

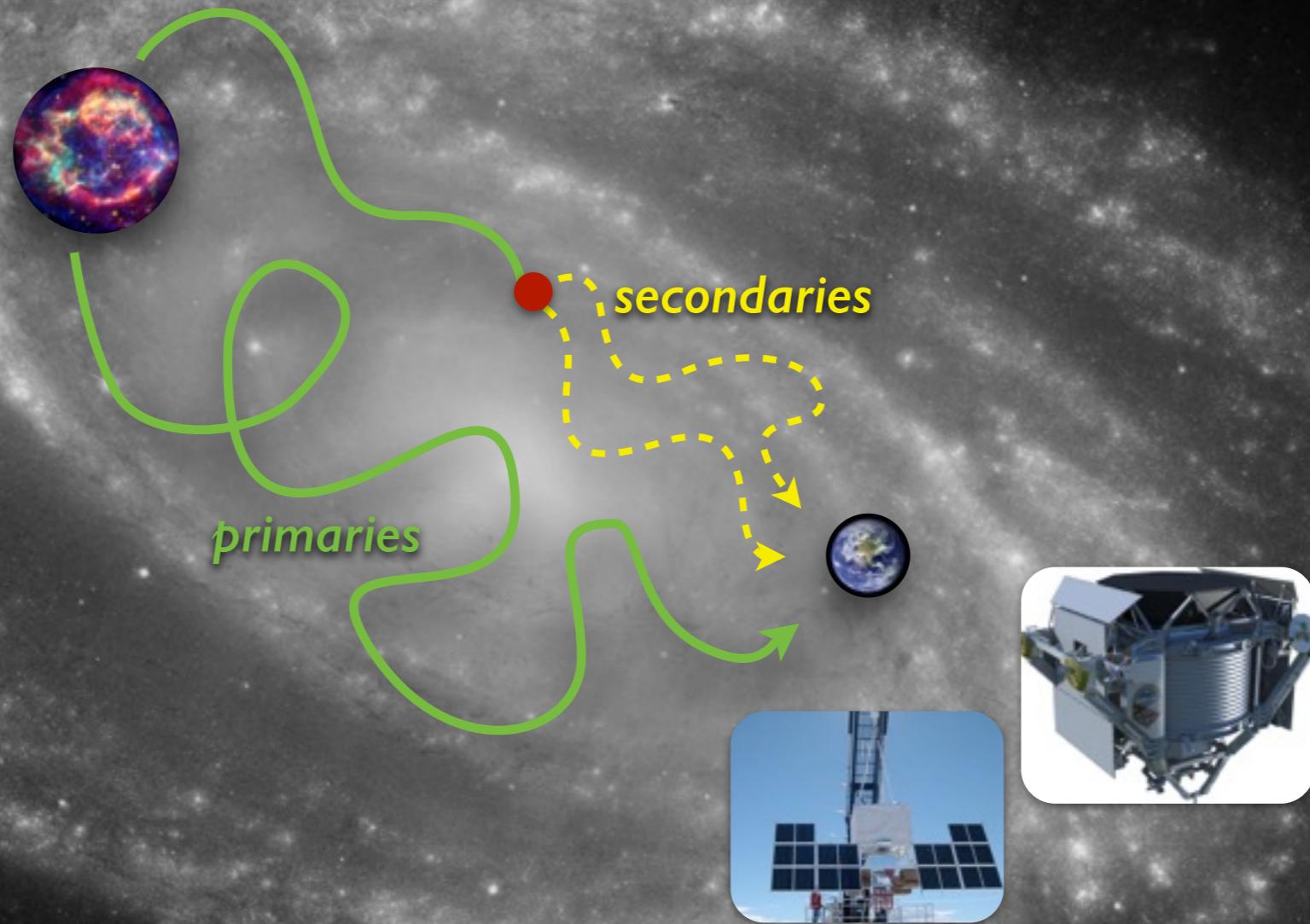
Cosmic-ray propagation models and their impact on indirect dark- matter searches

Antje Putze

LAPTh/LAPP

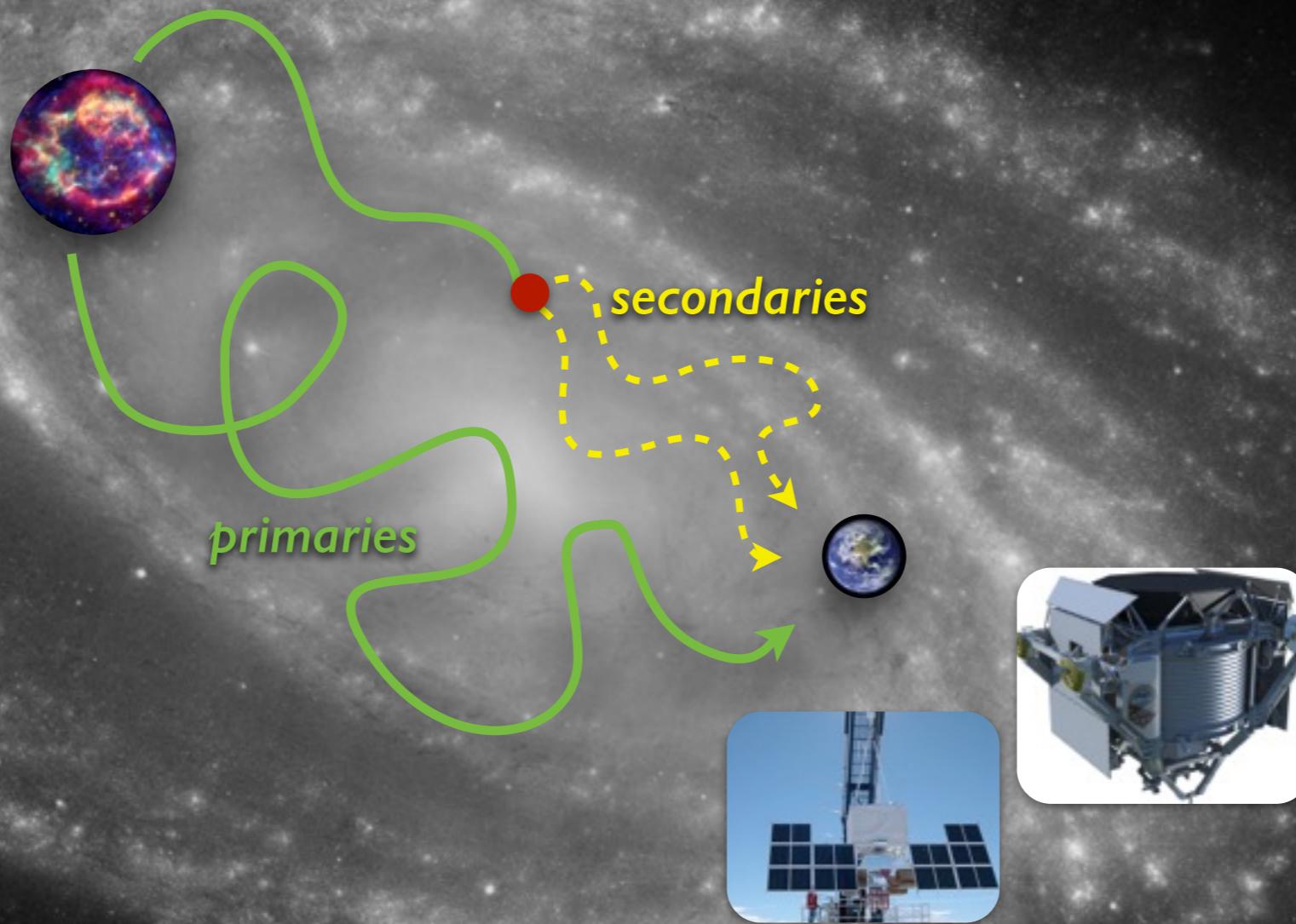
Rencontres de Physique des Particules 2016
LAPTh, Annecy-le-Vieux





