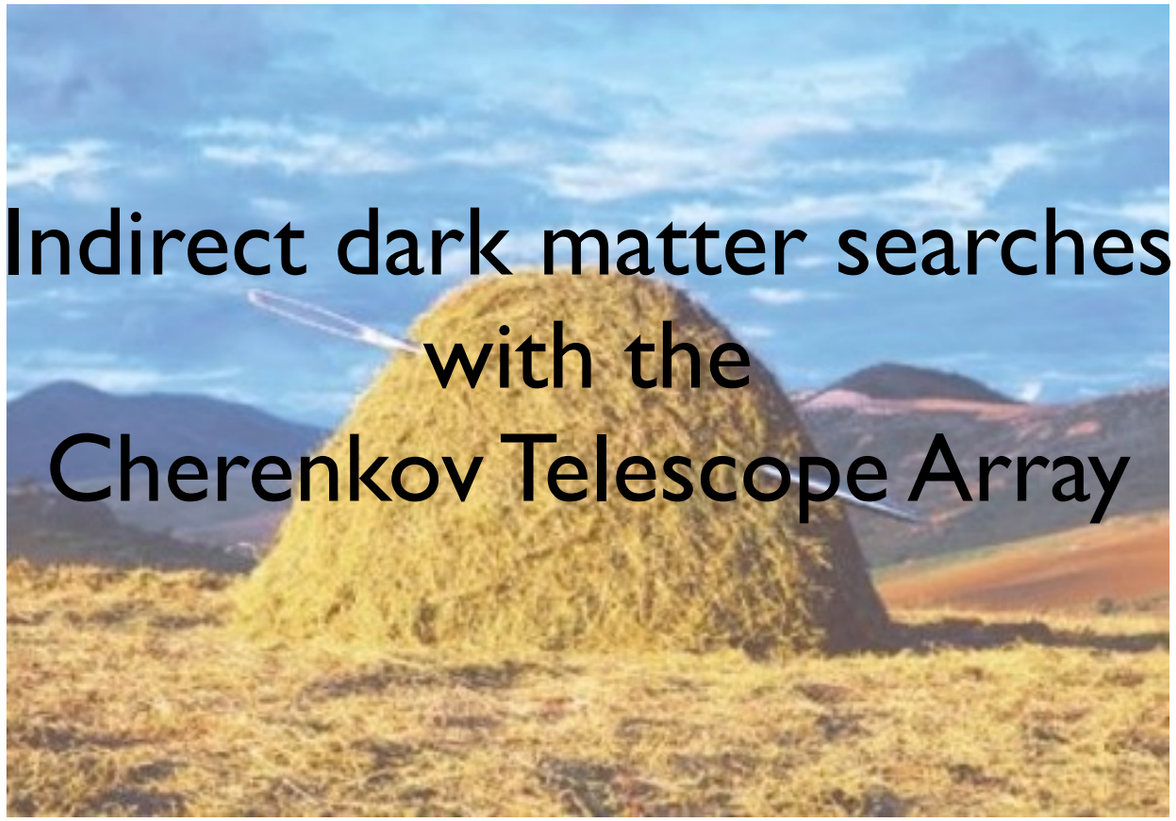
GRAPPA
GRavitation AstroParticle Physics Amsterdam
UNIVERSITY OF AMSTERDAM

cta
cherenkov telescope array



Indirect dark matter searches with the Cherenkov Telescope Array

Jennifer Gaskins

GRAPPA, University of Amsterdam

for the CTA Consortium

For more details, please see:
arXiv:1508.06128 — Carr et al. 2015 [CTA Consortium] (ICRC proceedings)
https://portal.cta-observatory.org/CTA_Observatory/performance/SitePages/Home.aspx

C. Balazs, T. Bringmann T. Buanes, J. Carr, M. K. Daniel, M. Doro, C. Farnier, M. Fornasa, J. Gaskins, G. A. Gomez-Vargas, M. Hayashida, K. Kohri, V. Lefranc, A. Morselli, E. Moulin, N. Mirabal, J. Rico, T. Saito, M.A. Sánchez-Conde, M. Wilkinson, M. Wood, G. Zaharijas, H.-S. Zechlin

Atmospheric Cherenkov Telescopes

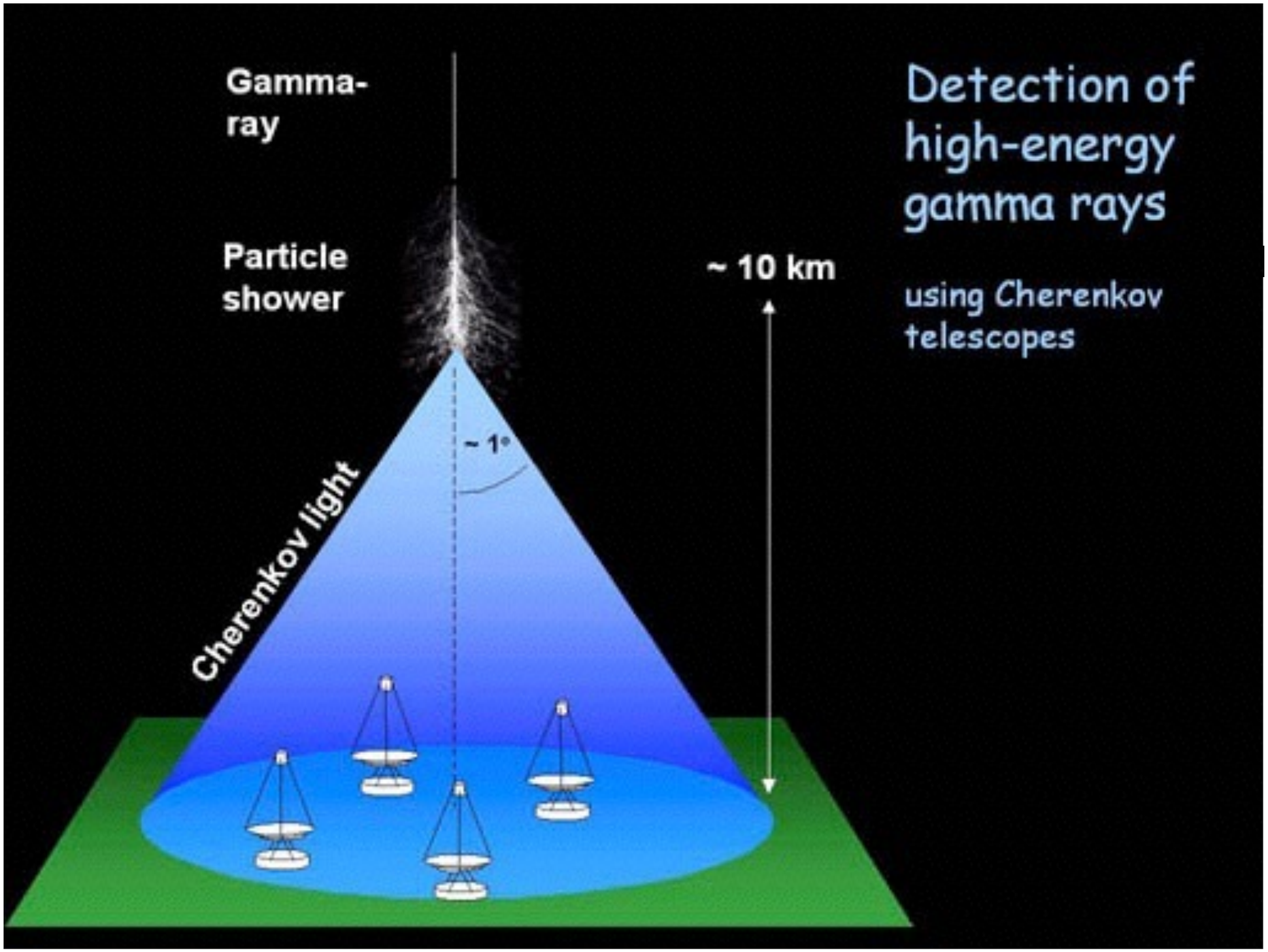


Image credit: H.E.S.S. Collaboration

The Cherenkov Telescope Array

- next-generation gamma-ray observatory with > 100 telescopes
- open observatory
- designed to operate for 30 years
- Northern and Southern sites
    - Southern: in Chile, near Paranal
    - Northern: La Palma, Canary Islands, Spain
- 31 nations, ~ €297M (construction costs)

