Cosmic ray backgrounds in dark matter searches

Stockholm,
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Concluding remarks

~~Joakim Edsjo~~

~~Joakim Edlago~~

Joakim Terra di passaggio tra le acque navigabili lago

The Oskar Klein Centre for Cosmoparticle physics

- Will not go through and summarize all talks

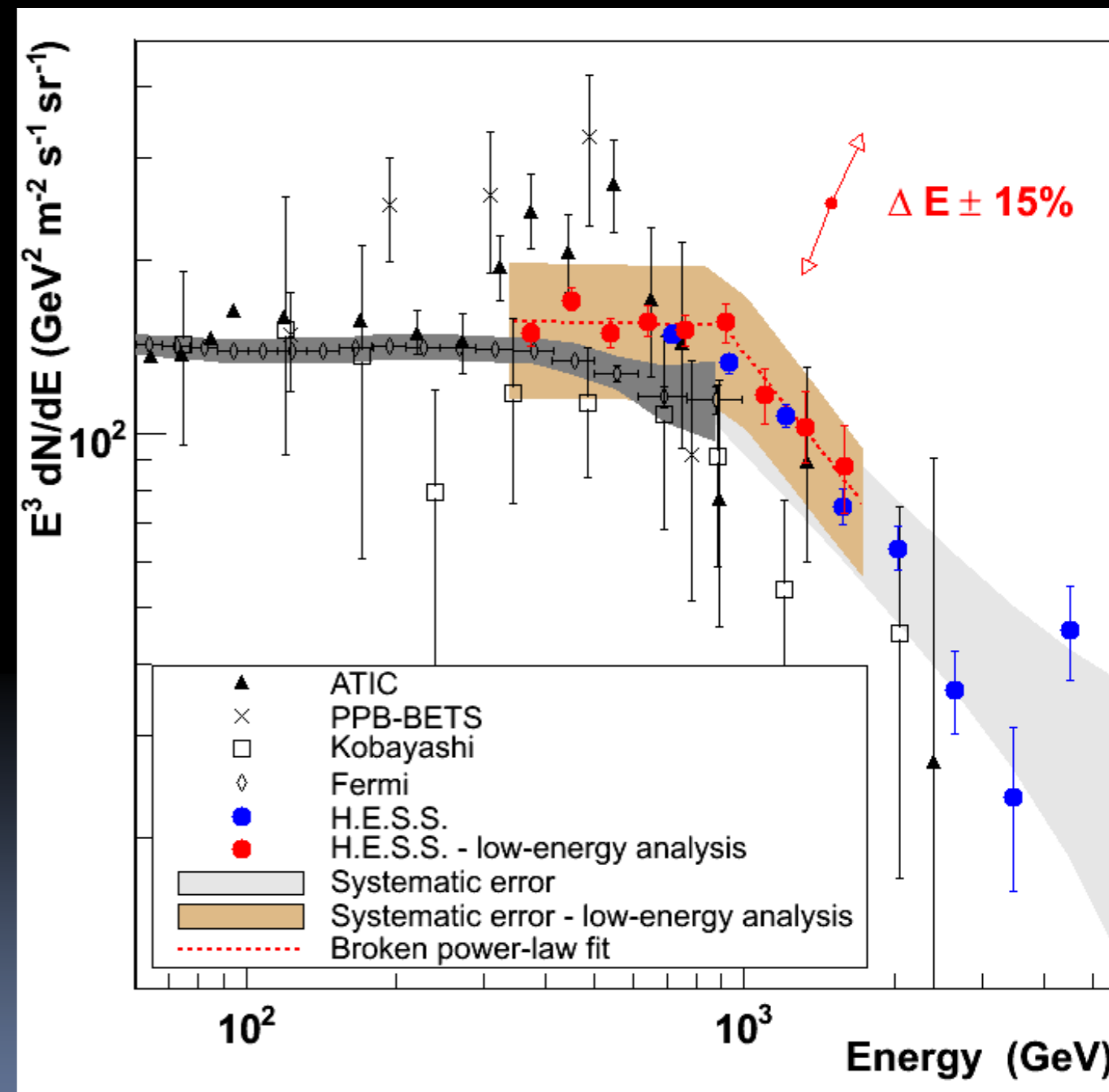- Instead, I will just mention a few items, as most issues have been discussed extensively already

Data

- Many interesting new measurements

- And more to come

- Reasonable agreement between the
different experiments
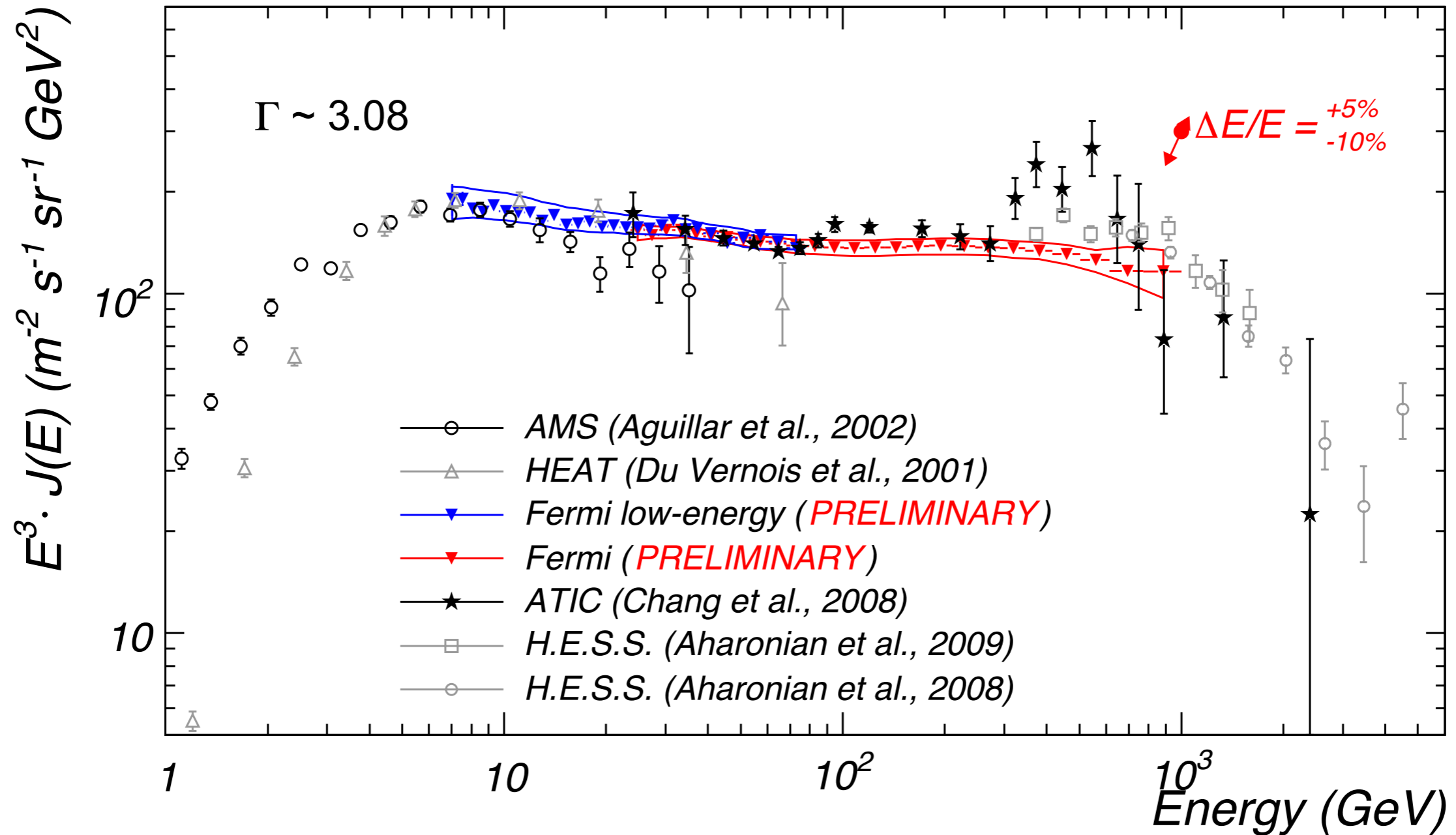
The H.E.S.S. Electron Spectrum

