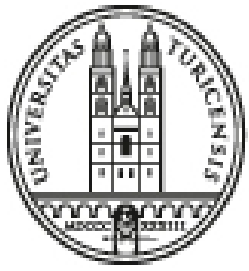

Universität Zürich[UZH]

DISCRIMINATING THE SOURCE OF HIGH-ENERGY POSITRONS WITH AMS-02

JCAP 1012:020 2010, arXiv:1010.5236

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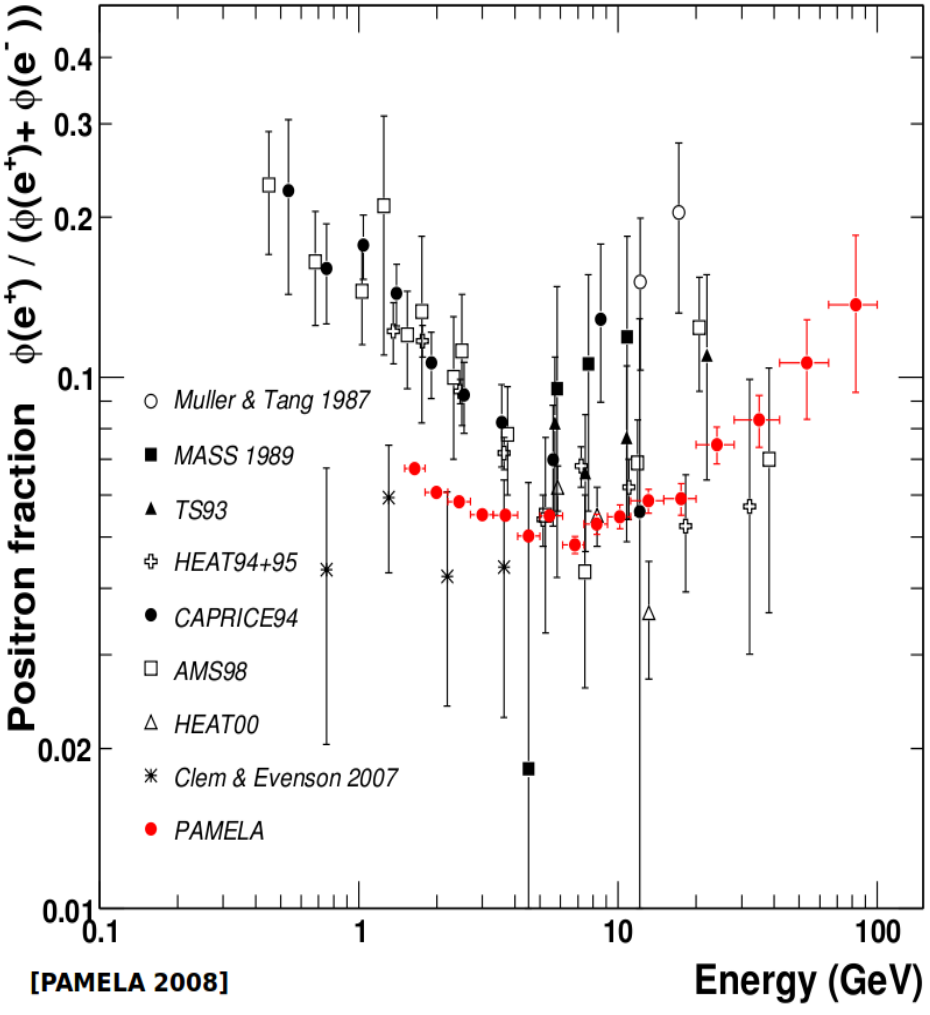
(in collaboration with M. Lattanzi, G. Bertone)

