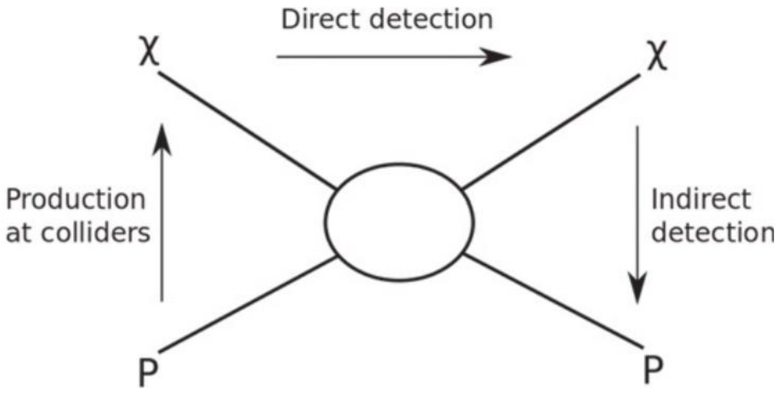
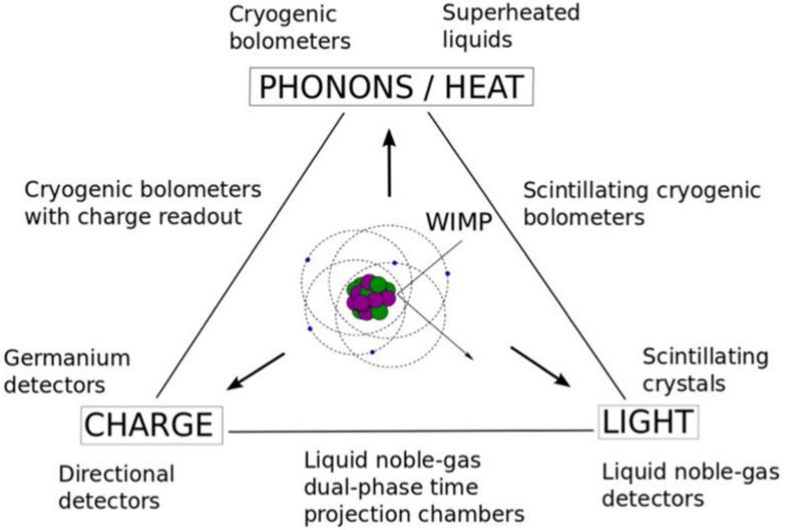
Muon-induced backgrounds in a new dark matter experiment - the Scintillating Bubble Chamber

By Patrick Hatch

Direct dark matter searches



Undagoitia, T. M., & Rauch, L. (2015).



Undagoitia, T. M., & Rauch, L. (2015).

-Direct DM searches look for signals of DM scattering off a standard model particle (typically a nucleus)

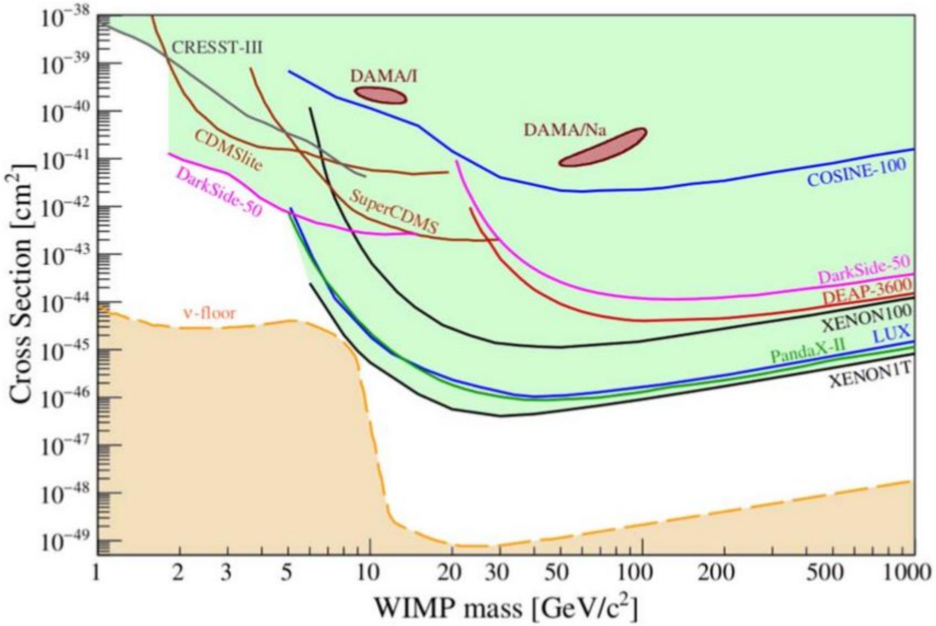
-These detectors look for energy deposits from ionization, scintillation, heat, or a combination to reject backgrounds

