Effective theory of DM decay into gamma-ray lines

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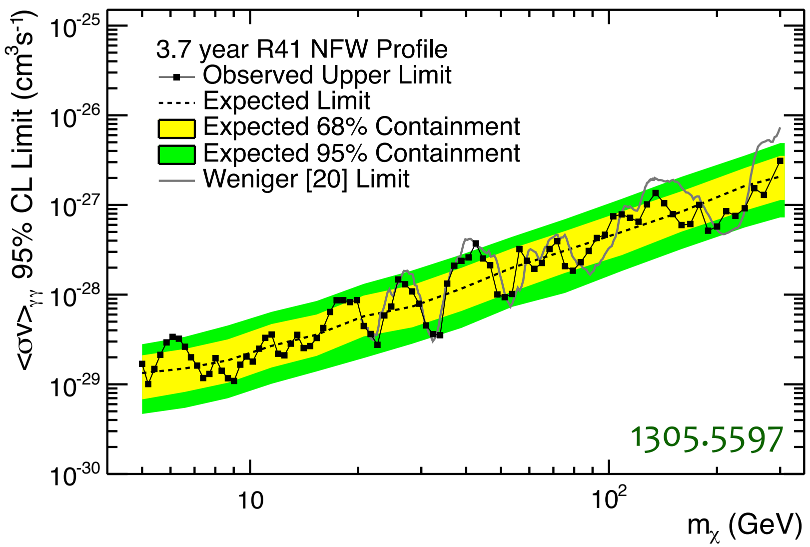
Based on a collaboration with Michael Gustafsson and Tiziana Scarna

DSU-SISSA-Trieste 14/10/2013

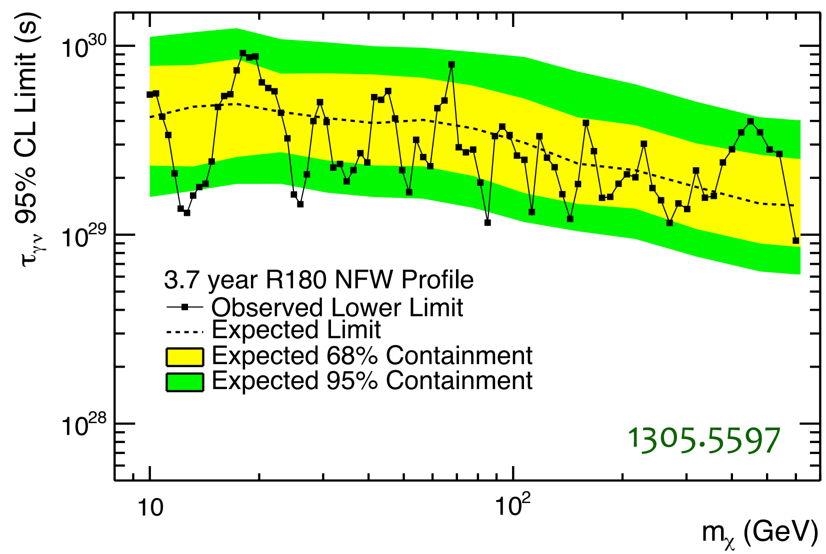
Search for smoking gun γ-lines produced by DM annihilation or decay

many recent experimental progresses!

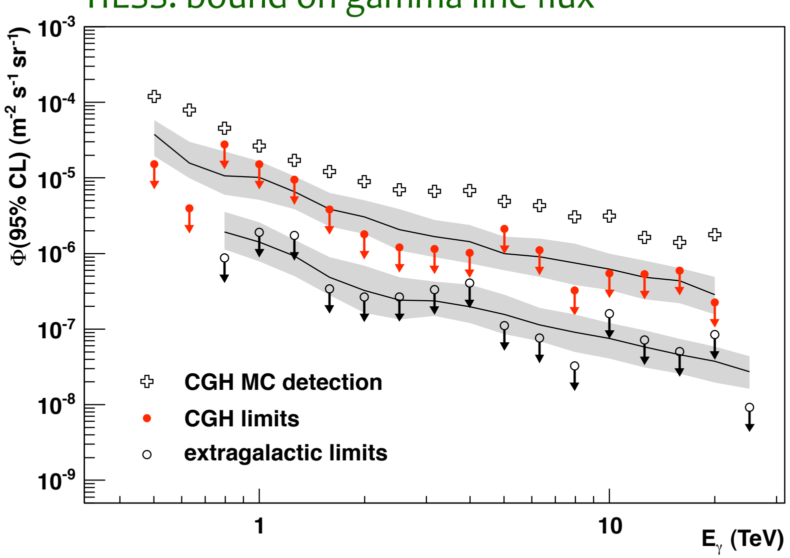
FERMI: bound on annihilation gamma-line



FERMI: bound on decay lifetime to gamma line



HESS: bound on gamma line flux



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Many theoretical studies too:

Annihilation: Bergstrom, Ullio, 97' 98';Bern, Gondolo, Perelstein 97'; Bergstrom, Bringmann, Eriksson, Gustafsson 04', 05'; Boudjema, Semenov, Temes 05'; Dudas, Mambrini, Pokorski, Romagnoni 09'; Jackson, Servant, Shaughnessy, Tait, Taoso 09','13; Ramajaran, Tait, Whiteson '12; Ramajaran, Tait, Wijangco '12; Cotta, Hewett, Le, Rizzo '12; Bringmann, Huang, Ibarra, Vogl, Weniger '12;Weniger '12; ....

Decay: Buchmuller, Covi, Hamagushi, Ibarra, Tran 07'; Ibarra, Tran 07'; Ishiwata, Matsumoto, Moroi 08'; Buchmuller, Ibarra, Shindou, Takayama, Tran 09'; Choi, Lopez-Fogliani, Munoz, de Austri 09' ; Garny, Ibarra, Tran, Weniger '10; Ibarra Tran, Weniger '13

This talk: the γ-line decay production scenario

unlike an annihilation the DM decay width is not limited by thermal freeze-out cross section value (and possible loop suppressions)

there exists a simple motivated framework for slow DM decay:

if DM stability is accidental just as for the proton in Standard Model

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UV physics has a priori no reason to respect an accidental low energy symmetry

$\Downarrow$

UV physics is expected to cause a DM decay suppressed by powers of UV scale

$$\mathcal{L} = \mathcal{L}_{dim=4} + \sum_i \frac{1}{\Lambda_{UV}} \mathcal{O}_i^{(5)} + \sum_i \frac{1}{\Lambda_{UV}^2} \mathcal{O}_i^{(6)} + \dots$$

$\Downarrow$

if UV scale is large the decay lifetime is naturally very large

kind of intriguing coincidence:

if $\Lambda_{UV} \sim \Lambda_{GUT}$ and $m_{DM} \sim \mathrm{TeV} \xrightarrow{\text{dim-6}} \tau_{DM} \sim 8\pi \frac{m_{DM}^5}{\Lambda_{GUT}^4} \sim 10^{28}\,\mathrm{sec}$

~ experimental sensitivity today!