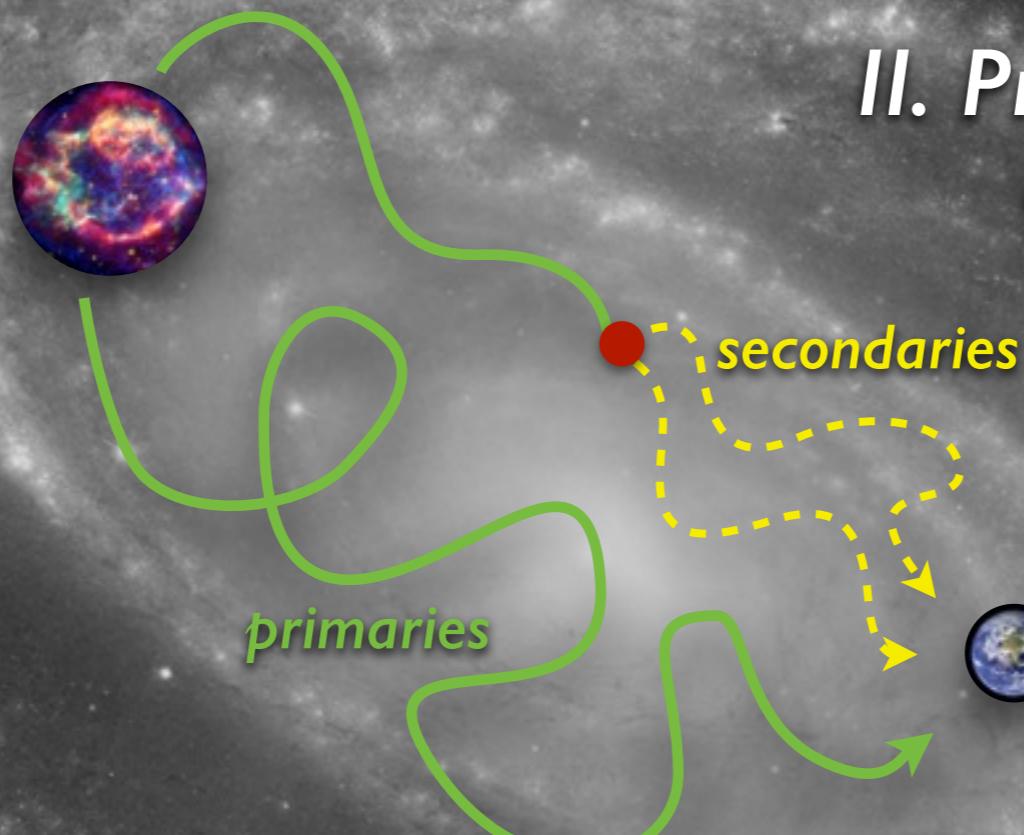
I. Sources & Acceleration

diffusive shock acceleration



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diffusive shock acceleration



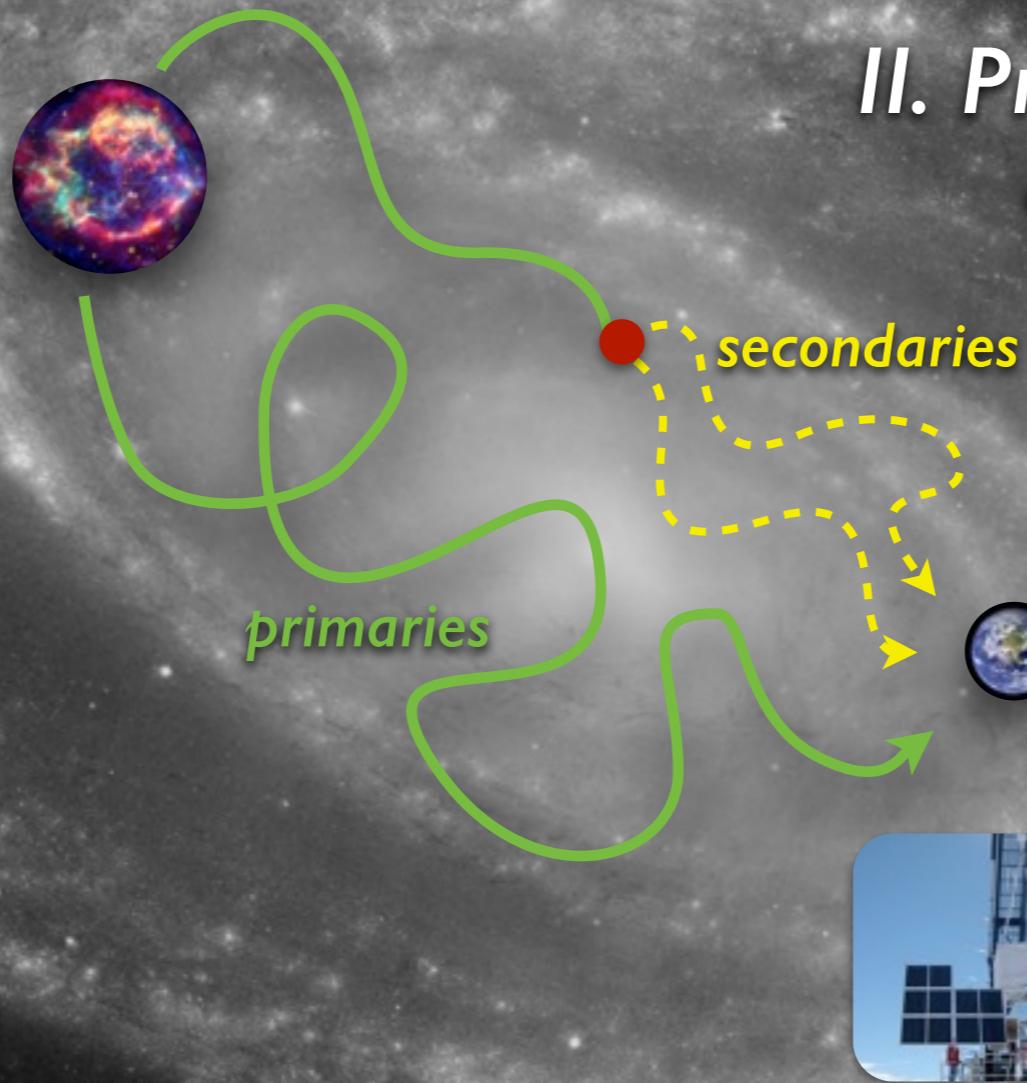
II. Propagation in the ISM

*diffusion, convection,
re-acceleration*



I. Sources & Acceleration

diffusive shock acceleration



II. Propagation in the ISM

*diffusion, convection,
re-acceleration*

III. Solar System & Detection

*solar modulation,
geomagnetic cut-off*

Diffusion Model

Diffusion equation becomes solvable assuming a cylindrical geometry of the Galaxy with 2 zones: **the galactic disc & the diffusive halo**

- **Semi-analytical approach**

e.g. USINE @ lpsc.in2p3.fr/usine

✓ fast computation

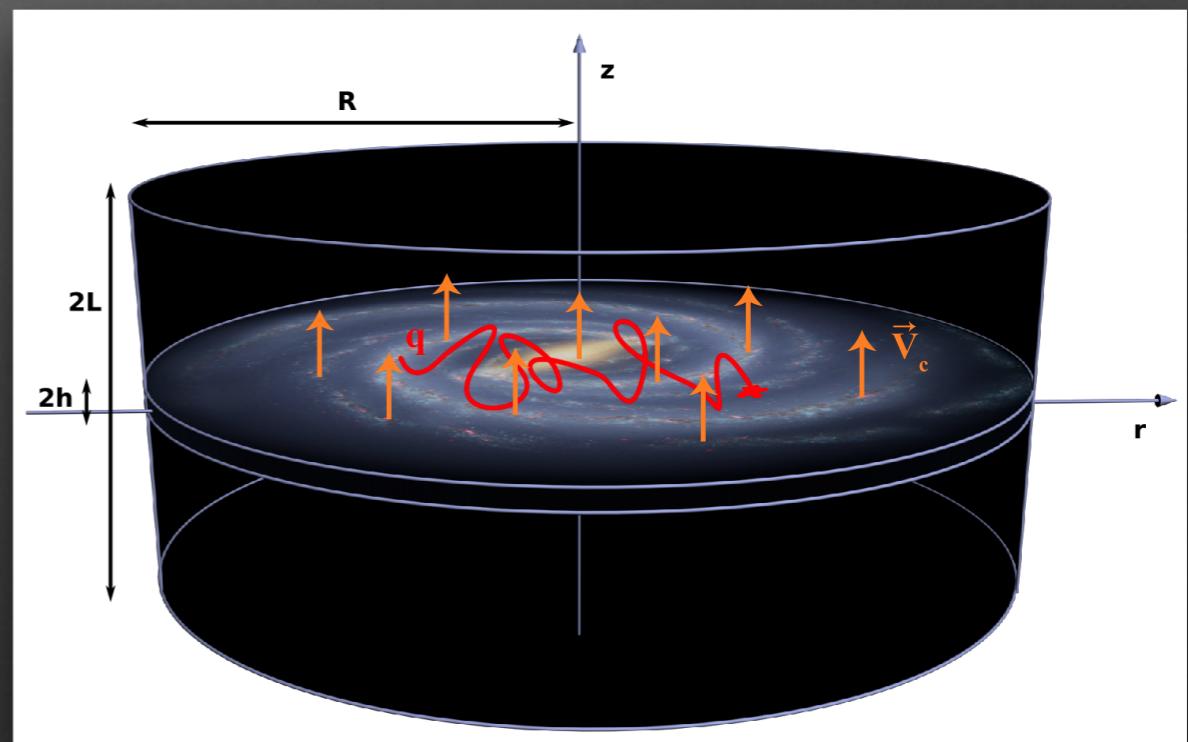
✗ simplified description of the interstellar medium

