^{3}HE NEUTRON CAPTURE IN XENON GAS EXPERIMENTS

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PAPER

Mitigation of backgrounds from cosmogenic ^{137}Xe in xenon gas experiments using ^{3}He neutron capture

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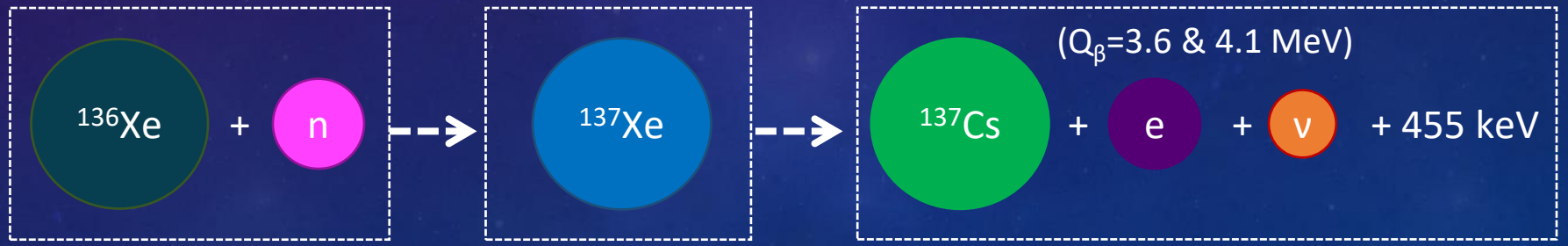
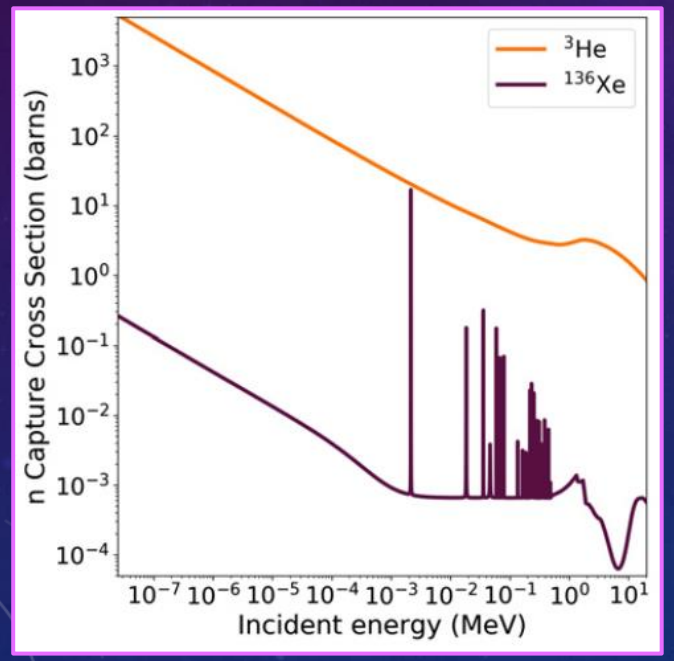
Neutron Capture Backgrounds

$^{136}Xe + n \rightarrow {}^{137}Xe \rightarrow {}^{137}Cs + e^- + \nu + \gamma$

- ^{137}Xe beta decays with a half-life of ~4 minutes and a Q_B of 3.6 and 4.1 MeV that can fall into our energy region of interest
- As the detector is scaled up these backgrounds begin dominating over radiogenic as the amount of ^{136}Xe available for neutron capture increases



Adding 3He to Xe Detectors



Impact of ^{3}He doping on cosmogenic backgrounds investigated since ^{3}He has a high neutron capture cross section

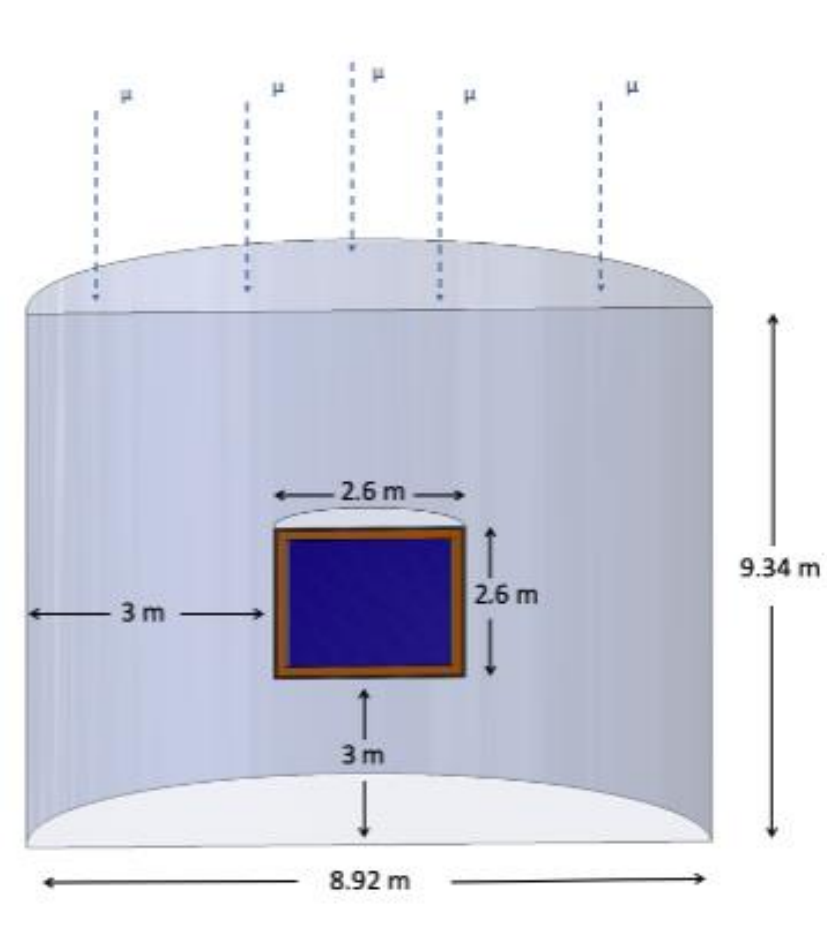
(Q_B>3.5 MeV)

