Search for Dark Matter Gamma-ray Emission from M31 with HAWC

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TeVPA
Dark Matter Parallel
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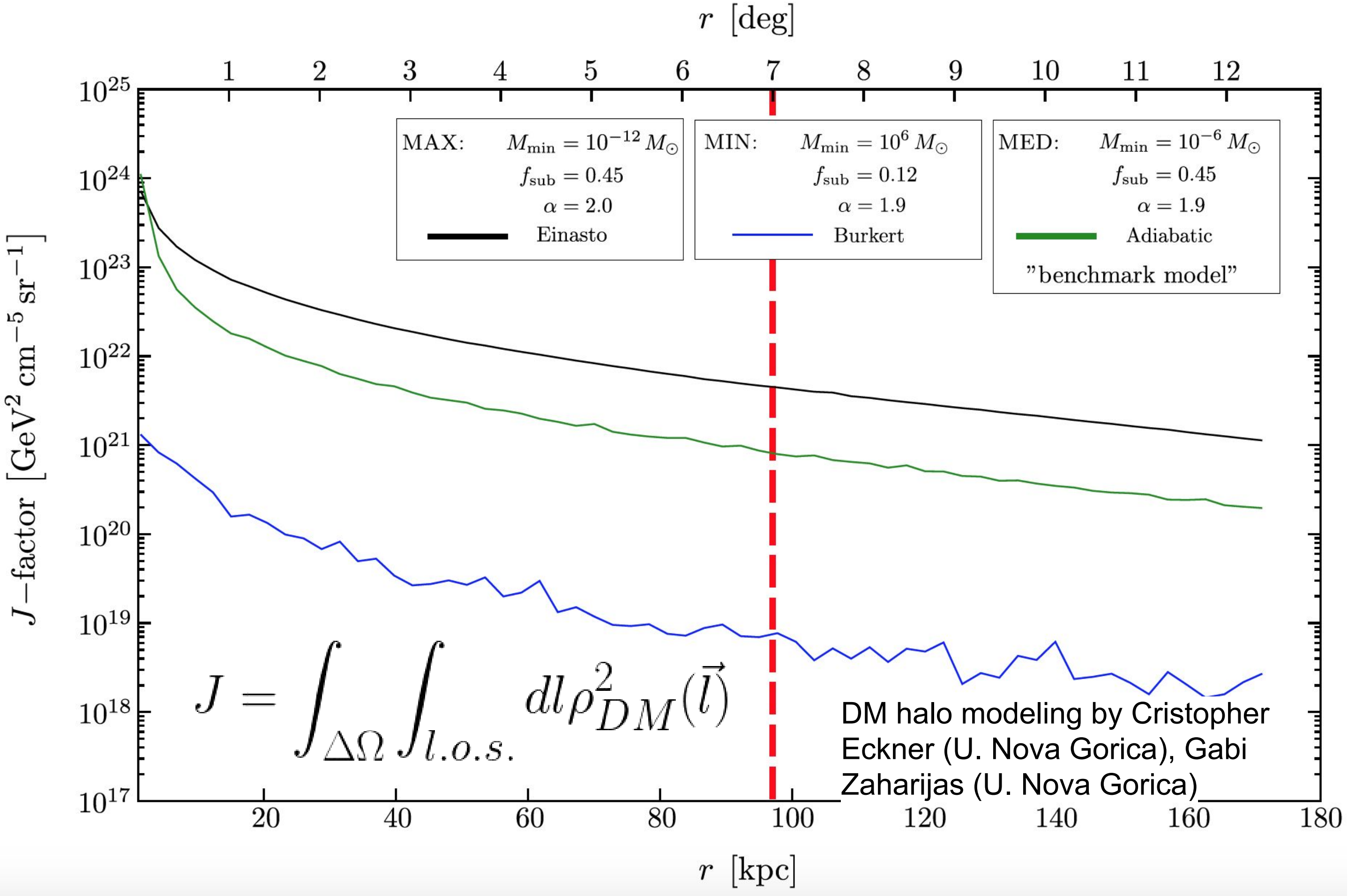
The Andromeda Galaxy (M31)

- Nearby (~780 kpc) spiral Galaxy similar to the Milky Way
- Stellar rotation curves -> resides in a large dark matter halo
- Good target to search for gamma rays produced via dark matter annihilation or decay

The Andromeda Galaxy (M31)

