Los Alamos NATIONAL LABORATORY EST.1943

HAWC High Altitude Water Cherenkov Gamma-Ray Observatory

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

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TeVPA

Dark Matter Parallel

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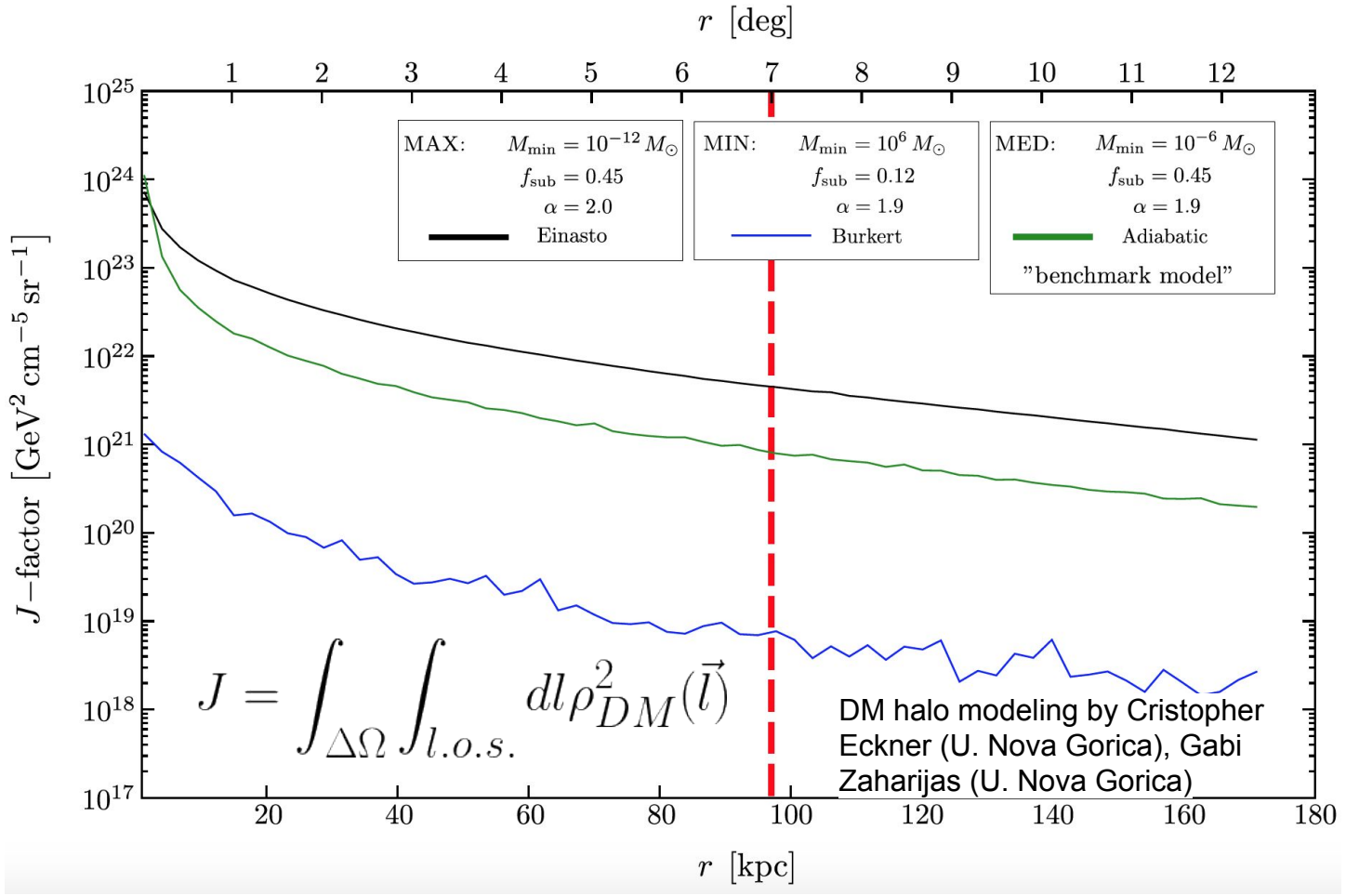
The Andromeda Galaxy (M31)