High energies (blue)

- Cuts:
    - impact distance < 200 m
    - image size in each camera > 200 photo electrons

- Spectral index:
  $3.9 \pm 0.1_{stat.} \pm 0.3_{syst}$

- Syst. uncertainty: atmospheric variations + model dependence of proton simulations (SIBYLL vs. QGSJET-II)

- H.E.S.S. energy scale uncertainty of 15%

$\Delta E \pm 15\%$

ATIC
PPB-BETS
Kobayashi
Fermi
H.E.S.S.
H.E.S.S. - low-energy analysis
Systematic error
Systematic error - low-energy analysis
Broken power-law fit

F. A. Aharonian et al., A&A, 508 (2) 561 (2009)

Egberts

16

Data and background - e⁺+e⁻

- Status as of May 2009 with

  - Fermi-LAT, 2009

  - HESS 2008

  - HESS LE 2009

  - PPB-BETS 2008

  - ATIC 1+2+4 2009

  - Conventional background, Strong et al 2004
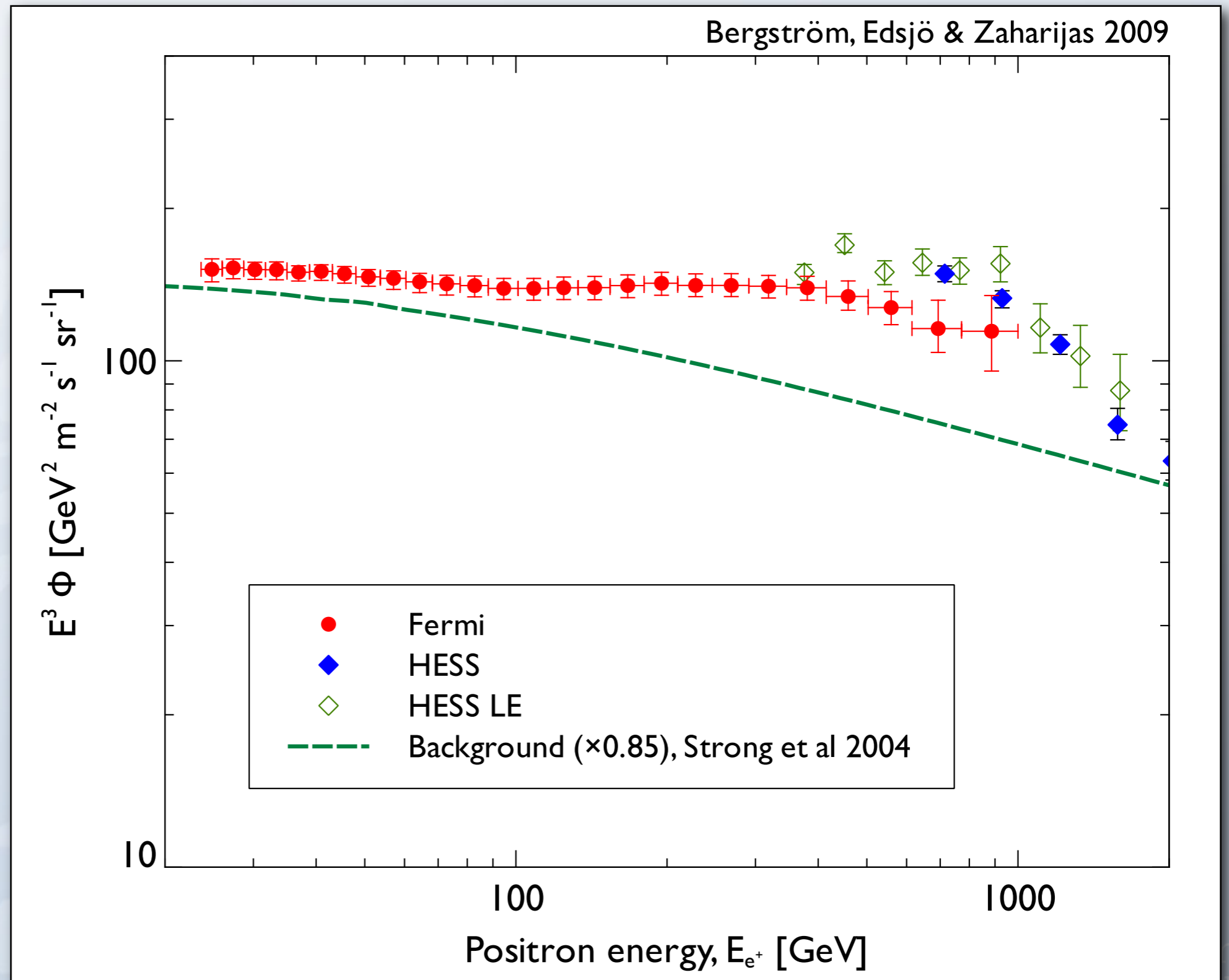

Bergström, Edsjö & Zaharijas 2009

Legend:
- Fermi
- HESS
- HESS LE
- ATIC 1+2+4
- PPB-BETS
- Background, Strong et al 2004

Y-axis: $E^3 \Phi$ [GeV^2 m^{-2} s^{-1} sr^{-1}]

X-axis: Positron energy, E_{e^+} [GeV]

Data and background - e⁺+e⁻

- Remove ATIC and PPB-BETS for the moment (ATIC peak not seen by HESS and Fermi)

