

"RENCONTRE DE PHYSIQUE DE PARTICULES"
(RPP) 2016, Annecy

"Global Constraints on vector-like
WIMP effectives interactions "

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LAPTH

work based on 1509.01587, in collab. with

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MOTIVATION (I)

- What is the global status of WIMP searches?
- Different experiments sensitive to different masses, channels, etc
- Can one be model-independent?

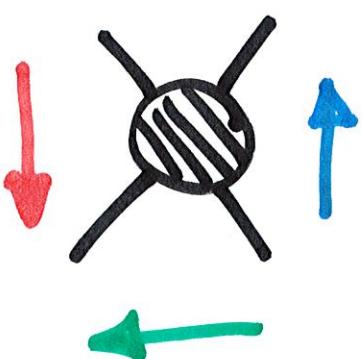
General ↑
↓ Useful

Compromis : Effective Field Theory

MOTIVATION (II)

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- We all know this :



Simple, handy, etc
but usually strong simplifications

- collider

$$\left(\frac{1}{M_*^2}\right) (\bar{\chi} \gamma^\mu \chi) (\bar{f} \gamma_\mu f)$$

universal
coupling

- Indirect Detection

$$\bar{\chi} \chi \rightarrow \bar{f} f$$

$$(Br^f = 1)$$

Direct Detection

$$\sigma_{\text{proton}} = \sigma_{\text{neutron}} = \sigma_n$$

WHAT IF WE WANT TO BE

MORE GENERAL ?

- e.g. assuming no coupling structure
 \Rightarrow 15 free couplings to SM fermions

For definiteness:

$$f_{\text{eff}} = (\bar{\chi} \gamma^\mu \chi) j_\mu^{\text{eff}}$$

$$\begin{aligned} j_\mu^{\text{eff}} &= \sum_i c_{iL} (\bar{\nu}_{iL} \bar{\ell}_L) \gamma_\mu \left(\begin{array}{c} \nu_{iL} \\ \ell_L \end{array} \right) \} \text{ leptons (LH)} \\ &+ \sum_i c_{ei} (\bar{u}_{iL} \bar{d}_{iL}) \gamma_\mu \left(\begin{array}{c} u_{iL} \\ d_{iL} \end{array} \right) \} \text{ quarks (LH)} \end{aligned}$$

$$+ \sum_F c_{FR} f_R \gamma_\mu f_R$$

$\} \text{ all (RH)}$

ANALYSIS

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$$\chi^2(c, m_\chi) = \sum_i \chi_i^2(c, m_\chi)$$

ϵ : different
observables

- Relic abundance

$$\chi_{\text{ab}}^2(c, m_\chi) = \left(\frac{\Omega_{\text{th}}(c, m_\chi) - \Omega_{\text{exp}}}{\sigma_{\text{ab}}} \right)^2$$

- Positron fraction

$$\chi_{\text{AMS}}^2(c, m_\chi) = \sum_j^{\text{bins}} \left(\frac{F_j(c, m_\chi) - F_j^{\text{exp}}}{\sigma_j} \right)^2$$

- Dwarf galaxies

$$\chi_{\text{dSph}}^2(c, m_\chi) = \frac{\langle \sigma v \rangle^{\text{th}}(c, m_\chi)}{\langle \sigma v \rangle^{\text{exp}}}$$

- CMB

$$\chi_{\text{CMB}}^2(c, m_\chi) = \left(\frac{P_{\text{ann}}^{\text{th}}(c, m_\chi)}{P_{\text{ann}}^{\text{exp}}} \right)^2$$

- LHC

$$\chi_{\text{LHC}}^2 = \left(\frac{(C_{\text{LHC}}^{\text{th}})^2}{(C_{\text{LHC}}^{\text{exp}})^2} \right)^2$$

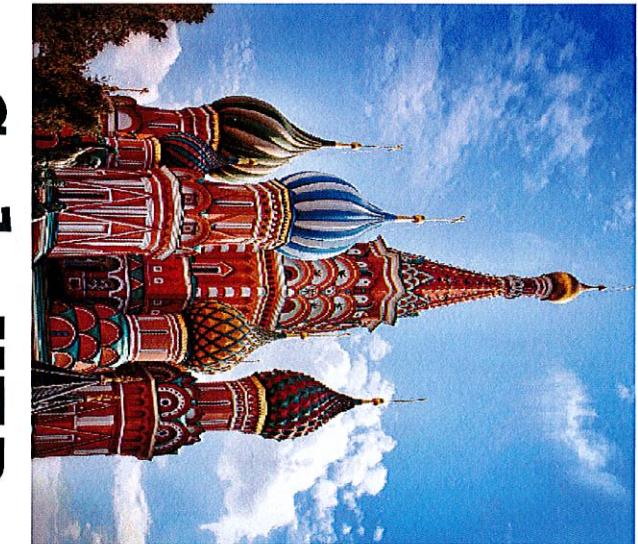
Altogether...