- 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

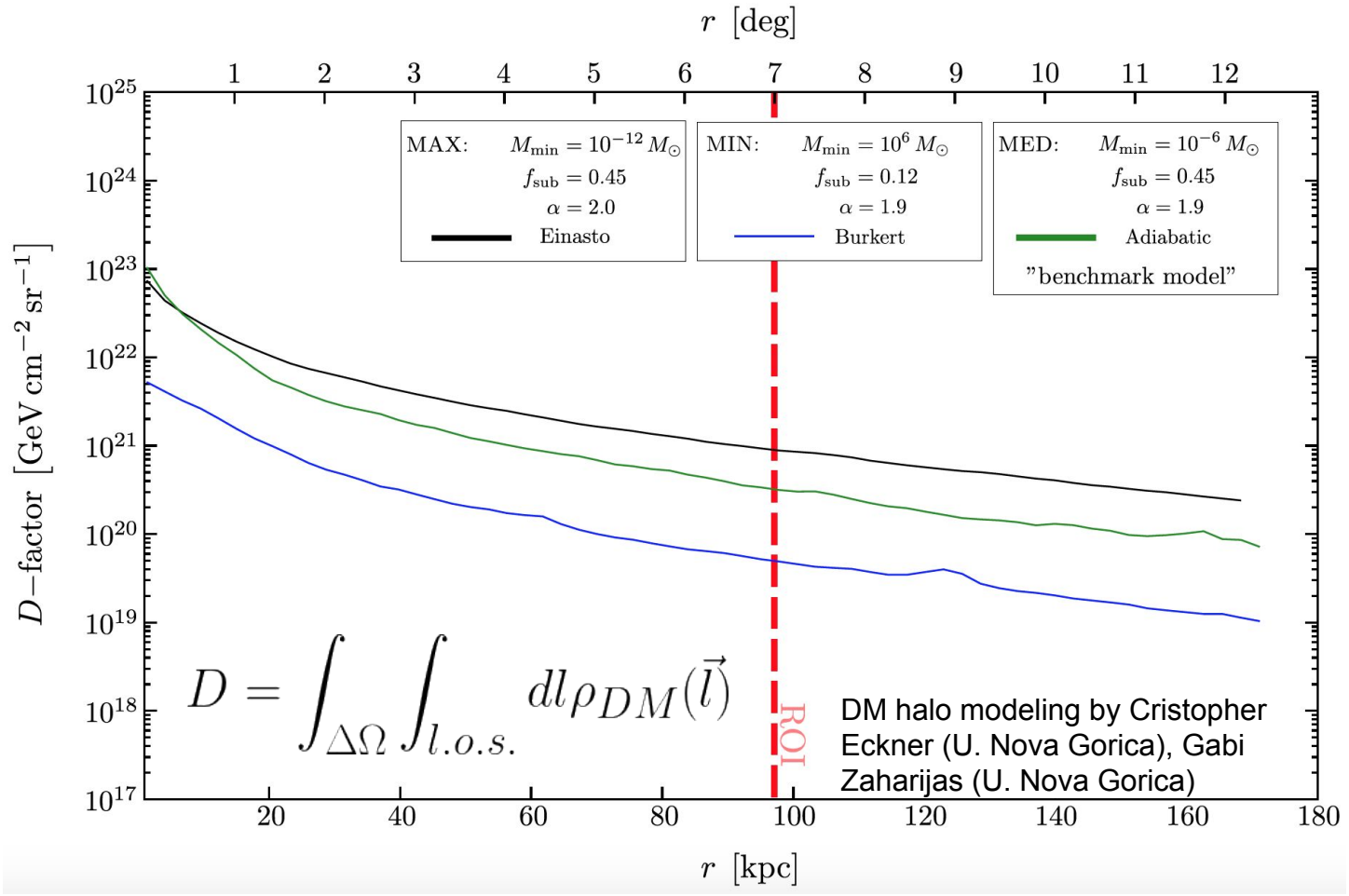
The Andromeda Galaxy (M31)



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

HAWC Observatory

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

Pico de Orizaba
(5,626 m)

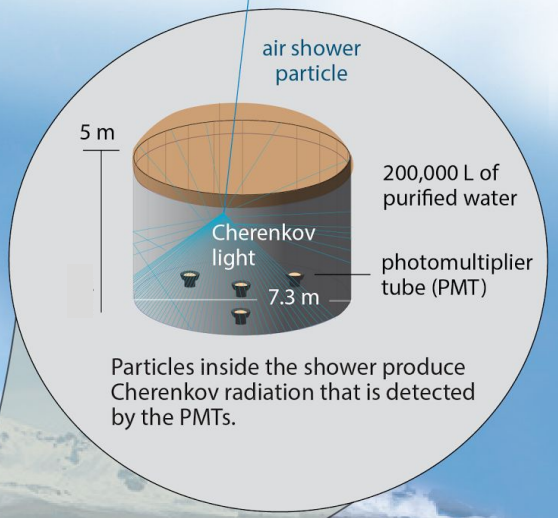
~17 rad lengths

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

150 m

Water Cherenkov tank

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

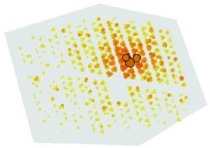


Particles inside the shower produce Cherenkov radiation that is detected by the PMTs.

