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Nuclear event source type characterization with three-dimensional spatial analysis of radioxenon isotopic activity ratios

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INTRODUCTION (1/2)

The three-dimensional (3D) spatial analysis of radioxenon isotopic activity ratios can be used to determine the source type of a nuclear event without any knowledge of the time of its generation.

This method requires at least a triple detection from the same sample among the four CTBT-relevant radioxenon isotopes, which are ^{131m}Xe, ^{133m}Xe, ^{133}Xe, and ^{135}Xe.

The 3D space of three different isotopic activity ratio axes can be turned around in such a way that the viewing perspective along the axis of decay without ingrowth is chosen.

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INTRODUCTION (2/2)

In this projection to a 2D plane any entry changing over time by radioactive decay would remain in the same spot.

The simulations and observations of different source types whether observed (data of Nevada Test Site releases, signatures from medical isotope production facilities and Fukushima accident data) or simulated (nuclear explosion scenarios, light water reactor operation cycles, neutron activation) are entered in the plot.

A cluster analysis marks the areas in which measurements of these source types can be found. This can be used to characterize the potential source of any observation that has three isotopes measured above the detection limit.

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METHODOLOGICAL APPROACH

As one can see, the real observations from underground nuclear tests (black circle markers) are distributed along the virtual time axis that is scaled in days from zero to infinity.

For each data point, the age is determined by projecting its coordinates onto the virtual axis

