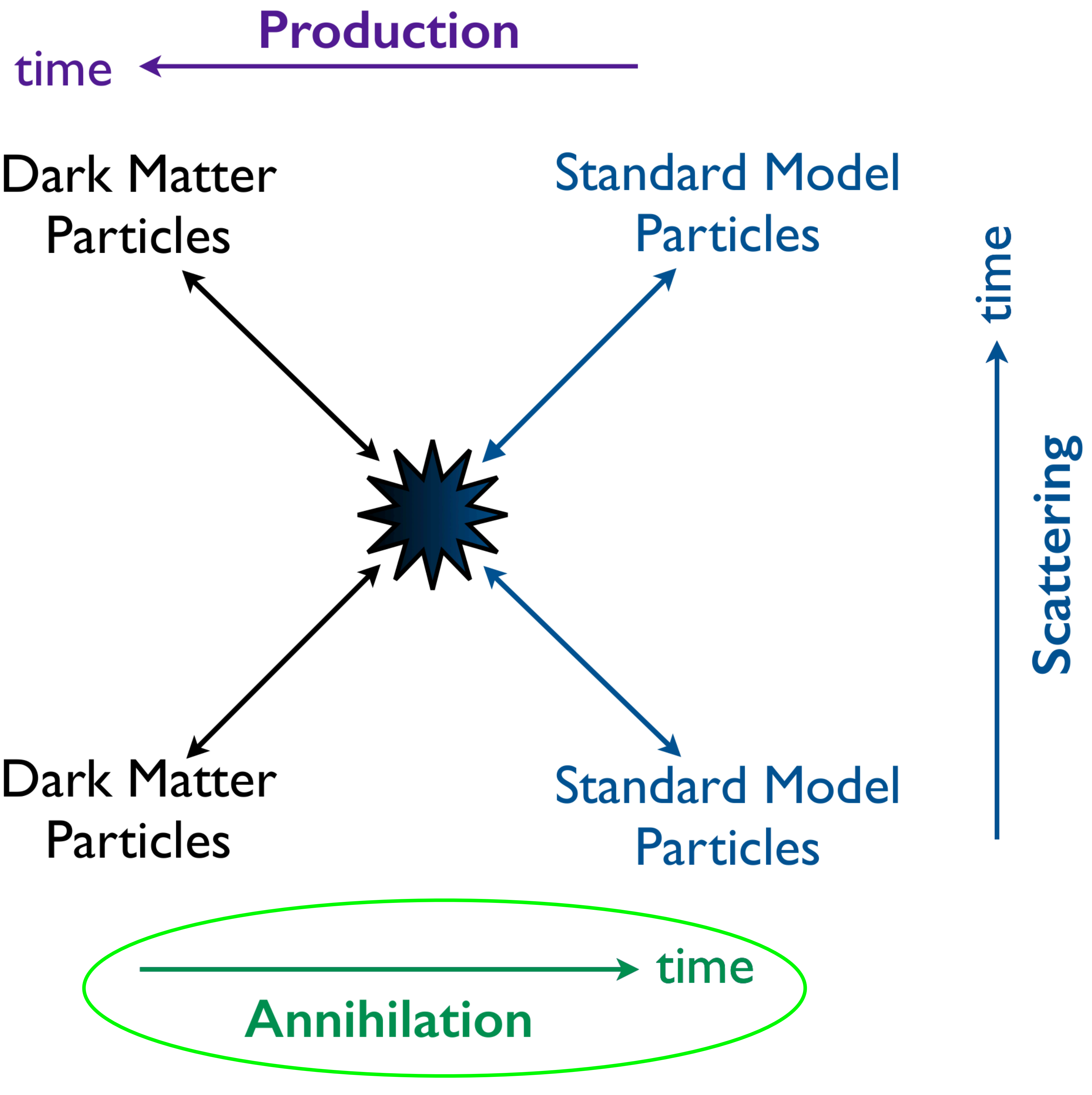
Indirect detection of dark matter: Cosmic rays and the Galactic center excess in gamma rays

Mattia Di Mauro

Indirect detection of dark matter



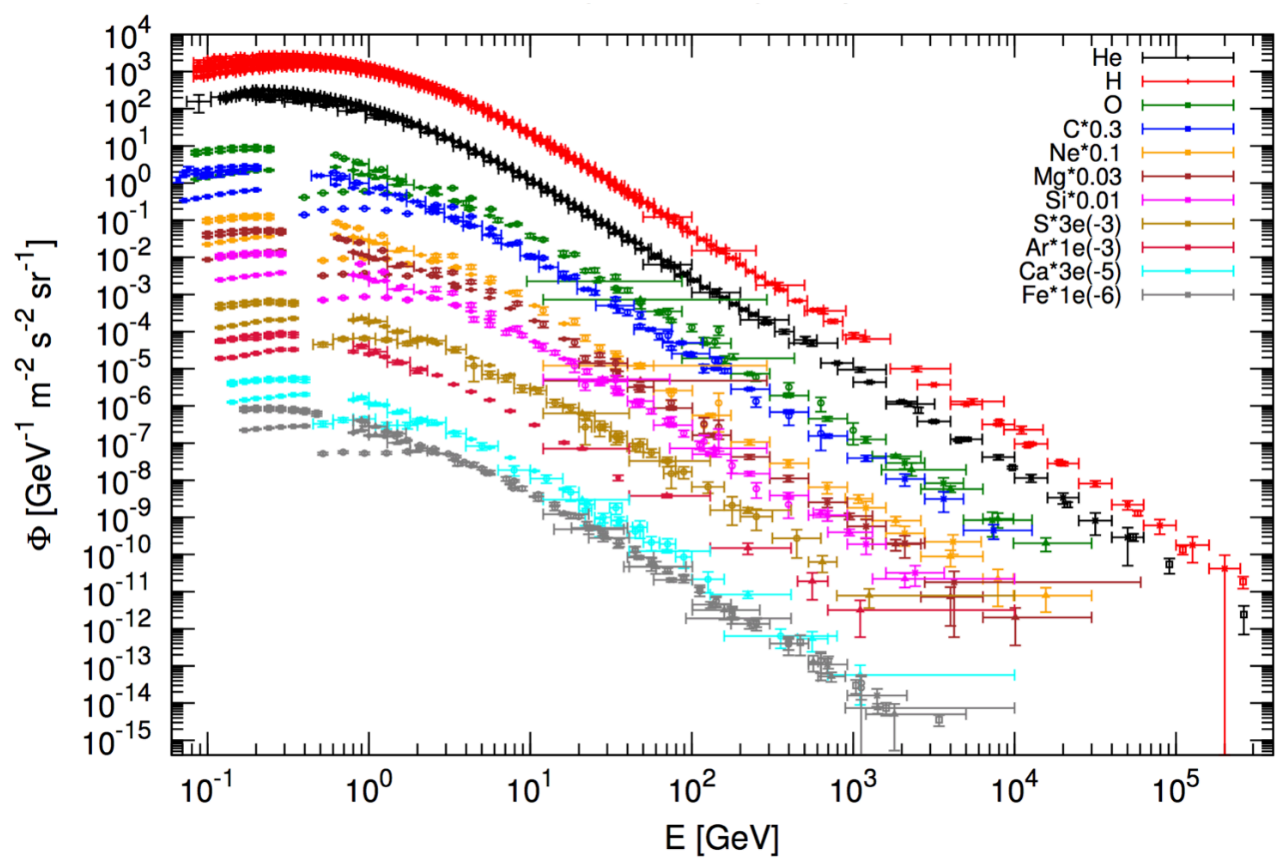
Origin of cosmic rays (CRs)