Image credit: CTA Collaboration

The Cherenkov Telescope Array

Image credit: CTA Collaboration

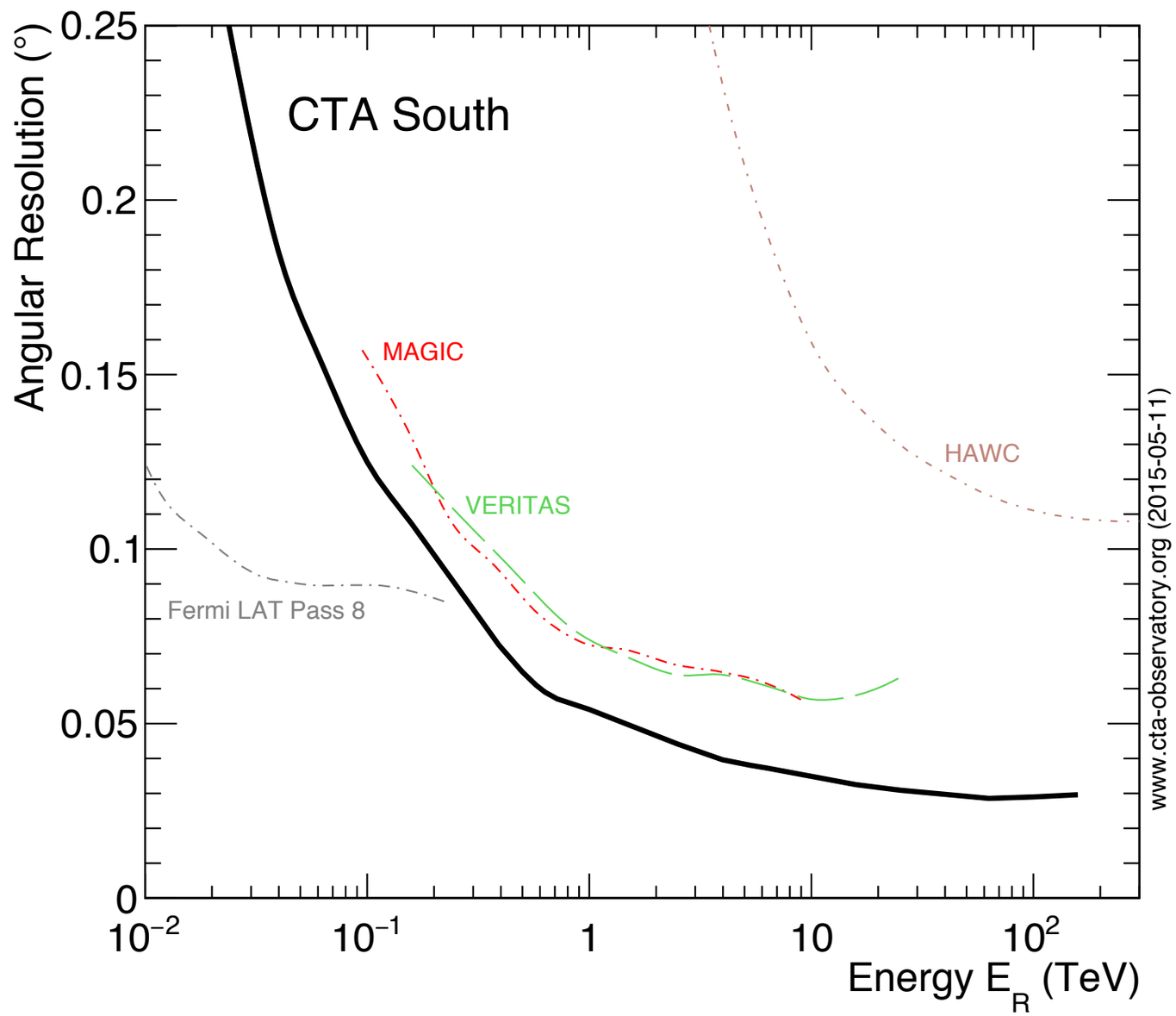
Array configuration assumed for results shown here:

- CTA Southern Site (area covered by the array of telescopes: ~4 km^2):
  - 4 large-size telescopes
  - 24 medium-size telescopes
  - 72 small-size telescopes
- CTA Northern Site (area covered by the array of telescopes: ~0.4 km^2):
  - 4 large-size telescopes
  - 15 medium-size telescopes

detailed expected performance information at
https://portal.cta-observatory.org/CTA_Observatory/performance/SitePages/Home.aspx

Current and future capabilities

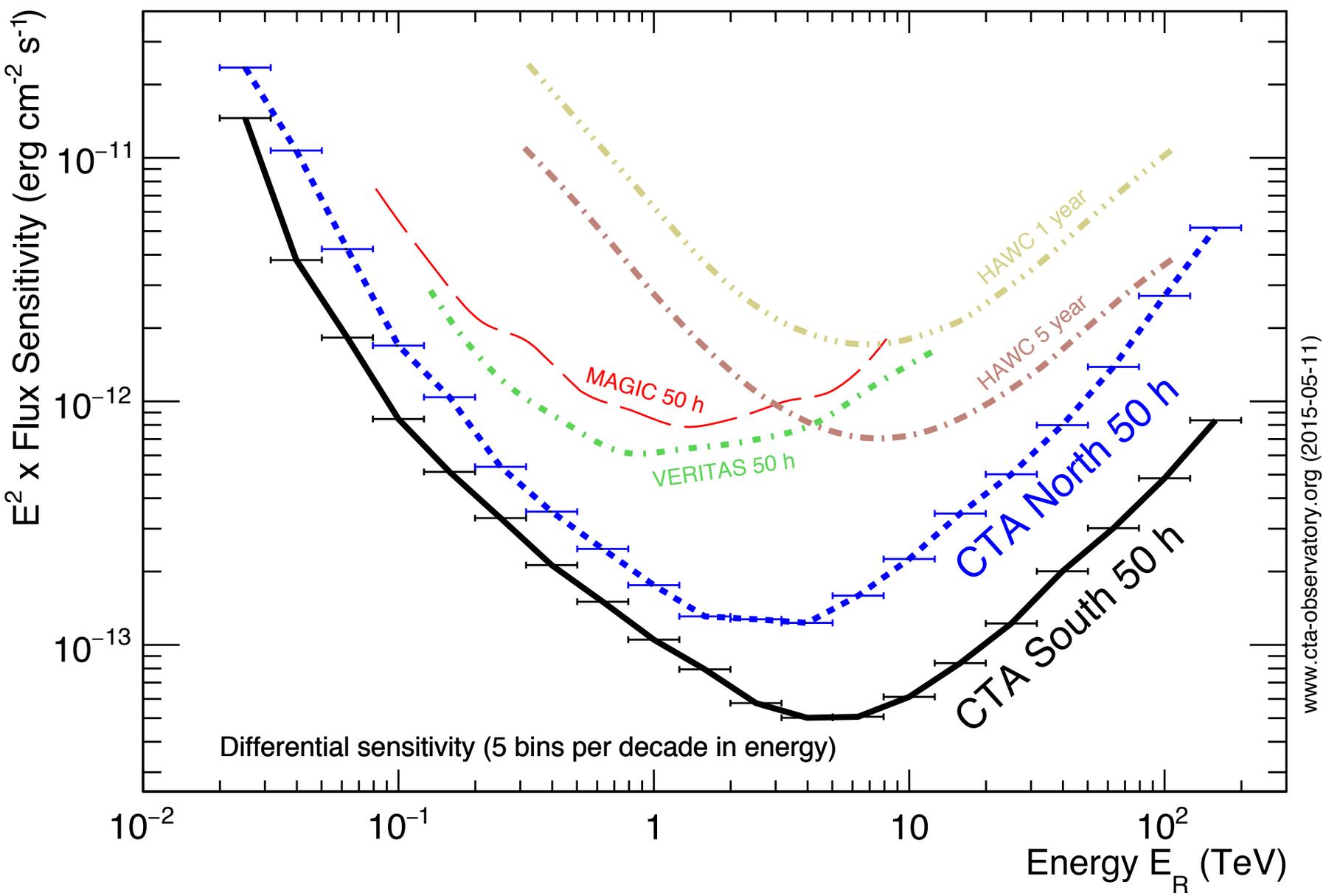
angular resolution (80% containment radius)



Courtesy of CTA Consortium 2015

Current and future capabilities

sensitivity vs energy



Courtesy of CTA Consortium 2015

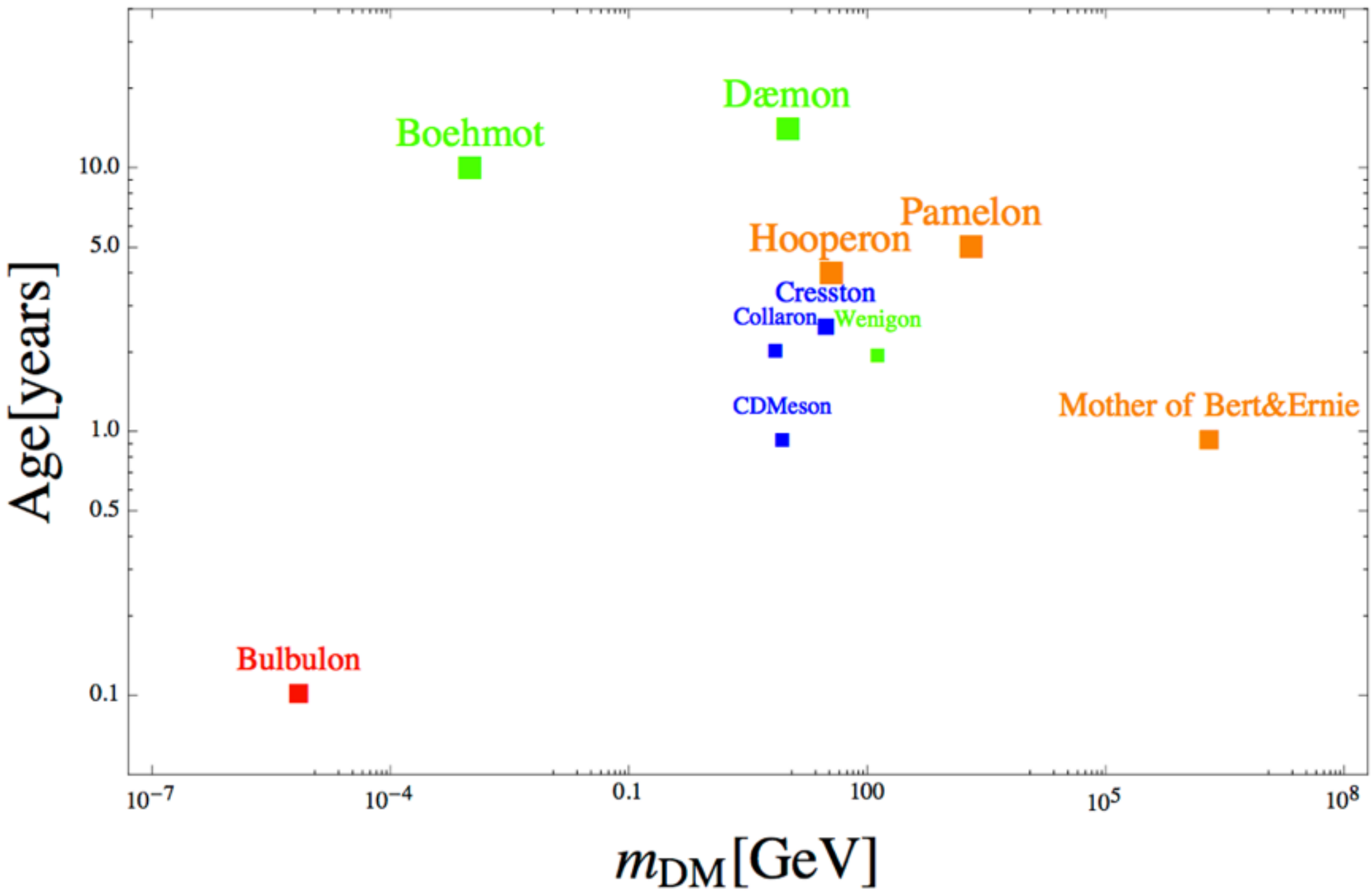
IACTs vs Fermi LAT

- IACTs have a large irreducible cosmic-ray background whereas the LAT can reject charged CRs at high efficiency

  ➡ this is a major challenge for searches for extended signals, such as dark matter annihilation in the Inner Galaxy

Anomalies!

