# calorimetric detectors for light dark matter

caveat: a rich topic, 5 minutes...
I'll just mention some simple fun ideas

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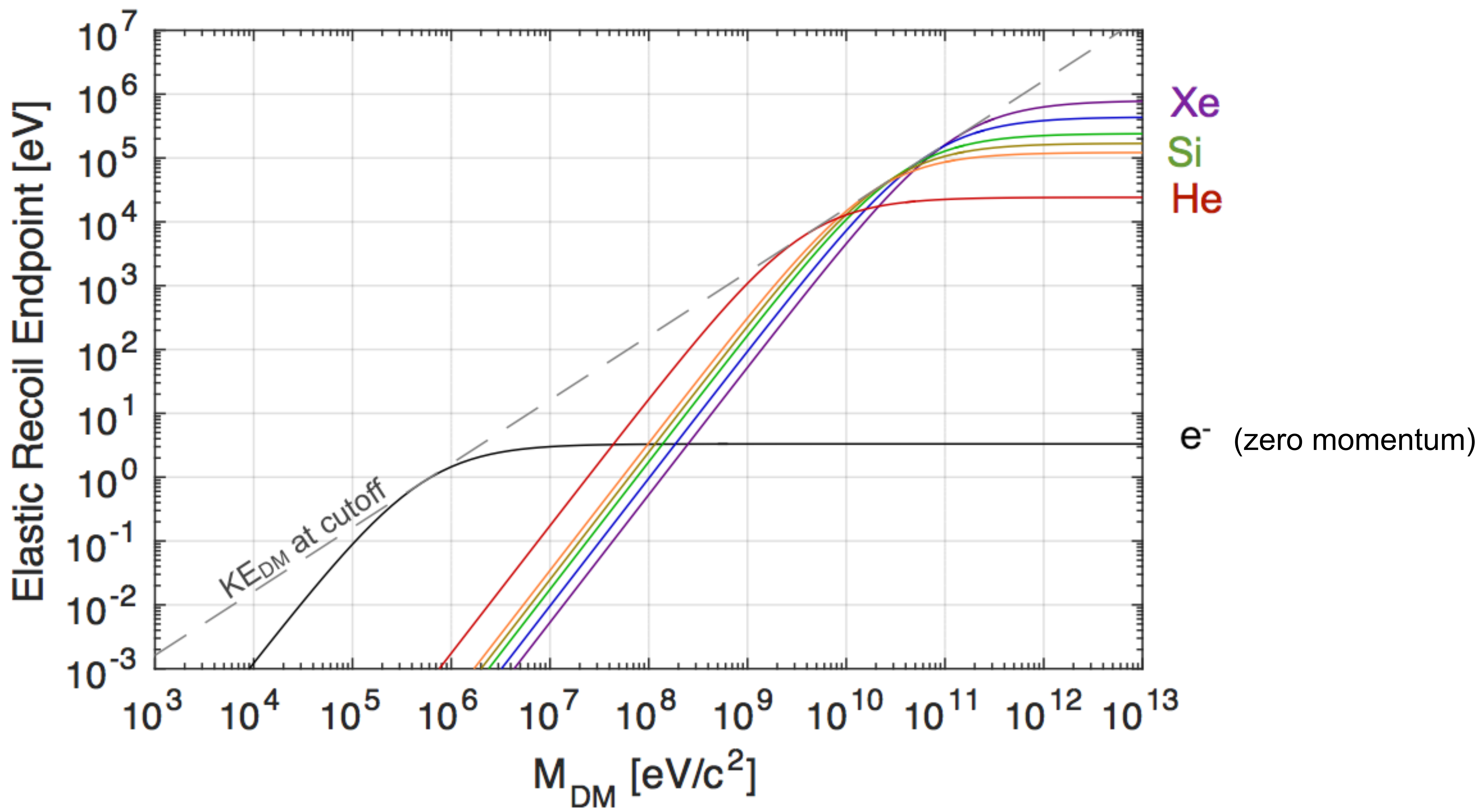
# the challenge: low-mass dark matter has a very small $mv^2$

