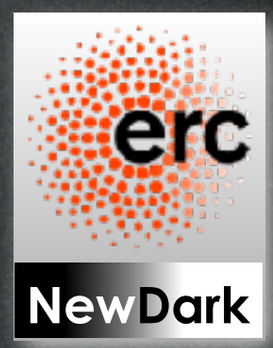
20 March 2017
Nils Bohr Institute, Copenhagen

Dark Matter Indirect Detection:

anti-p, anti-D, anti-He

Marco Cirelli
(CNRS LPTHE Jussieu)



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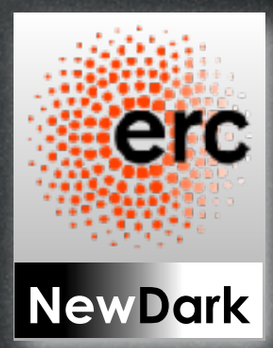

Introduction

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DM exists

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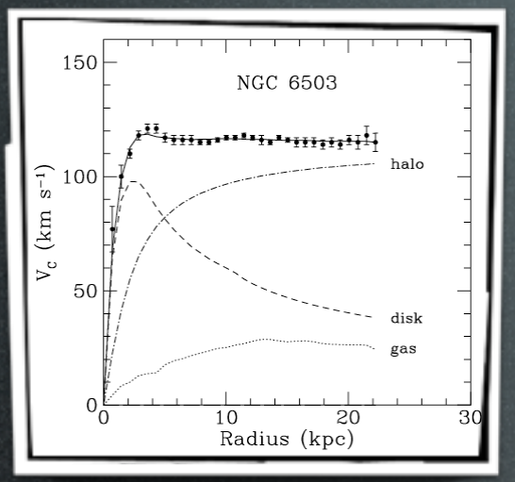
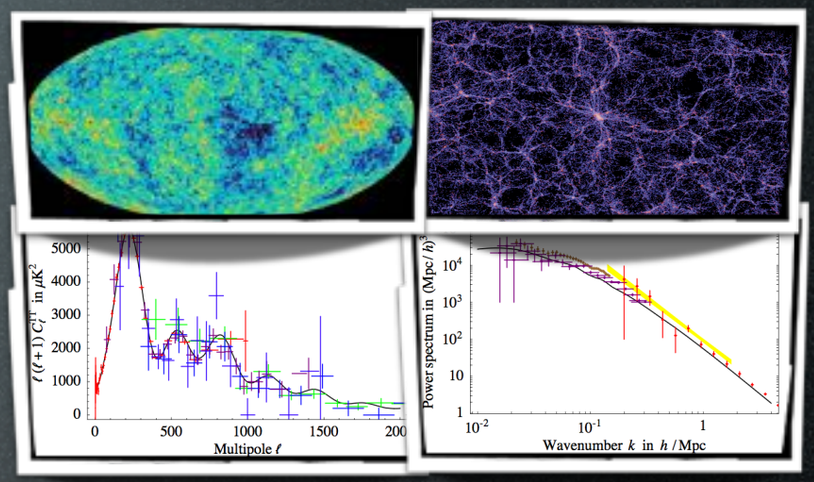


galactic rotation curves

weak lensing (e.g. in clusters)



'precision cosmology' (CMB, LSS)

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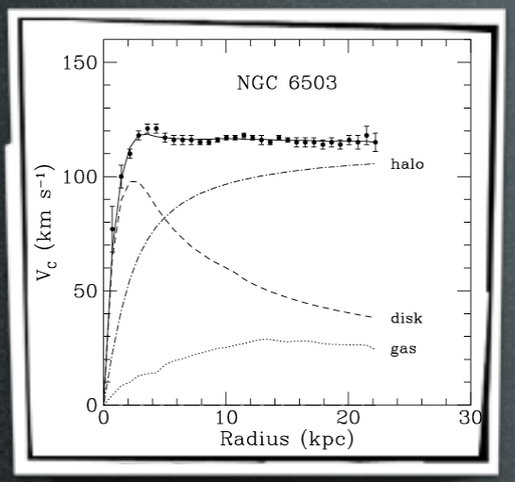

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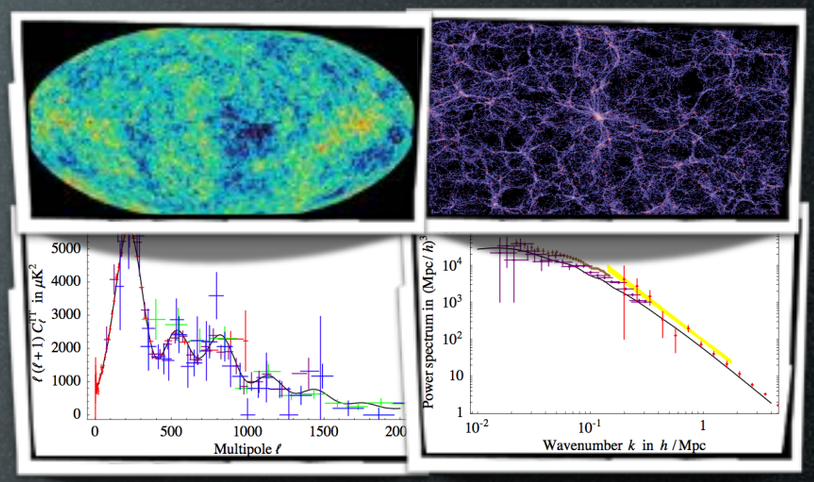

'precision cosmology' (CMB, LSS)

DM is a neutral, very long lived, feebly- interacting corpuscle.

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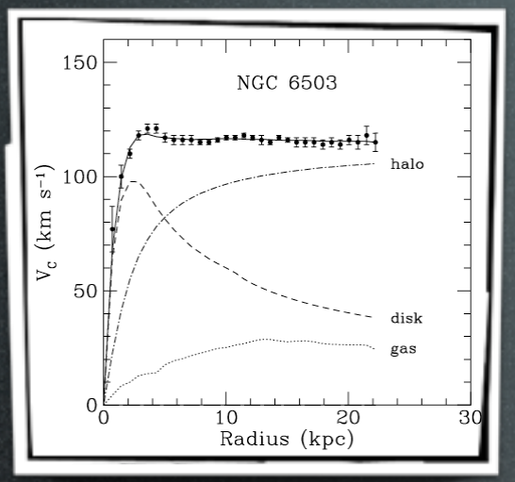

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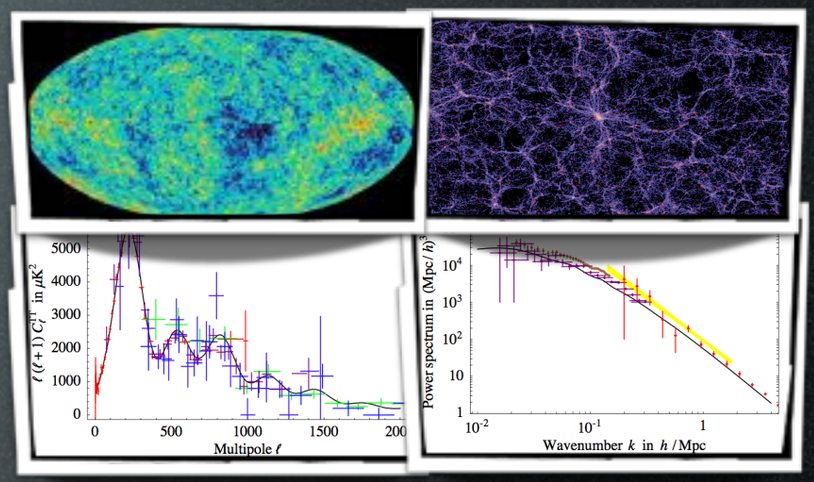
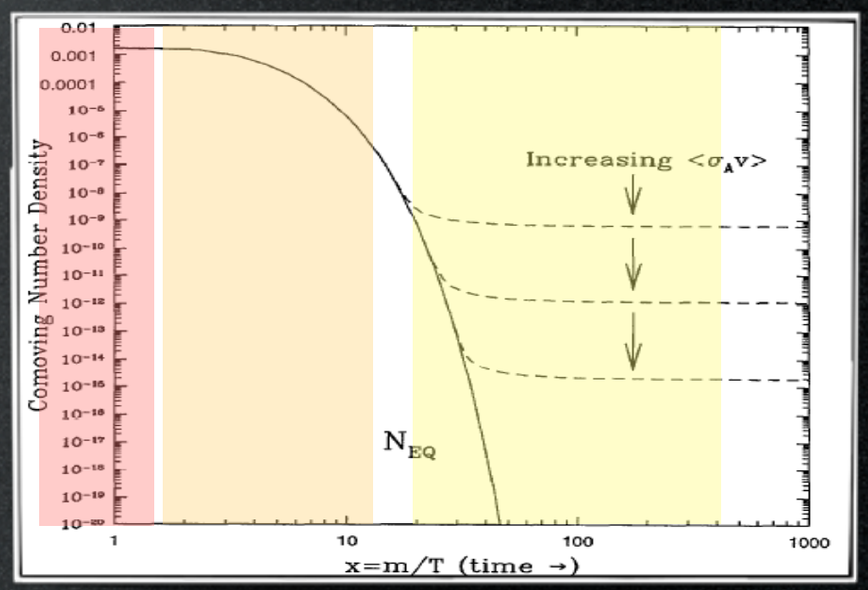


'precision cosmology' (CMB, LSS)

DM is a neutral, very long lived, weakly interacting particle.

Some of us believe in the WIMP miracle.

- *weak*-scale mass (10 GeV - 1 TeV)
- *weak* interactions $\sigma v = 3 \cdot 10^{-26} \mathrm{cm}^3/\mathrm{sec}$
- give automatically correct abundance



DM detection

direct detection

Xenon, CDMS, Edelweiss, LUX,... (CoGeNT, Dama/Libra...)

production at colliders

LHC

indirect

- γ from annihil in galactic center or halo and from secondary emission

  Fermi, ICT, radio telescopes...
- e^+ from annihil in galactic halo or center

  PAMELA, Fermi, HESS, AMS,balloons...
- $\bar{p}$ from annihil in galactic halo or center
- $\bar{d}$ from annihil in galactic halo or center

  GAPS, AMS
- $\nu, \bar{\nu}$ from annihil in massive bodies

  SK, Icecube, Km3Net

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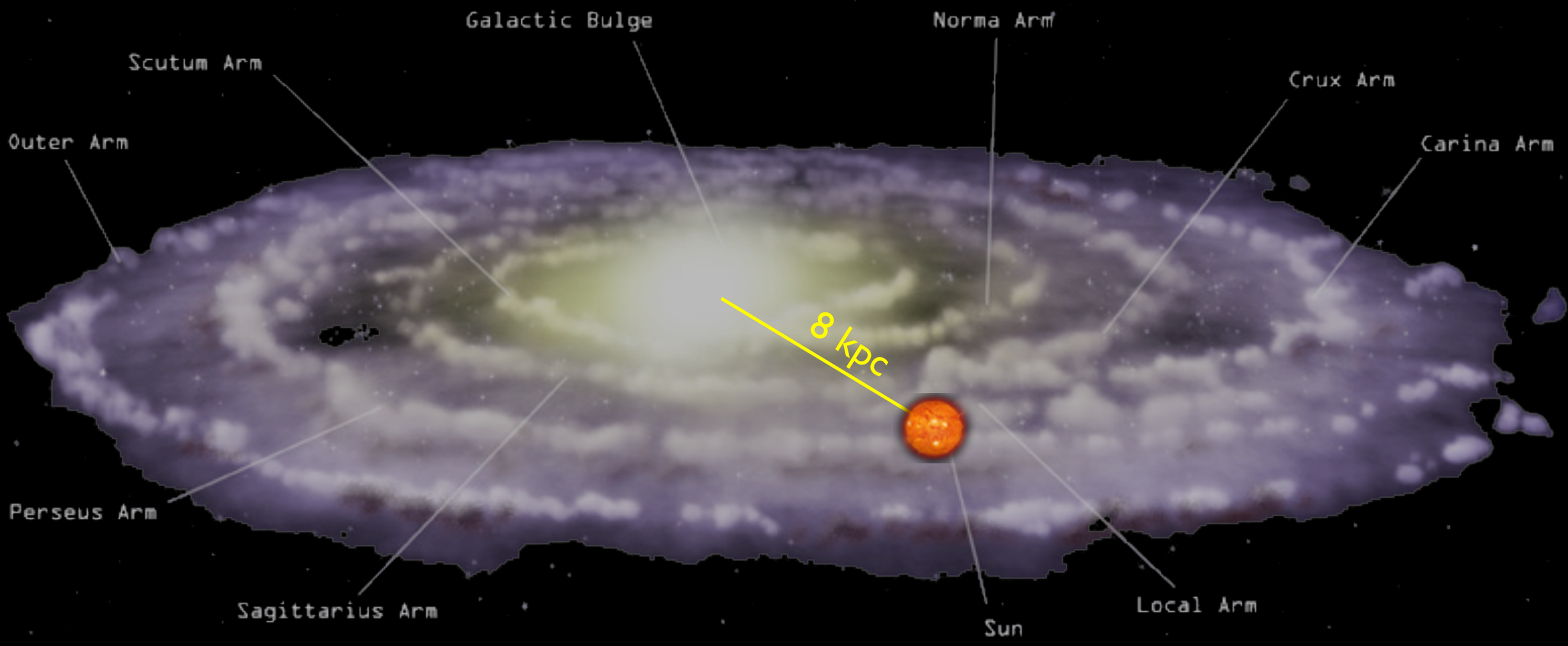
Predicting antiprotons from DM

Indirect Detection: charged CRs

$\bar{p}$ and e^+ from DM annihilations in halo



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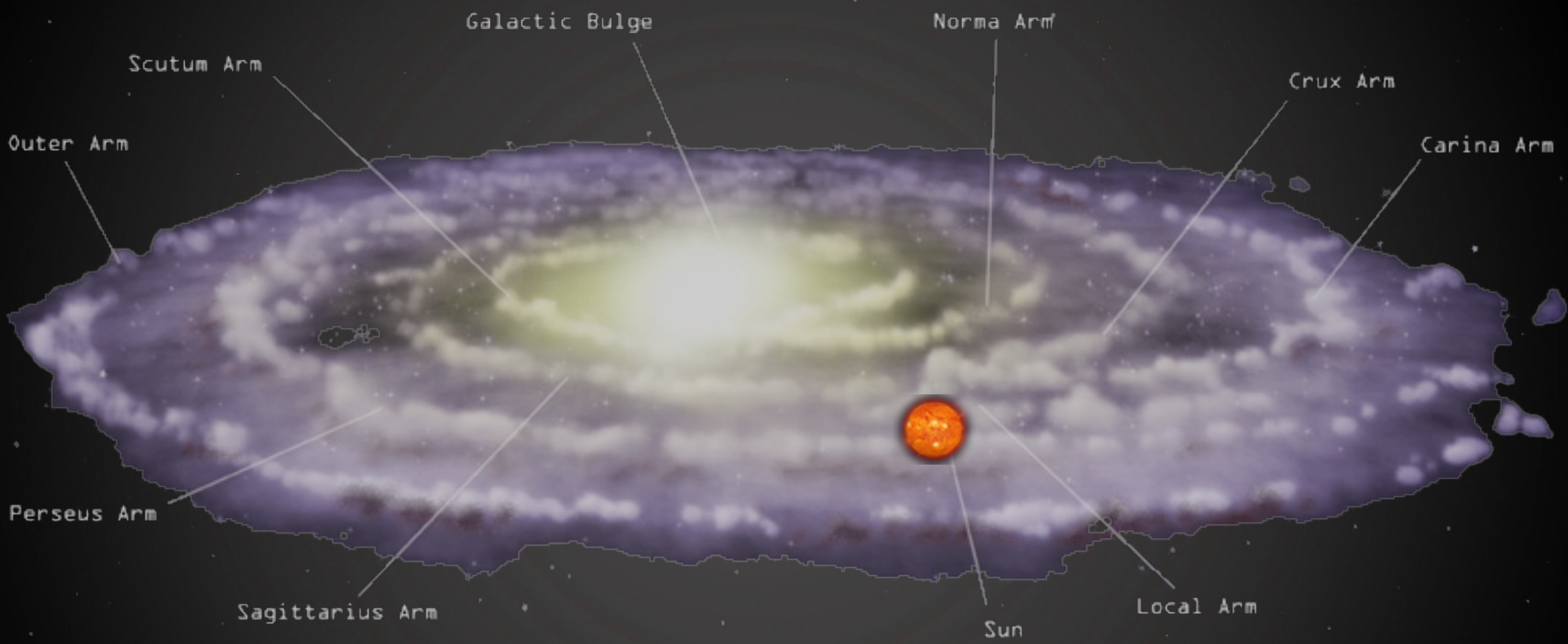

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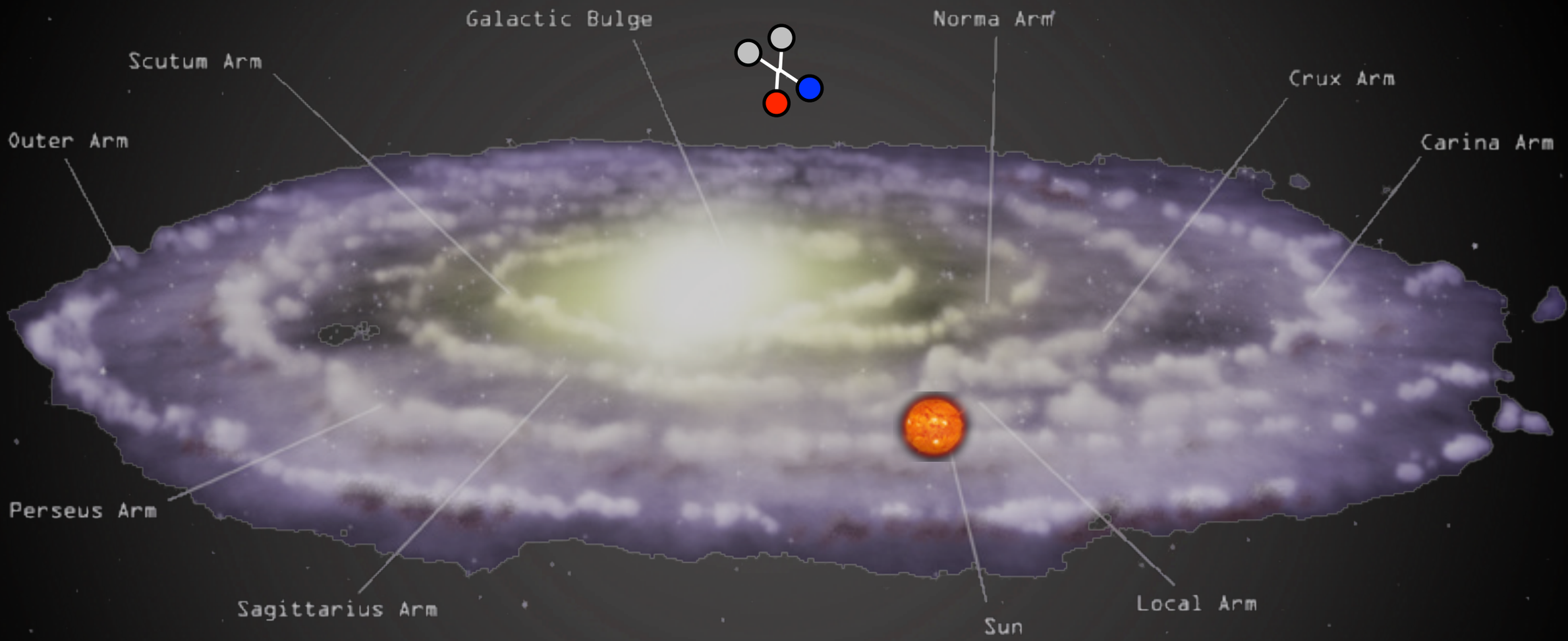
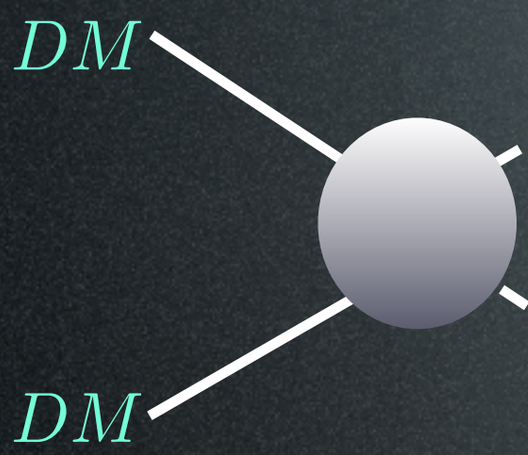


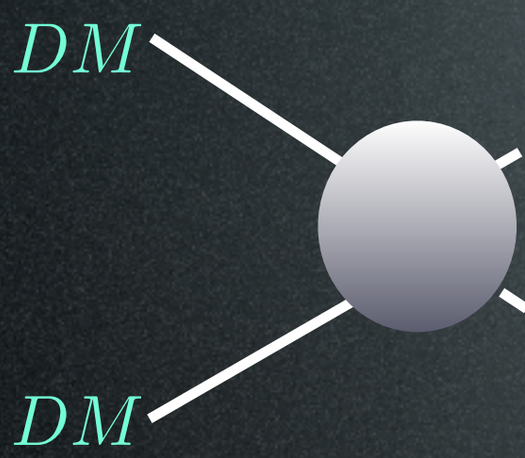
Indirect Detection: basics



$$W^-, Z, b, \tau^-, t, h \ldots \rightsquigarrow e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$$

$$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots \rightsquigarrow e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$$

Indirect Detection: basics

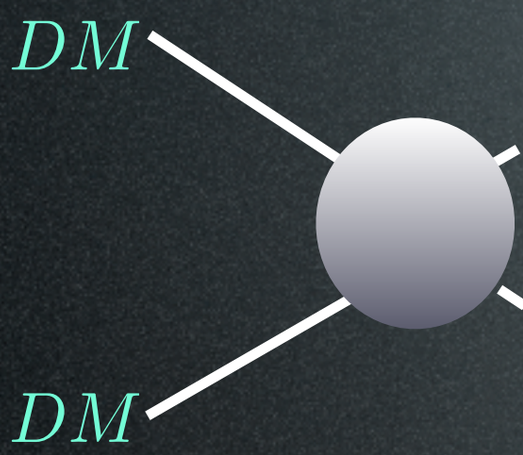


$W^-, Z, b, \tau^-, t, h \ldots \rightsquigarrow e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$

primary channels

$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots \rightsquigarrow e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$

Indirect Detection: basics



$W^-, Z, b, \tau^-, t, h \ldots$

primary channels

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decay

$\rightsquigarrow e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$

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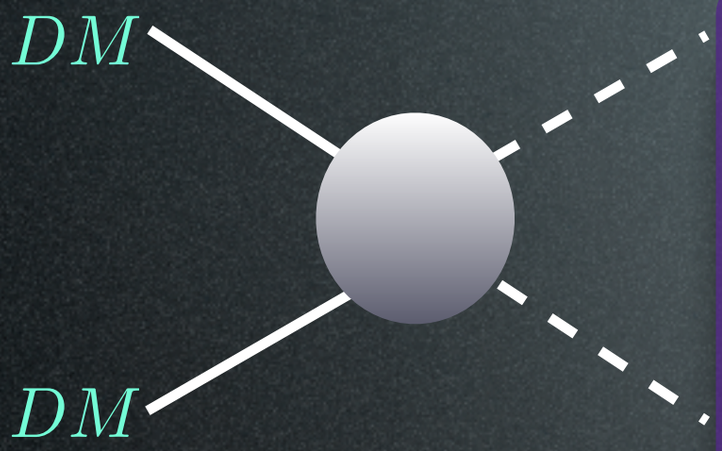
Indirect Detection: basics



$W^-, Z, b, \tau^-, t, h \ldots$

primary channels

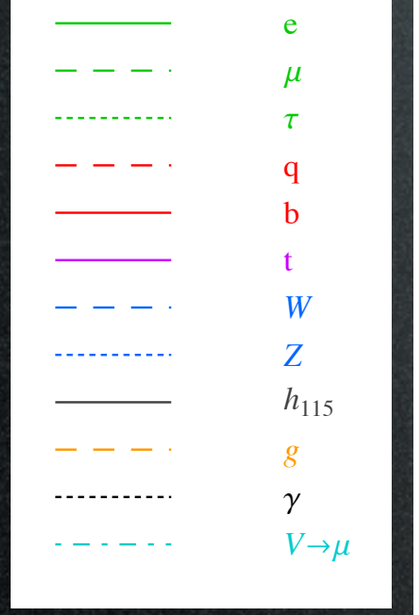
$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots$

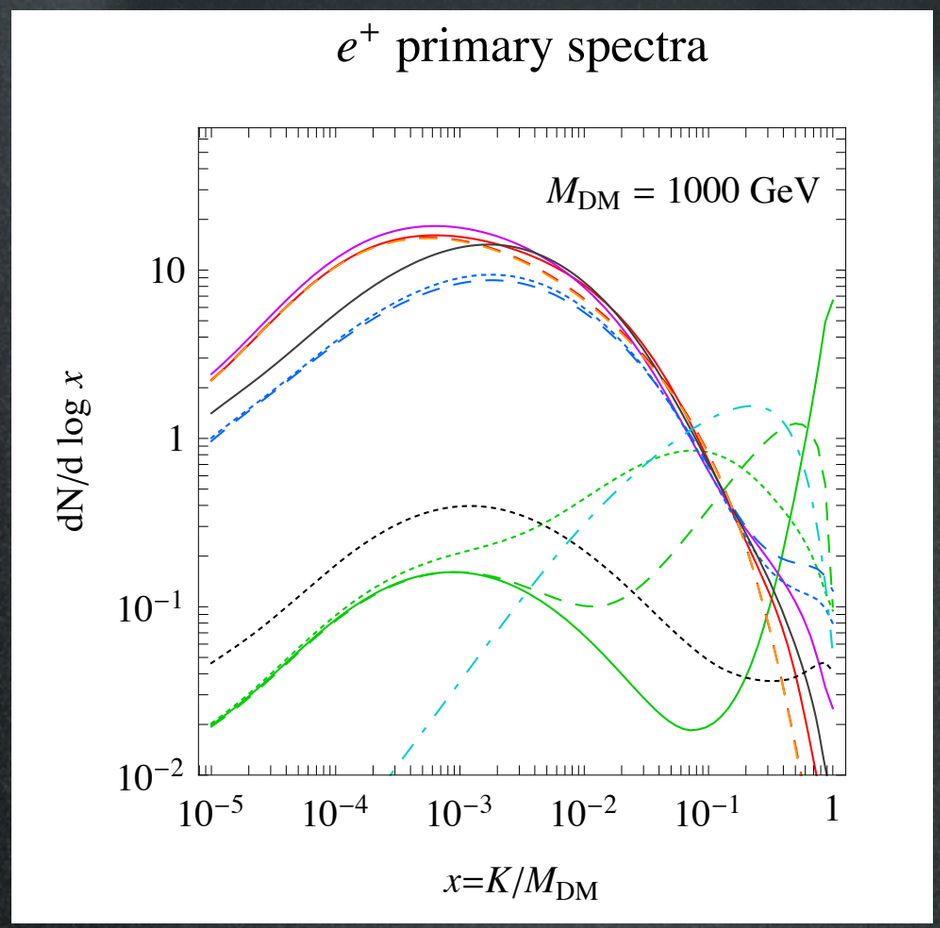
decay

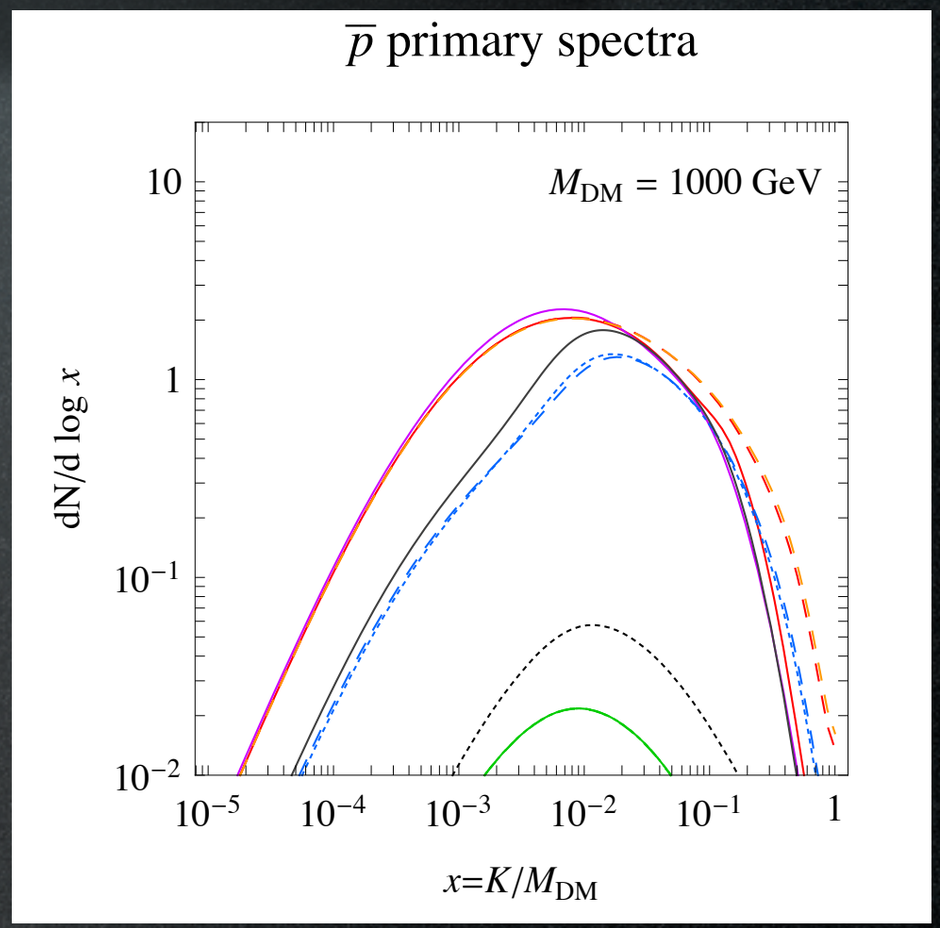
$e^\mp, \overset{(-)}{p}, \overset{(-)}{D} \ldots$

final products

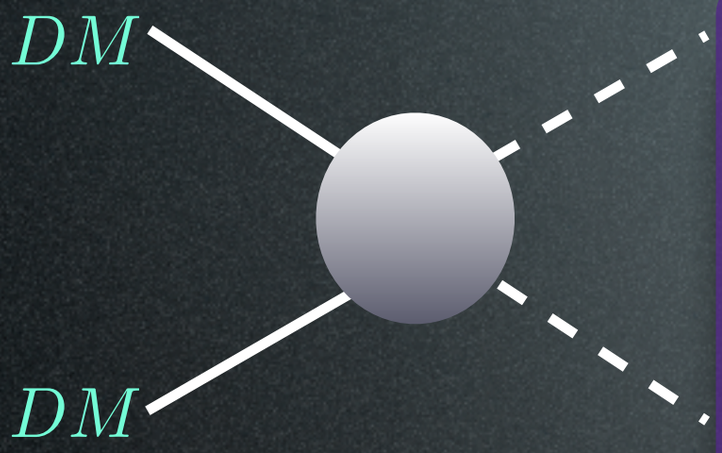
$e^\pm, \overset{(-)}{p}, \overset{(-)}{D} \ldots$







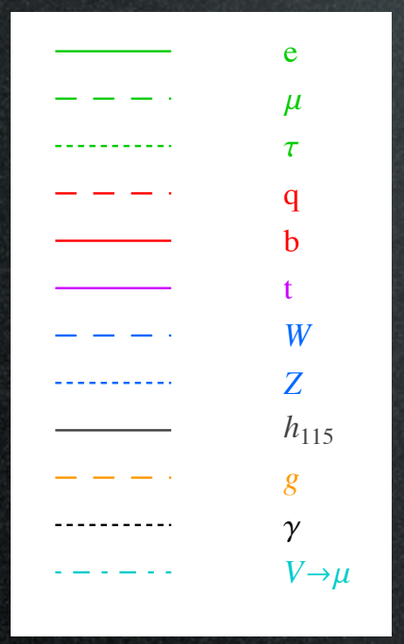
Indirect Detection: basics

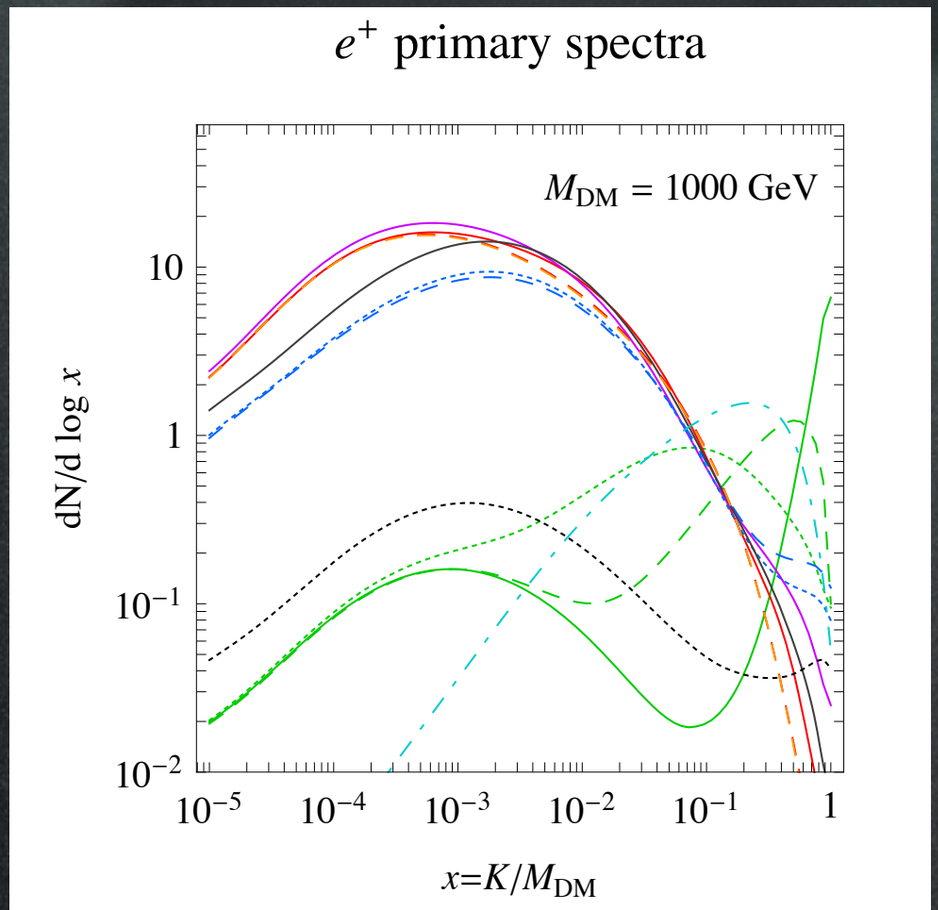


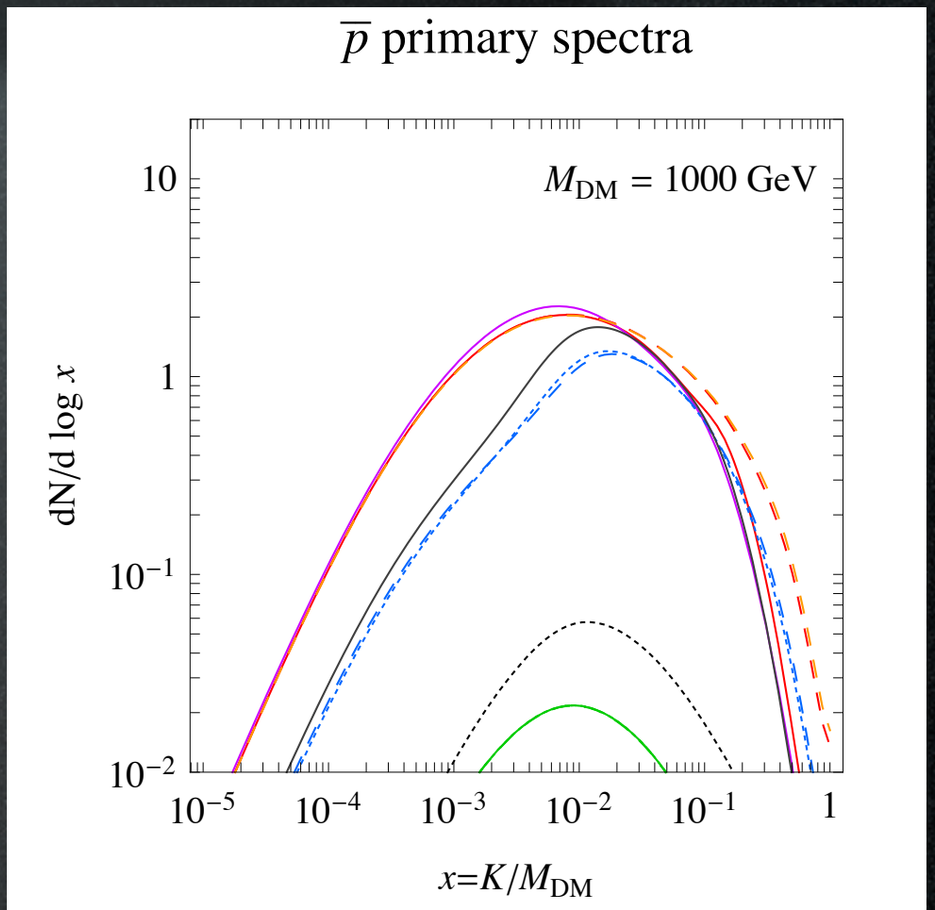
$W^-, Z, b, \tau^-, t, h \ldots$ primary channels $W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots$

decay

$e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$ final products $e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$



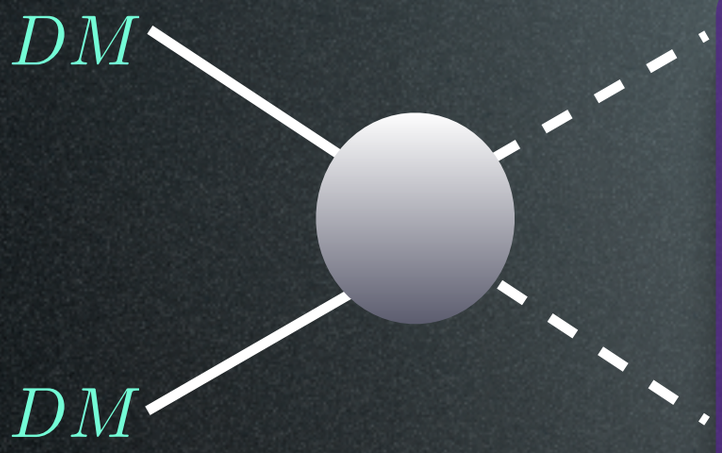




So what are the particle physics parameters?

