Observation of low-lying isomeric states in ^{136}Cs: a new avenue for dark matter and solar neutrino detection in xenon detectors

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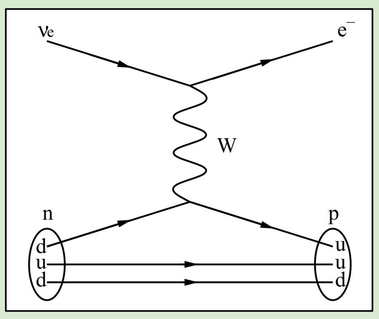
Neutrino / dark matter "capture" on ^{136}Xe

An unexplored channel in Xe detectors

^{136}Xe is a promising target for the detection of neutral lepton charged current (CC) interactions on nuclei

- ^{136}Xe is widely deployed in existing and future underground experiments
- $Q = M_{Cs} - M_{Xe} = 90.3$ keV
  → Low energy threshold!

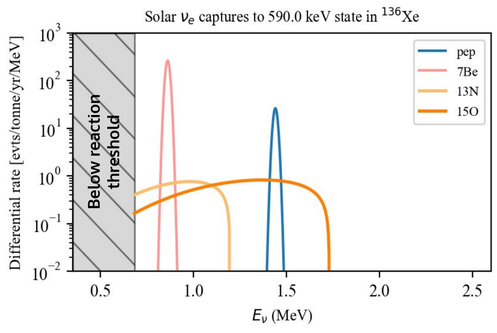


Low-energy solar neutrinos

$$\nu_e + {}^{136}\mathrm{Xe} \rightarrow {}^{136}\mathrm{Cs}^{*} + e^{-}$$

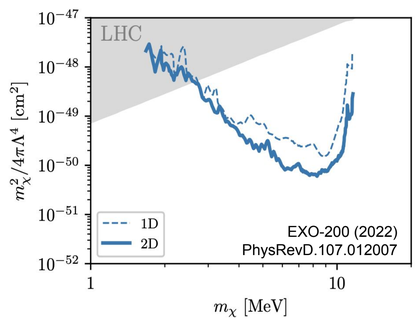
Neutrinos interact with nuclei via *W* exchange

Could offer spectroscopy of the elusive CNO neutrinos and sensitivity to the ^{7}Be line shape



Fermionic dark matter

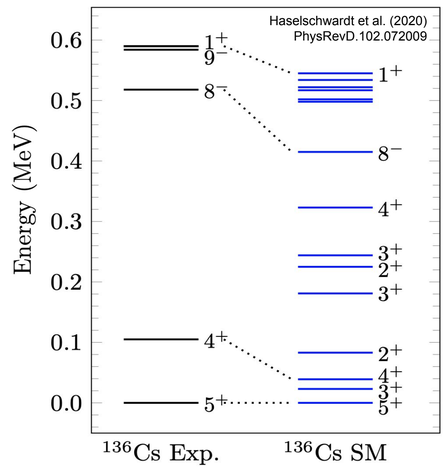
$$\chi + {}^{136}\mathrm{Xe} \rightarrow {}^{136}\mathrm{Cs}^{*} + e^{-}$$



Dark matter (DM) particle carries lepton number and interacts via a *W'*

Xenon-based experiments offer world-leading sensitivity to this signal for M_χ ~ O(MeV)

The importance of ^{136}Cs nuclear structure



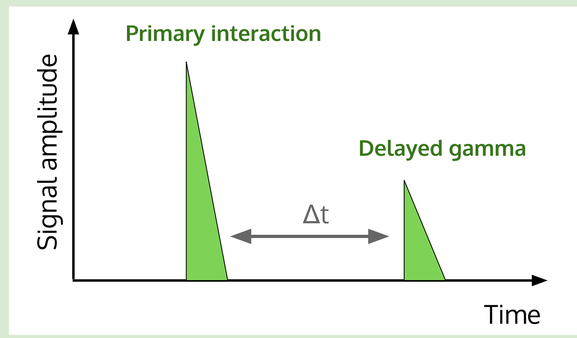
- CC interactions would populate $J^{\pi} = 1^{+}$ excited states in ^{136}Cs
- **Relaxation gamma rays need to be accounted for in modeling these events**
- Nuclear data for ^{136}Cs is sparse, but nuclear shell model calculations predict a complex level scheme

