

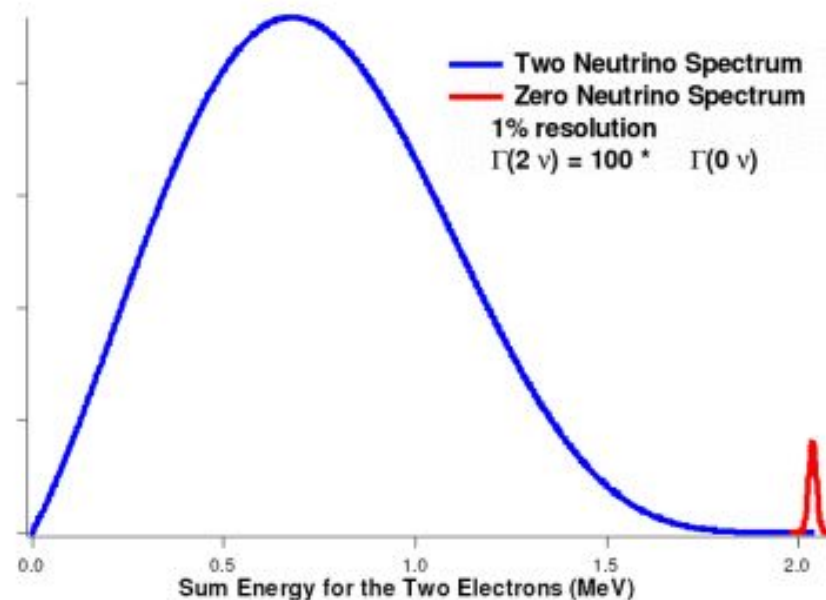
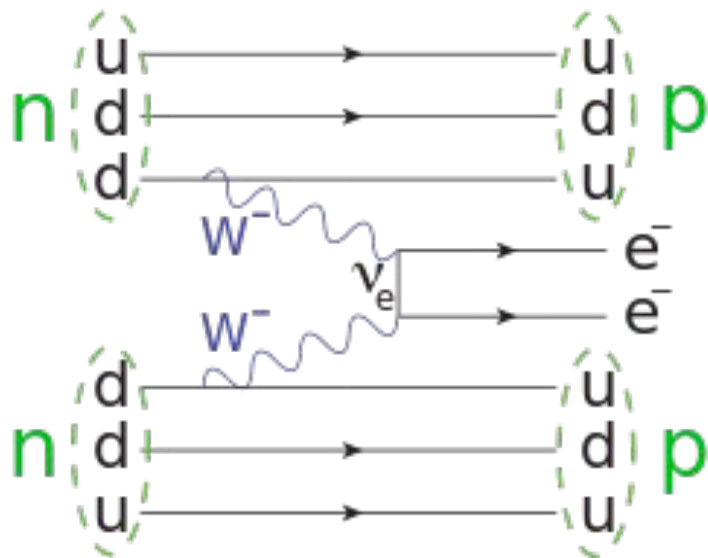


The NEXT Neutrinoless Double Beta Decay Experiment

Jonathan Haefner on behalf of the NEXT Collaboration
31 July 2019
2019 Meeting of the APS Department of Particles and Fields

Double Beta Decay Challenges

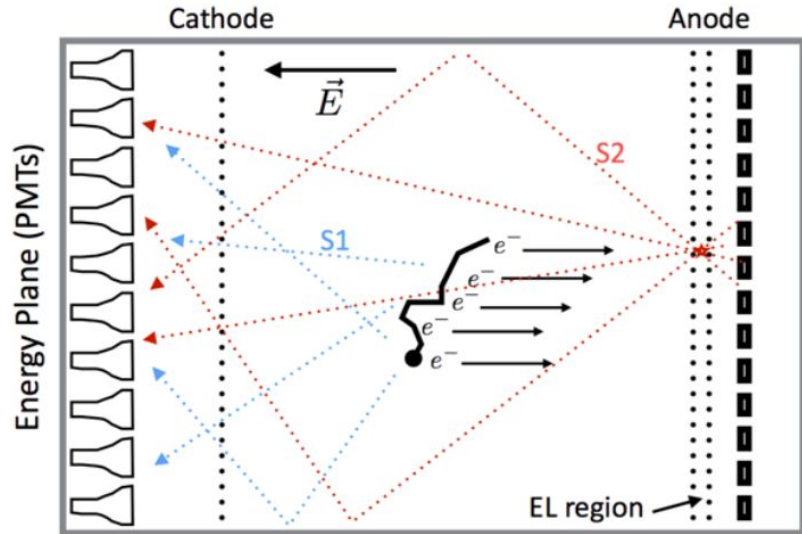
- Searching for neutrinoless double beta decay
 - (identifying the nature of neutrinos is a top scientific priority)
- Every neutrinoless double beta decay experiment needs:
 - Excellent energy resolution
 - Strong background rejection power
 - Good scalability



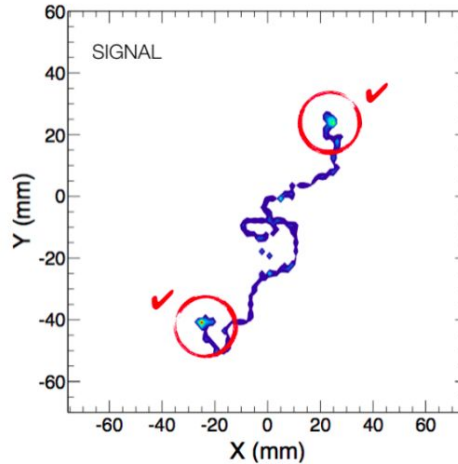
NEXT Concept and Design

The NEXT concept

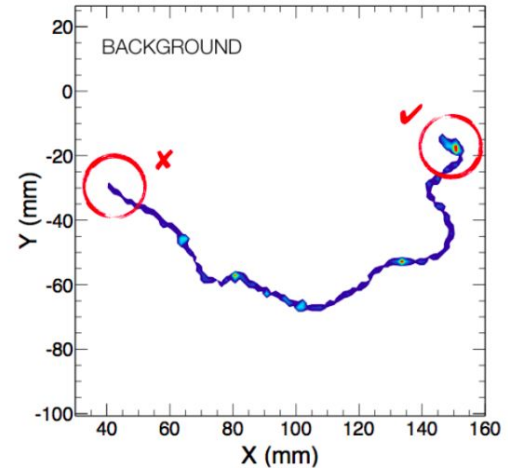
- High pressure gaseous, enriched xenon
- Optical time projection chamber (TPC)
 - Scintillation (S1) + [Ionization → Electroluminescence light] (S2)
- Energy reconstruction and tracking capabilities



Tracking Plane (SiPMs)

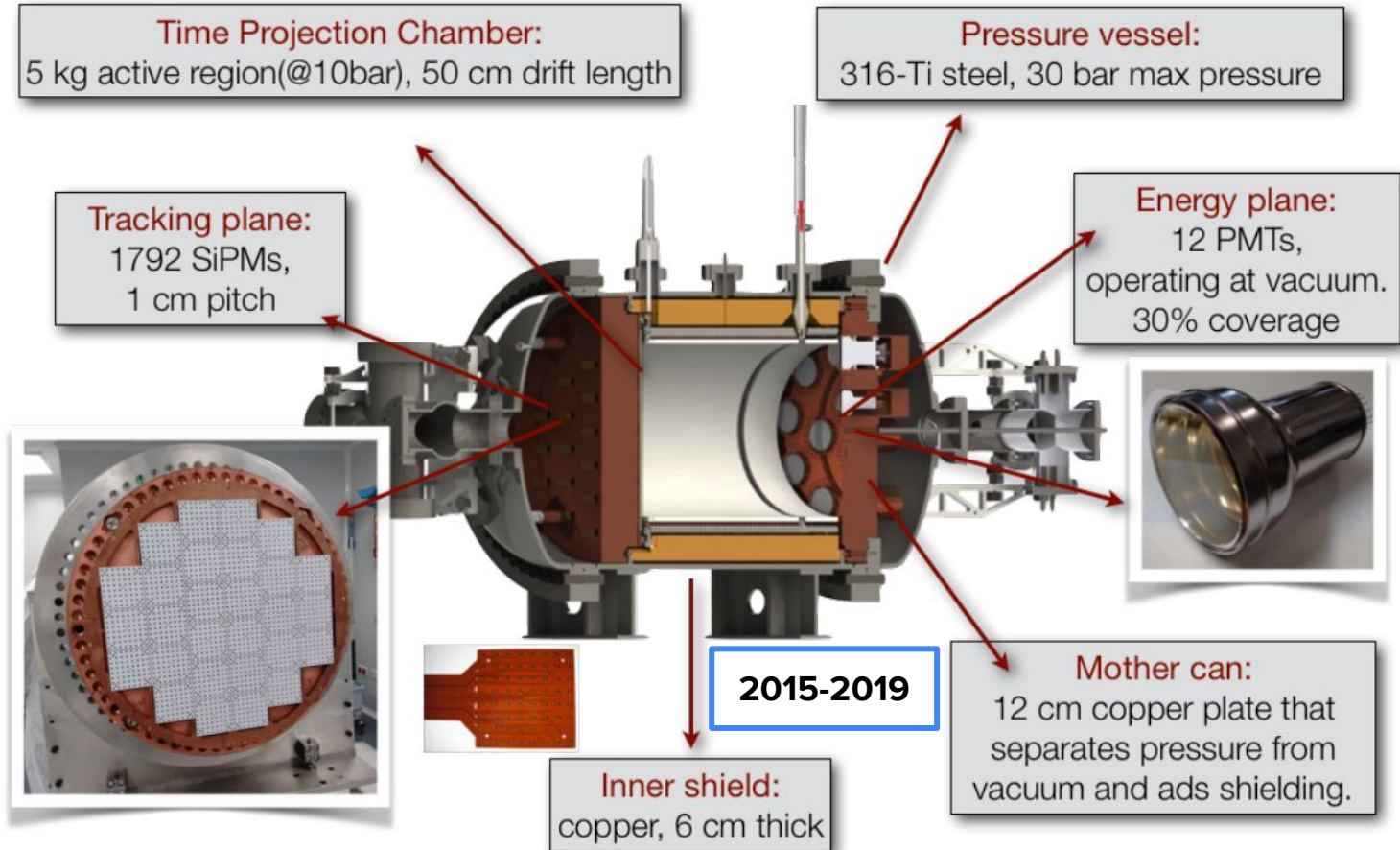


(a) Signal



(b) Background

The NEXT-White detector



The NEXT-White detector



Energy Resolution in NEXT

Krypton calibration concept

- Very good resolution → need to calibrate spatial dependence
- Inject $^{83\text{m}}\text{Kr}$ into the detector
- Gives pointlike events of known energy uniformly throughout the detector
- Half life of ~ 2 hours - no long term contamination
- Can use to correct for:
 - (x, y) dependence of light detection
 - Finite electron lifetime

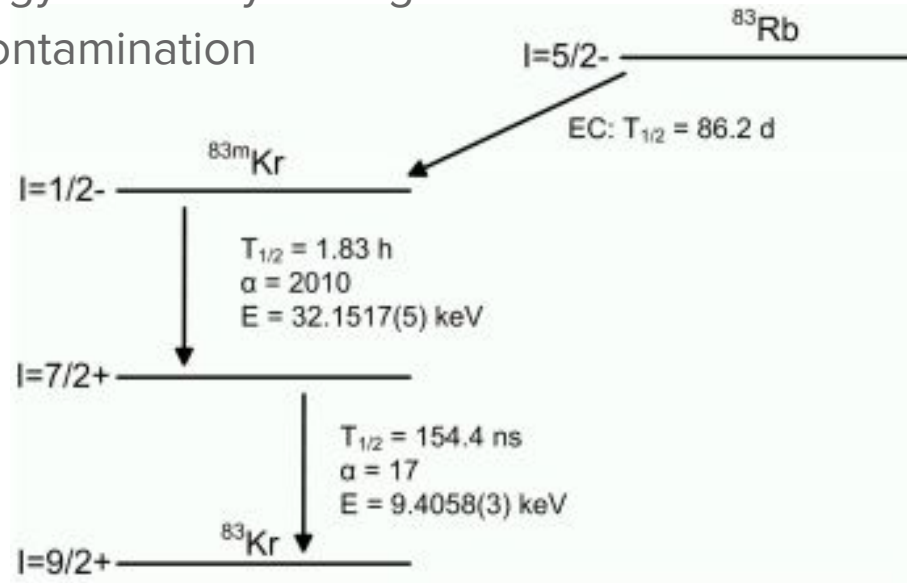
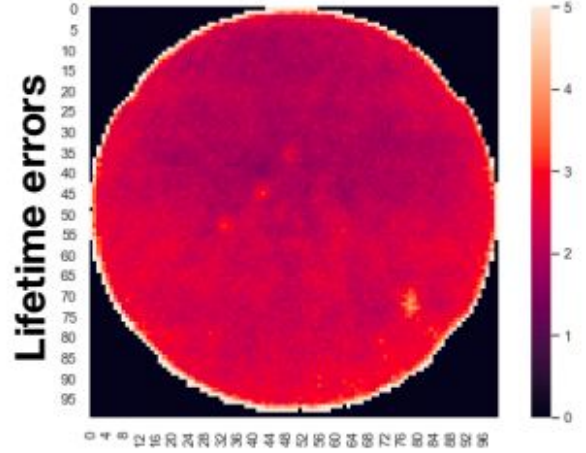
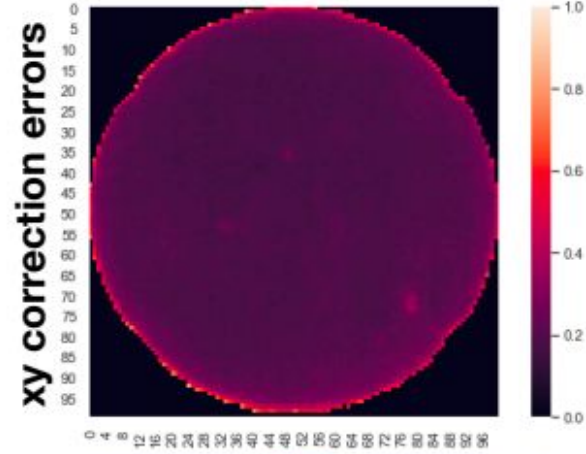
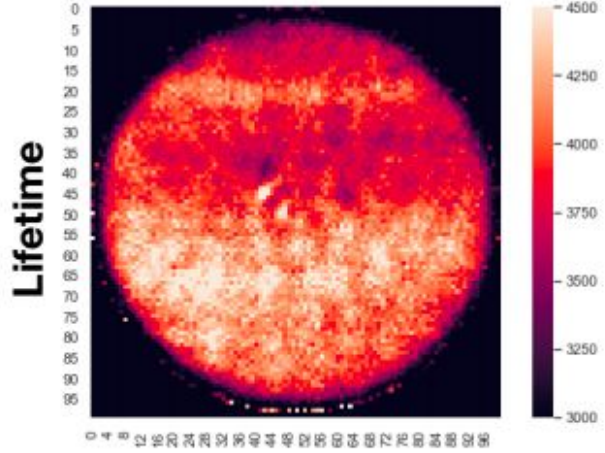
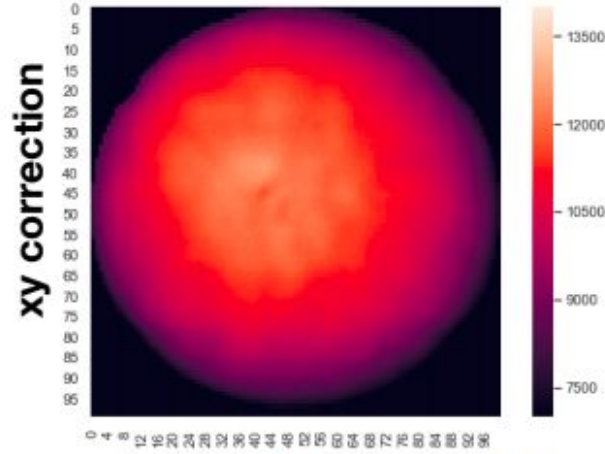


