Physics with Space Experiments

Aldo Morselli
INFN Roma Tor Vergata
on behalf of the Fermi-Lat Collaboration

Roma International Conference on Astro-Particle physics

Roma24 May 2013

36 presentations !!

- MAGIC latest results
- Oscar Blanch Bigas (IFAE)
- Constraints on the Galactic Halo Dark Matter from Fermi-LAT Diffuse Measurements
- Dr. Alessandro cuoco (University of Torino)
- Diffuse gamma-rays from Misaligned AGN and constraints on galactic Dark Matter
- Dr. Fiorenza Donato (Torino University)
- High and low energy puzzles in the AMS-02 positron fraction results
- Dario Grasso (PI)
- Perspectives of dark matter searches with antideuterons
- Andrea Vittino (T)
- Dark Matter implications of Fermi-LAT measurement of anisotropies in the diffuse gamma-ray background
- Mr. German Arturo Gomez Vargas (Universidad Autonoma de Madrid - IFT UAM/CSIC)
- Cosmological and astrophysical constraints on majoron dark matter
- Dr. Massimiliano Lattanzi (Università di Ferrara)
- Multiparticle Analysis of Forbush Decrease of the 13th December 2006 Solar Event with the PAMELA Experiment
- Mr. Matteo Mergè (INFN)
- Analysis on H and He production during the 2012 March 7 flare with the PAMELA experiment
- Matteo Martucci (LNF)

- The AGILE gamma-ray sky and the AGILE data center at ASDC
- Dr. Carlotta Pittori (INAF-OAR/ASDC)
- The Fermi view on GRBs
- Francesco Longo (TS)
- Lorentz Invariance Violation: the latest Fermi results and the GRB/AGN complementarity
- Dr. Julien Bolmont (LPNHE Paris)
- Gamma-ray emission from the SNR W44: confirmations and challenges for cosmic-ray acceleration.
- Mrs. Martina Cardillo (INAF-IAPS & Università di Roma Tor Vergata)
- Efficient turbulent amplification of magnetic field driven by dynamo effect at supernova remnant shocks
- Dr. Federico Fraschetti (University of Arizona)
- Fermi LAT recent results on AGNs
- Dr. Sara Buson (INFN & University of Padova)
- Radio constraints on Galactic WIMP dark matter
- Dr. Roberto A. Lineros (IFIC (CSIC/U.Valencia))
- The Pamela cosmic ray observatory: a platform for high precision measurements at 1 AU
- Marco Casolino (ROMA2)
- Fermi Large Area Telescope highlights after five years of operations
- Luca Latronico (TO)
- AMS: status and first results
- Roberto Battiston (PG)

UHECR observation by JEM-EUSO space mission: status and perspectives

- Prof. Piergiorgio Picozza (INFN and University of Rome Tor Vergata)
- INTEGRAL Observatory highlights
- Prof. Pietro Ubertini (IASP-INAF)
- Propagation of Cosmic Rays in the Heliosphere and in the Milky Way
- Paolo Lipari (ROMA1)
- The CR anisotropy below the knee: experiments and models of the last decade
- Dr. Roberto Iuppa (University of Rome Tor Vergata)
- TeV gamma-ray variability and duty cycle of Mrk 421 as determined by 3 Years of Milagro monitoring
- Dr. Barbara Patricelli (Astronomy Institute – UNAM)
- VERITAS Recent Results
- Dr. David Staszak (McGill)
- Scientific Verification Of The High Altitude Water Cherenkov Observatory
- Dr. Antonio Marinelli (UNAM - Physics Institute)
- Observation Of Tev Gamma-ray Extended Sources With ARGO-YBJ
- Dr. Silvia Vernetto (OATO – INAF)
- Gamma rays from Fermi bubbles as due to diffusive injection of Galactic cosmic rays
- Dr. Satyendra Thoudam (Department of Astrophysics, Radboud University The Netherlands)

- The Crab Nabula: observations and simulations
- Dr. Edoardo Striani (INAF-IAPS, Università di Roma Tor Vergata & INFN)
- Gamma-ray observations of Cygnus X-1 in the hard and soft states
- Dr. Sabina Sabatini (INAF IAPS)
- Transient gamma-ray emission from Cygnus X-3: AGILE observations and spectral constraints
- Dr. Giovanni Piano (INAF-IAPS Roma)
- TeV Astrophysics with the HAWC Gamma-Ray Observatory
- Dr. Gus Sinnis (Los Alamos National Laboratory)
- Status of LHAASO and Updates on the ARGO-YBJ Observations
- CAO ZHEN
- Fundamental physics with present and future Cherenkov telescopes
- Alessandro De Angelis (UD)
- Indirect Search for Dark Matter with Cherenkov Telescopes
- Measurement of Hydrogen and helium isotopes flux in galactic cosmic rays with the PAMELA experiment
- Valerio Formato (TS)
- Prospects for the detection of Gamma Ray Bursts with HAWC
- Ignacio Taboada (Georgia Institute of Technology)


Ricap07

RICAP'07

- ~ 1 year from PAMELA launch

- Launched in orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour cosmodrom.

RICAP'07

~ 1 month from
AGILE launch

Perfect launch of the AGILE satellite by ISRO from the SHAR base (Chennai), India,

April 23, 2007

The AGILE gamma-ray sky and the AGILE data center at ASDC
Carlotta Pittori

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Giovanni Piano

The Crab Nabula: observations and simulations
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Gamma-ray emission from the SNR W44: confirmations and challenges for cosmic-ray acceleration.
Martina Cardillo

The High Energy Astrophysics Division
of the
American Astronomical Society
hereby awards the

2012 BRUNO ROSSI PRIZE

to

Marco Tavani and the AGILE Team

For the discovery of gamma-ray flares from the Crab Nebula.

Founded 1899

Joel Bregman
Joel Bregman
Chair, HEAD

Randall Smith
Randall Smith
Secretary-Treasurer, HEAD

RICAP'09


RICAP'09
~ 1 year from Fermi launch
11 June 2008


RICAP'09
esa
0 days from Plank and Herschel launch
14 May 2009

RICAP'11


3rd Roma International Conference
on Astro-particle Physics


RICAP'11
~ 5 days from AMS-02 launch
19 May 2011

- no new launch this year ?

New projects in space

- CALET CALorimetric Electron Telescope launch planned for 2014

  arXiv:1302.1257

- Gamma-light

http://agenda.infn.it/getFile.py/access?contribId=67&resId=0&materialId=slides&confId=4267
(Proposed to ESA but not approved)

- JEM EUSO launch tentatively planned for 2017

  P. Picozza Ricap13

- Gamma-400 launch foreseen by end 2018

100 MeV – 3 TeV, an approved Russian γ-ray satellite.
Energy resolution (100 GeV) ~ 1 %. Effective area ~ 0.4 m2.
Angular resolution (100 GeV) ~ 0.01°.

Science with Gamma-400 Workshop

http://cdsagenda5.ictp.it/full_display.php?ida=a1311

New projects in space 2

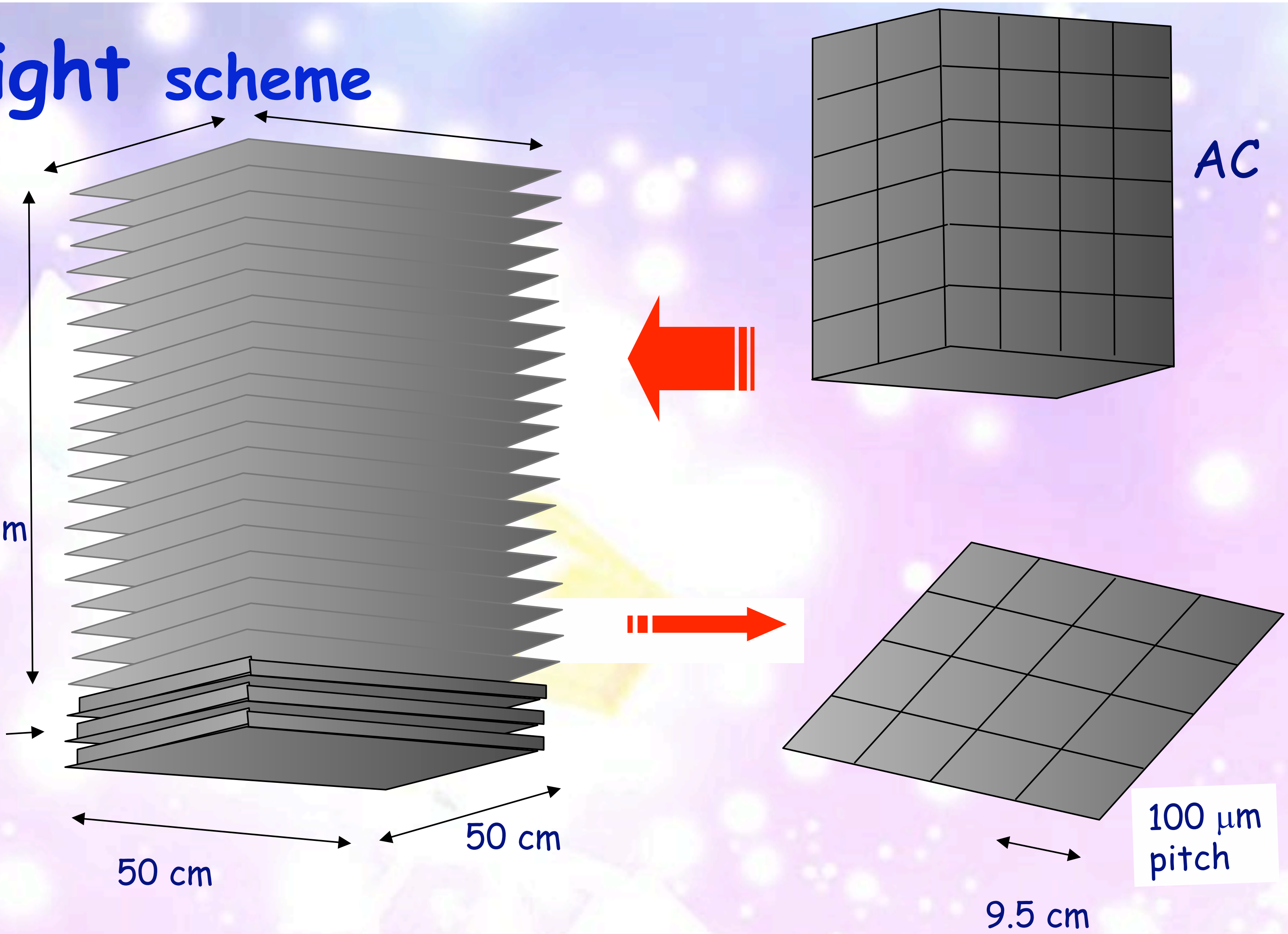
- **DAMPE**: Satellite of similar performance as Gamma-400. An approved Chinese γ-ray satellite. Planned launch 2015-16.

- **HERD**: Instrument on the planned Chinese Space Station. Energy resolution (100 GeV) ~ 1 %. Effective area ~ 1 - 2 m2. Angular resolution (100 GeV) ~ 0.01°. Planned launch around 2020.

Gamma-light scheme

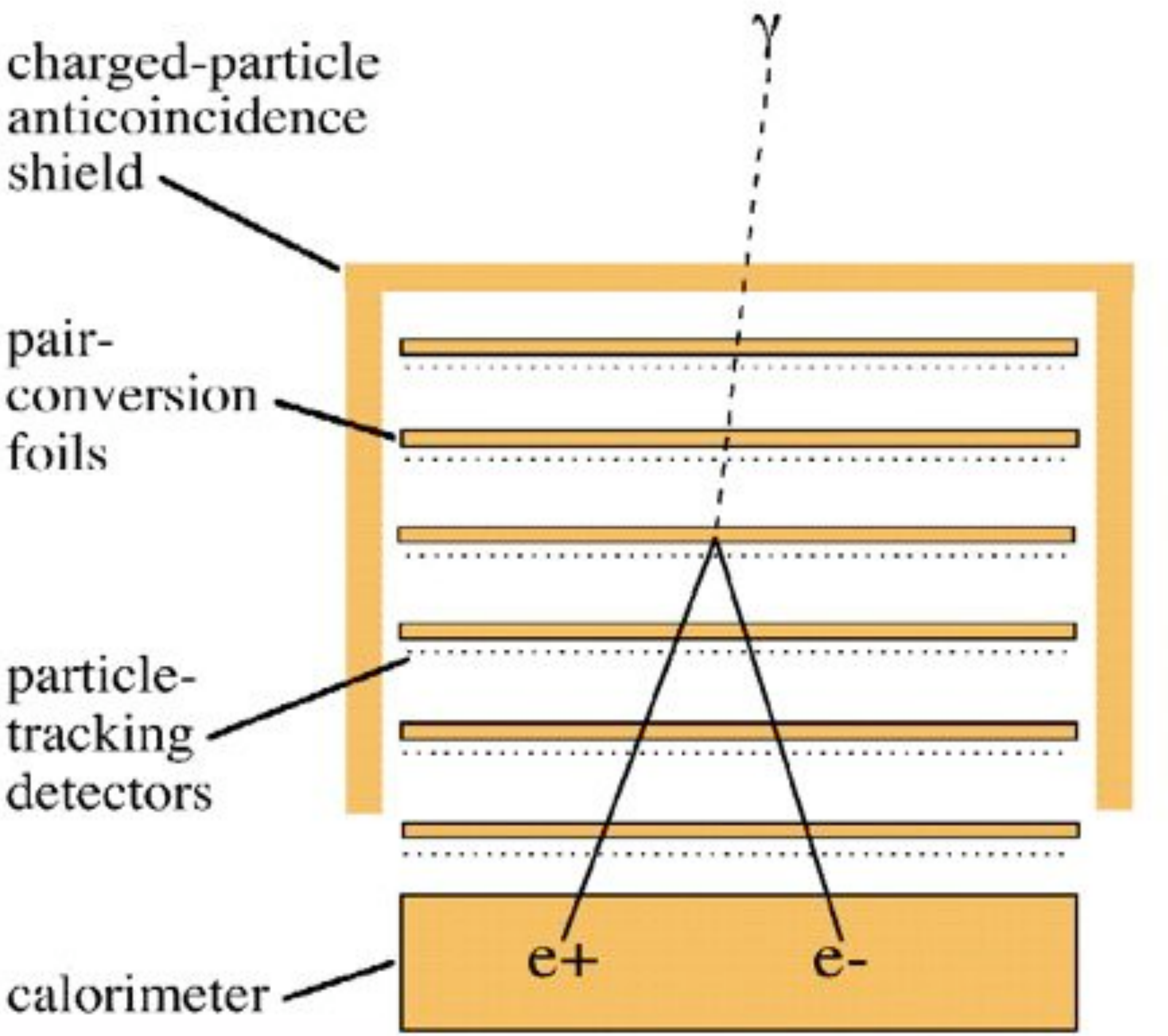
40+1 x-y planes
100 μm pitch
each
~0.025 X_0

Tot~ 1 X_0



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

Elements of a pair-conversion telescope



(energy measurement)

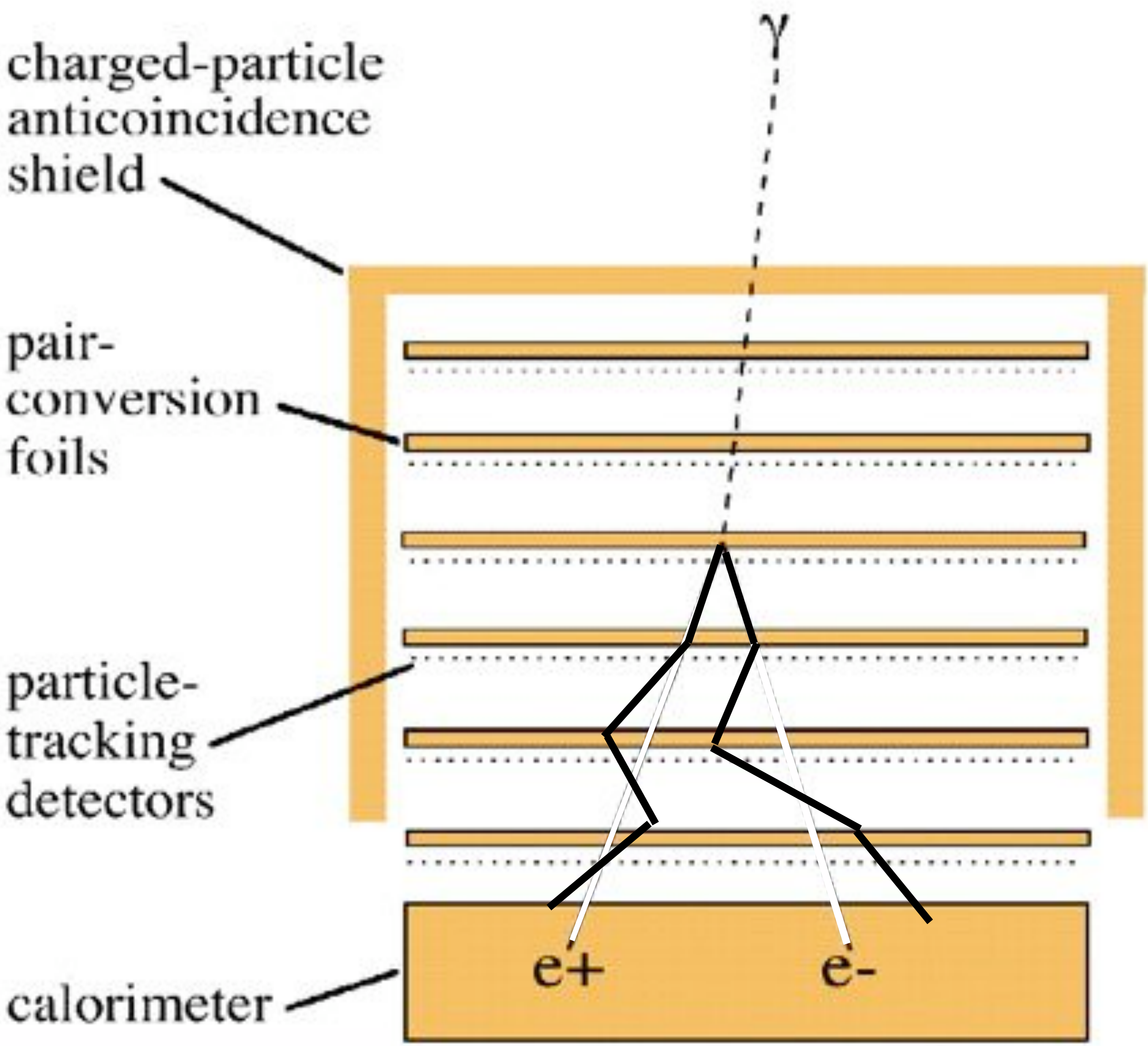
- photons materialize into matter-antimatter pairs:

  $E_\gamma \; \text{-->} \; m_{e^+}c^2 + m_{e^-}c^2$

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

Elements of a pair-conversion telescope

(more realistic scheme)



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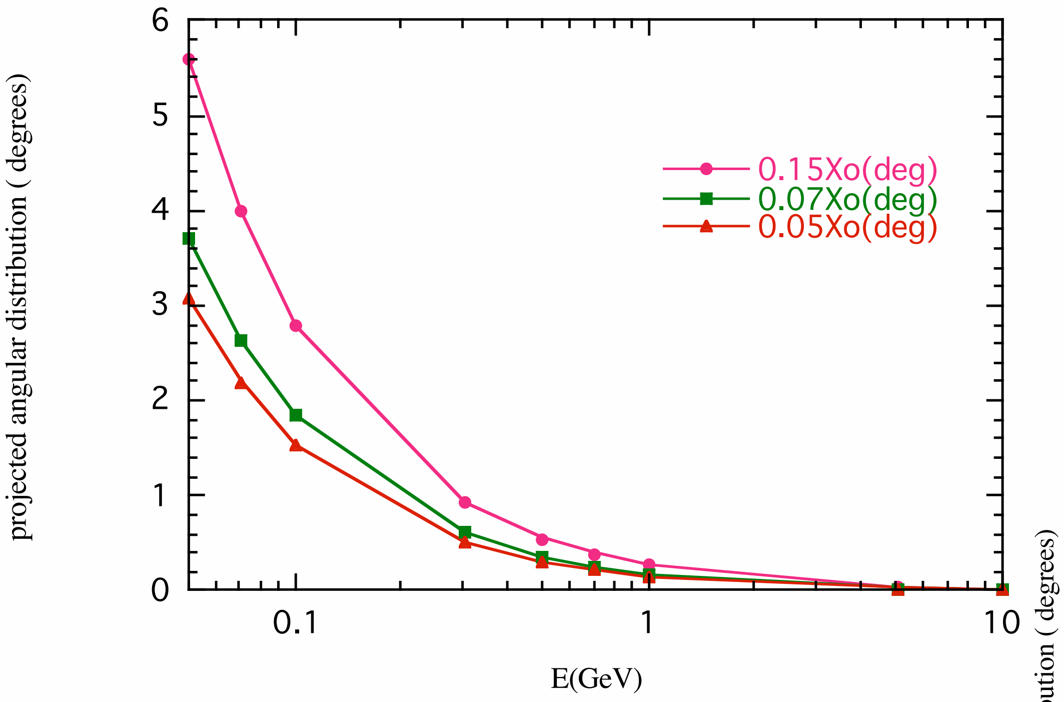
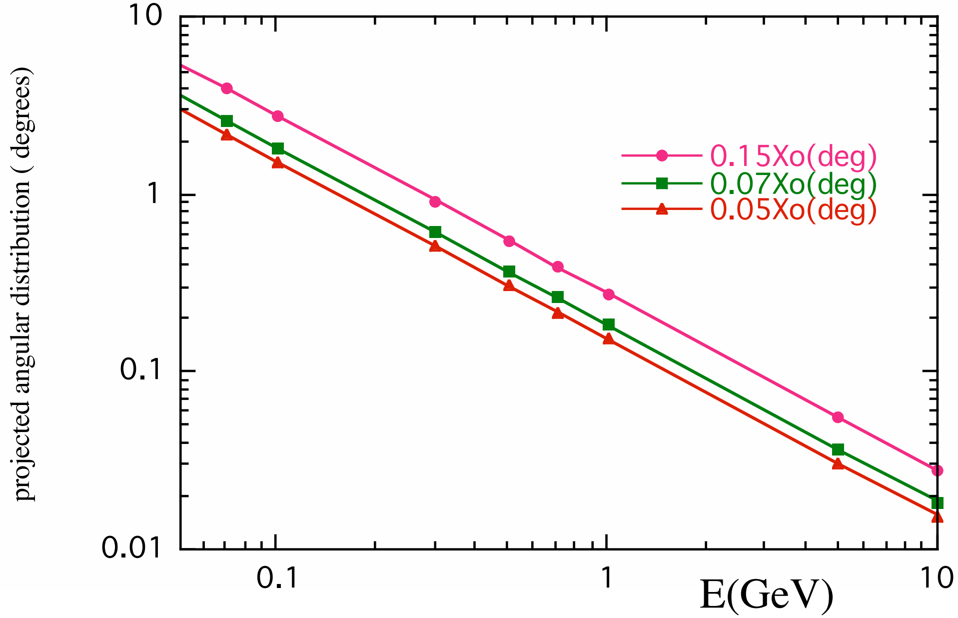


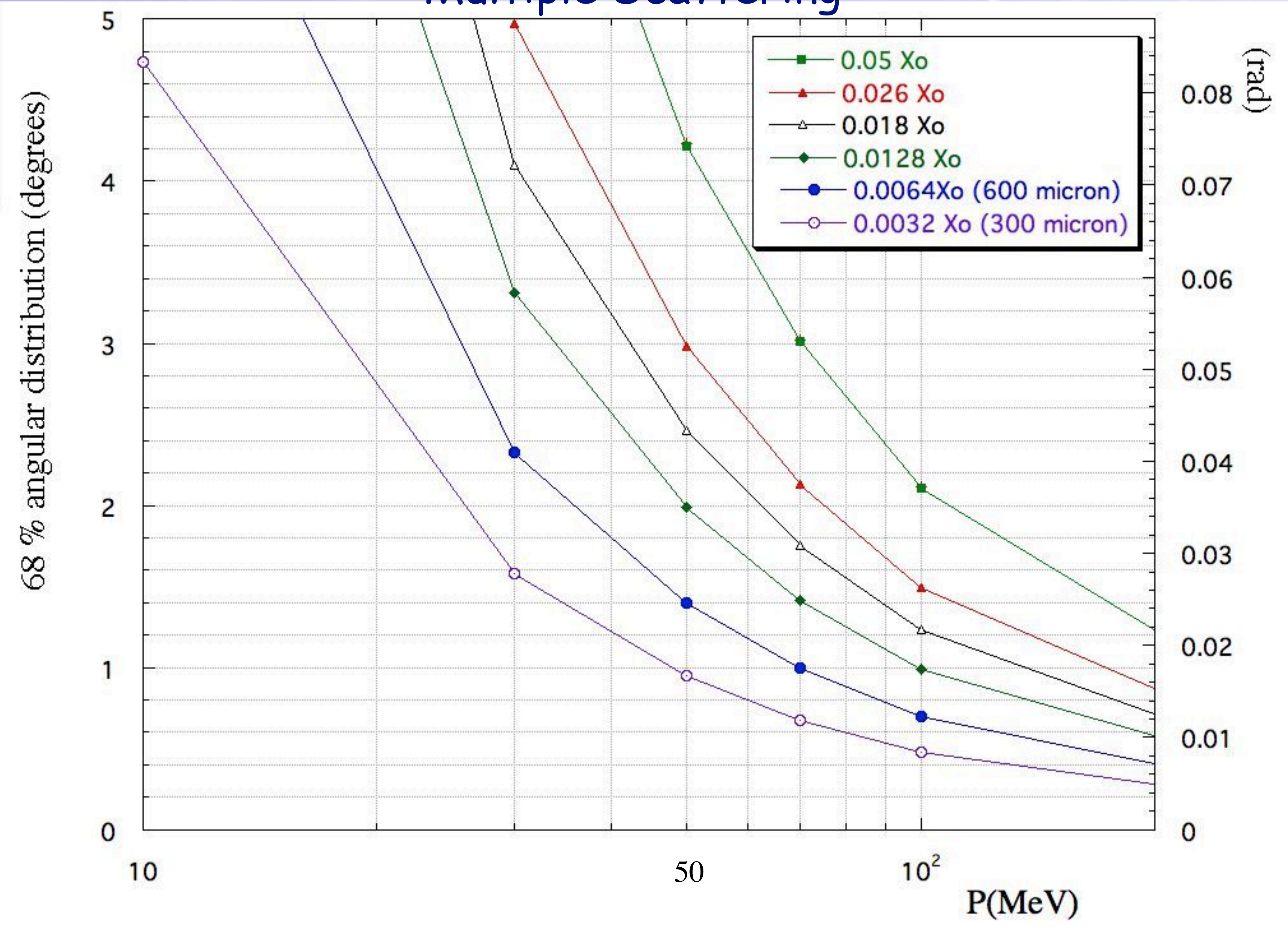
Multiple Scattering



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

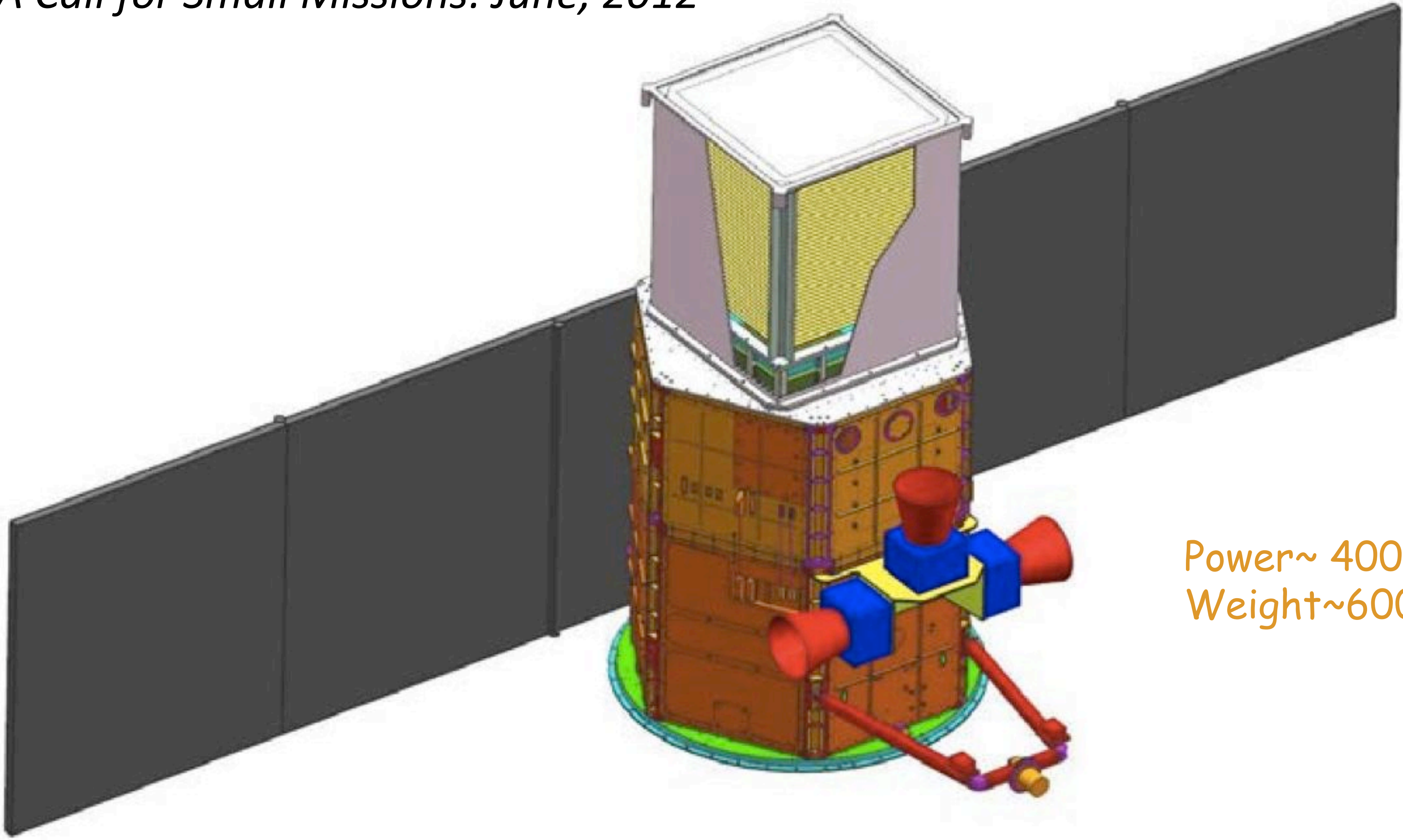
$$\theta_0 = \frac{13.6MeV}{\beta cp} z\sqrt{x/X_0}\,[1 + 0.038\ln(x/X_0)]$$

Multiple Scattering



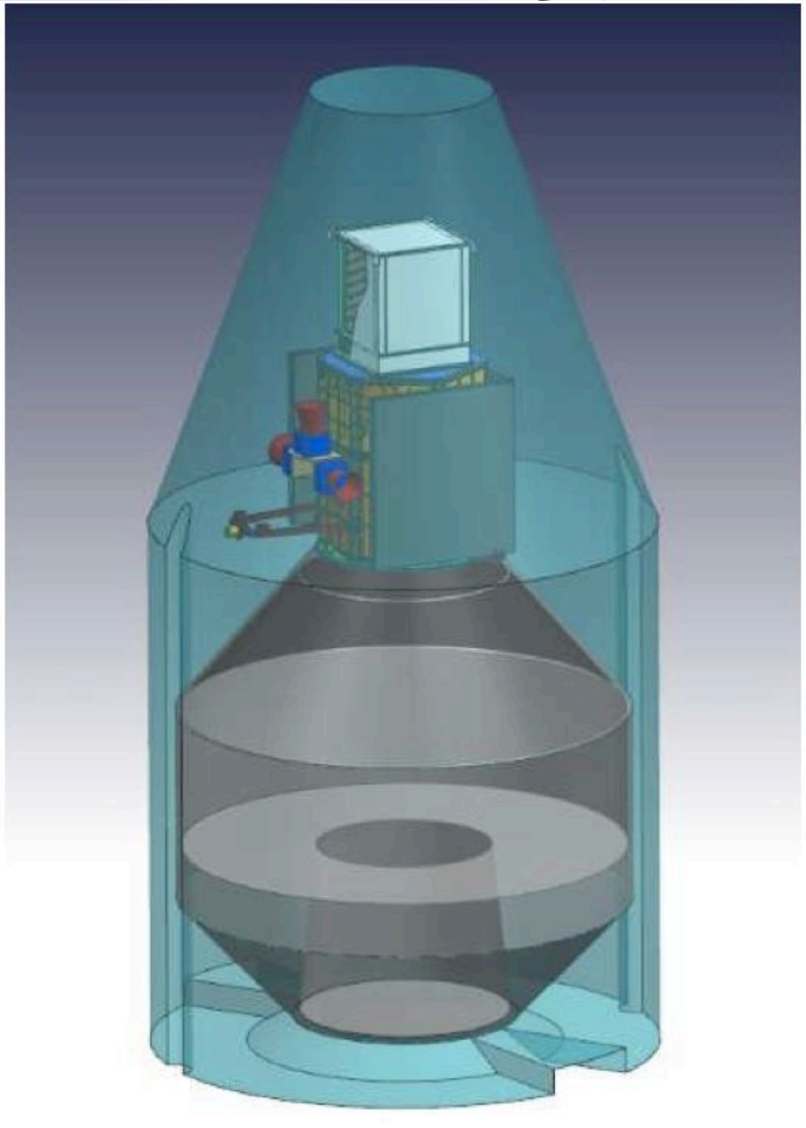
Gamma-light payload

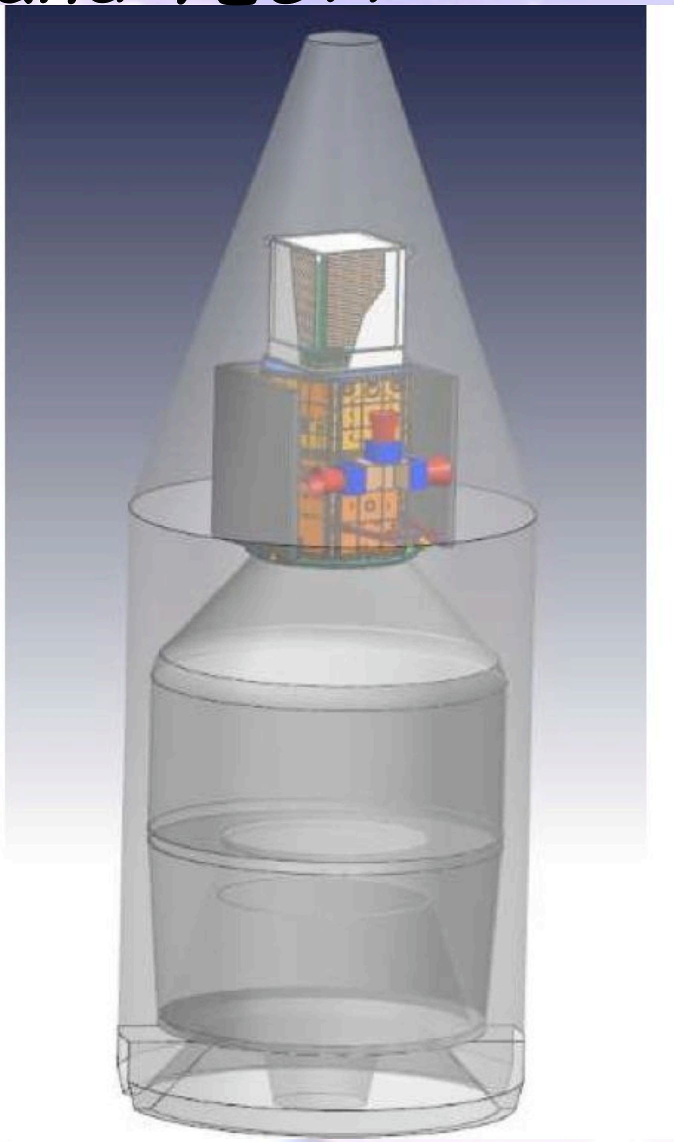
ESA Call for Small Missions: June, 2012



Power~ 400 W
Weight~600 Kg

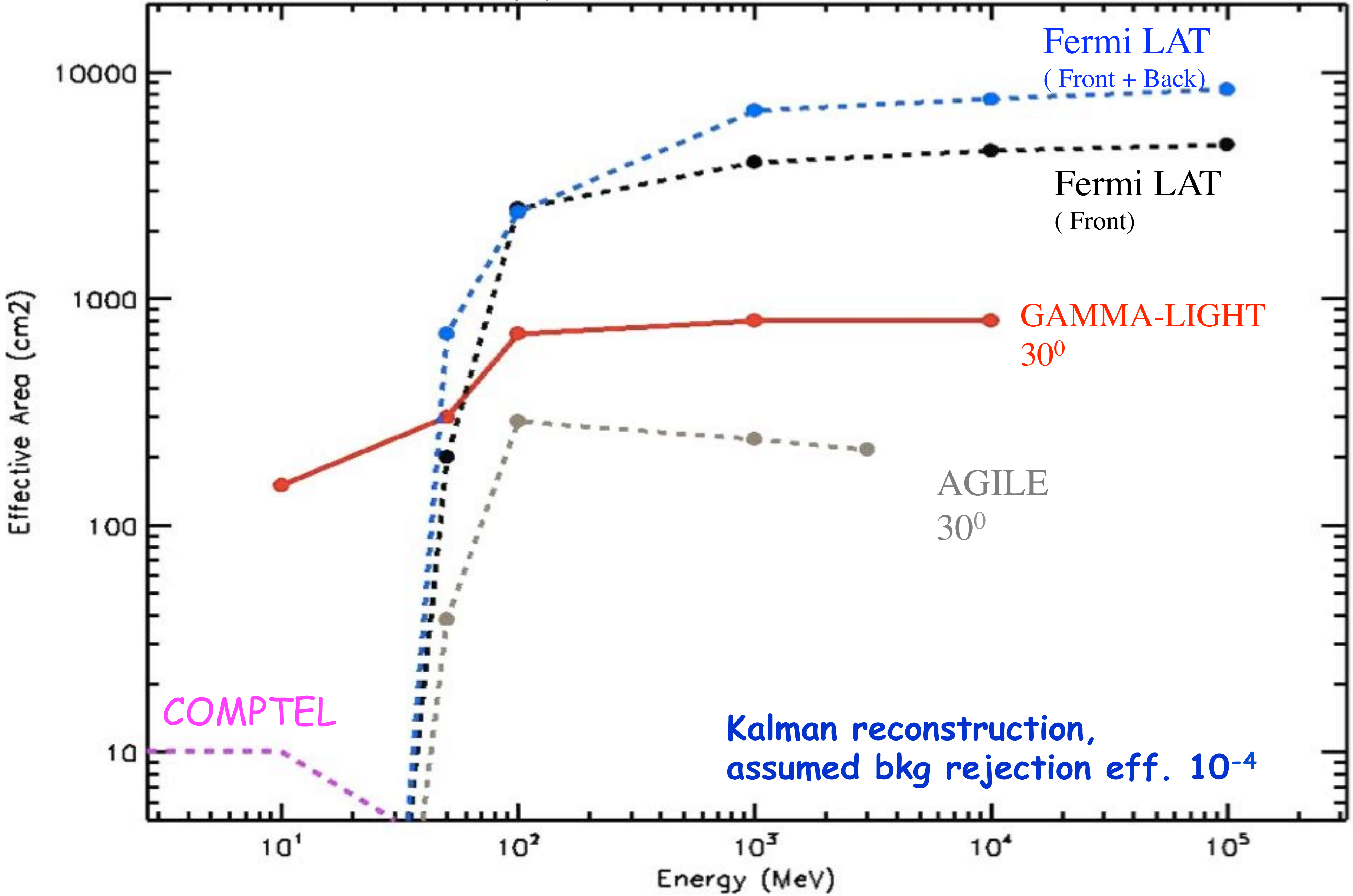
GAMMA-LIGHT satellite launch configurations for the PSLV and VEGA