Bergström, Edsjö & Zaharijas 2009

Legend:
- Fermi
- HESS
- HESS LE
- Background, Strong et al 2004

Axes: $E^3 \Phi$ [GeV^2 m^{-2} s^{-1} sr^{-1}] vs Positron energy, E_{e^+} [GeV]
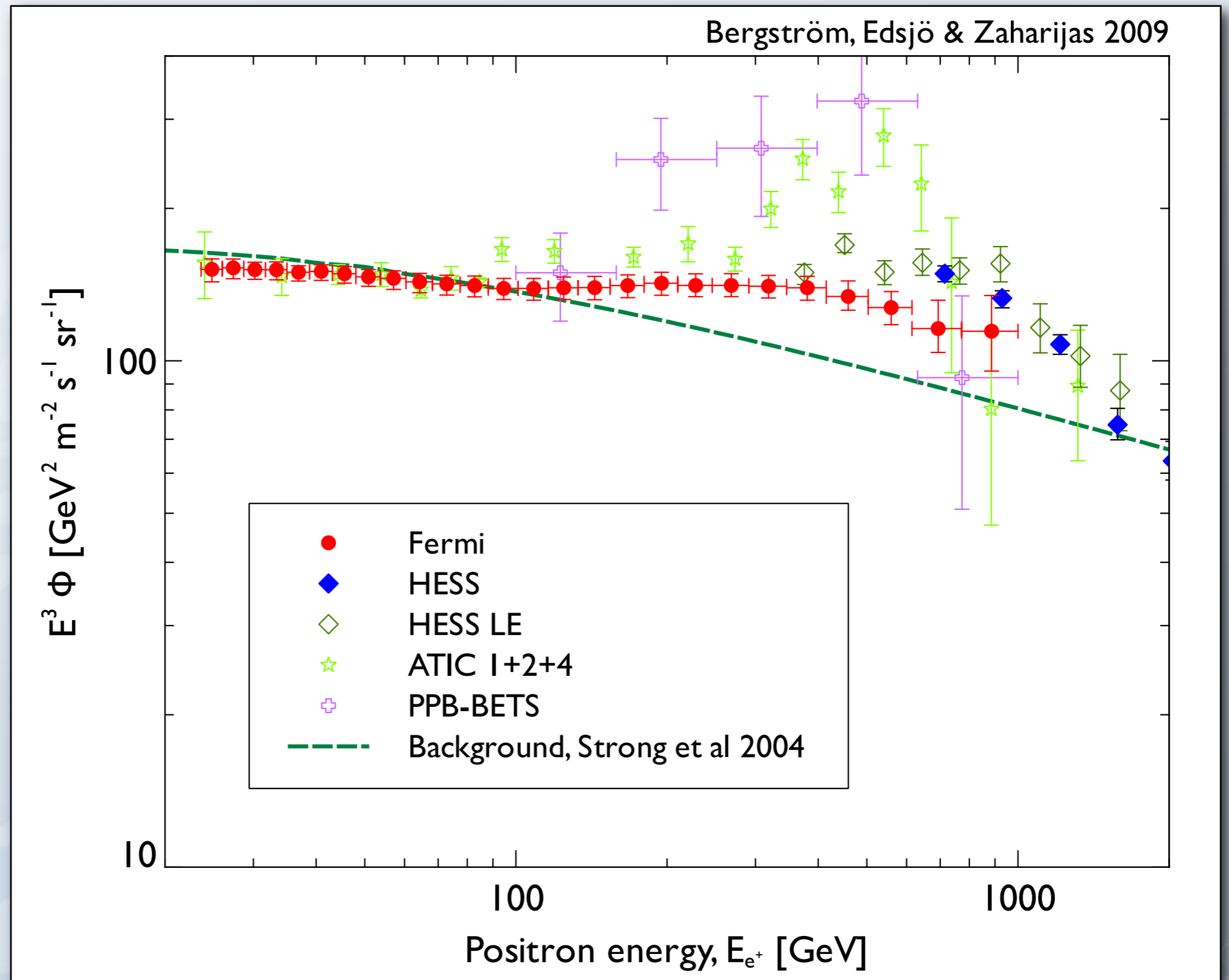
Data and background - e⁺+e⁻

- Rescale background with factor 0.85 (within systematic uncertainties)

Bergström, Edsjö & Zaharijas 2009

Legend:
- Fermi (red circles)
- HESS (blue diamonds)
- HESS LE (open green diamonds)
- Background (×0.85), Strong et al 2004 (dashed line)