GeV mass
-> keV KE

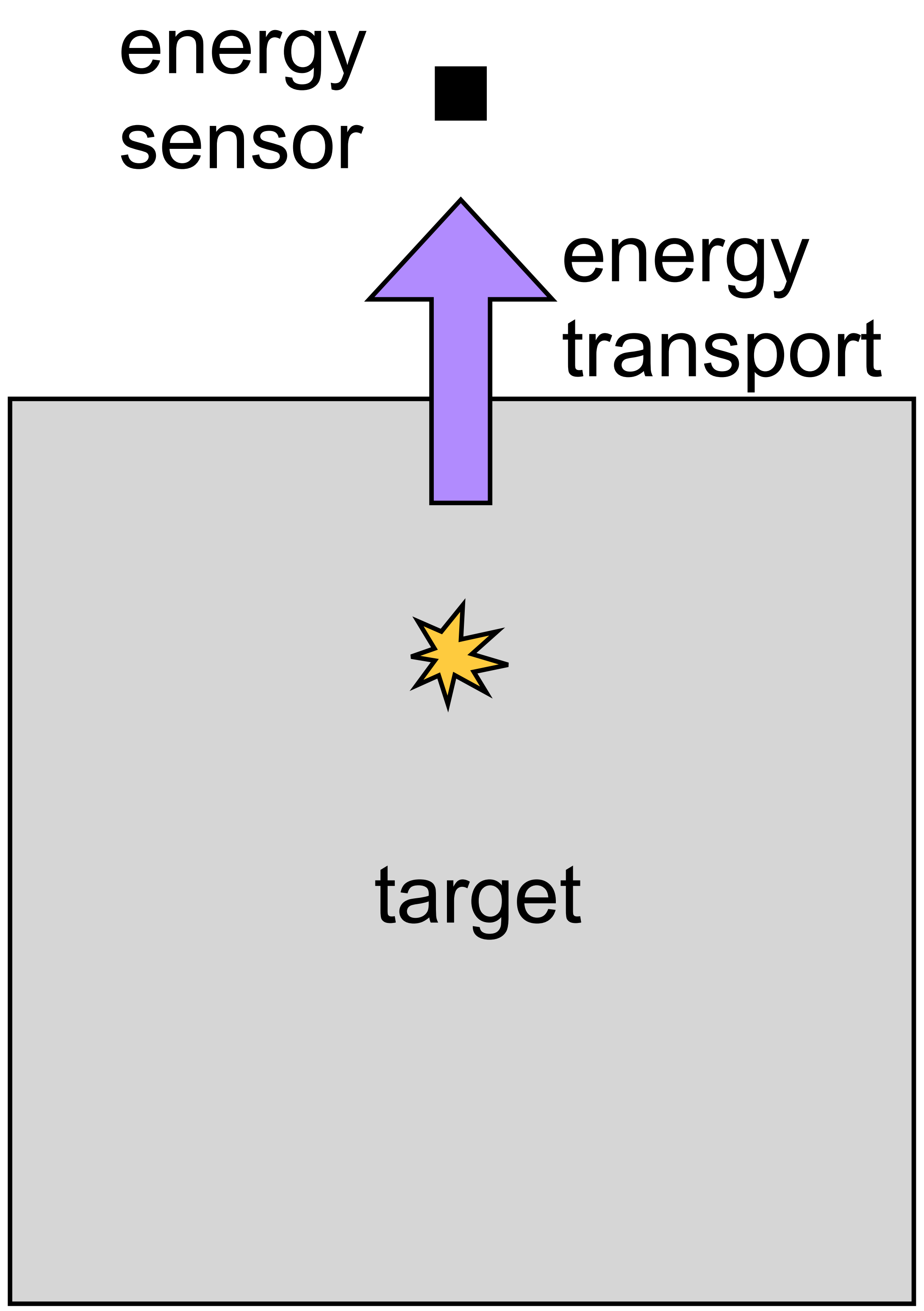
MeV mass
-> eV KE

keV mass
-> meV KE

(alternative: absorption, use rest mass energy)



# the challenge: macroscopic target mass, microscopic sensor



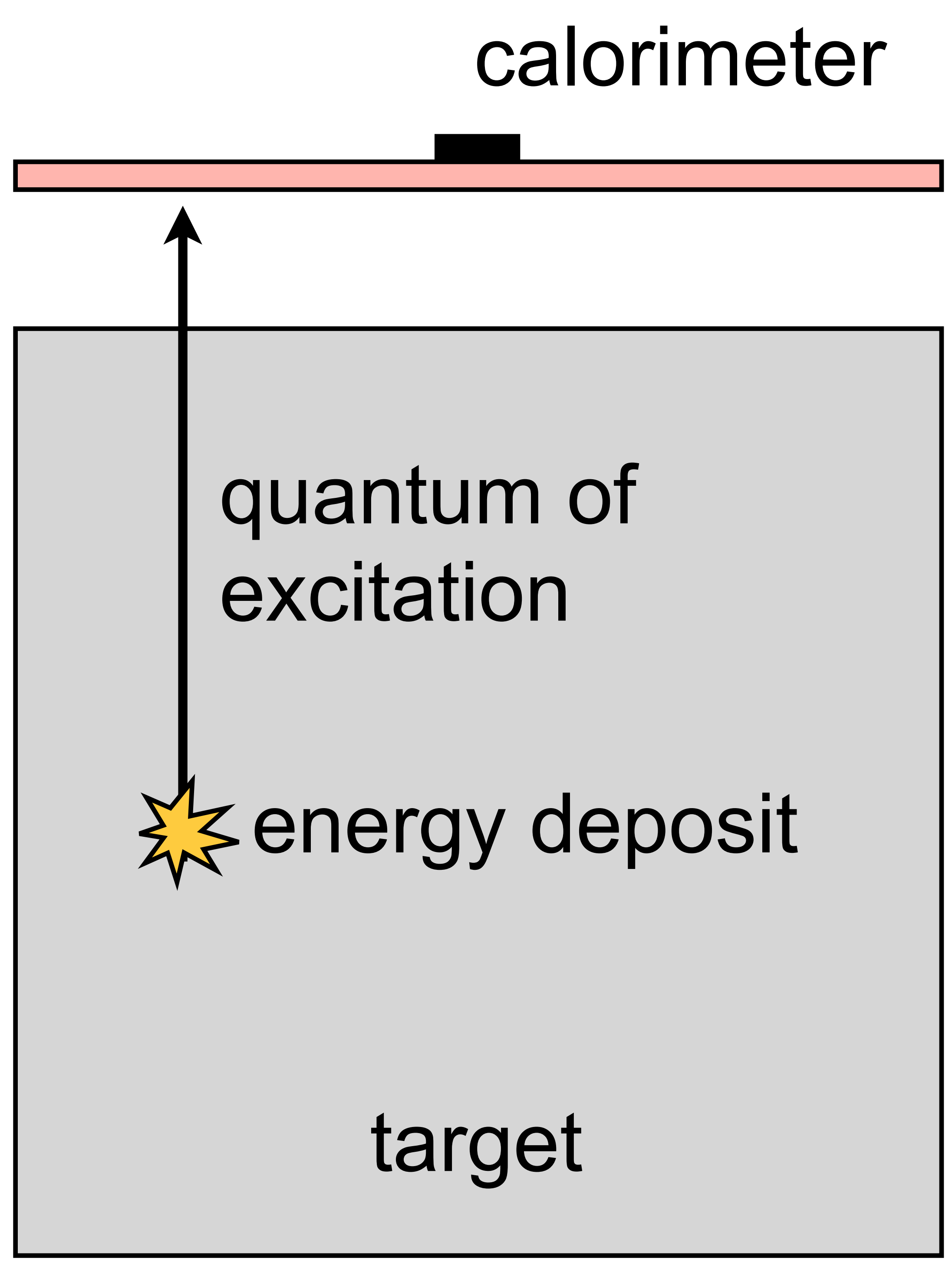

'micro' calorimetry: benefit from tiny heat capacity

TESs are a mature technology:
  Bare TES noise not far from theoretical limitations