^{136}Xe + n → ^{137}Xe → ^{137}Cs + e- + ν + γ

^{3}He + n → ^{1}H + ^{3}H + 764 keV → ^{1}H + ^{3}He + e-

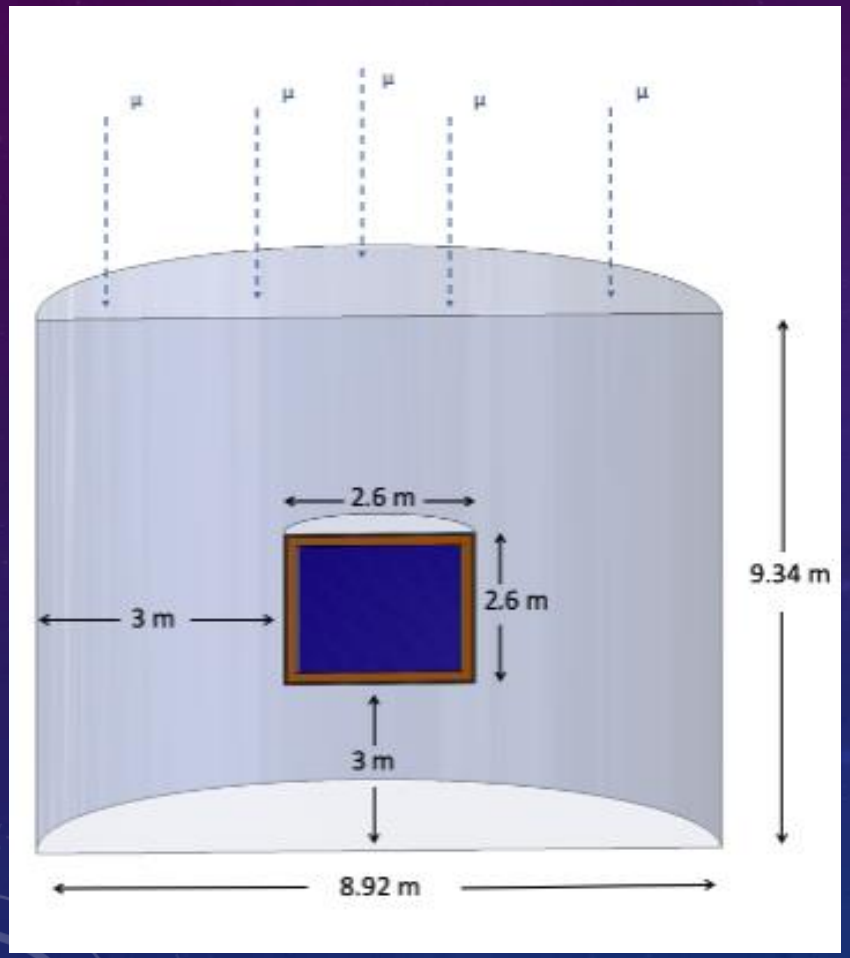
(Q_B=18.6 keV)

137Xe Production Over all Neutron Energies



- Simulated ton scale gaseous Xe surrounded by water to stop neutrons coming from the surrounding mountain, but muons can still come through and create neutrons
- Muons were studied by simulating them coming from outside the water tank

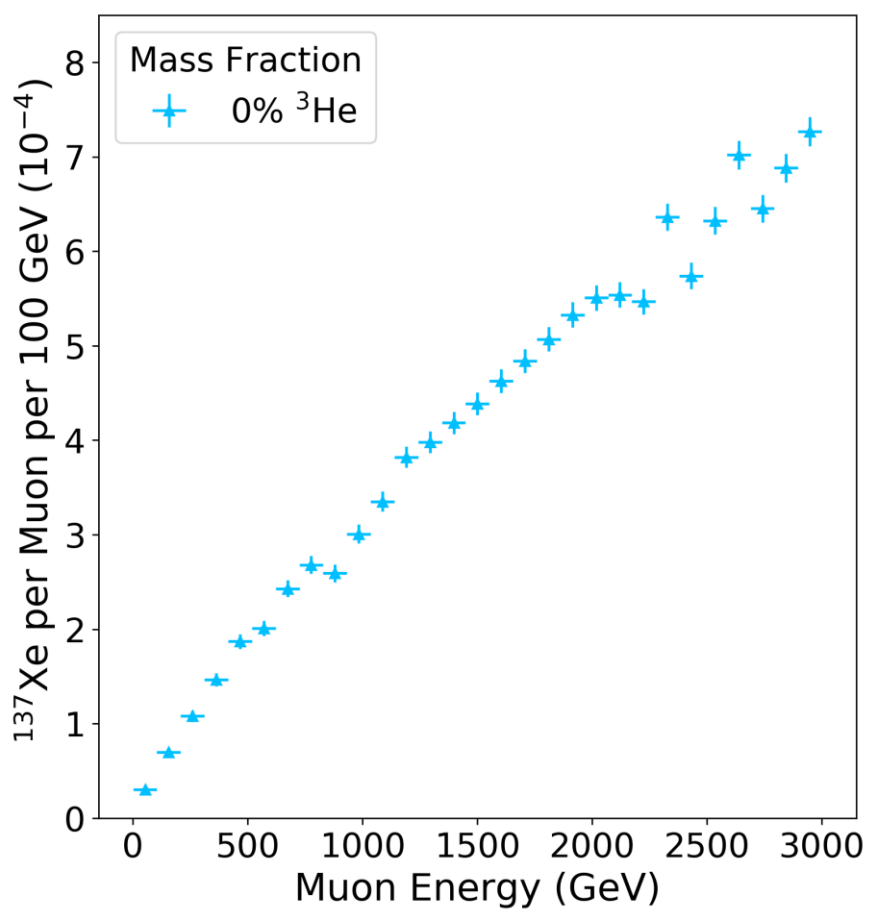
137Xe Production Over all Neutron Energies



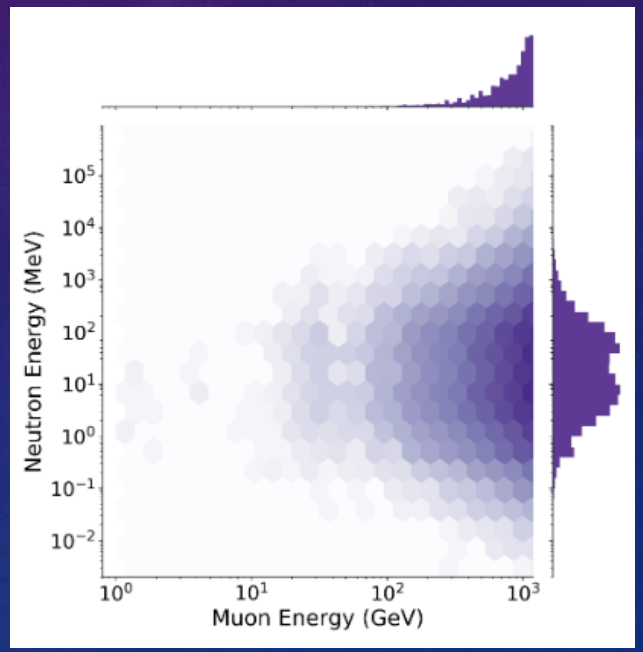
- Simulated ton scale gaseous Xe surround… top neutrons coming from the surr… ut muons can still come through
- Muons were studi… coming from outside the w…