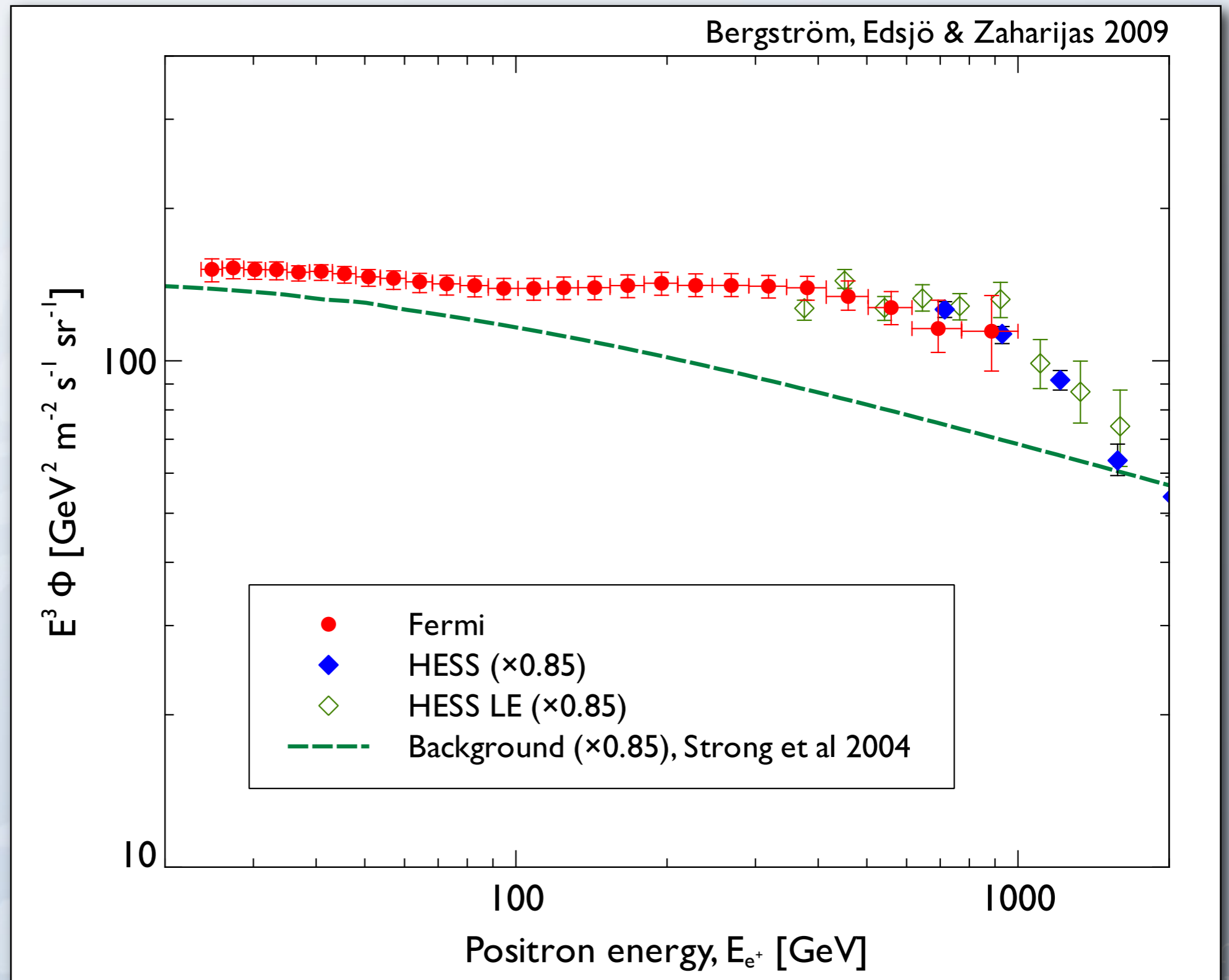Axes: $E^3 \Phi$ [GeV^2 m^{-2} s^{-1} sr^{-1}] vs Positron energy, E_{e^+} [GeV]
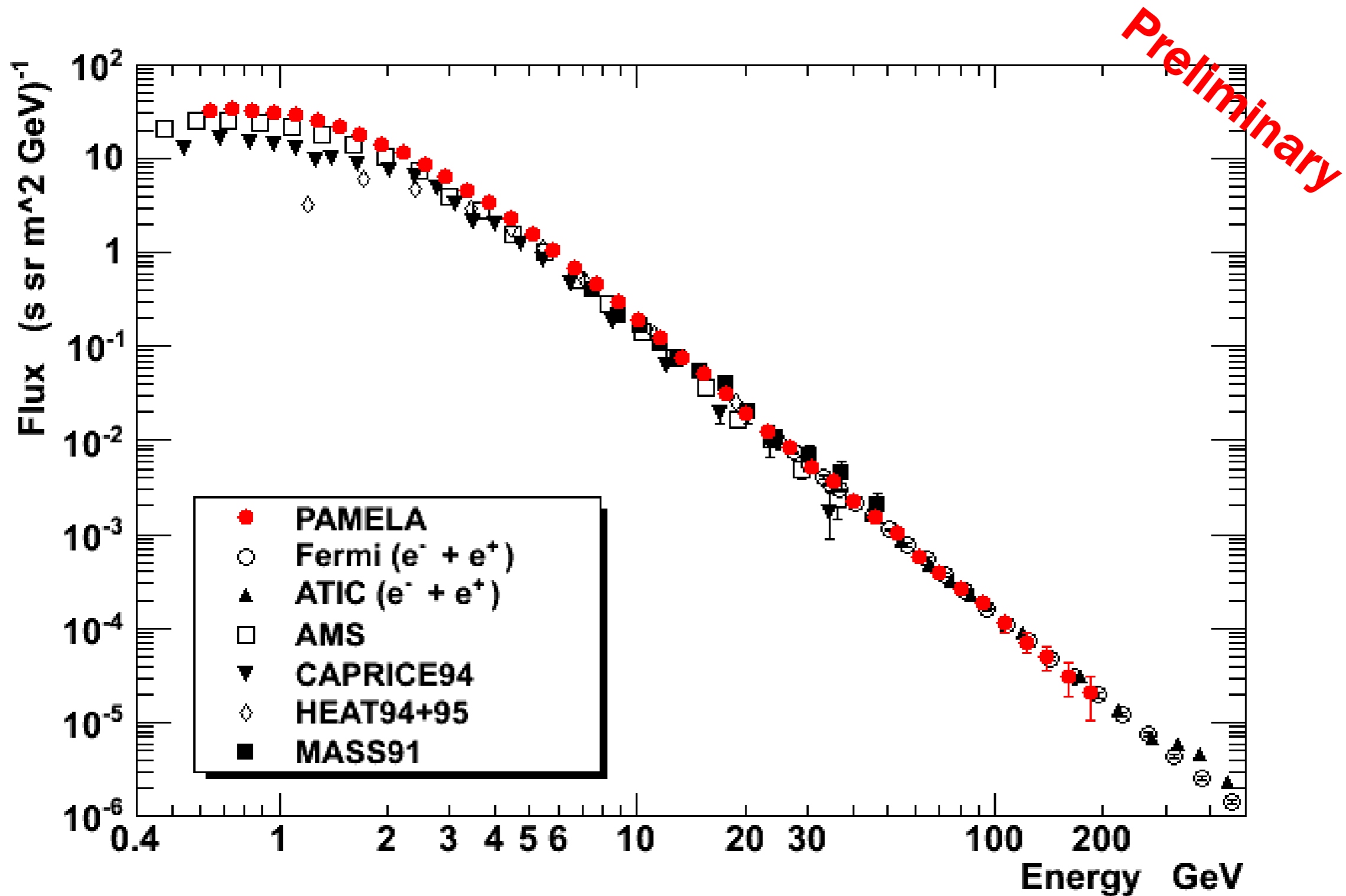
Data and background - e⁺+e⁻

- Rescale HESS with factor 0.85 (within systematic uncertainties)

- Good agreement between Fermi and HESS data.
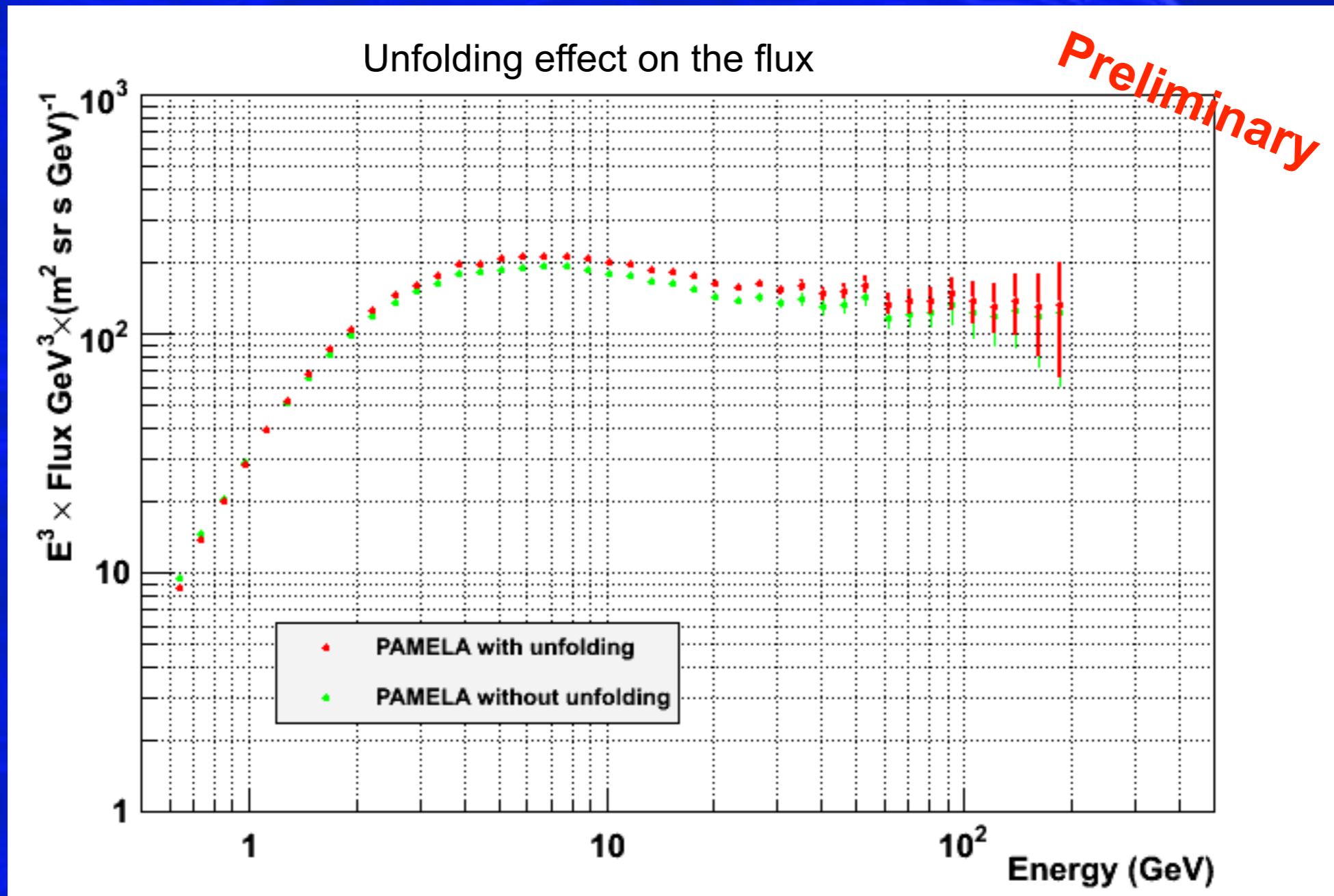
- Pre-Fermi background falls too steep.