Eichler; Nardi, Sannino, Strumia; Chen, Takahashi, Yanagida; Arvanitaki, Dimopoulos et al.; Bae, Kyae; Hamagushi, Shirai, Yanagida; Arina, TH, Ibarra, Weniger;...

Effective theory of DM decay into γ-line(s)

fully justified since UV scale expected much larger than SM and DM scales

is practically feasible: not too many operator structures

even if we allow for DM decay to a γ and a new unknown particle as we will do to be fully general

Many criteria an operator must fulfill:
- must contain the DM field in a linear way
- must contain the photon field strength
- must lead to a radiative 2-body decay
- must not have a one -to-one correspondence with another operator already in the list

List of possible dim-5 and dim-6 radiative operators

	dimension-5		dimension-6	
for a scalar DM candidate:	$O_{\phi_{DM}}^{(5)YY} \equiv \phi_{DM} F_{Y\mu\nu} F_Y^{\mu\nu}$	$\phi_{DM} = (1,0)$	$O_{\phi_{DM}}^{1YY} \equiv \phi_{DM} F_{Y\mu\nu} F_Y^{\mu\nu} \phi$	$\phi_{DM} \cdot \phi = (1,0)$
	$O_{\phi_{DM}}^{(5)YL} \equiv \phi_{DM} F_{L\mu\nu} F_Y^{\mu\nu}$	$\phi_{DM} = (3,0)$	$O_{\phi_{DM}}^{1YL} \equiv \phi_{DM} F_{L\mu\nu} F_Y^{\mu\nu} \phi$	$\phi_{DM} \cdot \phi = (3,0)$
	$O_{\phi_{DM}}^{(5)LL} \equiv \phi_{DM} F_{L\mu\nu} F_L^{\mu\nu}$	$\phi_{DM} = (1/3/5,0)$	$O_{\phi_{DM}}^{1LL} \equiv \phi_{DM} F_{L\mu\nu} F_L^{\mu\nu} \phi$	$\phi_{DM} \cdot \phi = (1/3/5,0)$
	$O_{\phi_{DM}}^{(5)YY'} \equiv \phi_{DM} F_{Y\mu\nu} F_{Y'}^{\mu\nu}$	$\phi_{DM} = (1,0)$	$O_{\phi_{DM}}^{1YY'} \equiv \phi_{DM} F_{Y\mu\nu} F_{Y'}^{\mu\nu} \phi$	$\phi_{DM} \cdot \phi = (1,0)$
	$O_{\phi_{DM}}^{(5)LY'} \equiv \phi_{DM} F_{L\mu\nu} F_{Y'}^{\mu\nu}$	$\phi_{DM} = (3,0)$	$O_{\phi_{DM}}^{1LY'} \equiv \phi_{DM} F_{L\mu\nu} F_{Y'}^{\mu\nu} \phi$	$\phi_{DM} \cdot \phi = (3,0)$
			$O_{\phi_{DM}}^{2Y} \equiv D_\mu \phi_{DM} D_\nu \phi F_Y^{\mu\nu}$	$\phi_{DM} \cdot \phi = (1,0)$
			$O_{\phi_{DM}}^{2L} \equiv D_\mu \phi_{DM} D_\nu \phi F_L^{\mu\nu}$	$\phi_{DM} \cdot \phi = (3,0)$
for a fermion DM candidate:	$O_{\psi_{DM}}^{(5)Y} \equiv \bar{\psi} \sigma_{\mu\nu} \psi_{DM} F_Y^{\mu\nu}$	$\psi_{DM} \cdot \psi = (1,0)$	$O_{\psi_{DM}}^{1Y} \equiv \bar{\psi} \sigma_{\mu\nu} \psi_{DM} F_Y^{\mu\nu} \phi$	$\bar{\psi} \cdot \psi_{DM} \cdot \phi = (1,0)$
	$O_{\psi_{DM}}^{(5)L} \equiv \bar{\psi} \sigma_{\mu\nu} \psi_{DM} F_L^{\mu\nu}$	$\psi_{DM} \cdot \psi = (3,0)$	$O_{\psi_{DM}}^{1L} \equiv \bar{\psi} \sigma_{\mu\nu} \psi_{DM} F_L^{\mu\nu} \phi$	$\bar{\psi} \cdot \psi_{DM} \cdot \phi = (3,0)$
			$O_{\psi_{DM}}^{2Y} \equiv D_\mu \bar{\psi} \gamma_\nu \psi_{DM} F_Y^{\mu\nu}$	$\bar{\psi} \cdot \psi_{DM} = (1,0)$
			$O_{\psi_{DM}}^{2L} \equiv D_\mu \bar{\psi} \gamma_\nu \psi_{DM} F_L^{\mu\nu}$	$\bar{\psi} \cdot \psi_{DM} = (3,0)$
			$O_{\psi_{DM}}^{3Y} \equiv \bar{\psi} \gamma_\mu D_\nu \psi_{DM} F_Y^{\mu\nu}$	$\bar{\psi} \cdot \psi_{DM} = (1,0)$
			$O_{\psi_{DM}}^{3L} \equiv \bar{\psi} \gamma_\mu D_\nu \psi_{DM} F_L^{\mu\nu}$	$\bar{\psi} \cdot \psi_{DM} = (3,0)$
for a spin-1 DM candidate:	$O_{V_{DM}}^{(5)Y} \equiv F_{\mu\nu}^{DM} F_Y^{\mu\nu} \phi$	$\phi = (1,0)$	$O_{V_{DM}}^{1} \equiv F_{\mu\nu}^{DM} F_Y^{\mu\rho} F_{Y'\rho}^{\nu}$	
	$O_{V_{DM}}^{(5)L} \equiv F_{\mu\nu}^{DM} F_L^{\mu\nu} \phi$	$\phi = (3,0)$	$O_{V_{DM}}^{2Y} \equiv F_{\mu\nu}^{DM} F_Y^{\mu\nu} \phi \phi'$	$\phi \cdot \phi' = (1,0)$
			$O_{V_{DM}}^{2L} \equiv F_{\mu\nu}^{DM} F_L^{\mu\nu} \phi \phi'$	$\phi \cdot \phi' = (3,0)$
			$O_{V_{DM}}^{3YY'} \equiv D_\mu^{DM} \phi D_\nu^{DM} \phi' F_Y^{\mu\nu}$	$\phi \cdot \phi' = (1,0)$
			$O_{V_{DM}}^{3LY'} \equiv D_\mu^{DM} \phi D_\nu^{DM} \phi' F_L^{\mu\nu}$	$\phi \cdot \phi' = (3,0)$

