Indirect dark-matter searches with gamma-rays experiments : status and future plans from 300 KeV to 100 TeV

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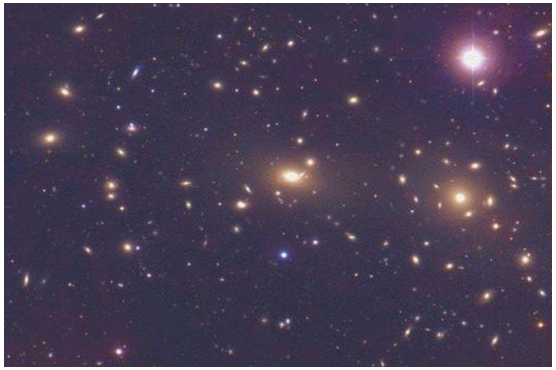
INFN Roma Tor Vergata

FROM NINE TO FORTY: THE SST TELESCOPES AND GAMMA-RAY SCIENCE WITH ASTRI AND CTAO

Sexten, July 23, 2026

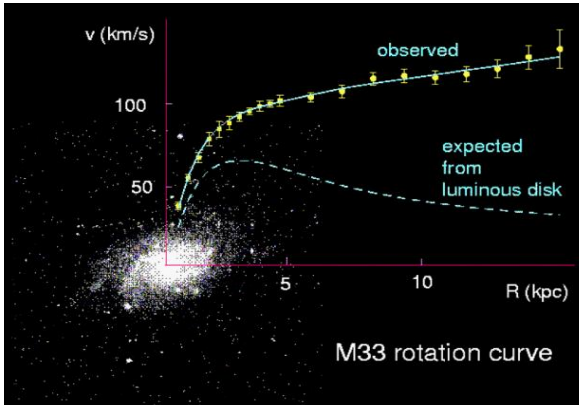
Dark Matter EVIDENCE



In 1933, the astronomer Zwicky realized that the mass of the luminous matter in the Coma cluster was much smaller than its total mass implied by the motion of cluster member galaxies.

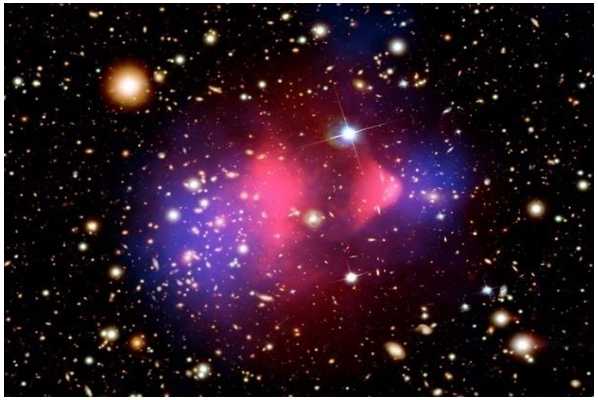
Since then, even more evidence:

Rotation curves of galaxies

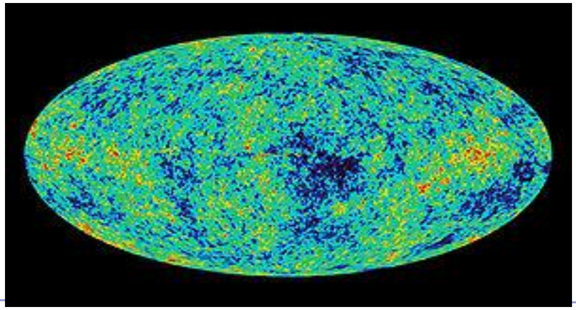


Gravitational lensing

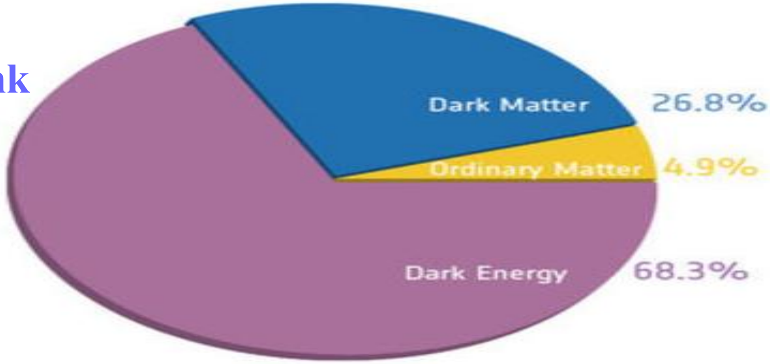
Bullet cluster



Structure formation as deduced from CMB



Data by Plank imply:



$\Omega_{DM} \approx 26.8\%$

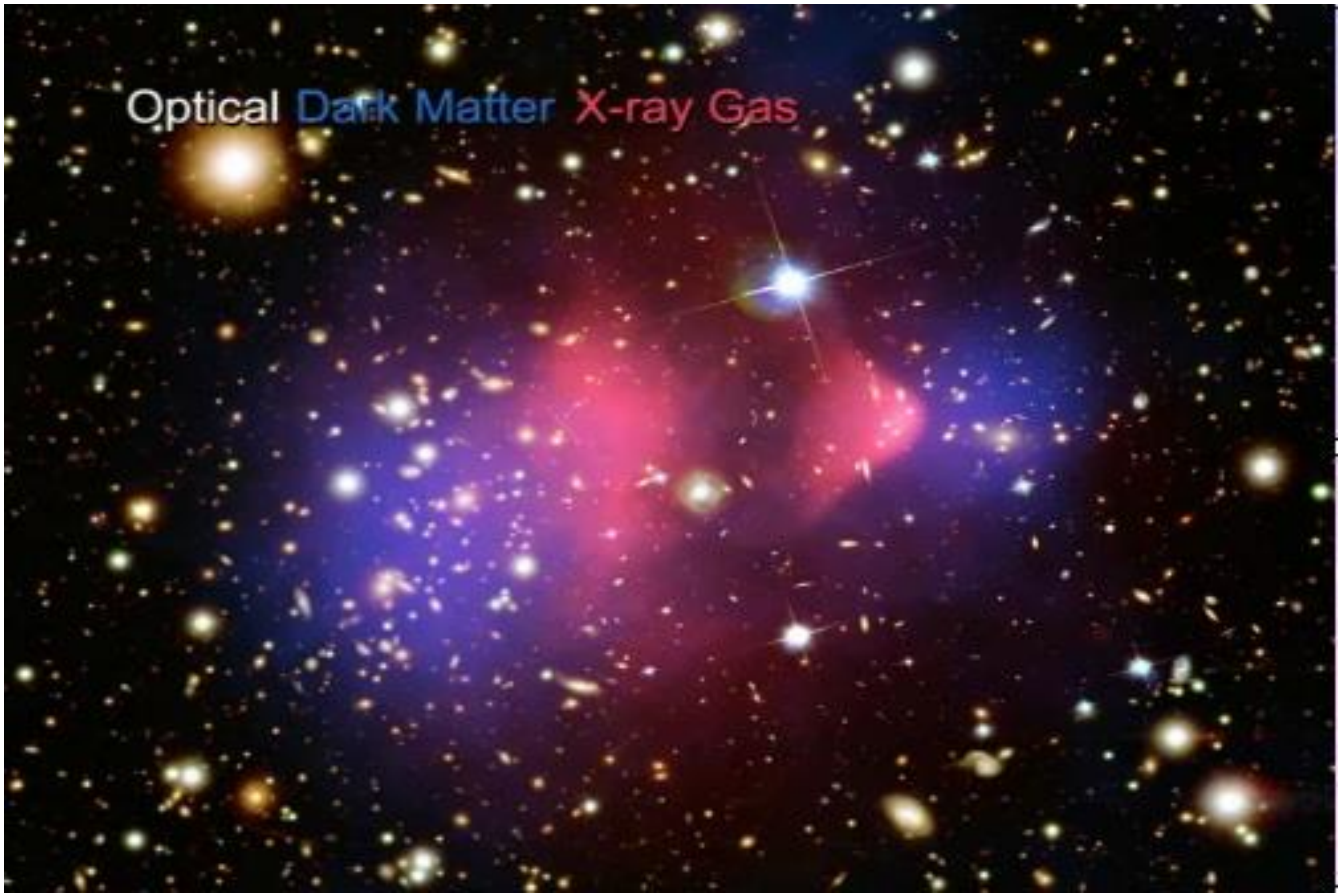
$\Omega_M \approx 4.9\%$

Dark Matter really exist ?

astro:ph/0608407

color image from the Magellan images of the merging cluster 1E0657−558

Chandra image of the cluster



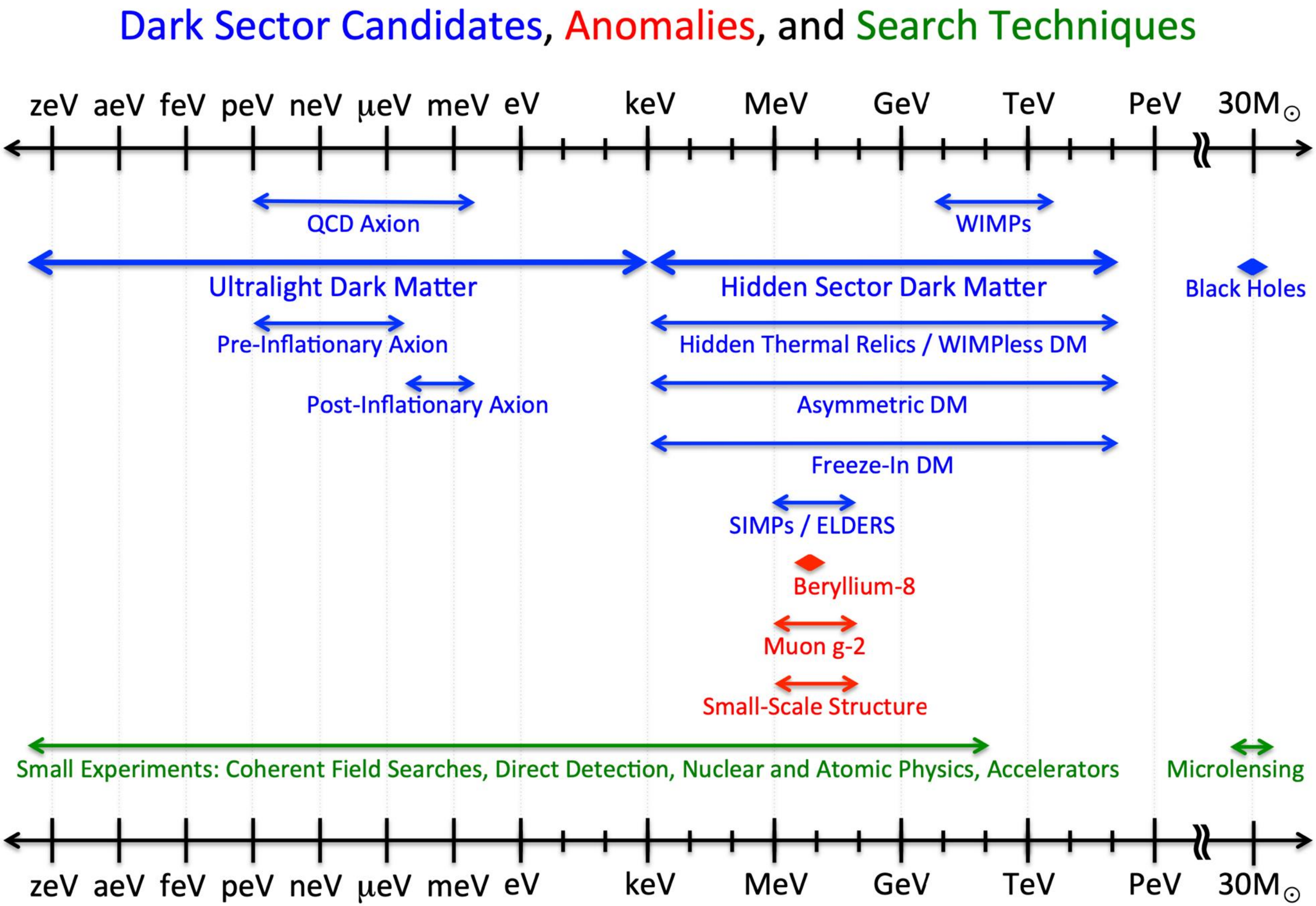
200 kpc

Due to the collision of two clusters, the dissipationless stellar component and the fluid-likeX-ray emitting plasma are spatially segregated

Dark Matter

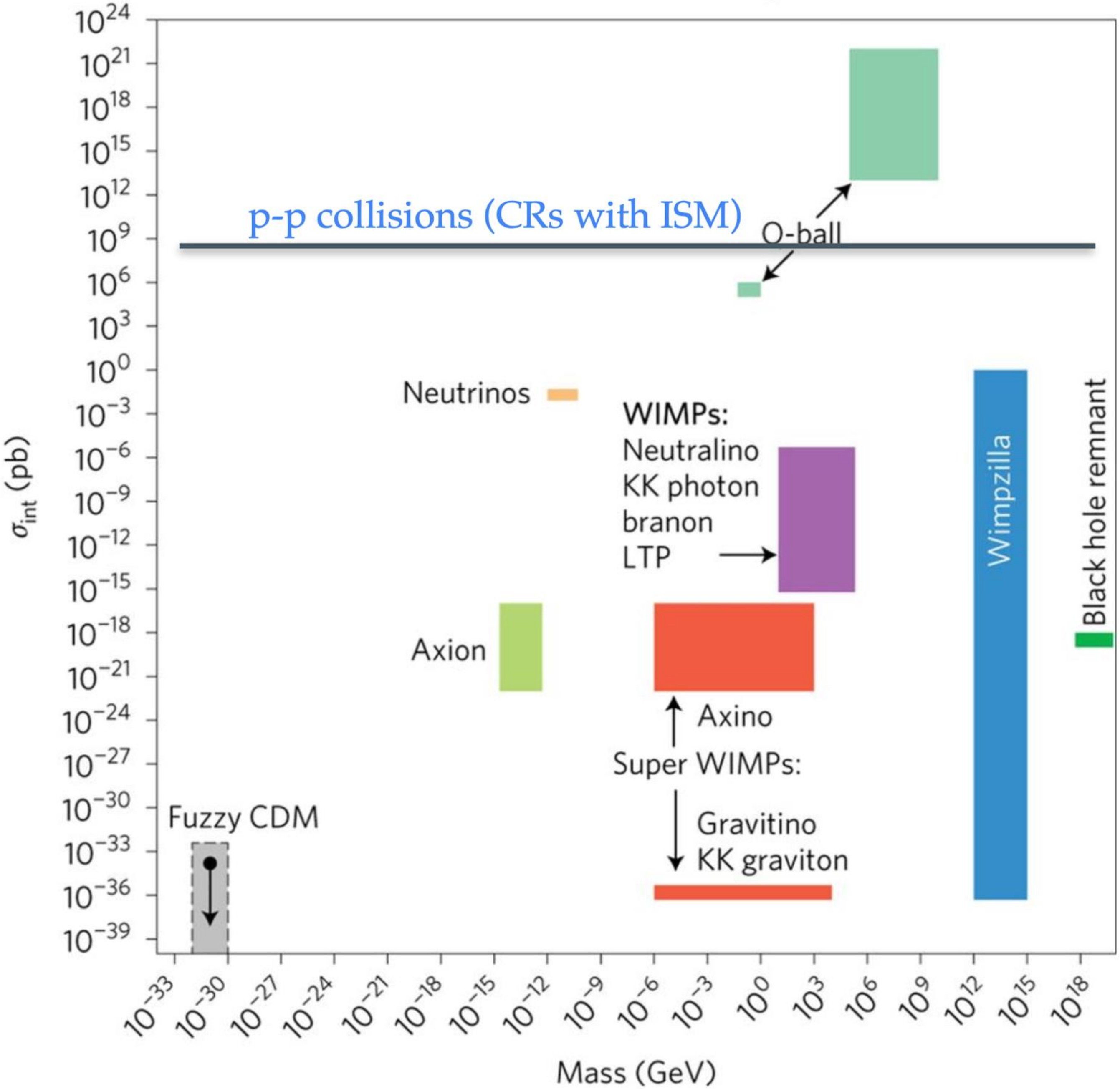
What is dark matter made of ?

Dark Sector Candidates, Anomalies, and Search Techniques



New Ideas in Dark Matter 2017 : Community Report arXiv:1707.04591

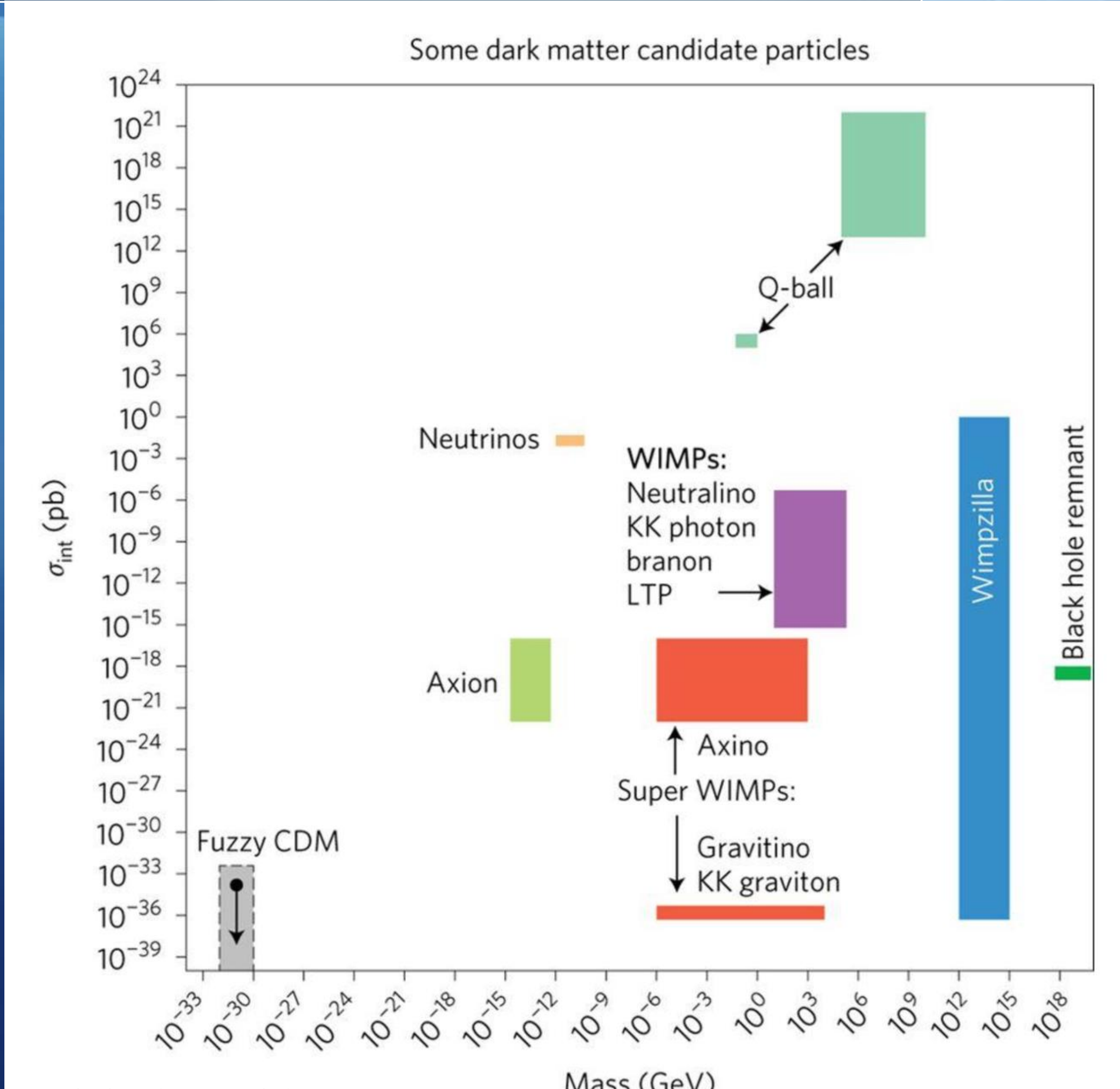
Some particle dark matter candidates




THEY ALL ASK "WHAT IS DARK MATTER?" AND "WHERE IS DARK MATTER?", BUT NOBODY ASKS "HOW IS DARK MATTER?"
TOM GAULD for NEW SCIENTIST

Dark Matter Candidates

- Kaluza-Klein DM in UED
- Kaluza-Klein DM in RS
- Axion
- Axino
- Gravitino
- Photino
- SM Neutrino
- Sterile Neutrino
- Sneutrino
- Light DM
- Little Higgs DM
- Wimpzillas
- Q-balls
- Mirror Matter
- Champs (charged DM)
- D-matter
- Cryptons
- Self-interacting
- Superweakly interacting
- Braneworld DM
- Heavy neutrino
- WIMP
- Messenger States in GMSB
- Branons
- Chaplygin Gas
- Split SUSY
- Primordial Black Holes



J. Conrad and O. Reimer Nature Physics 2017

Dark Matter Candidates

- Kaluza-Klein DM inUED
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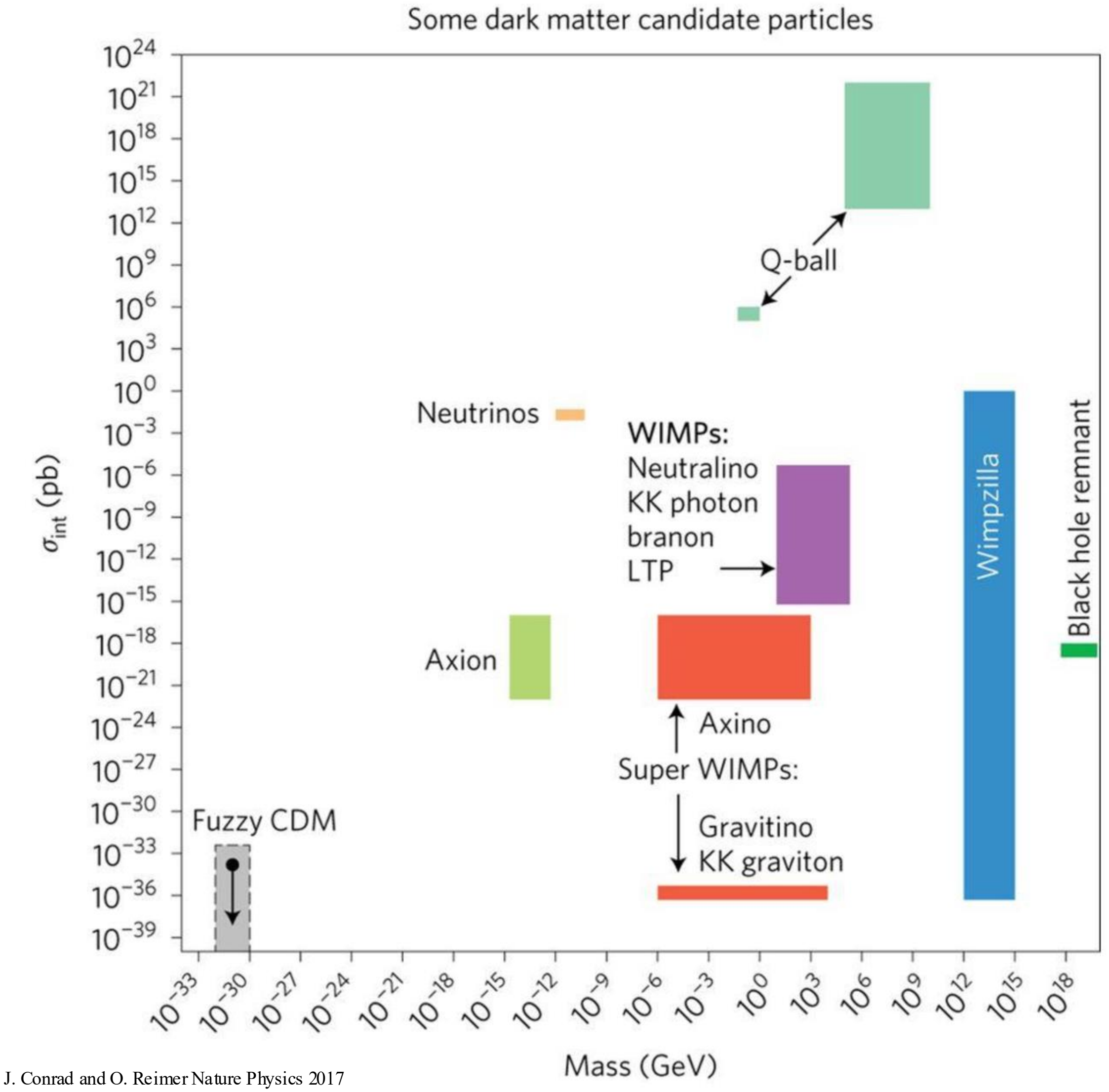


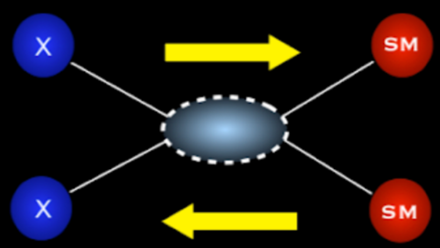
J. Conrad and O. Reimer Nature Physics 2017


THIS IS WHERE YOU LOST YOUR WALLET?
NO, I LOST IT IN THE PARK. BUT THIS IS WHERE THE LIGHT IS.

WIMPs

By far the most studied class of dark matter candidates.

The WIMP paradigm is based on a simple yet powerful idea:

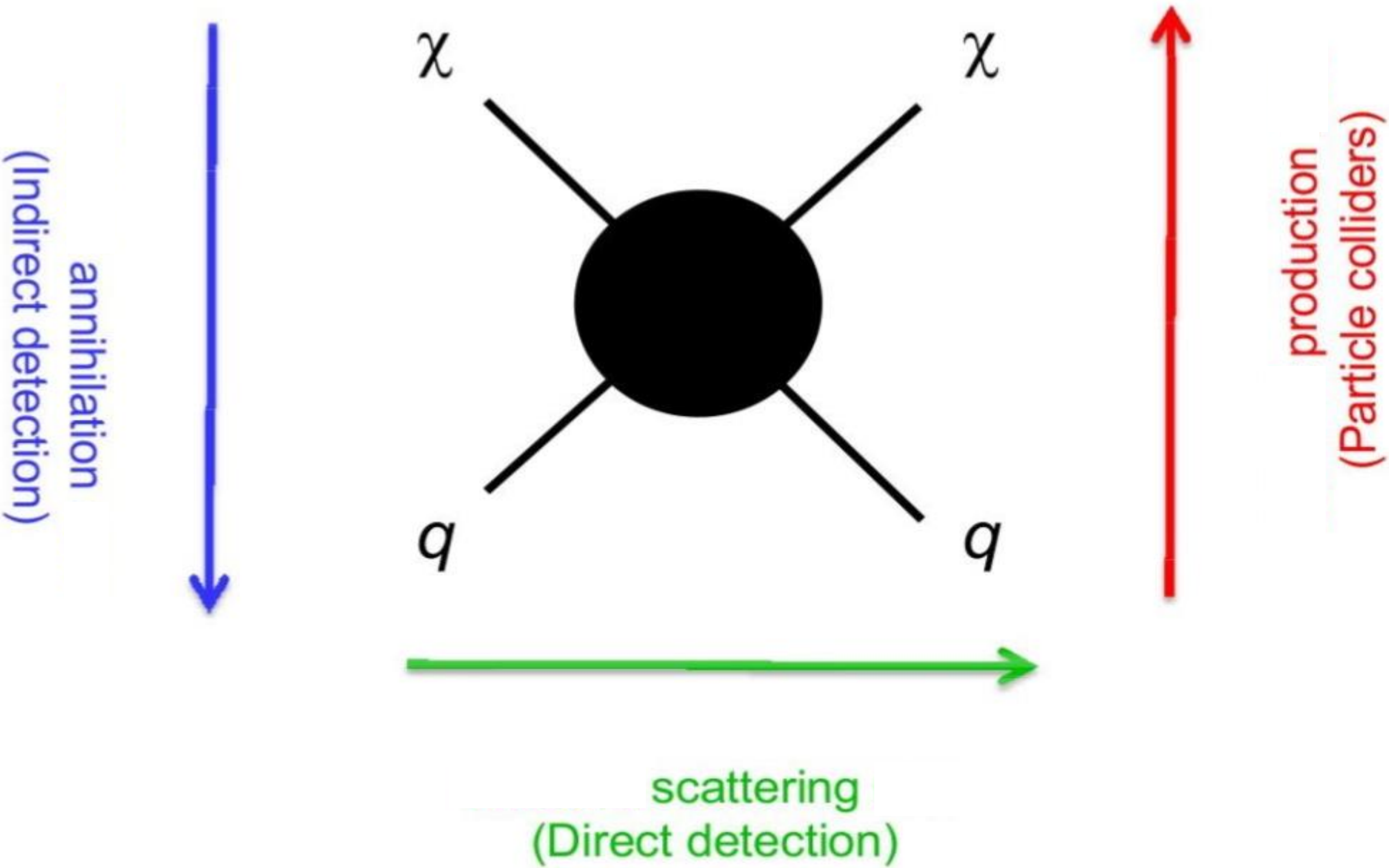


$$\frac{dn_\chi}{dt} - 3Hn_\chi = -\langle \sigma v \rangle \left[n_\chi^2 - (n_\chi^{eq})^2 \right]$$

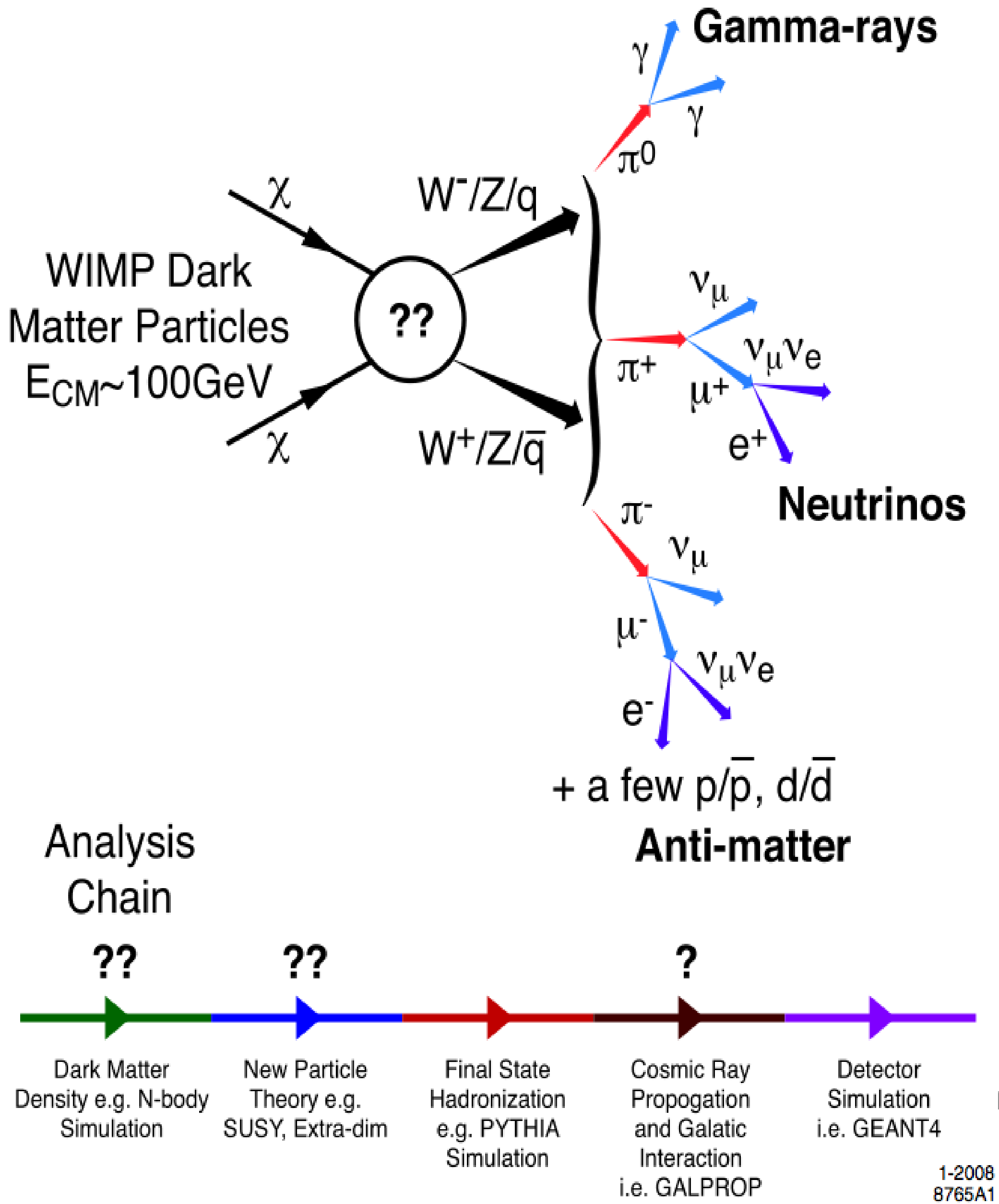
Weak-scale cross sections can reproduce observed relic density

