



# NEXT

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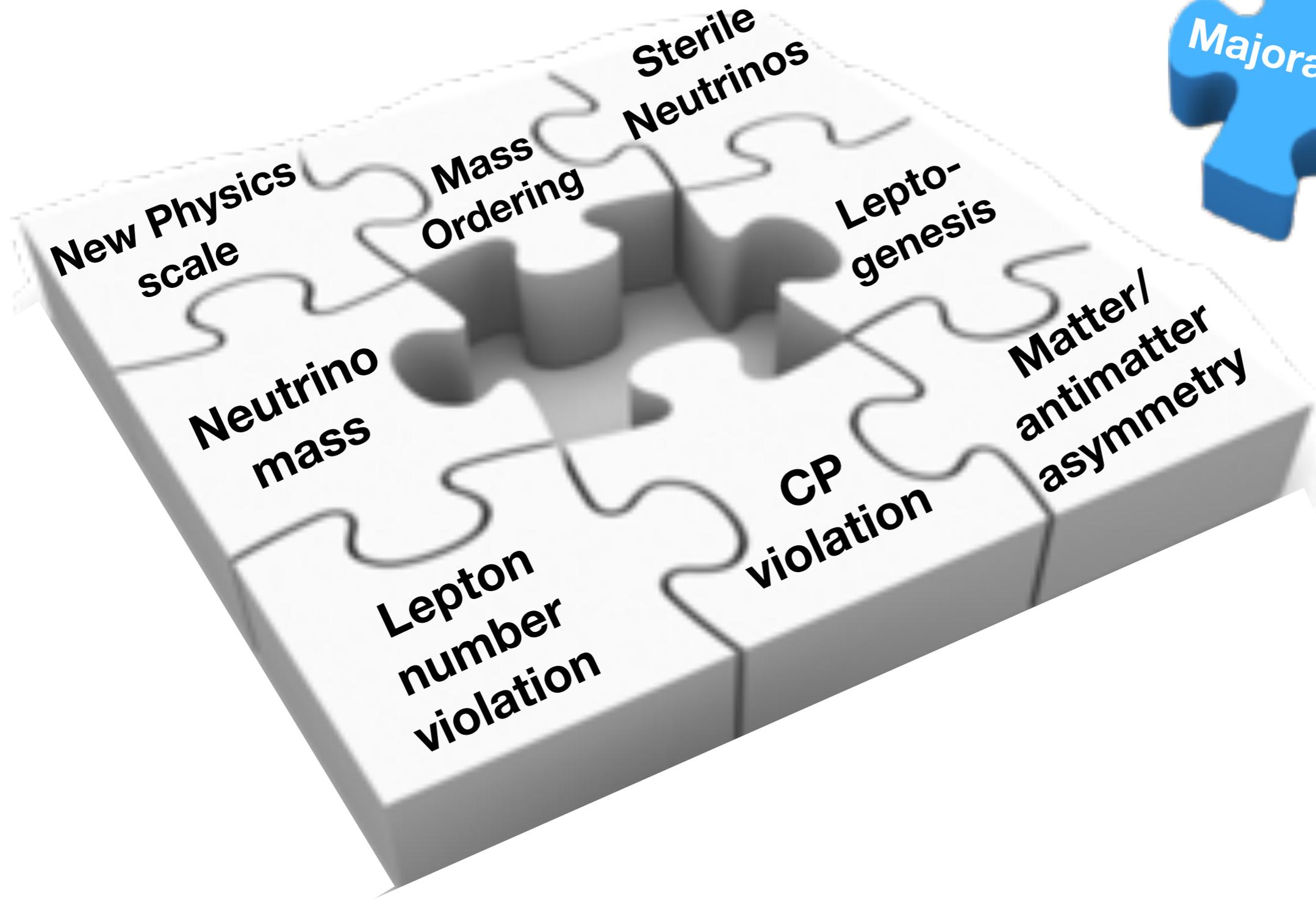
**Roxanne Guenette**  
Harvard University



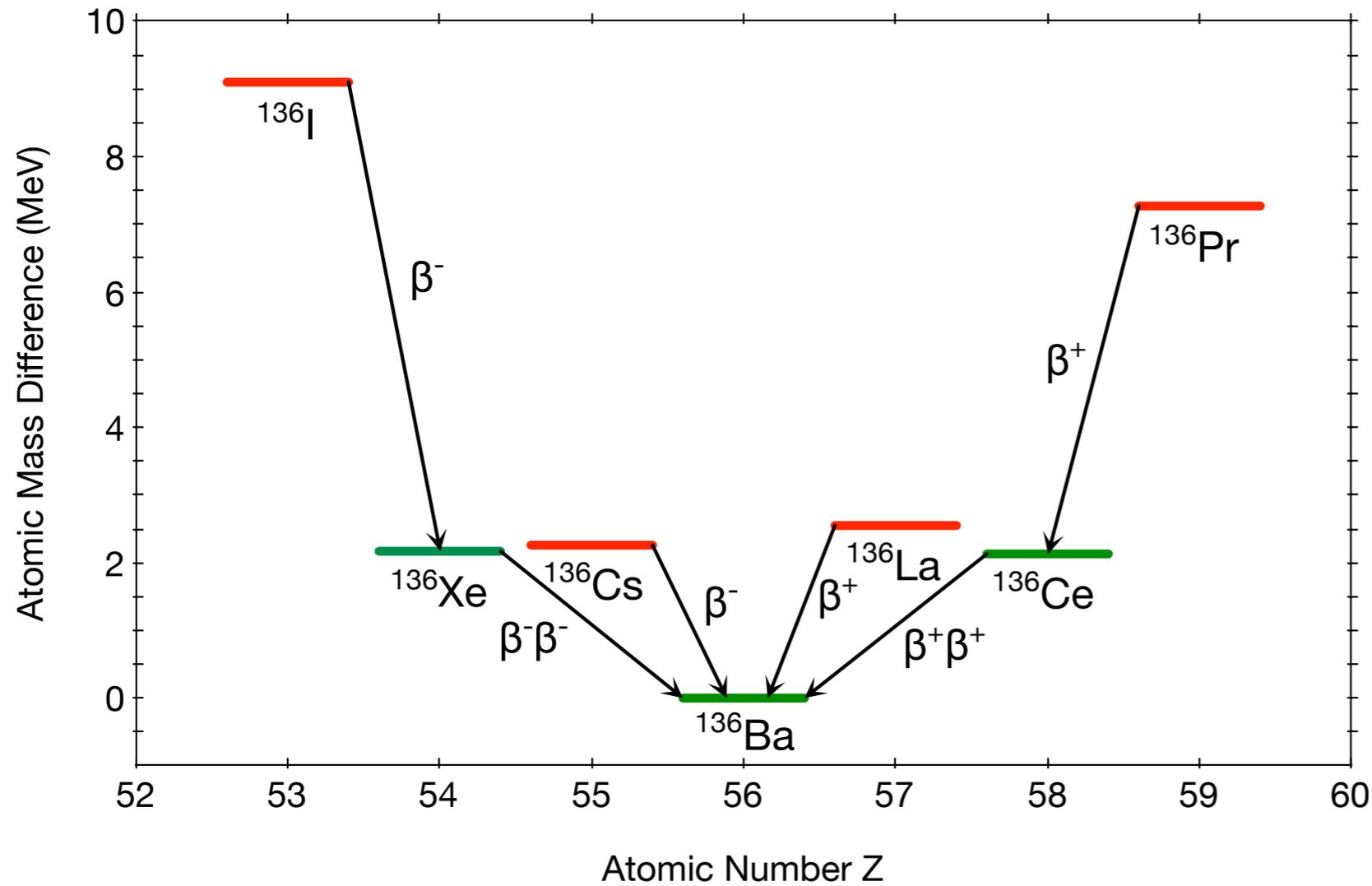
Future Projects Workshop  
SNOLAB, 15-17 July 2019

# Searching for Majorana neutrinos

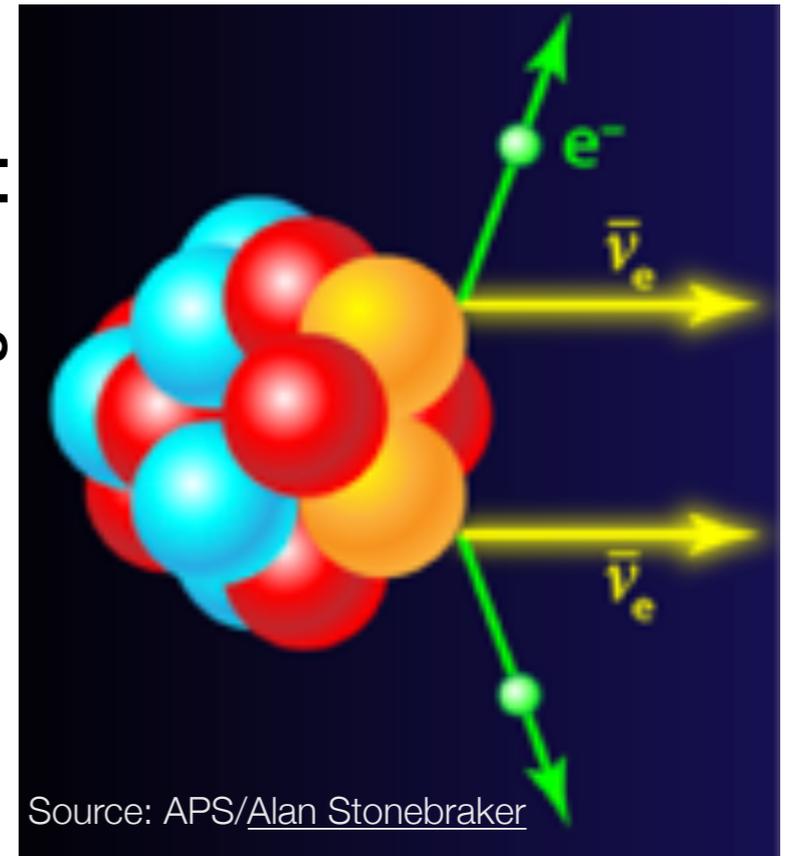
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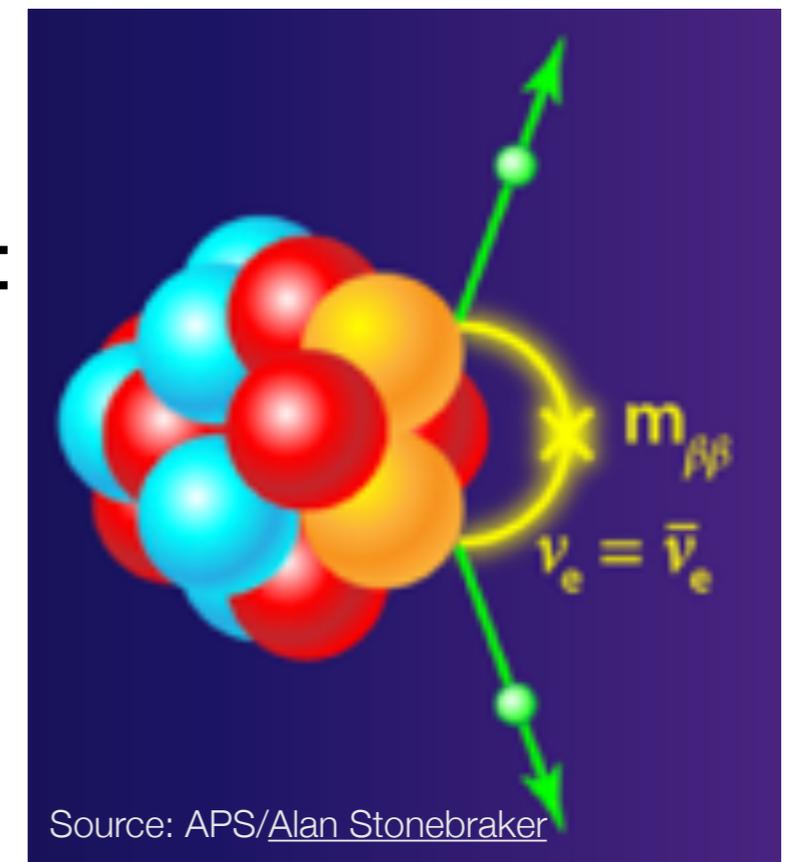
# Searching for Majorana neutrinos with Xenon



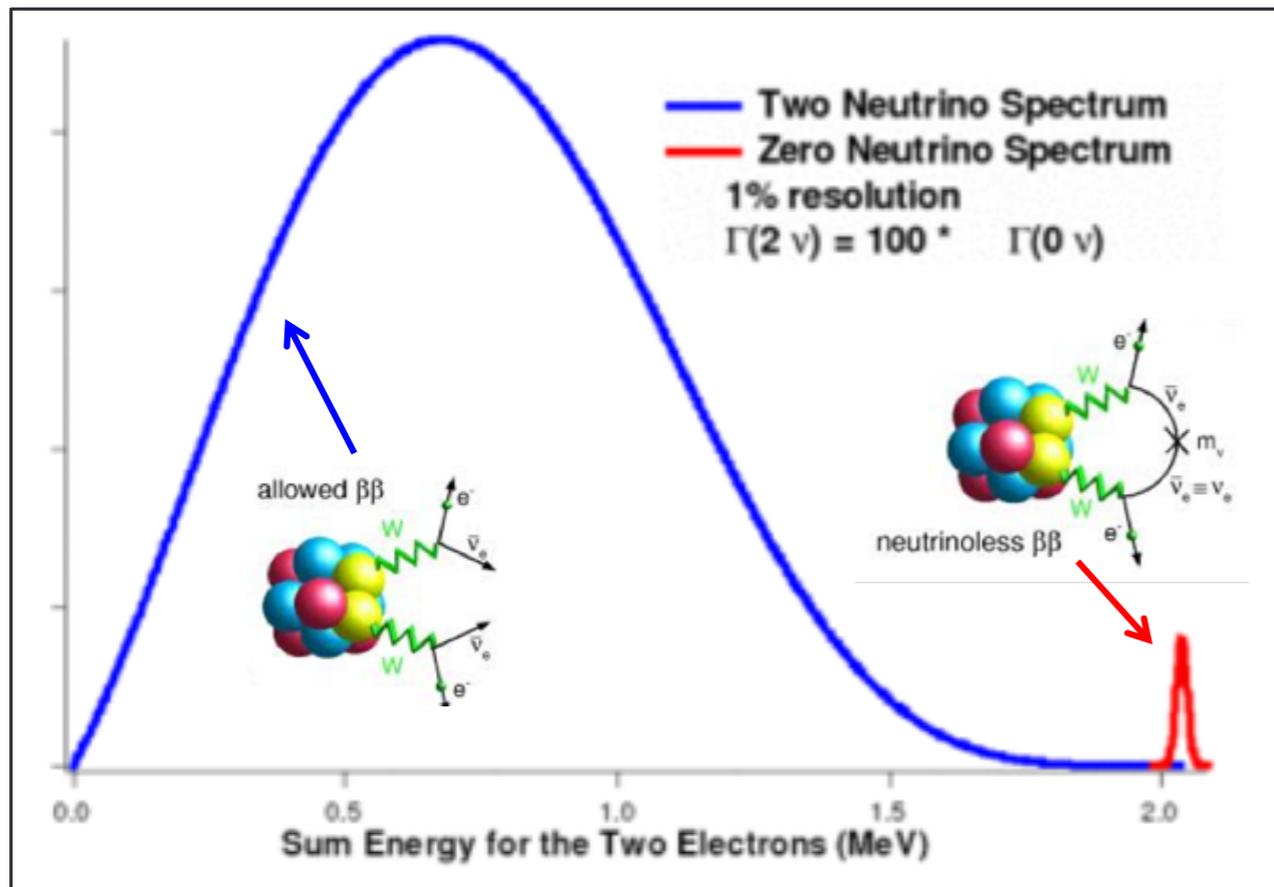
Allowed regular  $\beta\beta$



Neutrinoless  $\beta\beta$



# Searching for neutrino less double beta decays

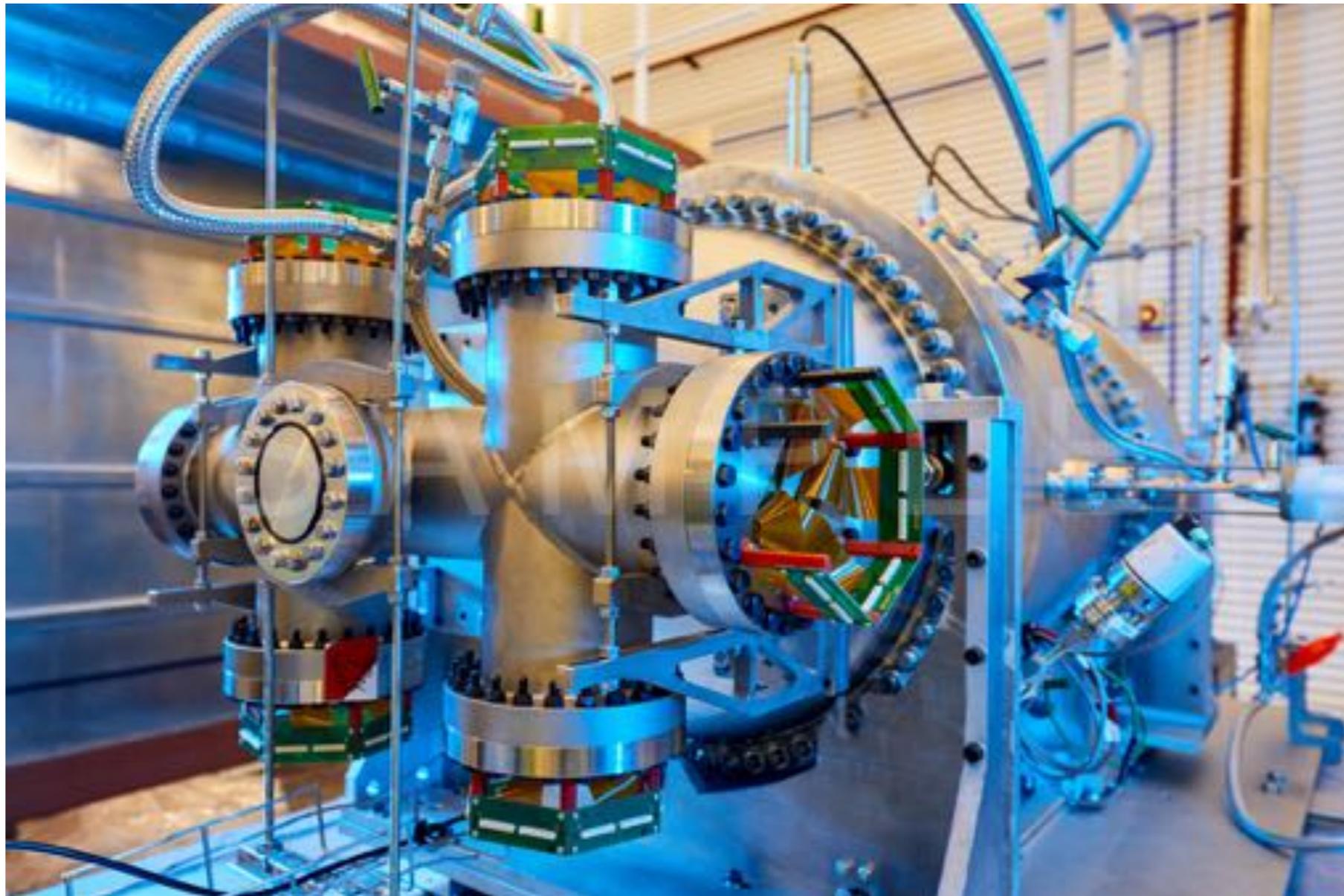


- 1. Require great energy resolution**  
(to identify the  $0\nu\beta\beta$  over the regular  $2\nu\beta\beta$ )
- 2. Require extremely low background**  
(to see the very rare signal over radioactive events)
- 3. Scalability**

NEXT (Neutrino Experiment with Xenon TPC)



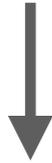
## High-pressure gas Xenon Time Projection Chamber



NEXT (Neutrino Experiment with Xenon TPC)



# High-pressure gas Xenon Time Projection Chamber

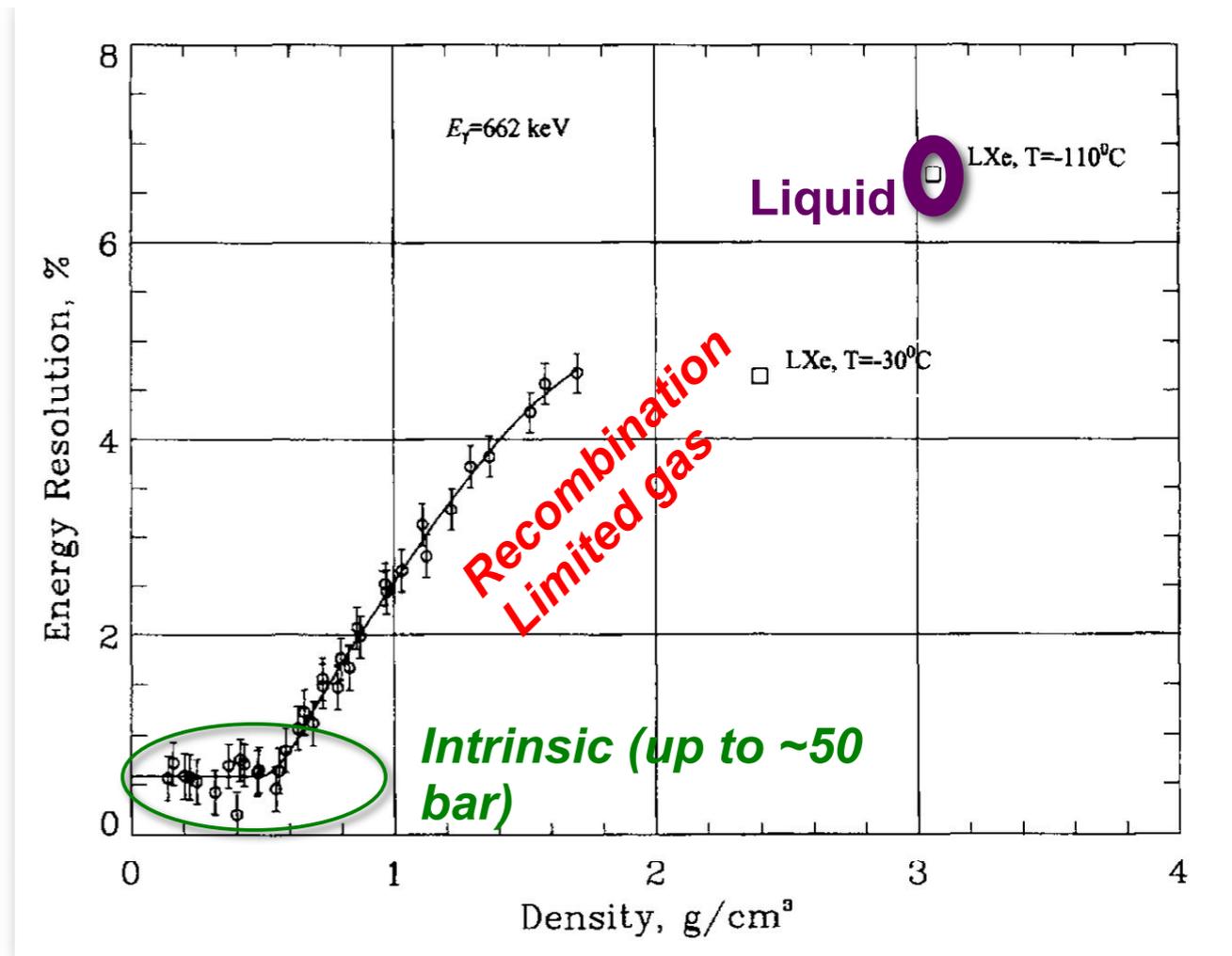


**Density:** Higher pressure means more isotope in same volume

# High-pressure gas Xenon Time Projection Chamber



- **Energy resolution:** Great intrinsic energy resolution in gas



Bolotnikov and Ramsey. "The spectroscopic properties of high-pressure xenon." NIM A 396.3 (1997): 360-370

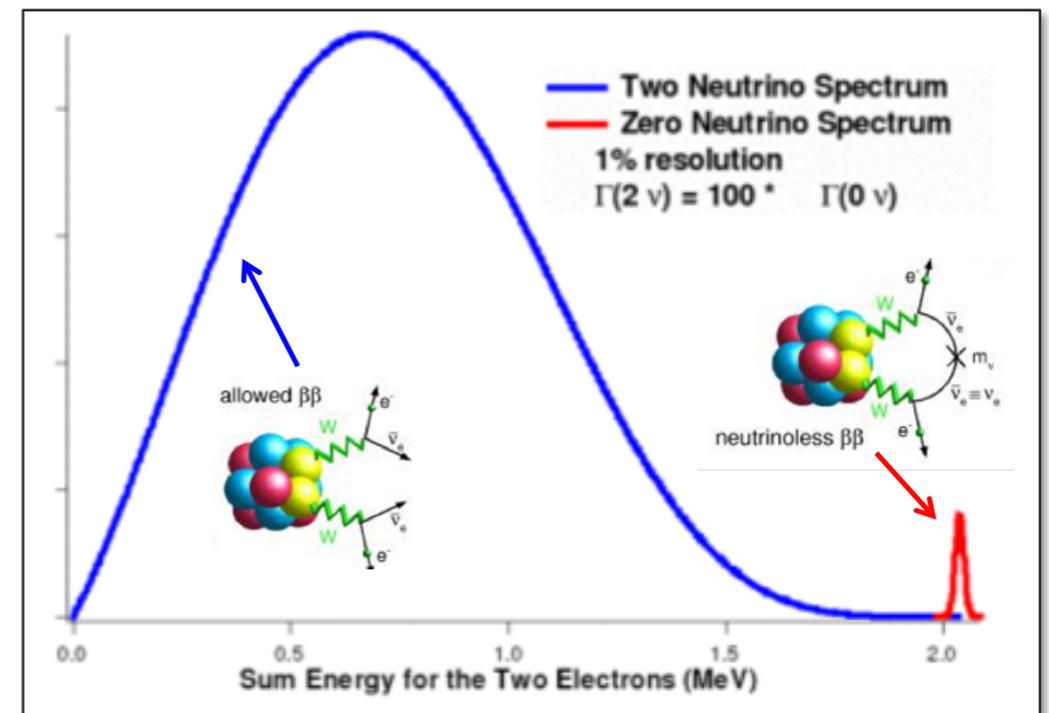
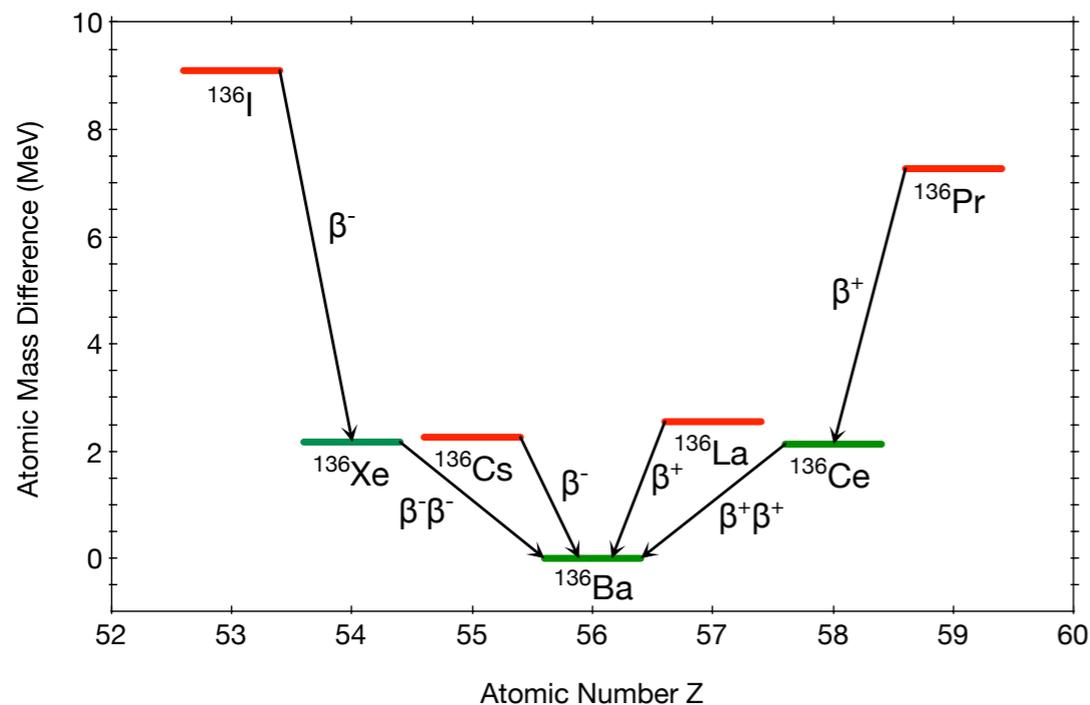
## High-pressure **gas Xenon Time Projection Chamber**