Note, we didn't simulate with liquid xenon because we assumed the helium would end up in ullage rather than distributed, but after some of yesterday's talks I am not convinced this would be an unsolvable issue

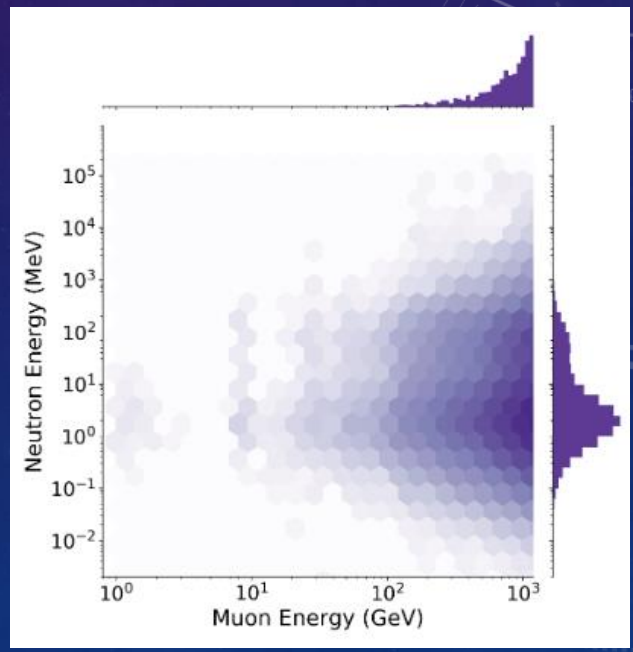
137Xe Production Over all Neutron Energies



Number of neutrons, and therefore ^{137}Xe, produced depends strongly on Muon energy, but their energy does not

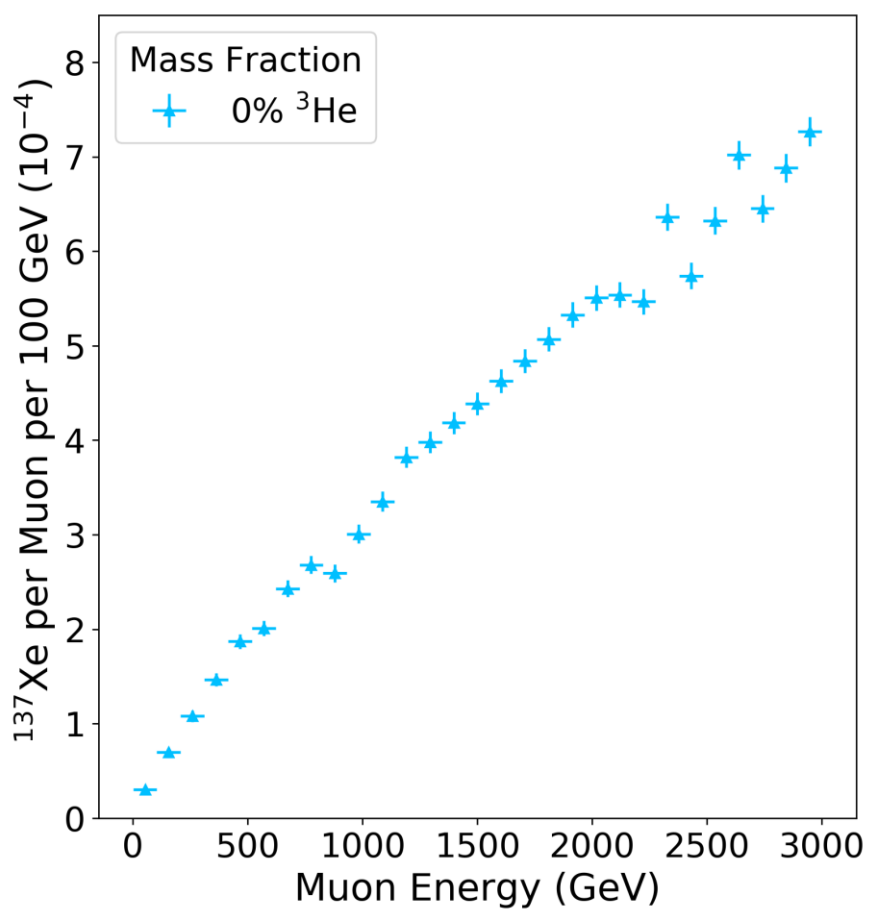


Neutrons created in water tank



Neutrons created in detector materials

137Xe Production Over all Neutron Energies



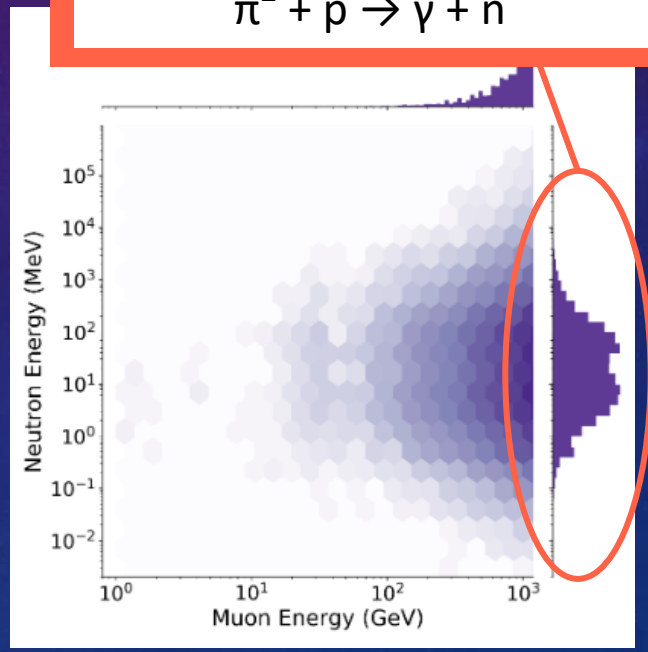
Number of neutrons, and therefore ^{137}Xe, produced depends on their energy

Capture Processes such as:

