CR propagation with numerical codes

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Outline

- Some generalities on CR
- How to determine the most important propagation parameters
- Results from CR nuclei and antiprotons
- News from leptons and gamma-rays

CR propagation

How to cast the problem?

$$n(E,\vec{r}_{\rm obs}) = \int_0^\infty dt \int d^3r_0 \int dE_0 \underbrace{\boxed{q(E_0,\vec{r}_0,t)}}_{\text{source function}} \underbrace{\boxed{f(E,\vec{r}_{\rm obs};E_0,\vec{r}_0,t)}}_{\text{propagation probability function}}$$

$$\phi = \frac{c\beta}{4\pi} n$$

Extremely complicated problem: needs simplifications

CR propagation

CRs obey essentially a diffusion equation (**Ginzburg & Syrovatsky, 1964**)

Diffusion tensor
$D(E) = D_0\,(\rho/\rho_0)^{\delta}$
$\rho = \text{rigidity} \sim p/Z$

Convection term

Energy loss

Reacceleration
$D_{pp} \propto \dfrac{p^2 v_A^2}{D}$

$$\frac{\partial N^i}{\partial t} - \nabla\cdot(D\,\nabla - v_c)N^i + \frac{\partial}{\partial p}\left(\dot{p} - \frac{p}{3}\nabla\cdot v_c\right)N^i - \frac{\partial}{\partial p}p^2 D_{pp}\frac{\partial}{\partial p}\frac{N^i}{p^2} =$$

$$= Q^i(p,r,z) + \sum_{j>i} c\beta n_{\rm gas}(r,z)\sigma_{ji}N^j - c\beta n_{\rm gas}\sigma_{\rm in}(E_k)N^i$$

SN source term.
We assume everywhere
a power law energy spectrum

Spallation cross section. Appearance of nucleus i due to spallation of nucleus j

Total inelastic cross section.
Disappearance of nucleus i

The height of the propagation/diffusion region is z_t $\quad D_0(z) \propto e^{z/z_t}$

Several approximations: stationary solution, smoothed source distribution… Turn out to be surprisingly good for hadronic cosmic rays.

Equation solvers...

Several ways of solving the diffusion equation:

- **leaky-box models**: $\boxed{D(E) \leftrightarrow \tau_{\rm esc}(E)}$
  Analytic and surprisingly meaningful solutions. Benchmark model!

- **semi-analytic models** assume simplified distributions for sources and gas, and try to solve the diffusion equation analytically (Maurin, Salati, Donato et al)
- **numerical models** (Galprop) try to use more realistic distributions

A new numerical model: DRAGON (Diffusion of cosmic RAys in the Galaxy modelizatiON)

Features (w.r.t. Galprop):
- same fragmentation cross sections
- position dependent, anisotropic diffusion
- boundary conditions in momentum and at R=0
- independent injection spectra for each nuclear species
- same results in same conditions
- faster (improved treatment of decays)
- interfaced with DarkSUSY
- only 2D
- not public (yet)

References:
C. Evoli et al. JCAP 0810 (2008) 018
G. Di Bernardo et al. arXiv:0909.4548
and works in preparation

Plan of work

Most important propagation parameters: D_0, δ

Standard wisdom: high energy spectra are just the result of diffusion and possibly spallation

At low energy other processes (reacceleration, convection, energy losses, change of diffusion regime at low energy) are relevant and may mask the effects of diffusion, see e.g. the recent **Maurin et al, 1001.0553 & 1001.0551**, also **Ptuskin et al, ApJ 642 (2006)**

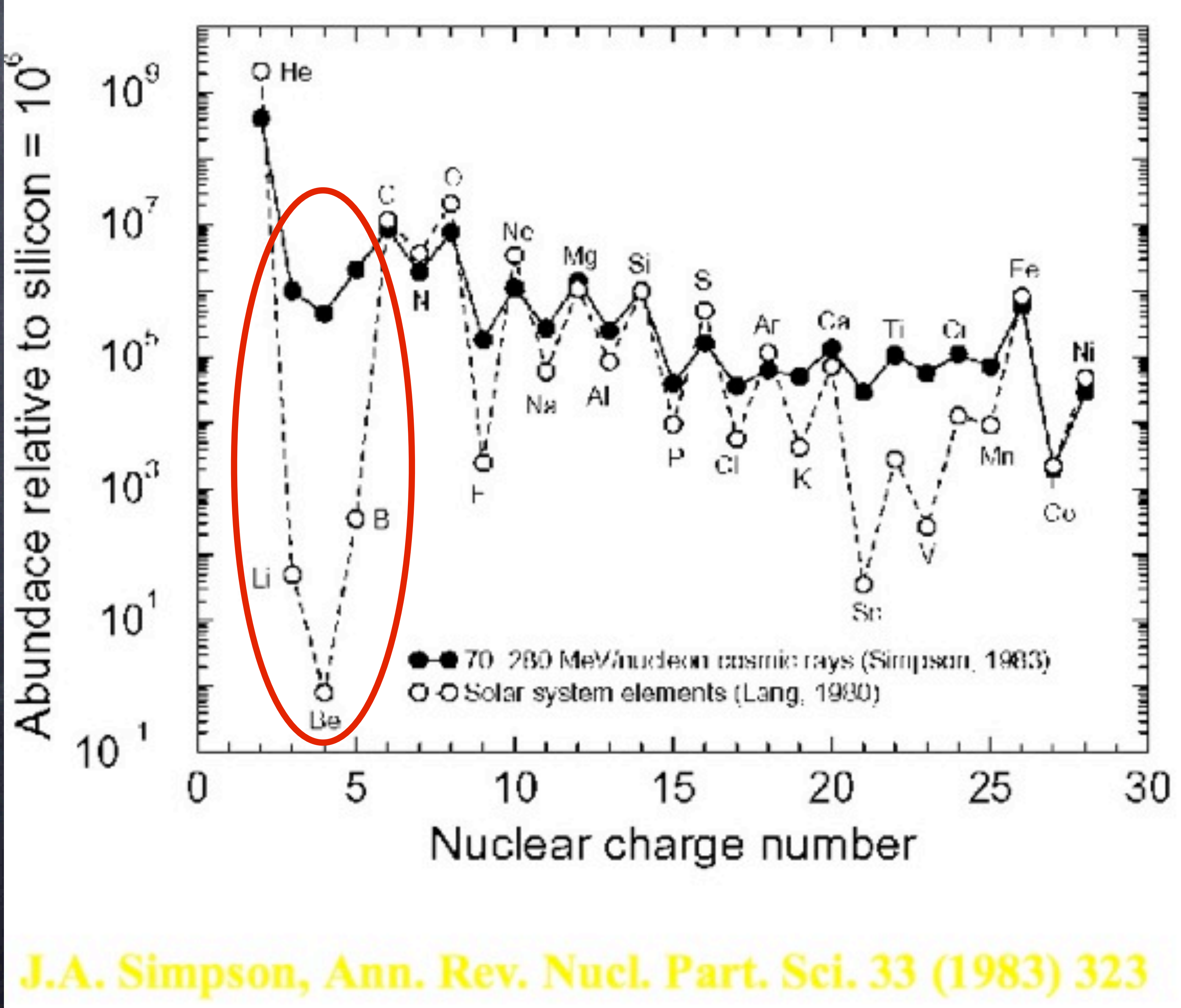
High energy data now available (**CREAM, PAMELA**)

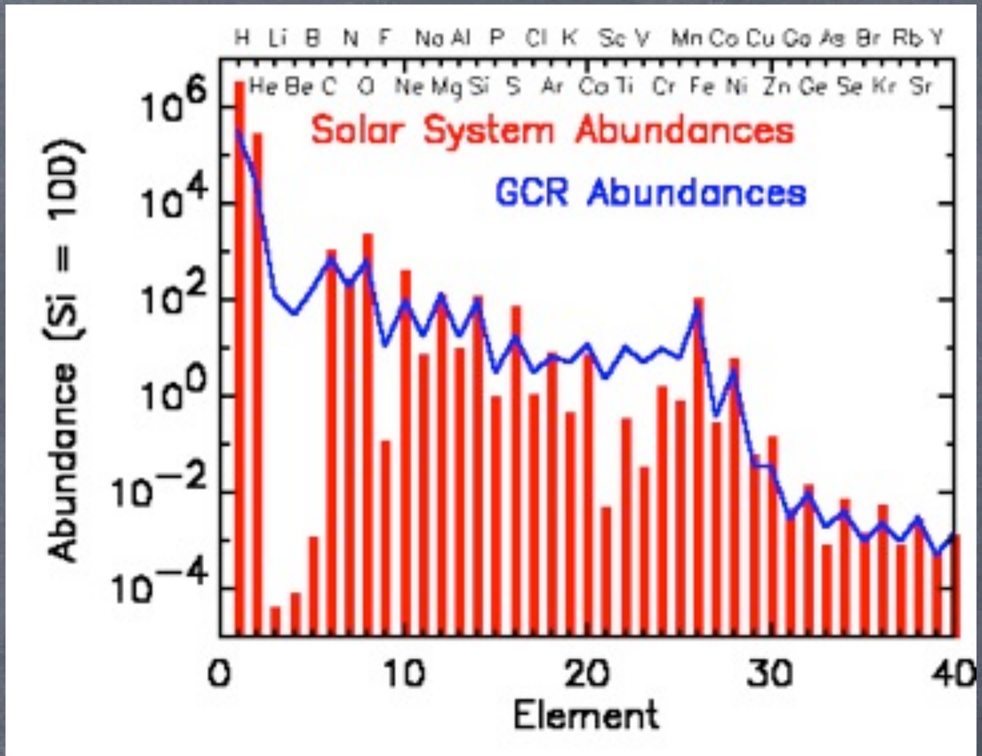
Perform an energy dependent analysis of data, to see where low energy effects kick in and disentangle their effects from diffusion

Final results: learning something about D_0, δ, v_A.

CR abundances

For some nuclei (CNO, Fe) abundances are the same as SSA.
Others (Li,Be,B,F...) are much more abundant.



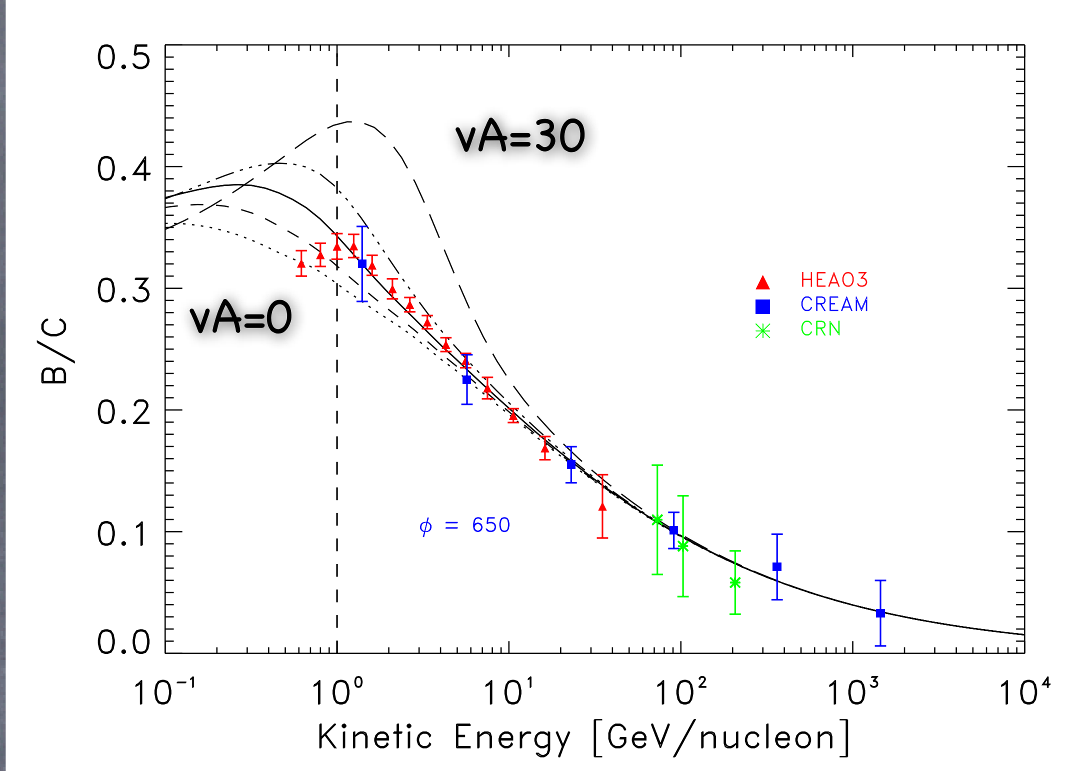


White points: Solar System abundances
Filled points: CR abundances

Secondary nuclei tell us about the diffusive propagation of CRs in the Galaxy

Our tools: secondary to primary ratios

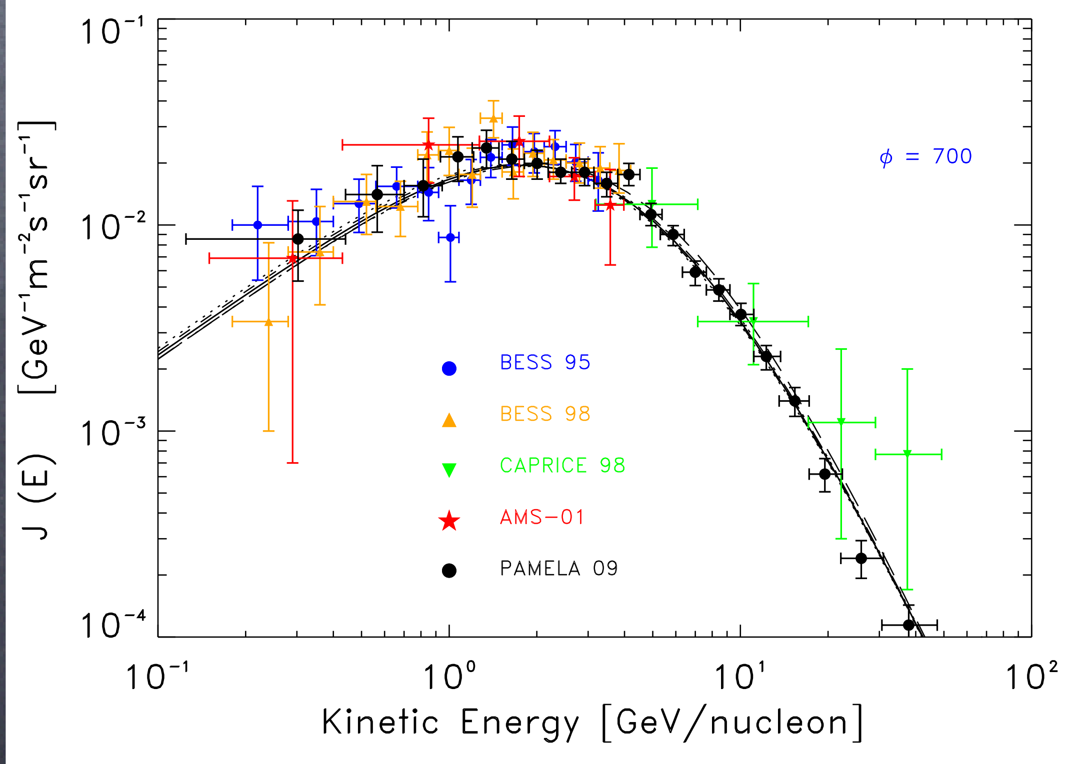
$$\frac{N_{\rm sec}}{N_{\rm pri}} \propto \frac{P_{\rm spall}(E)\tau_{\rm esc}(E)}{\tau_{\rm int}(E)} \to E^{-\delta}$$ at high E



We are interested in mainly in B/C and antiproton/proton ratios

It is very important to consider the high-energy part of these ratios (energy greater than some tens of GeV) because:

- Solar modulation plays a minor role
- Diffusive reacceleration (which introduces a new free parameter, the Alfven velocity) plays a minor role
- Energy losses due to spallation are less important
- Production cross section are known with less uncertainty



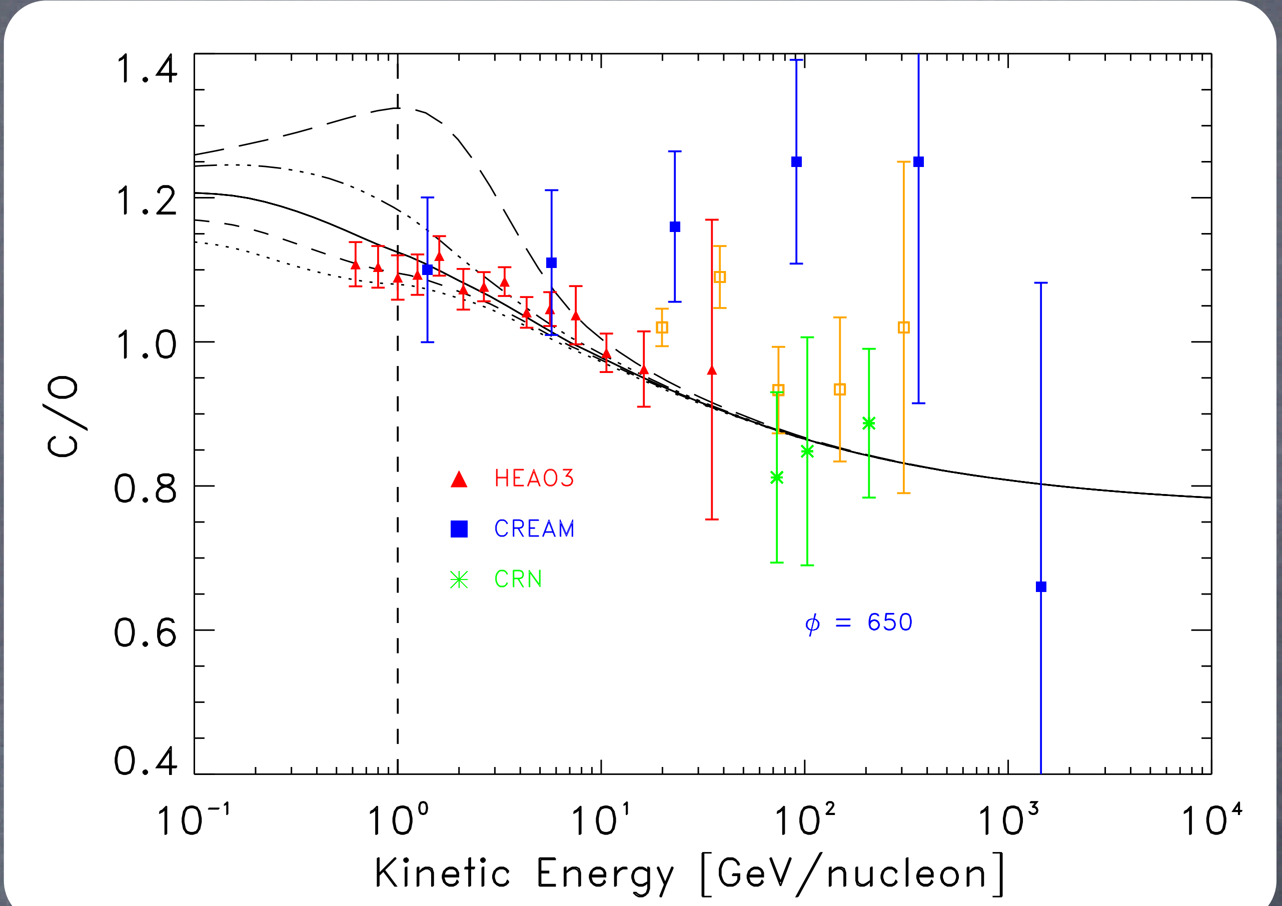
Antiprotons have a unique feature: secondary spectrum affected by threshold effects!

