LIGHT DARK MATTER DIRECT DETECTION WITH ANTI-FERROMAGNETS

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Light Dark Matter 2025, Genova

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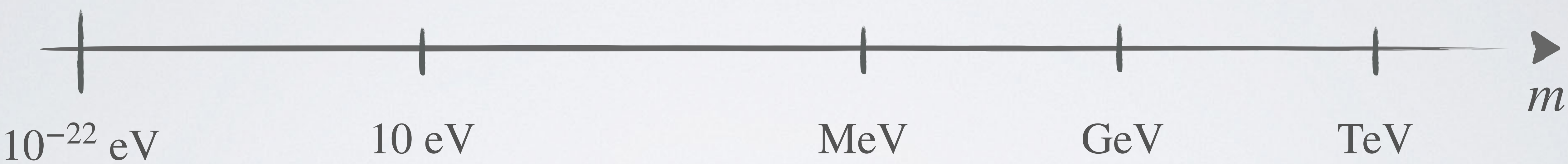

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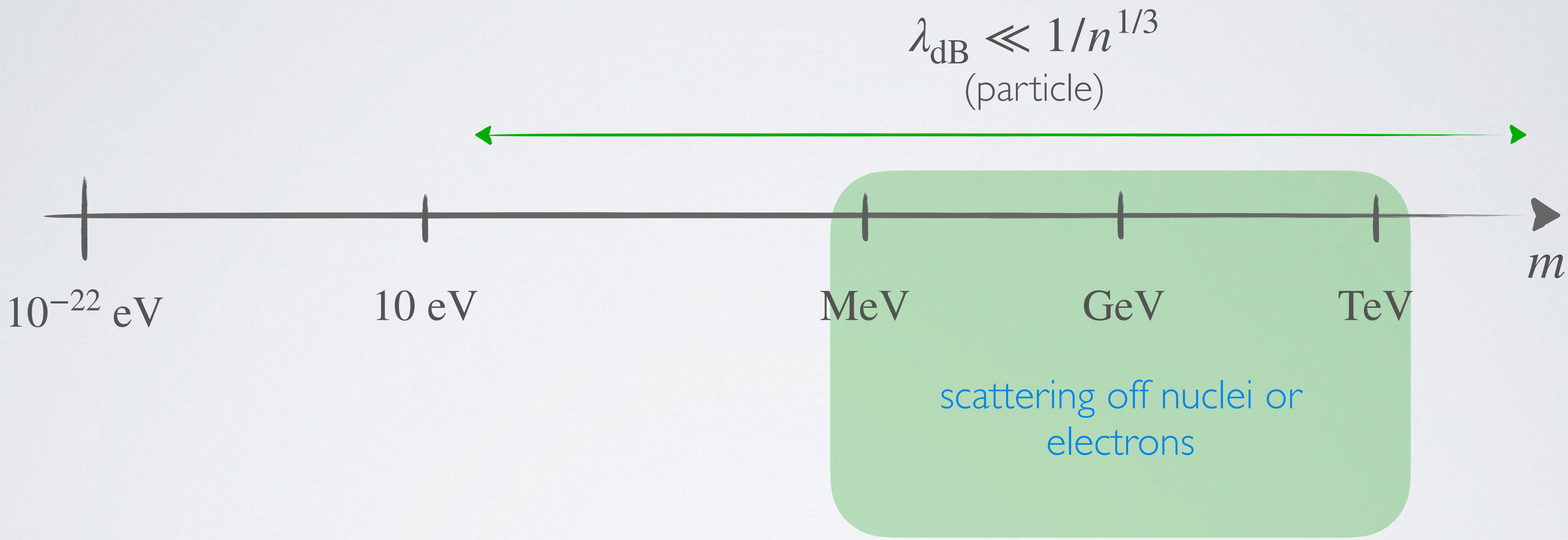

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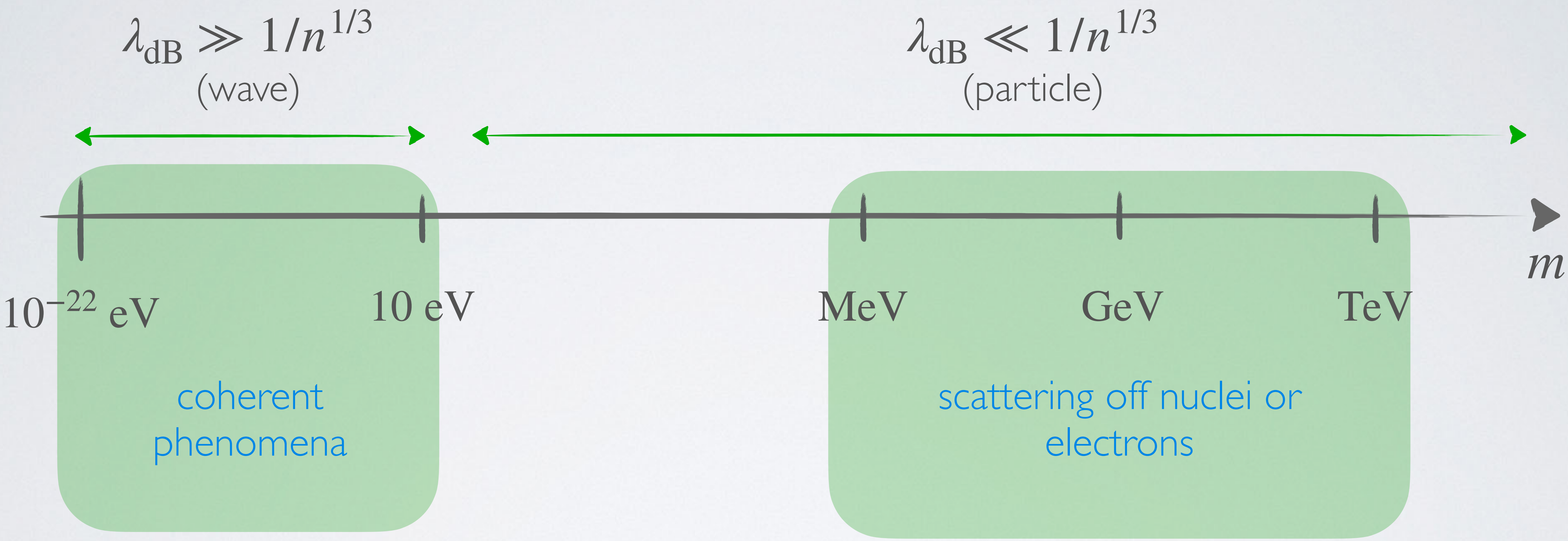

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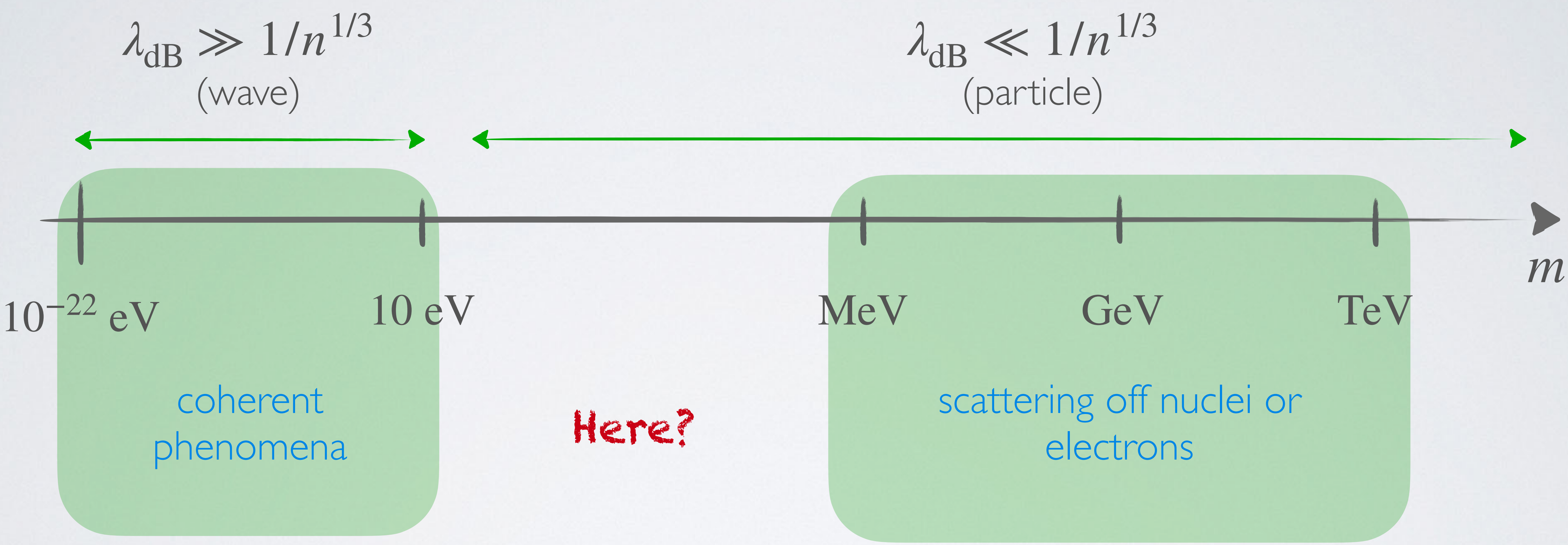