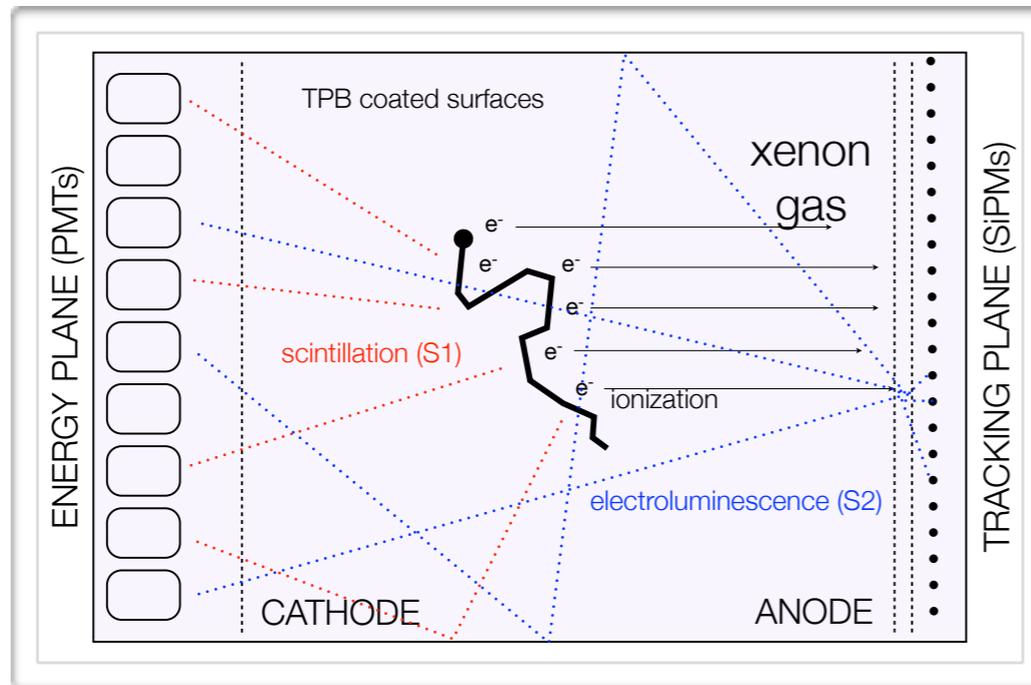
1. **Isotope:** High enough abundance,  $Q_{\beta\beta} = 2.5$  MeV

2. **Noble gas:** Ideally suited to detection technology (TPC)

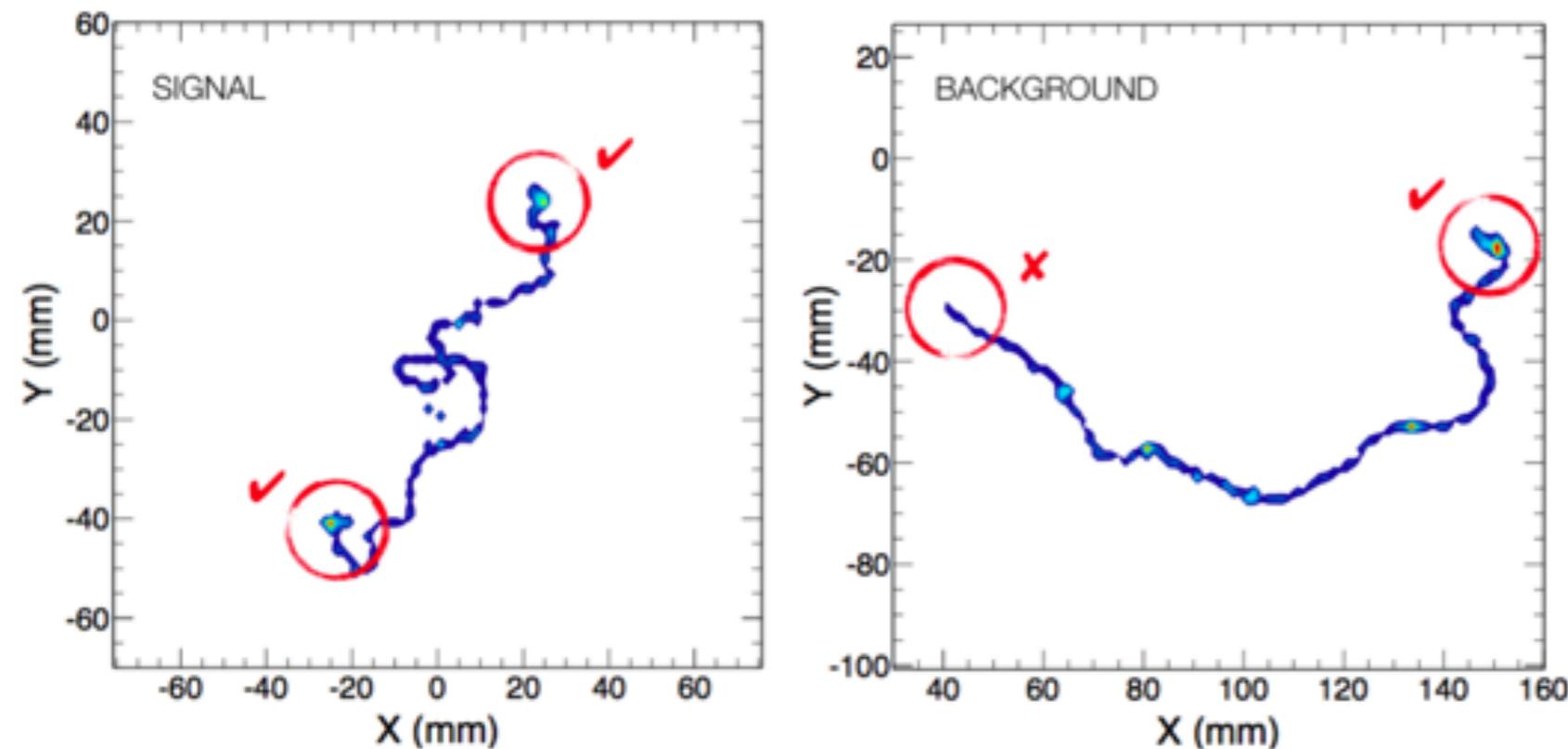
**Source = detector!**



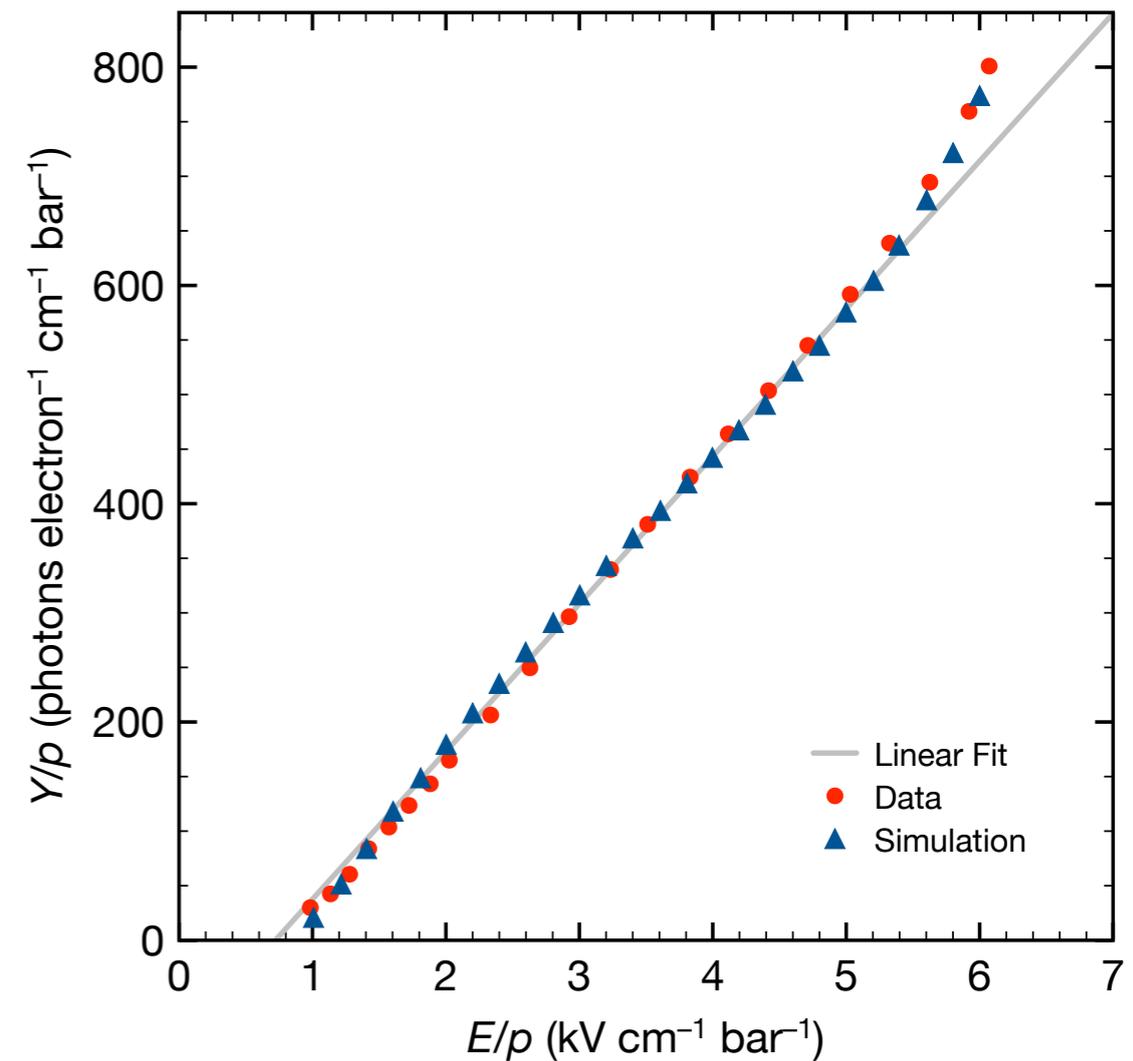
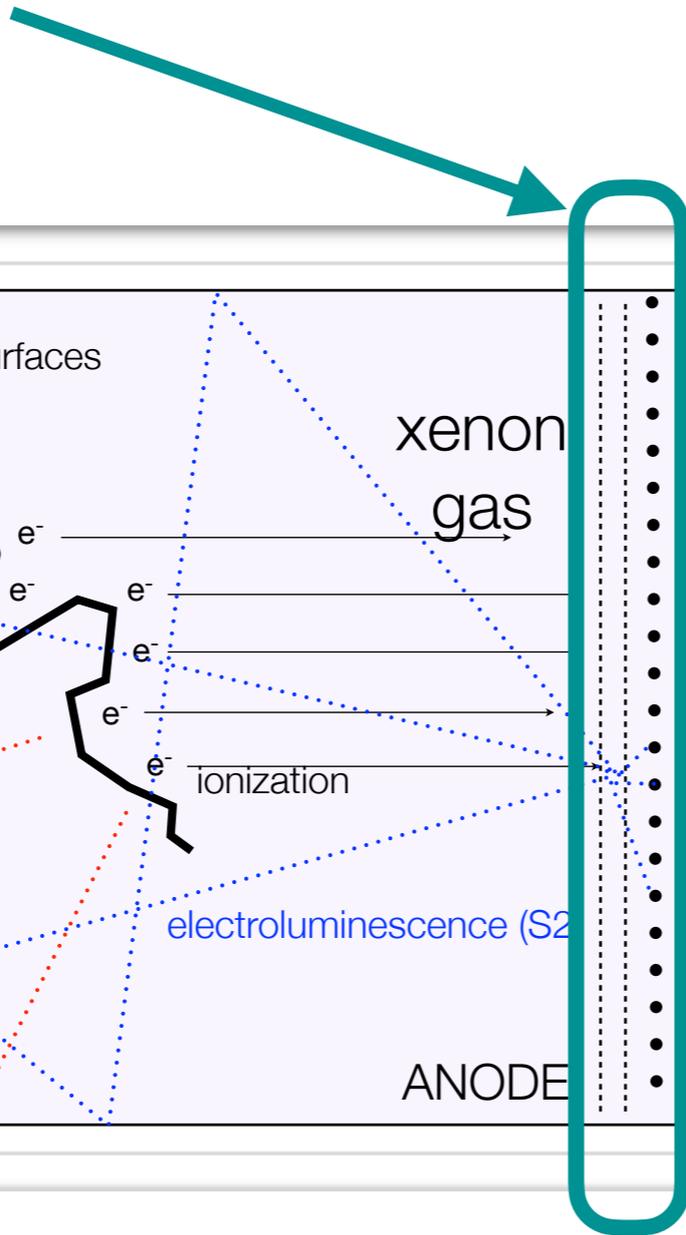
## High-pressure gas Xenon Time Projection Chamber



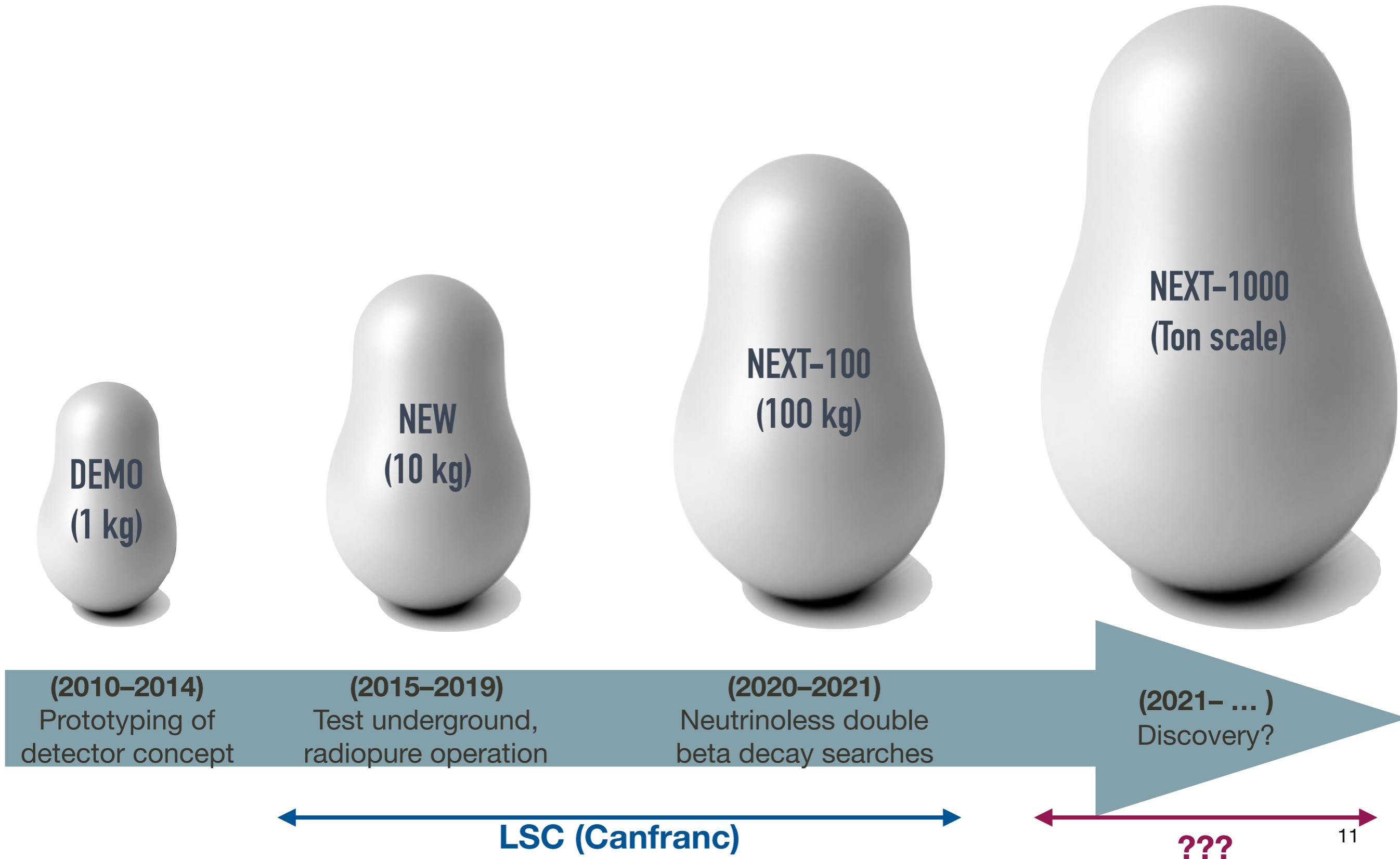
**Topology:** TPC offers high quality images of events



## Electroluminescence



# The NEXT project



# The NEXT project

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**Many new results**  
**Demonstration of technology**

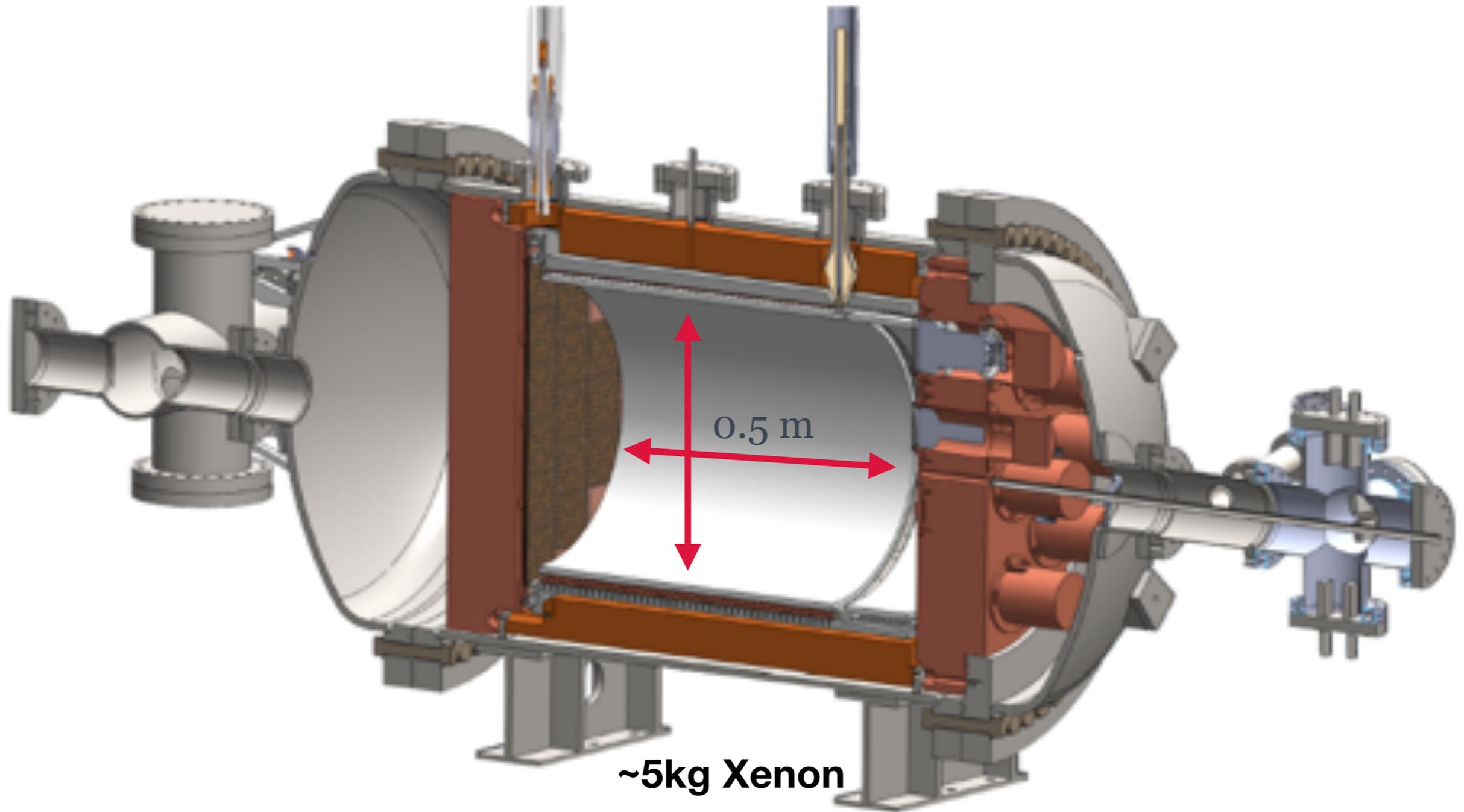
**Under construction**

# Next-White (NEW)

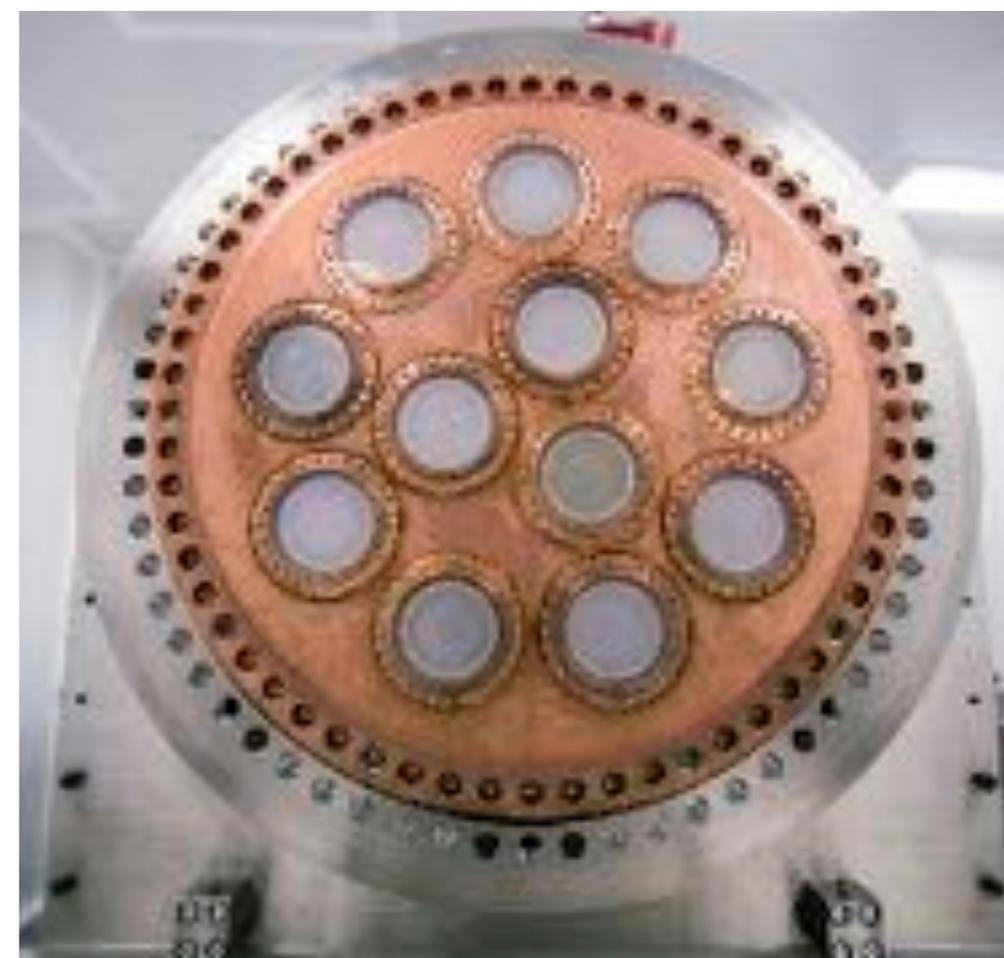
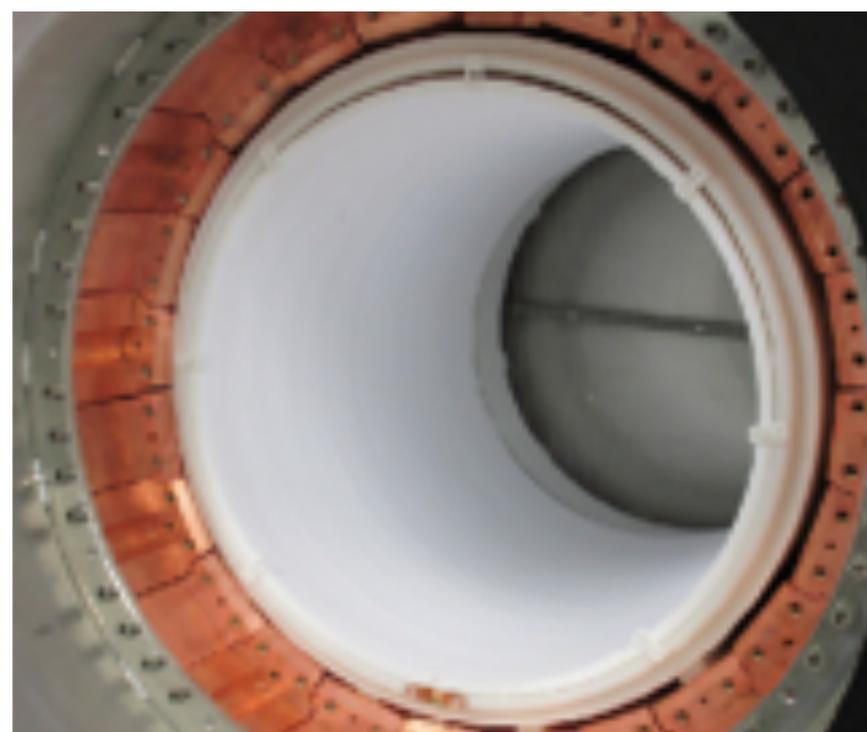
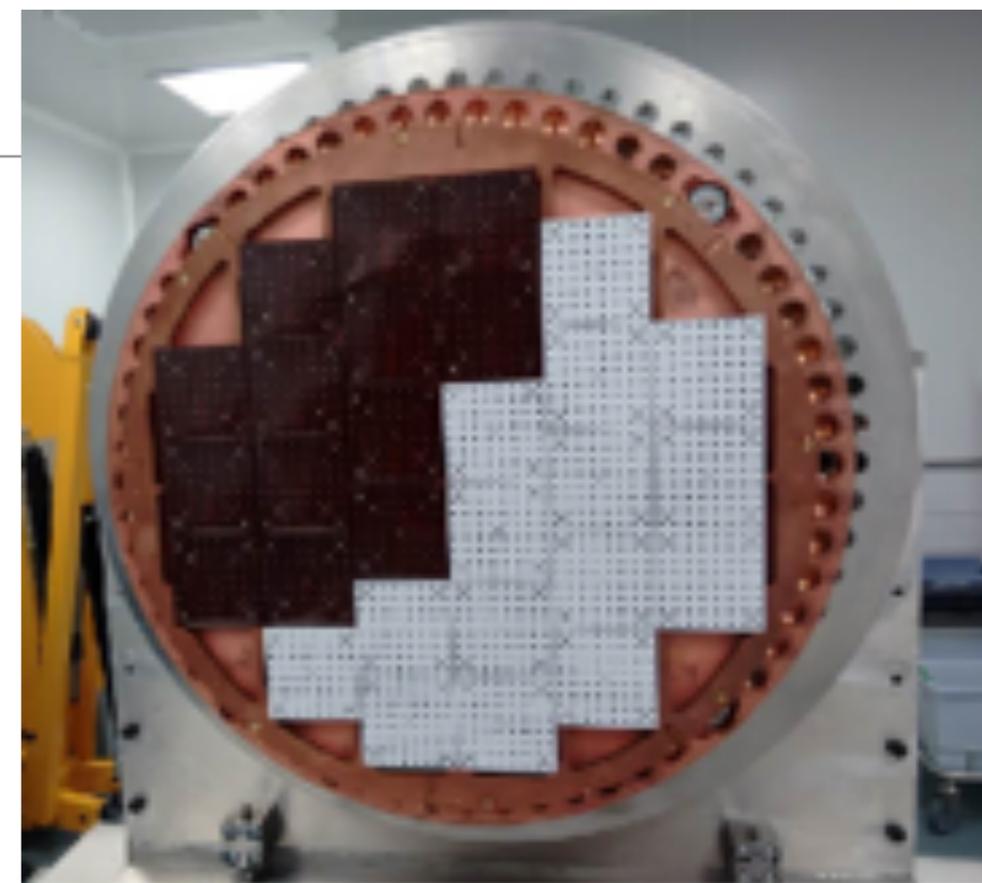