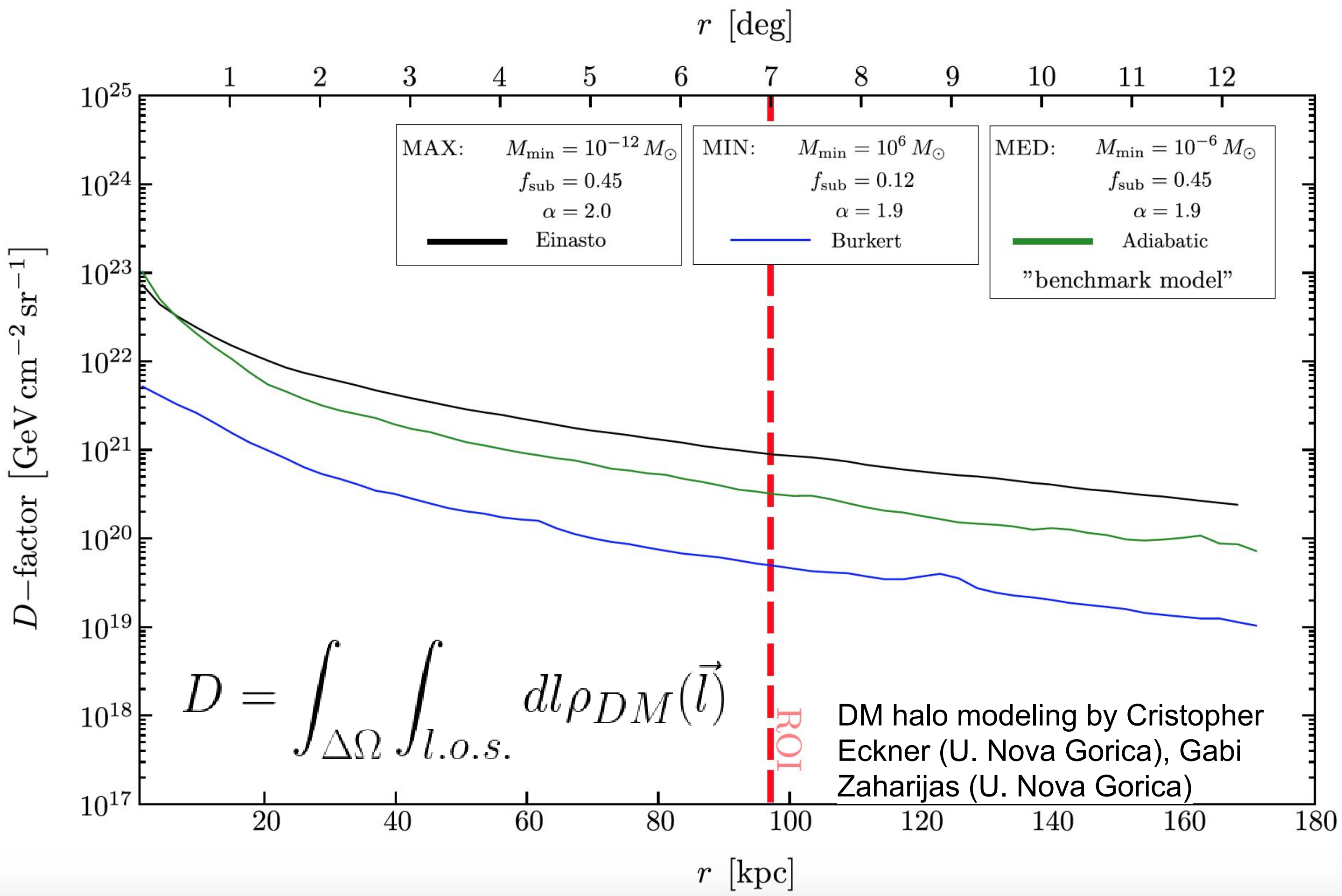


$$J = \int_{\Delta\Omega} \int_{l.o.s.} dl \rho^2_{DM}(\vec{l})$$

DM halo modeling by Cristopher Eckner (U. Nova Gorica), Gabi Zaharijas (U. Nova Gorica)

- **Need to model both the smooth DM component and substructure**
- **Define MIN and MAX models and a realistic benchmark MED**
- **Smooth components come from Tamm+ (2012)**
- **Full halo modeled using CLUMPY software**

The Andromeda Galaxy (M31)



