Searching for Dark Matter in Space

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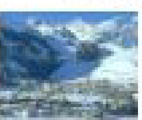
LES RENCONTRES DE PHYSIQUE DE LA VALLEE D'AOSTE La Thuile,
February 27-March 5 , 2005

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 --> p + X)
- So, any extra contribution from exotic sources ($\chi\,\chi$ annihilation) is an interesting signature
- ie: $\chi\,\chi$ --> $\bar{p}$ + X
- Produced from (e. g.) $\chi\,\chi$ --> q / g / gauge boson / Higgs boson and subsequent decay and/ or hadronisation.



Propagation Equation for Cosmic Rays in the Milky Way

$$\frac{\partial \psi(\mathbf{r},p,t)}{\partial t} = q(\mathbf{r},p) + \nabla \cdot (D_{xx}\nabla\psi - \mathbf{V}\psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p}\frac{1}{p^2}\psi - \frac{\partial}{\partial p}\left[\dot{p}\psi - \frac{p}{3}(\nabla\cdot\mathbf{V})\psi\right] - \frac{1}{\tau_f}\psi - \frac{1}{\tau_r}\psi$$

convection velocity field that corresponds to galactic wind and it has a cylindrical symmetry, as the geometry of the galaxy. It's z-component is the only one different from zero and increases linearly with the distance from the galactic plane

diffusion coefficient in the impulse space, quasi-linear MHD: $D_{pp}(D_{xx}, v_A)$

loss term: fragmentation

loss term: radioactive decay

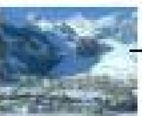
diffusion coefficient is function of rigidity

$$D_{xx} = \beta D_0 (\rho/\rho_0)^{\delta}$$

primary spectra injection index

$$dq(p)/dp \propto p^{-\gamma}$$

implemented in Galprop (Strong & Moskalenko, available on the Web)



Propagation parameters uncertainties

- Geometrical and dynamical parameters of the propagation
- Pbar and Isotopes Production Cross Section (~ 20 %)
- Gas distribution in the galaxy

- Secondary to primary CR ratios are the most sensitive quantities to parameters changing; B/C are measured with the highest statistic

- Good fits of B/C experimental data constrain possible variations of the unknown parameters; + consistency wit the other prim/sec CR ratios

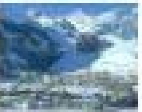
- Standard statistical test:

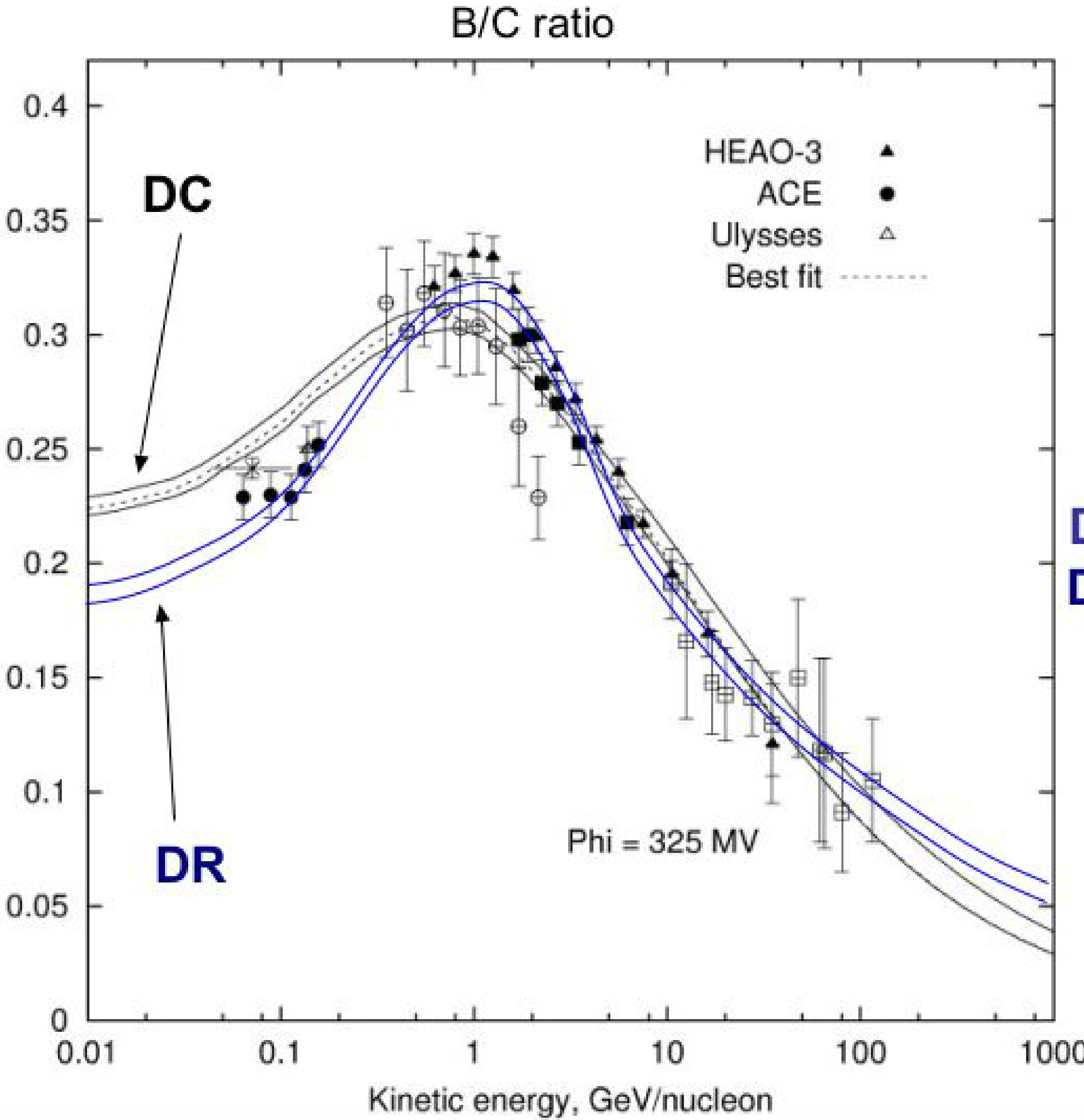
$$\chi^2 = \sum_n \frac{1}{(\sigma_n^{B/C_{exp}})^2} (\Phi_n^{B/C_{exp}} - \Phi_n^{B/C_{teo}})^2$$

Heliospheric modulation **z**
(depends on rigidity)

$$\frac{\Phi^{toa}(E^{toa})}{\Phi^{is}(E^{is})} = (\frac{p^{toa}}{p^{is}})^2$$

$$E^{is} - E^{toa} = |Ze|\phi$$





Enveloping curves of all the good fits of the experimental B/C data

Dashed line: Best fit

DR: diffusion+ reacceleration
DC: diffusion+convection

In DC model problem with the ACE data at low energy

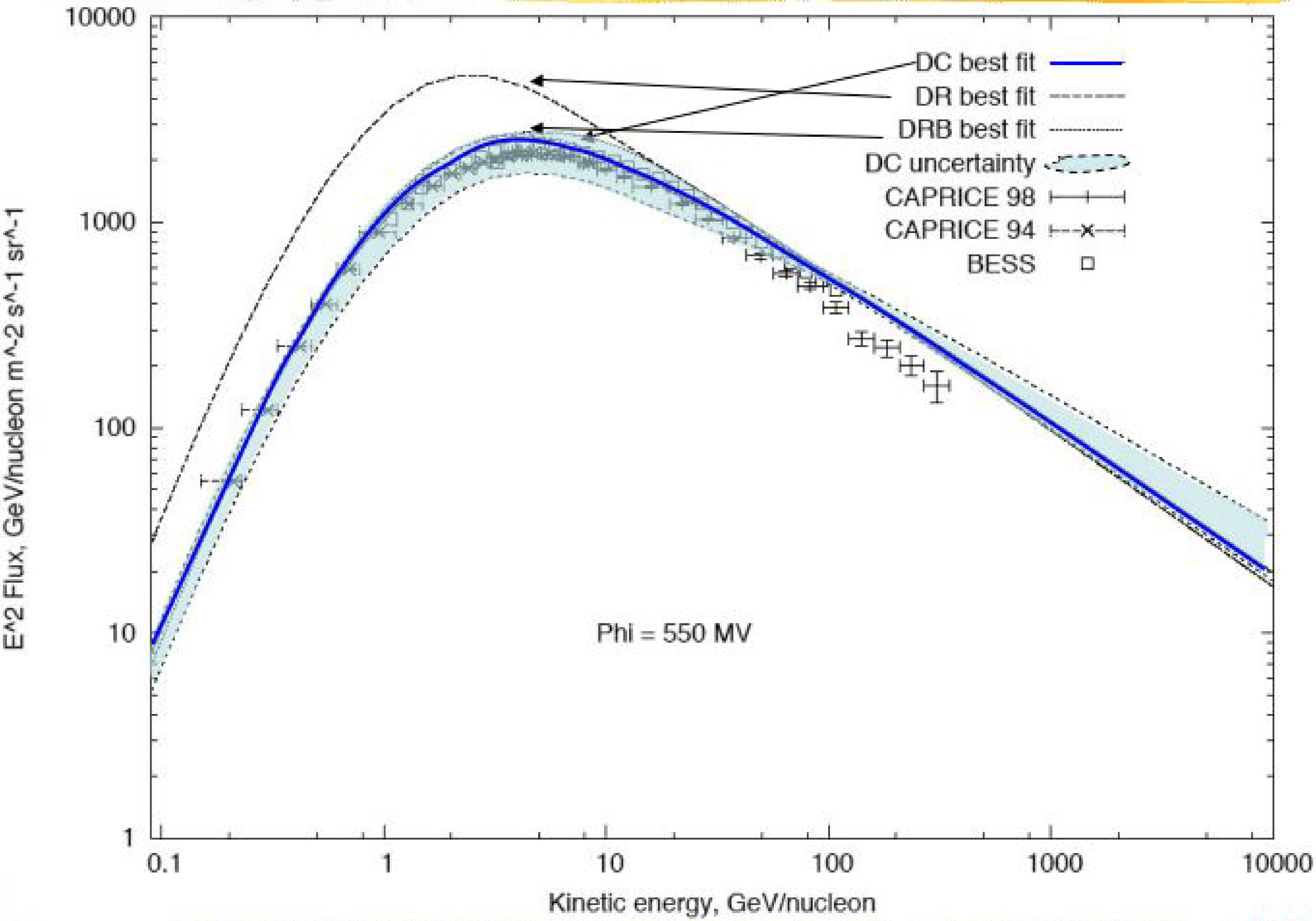
Allowed values for the propagation parameters for DR propagation

	halo size	diffusion constant	diff index	prim spec injection index	Alfven velocity
par./val.	$z[kpc]$	$D_0[cm^2s^{-1}]$	δ	γ	$v_A[kms^{-1}]$
minimal	3.0	5.2 10^{28}	0.25	2.35	22
best fit	4.0	5.8 10^{28}	0.29	2.47	26
maximal	5.0	6.7 10^{28}	0.36	2.52	35

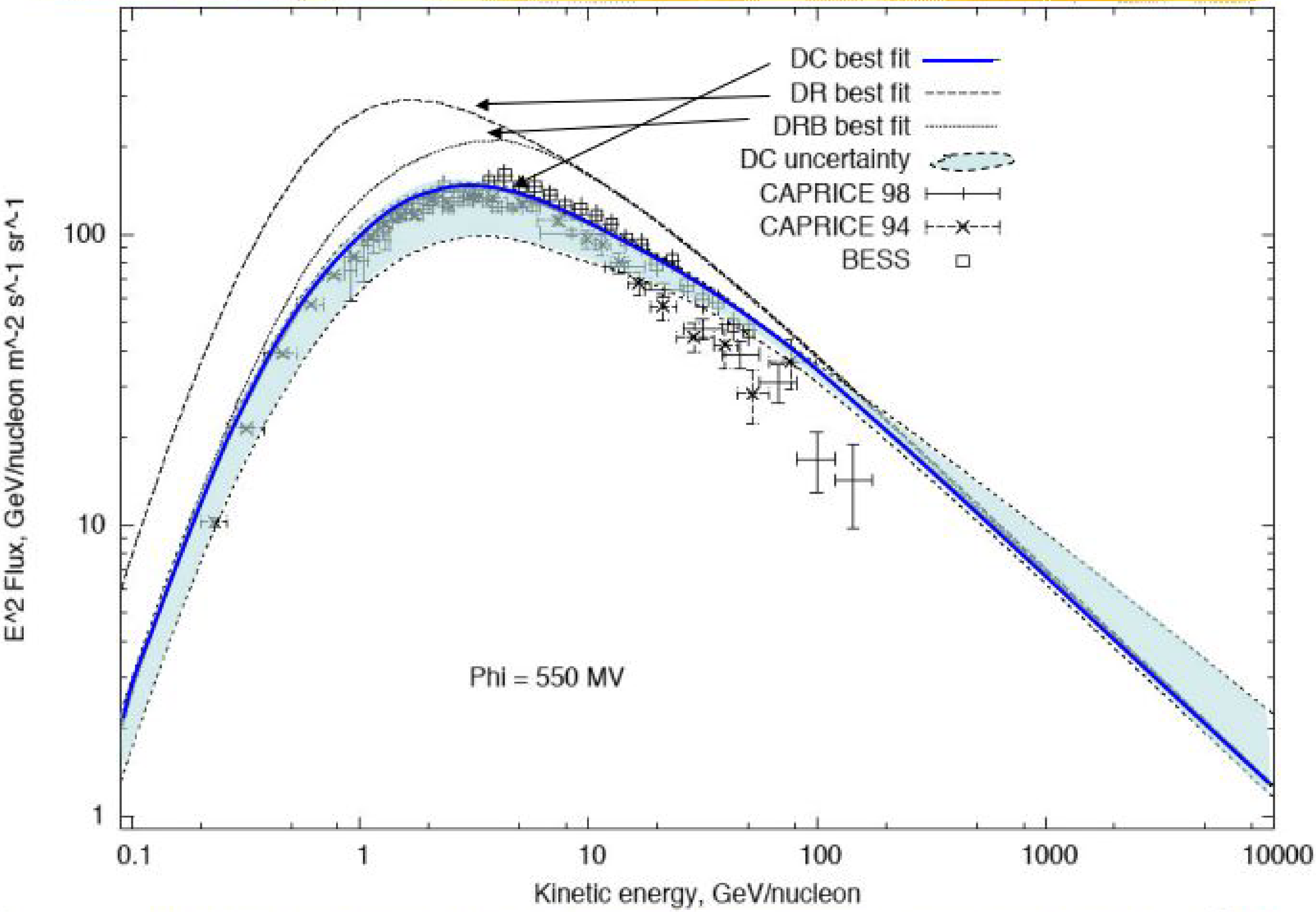
Allowed values for the propagation parameters for DC propagation

	halo size	diff constant	diff index	V_c gradient	injection indexes	
par./val.	$z[kpc]$	$D_0[\frac{cm^2}{s}]$	δ_2	$\frac{dV_C}{dz}[\frac{km}{skpc}]$	γ_1	γ_2
minimal	3.0	2.3 10^{28}	0.48	5.0	2.42	2.14
best fit	4.0	2.5 10^{28}	0.55	6.0	2.48	2.20
maximal	5.0	2.7 10^{28}	0.62	7.0	2.50	2.22