# NEW detector

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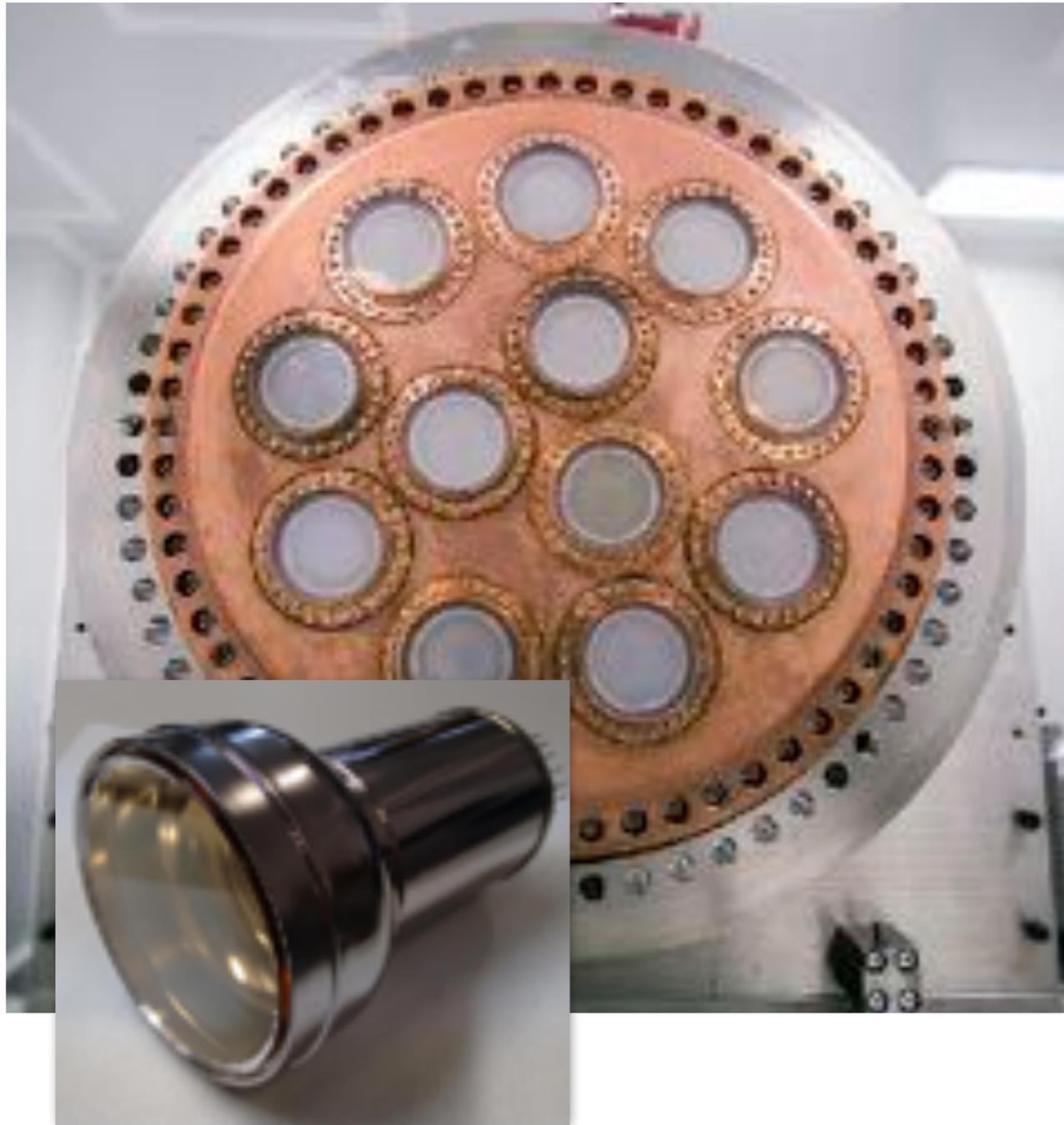
# NEW detector



# NEW readout

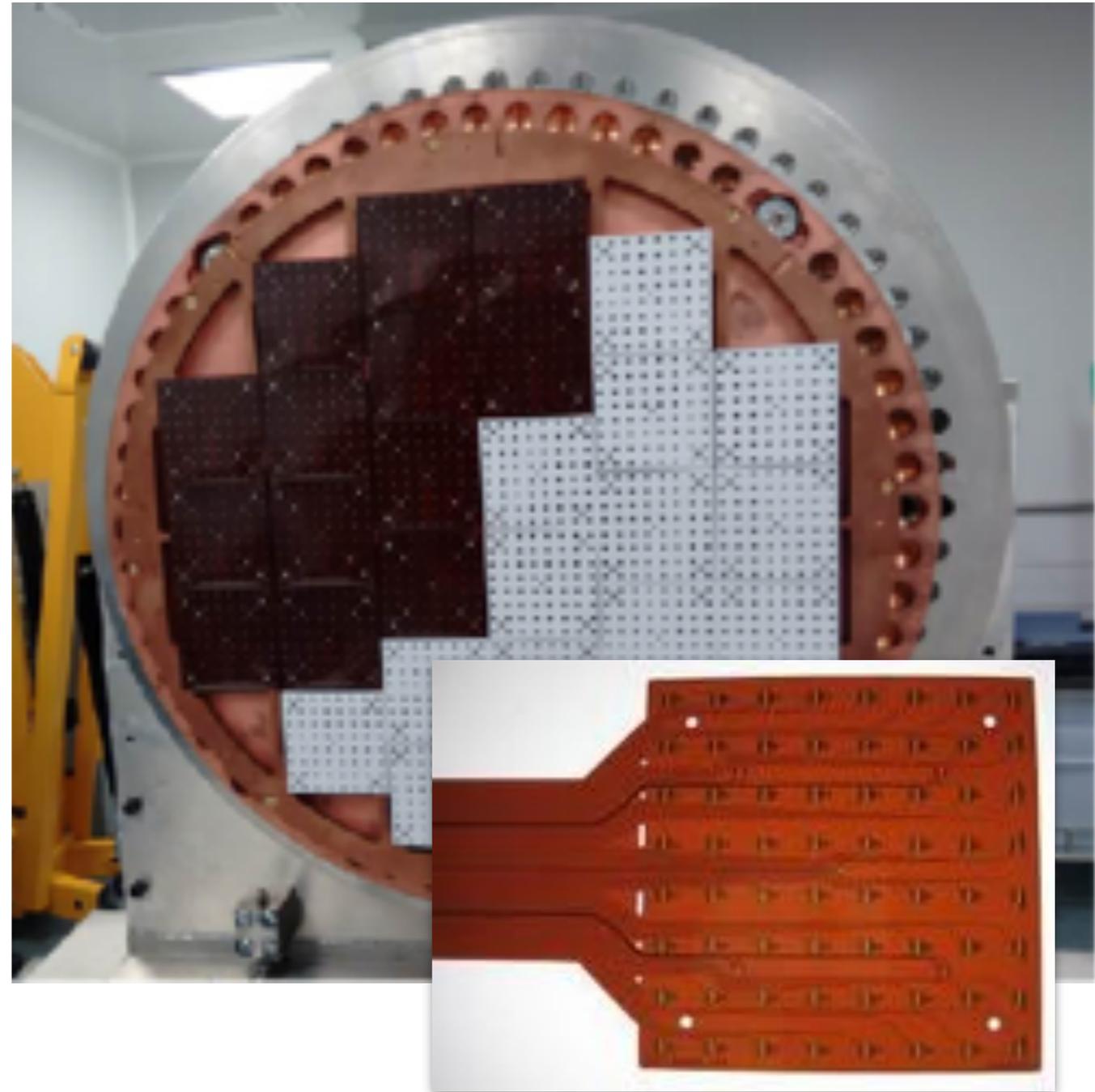
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## Energy plane



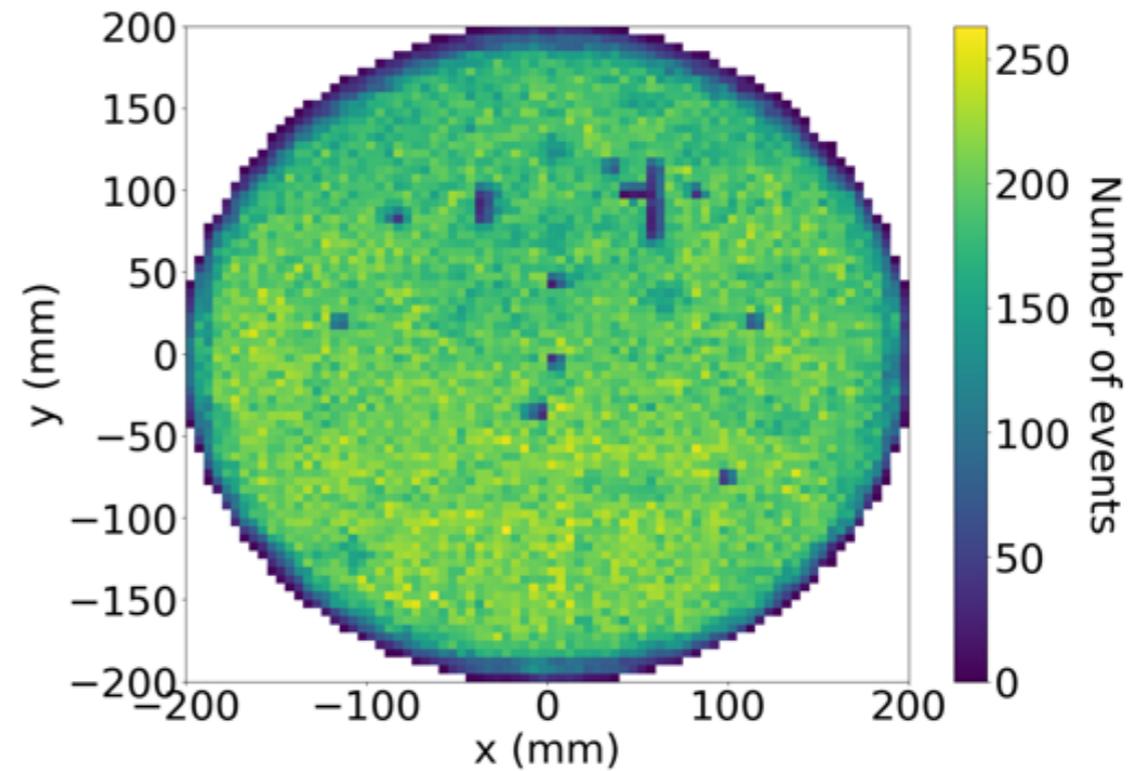
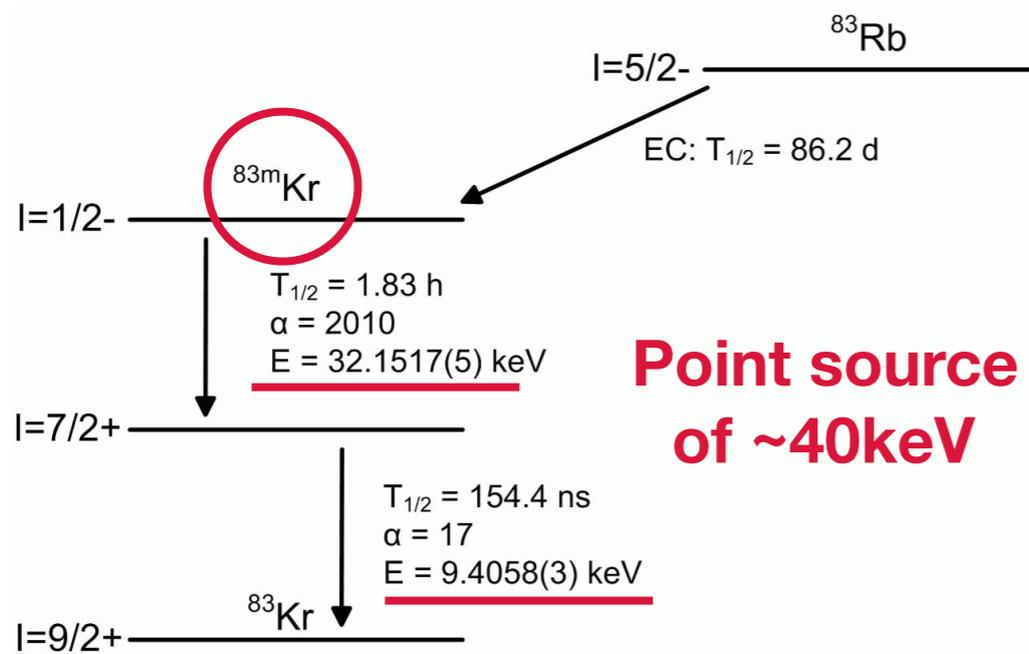
12 Hamamatsu R11410

## Tracking plane

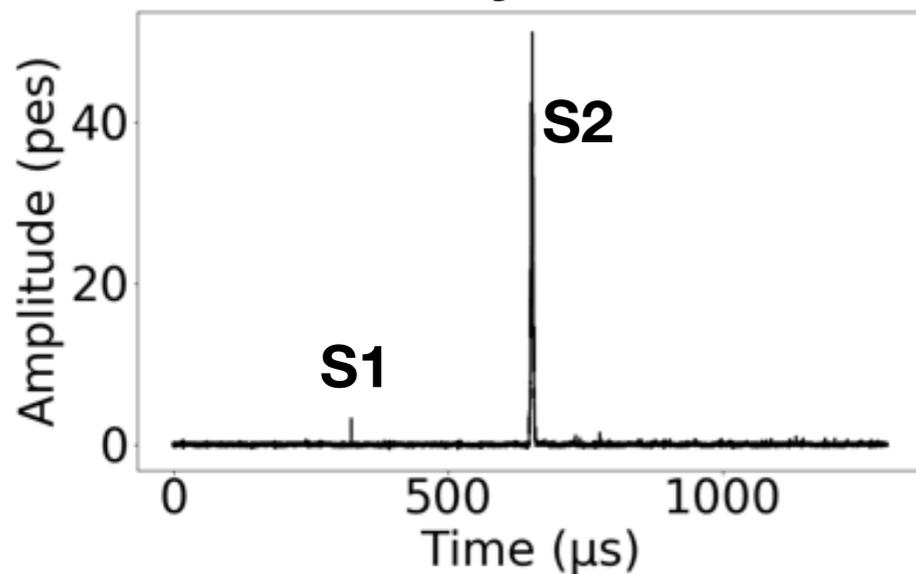


~2000 SensL 1-mm<sup>2</sup> SiPMs

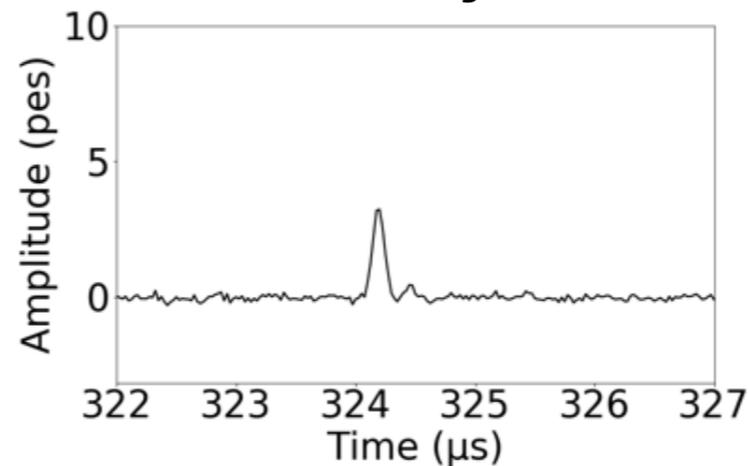
# NEW calibration with Krypton-83



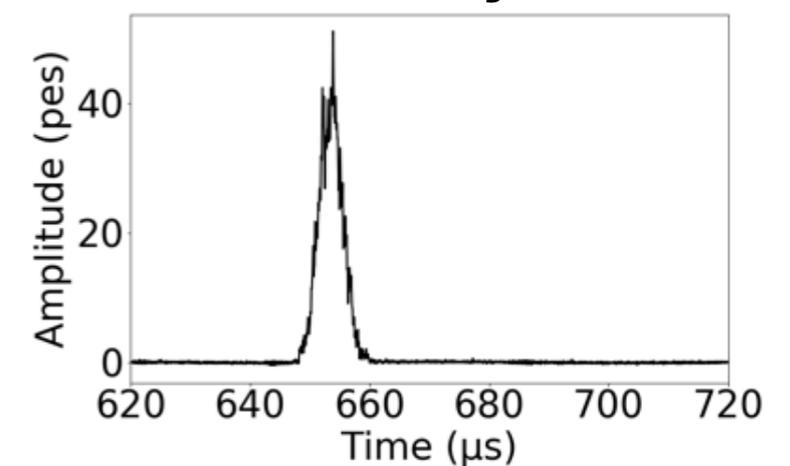
**Kr decay waveform**



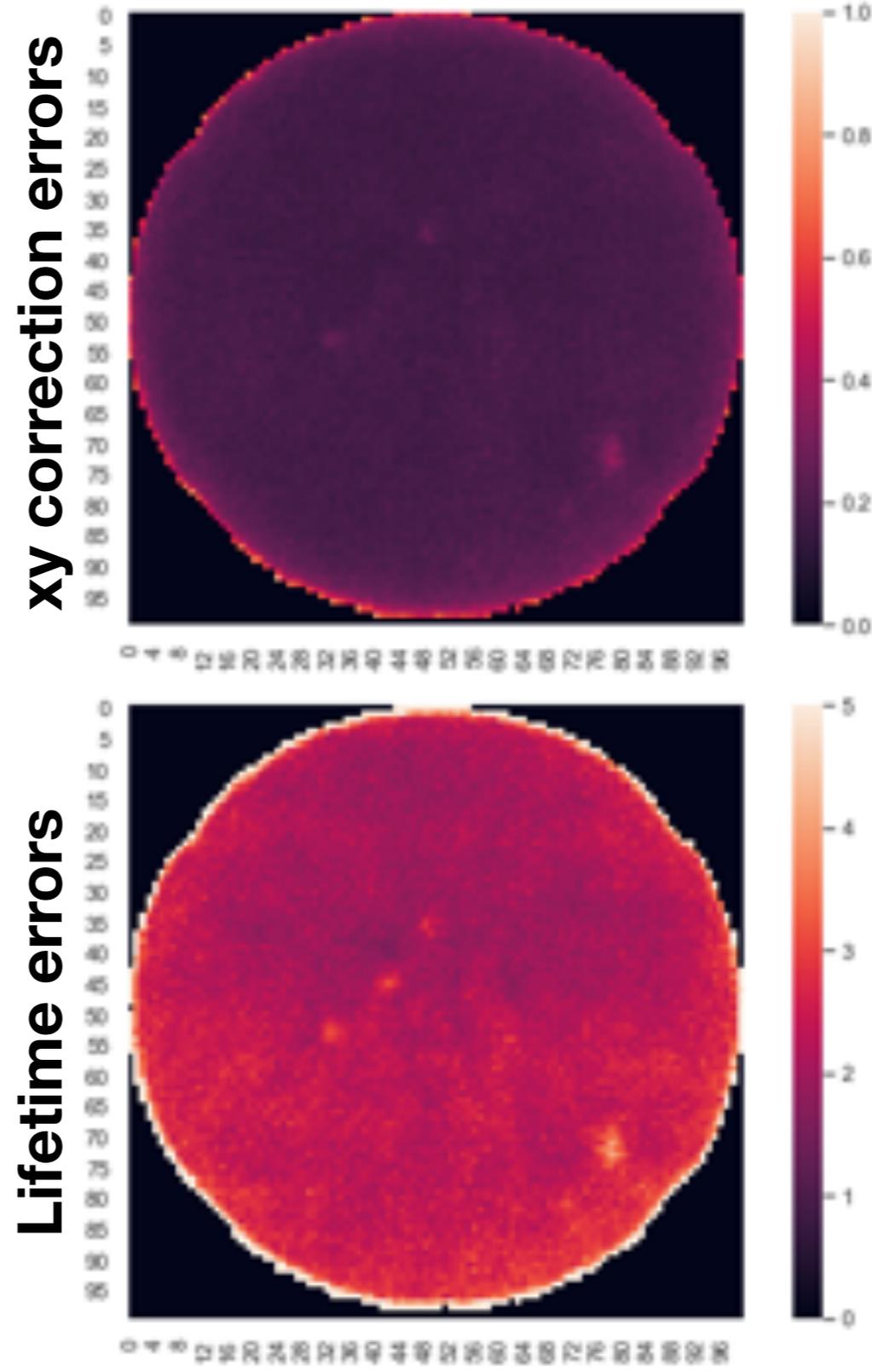
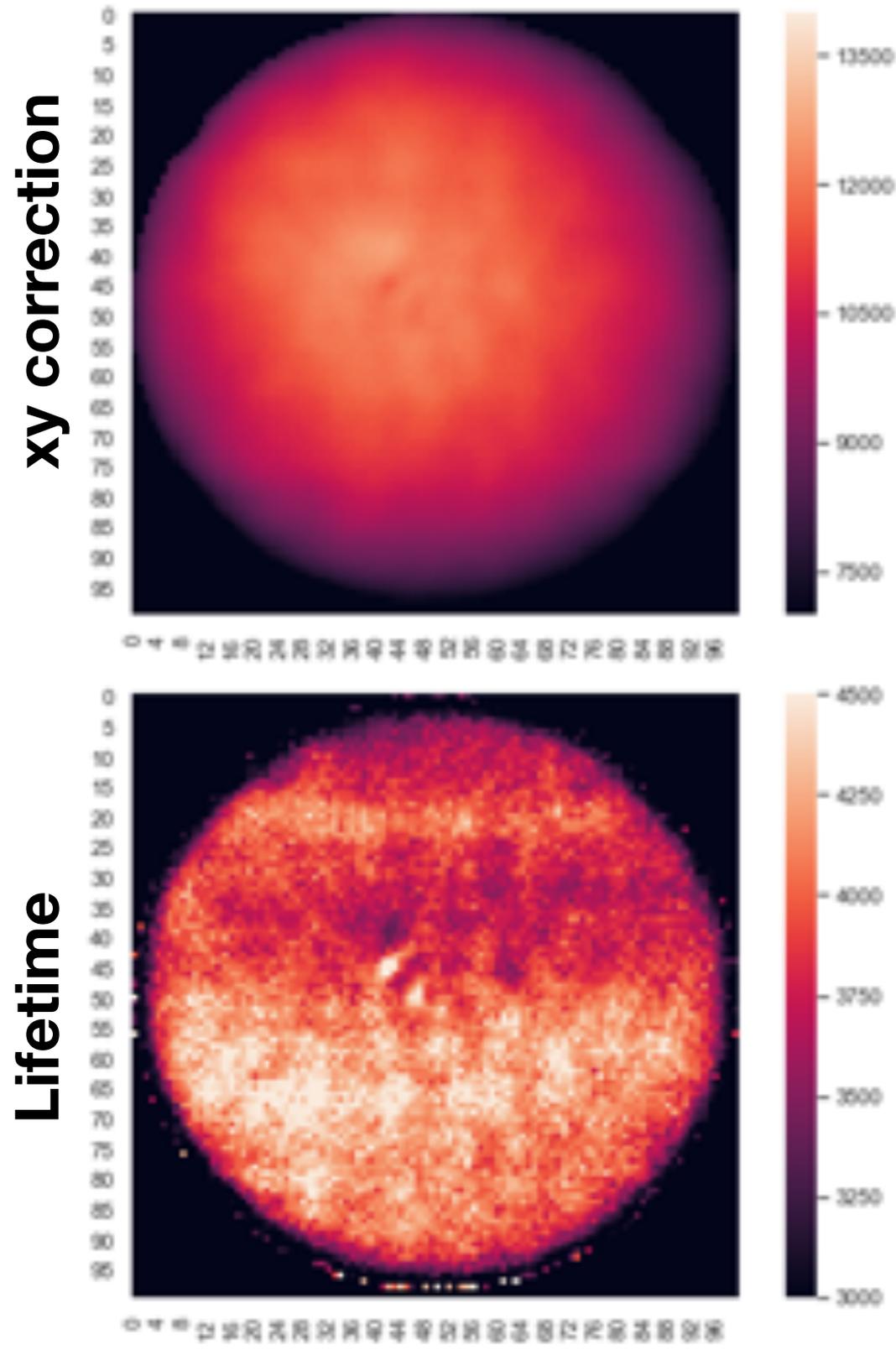
**Kr decay S1**



