

sub-GeV Dark Matter with Scintillating Targets

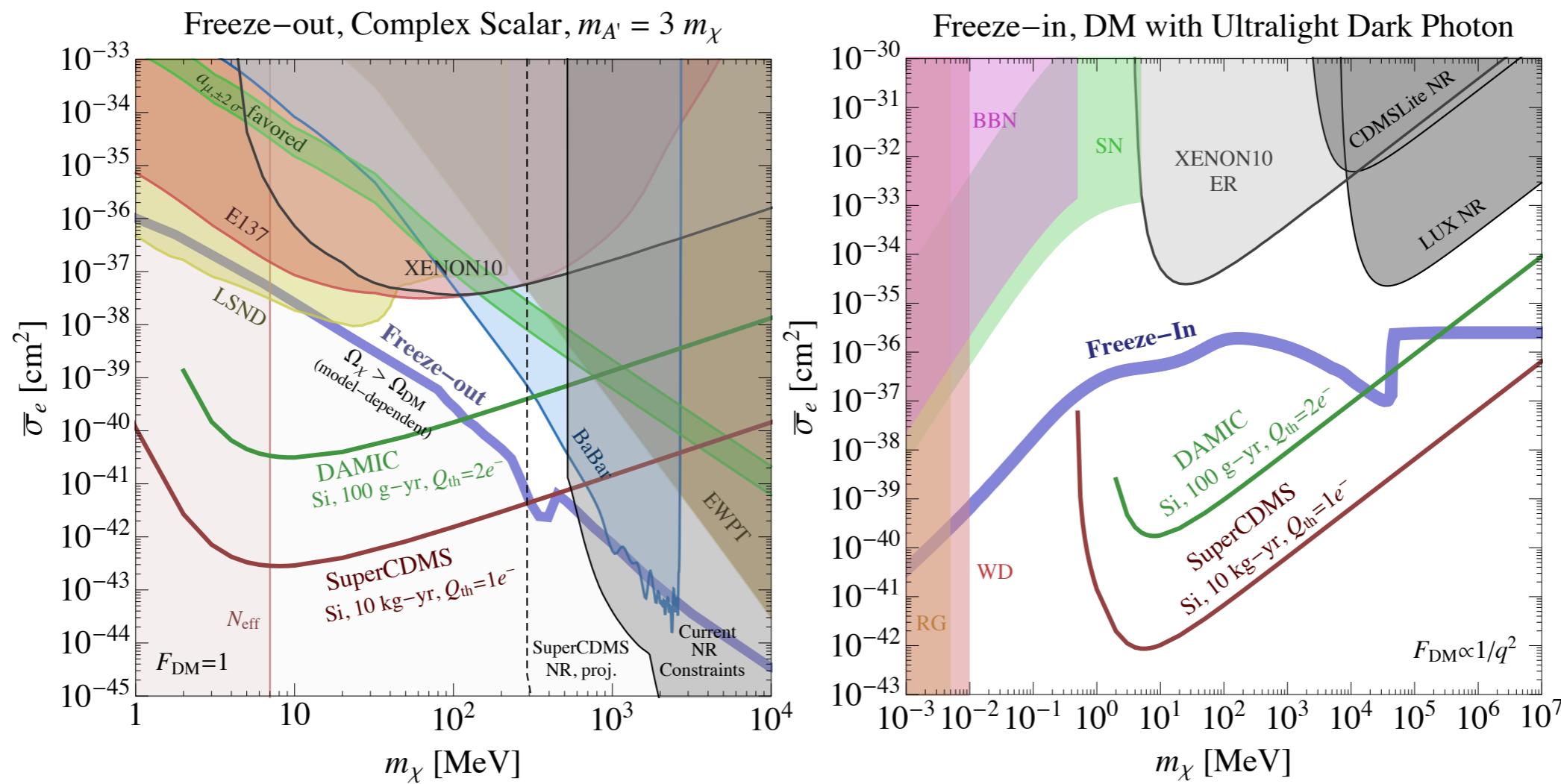
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April 29, 2016

