Cosmic-ray transport from AMS-02 B/C data: benchmark models and interpretation

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PHYSICAL REVIEW D 99, 123028 (2019)

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The goal: -> To provide up-to-date transport benchmark models, and their uncertainties, that encompass our ignorance about the physical processes @ low-rigidity.

The method: -> No global fit
-> New modelling ingredients
-> New fitting procedure (David) but also..

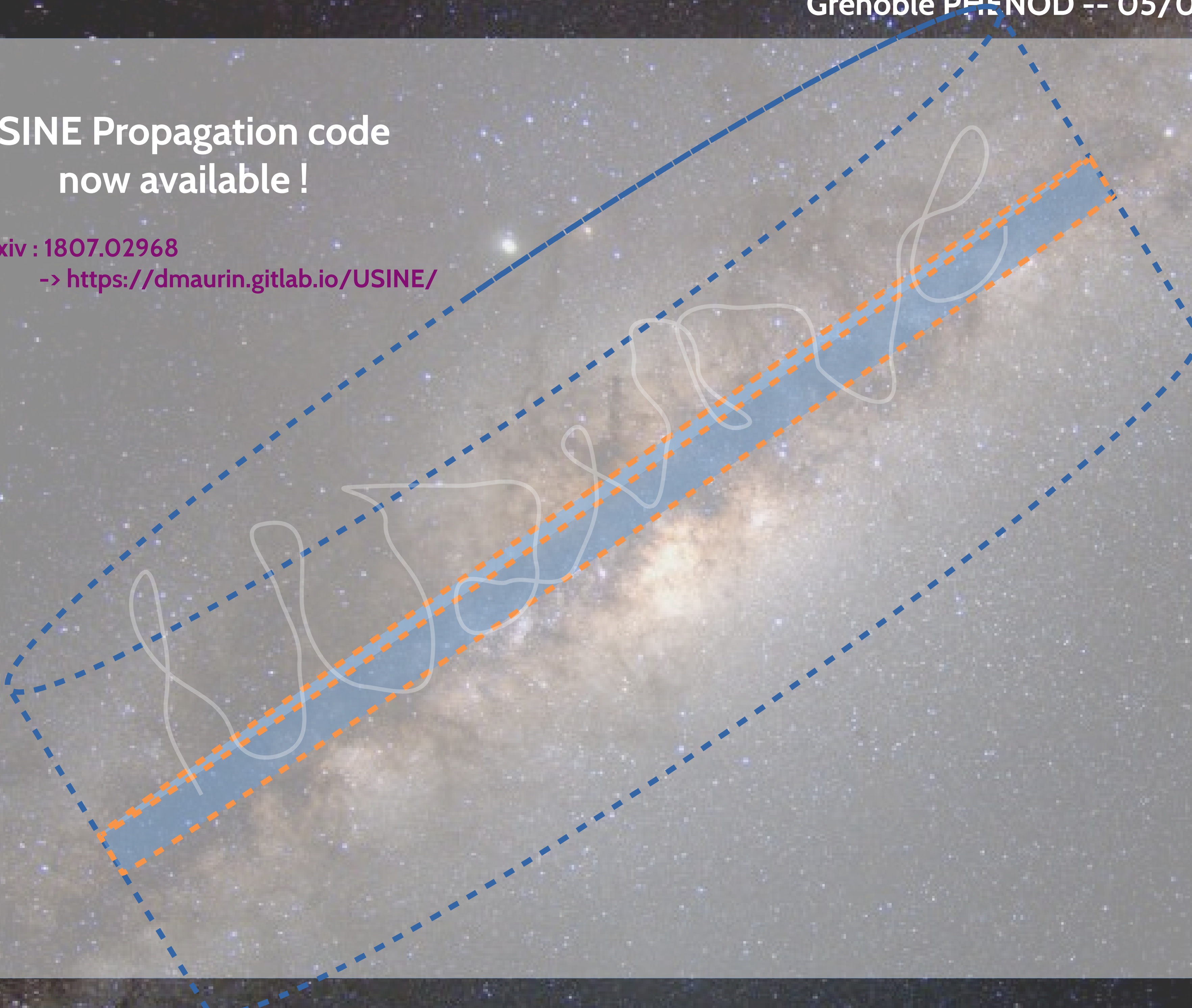
I - Novelties and benchmark models

II - Subtleties of the fitting procedure

III - Main results!

USINE Propagation code now available !