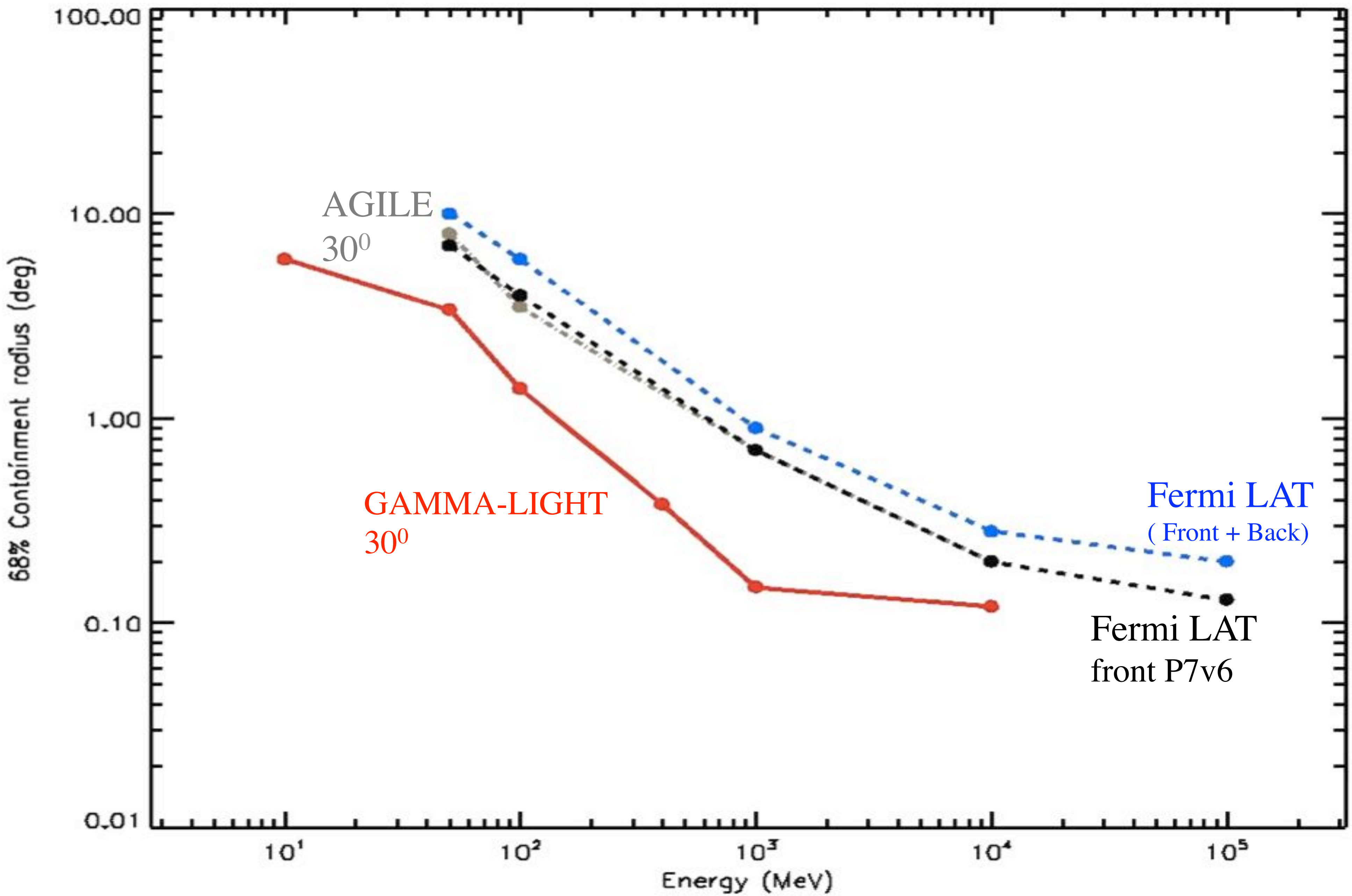


- a companion satellite similar to G-LIGHT can be accomodated.

Effective area



PSF (68% containment radius)



Gamma-400

Approved mission by ROSCOSMOS

Originally devoted Gamma rays study (30 GeV – 1 TeV) & high-energy electrons and positrons.

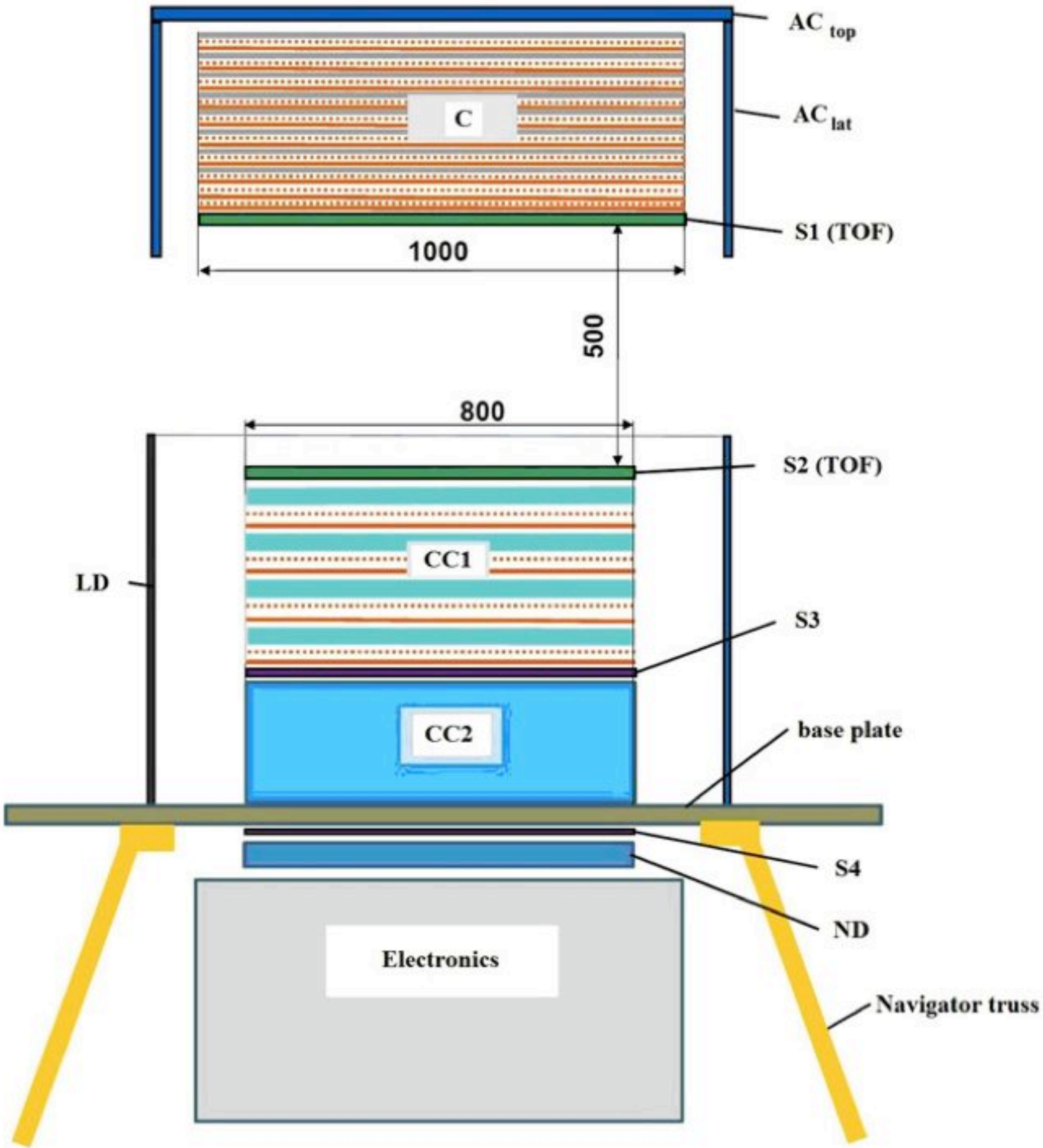
On going study for a revision of the project

- Launch foreseen by end 2018 unique opportunity to configure the apparatus for :

- gamma-rays from 100 MeV < up to 300 GeV
- proton & nuclei in cosmic-rays up to the "knee"
- electrons/positrons beyond TeV energy range

Gamma-400

cont.



Gamma-400 cont.

The collaboration

- Firenze, Pisa, Pavia, Roma2, Trieste =>=>=> PAMELA FERMI AGILE community

- At present:
  Russian, Italian, US collaboration
- Expressed interest from France, Spain and Sweden (KTH & OKC theorists and experimentalists)
- Current scientific interest from the TeV community (CTA)
- Ongoing contacts with the multi-wavelength community

- Open to possible contribution and collaborations

NEWS & ANALYSIS

Science, 20 May 2011

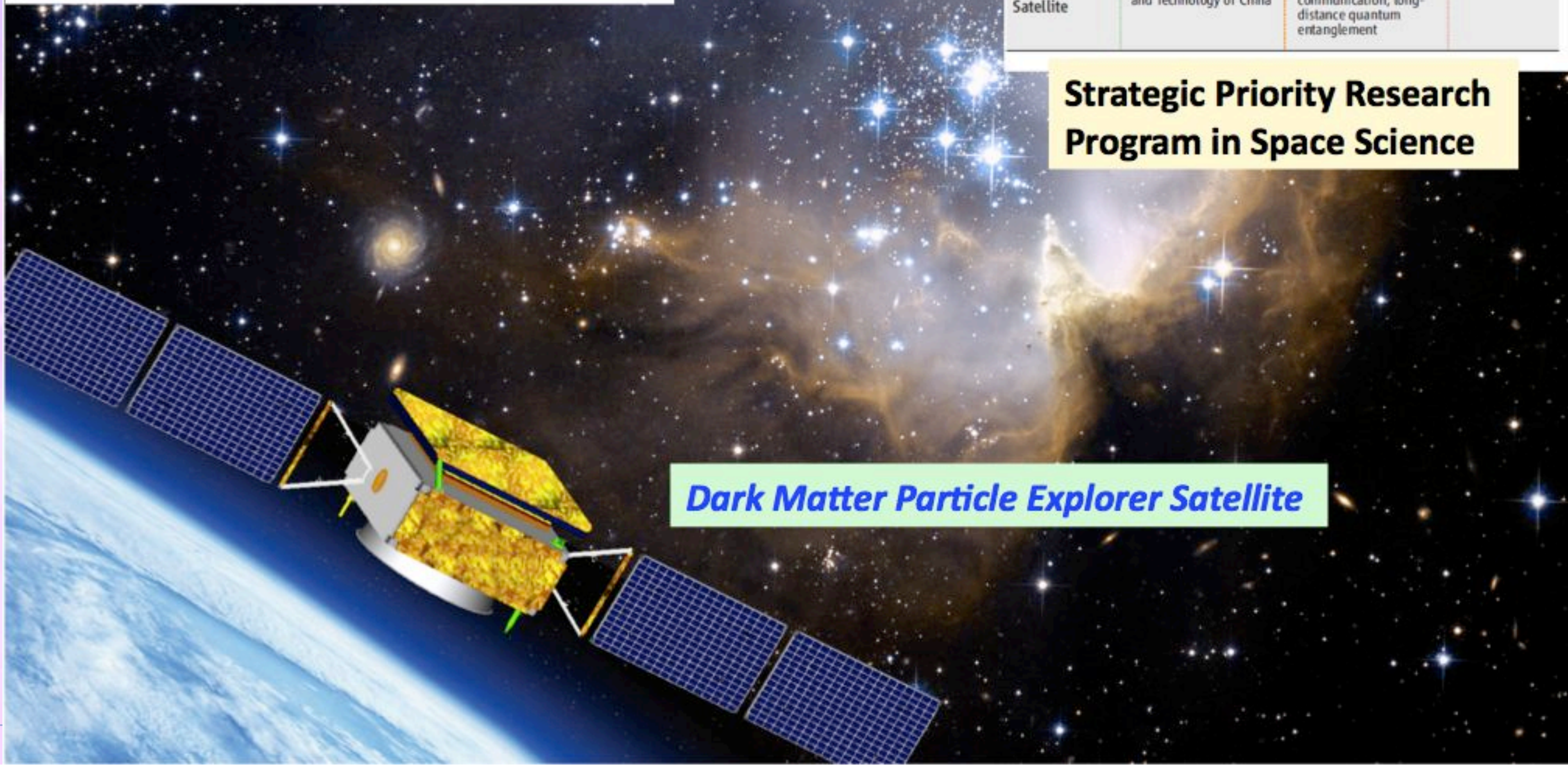
SPACE SCIENCE

Chinese Academy Takes Space Under Its Wing

LOFTY AMBITIONS

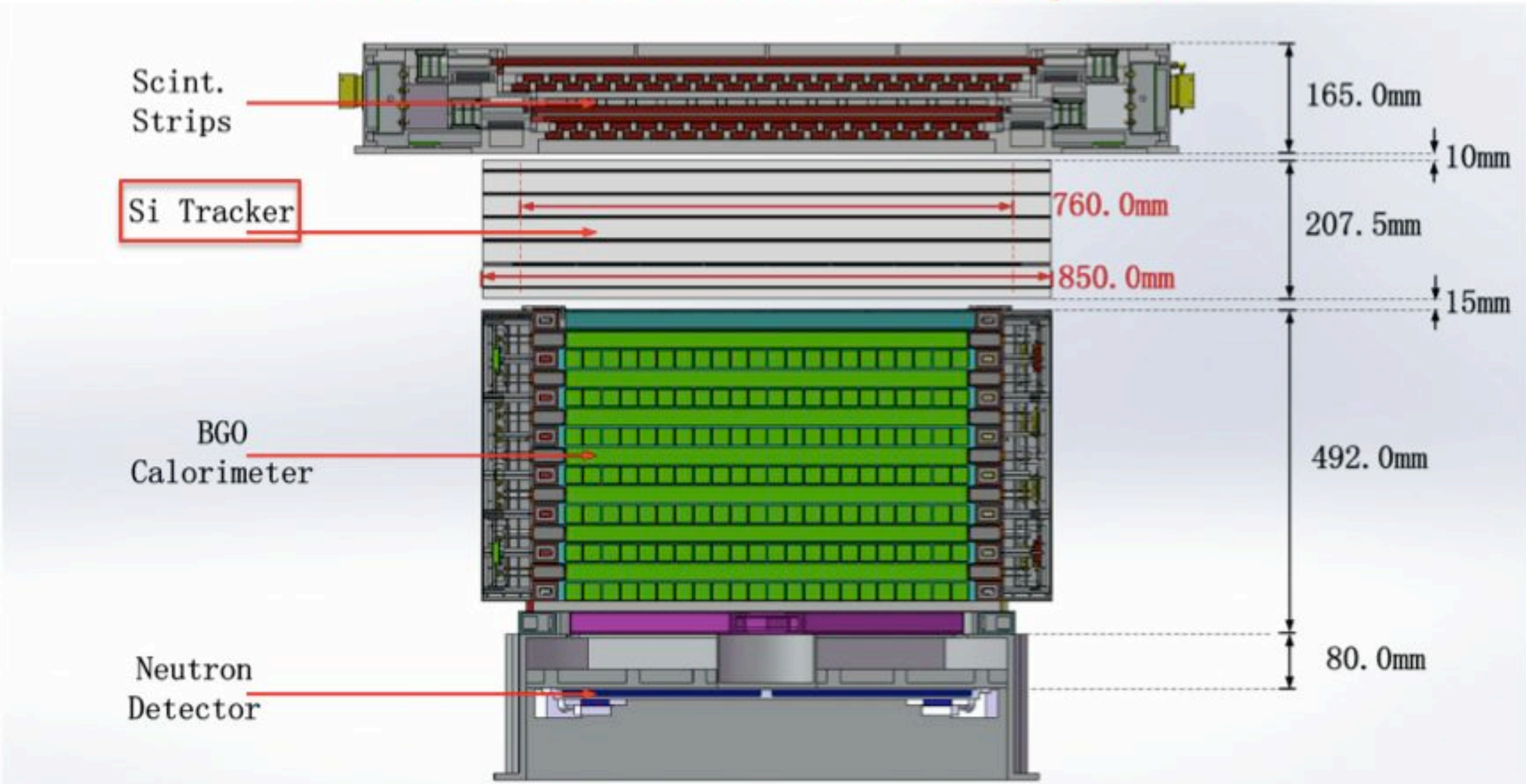
Mission	Chief scientist	Goals	Estimated launch
HXMT	Li Tipei, CAS Institute of High Energy Physics and Tsinghua University	Survey of x-ray sources; detailed observations of known objects	2014
Shijian-10	Hu Wenrui, CAS Institute of Mechanics	Study physical and biological systems in microgravity and strong radiation environment	Early 2015
KuaFu Project	William Liu, Canadian Space Agency and CAS Center for Space Science and Applied Research	Study solar influence on space weather	Mid-2015
Dark Matter Satellite	Chang Jin, CAS Purple Mountain Observatory	Search for dark matter; study cosmic ray acceleration	Late 2015
Quantum Science Satellite	Pan Jianwei, University of Science and Technology of China	Quantum key distribution for secure communication; long-distance quantum entanglement	2016

Strategic Priority Research Program in Space Science



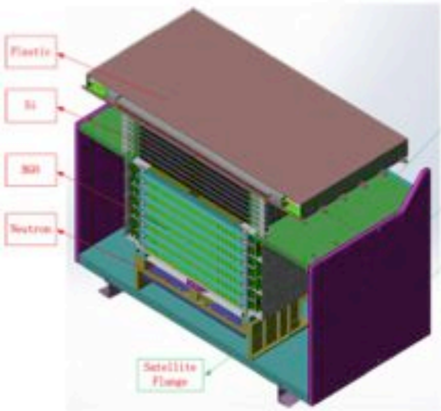
Dark Matter Particle Explorer Satellite

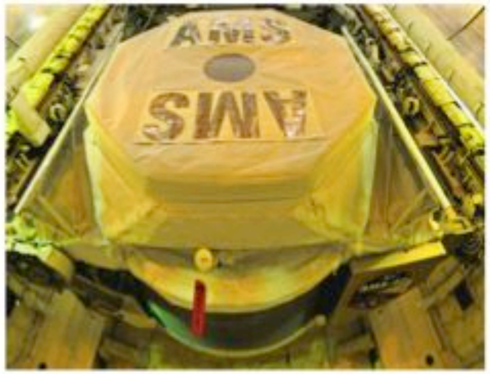
DAMPE Detector Layout

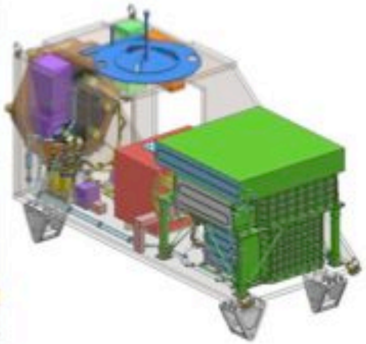
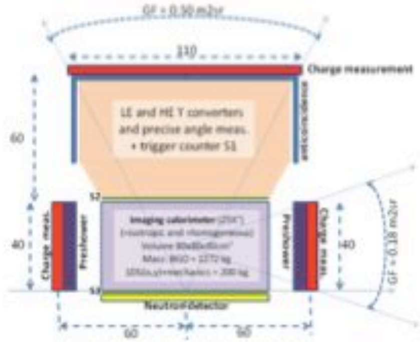


- Scintillator strips, Silicon tracker, BGO calorimeter, neutron detector
- Combine a γ-ray space telescope with a deep imaging calorimeter
  - Silicon tracker/converter + BGO imaging calorimeter
    - Total ~33 X_0 → deepest detector in space

DAMPE and other detectors





	DAMPE	AMS-02	Fermi LAT	CALET	GAMMA-400
Energy range (GeV)	5 - 10^4	0.1 - 10^3	0.02 - 300	1 - 10^3	0.1 – 3 10^3
e/γ Energy res.@100 GeV (%)	1.5	3	10	2	1
e/γ Angular res.@100 GeV (°)	0.1	0.3	0.1	0.1	0.01
e/p discrimination	10^5	10^5 - 10^6	10^3	10^5	10^6
Calorimeter thickness (X_0)	31	17	8.6	30	25
Geometrical accep. (m^2sr)	0.4	0.09	1	0.12	0.5

DAMPE Tracker Components

- Silicon sensor (Hamamatsu)
  - use AGILE specification
- FE ASIC (Gamma Medica-Ideas)
  - use updated version of the AMS-02 ASICs, already available thanks to INFN Perugia R&D
- Electronics (INFN Pg, DPNC for specs)
  - use updated version of the AMS readout and power electronics
- Silicon ladder (INFN Pg +DPNC)
  - similar to AMS-02
- Silicon plane and tracker assembly (DPNC + INFN Pg)
  - based on AMS-02 experience

Proven technologies and profiting from previous experiences!

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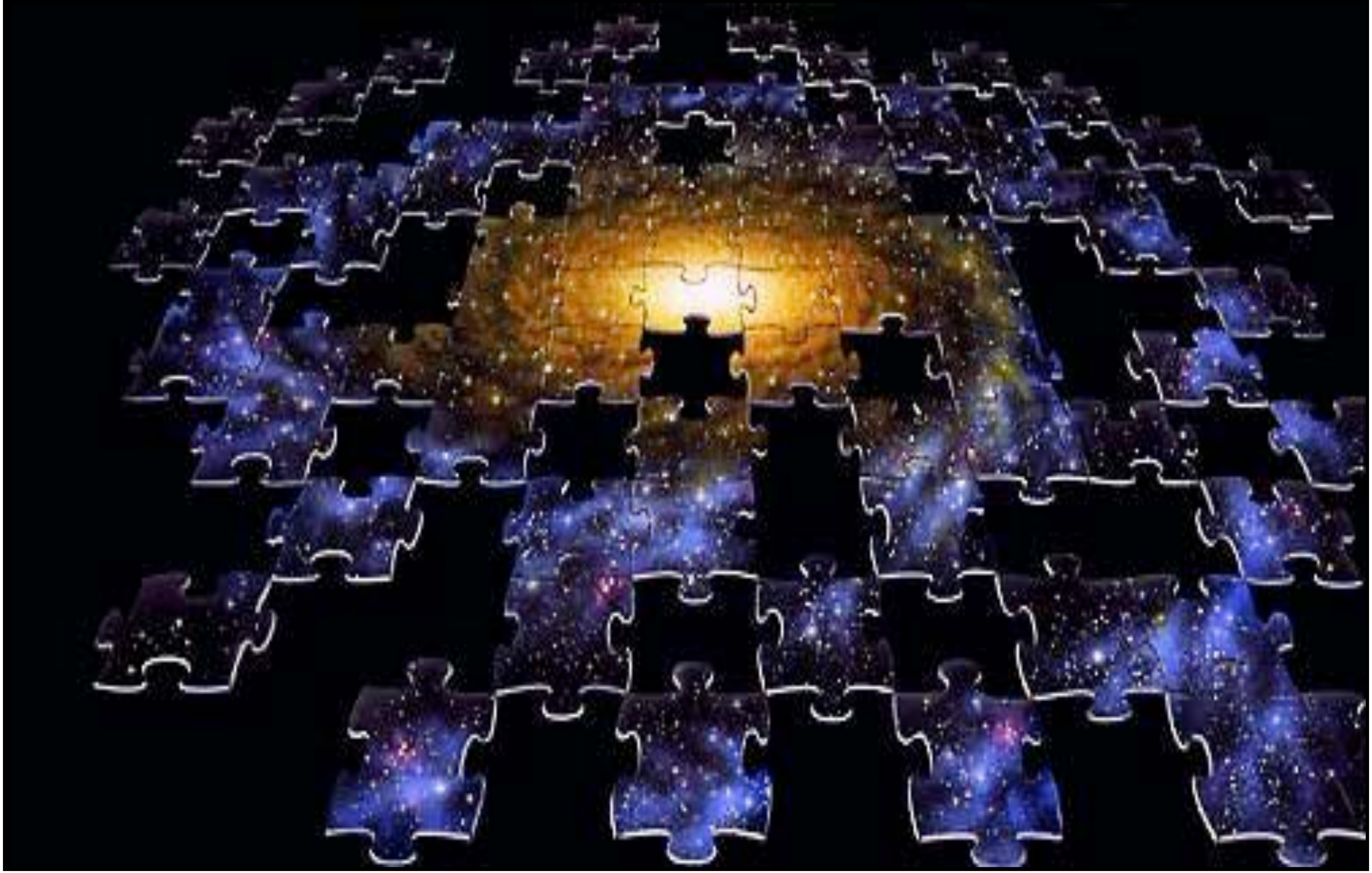
INFN

Dark Matter

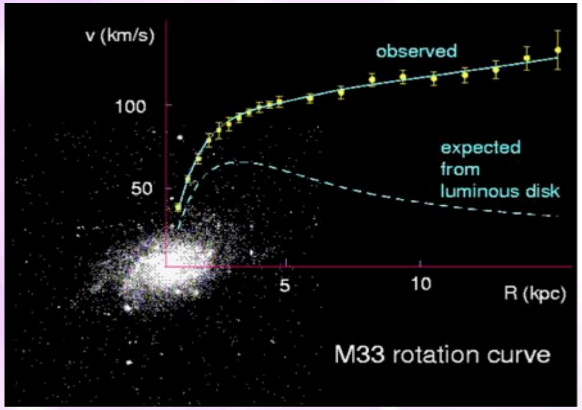



via
della Fisica
viale
dell'Astronomia

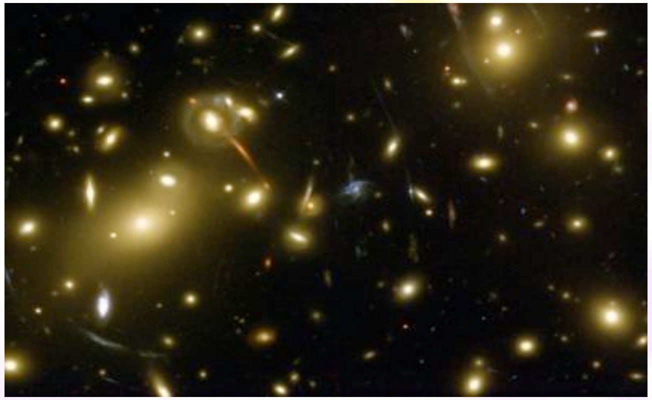
Dark Matter EVIDENCES

- 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, many other evidences:

Rotation curves of galaxies

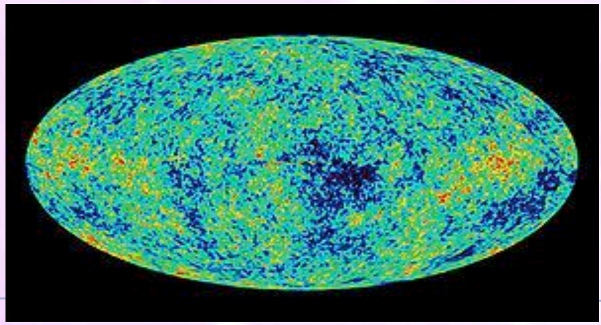


Gravitational lensing

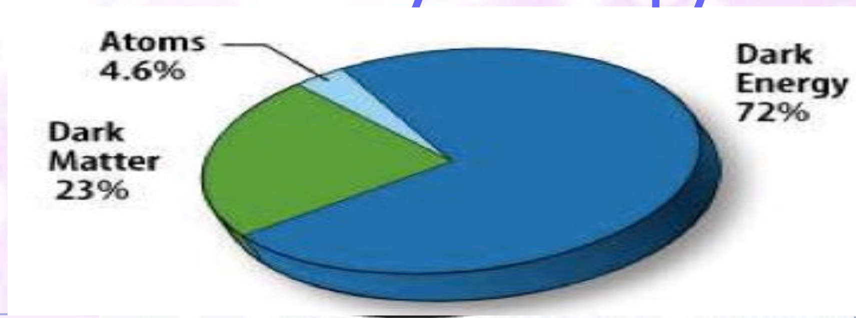


Bullet cluster

Structure formation as deduced from CMB



Data by WMAP imply:

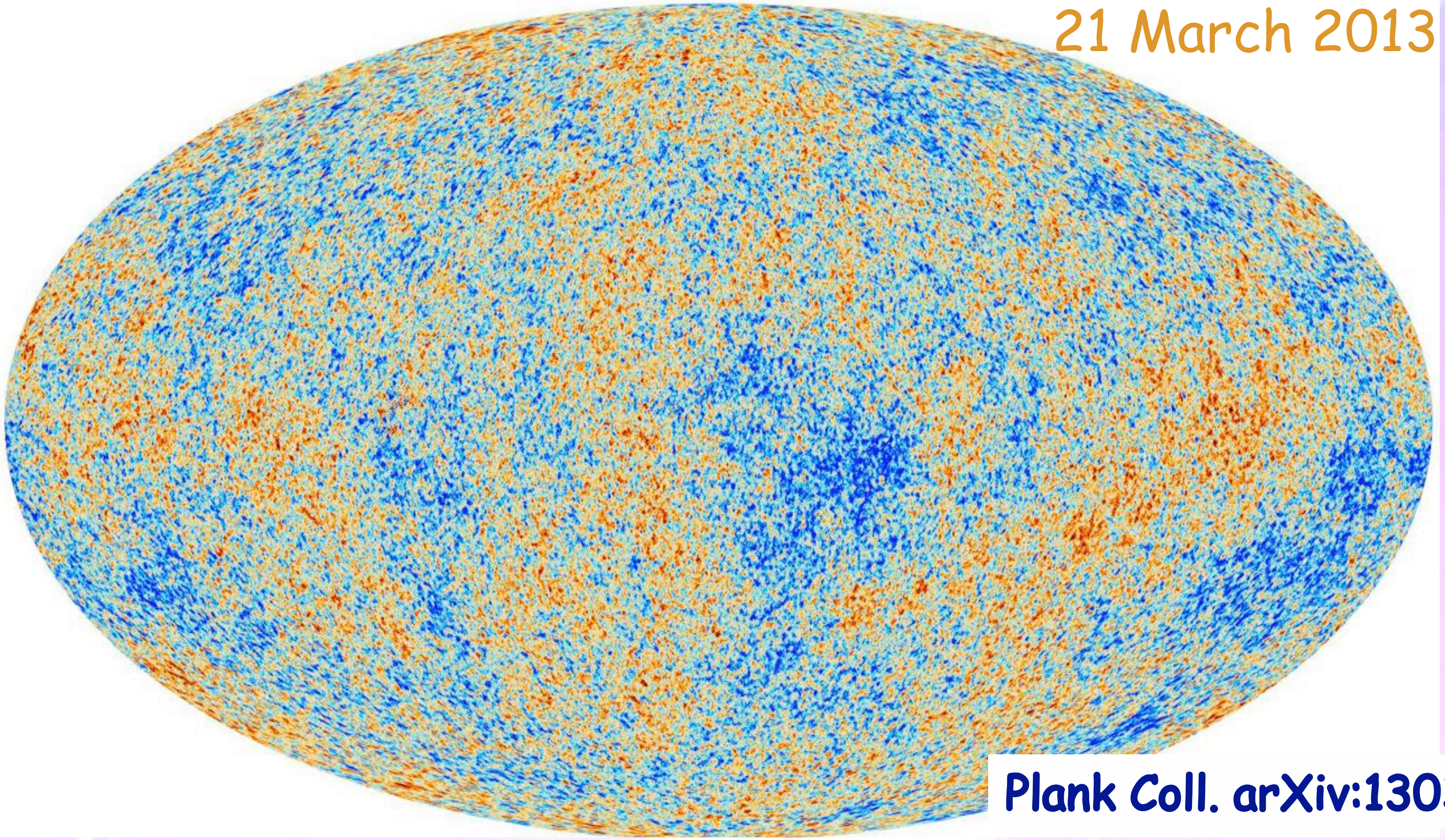


$\Omega_b h^2 \approx 0.02$

$\Omega_{DM} h^2 \approx 0.1$

The anisotropies of the Cosmic microwave background (CMB) as observed by Planck

21 March 2013



Plank Coll. arXiv:1303.5076

Past decades saw precision studies of 5 % of our Universe -> Discovery of the Standard Model

The LHC is delivering data

We are just at the beginning of exploring 95 % of the Universe.