**Kr decay S2**

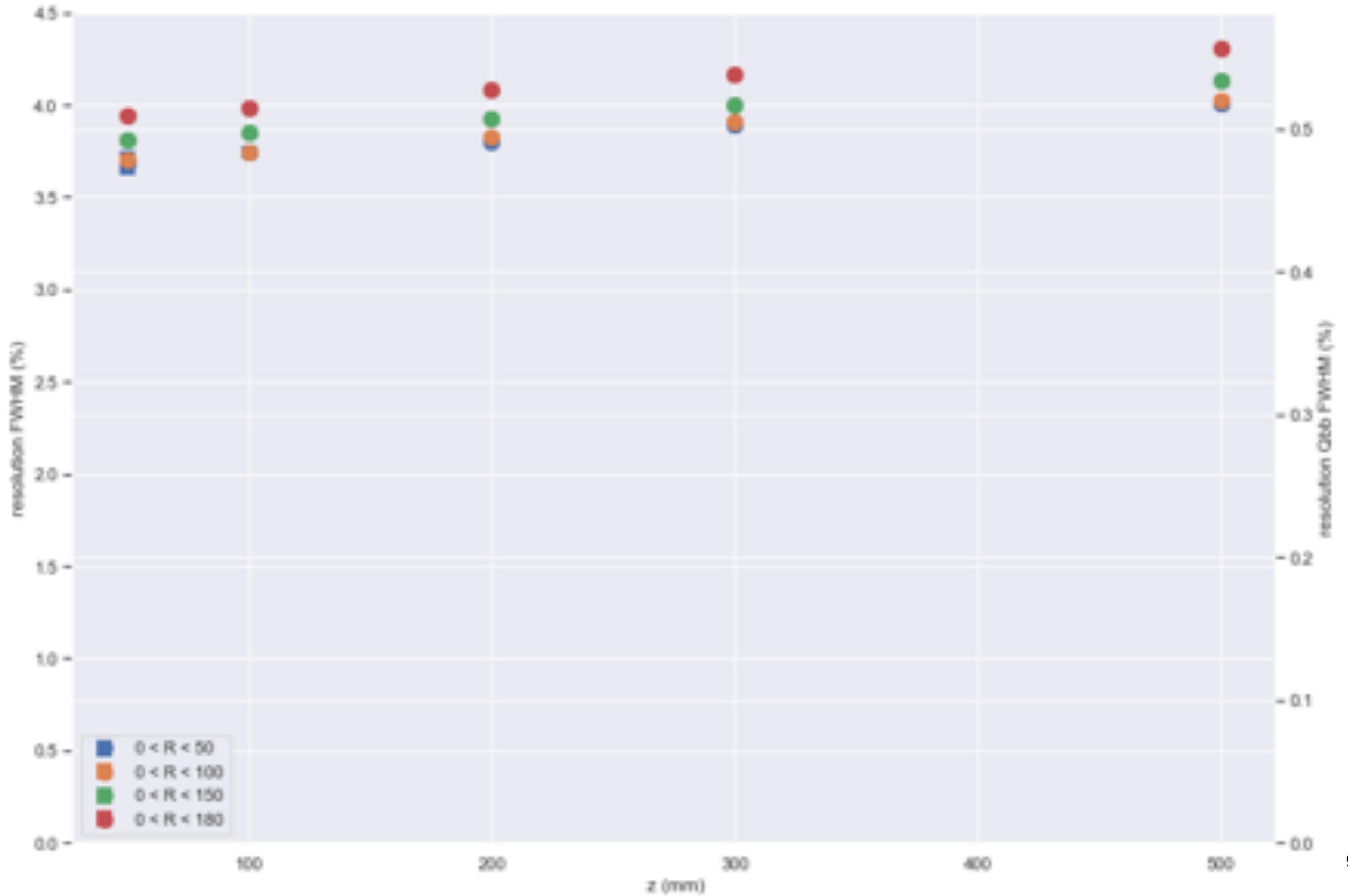


# NEW calibration with Krypton-83

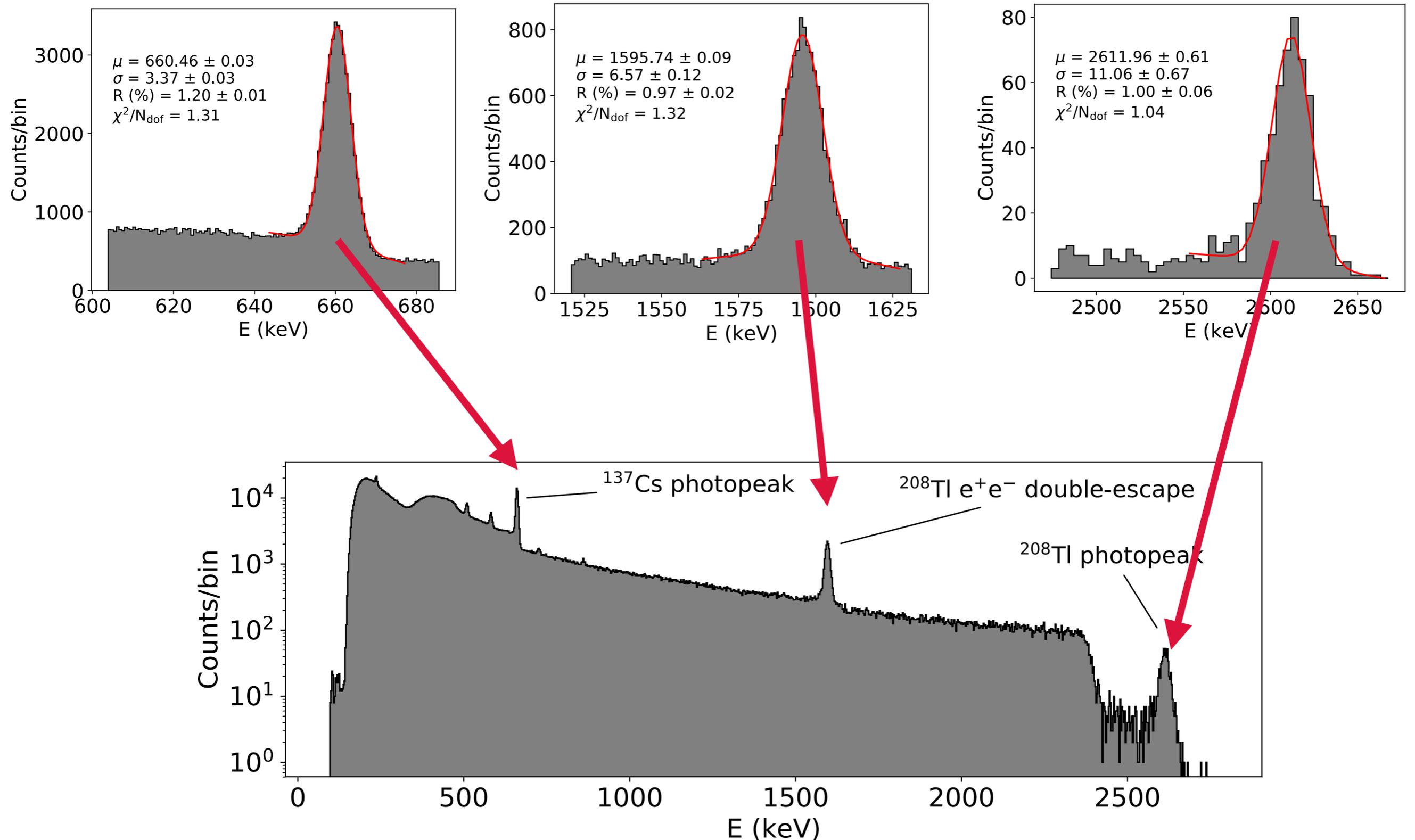


NEXT Collaboration, *JINST* **13** (2018) P10014

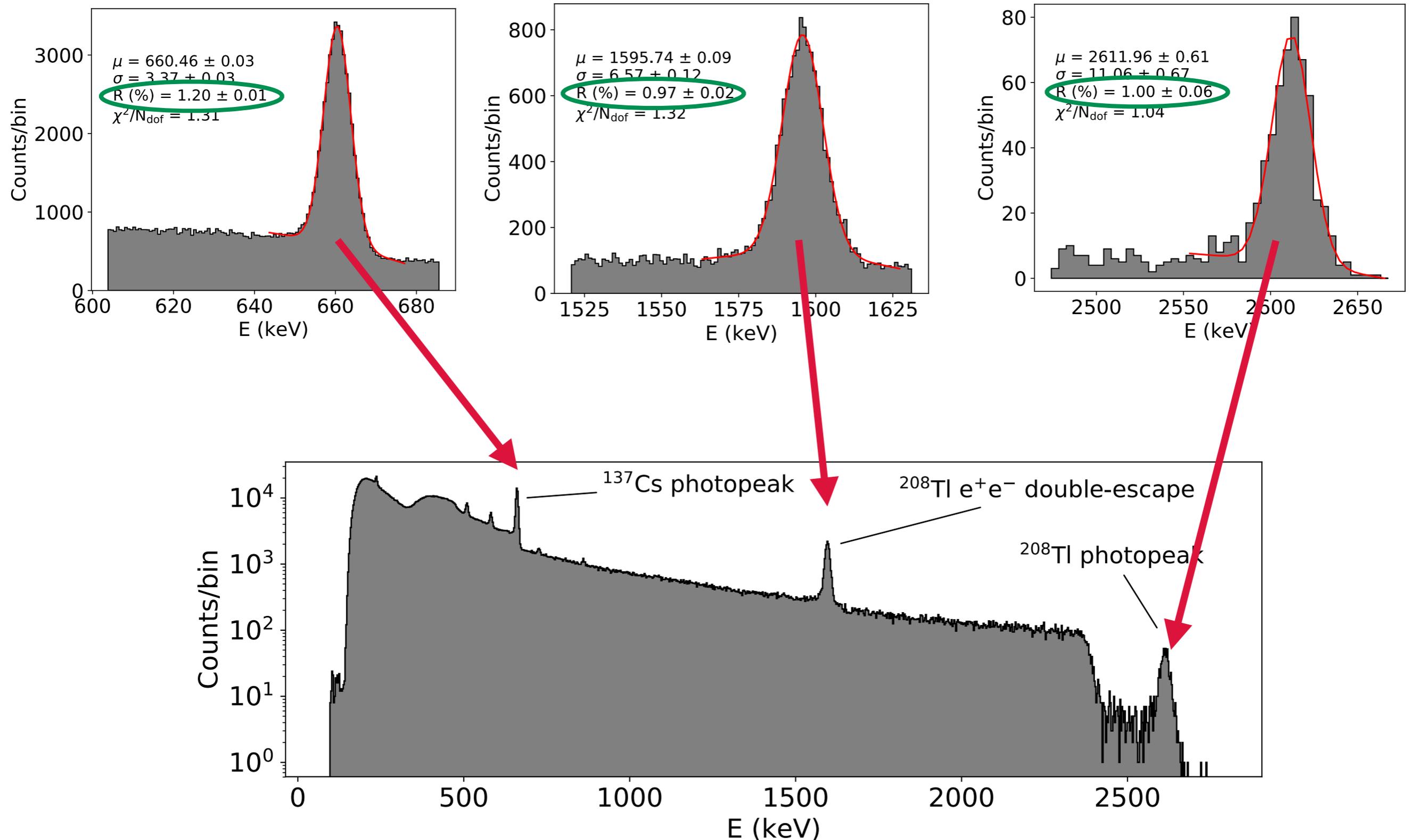
# NEW calibration with Krypton-83



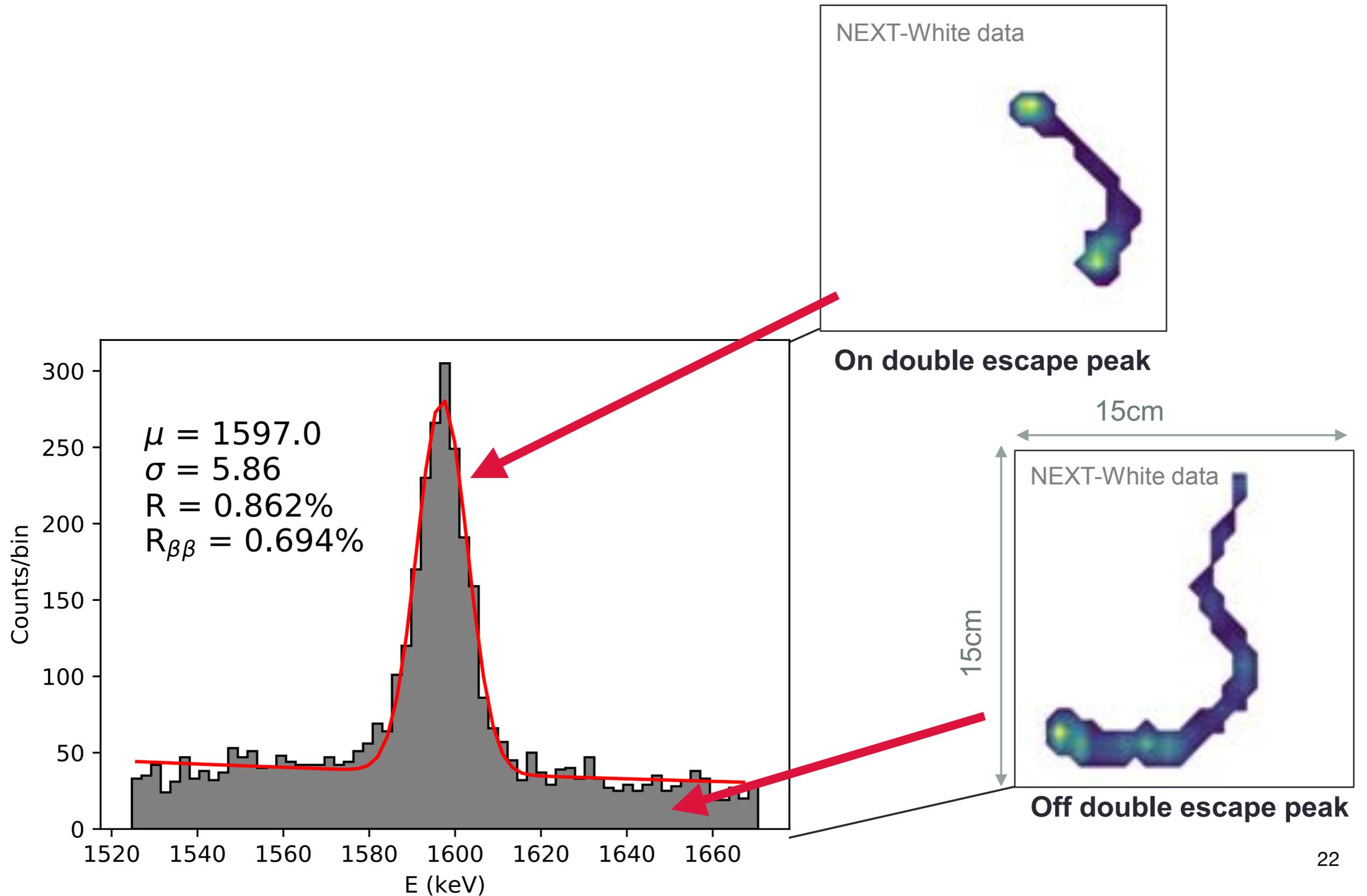
# NEW energy resolution (calibration sources)



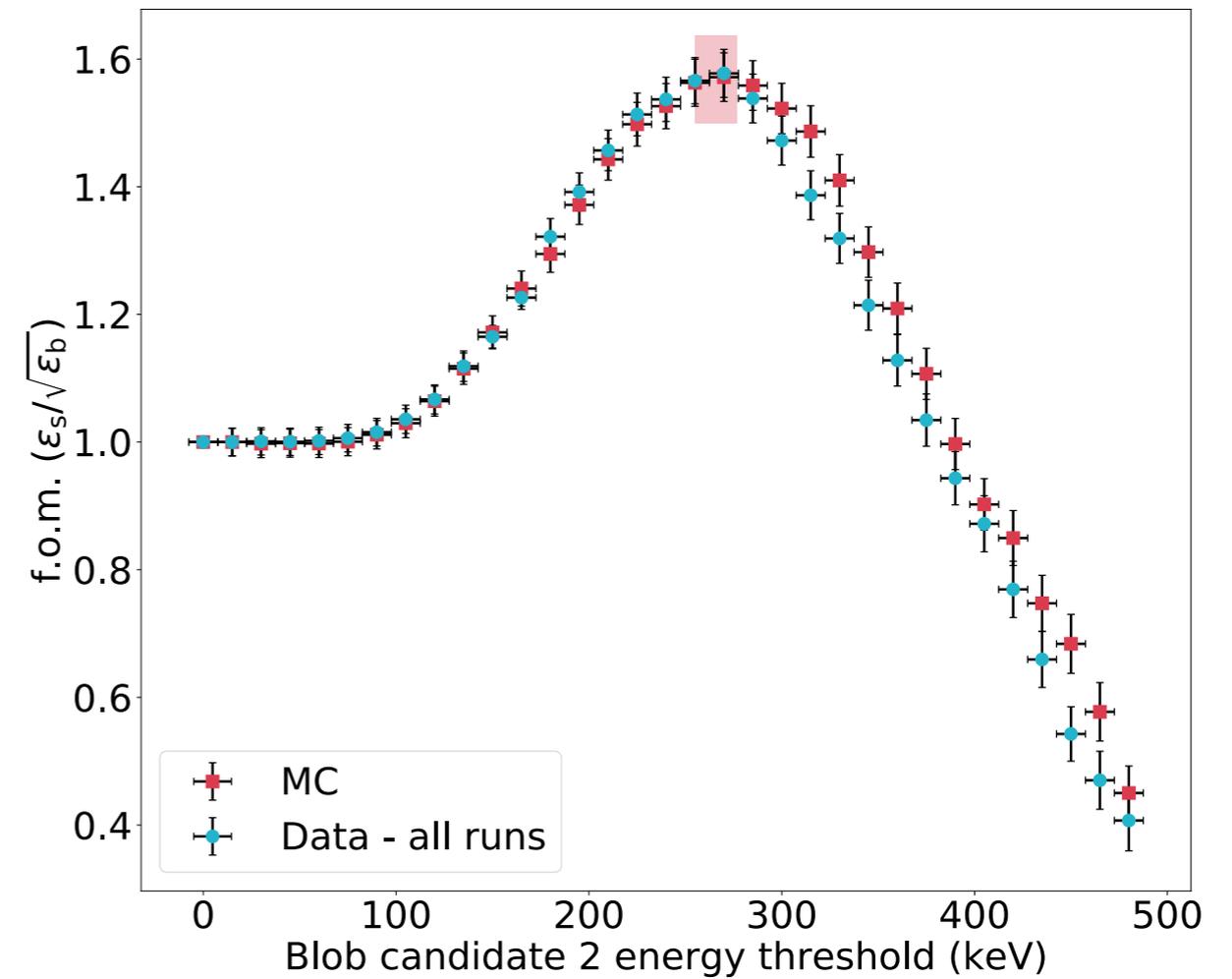
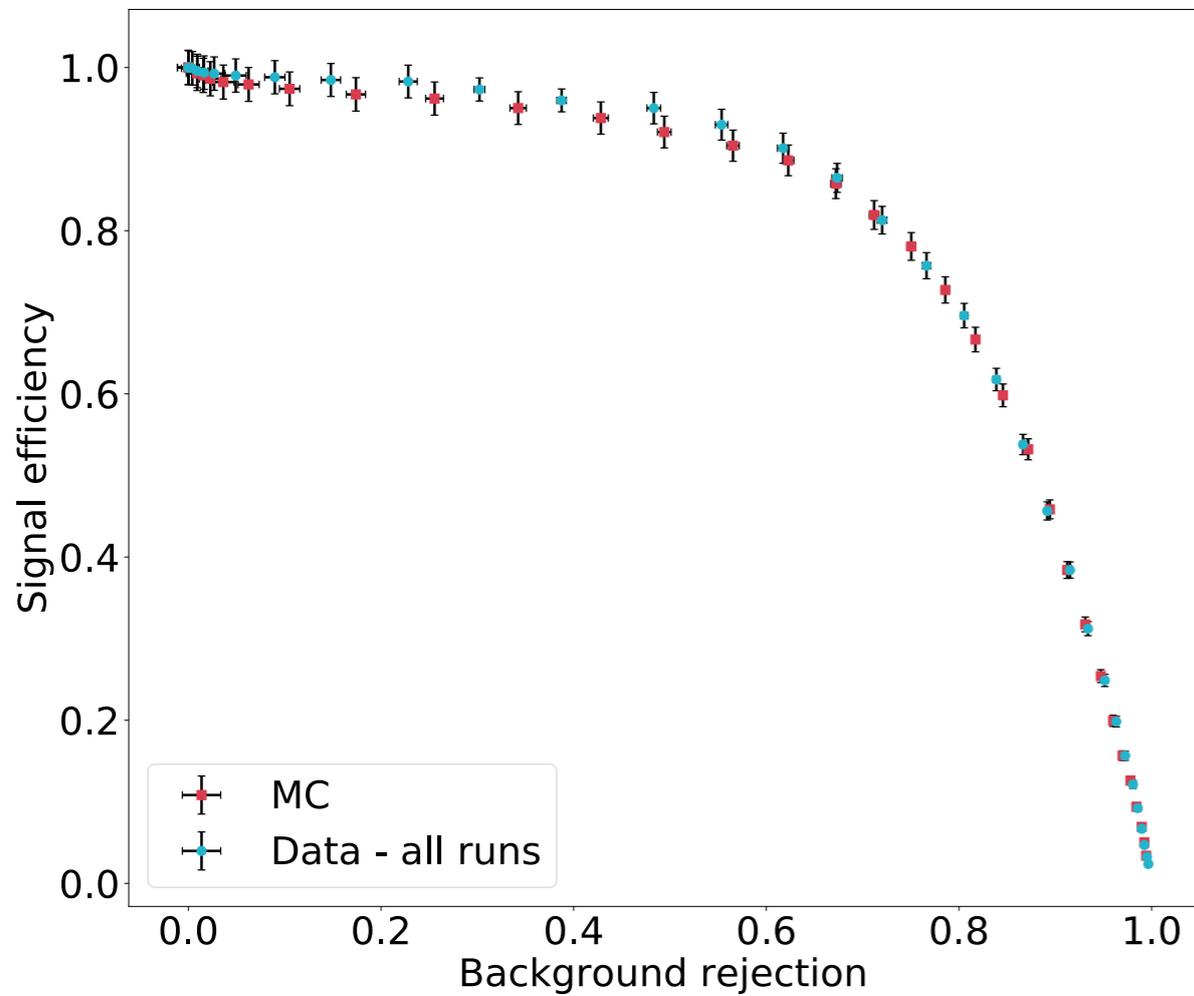
# NEW energy resolution (calibration sources)



# NEW topology



# NEW topology



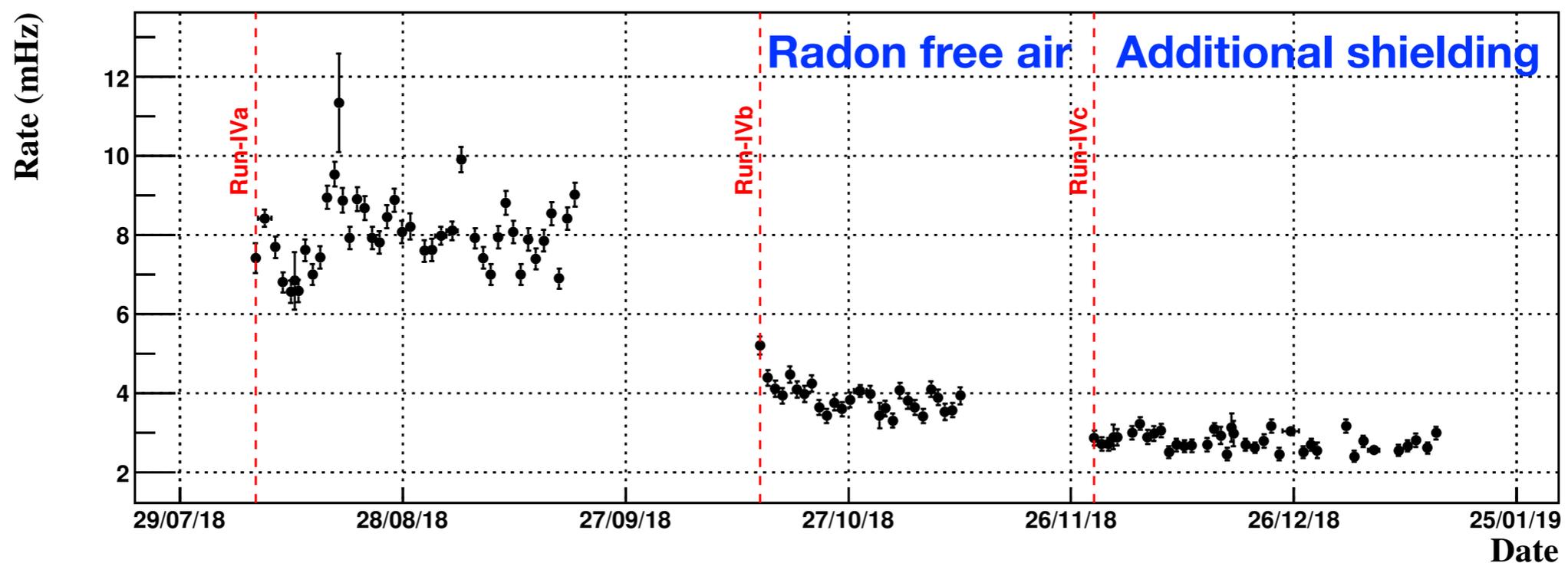
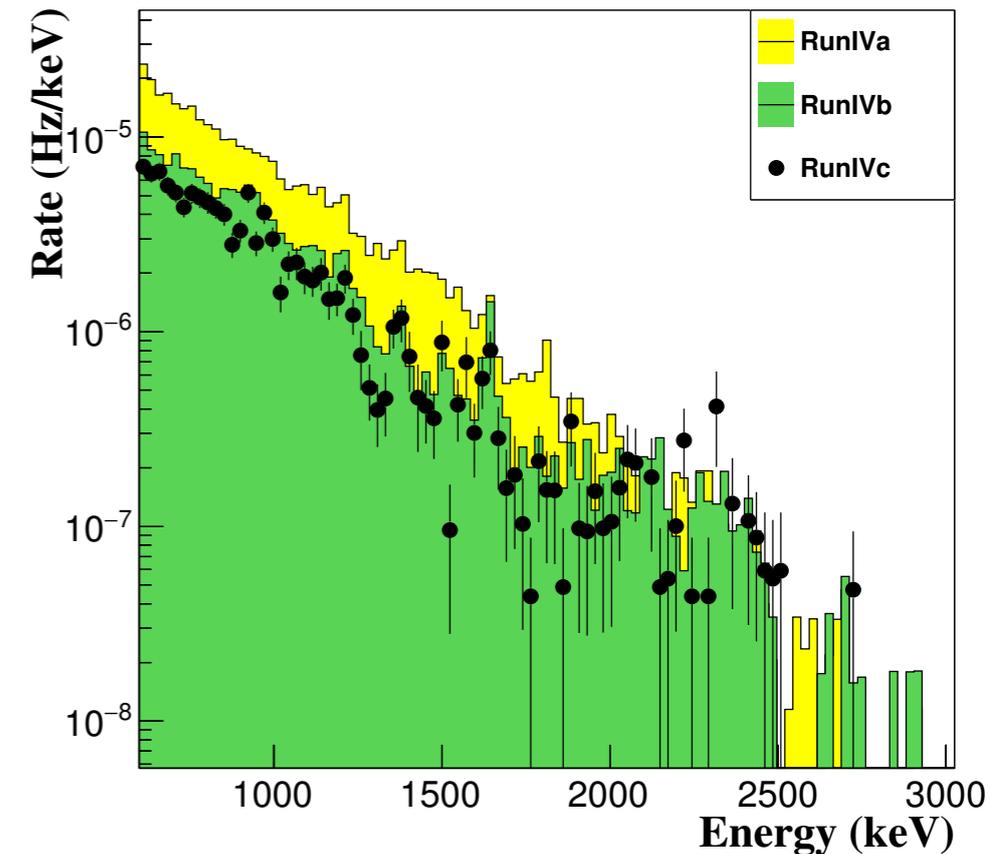
**~70% efficiency**  
**~20% bkg contamination**