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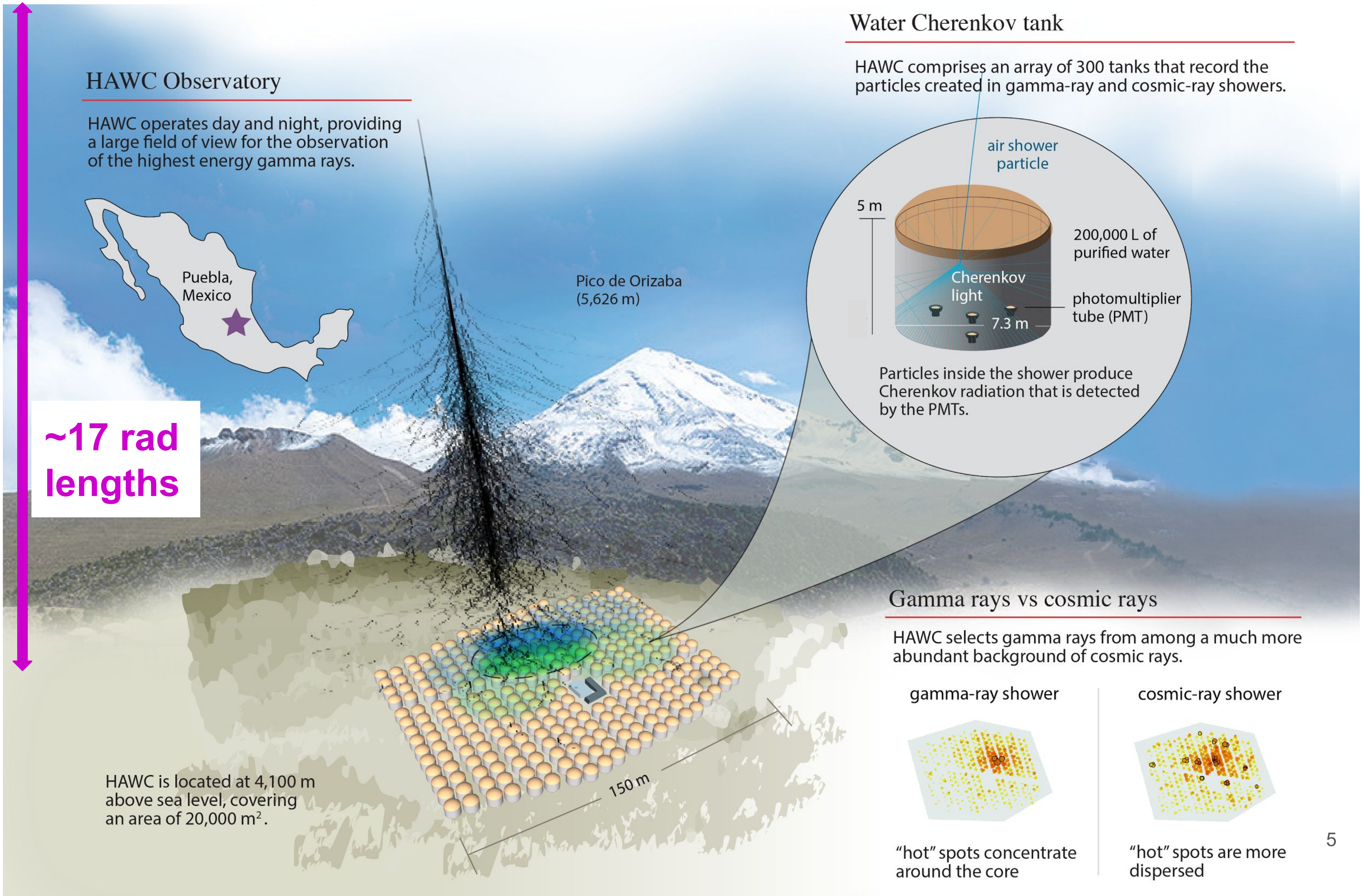
The HAWC Observatory



~17 rad lengths

HAWC Observatory

HAWC operates day and night, providing a large field of view for the observation of the highest energy gamma rays.

HAWC is located at 4,100 m above sea level, covering an area of 20,000 m^2.

Water Cherenkov tank

HAWC comprises an array of 300 tanks that record the particles created in gamma-ray and cosmic-ray showers.

Particles inside the shower produce Cherenkov radiation that is detected by the PMTs.

