Mitigating radon backgrounds with a novel ^{214}Pb-tag in the LUX-ZEPLIN experiment

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On behalf of the LZ collaboration

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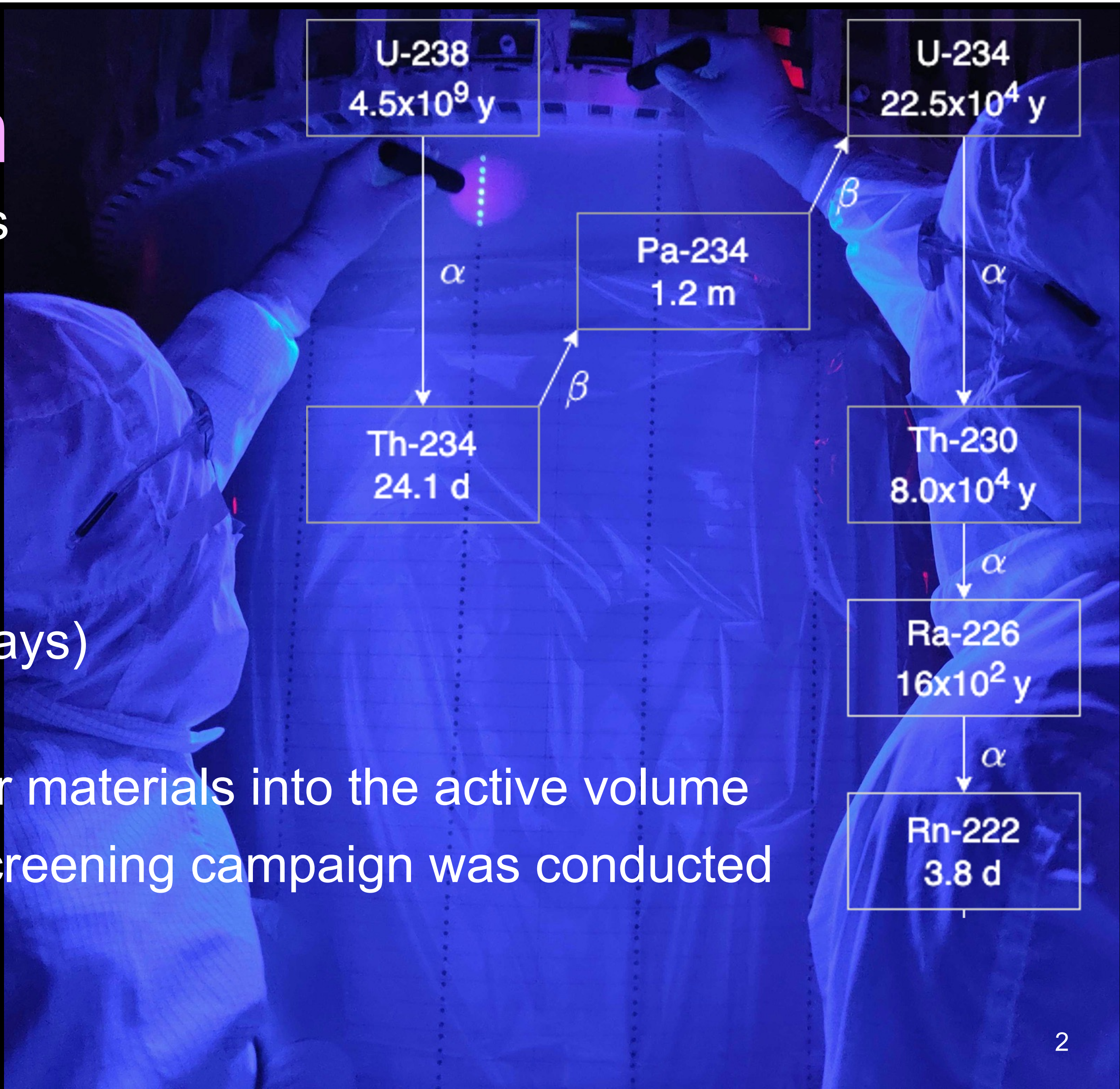
The Radon Problem

- ^{238}U naturally exists in most materials
- Decays via a sequence to ^{222}Rn
- Radon is a
  - Chemically inert noble gas
  - Hard to shield against
  - Difficult to remove chemically
  - Long half life ($\tau_{½}$ ^{222}Rn = 3.8 days)