Relevant questions

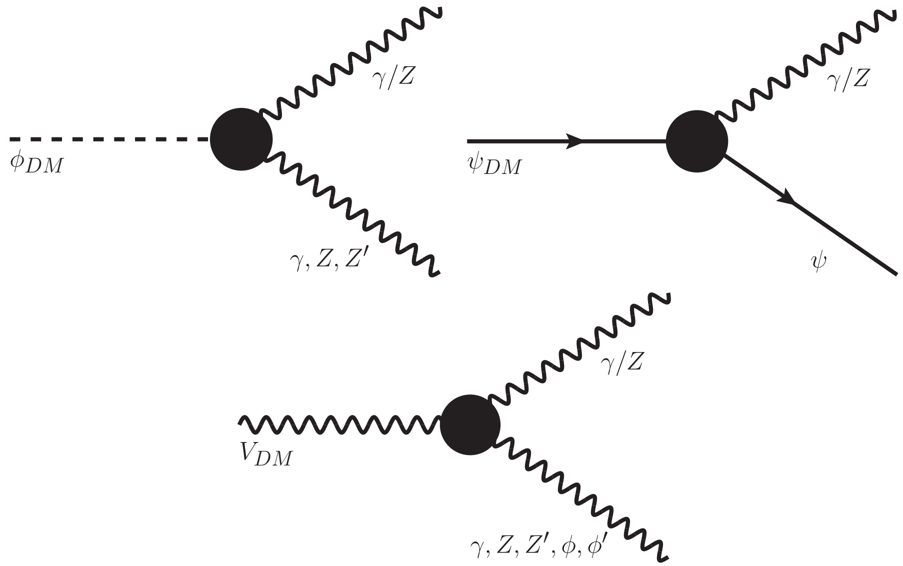
- bound on γ-line intensity for each operator?
- various correlated signals from each operator for a multichannel analysis?
- is an experimental operator discrimination possible?

$\Rightarrow$ getting information on DM particle nature and UV physics at the origin of the decay

2 main ways:

- from γ-line features: their number, energy and intensity
- from associated non-monochromatic cosmic ray production

Possible 2-body radiative decays and γ-ray line features



⇛ 3 categories of operators:

1) $F_{Y,L\mu\nu}F^{\mu\nu}_{Y,L}$ operators: give 2 γ-lines

$DM \to \gamma\gamma \qquad E_\gamma = \frac{m_{DM}}{2}$

$DM \to \gamma Z \qquad E_\gamma = \frac{m_{DM}}{2}(1 - m_Z^2/m_M^2)$

↪ energy of first peak fixes the energy of second peak!

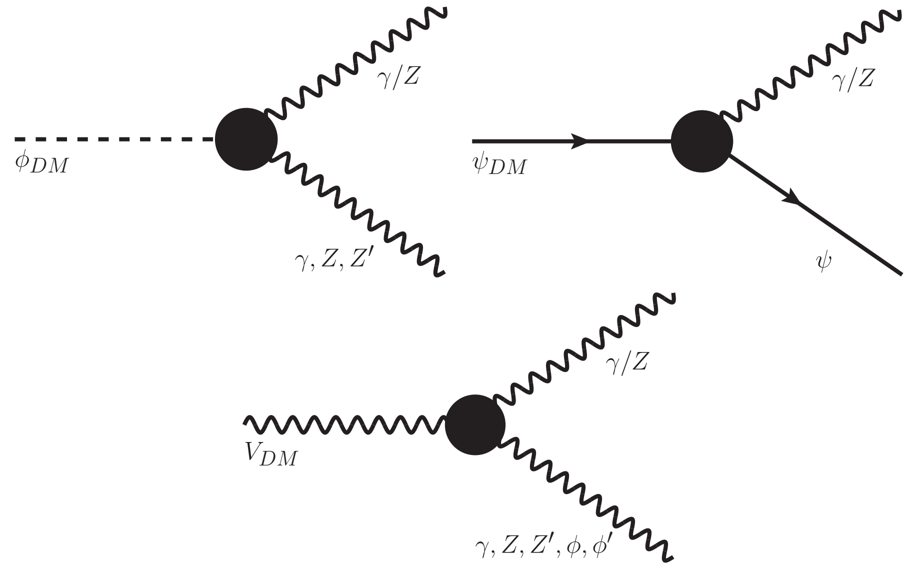
$F = m_{DM}^6/(m_{DM}^2 - m_Z^2)^3$

↪ intensity of peaks also predicted: $\Gamma_{\gamma\gamma}/\Gamma_{\gamma Z} = \frac{\cos^2\theta_W}{2\sin^2\theta_W}F, \ \frac{\sin^2 2\theta_W}{2\cos^2 2\theta_W}F, \ \frac{\sin^2\theta_W}{2\cos^2\theta_W}F$

only for scalar DM!

