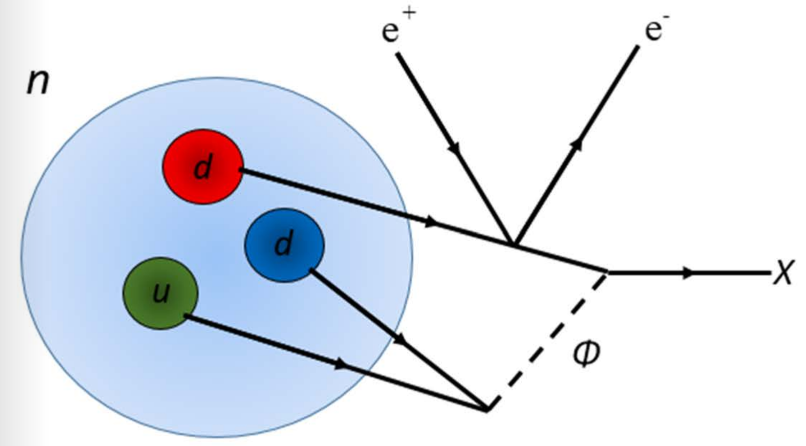
# Search for neutron dark decay: $n \to \chi + e^+e^-$

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## The Neutron Lifetime Anomaly

Current measurements of the neutron lifetime using two different techniques have results that differ by over 4σ. These two techniques are known as "bottle" experiments, experiments which store neutrons and measure their remaining density at different time intervals, and "beam" experiments, experiments which measure the decay of the free neutron to protons in a beam over a fixed length.