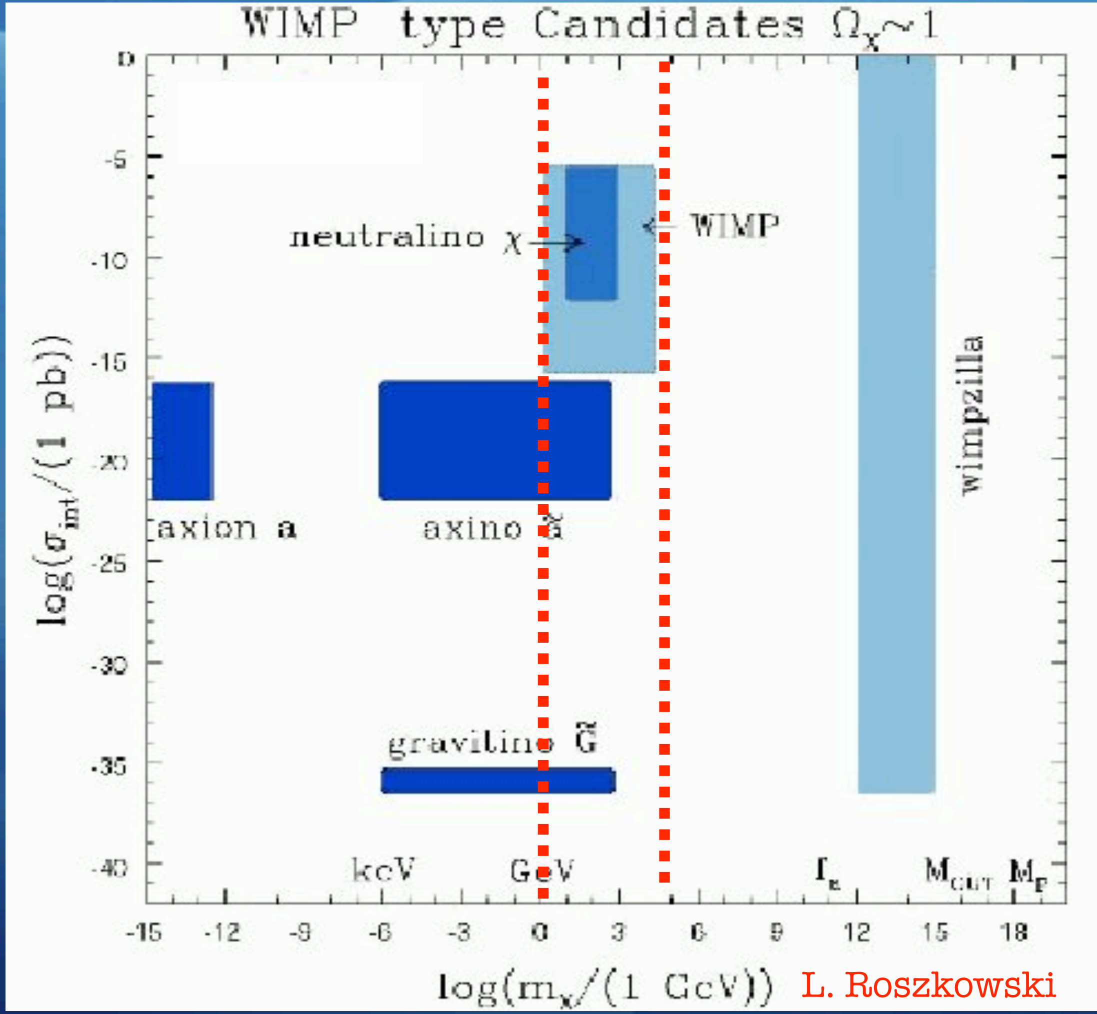
Exciting prospects

R.-D. Heuer, CERNGeneral Director36th International Conference on High Energy Physics ICHEP2012, Closing Talk

ICHEP2012
Melbourne

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
- NEUTRALINO
- Messenger States in GMSB
- Branons
- Chaplygin Gas
- Split SUSY
- Primordial Black Holes



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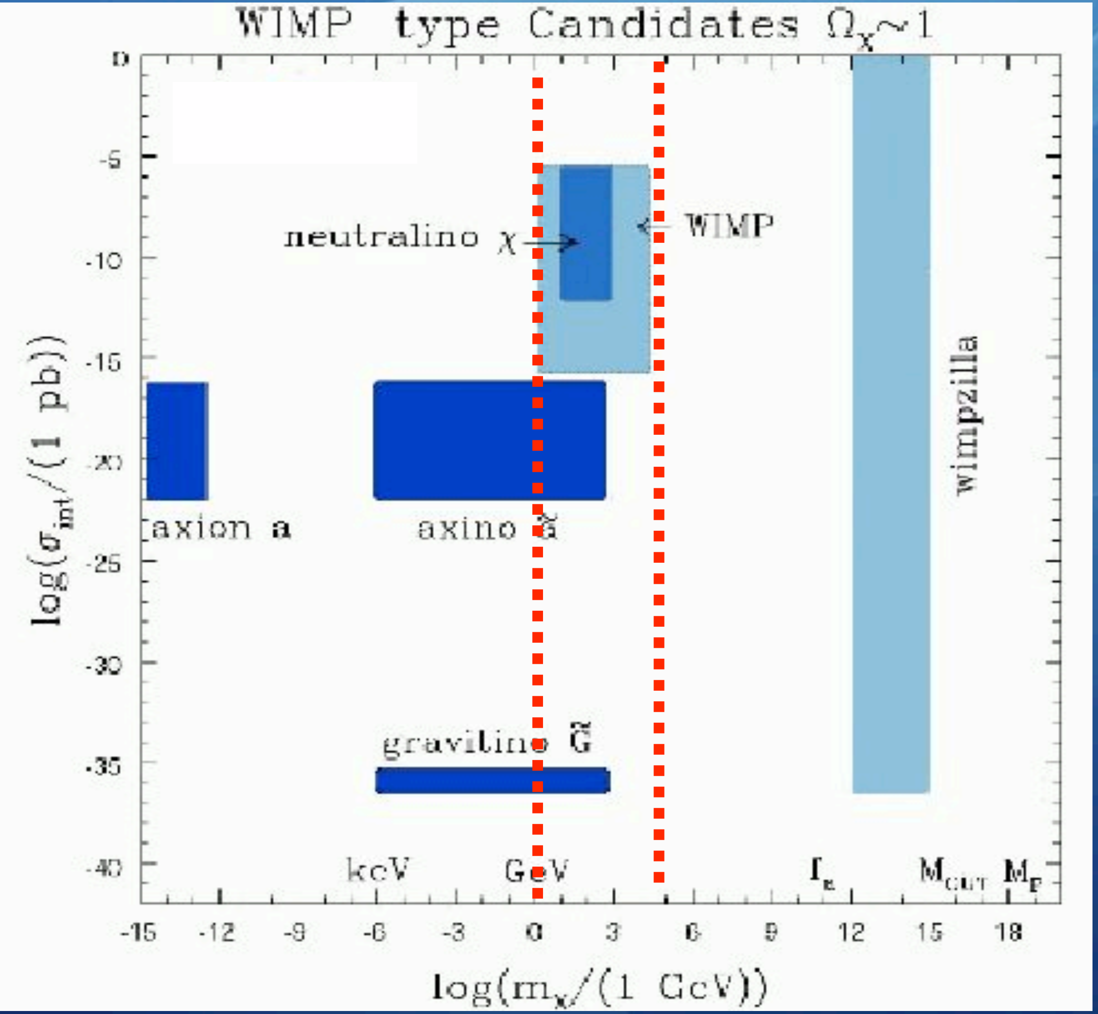
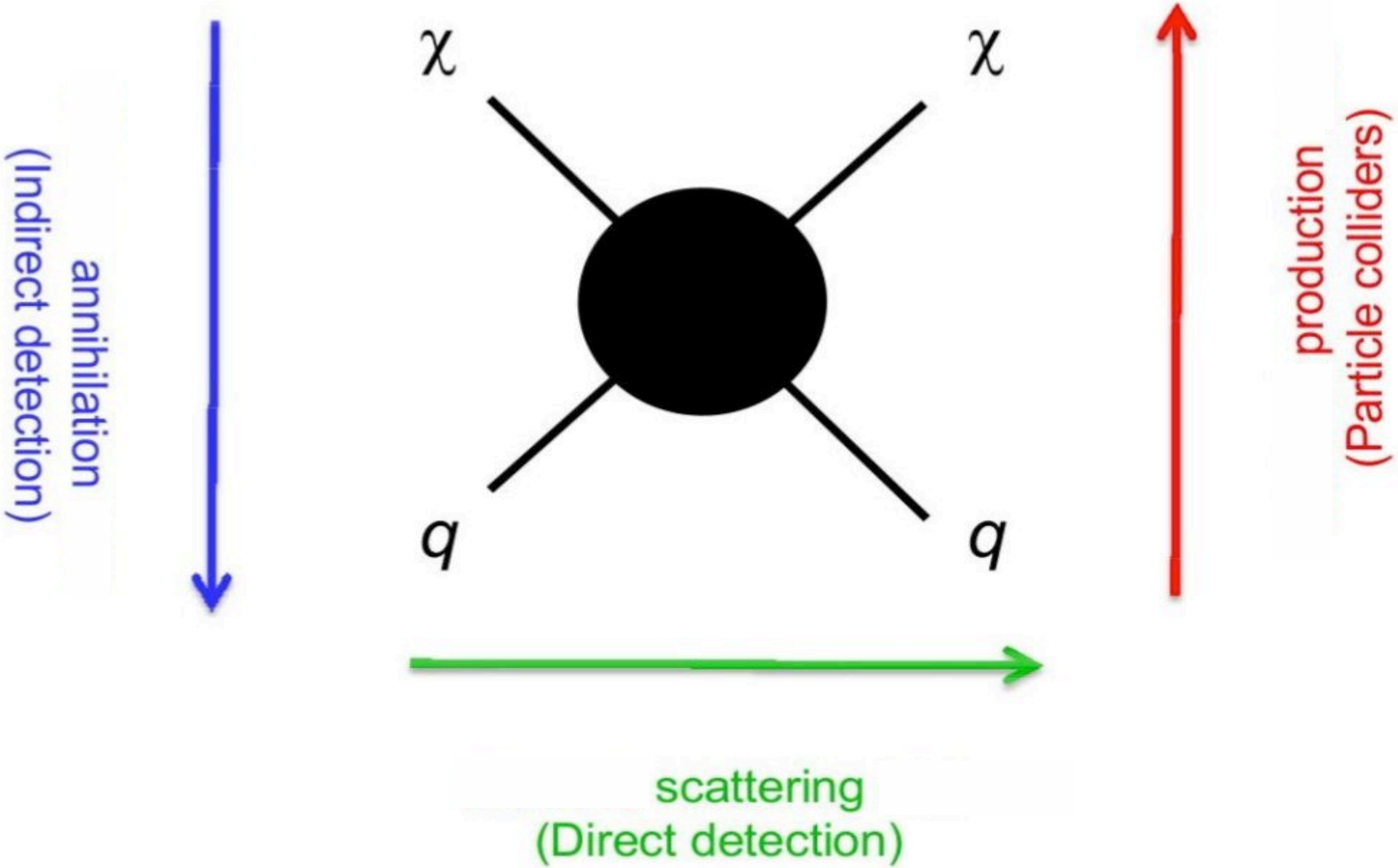
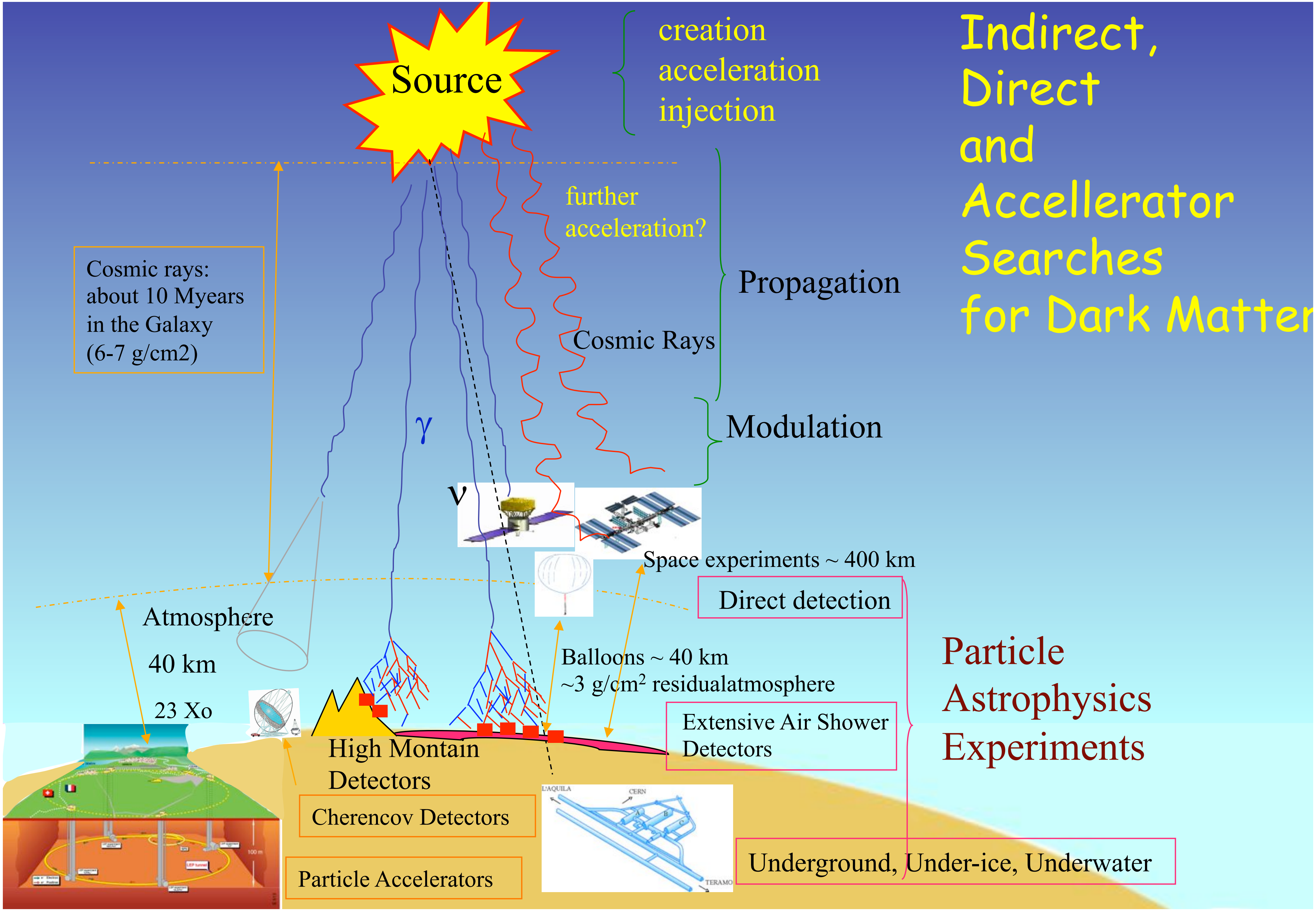
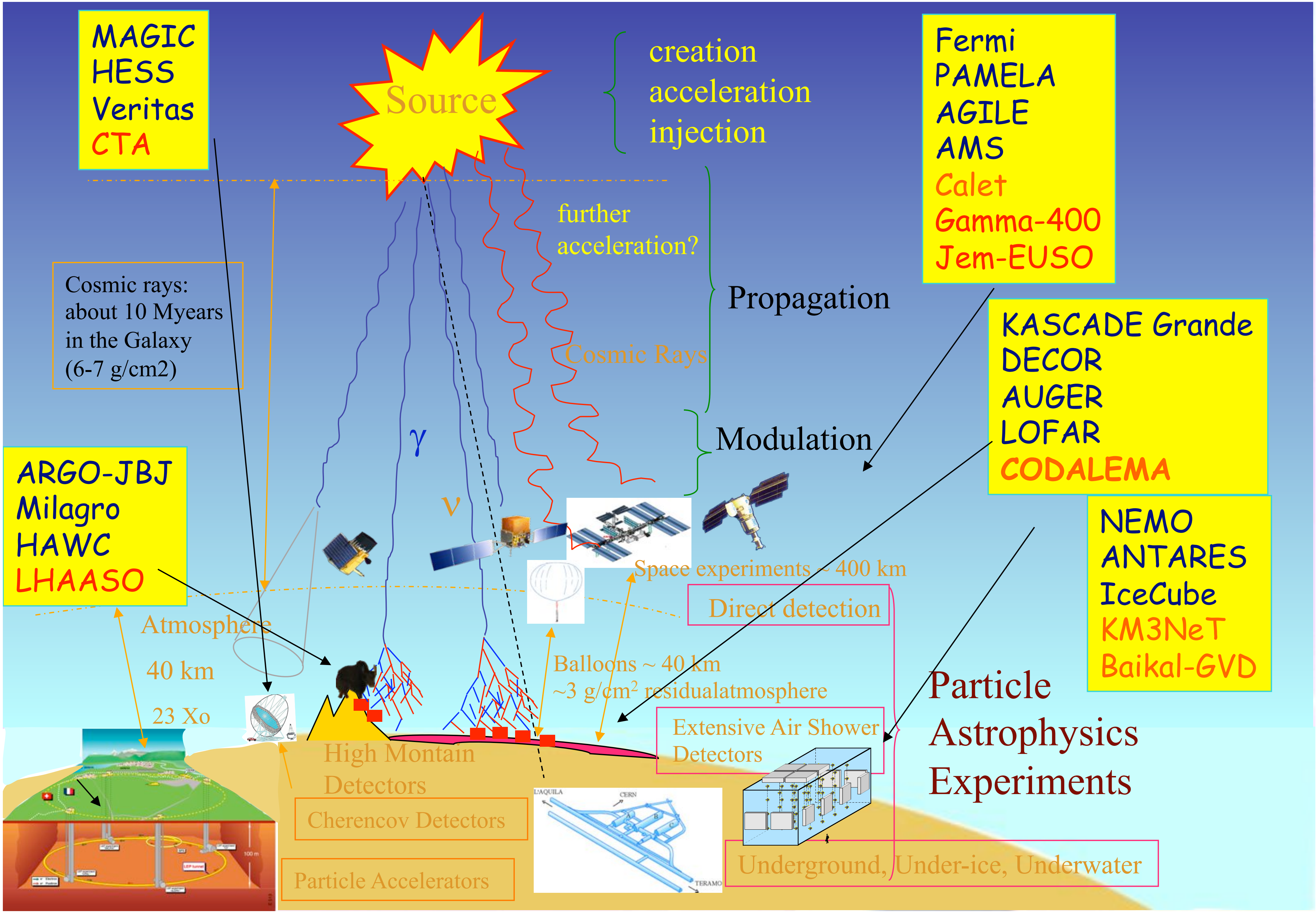



χ
χ
q
q
annihilation
(Indirect detection)
production
(Particle colliders)
scattering
(Direct detection)


Indirect, Direct and Accellerator Searches for Dark Matter
Source
creation
acceleration
injection
further acceleration?
Propagation
Cosmic Rays
Modulation
Cosmic rays: about 10 Myears in the Galaxy (6-7 g/cm2)
γ
ν
Space experiments ~ 400 km
Direct detection
Atmosphere
40 km
23 Xo
Balloons ~ 40 km
~3 g/cm² residualatmosphere
Extensive Air Shower Detectors
High Montain Detectors
Cherencov Detectors
Particle Accelerators
L'AQUILA
CERN
TERAMO
Underground, Under-ice, Underwater
Particle Astrophysics Experiments



MAGIC
HESS
Veritas
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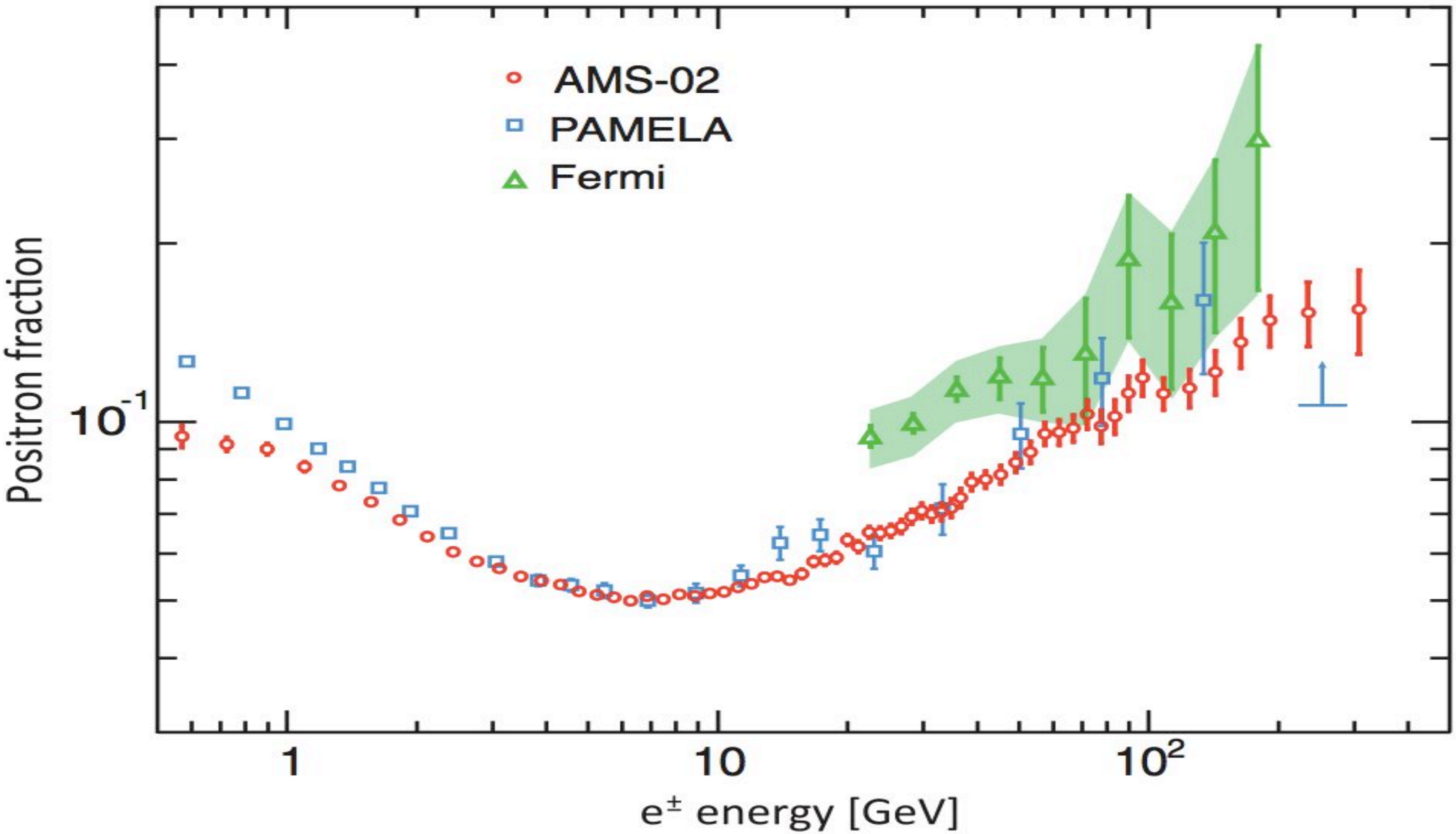
ν
ARGO-JBJ
Milagro
HAWC
LHAASO
NEMO
ANTARES
IceCube
KM3NeT
Baikal-GVD
Space experiments ~ 400 km
Direct detection
Atmosphere
40 km
23 Xo
Balloons ~ 40 km
~3 g/cm² residualatmosphere
Particle
Astrophysics
Experiments
Extensive Air Shower
Detectors
High Montain
Detectors
Cherencov Detectors
Particle Accelerators
L'AQUILA
CERN
TERAMO
Underground, Under-ice, Underwater

Neutralino WIMPs

Assume χ present in the galactic halo

- χ is its own antiparticle **=>** can annihilate in galactic halo producing gamma-rays, antiprotons, positrons….
- Antimatter not produced in large quantities through standard processes (secondary production through p + p **-->** anti p + X)
- So, any extra contribution from exotic sources (χ χ annihilation) is an interesting signature
- ie: χ χ -->anti p + X
- Produced from (e. g.) χ χ **-->** q / g / gauge boson / Higgs boson and subsequent decay and/ or hadronisation.

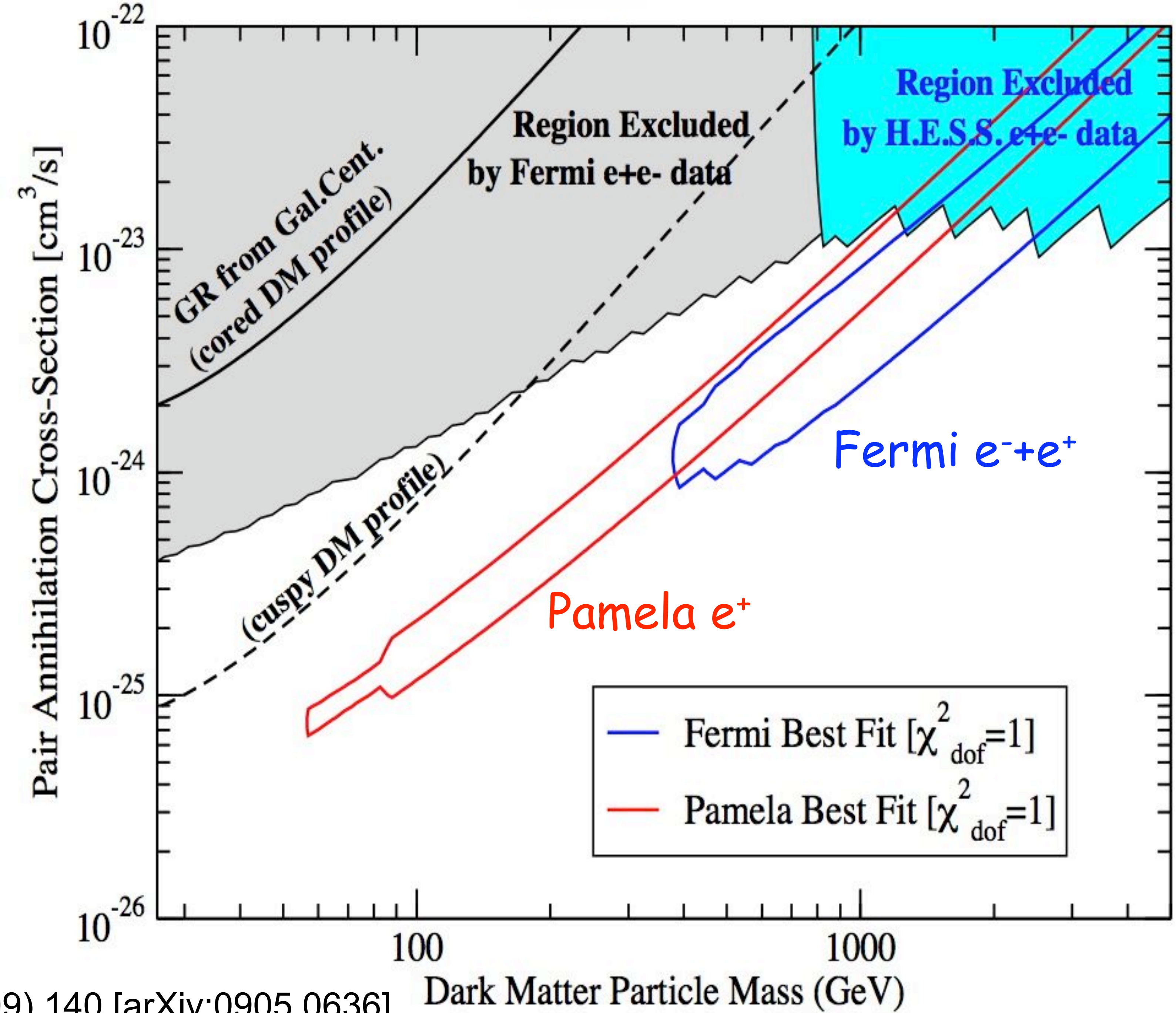
Positron Fraction 3/04/13new AMS results



Pamela, Astropart. Phys. 34, 1 (2010) and updateto be published
Fermi Coll., PRL, 108(2012) 011103arXiv:1109.0521AMS: PRL 110, 141102 (2013)

Lepto-philic Models

here we assume a democratic dark matter pair-annihilation branching ratio into each charged lepton species: 1/3 into e+e-, 1/3 into μ+ μ- and 1/3 into τ+ τ- Here too antiprotons are not produced in dark matter pair annihilation.



Astrp Phys.32 (2009) 140 [arXiv:0905.0636]

Lepto-philic Models

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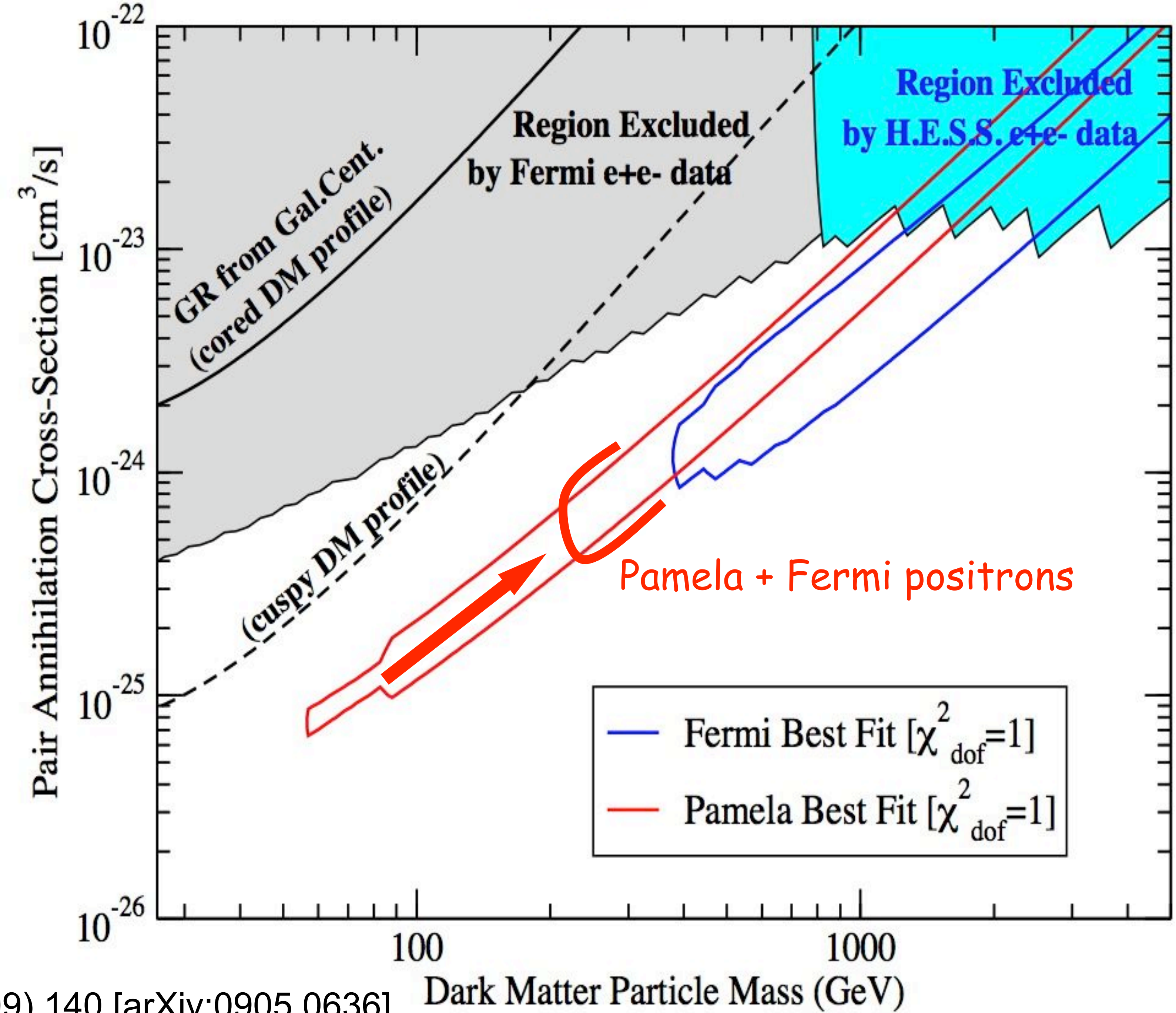

update of Astrp Phys.32 (2009) 140 [arXiv:0905.0636]

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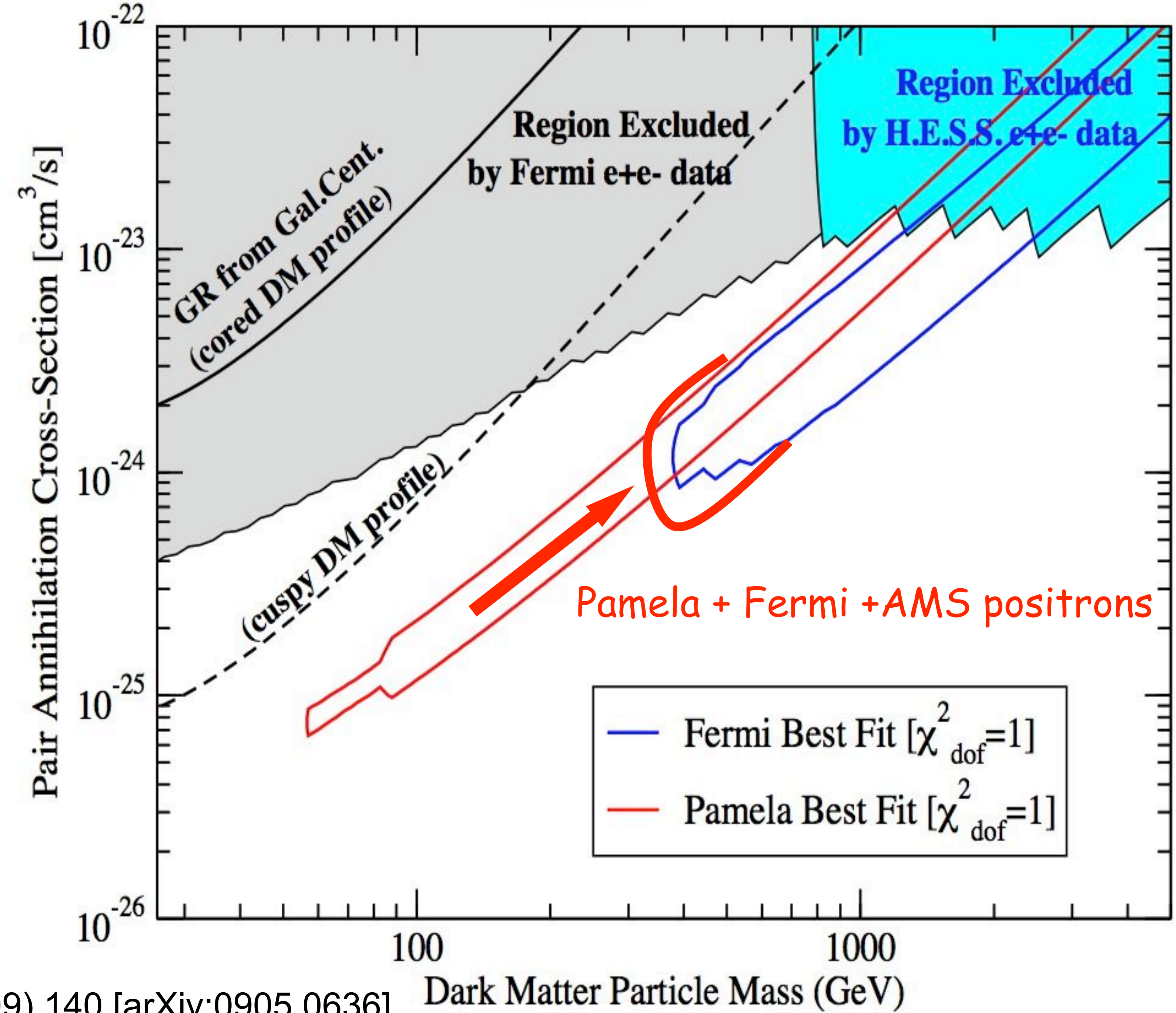


update of Astrp Phys.32 (2009) 140 [arXiv:0905.0636]

Pulsars

1. On purely energetic grounds they work (relatively large efficiency)

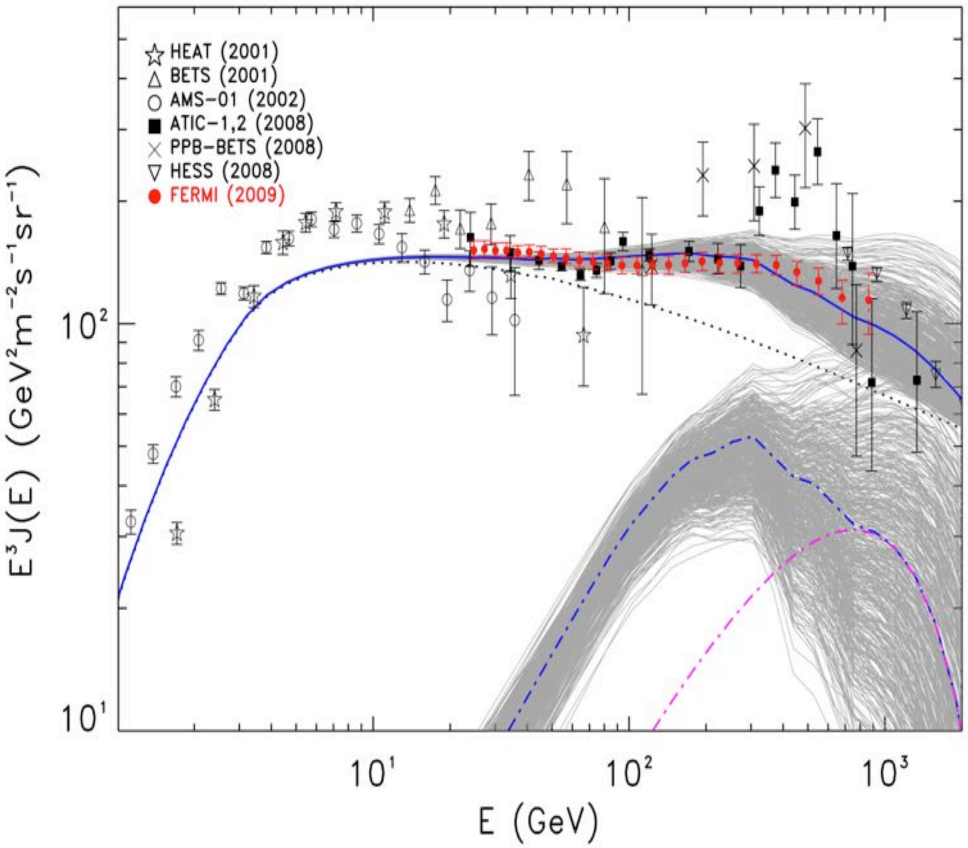
2. On the basis of the spectrum, it is not clear
   1. The spectra of PWN show relatively flat spectra of pairs at Low energies but we do not understand what it is
   2. The general spectra (acceleration at the termination shock) are too steep

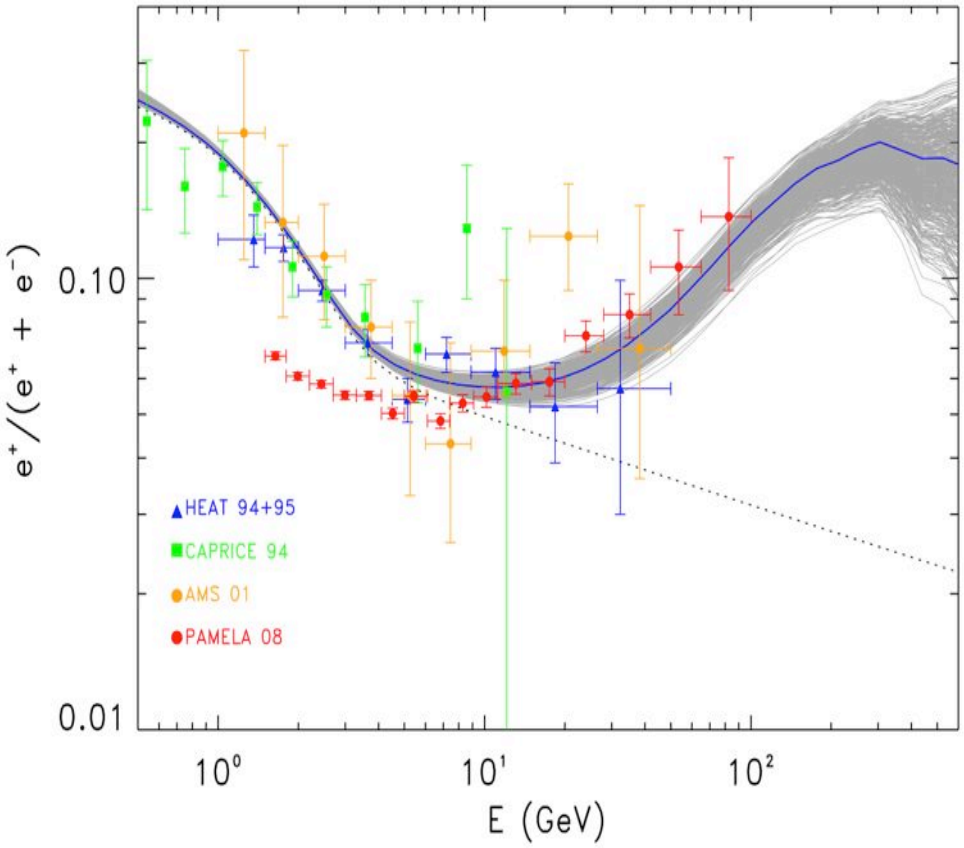
The biggest problem is that of escape of particles from the pulsar
1. Even if acceleration works, pairs have to survive losses
2. And in order to escape they have to cross other two shocks

New Fermi data on pulsars will help to constrain the pulsar models

What if we randomly vary the pulsar parameters relevant for e+e- production?