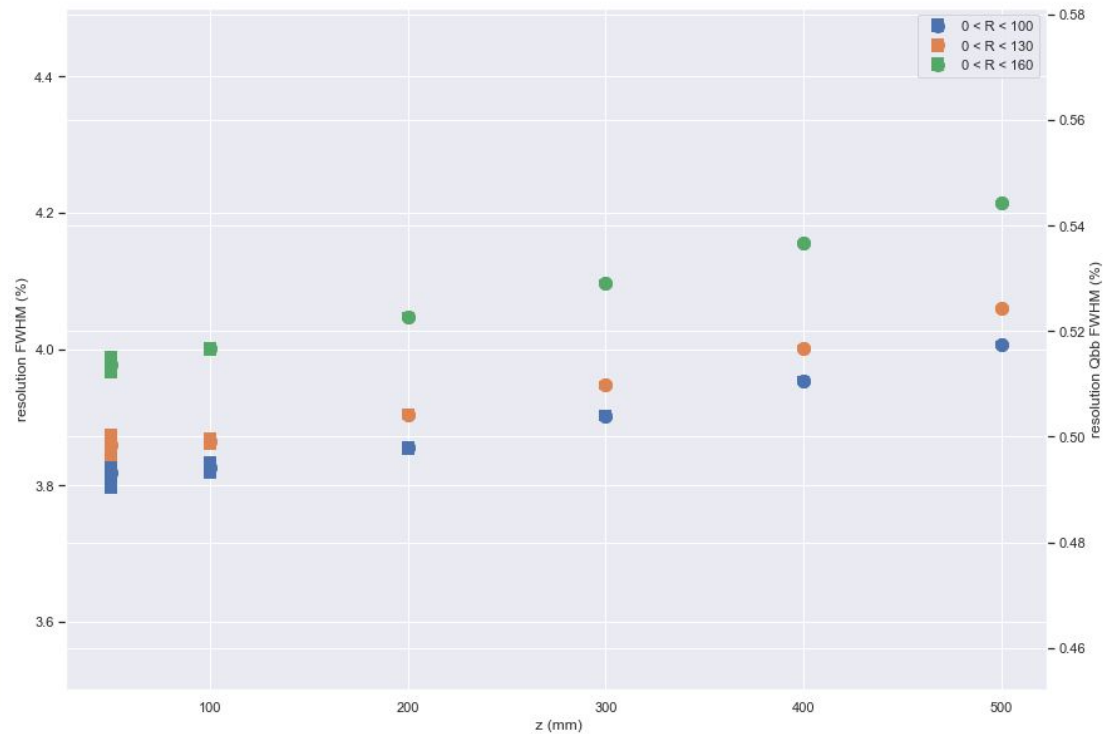
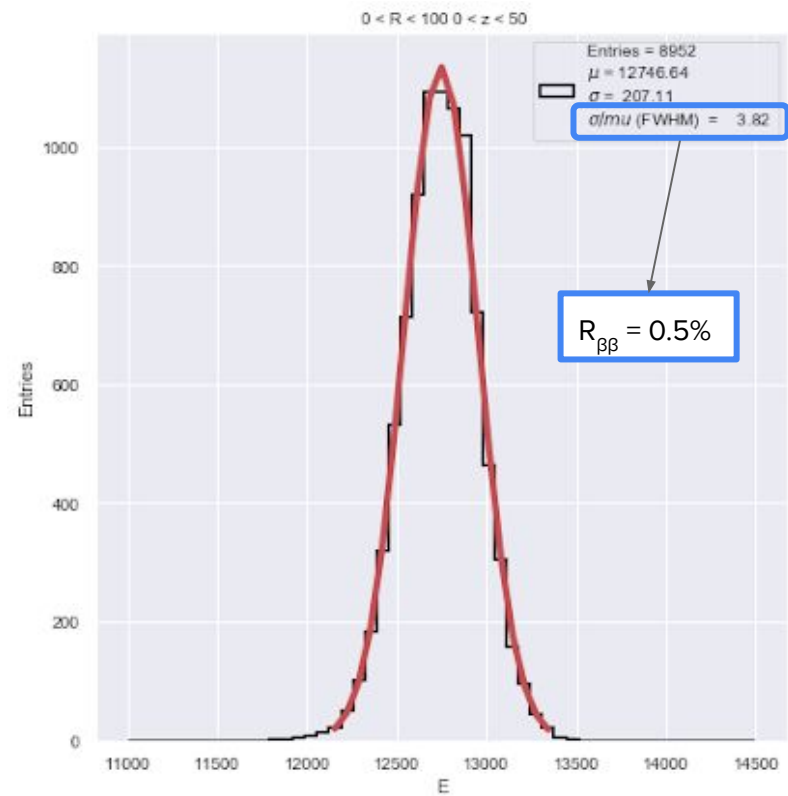
Figure 3: ^{83}Rb decay scheme.

Krypton calibration

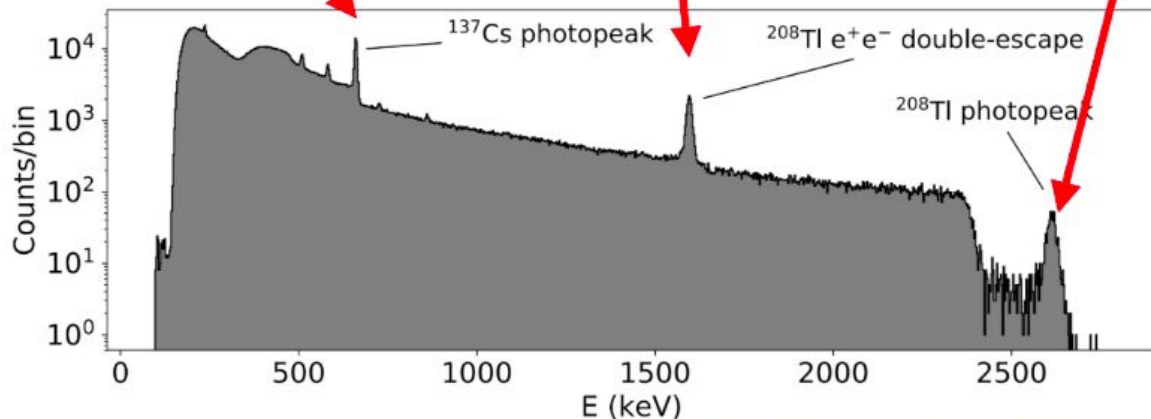
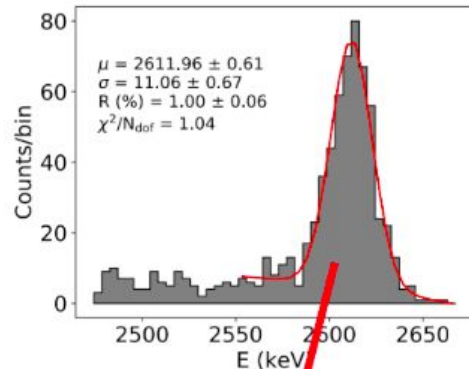
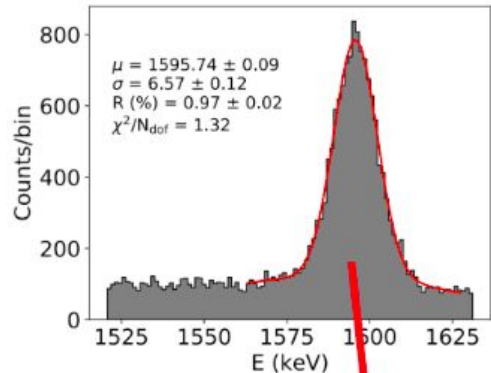
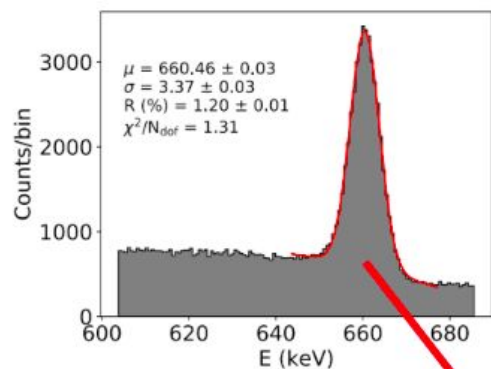


NEXT Collaboration, *JINST* **13** (2018) P10014

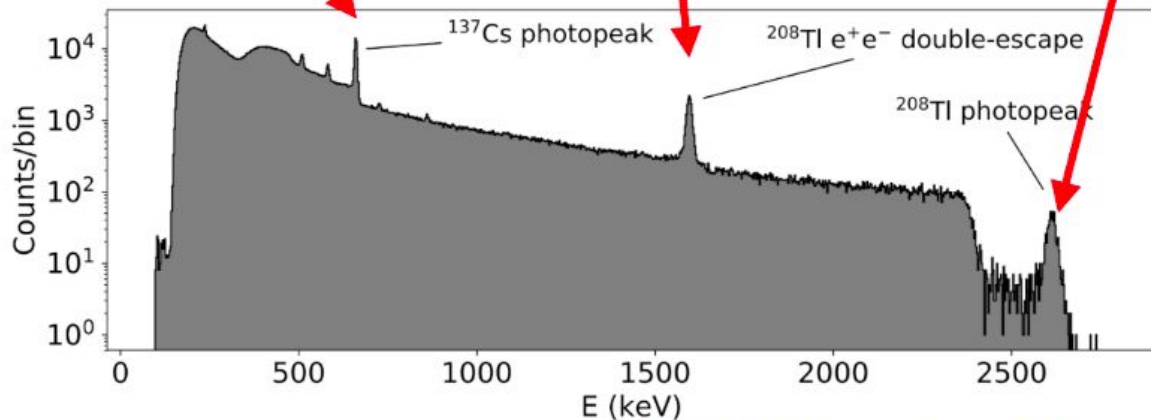
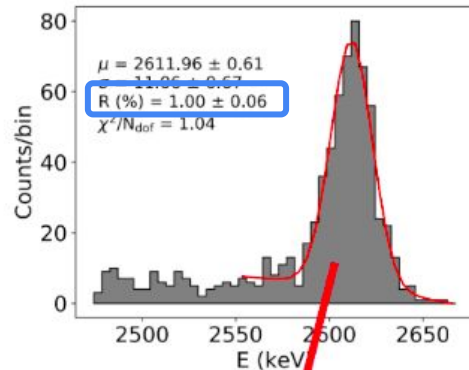
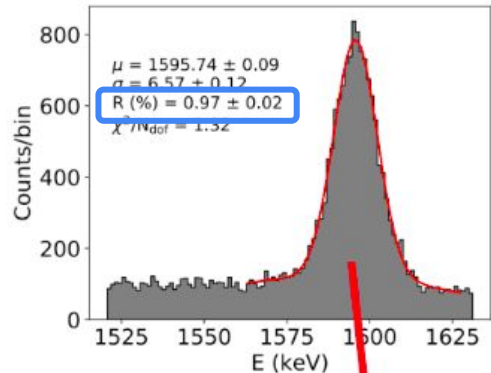
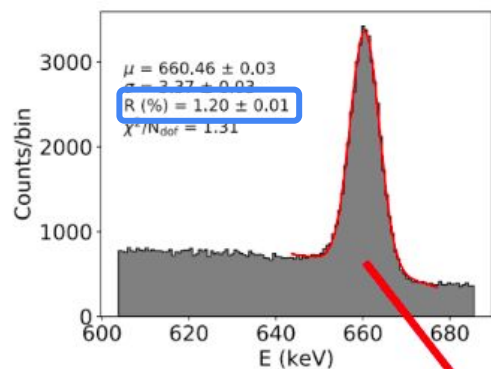
Krypton calibration



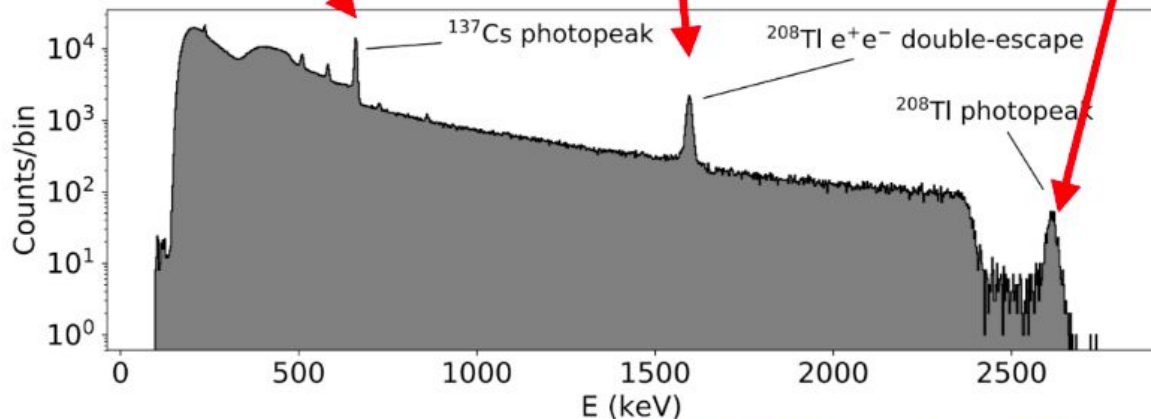
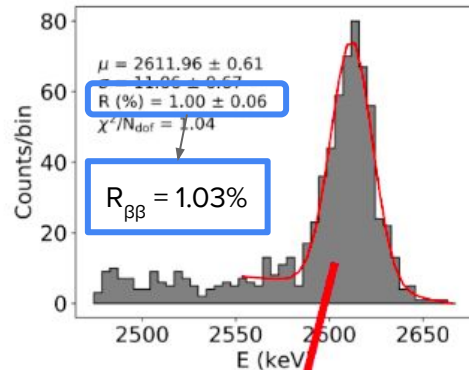
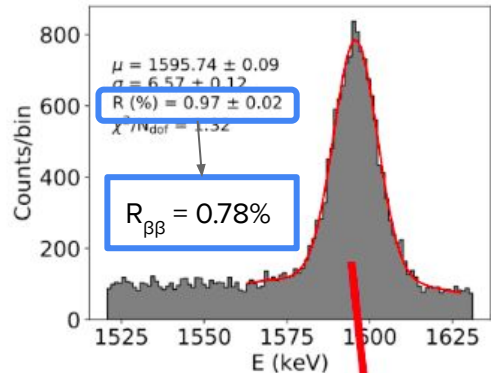
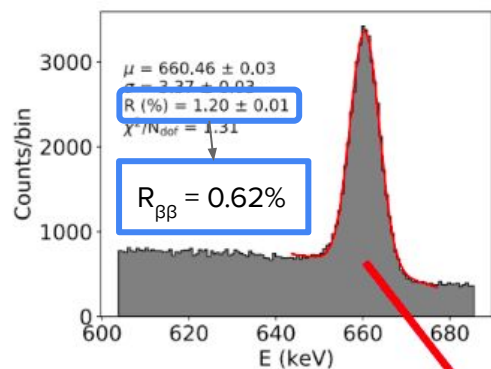
Energy resolution (calibration sources)



