

What do Galactic electrons and positrons tell us about Dark Matter?

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Paris, France

SLAP Meeting - Woerden

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Based on:

MB, E. F. Bueno, S. Caroff, Y. Genolini, V. Poulin, V. Poireau, A. Putze, S. Rosier, P. Salati and M. Vecchi
(arXiv:1612.03924)

MB, J. Lavalle and P. Salati
(arXiv:1612.07698)

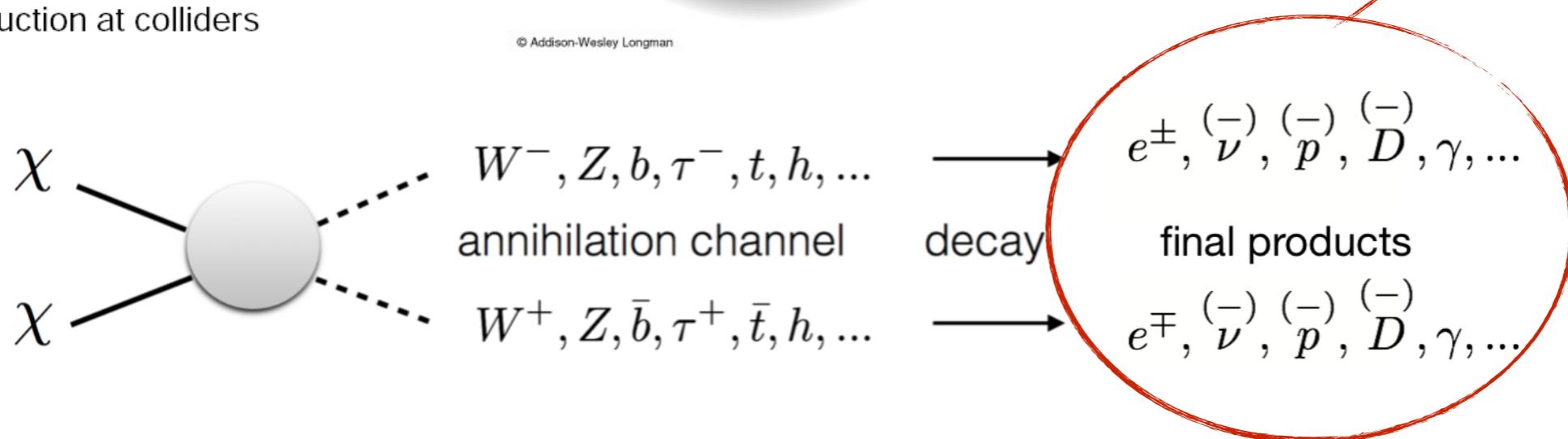
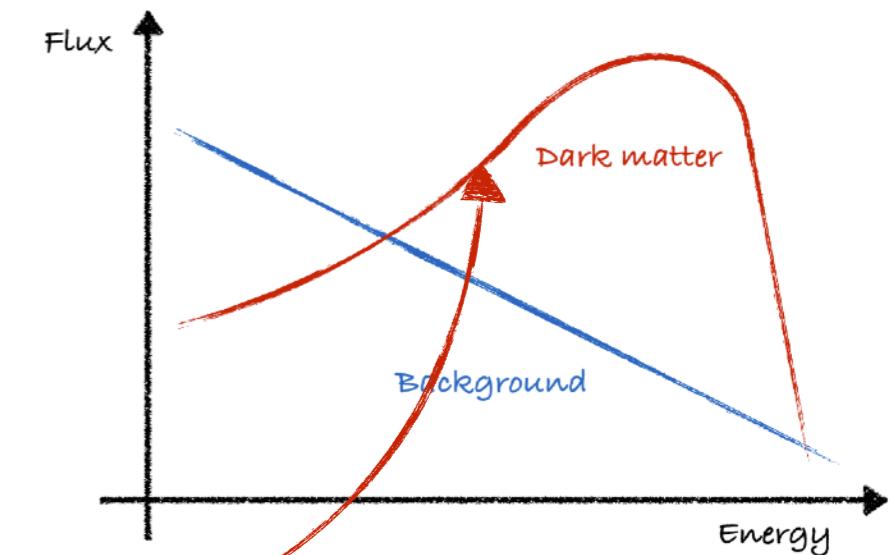
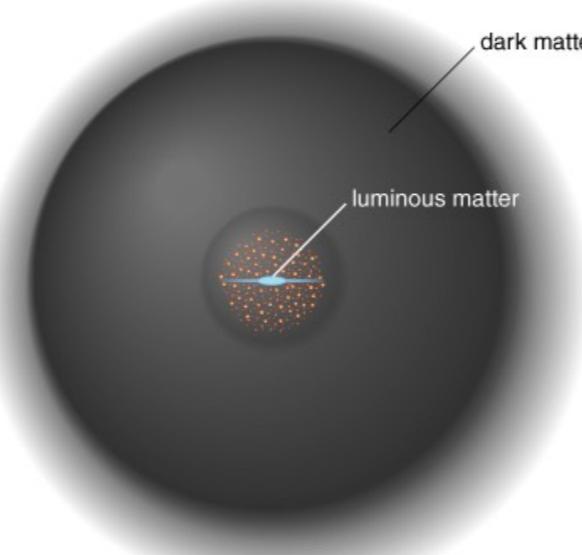
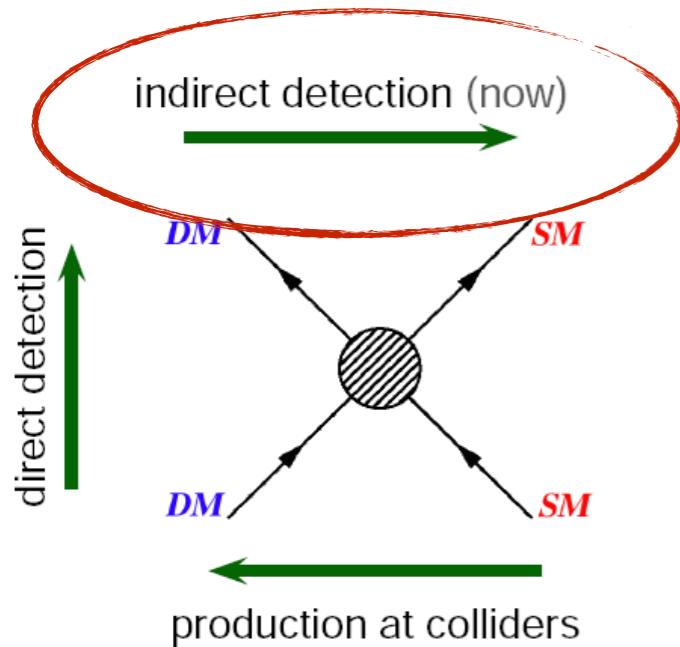


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Dark matter indirect detection

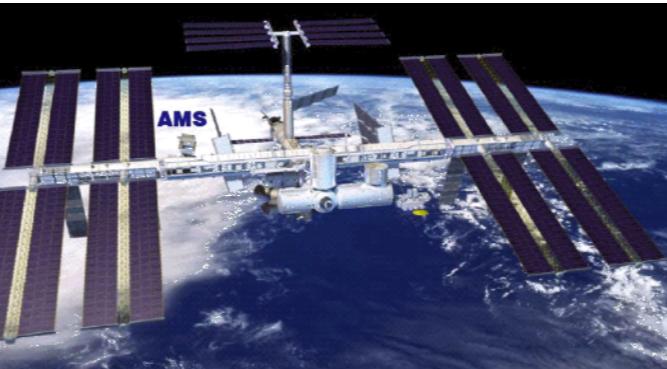
Measure an excess of cosmic rays with respect to the astrophysical background.



- Gamma rays

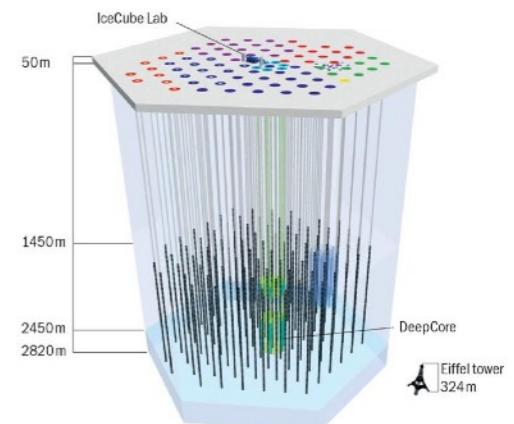


HESS



AMS-02

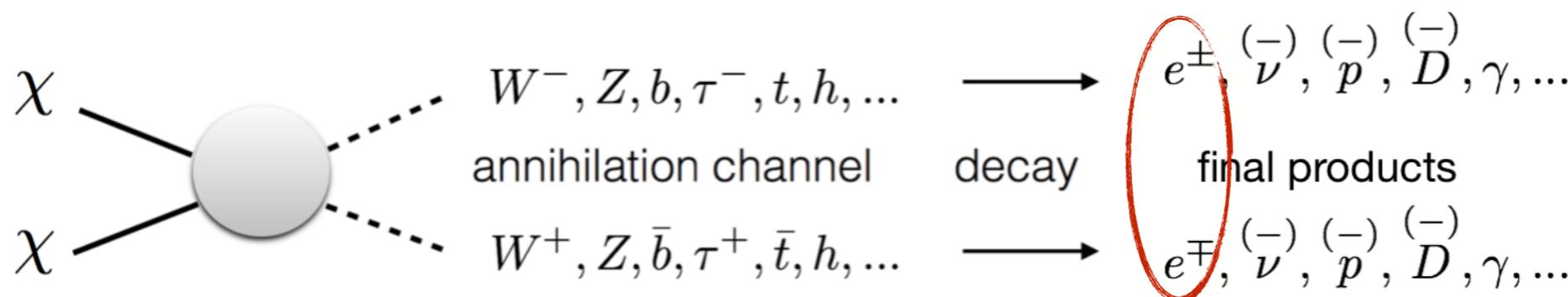
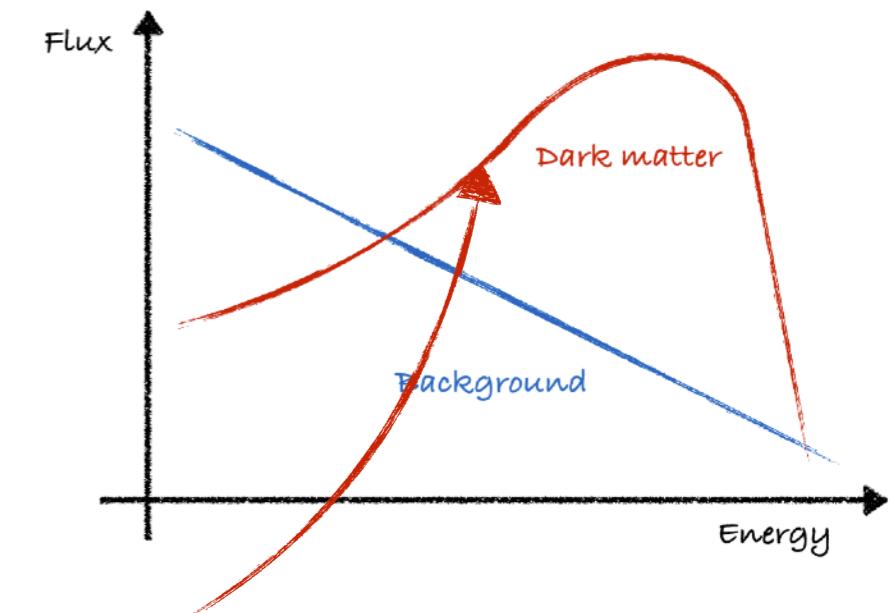
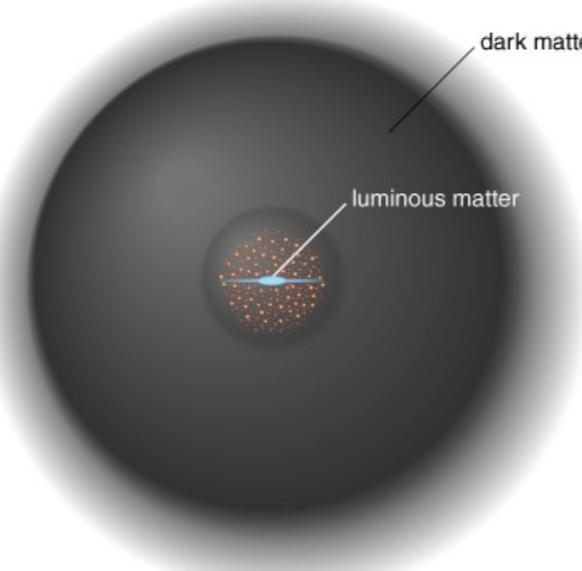
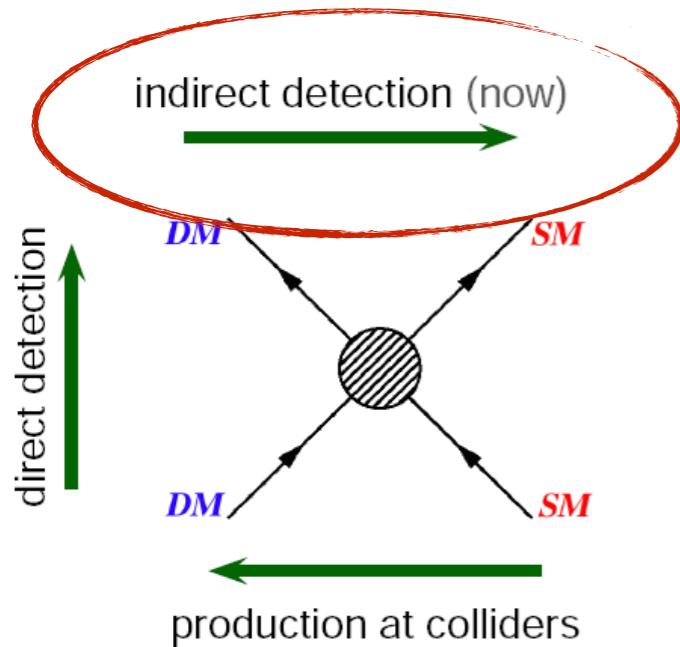
- Charged cosmic rays
- Neutrinos



IceCube

Dark matter indirect detection

Measure an excess of cosmic rays with respect to the astrophysical background.



- Gamma rays



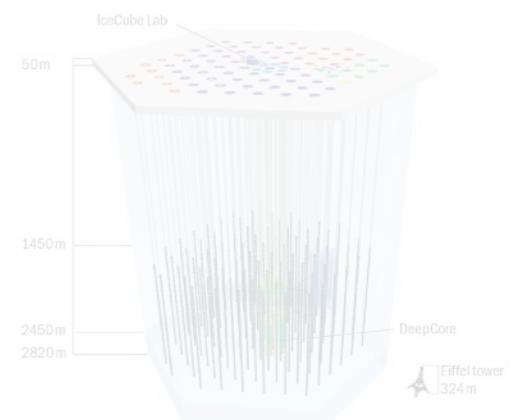
HESS



AMS-02

- Charged cosmic rays

- Neutrinos



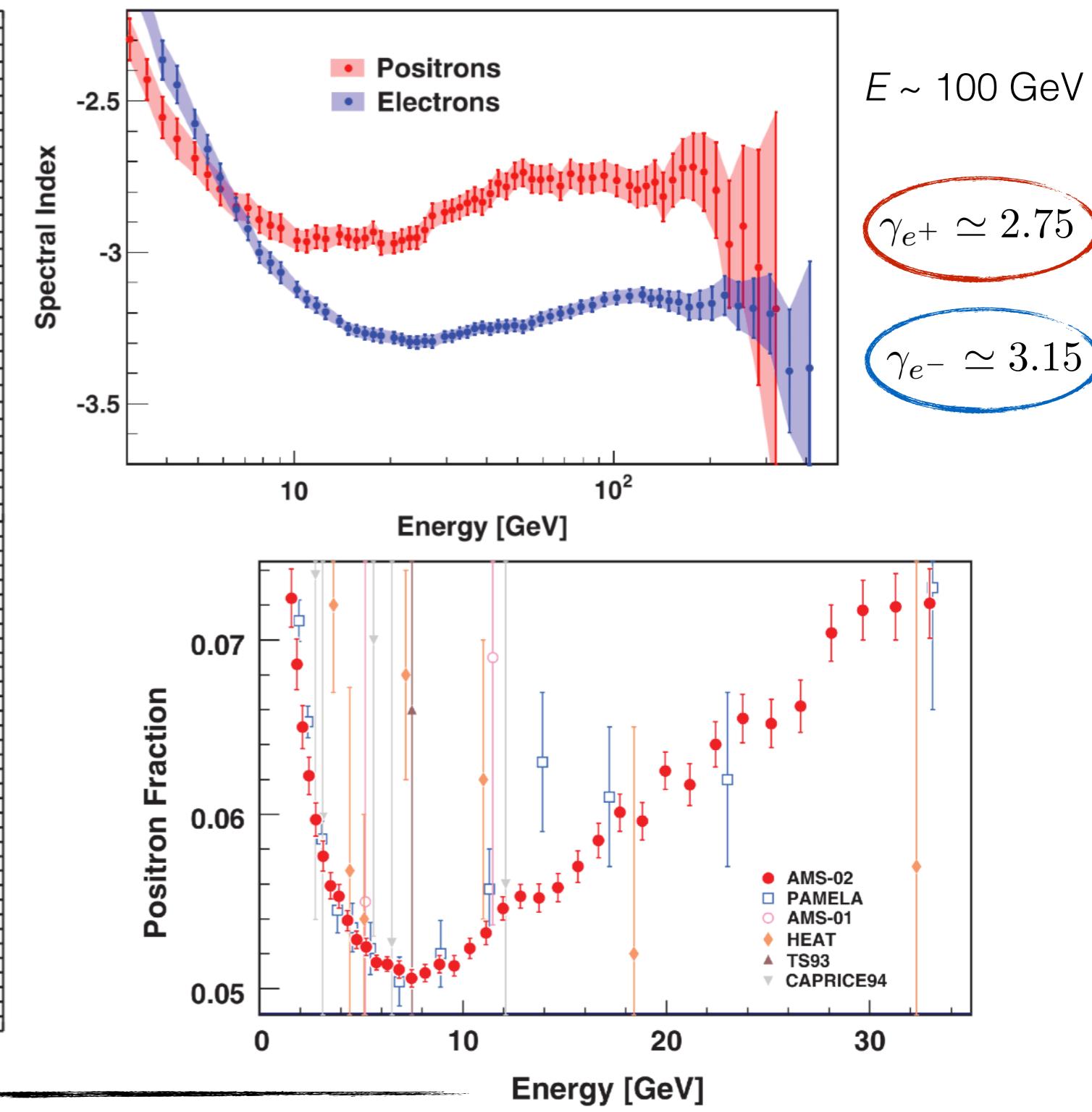
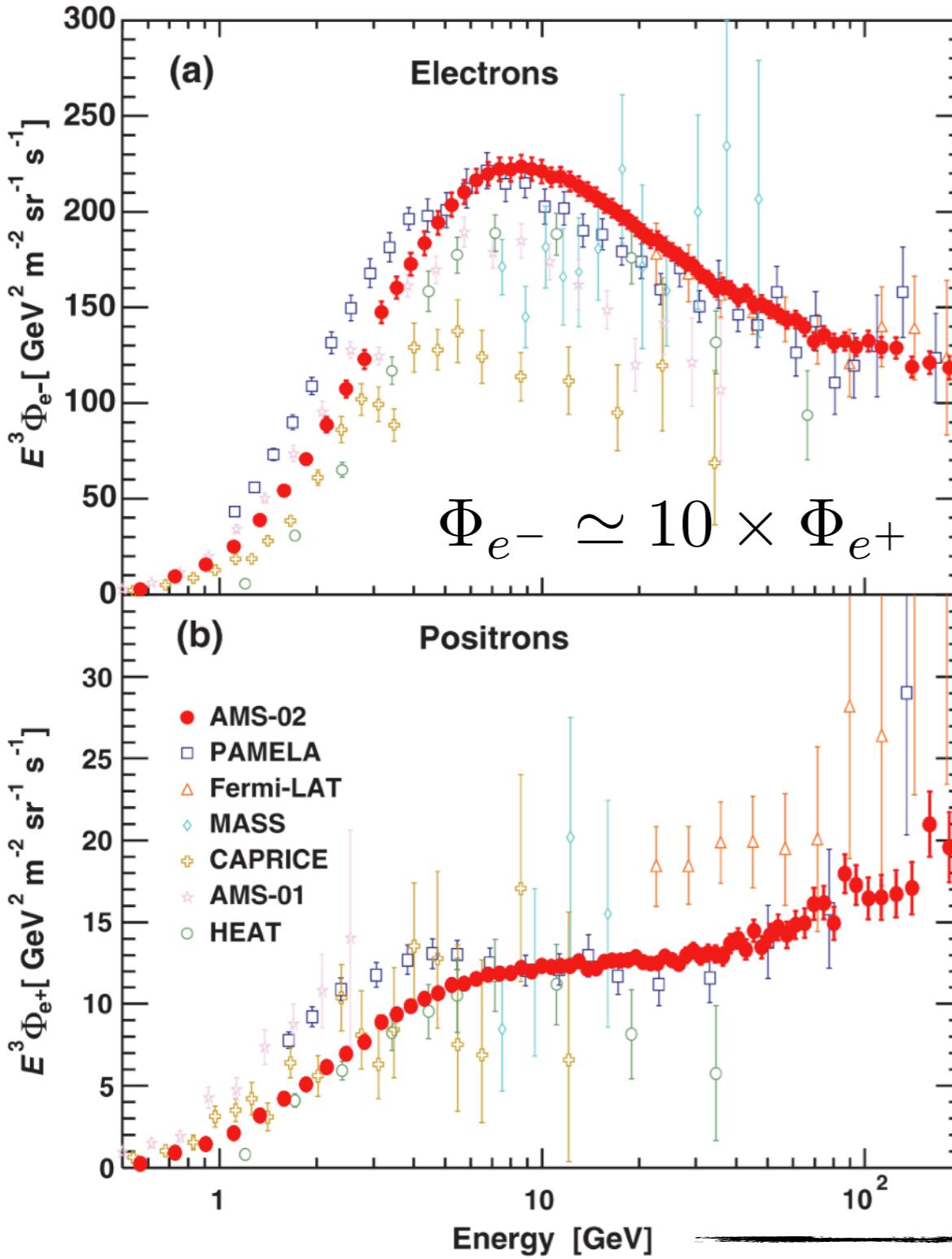
IceCube

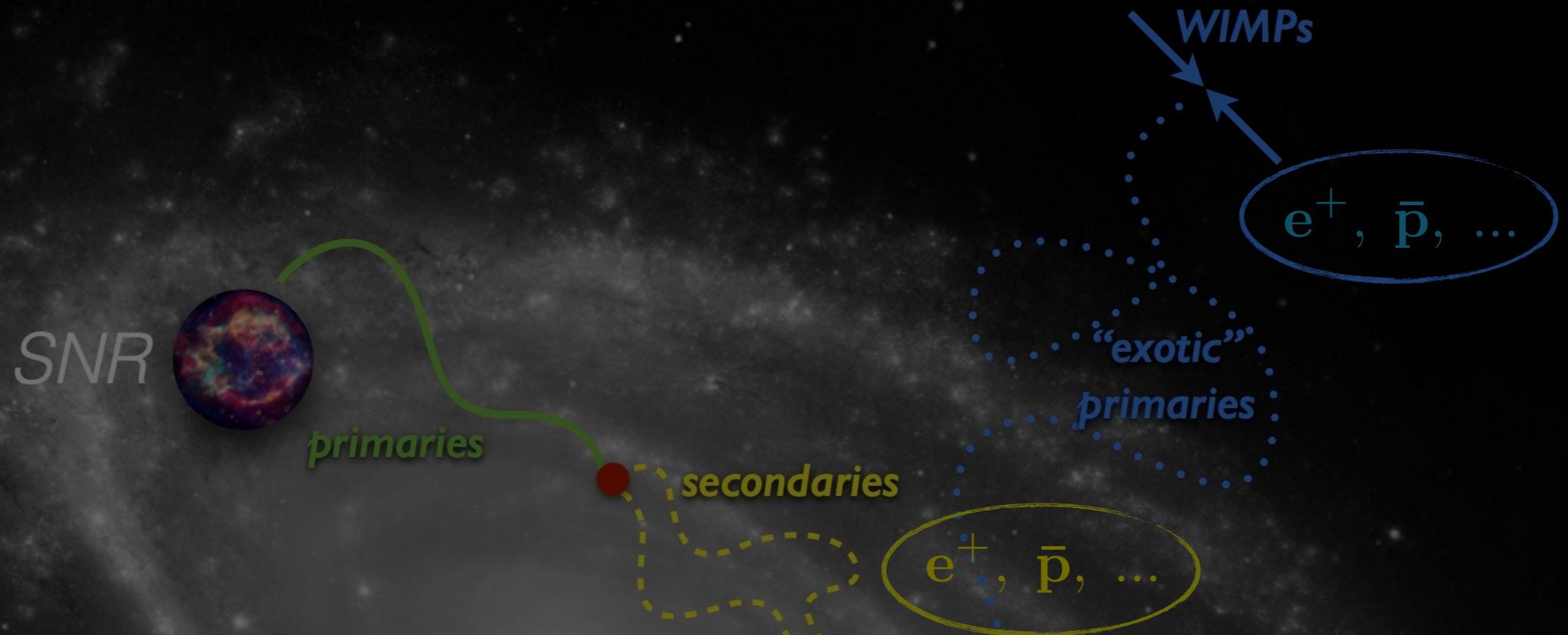
AMS-02 e⁺ and e⁻ data

AMS-02 collaboration has published the electrons, positrons flux and the positron fraction from ~ 0.5 GeV up to ~ 500 GeV with an unprecedented high accuracy.

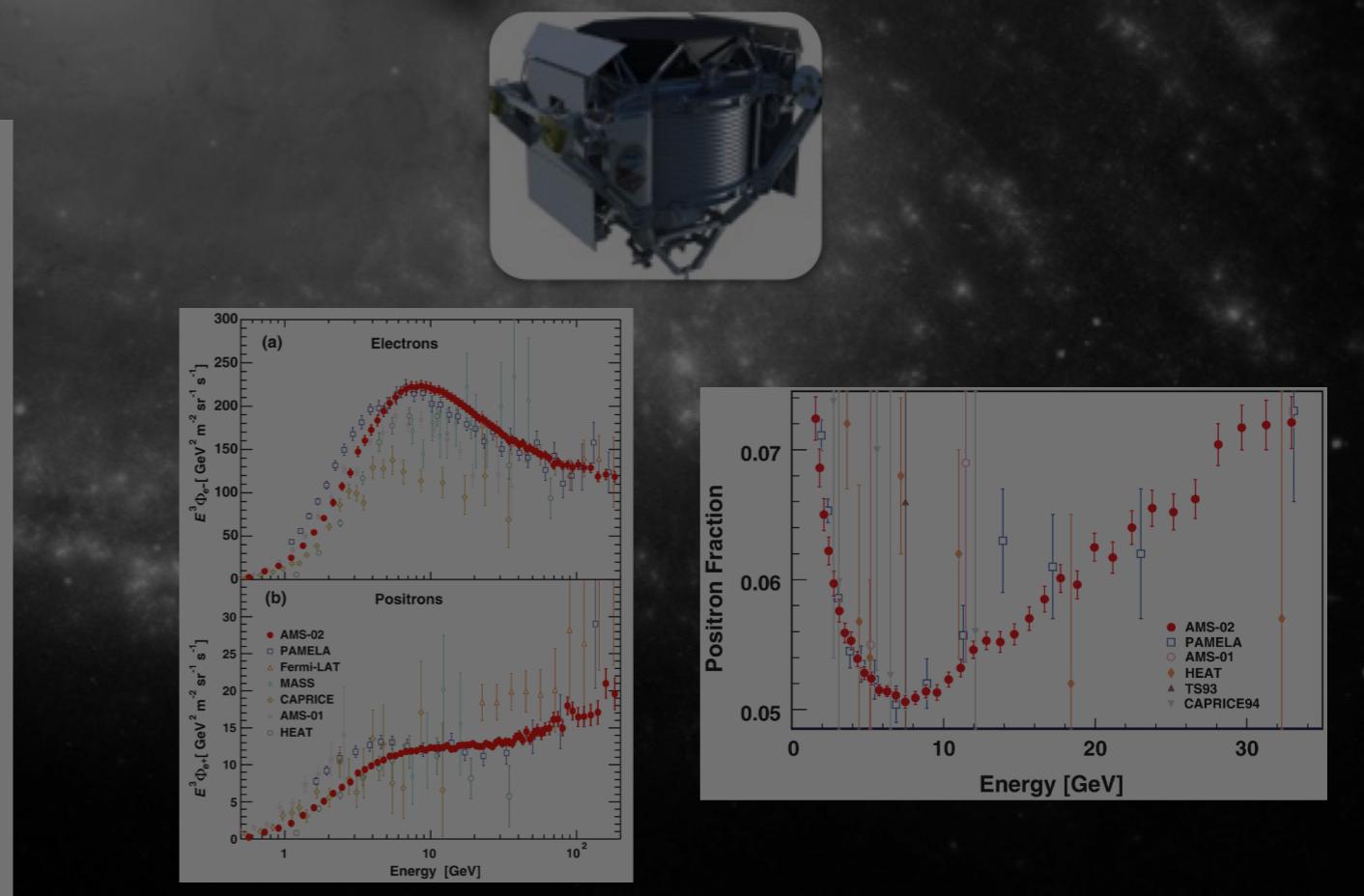
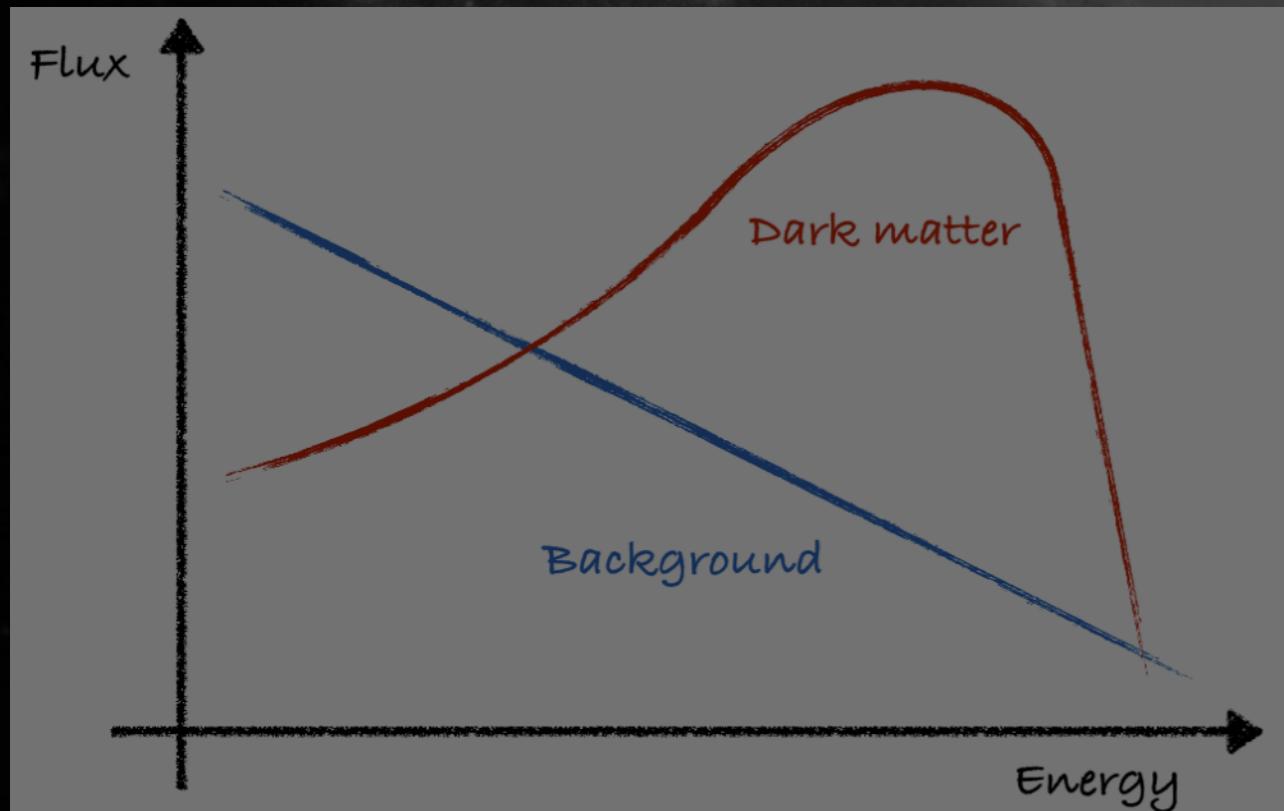
$$\text{PF} = \frac{\Phi_{e^+}}{\Phi_{e^- + e^+}}$$

PRL113, 121102 (2014), PRL113, 121101 (2014)





Is there any signal of dark matter in the e- and/or e+ data?



1- Introduction

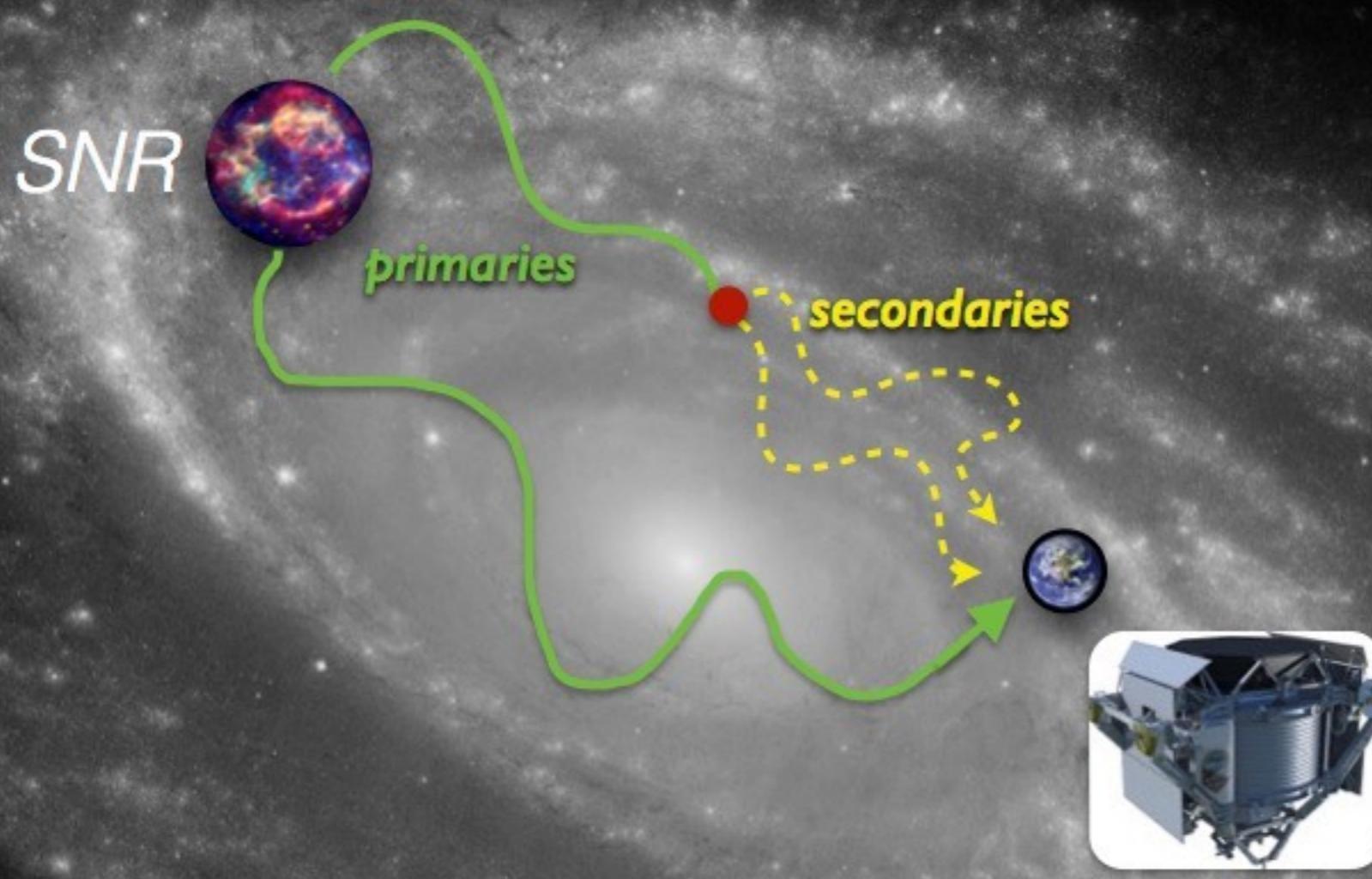
2- Propagation of cosmic rays: the diffusion model

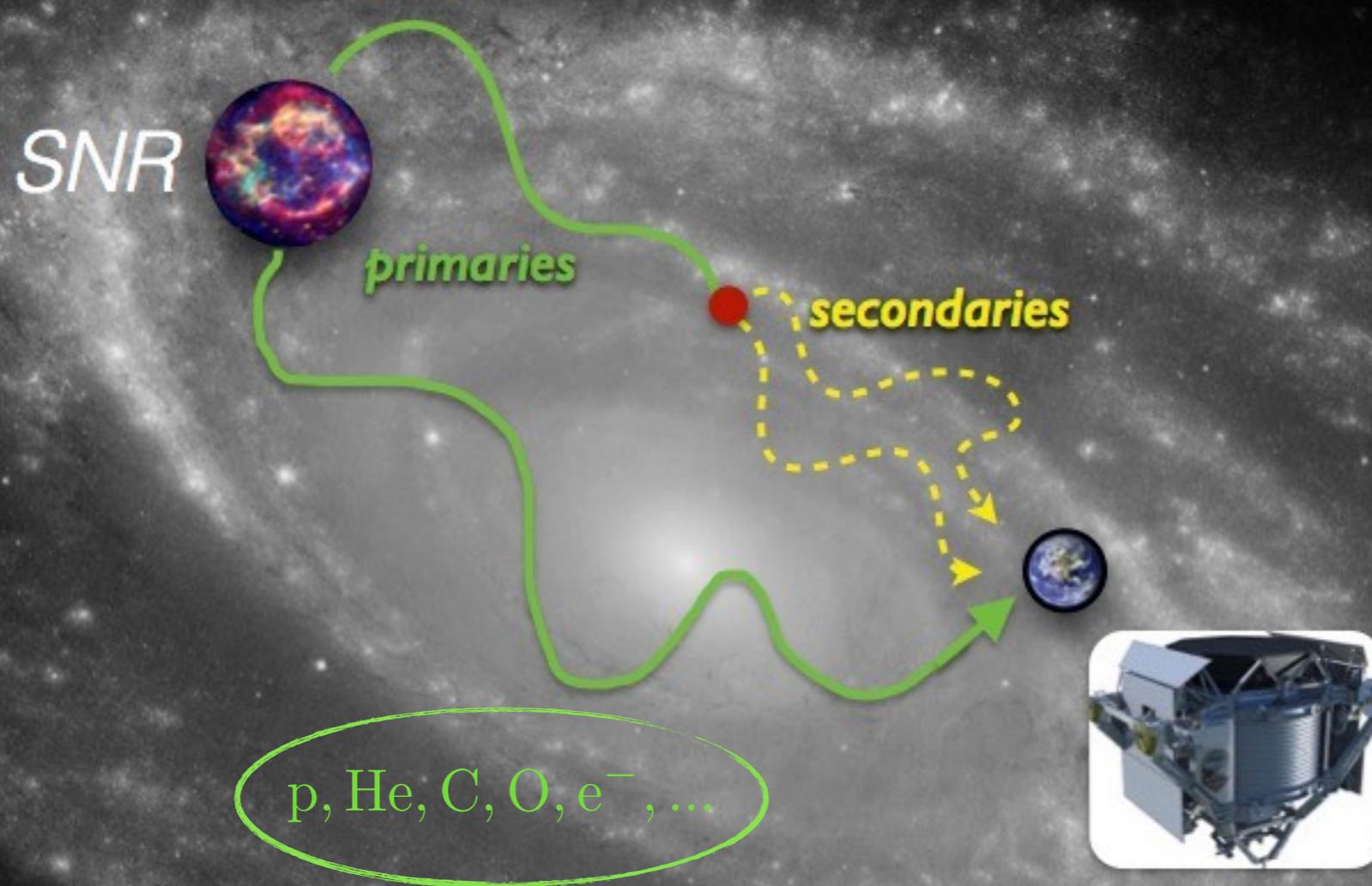
3- The *pinching method* for low energy e^- and e^+

