

studying cosmic-ray propagation with AMS-02

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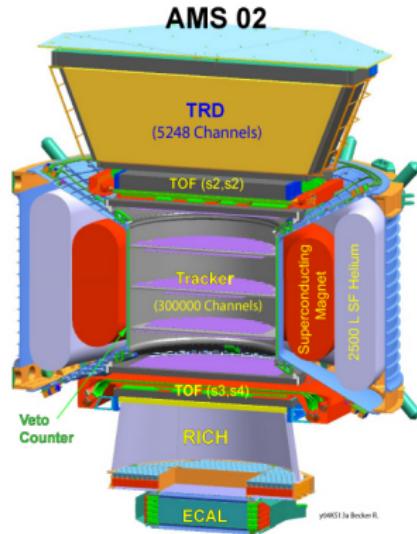
pinpointing cosmic ray propagation with AMS-02

main aim

study the implications of high precision measurements of
two key observables:

$$B/C \text{ and } {}^{10}\text{Be}/{}^9\text{Be}$$

[MP, Hooper & Simet]



use (conservative) projected capabilities of AMS-02 for B, C, ${}^{10}\text{Be}$, ${}^9\text{Be}$

$$\Delta T/T \simeq 20\% \quad \text{1-year data}$$

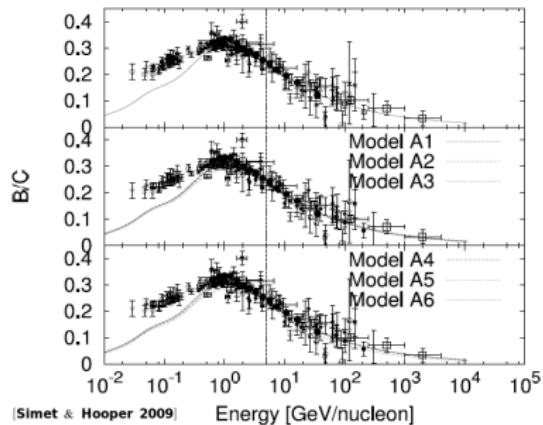
$$acc_B = acc_C = acc_{Be} = 0.45 \text{ m}^2\text{sr}$$

systematic misidentification of B and C: $\lesssim 1\%$

mass resolution of Be: $\Delta m/m \sim 2.5\%$

pinpointing cosmic ray propagation with AMS-02

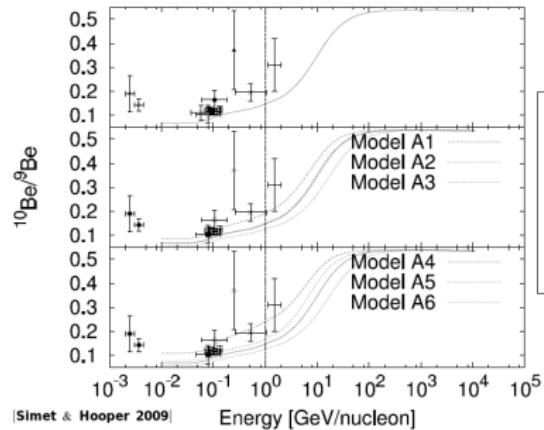
secondary-to-primary ratios



[Smet & Hooper 2009]

→ matter crossed by primaries

unstable ratios

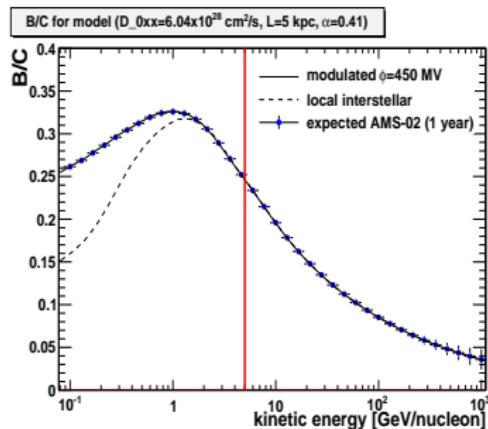


[Smet & Hooper 2009]