- **Numerical approach**

e.g. GALPROP @ galprop.stanford.edu

✓ data based description of the interstellar medium

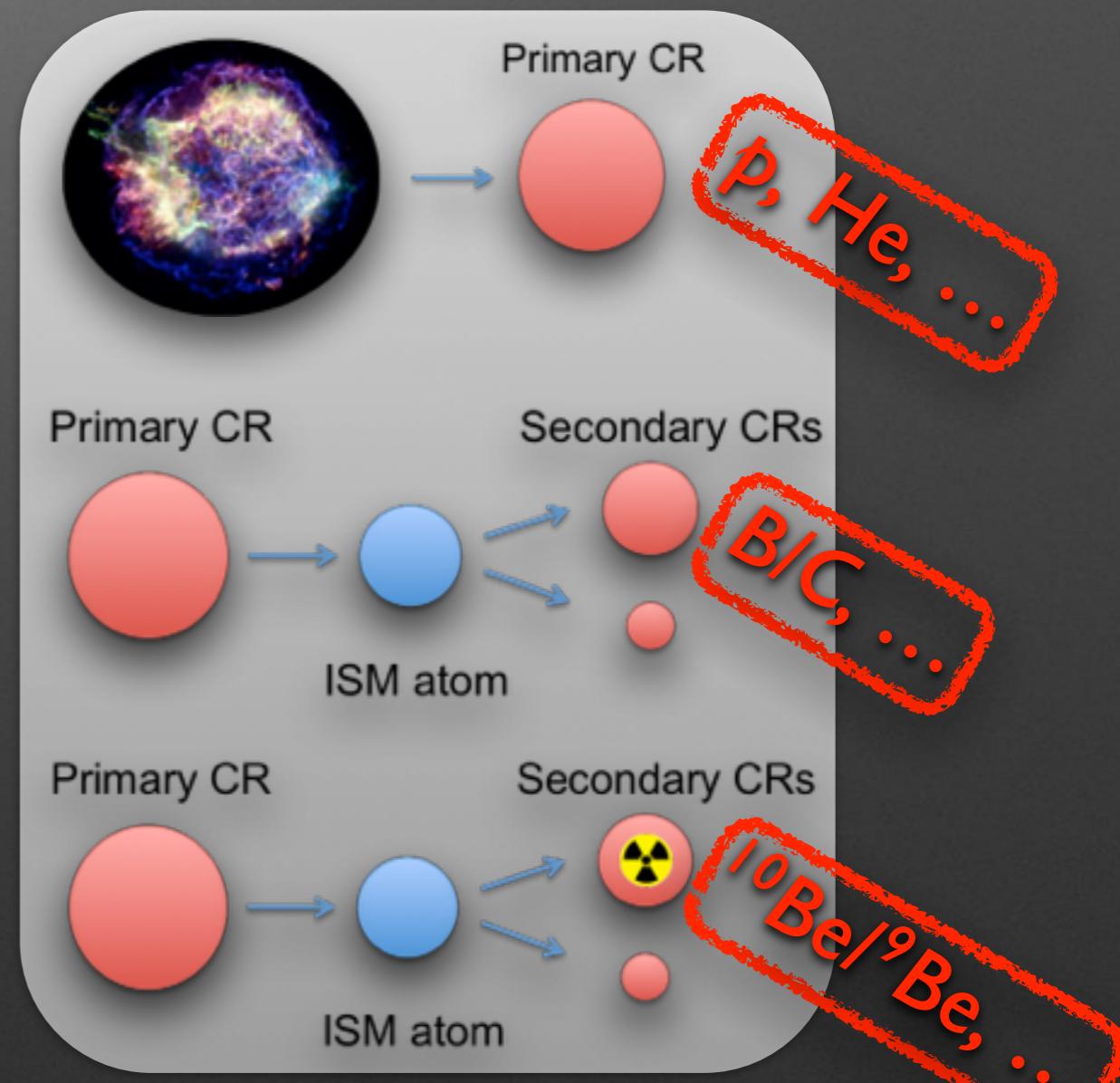
✗ very slow



Parameters and observables

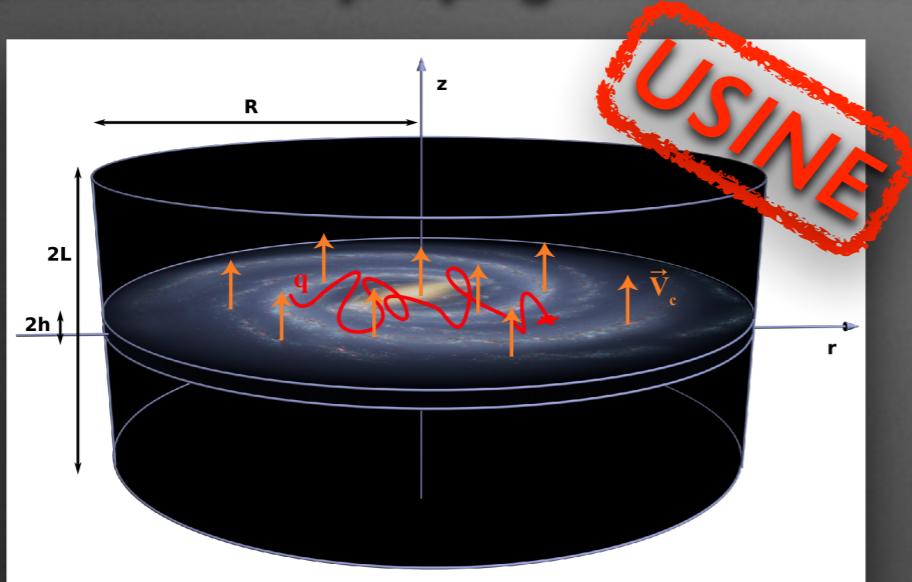
The most important parameters
are linked to

- the **acceleration** mechanisms
injection spectrum: $Q(R) \propto qR^{-\alpha}$
- the **propagation** mechanisms
diffusion: $K(R) \propto K_0 R^\delta$
convection:
re-acceleration:
- the **geometry** of the Galaxy
diffusive halo size: L



Constraining propagation models

sophisticated propagation models



precise experimental data



sophisticated statistical tools



parameters

observables

USINE @ lpsc.in2p3.fr/usine

GreAT @ lpsc.in2p3.fr/great

6 publications [Putze, Coste,⁵ Derome, Donato, Maurin, Perotto, Taillet (2009 - 2014)]

