

# EFT for Dark-Matter Direct Detection

Possible new QFET project

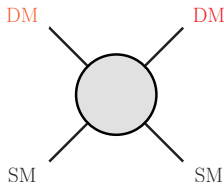
Joachim Brod



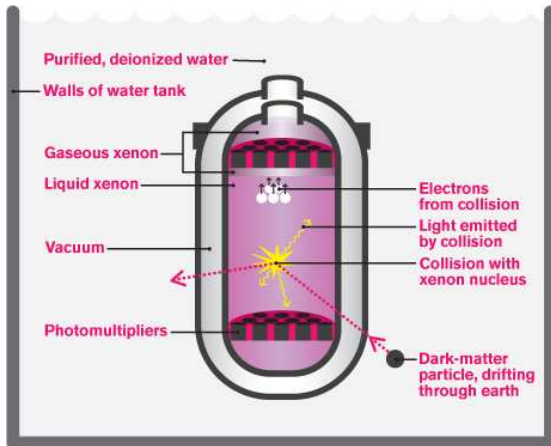
QFET Workshop, Siegen University  
January 18, 2016

# Dark Matter Direct Detection

- DM exists
  - All evidence via its gravitation
- What we know about DM
  - DM is non-baryonic, cold, and neutral
  - Relic abundance  $\Omega_{\text{DM}} h^2 = 0.1198(26)$   
[PLANCK / PDG 2014]
  - Particle nature?
- Direct detection: Scattering on atomic nuclei

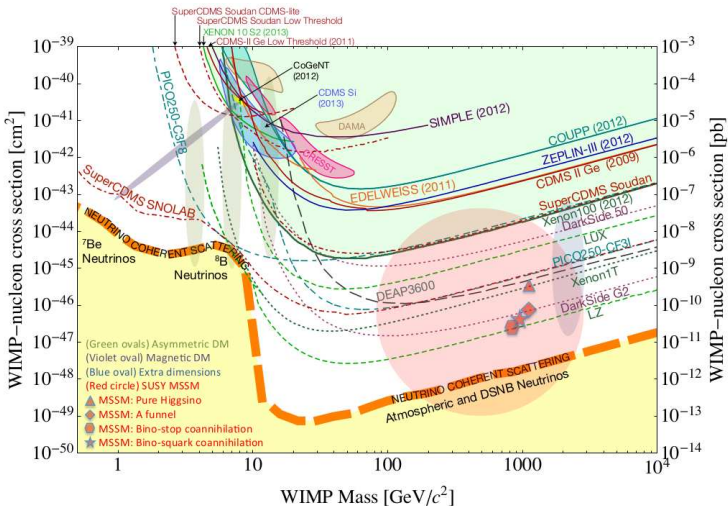


# Direct Detection Limits



**LUX detector**

# Direct Detection Limits



# Why EFT for Direct Detection?

- DM – nucleus scattering involves many different energy scales
  - $m_\chi, \Lambda_{\text{NP}}, v_{\text{EW}}, m_Q, \Lambda_{\text{QCD}}, E_R$
- EFTs provide the appropriate theory framework
  - Consistent **power counting**
  - Keep **dependence on UV physics explicit**
- Electroweak loops can **mix suppressed and unsuppressed operators**
  - Calculate **all relevant radiative corrections**

# Mixing Example – $W$ Exchange

$$(\bar{\chi}\gamma_\mu\gamma_5\chi)(\bar{Q}_L^i\gamma^\mu Q_L^i)$$

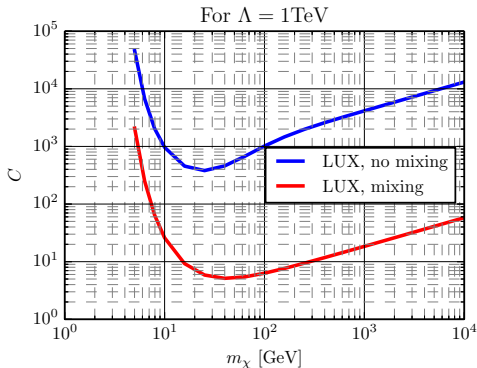
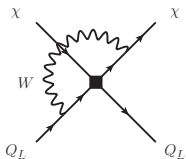
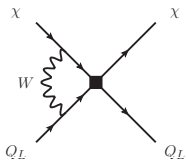
$$\sim v^{-3}$$

 $\Rightarrow$ 

$$\propto \frac{\alpha_{\text{weak}}}{4\pi} \log \frac{v_{\text{EW}}}{\Lambda}$$

$$(\bar{\chi}\gamma_\mu\tilde{\tau}^a\chi)(\bar{Q}_L^i\gamma^\mu\tau^a Q_L^i)$$

$$\sim v^0$$



# EFT for Direct Detection – what has been done

- Heavy DM ( $m_\chi \gg v_{EW}$ ) – dim.-4 gauge interactions
  - Electroweak matching [Hill et al., 1401.3339]
  - QCD running [Hill et al., 1409.8290]
- Mixing of effective operators (SM singlet DM)  
[Freytsis & Ligeti, 1012.5317; Haisch et al. 1302.4454; Crivellin et al. 1402.1173, 1408.5046; D’Eramo et al. 1409.2893]
- NNLO ChPT effects for scalar DM [Cirigliano et al., 1205.2695]
- NR EFT of nuclear scattering [Cirigliano et al., 1203.3542]

# EFT for Direct Detection – current status

[F. Bishara, J. Brod, B. Grinstein, J. Zupan; work in progress]

- Fermionic DM with arbitrary  $SU(2)_L \times U(1)_Y$  charges
  - Dimension-five and dimension-six operators in the UV
  - $m_\chi \sim v_{ew}$  and  $m_\chi \ll v_{ew}$
- ( $\rightarrow$ ) Running, and matching at all relevant scales
- Consistent matching to chiral effective theory
- $\rightarrow$  NR limit and matching to NR EFT of nuclear responses
- $\rightarrow$  Several multiplets and Higgs interactions



# EFT for Direct Detection – future work

[J. Brod, A. Gootjes-Dreesbach, M. Reininghaus, M. Pilch, N.N.; work in progress]

- Two-loop e/w matching conditions (gluonic operators)
- Dim.-7 operator mixing for fermionic DM
- Scalar and vector DM
  - Dim.-5, dim.-6, dim.-7 operators
- Operator mixing for heavy DM
- Non-trivial flavor structure
- Explicit mediators
- Provide public code
  - Automatic running from UV to nuclear scale
  - Calculation of nuclear scattering rates

# Points for Discussion

- Combine with DFG QFET group?
  - EFT aspect enough?
  - Investigate flavor aspects?