Search for DM signatures from dSphs with LHAASO-WCDA

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Shanghai

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Contents

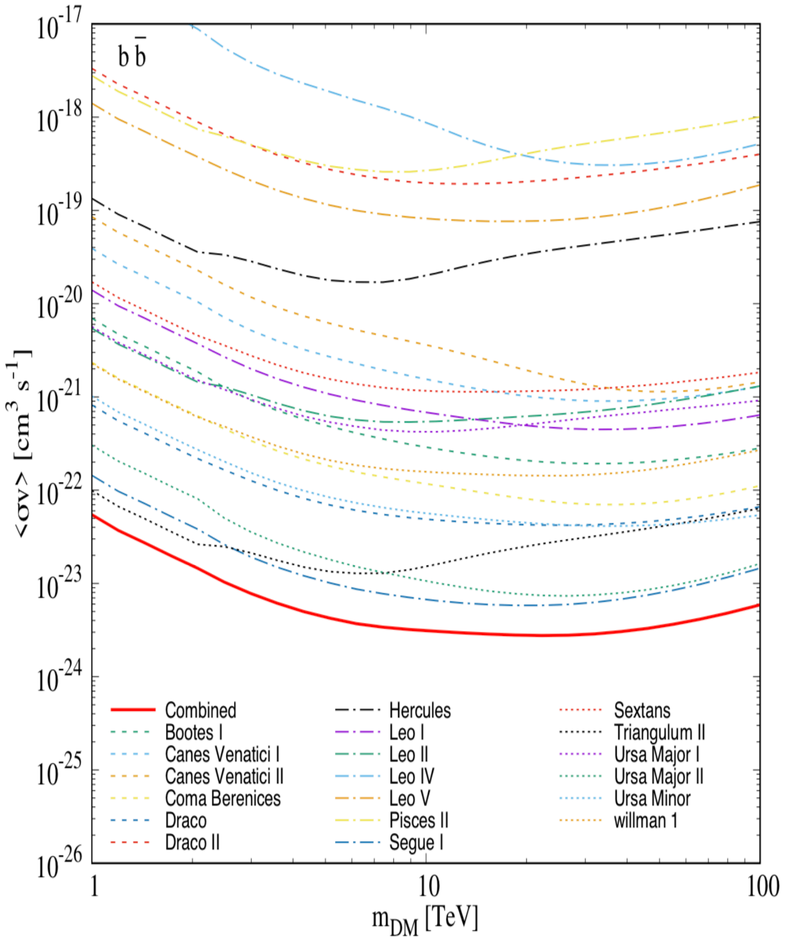
Dark matter indirect detection in dSphs

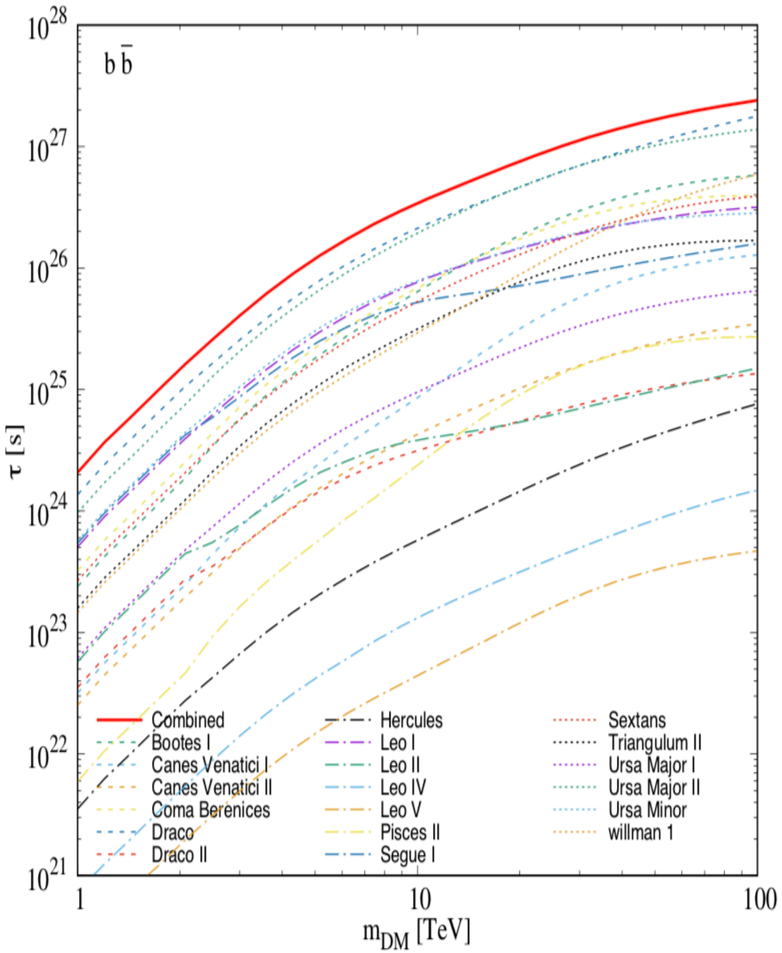
- Very large mass-to-light ratios
- Free of gamma ray contaminants
- Annihilation or decay of cold dark matter

LHAASO sensitivities

- Large FOV to involve more dSphs
- Background rejection
- Energy Range: 300GeV - 100TeV

Expected result by LHAASO-WCDA, 1 year full array





arxiv:1903.11910v2

- **Data**
  2020.6.1~2020.12.31 WCDA pool#1 *Gamma sample(pre-G/P cut)*
  effective time: 189.96 transits
  reconstruction version *CSZ*
  MC sample 0.1TeV - 1000TeV

- **Selection criteria**
  WCDA Crab SED CPC
  recflag == 0 && nhitu > 100 && nfilt > 60 && zen_cn < 45 && compactness >10 && *dAngle[ibin] < psf[ibin]
  6 nfilt (rec energy) bins: 60-100, **100-200, 200-300, 400-500, 500-800**. ***One ~ above ten TeV***