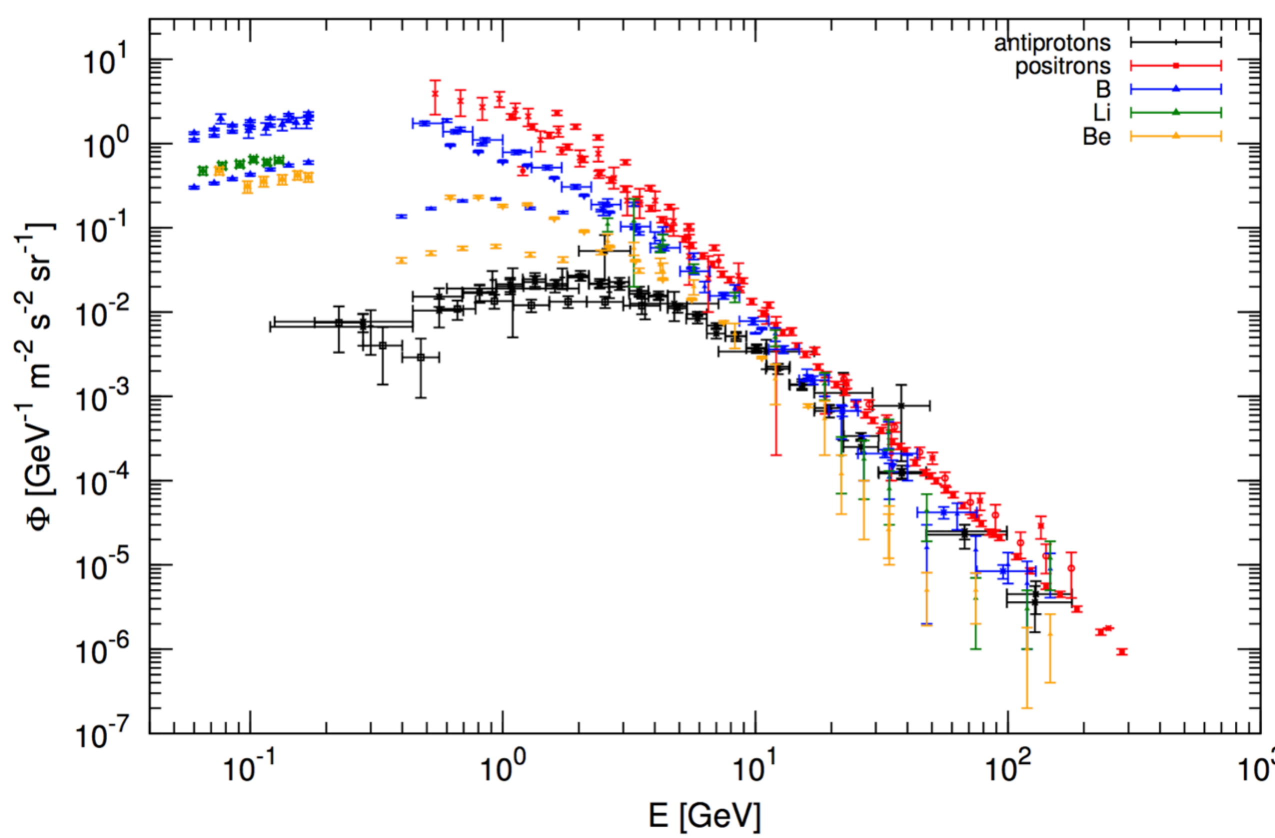
Primary CRs

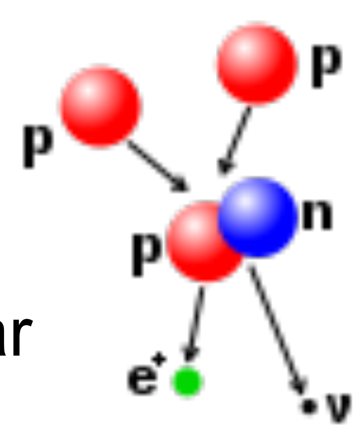
- Supernova remnants are believed to be the major accelerators, via a first-type Fermi mechanism.
- Pulsar wind nebulae (PWNe), rapidly spinning neutron stars with a strong surface magnetic field. They are the most powerful sources of positrons.

Secondary CRs

- Secondary production: secondary CRs originate from the spallation reactions of primary CR species with the interstellar material.







Cosmic particle detectors

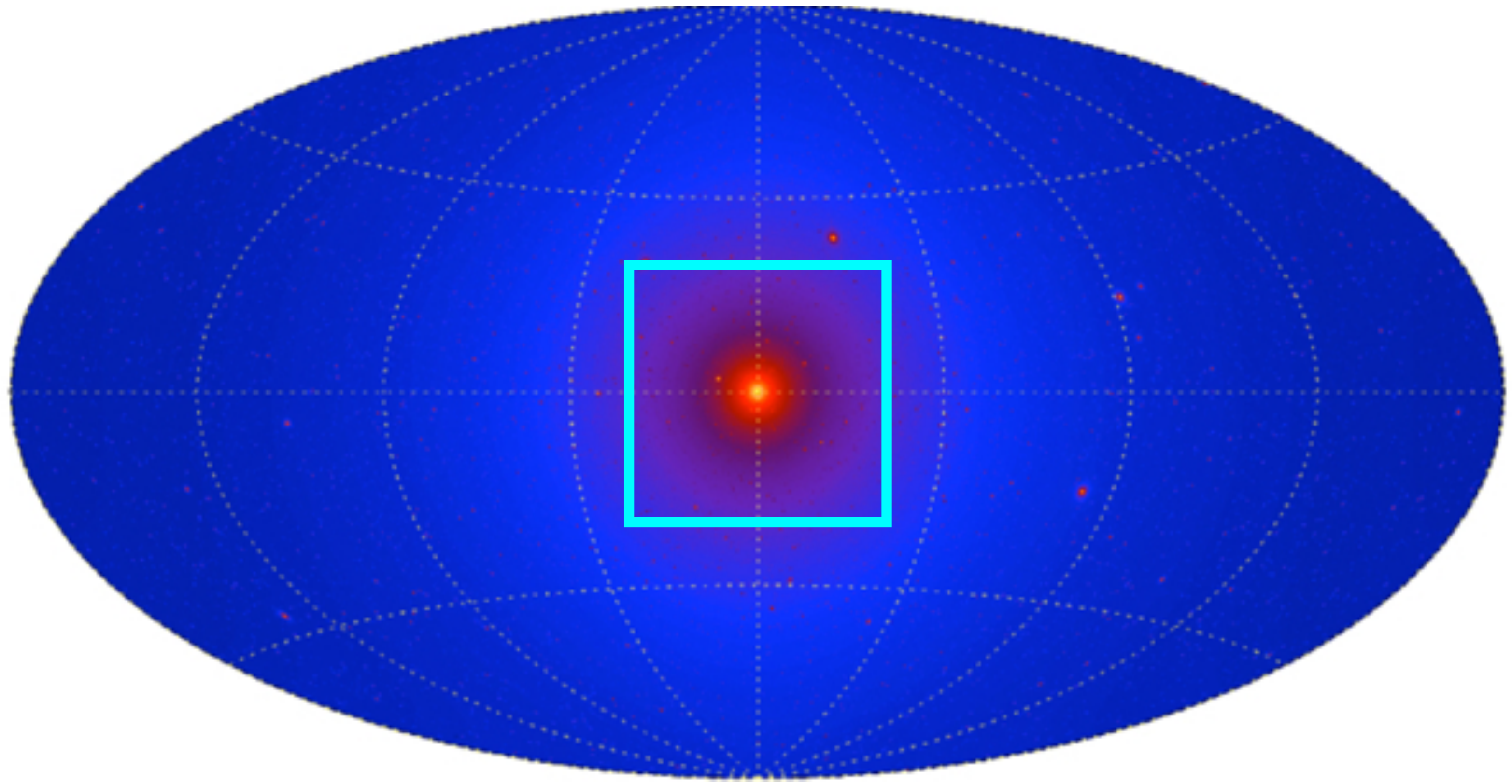
Cosmic rays
Satellite experiments:
PAMELA, AMS-02, CALET, DAMPE,…

Gamma rays
Satellite: Fermi-LAT (0.1-1000 GeV)
Ground-based experiments: HESS HAWC VERITAS MAGIC, HAWC (multi TeV)