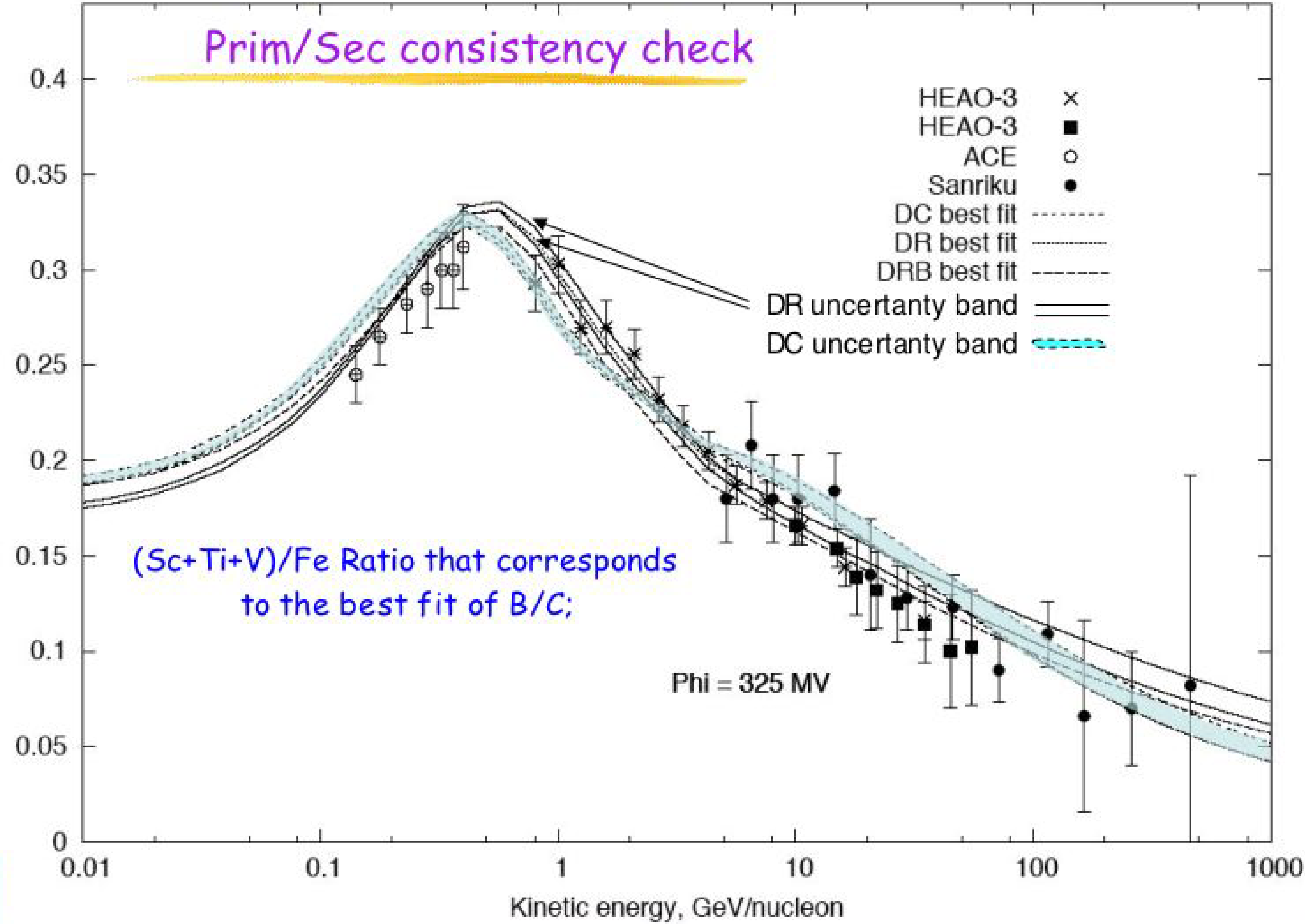
Proton spectra: Upper and lower bounds of due to the uncertainties of propagation parameters



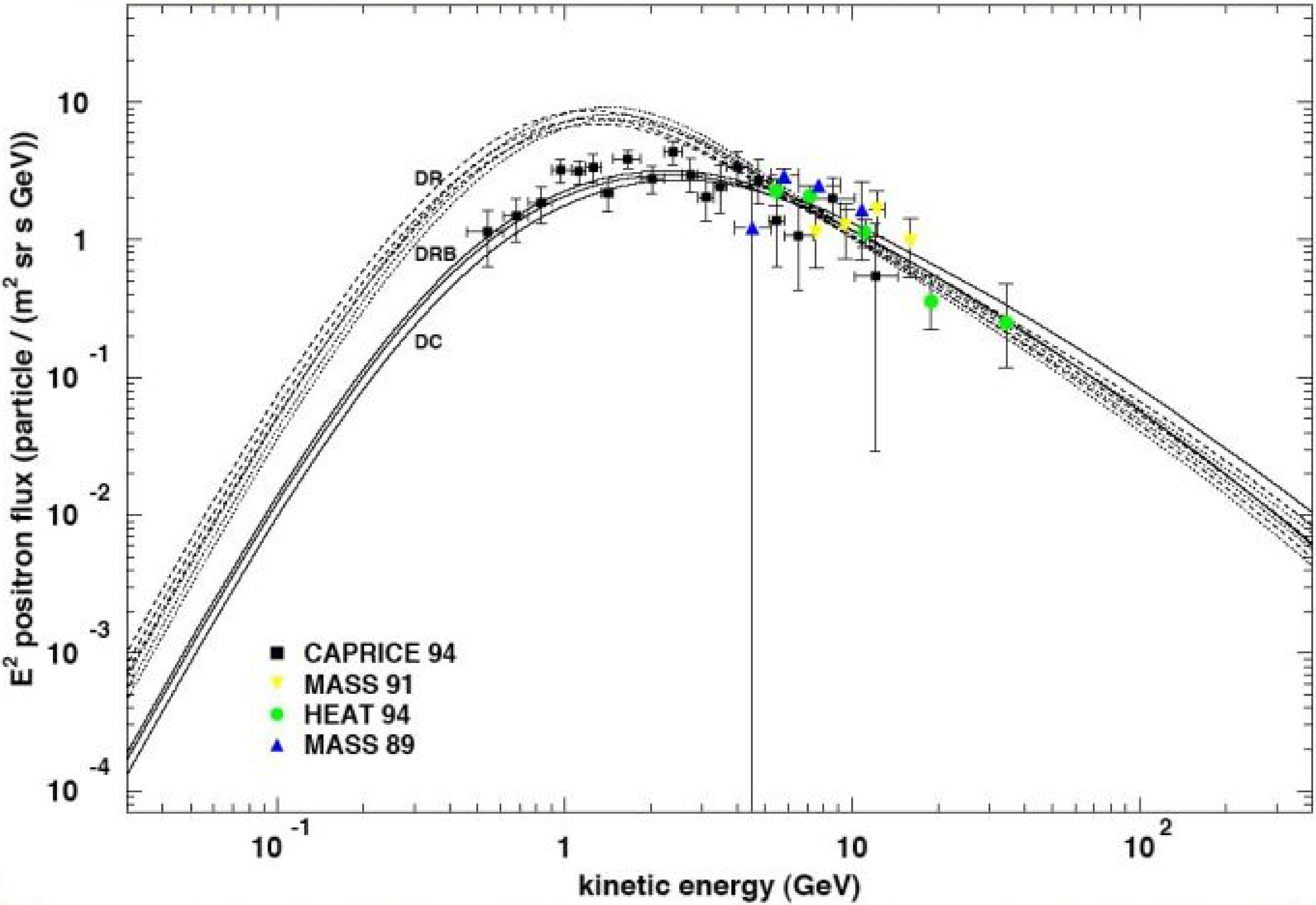
Helium spectra: Upper and lower bounds of due to the uncertainties of propagation parameters



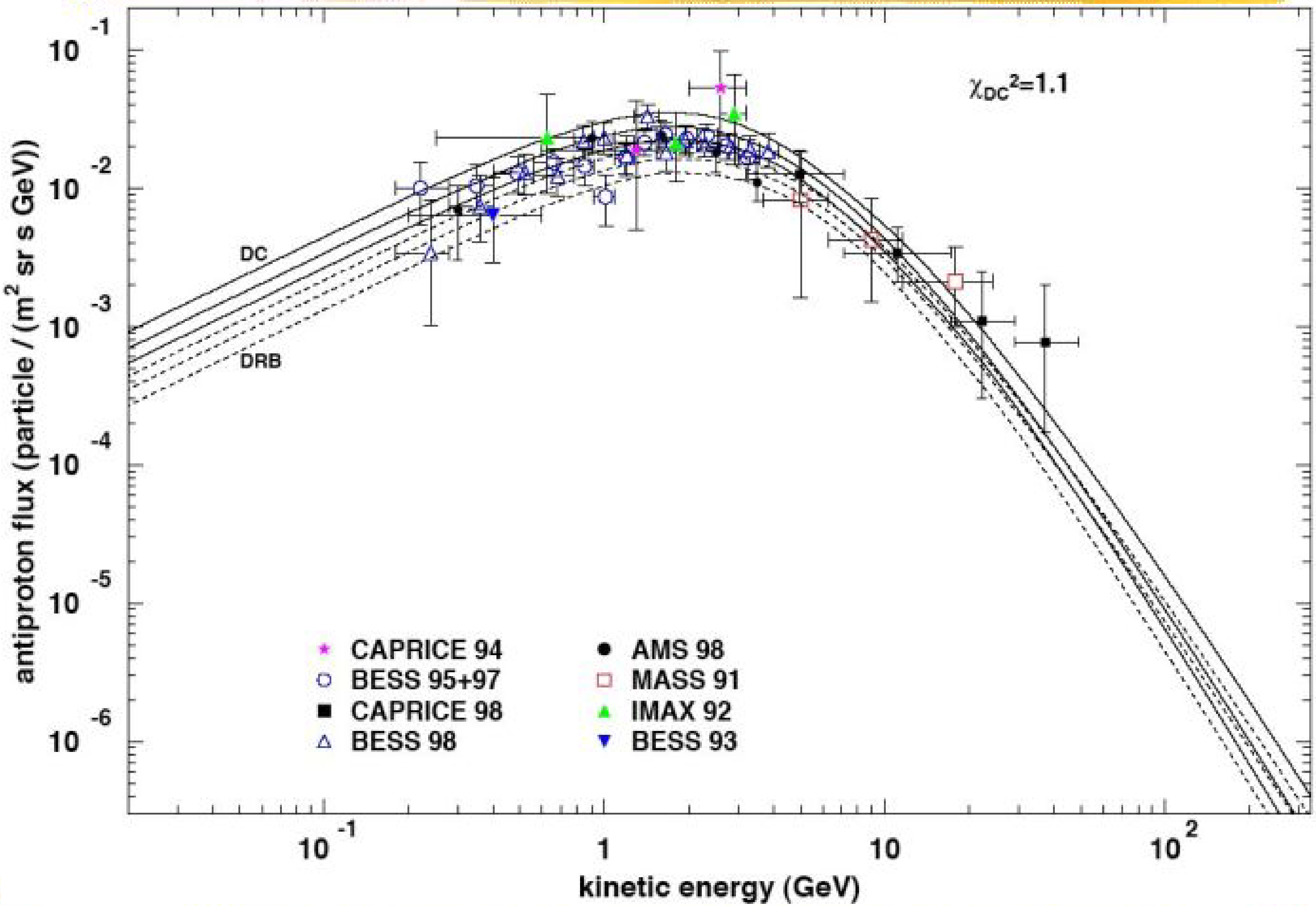
Prim/Sec consistency check



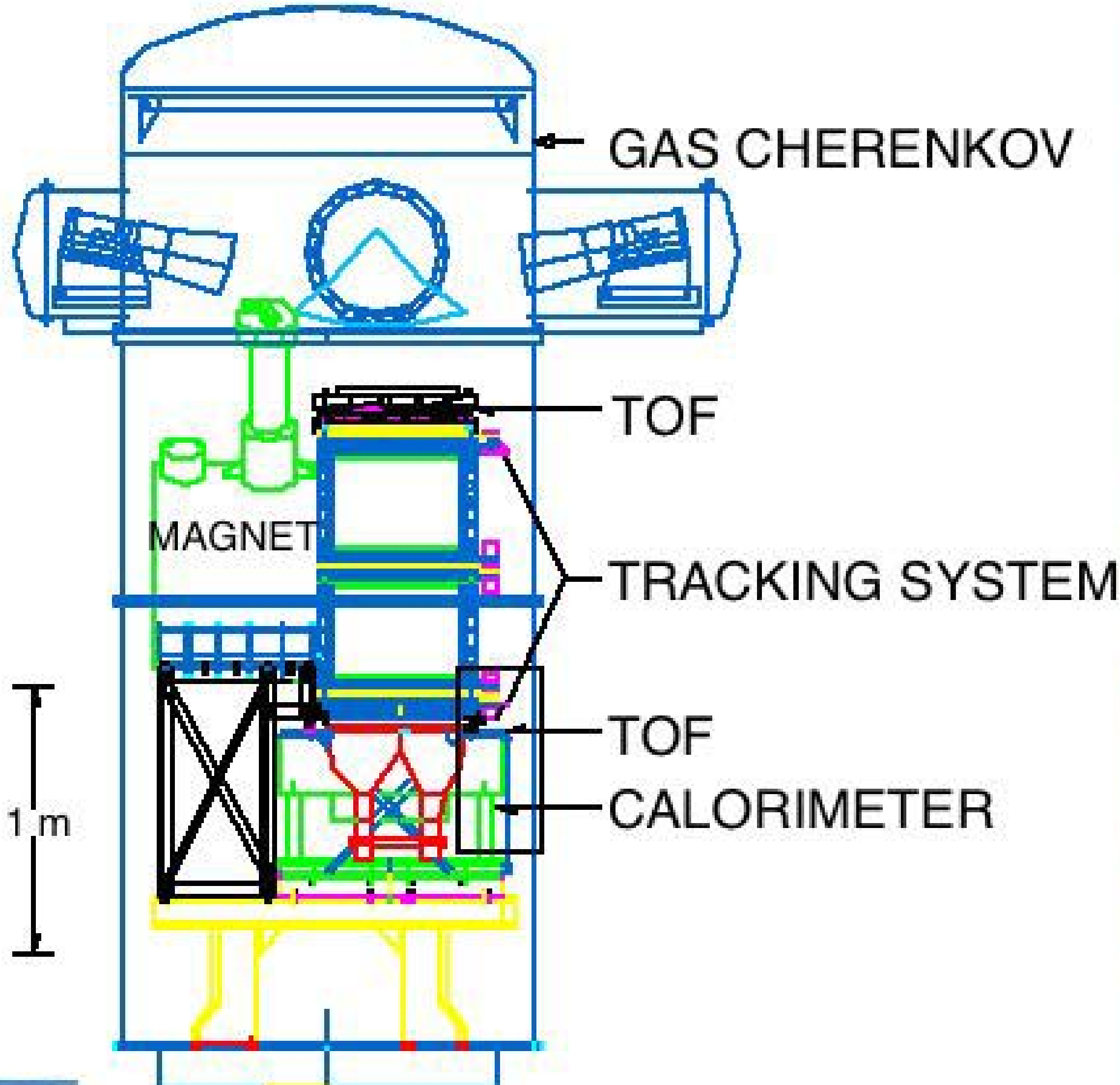
Positron spectra: Upper and lower bounds of due to the uncertainties of propagation parameters



Antiproton spectra: Upper and lower bounds of due to the uncertainties of propagation parameters



MASS Matter Antimatter Space Spectrometer (89&91)



MASS 89 flight

MASS 89 flight


MASS 89

PAMELA Apparatus

Flight Model , Jan 2005

ToF

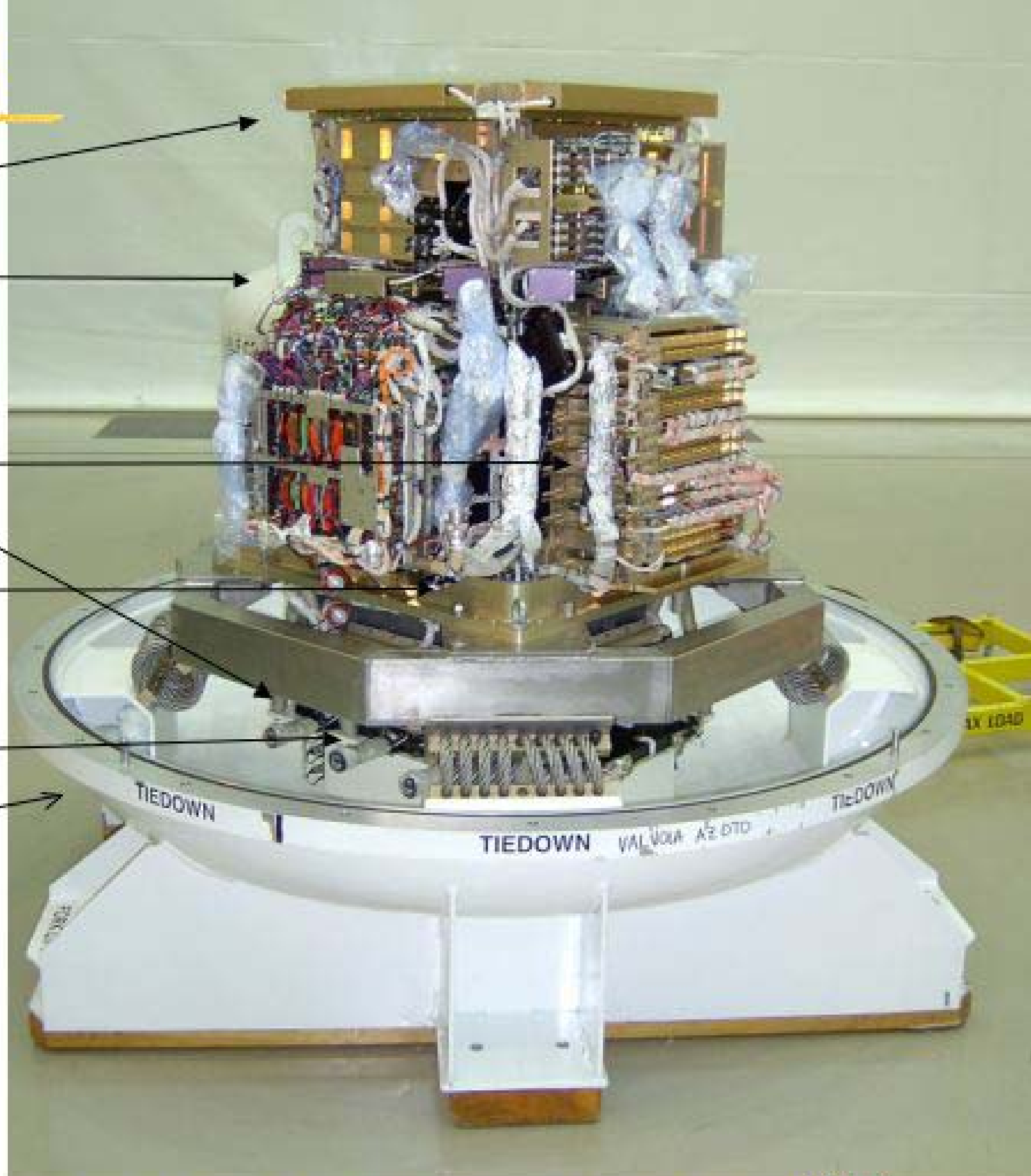
Magnetic spectrometer

Calorimeter

Neutron Detector

Transport Container

Design: > 5000 km flight & 1000 km rail, +40/-50°C outside



PAMELA scientific program

PAMELA is a magnetic spectrometer which will fly on a Russian satellite by Fall 2005. Its scientific scope is the measurement of the antiproton and positron spectra up to few hundred GeV, of the proton and electron spectra up to 700 GeV and that of light nuclei.