→ time since spallation

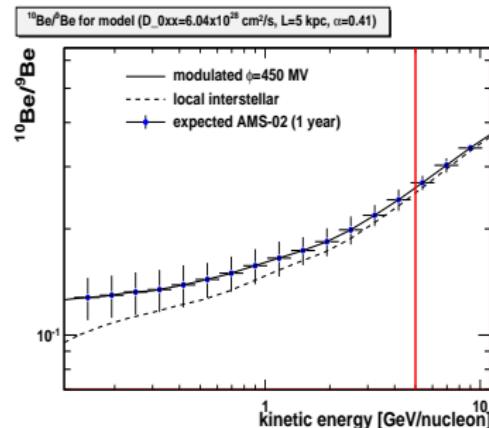
pinpointing cosmic ray propagation with AMS-02

secondary-to-primary ratios



→ matter crossed by primaries

unstable ratios



→ time since spallation

after AMS-02 how much better can we constrain propagation?

cosmic-ray propagation paradigm

$$\begin{aligned}\frac{\partial n_i}{\partial t} = & Q_{tot,i}(\mathbf{x}, p, t) + \vec{\nabla} \cdot \left(D_{xx}(\mathbf{x}, R) \vec{\nabla} n_i - \vec{V}_c(\mathbf{x}) n_i \right) \\ & + \frac{\partial}{\partial p} p^2 D_{pp}(\mathbf{x}, R) \frac{\partial}{\partial p} p^2 n_i - \frac{n_i}{\tau_{d,i}} - \frac{n_i}{\tau_{sp,i}} \\ & - \frac{\partial}{\partial p} \left(b_i(\mathbf{x}, p) n_i - \frac{p}{3} \vec{\nabla} \cdot \vec{V}_c(\mathbf{x}) n_i \right)\end{aligned}$$

$$D_{xx}(R) = (v/c) D_{0xx} (R/R_0)^\alpha$$

geometry: cylinder r_{max} , L

$$\vec{V}_c(\mathbf{x}) = sgn(z)(V_{c,0} + |z| dV_c/dz) \vec{e}_z$$

approximation: steady-state solution, $\frac{\partial n_i}{\partial t} = 0$

$$D_{pp}(R) = \frac{4p^2 v_A^2}{3\alpha(4-\alpha^2)(4-\alpha)D_{xx}(R)}$$

(semi-)analytical vs numerical

e.g. Galprop (v50.1p)

pinpointing cosmic ray propagation with AMS-02

strategy

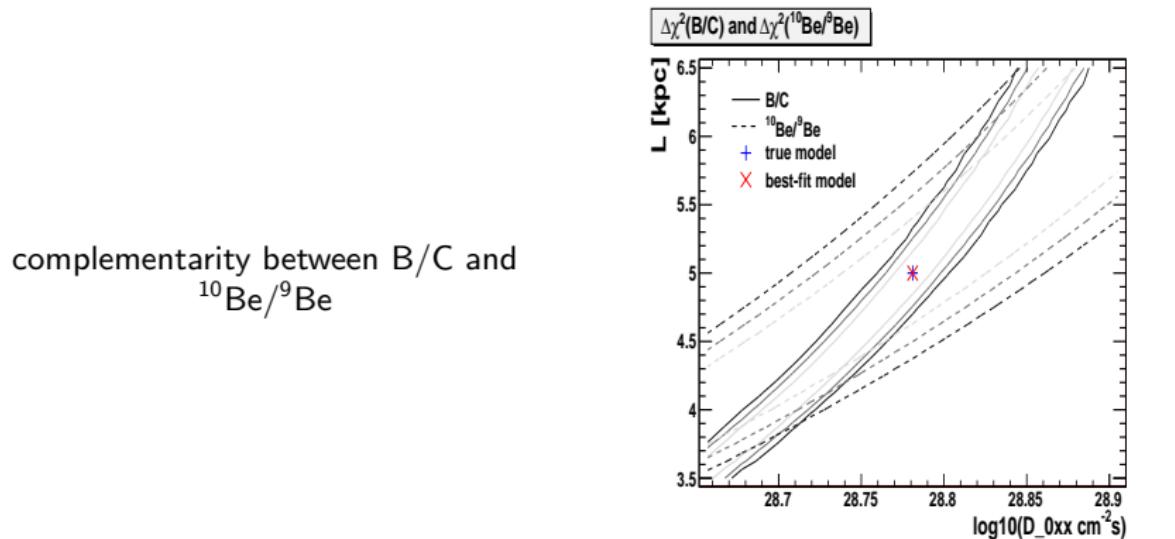
assume true model from Simet & Hooper 2009