Gamma rays vs cosmic rays

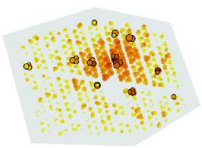
HAWC selects gamma rays from among a much more abundant background of cosmic rays.

gamma-ray shower



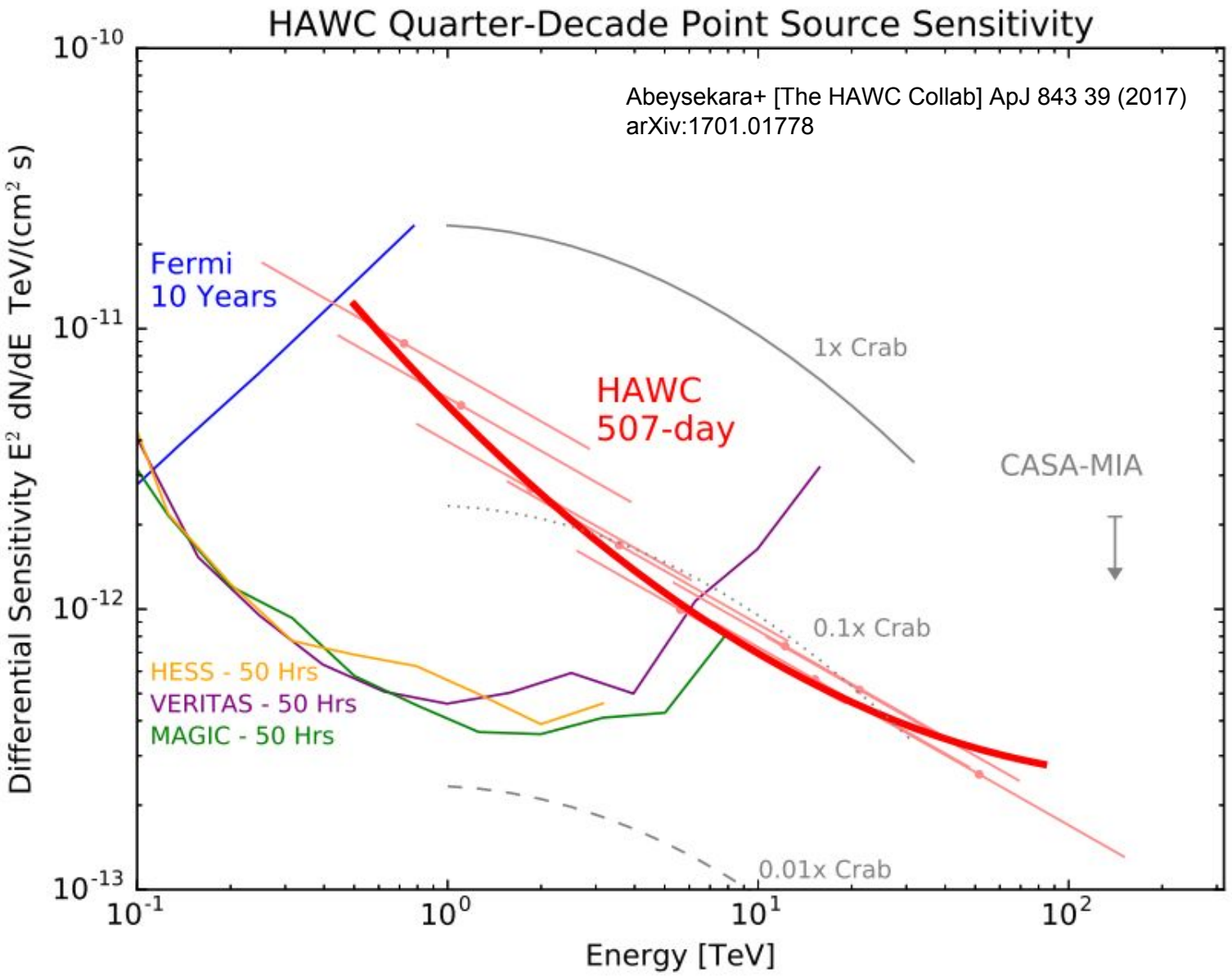
"hot" spots concentrate around the core

cosmic-ray shower



"hot" spots are more dispersed

The HAWC Observatory



Analysis Details

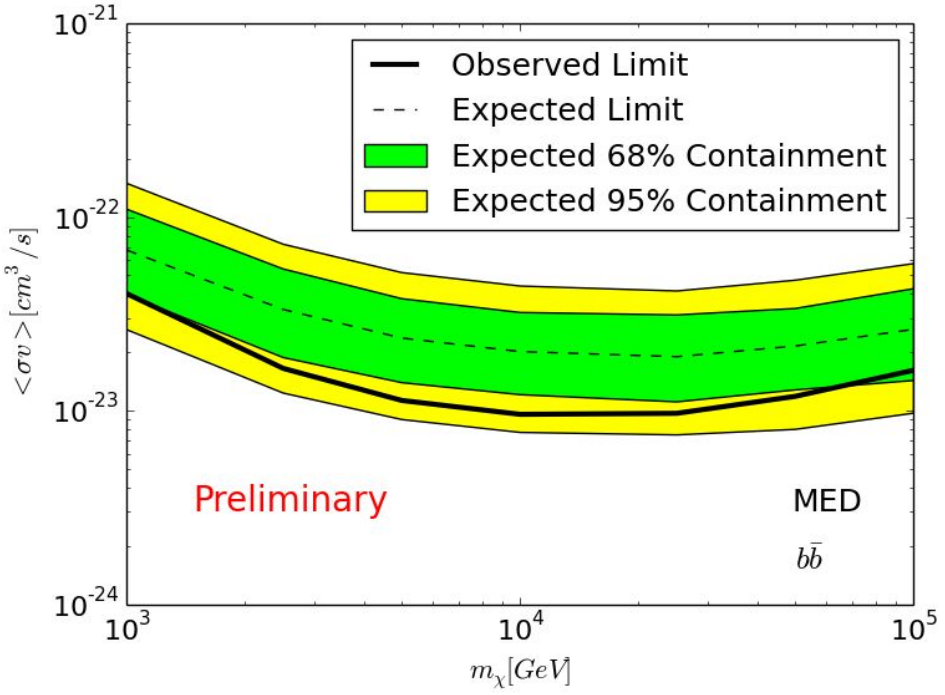
- 760 days of HAWC 300 data
- HAWC analysis in done in ‘fraction of available PMTs’ bins
  - Proxy for energy
  - See Abeysekara+ [The HAWC Collab] ApJ 843 39 (2017) arXiv:1701.01778
- Use the Multi-Mission Maximum Likelihood (3ML) software
  - Available on GitHub https://github.com/giacomov/3ML
  -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