Credit: Jester @ http://resonaances.blogspot.com



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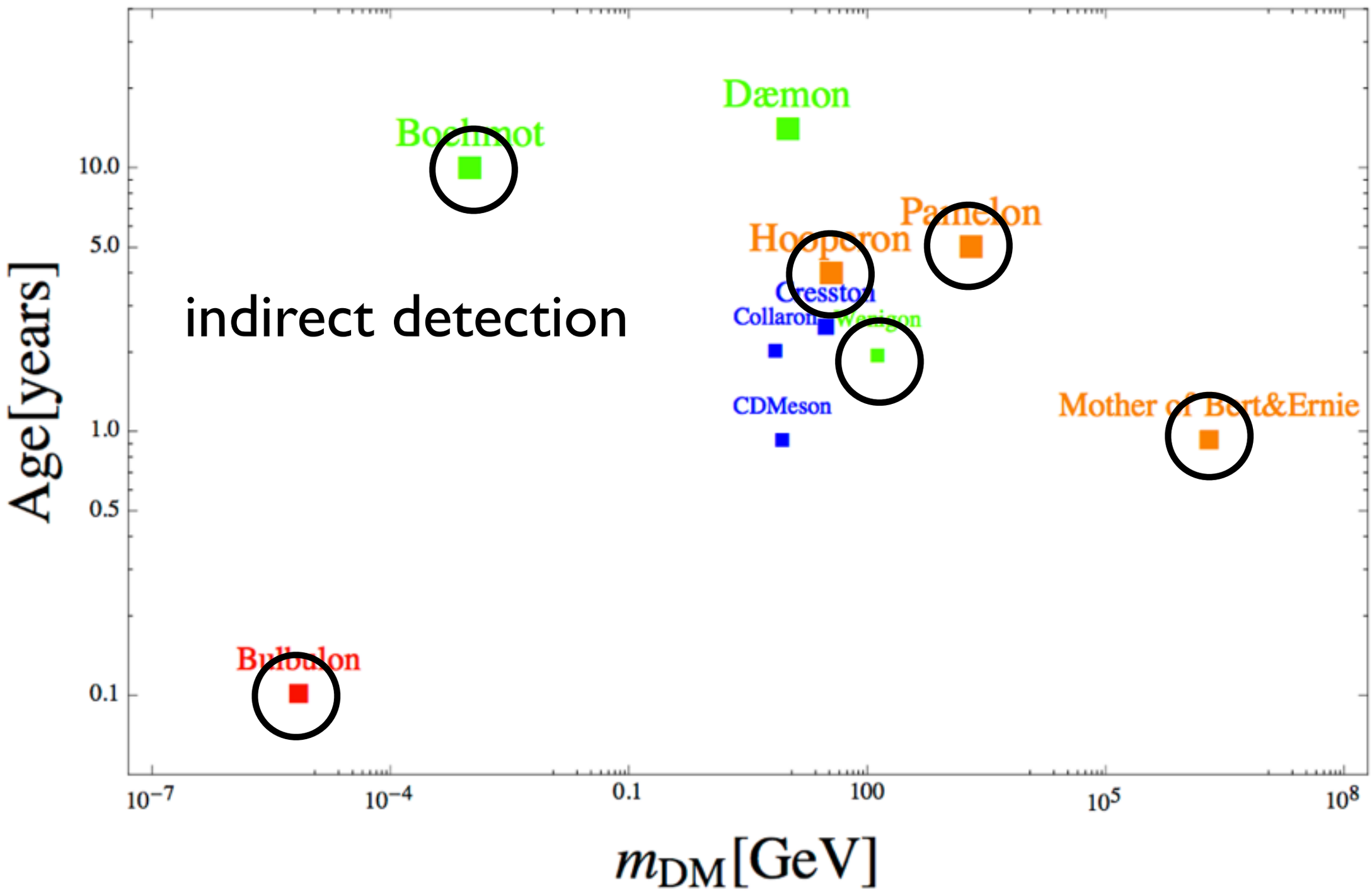

Anomalies!

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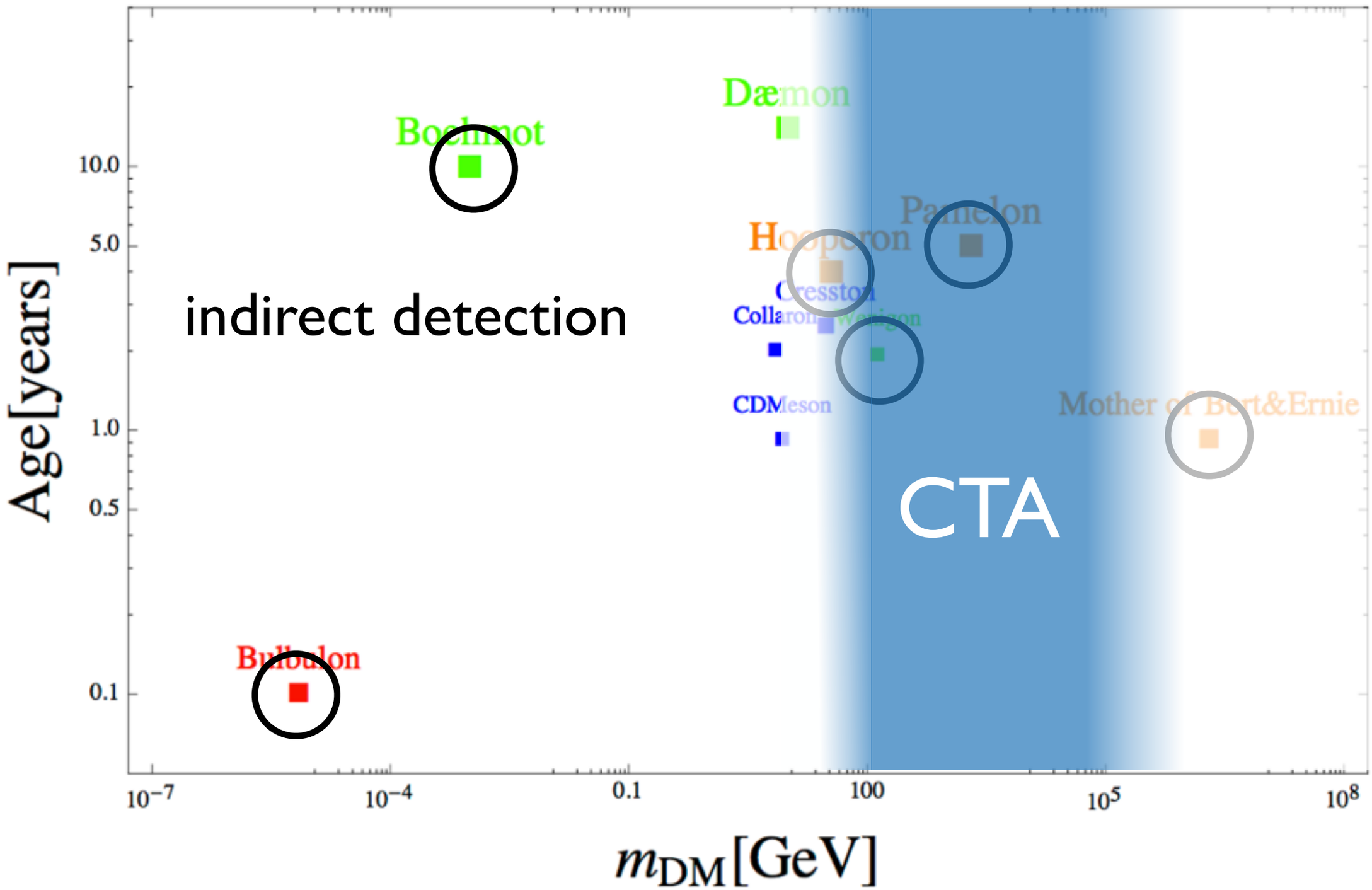
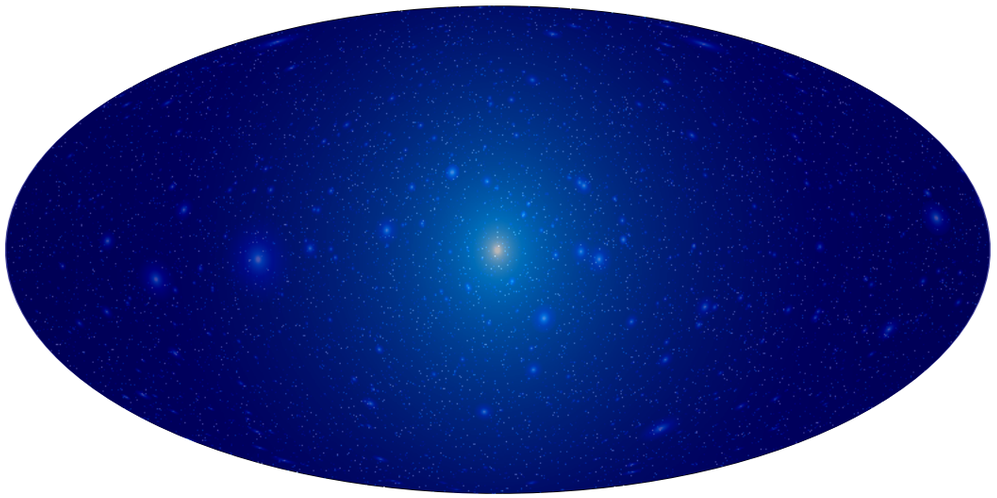