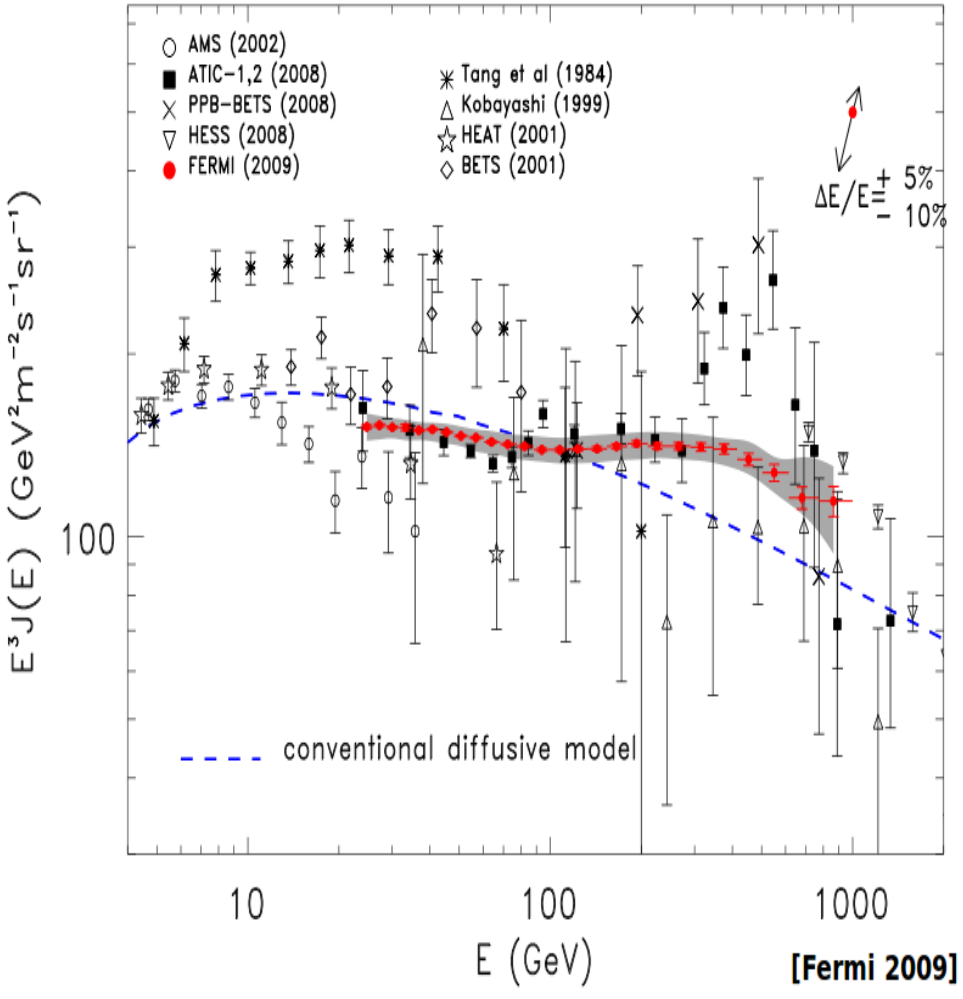
DESY Hamburg, June 15th 2011

THE FACTS: COSMIC-RAY $e^{\pm}$

positron fraction
$e^+/(e^+ + e^-)$



electron+positron flux
$e^+ + e^-$



INTERPRETING PAMELA $e^+/(e^+ + e^-)$

spectacular rise in $e^+/(e^+ + e^-)$

hint for nearby source of high-energy $e^\pm$

pulsars	[Hooper et al '08, ...]
annihilations/decays of DM	[everybody!]
secondary injection at CR sources	[Blasi & Serpico '09]

open questions

is the DM annihilation hypothesis feasible?

can we distinguish the DM and pulsar hypotheses?

[MP, Lattanzi & Bertone, JCAP 1012:020 2010]

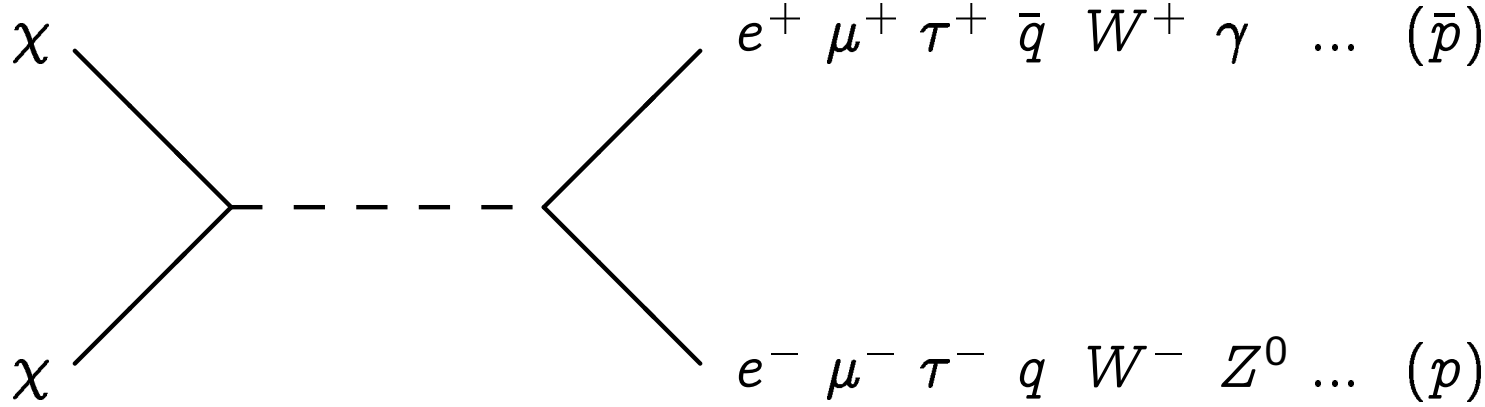
disclaimer: the CR-induced background is

rather uncertain (injection+propagation parameters unknown)

not fully understood yet (e.g. p, He hardenings at $\sim$TeV)

INDIRECT DARK MATTER DETECTION

driving idea: detect subproducts of annihilation/decay of DM



$$Q_{ann,i}(E,\vec{x}) \equiv \frac{\langle \sigma_{ann} v \rangle}{2m_\chi^2} \frac{dN_i}{dE}(E) \times \rho^2(\vec{x})$$

step 1. particle physics

step 2. astrophysics

step 3. propagation until the Earth

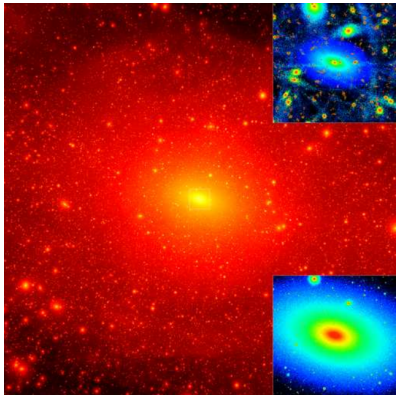
dark matter parameters: $\langle \sigma_{ann} v \rangle$, m_χ, # annihilation

INDIRECT DARK MATTER DETECTION

step 2. astrophysics: modelling galactic dark matter

rely on simulations of Milky Way-like halos: Via Lactea II & Aquarius

Via Lactea II
[Diemand et al. 2008]

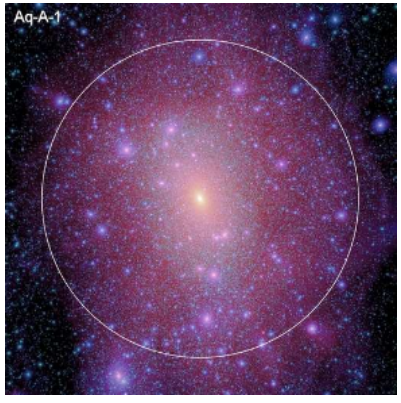


$\rho_{sm} \sim$ NFW

$\rho_{cl} \sim$ NFW

$dN/dM \propto M^{-2}$

Aquarius
[Springel et al. 2008]