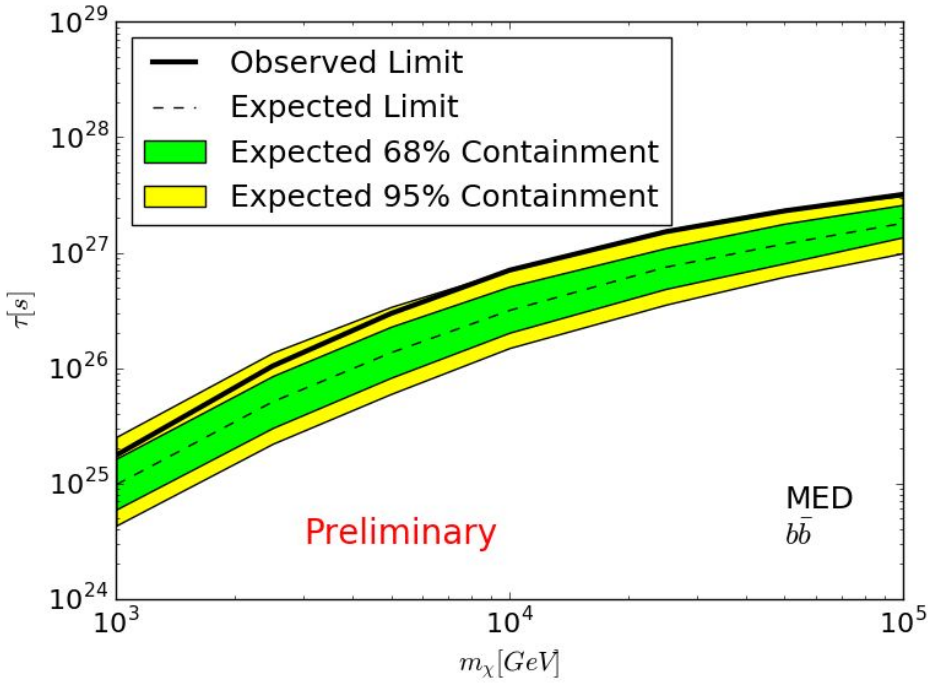
HAWC analysis bins

$\mathcal{B}$	$f_{\rm hit}$
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%