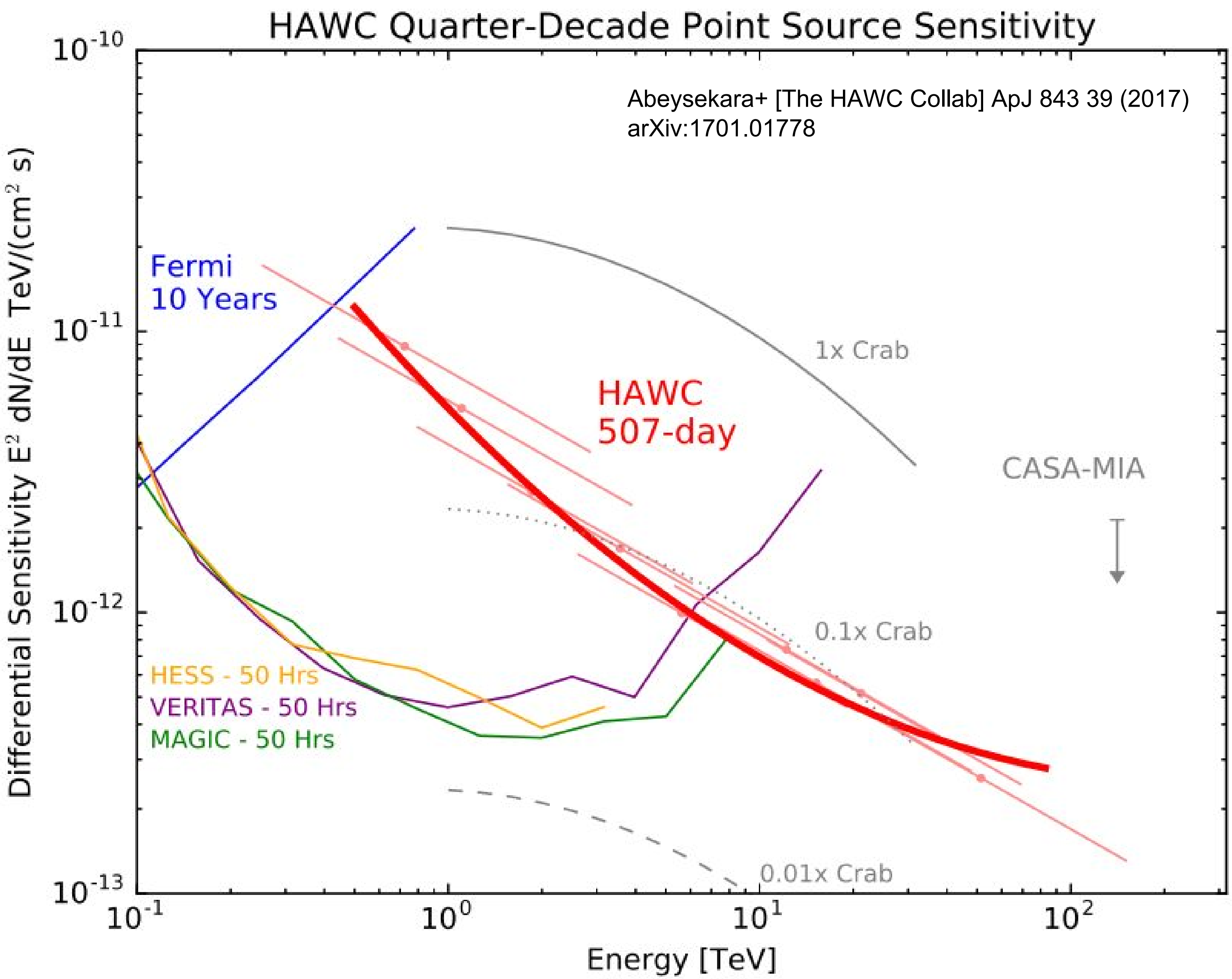
Gamma rays vs cosmic rays

HAWC selects gamma rays from among a much more abundant background of cosmic rays.