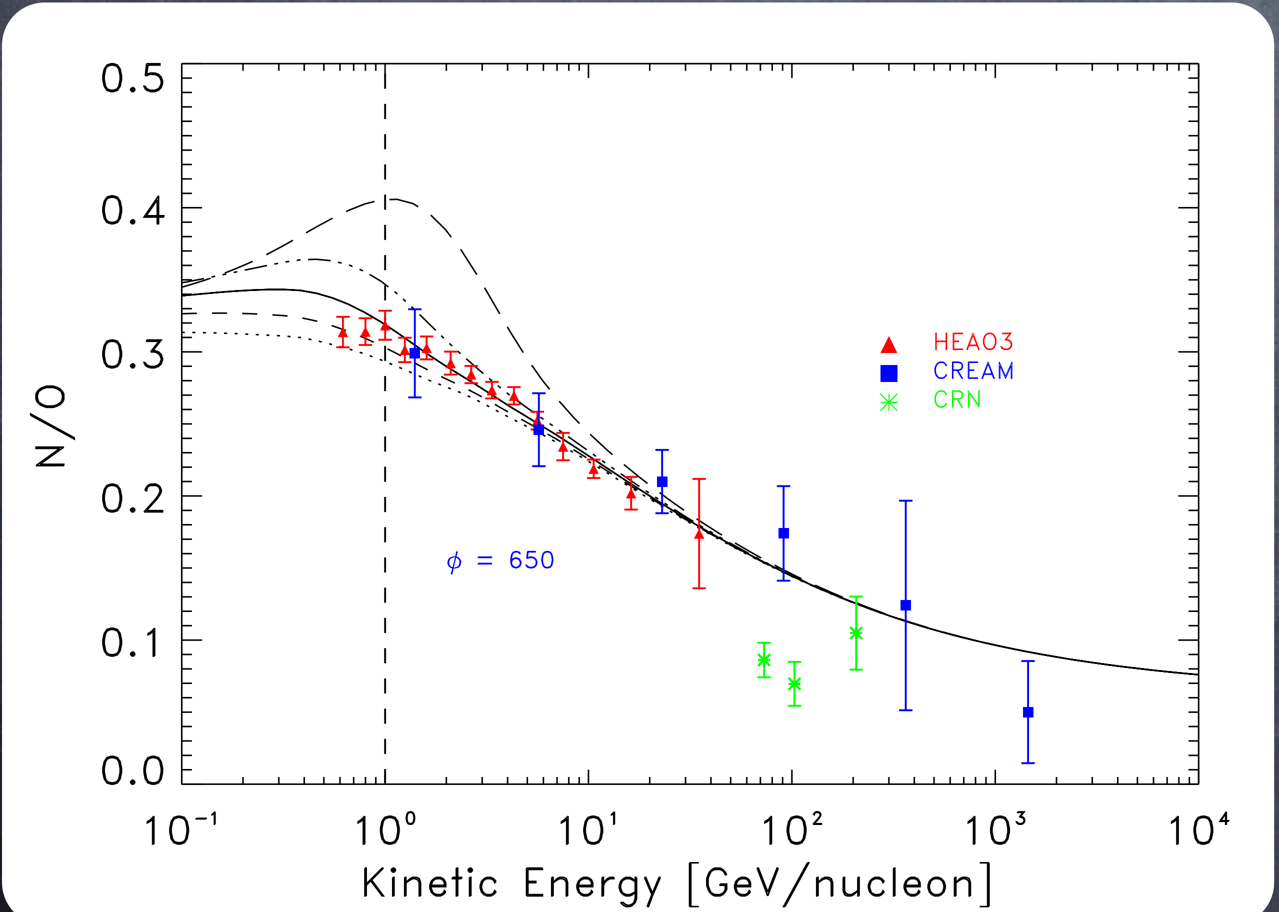
threshold energy ~ 7 GeV (in lab)

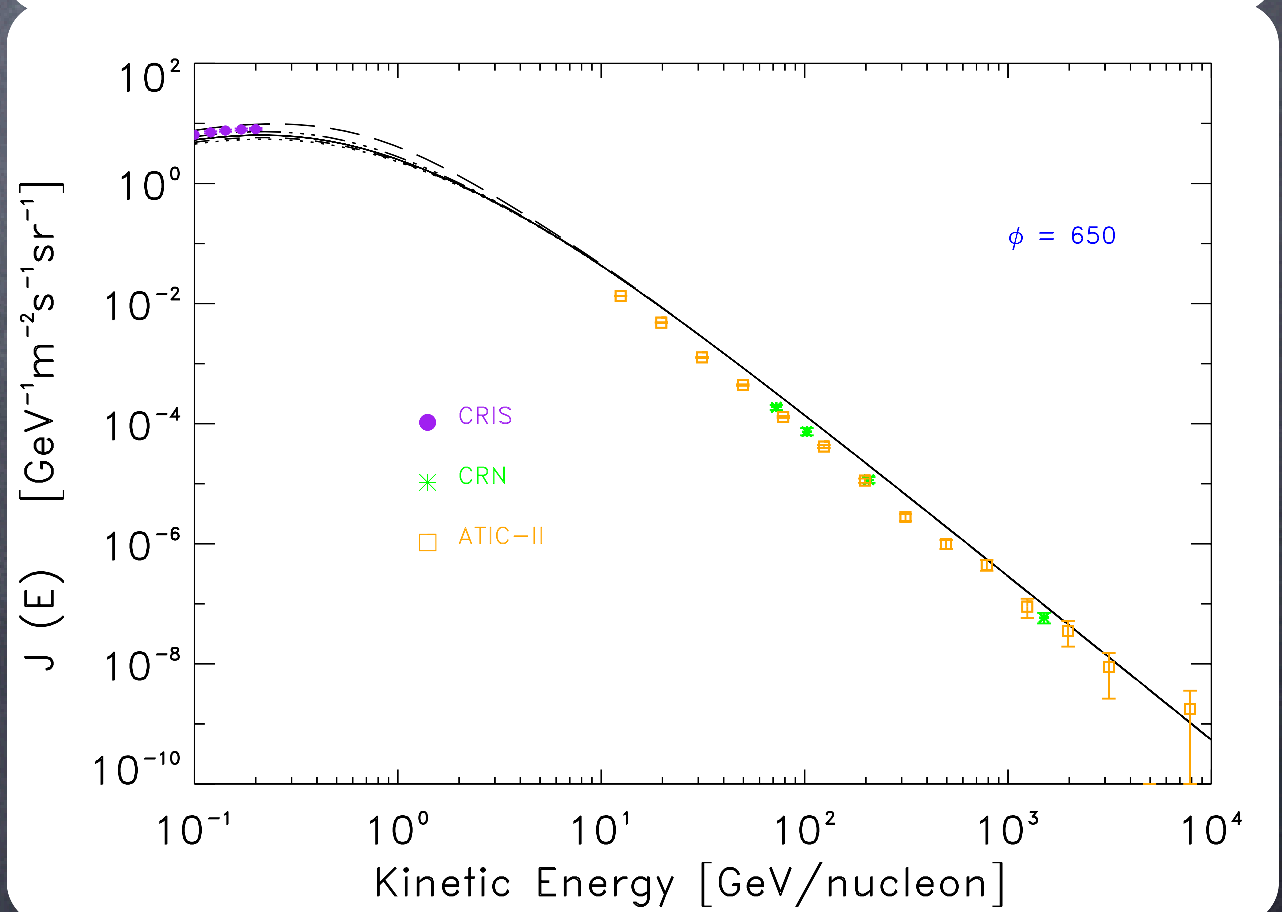
Our tools: secondary to primary ratios

Also data on the main B (and partially C) progenitors are extremely relevant

Also consider N/O and C/O ratios







Secondary/primary in our model

Aim:

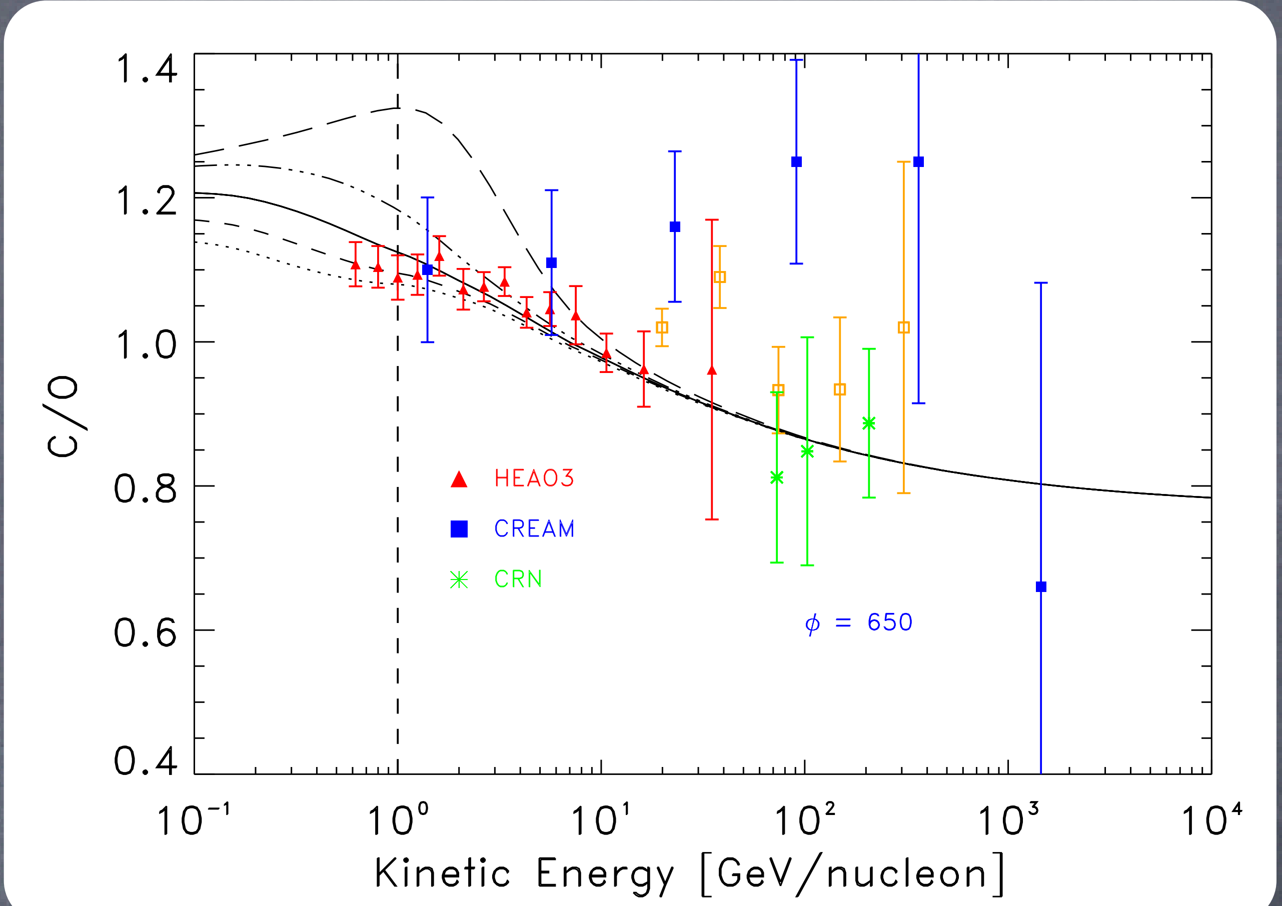
place limits on δ, v_A, D_0 (actually, D_0/z_t is the right quantity)

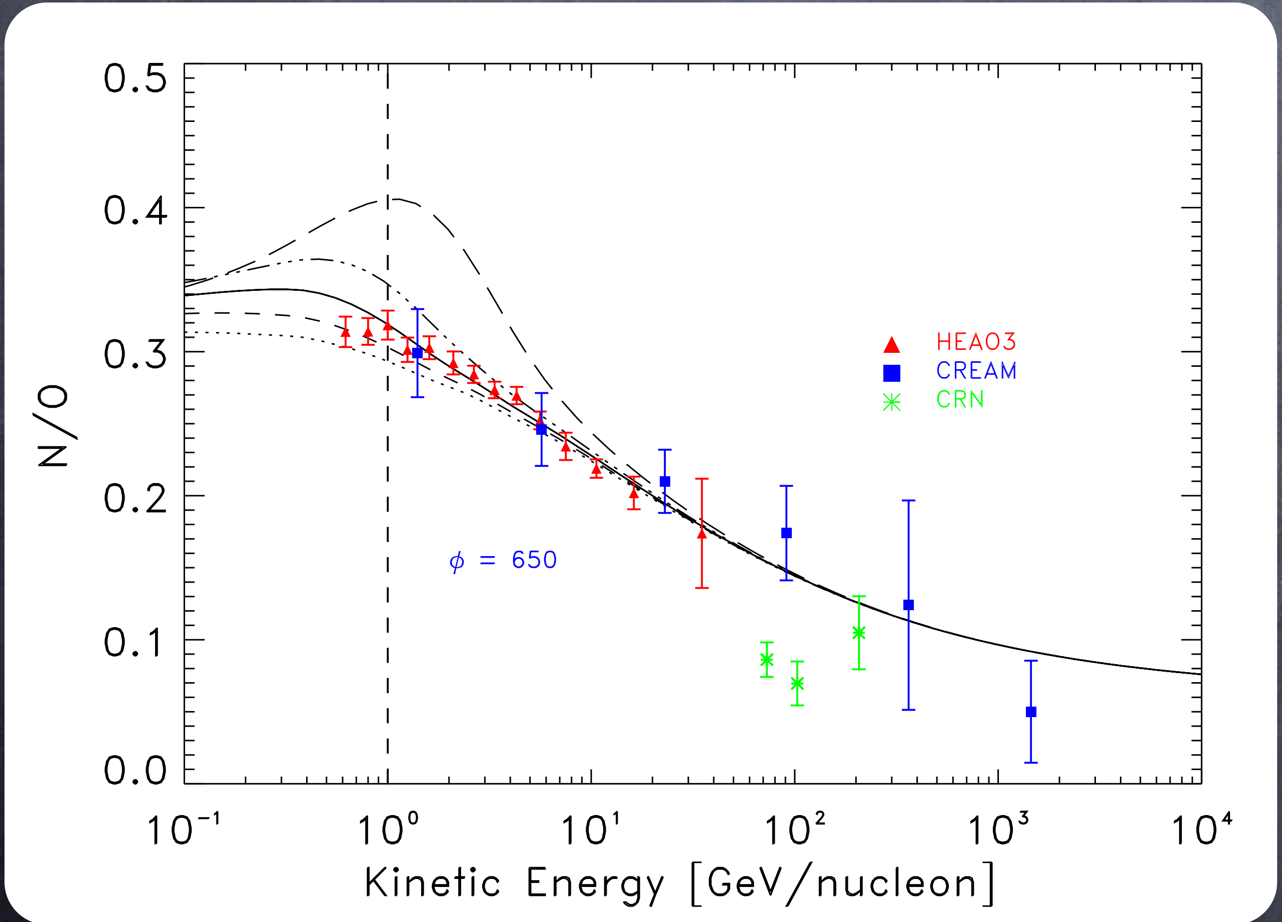
Strategy:

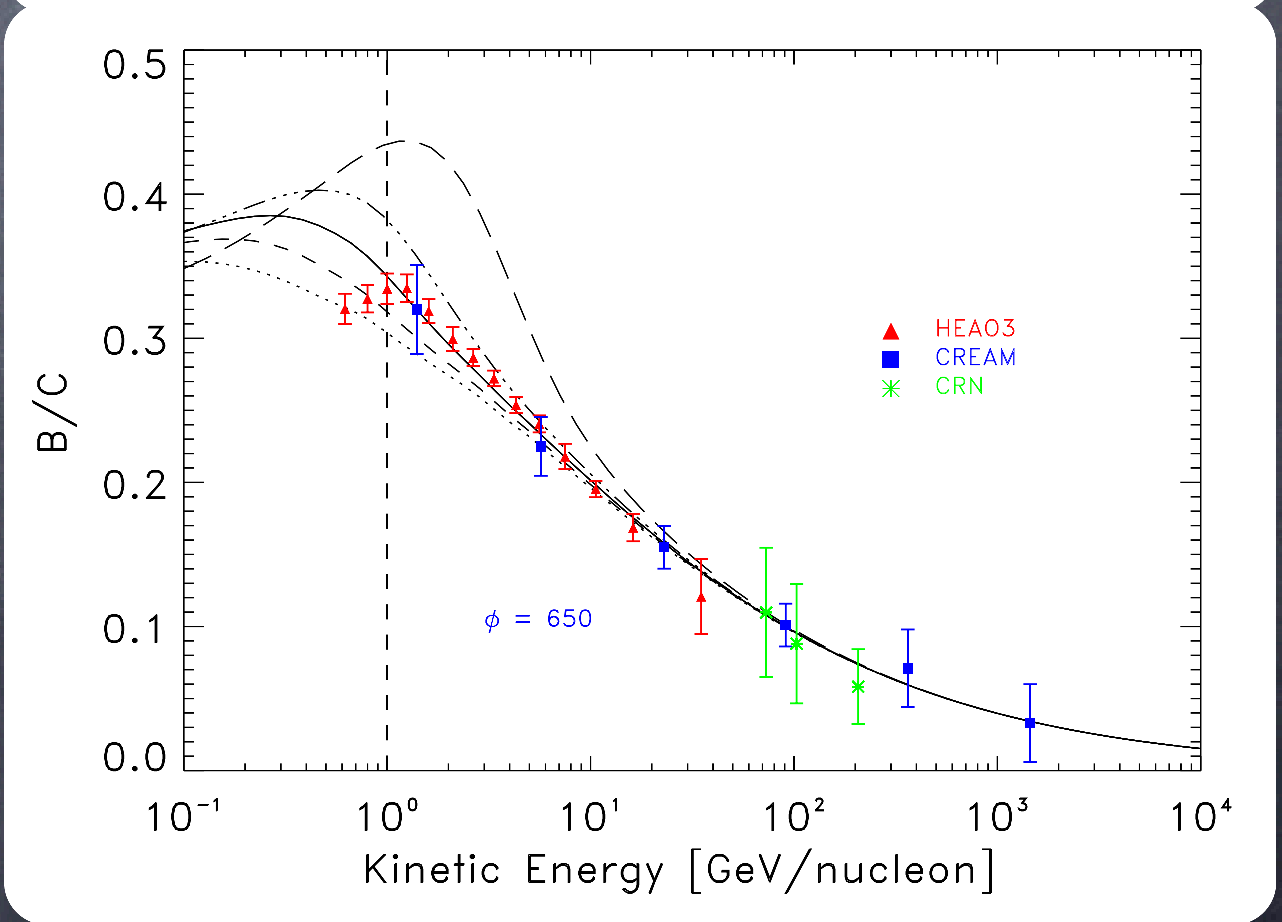
- ✓ for fixed values of the propagation parameters v_A, δ, and D_0/z_t we vary the **C/O and N/O source ratios** to compute the χ^2_{CNO} of the propagated, and modulated, C/O and N/O ratios against experimental data in the energy range 1 GeV < E_k < 1 TeV
- ✓ for the same fixed value of v_A, we finely sample the parameter space (δ, D_0/z_t) by using, for each couple of these parameters, the C/O and N/O source ratios which minimize χ^2_{CNO}; for each of these realizations we compute the χ^2_{BC} for the B/C modulated ratio against data in several energy ranges
- ✓ we repeat the same analysis for several values of v_A to probe the effect of diffusive reacceleration. For each value of v_A we then determine the allowed ranges of δ and D_0/z_t for several Confidence Levels
- ✓ we repeat steps 2 and 3 for the antiproton/proton ratios

Secondary/primary in our model

Dependence of secondary/primary ratios on the reacceleration level in the “best fit” case.
Modulation potential fixed by requiring to reproduce the proton spectrum





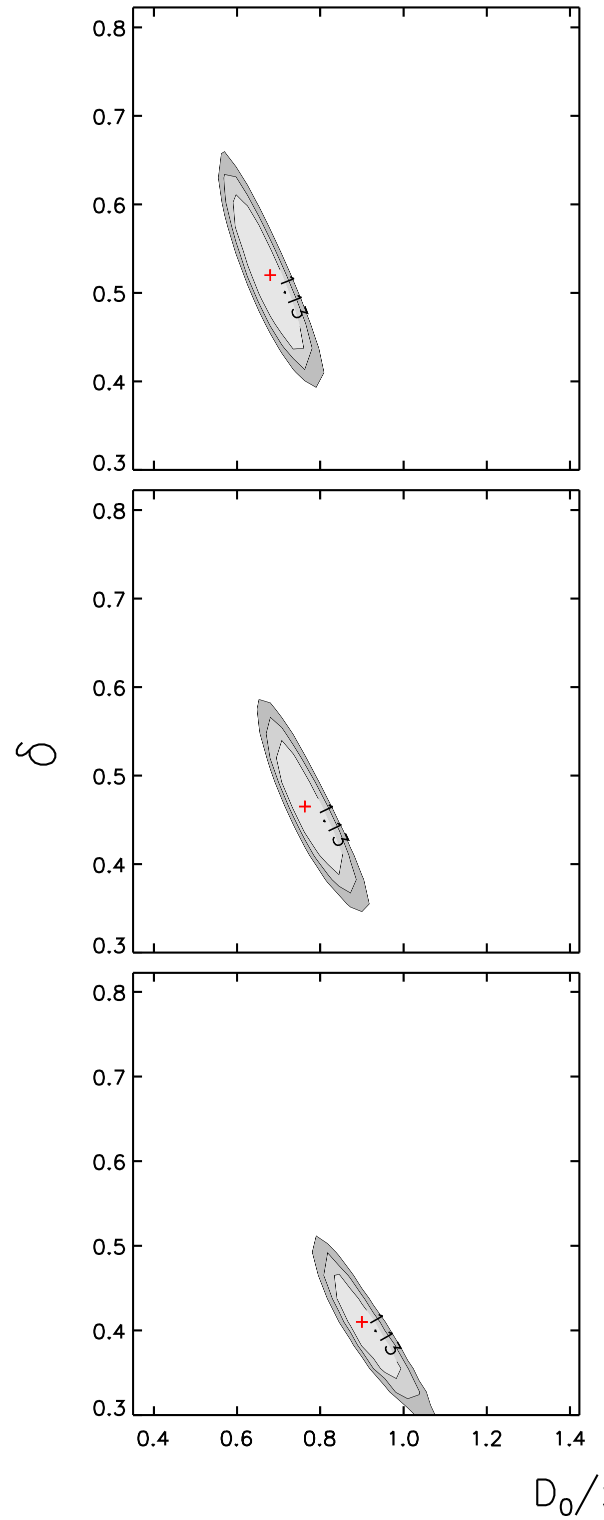


Statistical analysis I

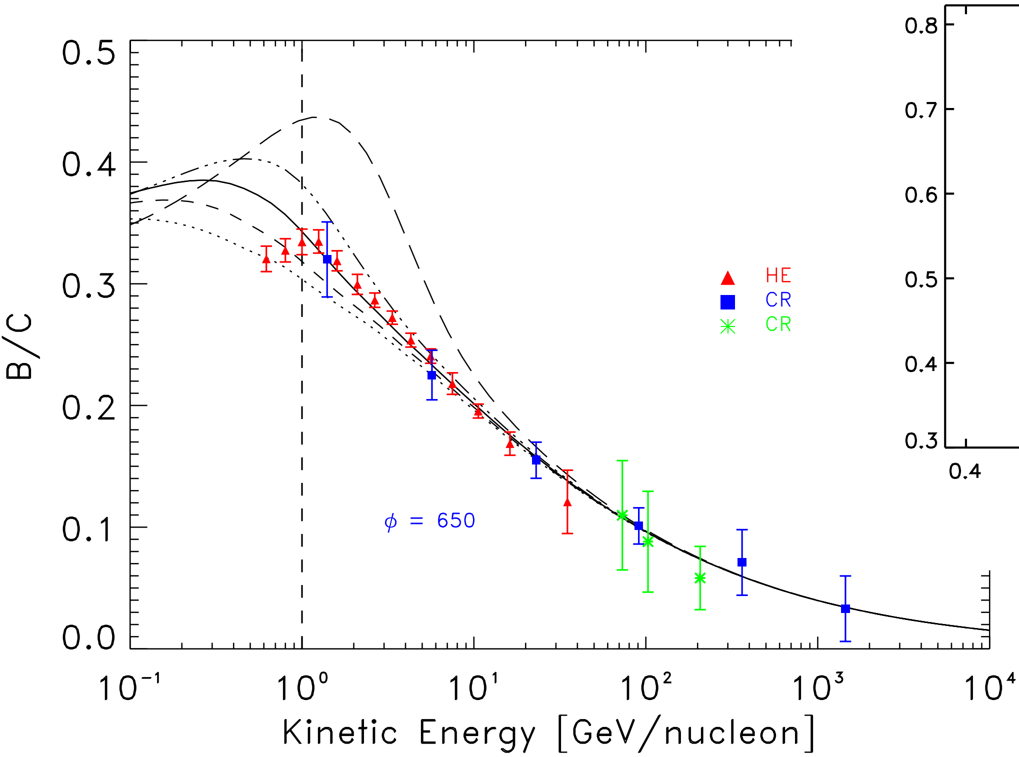
Confidence level contours for various v_A=10,15,20 km/s and E_k^{min} = 1 GeV/n