TESs coupled to small absorbers
  Also a mature technology (x-ray calorimetry, CMB,...)

TES coupling to a massive absorber:
  NOT a mature technology
  Still orders of magnitude from theoretical limitations
  Helped by making absorber smaller (ie, by cheating)

# a general-purpose detector technology:
# large collection area with sub-eV energy threshold

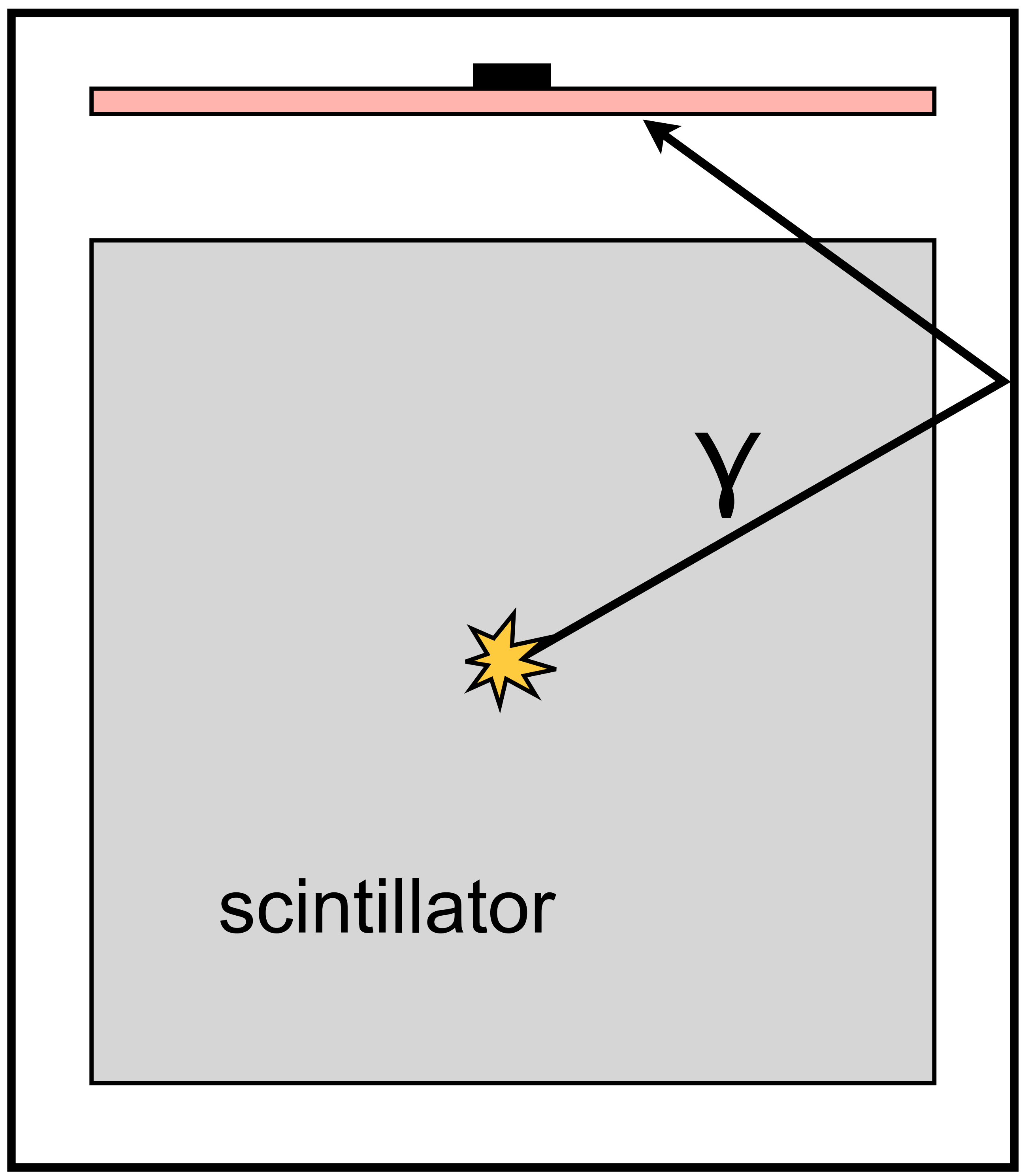



1) separate the target and the calorimetry

2) couple the calorimetry to a 2D collector
   smaller ‘absorber’ seen by TES
   side benefit: easy fab

