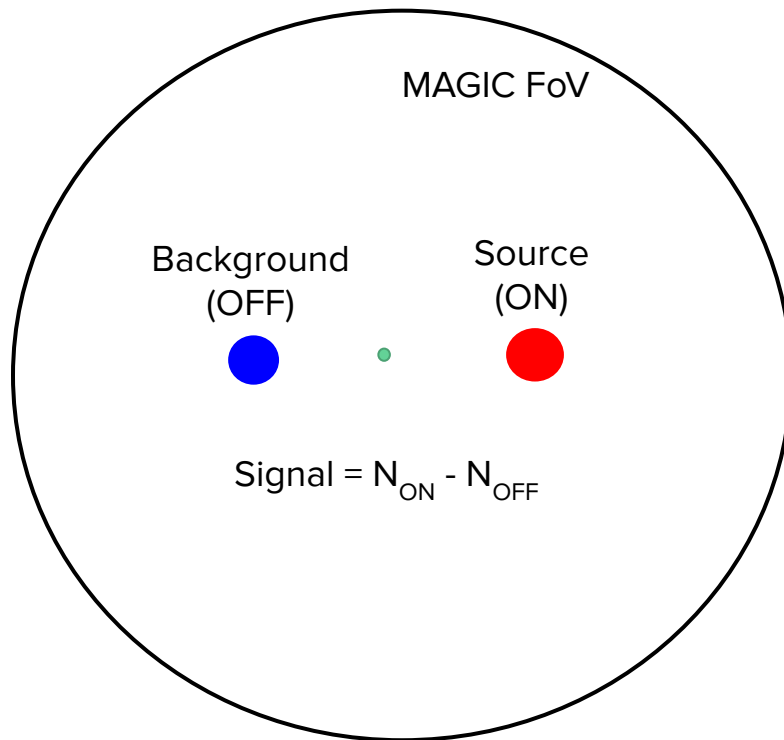
ween 70 GeV



Dark Matter observations with MAGIC

Standard MAGIC
Observation Scheme

- Dwarf satellite galaxies
- Galaxy clusters
- Galactic Center

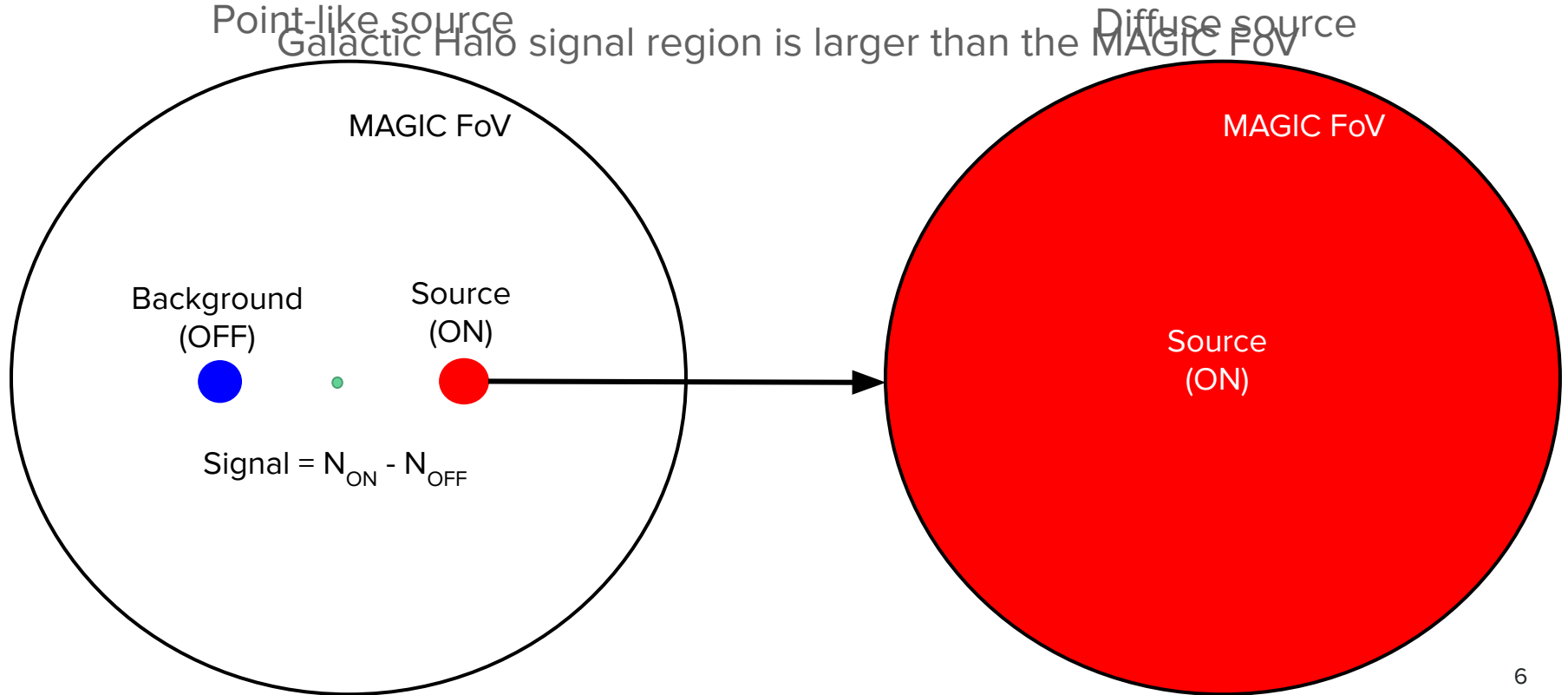


Galactic Halo observations with MAGIC