$F_{Y\mu\nu}F^{\mu\nu}_{Y} \qquad F_{L\mu\nu}F^{\mu\nu}_{L} \qquad F_{Y\mu\nu}F^{\mu\nu}_{L}$

Possible 2-body radiative decays and γ-ray line features



⇒ 3 categories of operators:

2) operators giving 2 γ-lines from decay to an unknown particle → $DM \to \gamma Z,\ \gamma\phi$; → $DM \to \gamma Z',\ \gamma\phi'$

$$E_\gamma = \frac{m_{DM}}{2}(1 - m^2_{Z',\phi,\phi'}/m^2_{DM})$$

↪ energy of peaks fixed by m_{DM} mass of unknowm particle $m_{Z',\phi,\phi'}$

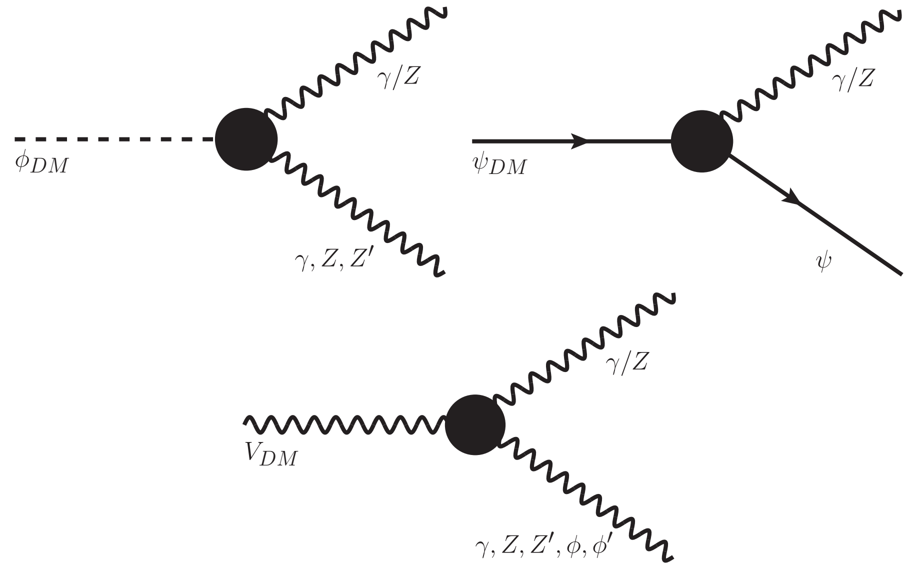
↪ intensity of peaks fixed by masses and quantum numbers of DM or scalar vev values

$$\Gamma_{\gamma Z}/\Gamma_{\gamma Z'} = \frac{g^2 T_3^2}{\cos^2\theta_W g_{Y'}^2 Y'^2}\left(\frac{m_{DM}^2 - m_Z^2}{m_{DM}^2 - m_{Z'}^2}\right)^3$$

$$\Gamma_{\gamma\phi}/\Gamma_{\gamma\phi'} = \frac{\langle\phi'\rangle^2}{\langle\phi\rangle^2}\left(\frac{m_{DM}^2 - m_Z^2}{m_{DM}^2 - m_{Z'}^2}\right)^3$$

only for scalar or vector DM!

Possible 2-body radiative decays and γ-ray line features



$\Rightarrow$ 3 categories of operators:

3) operators giving only one γ-line: $$E_\gamma = \frac{m_{DM}}{2}(1 - m^2_{Z',\phi,\phi',\psi}/m^2_{DM})$$

only for scalar, fermion or vector DM!

N.B.: a same DM particle can in principle give several lines from appearing in several operators

Cosmic ray production associated to a γ-line

each operator must be gauge invariant: involves $F_Y^{\mu\nu}$ or $F_L^{\mu\nu}$

$\Downarrow$

Z-channel is there if $E_\gamma >> m_Z$ ← as we will consider here

W^+W^-, ... channels are there by gauge invar. sometimes

......

$\Downarrow$

cosmic rays: $\bar{p}$, γ_D, e^+, ν, ...

$\Downarrow$

upper bounds on γ-line intensity from CR constraints!

Absolute upper bound on γ-line intensity from CR constraint

from a single operator (for several oper. see below)

$$\frac{n_\gamma}{n_Z} \leq \frac{\cos^2\theta_W}{\sin^2\theta_W} \quad \Rightarrow \quad R_{\gamma/CR} \equiv \frac{n_\gamma}{n_{CR}} \leq \frac{\cos^2\theta_W}{\sin^2\theta_W \, n_{CR/Z}}$$

can be saturated only for a few operators (e.g. some with a $F_Y^{\mu\nu}$)

other operators can only give a smaller ratio $\Rightarrow$ many possibilities

$\Downarrow$

one can nevertheless have a simple global picture in 2 steps

2 step procedure to classify the γ to CR ratio predictions

1) first write down the maximum ratio a given structure can give in full generality

there are only 5 maximum ratios:

$$A: \frac{n_\gamma}{n_Z} = \frac{\cos^2\theta_W}{\sin^2\theta_W} \quad \text{or} \quad R_{\gamma/CR} \equiv \frac{n_\gamma}{n_{CR}} = \frac{\cos^2\theta_W}{\sin^2\theta_W n_{CR/Z}}$$

characteristic of oper. with only $F_Y^{\mu\nu}$

$$B: R_{\gamma/CR} = \frac{1}{n_{CR/Z}}$$

characteristic of oper. with $F_Y^{\mu\nu} F_{L\mu\nu}$

$$C: R_{\gamma/CR} = \frac{\sin^2\theta_W}{\cos^2\theta_W n_{CR/Z}}$$

characteristic of some oper. with only $F_L^{\mu\nu}$

$$D,E: R_{\gamma/CR} = \frac{\sin^2\theta_W}{\cos^2\theta_W n_{CR/Z} + c_W(n_{CR/W^+} + n_{CR/W^-})}$$

characteristic of some oper. with only $F_L^{\mu\nu}$

$$c_W = 1/4,\ 1$$

2) see for each structure how the ratio can be reduced: 3 ways:

-the ratio can depend on the multiplet considered: can reduce n_γ/n_{CR} by a few