Arxiv : 1807.02968
-> https://dmaurin.gitlab.io/USINE/

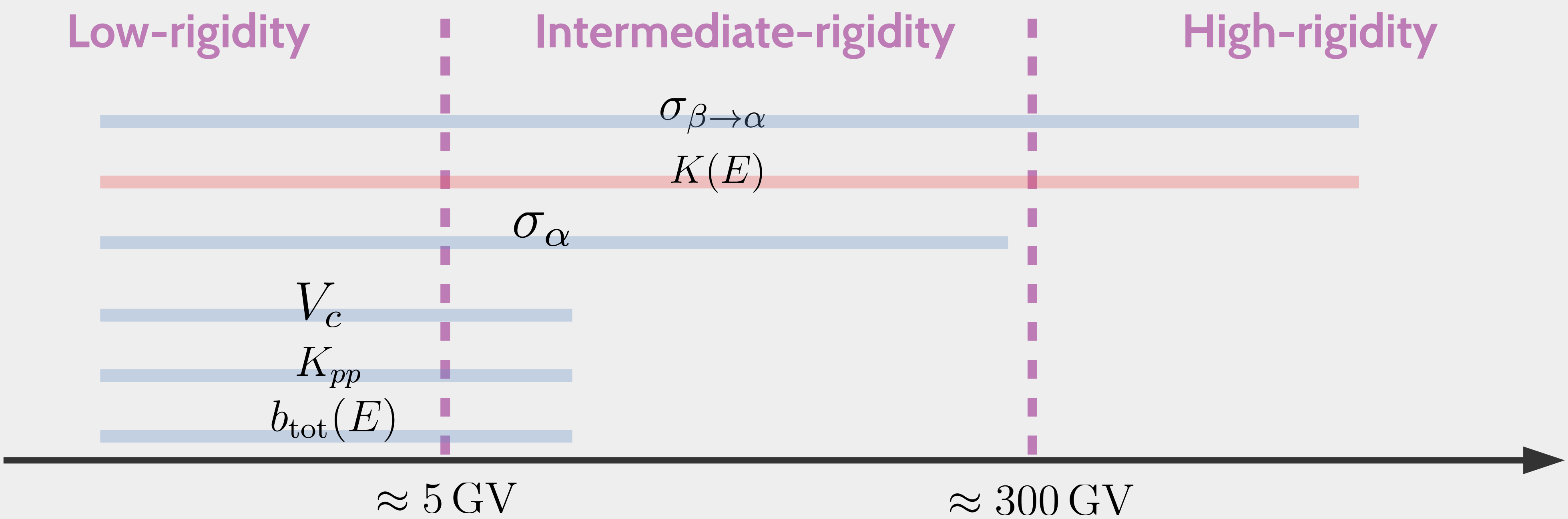


I - Novelties and benchmark models

We solve semi-analytically the famous propagation equation:

$$-\vec{\nabla}_{\mathbf{x}}\left\{K(E)\,\vec{\nabla}_{\mathbf{x}}\psi_\alpha-\vec{V}_{\rm c}\psi_\alpha\right\}+\frac{\partial}{\partial E}\left\{b_{\rm tot}(E)\,\psi_\alpha-\beta^2\,K_{pp}\,\frac{\partial\psi_\alpha}{\partial E}\right\}$$

$$+\sigma_\alpha\,v_\alpha\,n_{\rm ism}\,\psi_\alpha+\Gamma_\alpha\,\psi_\alpha=\;q_\alpha+\sum_\beta\left\{\sigma_{\beta\to\alpha}v_\beta n_{\rm ism}\,+\Gamma_{\beta\to\alpha}\right\}\,\psi_\beta\,.$$

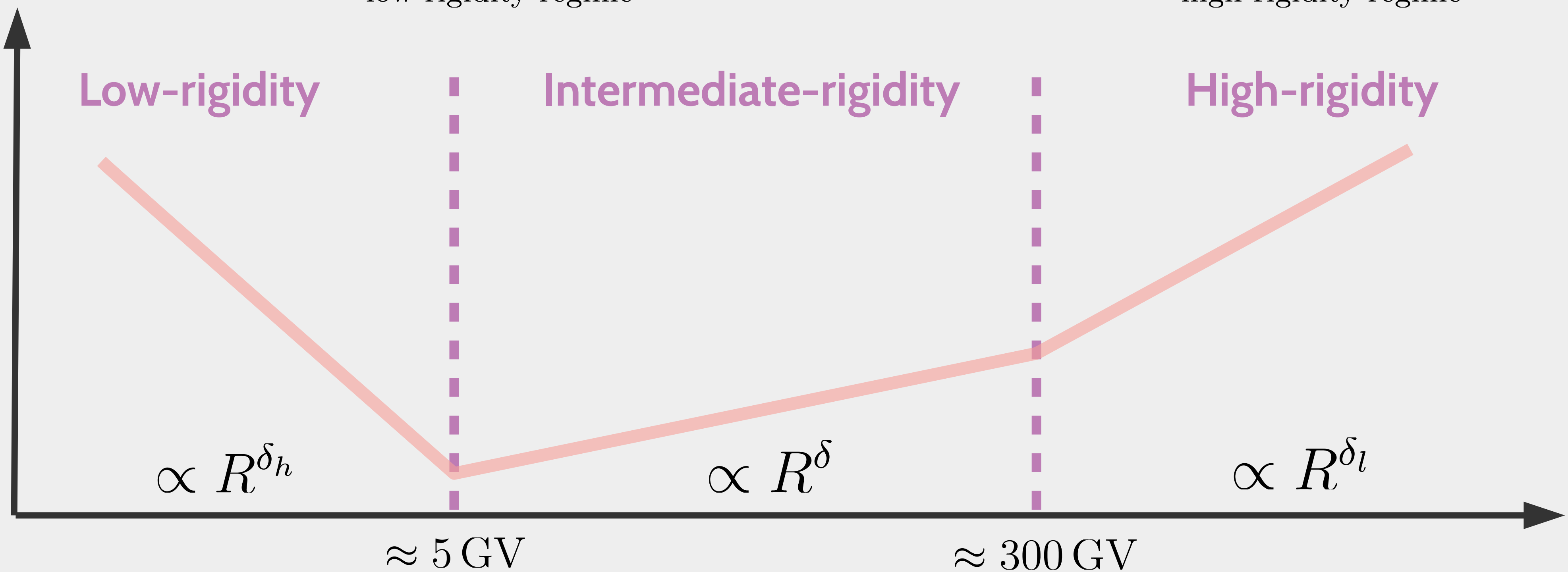


I - Novelties and benchmark models

-> Diffusion is assumed to be ***homogeneous*** and ***isotropic.***

-> We introduce several breaks in the diffusion coefficient:

$$K(R) = \beta^\eta K_{10} \underbrace{\left\{1 + \left(\frac{R}{R_\mathrm{l}}\right)^{\frac{\delta_\mathrm{l}-\delta}{s_\mathrm{l}}}\right\}^{s_\mathrm{l}}}_{\text{low-rigidity regime}} \underbrace{\left\{\frac{R}{(R_{10} \equiv 10\,\mathrm{GV})}\right\}^{\delta}}_{\text{intermediate regime}} \underbrace{\left\{1 + \left(\frac{R}{R_\mathrm{h}}\right)^{\frac{\delta-\delta_\mathrm{h}}{s_\mathrm{h}}}\right\}^{-s_\mathrm{h}}}_{\text{high-rigidity regime}} .$$