Energy resolution (calibration sources)

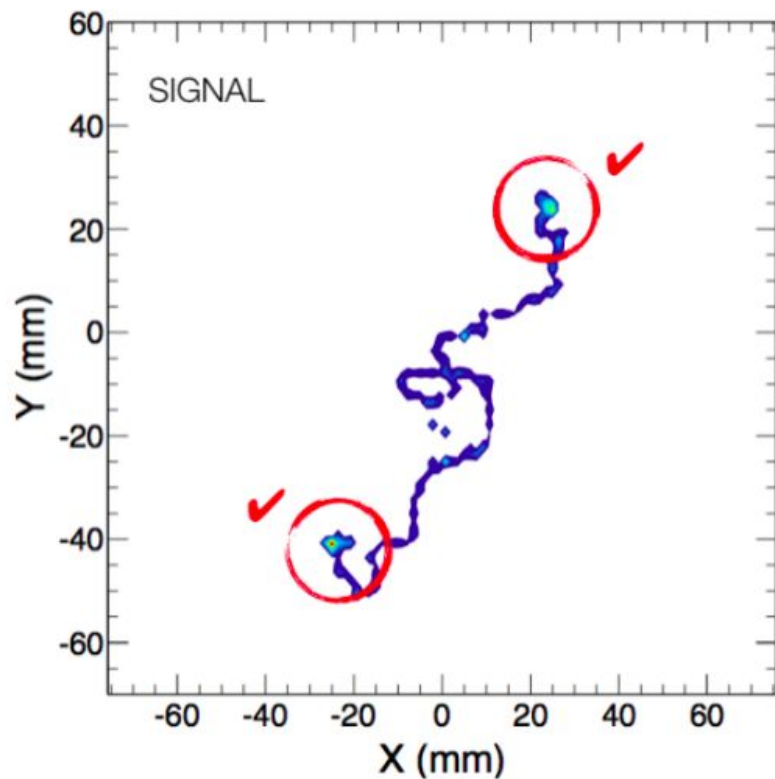


Energy resolution (calibration sources)

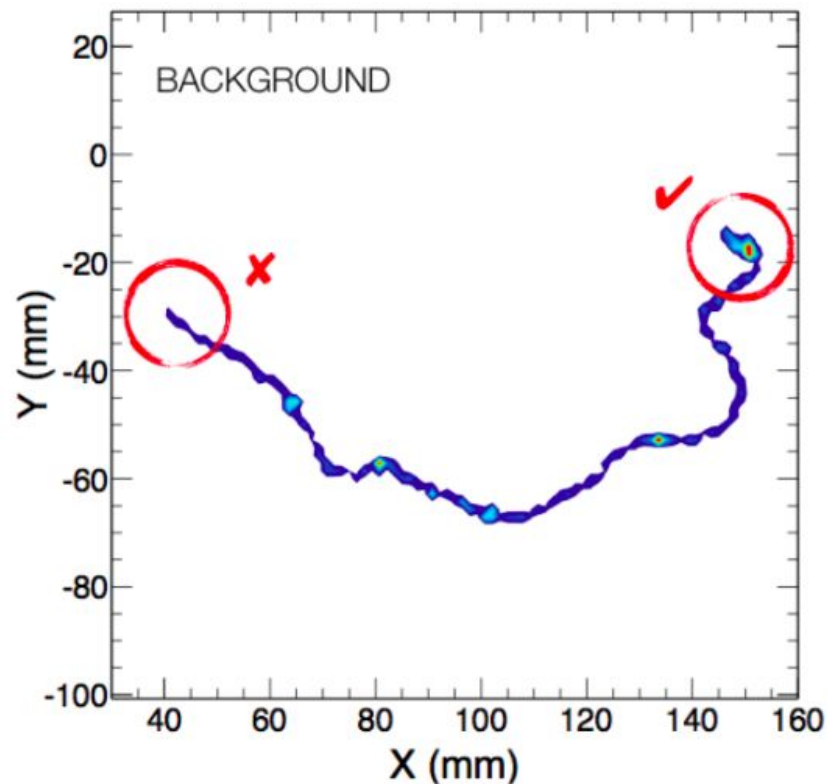


Topological discrimination

Topological signature



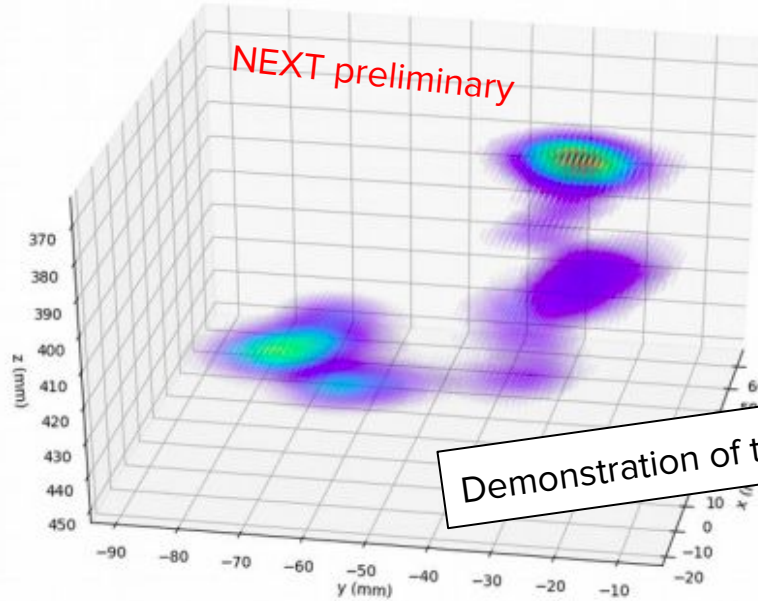
(a) Signal



(b) Background

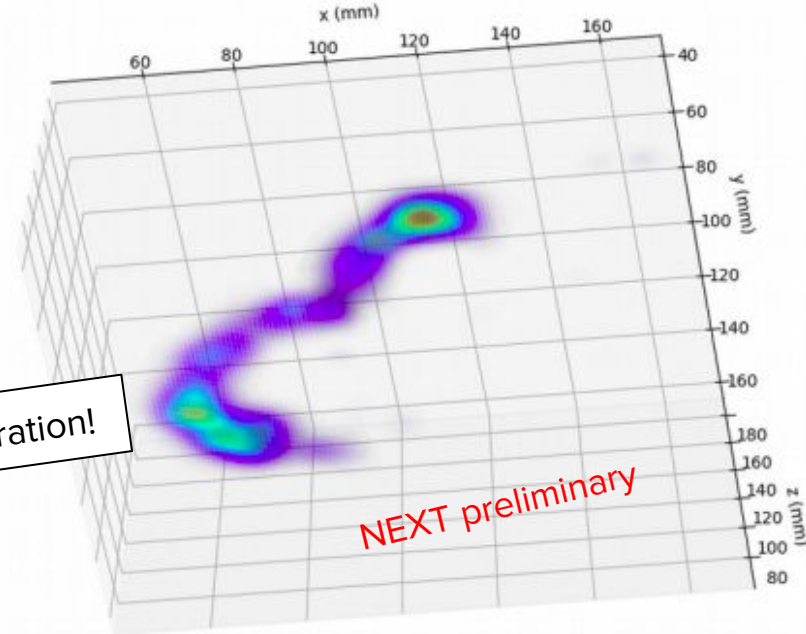
Topological signature

$E \sim 2.13$ MeV



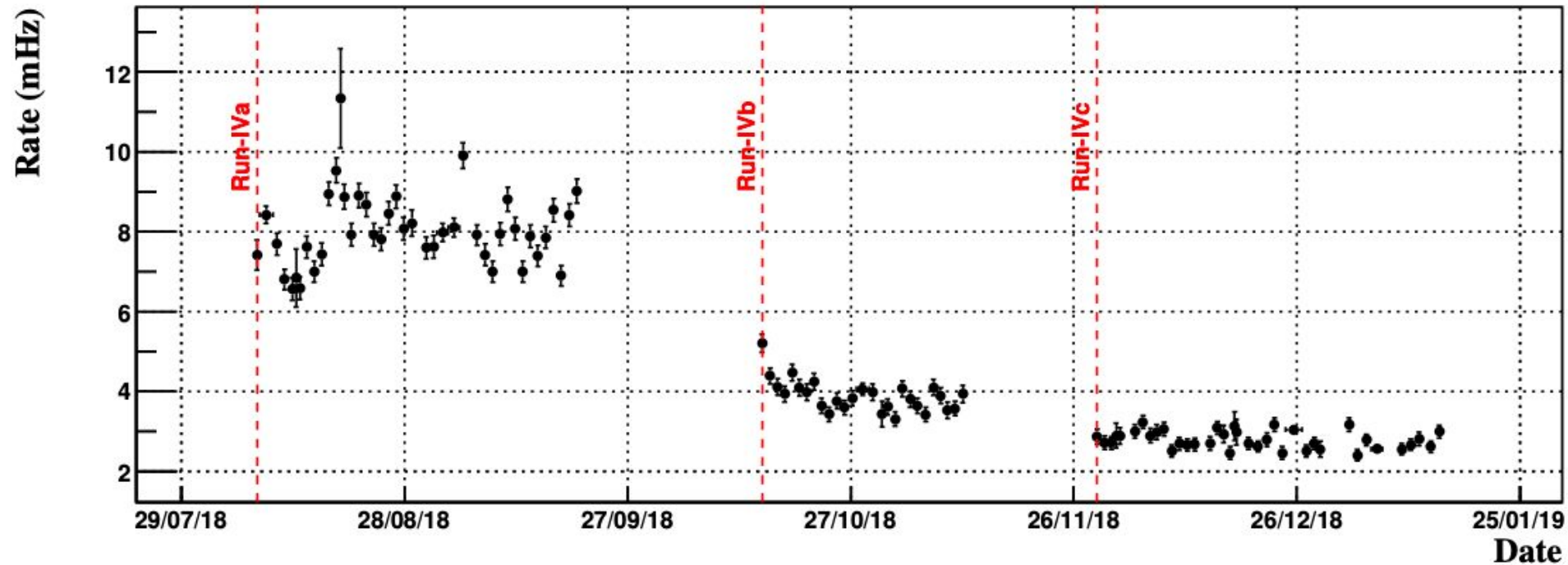
Demonstration of topology separation!

