nEXO background reduction for shallower depth I
- Proposed mitigation -

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Which background depends on the site?

Site	Depth [m.w.e.]	Muon flux [/cm² /s]	^{137}Xe produced [atoms/yr]
SNOLAB	6130	3.31e-10	18
SURF	4380	5.09e-9	265
LNGS	2990	3.41e-8	1700
YEMILAB	**2700**	**1.01e-7**	**5035**

The site enters only through the muon rate.

- Everything else — assumed site-independent, as in the site selection AoA study

How ^{137}Xe is made and reduced

(A) Tag gammas, then veto

$\mu + A \rightarrow n + X$

muon → neutrons

$n + {}^{136}\mathrm{Xe} \rightarrow {}^{137}\mathrm{Xe} + \gamma\ (4.0\ \mathrm{MeV})$

① this γ is what you tag

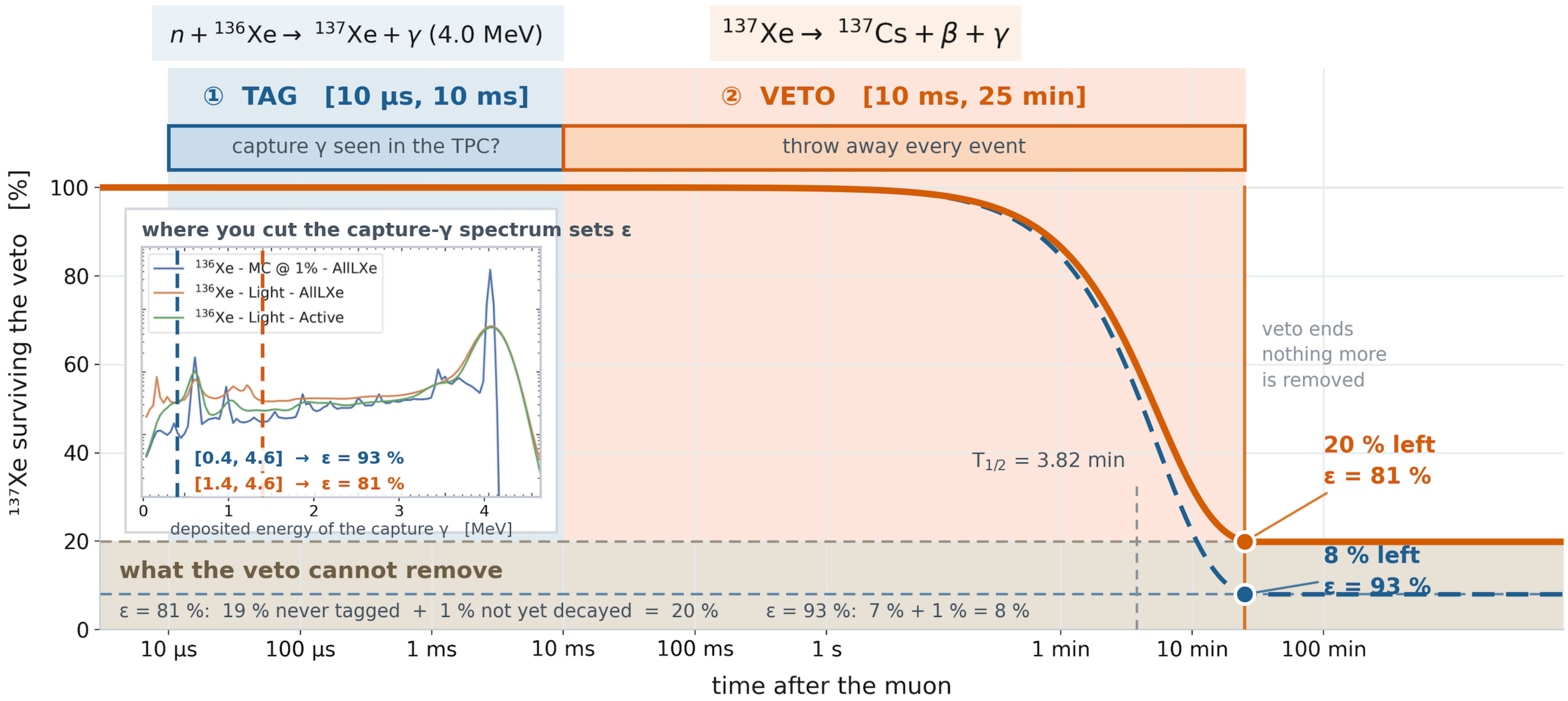
${}^{137}\mathrm{Xe} \rightarrow {}^{137}\mathrm{Cs} + \beta + \gamma$

② Q_β = 4.2 MeV → in ROI

(B) Never let the neutron reach ^{136}Xe:
^{131}Xe mixed into the xenon, ^{10}B outside—
BPE shell, boric acid, or ^{10}B in HFE

➔ design modification needed

How ^{137}Xe is tagged and vetoed



nEXO's AoA study at LNGS

1.4-4.6 MeV
(~81% eff)