WIMPs - the search so far

-The high mass spin-independent WIMP regime has been well explored

-New theories (e.g. asymmetric DM) suggest candidates with lower masses

-Searching for lower masses requires low energy threshold and low backgrounds



Schumann, M. (2019)

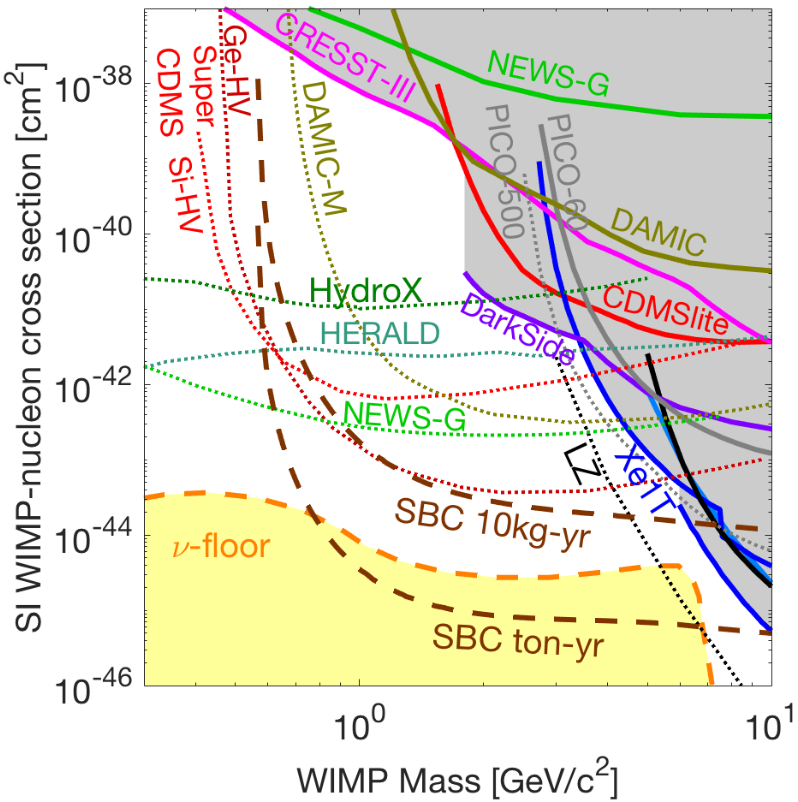
Enter the Scintillating Bubble Chamber (SBC)

-The SBC is a bubble chamber made of superheated liquid argon to be located at SNOLAB

-Energy from nuclear recoils are deposited as heat (producing bubbles) which we detect with cameras and acoustic sensors

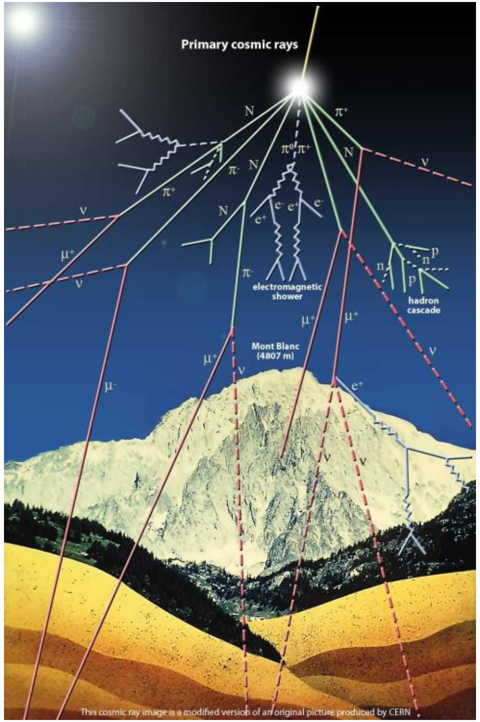
-Energy from electronic recoils are deposited as scintillation which we detect with SiPMs

-Energy threshold goal of 100 eV!