3) need excitation quanta that can jump the target-collector gap

# large area calorimeters as photon sensors

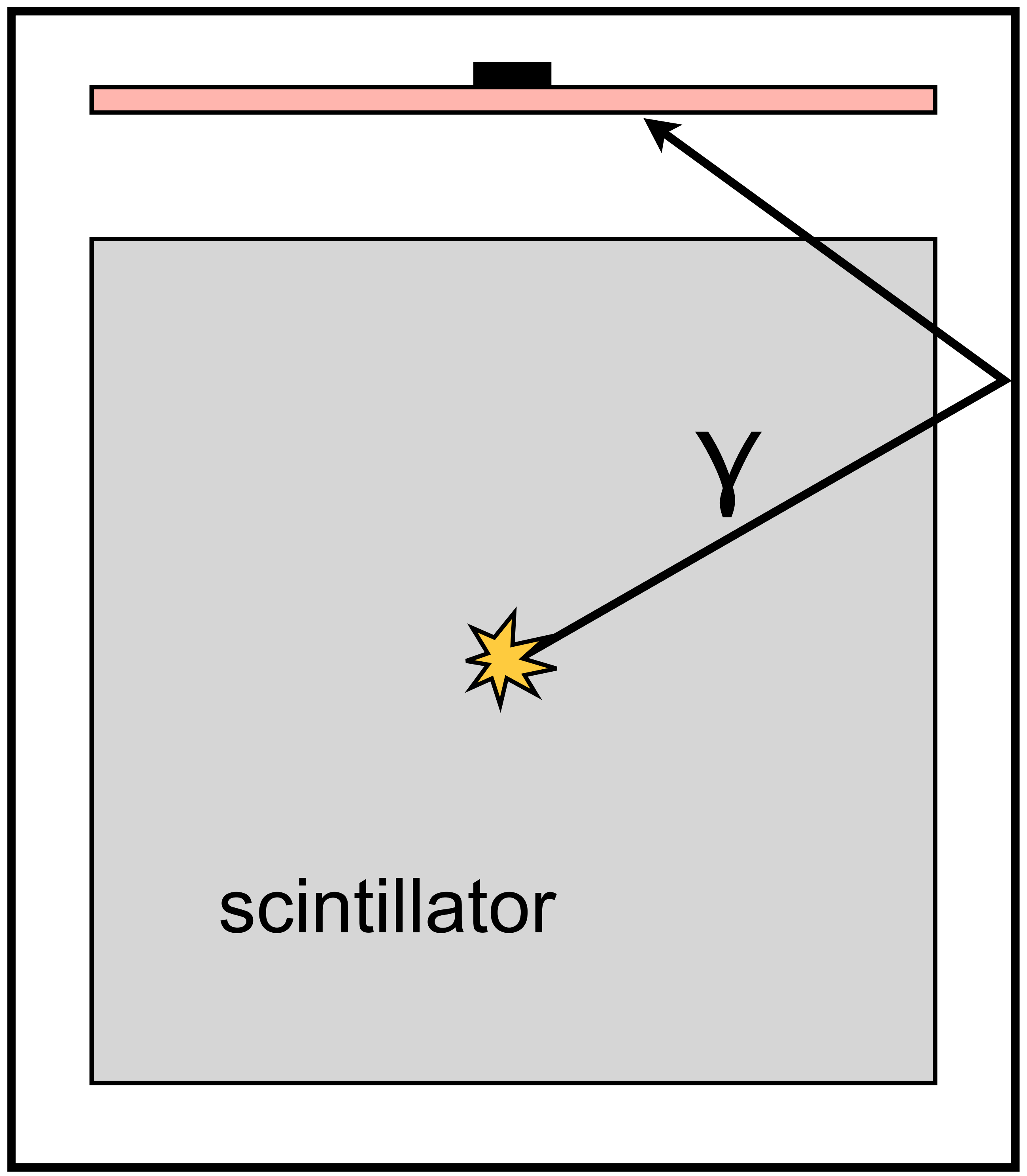



This device is already in use.

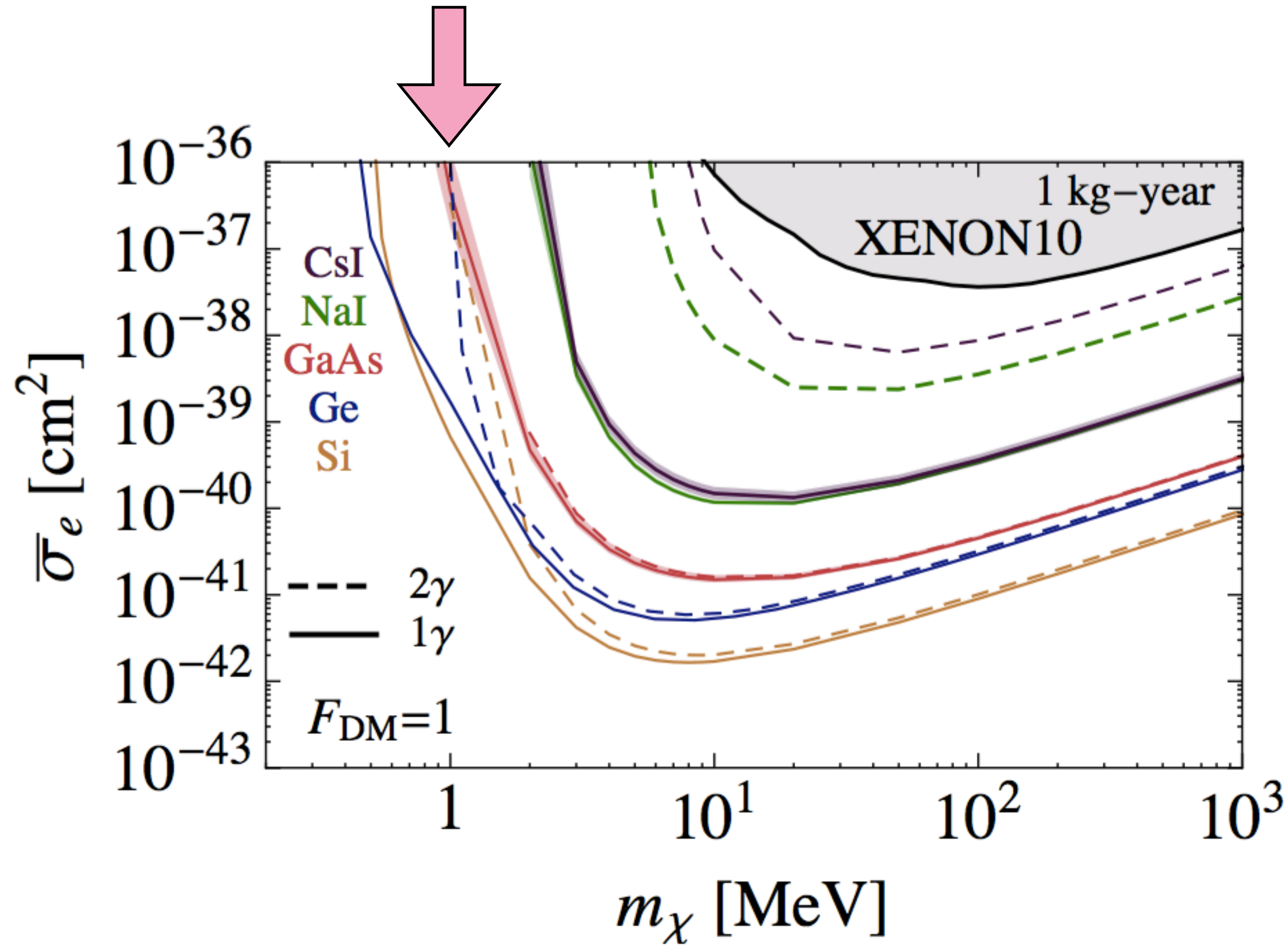
CRESST: 30mm x 30mm Si wafer: **σ = 8.5 eV**
arXiv:0809.1829