(injection spectrum, e+e- production efficiency, PWN "trapping" time)

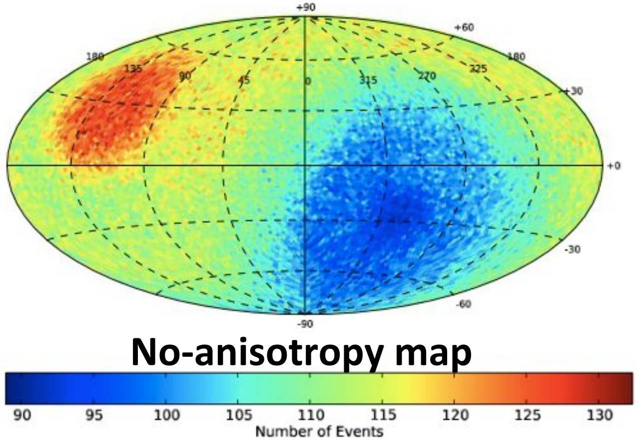




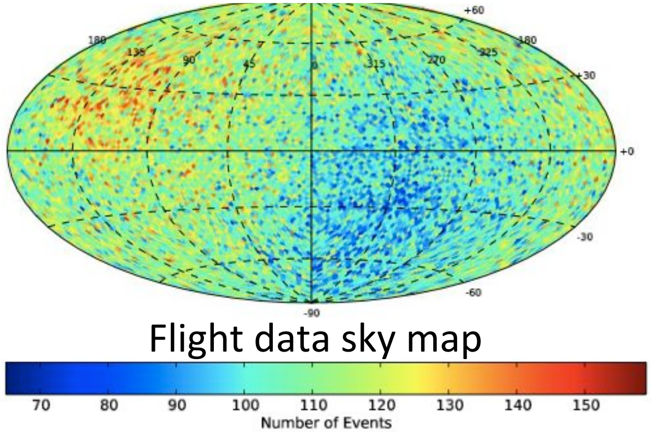
Under reasonable assumptions, electron/positron emission from pulsars offers a viable interpretation of Fermi CRE data which is also consistent with the HESS and Pamela results.

D.Grasso et al. Astropart. Phys. 32 (2009), pp.140 [arXiv:0905.0636]

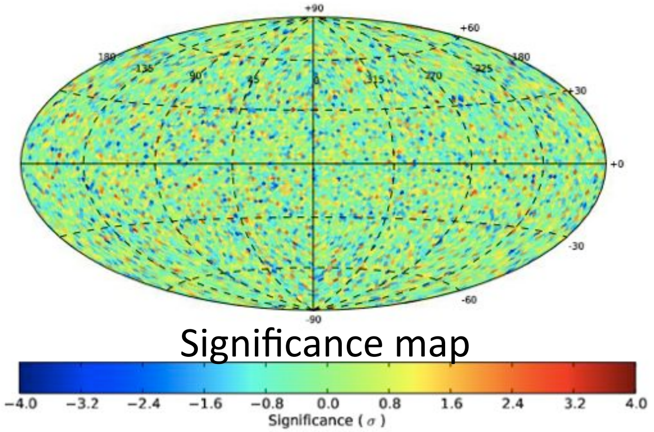
Cosmic Ray Electrons Anisotropy



No-anisotropy map



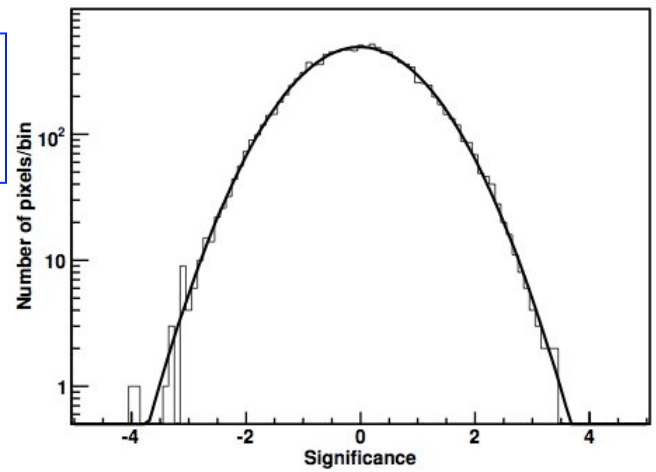
Flight data sky map



Significance map

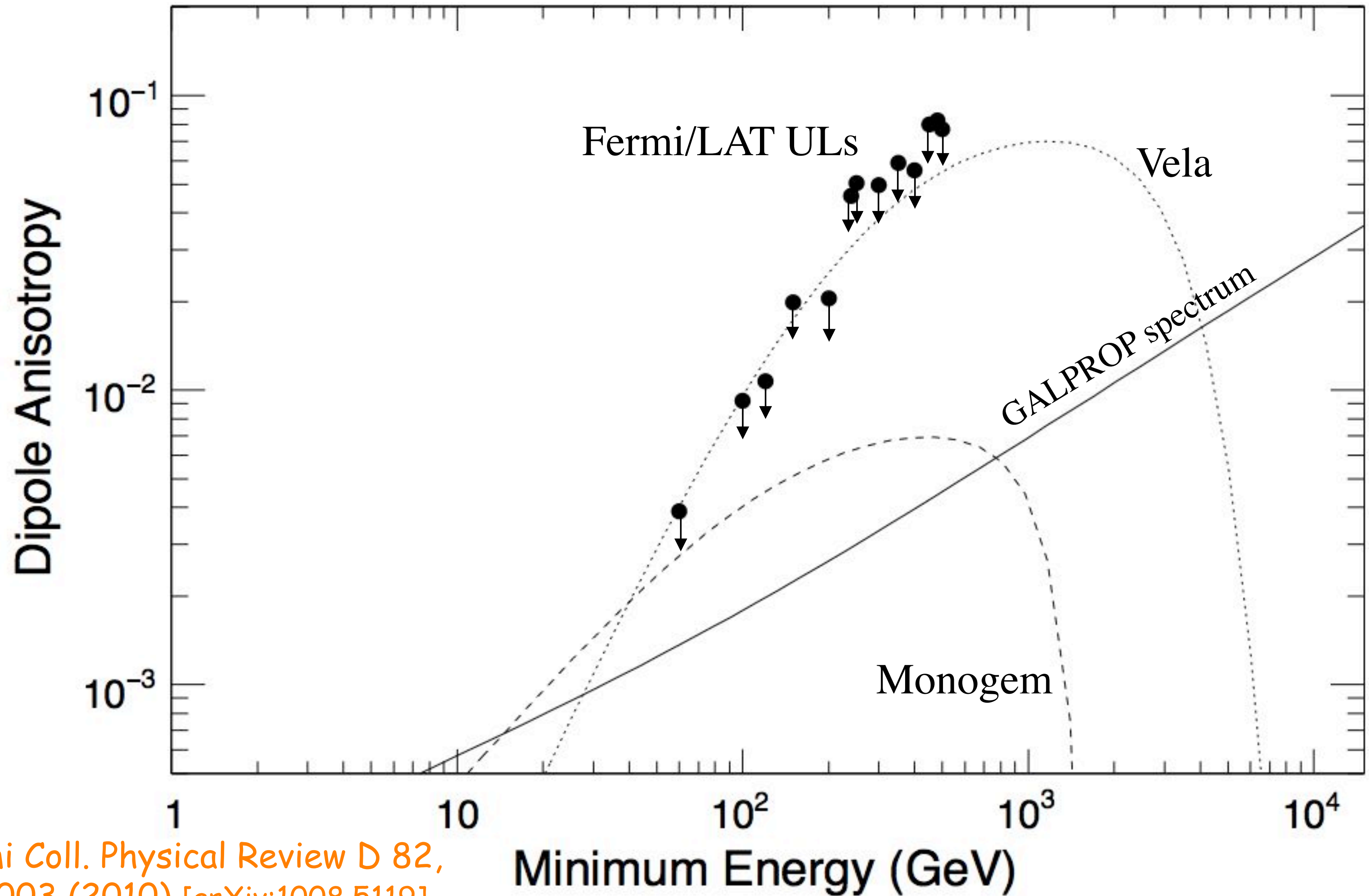
the levels of anisotropy expected for Geminga-like and Monogem-like sources (i.e. sources with similar distances and ages) seem to be higher than the scale of anisotropies excluded by the results
However, it is worth to point out that the model results are affected by large uncertainties related to the choice of the free parameters

Distribution of significance, fitted by a Gaussian →



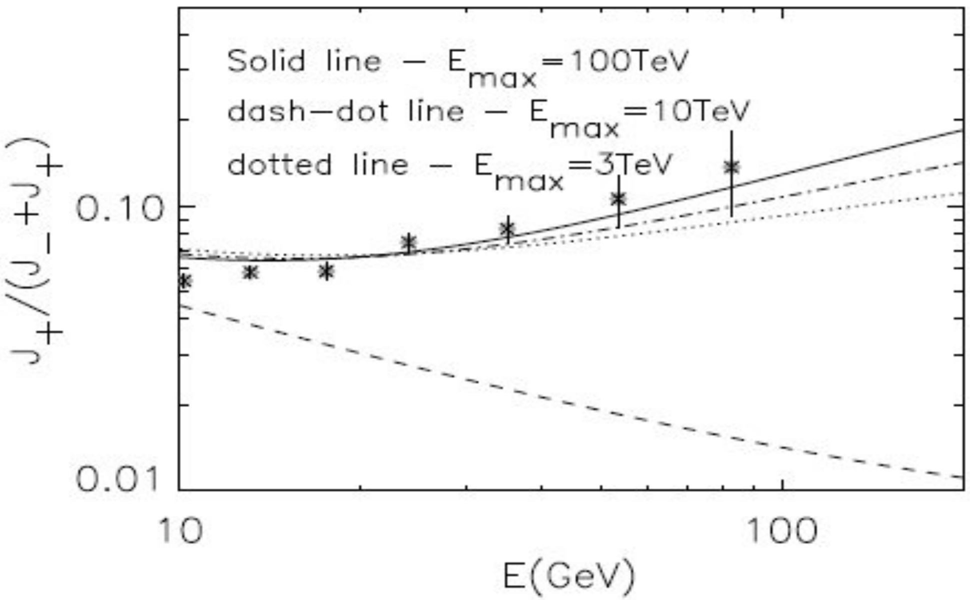
Fermi Coll. Physical Review D 82, 092003 (2010) [arXiv:1008.5119]

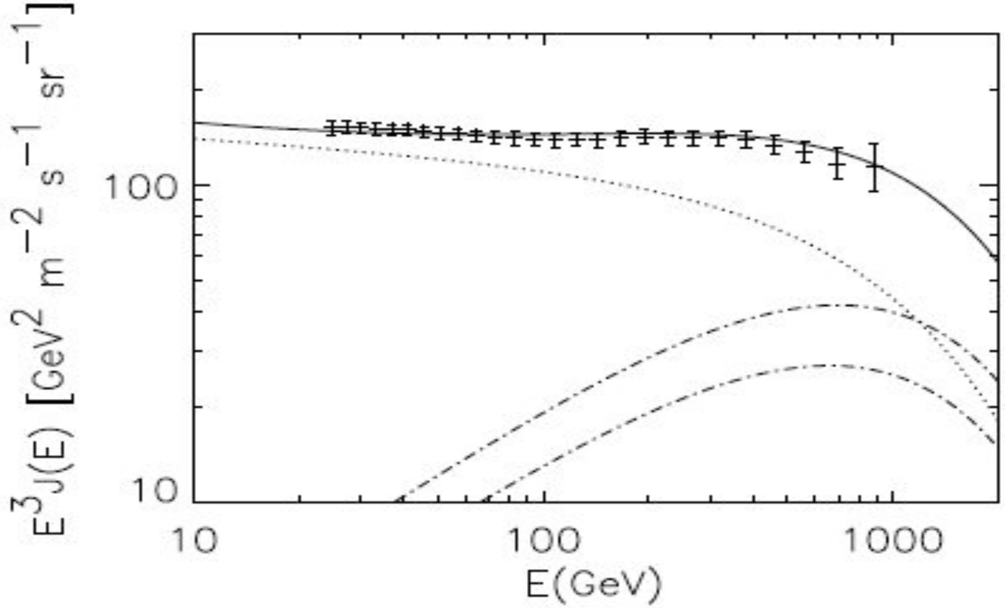
electron + positron expected anisotropy in the directions of Monogem and Vela



Fermi Coll. Physical Review D 82, 092003 (2010) [arXiv:1008.5119]

other Astrophysical solution



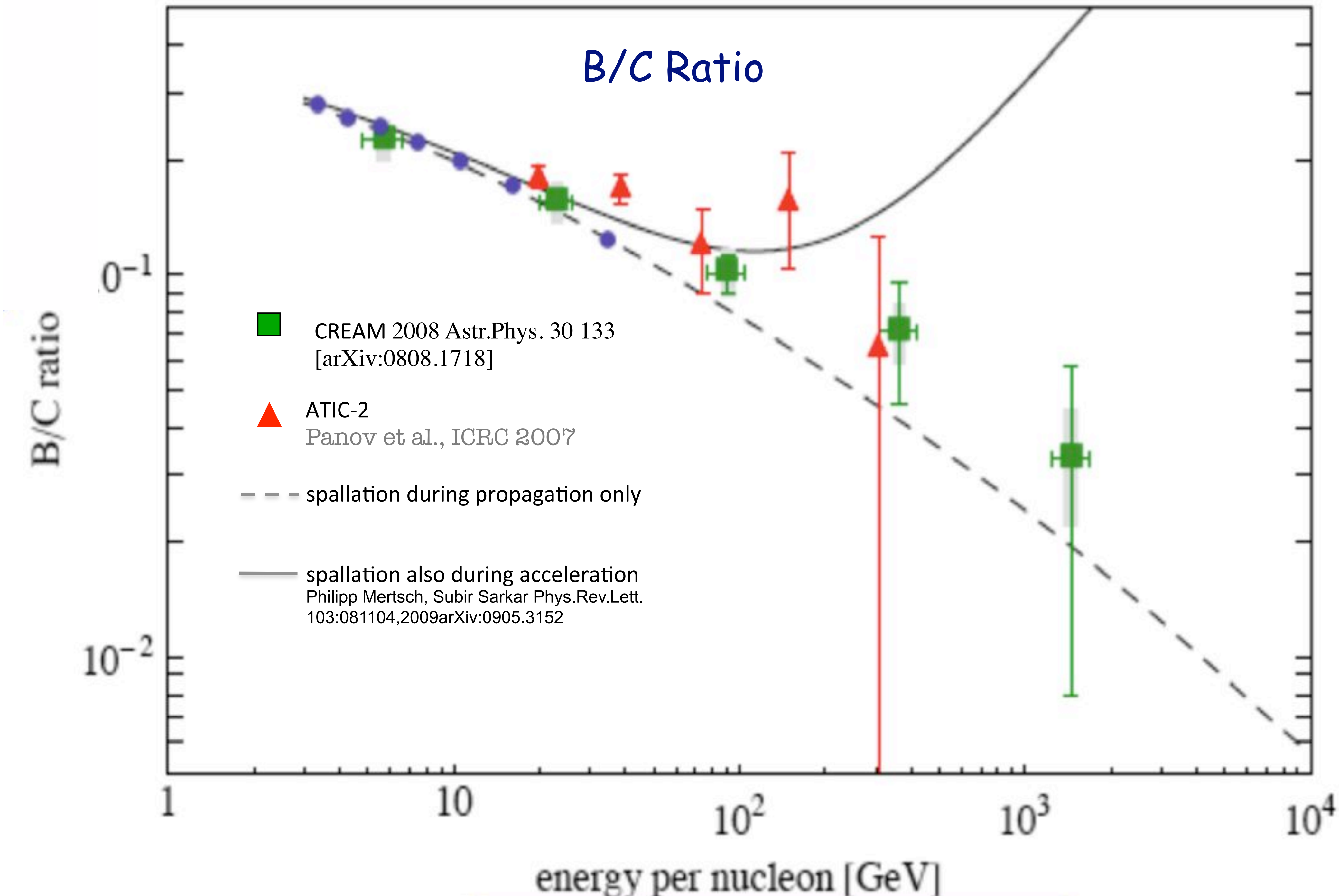


- Positrons created as secondary products of hadronic interactions inside the sources
- Secondary production takes place in the same region where cosmic rays are being accelerated

-> Therefore secondary positron have a very flat spectrum, which is responsible, after propagation in the Galaxy, for the observed positron excess

Blasi, arXiv:0903.2794

B/C Ratio



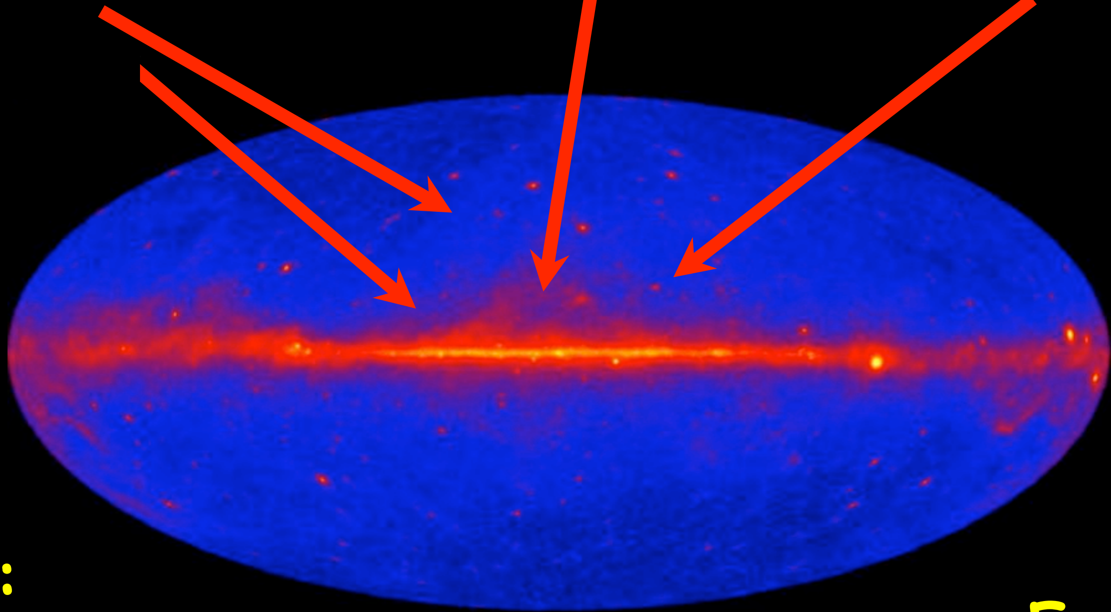
B/C ratio
10^{-1}
10^{-2}
1
10
10^2
10^3
10^4
energy per nucleon [GeV]
CREAM 2008 Astr.Phys. 30 133 [arXiv:0808.1718]
ATIC-2
Panov et al., ICRC 2007
spallation during propagation only
spallation also during acceleration
Philipp Mertsch, Subir Sarkar Phys.Rev.Lett. 103:081104,2009arXiv:0905.3152

Search 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



And electrons!
and
Anisotropies

Spectral lines:
No astrophysical uncertainties, good source id, but low statistics

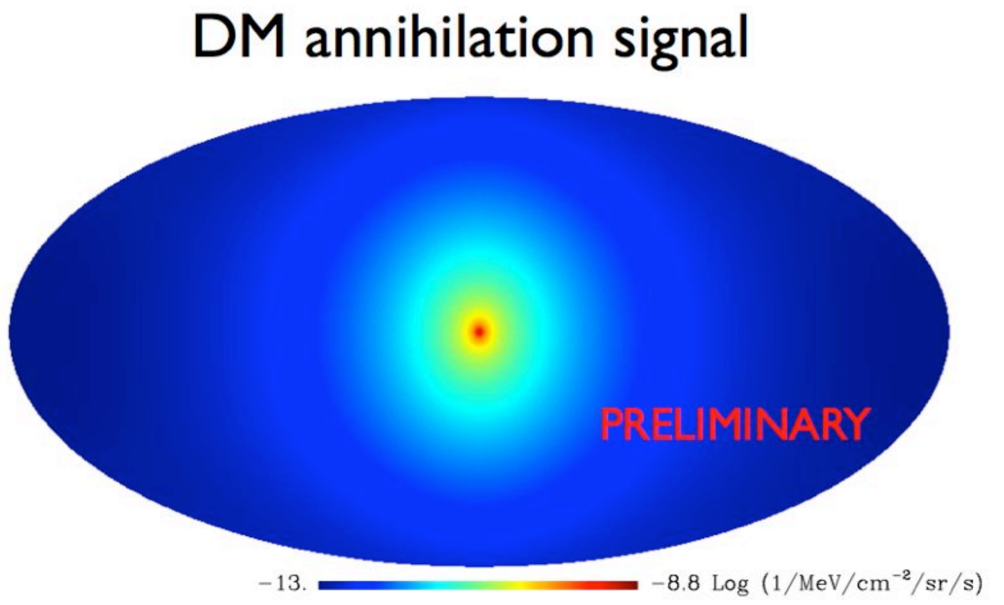
Galaxy clusters:
Low background but low statistics

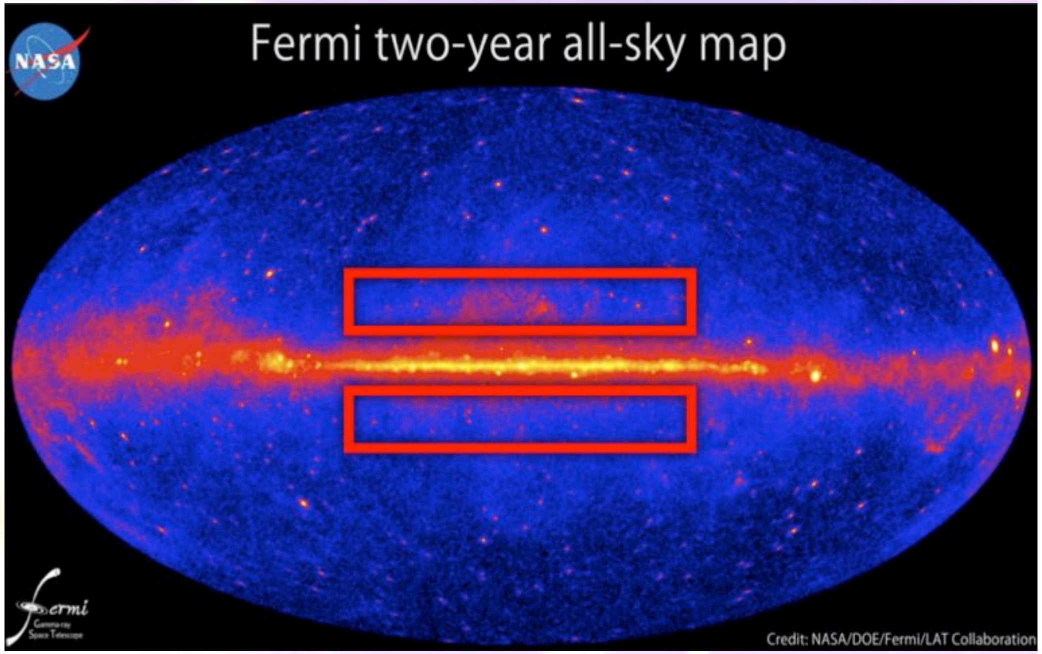
Extra-galactic:
Large statistics, but astrophysics,galactic diffuse background

Pre-launch sensitivities published in Baltz et al., 2008, JCAP0807:013[astro-ph/0806.2911]

Constraints from the Milky Way halo

testing the LAT diffuse data for a contribution from a Milky Way DM annihilation/decay signal



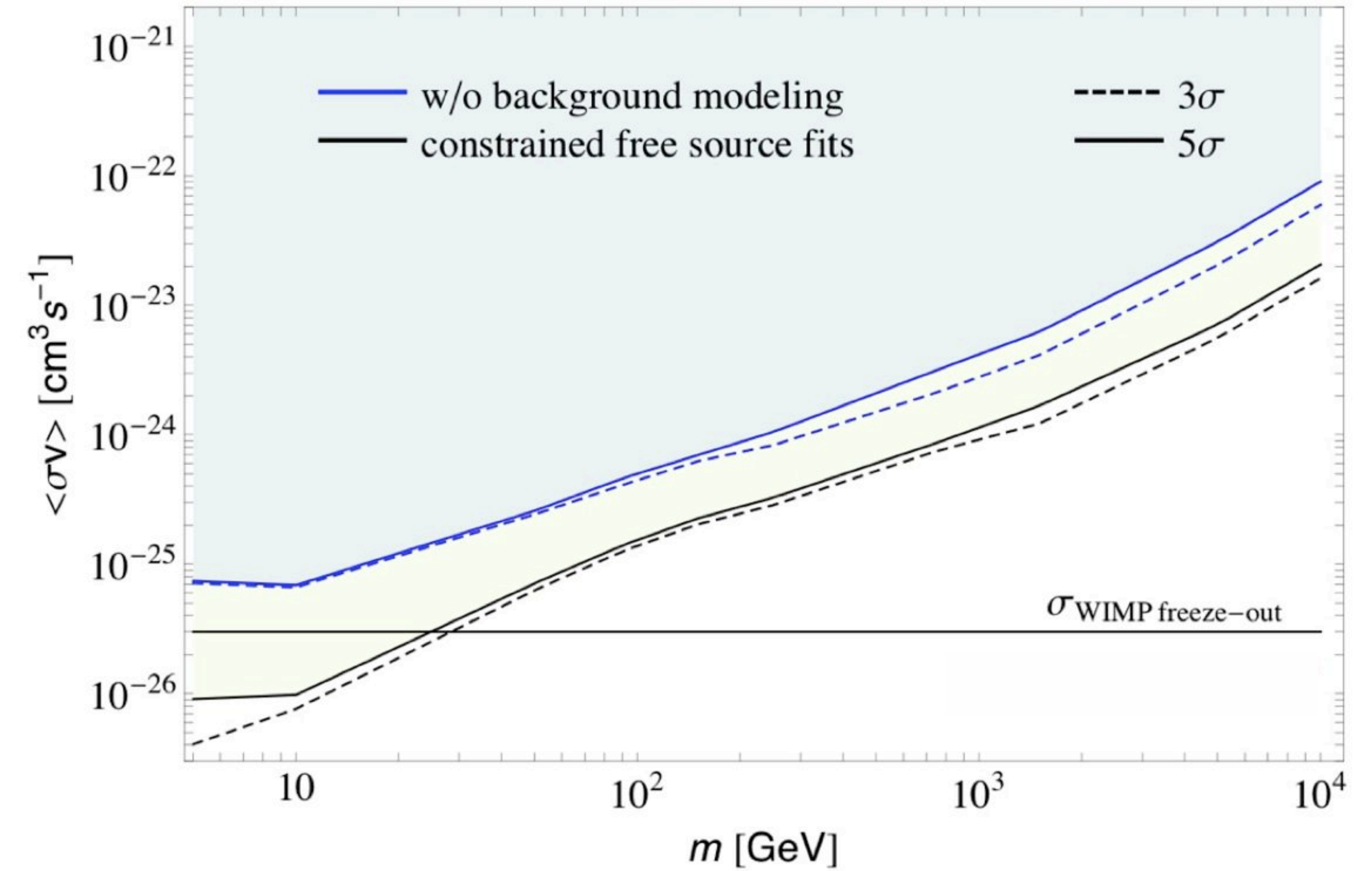


2 years of data 1-100 GeV energy range

ROI: 5° <|b|<15° and |l|<80°, chosen to:

- minimize DM profile uncertainty (highest in the Galactic Center region)
- limit astrophysical uncertainty by masking out the Galactic plane and cutting-out high- latitude emission from the Fermi lobes and Loop I

Constraints from the Milky Way halo



- Blue = "no-background limits"
- Black = limits obtained by marginalization over the CR source distribution, diffusive halo height and electron injection index, gas to dust ratio, and in which CR sources are held to zero in the inner 3 kpc
- Limits with NFW density profile (not shown) are only slightly stronger

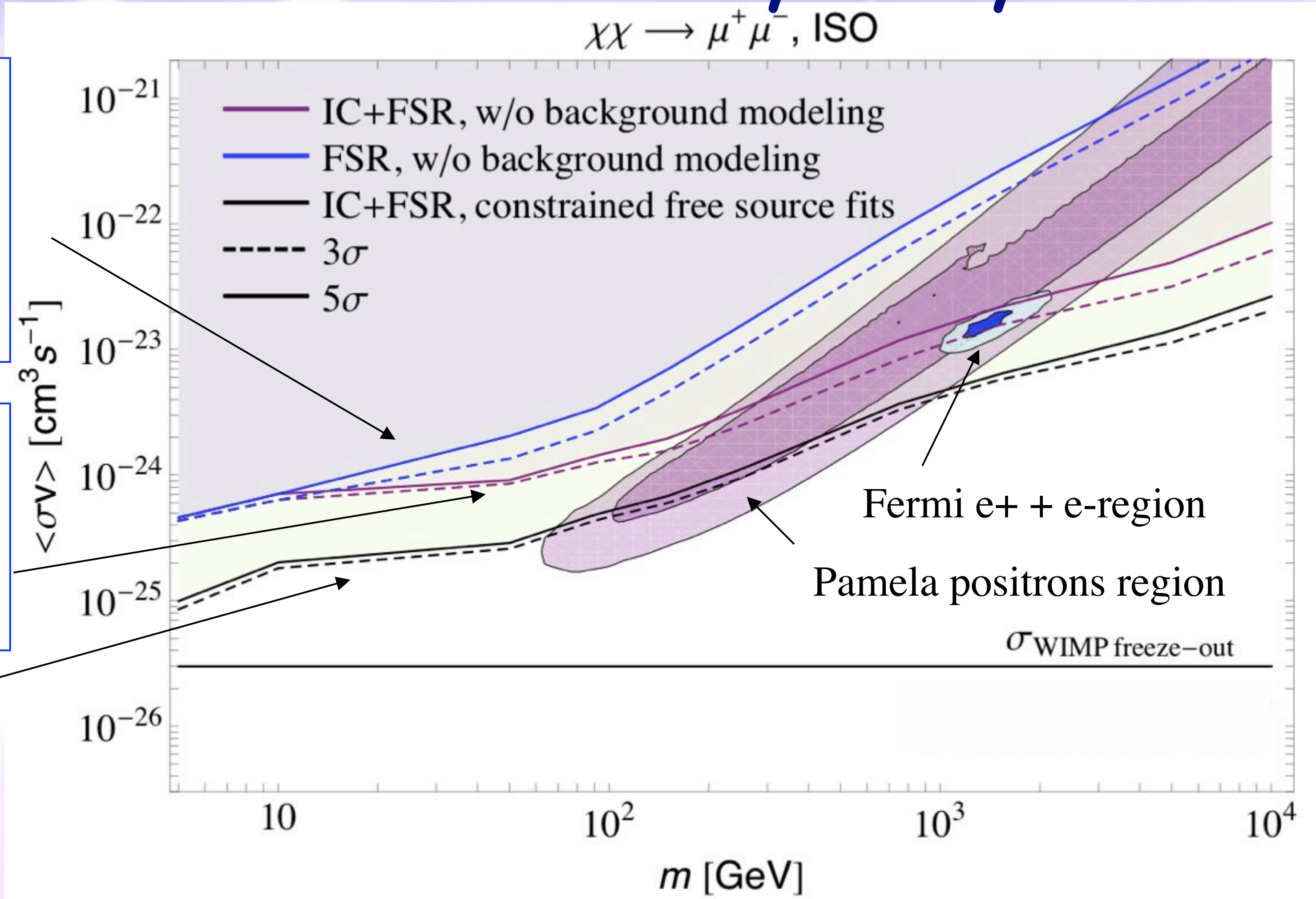
Fermi Coll.ApJ 761 (2012) 91 [arXiv:1205.6474]

Constraints from the Milky Way halo

only photons produced by muons (no electrons) to set "no-background limits"

"no-background limits" including FSR +IC from dark matter

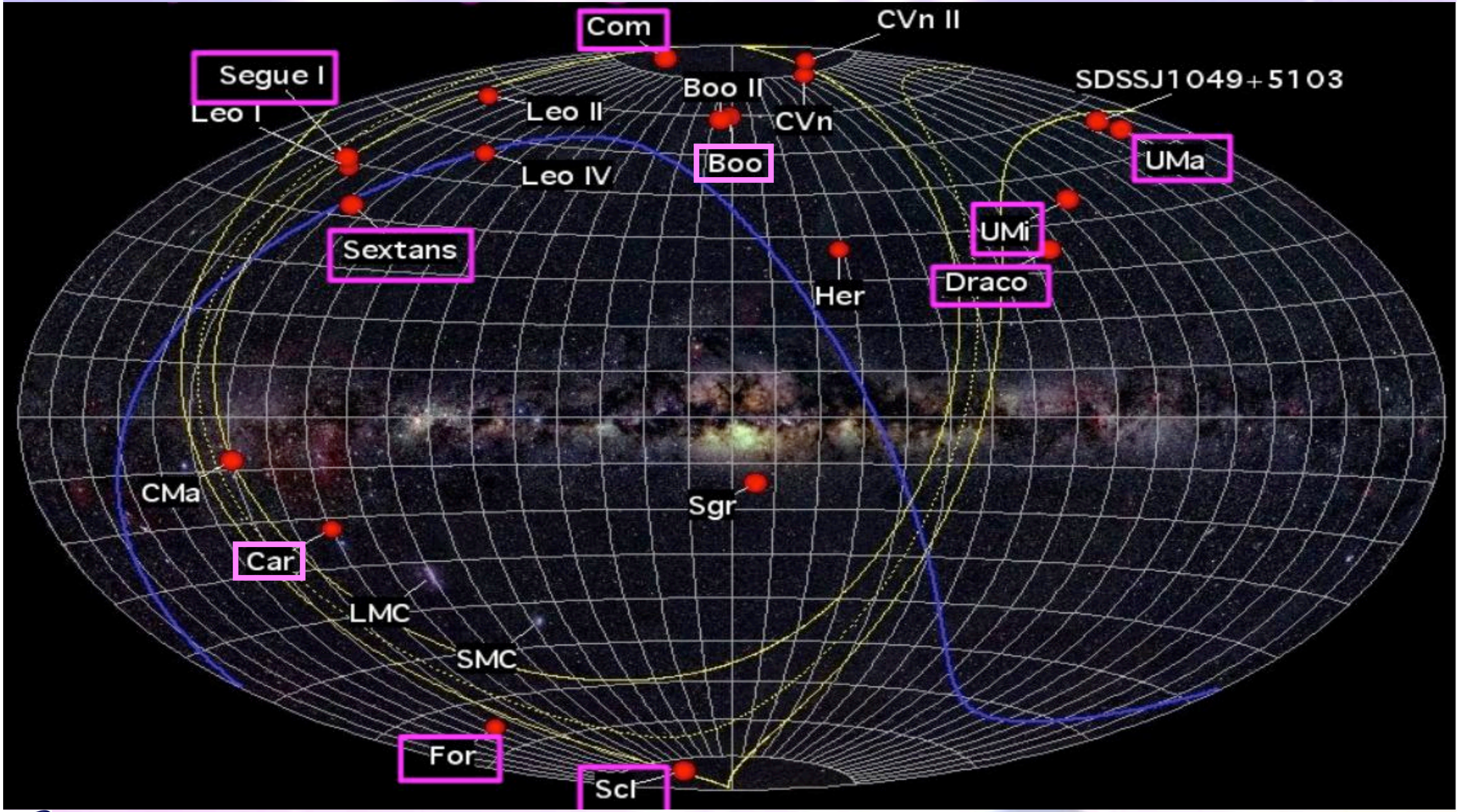
limits from profile likelihood and CR sources set to zero in the inner 3 kpc



DM interpretation of PAMELA/Fermi CR anomalies disfavored

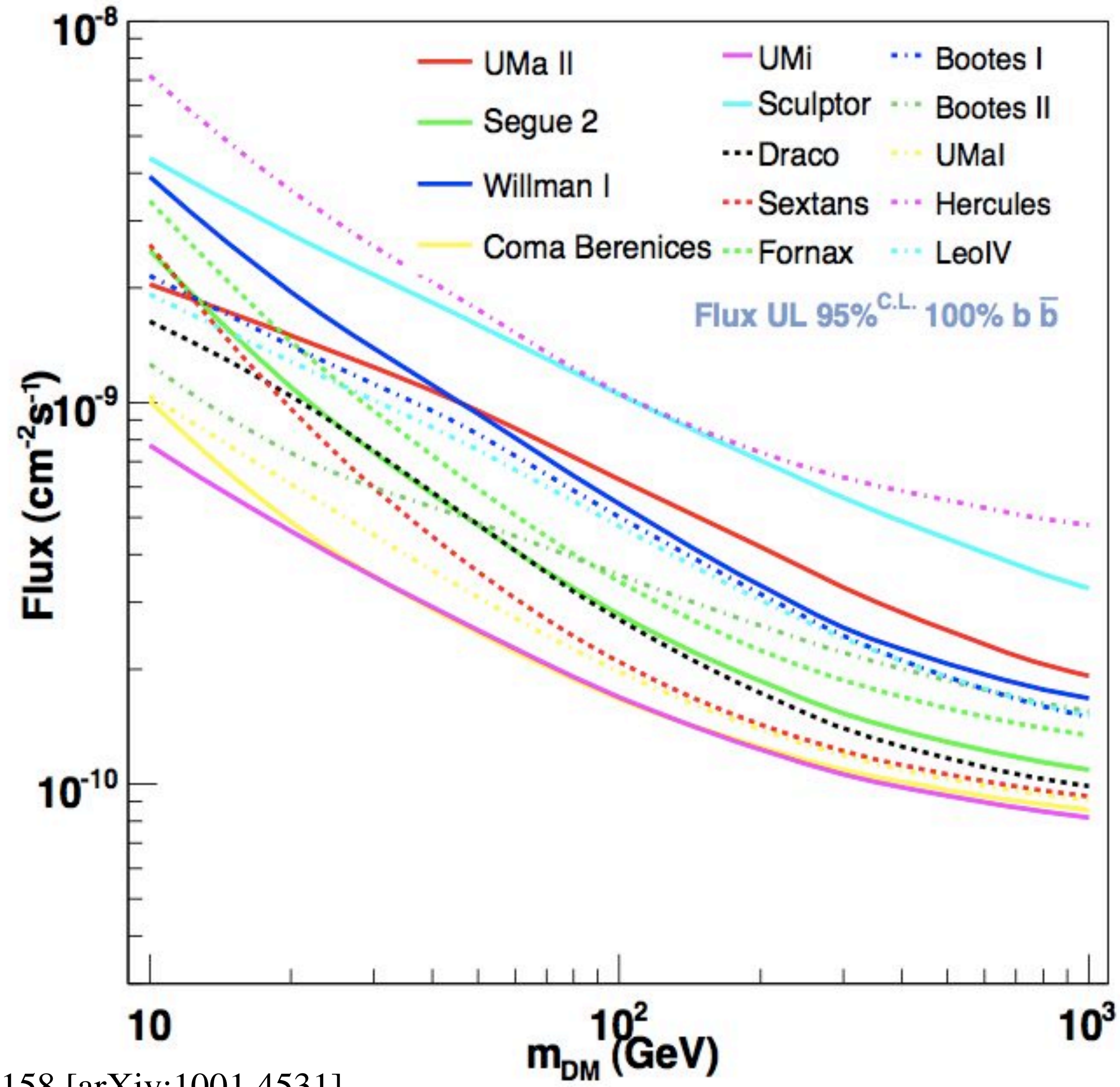
Fermi Coll.ApJ 761 (2012) 91 [arXiv:1205.6474]

Dwarf spheroidal galaxies (dSph) : promising targets for DM detection



Dwarf Spheroidal Galaxies upper-limits

No detection by Fermiwith 11 months of data. 95% flux upper limits are placed for several possible annihilation final states.