Dark matter search targets for CTA



The Galactic halo

Image credit: JG 2008

Milky Way satellites

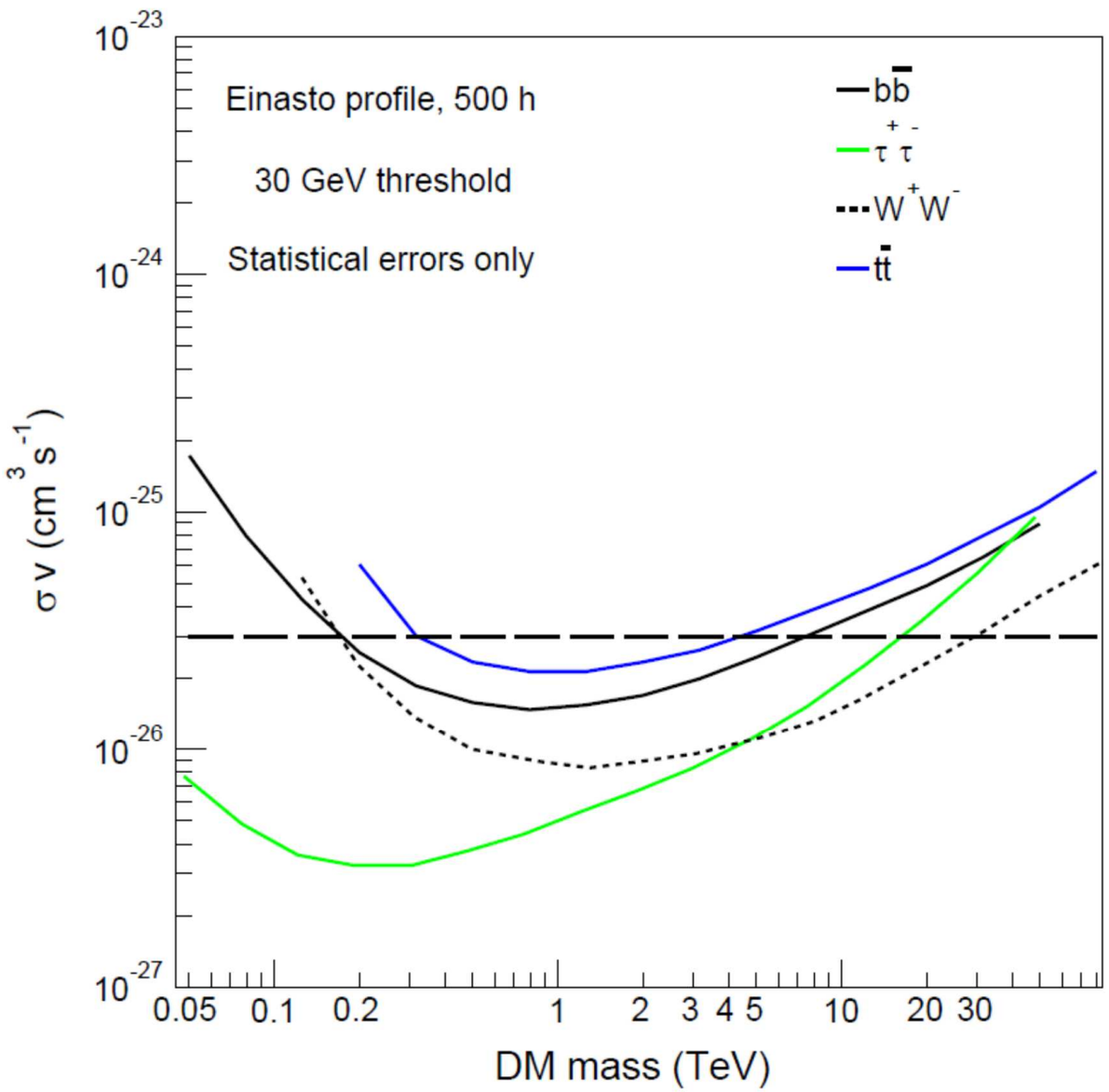
Draco. Image credit: J. Moore et al. 2012

The Large Magellanic Cloud

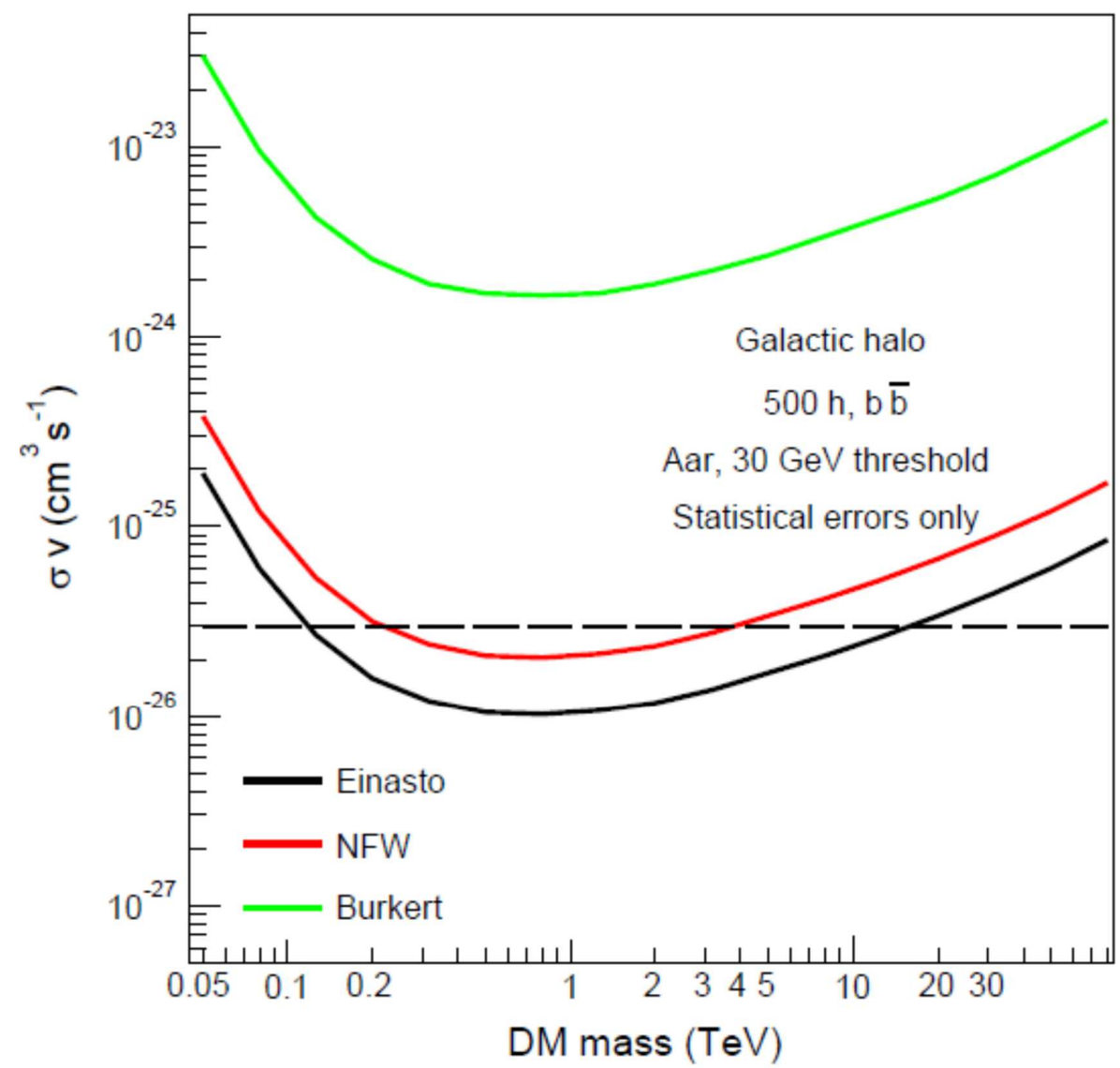
Image credit: NASA

Galactic halo projected sensitivity

500h, Einasto, different channels



500h, bb, different profiles

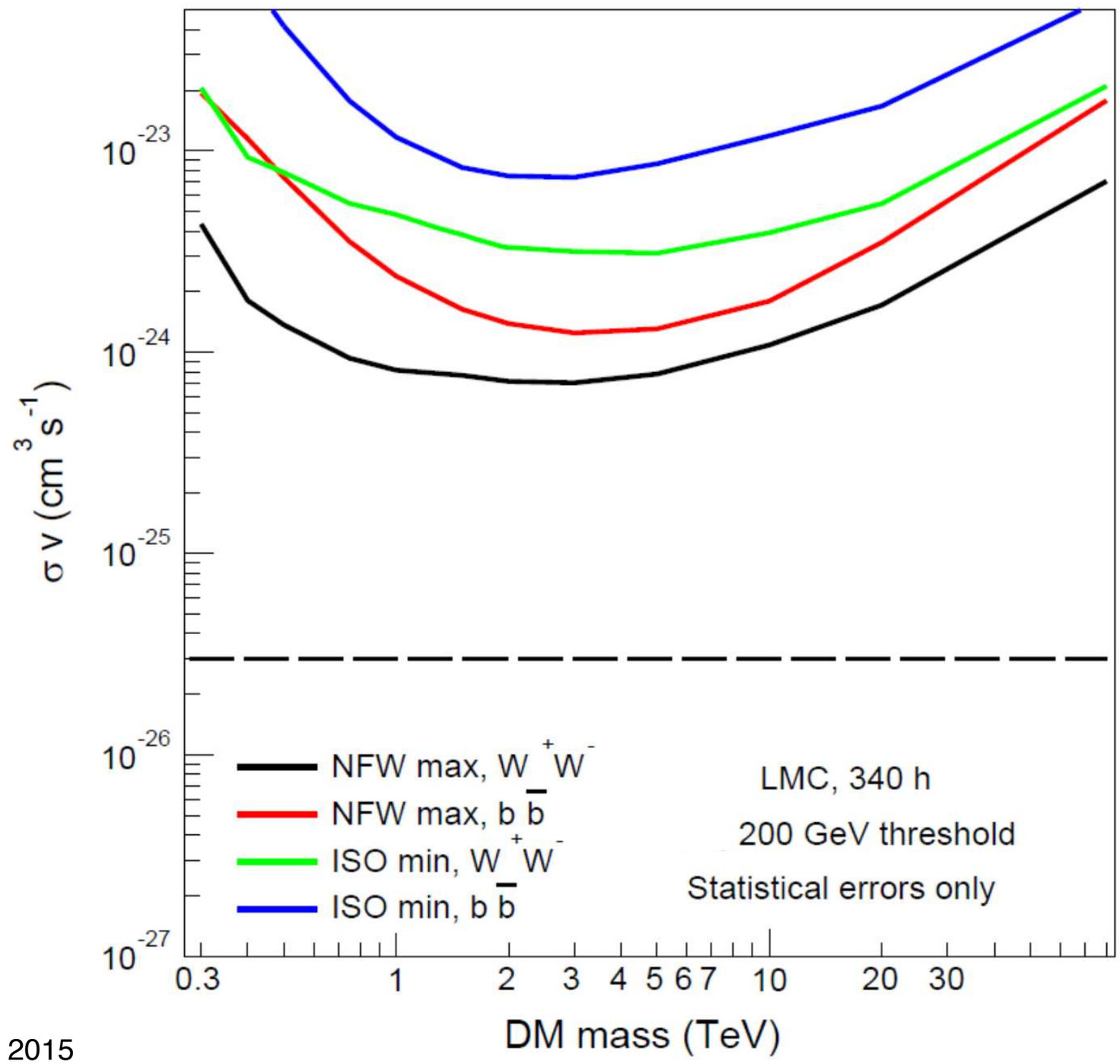


(statistical errors only)