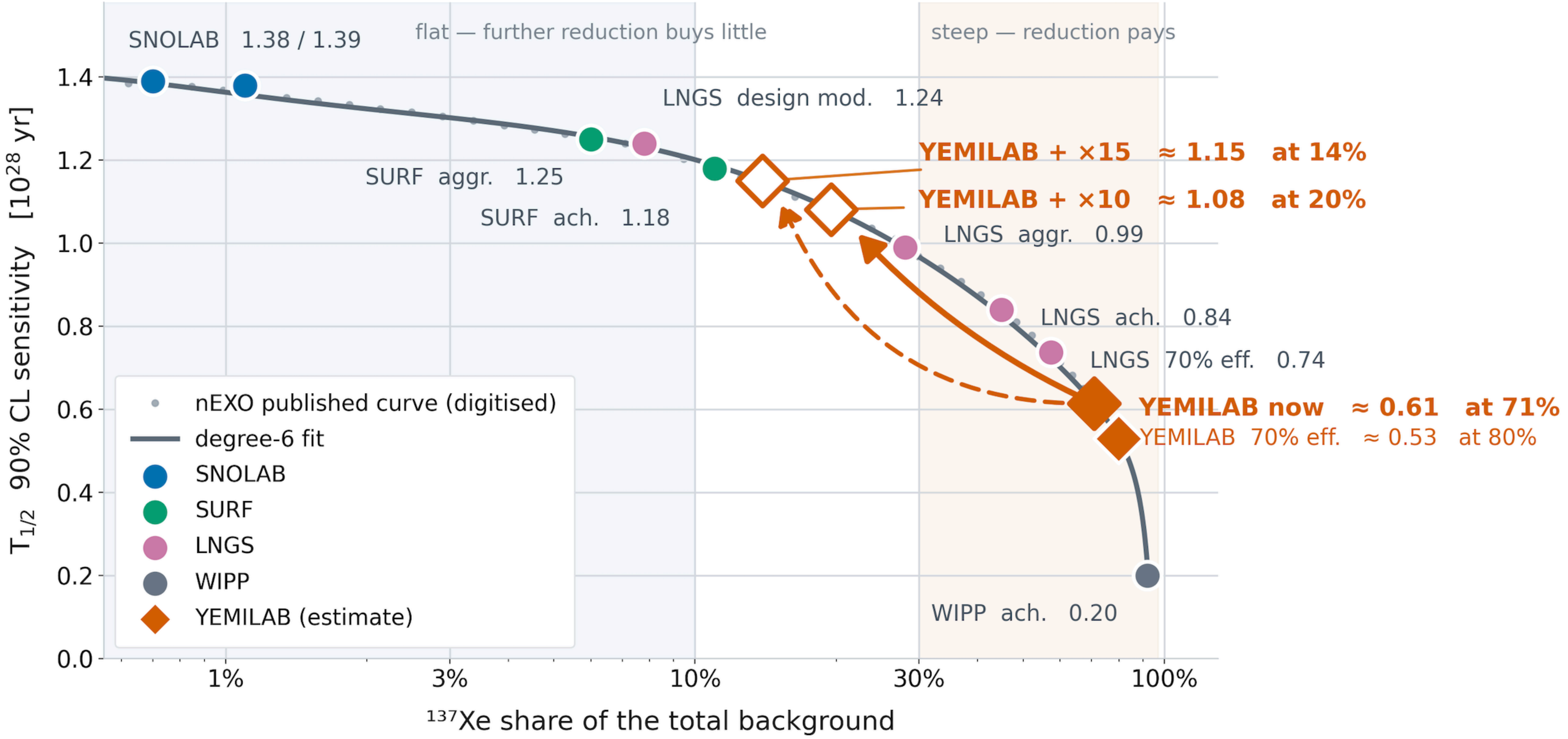
0.4-4.6 MeV
(~93% eff)

^{10}B in HFE > 3wt%; dissolving it in HFE is difficult

	Site	Mean ^{137}Xe ROI Bkgd [cts / y]	^{137}Xe Total Background Fraction [%]	Deadtime [days] (% of 10 yrs)	90% CL $0\nu\beta\beta$ Sensitivity [10^{28} y]	Discovery Potential, 3σ [10^{28} y]
Achievable	SNOLAB	0.006	1.1%	1.6 (0.04%)	1.38	0.77
	LNGS	0.44	45%	148 (4%)	0.84	0.45
	SURF	0.07	11%	23 (0.6%)	1.18	0.64
	WIPP	6.5	92%	1770 (48%)	0.2	nc
Aggressive	SNOLAB	0.004	0.7%	1.9 (0.05%)	1.39	0.80
	LNGS	0.21	28%	178 (5%)	0.99	0.53
	SURF	0.03	6%	28 (0.8%)	1.25	0.70
	WIPP	2.5	82%	2120 (58%)	nc	nc
Design Modification	SNOLAB	Design modifications not needed				
	LNGS	0.046	7.8%	15 (0.4%)	1.24	0.68
	SURF	Design modifications not needed				
	WIPP	0.65		177 (5%)		