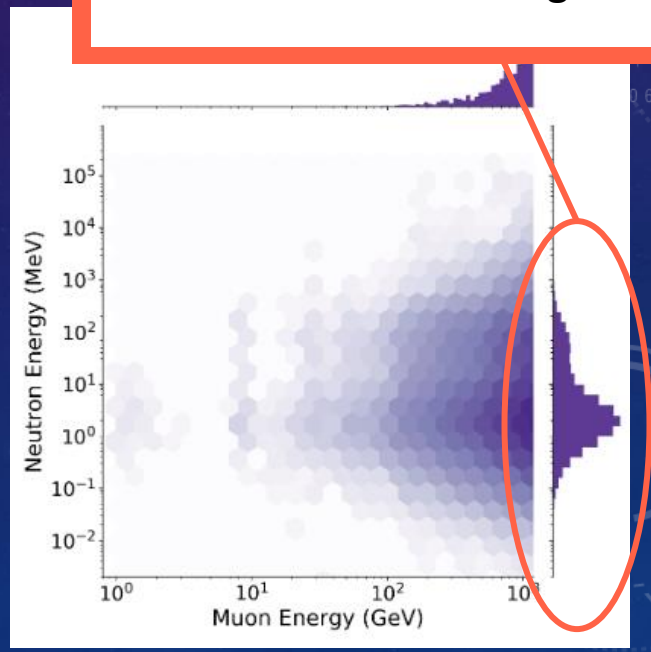
$\mu^- + p \rightarrow \nu + n$

$\pi^- + p \rightarrow \gamma + n$

Neutron, pion, and proton inelastic scattering

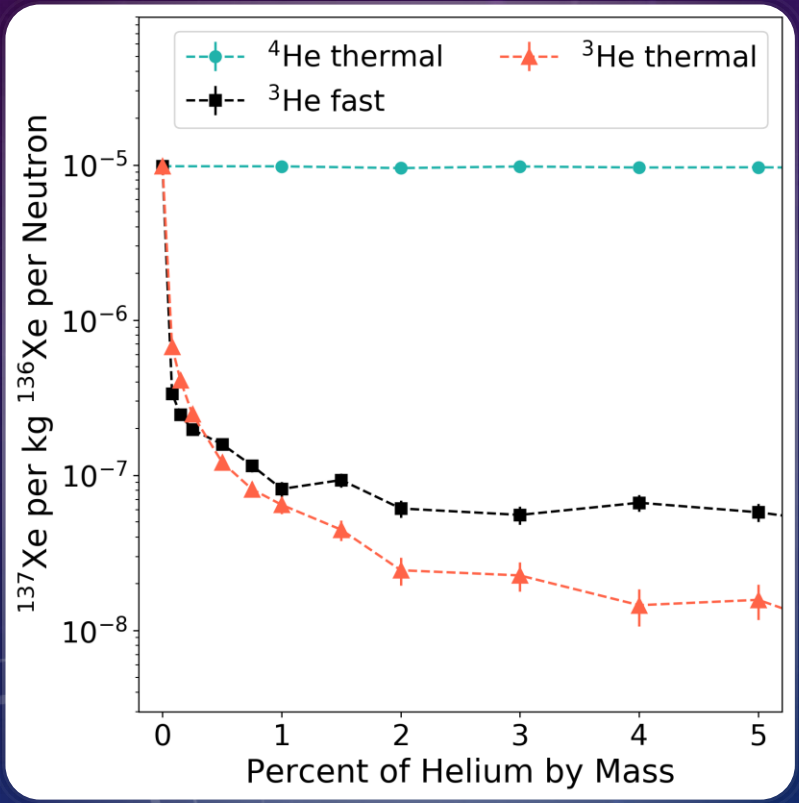


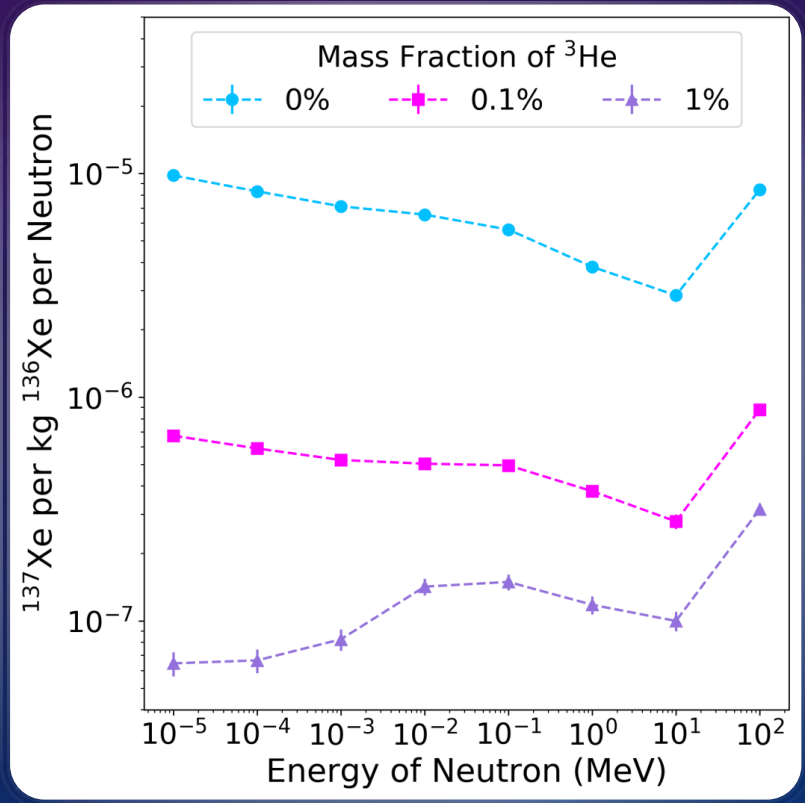
Neutrons created in water tank



Neutrons created in detector materials

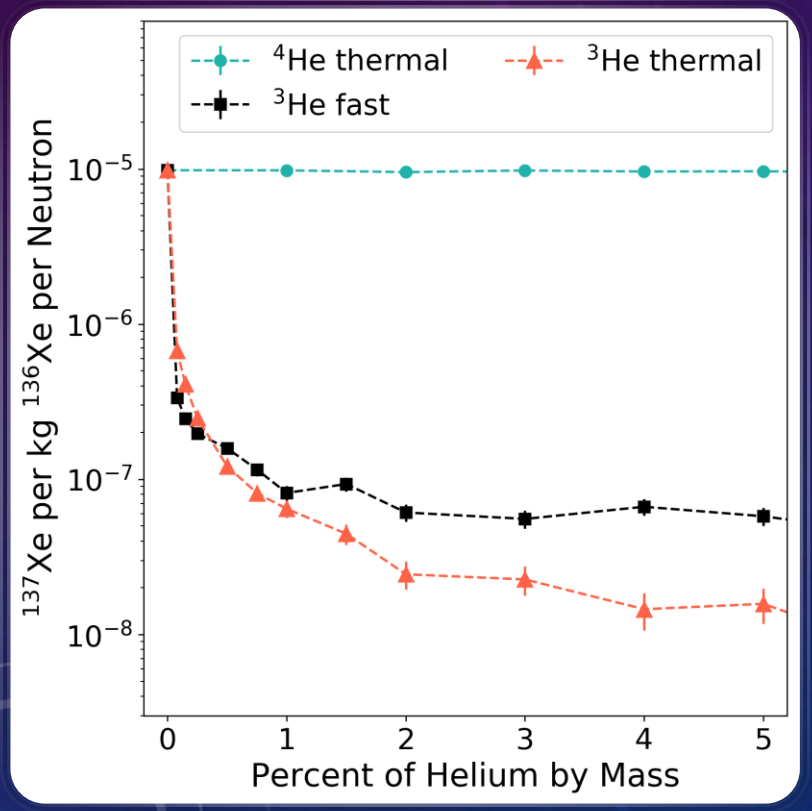
^{137}Xe production with ^{3}He and ^{4}He doping