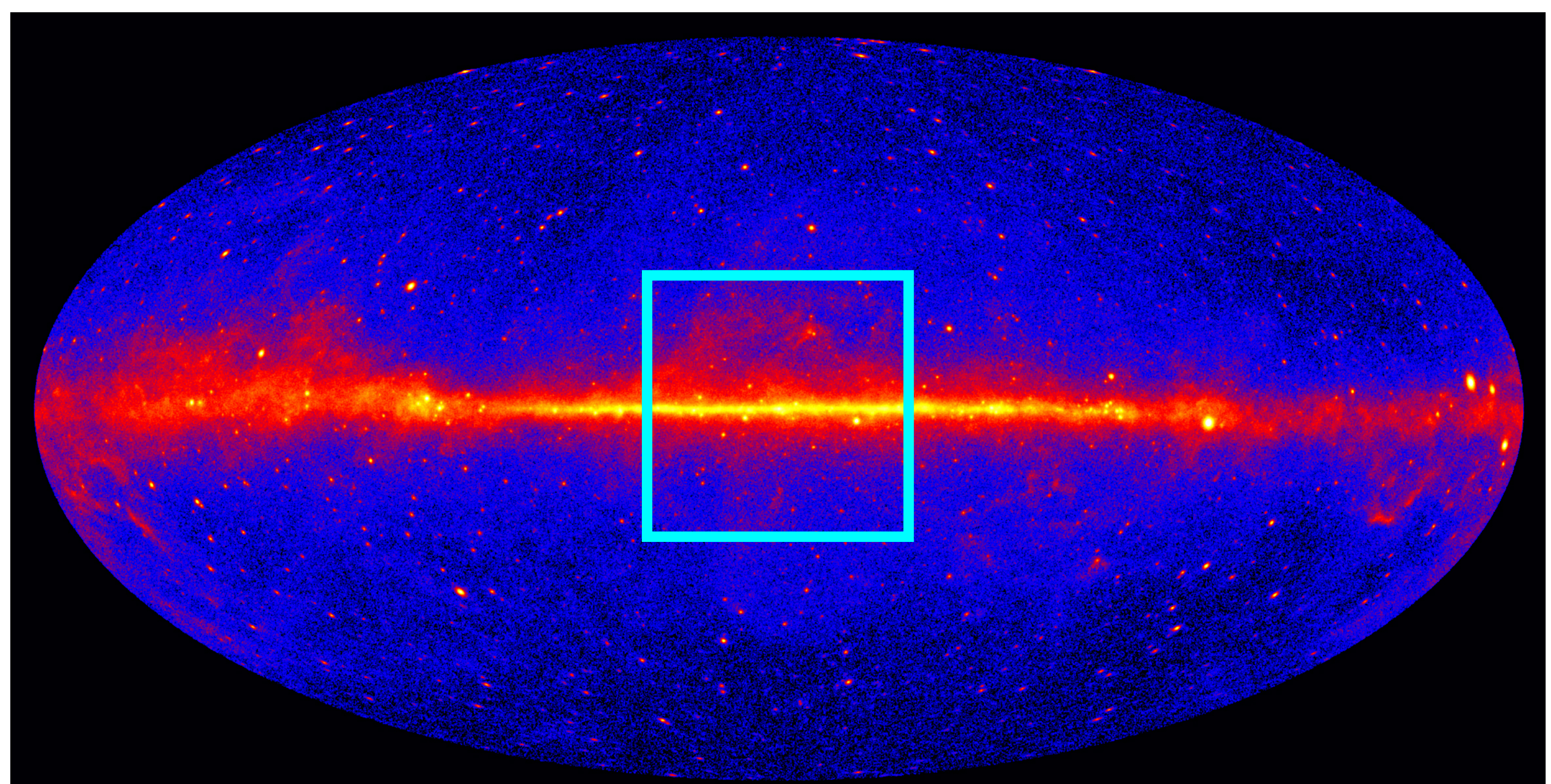
See Ruben Lopez-Coto presentation!

Fermi-LAT excess in the Galactic center

N-body simulation for the dark matter distribution in the Universe.