$\rho_{sm} \sim$ Einasto

$\rho_{cl} \sim$ Einasto

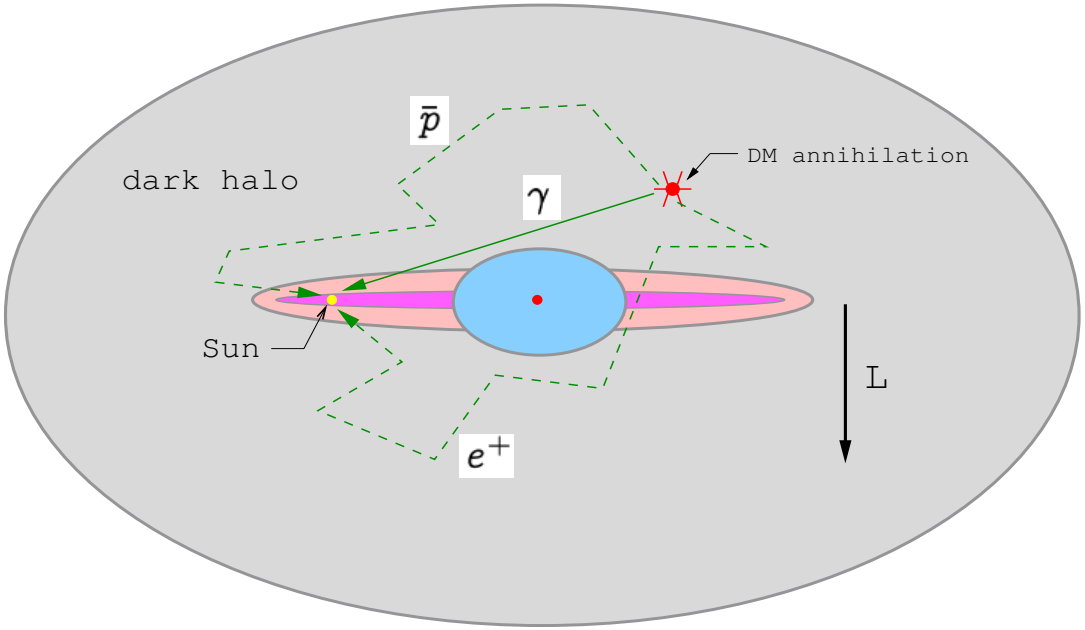
$dN/dM \propto M^{-1.9}$

many clumps + significant mass in clumps

$$\frac{d^2 N_{sh}}{dM dV} = N_{cl} \frac{dP_M}{dM} \frac{dP_V}{dV}$$

INDIRECT DARK MATTER DETECTION

step 3. propagation until the Earth



electrons/positrons:

$$-D_{e+}(E_{e+})\nabla^2 n_{e+} - \frac{\partial}{\partial E_{e+}}\left(b(E_{e+})n_{e+}\right) = Q_{e+}(\mathbf{x}, E_{e+})$$

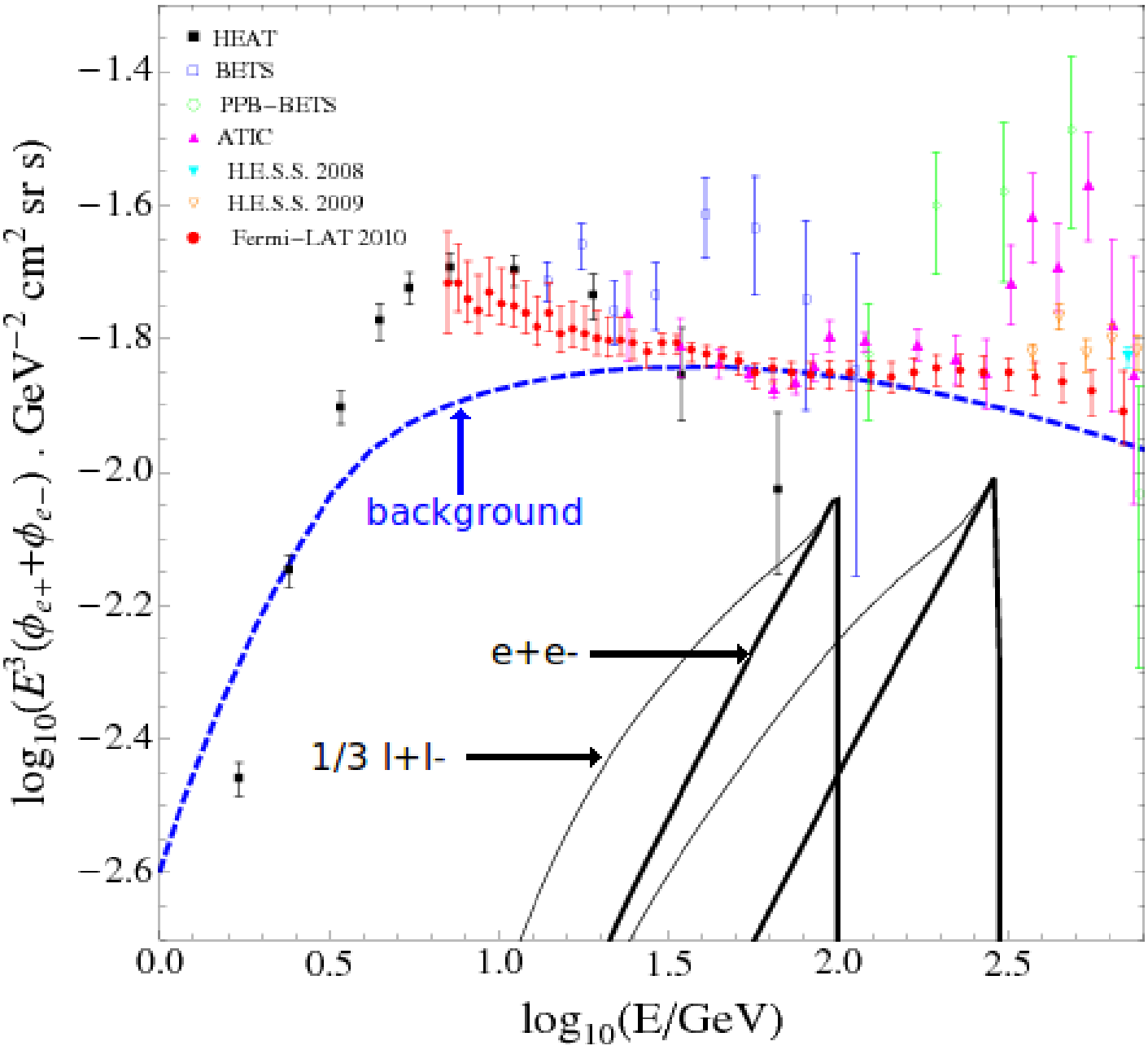
.. use semi-analytical methods to compute DM-induced $e^{\pm}$