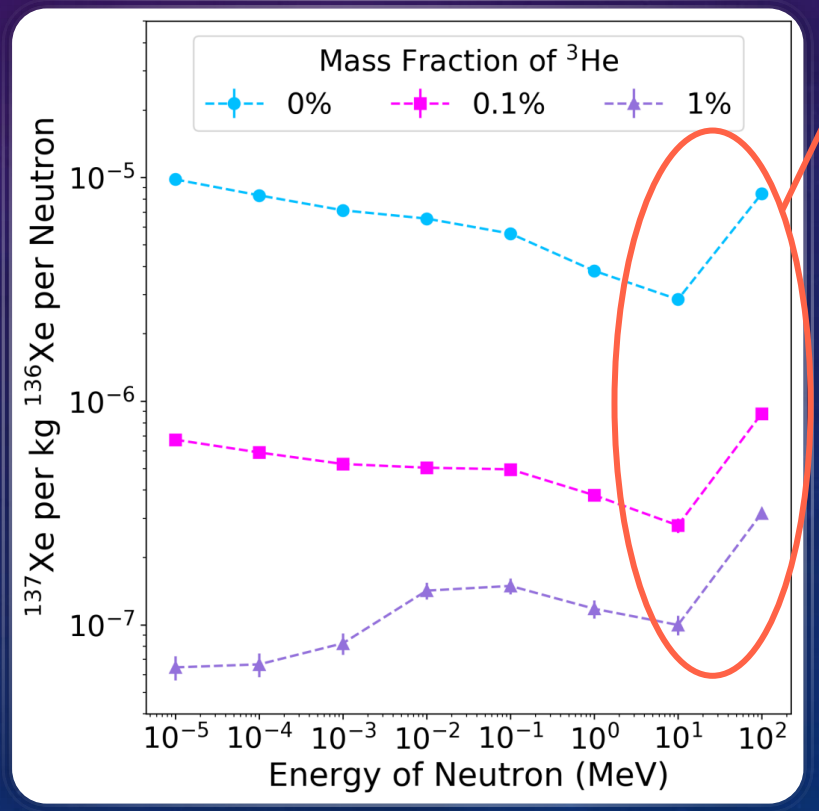


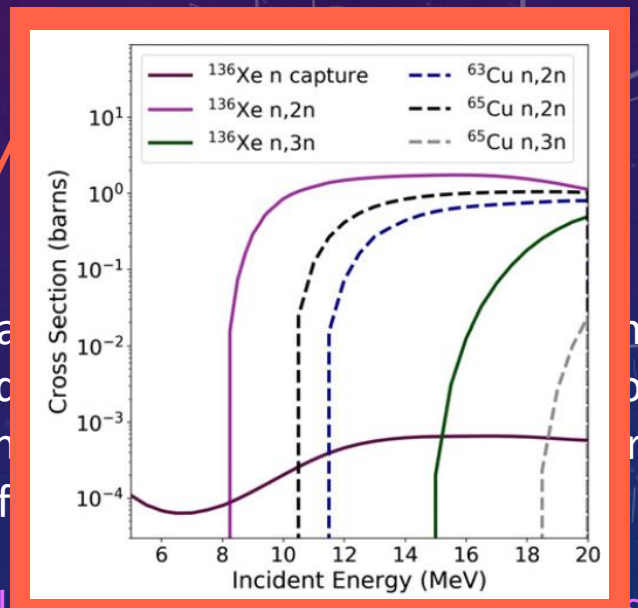


- Varying the percentage of helium added to xenon resulted in no change in the normalized number of activations with ^{4}He additives
- Clear decrease seen in activations with ^{3}He added for both fast and thermal neutrons
- This decreased rate continues across the span of all neutron energies