- **Background Estimation**
  Equal-zenith Method: 6 off windows

- **Expected signals**

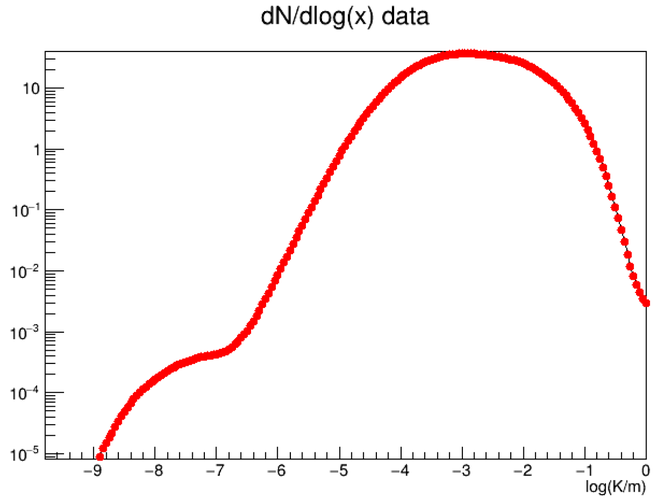
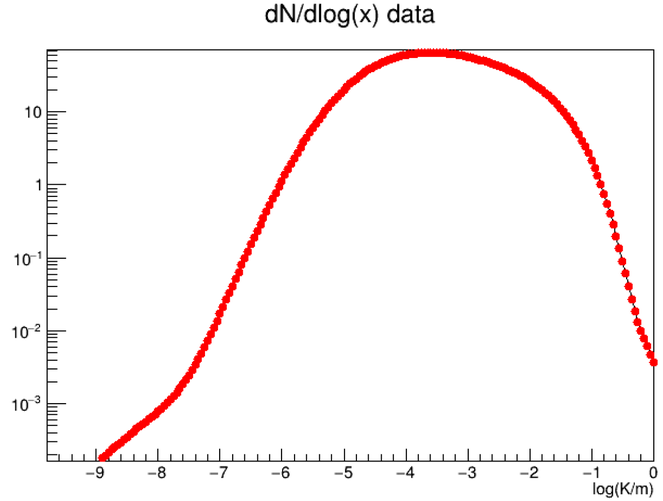
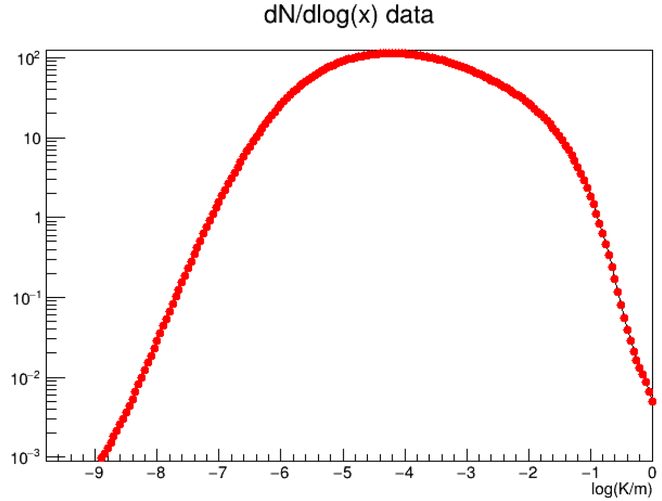
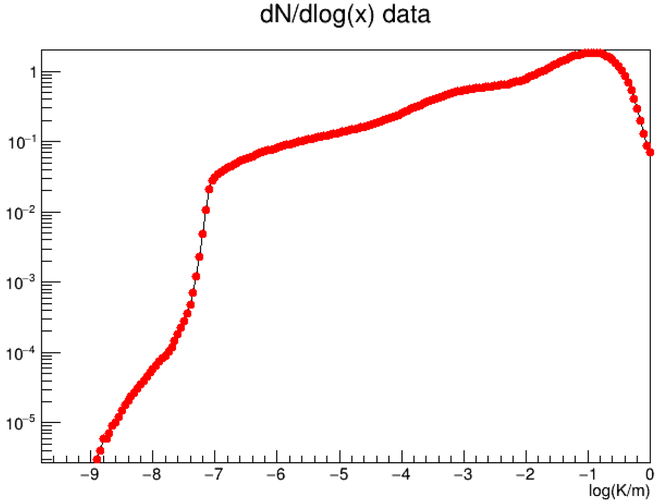
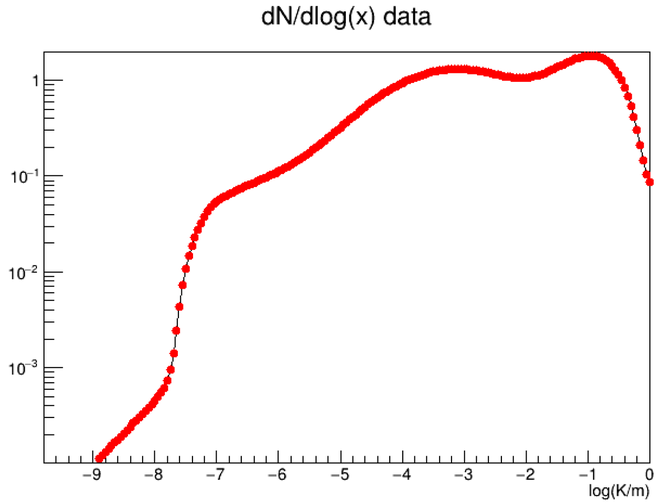
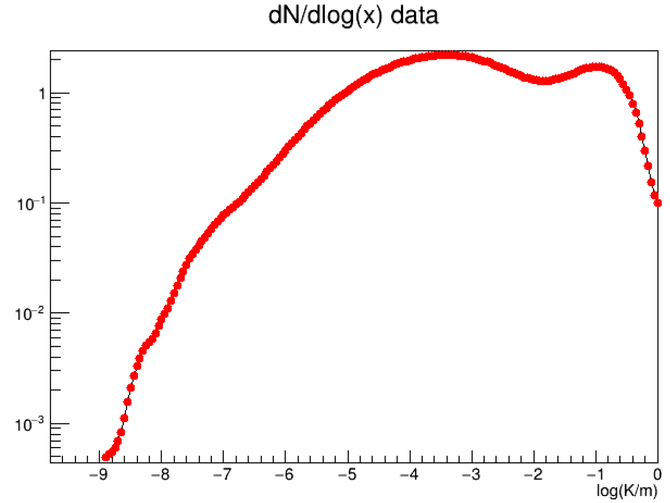
$$S = \epsilon_{\Delta\Omega} \int_{E_{\min}}^{E_{\max}} \int_0^T \Phi_\gamma(E) \cdot A_{\rm eff}^\gamma(E, \theta_{\rm zen}(t)) \cdot \varepsilon_\gamma(E) dt dE$$

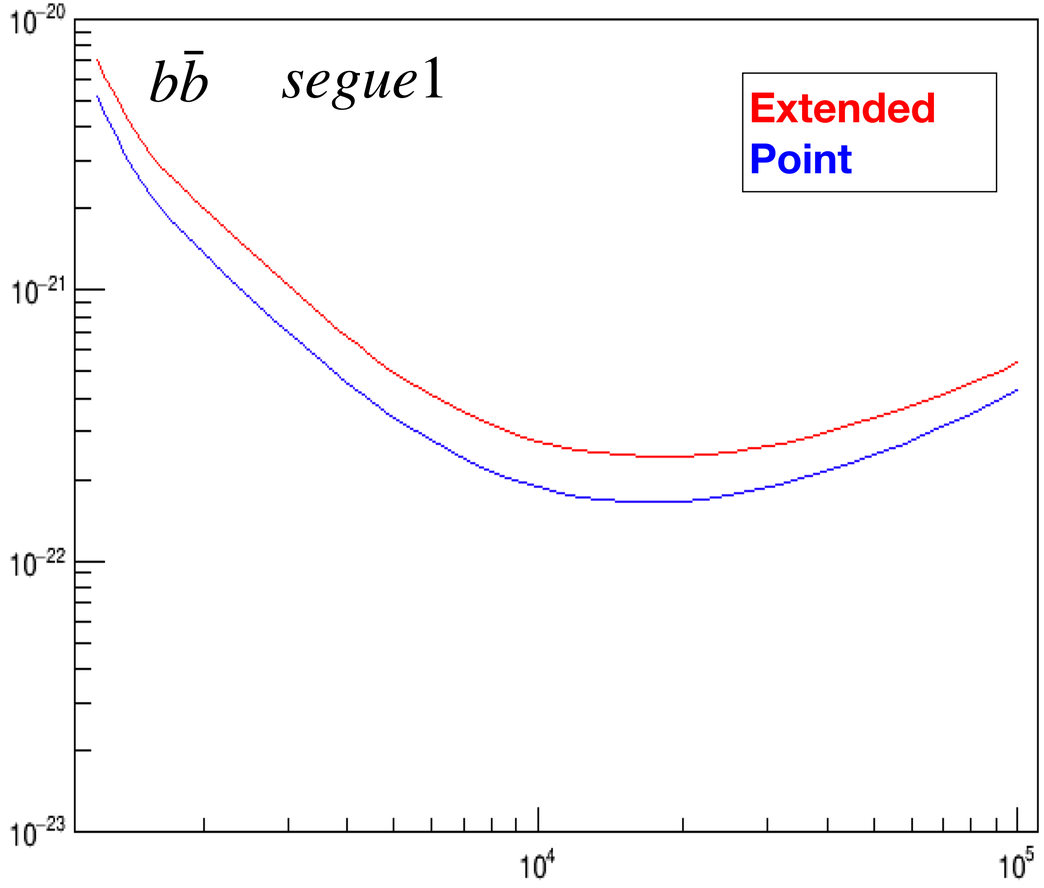
Decay $$\Phi = \frac{1}{4\pi} \frac{1}{m_\chi \tau} \int_{E_{\min}}^{E_{\max}} \frac{dN_\gamma}{dE_\gamma} dE_\gamma \times D, \qquad D = \int_{\rm source} d\Omega \int_{\rm l.o.s} dx \rho(r(\theta, x))$$

Annihilation $$\Phi = \frac{1}{4\pi} \frac{\langle \sigma v \rangle}{2m_\chi^2} \int_{E_{\min}}^{E_{\max}} \frac{dN_\gamma}{dE_\gamma} dE_\gamma \times J, \qquad J = \int_{\rm source} d\Omega \int_{\rm l.o.s} dx \rho^2(r(\theta, x))$$

using *PPPC4DM* or *HDSp*

Source	RA. (deg)	DEC. (deg)	$r_{\rm eff}$	$\theta_{\max}$ (deg)	$\log_{10} J_{\rm obs}$ ($\rm GeV^2 cm^{-5}$)
Boötes I	210.02	14.50	0.352	0.47	18.2 ± 0.4
Canes Venatici I	202.02	33.56	0.398	0.53	17.4 ± 0.3
Canes Venatici II	194.29	34.32	0.399	0.13	17.6 ± 0.4
Coma Berenices	186.74	23.90	0.377	0.31	19.0 ± 0.4
Draco	260.05	57.92	0.442	1.30	18.8 ± 0.1
Draco II*	238.20	64.56	0.451	–	18.1 ± 2.8
Hercules	247.76	12.79	0.348	0.28	16.9 ± 0.7
Leo I	152.12	12.30	0.346	0.45	17.8 ± 0.2
Leo II	168.37	22.15	0.372	0.23	18.0 ± 0.2
Leo IV	173.23	−0.54	0.303	0.16	16.3 ± 1.4
Leo V	172.79	2.22	0.314	0.07	16.4 ± 0.9
Pisces II*	344.63	5.95	0.327	–	16.9 ± 1.6
Segue 1	151.77	16.08	0.357	0.35	19.4 ± 0.3
Sextans	153.26	−1.61	0.299	1.70	17.5 ± 0.2
Triangulum II*	33.32	36.18	0.403	–	20.9 ± 1.3
Ursa Major I	158.71	51.92	0.432	0.43	17.9 ± 0.5
Ursa Major II	132.87	63.13	0.449	0.53	19.4 ± 0.4
Ursa Minor	227.28	67.23	0.455	1.37	18.9 ± 0.2
Willman 1*	162.34	51.05	0.430	–	19.5 ± 0.9