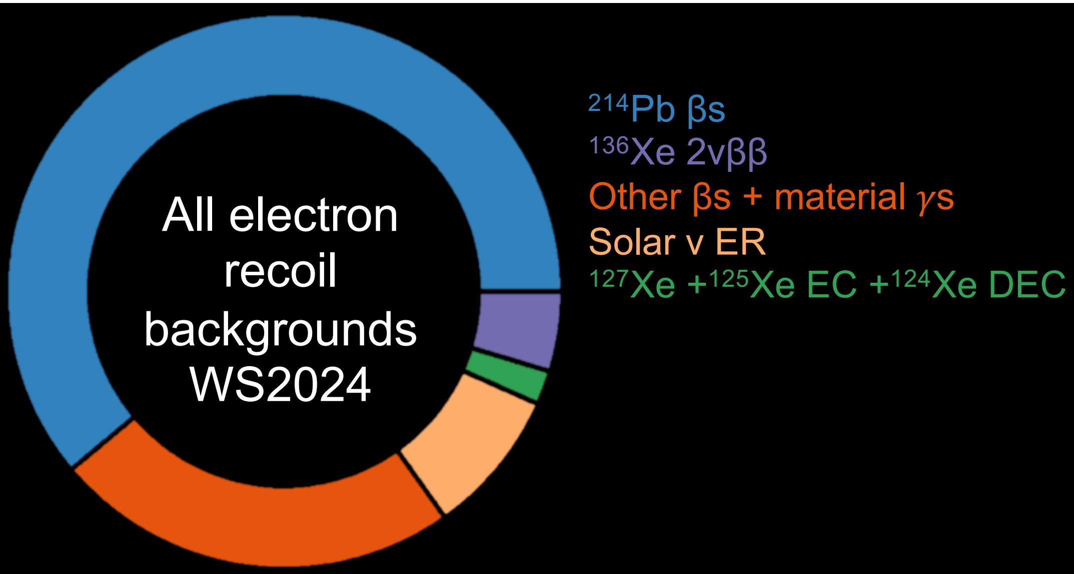


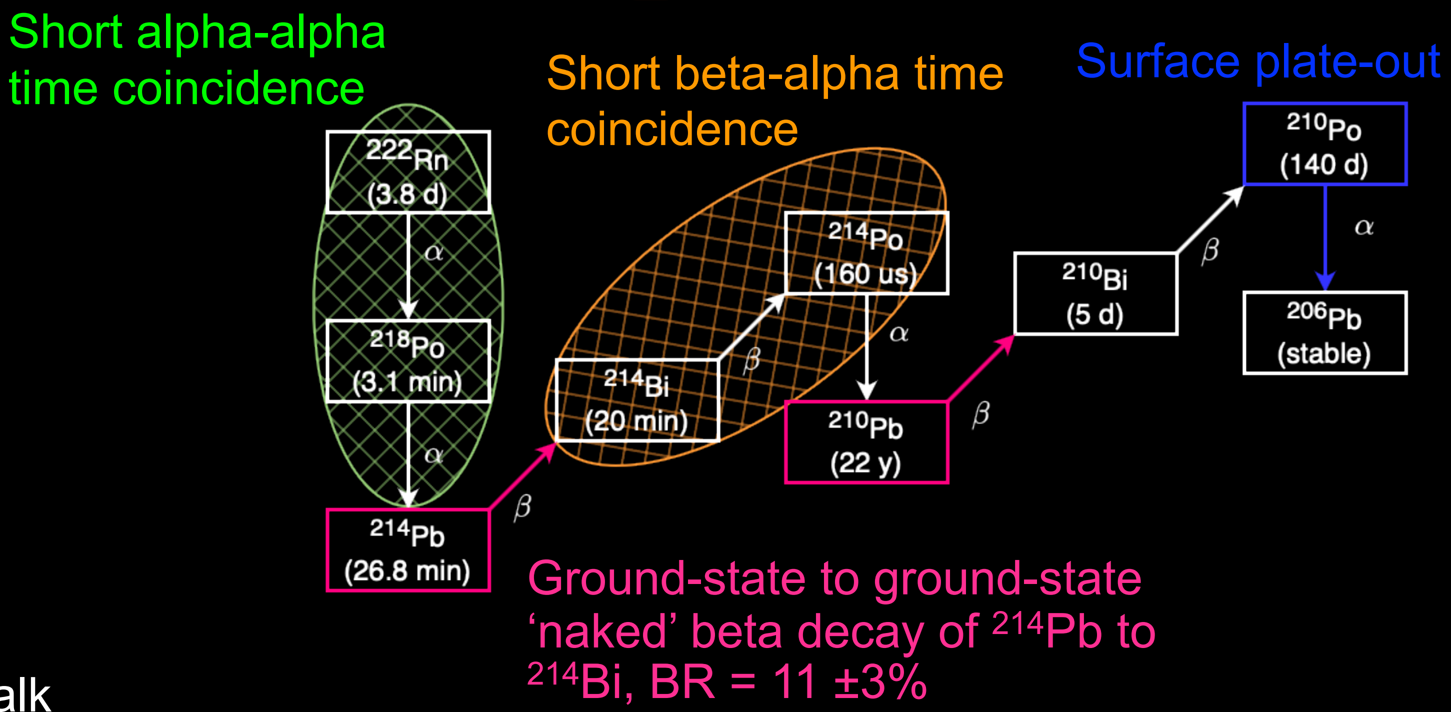
- As a result, it emanates from detector materials into the active volume
- To mitigate this, a 5 year materials screening campaign was conducted
- Low activity targets were reached*

* The LZ radioactivity and cleanliness control programs
https://doi.org/10.1140/epjc/s10052-020-8420-x

The ^{214}Pb Background

- Dominant background (~60% of ER*) can appear WIMP-like
- No method to identify these decays on an event-by-event basis
- Can see position and time of preceding alpha decays
- Solution: use information from the other decays