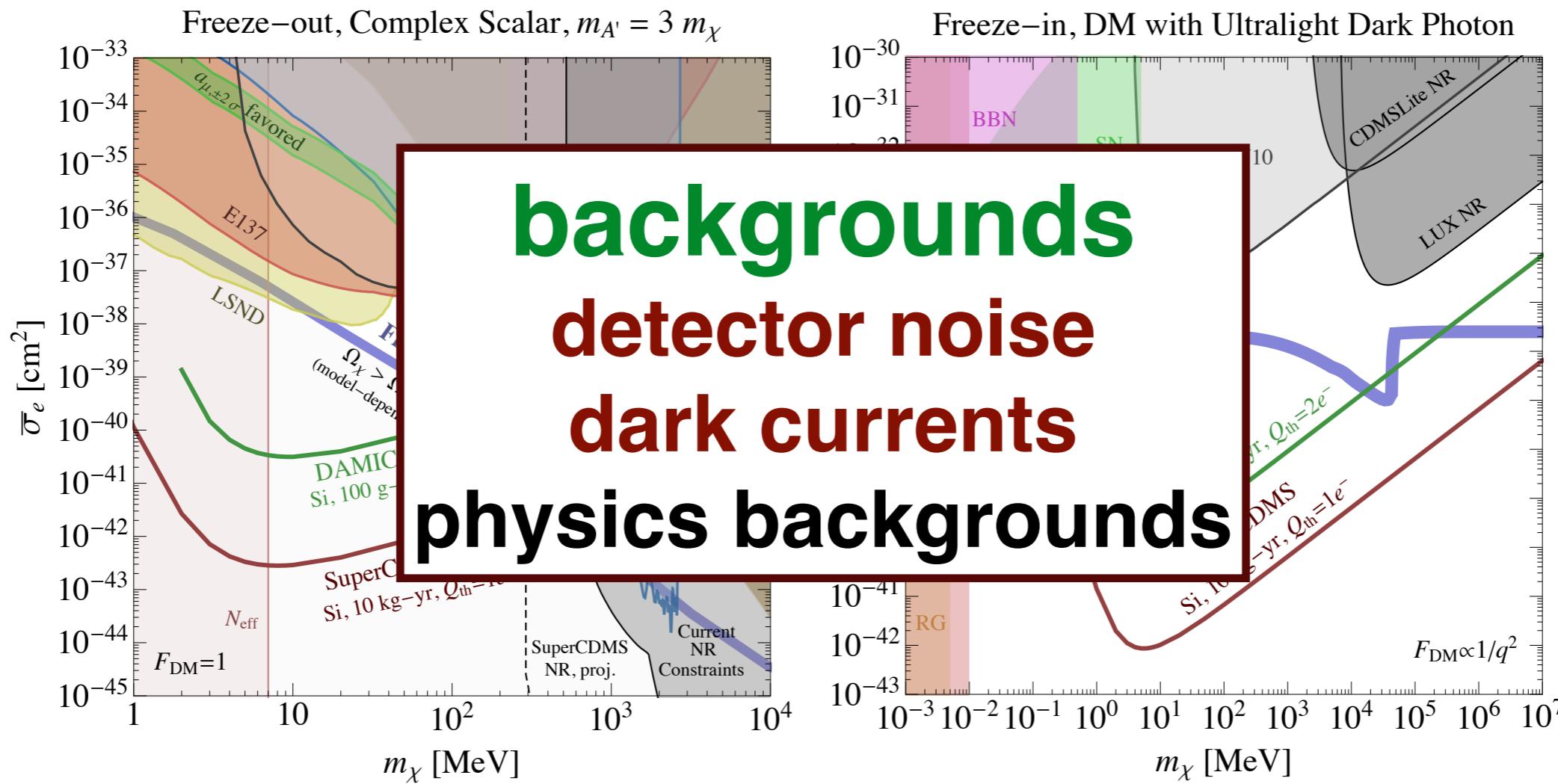
sub-GeV DM direct detection with semiconductors