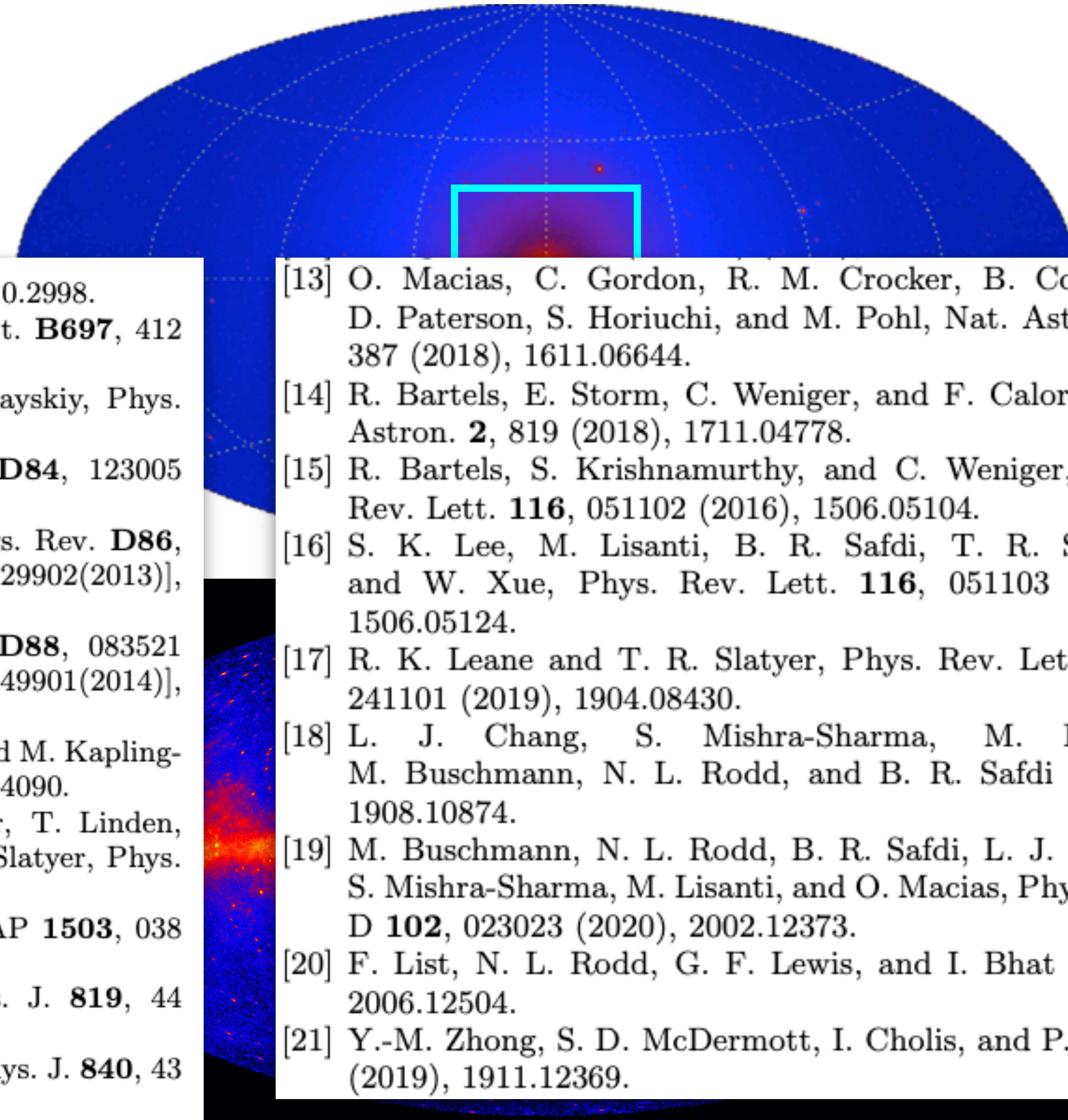


Map of gamma rays detected by Fermi-LAT



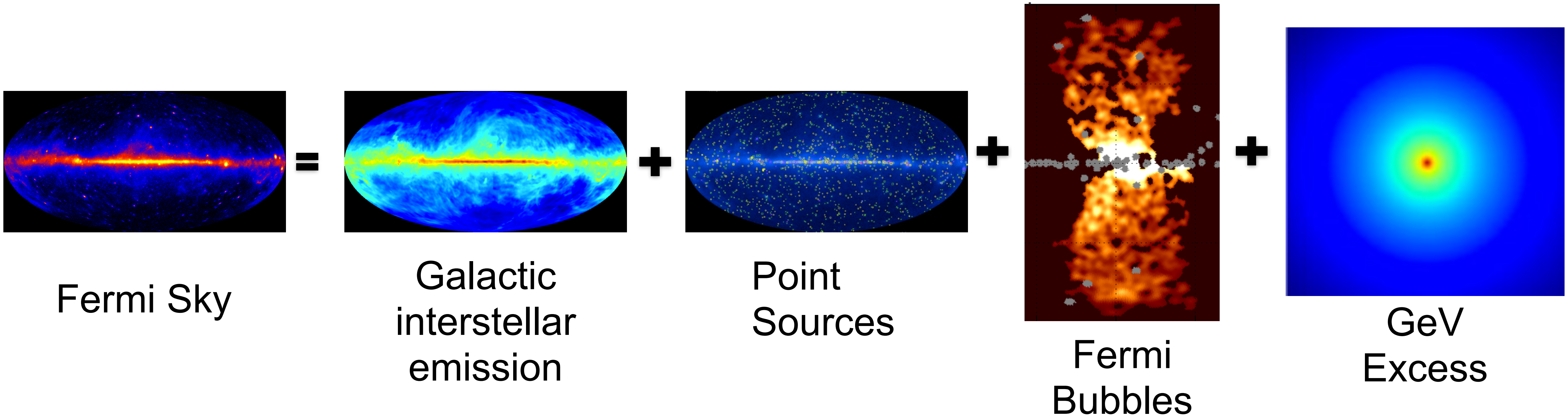
Fermi-LAT excess in the Galactic center

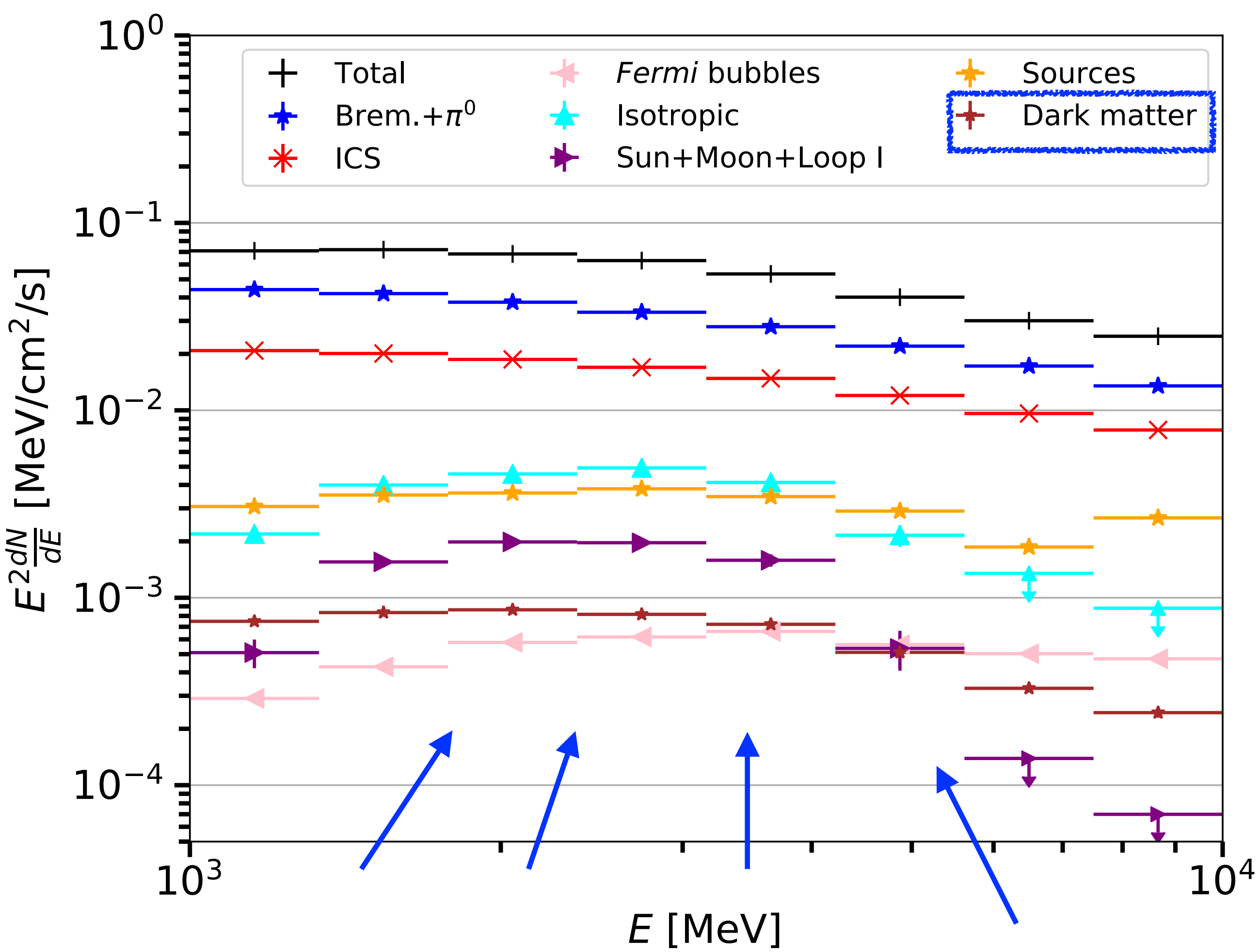
N-body simulation for
the dark matter



[1] L. Goodenough and D. Hooper (2009), 0910.2998.
[2] D. Hooper and L. Goodenough, Phys. Lett. **B697**, 412 (2011), 1010.2752.
[3] A. Boyarsky, D. Malyshev, and O. Ruchayskiy, Phys. Lett. **B705**, 165 (2011), 1012.5839.
[4] D. Hooper and T. Linden, Phys. Rev. **D84**, 123005 (2011), 1110.0006.
[5] K. N. Abazajian and M. Kaplinghat, Phys. Rev. **D86**, 083511 (2012), [Erratum: Phys. Rev.D87,129902(2013)], 1207.6047.
[6] C. Gordon and O. Macias, Phys. Rev. **D88**, 083521 (2013), [Erratum: Phys. Rev.D89,no.4,049901(2014)], 1306.5725.
[7] K. N. Abazajian, N. Canac, S. Horiuchi, and M. Kaplinghat, Phys. Rev. **D90**, 023526 (2014), 1402.4090.
[8] T. Daylan, D. P. Finkbeiner, D. Hooper, T. Linden, S. K. N. Portillo, N. L. Rodd, and T. R. Slatyer, Phys. Dark Univ. **12**, 1 (2016), 1402.6703.
[9] F. Calore, I. Cholis, and C. Weniger, JCAP **1503**, 038 (2015), 1409.0042.
[10] M. Ajello et al. (Fermi-LAT), Astrophys. J. **819**, 44 (2016), 1511.02938.
[11] M. Ackermann et al. (Fermi-LAT), Astrophys. J. **840**, 43 (2017), 1704.03910.
[13] O. Macias, C. Gordon, R. M. Crocker, B. Coleman, D. Paterson, S. Horiuchi, and M. Pohl, Nat. Astron. **2**, 387 (2018), 1611.06644.
[14] R. Bartels, E. Storm, C. Weniger, and F. Calore, Nat. Astron. **2**, 819 (2018), 1711.04778.
[15] R. Bartels, S. Krishnamurthy, and C. Weniger, Phys. Rev. Lett. **116**, 051102 (2016), 1506.05104.
[16] S. K. Lee, M. Lisanti, B. R. Safdi, T. R. Slatyer, and W. Xue, Phys. Rev. Lett. **116**, 051103 (2016), 1506.05124.
[17] R. K. Leane and T. R. Slatyer, Phys. Rev. Lett. **123**, 241101 (2019), 1904.08430.
[18] L. J. Chang, S. Mishra-Sharma, M. Lisanti, M. Buschmann, N. L. Rodd, and B. R. Safdi (2019), 1908.10874.
[19] M. Buschmann, N. L. Rodd, B. R. Safdi, L. J. Chang, S. Mishra-Sharma, M. Lisanti, and O. Macias, Phys. Rev. D **102**, 023023 (2020), 2002.12373.
[20] F. List, N. L. Rodd, G. F. Lewis, and I. Bhat (2020), 2006.12504.
[21] Y.-M. Zhong, S. D. McDermott, I. Cholis, and P. J. Fox (2019), 1911.12369.