# NEW backgrounds

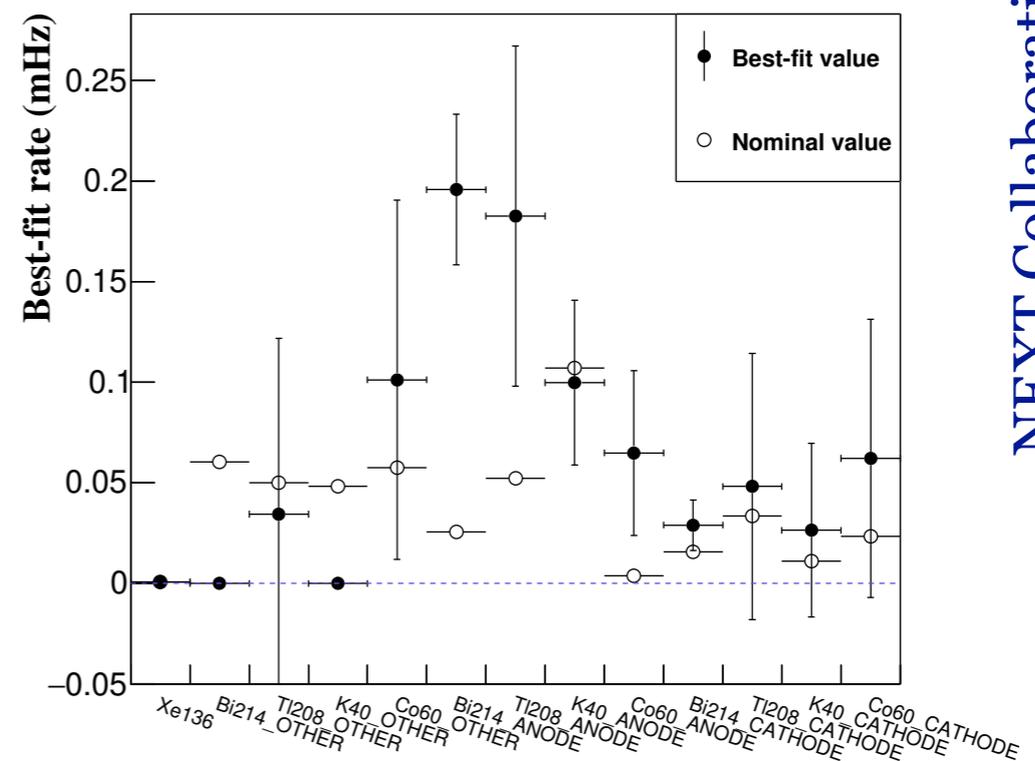
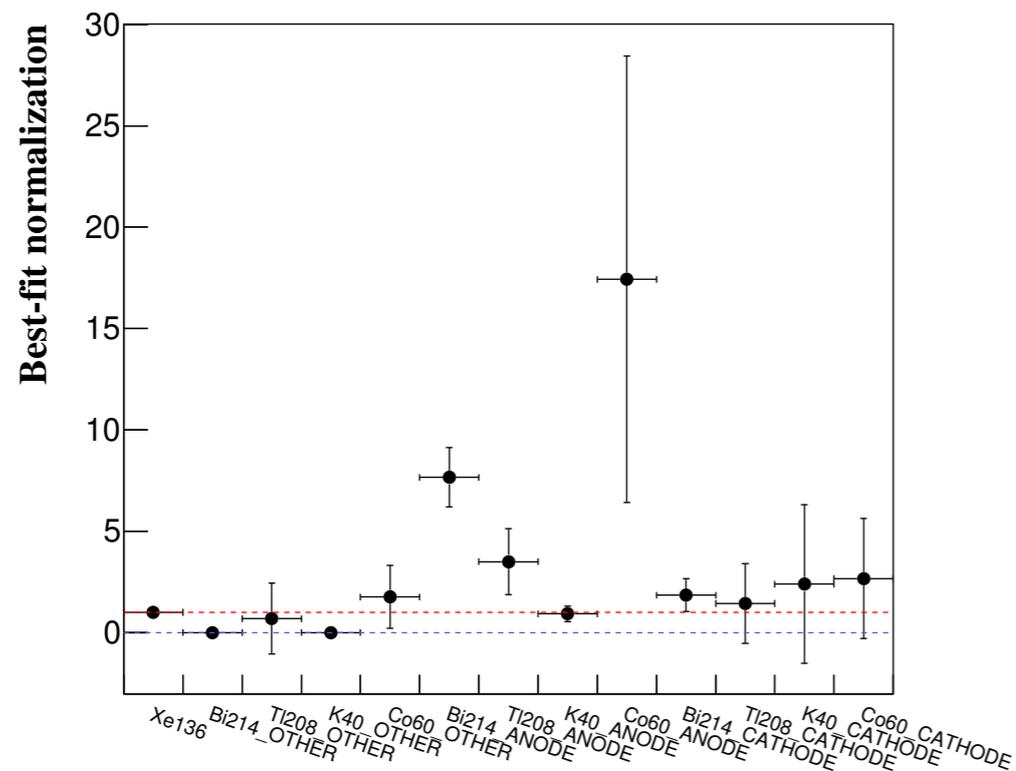
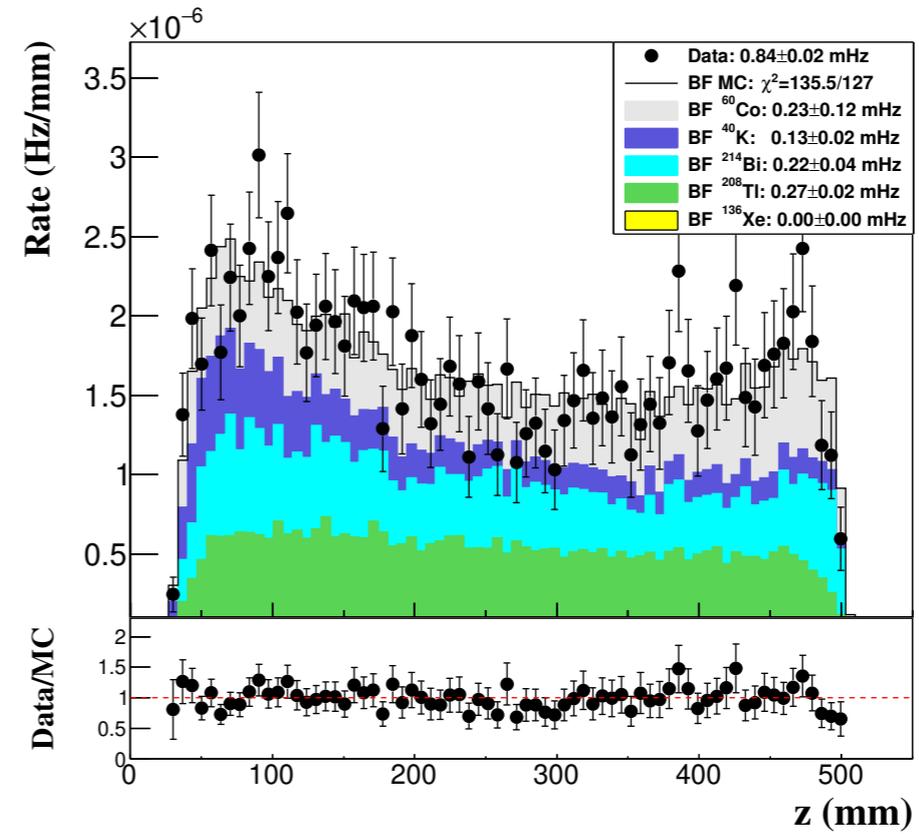
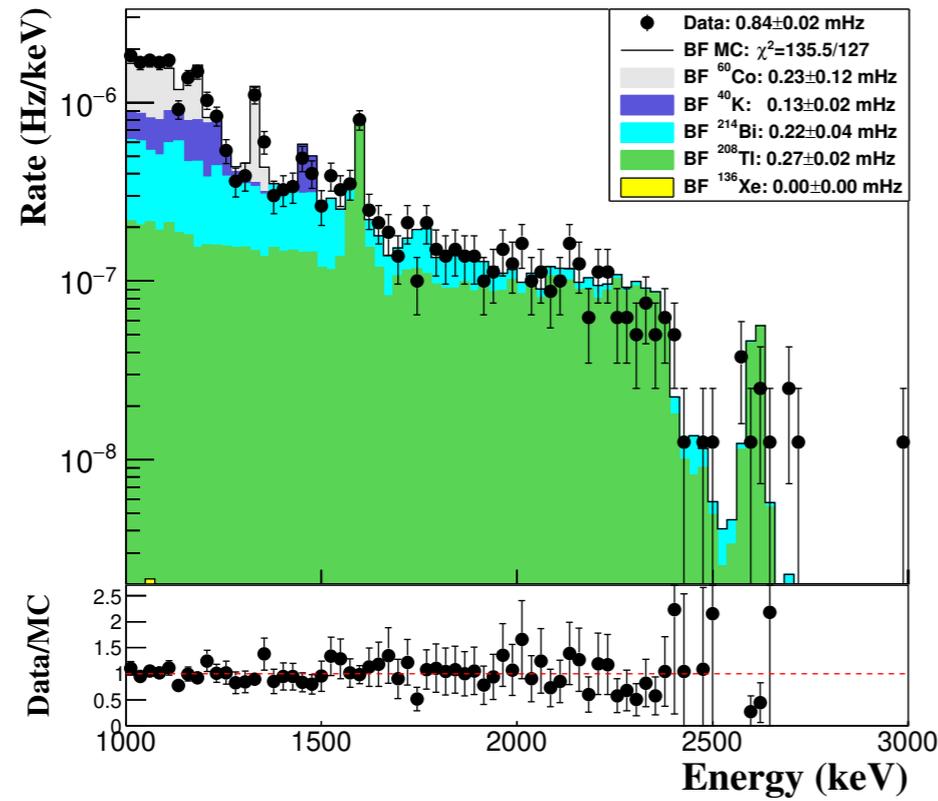
Low-background data taking proceeding after detector calibration campaign. NEXT background model assessed using these data.

Several improvements in the setup have reduced backgrounds by a factor of  $\sim 4$ :

- New radiopure components in field cage.
- Radon-free air introduced in lead shielding.
- Additional layer of shielding added.

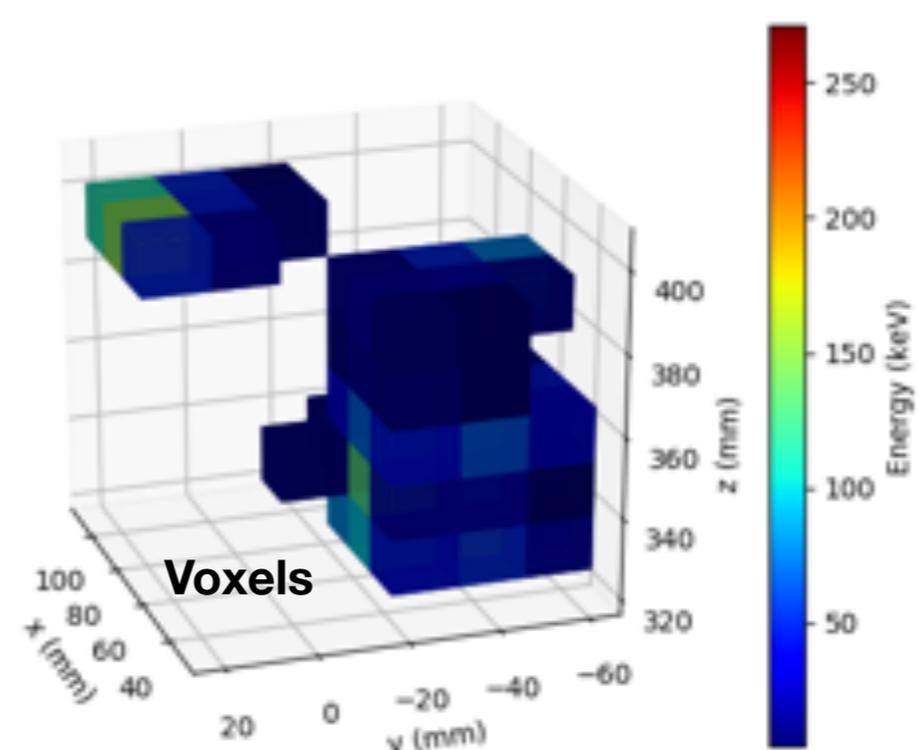
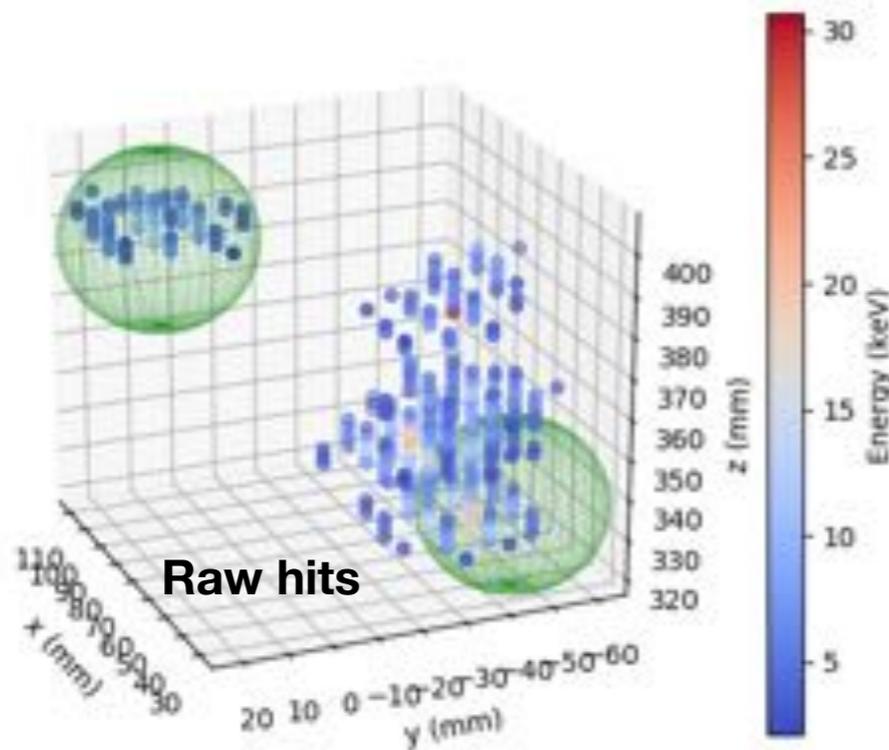
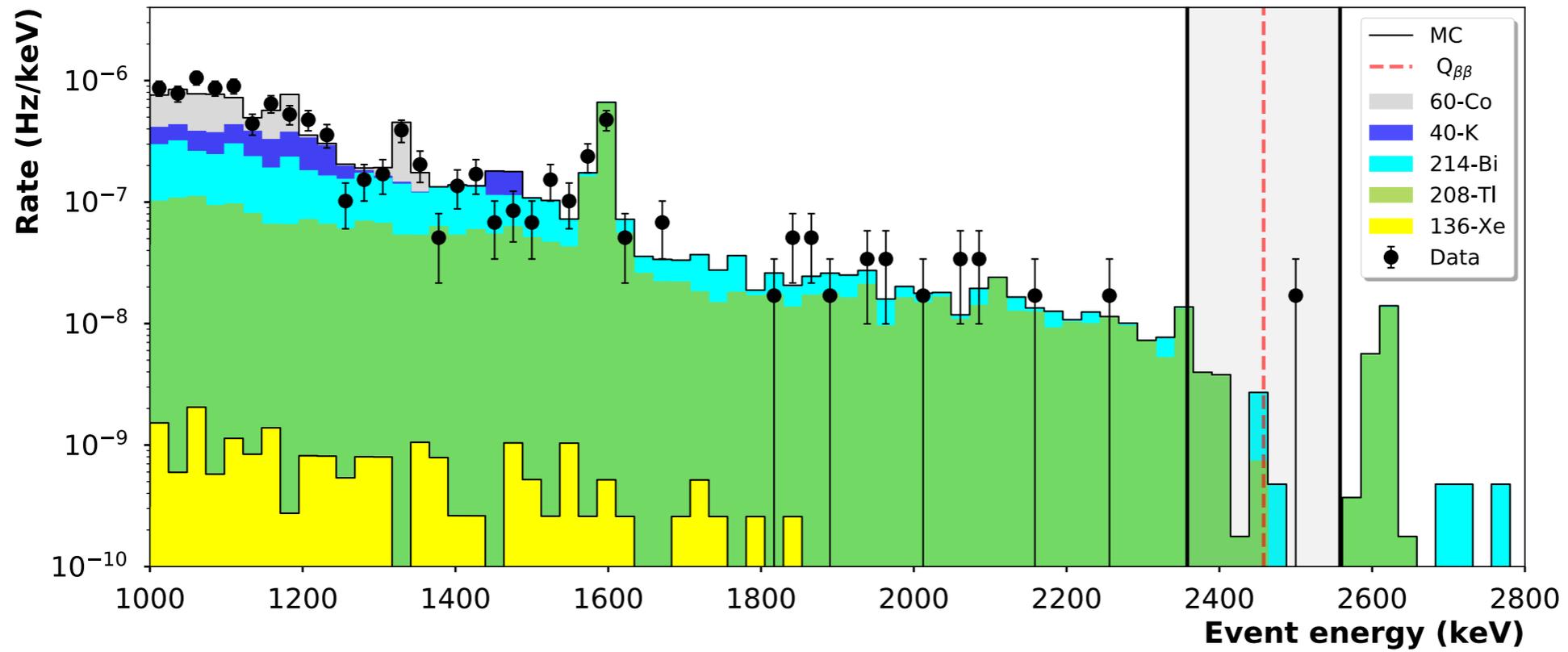


# NEW backgrounds



NEXT Collaboration, arXiv:1905.13625

# NEW backgrounds (after topology cuts)



NEXT Collaboration, arXiv:1905.13625

# Summary of NEW results

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**1. Great energy resolution** ✓ With several calibration sources (different energies), energy resolution better than 1% FWHM at  $Q_{\beta\beta}$  is achieved

**2. Low background** ✓

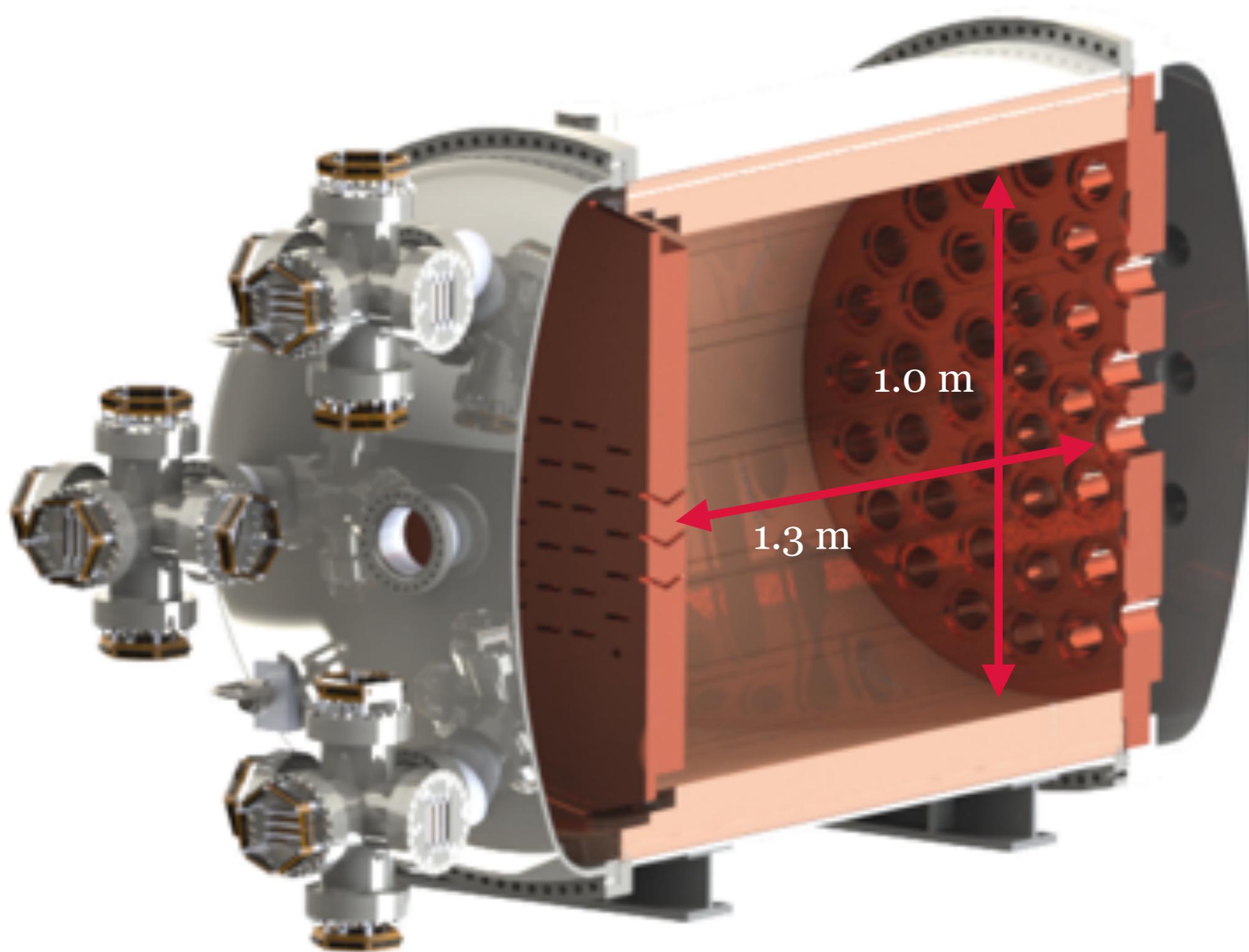
- Backgrounds measured in NEW and used for future predictions
- Identification of potential improvements

**3. Scalability**

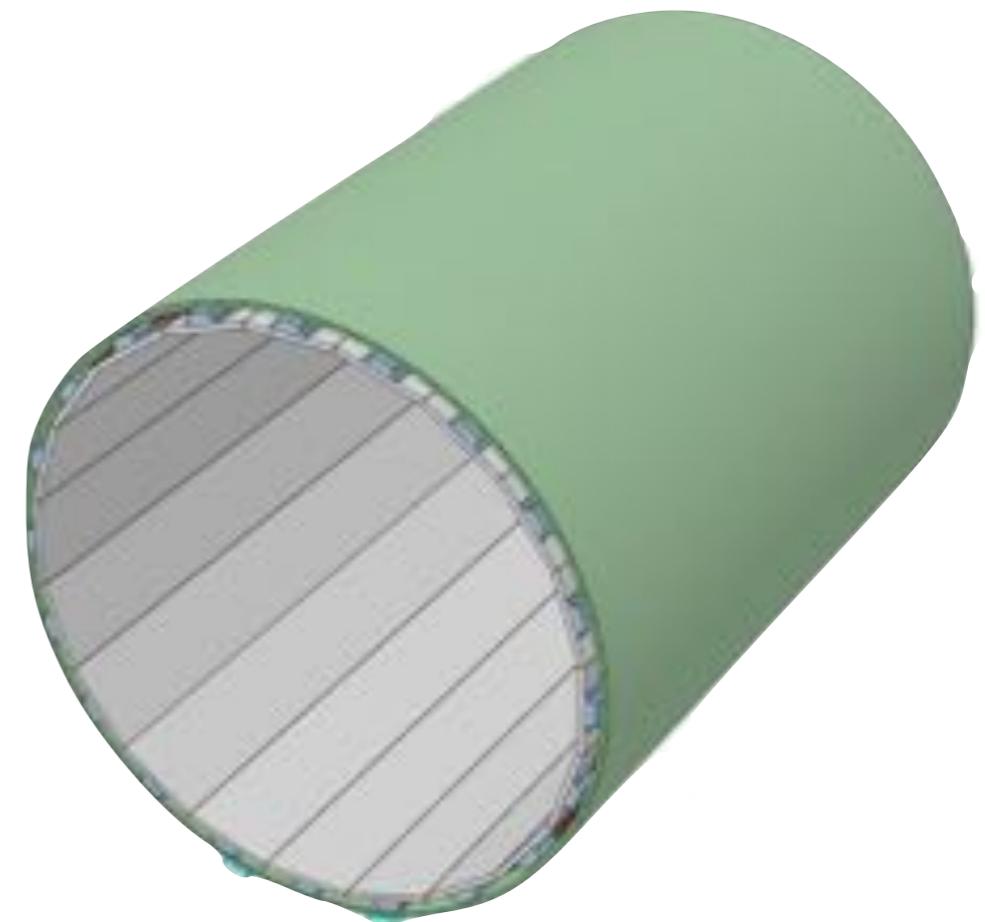
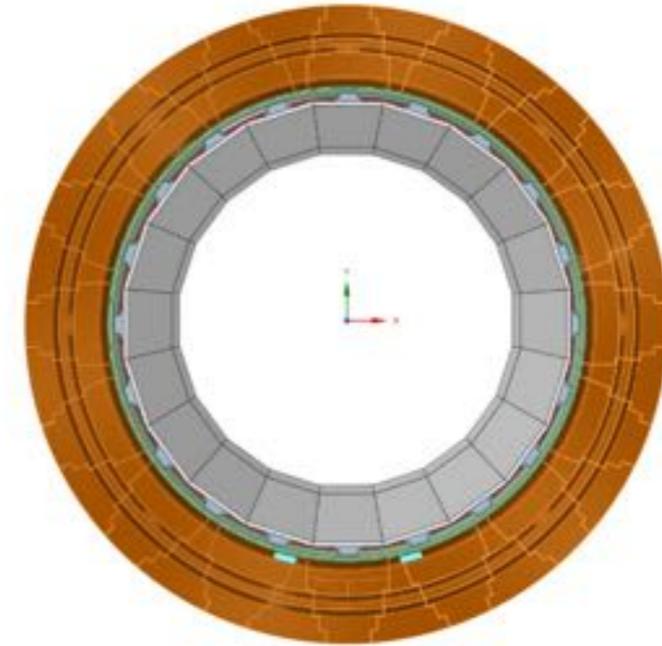
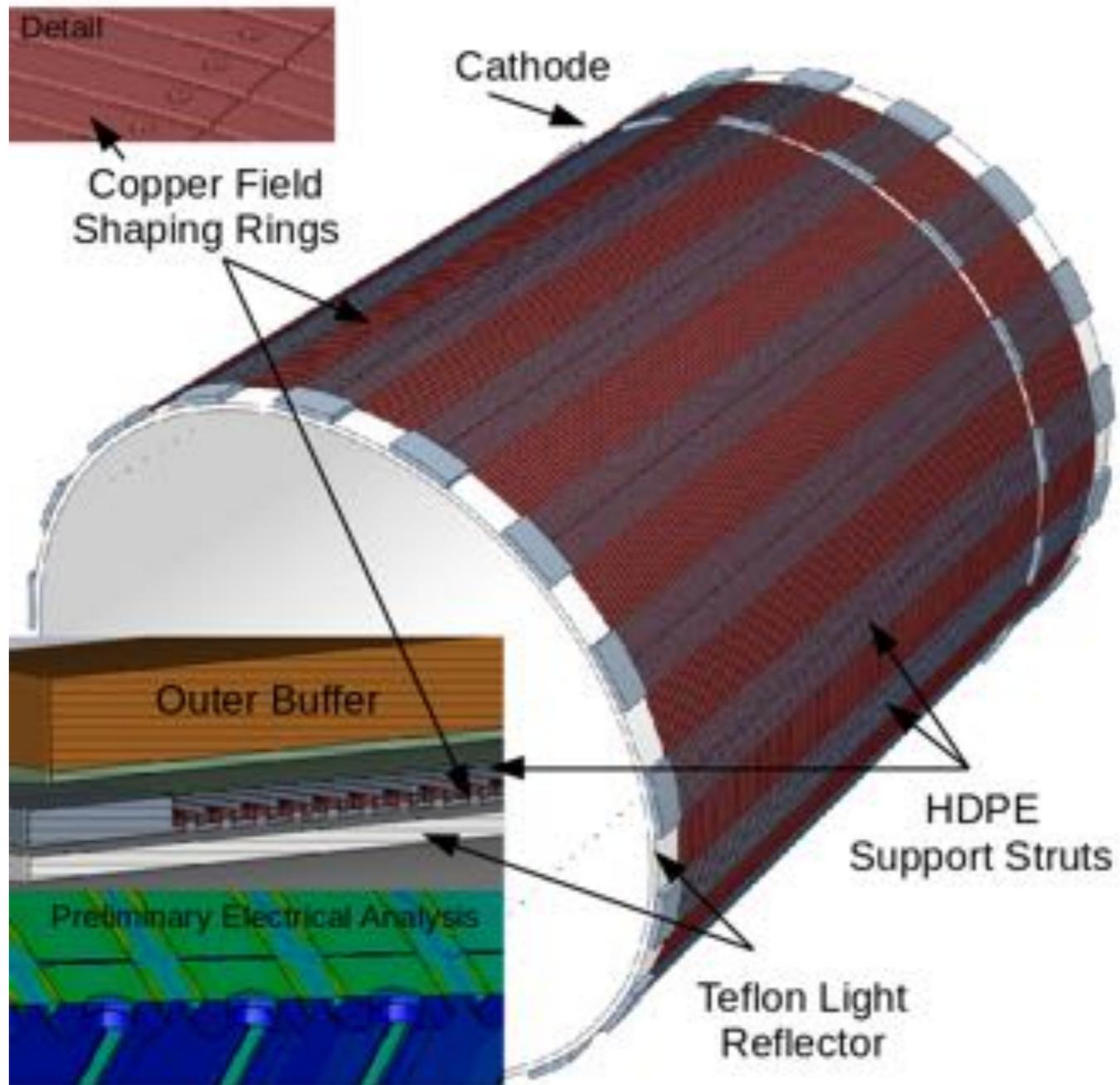
NEXT-100