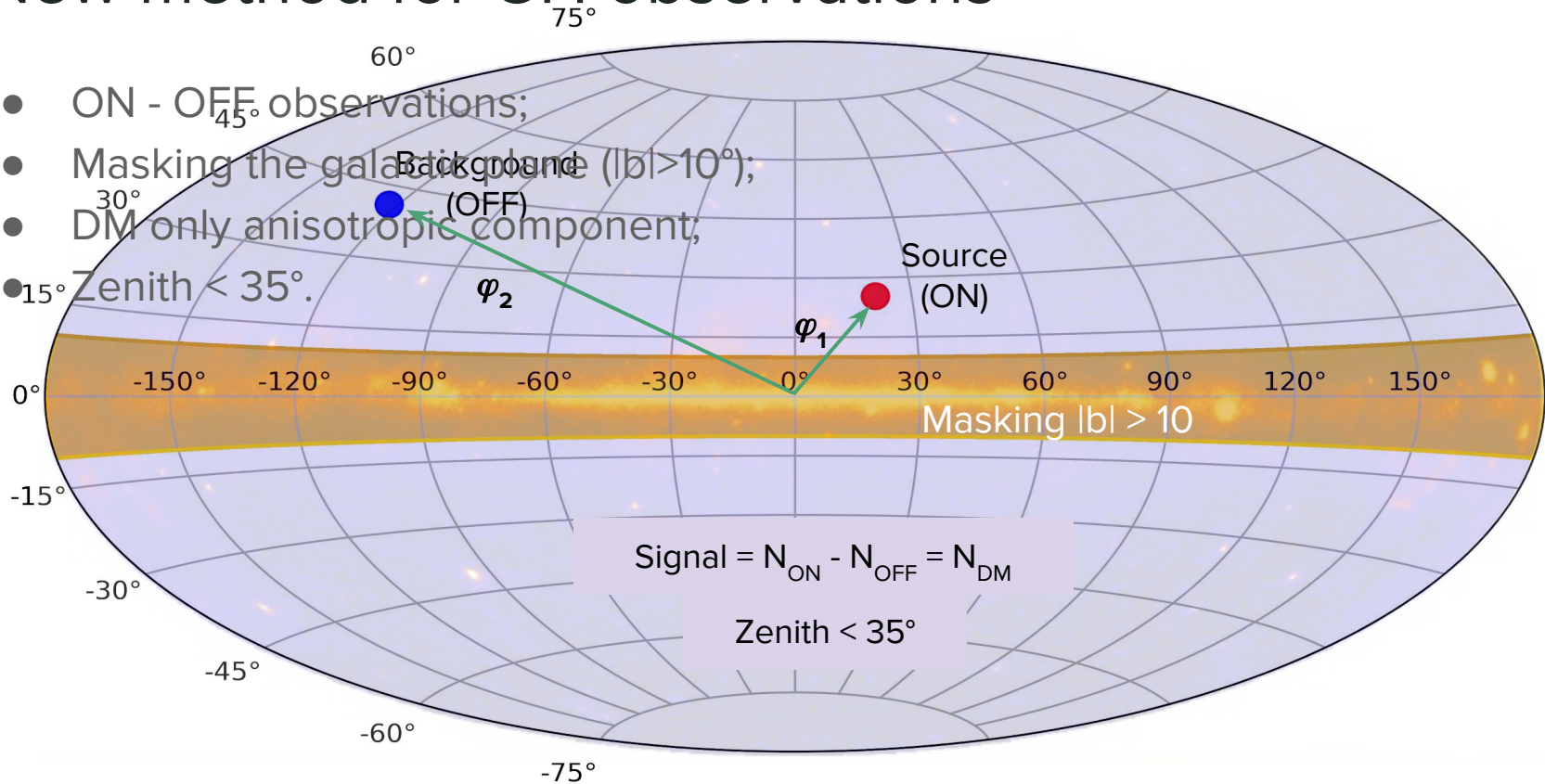
credit to Alice Donini

Galactic Halo observation with MAGIC



New method for GH observations

- ON - OFF observations;
- Masking the galactic plane ($|b| > 10^\circ$);
- DM only anisotropic component;
- Zenith $< 35^\circ$.