$E \sim 1.71$ MeV

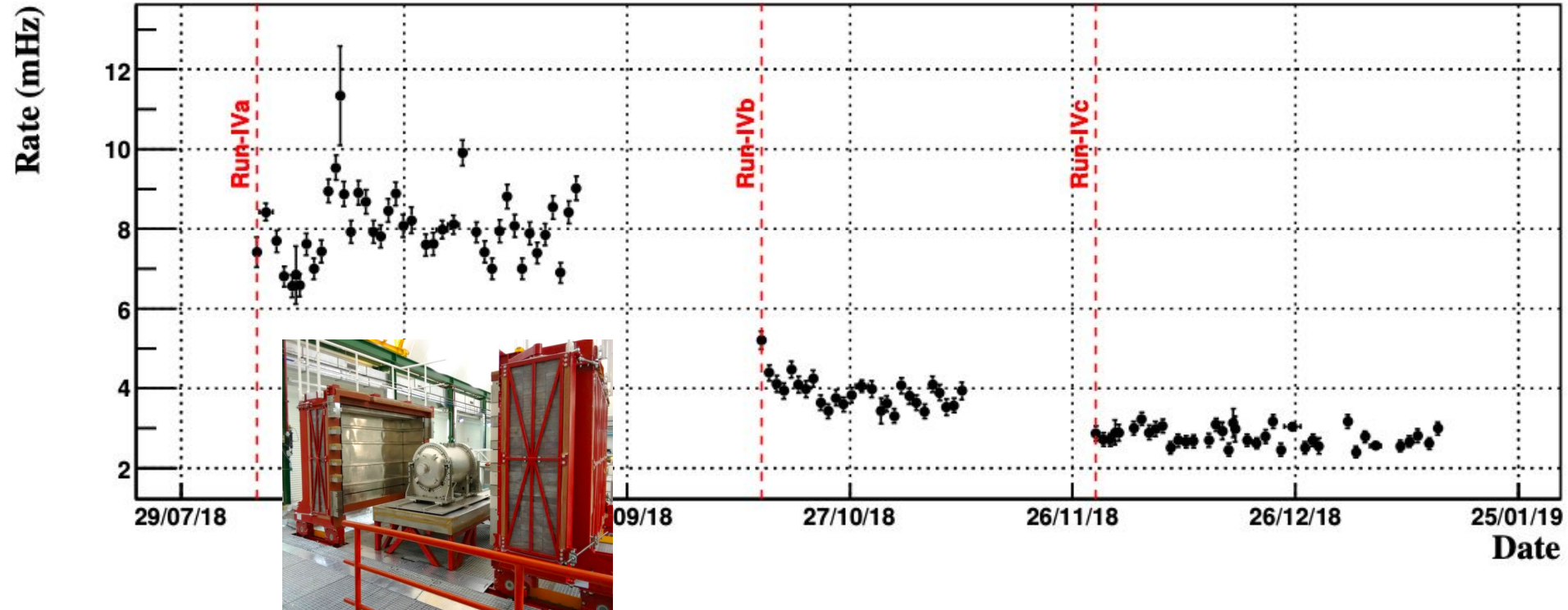


Background validation

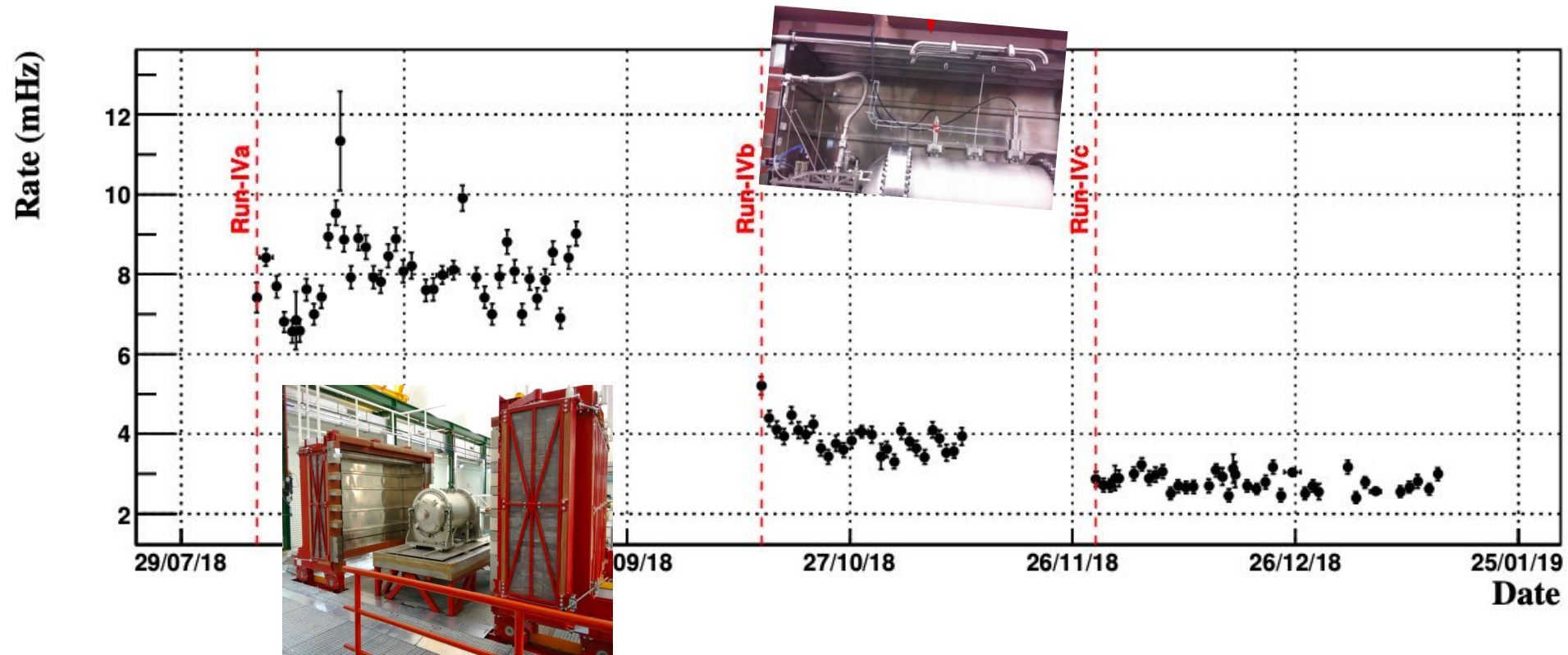
Run IV background measurement



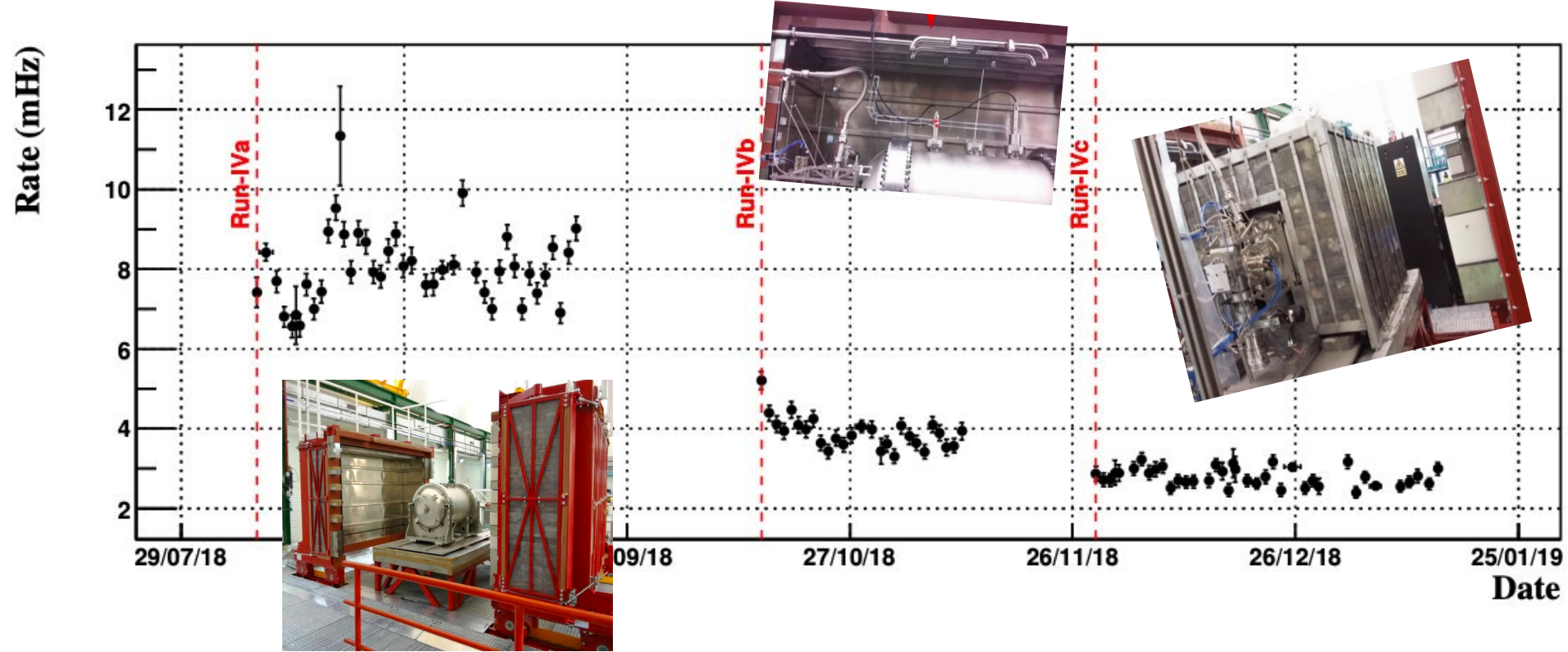
Run IV background measurement



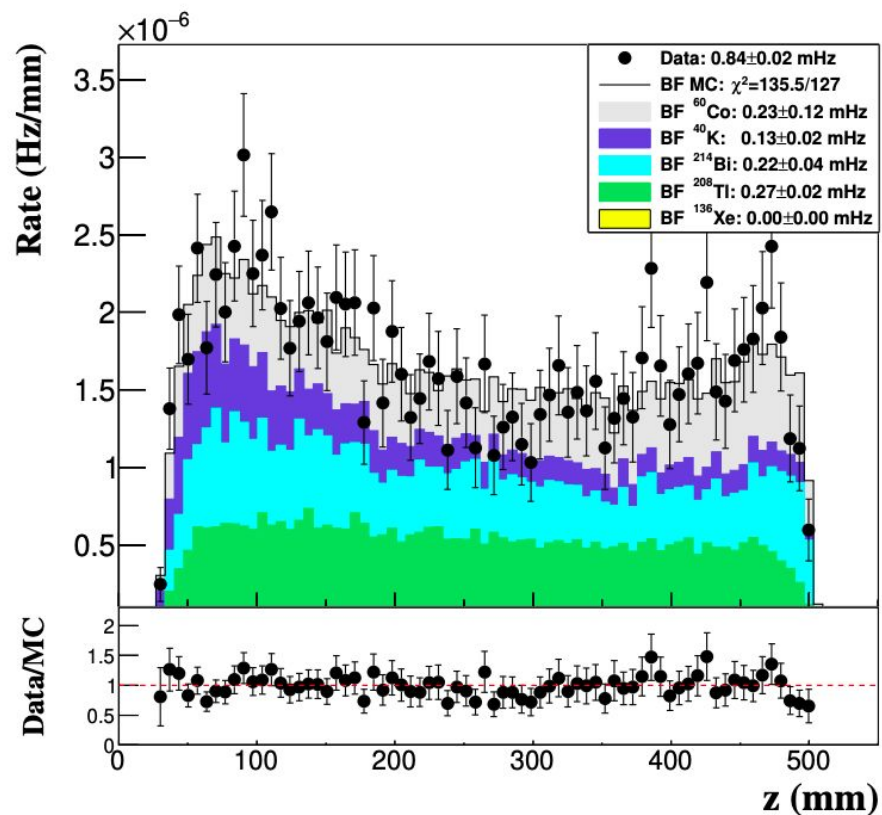
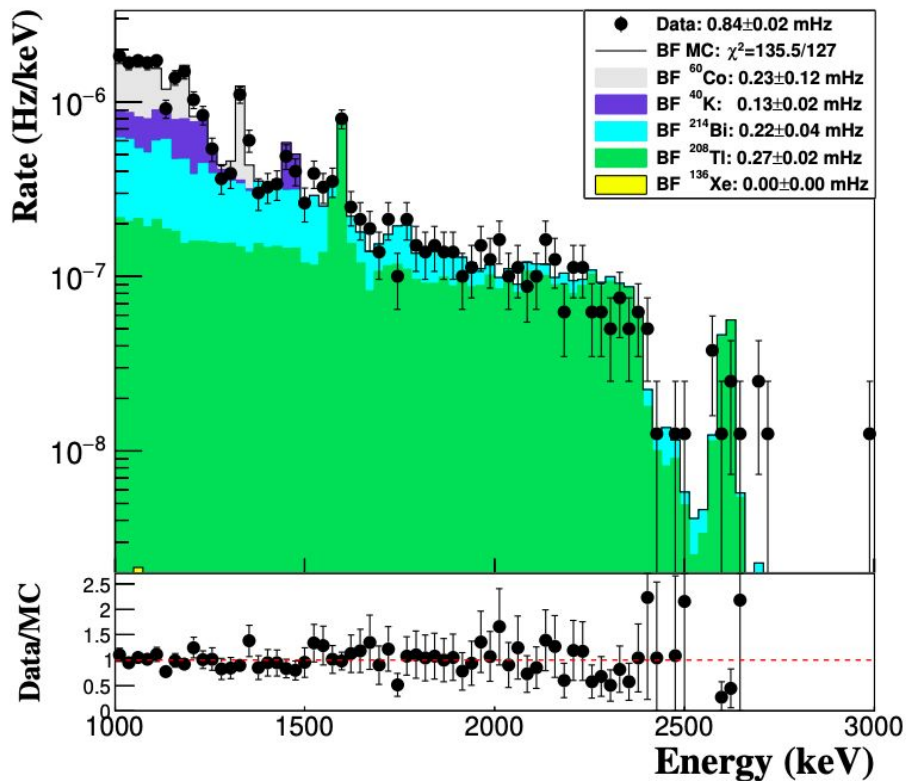
Run IV background measurement



Run IV background measurement



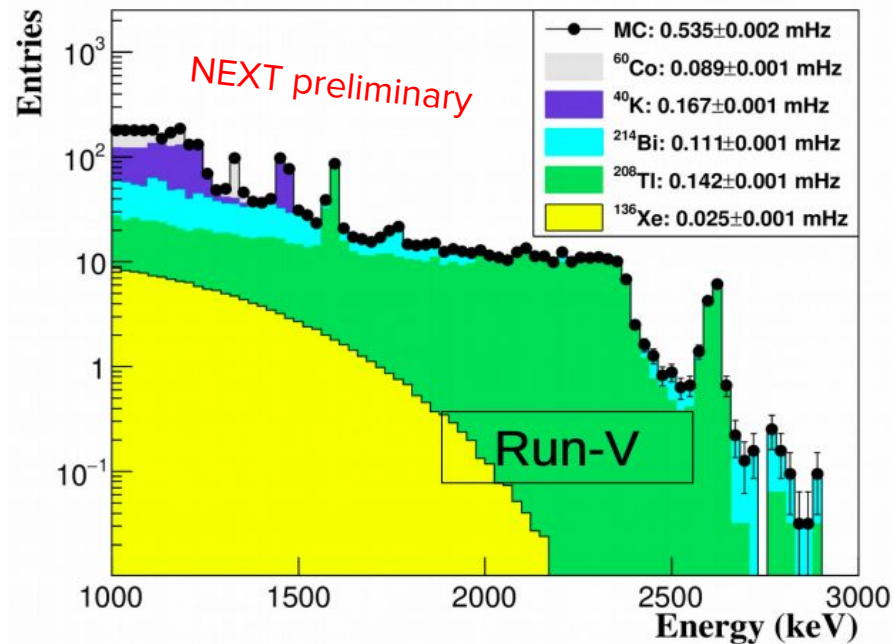
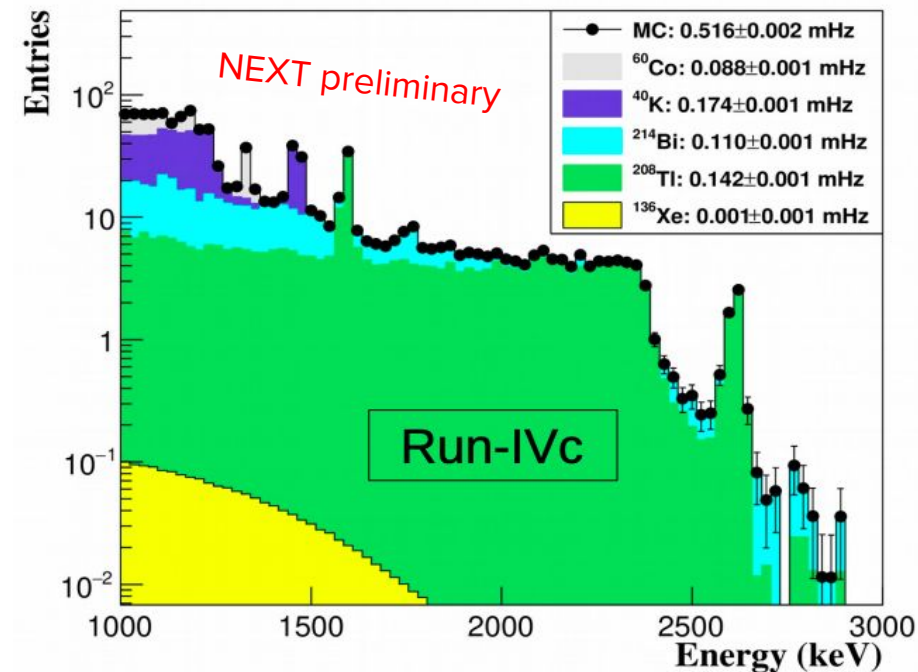
Background composition



Run V:
Preliminary $2\nu\beta\beta$
measurement

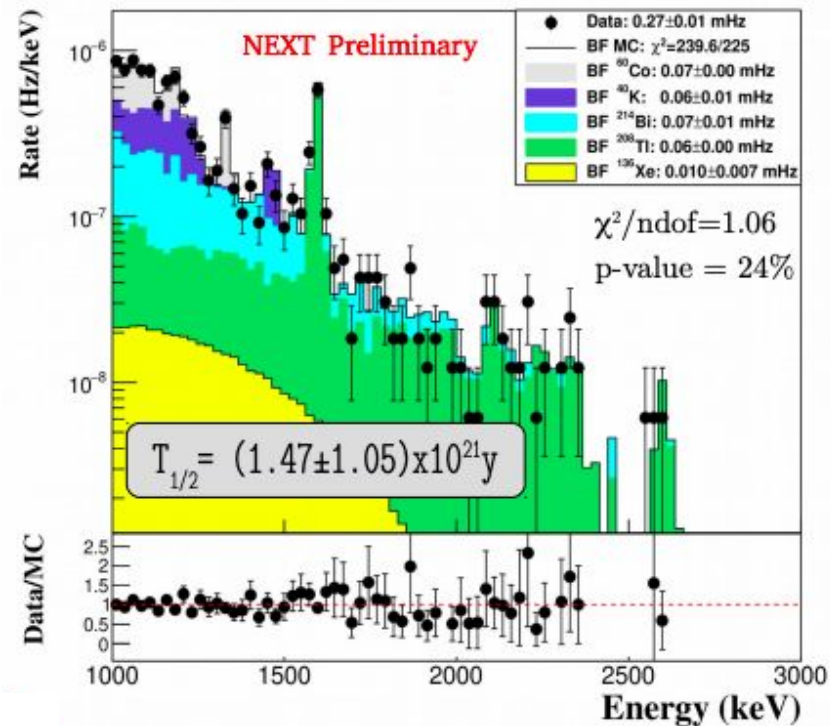
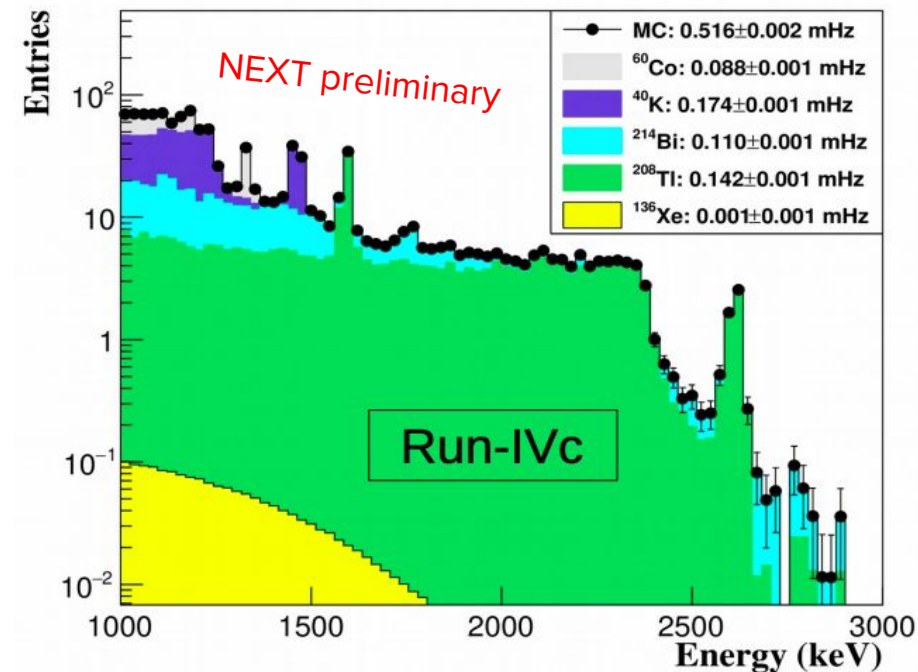
Run V: measuring $2\nu\beta\beta$ lifetime

