THE NEXT EXPERIMENT FOR DOUBLE BETA DECAY SEARCHES

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next

LSC

Laboratorio Subterráneo de Canfranc

THE NEXT COLLABORATION

DIPC • U. de Girona • IFIC • U. Autónoma de Madrid •
U. de Santiago de Compostela • U. Politécnica de Valencia •
U. de Zaragoza

ANL • U. Texas at Arlington • FNAL • Harvard U. •
Iowa State U. • LBNL • Texas A&M U.

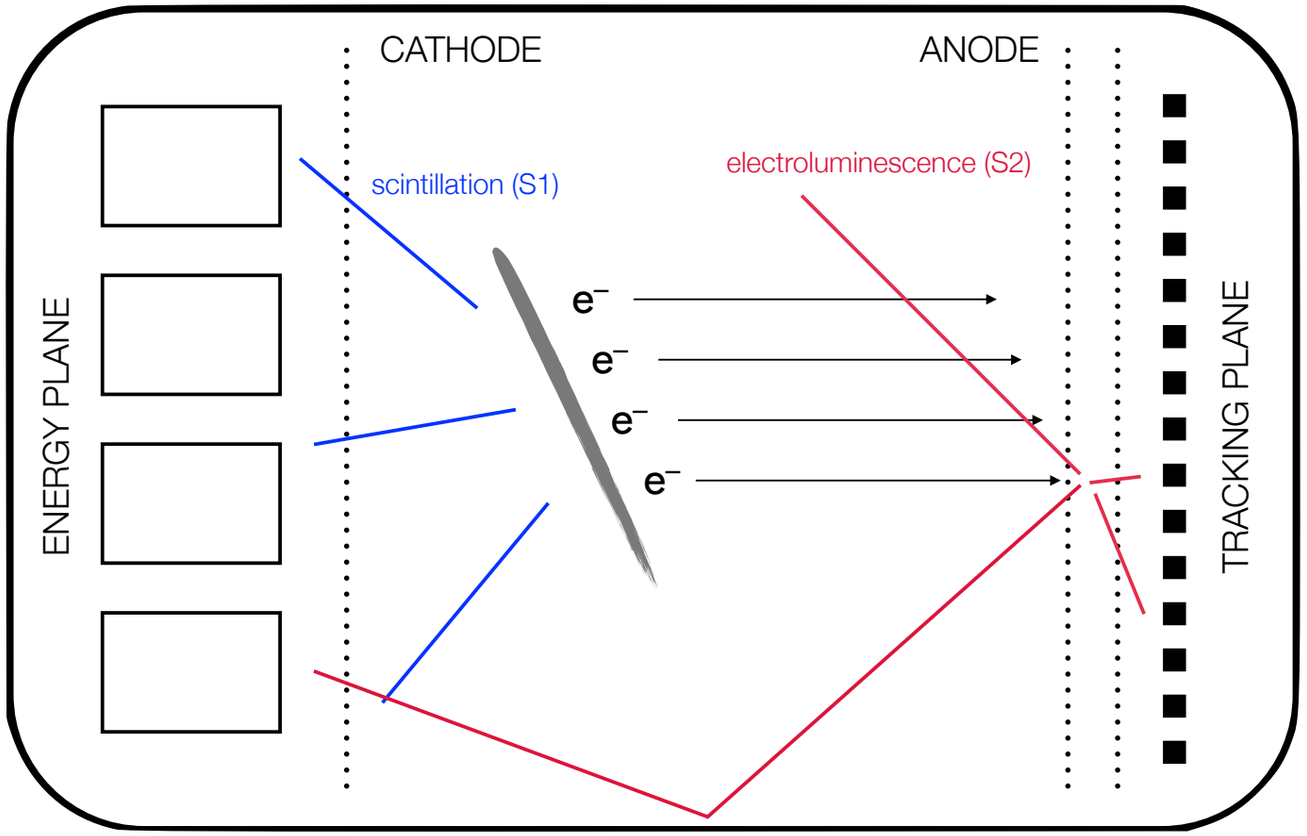
U. de Aveiro • U. de Coimbra

Ben-Gurion U. of the Negev

U. Antonio Nariño

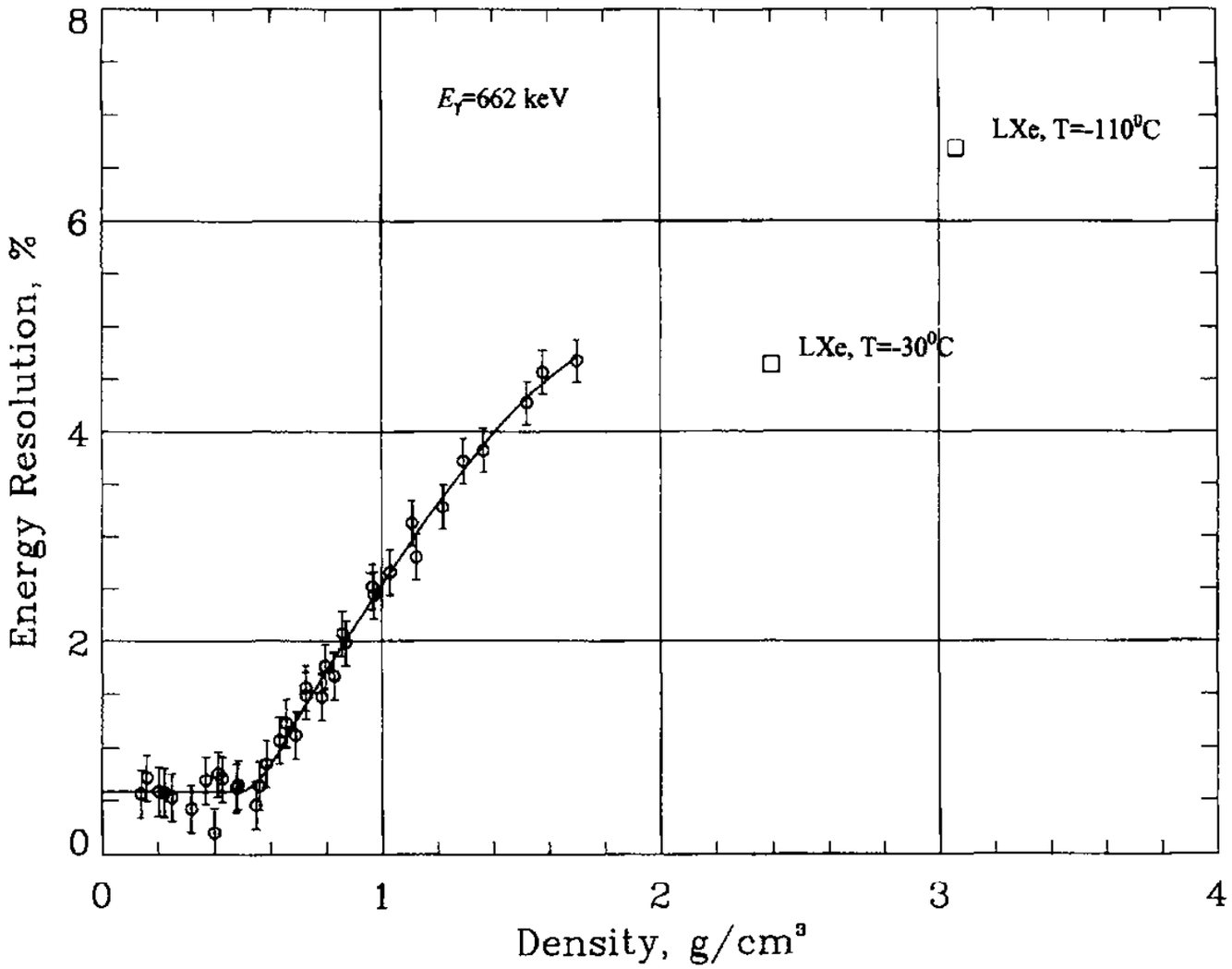
Co-Spokespeople: Prof. J.J. Gómez Cadenas (DIPC)
Prof. D. R. Nygren (UTA)

NEXT DETECTOR CONCEPT



A xenon gas time projection chamber with electroluminescent amplification. Primary scintillation (S1) establishes the start-of-event time; secondary scintillation (S2) is used for calorimetry and tracking. Specialised sensor arrays for each measurement.