DM search in the GH - Decay

J-factor \propto DM content in the FoV considered

RoI for this work

Decay

Annihilation

ϕ [deg]

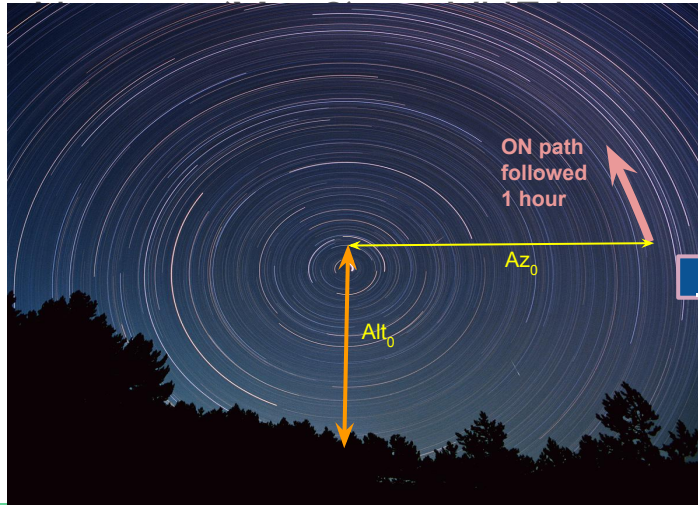
For $\theta > 10^\circ$ the expected flux for DM decay process is comparable with GC observations

DM search in the GH: how to select the FoVs

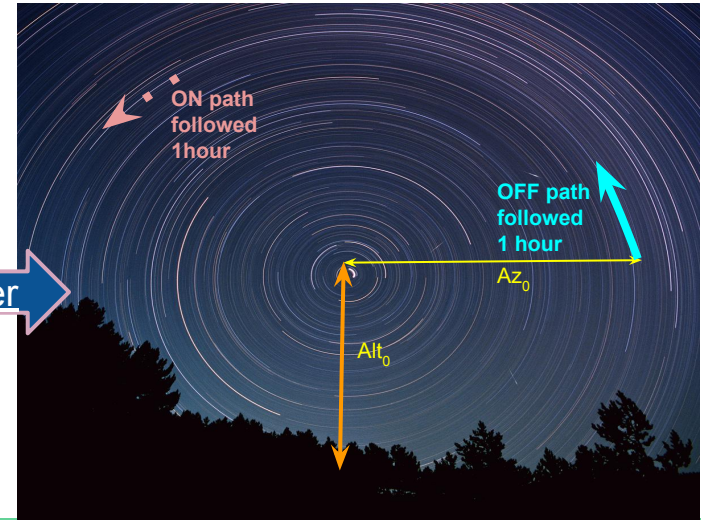
Task: minimize the systematic uncertainty in the OFF/ON relative acceptance.

- Observations performed during the same night;
- Following the same (Zd,Az) trajectory;
- Excellent weather condition;
-