“hot” spots concentrate around the core

“hot” spots are more dispersed

The HAWC Observatory

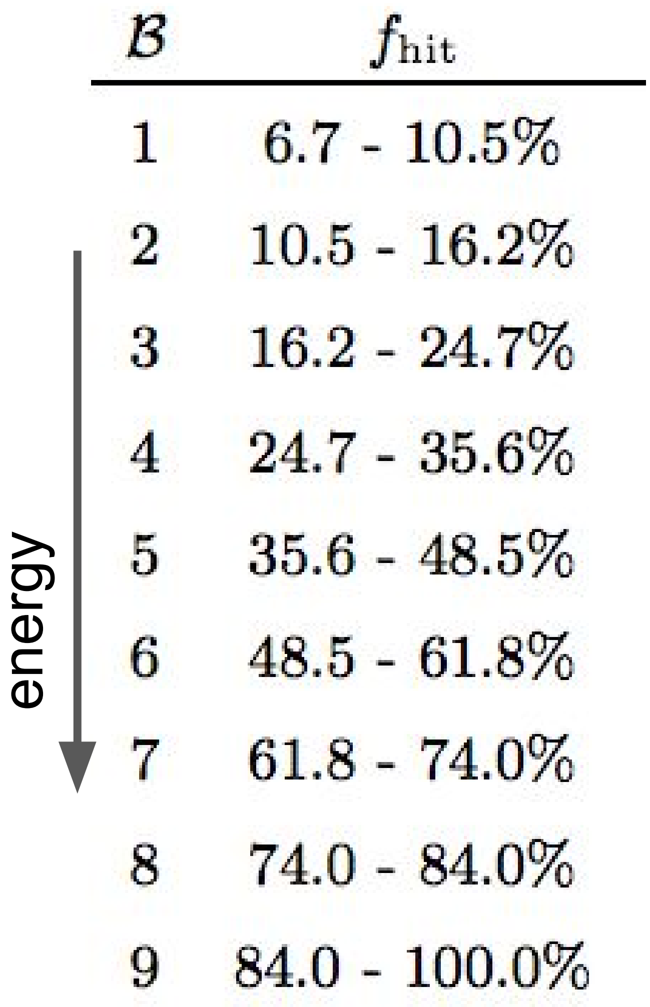


Abeysekara+ [The HAWC Collab] ApJ 843 39 (2017)
arXiv:1701.01778

Analysis Details

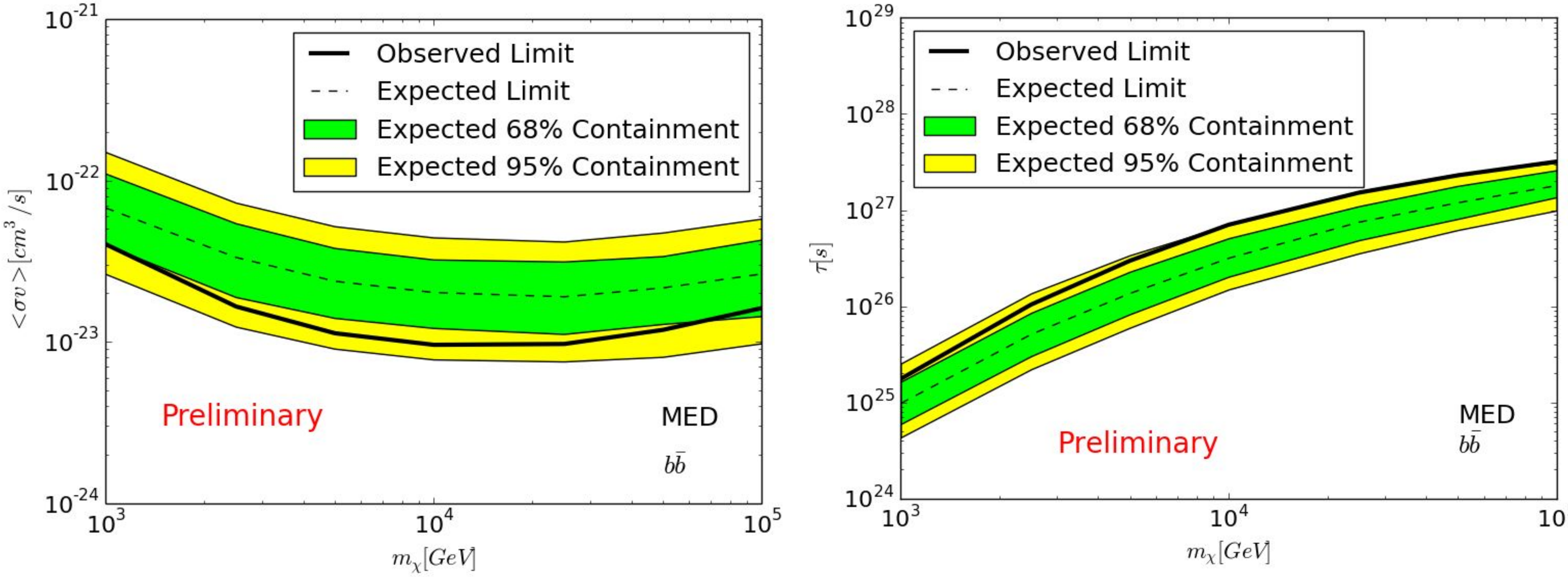
- **760 days of HAWC 300 data**
- **HAWC analysis in done in 'fraction of available PMTs' bins**
  - **Proxy for energy**
  - **See Abeysekara+ [The HAWC Collab] ApJ 843 39 (2017) arXiv:1701.01778**
- **Use the Multi-Mission Maximum Likelihood (3ML) software**
  - **Available on GitHub https://github.com/giacomov/3ML**
  - **See Vienello+ arXiv:1507.08343**

