

A volte ritornano

Buon Pomeriggio

Federica Mescia



Frascati, July 9th, 2024

A volte ritornano

Buon Pomeriggio

Federica Mescia

- **Mi presento:** _____

❖ 2007 - Art.23 @ **LNf**

❖ 2009 - RTDB (Ramón y Cajal) @ **UB**

❖ 2013 - Prof. Associato

❖ 2019 - Prof. Ordinario @ **UB**

❖ 2024 - Chiamata diretta @ **LNf** 



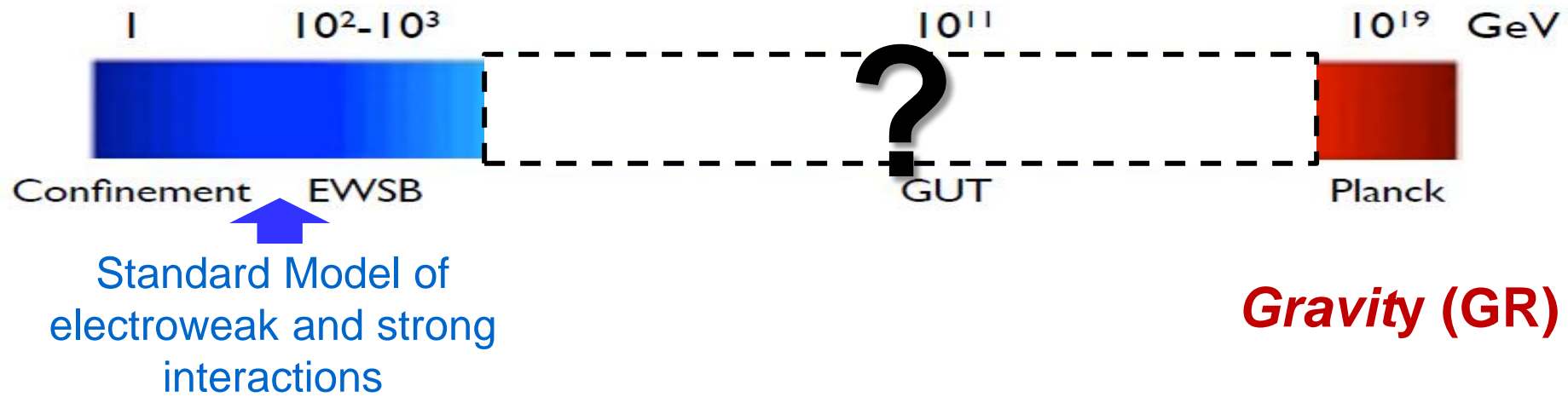
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Eh mo' che?

Federica Mescia

*“Establishing Physics Beyond the
Standard Model in the light of Data”*

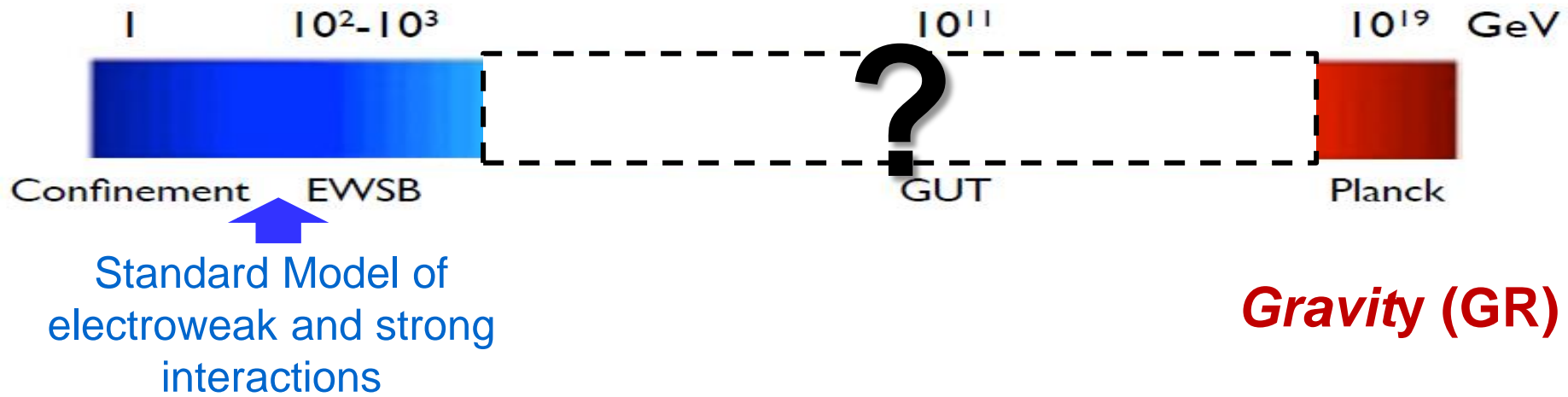
Beyond Standard Model: Why?