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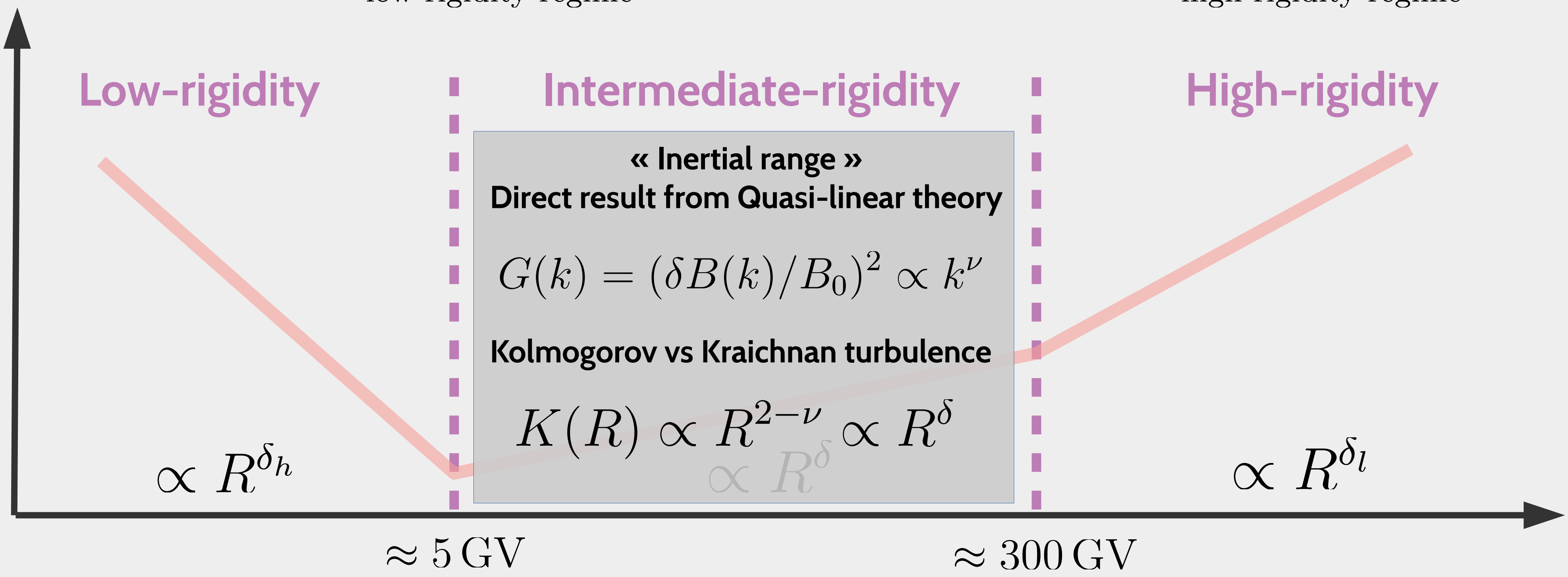

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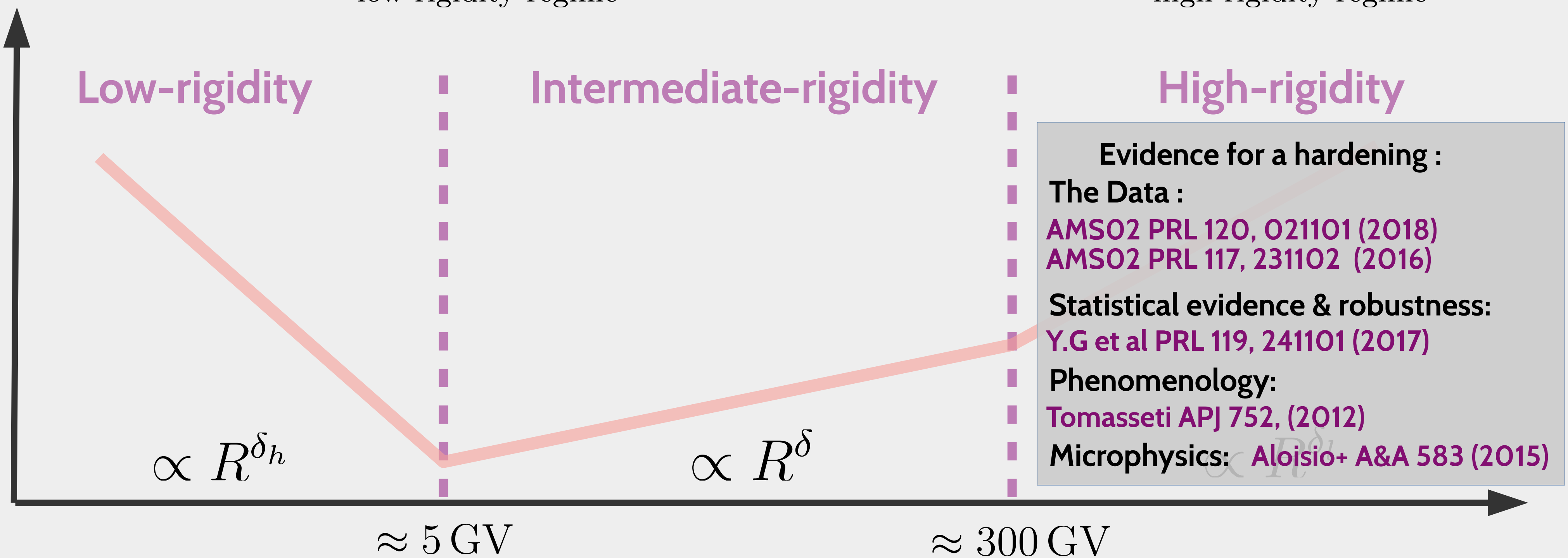

Evidence for a hardening :

The Data :

AMS02 PRL 120, 021101 (2018)
AMS02 PRL 117, 231102 (2016)

Statistical evidence & robustness:

Y.G et al PRL 119, 241101 (2017)

Phenomenology:

Tomasseti APJ 752, (2012)

Microphysics: Aloisio+ A&A 583 (2015)