HAWC analysis bins



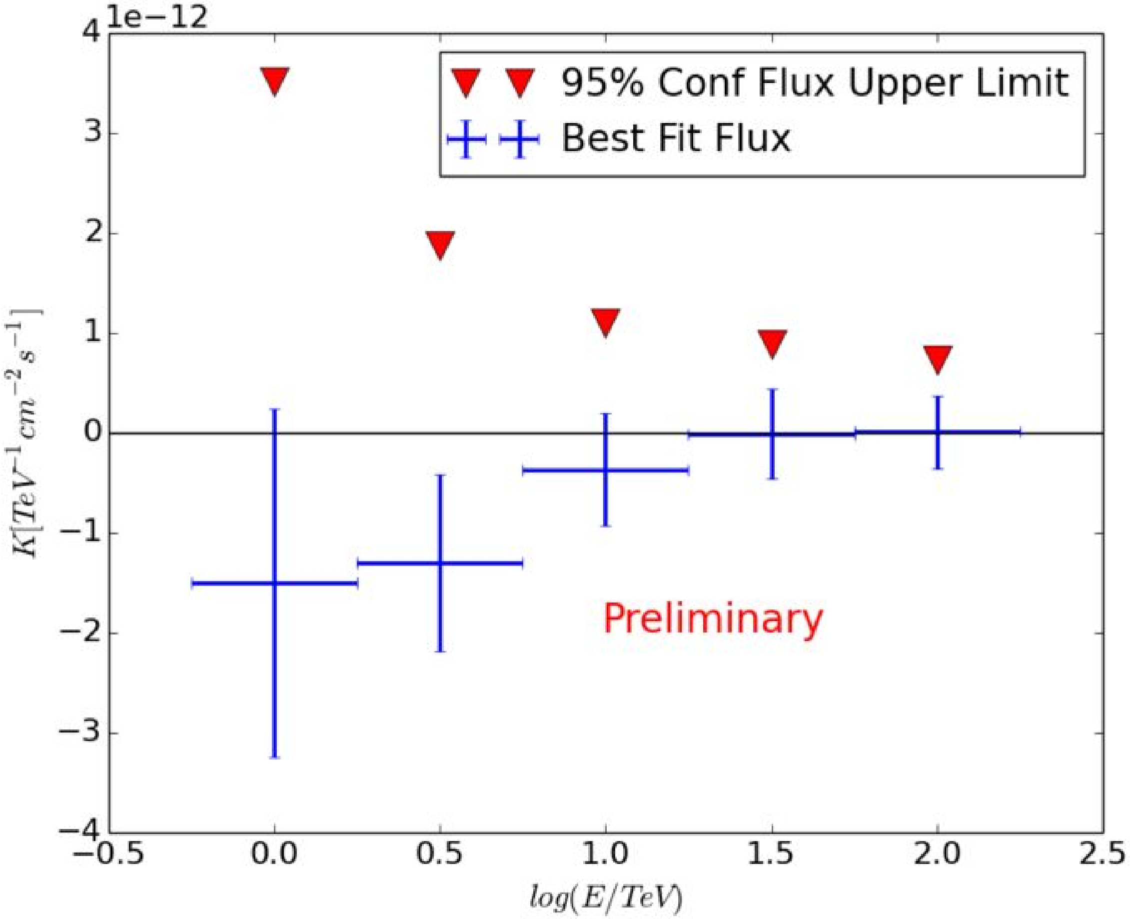
$\mathcal{B}$	f_{hit}
1	6.7 - 10.5%
2	10.5 - 16.2%
3	16.2 - 24.7%
4	24.7 - 35.6%
5	35.6 - 48.5%
6	48.5 - 61.8%
7	61.8 - 74.0%
8	74.0 - 84.0%
9	84.0 - 100.0%

Results -- $b\bar{b}$



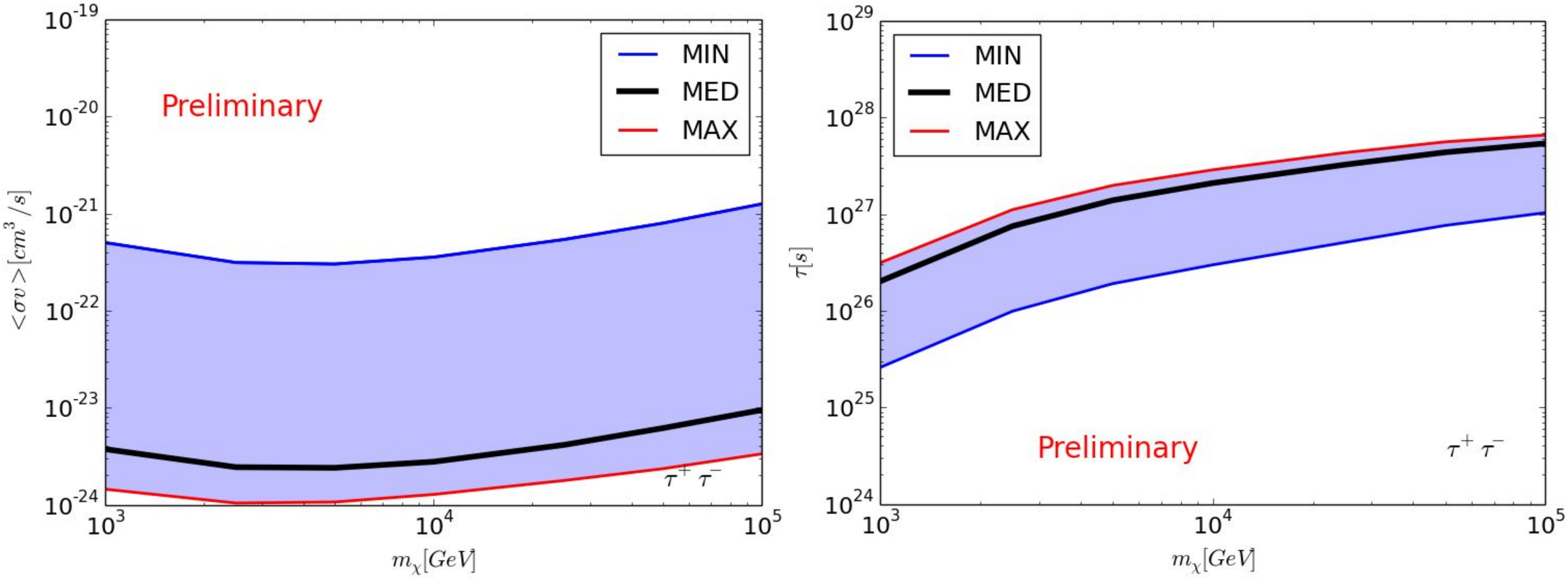
- **No gamma-ray excess detected**
- **Limits set on DM annihilation cross section and decay lifetime**
- **Limits are 1 to 1.5 sigma below expectation**