Sensitivity set by ^{137}Xe share

Where Yemilab sits



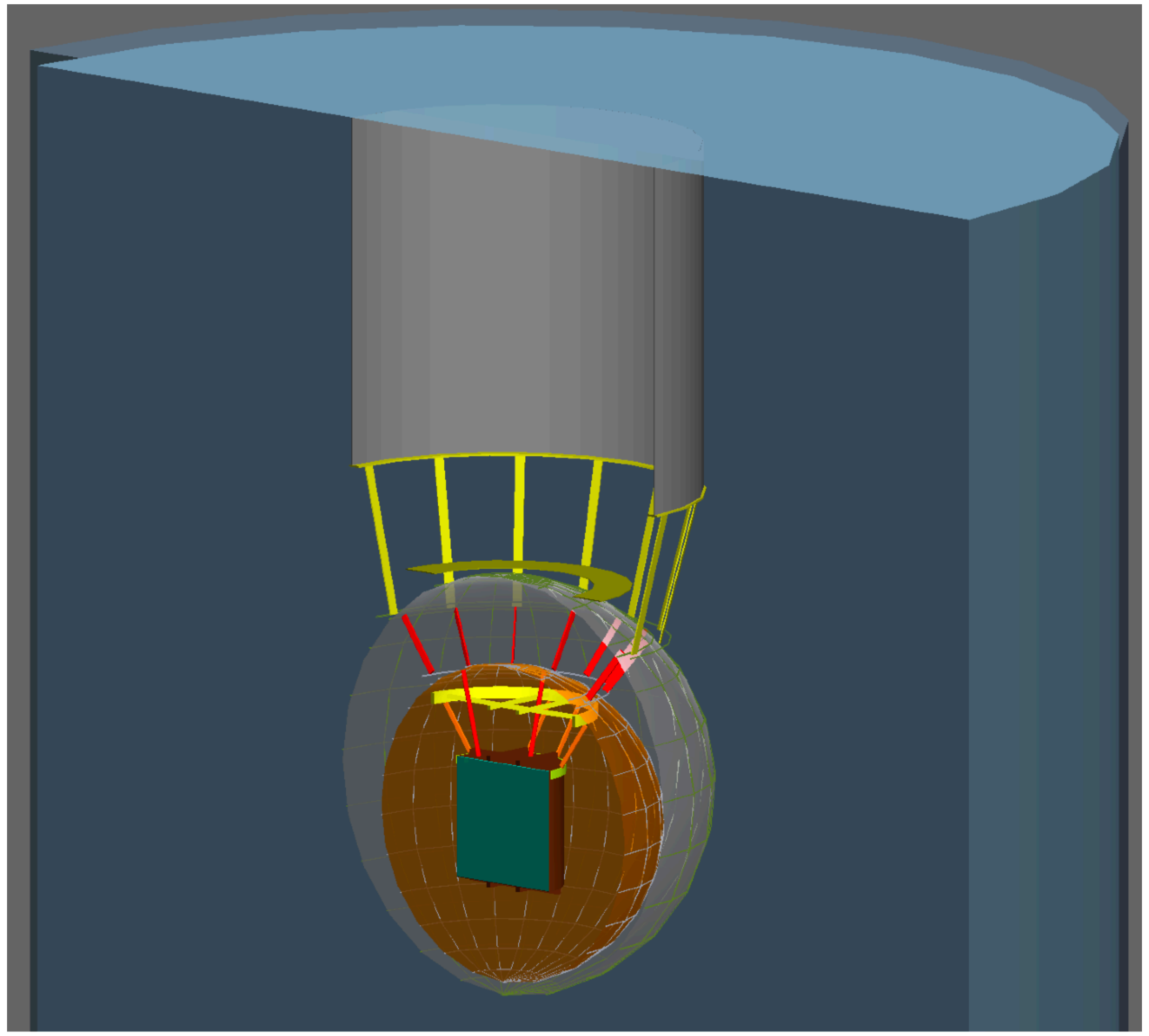
(1) Adding ^{131}Xe

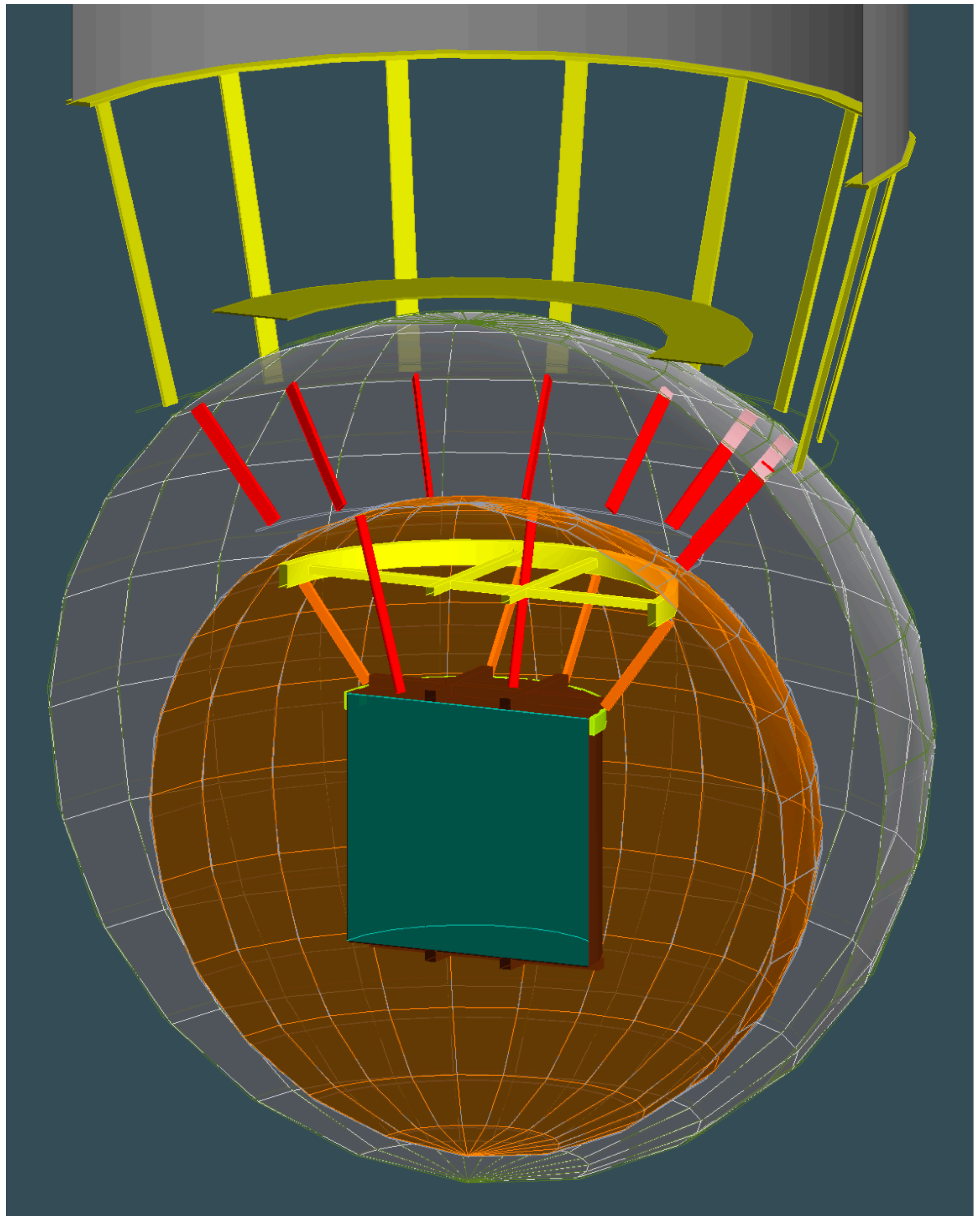
isotopic ratios and expected ~22

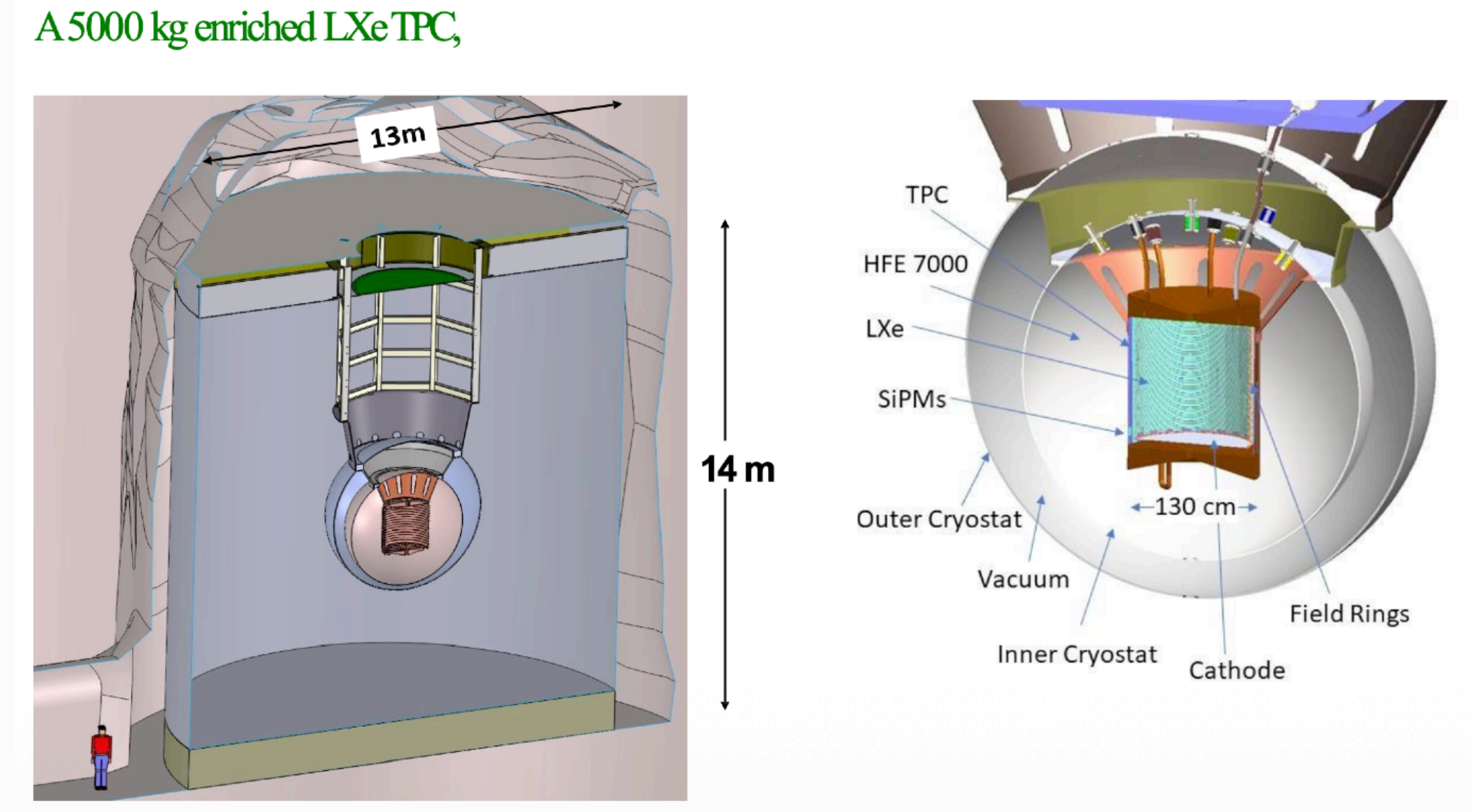
		Baseline	Proposed
LXe Composition			
	^{136}Xe (σ = 0.26 b)	90.0%	84.3%
	^{134}Xe (σ = 0.26 b)	10.0%	9.5%
	^{131}Xe (σ = 90 b)	—	5.6%
	^{132}Xe (σ = 0.45 b)	—	0.6%
Theoretical Capture Fraction			
	σ_eff (LXe)	0.260 barn	5.007 barn
	^{131}Xe + n → ^{132}Xe	—	95.3%
	^{136}Xe + n → ^{137}Xe	90.0%	4.1%
	^{134}Xe + n → ^{135}Xe	10.0%	0.5%
	^{132}Xe + n → ^{133}Xe		0.1%
	Predicted suppression	1×	90.0% / 4.1% = 22×