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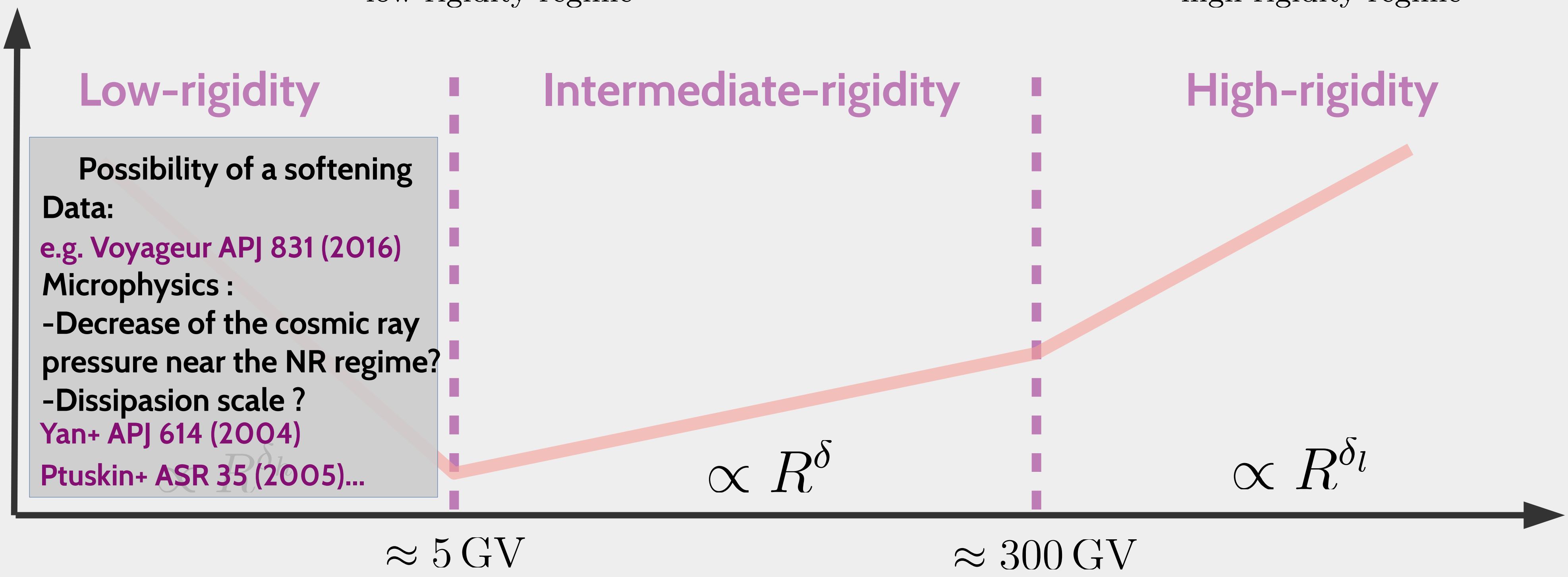

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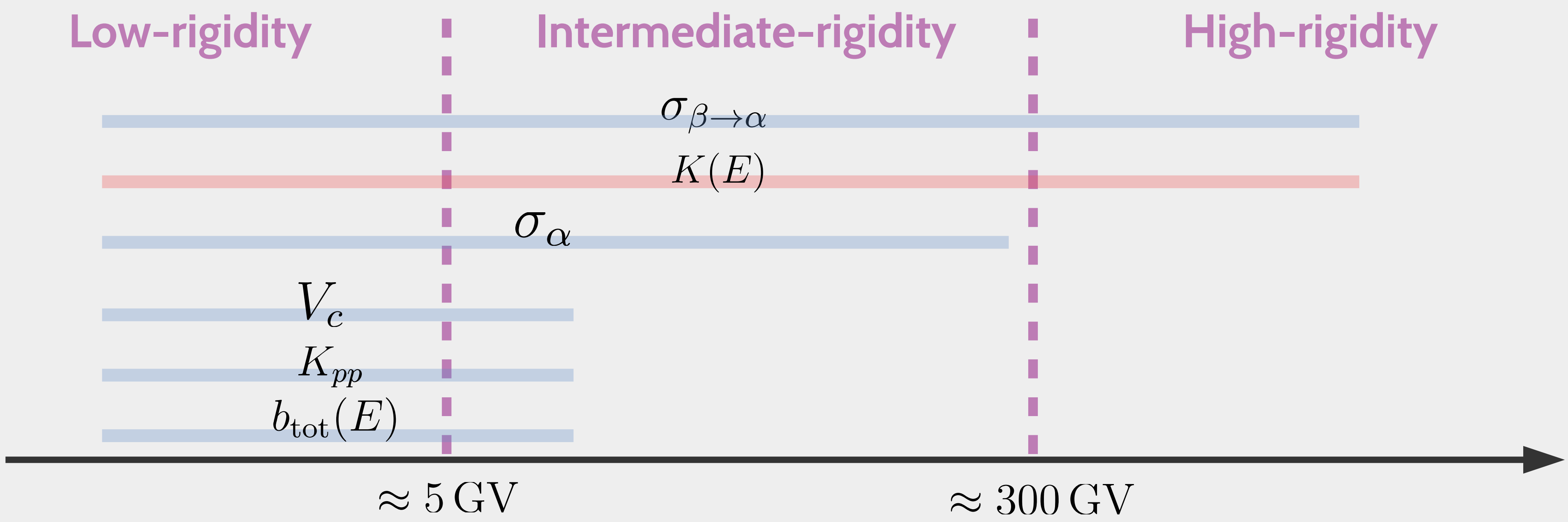
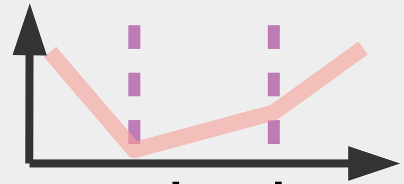
$$+ \sigma_\alpha\, v_\alpha\, n_{\rm ism}\, \psi_\alpha + \Gamma_\alpha\, \psi_\alpha = q_\alpha + \sum_\beta \left\{ \sigma_{\beta\to\alpha} v_\beta n_{\rm ism} + \Gamma_{\beta\to\alpha} \right\} \psi_\beta .$$



I - Novelties and benchmark models

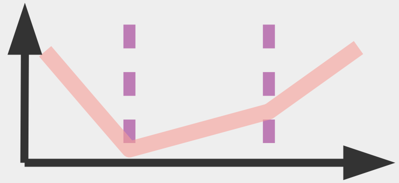
We define three benchmark models:

BIG V_c K_{pp} $K(E)$



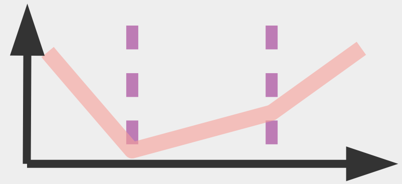
Two breaks

SLIM $K(E)$



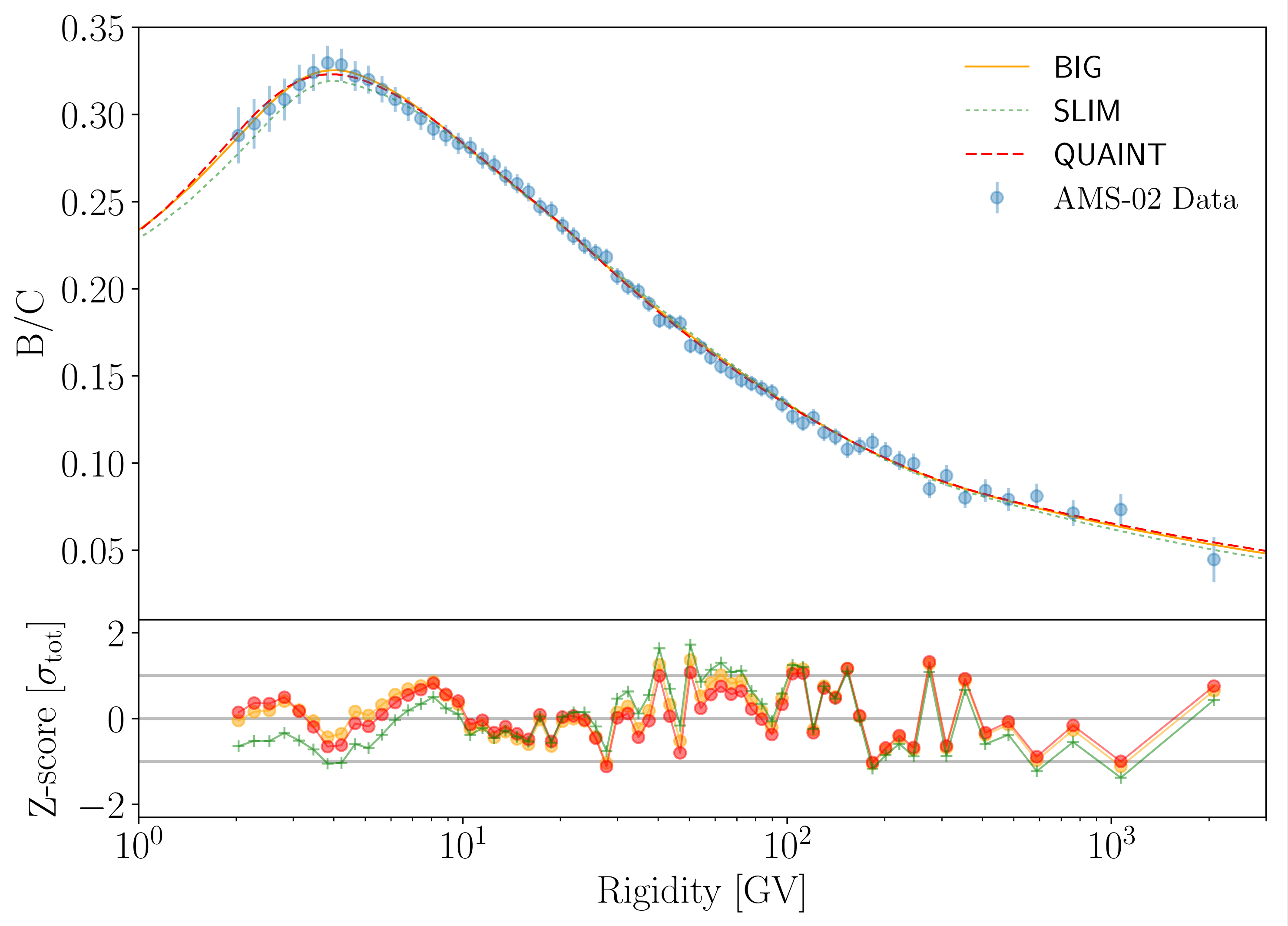
Two breaks

QUAINT K_{pp} $K(E)$



One break + η free

I - Novelties and benchmark models



A priori no preference for one model compare to the others !

I - Novelties and benchmark models

II - Subtleties of the fitting procedure

III - Main results!

II - Subtleties of the fitting procedure

Methodology -> 1–Covariance matrix for data uncertainties

Errors are dominated by systematics

-> 2-Theoretical errors are handled with *nuisance* parameters

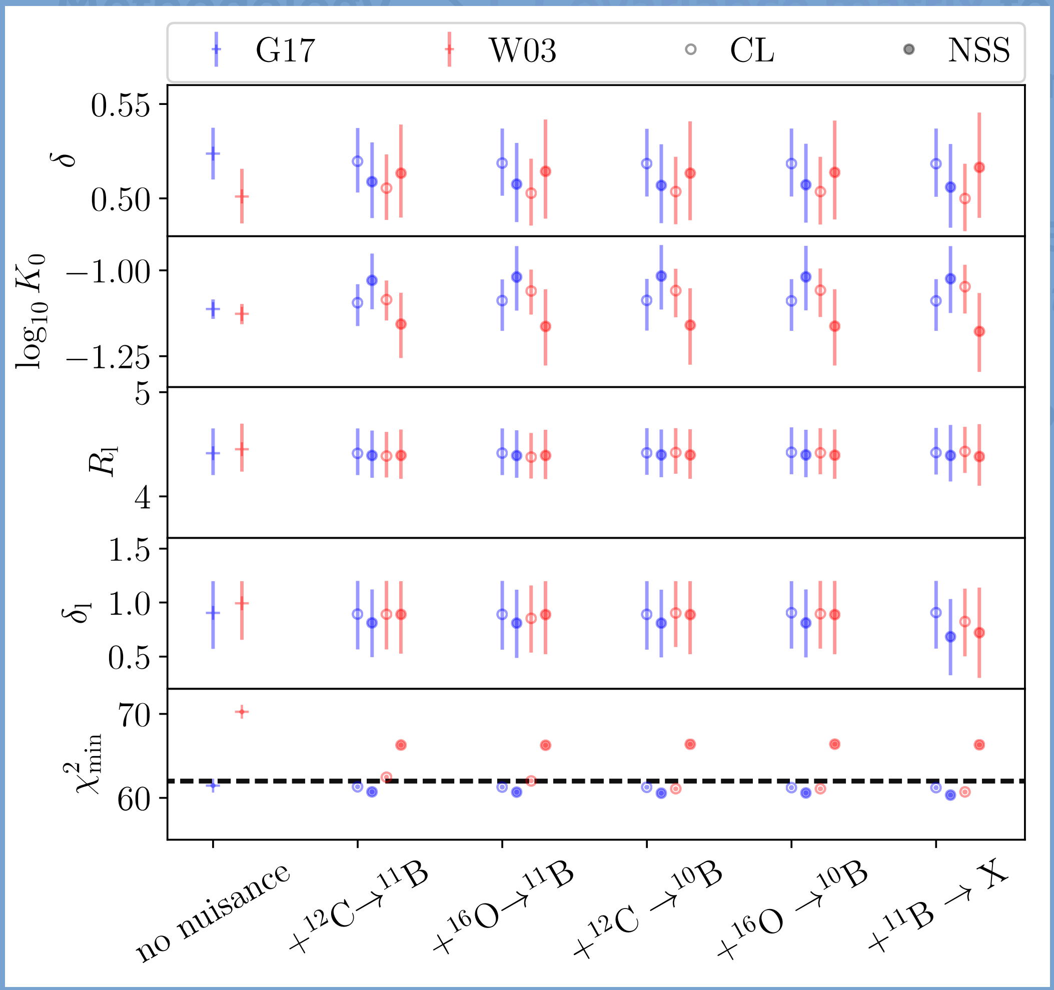
Solar modulation : force field approximation