<u>New nuclear structure data is needed!</u>

A key prediction

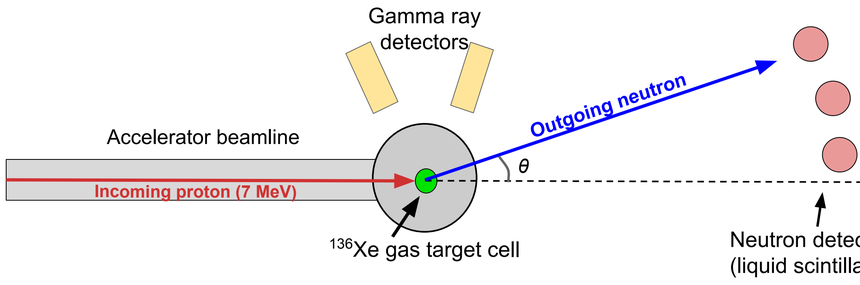
Relaxation populates long-lived ***isomeric states***, which then emit ***delayed gamma rays***

<u>Powerful background rejection could be possible via delayed coincidence analysis!</u>

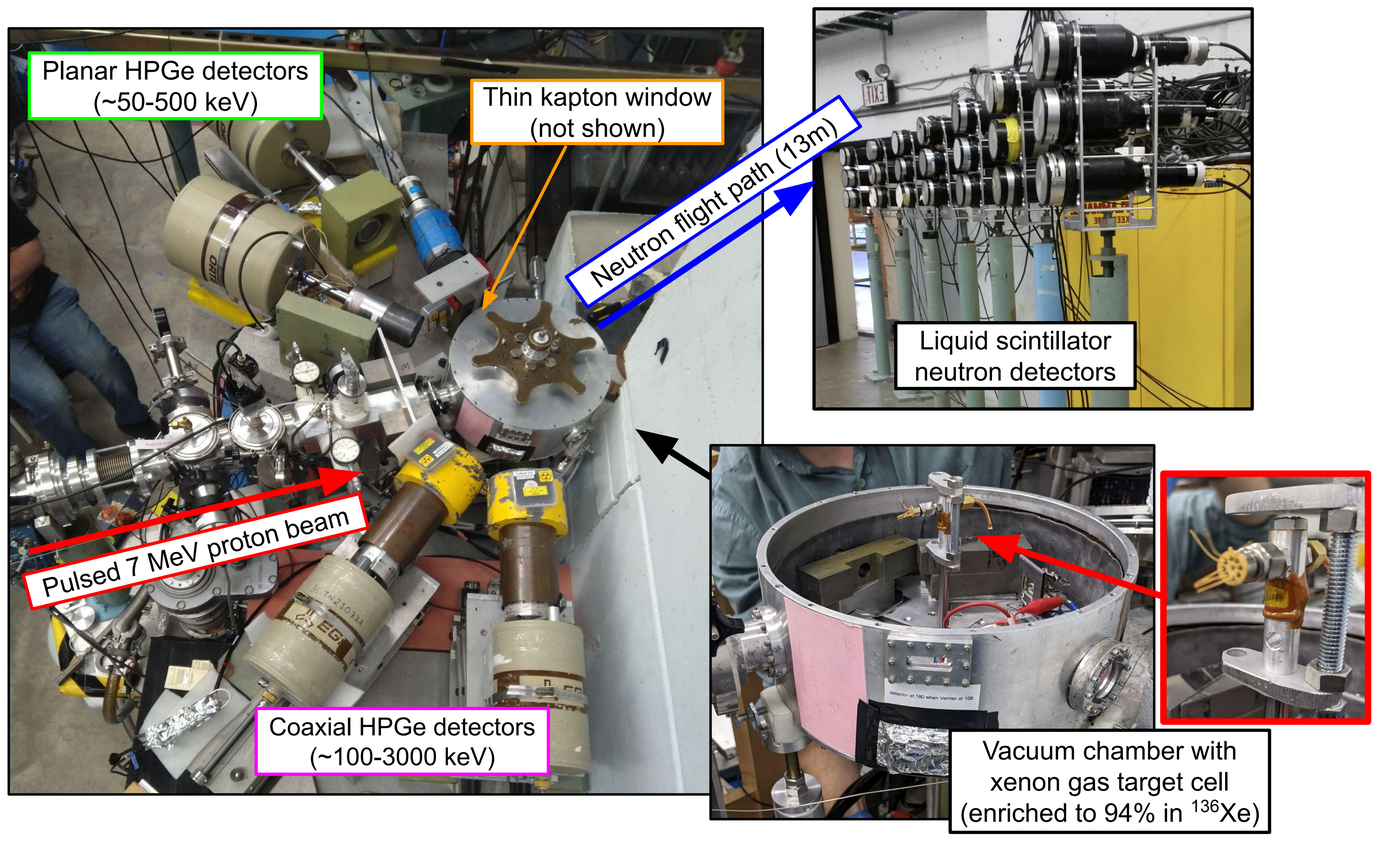


Measuring ^{136}Cs at Triangle Universities Nuclear Laboratory (TUNL)

^{136}Xe(p,n)^{136}Cs charge-exchange reactions

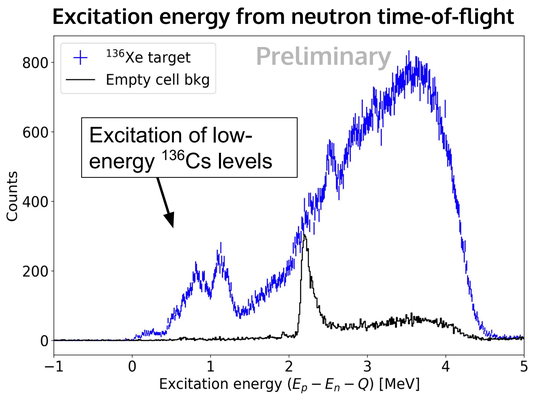