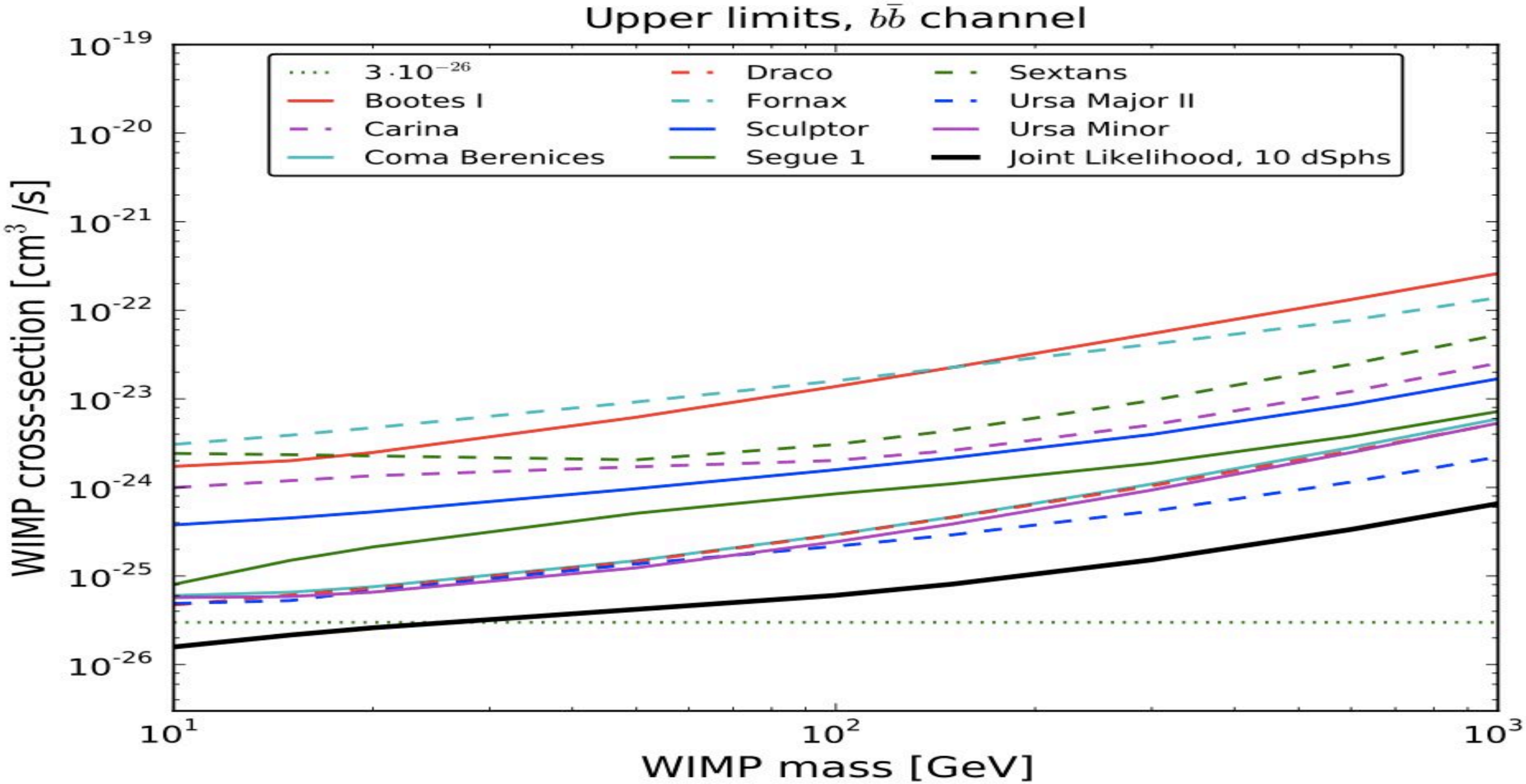


- Flux upper limits are combined with the DM densityinferred by the stellar data(*)for a subset of 8 dSph (based on quality of stellar data) to extract constraints on < σ v> vs WIMP mass for specific DM models

(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)

Fermi Coll. ApJ712 (2010) 147-158 [arXiv:1001.4531]

Dwarf Spheroidal Galaxies combined analysis

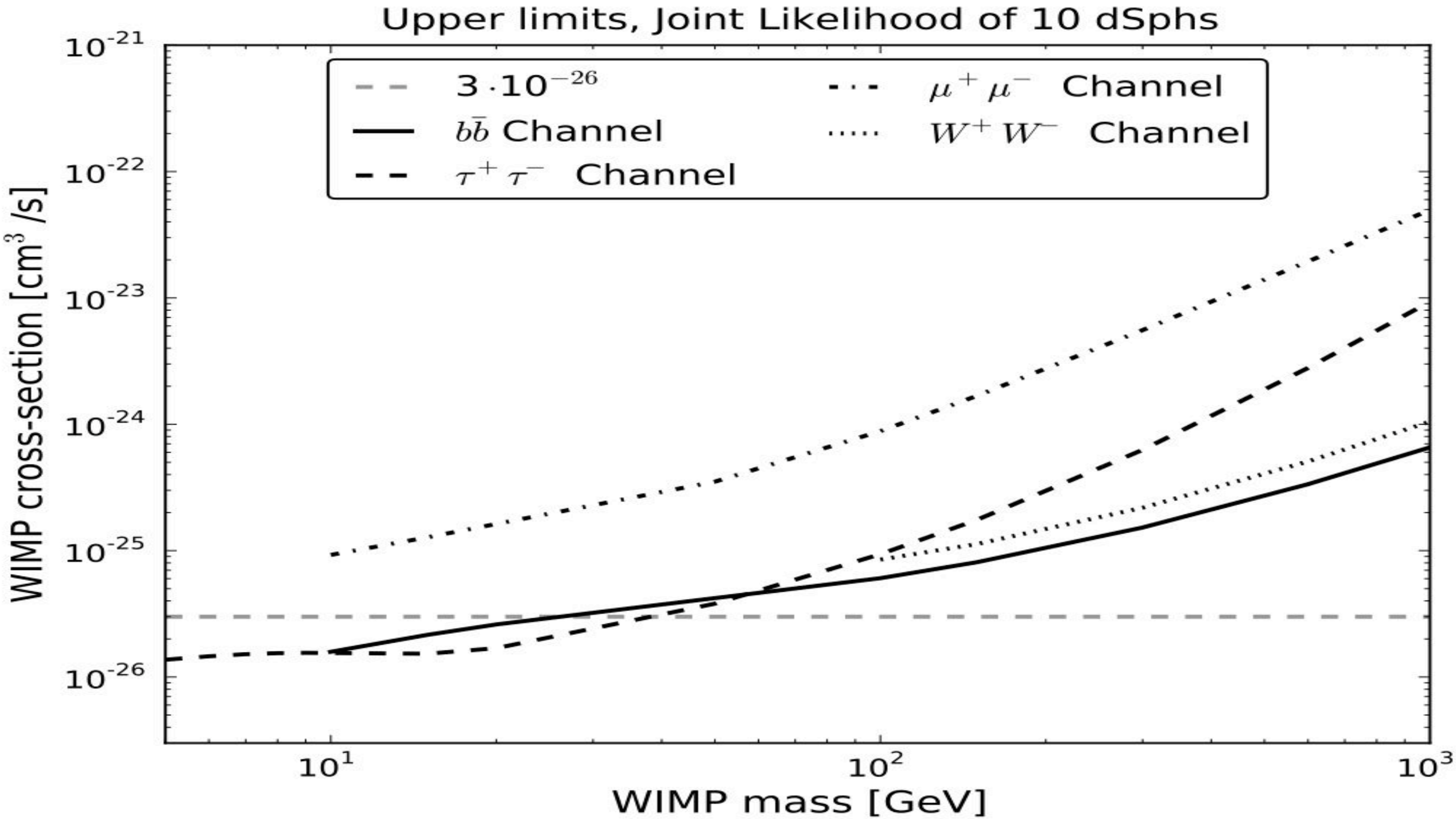


robust constraints including J-factoruncertainties from the stellar data statistical analysis

NFW. For cored dark matter profile, the J-factors for most of the dSphs would either increase or not change much

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

Dwarf Spheroidal Galaxies combined analysis



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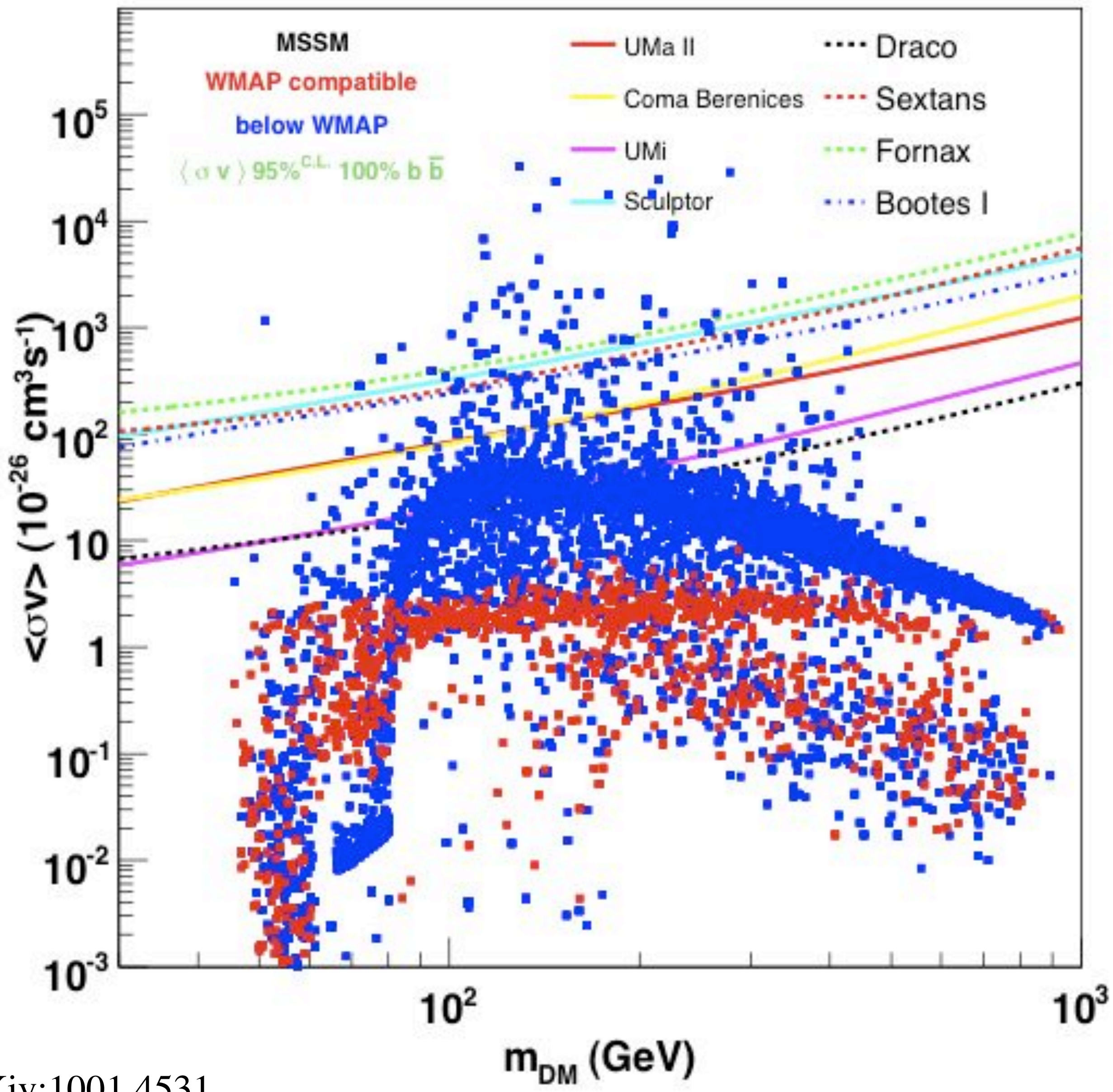
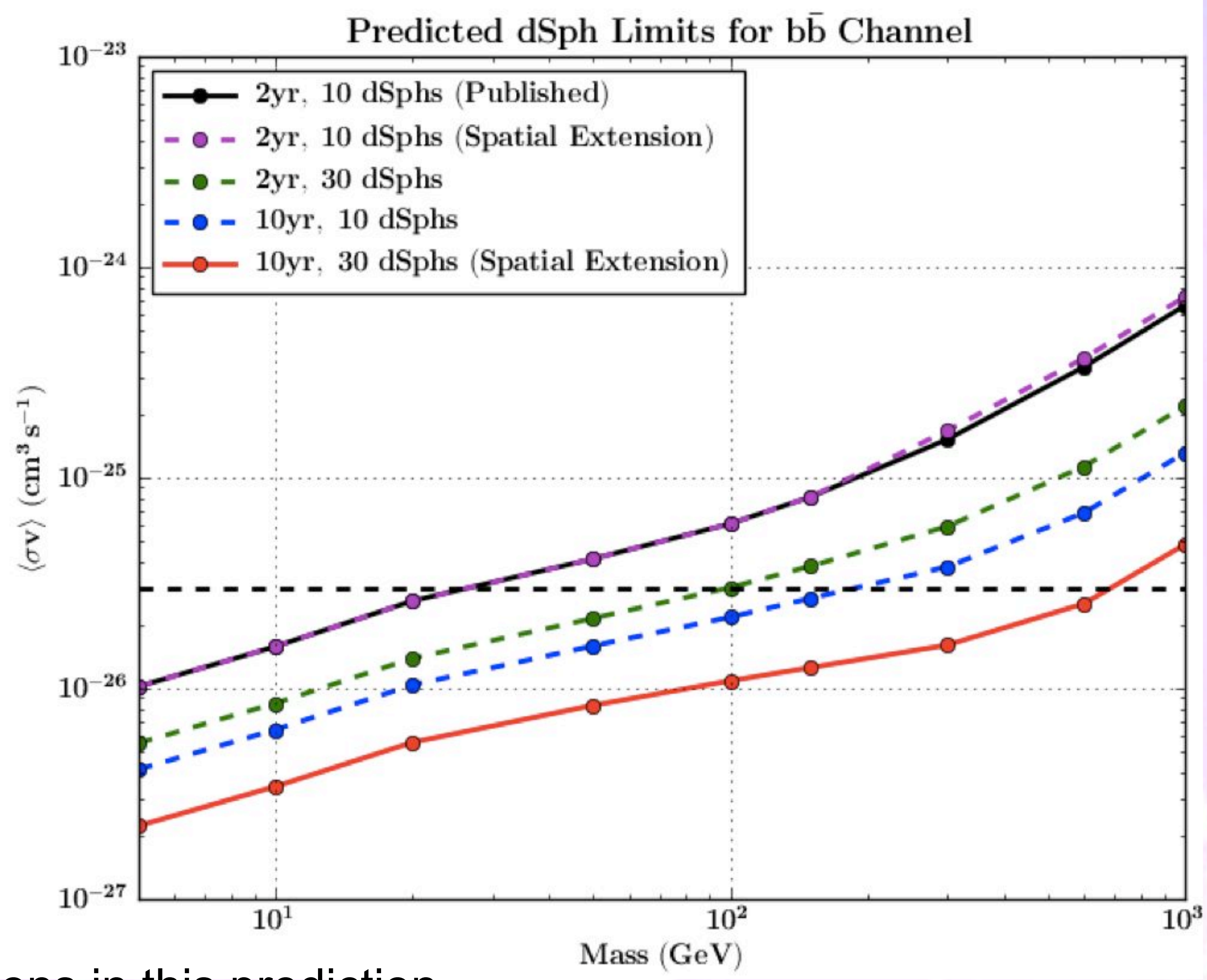


Fermi Coll. ApJ712 (2010) 147-158 arXiv:1001.4531

DM limit improvement estimate in 10 years with the composite likelihood approach (2008- 2018)

- 10 years of data instead of 2(5x)
- 30 dSphs (3x) (supposing that the new optical surveys will find new dSph)
- -10% from spatial extension (source extension increases the signal region at high energy E > 10 GeV, M > 200 GeV)

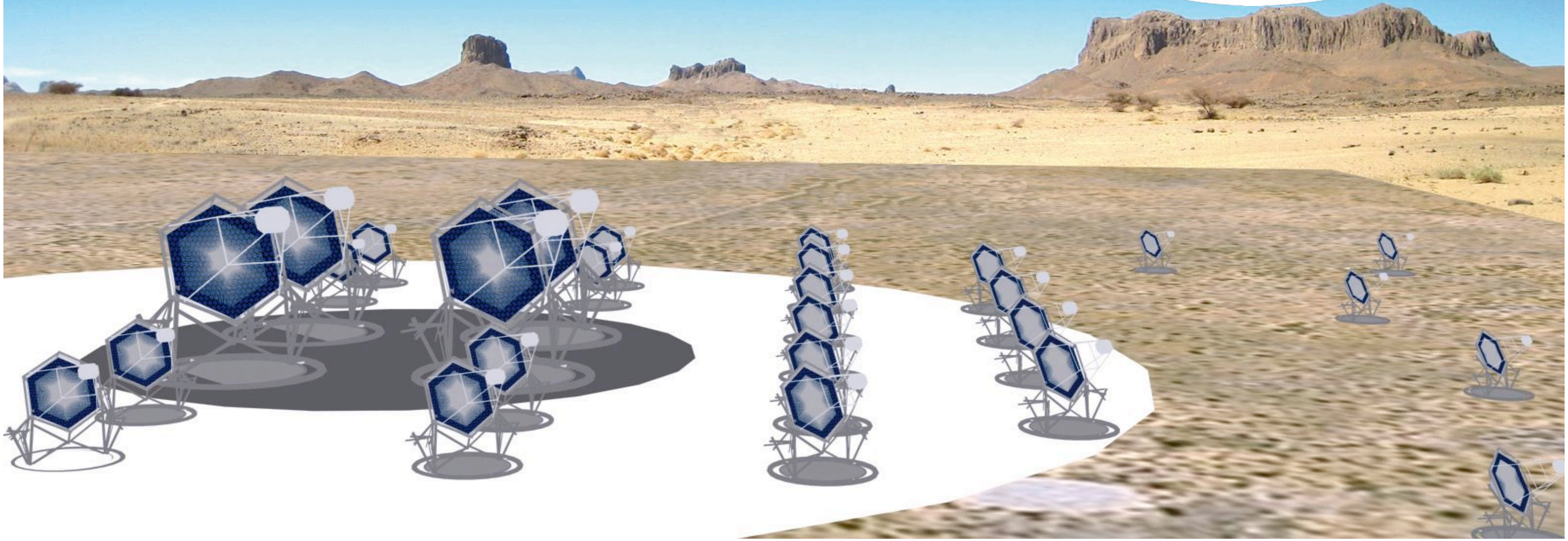


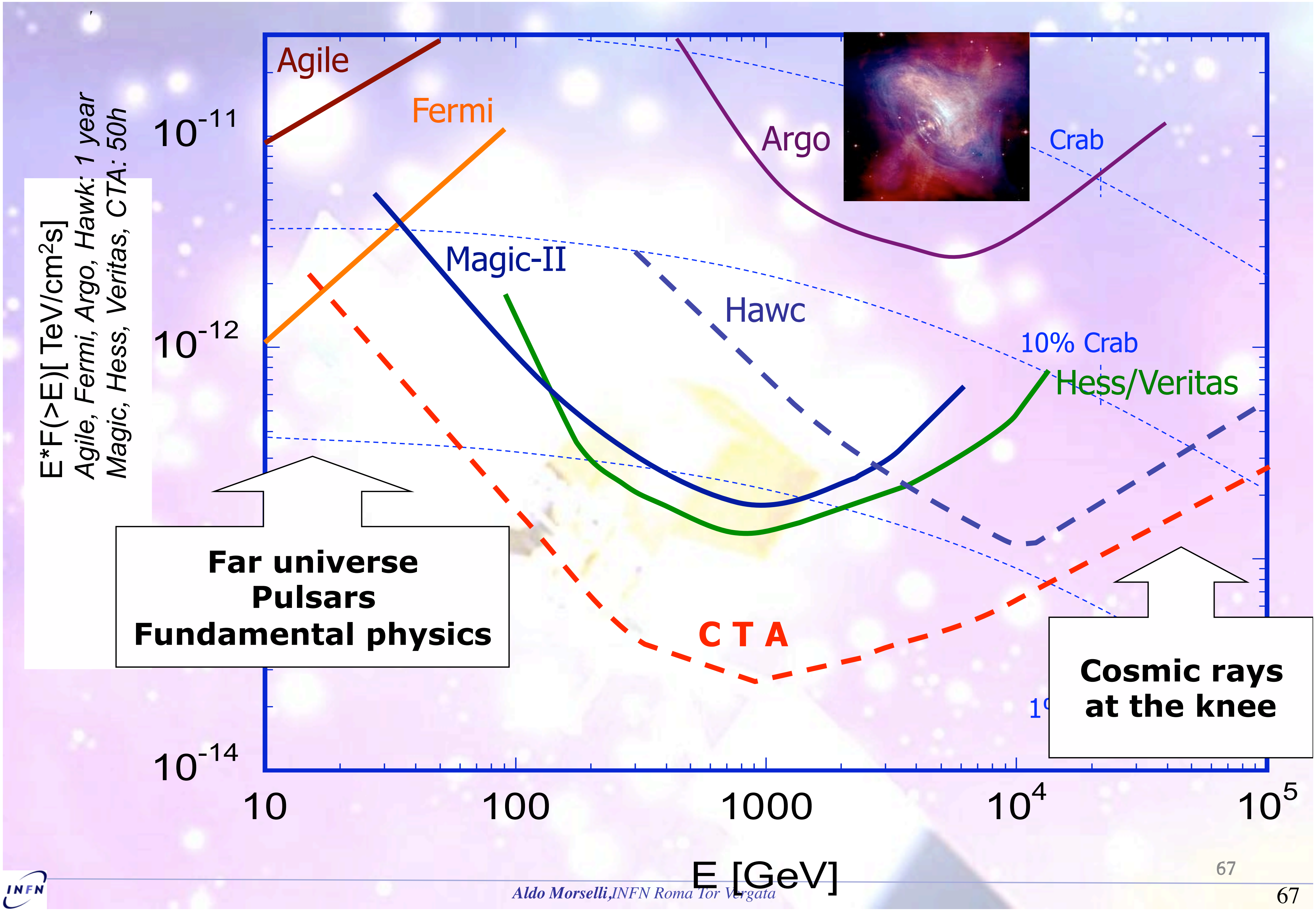
- There are many assumptions in this prediction
- Doesn't deal with a possible detections.

INFN and the Cherenkov Telescope Array

The future in VHE gamma ray astrophysics:

De Angelis talk

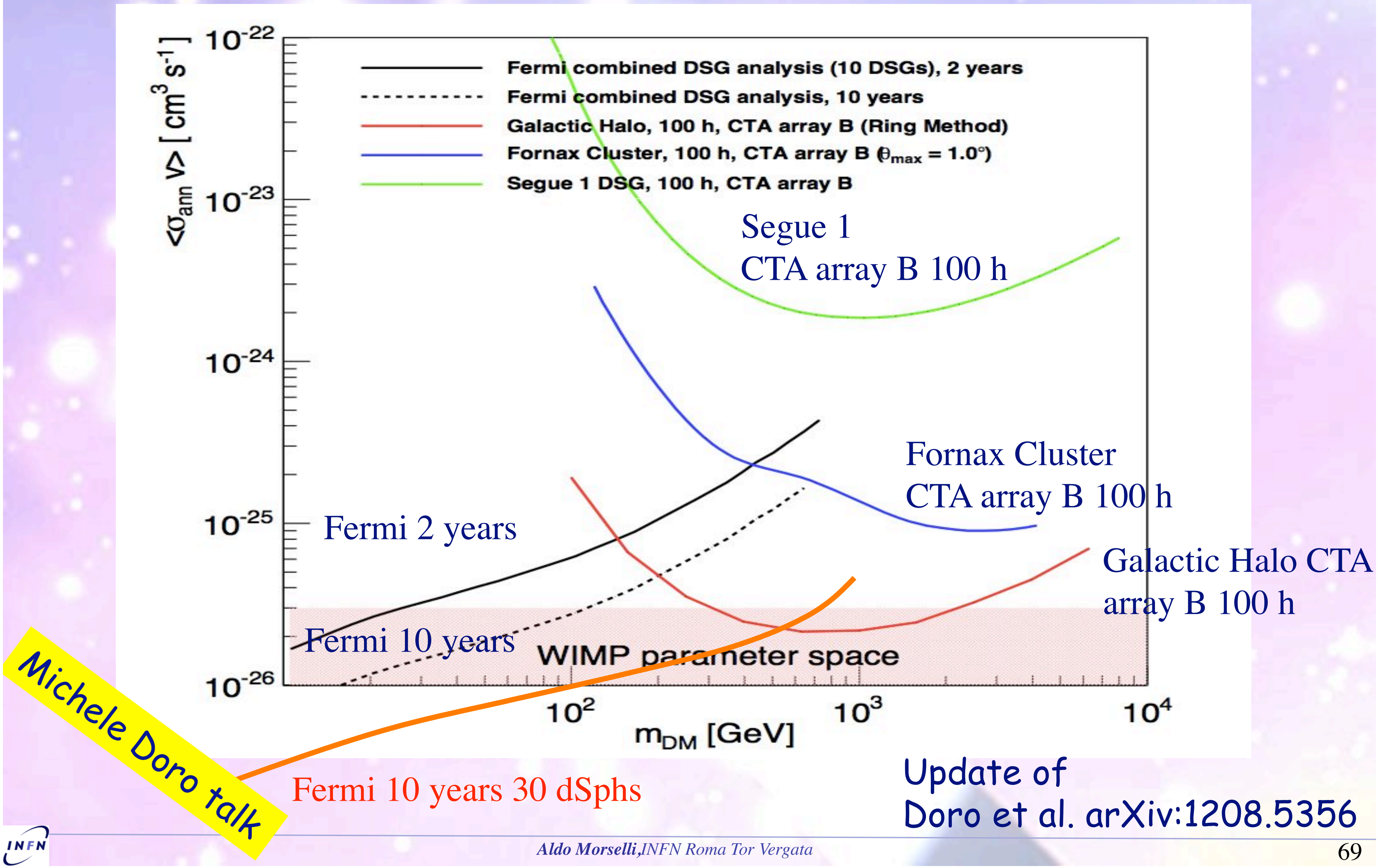




Agile
Fermi
Argo
Crab
Magic-II
Hawc
10% Crab
Hess/Veritas
C T A
Far universe
Pulsars
Fundamental physics
Cosmic rays
at the knee
E*F(>E)[TeV/cm2s]
Agile, Fermi, Argo, Hawk: 1 year
Magic, Hess, Veritas, CTA: 50h
10-11
10-12
10-14
10
100
1000
10^4
10^5
E [GeV]
67


The HAWC Gamma Ray Observatory
G. Sinnis
Los Alamos National Laboratory
Rome International Conference on Astroparticle Physics
22-24, 2013
And also
Ignacio Taboada on GRB's

Dwarf Spheroidal Galaxies upper-limits

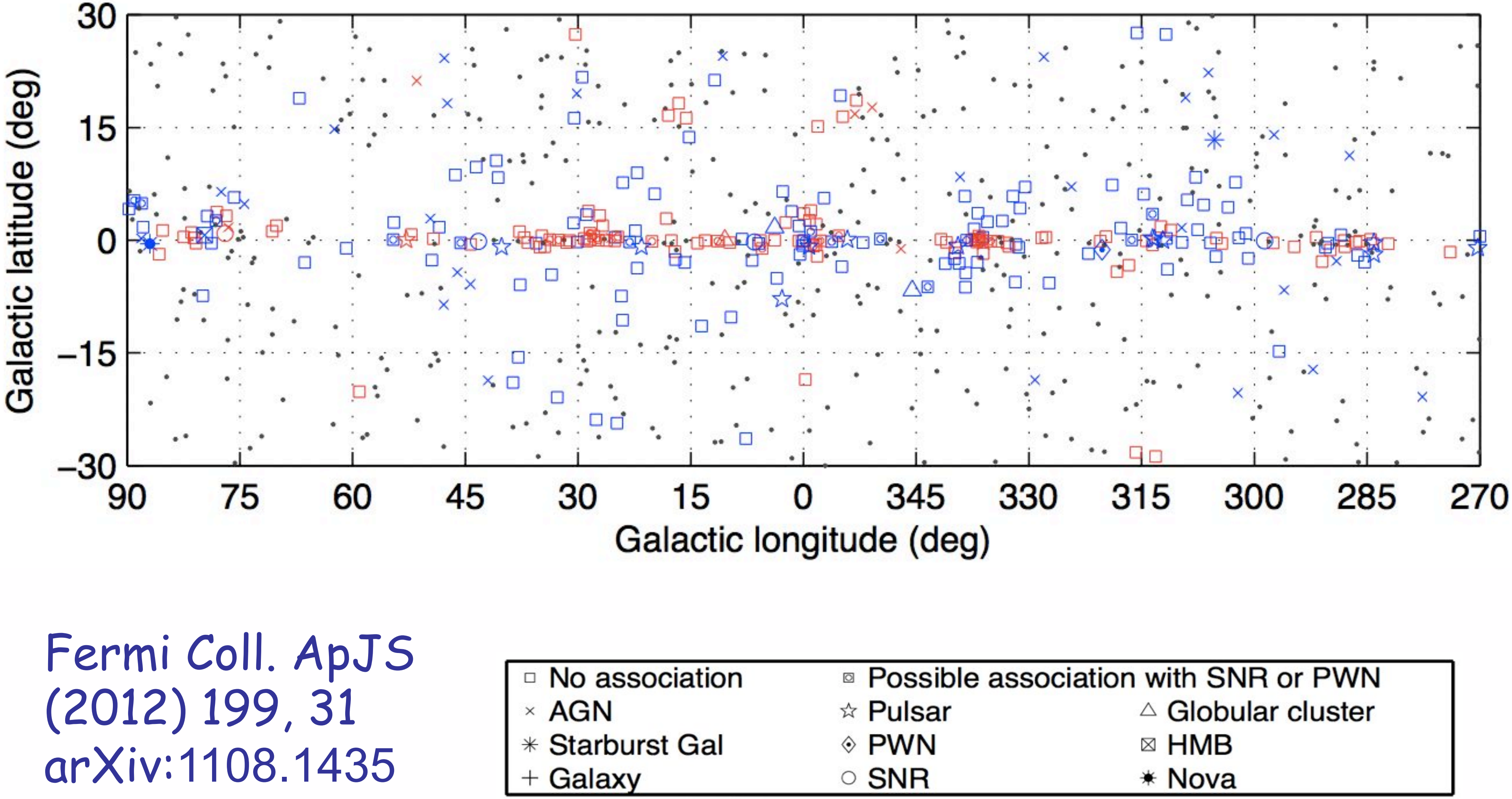


Update of
Doro et al. arXiv:1208.5356

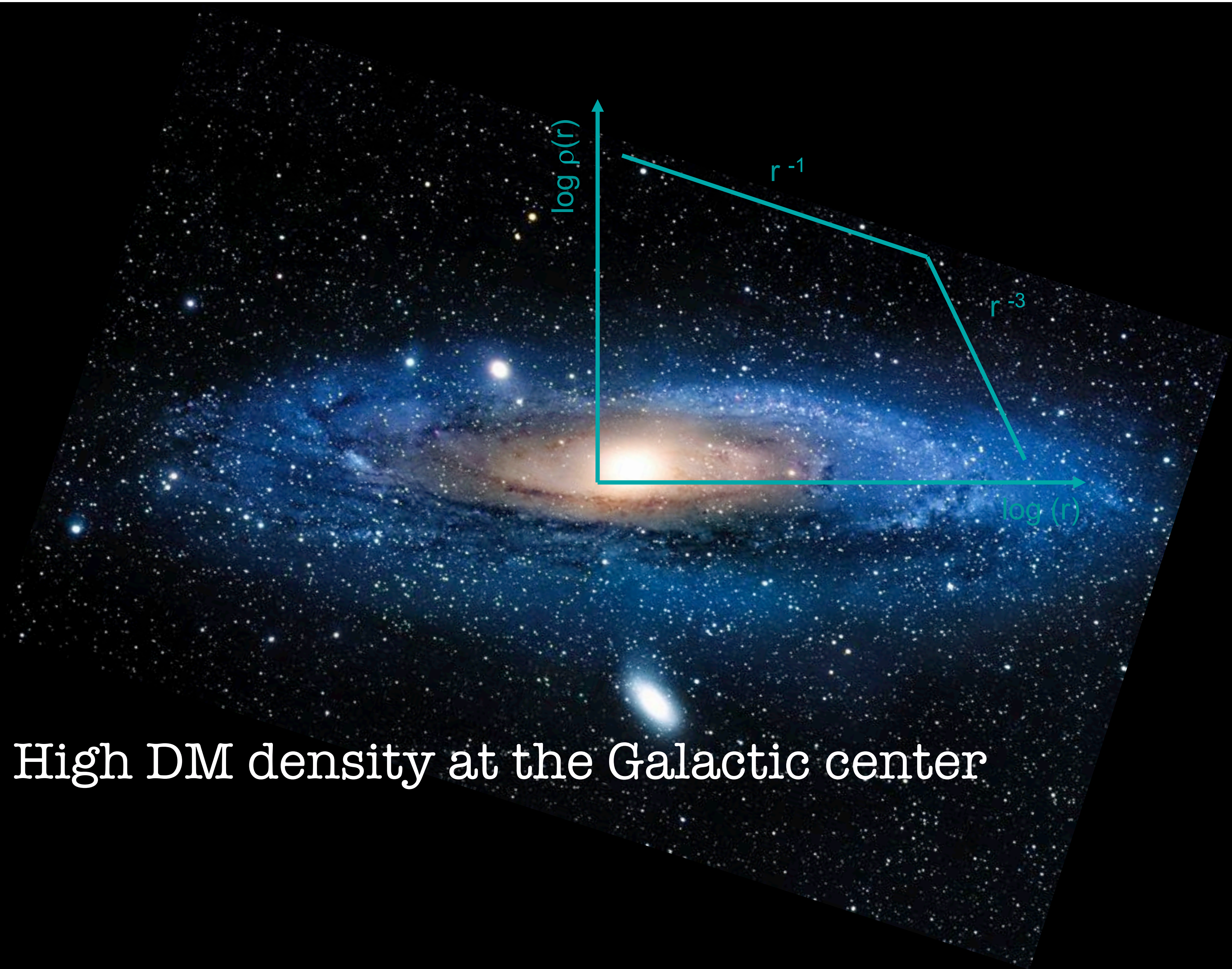
The Fermi LAT 2FGLInner Galactic Region

August 4, 2008, to July 31, 2010

100 MeV to 100 GeV energy range



Fermi Coll. ApJS (2012) 199, 31
arXiv:1108.1435



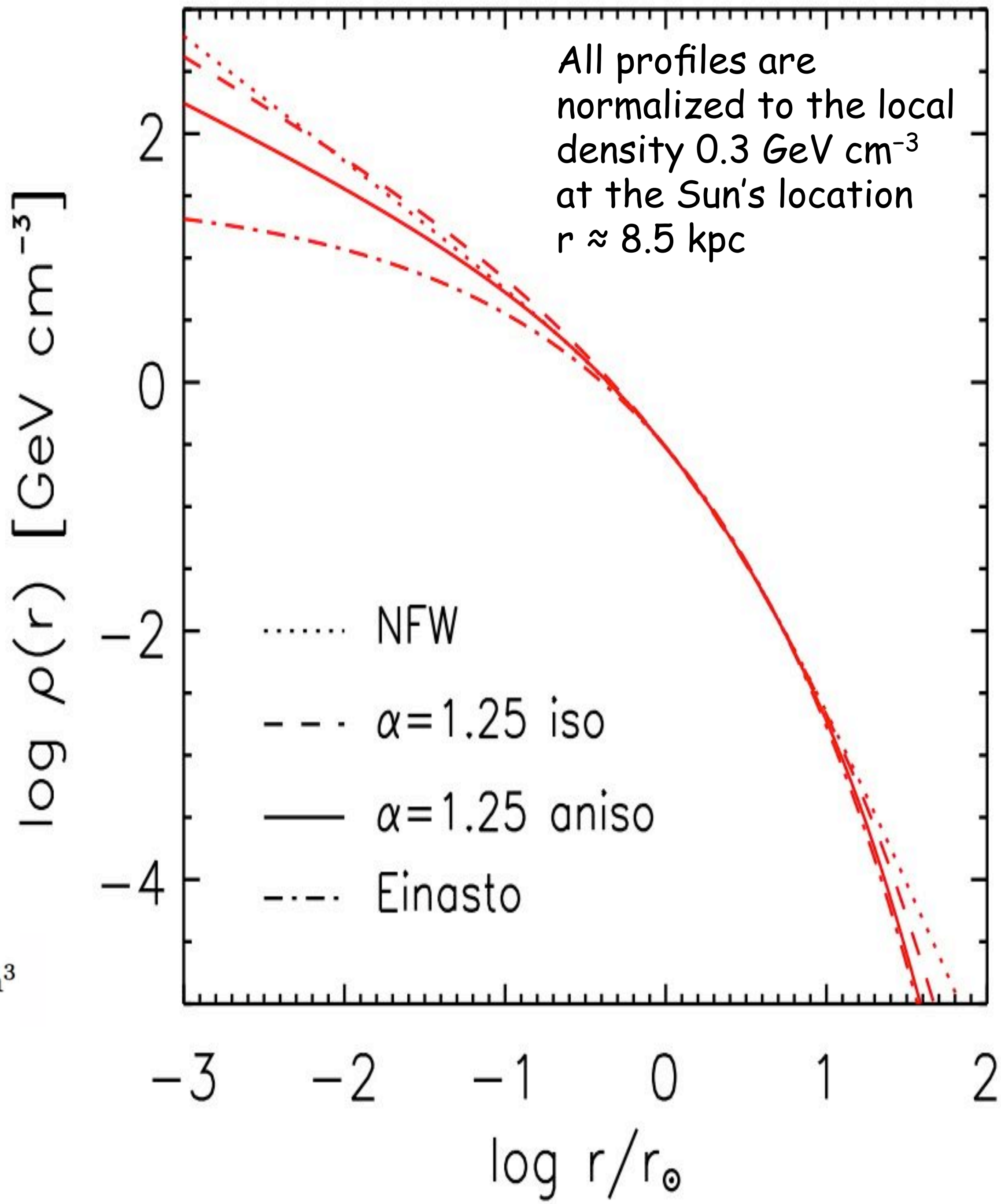
High DM density at the Galactic center

Milky Way Dark Matter Profiles

$$\rho(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1 + (r_\odot/r_s)^\alpha}{1 + (r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$$