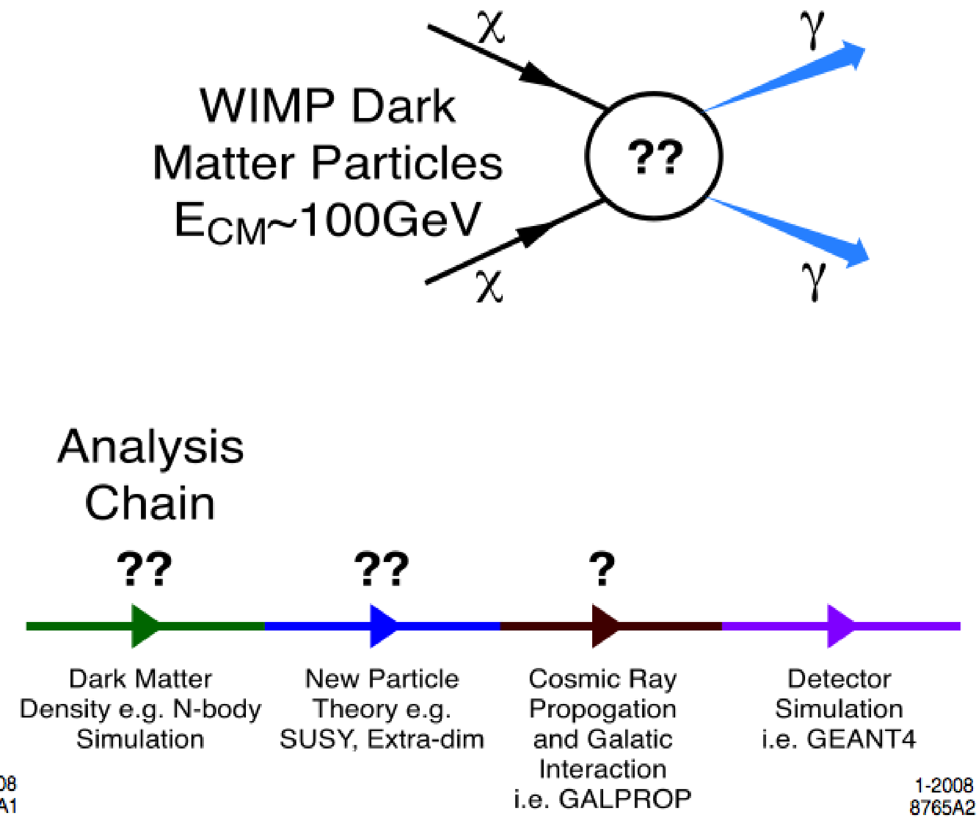
$$\Omega h^2 \approx \frac{3 \times 10^{-27} cm^3 s^{-1}}{< \sigma v >}$$

'WIMP miracle': new physics at ~1TeV solves at same time fundamental problems of particle physics (*hierarchy problem*) AND DM


χ
χ
q
q
annihilation
(Indirect detection)
production
(Particle colliders)
scattering
(Direct detection)

Annihilation channels





Signal rate from WIMP annihilation

gamma-ray flux from
WIMP annihilation

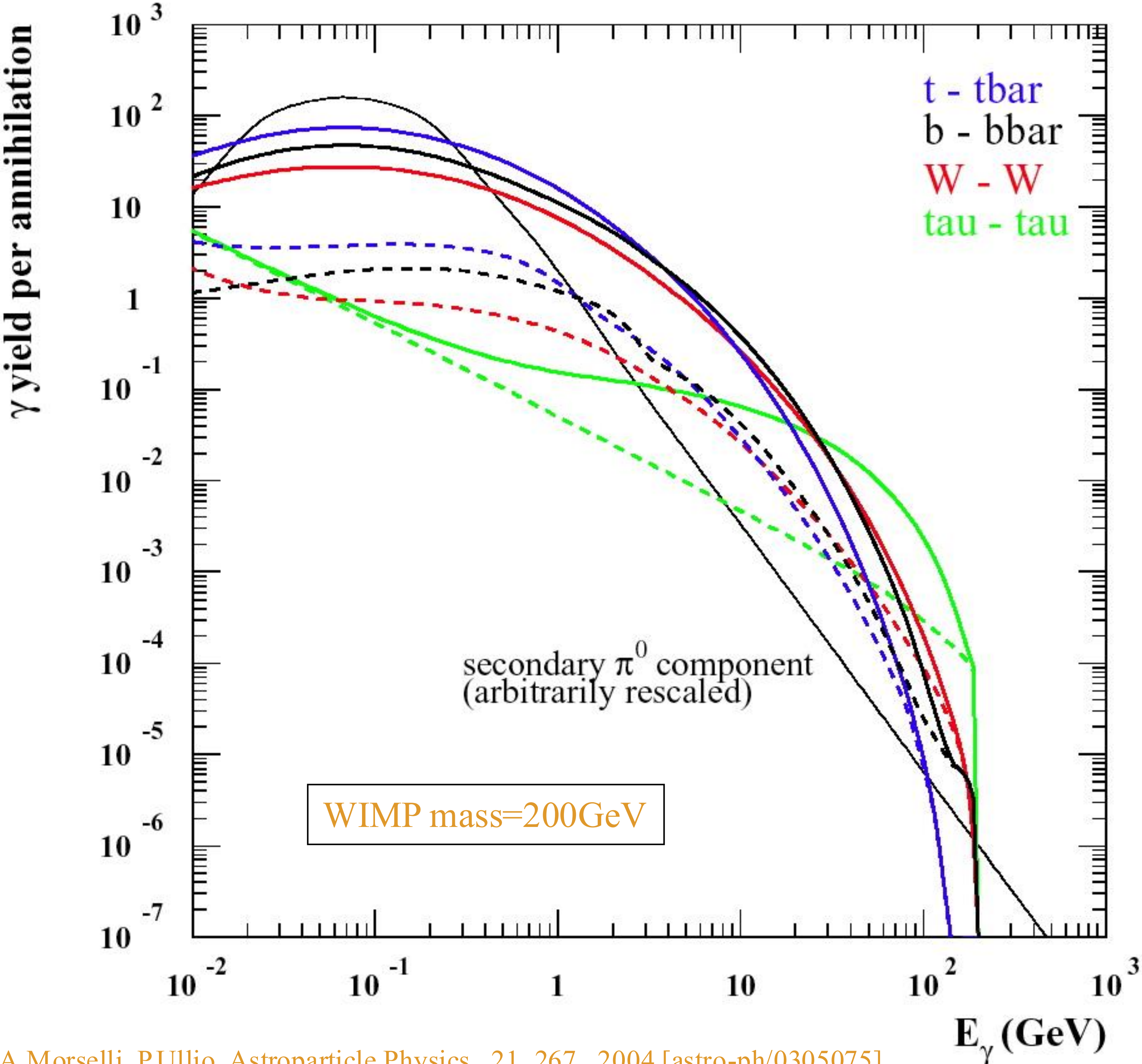
$$\phi(E,\Delta\Omega) \propto \left(\frac{\sigma v}{m_\chi^2}\right) \int_{l.o.s} \int_{\Delta\Omega} \rho^2(l)\, dl\, d\Omega)$$

governed by
particle physics
(supersymmetric
parameters .. etc)

J(φ):

governed by
halo distribution

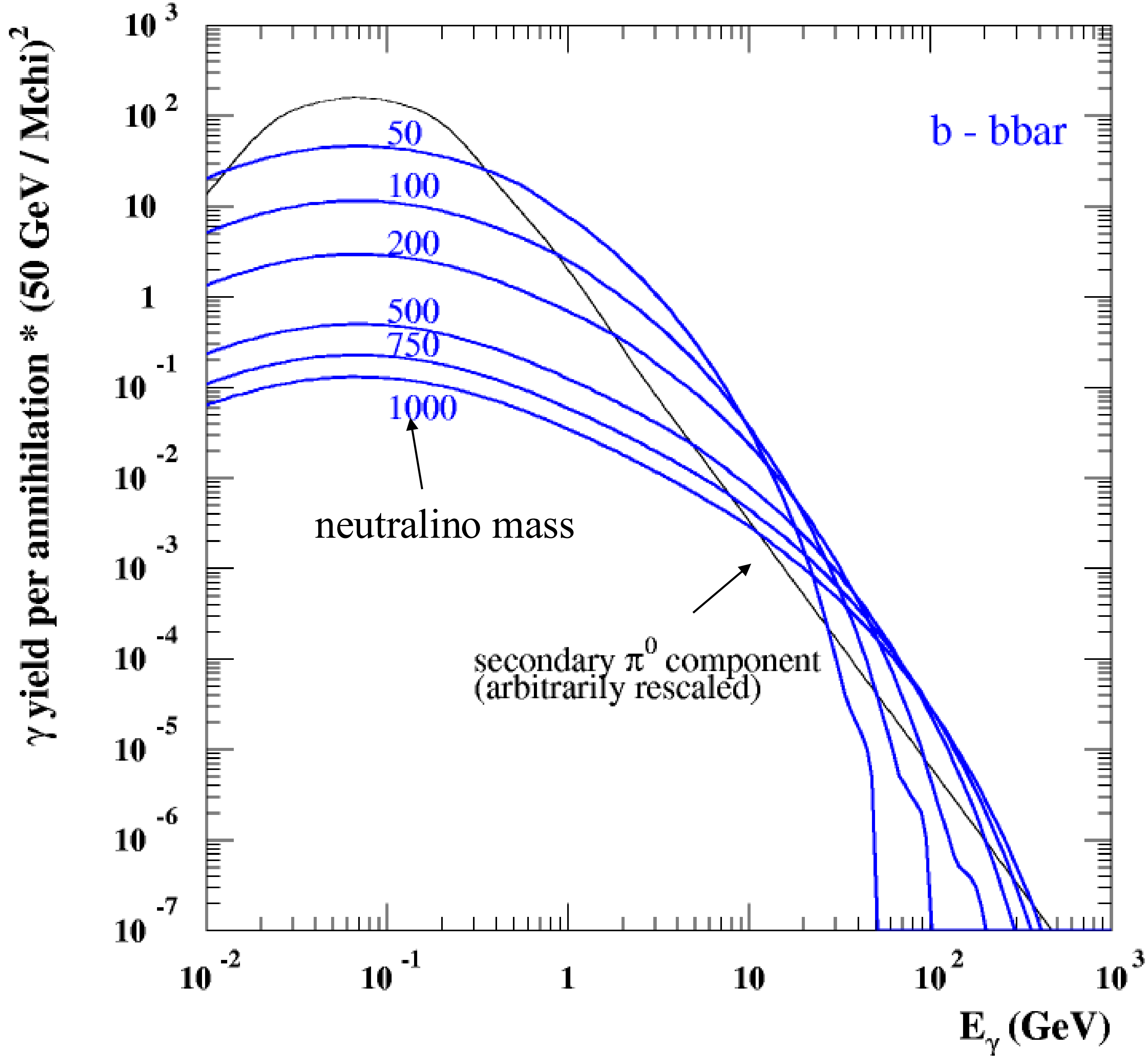
Differential yield for each annihilation channel



dashed lines are components not due to π^0 decay.

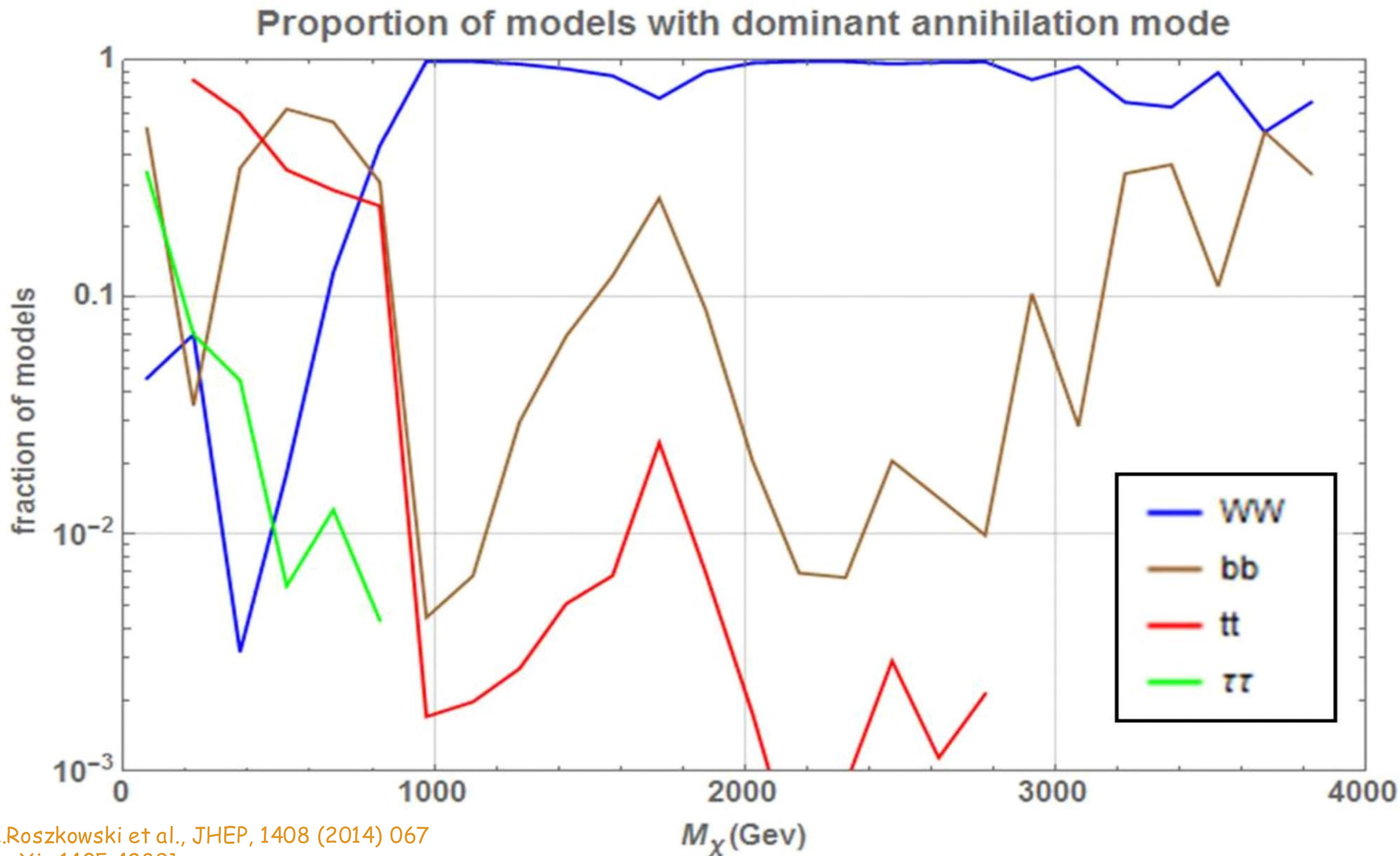
A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267, 2004 [astro-ph/0305075]

Differential yield for b bar



A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]

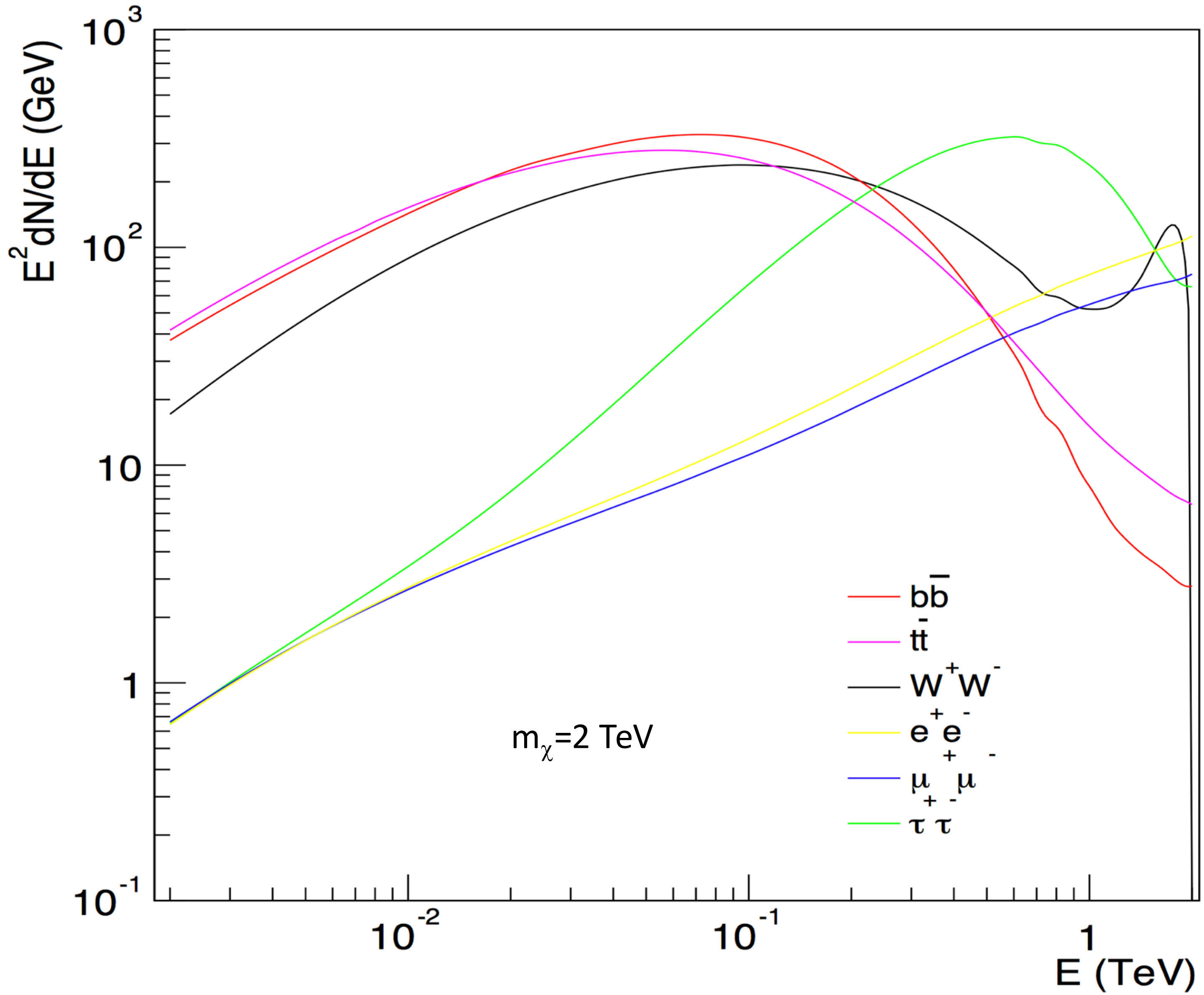
Which channel to choose?
Example: The dominant annihilation modes in the pMSSM scan



L.Roszkowski et al., JHEP, 1408 (2014) 067
[arXiv:1405.4289]

Annihilation spectra for the continuum signal from the quark, lepton and gauge boson primary channels

The line-like feature expected from the virtual internal Bremsstrahlung process contribution is particularly prominent for the W^+W^- channel



Dark Matter Search: Targets and Strategies

Satellites

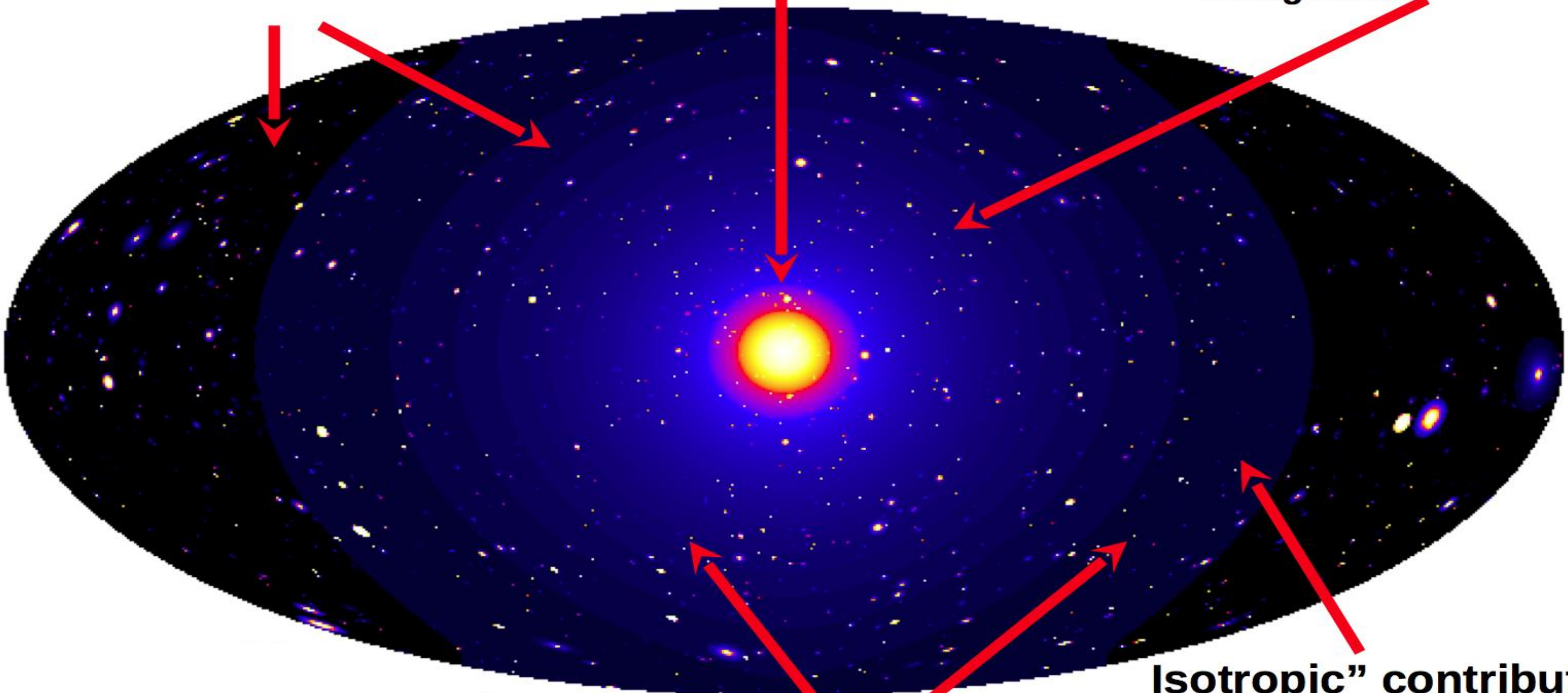
Low background and good source id, but low statistics

Galactic Center

Good Statistics, but source confusion/diffuse background

Milky Way Halo

Large statistics, but diffuse background



Isotropic" contributions

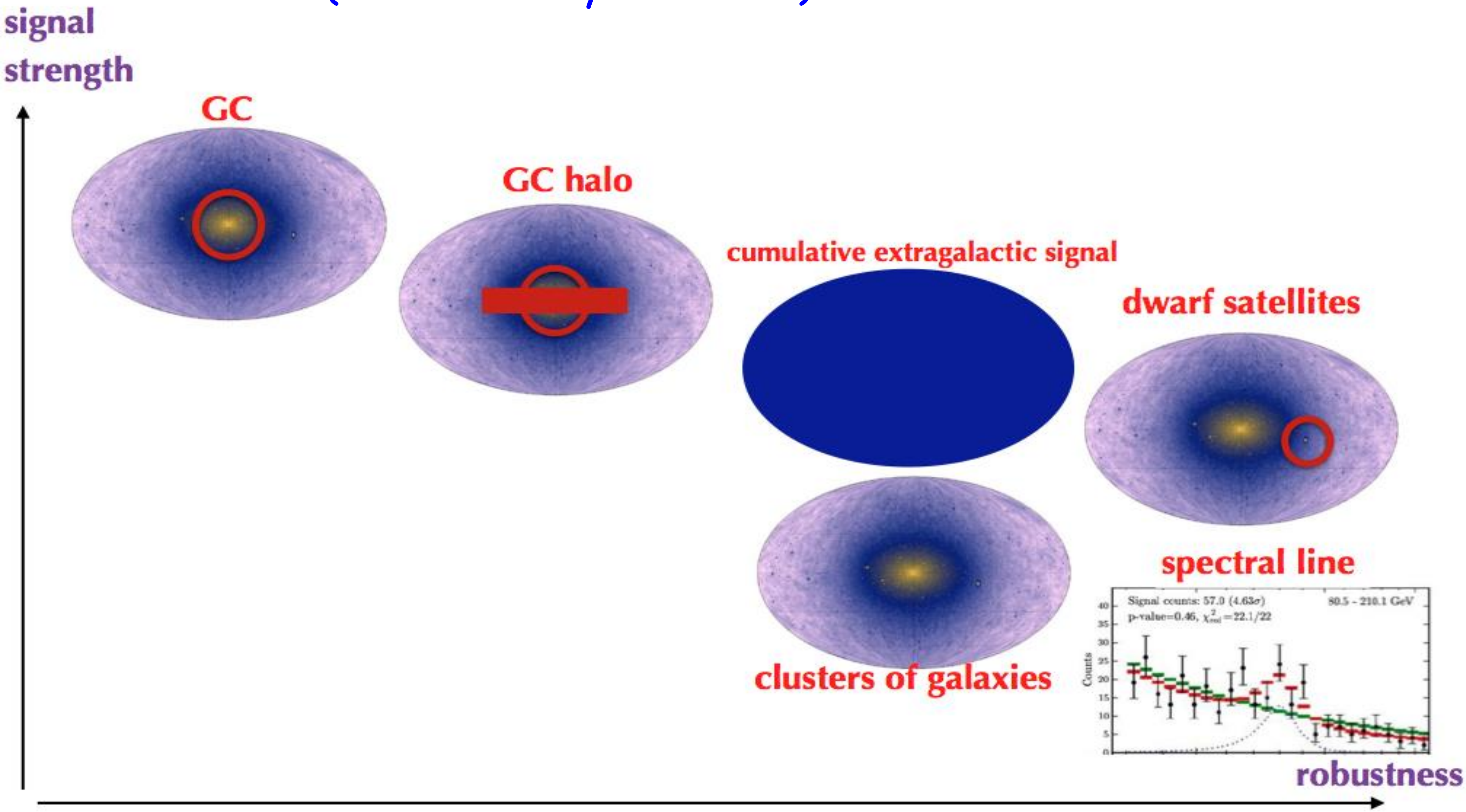
Large statistics, but astrophysics, galactic diffuse background

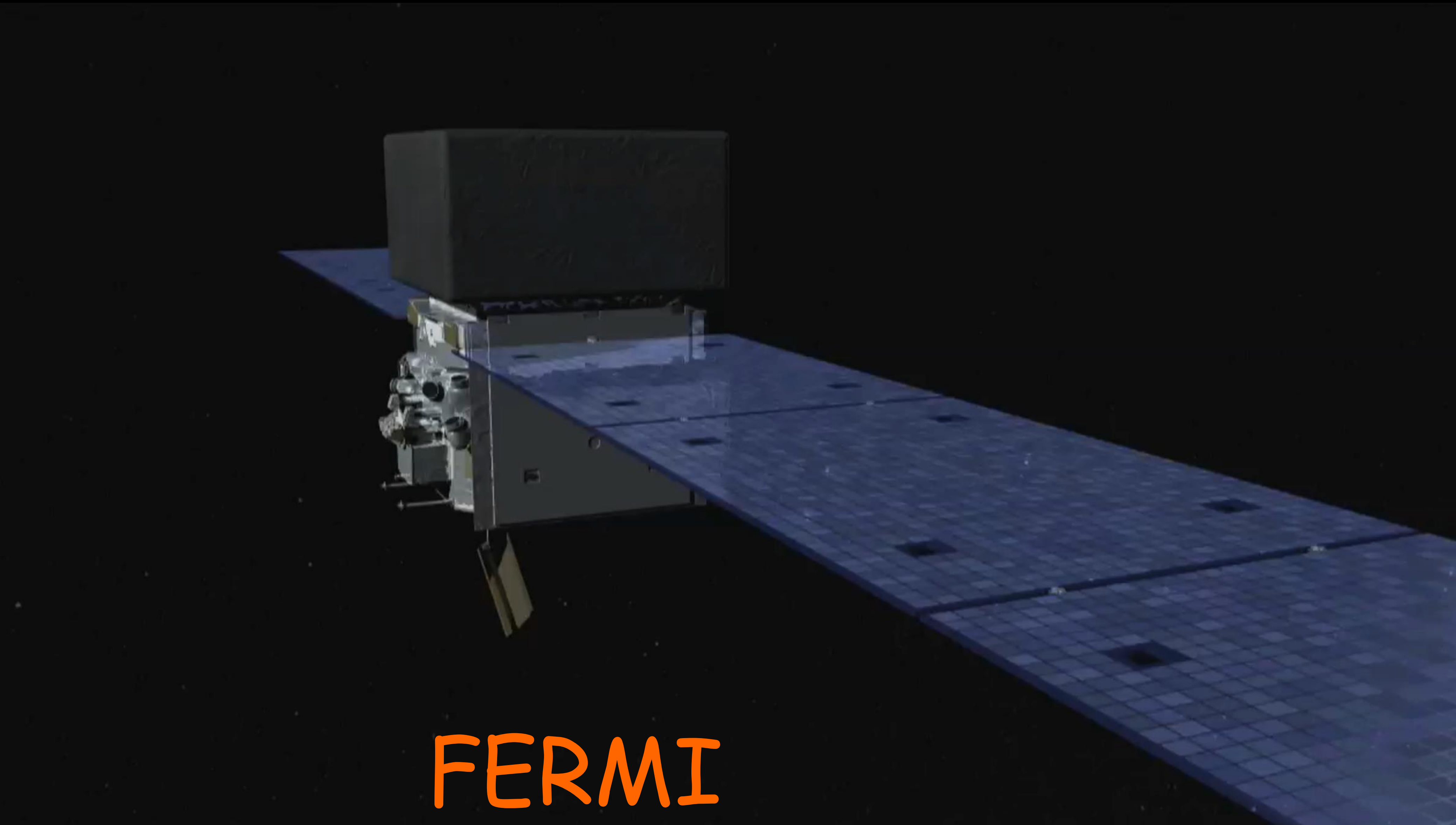
Galaxy Clusters

Low background, but low statistics

Dark Matter Search: Targets and Strategies

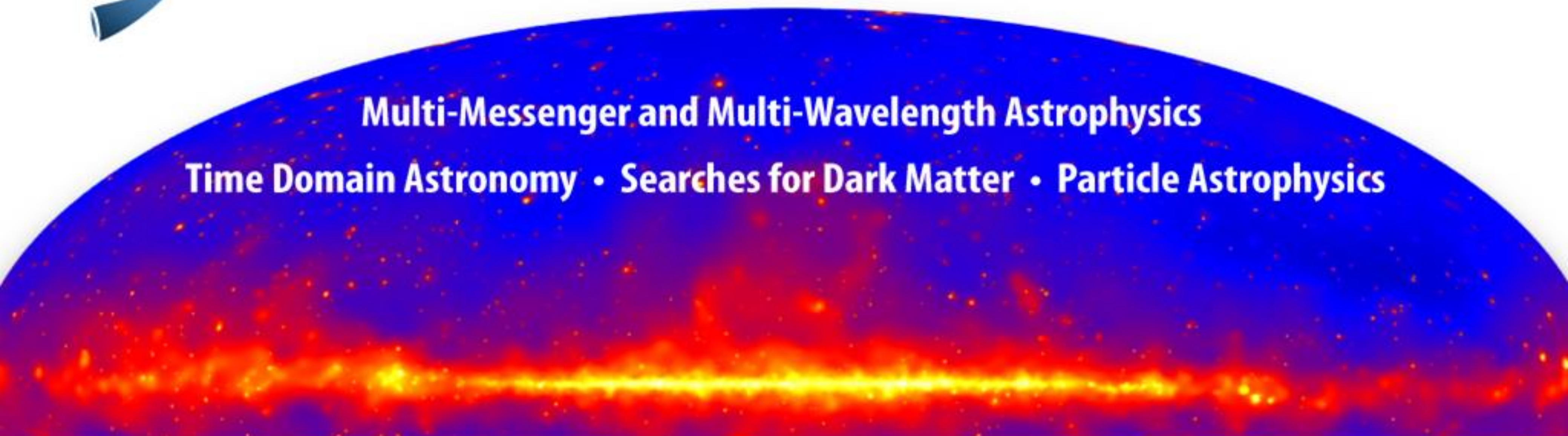
(Another way to see it)