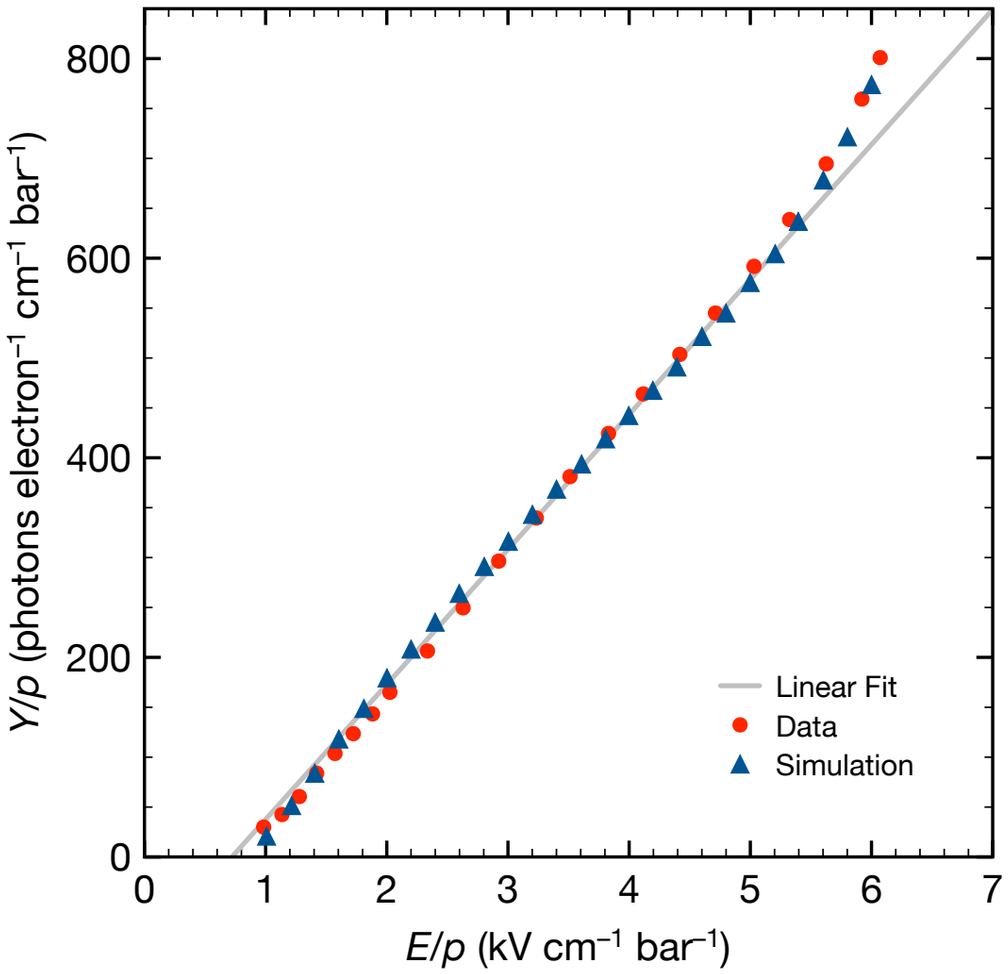
ENERGY RESOLUTION IN XENON

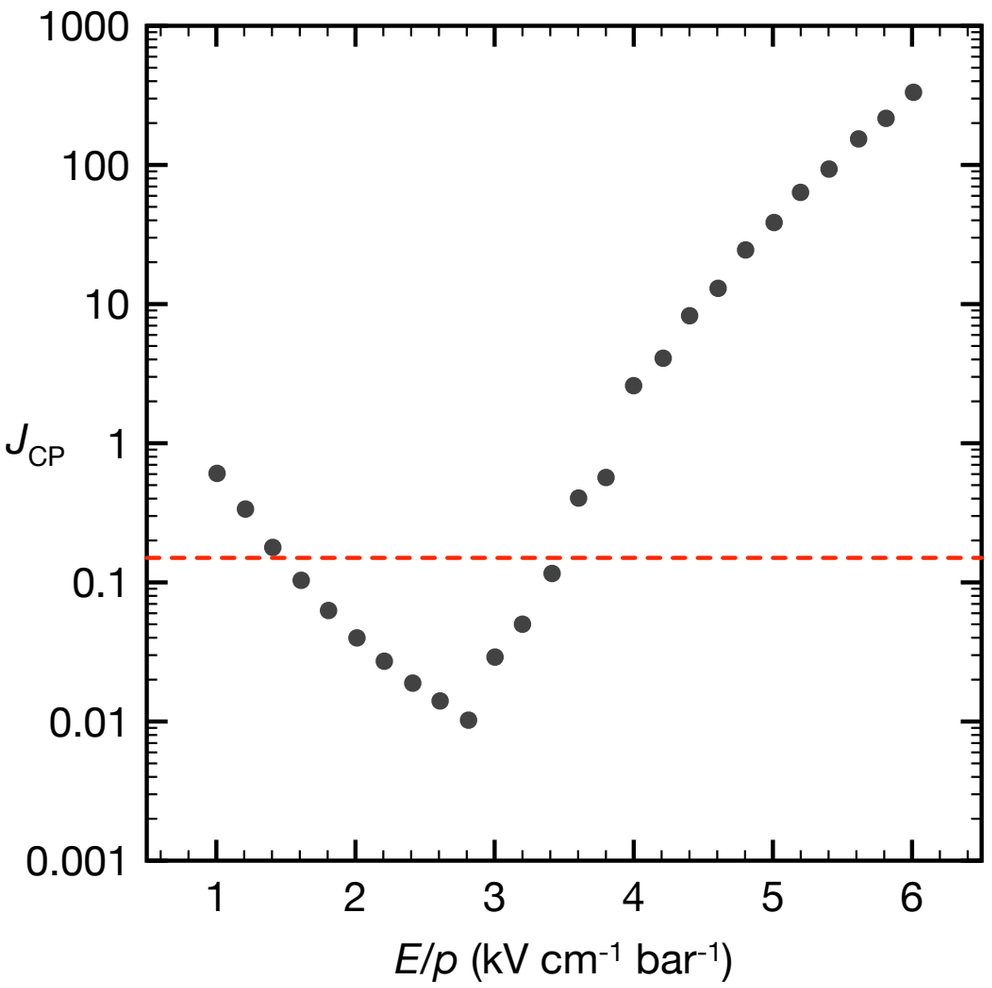


Bolotnikov and Ramsey, *NIM A* **396** (1997) 360

Intrinsic energy resolution of xenon gas close to 0.3% at 2.5 MeV. Fano factor of xenon significantly smaller in gaseous phase (0.15) than in liquid (>20).