Production cross section : NSS nuisance method only on $\sigma_{^{12}\mathrm{C}\to^{11}\mathrm{B}}$

Most important XS

see Y.G et al PRC 034611 (2018)

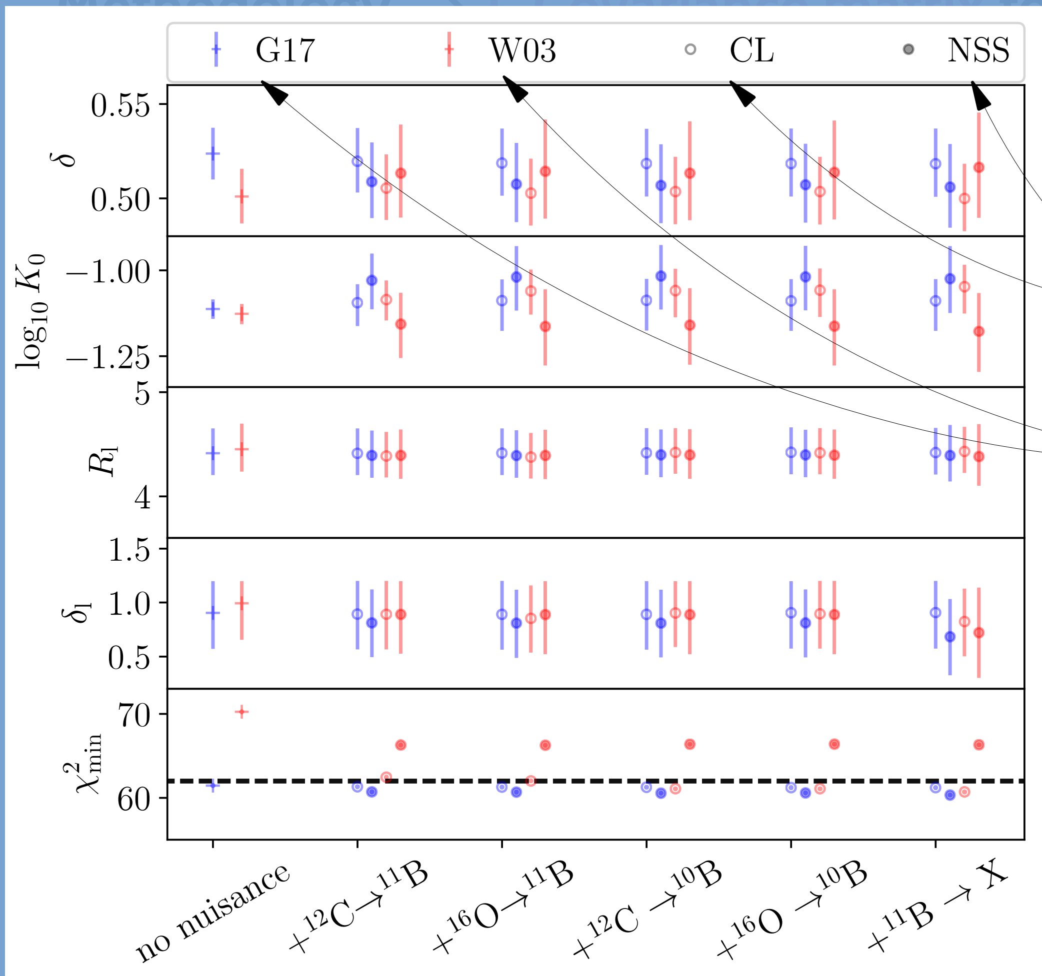
II - Subtleties of the fitting procedure



Derome et al 1904.08210

Best fit propagation parameters with uncertainties increasing the number of XS as nuisance following Y.G et al PRC 034611 (2018)

II - Subtleties of the fitting procedure



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Two methods of nuisance

Using Galprop or Weeber XS

Three conclusions :

1- The tension btw the two XS sets is released using one xs as nuisance only.

2- Adding more XS as nuisance does not increase further the error bars.
->Data systematics dominates

3- NSS method give a little bit more freedom so we use it.

