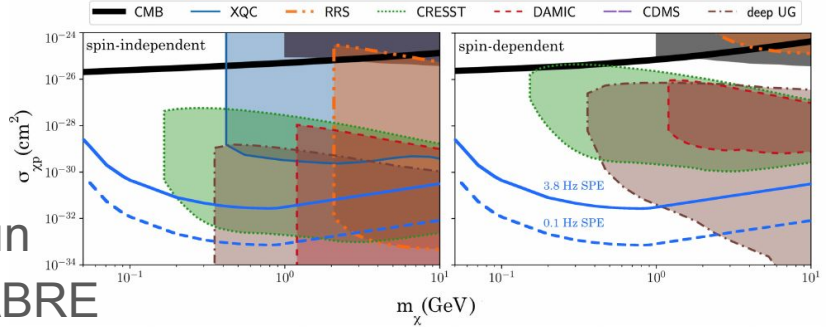
SIMP search with the SABRE veto

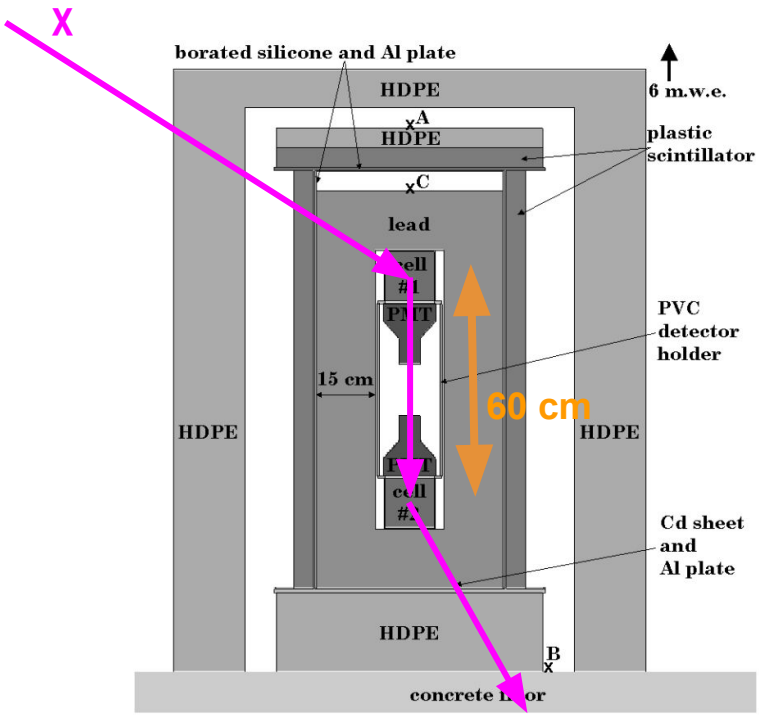
Original idea: DM is strongly interacting but light.

Underground detectors are blind -- need surface run

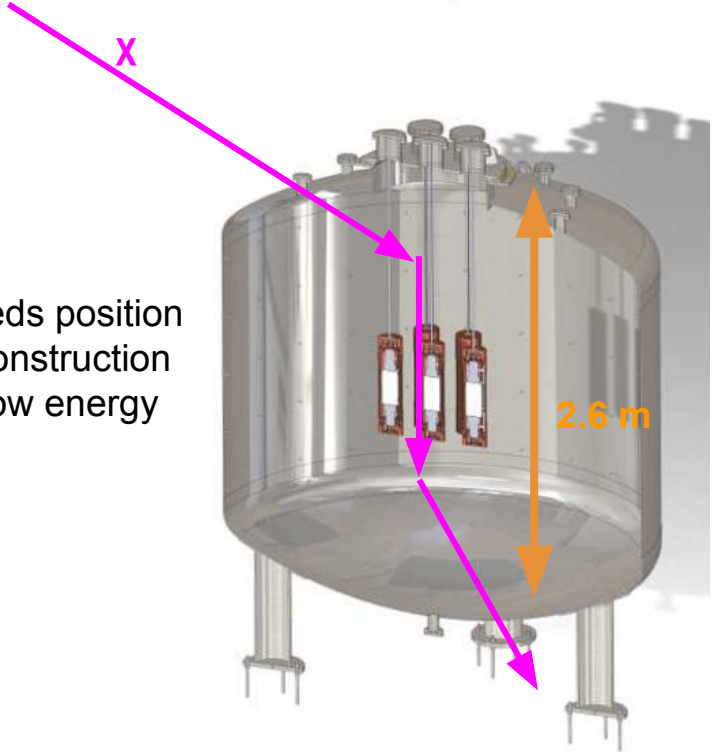
Collar (https://arxiv.org/pdf/1805.02646.pdf)