20 B/C points

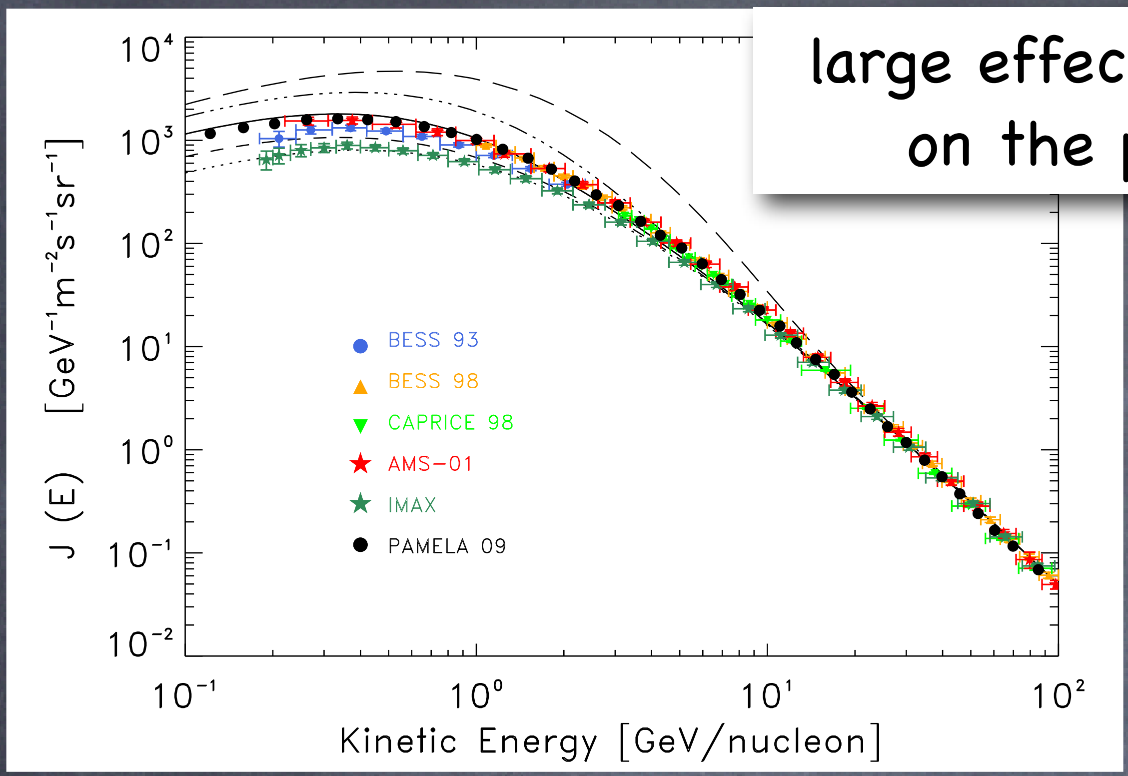
B/C



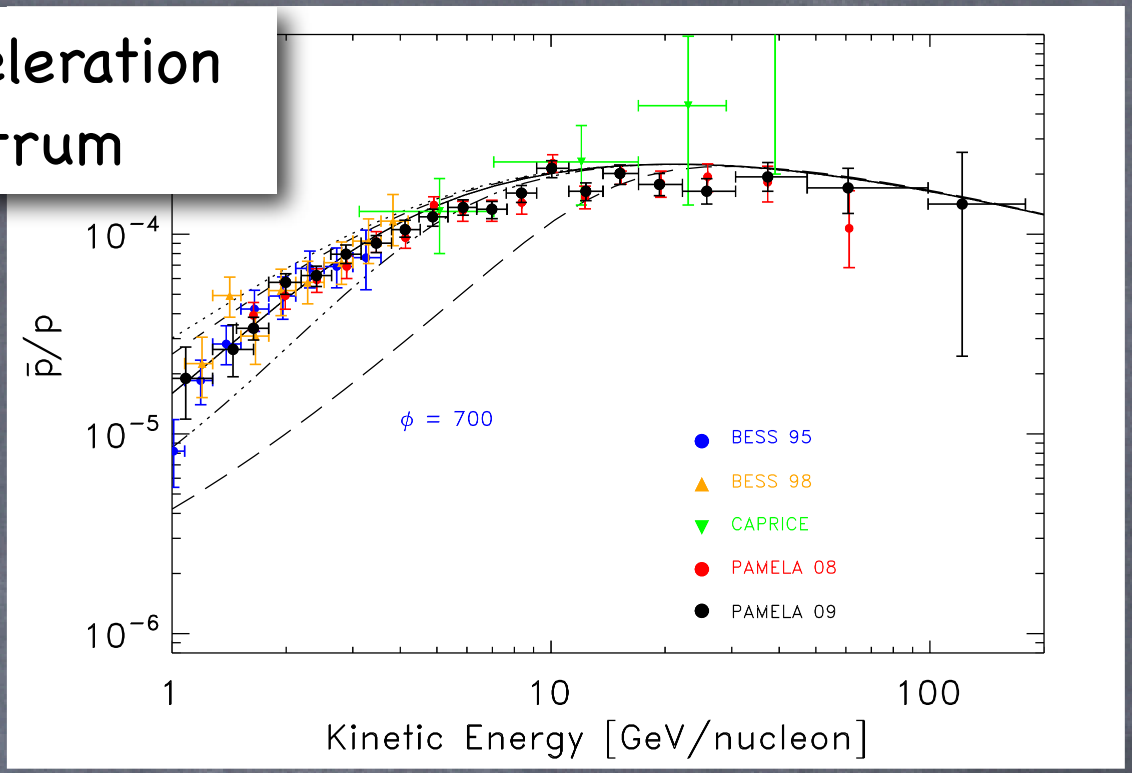
B/C analysis				
v_A [km/s]	$E_{\rm min}$ [GeV/n]	δ	D_0/z_t	χ^2
0	1	0.57	0.60	0.38
	5	0.49	0.68	0.38
	10	0.46	0.73	0.19
10	1	0.52	0.68	0.32
	5	0.46	0.73	0.40
	10	0.44	0.79	0.19
15	1	**0.46**	**0.76**	0.33
	5	0.44	0.79	0.36
	10	0.44	0.82	0.20
20	1	0.41	0.90	0.47
	5	0.46	0.79	0.29
	10	0.41	0.87	0.21
30	1	0.33	1.20	0.40
	5	0.38	1.04	0.19
	10	0.41	0.95	0.16



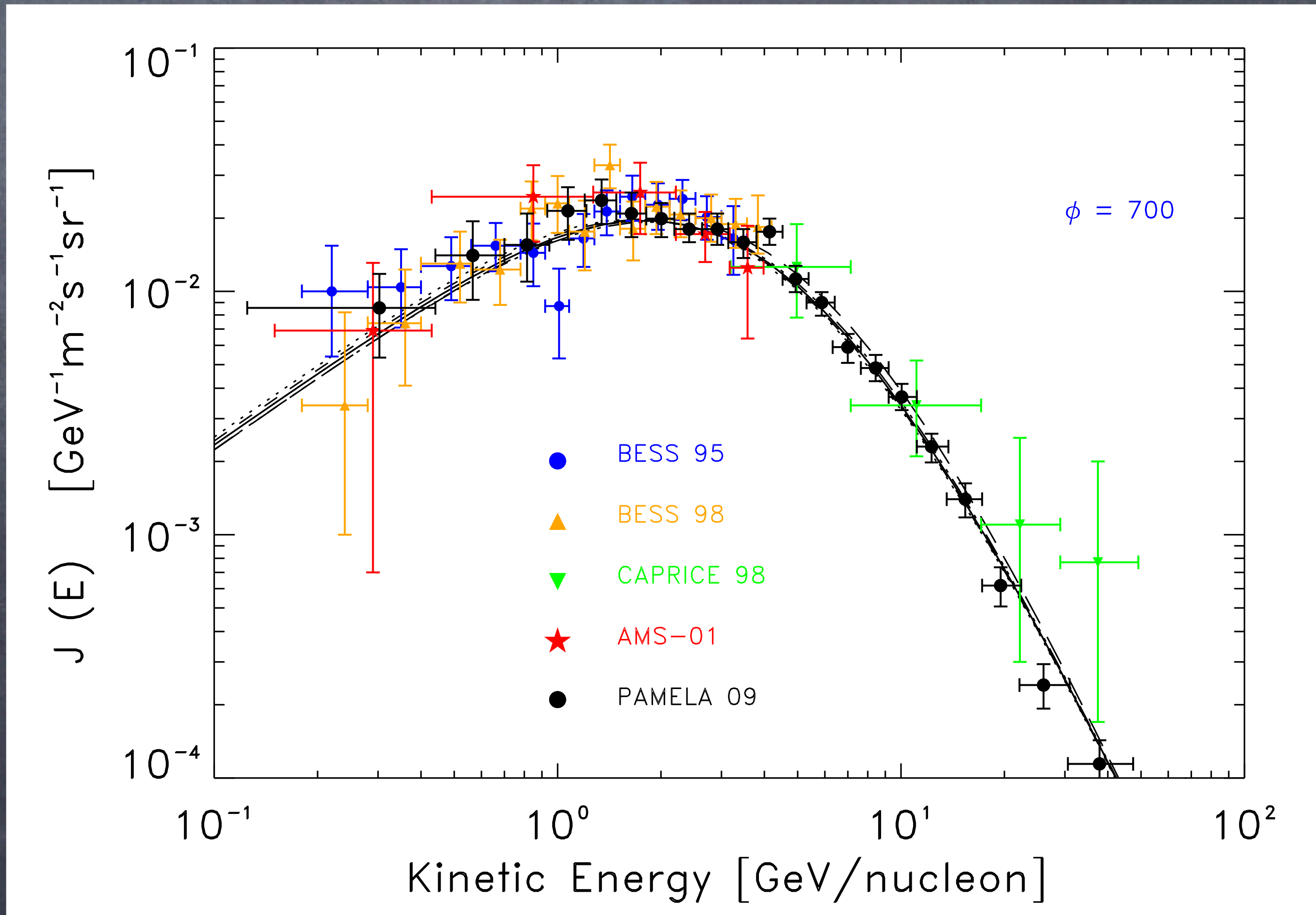
ap/p in our model



large effects of reacceleration on the proton spectrum



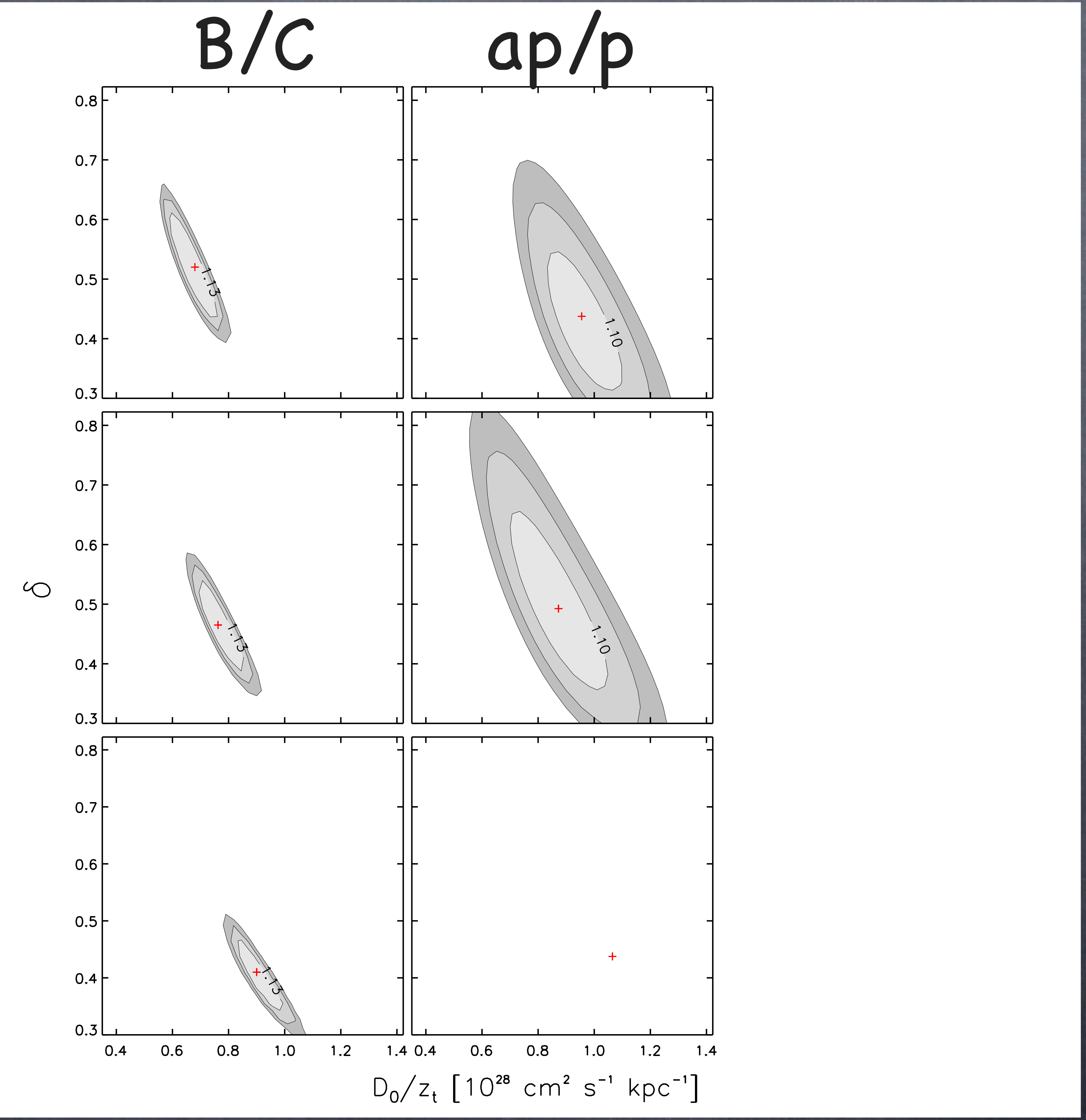
Interesting feature:
the antiproton flux does not depend on v_A
(hence on reacceleration)



Statistical analysis I

Confidence level contours for various v_A=10,15,20 km/s and E_k^{min} = 1 GeV/n

20 B/C points
38 ap/p points



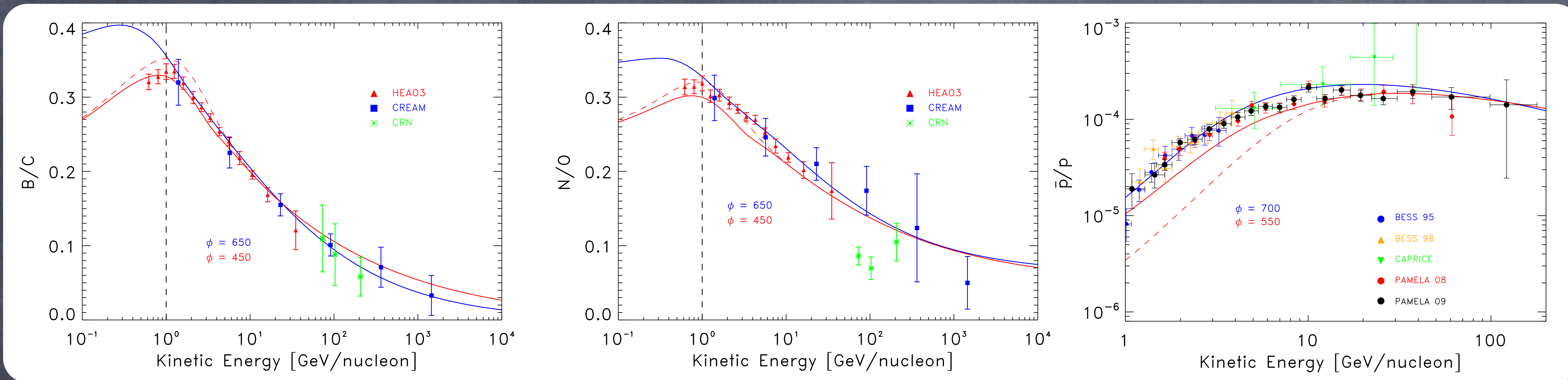
Statistical analysis II

Ideally: in the energy dependent analysis the best model is the one without energy variation of the parameters.

More statistics at high energy is required, with small error bars...

		B/C analysis			joint analysis		
v_A [km/s]	$E_{\min}$ [GeV/n]	δ	D_0/z_t	χ^2	δ	D_0/z_t	χ^2
	1	0.57	0.60	0.38	0.49	0.79	1.63
0	5	0.49	0.68	0.38	0.49	0.96	0.85
	10	0.46	0.73	0.19	0.55	0.90	1.63
	1	0.52	0.68	0.32	0.49	0.79	0.87
10	5	0.46	0.73	0.40	0.52	0.90	1.92
	10	0.44	0.79	0.19	0.60	0.79	3.46
	1	**0.46**	**0.76**	0.33	0.49	0.79	0.87
15	5	0.44	0.79	0.36	0.52	0.90	1.92
	10	0.44	0.82	0.20	0.60	0.79	3.46
	1	0.41	0.90	0.47	0.41	1.01	1.92
20	5	0.46	0.79	0.29	0.49	0.98	1.09
	10	0.41	0.87	0.21	0.52	0.98	1.91
	1	0.33	1.20	0.40	0.41	1.01	1.92
30	5	0.38	1.04	0.19	0.49	0.98	1.09
	10	0.41	0.95	0.16	0.52	0.98	1.91

Comparison with other's results



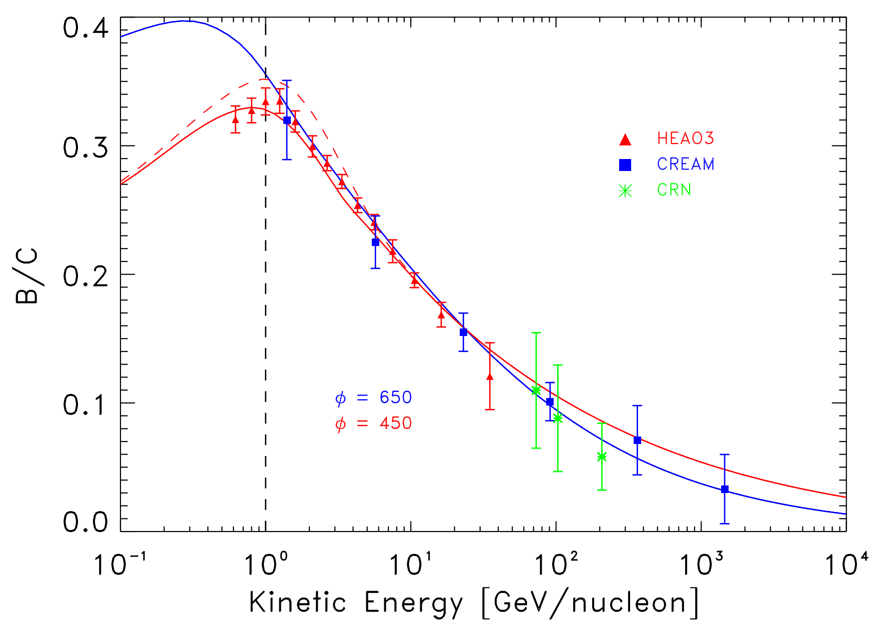
<u>Galprop models:</u>
$\delta = 0.33$
$v_A = 30$ km/s
break in CR injection spectrum at 9 GV
(required to fit low energy data)

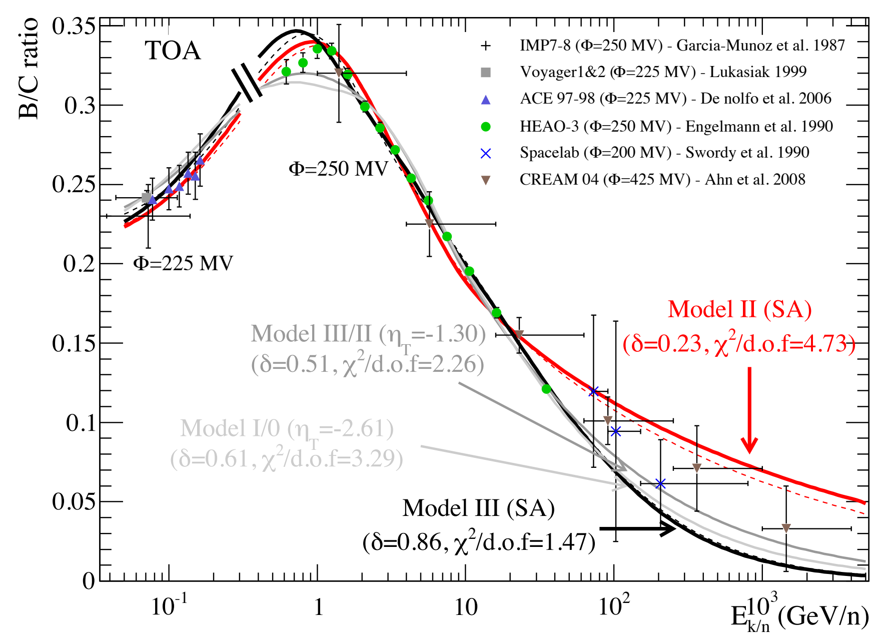
- ★ fit B/C down to low energy
- ★ problems with N/O
- ★ problems with antiprotons (if no break is introduced)
- ★ no quantitative estimate of quality of fit and more free parameters

<u>DRAGON models:</u>
$\delta = 0.46$
$v_A = 15$ km/s
no break in CR injection

- ★ work well above 1 GeV/n for both nuclei and ap (no discrepancy between B/C and ap/p measurements)
- ★ problems at lower energy
- ★ less free parameters

Comparison with other's results





<u>Semi-analytic models:</u>
more difficult to compare,
due to different assumptions.
Consider Maurin et al, 1001.0553
and a model without convection
$\delta = 0.51$
v_A (rescaled) = 7 km/s
+ low energy effects on diffusion

Overall good agreement.