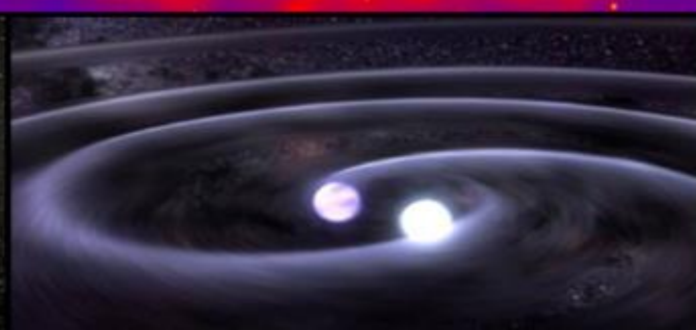


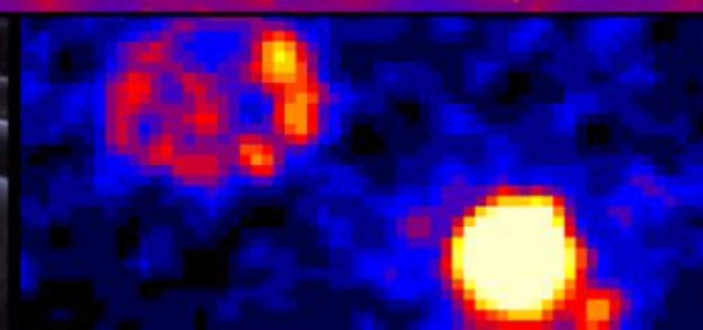


FERMI
Large Area Telescope

Fermi Gamma-Ray Space Telescope

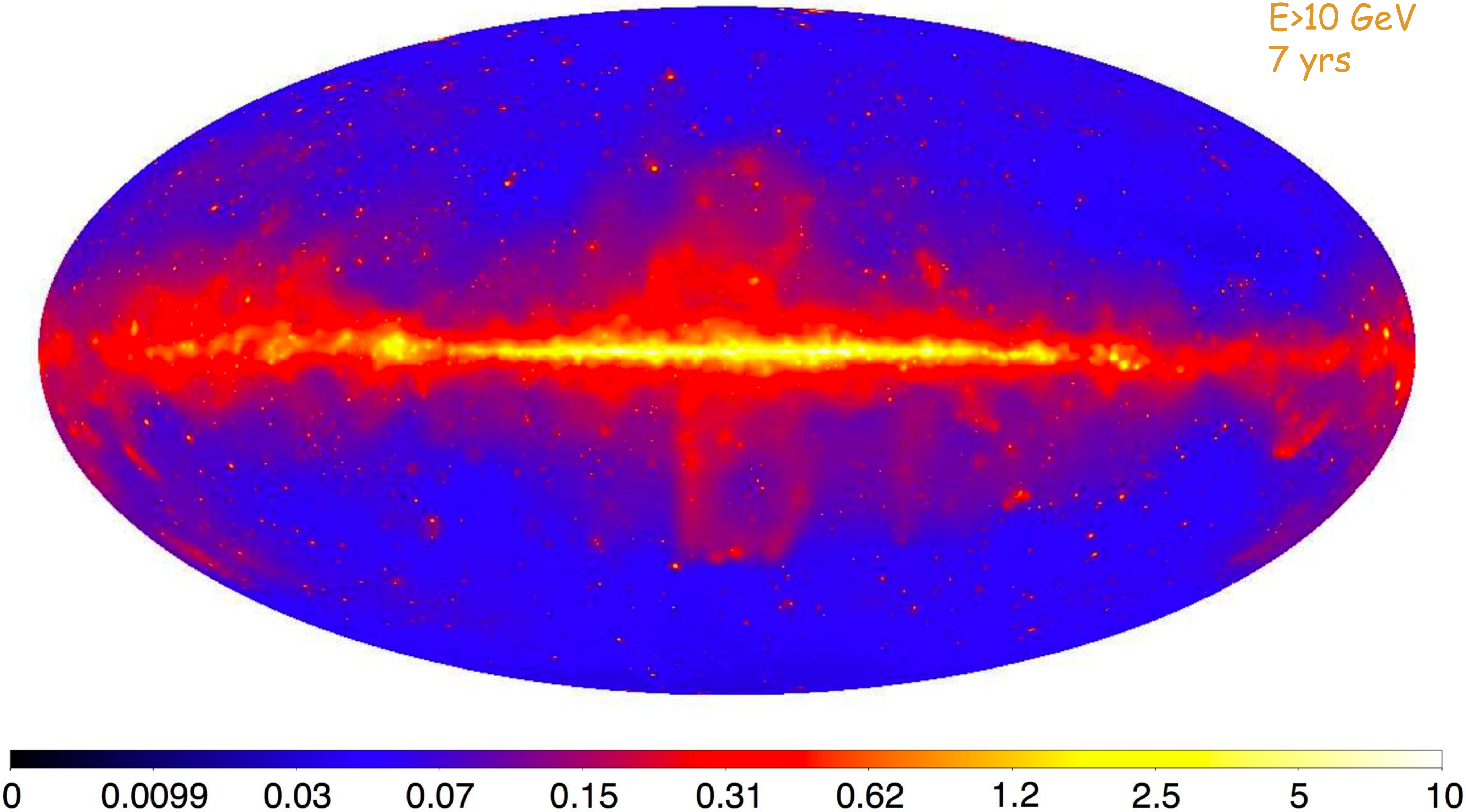






The sky in gamma-rays

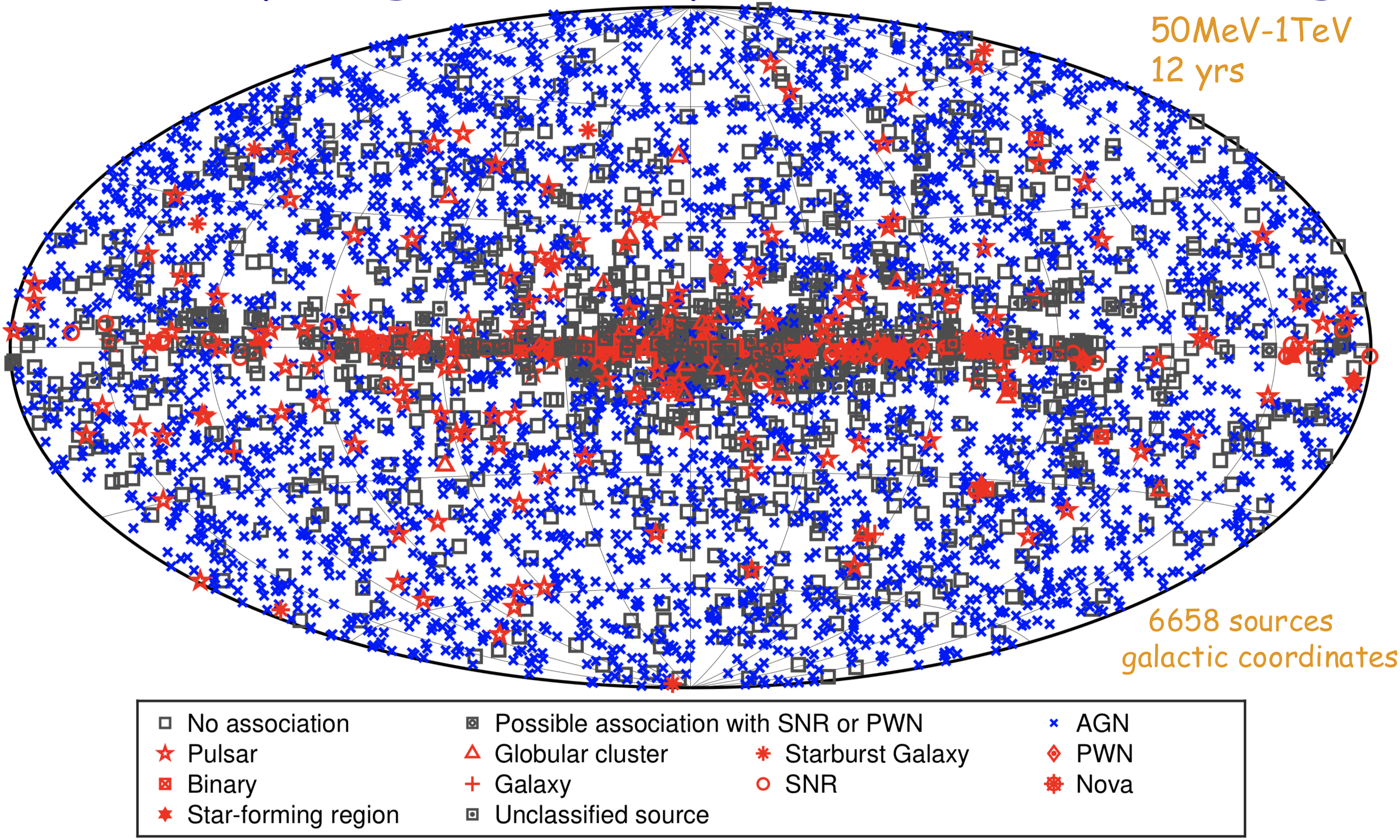
E>10 GeV
7 yrs



M.Ackermann et al. [Fermi Coll.] 3FHL: The Third Catalog of Hard Fermi-LAT Sources ApJS 2017 232 arXiv:1702.00664

Fermi
Gamma-ray
Space Telescope

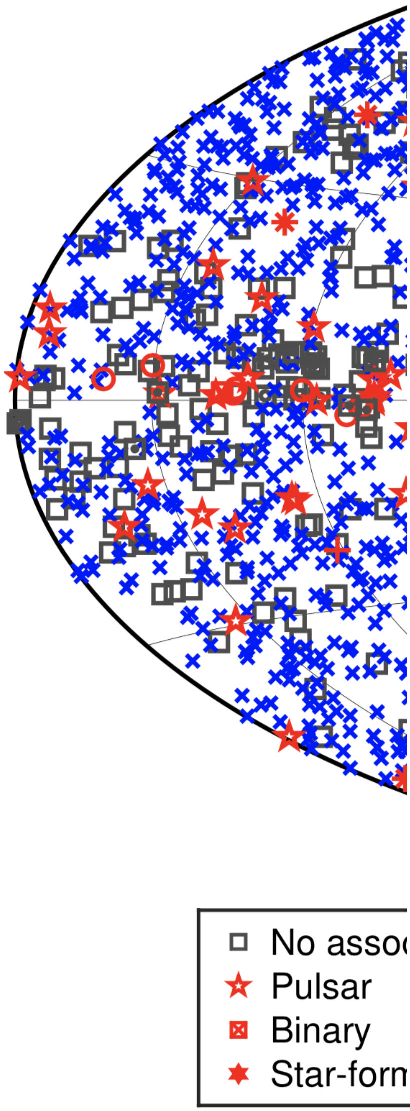
The sky in gamma-rays 4th source catalog



Incremental Fermi Fouth Source Catalog, ApJS 260, 53 (2022) arXiv: 2201.11184

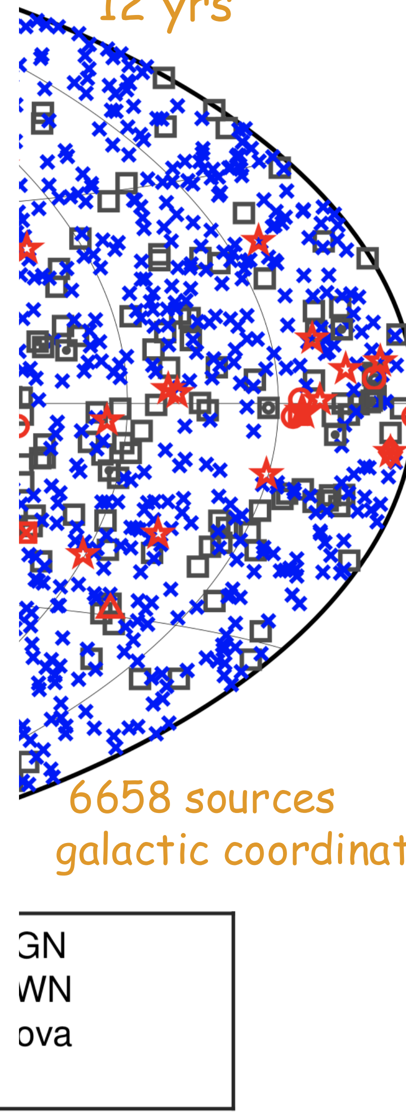
The sky in gamma-rays 4th source catalog

50MeV-1TeV
12 yrs



Description	Identified		Associated	
	Designator	Number	Designator	Number
Galactic center	GC	1	...	...
Young pulsars, identified by pulsations	PSR	135	...	...
Young pulsars, no pulsations seen in LAT yet	...	...	psr	2
Millisecond pulsars, identified by pulsations	MSP	120	...	...
Millisecond pulsars, no pulsations seen in LAT yet	...	...	msp	35
Pulsar wind nebula	PWN	11	pwn	8
Supernova remnant	SNR	24	snr	19
Supernova remnant / Pulsar wind nebula	SPP	0	spp	114
Globular cluster	GLC	0	glc	35
Star-forming region	SFR	3	sfr	2
High-mass binary	HMB	8	hmb	3
Low-mass binary	LMB	2	lmb	6
Binary	BIN	1	bin	6
Nova	NOV	4	nov	0
BL Lac type of blazar	BLL	22	bll	1435
FSRQ type of blazar	FSRQ	44	fsrq	750
Radio galaxy	RDG	6	rdg	39
Nonblazar active galaxy	AGN	1	agn	8
Steep spectrum radio quasar	SSRQ	0	ssrq	2
Compact steep spectrum radio source	CSS	0	css	5
Blazar candidate of uncertain type	BCU	1	bcu	1491
Narrow-line Seyfert 1	NLSY1	4	nlsy1	4
Seyfert galaxy	SEY	0	sey	2
Starburst galaxy	SBG	0	sbg	8
Normal galaxy (or part)	GAL	2	gal	4
Unknown	UNK	0	unk	134
Total	...	389	...	4112
Unassociated	...	...	...	2157

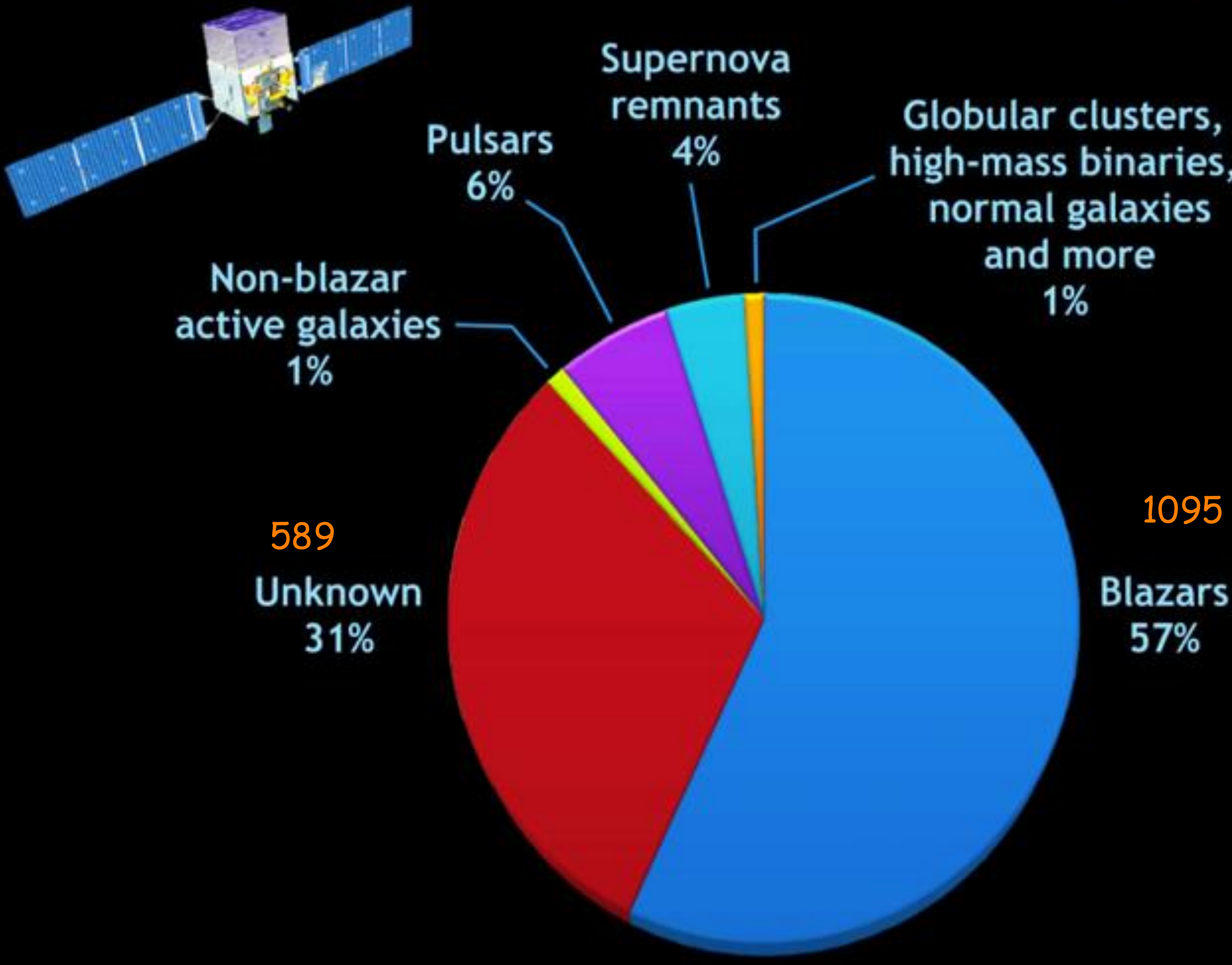
NOTE—The designation 'spp' indicates potential association with SNR or PWN. 'Unknown' are $|b| < 10°$ sources solely associated with the likelihood-ratio method from large radio and X-ray surveys. Designations shown in capital letters are firm identifications; lower-case letters indicate associations.



6658 sources
galactic coordinates

Incremental Fermi Fouth Source Catalog, ApJS 260, 53 (2022) arXiv: 2201.11184

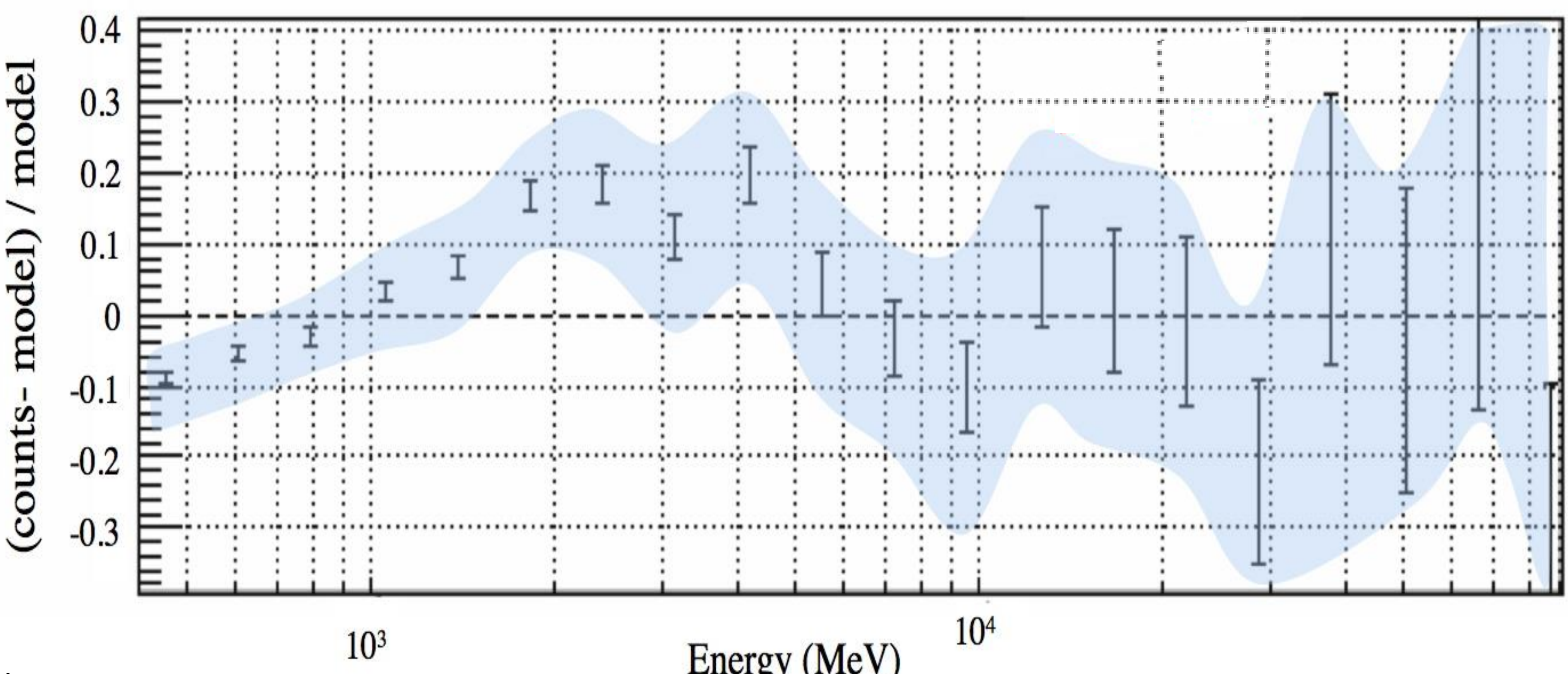
What has Fermi found: The LAT two-year catalog



The GeV excess 7° x7° region centered on the Galactic Center

11 months of data, E >400 MeV, front-converting events analyzed with binned likelihood analysis)

- The systematic uncertainty of the effective area (blue area) of the LAT is ~10% at 100 MeV, decreasing to 5% at 560 MeV and increasing to 20% at 10 GeV



V.Vitale, A.Morselli, Fermi Coll. 2009 arXiv:0912.3828 Fermi Symposium eConf Proceedings C091122

the GALACTIC CENTER : any hints of Dark Matter?

the beginning of the history :

The Galactic Center as a Dark Matter Gamma-Ray Source
A.Morselli, A. Lionetto, A. Cesarini, F. Fucito, P. Ullio, Nuclear Physics B 113B (2002) 213-220 [astro-ph/0211327]
A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio Astroparticle Physics 21, 267-285, 2004 [astro-ph/0305075]

Possible Evidence For Dark Matter Annihilation In The Inner Milky Way From The Fermi Gamma Ray Space Telescope
Lisa Goodenough, Dan Hooper arXiv:0910.2998

Indirect Search for Dark Matter from the center of the Milky Way with the Fermi-Large Area Telescope
Vincenzo Vitale, Aldo Morselli, the Fermi/LAT Collaboration
Proceedings of the 2009 Fermi Symposium, 2-5 November 2009, eConf Proceedings C091122 **arXiv:0912.3828** **21 Dec 2009**

Search for Dark Matter with Fermi Large Area Telescope: the Galactic Center
V.Vitale, A.Morselli, the Fermi-LAT Collaboration NIM A 630 (2011) 147–150 (Available online 23 June 2010)

Dark Matter Annihilation in The Galactic Center As Seen by the Fermi Gamma Ray Space Telescope
Dan Hooper, Lisa Goodenough. (21 March 2011). 21 pp. **Phys.Lett. B697 (2011) 412-428**
....

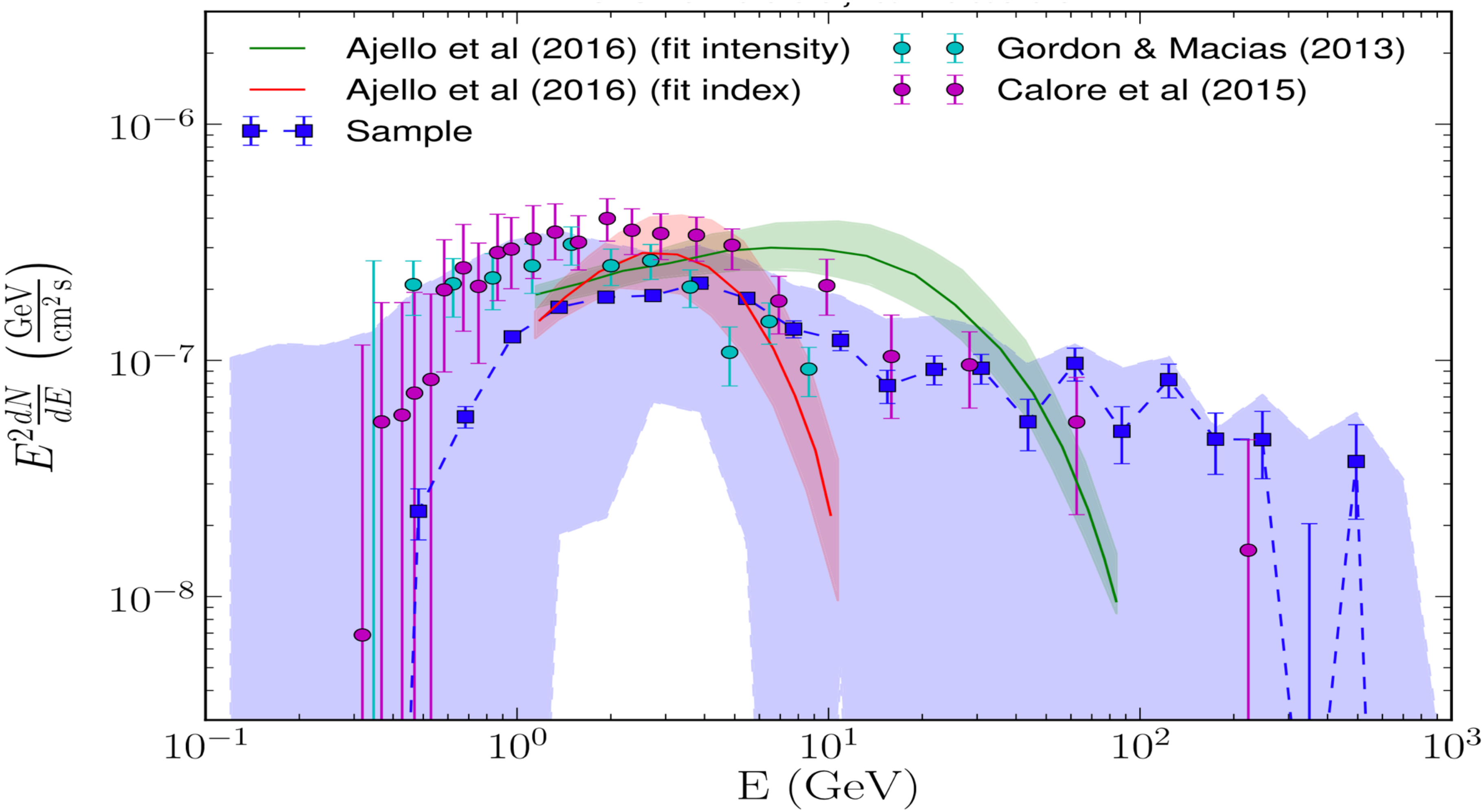
Background model systematics for the Fermi GeV excess
F.Calore, I. Cholis, C. Weniger JCAP03(2015)038 **arXiv:1409.0042v1**

Fermi–LAT observations of high-energy γ-ray emission toward the galactic centre
M. Ajello et al.[Fermi-LAT Coll.] **Apj 819:44 2016 arXiv:1511.02938**

The Fermi galactic center GeV excess and implications for dark matter
M. Ajello et al.[Fermi-LAT Coll.] **Apj 819:44 2016 arXiv:1511.02938**

Revisiting the Gamma-Ray Galactic Center Excess with Multi-Messenger Observations
IC, Zhong, McDermott, Surdutovich, PRD 105, 103023 (2022)

The GeV excess (Pass8 analysis)



following uncertainties have relatively small effect on the excess spectrum

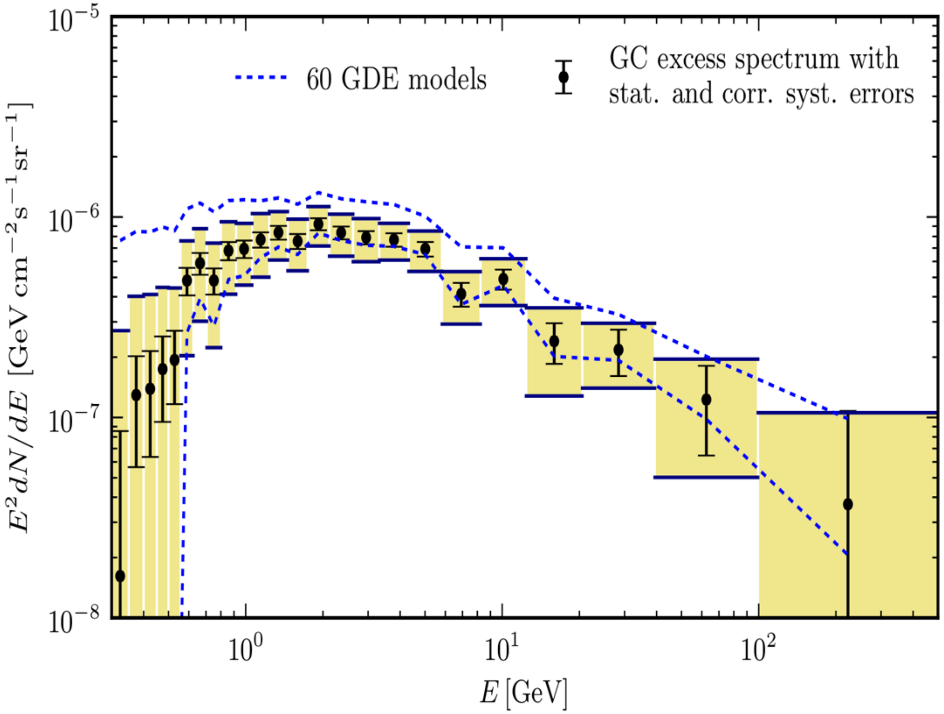
– Variation of GALPROP models – Distribution of gas along the line of sight

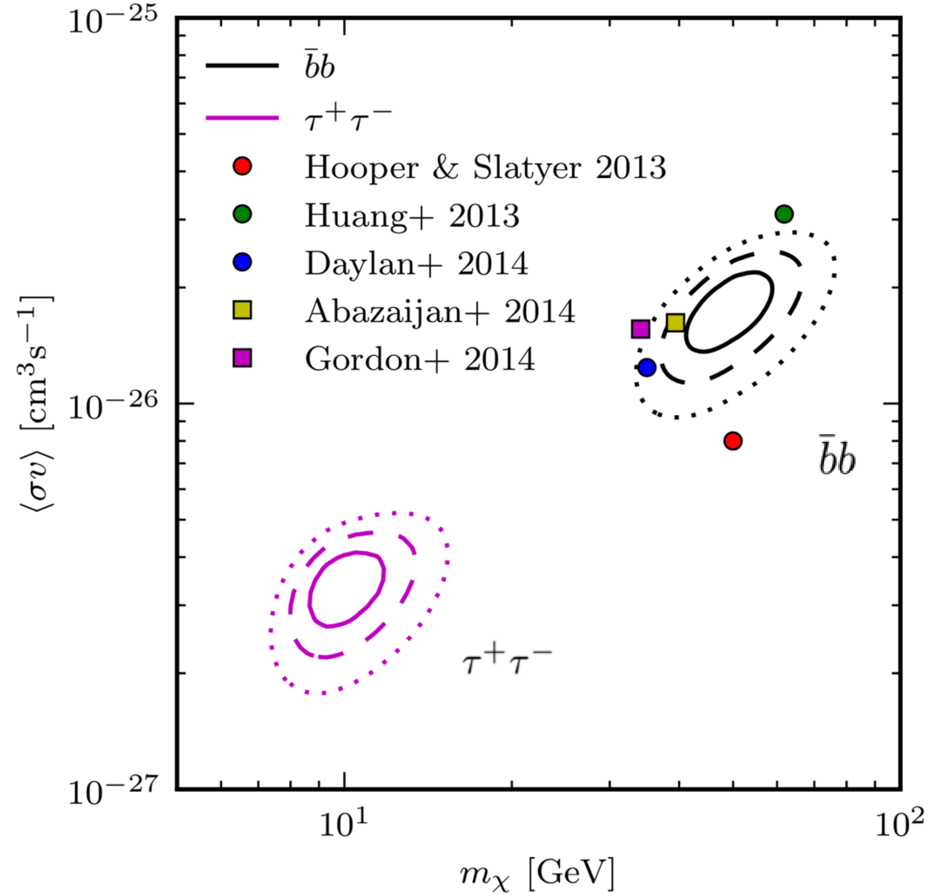
- **Most significant sources of uncertainty are:**