^{137}Xe production with ^{3}He and ^{4}He doping

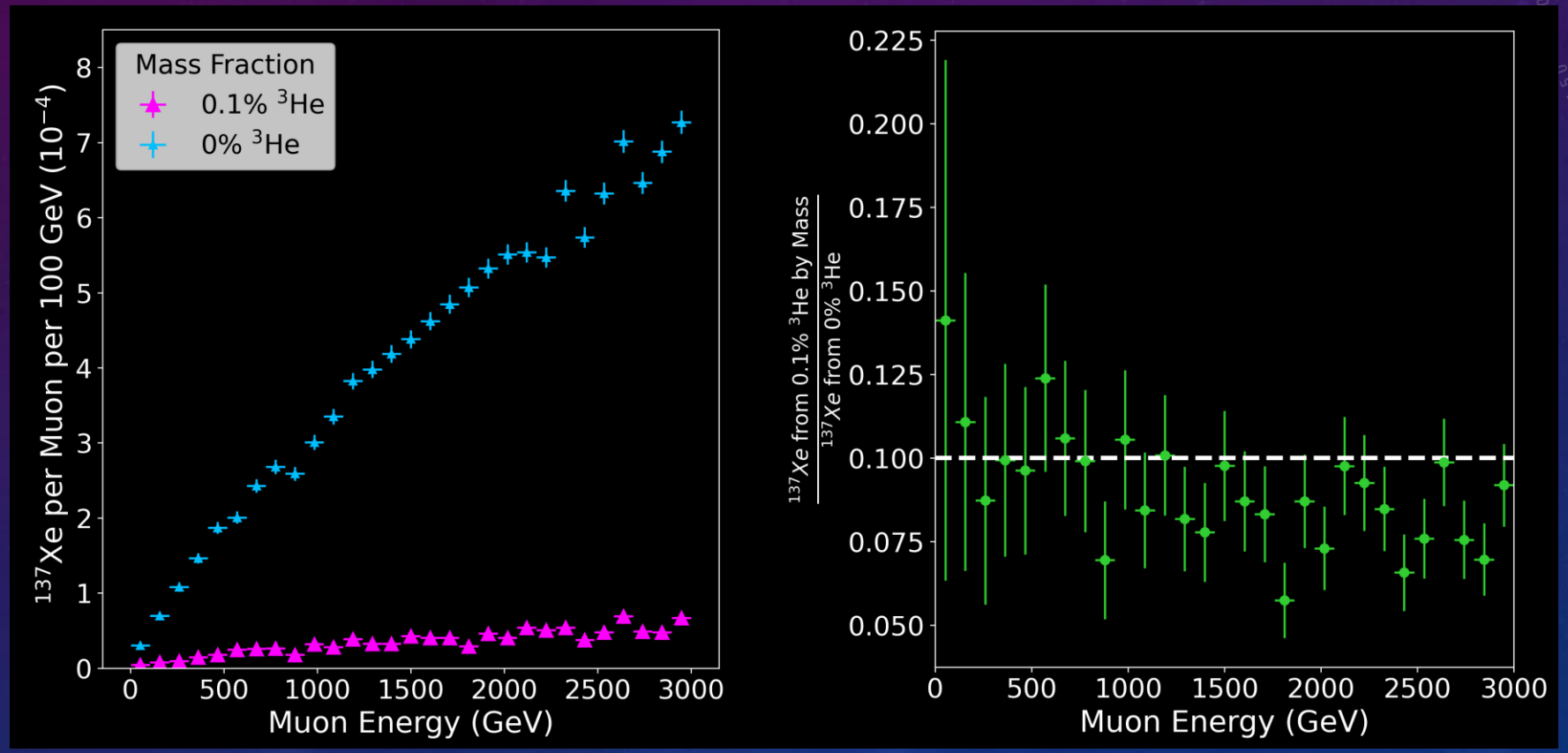






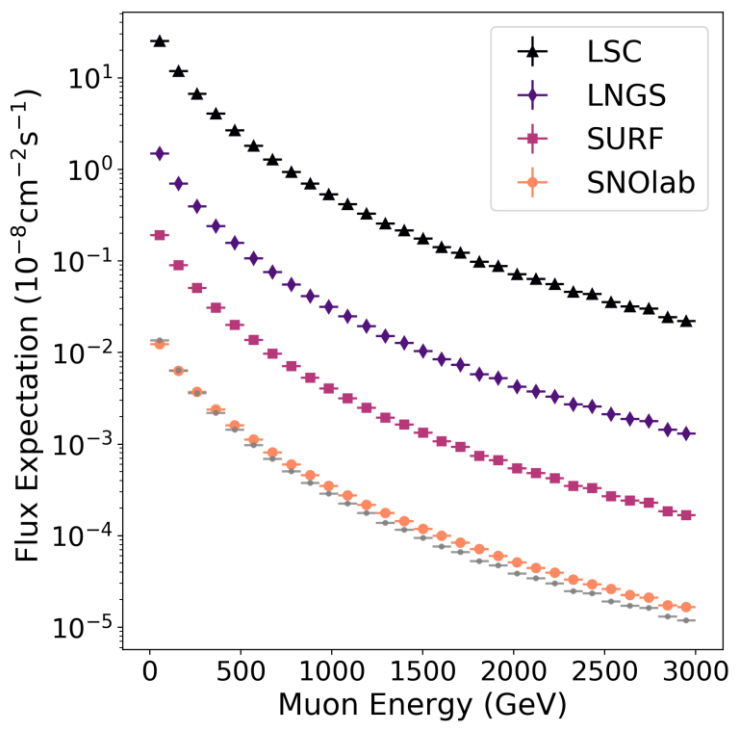
- Va… ac… ch… of…
- Cl… with ^{3}He added for both fast and thermal neutrons
- This decreased rate continues across the span of all neutron energies

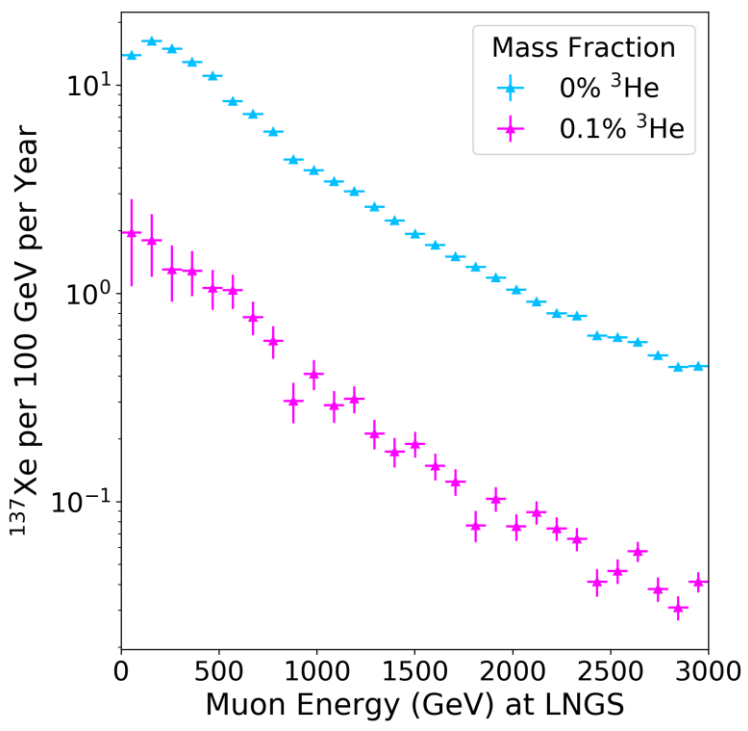
137XE PRODUCTION FROM MUONS

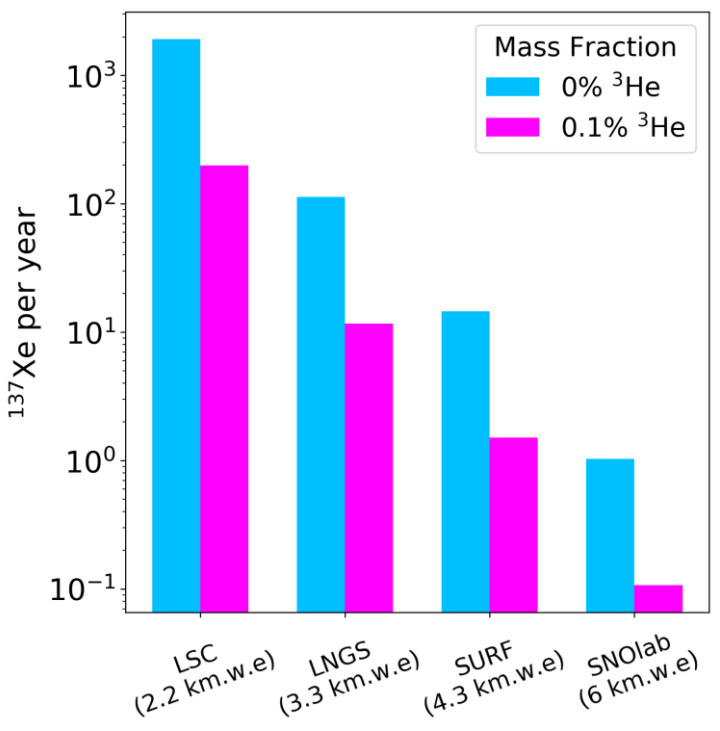


Over 10 times decrease in ^{137}Xe production in the 0.1% ^{3}He-Xe mixture!