next-generation 0vbb
wafer-calorimeter adds a signal for rejection of backgrounds: alphas and multiple-scatters

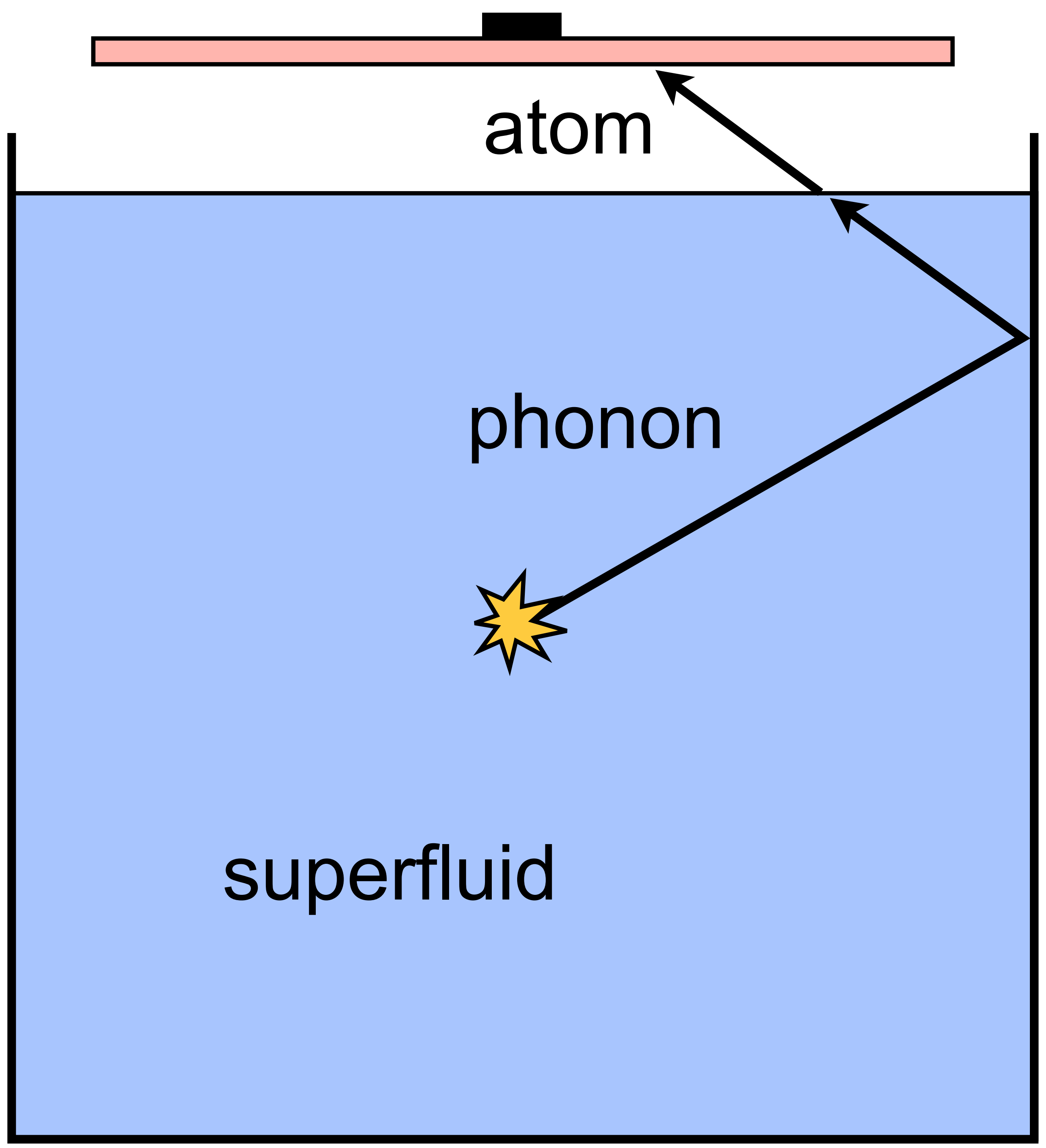
# large area calorimeters as photon sensors