1509.01598



sub-GeV DM direct detection with semiconductors

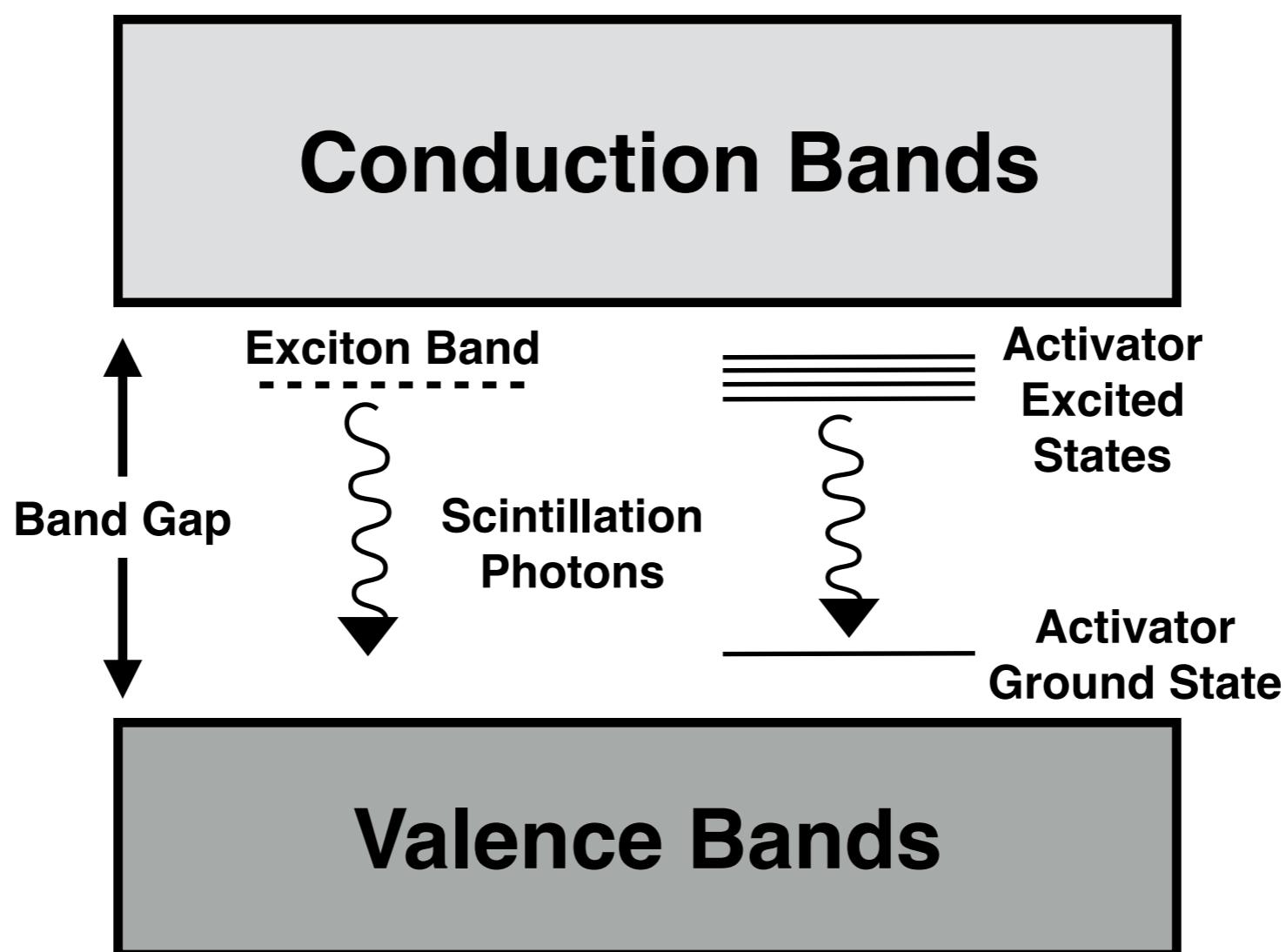
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single photon detection
with scintillating targets

scintillators

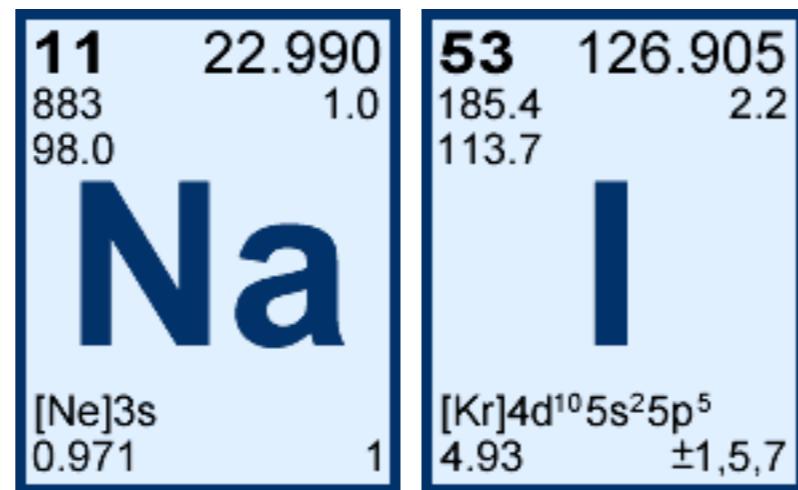
A **scintillator** is a material that, when struck by an incoming particle, absorb its energy **re-emits** the absorbed energy in the form of **light**



figures of merit

- fraction of electrons in crystal that are in valence bands
- density: number of electrons/cubic cm
- band gap: not too large
- scintillation efficiency: high at low temperatures