– Fermi bubbles morphology at low latitude – Sources of CR electrons near the GC

Fermi-LAT Collaboration Apj 840:43 2017 May 1 arXiv:1704.03910

The GeV excess





A lot of activity outside the Fermi collaboration with claims of evidence for dark matter in the Galactic Center

Calore et al., arXiv:1409.0042
Cholis et al., Phys. Rev. D 105, 103023 (2022) arXiv:2112.09706

The GeV excess : Other explanations exist

• past activity of the Galactic center

(e.g. Petrovic et al., arXiv:1405.7928, Carlson & Profumo arXiv:1405.7685)

• Series of Leptonic Cosmic-Ray Outbursts

Cholis et al. arXiv:1506.05119

• Stellar population of the X-bulge and the nuclear bulge

Macias et al. arXiv:1611.06644

• Population of pulsars in the Galactic bulge

e.g. , Yuan and Zhang arXiv:1404.2318v1, Lee et al. arXiv:1506.05124, Bartels et.al. 1506.05104

M.Ajello et al. [Fermi-LAT Coll.] Phys. Rev. D 95, 082007 (2017) [arXiv:1704.07195]

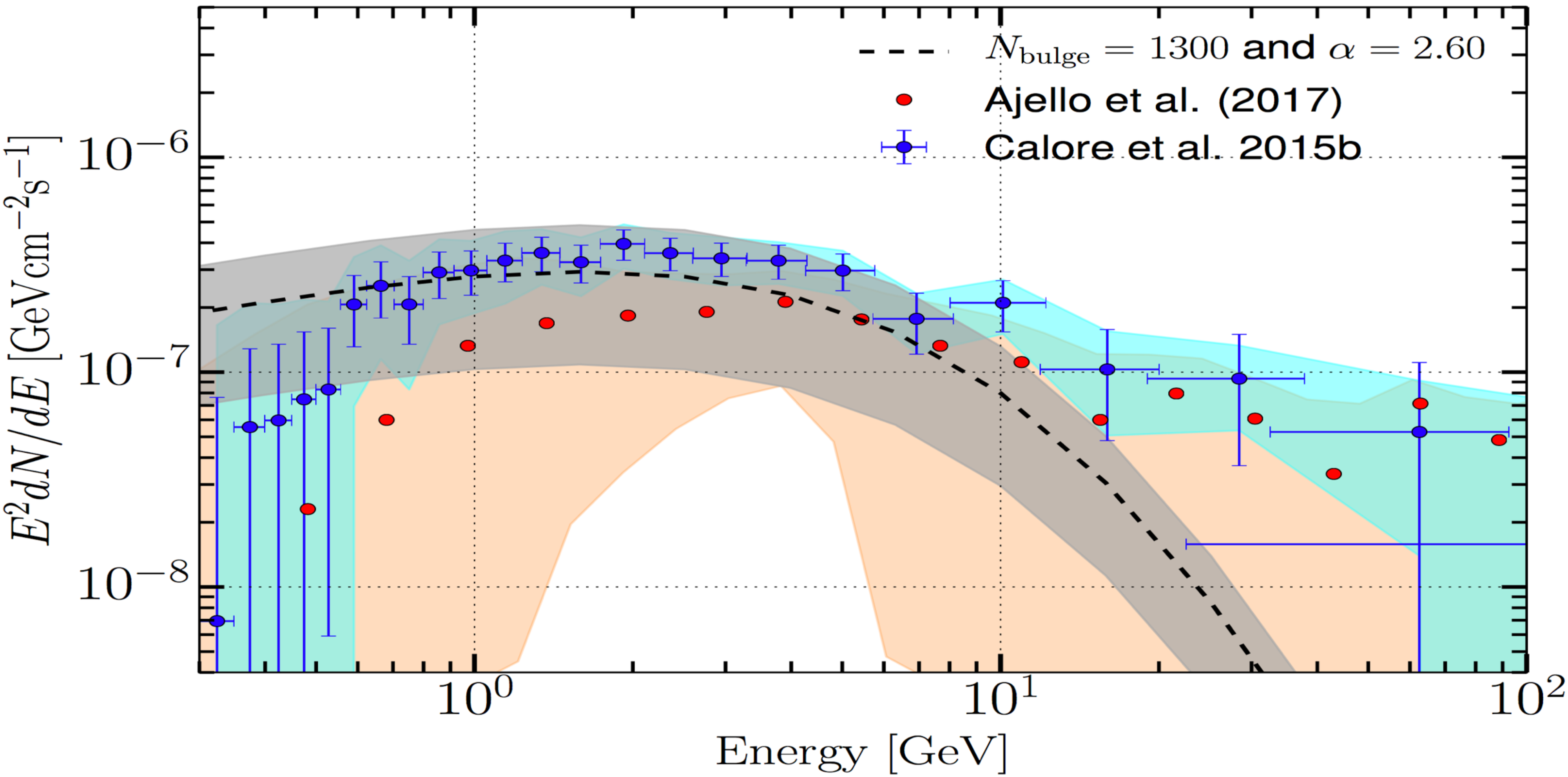
……………

• Robustness of the Galactic Center Excess

leading explanations being annihilating dark matter or an unresolved population of millisecond pulsars Zhong & Cholis arXiv:2401.02481

How to discriminate between different hypothesis ?

Population of pulsars in the Galactic bulge and the GeV excess



the Galactic bulge must include 800-3600 pulsars (most of them unresolved) in order to explain the GC excess

M.Ajello et al. [Fermi-LAT Coll.] Apj sub. [arXiv:1705.00009v2]

How to discriminate between different hypothesis ?

eROSITA

- Modeling of the Fermi bubbles
- Look for correlated features near the Galactic center

HESS, MAGIC, CTA

- Fermi bubbles near the GC are much brighter
- Possible to see with Cherenkov telescopes?

Radio observations, MeerKAT, SKA

- Search for individual pulsars in the halo around the GC

Radio surveys, Planck

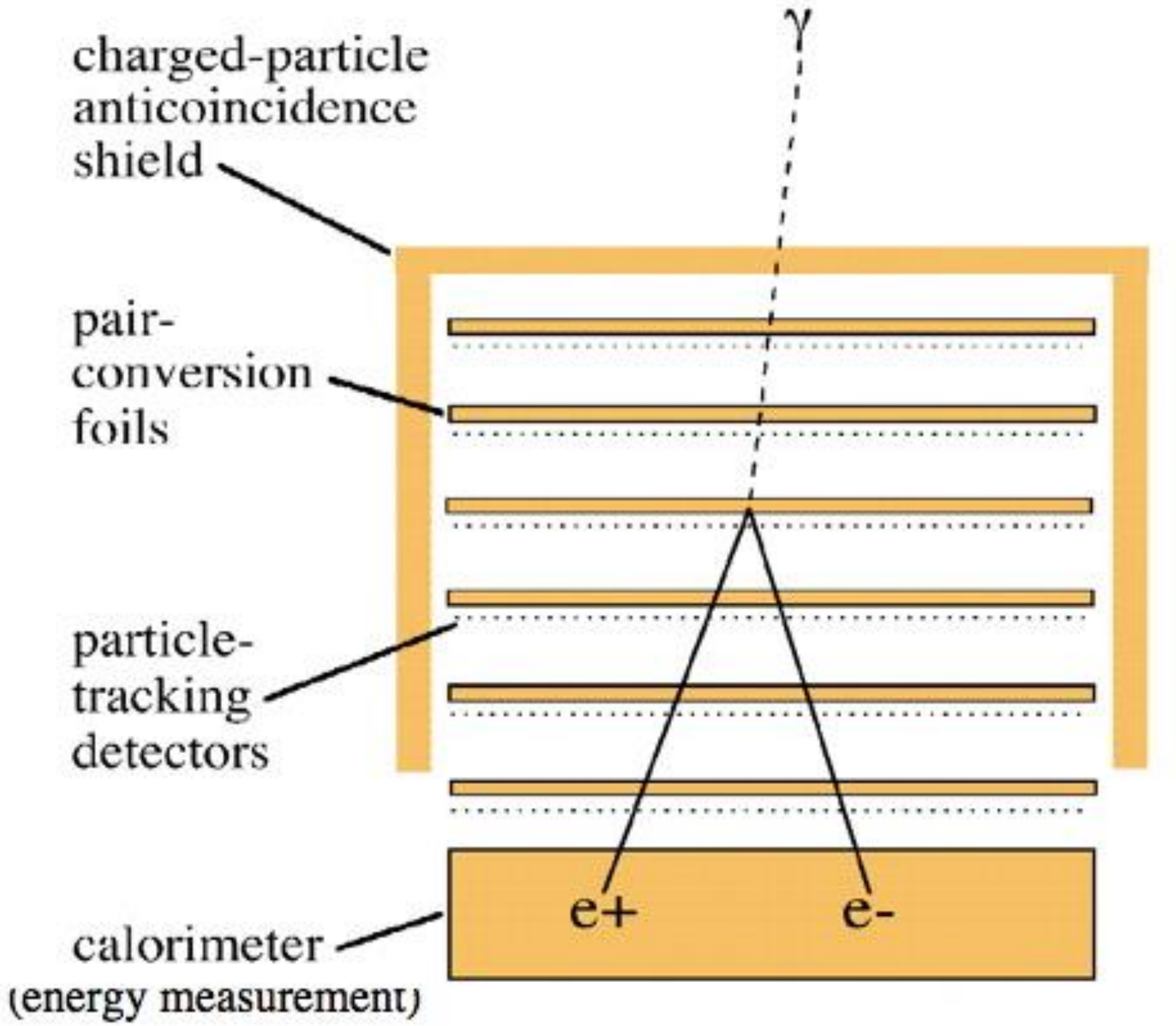
- Look for correlated synchrotron emission near the GC

More Fermi LAT analysis

- Diffuse emission modeling
- Analysis of point sources near the GC

But ultimately We need a new experiment with better angular resolution below 100 MeV

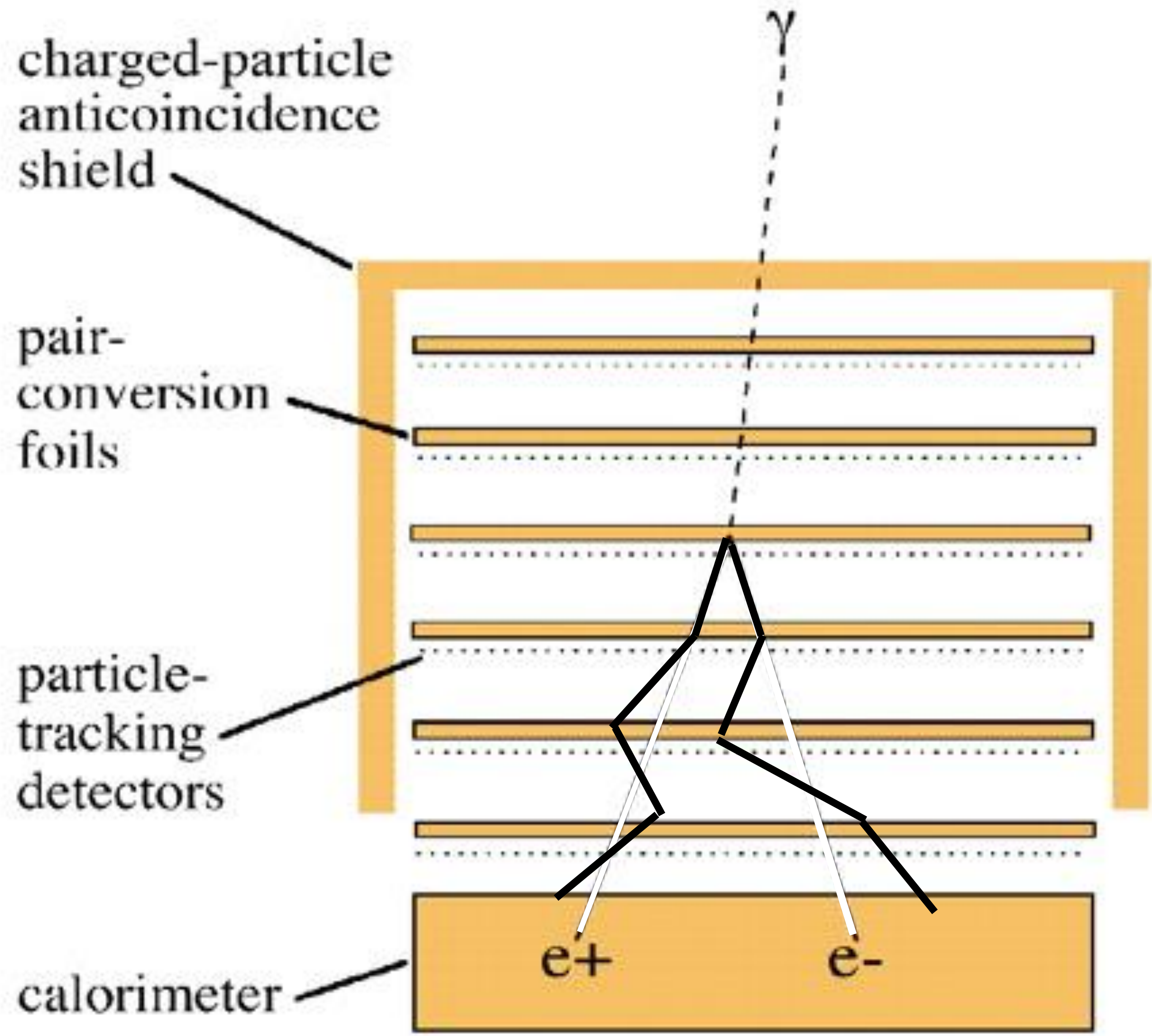
Elements of a pair-conversion telescope



- photons materialize into matter-antimatter pairs:
  E_γ --> $m_{e^+}c^2 + m_{e^-}c^2$
- electron and positron carry information about the direction, energy and polarization of the γ-ray

Elements of a pair-conversion telescope

(more realistic scheme)

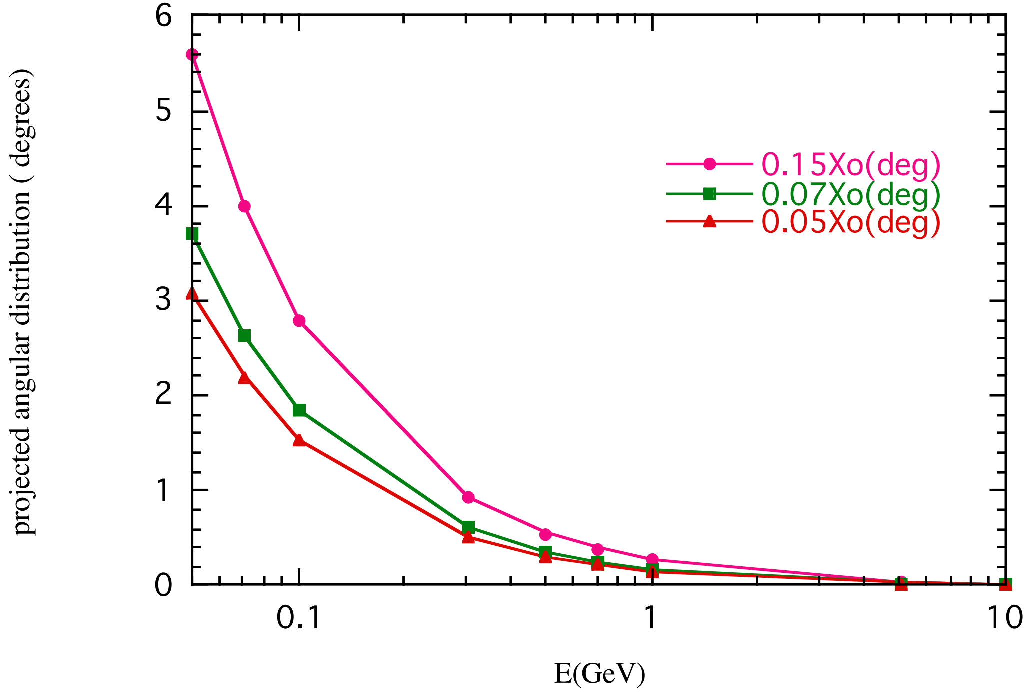


(energy measurement)

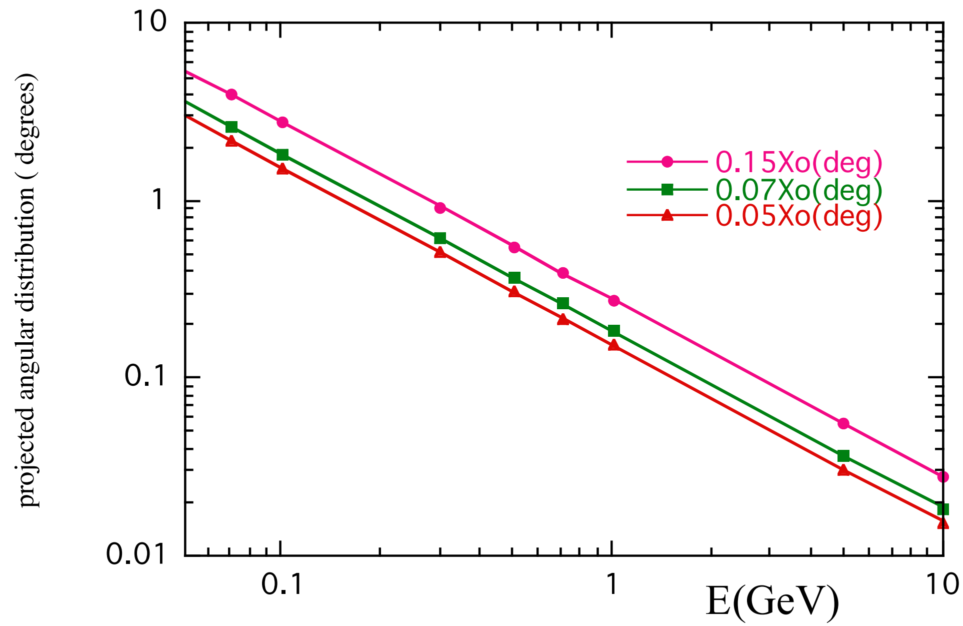
- photons materialize into matter-antimatter pairs:

  E_γ --> $m_{e^+}c^2 + m_{e^-}c^2$

- electron and positron carry information about the direction, energy and polarization of the γ-ray



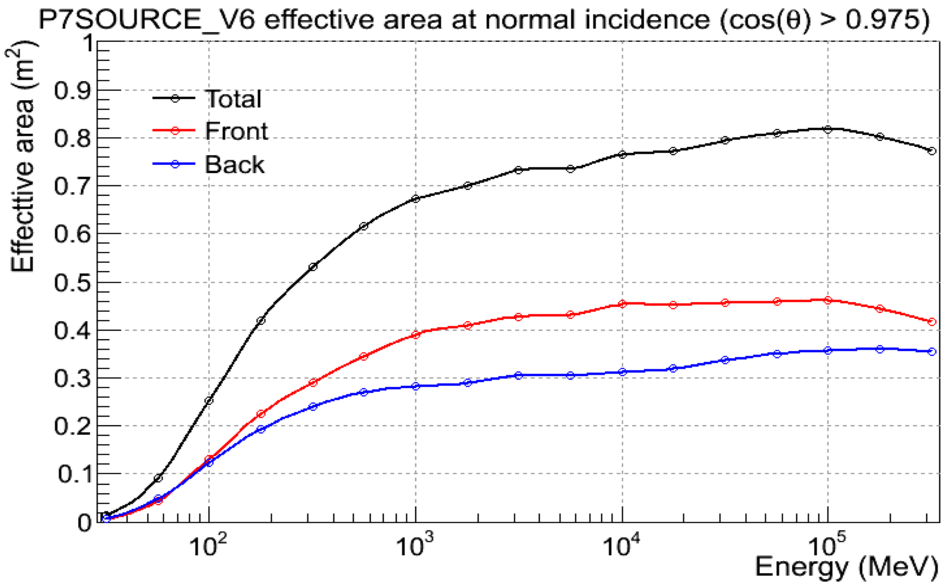
Multiple Scattering

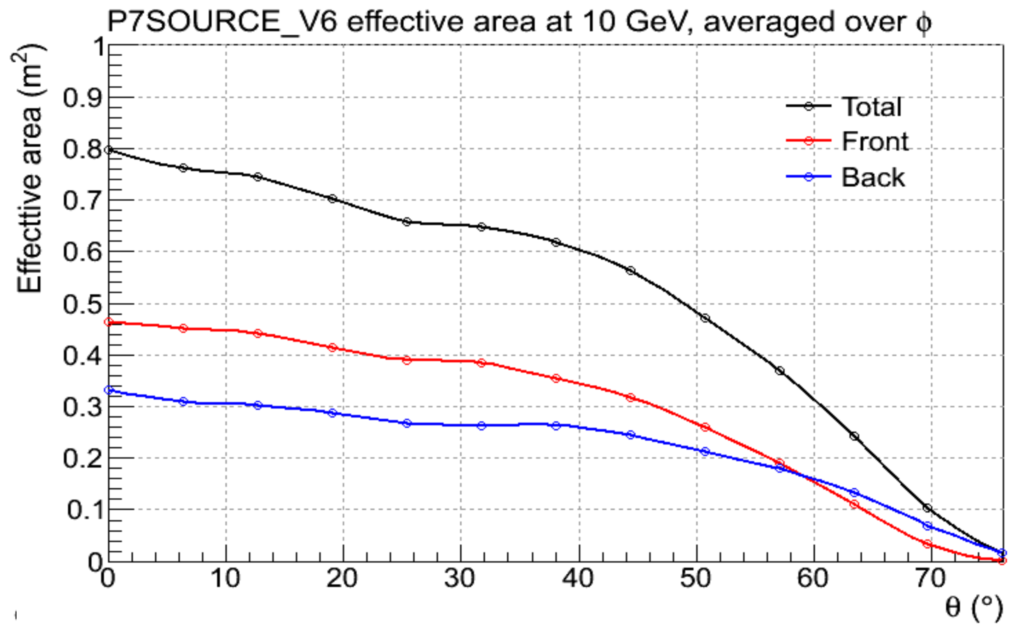


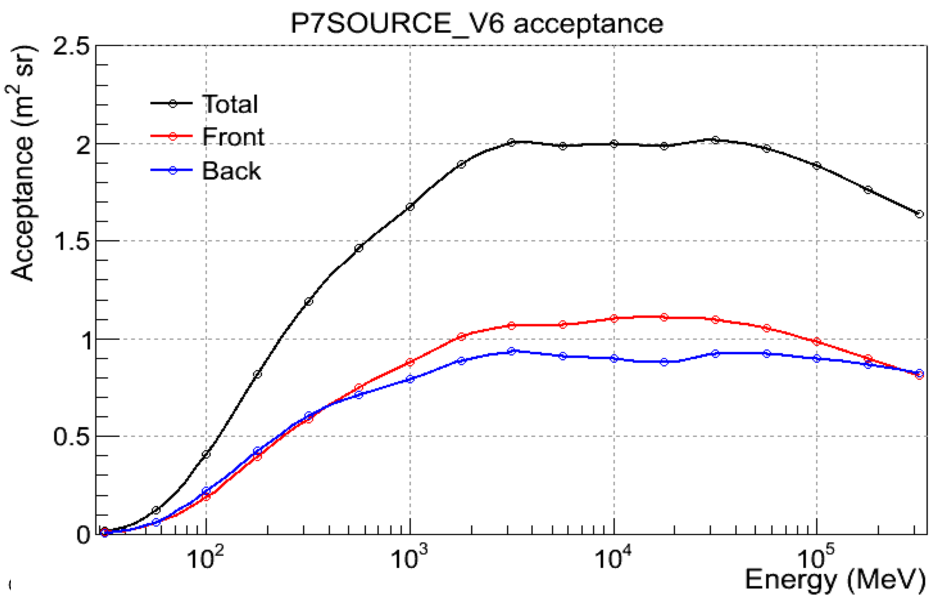
$$\theta_0 = \theta_{plane}^{rms} = \frac{1}{\sqrt{2}}\theta_{space}^{rms}$$

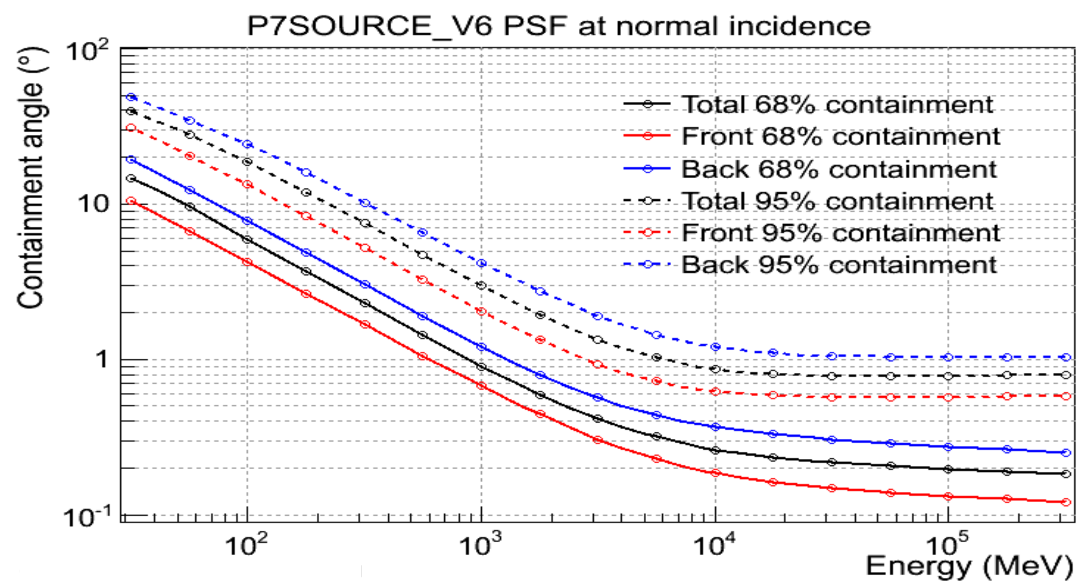
$$\theta_0 = \frac{13.6MeV}{\beta cp} z\sqrt{x/X_0}\,[1 + 0.038\ln(x/X_0)]$$

Fermi Instrument Response Function



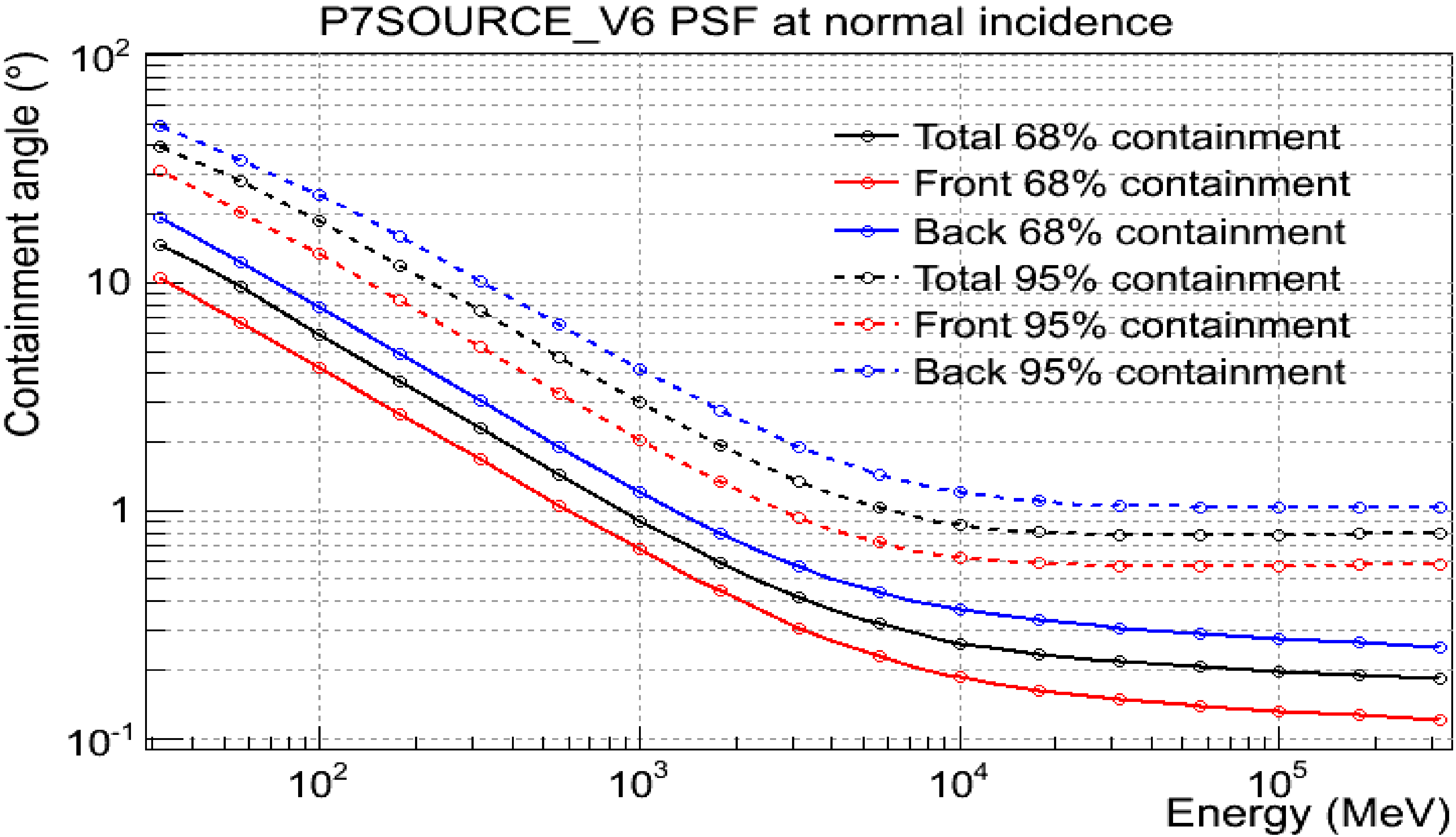






http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

Fermi Instrument Response Function

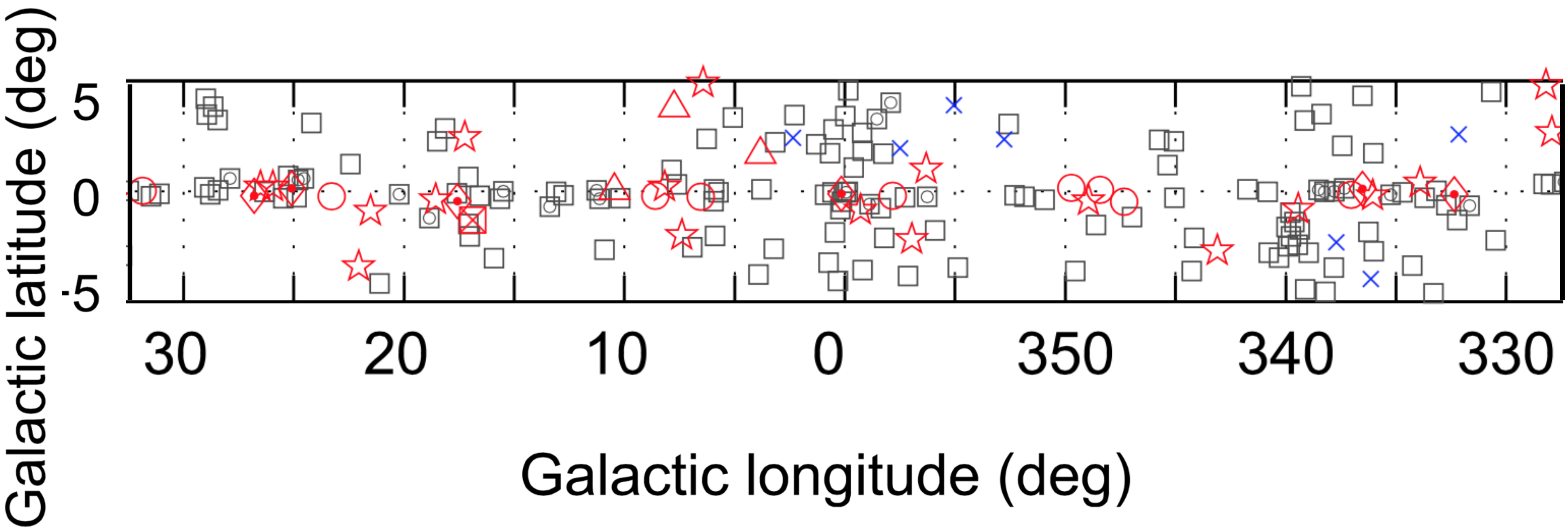


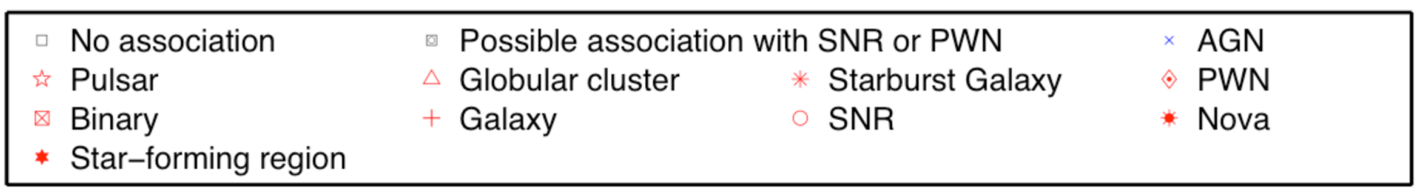
http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