	$m_{DM} = 1TeV$	$m_{DM} = 10TeV$	$m_{DM} = 100TeV$
$b\bar{b}$			
$\tau^+\tau^-$			



Taking dSphs as extended source in this work

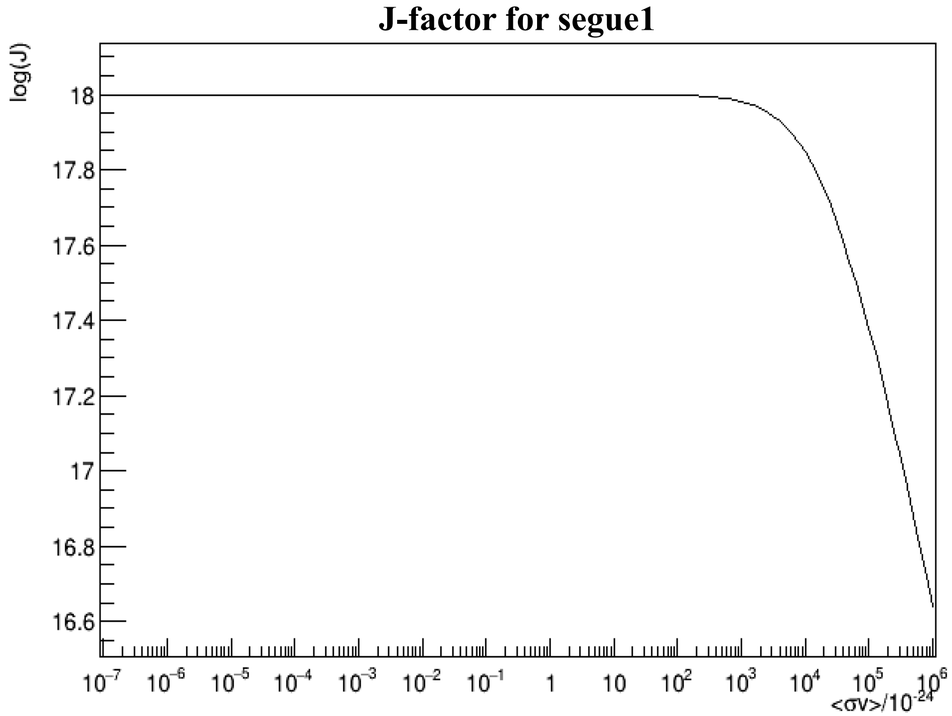
$$\theta = \sqrt{psf^2 + r_{ext}^2}$$

- **Likelihood analysis**

$$\mathscr{L}_j = Poisson(N_{obs_j}, N_{s_j} + N_{bkg_j}) \times \mathscr{J}(J_j \,|\, J_{obs_j}, \sigma_j)$$

Fixing σv, to maximize $\mathscr{L}_j$

to get J for every source

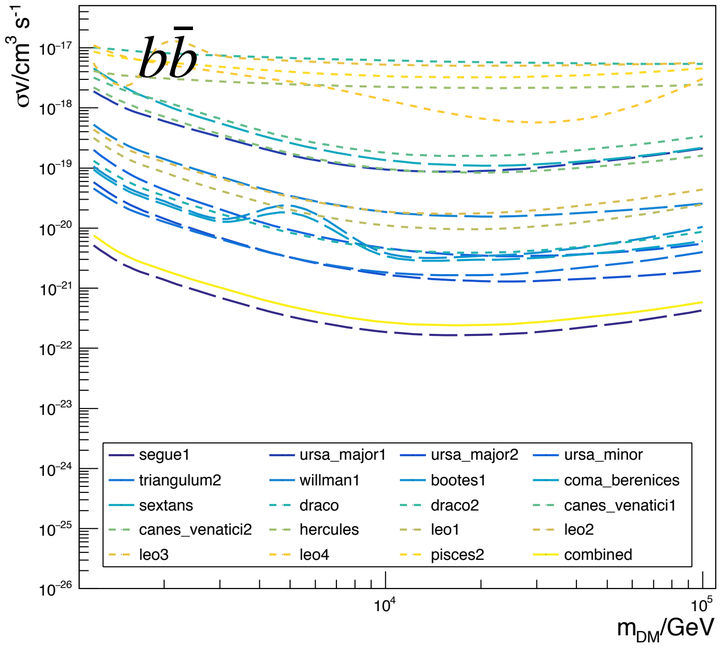


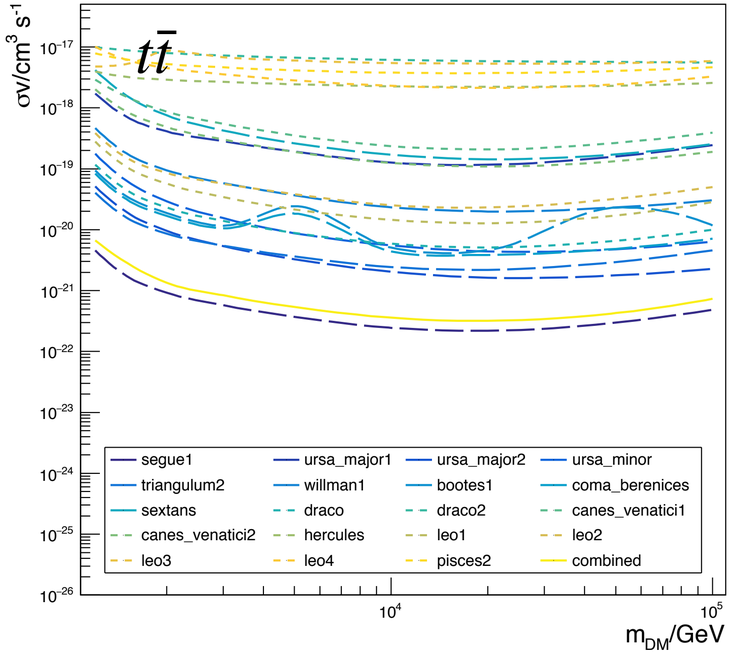
$$\mathscr{L} = \prod_{jsources} \mathscr{L}_j$$

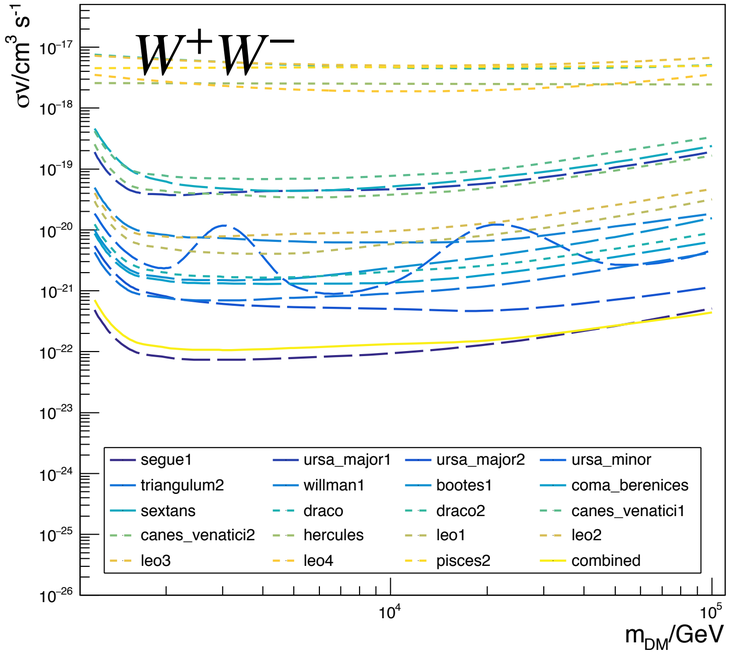
$$TS = -2\ln\frac{\mathscr{L}_0}{\mathscr{L}_{max}} \qquad \Delta TS = TS - TS_{95} = 2(ln\mathscr{L}_{max} - ln\mathscr{L}_{95}) = 2.71$$