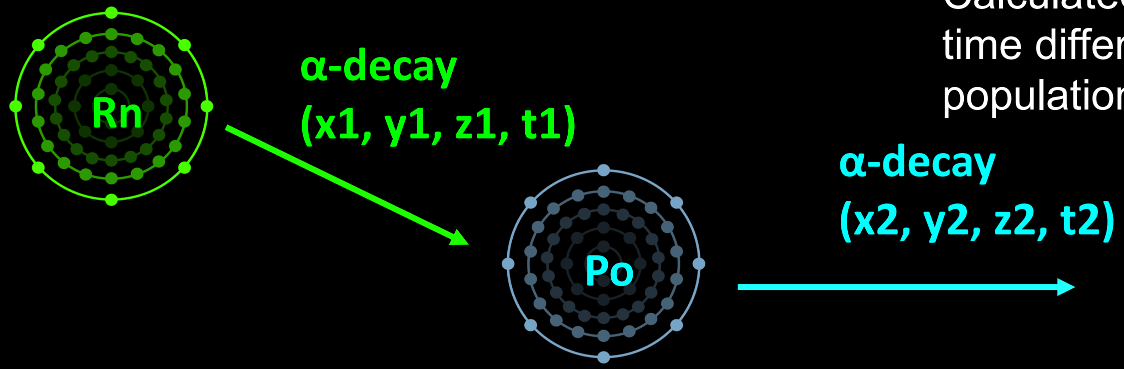


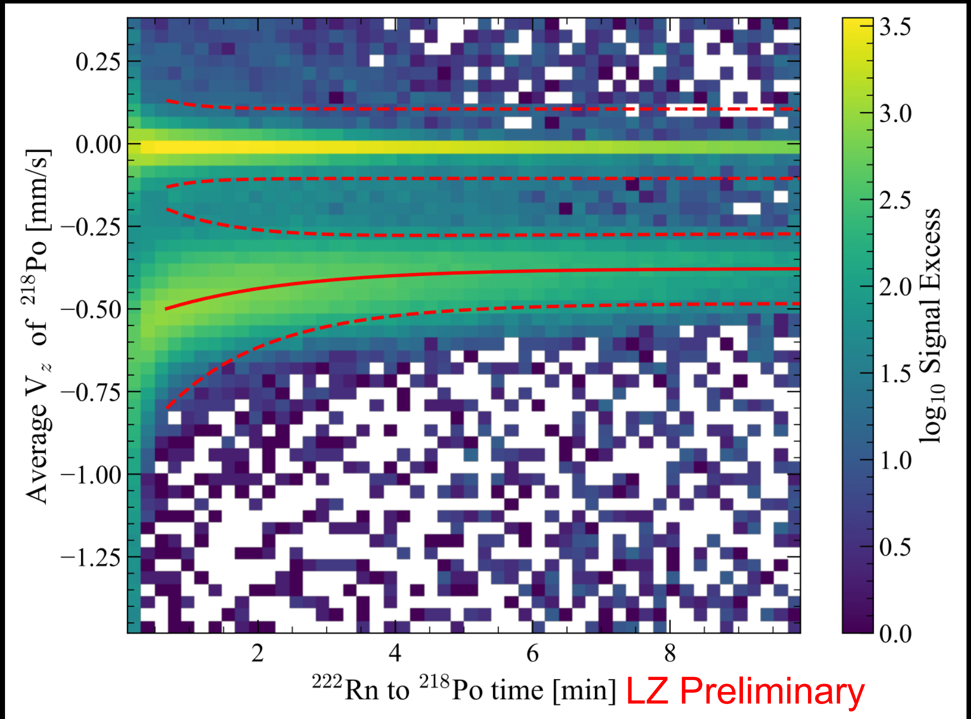


*Electron Recoil, see Albert Baker's LZ results talk

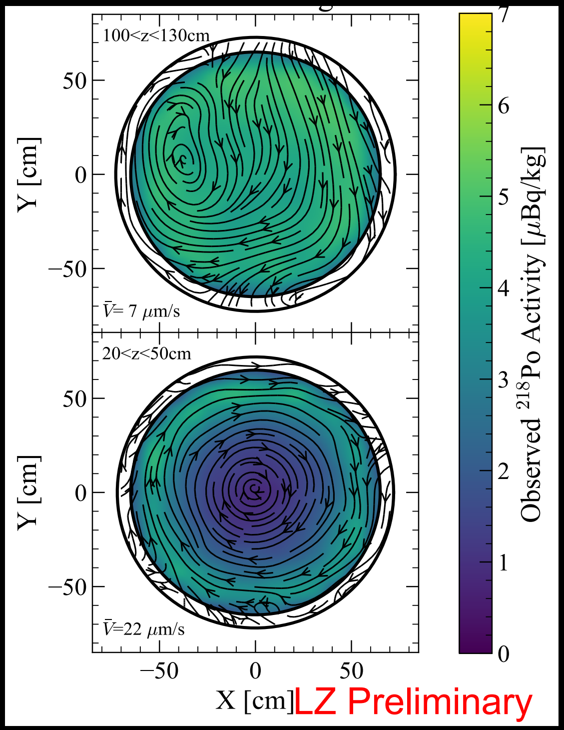
Rn-Po studies

- Short alpha-alpha time coincidence ($\tau_{½}$ ^{218}Po = 3.1 min)
- As a result, Rn-Po pairs can be made and the *x, y, z, t* of each decay can be tracked
- Can extract useful information, like ion mobility
- Can also generate a flow model from these vector pairs