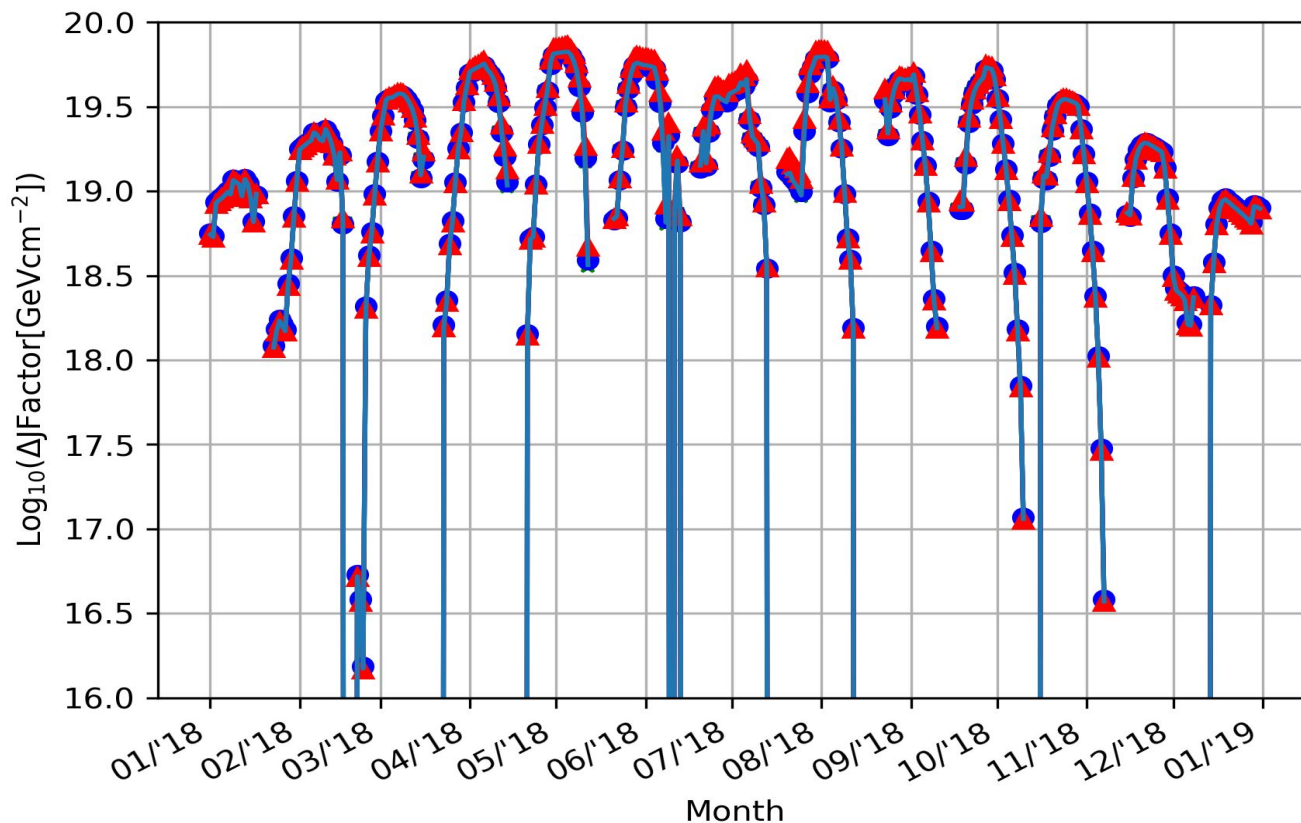
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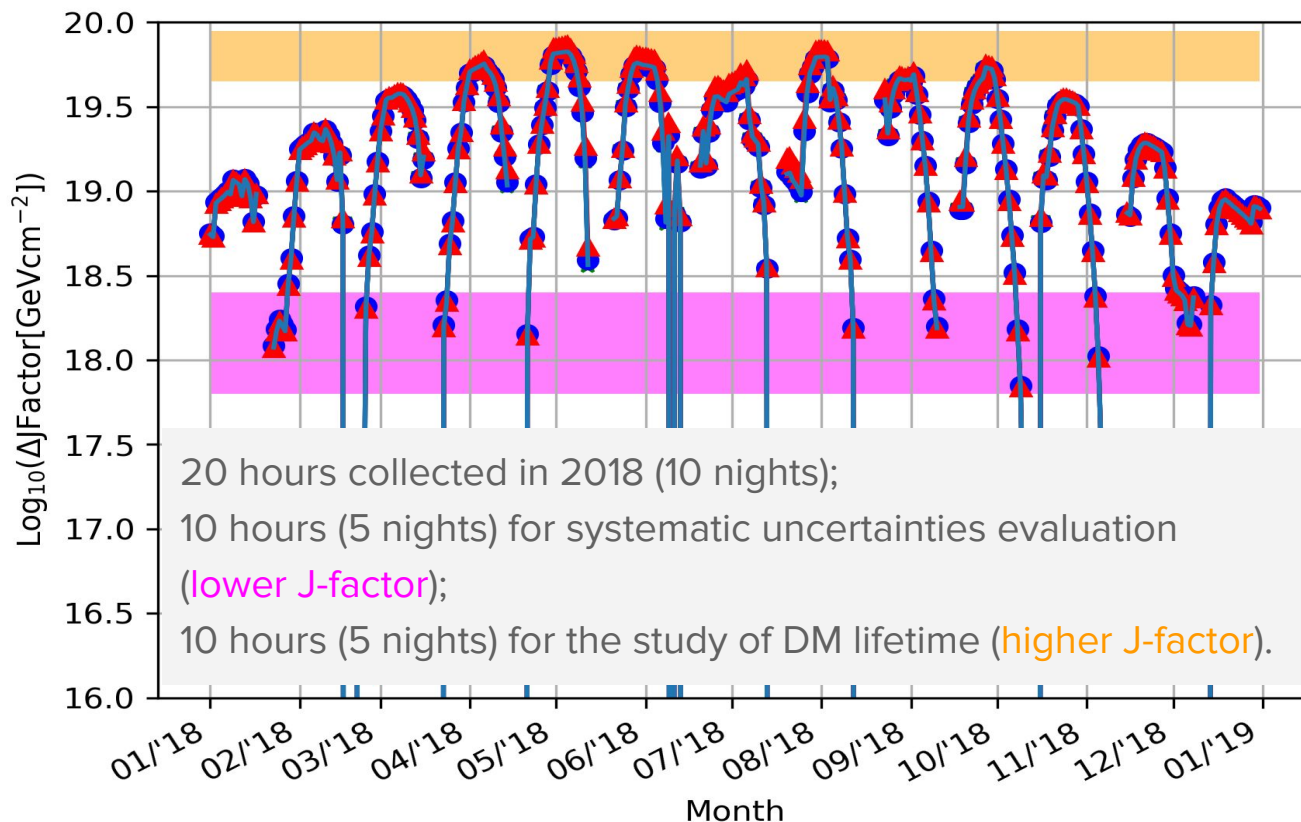
Few hours later