SABRE



Needs position reconstruction at low energy



How well can the SABRE veto reconstruct position?

Simulation study:

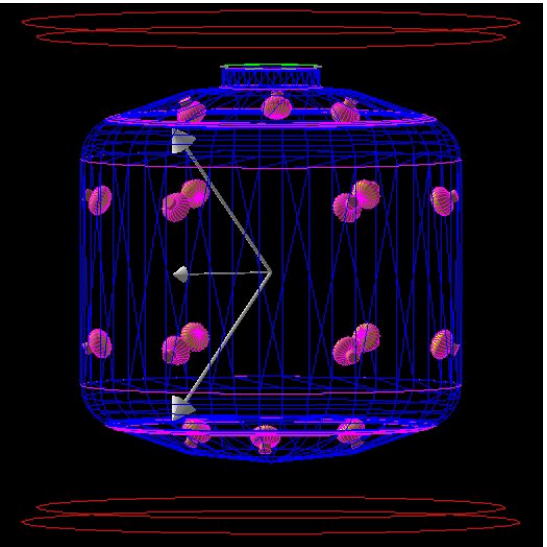
* 50 & 20 keV electrons.
* 4 locations:

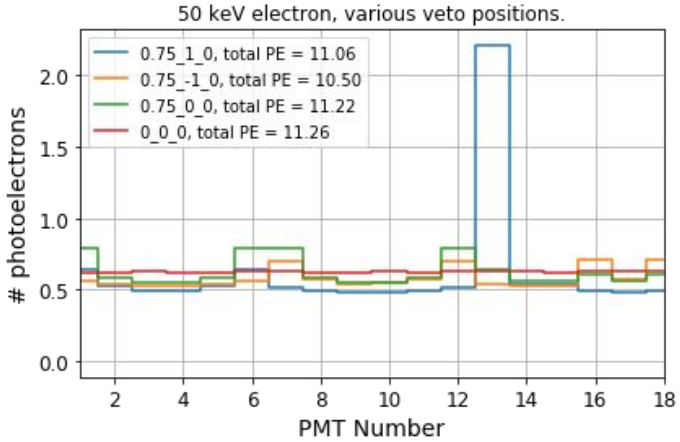
(0.75, 1, 0) m, (0.75, -1, 0) m, (0.75, 0, 0) m, and (0,0,0) m