SI WIMP-nucleon cross section [cm^2]
WIMP Mass [GeV/c^2]
10^{-38}
10^{-40}
10^{-42}
10^{-44}
10^{-46}
10^{0}
10^{1}
CRESST-III
NEWS-G
Ge-HV
Super CDMS Si-HV
DAMIC-M
PICO-500
PICO-60
DAMIC
HydroX
CDMSlite
DarkSide
HERALD
NEWS-G
LZ
Xe1T
SBC 10kg-yr
ν-floor
SBC ton-yr

Neutron backgrounds

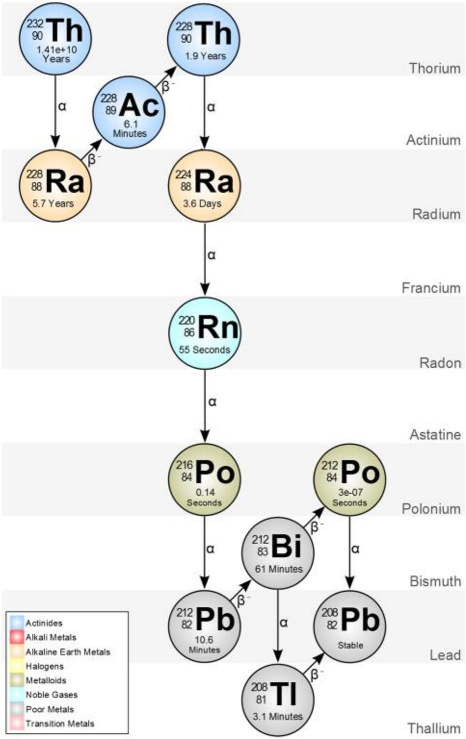


KTH space center

-Neutrons can scatter off a nuclei and thus present a major background for DM searches

-Radiogenic neutrons come from radioactive processes such as spontaneous fission and (α,n) reactions

-Cosmogenic neutrons come from atmospheric muons spallating neutrons directly or indirectly



Courtesy of Wikipedia

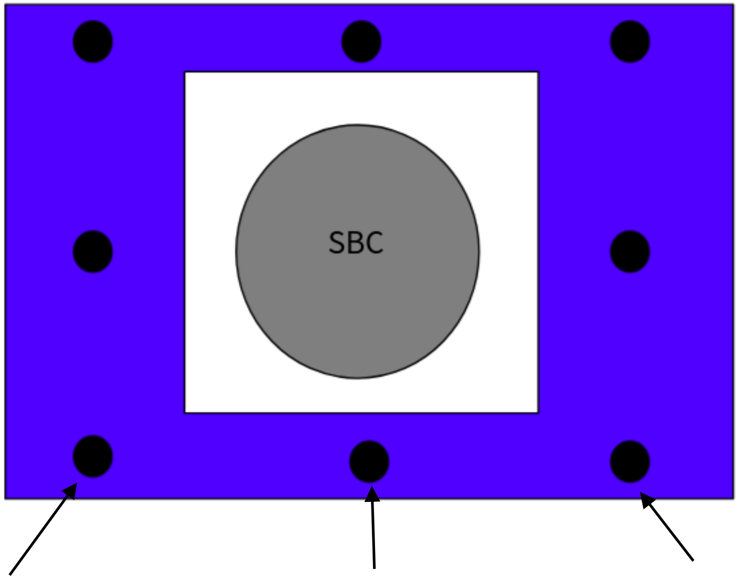
The muon veto

-One way to cut (most) cosmogenic neutrons is with a muon veto (and go underground)

-SBC's muon veto is 8 PMTs placed within a water shield made of HDPE

-As a muon passes through the veto it produces Cerenkov light detected by the PMTs