<u>DRAGON models:</u>
$\delta = 0.46$
v_A = 15 km/s
no break in CR injection

- ★ work well above 1 GeV/n for both nuclei and ap (no discrepancy between B/C and ap/p measurements)
- ★ problems at lower energy
- ★ less free parameters

Systematic uncertainties

see **Maurin et al, 1001.0553**

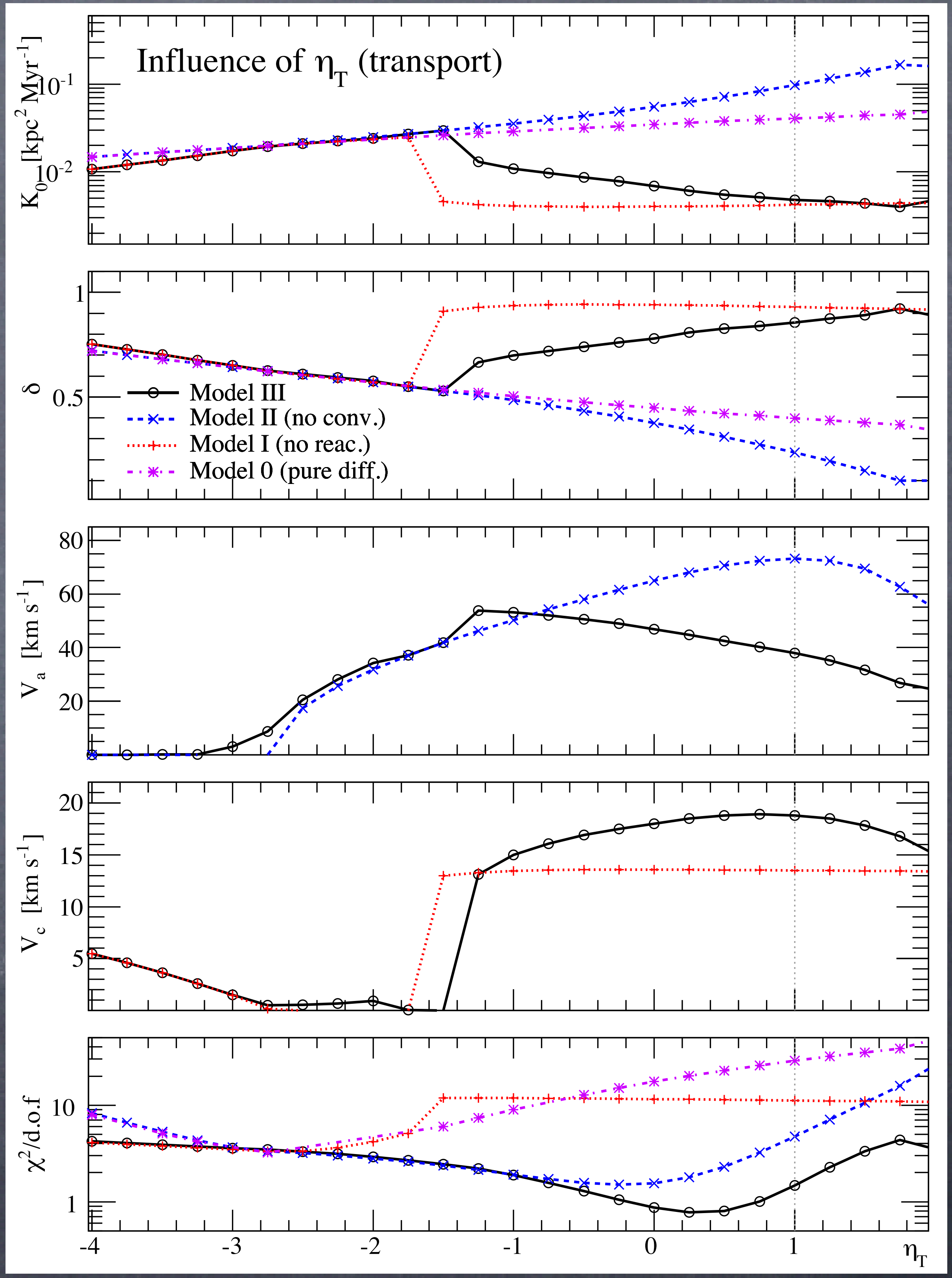
Fragmentation cross section:
- from the cross section itself ~ 20%

Allowing for some systematic energy bias
- factor of 2 on D_0
- 10% on δ
- 50% on v_A

Unknown low energy physics: parametrized as

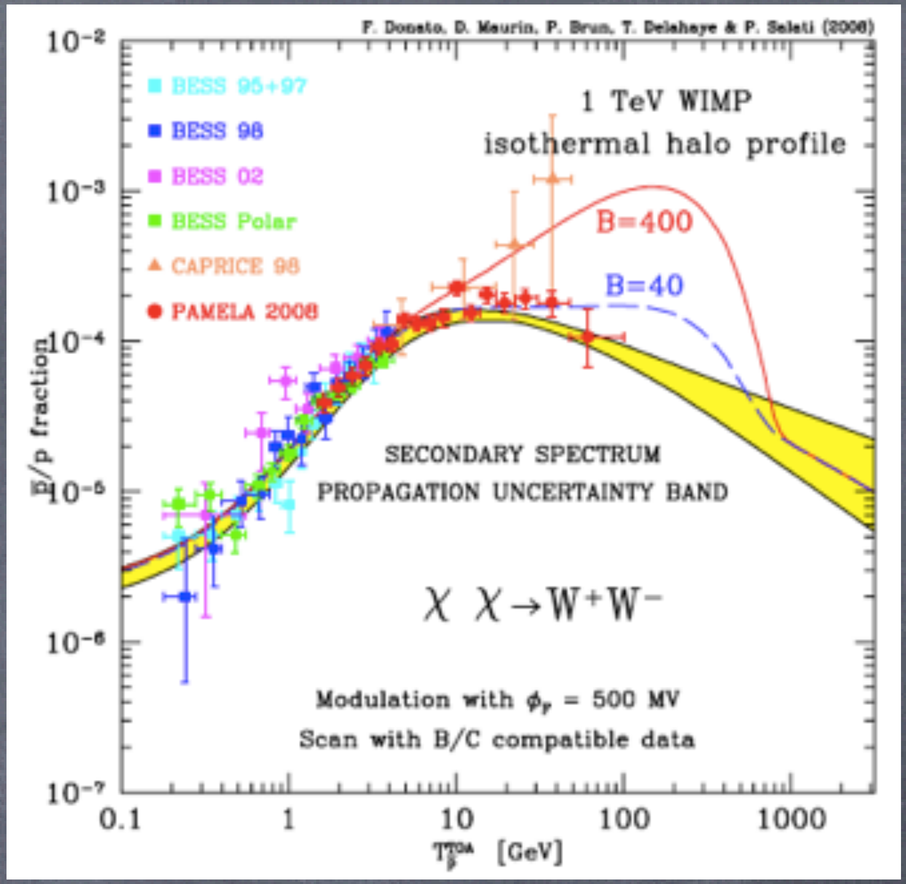
$$D \propto \beta^{\eta_T} \left(\rho/\rho_0\right)^{\delta}$$

large effects, especially on v_A



In view of DM studies... study the BG!

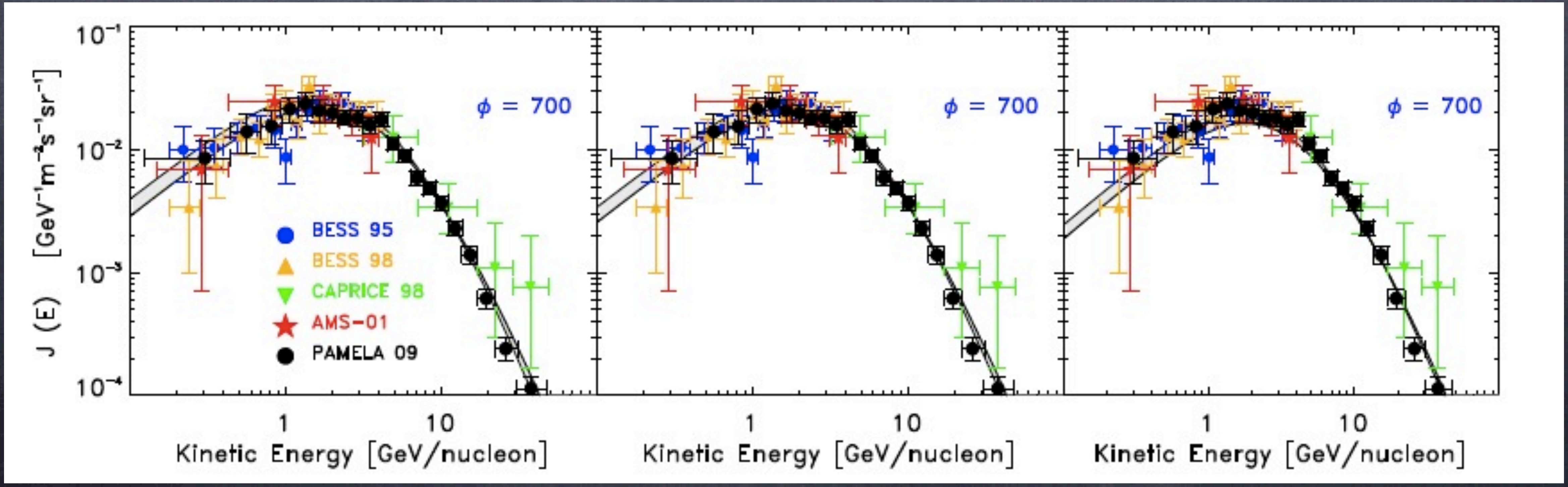
Antiprotons can be produced by exotic galactic components, as DM, together with positrons



We estimate the max and min flux of CR antiprotons in agreement with B/C data (2σ).

The predicted astrophysical ap flux is almost independent of reacceleration

Not too large variation, and overall agreement with data. Strong constraints are likely.



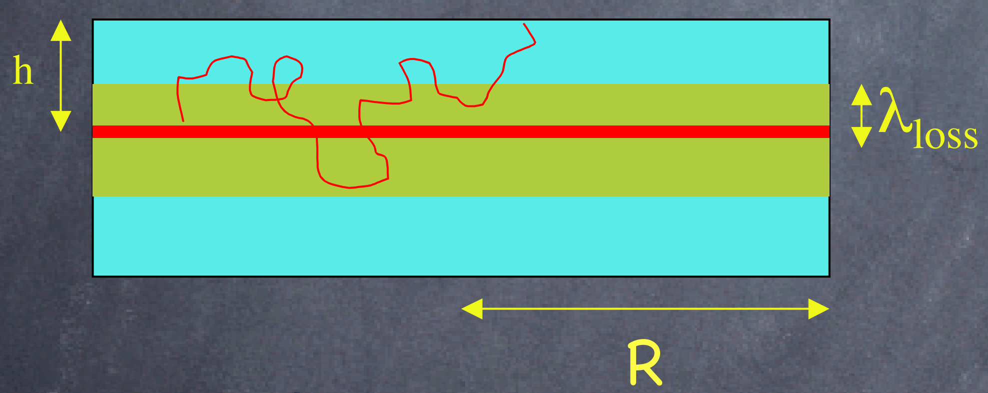
Propagation of Cosmic Ray Electrons (CRE)

mainly contributed by
D. Grasso and D. Gaggero

Propagation of CRE

$$0 \simeq \frac{\partial n(E,\vec{x},t)}{\partial t} = \underbrace{\boxed{q(E,\vec{x},t)}}_{\text{Source}} + \underbrace{\boxed{\nabla D(E,\vec{x})\, \nabla\, n(E,\vec{x},t)}}_{\text{Diffusion}} \underbrace{\boxed{-\frac{\partial}{\partial E}\left[\beta(E)\; n(E,\vec{x},t)\right]}}_{\text{Energy Loss}}$$

For E > 10 GeV solar modulation, re-acceleration, convection have sub-dominant effects; only synchrotron and IC losses and plain diffusion play relevant role.
A simple approximate analytical solution can be found (see e.g. *Bulanov & Dogiel ASS (1974))*



if $\boxed{Q(E) \propto E^{-\gamma_0} \quad D(E) \propto E^{\delta}}$

since $\beta \simeq 10^{-16}\ \mathrm{GeV\ s^{-1}} \quad \tau_{\mathrm{loss}} = 1/\beta E$

$$Q(E) \propto E^{\gamma_0}$$

$$\lambda_{loss} = \left(\int_E \frac{D(E')}{b(E')}\, dE'\right)^{1/2} \simeq 3\, \frac{D(E_0)}{10^{28}\ \mathrm{cm^2 s^{-1}}} \left(\frac{E}{E_0}\right)^{(\delta-1)/2} \ \mathrm{kpc}$$

$$\boxed{N_e(E) \propto \frac{Q(E)\ \tau_{\mathrm{loss}}}{\lambda_{\mathrm{loss}}} \propto E^{-\left(\gamma_0 + \frac{\delta}{2} + \frac{1}{2}\right)}}$$

In the case of Kolmogorov diffusion $\delta = 1/3 \quad \gamma_0 \simeq 2.5(2.4)$ to account for $N_e(E) \propto E^{-3.2\ (3.0)}$

Propagation of CRE with numerical diffusion packages

Respect to analytical or semi-analytical models <u>it is required</u>

✳to account for more complex source spectra/spatial distributions

✳to model consistently the secondary gamma-ray and synchrotron emissions

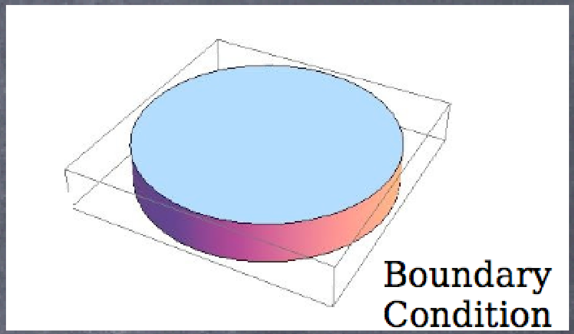
✳to possibly account for more complex diffusion scenario (inhomogeneous and anisotropic D)

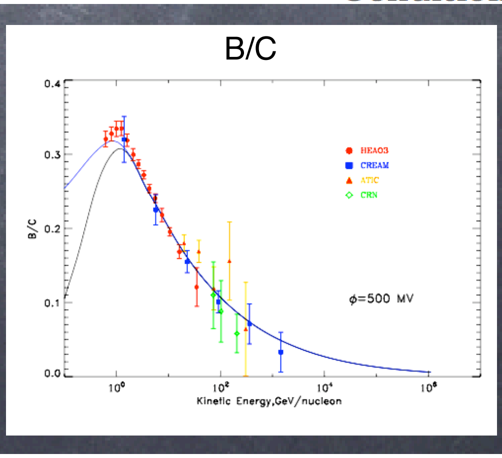
<u>Main logical steps</u>

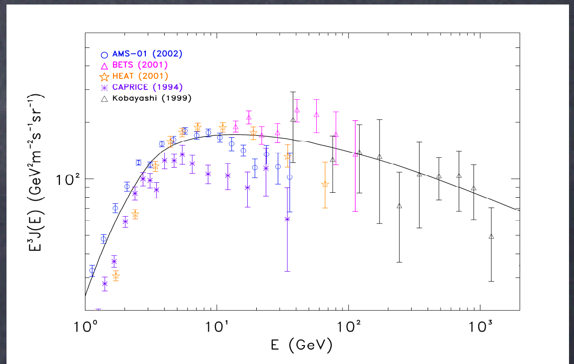
- The diffusion equation is solved in the stationary limit by imposing null conditions at some (unknown) boundary (tipically a cylinder with R_{max} ~ 10 kpc, z_{max} ~ 1 - 10 kpc) reacceleration and subdominant loss processes are included

- The diffusion coefficient normalization and spectral slope is fixed against the secondary/primary light nuclei data (with large uncertainties yet)

- The electron source spectrum is tuned to match the observed propagated spectrum







Propagation of CRE with numerical diffusion packages

(some possible caveats)

- The local CRE flux may fluctuate respect to Galactic distribution
  (such an effect was invoked to explain EGRET γ-ray GeV excess)

- The source distribution is assumed to be continuos.

Above the TeV $\lambda_{loss} \leq 1 \text{ kpc}$ which is comparable to the mean active SNR's distance

this may be a limit for numerical diffusion codes especially if there is a sub-class of sources dominating the high energy tail of the electron spectrum (e.g. pulsars)

The possible role of fluctuations/nearby

It was studied either by combining analytical propagation with Montecarlo generated sources

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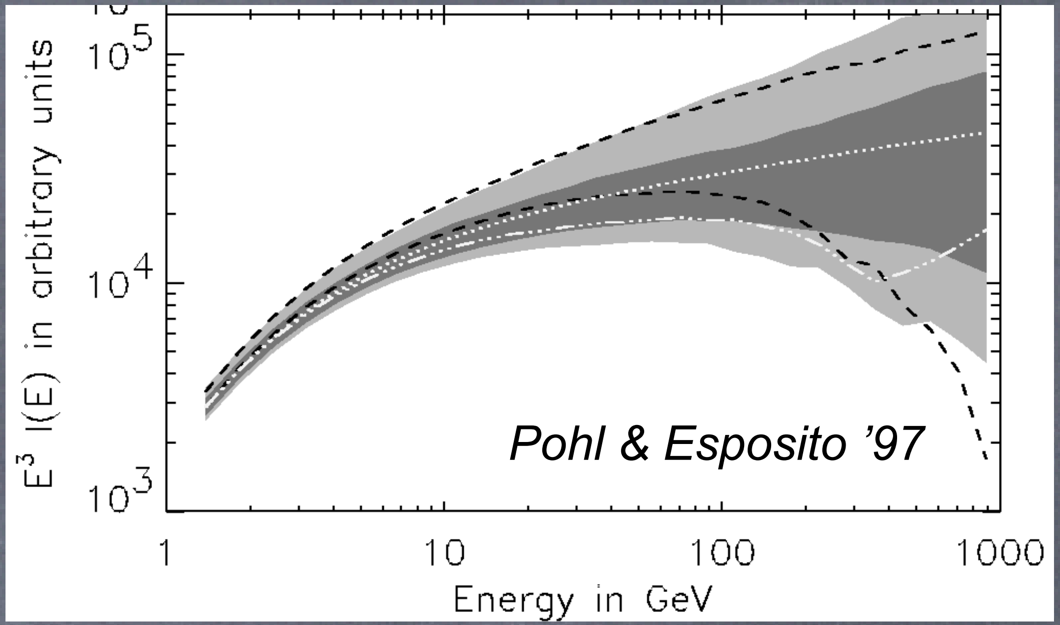