# NEXT-100

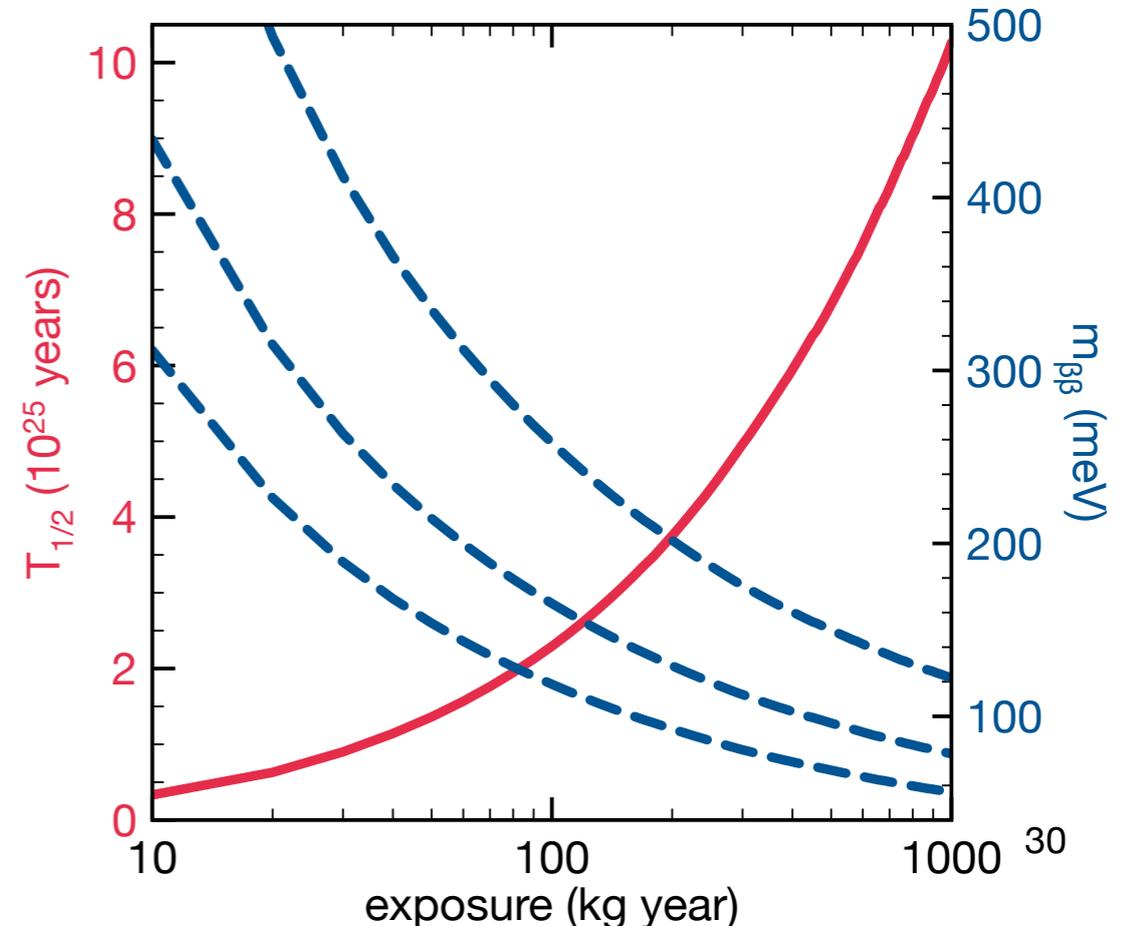
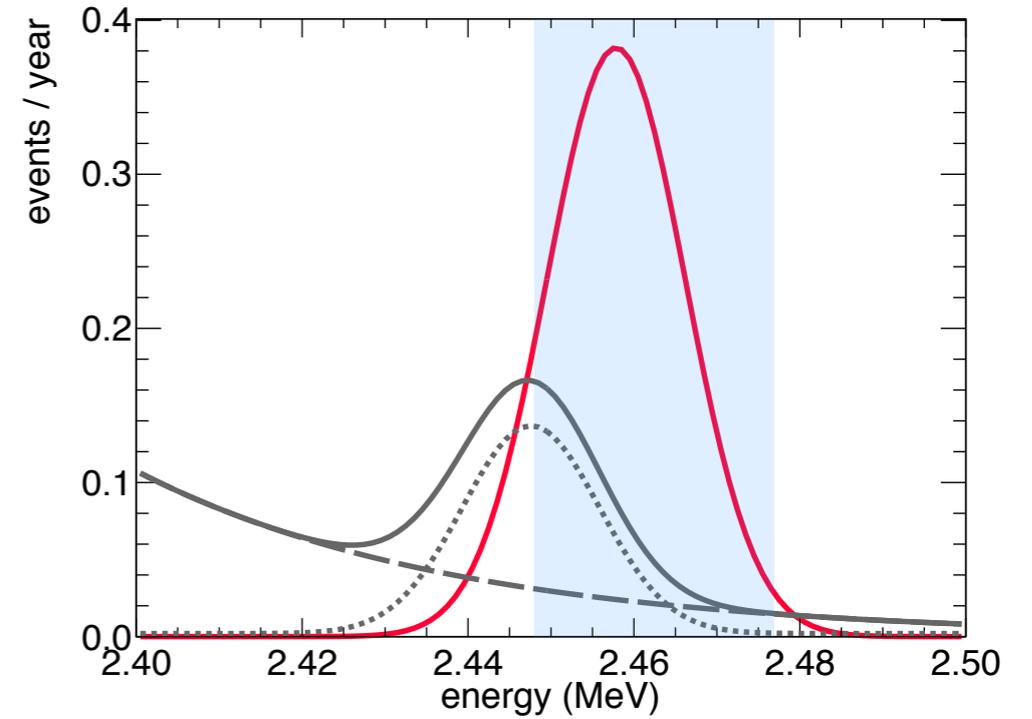
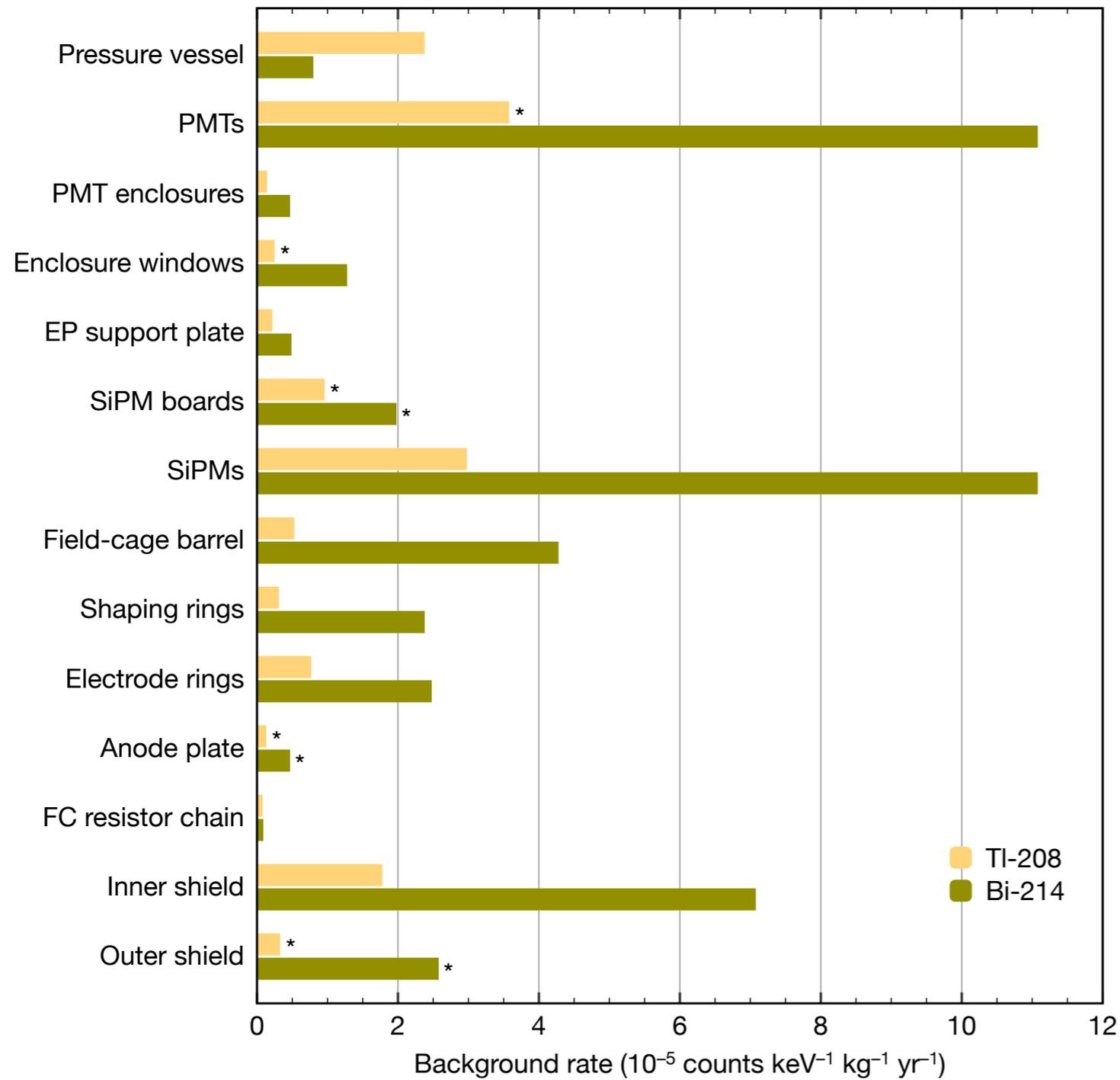
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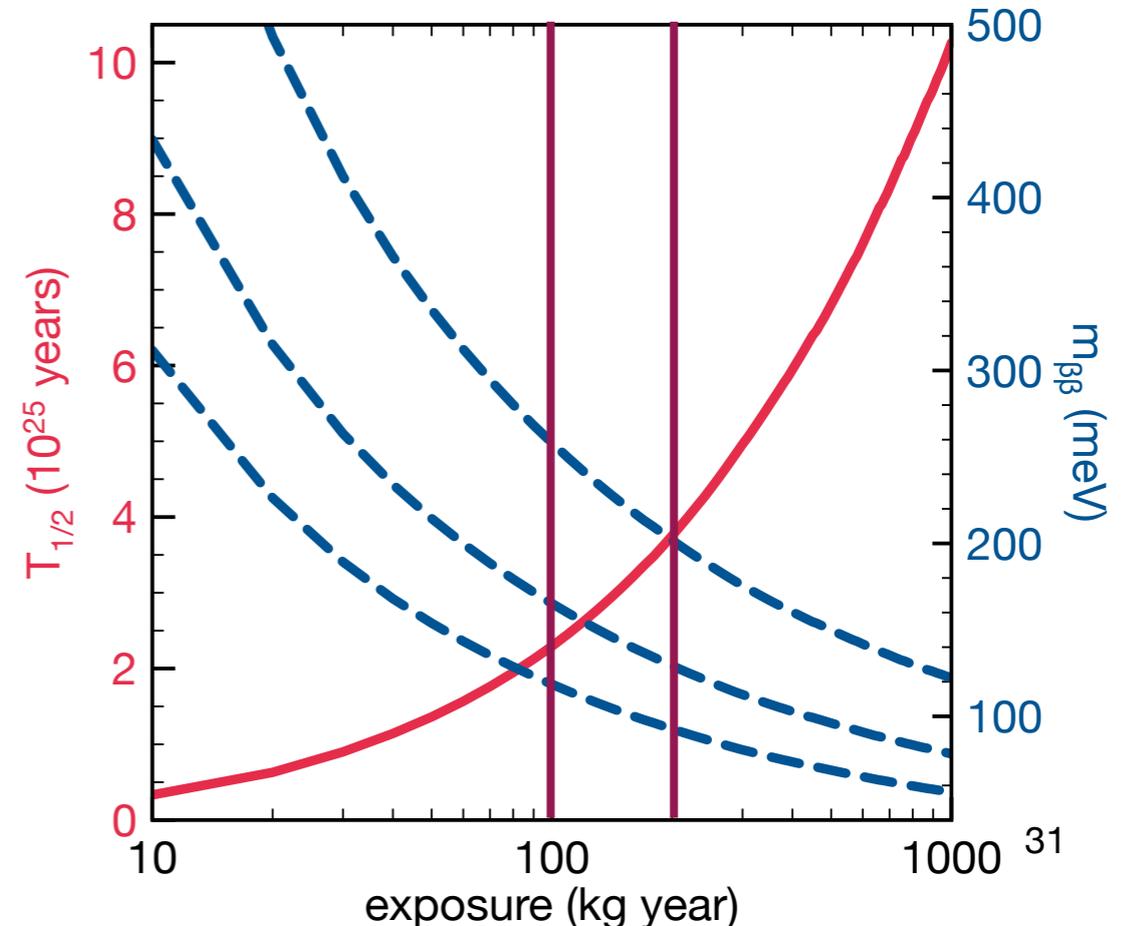
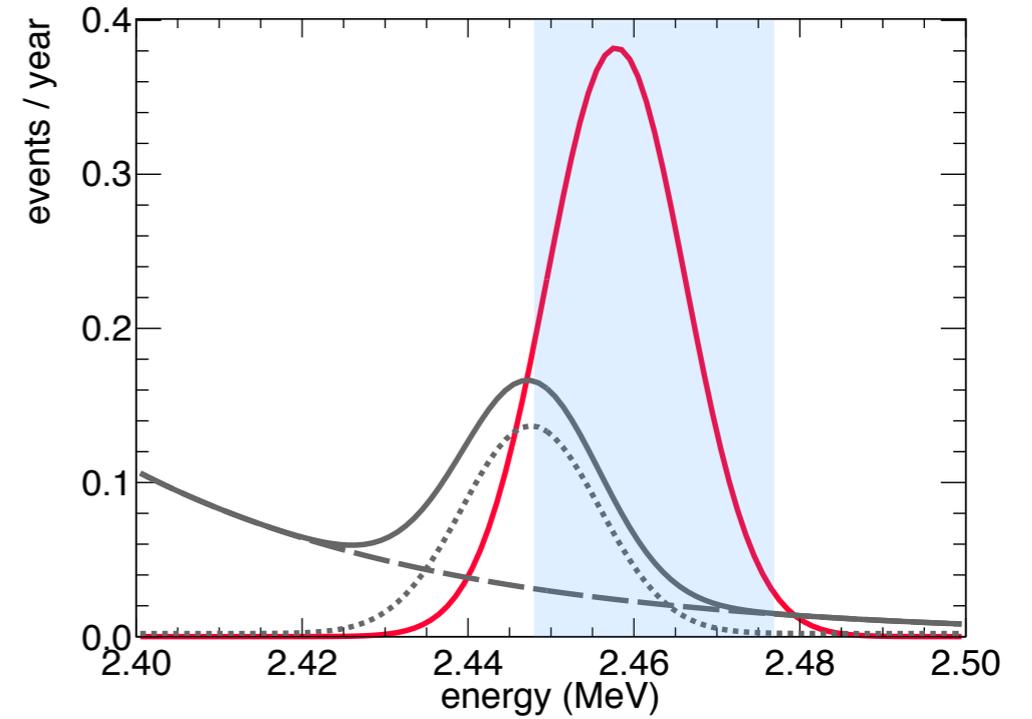
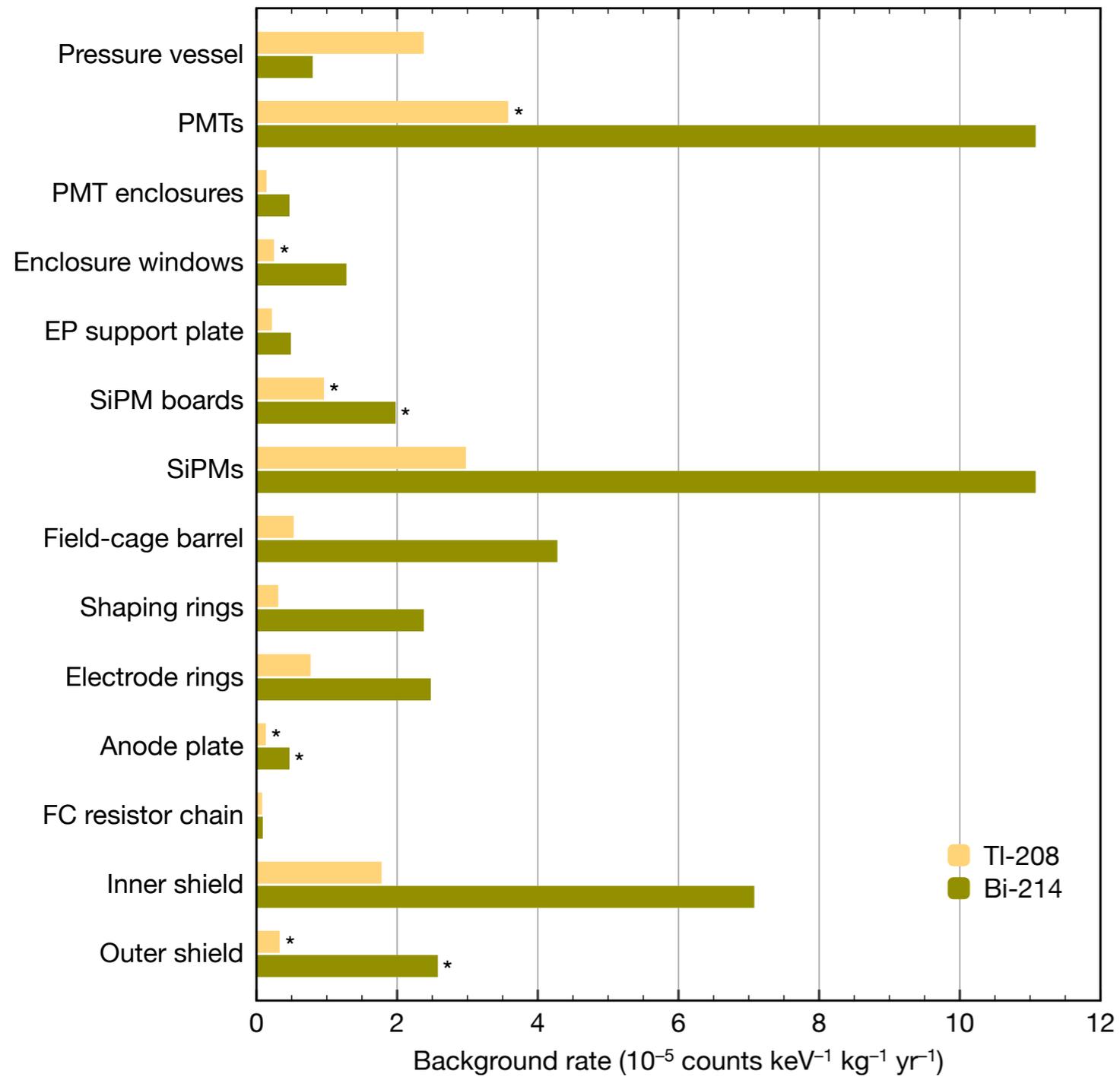
# NEXT-100 design



# NEXT-100 sensitivity



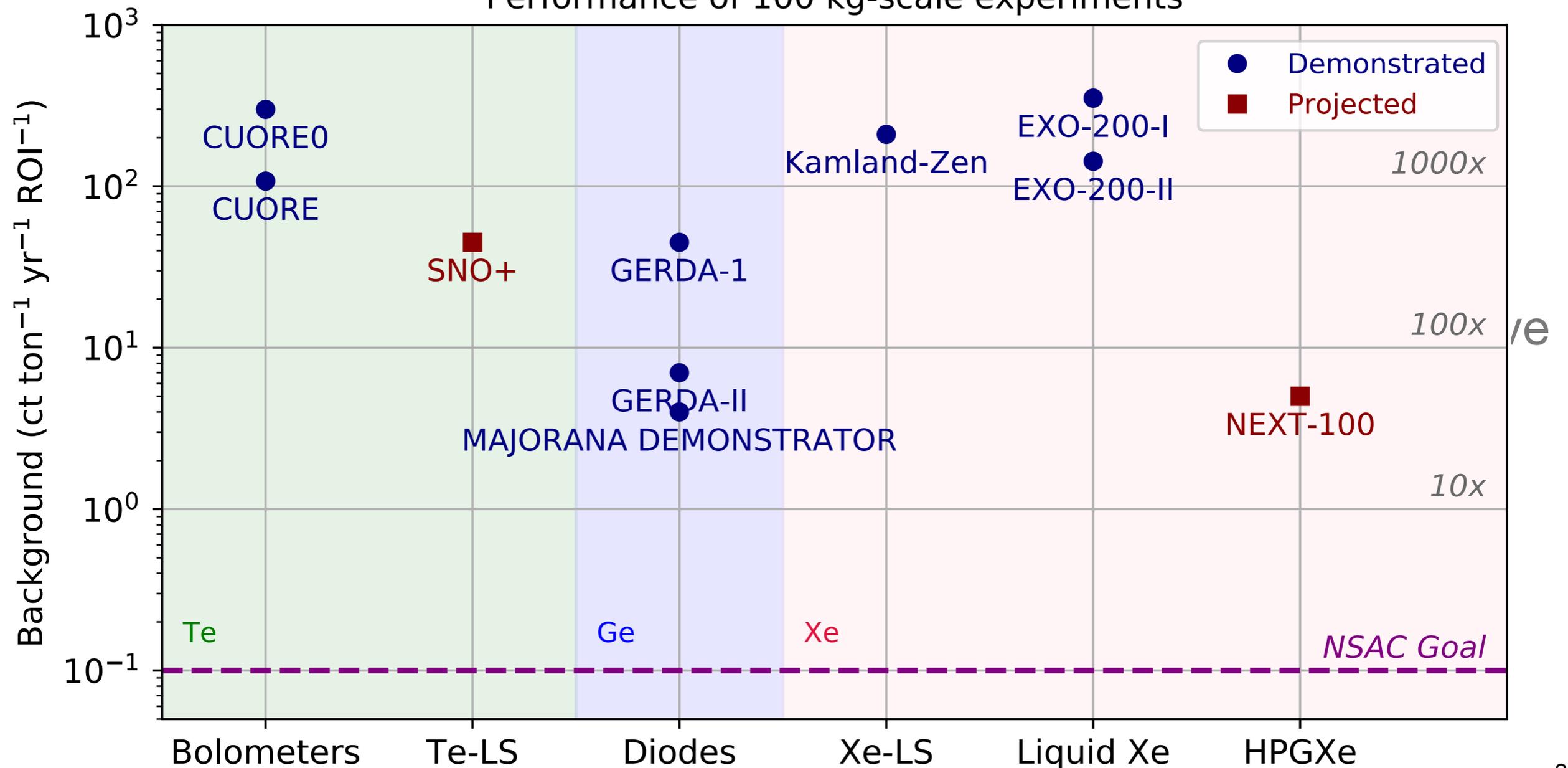
# NEXT-100 sensitivity



# Towards the ton-scale

NEXT-100 should demonstrate a background rate competitive with HPGe detectors: a few counts per ton and year in ROI

Performance of 100 kg-scale experiments



# Towards the ton-scale

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- NEXT-100 should demonstrate a background rate competitive with HPGe detectors: a few counts per ton and year in ROI
- Ample room for improvement in several areas:
  - ✓ Reconstruction algorithms (i.e. better energy resolution and topological discrimination)
  - ✓ Radiopurity (e.g. get rid of PMTs)
  - ✓ Low-diffusion gas mixtures and denser tracking plane to improve tracking signature