The GeV Excess in the Galactic Center (GCE)

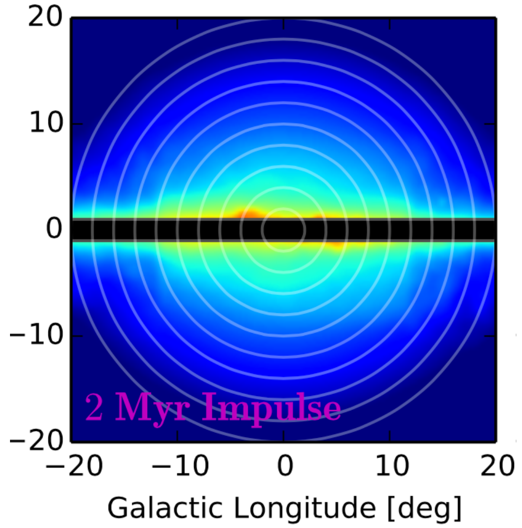




- **Bright** and highly significant.
- **Energy spectrum peaked at a few GeV.**
- **Spatially symmetric** around the Galactic center.
- Centered on the Galactic center.
- The GCE spectrum is at the **% level** wrt. the data

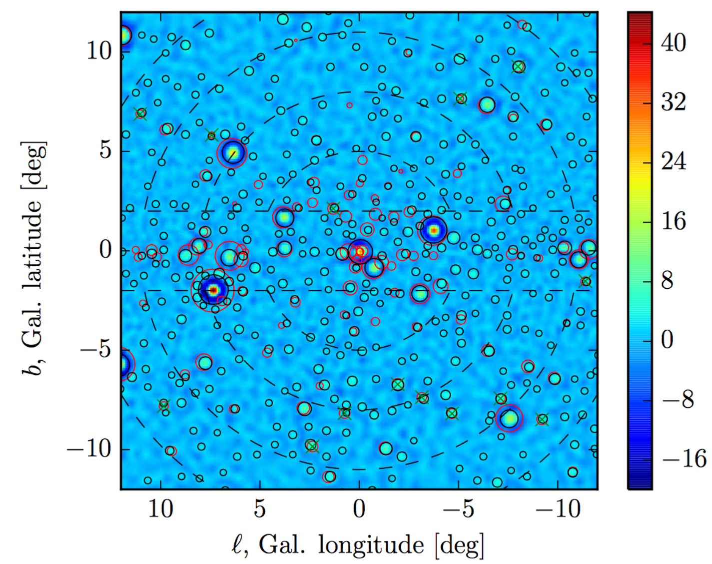
Current situation about the GCE interpretation

Cosmic-ray e^- or p

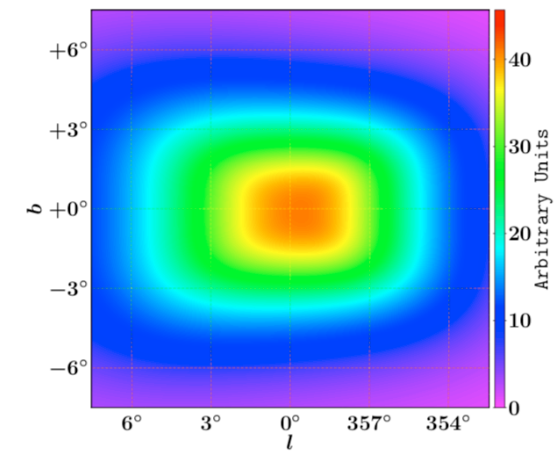


Carlson et al. 2014

Pulsars in the Galactic bulge

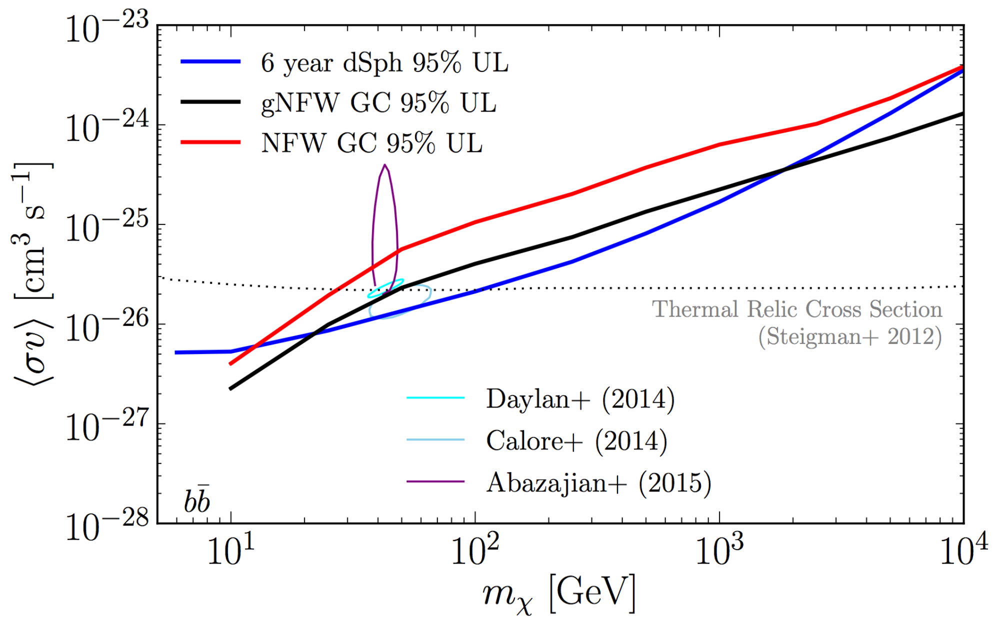


Bartels et al. 2015



Lee et al. 2015

Dark Matter



Fermi-LAT 2018

- No previous study has searched for DM in the GCE, dwarf spheroidal galaxies and cosmic rays in a consistent way.
- The pulsar interpretation has been recently questioned in recent papers (*Leane et al. 2019, Chang et al. 2019, Zhong et al. 2019, Buschmann et al. 2020…*).
- Cosmic rays injected from the Galactic center cannot be compatible with all the characteristics of the GCE.

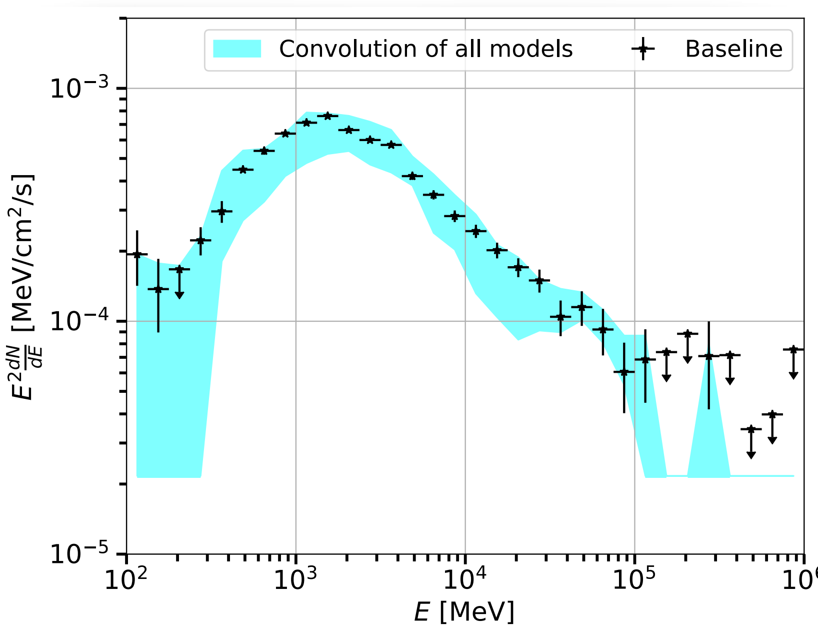
Characteristics of the GCE: Summary

The characteristics of the Galactic center excess measured with 11 years of *Fermi*-LAT data

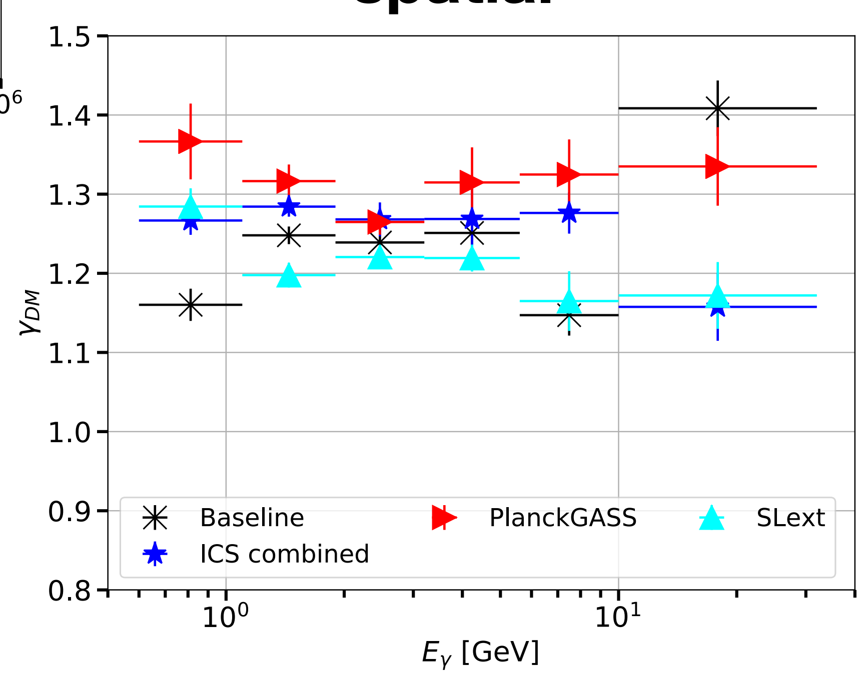
Recently accepted by PRD

Mattia Di Mauro,*
NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA and
Catholic University of America, Department of Physics, Washington DC 20064, USA