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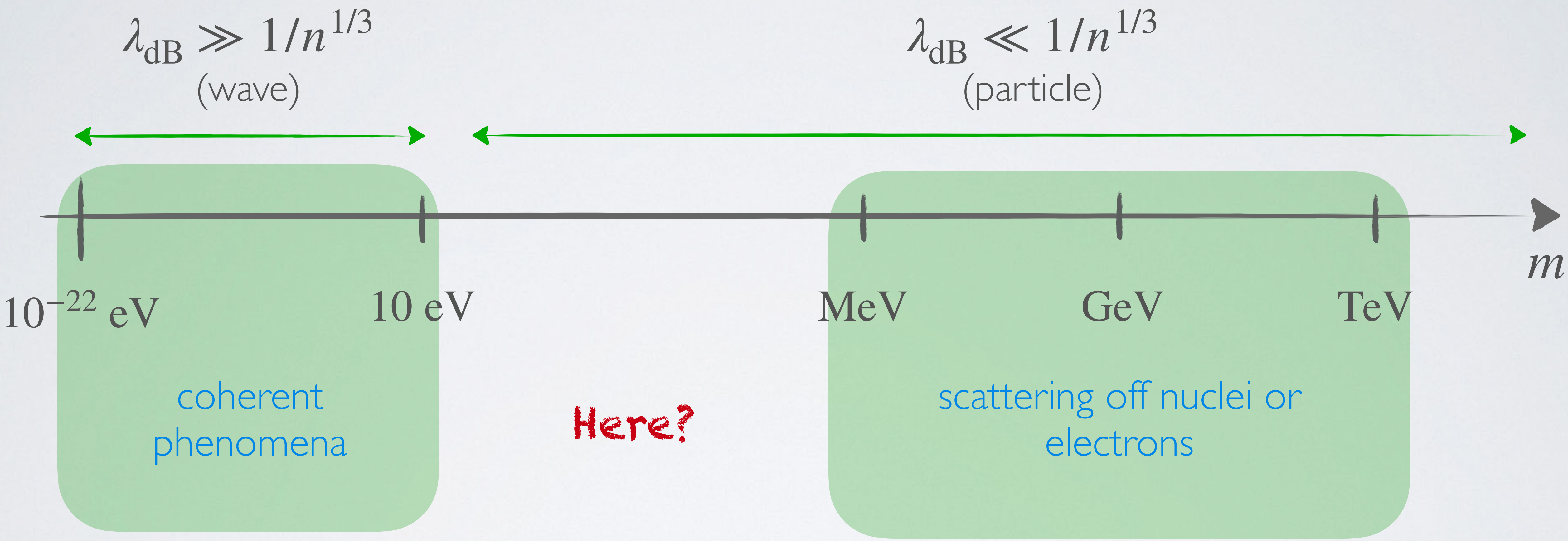

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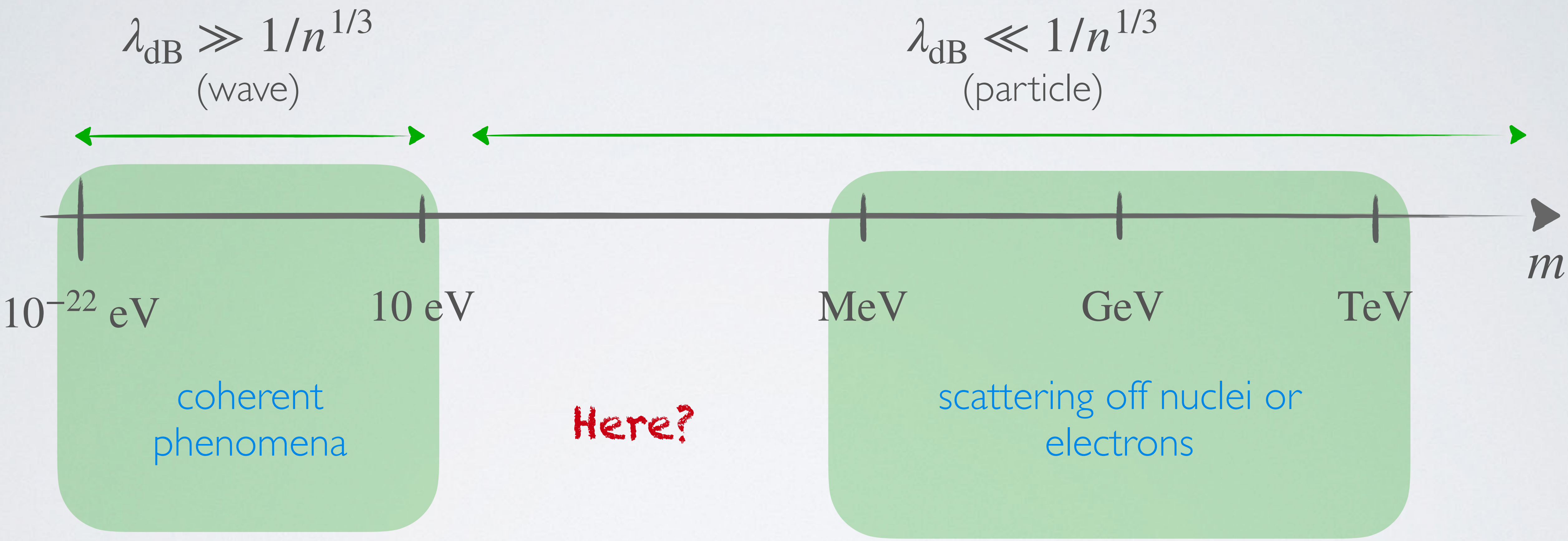

- Dark matter is a particle but too light for recoil off nuclei / electrons
- Need new materials and/or observables

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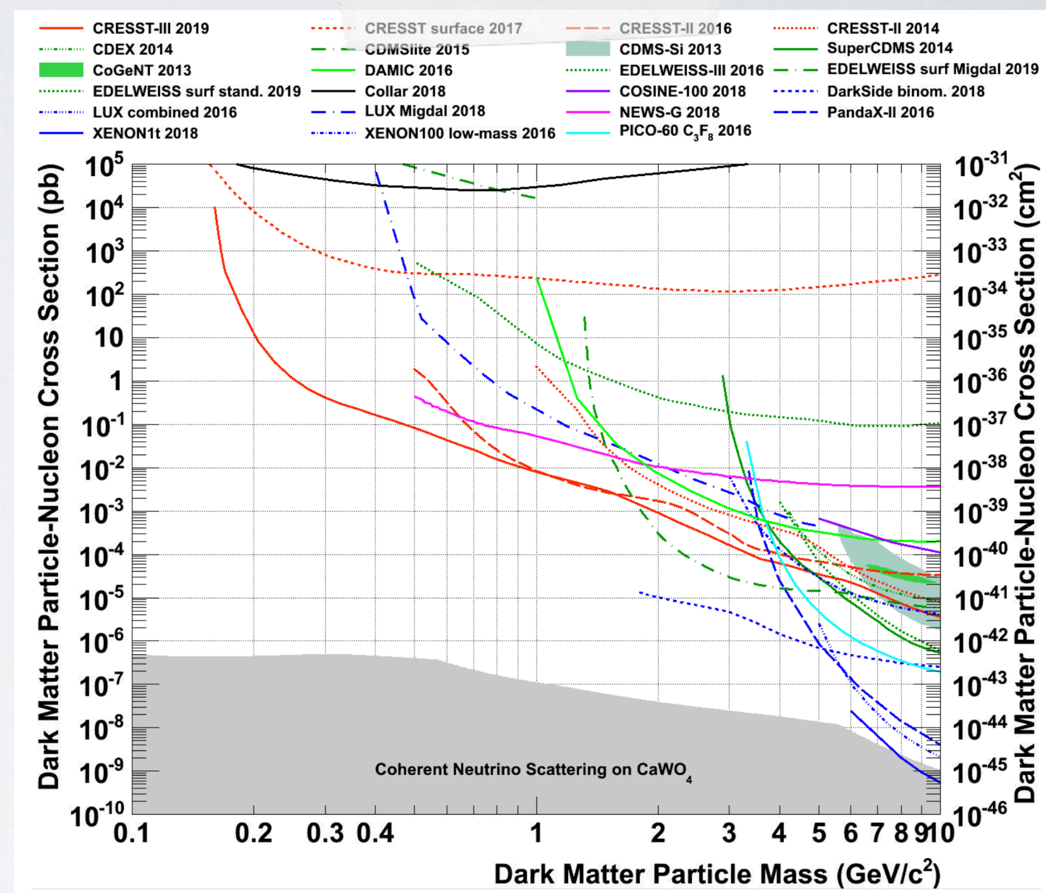

[CRESST PRD 2019]