1. Dark Matter mass
2. primary channel(s)

Indirect Detection: basics



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decay $\rightsquigarrow$

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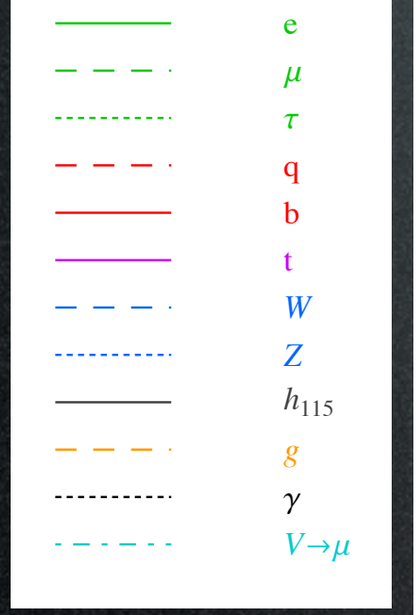

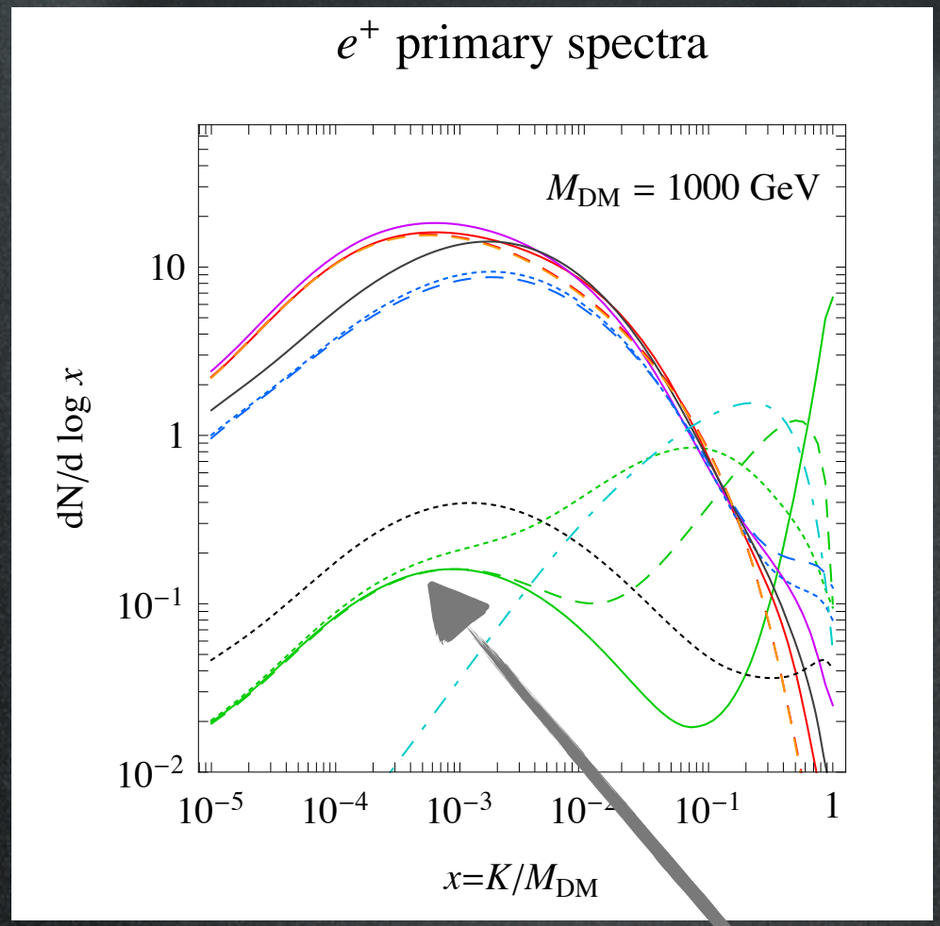

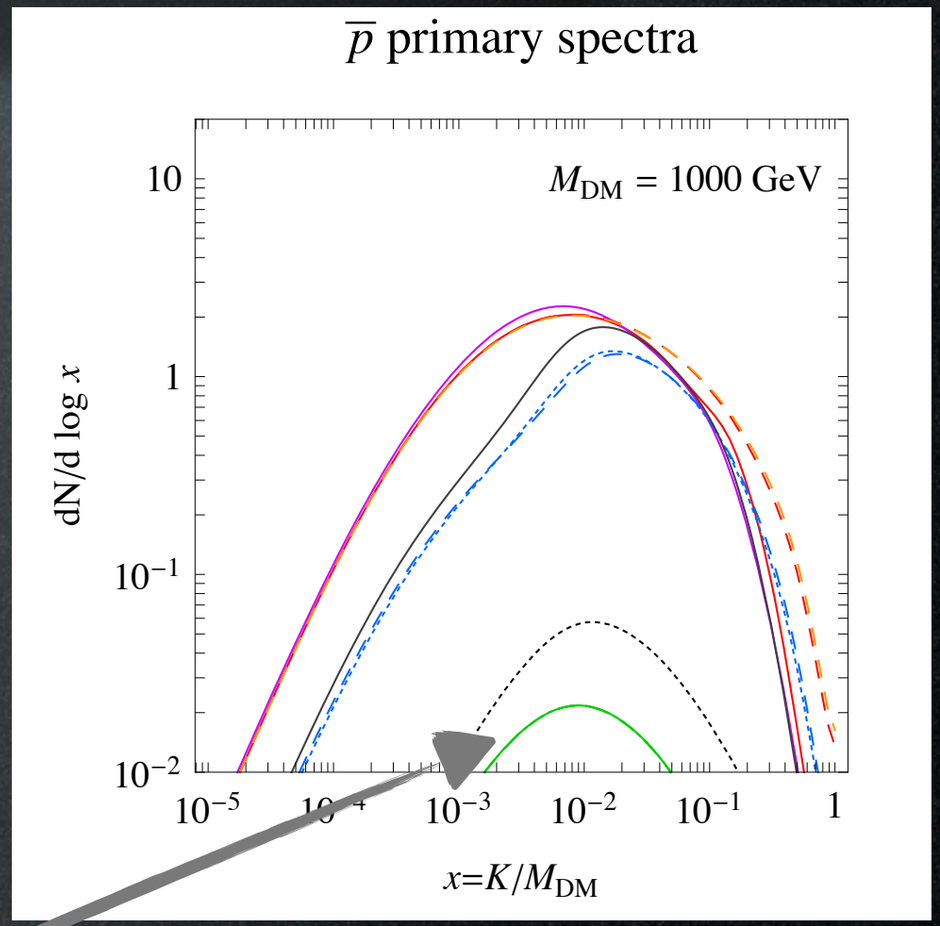

ElectroWeak corrections!

Sala et al., 1009.0224

Cirelli, Panci, Sala et al., 1012.4515

Fluxes at production

ElectroWeak corrections are important!

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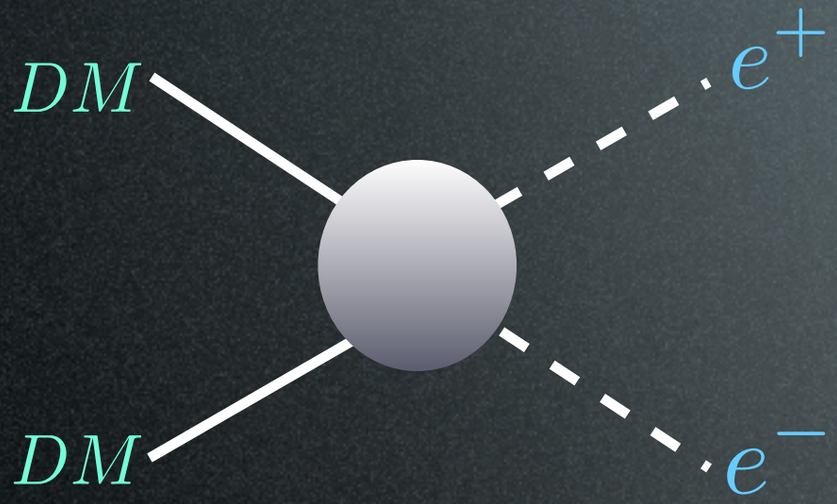

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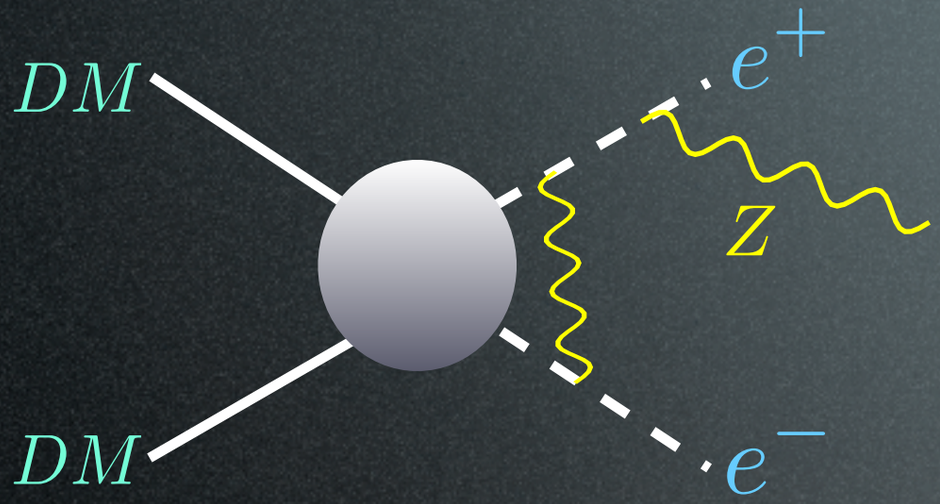

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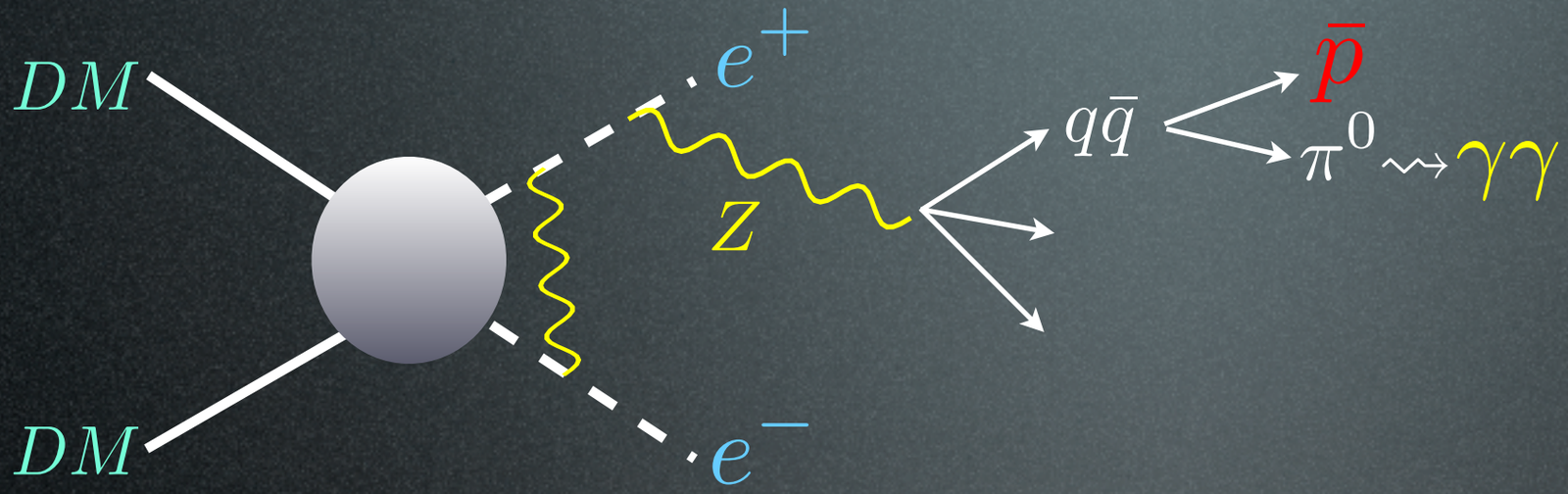

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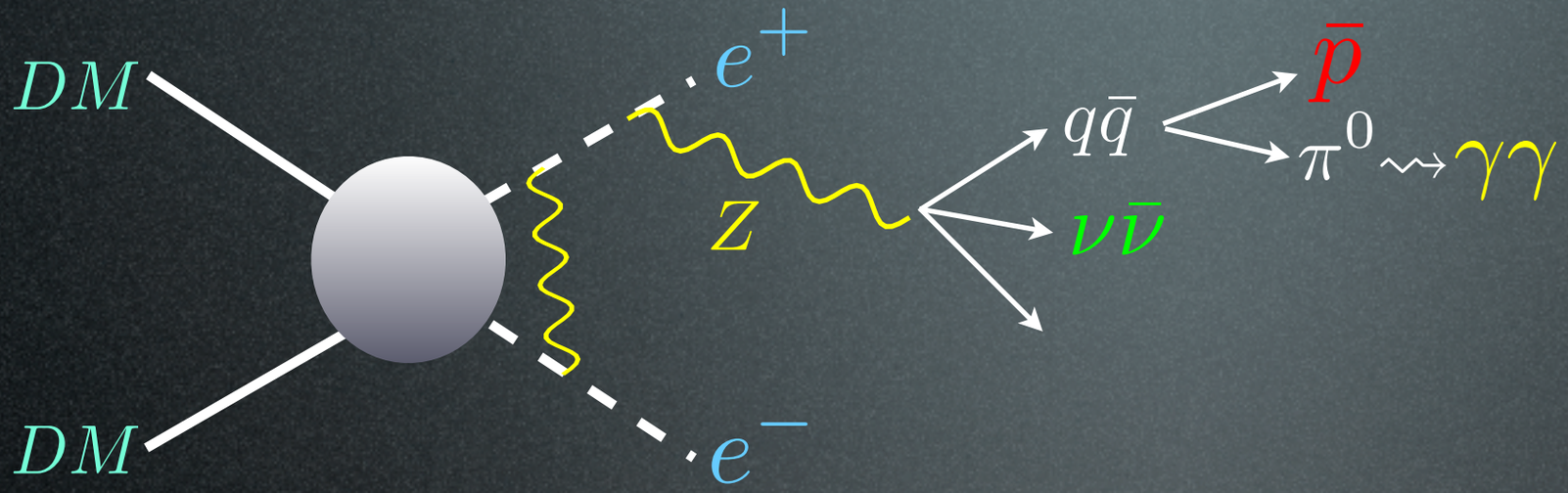

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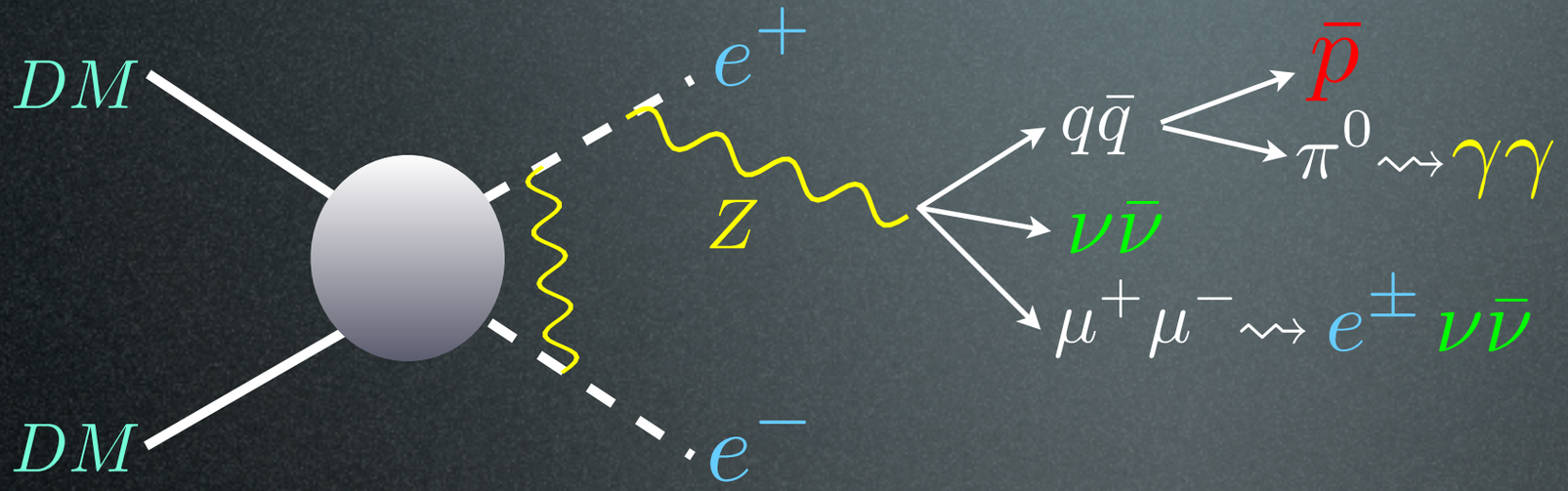

Ciafaloni et al., JCAP 1103 (2011)
See also: Serpico et al., Bell et al.

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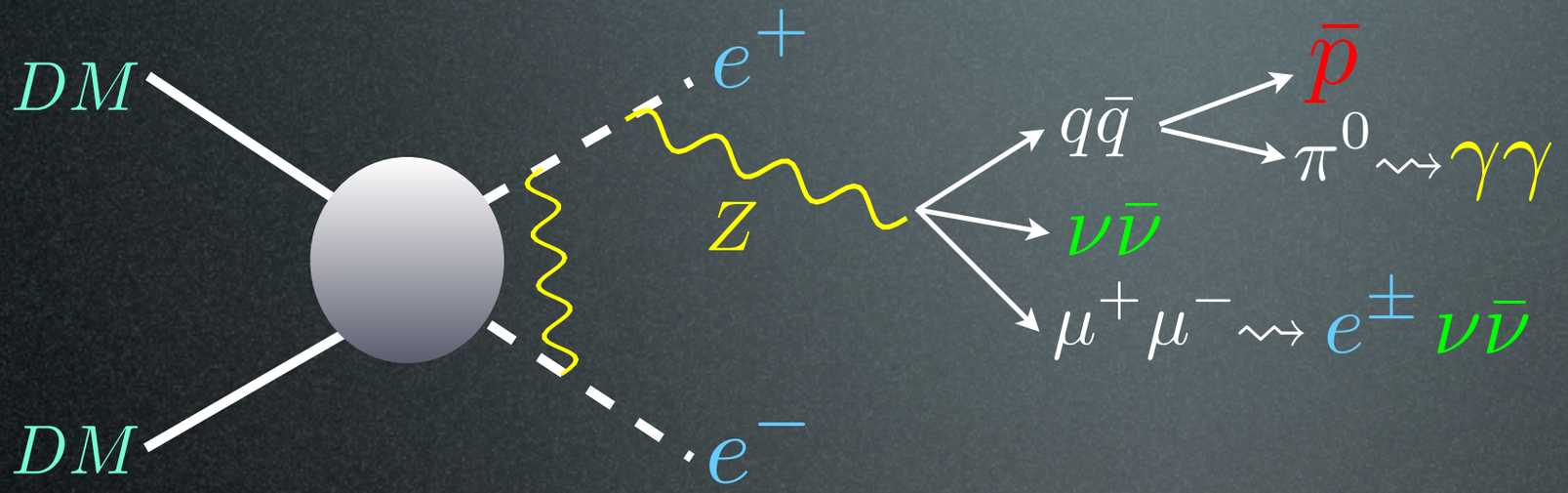

$$\frac{\Delta\sigma}{\sigma} \propto \alpha_{\text{weak}} \ln^2\left(\frac{M_{\text{DM}}^2}{M_{\text{Z}}^2}\right)$$

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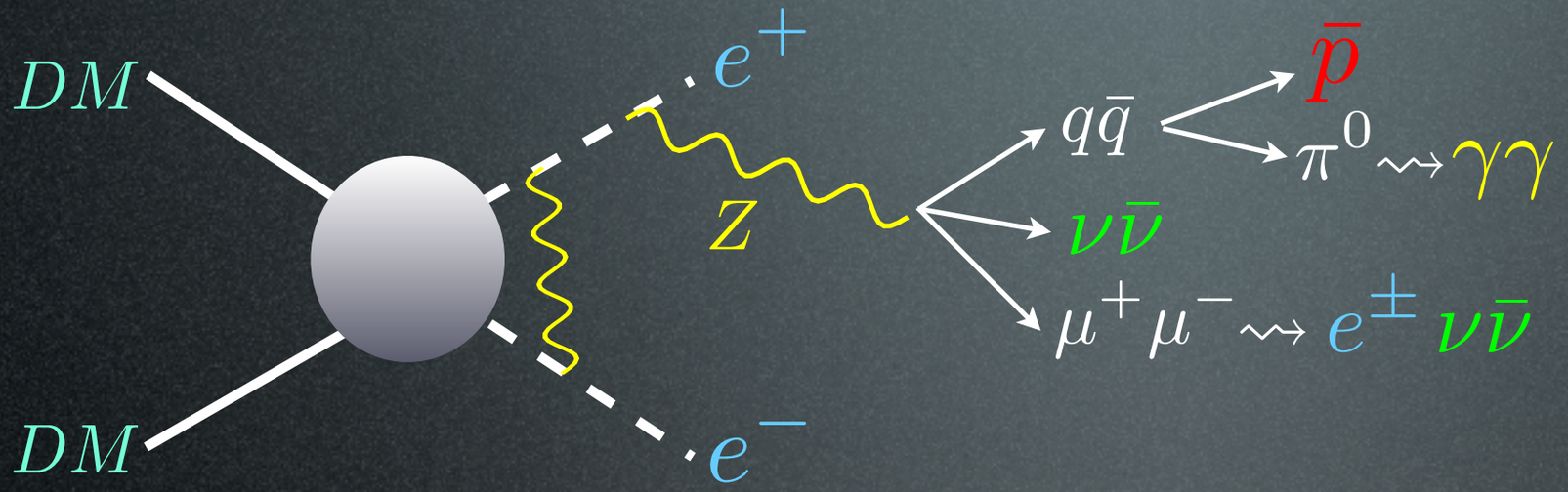

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~ TeV

$\alpha_{\text{weak}} \sim 0.03$

$\ln^2\left(\frac{M_{\text{DM}}^2}{M_{\text{Z}}^2}\right) \sim 25$

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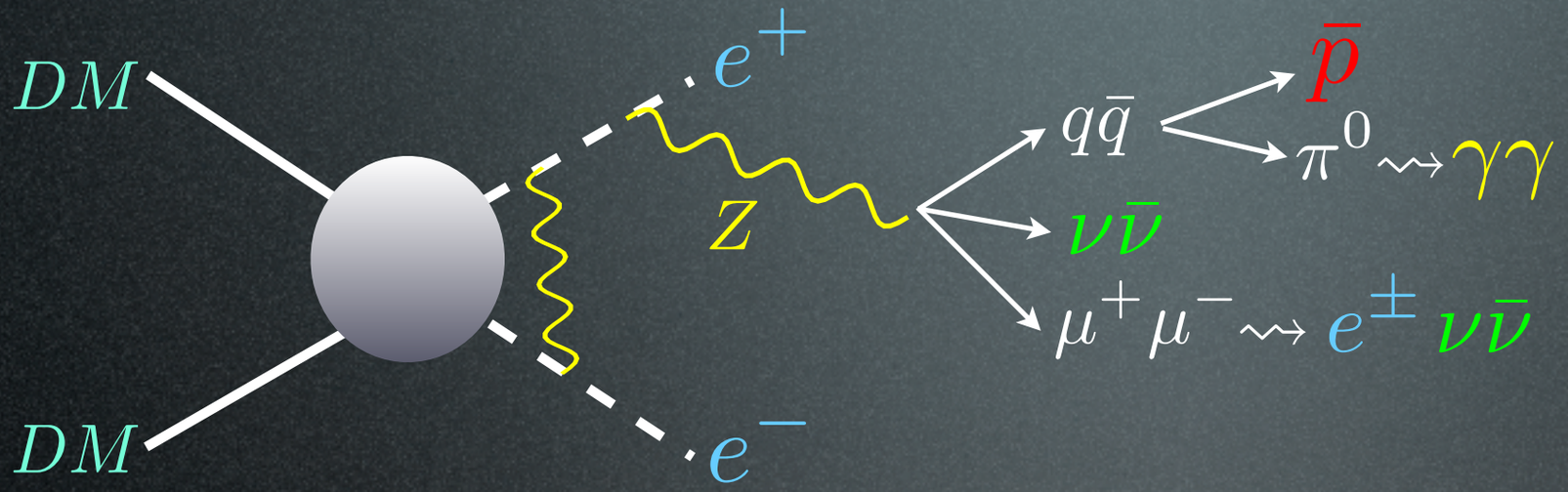

$$\frac{\Delta\sigma}{\sigma} \propto \alpha_{\text{weak}} \ln^2\left(\frac{M^2_{\text{DM}}}{M^2_{\text{Z}}}\right)$$

~ TeV

$\alpha_{\text{weak}} \sim 0.03$

$\ln^2\left(\frac{M^2_{\text{DM}}}{M^2_{\text{Z}}}\right) \sim 25$

$\sim 75\%$

(NB the finite mass of Z, W regulates the divergencies, only log terms left)

Ciafaloni et al., JCAP 1103 (2011)
See also: Serpico et al., Bell et al.

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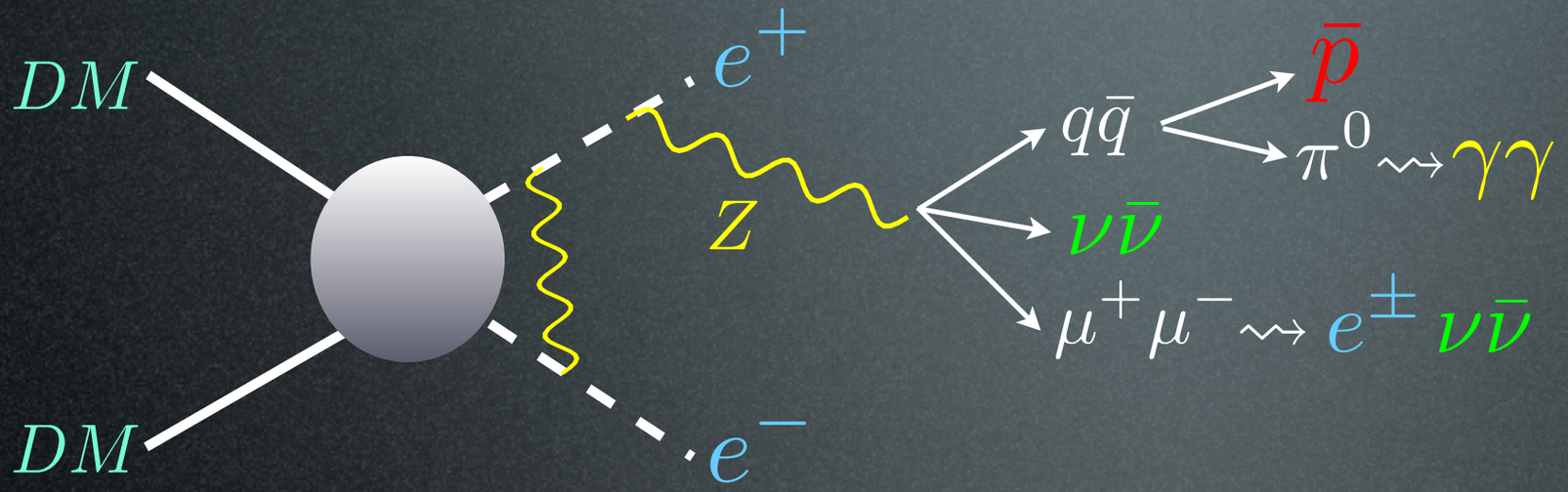
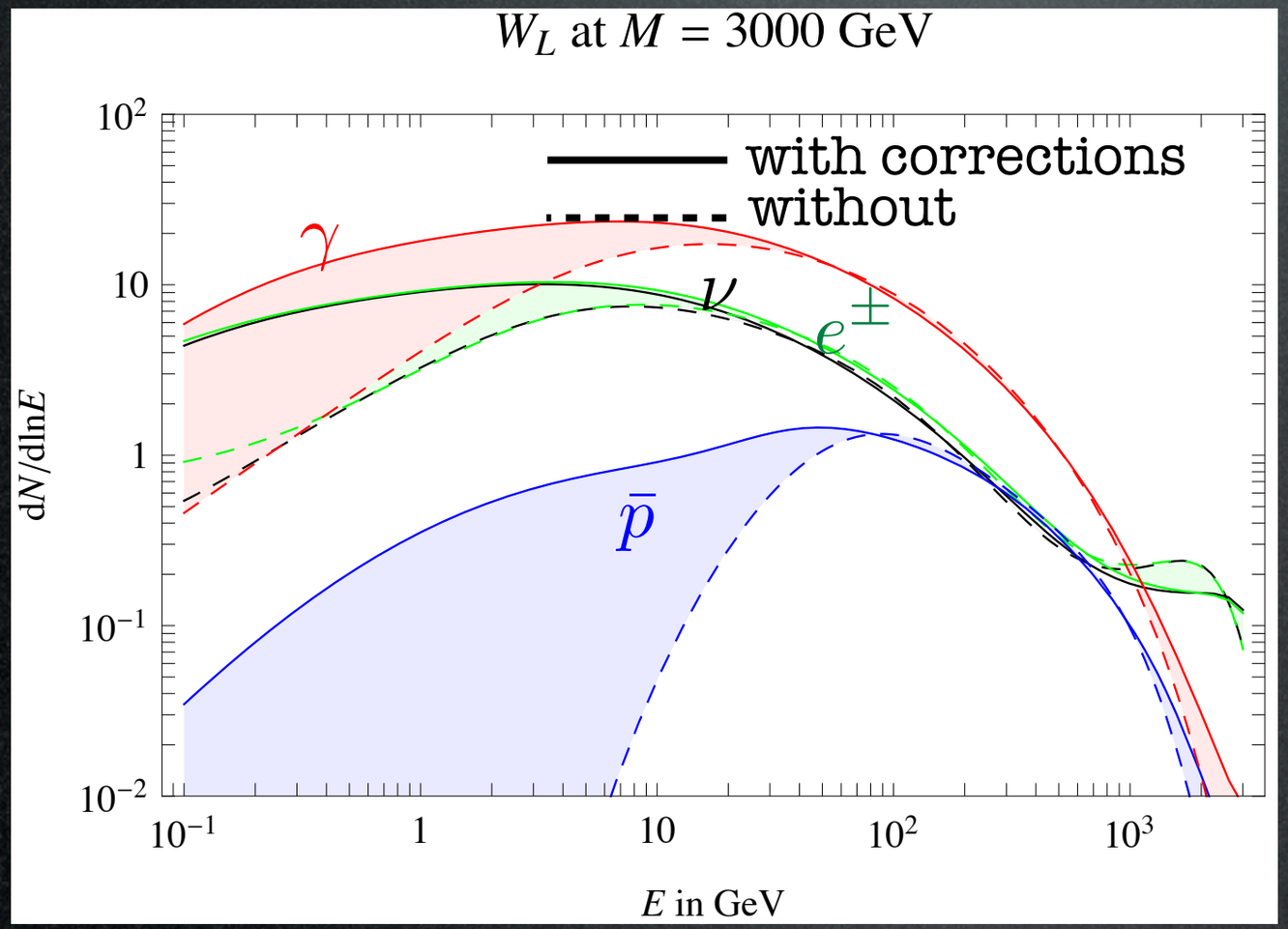
ElectroWeak corrections are important!





- unexpected species
- different spectra
  (especially at low energy, but not only)

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Fluxes at production

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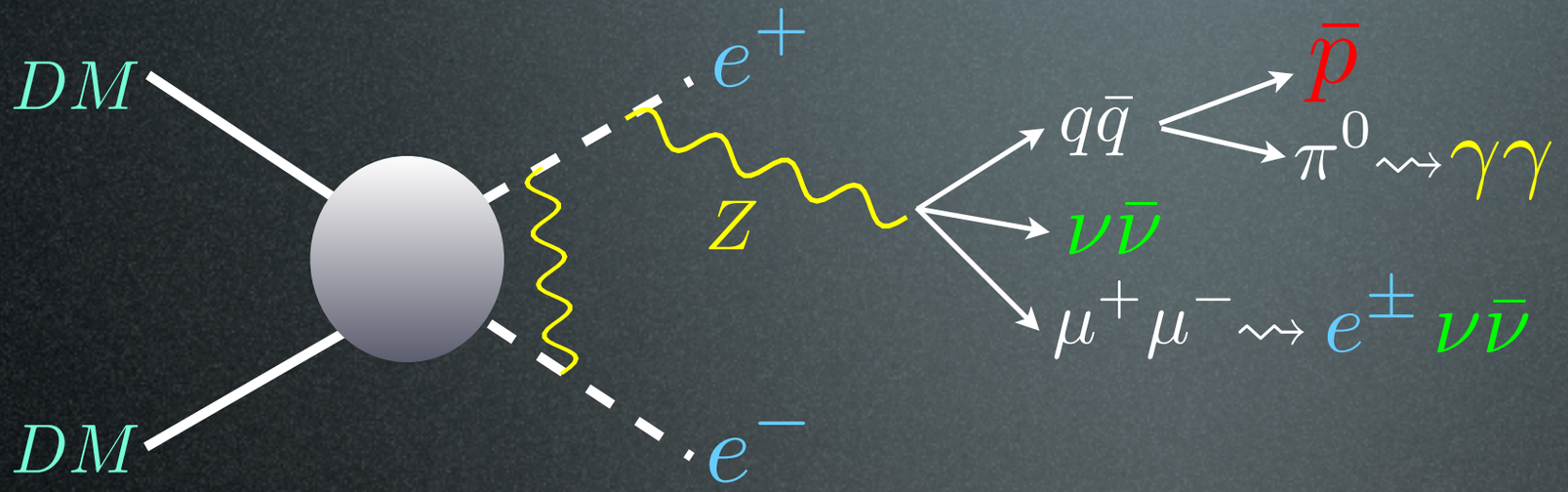

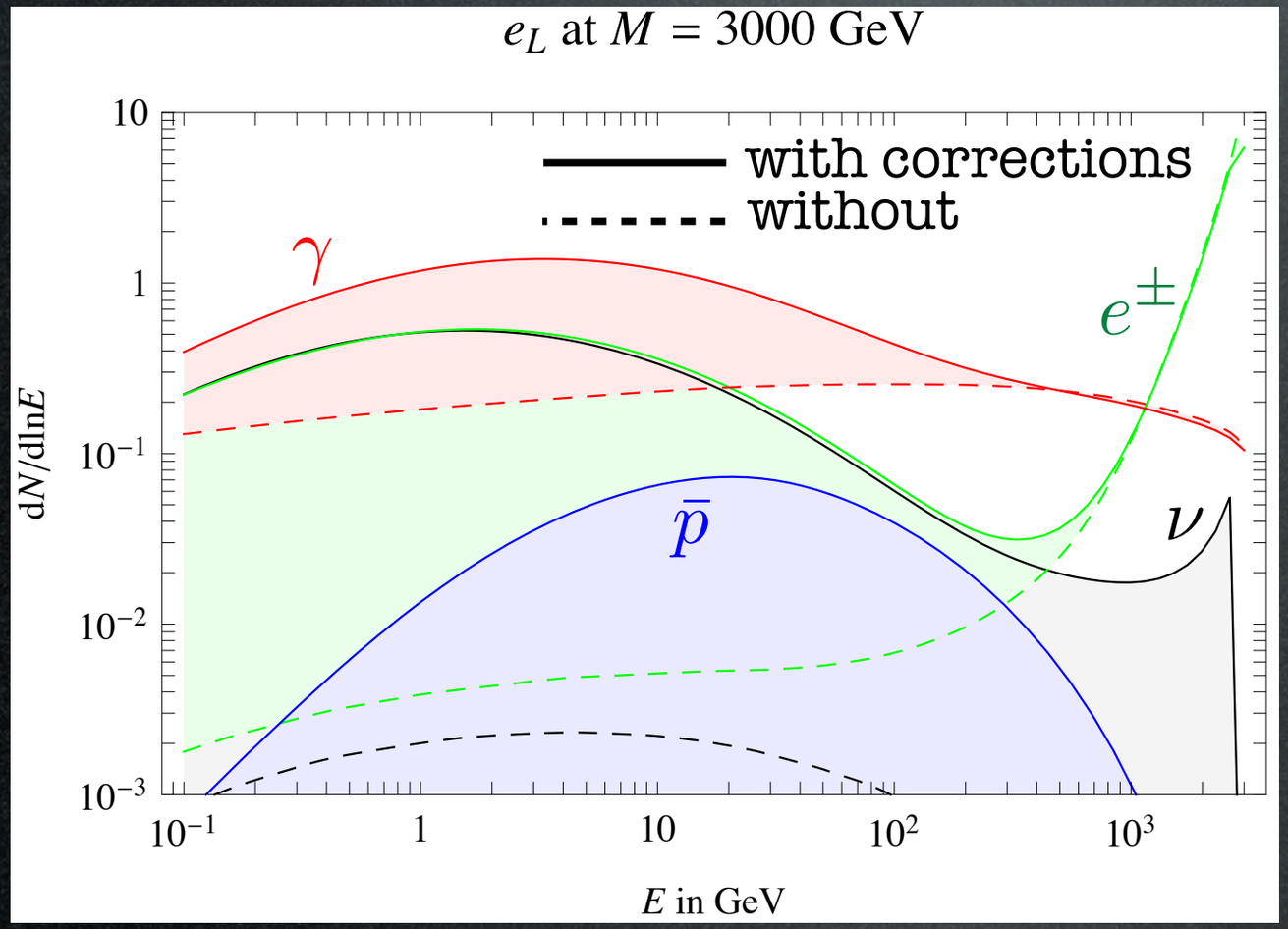

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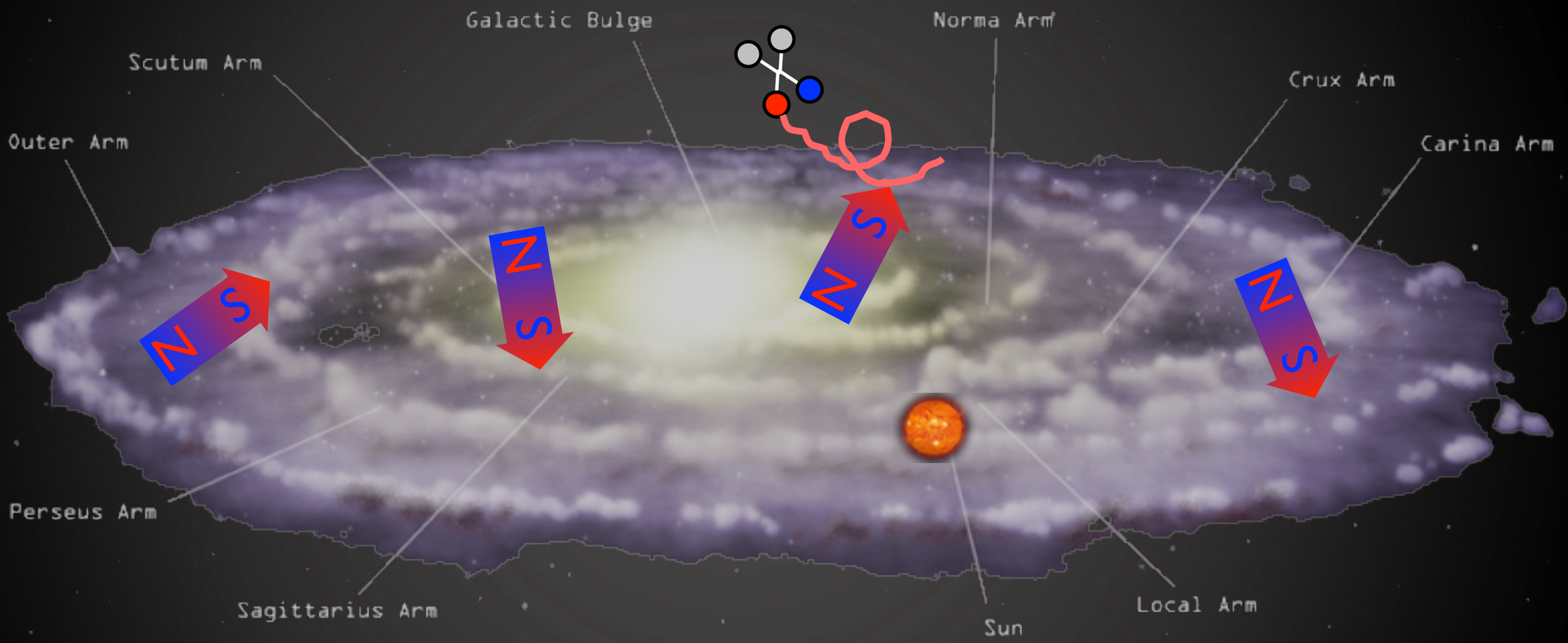
Indirect Detection: charged CRs

$\bar{p}$ and e^+ from DM annihilations in halo



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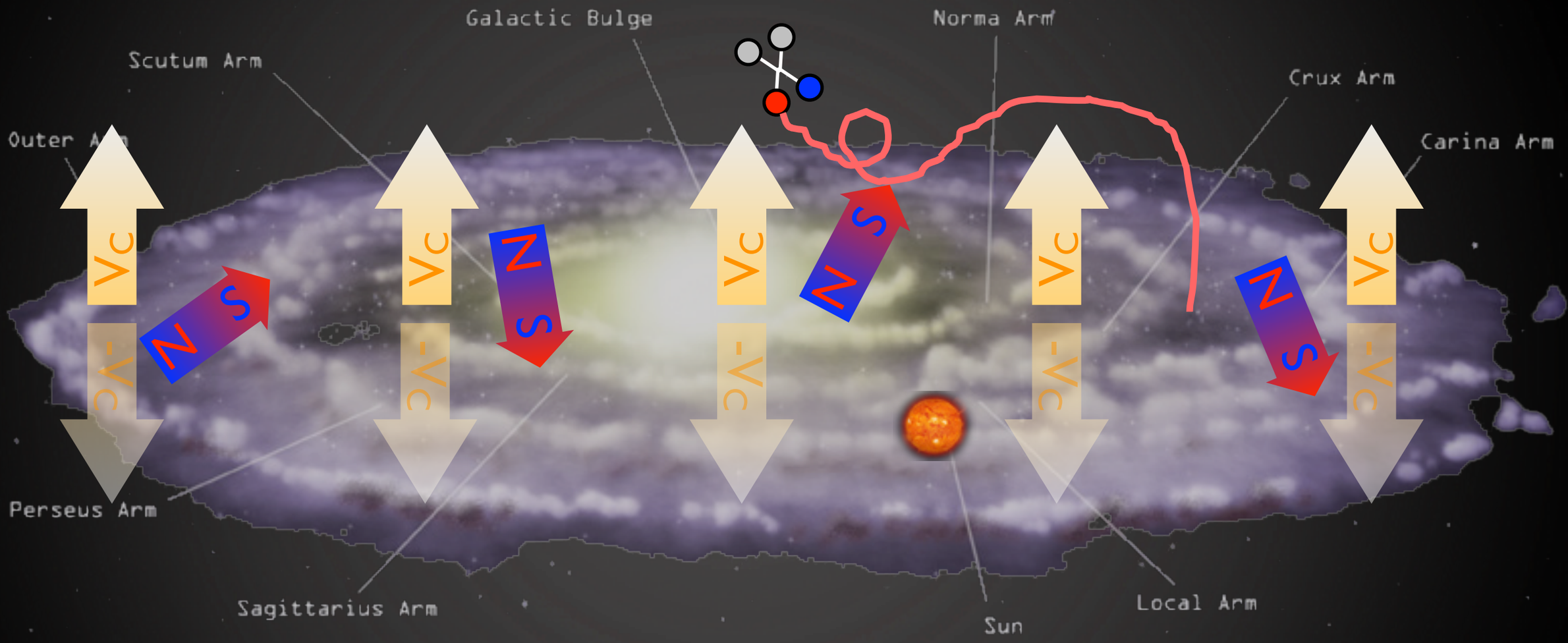