Flux Limits



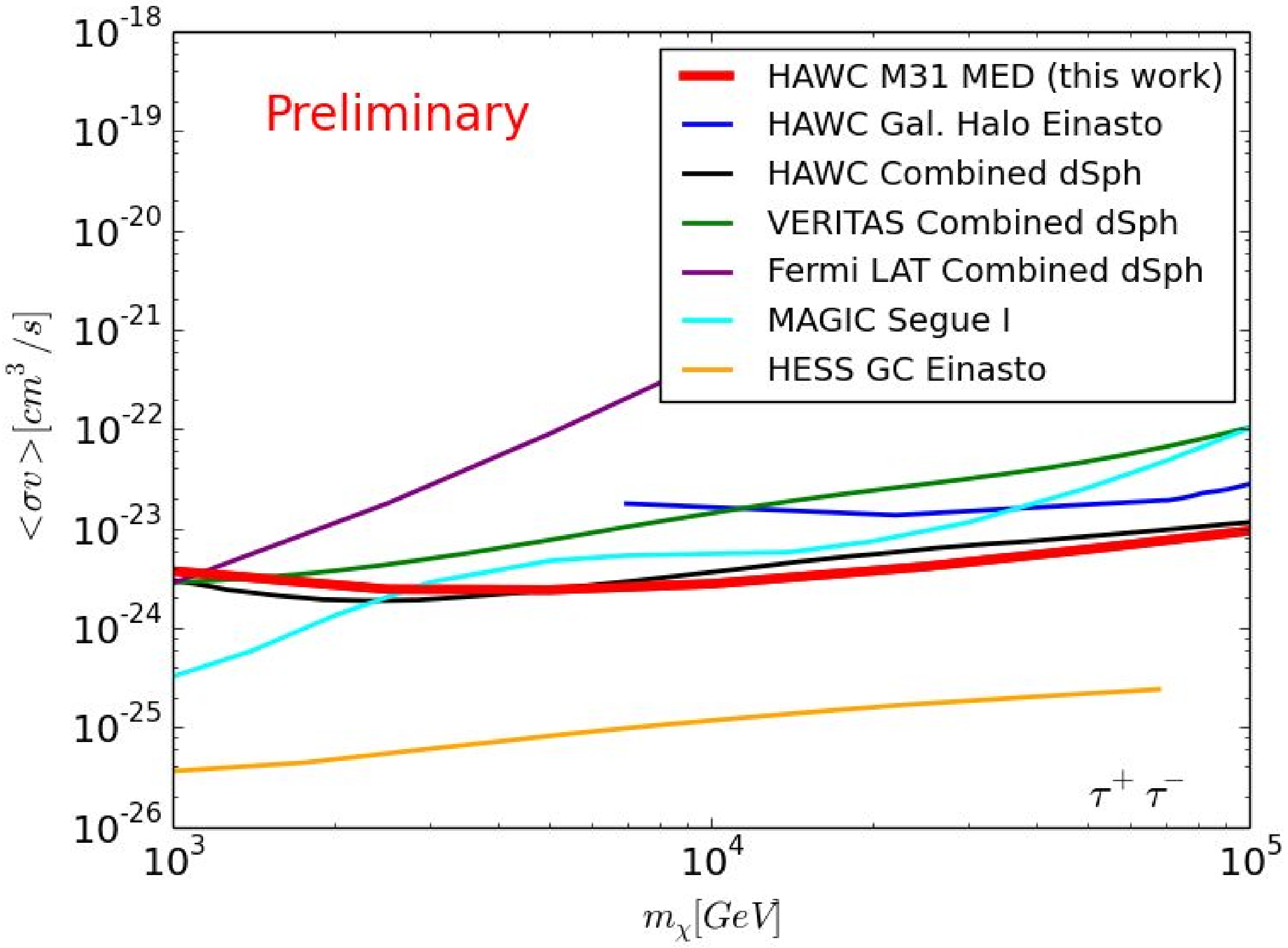
- **Calculate quasi-differential DM model-independent flux limits**
  - **See Aartsen+ arXiv:1702.06131 and Albert+ arXiv:1706.01277**
- **Find best fit normalization of powerlaw (Γ=2) restricted to half decade in log(E/TeV)**
  - **Calculate 95% CL limit to be where ΔTS = 2.71**