Carr et al. 2015 (CTA Consortium)

LMC projected sensitivity

340h
200 GeV threshold
different profiles
and channels



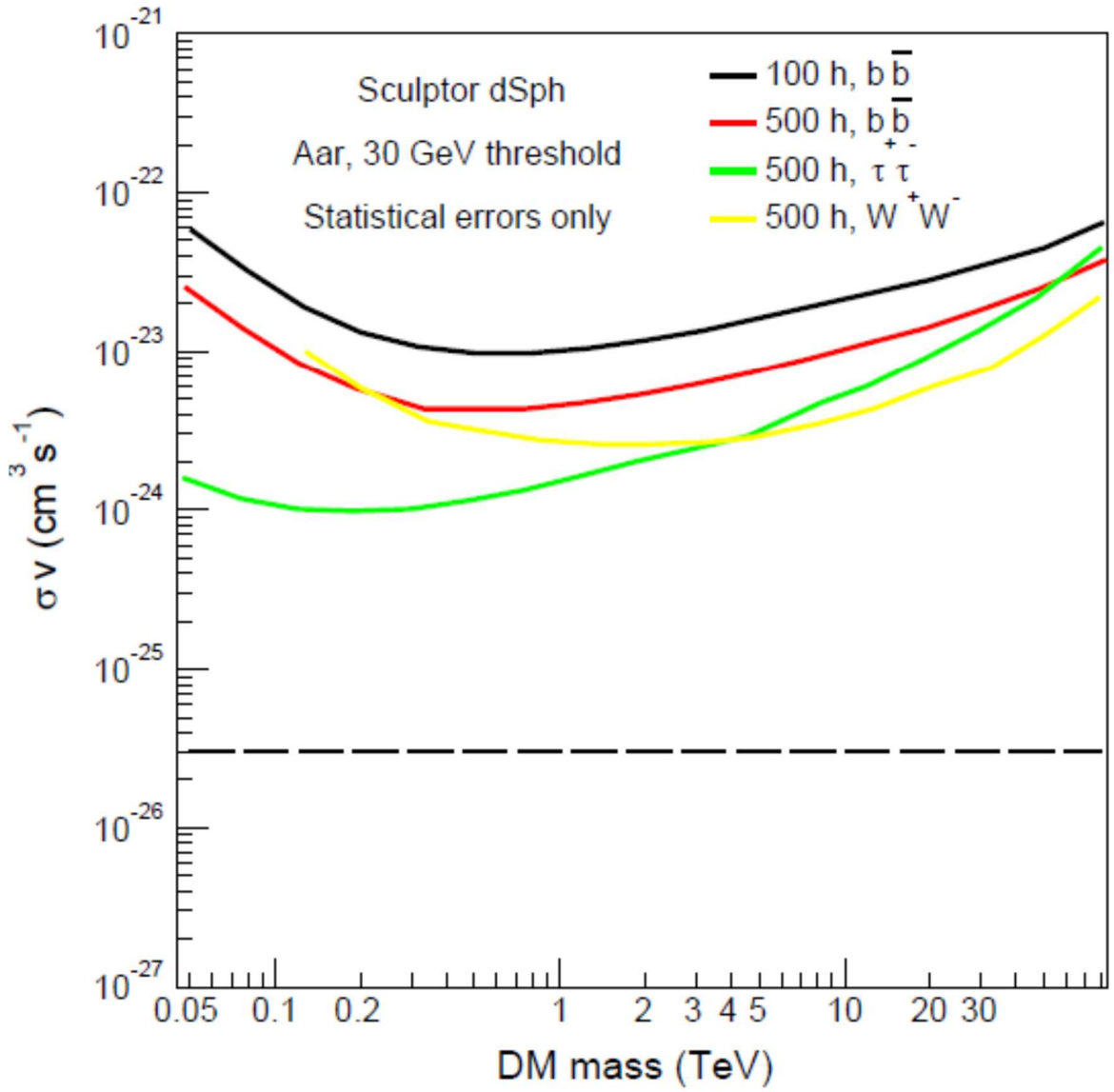
(statistical errors only)

; 2015

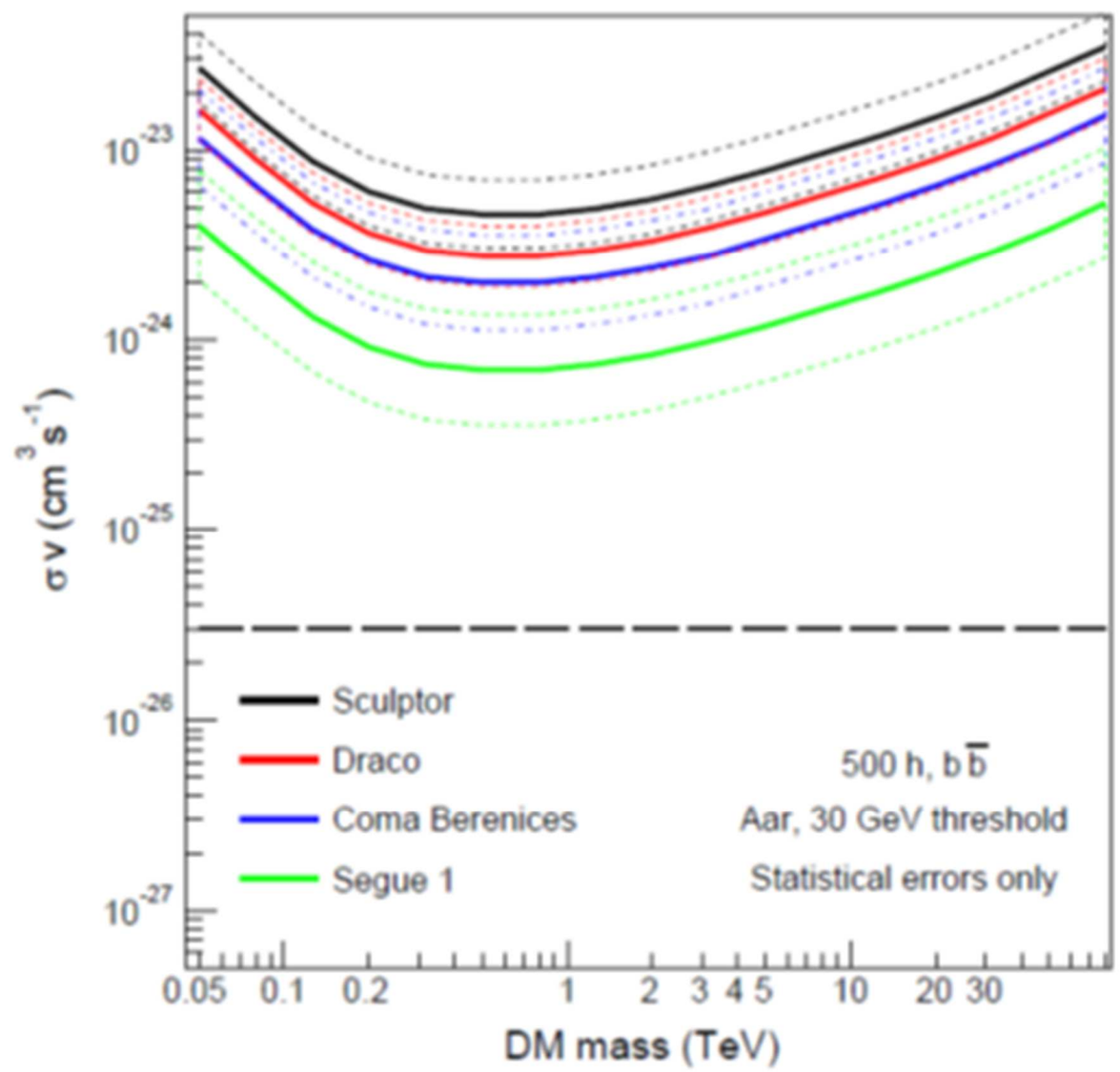
Courtesy of CTA Consortium 2015

Satellites projected sensitivity

500h, Sculptor, different channels



500h, bb, different dSph



(statistical errors only)

Carr et al. 2015 (CTA Consortium)