$$D_{0xx} = 6.04 \cdot 10^{28} \text{ cm}^2/\text{s} \quad (R_0 = 4 \text{ GV}), \quad L = 5 \text{ kpc}, \quad \alpha = 0.41, \quad v_A = 36 \text{ km/s}, \quad dV_c/dz = 0$$

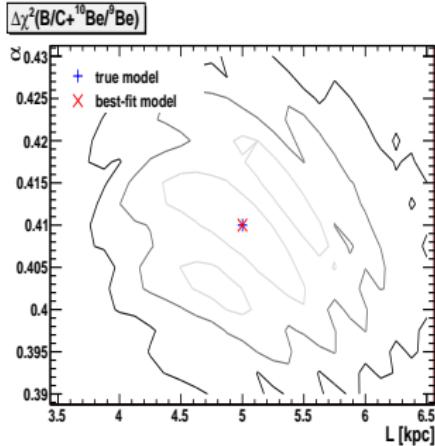
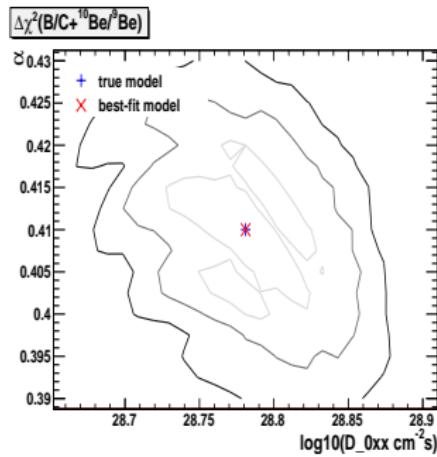
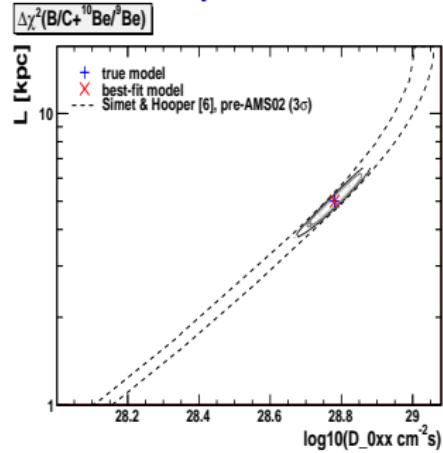
project AMS-02 B/C, ${}^{10}\text{Be}/{}^9\text{Be}$ data $T > 5 \text{ GeV}$