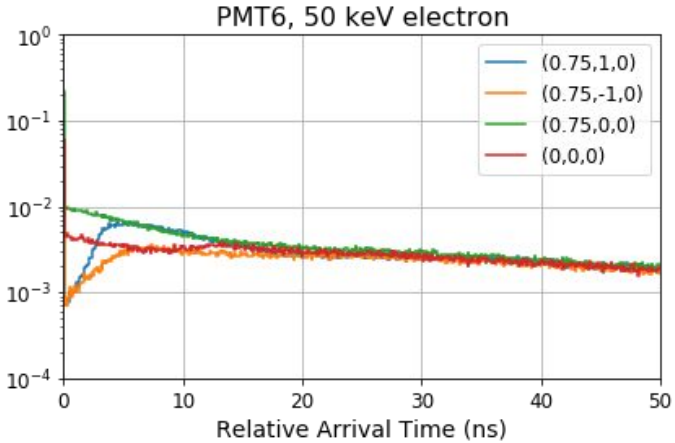
* Applied averaged QE for photons→PE

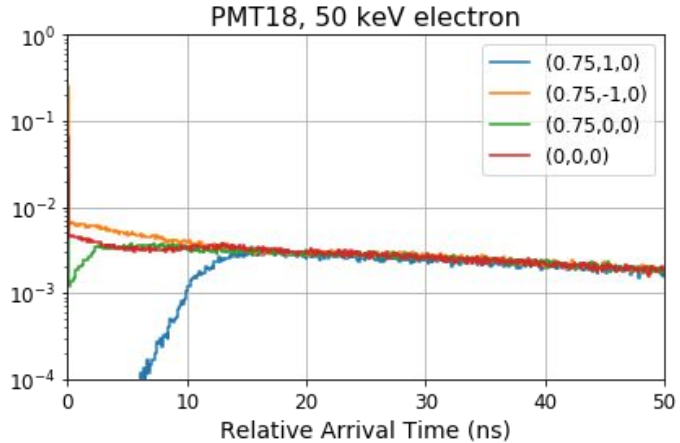
NB: this is an old SABRE PMT configuration.

Used likelihood analysis to assess most probable of the 4 starting locations event-by-event.