	L [kpc]	D_0 [cm^2/s]	α
model 1	4	3.6×10^{28}	0.33

(tuned to match Fermi-LAT)

bottomline: DM can produce significant $e^{\pm}$ but uncertainties are crucial

INDIRECT DARK MATTER DETECTION



PULSAR PHENOMENOLOGY

pulsars are highly magnetised, rotating neutron stars

spin-down due to magnetic braking (among others)

$$\Omega(t) = \Omega_0 \left(1 + \frac{t}{\tau_0}\right)^{-1/2} \qquad t_{ch} = -\Omega/(2\dot{\Omega})$$

$e^{\pm}$ output of mature pulsars (i.e. $t \gg \tau_0$)

$$E_{e^\pm}(t_{ch}) \simeq \eta_{e^\pm} |\dot{E}| \frac{t_{ch}^2}{\tau_0}$$

$$Q_{e^\pm}(E) = Q^0_{e^\pm}(E/\mathrm{GeV})^{-\Gamma} \exp(-E/E_{cut})$$

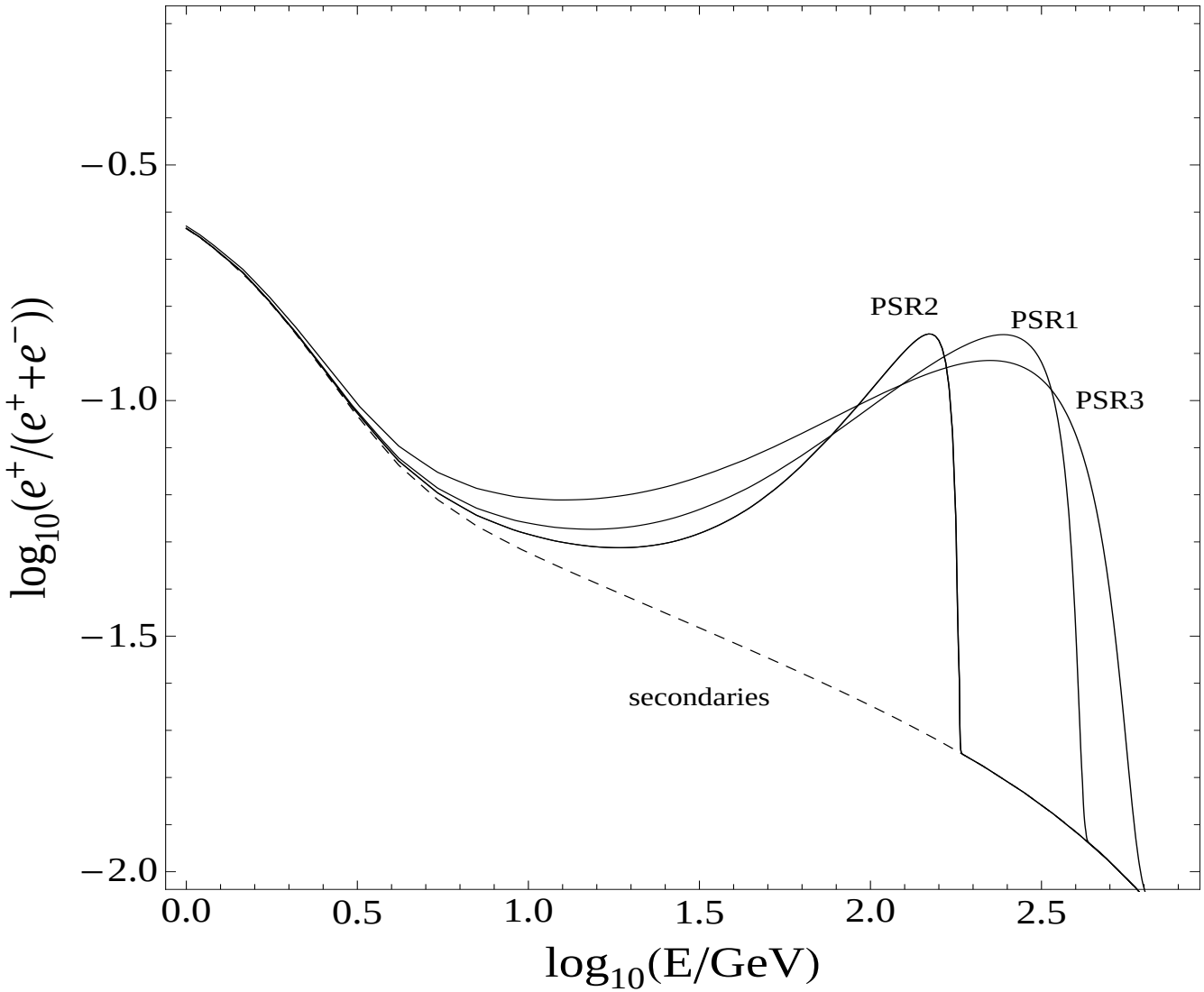
propagation until the Earth

$$n_{e^\pm}(d, E, t_{ch}) = \frac{Q_{e^\pm}(E')b(E')}{b(E)\pi^{3/2} r^3_{dif}(E, t_{ch})} \exp\left(-\frac{d^2}{r^2_{dif}(E, t_{ch})}\right)$$

pulsar parameters

spin-down luminosity	$\lvert\dot{E}\rvert$
distance	d
age	t_{ch}

PULSAR PHENOMENOLOGY



	Γ	E_{cut} [GeV]	$\lvert\dot{E}\rvert$ [erg/s]	t_{ch} [yr]	E_{max} [GeV]	d [kpc]	f
PSR1	1.7	1000	10^{35}	5×10^5	453	0.75	0.9
PSR2	1.3	1000	4×10^{34}	12×10^5	189	0.4	0.9
PSR3	1.7	500	8×10^{34}	3×10^5	755	0.2	0.9

DISTINGUISHING DM AND PULSARS WITH AMS-02

motivation: AMS-02 is at the ISS!

Ten seconds after the liftoff - Credit: Michael Struik - CERN

DISTINGUISHING DM AND PULSARS WITH AMS-02

key question

can we distinguish DM and pulsars with future $e^{\pm}$ data?