	energy range	particles/3 years
Antiproton flux	**80 MeV - 190 GeV**	**$>3\ 10^4$**
Positron flux	**50 MeV – 270 GeV**	**$>3\ 10^5$**
Electron flux	**up to 400 GeV**	**$6\ 10^6$**
Proton flux	**up to 700 GeV**	**$3\ 10^8$**
Electron/positron flux	**up to 2 TeV**	
Light Nuclei (up to Z=6)	**up to 200 GeV/n**	**He/Be/C: $4\ 10^{7/4/5}$**
AntiNuclei search	**(sensitivity of $3\ 10^{-8}$ in $\overline{He}/He$)**	

→ Unprecedented Statistics and new Energy Range in Cosmic Rays

Actual limits: antip&positrons ≈ 40 GeV

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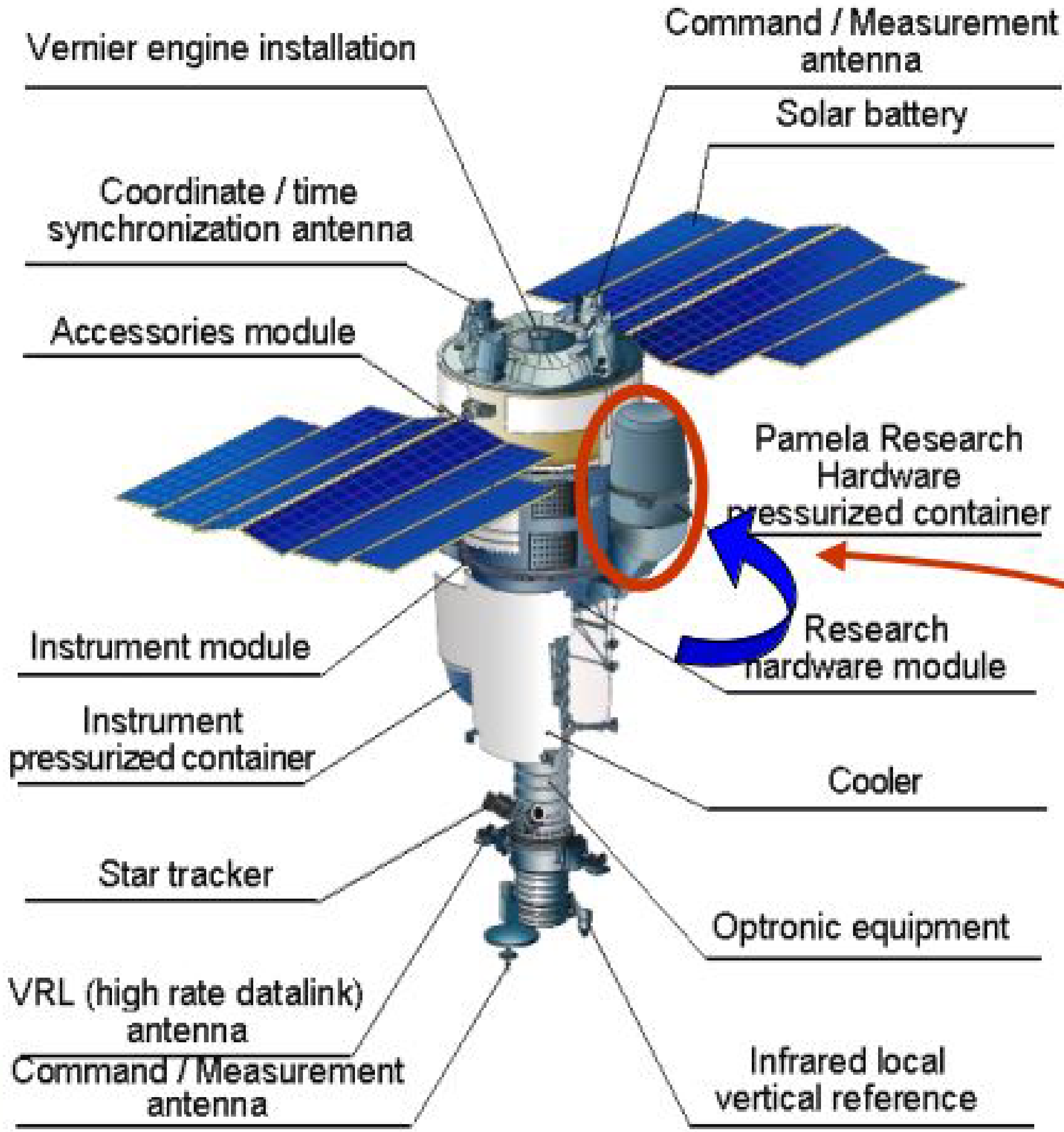
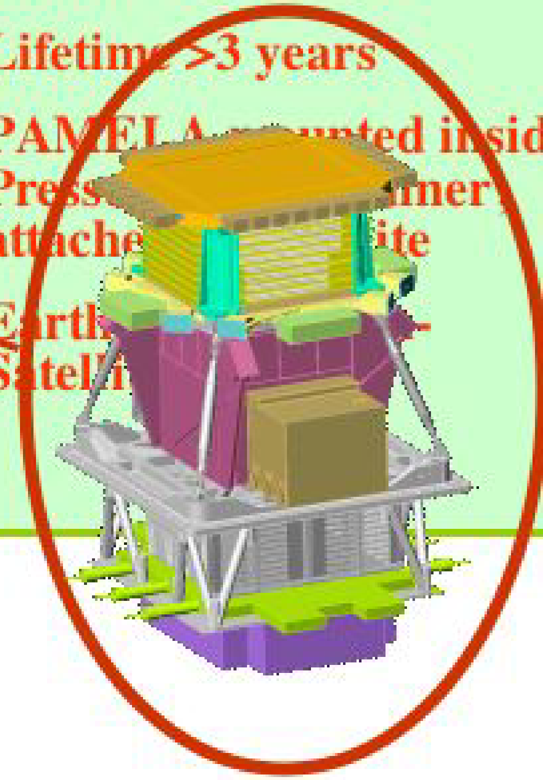
The Satellite: Resurs DK1



- Soyuz-TM Launcher from Baikonur
- Launch in 2005
- Lifetim… >3 years
- PAM… …nted in…side a Press… …iner… attache… …ite
- Earth… Satelli…



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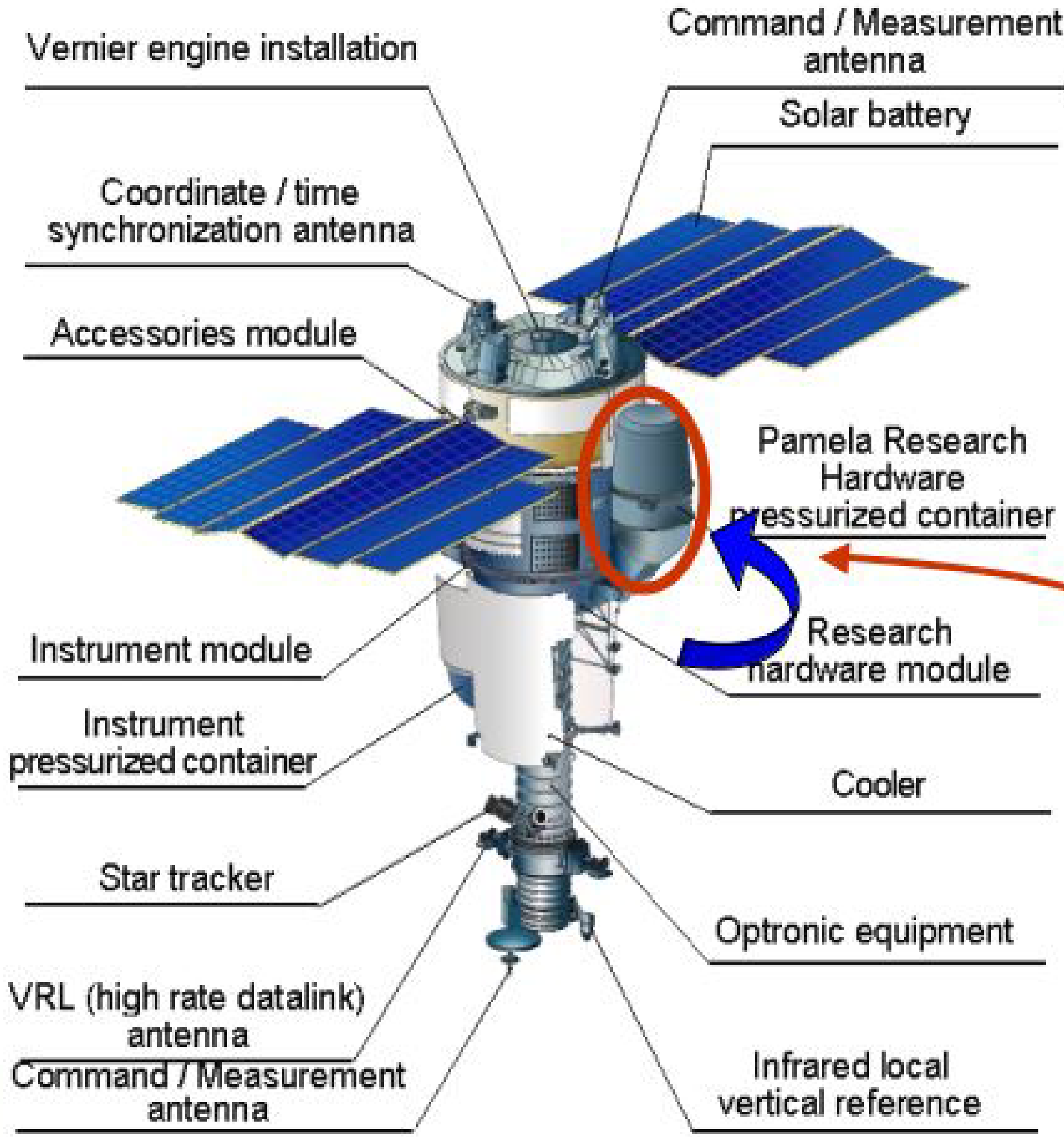

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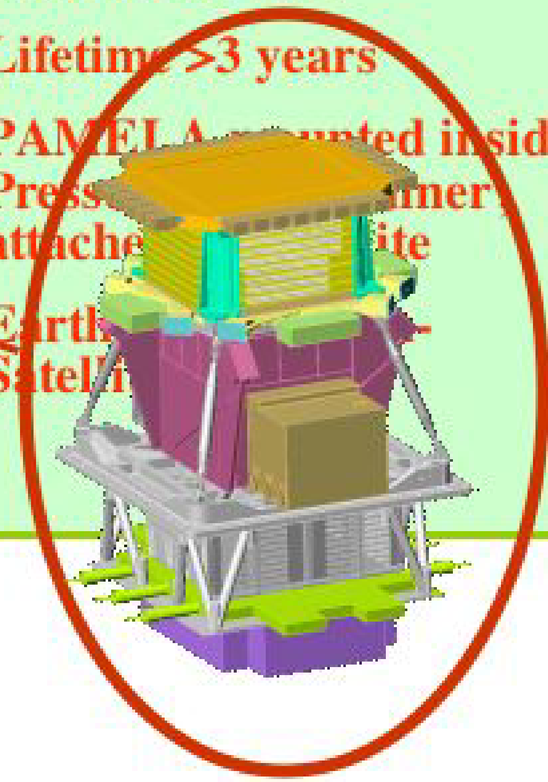
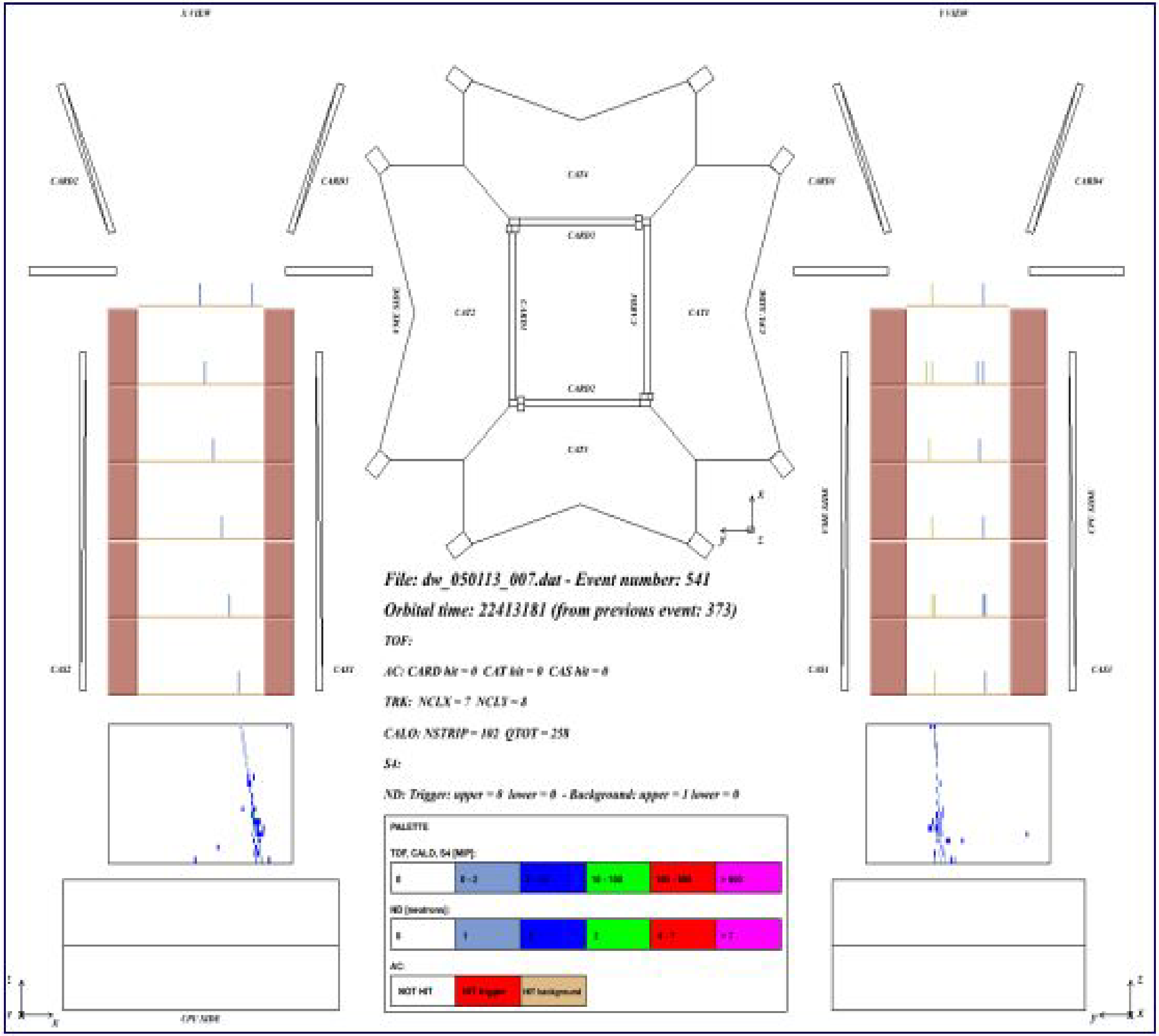