-the ratio can depend on the unknown CR amount produced by new particle

-the ratio can depend on the unknown value of vev of new scalar

can give very suppressed "F" cases

Classification of operators along the n_γ/n_{CR} ratio they give

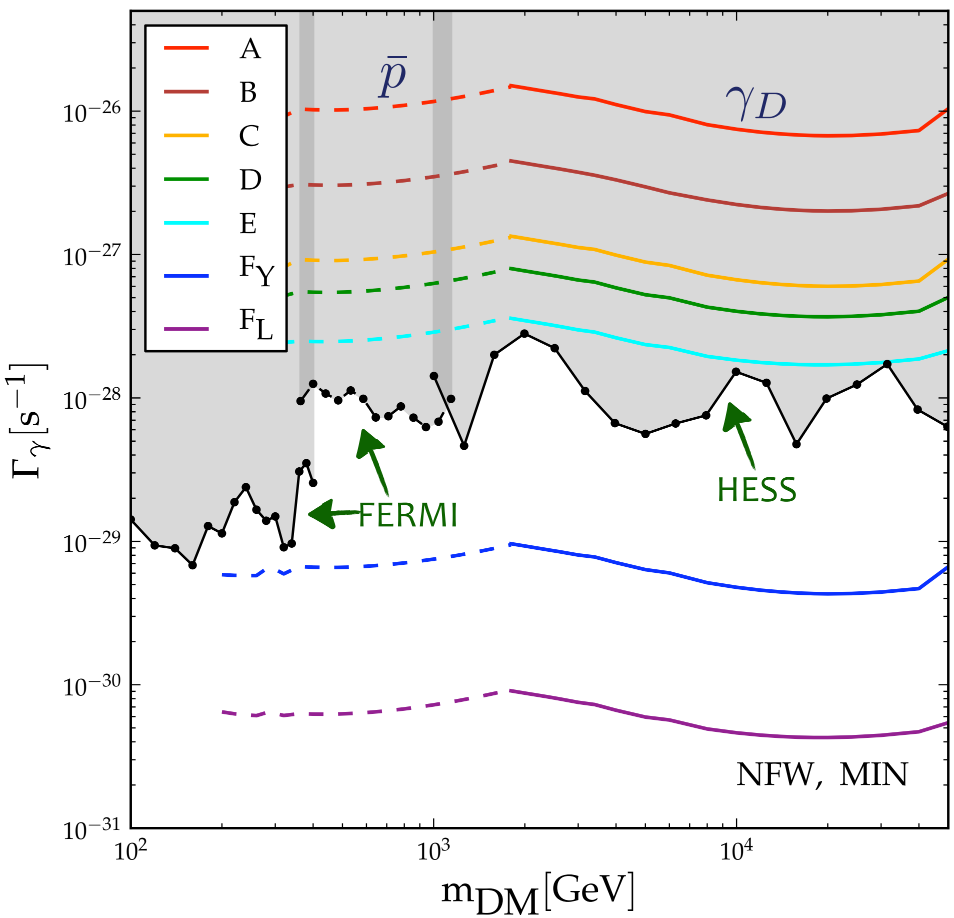
$$
\begin{array}{llll}
O^{(5)YY}_{\phi_{DM}} & \equiv \phi_{DM} F_{Y\mu\nu} F_Y^{\mu\nu} & \phi_{DM} = (1,0) & A \\
O^{(5)YL}_{\phi_{DM}} & \equiv \phi_{DM} F_{L\mu\nu} F_Y^{\mu\nu} & \phi_{DM} = (3,0) & B \\
O^{(5)LL}_{\phi_{DM}} & \equiv \phi_{DM} F_{L\mu\nu} F_L^{\mu\nu} & \phi_{DM} = (1/3/5,0) & D_m \\
O^{(5)YY'}_{\phi_{DM}} & \equiv \phi_{DM} F_{Y\mu\nu} F_{Y'}^{\mu\nu} & \phi_{DM} = (1,0) & A_x \\
O^{(5)LY'}_{\phi_{DM}} & \equiv \phi_{DM} F_{L\mu\nu} F_{Y'}^{\mu\nu} & \phi_{DM} = (3,0) & C_x \\
O^{(5)Y}_{\psi_{DM}} & \equiv \bar\psi \sigma_{\mu\nu} \psi_{DM} F_Y^{\mu\nu} & \psi_{DM}\cdot\psi = (1,0) & A_x \\
O^{(5)L}_{\psi_{DM}} & \equiv \bar\psi \sigma_{\mu\nu} \psi_{DM} F_L^{\mu\nu} & \psi_{DM}\cdot\psi = (3,0) & C_{x,m} \\
O^{(5)Y}_{V_{DM}} & \equiv F^{DM}_{\mu\nu} F_Y^{\mu\nu} \phi & \phi = (1,0) & A_x \\
O^{(5)L}_{V_{DM}} & \equiv F^{DM}_{\mu\nu} F_L^{\mu\nu} \phi & \phi = (3,0) & E_x
\end{array}
$$

“m” label: multiplet dependence,
“x” label: CR from new particle
“v” label: vev of new scalar dependence