DM search in the GH: how to select the FoVs

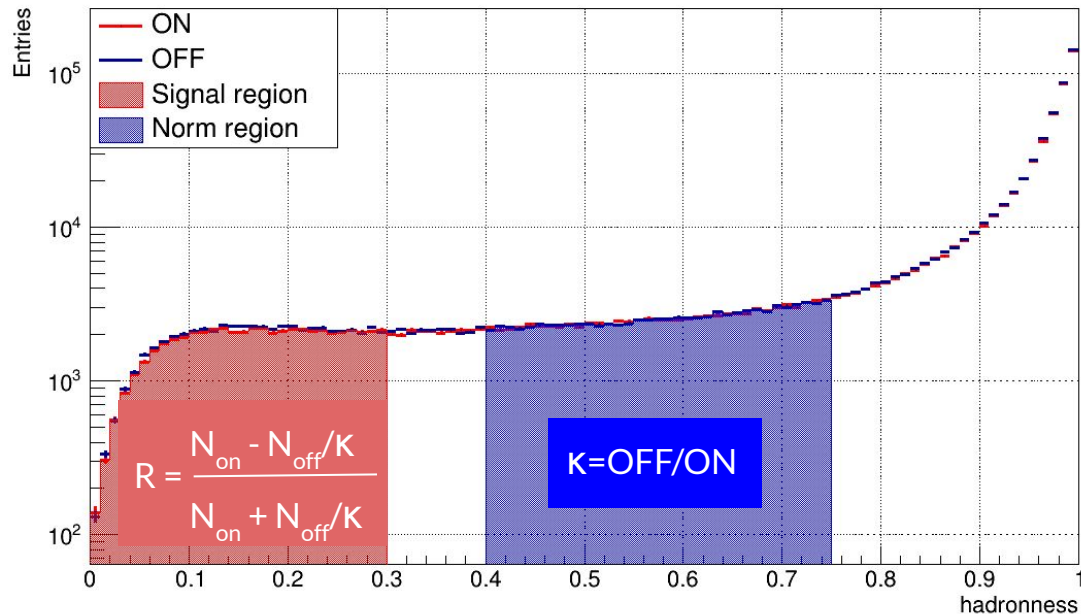


DM search in the GH: how to select the FoVs



Systematic uncertainty evaluation: 5 nights

- Best Cuts: $\{E > 60 \text{ GeV}, \theta < 1.2^\circ, \text{hadronness} < 0.3\}$
- The hadronness is the output of a test statistic for particle classification computed by a random forest