The Fermi LAT 3FGL Inner Galactic Region

August 4, 2008, to July 31, 2010

100 MeV to 300 GeV energy range

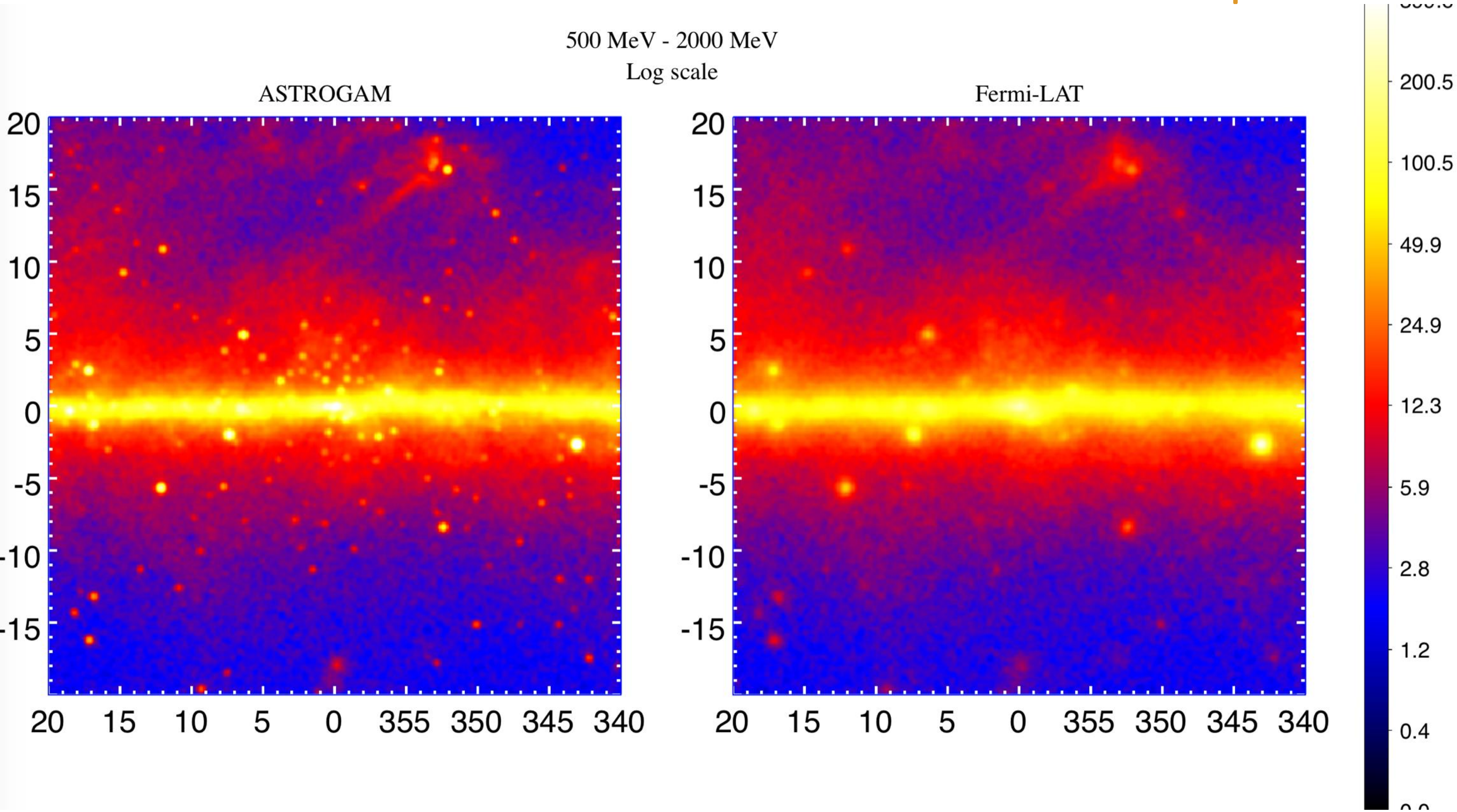




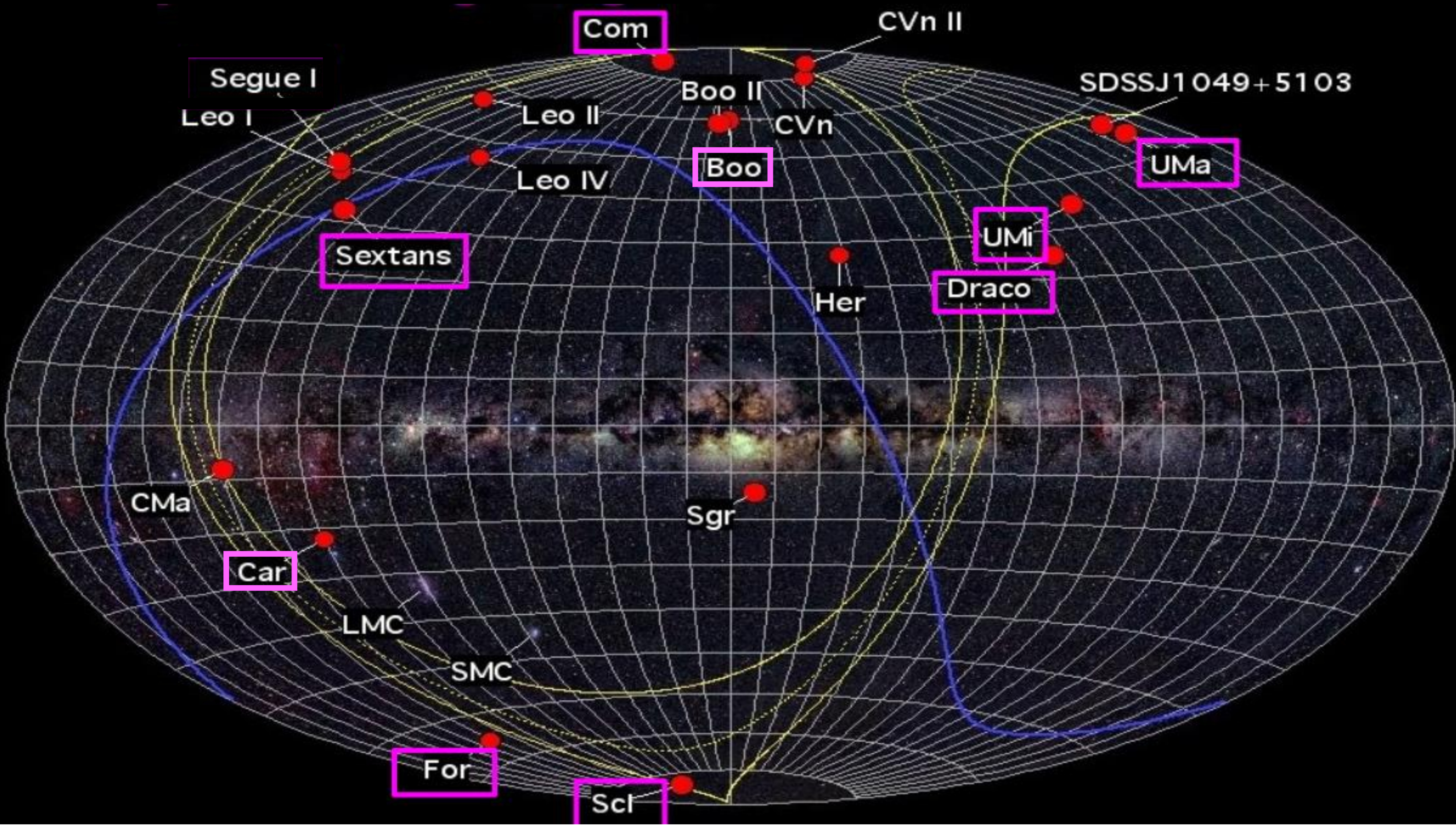
Fermi Coll. ApJS (2015) 218 23
arXiv:1501.02003

Galactic Center Region 0.5-2 GeV

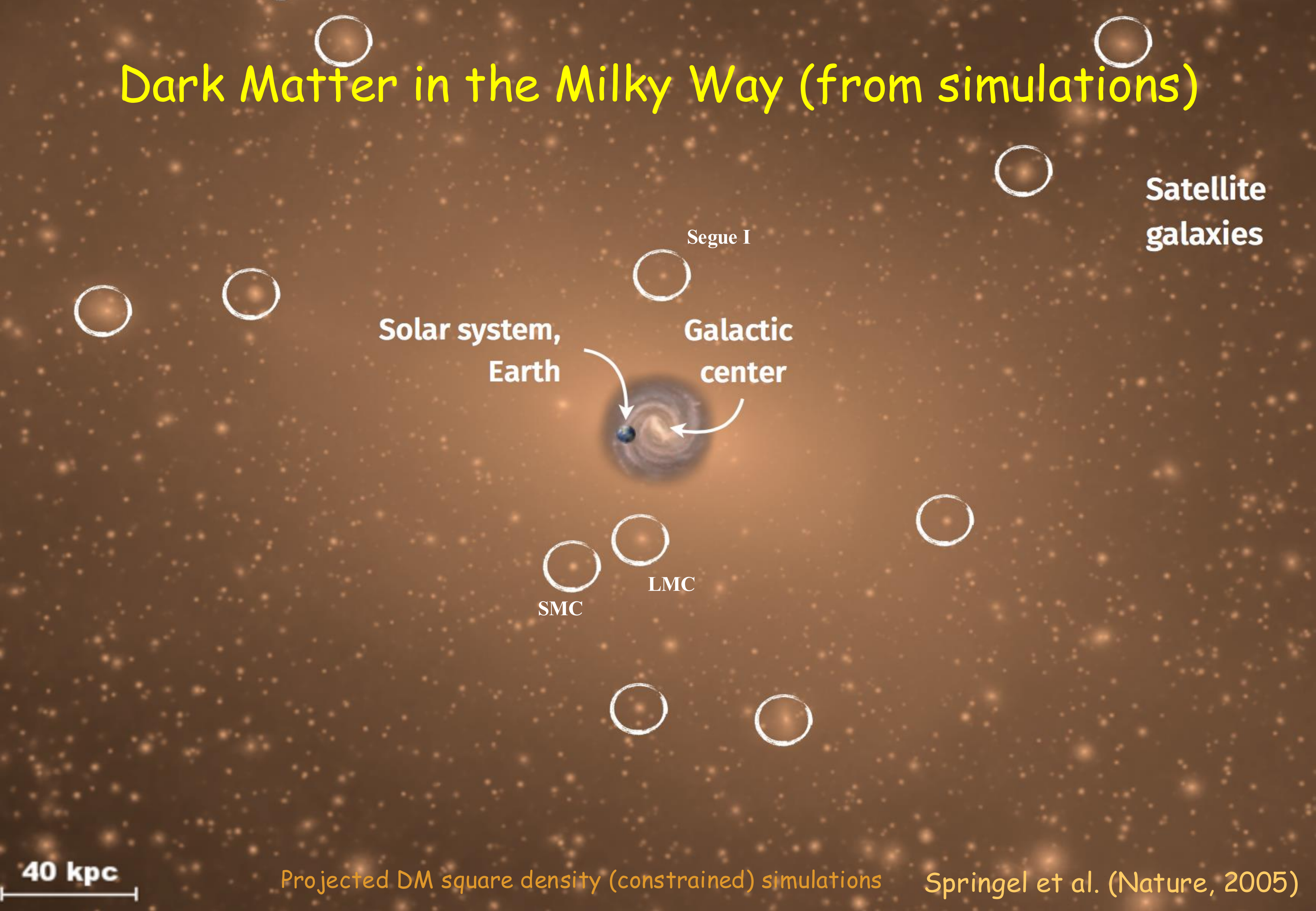
Fermi PSF Pass7 rep v15 source



Classical Dwarf spheroidal galaxies: promising targets for DM detection



Dark Matter in the Milky Way (from simulations)

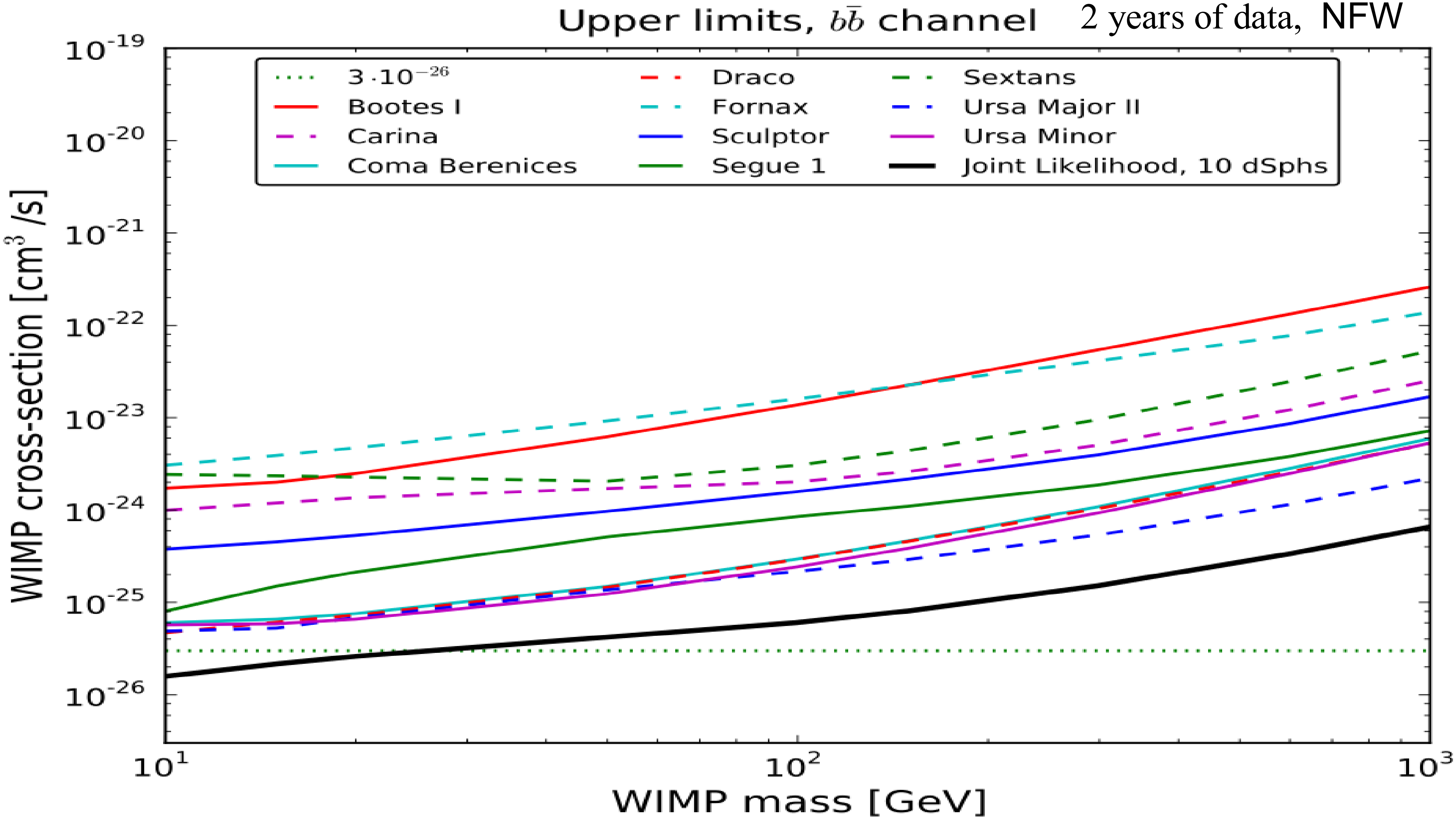


Projected DM square density (constrained) simulations

Springel et al. (Nature, 2005)

Dwarf Spheroidal Galaxies combined analysis

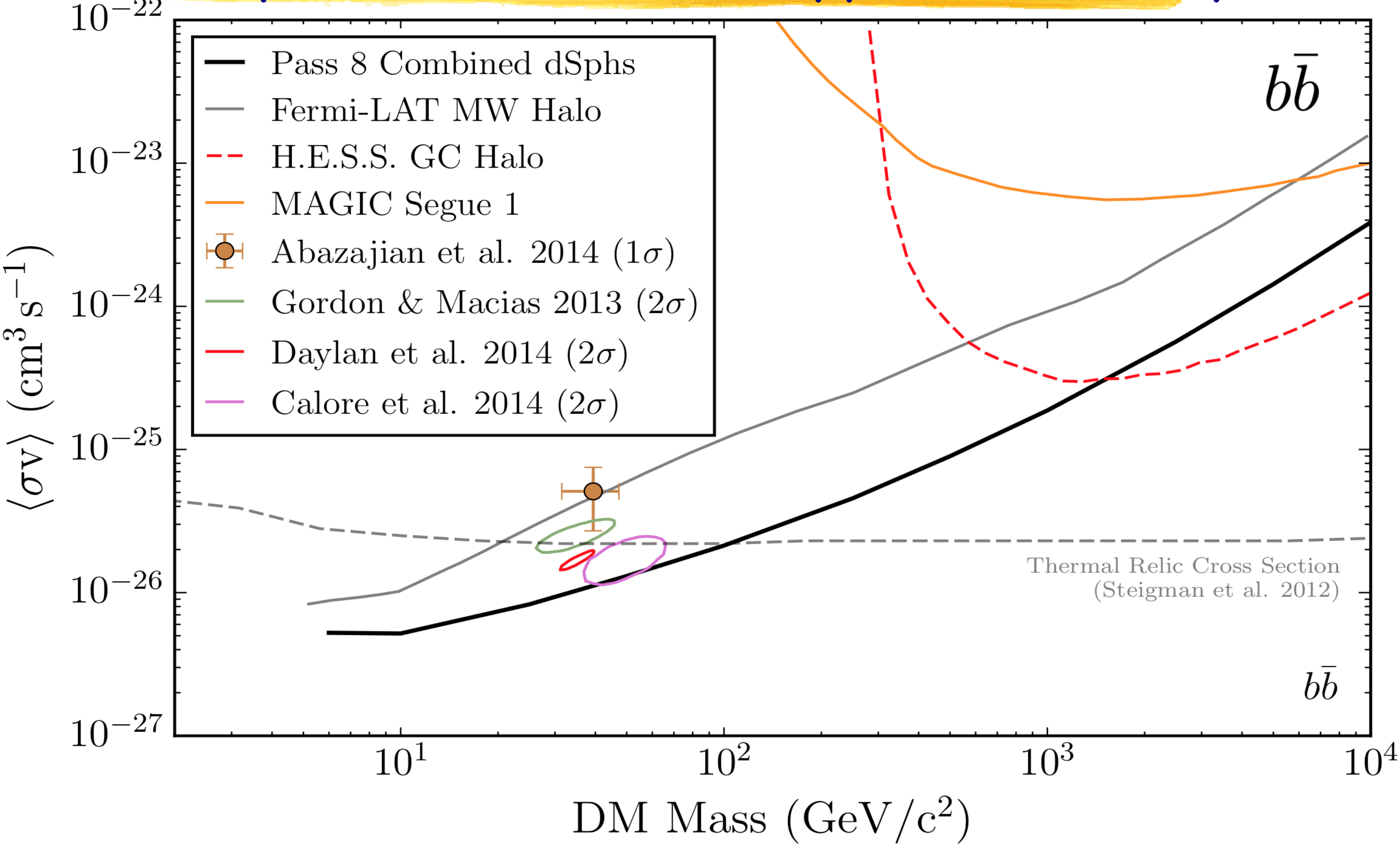
2 years of data, NFW



robust constraints including J-factor uncertainties from the stellar data statistical analysis

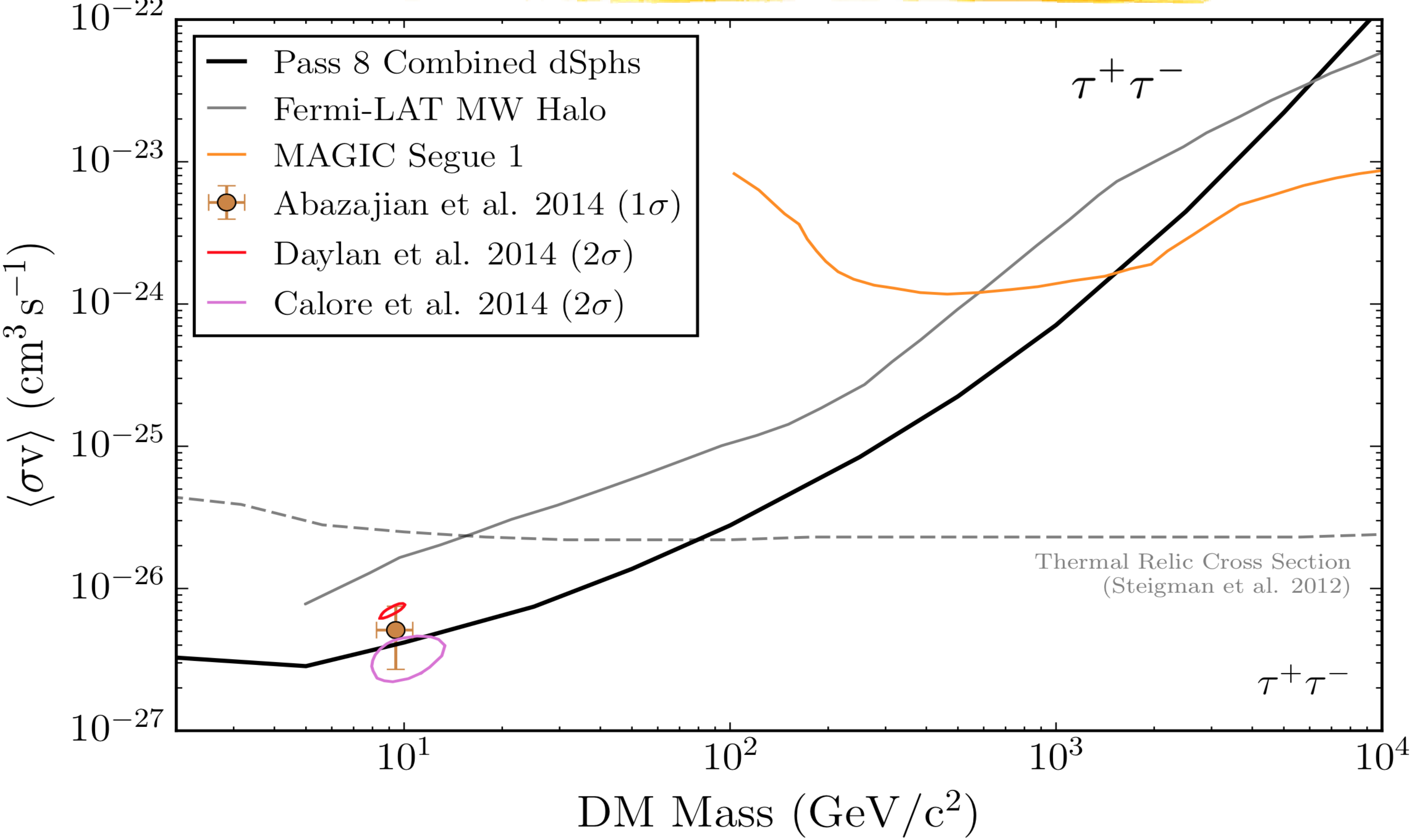
Fermi Lat Coll., PRL 107, 241302 (2011) [arXiv:1108.3546]

Dwarf Spheroidal Galaxies upper-limits (6 years)



M.Ackermann et al., [Fermi Coll.] PRL 115, 231301 (2015) [arXiv:1503.02641]

Dwarf Spheroidal Galaxies upper-limits (6 years)



M.Ackermann et al., [Fermi Coll.] PRL 115, 231301 (2015) [arXiv:1503.02641]

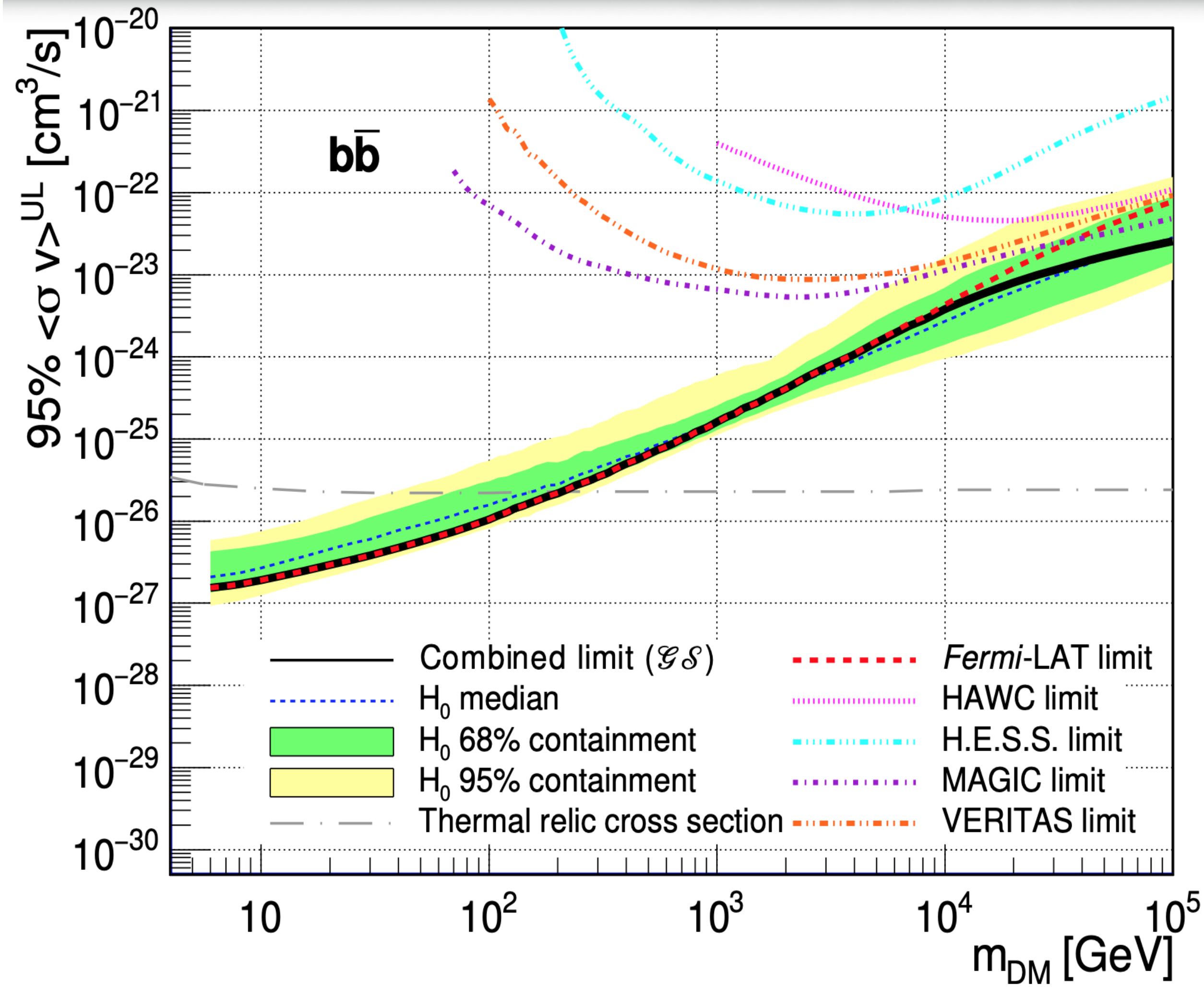
Combining all dSph observations

- Combination of the observation results towards 20 dwarf spheroidal galaxies (dSphs)
- Significant increase of the statistics

-> Increase the sensitivity to potential dark matter signals

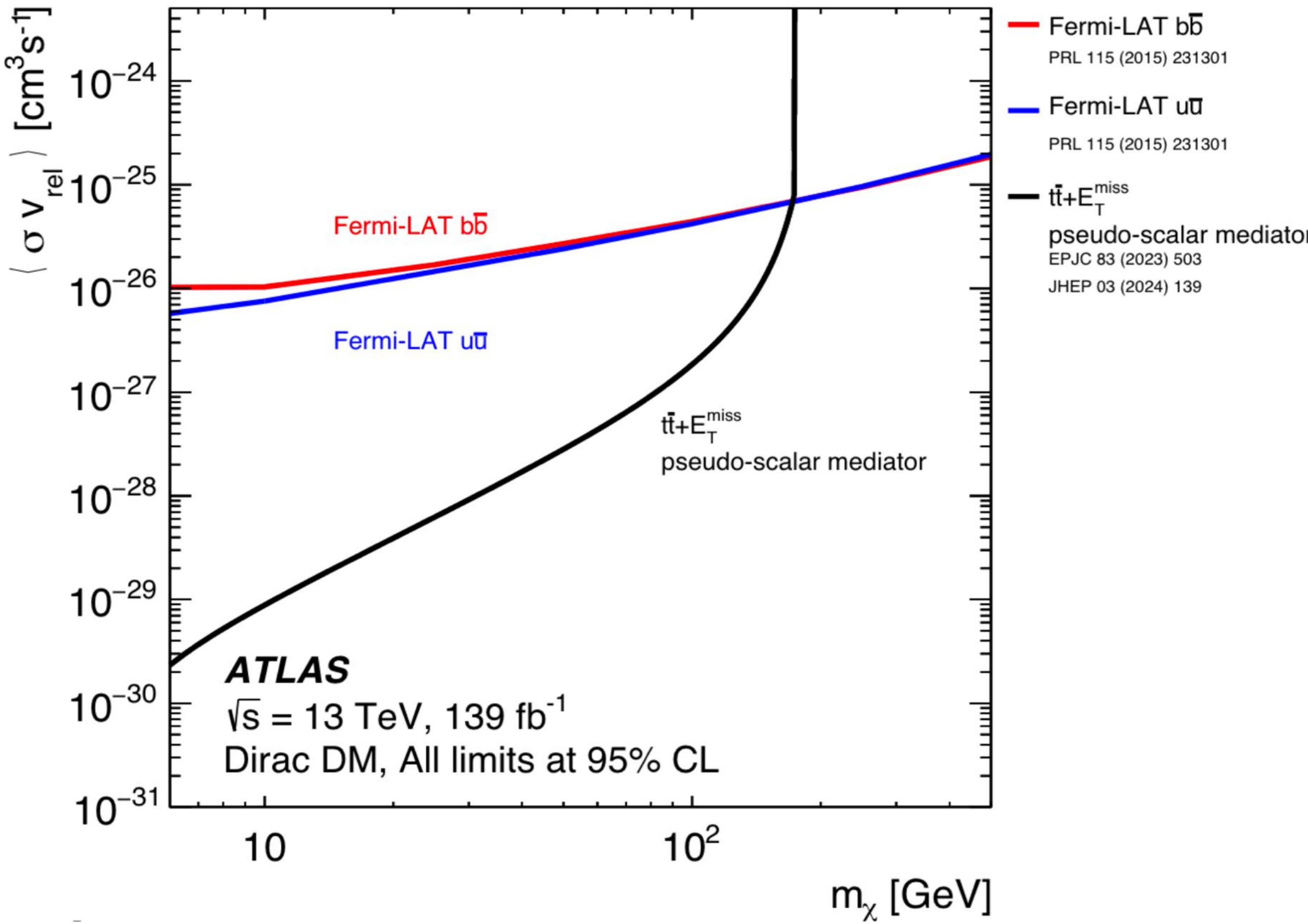
- Cover the widest energy range ever investigated : 20 MeV – 80 TeV