I: sodium iodide



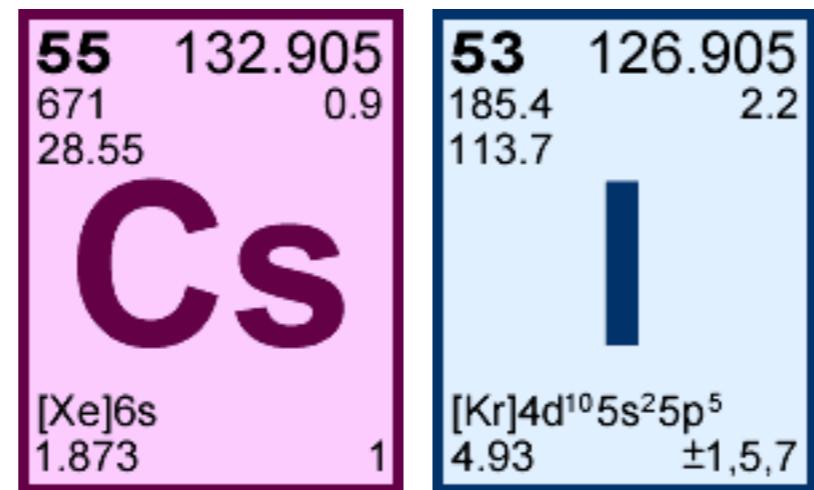
The image shows two adjacent periodic table entries. The left entry is for Sodium (Na), which has atomic number 11, an atomic mass of 22.990, and a density of 0.971 g/cm³. It also lists ionization energies of 883 and 98.0 kJ/mol. The right entry is for Iodine (I), which has atomic number 53, an atomic mass of 126.905, and a density of 4.93 g/cm³. It also lists ionization energies of 185.4 and 113.7 kJ/mol. The symbol for Iodine is a vertical bar.

11	22.990
883	1.0
98.0	
Na	
[Ne]3s	
0.971	1

53	126.905
185.4	2.2
113.7	
I	
[Kr]4d ¹⁰ 5s ² 5p ⁵	
4.93	±1,5,7

used in DAMA
5.9 eV band gap
very bright (80 photons/keV)

II: cesium iodide



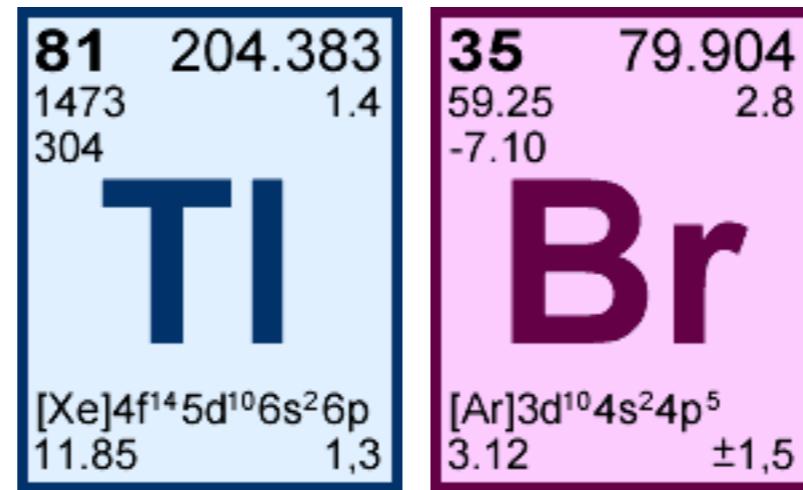
The image shows two adjacent periodic table entries. The first entry for Cs (Cesium) is on the left, featuring a pink background. It contains the atomic number 55, the symbol Cs, the atomic mass 132.905, ionization energies 671 and 28.55 eV, and the electron configuration [Xe]6s¹. The second entry for I (Iodine) is on the right, featuring a blue background. It contains the atomic number 53, the symbol I, the atomic mass 126.905, ionization energies 185.4 and 113.7 eV, and the electron configuration [Kr]4d¹⁰5s²5p⁵. Both entries include a small error bar ±1,5,7.

55	132.905
671	0.9
28.55	
Cs	
[Xe]6s	
1.873	1

53	126.905
185.4	2.2
113.7	
I	
[Kr]4d ¹⁰ 5s ² 5p ⁵	
4.93	±1,5,7

used in CRESST
6.4 eV band gap
even brighter (100 photons/keV)