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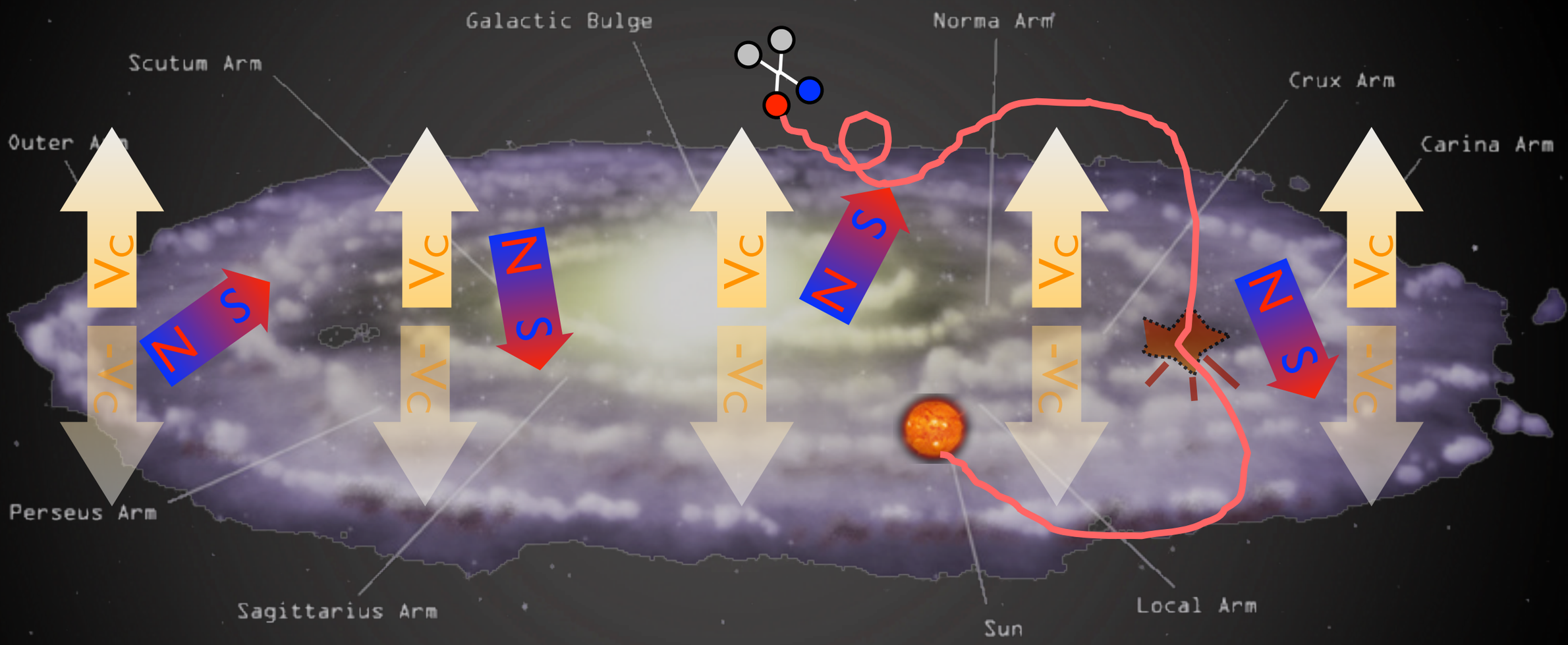

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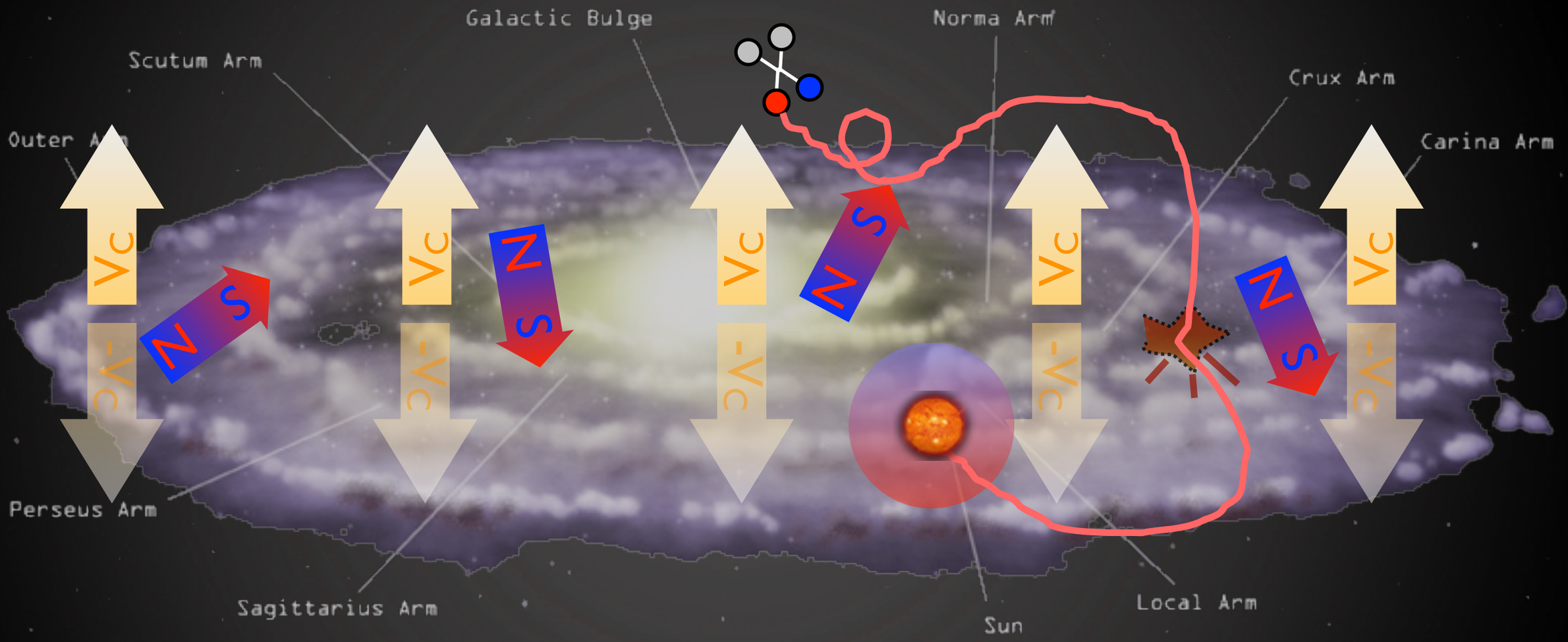

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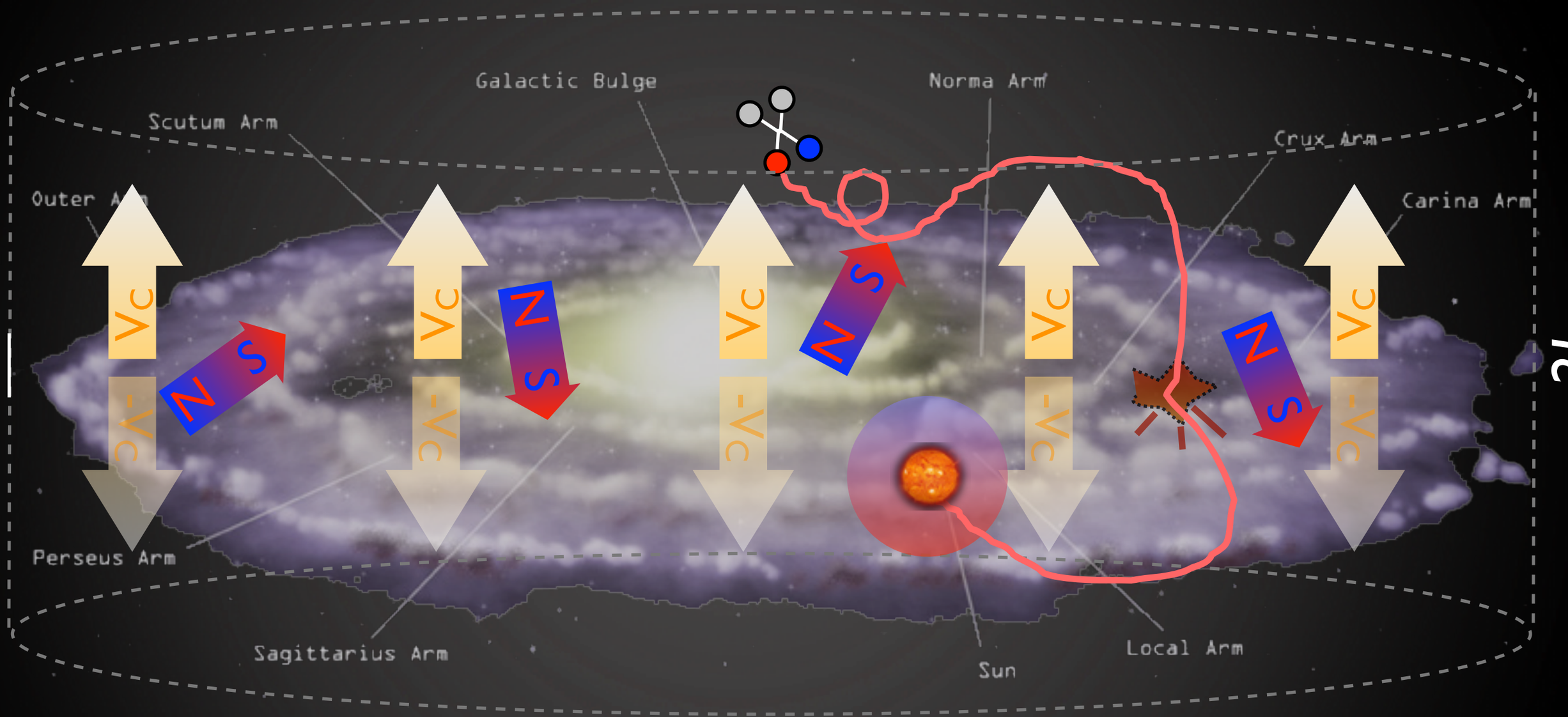


Salati, Chardonnay, Barrau, Donato, Taillet, Fornengo, Maur Brun... '90s, '00s

spectrum

$$\frac{\partial f}{\partial t} - K(E)\cdot\nabla^2 f - \frac{\partial}{\partial E}\left(b(E) f\right) + \frac{\partial}{\partial z}(V_c f) = Q_{\rm inj} - 2h\delta(z)\Gamma_{\rm spall} f$$

diffusion | energy loss | convective wind | source | spallations [uncert]

Indirect Detection: charged CRs

$\bar{p}$ and e^+ from DM annihilations in halo

	KRA	KOL	CON	THK	THN	THN2	THN3
thickness L [kpc]	4	4	4	10	0.5	2	3
diffusion D_0 $[10^{28}\ \mathrm{cm^2\,s^{-1}}]$	2.64	4.46	0.97	4.75	0.31	1.35	1.98
diffusion δ	0.50	0.33	0.6	0.50	0.50	0.50	0.50
diff. reacc. η	-0.39	1	1	-0.15	-0.27	-0.27	-0.27
diff. reacc. v_A $[\mathrm{km\,s^{-1}}]$	14.2	36	38.1	14.1	11.6	11.6	11.6
p index γ	2.35	1.78/2.45	1.62/2.35	2.35	2.35	2.35	2.35
convection dv_c/dz $[\mathrm{km\,s^{-1}\,kpc^{-1}}]$	0	0	50	0	0	0	0
solar mod. ϕ_F^p [GV]	0.650	0.335	0.282	0.687	0.704	0.626	0.623
$\chi^2_{\mathrm{min}}/\mathrm{dof}$ (p in [25])	0.462	0.761	1.602	0.516	0.639	0.343	0.339

Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173
cfr. Evoli, Cholis, Grasso, Maccione, Ullio, 1108.0664

	Electrons or positrons		Antiprotons (and antideuterons)			
Model	δ	$\mathcal{K}_0$ [kpc^2/Myr]	δ	$\mathcal{K}_0$ [kpc^2/Myr]	V_{conv} [km/s]	L [kpc]
MIN	0.55	0.00595	0.85	0.0016	13.5	1
MED	0.70	0.0112	0.70	0.0112	12	4
MAX	0.46	0.0765	0.46	0.0765	5	15

Donato et al., 2003+

Indirect Detection: charged CRs

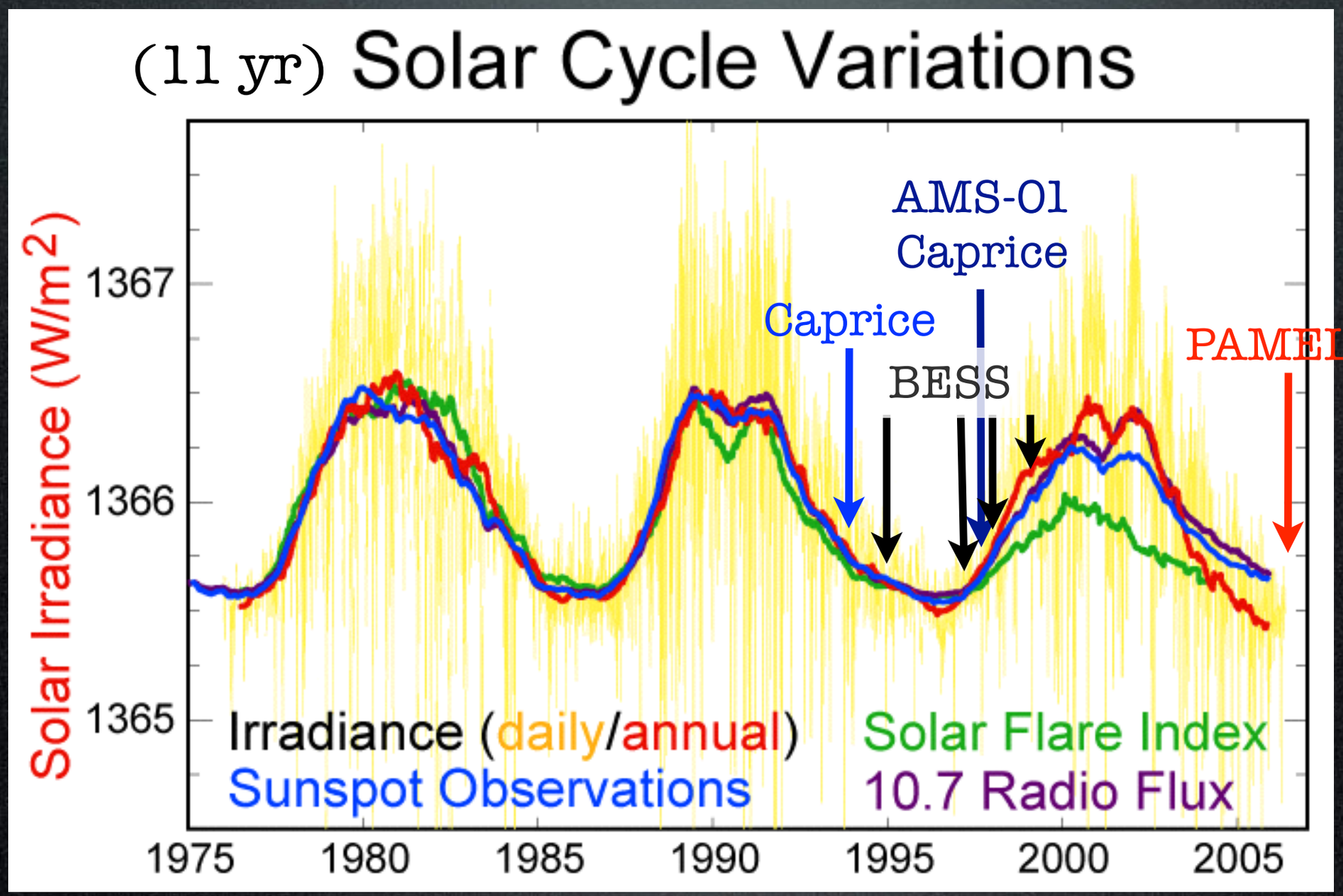
Solar wind Modulation of cosmic rays:

$$\frac{d\Phi_{\bar{p}\oplus}}{dT_\oplus} = \frac{p_\oplus^2}{p^2}\frac{d\Phi_{\bar{p}}}{dT}, \qquad T = T_\oplus + |Ze|\phi_F$$

spectrum at Earth

spectrum far from Earth

Fisk potential $\phi_F \simeq 500$ MV



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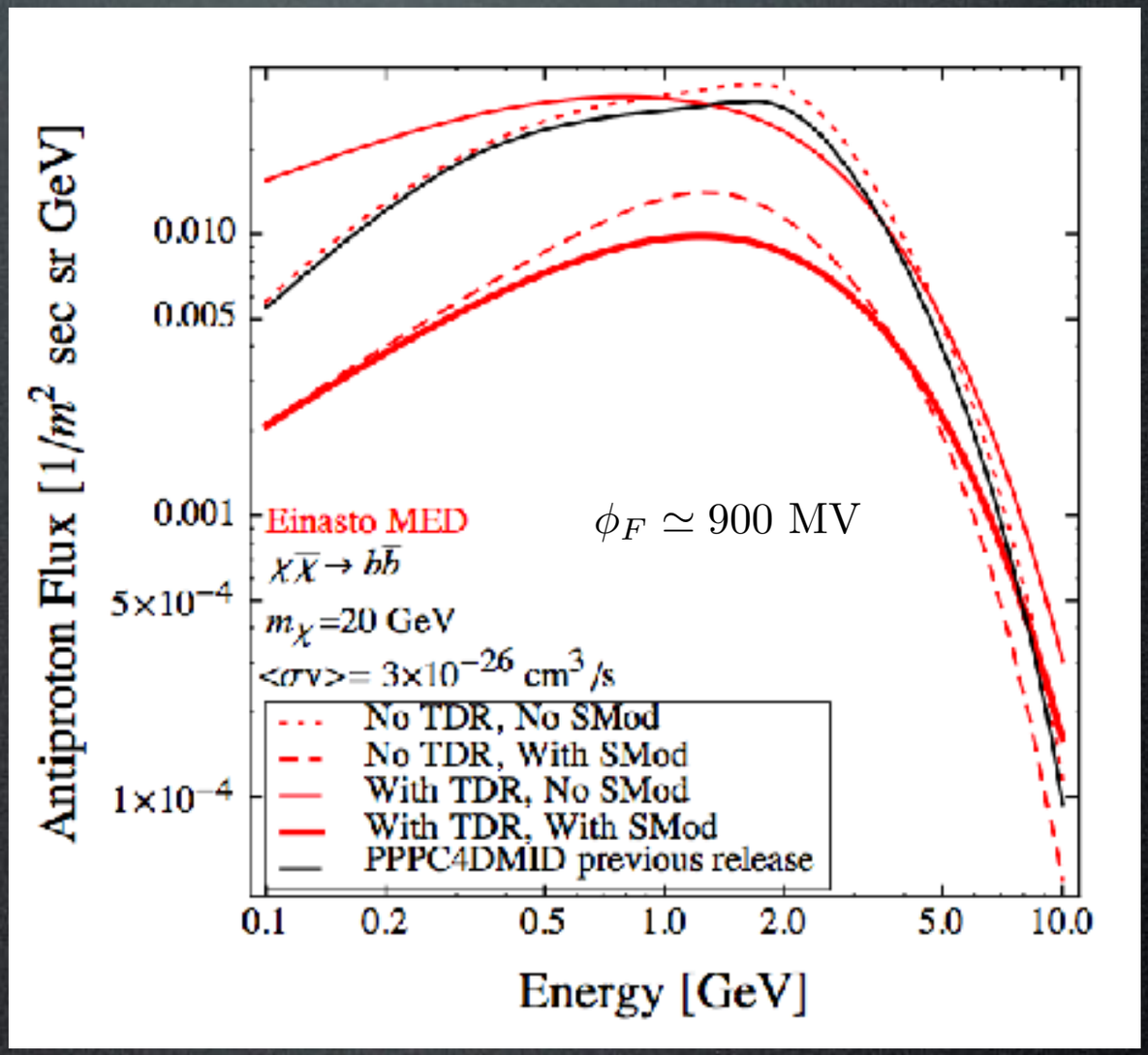
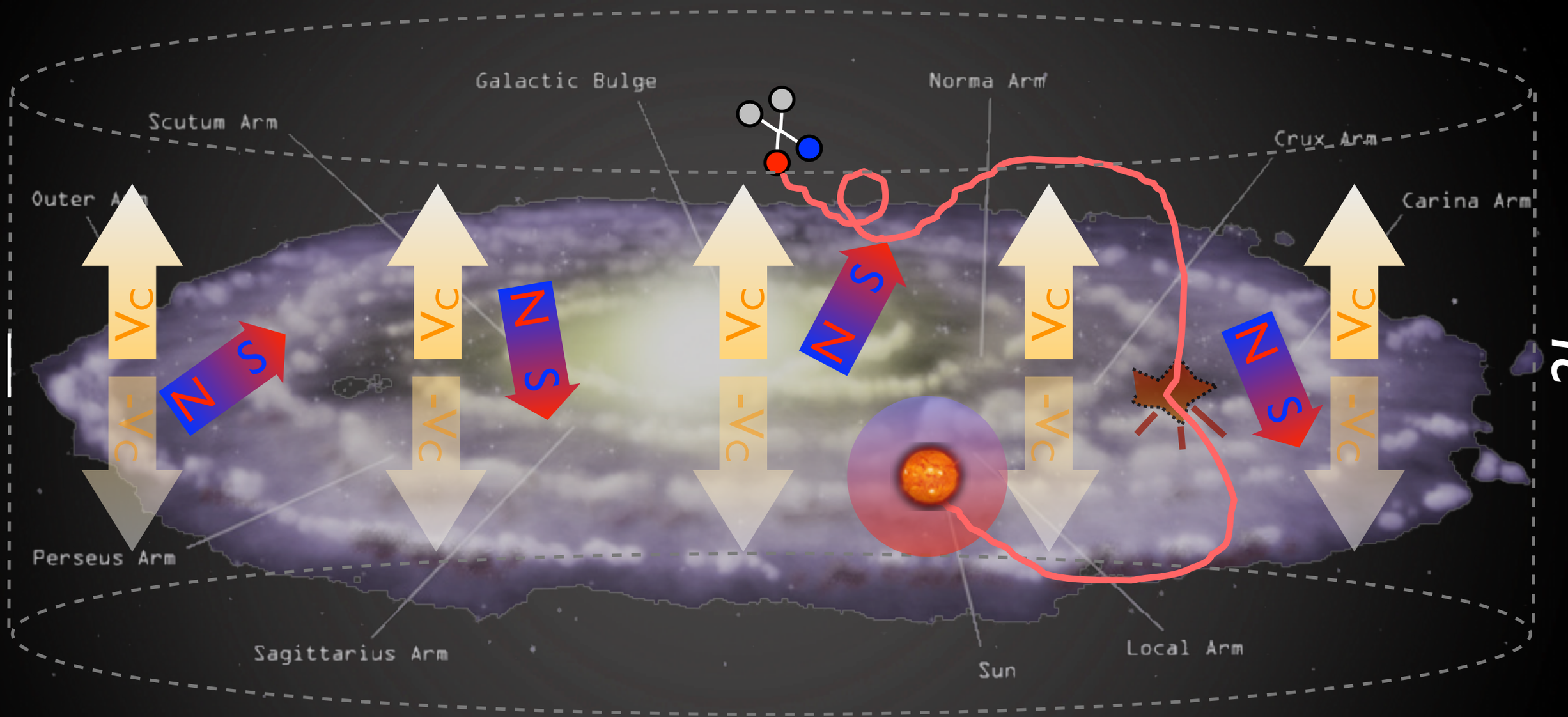
E.g.



Boudaud, Cirelli, Giesen, Salati, 1412.5696

Indirect Detection: charged CRs

$\bar{p}$ and e^+ from DM annihilations in halo



spectrum

$$\frac{\partial f}{\partial t} - K(E)\cdot\nabla^2 f - \frac{\partial}{\partial E}\left(b(E) f\right) + \frac{\partial}{\partial z}(V_c f) = Q_{\rm inj} - 2h\delta(z)\Gamma_{\rm spall} f$$

diffusion | energy loss | convective wind | source | spallations

Salati, Chardonnay, Barrau, Donato, Taillet, Fornengo, Maur Brun... '90s, '00s

[uncert]

DM halo profiles

From N-body numerical simulations:

$$\text{NFW}: \quad \rho_{\rm NFW}(r) = \rho_s \frac{r_s}{r}\left(1+\frac{r}{r_s}\right)^{-2}$$

$$\text{Einasto}: \quad \rho_{\rm Ein}(r) = \rho_s \exp\left\{-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha}-1\right]\right\}$$

$$\text{Isothermal}: \quad \rho_{\rm Iso}(r) = \frac{\rho_s}{1+(r/r_s)^2}$$

$$\text{Burkert}: \quad \rho_{\rm Bur}(r) = \frac{\rho_s}{(1+r/r_s)(1+(r/r_s)^2)}$$

$$\text{Moore}: \quad \rho_{\rm Moo}(r) = \rho_s \left(\frac{r_s}{r}\right)^{1.16}\left(1+\frac{r}{r_s}\right)^{-1.84}$$

DM halo	α	r_s [kpc]	ρ_s [GeV/cm^3]
NFW	–	24.42	0.184
Einasto	0.17	28.44	0.033
EinastoB	0.11	35.24	0.021
Isothermal	–	4.38	1.387
Burkert	–	12.67	0.712
Moore	–	30.28	0.105

At small r: $\rho(r) \propto 1/r^{\gamma}$

6 profiles:

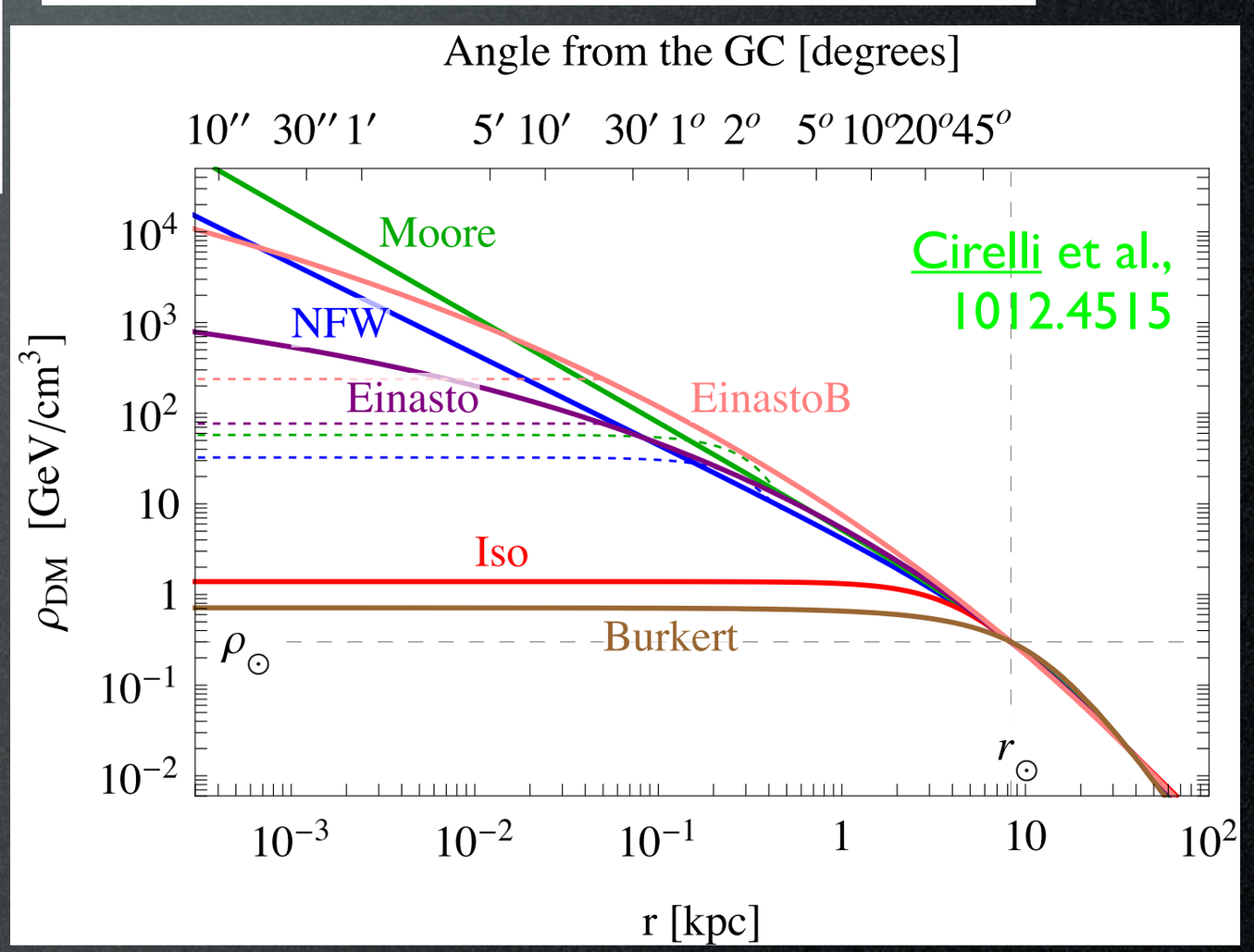
cuspy: NFW, Moore

mild: Einasto

smooth: isothermal, Burkert

EinastoB = steepened Einasto

(effect of baryons?)

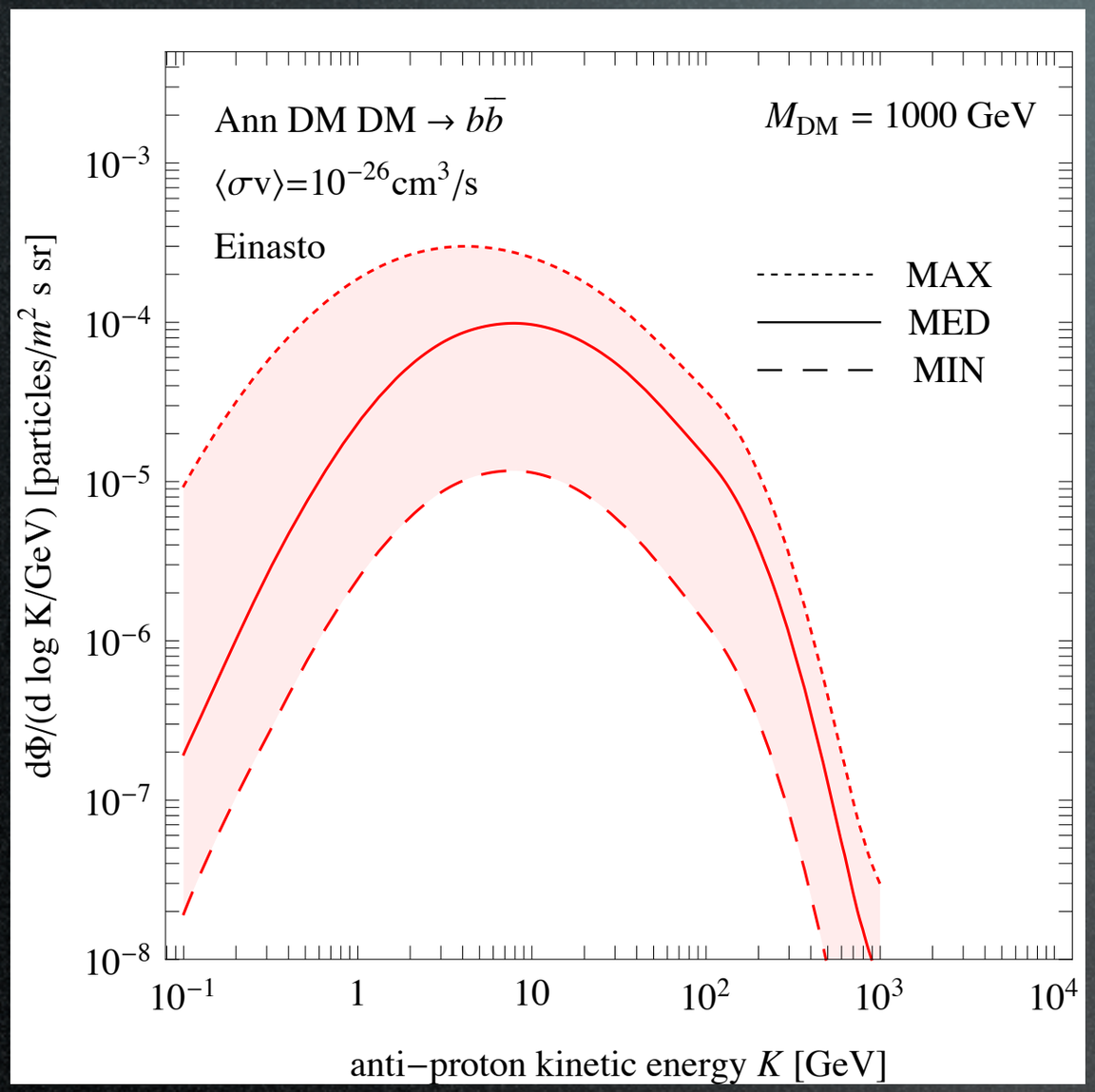


Propagated fluxes

Antiprotons

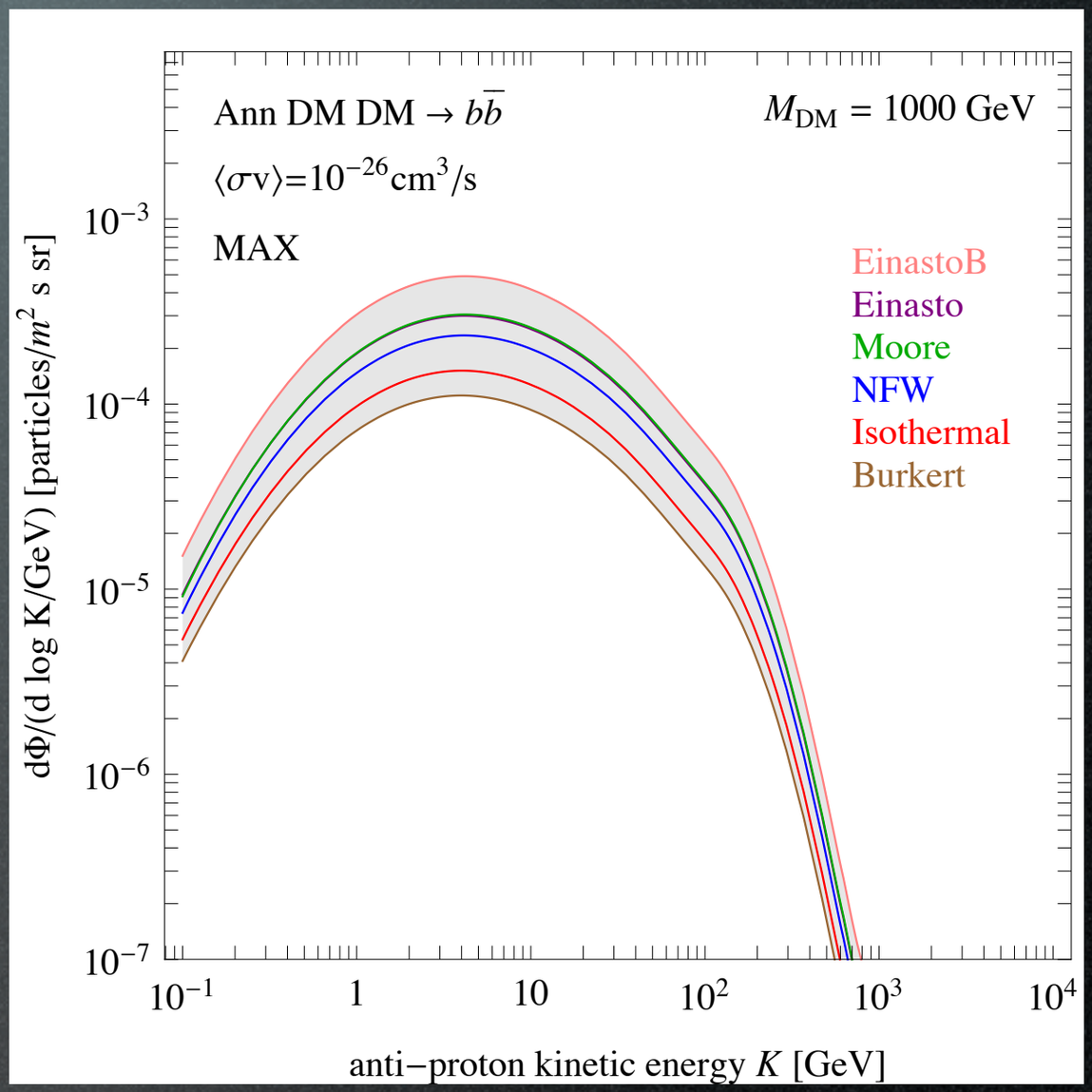
Cirelli, Panci, Sala et al., 1012.4515
Boudaud, Cirelli, Giesen, Salati 1412.5696

Varying prop parameters



Almost 2 orders of magnitude

Varying halo profile



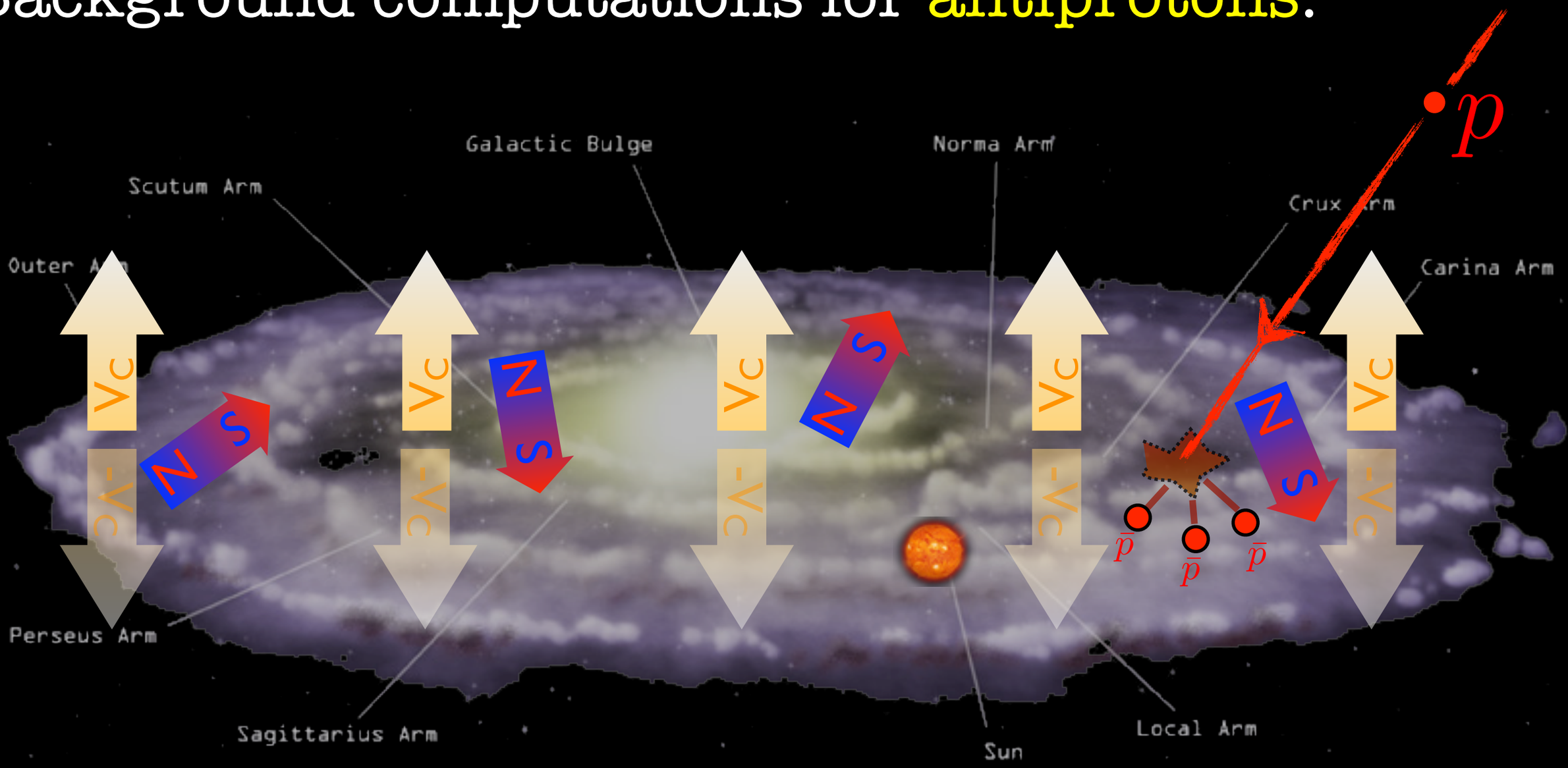
Almost 1 order of magnitude

Bottom line: Antiprotons are quite affected by propagation, but spectral shape somewhat preserved

Predicting antiprotons from astrophysics

Antiprotons

Background computations for antiprotons:



Antiprotons

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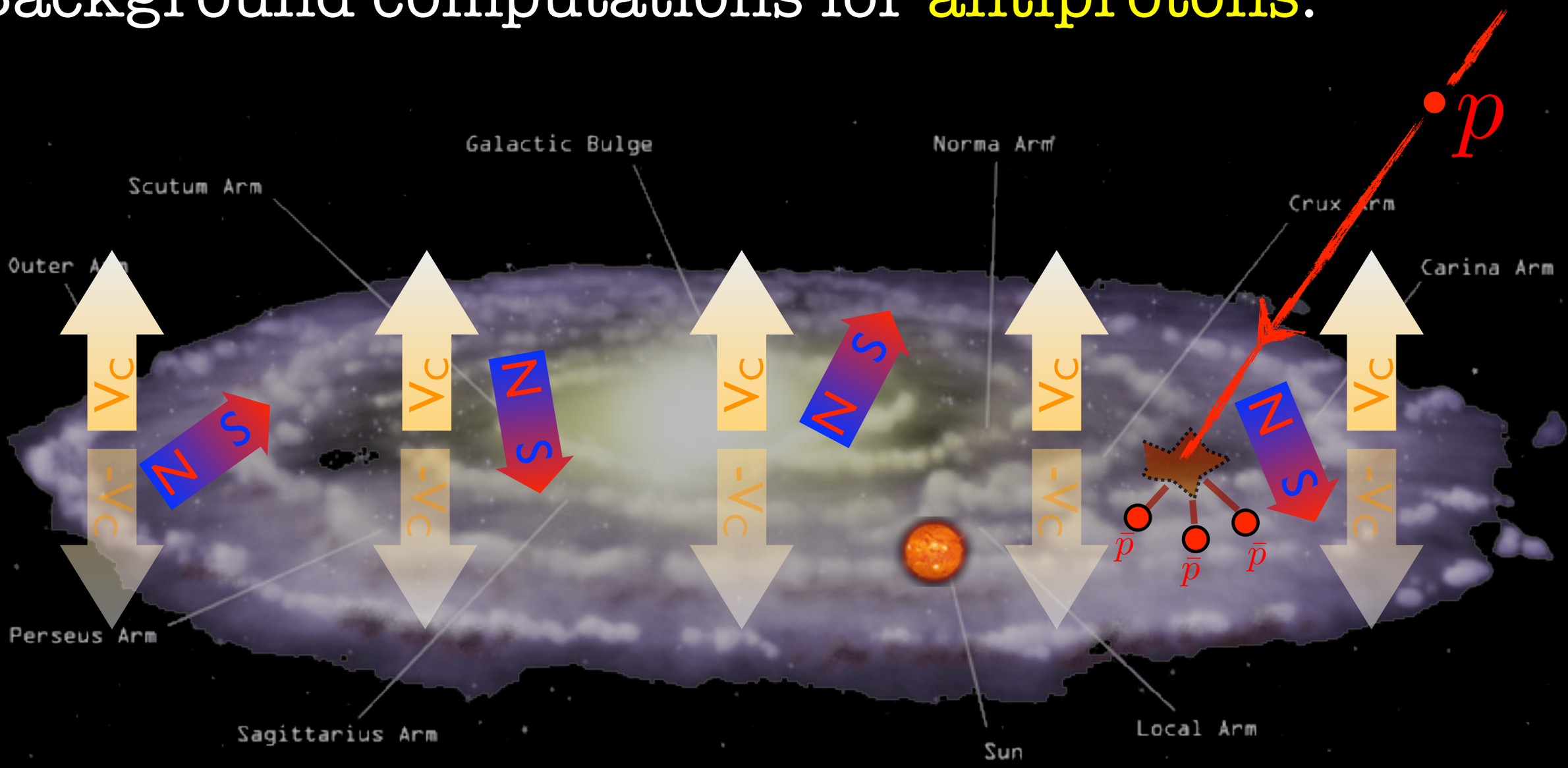
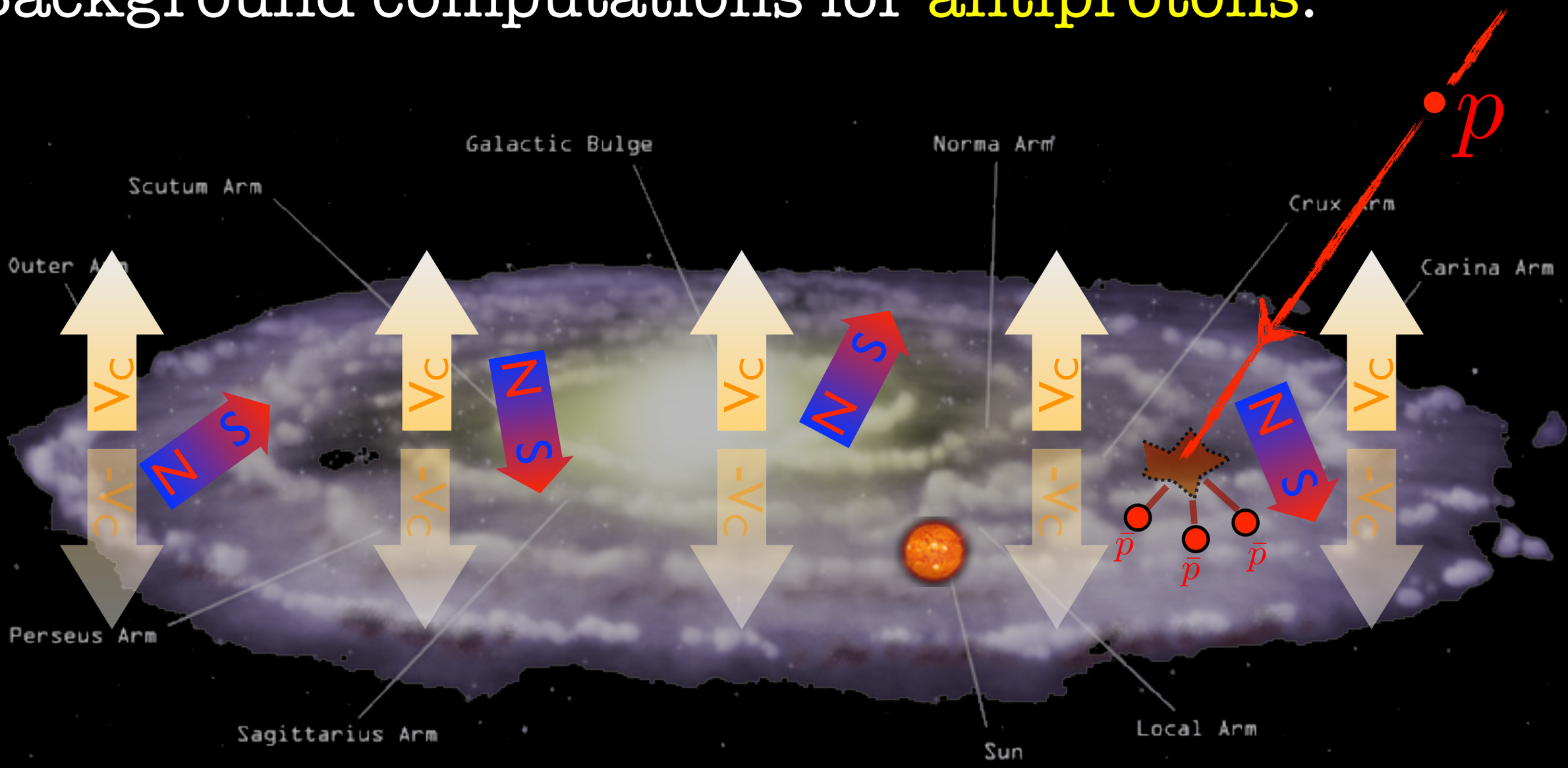


Main ingredients:

- primary p (and He)
- spallation cross-sections $\sigma_{p\mathrm{H}\to\bar{p}\mathrm{X}}$, $\sigma_{p\mathrm{He}\to\bar{p}\mathrm{X}}$, $\sigma_{\mathrm{He}\mathrm{H}\to\bar{p}\mathrm{X}}$, $\sigma_{\mathrm{He}\mathrm{He}\to\bar{p}\mathrm{X}}$
- propagation
- solar modulation

Antiprotons

Background computations for antiprotons:



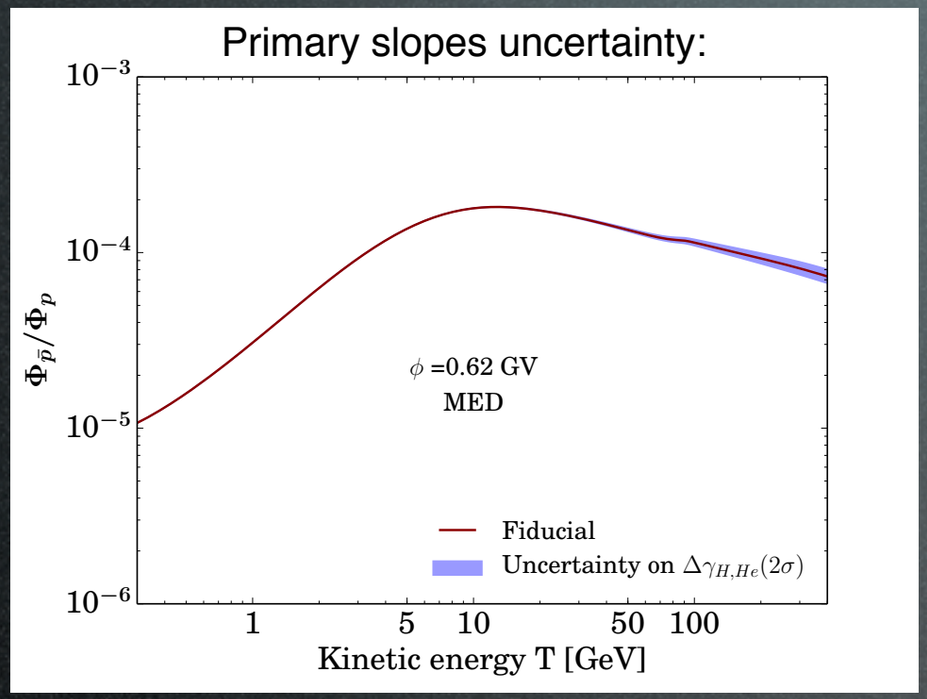
Main ingredients:

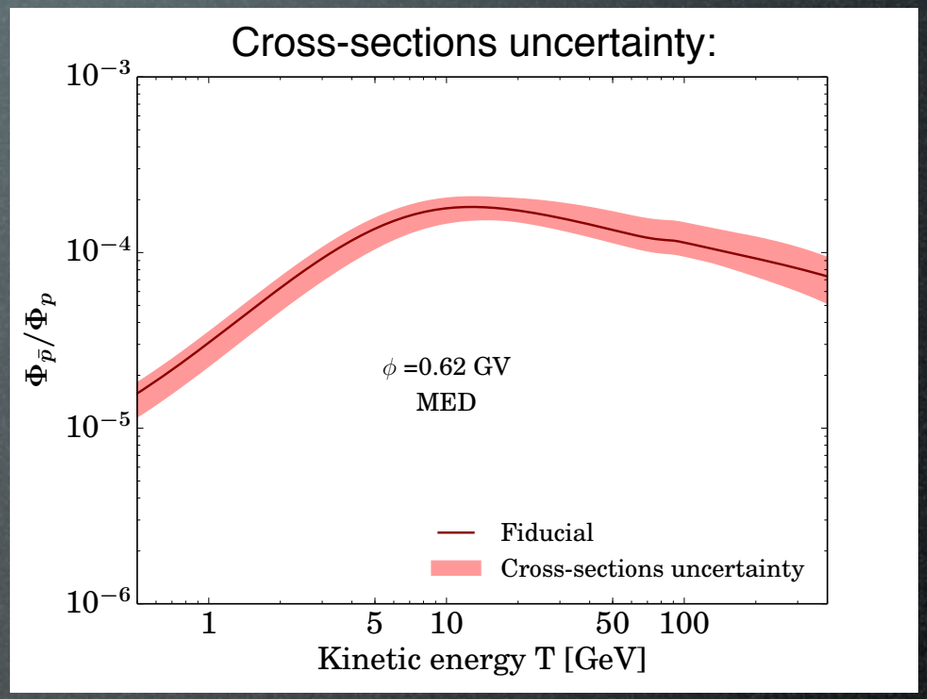
- primary p (and He) **New!** AMS-02 2015/16
- spallation cross-sections $\sigma_{p\mathrm{H}\to\bar{p}\mathrm{X}},\ \sigma_{p\mathrm{He}\to\bar{p}\mathrm{X}},\ \sigma_{\mathrm{He}\mathrm{H}\to\bar{p}\mathrm{X}},\ \sigma_{\mathrm{He}\mathrm{He}\to\bar{p}\mathrm{X}}$ **New!** NA49, BRAHMS
- propagation DiMauro, Donato, Goudelis, Serpico 1408.0288 + Winkler 1701.04866
- solar modulation

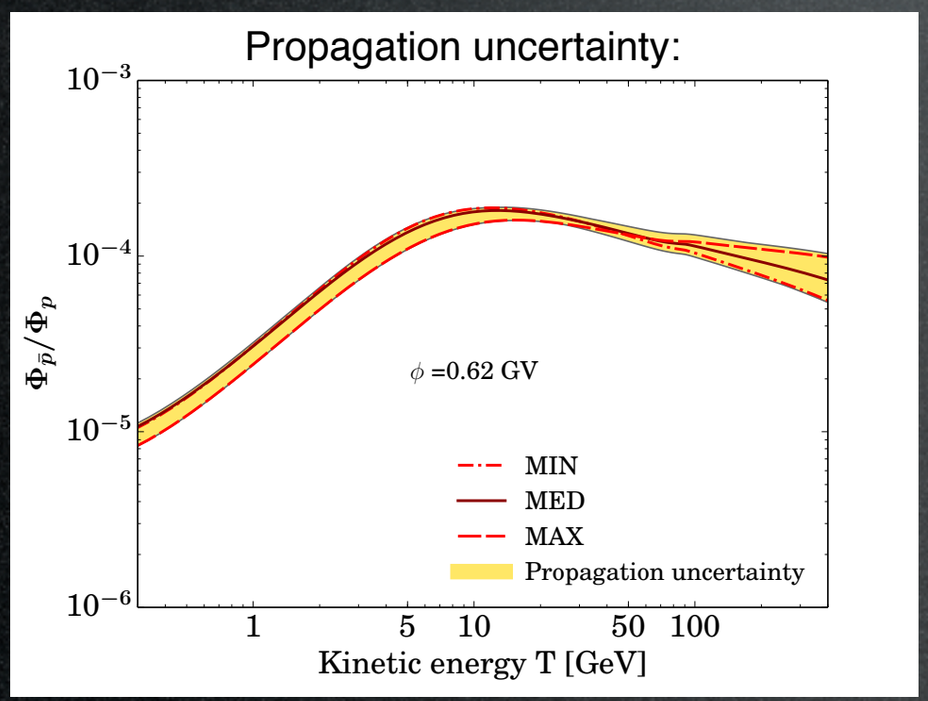
Antiprotons

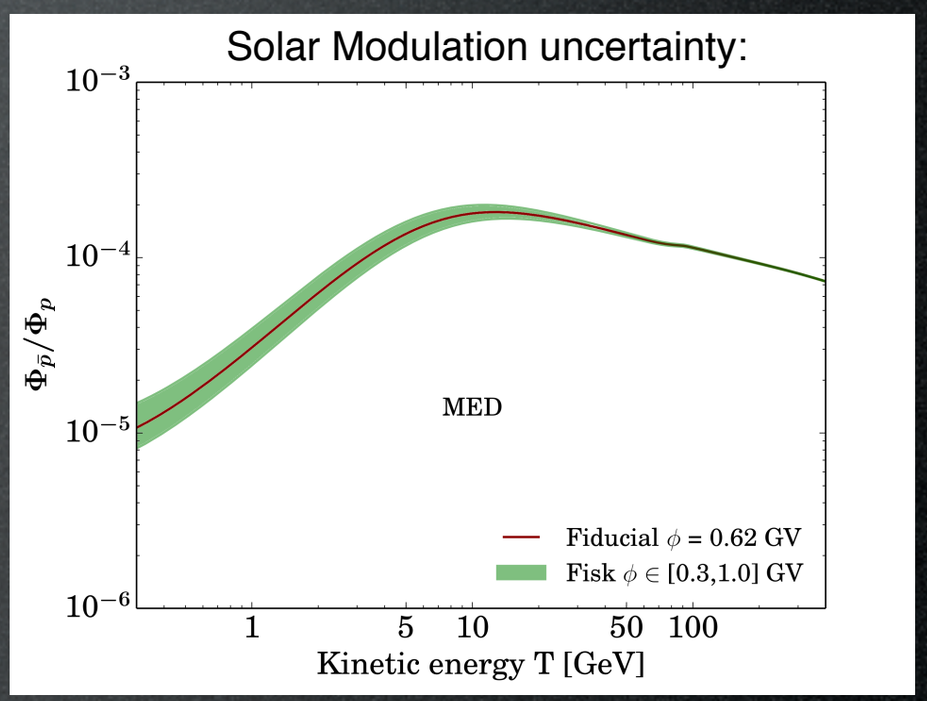
Background computations for antiprotons:

Uncertainties:





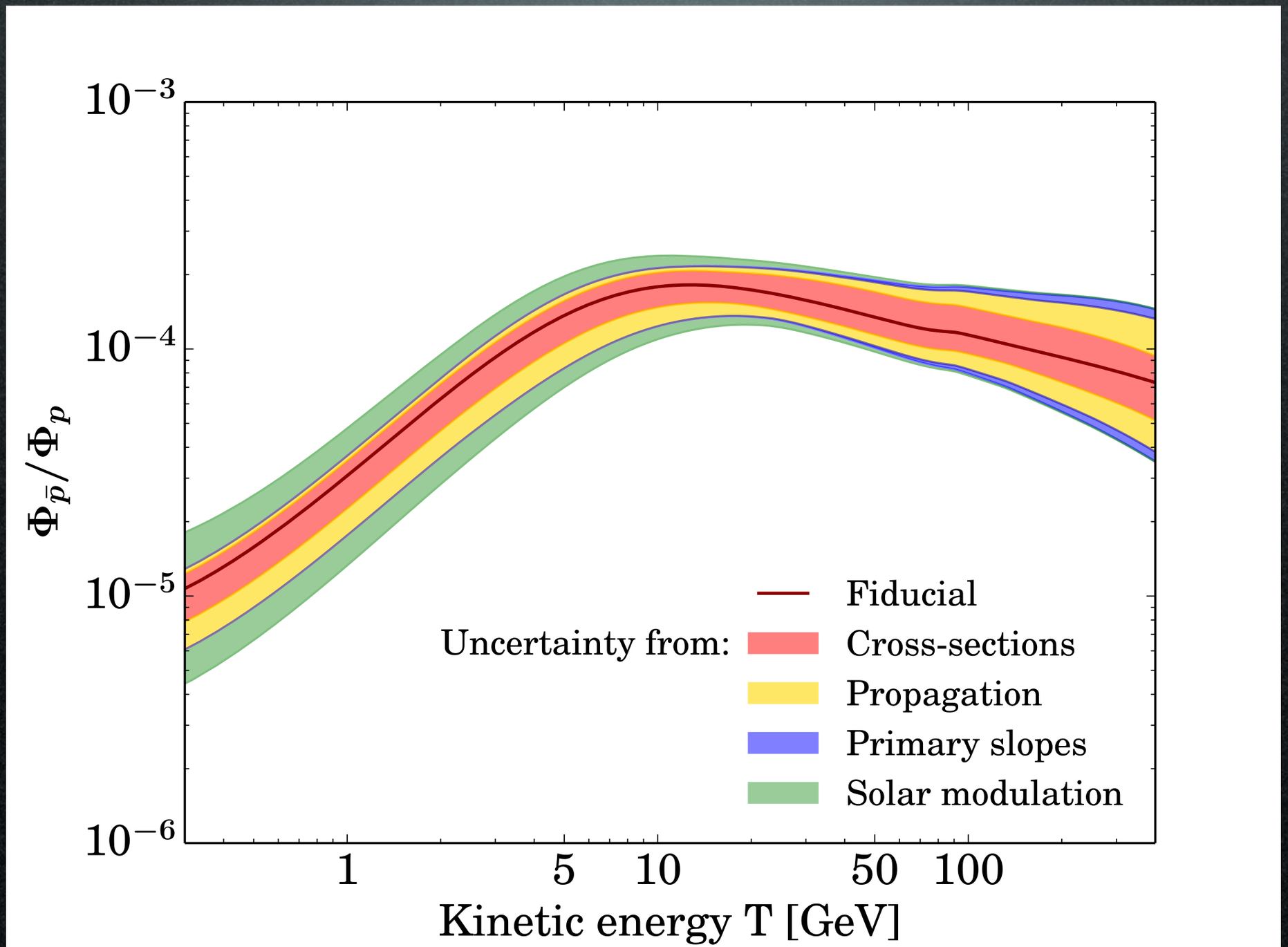




Giesen, Boudaud, Genolini, Poulin, Cirelli, Salati, Serpico 1504.04276

Antiprotons

Background computations for antiprotons:

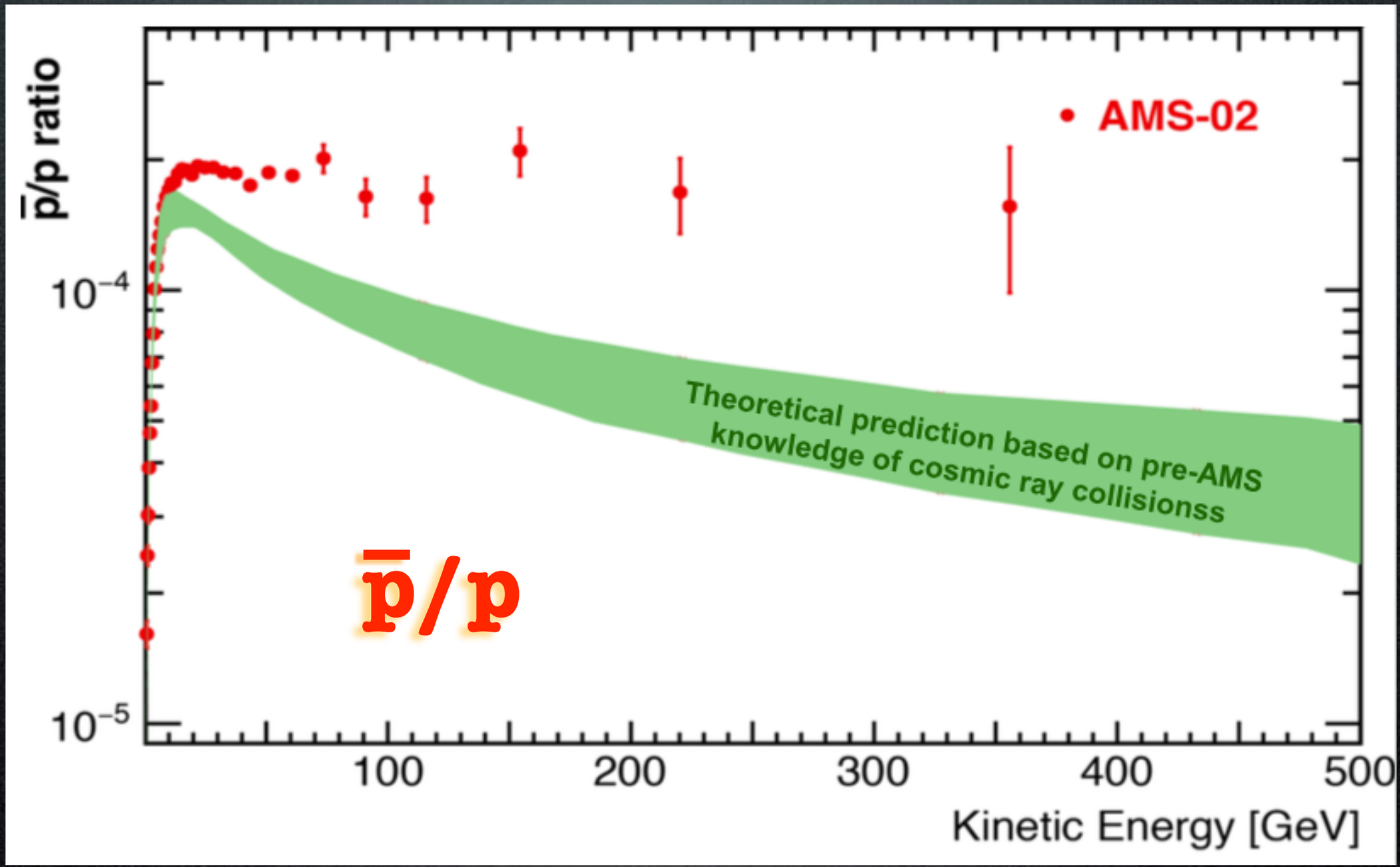


Giesen, Boudaud, Genolini, Poulin, Cirelli, Salati, Serpico 1504.04276

Data

Data: antiprotons

AMS-02

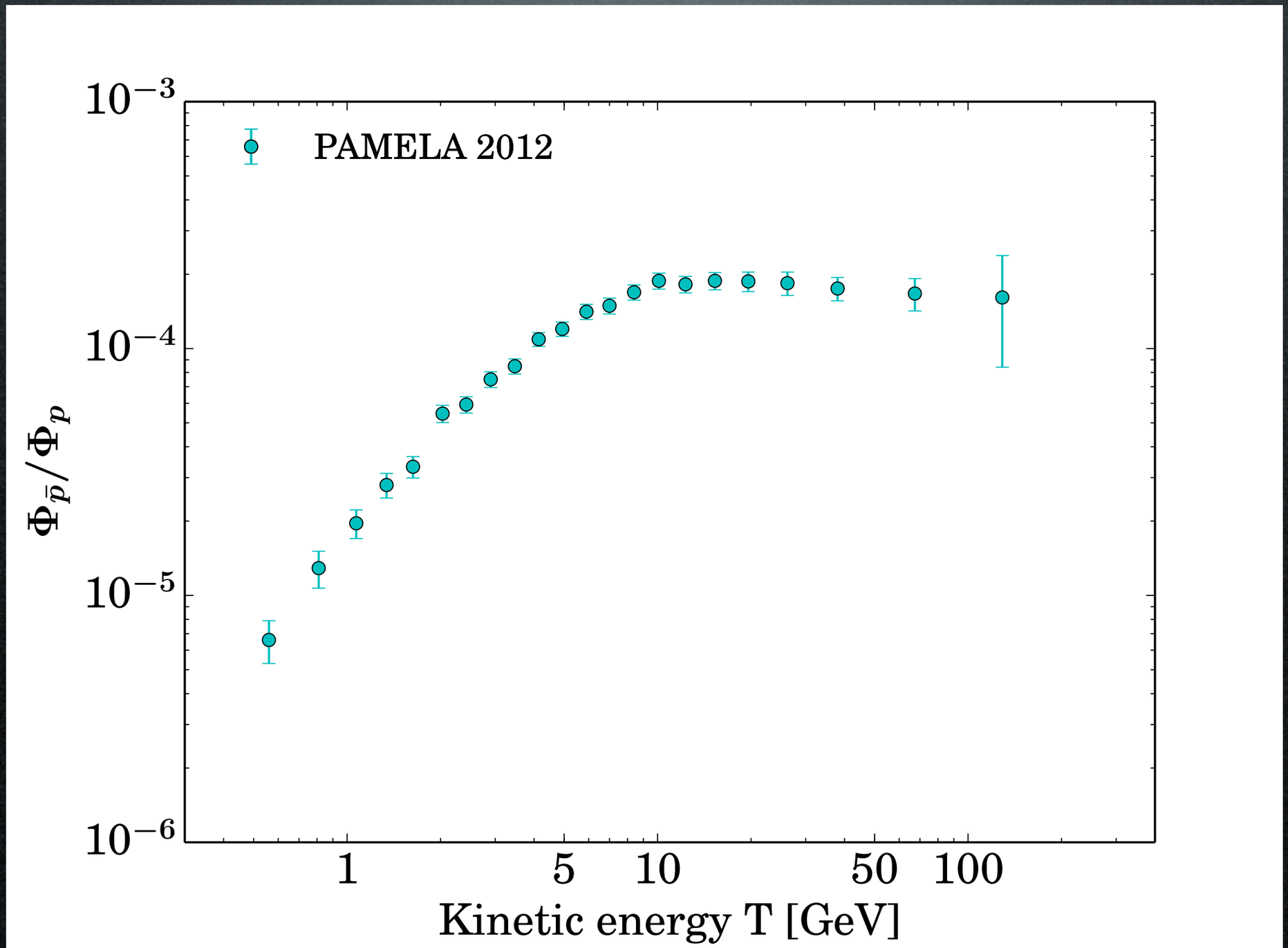


S. Ting - AMS days @ CERN apr 2015

A. Kounine - AMS days @ CERN apr 2015

Antiprotons

Antiproton data vis-à-vis the secondaries:



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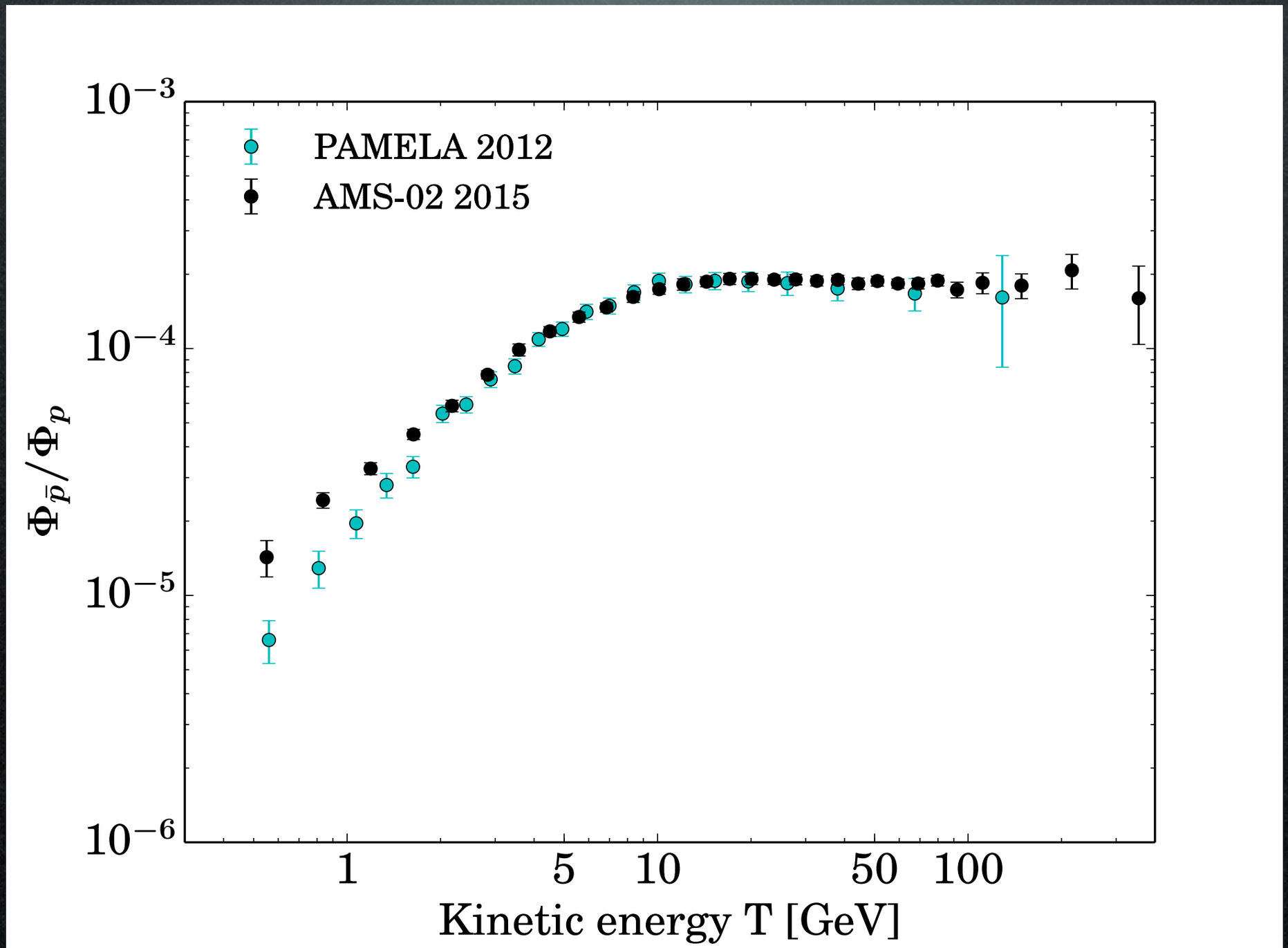

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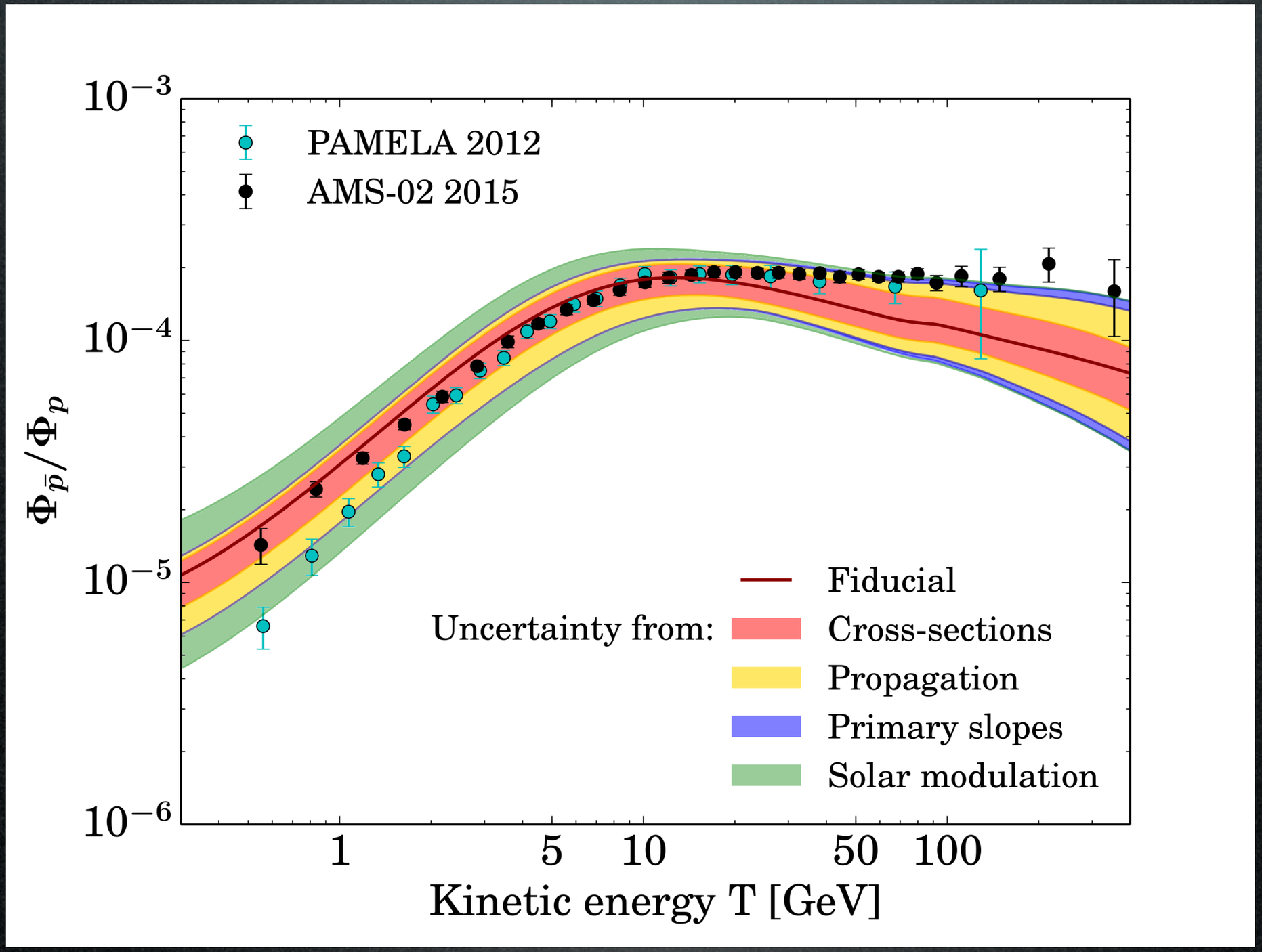

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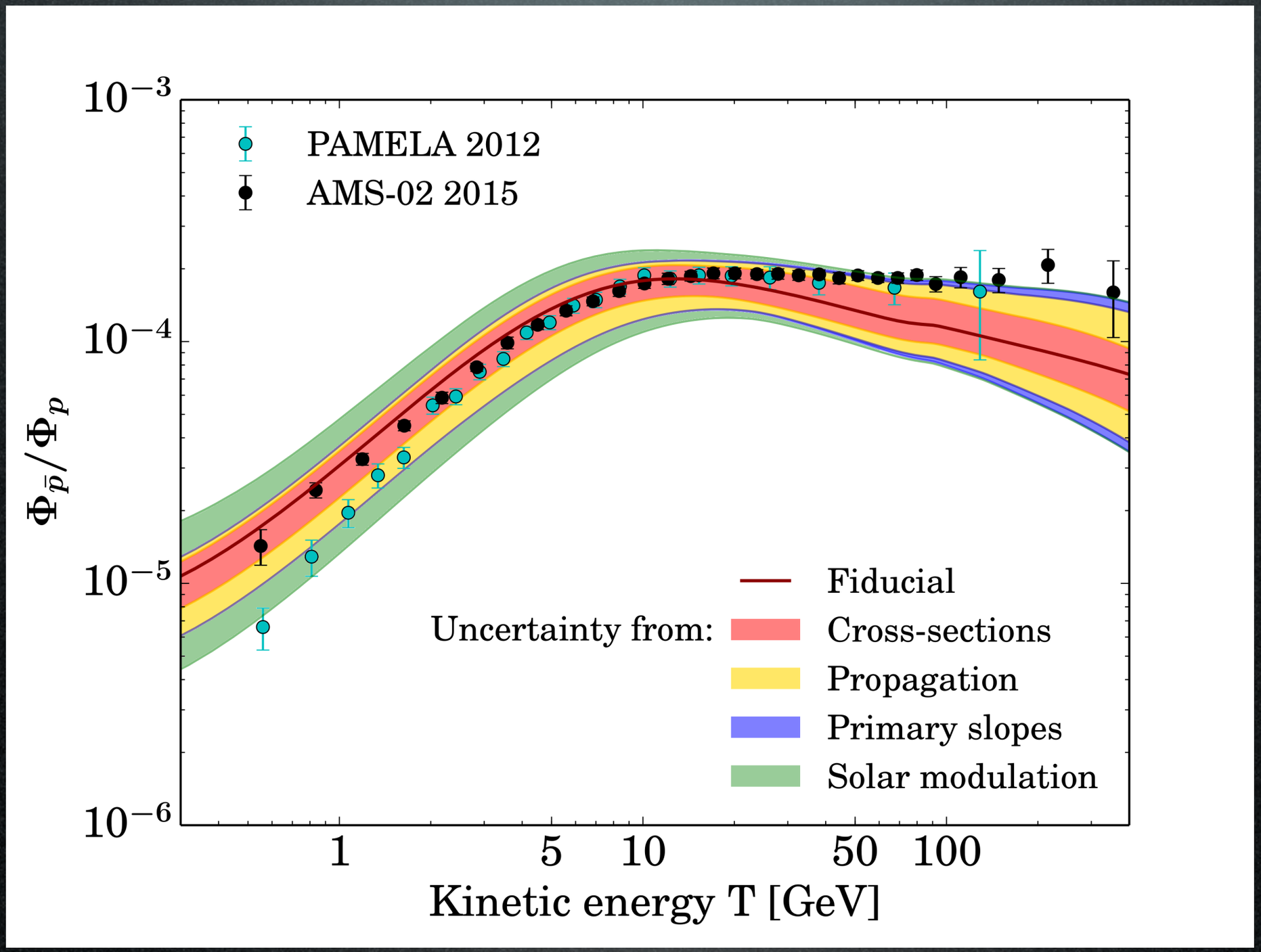

No evident **excess**

Giesen, Boudaud, Génolini, Poulin, Cirelli, Salati, Serpico 1504.04276

Antiprotons

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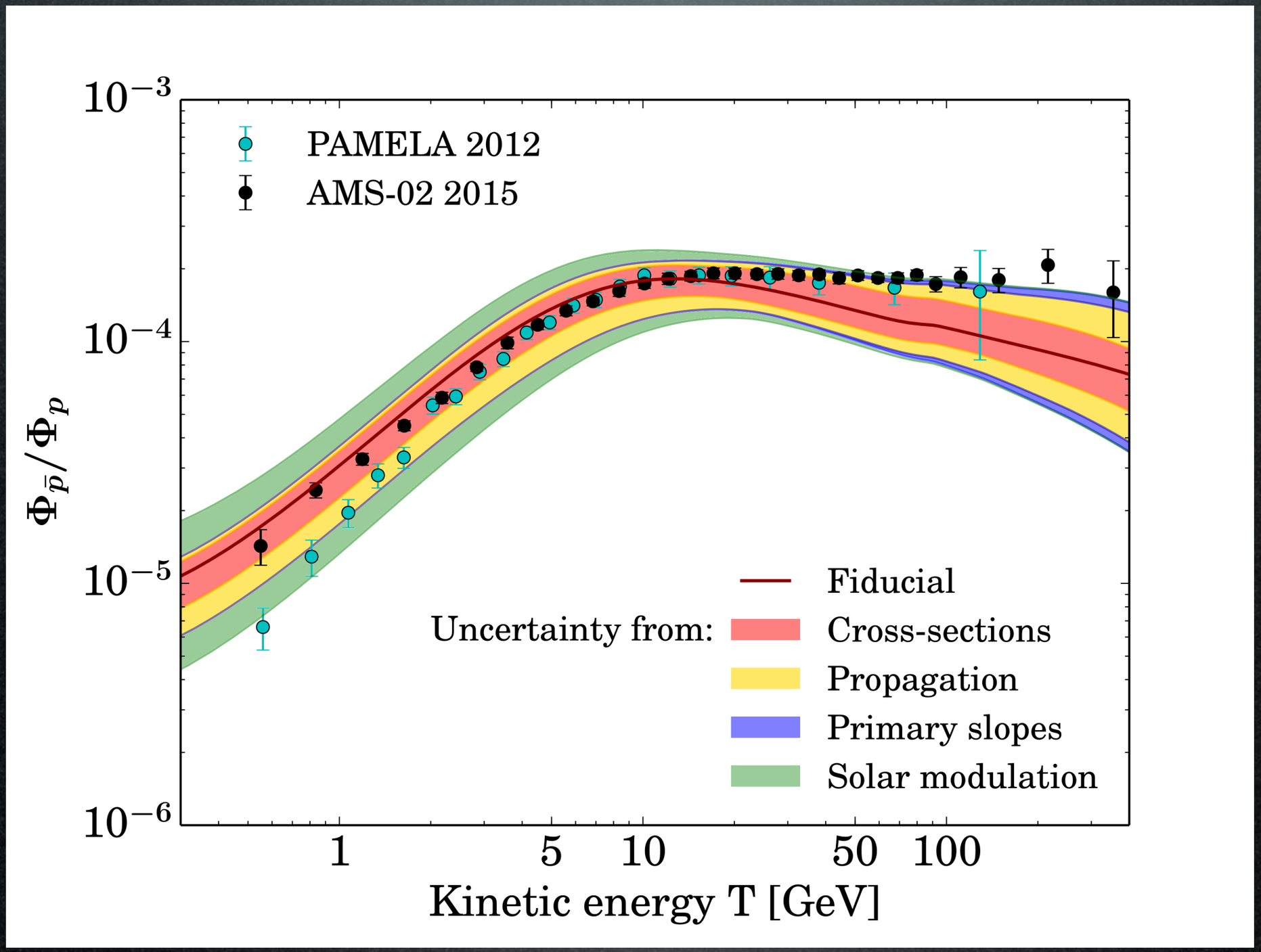


