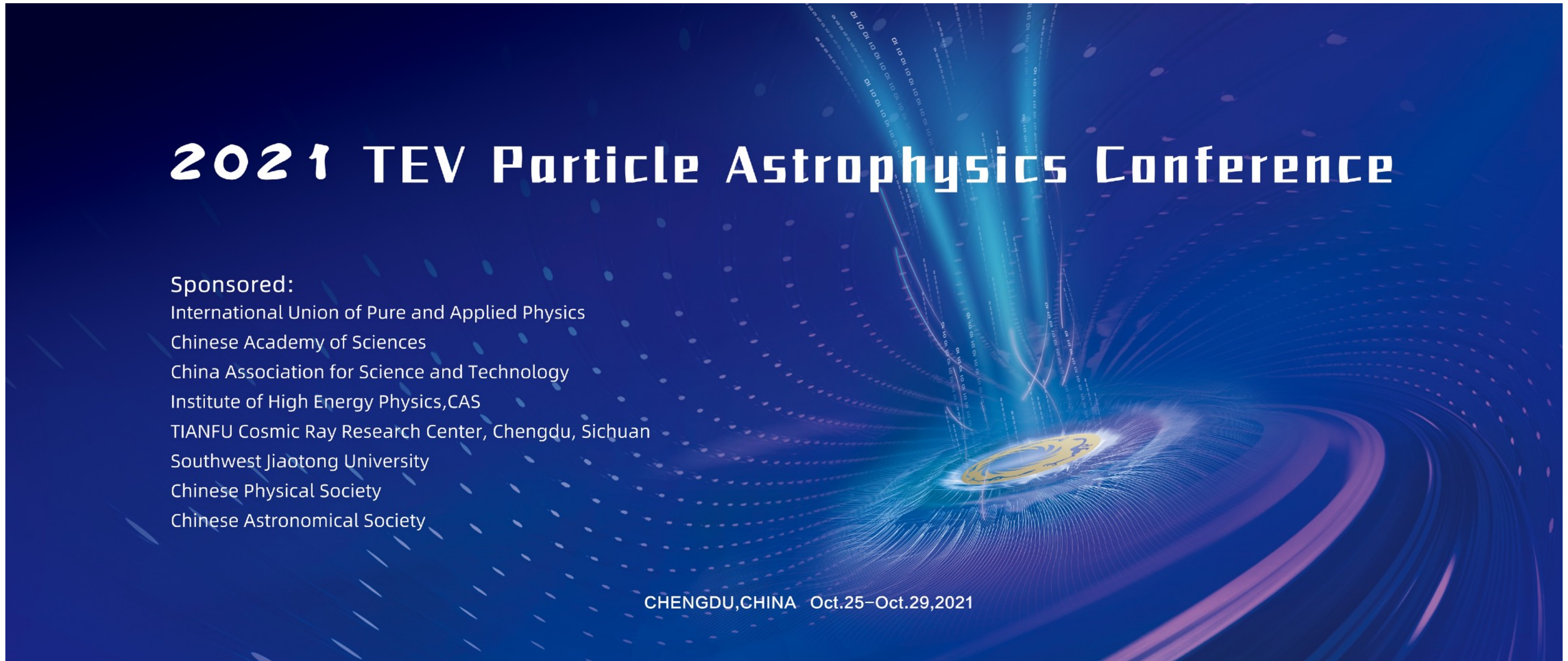
Implications of Li to O data of AMS-02 on our understanding cosmic-ray propagation

Michael Korsmeier
in collaboration with Alessandro Cuoco

Mostly based on:
Phys.Rev.D 103 (2021) 10, 103016



Outline

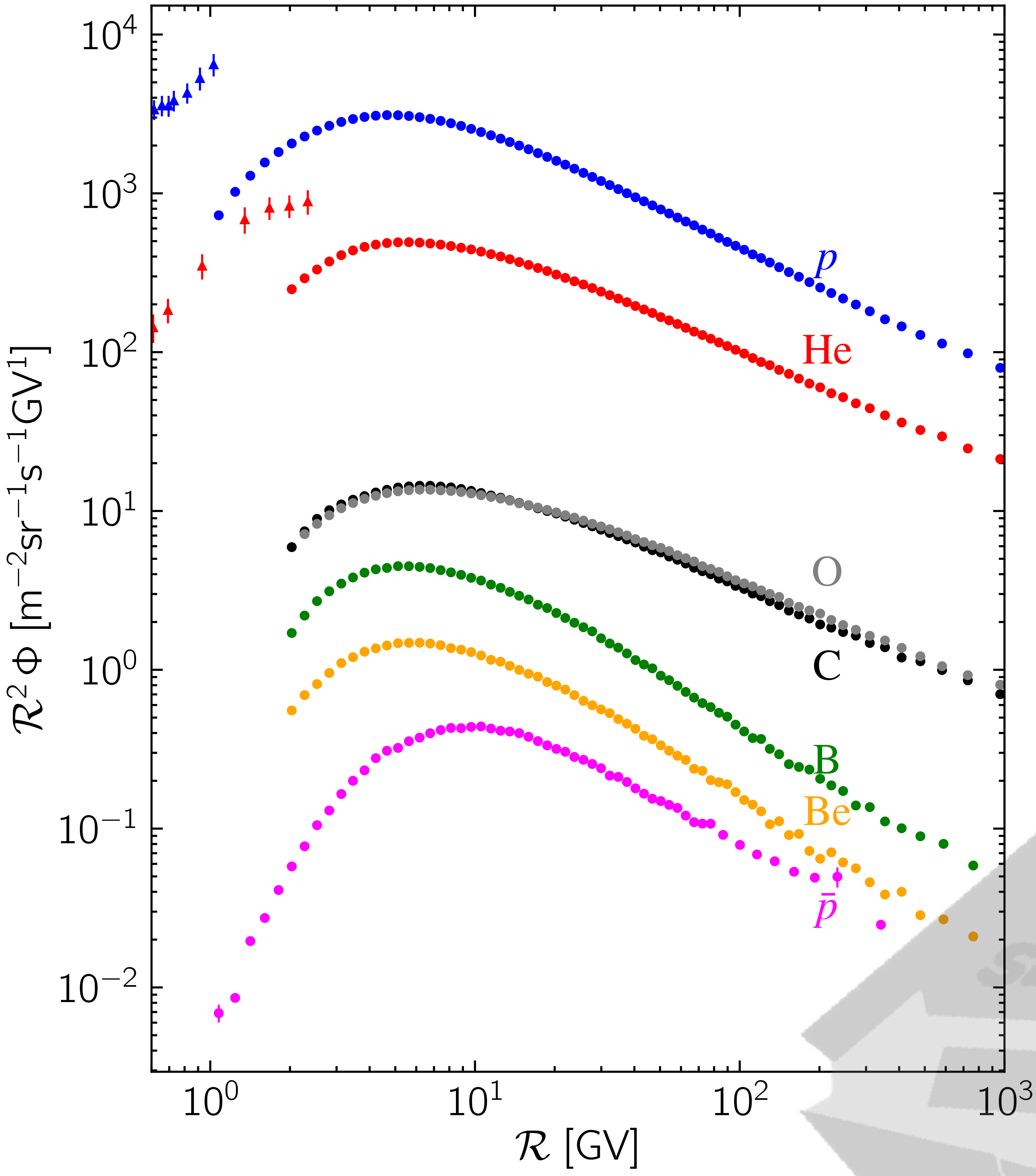
Introduction to CR propagation

Global fit of CR data from Li to O

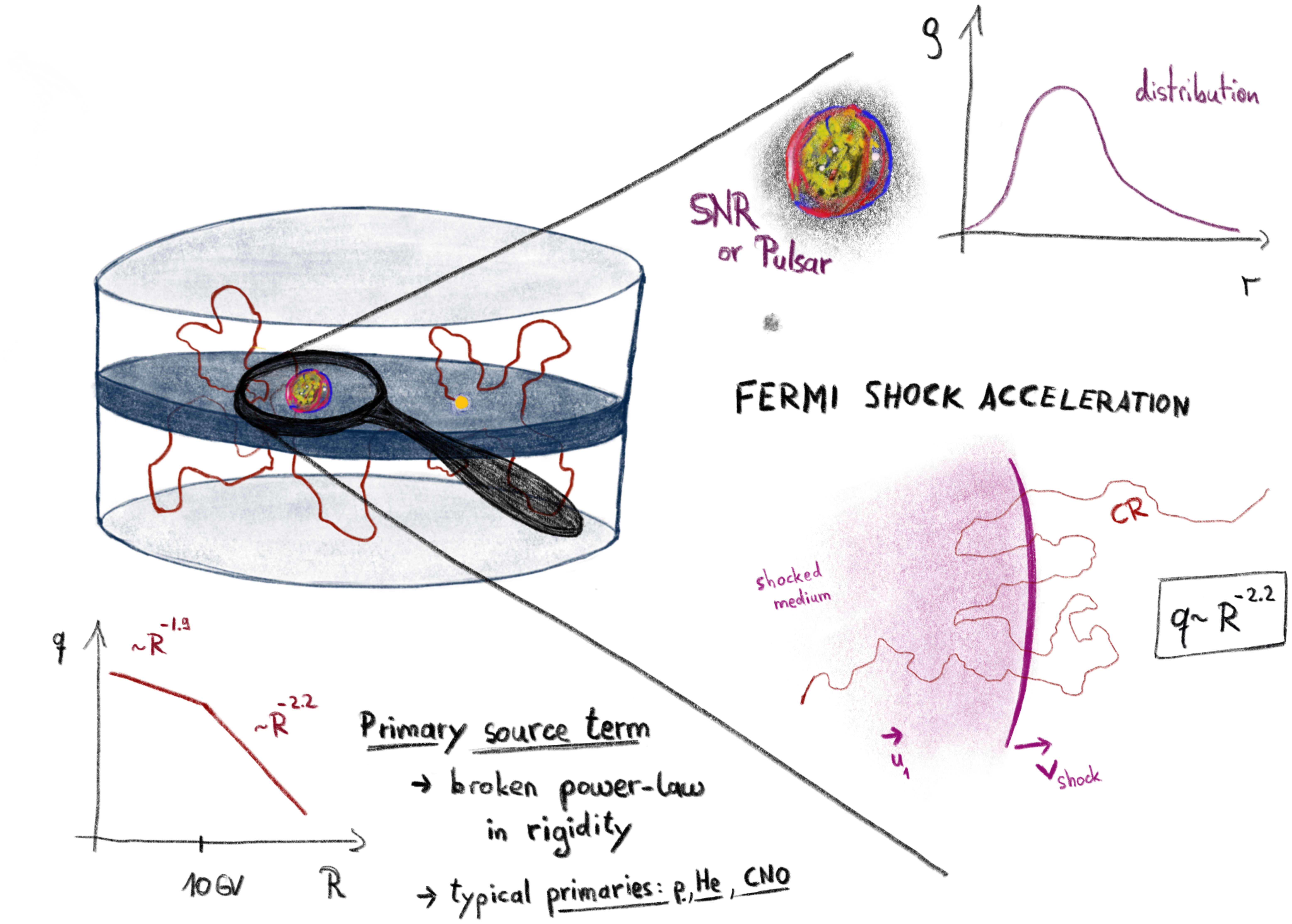
Cross section uncertainties

Correlations in the AMS-02 data

Conclusion & outlook



Modeling cosmic-ray propagation



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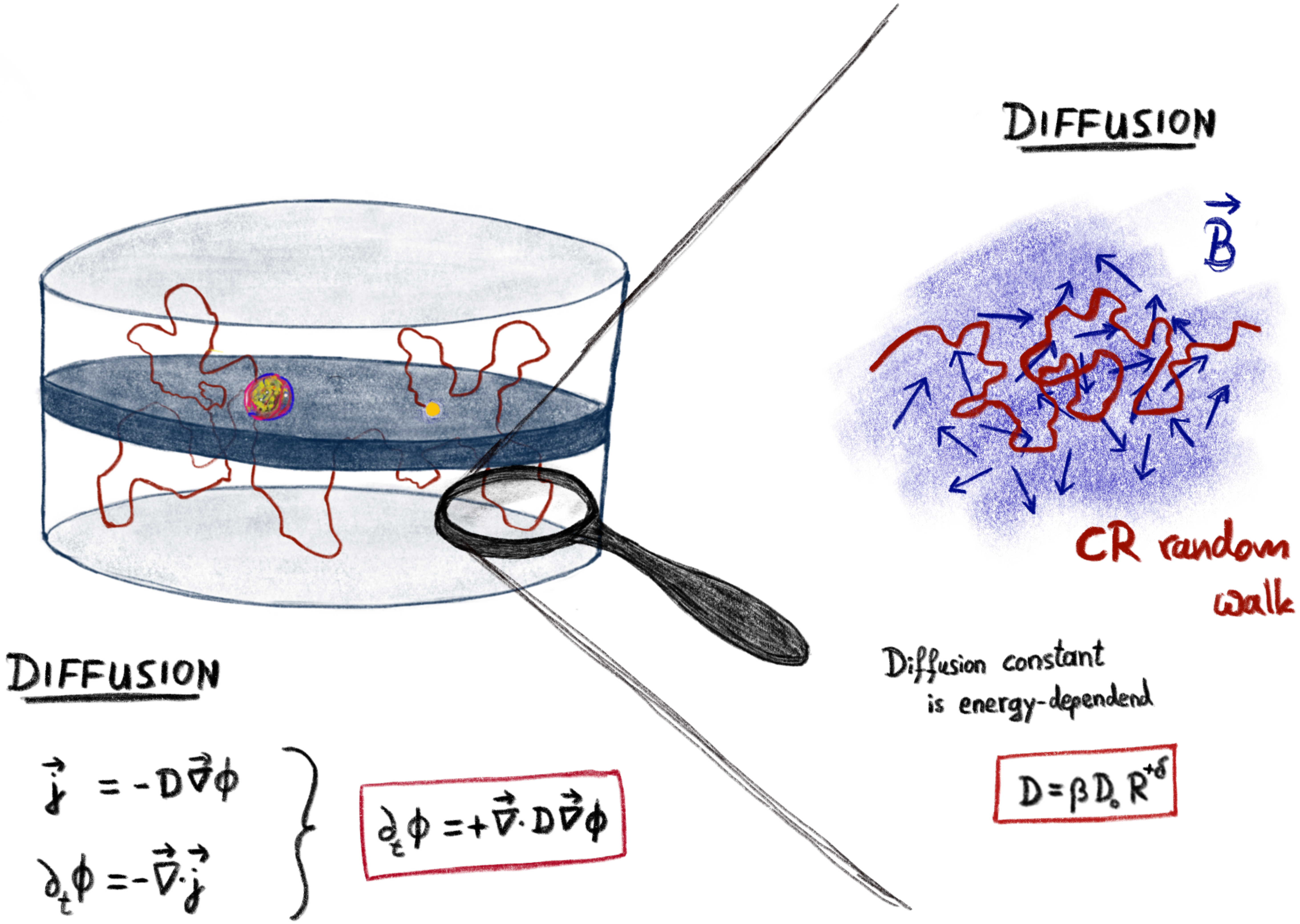