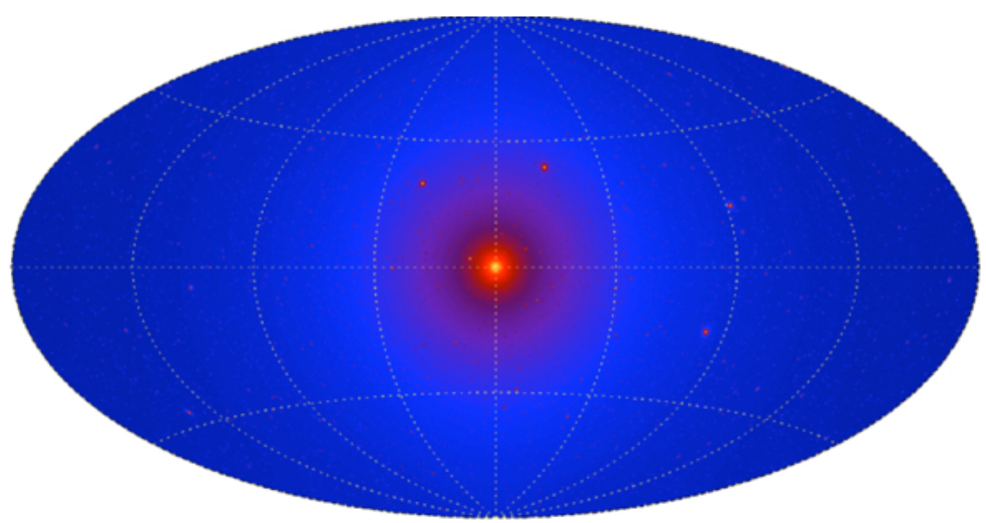
Spectrum peaked at a few GeV



No energy dependence of spatial



The GCE is approximatively spherically symmetric and located in



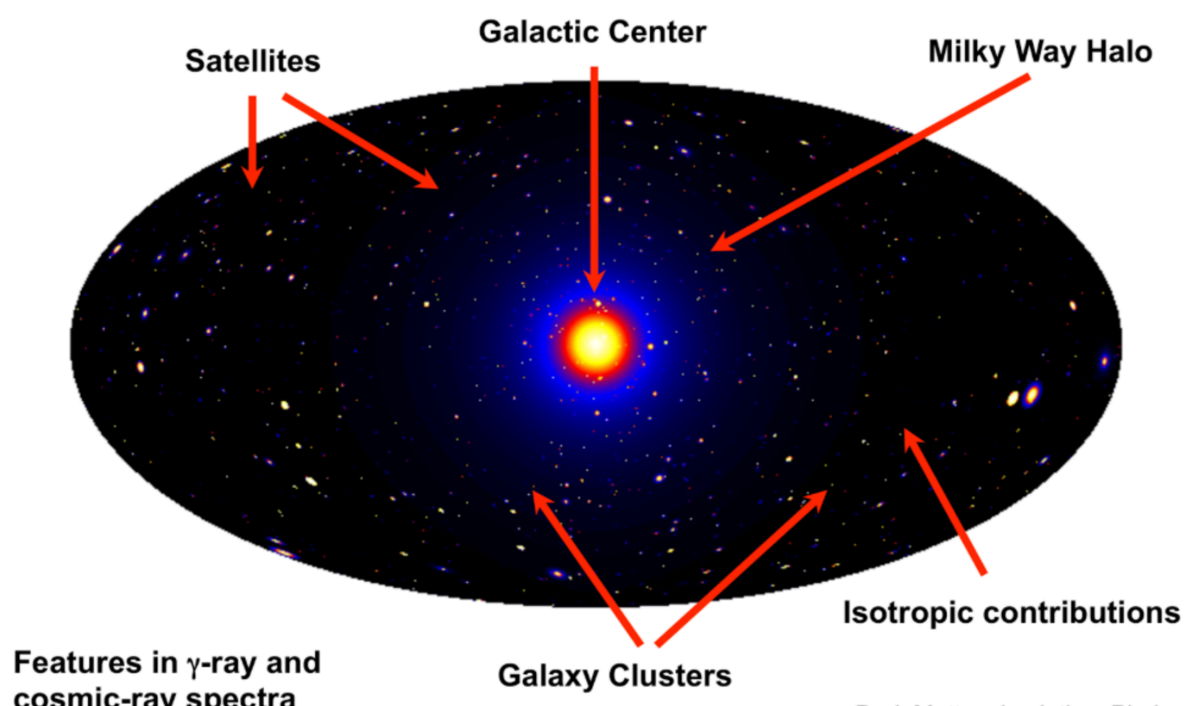
Multimessenger and Multitarget search for DM

Multimessenger constraints on the dark matter interpretation of the *Fermi*-LAT Galactic center excess

Mattia Di Mauro
Istituto Nazionale di Fisica Nucleare, via P. Giuria, 1, 10125 Torino, Italy

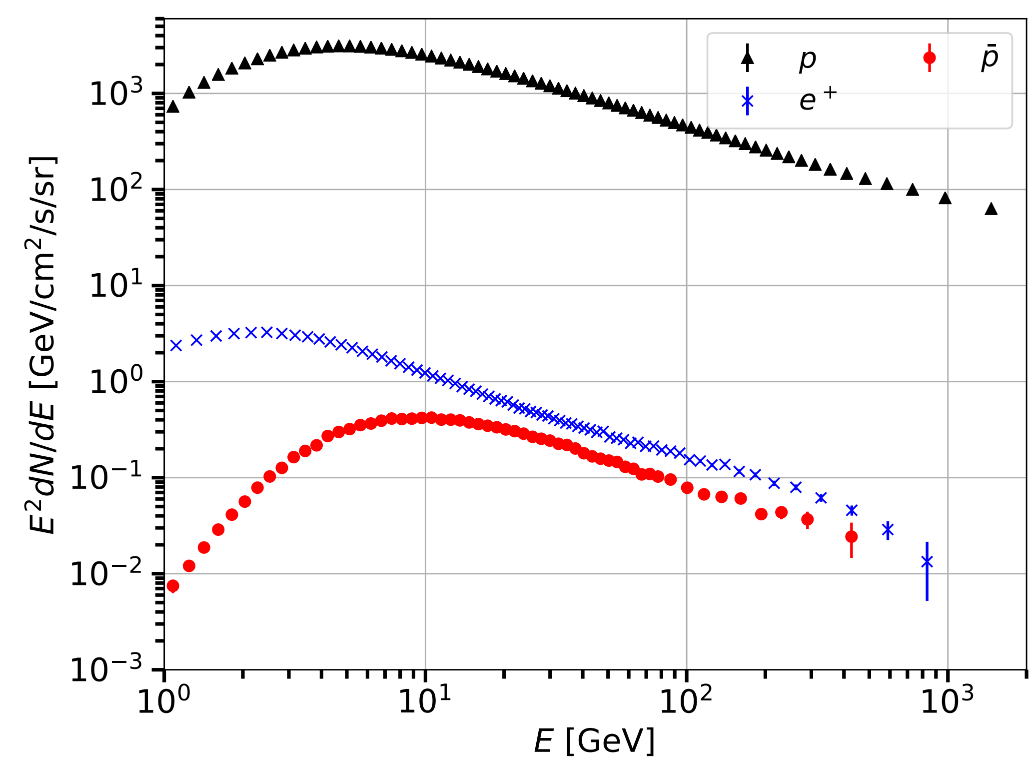
Martin Wolfgang Winkler
Stockholm University and The Oskar Klein Centre for Cosmoparticle Physics, Alba Nova, 10691 Stockholm, Sweden

If DM explains the GCE, gamma rays from annihilation of DM particles should also emitted from other astrophysical sources.