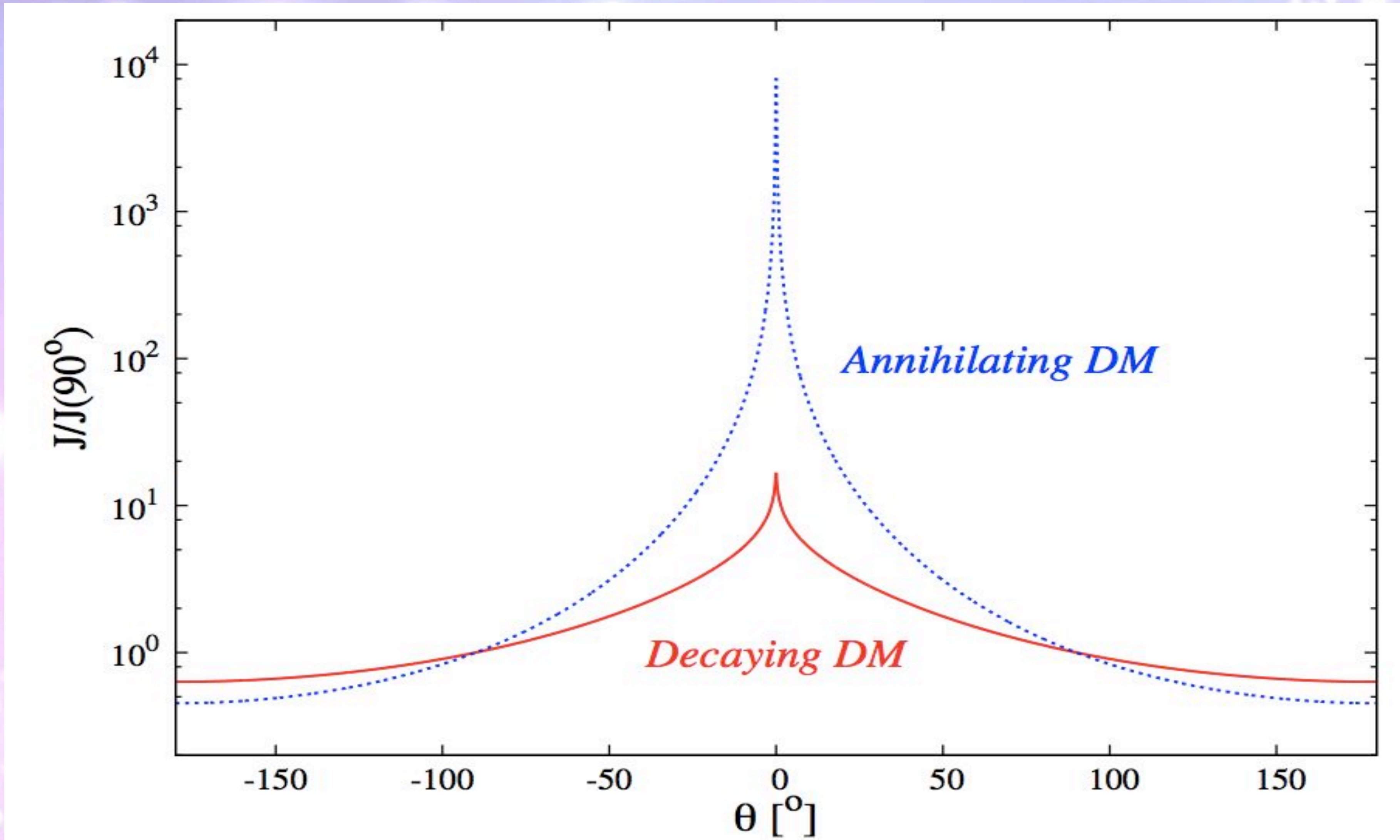
Halo model	α	β	γ	r_s in kpc
Cored isothermal	2	2	0	5
Navarro, Frenk, White	1	3	1	20
Moore	1	3	1.16	30

Einasto | $\alpha = 0.17$ $r_s = 20\,\text{kpc}$ $\rho_s = 0.06\,\text{GeV/cm}^3$



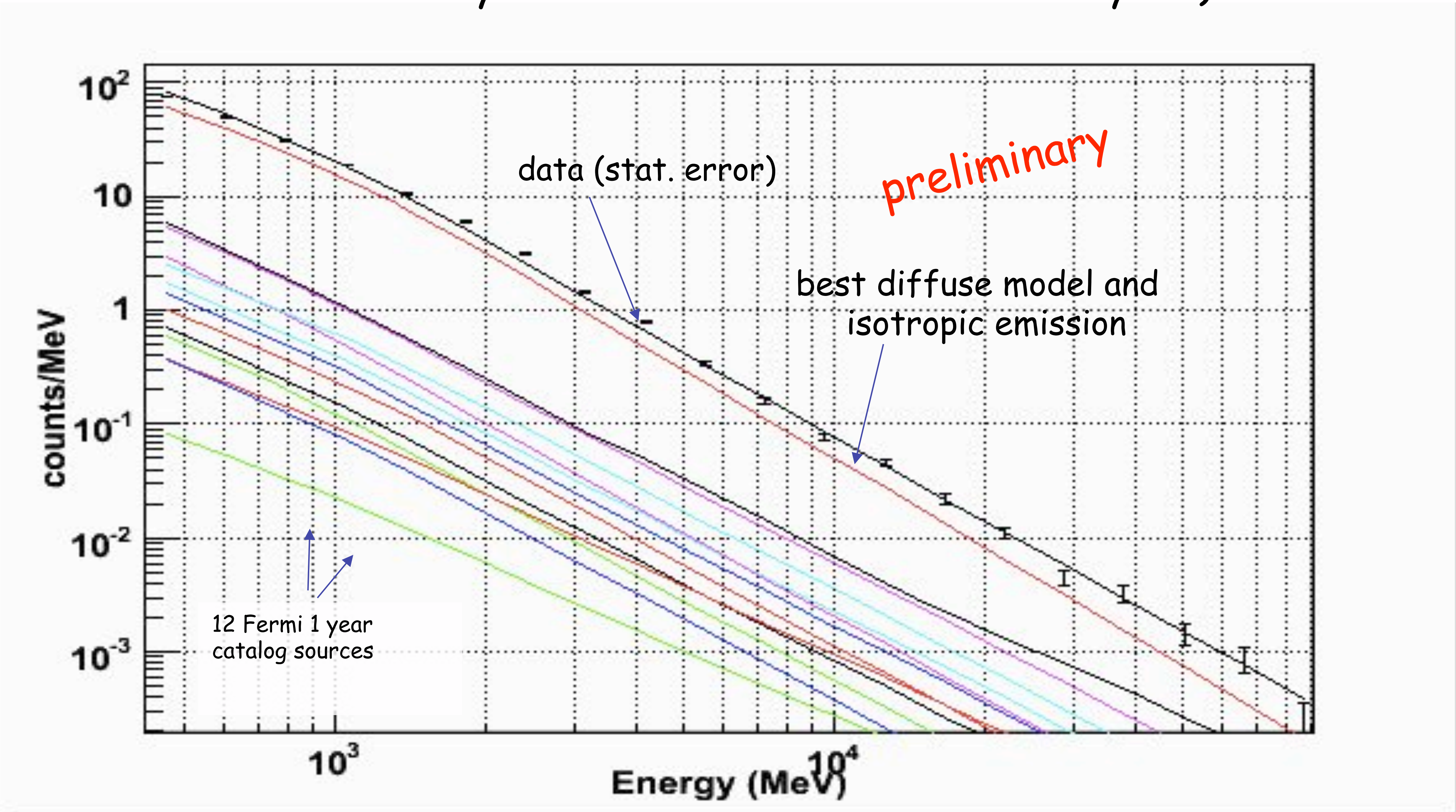
A.Lapi et al. arXiv:0912.1766

Different spatial behaviour for decaying or annihilating dark matter



The angular profile of the gamma-ray signal is shown, as function of the angle θ to the centre of the galaxy for a Navarro-Frenk-White (NFW) halo distribution for decaying DM, solid (red) line, compared to the case of self-annihilating DM, dashed (blue) line

Spectrum (E> 400 MeV, 7°x7°region centered on the Galactic Center analyzed with binned likelihood analysis)

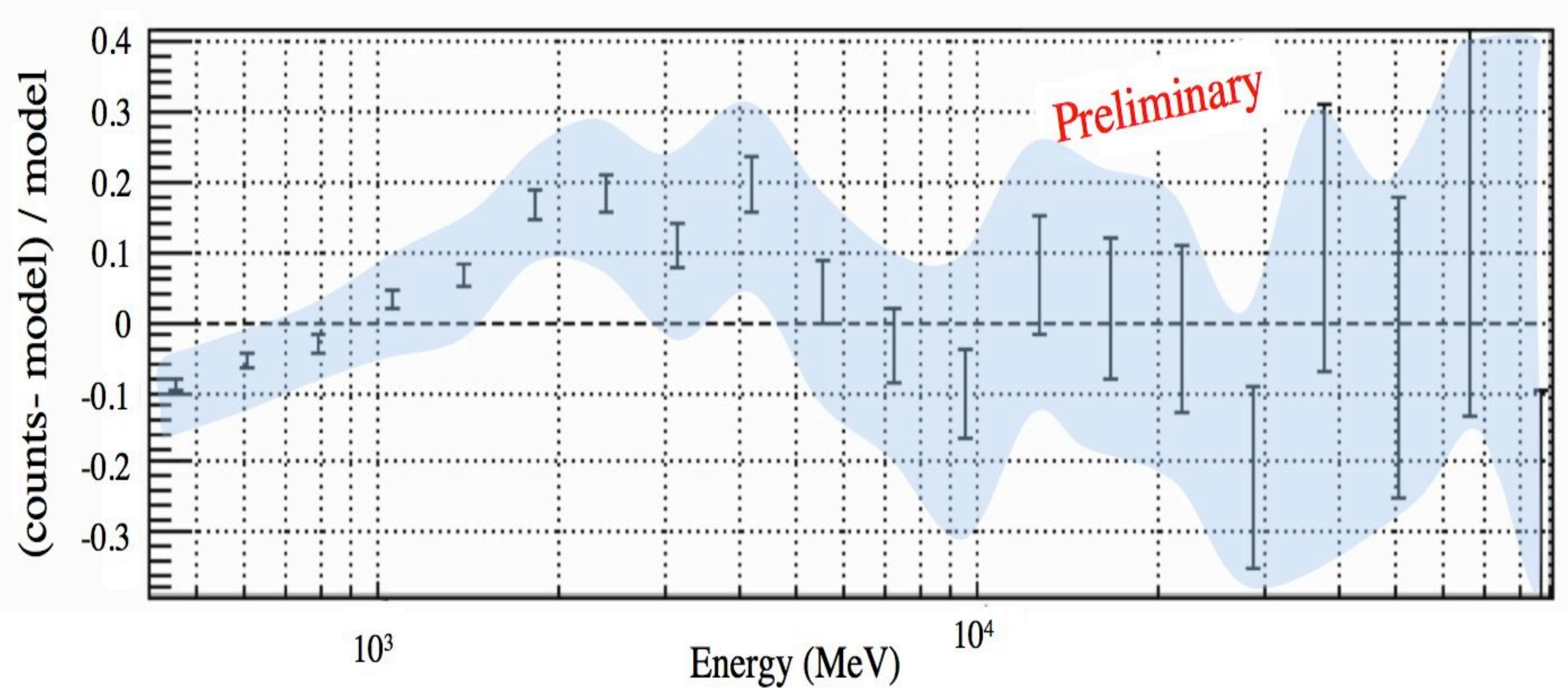


Fermi Coll. NIM A630 (2011) 147 [arXiv:0912.3828]

GC Residuals 7°x7°region centered on the Galactic Center

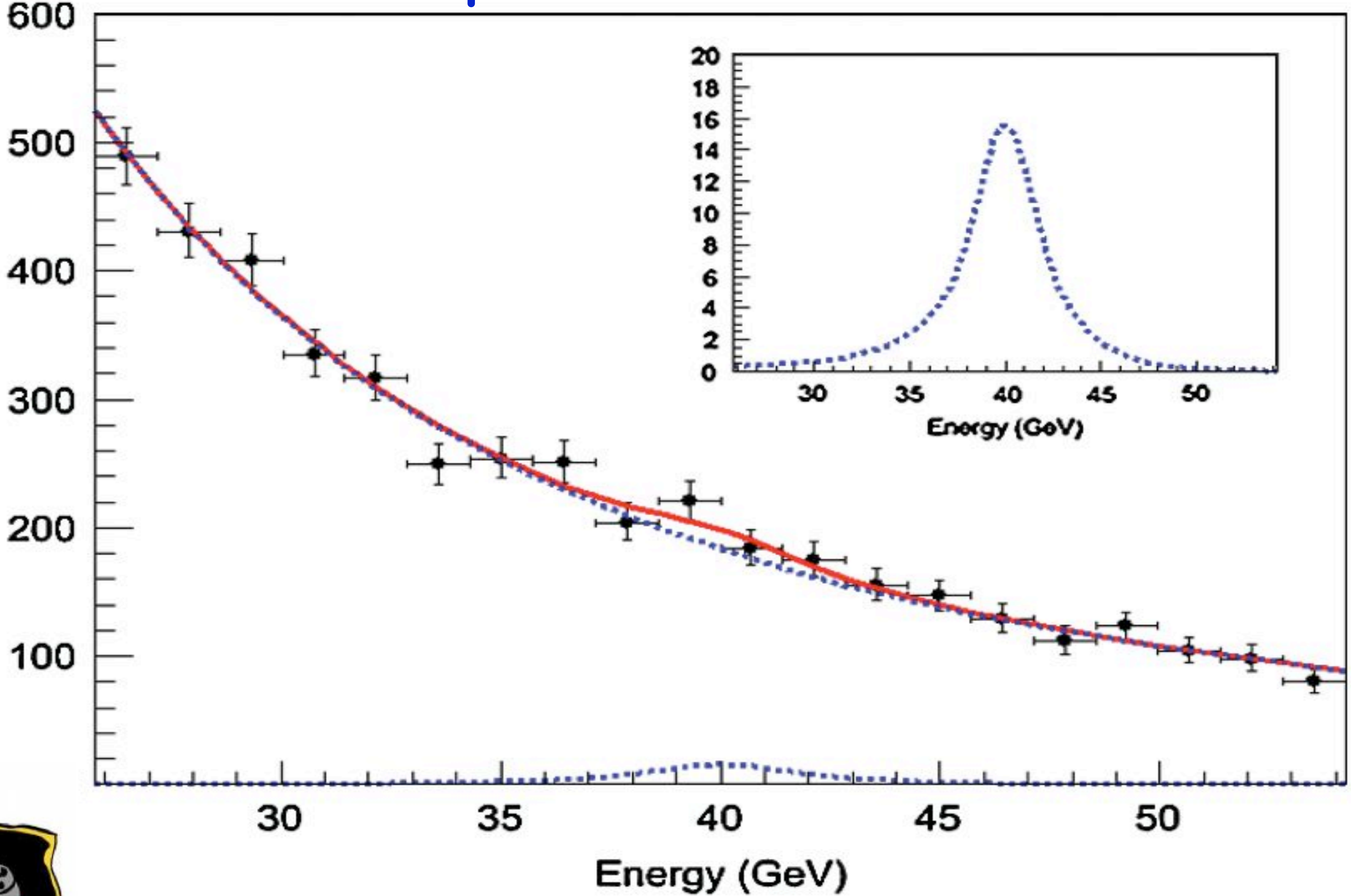
11 months of data, E >400 MeV, front-converting events analyzed with binned likelihood analysis)

- 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 10GeV



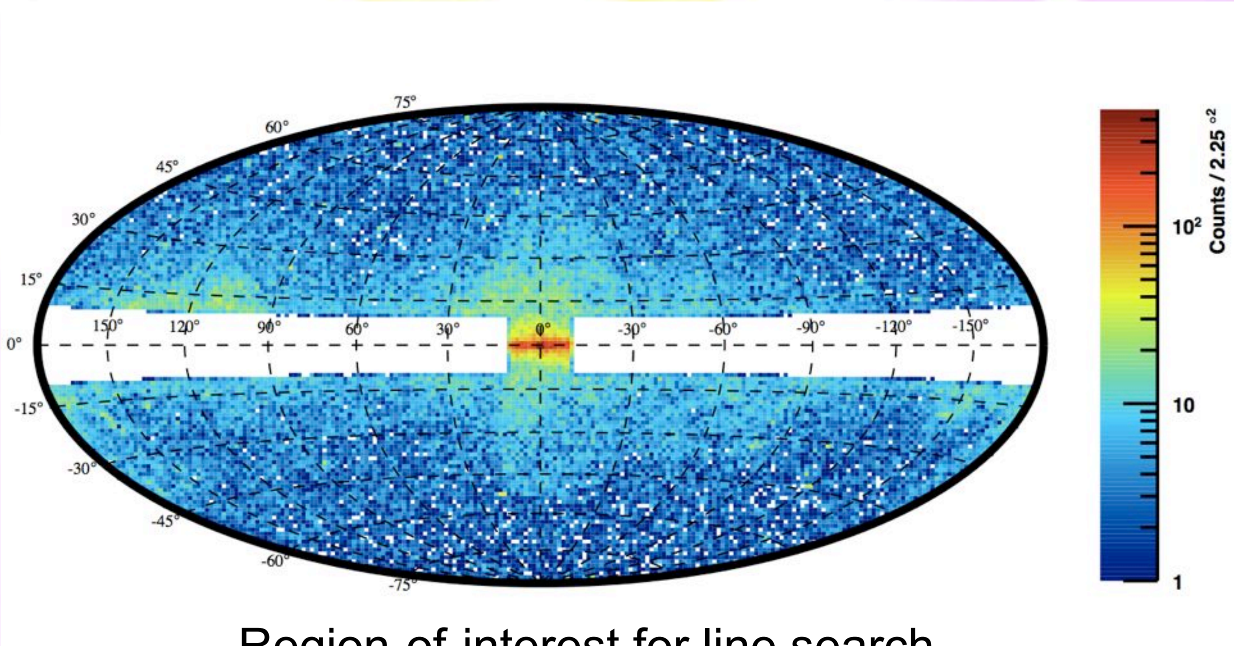
Fermi Coll. NIM A630 (2011) 147 [arXiv:0912.3828]

Wimp lines search



Search for Spectral Gamma Lines

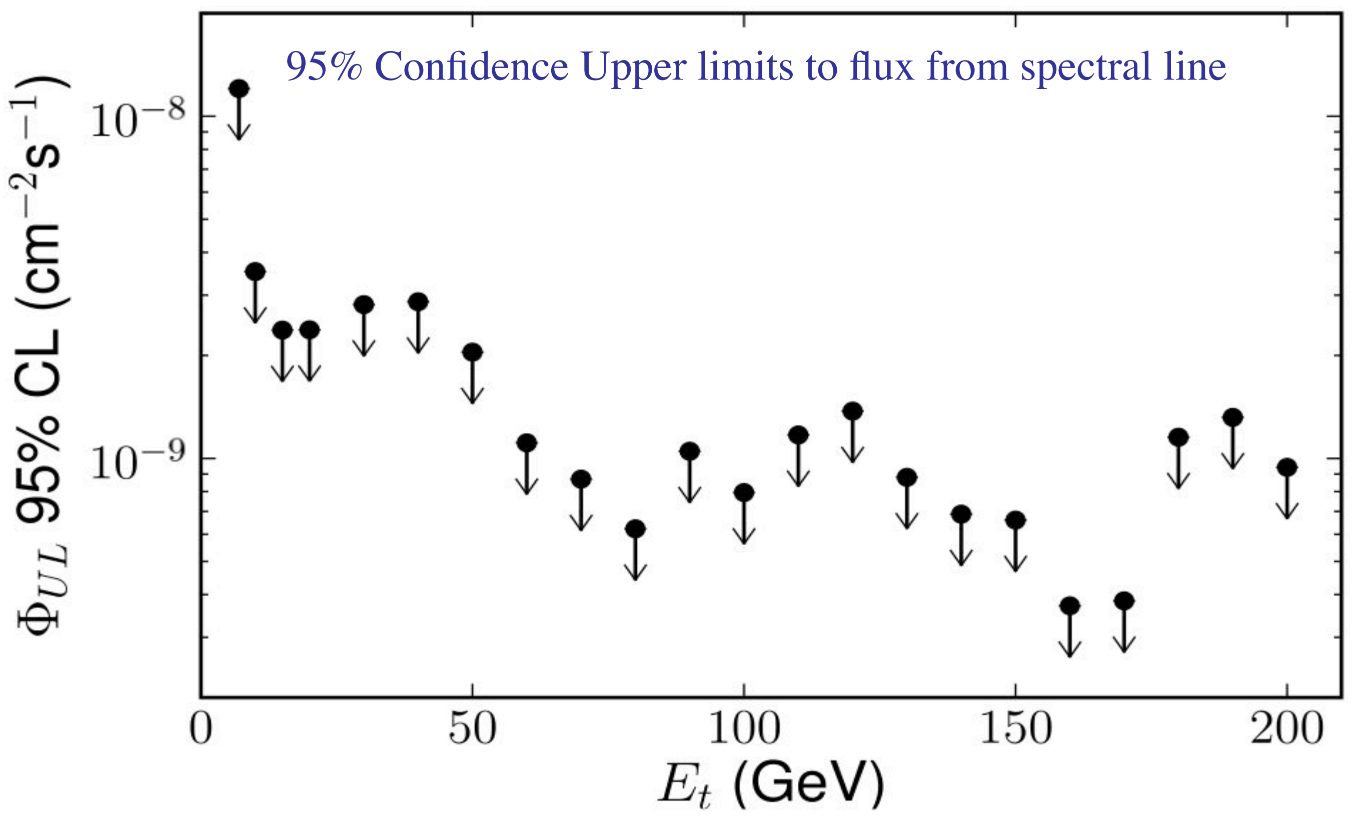
- Smoking gun signal of dark matter
- Search for lines in the first 23 months of Fermi data(7-200 GeV en.range)
- Search region|b|>10°plus a 20°x 20° square centered at the galactic center
- For the region within 1°of the GC, no point source removal was done as this would have removed the GC
- For the remaining part of the ROI, point sourceswere masked from the analysis using a circle of radius 0.2 deg
- The data selection includes additional cuts to remove residual charged particle contamination.



Region-of-interest for line search

Fermi LAT 23 Month Line search results Flux Upper Limits, 7 GeV - 200 GeV

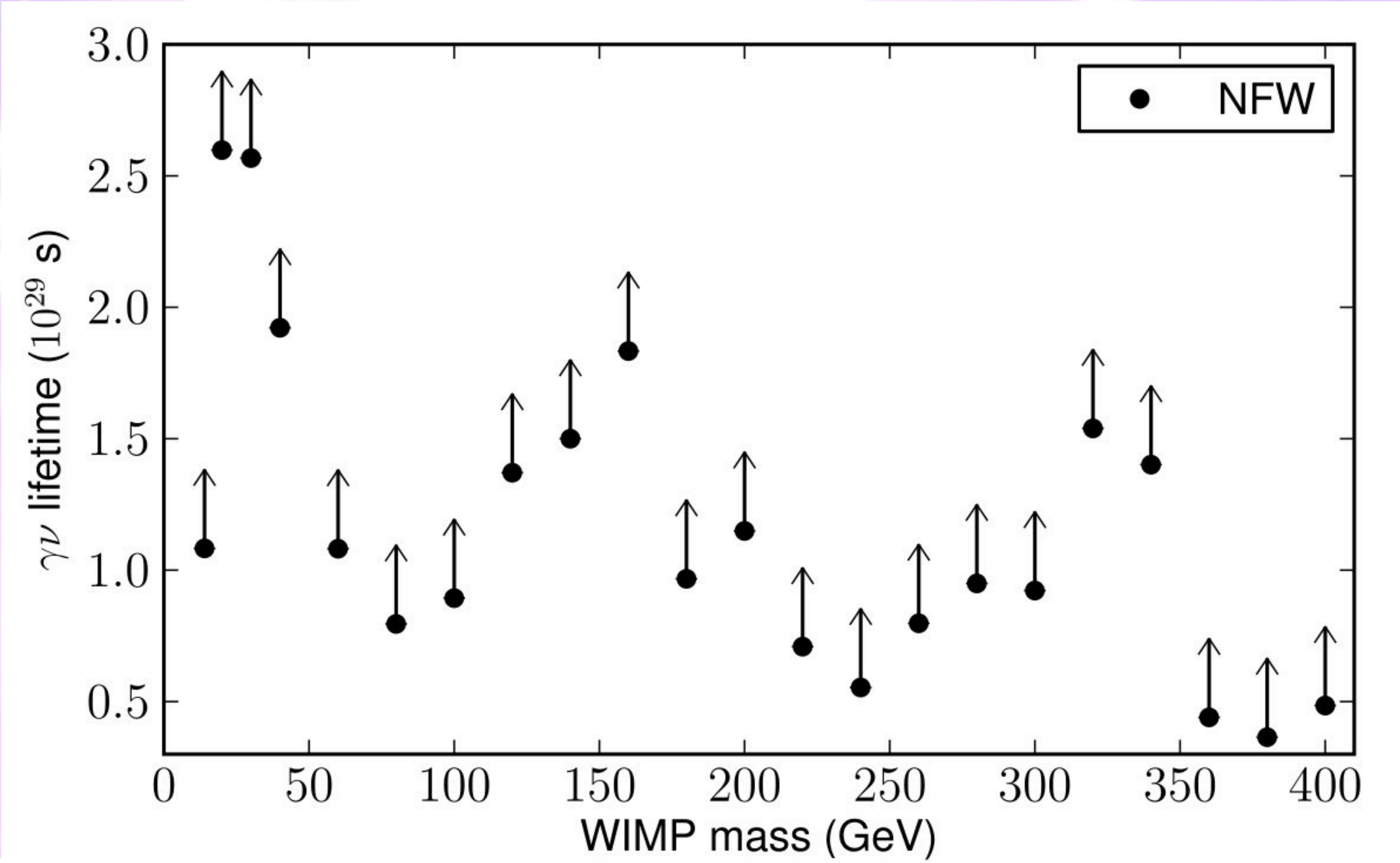
- 23 % systematic uncertainty forE < 130 GeV and 30% for E > 130 GeV
- **7 and 10 GeV bins use a modified event selection to reduce the systematic uncertainty associated with public IRFs**.
- For E > 12 GeV no indication of a spectral structure systematic effect is seen.



Fermi Lat Coll., PRD 86, (2012) 022002arXiv:1205.2739

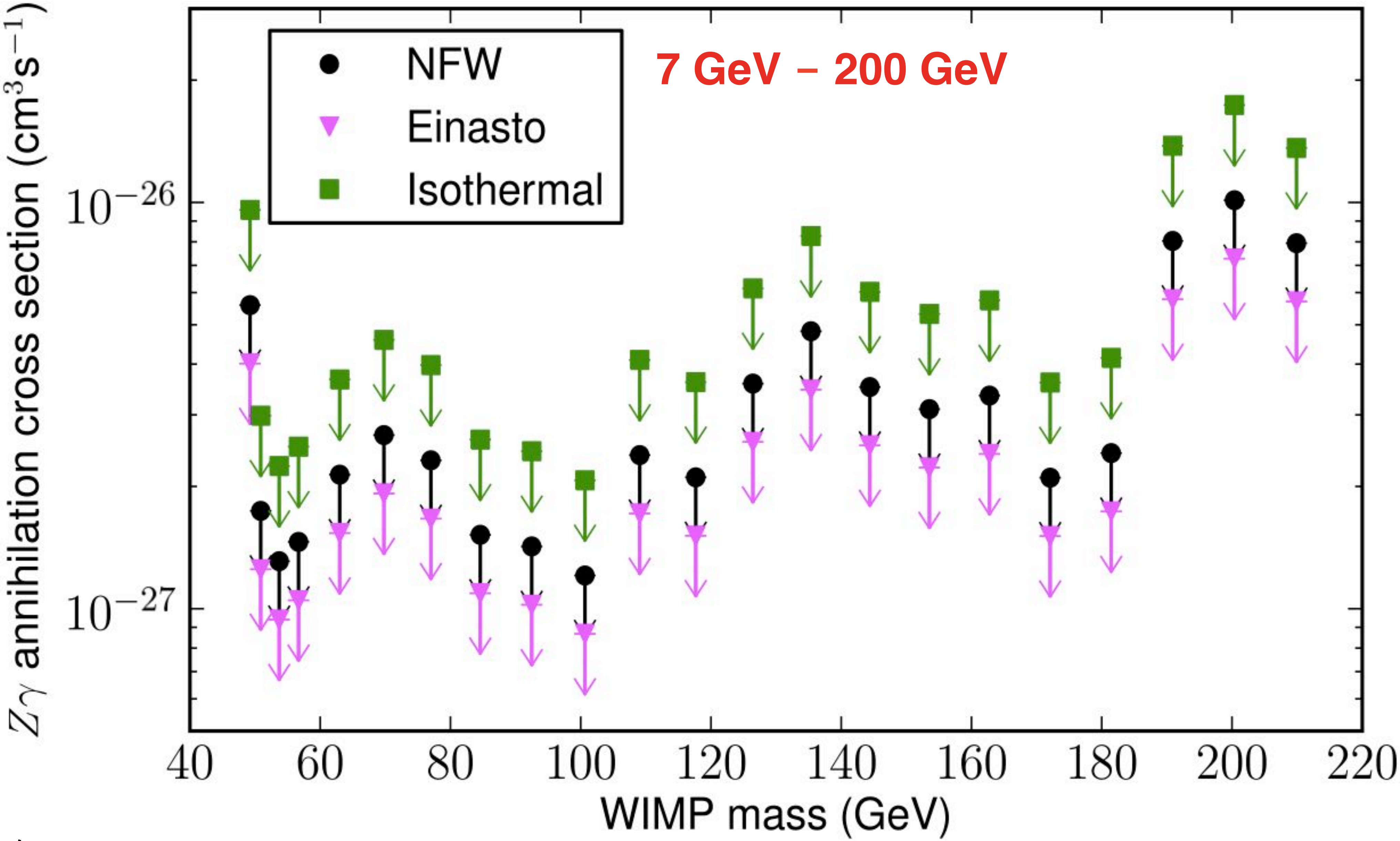
Decay lifetime lower limits

- Limits similar for all 3 DM density profiles due to linear dependence of flux on ρ
- Disfavors lifetimes smaller than 10^{29} s



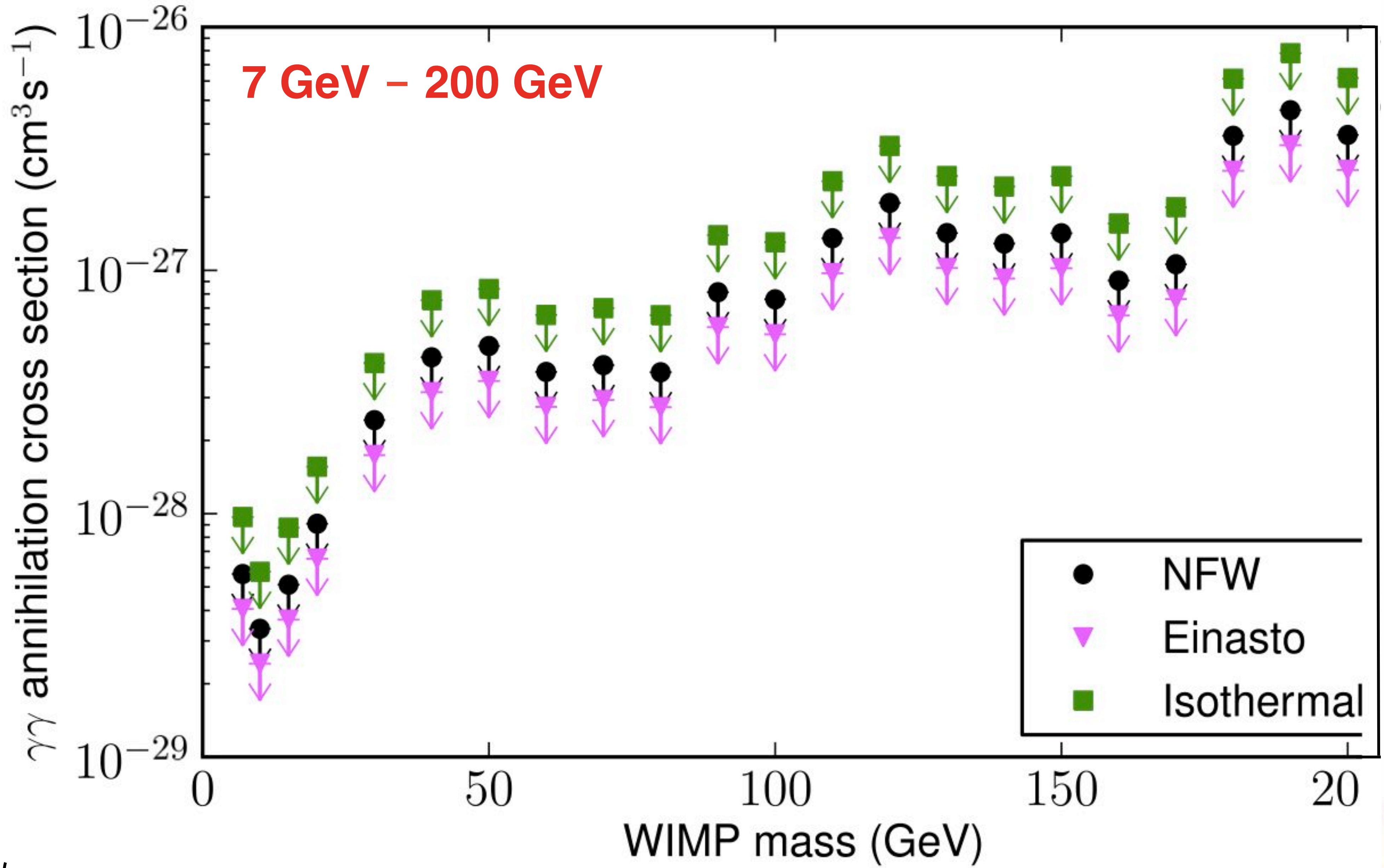
Fermi Lat Coll., PRD 86, (2012) 022002arXiv:1205.2739

Fermi LAT 23 Month Zγ-Cross-section limits



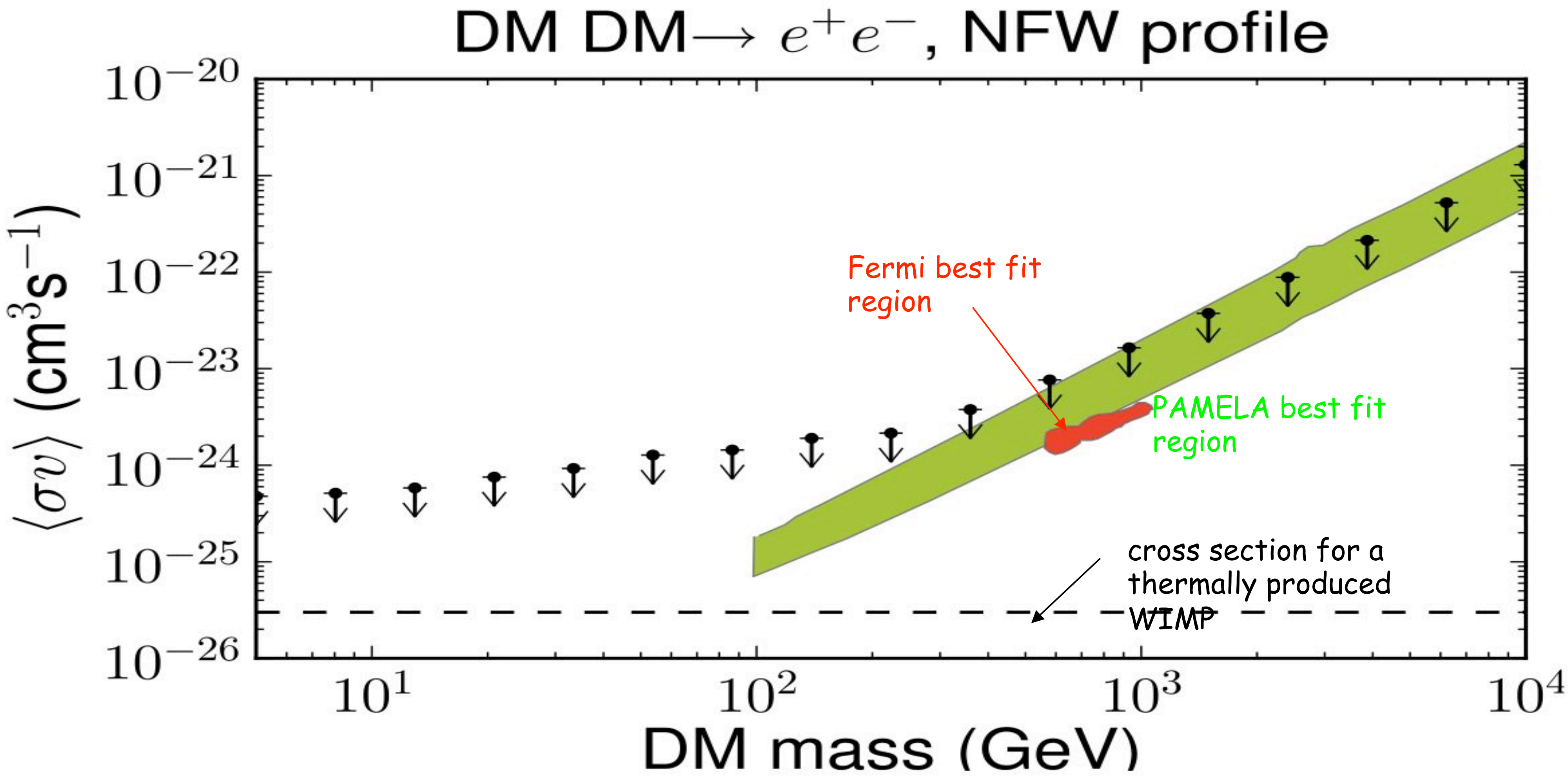
Fermi Lat Coll., PRD 86, (2012) 022002arXiv:1205.2739

Fermi LAT 23 Month $\gamma\gamma$-Cross-section limits



Fermi Lat Coll., PRD 86, (2012) 022002arXiv:1205.2739

Cross section upper limits for dark matter annihilation



No photons from astrophysical background sources have been included, making these limits very conservative.