Comparison of targets

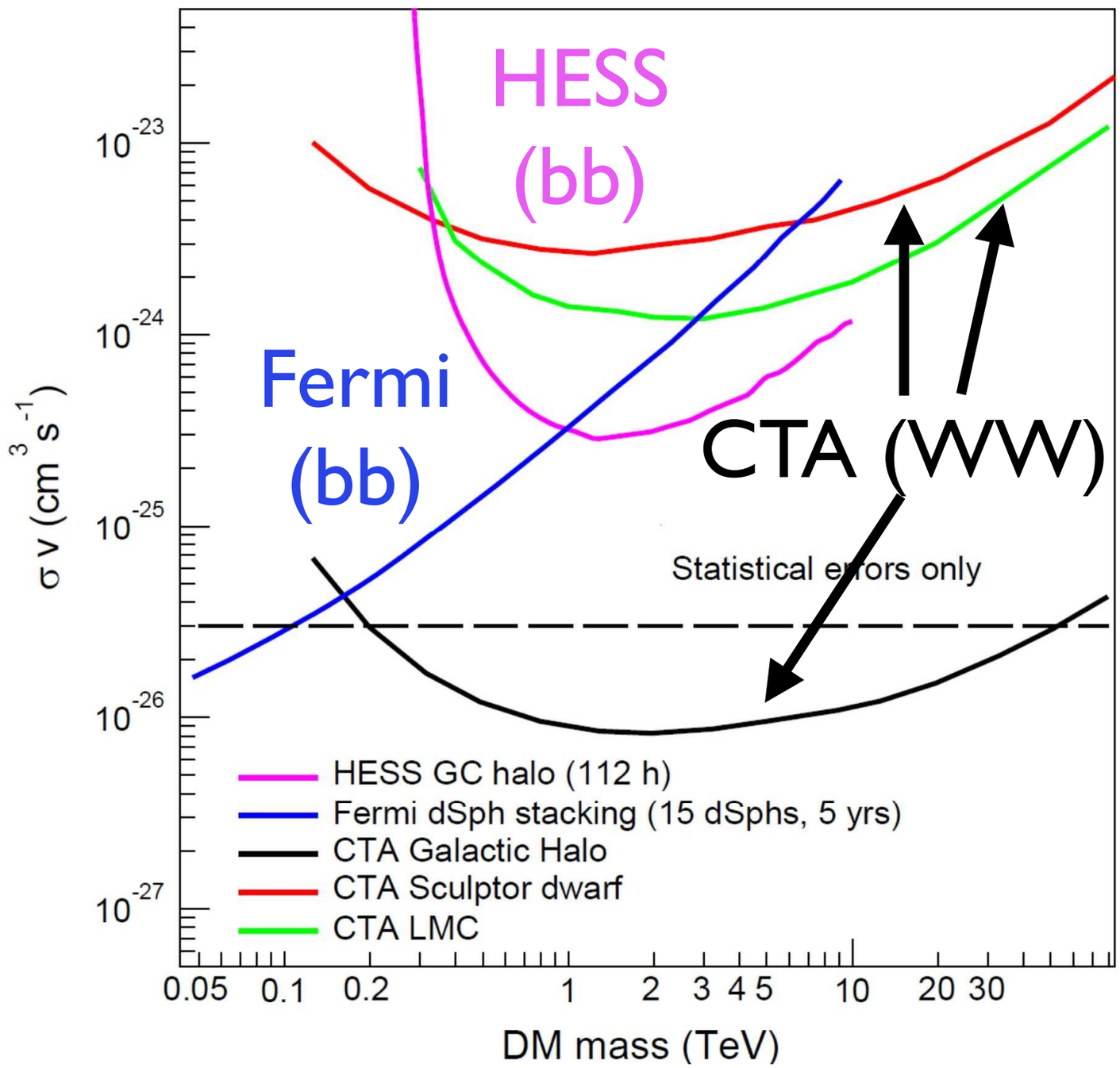
CTA Halo/Sculptor: 30 GeV threshold

CTA LMC: 200 GeV threshold

(statistical errors only)

SYSTEMATICS MUST BE CONTROLLED EXTREMELY WELL TO ACHIEVE STATISTICALLY-POSSIBLE SENSITIVITY

500h, WW / bb, different targets

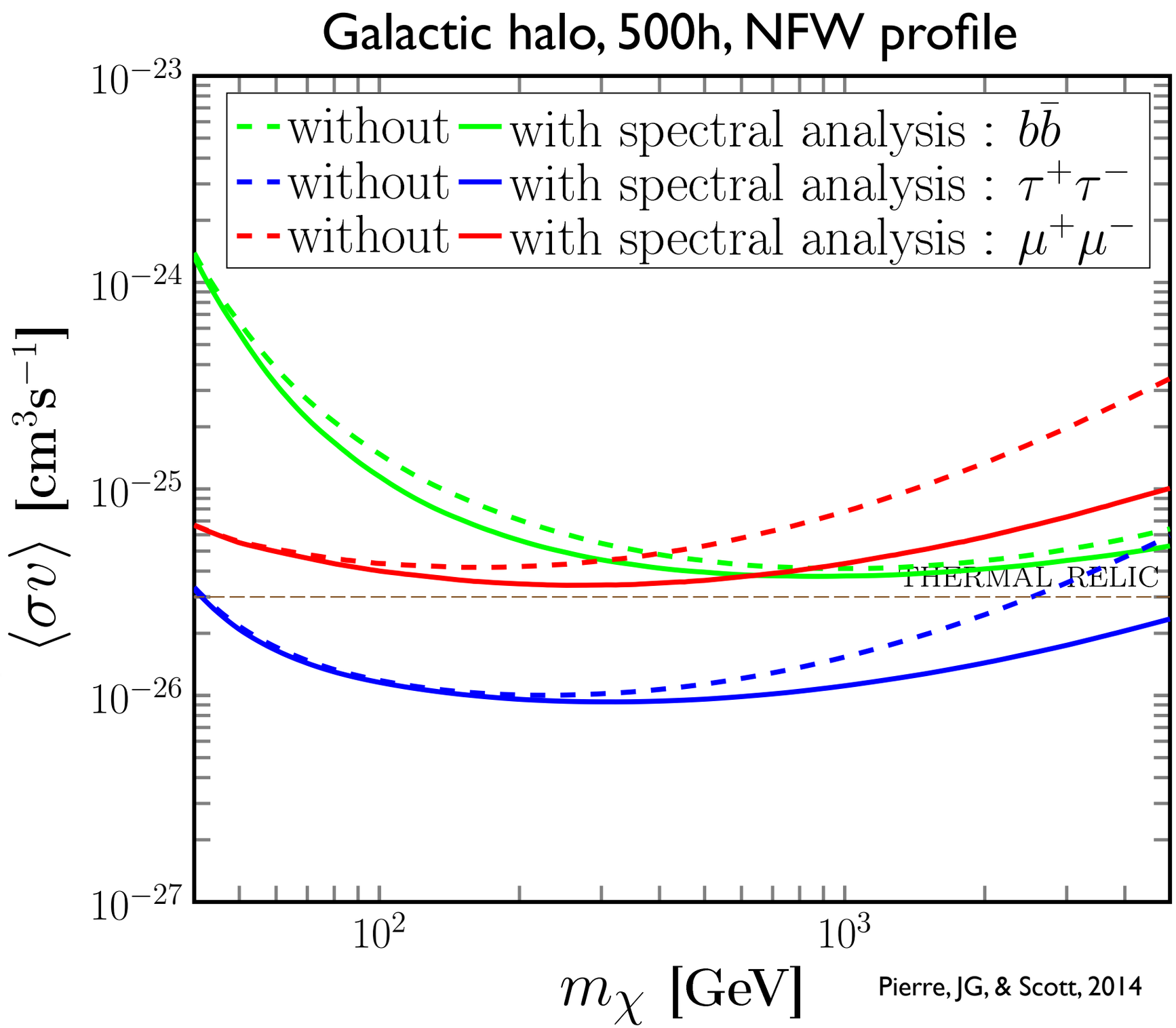


Carr et al. 2015 (CTA Consortium)

Spectral information

using full spectral information in analysis improves sensitivity at moderate/high dark matter masses

(now included in recent CTA projections shown here)



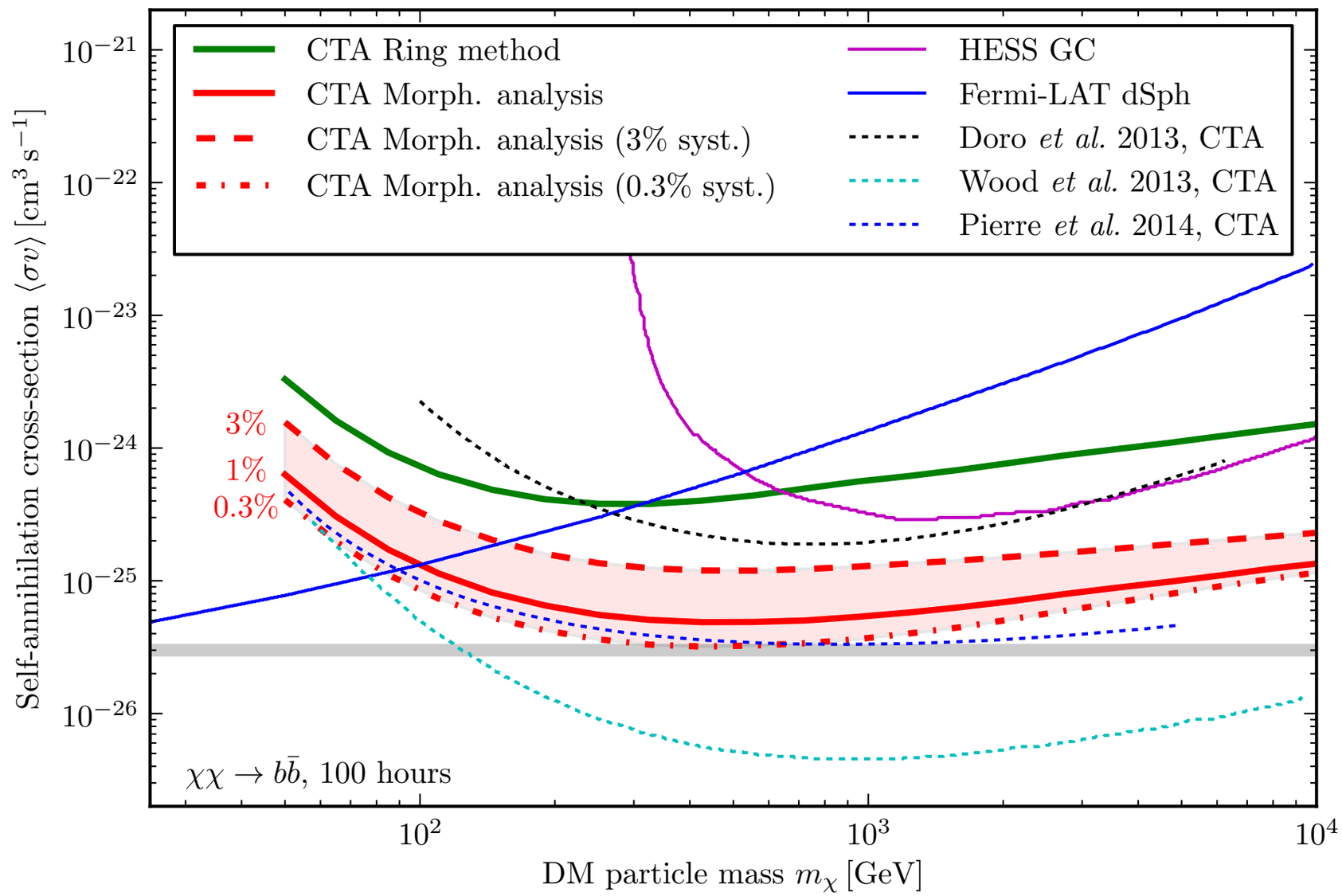
Pierre, JG, & Scott, 2014

Morphological information

using full morphological information (as opposed to simple ON-OFF techniques) in analysis improves sensitivity