Top down view of SBC + water shield

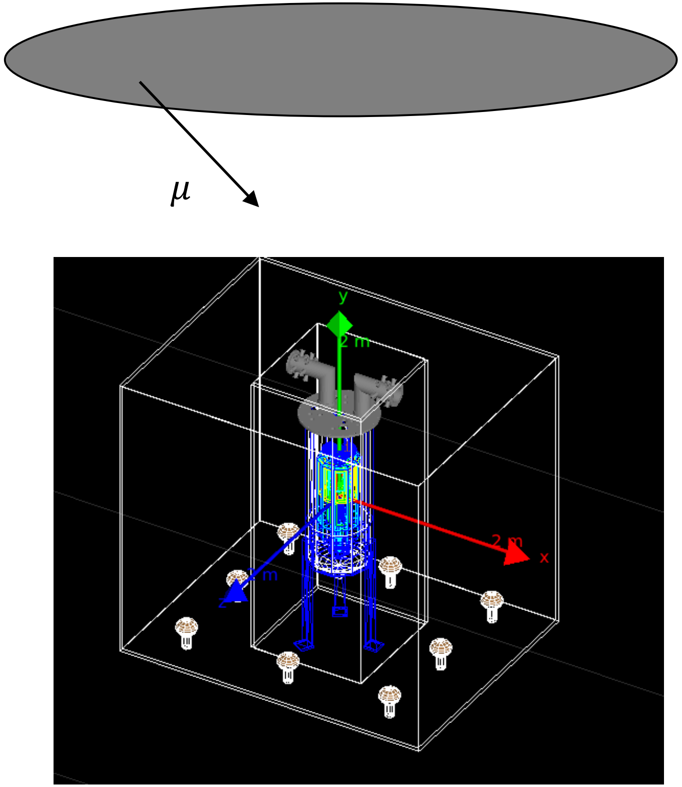


PMTs on the bottom of the water shield facing upward

Designing an efficient muon veto

-To test the best water shield design we first build a model of the water shield in Geant4

-Then we shoot muons at the model and find out what percentage of muons were detected by the PMTs

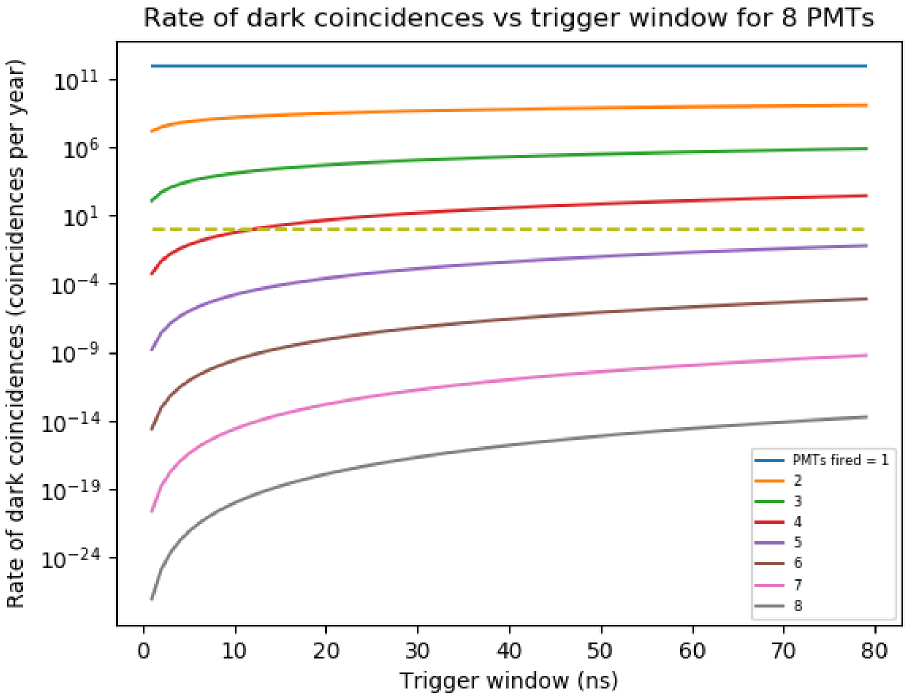


Dark coincidences

-PMTs have “dark noise” in which they activate without a detection of photons (hence “dark”)