III: thallium bromide



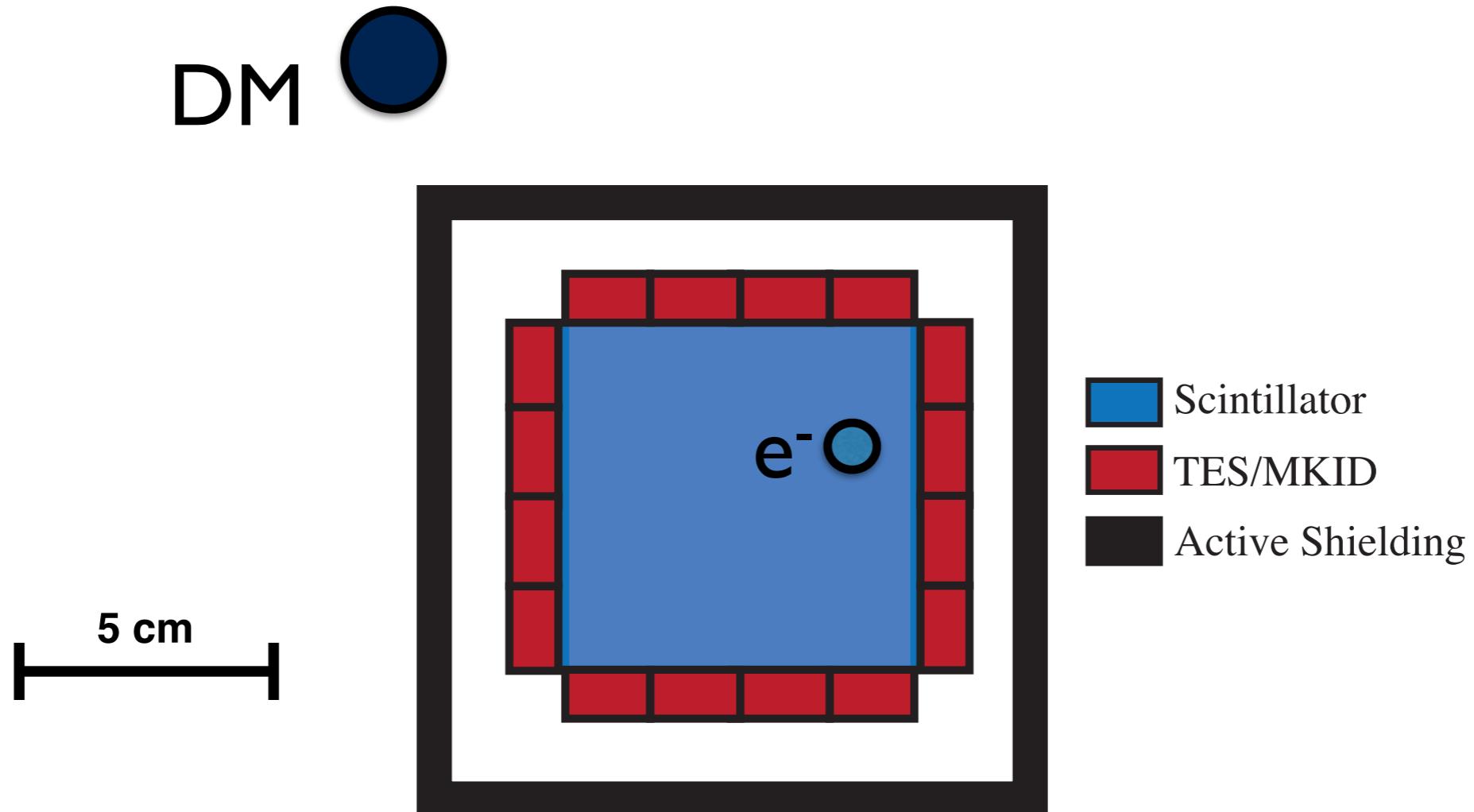
Two periodic table cards side-by-side. The left card is for Thallium (Tl), which has atomic number 81, mass 204.383, ionization energy 1473, electron affinity 304, and electron configuration [Xe]4f¹⁴5d¹⁰6s²6p¹. The right card is for Bromine (Br), which has atomic number 35, mass 79.904, ionization energy 59.25, electron affinity -7.10, and electron configuration [Ar]3d¹⁰4s²4p⁵.