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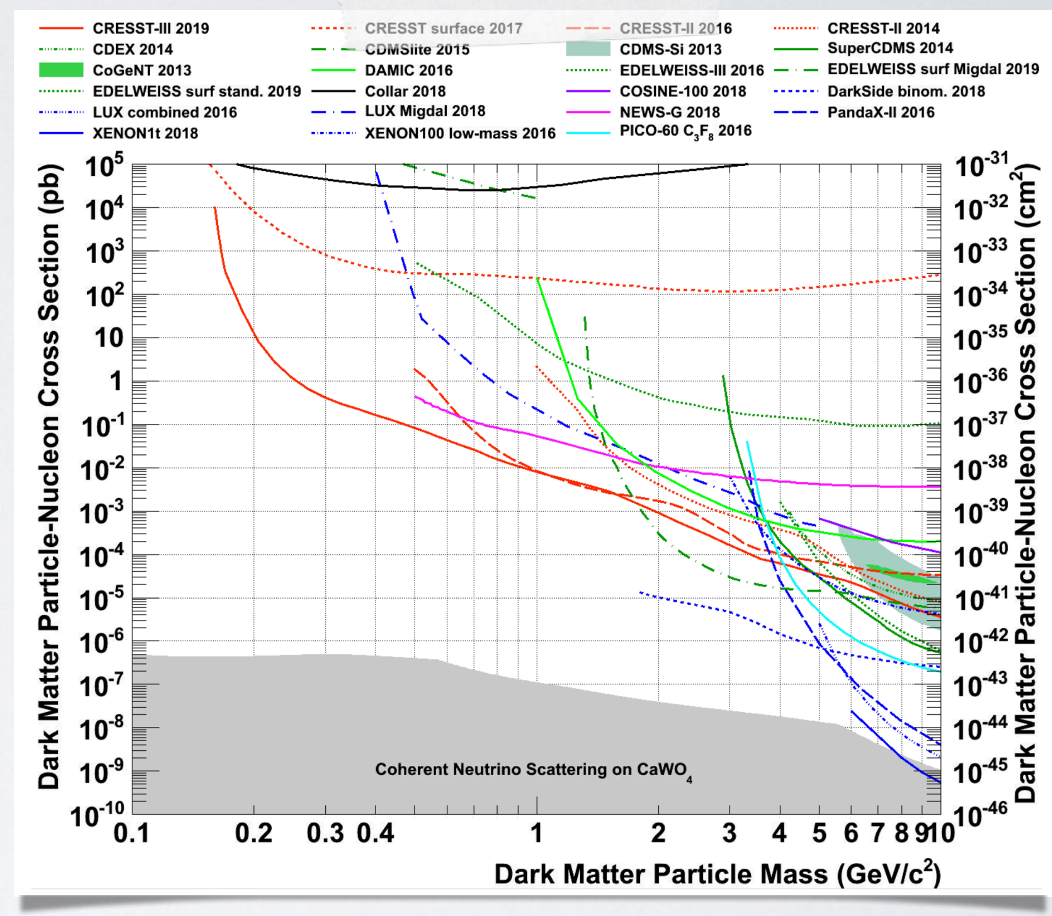

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- To evade this we must look into inelastic processes

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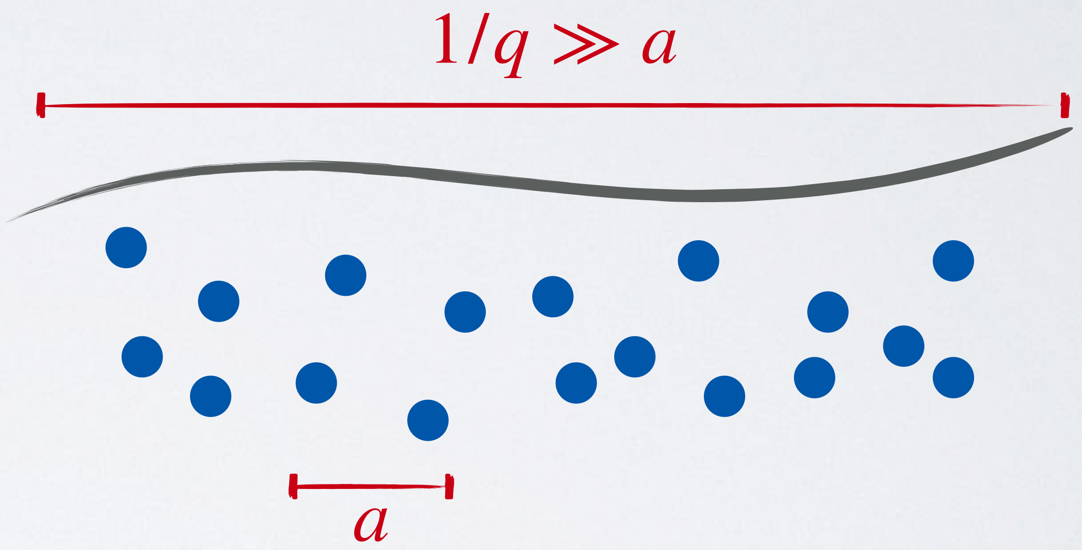
$$\frac{1}{q} \sim \frac{1}{m_\chi v_\chi} \gtrsim 1 \text{ Å}$$



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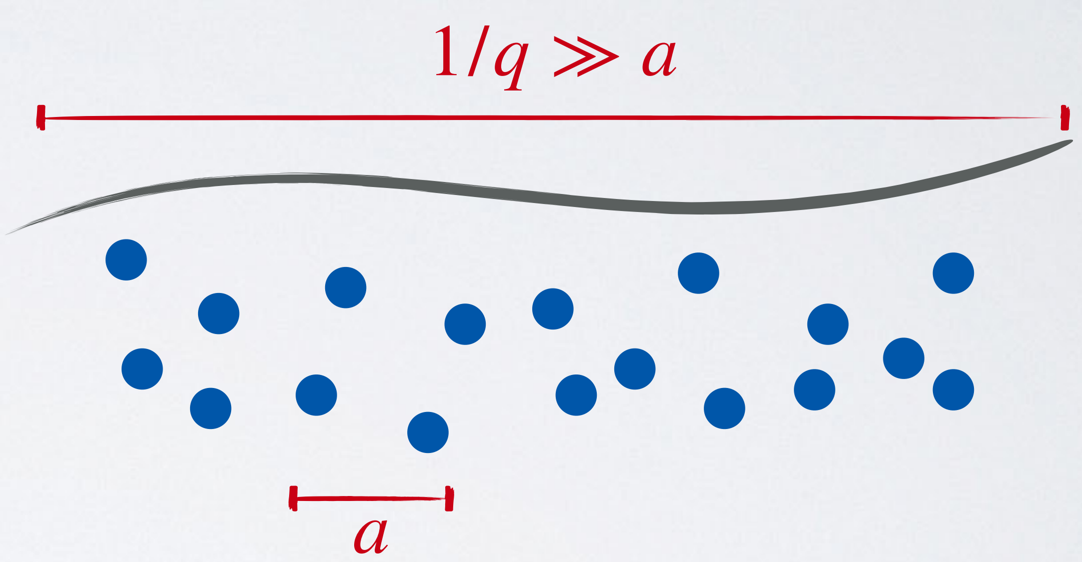

- Interesting and active field with plenty of ideas
  - ✳ phonons on solid crystals [e.g., Knapen et al. PLB 2018; Griffin et al. PRD 2021]
  - ✳ phonons in superfluid ^{4}He [e.g., Guo, McKinsey PRD 2013; Schutz, Zurek PRL 2016; Caputo, **AE**, Polosa PRD 2019]
  - ✳ many others… [for a review, Kahn, Lin Rept.Prog.Phys. 2022]

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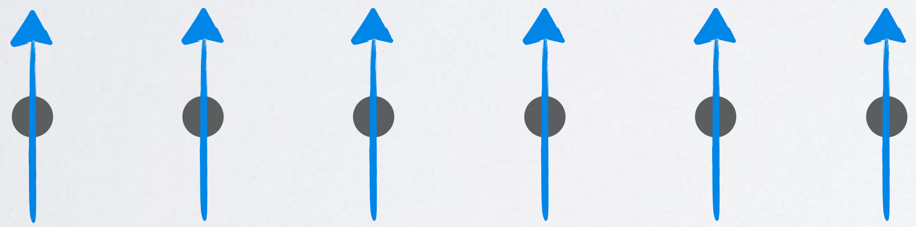

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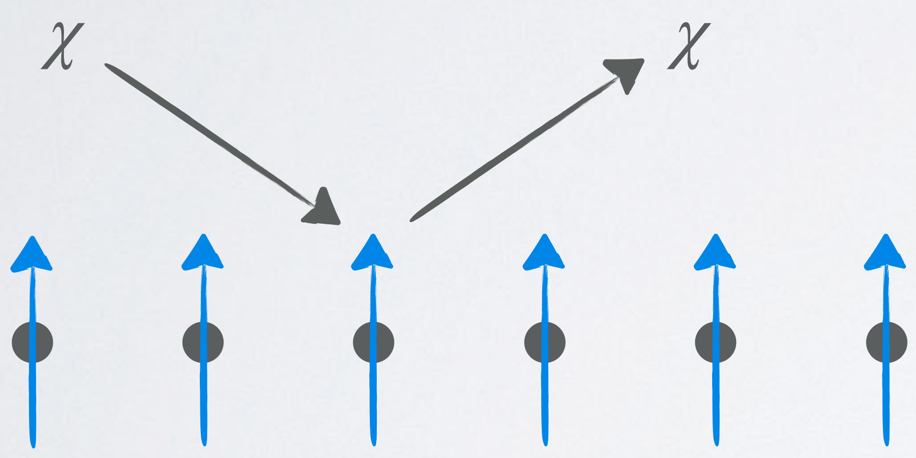

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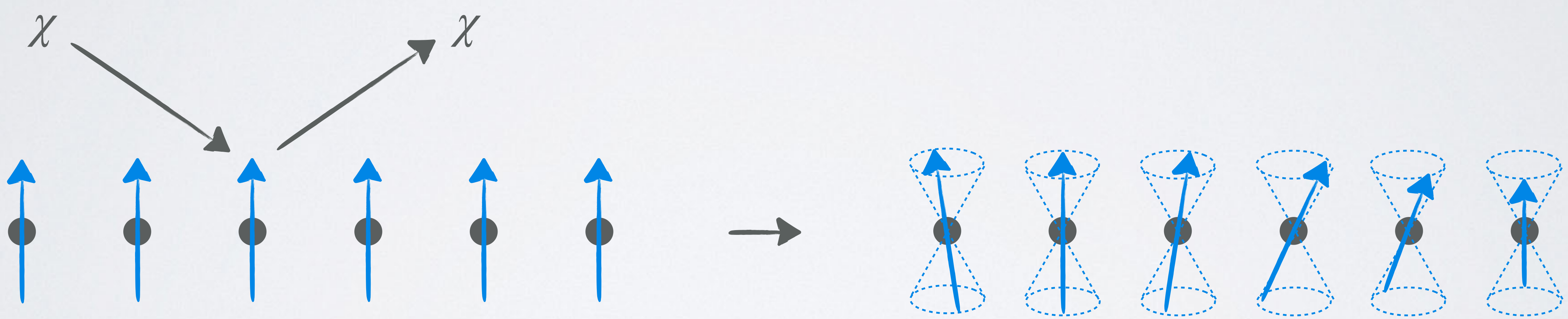