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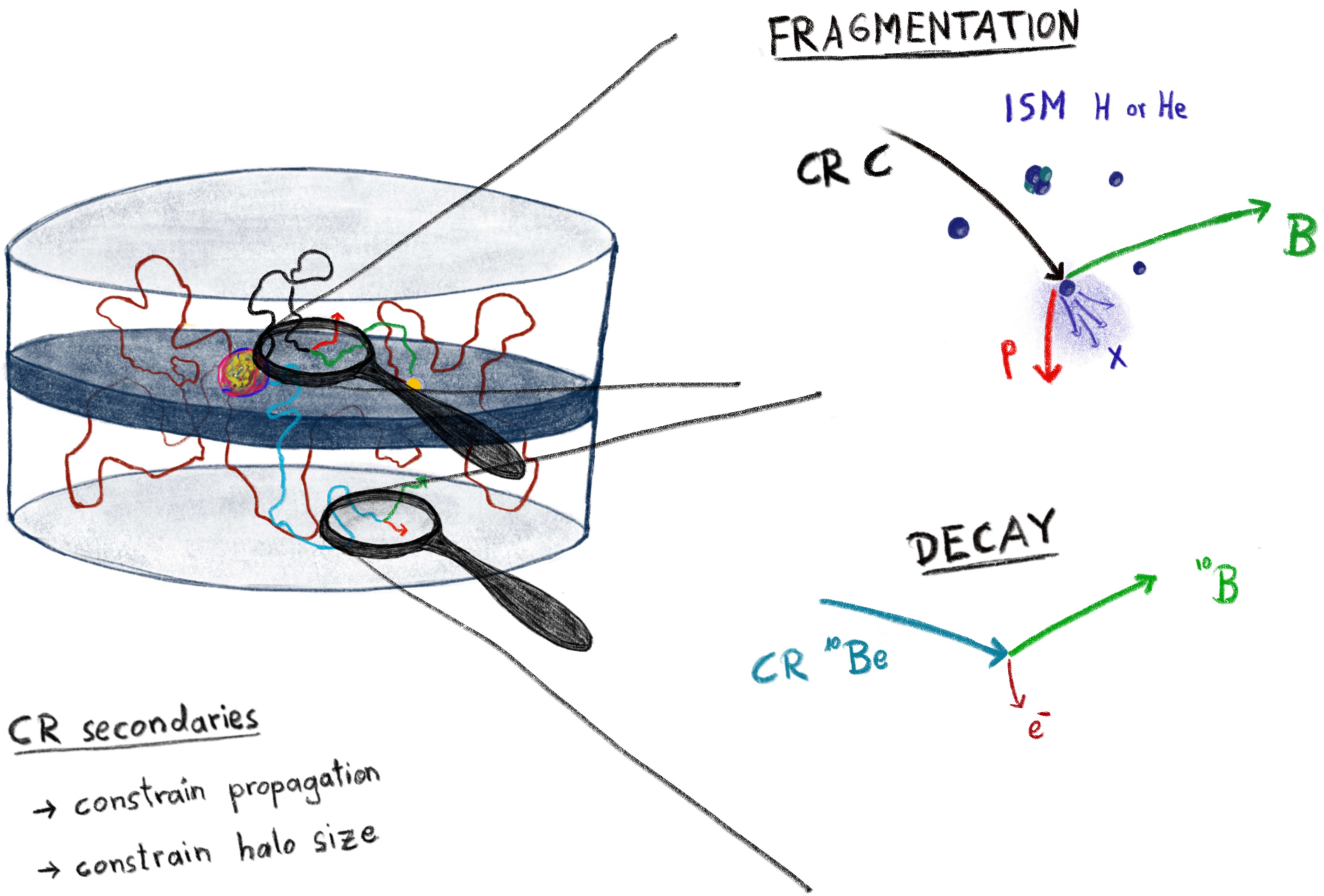
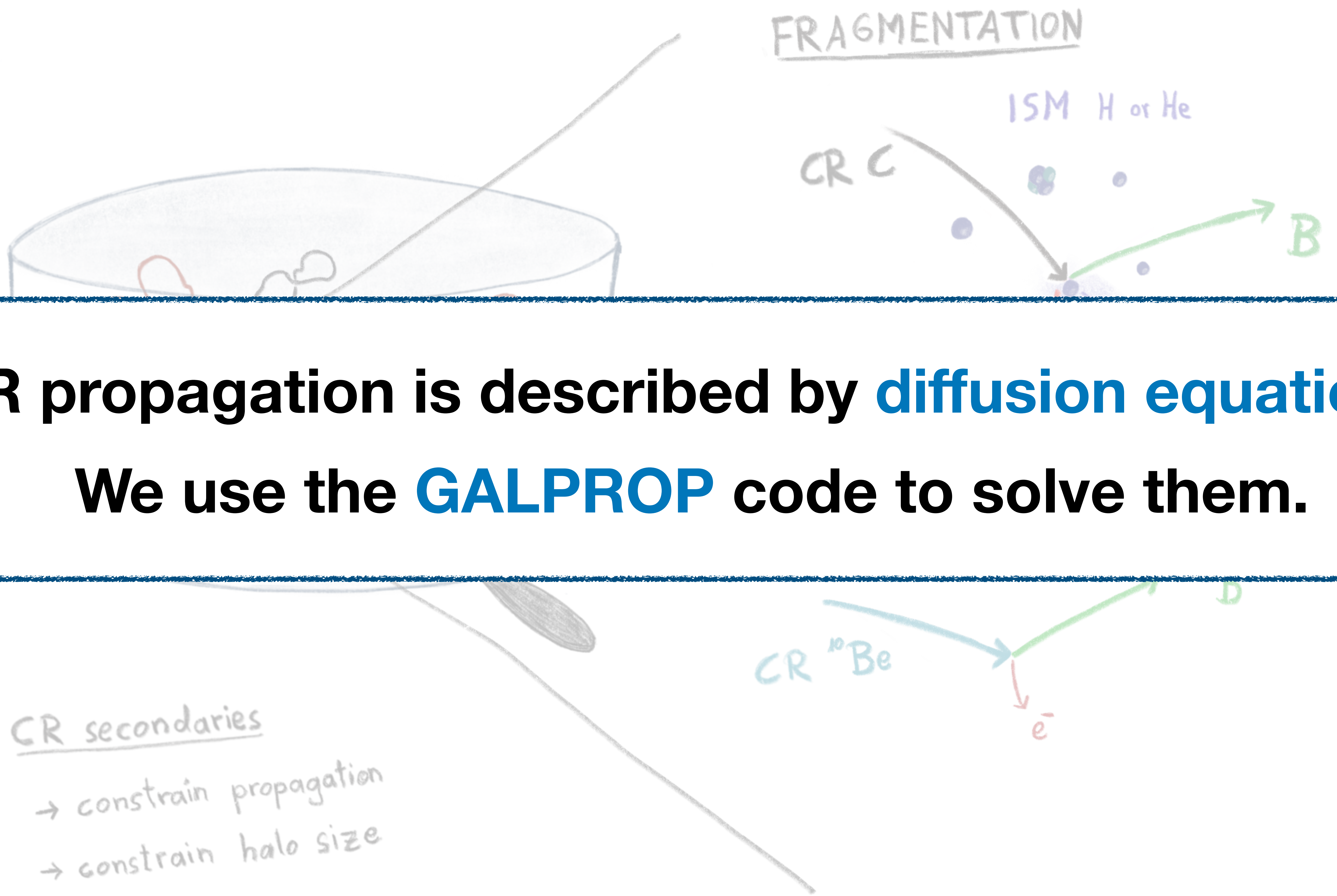


Modeling cosmic-ray propagation

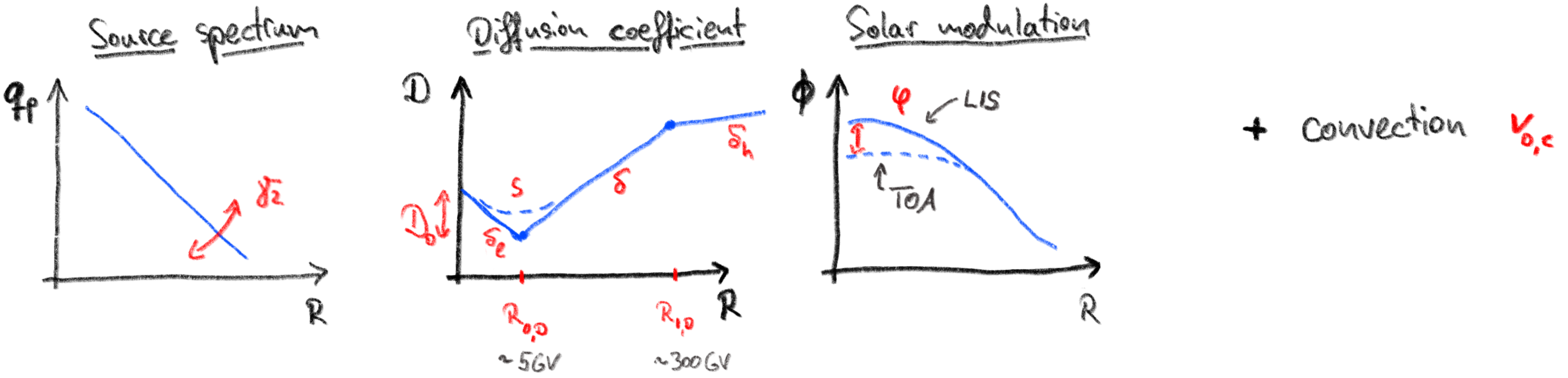


CR propagation is described by diffusion equations.

We use the GALPROP code to solve them.

We explore 5 different setups for CR propagation:

BASE BASE+v_A BASE+inj BASE+inj+v_A BASE+inj+v_A-diff.brk



$$\frac{\mathrm{d}\psi}{\mathrm{d}t} = q(\boldsymbol{x},p) + \boldsymbol{\nabla}\cdot(D_{xx}\boldsymbol{\nabla}\psi - \boldsymbol{V}\psi) + \frac{\partial}{\partial p}p^2 D_{pp}\frac{\partial}{\partial p}\frac{1}{p^2}\psi - \frac{\partial}{\partial p}\left(\frac{\mathrm{d}p}{\mathrm{d}t}\psi - \frac{p}{3}\boldsymbol{\nabla}\cdot\boldsymbol{V}\psi\right) - \frac{1}{\tau_f}\psi - \frac{1}{\tau_r}\psi$$

CR propagation models

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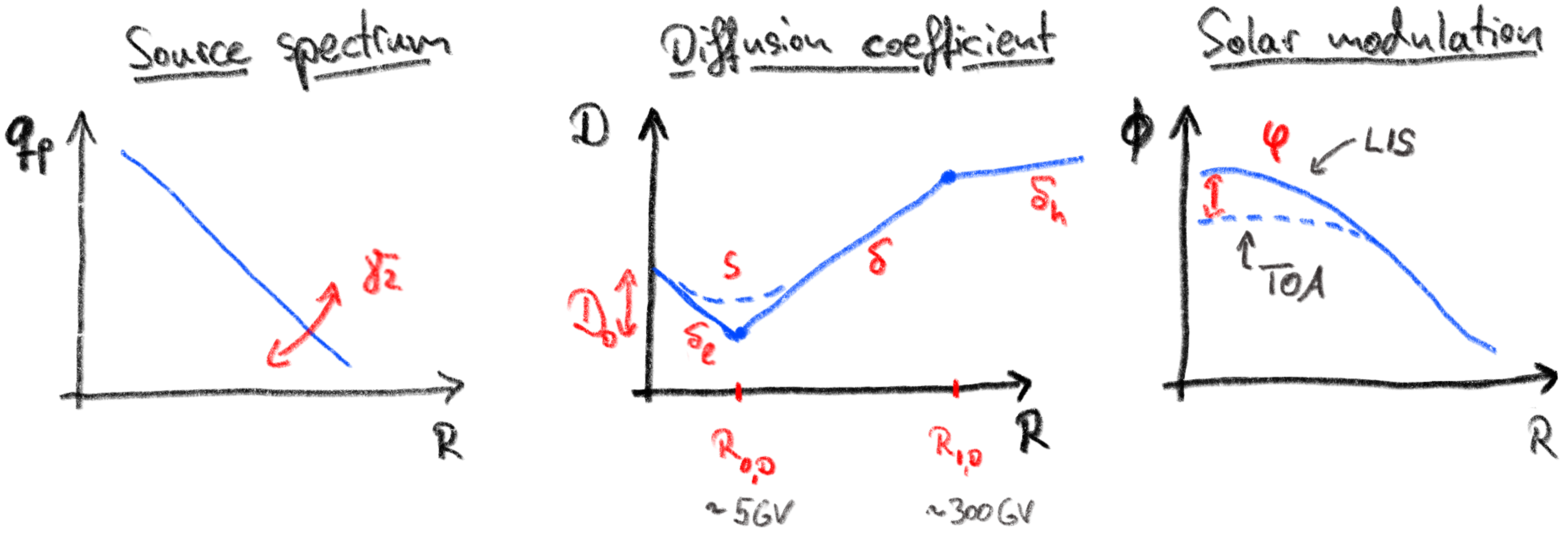

+ convection $v_{0,c}$
+ reacceleration v_A

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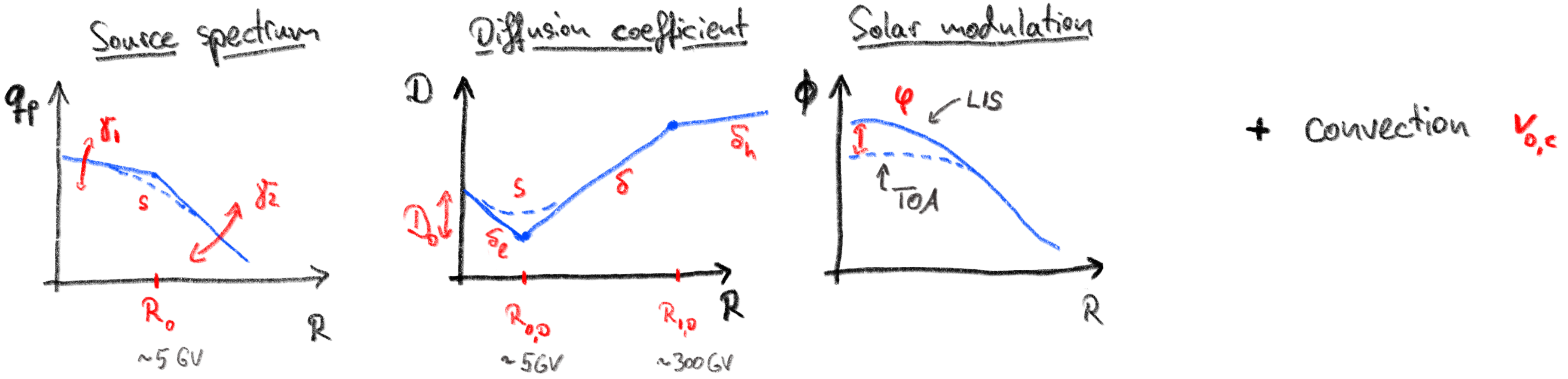

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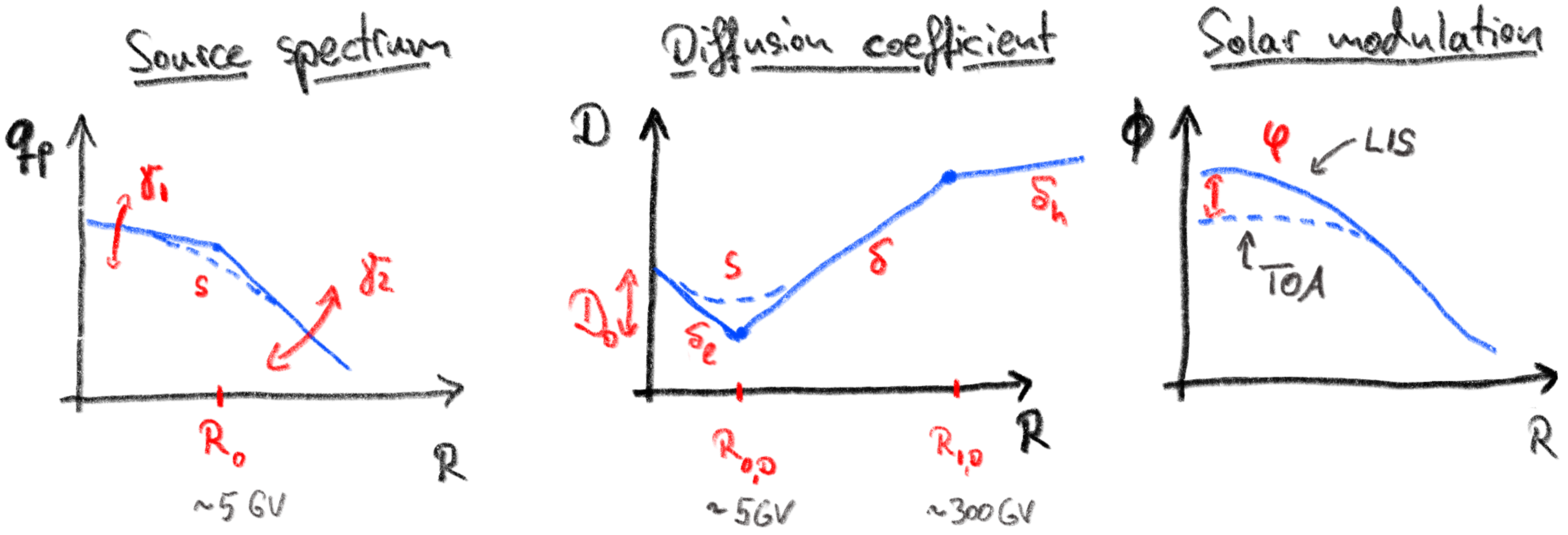