Background fits indicate a significant increase in 2ν events over run IVc:



Run V: measuring $2\nu\beta\beta$ lifetime

Can fit to obtain preliminary measurement of $2\nu\beta\beta$ lifetime:

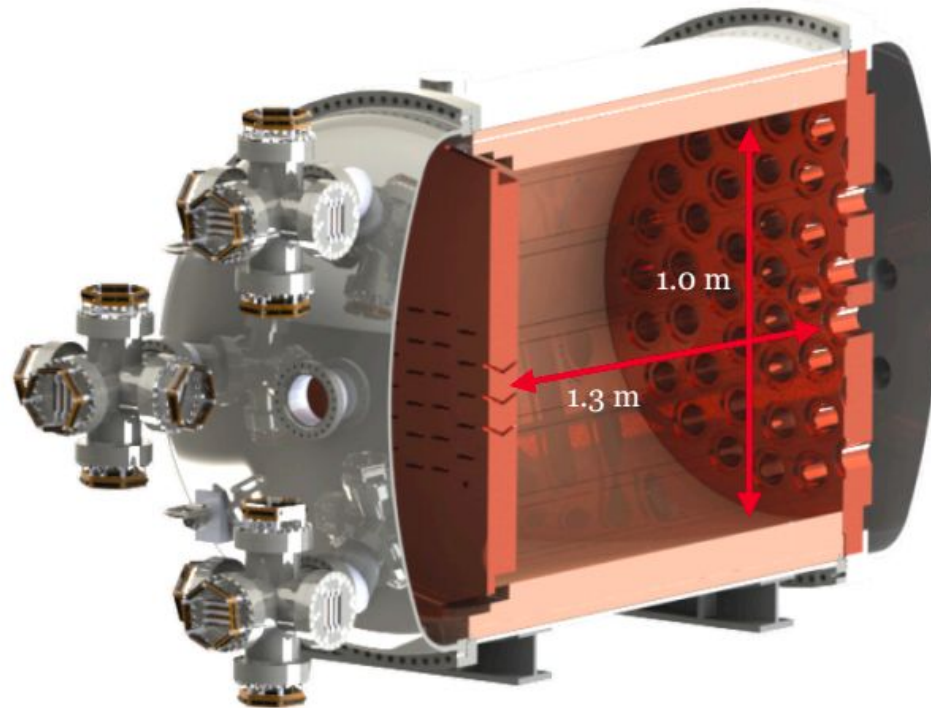


~ 78 day exposure

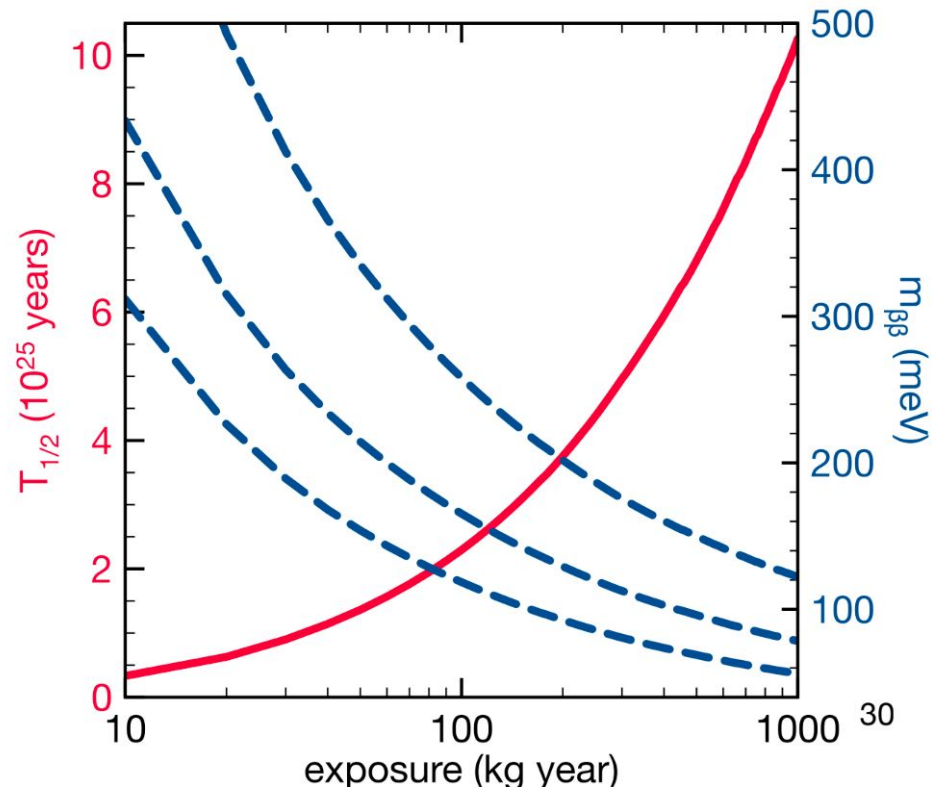
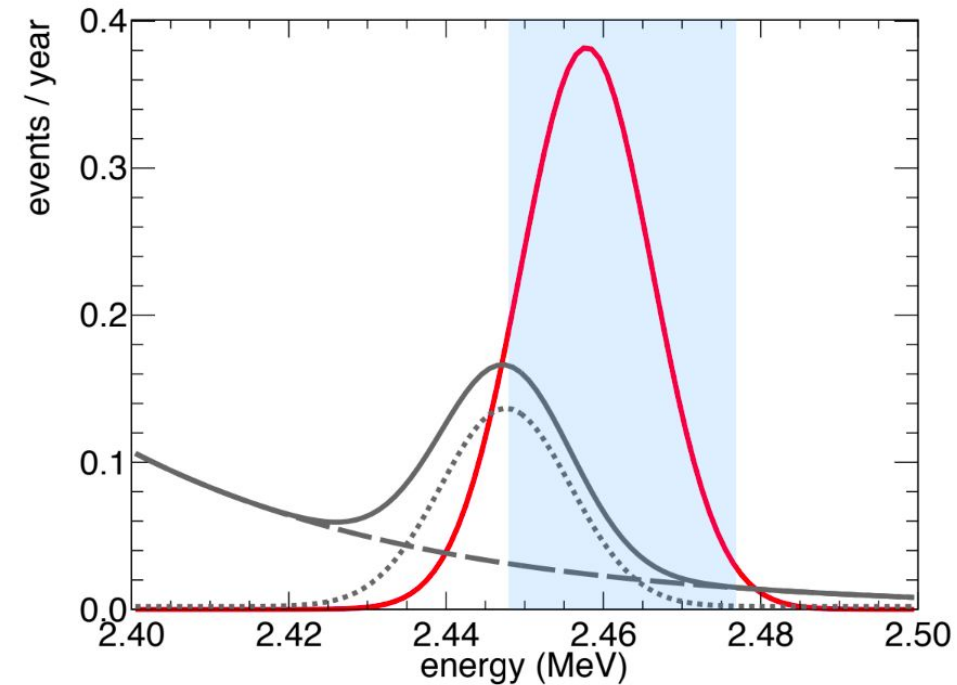
**Looking towards
the future**

NEXT-100

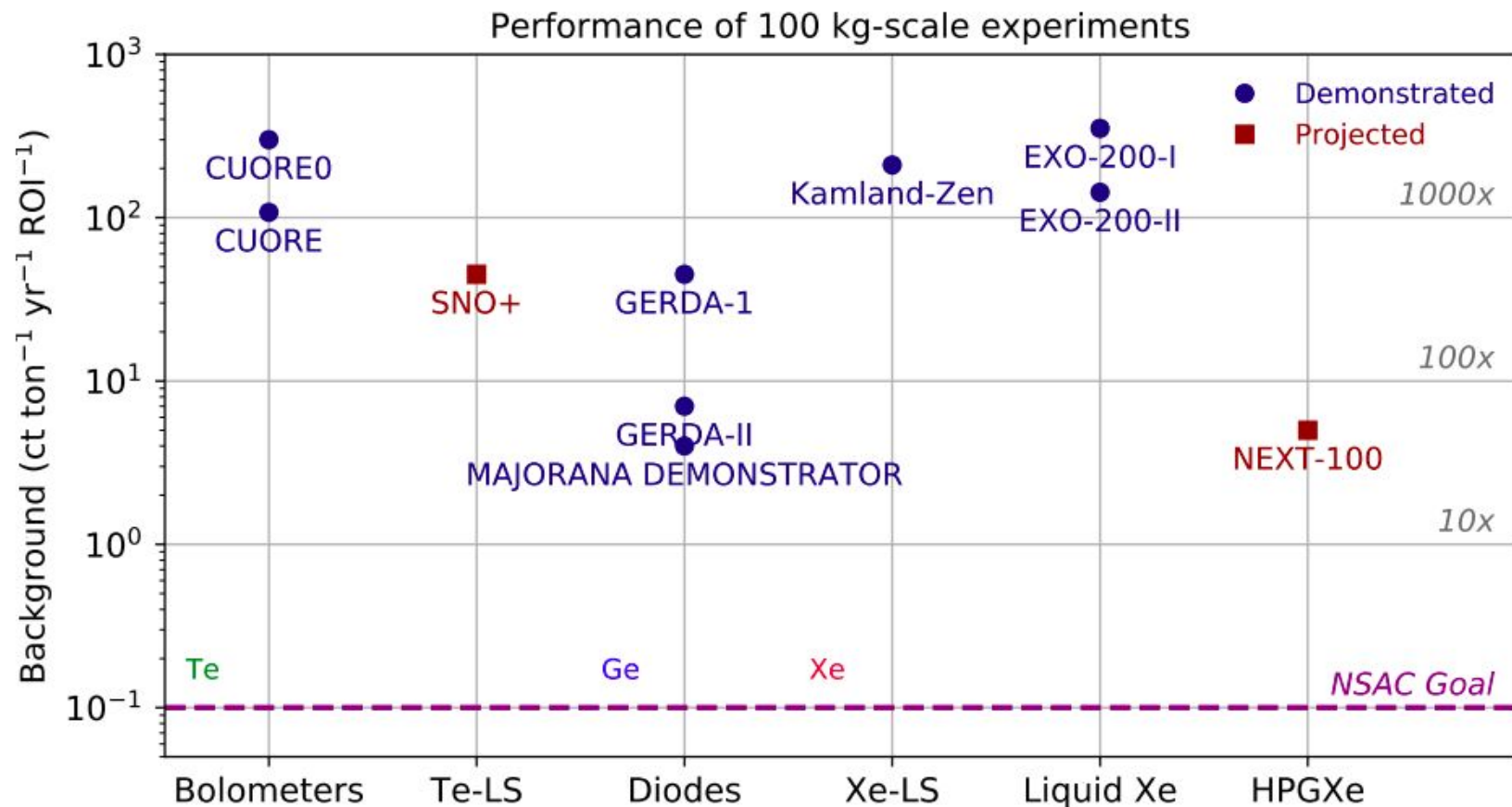
- The NEW phase will be followed by the NEXT-100 phase (100 kg)
- Design is well underway, commissioning expected in 2020



NEXT-100 sensitivity



NEXT-100 expected performance

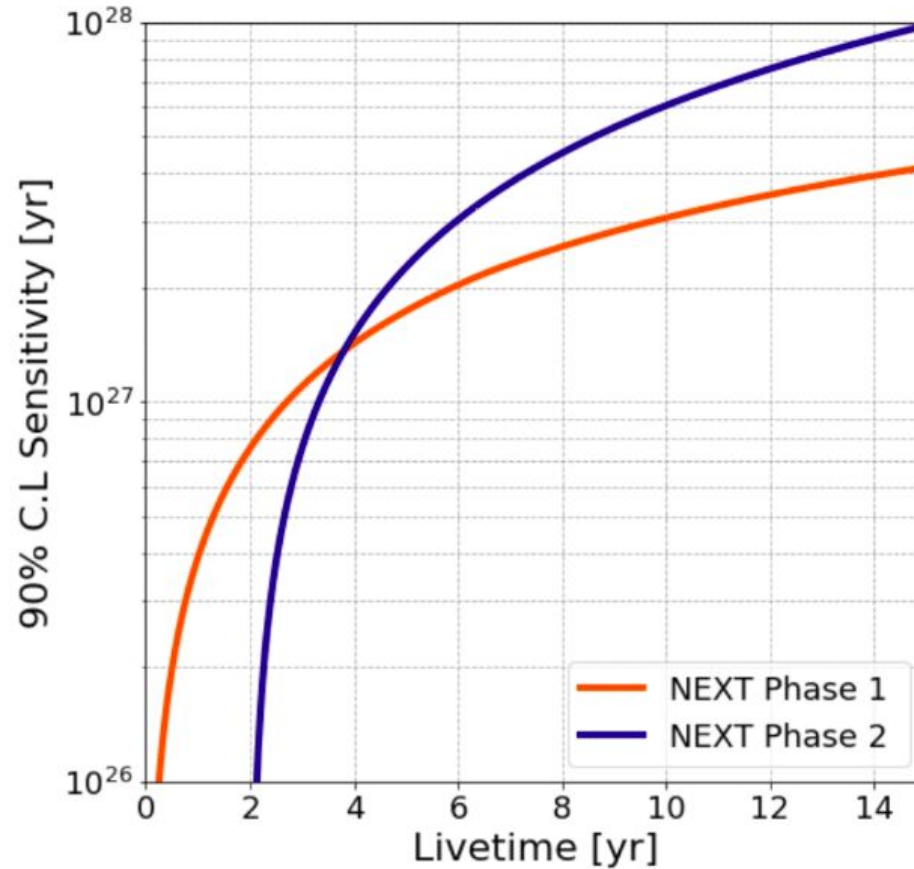


Ton scale plans and progress

- Following NEXT-100, plan to build a **one ton module** (1000 kg → approx 2x in each dimension)
- NEXT-100 should demonstrate a competitive background rate of a few counts per ton and year in ROI
- Many avenues of planned improvement underway:
 - Reconstruction algorithms (better resolution through calibration, improved topological selection with machine learning, ...)
 - Radiopurity (replacement of PMTs with SiPMs)
 - Tracking signature (introduce low diffusion gas mixtures, denser tracking plane, ...)
 - **Potential for background free experiment using barium tagging**

See next talk: Nicholas Byrnes “Barium Tagging for the NEXT Neutrinoless Double Beta Decay Experiment”

Ton scale expected sensitivity



NEXT-Ton sensitivity initially (phase 1) and with Ba tagging (phase 2)

Conclusion

- NEW provides a solid demonstration of NEXT capabilities
 - Excellent energy resolution demonstrated (0.54%~0.82% at $Q_{\beta\beta}$)
 - Effective topological background rejection
 - Well understood background
 - Measuring two neutrino half life underway, preliminary results reasonable
- Preparing for the future
 - Measure the two neutrino half life in NEW
 - Construct and install NEXT-100 (2020)
 - Actively working on the NEXT-ton Conceptual Design Report
 - **Pursuing Ba tagging development**



See next talk: Nicholas Byrnes “Barium Tagging for the NEXT Neutrinoless Double Beta Decay Experiment



CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS



UNIVERSITY OF TEXAS ARLINGTON

THANK YOU!