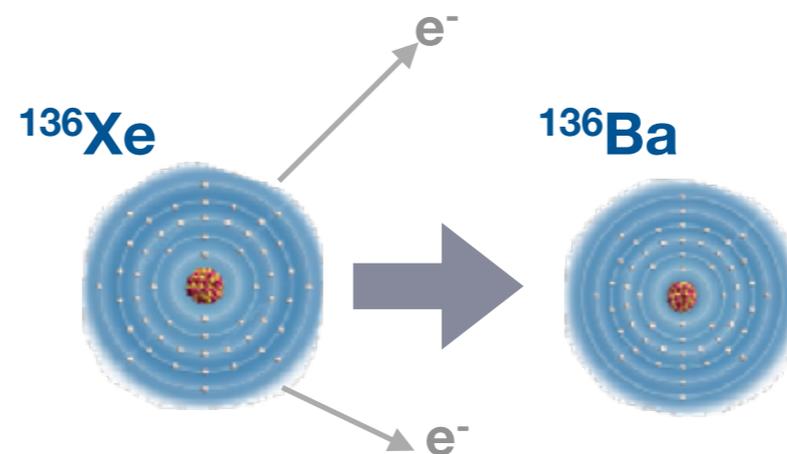
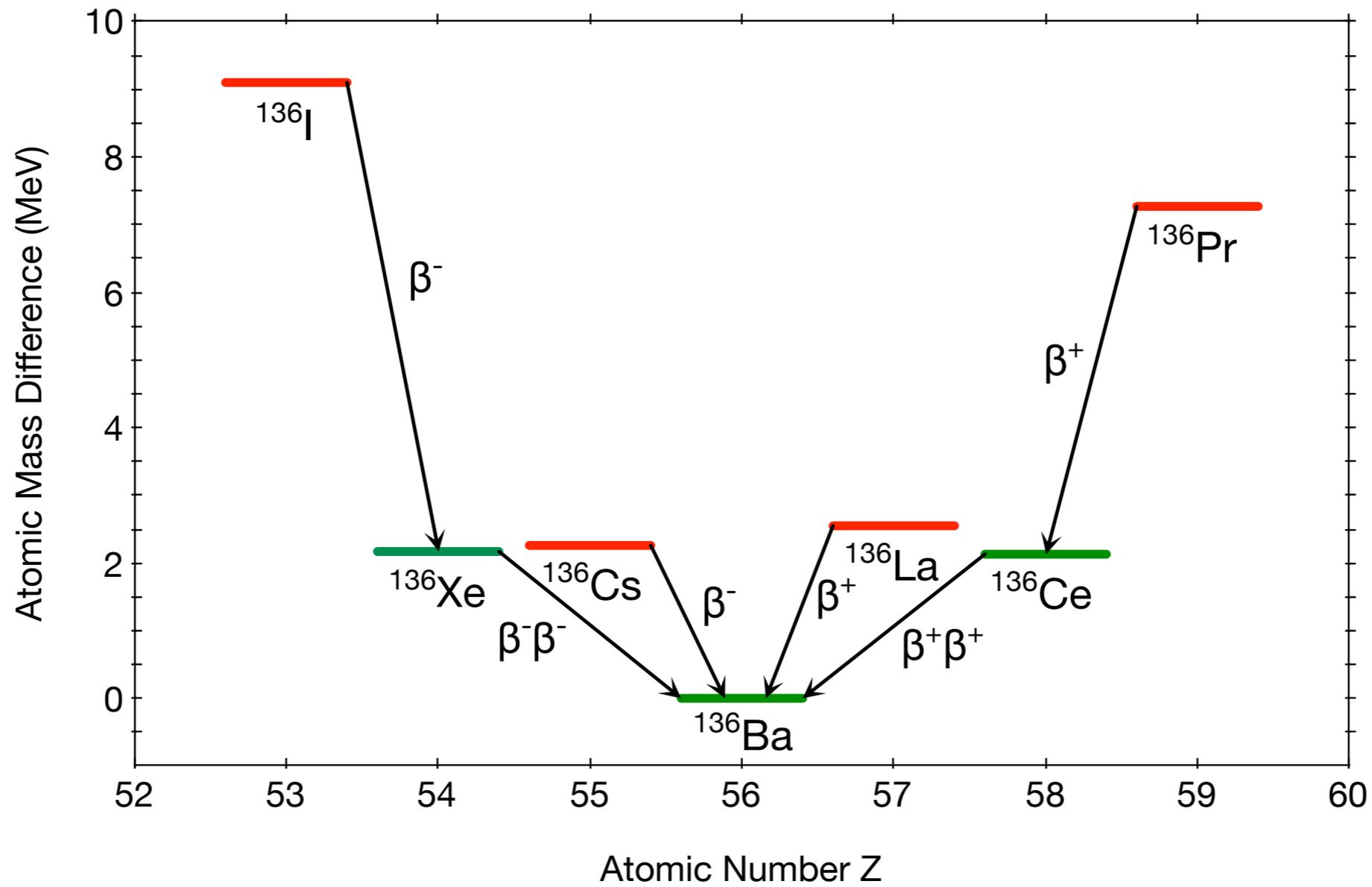
**Focused R&D devoted to these 3 points!**

# Towards the ton-scale

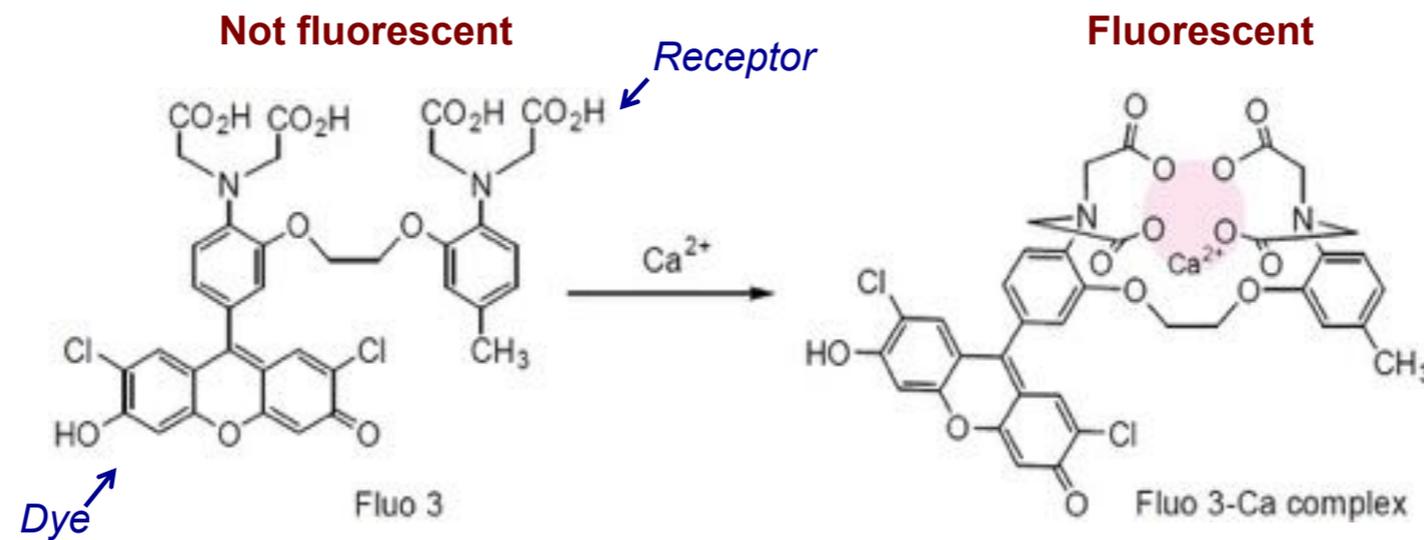
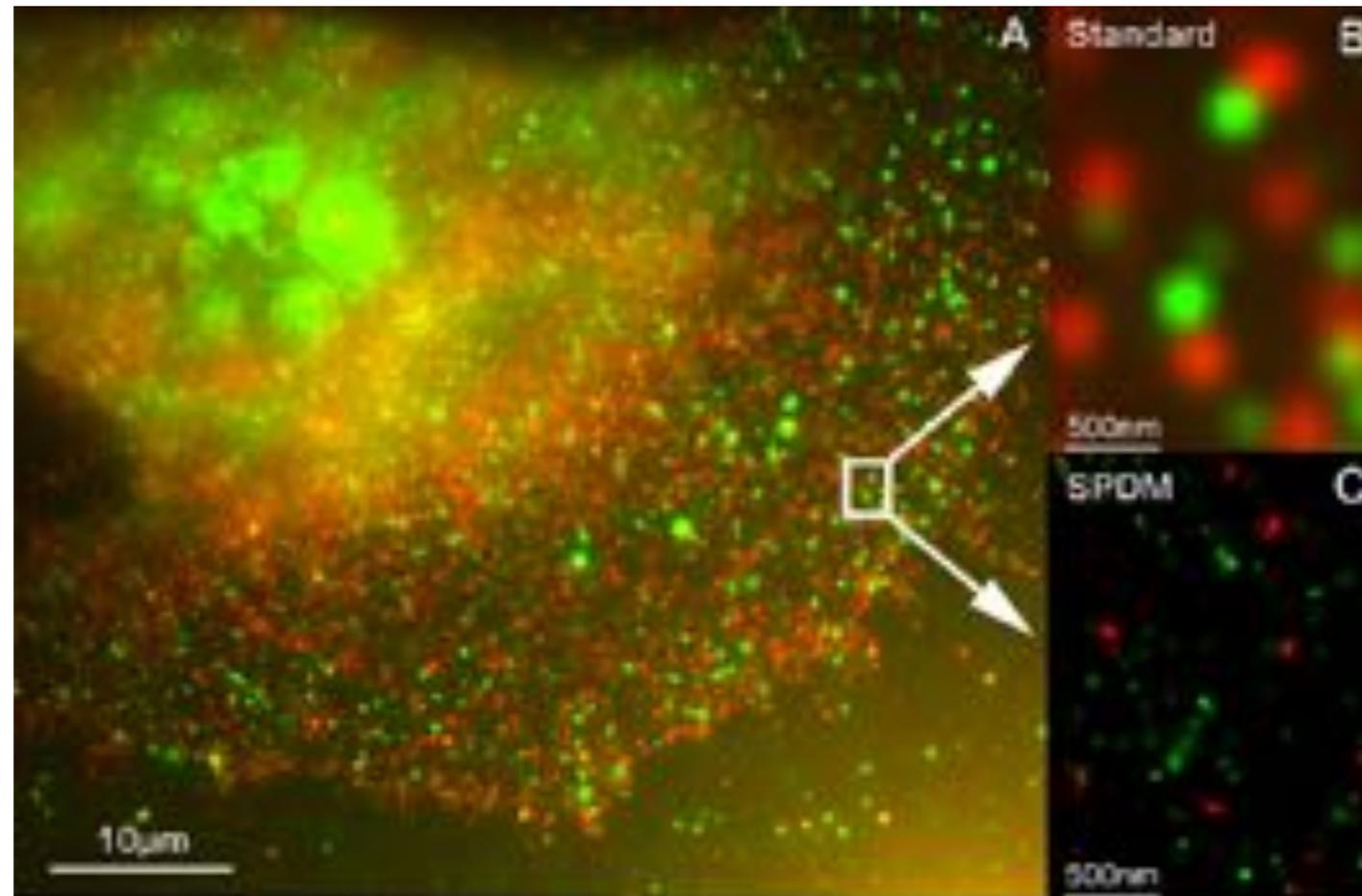
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- Last but not least: gaseous xenon could make possible a true background-free experiment via tagging of the barium decay product

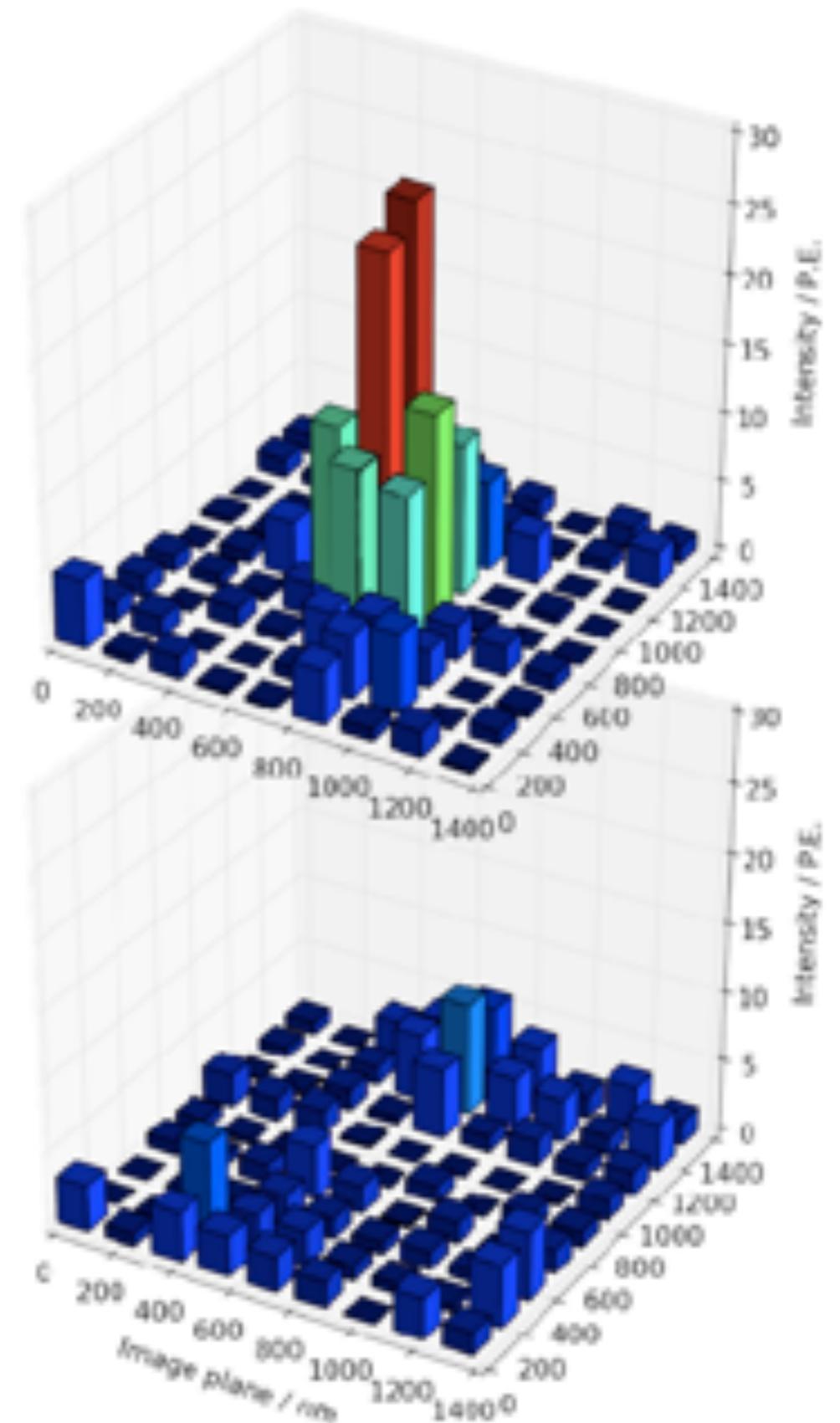
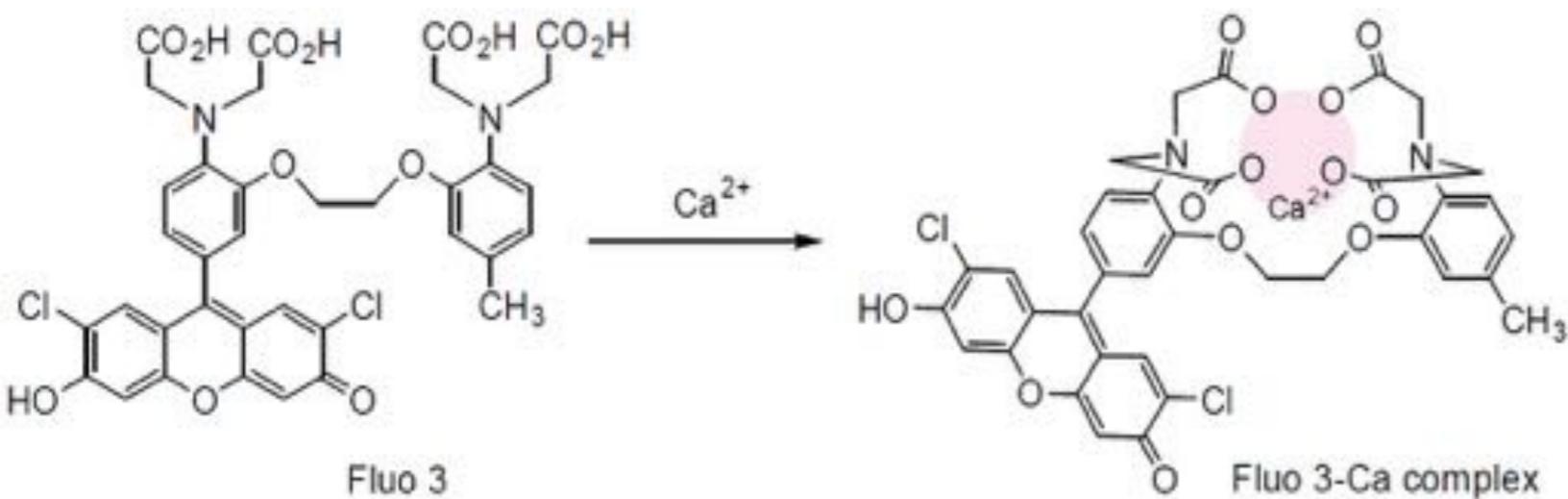
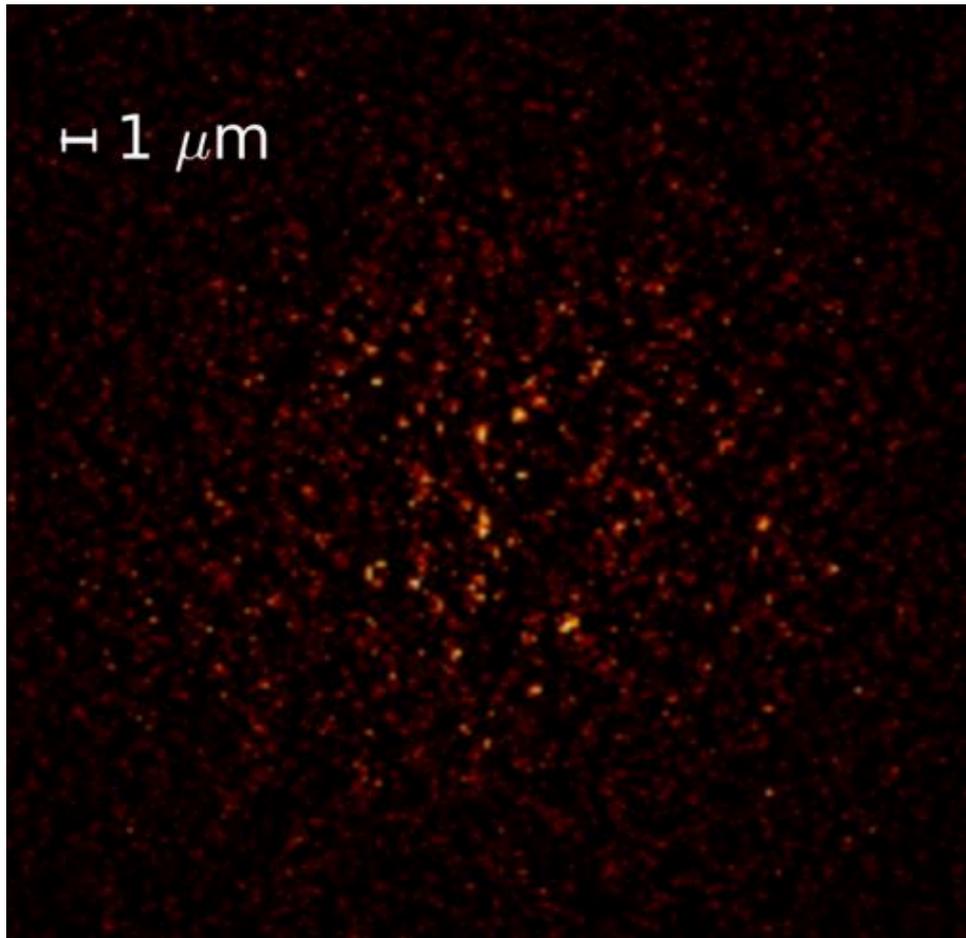
# Ba tagging



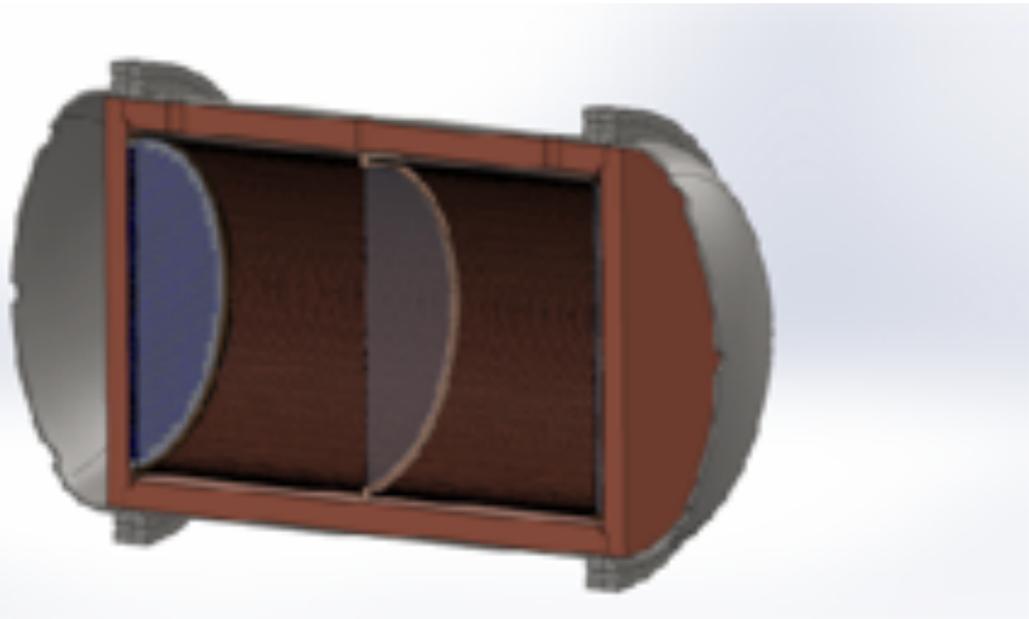
# Ba tagging



# Ba tagging



# Plans for the ton-scale

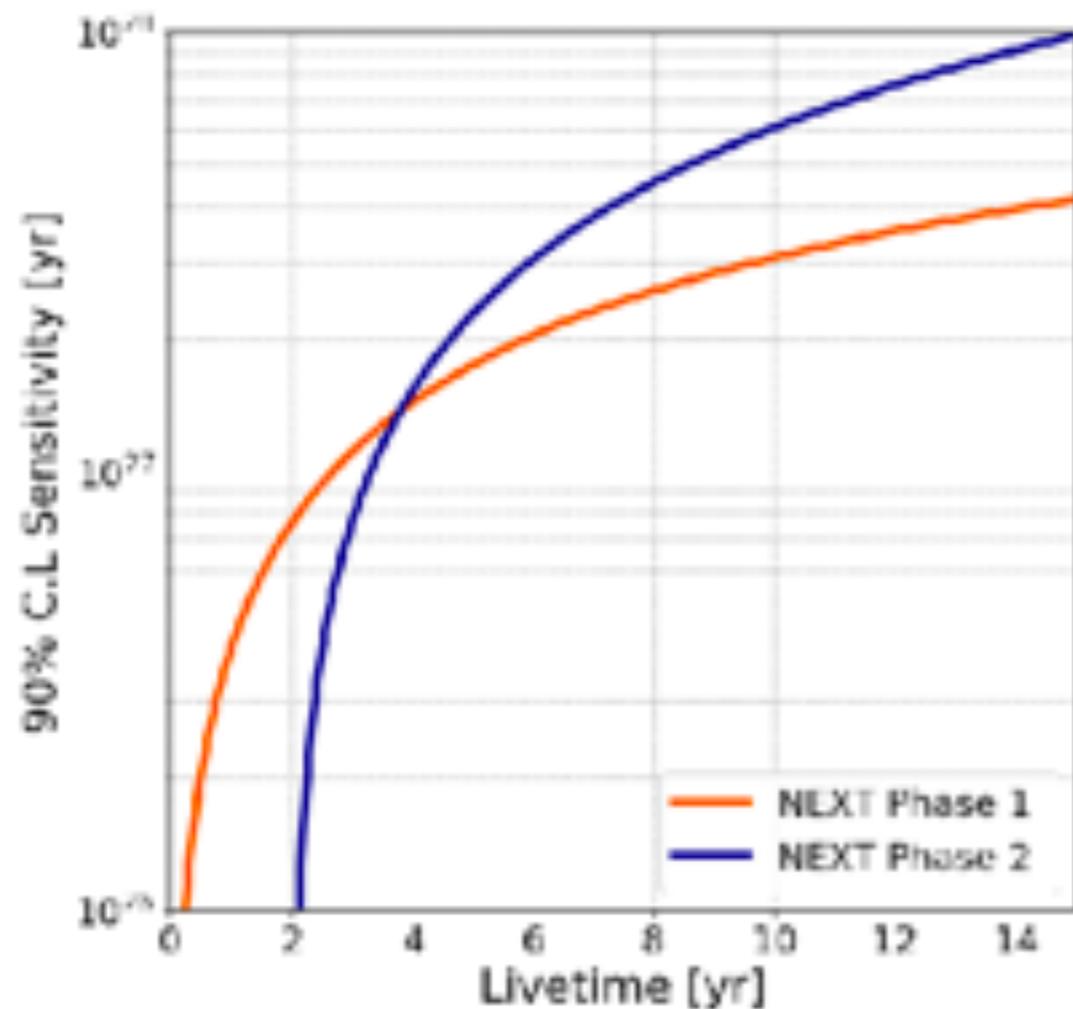


## Two approaches developed in parallel:

- Phase 1, High Definition: incremental approach, using/improving existing technology.
- Phase 2, Barium Tagging: based on disruptive new concept (SMFI Ba++ tagging).

## Phased approach

- ~1 ton of  $^{136}\text{Xe}$  introduced per phase.
- Ultra pure materials. SiPMs as the only sensor.