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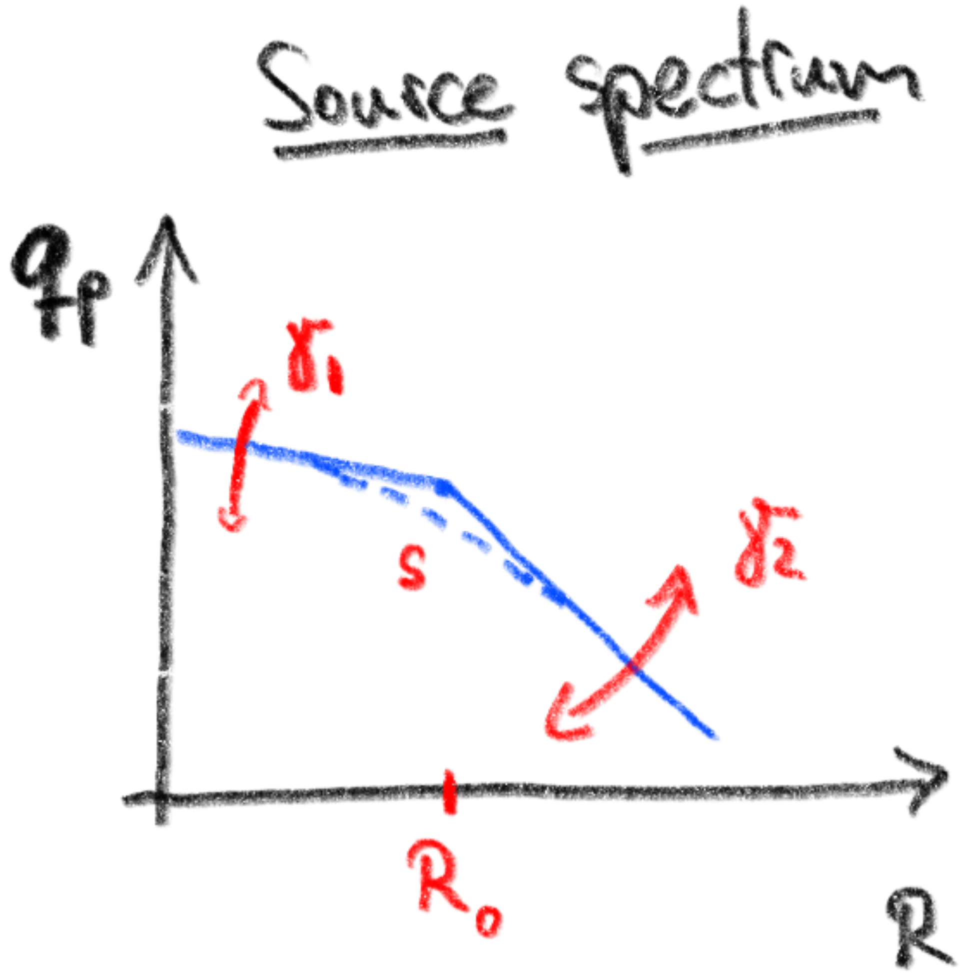

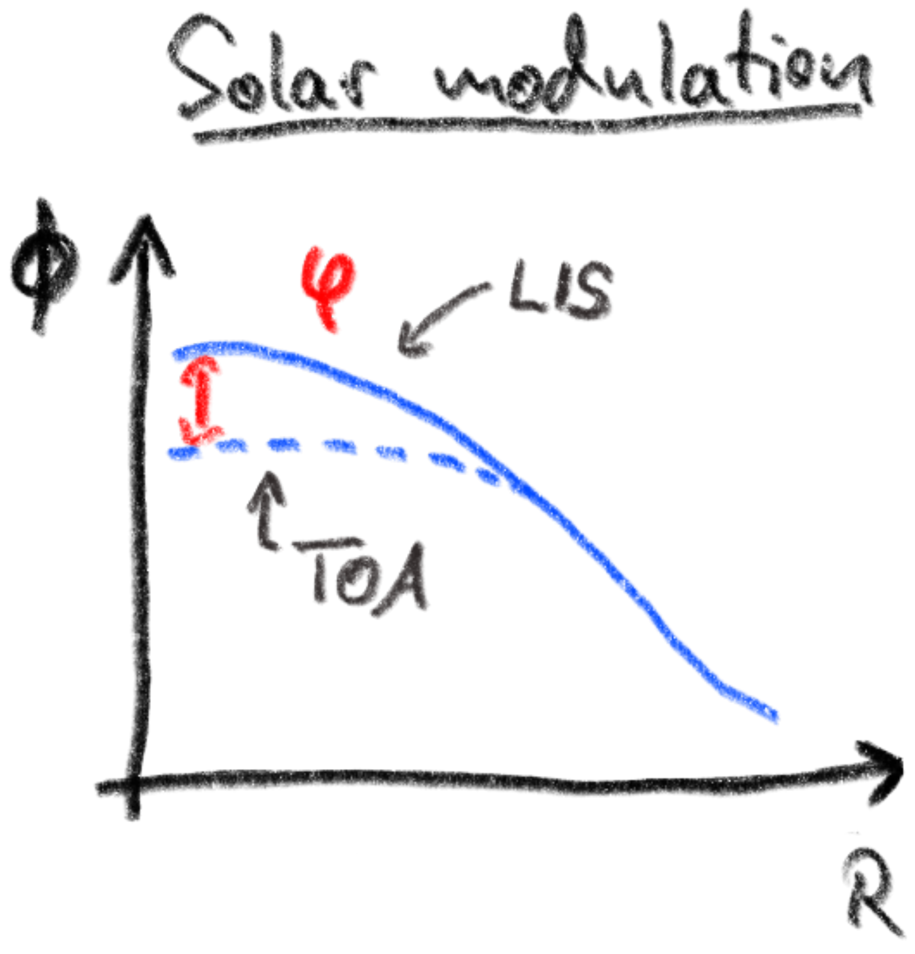

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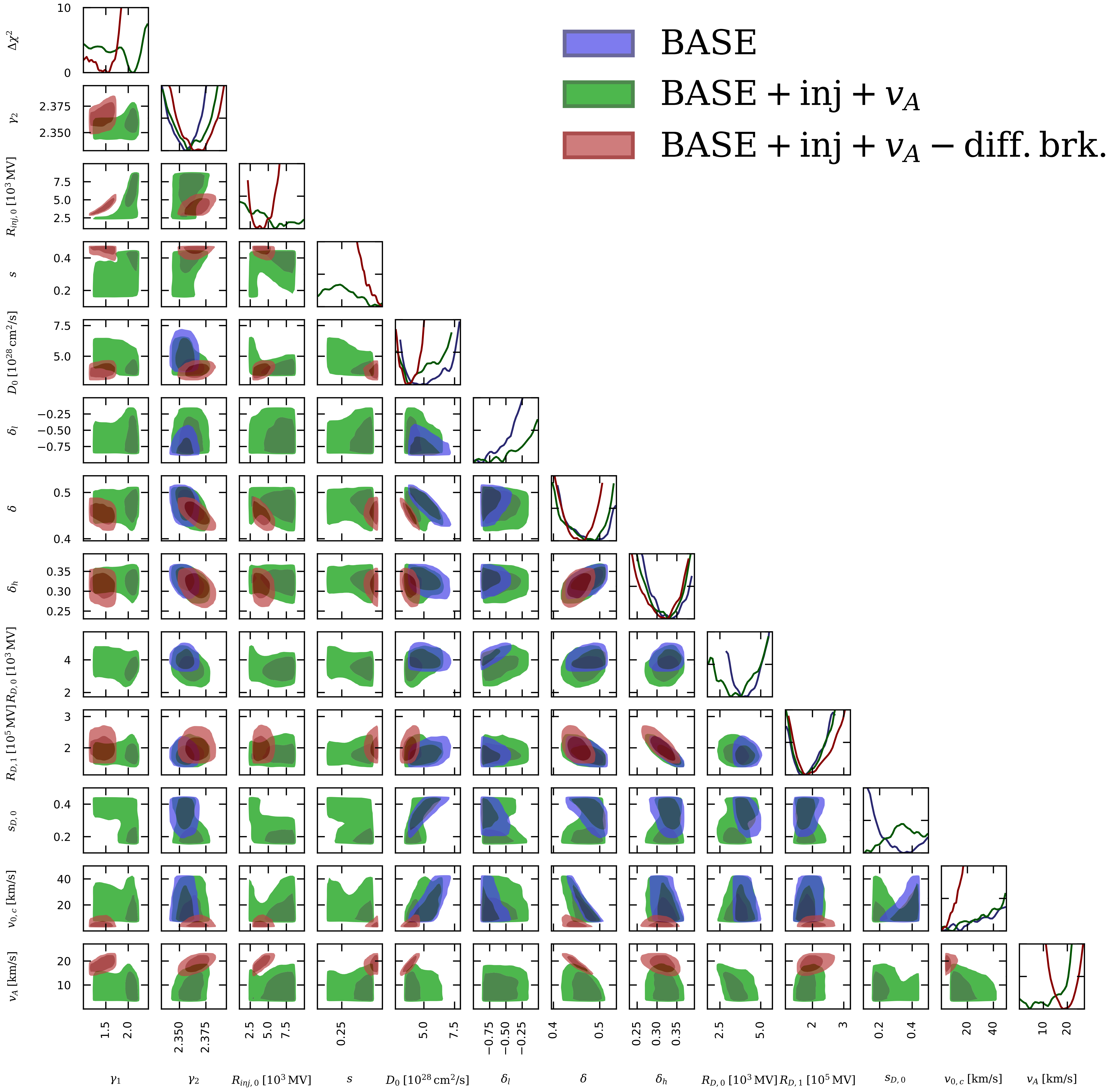
Global fit

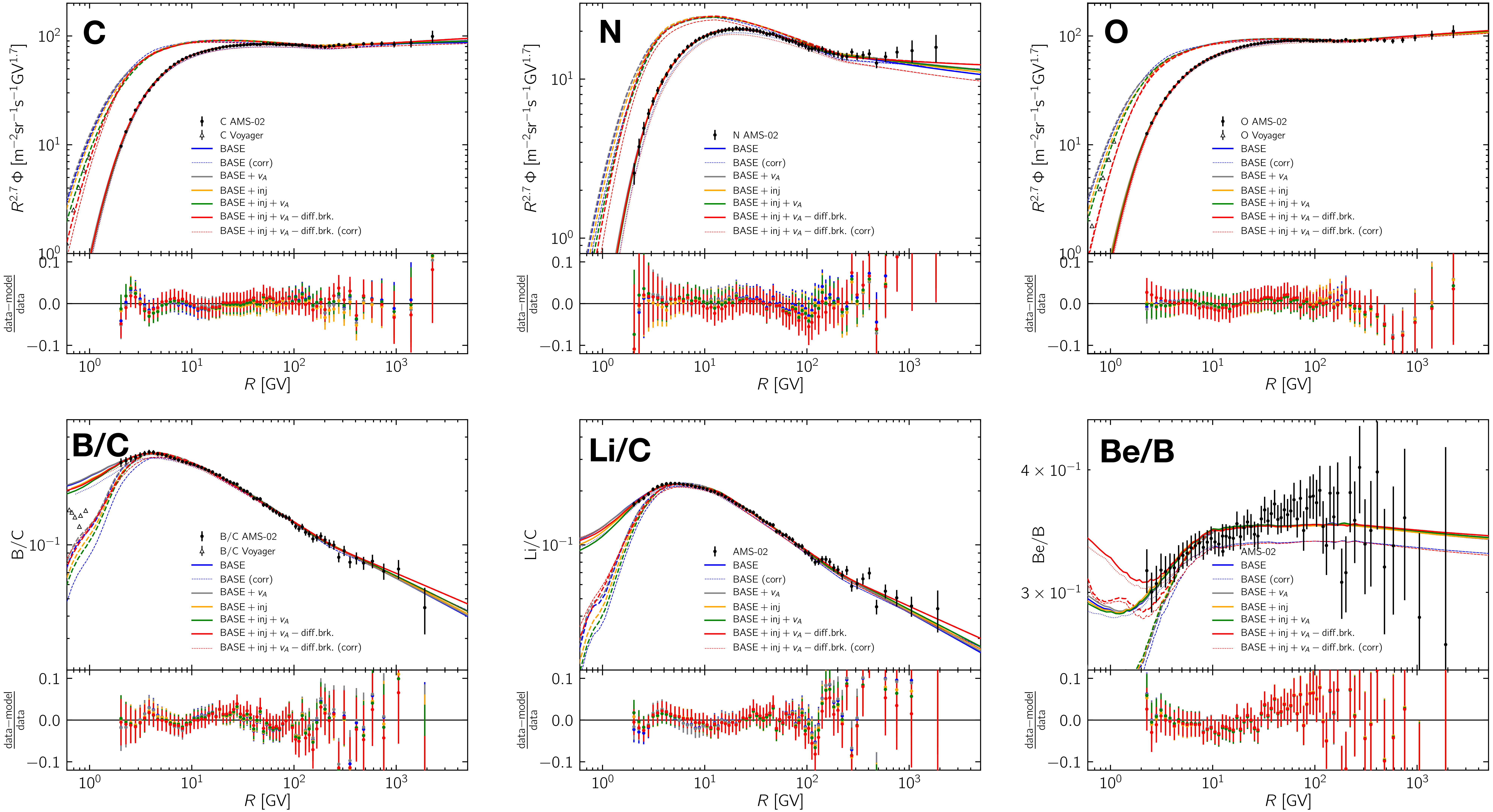


We investigate five propagation setups and perform several consistency checks

We use MultiNest to sample the large parameter space of up to 27 parameters

Parameters for CR propagation and cross section nuisance parameters are sampled at the same time