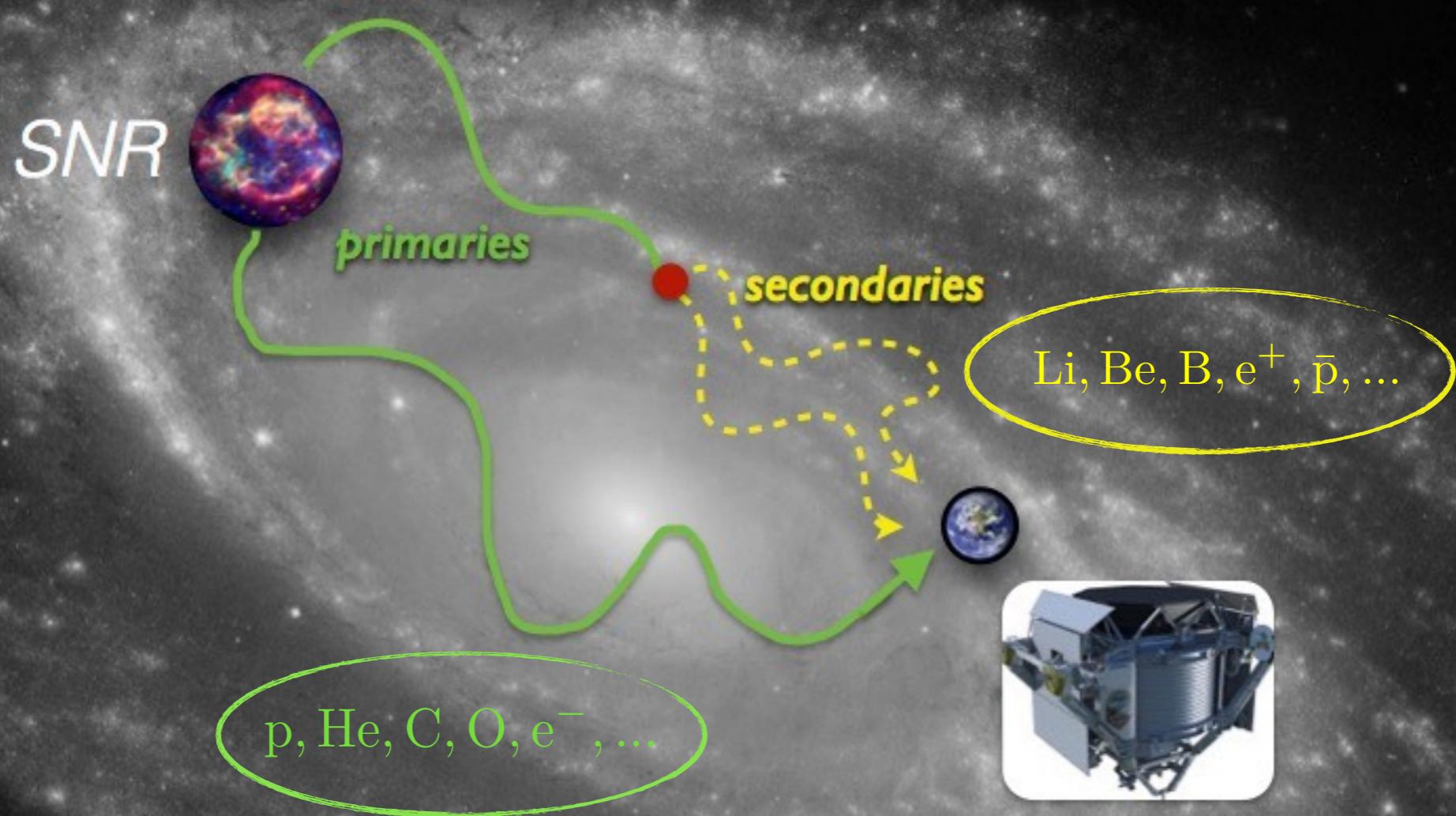
4- Implications for dark matter searches

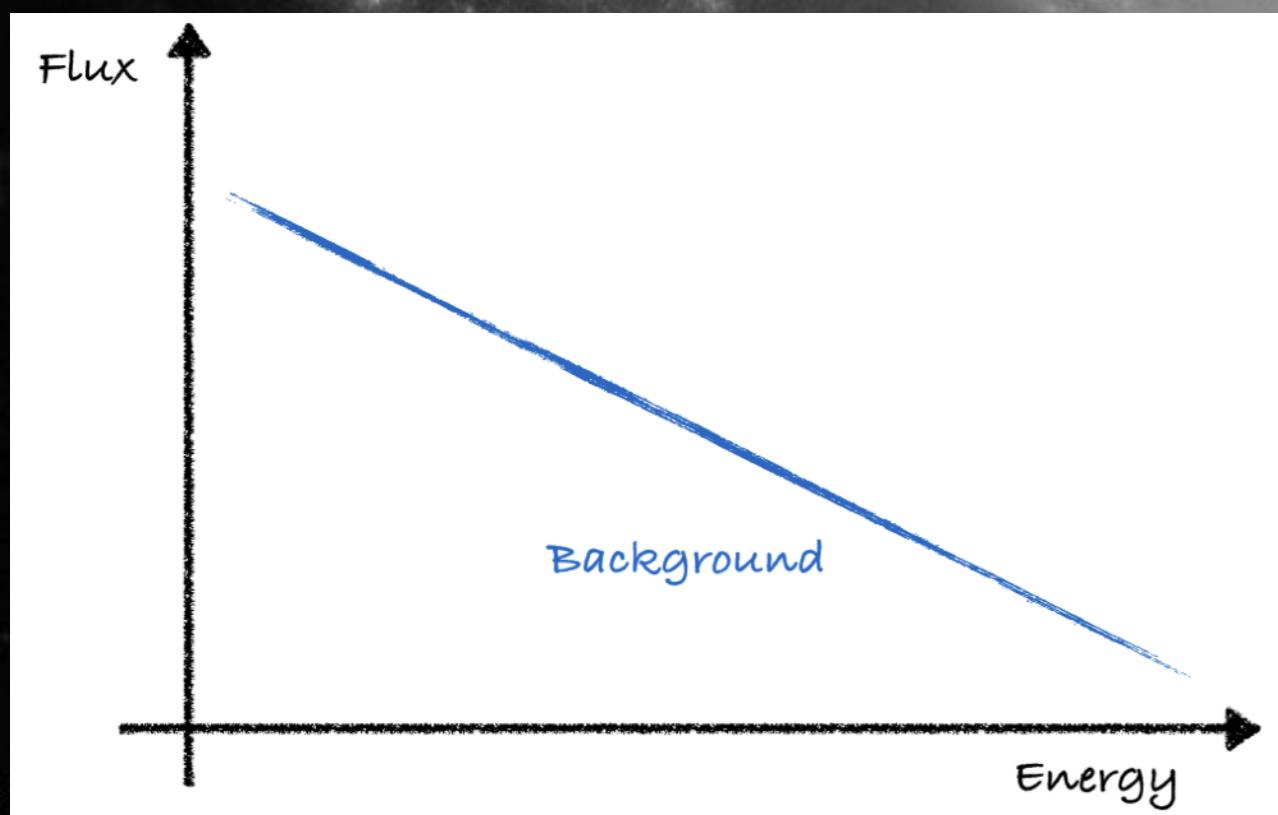
6- Conclusions and outlooks

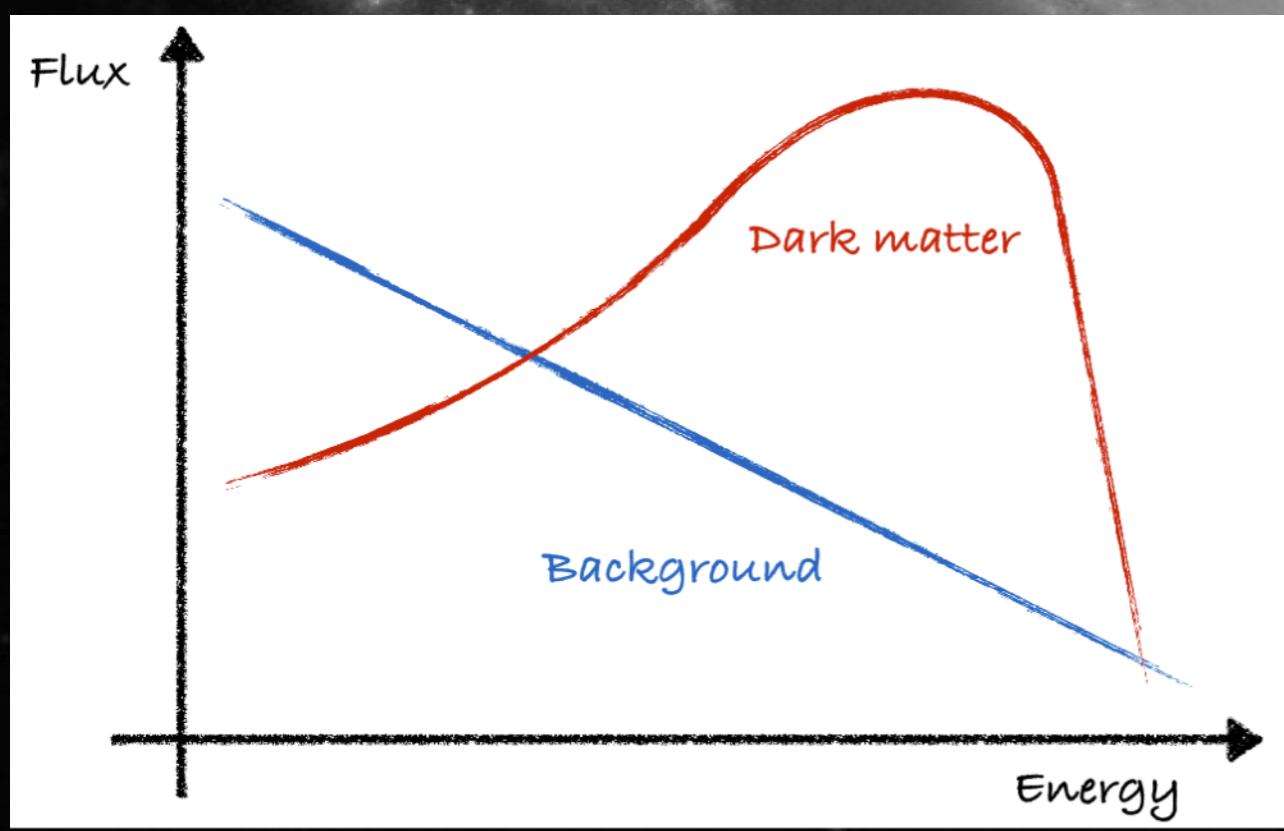
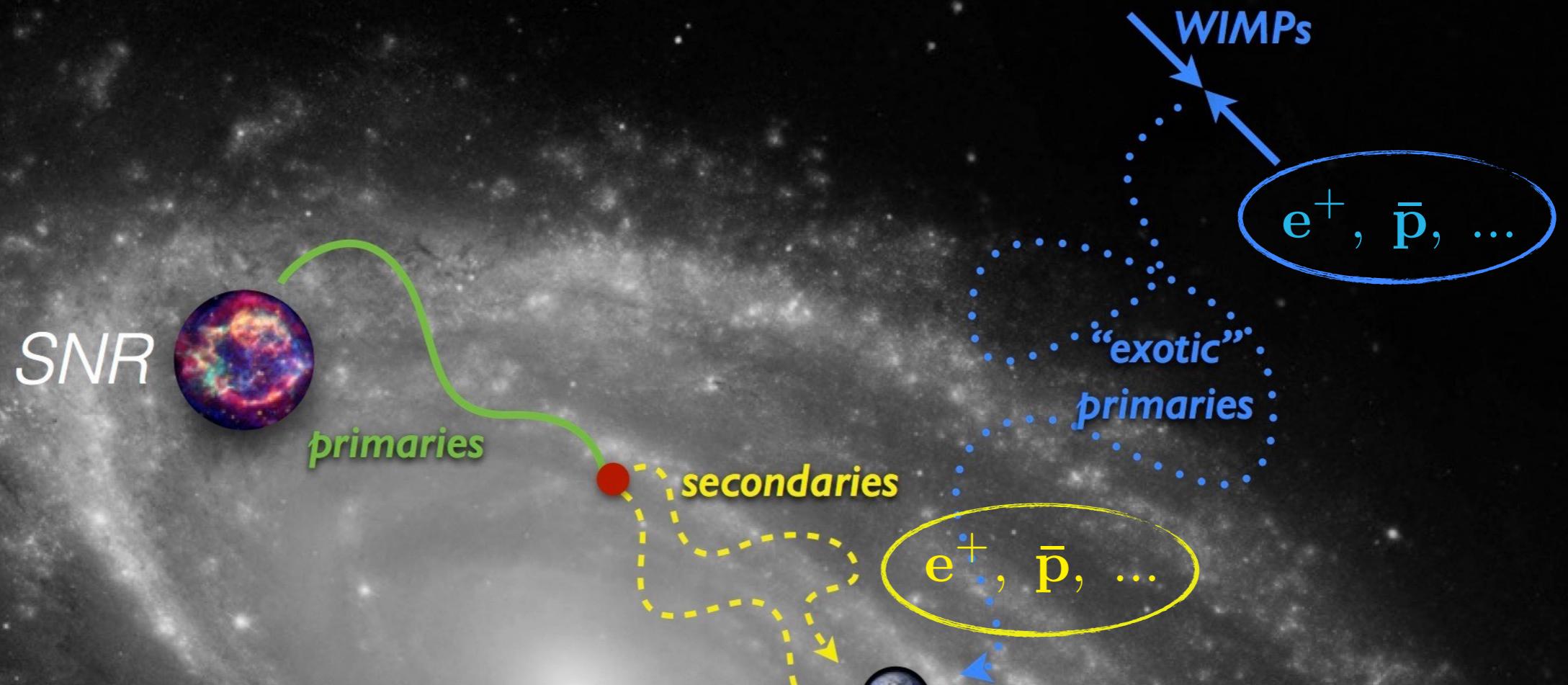
Propagation of cosmic rays: the diffusion model









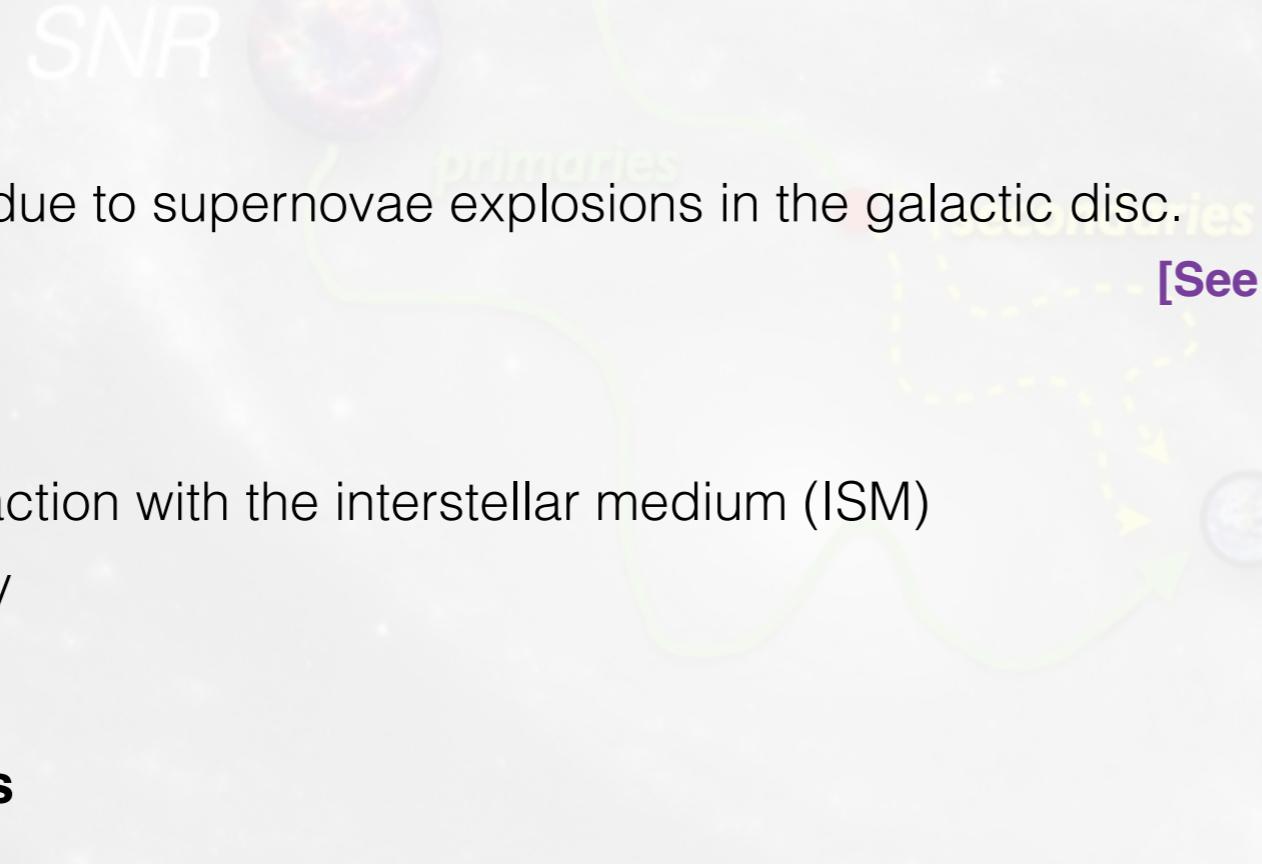


Interaction of cosmic rays

- **Space diffusion**

Diffusion on the turbulent component of the magnetic field.

$$K(E, \vec{x})$$



SNR

- **Convection**

Galactic wind due to supernovae explosions in the galactic disc.

$$\vec{V}_C(\vec{x})$$

[See Sarah's talk at 10:00]

- **Destruction**

- Interaction with the interstellar medium (ISM)
- Decay

$$Q^{sink}(E, \vec{x})$$



- **Energy losses**

- Interaction with the ISM (Coulomb, ionisation, bremsstrahlung, adiabatic expansion) $b(E, \vec{x})$
- Synchrotron emission, inverse Compton scattering (electrons)

- **Diffusive reacceleration**

Second order Fermi mechanism. Diffusion in momentum space.
Depends on the velocity of the Alfvén waves V_A .

$$D(E, \vec{x}) = \frac{2}{9} V_A^2 \frac{E^2 \beta^4}{K(E, \vec{x})}$$

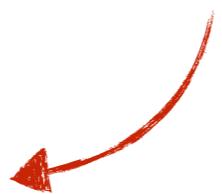
The transport equation

$$\psi(E, t, \vec{x}) = \frac{d^4 N}{d^3 x dE}$$

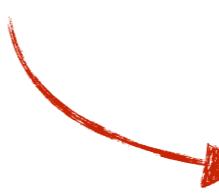
$$\partial_t \psi - K(E, \vec{x}) \Delta \psi + \vec{\nabla} \cdot [\vec{V}_C(\vec{x}) \psi] + \partial_E [b(E, \vec{x}) \psi - D(E, \vec{x}) \partial_E \psi] = Q(E, t, \vec{x})$$

$$Q(E, t, \vec{x}) = Q^{source}(E, t, \vec{x}) - Q^{sink}(E, \vec{x})$$

Production

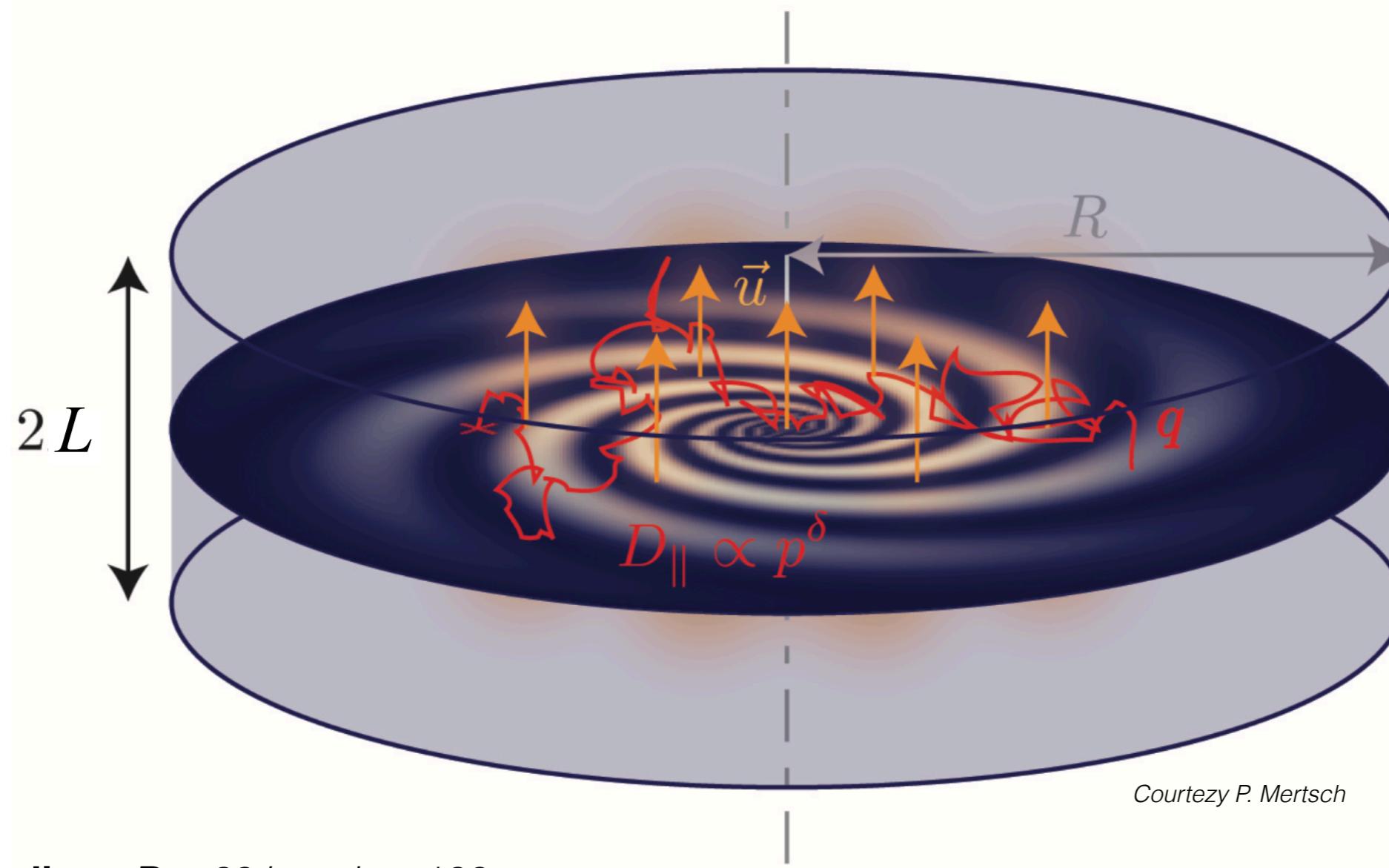


Destruction



- Acceleration in supernova remnants (SNRs)
- Pulsar wind nebulae (PWNe)
- Spallation of primary CRs
- Decay of primary CRs
- *Dark matter?*
- Spallation
- Decay
- Annihilation

The two-zone diffusion model



The galactic disc - $R \sim 20 \text{ kpc}$, $h \sim 100 \text{ pc}$

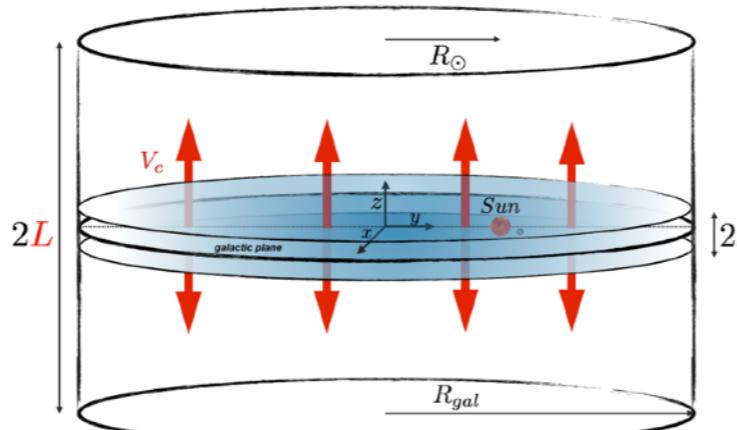
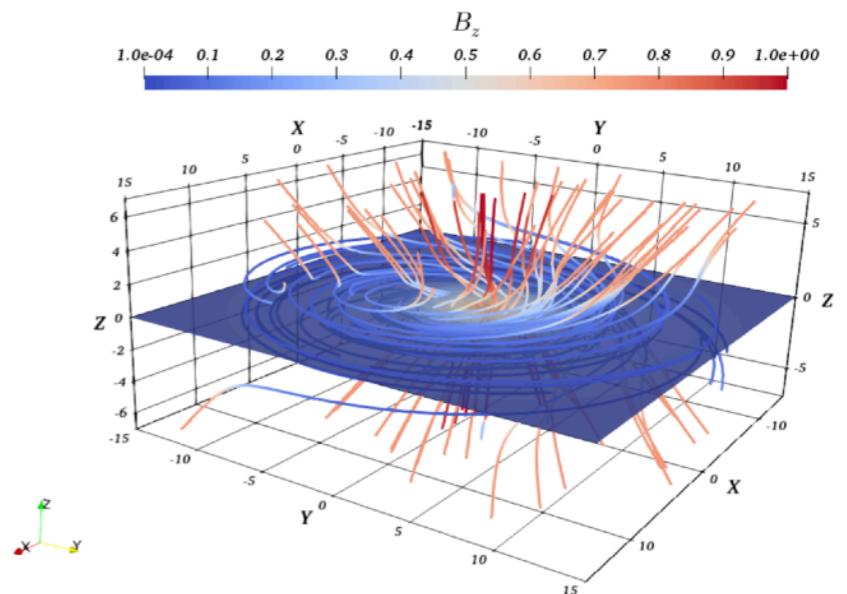
Contains the gas, the stars and the dust of the Galaxy. Distributed in the spiral arms.
Cosmic rays are accelerated in the galactic disc.

The magnetic halo - $R \sim 20 \text{ kpc}$, $1 \leq L \leq 20 \text{ kpc}$

The diffusion zone of the model. Cosmic rays that escape the magnetic halo cannot go back.

Cosmic rays propagation

$$\partial_t \psi - K(E, \vec{x}) \Delta \psi + \vec{\nabla} \cdot [\vec{V}_C(\vec{x}) \psi] + \partial_E [b(E, \vec{x}) \psi - D(E, \vec{x}) \partial_E \psi] = Q^{source}(E, t, \vec{x}) - Q^{sink}(E, \vec{x})$$

	Semi-analytical	Numerical
Approach	<p>Simplify the geometry Green functions, Bessel and Fourier expansion</p> 	<p>Discretise the equation Numerical solvers</p> 
Pros	<p>Useful to understand the physics Fast-running time (extensive scans)</p>	<p>Structure of the Galaxy Any new input easily included</p>
Cons	<p>Only solve approximate model</p>	<p>Slow-running time</p>
Codes	<p>USINE, PPPC4DMID, my code, etc.</p>	<p>GALPROP, DRAGON, PICARD, etc.</p>

The propagation parameters

The diffusion model depends on **5** parameters.

$$1 < \textcolor{red}{L} < 15 \text{ kpc}$$

$$\vec{V}_C = \textcolor{red}{V}_C \operatorname{sign}(z) \vec{e}_z$$

$$K(E) = \textcolor{red}{K}_0 \beta \left(\frac{R}{1 \text{ GV}} \right)^{\delta}$$

$$D(E) = \frac{2}{9} \textcolor{red}{V}_A^2 \frac{E^2 \beta^4}{K(E)}$$

These parameters can be constrained using the ratio between secondary to primaries species (B/C, etc.)

The propagation parameters

The diffusion model depends on **5** parameters.

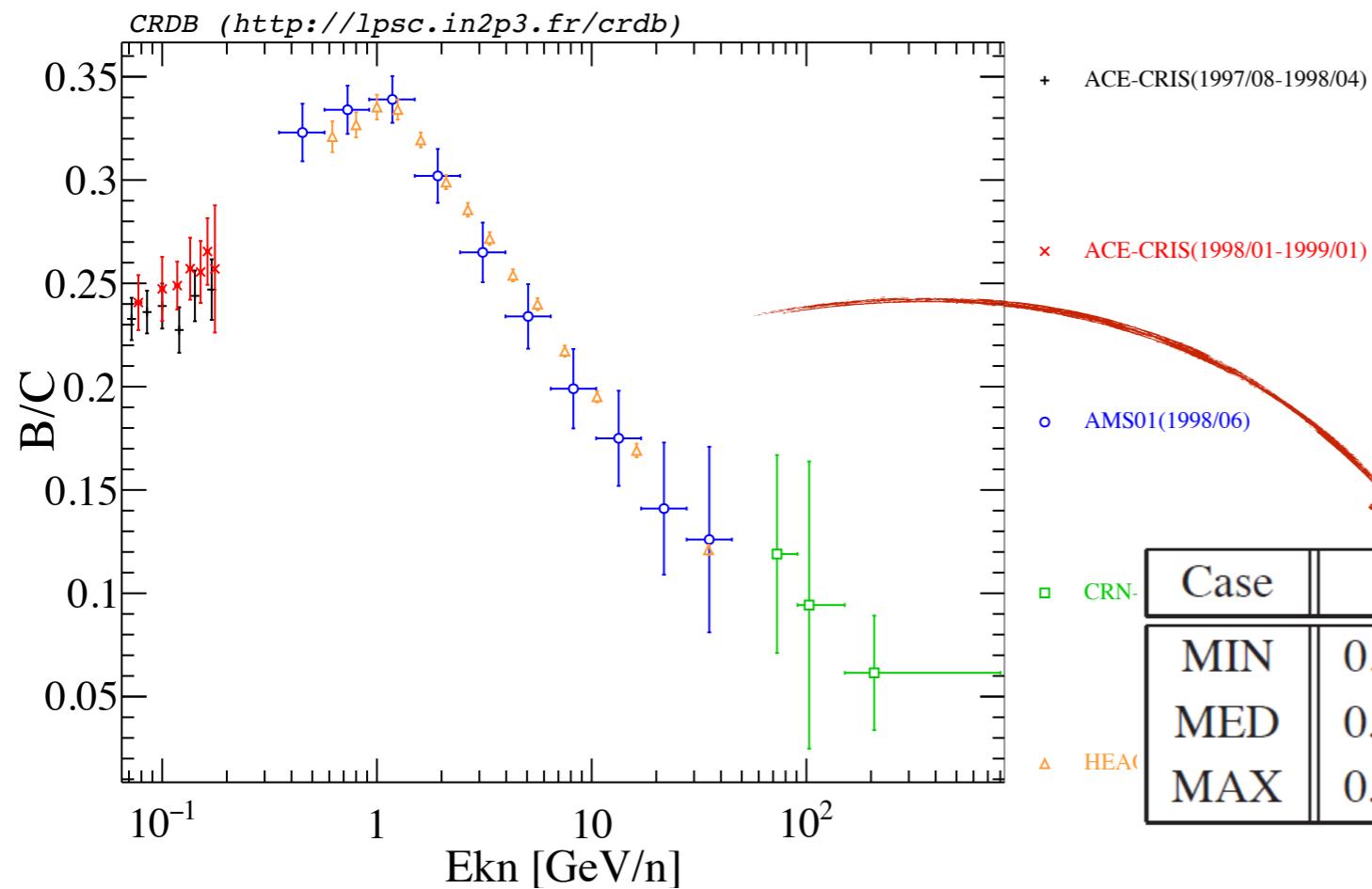
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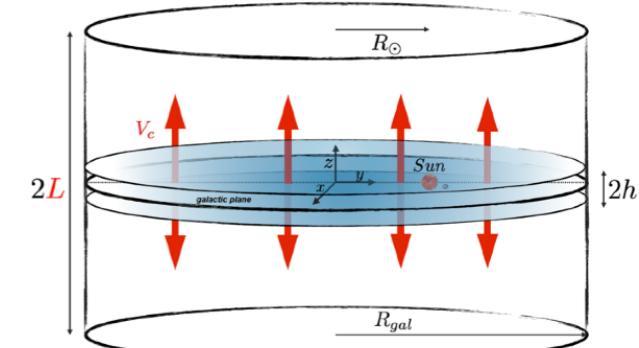
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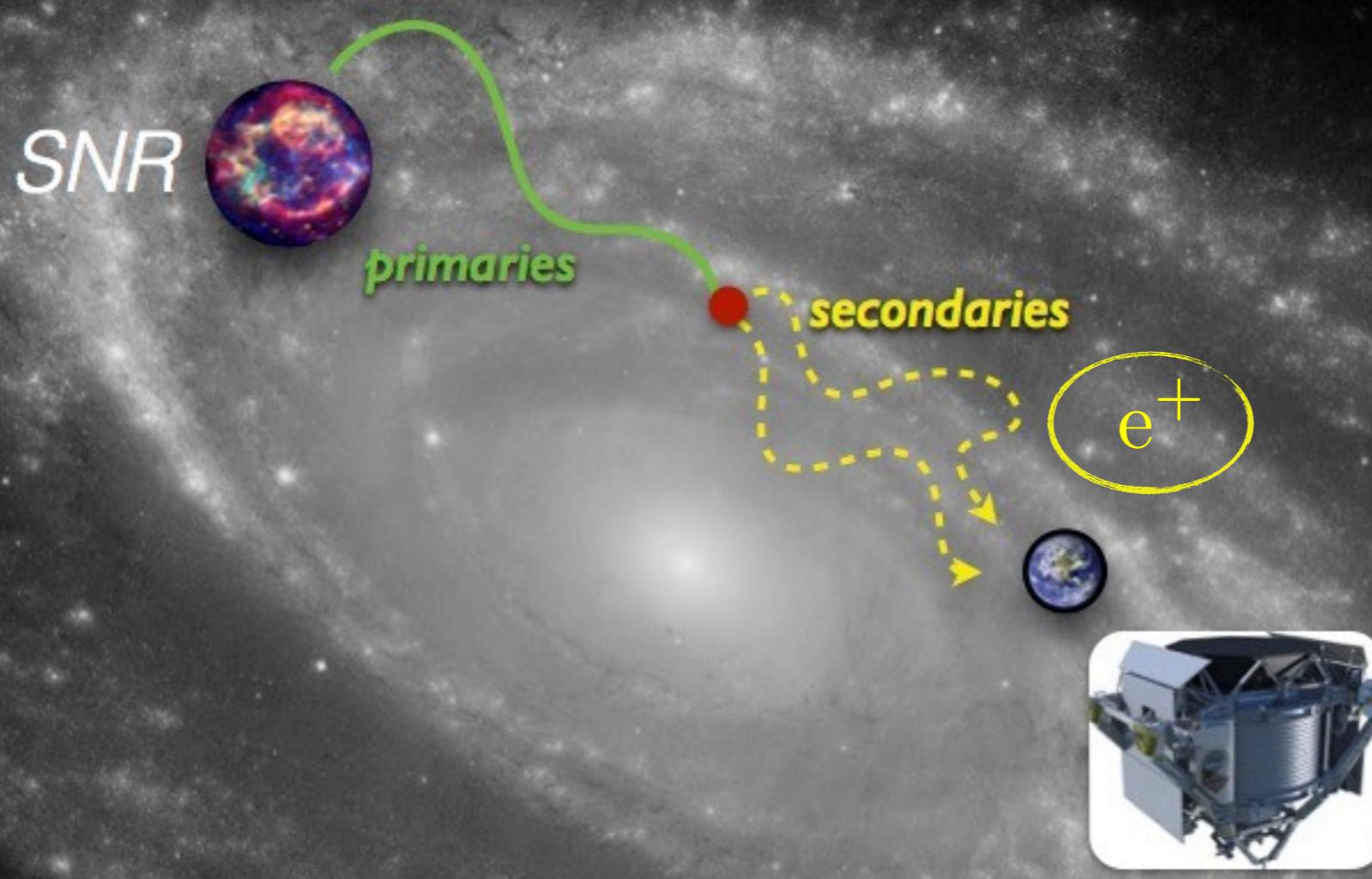


Semi-analytical

Maurin et al. (2001)
&
Donato et al. (2003)