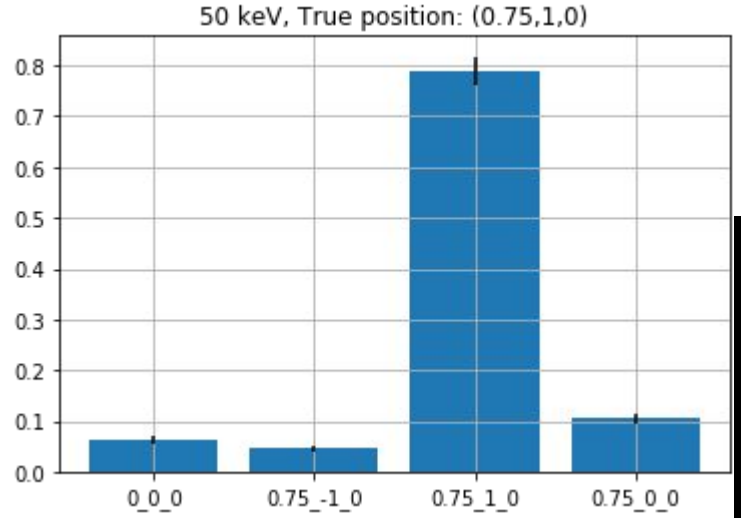


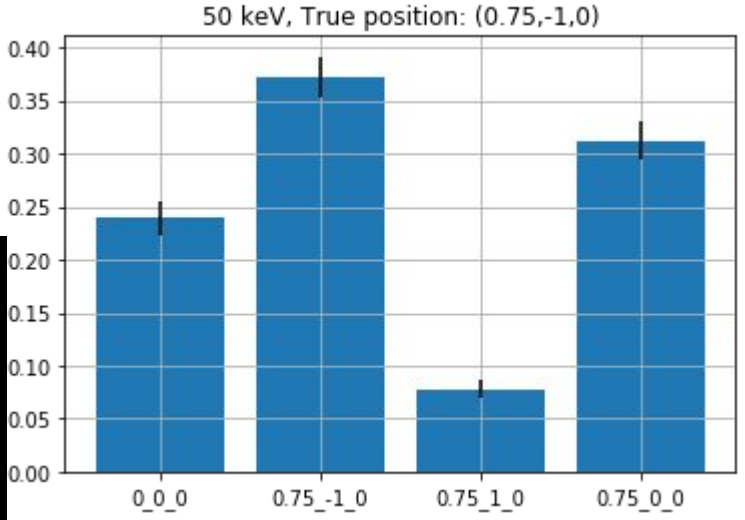


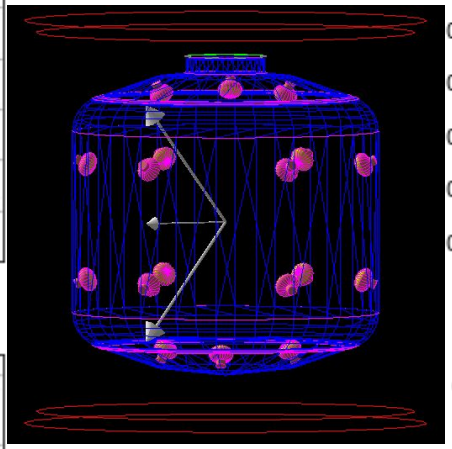


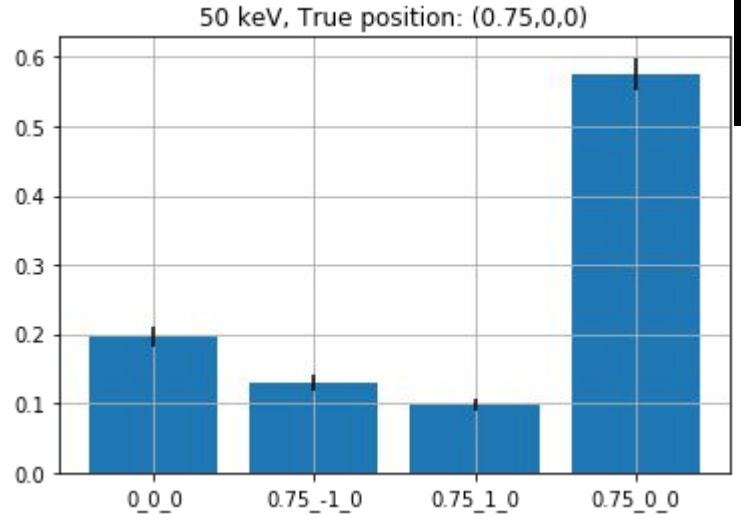


50 keV

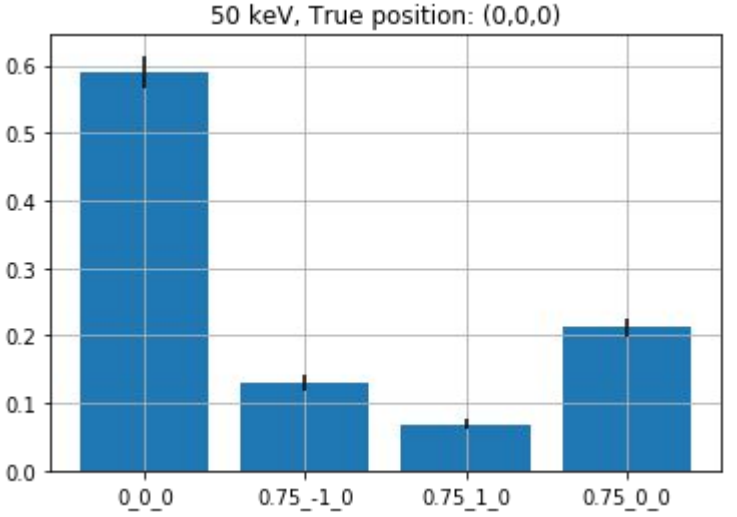








Insufficient position reconstruction?
Partitions?

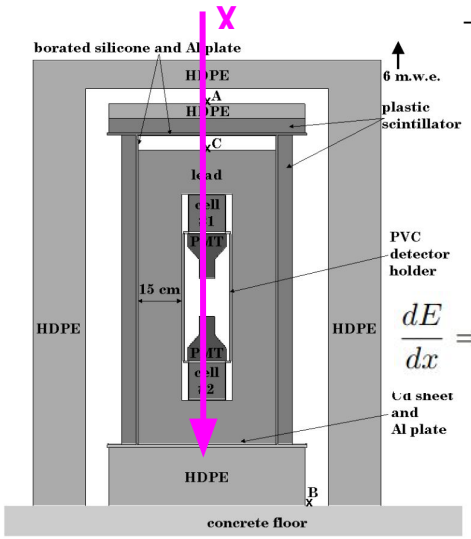


~~SIMP~~ Composite DM search with the SABRE veto

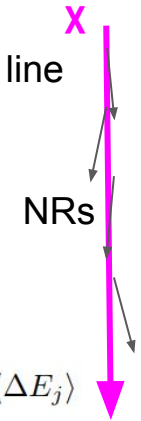
(Not as) Big as a Barn: Upper Bounds on Dark Matter-Nucleus Cross Sections

https://arxiv.org/pdf/1907.10618.pdf → point-like DM undergoing contact interactions can't have cross-sections > geometric nuclear size.