Results of the global fits



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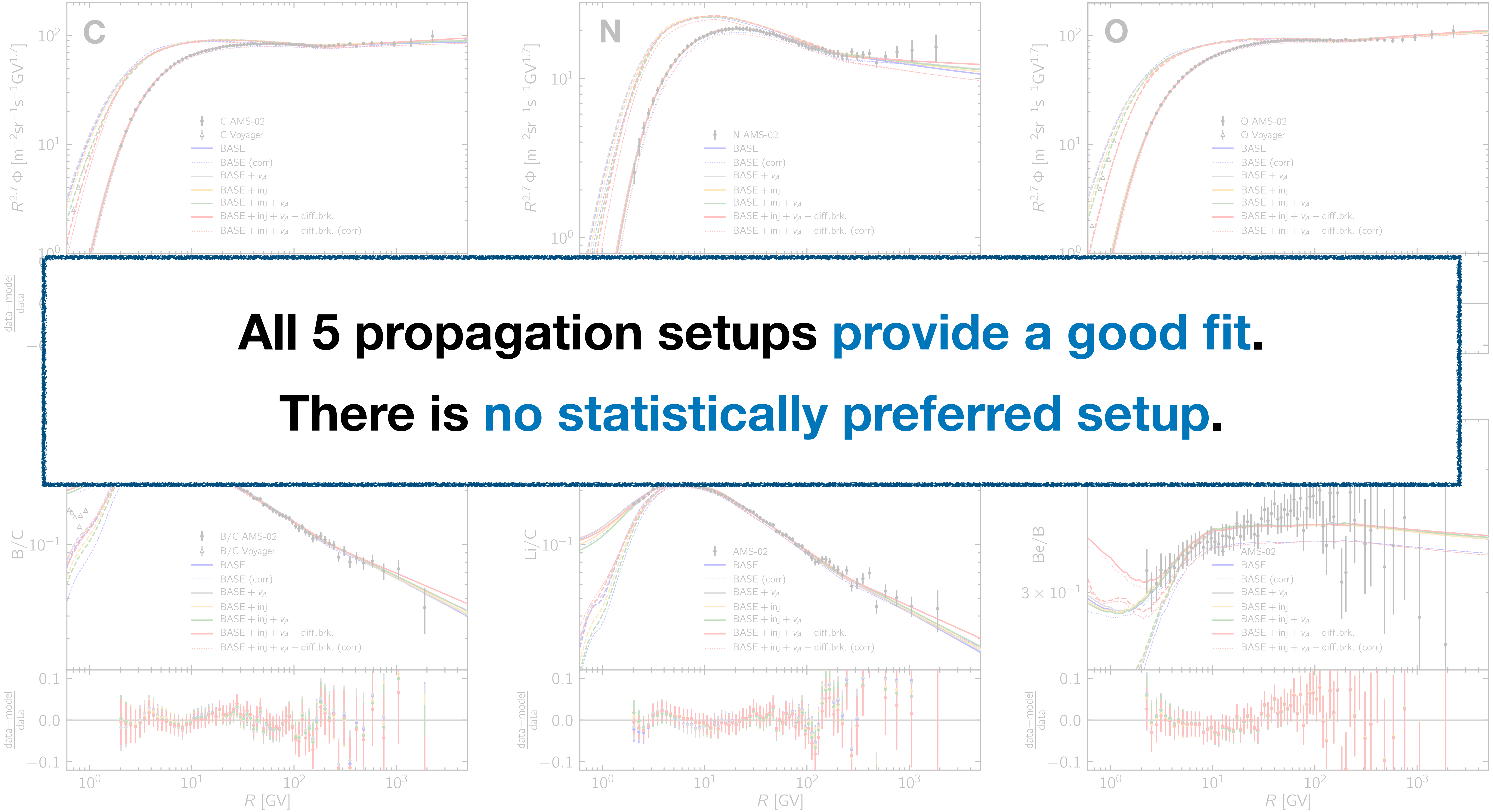
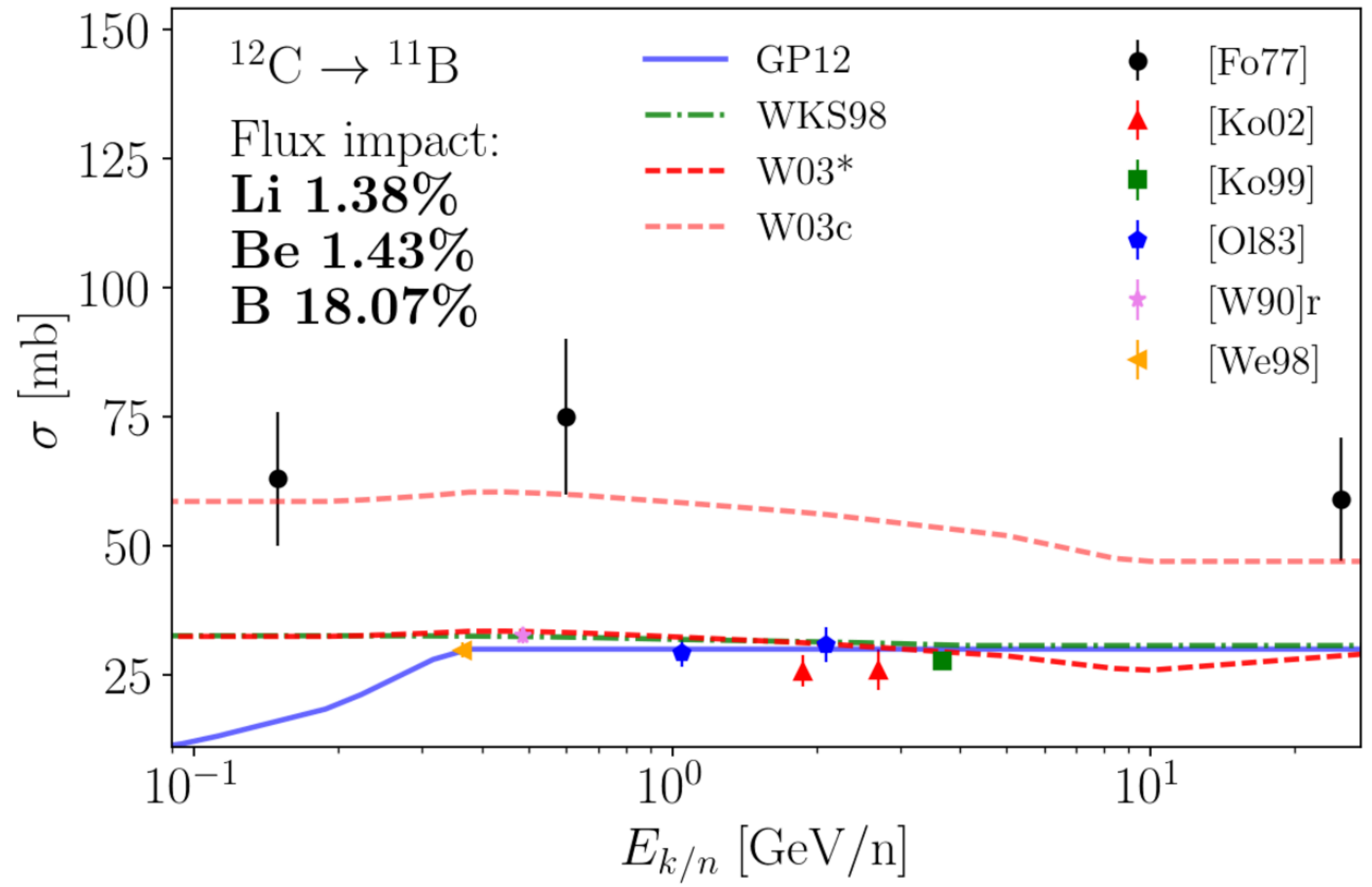


All 5 propagation setups provide a good fit.

There is no statistically preferred setup.

Systematic uncertainty: fragmentation cross sections

Example: Fragmentation of ^{12}C to ^{11}B



[Genolini *et al.*, Phys.Rev.C 98 (2018) 3, 034611]

Systematic uncertainties in the fragmentation cross sections are larger than those in the measured CR spectra!

→ See also: Talk by P. De la Torre Luque

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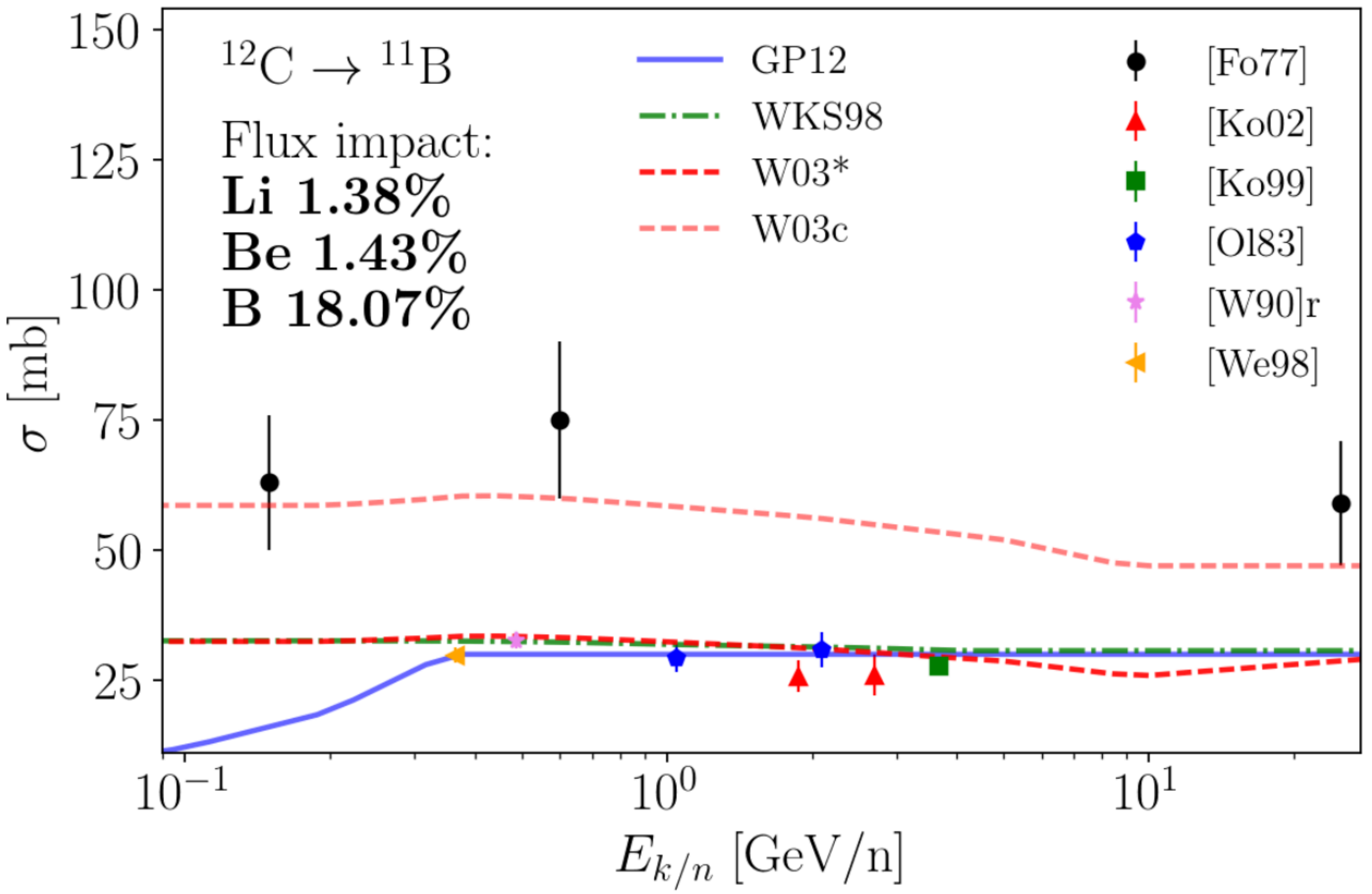

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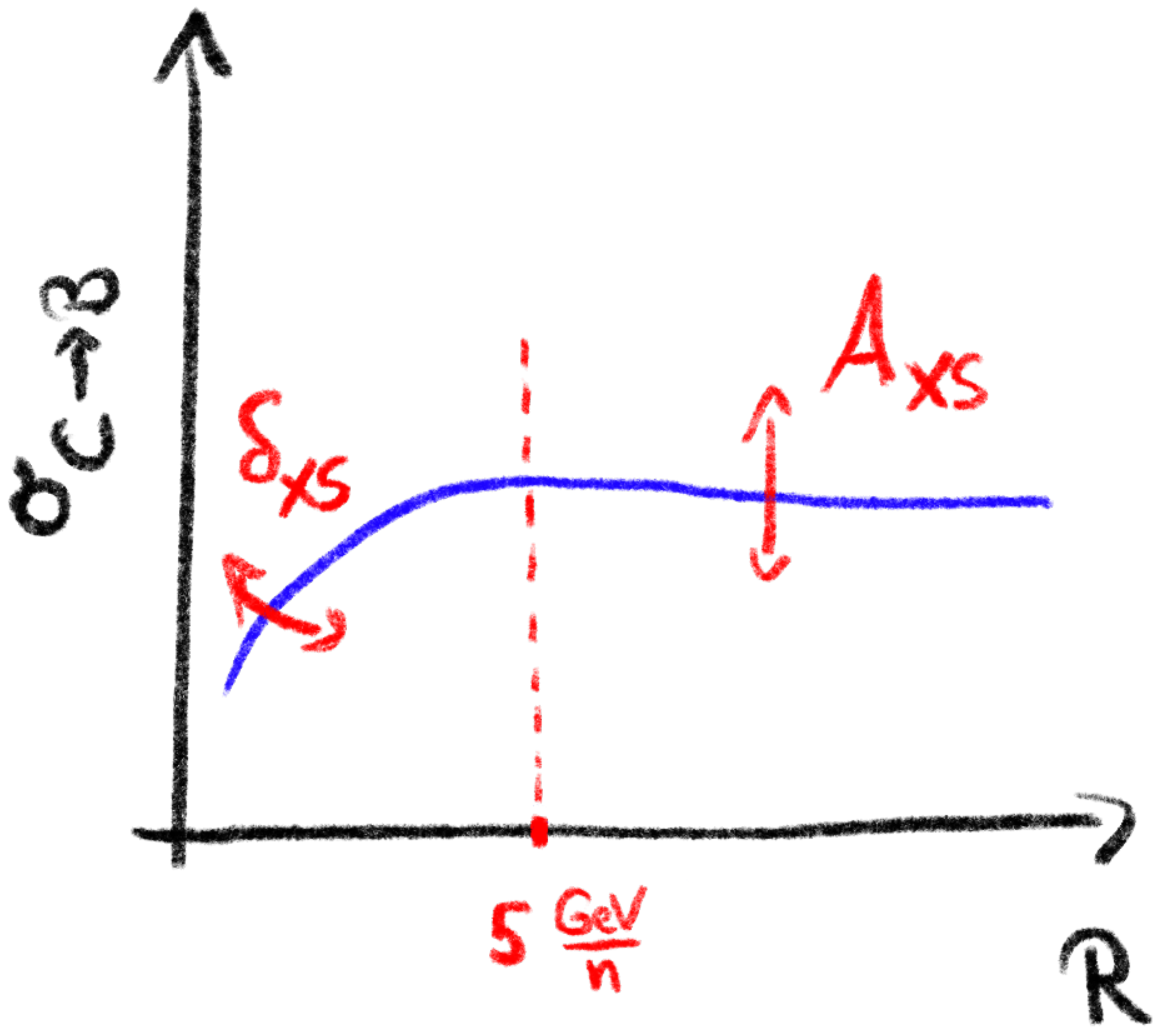

Systematic uncertainties in the fragmentation cross sections are larger than those in the measured CR spectra!

We perform a global fit and profile over nuisance parameters in the most relevant fragmentation cross sections.

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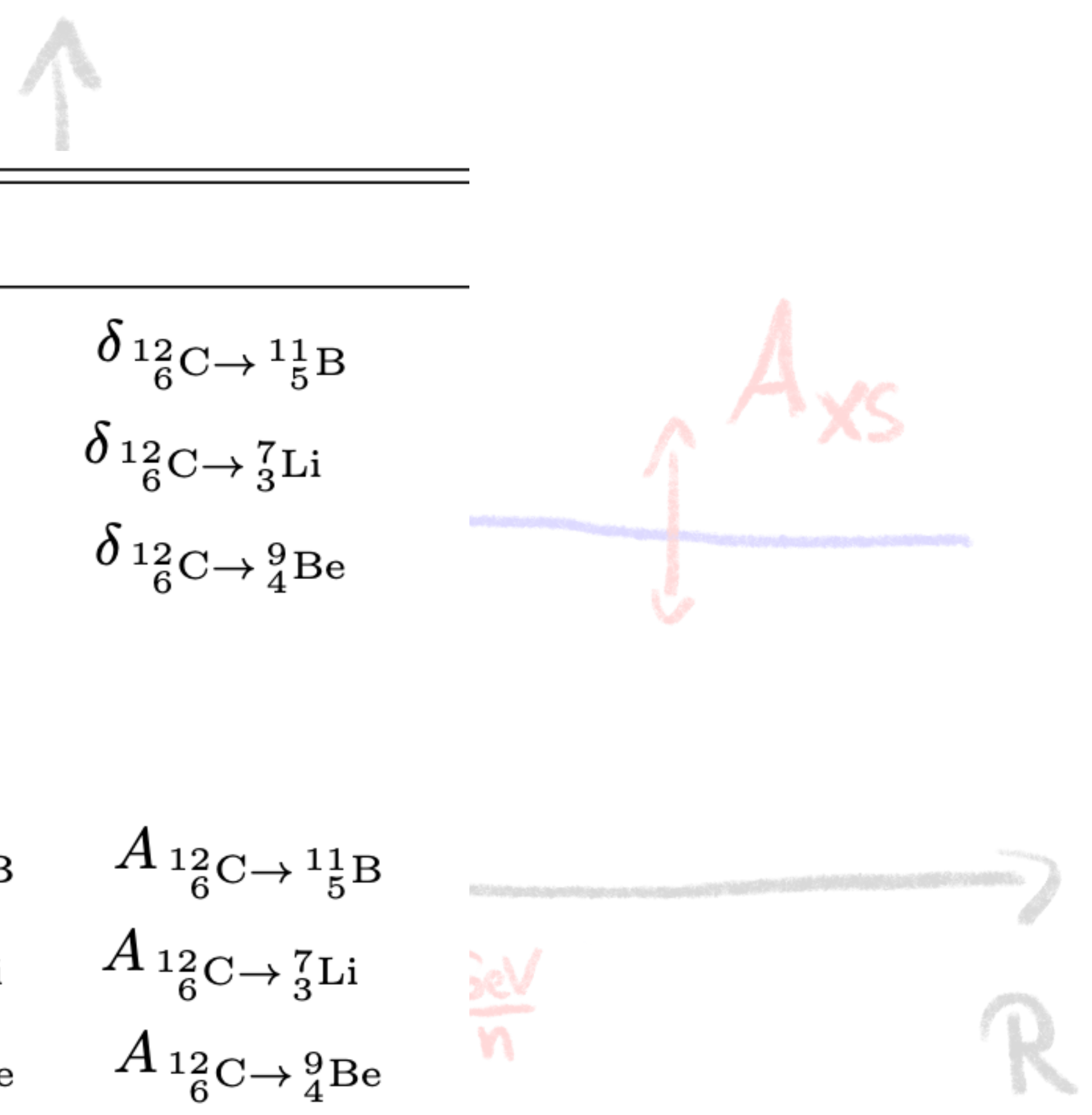
Systematic uncertainty: fragmentation cross sections