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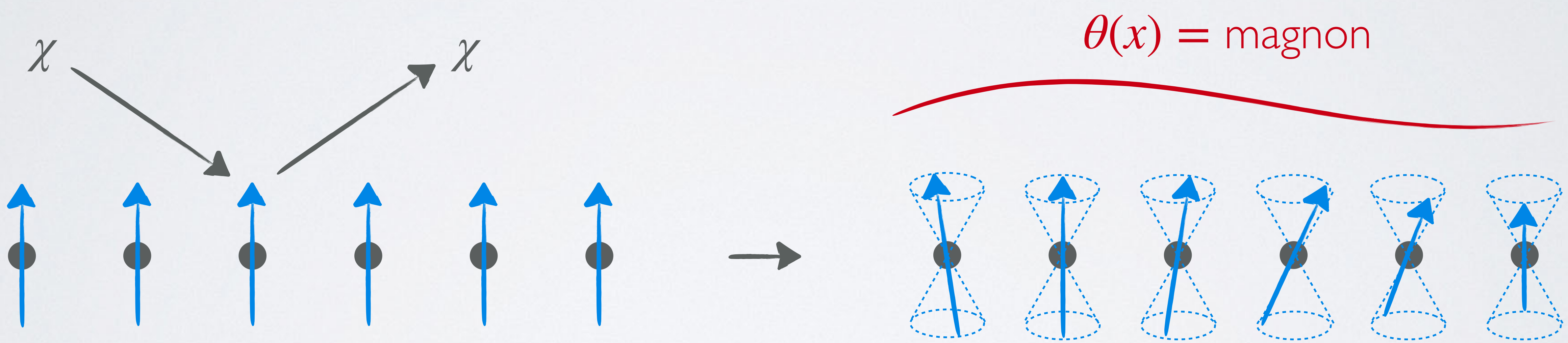

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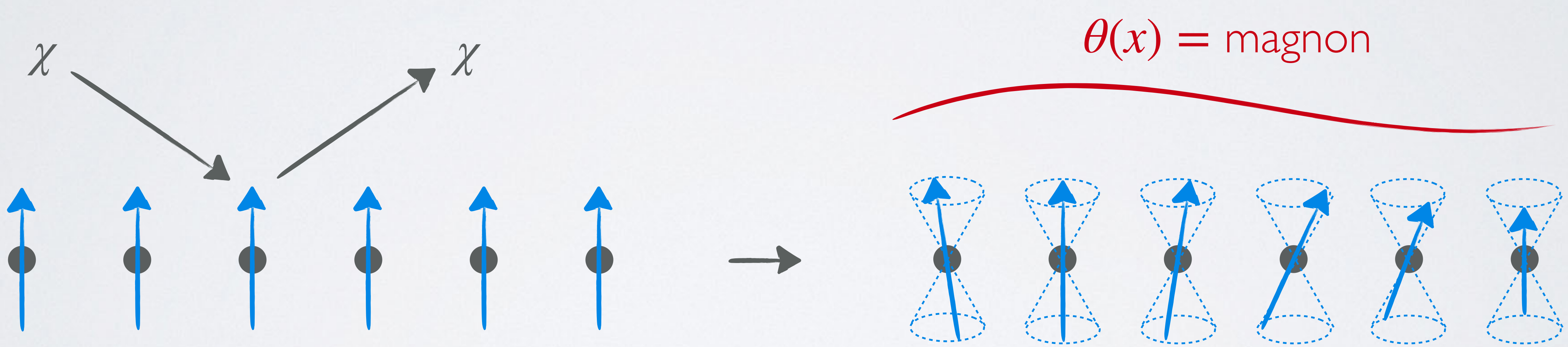

- Ways to detect few magnons have been proposed (TES? SQUIDs? quantum sensors? cavities?) [Trickle, Zhang, Zurek PRL 2020; Lachance-Quirion et al. Science Advances 2017; Lachance-Quirion et al. Science 2020]

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[e.g., Sigurdson et al. PRD 2004; Chang, Weiner, Yavin PRD 2010]

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spin density

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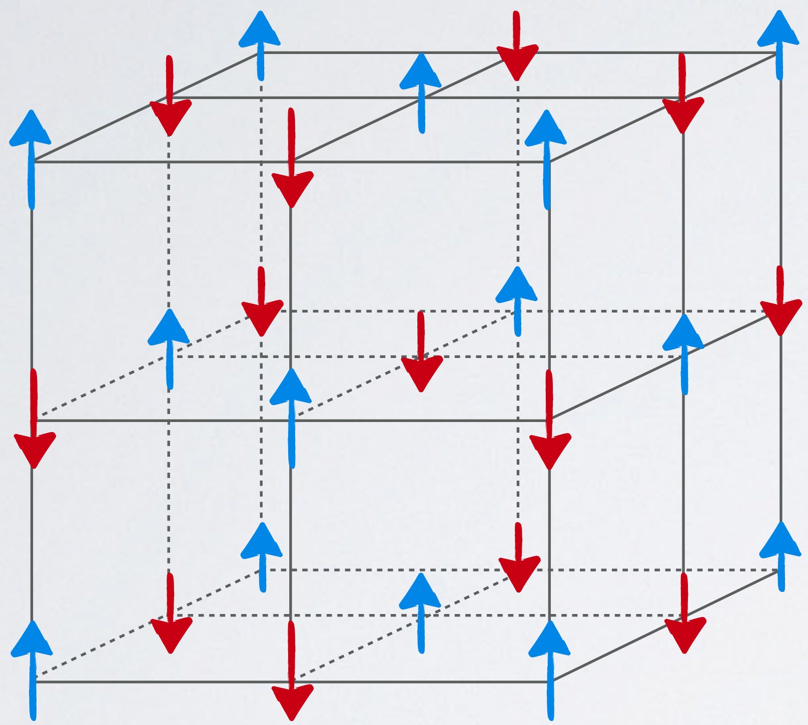

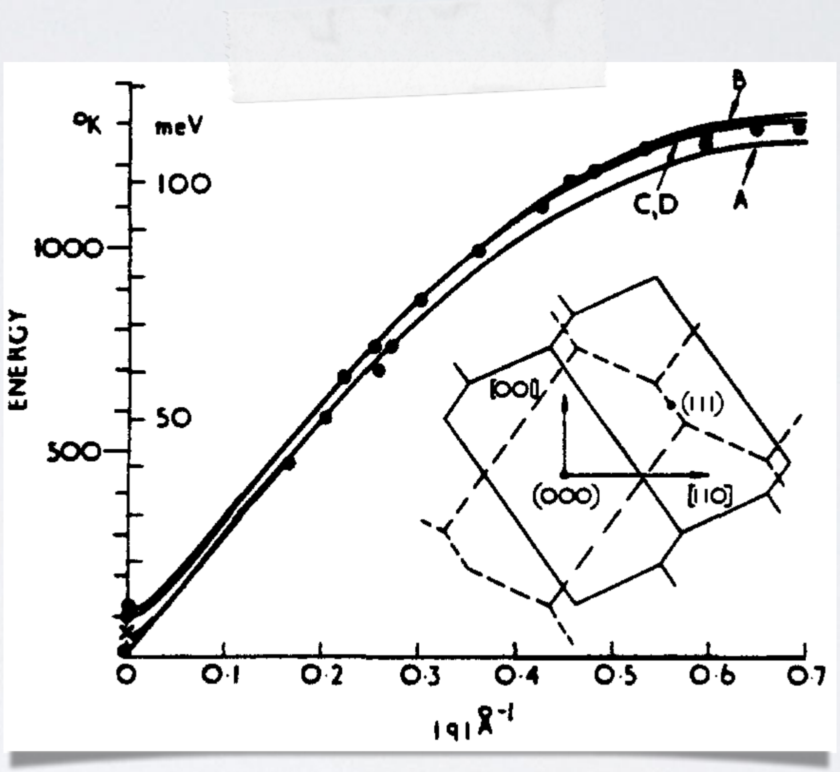

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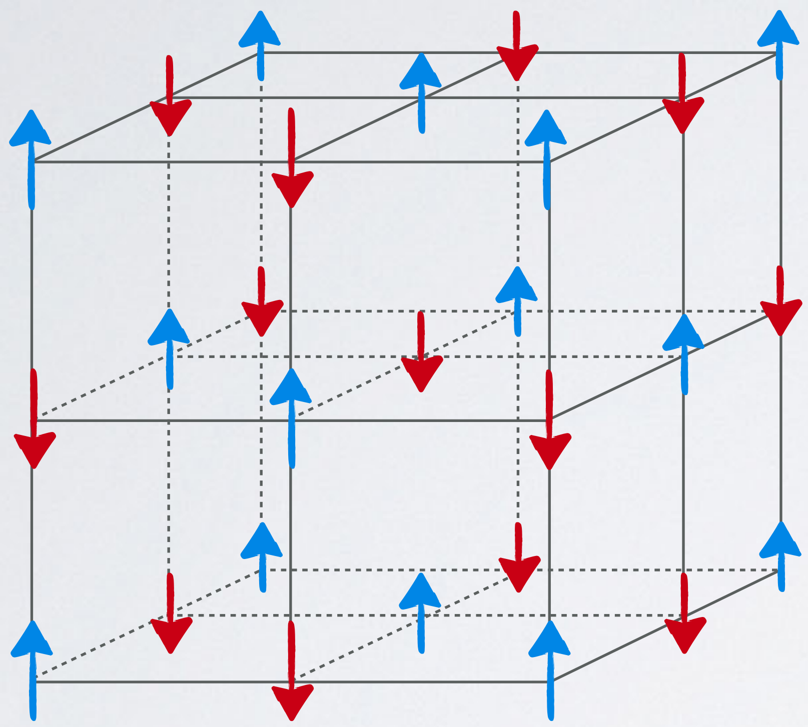