- Common elements :
  - Agreed model parameters
  - Sharable likelihood table formats
  - Joint likelihood test statistic

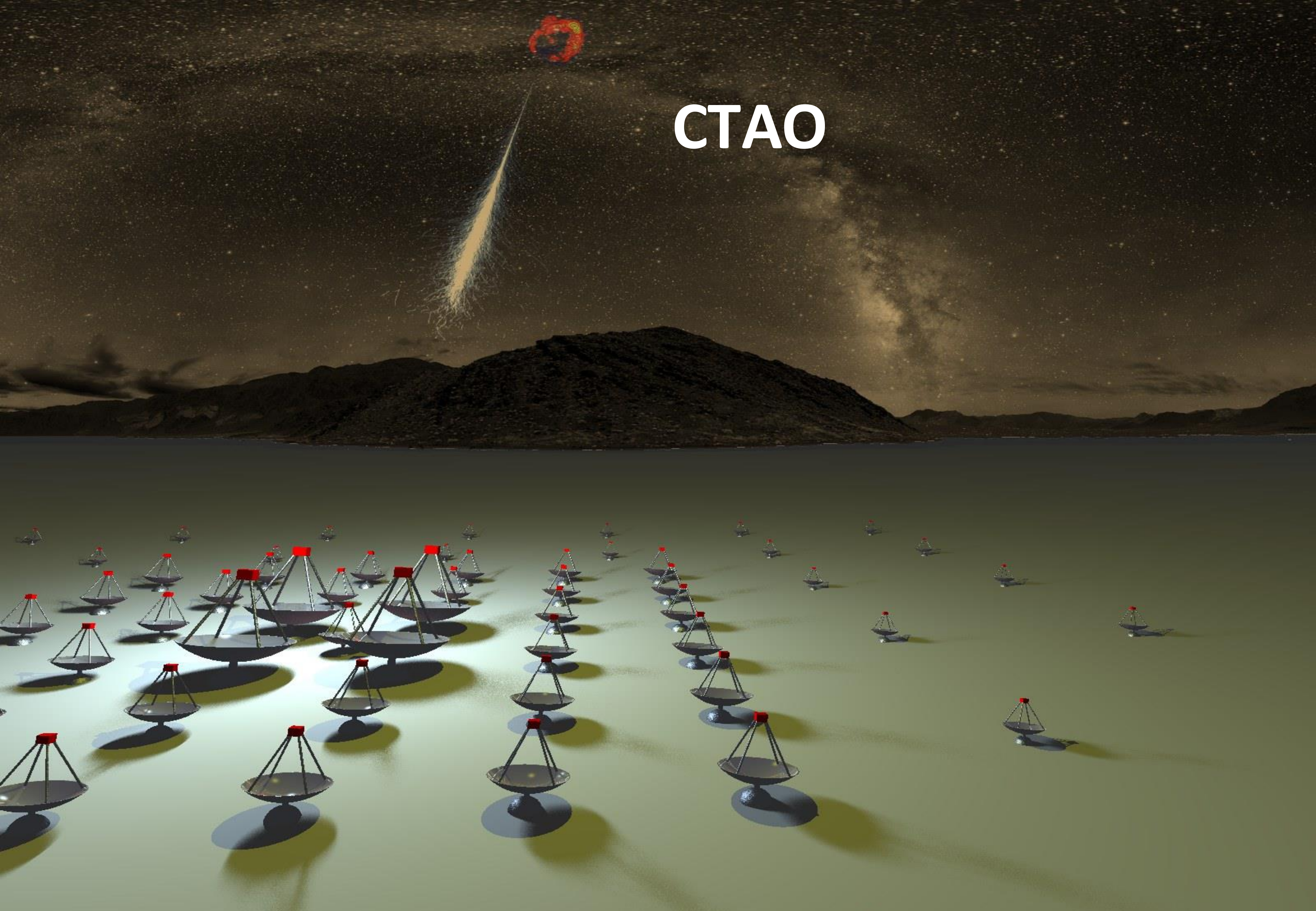


Fermi, HAWC, H.E.S.S., MAGIC, and VERITAS Collaborations) JCAP 03 (2026) 035 [arXiv:2508.20229]

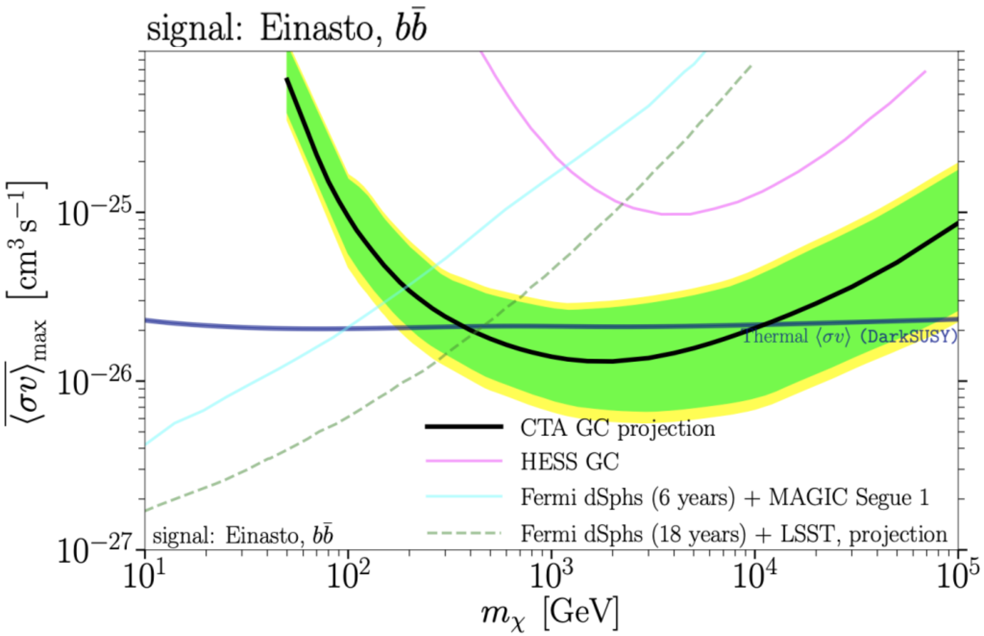
Comparison of ATLAS scalar/pseudo-scalar results with Fermi LAT indire

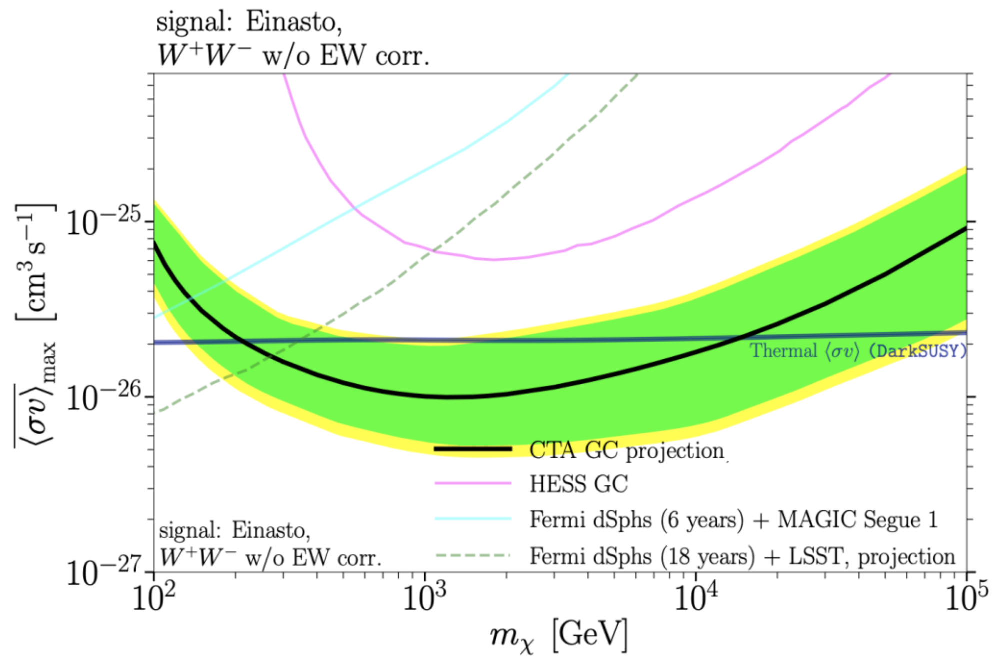


Annihilation cross section** (cross-section x relative velocity v_{rel}) averaged over the DM velocity distribution for a **pseudo-scalar mediator


CTAO

Galactic center CTAO Sensitivity





- Einasto profile

520 h

$$\rho_{\rm DM} = \rho_s \exp\left[-\frac{\alpha}{2}\left(\frac{r}{r_s}\right)^\alpha - 1\right],\ J \sim 7.1\times10^{22}{\rm GeV}^2/{\rm cm}^5$$

- Main source of background : sources, Fermi Bubble, interstellar γ, residual CR

The CTA Consortium JCAP01(2021) 057 January 27, 2021 [arXiv:2007.16129]

Measuring DM densities in dSph halos

Optimal dSphs selected according to:
1. Distance(d<100pc)
2. Culmination zenith angle (ZAmin < 30°)

Targets with no/poor brightness and/ or kinematic data excluded from the MCMC Jeans analysis.

Surviving sample:

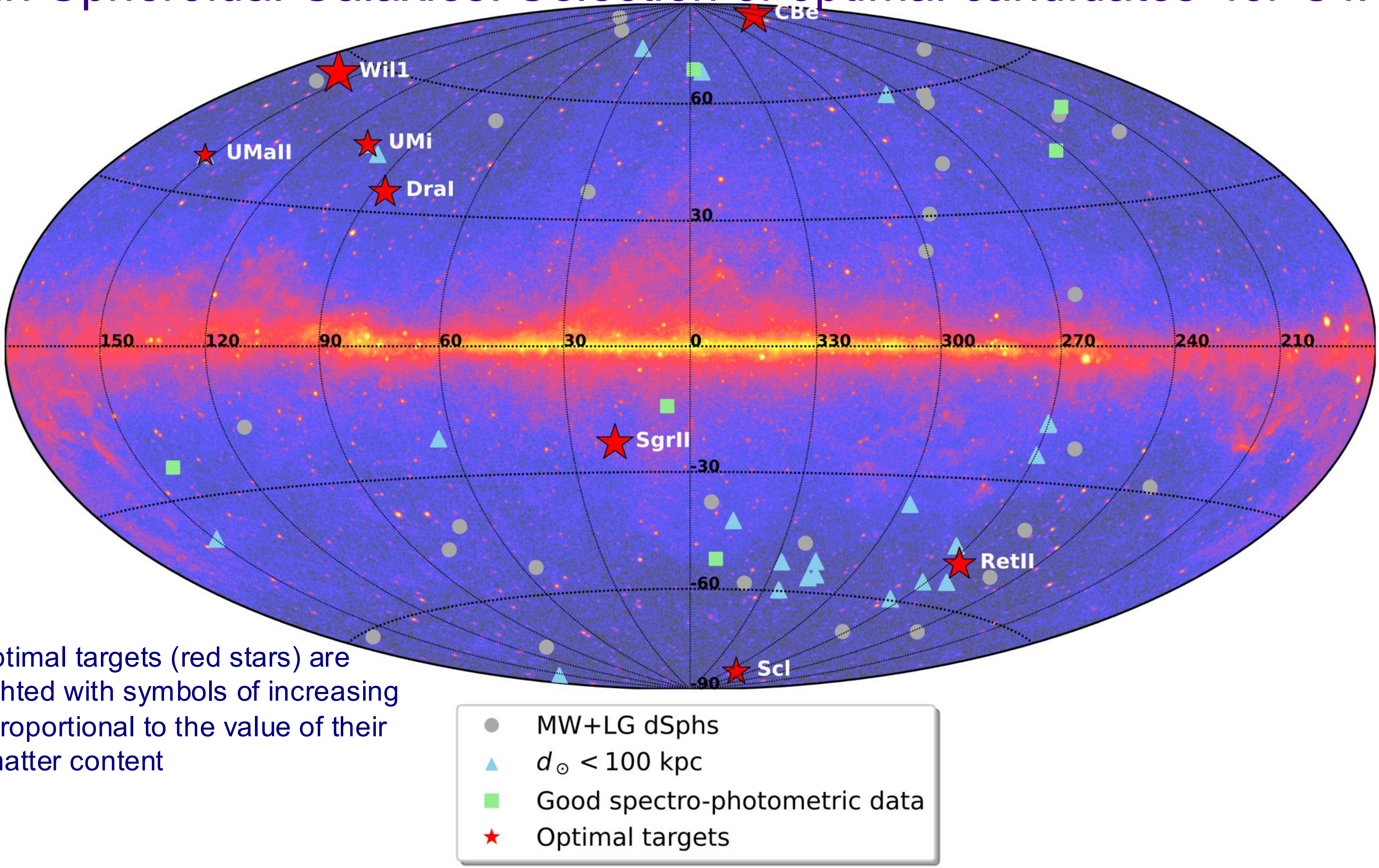
— 5 Northern dSphs (1 classical + 5 ultra-faint)

— 3 Southern dSphs (1 classical + 2 ultra-faint)

Name	Abbr.	Type	R.A. (hh mm ss)	dec. (dd mm ss)	Distance (kpc)	ZA_{culm} N (deg)	ZA_{culm} S (deg)	Month	Ref.
CTAO-N candidate dSphs									
Boötes I	BoöI	uft	14 00 06.0	+14 30 00	65 ± 3	14.3	39.1	Apr	1,2
Boötes II	BoöII	uft	13 58 00.0	+12 51 00	39 ± 2	15.9	37.5	Apr	1,3
Boötes III	BoöIII	uft	13 57 12.0	+26 48 00	46 ± 2	2.0	51.4	Apr	1,3
Coma Berenices	CBe	uft	12 26 59.0	+23 54 15	42 ± 2	4.9	48.5	Mar	1,4
Draco I	DraI	cls	17 20 12.4	+57 54 55	75 ± 4	29.2	82.5	Jun	1,5
Draco II	DraII	uft	15 52 47.6	+64 33 55	20 ± 3	35.8	89.2	May	6
Laevens 3	Lae3	uft	21 06 54.3	+14 58 48	67 ± 3	13.8	39.6	Aug	7
Segue 1	Seg1	uft	10 07 04.0	+16 04 55	23 ± 2	12.7	40.7	Feb	1,8
Segue 2	Seg2	uft	02 19 16.0	+20 10 31	36 ± 2	8.6	44.8	Oct	1,9
Triangulum II	TriII	uft	02 13 17.4	+36 10 42	30 ± 2	7.4	60.8	Oct	10
Ursa Major II	UMaII	uft	08 51 30.0	+63 07 48	35 ± 2	34.4	87.8	Feb	1,11
Ursa Minor	UMi	cls	15 09 08.5	+67 13 21	68 ± 2	38.5	—	May	1,12
Willman 1	Wil1	uft	10 49 21.0	+51 03 00	38 ± 7	22.3	75.7	Mar	1,8
CTAO-S candidate dSphs									
Carina II	CarII	uft	07 36 26.3	−58 00 00	36 ± 1	86.7	33.3	Jan	13
Carina III	CarIII	uft	07 38 31.2	−57 54 00	28 ± 2	86.7	33.3	Jan	13
Cetus II	CetII	uft	01 17 52.8	−17 25 12	30 ± 3	46.2	7.2	Oct	14
Eridanus III	EriIII	uft	02 22 45.5	−52 16 48	95 ± 27	81.0	27.7	Oct	15
Grus II	GruII	uft	22 04 04.8	−46 26 24	53 ± 5	75.2	21.8	Aug	14
Horologium I	HorI	uft	02 55 28.9	−54 06 36	87 ± 13	82.9	29.5	Oct	15
Horologium II	HorII	uft	03 16 26.4	−50 03 00	78 ± 8	77.5	26.7	Nov	16
Hydrus I	HyiI	uft	02 29 33.7	−79 18 36	28 ± 1	—	53.3	Oct	17
Indus I	IndI	uft	21 08 48.1	−51 09 36	69 ± 16	79.9	26.5	Aug	15
Phoenix II	PheII	uft	23 39 57.6	−54 24 36	95 ± 18	83.2	29.8	Sep	15
Pictor II	PicII	uft	06 44 43.1	−59 54 00	45 ± 5	88.3	35.8	Jan	18
Reticulum II	RetII	uft	03 35 40.9	−54 03 00	32 ± 2	82.8	29.4	Nov	15
Reticulum III	RetIII	uft	03 45 26.3	−60 27 00	92 ± 13	89.2	35.8	Nov	19
Sagittarius I	SgrI	cls	18 55 19.5	−30 32 43	31 ± 1	59.3	5.9	Jul	1,20
Sagittarius II	SgrII	uft	19 52 40.5	−22 04 05	67 ± 5	50.8	2.6	Jul	7
Sculptor	Scl	cls	01 00 09.4	−33 42 33	84 ± 2	62.5	9.1	Oct	1,21
Sextans	Sex	cls	10 13 03.0	−01 36 53	84 ± 3	30.4	23.0	Feb	1,22
Tucana II	TucII	uft	22 52 16.7	−58 33 36	58 ± 6	87.3	33.9	Sep	15
Tucana III	TucIII	uft	23 56 35.9	−59 36 00	25 ± 2	88.4	35.0	Sep	14
Tucana IV	TucIV	uft	00 02 55.3	−60 51 00	48 ± 4	89.6	36.2	Sep	14
Tucana V	TucV	uft	23 37 23.9	−63 16 12	55 ± 9	—	38.3	Sep	23
Virgo I	VirI	uft	12 00 09.1	−00 40 52	87 ± 11	40.0	24.2	Mar	24

Prospects for dark matter observations in dwarf spheroidal galaxies with the Cherenkov Telescope Array Observatory
CTAO Consortium. c.a. M. Doro, A. Morselli, G. Rodríguez-Fernández, F. G. Saturni MNRAS 544, 2946–2986 (2025) arXiv:2508.19120

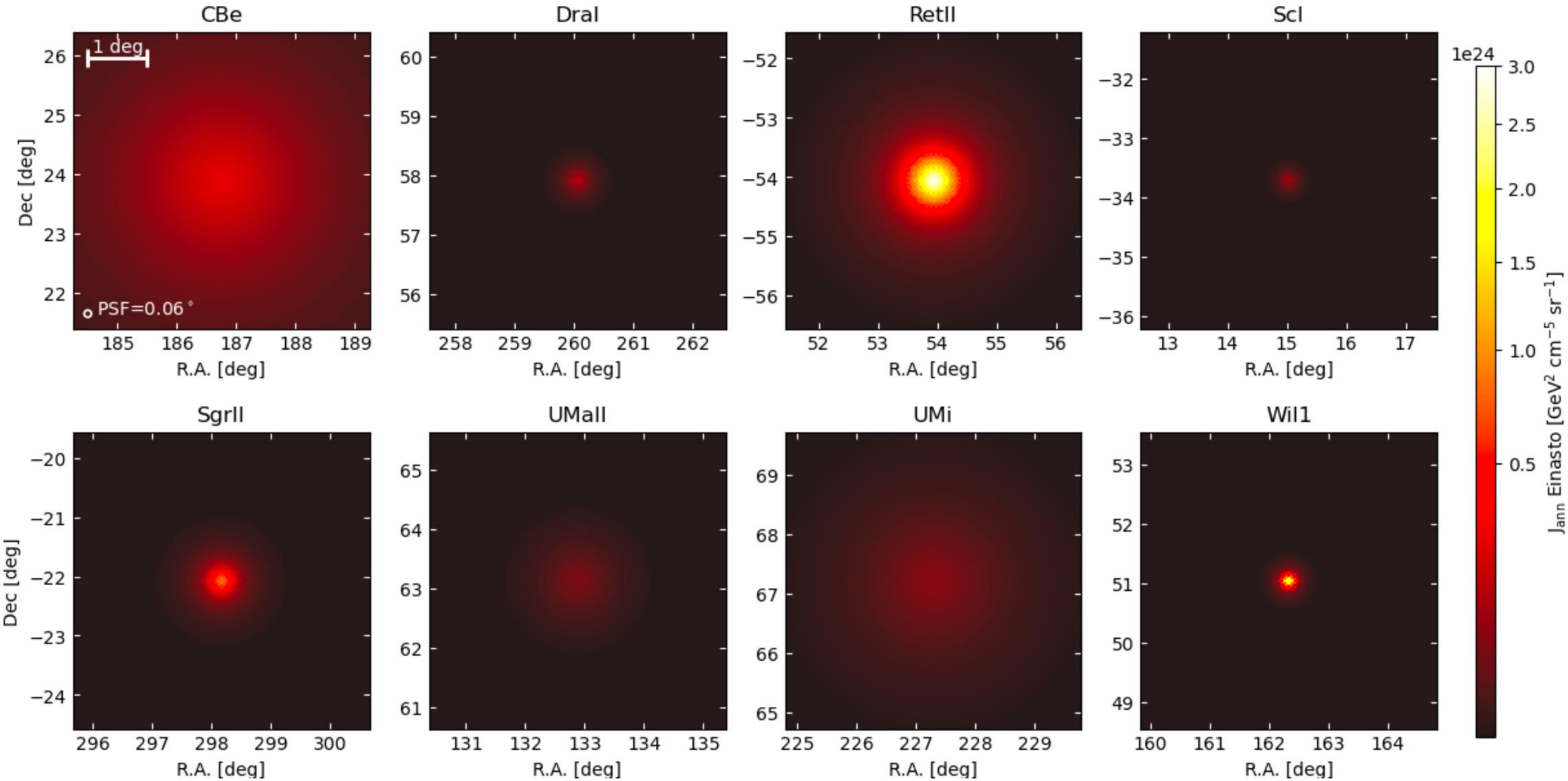
Dwarf Spheroidal Galaxies: Selection of optimal candidates for CTAO



The optimal targets (red stars) are highlighted with symbols of increasing size, proportional to the value of their dark matter content

Prospects for dark matter observations in dwarf spheroidal galaxies with the Cherenkov Telescope Array Observatory
CTAO Consortium. c.a. M. Doro, A. Morselli, G. Rodríguez-Fernández, F. G. Saturni MNRAS 544, 2946–2986 (2025) arXiv:2508.19120

Dark matter density of the selected dSphs

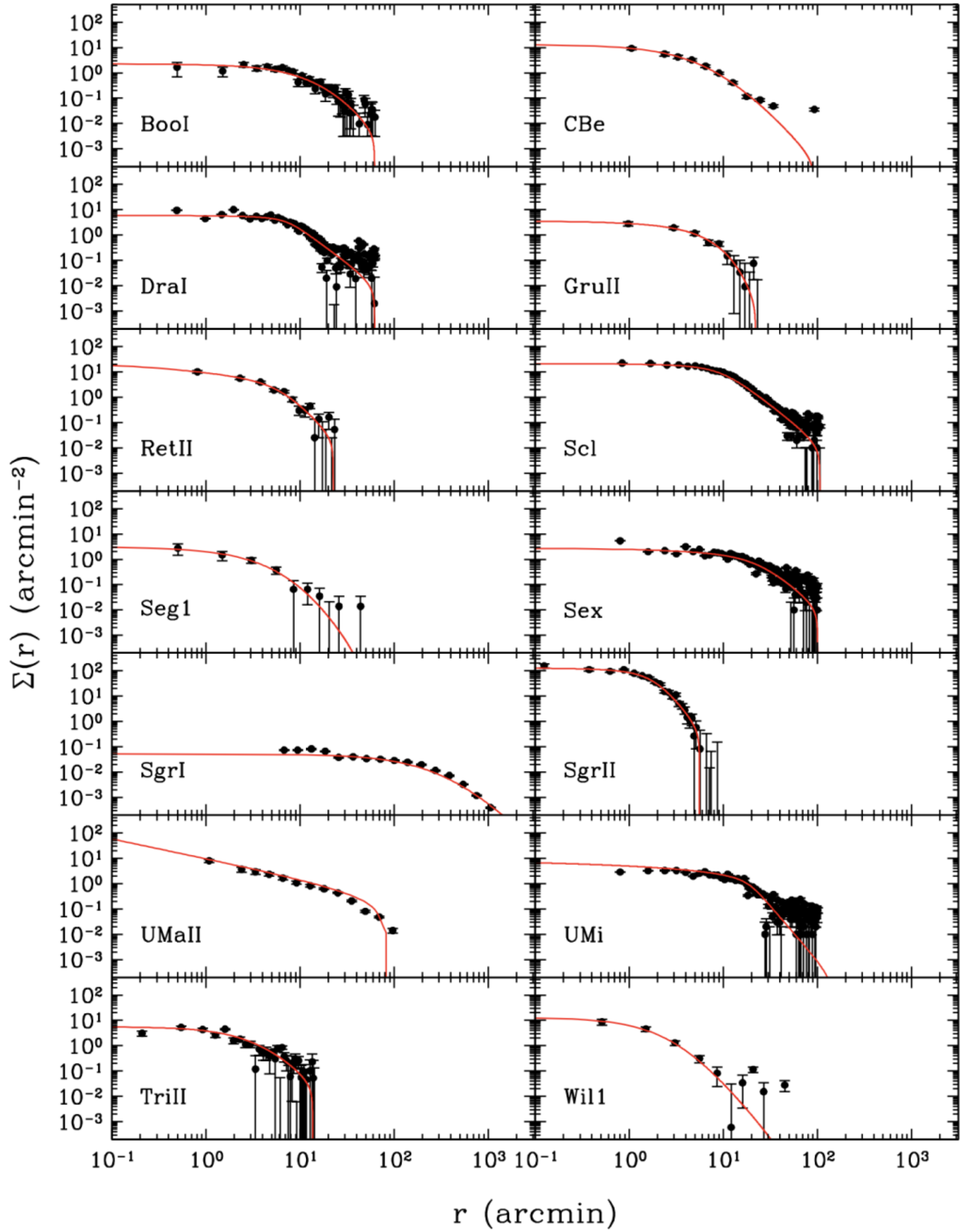


2D distributions of the astrophysical factors of the selected dSphs obtained with CLUMPY for an Einasto profile. The CTAO PSF (white circle) is indicated in the first panel

Prospects for dark matter observations in dwarf spheroidal galaxies with the Cherenkov Telescope Array Observatory
CTAO Consortium. c.a. M. Doro, A. Morselli, G. Rodríguez-Fernández, F. G. Saturni MNRAS 544, 2946–2986 (2025) arXiv:2508.19120

Measuring Dark Matter densities in dSph halos

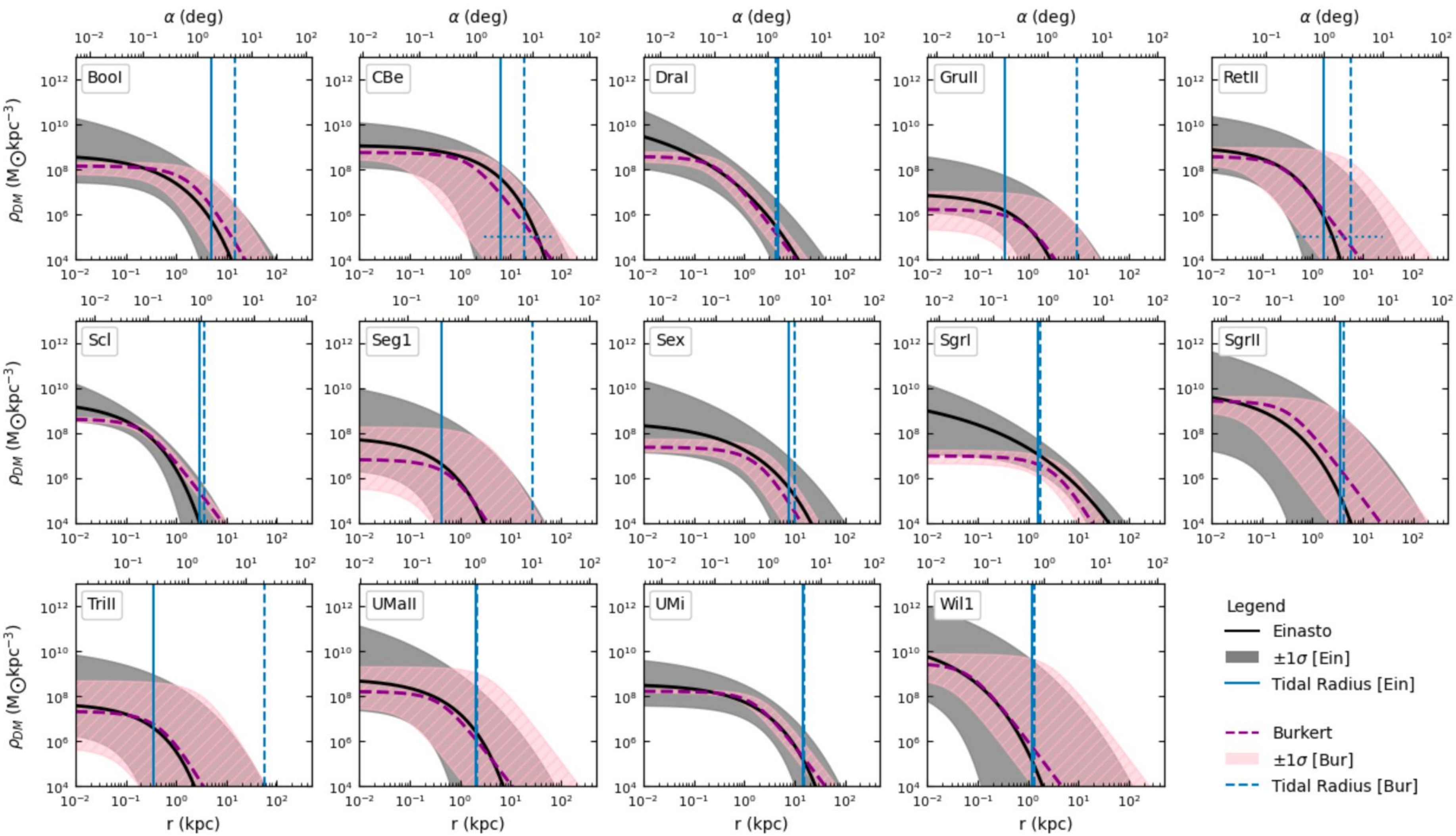
Best-fit brightness profiles Σ(r) of the analyzed dSphs as a function of the object's projected (2D) radial coordinate r from the dSph centroid



Prospects for dark matter observations in dwarf spheroidal galaxies with the Cherenkov Telescope Array Observatory
CTAO Consortium. c.a. M. Doro, A. Morselli, G. Rodríguez-Fernández, F. G. Saturni MNRAS 544, 2946–2986 (2025) arXiv:2508.19120