Example: Fragmentation of ^{12}C to ^{11}B

fit parameter	nuisance parameters			
$\delta_{XS\to B}$	$\delta\ ^{16}_{8}O\to\ ^{10}_{5}B$	$\delta\ ^{12}_{6}C\to\ ^{10}_{5}B$	$\delta\ ^{16}_{8}O\to\ ^{11}_{5}B$	$\delta\ ^{12}_{6}C\to\ ^{11}_{5}B$
$\delta_{XS\to Li}$	$\delta\ ^{16}_{8}O\to\ ^{6}_{3}Li$	$\delta\ ^{12}_{6}C\to\ ^{6}_{3}Li$	$\delta\ ^{16}_{8}O\to\ ^{7}_{3}Li$	$\delta\ ^{12}_{6}C\to\ ^{7}_{3}Li$
$\delta_{XS\to Be}$	$\delta\ ^{16}_{8}O\to\ ^{7}_{4}Be$	$\delta\ ^{12}_{6}C\to\ ^{7}_{4}Be$	$\delta\ ^{16}_{8}O\to\ ^{9}_{4}Be$	$\delta\ ^{12}_{6}C\to\ ^{9}_{4}Be$
$\delta_{XS\to C}$		$\delta\ ^{16}_{8}O\to\ ^{12}_{6}C$	$\delta\ ^{16}_{8}O\to\ ^{13}_{6}C$	
$\delta_{XS\to N}$		$\delta\ ^{16}_{8}O\to\ ^{14}_{7}N$	$\delta\ ^{16}_{8}O\to\ ^{15}_{7}N$	
$A_{XS\to B}$	$A\ ^{16}_{8}O\to\ ^{10}_{5}B$	$A\ ^{12}_{6}C\to\ ^{10}_{5}B$	$A\ ^{16}_{8}O\to\ ^{11}_{5}B$	$A\ ^{12}_{6}C\to\ ^{11}_{5}B$
$A_{XS\to Li}$	$A\ ^{16}_{8}O\to\ ^{6}_{3}Li$	$A\ ^{12}_{6}C\to\ ^{6}_{3}Li$	$A\ ^{16}_{8}O\to\ ^{7}_{3}Li$	$A\ ^{12}_{6}C\to\ ^{7}_{3}Li$
$A_{XS\to Be}$	$A\ ^{16}_{8}O\to\ ^{7}_{4}Be$	$A\ ^{12}_{6}C\to\ ^{7}_{4}Be$	$A\ ^{16}_{8}O\to\ ^{9}_{4}Be$	$A\ ^{12}_{6}C\to\ ^{9}_{4}Be$
$A_{XS\to C}$		$A\ ^{16}_{8}O\to\ ^{12}_{6}C$	$A\ ^{16}_{8}O\to\ ^{13}_{6}C$	
$A_{XS\to N}$		$A\ ^{16}_{8}O\to\ ^{14}_{7}N$	$A\ ^{16}_{8}O\to\ ^{15}_{7}N$	



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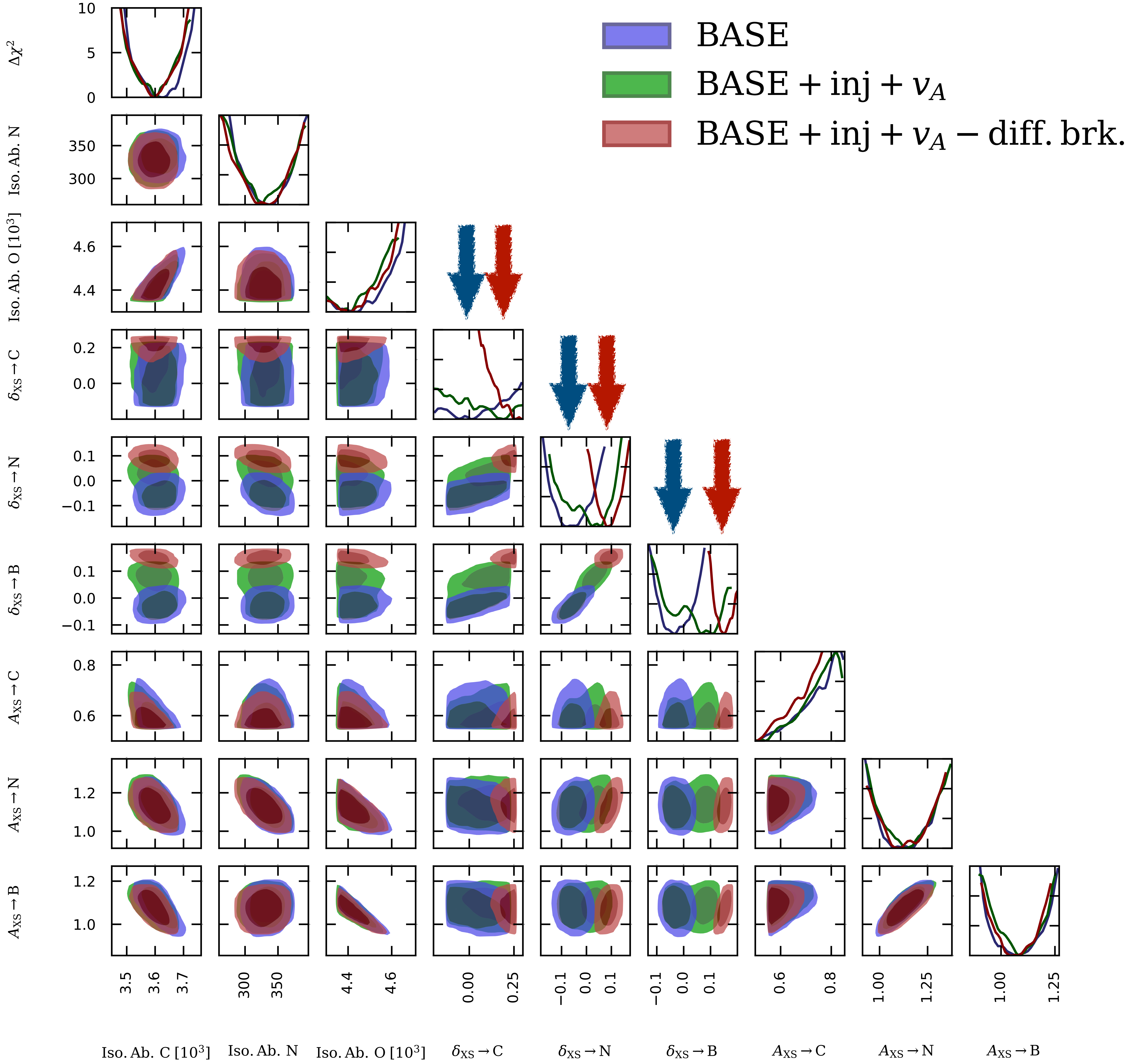
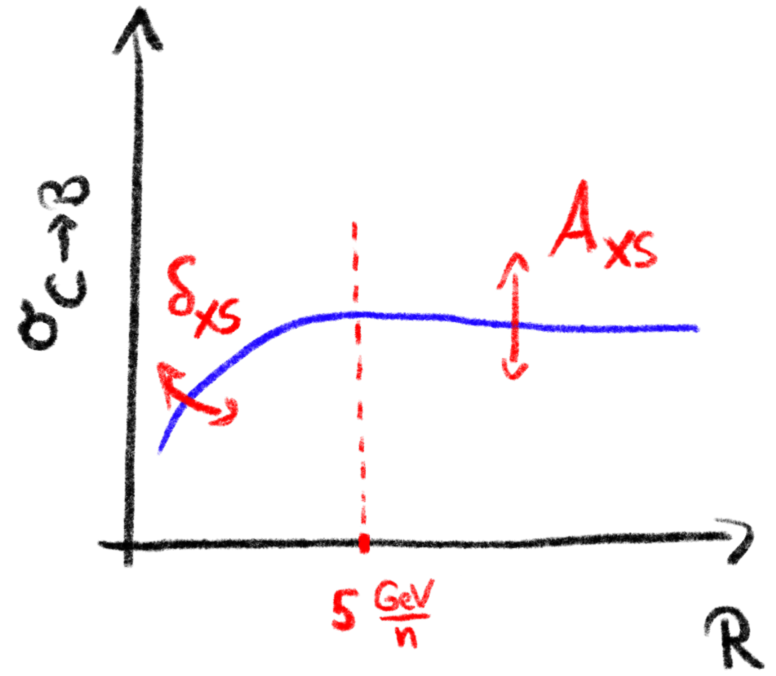
Cross section nuisance parameters





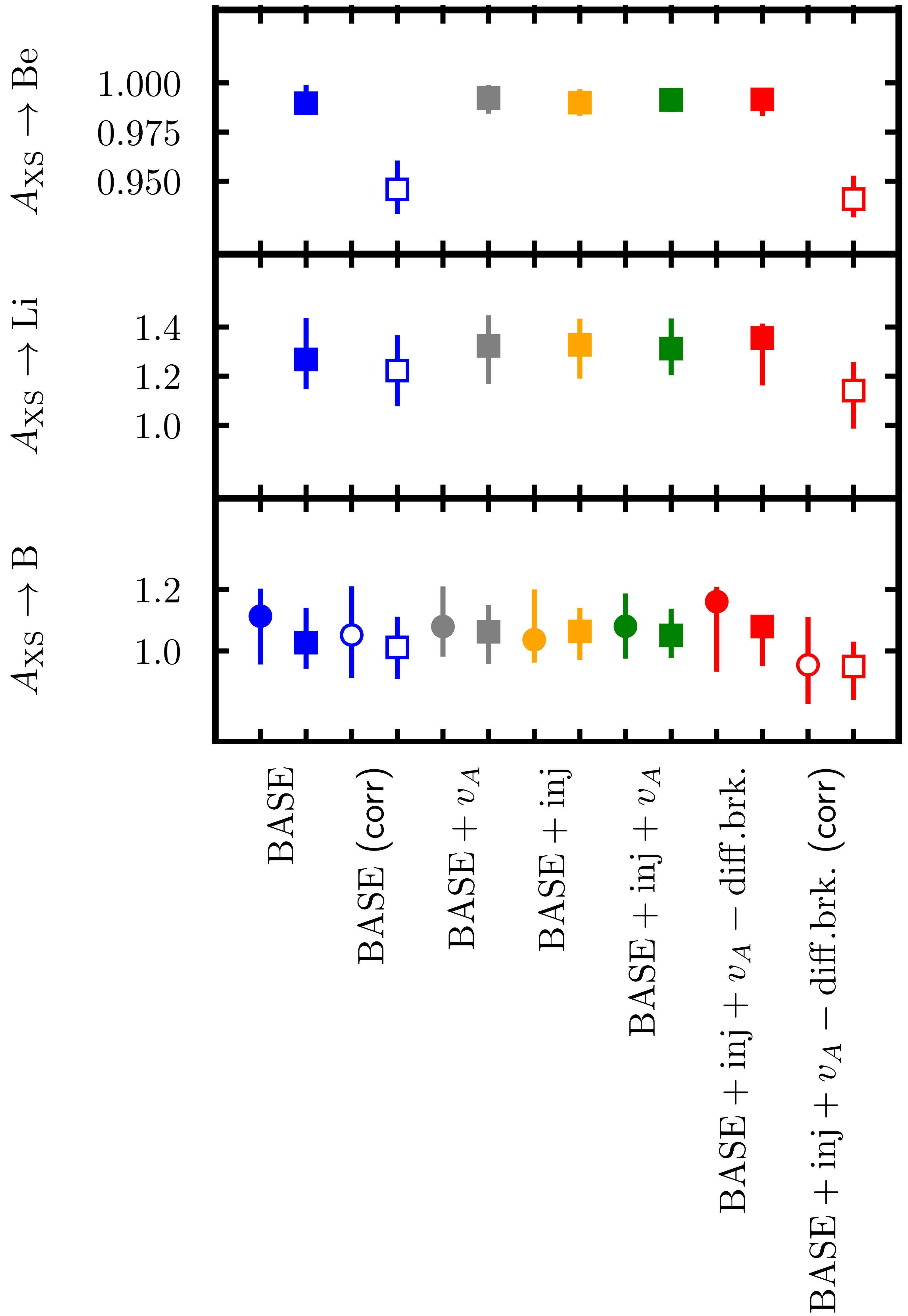
The default cross section parametrization is "GALPROP 12"

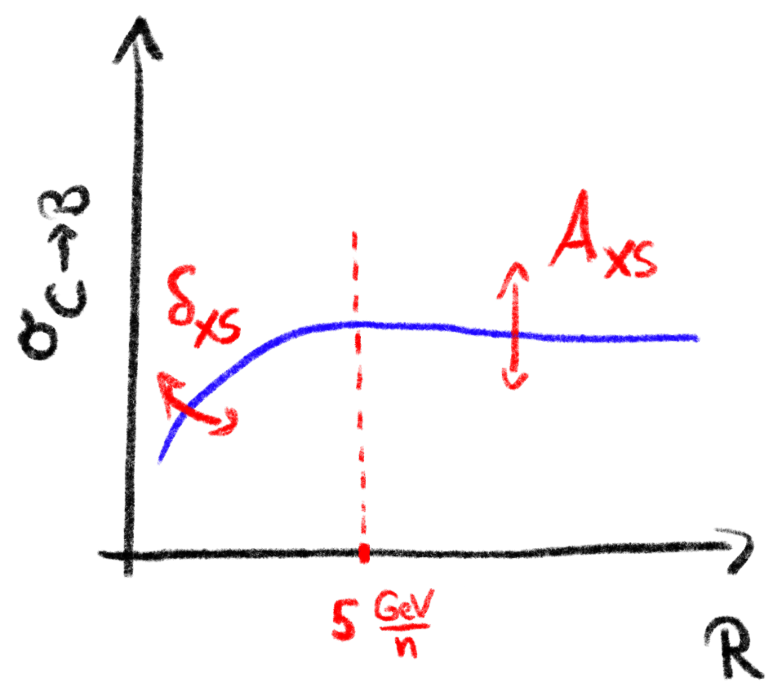
BASE is compatible with the default cross section

BASE+inj+v_A-diff.brk converges at δ_{XS} ~0.2

Li cross section are increased by ~25%

Cross section nuisance parameters





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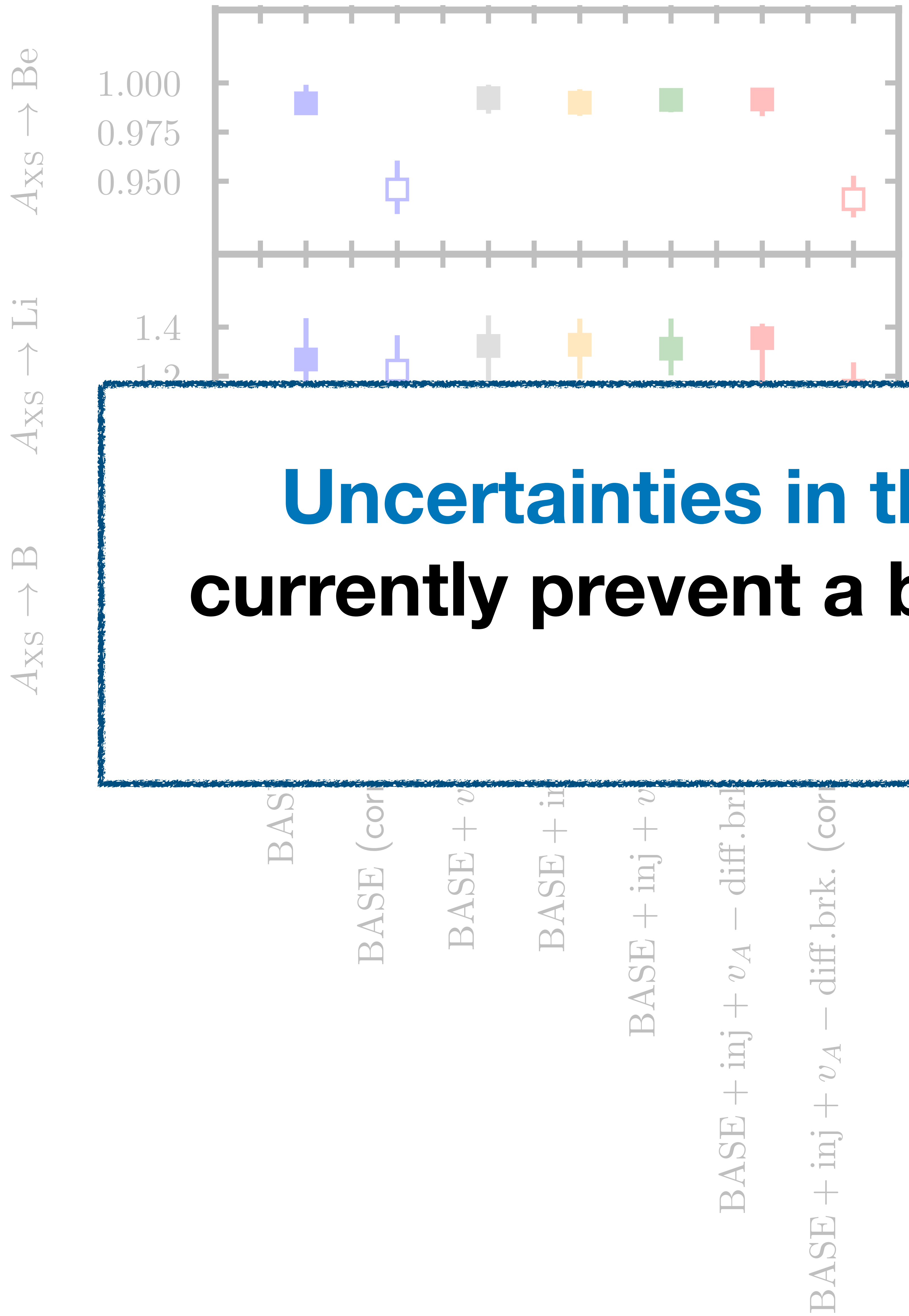

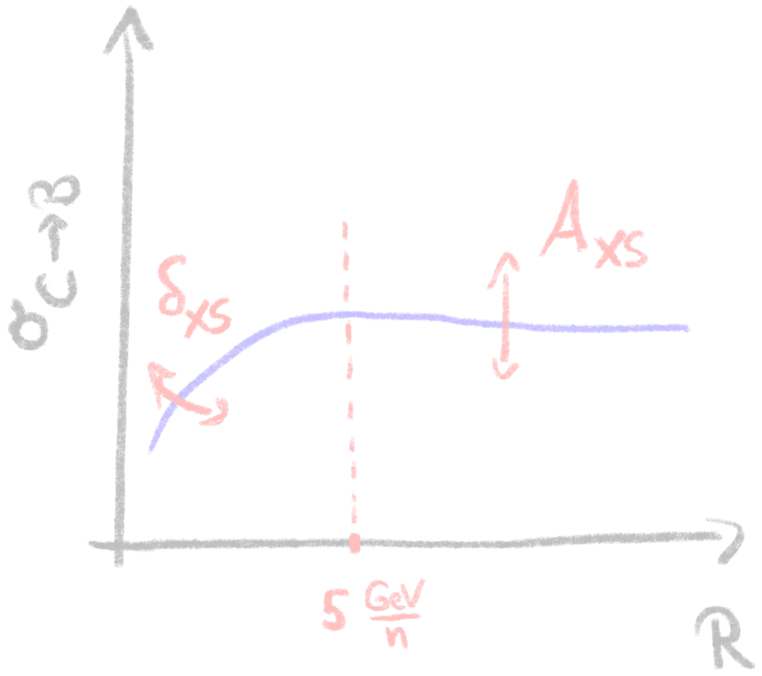

Uncertainties in the fragmentation cross sections currently prevent a better understanding of cosmic ray propagation.