goal: ~eV threshold
eg, photon-counting regime
-> DM mass threshold: ~1 MeV



# large area calorimeters as 4He atom sensors



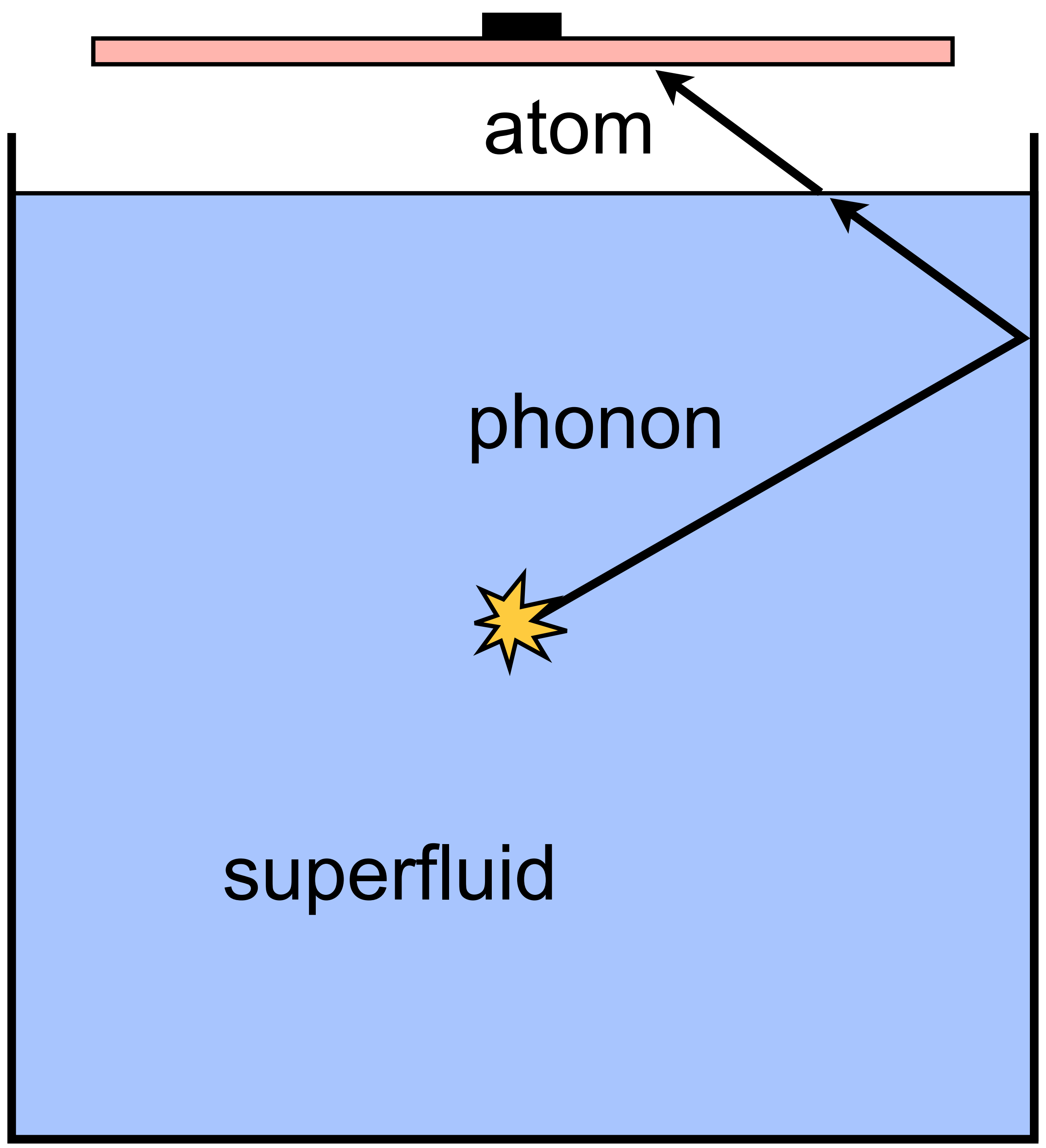

superfluid 4He:  ~1meV-scale phonons and rotons

quantum evaporation
one phonon  ->  one free atom

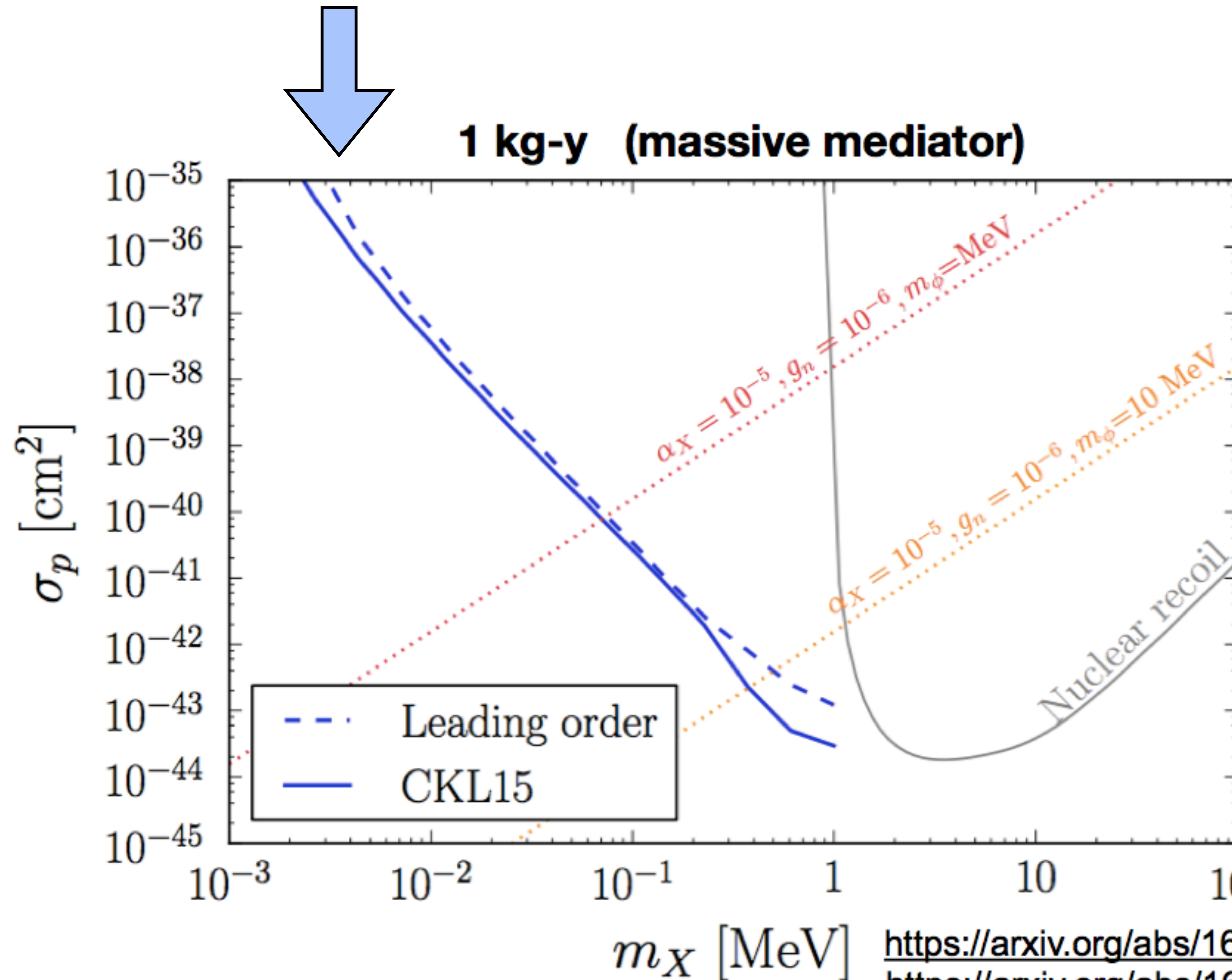
gain via atom adsorption
van der Waals attraction to calorimeter
10meV on Si      40meV on polar surface

example:
**1 eV recoil** (endpoint of 1 MeV dark matter spectrum)
➜ ~1000 meV-scale phonons and rotons
➜ (1000 atoms)x(40meV)x(efficiency)
➜ **40eV on calorimeter (x efficiency)**