Axis ratios use all radioxenon isotopes except for ^{131m}Xe

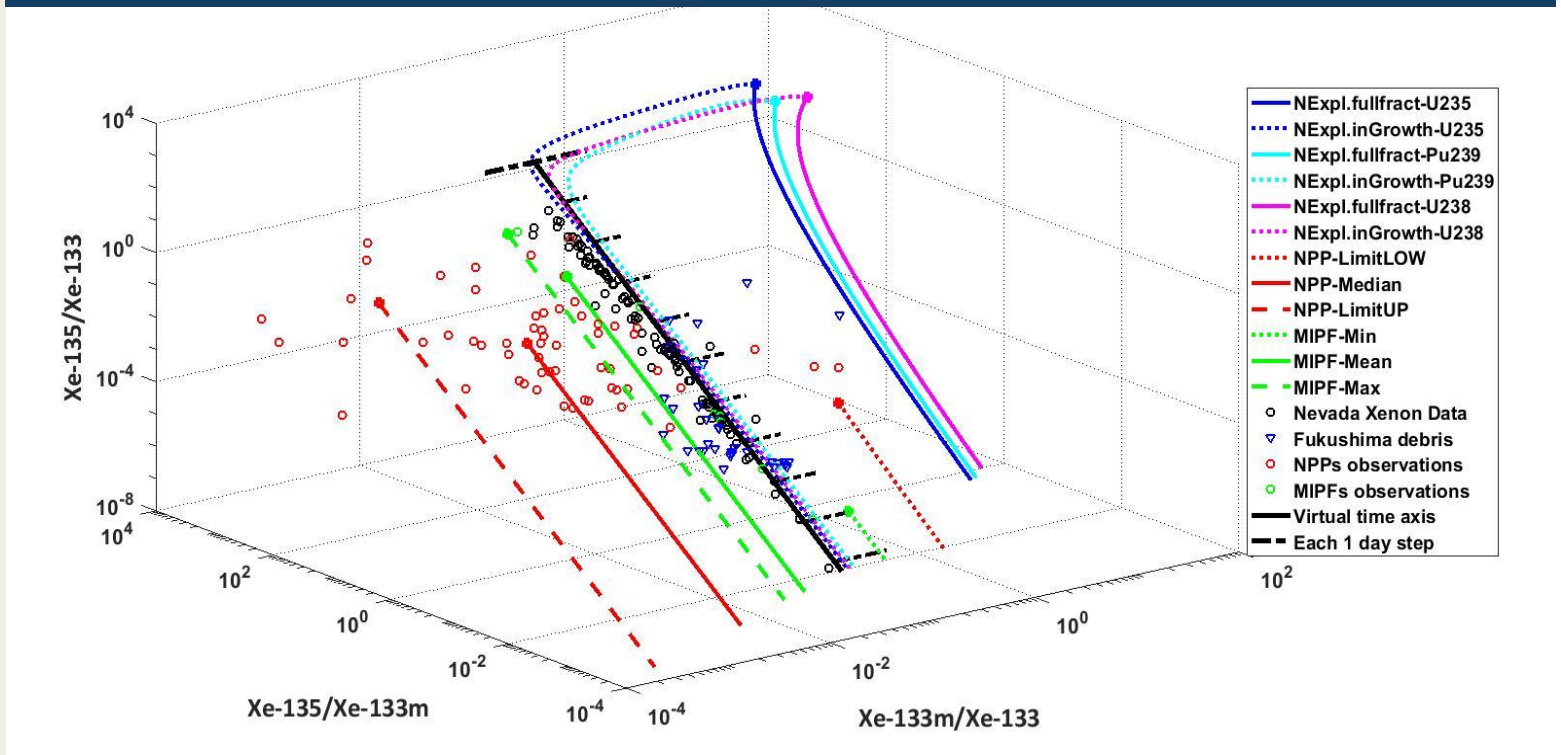

Figure : 3-D isotopic ratio plot using the radioxenon isotopes ^{135}Xe, ^{133m}Xe and ^{133}Xe. It is found that this combination of isotopes is usable between 1 and 11 days following the explosion

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METHODOLOGICAL APPROACH

The analysis of the isotopes set ^{135}Xe /^{133m}Xe /^{131m}Xe (i.e., without ^{133}Xe) shows that the isotope set under consideration here is useful for nuclear event timing only in the time interval going from a number of days to infinity.

Thus, a usability threshold needs to be investigated in order to determine exactly the position of the valid range of the VTA