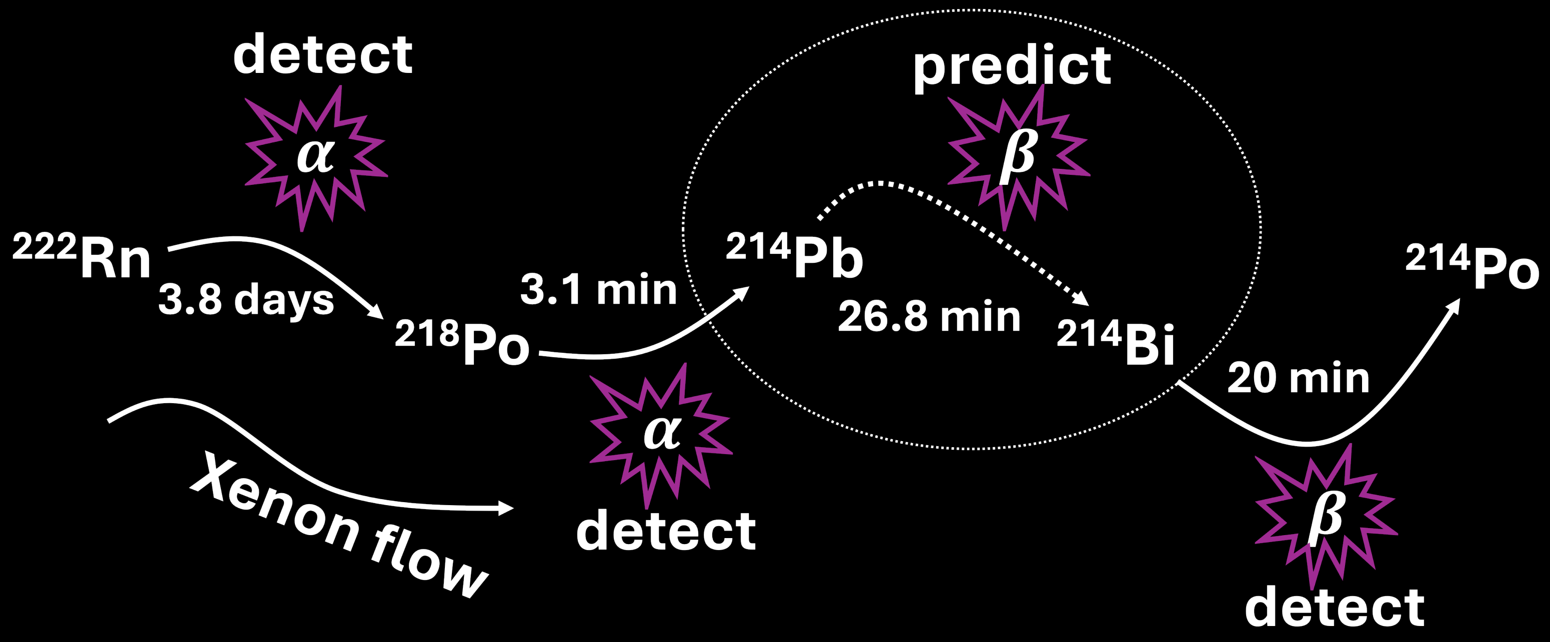


Calculated average velocity of Rn-Po pairs with time difference between the two decays. Upper population: neutral pairs. Lower: charged pairs