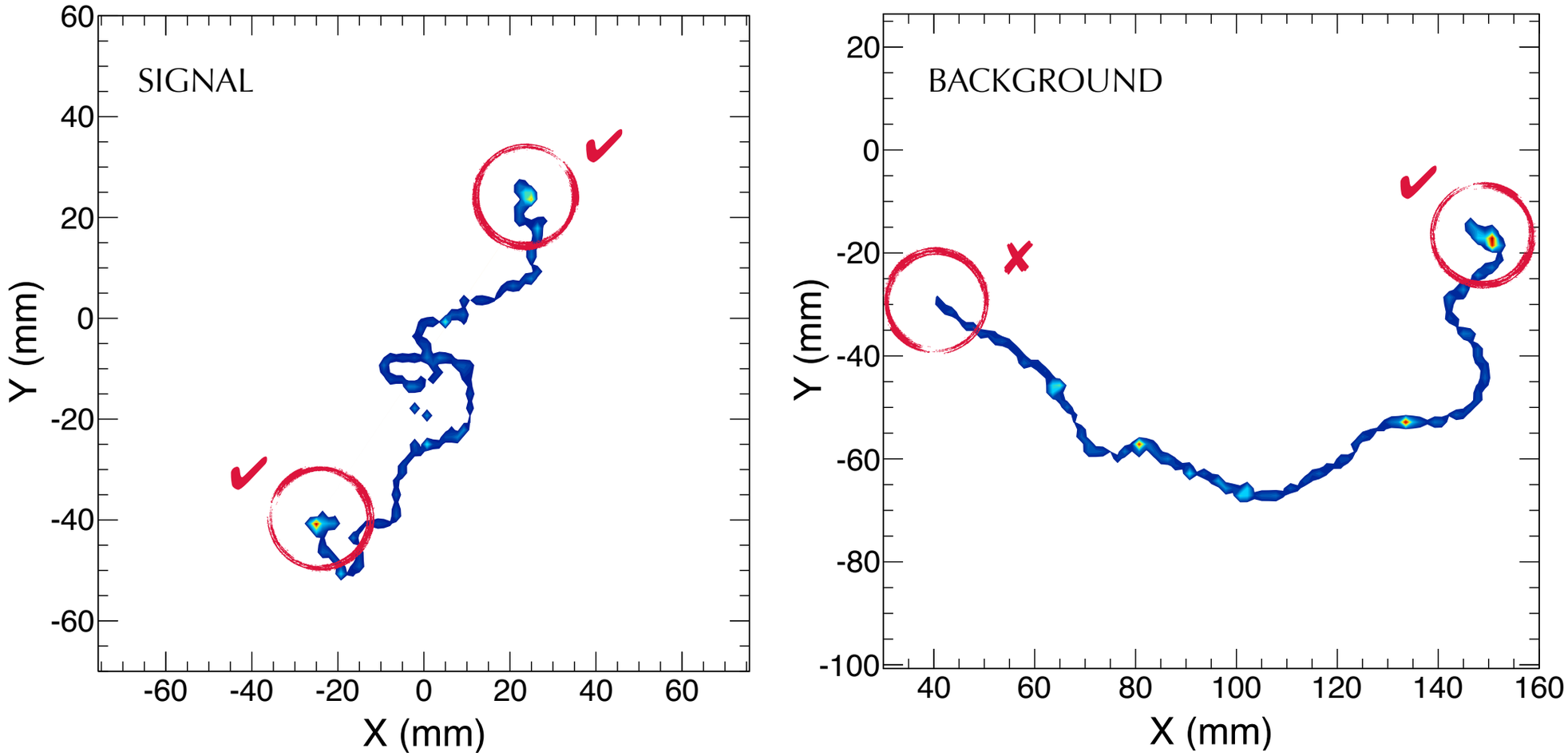
ELECTROLUMINESCENCE





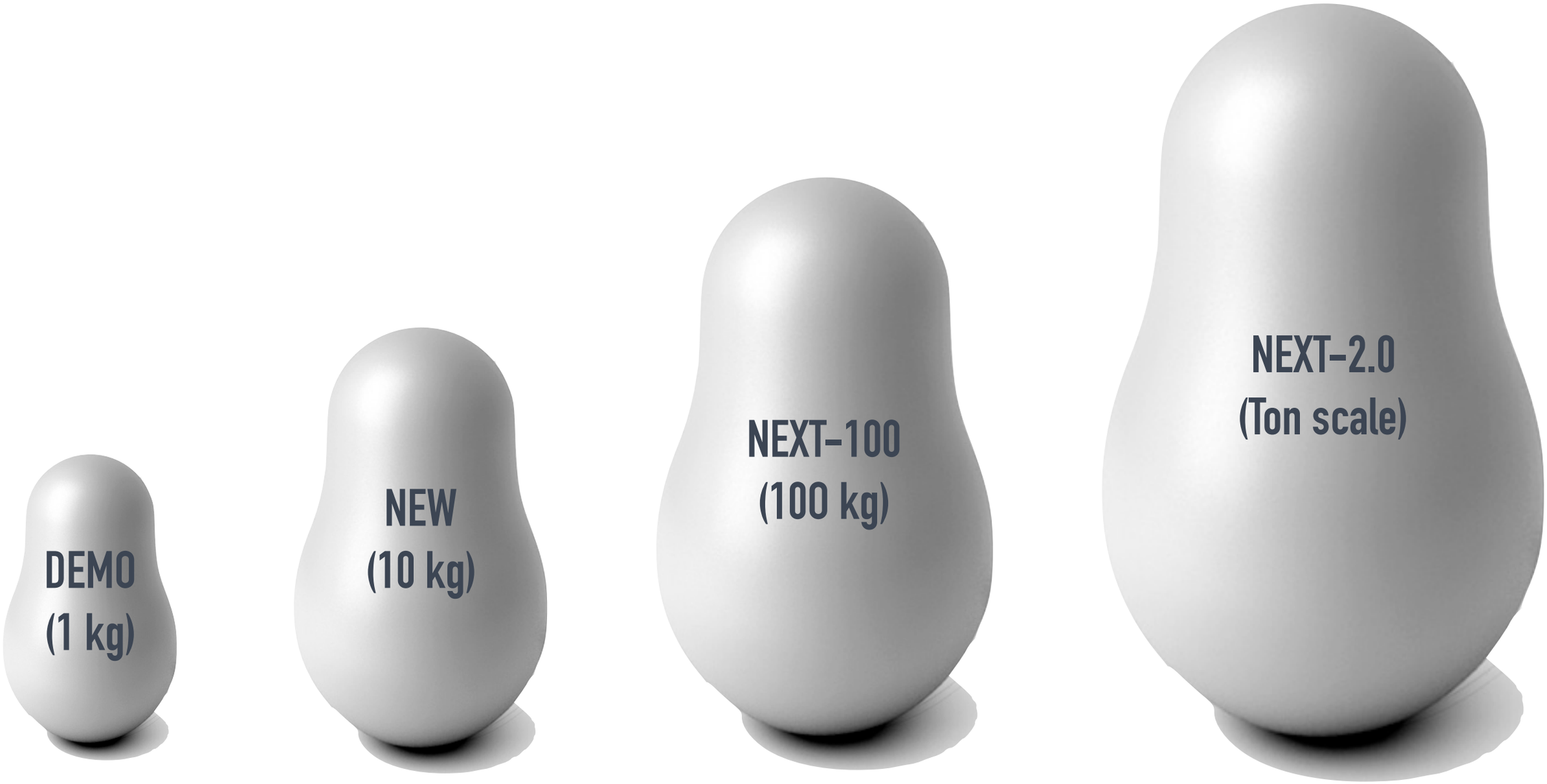
Emission of scintillation light by atoms excited by a charge accelerated by an electric field. High, linear amplification gain with sub-Poissonian fluctuations.

TRACKING IN GASEOUS XENON



Signal events (two electron tracks with a common vertex) feature dE/dx blobs at both ends, unlike most common background events (single electrons).

THE NEXT PROJECT



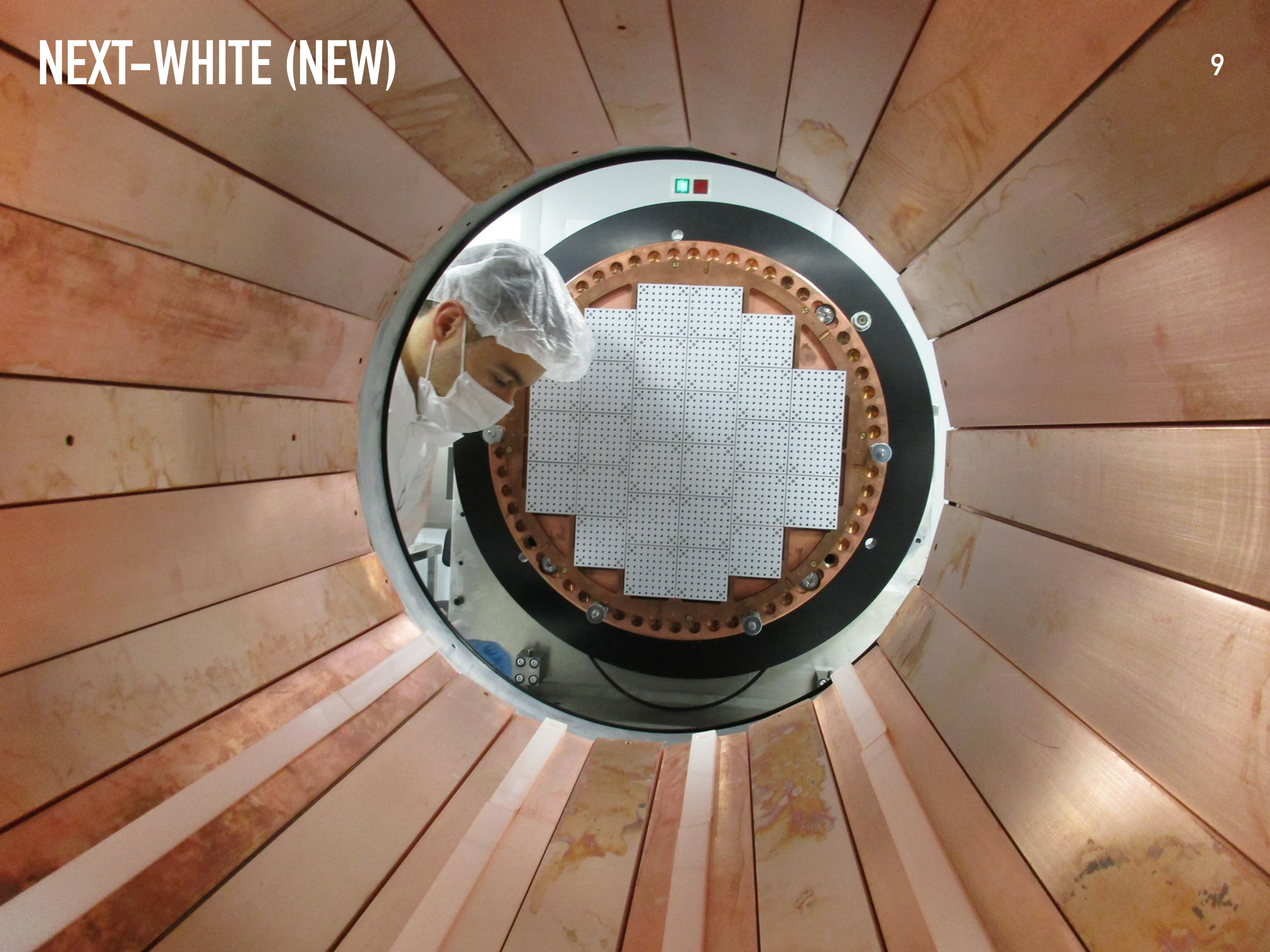
(2010–2014)
Prototyping of detector concept

(2015–2018)
Test underground, radiopure operation

(2019–2021)
Neutrinoless double beta decay searches

(2021– …)
Discovery?

NEXT-WHITE (NEW)