... like a Cuban
Dish !!

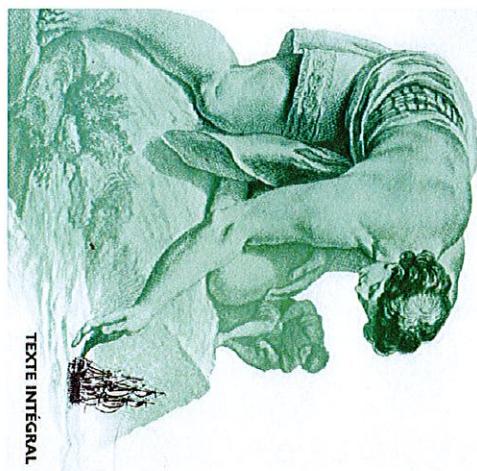
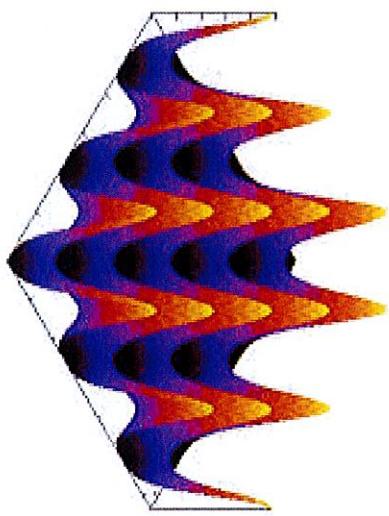
TOOLS

FeynRules



calCHEP

Multinest



TEXTE INTÉGRAL

ÉTONNANTS • CLASSIQUES

Micromégas

Voltaire

ABOUT RELIC ABUNDANCE

$$\sum_i \chi \begin{array}{c} \diagup \\ \diagdown \end{array} f_i \quad \left\} \langle \sigma v \rangle = \sum_i w_i \langle \sigma v \rangle_i \propto m_\chi^2 \sum_c^2 \right.$$

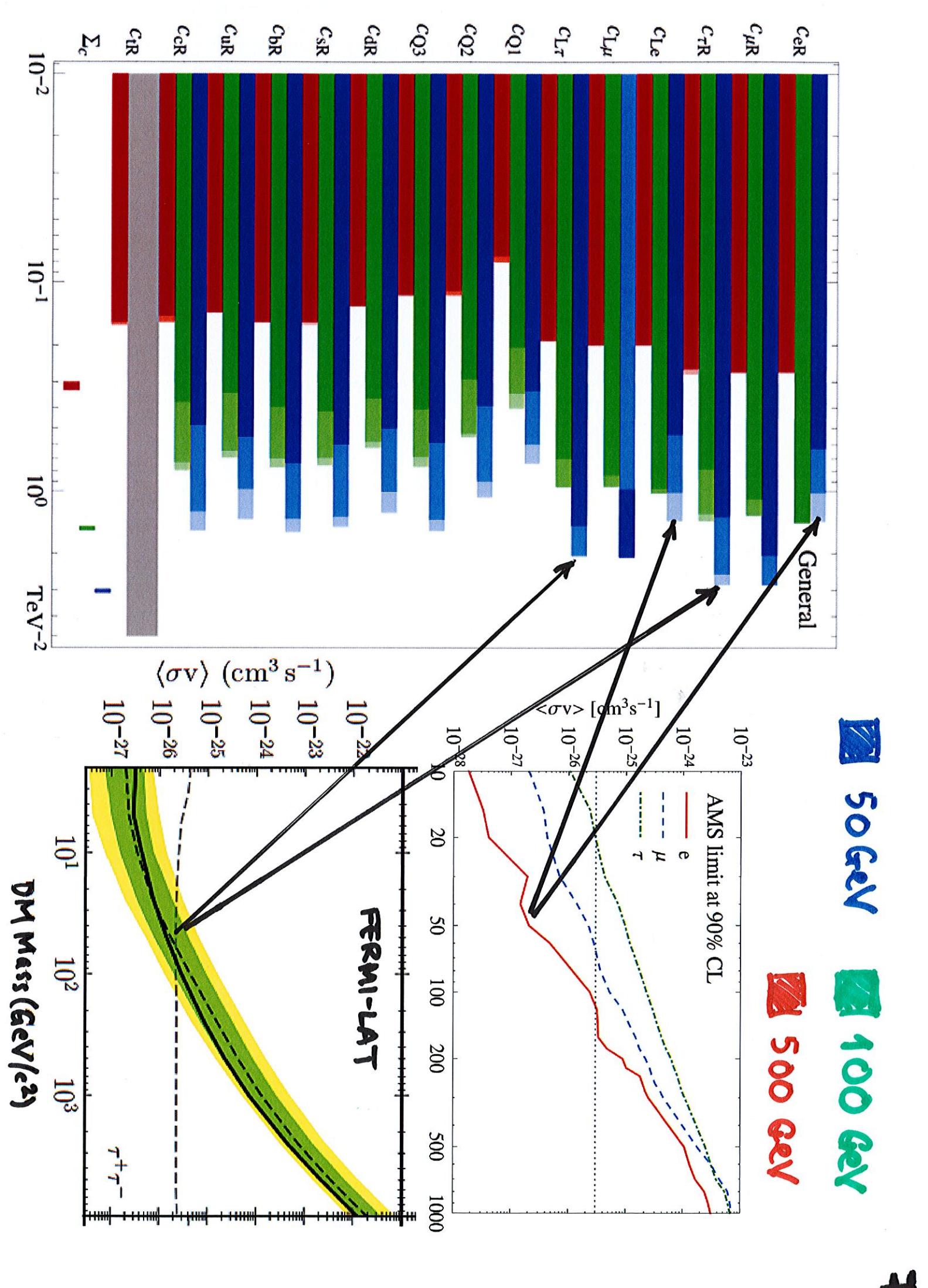
$$\Sigma_c \equiv \sqrt{\sum_i w_i c_i^2}$$