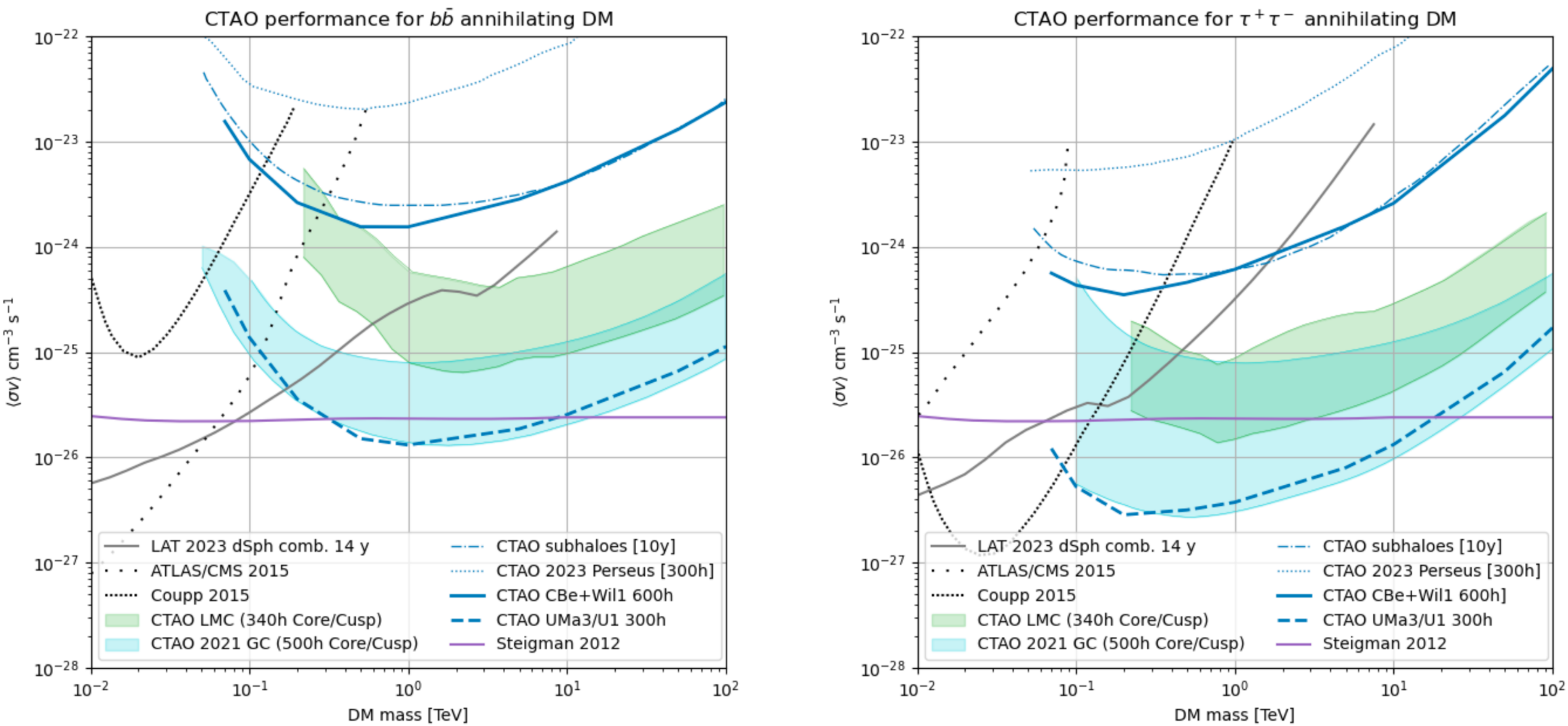
Measuring Dark Matter densities in dSph halos

DM density profiles of the 14 optimal dSphs for both cored (Burkert 1995, purple dashed lines) and cuspy models (Einasto 1965, black solid lines)



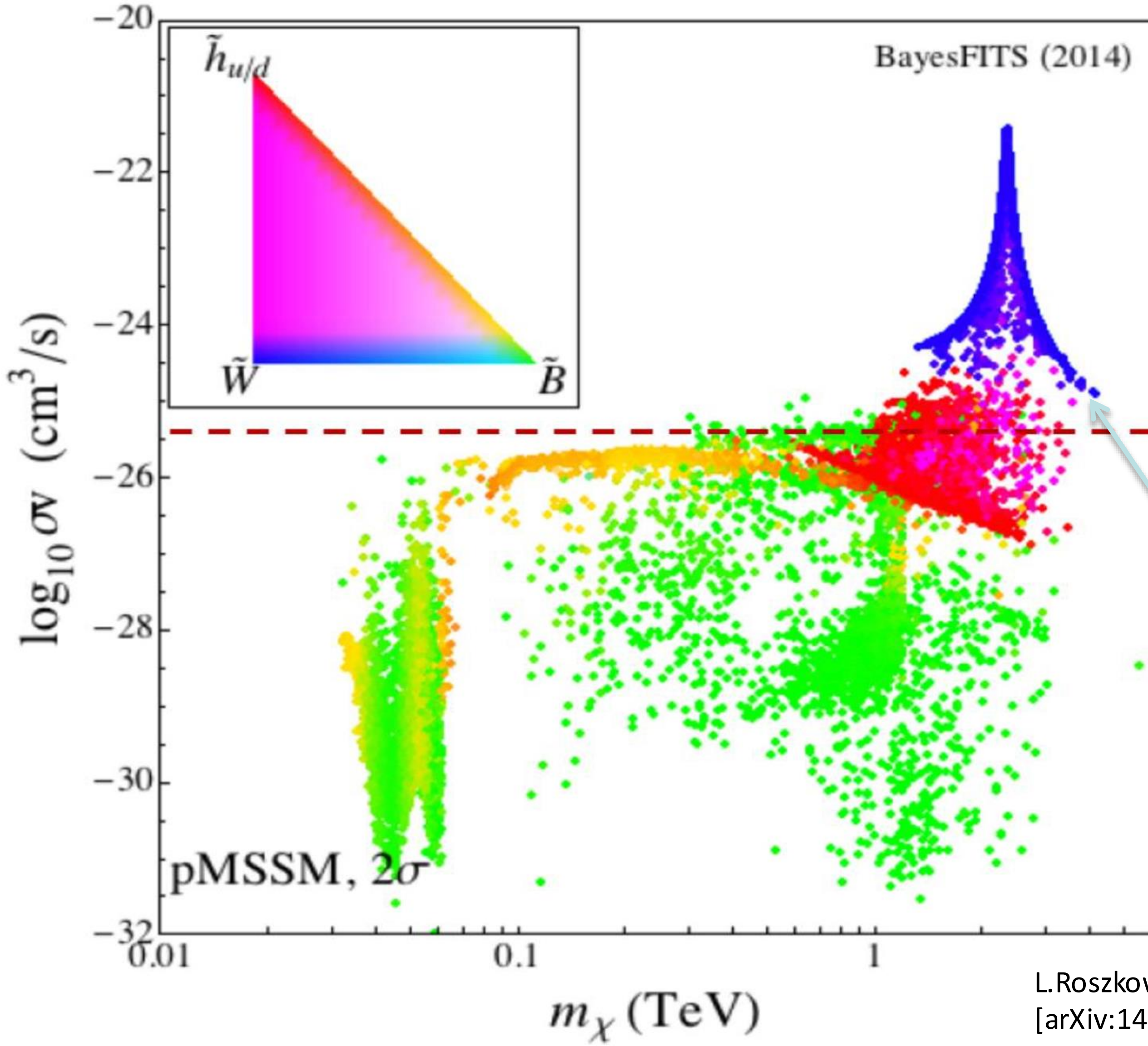
Prospects for dark matter observations in dwarf spheroidal galaxies with the Cherenkov Telescope Array Observatory
CTAO Consortium. c.a. M. Doro, A. Morselli, G. Rodríguez-Fernández, F. G. Saturni MNRAS 544, 2946–2986 (2025) arXiv:2508.19120

Dwarf Spheroidal Galaxies:
CTAO Sensitivity compared with other targets and experiments



Prospects for dark matter observations in dwarf spheroidal galaxies with the Cherenkov Telescope Array Observatory
CTAO Consortium. c.a. M. Doro, A. Morselli, G. Rodríguez-Fernández, F. G. Saturni MNRAS 544, 2946–2986 (2025) arXiv:2508.19120

note:the “thermal” cross section is only a reference value. The real cross section can be higher or lower



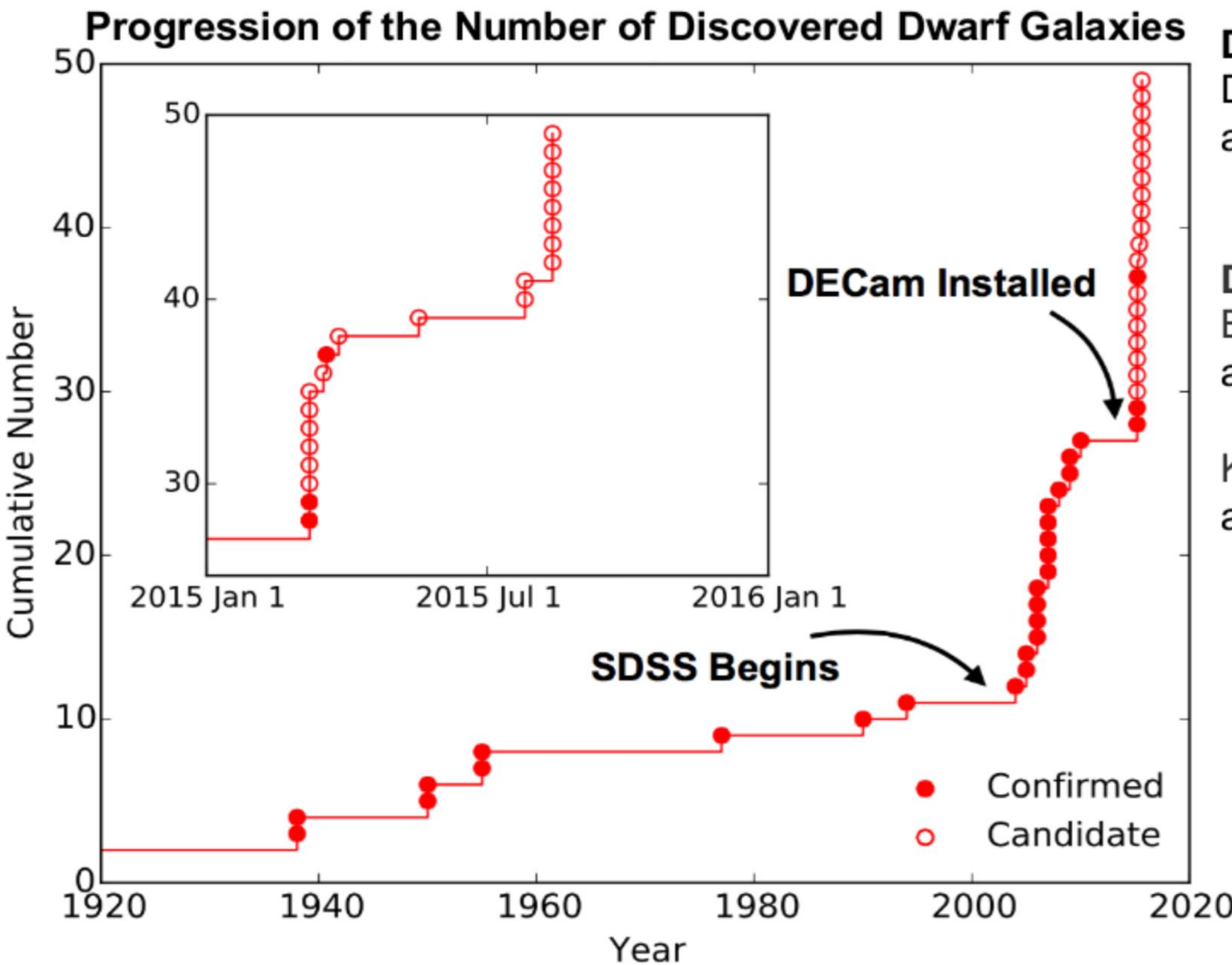
Example: Annihilation cross-section points from a 19 dimensional pMSSM fit

“thermal” cross-section
3×10^{-26} cm^3 s^{-1}

Note that a strong enhancement of the annihilation cross section occurs for winos around 2-3 TeV due to Sommerfeld enhancement.

L.Roszkowski et al., JHEP 1502 (2015) 014 [arXiv:1411.5214]

Dwarf Spheroidal Galaxies: Growing number of known targets

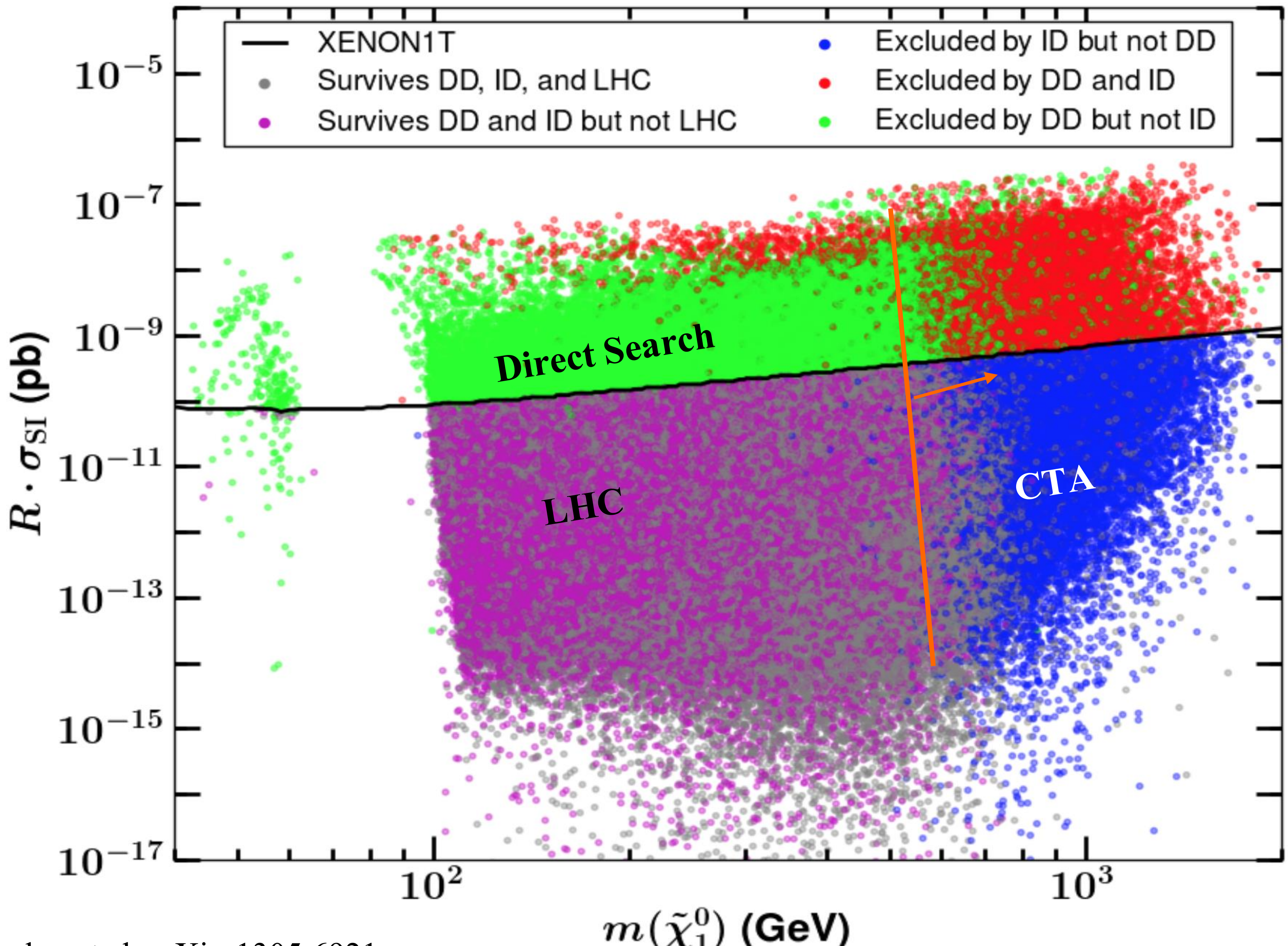


DES Year 2 Data:
Drlica-Wagner+,
arXiv:1508.03622

DES Year 1 Data:
Bechtol+:
arXiv:1503.02584

Koposov+:
arXiv:1503.02079

Complementarity and Searches for Dark Matter in the pMSSM



Cahill-Rowley et al. arXiv:1305.6921

CTA Search for Dark Matter beyond WIMP

Axion Like Particle (ALP) search prospects

γ + B -> a + B -> γ' + ...

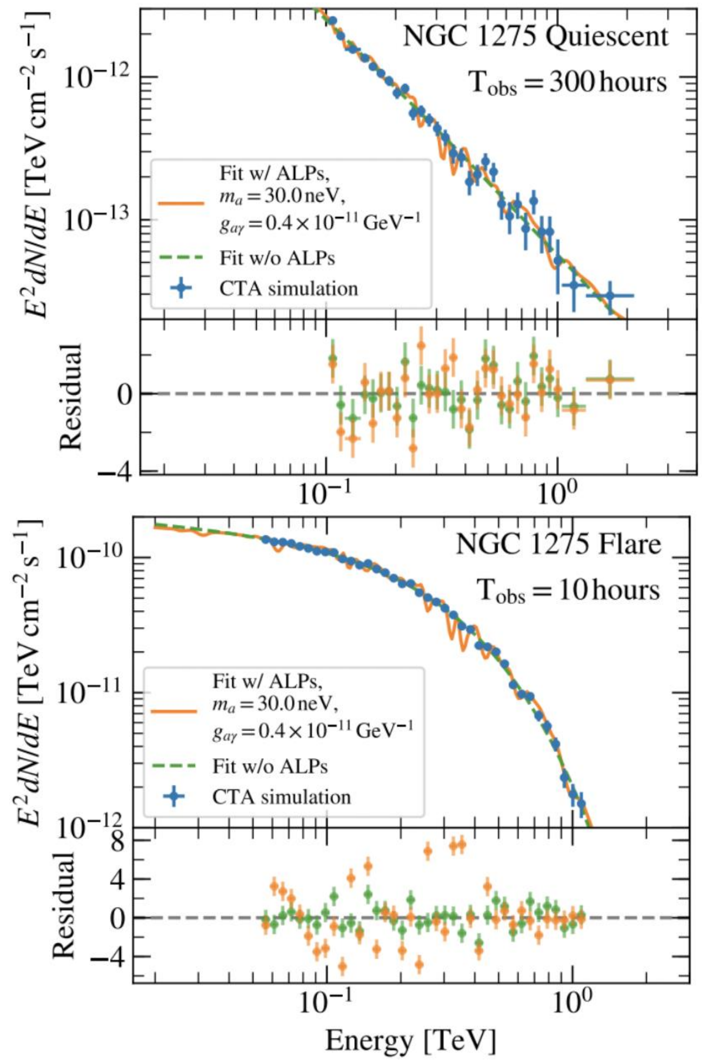
conversion probability ($E > E_{crit}$)

$$P_{a\gamma} \sim \sin^2\left(\frac{g_{a\gamma}Bl}{2}\right),$$

$$E_{\rm crit} \sim 2.5\ {\rm GeV} \times \left(\frac{|m_a - \omega_{\rm pl}|}{1{\rm neV}}\right)^2 \left(\frac{B}{1\mu{\rm G}}\right)^{-1} \left(\frac{g_{a\gamma}}{10^{-11}{\rm GeV}^{-1}}\right)^{-1}$$

the observation is simulated without an ALP effect and is modeled both without ALPs and with a fixed set of magnetic-field realization and ALP parameters that are excluded at 95 % confidence level by the flaring state simulation

Simulated spectra of the radio galaxy NGC 1275

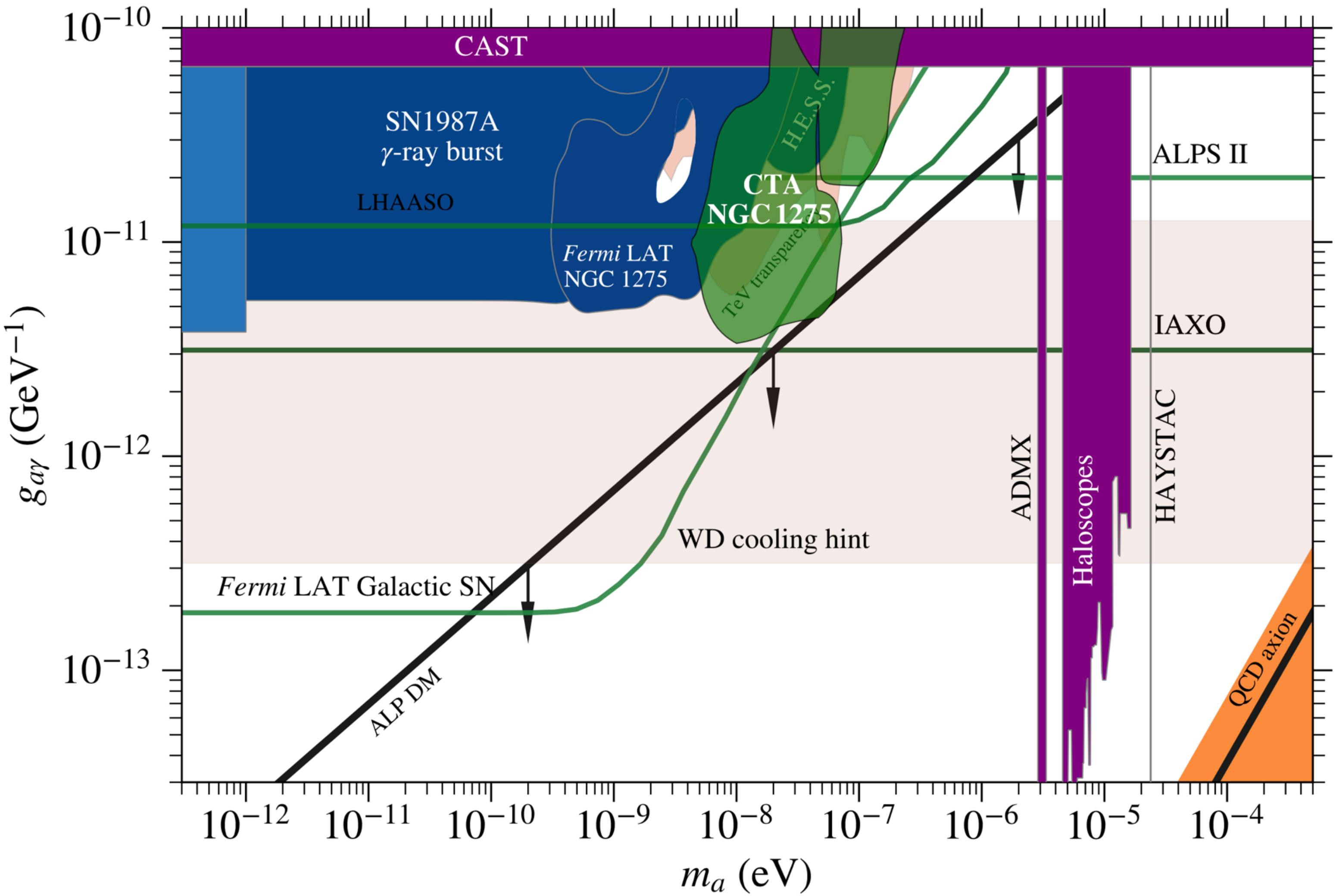


The CTA Consortium, JCAP 02 (2021) 048, 2021 [arXiv:2010.01349]

Search for Dark Matter beyond WIMP

Axion Like Particle (ALP) search prospects

- Observation of a flaring state of the radio galaxy NGC 1275 inside the Perseus cluster

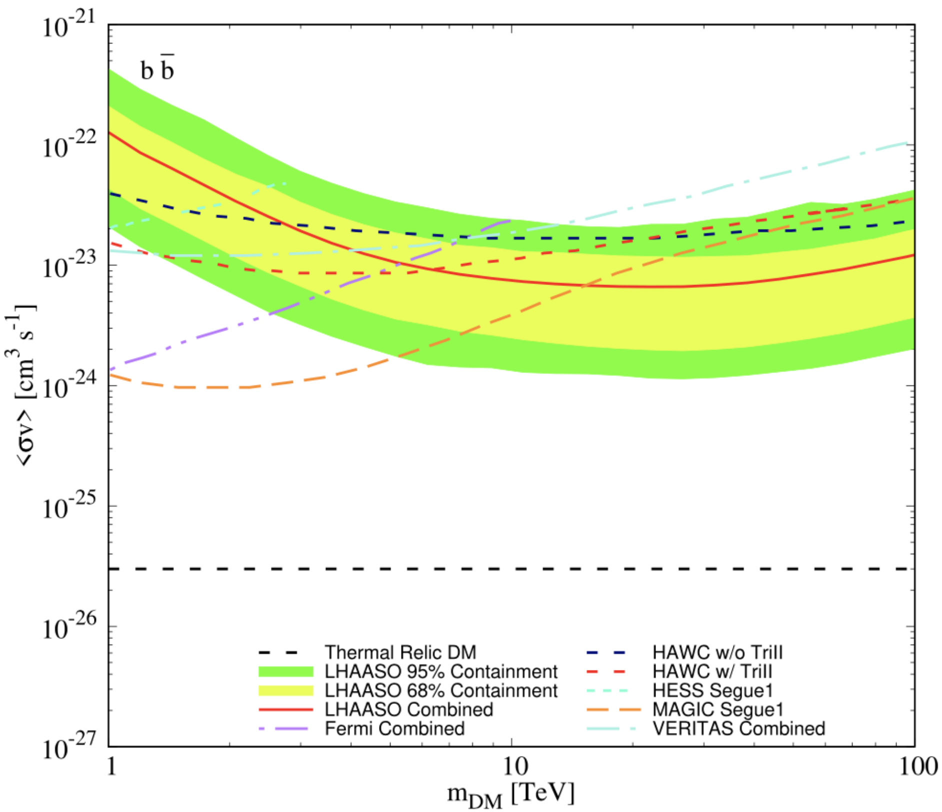


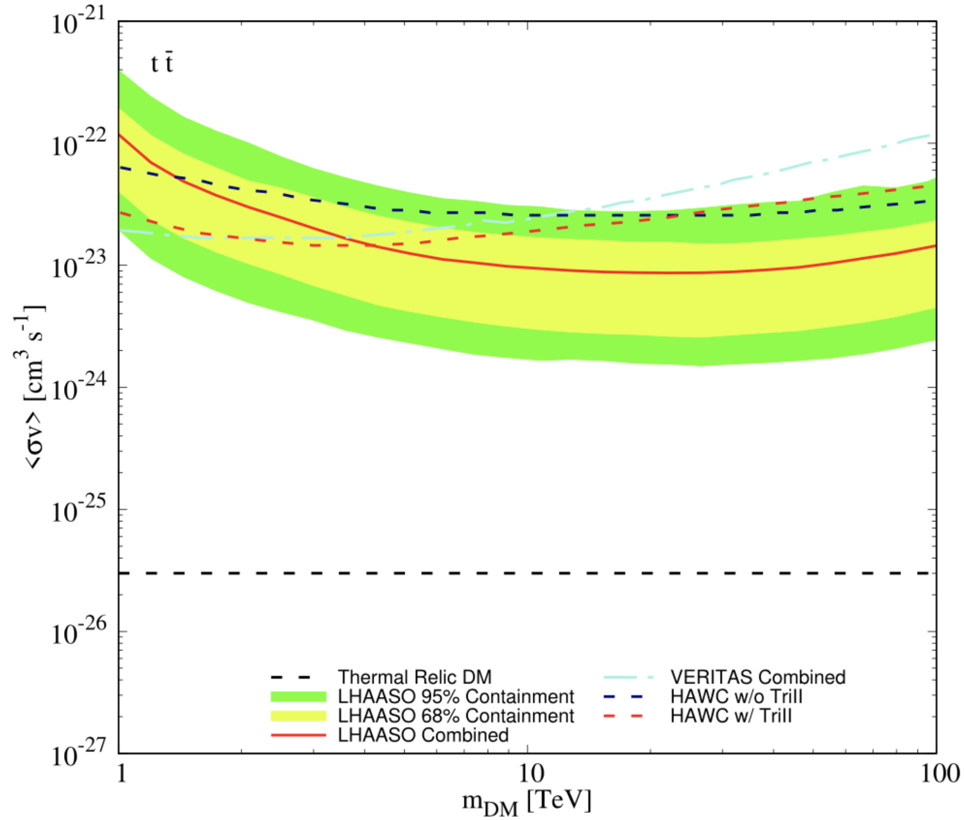
The CTA Consortium, JCAP 02 (2021) 048, 2021 [arXiv:2010.01349]

LHAASO

Mt. Haizi 4410 altitude

Combined one-year LHAASO sensitivities

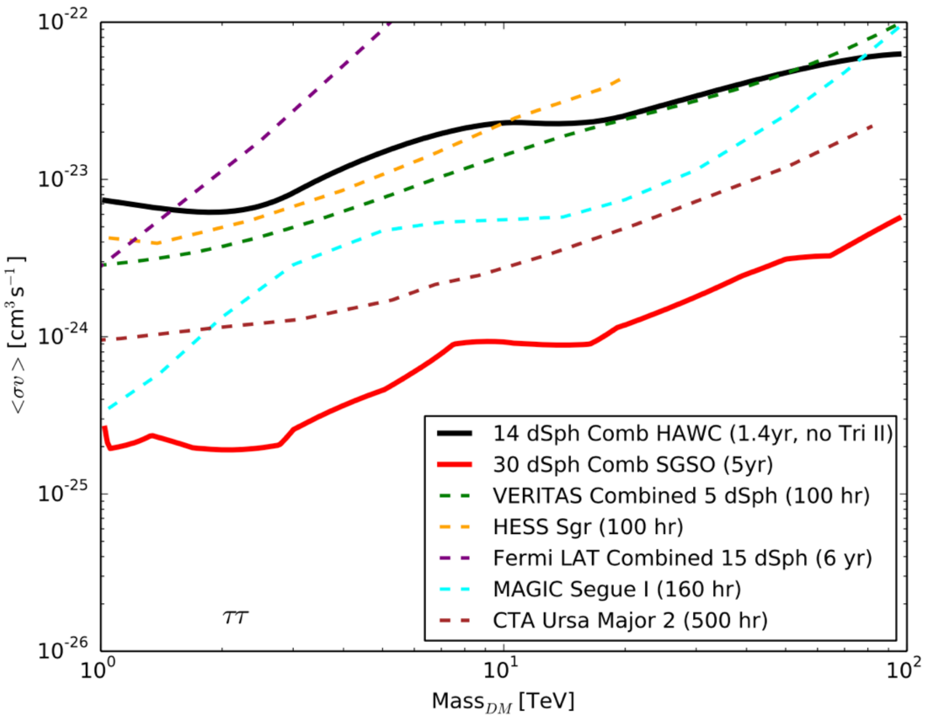


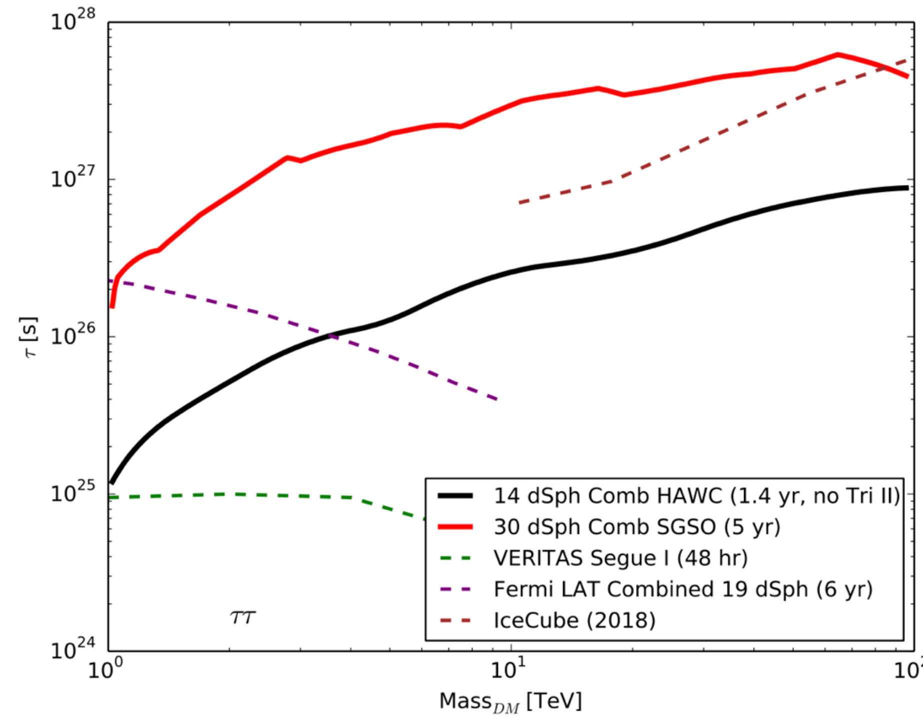


The LHAASO median combined sensitivities (red solid lines) and related two-sided 68% (yellow bands) and 95% (green bands) containment bands of one year for the $b\bar{b}$, $\bar{t}t$ for 19 dSphs within the LHAASO FOV

Dong-Ze He et al., Phys. Rev. D 100, 083003 (2019)