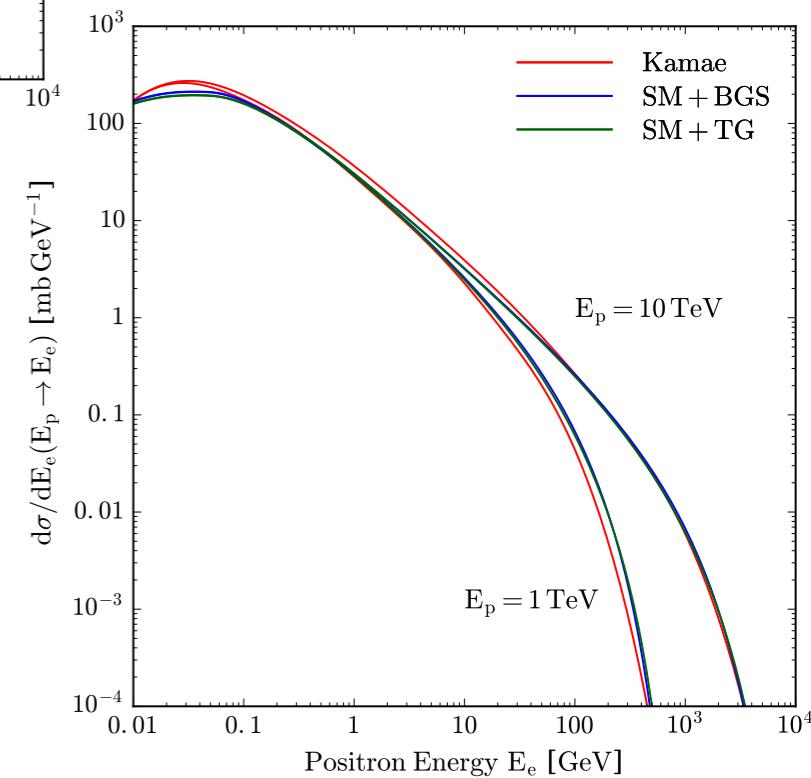
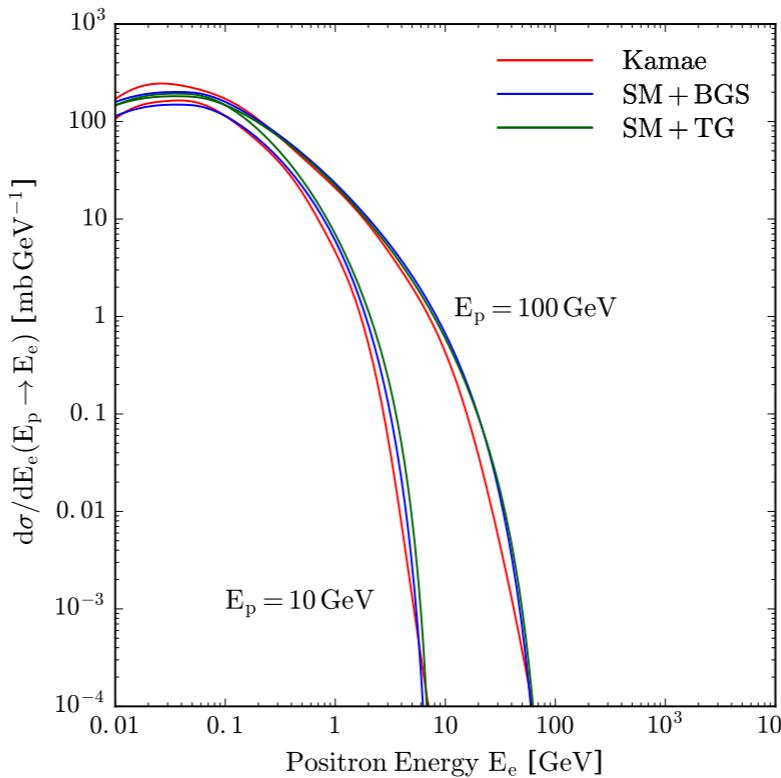
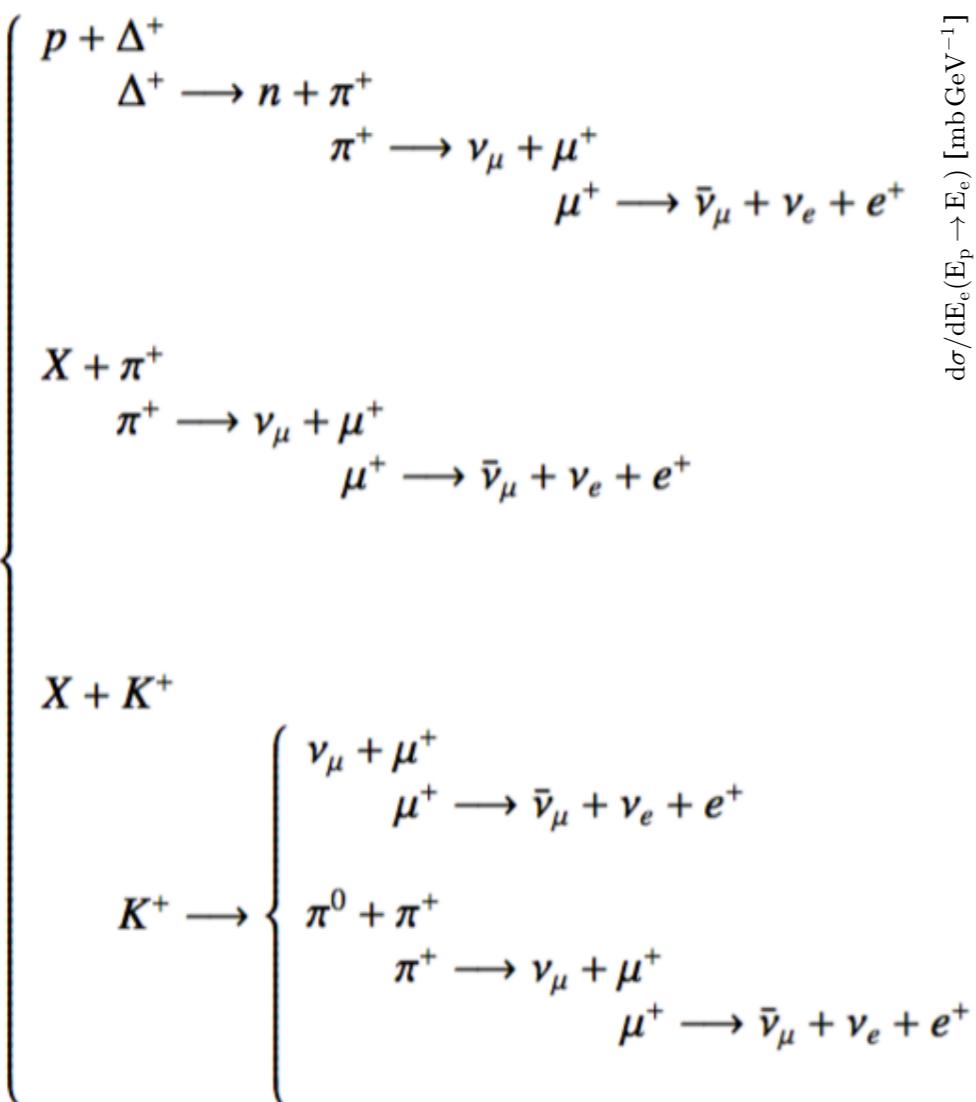
Case	δ	$K_0 [\text{kpc}^2/\text{Myr}]$	$L [\text{kpc}]$	$V_C [\text{km/s}]$	$V_a [\text{km/s}]$
MIN	0.85	0.0016	1	13.5	22.4
MED	0.70	0.0112	4	12	52.9
MAX	0.46	0.0765	15	5	117.6



Astrophysical background of secondary positrons

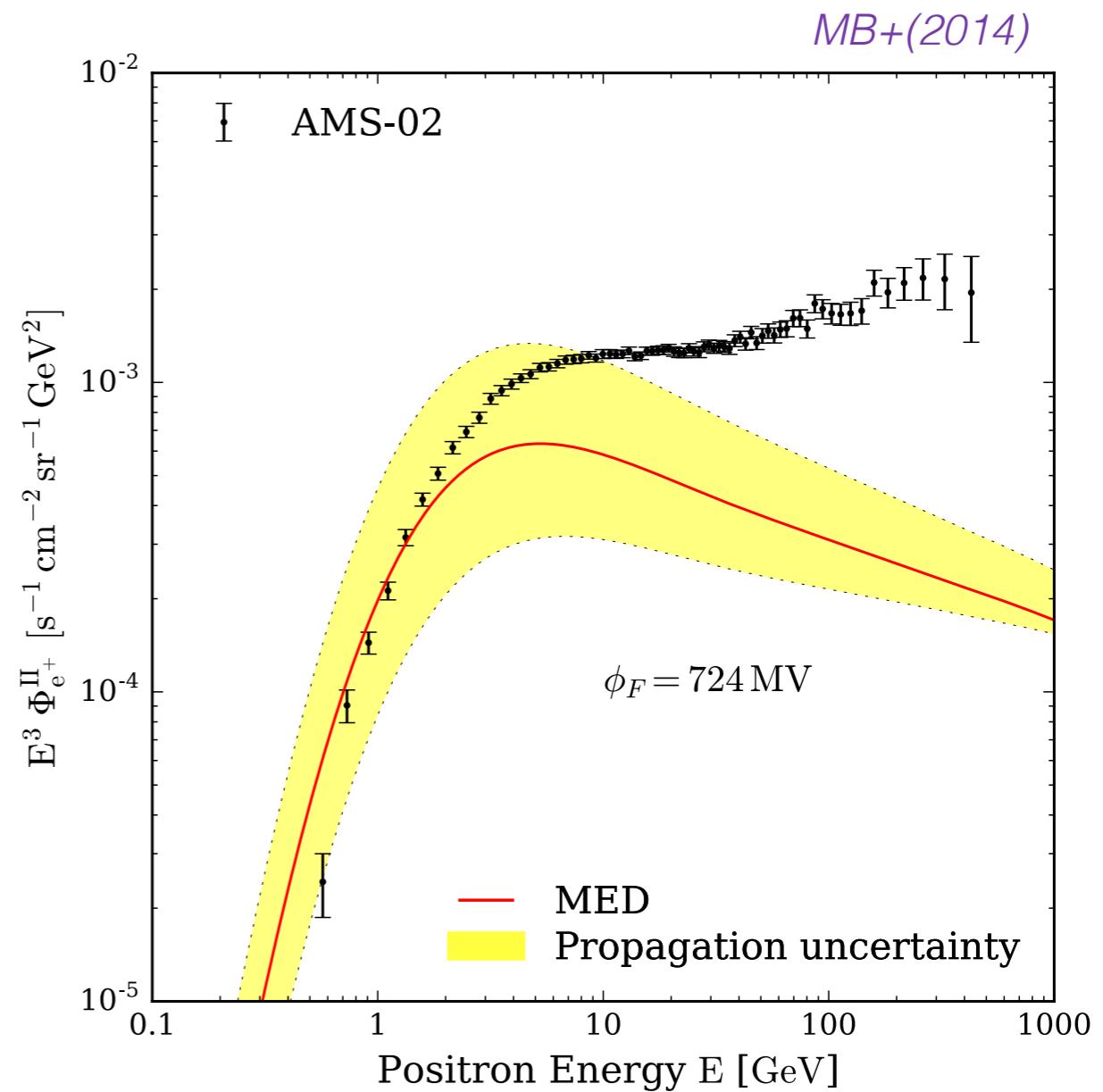
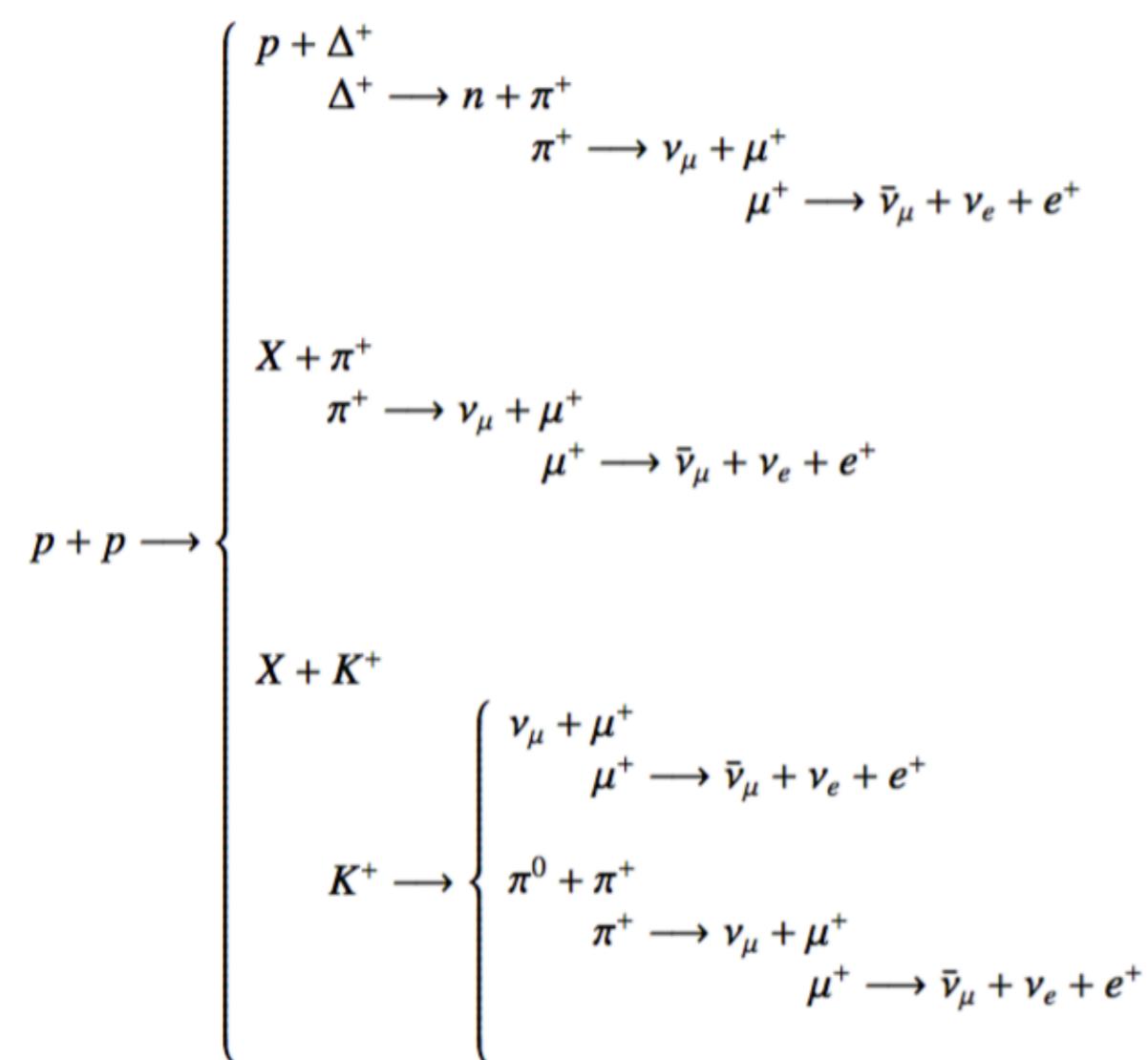
$$Q^{\text{II}}(E, \vec{x}) = 4\pi \sum_{i=p,\alpha} \sum_{j=H,He} n_j \int_{E_0}^{+\infty} dE_i \phi_i(E_i, \vec{x}) \frac{d\sigma}{dE_i}(E_j \rightarrow E)$$

$i = \text{projectile}$
 $j = \text{target}$



Astrophysical background of secondary positrons

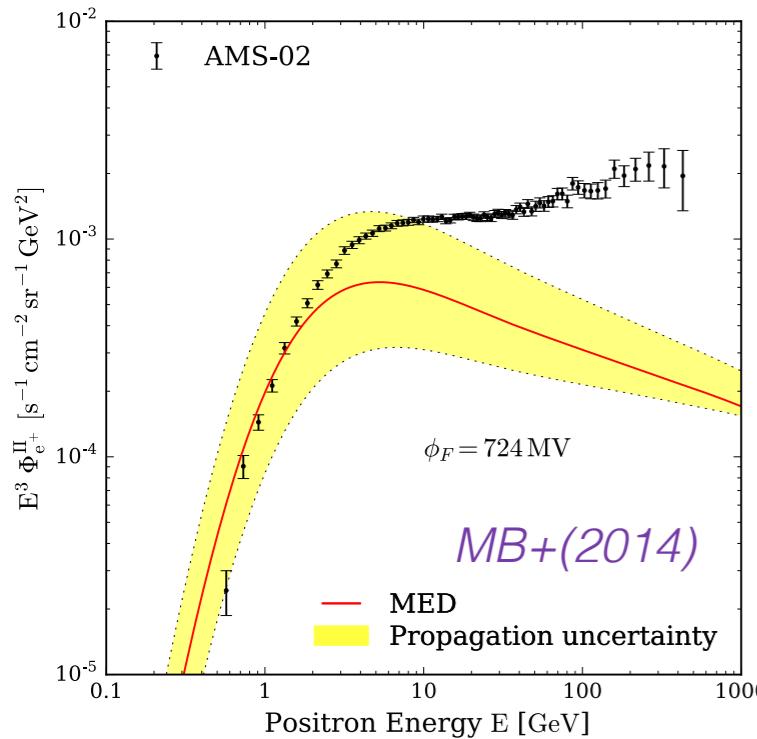
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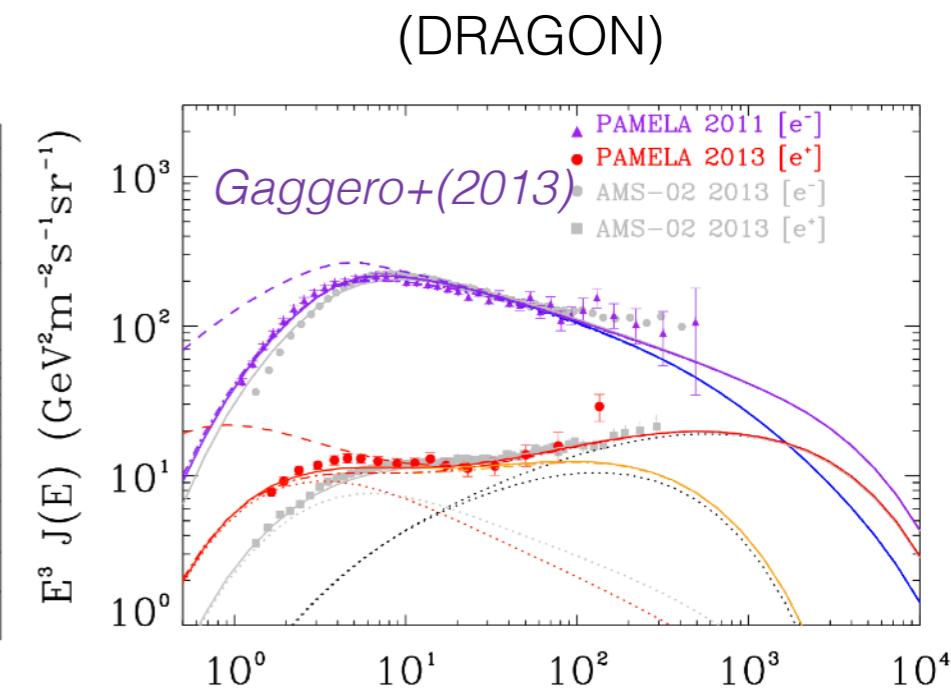
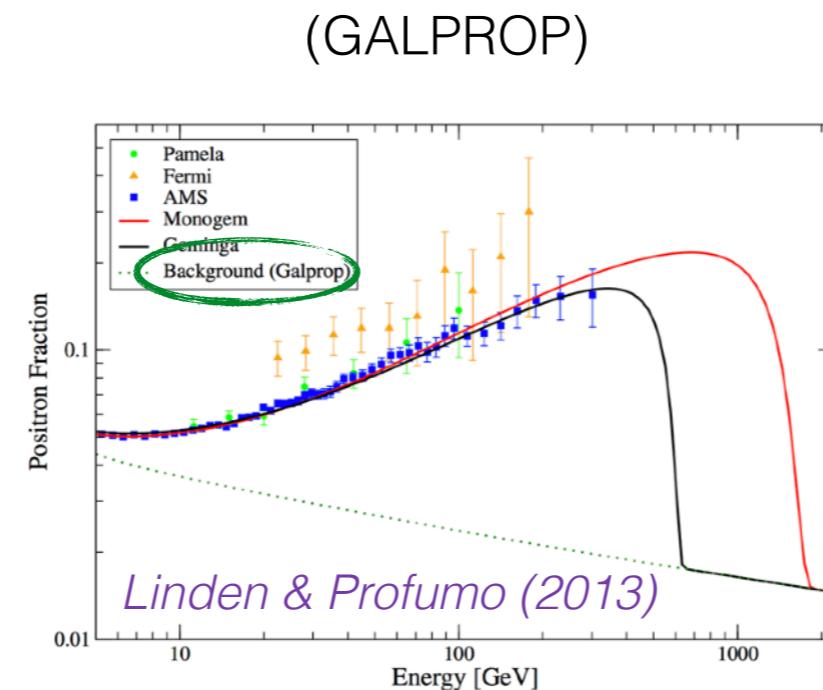
Positron excess above ~ 10 GeV!

The positron excess

Semi-analytical



Numerical



- Nearby and young PWNe

e.g.: *Linden & Profumo (2013)*
Gaggero+(2013)
Di Mauro+(2014)
MB+(2014)

[See Tim's talk at 2:30]

- Primary e+ produced inside SNRs

e.g.: *Blasi & Serpico (2009)*
Mertsch & Sarkar (2014)

- Primary e+ from dark matter

e.g.: *Baltz & Edsjö (1998)*
Cirelli & Strumia (2008)
MB+(2014)

- Nearby and ~2-3 Myr old SNR

e.g.: *Kachelriess, Neronov & Semikoz (2017)*

Unlikely scenario ($p < 0.1\%$)

Genolini, Salati, Serpico & Taillet (2016)

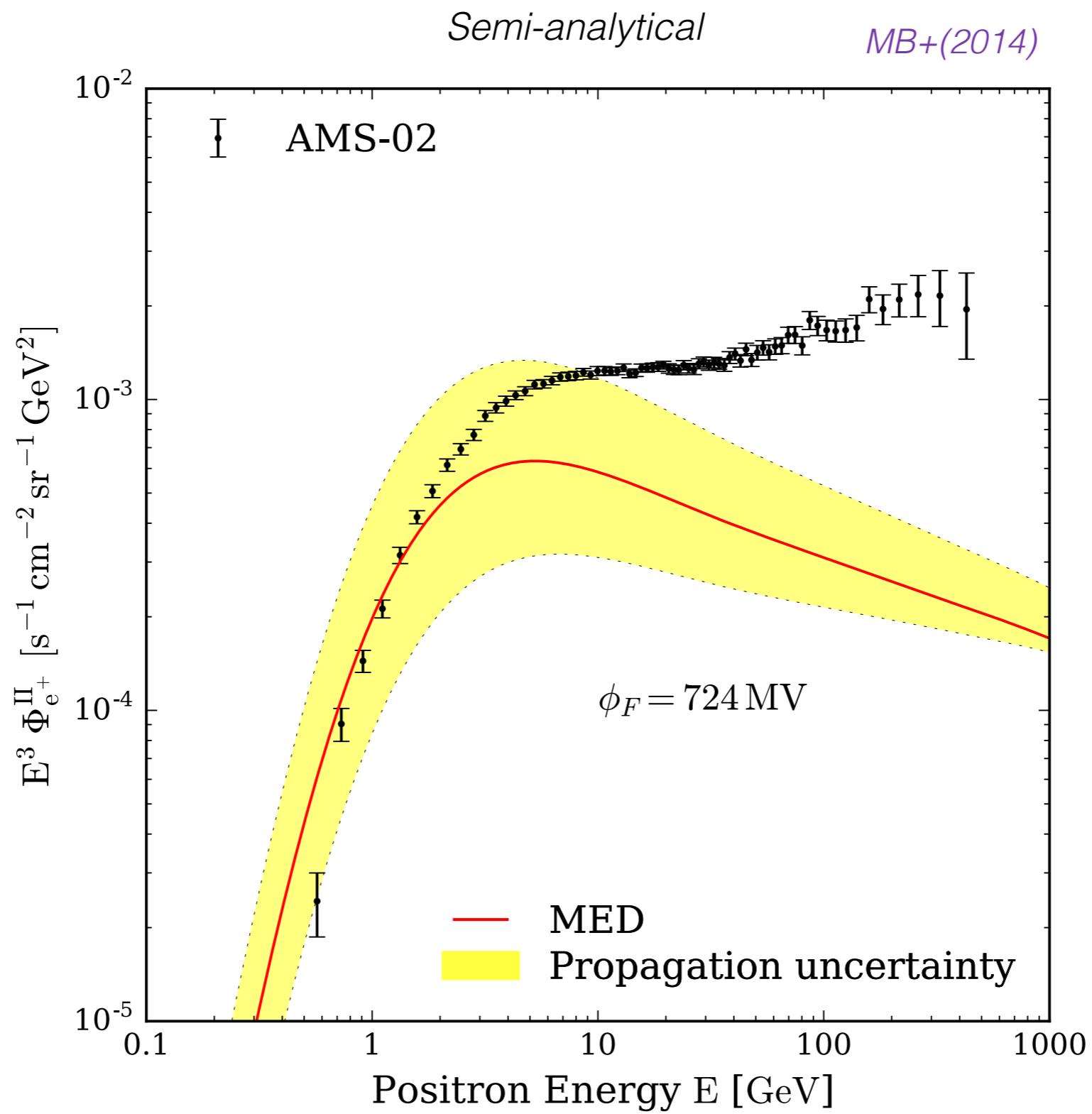
- Different propagation model

e.g.: *Lipari (2017)*

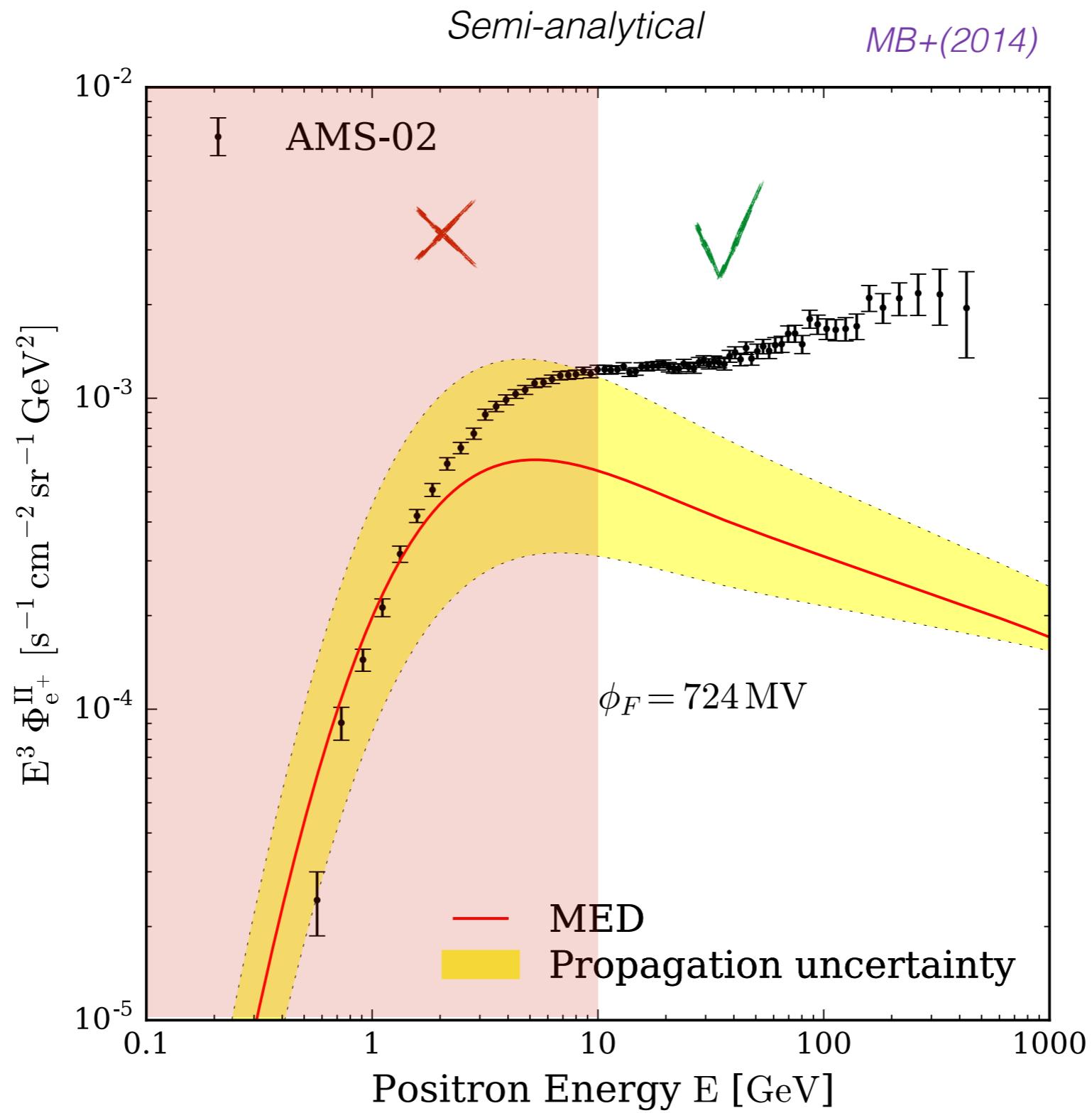
Blum, Sato & Waxman (2017)

Inconsistent with CR nuclei

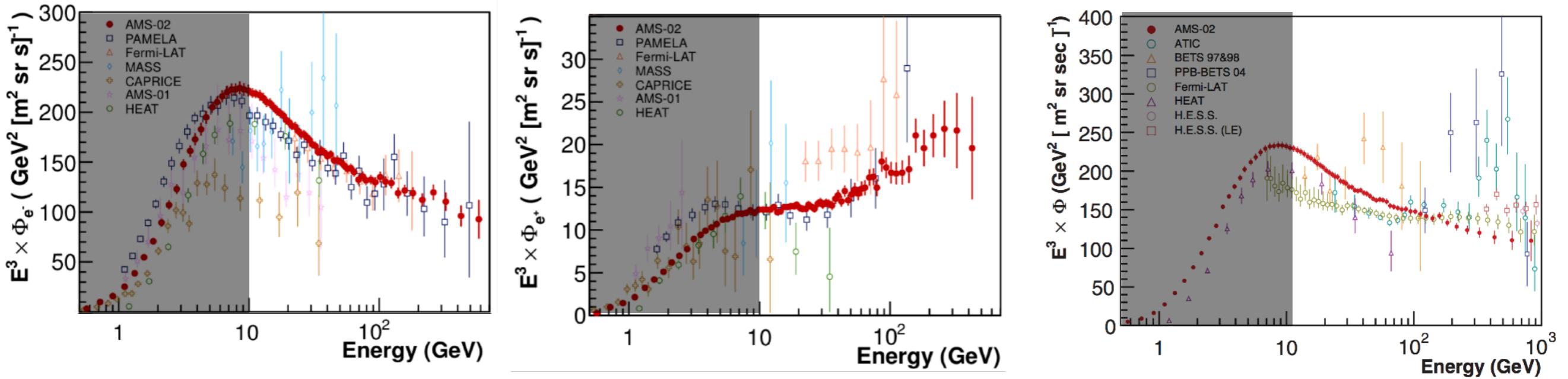
The positron excess



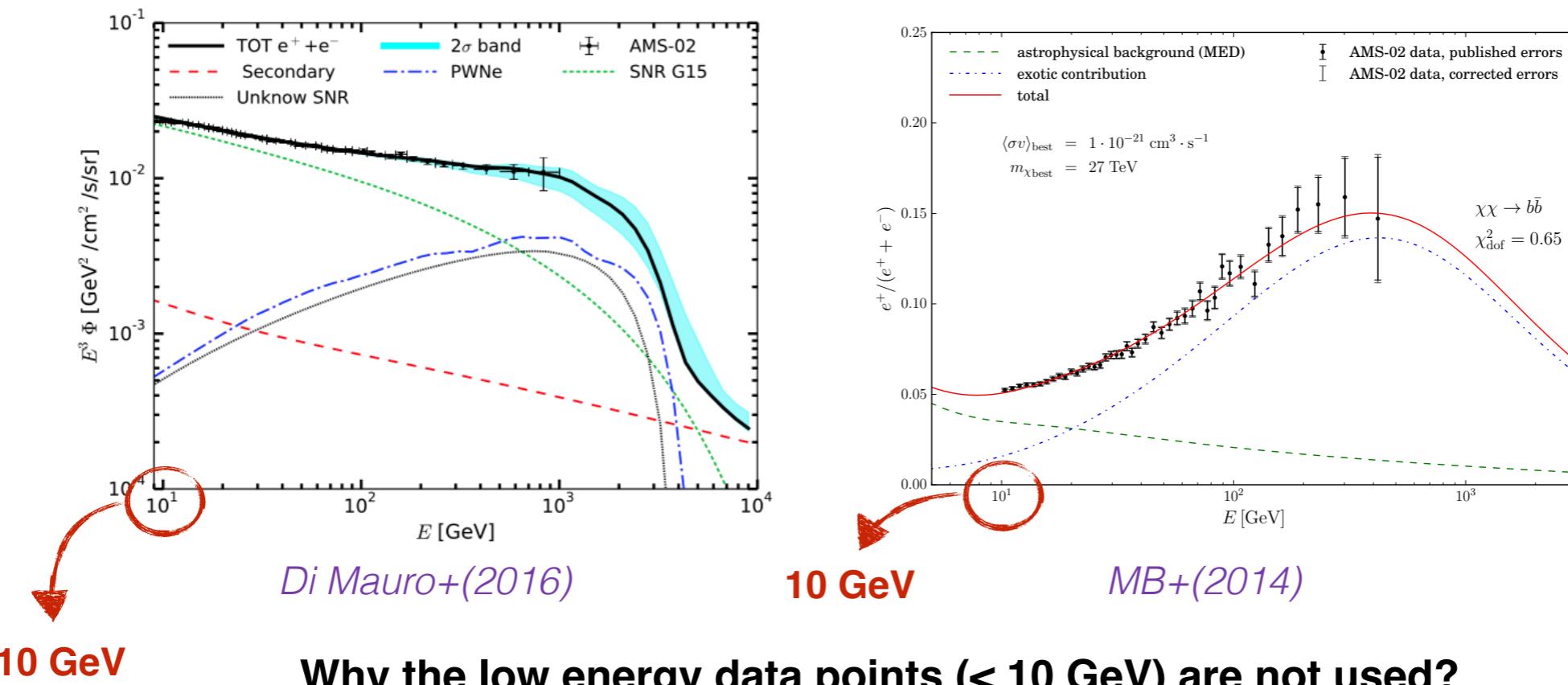
The positron excess



Interpretation of AMS-02 e⁺/e⁻ data



Semi-analytic method analysis e.g.:



- 1- Introduction
- 2- Propagation of cosmic rays: the diffusion model
- 3- The *pinching method* for low energy e⁻ and e⁺**
- 4- Implications for dark matter searches
- 6- Conclusions and outlooks

The *pinching method* for low energy e⁻ and e⁺

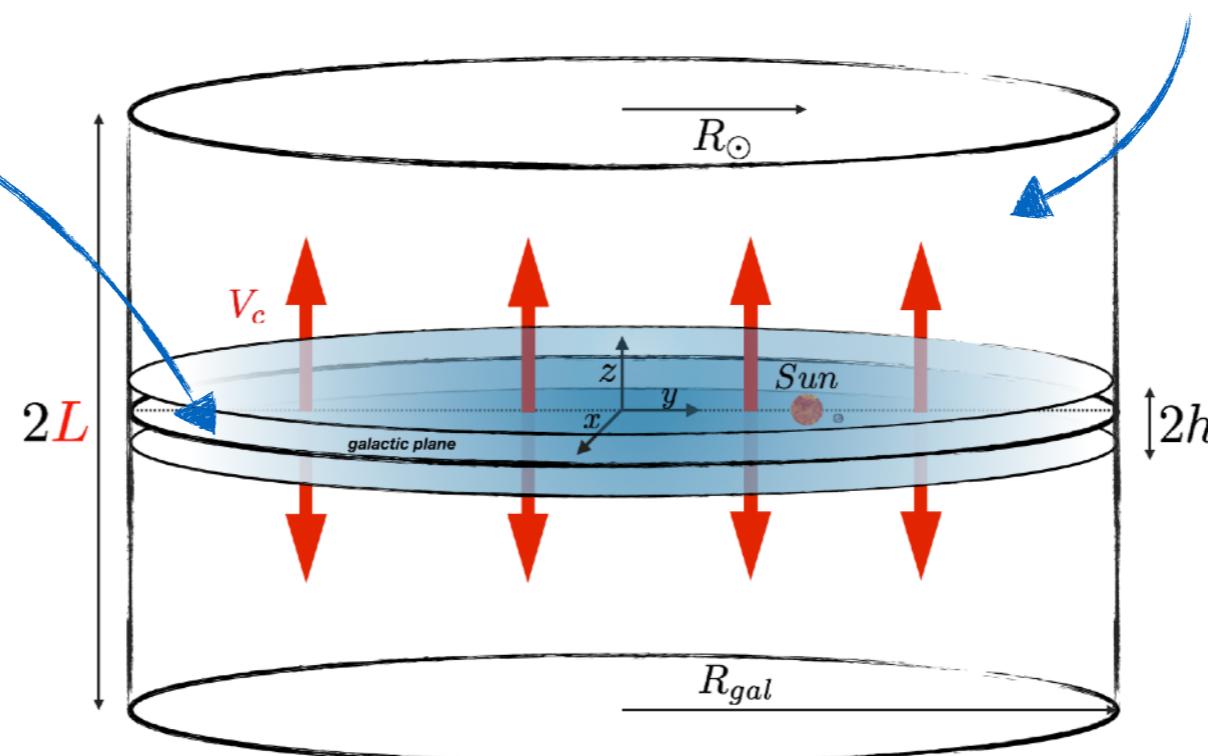
Semi-analytic method for cosmic ray e⁻ and e⁺

Cosmic rays transport equation (steady state)

$$\partial_z [V_C \operatorname{sign}(z) \psi] - K(E) \Delta \psi + 2h \delta(z) \partial_E [b_{\text{disc}}(E) \psi - D(E) \partial_E \psi] + \partial_E [b_{\text{halo}}(E) \psi] = Q(E, \vec{x})$$

$$b_{\text{disc}} = b_{\text{adia}} + b_{\text{ioni}} + b_{\text{brem}} + b_{\text{coul}}$$

$$b_{\text{halo}} = b_{\text{IC}} + b_{\text{sync}}$$



We cannot solve analytically the transport equation when cosmic rays lose energy in the hole magnetic halo!

We need a **numerical** algorithm to solve the transport equation (GALPROP, DRAGON, PICARD, etc.)