BASE+inj+v$_A$-diff.brk converges at δ_{XS} ~0.2

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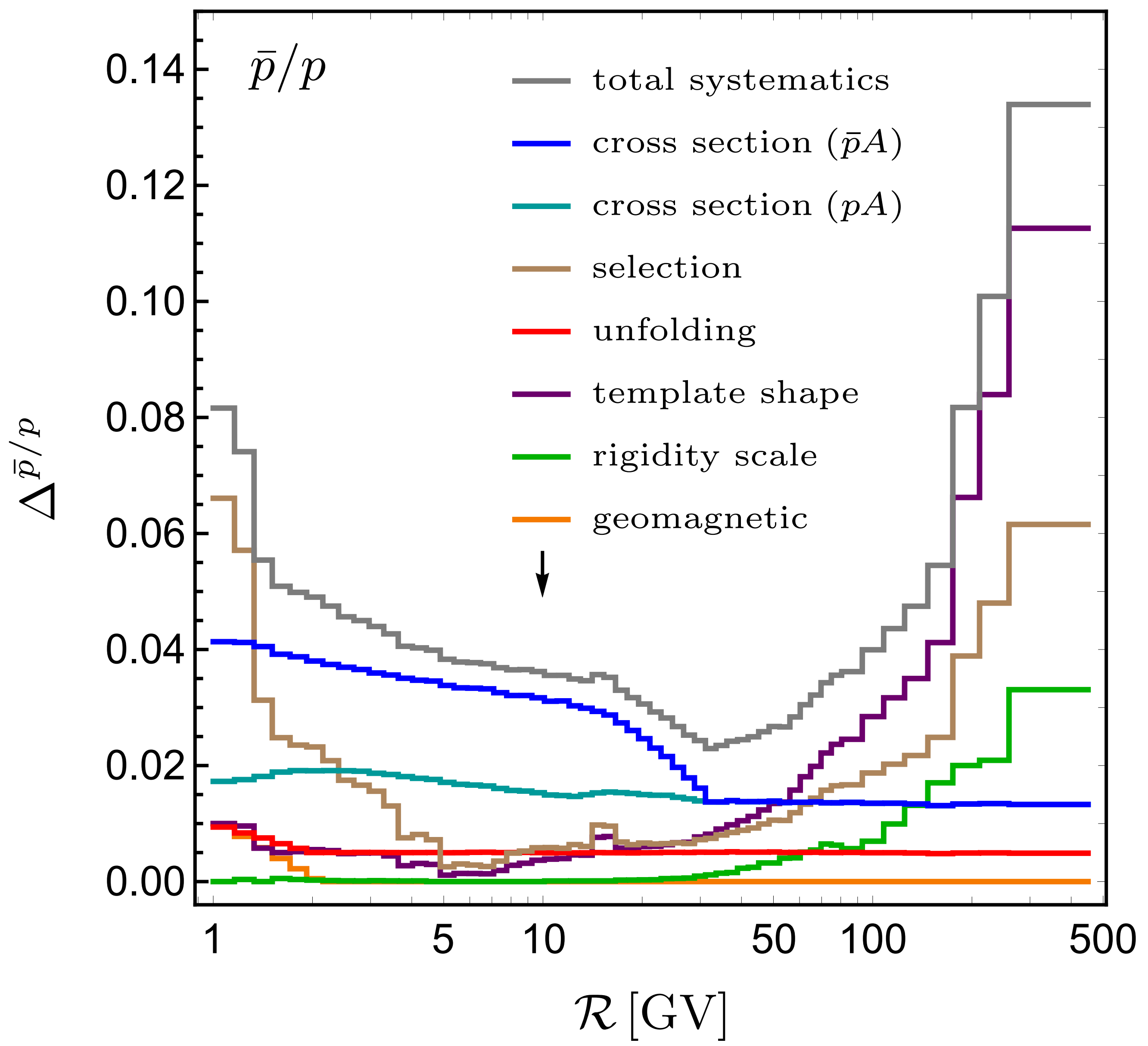
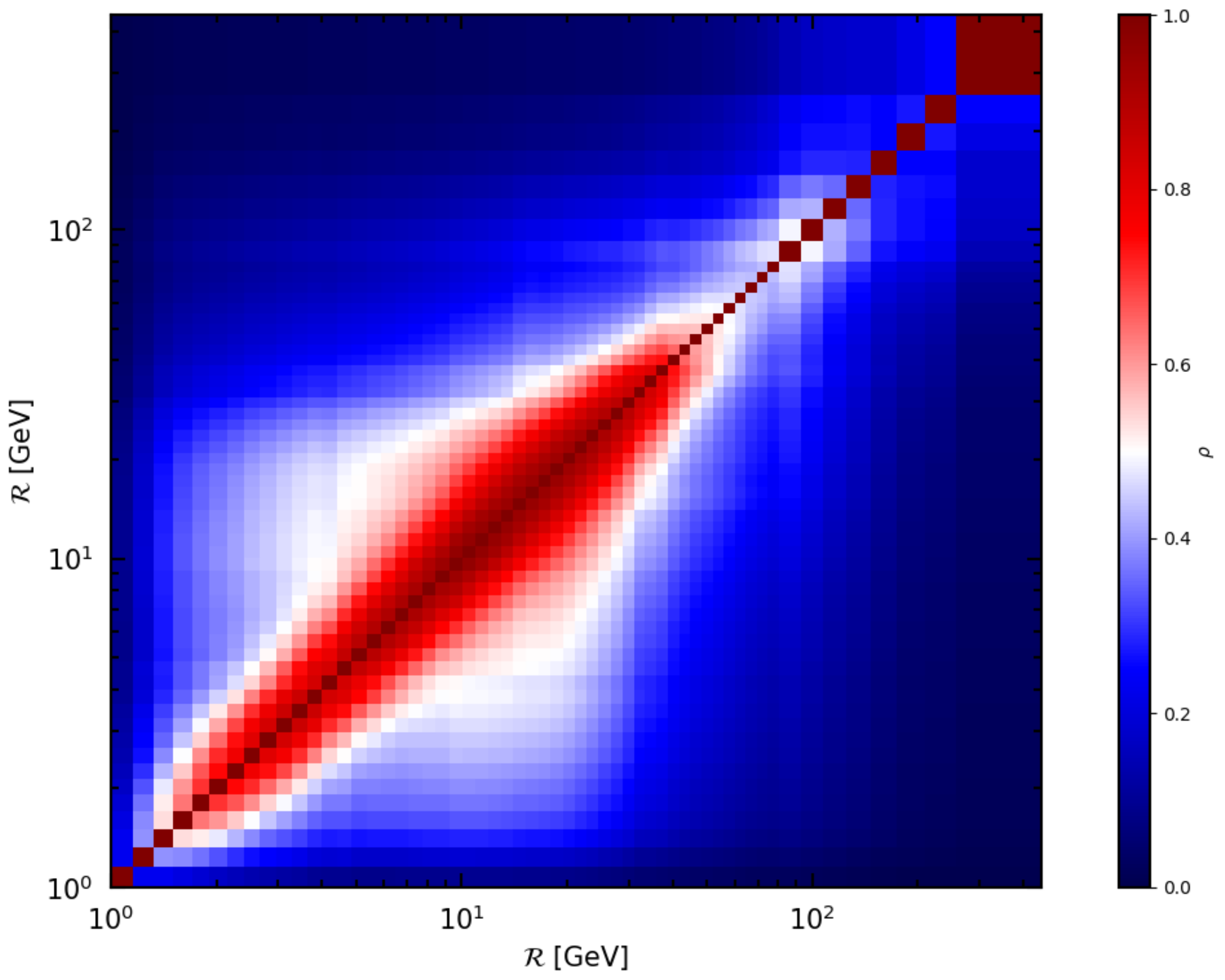
Correlation in the cosmic-ray data of AMS-02

[Heisig, MK, Winkler; PRR; 2020]





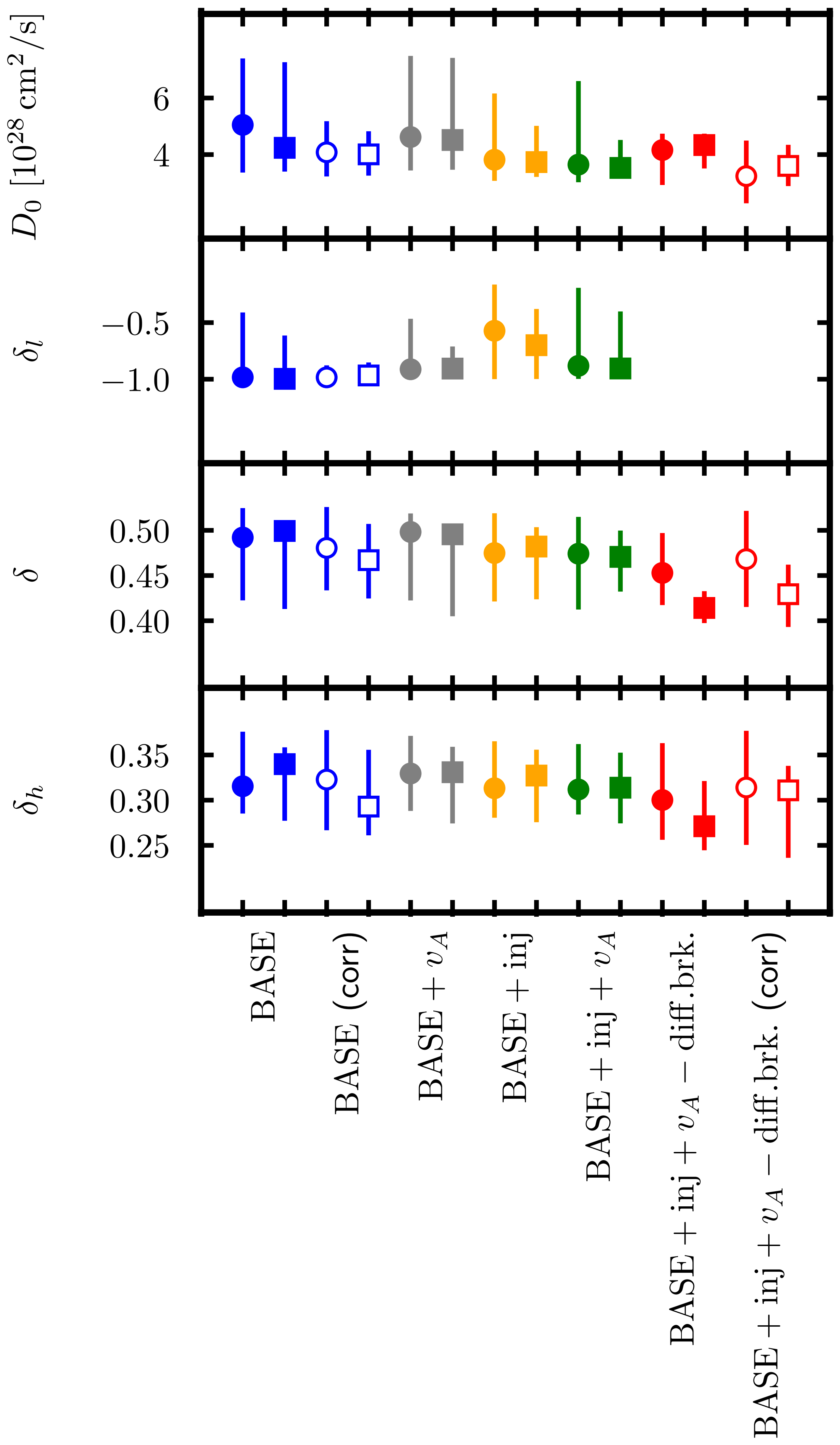
The AMS-02 collaboration does not provide the correlation of the flux data points

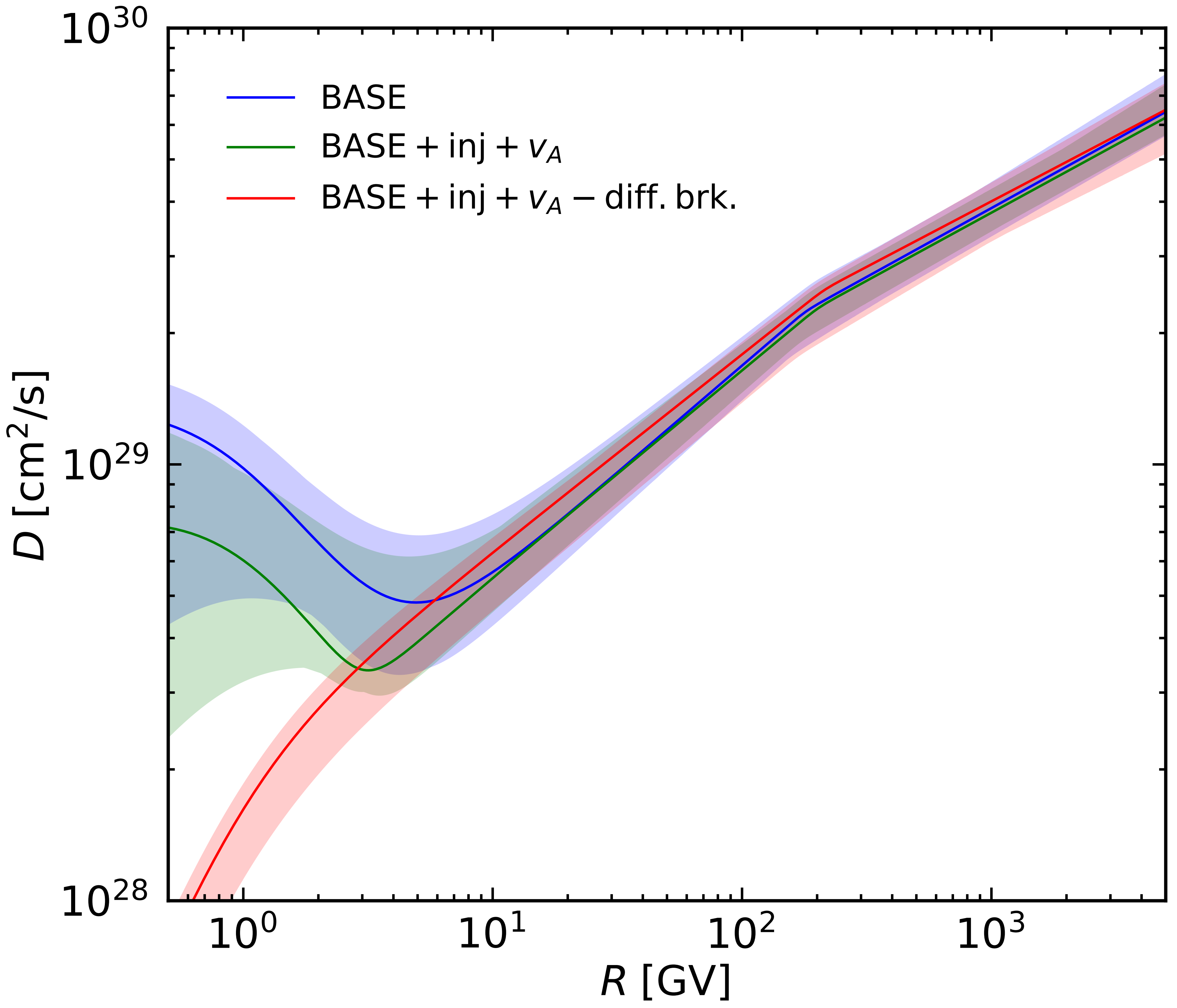
We model the covariance matrix by splitting the systematic uncertainties into separate contributions and attributing a correlation length to each contribution