Axis ratios use all radioxenon isotopes except for ^{133}Xe

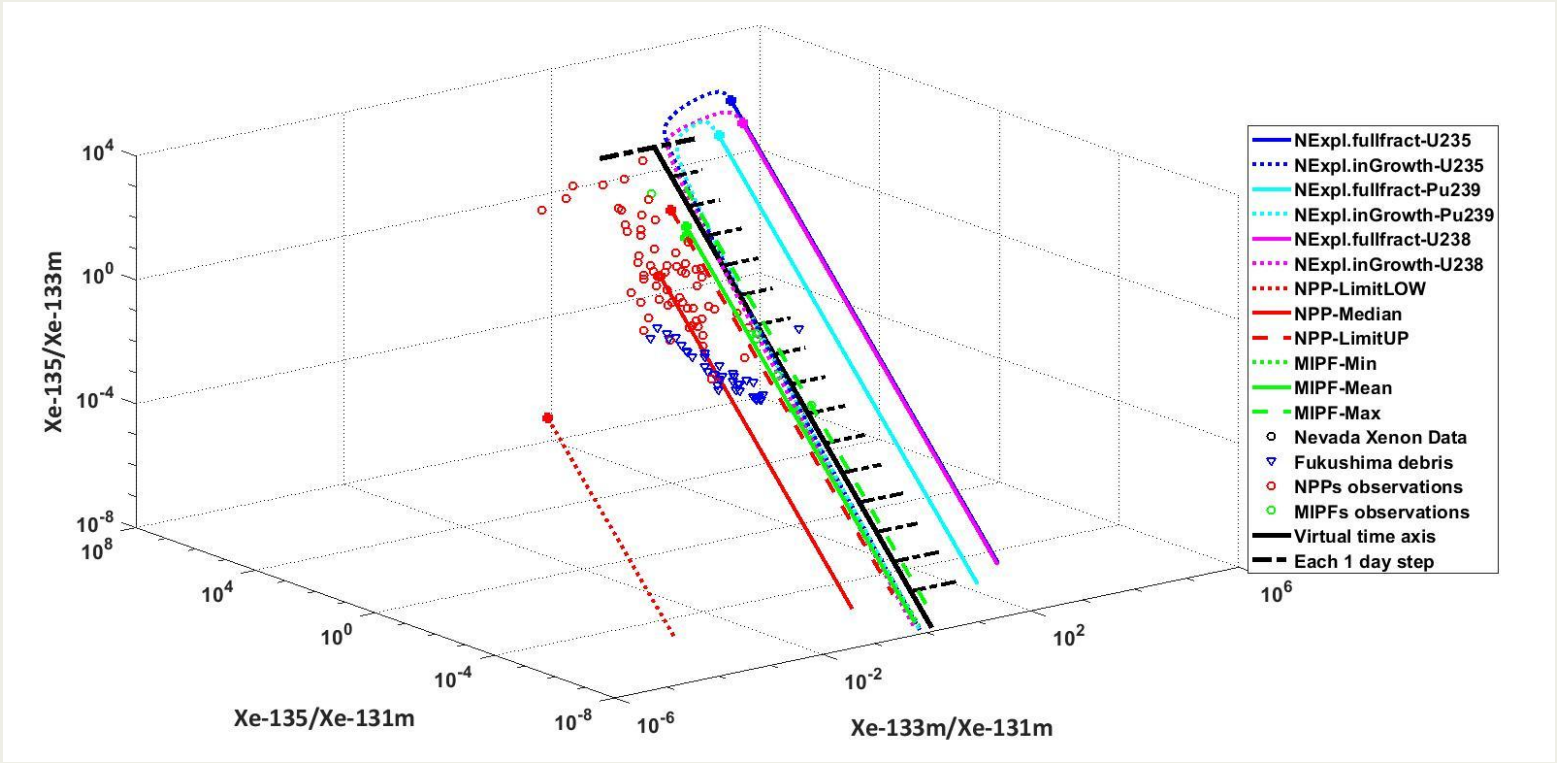

Figure : 3-D isotopic ratio plot using radioxenon isotopes ^{135}Xe, ^{133m}Xe and ^{131m}Xe. This combination of isotopes is usable only after 10 days following the explosion

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METHODOLOGICAL APPROACH

The analysis of the isotopes set ^{135}Xe /^{133}Xe/^{131m}Xe (i.e., without ^{133m}Xe) shows that due to the definition of the VTA, this axis seems to be almost parallel to the trajectories for the explosion scenario with full in-growth only after a significant number of days has passed.