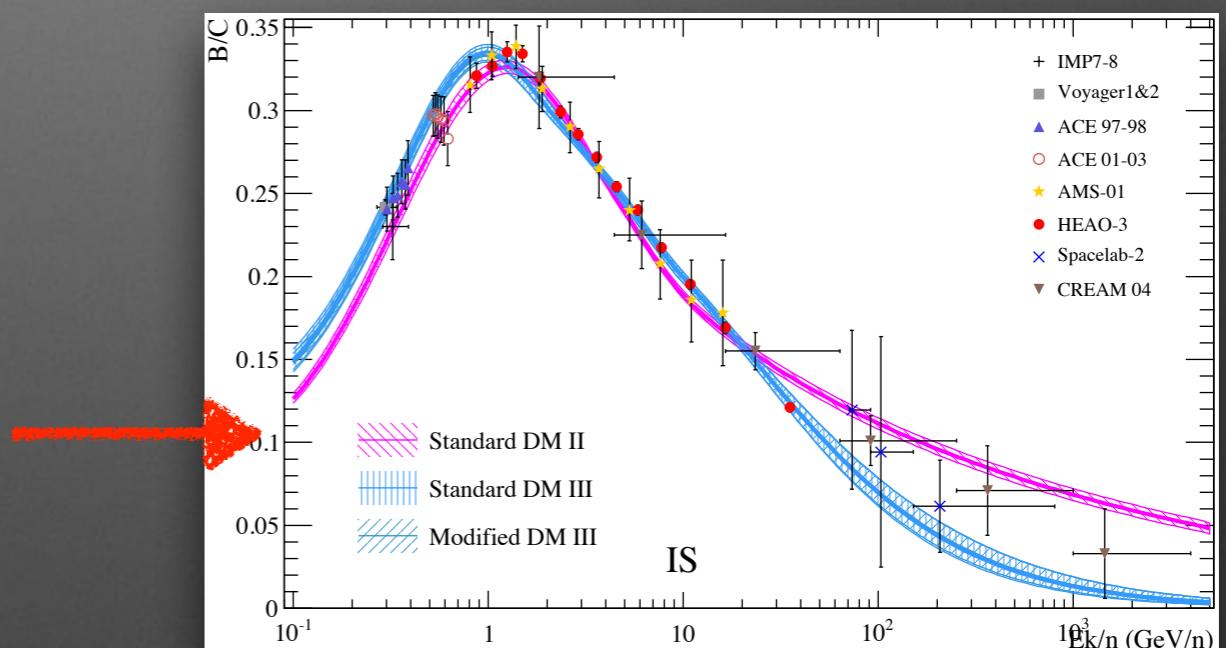
Which model is the best?

Diffusion models **with re-acceleration and/or convection** preferred, but **diffusion slope δ varies from 0.3 to 0.8**

Same results for

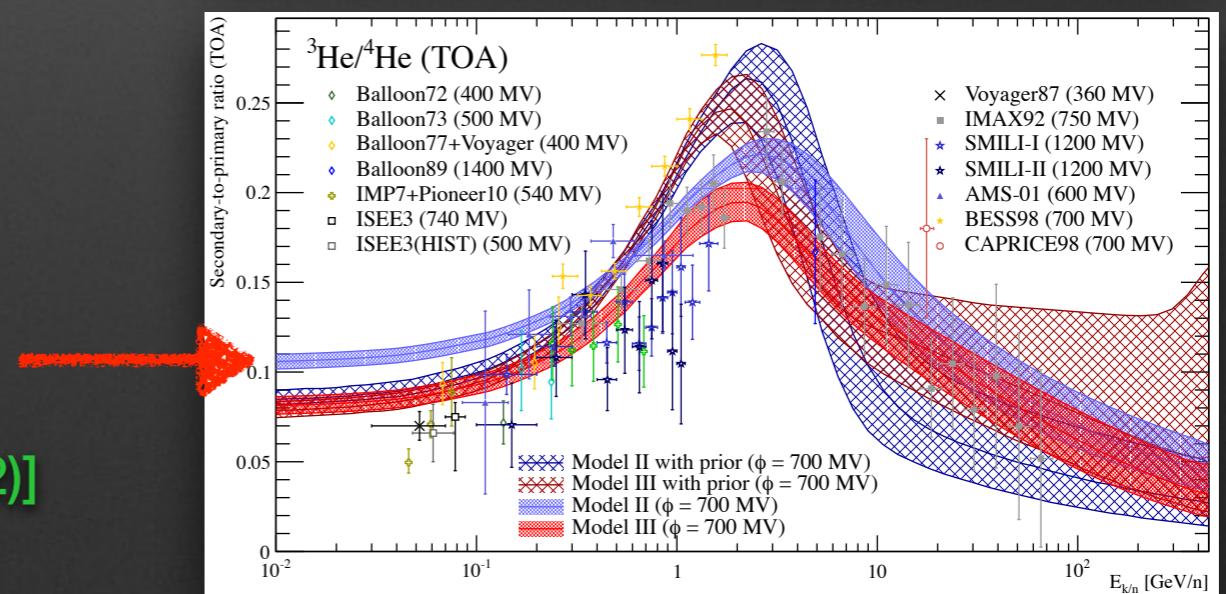
- **B/C**
 - ✓ abundant
 - ✓ elemental separation needed

[Putze, Derome, Maurin, A&A (2010)]



- **${}^3\text{He}/{}^4\text{He}$**
 - ✓ very abundant
 - ✗ isotopic separation needed

[Coste, Derome, Maurin, Putze, A&A (2012)]



How big is the diffusive halo?

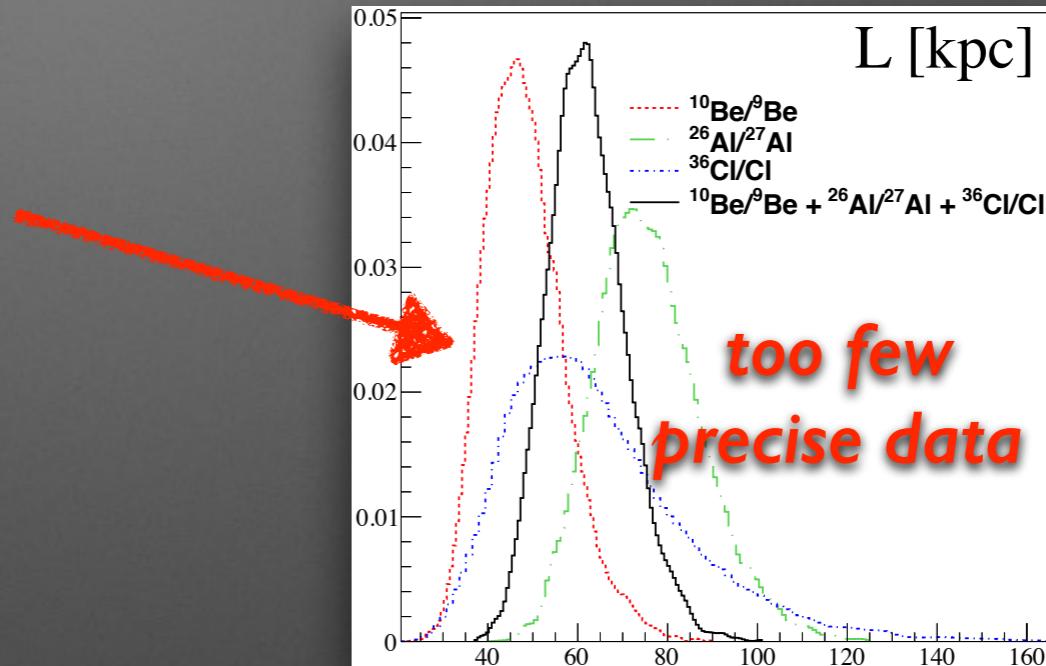
L determines the amount of dark matter contribution in cosmic rays!

Radioactive secondaries:

first PDF of L from an MCMC analysis

- too few precise data
- very sensitive to the LISM

[Putze, Derome, Maurin, A&A (2010)]