scan over α, D_{0xx}, L

draw 1, 2, 3 σ contours



the inverse problem



accuracy at 1σ

$$\Delta D_{0xx} \sim 1.4 \cdot 10^{28} \text{ cm}^2/\text{s}$$

$$\Delta L \sim 1.0 \text{ kpc}$$

$$\Delta \alpha \sim 0.02$$

much better than with present data

varying reacceleration and convection

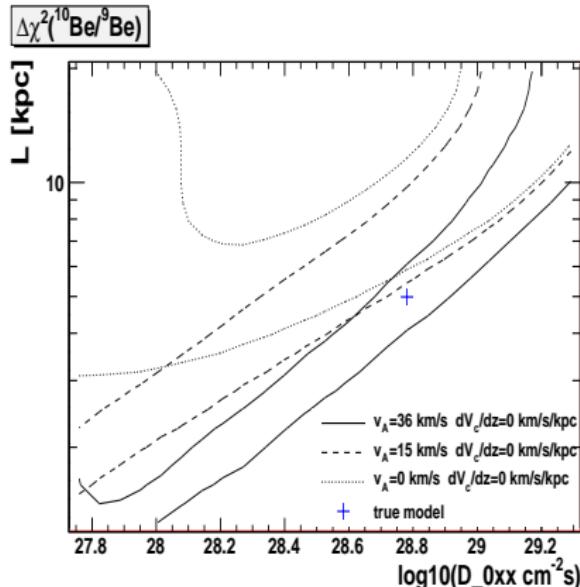
assume true model from Simet & Hooper 2009 for data projection

scan over α , D_{0xx} , L using different $(v_A, dV_z/dz)$

[lower v_A counterbalanced by higher L/D_{0xx}]

bottomline: AMS-02 fairly sensitive to details of reacceleration and convection

B/C + $^{10}\text{Be}/^{9}\text{Be}$ best-fit model ($N_{dof} = 21$)			
v_A	dV_c/dz	$(D_{0xx} [10^{28}\text{cm}^2\text{s}], L [\text{kpc}], \alpha)$	χ^2/N_{dof}
36	0	(6.04, 5.000, 0.4100)	0
15	0	(6.04, 8.000, 0.4850)	1.36
0	0	(6.04, 8.997, 0.5000)	2.17
0	10	(3.89, 5.623, 0.5000)	12.78



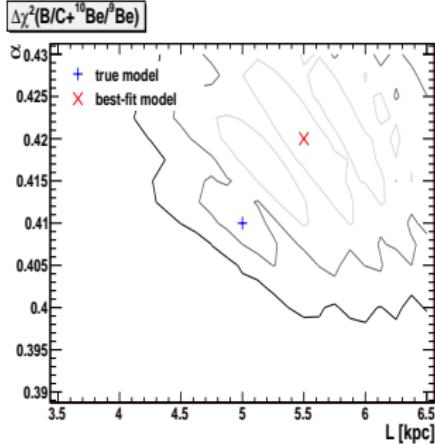
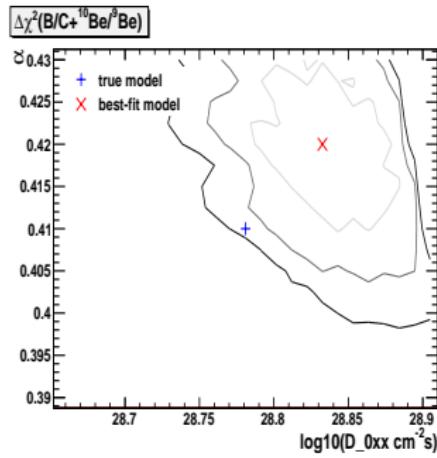
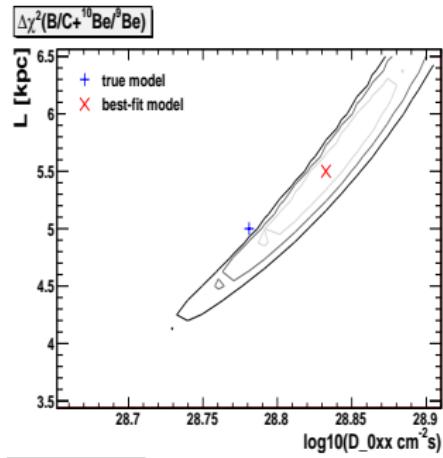
breaking the assumptions

can we fit AMS-02 B/C + $^{10}\text{Be}/^{9}\text{Be}$ data even with wrong assumptions?