TWO UNEXPLAINED EXPERIMENTAL EVIDENCES in the SM

1. *Baryon – Antibaryon Asymmetry*
2. *Dark Matter*

Beyond Standard Model: Why?

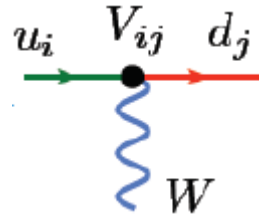


TWO UNEXPLAINED EXPERIMENTAL EVIDENCES in the SM

1. *Baryon – Antibaryon Asymmetry* \Rightarrow **Violation of CP required!**

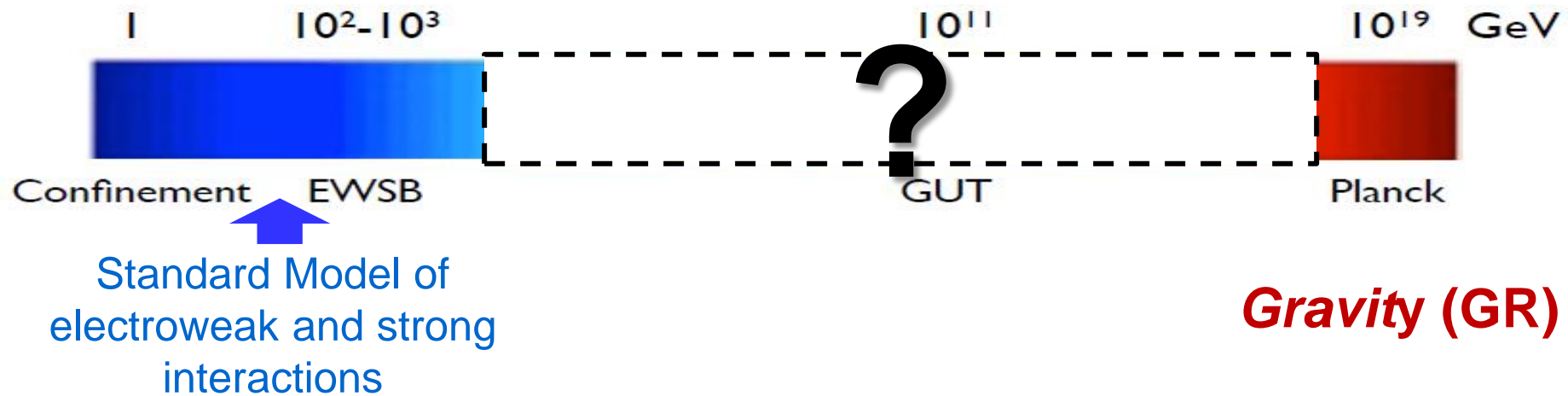
2. *Dark Matter*

In the SM, weak interactions violate CP but not enough!



\rightarrow **New (heavy or light) particles carrying CPV.**

Beyond Standard Model: Why?



TWO UNEXPLAINED EXPERIMENTAL EVIDENCES in the SM

1. *Baryon – Antibaryon Asymmetry*

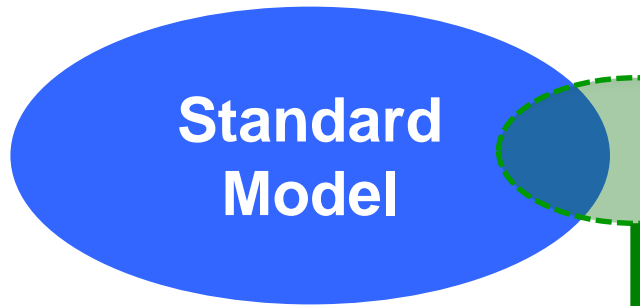
2. *Dark Matter*



The SM does not host a particle candidate for DM.

