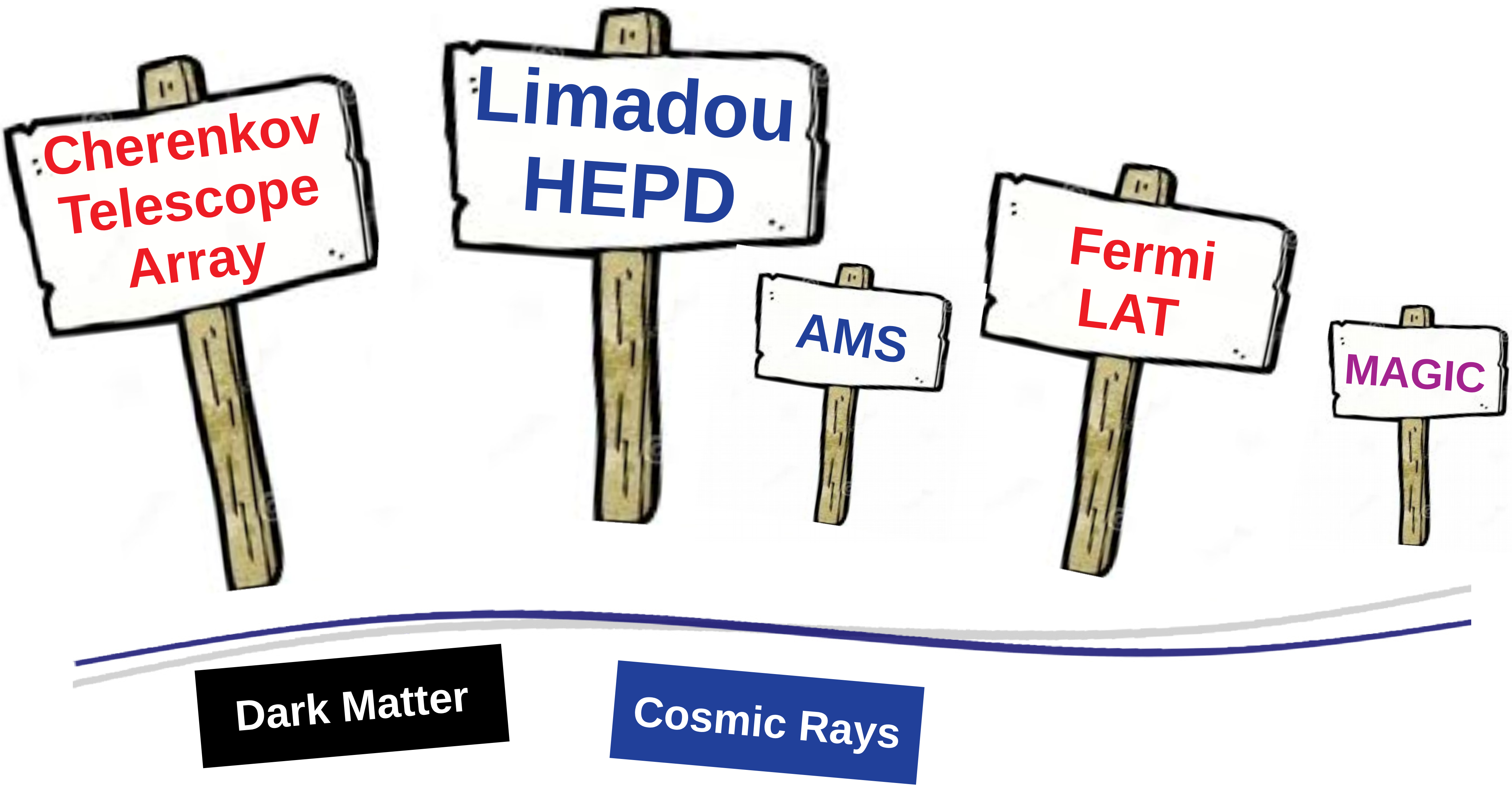
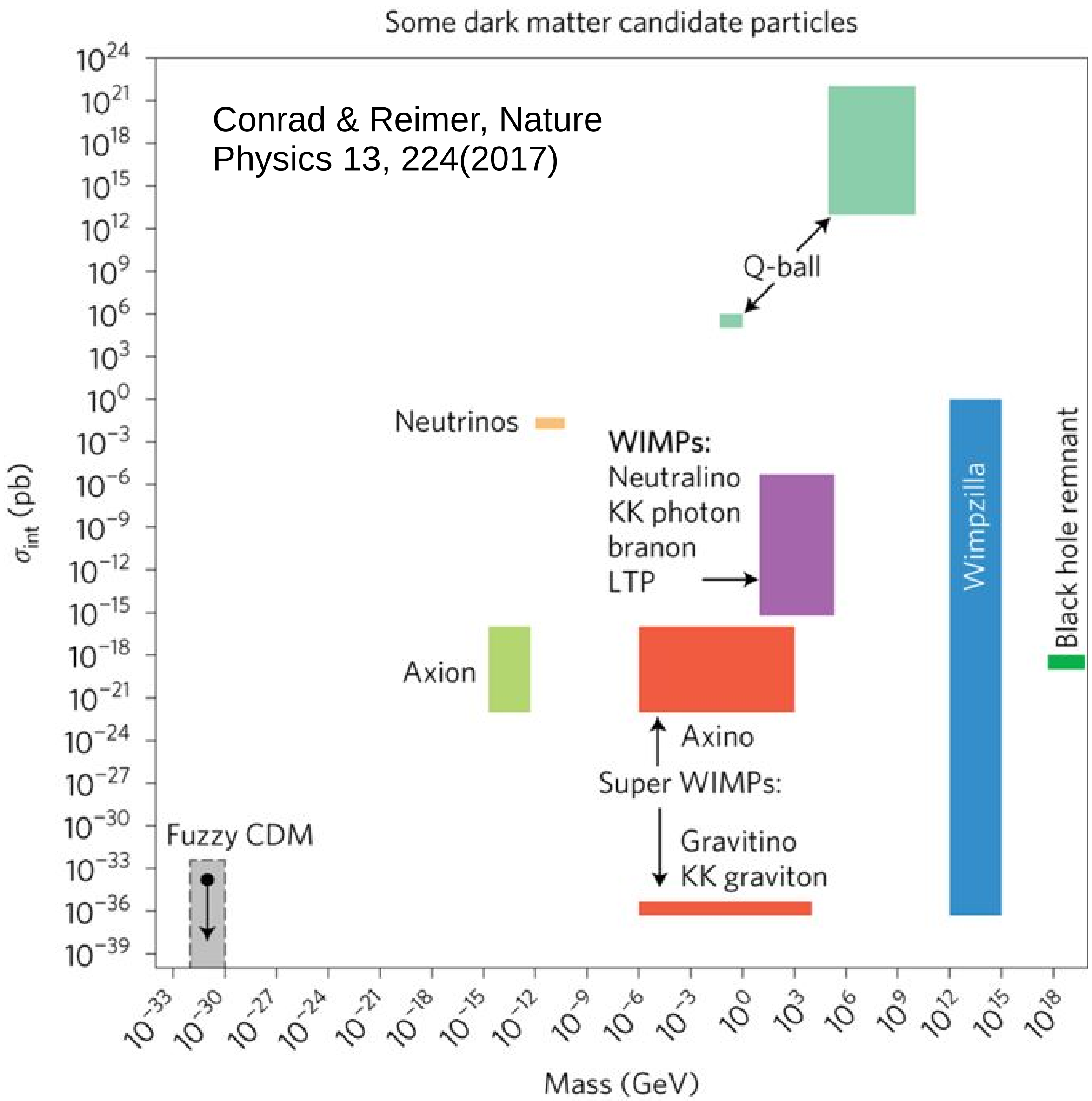
A self introduction