^{131}Xe gives 6.8x, not 22x

Geant4, full nEXO geometry, 10000 330 GeV muons





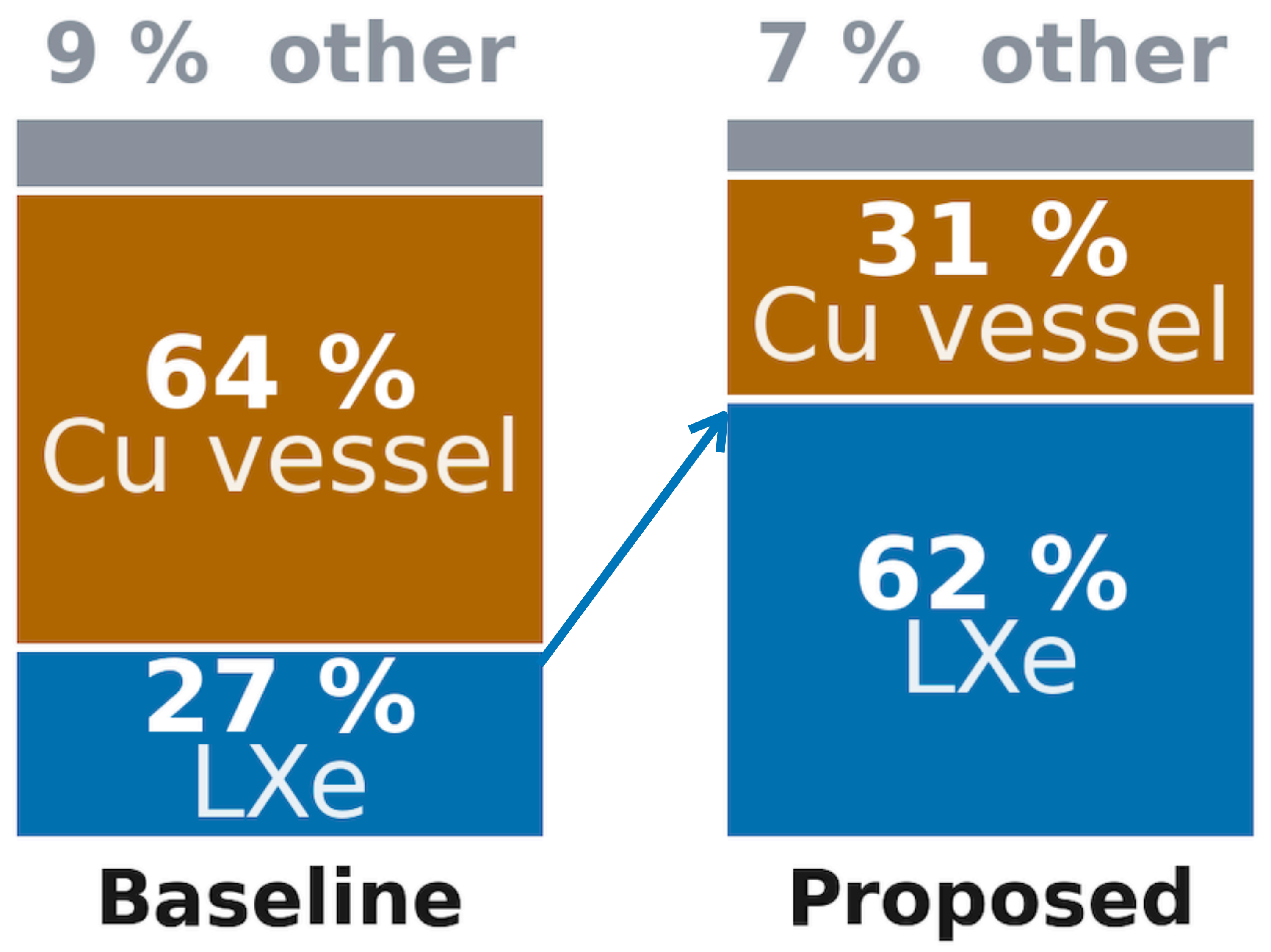


Why 22x becomes 6.8x

Where the neutrons are captured

× 0.44

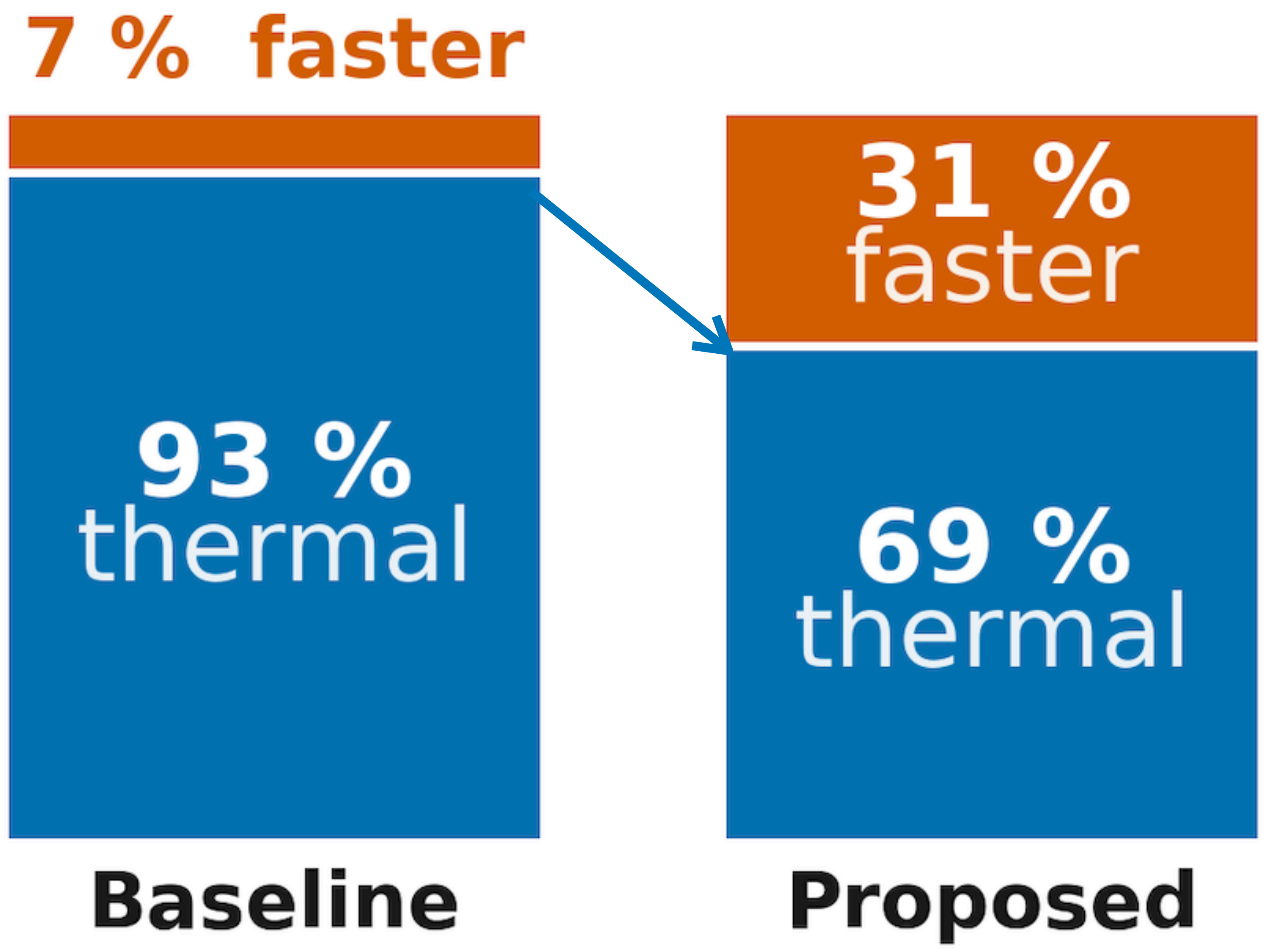