TS_{95} at 95% C.L. would lead to a limit of parameters

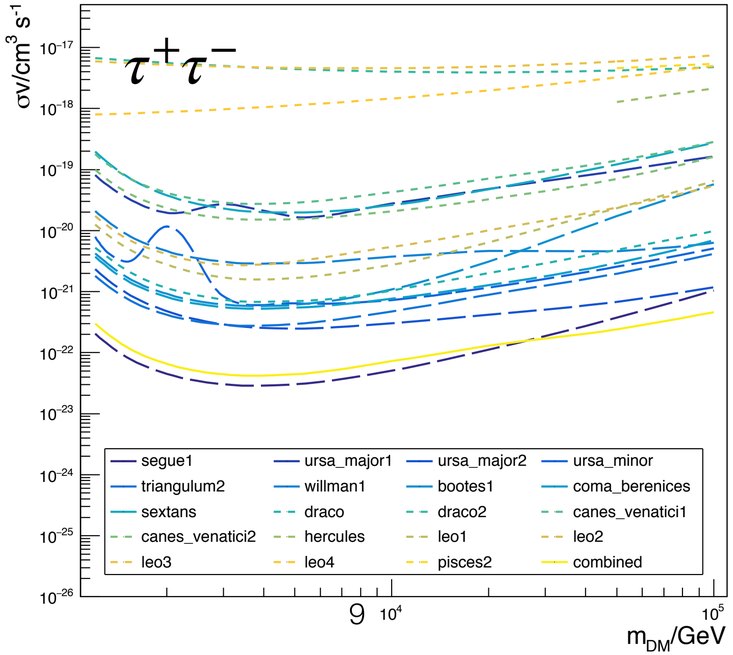
Result

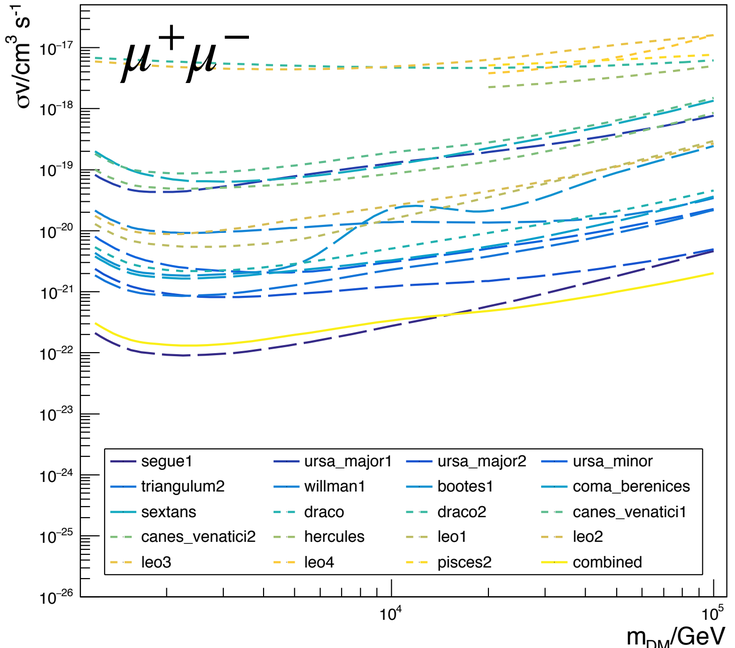




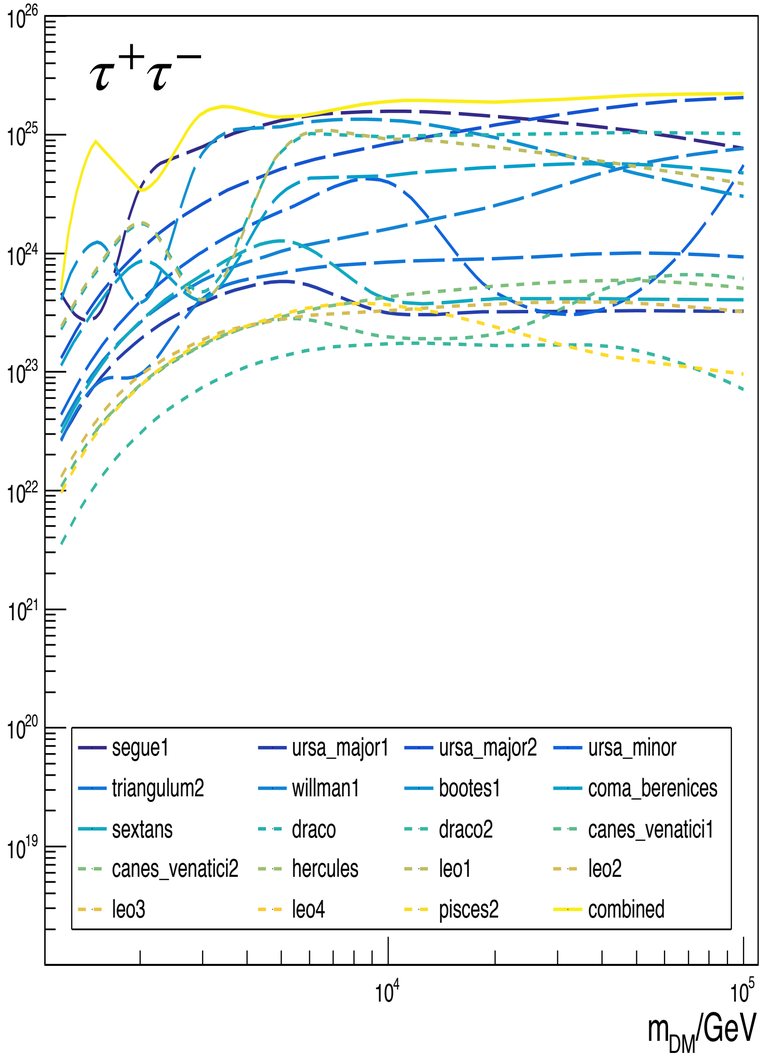


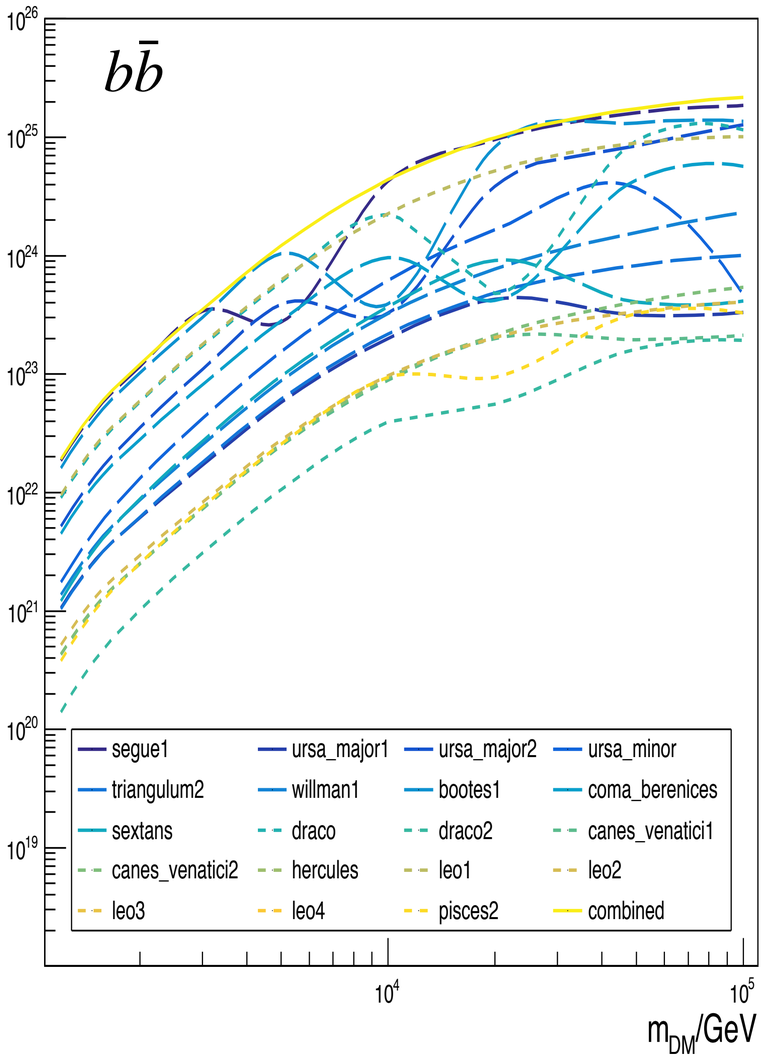
Annihilation
dSphs as EXTENDED sources

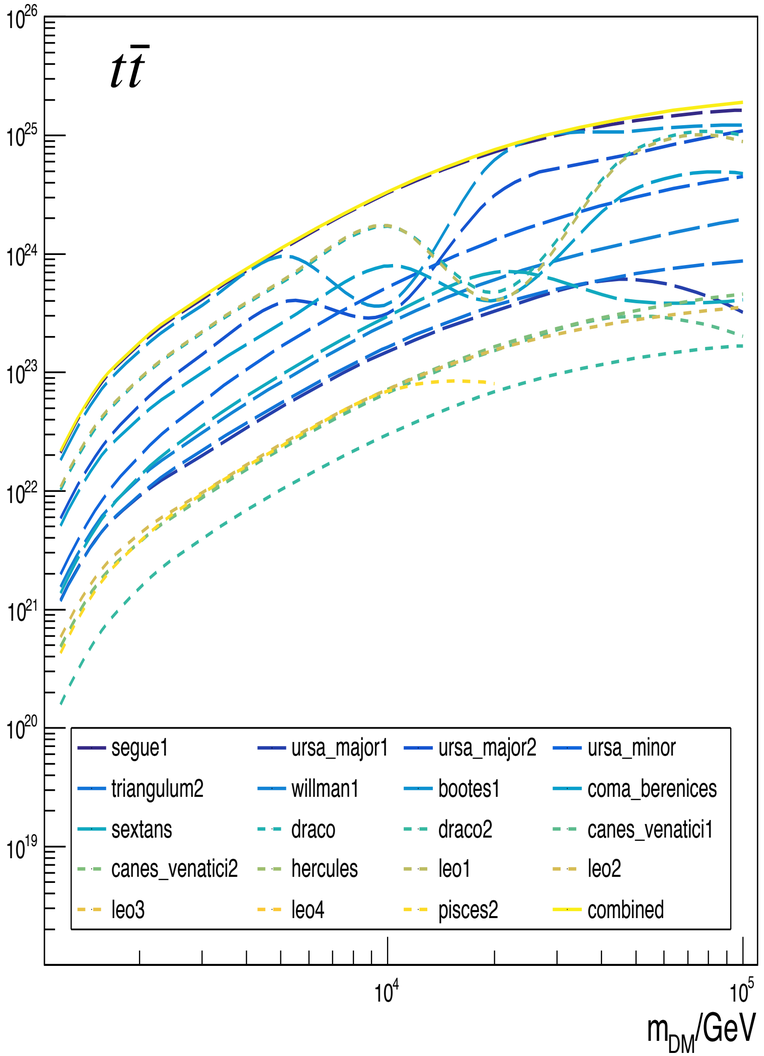




Decay
dSphs as EXTENTED sources







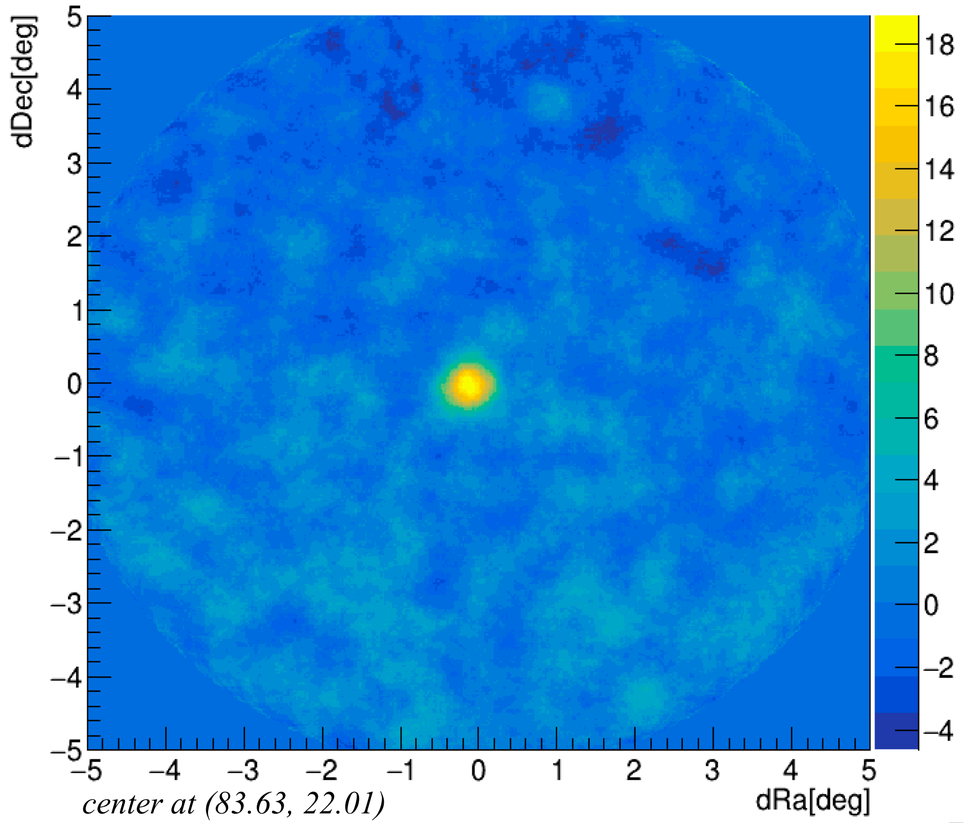
- **Data check using Crab**

Crab SED(Selection criteria same as *CPC*)

This work $\phi_0 = (2.06 \pm 0.26) \times 10^{-12}$ $\alpha = 2.52 \pm 0.09$ $\beta = 0.0025 \pm 1.14$

data from *Gamma sample*

CPC result $\phi_0 = (2.32 \pm 0.19) \times 10^{-12}$ $\alpha = 2.57 \pm 0.06$ $\beta = 0.02 \pm 0.05$



Why a decrease in significance

- The pre-G/Pcut lowers efficiency
- Events pulled towards pool#2