Vincenzo Vitale, 2018



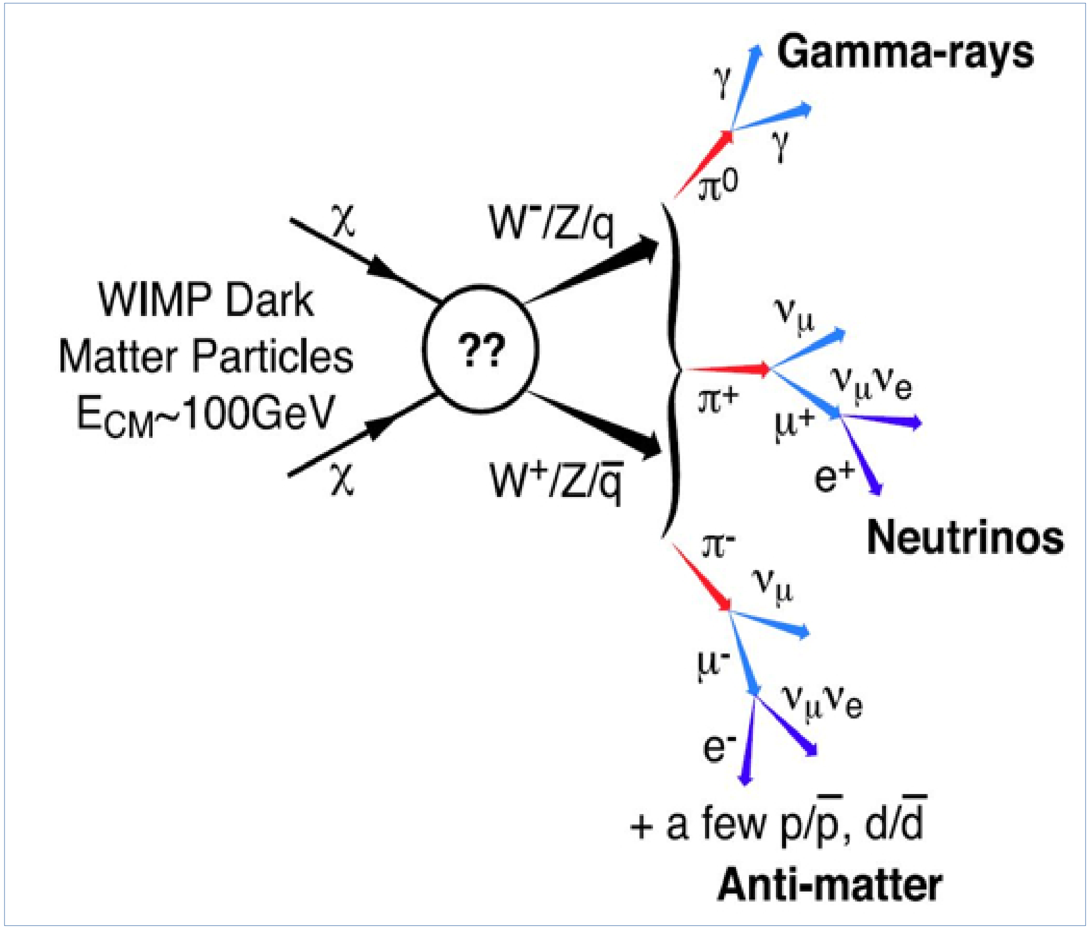
Dark Matter

- Elegant solution to several problems: celestial dynamics anomalies, gravitational lensing, cosmological data
- ΛCDM model: 23% dark matter, 4% baryonic matter, 73% something else
- DM **gravitational**ly coupled, **dark** (no electro-magn.), **cold** (structure formation), **stable** on cosmological timescales
- For thermal relics <σv> constrained to **$3*10^{-26}$ cm3/s** (Jungman,et al, Physics Reports 267 (1996) 195-373)



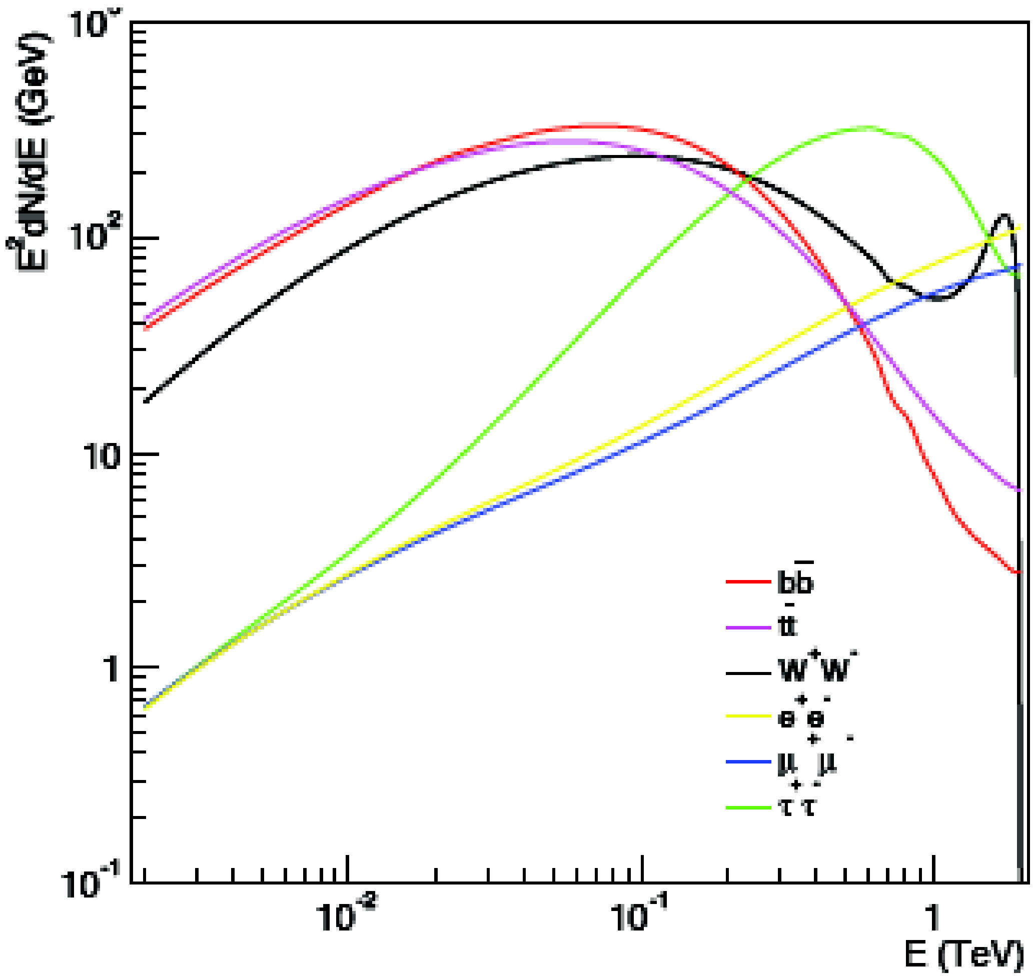
Indirect Searches

- Neutral secondaries (γ,ν):
  (i) have simpler propagation;
  (ii) carry both spectral and spatial signatures
- Expected gamma flux typically factorized in Particle Physics factor and J factor