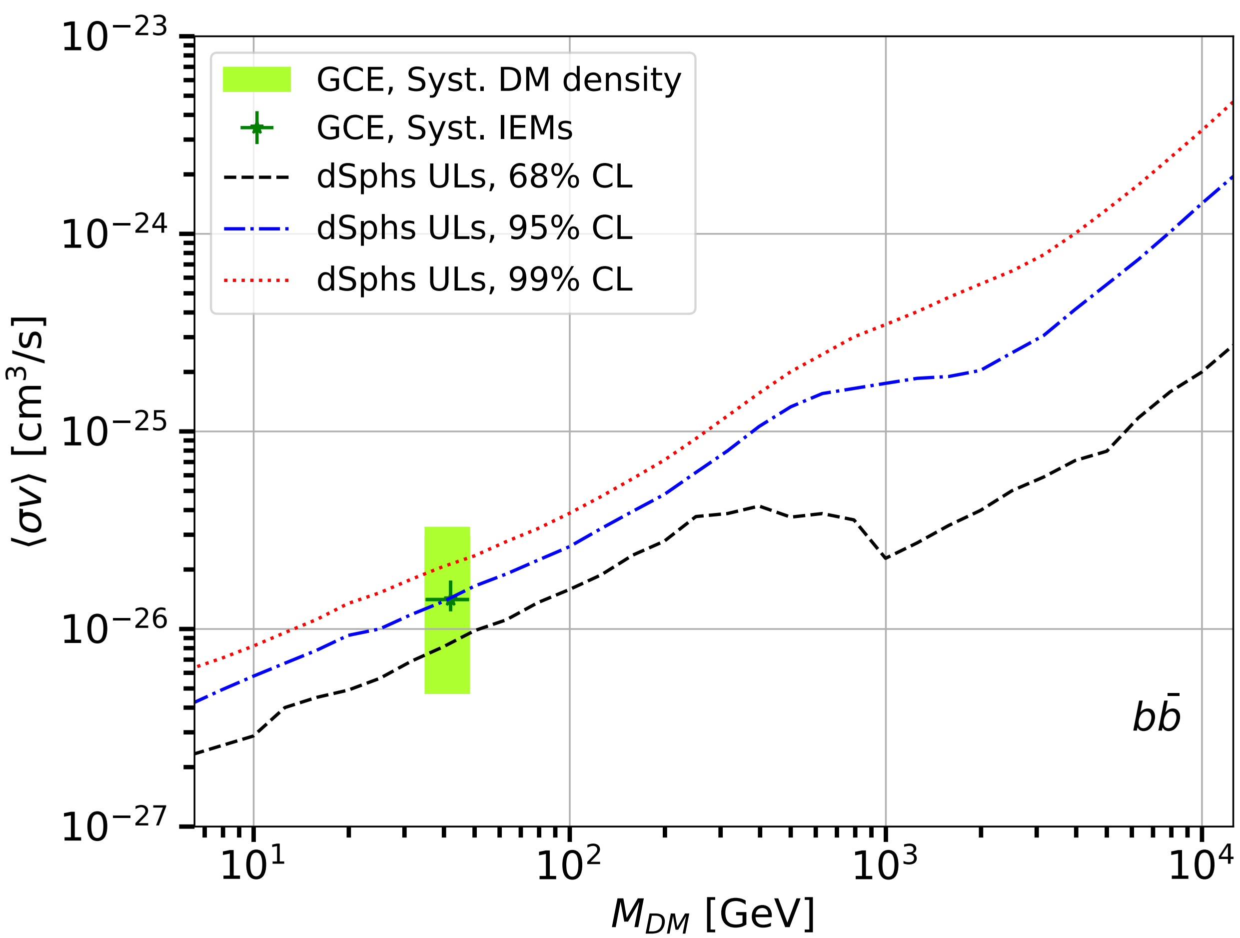
Dark Matter simulation: Pieri+
2011PhRvD..83b3518P