energy

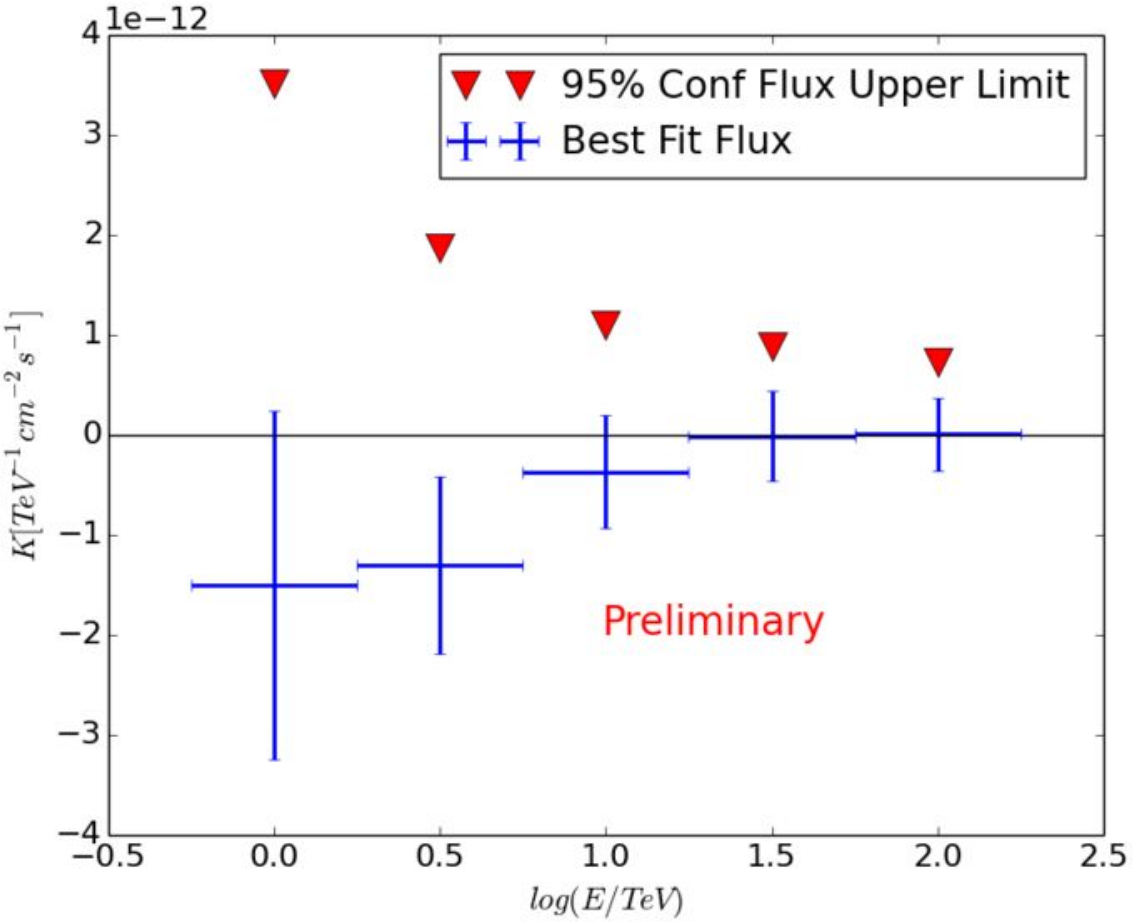
Results -- $b\bar{b}$





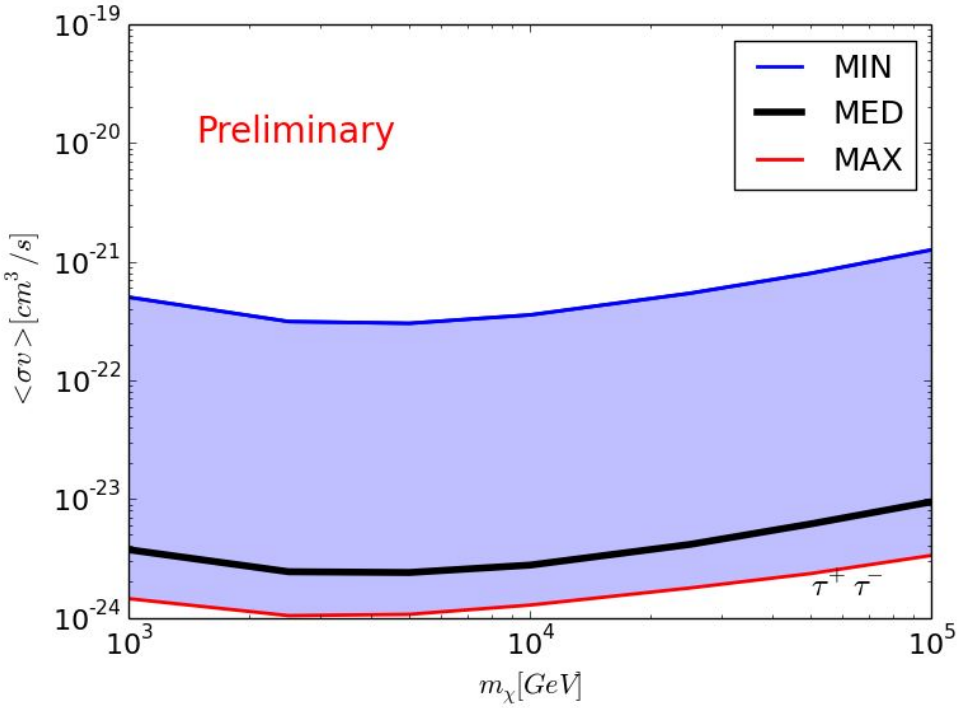
- **No gamma-ray excess detected**
- **Limits set on DM annihilation cross section and decay lifetime**
- **Limits are 1 to 1.5 sigma below expectation**