$$\phi_{\rm WIMP}(E,\psi) = J(\psi) \times \Phi^{\rm PP}(E)$$

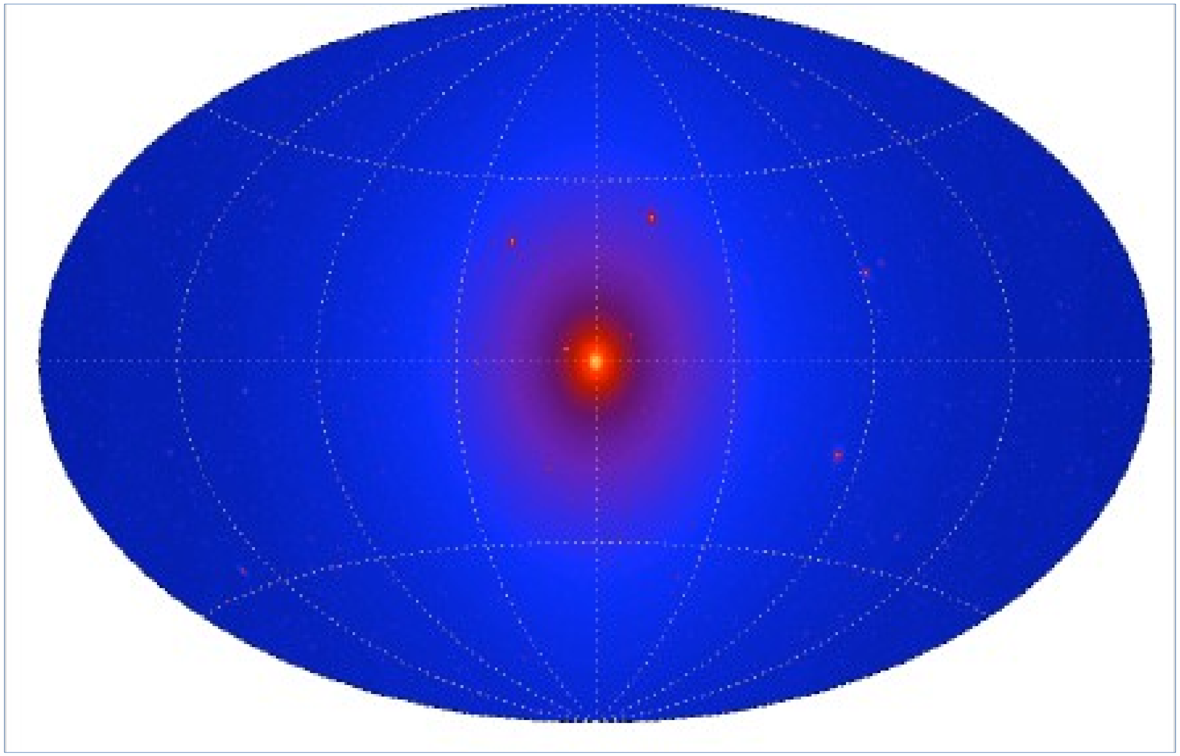
Annihilation gamma-ray yield



$$\Phi^{PP}(E) = \frac{1}{2}\frac{\langle \sigma v \rangle}{4\pi\ m^2_{\mathrm{WIMP}}} \sum_f \frac{dN_f}{dE} B_f$$

- Gamma ray yield depends on particles produced after annihilation
- Quark and bosons pairs → hadronization
- Lepton pairs → final state radiation, secondary gamma emission
- Direct gamma-gamma, gamma-Zeta production loop suppressed

Dark Matter Halos



Pieri et al 2009, the predicted flux of gamma-ray above 3 GeV, produced by DM annihilation (m_χ = 40 GeV, b-bbar, thermal annihilation cross-section) with the Via Lactea II simulations

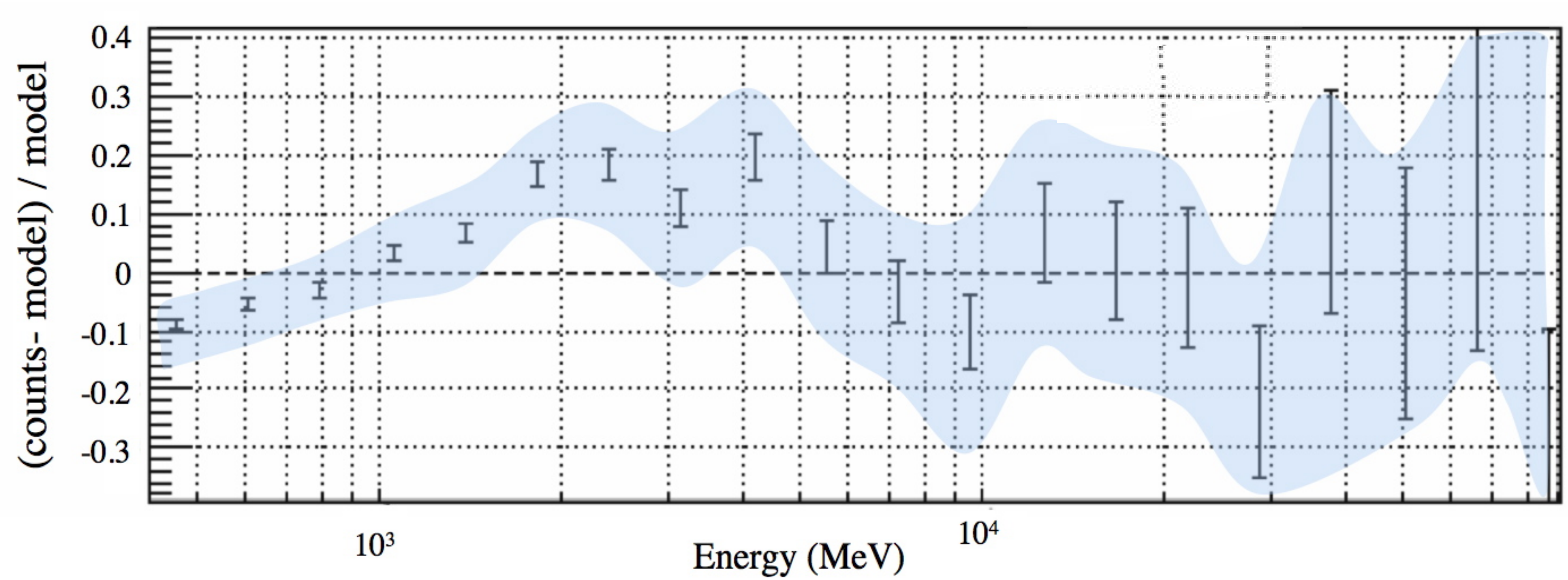
- DM forms gravitationally bounded structures (halos)
- Halos have:
  - larger central density
  - substructures at severals mass-scales
- Spiral galaxies are co-located with larger DM halos

$$J(\psi) = \int_{\text{l.o.s}} dl(\psi)\rho^2(l(\psi))$$

Studies with Fermi/LAT

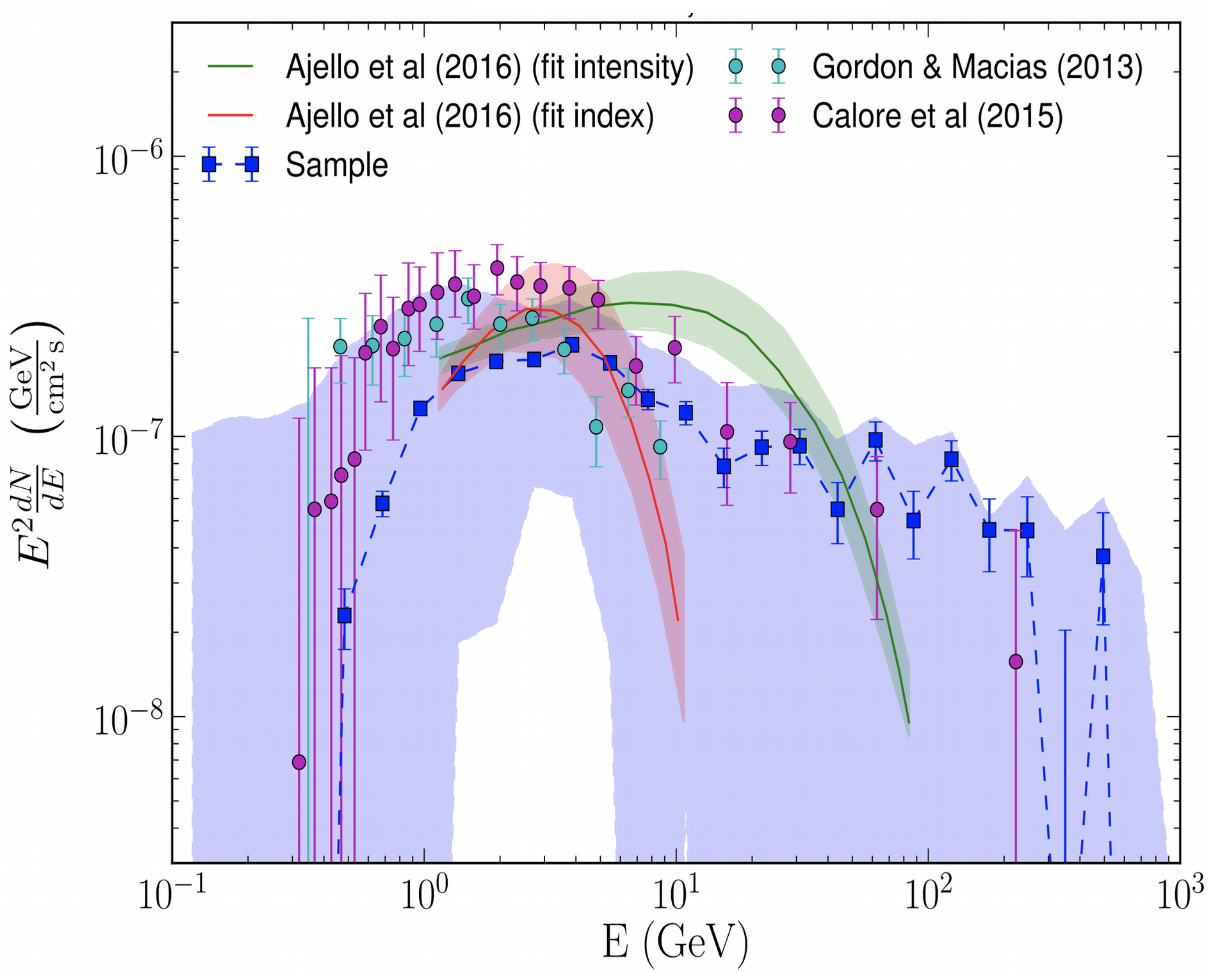
- Launched on june 11th 2008
- 2011 Bruno Rossi Prize: to W.B. Atwood, P. Michelson and the Fermi Gamma-ray Space Telescope LAT team
- Celebrated 10 years during 2018
- Details on backup slides