$$
\begin{array}{llll}
O^{1YY}_{\phi_{DM}} & \equiv \phi_{DM} F_{Y\mu\nu} F_Y^{\mu\nu} \phi & \phi_{DM}\cdot\phi = (1,0) & A \\
O^{1YL}_{\phi_{DM}} & \equiv \phi_{DM} F_{L\mu\nu} F_Y^{\mu\nu} \phi & \phi_{DM}\cdot\phi = (3,0) & B \\
O^{1LL}_{\phi_{DM}} & \equiv \phi_{DM} F_{L\mu\nu} F_L^{\mu\nu} \phi & \phi_{DM}\cdot\phi = (1/3/5,0) & C_{x,m} \\
O^{1YY'}_{\phi_{DM}} & \equiv \phi_{DM} F_{Y\mu\nu} F_{Y'}^{\mu\nu} \phi & \phi_{DM}\cdot\phi = (1,0) & A_x \\
O^{1LY'}_{\phi_{DM}} & \equiv \phi_{DM} F_{L\mu\nu} F_{Y'}^{\mu\nu} \phi & \phi_{DM}\cdot\phi = (3,0) & C_x \\
O^{2Y}_{\phi_{DM}} & \equiv D_\mu \phi_{DM} D_\nu \phi F_Y^{\mu\nu} & \phi_{DM}\cdot\phi = (1,0) & A_{x,m,v} \\
O^{2L}_{\phi_{DM}} & \equiv D_\mu \phi_{DM} D_\nu \phi F_L^{\mu\nu} & \phi_{DM}\cdot\phi = (3,0) & C_{x,m,v} \\
O^{1Y}_{\psi_{DM}} & \equiv \bar\psi \sigma_{\mu\nu} \psi_{DM} F_Y^{\mu\nu} \phi & \bar\psi\cdot\psi_{DM}\cdot\phi = (1,0) & A_{x,m} \\
O^{1L}_{\psi_{DM}} & \equiv \bar\psi \sigma_{\mu\nu} \psi_{DM} F_L^{\mu\nu} \phi & \bar\psi\cdot\psi_{DM}\cdot\phi = (3,0) & C_{x,m} \\
O^{2Y}_{\psi_{DM}} & \equiv D_\mu \bar\psi \gamma_\nu \psi_{DM} F_Y^{\mu\nu} & \bar\psi\cdot\psi_{DM} = (1,0) & A_x \\
O^{2L}_{\psi_{DM}} & \equiv D_\mu \bar\psi \gamma_\nu \psi_{DM} F_L^{\mu\nu} & \bar\psi\cdot\psi_{DM} = (3,0) & C_{x,m} \\
O^{3Y}_{\psi_{DM}} & \equiv \bar\psi \gamma_\mu D_\nu \psi_{DM} F_Y^{\mu\nu} & \bar\psi\cdot\psi_{DM} = (1,0) & A_x \\
O^{3L}_{\psi_{DM}} & \equiv \bar\psi \gamma_\mu D_\nu \psi_{DM} F_L^{\mu\nu} & \bar\psi\cdot\psi_{DM} = (3,0) & C_{x,m} \\
O^{1}_{V_{DM}} & \equiv F^{DM}_{\mu\nu} F_Y^{\mu\rho} F^{\nu}_{Y'\rho} & & A_x \\
O^{2Y}_{V_{DM}} & \equiv F^{DM}_{\mu\nu} F_Y^{\mu\nu} \phi\phi' & \phi\cdot\phi' = (1,0) & A_x \\
O^{2L}_{V_{DM}} & \equiv F^{DM}_{\mu\nu} F_L^{\mu\nu} \phi\phi' & \phi\cdot\phi' = (3,0) & D_{x,m} \\
O^{3YY'}_{V_{DM}} & \equiv D^{DM}_\mu \phi D^{DM}_\nu \phi' F_Y^{\mu\nu} & \phi\cdot\phi' = (1,0) & A_{x,m} \\
O^{3LY'}_{V_{DM}} & \equiv D^{DM}_\mu \phi D^{DM}_\nu \phi' F_L^{\mu\nu} & \phi\cdot\phi' = (3,0) & D_{x,m}.
\end{array}
$$

Upper bound on γ-line intensity

the most stringent constraints are from $\bar{p}$ below ~TeV
from γ_D above ~TeV



$\bar{p}$ constraint with MIN setup

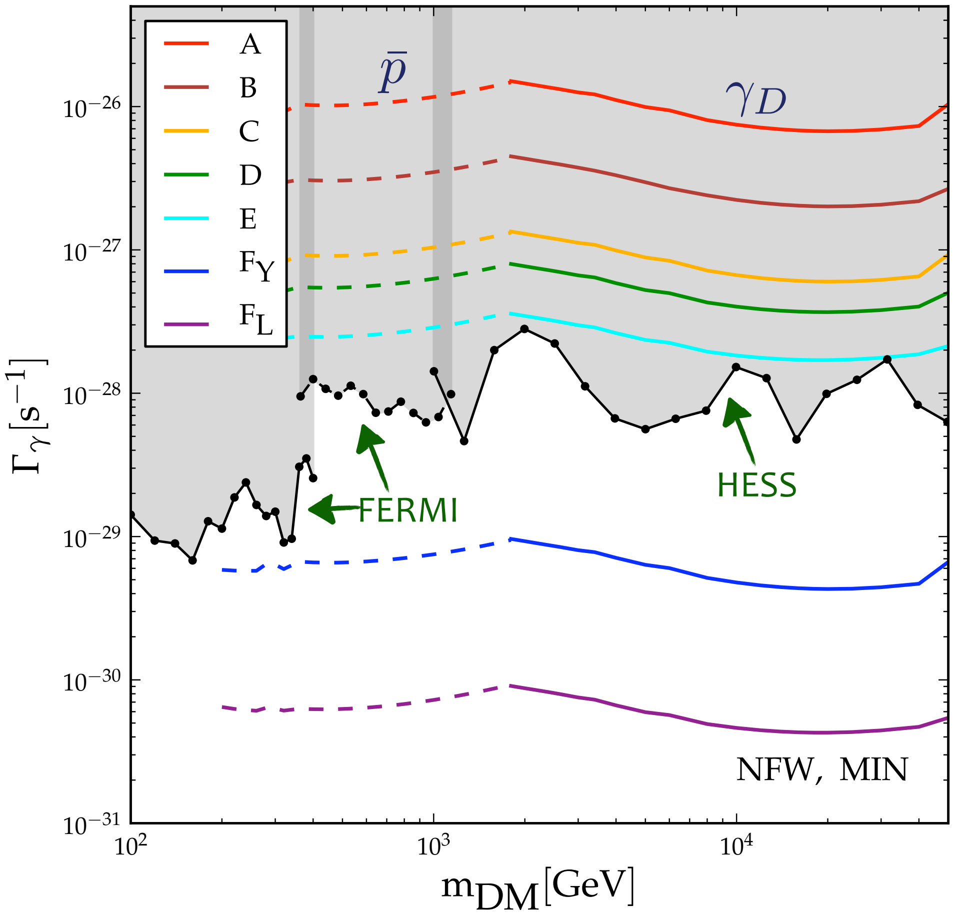
⟹ bounds from CR relatively close to direct search bounds