UNIVERSITAT POLITÈCNICA DE VALÈNCIA

IOWA STATE UNIVERSITY

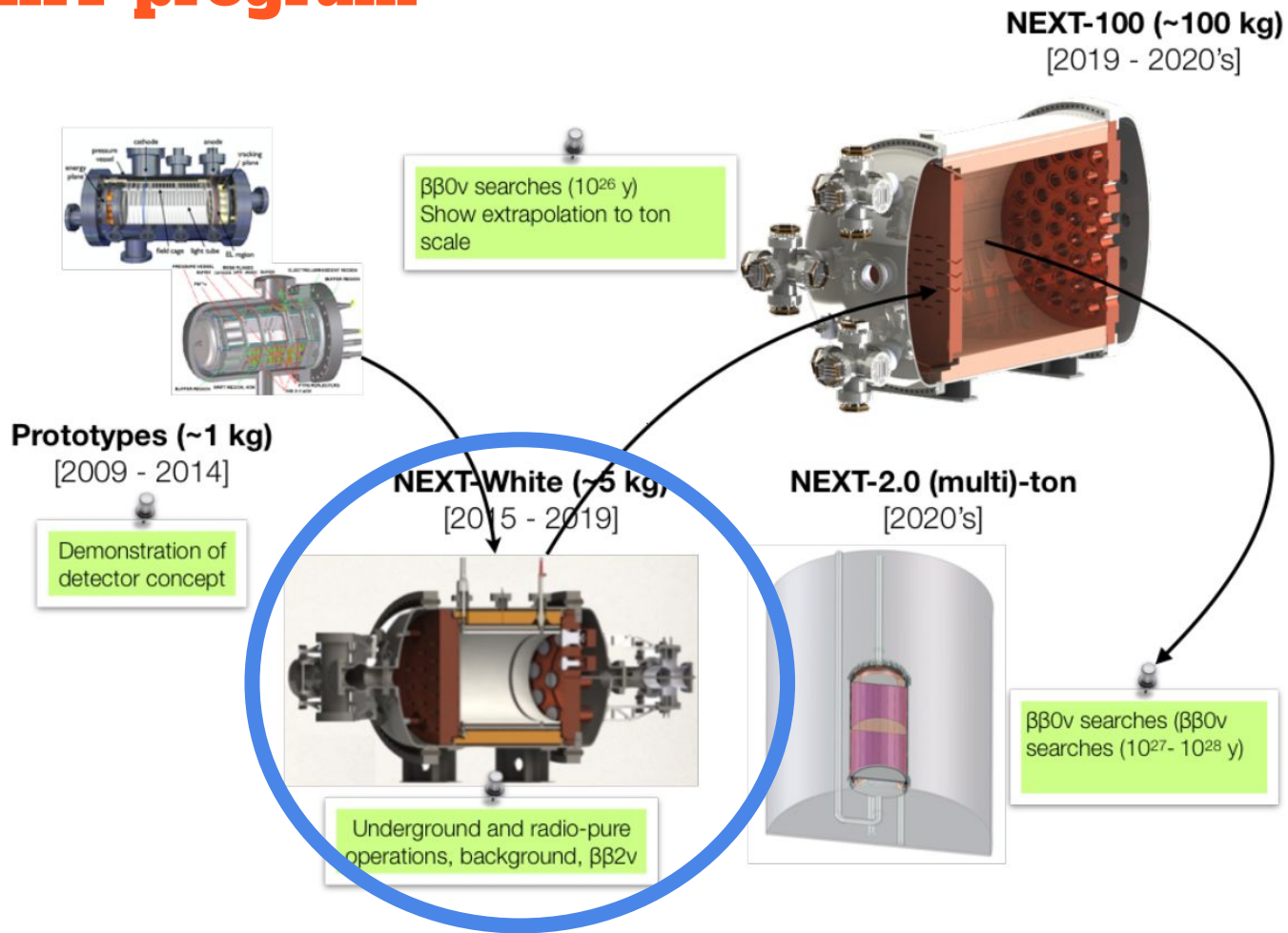
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ikerbasque Basque Foundation for Science

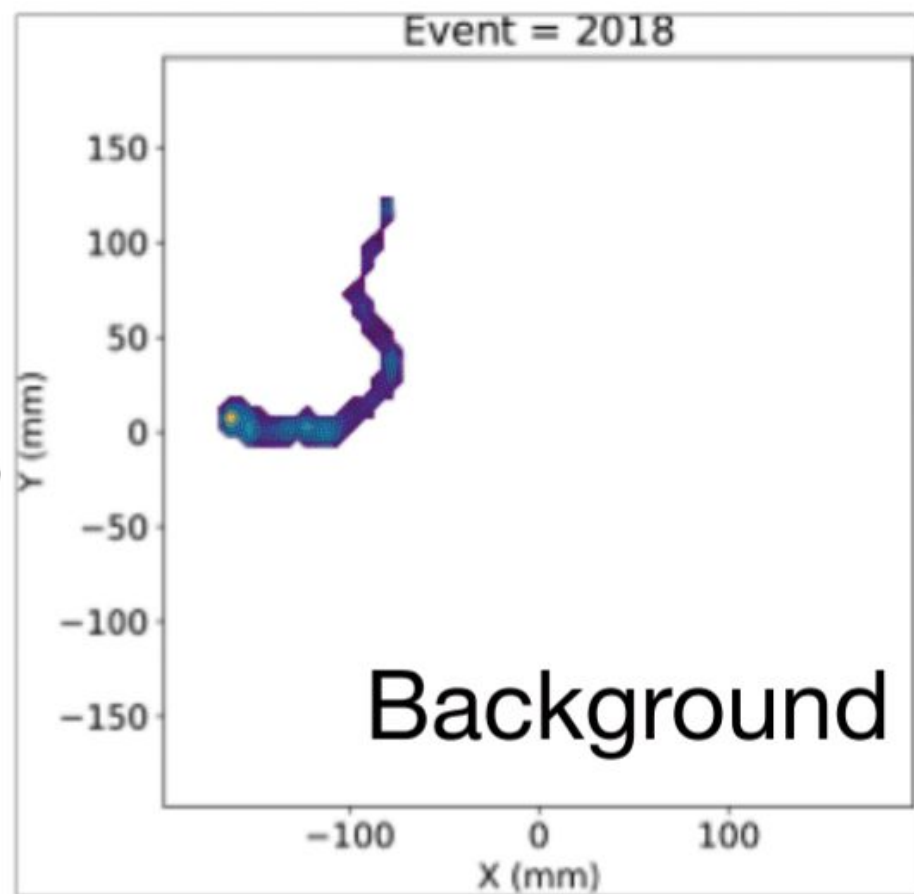
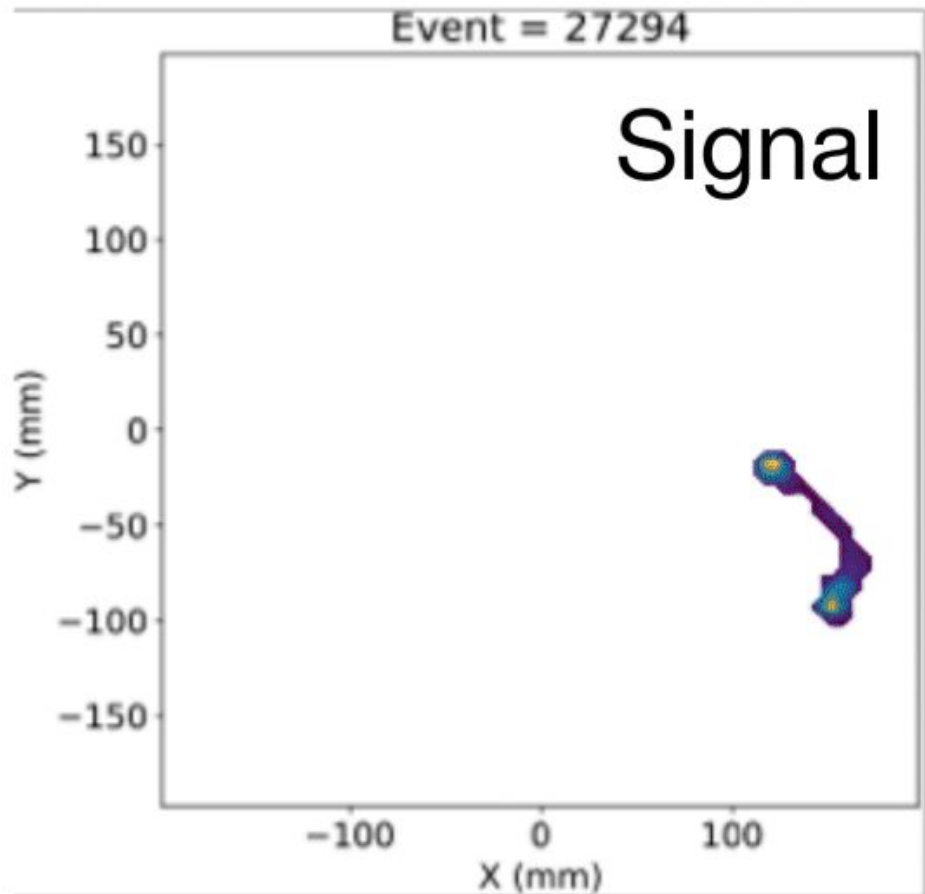