Galactic Centre – GeV Excess



- 7°x7°region centered in the Galactic Center
- 11 months of data, E >400 MeV, front-converting events
- binned likelihood analysis
- effective area systematics (blue area) of the LAT is ~10% at 100 MeV, 5% at 560 MeV, 20% at 10 GeV
- V.Vitale, A.Morselli, Fermi Coll. 2009, arXiv:0912.3828, Fermi Symposium, eConf Proceedings C091122

GeV Excess (Pass8)

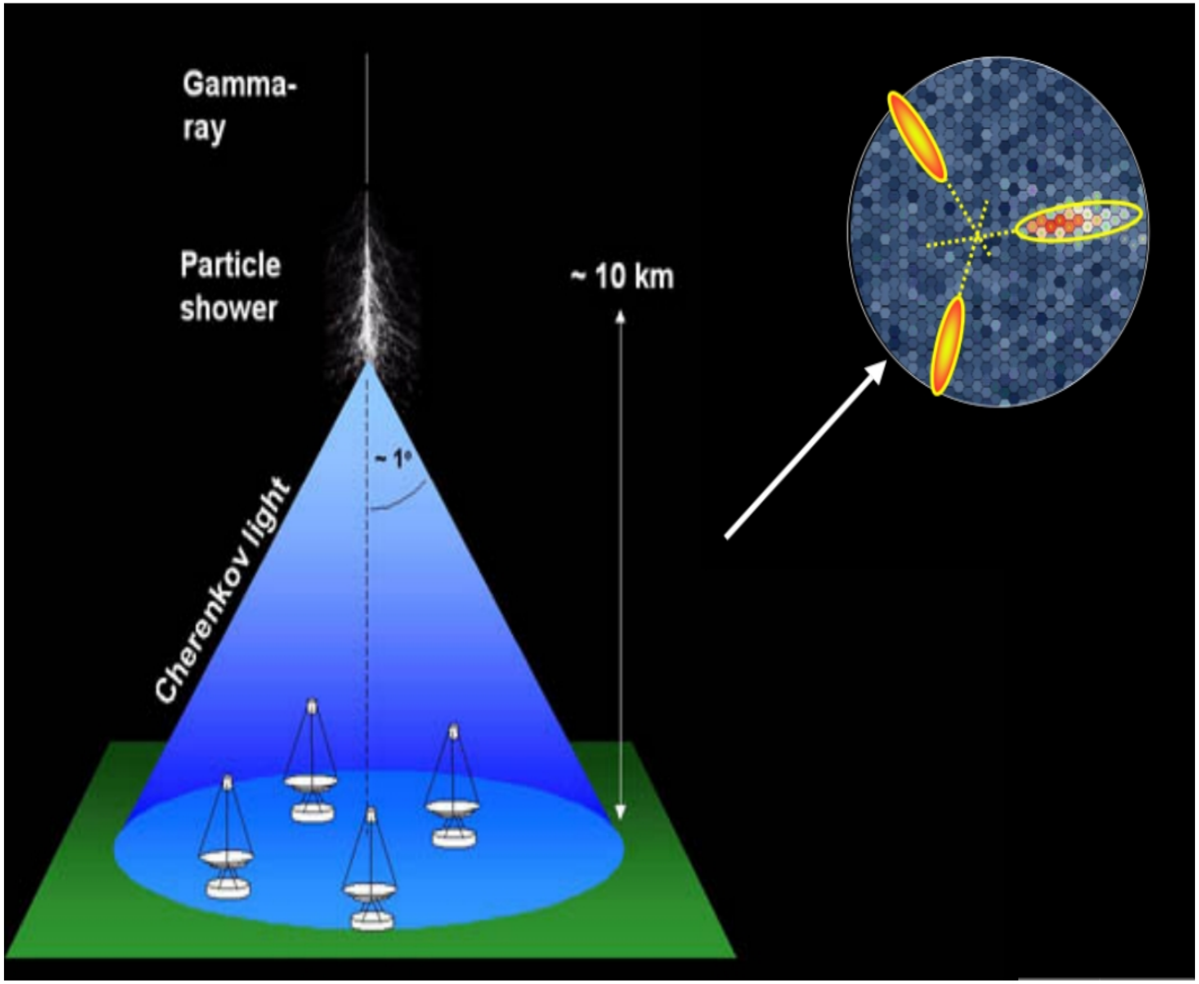


Fermi/LAT collaboration Apj 840:43 2017 May 1 arXiv:1704.03910

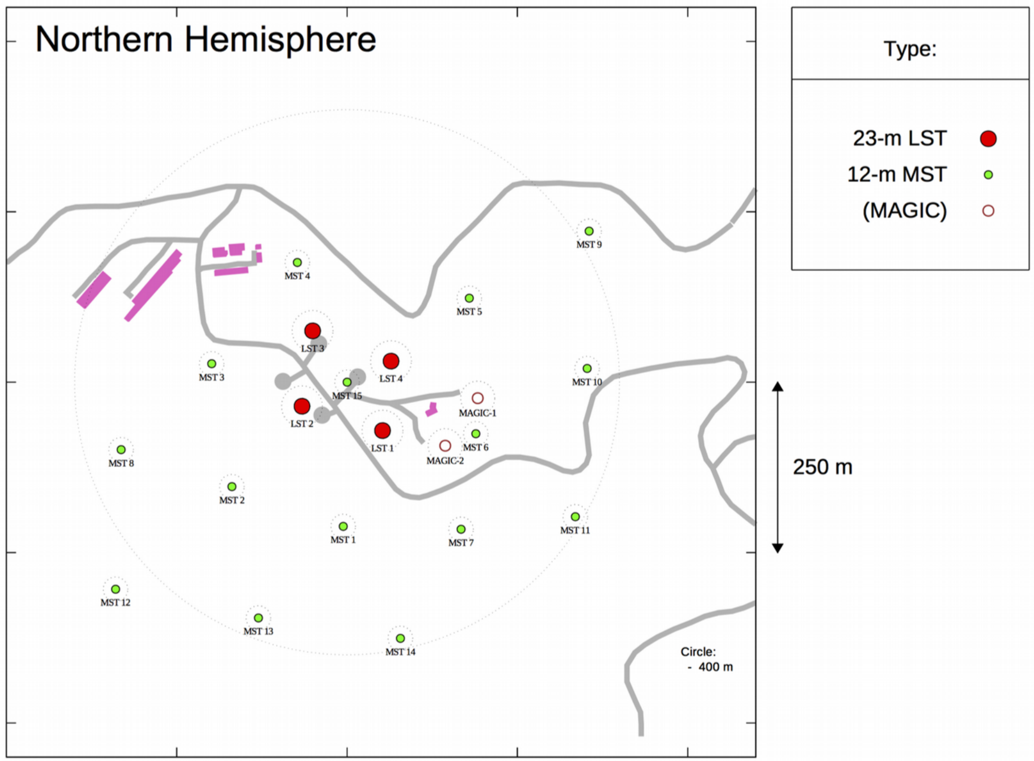
- Strong effort to understand the background sources
- Most significant uncertainty from:
  - Fermi bubbles morphology at low latitude
  - Sources of CR electrons near the GC
- Less dominant factors:
  - Variation of GALPROP models
  - Distribution of gas along the line of sight
- Main candidate as source of the excess:
  - a large population of pulsar in the GC;
  - DM annihilation signal
- An instrument with better resolution, such as e-ASTROGAM might help