Bergström, Edsjö & Zaharijas 2009

Legend:
- Fermi
- HESS (×0.85)
- HESS LE (×0.85)
- Background (×0.85), Strong et al 2004

Axes: $E^3 \Phi$ [GeV² m⁻² s⁻¹ sr⁻¹] vs Positron energy, E_{e^+} [GeV]

PAMELA Electron (e⁻) Spectrum

See E. Mocchiutti's talk

Boezio

Comment: Should experiments present unfolded fluxes?

Electron flux - tracker-based

Unfolding effect on the flux

Preliminary

Legend:
- PAMELA with unfolding (red)
- PAMELA without unfolding (green)

Y-axis: $E^3 \times$ Flux GeV$^3 \times$(m^2 sr s GeV)$^{-1}$

X-axis: Energy (GeV)

Propagation

- By the summer of 2010, we should have at least three new code releases:

  - Galprop (numerical), Strong

  - USINE (semi-analytical), Maurin

  - Dragon (numerical), Maccione

- All of which should have interfaces to DarkSUSY and other signal codes
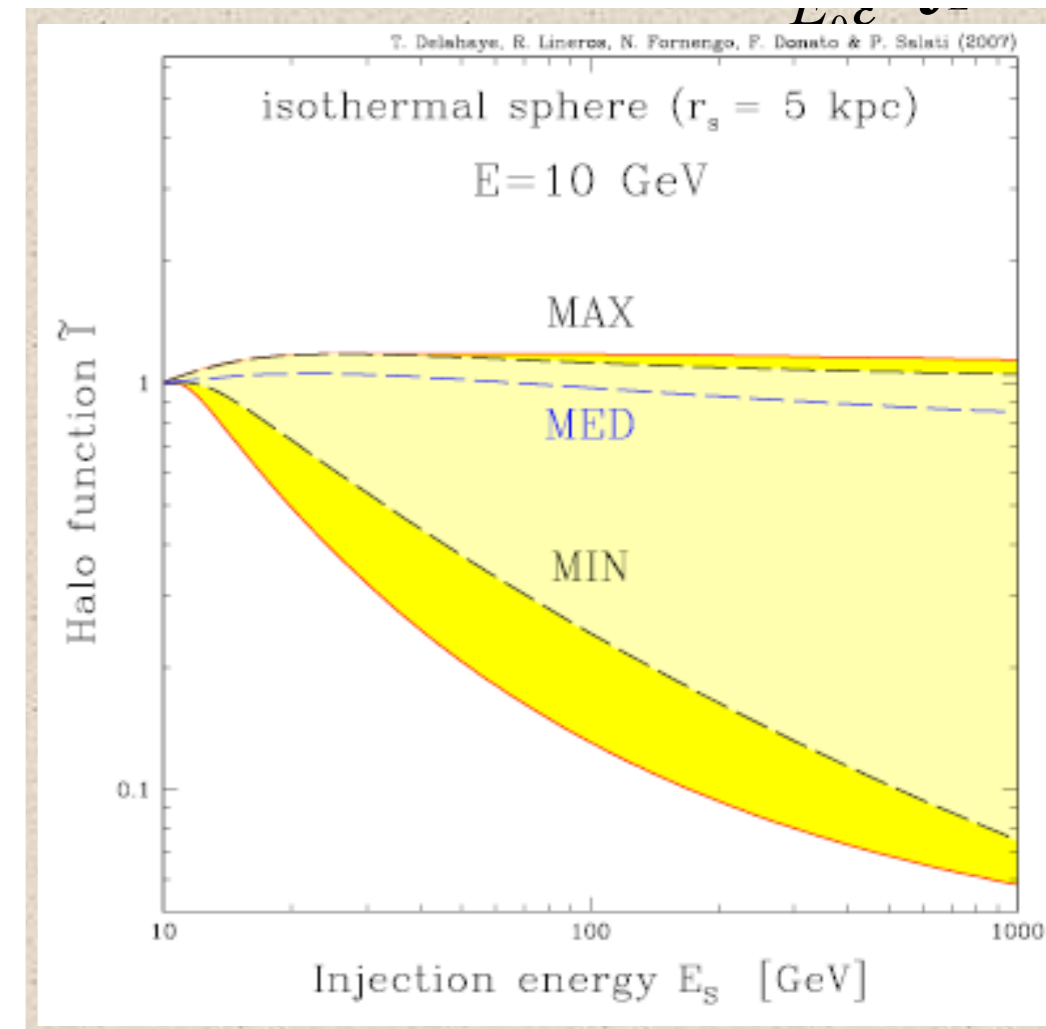
Some recent developments

- Better interstellar radiation field estimates (Porter/Galprop) and energy losses (Delahaye)

- Inhomogenous source distribution (Delahaye, Piran, Serpico, ...)