Axis ratios use all radioxenon isotopes except for ^{133m}Xe

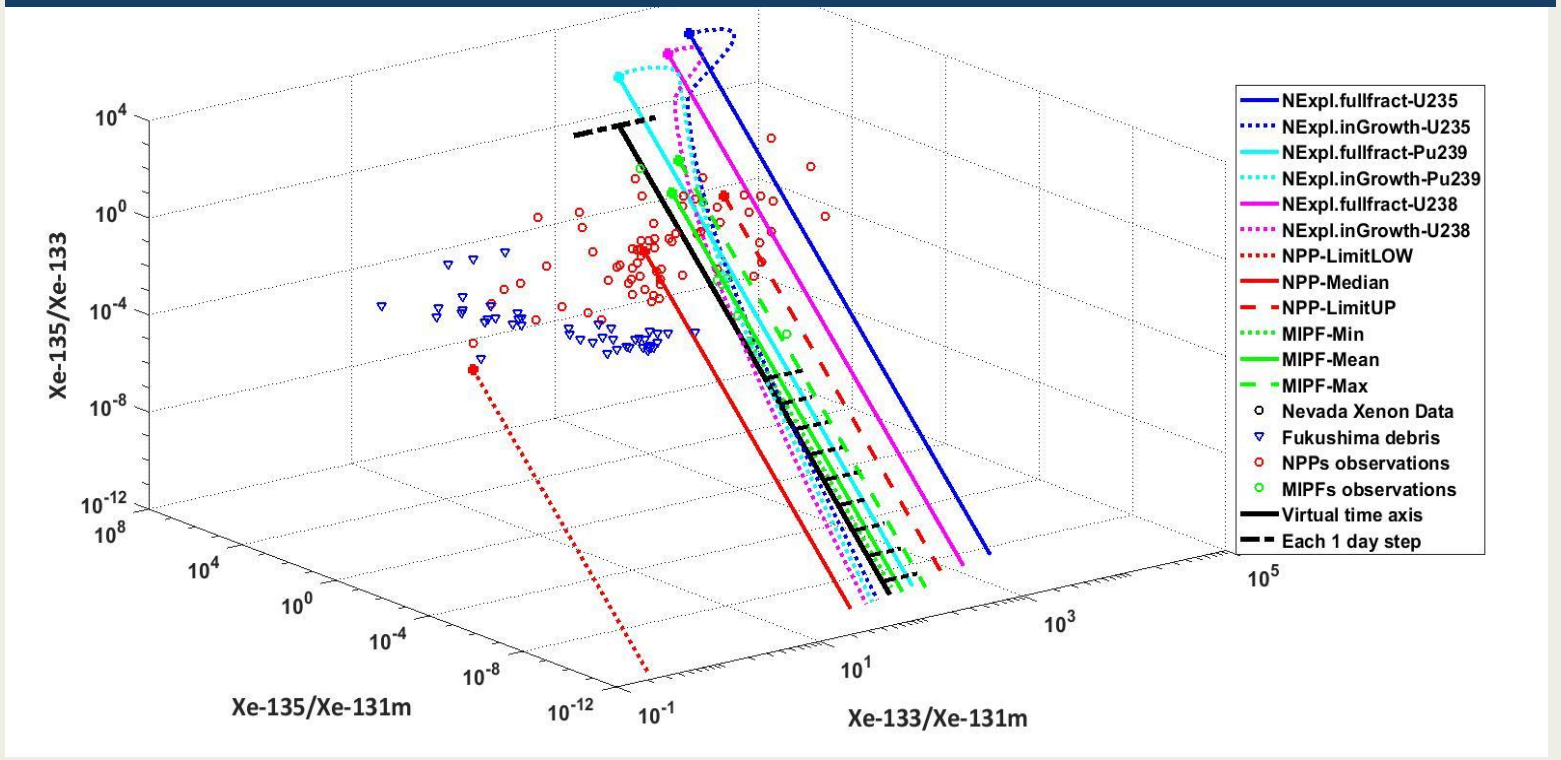

Figure : 3-D isotope ratio plot using the radioxenon isotopes ^{135}Xe, ^{133}Xe and ^{131m}Xe. During the first 11 days following the explosion, these isotopes are not useful.

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METHODOLOGICAL APPROACH

The analysis of the isotopes set ^{133}Xe/^{133m}Xe /^{131m}Xe (i.e., without ^{135}Xe) in Figure 4 shows that the VTA appears to be almost parallel to the trajectories for the explosion scenario with full in-growth only a significant time later.

In our eposter P2.1-308, the usability threshold is investigated that determines exactly the position of the valid range of the virtual time axis.