Backup

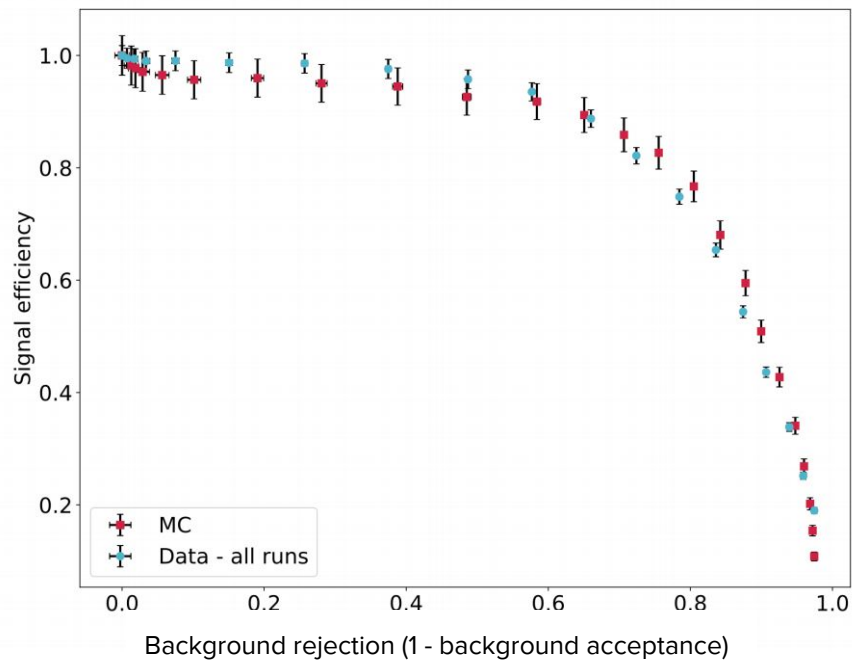
The NEXT program



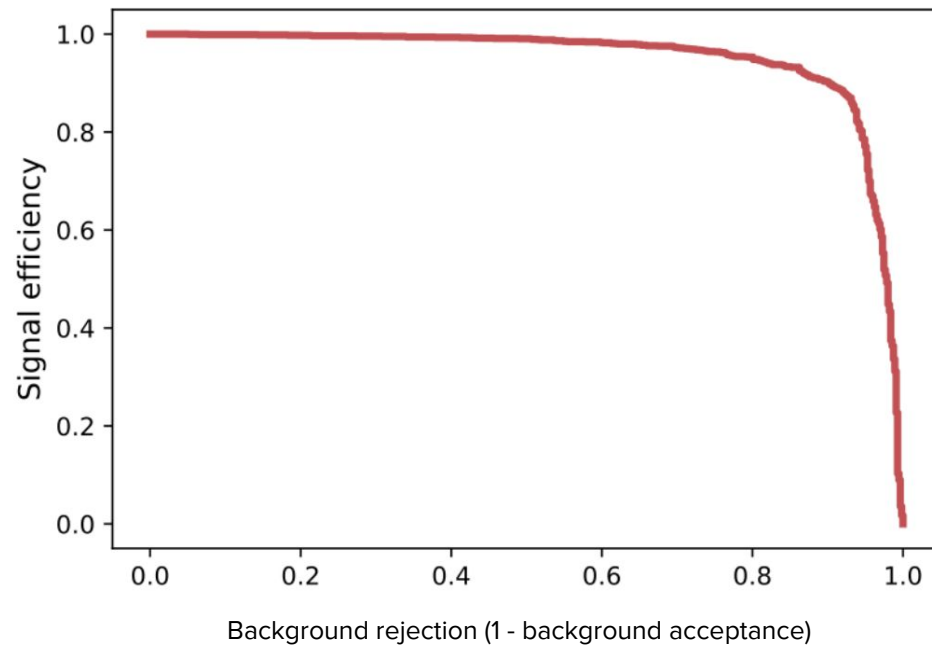
Topological signature in data



Topological cut performance

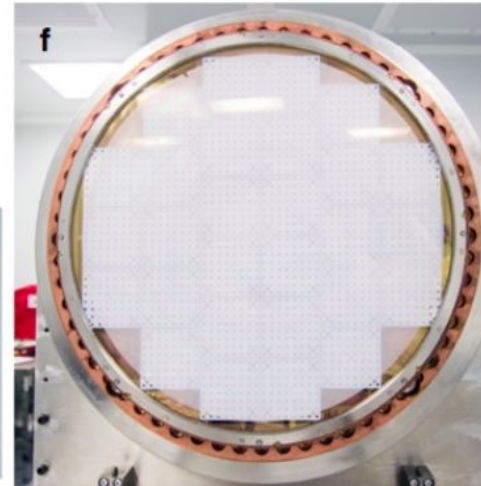


Blob analysis in ^{208}Tl double escape peak shows good agreement data/MC



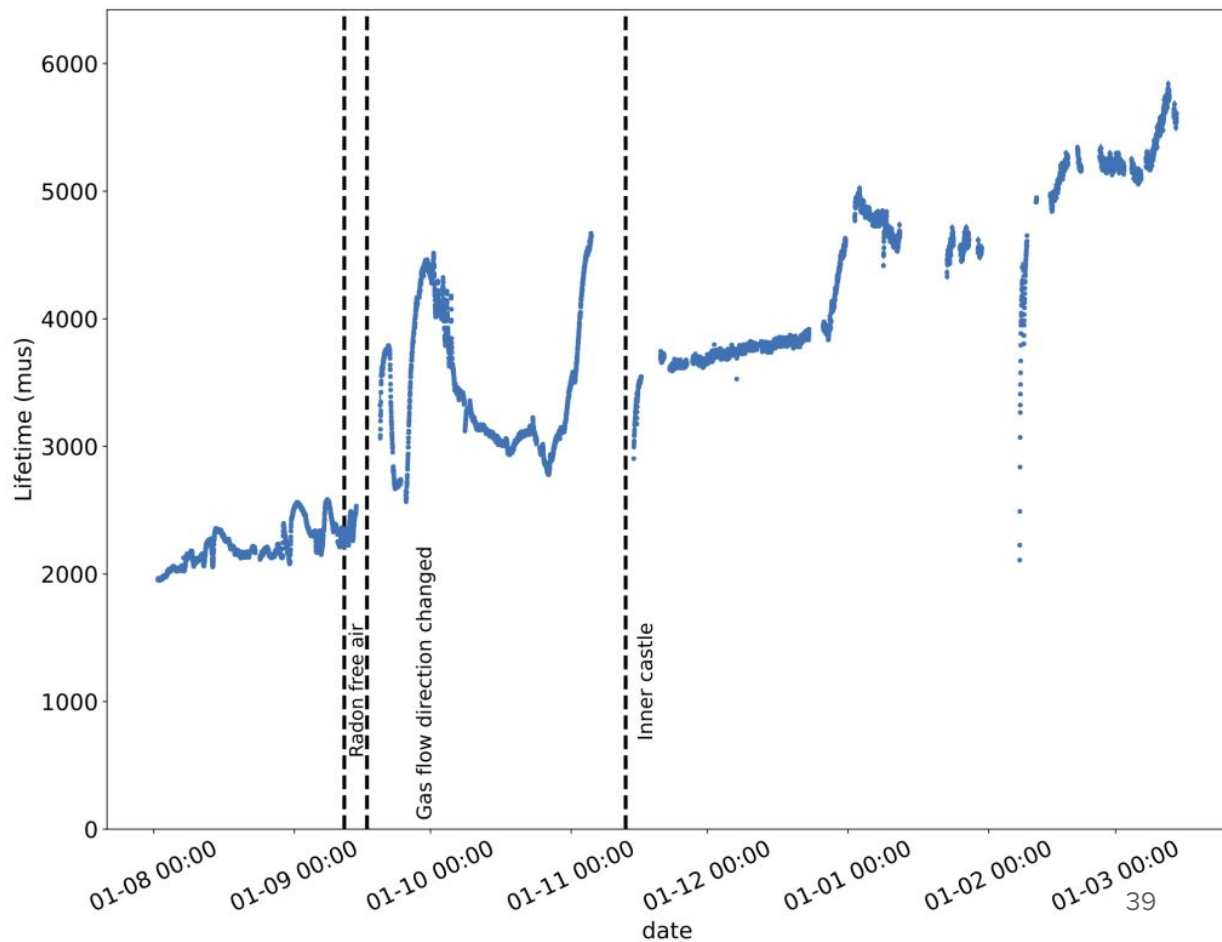
DNN analysis, optimizes separation signal / background. Find 1.2-1.6x improvement, hope for future improvement

The NEXT-White detector

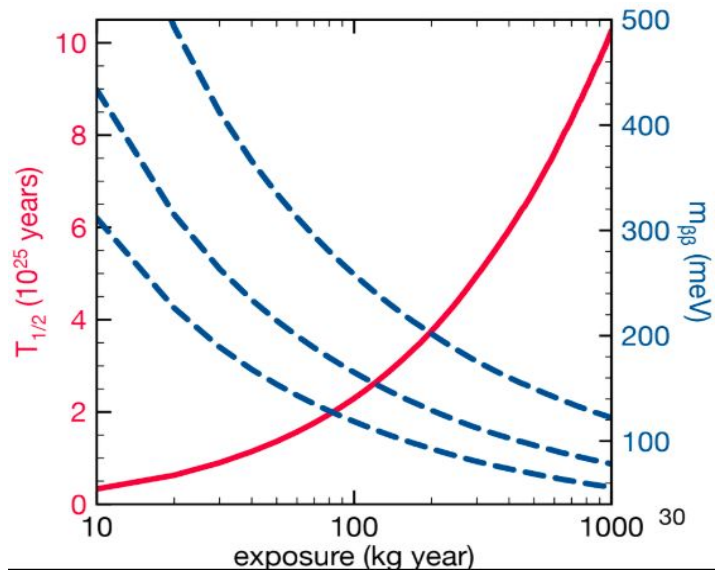
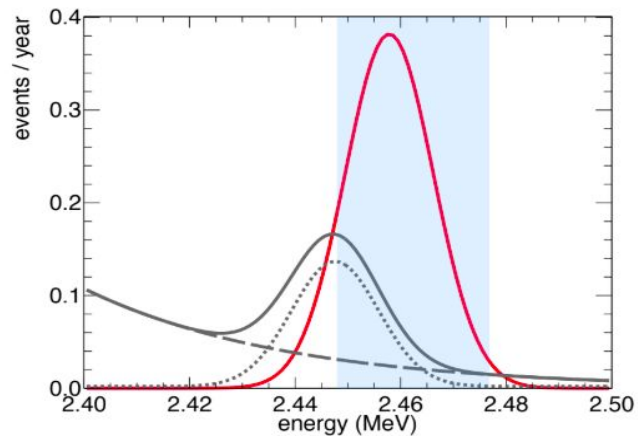
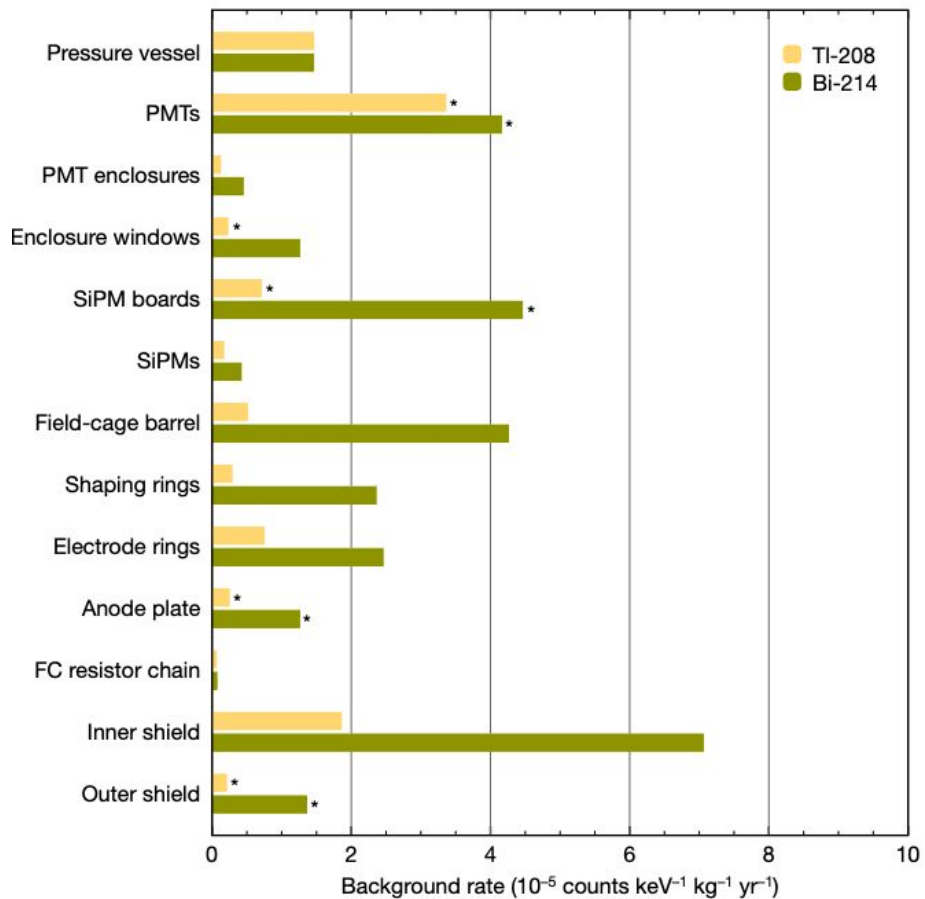


Operation of NEW

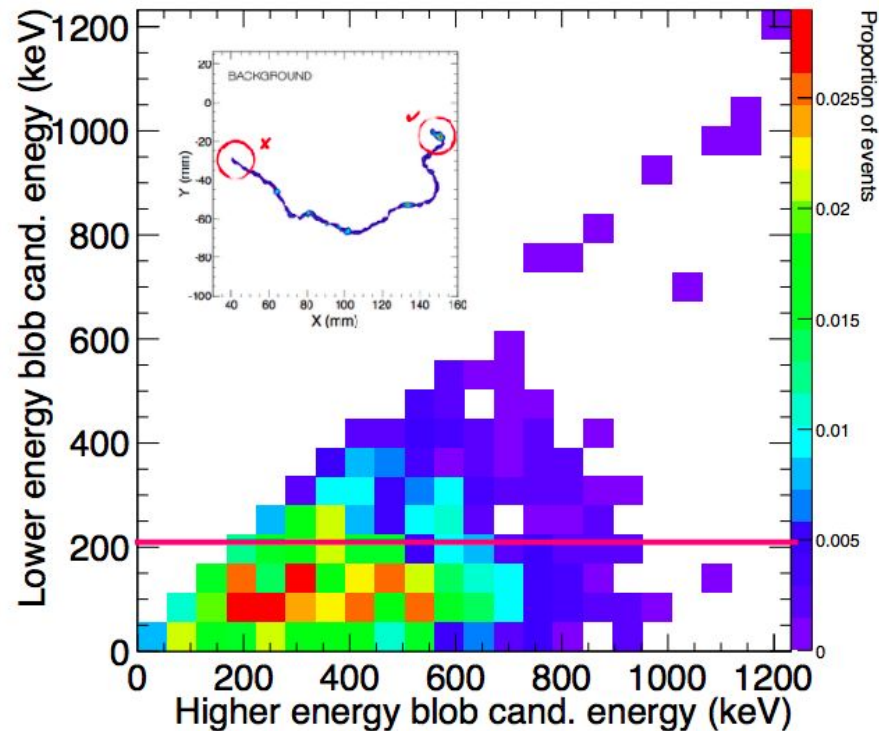
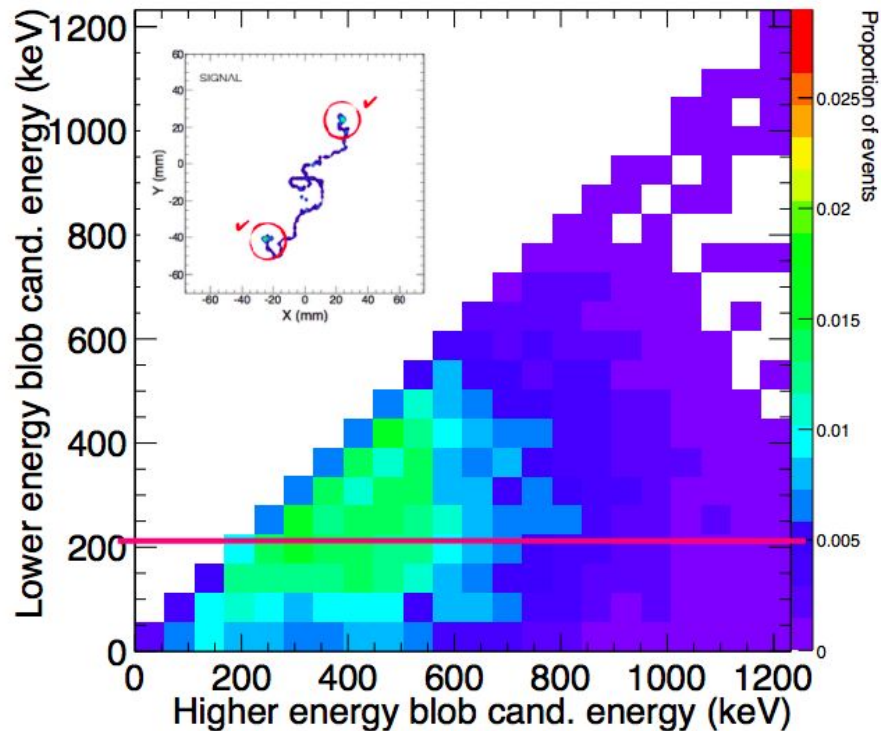
- Taking data since 2016, very stable since 2017
- Less than 1 gram of Xe lost / year
- Very high lifetime, measured daily with Kr



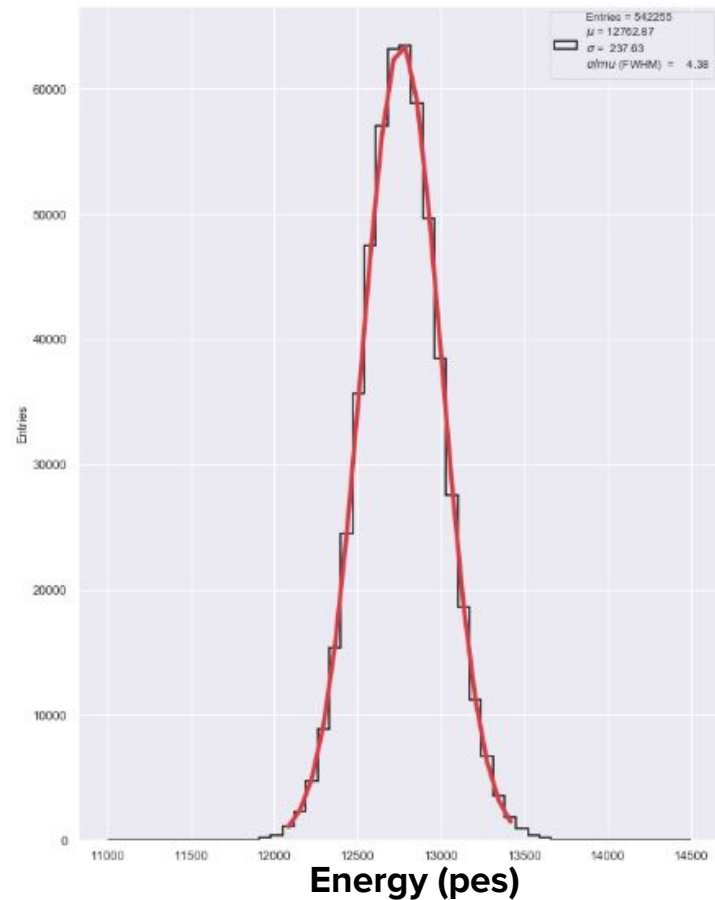
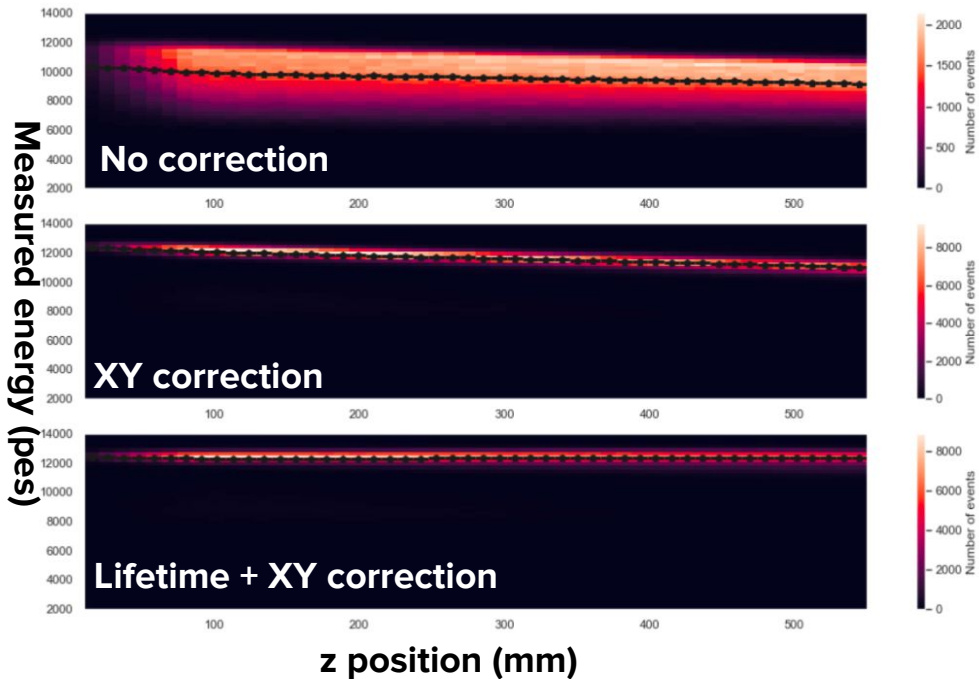
NEXT-100 sensitivity