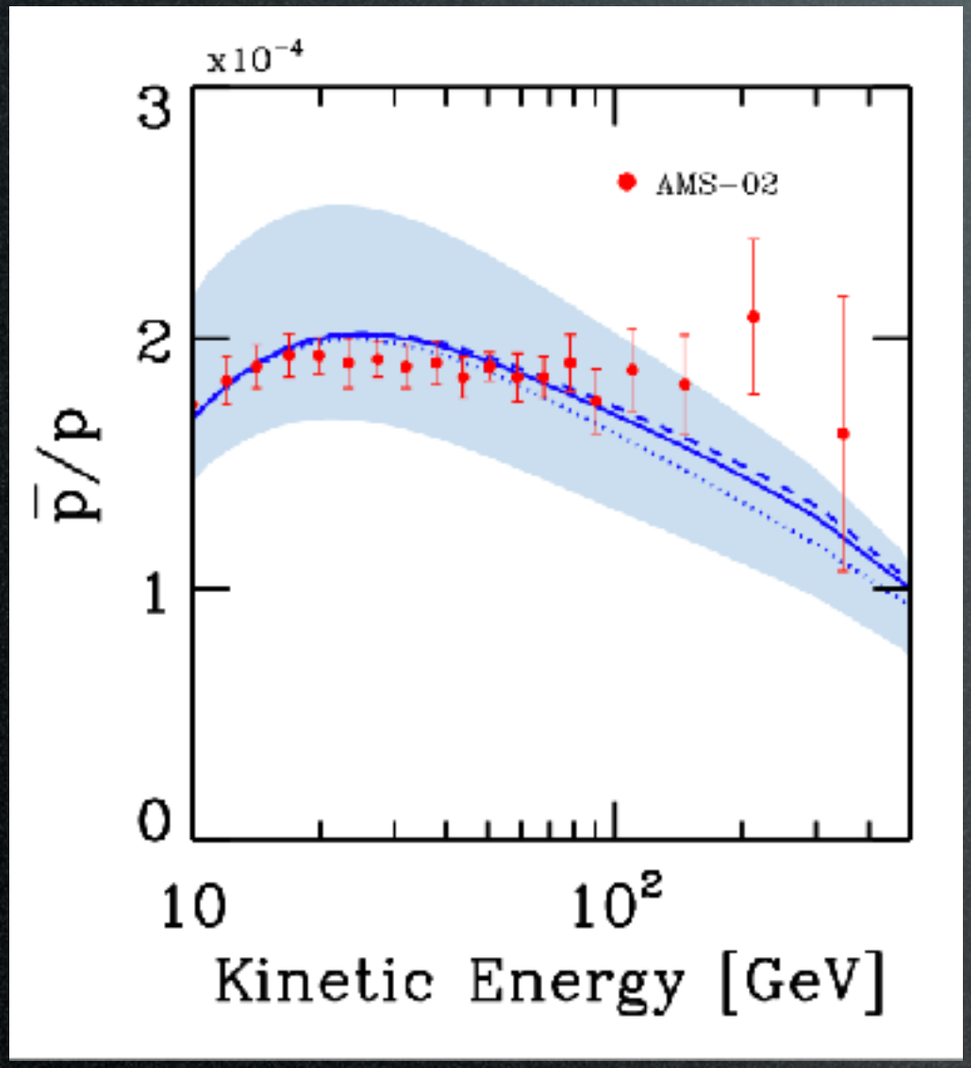
No evident **excess**

Some preference for flatness

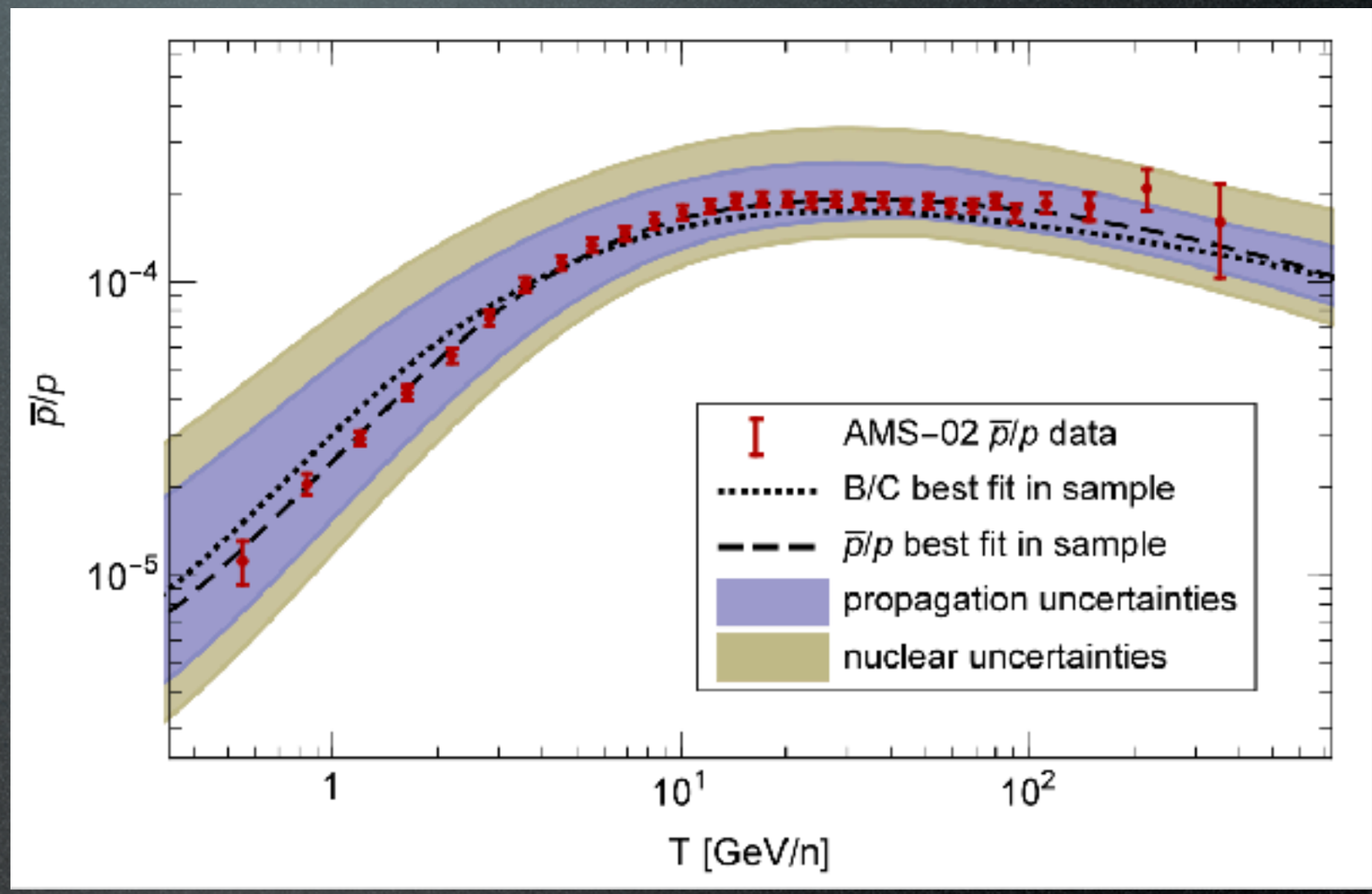
Giesen, Boudaud, Génolini, Poulin, Cirelli, Salati, Serpico 1504.04276

Antiprotons

Antiproton data vis-à-vis the secondaries:



Evoli, Gaggero, Grasso 1504.05175



Kappl, Reinert, Winkler 1506.04145

consistent results

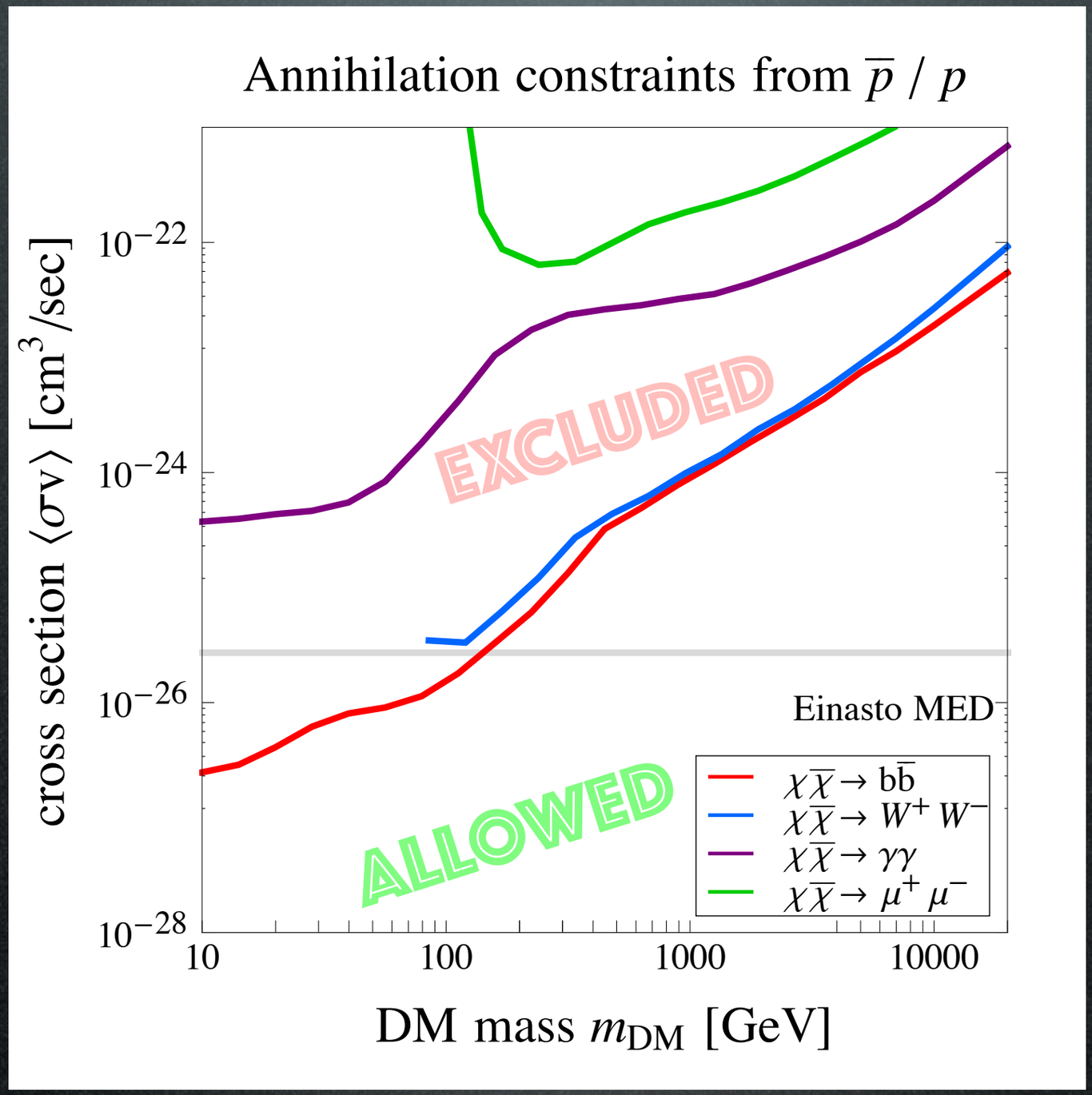
Constraints

Model independent bounds

Based on AMS-02 $\bar{p}/p$ data (april 2015)

Model independent bounds

Based on AMS-02 $\bar{p}/p$ data (april 2015)



Giesen, Boudaud, Genolini, Poulin, Cirelli, Salati, Serpico
1504.04276

NB: direct comparison with former PAMELA-based bounds (Boudaud et al., 1412.5695) is tricky because secondaries are reevaluated in between, but these are **similar** or very marginally **stronger**

Model independent bounds

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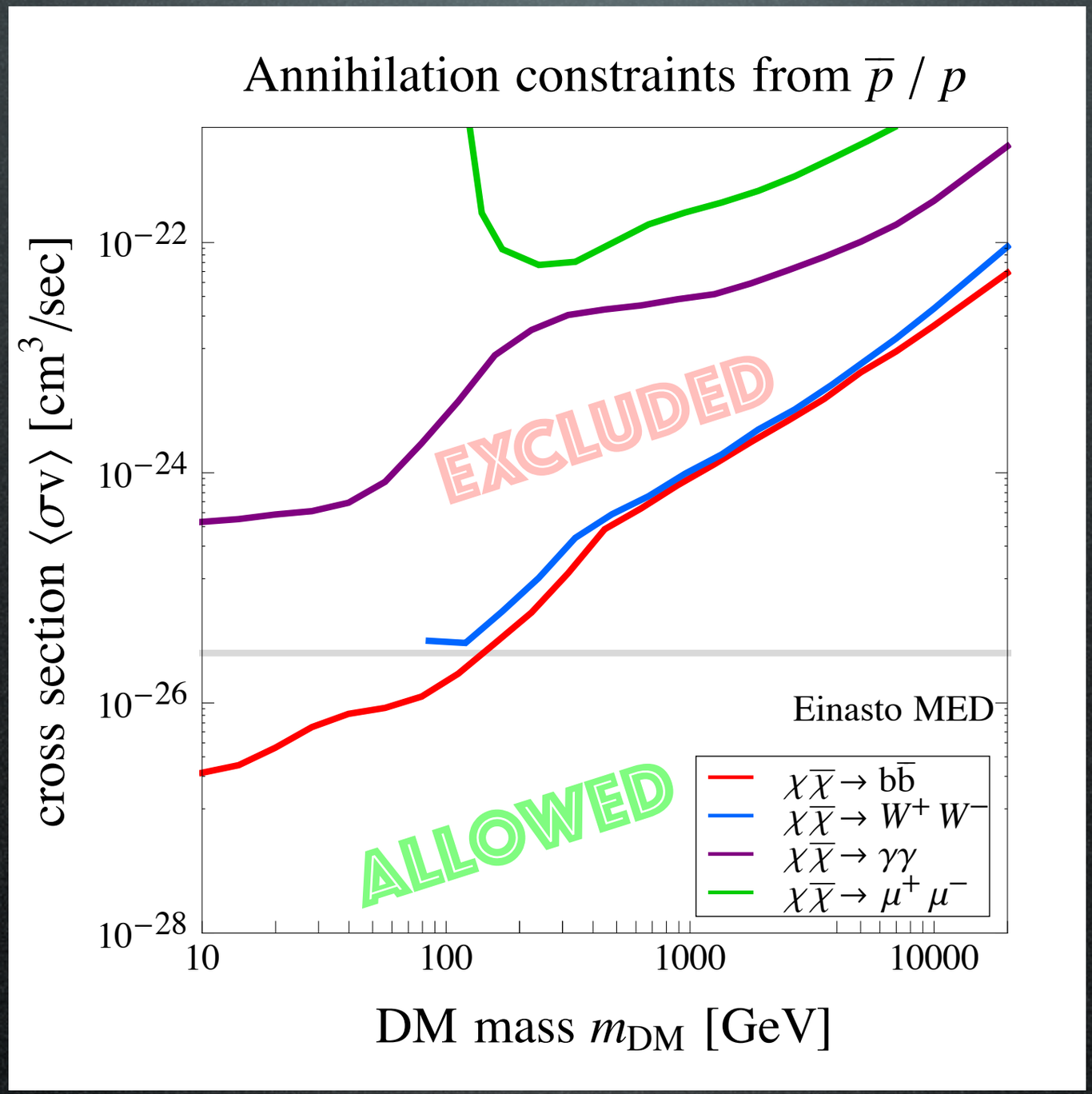

Giesen, Boudaud, Genolini, Poulin, Cirelli, Salati, Serpico 1504.04276

$m_{\rm DM} > 150$ GeV (bb Ein MED)

bounds on leptonic channels

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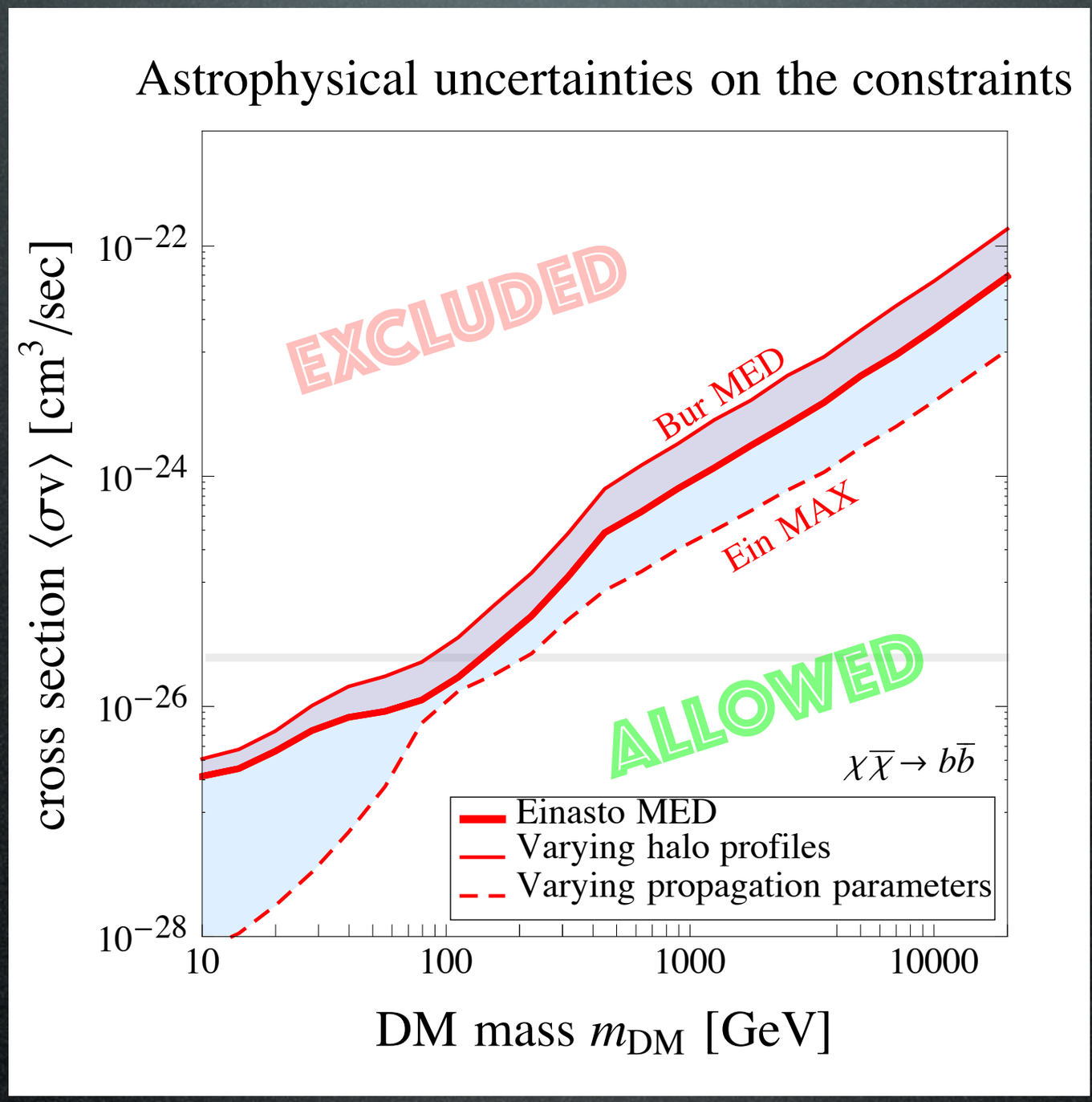

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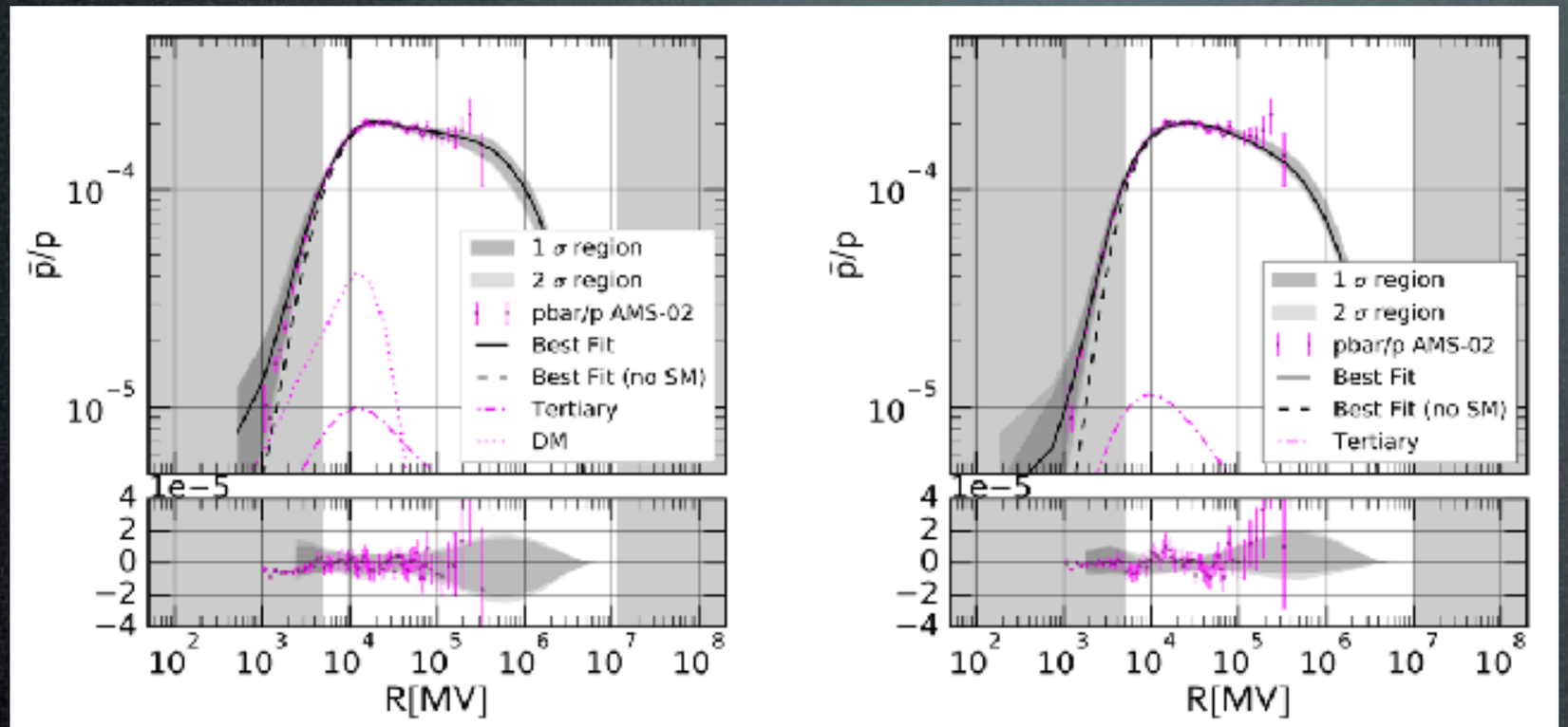
Antiprotons

Recent developments

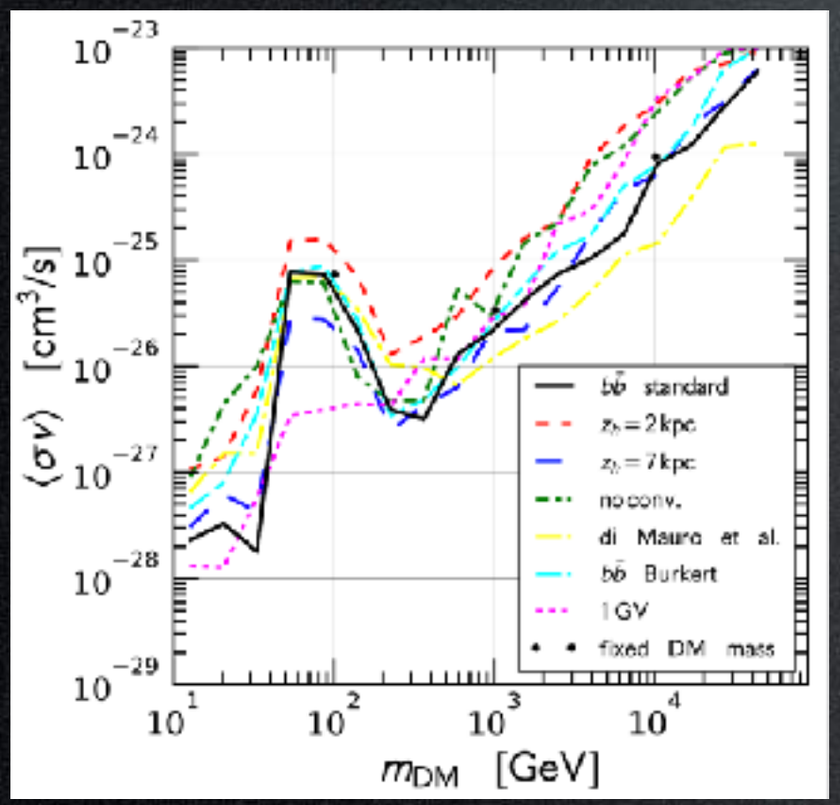
Cuoco, Krämer, Korsmeier 1610.03071

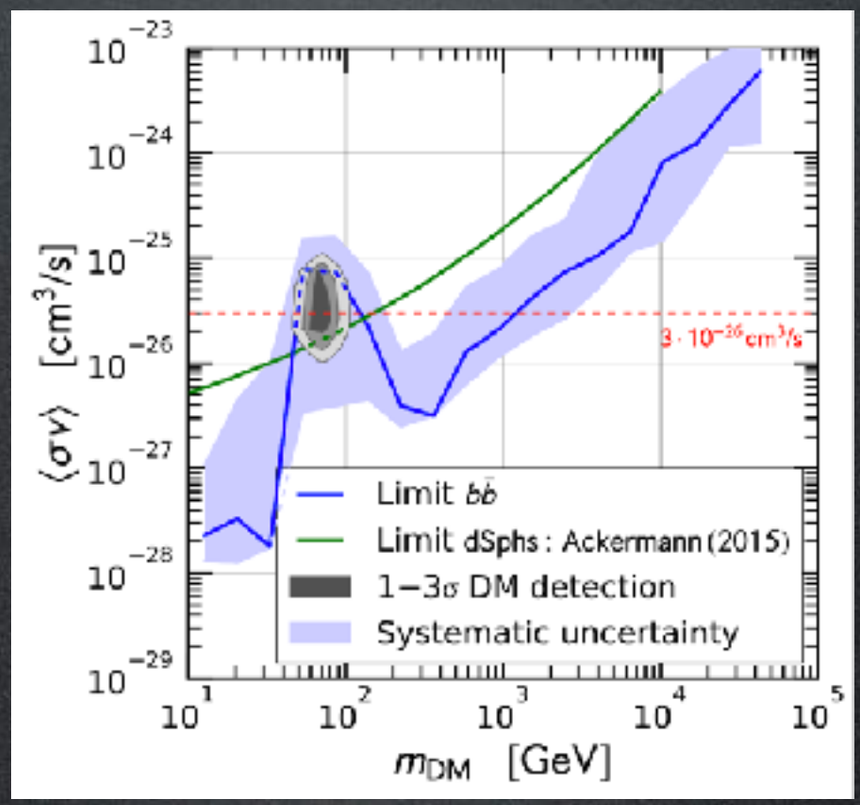


finds a possible excess

m_{DM} = 80 GeV, bb,
thermal cross-section

similarly:
Cui, Yuan, Tsai, Fang 1610.03840
Huang, Wei,Wu, Zhang, Zhou 1611.01983
(light mediators)
Feng, Zhang 1701.02263





Antiprotons

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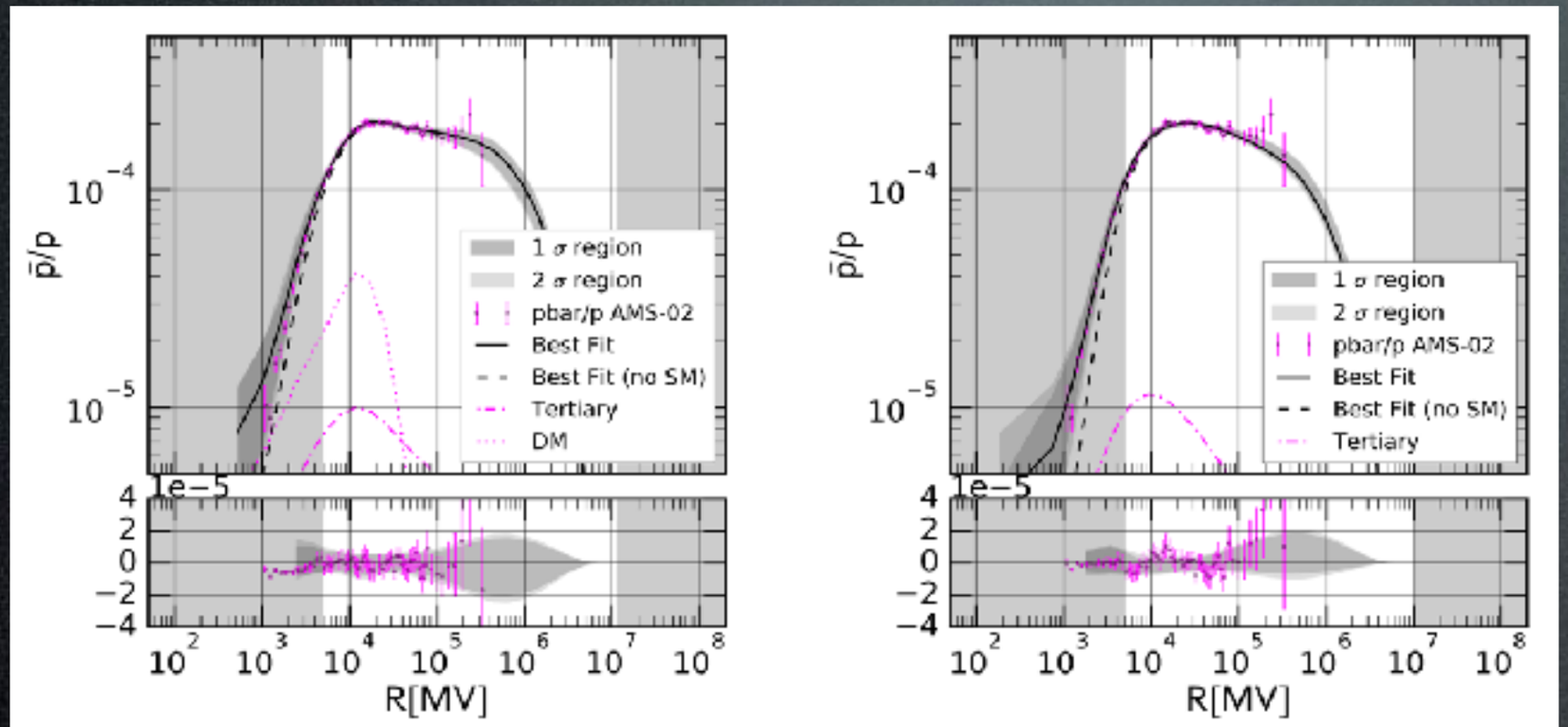

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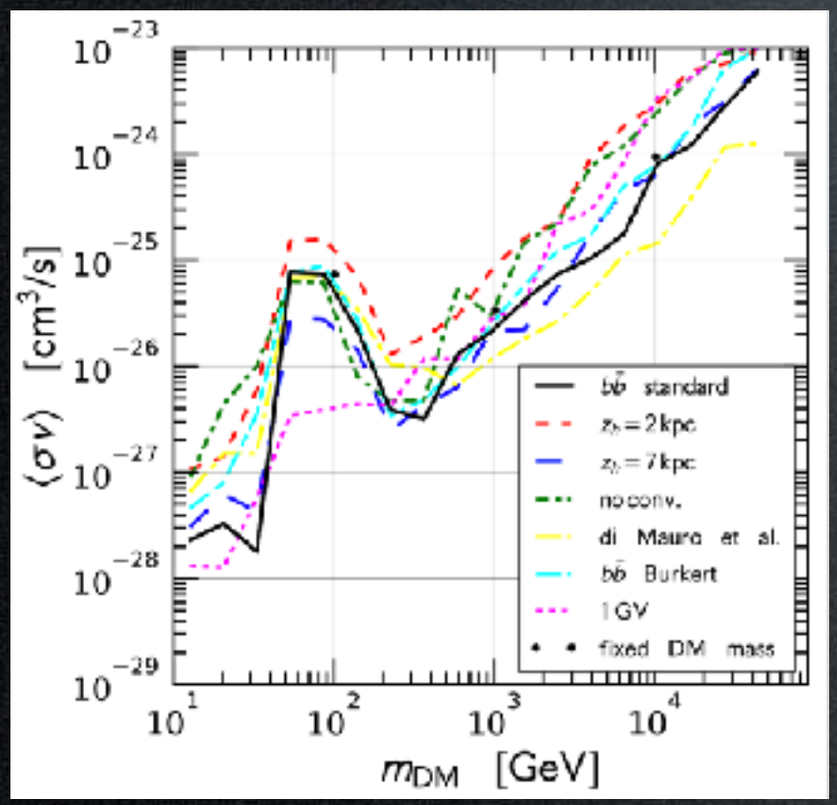
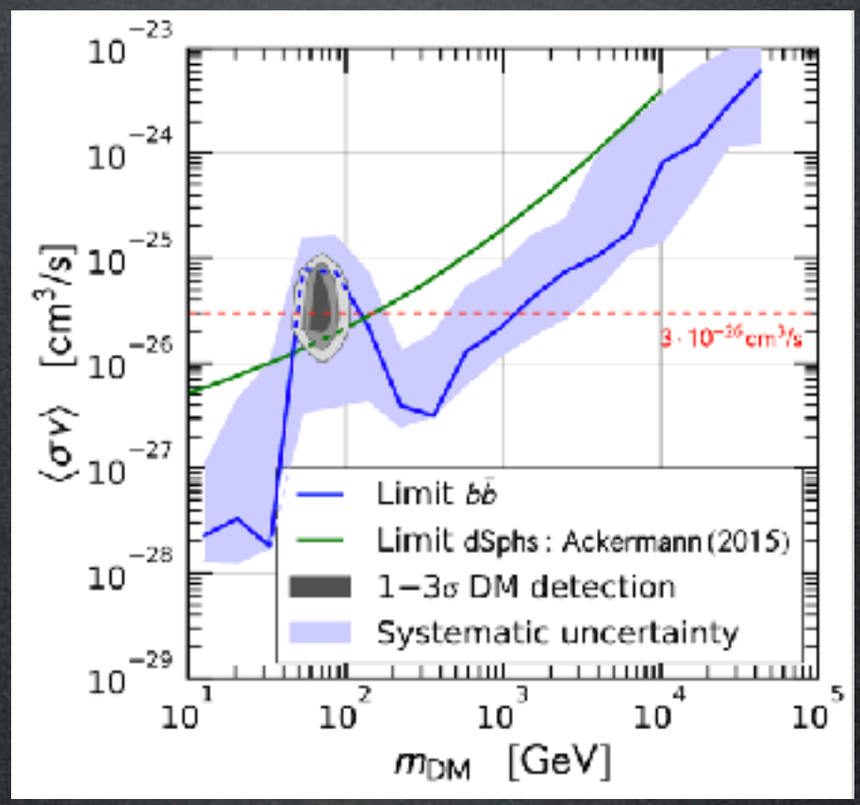
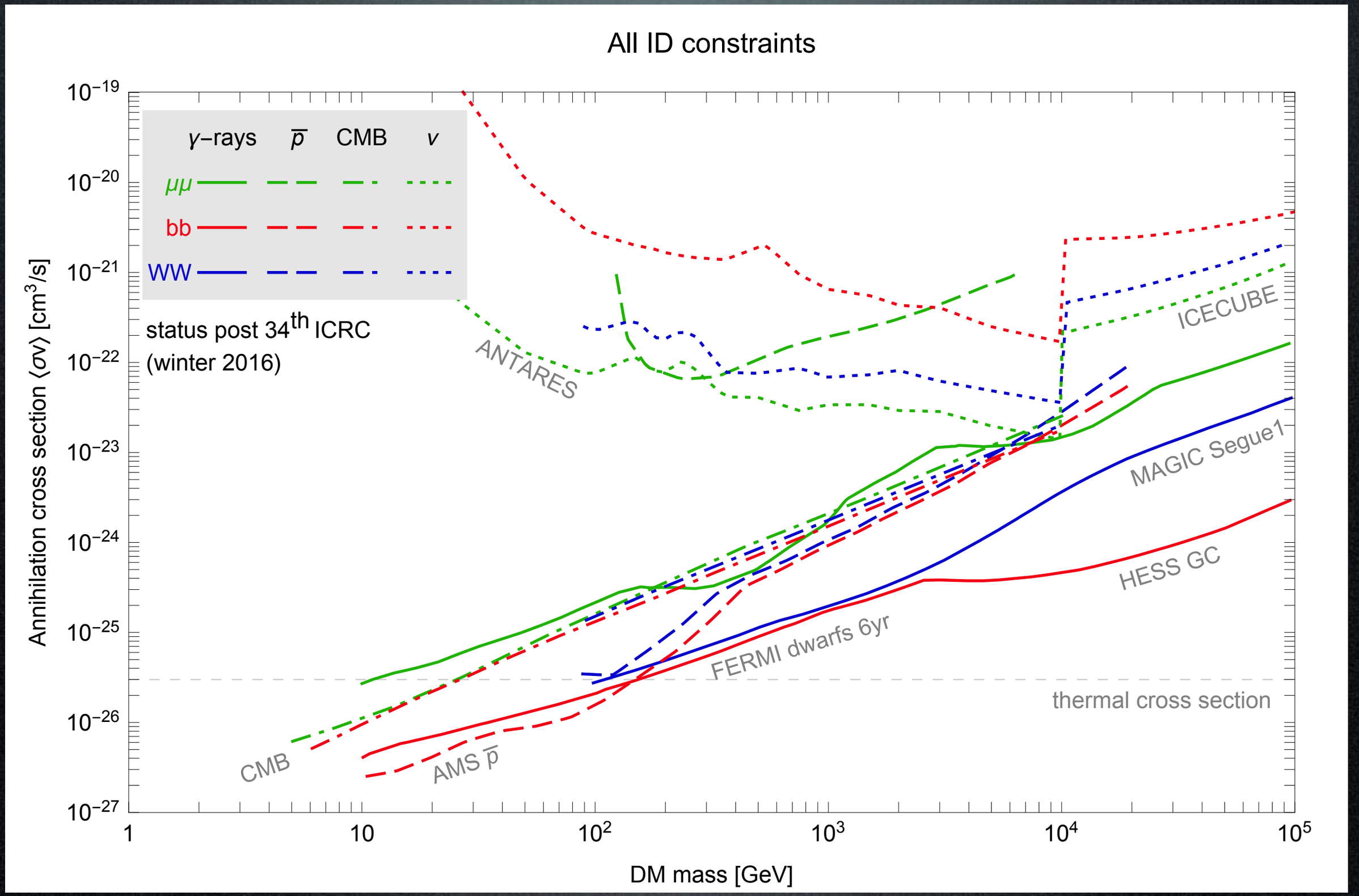




propagation parameters determined with p, He data only, w/o B/C

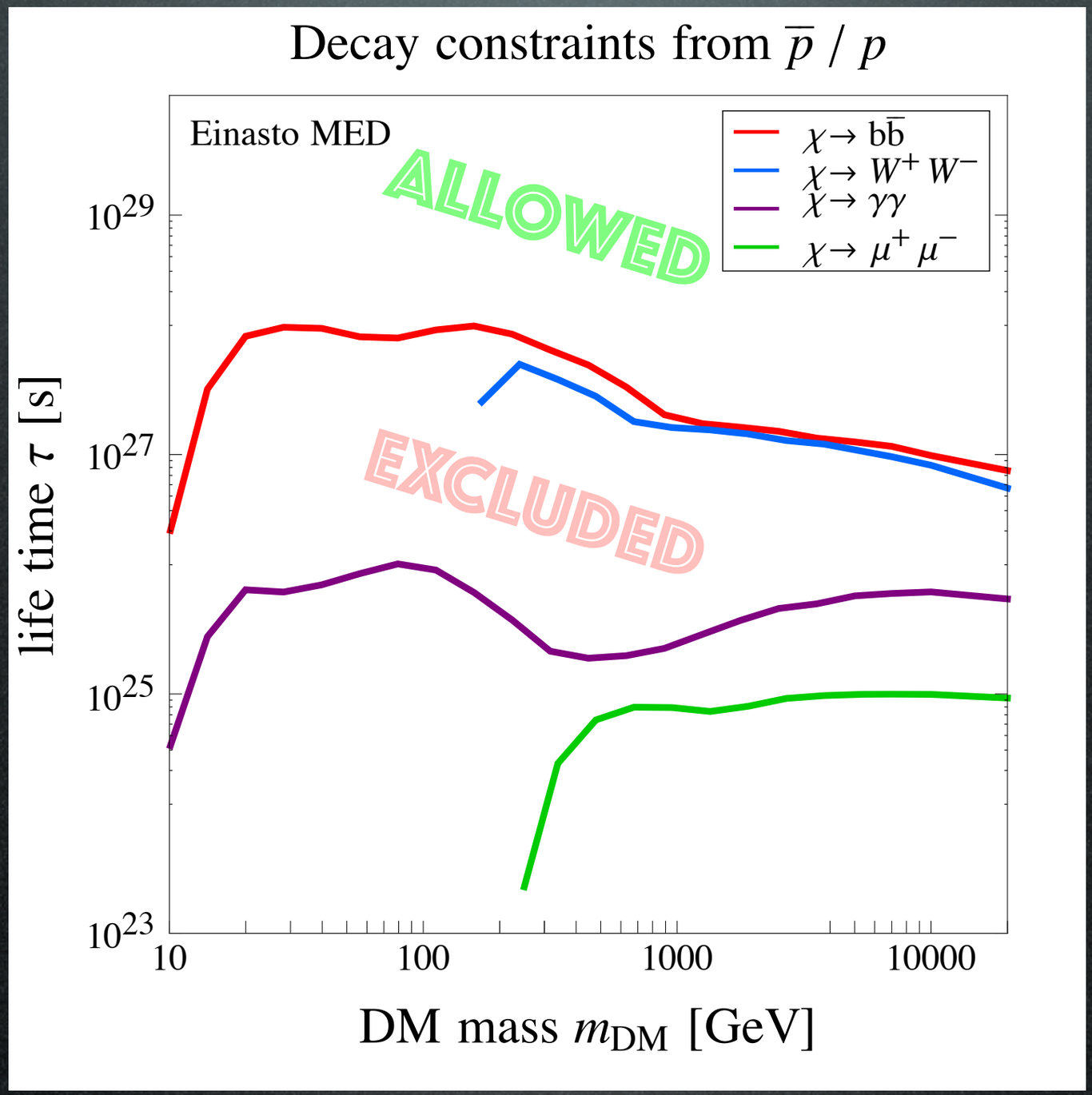
excess evaporates including low energies