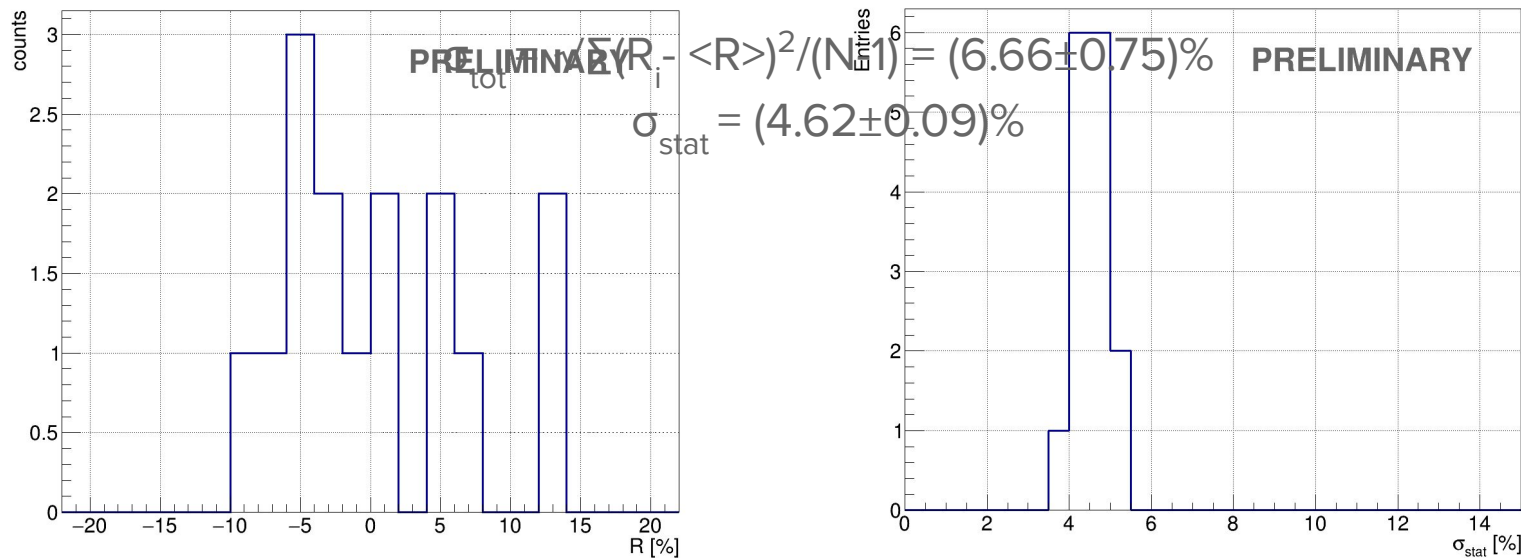


$$\sigma_{\text{tot}}^2 = \sigma_{\text{stat}}^2 + \sigma_{\text{syst}}^2$$



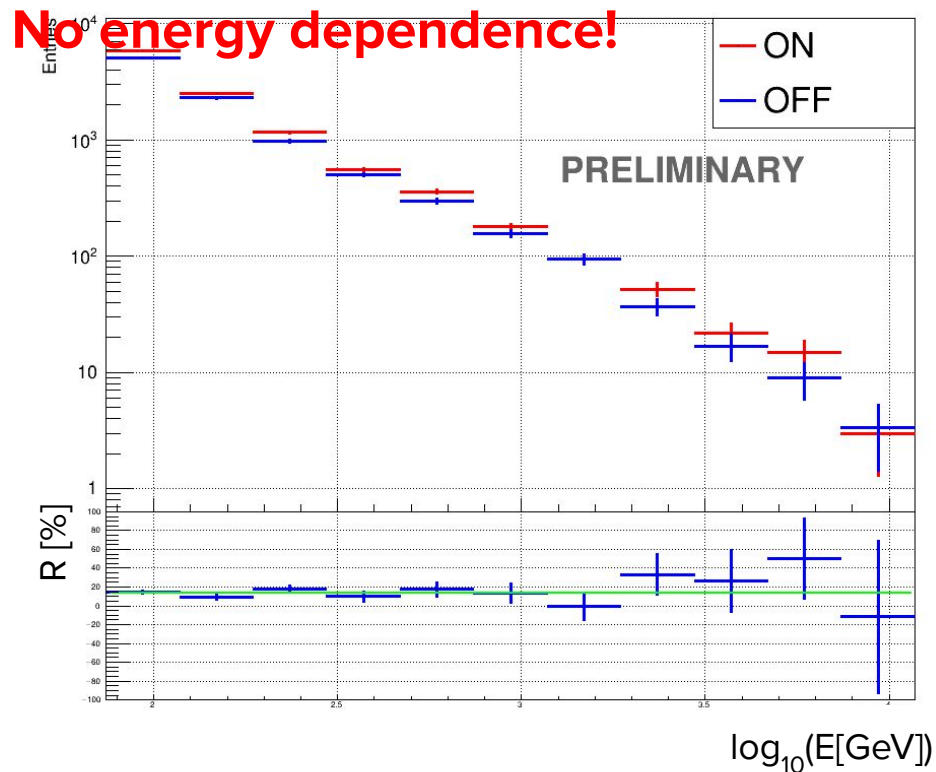
$$\sigma_{\text{syst}}^2 = \sigma_{\text{tot}}^2 - \sigma_{\text{stat}}^2$$

Systematic uncertainty evaluation



$$\sigma_{\text{syst}} = (4.8 \pm 1.0)\%$$

Systematic uncertainty: energy dependence



Night	χ^2/ndf
2018-01-13	5.4/10
2018-01-21	3.1/10
2018-02-15	5.7/10
2018-02-17	7.6/10
2018-02-18	8.5/10

DM lifetime limits: 10 hours with the largest ΔJ

We perform an analysis based on the likelihood ratio test .

$$\mathcal{L}(1/\tau_{DM}; \mathbf{v} | \mathcal{D}) = \mathcal{G}(\kappa_i | \kappa_{obs}, \sigma_{\kappa,i})$$

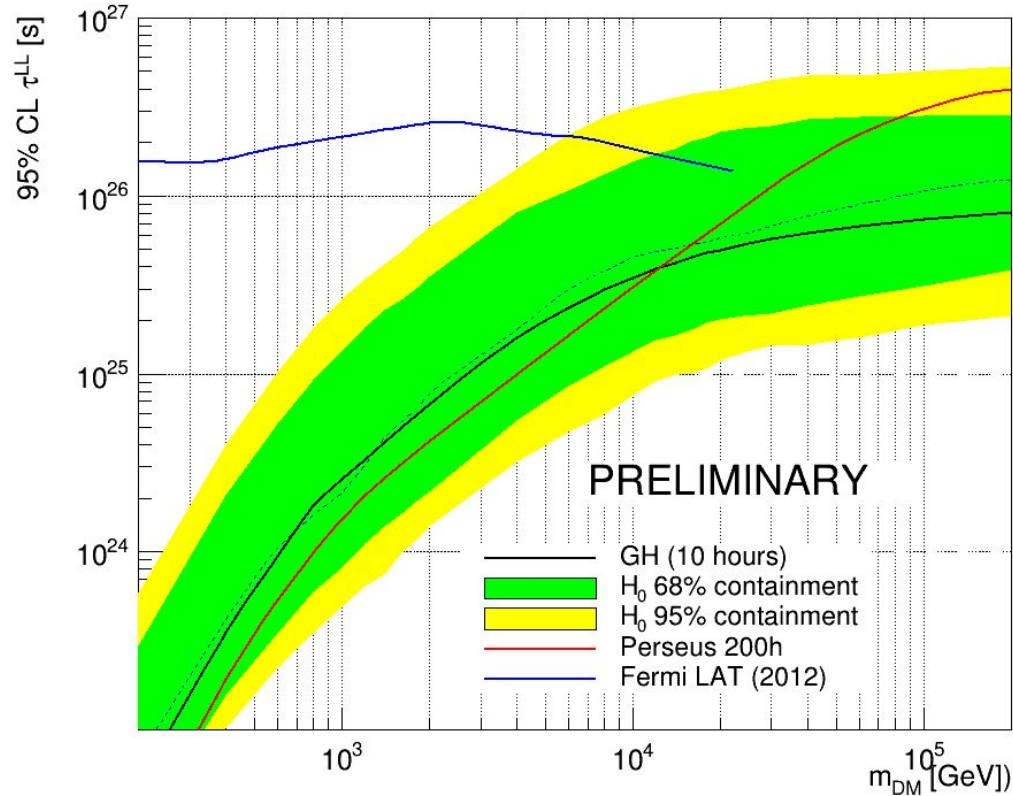
$$\times \prod_{j=0}^{N_{bins}} \frac{(g_{ij}(1/\tau_{DM}) + b_{ij})^{N_{ON,ij}}}{N_{ON,ij}!} \cdot e^{-(g_{ij} + b_{ij})} \times \frac{(\kappa_i b_{ij})^{N_{OFF,ij}}}{N_{OFF,ij}!} \cdot e^{-\kappa_i b_{ij}}$$