SWGO sensitivities

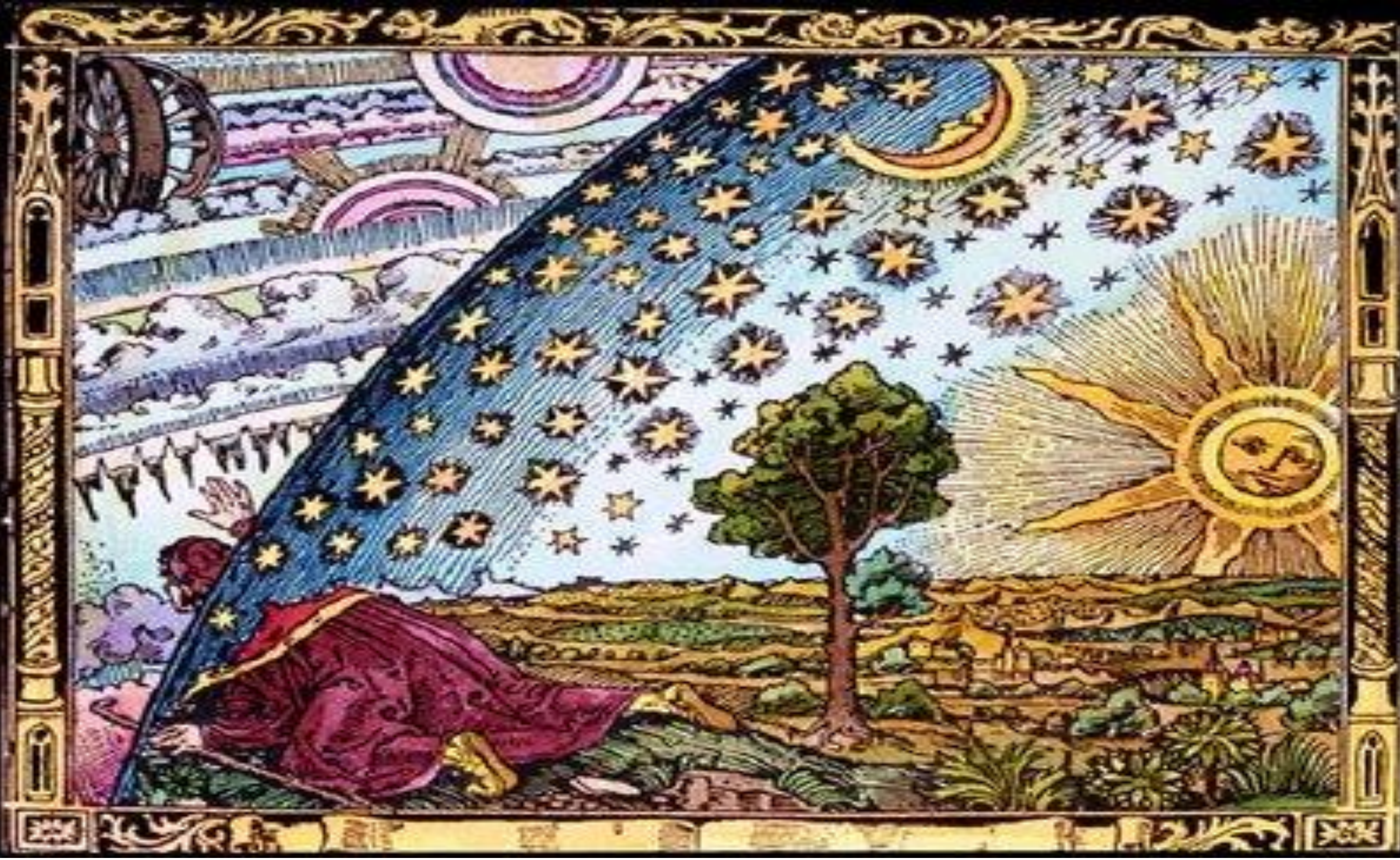


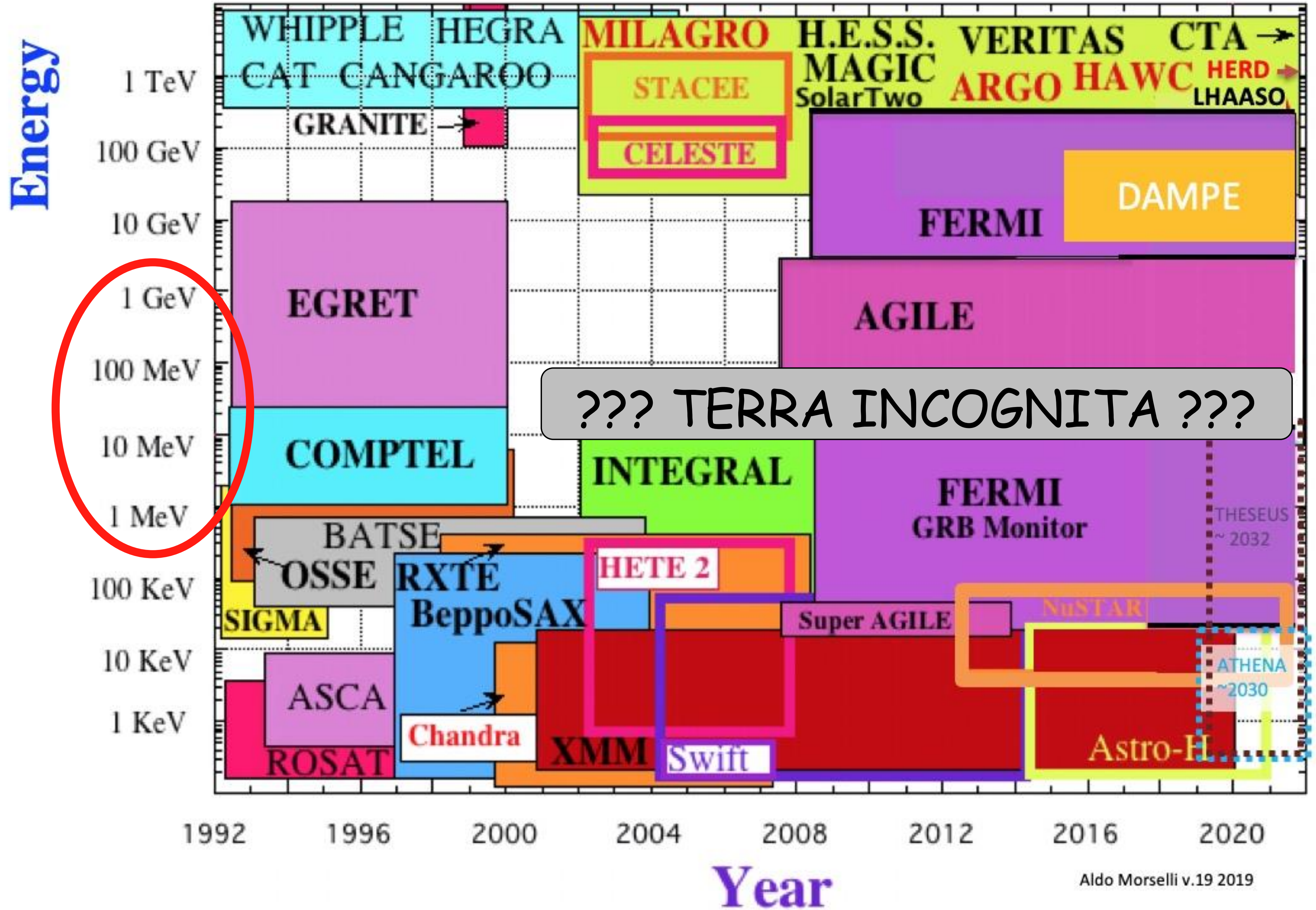


Assumed new dSph discovery and
J-factor and D-factor distributions of the new dSphs matches that of the previously known dSphs

SWGO White paper arXiv:1902.08429

The Low Energy Frontier



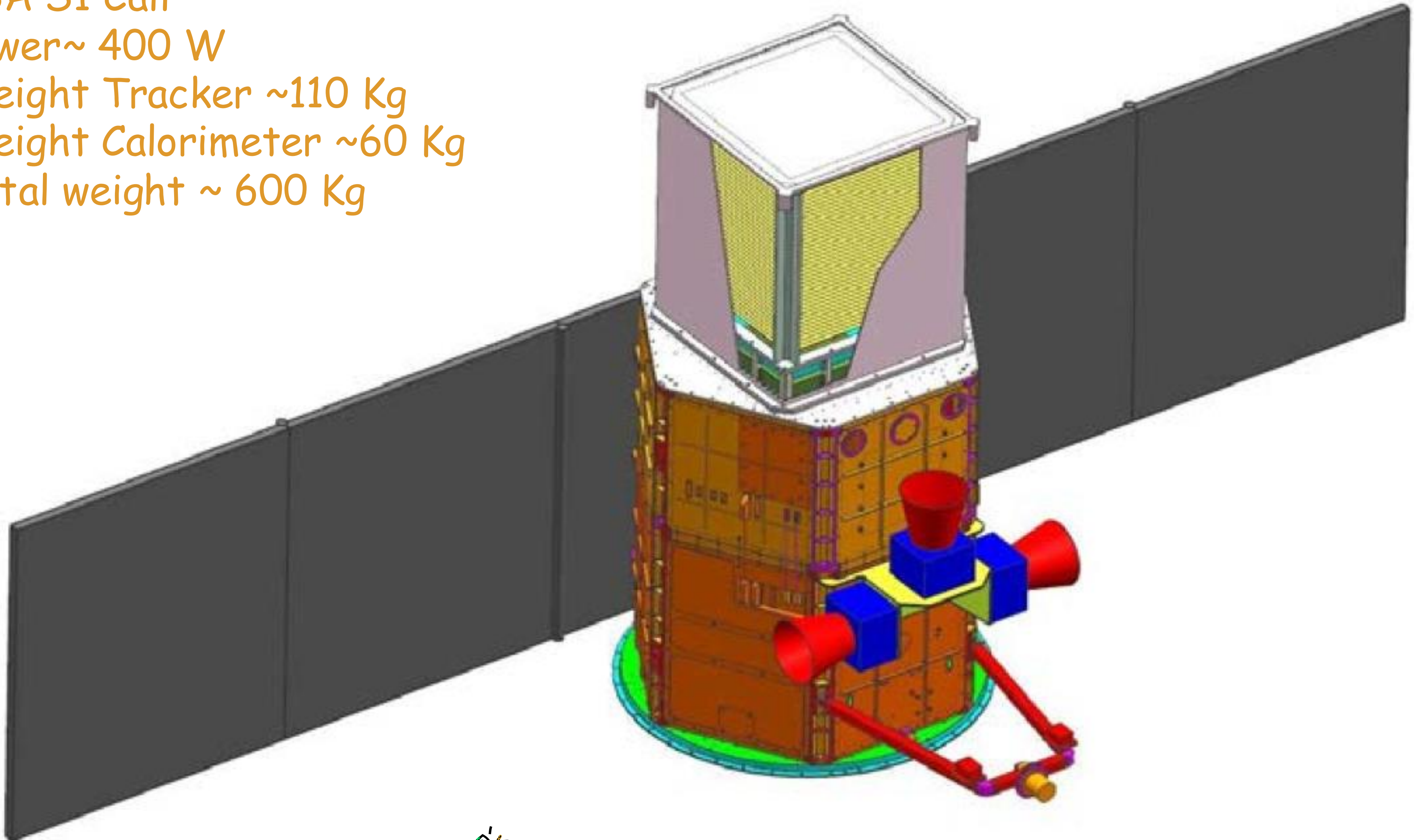


Energy
1 TeV
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
100 KeV
10 KeV
1 KeV
WHIPPLE HEGRA
CAT CANGAROO
GRANITE
MILAGRO
STACEE
CELESTE
H.E.S.S.
MAGIC
SolarTwo
VERITAS
CTA
ARGO
HAWC
HERD
LHAASO
DAMPE
FERMI
EGRET
AGILE
??? TERRA INCOGNITA ???
COMPTEL
INTEGRAL
FERMI
GRB Monitor
THESEUS
~ 2032
BATSE
OSSE
RXTE
BeppoSAX
HETE 2
SIGMA
Super AGILE
NuSTAR
ASCA
Chandra
XMM
Swift
ATHENA
~2030
Astro-H
ROSAT
1992
1996
2000
2004
2008
2012
2016
2020
Year
Aldo Morselli v.19 2019

- 1-100 MeV unexplored domain for
  - Dark Matter searches
  - Galactic compact stars and nucleosynthesis
  - Cosmic rays
  - Relativistic jets, microquasars
  - Blazars
  - Gamma-Ray Bursts
  - Solar physics
- and…
  - Terrestrial Gamma-Ray Flashes

Gamma-light project

ESA S1 Call
Power~ 400 W
Weight Tracker ~110 Kg
Weight Calorimeter ~60 Kg
Total weight ~ 600 Kg



A.Morselli et al. , Nuclear Physics B Proc. Supp. 239–240 (2013) 193-198 [arXiv:1406.1071]

Gamma-light scheme

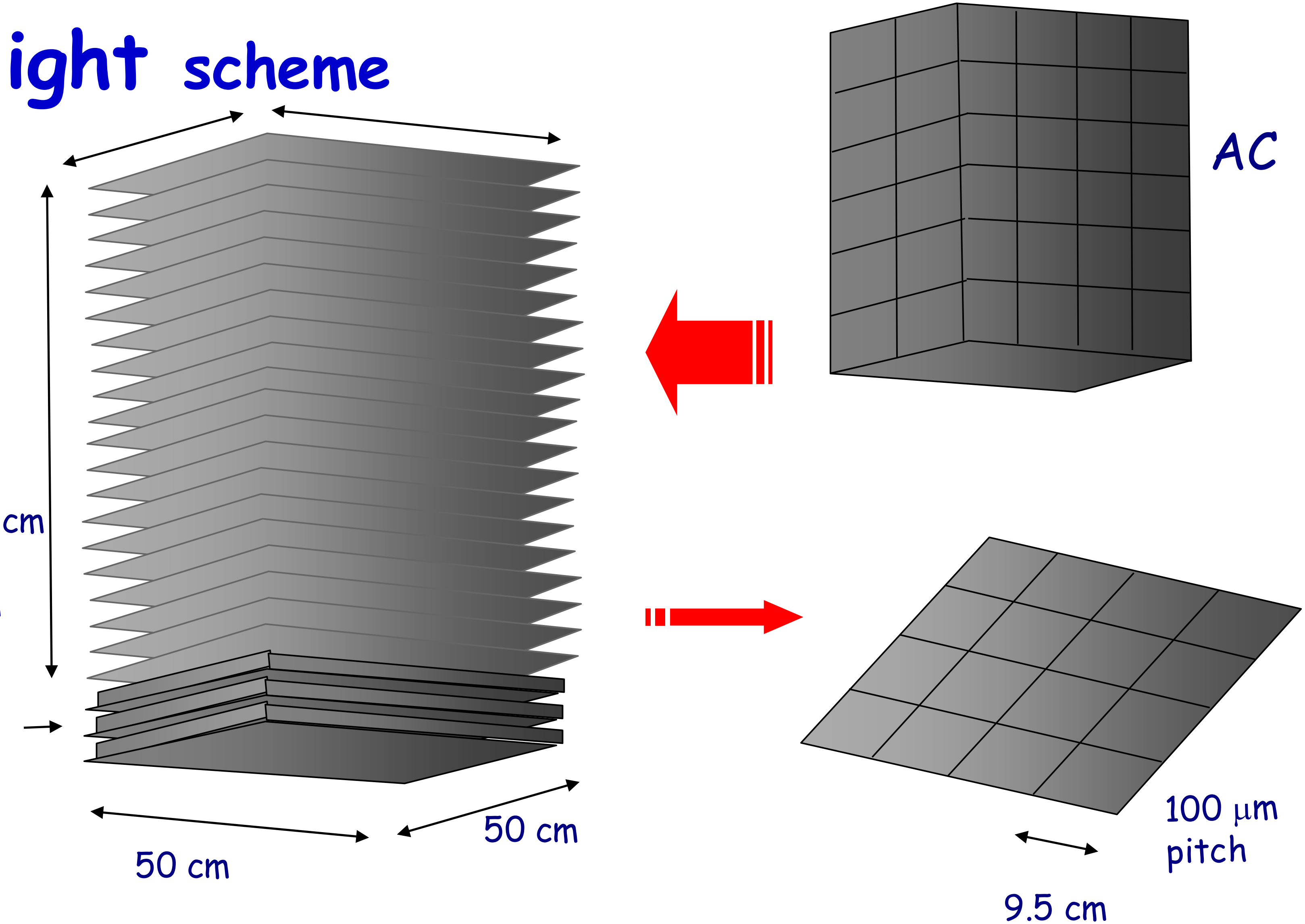
40+1 x-y planes
100 μm pitch
each
~0.025 X_0

Tot~ 1 X_0

54.7 cm

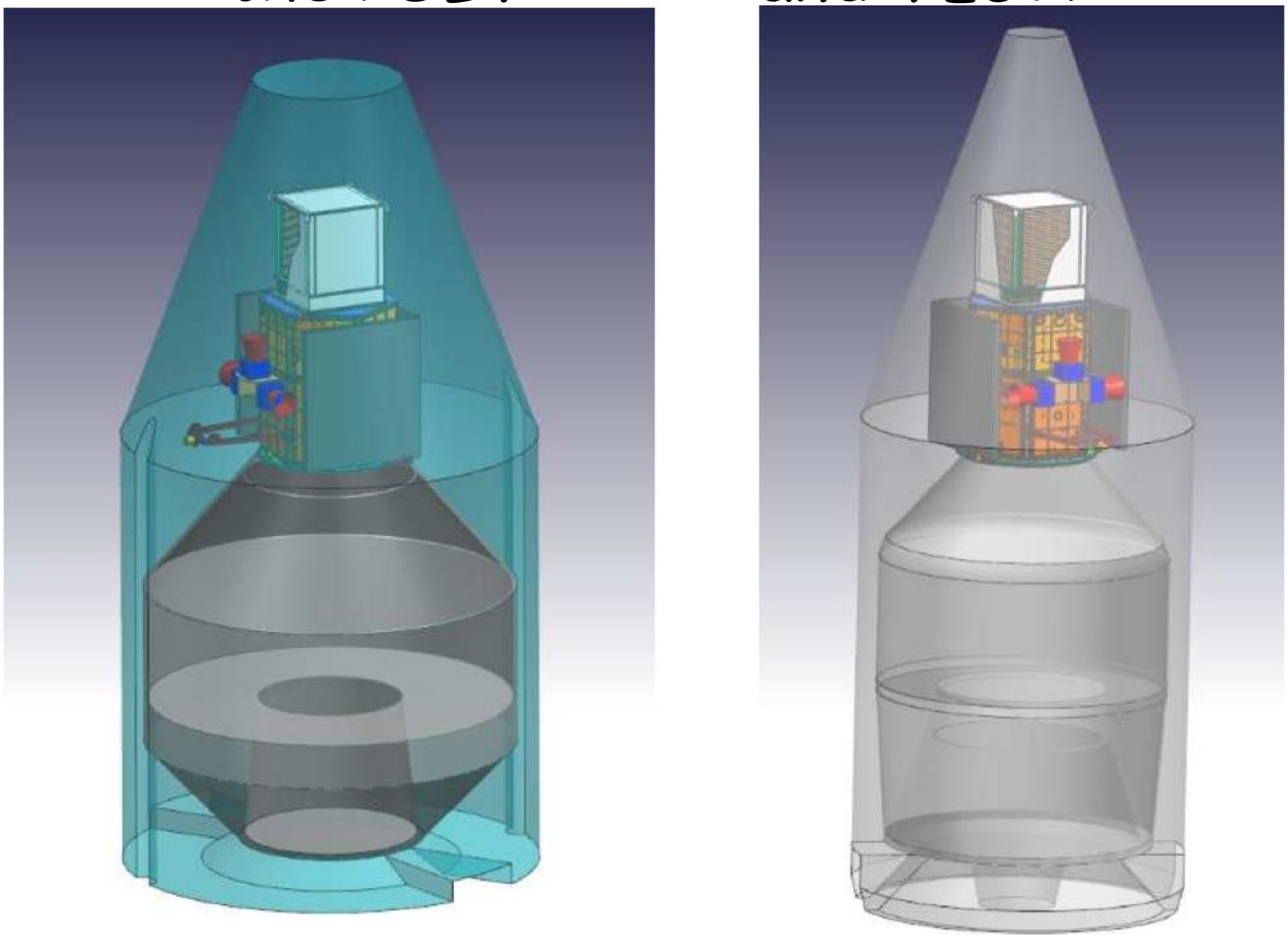
height of a plane 1.3 cm

2 Xo Calorimiter



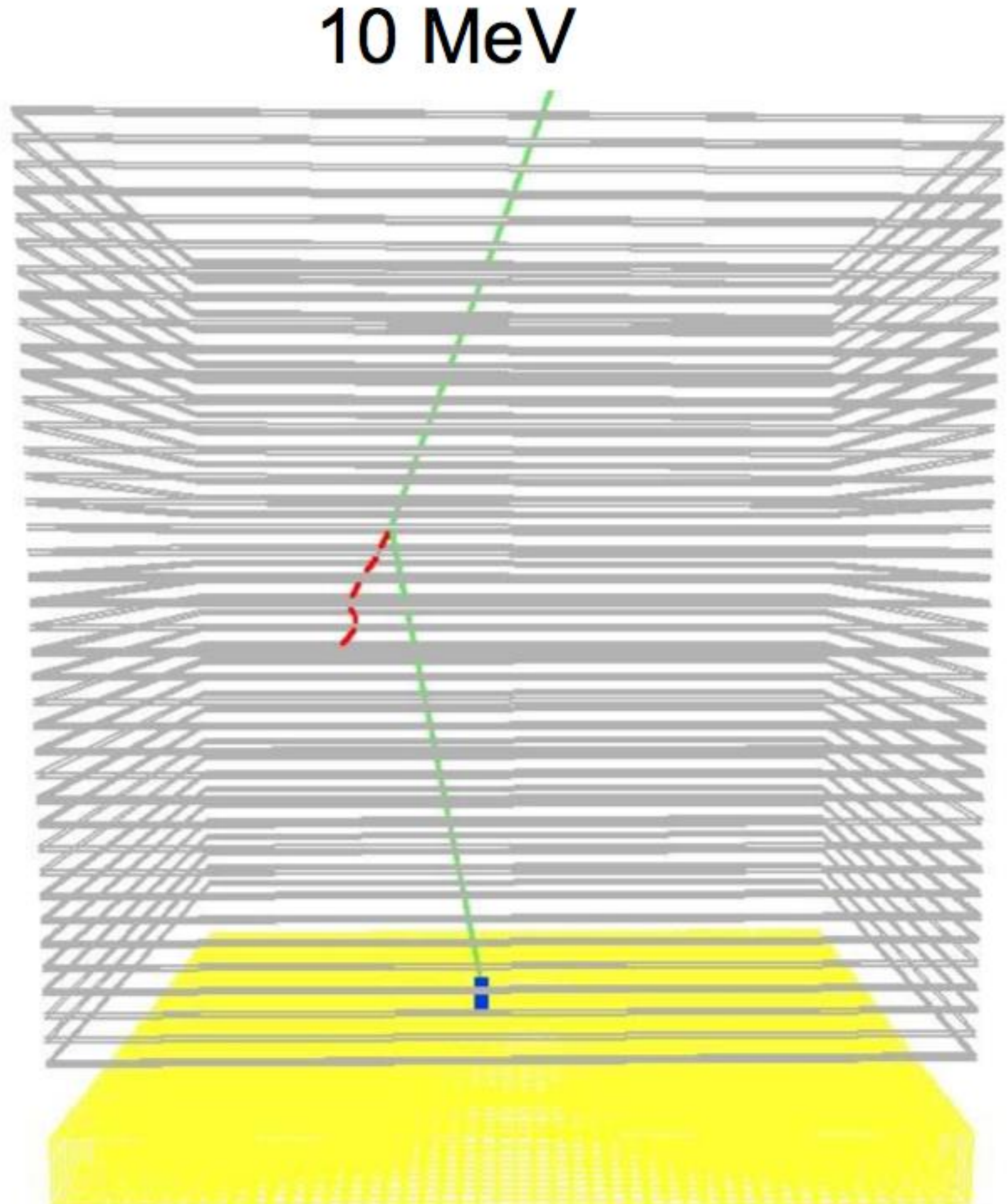
*Compton scattering **and** pair production telescope*

GAMMA-LIGHT satellite launch configurations for the PSLV and VEGA



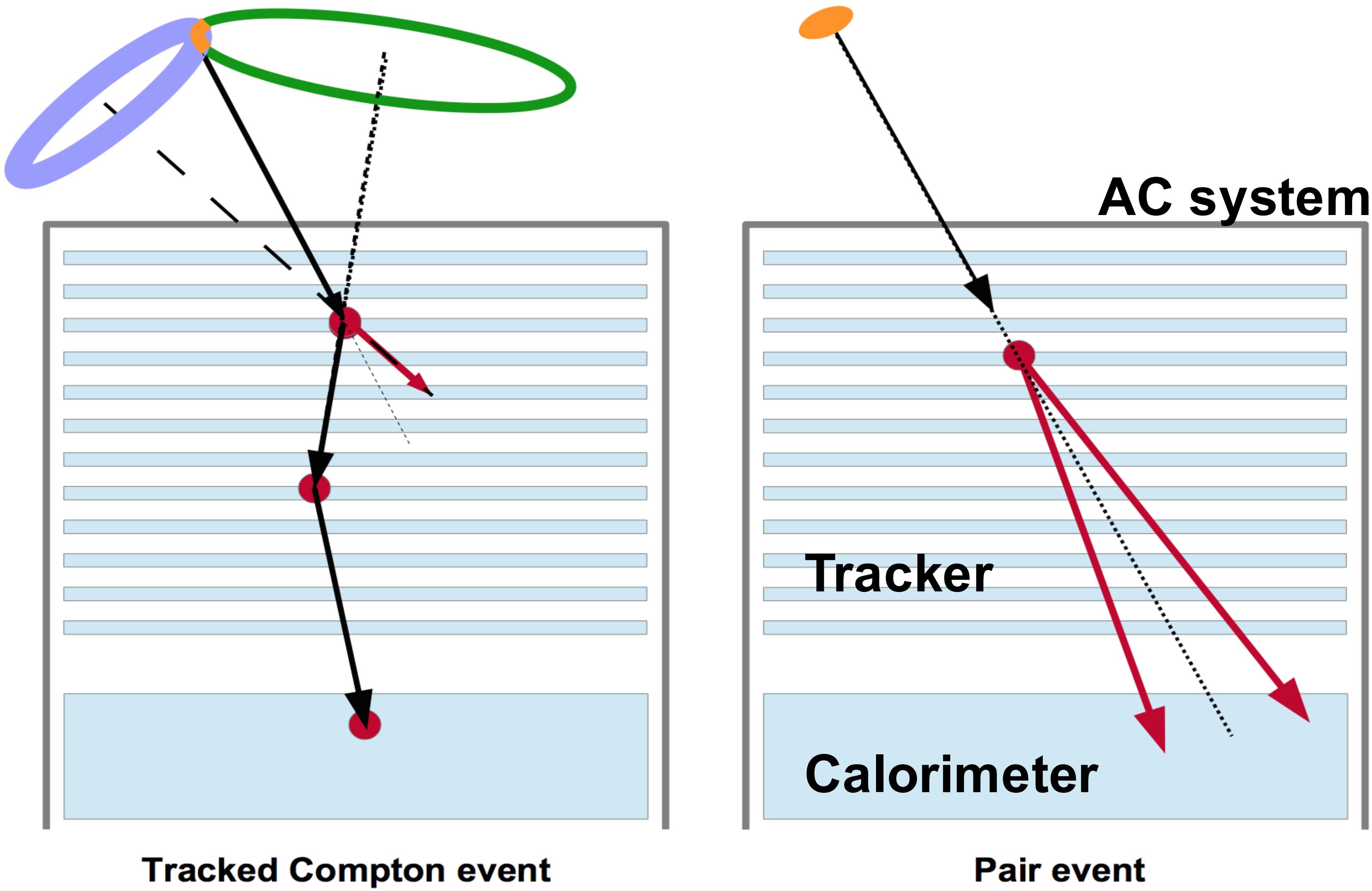
- a companion satellite similar to G-LIGHT can be accomodated.

G-LIGHT Simulation

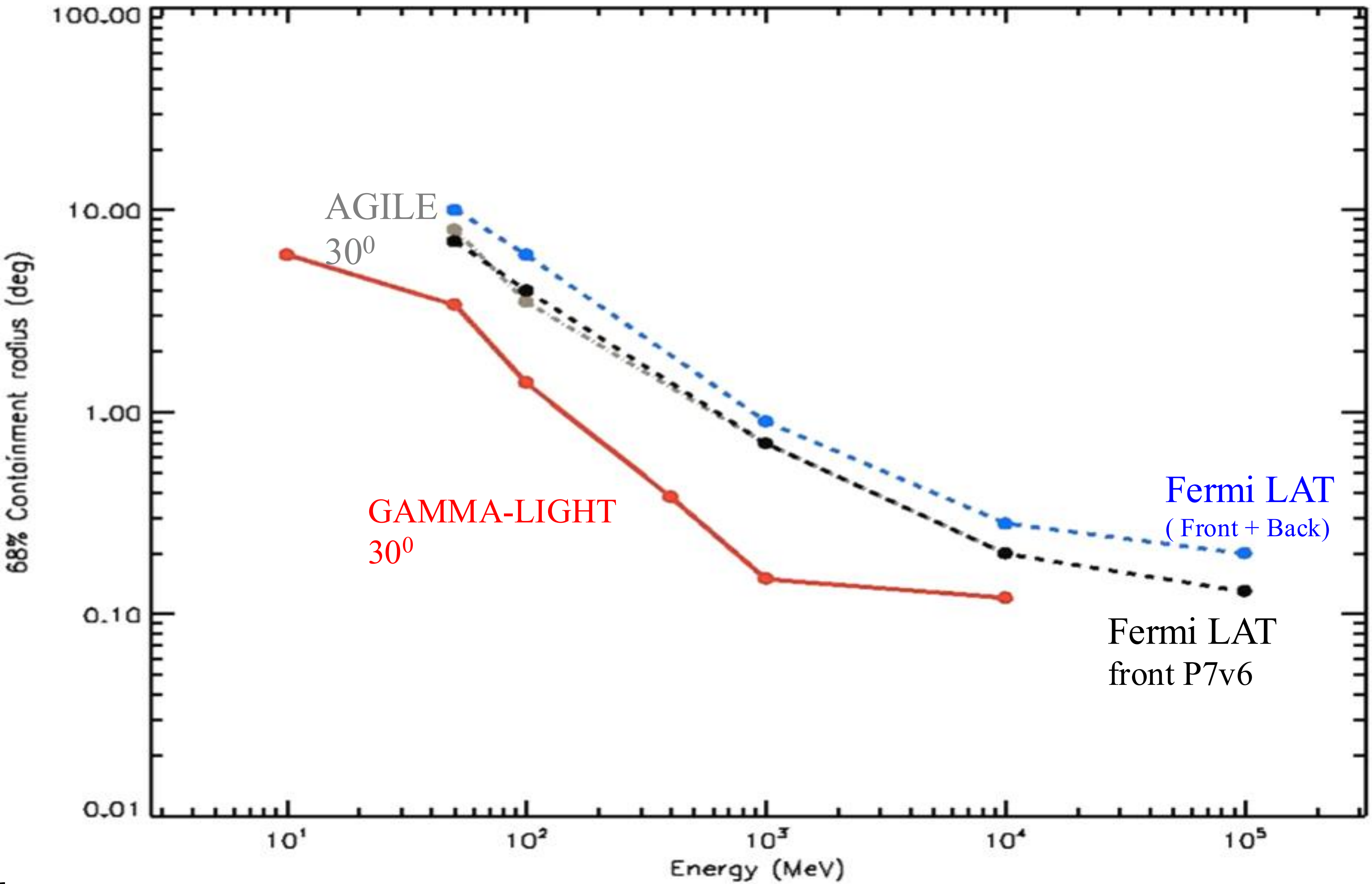


Compton interaction of a 10 MeV photon producing a low-energy single-track electron, and depositing energy in the Calorimeter for a 30^0 incidence

An instrument that combine two detection techniques



Gamma-Light Point Spread Function (angular resolution)



A.Morselli et al. , Nuclear Physics B Proc. Supp. 239–240 (2013) 193-198 [arXiv:1406.1071]

newASTROGAM

Proposed for ESA M8 Call

Detector paper: Exp. Astronomy 2017, 44, 25 arXiv:1611.02232
Science White Book: arXiv:1711.01265 (213 pages)

Summary

- Indirect search of Dark Matter with gamma rays is complementary to all other research in the underground laboratories and at LHC
- CTA, SWGO and LHAASO can explore the high -energy domain
- Fermi is still in orbit but we need a new mission

with a focus in the low energy range (below 100 MeV)

- The whole astroparticle-multimessenger community is expecting a mission after Fermi

The energy band just below Fermi energy is not explored since Comptel.

We submitted Gemma to the ASI small mission program

We hope that everybody will help in any possible way to have that mission approved.

thank you !