→ A new particle as DM.

Beyond Standard Model: yes, but how?



extra fermions?

extra bosons?

how?

Bottom-up approach



1. Why 3 flavours in the SM?

CPV in $K_L \rightarrow 2\pi$
from 3rd family (top loops)



LNF
First love

2. Why not CPV in QCD?

Axion hypothesis and
(light) DM candidate



next love

$$\mathcal{L}_{CPV}^{QCD} = \mathcal{L}^{QCD} + \bar{\theta} \frac{\alpha_s}{8\pi} G_a^{\mu\nu} G_{a,\mu\nu}$$

☐ *My research priorities (2024)*

1. Axion physics (G. Landini (UV) and PD)

2. Theory support to the FLASH proposal
(with RM1-laureando, U. Sofia, G. Grilli di C.)

3. DM vs Flavour Physics: **post anomaly era** ☹️
(with KEK, Phd student@UB)

4. DM@collider (LHC, FCC)
(with Pisa, RM3, RM1-laureanda)

Daily physics discussions: Antonellis, Babusci,
Bloise, Gatti, Giovanella, Miscetti, Palutan,
Rotondo, Spadaro, Sciascia (**Lavoro in sede**)



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Axion Theory?

- **Axion** → pNGB of spontaneously broken U(1) with QCD **anomaly**

$$\frac{\theta}{f_a} \frac{\alpha_s}{8\pi} GG \rightarrow \frac{a}{f_a} \frac{\alpha_s}{8\pi} GG + C_\gamma \frac{a}{f_a} \frac{\alpha}{8\pi} F_{\mu\nu} F^{\mu\nu} + C_f \frac{\partial_\mu a}{f_a} \bar{f} \gamma^\mu \gamma_5 f$$

$$\varphi = (f_a + \rho) e^{ia/f_a}$$

$U(1)_{PQ}$

The lighter the axion, the weaker are its interactions!



BUT the PQ solution suffers from some TH issues

- Which is the origin of U(1)? U(1) is broken, why not ϕ , ϕ^2 , ϕ^3 ?
- Quantum Gravity is in odds with global symmetries

U(1) must be an extremely good symmetry up to the Planck scale

Peccei Quinn Quality Problem: UV completion of axion needed!

Solution to the PQ quality problem: PQ and Flavor?

→ The PQ symmetry arises **accidentally** at low-energy **by a new gauge symmetries, G ?**

NOW, if SM quarks are charged under G ,
 G is a flavor symmetry



Project Goal: determining G and its breaking pattern
such as



- (i) to predict an accidental U(1) symmetry **origin of PQ** 😊
- (ii) to protect the U(1) symmetry from UV-breaking sources **PQ quality** 😊
- (iii) to reproduce the fermion masses/mixing of the SM **Flavor as gift**

Solution to the PQ quality problem: Pati-Salam and Flavor?

Pati-Salam with gauged $SU(3)_R$ flavor

	$SU(4)_c$	$SU(2)_L$	$SU(2)_R$	$SU(3)_R$	Generations	$U(1)_{PQ}$
Q_L	4	2	1	1	3	+3/2
Q_R	4	1	2	3	1	+1/2
Ψ_R	1	1	1	$\bar{3}$	8	check!
Φ	1	2	2	$\bar{3}$	≥ 1	+1
Σ	15	2	2	$\bar{3}$	≥ 2	+1
Δ_R	10	1	3	3	1	+1
χ_R	4	1	2	$\bar{3}$	1	-1/2

G. Landini & PD on-going project

- A suitable model with Pati-Salam vertical symmetry and $SU(3)_R$ for horizontal (flavour) symmetry has been found! 😊
- The PQ symmetry arises accidentally and highly protected!

Solution to the PQ quality problem: Pati-Salam and Flavor?