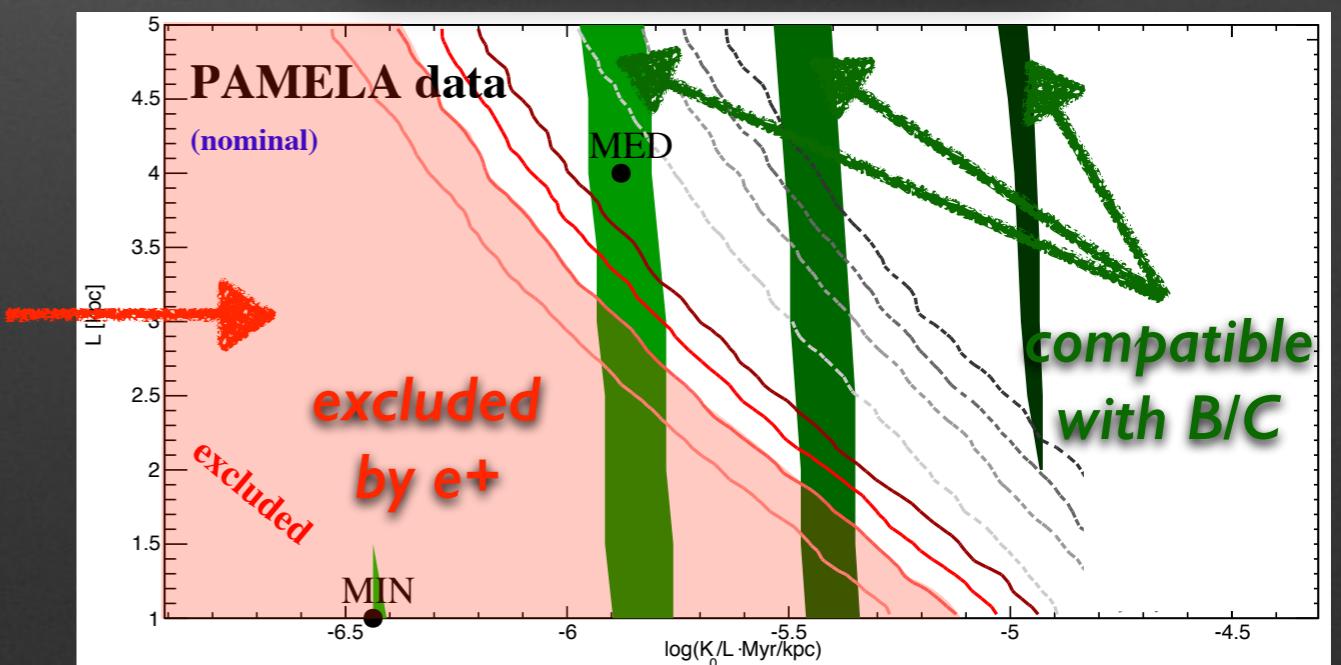


Secondary positrons:

first direct exclusion of small values of L

- ✓ precise data available
- sensitive to solar modulation

[Lavalle, Maurin, Putze, PRD (2014)]



What about theoretical uncertainties?

Theoretical uncertainties from model ingredients and hypotheses are dominating statistical uncertainties!

Cross sections

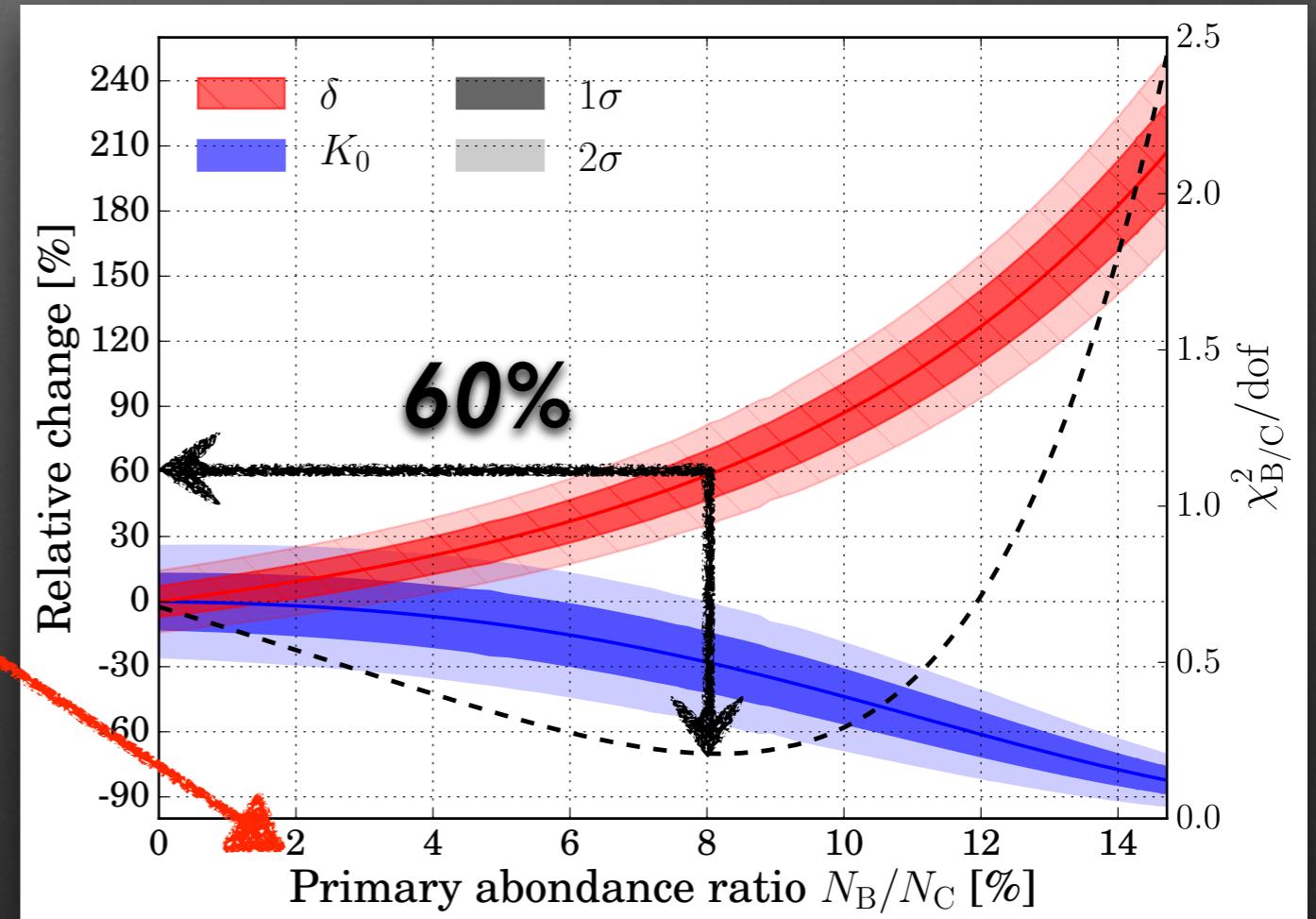
First estimation of their impact on parameter constraints: 100%

[Maurin, Putze, Derome, A&A (2010)]

Primary boron injected at source

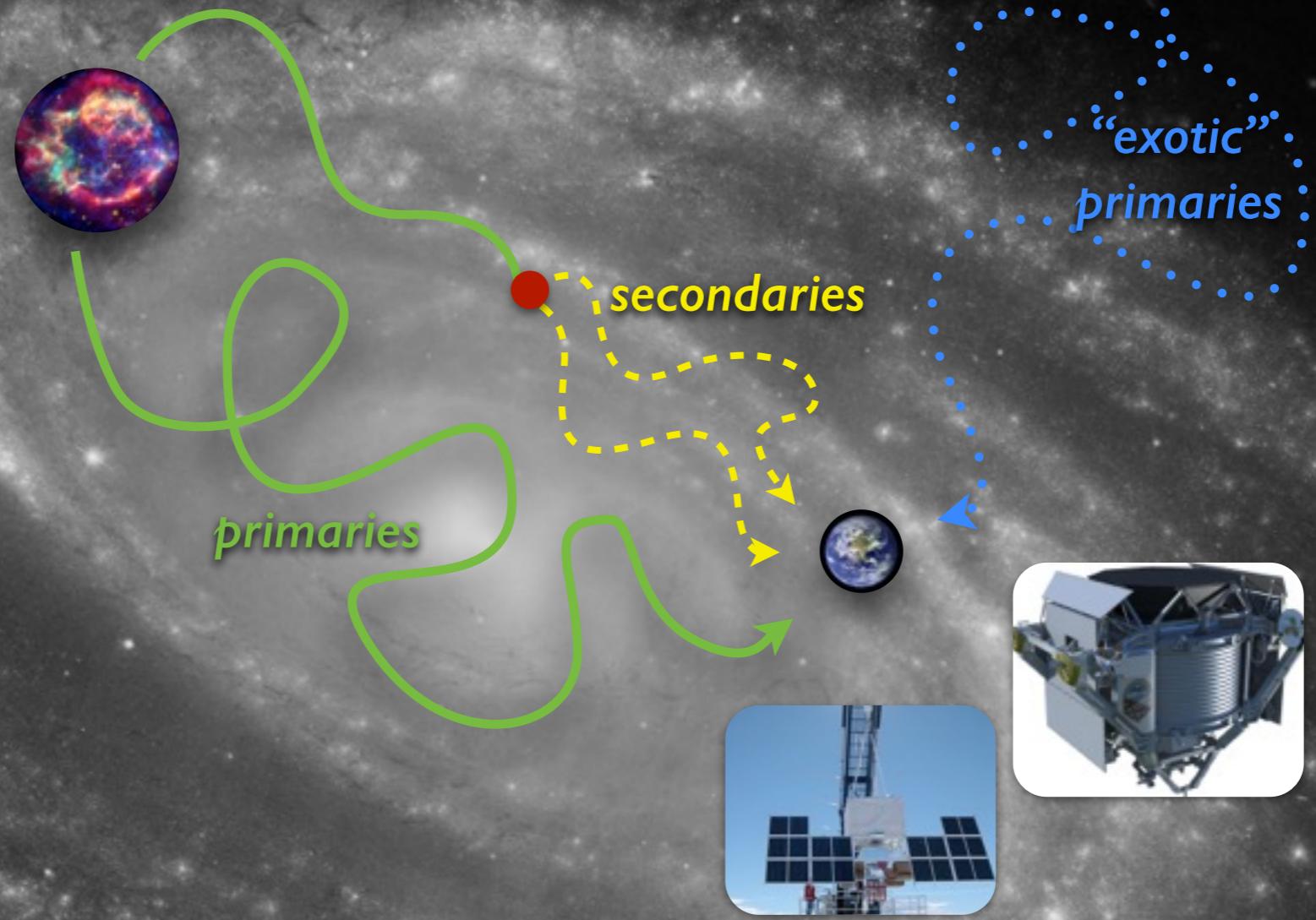
First estimation of their impact on parameter constraints: 60%