Electrons and positrons: the high-energy approximation

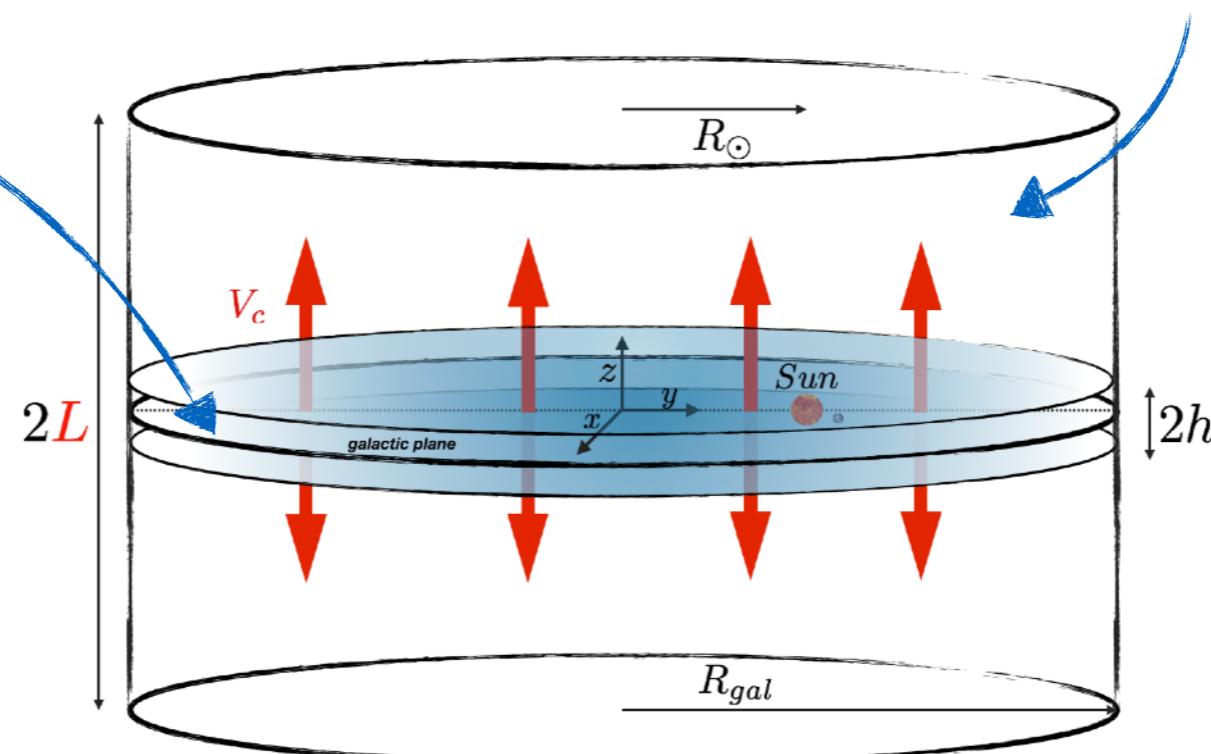
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$$b_{\text{halo}} = b_{\text{IC}} + b_{\text{sync}}$$

$E > 10 \text{ GeV}$



High energy approximation

$$-K(E) + \partial_E [b_{\text{halo}}(E) \psi] = Q(E, \vec{x})$$

Baltz & Edsjö (1998)

Delahaye+ (2008)

Di Mauro+ (2014)

MB+ (2014)

etc.

Is $E = 10 \text{ GeV}$ a correct threshold to get rid of low energy effects?
(Especially with the high accuracy of the AMS-02 data at $E \sim 10 \text{ GeV}$)

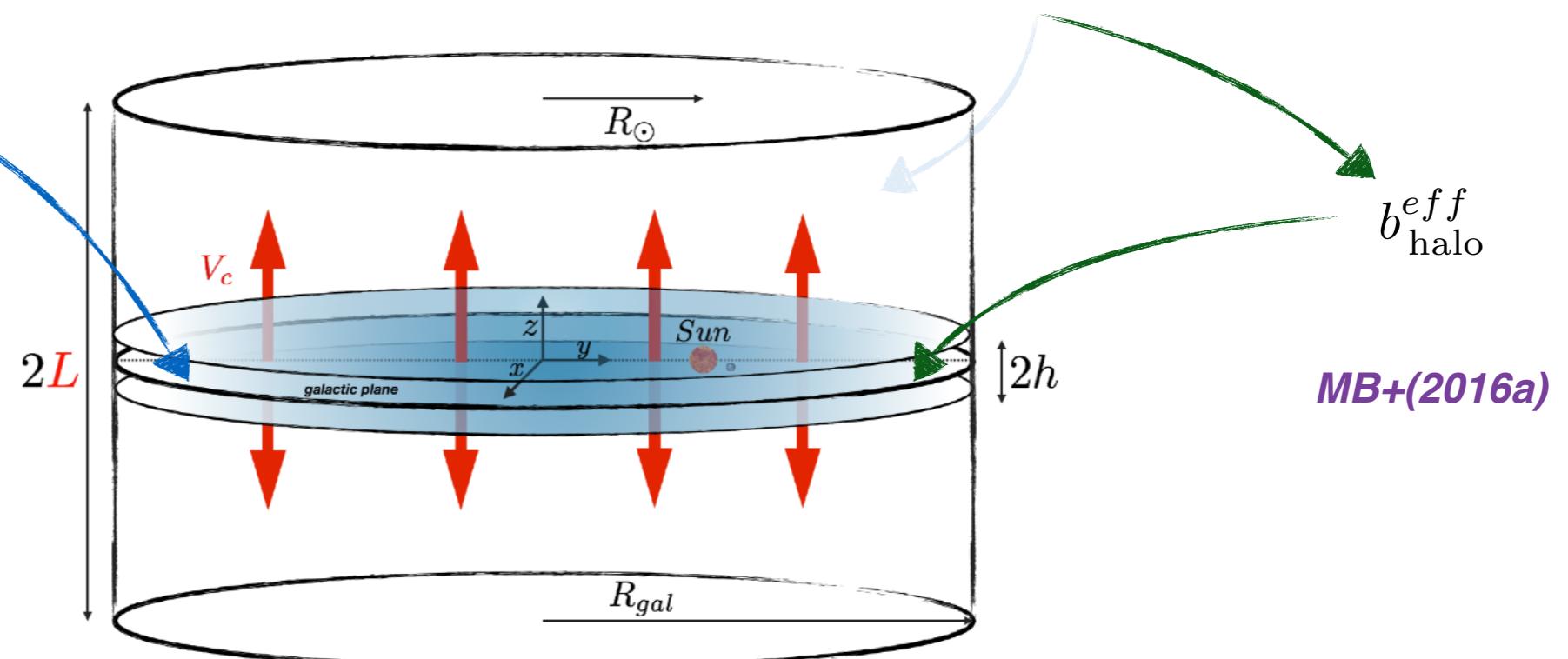
Semi-analytic method for cosmic ray e^- and e^+

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The pinching method

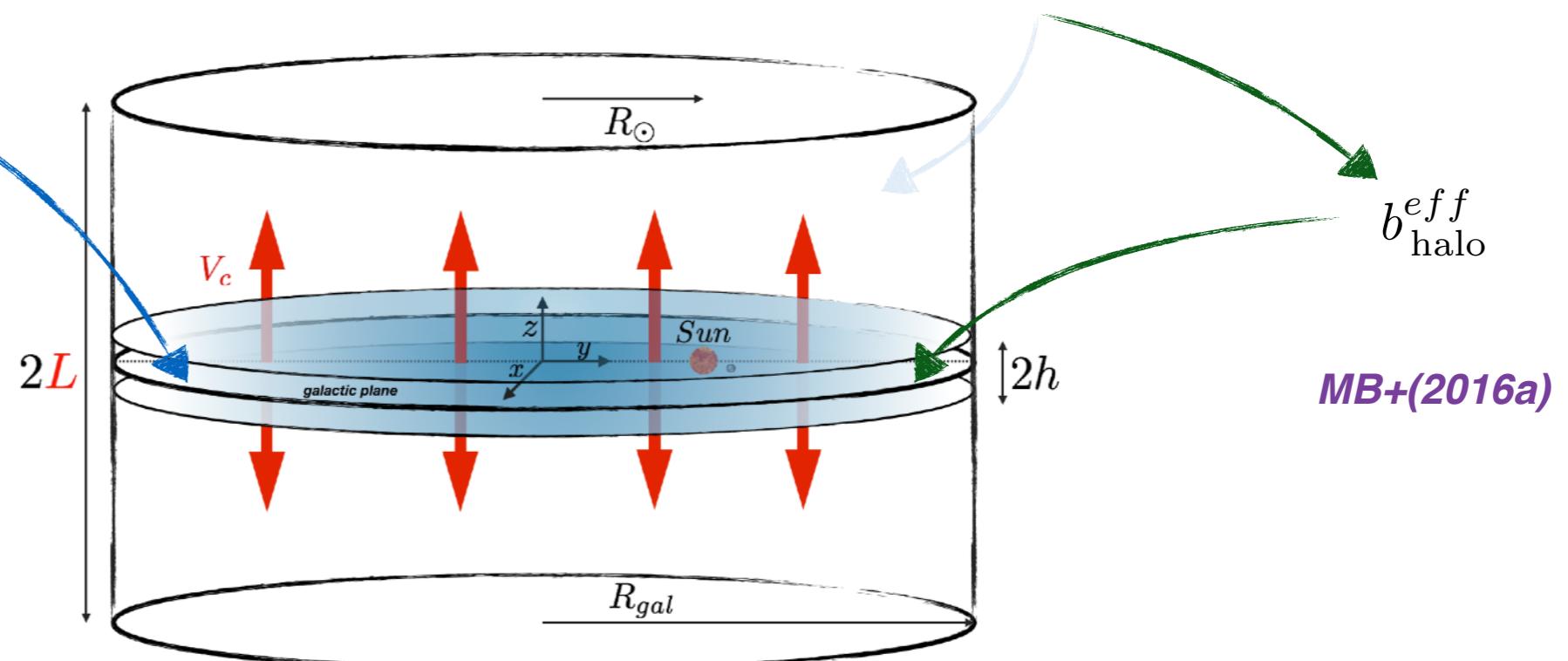
Semi-analytic method for cosmic ray e⁻ and e⁺

Cosmic rays transport equation (steady state)

$$\partial_z [V_C \operatorname{sign}(z) \psi] - K(E) \Delta \psi + 2h \delta(z) \partial_E [b_{\text{disc}}(E) \psi - D(E) \partial_E \psi] + \partial_E [b_{\text{halo}}(E) \psi] = Q(E, \vec{x})$$

$$b_{\text{disc}} = b_{\text{adia}} + b_{\text{ioni}} + b_{\text{brem}} + b_{\text{coul}}$$

$$b_{\text{halo}} = b_{\text{IC}} + b_{\text{sync}}$$



The pinching method

$$\partial_z [V_C \operatorname{sign}(z) \psi] - K(E) \Delta \psi + 2h \delta(z) \partial_E \left\{ \left[b_{\text{disc}}(E) + b_{\text{halo}}^{\text{eff}}(E) \right] \psi - D(E) \partial_E \psi \right\} = Q(E, \vec{x})$$

The pinching method

MB+(2016a)

$$\partial_z [V_C \operatorname{sign}(z) \psi] - K(E) \Delta \psi + 2h \delta(z) \partial_E \left\{ \left[b_{\text{disc}}(E) + b_{\text{halo}}^{eff}(E) \right] \psi - D(E) \partial_E \psi \right\} = Q(E, \vec{x})$$

$$b_{\text{halo}} = b_{\text{IC}} + b_{\text{sync}} \longrightarrow b_{\text{halo}}^{eff}(E, r) = \bar{\xi}(E, r) b_{\text{halo}}(E)$$

pinching factor

$$\bar{\xi}(E, r) = \frac{1}{\psi(E, r, 0)} \sum_{i=1}^{+\infty} J_0(\alpha_i \frac{r}{R}) \bar{\xi}_i(E) P_i(E, 0)$$

$$\bar{\xi}_i(E) = \frac{\int_E^{+\infty} dE_S \left[J_i(E_S) + 4k_i^2 \int_E^{E_S} dE' \frac{K(E')}{b(E')} B_i(E', E_S) \right]}{\int_E^{+\infty} dE_S B_i(E, E_S)}$$

$$J_i(E_S) = \frac{1}{h} \int_0^L dz_S \mathcal{F}_i(z_S) Q_i(E_S, z_S)$$

$$Q_i(E, z) = \frac{2}{R^2 J_1^2(\alpha_i)} \int_0^R dr r J_0(\xi_i) Q(E, r, z)$$

$$B_i(E, E_S) = \sum_{n=2m+1}^{+\infty} Q_{i,n}(E_S) \exp[-C_{i,n} \lambda_D^2]$$

$$C_{i,n} = \frac{1}{4} \left[\left(\frac{\alpha_i}{R} \right)^2 + (nk_0)^2 \right]$$

$$Q_{i,n}(E) = \frac{1}{L} \int_{-L}^L dz \varphi_n(z) \frac{2}{R^2 J_1^2(\alpha_i)} \int_0^R dr r J_0 \left(\alpha_i \frac{r}{R} \right) Q(E, r, z)$$

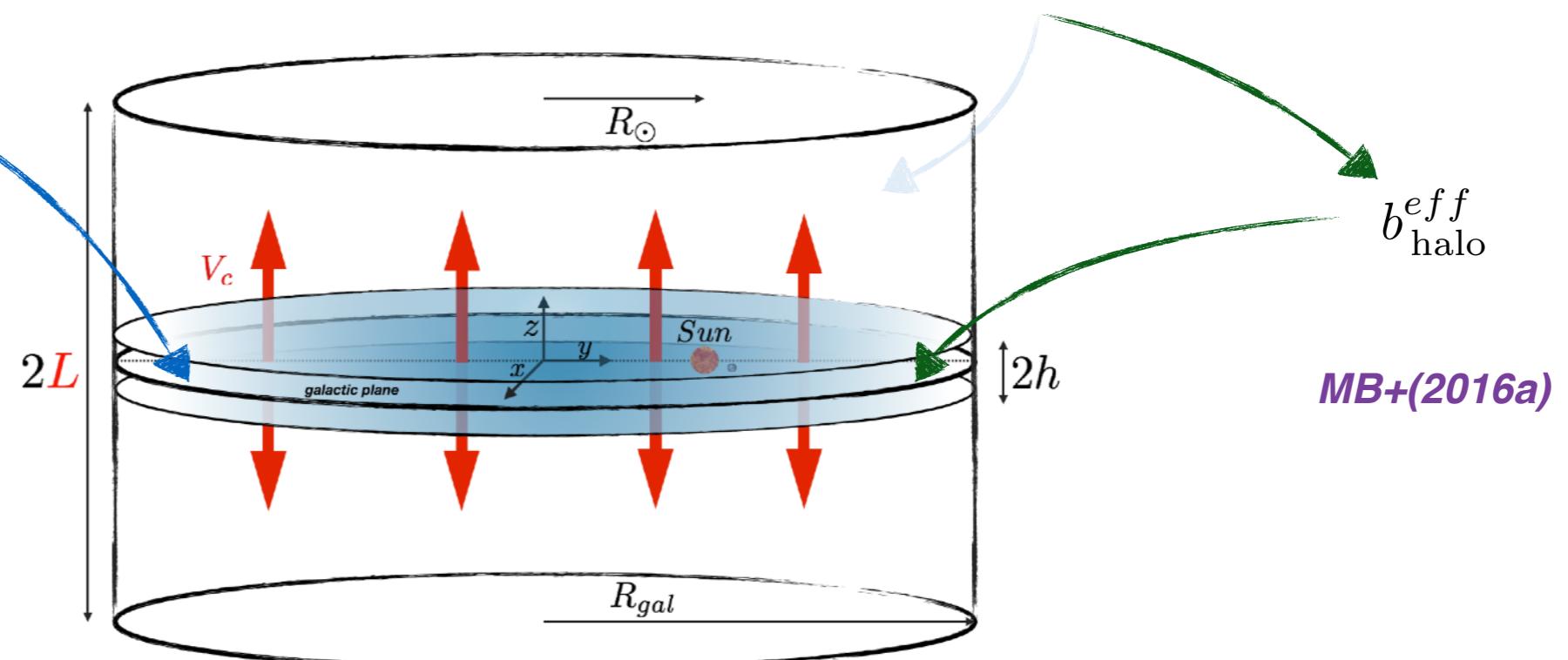
Semi-analytic method for cosmic ray e^- and e^+

Cosmic rays transport equation (steady state)

$$\partial_z [V_C \operatorname{sign}(z) \psi] - K(E) \Delta \psi + 2h \delta(z) \partial_E [b_{\text{disc}}(E) \psi - D(E) \partial_E \psi] + \partial_E [b_{\text{halo}}(E) \psi] = Q(E, \vec{x})$$

$$b_{\text{disc}} = b_{\text{adia}} + b_{\text{ioni}} + b_{\text{brem}} + b_{\text{coul}}$$

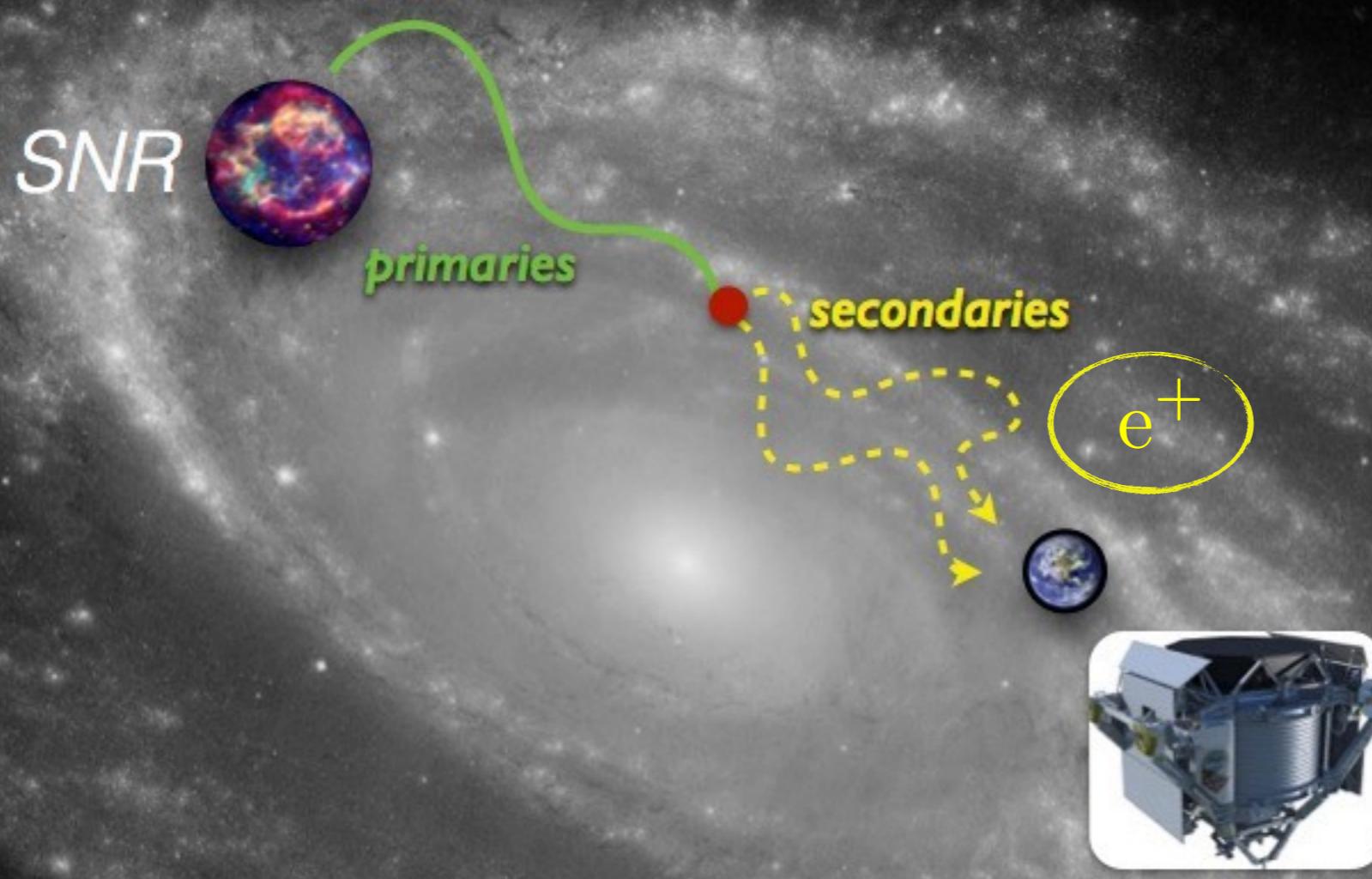
$$b_{\text{halo}} = b_{\text{IC}} + b_{\text{sync}}$$



The pinching method

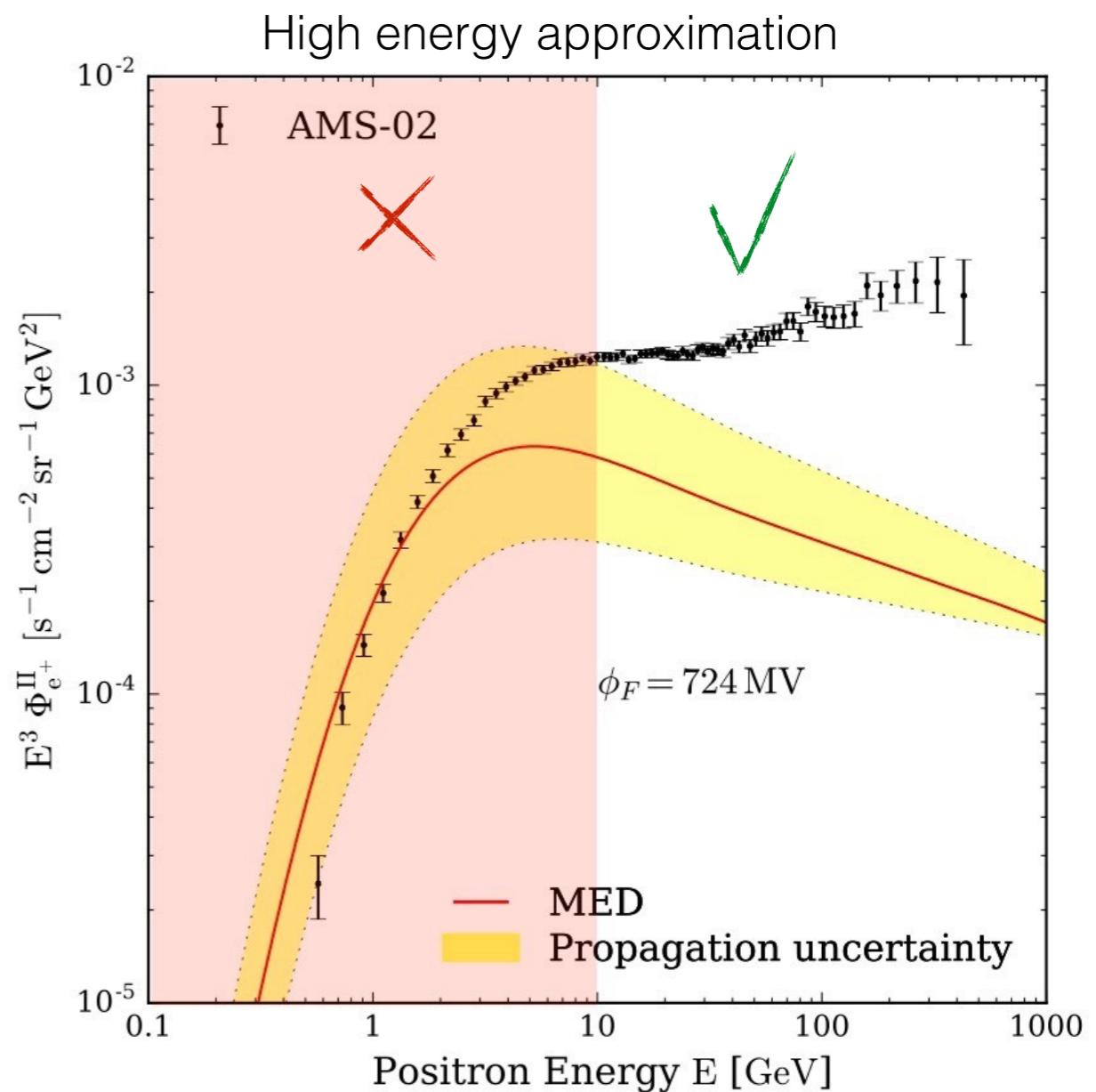
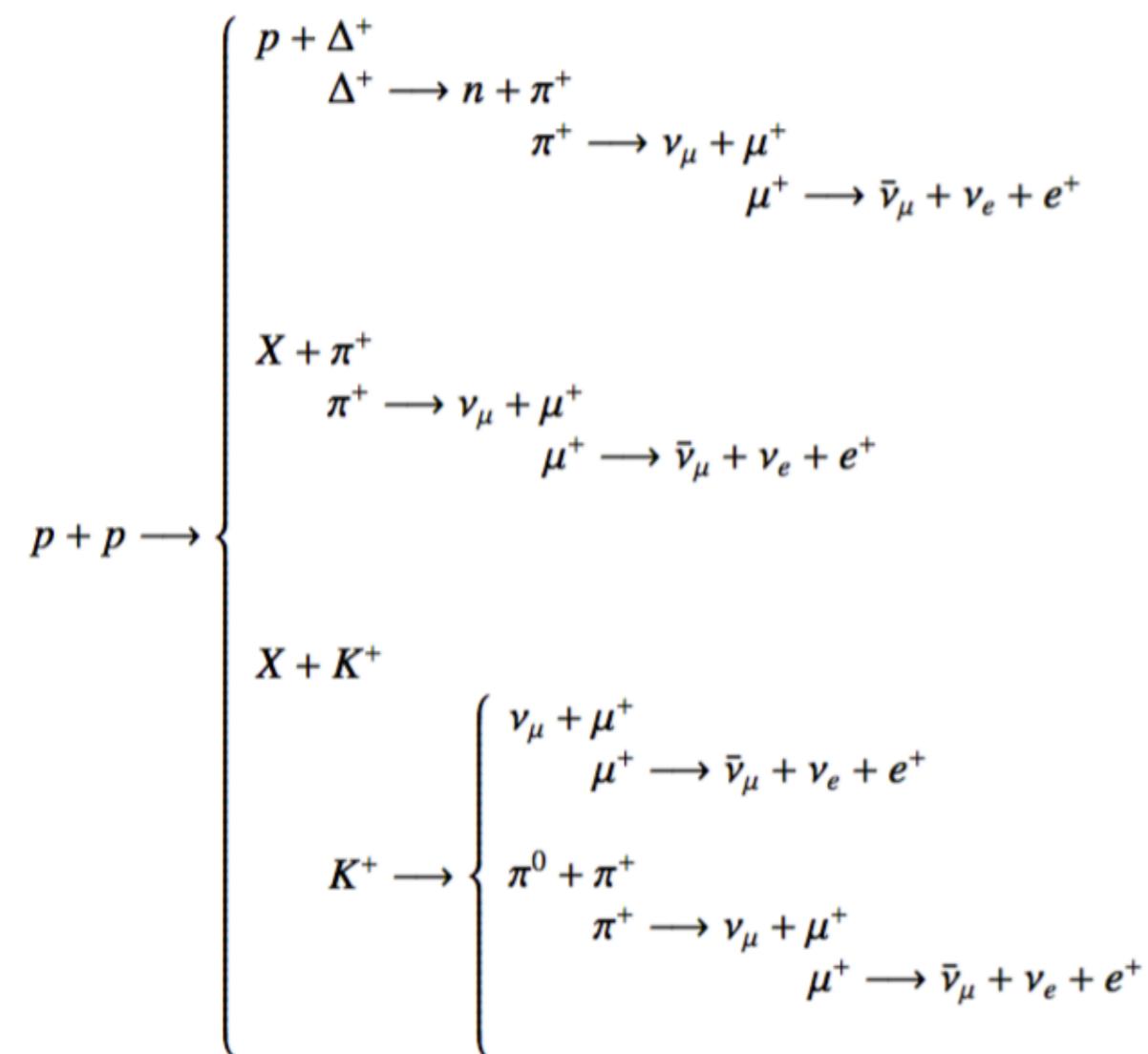
$$\partial_z [V_C \operatorname{sign}(z) \psi] - K(E) \Delta \psi + 2h \delta(z) \partial_E \left\{ \left[b_{\text{disc}}(E) + b_{\text{halo}}^{\text{eff}}(E) \right] \psi - D(E) \partial_E \psi \right\} = Q(E, \vec{x})$$

From now we are able to compute the positron flux **analytically, including all propagation effects!**



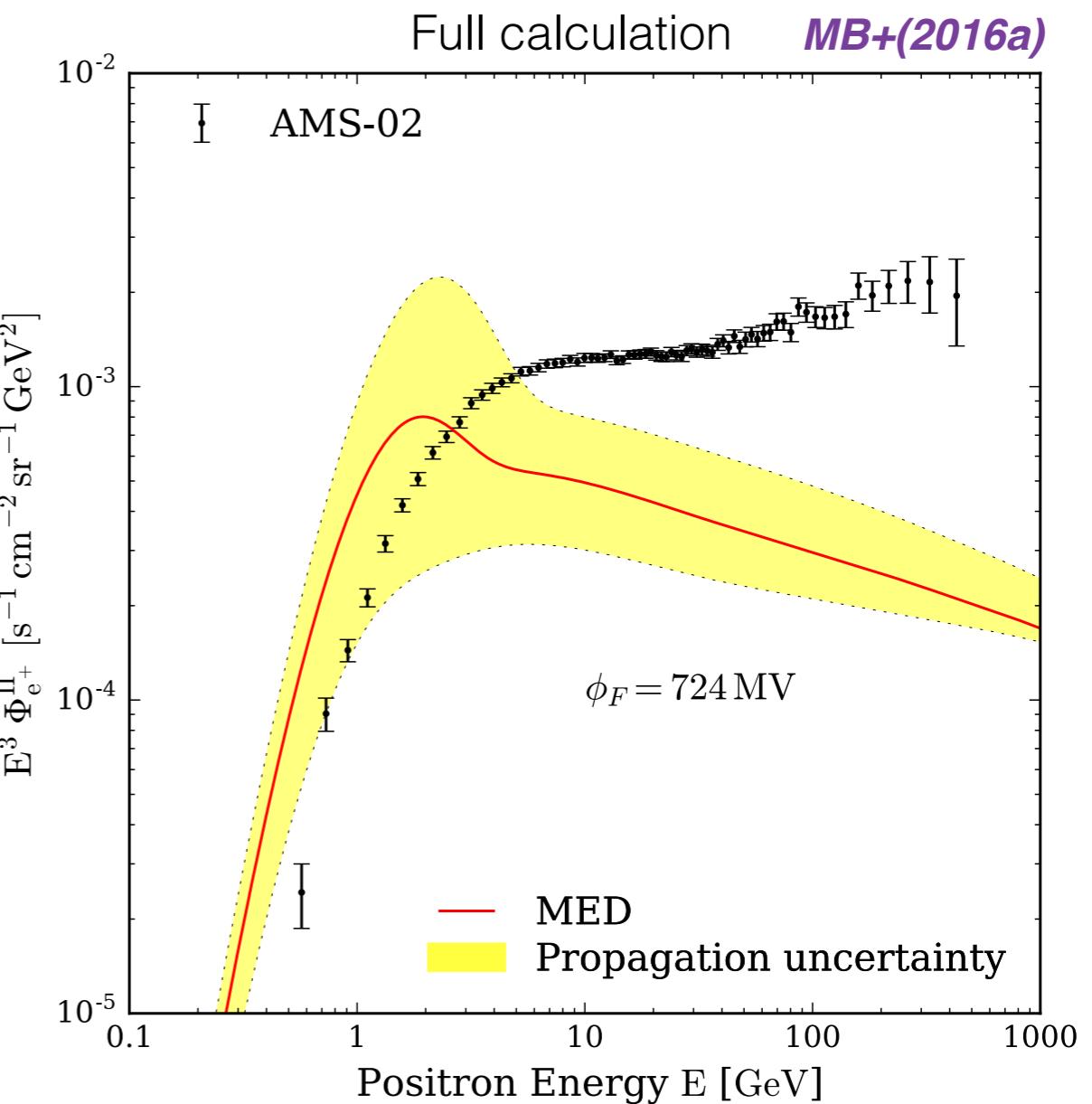
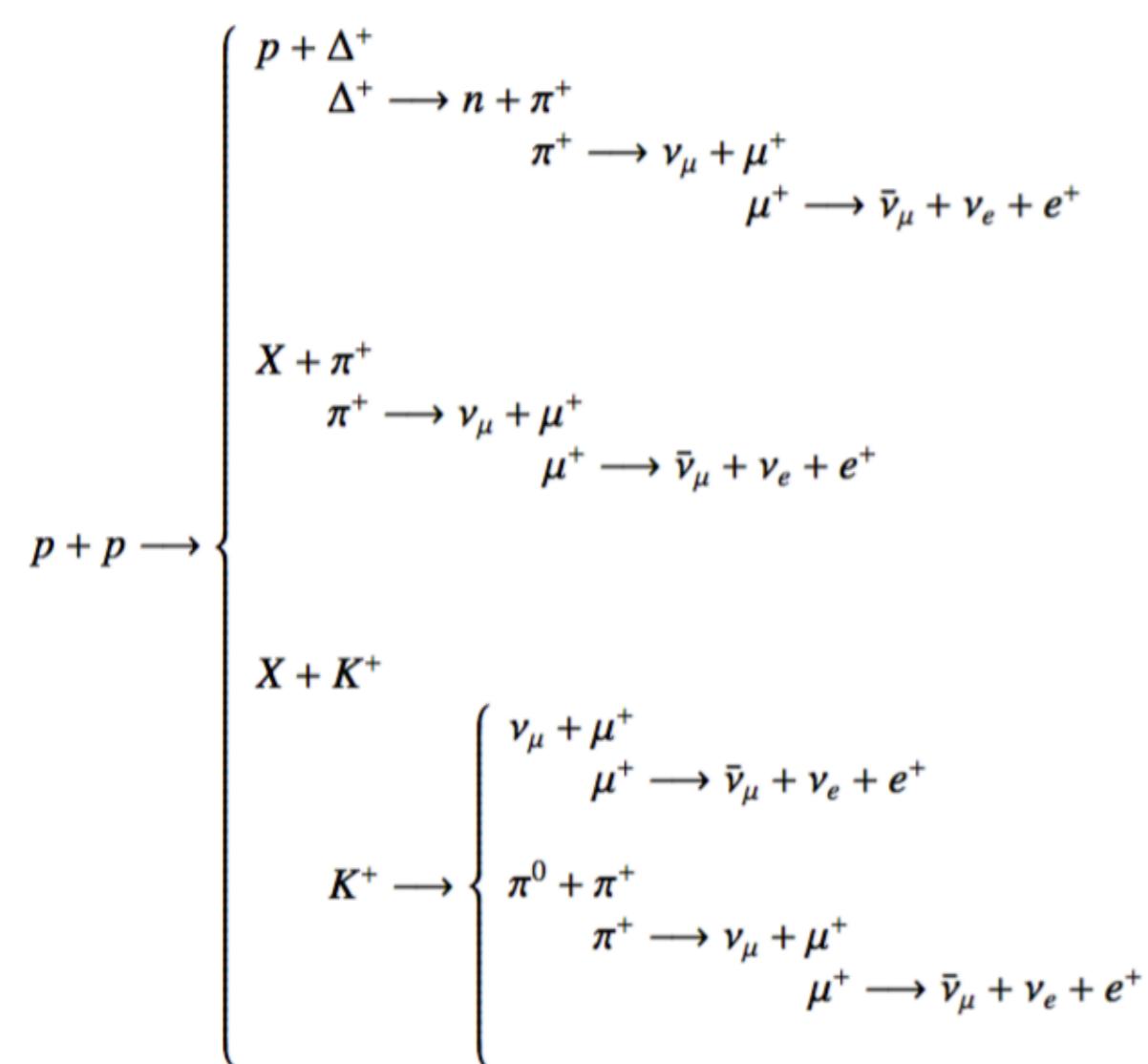
Astrophysical secondary positrons

$$Q^{II}(E, \vec{x}) = 4\pi \sum_{i=p,\alpha} \sum_{j=H,He} n_j \int_{E_0}^{+\infty} dE_i \phi_i(E_i, \vec{x}) \frac{d\sigma}{dE_i}(E_j \rightarrow E) \quad \begin{cases} i = \text{projectile} \\ j = \text{target} \end{cases}$$



Astrophysical secondary positrons

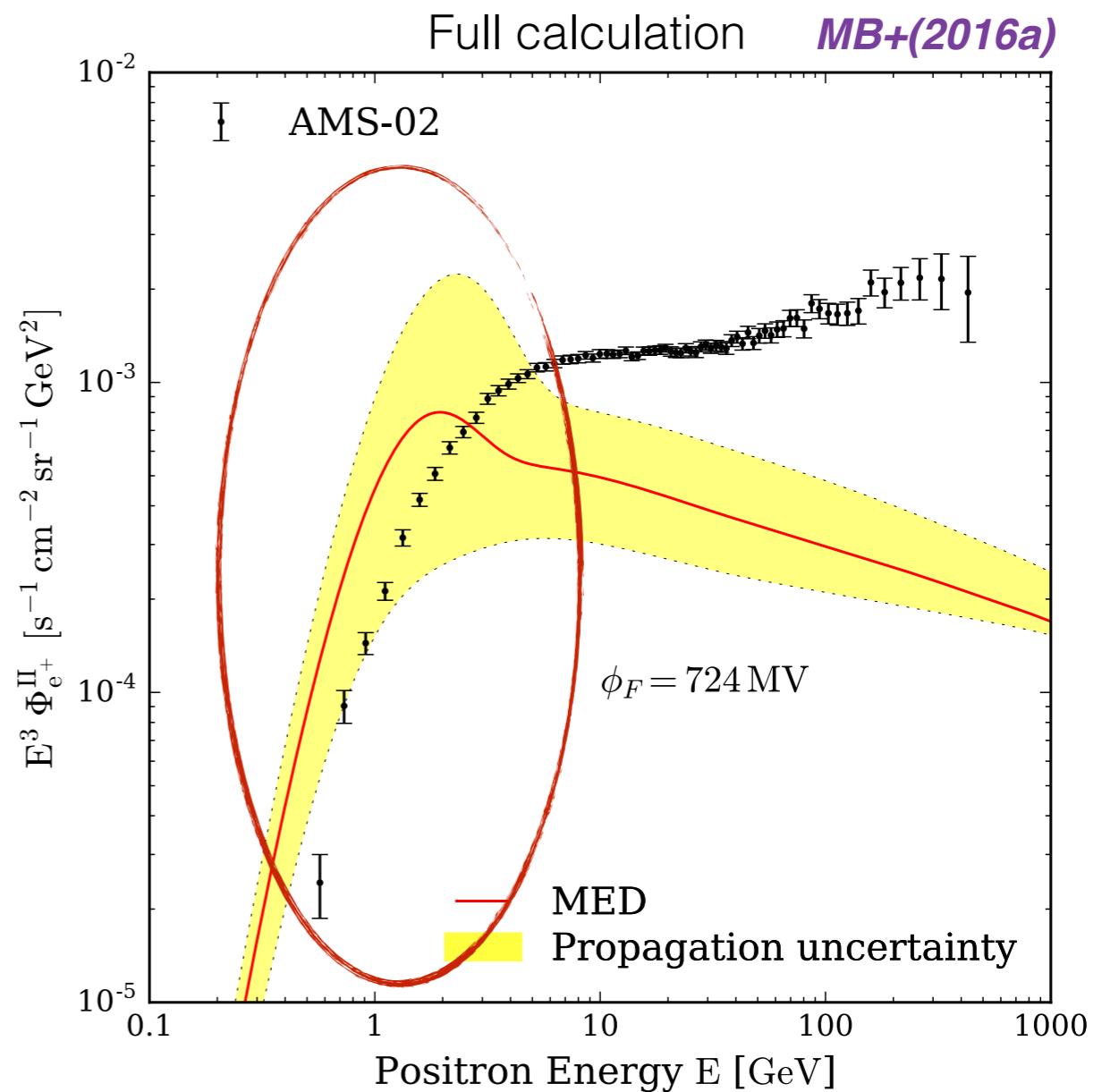
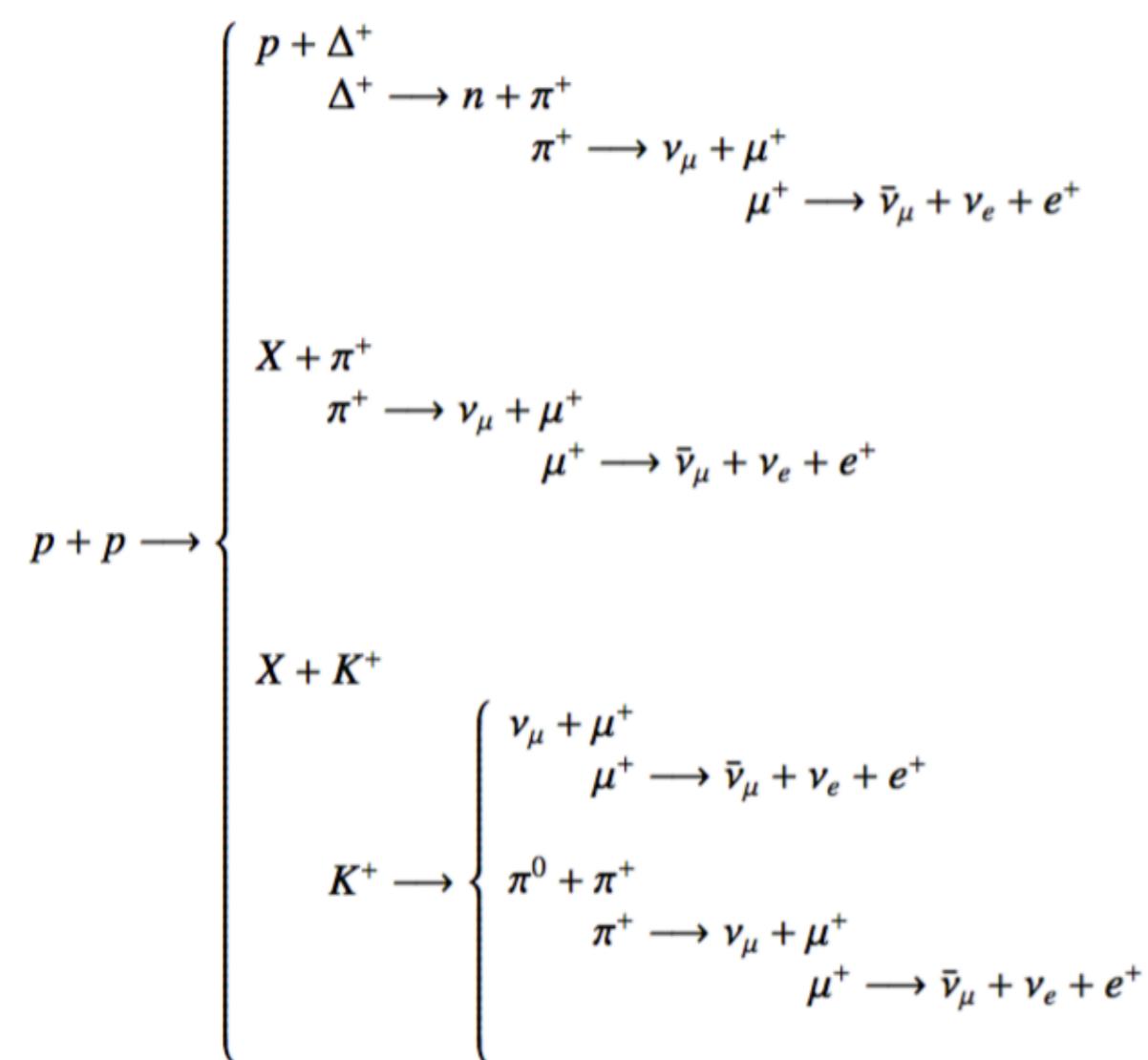
$$Q^{\text{II}}(E, \vec{x}) = 4\pi \sum_{i=p,\alpha} \sum_{j=H,He} n_j \int_{E_0}^{+\infty} dE_i \phi_i(E_i, \vec{x}) \frac{d\sigma}{dE_i}(E_j \rightarrow E) \quad \begin{cases} i = \text{projectile} \\ j = \text{target} \end{cases}$$



The HE approximation \Rightarrow error up to 50% at 10 GeV!