Imaging Atmospheric Cherenkov Telescope

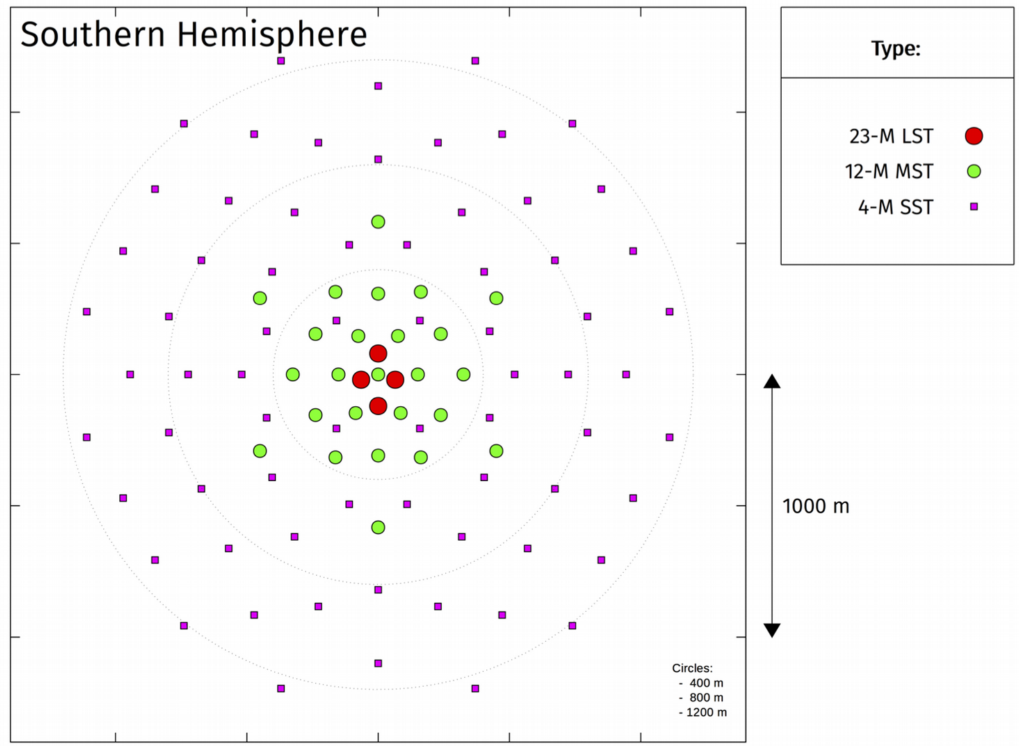
- Atmosphere as a large calorimeter (1030g/cm^2)
- Huge effective area (10^4 to 10^5 m^2)
- Type, energy and incoming direction from the image analysis
- Strong background rejection (1/1000)
- 0.1 deg angular resolution



Cherenkov Telescope Array



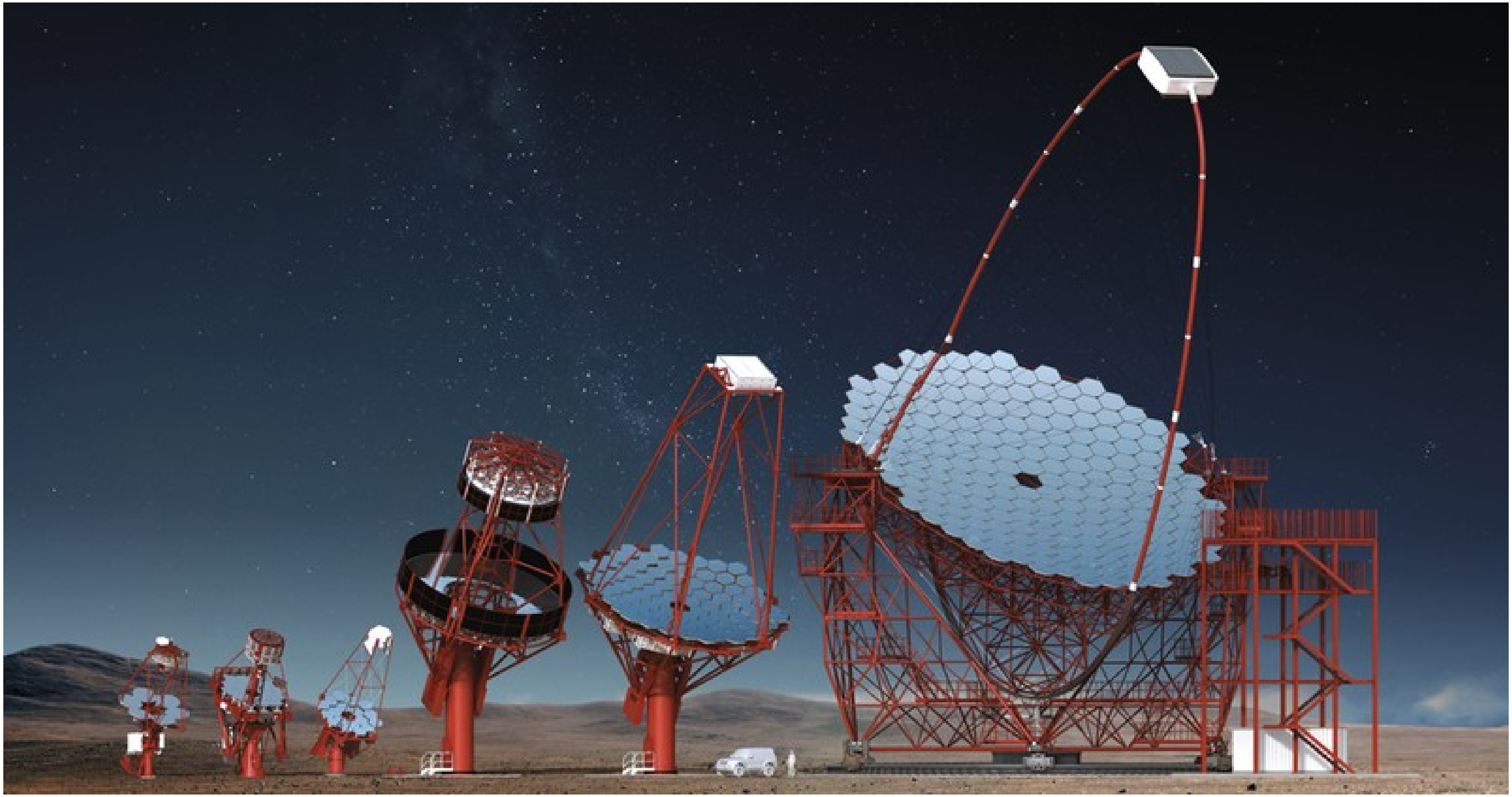
4 LS4 LSTs, 15 MSTs



4 LSTs, 25 MSTs, 70 SSTs

- 1300 scientists from 33 countries
- Two sites (Paranal, Chile and La Palma, Canary Islands)
- 100+ telescopes, with km squared effective area
- **Yesterday press release**: Final Agreements Signed for CTA's Southern Hemisphere Site in Chile