use different 'true' models and scan over α , D_{0xx} , L ($v_A = 36 \text{ km/s}$, $\frac{dV_c}{dz} = 0$)

		$B/C + ^{10}\text{Be}/^{9}\text{Be}$ best-fit model ($N_{dof} = 21$)	
broken assumption	specification	$(D_{0xx} [10^{28} \text{ cm}^2/\text{s}], L [\text{kpc}], \alpha)$	χ^2/N_{dof}
true model (3D) (*)		(6.04, 5.000, 0.4175)	0.03
Stochasticity (*)	$x = 7 \text{ kpc}, y = 0 \text{ kpc}$	(4.76, 4.000, 0.4000)	0.03
	$x = 8 \text{ kpc}, y = 0 \text{ kpc}$	(5.24, 4.375, 0.4125)	0.02
	$x = 8 \text{ kpc}, y = 1 \text{ kpc}$	(5.24, 4.375, 0.4125)	$8 \cdot 10^{-3}$
	$x = 9 \text{ kpc}, y = 0 \text{ kpc}$	(7.48, 6.375, 0.4275)	0.05
	$x = 9 \text{ kpc}, y = 1 \text{ kpc}$	(7.66, 6.500, 0.4250)	0.06
	$x = 10 \text{ kpc}, y = 0 \text{ kpc}$	(8.03, 6.500, 0.4300)	0.41
Diffusion Coefficient	$\alpha_1 = 0.39, \alpha_2 = 0.43, \rho_0 = 4 \text{ GV}$	(6.18, 5.250, 0.4300)	0.07
	$\alpha_1 = 0.39, \alpha_2 = 0.43, \rho_0 = 10 \text{ GV}$	(5.76, 5.000, 0.4300)	0.03
	$\alpha_1 = 0.39, \alpha_2 = 0.43, \rho_0 = 10^2 \text{ GV}$	(6.04, 5.125, 0.4000)	0.13
	$\alpha_1 = 0.39, \alpha_2 = 0.43, \rho_0 = 10^3 \text{ GV}$	(6.04, 5.000, 0.3900)	$8 \cdot 10^{-4}$
Source Abundances	$^{12}\text{C} \times 1.2$	(6.80, 5.500, 0.4200)	0.02
	$^{12}\text{C} \times 0.8$	(5.11, 4.375, 0.3975)	0.04
	$(^{12}\text{C}, ^{14}\text{N}, ^{16}\text{O}) \times 2$	(6.18, 4.875, 0.4125)	0.03
Source Distribution	SNR distribution	(5.76, 4.625, 0.4000)	0.04
	pulsar distribution	(5.36, 4.750, 0.3925)	0.12
	reference + nearby source (*)	(6.33, 5.250, 0.4200)	0.03