PAMELA

Cosmic ray tracks

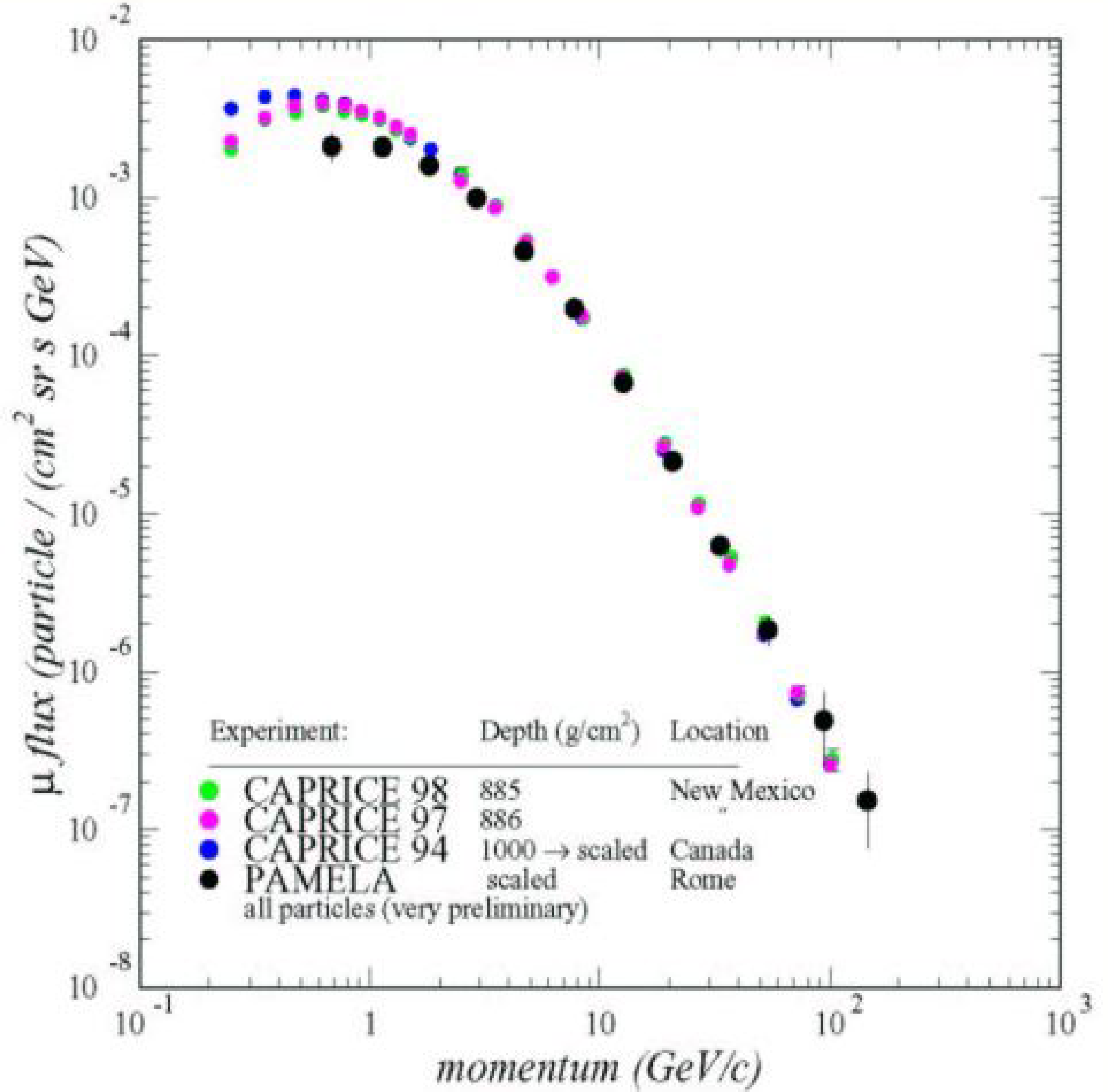
(Dec. 2004)

Since November 2004 PAMELA is set in cosmic-ray acquisition during night shifts.



PAMELA First "physics" results

From the statistics acquired by cosmic-ray acquisitions we are analyzing PAMELA performance and comparing with literature.



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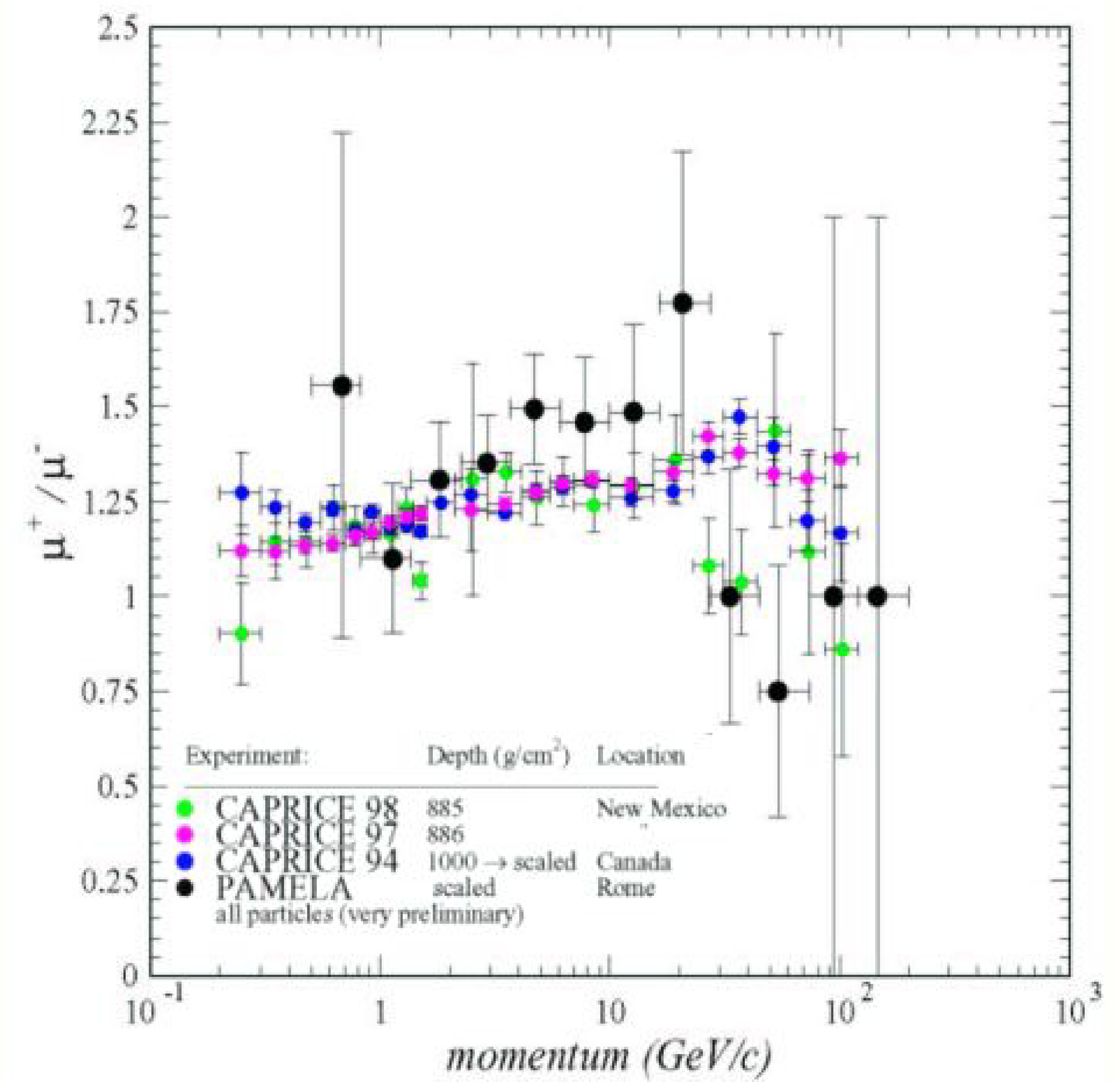
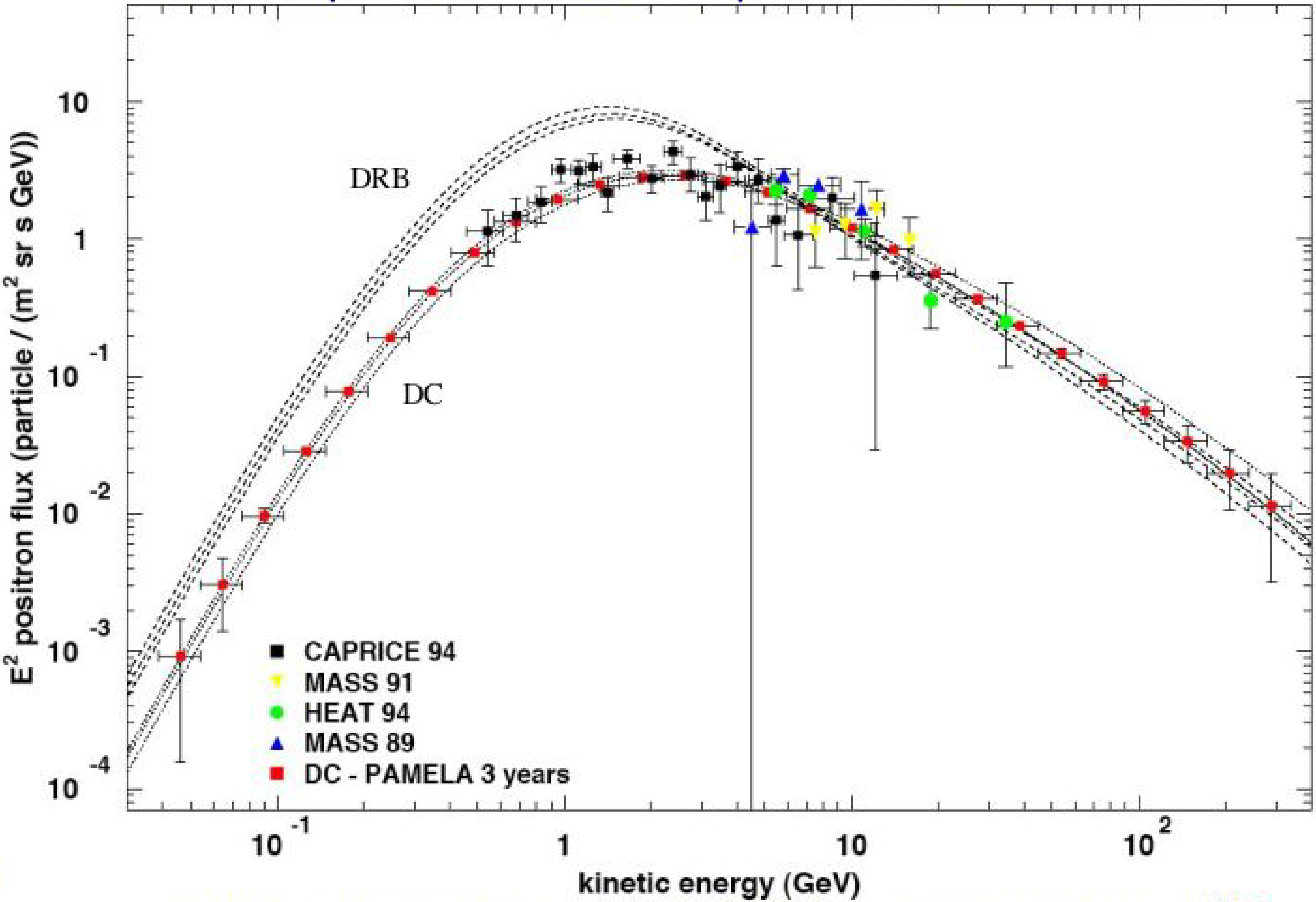
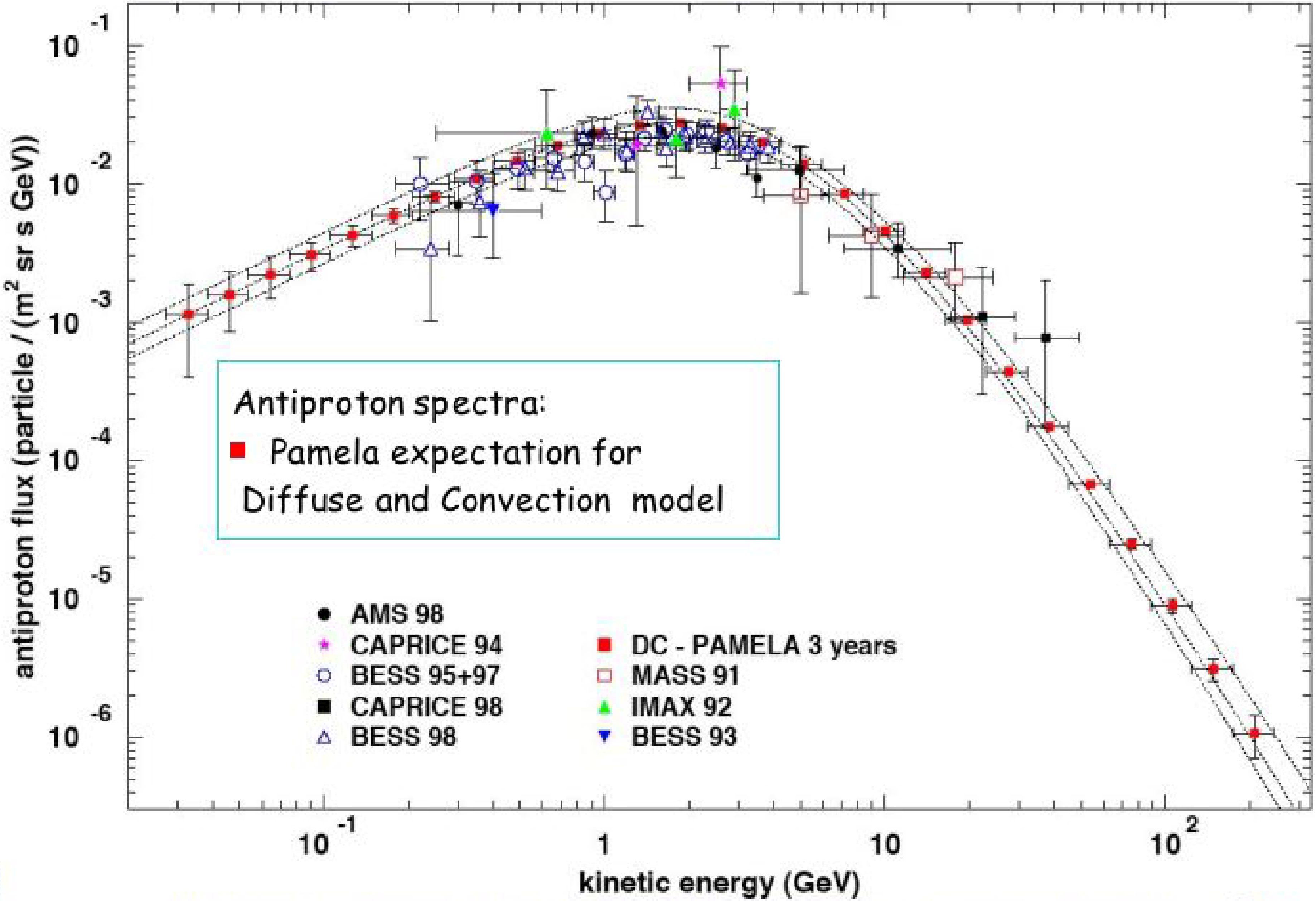