CTA Telescopes

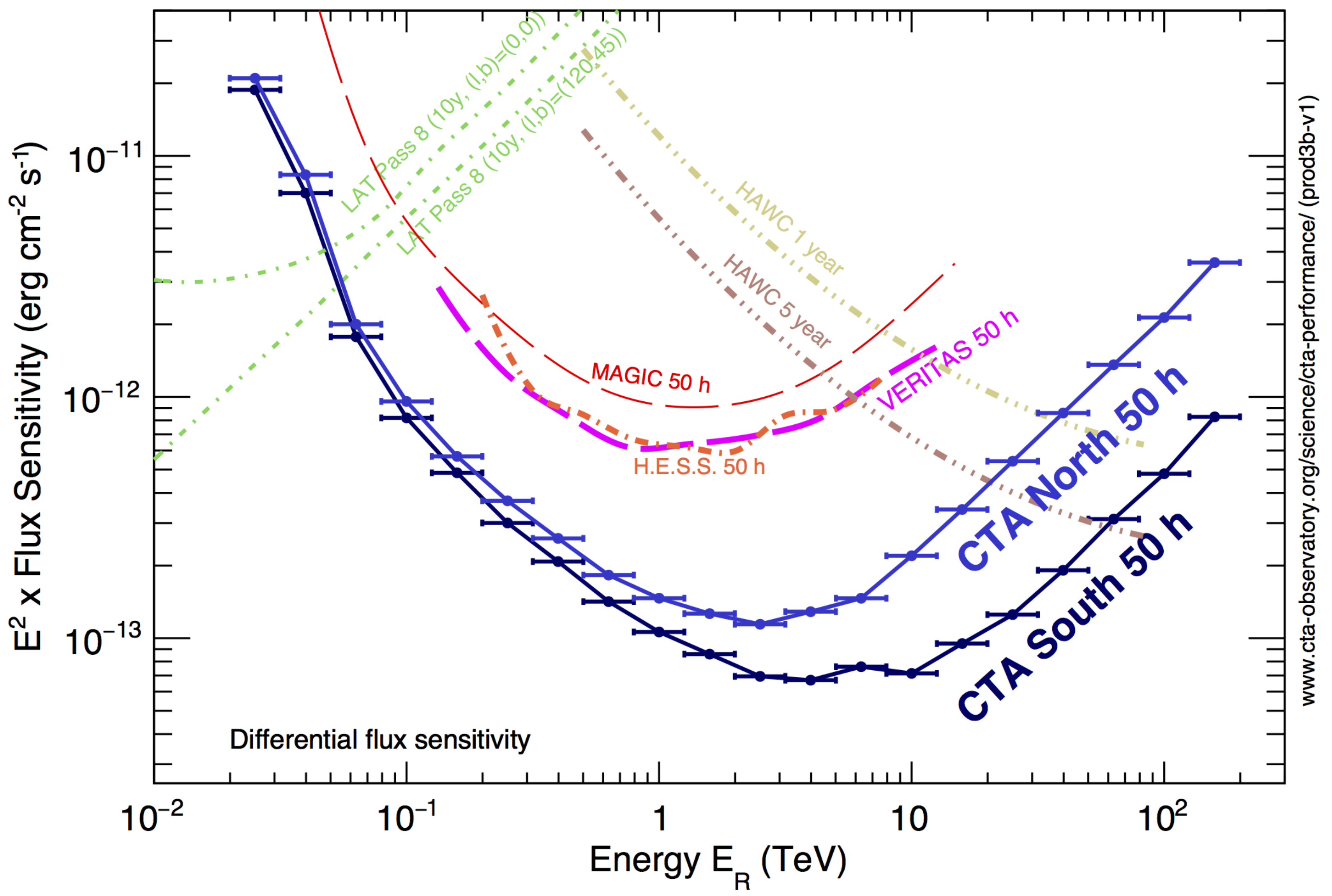


- LST: 23 m ϕ × 4,   20 GeV – 200 GeV (8Meu)
- MST: 12 m ϕ × 20, 100 GeV – 10 TeV   (2.5Meu)
- SST: 4 m ϕ × 70,   5 TeV – 300 TeV   (0.5Meu)