[Génolini, Putze, Salati, Serpico, A&A (2015)]



Parameter estimation already very tricky in a simple configuration...

Indirect dark matter searches



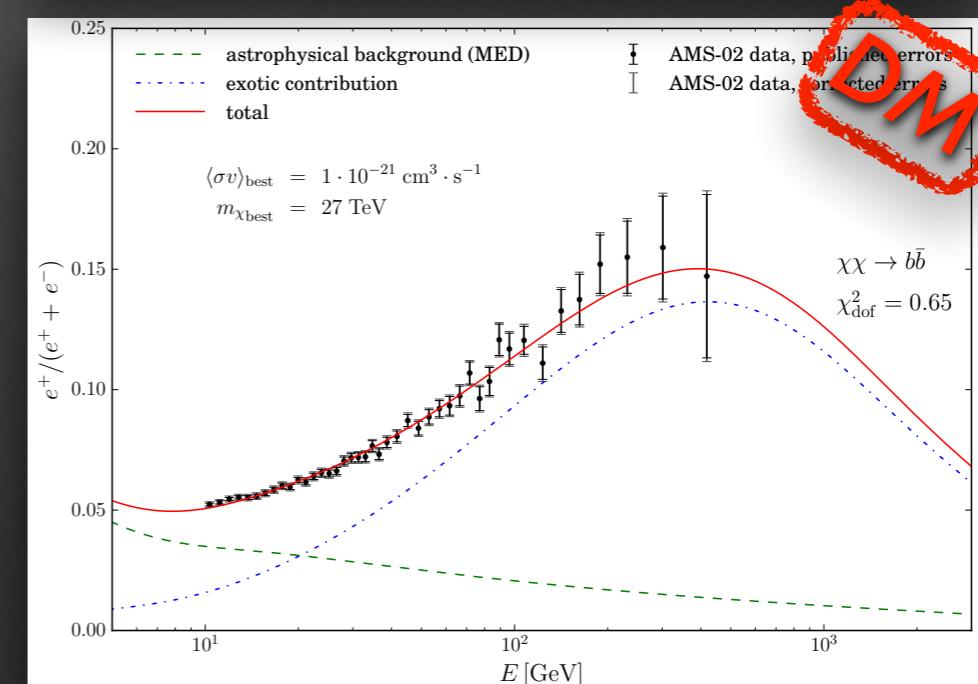
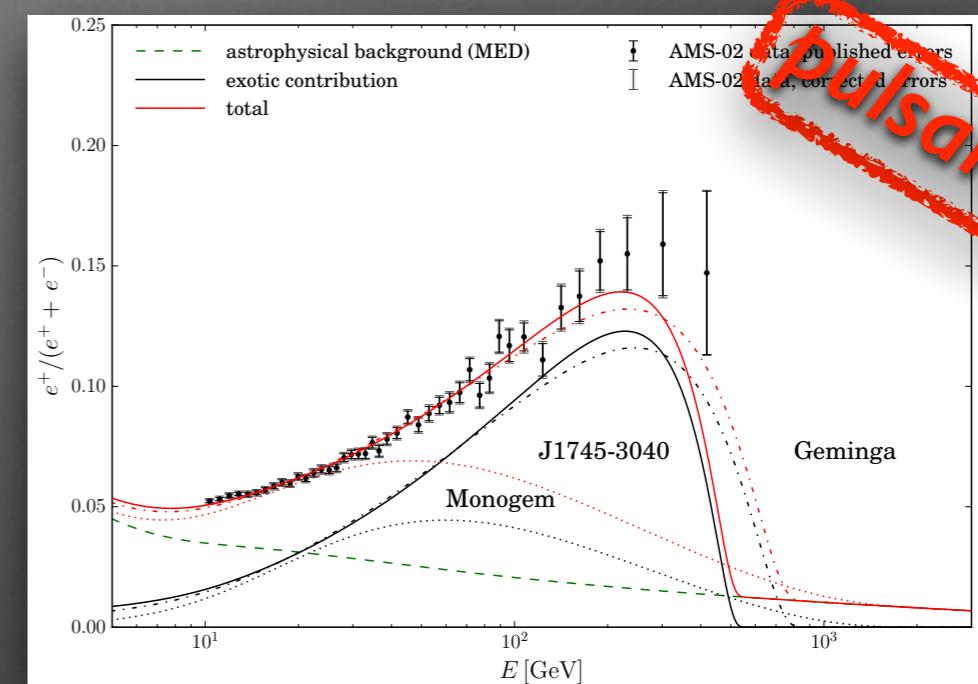
charged cosmic-ray channels: e^+ , \bar{p} , ...