Local sources — Delahaye
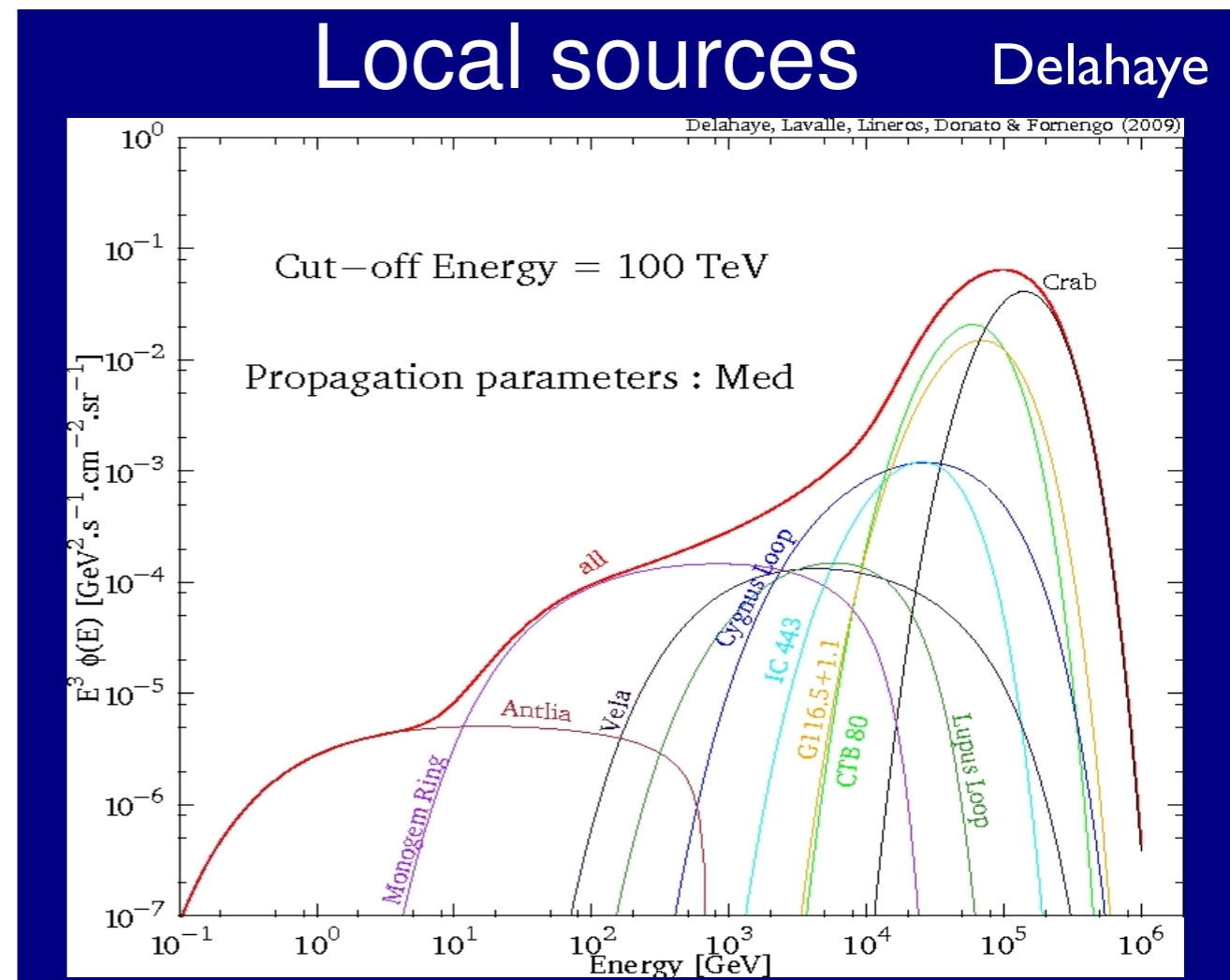
Degeneracy

- Degeneracy in D/L for fits to heavier isotopes (B/C, ...).

- However, DM signal typically increases with L (as our diffusion box includes more sources)

- Additional uncertainty on the dark matter signal (Delahaye, Donato, ...)

T. Delahaye, R. Lineros, N. Fornengo, F. Donato & P. Salati (2007)

isothermal sphere (r_s = 5 kpc)

E=10 GeV

MAX

MED

MIN

Global fits

- MCMC fitting of parameters being carried out:

  - Putze et al using USINE

- Similar efforts being carried out with other codes
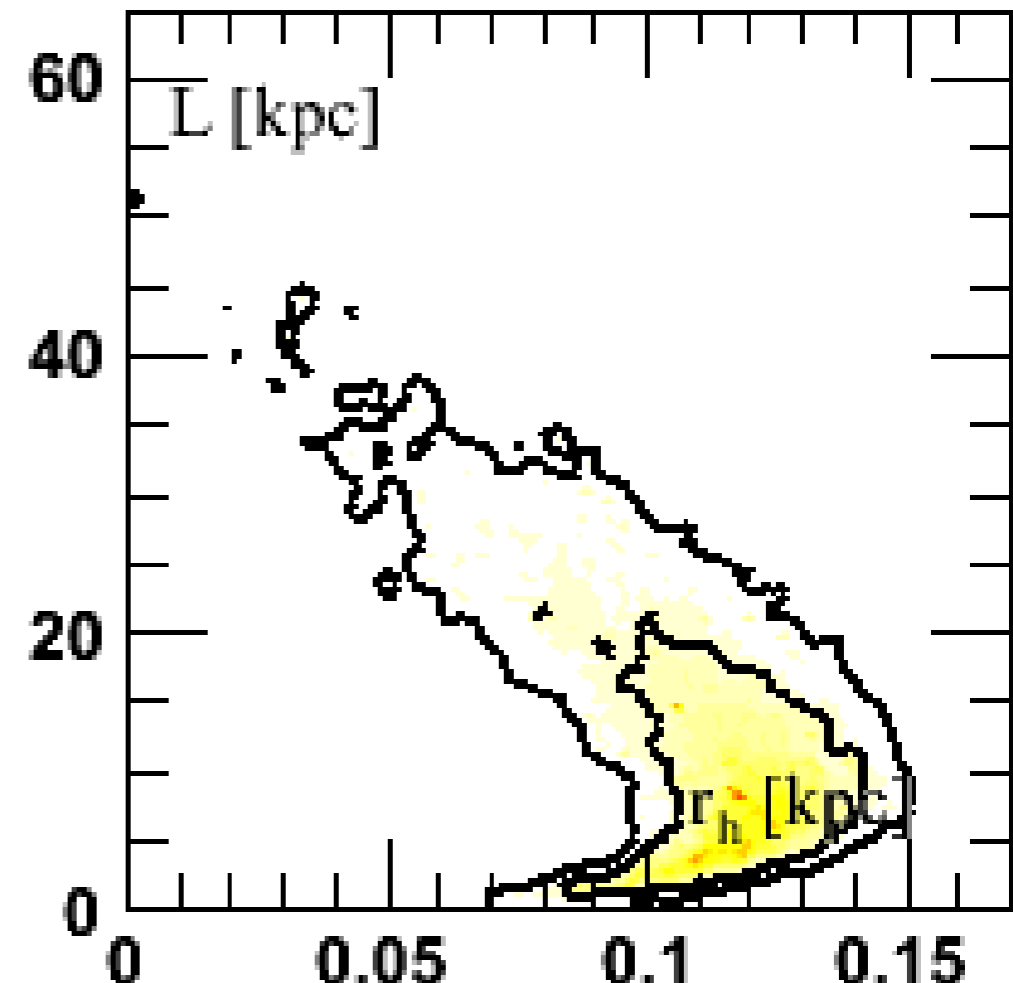
Astrophysical sources

- Pulsars getting better understood (outer gap seems preferred). Could likely give enough electrons/positrons. Not well-enough understood to give precise predictions.

  Bregeon, Serpico, Bucciantini, ...

- SNR likely source for CR. Reacceleration at shock fronts could give extra positrons, but also increased fluxes of heavier elements. Possibly at tension with data. Could be tested by e.g. Pamela

  Blasi, Mertsch, ...