Conclusion & Discussion

- **Flux of gamma sources such as Crab would be lowered. However, it wouldn't drastically effect the result on DM .**

- **More lower energy events will greatly improve the result**

- **Forward**

  Full array data
  Combine with KM2A
  Remove gamma sources from skymap

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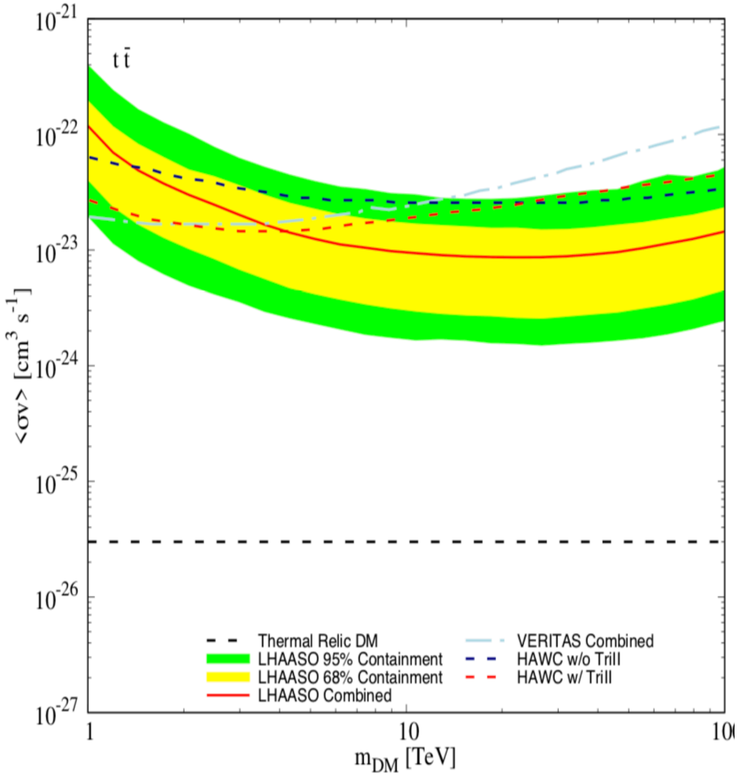
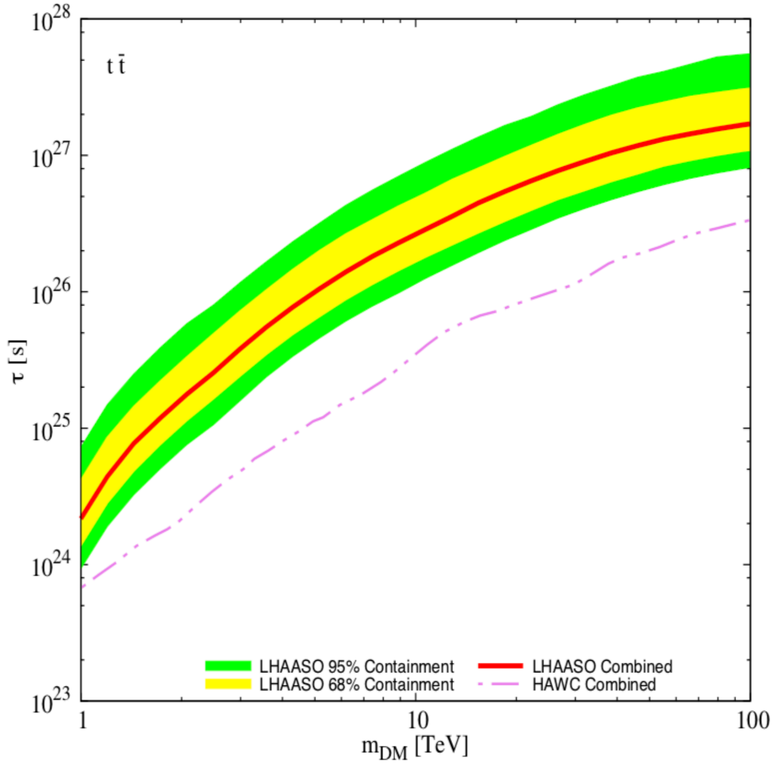




arxiv:1903.11910v2

Backup

- **Non, Noff from different sample data**

reconstructed from *Crab sample*

Period	Non	Noff	Ns
2020.3 -2020.10	11647	10029.67	1617.33
	2210	1721.67	488.33
	750	521	229
	194	123.5	70.5
	160	75.17	84.83

reconstructed from *Gamma sample*

Period	Non	Noff	Ns
2020.6 -2020.12	2961	2440.33	520.67
	938	680.17	257.83
	247	163.83	83.17
	80	36.67	43.33
	66	24.50	41.5