or by analytical propagation from a distribution of local sources

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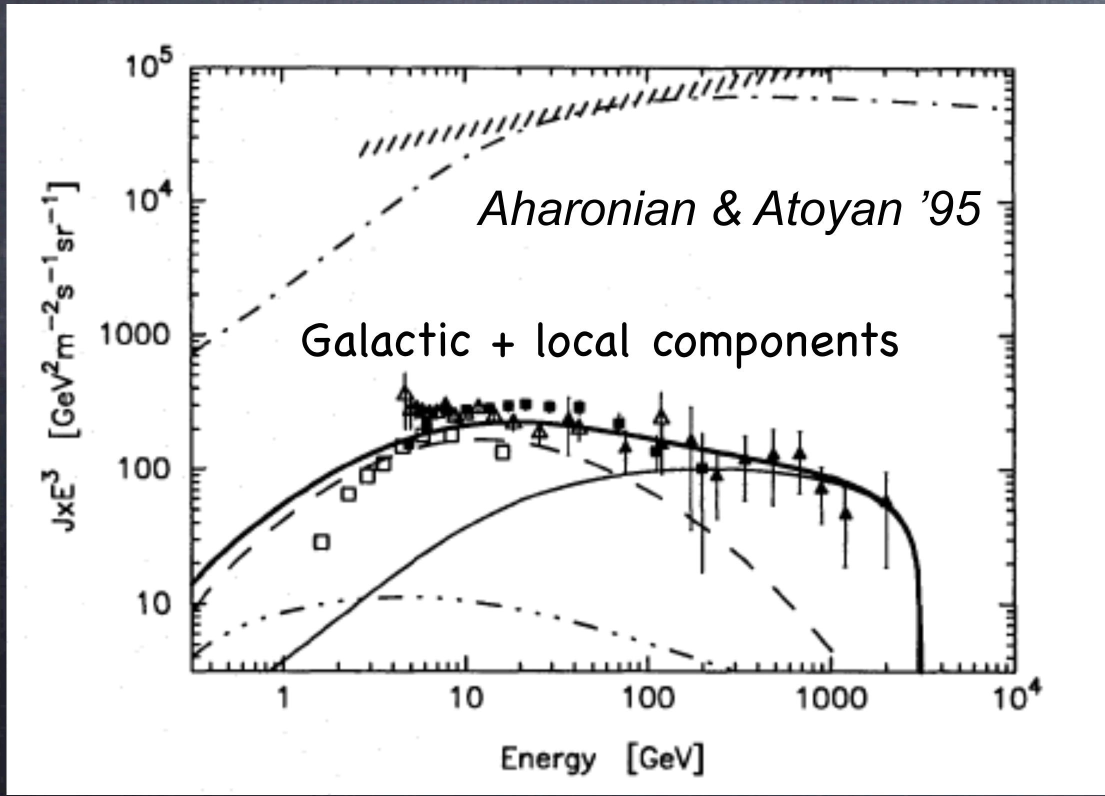
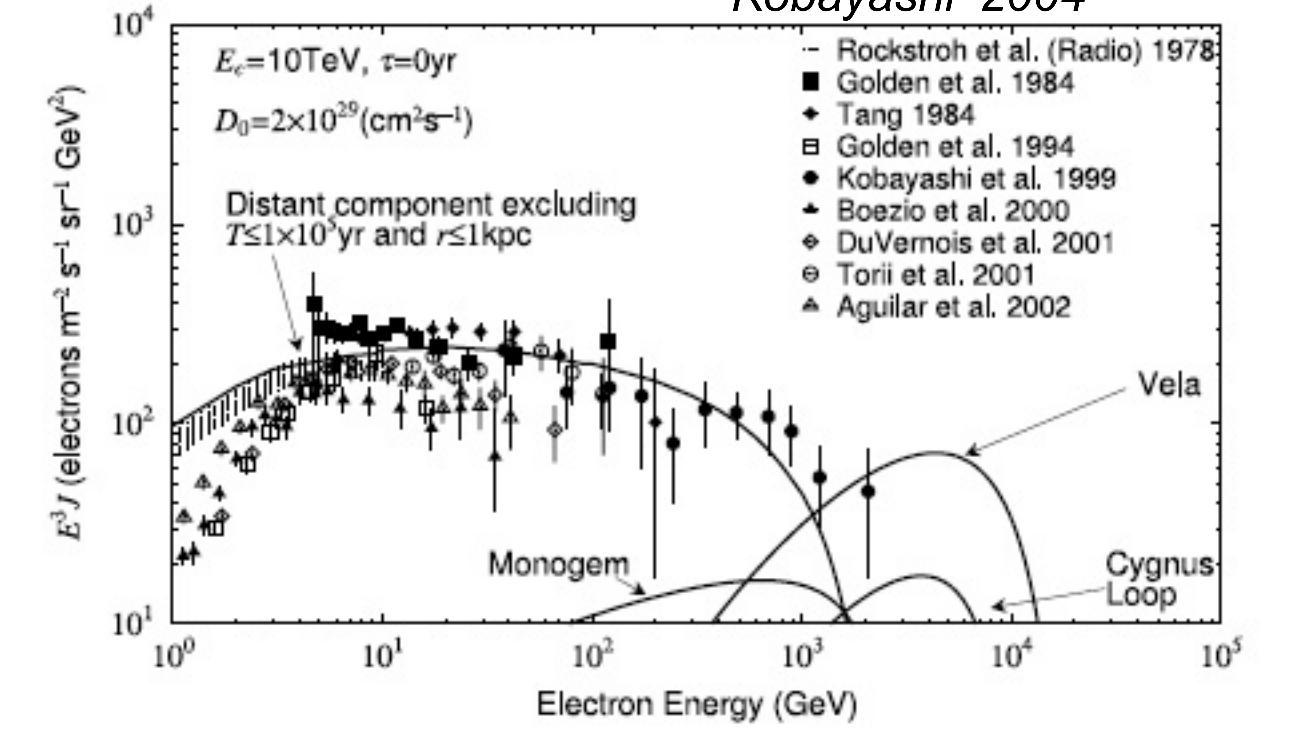


or by analytical propagation from actually observed candidate sources

⇓

Kobayashi '2004



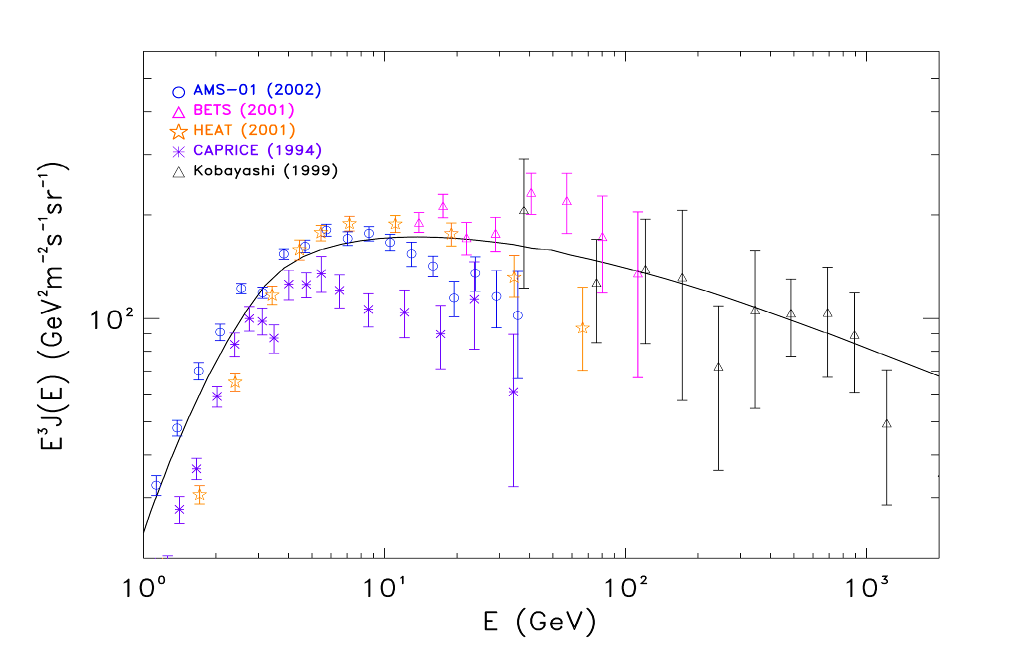
The experimental situation before 2008

Electron + positron spectrum

Above few GeV the spectrum was fitted by a power-law $\sim E^{-3.2}$
(with large uncertainty)

in the figure GALPROP model with
$\delta = 0.33$ $\quad \gamma_0 = 2.54$

(Alfven vel. V_A = 30 km/s , no convection)

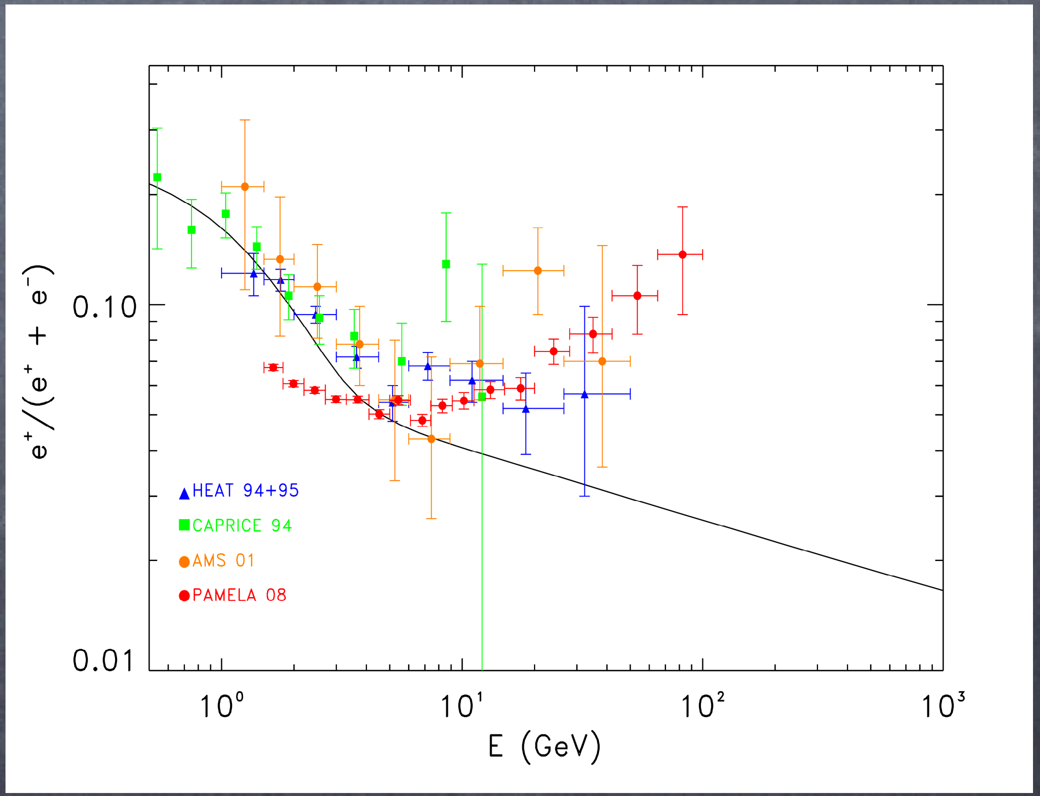


Positron fraction

tension with AMS-01 and HEAT
strong disagreement with PAMELA if positrons are only secondary products of CR p and nuclei

$$\frac{e^+}{e^- + e^+} \propto \frac{E^{-(\gamma_p+\delta/2+0.5)}}{E^{-(\gamma_0+\delta/2+0.5)}} = E^{-\gamma_p+\gamma_0}$$

it decreases if $\gamma_0 < \gamma_p \cong 2.7$



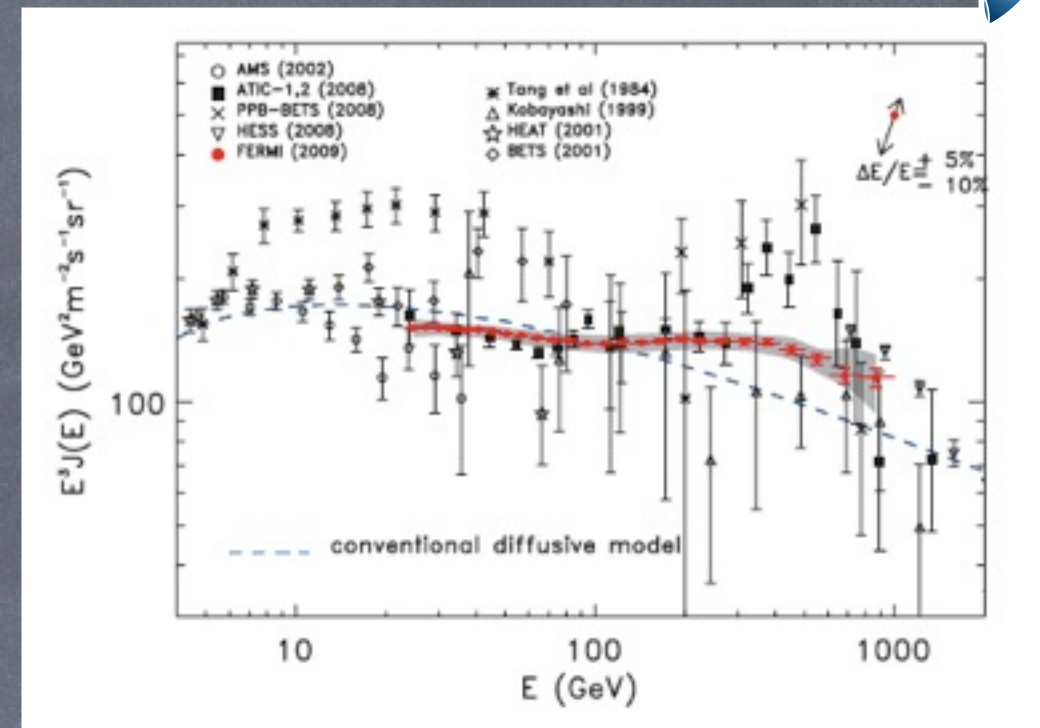
The Fermi-LAT CRE spectrum

Fermi Gamma-ray Space Telescope

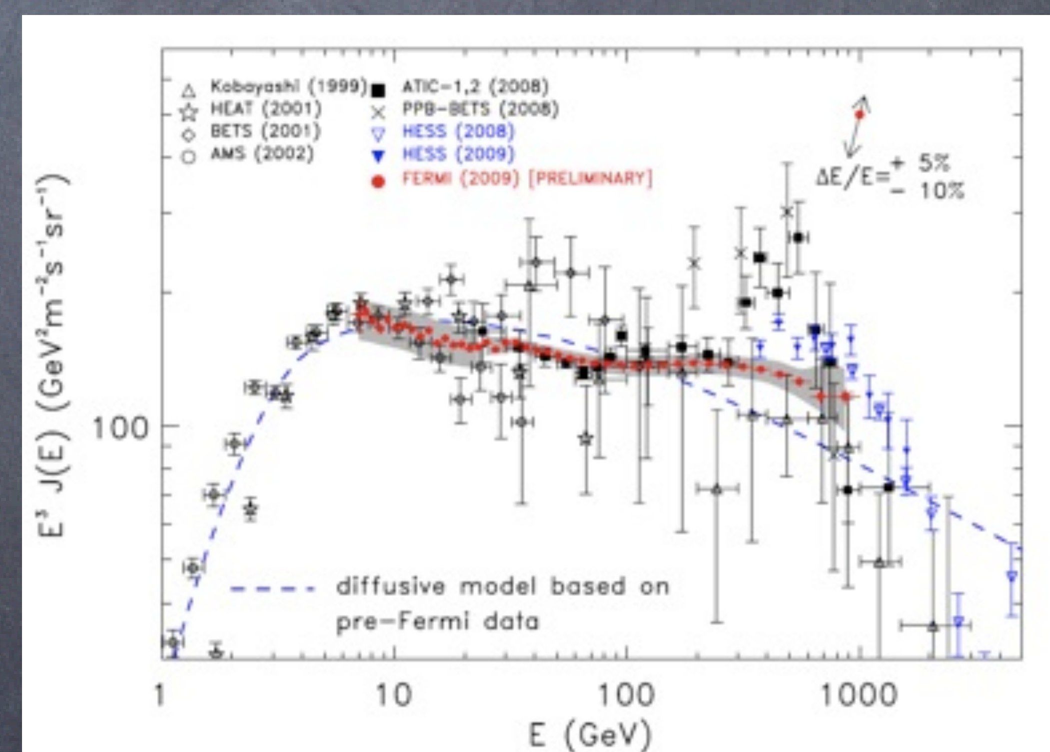
Electron + positron spectrum published in PRL, May 2009 based on 6 months data

compared with most significant previous data and the conventional GALPROP model with

$\delta = 0.33 \qquad \gamma_0 = 2.54$



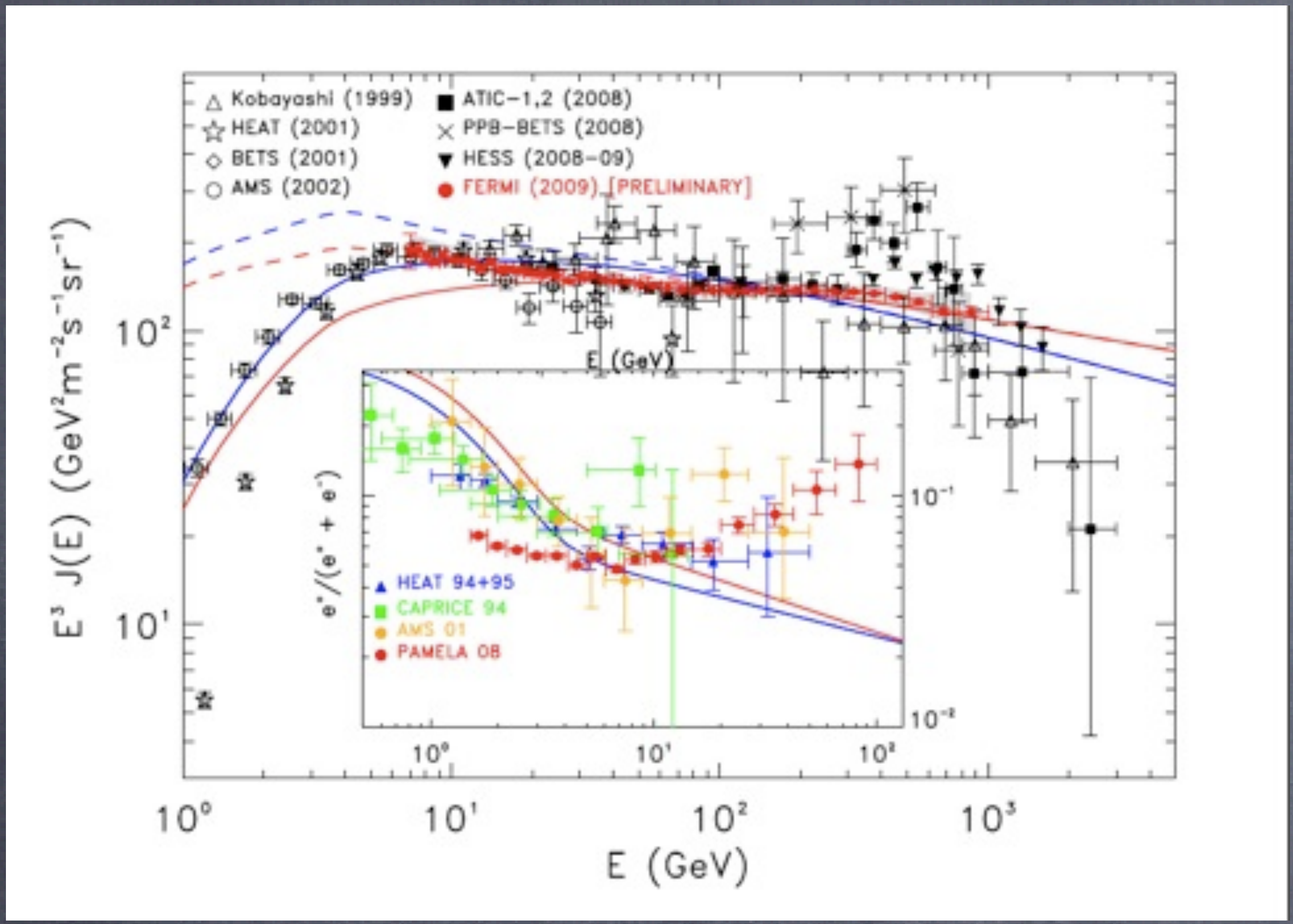
Preliminary spectrum based on the 12th months data, down to 7 GeV
Latronico - 2nd Fermi symp. 2009



The spectrum is fitted by a E^(-3.06) power-law

with hints for a hardening at ~100 GeV and a steeping above 500 GeV

A conservative interpretation of the Fermi-LAT CRE spectrum



if $\delta = 0.33$ is assumed

$\gamma_0 = 2.42$ modulated, force-field with Φ = 550 MV

" unmodulated

$\gamma_0 = 2.5$ modulated, force-field with Φ = 550 MV

" unmodulated

this requires v_A = 30 km/s and strong spectral breaks at the source (see next slide)

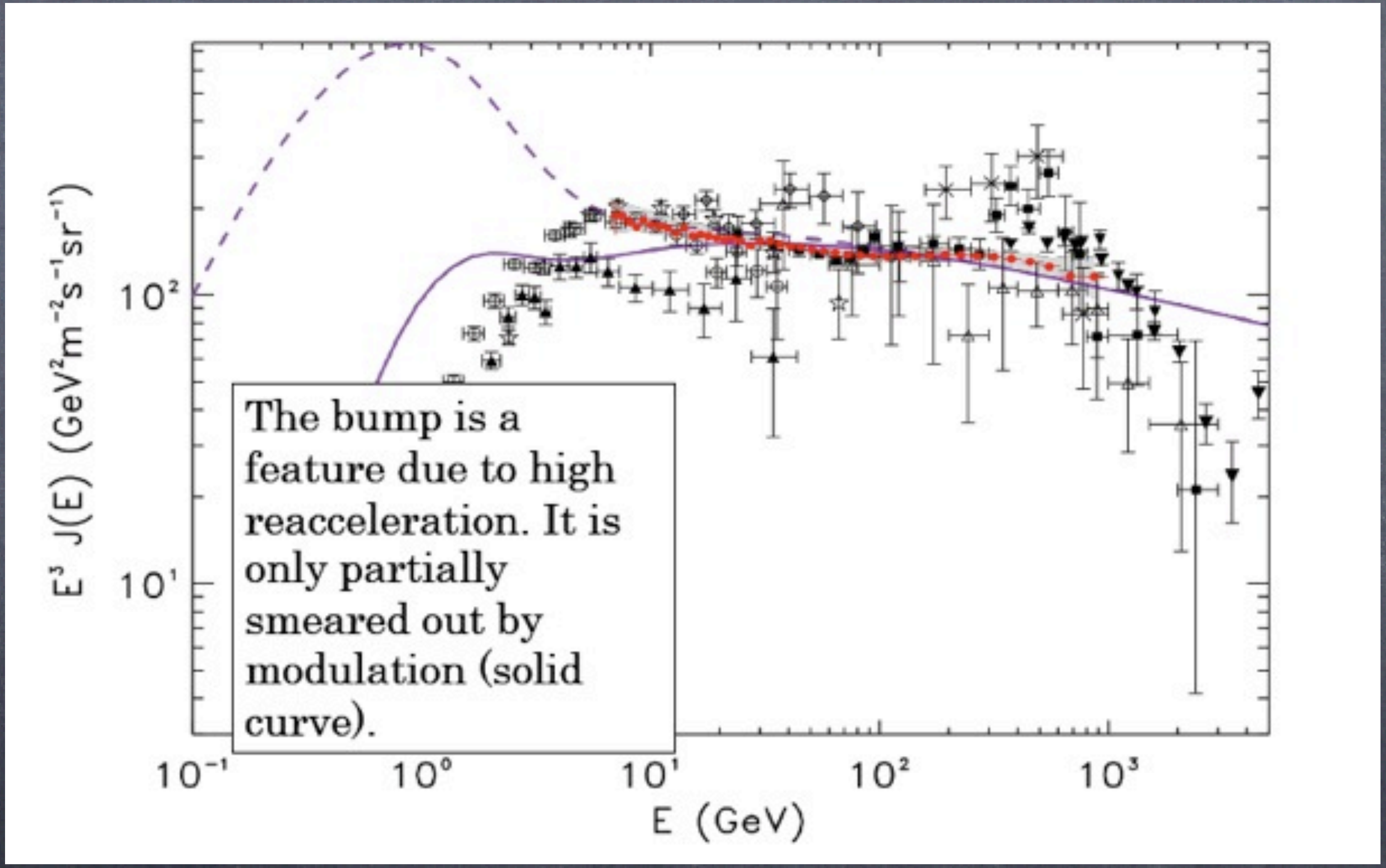
- either do not match low energy Fermi-LAT data ($\gamma_0 = 2.42$) or gives a bad fit at higher energies ($\gamma_0 = 2.5$)
- do not match PAMELA both at high and low energies [Note that the hard electron spectrum measured by Fermi makes the anomaly more seriuos !!]