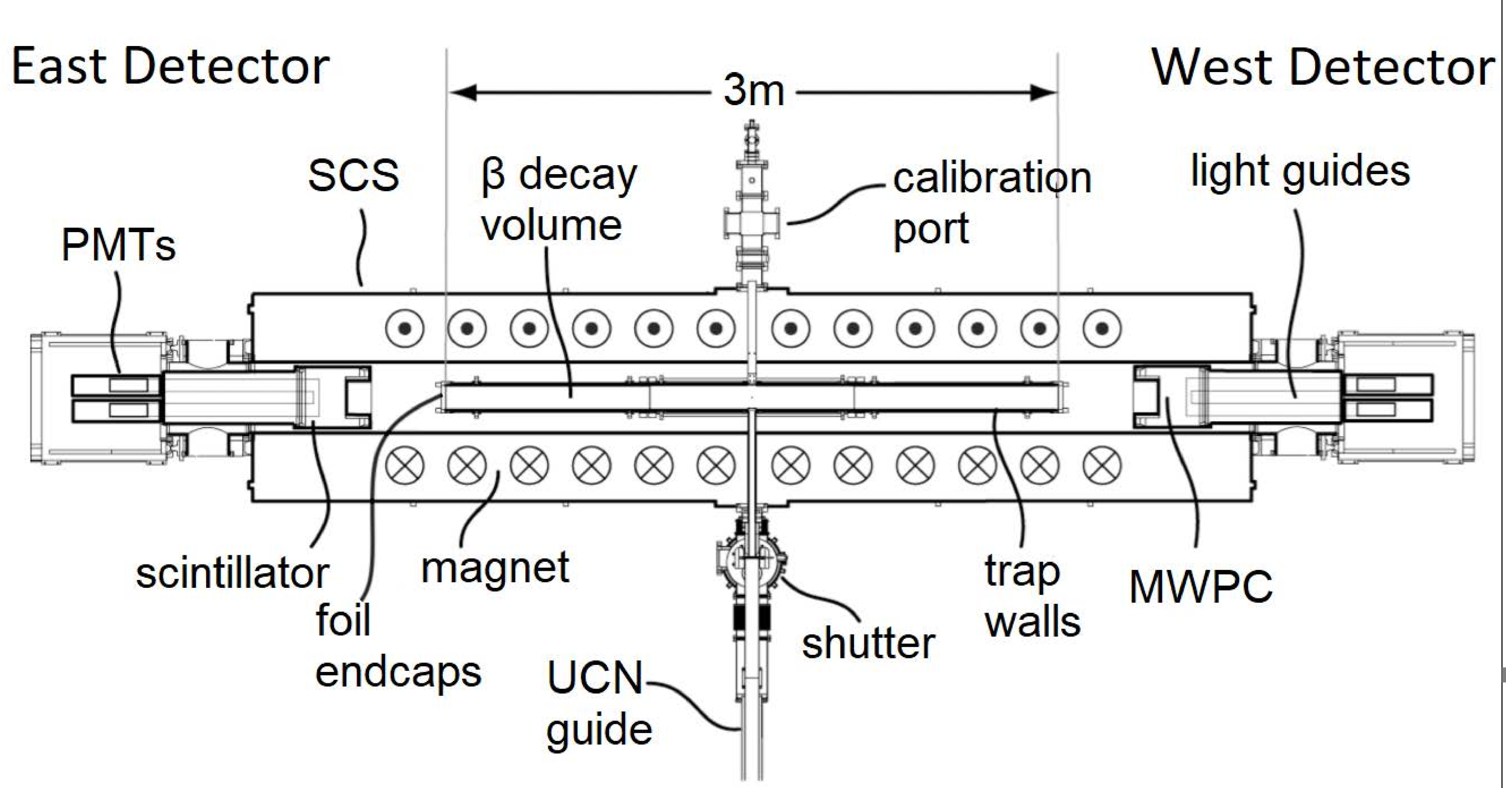
## A Hypothesized Solution

- What if the neutron could decay to dark matter?
- Fornal and Grinstein proposed such a theory [1]. Other decay products: a photon [2], an electron-positron pair [3], or purely dark decay products.
- We investigated the electron-positron decay channel [3].

n → 99% $p + e^- + \nu_e$

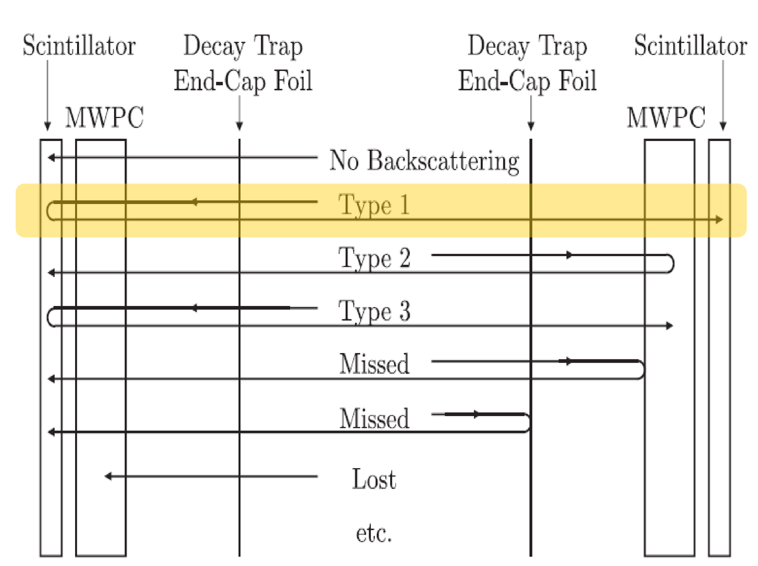
n → 1% $\chi + e^+e^-$ or $\chi + \gamma$ or $\chi + others$