137XE PRODUCTION PER YEAR IN VARIOUS LABS







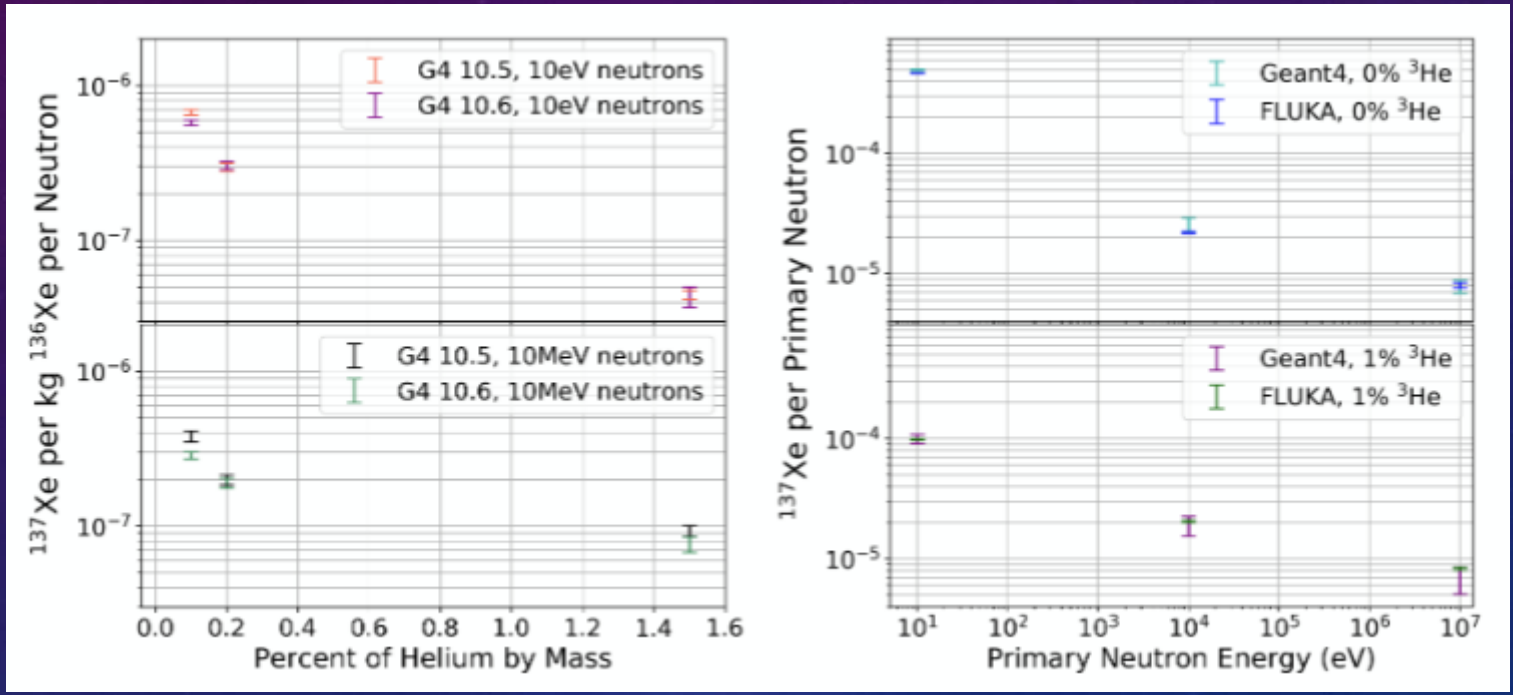
A 0.1% ^{3}He-Xe mix produces about as much background in LSC than a non-doped detector in the deeper LNGS lab

CONCLUSIONS OF HELIUM 3 DOPING

- ^{137}Xe is a potential background concern caused by neutron capture on ^{136}Xe
- To reduce this neutron capture we can either decrease the number of neutrons or add something that captures the neutrons before the ^{136}Xe can
- Given background reduction against beta decays from ^{137}Xe, it is expected that any moderately deep underground $^{136}Xe/^{3}He$ experiment will be entirely free of background from cosmogenically produced ^{137}Xe

BACKUP SLIDES

CROSS CHECKS



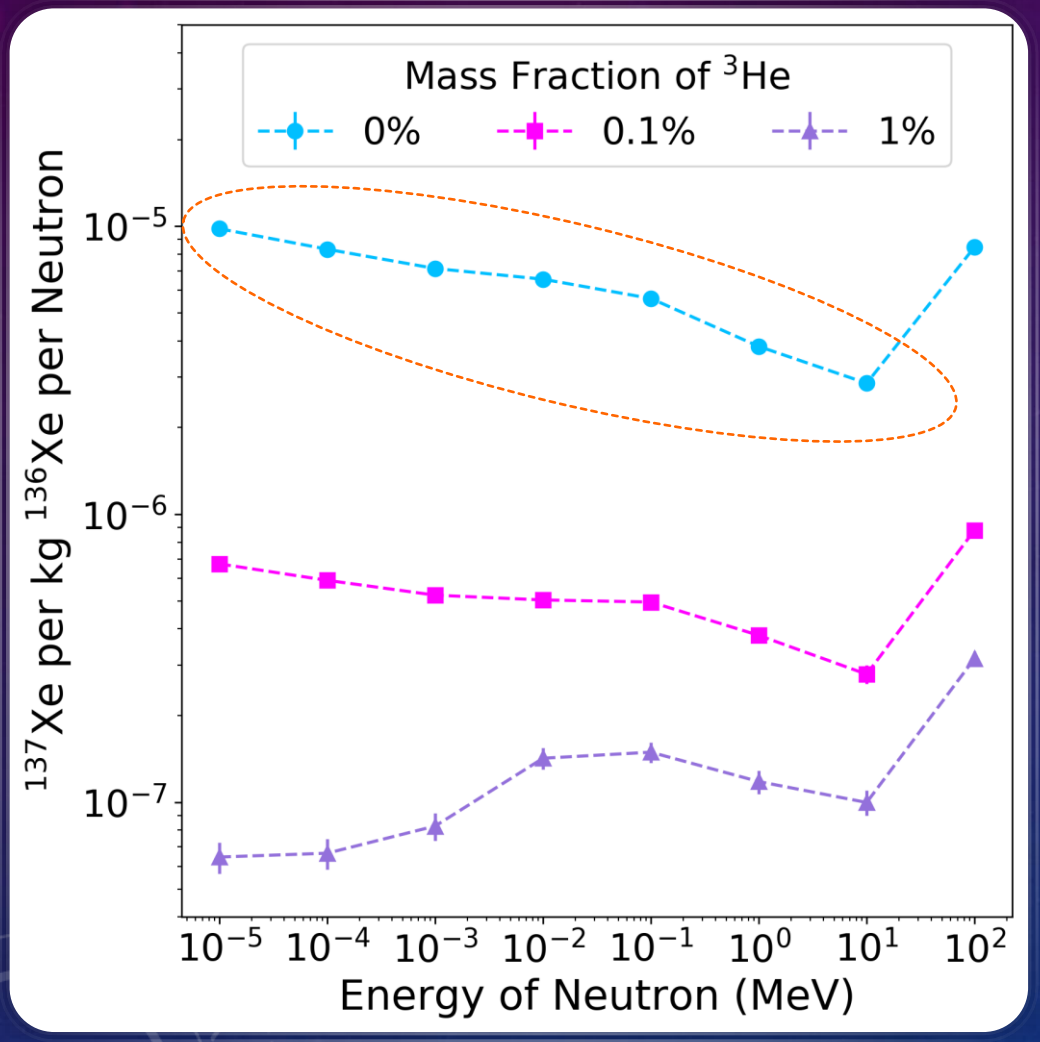
- ^{137}Xe is a potential background concern for Xenon detectors looking for neutrinoless double beta decay caused by neutron capture on ^{136}Xe