Positron spectra: PAMELA expectation for DC model



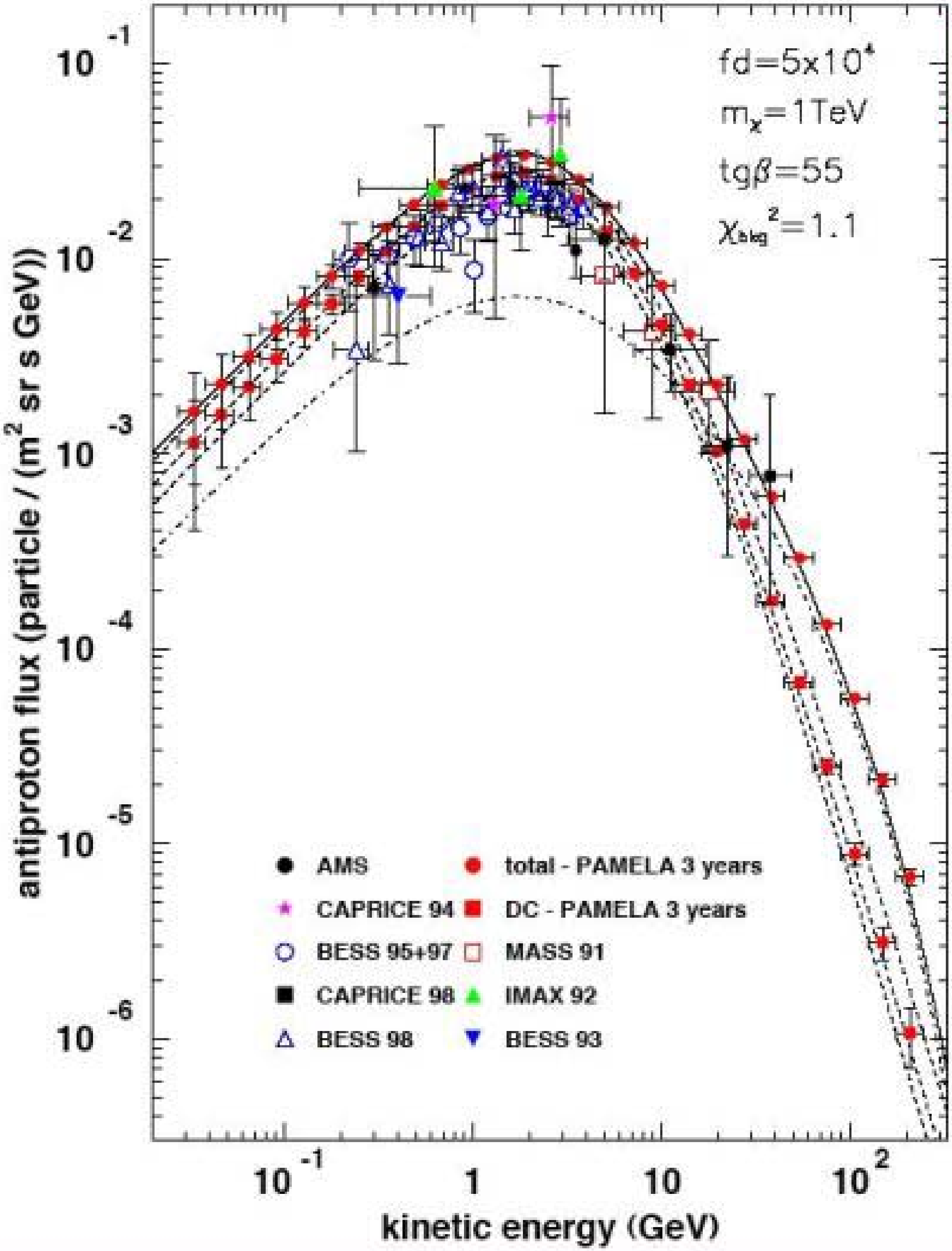
Antiproton spectra: PAMELA expectation for DC model



PAMELA:

Cosmic-Ray Antiparticle Measurements: Antiprotons

MSSM



fd: Clumpiness factors needed to disentangle a neutralino induced component in the antiproton flux

astro-ph/0502406, 21 Feb. 05

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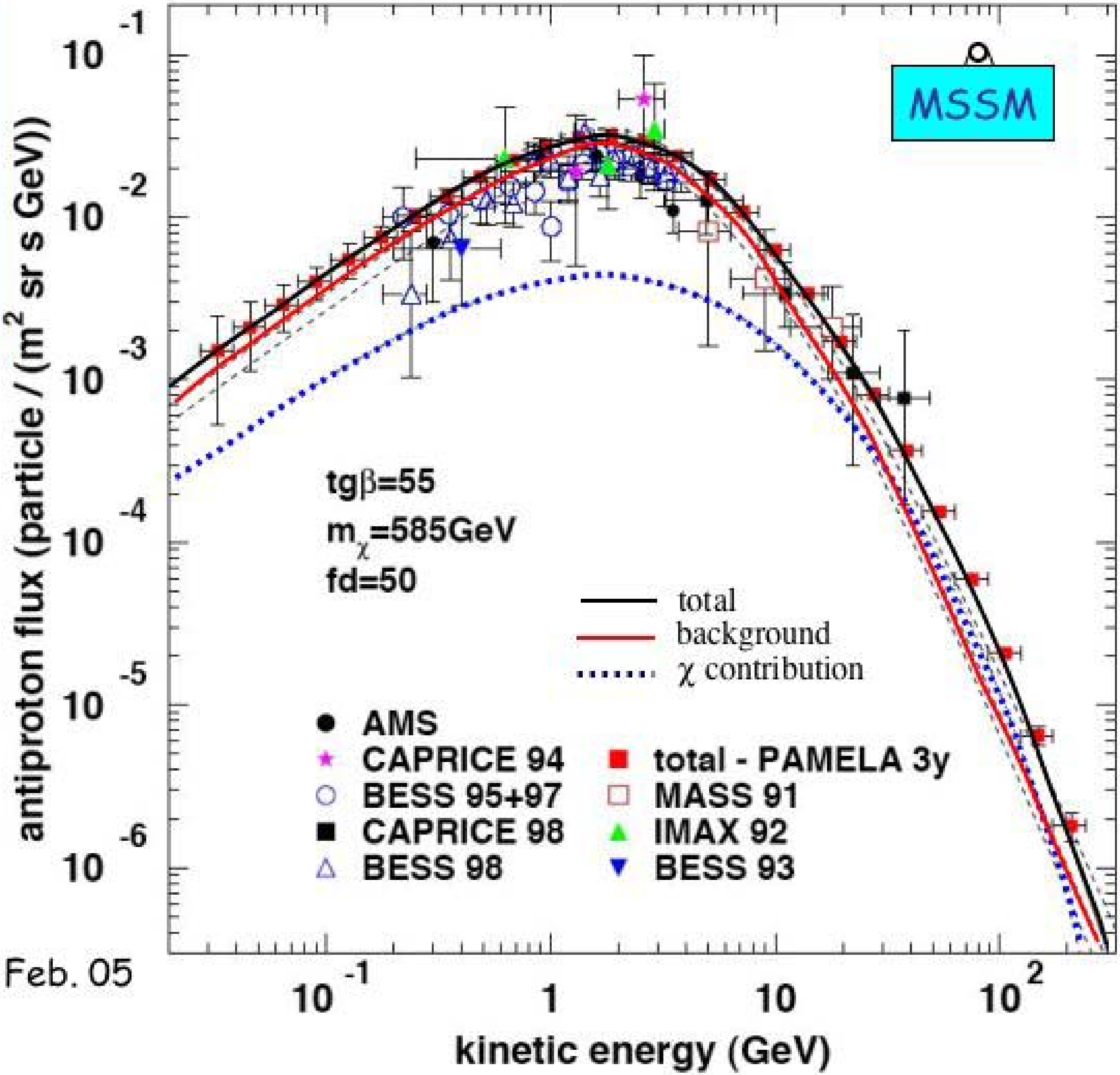
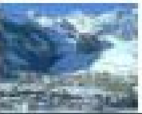


astro-ph/0502406, 21 Feb. 05



Estimated reaches with Pamela

MSSM

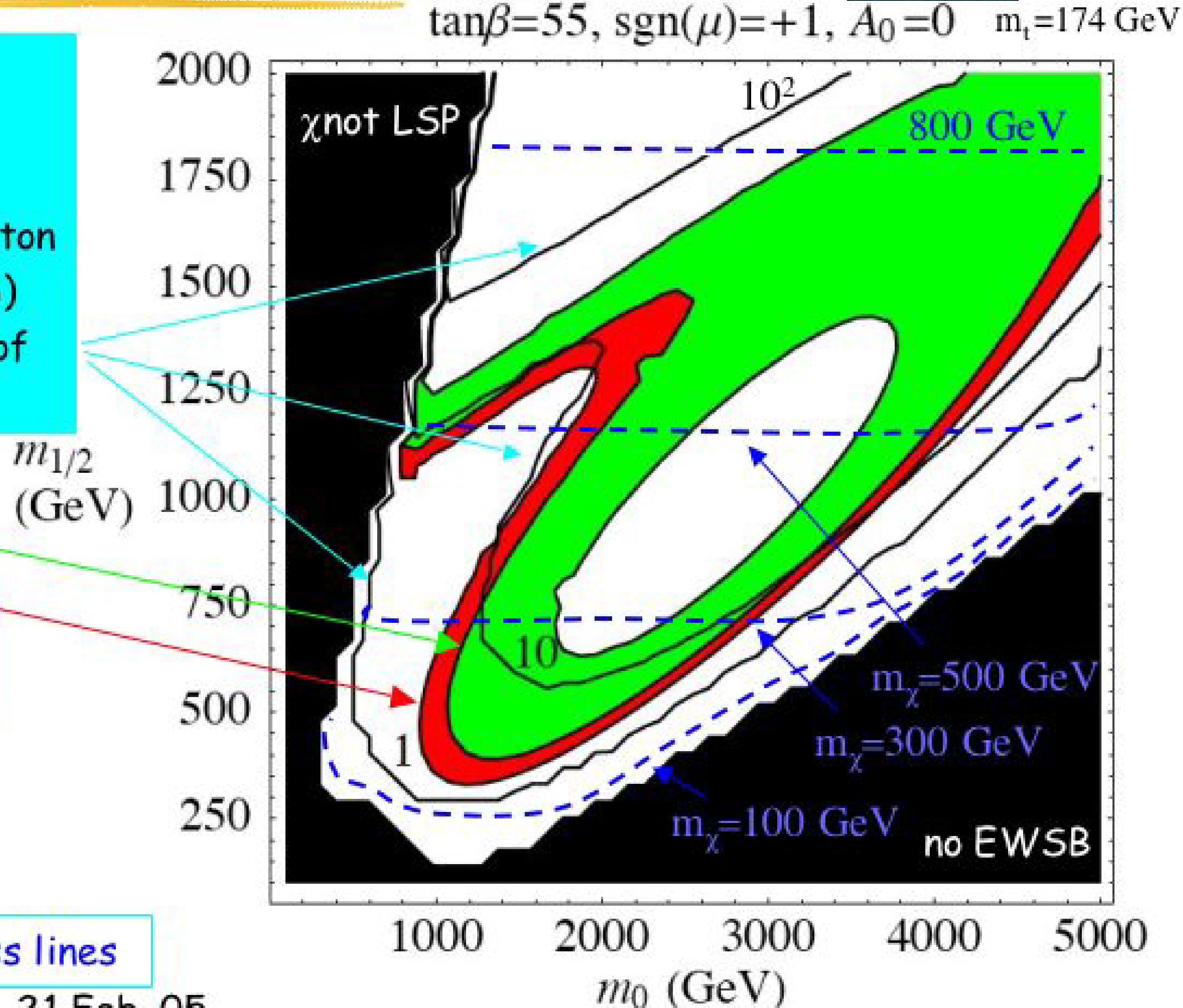
Clumpiness factors fd needed to disentangle a neutralino induced component in the antiproton flux with PAMELA (χ^2>1.8) that still give a good fit of the present data

region where $0.13 < \Omega_{CDM.}h^2 < 0.3$

region where $0.09 < \Omega_{CDM.}h^2 < 0.13$

Equi-clumpiness factor density in respect to a NFW

- - - Equi-neutralino mass lines



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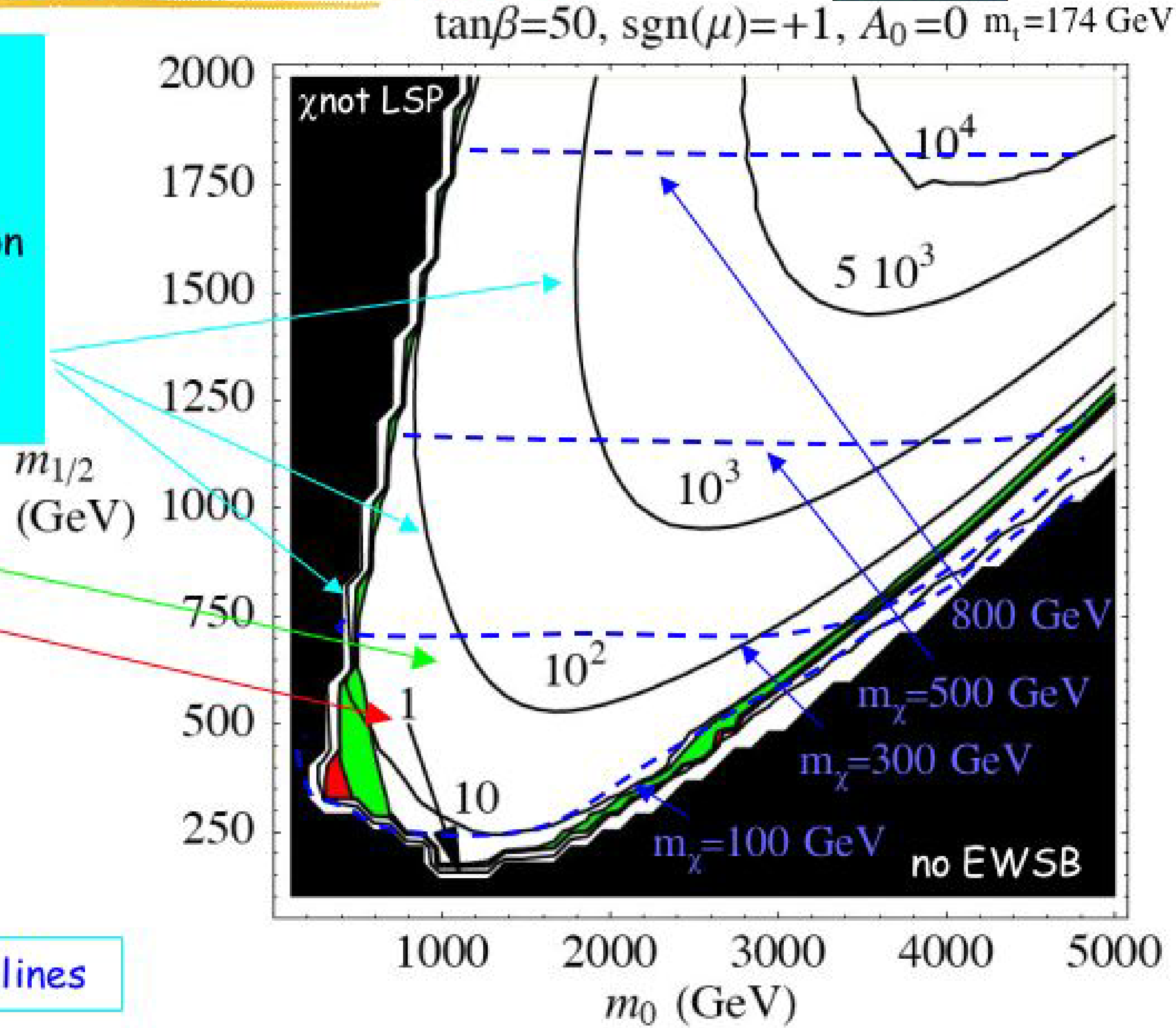