LXe share 27 % → 62 %



Which neutrons make the ^{137}Xe

× 0.74

thermal (< 1 eV) share 93 % → 69 %



$$22 \times 0.44 \times 0.74 \approx 7$$

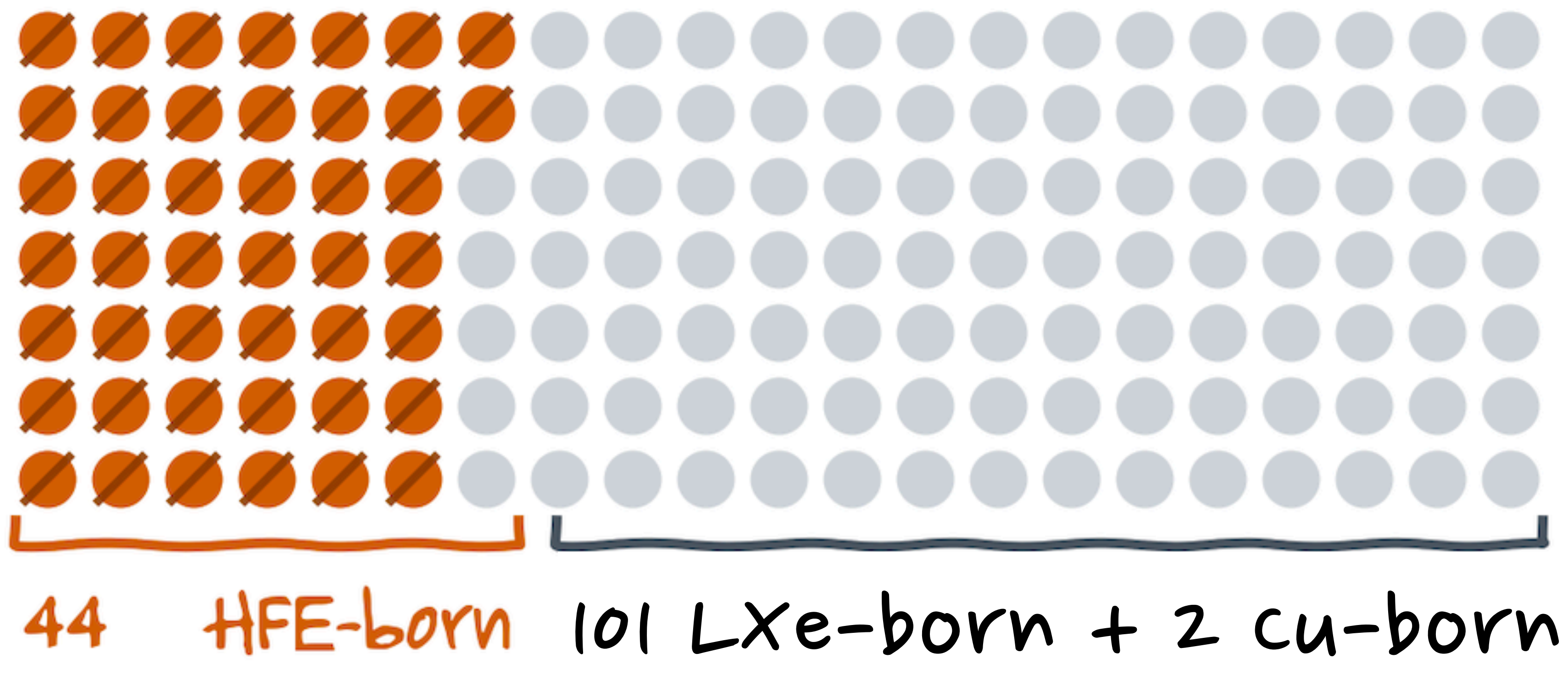
Simulation: 1005 ^{137}Xe / 147 ^{137}Xe = 6.8