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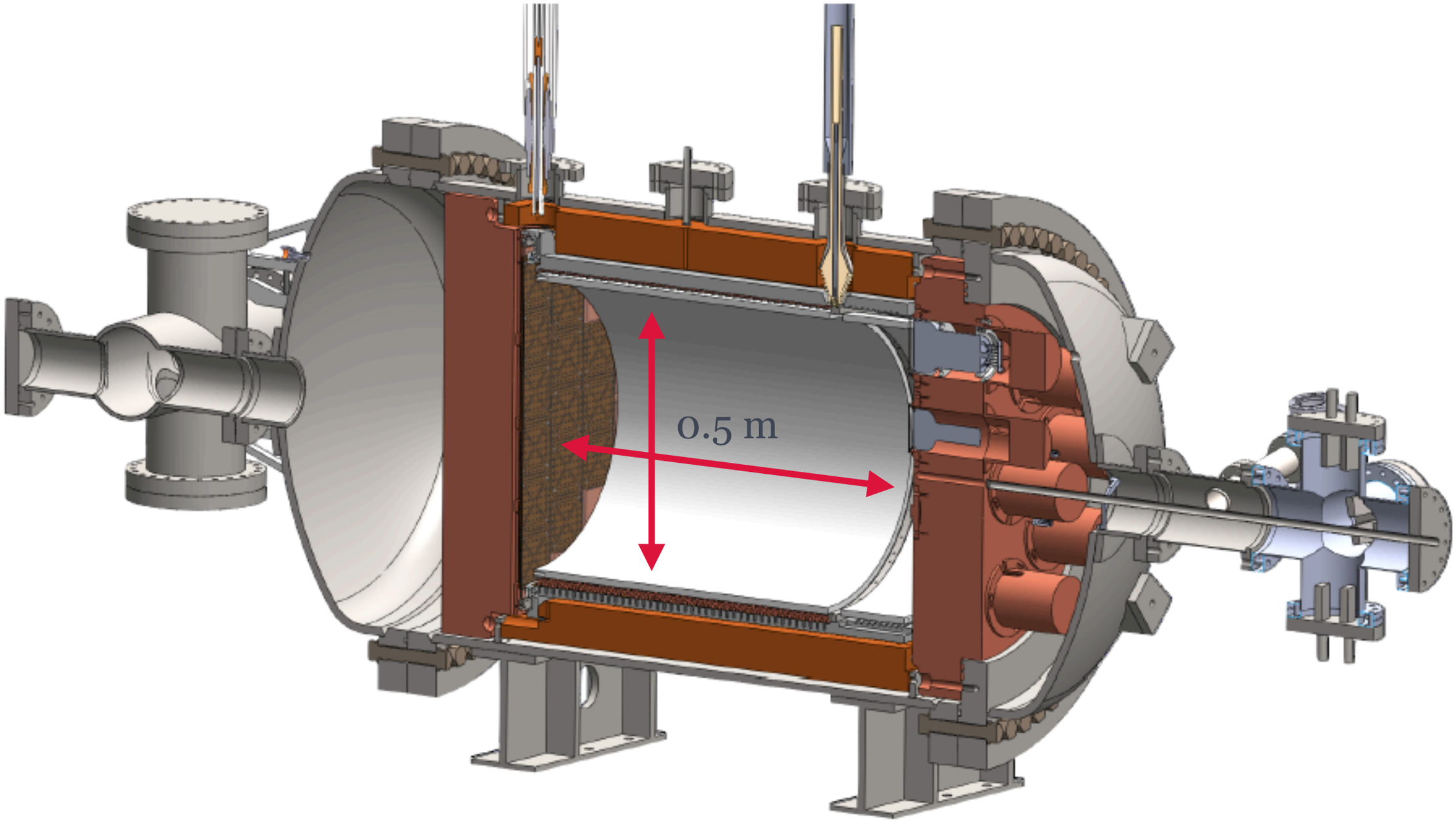

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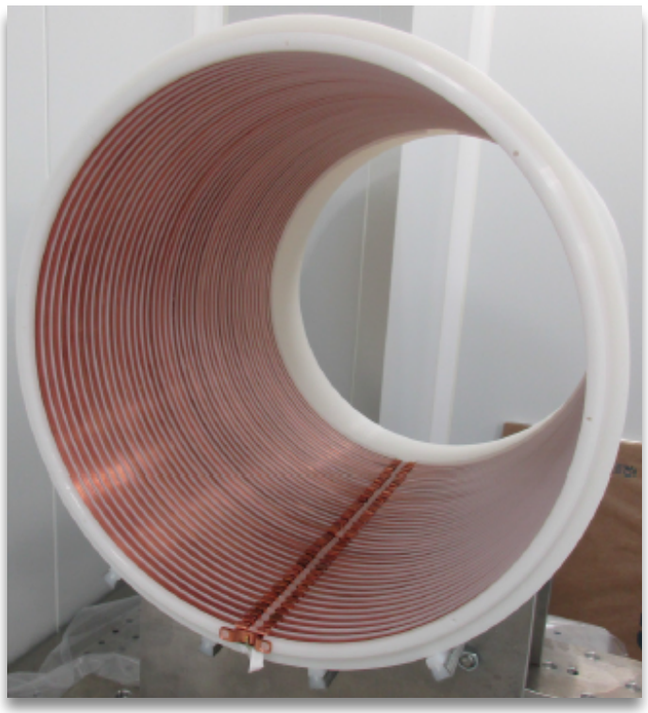