Xenon flow model

Predicting ^{214}Pb Position

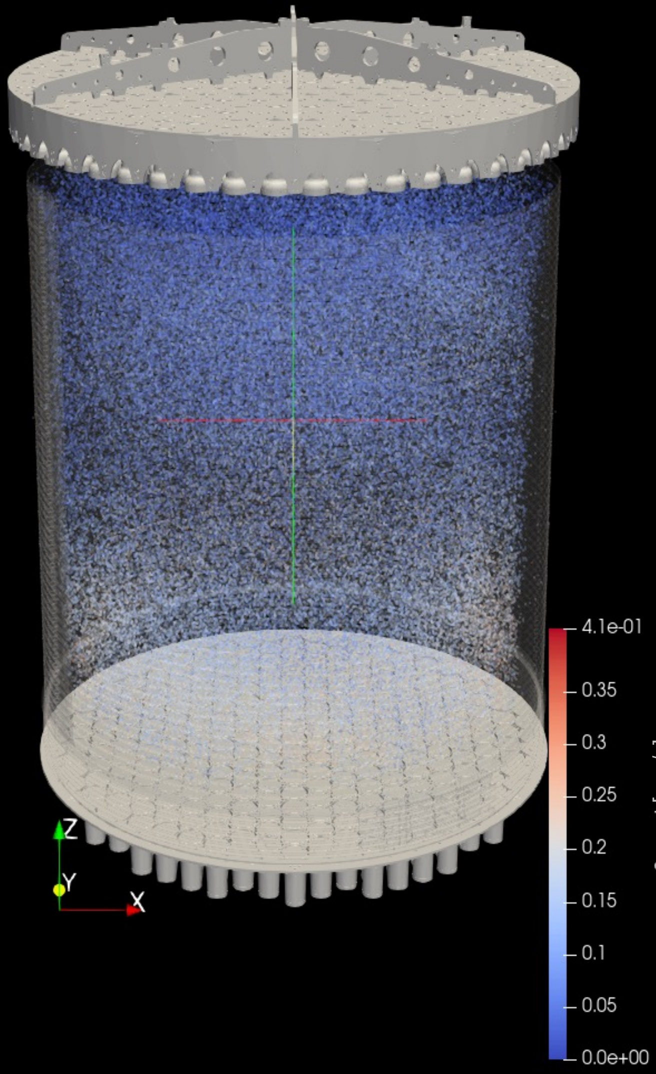


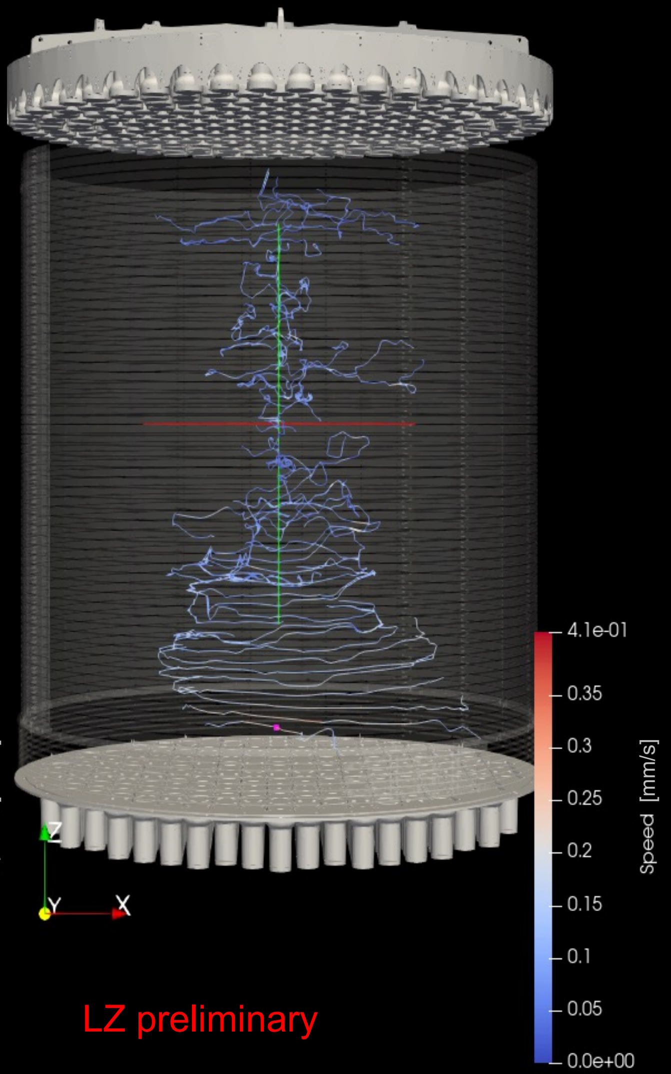
- Now we have a xenon flow model
- Starting with ^{218}Po decays, the flow model can be followed for an individual sequence of decays
- This is called a streamline

→ Allows us to predict ^{214}Pb position

From Flow Model to Streamline

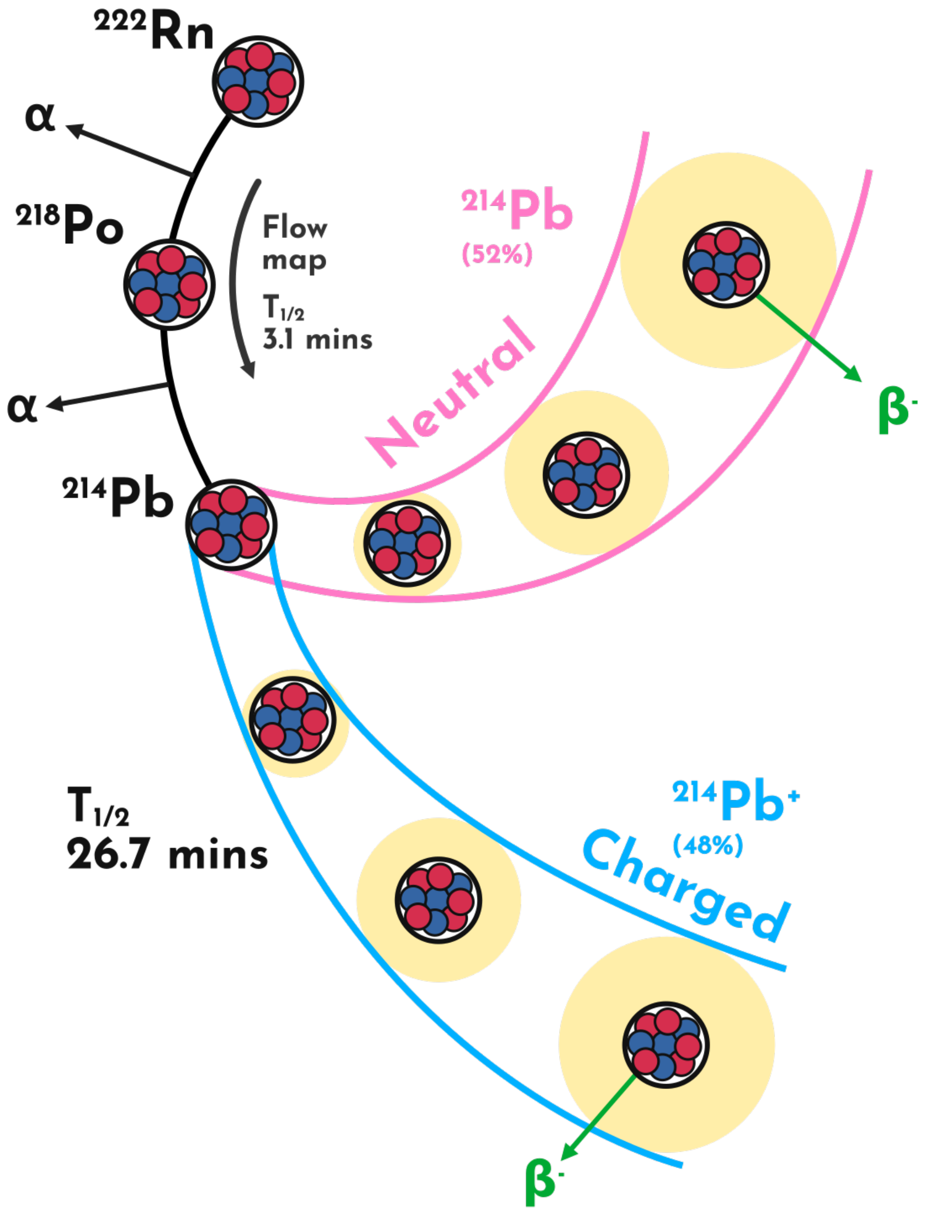
Flow vectors representing the flow from individual ^{222}Rn decays to their associated ^{218}Po decays





Sample of 50 streamlines with a time cut off of 81 min, produced using the discrete flow map on the left