But, composite DM (with a finite geometric extent) can have large cross-sections.
σ~geometric DM size



$m_\chi >> m_N$
→ Straight line



$$\frac{dE}{dx} = -\sum_j n_j \sigma_\chi \langle \Delta E_j \rangle$$

~1/A

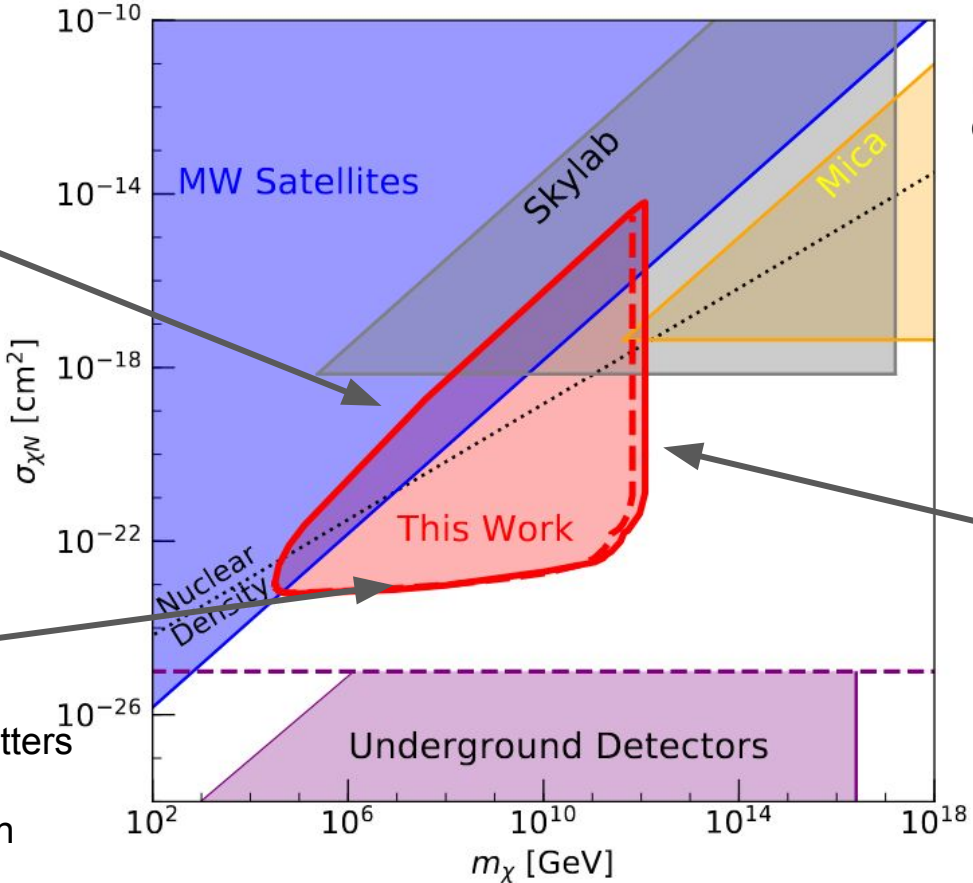
$$\langle \Delta E_j \rangle \simeq 2E\frac{m_j}{m_\chi}$$

~A

Stopping power ~ constant for all materials

Composite DM search with the SABRE veto

Collar https://arxiv.org/pdf/2008.10646.pdf



NB: Collar ignores directionality.