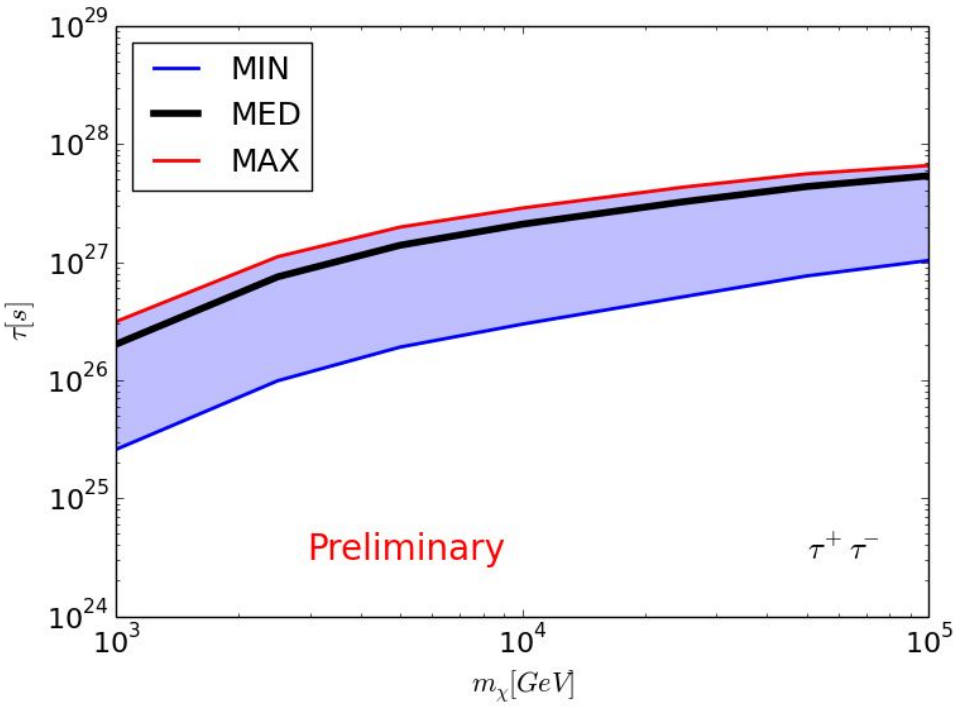
Flux Limits



- **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**

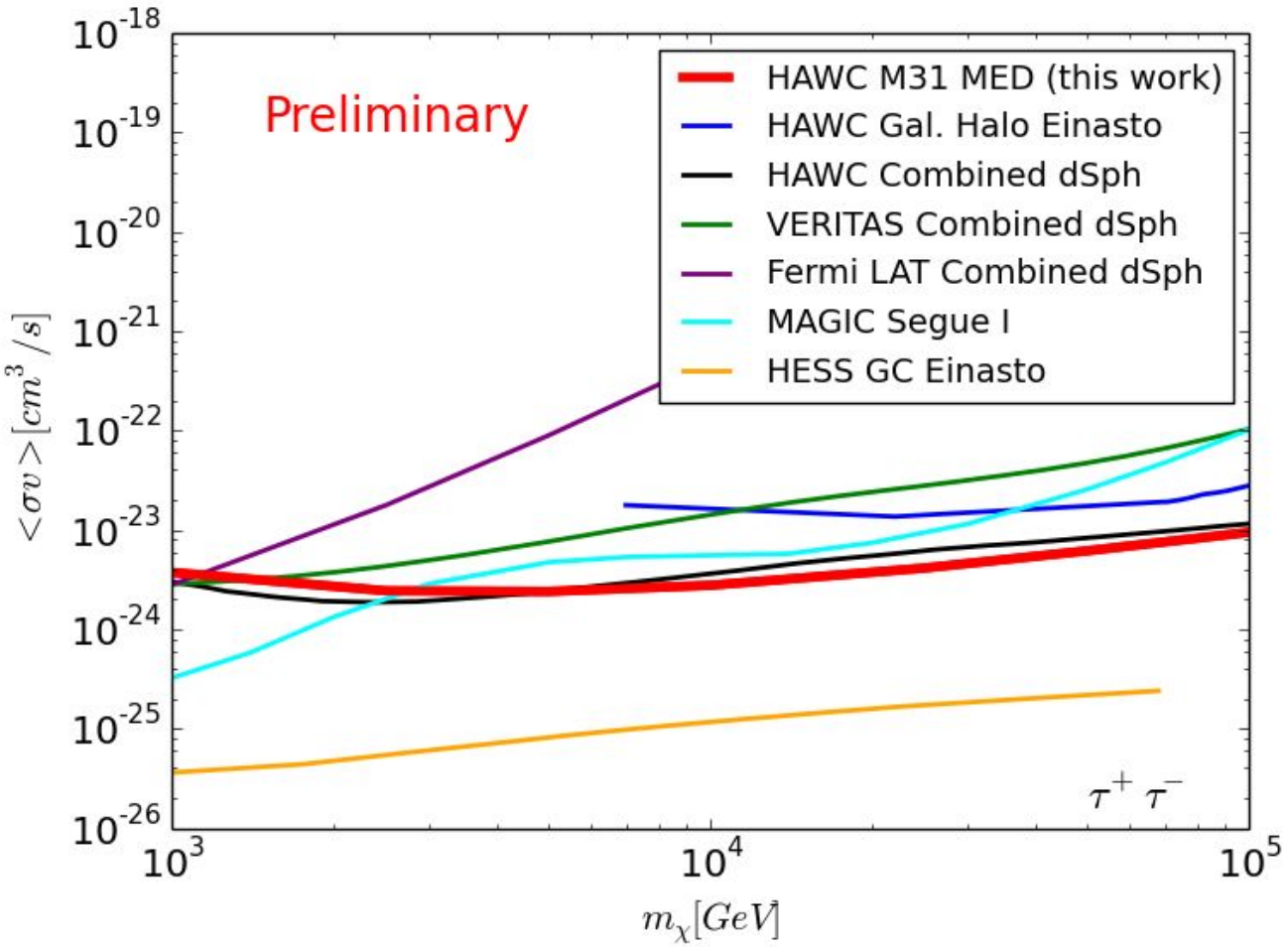
Results -- $\tau^+\tau^-$





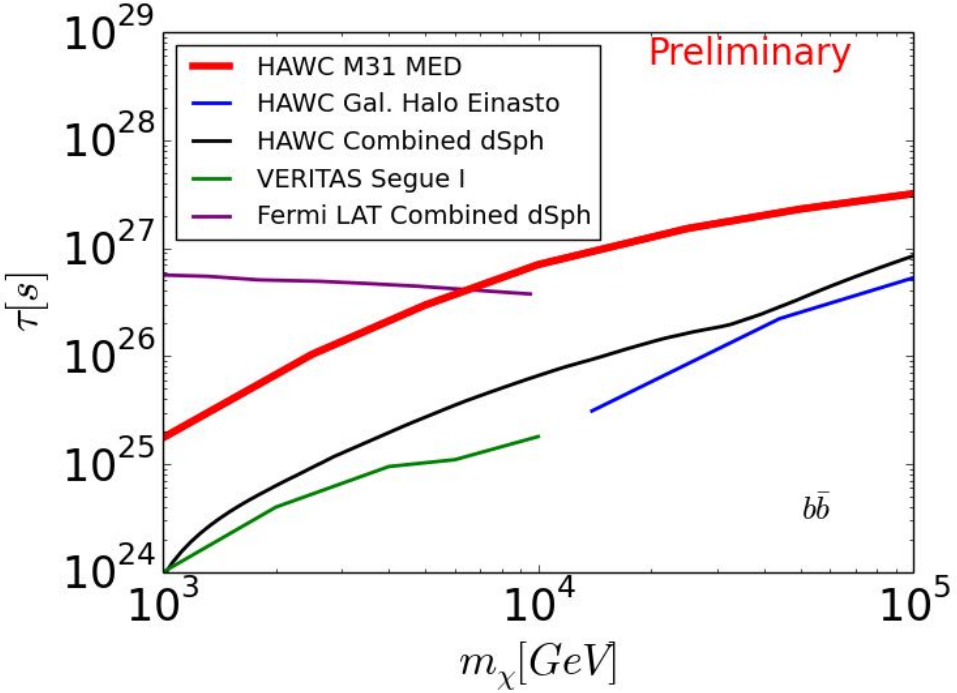
- **No gamma-ray excess detected**
- **Limits set on DM annihilation cross section and decay lifetime**