Poissonian \mathcal{L} for the ON

Poissonian \mathcal{L} for the OFF

$$\sigma_{\kappa,i} = \sqrt{(\sigma_{\kappa,stat})^2 + (\kappa \sigma_{syst})^2}$$

DM lifetime limits: 10 hours with the largest ΔJ



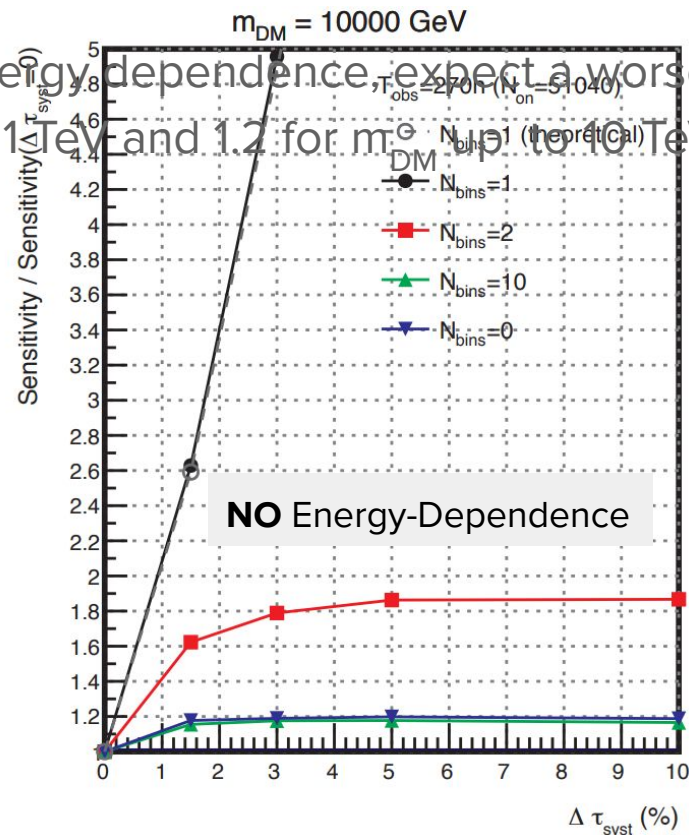
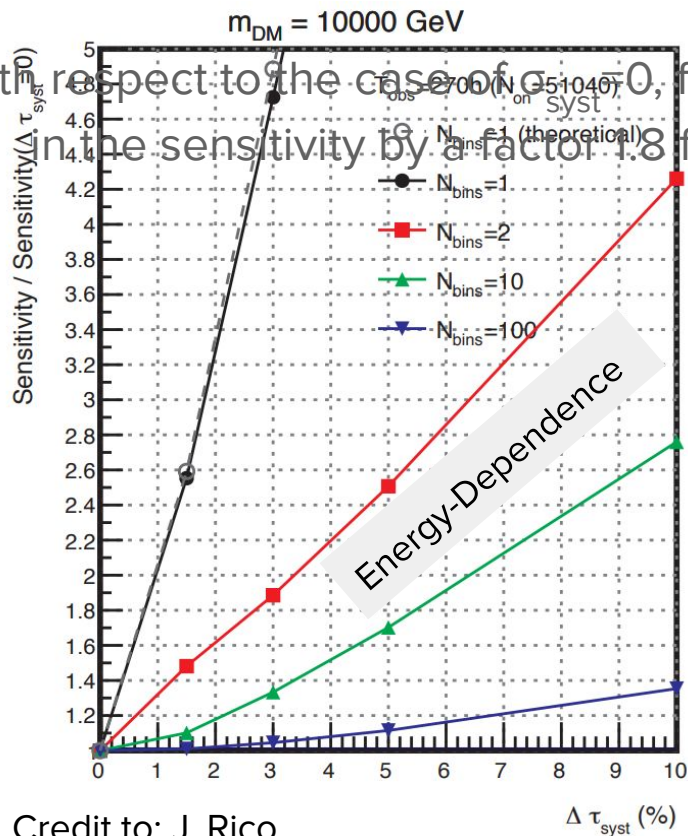
Conclusion