(under study for implementation in future CTA analyses)

Galactic halo, 100h, comparison of analyses



Silverwood et al. 2014

see also Lefranc et al. 2015 for impact of spectral and morphological analysis

Summary

- CTA will improve dramatically on existing sensitivity to DM annihilation for a range of interesting DM masses
- for many annihilation channels CTA will test the canonical thermal relic annihilation cross section if the Galactic halo density profile is NFW/Einasto
- while less promising, the LMC and Milky Way satellite galaxies are complementary targets with different uncertainties
- understanding and controlling systematics will be key for interpreting a possible detection or placing constraints using any targets

Additional slides

Calculating indirect signals

(for particles that propagate directly to the observer without deflection, attenuation, or secondary production)

differential intensity = particle physics term "K" • astrophysics term "J"

ANNIHILATION:

$$K_{\rm ann} = \frac{{\rm d}N}{{\rm d}E}\frac{\langle\sigma v\rangle}{2m_\chi^2} \qquad J_{\rm ann}(\psi) = \frac{1}{4\pi}\int_{los} {\rm d}s\ \rho^2(s,\psi)$$

DECAY:

$$K_{\rm decay} = \frac{{\rm d}N}{{\rm d}E}\frac{1}{m_\chi\tau_\chi} \qquad J_{\rm decay}(\psi) = \frac{1}{4\pi}\int_{los} {\rm d}s\ \rho(s,\psi)$$

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spectrum of particles produced

DECAY:

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dark matter particle mass

DECAY:

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$$J_{\rm ann}(\psi) = \frac{1}{4\pi}\int_{los} {\rm d}s\ \rho^2(s,\psi)$$

average of pair annihilation cross section times relative velocity

DECAY:

$$K_{\rm decay} = \frac{{\rm d}N}{{\rm d}E}\frac{1}{m_\chi\tau_\chi}$$

$$J_{\rm decay}(\psi) = \frac{1}{4\pi}\int_{los} {\rm d}s\ \rho(s,\psi)$$

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dark matter particle lifetime

Calculating indirect signals

(for particles that propagate directly to the observer without deflection, attenuation, or secondary production)

differential intensity = particle physics term "K" • astrophysics term "J"

ANNIHILATION:

$$K_{\rm ann} = \frac{{\rm d}N}{{\rm d}E}\frac{\langle\sigma v\rangle}{2m_\chi^2}$$

$$J_{\rm ann}(\psi) = \frac{1}{4\pi}\int_{los} {\rm d}s\, \rho^2(s,\psi)$$

dark matter density

DECAY:

$$K_{\rm decay} = \frac{{\rm d}N}{{\rm d}E}\frac{1}{m_\chi \tau_\chi}$$

$$J_{\rm decay}(\psi) = \frac{1}{4\pi}\int_{los} {\rm d}s\, \rho(s,\psi)$$

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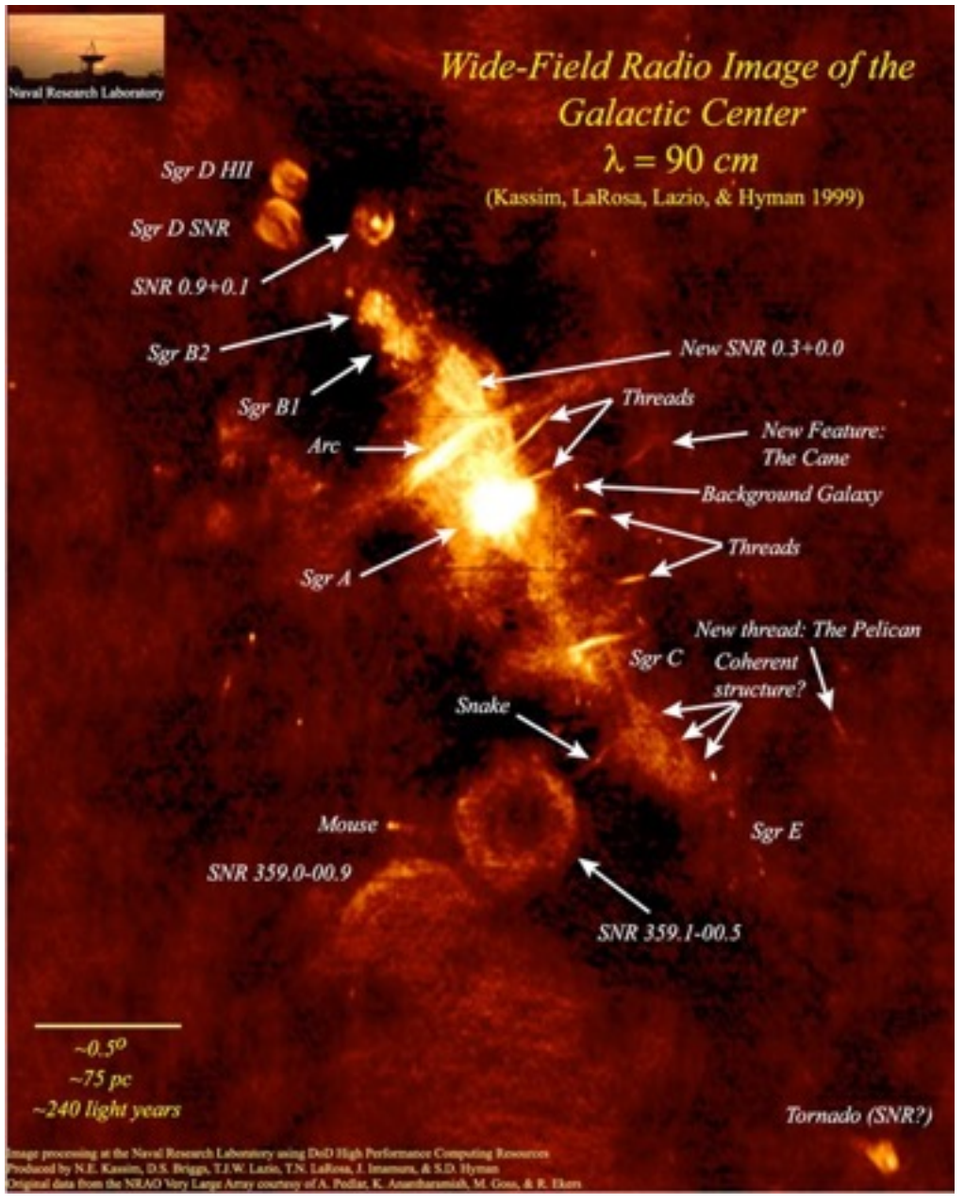
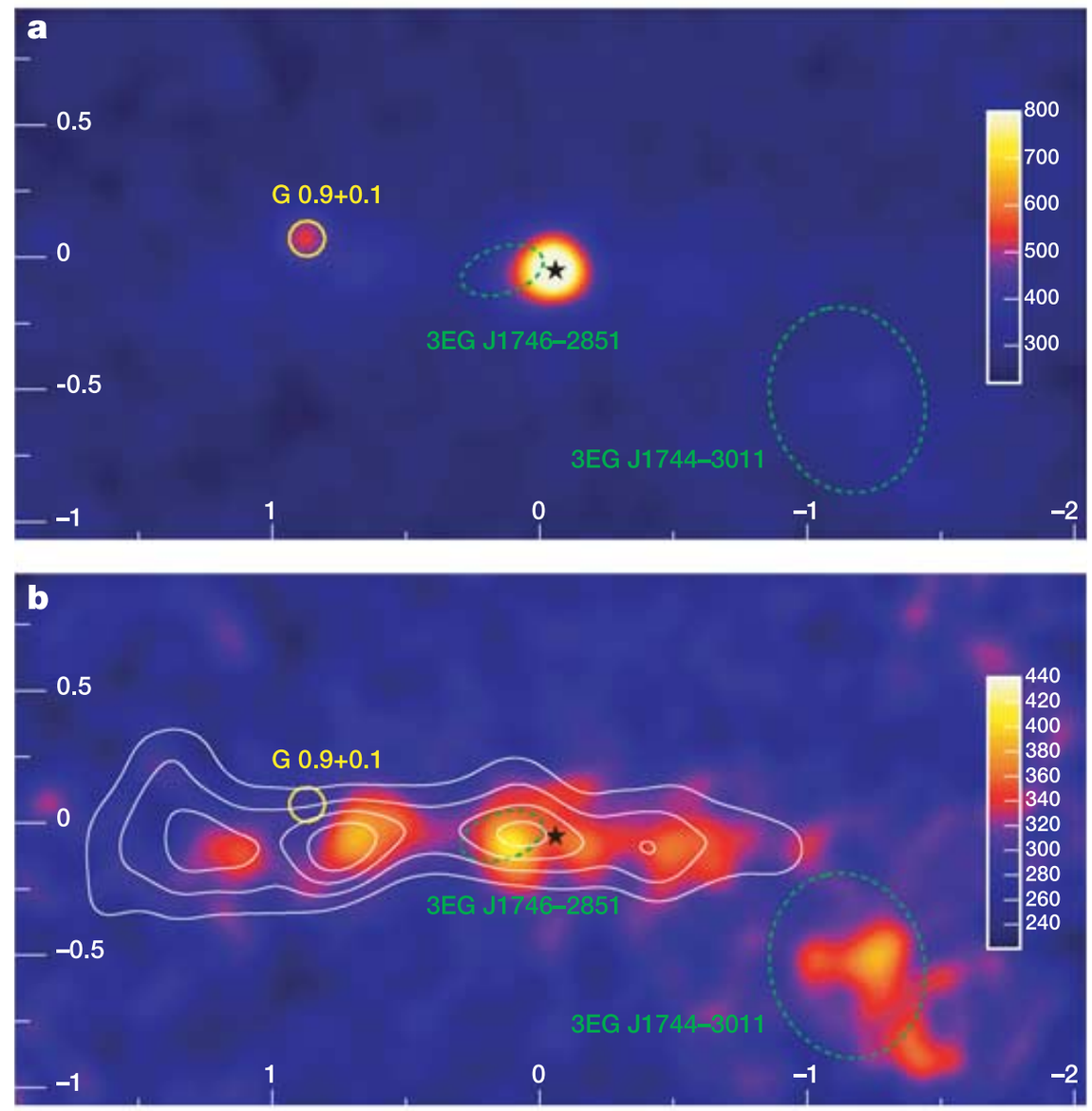
The multi-wavelength Inner Galaxy