II - Subtleties of the fitting procedure

Methodology -> 1–Covariance matrix for data uncertainties

Errors are dominated by systematics

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Solar modulation : force field approximation

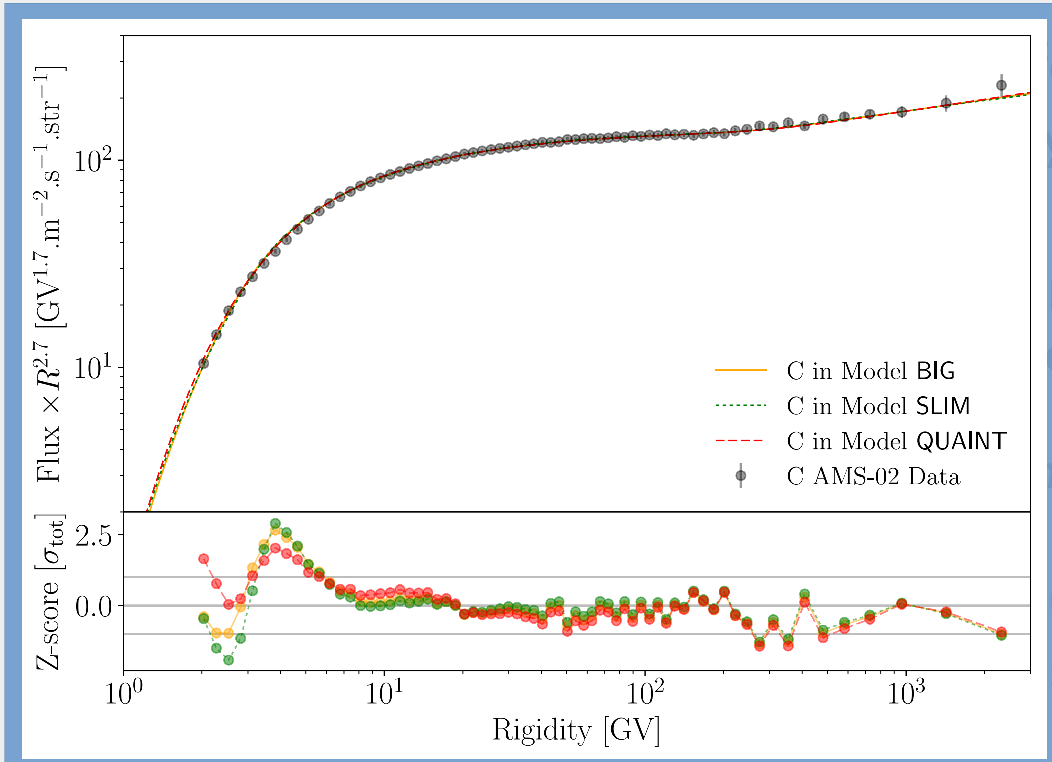
Production cross section : NSS nuisance method only on $\sigma_{^{12}\mathrm{C}\to^{11}\mathrm{B}}$

-> 3-Iterative fitting procedure using C, and O AMS02 data

T*wo reasons* : - Be consistent with primary AMS02 data

- Better constraint the high-rigidity break

II - Subtleties of the fitting procedure



or data uncertainties

Excellent fit to O and C AMS02 data !

y sy **Injection is a purepower law of the rigidity**

re handled with *nuisance* parameters

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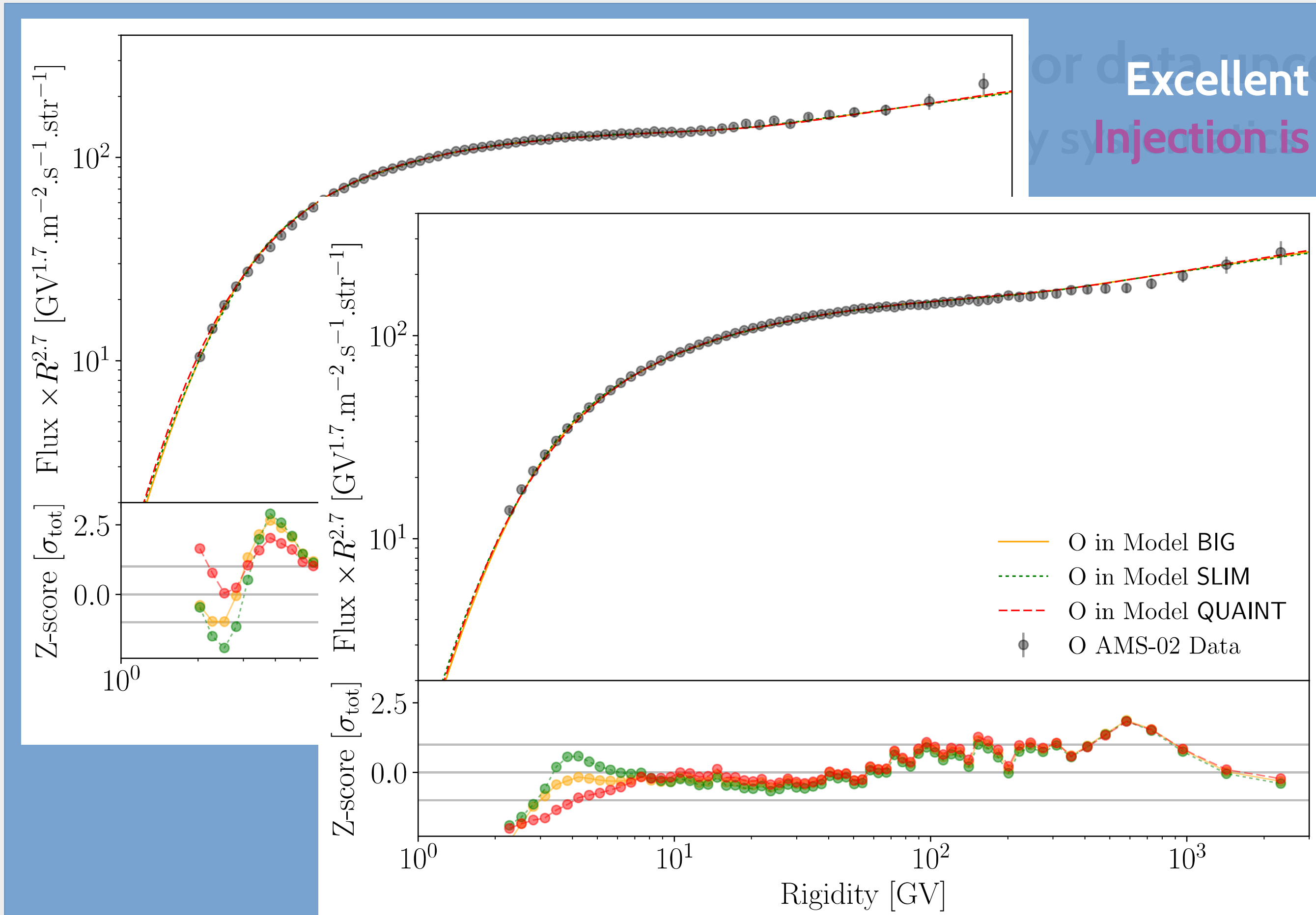
II - Subtleties of the fitting procedure



Excellent fit to O and C AMS02 data !