(2) 30% of ^{137}Xe-producing neutrons are born in the HFE

9.8x if those are absorbed

	Baseline 1005 ^{137}Xe	Proposed 147 ^{137}Xe
LXe born	54%	69%
HFE born	42%	30%

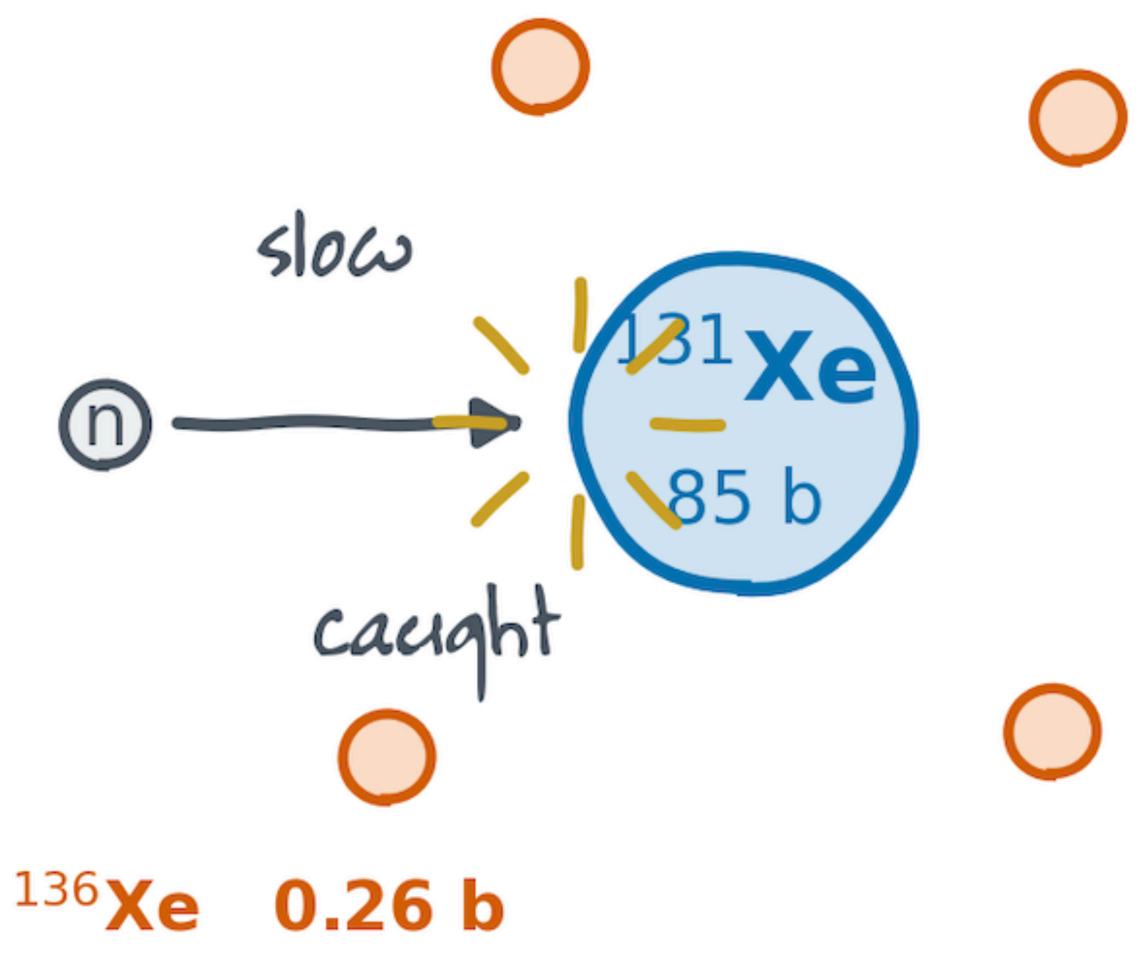
- If the HFE-born neutrons were absorbed, the reduction would be 9.8×: 1005/103 =9.8
- Absorbers: BPE shell or boric acid outside the Cu vessel