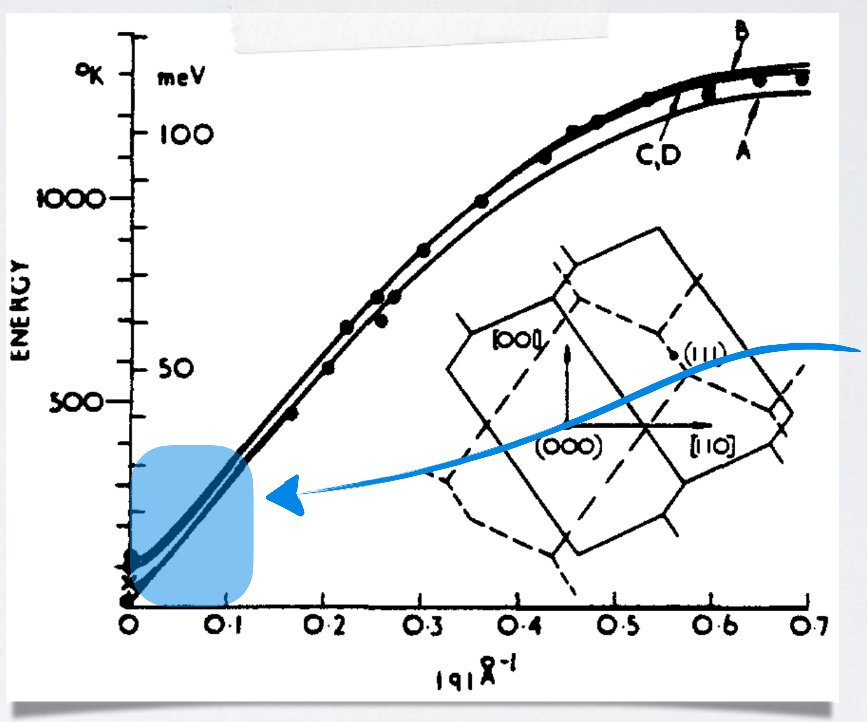

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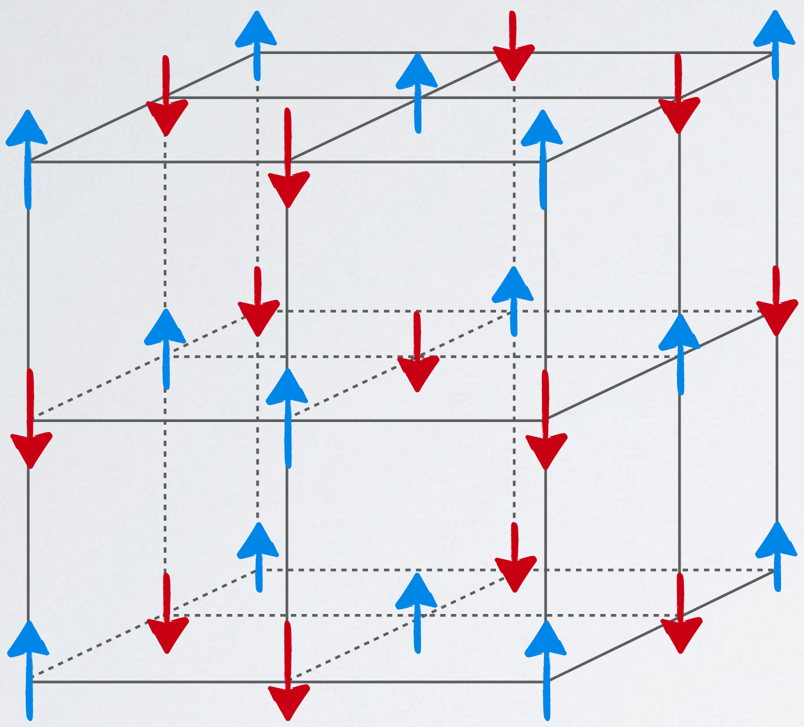

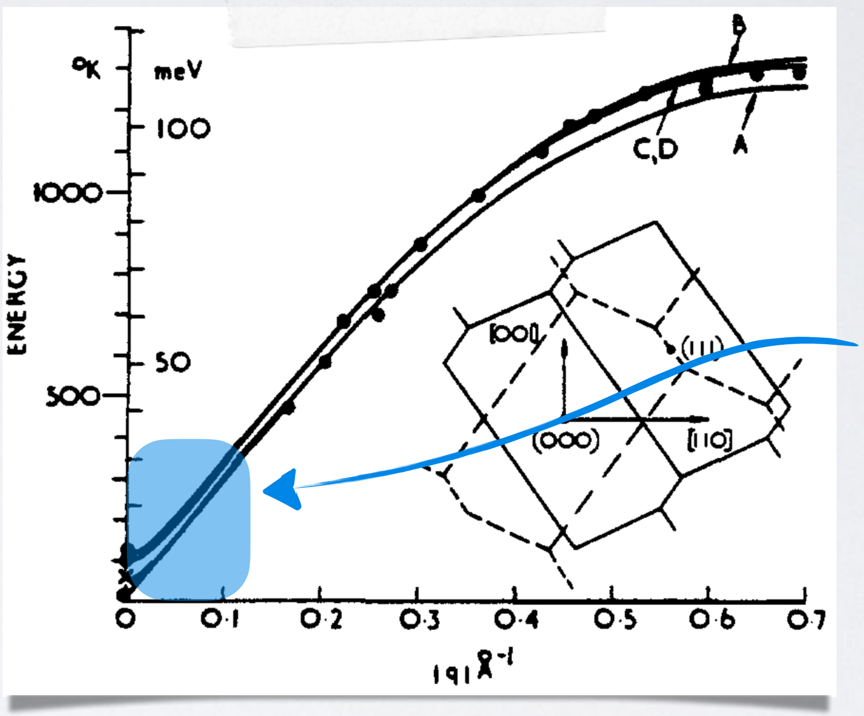

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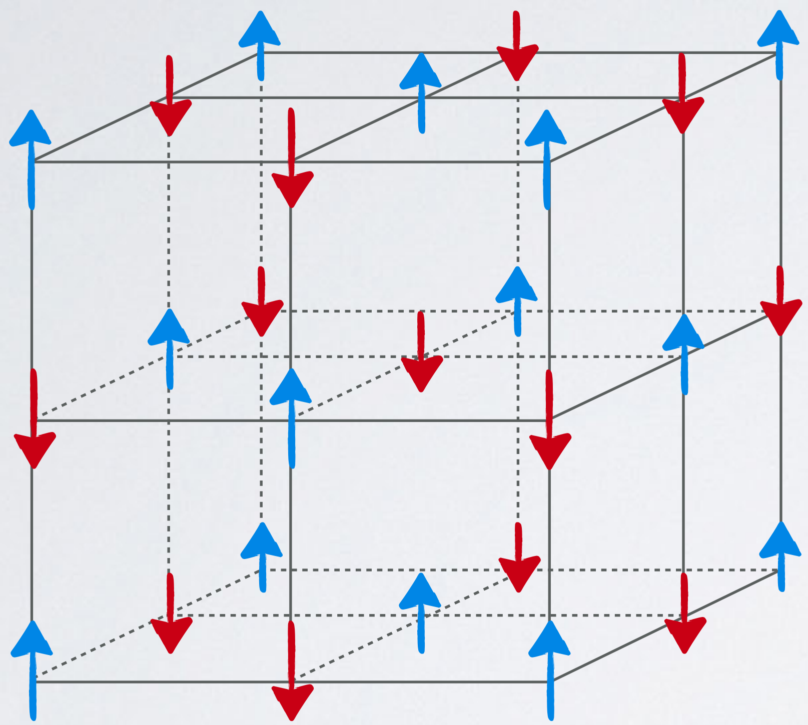