Pati-Salam with gauged $SU(3)_R$ flavor

	$SU(4)_c$	$SU(2)_L$	$SU(2)_R$	$SU(3)_R$	Generations	$U(1)_{PQ}$
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G. Landini & PD on-going project

- Gauge anomalies successfully cancelled out, but extra fields needed to cancel the $SU(3)_R$ anomalies
- Now time for a rich phenomenology: Dark Matter? Dark radiation? Flavor puzzle

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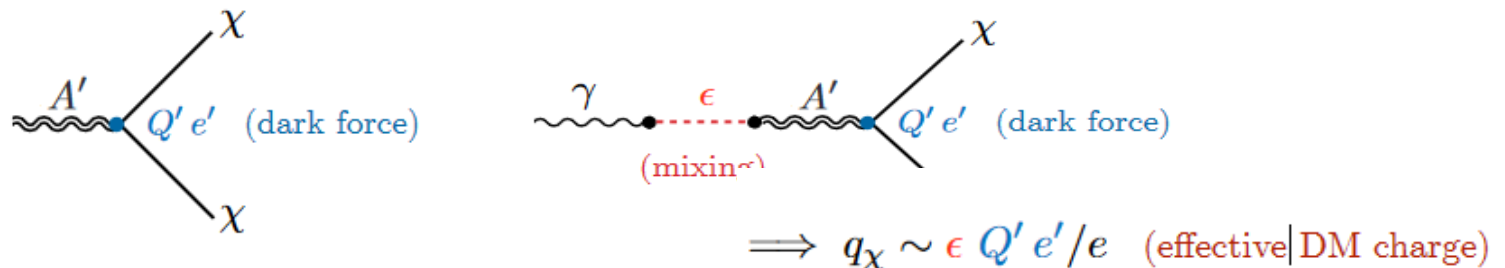
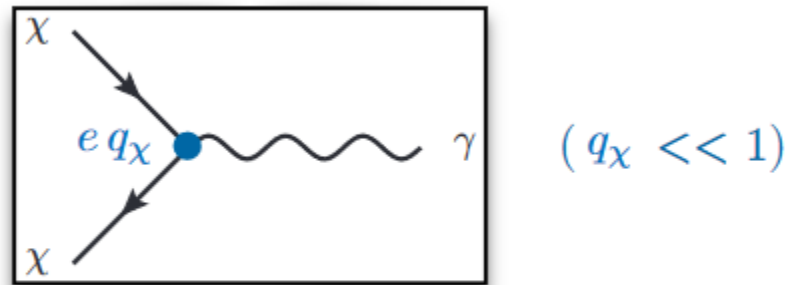
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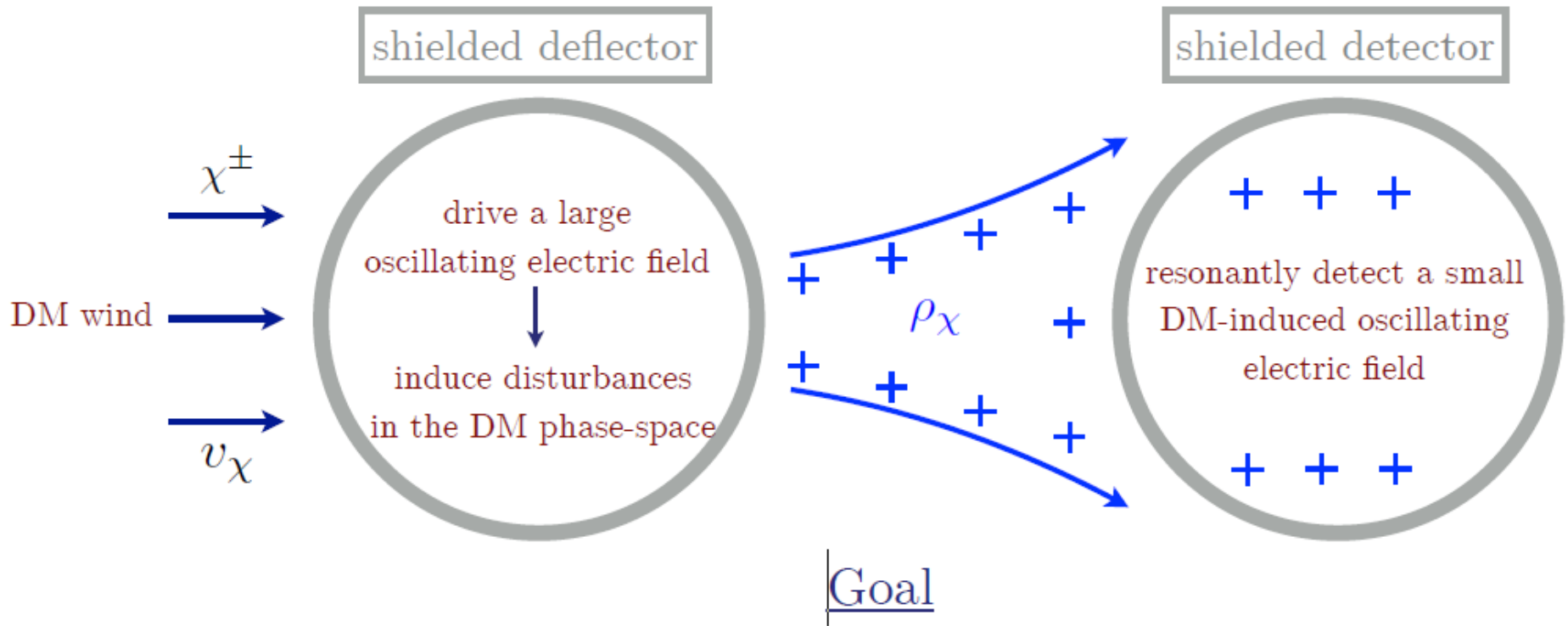
Millicharged DM