Compared to other bounds



Model independent bounds

Based on AMS-02 $\bar{p}/p$ data (april 2015)



Giesen, Boudaud, Genolini, Poulin, Cirelli, Salati, Serpico 1504.04276

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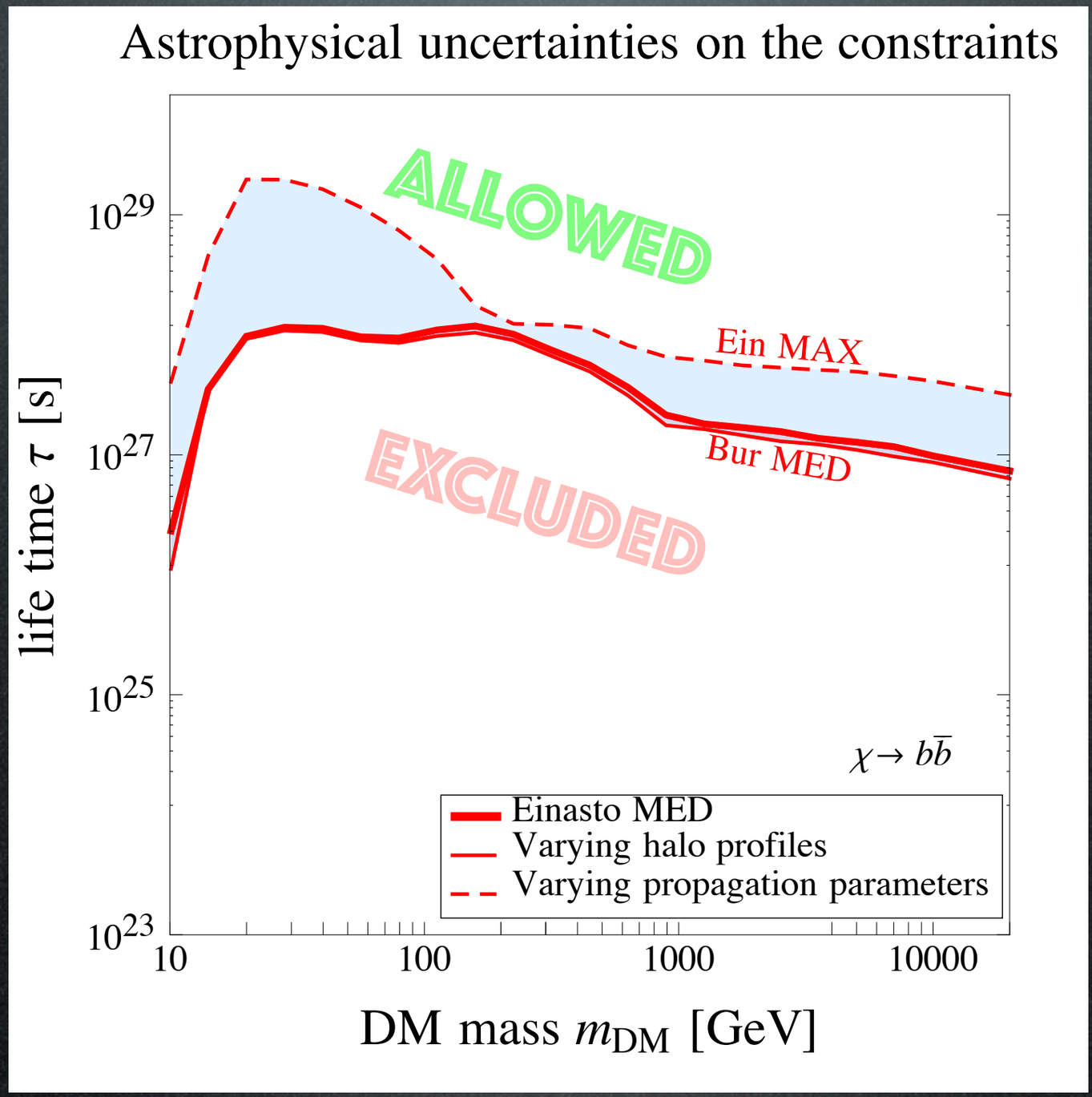


Giesen, Boudaud, Genolini, Poulin, Cirelli, Salati, Serpico
1504.04276

NB: direct comparison with former PAMELA-based bounds (Boudaud et al., 1412.5695) is tricky because secondaries are reevaluated in between, but these are **similar** or very marginally **stronger**

DM detection

direct detection

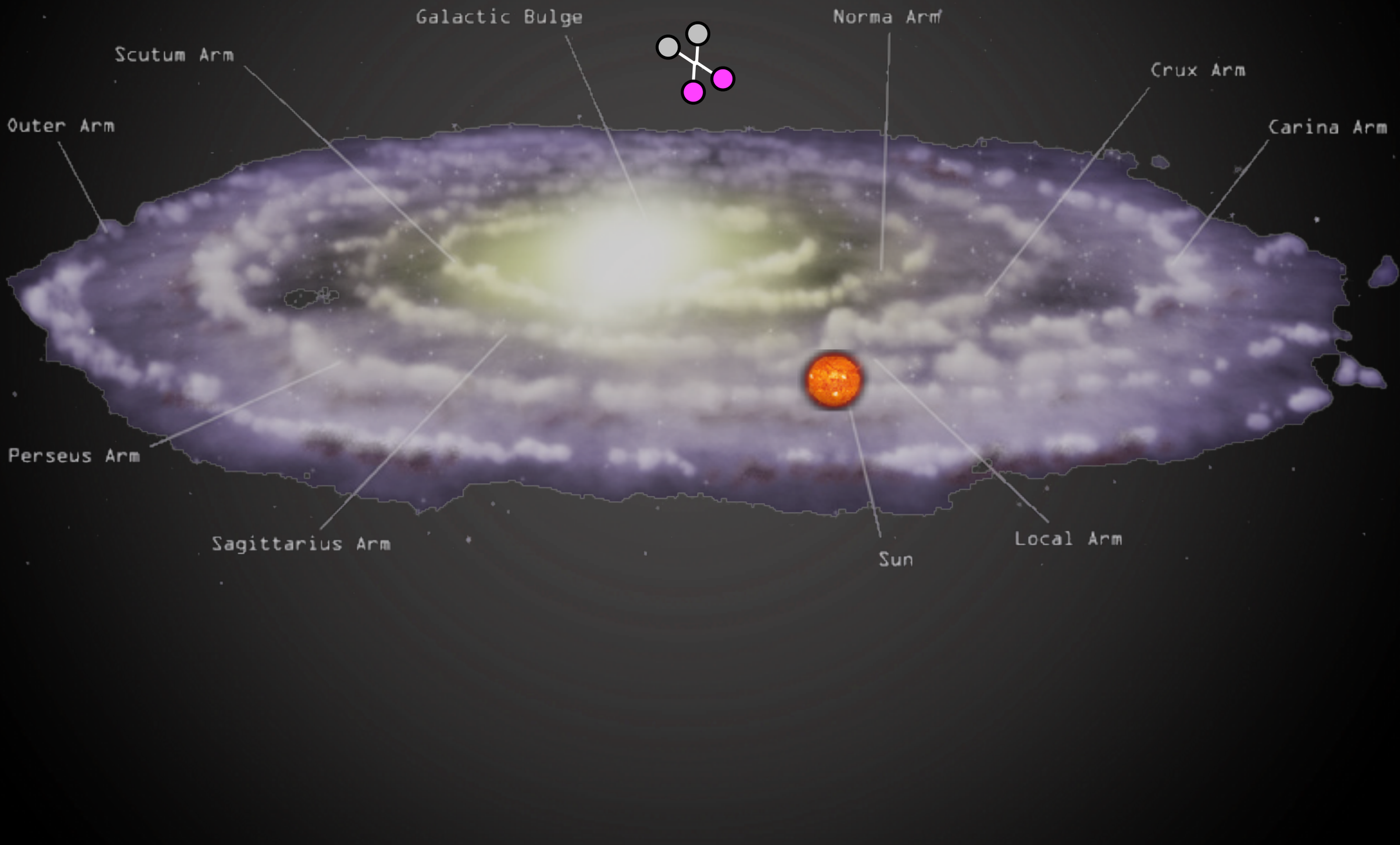
production at colliders

indirect

- γ from annihil in galactic center or halo and from secondary emission
  Fermi, **ICT**, radio telescopes...
- e^+ from annihil in galactic halo or center
  PAMELA, **Fermi**, **HESS**, **AMS**,**balloons**...
- $\bar{p}$ from annihil in galactic halo or center
- $\bar{d}$ from annihil in galactic halo or center
  GAPS, AMS
- $\nu, \bar{\nu}$ from annihil in massive bodies
  SK, **Icecube**, Km3Net

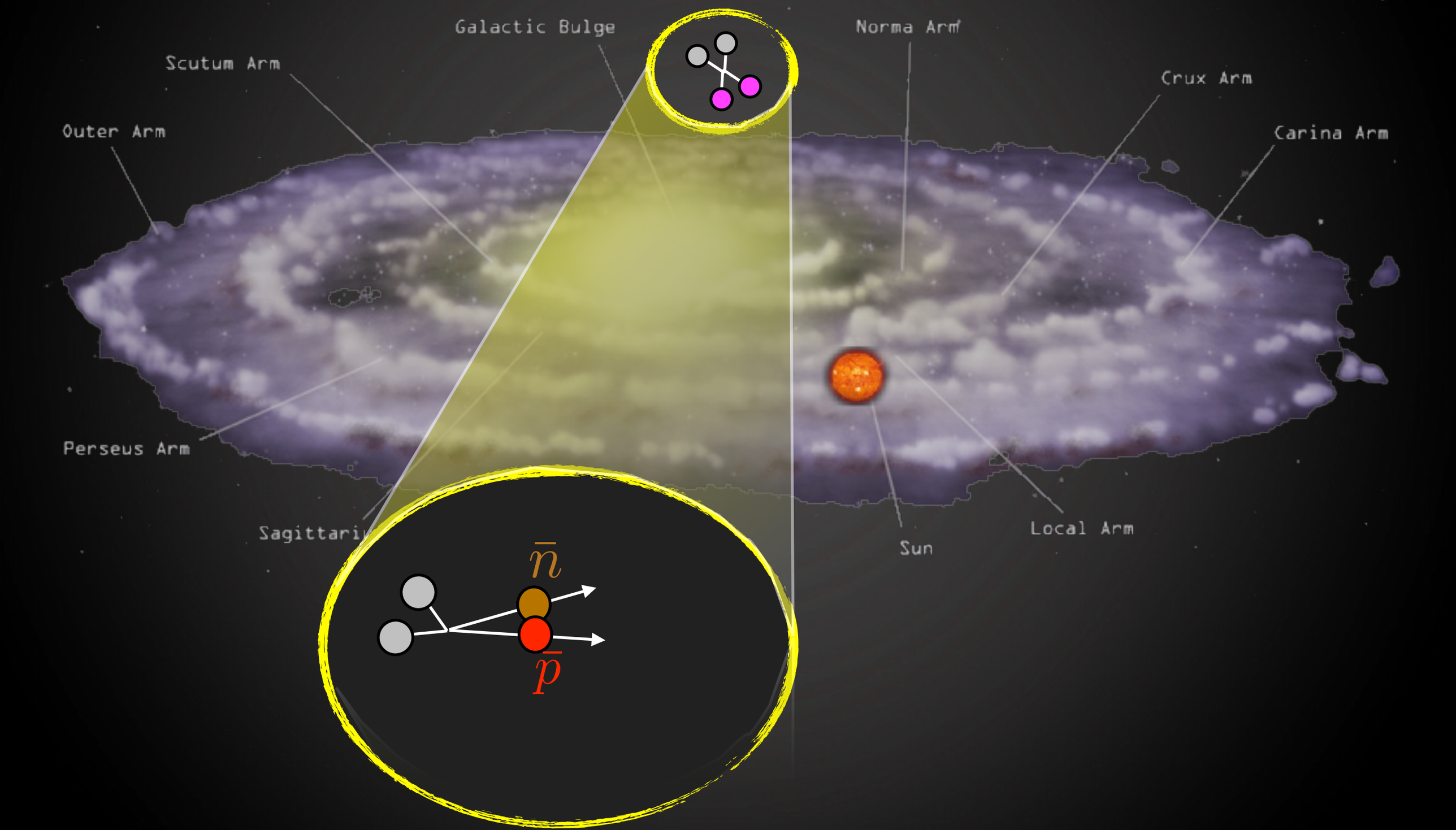
Indirect Detection

$\bar{d}$ from DM annihilations in halo



Indirect Detection

$\bar{d}$ from DM annihilations in halo



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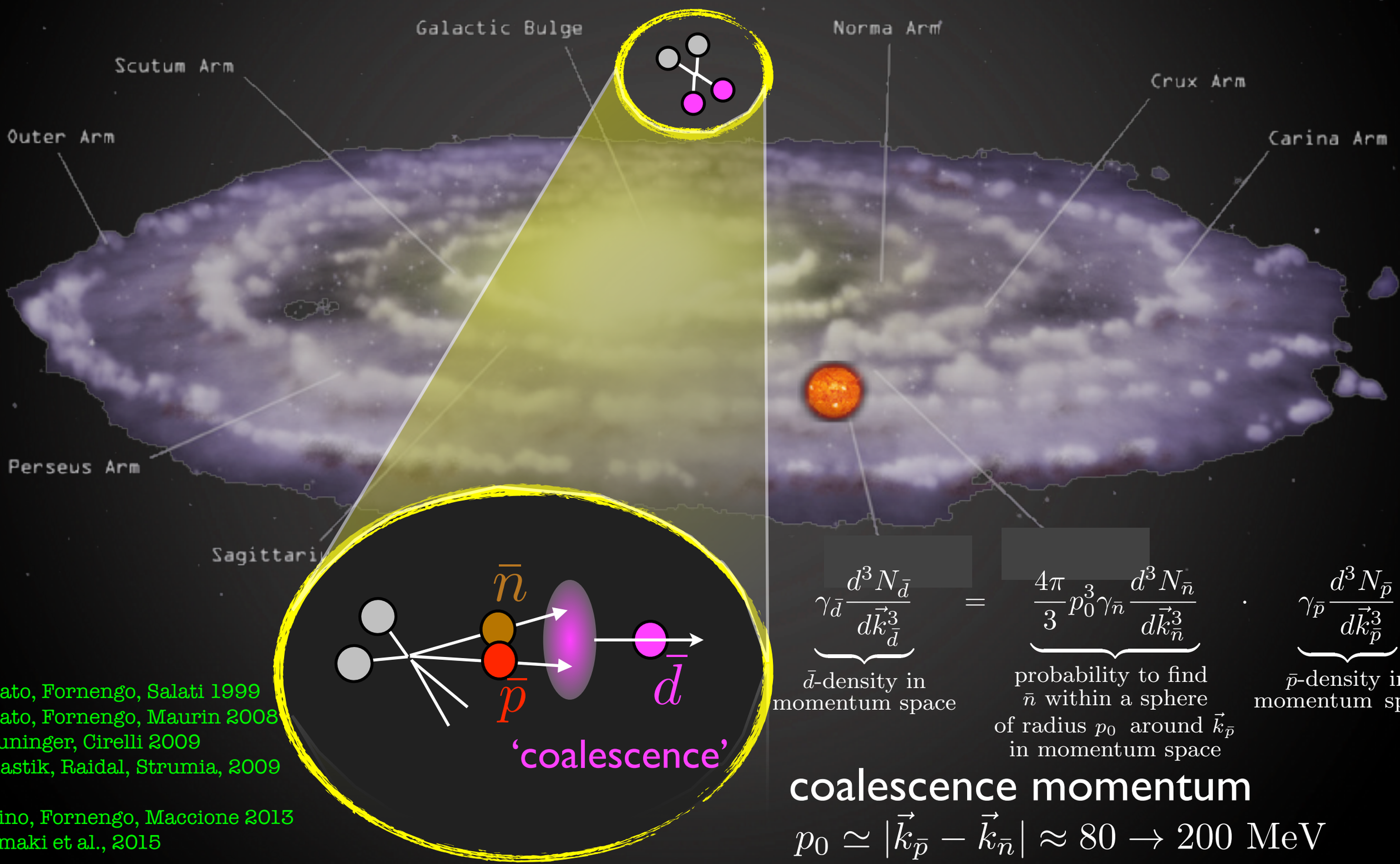


Donato, Fornengo, Salati 1999
Donato, Fornengo, Maurin 2008
Bräuninger, Cirelli 2009
Kadastik, Raidal, Strumia, 2009
...
Vittino, Fornengo, Maccione 2013
Aramaki et al., 2015

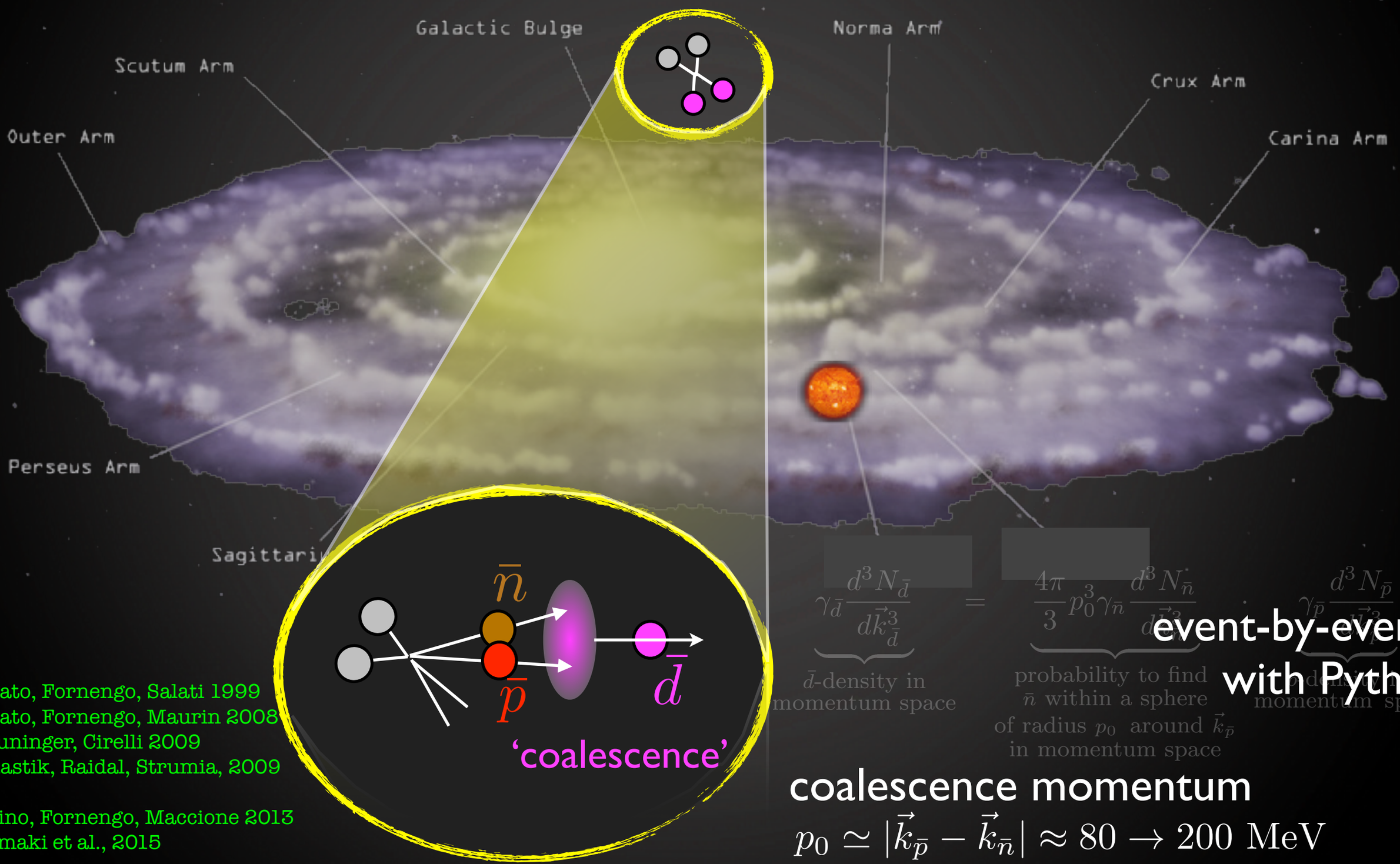
$$\underbrace{\gamma_{\bar{d}} \frac{d^3 N_{\bar{d}}}{d\vec{k}^3_{\bar{d}}}}_{\bar{d}\text{-density in momentum space}} = \underbrace{\frac{4\pi}{3} p_0^3 \gamma_{\bar{n}} \frac{d^3 N_{\bar{n}}}{d\vec{k}^3_{\bar{n}}}}_{\substack{\text{probability to find } \bar{n} \text{ within a sphere} \\ \text{of radius } p_0 \text{ around } \vec{k}_{\bar{p}} \\ \text{in momentum space}}} \cdot \underbrace{\gamma_{\bar{p}} \frac{d^3 N_{\bar{p}}}{d\vec{k}^3_{\bar{p}}}}_{\substack{\bar{p}\text{-density in} \\ \text{momentum space}}}$$

coalescence momentum

$$p_0 \simeq |\vec{k}_{\bar{p}} - \vec{k}_{\bar{n}}| \approx 80 \to 200 \text{ MeV}$$

Indirect Detection

$\bar{d}$ from DM annihilations in halo



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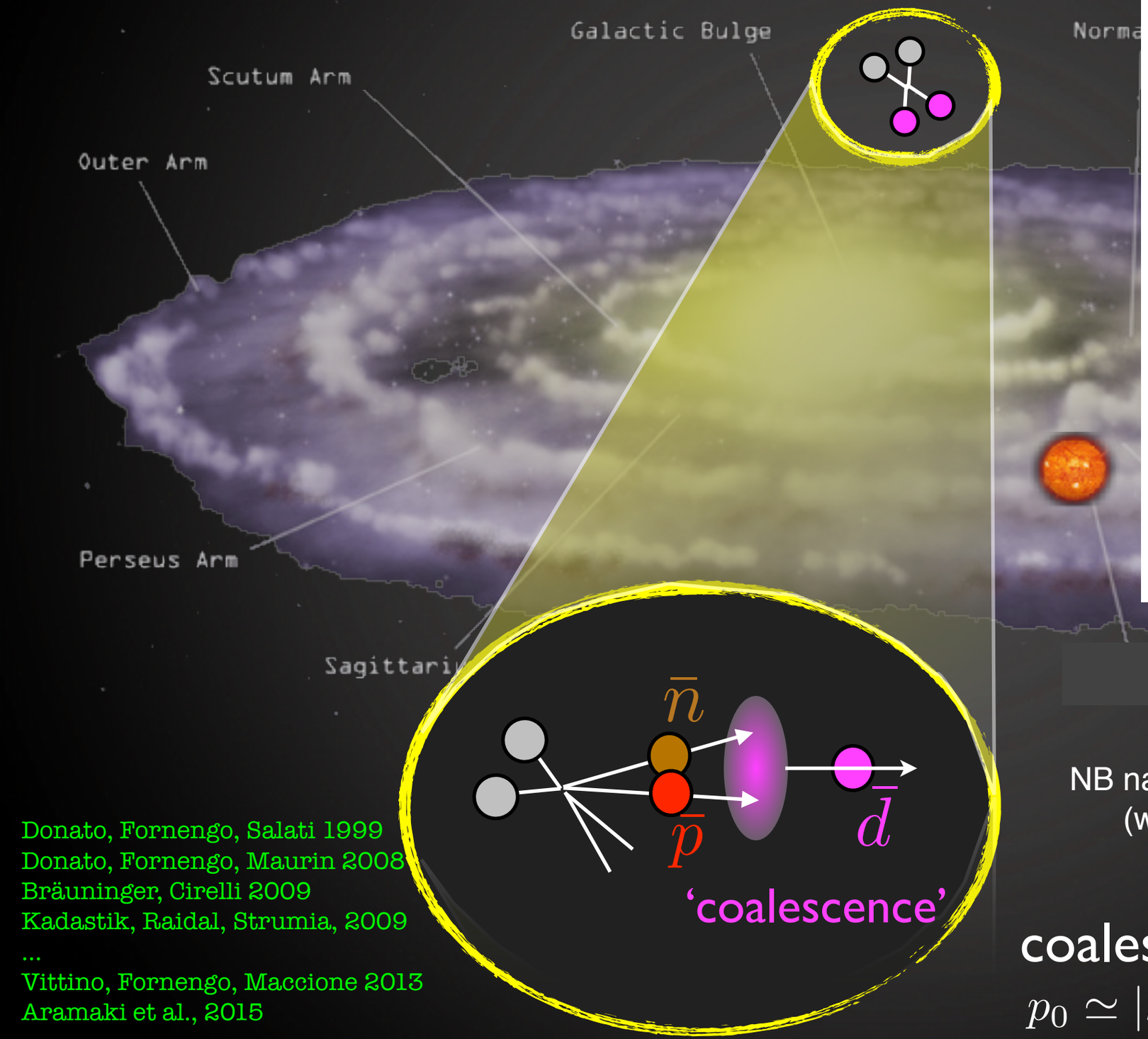
event-by-event with Pythia

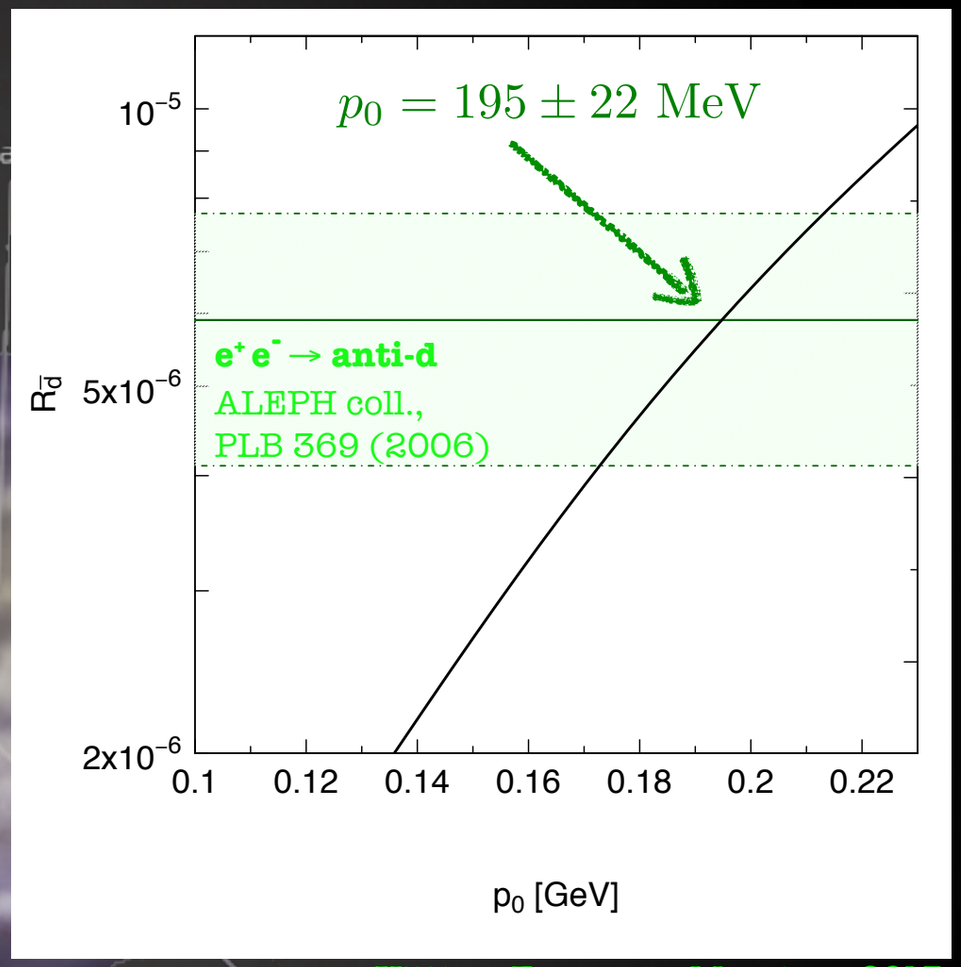
coalescence momentum

$$p_0 \simeq |\vec{k}_{\bar{p}} - \vec{k}_{\bar{n}}| \approx 80 \to 200 \text{ MeV}$$

Indirect Detection

$\bar{d}$ from DM annihilations in halo





Vittino, Fornengo, Maccione 2013

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Bräuninger, Cirelli 2009
Kadastik, Raidal, Strumia, 2009
...
Vittino, Fornengo, Maccione 2013
Aramaki et al., 2015

NB naïve guess would be $p_0 = \sqrt{E_b\, m_p} = 47$ MeV (with E_b the d binding energy): not too far…

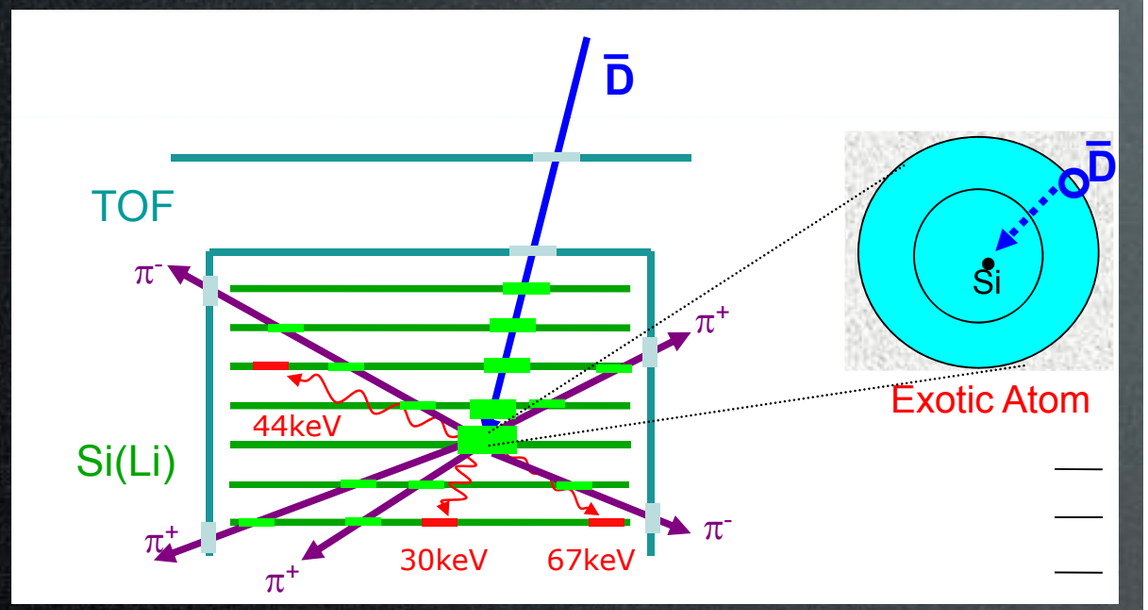
coalescence momentum

$$p_0 \simeq |\vec{k}_{\bar{p}} - \vec{k}_{\bar{n}}| \approx 80 \to 200 \text{ MeV}$$

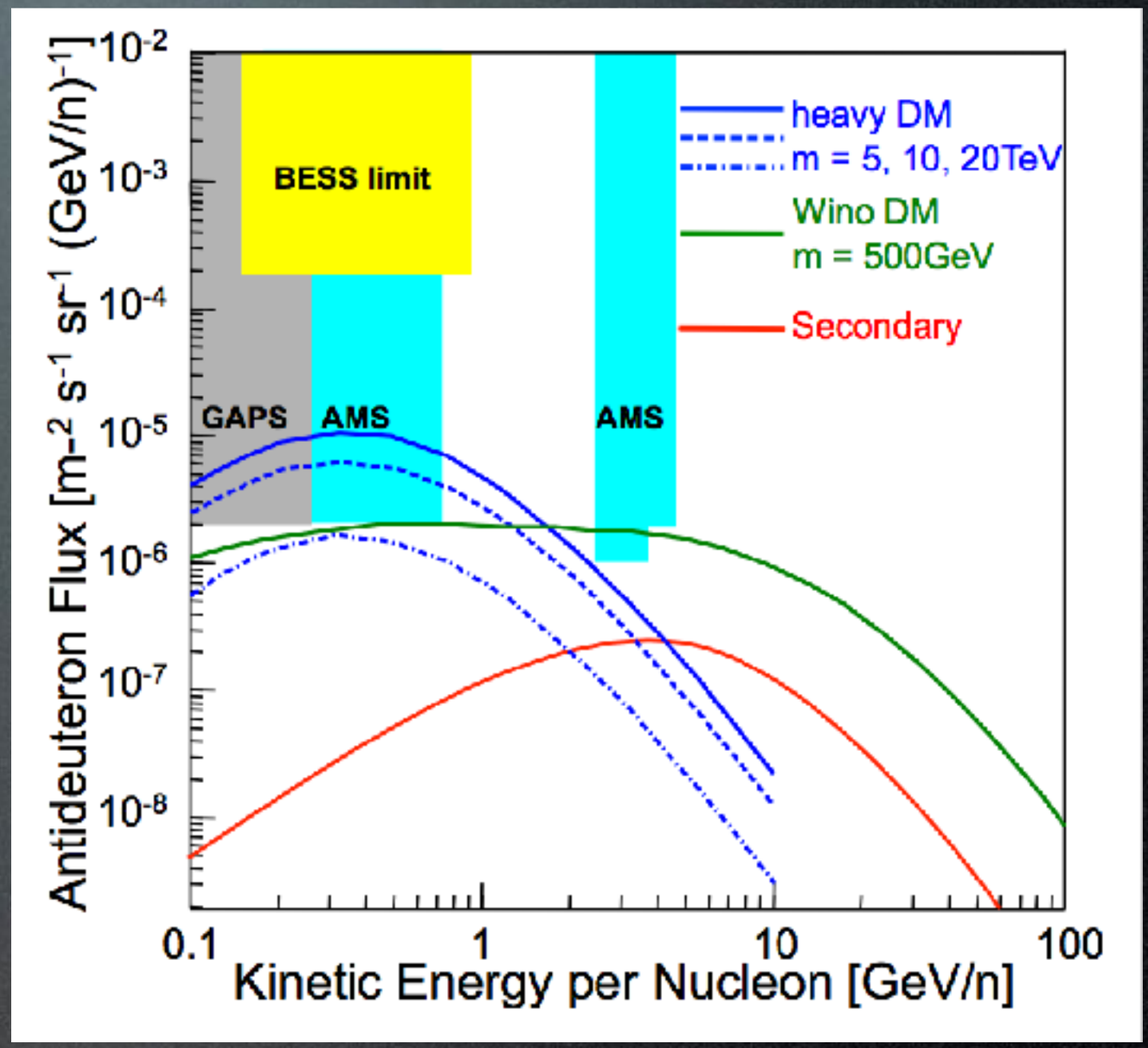
Indirect Detection

$\bar{d}$ from DM annihilations in halo

GAPS detection principle



$\bar{d}$ is slowed down,
captured (exotic atom),
annihilates w distinctive emissions



P. von Doetinchem et al., 2015

DM signal in the reach of GAPS and AMS-02

DM detection

direct detection

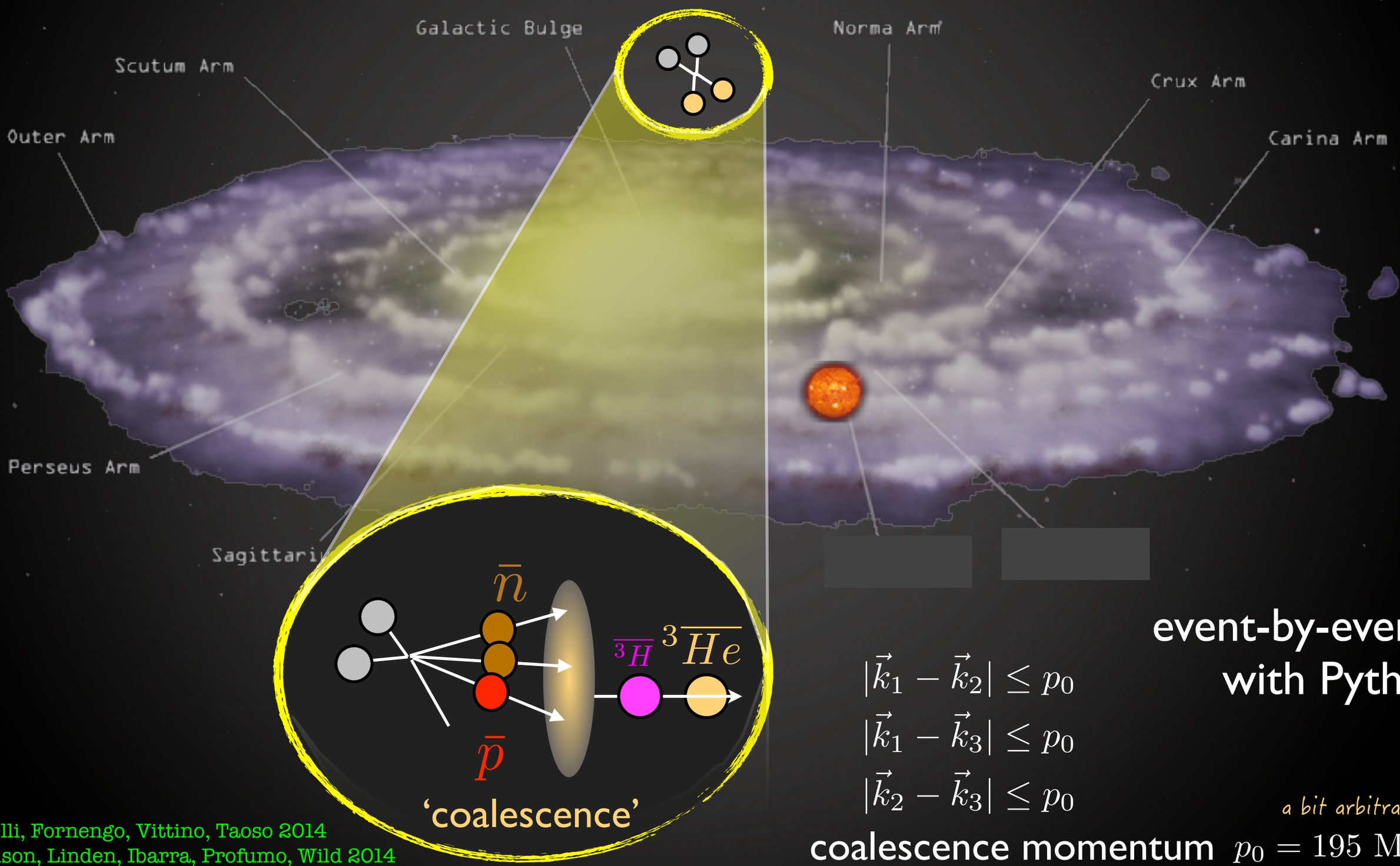
production at colliders

indirect

- γ from annihil in galactic center or halo and from secondary emission
  Fermi, **ICT**, radio telescopes...
- e^+ from annihil in galactic halo or center
  PAMELA, **Fermi**, **HESS**, **AMS**,**balloons**...
- $\bar{p}$ from annihil in galactic halo or center
- $\bar{d}$ from annihil in galactic halo or center
  GAPS, AMS
- $\nu, \bar{\nu}$ from annihil in massive bodies
  SK, **Icecube**, Km3Net
- $\overline{He}$ from annihil in galactic halo or center
  AMS?