[MP, Lattanzi & Bertone, JCAP 1012:020 2010]

AMS-02 has good capabilities to measure GeV-TeV $e^{\pm}$

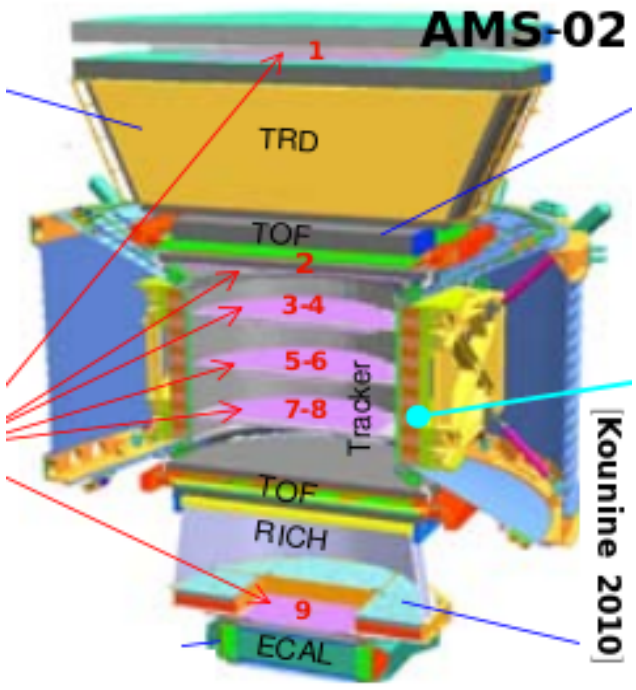
$E = 1 - 800$ GeV $\quad \Delta t = 18$ yr (!)

$$\frac{\Delta E}{E} = \sqrt{(0.106/\sqrt{E/\mathrm{GeV}})^2 + (0.0125)^2}$$

$A_{e^-} = A_{e^+} = 0.045$ cm^{2}sr

$e^- : p = 3 \times 10^5$

$e^+ : p = 3 \times 10^5 \quad e^+ : e^- = 10^4$



DISTINGUISHING DM AND PULSARS WITH AMS-02

[MP, Lattanzi & Bertone, JCAP 1012:020 2010]

1. assume DM benchmark DM DM $\rightarrow e^+ e^-$

	m_{DM} [GeV]	$\langle \sigma_{ann} v \rangle$ [cm^3/s]	f
DM1	100	5.0×10^{-26}	0.97
DM2	300	3.5×10^{-25}	0.87
DM3	500	9.0×10^{-25}	0.83

DISTINGUISHING DM AND PULSARS WITH AMS-02

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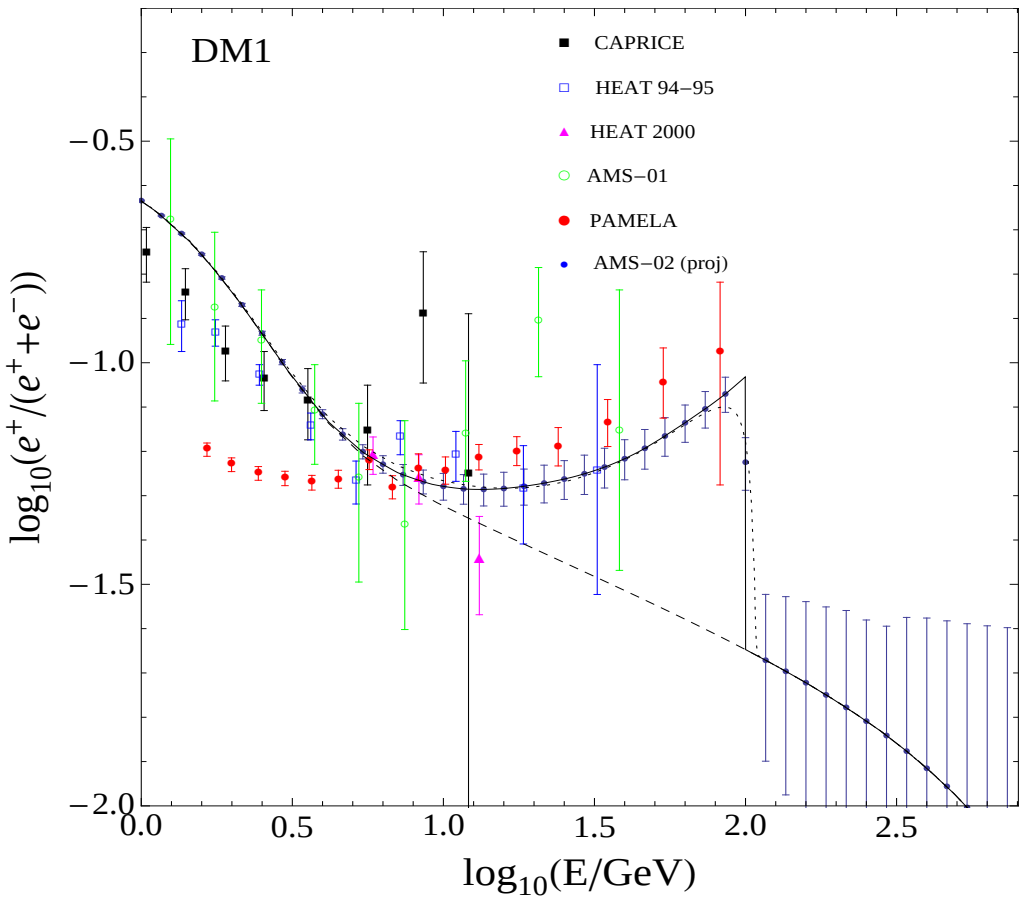
1. assume DM benchmark DM DM $\to e^+ e^-$
2. generate AMS-02 mock $e^\pm$ data