less stringent for A and B by 1-2 orders of magnitudes

less stringent for C, D, E cases by a factor of a few

Upper bound on γ-line intensity

the most stringent constraint are from $\bar{p}$ below ~TeV
from γ_D above ~TeV



$\bar{p}$ constraint with MIN setup

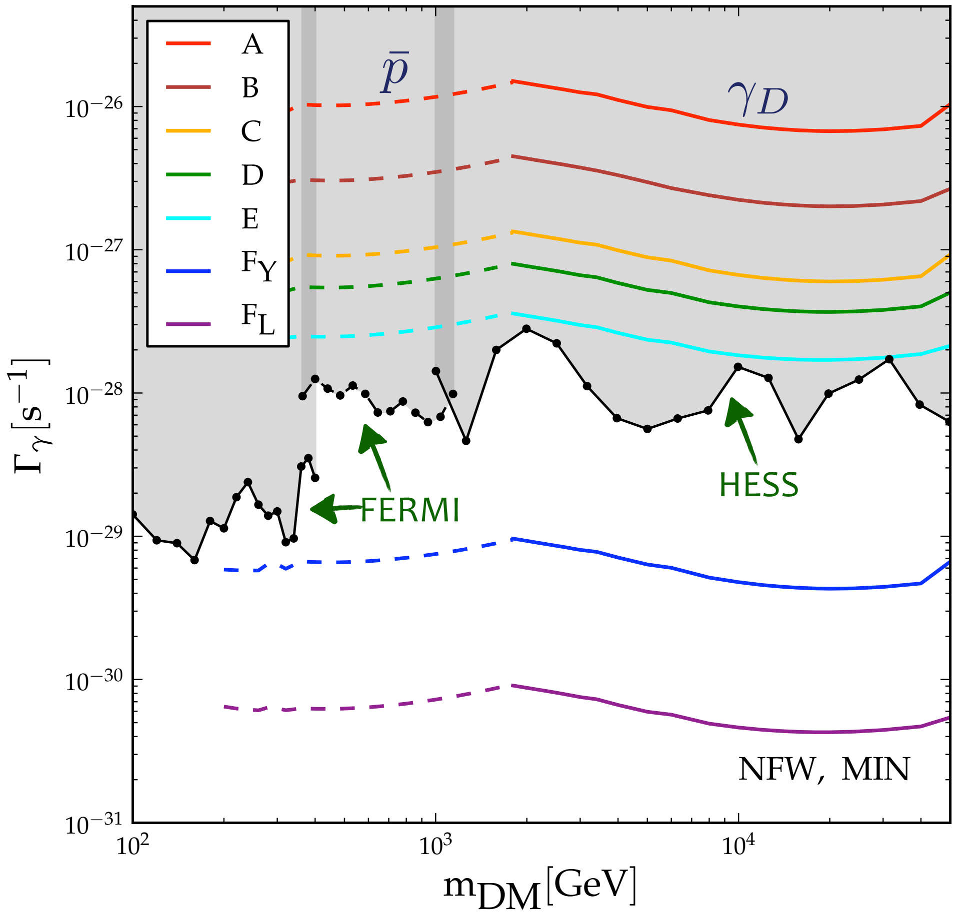
if a γ-line is found around the corner: A->E are possible

for C->E this would imply associated CR flux excess around the corner

conversely observation of CR excess around the corner not compatible with A, B

Upper bound on γ-line intensity

the most stringent constraint are from $\bar{p}$ below ~TeV
from γ_D above ~TeV



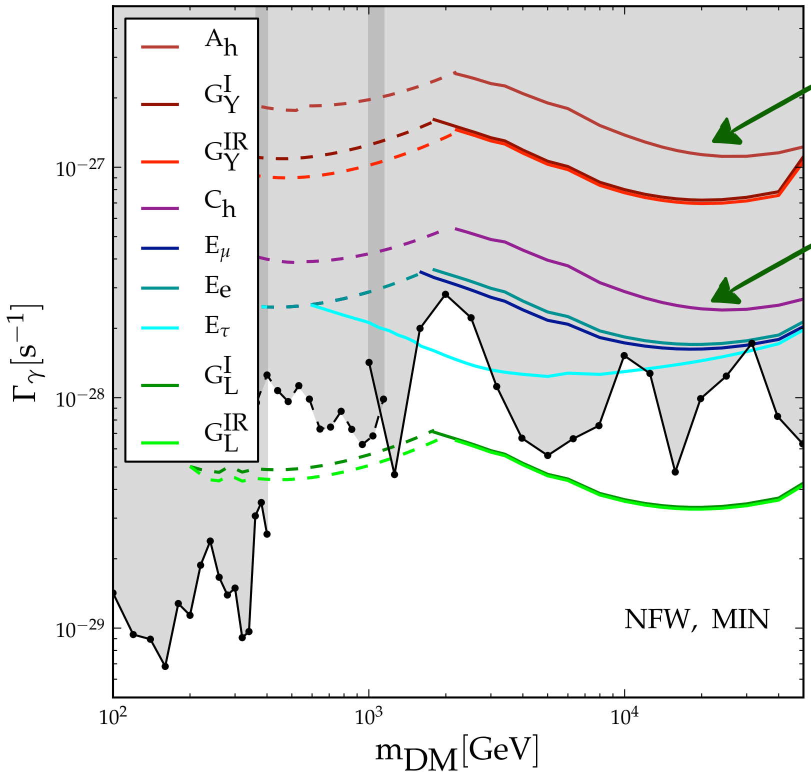
$\bar{p}$ constraint with MIN setup

future: - better knowledge of CR flux would lower A-E lines by up to one order of magnitude

example: if MED instead of MIN: C->E go below direct constraint

- CTA, HESS-2,...: direct search improvement by ~1 order of magnitude

Upper bound on γ-line intensity for operators with only SM and DM fields



$\gamma + h$ (with $F_Y^{\mu\nu}$)

$\gamma + h$ (with $F_L^{\mu\nu}$)

What if UV physics generates several operators in correlated way?

in most situations it marginally changes the CR constraints

example: $\mathcal{L} \ni \frac{a}{\Lambda_{UV}^2}\phi_{DM}\phi F_{Y\mu\nu}F_Y^{\mu\nu} + \frac{b}{\Lambda_{UV}^2}\phi_{DM}\phi F_{Y\mu\nu}F_L^{\mu\nu} + \frac{c}{\Lambda_{UV}^2}\phi_{DM}\phi F_{L\mu\nu}F_L^{\mu\nu}$

to reduce CR emission one needs to suppress several channels: $\gamma Z,\ ZZ,\ W^+W^-, \ldots$

impossible or at the price of several fine-tunings

An explicit example of accidental symmetry setup: hidden vector DM

if DM is a massive gauge boson, abelian or non abelian

TH 08'; TH, Tytgat 09'
Arina, TH, Ibarra, Weniger 10'

$\Downarrow$

"Hidden vector": accidental custodial symmetry

$\Downarrow$

a gauged SU(2) + SSB from a scalar doublet ϕ

$$\mathcal{L} = -\frac{1}{4}F^{\mu\nu a}F^{a}_{\mu\nu} + (D^\mu\phi)^\dagger(D_\mu\phi) - \mu_\phi^2\phi^\dagger\phi - \lambda_\phi(\phi^\dagger\phi)^2$$

$\Downarrow$ ϕ gets a vev v_ϕ

3 massive gauge bosons V_i + a real scalar η

$$m_V = \frac{g_\phi v_\phi}{2}$$
$$m_\eta = \sqrt{2\lambda_\phi}\, v_\phi$$

stable due to residual SU(2) custodial sym.