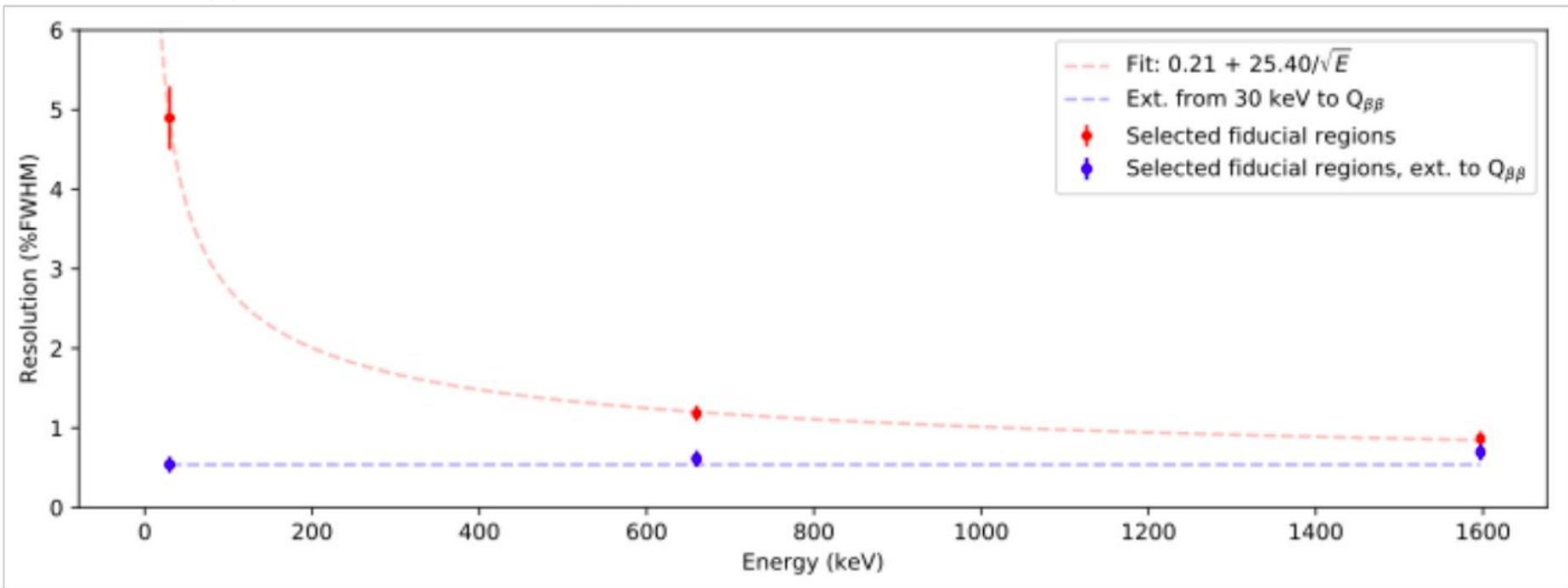
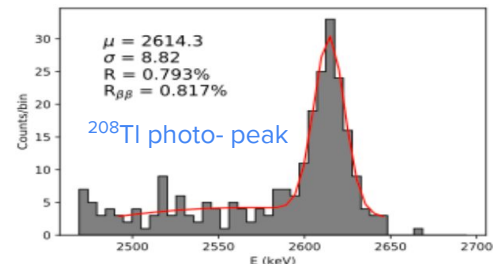
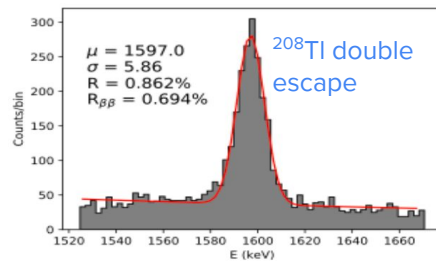
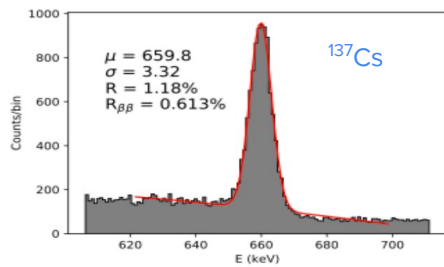
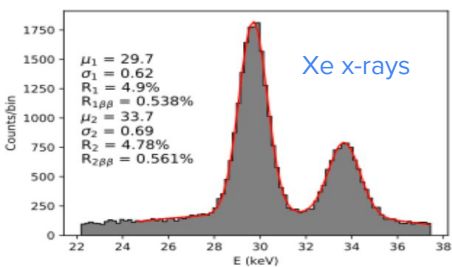
Blob energy cut



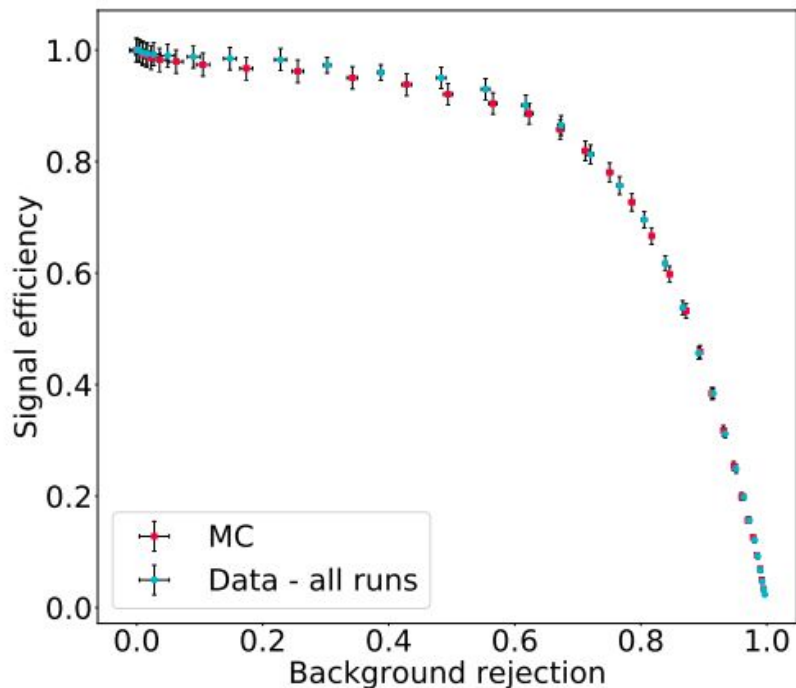
Corrections using Krypton



Energy resolution



Topological cut performance



Blob analysis in ^{208}Tl double escape peak shows good agreement data/MC. 71.6% background efficiency, 20.6% background acceptance

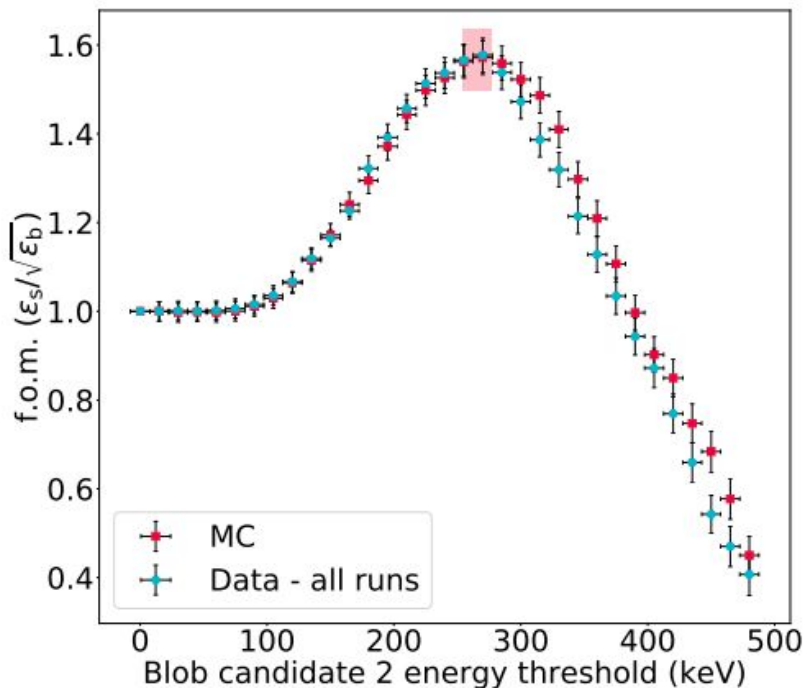
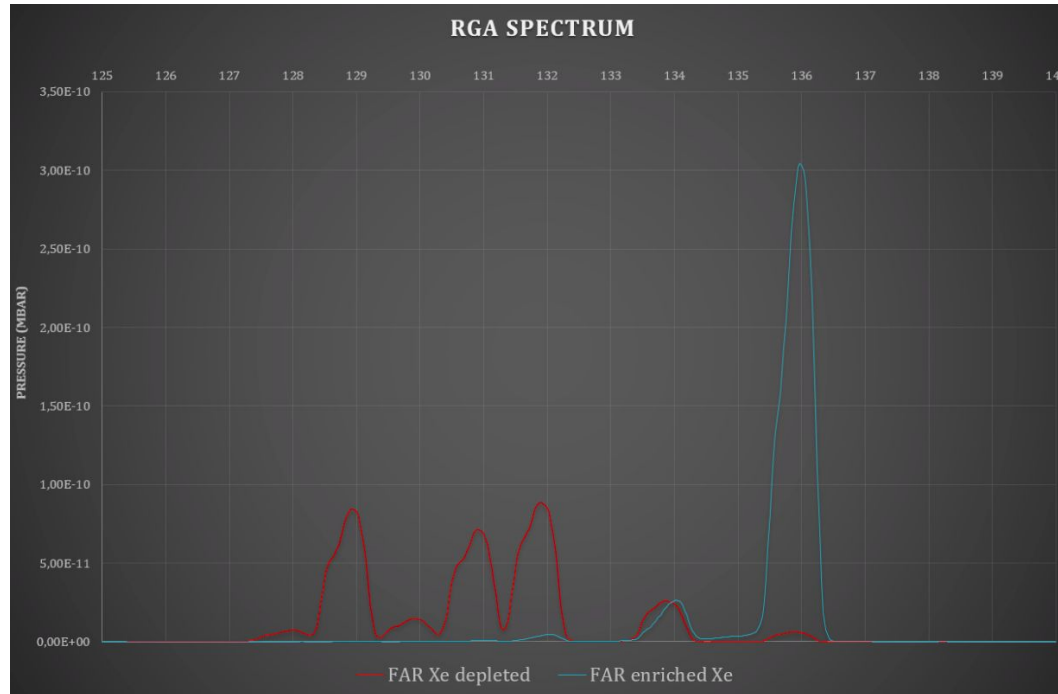


Figure of merit shows optimal cutoff of around 266 keV for efficiency of $\sim 72\%$ and background acceptance of $\sim 21\%$

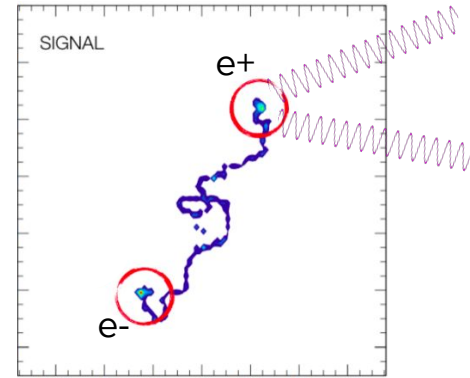
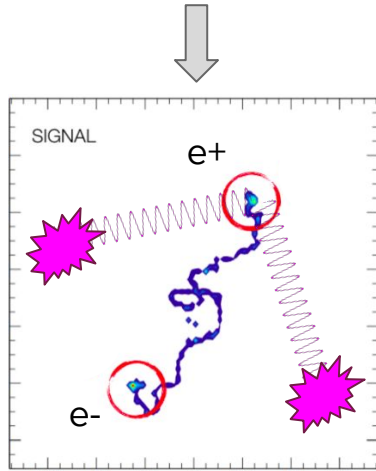
Run V: measuring $2\nu\beta\beta$ lifetime

We have enriched Xe and have begun measuring the spectrum. Will run until end of year to get measurement of lifetime.

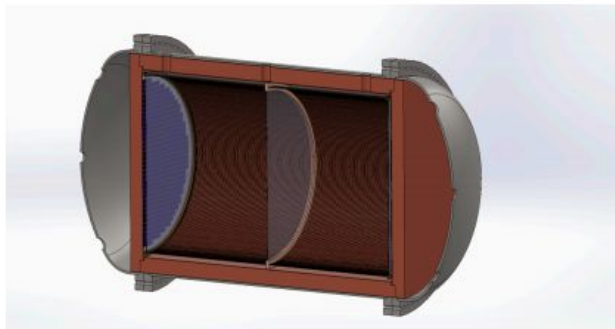


Calibration sources

- Xe K-alpha and K-beta x ray lines (30 keV, 34 keV)
- $^{84\text{m}}\text{Kr}$ (42 keV)
- ^{137}Cs (662 keV)
- ^{208}Tl double escape peak (1593 keV) →
- ^{208}Tl photopeak (2614 keV)



NEXT-ton (~2025)

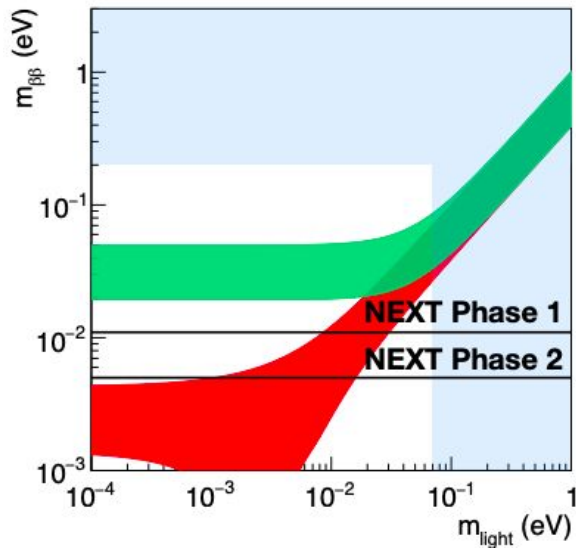


Two approaches developed in parallel:

- 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}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
- 2.6×10^{-6} cts / keV · kg · year total background rate

Phase 2:

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