## The UCNA Detector

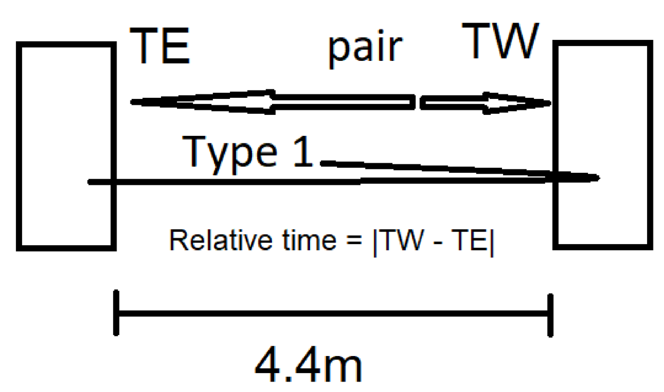



- Ultracold Neutron Asymmetry (UCNA) experiment: UCNs loaded in a main decay trap, charged decay products directed towards the sides by 1T magnetic field.
- 'East' and 'West' side detectors contain multi-wire proportional chamber (MWPC) and a plastic scintillator.
- TDCs using a 'common-stop' provide timing information between detector signals.
- Known electronics set-up and background runs allow for calibrating cable delays and timing of background events.

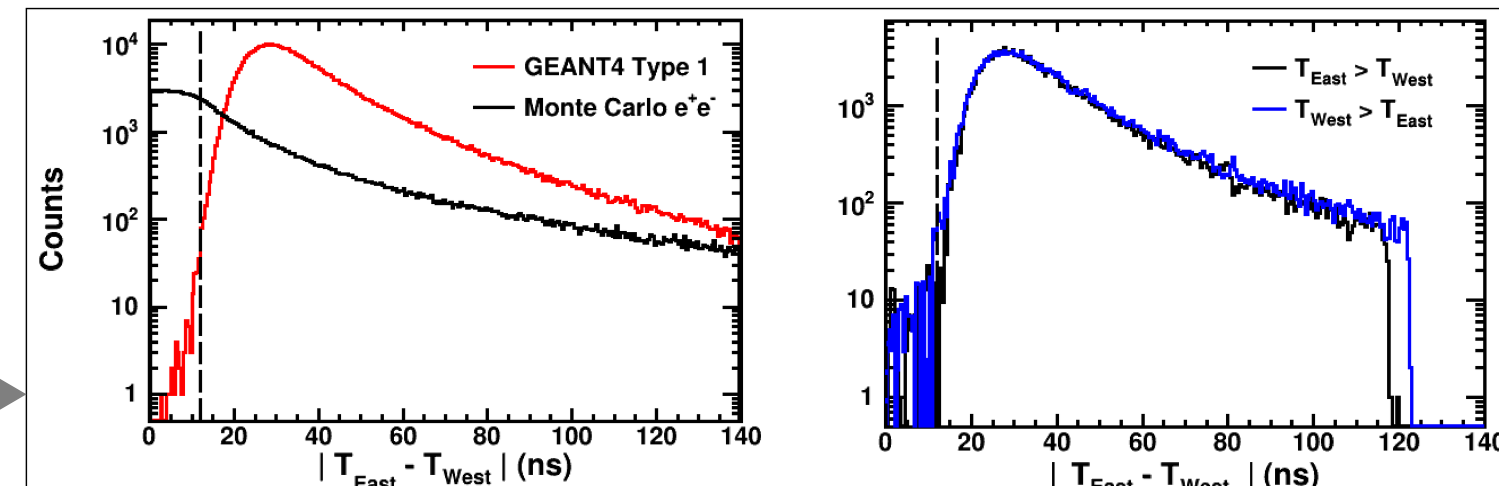
## Detected Event Types




- Events classified by types based on how many "triggers".
- Type 1 events: backscatter and trigger both MWPCs and scintillators.
- $n \to \chi + e^+e^-$ has same detector trigger as Type 1 events.