Panov *et al.* (ATIC), ICRC 2007
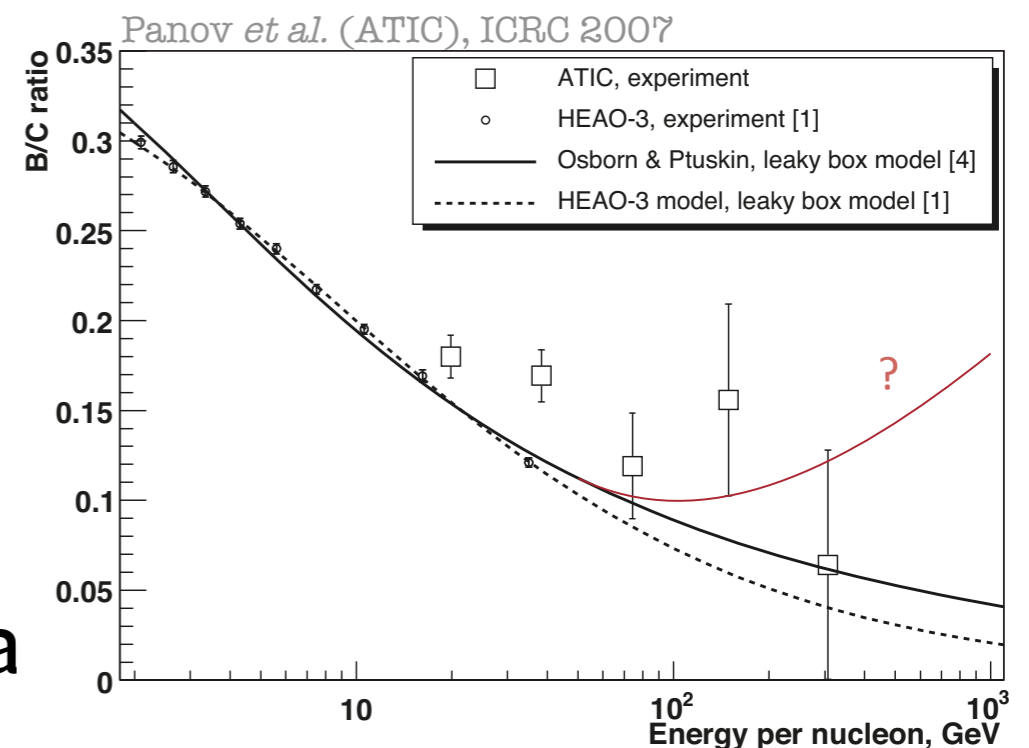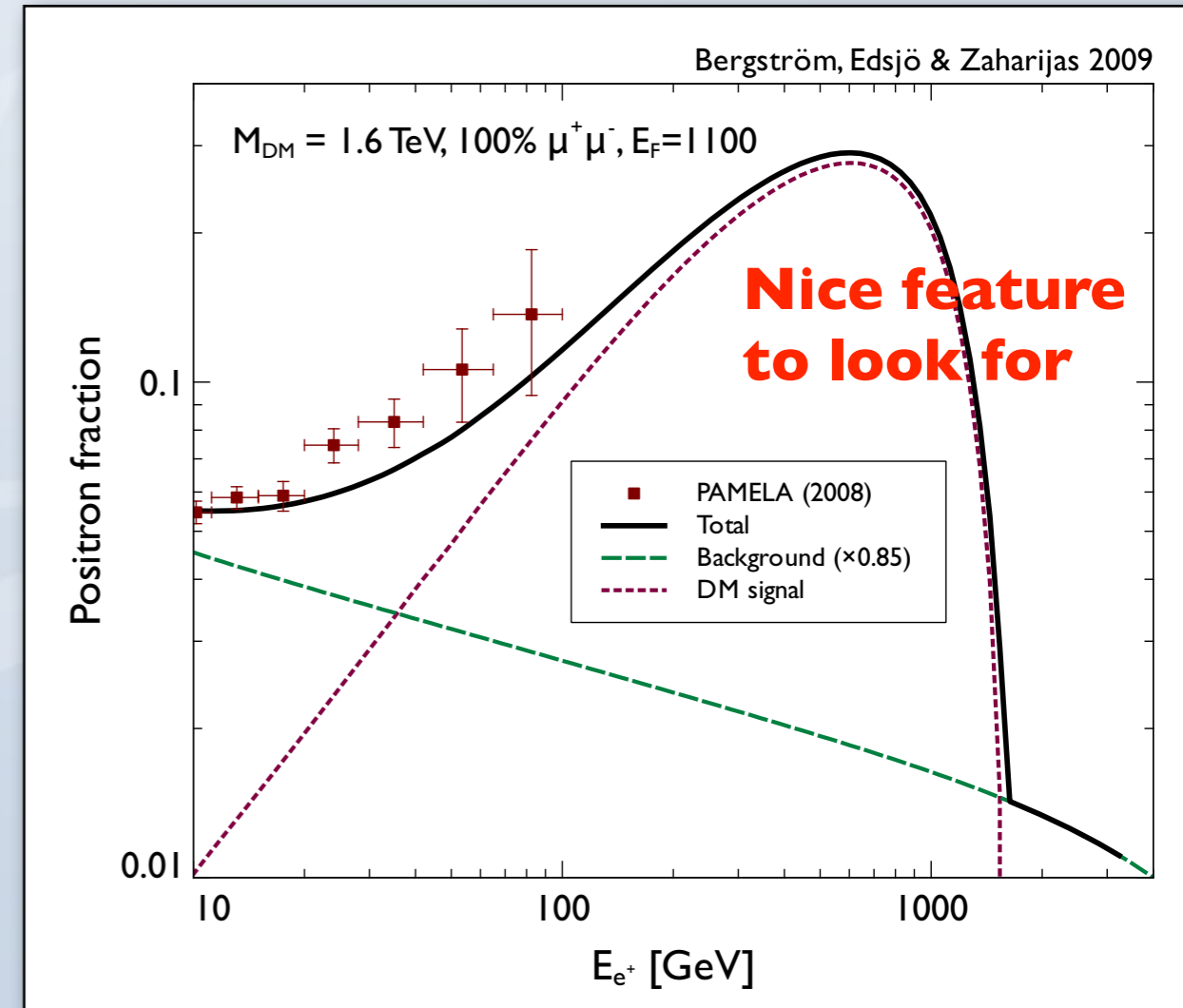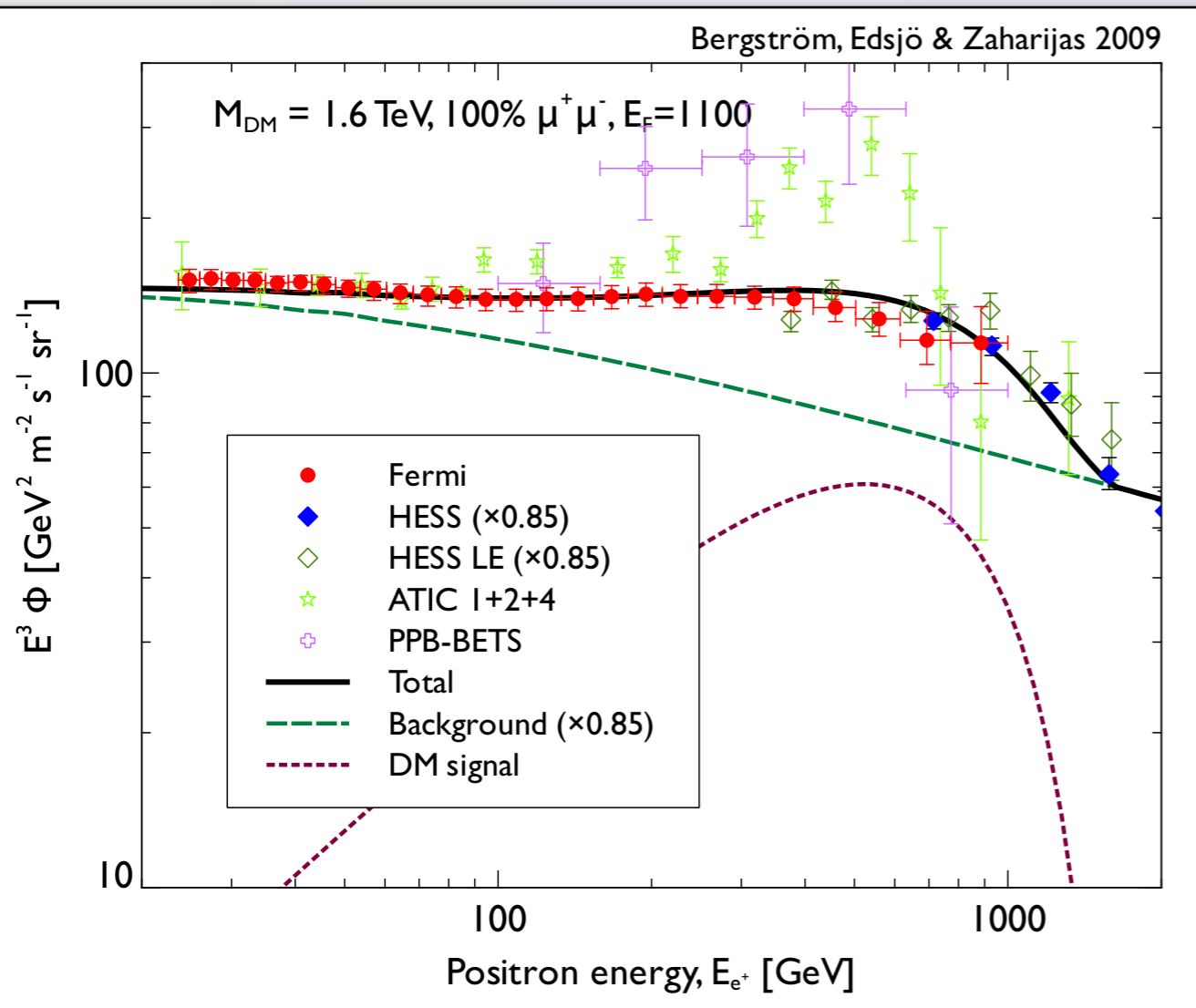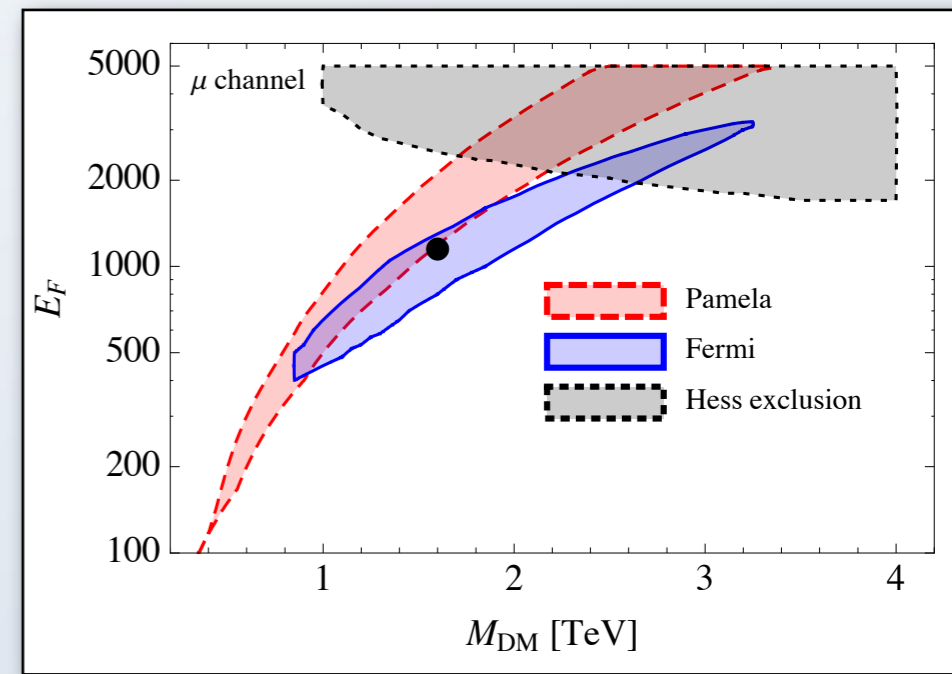
Dark matter fits