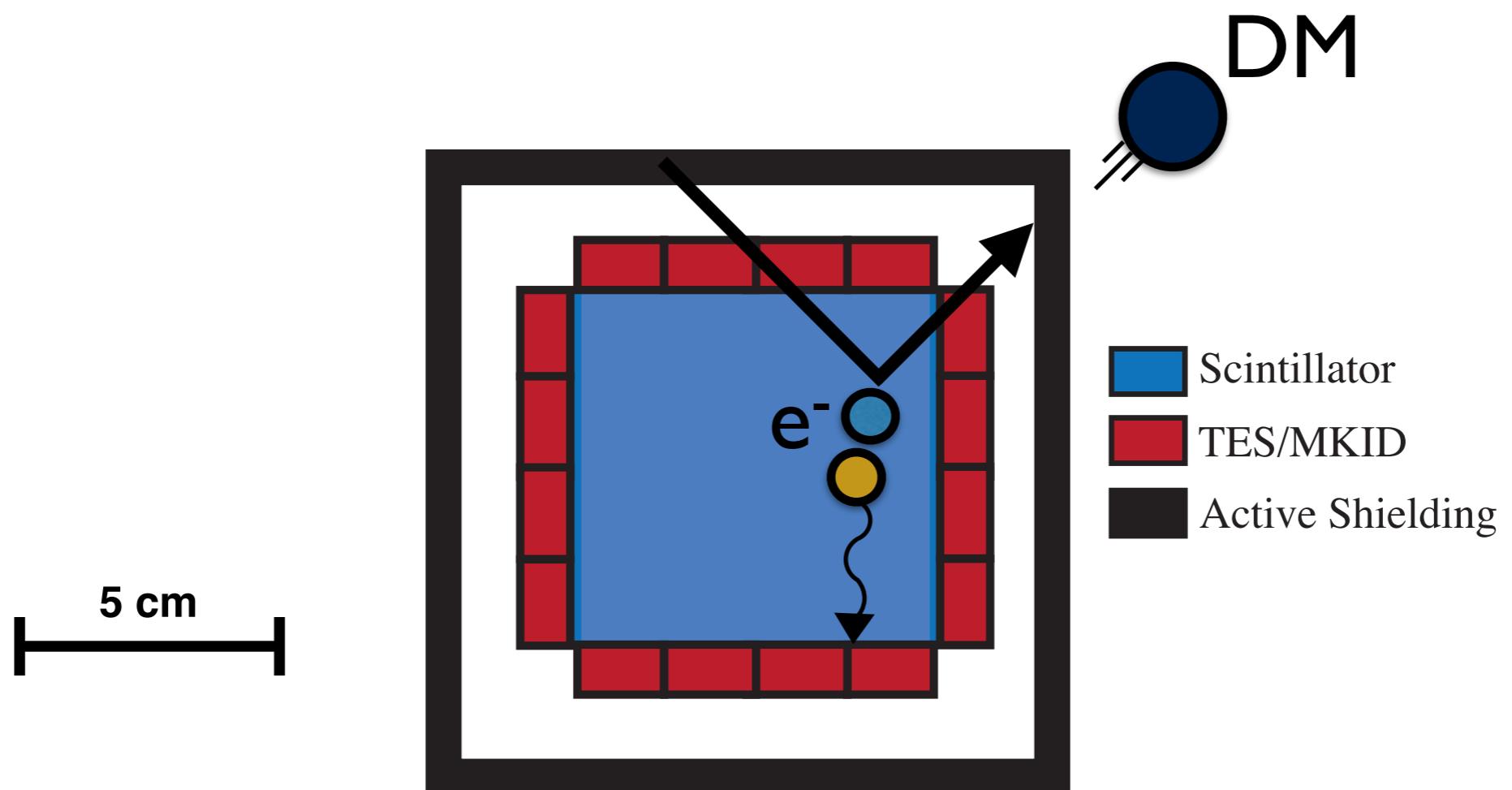
81	204.383
1473	1.4
304	
Tl	
[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ¹	
11.85	1.3

35	79.904
59.25	2.8
-7.10	
Br	
[Ar]3d ¹⁰ 4s ² 4p ⁵	
3.12	±1.5

Can be grown as clear crystals
Very good semiconductor
2.68 eV band gap

*Good scintillator at cryogenic temperatures (40 photons/keV)