Raw data: /eos/lhaaso/rec/wcda/EventSelect/Rb/sampdata/Gamma/2020/0701/ES.52869.WCDA_EVENT.P110MC15_M2_Z.es-1.20200701000003.573.samp.root

on 12 off 68

…/Crab/2020/0701/…root

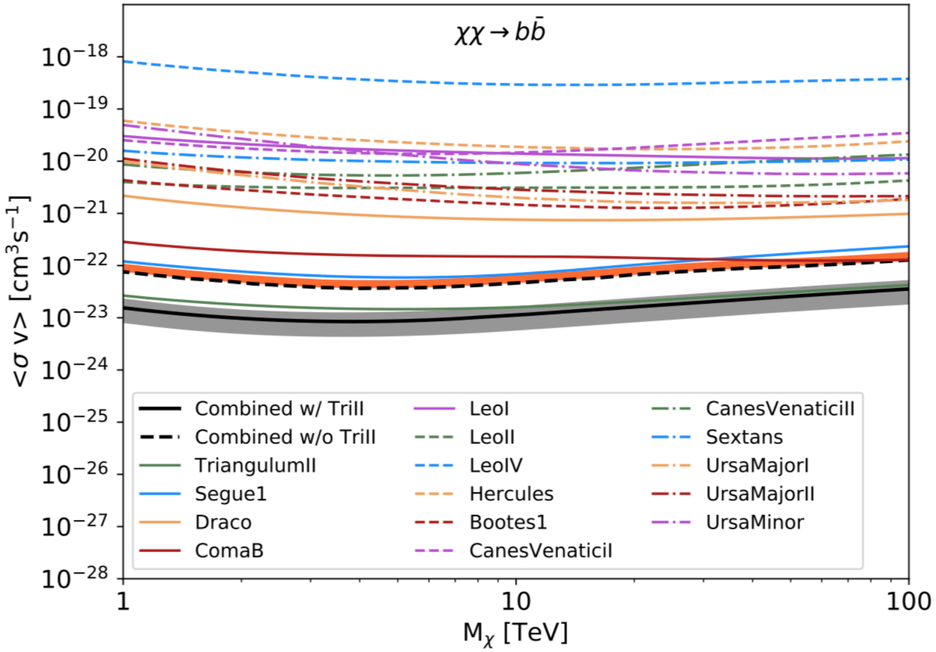
on 39 off 225

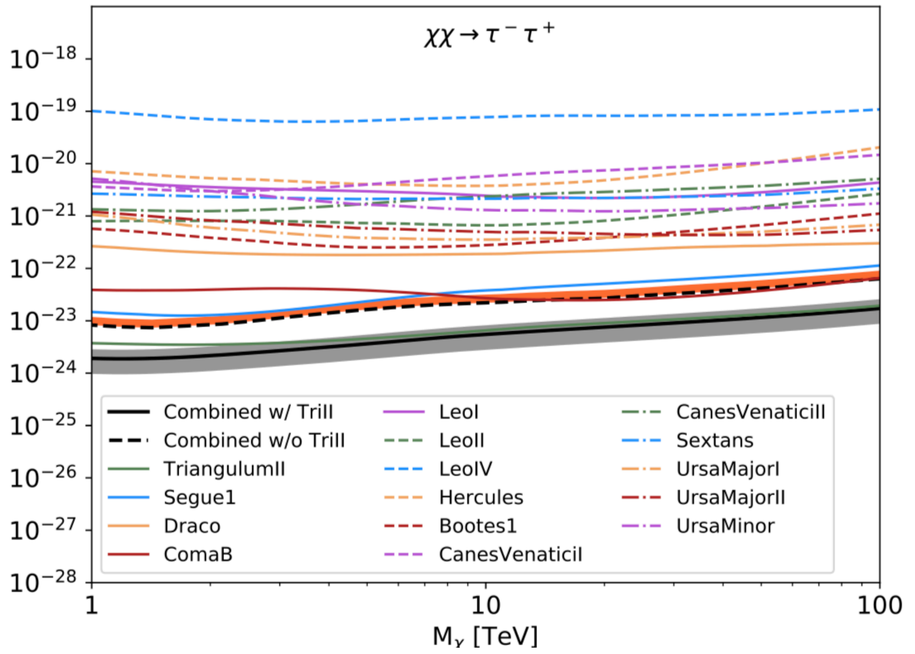
Annihilation

Previous limits by HAWC

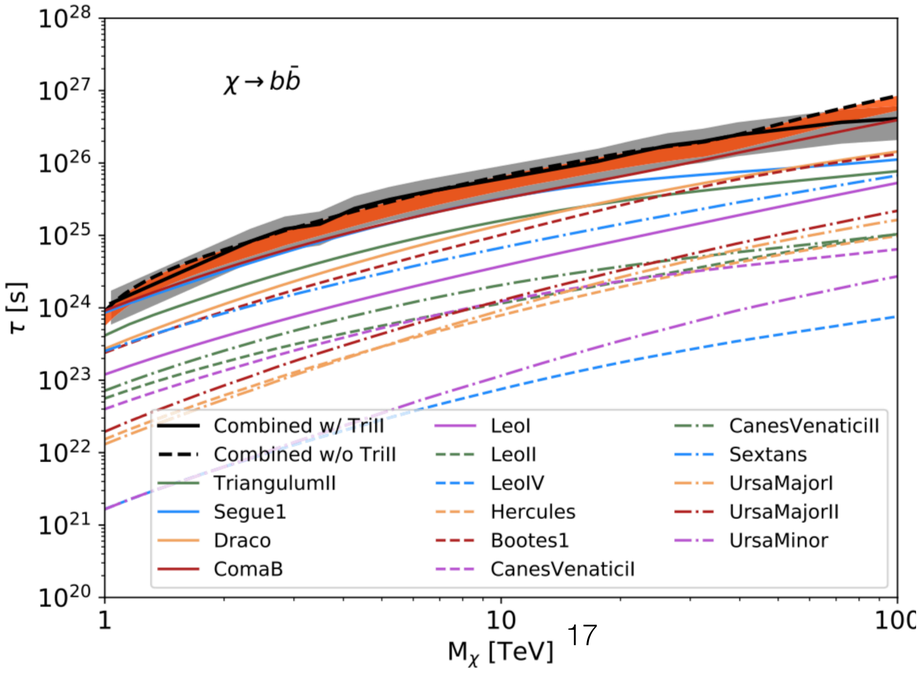
507days ~22000m^2 WCDs

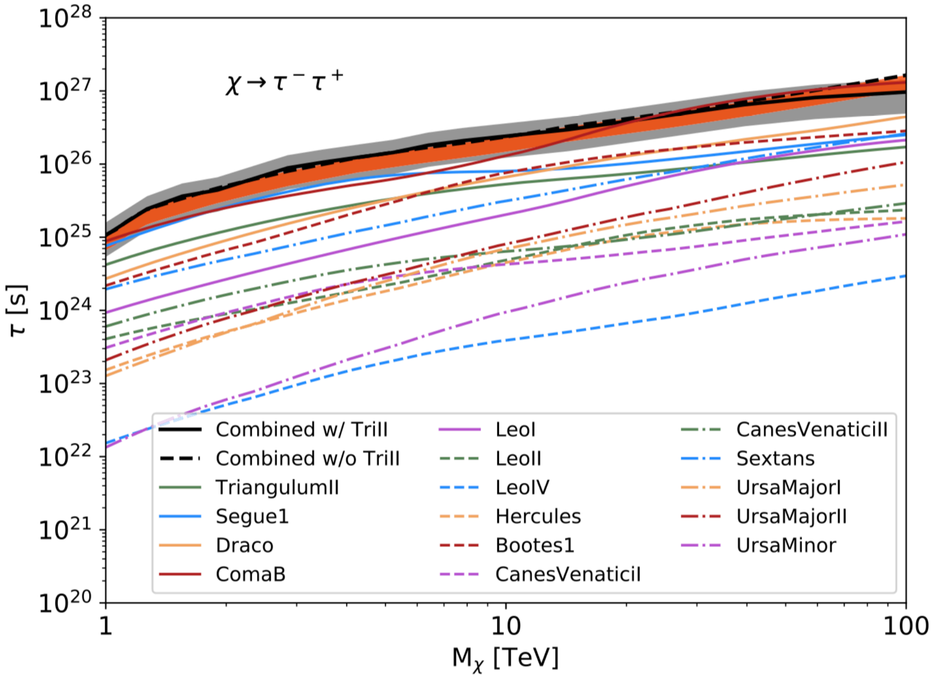
arxiv:1706.01277.