Astrophysical secondary positrons

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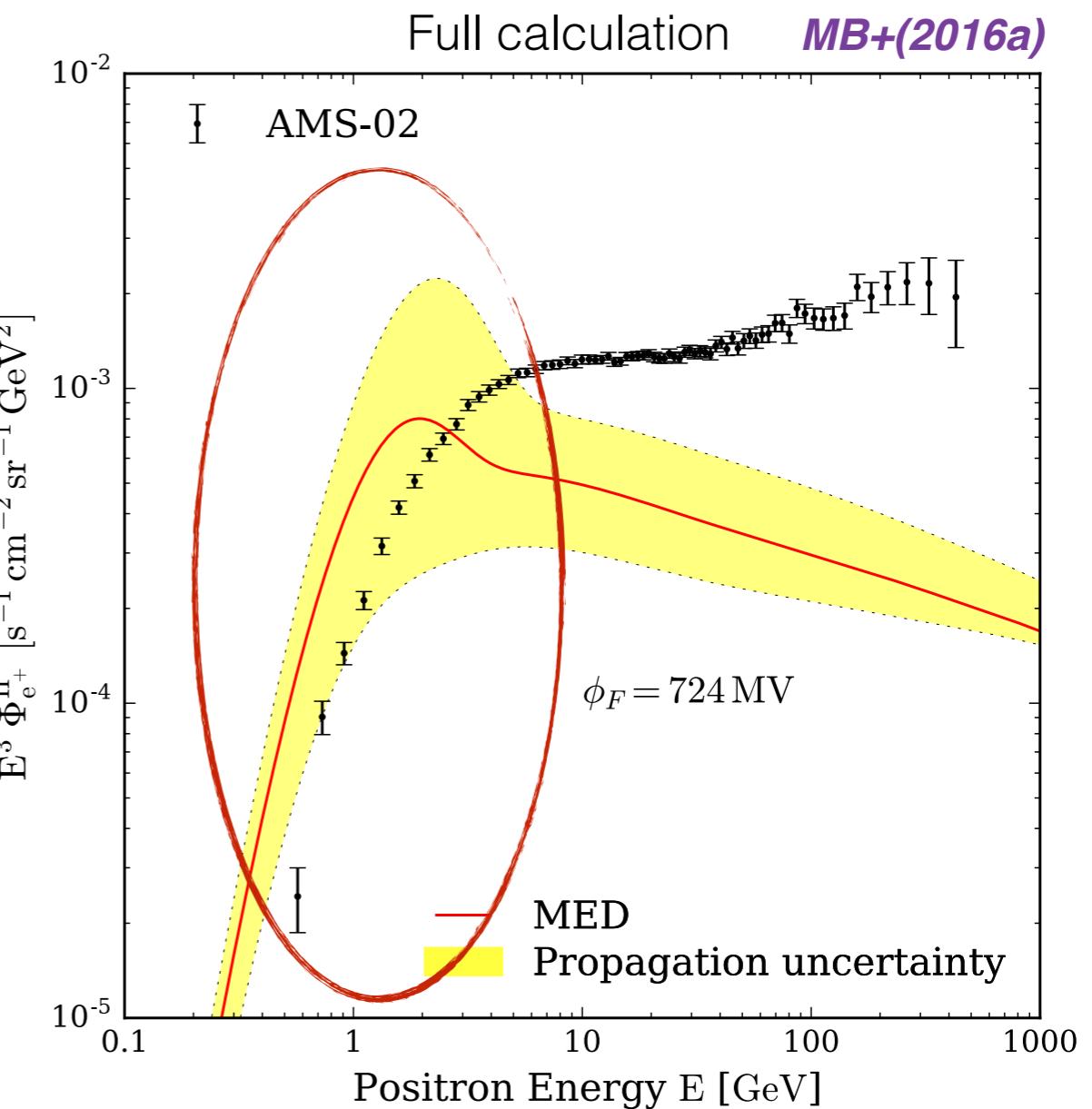
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Positrons can be used as an independent probe for the propagation parameters.

The degeneracy between K_0 and L can be lifted!

Lavalle+ (2014)



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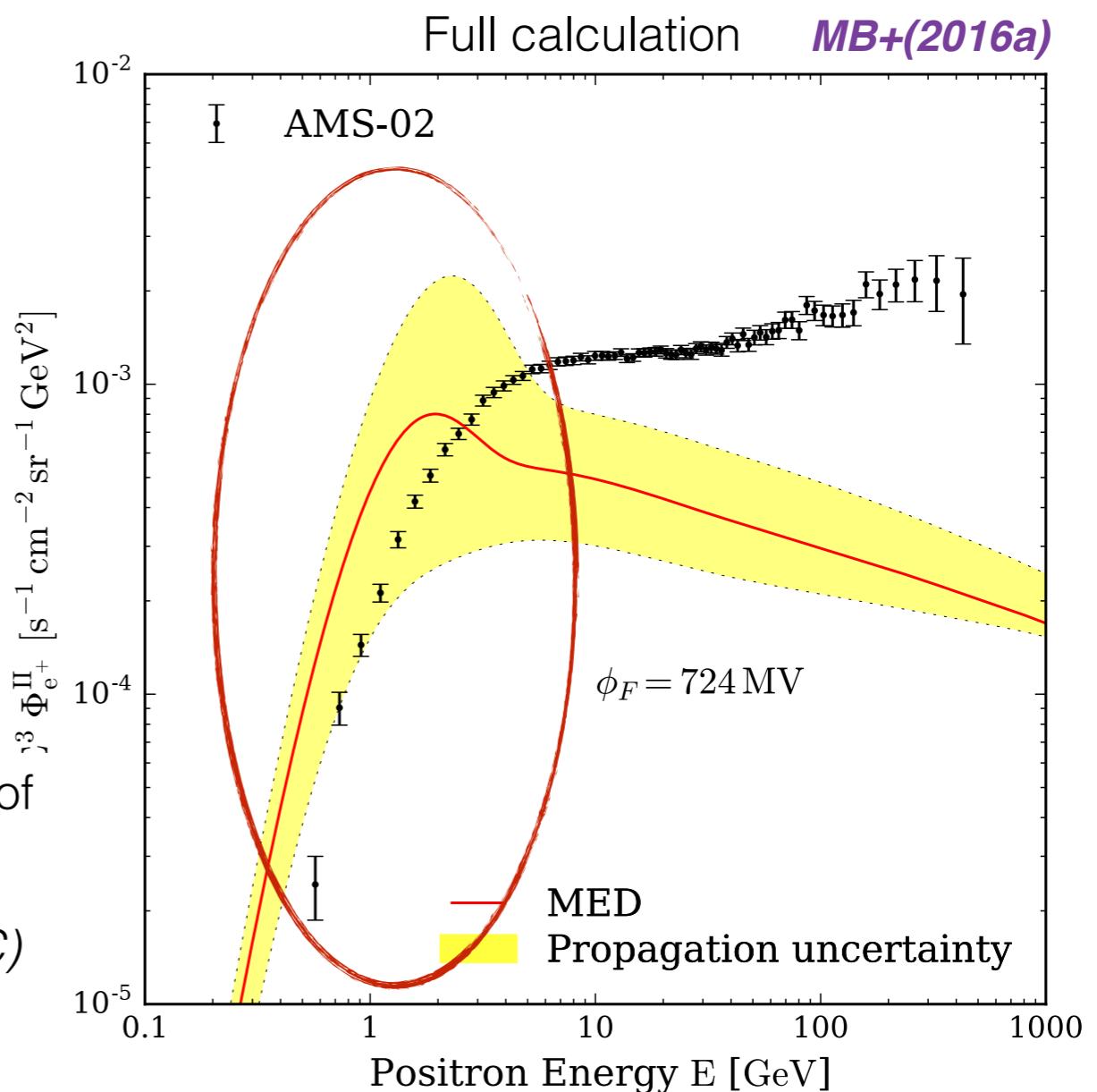
Lavalle+(2014)

Case	δ	K_0 [kpc ² /Myr]	L [kpc]	V_C [km/s]	V_a [km/s]
MIN	0.85	0.0016	1	13.5	22.4
MED	0.70	0.0112	4	12	52.9
MAX	0.46	0.0765	15	5	117.6

Ruled out!

The AMS-02 positrons data favour the **MAX-type** sets of propagation parameters.

(result confirmed by AMS-02 antiprotons and recent B/C)



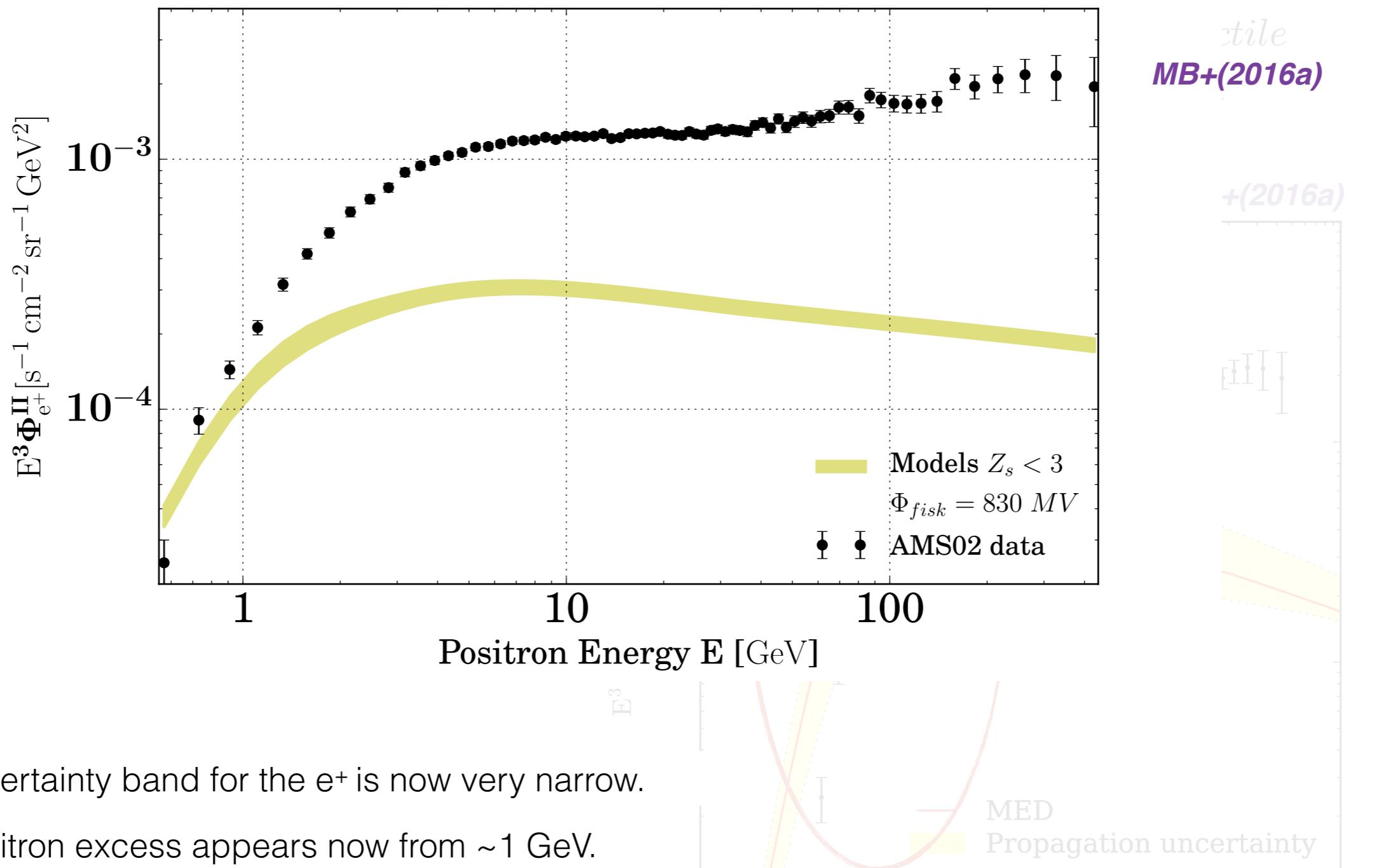
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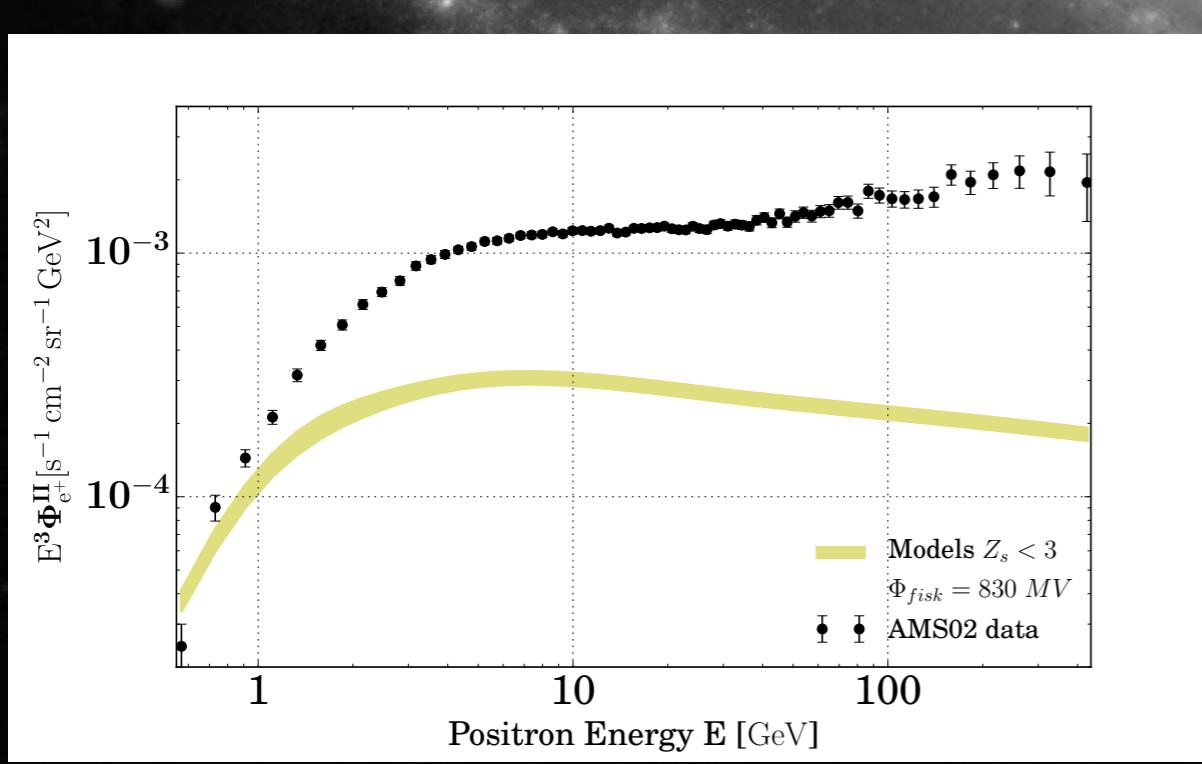
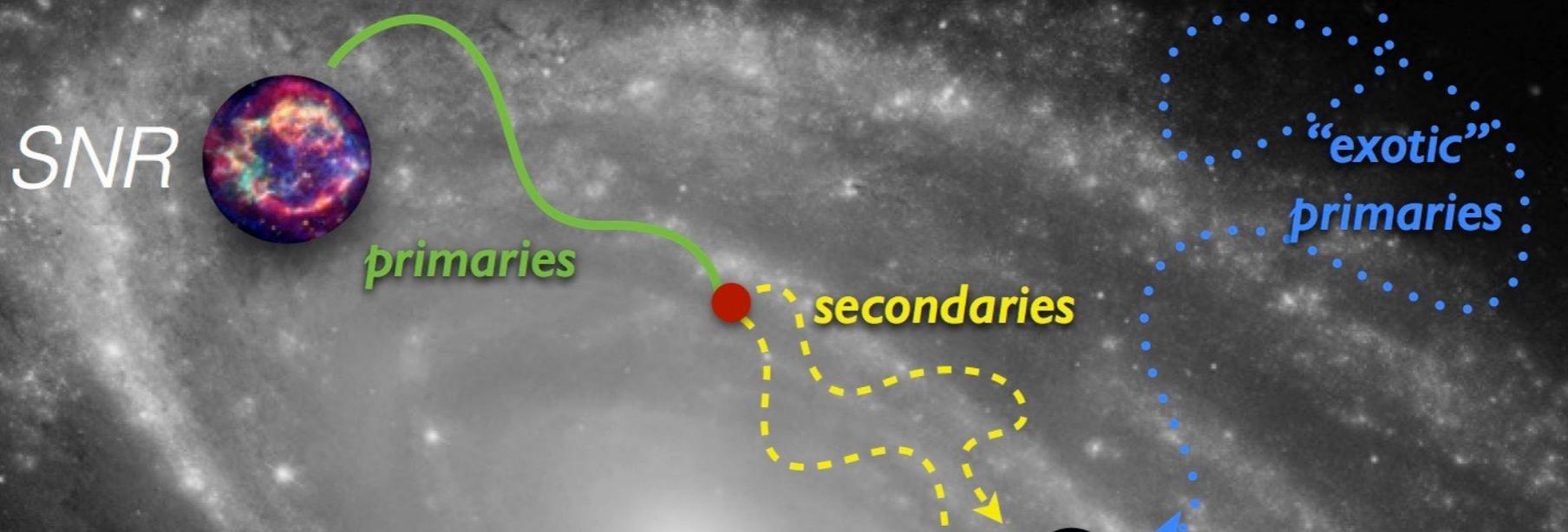


- The uncertainty band for the e⁺ is now very narrow.
- The positron excess appears now from ~1 GeV.
- Where do come from the remaining positrons?
- We need another component(s) to explain the positron data **from ~1 GeV to ~500 GeV**.

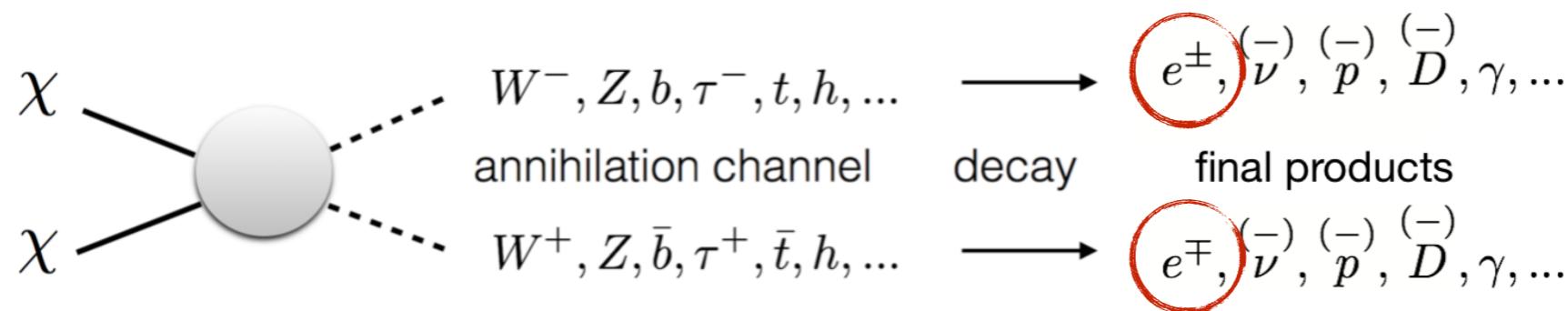
- 1- Introduction
- 2- Propagation of cosmic rays: the diffusion model
- 3- The *pinching method* for low energy e^- and e^+
- 4- Implications for dark matter searches**
- 6- Conclusions and outlooks

Implications for dark matter searches

The dark matter scenario



The dark matter scenario



A very generic class of models

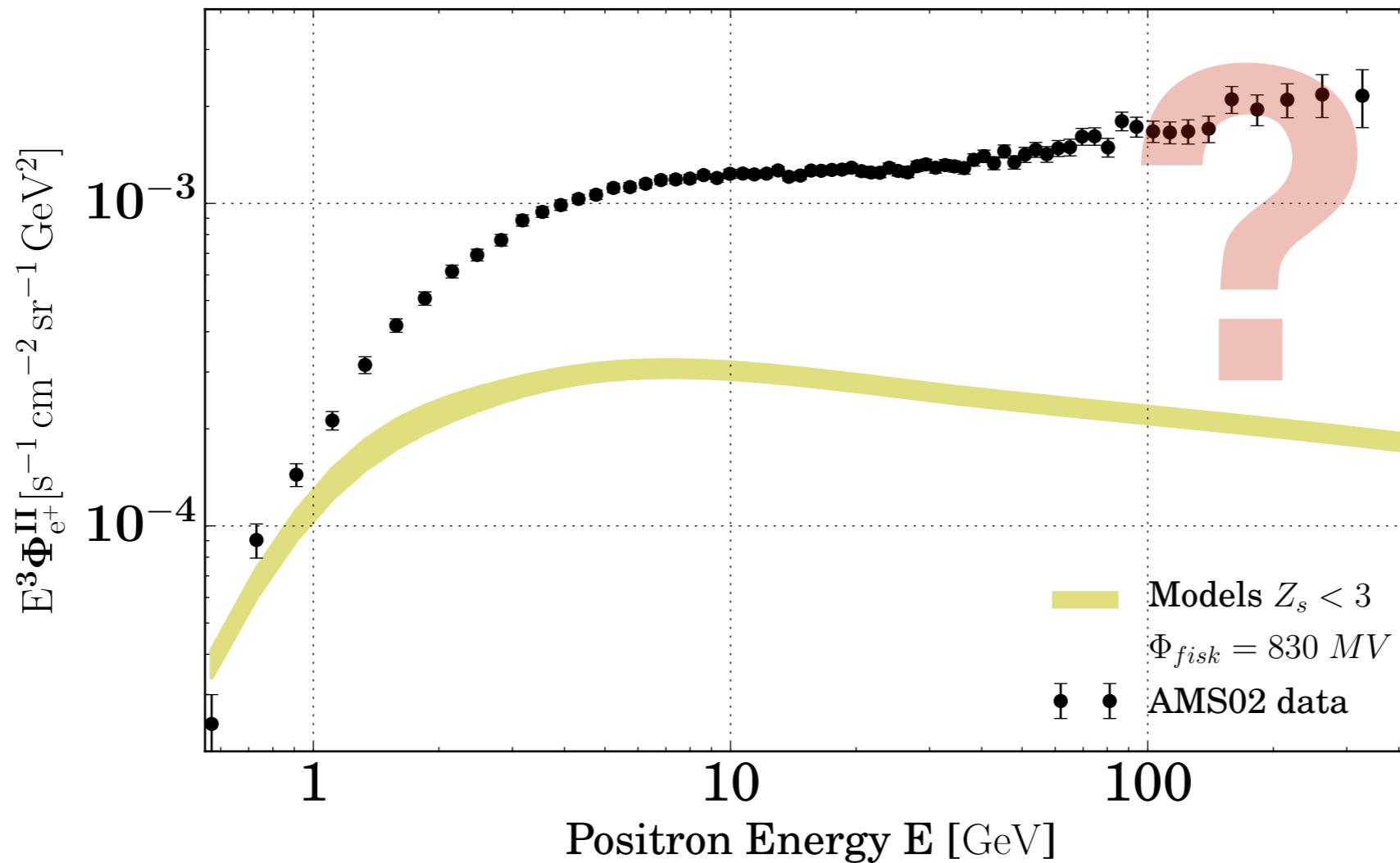
$$\chi\chi \rightarrow B_b \bar{b}b + B_W W^+W^- + B_\tau \tau^+\tau^- + B_\mu \mu^+\mu^- + B_e e^+e^-$$

Free parameters

- Propagation parameters
(consistent with secondaries)
 K_0, δ, L, V_C, V_A
- Dark matter parameters
The mass m_χ
The annihilating cross section $\langle \sigma v \rangle$
- Solar modulation (Phisk potential)
 $\phi_F \in [647, 830] \text{ MV}$ (3 σ CL) *Ghelfi+(2015)*
- The branching ratios $B_b, B_W, B_\tau, B_\mu, B_e$

The Dark Matter scenario

Is it possible to obtain a satisfactory fit to the AMS-02 data?



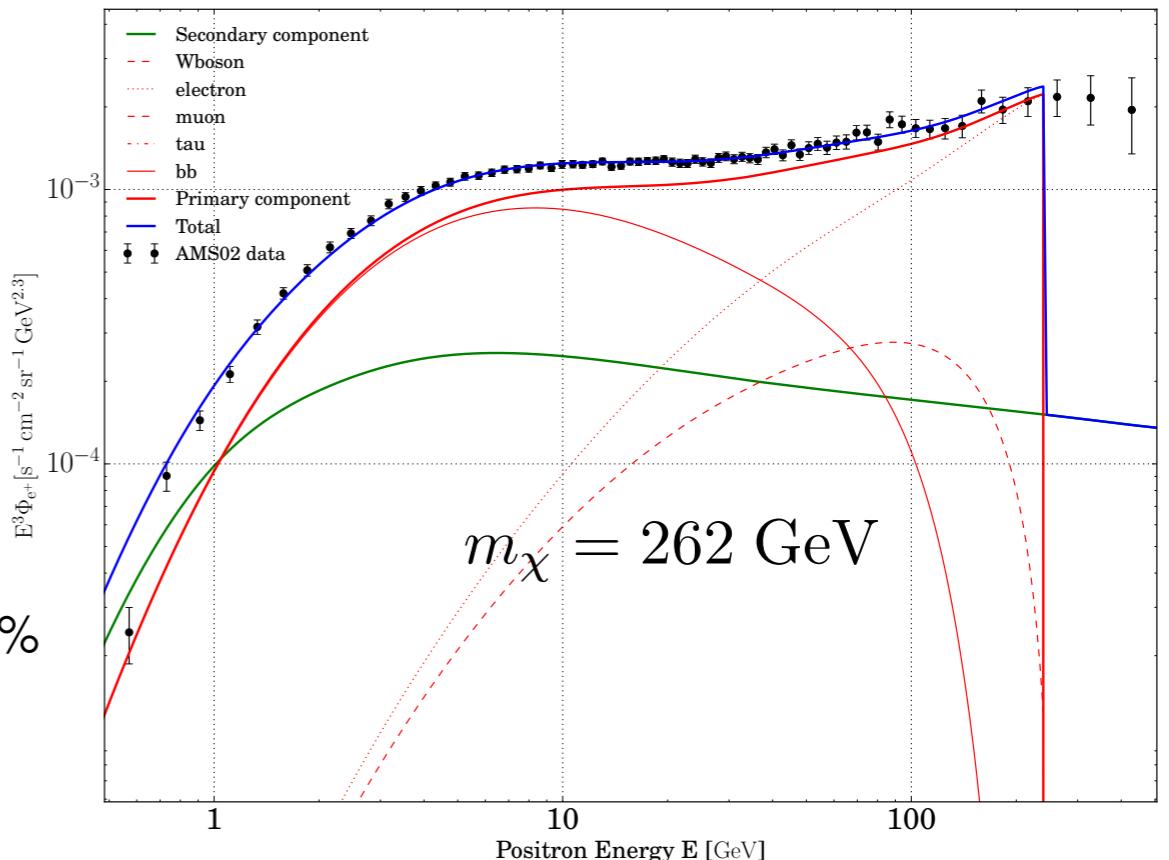
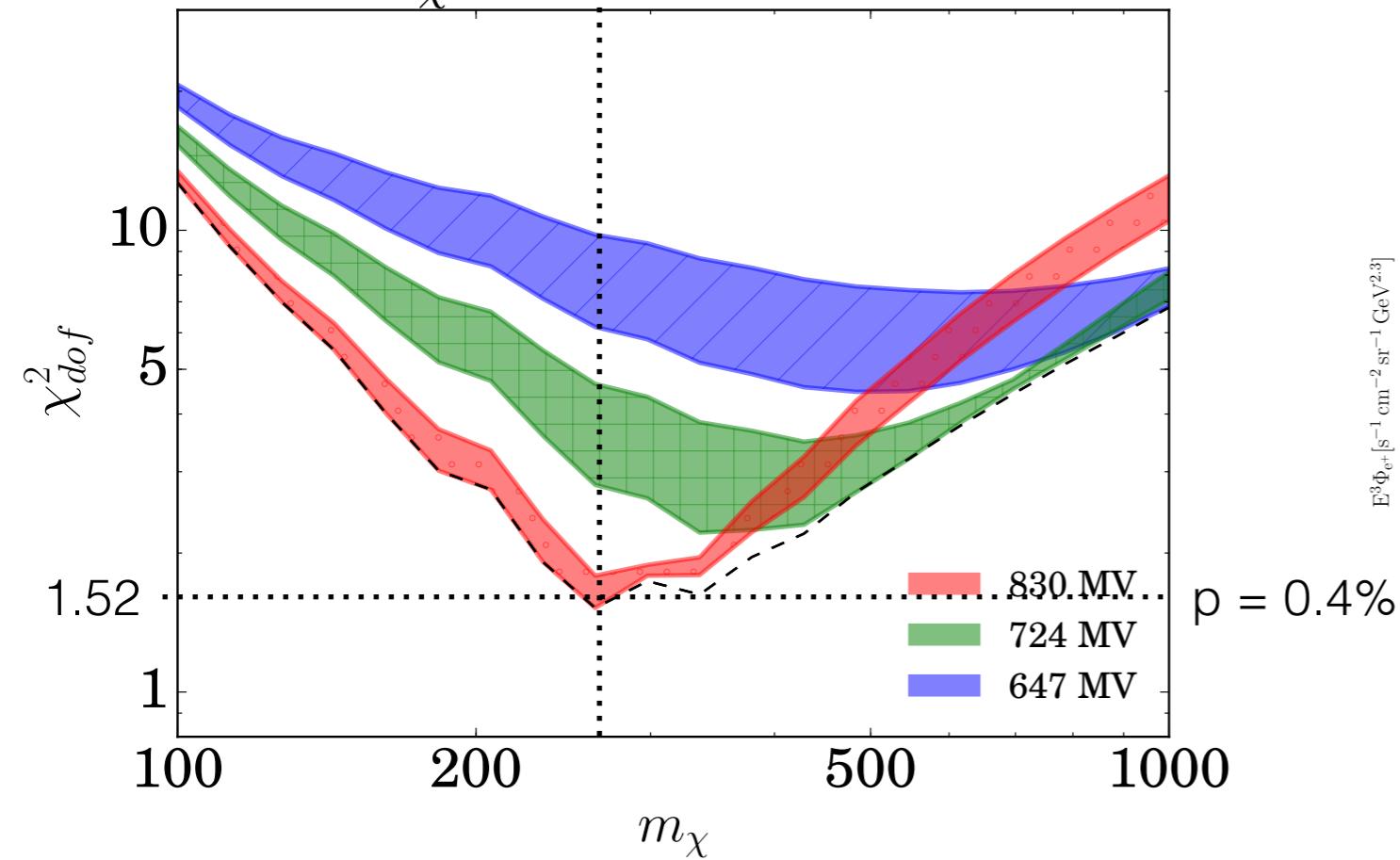
The Dark Matter scenario

Is it possible to obtain a satisfactory fit to the AMS-02 data?

NO !

MB+(2016a)

$m_\chi = 262 \text{ GeV}$



The spectrum of e^+ from DM annihilations **cannot** account for the **shape** of the spectrum measured by AMS-02.

The positron flux produced by DM is restricted « around » the DM mass.

The poor quality of the fit disfavours a pure DM explanation for the positron excess!