- we assume thermal relic at 100%

The larger the DM mass, the smaller
the couplings should be

- At least one coupling should be non-zero

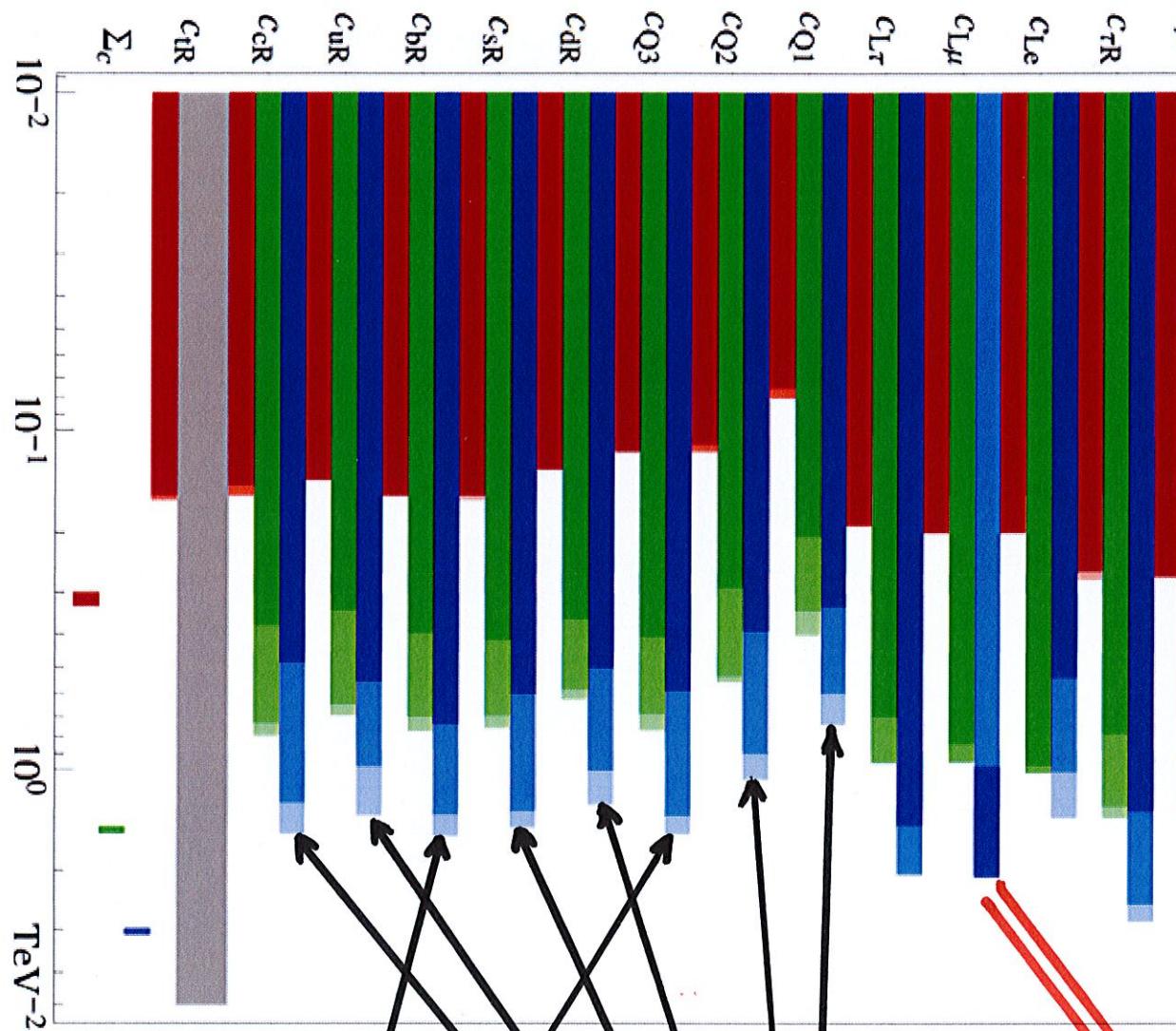
Results



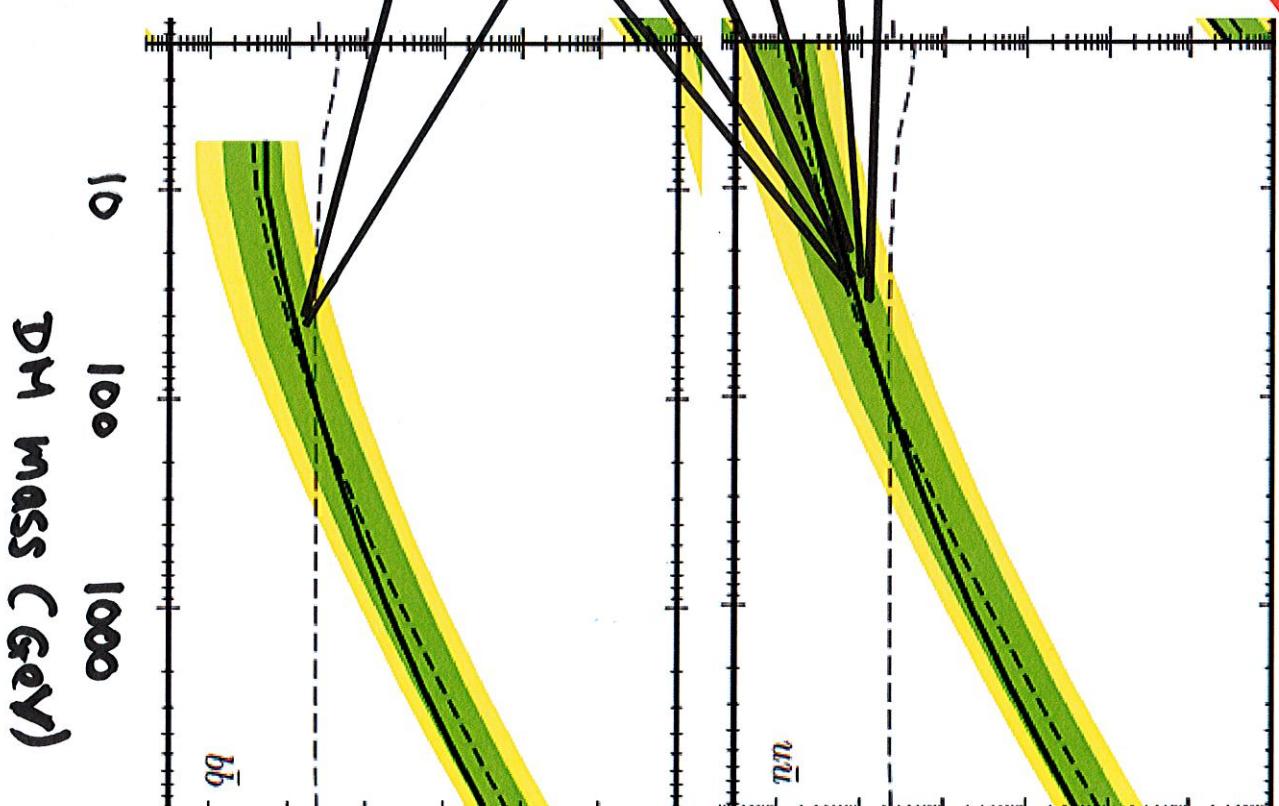
RELIC ABUNDANCE !