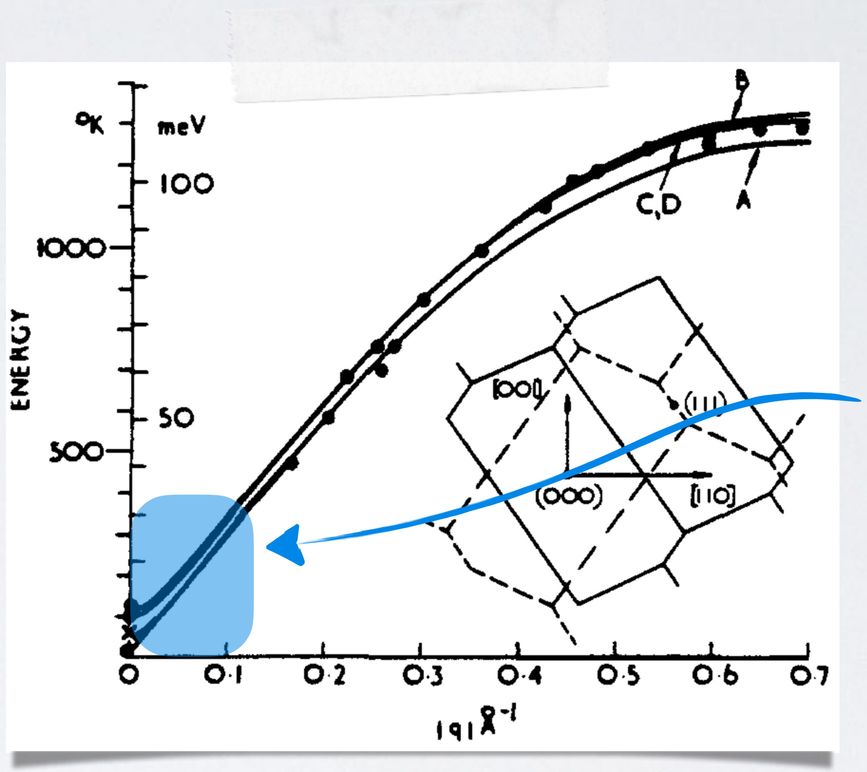

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- Nickel-oxide has $v_\theta \sim 0.1\, v_\chi$ $\rightarrow$ very efficient at absorbing dark matter energy [**AE**, Pavaskar PRD 2023]

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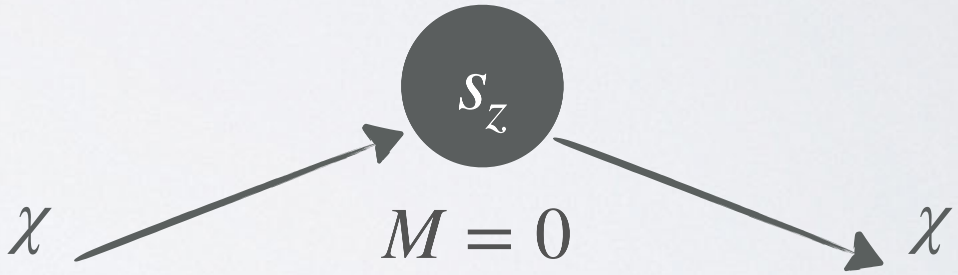

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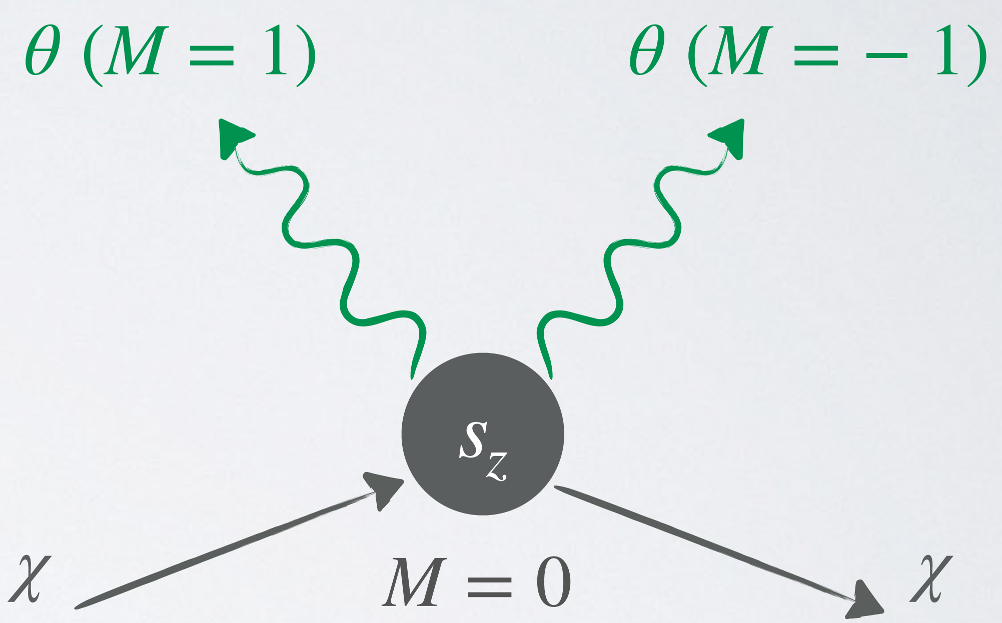

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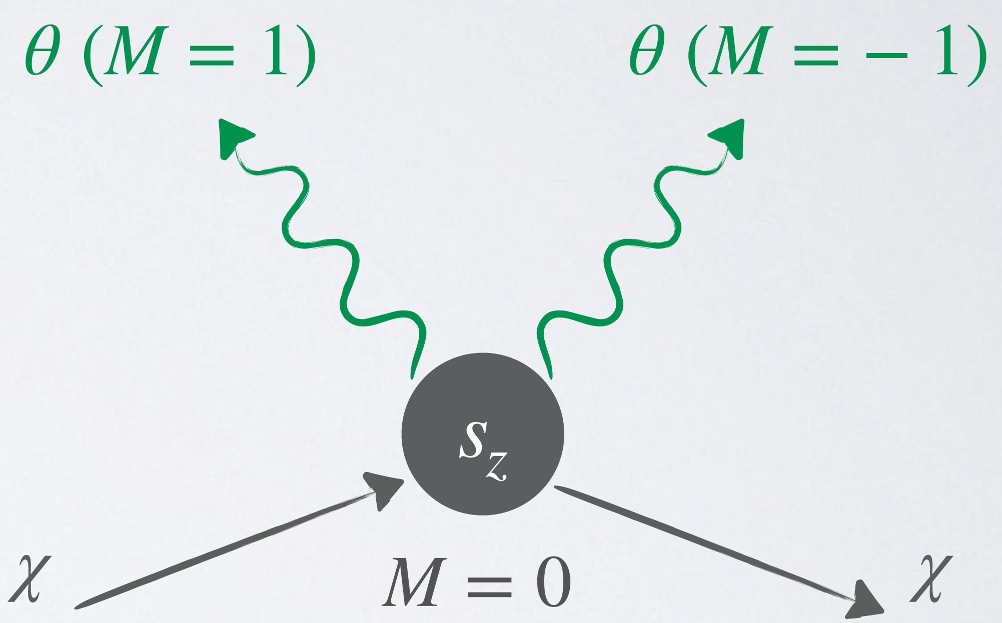

- Multi-magnon emission process evades the kinematical constraints and get down to $m_\chi \sim \mathcal{O}(\text{keV})$

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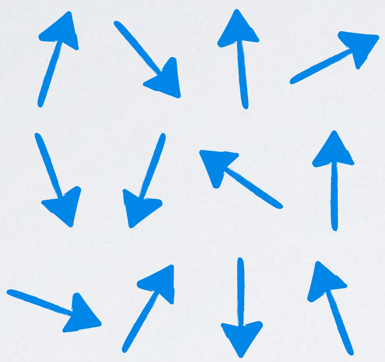

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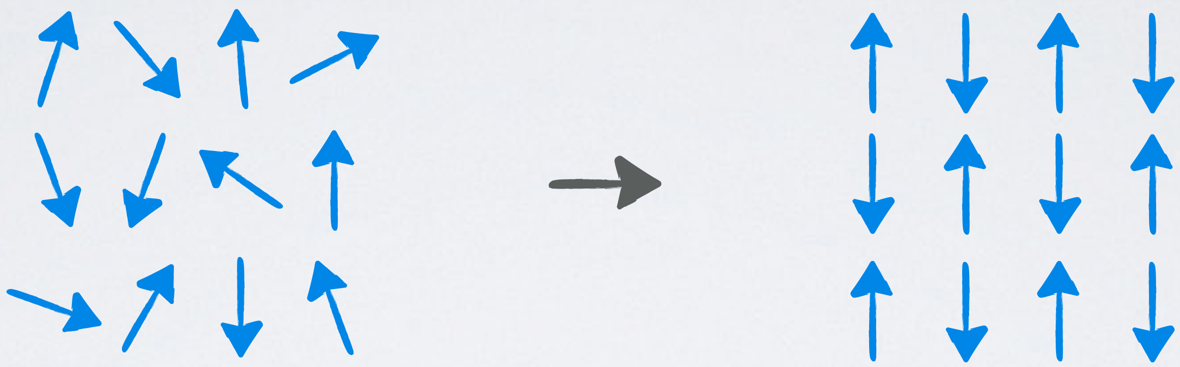

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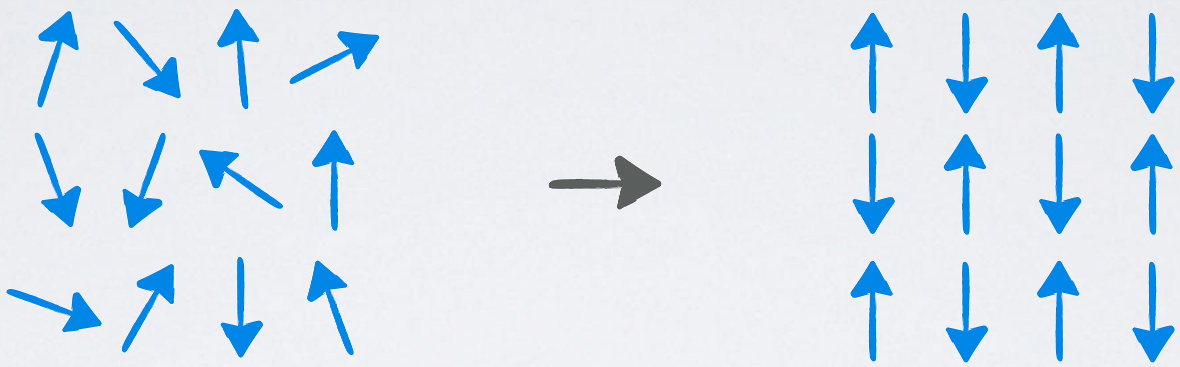