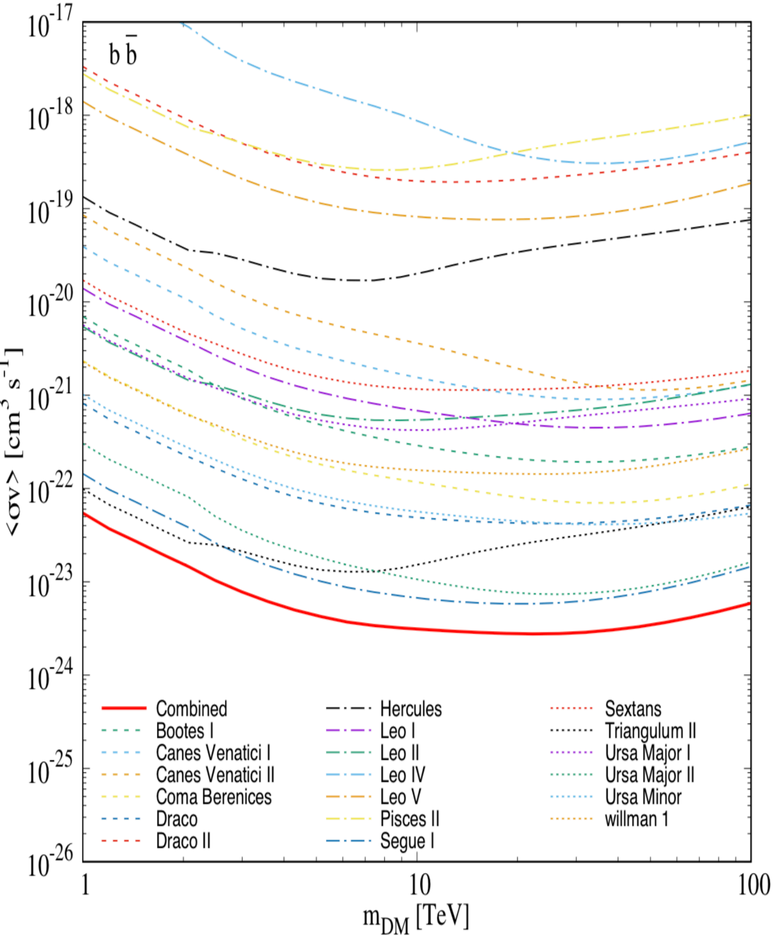


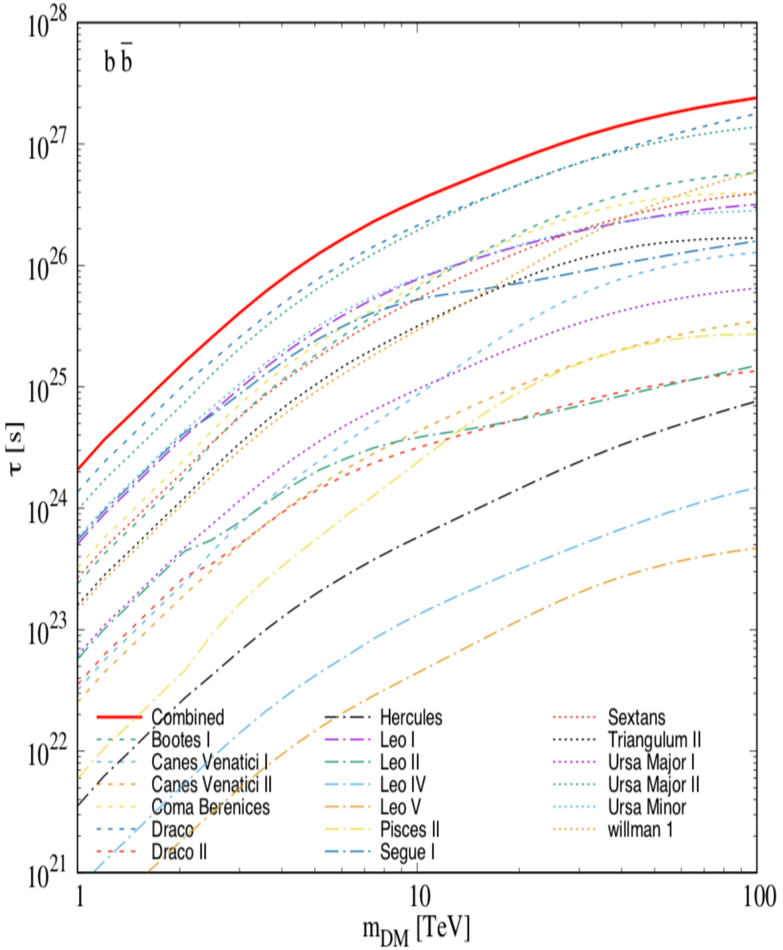
Decay

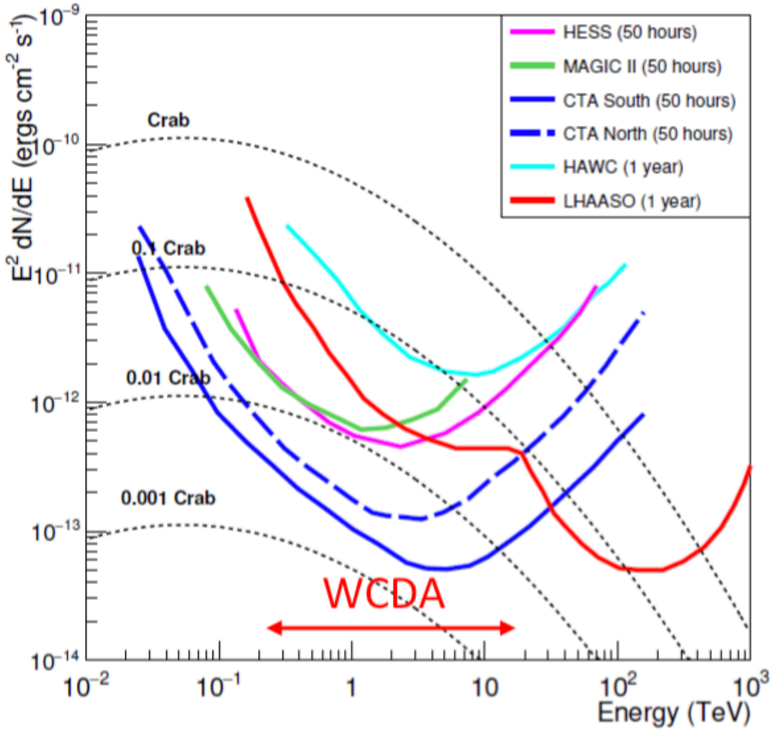




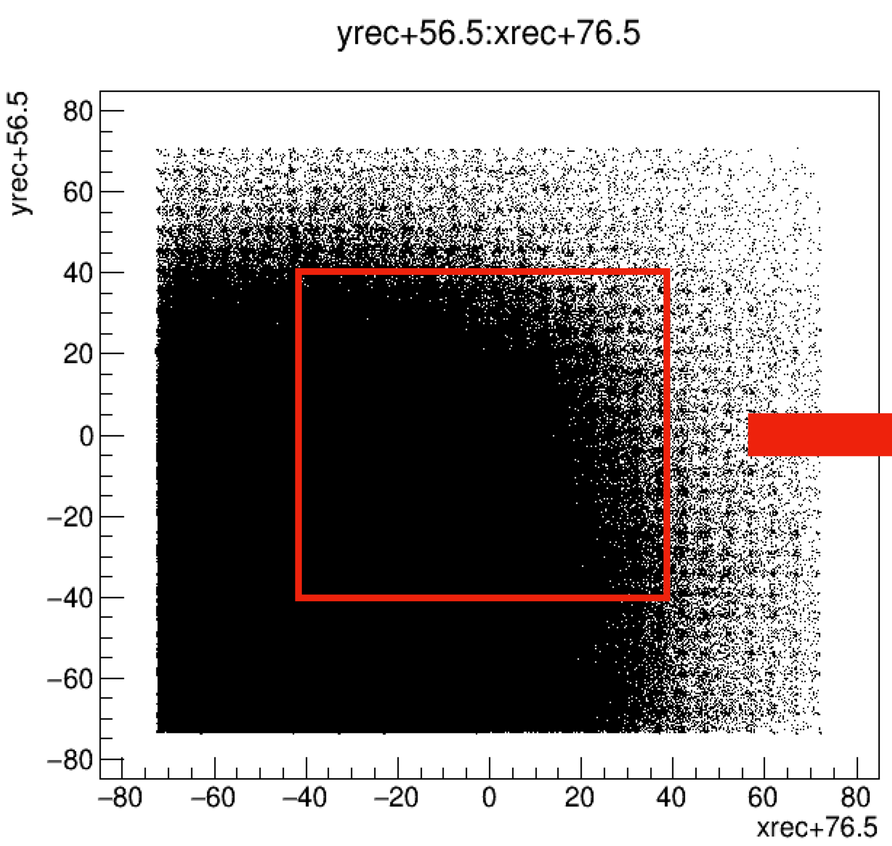
Expected result by LHAASO-WCDA, 1 year full array