Experimental setup

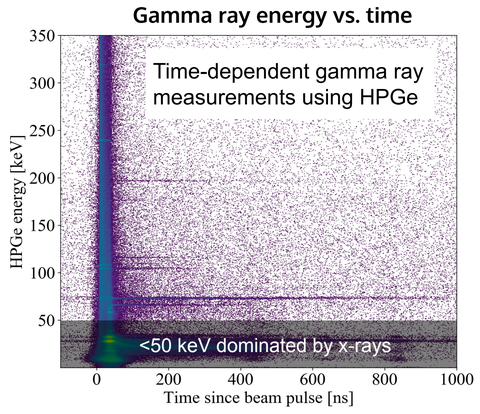


^{136}Cs excitation and gamma ray emission

Excitation energy from neutron time-of-flight



Gamma ray energy vs. time



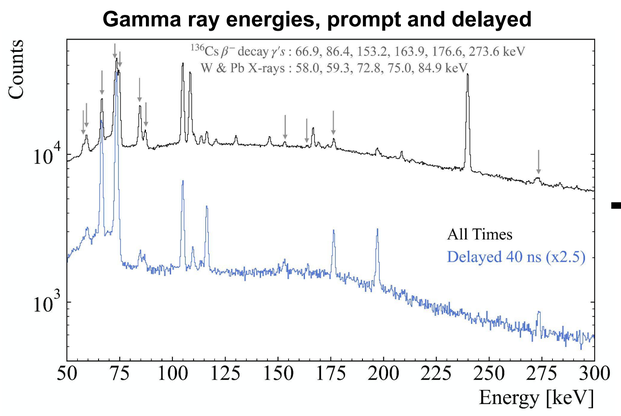
Analysis and results

Reconstructed level scheme (below) agrees with charged-particle scattering measurements (PRL.131.052501, PRC.84.051305), but we offer **improved energy resolution** and **gamma ray emission branching fractions**