modulated, force-field with Φ = 550 MV

- do not match HESS data

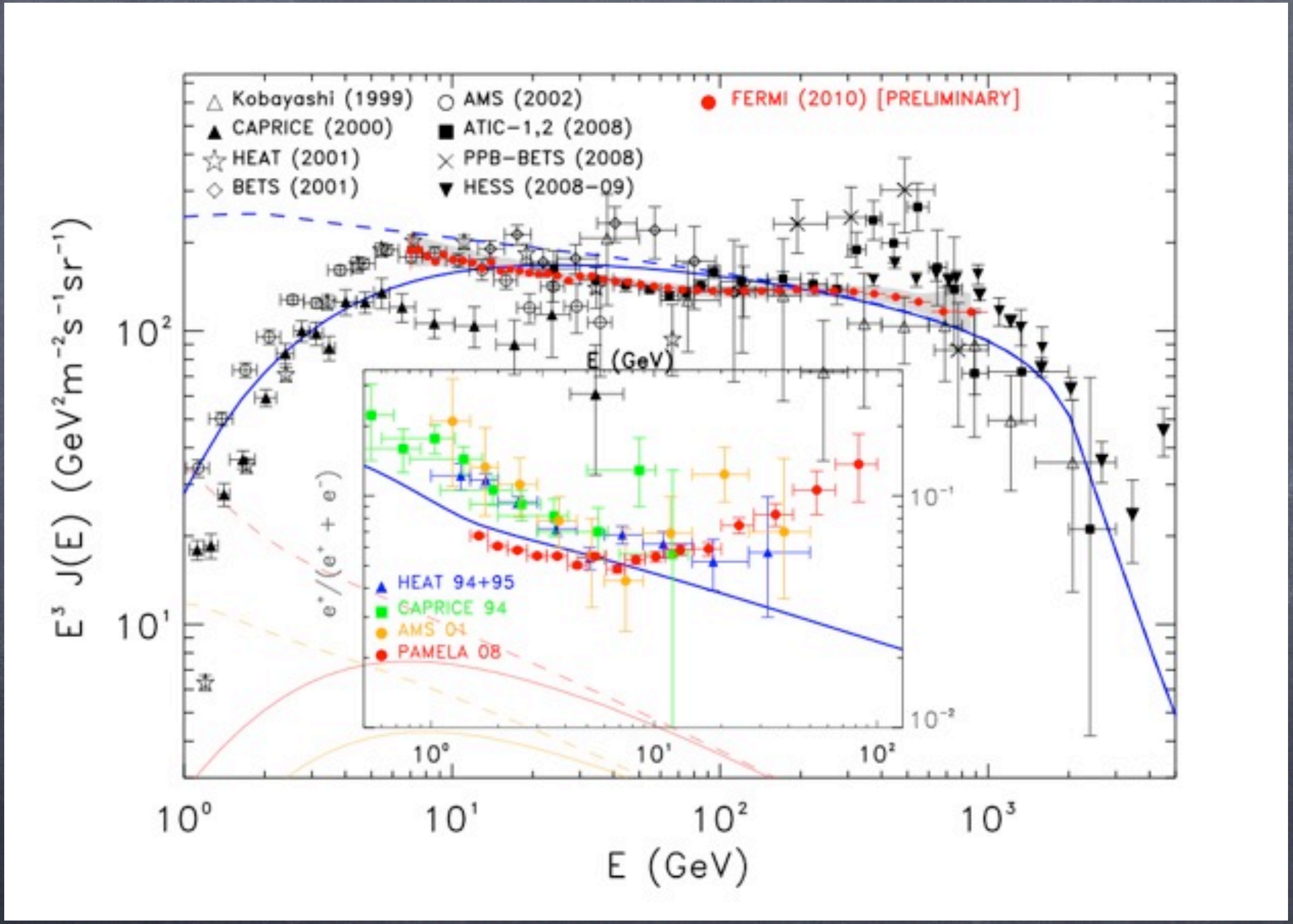
Why models with moderate reacceleration should be preferred

Even more dramatically than what happen for protons, models with large v_A can't avoid a low-energy break. Indeed with (2.45/2.45) a huge bump appears which need to be cured by a strong (ad hoc) break at injection.



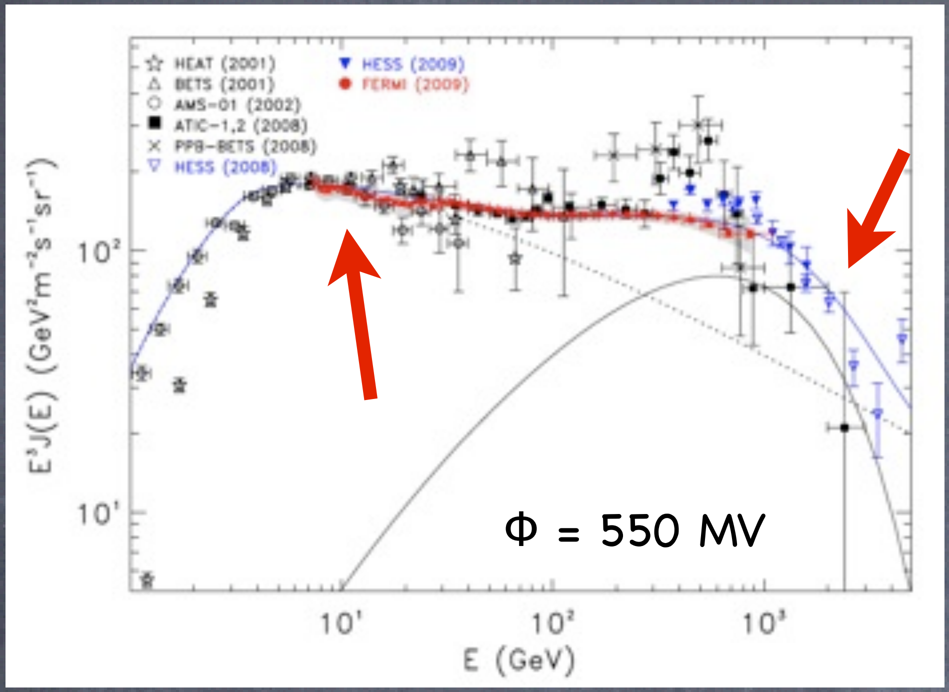
A better fit of PAMELA positron fraction data at low energy can also be obtained in this case with the simple modulation set-up

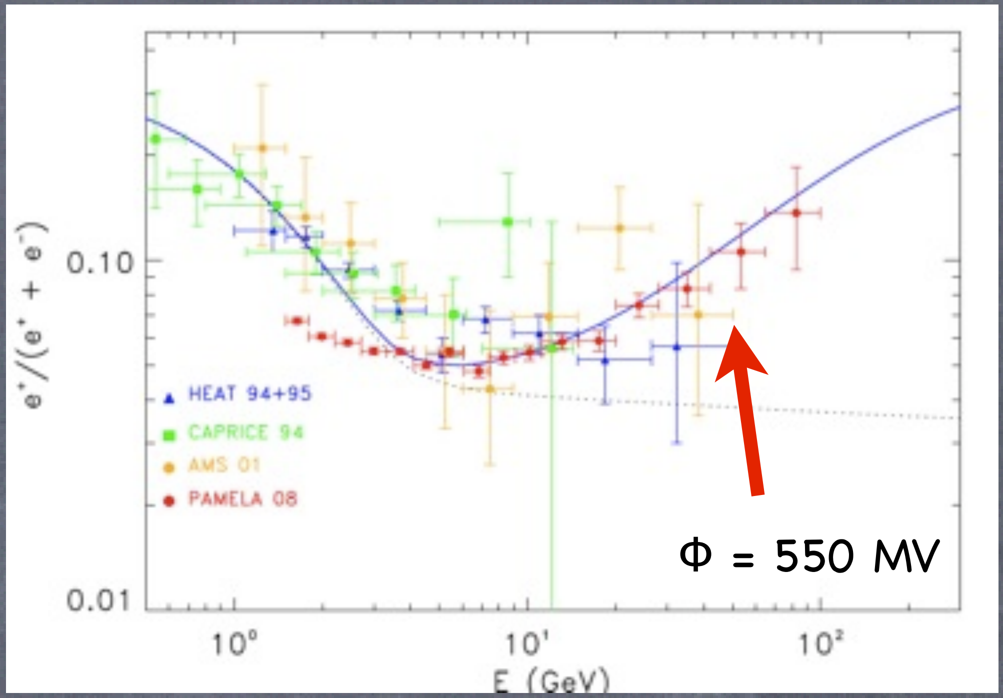
γ_0 = 2.0/2.5 above/below 4 GeV
δ = 0.46



Two components interpretations: main motivations

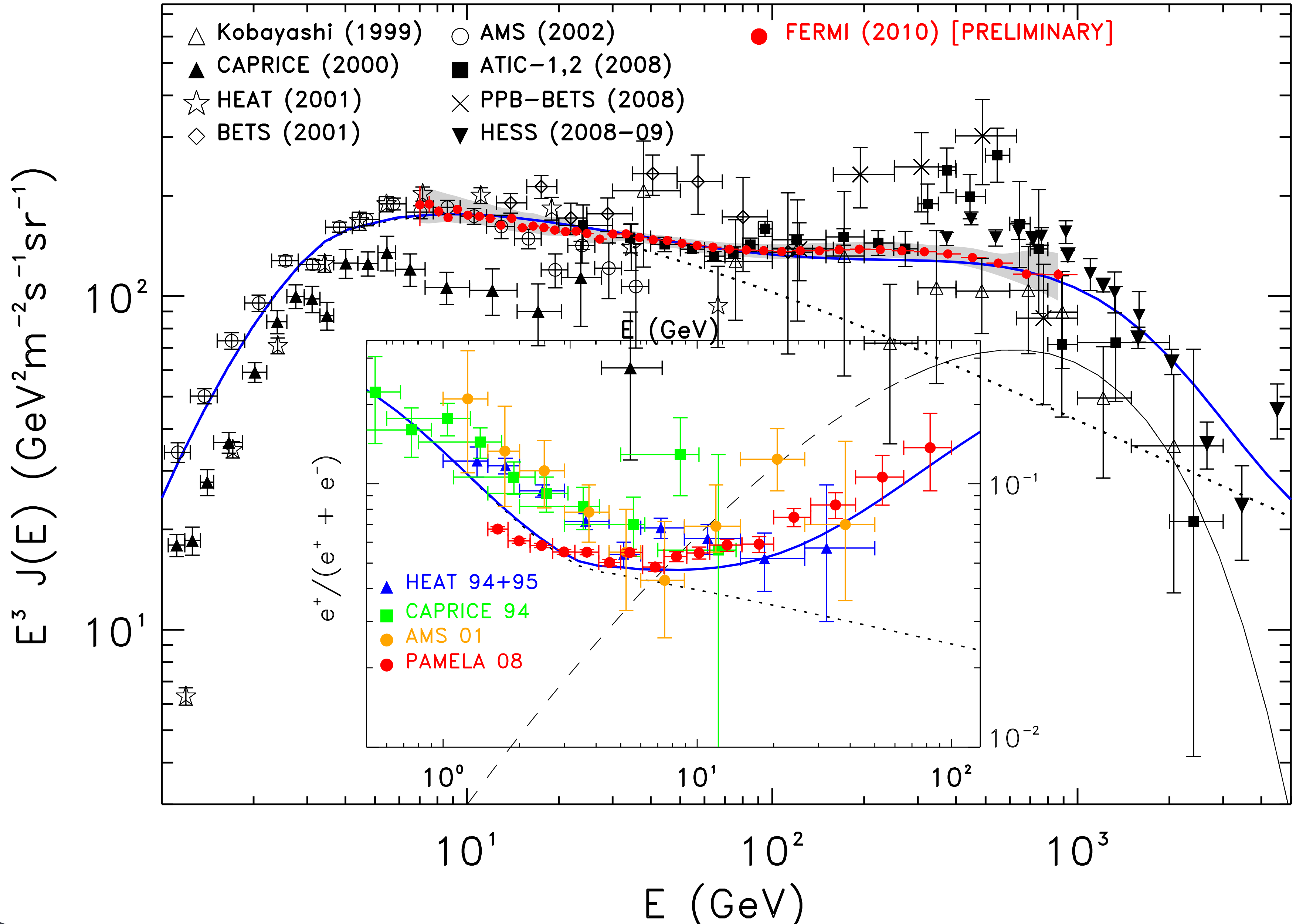
Toy model with a Galactic $N_{\rm extra} \propto E^{-1.5}\, e^{-E/1\ {\rm TeV}}$ added to a conv. bkg with $\gamma_0 = 2.54$ $\delta = 0.33$





- If the extra component is charge symmetric it allows to match PAMELA growing ratio above 10 GeV
- It the only way to match low energy Fermi and AMS-01 (both taken in a low solar activity phase) without invoking more involved modulation scenarios
- it allows a better fit of Fermi-LAT data at high energy as well as HESS data
- under some conditions it also allows to improve the fit of low energy PAMELA data (see below)

Our best two components model



A more realistic treatment of local sources

it can be obtained by a proper combination of numerical and analytical results

- The propagation of e± from local sources (SNR, pulsars, DM substructures..) can be treaded analytically.
- A consistent approach requires to use the same conditions (propagation parameters, energy losses) as in the numerical code used to treat the large scale Galactic component
- In the case of astrophysical sources, actual observed properties of the source can be used

- GALPROP or DRAGON can be used in combination with analytical solutions from point-like sources implemented in the IDL package

Pulsar interpretation

- Energy source: rotational energy of the NS . The total $e^{\pm}$ energy release can be determined by pulsar timing (modulo an unknown efficiency factor $\eta_{e\pm}$) and can be as large as 10^{48} erg .

- Particles from the pulsar are re-accelerated at the pulsar wind/shock - power law spectrum with index $-1 < \Gamma < -2$

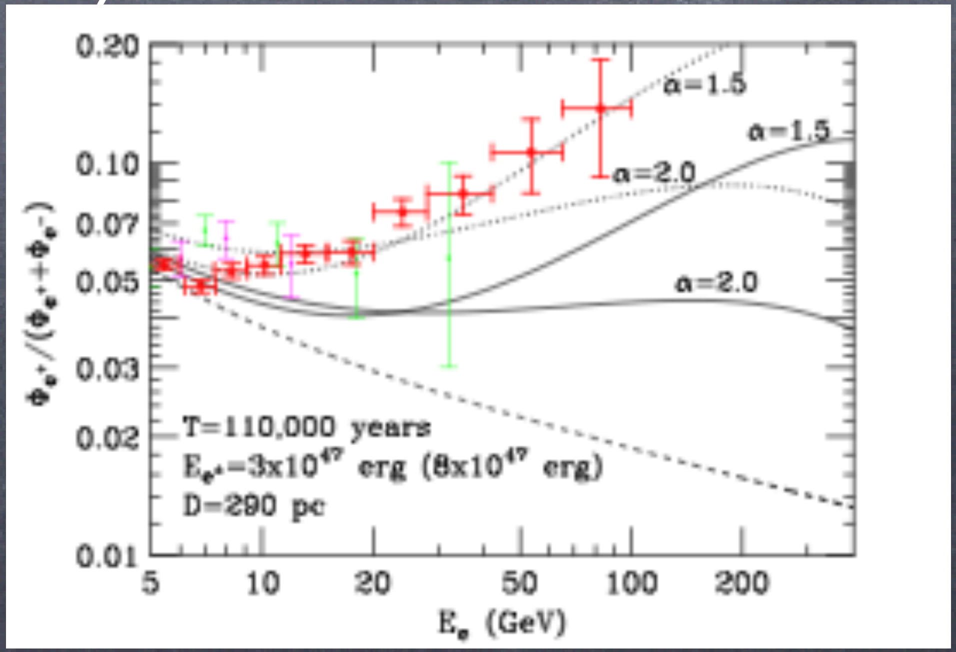
- PWN breakup $\Delta T \approx 10 - 100$ kyr after the birth of the pulsar, releasing the trapped $e^{\pm}$ ($Ne^{+} \approx Ne^{-}$)

- $E_{cut} \sim 10^{3}$ TeV for young PWN (T ~ 1 kyr) it is expected to decrease with the pulsar age/luminosity for middle-age pulsars (T ~ 10 - 100 kyr) $E_{cut} = 0.1 - 10$ TeV is a natural range

expected spectral shape at the source: $N_{e\pm}(E) = Q_0 \, (E/E_0)^{-\Gamma} \, \exp\{-E/E_{cut}\}$

It was shown that $e^{\pm}$ emission from nearby pulsars may account for the PAMELA e + anomaly

see e.g. *Blasi & Serpico 2008* →

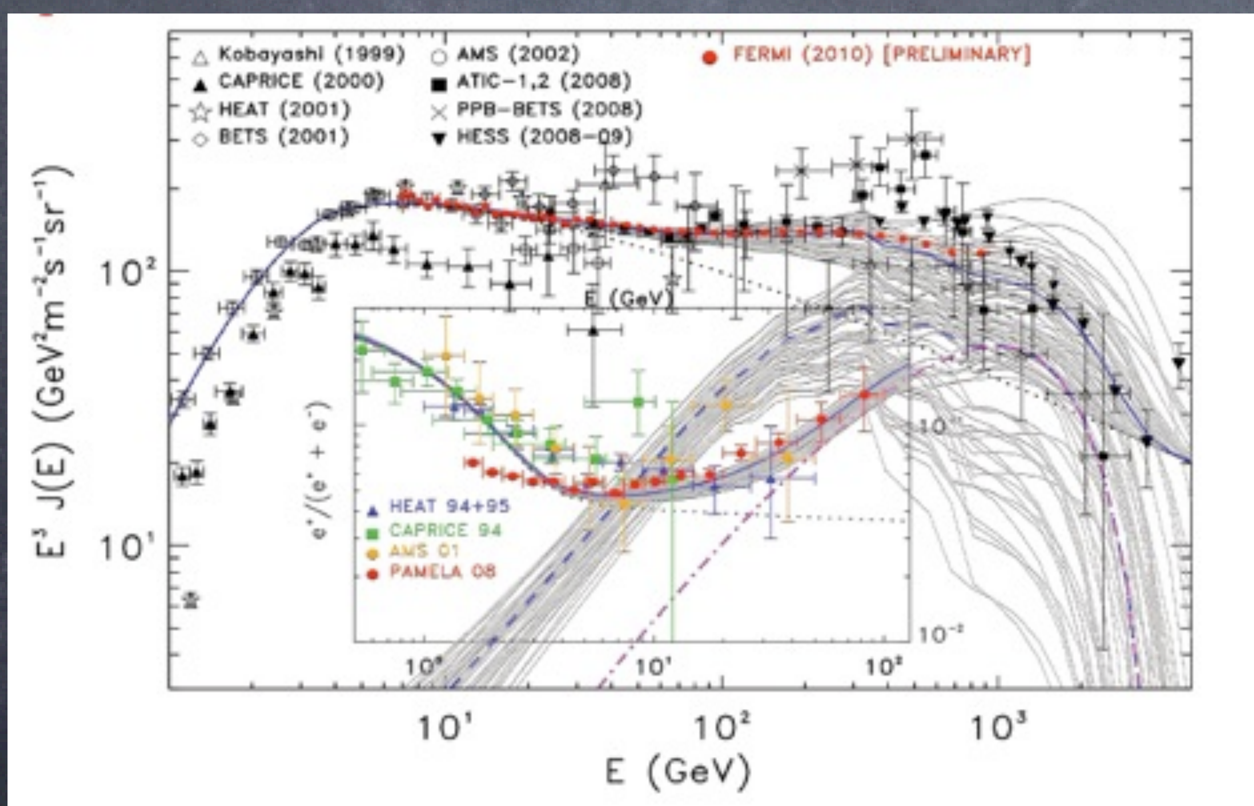


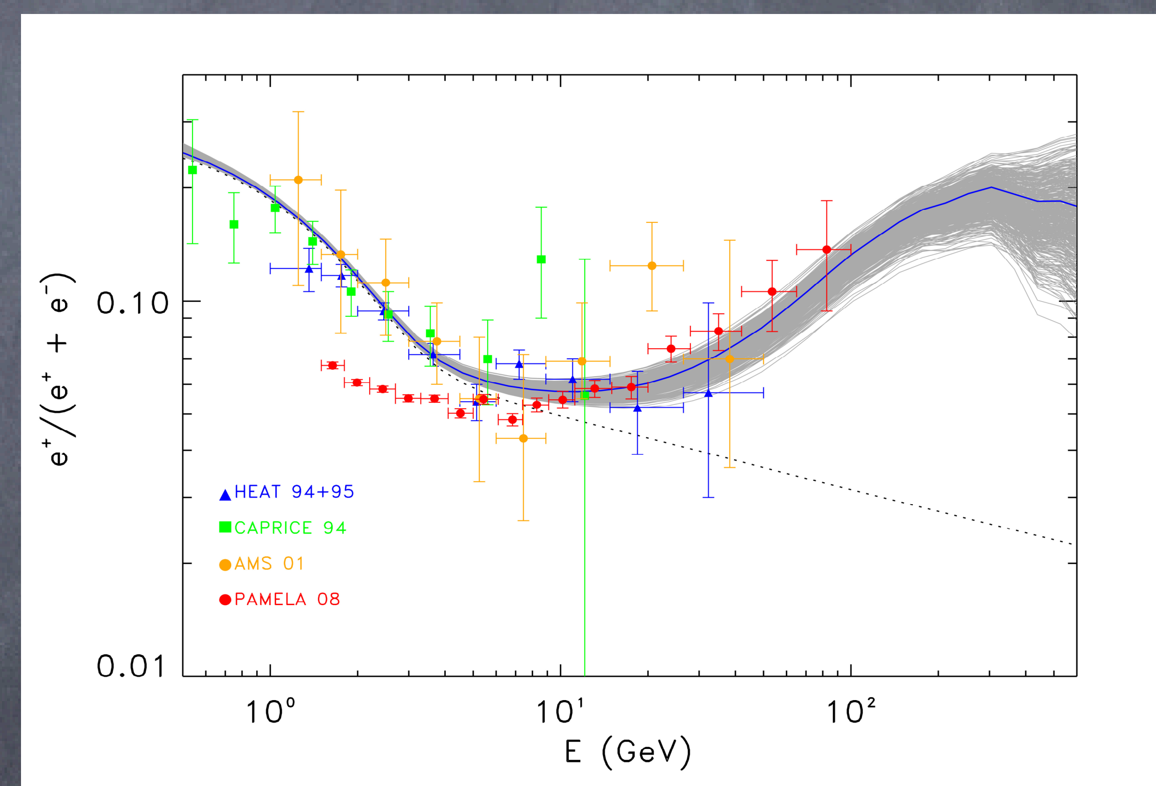
Pulsar interpretation

In *D.G. et al. [Fermi coll.] 2009*, the CRE background computed with GALPROP was summed to the analytically computed flux from actually observed pulsars taken from the ATNF radio catalogue

consistent choice of the propagation parameters and loss rates were used

Including the contribution of all observed pulsars with d < 3 kpc and allowing for the relevant pulsar parameters two vary in reasonable ranges, they got:



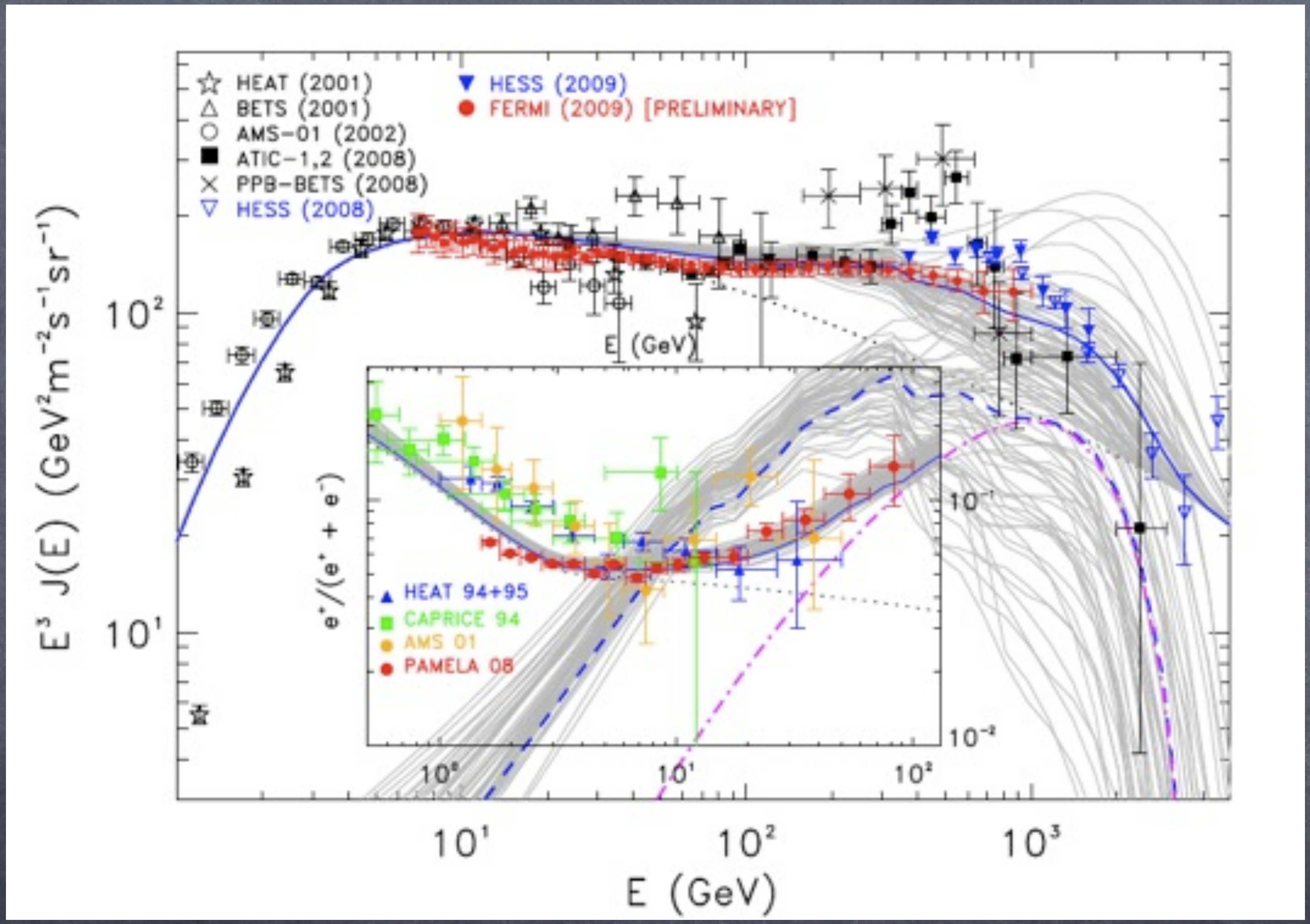


e± production efficiency: 10% - 30% ; $1.5 < \Gamma < 1.9$; $800 < E_{cut} < 1400$ GeV

$\Gamma = 1.7$; $E_{cut} = 1$ TeV ; Delay = 60 kyr; **e± efficiency = 40%** - background: conventional GALPROP with $\gamma_0 = 2.7$

Pulsar interpretation using our propagation best-fit model

Modified background "DRAGON" model with $\gamma_0 = 2.64$ and $\delta = 0.46$ (and no break in the source proton spectrum) based on new analysis of CREAM (B/C) and PAMELA (proton and antiproton) recent data



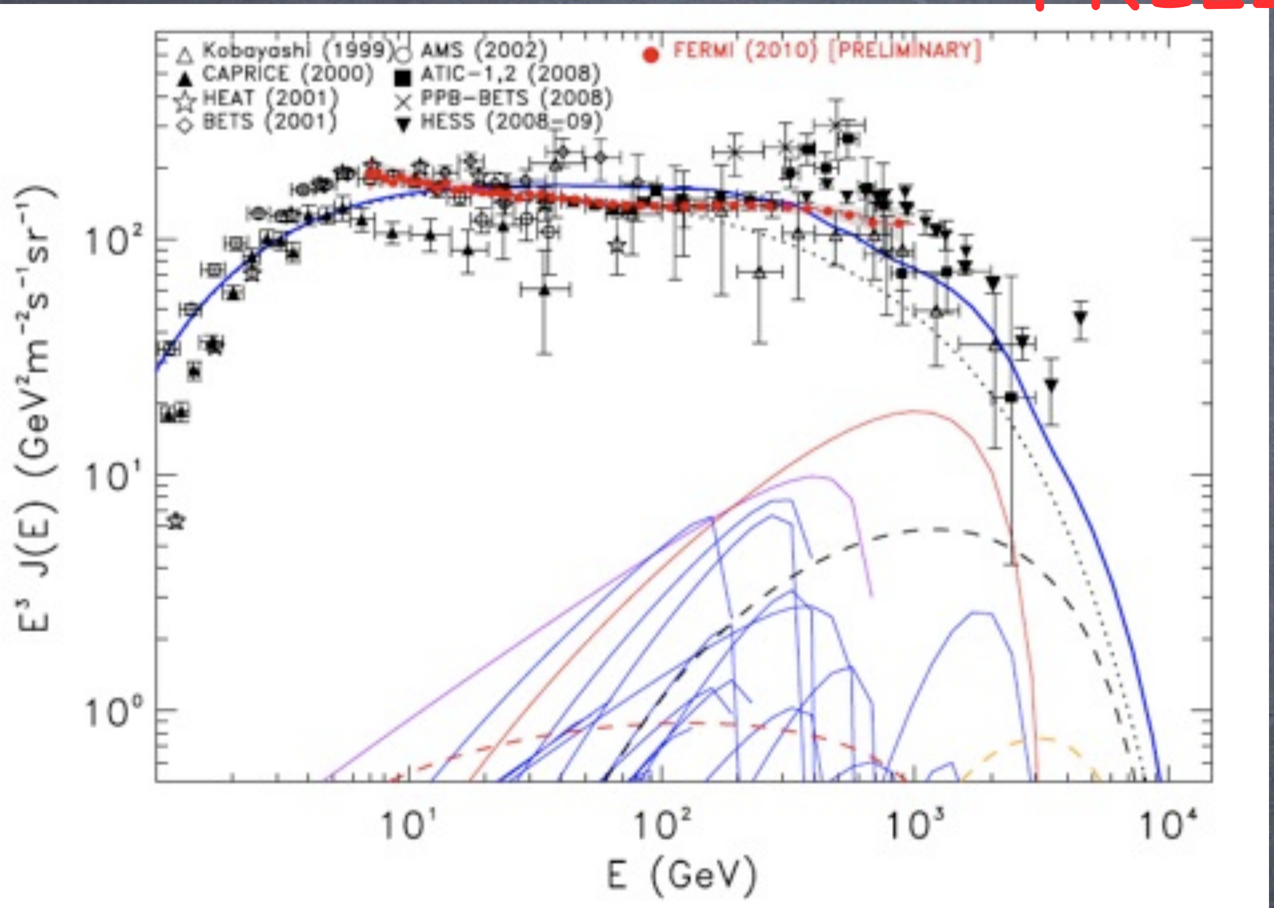
a much better fit of PAMELA positron fraction low energy data is obtained

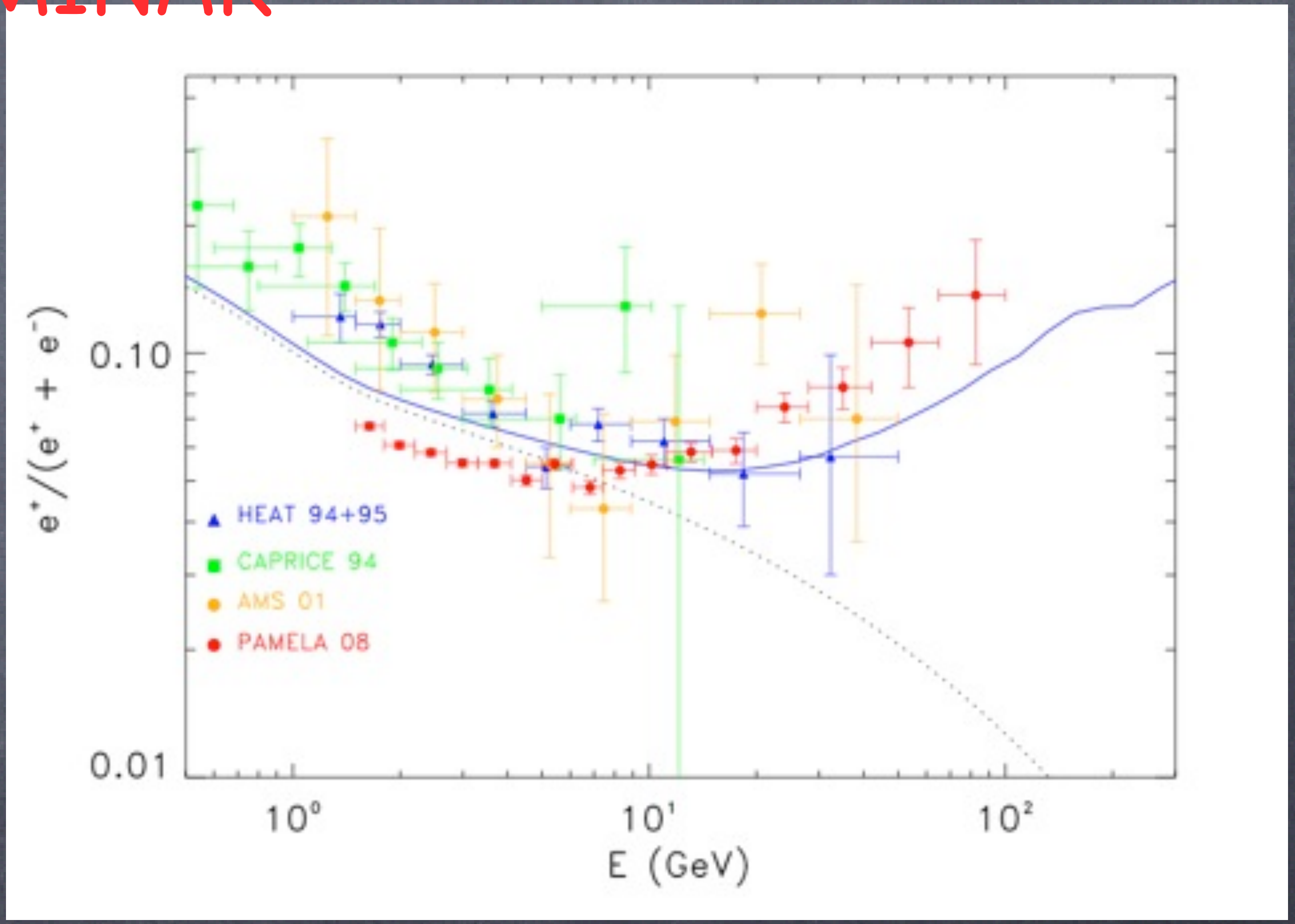
Pulsars + SNRs local contribution

For illustrative purposes, we consider here all observed radio pulsars (dashed lines)+ SNRs (solid) with d < 2 kpc

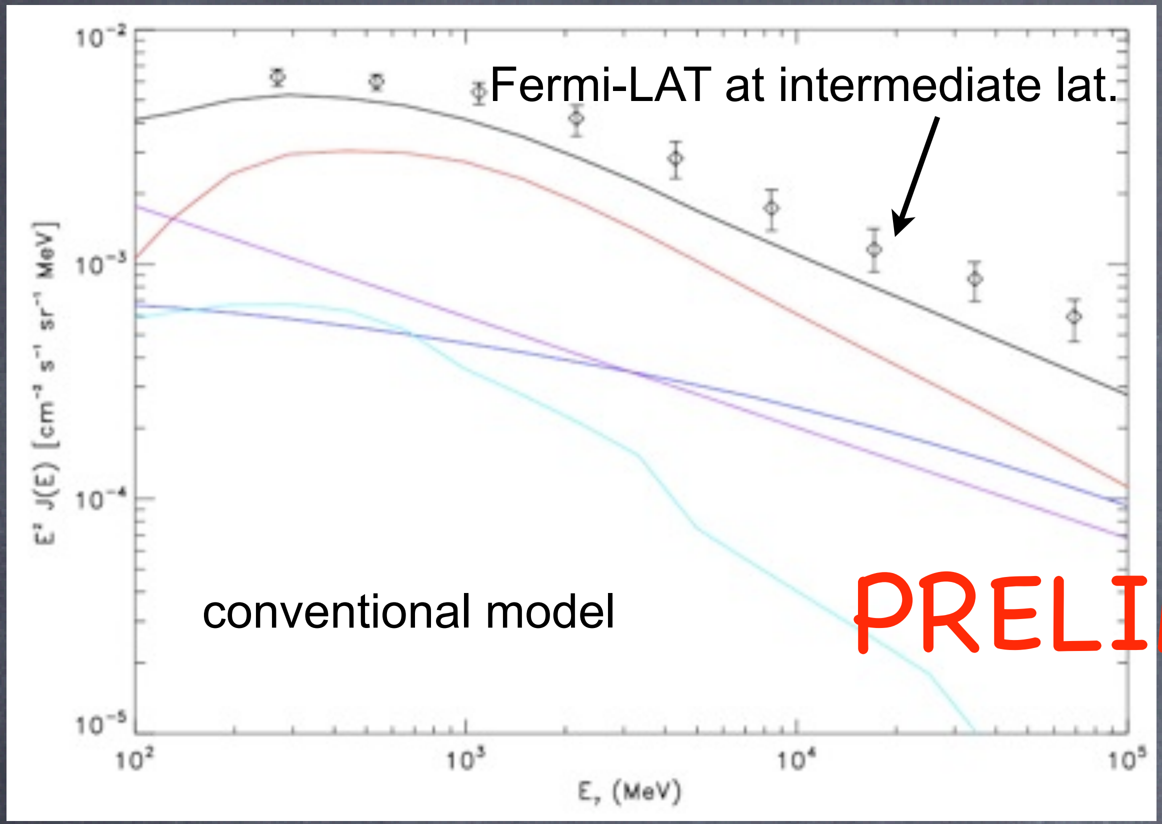
Modified background model with $\gamma_0 = 2.4$ and $\delta = 0.46$ and $E_{cut} = 2$ TeV

PRELIMINAR

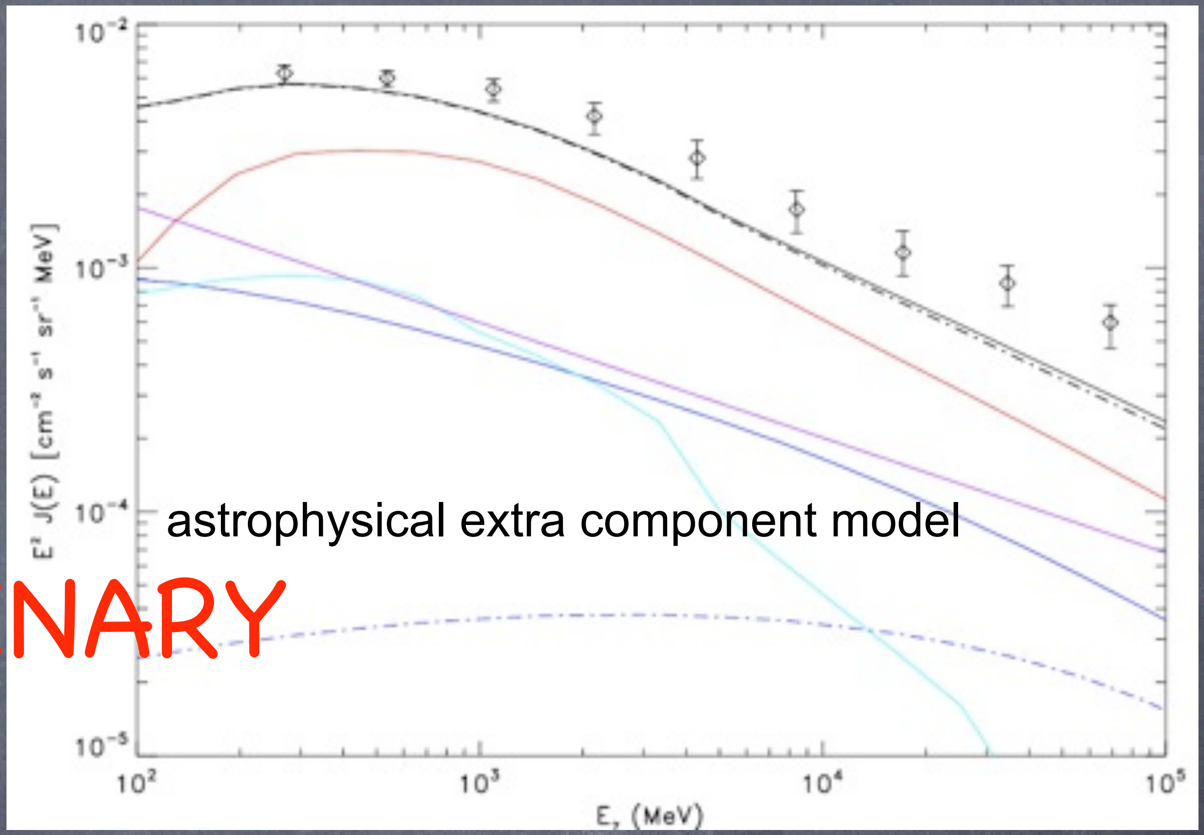




Is this consistent with γ-ray measurements ?