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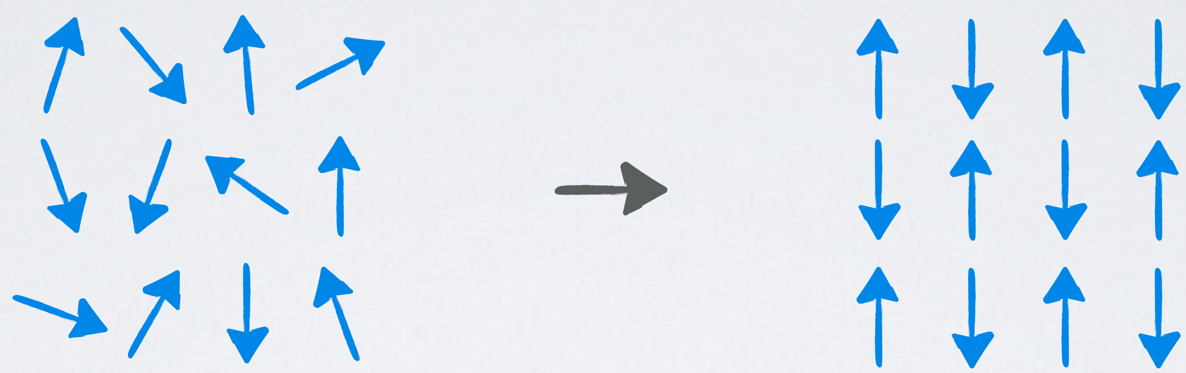

$SO(3)$ $\quad\quad$ $SO(2)$

Gapless magnon = Goldstone

- At low energies/momenta magnons can be described by an EFT:
  - ✳ invariant under the full symmetry group
  - ✳ organized in a derivative expansion

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can be extracted from dispersion relation + neutron scattering data

$v_\theta = c_2/c_1$

$\sigma_n \propto c_1$

[Pavaskar, Penco, Rothstein SciPost Phys. 2022; **AE**, Pavaskar PRD 2023]

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- Much more "HEP friendly" than standard language

IDEAL REACH

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- Local QFT Lagrangian $\rightarrow$ use standard QFT methods to compute event rates [**AE**, Pavaskar PRD 2023]

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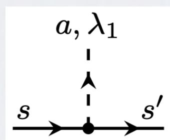

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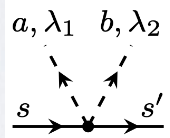

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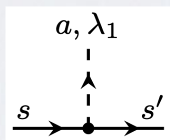

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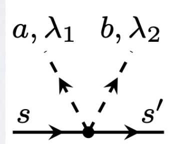

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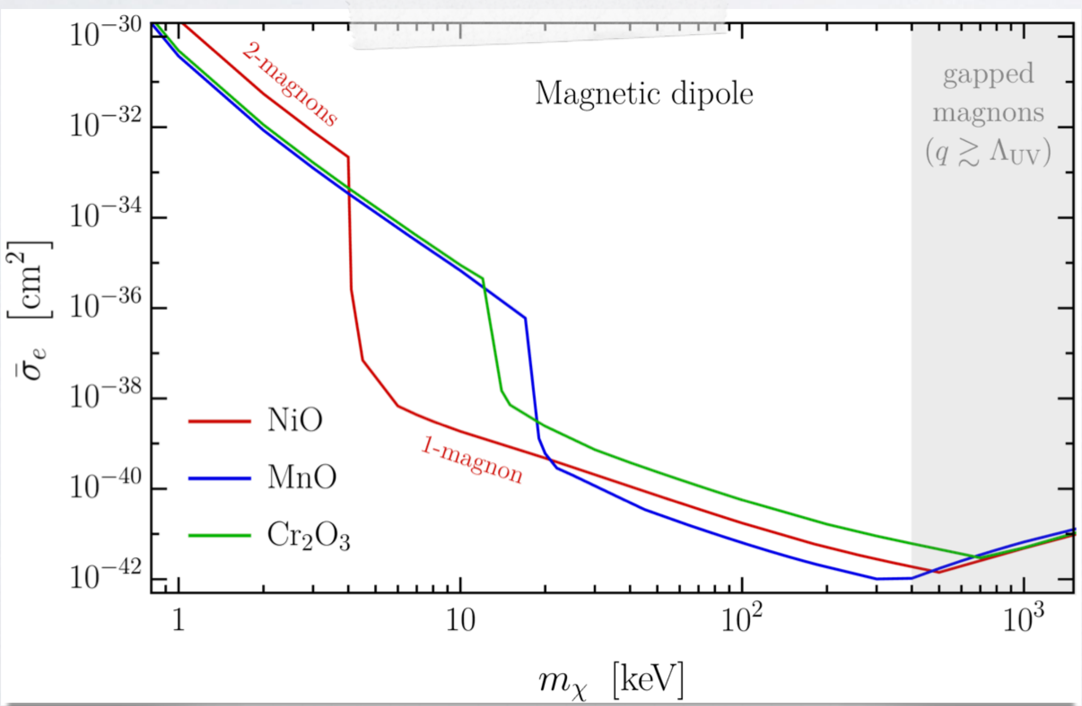

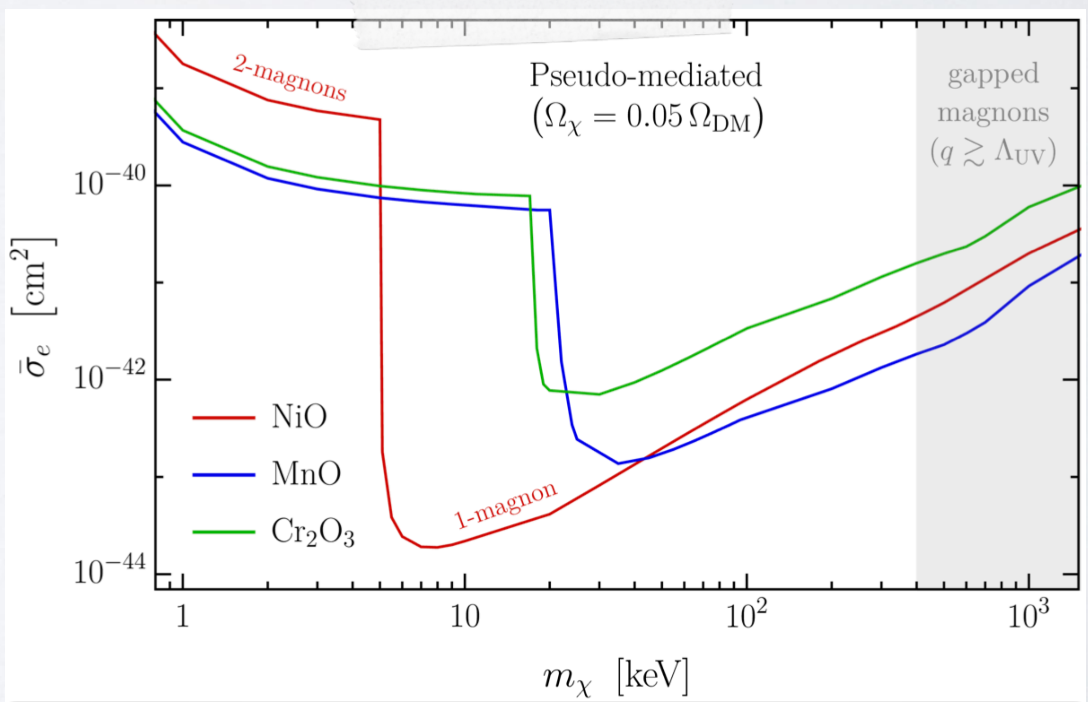

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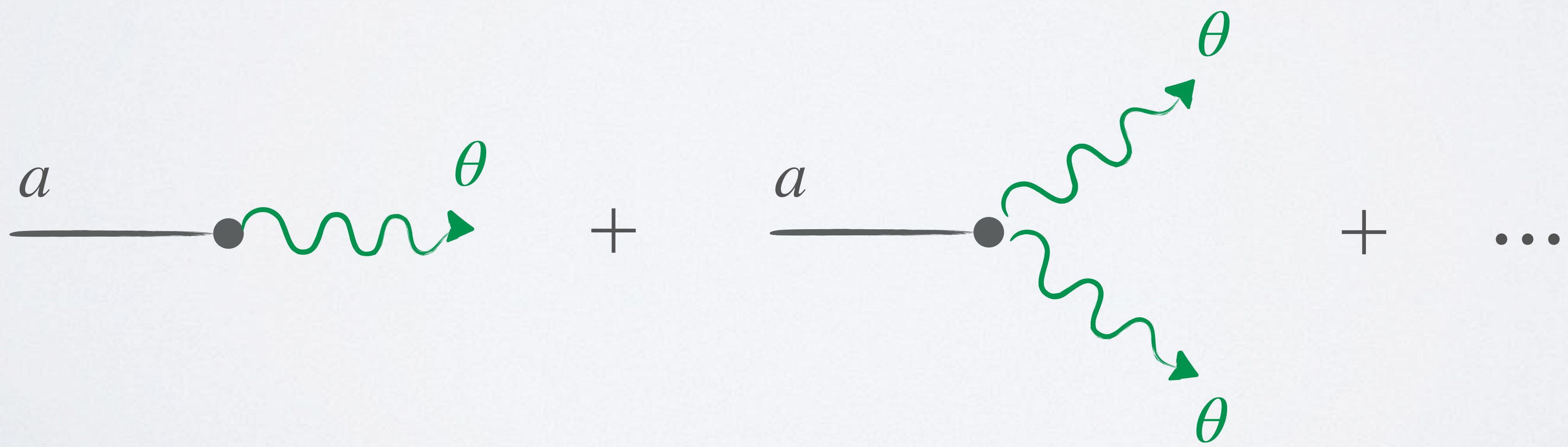