Results -- $\tau^+\tau^-$



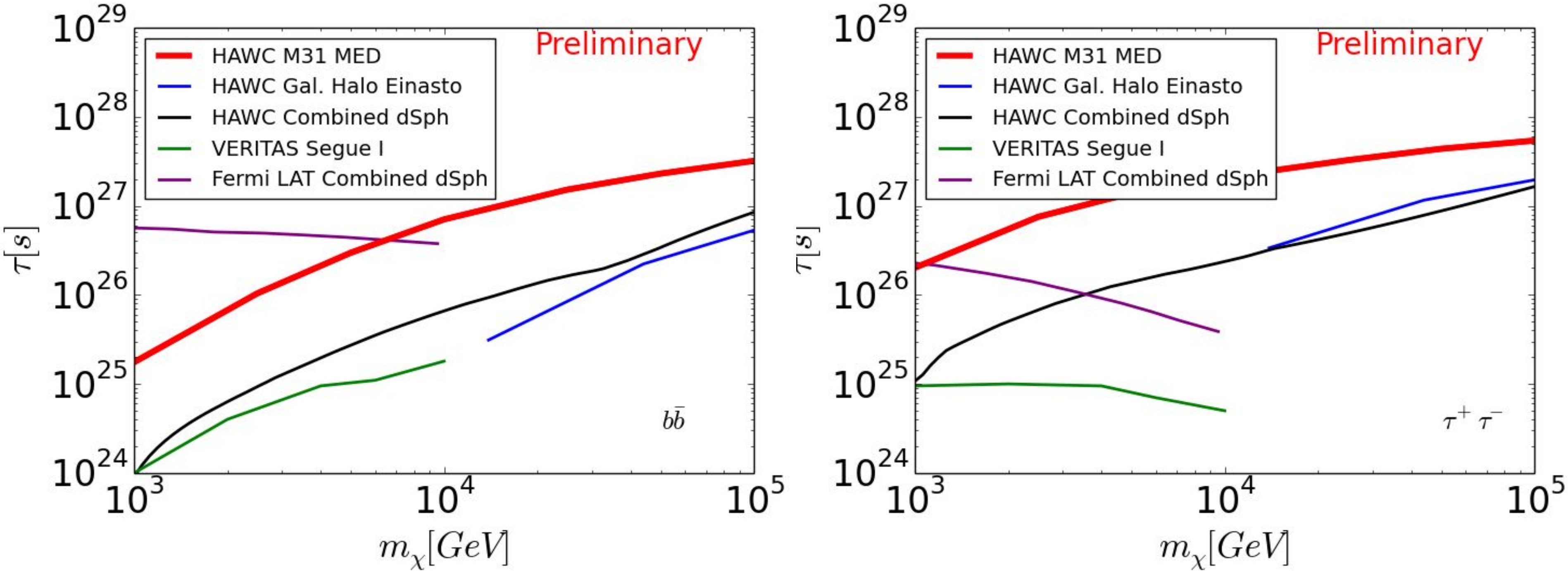
- **No gamma-ray excess detected**
- **Limits set on DM annihilation cross section and decay lifetime**
- **Spread in limits between MIN and MAX models from DM halo modeling uncertainties**

Results Compared to other Experiments



- **HAWC M31 limits complement DM limits from other experiments**
- **Most constraining annihilation limits for mass > 70 TeV**

Results Compared to other Experiments



- **HAWC M31 limits complement DM limits from other experiments**
- **Most constraining decay limits in bƃ for mass > 7 TeV**
- **Most constraining decay limits in $\tau^+\tau^-$ for mass > 1 TeV**

Summary

- M31 being close by and in a large dark matter halo makes it a good target for indirect dark matter searches

- We find no gamma-ray excess in the direction of M31 in 760 days of HAWC data

- We calculate annihilation and decay limits using 3 different dark matter halo models: MIN, MED, MAX

- HAWC M31 limits complement dark matter limits obtained from other experiments