Positrons – difficult probes for dark matter searches

Well modelled with

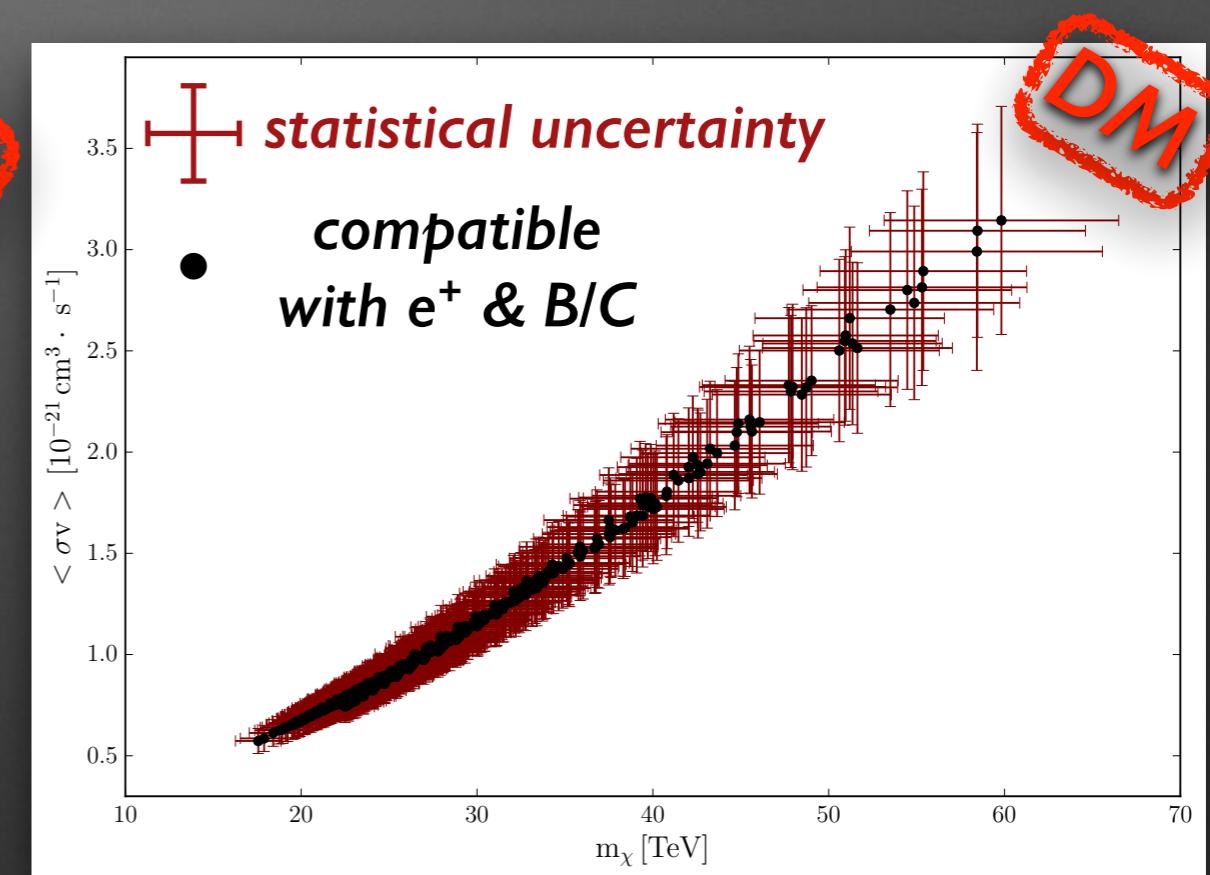
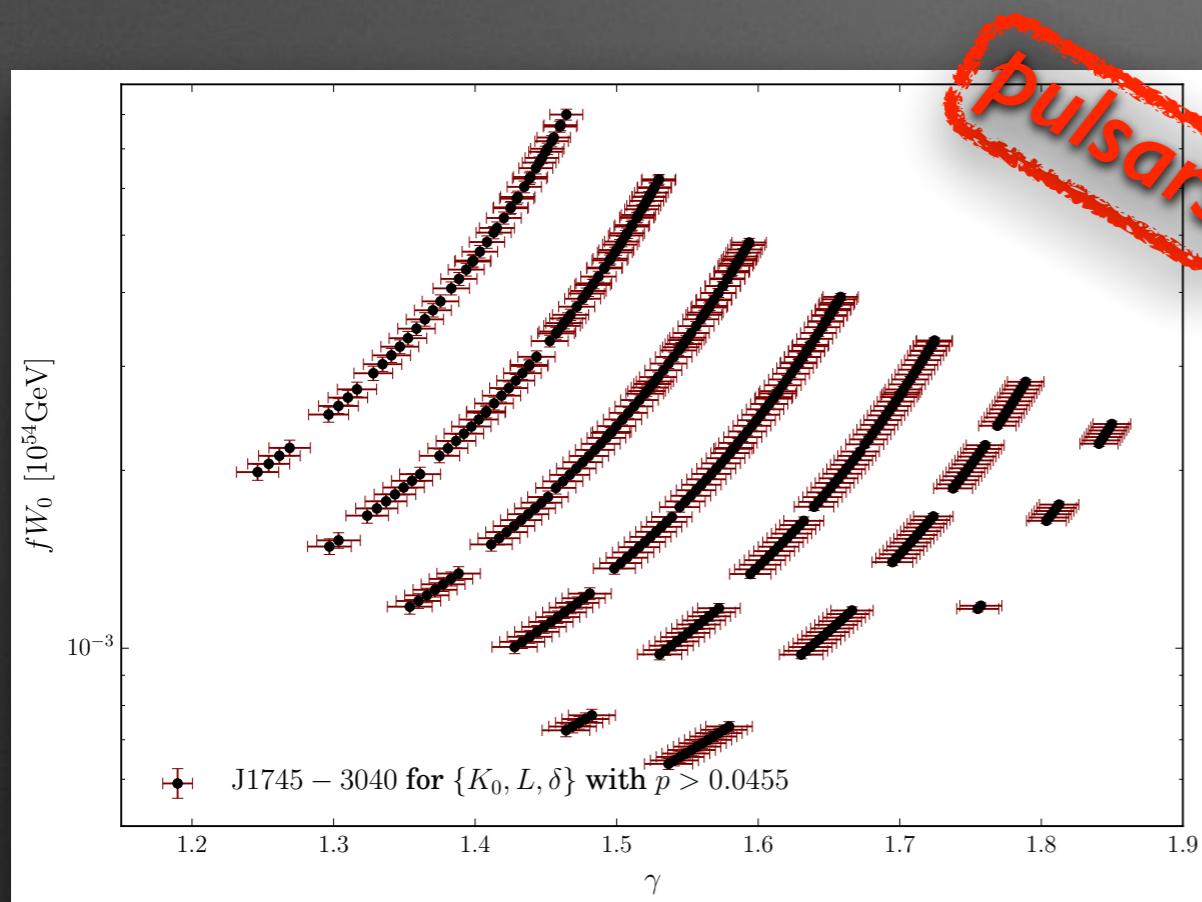
- **secondaries:**
 - ✓ diffusion models
 - ✗ uncertainties on propagation parameters
- **primaries:**
 - ✓ pulsars, dark matter annihilation/decay, acceleration of secondaries in sources, ...
 - ✗ very large uncertainties
 - ✗ large boost factor needed for dark matter interpretation

but no unique interpretation...