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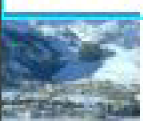


astro-ph/0502406

Signal rate from Supersymmetry

gamma-ray flux from neutralino annihilation

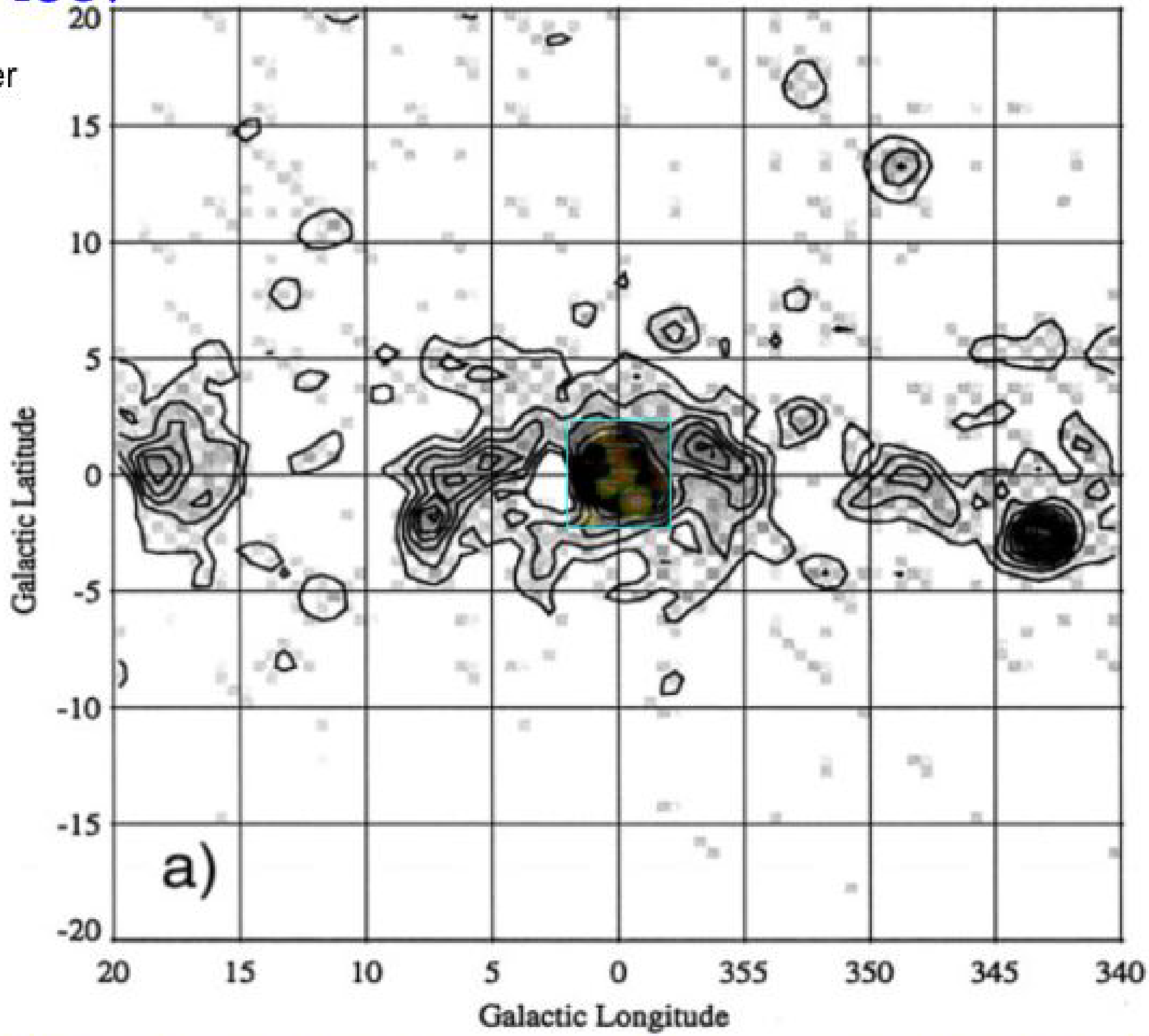
$$\phi(E,\Delta\Omega) \propto \left(\frac{\sigma v}{m_\chi^2}\right) \int_{l.o.s} \int_{\Delta\Omega} \rho^2(l) dl d\Omega)$$

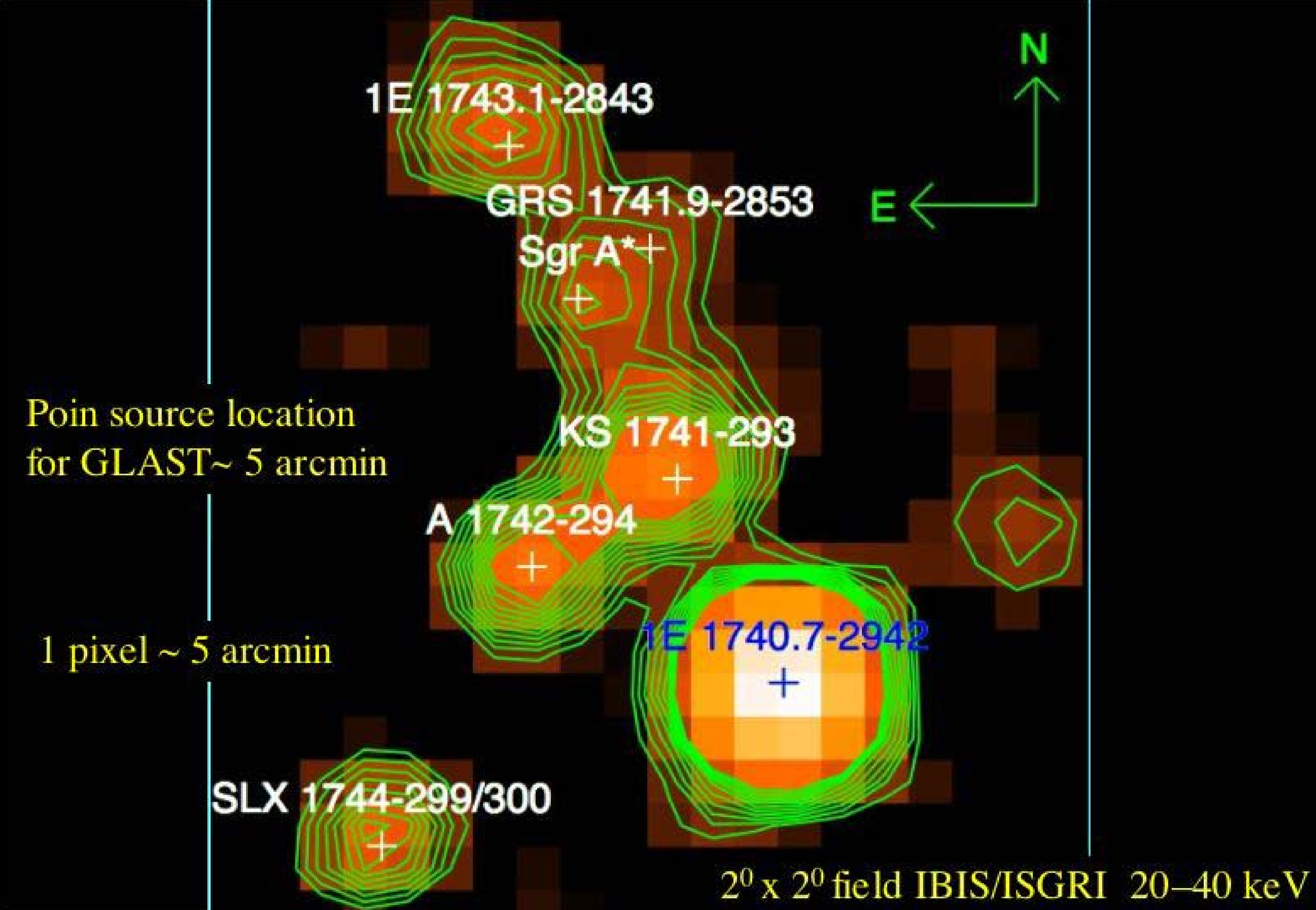
governed by supersymmetric parameters

J(φ): governed by halo distribution

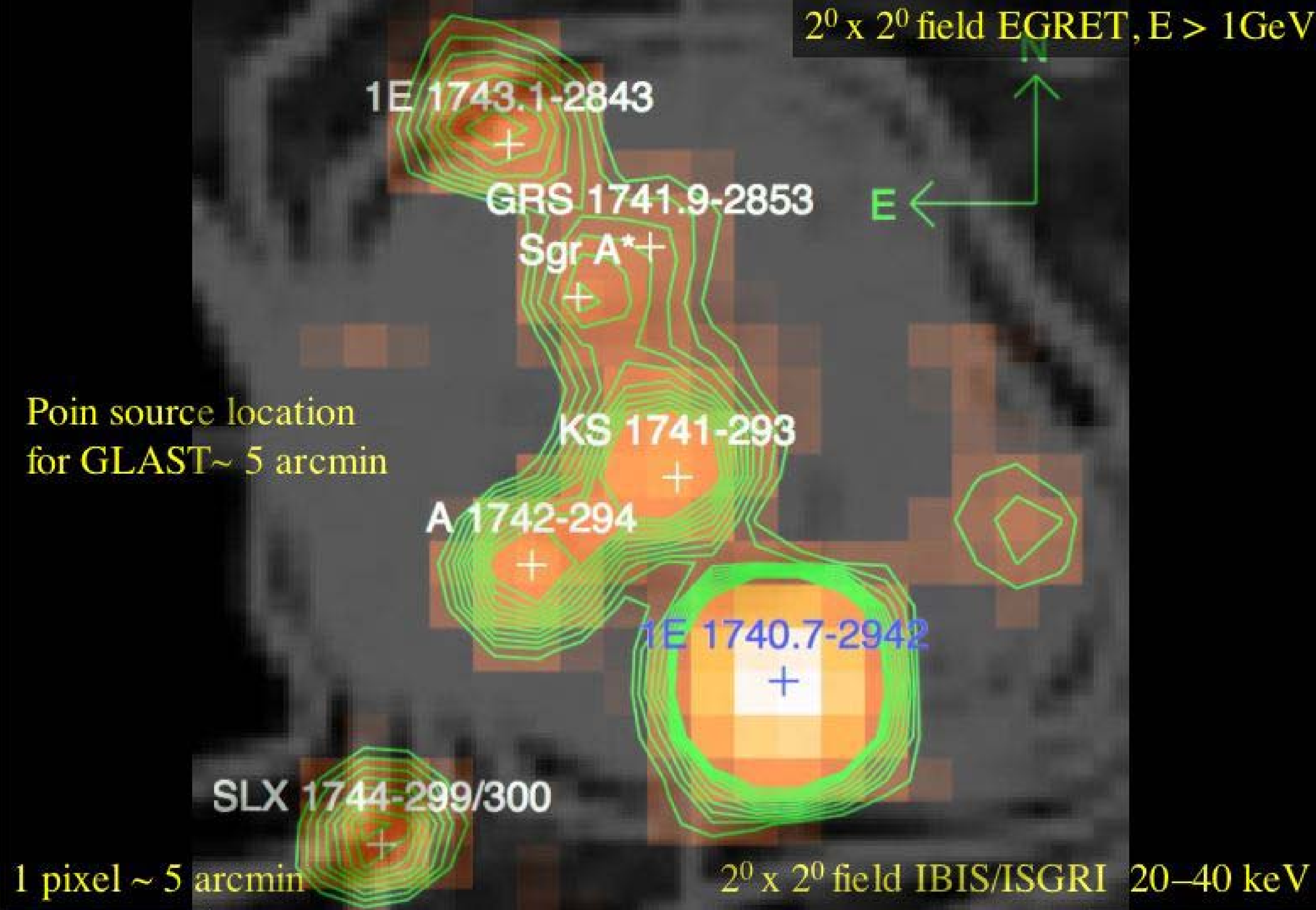
EGRET, E > 1GeV

Mayer-Hasselwander et al, 1998





1E 1743.1-2843
GRS 1741.9-2853
Sgr A*
N
E
Poin source location
for GLAST~ 5 arcmin
KS 1741-293
A 1742-294
1 pixel ~ 5 arcmin
1E 1740.7-2942
SLX 1744-299/300
2^0 x 2^0 field IBIS/ISGRI 20–40 keV



2⁰ x 2⁰ field EGRET, E > 1GeV
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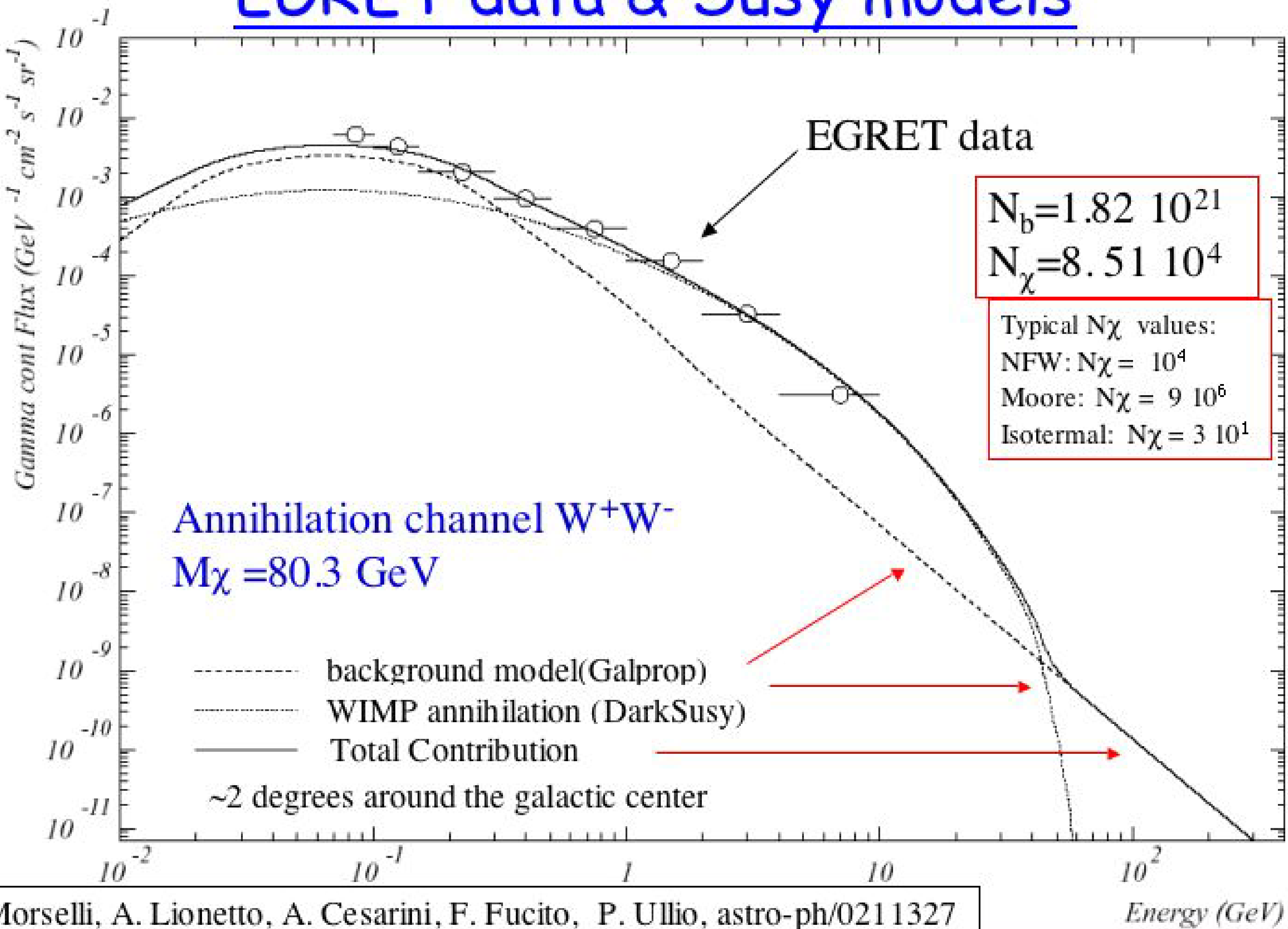
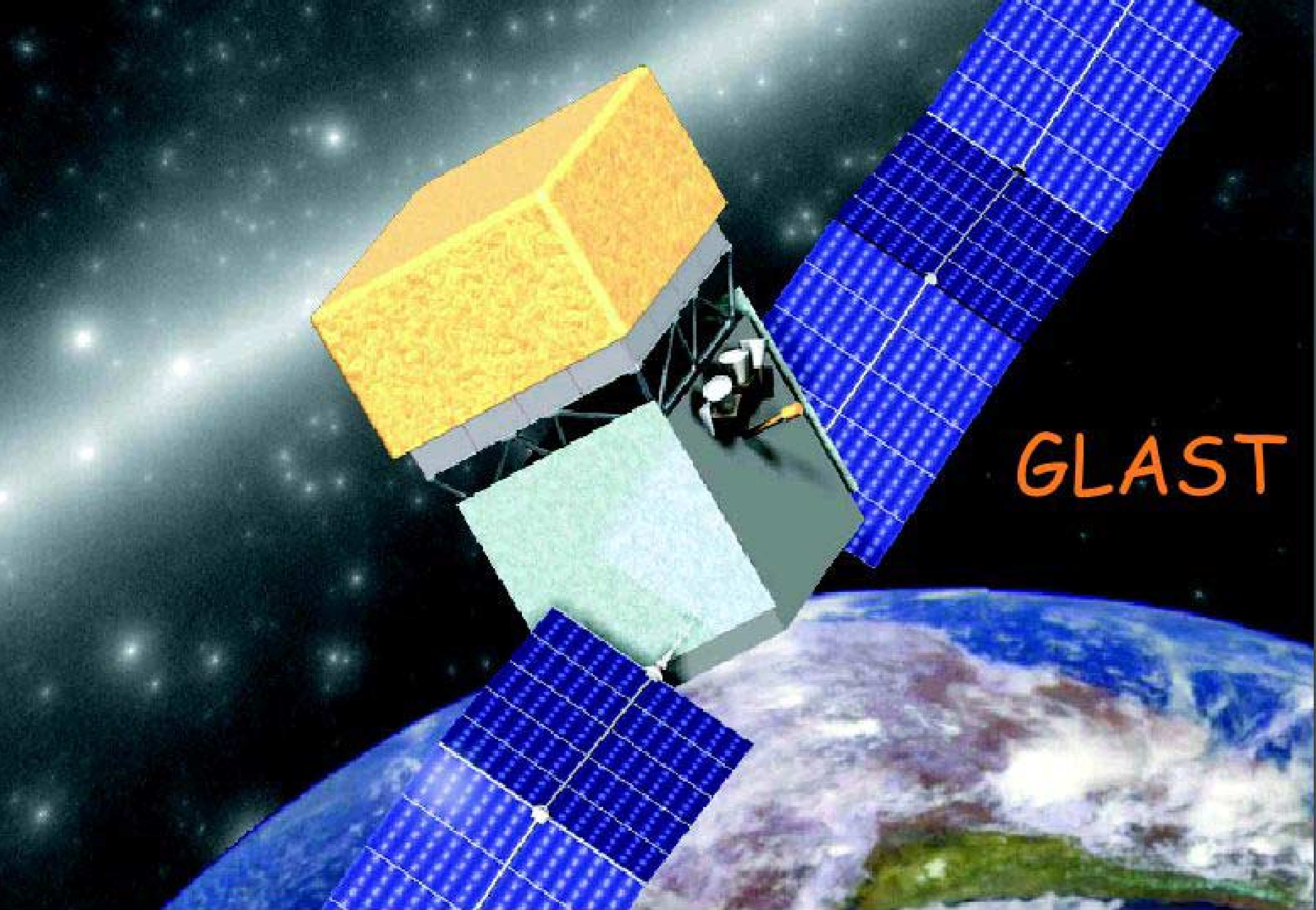
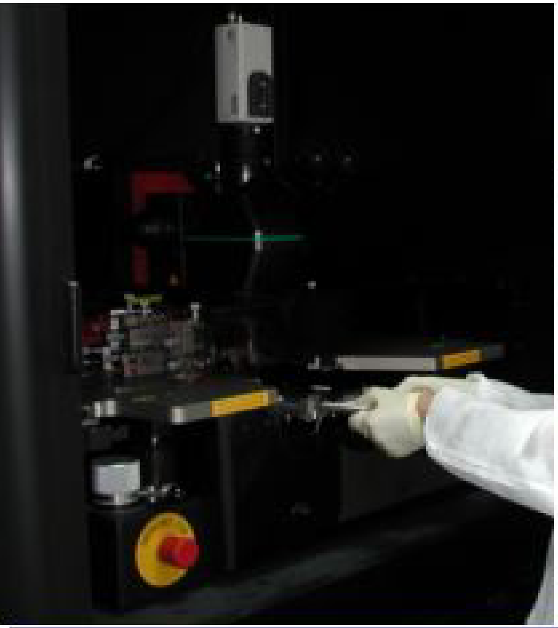
EGRET data & Susy models