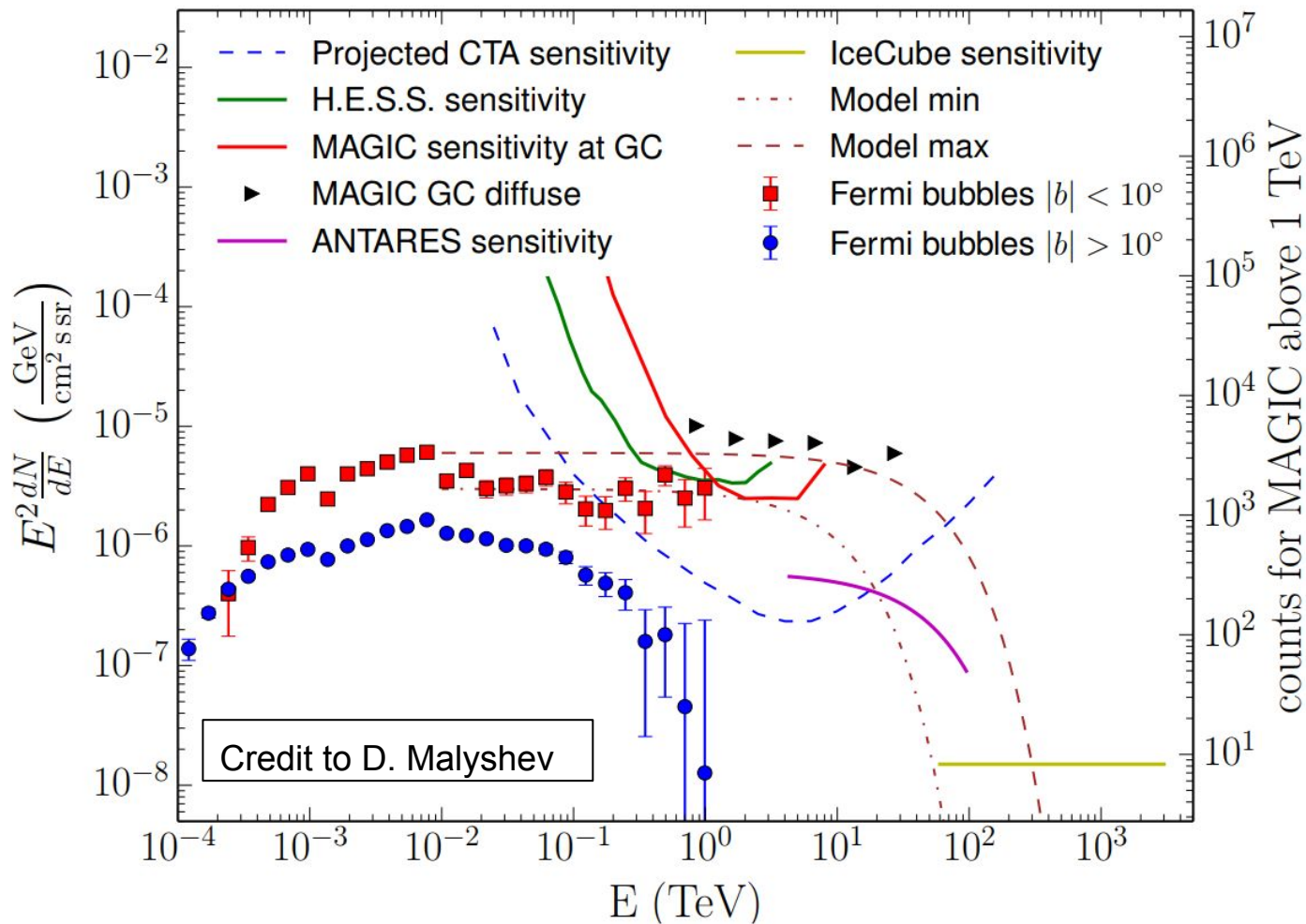
- We present a *new method* for searching for DM decay signal in the GH with Cherenkov telescopes:
 - Comparing ON and OFF FoVs from different sky regions selected by minimizing the systematic uncertainties in the OFF/ON acceptance and maximizing the expected DM intensity signal
- We estimated the OFF/ON systematic uncertainty in the acceptance ratio. The value results to be 4.8% and with no energy dependence.
- We computed the 95% CL for DM lifetime, resulting in constraints $> 10^{26}$ s for $m_{\text{DM}}=100$ TeV. This is one of the most constraining limits using only 10 hours of data.
- The method can be extended to the archival data that respect the constraints presented here, thus increasing significantly the observation time available for the DM lifetime study.

THANK YOU
FOR YOUR ATTENTION!

Sensitivity vs Systematics

With respect to the case of $\alpha = 0$, for no energy dependence, expect a worsening in the sensitivity by a factor 1.8 for $m_{\text{DM}} < 1 \text{ TeV}$ and 1.2 for $m_{\text{DM}} > 1 \text{ TeV}$





Available ON OFF position