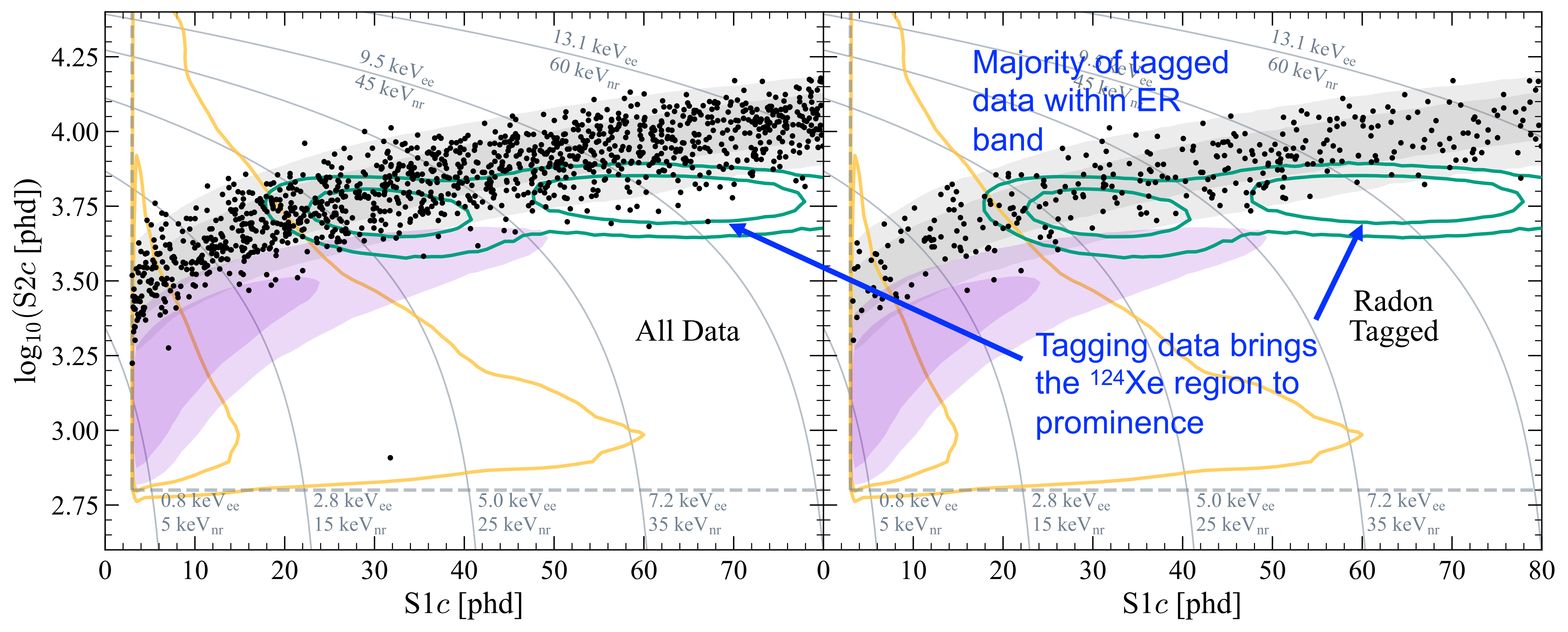
From Streamline to Tagging



- Neutral and charged streamlines and the associated ‘exclusion volumes’
- Neutral and charged pairs behave differently due to the applied electric field
- Streamlines are cut off at ~3 ^{214}Pb half-lives
- Exclusion volumes grow in size as you move along the streamline
- Event occurs within an exclusion volume → tag as ^{214}Pb-related background