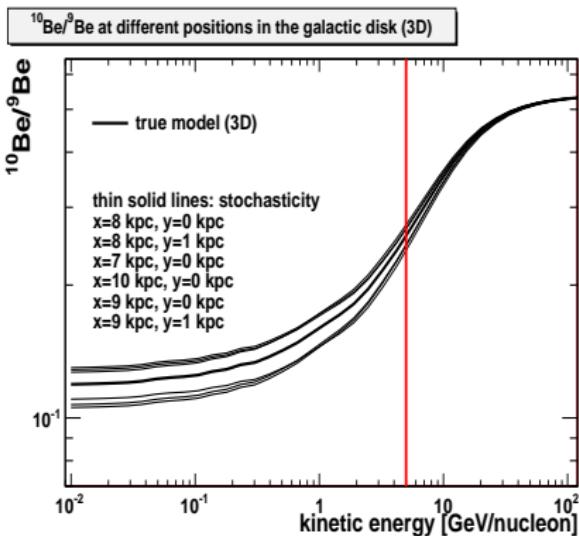
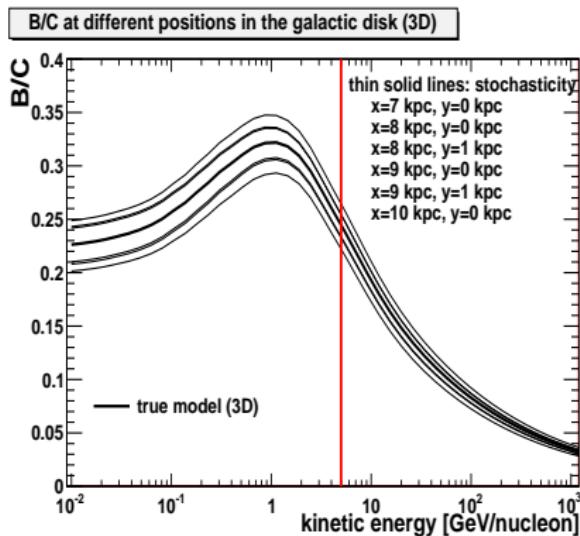
source abundances: $^{12}\text{C} \times 1.2$



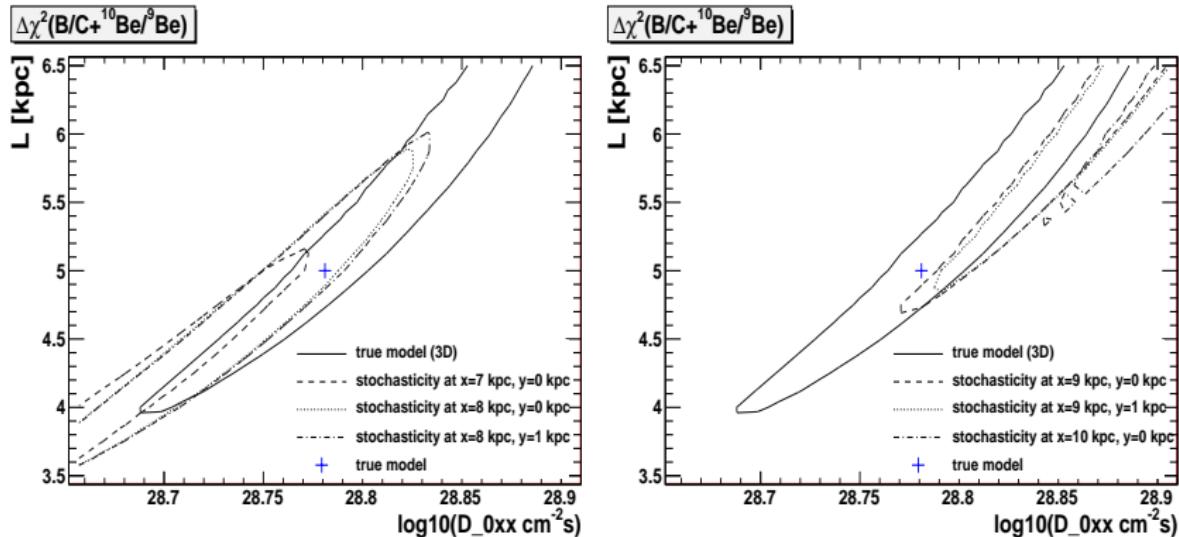
/ quality fits
 / wrong best-fit parameters

stochasticity

cosmic ray injection proceeds through stochastic events
temporal and spatial variations are expected in cosmic-ray fluxes
will AMS-02 be sensitive to such fluctuations?



stochasticity



short conclusions for AMS-02

within simple propagation models, the propagation parameters can be inferred
some degree of sensitivity to reacceleration/convection is expected
inaccurate assumptions produce good fits but wrong best-fit parameters