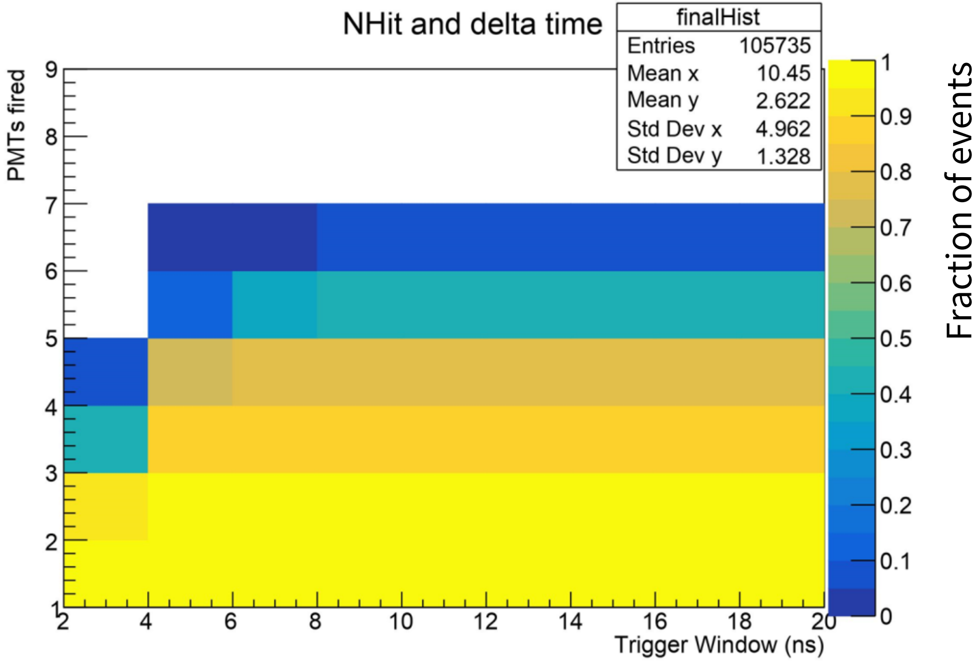
-If many PMTs experience dark noise simultaneously it could look like a muon signal

-At least 5 PMTs fired is desirable for muon detection



Dashed horizontal line indicates one coincidence per year

Simulation results (HDPE alone)



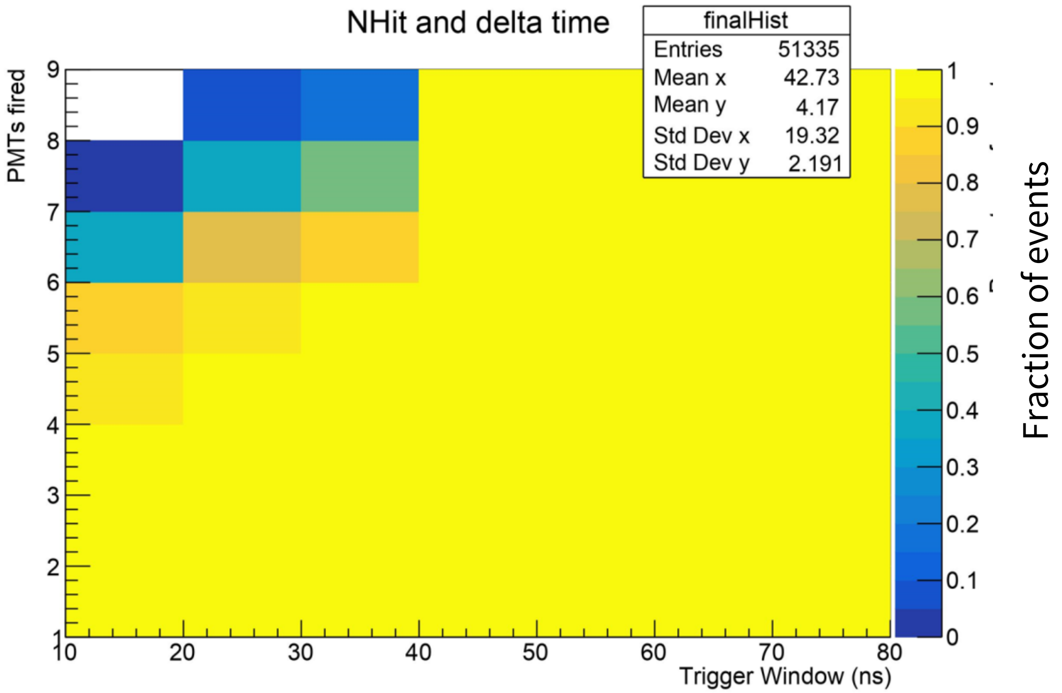
-Not very effective at detecting muons above the dark noise limit!