Positrons – propagation uncertainties

Scan over propagation parameters **compatible with the B/C ratio**

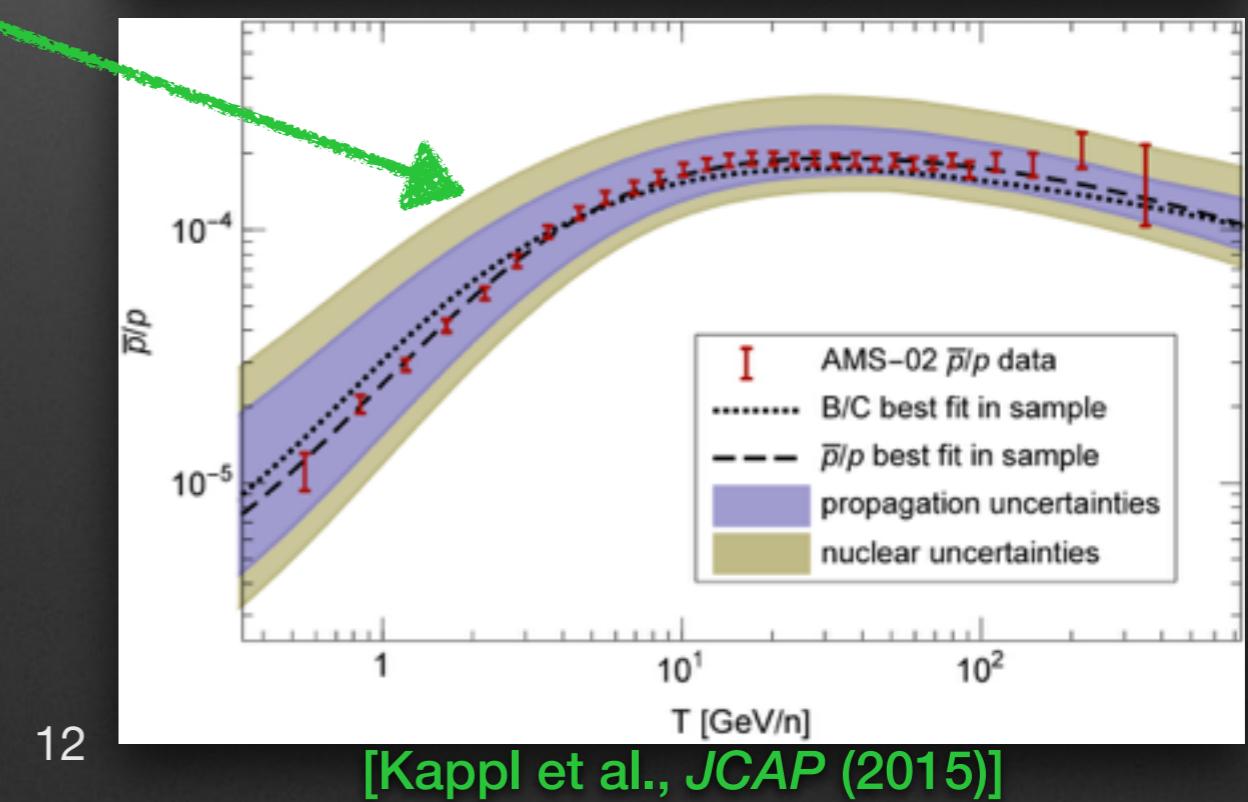
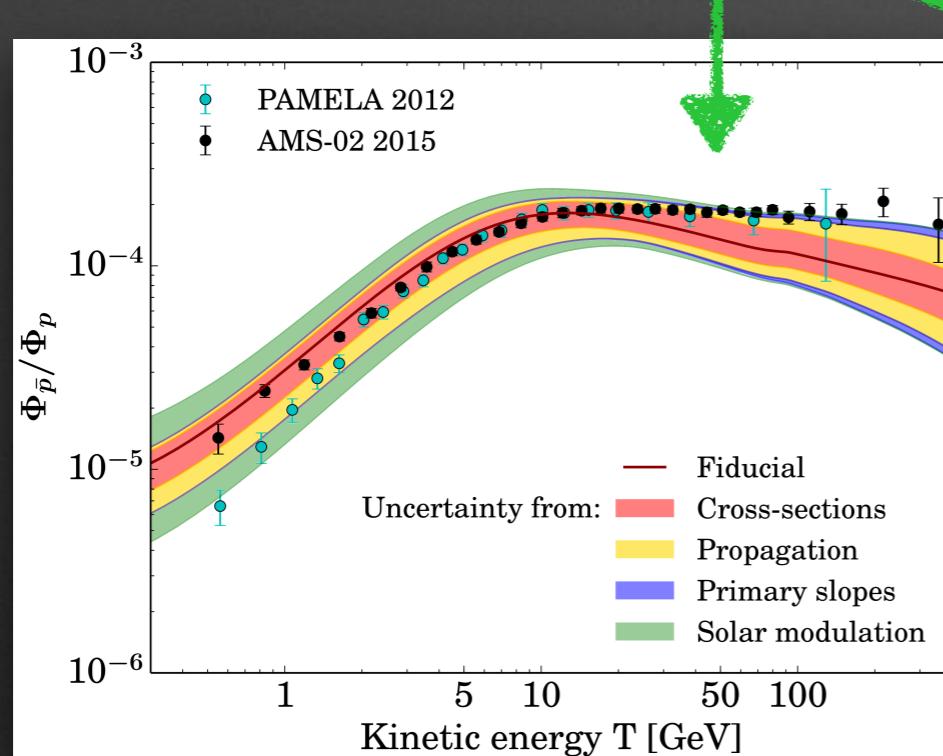
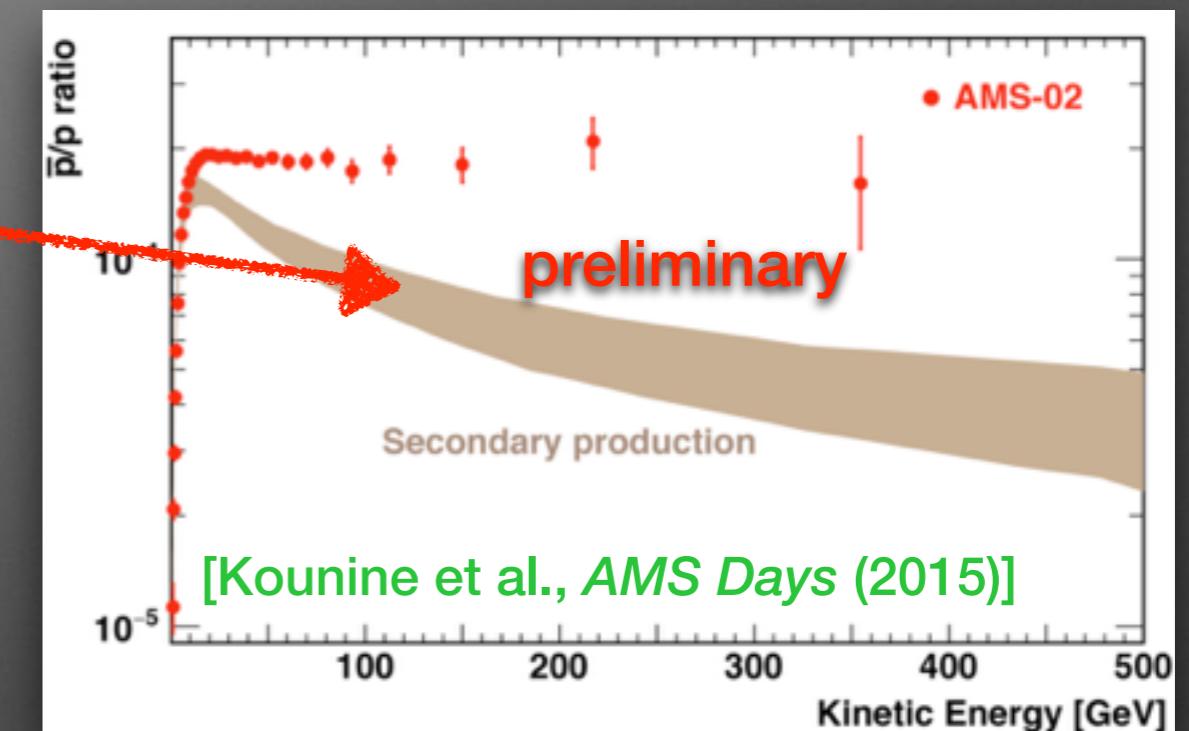


Systematic uncertainties from propagation parameters are dominating!

Antiprotons – strong constraints for dark matter

Theoretical prediction based on pre-AMS knowledge

Updated secondary production and its uncertainties *not* in tension with antiproton-to-proton ratio



Conclusion

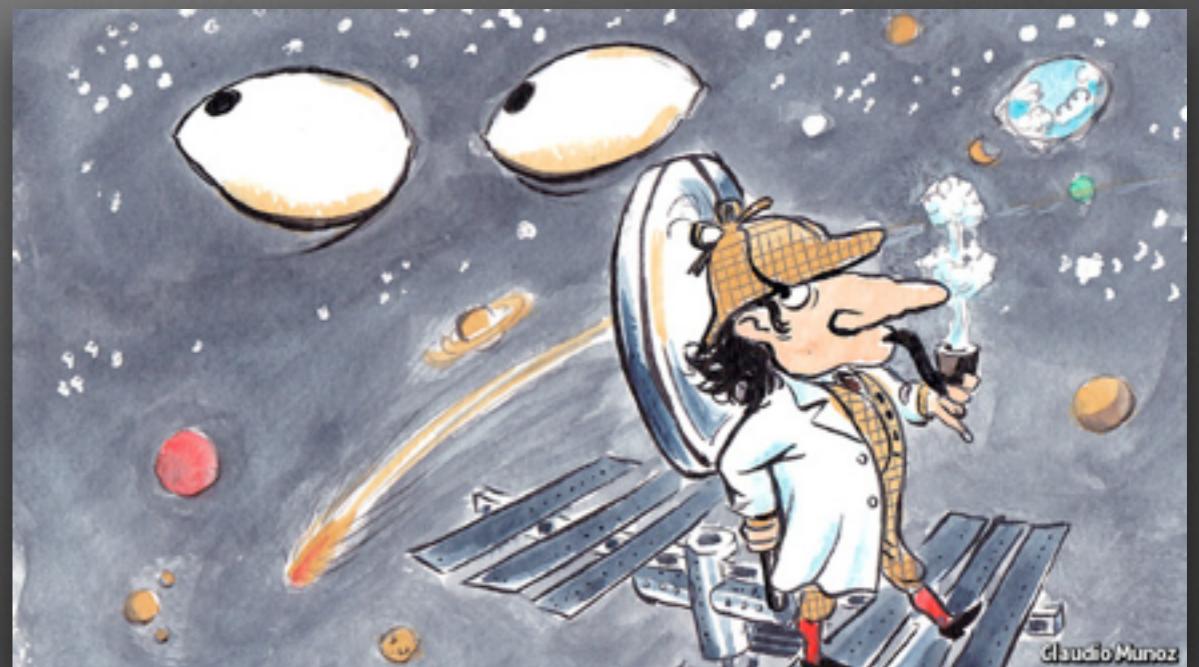
- Current propagation models **suffer from large uncertainties on ingredients**

What you get out depends on what you put in...

- **More and more precise cosmic-ray data will be available soon**

Need for better models/ingredients

- Cosmic rays are **complementary and competitive** with collider and direct dark matter searches



Are you hunting for dark matter?

- Your dark matter candidate should reproduce all the available data
 - **global fits**
 - **GAMBIT**