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c_{eR}
 $c_{\mu R}$
 $c_{\tau R}$
 $c_{L e}$
 $c_{L \mu}$
 $c_{L \tau}$
General



FERMI-LAT



$\langle \sigma v \rangle$

A WORD ABOUT DIRECT DETECTION

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- Our setup leads to Spin-Independent scattering

DM-nucleon coupling:

$$C_N = \frac{1}{2A} [3AC_{Q_1} + (A+2)C_{u_R} + (2A-2)C_{d_R}]$$

Degeneracy: $2c_{Q_1} + c_{u_R} + c_{d_R} \approx 0 \quad \{ z \approx A/2$

LUX

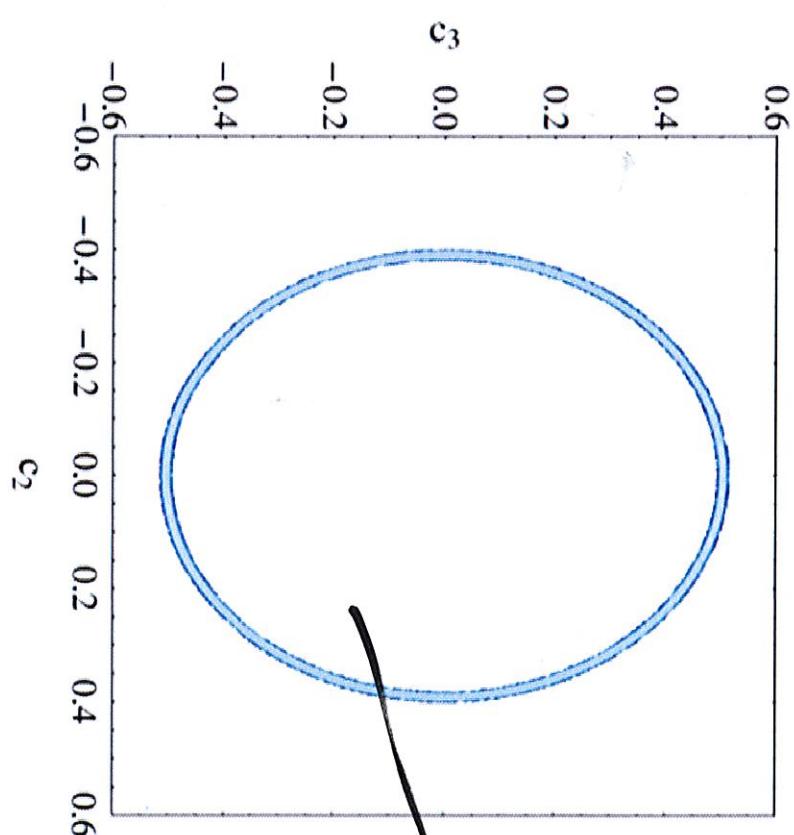
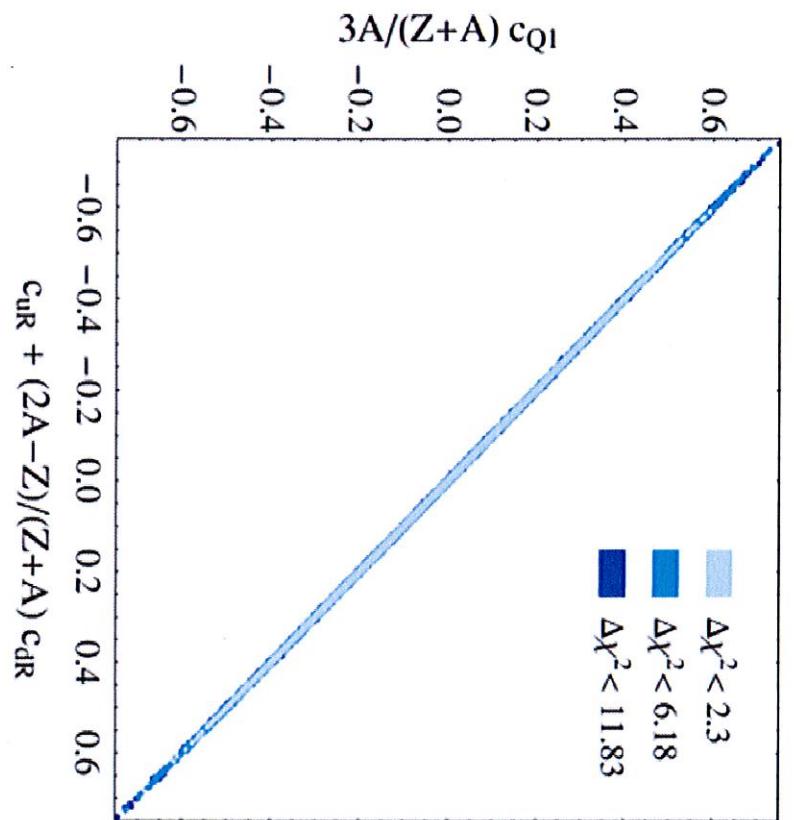