Indirect Detection

$\overline{He}$ from DM annihilations in halo



Cirelli, Fornengo, Vittino, Taoso 2014
Carlson, Linden, Ibarra, Profumo, Wild 2014

event-by-event with Pythia

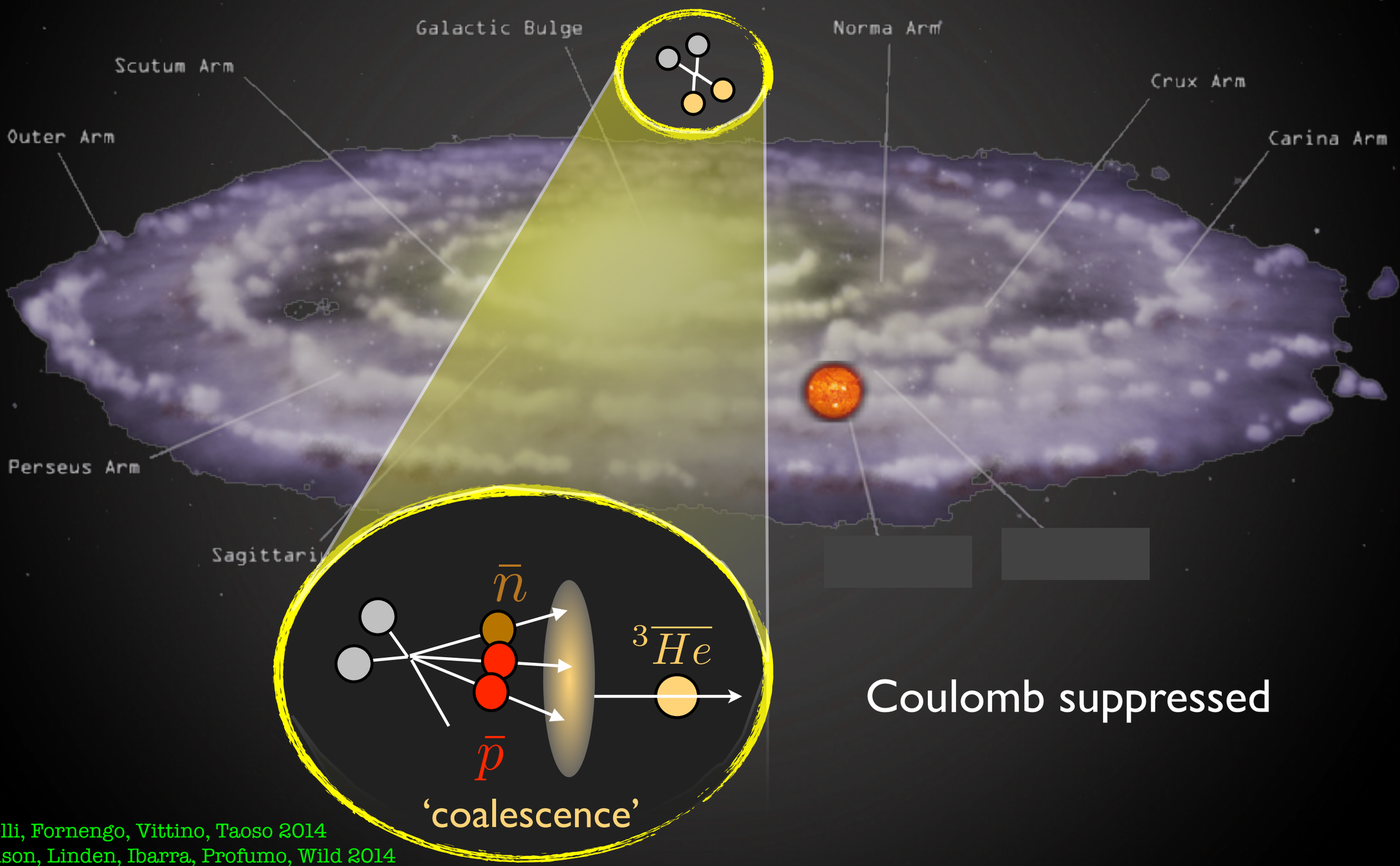
$$|\vec{k}_1 - \vec{k}_2| \leq p_0$$
$$|\vec{k}_1 - \vec{k}_3| \leq p_0$$
$$|\vec{k}_2 - \vec{k}_3| \leq p_0$$

a bit arbitrary…

coalescence momentum $p_0 = 195$ MeV

Indirect Detection

$\overline{He}$ from DM annihilations in halo

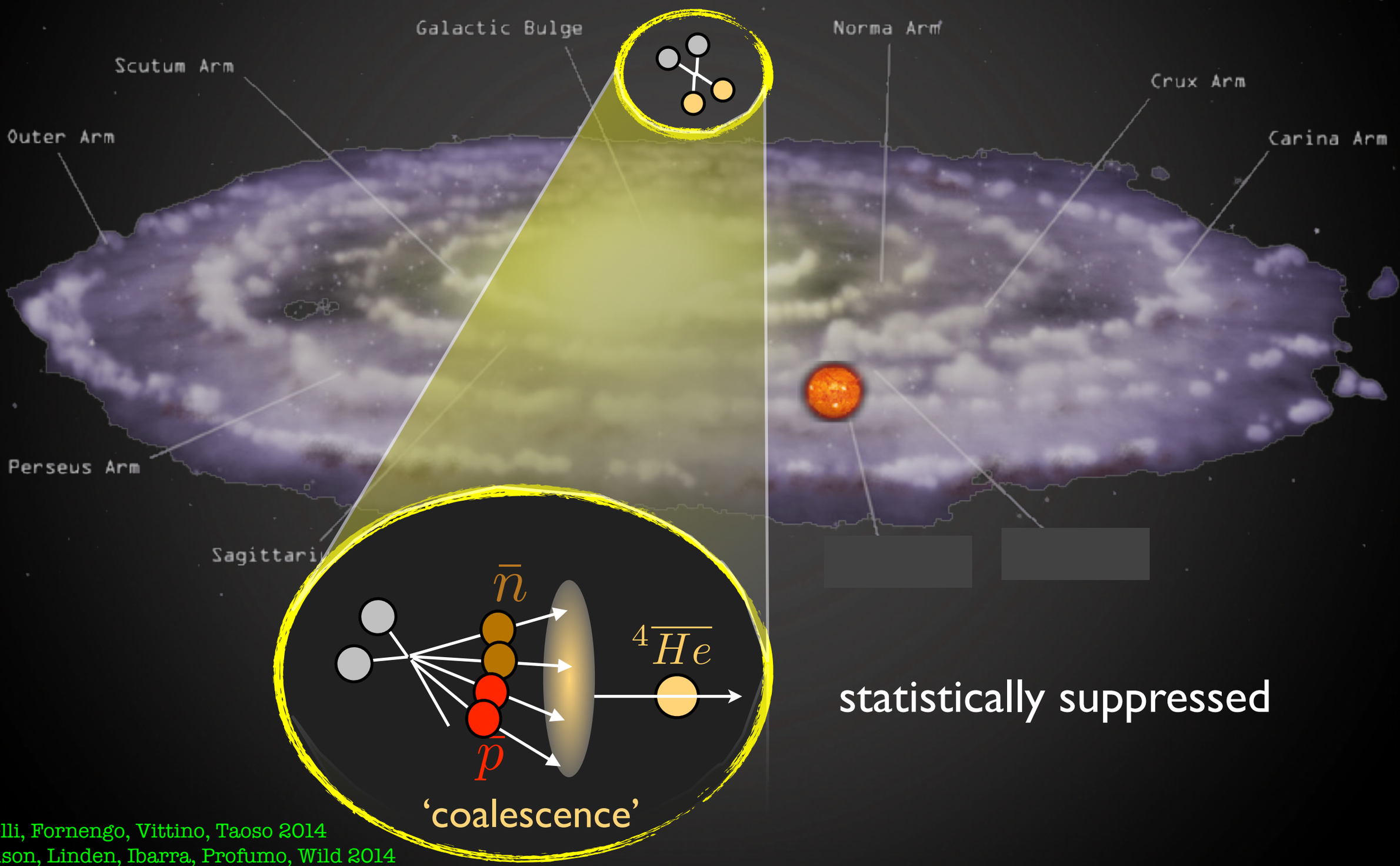


Coulomb suppressed

Cirelli, Fornengo, Vittino, Taoso 2014
Carlson, Linden, Ibarra, Profumo, Wild 2014

Indirect Detection

$\overline{He}$ from DM annihilations in halo

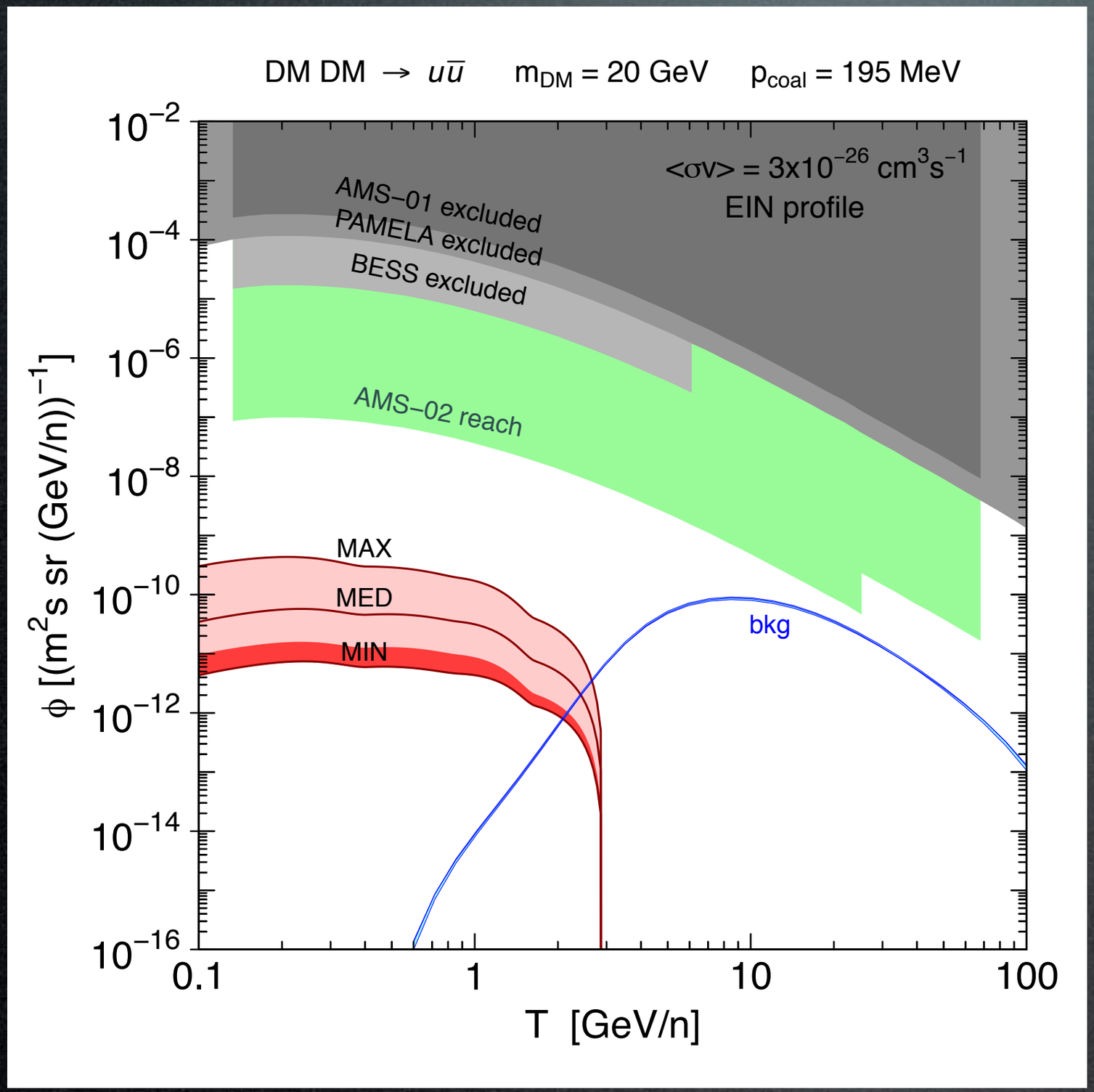


statistically suppressed

Cirelli, Fornengo, Vittino, Taoso 2014
Carlson, Linden, Ibarra, Profumo, Wild 2014

Indirect Detection

$\overline{He}$ from DM annihilations in halo



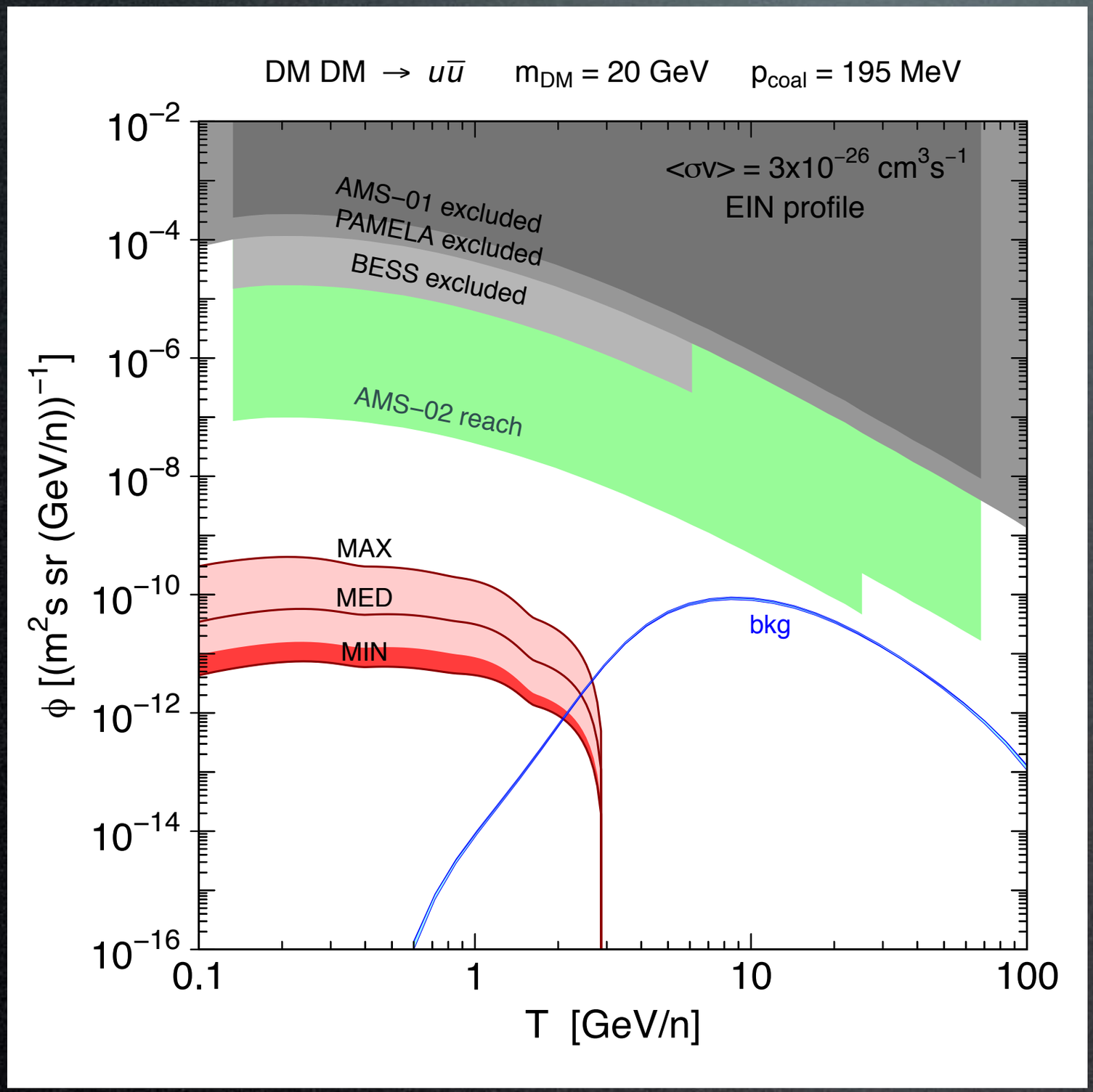
all

consistent with antiproton bounds

some tension $^3\overline{He}/\bar{p}$

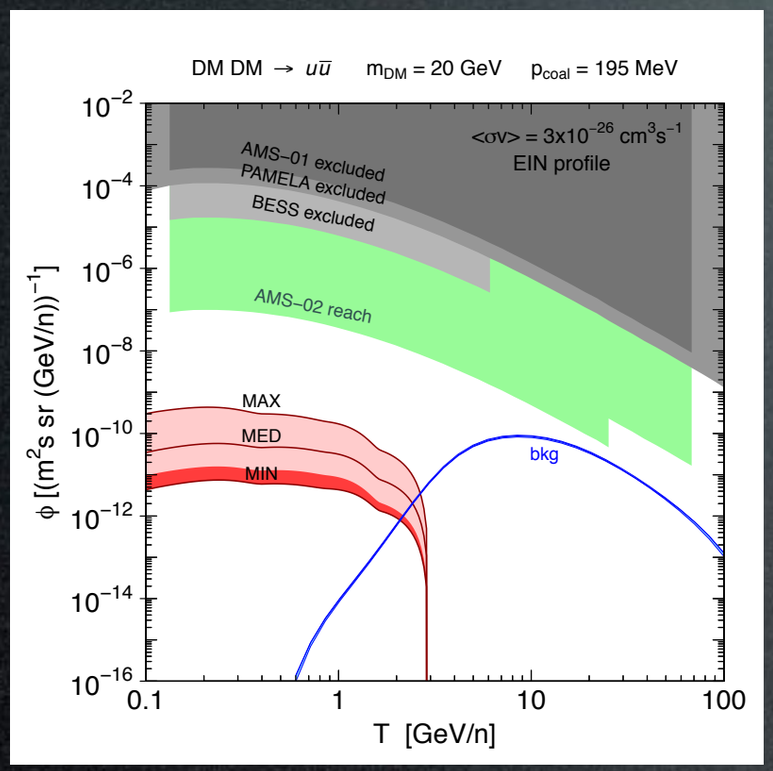
Indirect Detection

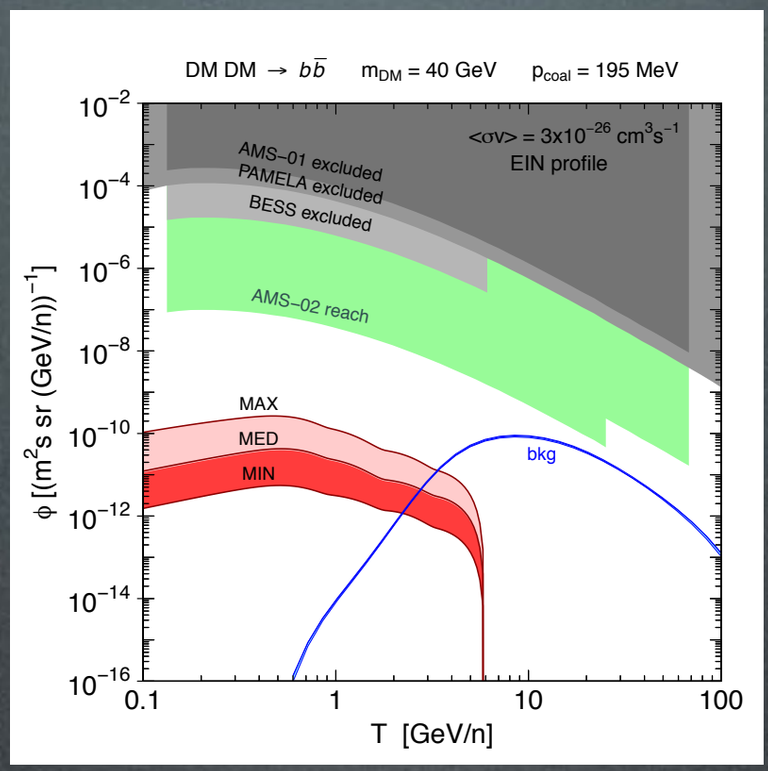
$\overline{He}$ from DM annihilations in halo

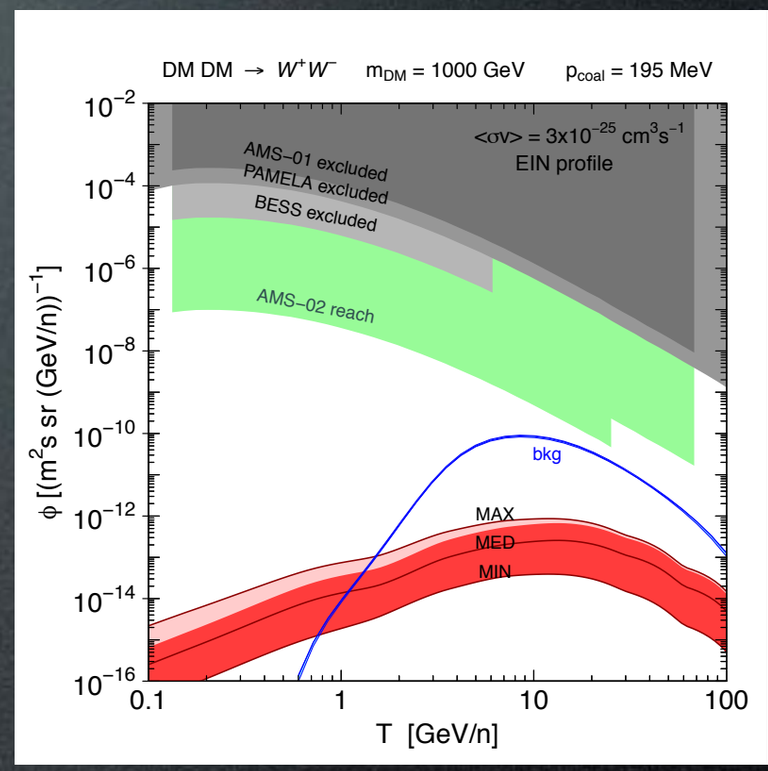


Indirect Detection

$\overline{He}$ from DM annihilations in halo







Indirect Detection

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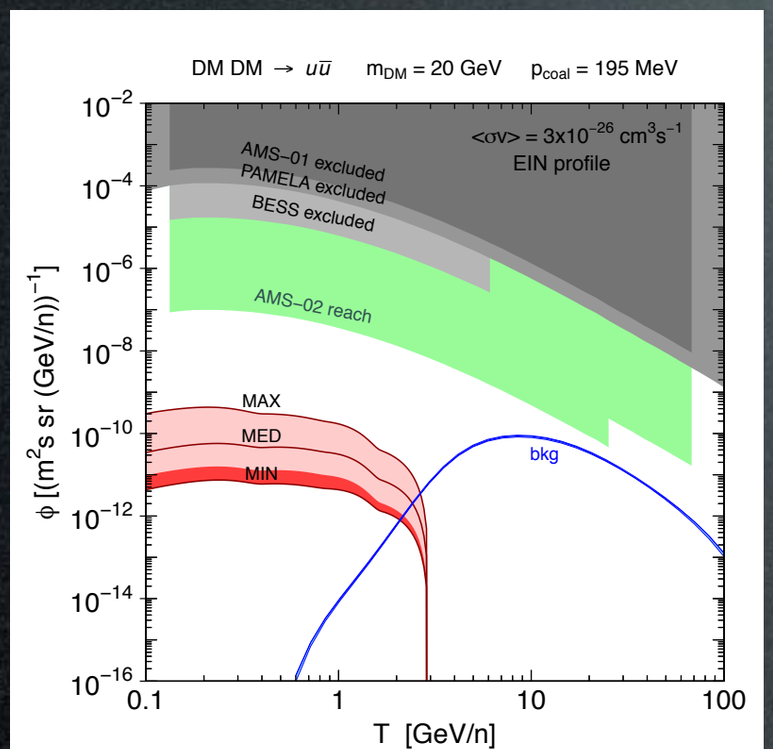

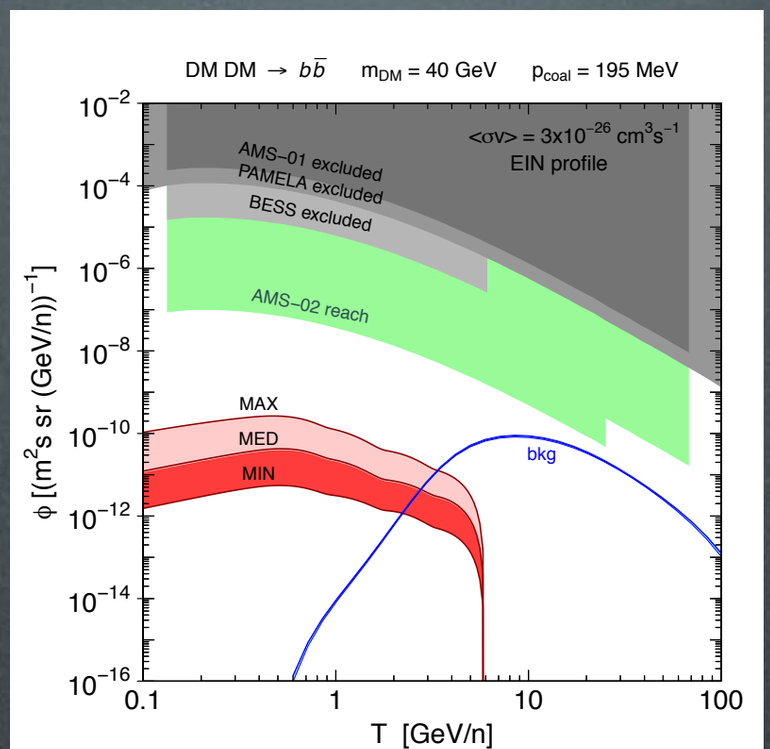

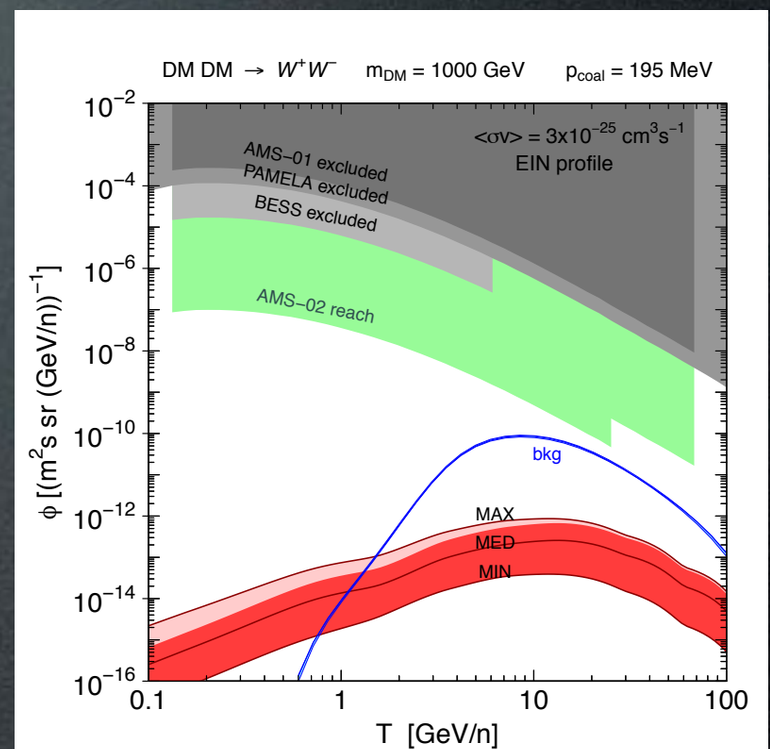

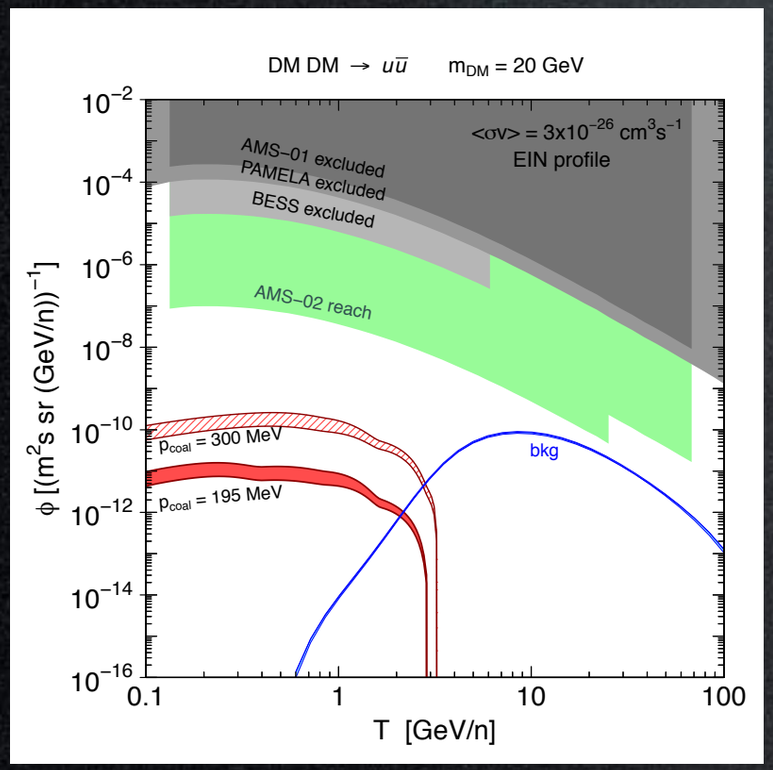

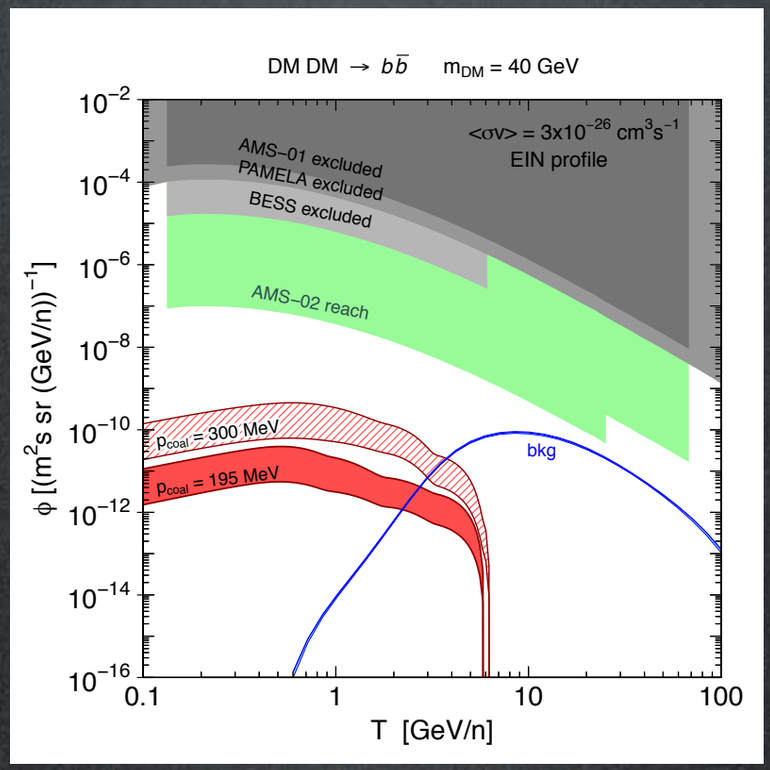

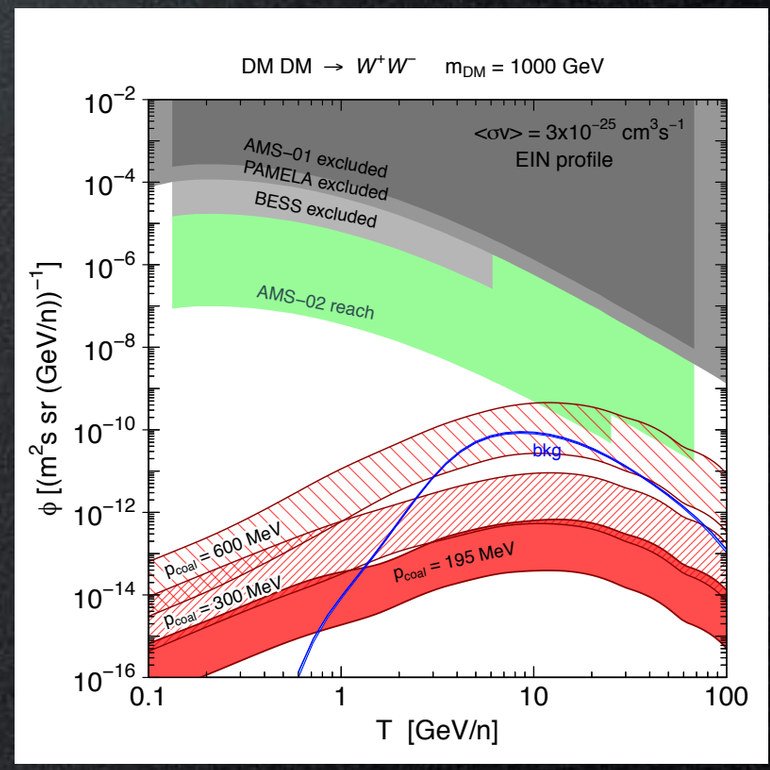

Indirect Detection

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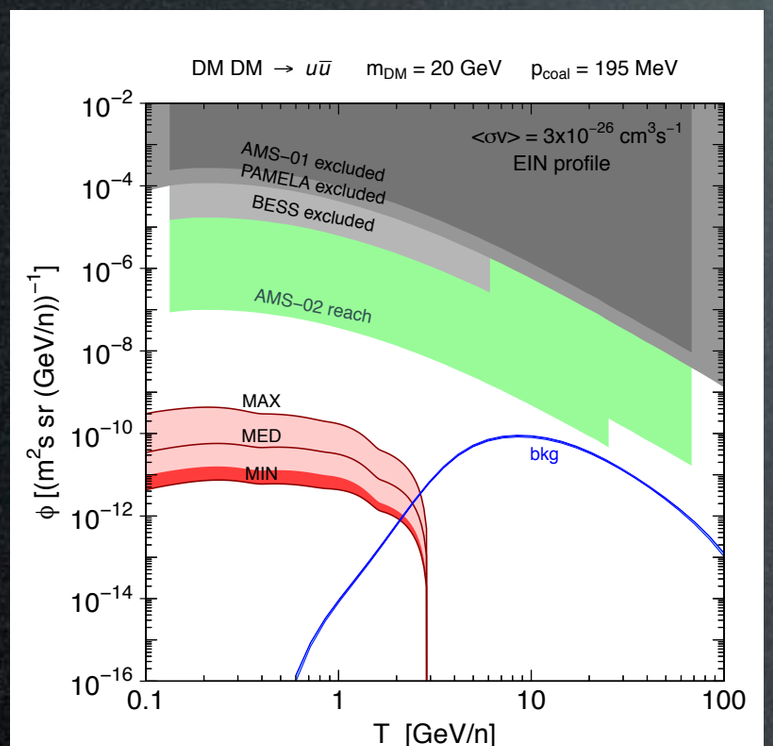

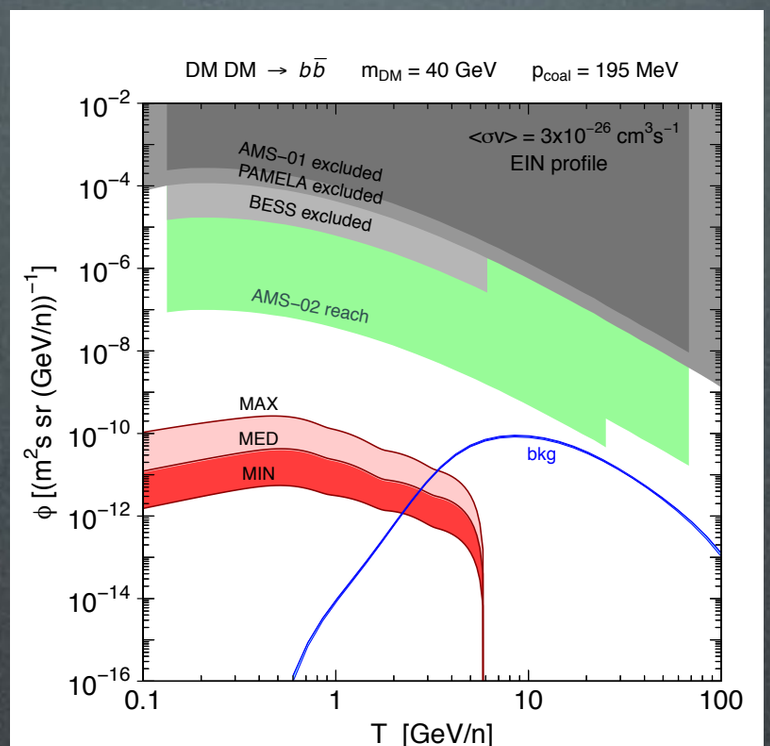

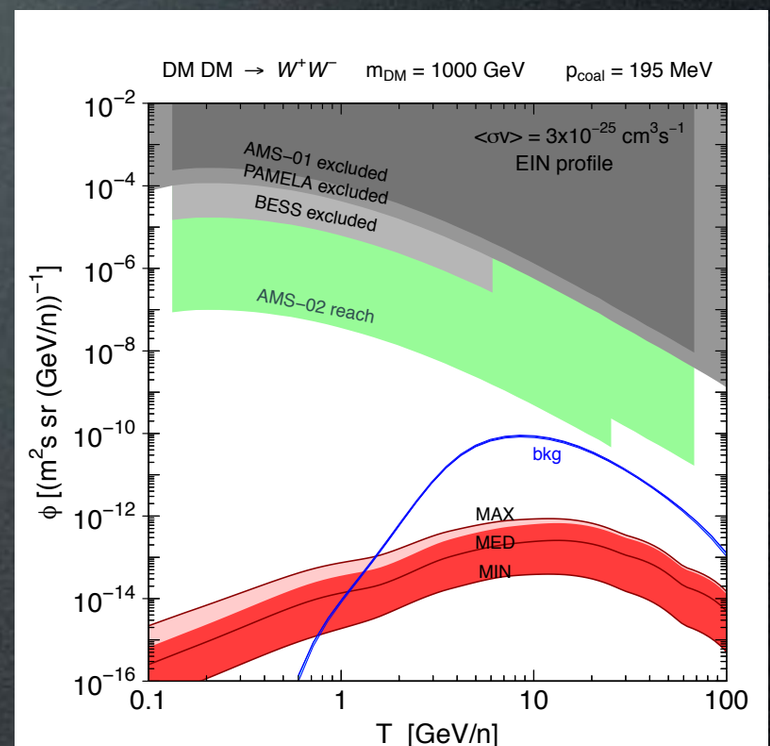

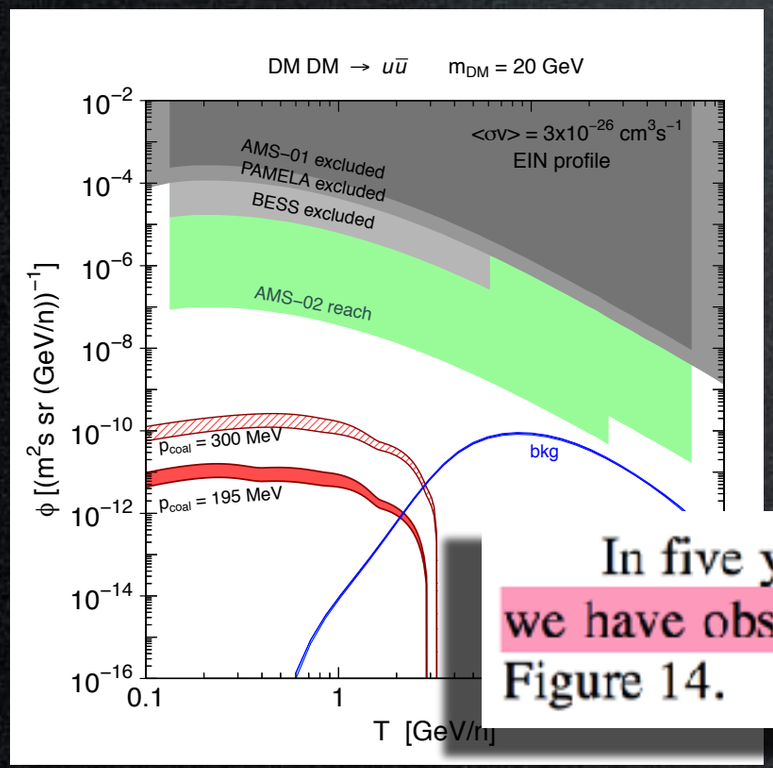

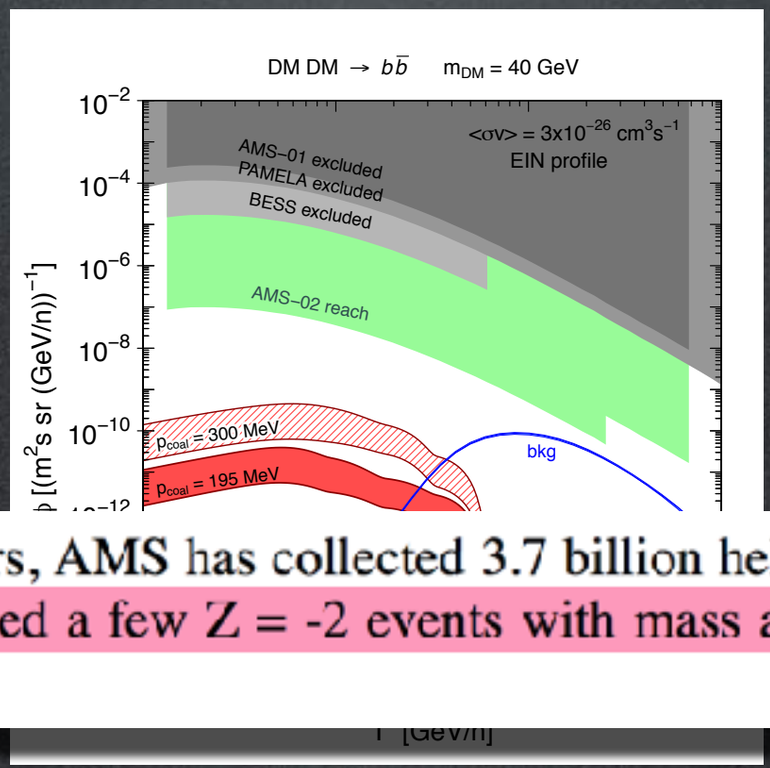

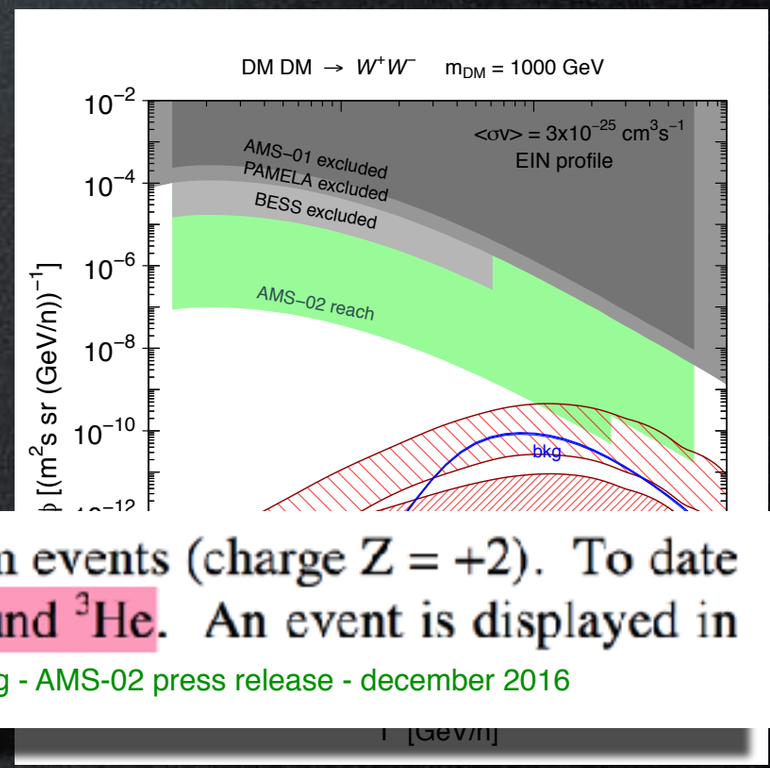

In five years, AMS has collected 3.7 billion helium events (charge Z = +2). To date we have observed a few Z = -2 events with mass around ^{3}He. An event is displayed in Figure 14.