UCL

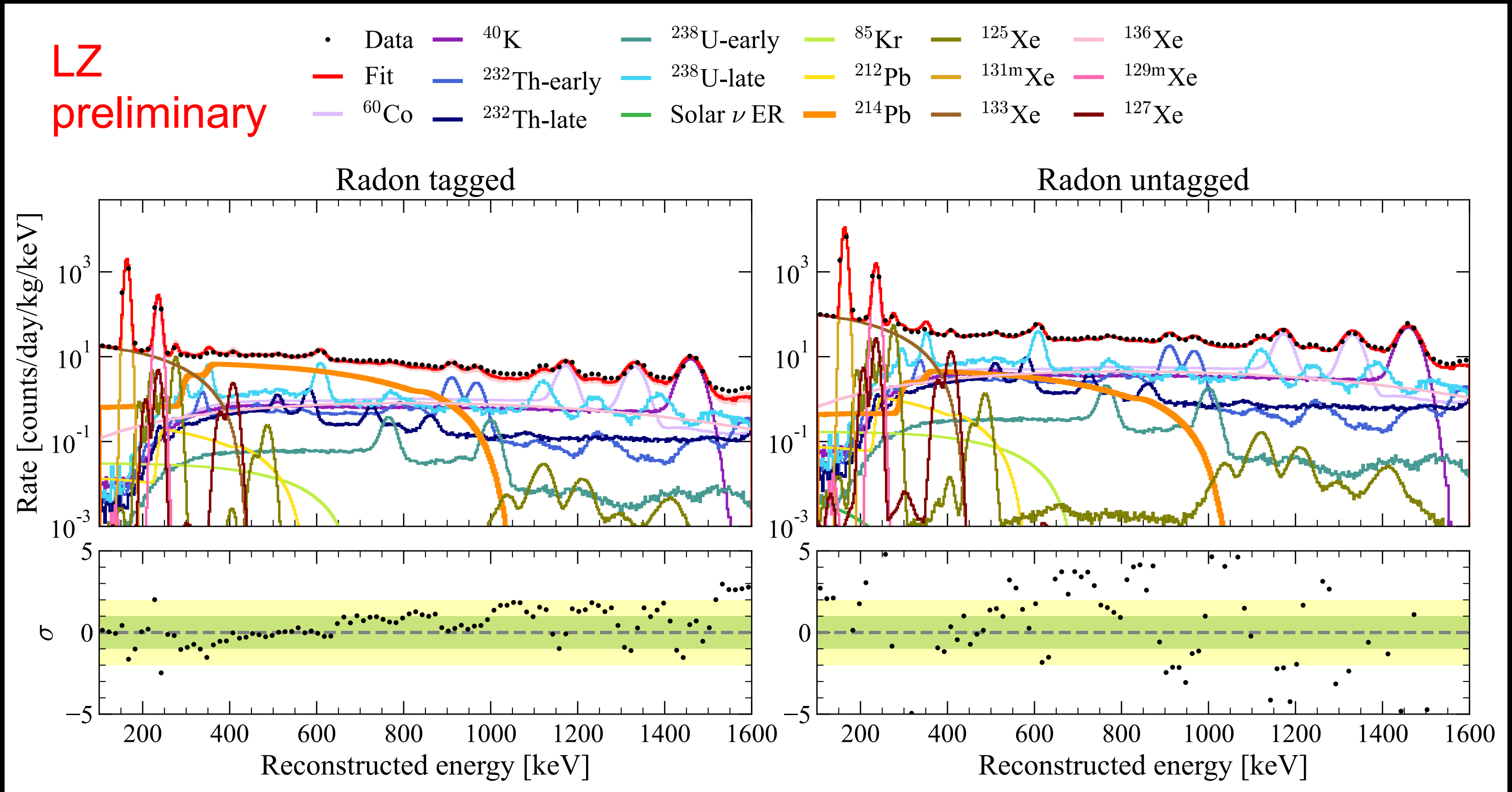
A Look at Tagged Data



Black points: final WS2024 data points from 4.2 ±0.1 tonne-years of exposure passing all selection cuts, with all data (left) and tagged data (right) separated. Purple shaded regions show 68% and 95% quantiles for a 40GeV/c² WIMP. Green contours show the same quantiles for ^{124}Xe distribution.

Tag Performance

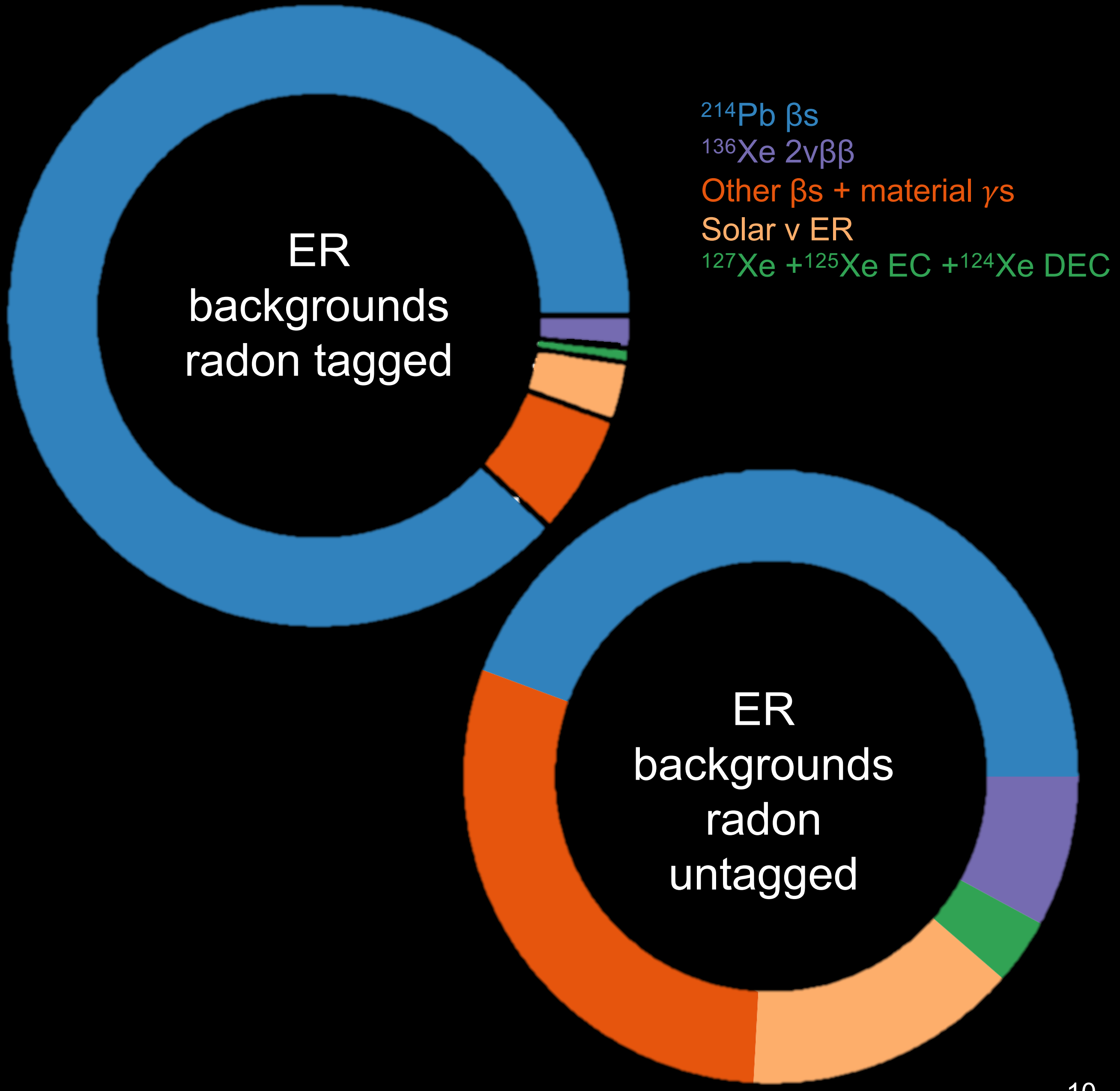
- A full spectral background fit was performed
- ^{214}Pb rate reduced from 3.9 ±0.6 µBq/kg (all data) to 1.8 ±0.3 µBq/kg (untagged)
- Extracted a ^{214}Pb-tagging efficiency of 60 ±4%