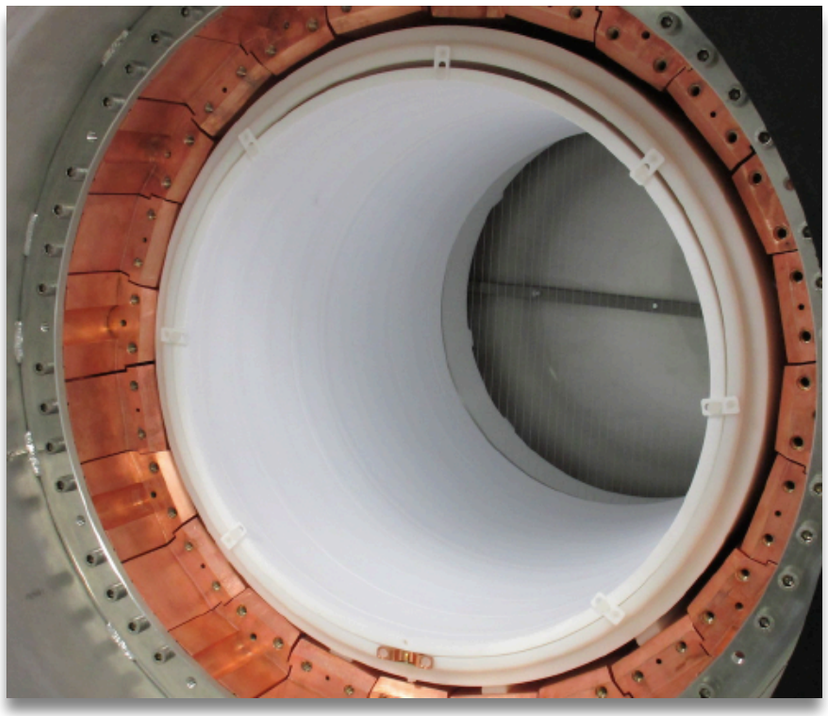

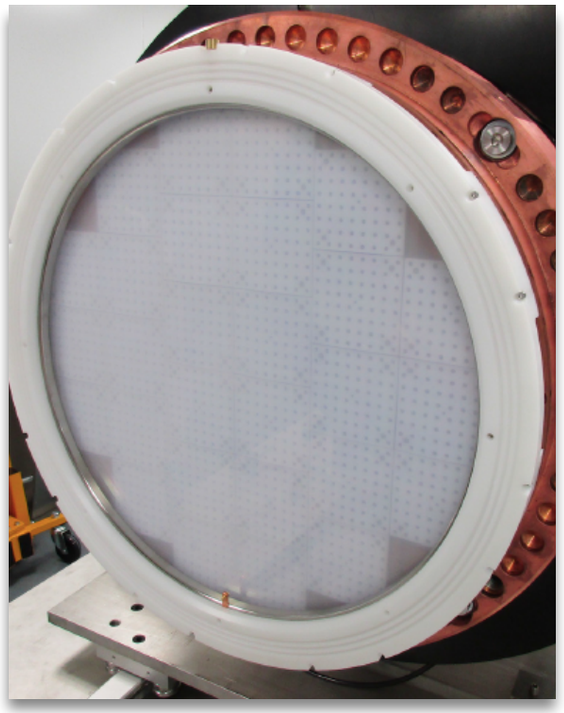

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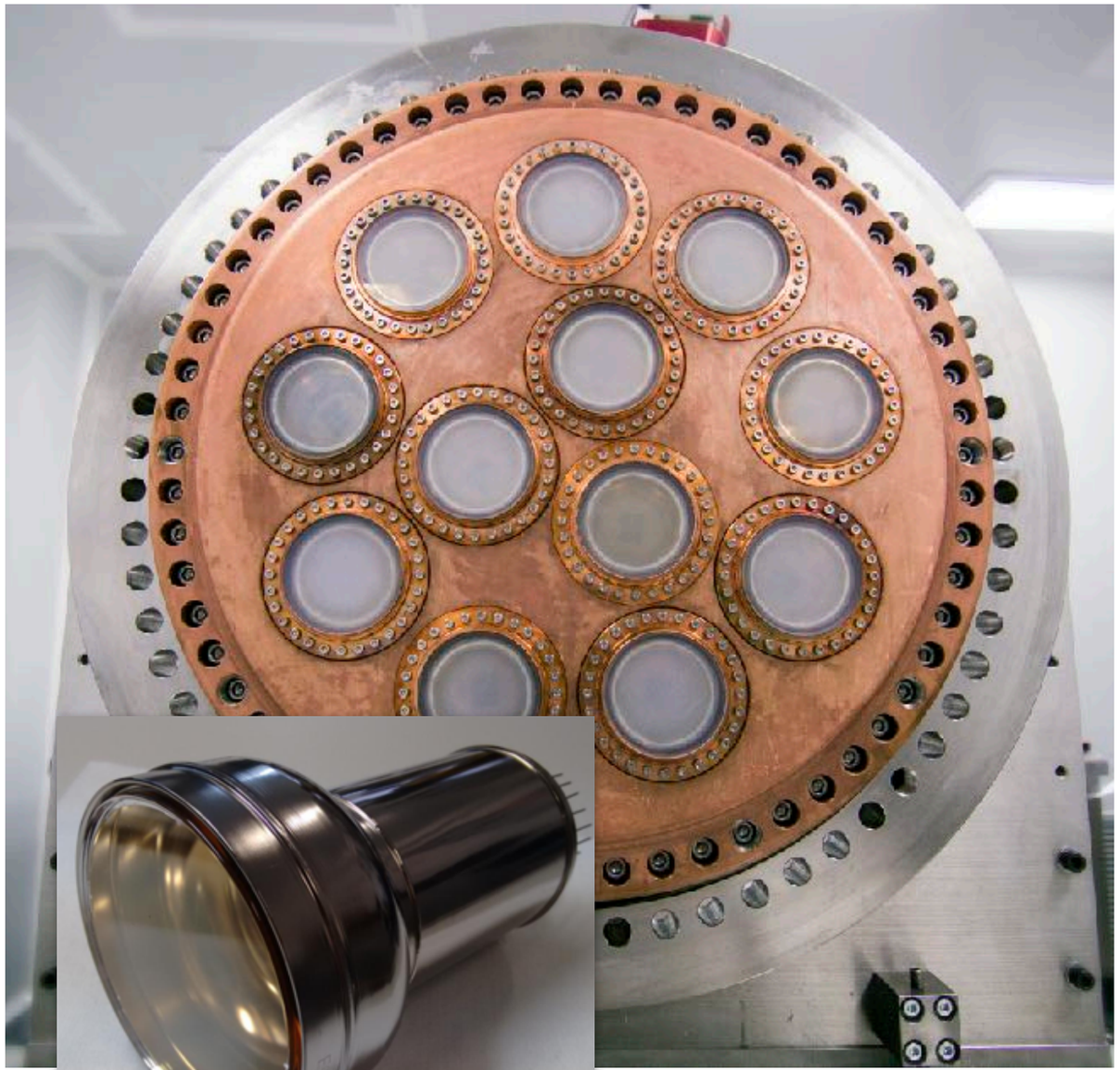
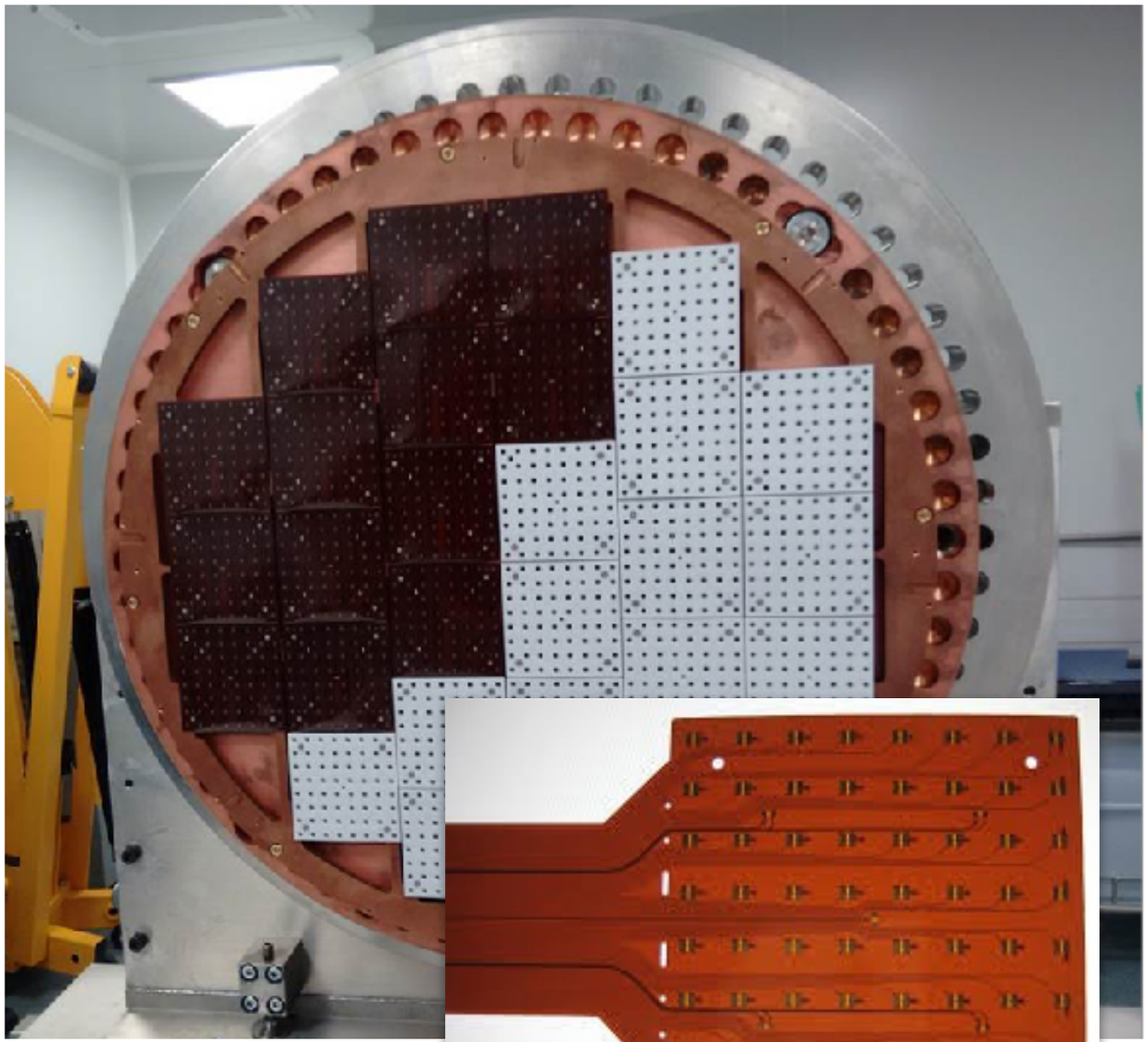


12 Hamamatsu R11410



2000+ SensL 1-mm² SiPMs

NEXT-WHITE (NEW)

NEXT-WHITE (NEW)

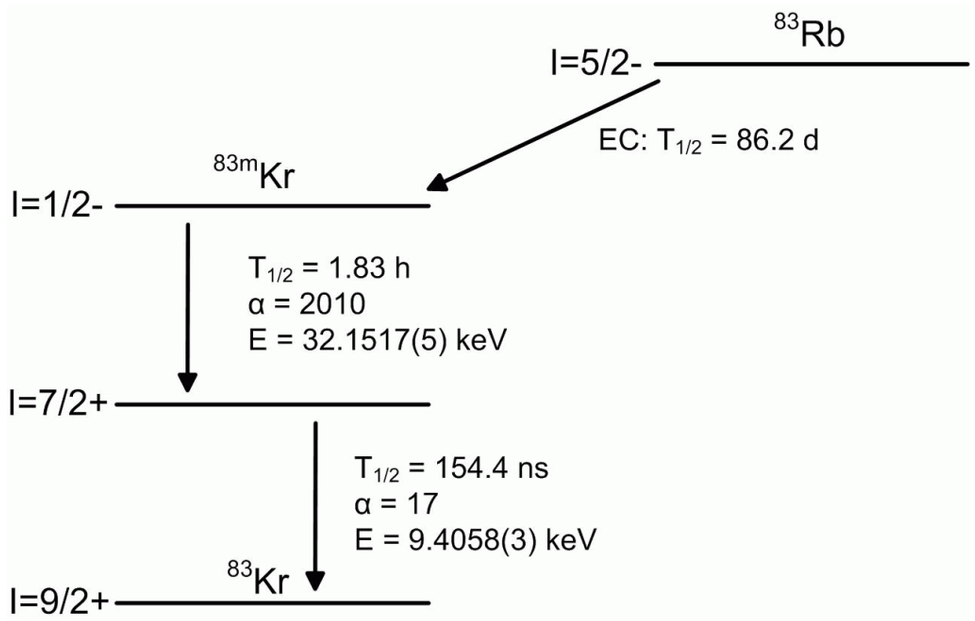
NEXT-WHITE (NEW)

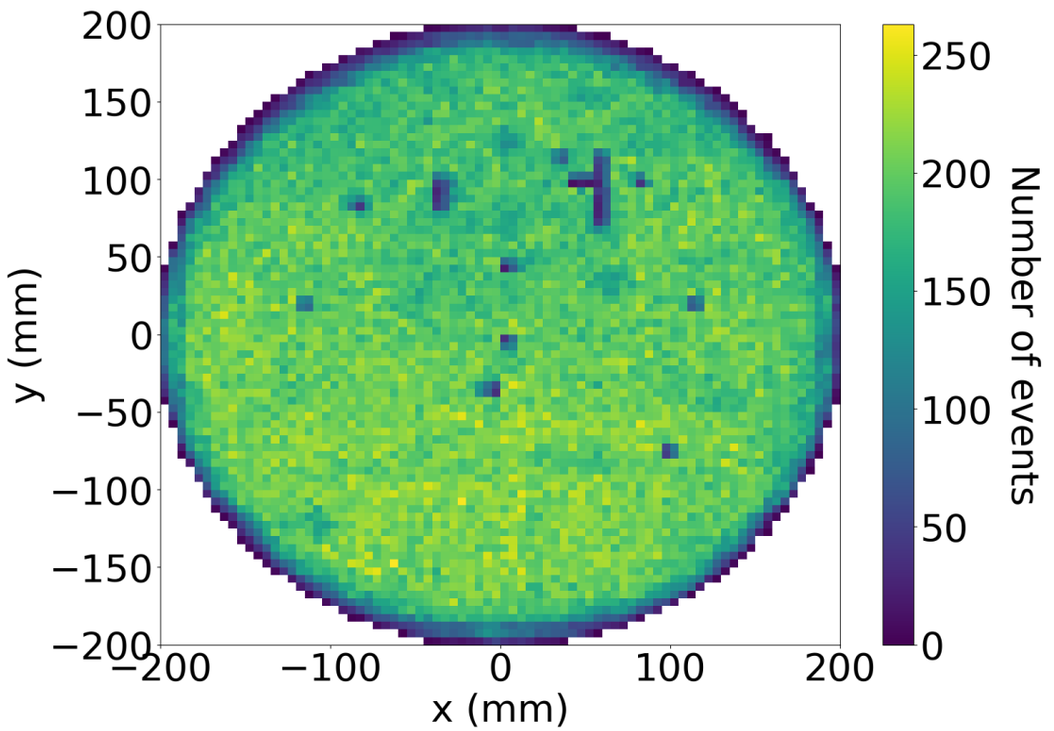
NEXT-WHITE (NEW)