Axis ratios use all radioxenon isotopes except for ^{135}Xe

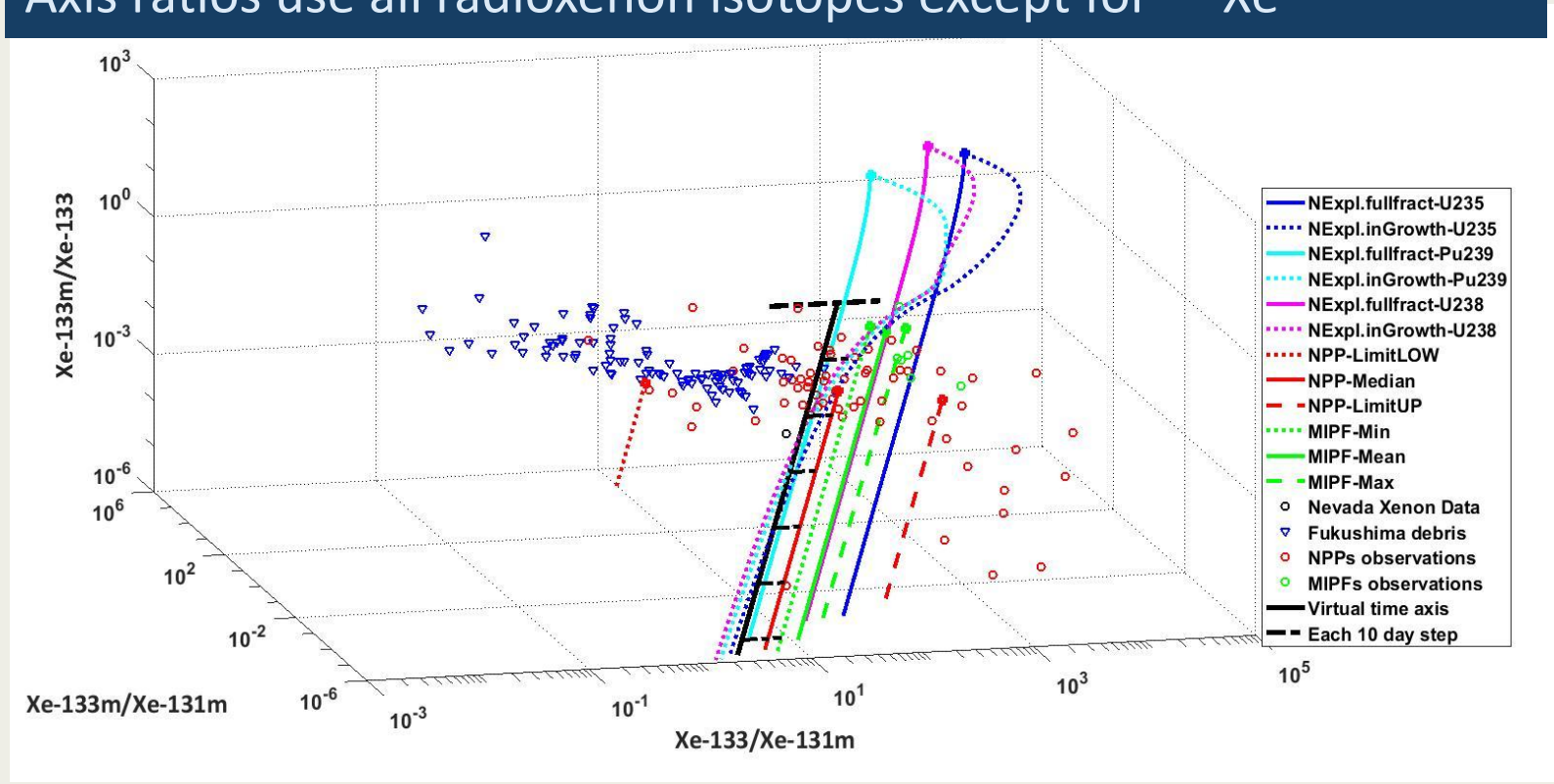

Figure : 3-D isotopic ratio plot using the radioxenon isotopes ^{133}Xe, ^{133m}Xe and ^{131m}Xe. These isotopes are usable for this 3D method after about 9 weeks following the explosion.

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METHODOLOGICAL APPROACH

The 3-D space is turned such a way the Virtual time axis is seen as a dot.