The inclusion of correlation does not change our conclusions!

$$\mathcal{V}_{ij} = \sigma_i \sigma_j \exp\left(-\frac{1}{2}\left(\frac{R_i - R_j}{\ell_{\mathrm{corr}}}\right)^2\right)$$

Parameter constraints





The diffusion coefficient is well constrained above 10 GV

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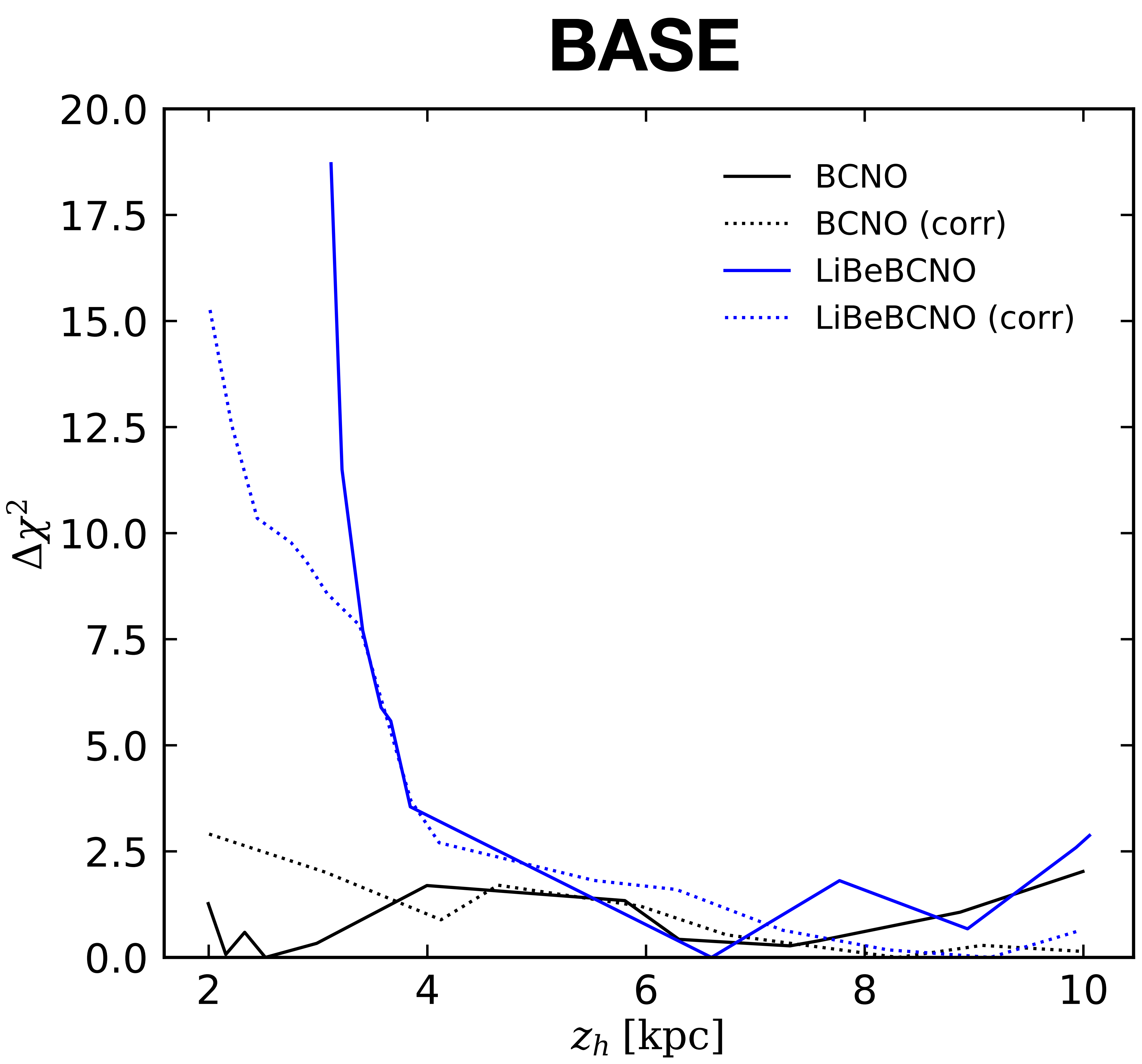
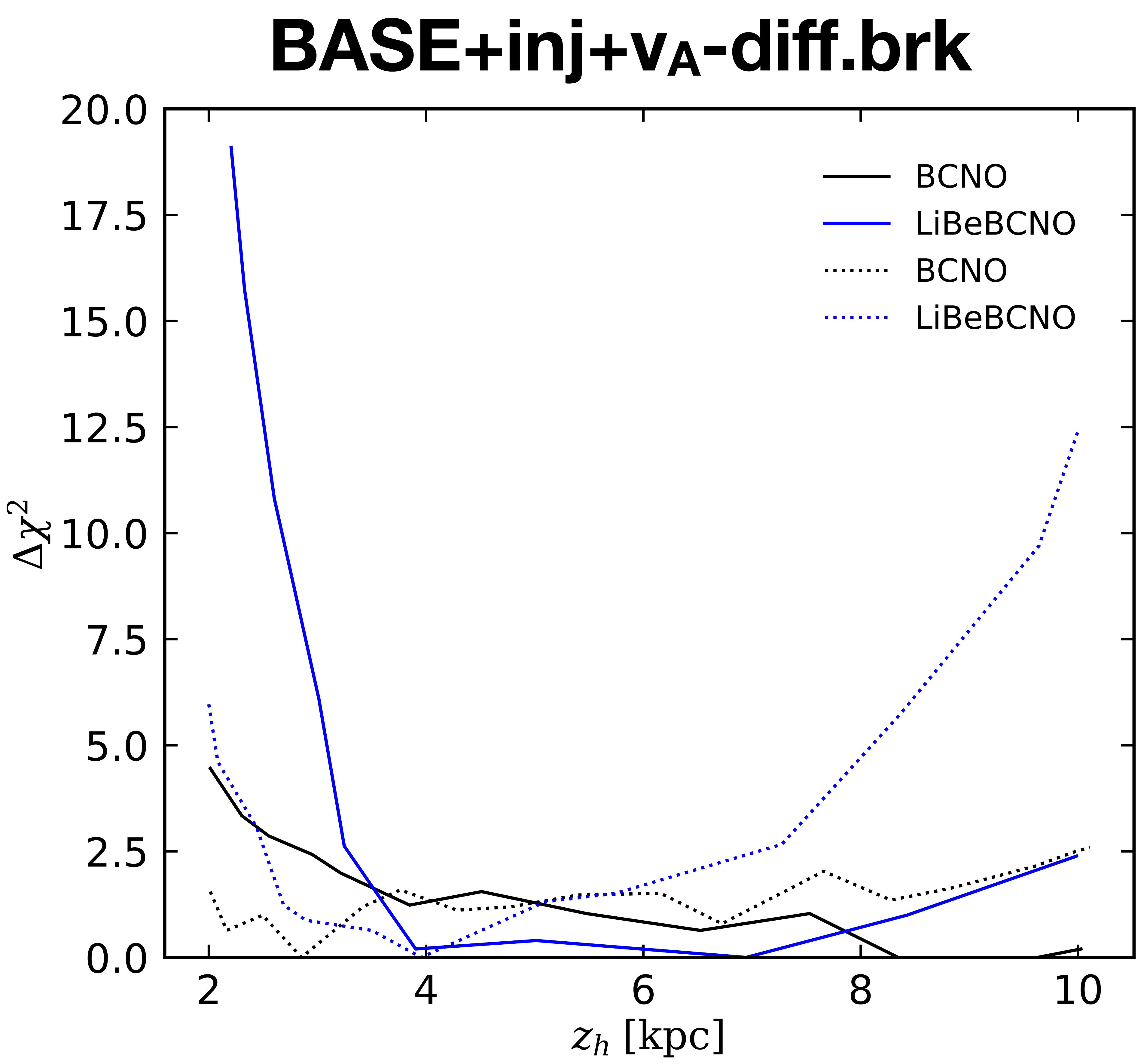




The combination of B and Be data allows to constrain z_h

Conclusions

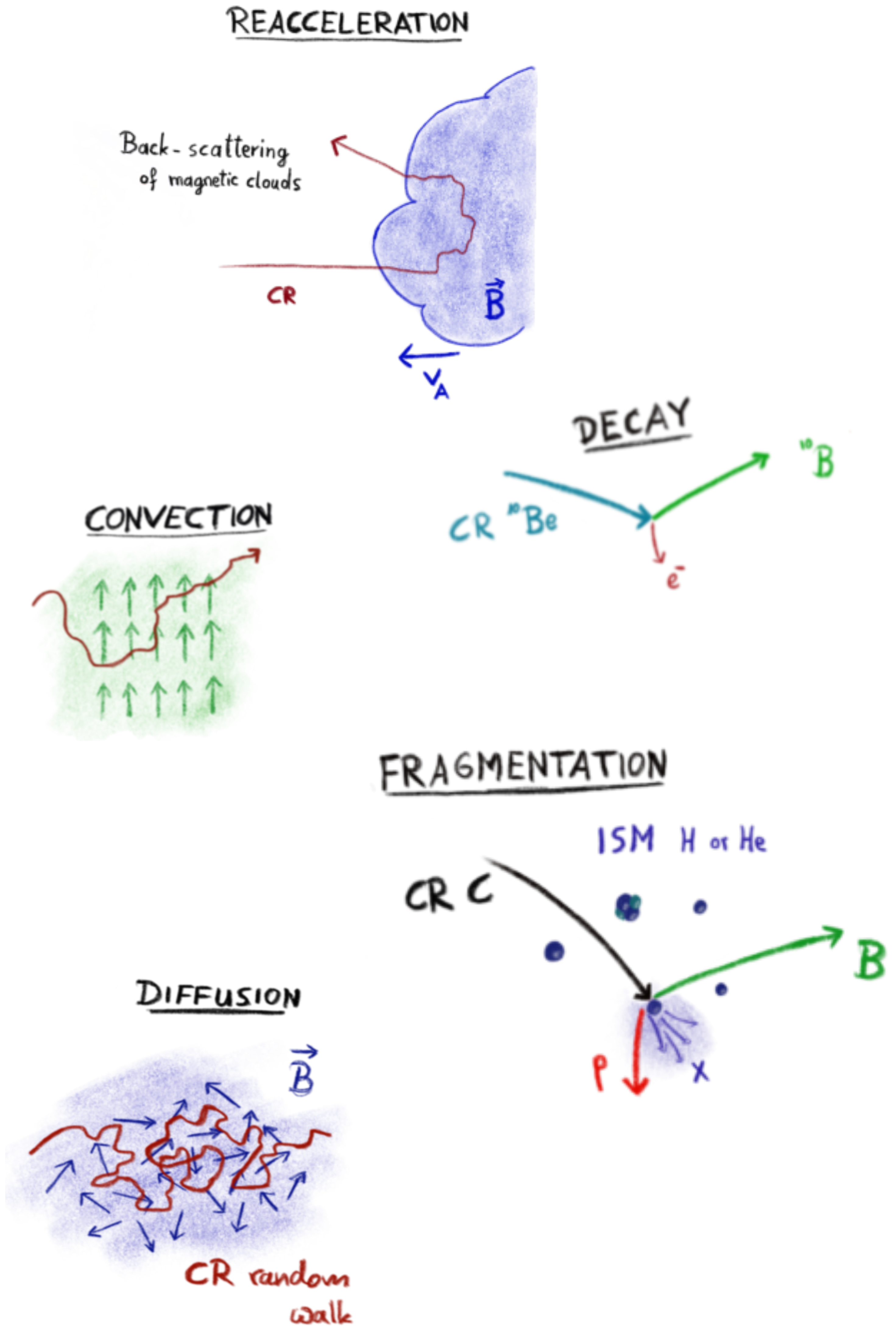
Precision data requires precision analysis and an honest treatment of systematic uncertainties

CR nuclei from Li to O are consistent with the traditional CR diffusion models

There is no clear preference for one CR propagation model because of uncertainties in the secondary fragmentation cross sections

Small halo heights of $z_\mathrm{h} < 3\ \mathrm{kpc}$ are excluded

The diffusion coefficient is well constrained above 10 GeV



Backup

Free parameters

TABLE III. Summary of free CR parameters in the five different frameworks adopted to describe CR propagation.

	BASE	BASE+v_A	BASE+inj	BASE+inj+v_A	BASE+inj+v_A−diff.brk.	prior
γ_1	$\gamma_1 = \gamma_2$	$\gamma_1 = \gamma_2$	free	free	free	[0.0, 2.0]
γ_2	free	free	free	free	free	[2.1, 2.5]
$R_{\mathrm{inj},0}$	-	-	free	free	free	[1, 10] GV
s	-	-	free	free	free	[0.1, 0.7]
D_0	free	free	free	free	free	[1e28, 1e29] $\mathrm{cm^2 s^{-1}}$
δ_l	free	free	free	free	$\delta_l = \delta$	[-1, 0]
δ	free	free	free	free	free	[0.2, 0.7]
δ_h	free	free	free	free	free	[0.2, 0.7]
$R_{D,0}$	free	free	free	free	-	[1, 10] GV
$R_{D,1}$	free	free	free	free	free	[1e5, 5e5] GV
$s_{D,0}$	free	free	free	free	-	[0.1, 0.7]
$v_{0,c}$	free	free	free	free	free	[0, 50] km/s
v_A	-	free	-	free	free	[0, 50] km/s
Iso. Ab. $^{12}_{6}$C	free	free	free	free	free	[3300, 4000]
Iso. Ab. $^{14}_{7}$N	free	free	free	free	free	[200, 500]
Iso. Ab. $^{16}_{8}$O	free	free	free	free	free	[4200, 5000]
$\varphi_{\text{AMS-02}}$	free	free	free	free	free	600±30 MV
#par	13	14	16	17	14	

Best fit table

TABLE IV. Fit results. For all 14 fits we report the total χ^2, the contribution to the χ^2 form each single species, the number of degrees of freedom, and the best-fit value and 1 σ error for each parameter.