$V_i \to \eta\eta, \ldots$ forbidden:

$(V_1^\mu, V_2^\mu, V_3^\mu) =$ triplet

$\eta =$ singlet

+ communication with the SM through Higgs portal: $\mathcal{L}_{Higgs\,portal} = -\lambda_m \phi^\dagger\phi H^\dagger H$

relic density, direct detection, ...

Intense γ-lines from accidental custodial symmetry

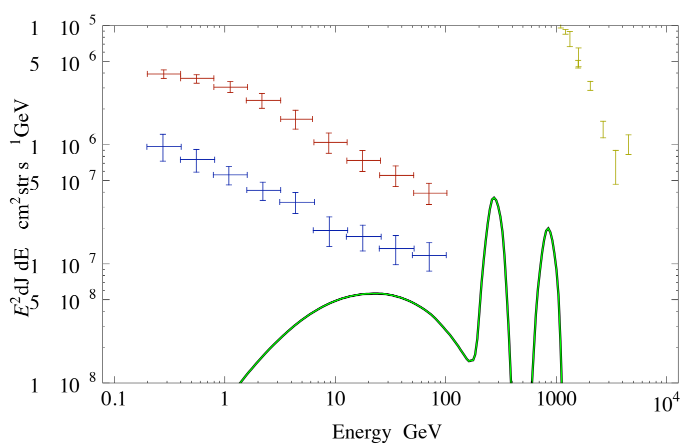
Hidden vector: no reason that the custodial sym. not violated in the UV $\Rightarrow$ only 2 possible dim 6 operators:

$$(I)\ \ \frac{1}{\Lambda^2} D_\mu \phi^\dagger D_\nu \phi F^{Y\,\mu\nu}$$

$$(II)\ \ \frac{1}{\Lambda^2} F^a_{\mu\nu} \frac{\tau^a}{2} \phi\, F^{Y\,\mu\nu}$$

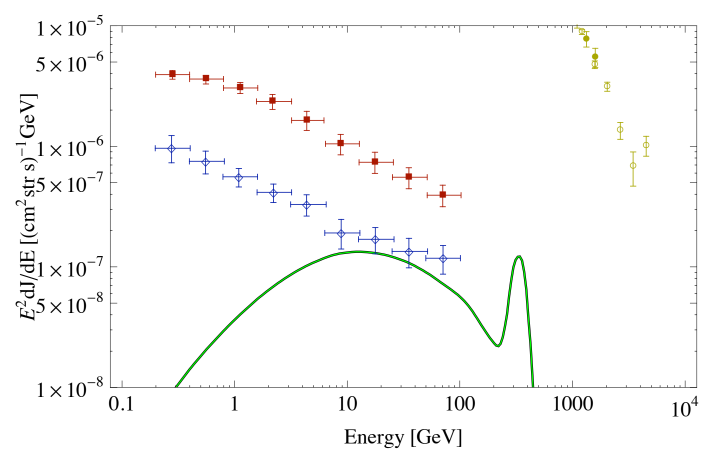
operator I

$m_{DM} = 1.5\,\mathrm{TeV}\ \ \Lambda = 1.2 \cdot 10^{16}\,\mathrm{GeV}$



operator II

$m_{DM} = 600\,\mathrm{GeV}\ \Lambda = 1.5 \cdot 10^{16}\,\mathrm{GeV}$



C. Arina, T.H., A. Ibarra, C. Weniger 10'

Summary

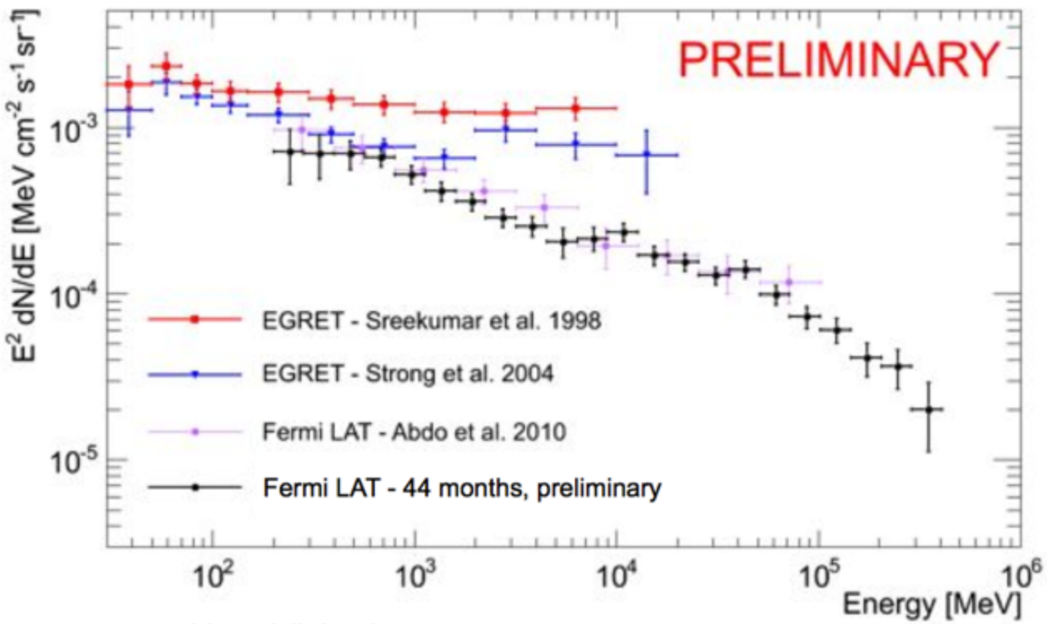
A systematic study of γ-line production and associated multichannel CR production can be done in principle and in practice for a DM decay:

- use of effective theory fully justified
- not too many operator structures

→ bounds from basically unavoidable CR emission are in most cases slightly less stringent than direct γ-line search bounds

→ real possibilities of operator discrimination do exist:

- observing both a γ-line and associated CR's
- from number, energy and intensity of γ-lines



FERMI: bound on decay lifetime to gamma line