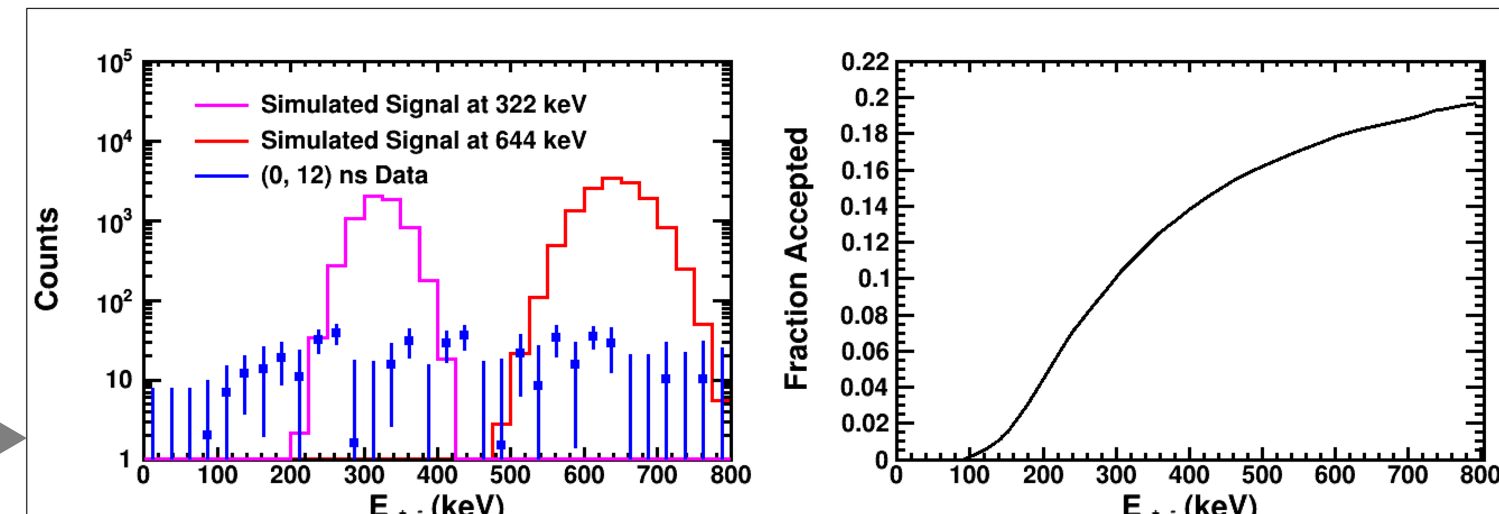



## A Unique Timing Spectrum



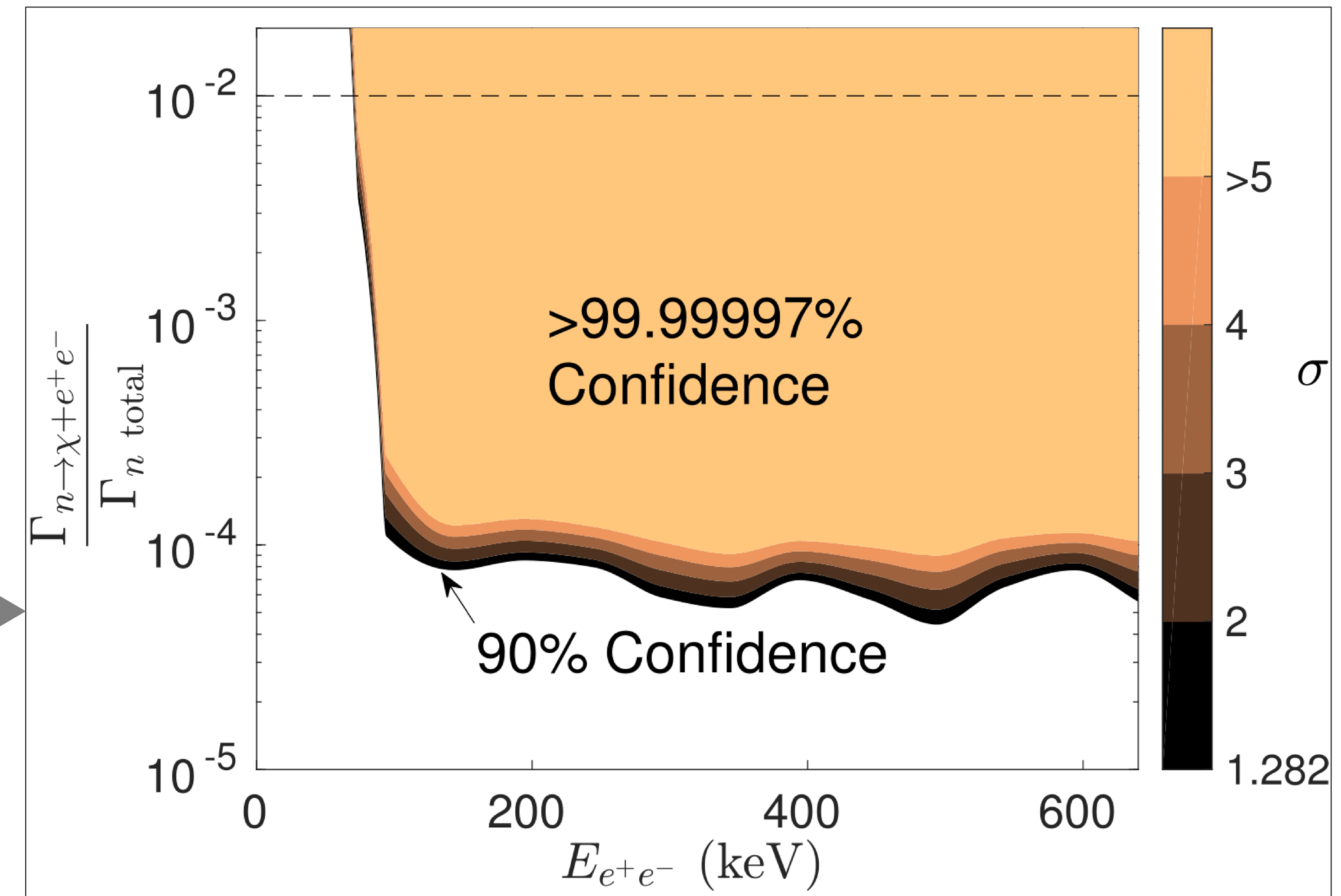

- Same signature in both detectors between Type 1 and $e^+e^-$ events; namely energy is deposited in both. However, the TDC spectrum is very different.
- Left graph shows simulations of both decays. Right graph shows our data.
- Single backscatter events have a minimum crossing time of 16ns.
- Strongly reduced background gives a 'clean' signal.

## Do We See A Signal?




- Look for two-detector trigger events.
- Adjust for acceptance (right graph): kinematic, trigger, and timing window.
- Additional correction for positron-electron differences in detector.
- Compare to a positive signal (left graph) to set confidence limits.

## Final Confidence Limits




- Correct for 'look-elsewhere' effect.
- Final confidence limits show that we exclude the $n \to \chi + e^+e^-$ decay at >> 5σ for summed kinetic energy $E_{e^+e^-}$ > 100 keV, if it is the only decay channel and exists at the 1% level necessary to resolve the lifetime anomaly.
- If $n \to \chi + e^+e^-$ is not the only decay channel, we set a branching ratio limit of $10^{-4}$ at the 90% confidence level for $E_{e^+e^-}$ > 100 keV.

## Summary & Conclusion

- Neutron lifetime anomaly: two measurement techniques yield a 4σ discrepancy.
- Proposed theory: a dark matter decay channel. Our experiment looks at such a decay that has $e^+e^-$ visible decay products.
- Using the UCNA detector 2012-2013 dataset, we rule out this decay channel, if it were the only dark decay channel, at >> 5σ for $E_{e^+e^-} > 100$keV. Furthermore, we set a branching ratio $\frac{\Gamma_{n\to\chi+e^+e^-}}{\Gamma_{n\,total}} < 10^{-4}$ at the 90% confidence level for $E_{e^+e^-} > 100$keV.

## References & Acknowledgements


- [1] B. Fornal and B. Grinstein, Phys. Rev. Lett. 120, 191801 (2018).
- [2] Z. Tang et al, (2018), arXiv:1802.01595 [nucl-ex].
- [3] X. Sun et al, (2018), arXiv:1803.10890 [nucl-ex]. Published May 21, 2018 in PhysRevC. DOI: 10.1103/PhysRevC.97.052501.



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