# large area calorimeters as 4He atom sensors

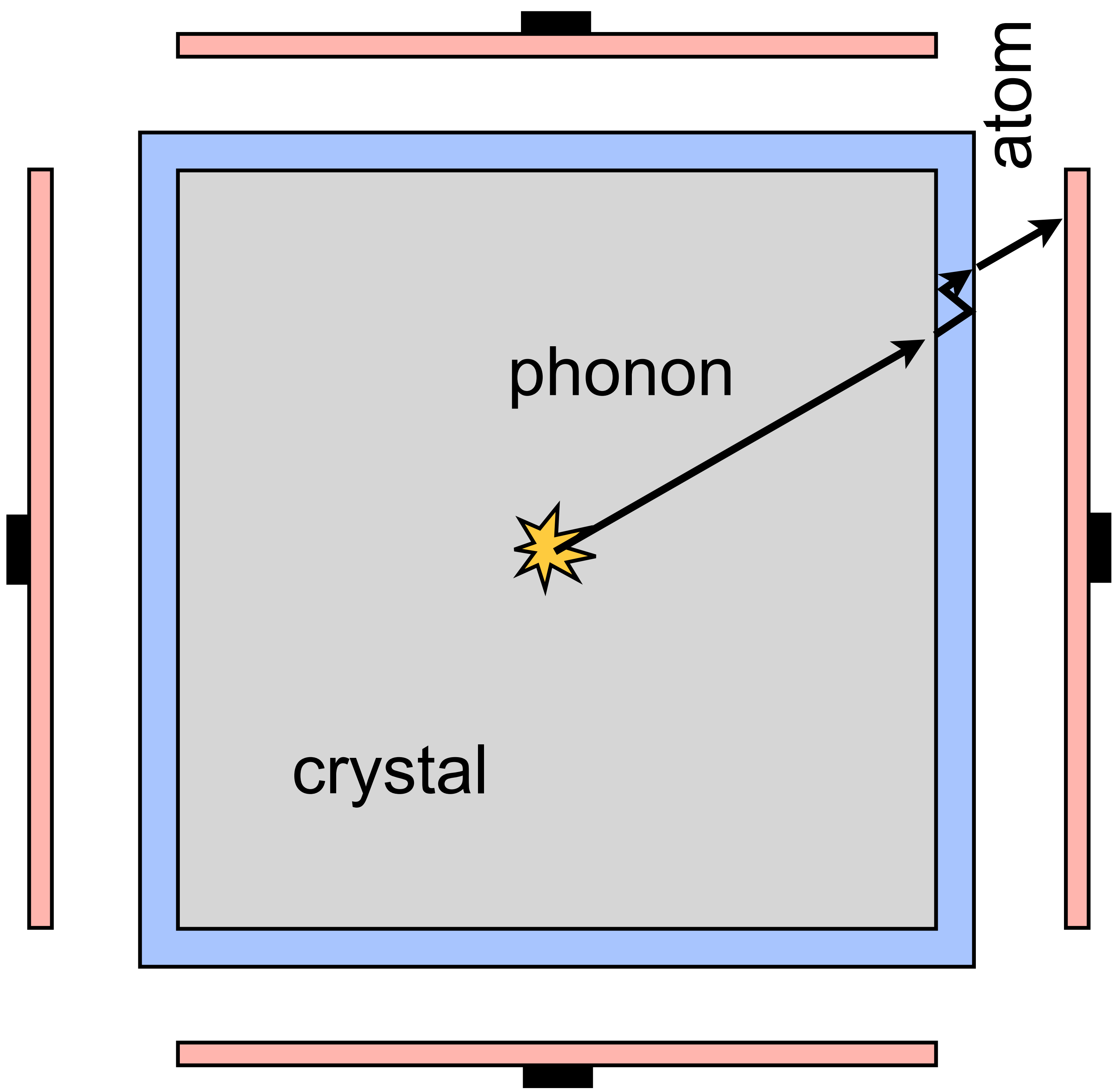



trick: use diagrams with off-shell virtual phonons
result: keV-scale mass threshold




https://arxiv.org/abs/1604.08206
https://arxiv.org/abs/1611.06228

# large area calorimeters as 4He atom sensors

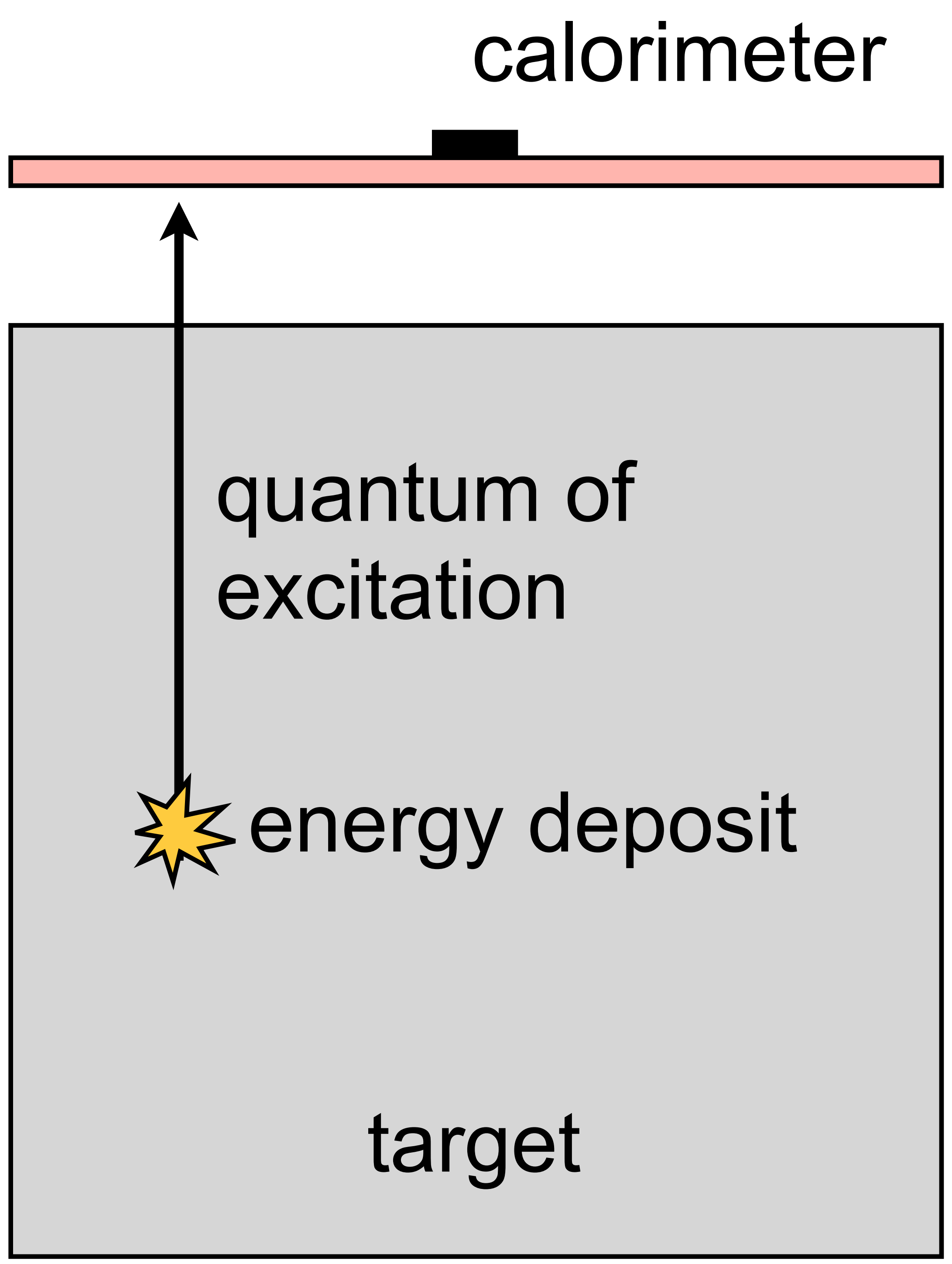



'generalized' evaporation-based detector

coat any phonon-carrying target mass with 4He film

con: more interfaces
pros: swappable targets, natural 4pi coverage

# summary




| application | calorimeter threshold | dark matter mass threshold |
|---|---|---|
| 0vbb | ~50eV | |
| photon-counting | ~1eV | ~1MeV |
| evaporation-counting | ~10meV | ~1keV |