The visible universe is governed by a rich spectrum of forces and particles.

Generic to expect that dark matter couples to new long-ranged forces.



Millicharged DM deflected by “Electric field”



Induce and measure disturbances of the dark matter “fluid,”

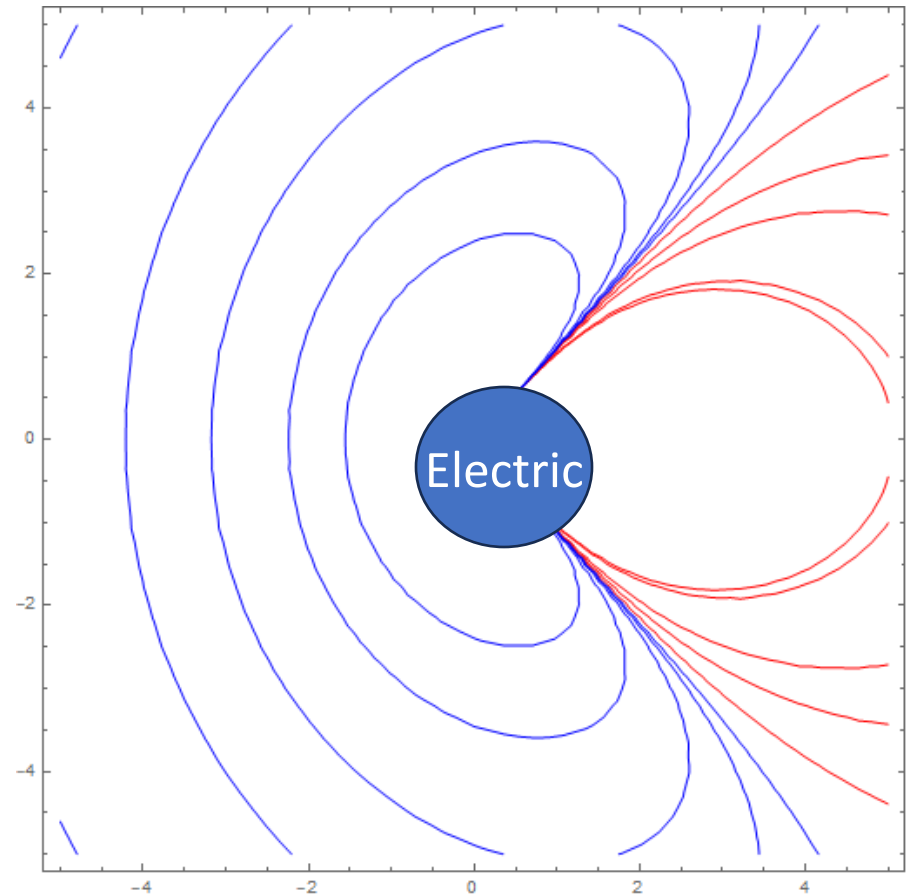
A. Berlin, R. T. D'Agnolo, S. A. R. Ellis, P. Schuster and N. Toro,
“Directly Deflecting Particle Dark Matter,” Phys. Rev. Lett. 124 19.