- Dark matter is **not** ad hoc, we have strong evidence for the existence of dark matter. However...

- ...off the shelf, standard dark matter models do not work.

- ...need boost: Sommerfeld, non-standard early Universe, non-thermal production, ...

Dark matter models

- WIMPs

  - Neutralinos

  - Leptophilic models

  - Sommerfeld boosted models

- Axions

- ...

Results – μ channel

Bergström, Edsjö & Zaharijas 2009

$M_{DM} = 1.6$ TeV, 100% $\mu^+\mu^-$, $E_F=1100$

Legend:
- Fermi
- HESS (×0.85)
- HESS LE (×0.85)
- ATIC 1+2+4
- PPB-BETS
- Total
- Background (×0.85)
- DM signal

$E^3 \Phi$ [GeV^2 m^{-2} s^{-1} sr^{-1}]

Positron energy, E_{e^+} [GeV]

Bergström, Edsjö & Zaharijas 2009

$M_{DM} = 1.6$ TeV, 100% $\mu^+\mu^-$, $E_F=1100$

Nice feature to look for

Positron fraction

- PAMELA (2008)
- Total
- Background (×0.85)
- DM signal

E_{e^+} [GeV]

μ channel

E_F

M_{DM} [TeV]

- Pamela
- Fermi
- Hess exclusion

L. Bergström, J. Edsjö & G. Zaharijas,
PRL, arXiv:0905.0333

Good fits to Fermi, HESS and PAMELA data

Stockholm University

Consistency

- Need to use more realistic models than is used in most analyses with realistic background estimates

- Need to calculate all fluxes (e^+, antiprotons, antideuterons, radio, IR, X-rays, γ, ...) from all sources (SNR, pulsars, DM, ...) in a consistent framework

Donato, Ullio, Cuoco, ...

Donato: "It is not hopeless, simply difficult!"

Ullio: Hard to extract information on DM properties if enhancement comes from substructure.

Pulsars (Serpico, Bucciantini)	New SNRs mechanisms (Blasi, Mertsch)	Localized SNR (Piran)	Dark matter (Donato, Ullio, Gaggero, Cuoco)	?
Uncertainties				
• Acceleration model (polar cap, outer gap, …) • Injection spectrum $E^{-\alpha}$? • Release into the ISM (when, how much?) • Source locations, ages, …	• Environmental parameters at SNR (production mechanism) • Distance to closest source • Cut-off energies • …	• Source properties • Local environment • Diffusion model • …	• Particle physics model • Particle physics enhancement (Sommerfeld) • Substructure enhancement (halo model) • …	?
Tests				
• Anisotropy of flux • Fluctuations in spectrum (arXiv: 0903.1310) • consistency checks (gamma, X-ray, …)	• Antiproton fluxes • Secondary nuclei	• Positron fraction down at several hundred GeV • B/C, antiprotons • Anisotropy	• FSR & IC photons • Continuing positron fraction rise • CMBR distortions • LHC signatures	?

+ need updated background model (with e.g. proper handling of local sources)

Stockholm University

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Thanks for coming and contributing to this workshop!

Mirko Boezio, Jan Conrad, Alessandro Cuoco,
Joakim Edsjö, Klas Hultkvist, Mark Pearce, Antje Putze,