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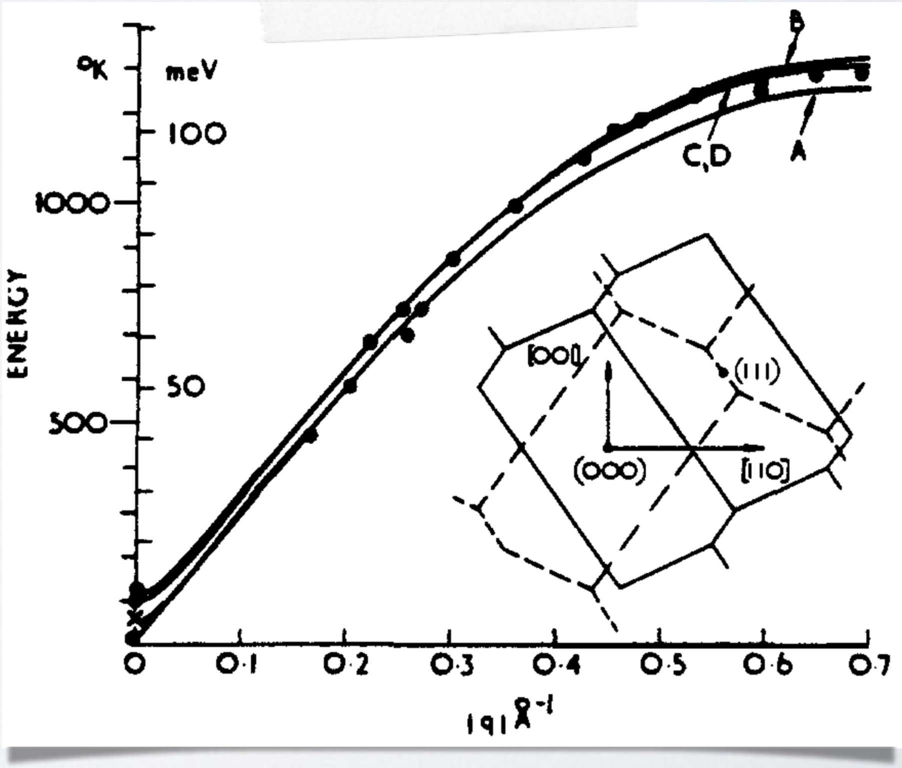

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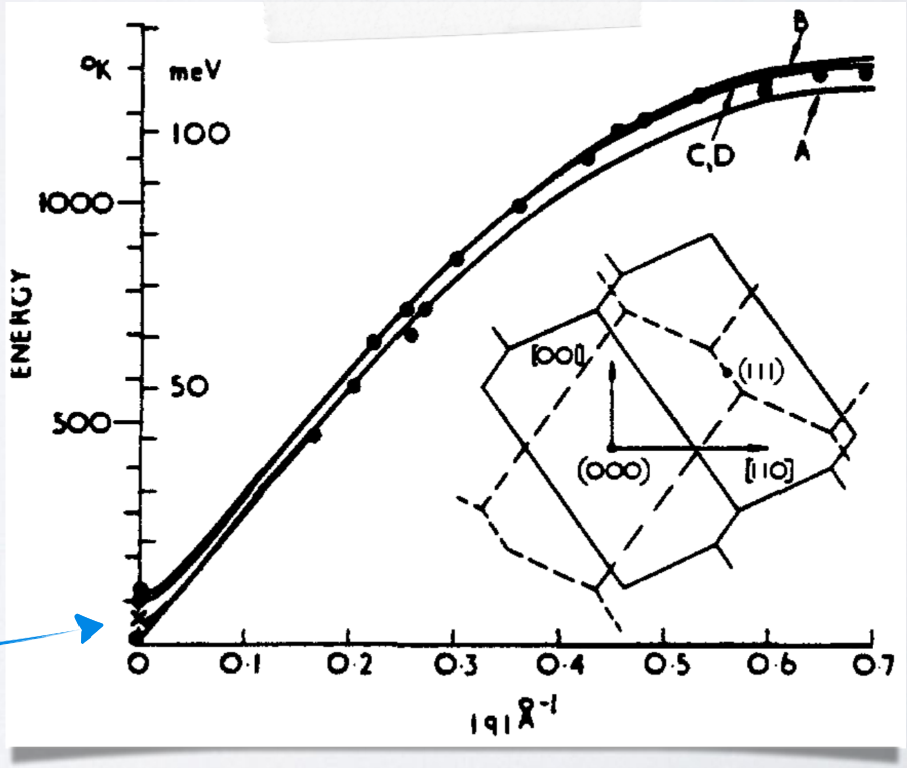

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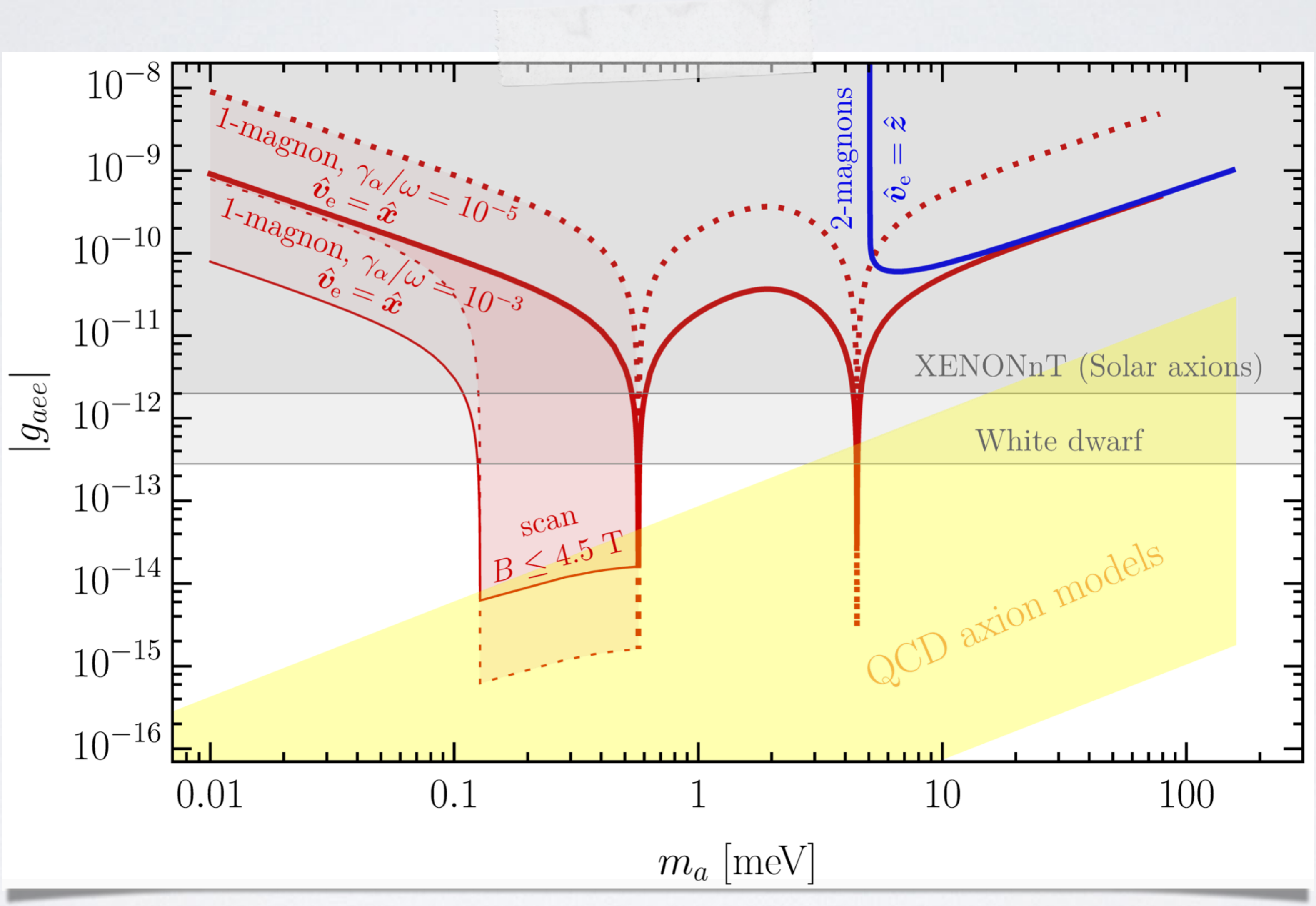

[Catinari, **AE**, Pavaskar 2411.09761]

WHAT NEXT?

- A plethora of open questions:
  - is any other good material out there? [Marocco, Wheater 2501.18120]
  - what is the actual observable? How do we see magnons?

$$H = \mu \mathbf{B} \cdot \mathbf{S} \quad \Rightarrow \quad |\,\mathrm{phys}\rangle = |\,\theta\rangle + \alpha\,|\,\gamma\rangle$$

produce

detect

  - What the actual magnon lifetime? [work in progress w/ Carugno, Catinari, Pavaskar]

$$\frac{\Gamma(\theta \to \gamma)}{\Gamma(\theta \to \mathrm{phonons})} = ?$$

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Thank you for the attention!