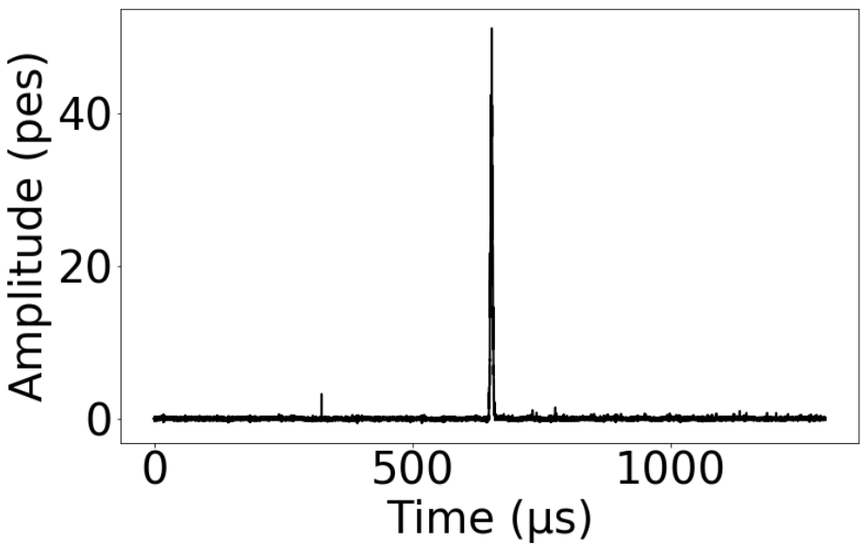
NEXT-WHITE (NEW)

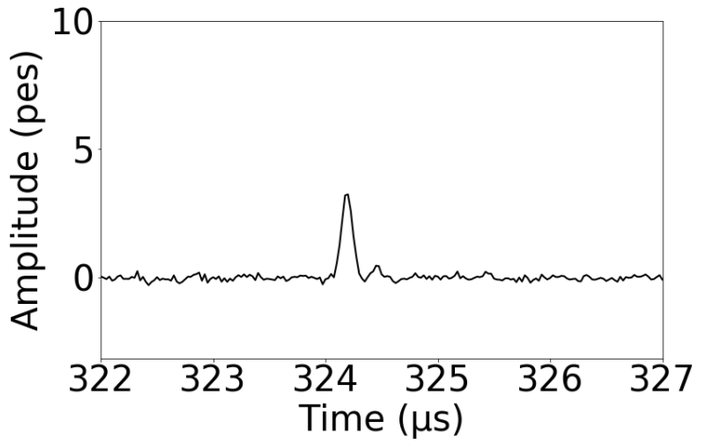
The NEXT-White setup in Hall A at the Laboratorio Subterráneo de Canfranc.