Injection is a purepower law of the rigidity

They are used to constrain the high-rigidity break parameters, nuisances of the B/C fit

I - Novelties and benchmark models

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III - Main results!

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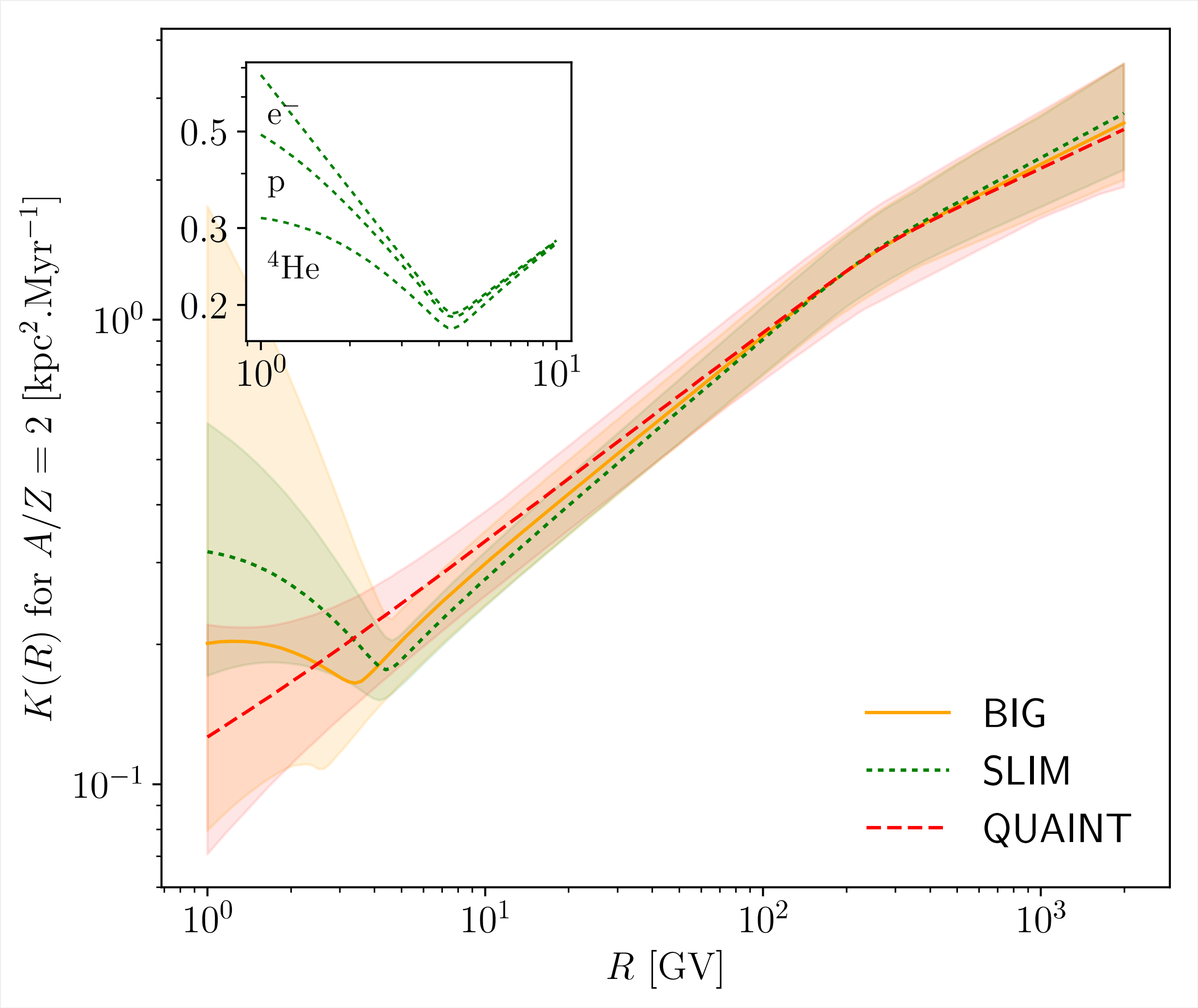
The best fit parameters:



Parameters	BIG	SLIM	QUAINT
χ^2/dof	$61.7/61=1.01$	$61.8/63=0.98$	$62.1/62=1.00$
Intermediate-rigidity parameters			
K_{10} [kpc^2 Myr^{-1}]	$0.30^{+0.03}_{-0.04}$	$0.28^{+0.02}_{-0.02}$	$0.33^{+0.03}_{-0.06}$
δ	$0.48^{+0.04}_{-0.03}$	$0.51^{+0.02}_{-0.02}$	$0.45^{+0.05}_{-0.02}$
Low-rigidity parameters			
V_c [km s^{-1}]	$0^{+7.4}$	N/A	0.0^{+8}
V_A [km s^{-1}]	67^{+24}_{-67}	N/A	101^{+14}_{-15}
η	1 (fixed)	1 (fixed)	$-0.09^{+0.35}_{-0.57}$
δ_l	$-0.69^{+0.61}_{-1.26}$	$-0.87^{+0.33}_{-0.31}$	N/A
R_l [GV]	$3.4^{+1.1}_{-0.9}$	$4.4^{+0.2}_{-0.2}$	N/A
High-rigidity break parameters (nuisance parameters)			
Δ_h	0.18	0.19	0.17
R_h [GV]	247	237	270
s_h	0.04	0.04	0.04

III – Main results!

Uncertainty on the diffusion coefficient :



III – Main results!

Other results:

-> We confirm the high-rigidity break using the B/C only

Y.G et al PRL 119, 241101 (2017)

-> We povide a dictionary to go from our 1D model to 2D

Direct impact on -> Secondary (antiparticles) predictions

-> Study of the propagation at low-rigidity