Fermi Lat Coll., PRD D 86, (2012) 022002[arXiv:1205.2739]

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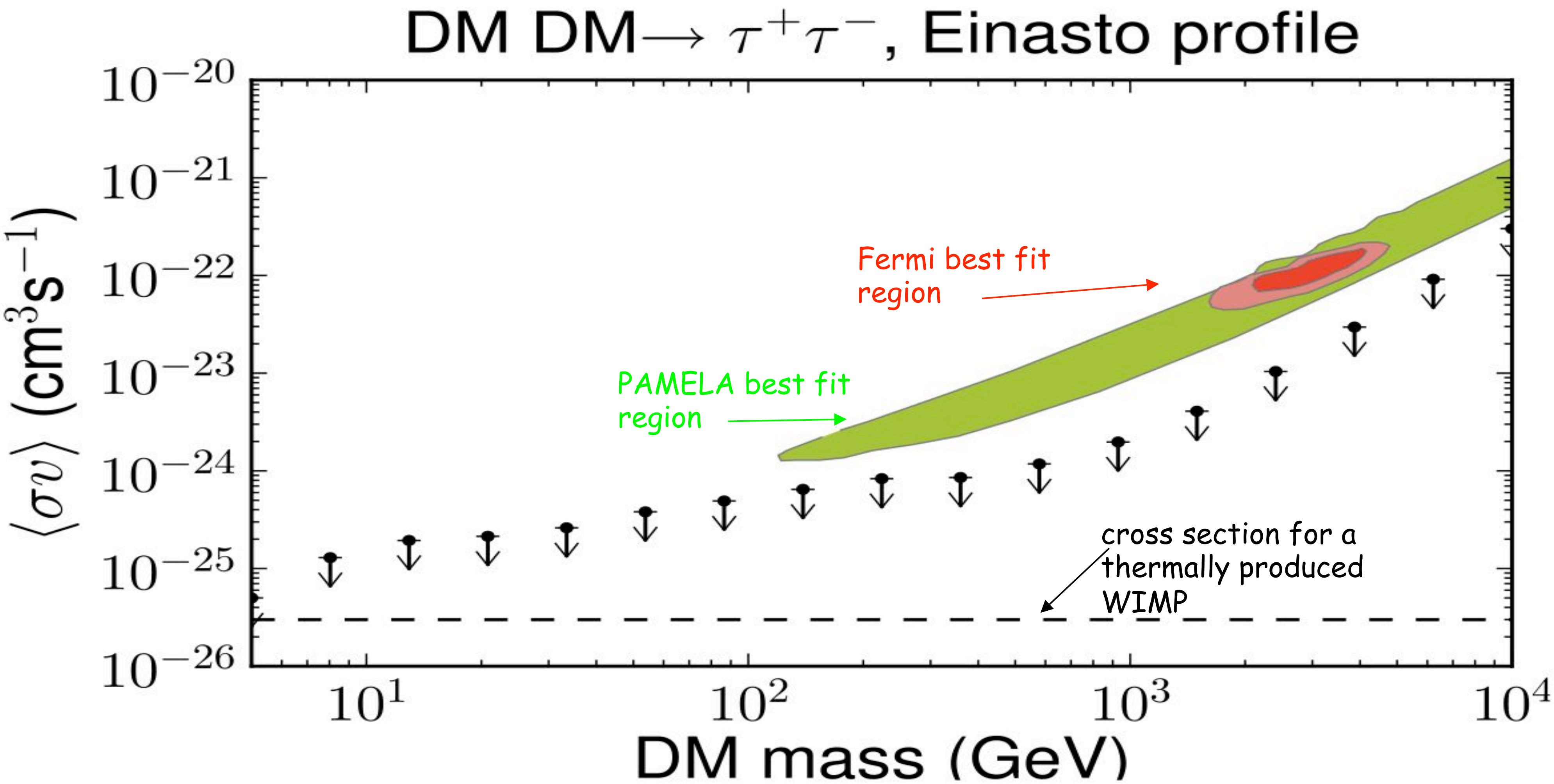

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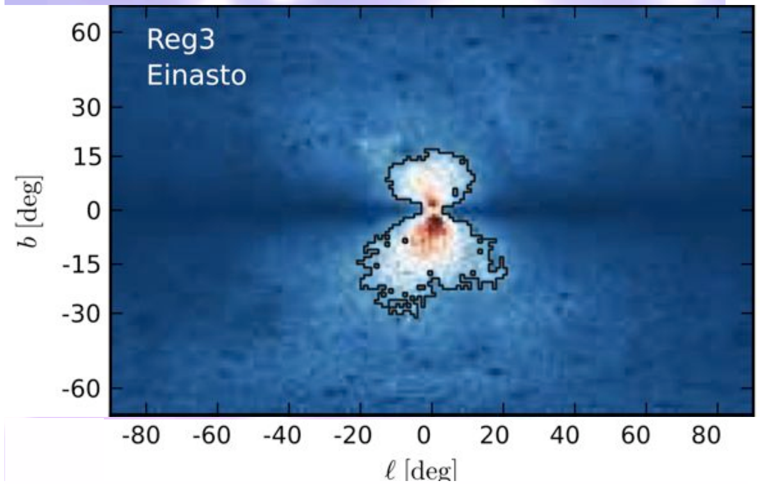
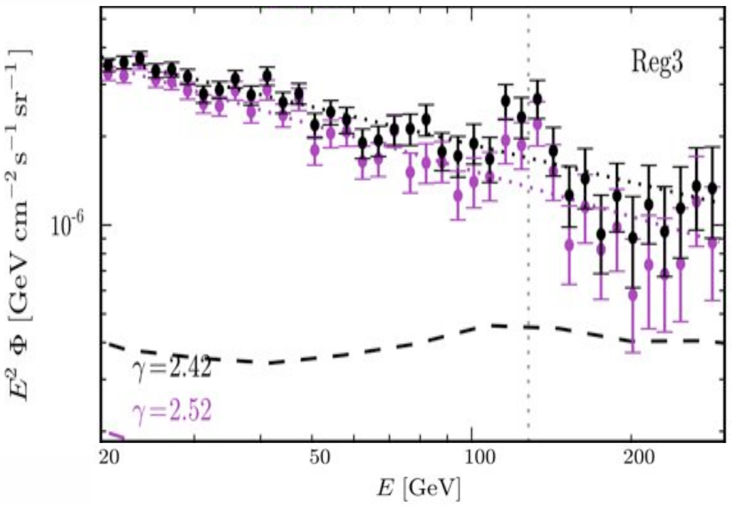
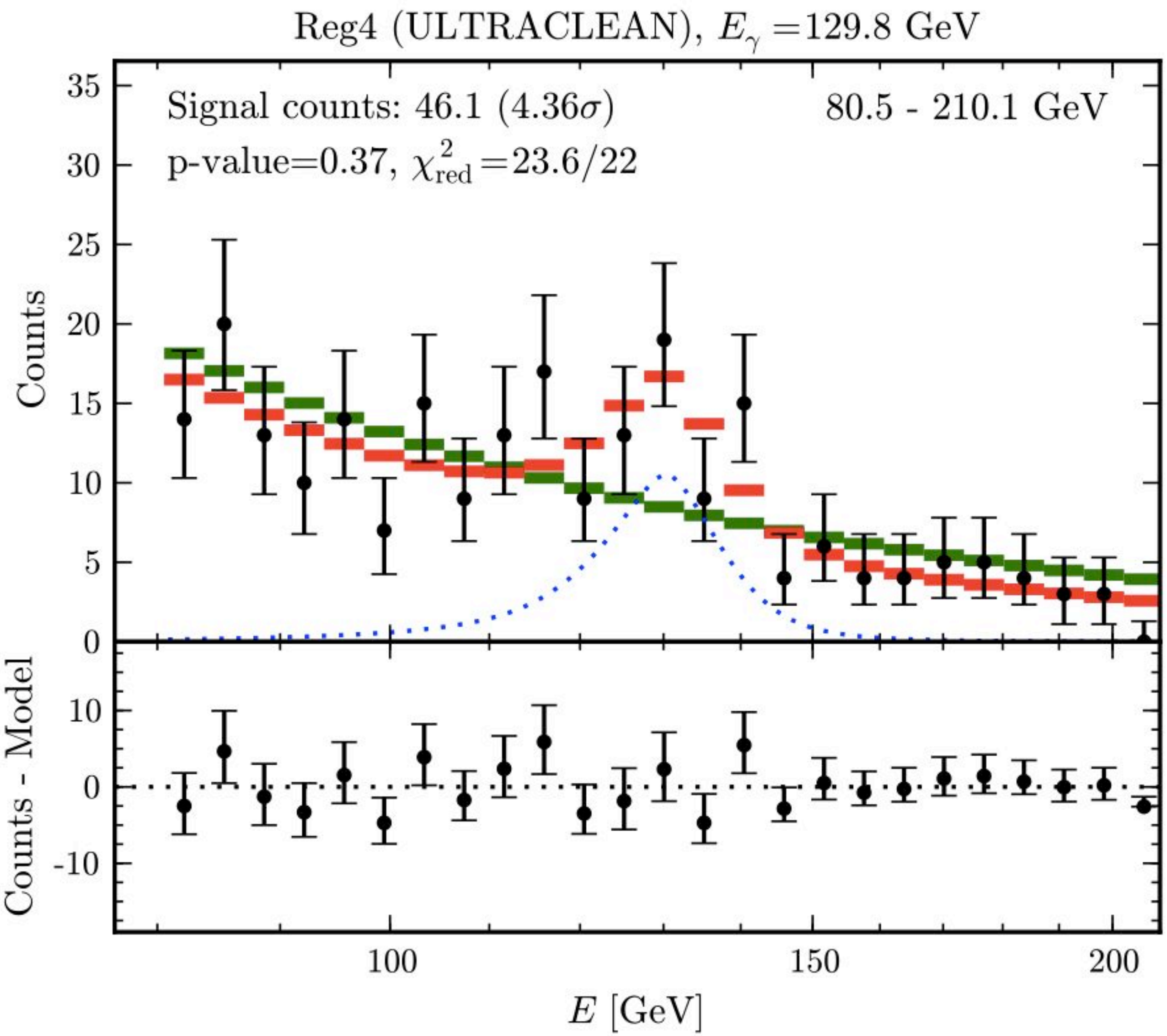
A line at ~ 130 GeV ?







Weniger arXiv:1204.2797

A line at ~ 130 GeV ?

see also

Tempel et al. arXiv:1205.1045

Kyae & Park arXiv:1205.4151

Dudas Mambrini et al. arXiv:1205.1520

Boyarsky et al. arXiv:1205.4700

Lee et al. arXiv:1205.4700

Acharya, Kane et al. arXiv:1205.5789

Buckley, HooperarXiv:1205.6811

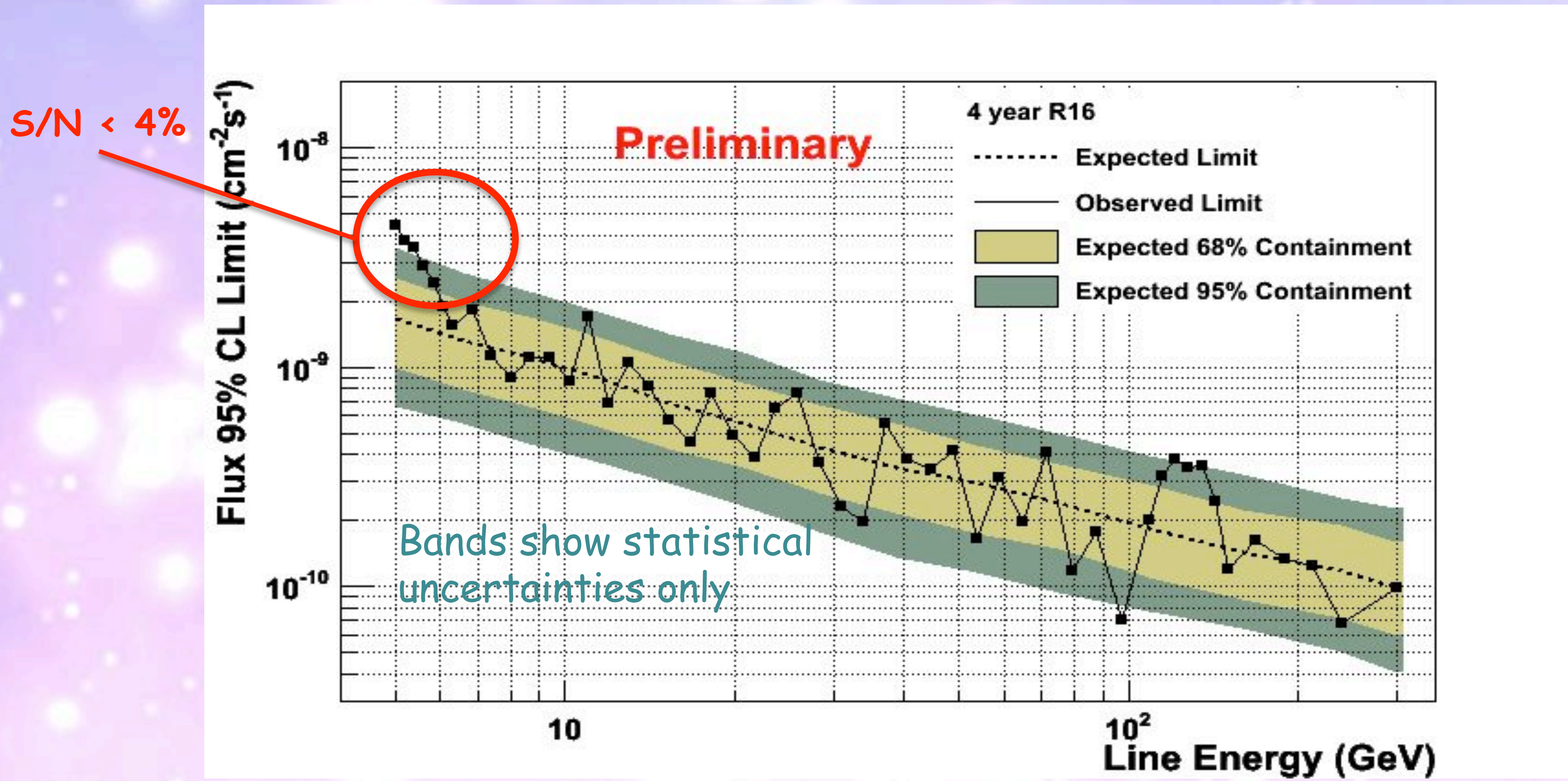
Su, Finkbeiner arXiv:1206.1616

Chu,Hambye et al. arXiv:1206.2279

Finkbeiner, Su, WenigerarXiv:1209.4562

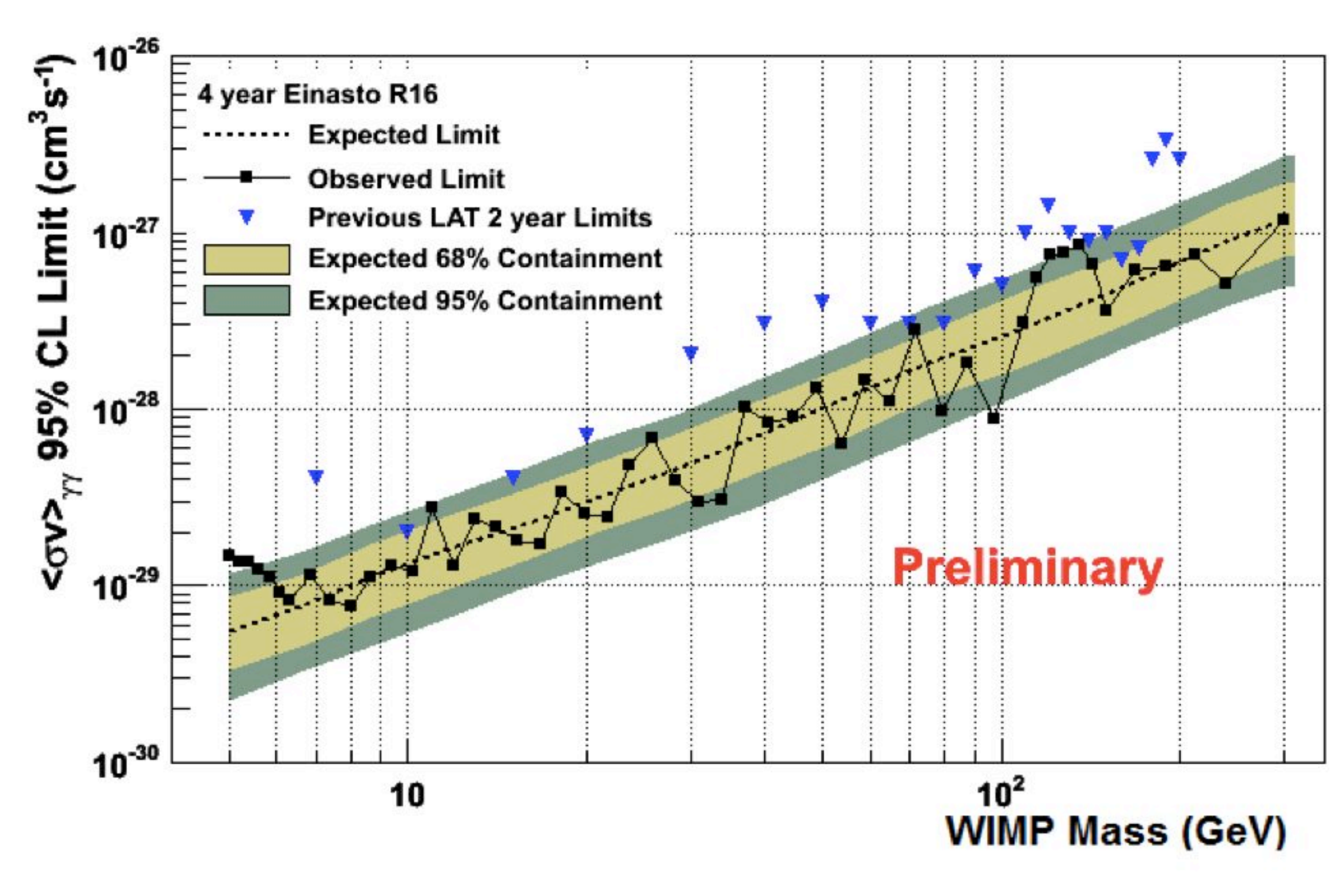
.... Fermi-LAT analysis is in progress

Fermi-LAT Line Search Flux Upper Limits



- Most of the limits fall within the expected bands.
- Near 135 GeV the limits are near the upper edge of the bands.
- The huge statistics at low energies mean small uncertainties in the collecting area can produce statistical significant spectral features.

Fermi-LAT Line Search<σv> upper limits (Einasto)



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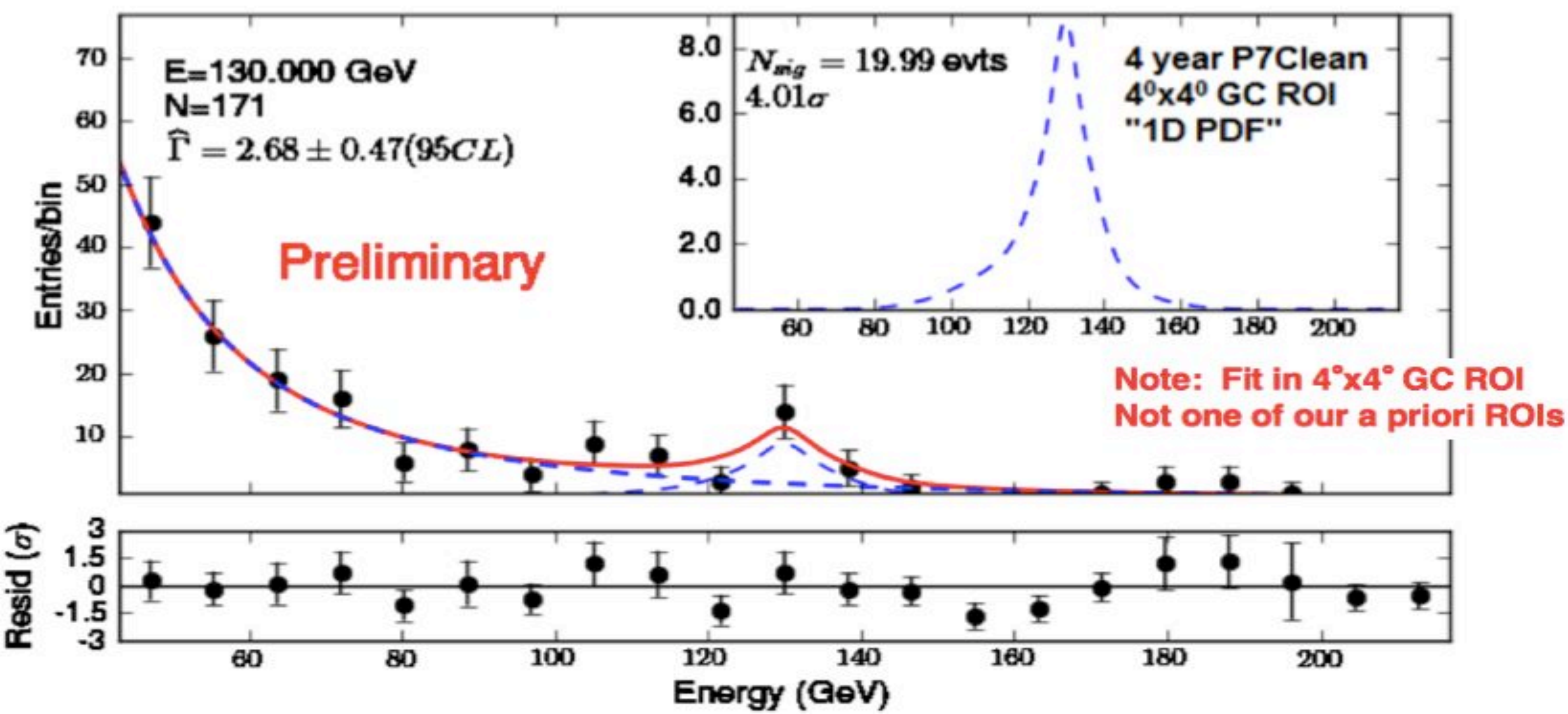
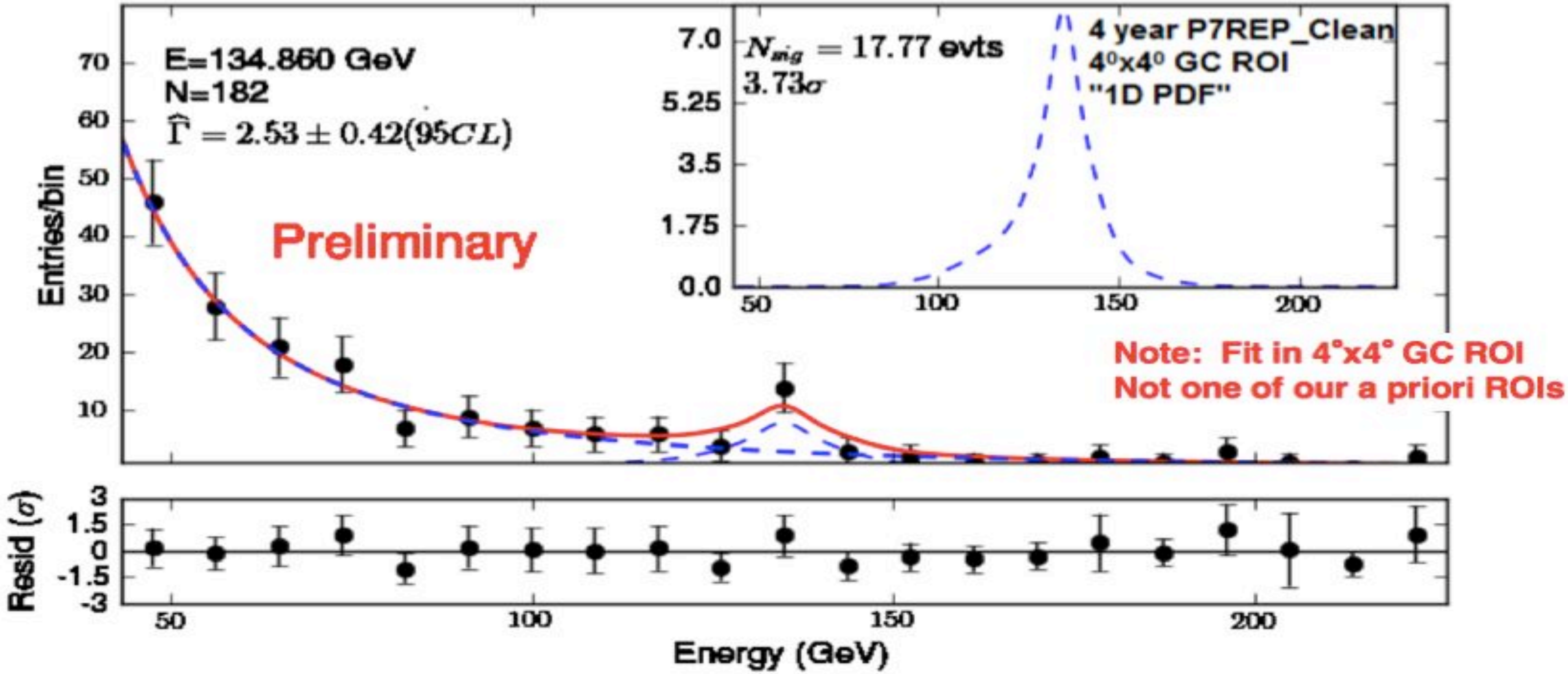
- The huge statistics at low energies mean small uncertainties in the collecting area can produce statistical significant spectral features.

Fermi-LAT feature near 135 GeV



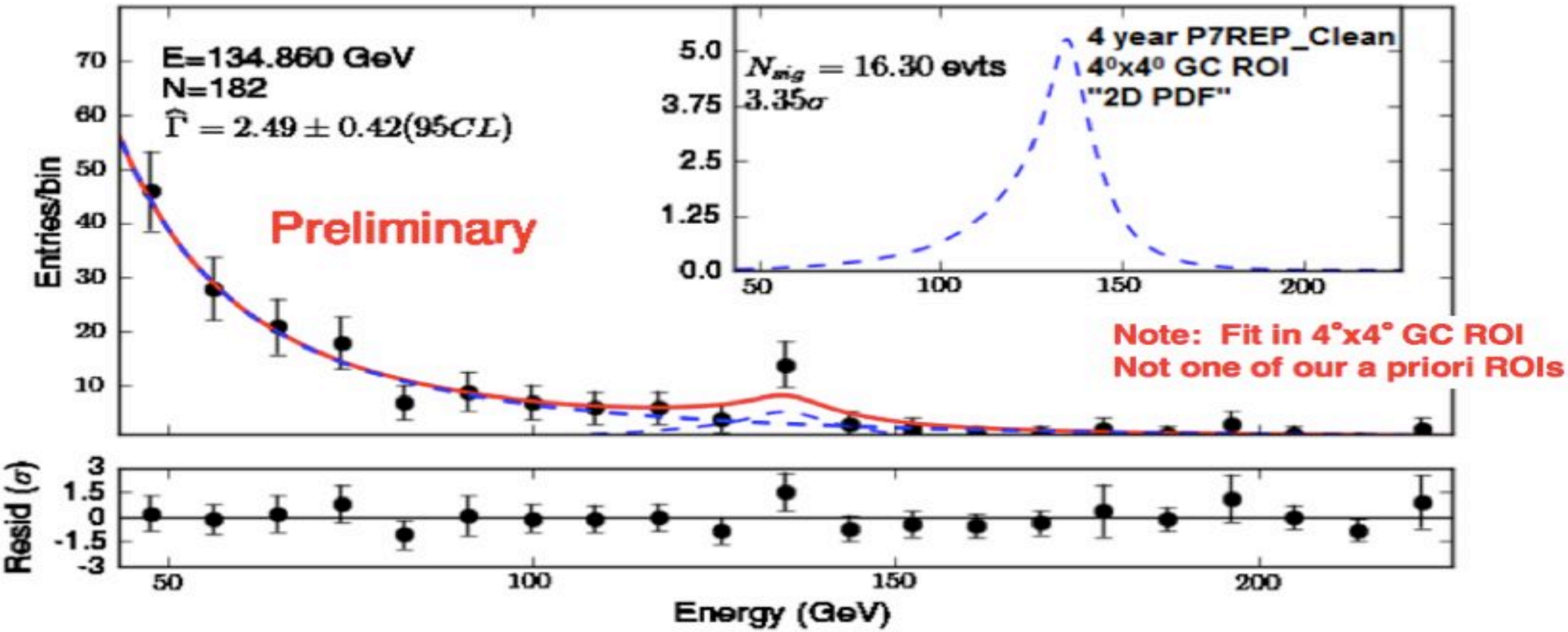
- 4.01σ (local) 1D fit at 130 GeV with 4 year unreprocessed data
- Look in 4°x4°GC ROI, Use 1D PDF (no use of P_E)

Fermi-LAT feature near 135 GeV



- 4.01σ (local) 1D fit at 130 GeV with 4 year unreprocessed data
  - Look in 4°x4°GC ROI, Use 1D PDF (no use of P_E)
- 3.73σ (local) 1D fit at 135 GeV with 4 year reprocessed data
  - Look in 4°x4°GC ROI, Use 1D PDF (no use of P_E)

Fermi-LAT feature near 135 GeV



- 4.01σ (local) 1D fit at 130 GeV with 4 year unreprocessed data
  - Look in 4°x4°GC ROI, Use 1D PDF (no use of P_E)
- 3.73σ (local) 1D fit at 135 GeV with 4 year reprocessed data
  - Look in 4°x4°GC ROI, Use 1D PDF (no use of P_E)
- 3.35σ (local) 2D fit at 135 GeV with 4 year reprocessed data
  - Look in 4°x4°GC ROI, Use 2D PDF (P_E in data)
  - <2σ global significance after trials factor

Future Surprises (...like CR Origin)

We are just beginning...

- •Exposure continues to increase
- -Fainter sources become detectable
- -Increasingly detailed studies of bright sources
- -Catalogs become deeper and more detailed
- •Time domain studies enter longer regimes
- •Solar cycle beginning to warm up
- •Plus, efforts continue to further improve performance and enhance analysis, particularly at low and high energies

Exciting progress on Pass8, expected to be the ultimate IRF version.

The longer we look, the more surprises we will see


Come to
the dark side.
We have cookies...
-V
Come to
the dark side.
We have cookies...

Not only Dark Matter

Origin of Cosmic Rays

Cosmic rays are particles (mostly protons) accelerated to relativistic speeds.
Despite wide agreement that supernova remnants (SNRs) are the sources of galactic cosmic rays, unequivocal evidence for the acceleration of protons in these objects is still lacking.
When accelerated protons encounter interstellar material they produce neutral pions, which in turn decay into gamma rays. This offers a compelling way to detect the acceleration sites of protons.
The identification of pion-decay gamma rays has been difficult because high-energy electrons also produce gamma rays via bremsstrahlung and inverse Compton scattering.