Millicharged DM deflected by “Electric field”

- ❑ Tool (python/root) to simulate the deflection and detection phases

**G. Grilli di Cortona, F. La Valle
(RM1 laureando) & M.Navydenov,**

- ❑ Tool tested for spherical electric field
- ❑ Tool ready for more realistic setup (discussing with D. Alesini per la configurazione finale)

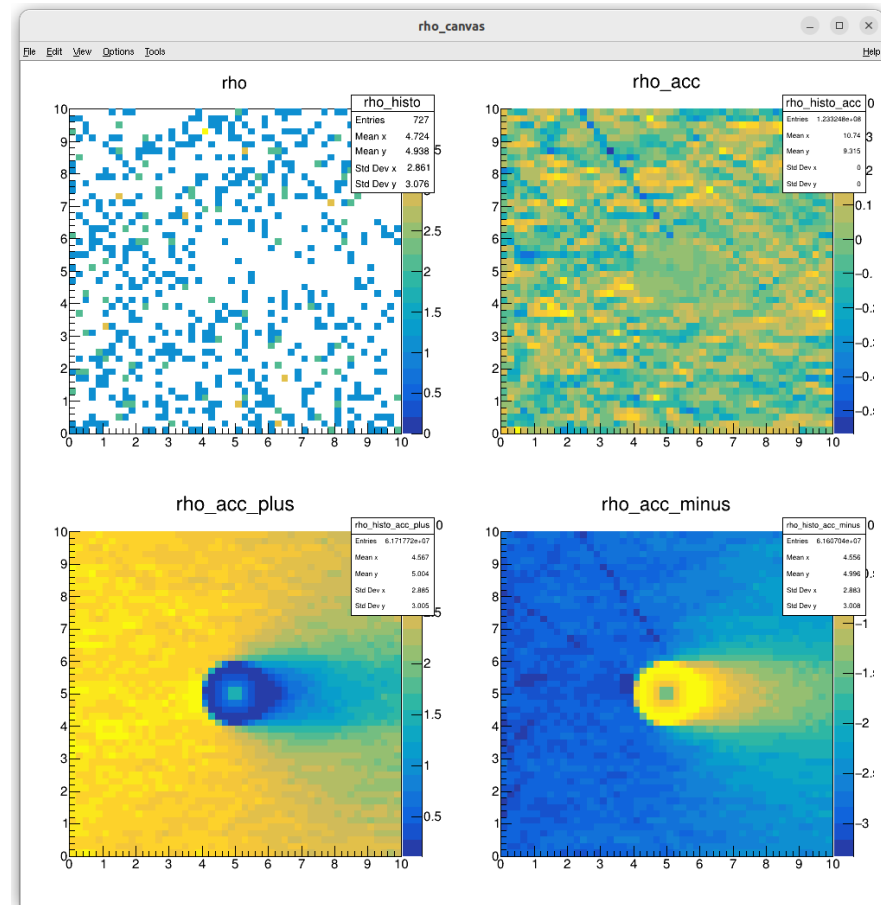


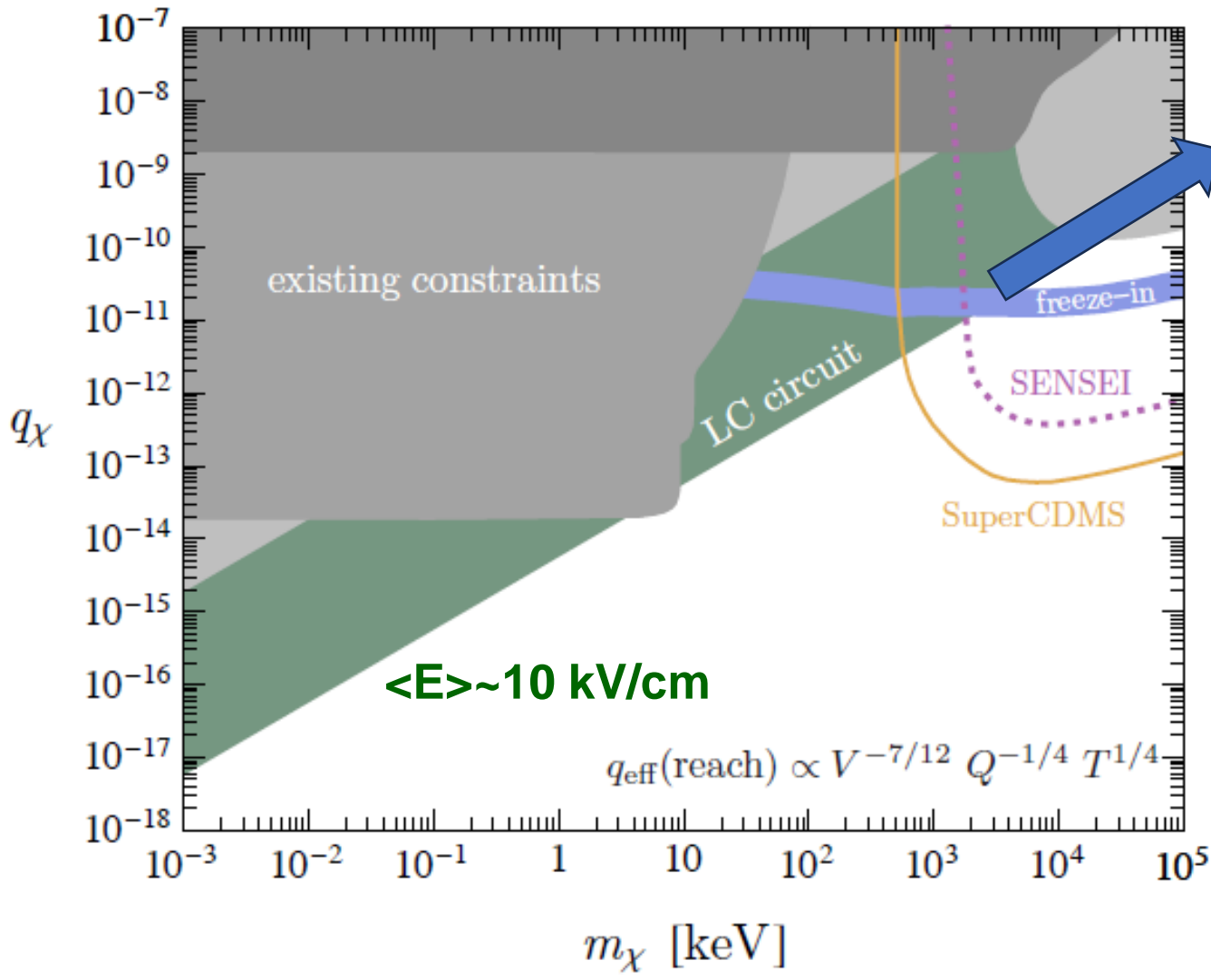
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Future theoretical work: studying other mechanisms of DM production

□ *My research priorities (2024)*

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DM and Flavour Physics (MFV)

No-anomalies: No panic!

All interactions respect the MFV pattern

MFV hypothesis → Stability of flavored dark matter

□ more details [today at 16:30 on the talk](#) of Shohei Okawa (KEK),
“Multi-component Dark Matter from Minimal Flavour Violation”, at the 15th
International Workshop on Identification of Dark Matter 2024 @ L'Aquila



DM and Flavour Physics (MFV)

No-anomalies: No panic!