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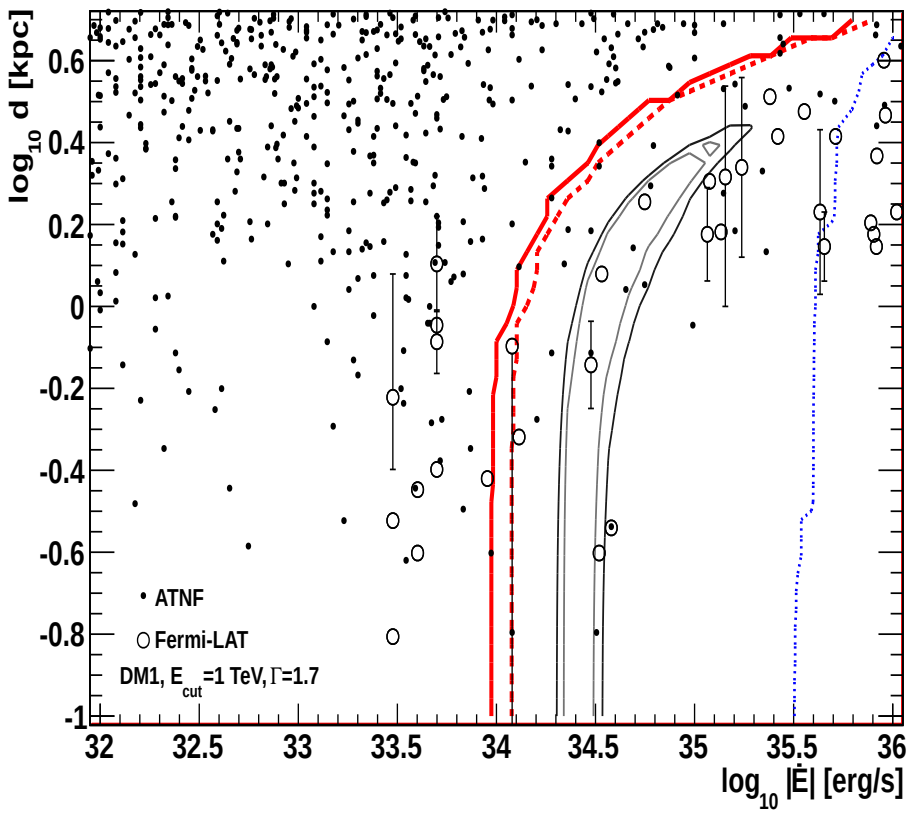
3. fit pulsar parameters



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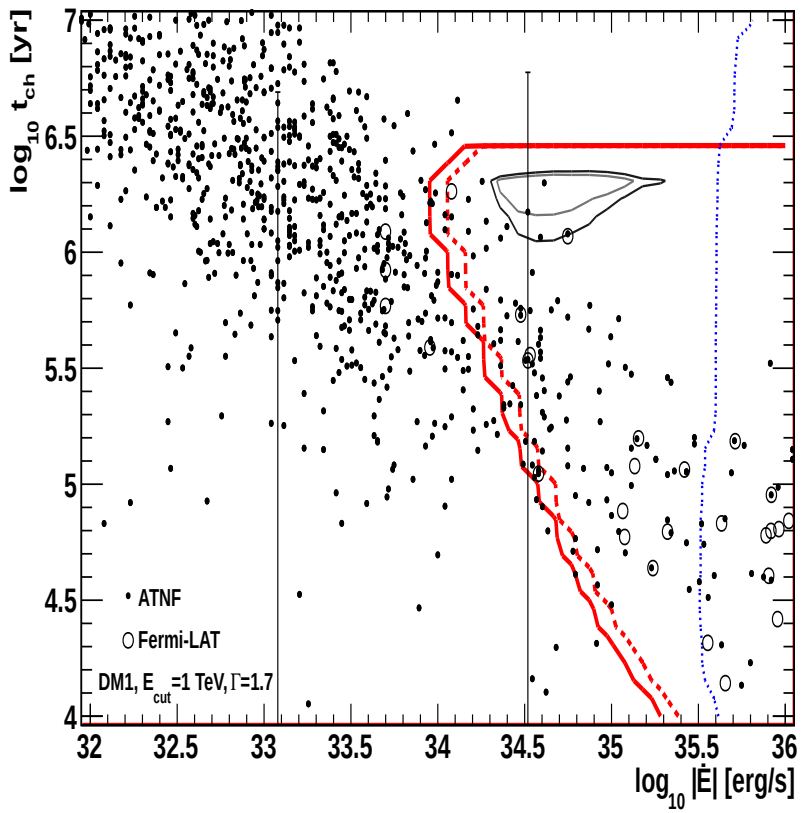

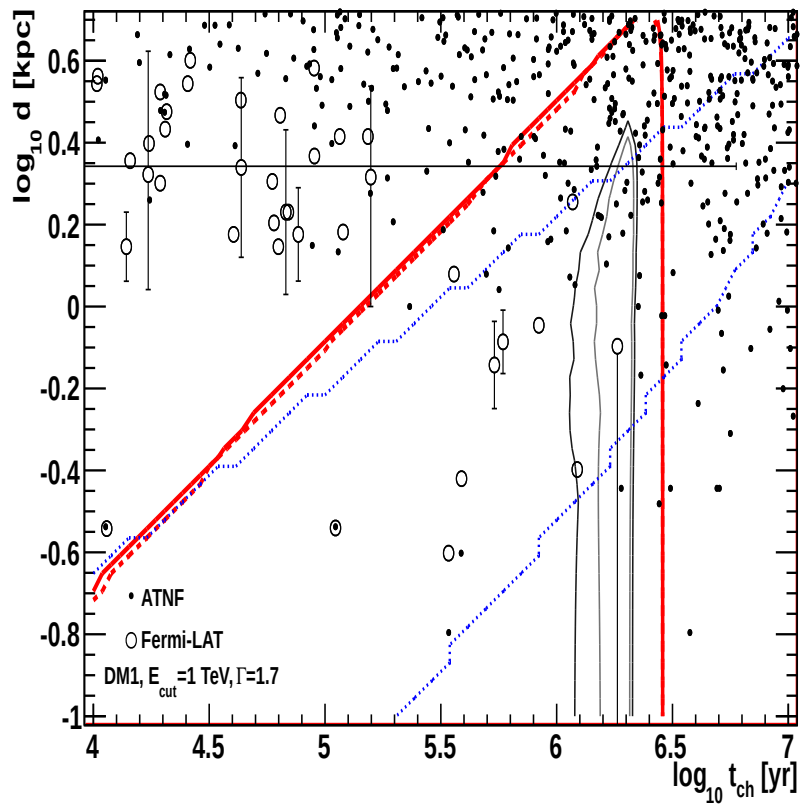

DISTINGUISHING DM AND PULSARS WITH AMS-02

[MP, Lattanzi & Bertone, JCAP 1012:020 2010]