Overburden limited

Flux limited (detector size)
$m_{\chi max} \propto A_{top} \Omega\, t$

$\sigma_{min} \sim N_{min}/(n_H L)$

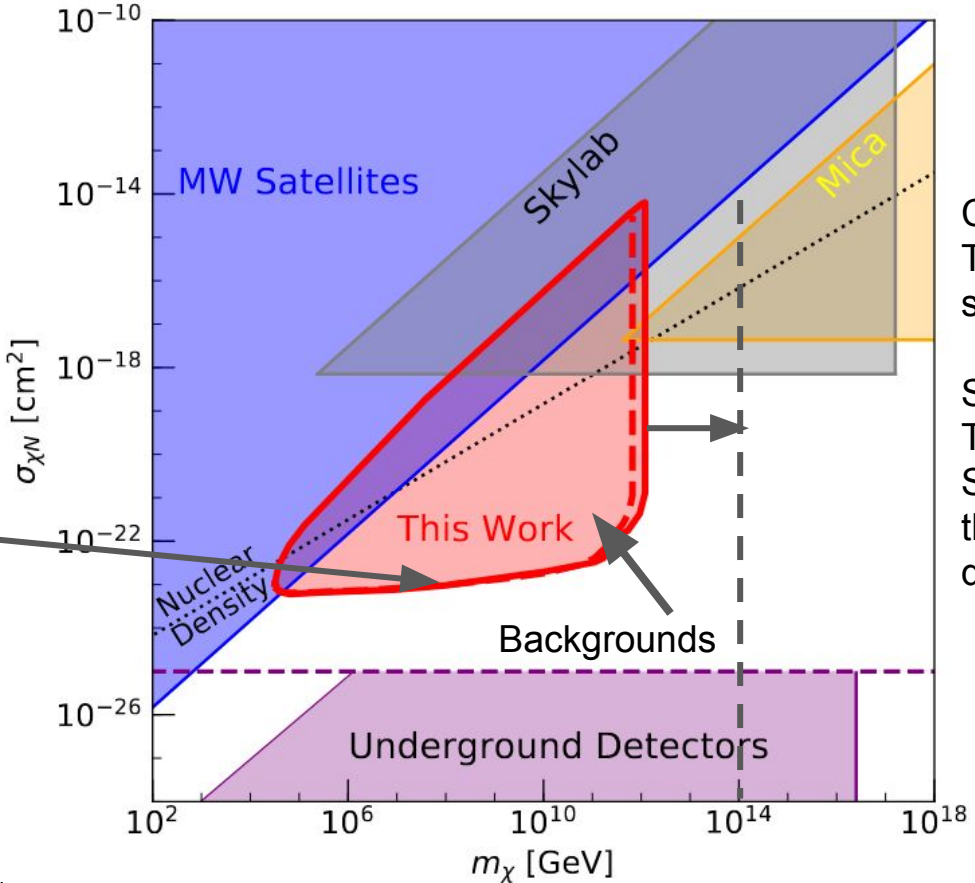
N_{min} = minimum # proton scatters (threshold)
$n_H L$ = # protons in path length

Composite DM search with the SABRE veto

Collar https://arxiv.org/pdf/2008.10646.pdf

Collar:
2*5” cells, L ~ 25 cm,
10 keVee threshold

SABRE veto:
L~2.5 m
→ need ~ 100 keVee threshold to match limit (feasible).



Collar:
Top area ~80 cm^2,
solid angle penalty ~10^{-3}

SABRE veto:
Top area ~ 5x10^4 cm^2
Solid angle → better than Collar but harder to quantify.

Composite DM search with the SABRE veto

Questions:

- Would an underground search (concurrent with SABRE) be possible?
  - What would we need to modify?
    - Trigger?
    - Calibration method?
- How feasible would it be for other detectors to carve out this parameter space?
  - Above-ground segmented LS → PROSPECT
  - Surface runs of other DM detectors?
  - Very large detectors with a decent threshold like Borexino?
- How does directionality change these limits?
- Does the daily modulation from being in the lee of the DM wind help?
- Alternatively, does the lowered flux by attenuation in the Earth hurt?
- How interesting is composite DM generally?