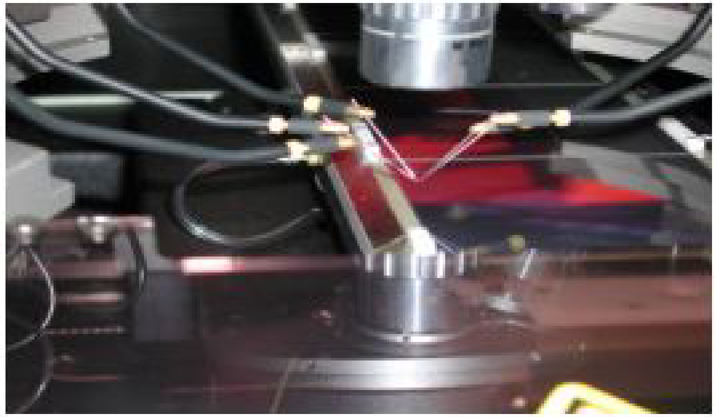
A.Morselli, A. Lionetto, A. Cesarini, F. Fucito, P. Ullio, astro-ph/0211327

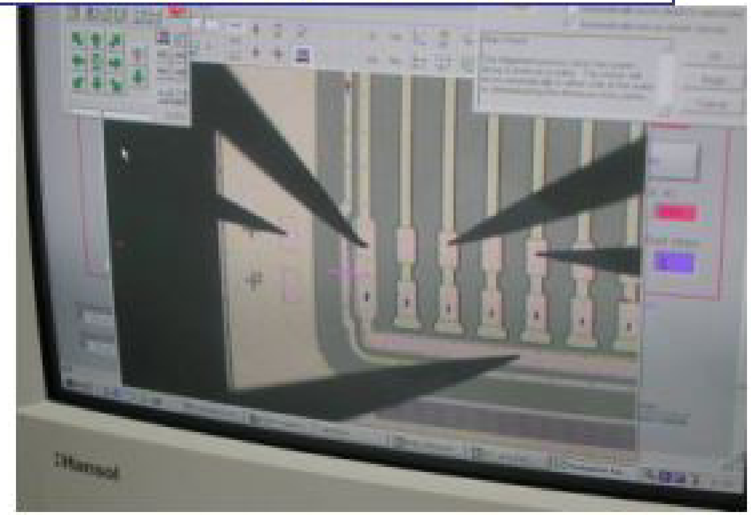

GLAST

Ladders testing



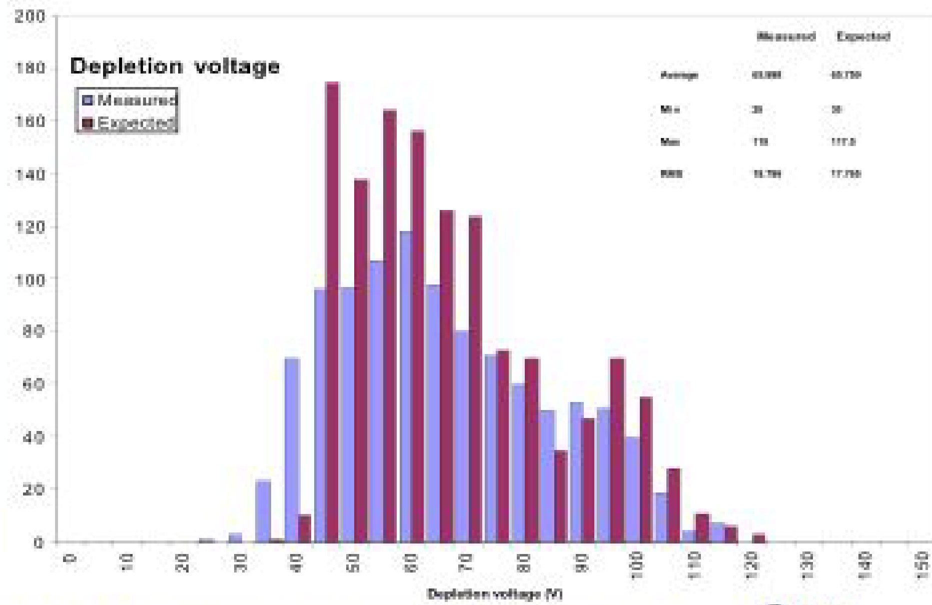
Ladders probe station: 5 probes are used to measure body and single strip I, C to check sanity of each single channel





Flight ladders production status:

- Completed and tested (INFN BA/RM2/PG) 1900
- Under construction 800
- rejected ~ 1%
- 0.016% bad chans caused by bonding or probing
- 2μm RMS alignment spread
- All results in good agreement with what expected from SSDs



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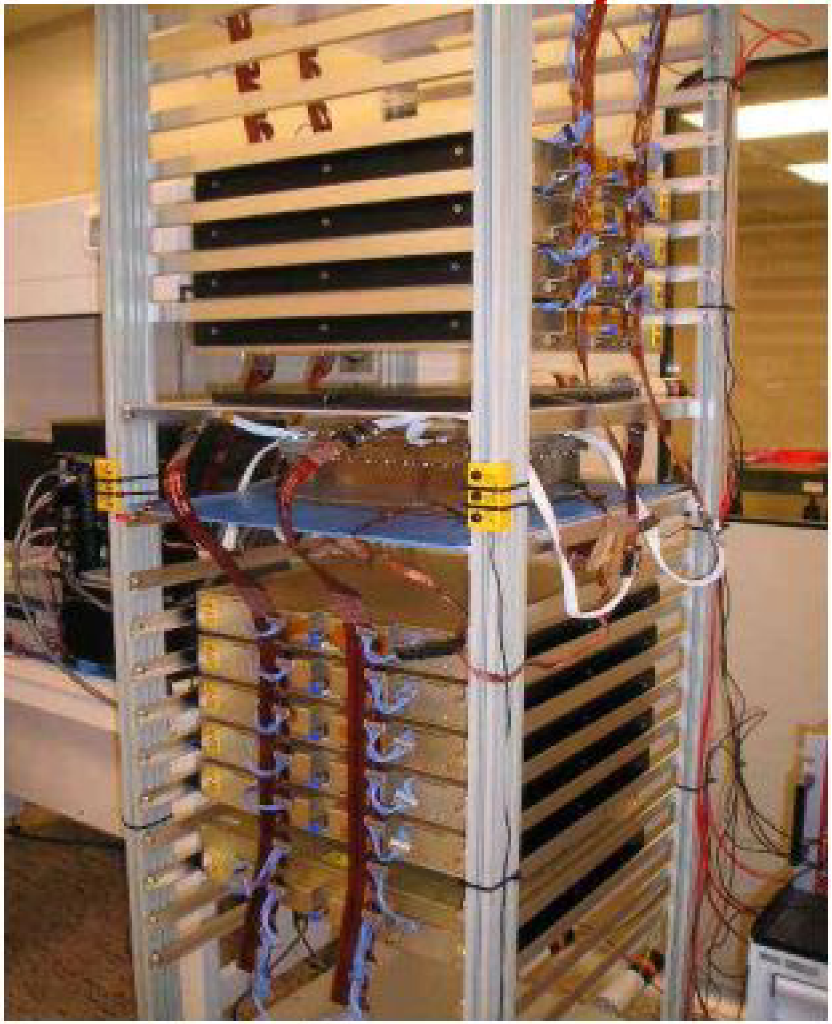
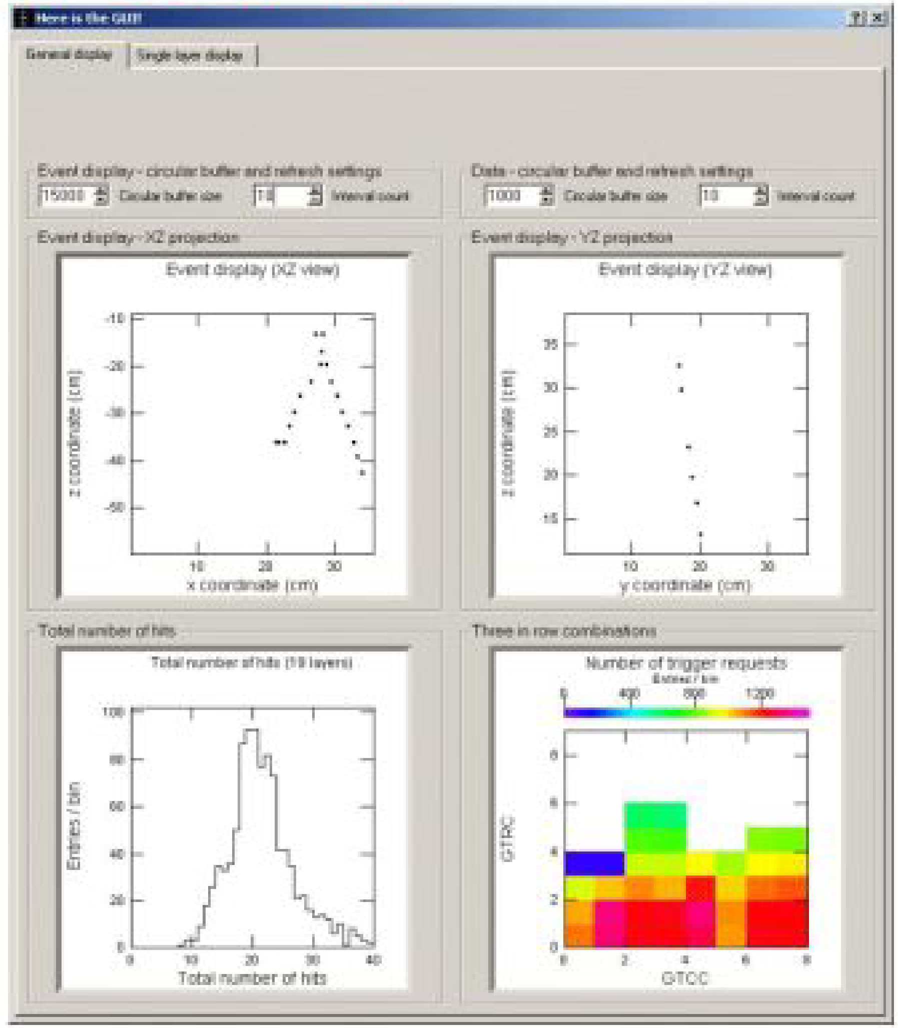
Tray test at INFN

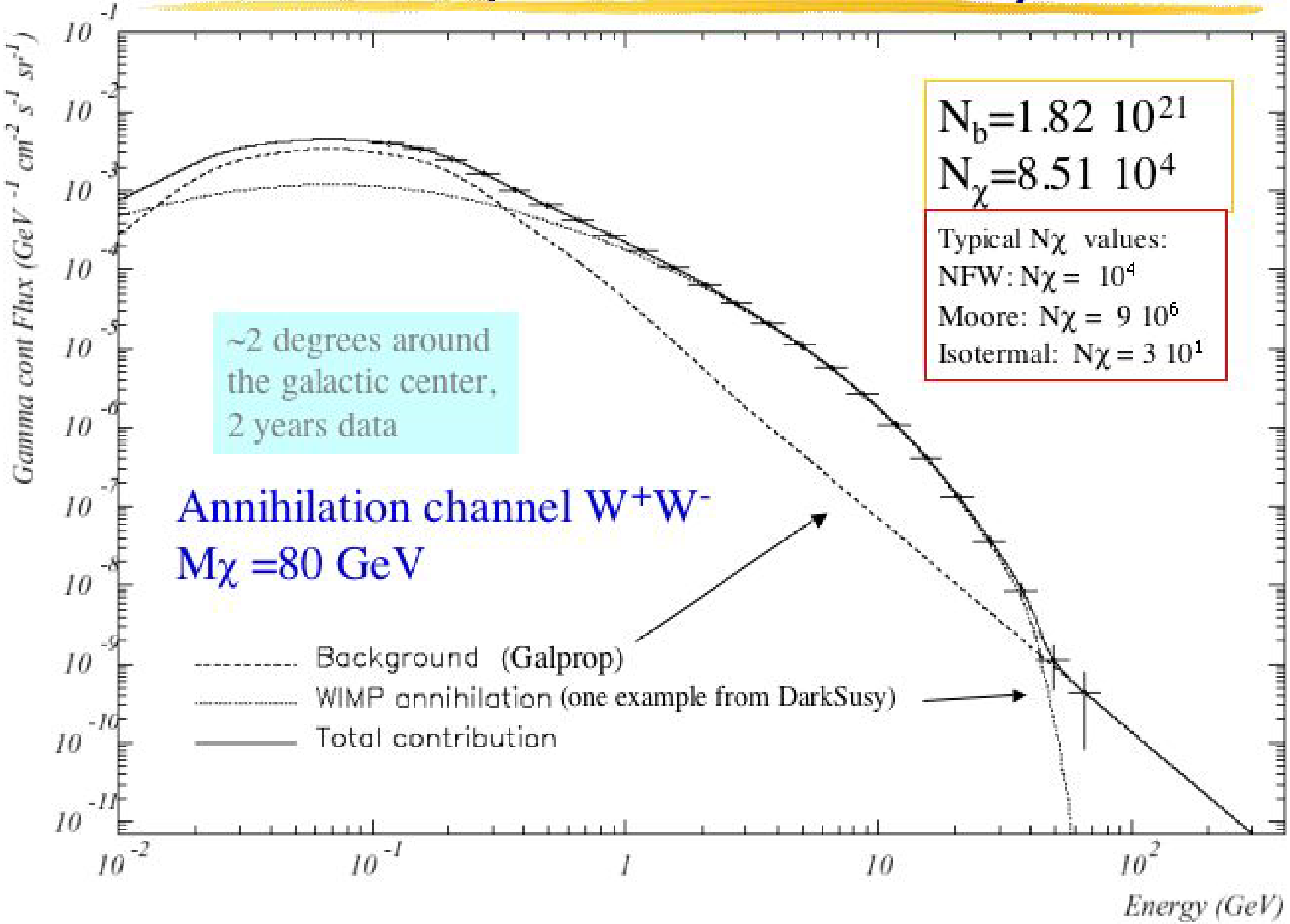




<u>Stack of trays:</u>

- functional tests/CR burn-in for a whole tower in parallel
- external trigger capability
- 4 stacks operating in parallel at INFN (Pi/Pg/Rm2/Ba)