1. assume DM benchmark DM DM $\to e^+ e^-$
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3. fit pulsar parameters

benchmark	Γ	E_{cut} [GeV]	N_1^{50}	N_1^{99}	N_2	N_3
DM1	1.3	1000	0	0	5	3
DM1	1.5	1000	0	0	5	5
DM1	1.7	1000	0	0	5	3
DM1	1.9	1000	0	0	1	1
DM1	1.7	500	0	1	4	4
DM1	1.7	5000	0	0	1	1
DM1	1.7	10^4	0	0	1	1
DM2	1.5	1000	0	0	8	6
DM2	1.7	1000	0	0	6	5
DM2	1.9	1000	0	0	3	1
DM3	1.5	1000	0	0	8	6
DM3	1.7	1000	0	0	8	5
DM3	1.9	1000	0	0	4	2

bottomline:

.. no known pulsar within contours (but catalog is incomplete)
.. many known pulsars contributing >50% (but $\eta_{e^\pm}$ high)

if sharp cutoff is seen by AMS-02, pulsar spectra cannot be discarded

DISTINGUISHING DM AND PULSARS WITH AMS-02

[MP, Lattanzi & Bertone, JCAP 1012:020 2010]

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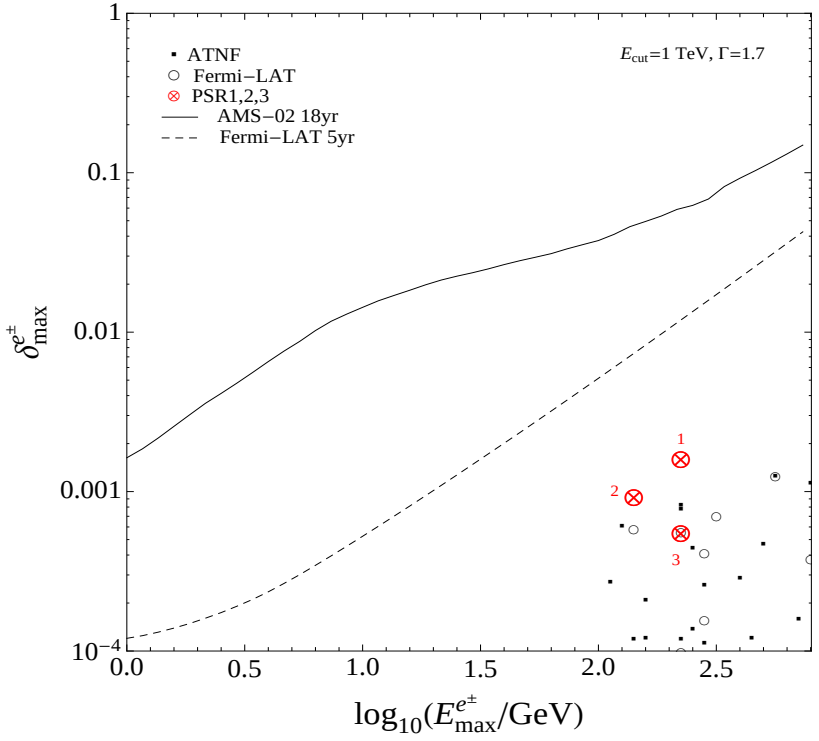
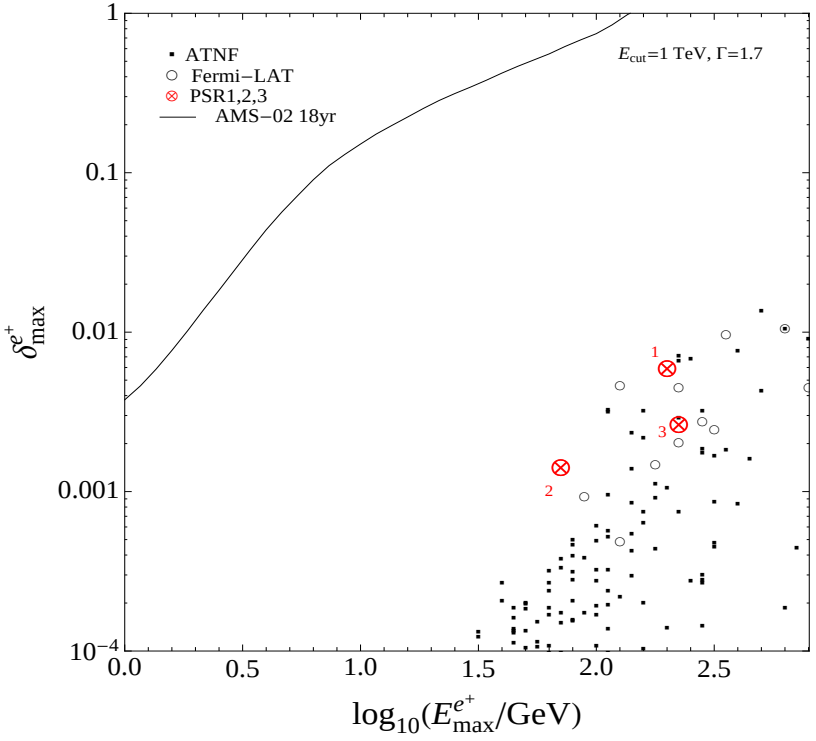




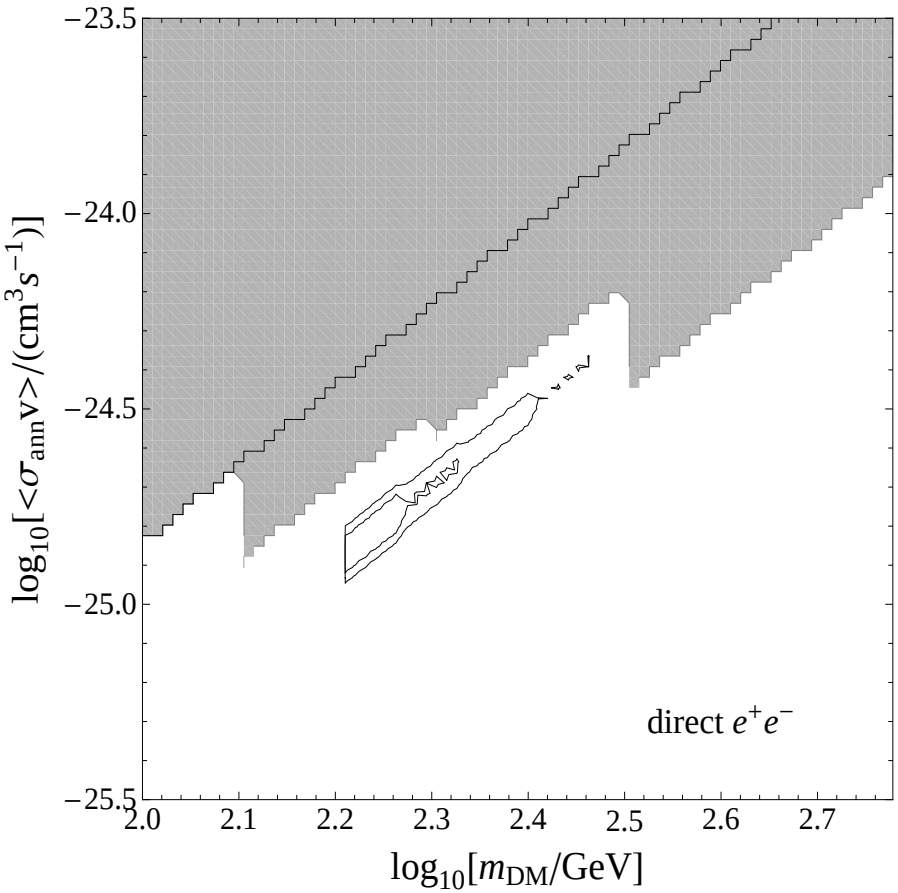
what about anisotropies?