EDELWEISS



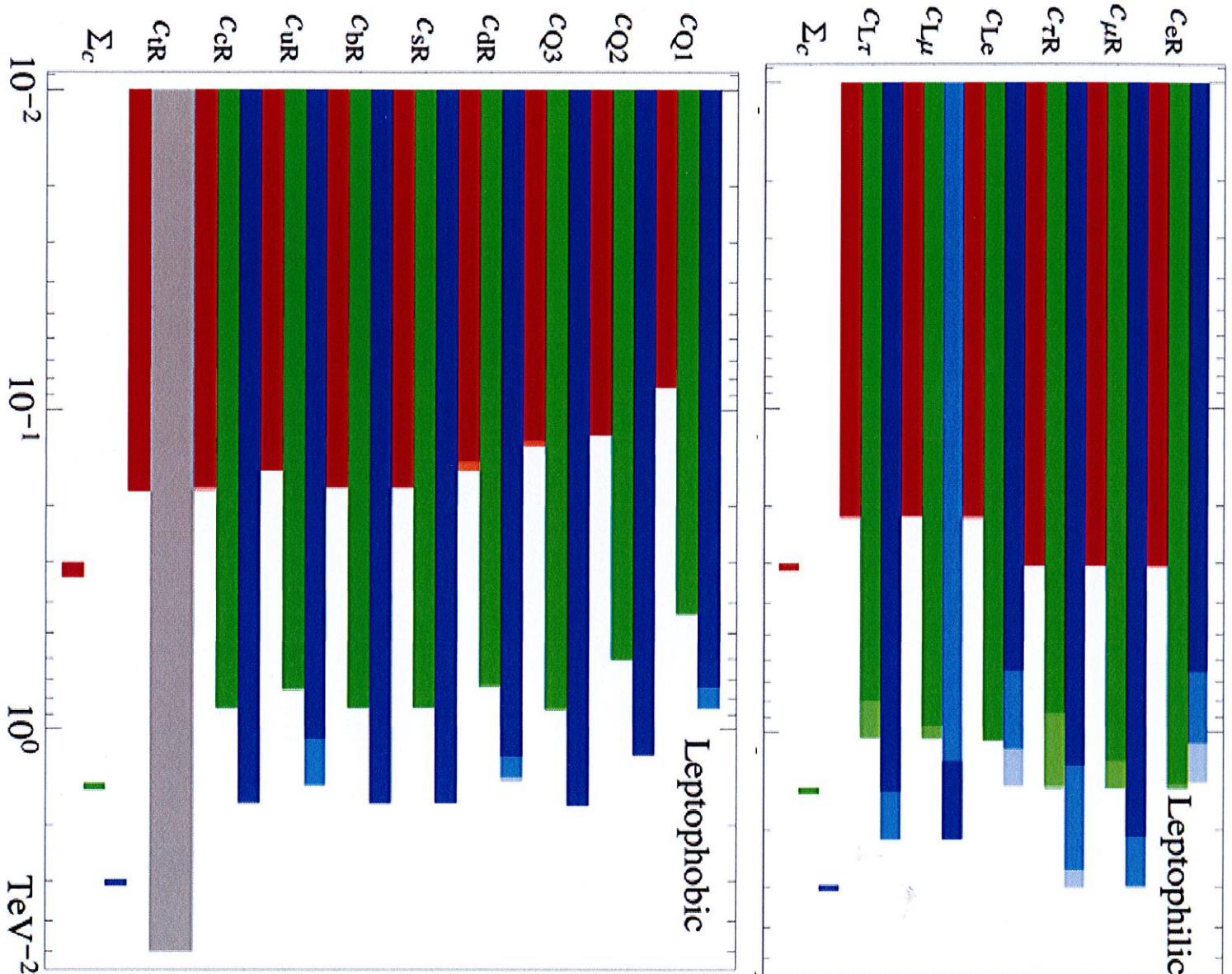
DD Degeneracies

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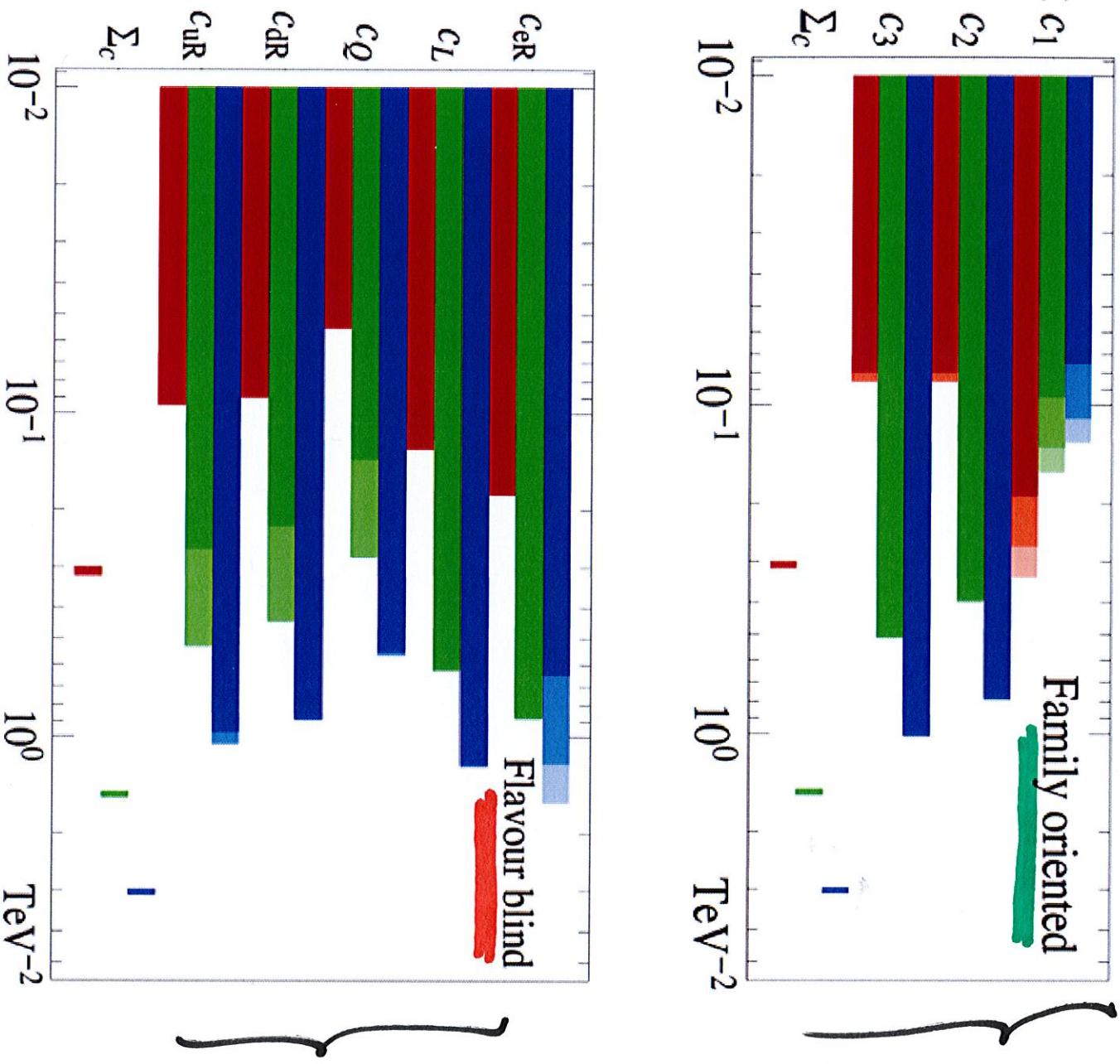
- All the points of the mcmc so inside this region

WHAT ABOUT OTHER SETUPS,
LESS GENERAL THAN "GENERAL"?

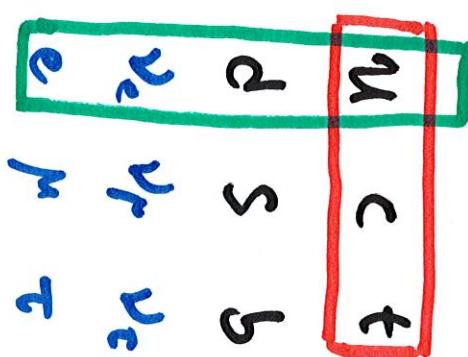


More constrained
couplings to quarks
(not good but
at 50 GeV)