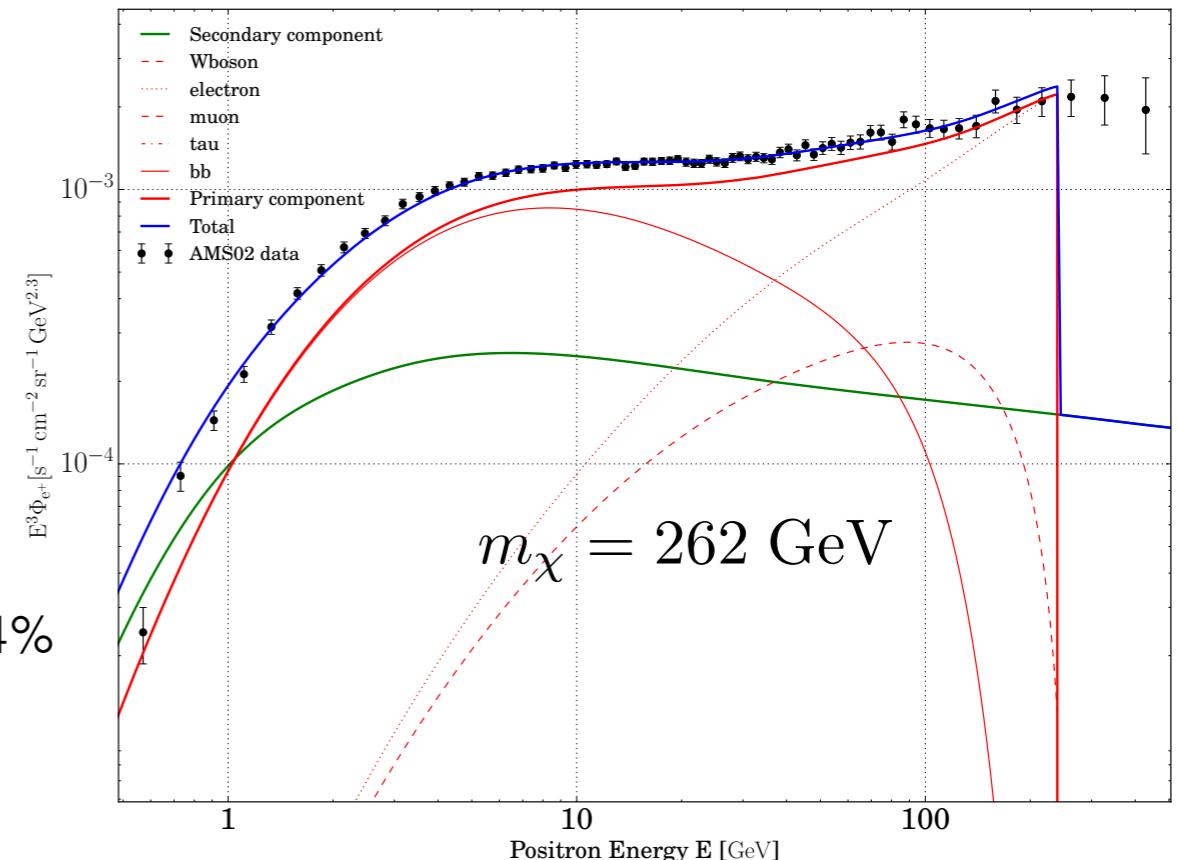
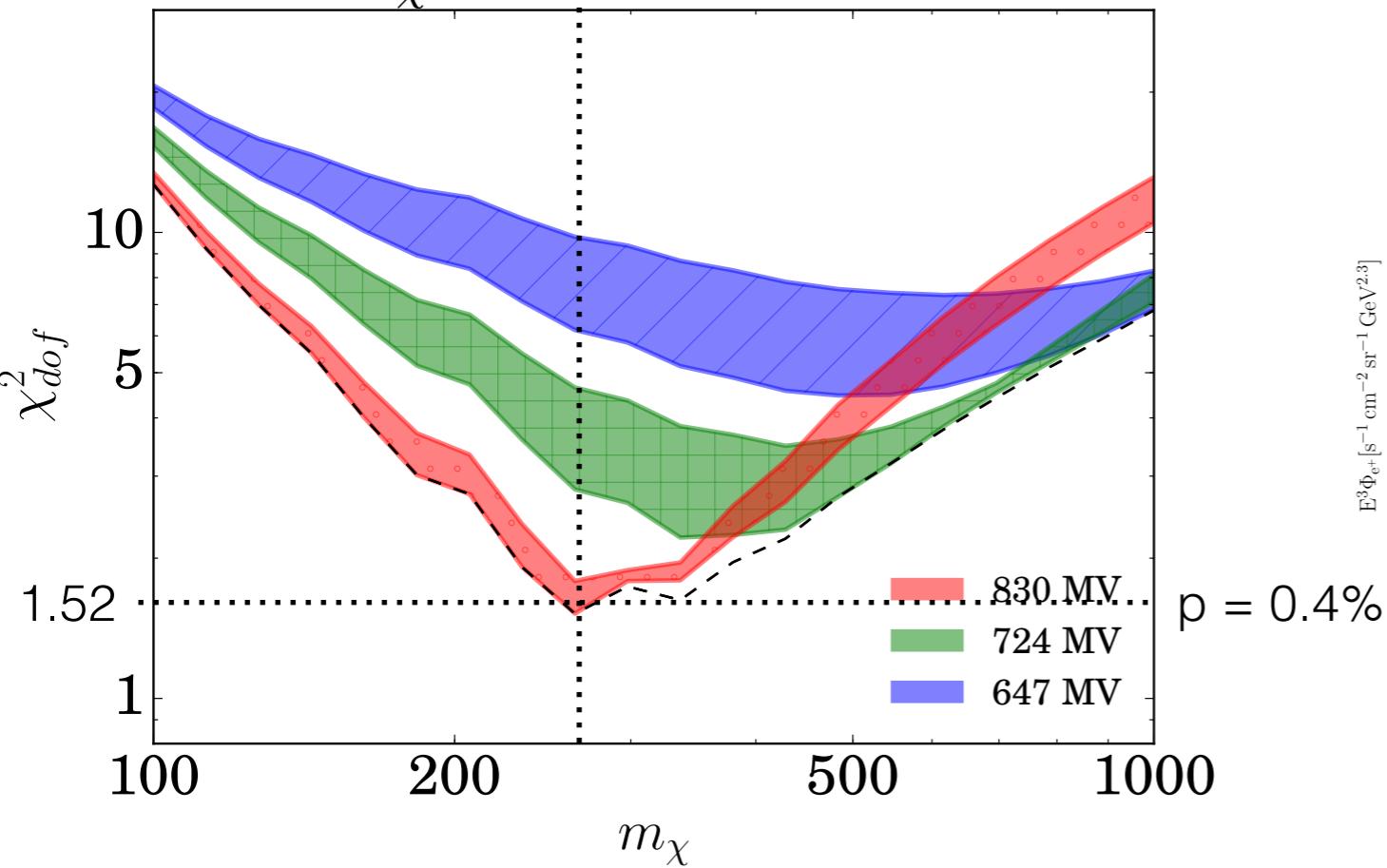
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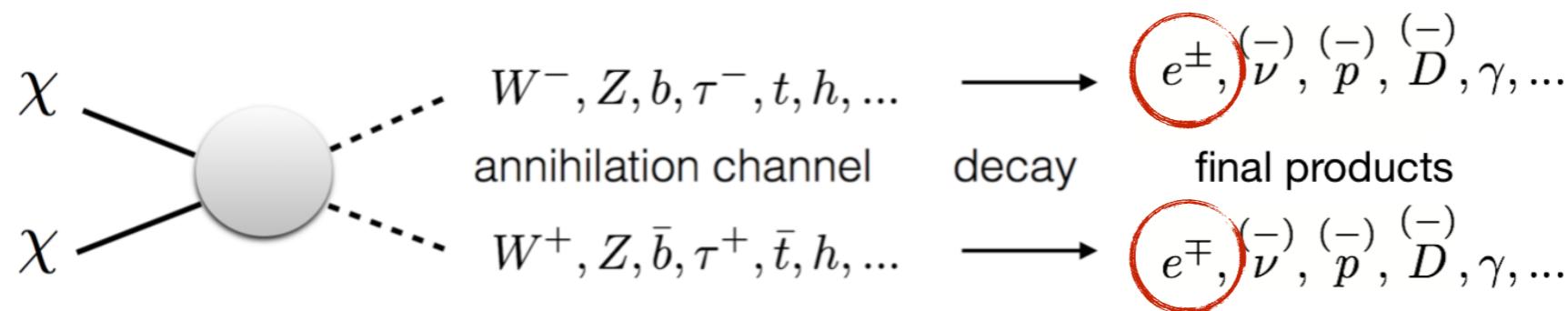
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$$\chi\chi \rightarrow \phi\phi \rightarrow 2B_e e^+e^- + 2B_\mu \mu^+\mu^- + 2B_\tau \tau^+\tau^-$$

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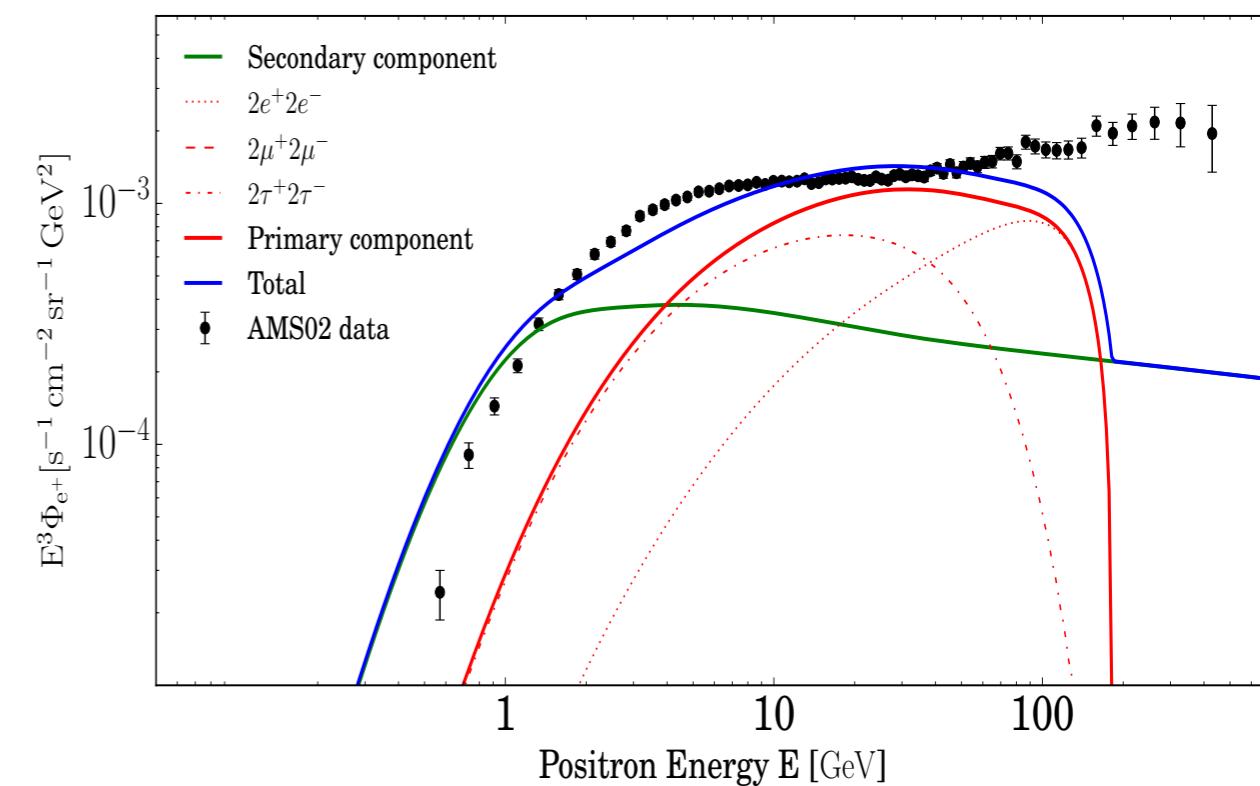
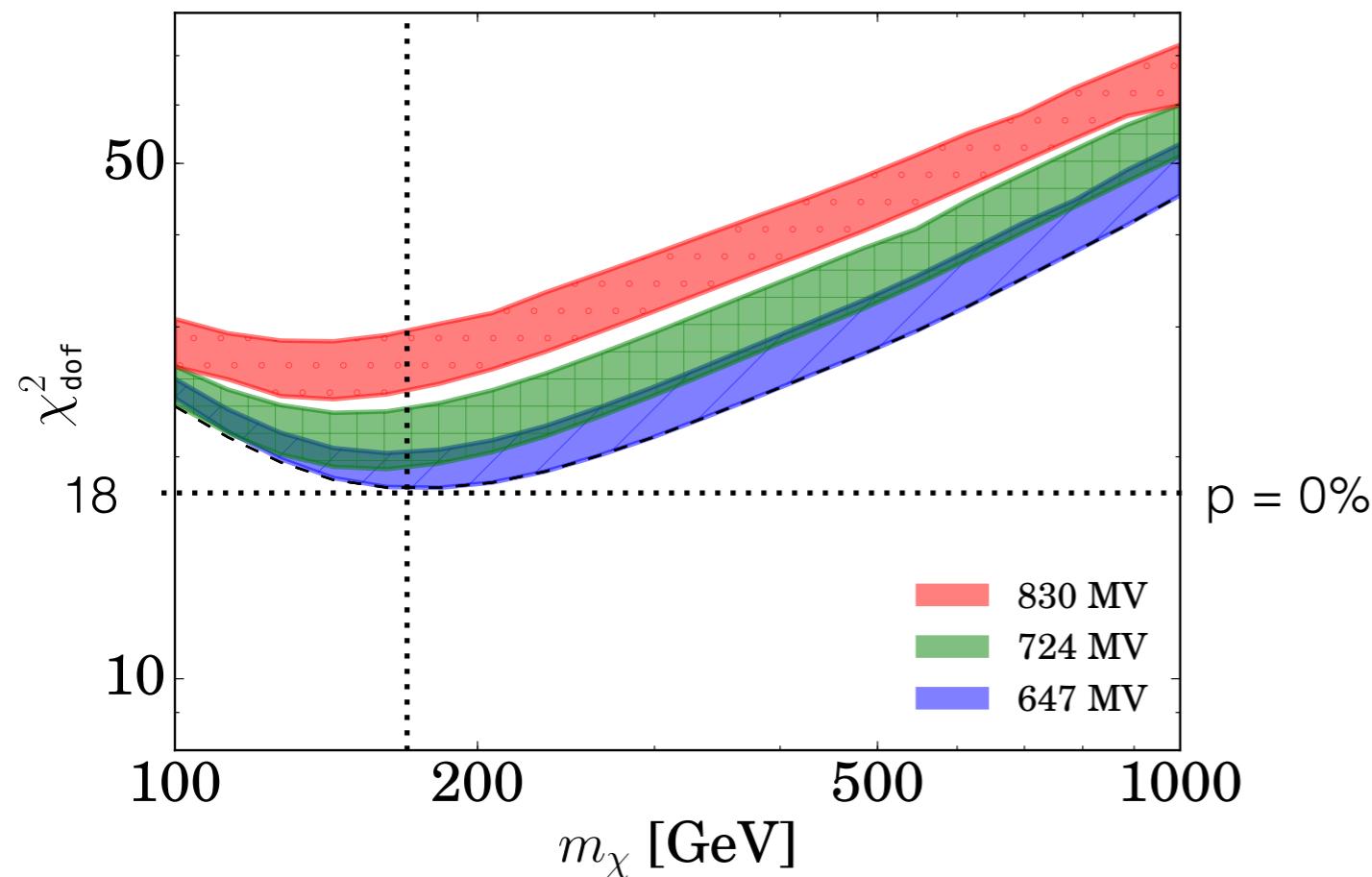
The Dark Matter scenario

Is it possible to obtain a satisfactory fit to the AMS-02 data?

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$$m_\chi = 183 \text{ GeV}$$

MB+(2016a)



The spectrum of e^+ from DM annihilations **cannot** account for the **shape** of the spectrum measured by AMS-02.

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This conclusion is based only on the positron data and does not require constraints from other channels
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Why there is no constraints on MeV dark matter from CR e⁻ and e⁺?

- So far, we needed numerical codes to solve the transport equation in the sub-GeV energy range to predict the interstellar (IS) flux of e⁻ and e⁺. Important CPU time to derive bounds on the DM particle annihilation cross-section.

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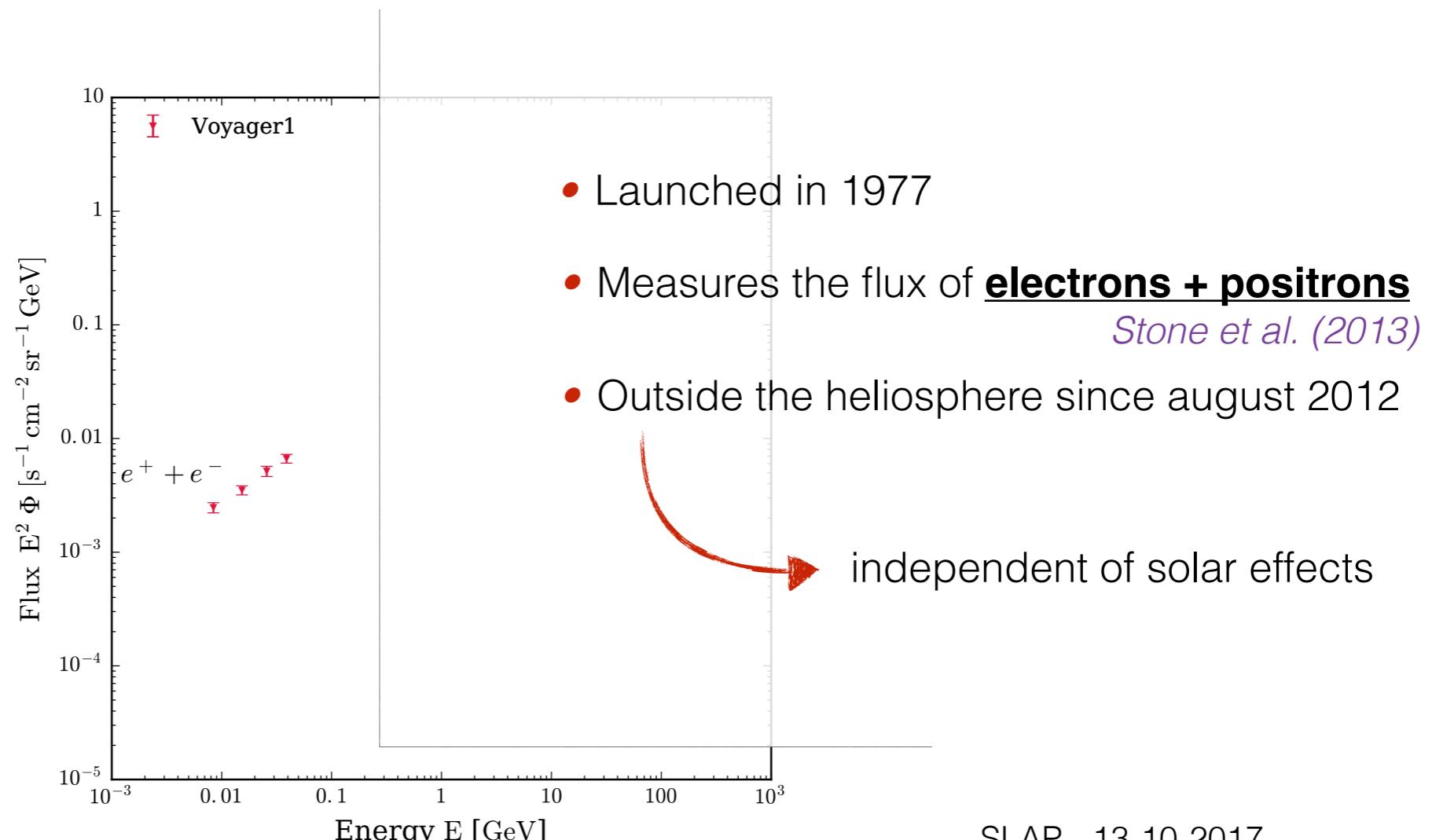
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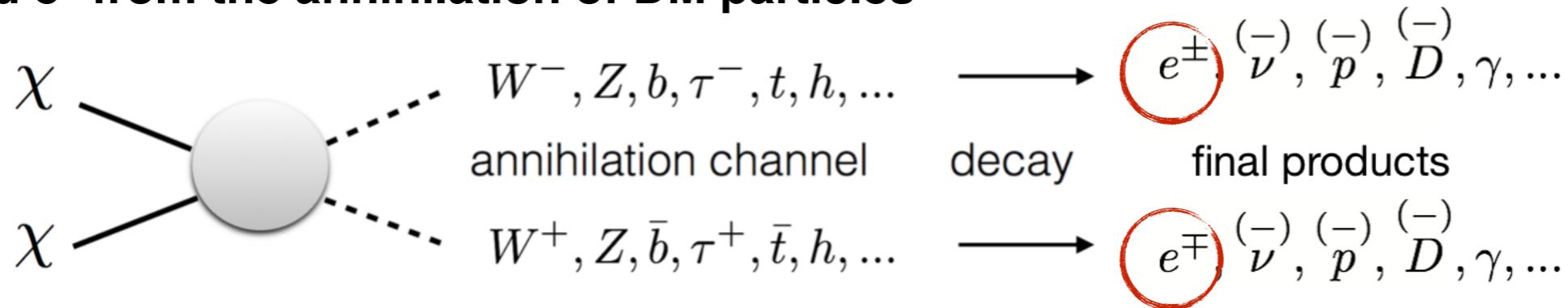
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✓ **Voyager-1 spacecraft has crossed the heliopause during summer 2012.**



e⁻ and e⁺ from the annihilation of DM particles



$$Q_{e^+}^{\text{DM}}(E, \vec{x}) = \underbrace{\left(\frac{\rho(\vec{x})}{m_\chi} \right)^2}_{\text{astrophysics}} \times \frac{1}{2} \sum_i \langle \sigma v \rangle B_i \frac{dN_i(E)}{dE}$$

$\rho(\vec{x})$: DM density profile
NFW *McMillan(2016)*

$\frac{dN_i}{dE}$: e⁻ and e⁺ spectrum at source
MicrOmegas

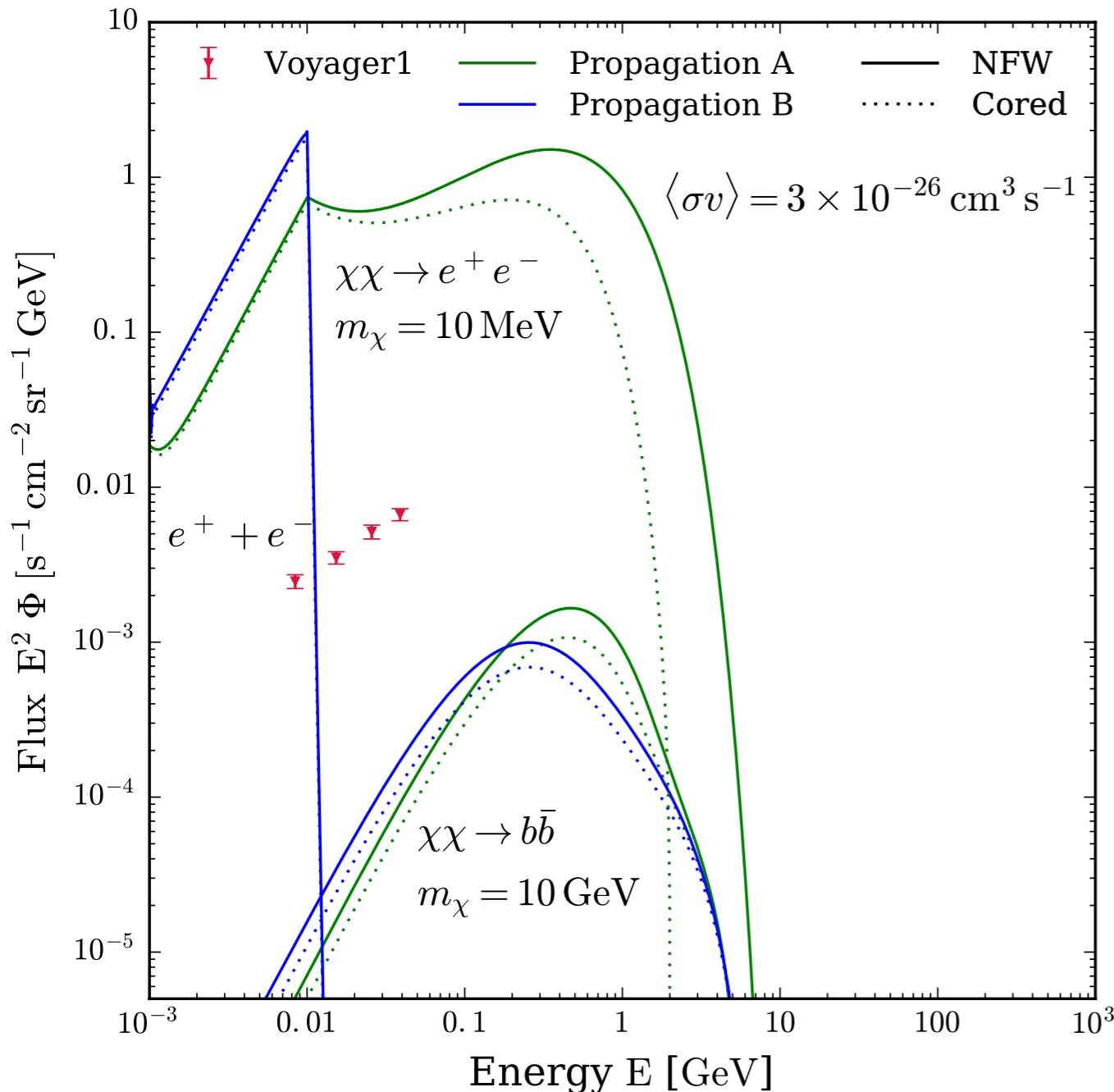
Cored *McMillan(2016)*

Cosmic rays propagation parameters

- **Model A:** MAX from B/C analysis of *Maurin+(2001)* consistent with AMS-02 positrons and antiprotons data.
- **Model B:** best fit model of *Kappl+(2015)* on preliminary AMS-02 B/C data.

$V_A = 117.6 \text{ km/s}$
 $V_A = 31.9 \text{ km/s}$

Constraints on DM annihilating cross section



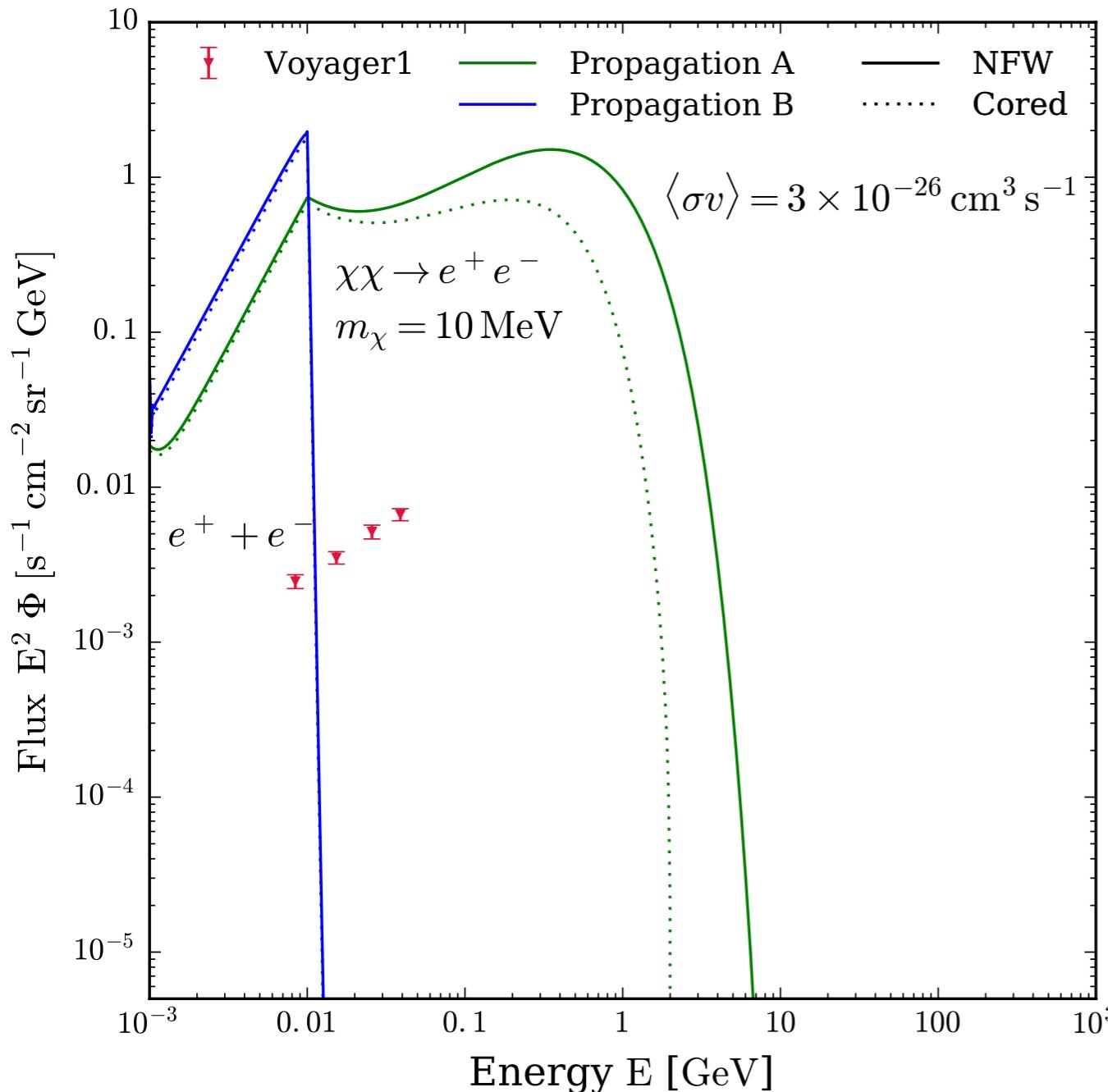
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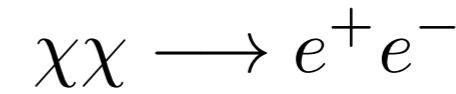


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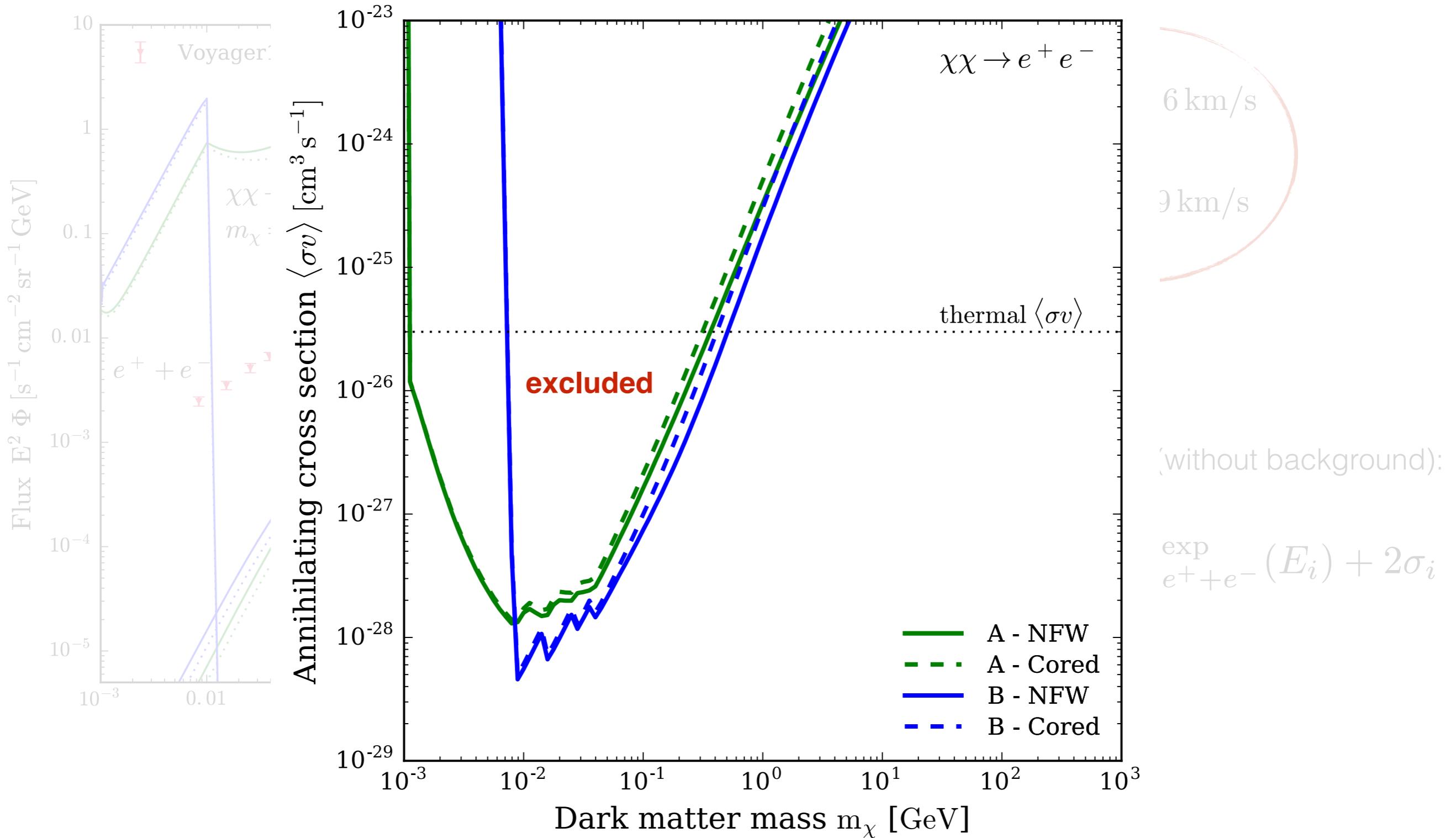
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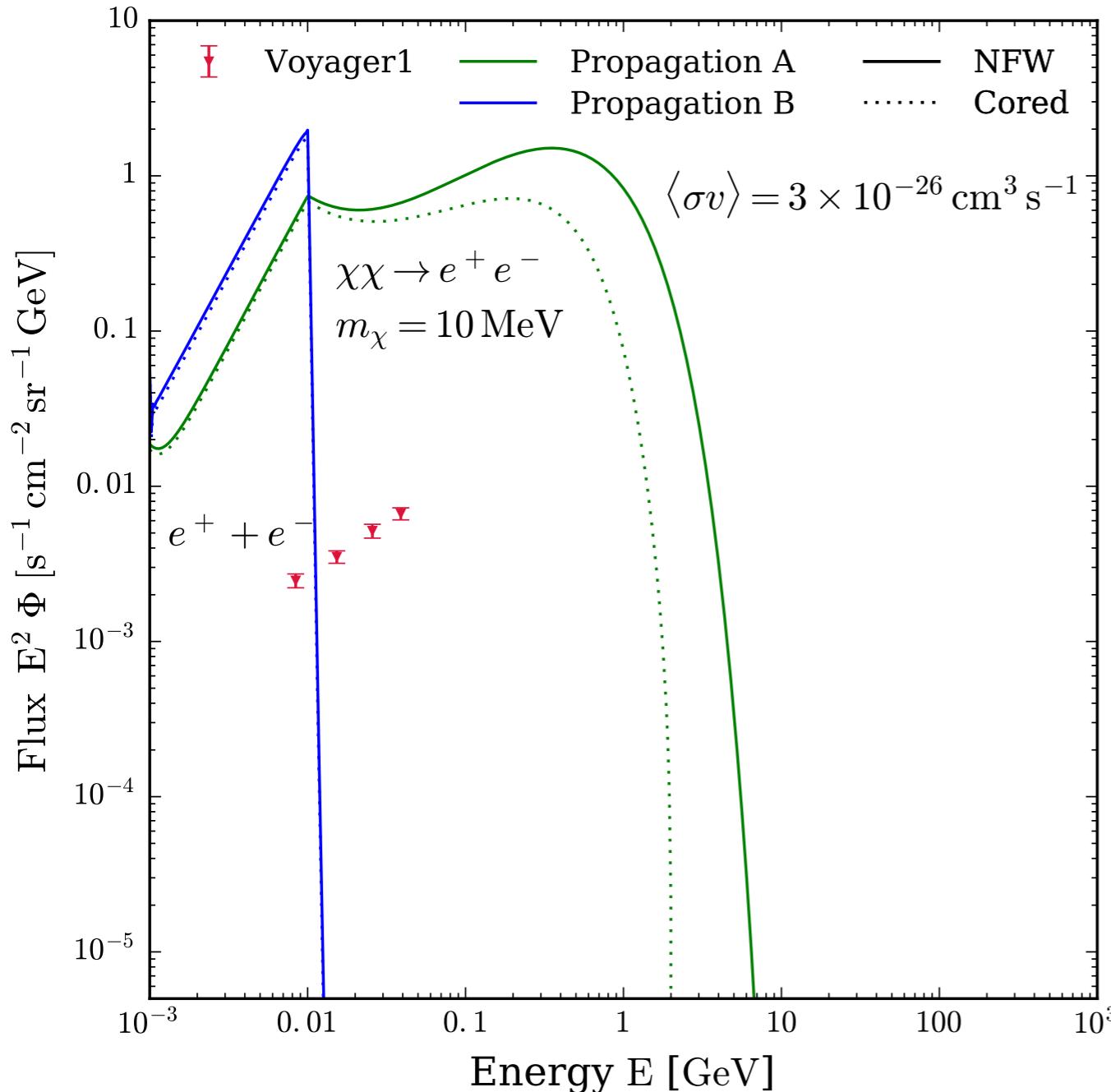
Conservative constraints (without background):

$$\Phi_{e^+ + e^-}^{\text{DM}}(E_i) \leq \Phi_{e^+ + e^-}^{\text{exp}}(E_i) + 2\sigma_i$$

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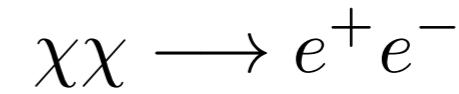


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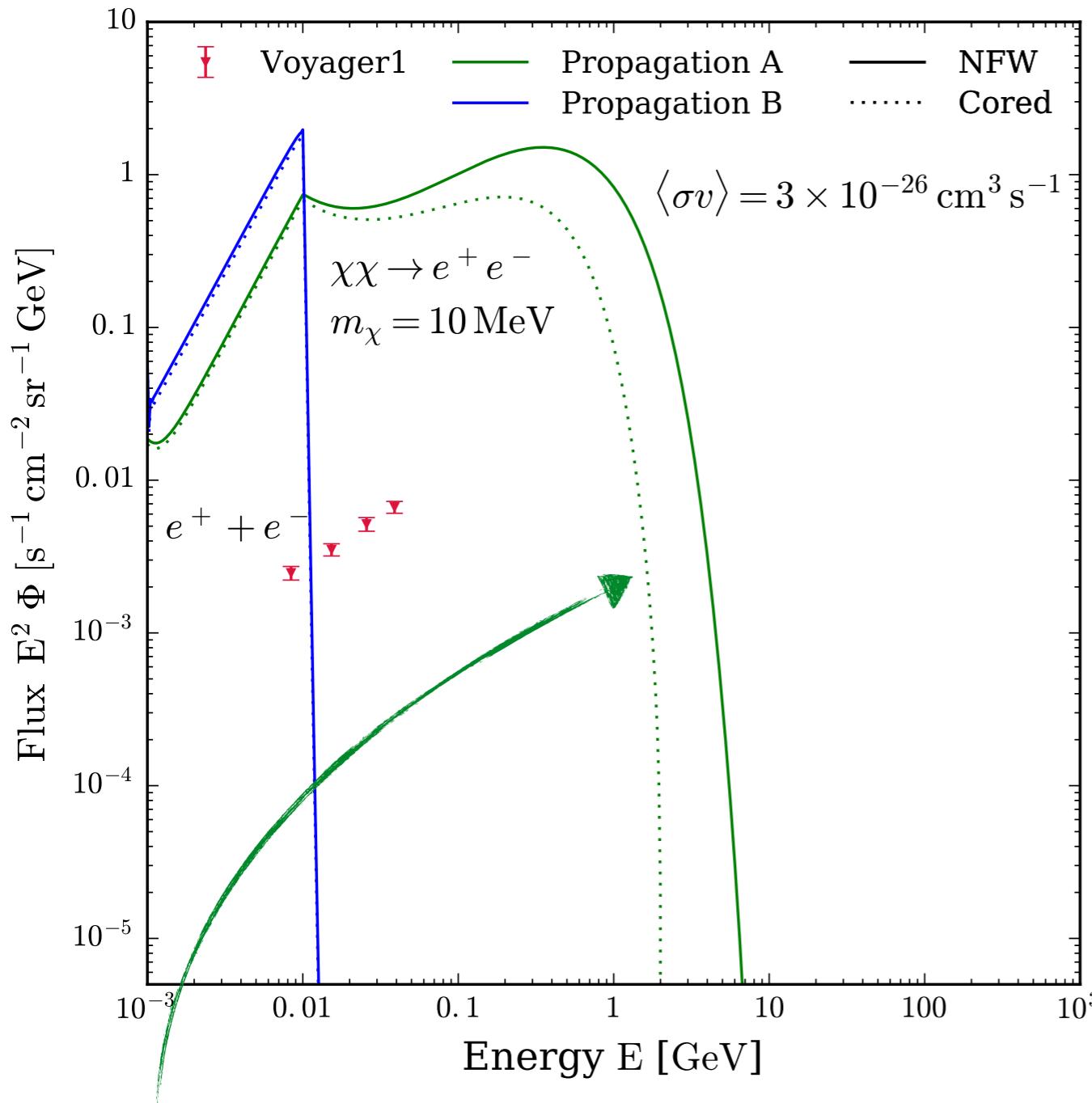
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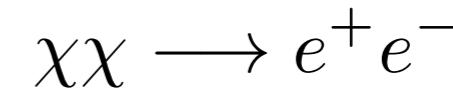
Models with strong diffusive reacceleration enable to detect positrons above the DM mass!