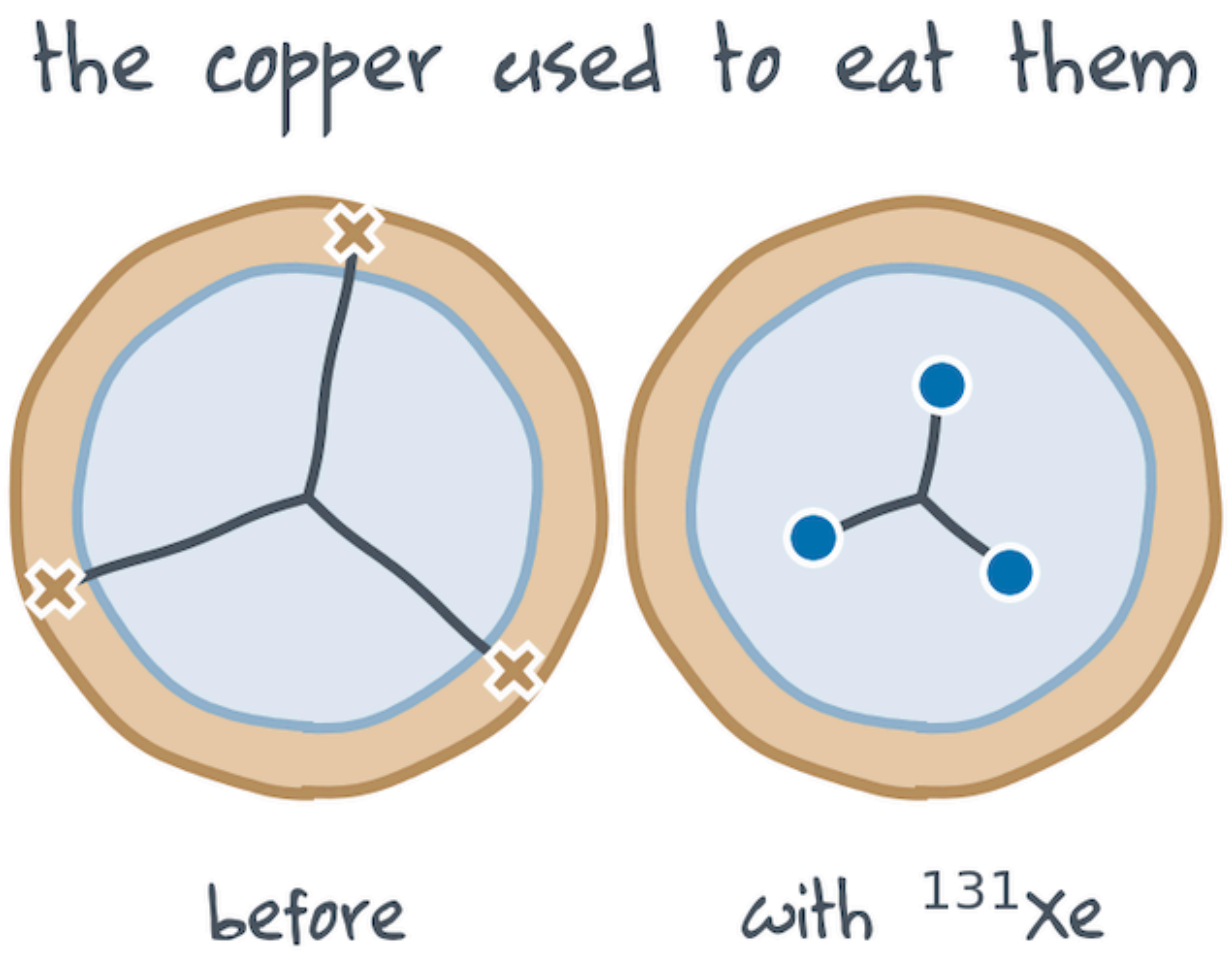
Summary

- ^{137}Xe is the dominant background at Yemilab
- Adding ^{131}Xe to the xenon gives about a 6.8-fold reduction in simulation – short of the 22x expected from the thermal cross sections
    - Quick check with 10000 330 GeV muons – see Lin's simulation
- 30% of ^{137}Xe-producing neutrons are born in the HFE
    - If those were absorbed, the reduction would be 9.8x;
    - BPE shell or boric acid outside the Cu vessel – proposed for simulation (Lin Si)
    - $T_{1/2}$ sensitivity at Yemilab 0.61 ➔ 1.08×10^{28} yr

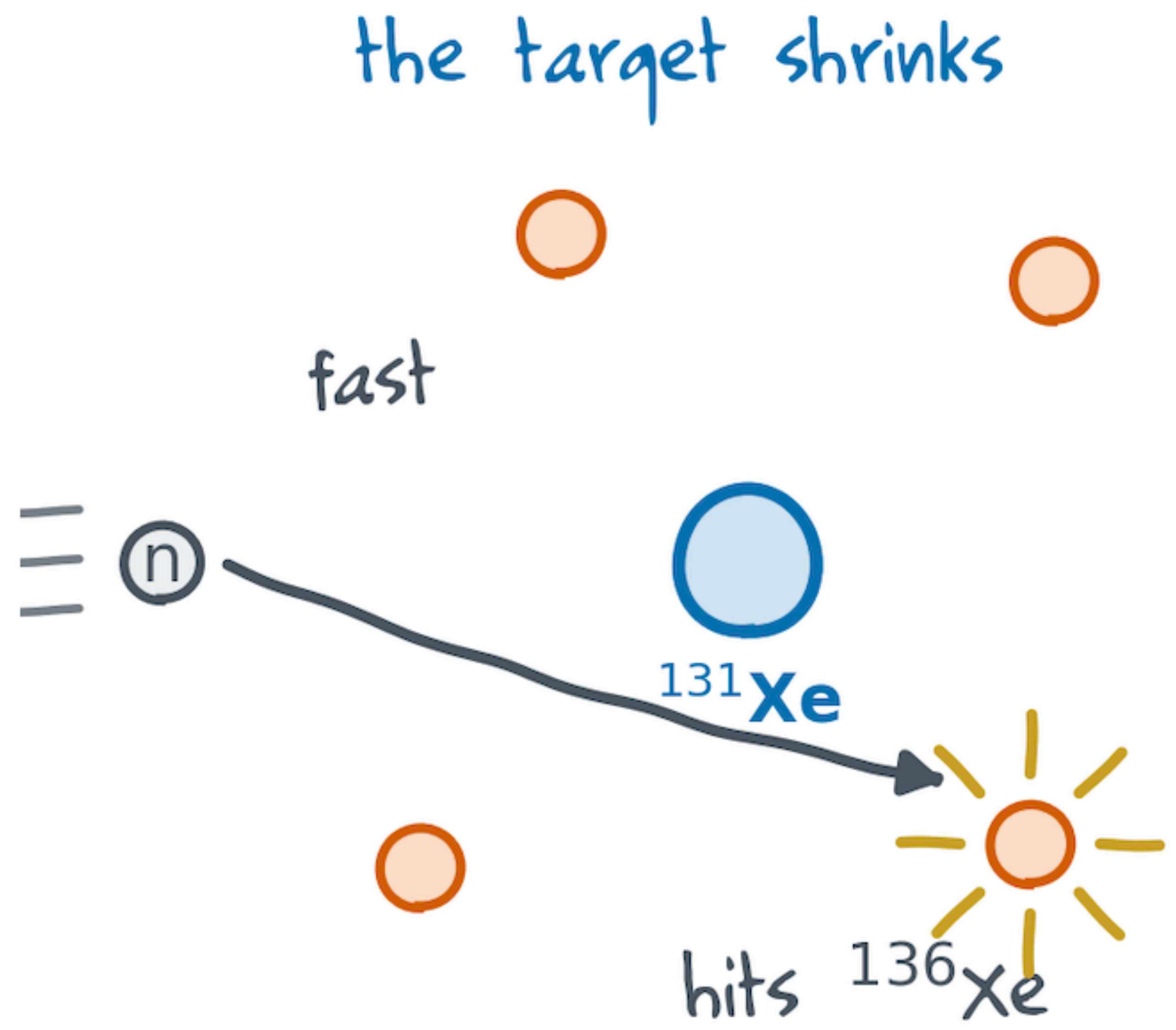
Backup



a slow neutron almost always hits the big ^{131}Xe target



the xenon now stops the neutrons the copper used to absorb



for a fast neutron the ^{131}Xe target is no longer big