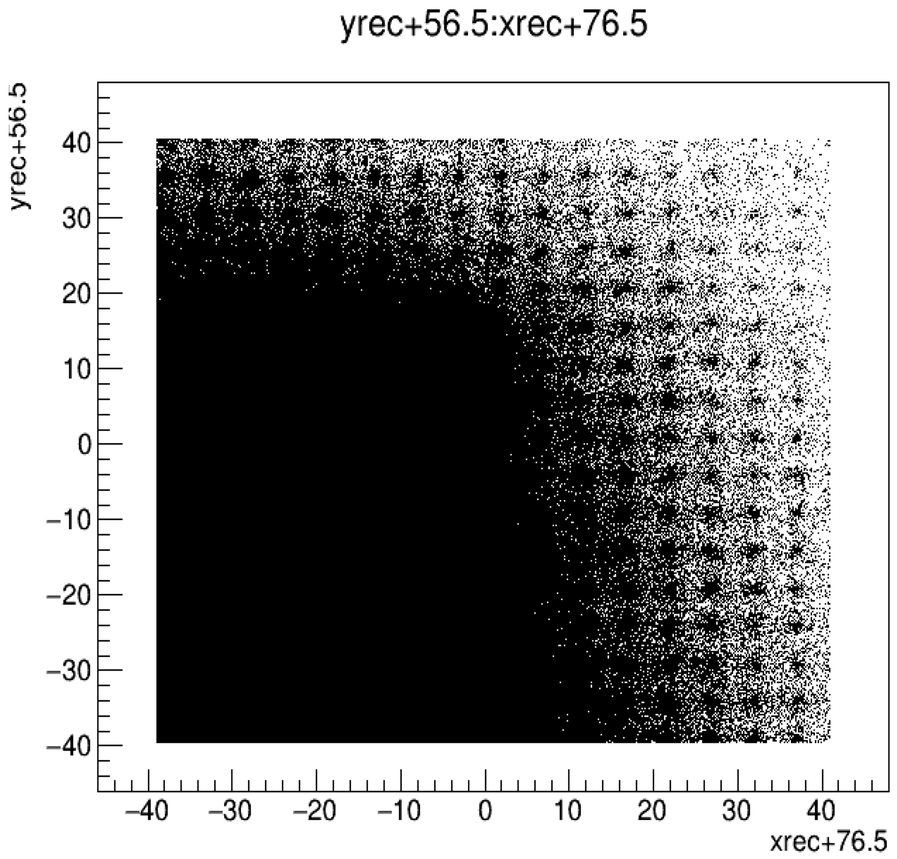




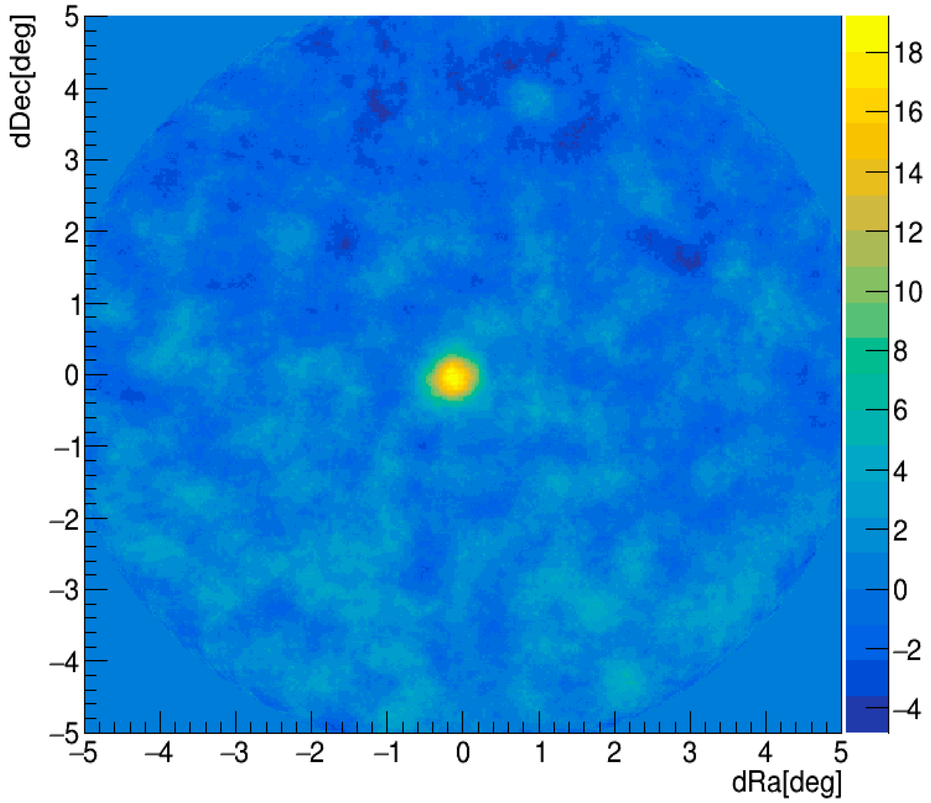
arxiv:1903.11910v2



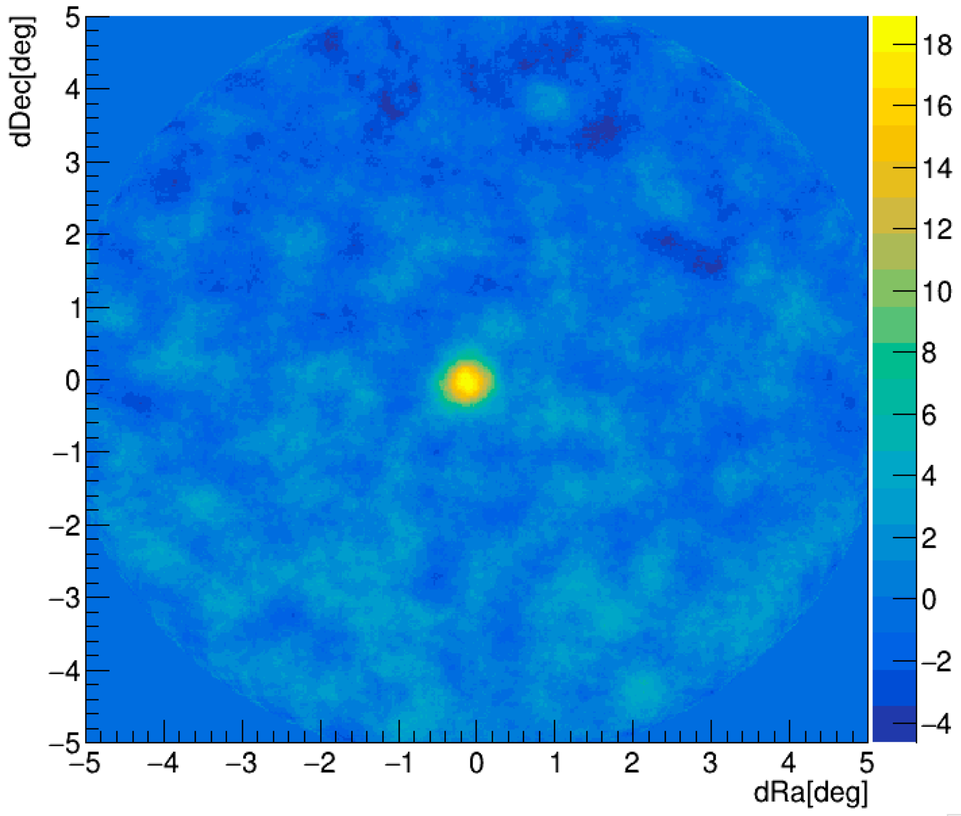
202000601-1231 Crab from Gamma sample



Crab inner events from Gamma sample



all events



inner(80*80m^2) events