PRELIMINARY



The extra component can be safely approximated here with a continuos distribution

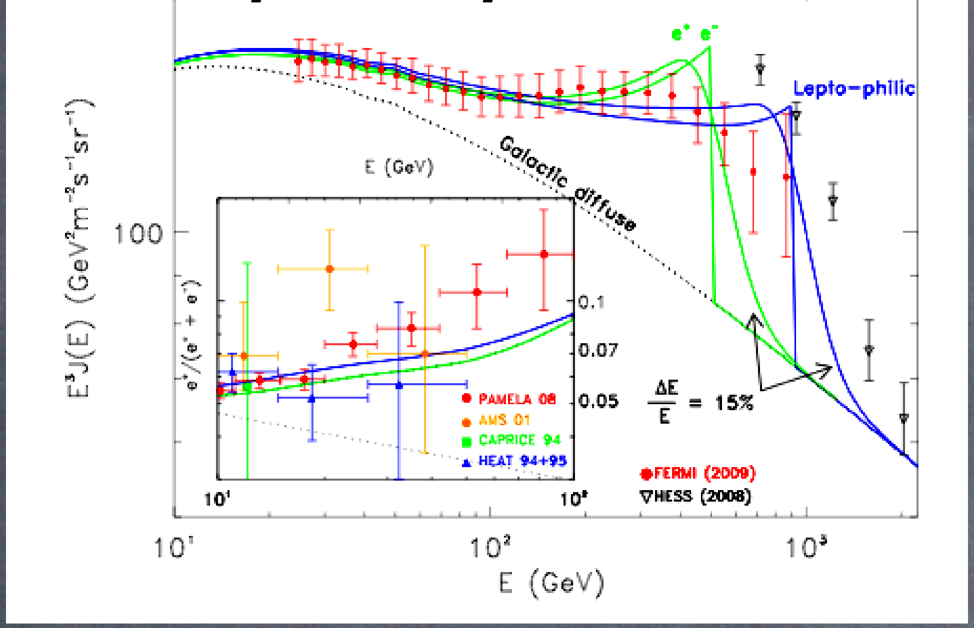
Accurate data by Fermi-LAT and AMS-02 may help to disentangle those scenario

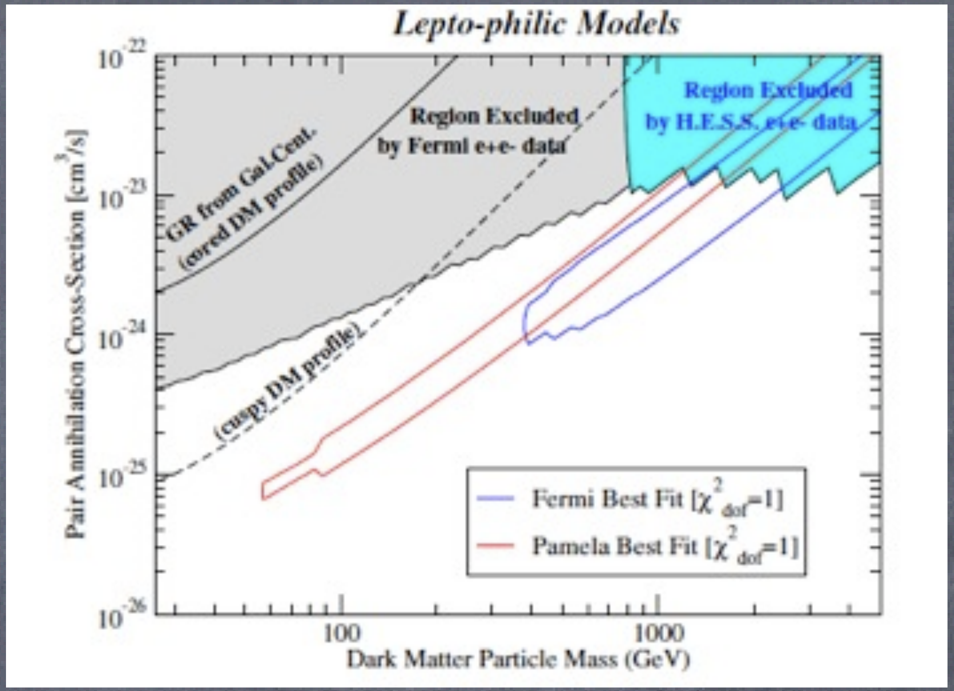
The predicted flux should be compared with observations at different latitudes (work in progress) in order to disentangle astrophysical from dark matter signatures (see below).

Dark matter annihilation interpretation(s)

Recent models invoke new (pseudo)scalar particle(s) which may decay mainly into leptons (such to avoid PAMELA antiproton constraints) and boost the annihilation cross above the value expected from standard cosmology due to the Born-Sommerfeld effect

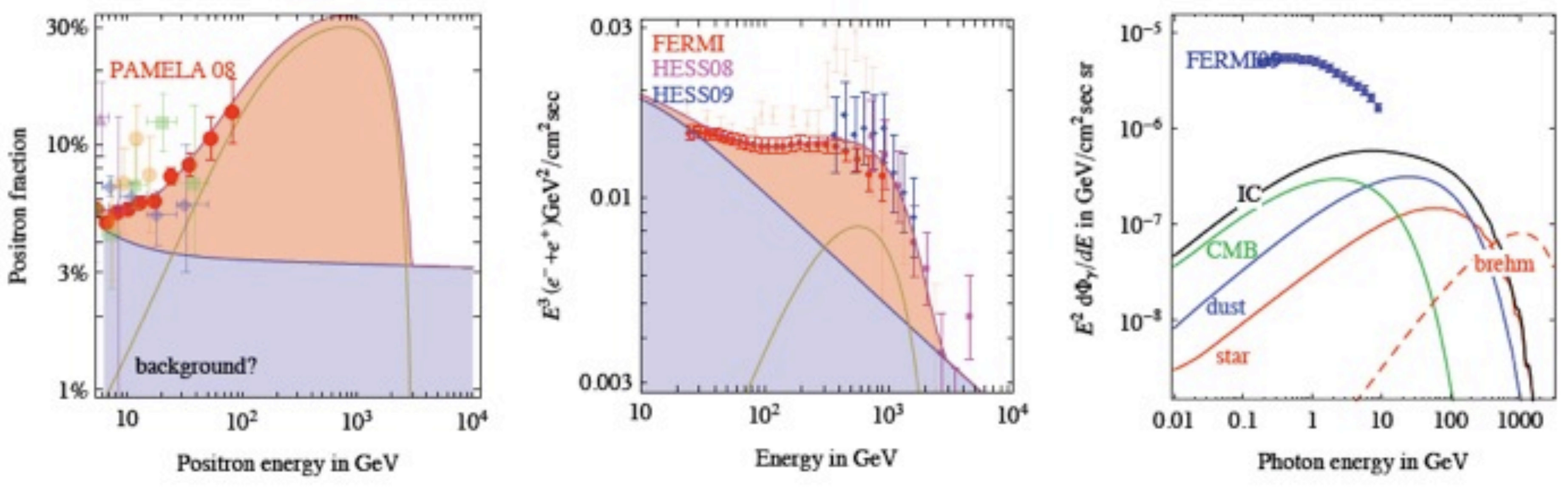
D.G. et al. [Fermi coll.] 2009



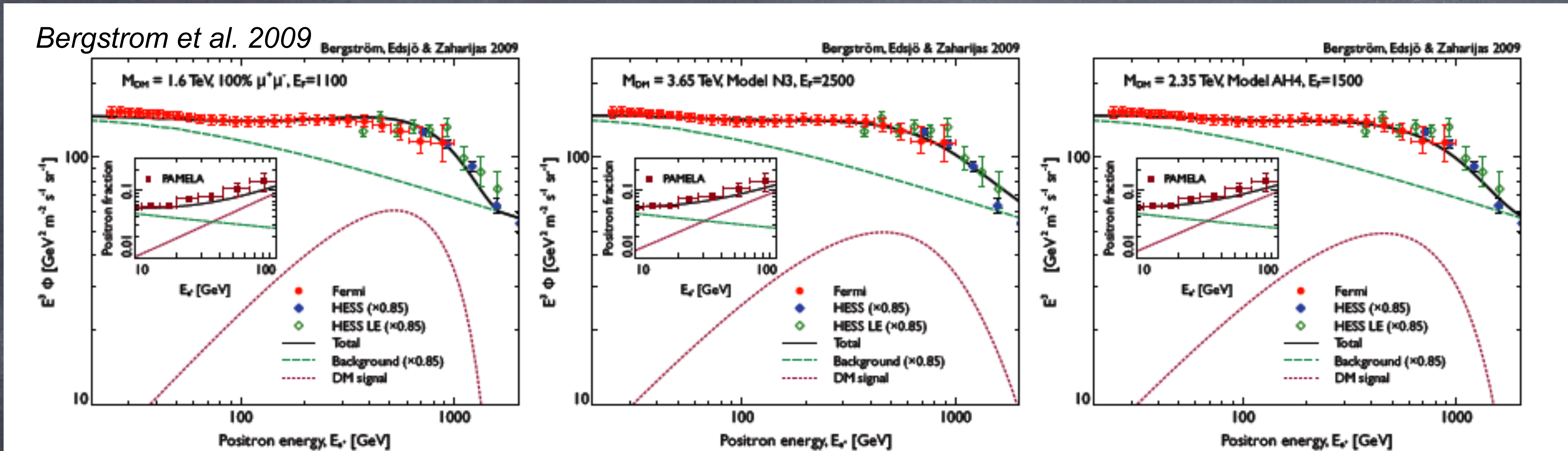


Meade, Papucci, Strumia, Volansky, 2009

DM with $M = 3.$ TeV that annihilates into 4μ with $\sigma v = 8.8 \times 10^{-23}$ cm^3/s



Dark matter annihilation interpretation(s)



Combined interpretations of PAMELA and Fermi-LAT results have been proposed also for decaying DM scenarios

Constraints to those models have been obtained on the basis of antiproton data and gamma-ray measurements (see next talks)

<u>It is crucial, in order to impose meaningful constraints on particle physics parameters from observations, to treat dark matter annihilation/decay products propagation consistently with the computation of the astrophysical background</u>
Quite often this was not done properly !

Astrophysical degeneracy's should also be taken into proper account

Astrophysical vs dark matter interpretations
possible targets for AMS-02

• Spectral features

- Spectral breaks both in the e- and e+ spectra should be confirmed to validate the presence of the extra e± component (either astrophysical or DM): PAMELA positron anomaly need to be confirmed by AMS-02 and the CRE spectrum has to measured with better accuracy.

- Some bumpiness in the CRE spectrum may be expected for the astrophysical interpretation. Bumpiness may also affect the DM constraints.
Its level depends on the propagation parameters which need to be constrained as better as possible by AMS-02 CR nuclei measurements.

• Electron Flux Anisotropy

- In the case of pulsars it should detectable by Fermi-LAT and possibly better by AMS-02 and point to some nearby object
- For DM annihilation the anis. should point to the GC; from a local clump is expected to be small. In both cases it strongly depend on the propagation parameters.

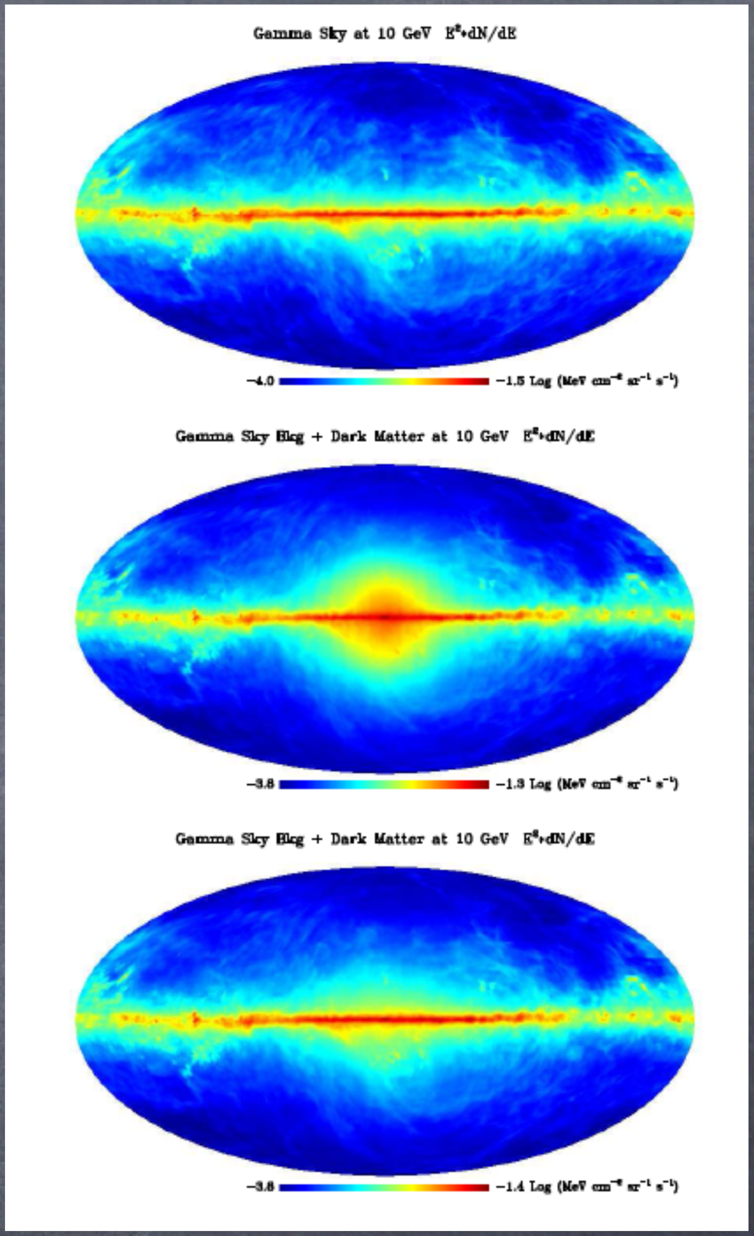
Astrophysical vs dark matter interpretations

• Gamma-ray measurements

- The presence of an extra CRE component should give rise to spectral breaks in the IC component of the diffuse emission of the Galaxy
- the effect should change differently for astrophysical, DM annihilation, DM decay, with Galactic latitude

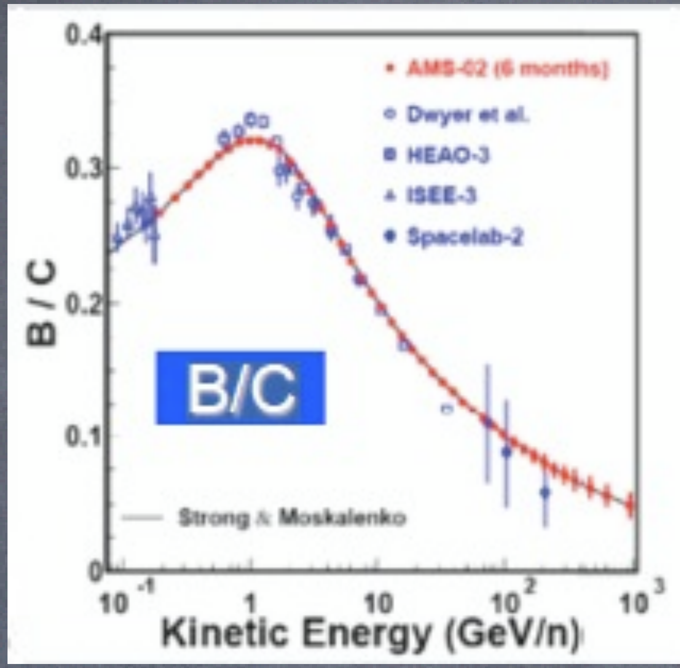
Fermi-LAT will soon provide detailed maps and spectra

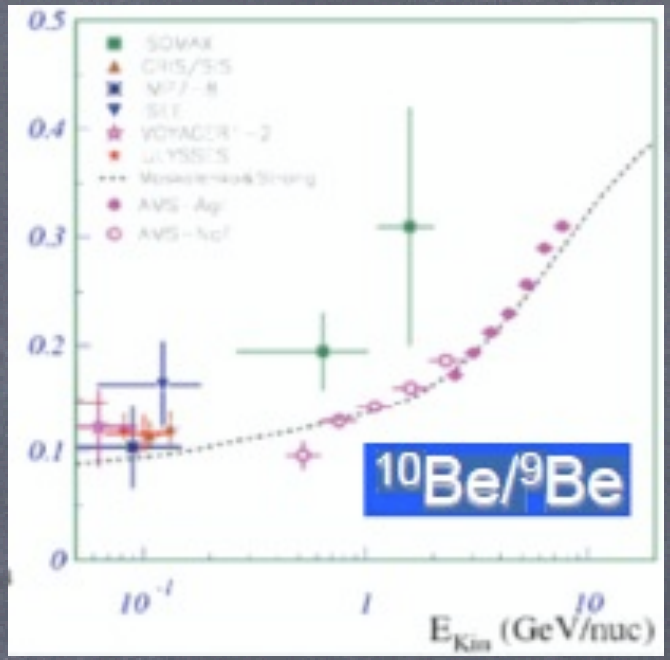
Similar considerations apply for the synchrotron haze to be observed by PLANCK



Again, the correct interpretation of those results requires a better knowledge of CR propagation (z_{max} , D_0, δ) which need to be inferred from independent CR measurements)

AMS-02 related science targets





Note that so far the uncentainty is quite large: the MIN/MED/MAX models in *Bottino et al. 2005* - δ = 0.85/0.7/0.46 - *Strong & Moskalenko 2004* use δ = 0.33, *Evoli et al. 2009* best fit δ = 0.46; *while* $1 < z_{max} < 10$ kpc

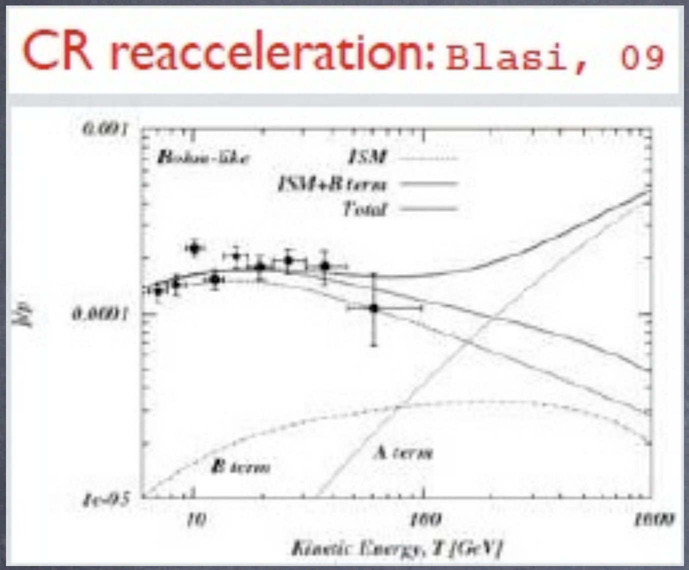
IT IS CRUCIAL TO REDUCE THE UNCERTANTIES ON THOSE PARAMETERS

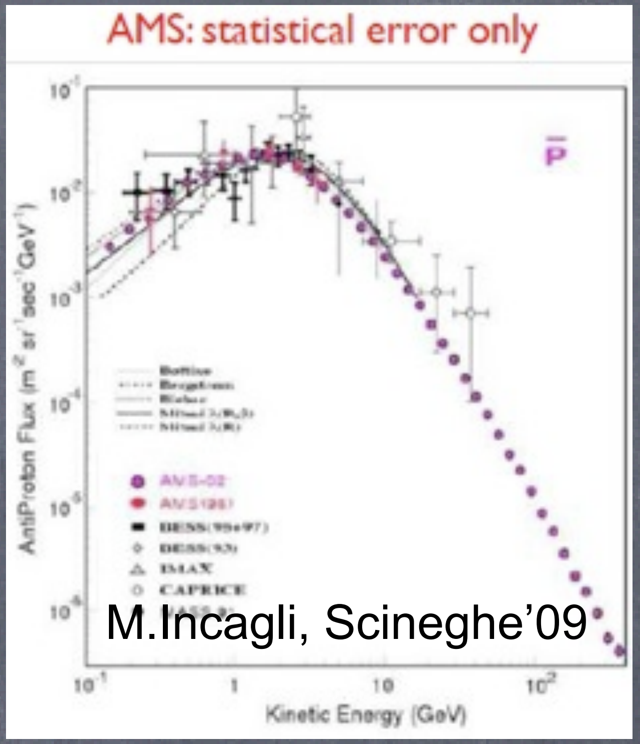
MEASUREMENTS ARE NOT ENOUGH - all this requires semi-analytical or numerical models (GALPROP or DRAGON) and a lot of expertise.

Our group (Di Bernardo, Evoli, Maccione, Gaggero, D.G.) already worked on this issue (see Maccione talk) and it is willing to widen the collaboration

AMS-02 related science targets

Antiprotons can then be used either to confirm those measurements or to look for signal of new physics or to exclude some interpretations

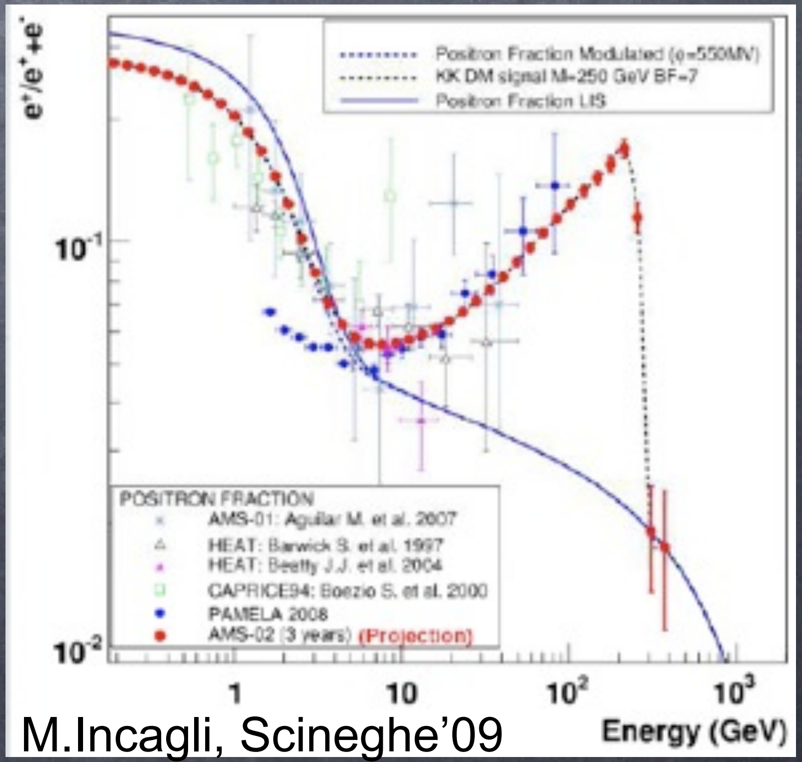




This requires the same tools as for the CR

The positron fraction anomaly has to be confirmed and explored to higher energies.
It would be the strongest evidence in favour of an extra component

It should be compared with CR tuned astrophysical and DM models



AMS-02 related science targets

Electron spectrum may be measured by AMS-02 up to few TeV with the best energy resolution and lowest hadron contamination

this will be crucial to confirm the spectral features hints by Fermi-LAT and to better measure the spectrum around the TeV

The great advantage of AMS-02 is to allow to perform all these measurments with the same experiment, at the same time and out of the atmosphere

All this, however, may not be enough to disentangle astrophysical from DM interpretations of PAMELA positron anomaly (if confirmed) without complementary γ-ray and radio observations

Consistent interpretations of all those data requires the use of comprehensive numerical codes as GALPROP or the upgraded DRAGON(e)

We look for people willing to help us to upgrade DRAGON(e) and to do physics with it

- already works for light nuclei; electrons; gamma-ray
- already interfaced with DARKSUSY
- should be possibly implemented to 3D to better account for local source and to account for anisotropic diffusion