All interactions respect the MFV pattern

MFV hypothesis → Stability of flavored dark matter

$SU(3)_Q \times SU(3)_{u_R} \times SU(3)_{d_R}$	Stable?
(1, 1, 1)	
(3, 1, 1), (1, 3, 1), (1, 1, 3)	Yes
($\bar{3}$, 1, 1), (1, $\bar{3}$, 1), (1, 1, $\bar{3}$)	Yes
(6, 1, 1), (1, 6, 1), (1, 1, 6) (3, 3, 1), (3, 1, 3), (1, 3, 3)	Yes
($\bar{6}$, 1, 1), (1, $\bar{6}$, 1), (1, 1, $\bar{6}$) ($\bar{3}$, $\bar{3}$, 1), ($\bar{3}$, 1, $\bar{3}$), (1, $\bar{3}$, $\bar{3}$)	Yes

- Applied for any spin and EW representation of χ
- Only the lightest flavored particle is stable
 - All heavier particles are unstable and rapidly decay away in a case

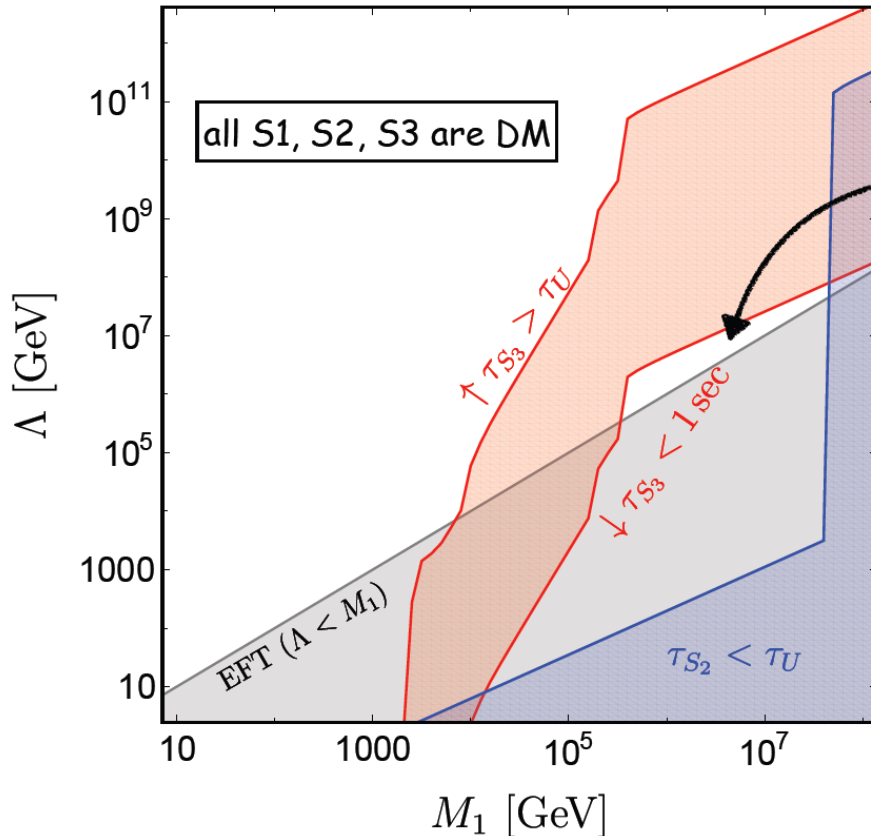
Is it possible that the heavier components are also long-lived to constitute part of DM?

□ more details [today at 16:30 on the talk](#) of Shohei Okawa (KEK), “Multi-component Dark Matter from Minimal Flavour Violation”, at the 15th International Workshop on Identification of Dark Matter 2024 @ L’Aquila



DM under MFV hypothesis

Multi-component flavored DM



- $\tau_{S_i} > \tau_U \rightarrow$ DM
- $\tau_{S_i} < \tau_U \rightarrow$ not DM and have to decay prior to the BBN (we require $\tau_{S_i} < 1 \text{ sec}$ in that case)
- DM are composed of two or three components in the white region

□ more details [today at 16:30 on the talk](#) of Shohei Okawa (KEK), “Multi-component Dark Matter from Minimal Flavour Violation”, at the 15th International Workshop on Identification of Dark Matter 2024 @ L’Aquila



**Theory-Exp
common
effort**

Se po' fa



Grazie e alla prossima!

- ❖ Extensive Research Program:
from Experiment to Fundamental
questions of Physics
 - ❖ Strong Background in QCD
 - ❖ Explored Many Research Lines over
the Years:
 - ✓ Heavy new particles (CPV/DM)
@LHC/flavour (by loops)
 - ✓ Light particles (as GB)
@astro/cosmo
-

Força, Equilibri, Valor i Seny