CORRELATED BACKGROUND RATES

	Activation rate		Background index	
	0% ^{3}He [kg^{-1} yr^{-1}]	0.1% ^{3}He [kg^{-1} yr^{-1}]	0% ^{3}He [$keV^{-1}kg^{-1}yr^{-1}$]	0.1% ^{3}He [$keV^{-1}kg^{-1}yr^{-1}$]
LSC	1.72×10^{0}	1.79×10^{-1}	1.29×10^{-5}	1.34×10^{-6}
LNGS	1.02×10^{-1}	1.06×10^{-2}	7.65×10^{-7}	7.91×10^{-8}
SURF	1.31×10^{-2}	1.36×10^{-3}	9.83×10^{-8}	1.02×10^{-8}
SNOlab	9.29×10^{-4}	9.65×10^{-5}	6.97×10^{-9}	7.24×10^{-10}

Table 1. ^{137}Xe Activation rate expectations with various percents of helium 3 by mass and example background indices given an analysis described in the text.

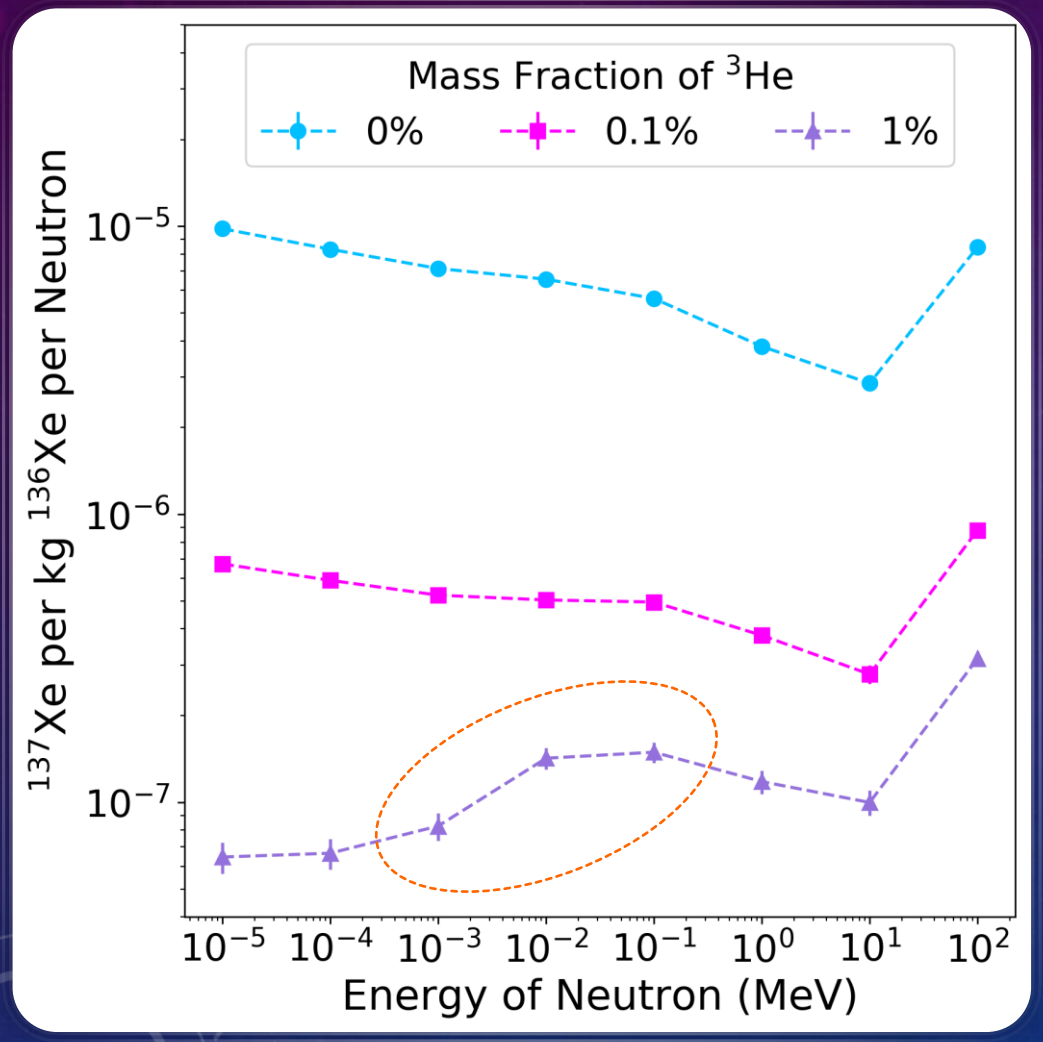
^{137}XE PRODUCTION OVER ALL NEUTRON ENERGIES



Decreased ^{137}Xe with ^{3}He additive over all neutron energies

- Steady fall in pure xenon corresponds to increasing probability that a neutron will leave the active volume without thermalizing

^{137}XE PRODUCTION OVER ALL NEUTRON ENERGIES



Decreased ^{137}Xe with ^{3}He additive over all neutron energies

- Steady fall in pure xenon corresponds to increasing probability that a neutron will leave the active volume without thermalizing
- Sharp increase in 137Xe production around 10 MeV corresponds to sharp up-kick in rates of multi-neutron production
- Bump in rate of capture in the ^{3}He/^{136}Xe mix system is attributed to capture of fast neutrons by resonances in the ^{136}Xe neutron capture cross section