Large Scale Telescope

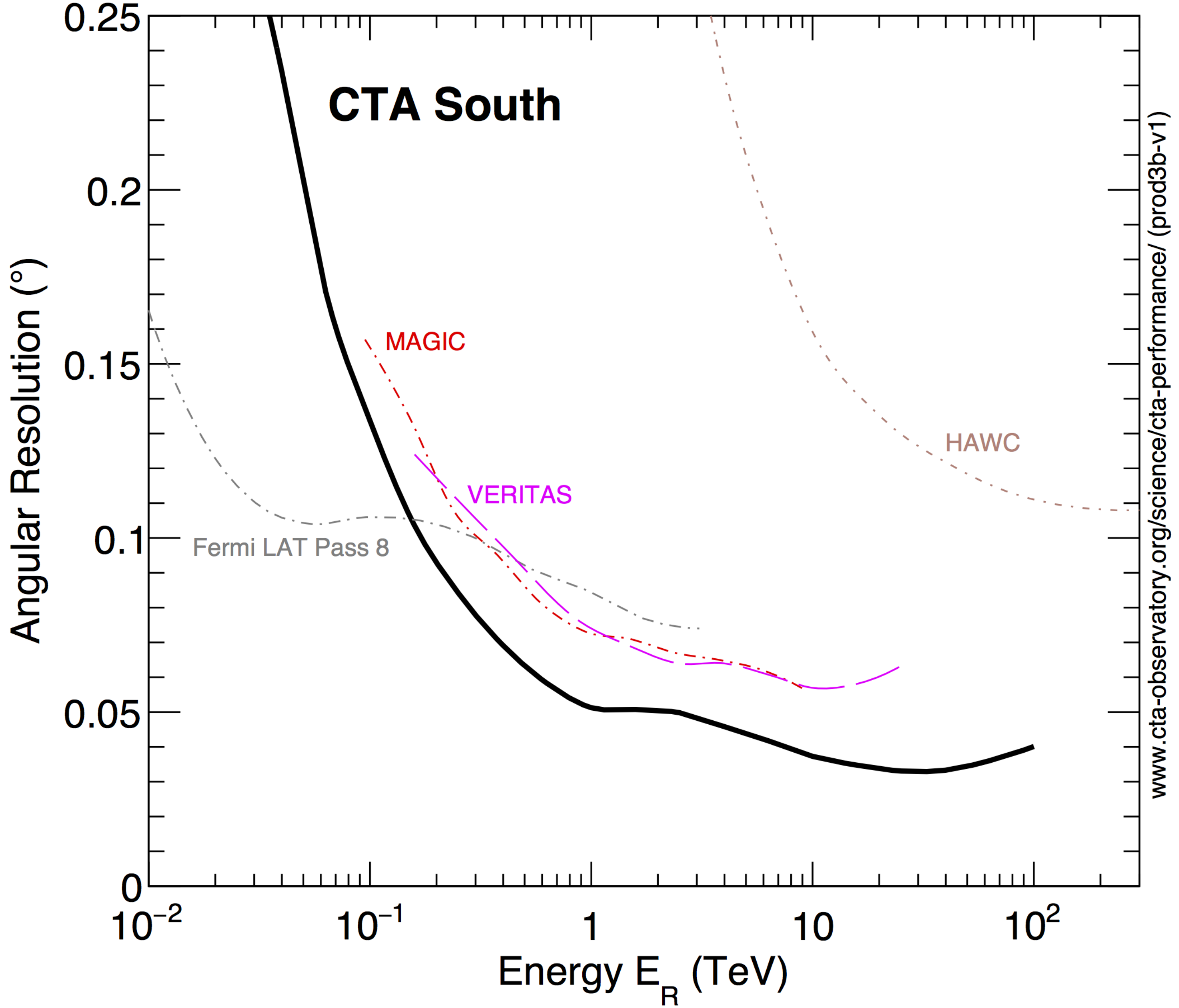
Real picture

CTA Performances



LAT & HAWC are large FOV instruments

CTA Performances



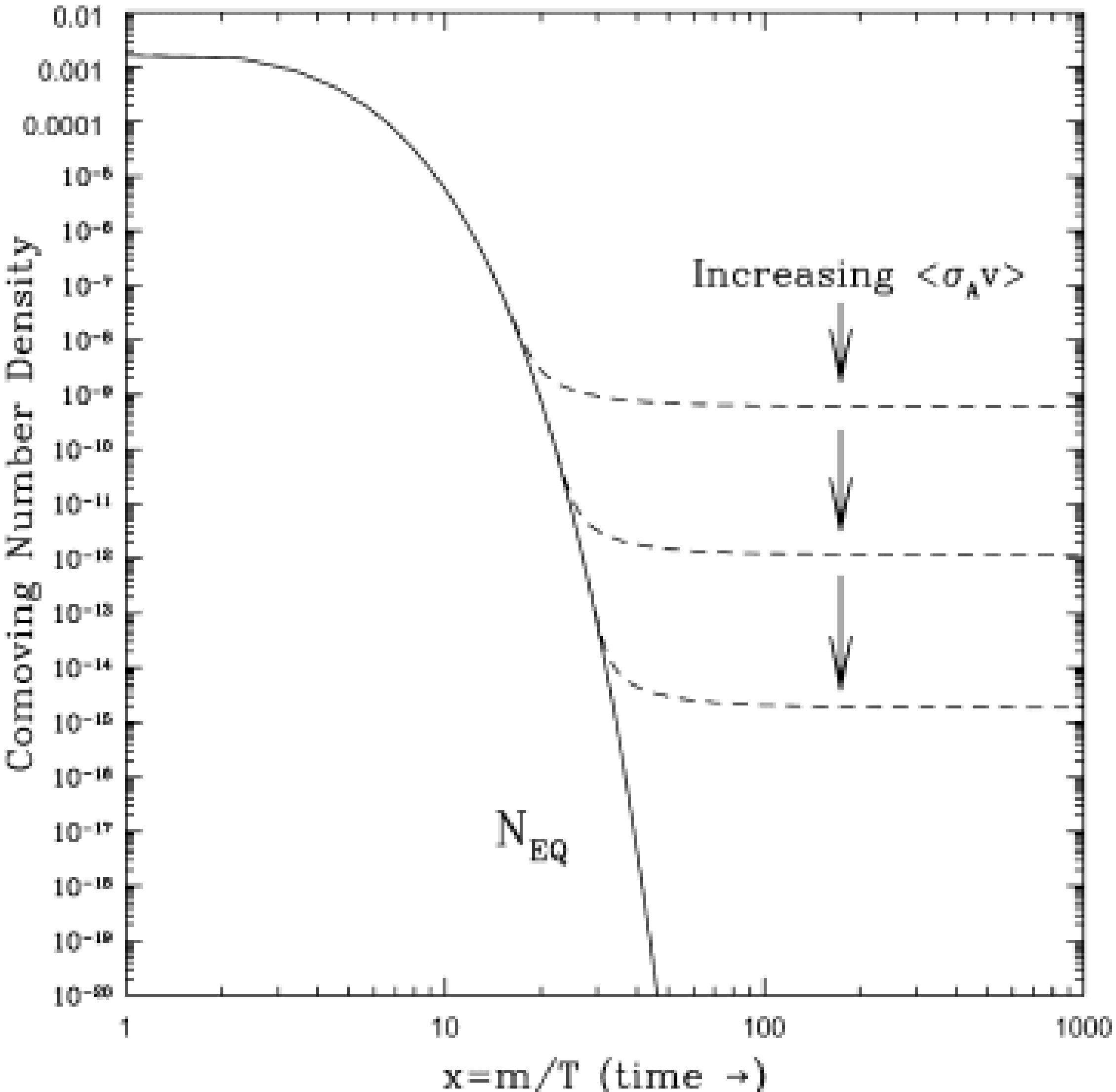
Conclusions

- Very happy to start a (not so) new job in Tor Vergata

Backup

Vincenzo Vitale, December 2018

Dark Matter

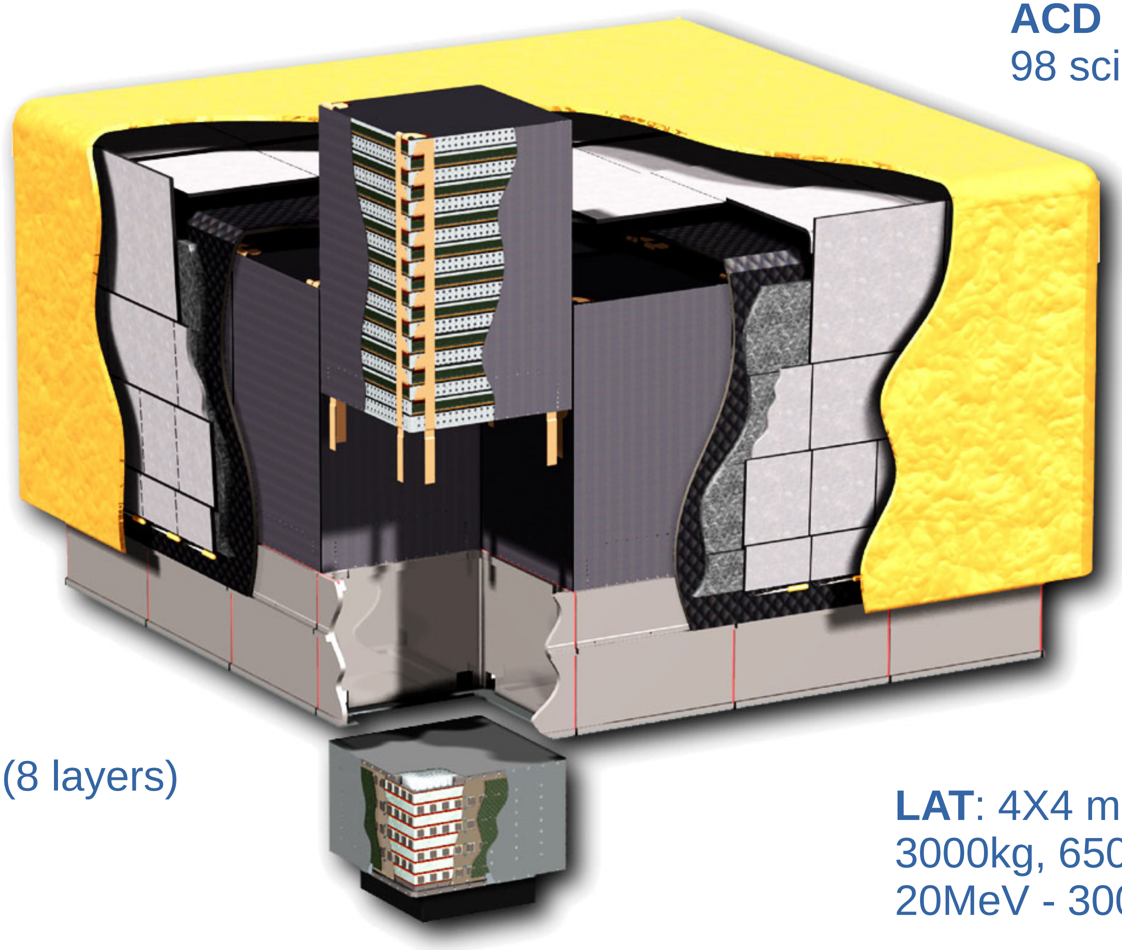


(Jungman, Kamionkowski & Griest 1990)

Fermi Large Area Telescope

Si Tracker
pitch = 228 µm
8.8 10^5 channels
18 planes

ACD
98 scintillator tiles



CsI Calorimeter
hodoscopic array (8 layers)
6.1 10^3 channels

LAT: 4X4 modular array
3000kg, 650W
20MeV - 300GeV

Gamma-Ray Anisotropies

- Diffuse background can originate from unresolved faint sources (DM Halos and sub-structures, for example)
- Difference from Poisson noise and energy-dependence might allow the identification of the source population
- Diffuse emission fluctuations can be studied with spherical harmonics expansions

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$$I(\psi) = \sum_{\ell,m} a_{\ell m} Y_{\ell m}(\psi)$$