Tagged: data that was tagged as containing a ^{214}Pb decay
Untagged: data that was not tagged as containing a ^{214}Pb decay
^{214}Pb rate in untagged sample (orange) visibly lower than in tagged

Conclusions

- First implementation of a technique to tag ^{214}Pb decays in LZ
- Successfully tagged 60 ±4% of the largest ER background
- No loss in exposure as both tagged and untagged samples are used in the final analysis
- Reduced ^{214}Pb rate in untagged sample by 54%



LZ (LUX-ZEPLIN) Collaboration, 38 Institutions

250 scientists, engineers, and technical staff

@lzdarkmatter

https://lz.lbl.gov/

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- Brown University
- Center for Underground Physics
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- Fermi National Accelerator Lab.
- Imperial College London
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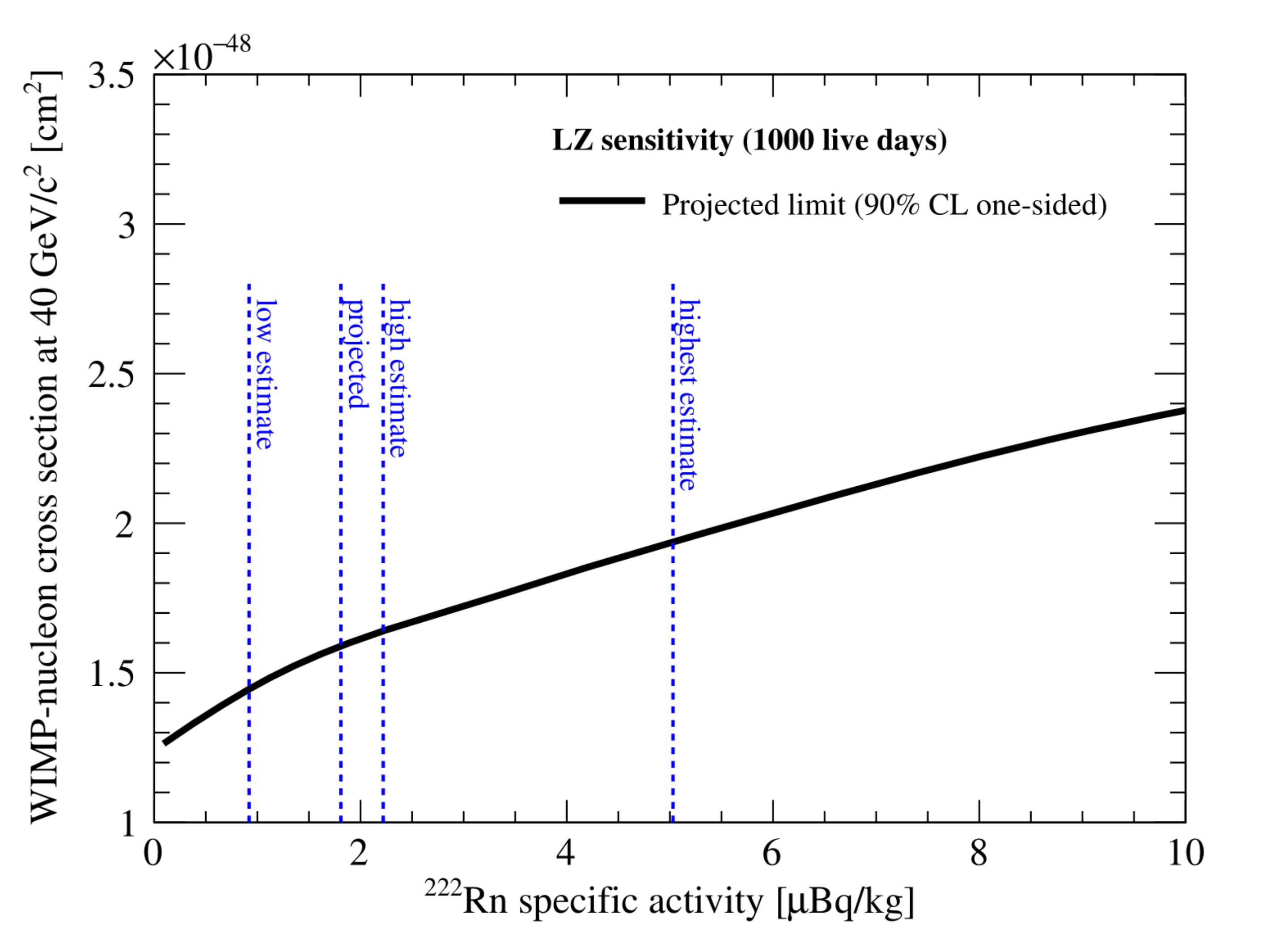
Backup

Impact on Sensitivity



Flow Model Stability