Similar to "general
model":
you can hide in the
mu channel



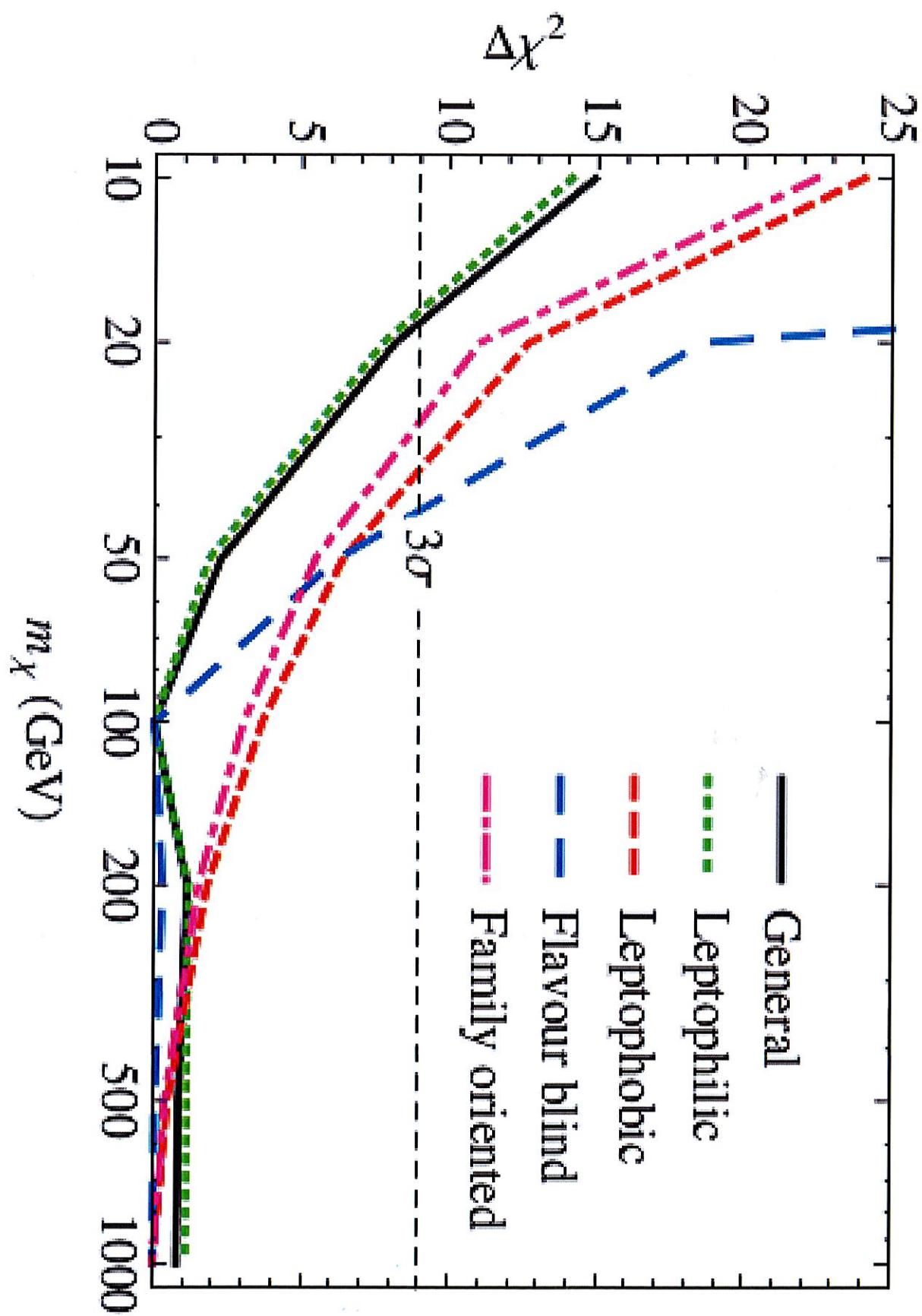
Coupling to muons
correlated with 2nd
generation quarks



coupling to muons
unrelated with electrons
and taus

we expect stronger
constraints than for
general model

Money plot



Conclusions

- Cooking a dish with a lot of ingredients at the same time is risky, but may be worthy
- We have developed a tool being
 - [Hierarchies] + [Exp. results]
 - Multinest \Rightarrow Global Exclusion
- General model like
$$J = (\bar{\chi} \gamma^\mu \chi) j_\mu^{\text{eff}} \quad (j_\mu^{\text{eff}}: \text{SM fermions})$$

excluded for $m_\chi \lesssim 20 \text{ GeV}$
- Couplings to 2nd generation LH leptons are the less constrained from all experiments
- Masses below 30–40 GeV excluded if correlation exists

~~Thanks~~

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