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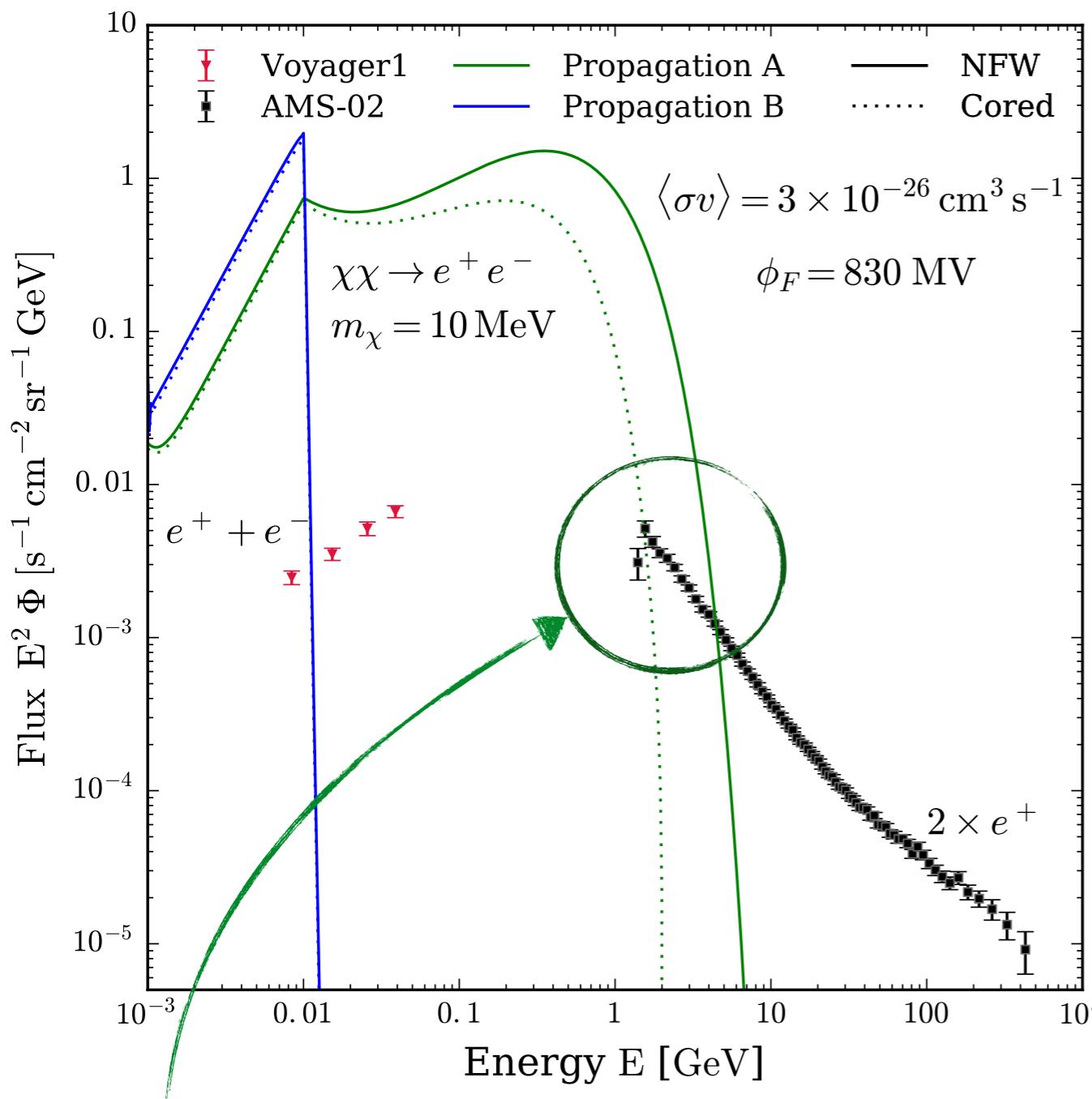
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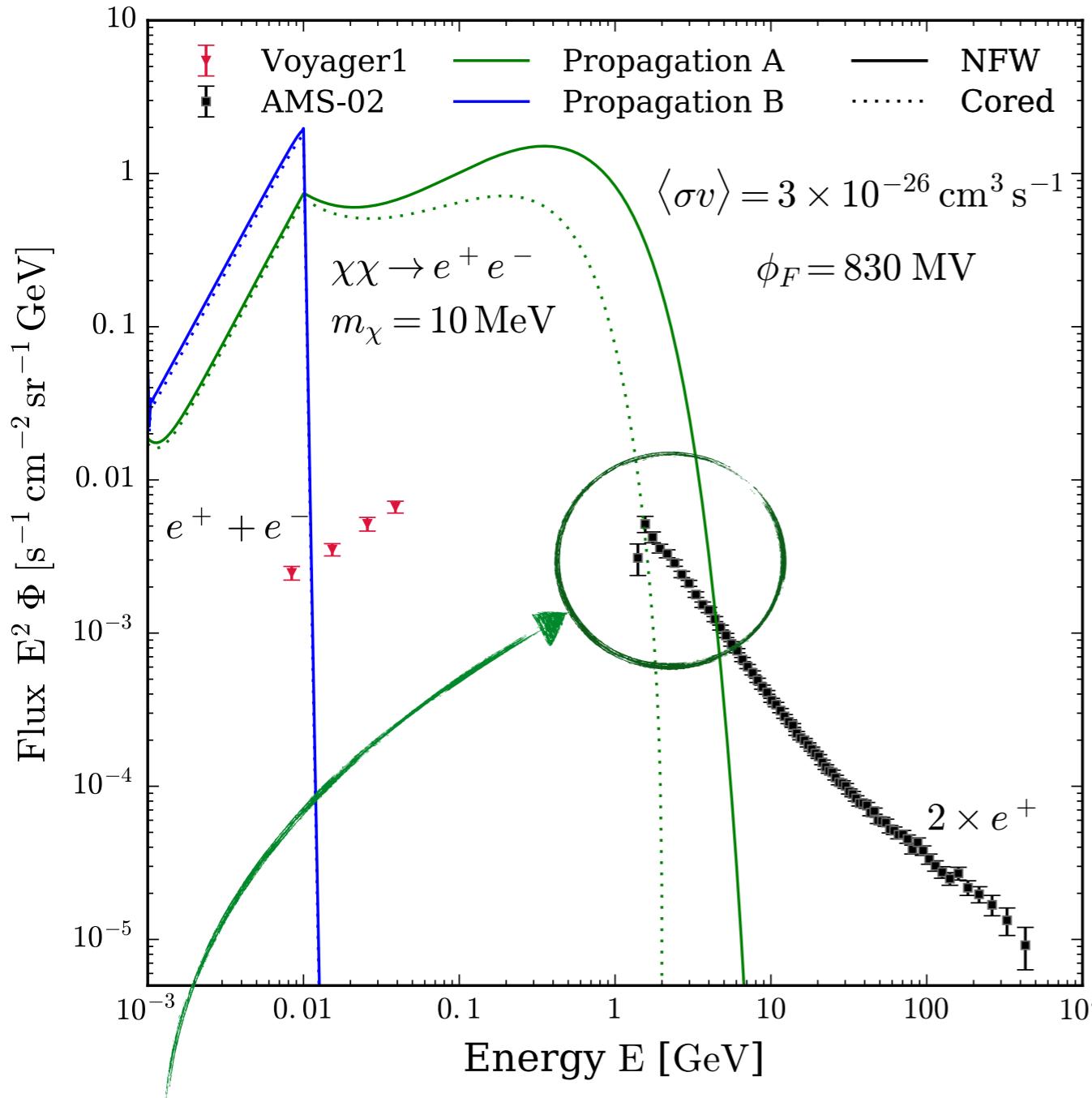
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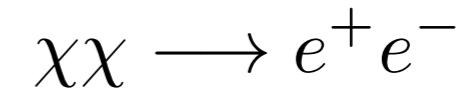


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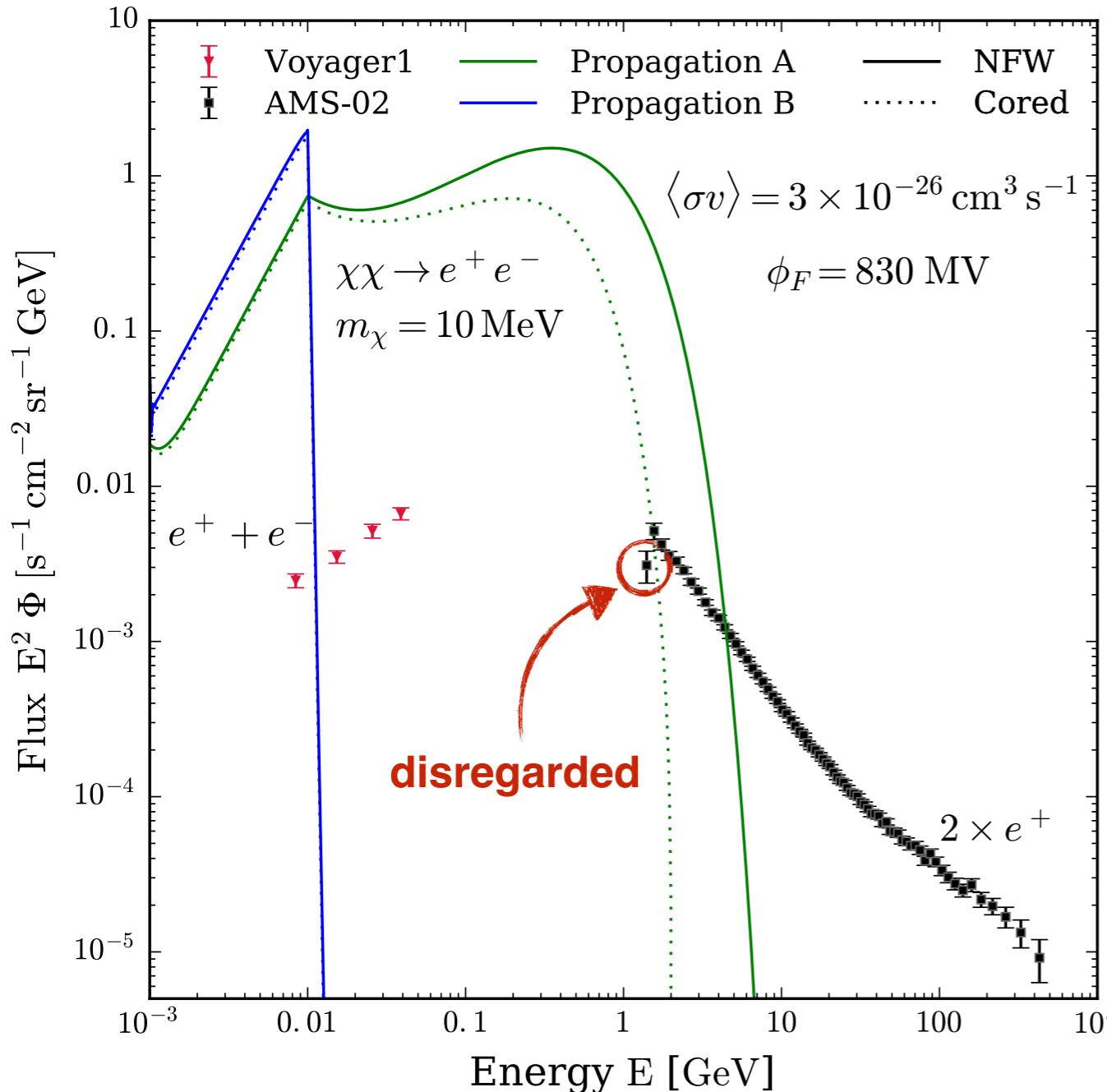
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Models with strong diffusive reacceleration enable to detect positrons above the DM mass!

We can combine the **Voyager1** and **AMS-02** data to improve the constraints.

Constraints on DM annihilating cross section

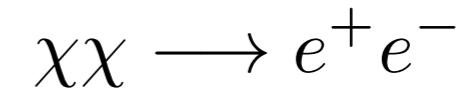


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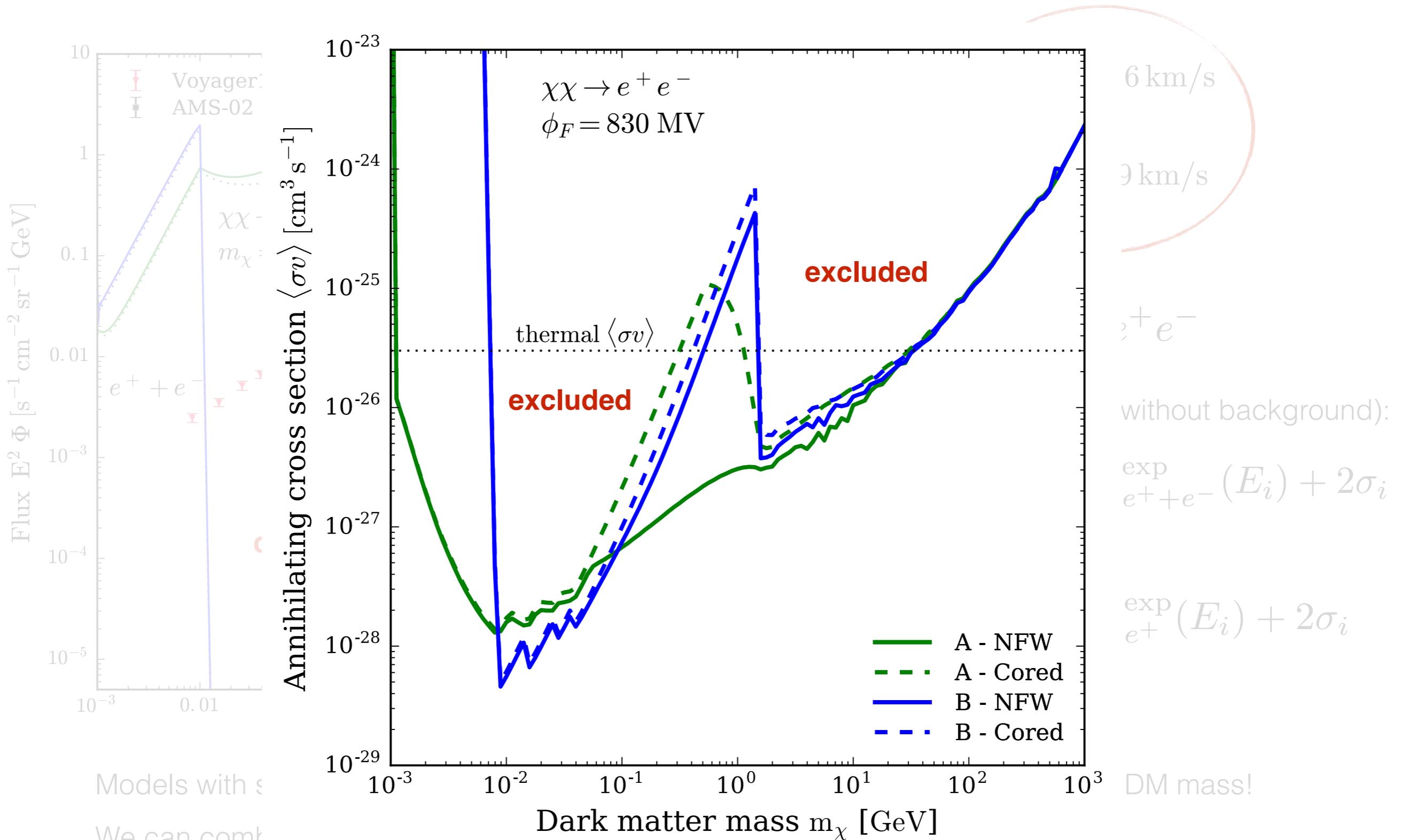
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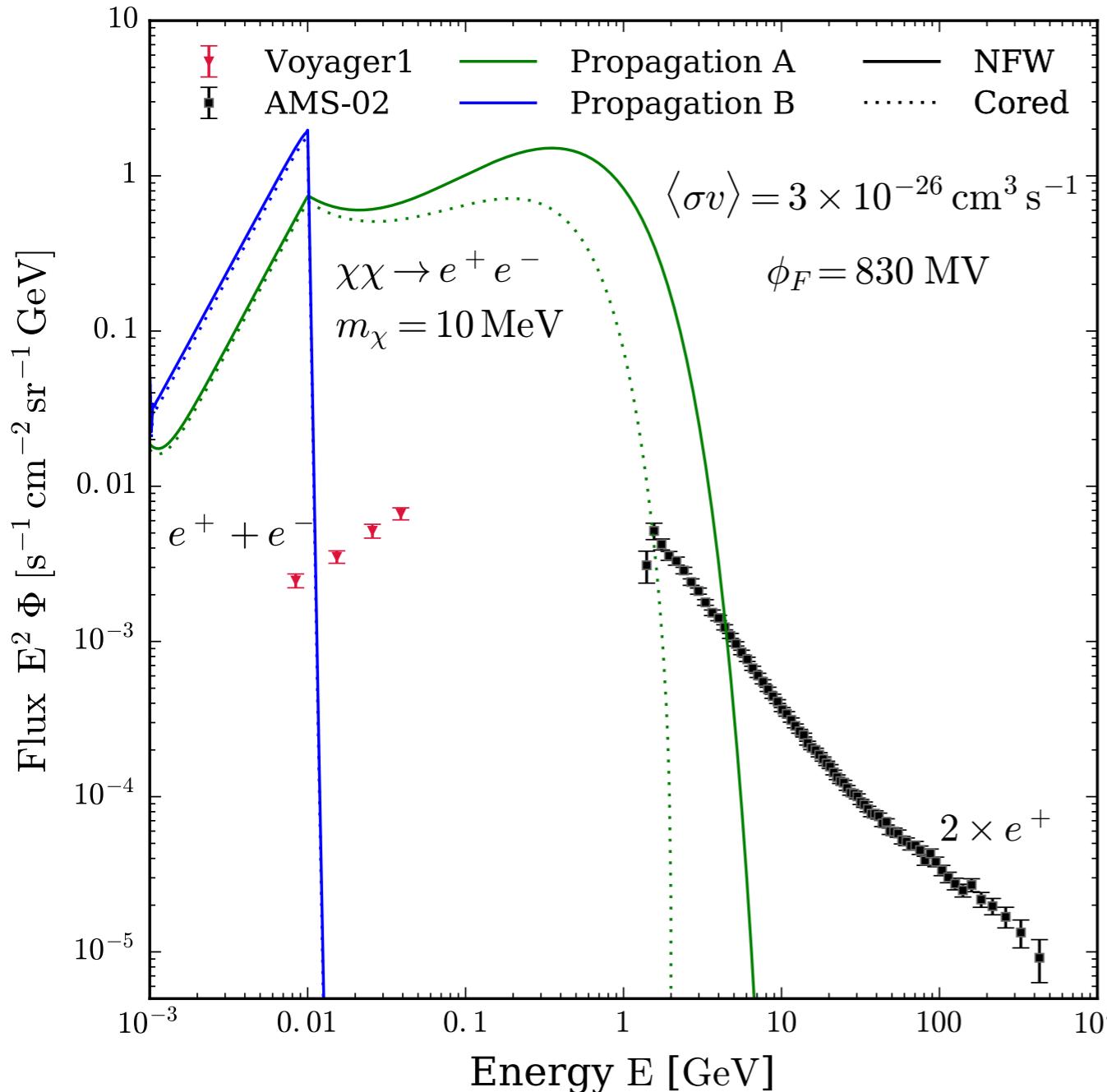
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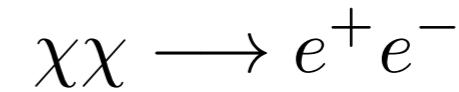


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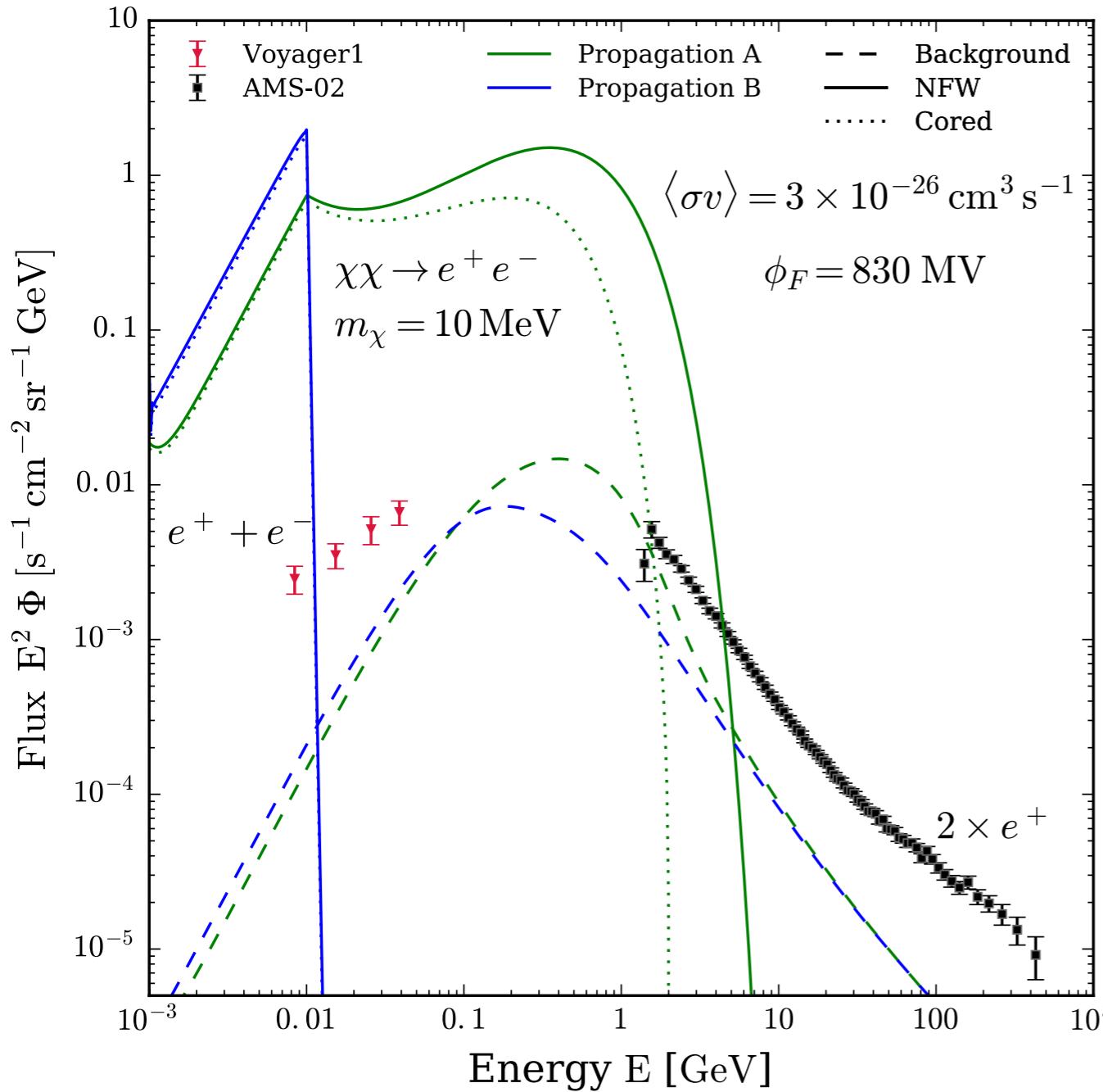
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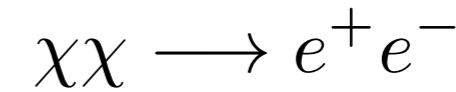


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With astrophysical background of secondary e^+ :

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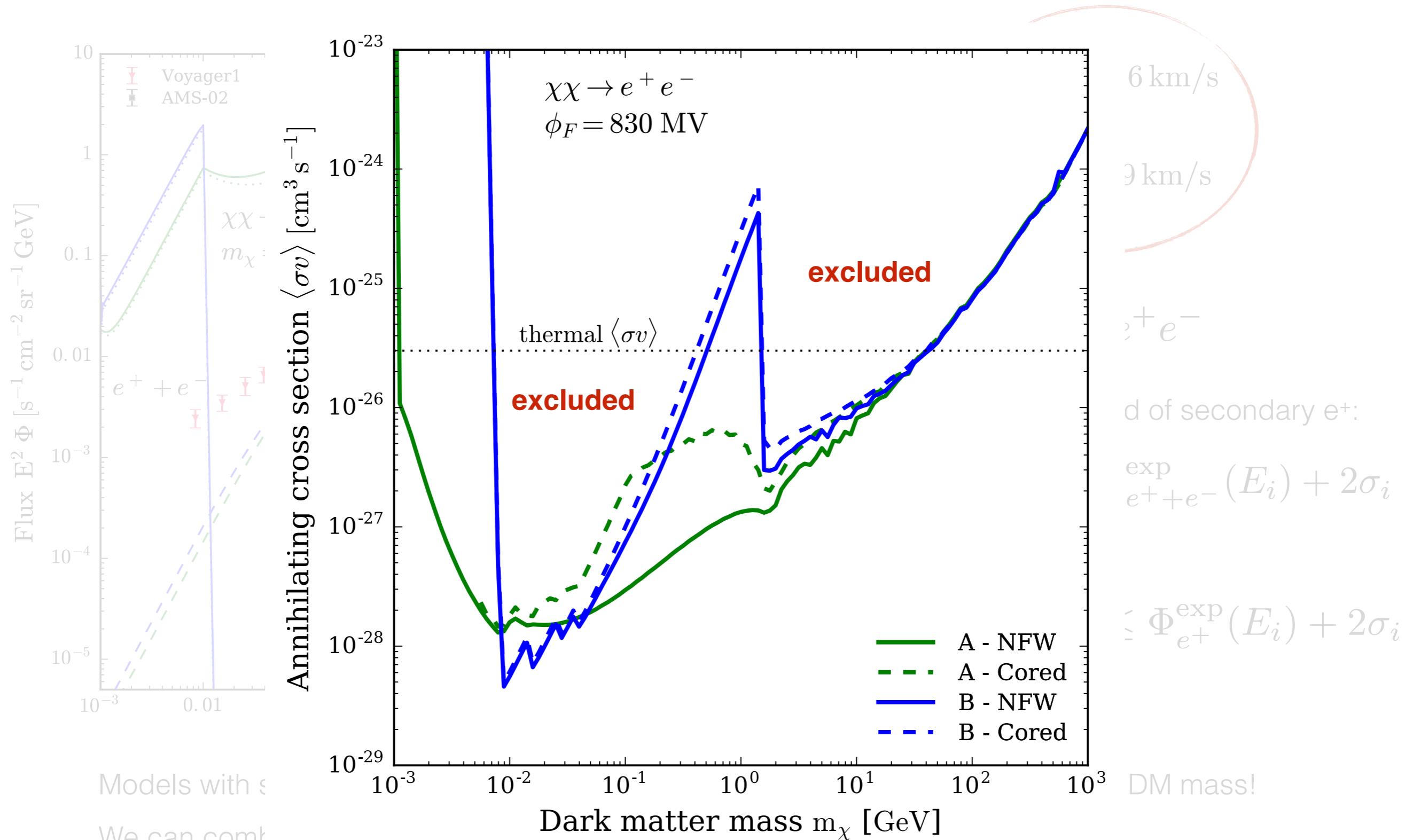
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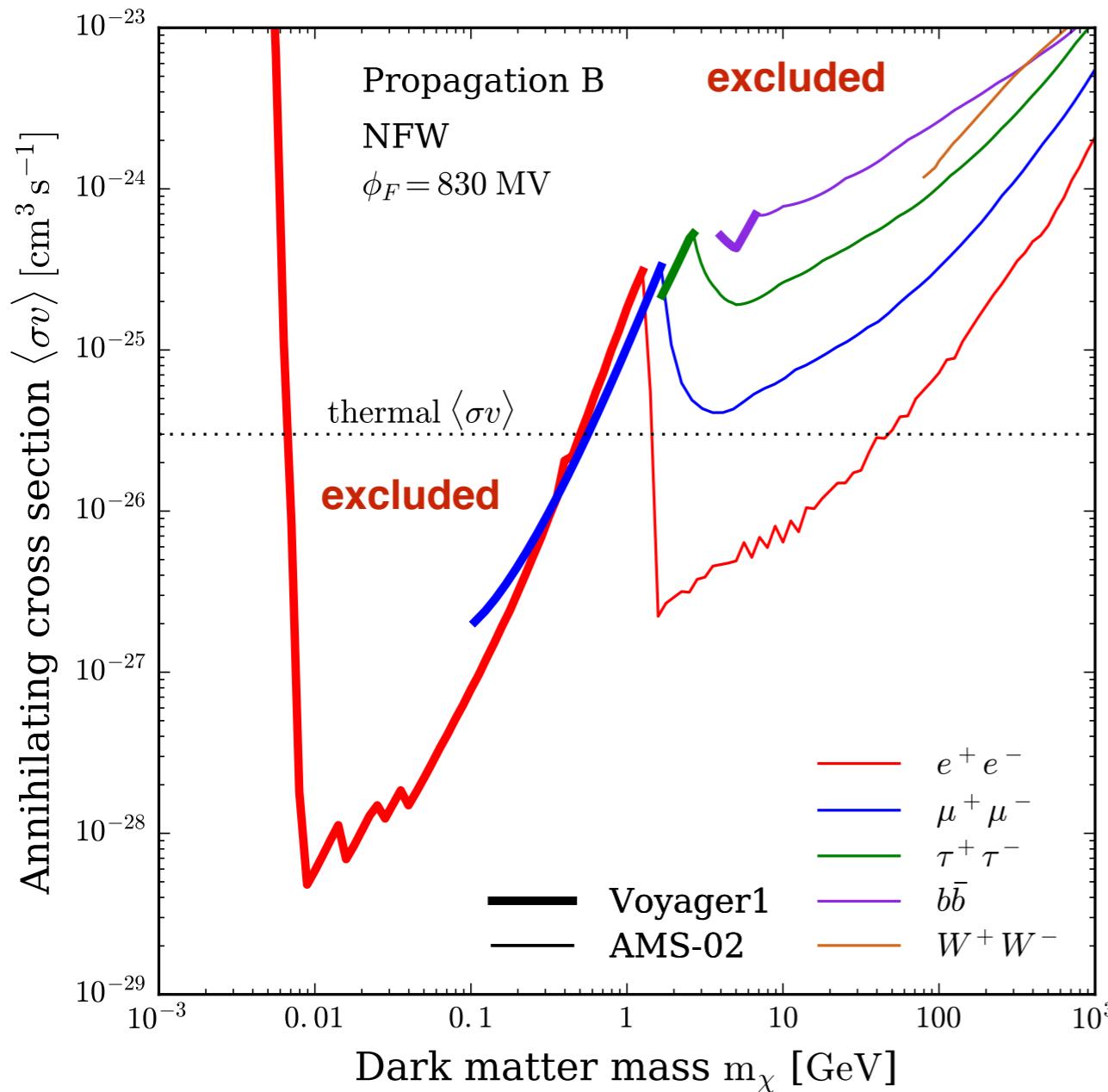
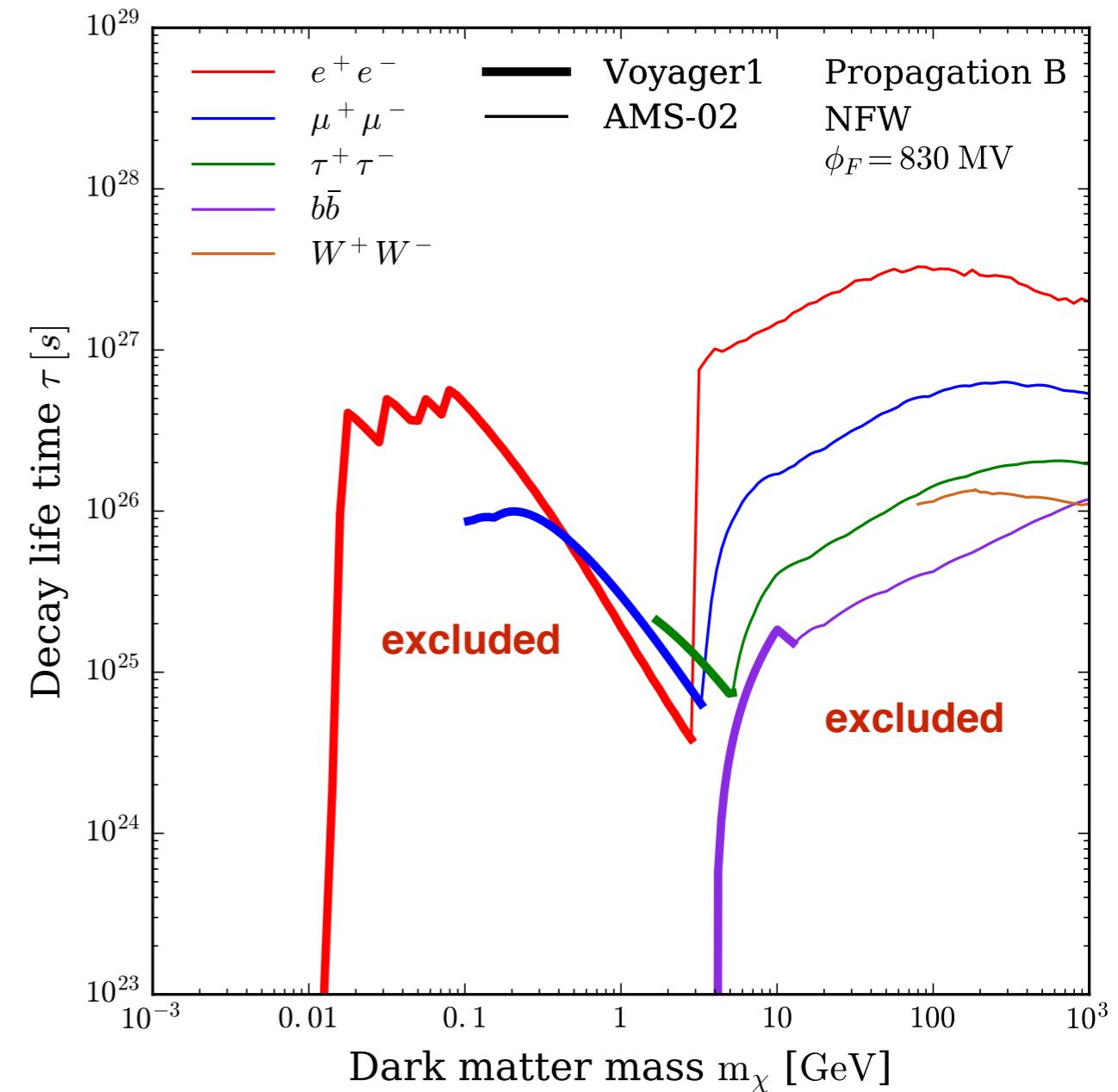
$$\Phi_{e^+}^{\text{DM}}(E_i) + \Phi_{e^+}^{\text{II}}(E_i) \leq \Phi_{e^+}^{\text{exp}}(E_i) + 2\sigma_i$$

Models with strong diffusive reacceleration enable to detect positrons above the DM mass!

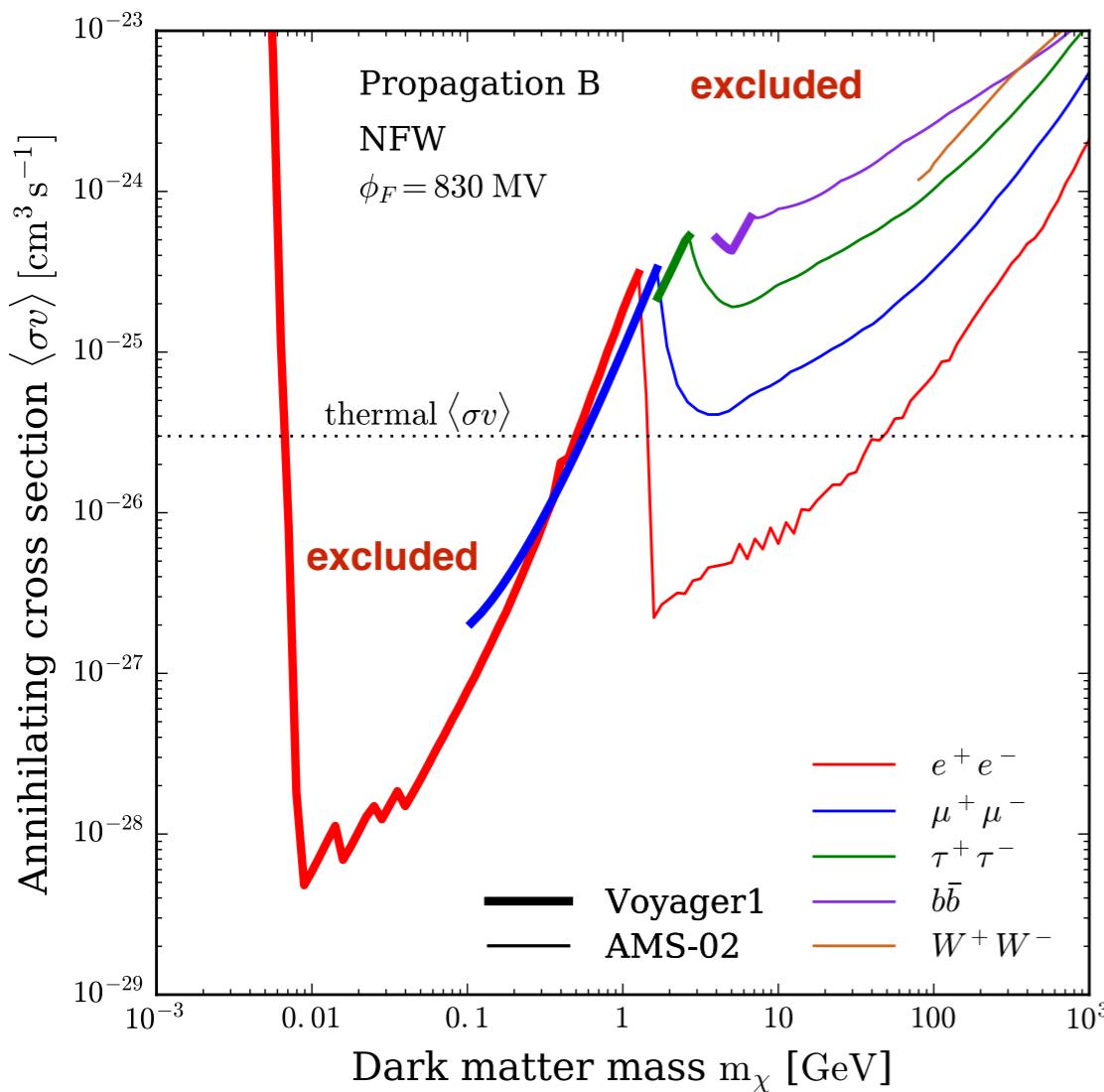
We can combine the **Voyager1** and **AMS-02** data to improve the constraints.