Simulation results (Reflective paint)

-Using flat-white paint

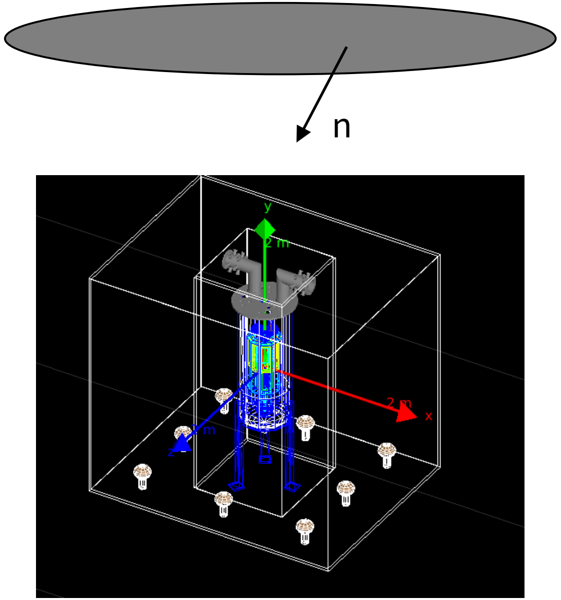
-Set reflectivity to 75%

-**Much more effective at detecting muons above the dark noise limit!**

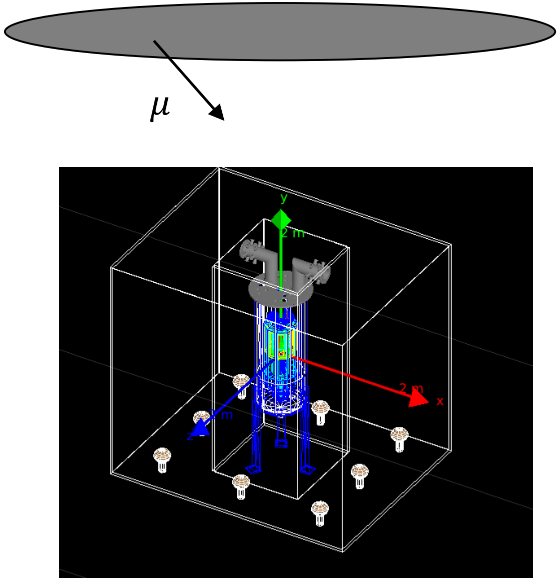


How many neutrons do we expect?

Cosmogenic neutrons from rock: make neutron gun from published spectra



Cosmogenic neutrons produced in SBC and water shield: use muon gun to spallate neutrons



Results with water shield and without

	CN from rock: 0-1 MeV	1-10 MeV	>10MeV	CN from everything else	Total
No WS	0.095 ±0.032	0.013 ±0.013	0.123 ±0.035	< 0.01	0.231 ±0.049 *
WS	0.008 ±0.01	0.002 ±0.004	0.068 ±0.020	0.01 ±0.03	0.088 ±0.038

* Number comes adding CN from rock

-This table is for single nuclear recoil events per year (CN = cosmogenic neutron

WS = water shield)

-Cosmogenic neutrons from water shield doesn’t produce many events

-Not very many cosmogenic neutrons events in total, especially with water shield

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Main takeaways

-Adding a reflective property to SBC’s muon veto will allow it to be efficient, but based on the number of events we expect to see, a muon veto may not be necessary

-A water shield doesn’t add many cosmogenic neutrons as feared

-Will later consider cosmogenic neutron backgrounds and a muon veto for a bigger SBC

-SBC is an exciting new dark matter experiment that will carve out new parameter space in the low-mass spin-independent WIMP regime (or actually detect DM 😮)

-Muons are evil 😈

NSERC
CRSNG

Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

Ontario

Thank you!

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