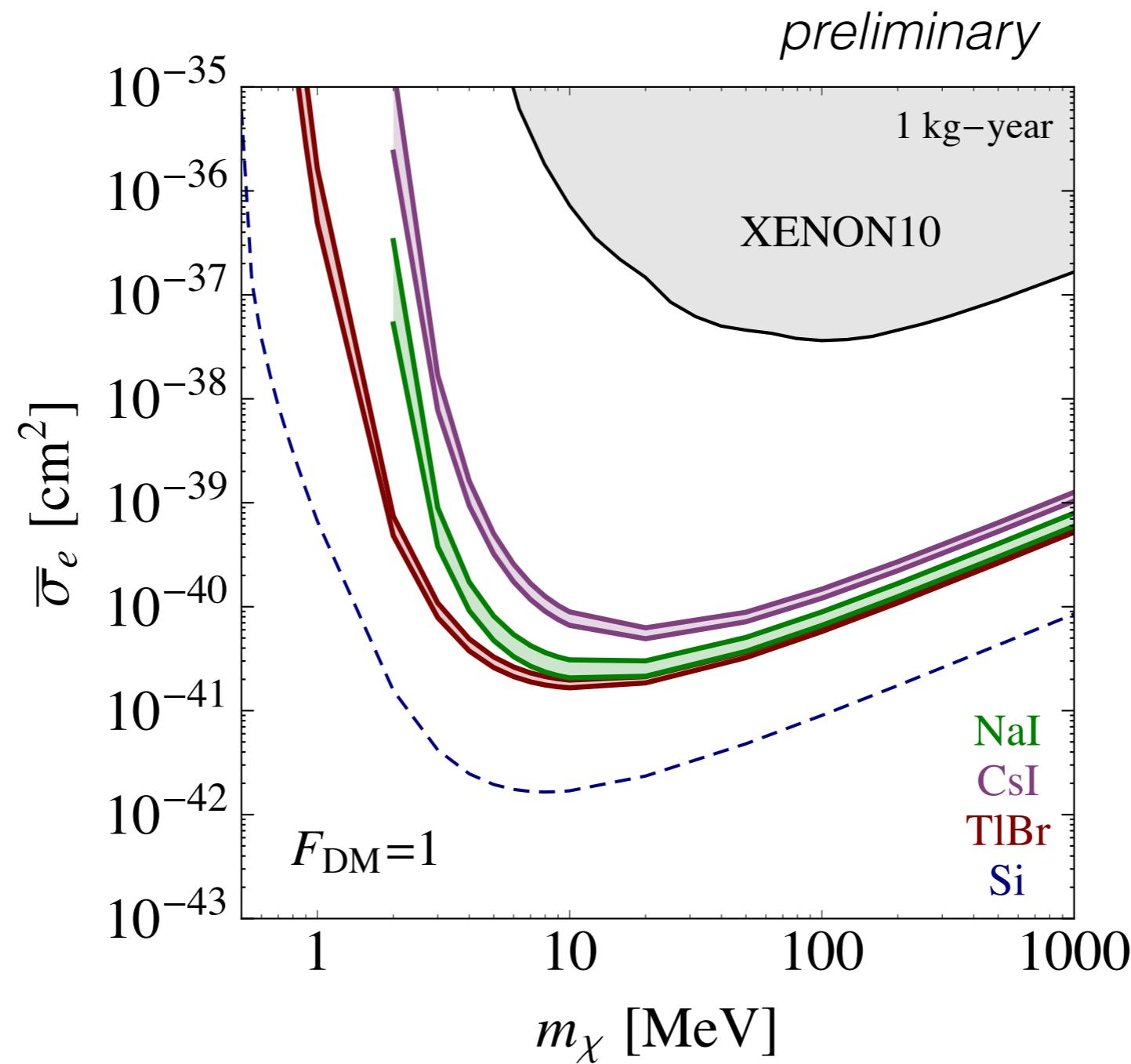
Efficiencies:

NaI 0.95

CsI 1.00

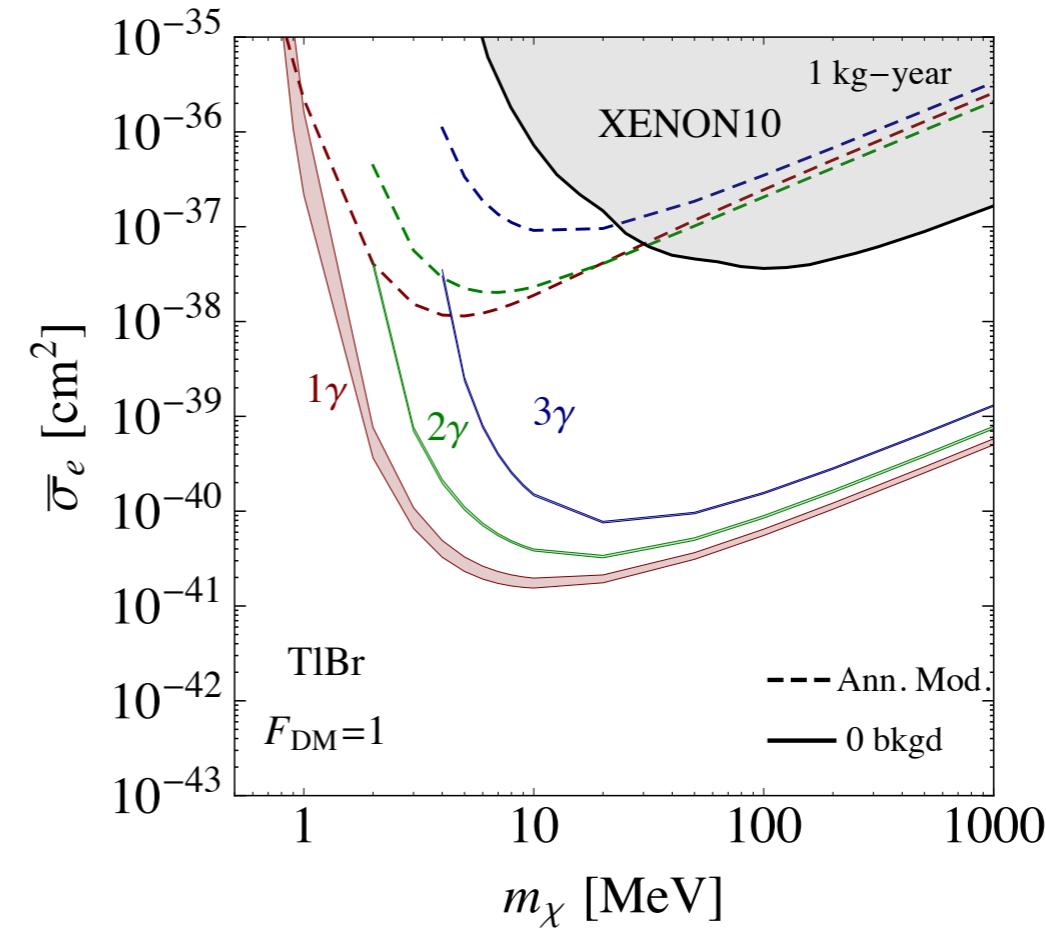
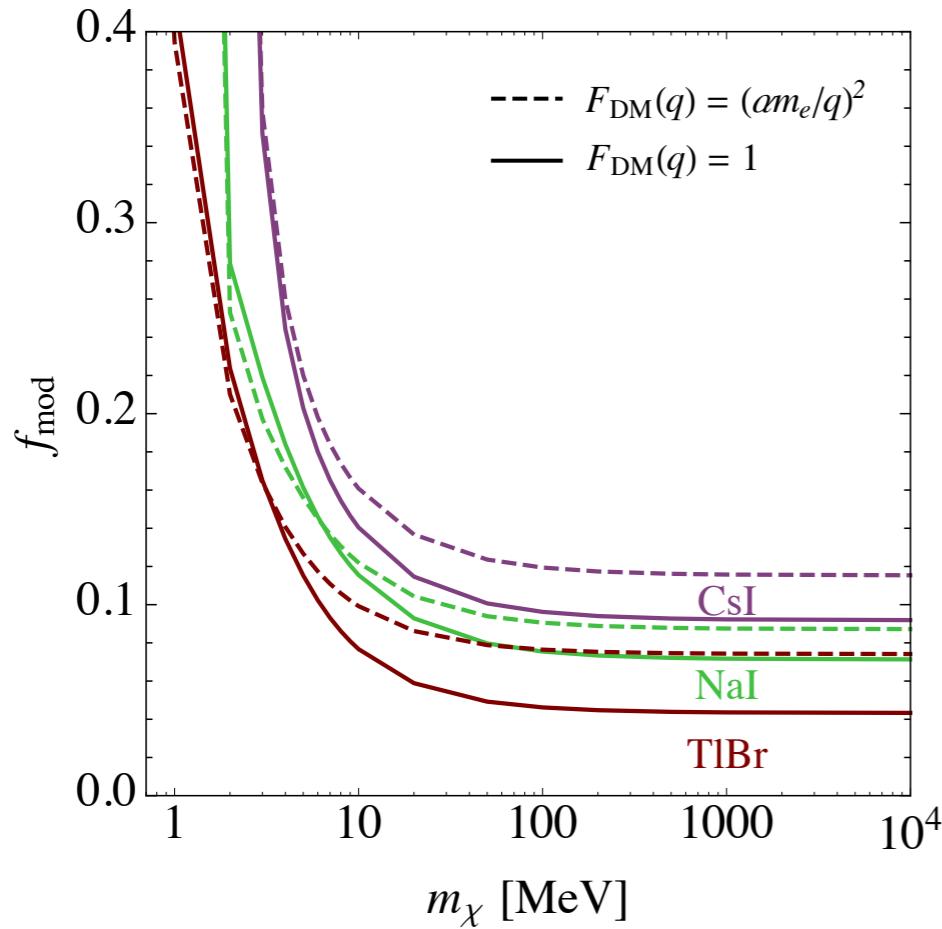
TlBr 0.25

Si 1.00



annual modulation

preliminary



challenges

- growing the crystals
- purity of crystal
- **BACKGROUNDS**

backgrounds

- contaminants in detector material
- TIBr, NaI, CsI have no long lived isotopes
- but Rb, K can be present in trace amounts
- 1 microgram of Rb-87 can produce several single photon events per year