GLAST Expectation & Susy models



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

Estimated reaches with GLAST

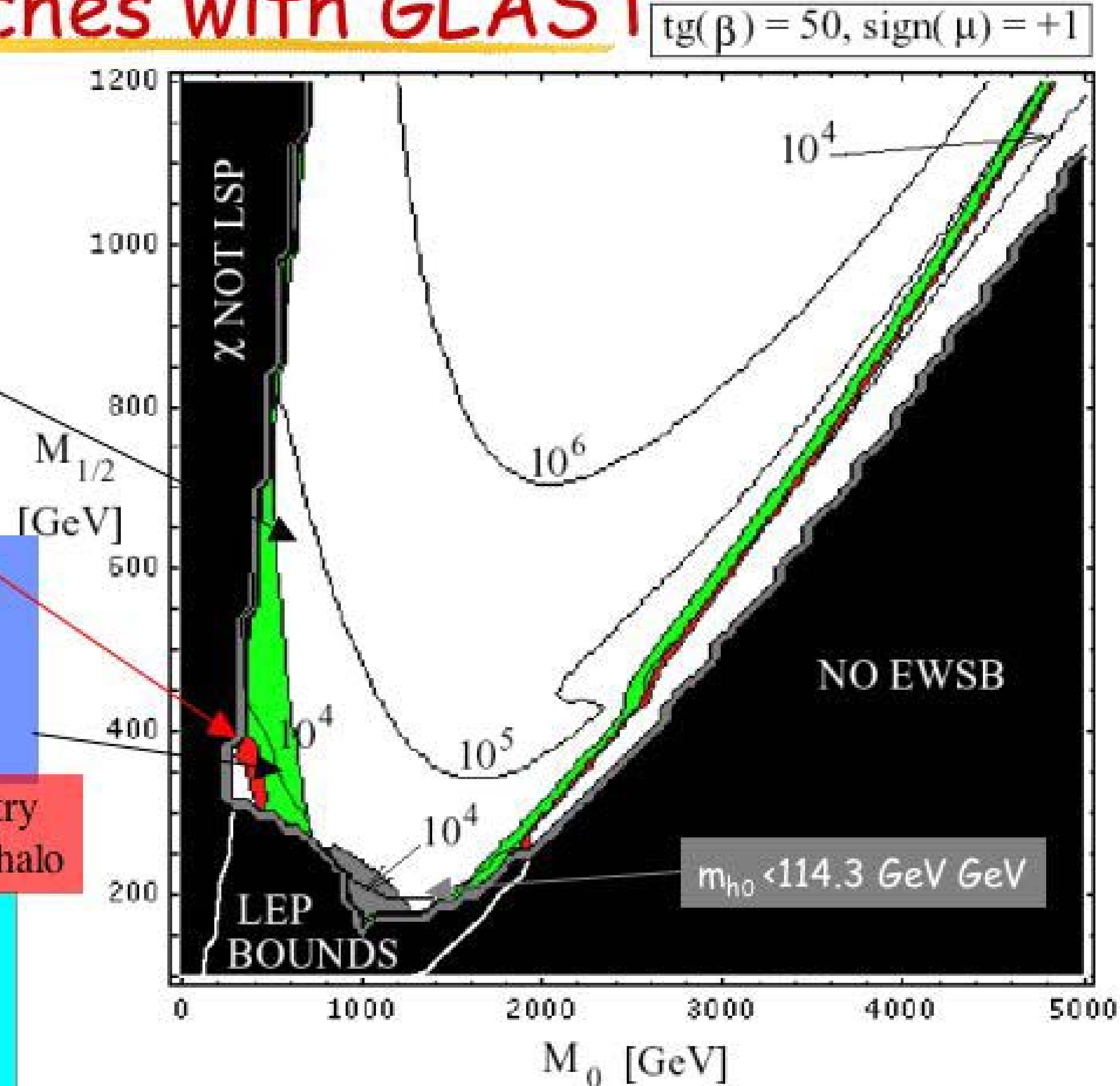
Minimal Supersymmetric Standard Model with: $A_0 = 0$, $\mu > 0$, $m_t = 174$ GeV

region where $0.13 < \Omega_{CDM.} h^2 < 1$

region where $0.09 < \Omega_{CDM} h^2 < 0.13$

GLAST sensitivity (5 σ) for a neutralino density Nχ of 10^4 in a $\Delta\Omega = 10^{-5}$ sr region around the galactic center

if GLAST do not see Supersymmetry this region is excluded for a NFW halo



Typical Nχ values for $\Delta\Omega = 10^{-5}$ sr :
NFW: Nχ = 10^4
Moore: Nχ = $9\ 10^6$
Isotermal: Nχ = $3\ 10^1$

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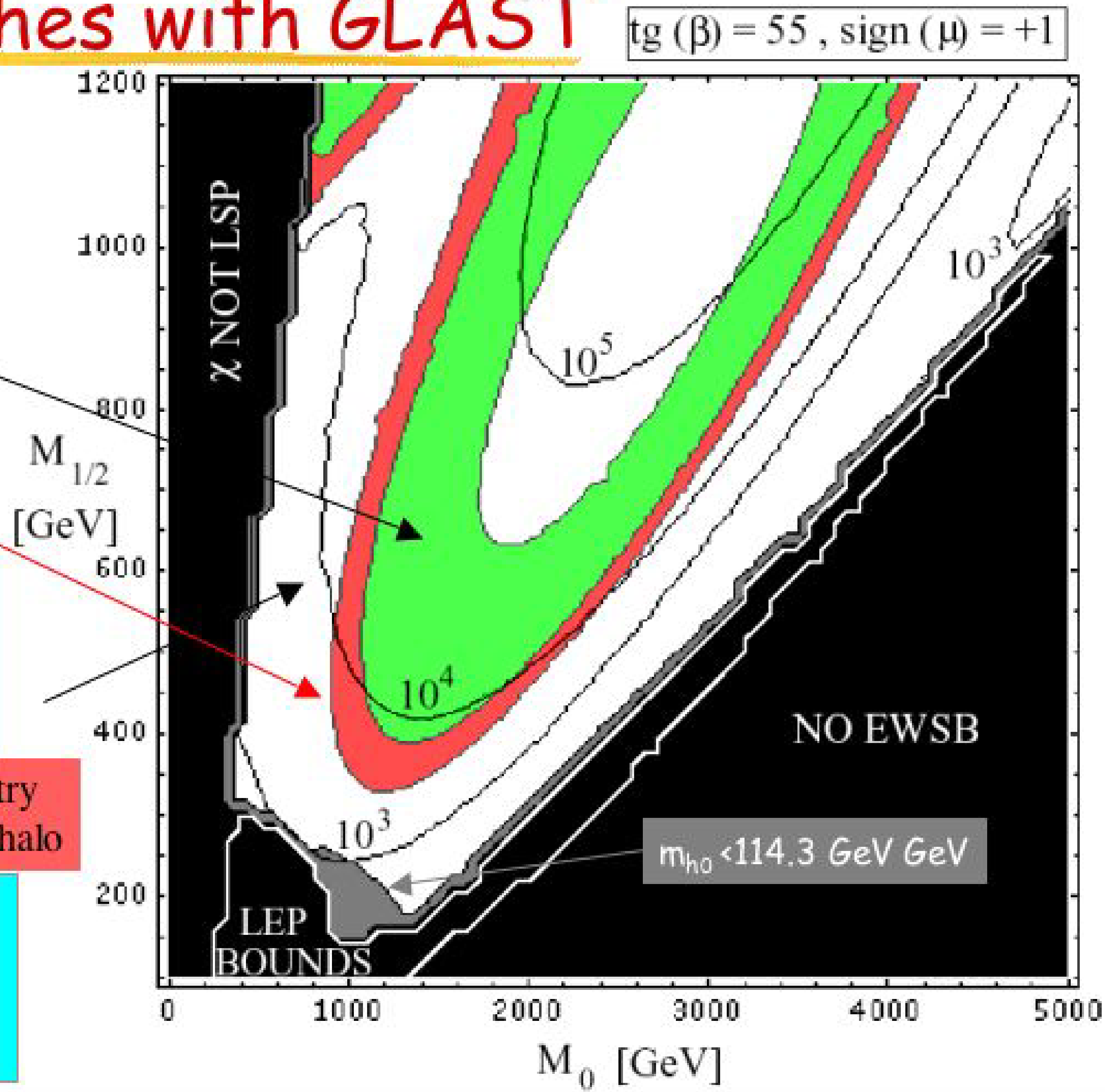

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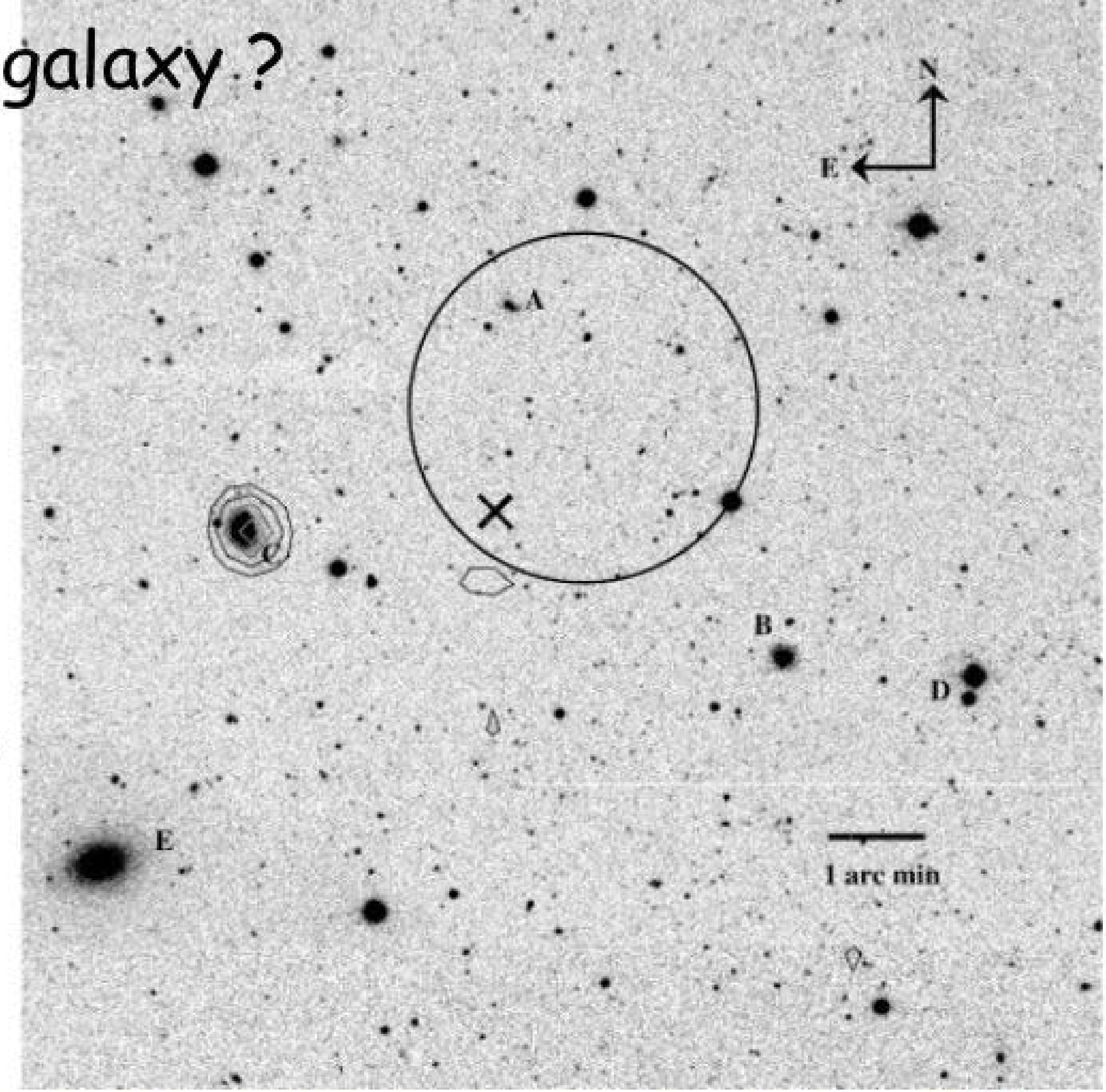
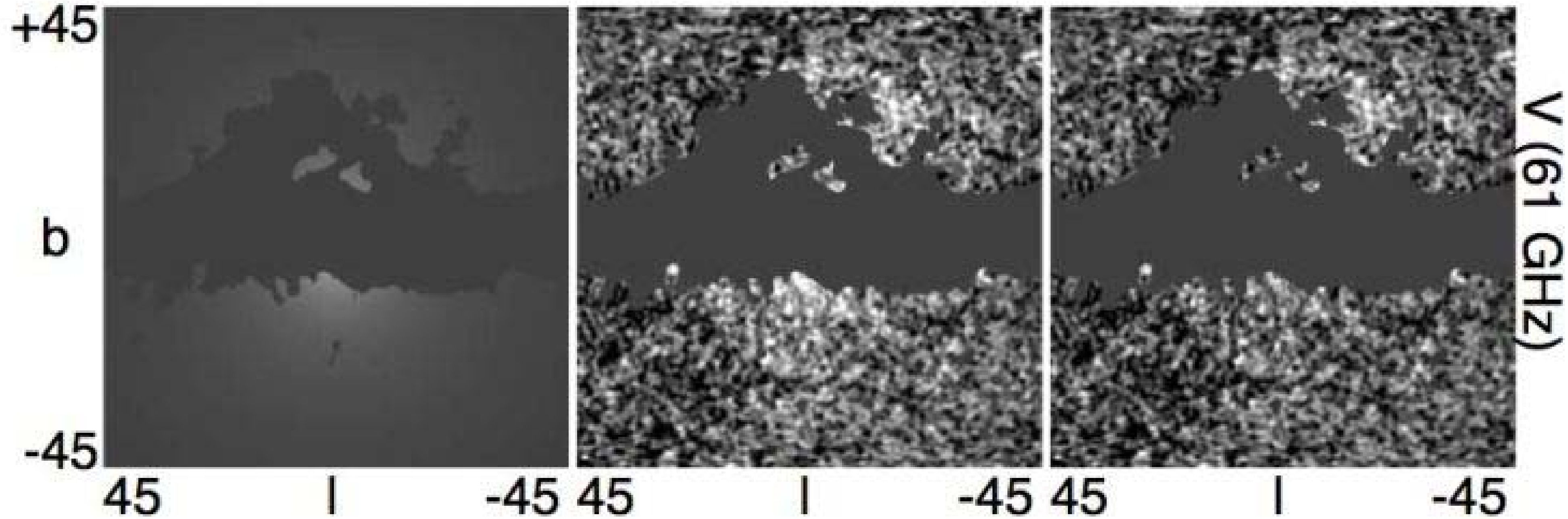
Where is the galaxy ?

R.Minchin et al.
astro-ph/0502312
16 Feb 2005

VIRGOHI21 contain no stars, a cloud of hydrogen atoms of 10^8 solar mass, but it is is thousand times more massive



Other hints? **WMAP data**



Excess microwave emission observed in the inner Galaxy (1-2 Kpc, 7-14 deg) consistent with synchrotron emission from highly relativistic e^{+} e^{-} produced by 100 GeV dark matter particle annihilation.

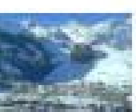
D. P. Finkbeiner **astro-ph/0409027**

Conclusions

PAMELA will explore antiprotons and positrons starting from 2005

- GLAST will explore a good portion of the supersymmetric parameter space with gamma rays

… and this is only an additional item for GLAST !



2nd Conclusions

- GLAST will be an important step in gamma ray astronomy (~10 000 sources compared to ~ 200 of EGRET)
- A partnership between High Energy Physics and γ Astrophysics
- Beam test and software development well on the way
- Wide range of possible answers/discoveries
- Gold era for multiwavelenght studies ← open to the Community HEAPNET Proposal

and you are invited to : Third Workshop on:

"Science with the New Generation of High Energy Gamma-ray Experiments "

Cividale del Friuli, Italy - May 30-31 and June 1, 2005

www.fisica.uniud.it/~glast/GammaWorkshop/