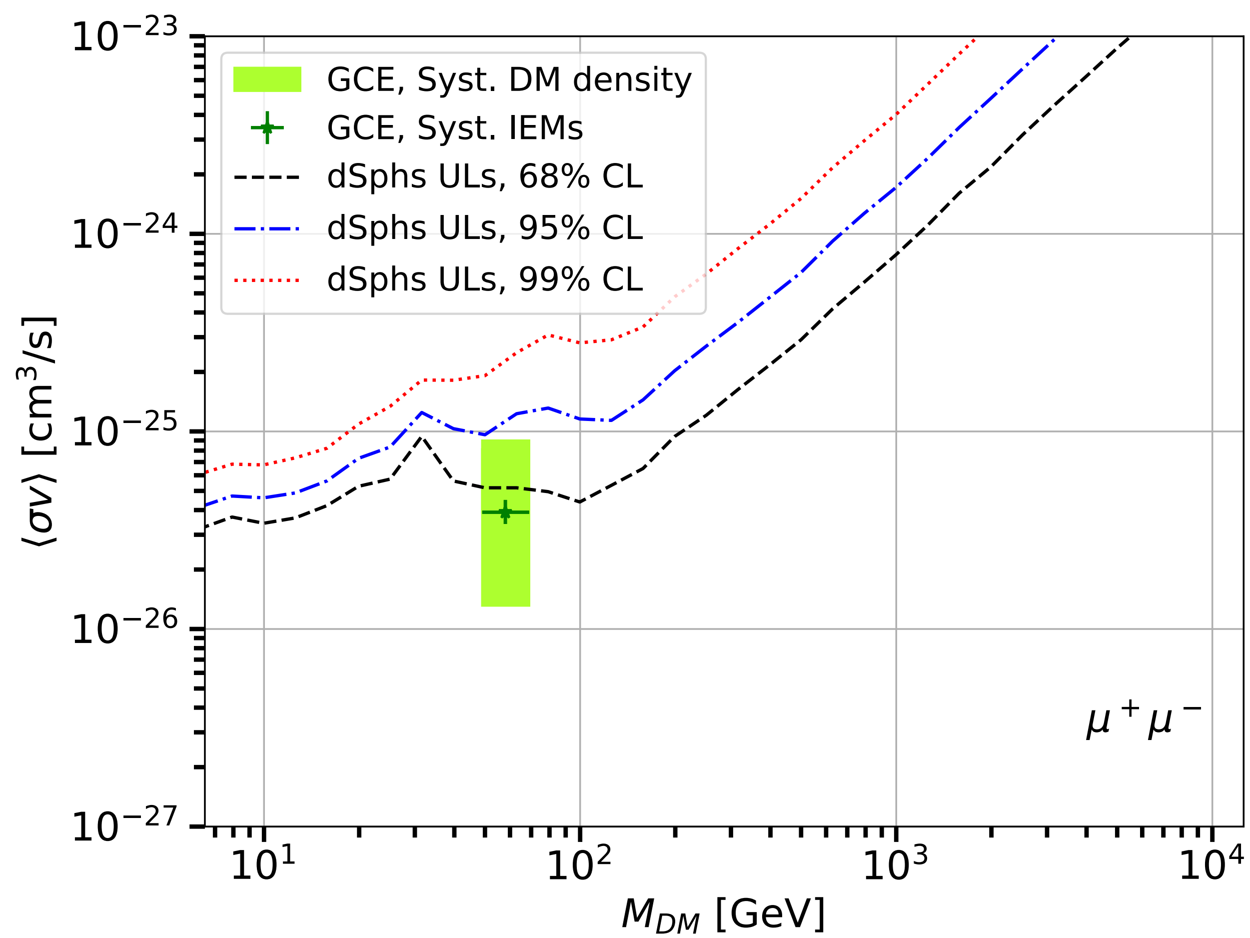
AMS-02



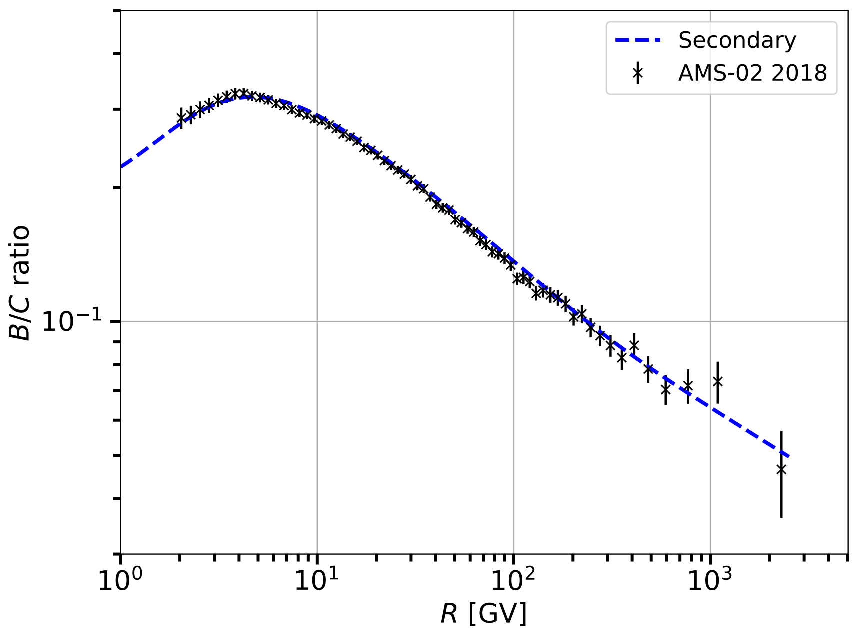
Combined analysis of dSphs

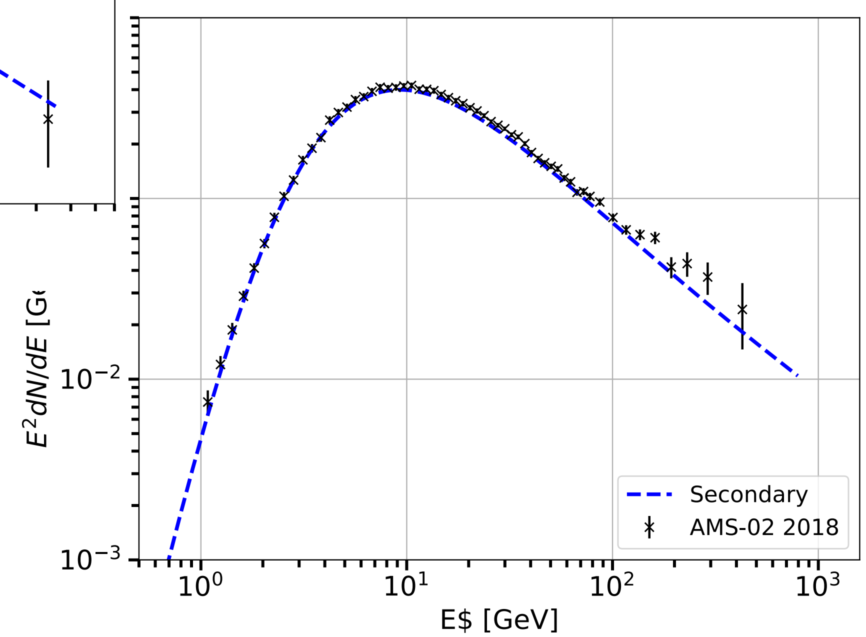
- We perform a stacking analysis of dSphs using the sample of 48 objects from Pace and Strigari 2018.
  - We also test the sample from Albert et al. 2017.
- The pipeline we use is the one employed in previous *Fermi*-LAT papers.
- There is no significant emission in the stacked sample.

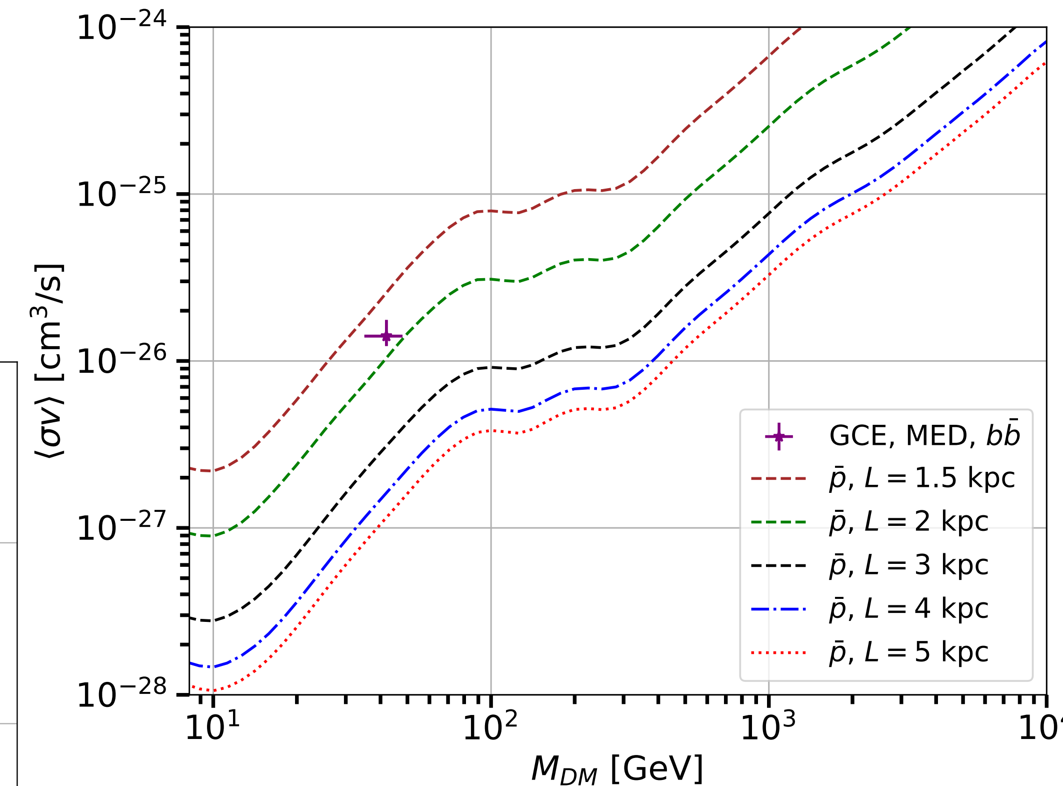


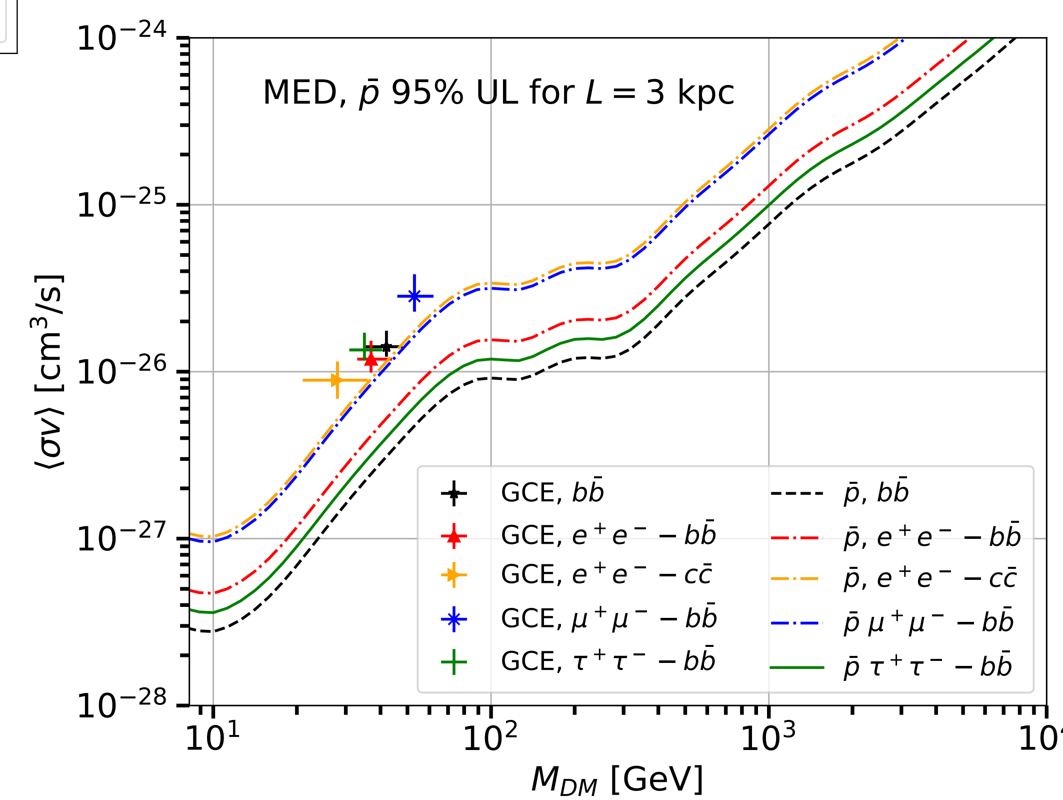


Antiprotons vs GCE









- We use the same analysis as in **Reinert and Winkler 2018**.
    - A combined fit to AMS-02 and Voyager p, AMS-02 and Pamela anti-p, AMS-02 B/C is performed.
- **The DM interpretation of the GCE is compatible with the GCE for L<2 kpc and for a few two channels cases.**

Dark matter search in the AMS-02 positron data

- The conservative upper limits are all compatible with the GCE.
- Instead, the optimistic ones are compatible for the bb, and mixed channels with muons and tau leptons.
- The channels with electrons are below the GCE DM candidates cross sections.