S.Ting - AMS-02 press release - december 2016

Conclusions

DM not seen yet. (Damn!...)

Constraints are stronger and stronger.

Antiproton constraints are interesting
and competitive with (e.g.) gamma ray ones.
But they have important uncertainties.

Antideuterons are challenging
but potentially very rewarding.

Antihelium is probably hopeless.

Back up slides

Propagation

Propagation for antiprotons:

$$\frac{\partial f}{\partial t} - K(T)\cdot\nabla^2 f + \frac{\partial}{\partial z}\left(\mathrm{sign}(z)\, f\, V_{\mathrm{conv}}\right) = Q - 2h\,\delta(z)\,\Gamma_{\mathrm{ann}} f$$

diffusion

convective wind

spallations

$K(T) = K_0 \beta\,(p/\mathrm{GeV})^{\delta}$

T kinetic energy

Propagation

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diffusion — convective wind — spallations

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T kinetic energy

Model	δ	K_0 in kpc^2/Myr	L in kpc	V_{conv} in km/s
min	0.85	0.0016	1	13.5
med	0.70	0.0112	4	12
max	0.46	0.0765	15	5

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Solution:

$$\Phi_{\bar{p}}(T,\vec{r}_{\odot}) = B\frac{v_{\bar{p}}}{4\pi}\left(\frac{\rho_{\odot}}{M_{\mathrm{DM}}}\right)^2 R(T)\sum_k \frac{1}{2}\langle\sigma v\rangle_k \frac{dN_{\bar{p}}^k}{dT}$$

Propagation

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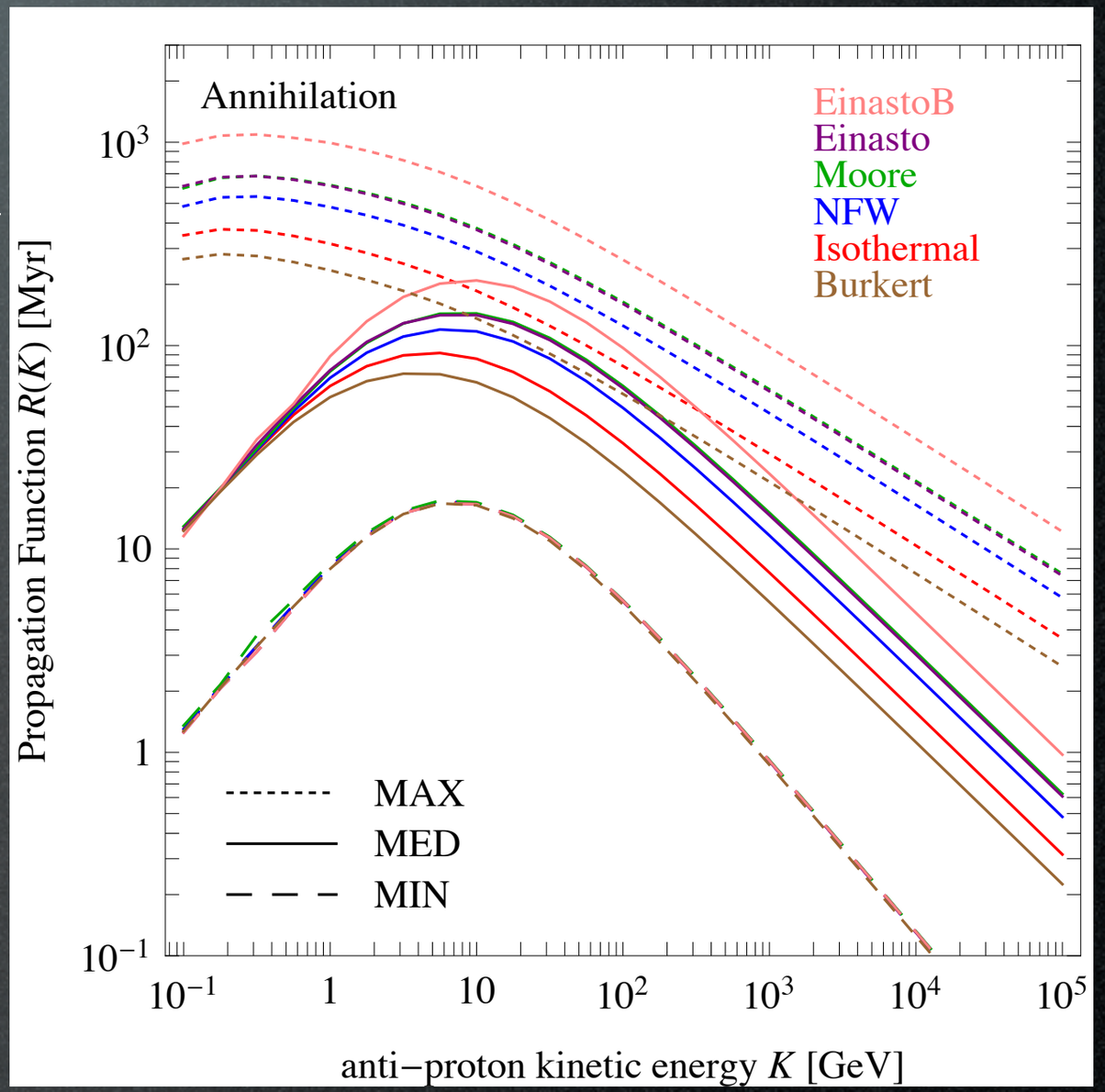
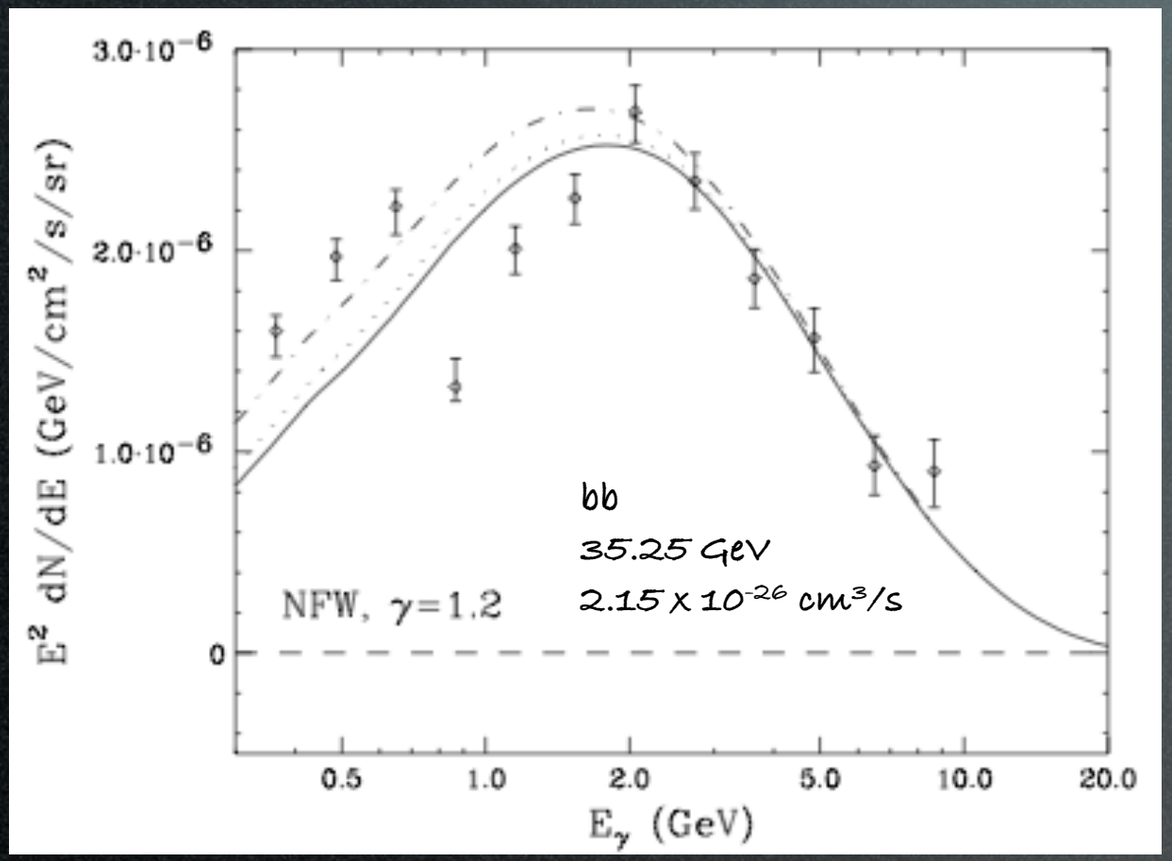
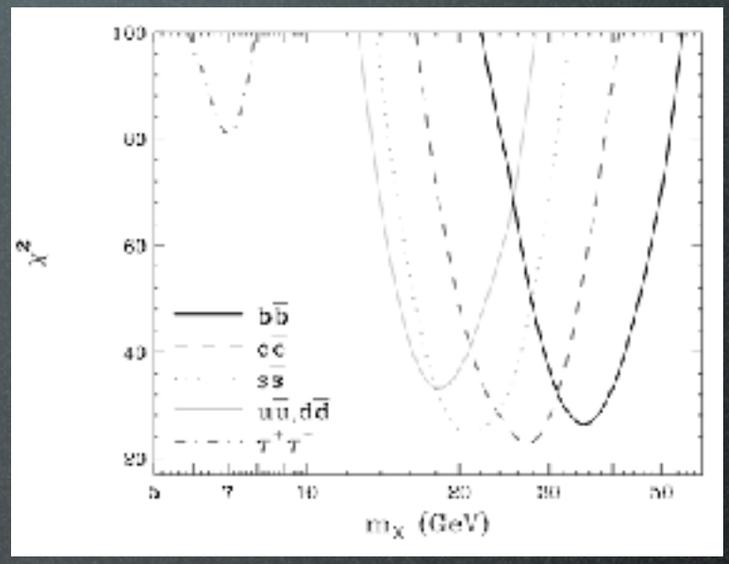


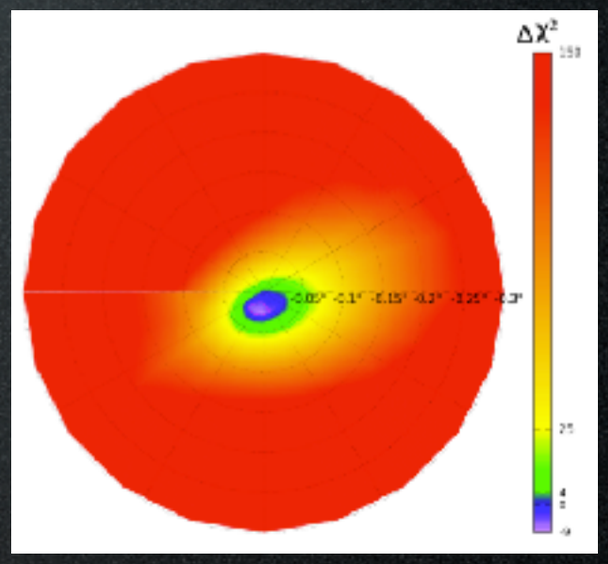
GC GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Using events with accurate directional reconstruction





Best fit:
~35 GeV, quarks, ~thermal σv

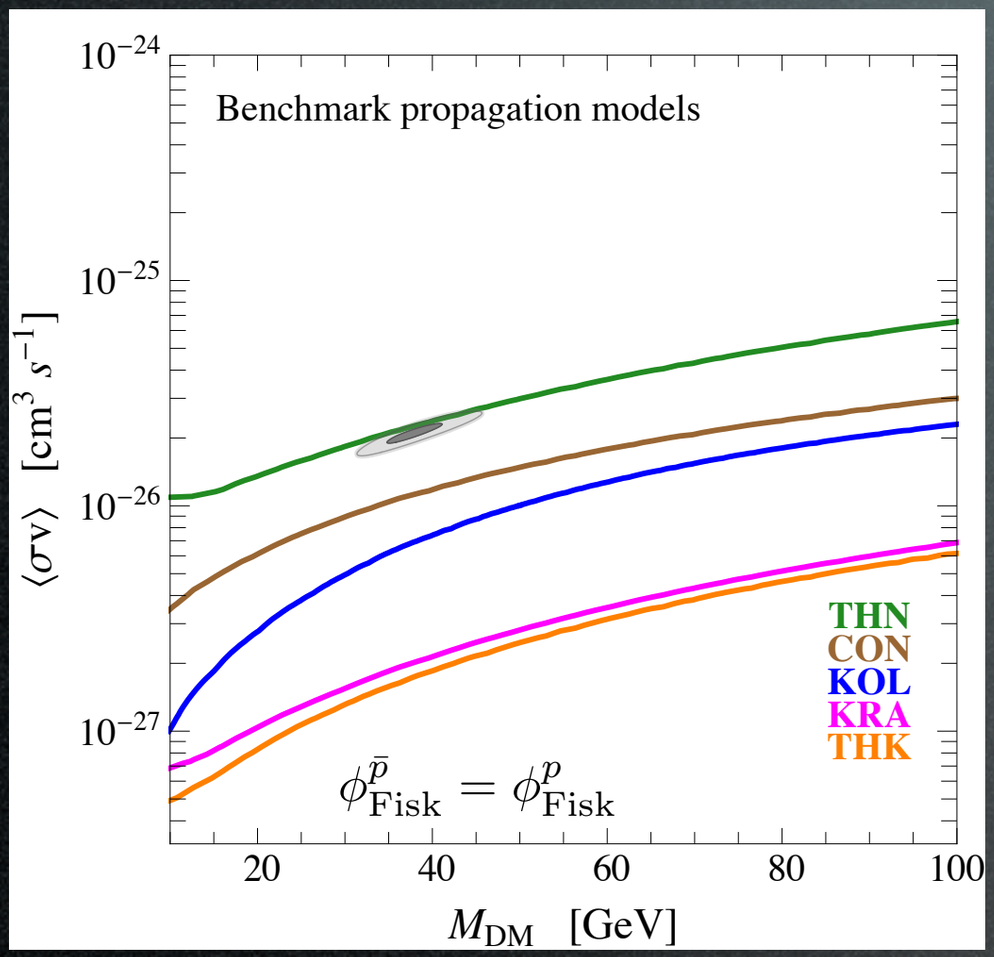
A compelling case for annihilating DM

Daylan, Finkbeiner, Hooper, Linden, Portillo, Rodd, Slatyer 1402.6703

As found in previous studies [8, 9], the inclusion of the dark matter template dramatically improves the quality of the fit to the *Fermi* data. For the best-fit spectrum and halo profile, we find that the inclusion of the dark matter template improves the formal fit by $\Delta\chi^2 \simeq 1672$, corresponding to a statistical preference greater than 40σ.

GC GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

Antiproton constraints may be very relevant! But not robust.

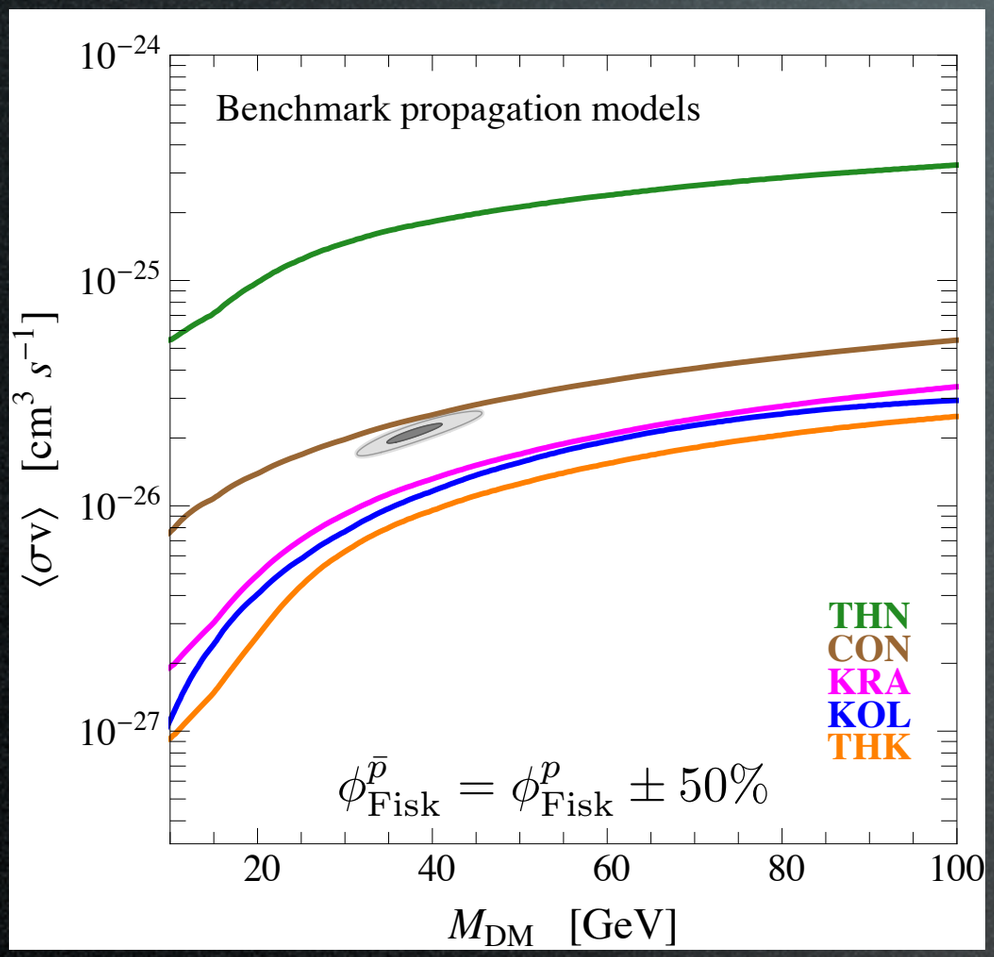
Assumption: fixed solar modulation

Result: hooperon excluded
(except unrealistic THN)

Fermi-LAT excess

GC GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

Antiproton constraints may be very relevant! But not robust.

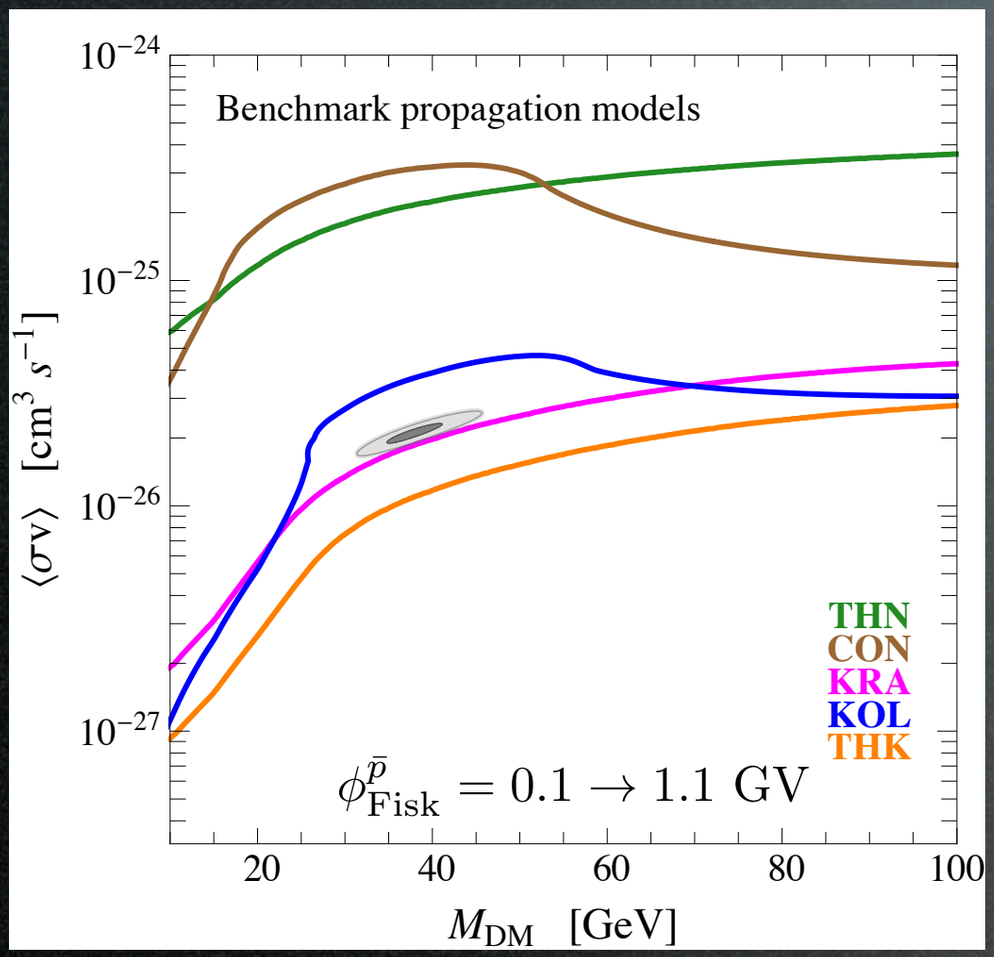
Assumption: flexible solar modulation

Result: hooperon may be excluded or not

Fermi-LAT excess

GC GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Fermi-LAT excess

Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

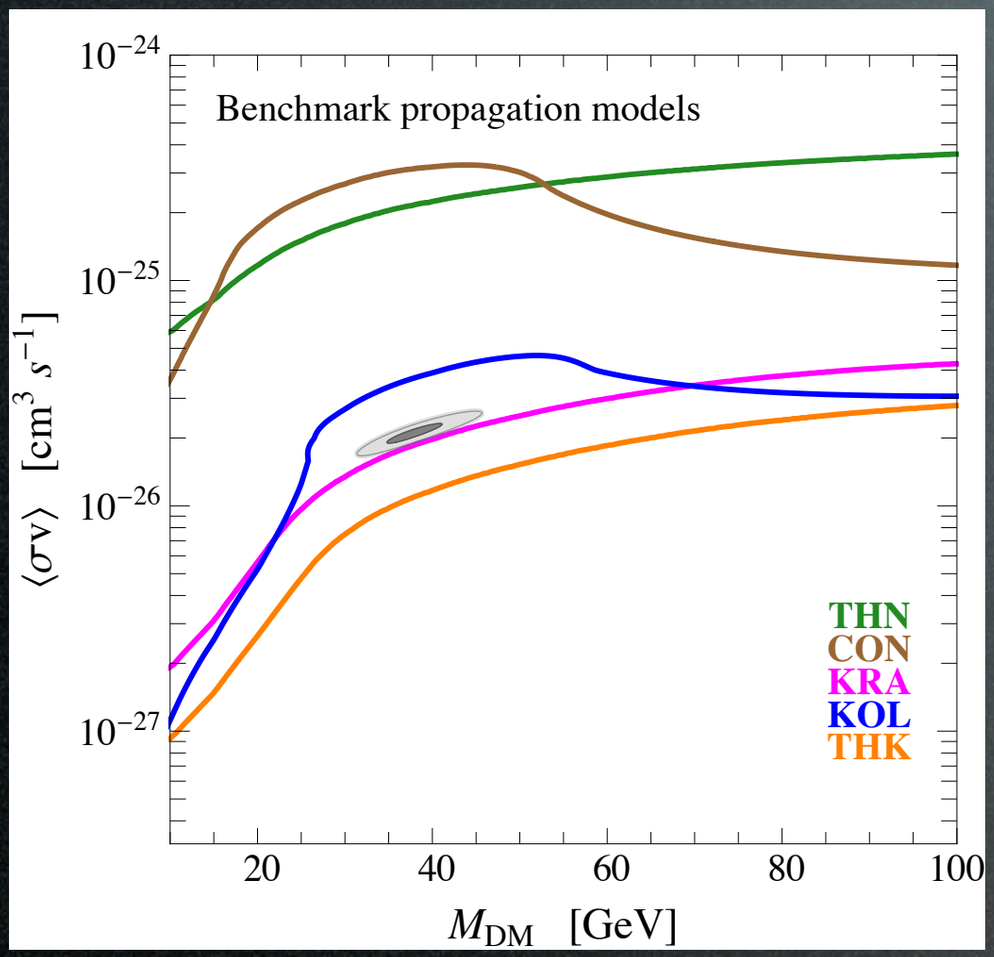
Antiproton constraints may be very relevant! But not robust.

Assumption: conservative solar modulation

Result: hooperon probably reallowed (except THK models)

GC GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Fermi-LAT excess

Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

Antiproton constraints may be very relevant! But not robust.

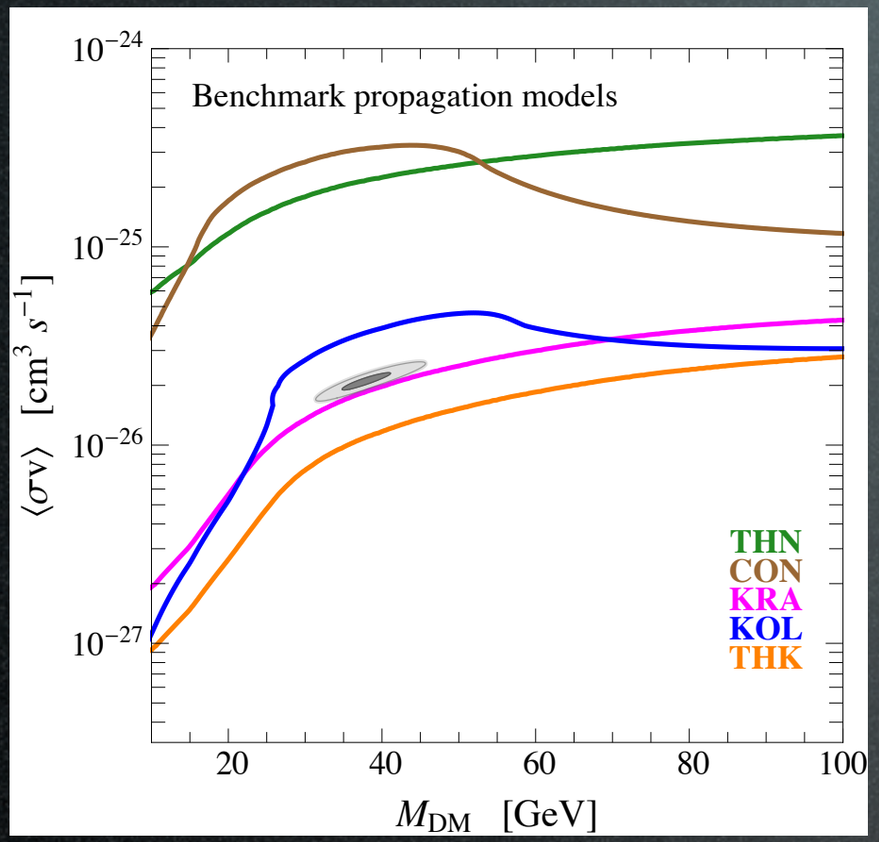
Assumption: conservative solar modulation

Result: hooperon probably reallowed (except THK models)

NB Conclusion differs from Bringmann, Vollmann, Weniger 1406.6027 which finds exclusion / strong tension

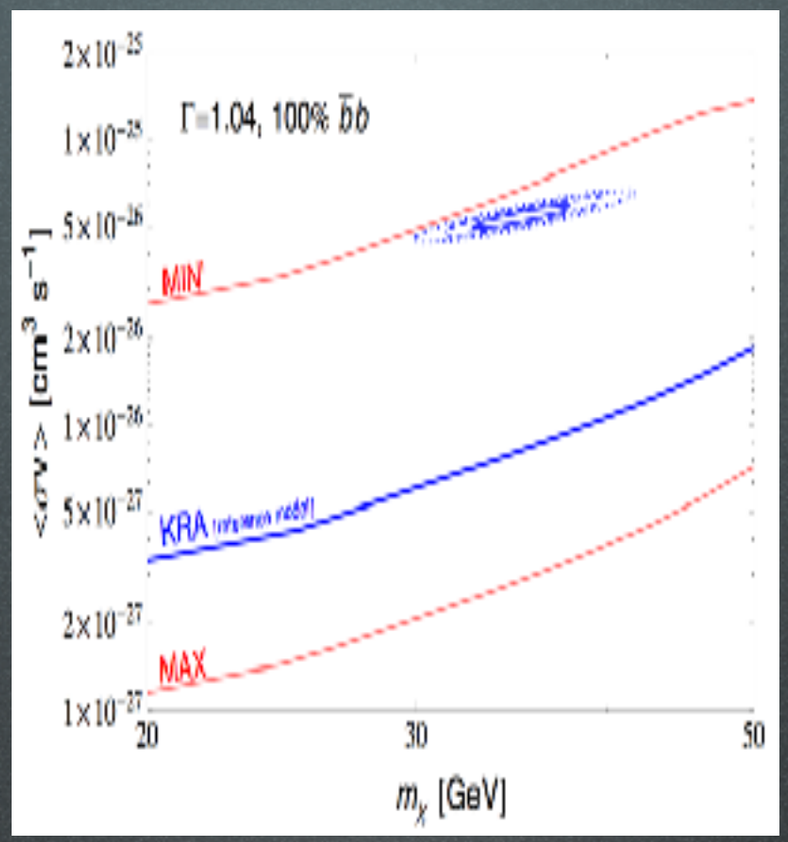
GC GeV gamma excess?

Antiproton constraints compared:



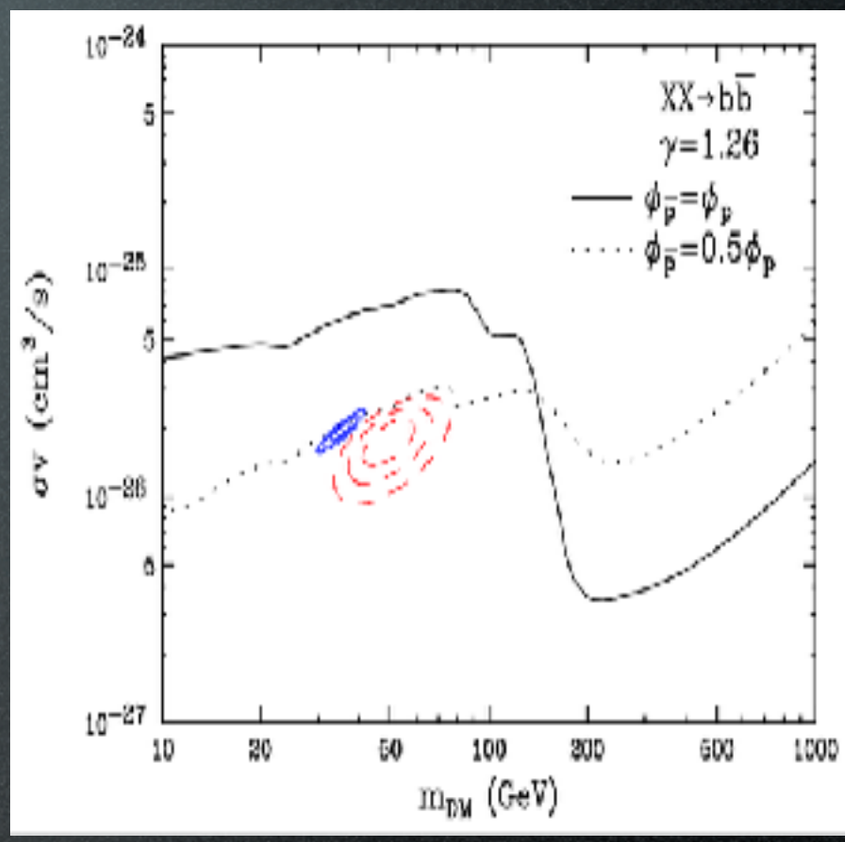
Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

May be very relevant!
But not robust.



Bringmann, Vollmann, Weniger 1406.6027

'Rule out' or
'considerable tension'.



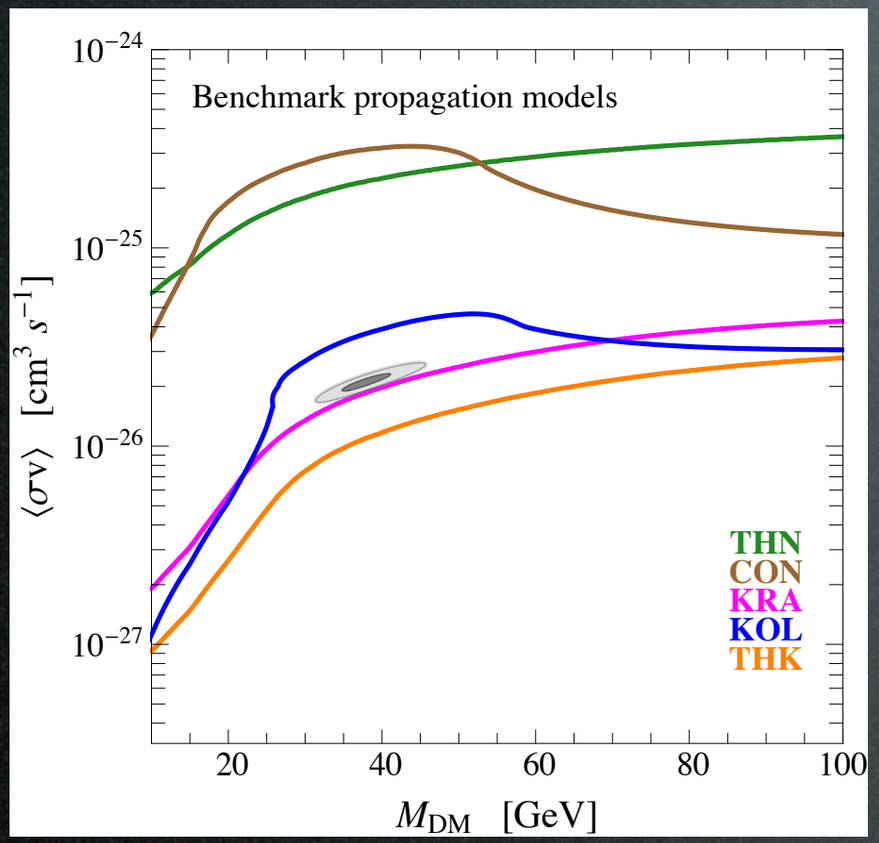
Hooper, Linden, Mertsch 1410.1527

'Significantly less stringent'.

How come?!?

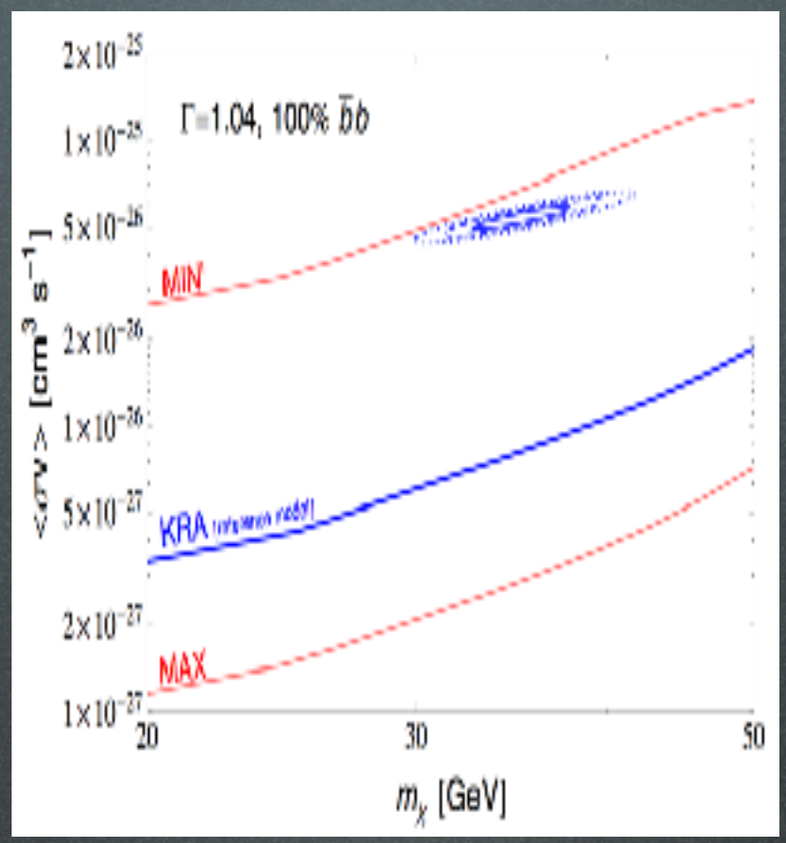
GC GeV gamma excess?

Antiproton constraints compared:



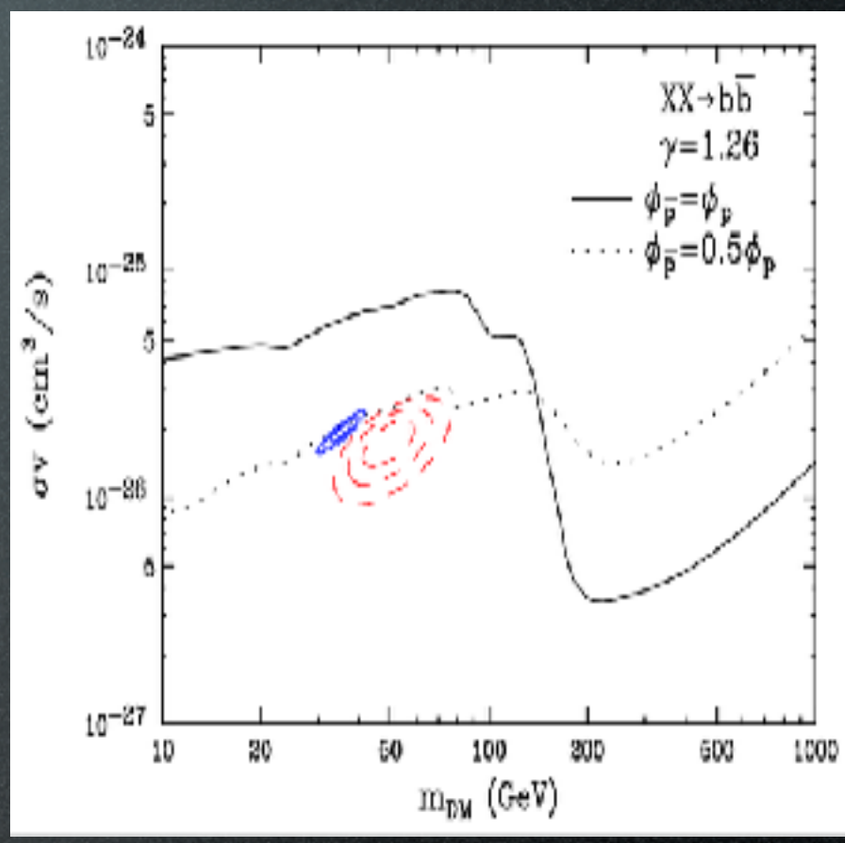
Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

May be very relevant!
But not robust.



Bringmann, Vollmann, Weniger 1406.6027

'Rule out' or
'considerable tension'.



Hooper, Linden, Mertsch 1410.1527

'Significantly less stringent'.

How come?!? The devil is in the (CR propagation) details:
solar modulation, convection, primary injection spectrum, tertiaries...