Constraints on DM annihilating cross section



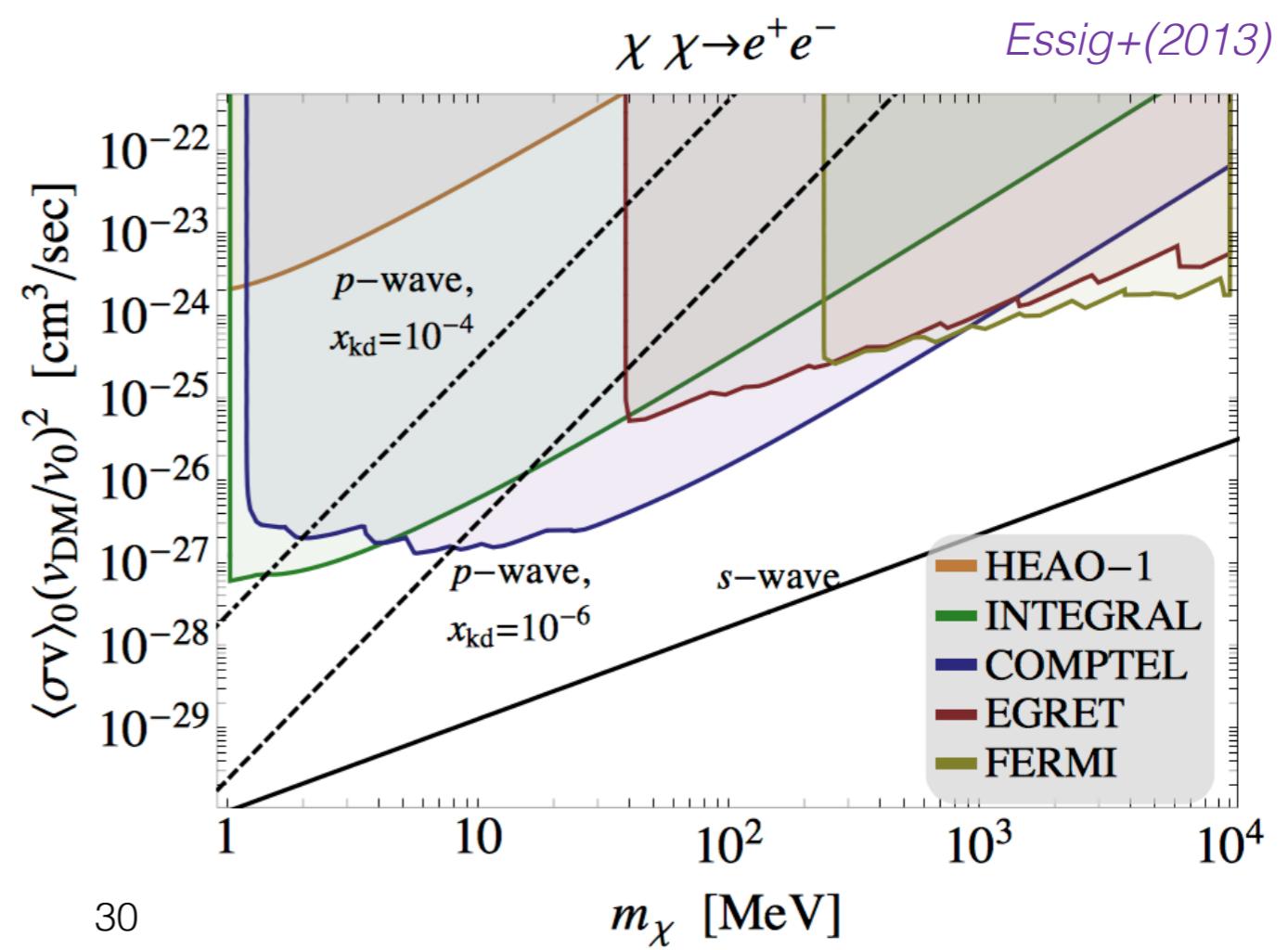
Annihilating Dark Matter*MB+(2016b)***Decaying Dark Matter**

Comparison with other constraints

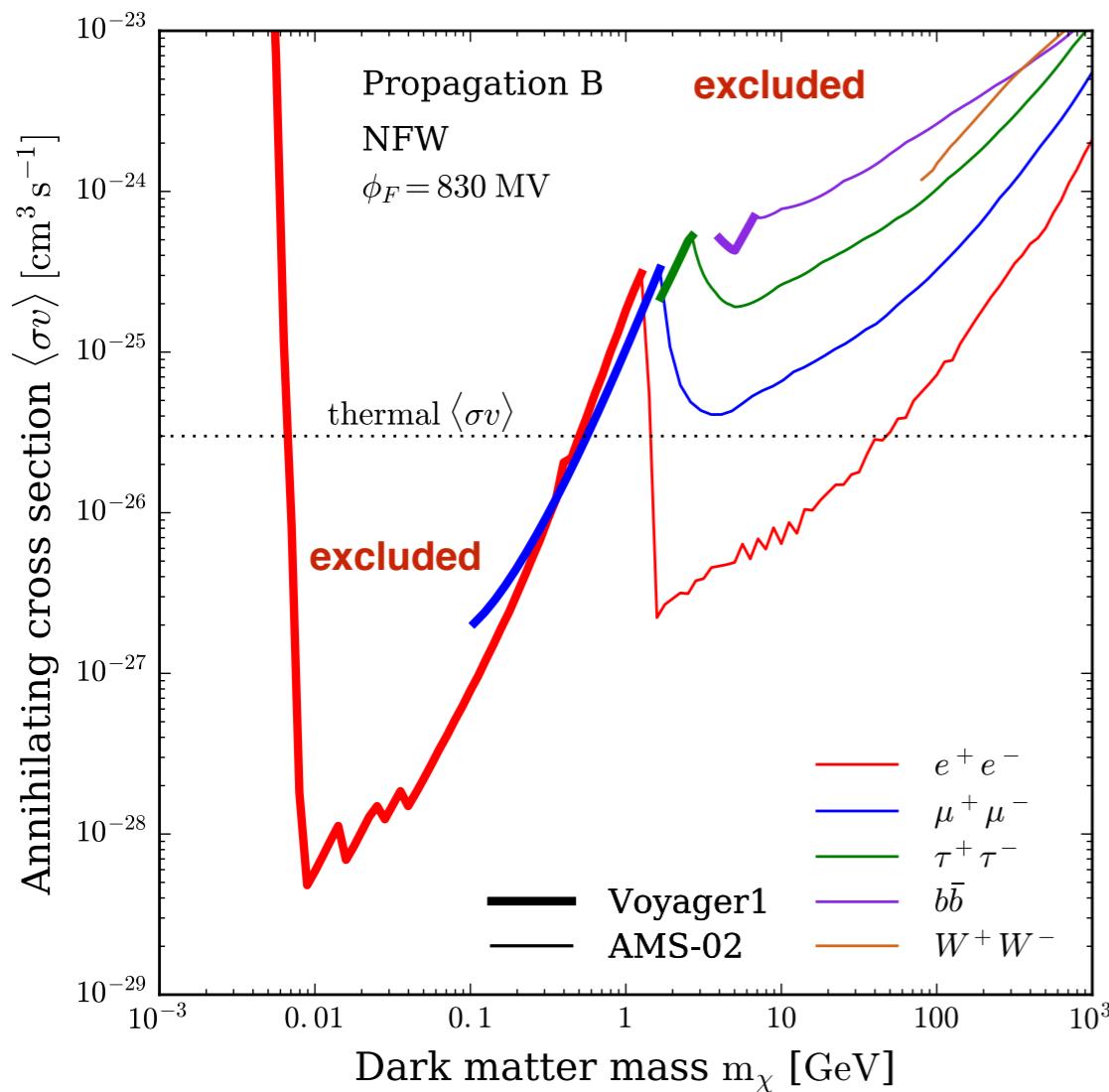


X-rays and γ -rays

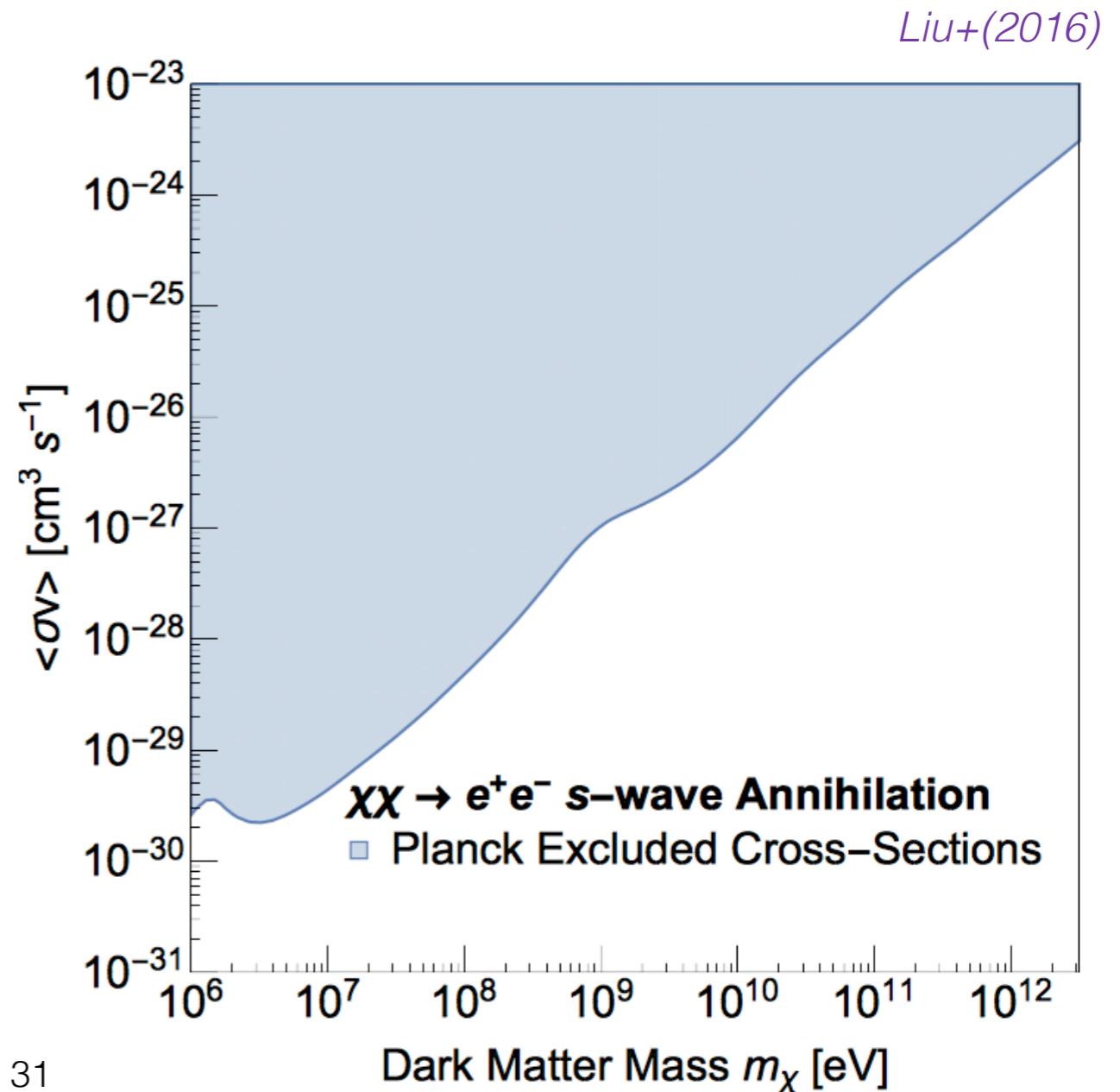
- **More** stringent by more than 1 order of magnitude.
- **Less** sensitive to the DM halo shape.



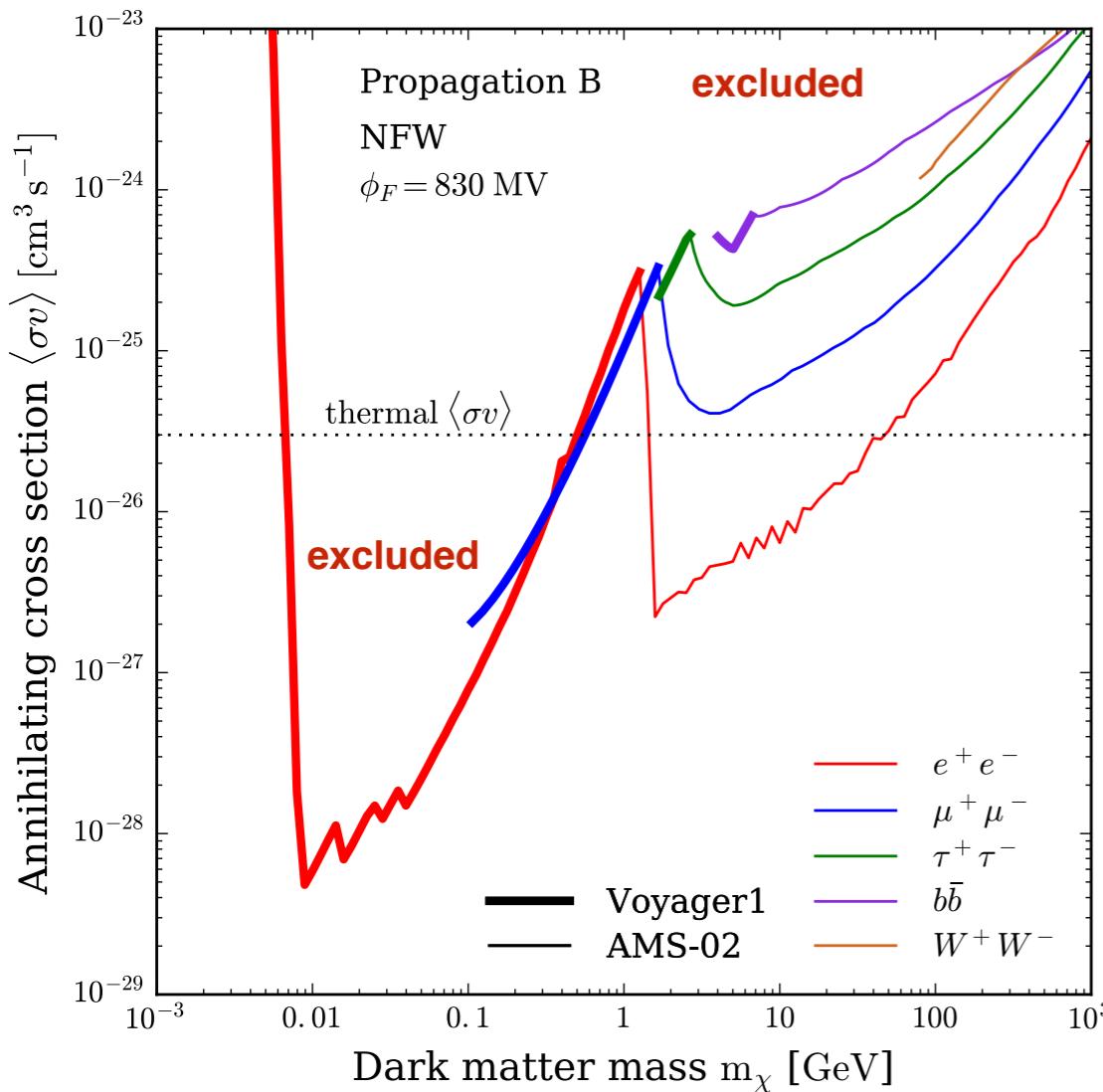
Comparison with other constraints

**CMB**

- **Less** stringent by 1 order of magnitude for s-wave $\langle\sigma v\rangle$.

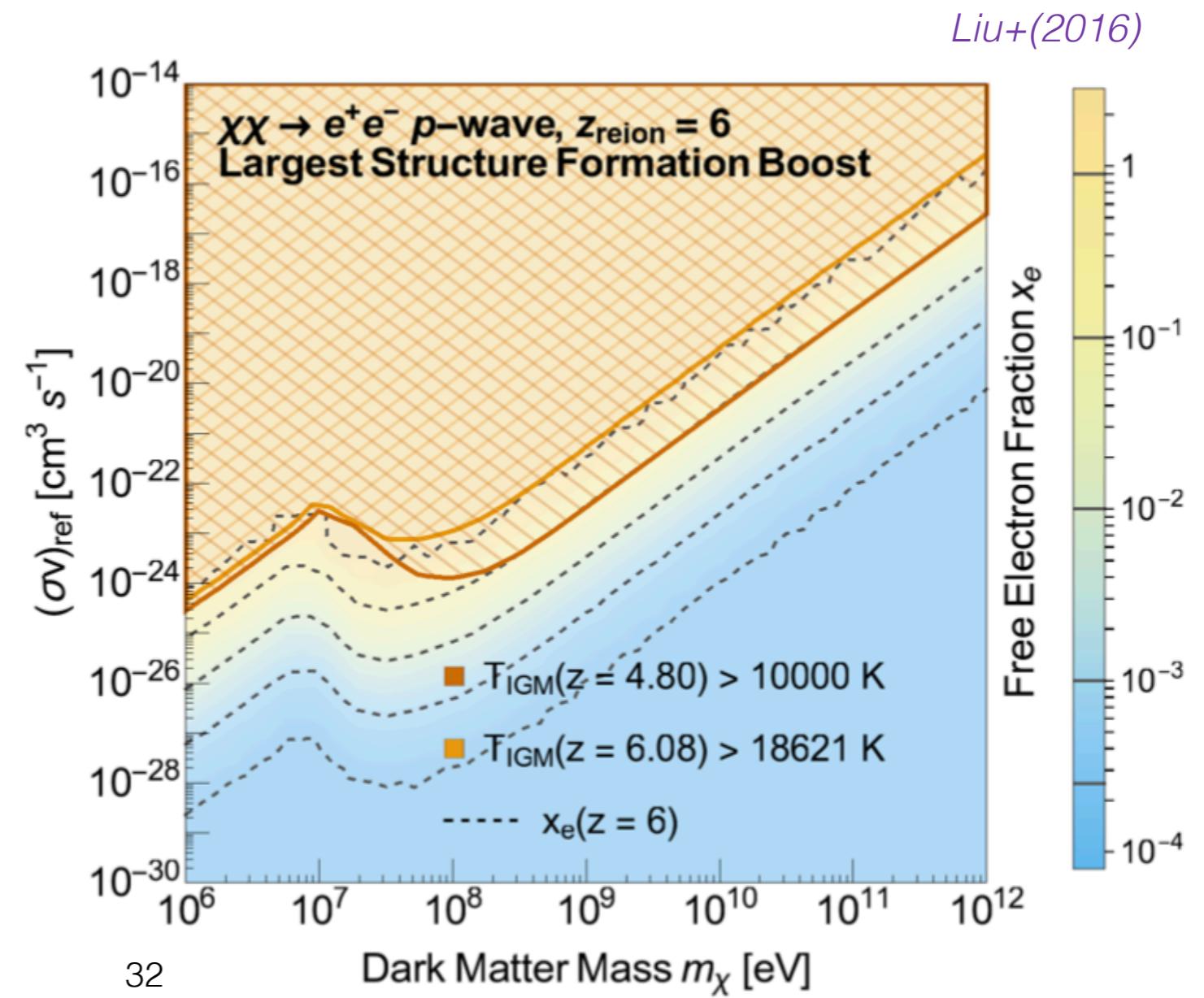


Comparison with other constraints



CMB

- **Less** stringent by 1 order of magnitude for s-wave $\langle \sigma v \rangle$.
- **More** stringent by 5 orders of magnitude for p-wave $\langle \sigma v \rangle$.



Conclusions and outlook

- The **pinching method** enables to compute **analytically** the electrons and positrons flux below 10 GeV taking into account all propagation effects.

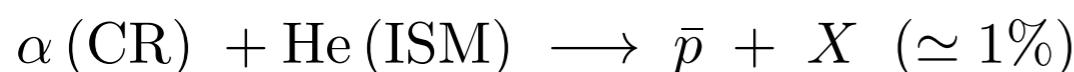
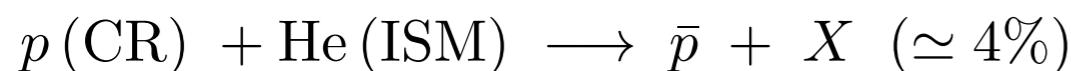
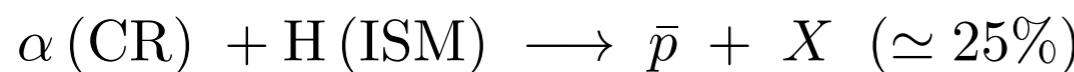
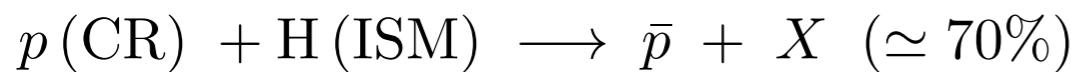
Conclusions and outlook

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Astrophysical background of secondary antiprotons

$$q^{\text{II}}(E, r) = 4\pi \sum_{i=p,\alpha} \sum_{j=\text{H,He}} \int_{E^0}^{+\infty} dE_i \frac{d\sigma_{ij \rightarrow \bar{p}X}}{dE}(E_i \rightarrow E) \phi_i(E_i, r) n_j$$

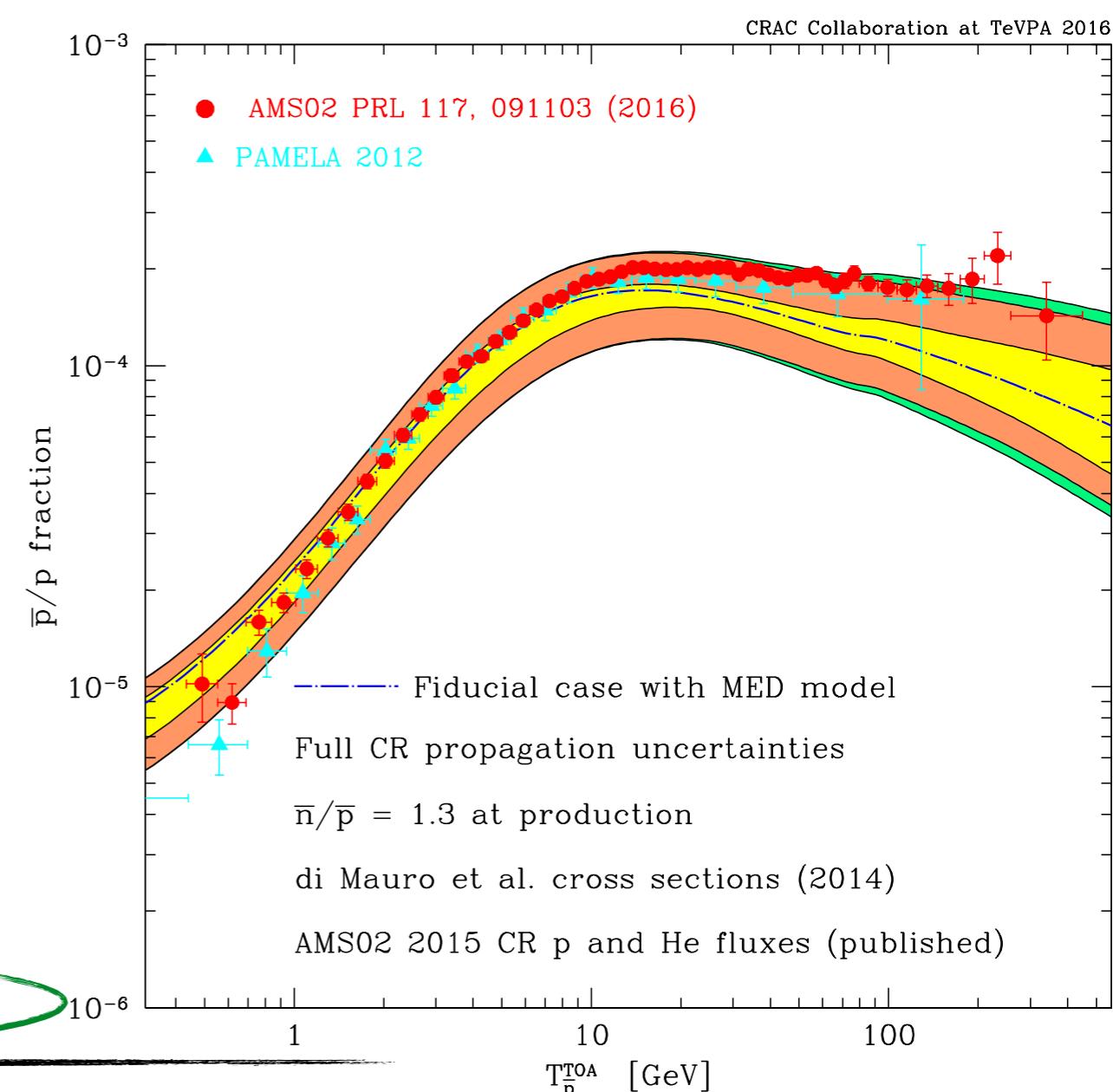
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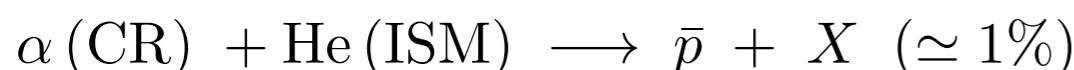
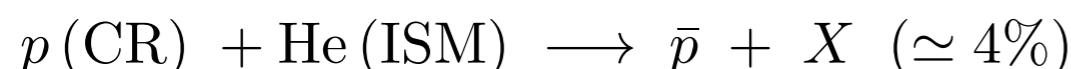
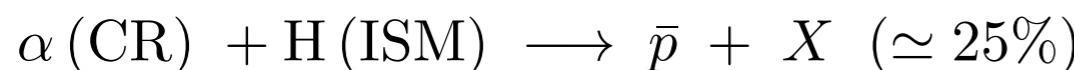
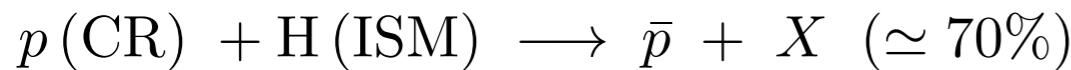
Case	δ	$K_0 [\text{kpc}^2/\text{Myr}]$	$L [\text{kpc}]$	$V_C [\text{km/s}]$	$V_a [\text{km/s}]$
MIN	0.85	0.0016	1	13.5	22.4
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MAX	0.46	0.0765	15	5	117.6



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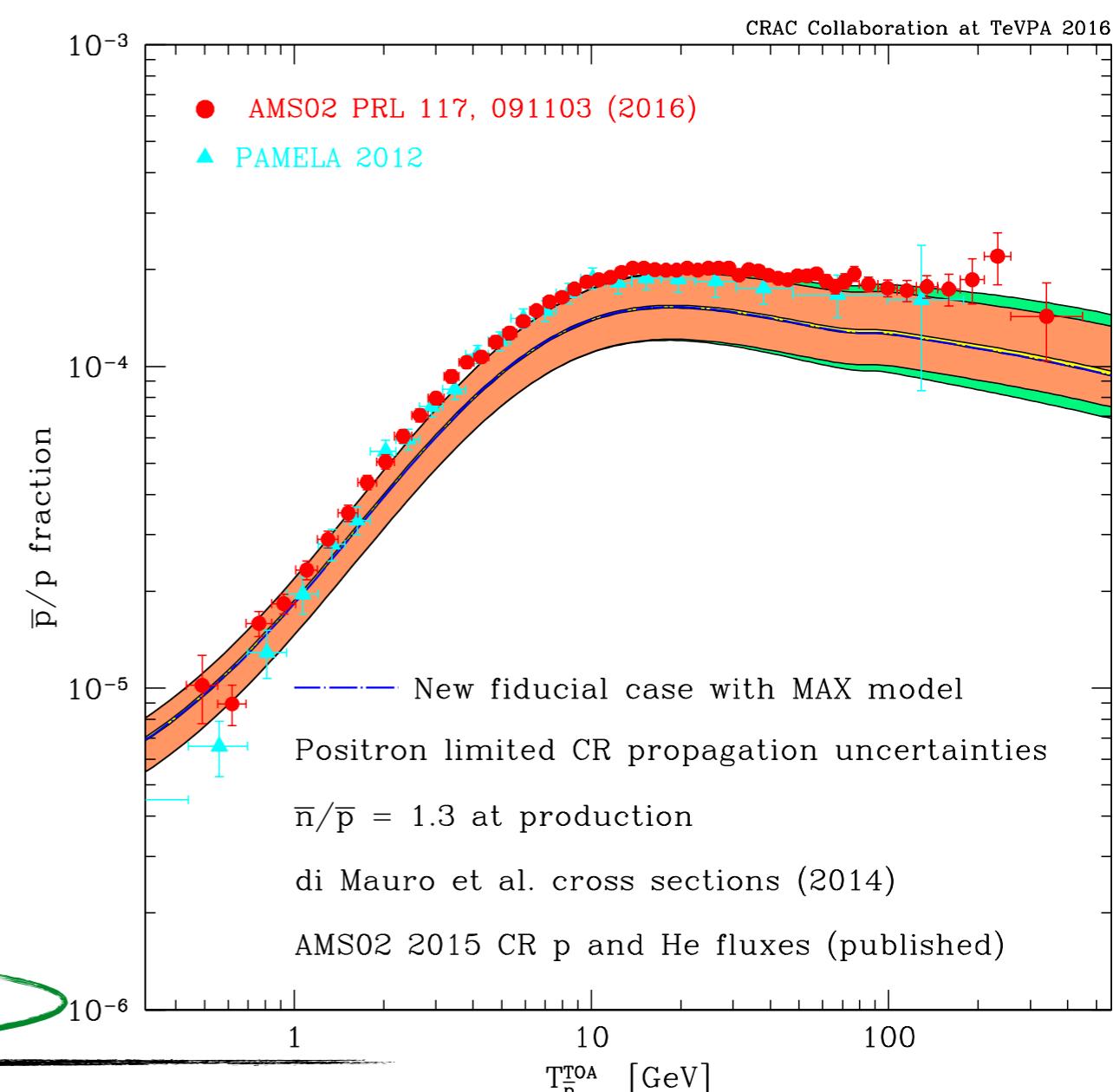
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- We derive constraints on **MeV** Dark Matter using **Voyager-I** and **AMS-02 data**. Our constraints are competitive with X-rays and γ -rays ones as well as CMB ones.

The constraints are more stringent than the one obtained from X-rays and γ -rays.

Less (more stringent) compared to CMB constraints for s-wave (p-wave) $\langle\sigma v\rangle$

Thank you for your attention!

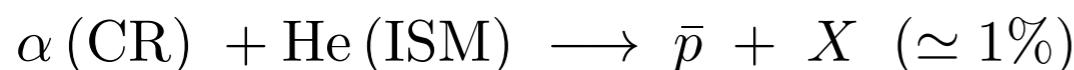
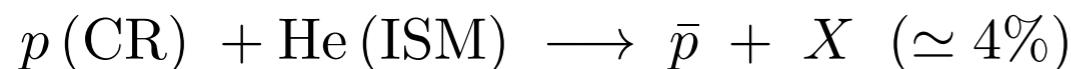
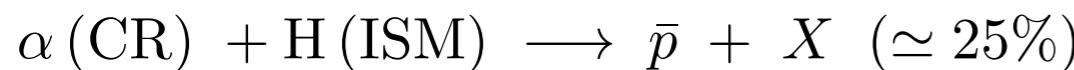
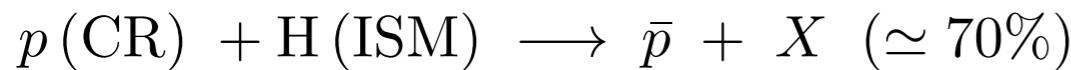
Questions?

Back up

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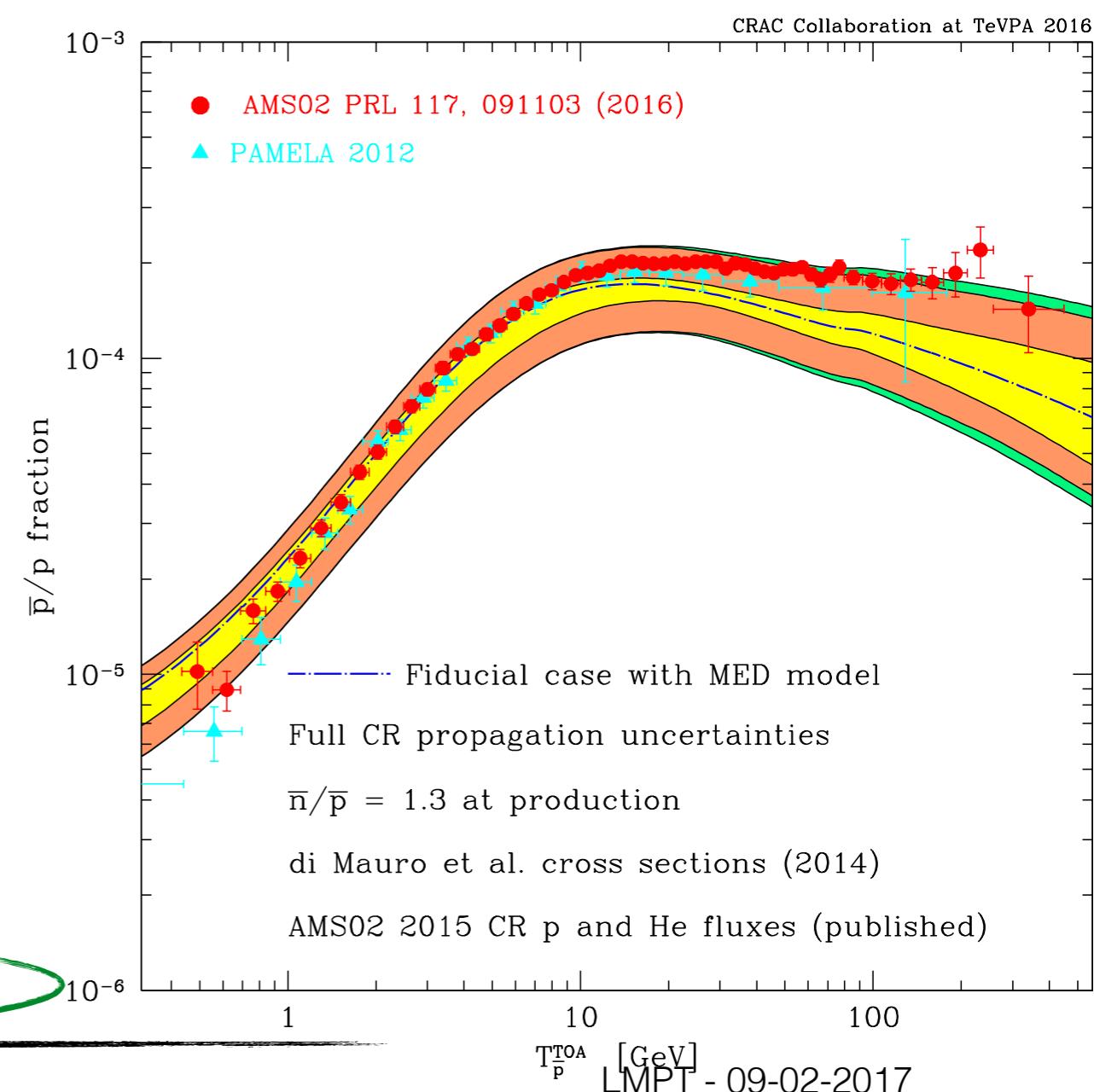
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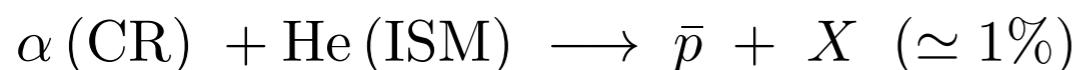
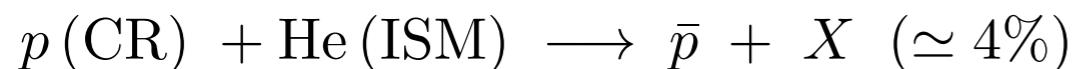
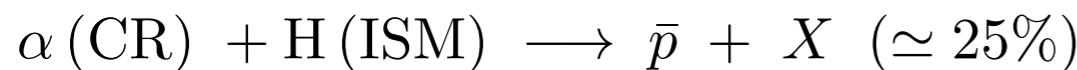
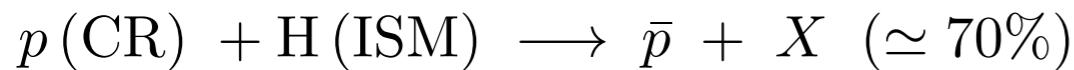
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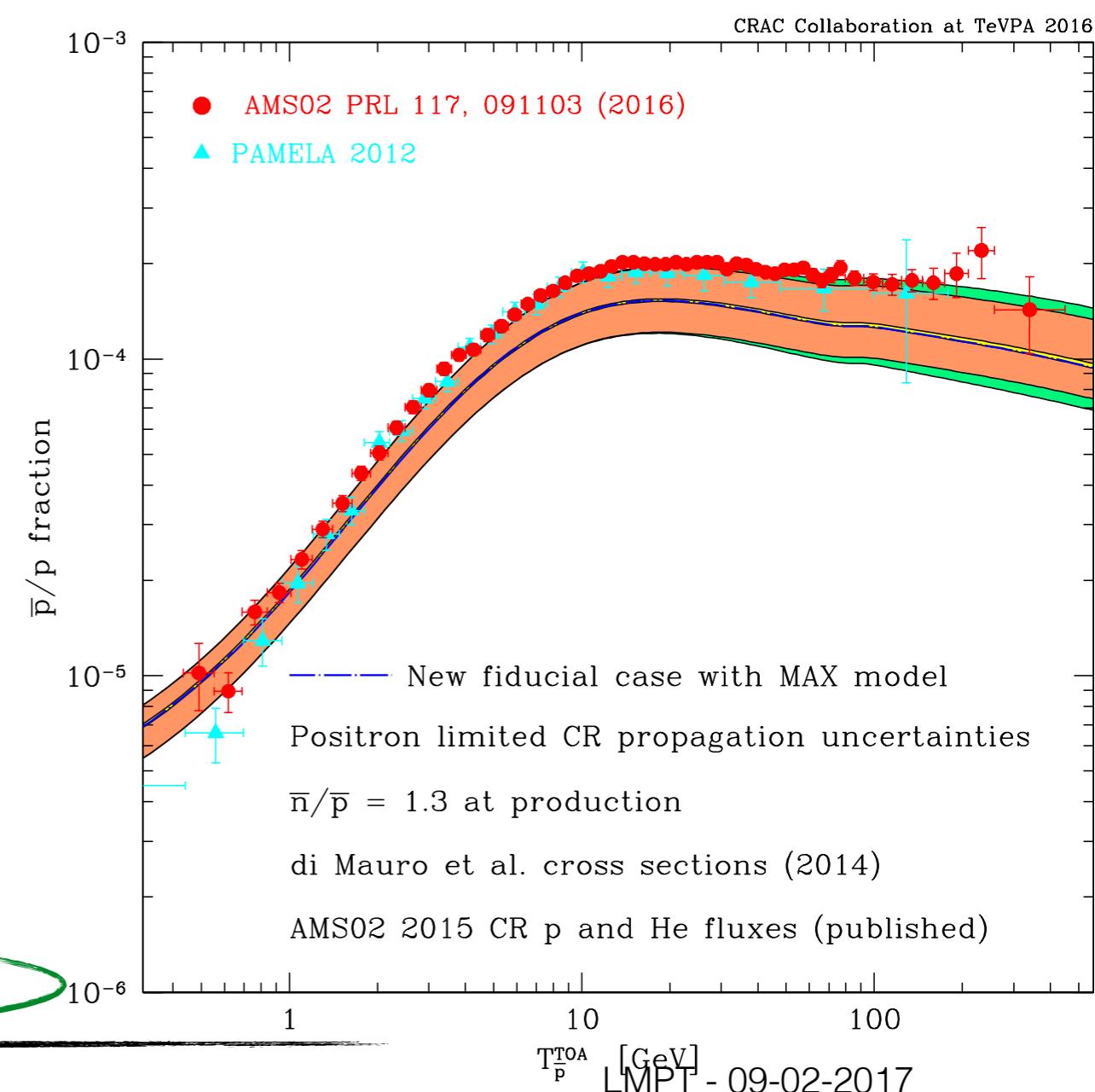
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Dark matter indirect detection

Measure an excess of cosmic rays with respect to the astrophysical background.