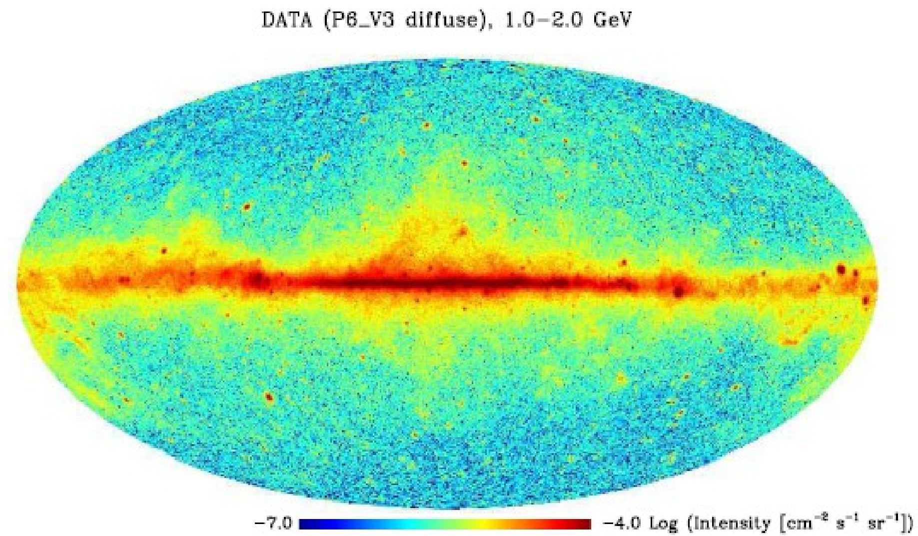
$$C_\ell = \langle |a_{\ell m}|^2 \rangle$$

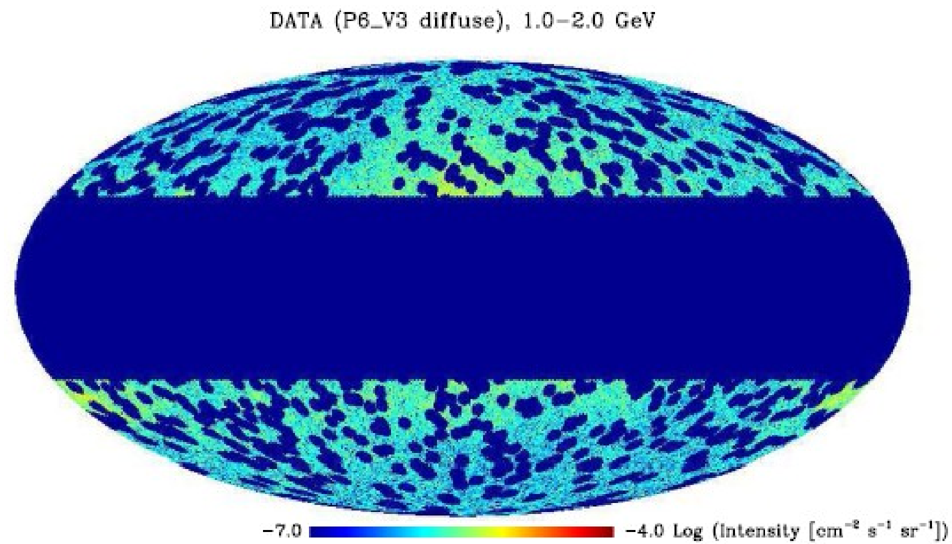
$$\delta C_\ell^{\mathrm{s}} = \sqrt{\frac{2}{(2\ell+1)\,\Delta\ell\, f_{\mathrm{sky}}}}\left(C_\ell^{\mathrm{s}} + \frac{C_{\mathrm{N}}}{W_\ell^2}\right)$$

Cl = intensity angular power spectrum (APS)
Cl / < I >2 = fluctuation APS: dimensionless
fsky= un-masked fraction of the sky,
Wl=window function;
Δl =multipole bin,
Cn= noise angular power;

Gamma-ray Anisotropies

- Fermi/LAT all-sky observations from the first 22 months of operation
- The APS of the data are obtained from binned Intensity maps;
- HEALPix (Gorski et al 2005) used;
- Known sources and Galactic diff. em. minimized with masking;
- In the main analysis branch gtools were used for the exposure maps calc.
- An independent method (Shuffling) used to cross-check the exposure;
- APS of real data and detailed all-sky simulations have been obtained and compared;
- A Foreground Cleaning has been used to estimate the possible effects of residual Galactic diffuse emission





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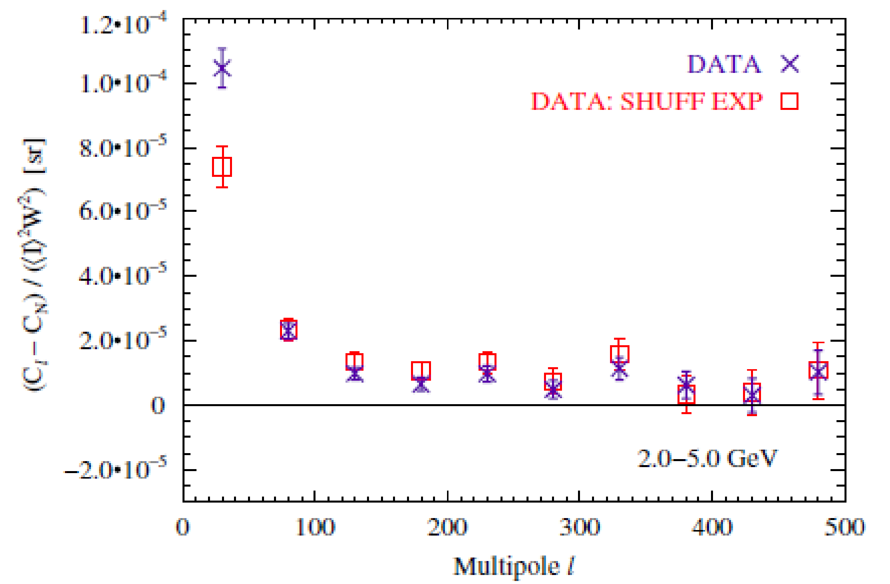
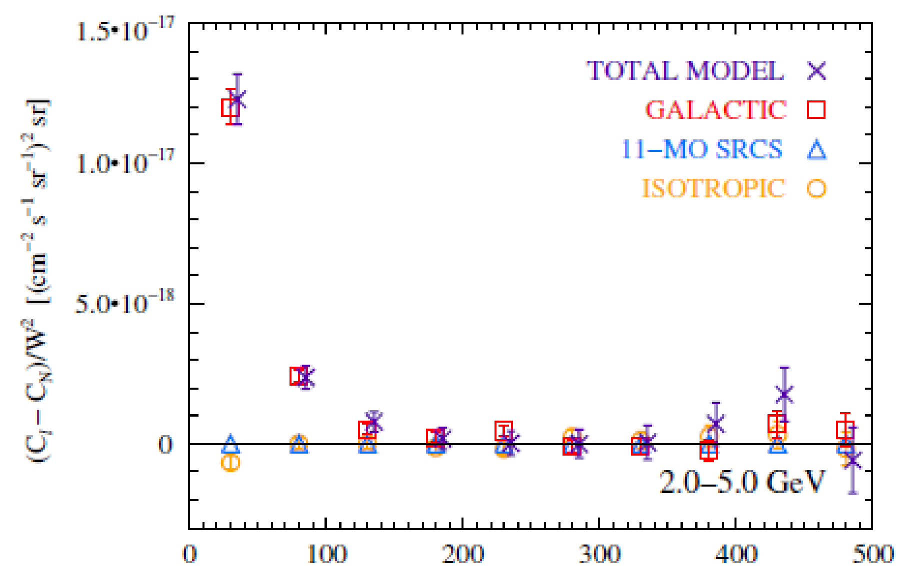
Gamma-ray Anisotropies

- For multipoles > 150 an excess of angular power is detected: Angular power detect with high significance up to 10GeV, and with a lower one at larger energies
- All-sky simulations APS compared to real data ones
- Simulated:
  - 1FGL sources (1451), Galactic diffuse emission (the standard
  - gll_iem_v02.fit at 0.5deg resolution and a version at 0.125deg resolution,
  - Isotropic diffuse emission;
- Galactic diff. Model shows low multipole (l<100) excess
- Isotropic diffuse and sources follow expected behaviour





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