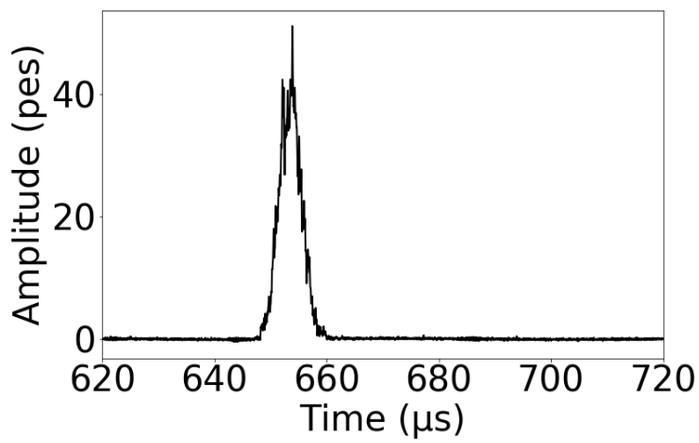
NEXT-WHITE: CALIBRATION WITH KRYPTON-83





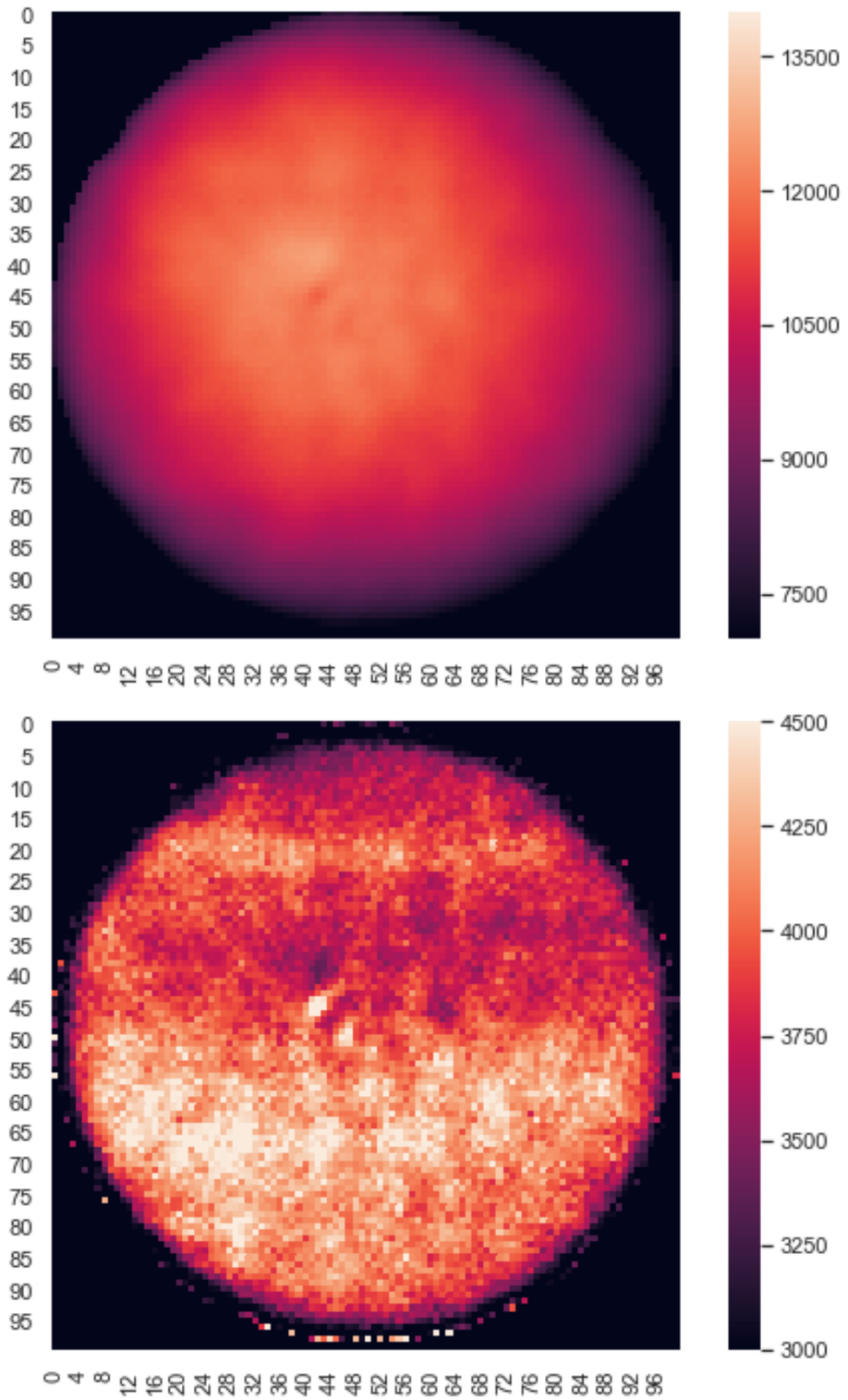


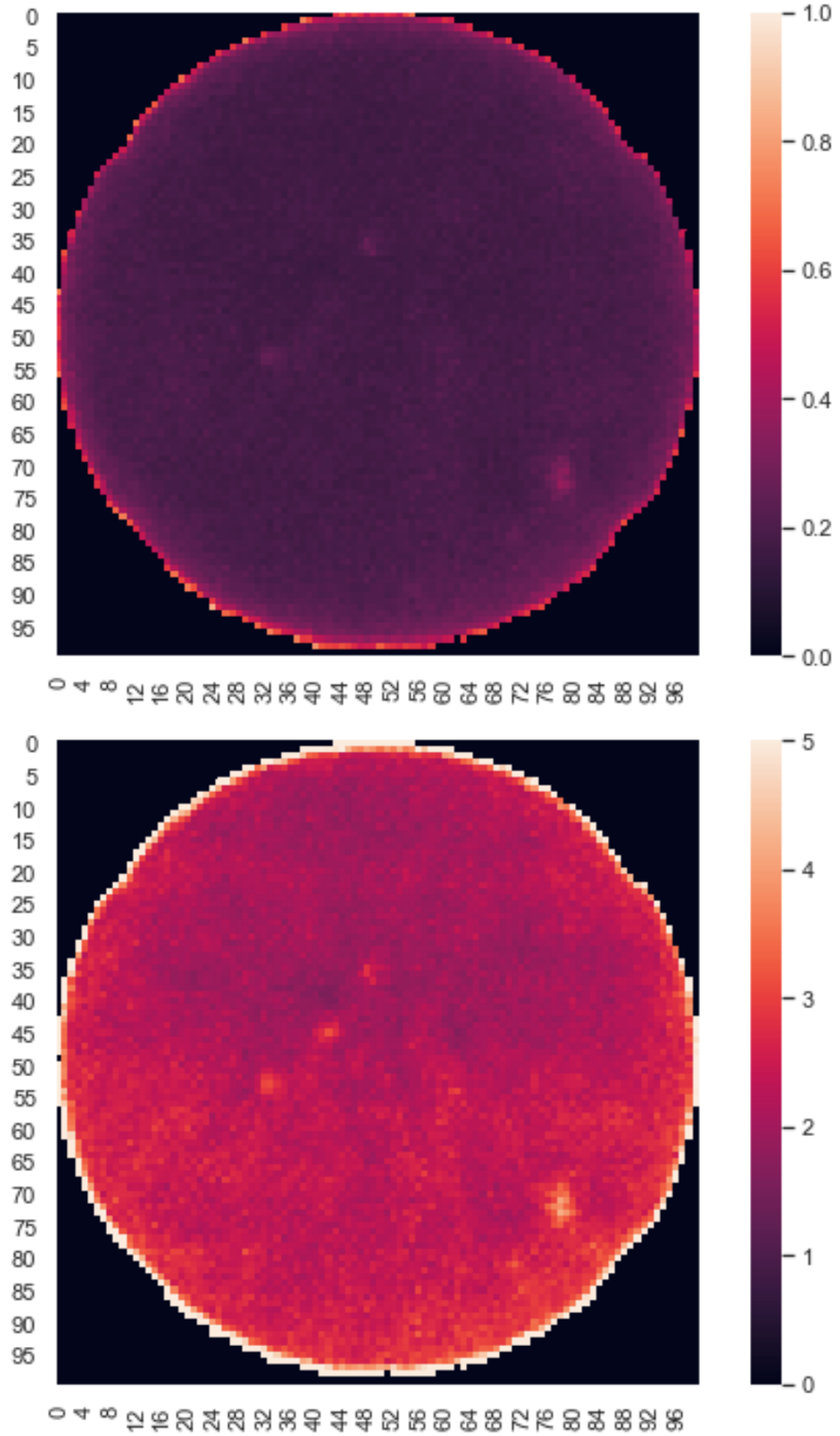




NEXT Collaboration, *JINST* **13** (2018) P10014

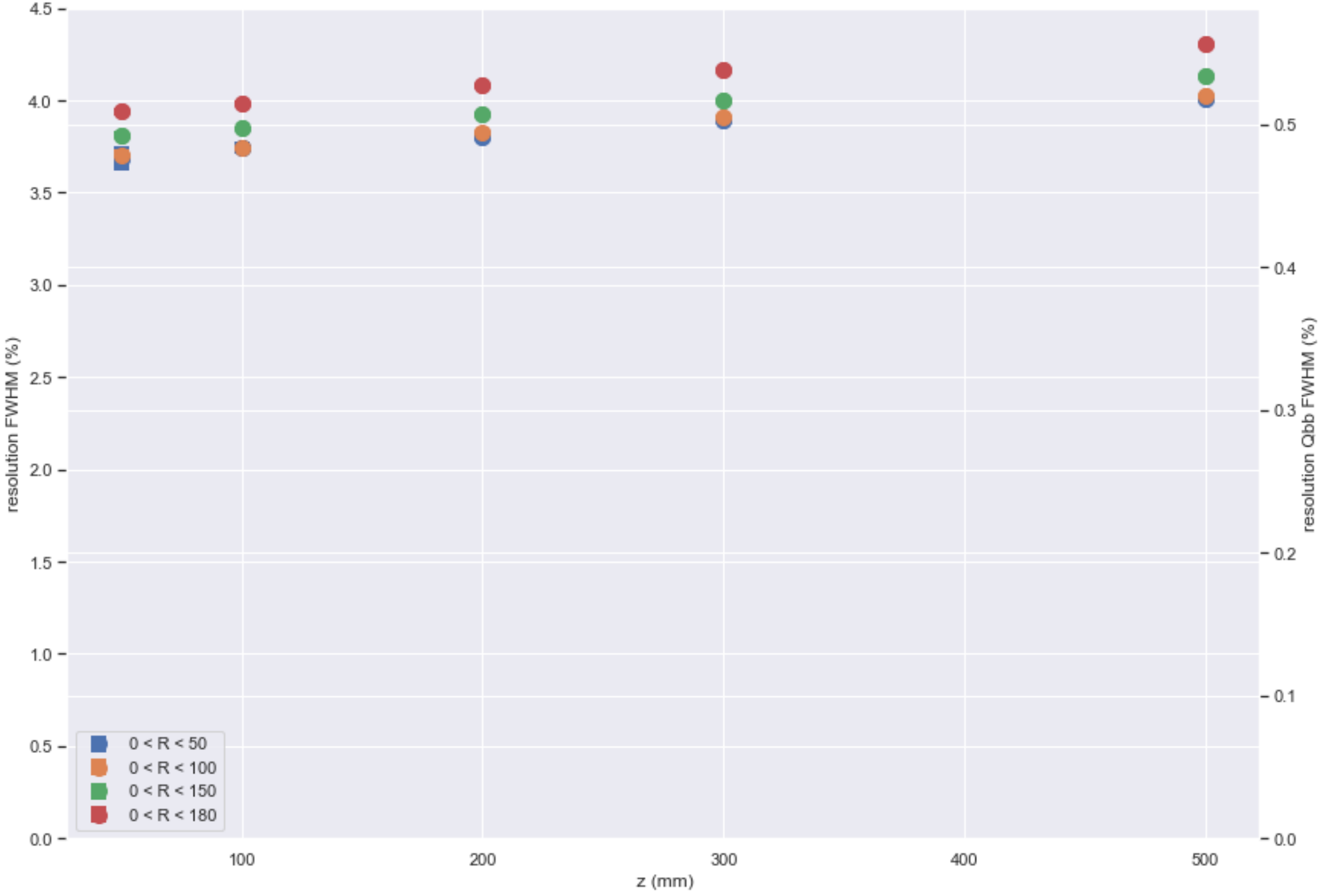
NEXT-WHITE: CALIBRATION WITH KRYPTON-83



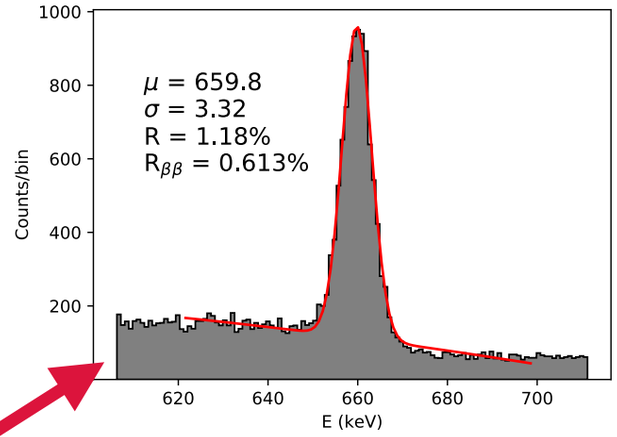


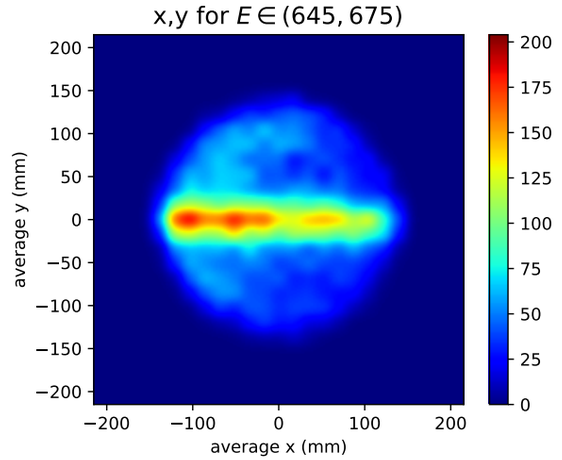
NEXT Collaboration, *JINST* **13** (2018) P10014