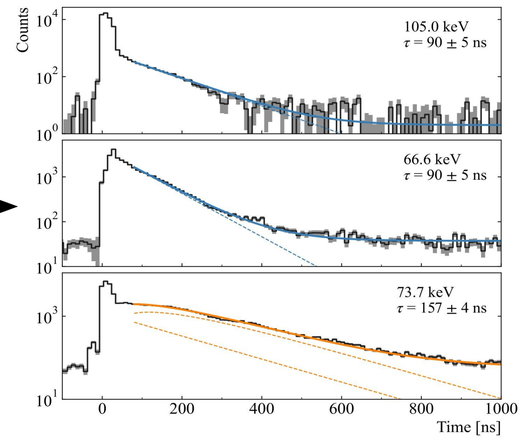
Combining this with timing information (right), we identify **two isomeric states in the level scheme**: 140.3 keV (τ = 157±4 ns) and 73.7 keV (τ = 90±5 ns)

Measurement of lifetimes

Gamma ray energies, prompt and delayed

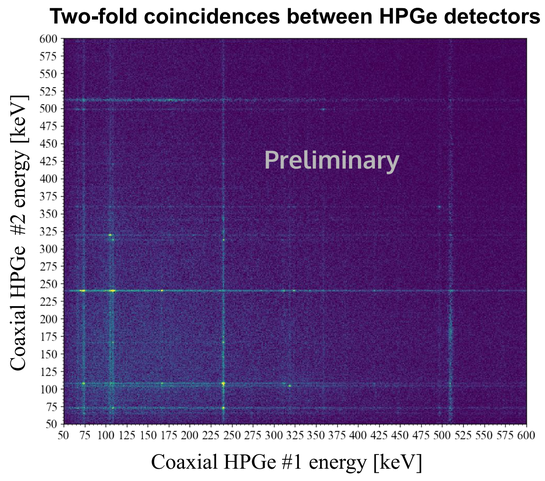


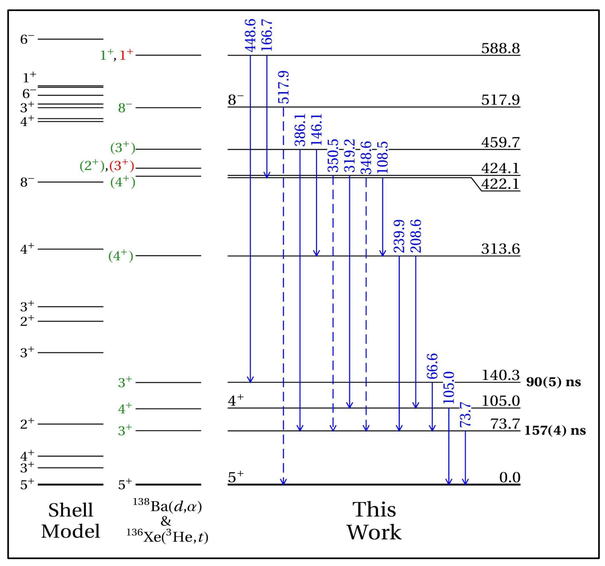
Time distributions of transitions from level scheme



Constructing level scheme using γ-γ coincidences

Two-fold coincidences between HPGe detectors





Gamma ray emissions from lowest-lying 1^{+} states in ^{136}Cs have been measured for the first time

→ Enables robust signal modeling for CC interactions on ^{136}Xe

Two isomeric states with lifetimes of O(100) ns have been identified and measured

→ Enables powerful background rejection for the detection of solar ν's and fermionic DM in current and next-gen Xe experiments

For more info see: Haselschwardt et al., Phys. Rev. Lett. ***131*** *052502 (2023)*