	BASE		BASE(corr)		BASE + v_A		BASE + inj		BASE + inj + v_A		BASE + inj + v_A − diff.brk.		BASE + inj + v_A − diff.brk. (corr)	
data set	BCNO	LiBeBCNO	BCNO	LiBeBCNO	BCNO	LiBeBCNO	BCNO	LiBeBCNO	BCNO	LiBeBCNO	BCNO	LiBeBCNO	BCNO	LiBeBCNO
#dof	252	383	252	383	251	382	249	380	248	379	251	382	251	382
χ^2	72.4	170.0	423.2	593.6	72.8	169.0	67.9	160.7	67.3	158.9	74.2	168.9	415.4	590.2
χ^2_{N}	15.9	18.7	148.1	146.9	19.3	17.2	14.8	15.2	19.3	16.5	17.2	20.0	151.5	149.1
χ^2_{O}	14.0	13.7	61.8	63.0	11.3	14.8	12.8	13.8	11.2	12.4	14.8	12.1	62.1	62.2
χ^2_{C}	13.1	15.2	127.8	124.9	12.7	12.7	16.0	16.9	11.7	15.6	13.7	15.4	122.4	122.5
$\chi^2_{\mathrm{Be/B}}$	-	42.2	-	82.9	-	42.0	-	43.3	-	42.4	-	40.6	-	83.3
$\chi^2_{\mathrm{Li/C}}$	-	46.5	-	82.5	-	47.5	-	39.1	-	39.2	-	41.2	-	85.3
$\chi^2_{\mathrm{B/C}}$	27.8	30.2	78.4	80.5	28.7	29.5	24.1	26.9	24.0	28.1	25.8	33.4	75.8	82.7
γ_1	-	-	-	-	-	-	$2.18^{+0.04}_{-0.51}$	$2.21^{+0.04}_{-0.07}$	$2.08^{+0.10}_{-0.30}$	$2.10^{+0.10}_{-0.06}$	$1.20^{+0.42}_{-0.16}$	$1.64^{+0.04}_{-0.07}$	$1.15^{+0.08}_{-0.12}$	$1.14^{+0.24}_{-0.11}$
γ_2	$2.357^{+0.003}_{-0.005}$	$2.365^{+0.005}_{-0.002}$	$2.34^{+0.01}_{-0.01}$	$2.360^{+0.014}_{-0.009}$	$2.353^{+0.006}_{-0.004}$	$2.361^{+0.009}_{-0.002}$	$2.368^{+0.002}_{-0.017}$	$2.371^{+0.004}_{-0.005}$	$2.360^{+0.008}_{-0.004}$	$2.378^{+0.003}_{-0.005}$	$2.362^{+0.016}_{-0.004}$	$2.389^{+0.005}_{-0.004}$	$2.365^{+0.008}_{-0.020}$	$2.373^{+0.013}_{-0.005}$
$R_{inj,0}$ [10^3 MV]	-	-	-	-	-	-	$8.85^{+1.15}_{-4.33}$	$8.31^{+0.91}_{-1.05}$	$6.20^{+1.87}_{-1.84}$	$6.98^{+2.10}_{-0.33}$	$3.28^{+1.82}_{-0.59}$	$5.18^{+0.65}_{-0.30}$	$2.93^{+0.20}_{-0.37}$	$2.61^{+1.01}_{-0.10}$
s	-	-	-	-	-	-	$0.48^{+0.02}_{-0.27}$	$0.45^{+0.04}_{-0.06}$	$0.45^{+0.03}_{-0.20}$	$0.487^{+0.006}_{-0.043}$	$0.490^{+0.009}_{-0.052}$	$0.493^{+0.007}_{-0.044}$	$0.39^{+0.10}_{-0.06}$	$0.494^{+0.005}_{-0.038}$
D_0 [10^{28} cm^2/s]	$5.05^{+0.99}_{-1.34}$	$4.24^{+0.96}_{-0.44}$	$4.08^{+0.33}_{-0.55}$	$4.01^{+0.32}_{-0.45}$	$4.62^{+1.28}_{-0.46}$	$4.52^{+1.94}_{-0.39}$	$3.82^{+1.03}_{-0.30}$	$3.73^{+0.69}_{-0.20}$	$3.65^{+0.87}_{-0.18}$	$3.53^{+0.25}_{-0.10}$	$4.16^{+0.33}_{-0.88}$	$4.34^{+0.14}_{-0.66}$	$3.24^{+0.94}_{-0.36}$	$3.60^{+0.19}_{-0.33}$
δ_l	$-0.98^{+0.22}_{-0.01}$	$-0.997^{+0.111}_{-0.001}$	$-0.98^{+0.03}_{-0.02}$	$-0.97^{+0.03}_{-0.02}$	$-0.91^{+0.11}_{-0.07}$	$-0.91^{+0.08}_{-0.09}$	$-0.57^{+0.22}_{-0.37}$	$-0.70^{+0.09}_{-0.28}$	$-0.88^{+0.36}_{-0.06}$	$-0.91^{+0.13}_{-0.04}$	-	-	-	-
δ	$0.49^{+0.03}_{-0.04}$	$0.499^{+0.002}_{-0.033}$	$0.48^{+0.03}_{-0.01}$	$0.47^{+0.02}_{-0.01}$	$0.498^{+0.007}_{-0.045}$	$0.496^{+0.004}_{-0.056}$	$0.47^{+0.02}_{-0.03}$	$0.48^{+0.01}_{-0.03}$	$0.47^{+0.02}_{-0.03}$	$0.471^{+0.009}_{-0.014}$	$0.45^{+0.02}_{-0.02}$	$0.414^{+0.013}_{-0.005}$	$0.47^{+0.02}_{-0.04}$	$0.43^{+0.02}_{-0.01}$
δ_h	$0.315^{+0.045}_{-0.008}$	$0.340^{+0.007}_{-0.033}$	$0.32^{+0.03}_{-0.02}$	$0.293^{+0.032}_{-0.009}$	$0.33^{+0.02}_{-0.02}$	$0.331^{+0.008}_{-0.027}$	$0.31^{+0.03}_{-0.02}$	$0.33^{+0.02}_{-0.03}$	$0.31^{+0.03}_{-0.01}$	$0.31^{+0.01}_{-0.01}$	$0.30^{+0.04}_{-0.02}$	$0.271^{+0.026}_{-0.007}$	$0.31^{+0.02}_{-0.03}$	$0.311^{+0.007}_{-0.044}$
$R_{D,0}$ [10^3 MV]	$3.94^{+0.52}_{-0.35}$	$4.05^{+0.43}_{-0.14}$	$3.87^{+0.14}_{-0.12}$	$3.85^{+0.16}_{-0.05}$	$3.97^{+0.21}_{-0.36}$	$4.25^{+0.10}_{-0.35}$	$4.07^{+0.20}_{-0.53}$	$4.01^{+0.14}_{-0.37}$	$3.02^{+0.81}_{-0.23}$	$3.37^{+0.43}_{-0.41}$	-	-	-	-
$R_{D,1}$ [10^5 MV]	$1.80^{+0.13}_{-0.30}$	$1.52^{+0.48}_{-0.08}$	$2.00^{+0.25}_{-0.22}$	$2.09^{+0.14}_{-0.42}$	$1.88^{+0.12}_{-0.35}$	$1.63^{+0.19}_{-0.07}$	$1.65^{+0.35}_{-0.13}$	$1.49^{+0.36}_{-0.06}$	$2.02^{+0.09}_{-0.46}$	$1.68^{+0.12}_{-0.08}$	$2.14^{+0.16}_{-0.40}$	$2.33^{+0.16}_{-0.46}$	$1.96^{+0.62}_{-0.11}$	$2.12^{+0.25}_{-0.29}$
$s_{D,0}$	$0.38^{+0.06}_{-0.11}$	$0.32^{+0.06}_{-0.07}$	$0.15^{+0.03}_{-0.02}$	$0.16^{+0.03}_{-0.01}$	$0.36^{+0.06}_{-0.07}$	$0.31^{+0.13}_{-0.05}$	$0.12^{+0.19}_{-0.02}$	$0.13^{+0.06}_{-0.02}$	$0.13^{+0.20}_{-0.02}$	$0.109^{+0.033}_{-0.004}$	-	-	-	-
$v_{0,c}$ [km/s]	$3.34^{+21.76}_{-2.49}$	$1.81^{+17.74}_{-0.70}$	$9.09^{+7.89}_{-8.68}$	$12.11^{+5.83}_{-6.91}$	$0.27^{+23.83}_{-0.06}$	$0.84^{+27.41}_{-0.22}$	$13.18^{+14.33}_{-12.26}$	$4.92^{+10.66}_{-4.85}$	$5.02^{+18.32}_{-2.27}$	$2.30^{+6.45}_{-1.31}$	$0.34^{+3.88}_{-0.23}$	$0.004^{+1.515}_{-0.000}$	$0.89^{+5.05}_{-0.75}$	$1.81^{+2.30}_{-1.63}$
v_A [km/s]	-	-	-	-	$8.65^{+3.51}_{-7.81}$	$0.54^{+6.04}_{-0.24}$	-	-	$10.68^{+2.94}_{-9.29}$	$10.85^{+3.55}_{-4.79}$	$19.23^{+3.65}_{-3.77}$	$24.04^{+0.91}_{-2.90}$	$16.24^{+5.30}_{-1.35}$	$20.14^{+1.44}_{-1.49}$
Iso.Ab. C [10^3]	$3.59^{+0.08}_{-0.02}$	$3.59^{+0.04}_{-0.02}$	$3.48^{+0.03}_{-0.14}$	$3.37^{+0.11}_{-0.06}$	$3.63^{+0.02}_{-0.04}$	$3.60^{+0.03}_{-0.02}$	$3.58^{+0.05}_{-0.03}$	$3.59^{+0.03}_{-0.04}$	$3.640^{+0.009}_{-0.068}$	$3.57^{+0.03}_{-0.02}$	$3.58^{+0.06}_{-0.04}$	$3.54^{+0.05}_{-0.01}$	$3.47^{+0.08}_{-0.12}$	$3.36^{+0.16}_{-0.02}$
Iso.Ab. N	$325.38^{+17.75}_{-6.27}$	$306.87^{+17.12}_{-7.38}$	$276.35^{+44.56}_{-20.91}$	$280.12^{+23.61}_{-35.03}$	$348.86^{+7.40}_{-25.27}$	$323.27^{+9.25}_{-17.15}$	$333.27^{+23.85}_{-21.66}$	$307.74^{+18.80}_{-8.56}$	$327.91^{+14.14}_{-8.92}$	$313.82^{+8.68}_{-16.42}$	$337.18^{+26.21}_{-38.86}$	$300.77^{+14.11}_{-14.55}$	$308.24^{+16.04}_{-49.55}$	$228.85^{+61.43}_{-7.77}$
Iso.Ab. O [10^3]	$4.35^{+0.18}_{-0.02}$	$4.41^{+0.05}_{-0.04}$	$4.40^{+0.05}_{-0.10}$	$4.40^{+0.05}_{-0.08}$	$4.41^{+0.05}_{-0.05}$	$4.41^{+0.03}_{-0.09}$	$4.38^{+0.05}_{-0.04}$	$4.37^{+0.04}_{-0.07}$	$4.42^{+0.03}_{-0.09}$	$4.34^{+0.07}_{-0.01}$	$4.313^{+0.181}_{-0.004}$	$4.34^{+0.11}_{-0.02}$	$4.32^{+0.23}_{-0.01}$	$4.41^{+0.12}_{-0.05}$
$\delta_{\mathrm{XS}} \to$ C	$-0.08^{+0.23}_{-0.08}$	$0.03^{+0.14}_{-0.13}$	$0.17^{+0.09}_{-0.13}$	$0.13^{+0.14}_{-0.07}$	$-0.05^{+0.08}_{-0.05}$	$-0.12^{+0.18}_{-0.06}$	$0.17^{+0.06}_{-0.21}$	$0.11^{+0.12}_{-0.07}$	$0.23^{+0.03}_{-0.24}$	$0.15^{+0.05}_{-0.07}$	$0.28^{+0.02}_{-0.09}$	$0.25^{+0.04}_{-0.03}$	$0.26^{+0.03}_{-0.06}$	$0.22^{+0.08}_{-0.09}$
$\delta_{\mathrm{XS}} \to$ N	$-0.08^{+0.07}_{-0.03}$	$-0.06^{+0.04}_{-0.04}$	$0.15^{+0.02}_{-0.04}$	$0.12^{+0.03}_{-0.02}$	$-0.10^{+0.06}_{-0.01}$	$-0.06^{+0.03}_{-0.05}$	$0.02^{+0.06}_{-0.06}$	$0.01^{+0.02}_{-0.02}$	$0.05^{+0.02}_{-0.07}$	$0.050^{+0.009}_{-0.032}$	$0.10^{+0.02}_{-0.04}$	$0.110^{+0.005}_{-0.034}$	$0.189^{+0.008}_{-0.037}$	$0.189^{+0.004}_{-0.045}$
$\delta_{\mathrm{XS}} \to$ Li	-	$0.00^{+0.05}_{-0.03}$	-	$0.16^{+0.03}_{-0.03}$	-	$-0.02^{+0.05}_{-0.06}$	-	$0.14^{+0.03}_{-0.02}$	-	$0.16^{+0.01}_{-0.02}$	-	$0.193^{+0.007}_{-0.005}$	-	$0.190^{+0.005}_{-0.014}$
$\delta_{\mathrm{XS}} \to$ Be	-	$0.07^{+0.05}_{-0.04}$	-	$0.186^{+0.010}_{-0.044}$	-	$0.07^{+0.04}_{-0.05}$	-	$0.22^{+0.02}_{-0.04}$	-	$0.23^{+0.02}_{-0.02}$	-	$0.280^{+0.008}_{-0.012}$	-	$0.27^{+0.01}_{-0.03}$
$\delta_{\mathrm{XS}} \to$ B	$-0.065^{+0.084}_{-0.008}$	$-0.06^{+0.03}_{-0.02}$	$0.07^{+0.02}_{-0.03}$	$0.066^{+0.009}_{-0.025}$	$-0.05^{+0.03}_{-0.02}$	$-0.07^{+0.03}_{-0.03}$	$0.05^{+0.05}_{-0.05}$	$0.04^{+0.01}_{-0.02}$	$0.09^{+0.01}_{-0.07}$	$0.05^{+0.02}_{-0.01}$	$0.16^{+0.03}_{-0.04}$	$0.117^{+0.005}_{-0.014}$	$0.12^{+0.03}_{-0.02}$	$0.12^{+0.02}_{-0.02}$
$A_{\mathrm{XS}} \to$ C	$0.55^{+0.04}_{-0.04}$	$0.57^{+0.03}_{-0.06}$	$0.63^{+0.37}_{-0.07}$	$0.81^{+0.11}_{-0.27}$	$0.54^{+0.05}_{-0.03}$	$0.54^{+0.05}_{-0.04}$	$0.51^{+0.15}_{-0.01}$	$0.53^{+0.05}_{-0.02}$	$0.511^{+0.074}_{-0.006}$	$0.514^{+0.031}_{-0.006}$	$0.54^{+0.04}_{-0.04}$	$0.52^{+0.03}_{-0.02}$	$0.500^{+0.334}_{-0.000}$	$0.83^{+0.06}_{-0.28}$
$A_{\mathrm{XS}} \to$ N	$1.18^{+0.04}_{-0.16}$	$1.11^{+0.04}_{-0.04}$	$1.18^{+0.10}_{-0.13}$	$1.15^{+0.10}_{-0.09}$	$1.09^{+0.07}_{-0.03}$	$1.13^{+0.06}_{-0.04}$	$1.07^{+0.13}_{-0.03}$	$1.15^{+0.04}_{-0.04}$	$1.14^{+0.06}_{-0.04}$	$1.13^{+0.04}_{-0.03}$	$1.19^{+0.03}_{-0.17}$	$1.20^{+0.01}_{-0.13}$	$1.02^{+0.17}_{-0.05}$	$1.15^{+0.04}_{-0.15}$
$A_{\mathrm{XS}} \to$ Li	-	$1.27^{+0.07}_{-0.04}$	-	$1.22^{+0.07}_{-0.06}$	-	$1.32^{+0.10}_{-0.05}$	-	$1.33^{+0.06}_{-0.04}$	-	$1.31^{+0.04}_{-0.05}$	-	$1.36^{+0.02}_{-0.15}$	-	$1.14^{+0.04}_{-0.07}$
$A_{\mathrm{XS}} \to$ Be	-	$0.990^{+0.006}_{-0.004}$	-	$0.946^{+0.004}_{-0.003}$	-	$0.992^{+0.005}_{-0.003}$	-	$0.990^{+0.005}_{-0.002}$	-	$0.991^{+0.002}_{-0.003}$	-	$0.992^{+0.001}_{-0.005}$	-	$0.941^{+0.007}_{-0.009}$
$A_{\mathrm{XS}} \to$ B	$1.11^{+0.04}_{-0.13}$	$1.03^{+0.04}_{-0.03}$	$1.05^{+0.09}_{-0.08}$	$1.01^{+0.05}_{-0.05}$	$1.08^{+0.05}_{-0.04}$	$1.06^{+0.07}_{-0.03}$	$1.04^{+0.11}_{-0.02}$	$1.06^{+0.04}_{-0.03}$	$1.08^{+0.05}_{-0.03}$	$1.05^{+0.03}_{-0.03}$	$1.16^{+0.01}_{-0.17}$	$1.08^{+0.01}_{-0.10}$	$0.95^{+0.11}_{-0.06}$	$0.95^{+0.02}_{-0.05}$
$\varphi_{\mathrm{AMS-02}}$	$613.67^{+44.11}_{-13.66}$	$615.56^{+34.46}_{-16.99}$	$678.15^{+16.99}_{-21.33}$	$697.68^{+2.03}_{-21.99}$	$608.98^{+34.11}_{-7.58}$	$614.39^{+24.90}_{-17.40}$	$594.81^{+31.64}_{-11.66}$	$614.82^{+12.74}_{-40.06}$	$618.80^{+15.41}_{-25.78}$	$593.84^{+13.47}_{-8.50}$	$590.95^{+56.33}_{-13.03}$	$600.02^{+12.65}_{-23.88}$	$655.17^{+17.48}_{-45.23}$	$658.61^{+27.11}_{-36.18}$