- **Spread in limits between MIN and MAX models from DM halo modeling uncertainties**

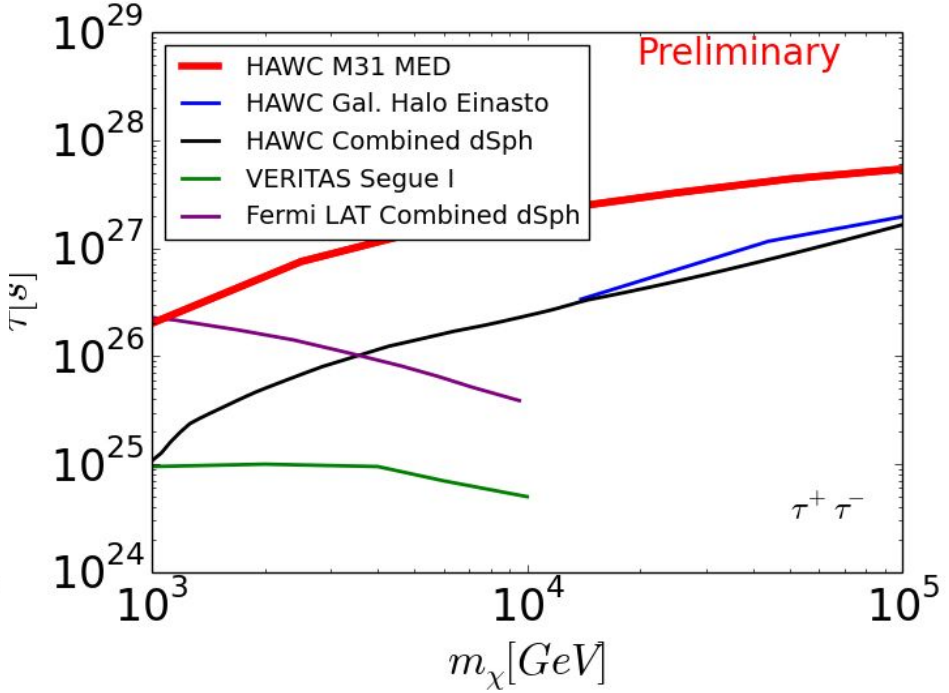
Results Compared to other Experiments



- **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 $b\bar{b}$ 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
  - Most constraining decay limits in $b\bar{b}$ for m>7 TeV and $\tau^+\tau^-$ for m>1 TeV