The π^0-decay bump

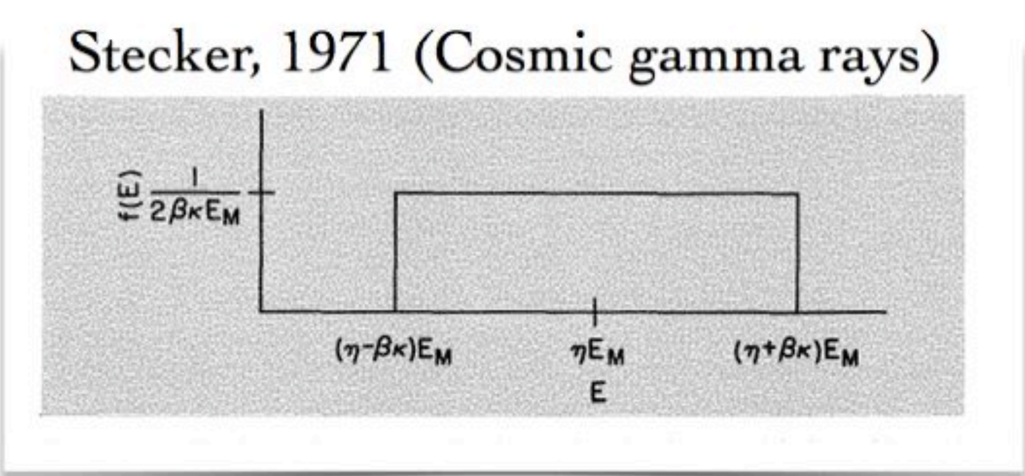
- Neutral pion-decay: in the rest-frame of the pion, the two γ rays have 67.5 MeV each (i.e. a line)

Stecker, 1971 (Cosmic gamma rays)

- Transforming into the lab-frame smears the line but keeps it symmetric about 67.5 MeV (in dN/dE)

Dermer, 1986

- Transforming to E2 dN/dE and drop in pion-production cross section destroys symmetry and generates the "bump"



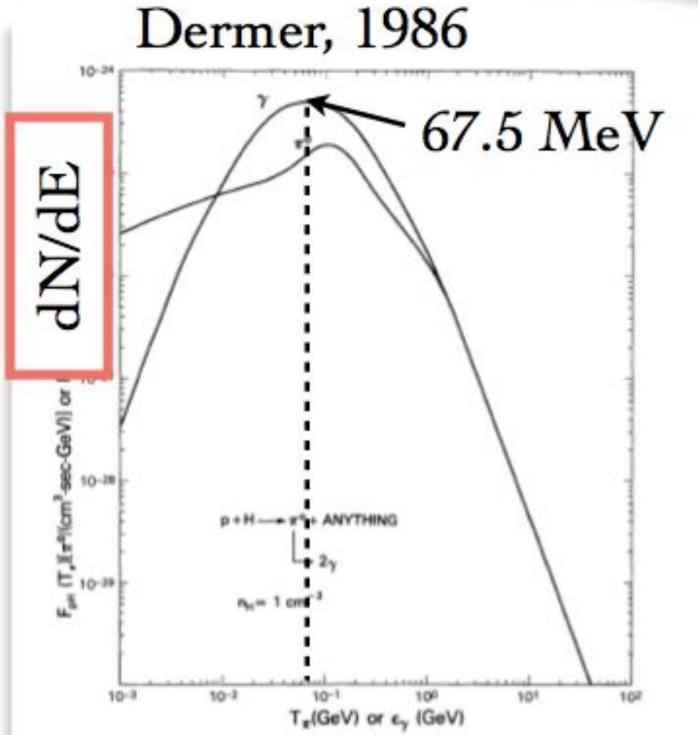
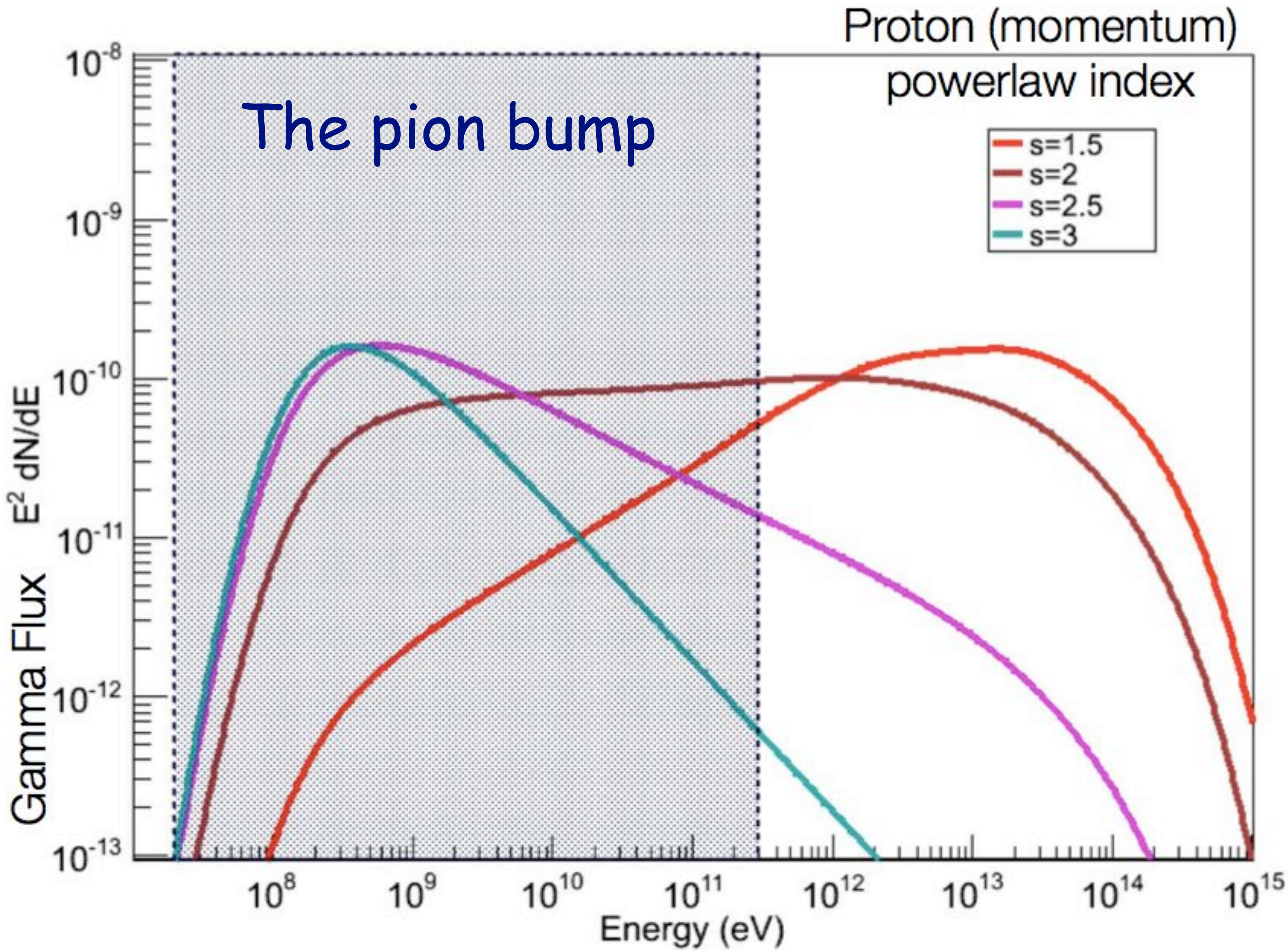


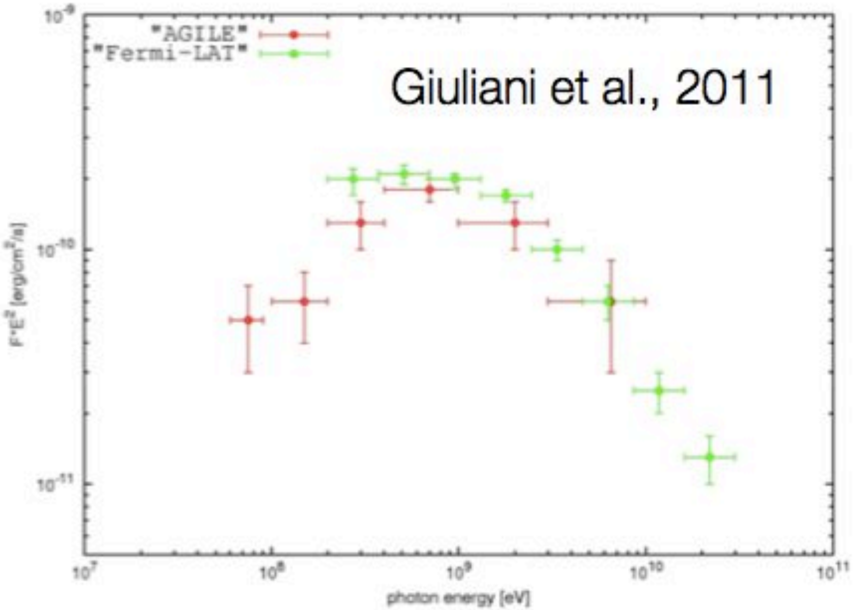
Fig. 7. The secondary π^0 and γ-ray emissivities from the interaction of the local demodulated cosmic ray proton spectrum with unit density of atomic hydrogen

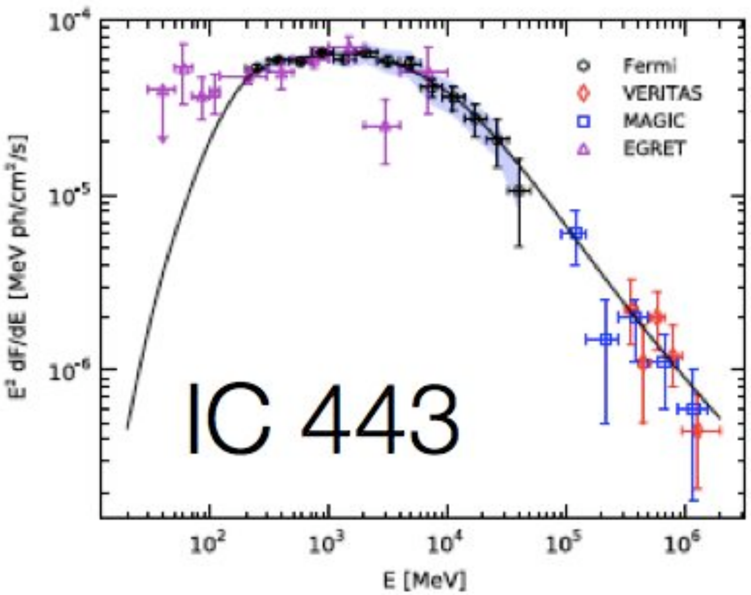


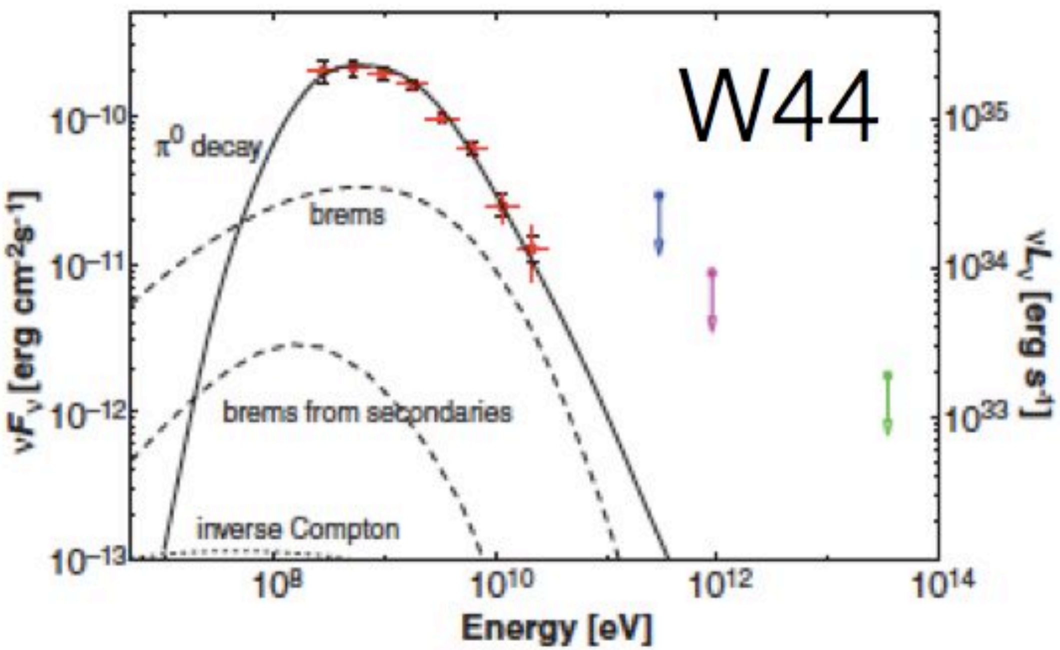
Smoking gun feature for accelerated protons

Earlier observations

- Seen with EGRET in the Galactic diffuse
- AGILE detection of "bump" in W44 (Giuliani et al., 2011)
- Previous Fermi-LAT analyses started at 200 MeV (rapidly changing effective area)



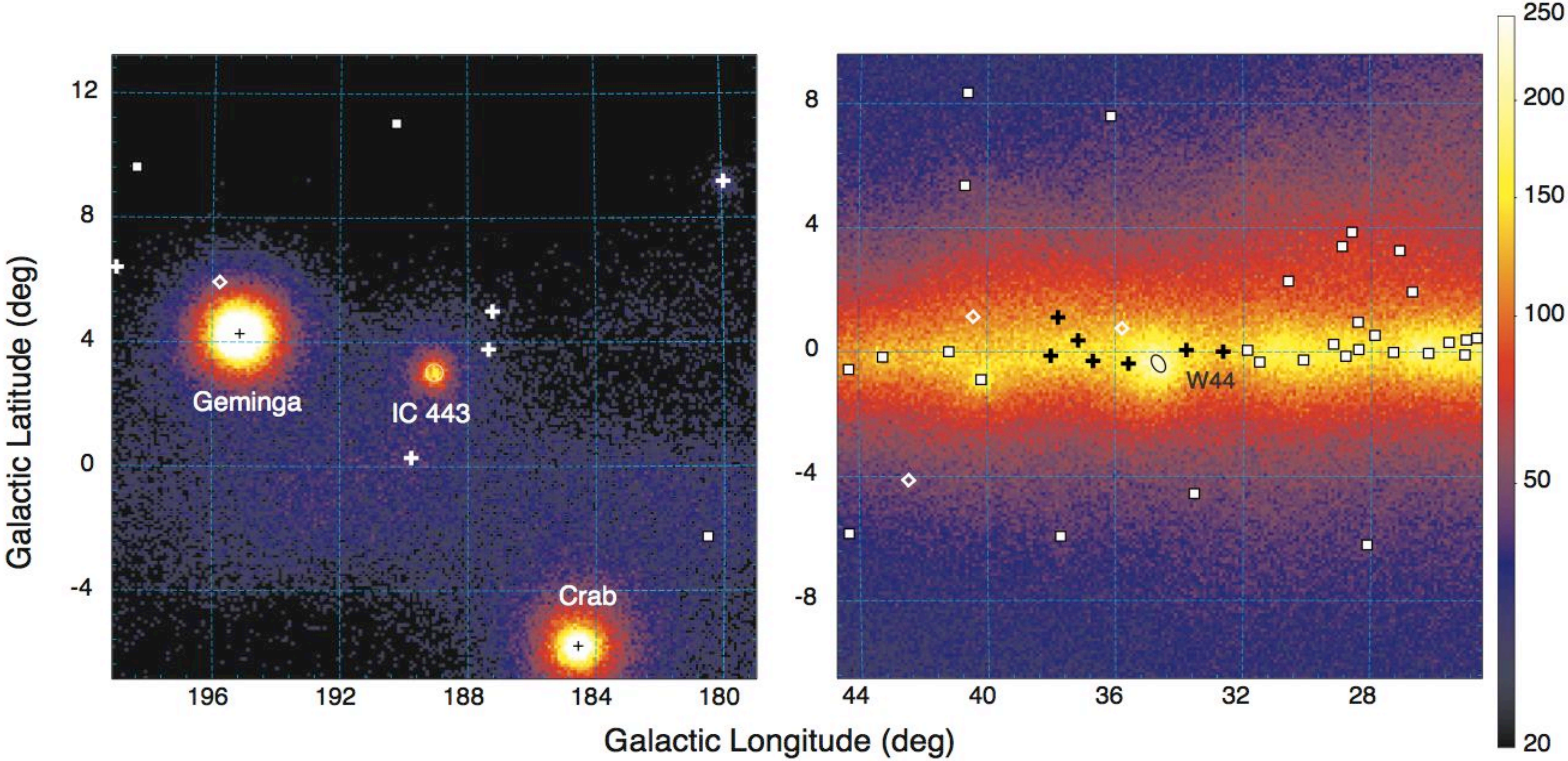




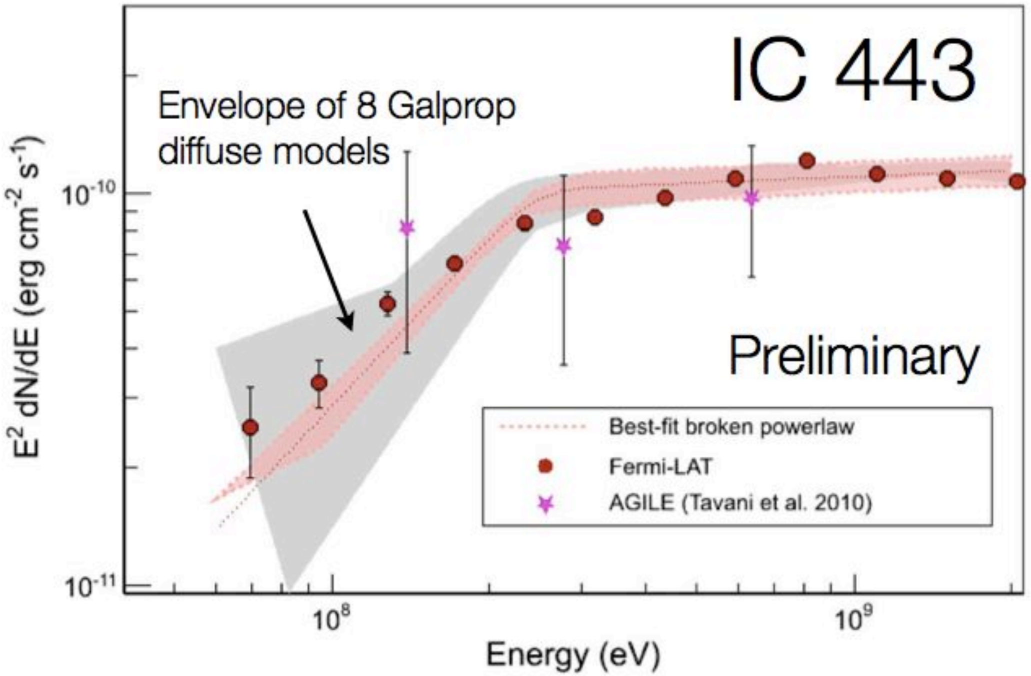
New Fermi Large Area Telescope analysis:

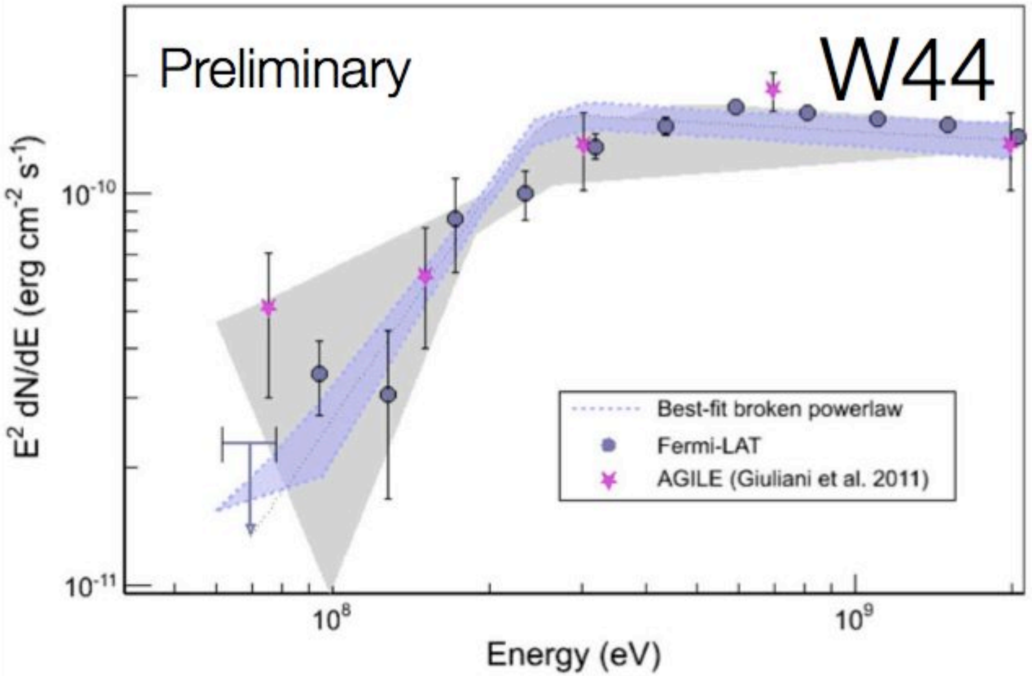
Time range: 2008 August, 4th to 2012 July 16th

Gamma-ray count maps of the 20° × 20° fields around **IC 443**and **W44** in the energy range 60 MeV to 2 GeV



Energy spectra down to 60 MeV

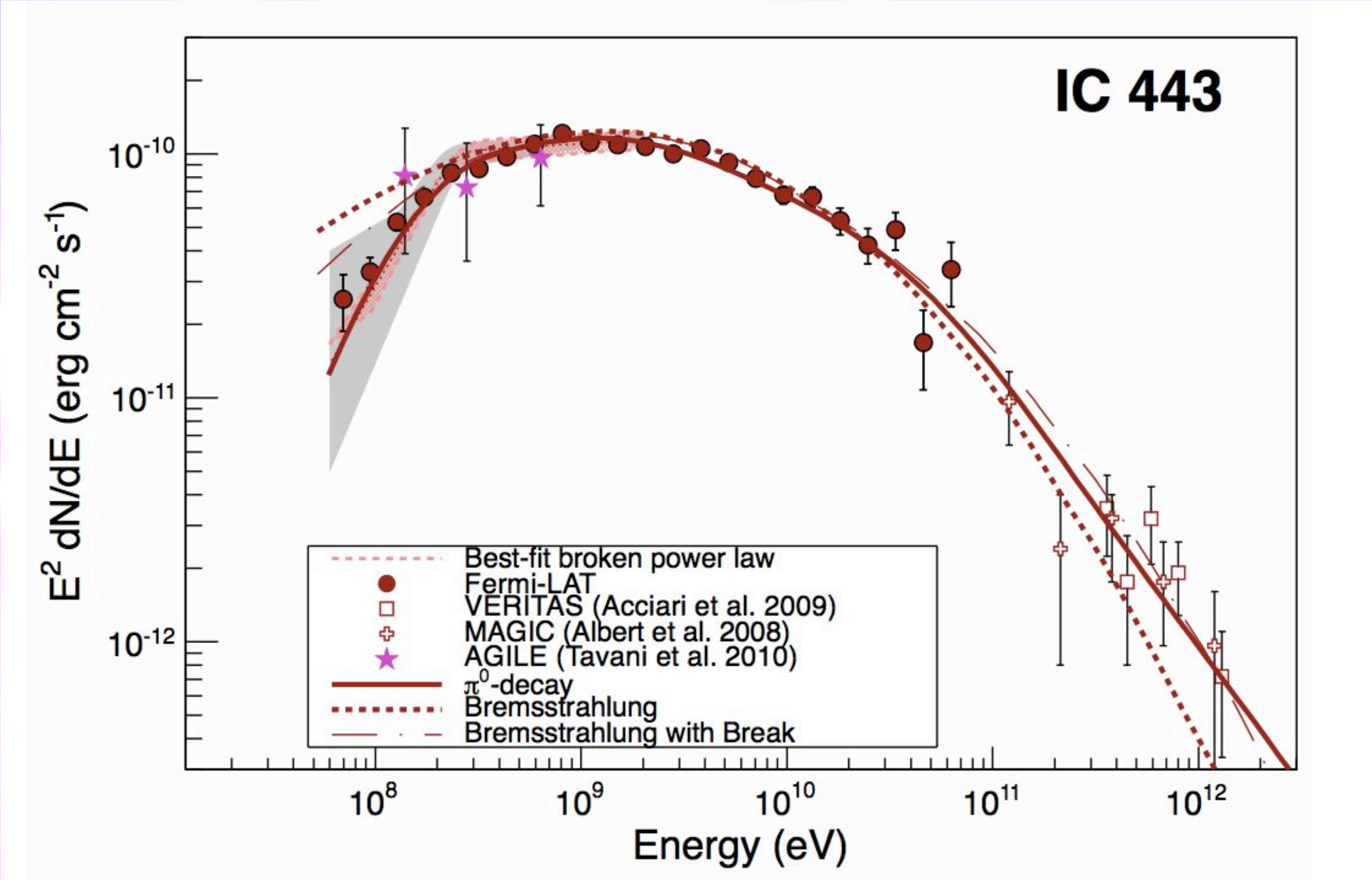




- Clear indication of a low-energy “turnover”
- Gray systematic error band estimated from 8 Galprop models of diffuse emission

Detection of the Characteristic Pion-decay Signature in Supernova Remnants

Direct evidence that cosmic-ray protons are accelerated in SNR



Science339, (2013)807[arXiv:1302.3307]15 Feb. 2013

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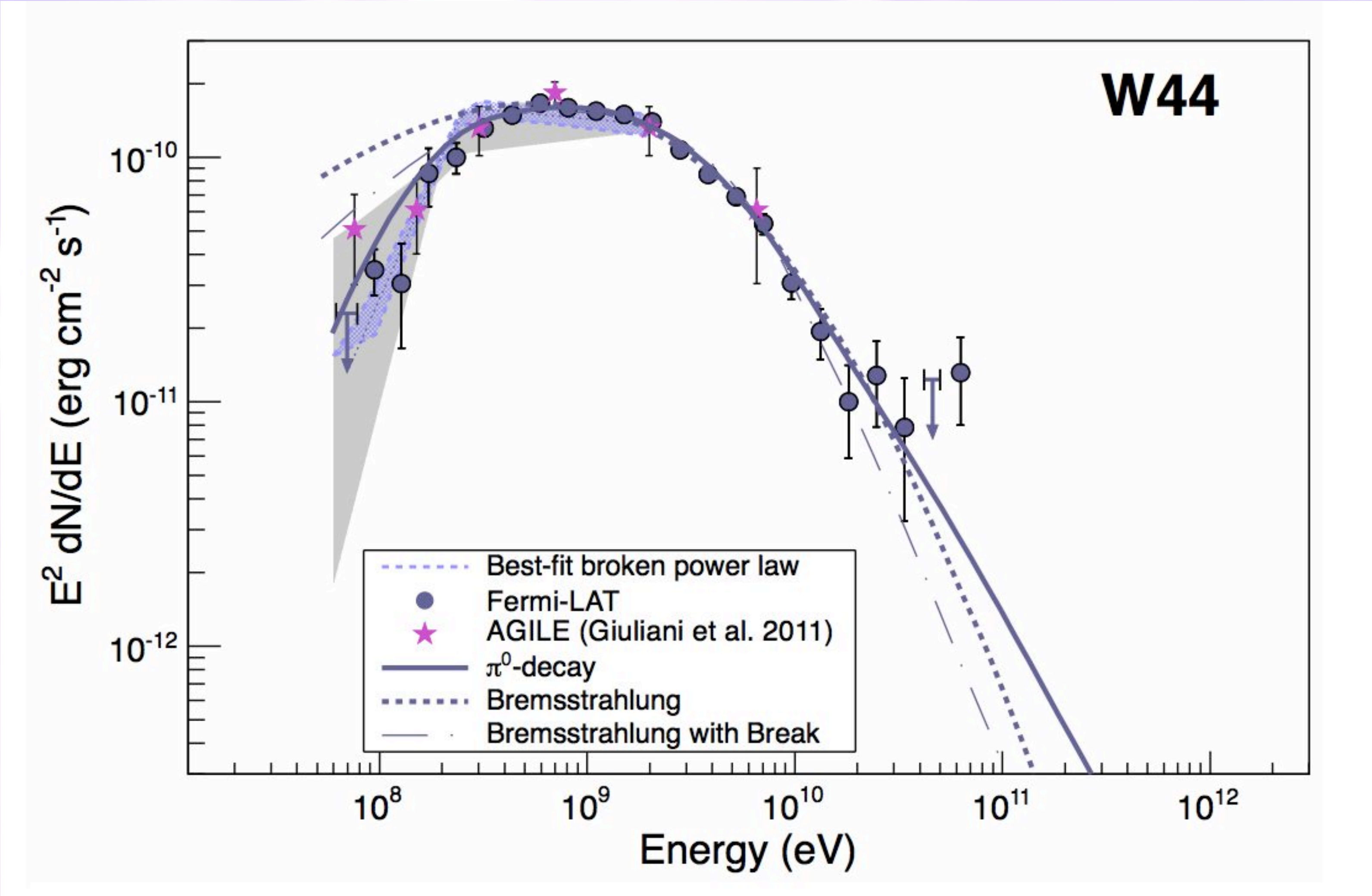

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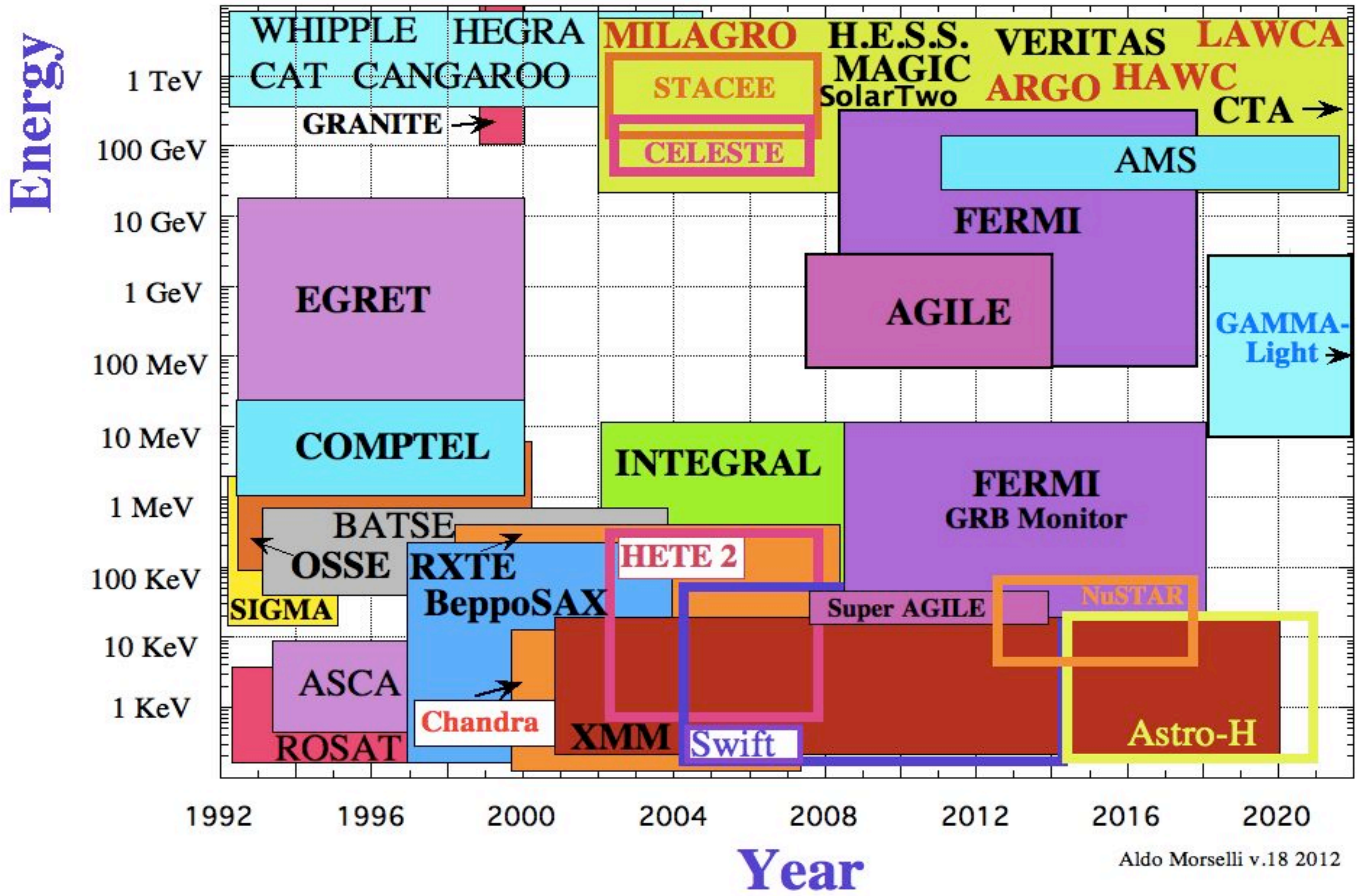
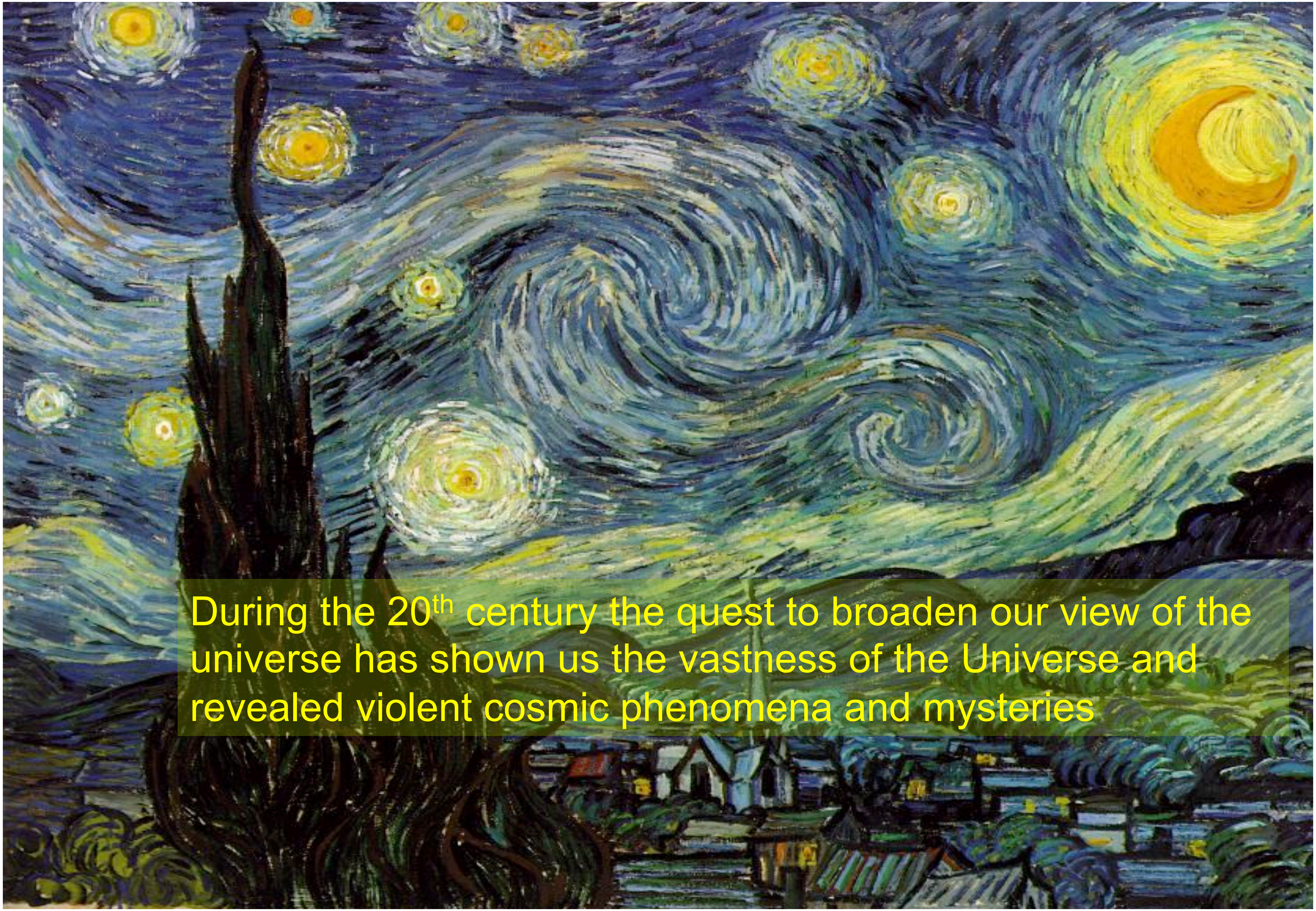
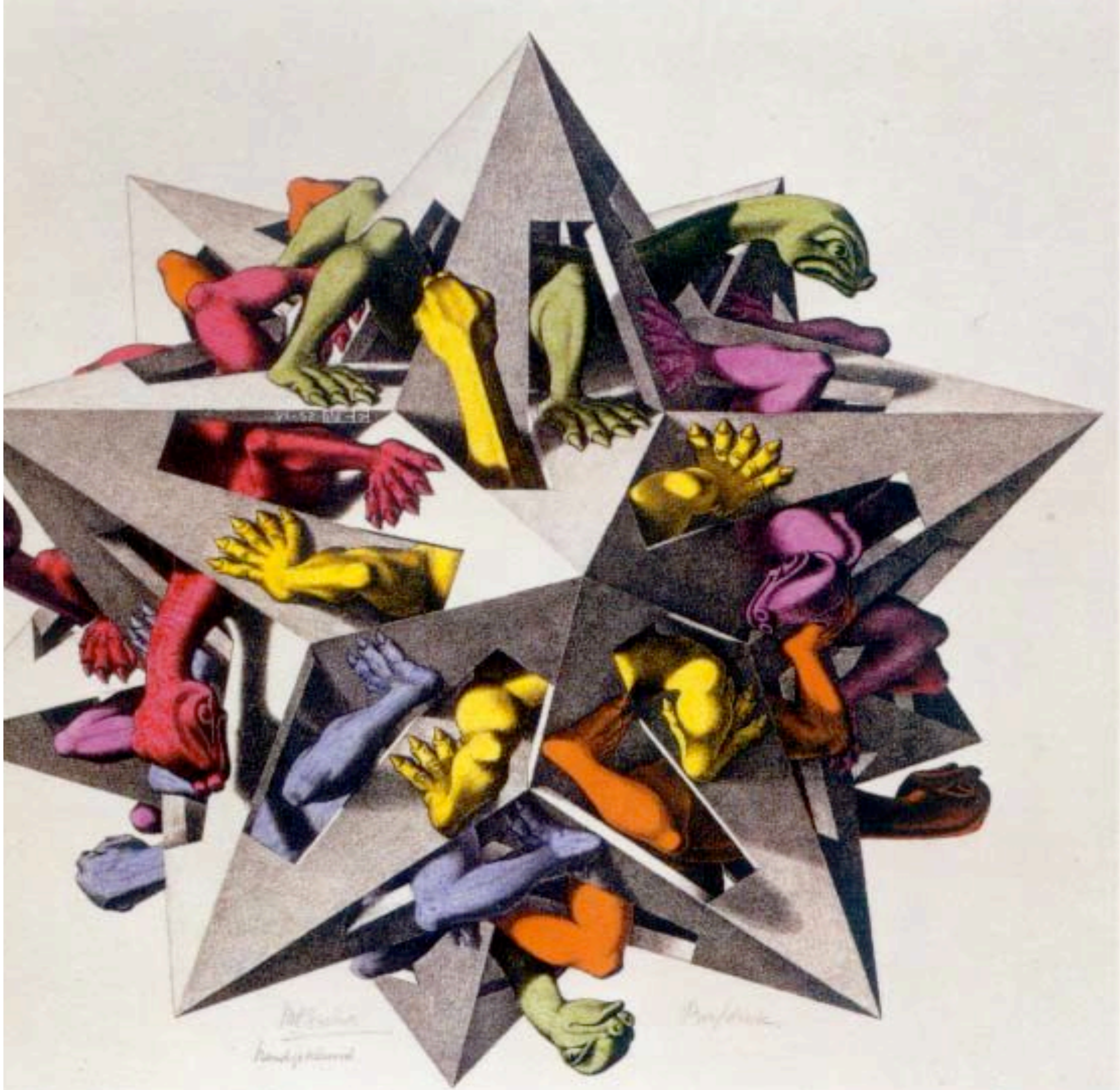


Energy
1 TeV
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
100 KeV
10 KeV
1 KeV
WHIPPLE
HEGRA
CAT
CANGAROO
GRANITE
MILAGRO
STACEE
CELESTE
H.E.S.S.
MAGIC
SolarTwo
VERITAS
ARGO
LAWCA
HAWC
CTA
AMS
FERMI
EGRET
AGILE
GAMMA-Light
COMPTEL
INTEGRAL
FERMI
GRB Monitor
BATSE
OSSE
RXTE
BeppoSAX
HETE 2
Super AGILE
NuSTAR
SIGMA
ASCA
ROSAT
Chandra
XMM
Swift
Astro-H
1992
1996
2000
2004
2008
2012
2016
2020
Year
Aldo Morselli v.18 2012

Summary of the summary


During the 20th century the quest to broaden our view of the universe has shown us the vastness of the Universe and revealed violent cosmic phenomena and mysteries




The future?

Thank you for the attention !!