... way out of reach

DISTINGUISHING DM AND PULSARS WITH AMS-02

[MP, Lattanzi & Bertone, JCAP 1012:020 2010]

1. assume DM benchmark DM DM $\to e^+ e^-$
2. generate AMS-02 mock $e^\pm$ data
3. fit pulsar parameters
4. redo inversely: assume pulsars and fit DM



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2. generate AMS-02 mock $e^\pm$ data
3. fit pulsar parameters
4. redo inversely: assume pulsars and fit DM

bottomline

challenging to distinguish DM/pulsar hypotheses

precise $e^\pm$ is not enough to settle this issue

complementary data or better understanding of sources needed

DISTINGUISHING DM AND PULSARS WITH AMS-02

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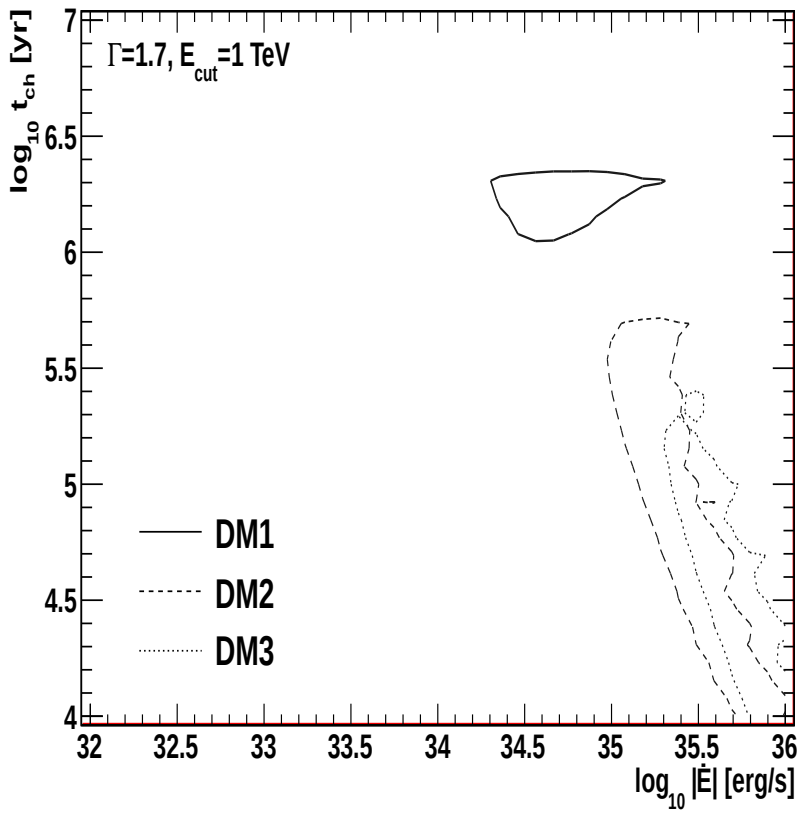

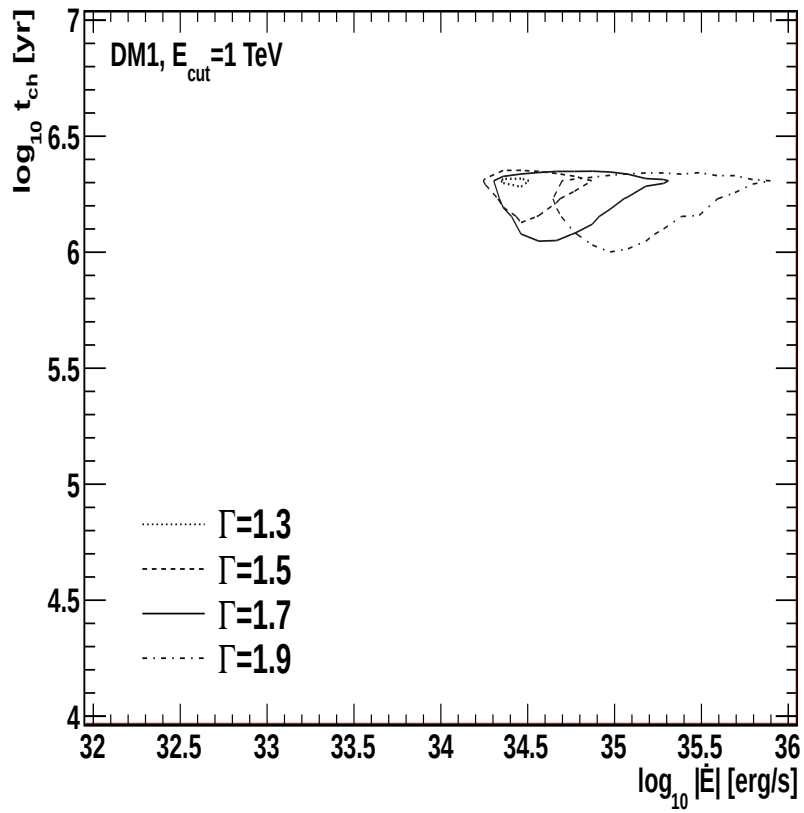

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