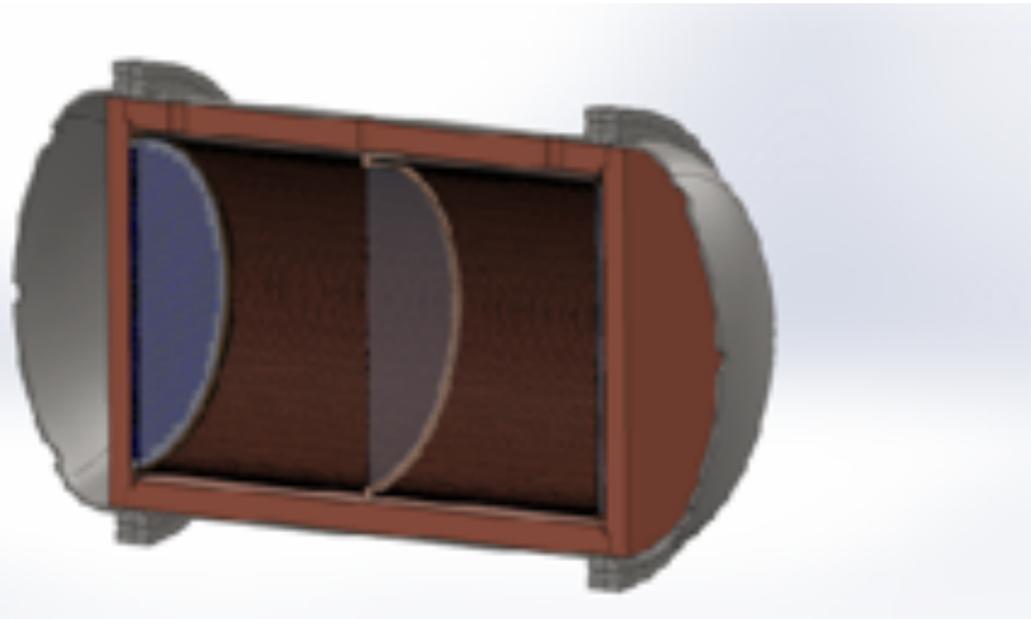
## Phase 1:

- Improves topological signature, improves energy resolution
- Reduces radioactive budget (no PMTs)
- Energy plane made of large area SiPMs (design similar to that of Dark Side)
- Potential to reduce SiPM dark count by cooling detector
- $2.6 \times 10^{-6}$  cts / keV·kg·year total background rate

## Phase 2:

- Tracking and energy measured in anode.
- Cathode implements Barium Tagging System
- Virtually background free

# Plans for the ton-scale

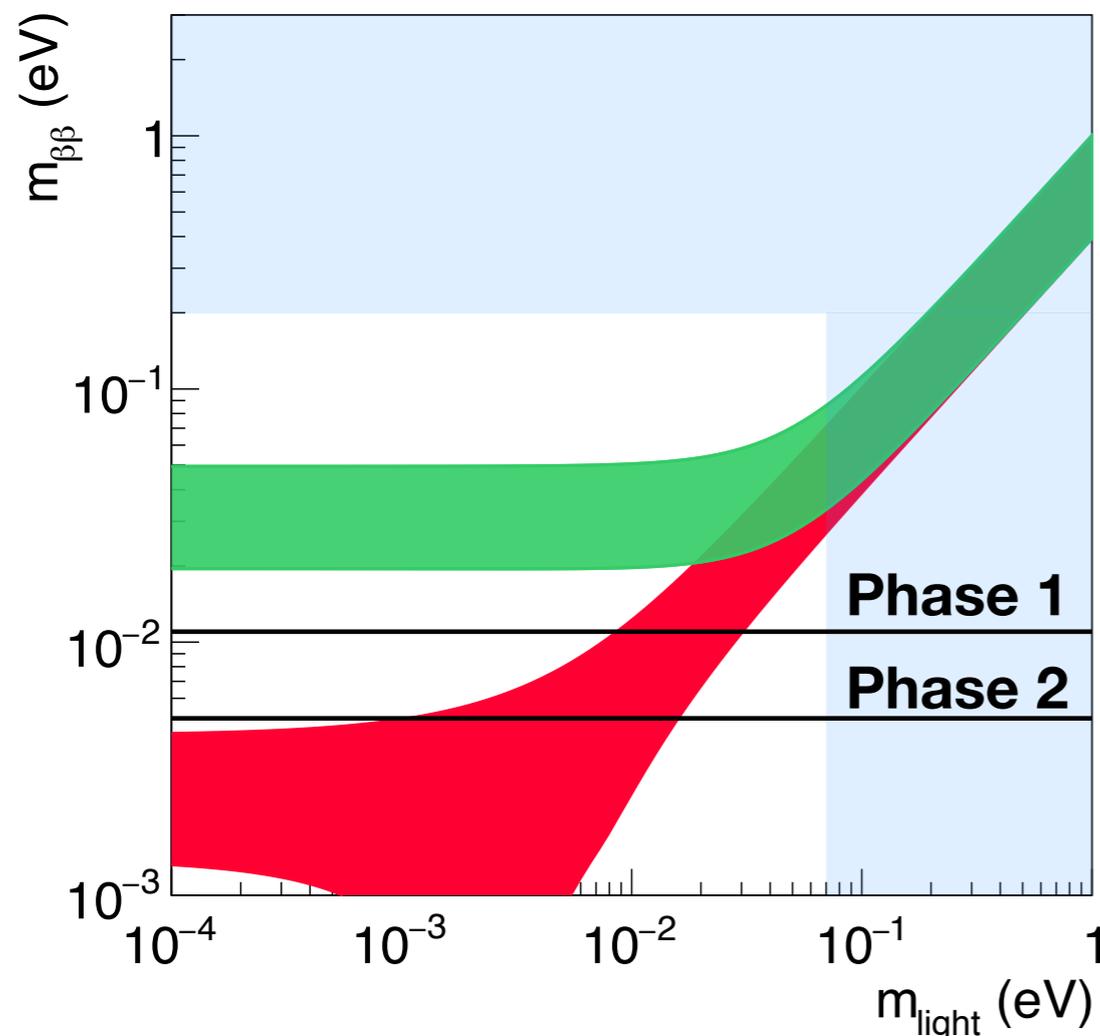


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# Summary

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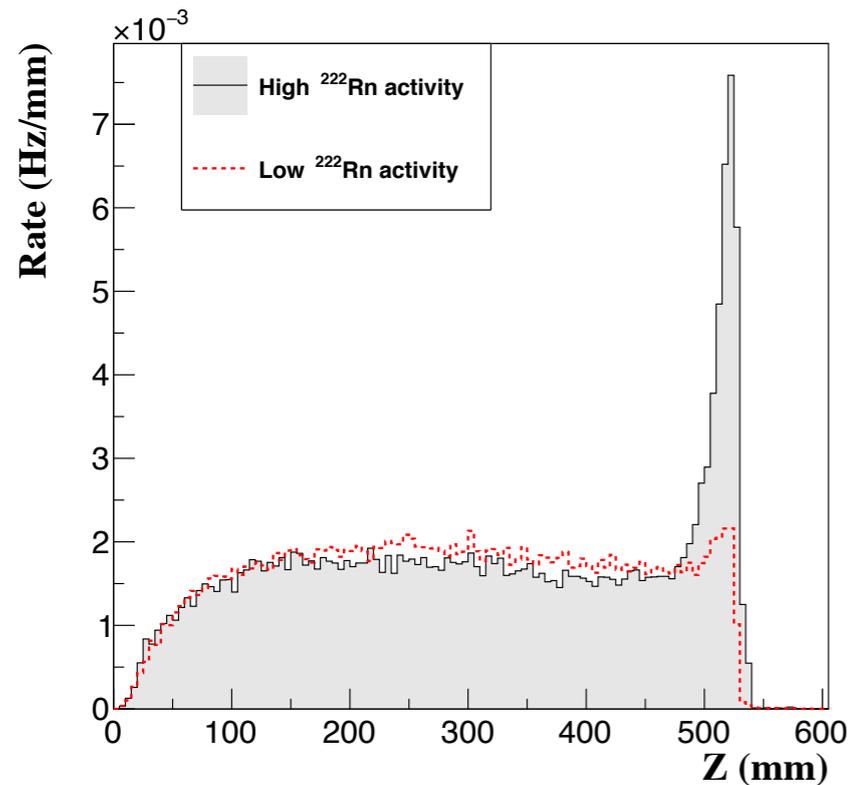
- HPGTPCs have unique advantages for neutrinoless double-beta decay searches
- NEW demonstrated that topology selection and great energy resolution can be achieved
- NEXT-100 is underway, will demonstrate scalability and will have sensitivity similar to current generation of experiments
- The ton-scale is really where we want to go and NEXT proposes a staged approach with unique potential to reach near the normal mass ordering phase space



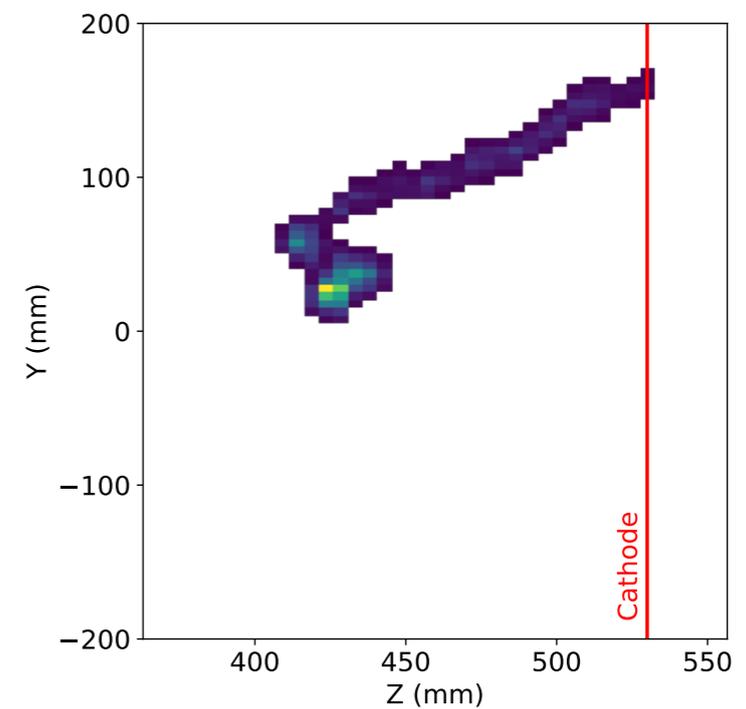
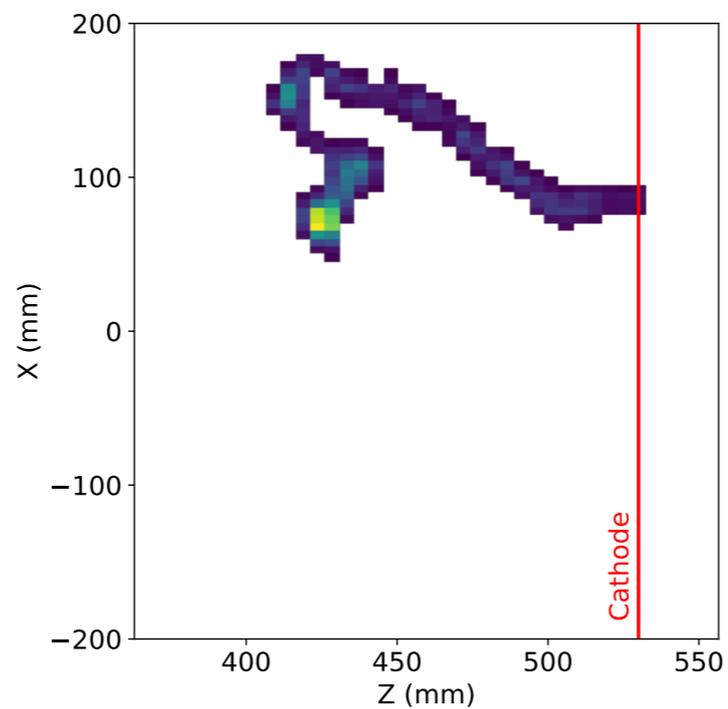
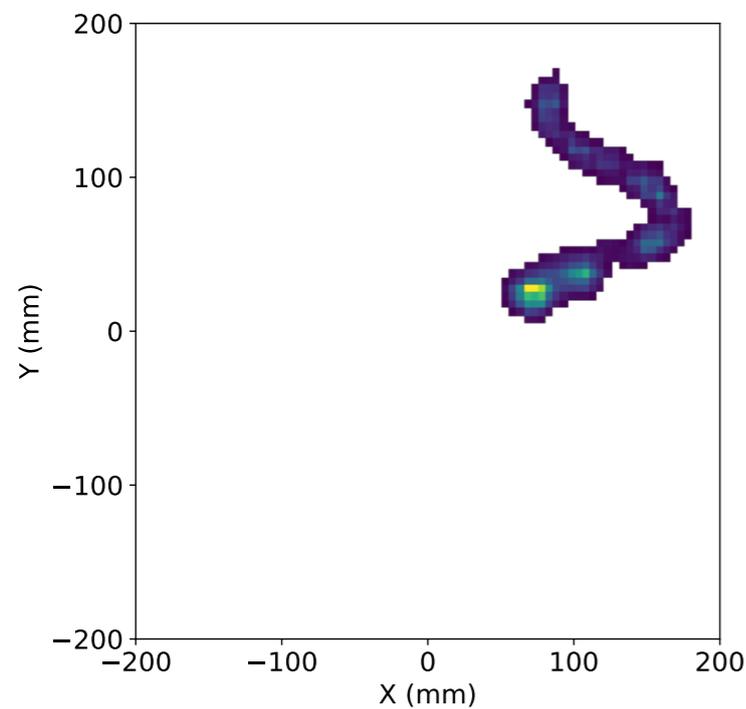
# Backup

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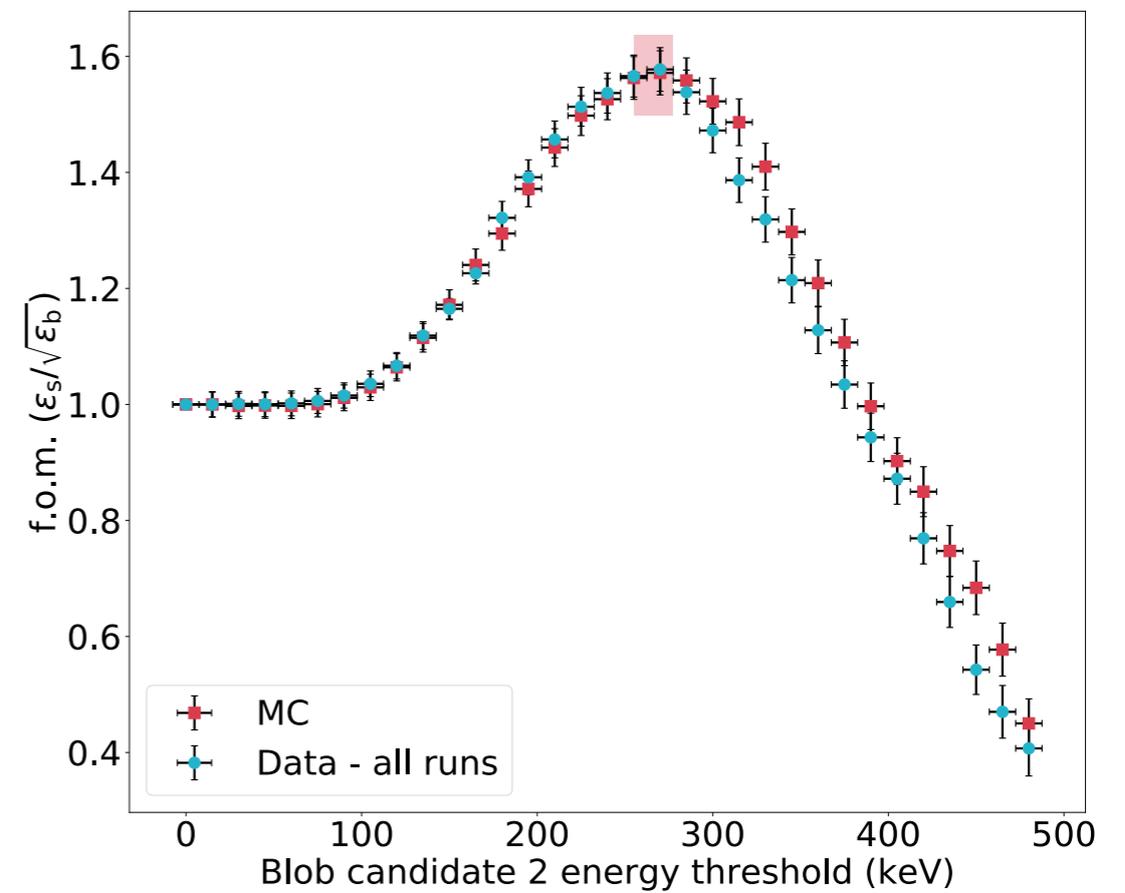
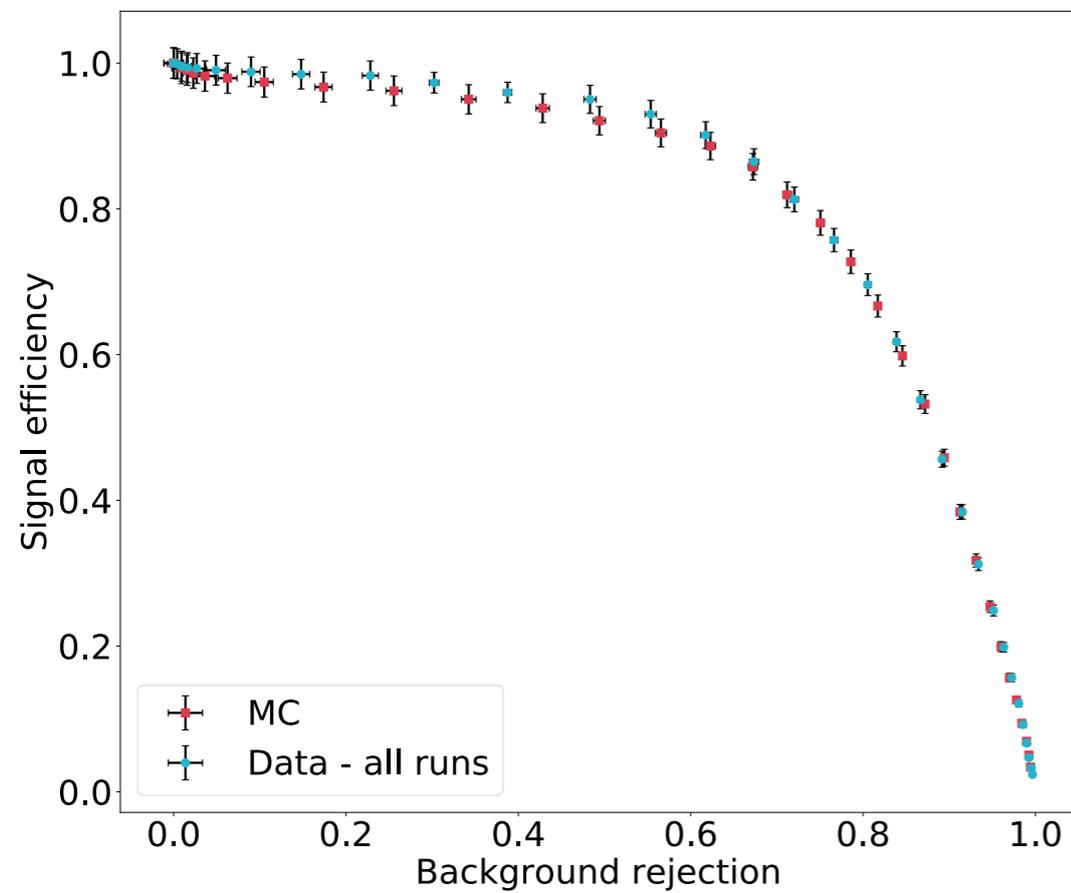
# NEW backgrounds



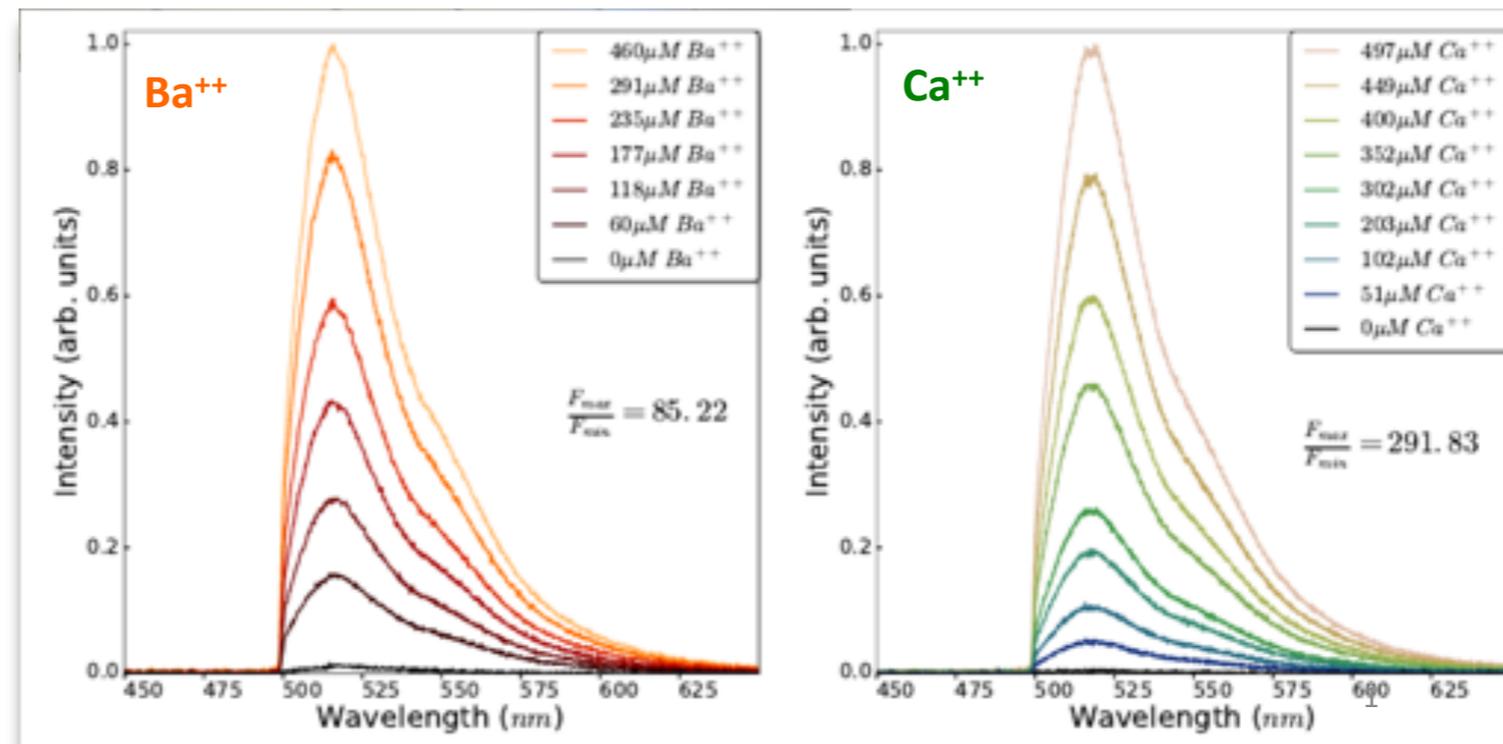
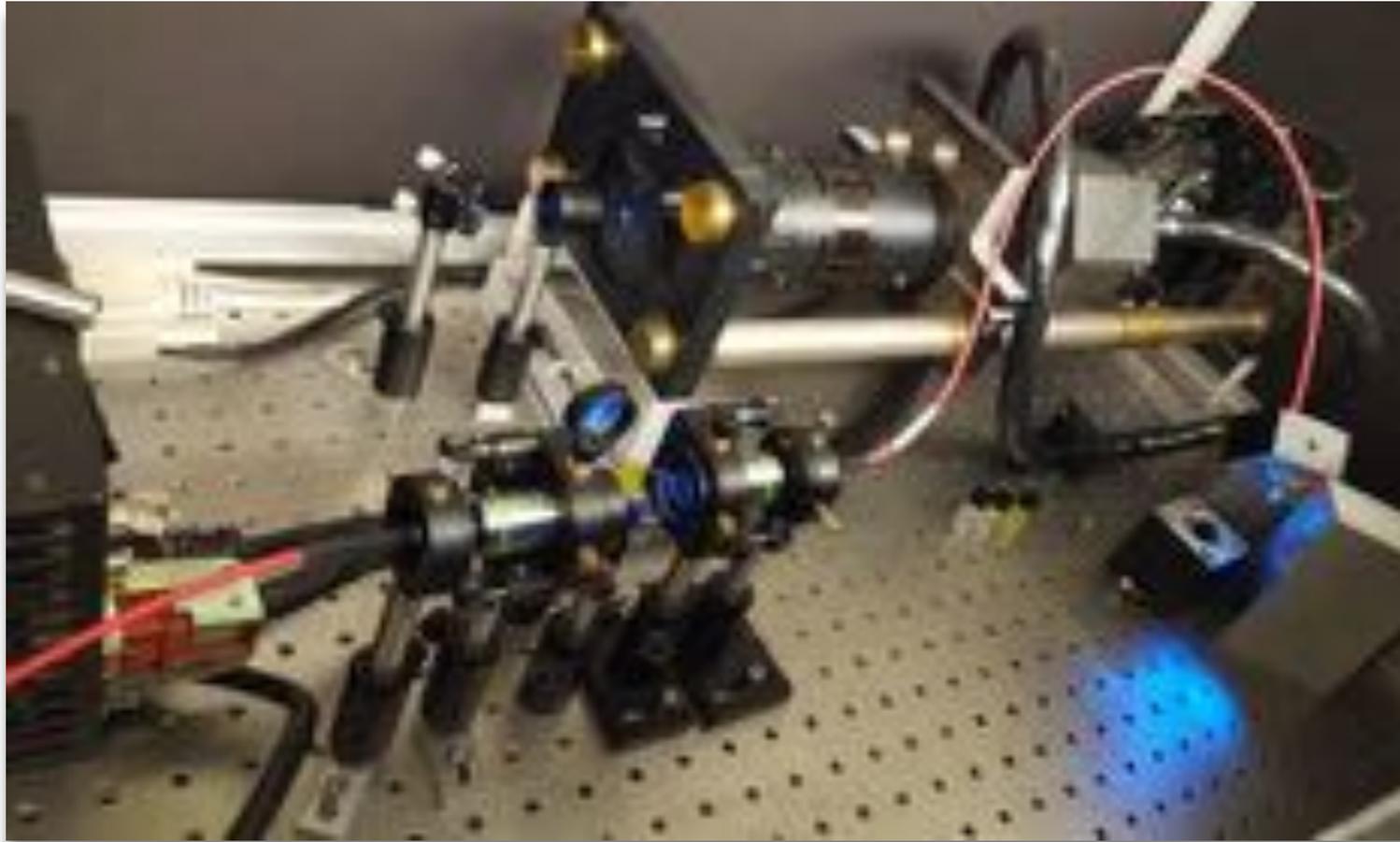
Backgrounds from radon activity inside the detector have been measured in NEW, and their impact on the sensitivity of NEXT-100 has been evaluated.



# NEW topology



# Ba tagging



# Machine Learning techniques for HPGTPC

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We have many new recent developments:

1. Use **Sparse Neutral Network** (accelerate classification and is scalable)
2. Use **Distributed learning** (quicker training, hyper-parameter optimization)
3. Map PMAPS to voxel via neural networks (accelerate/improve classification)

**Now ready to perform physics studies...**

Voxels fed to the network