VLA @ 330 MHz



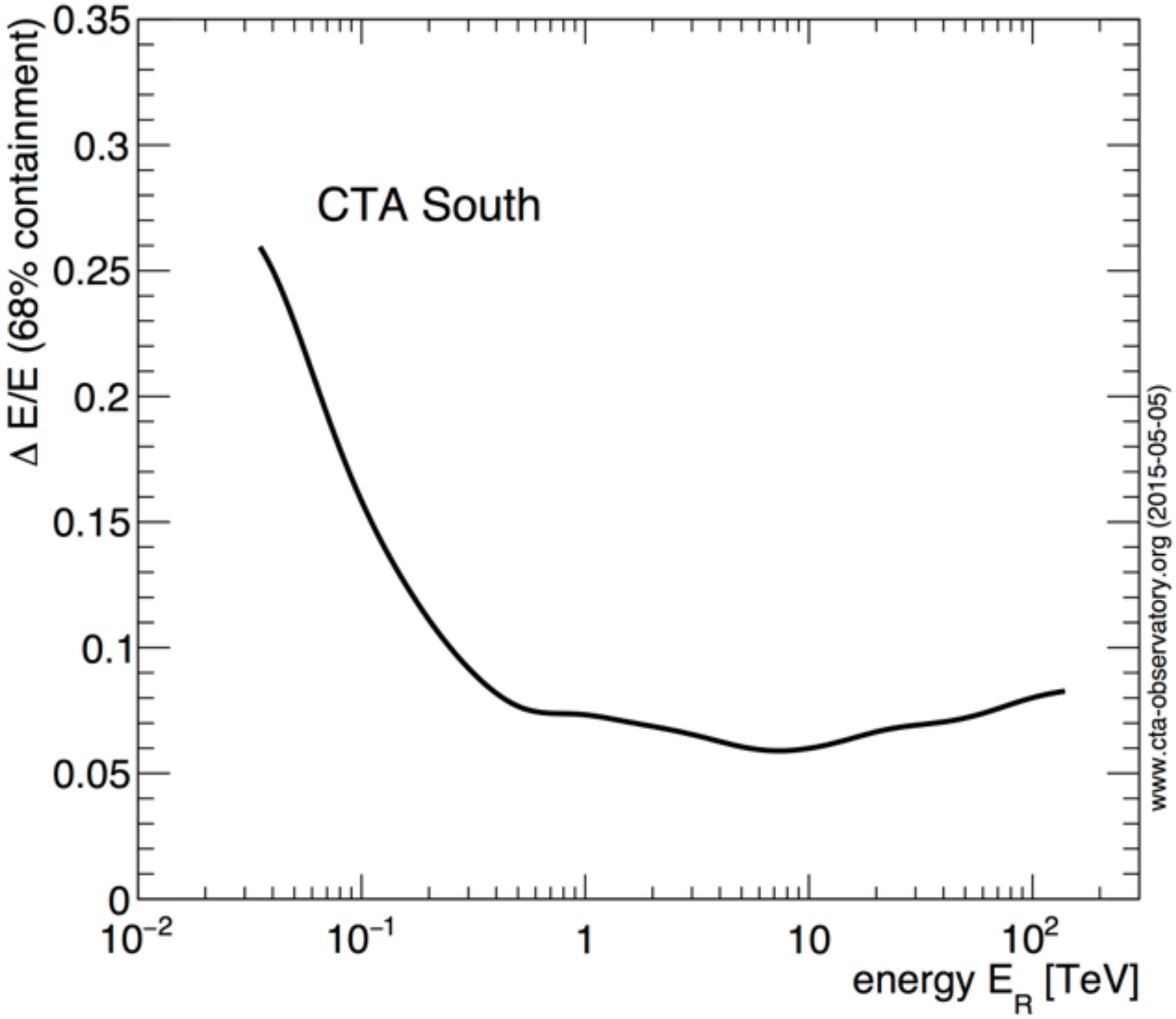
HESS > 380 GeV



Aharonian et al. 2006

Sensitivity to gamma-ray lines

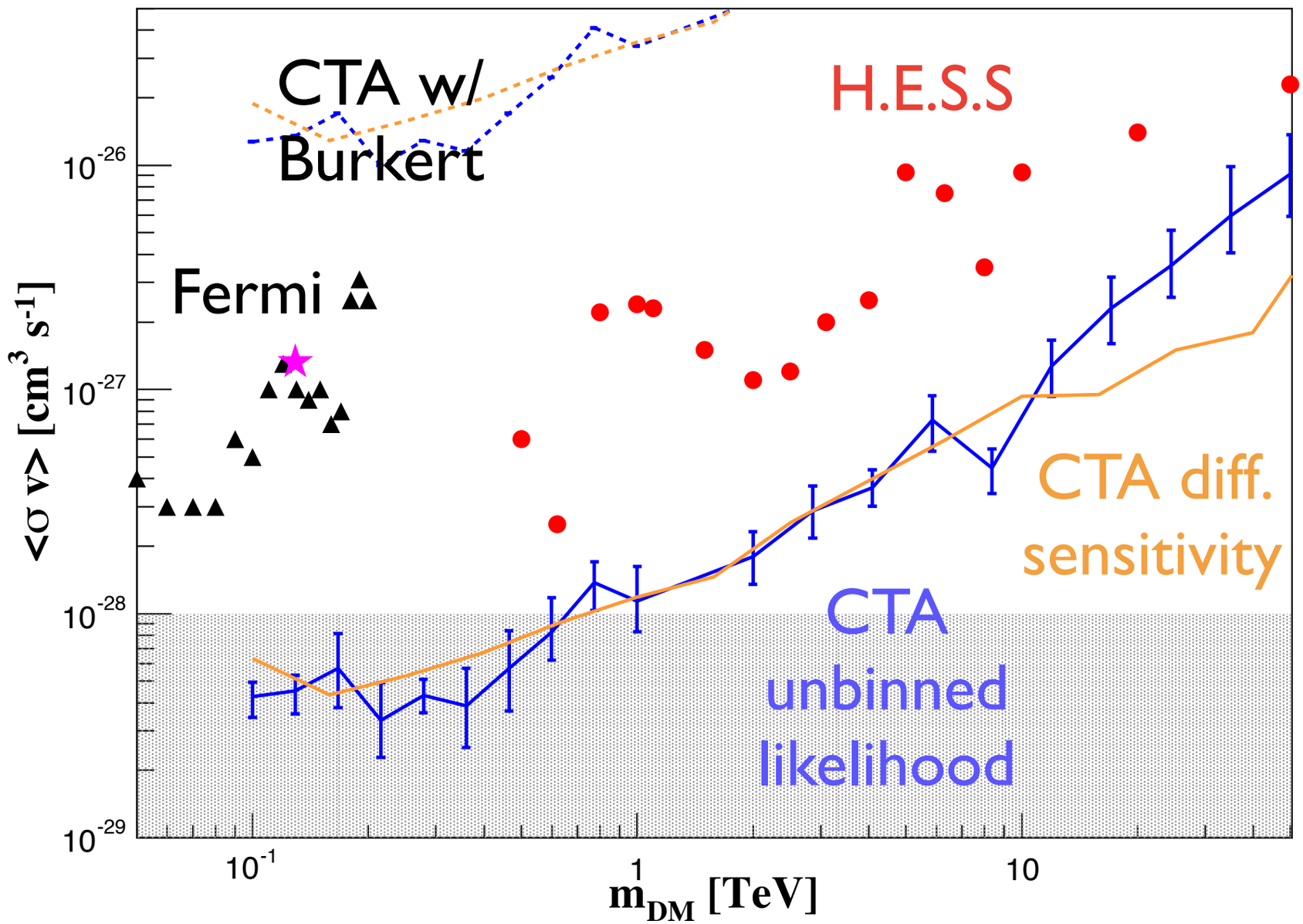
energy resolution vs energy



Courtesy of CTA consortium 2015

Sensitivity to gamma-ray lines

CTA: 500h, 1 deg around GC, Einasto



Courtesy of CTA consortium 2015

Proposed search strategy

Year	1	2	3	4	5	6	7	8	9	10
Galactic halo	175 h	175 h	175 h							
Segue 1 (or best) dSph	100 h	100 h	100 h							
				in case of detection at GC, large σv						
Segue 1 (or best) dSph				150 h	150 h	150 h	150 h	150 h	150 h	150 h
Galactic halo				100 h	100 h	100 h	100 h	100 h	100 h	100 h
				in case of detection at GC, small σv						
Galactic halo				100 h	100 h	100 h	100 h	100 h	100 h	100 h
				in case of no detection at GC						
Best Target				100 h	100 h	100 h	100 h	100 h	100 h	100 h

Courtesy of CTA consortium 2015