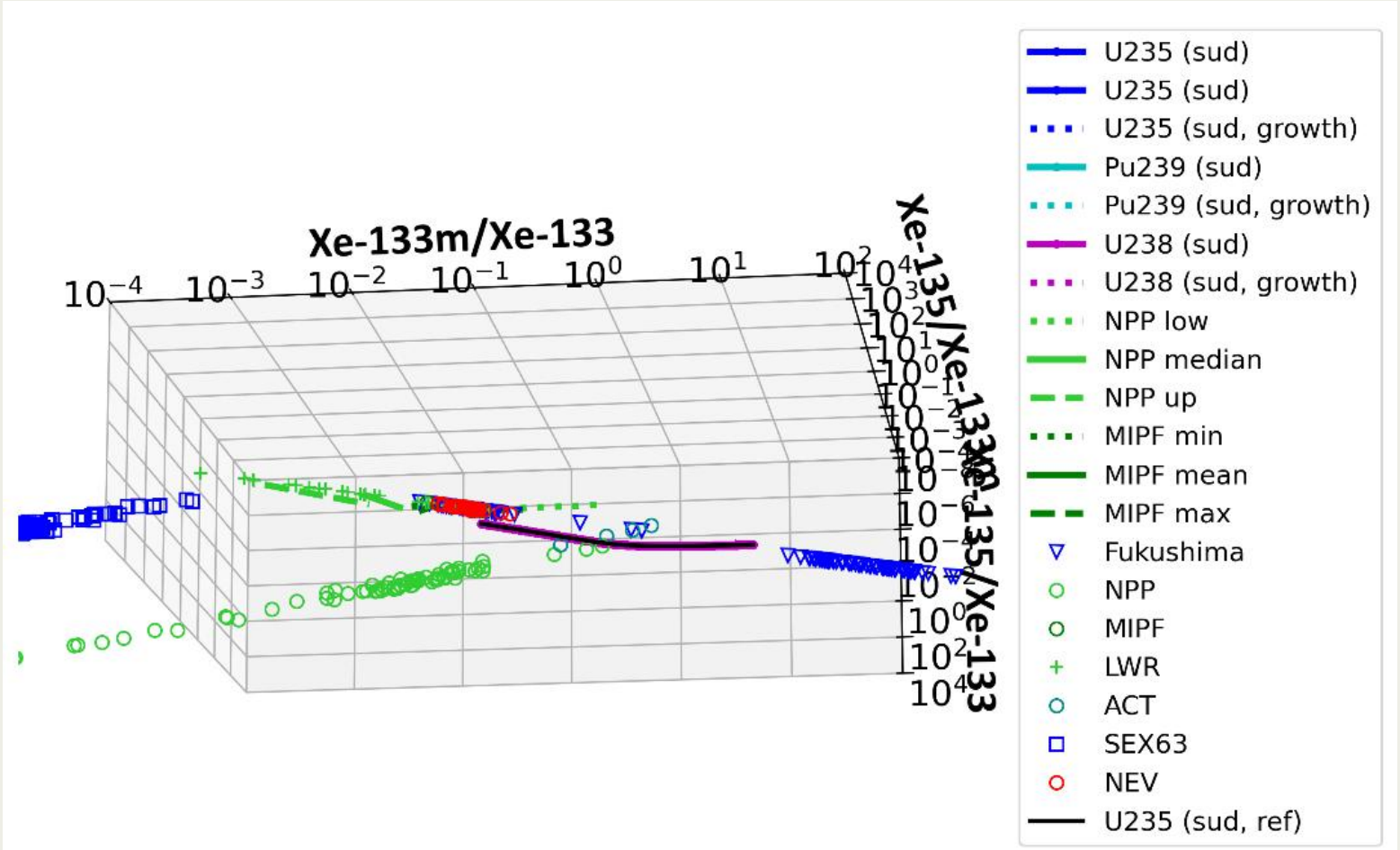

Figure : New approach using radioxenon 3-D isotopic ratio plot

Axis ratios use all radioxenon isotopes except for ^{131m}Xe

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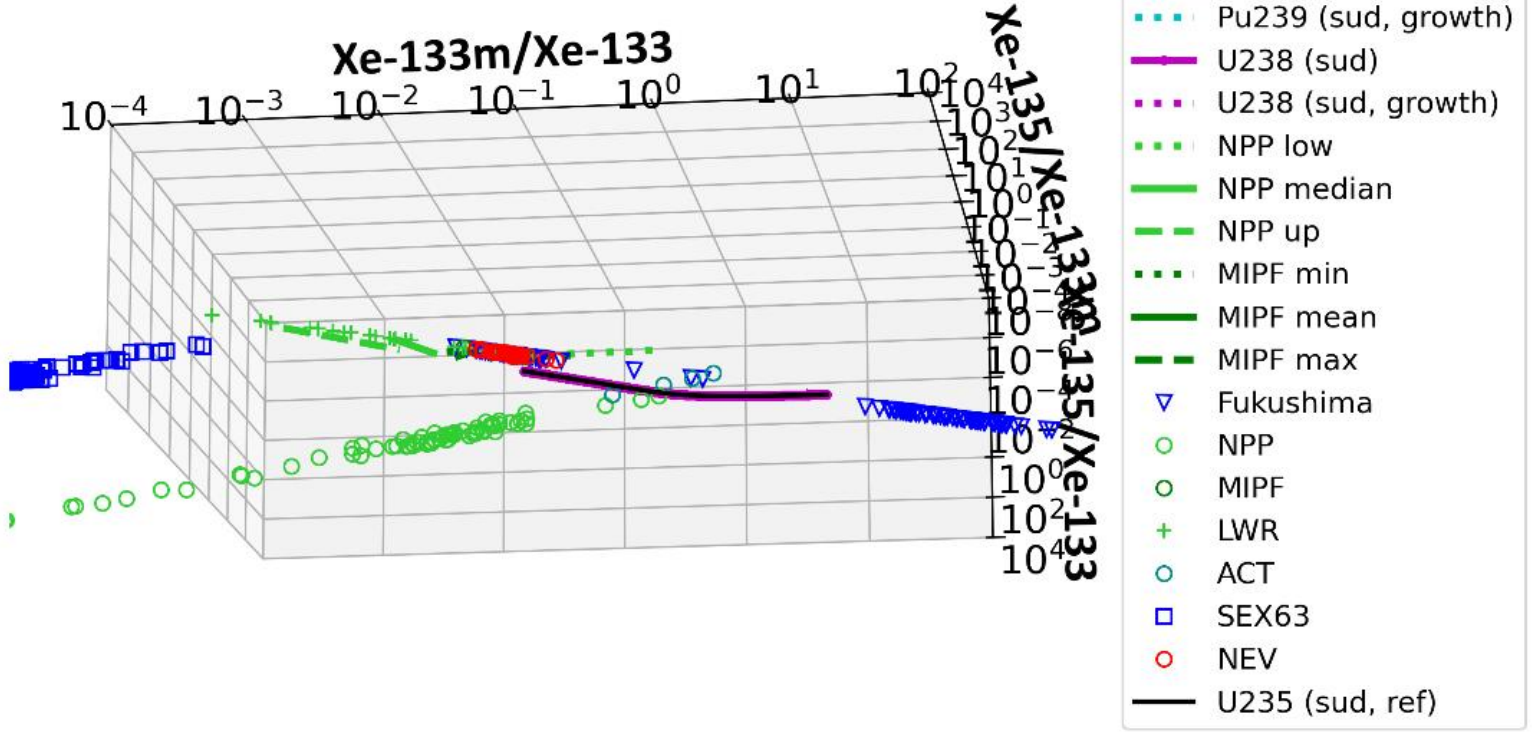
RESULTS & DISCUSSION

1. The spatial overlap of different source types is consistent with 2D projections.
2. Large spaces remain free.
3. Surprise: Source type clusters are narrow lines with little scatter.
4. Source type identification can be done by association with one of the linear clusters.
5. There is minimal ambiguity: only at the cross-section of two linear clusters.

Figure : New approach using radioxenon 3-D isotopic ratio plot with projection along decay.



Axis ratios use all radioxenon isotopes except for ^{131m}Xe

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CONCLUSION

For 3D timing, the combination being most likely of practical relevance is the one without ^{131m}Xe. This happens to be the one for which a large Nevada data set of about 100 observations is available.

The same isotope combination is used to explore the source type distribution with a time-independent projection along the virtual time axis.

1. Surprise: Source type clusters are narrow lines with little scatter.
2. Source type identification can be done by association with one of the linear clusters.
3. There is minimal ambiguity: only at the cross-section of two linear clusters.

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THANK YOU