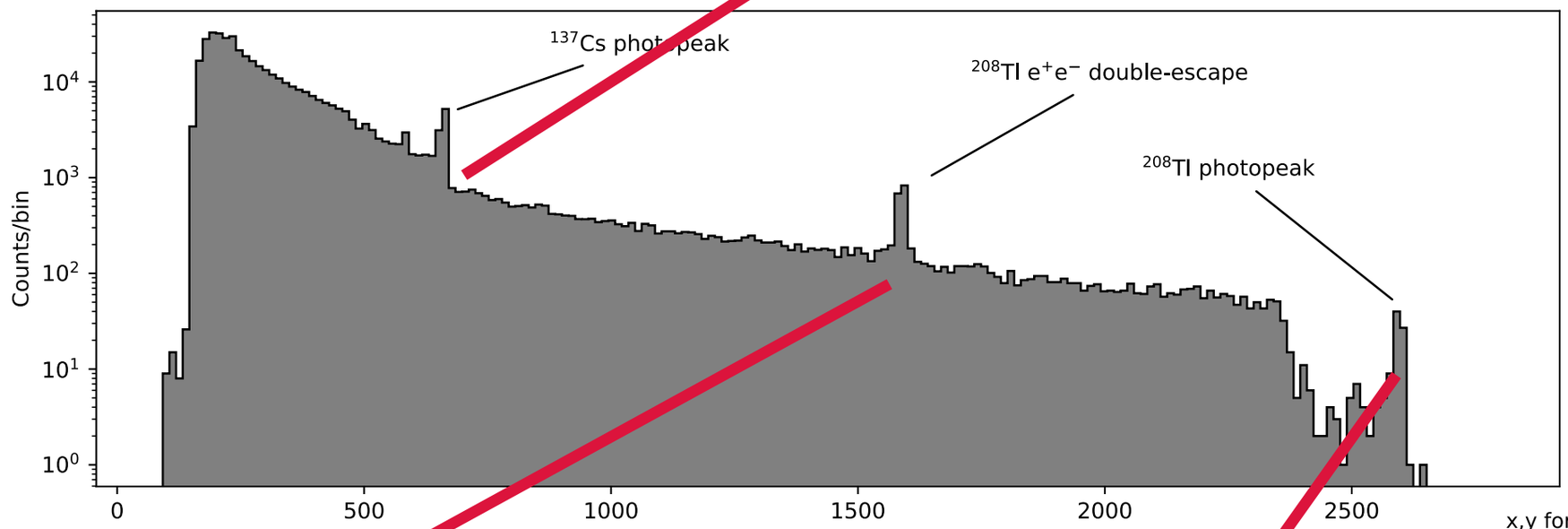
NEXT-WHITE: CALIBRATION WITH KRYPTON-83

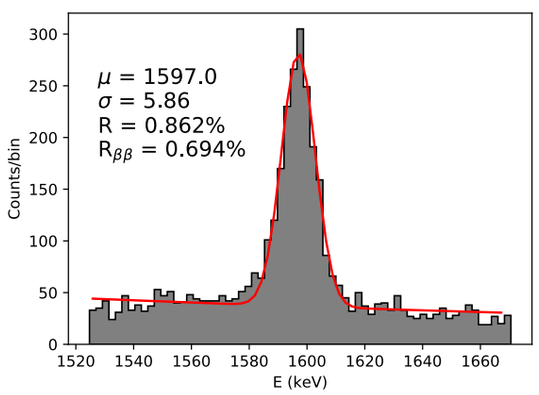


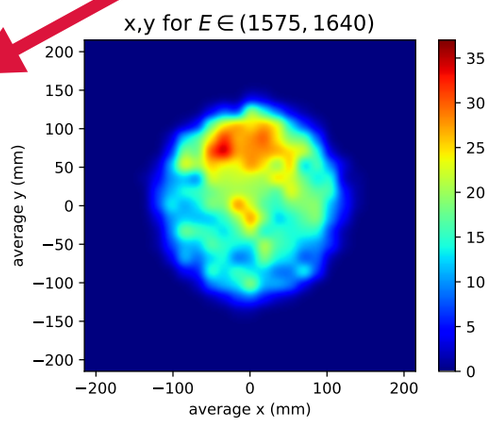
NEXT-WHITE: ENERGY RESOLUTION

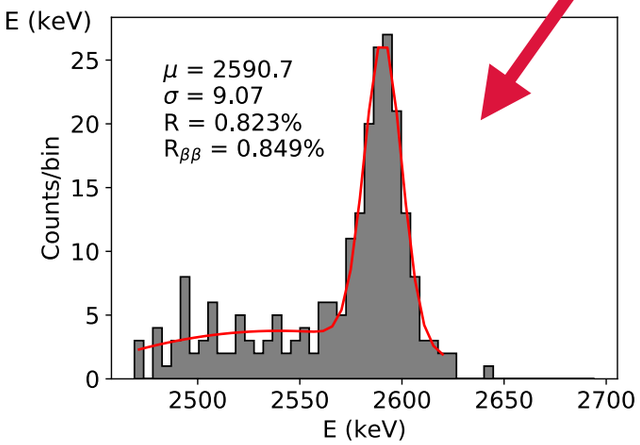


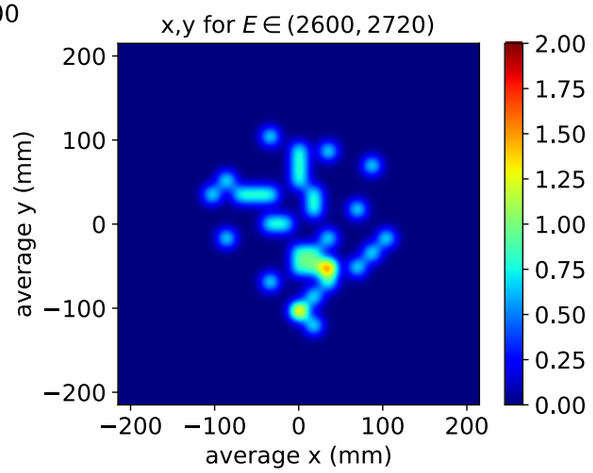






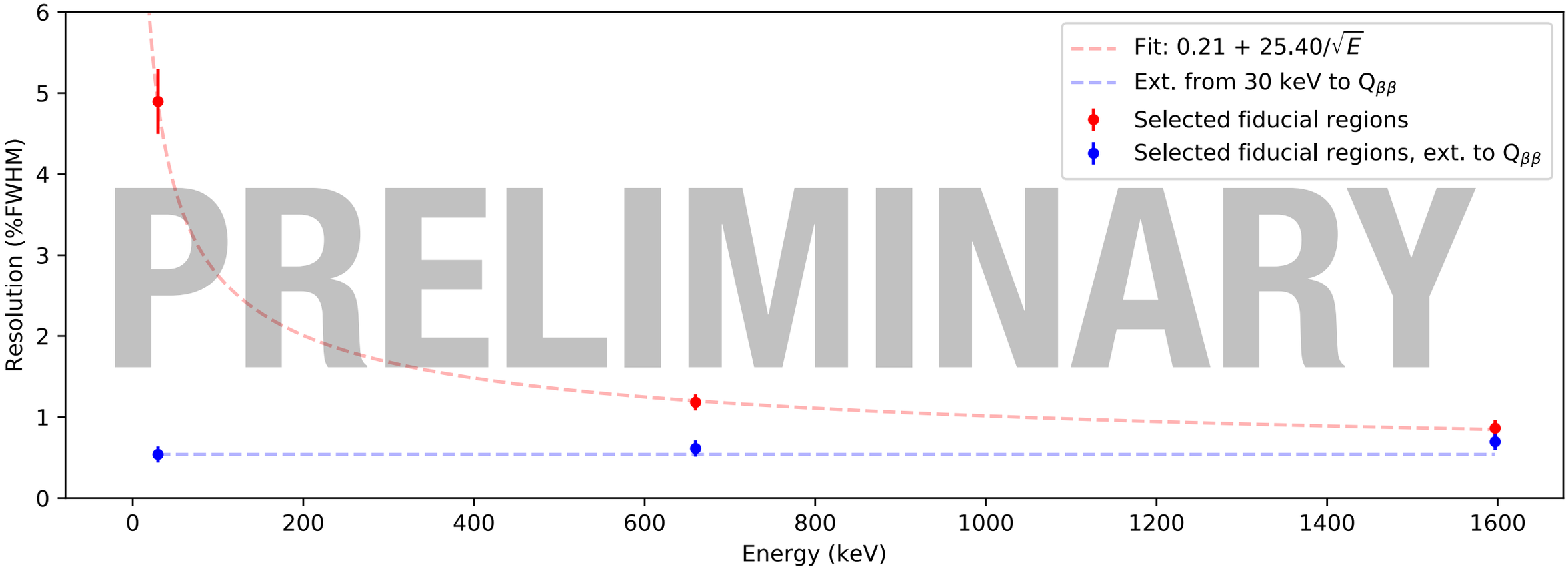






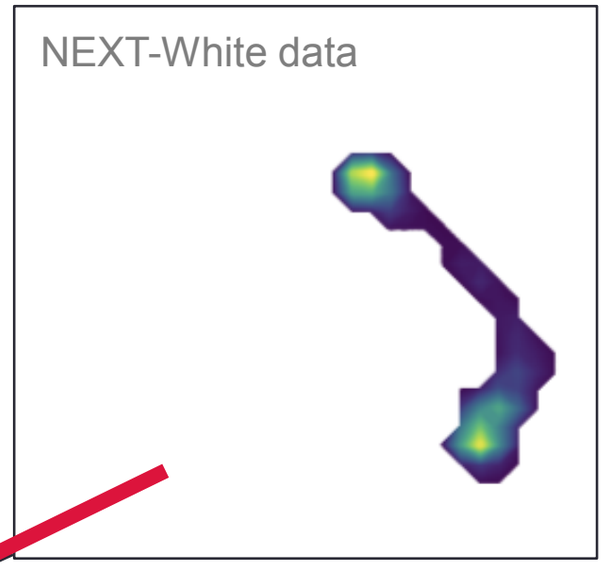
NEXT Collaboration, *JINST* **13** (2018) P10020

NEXT-WHITE: ENERGY RESOLUTION

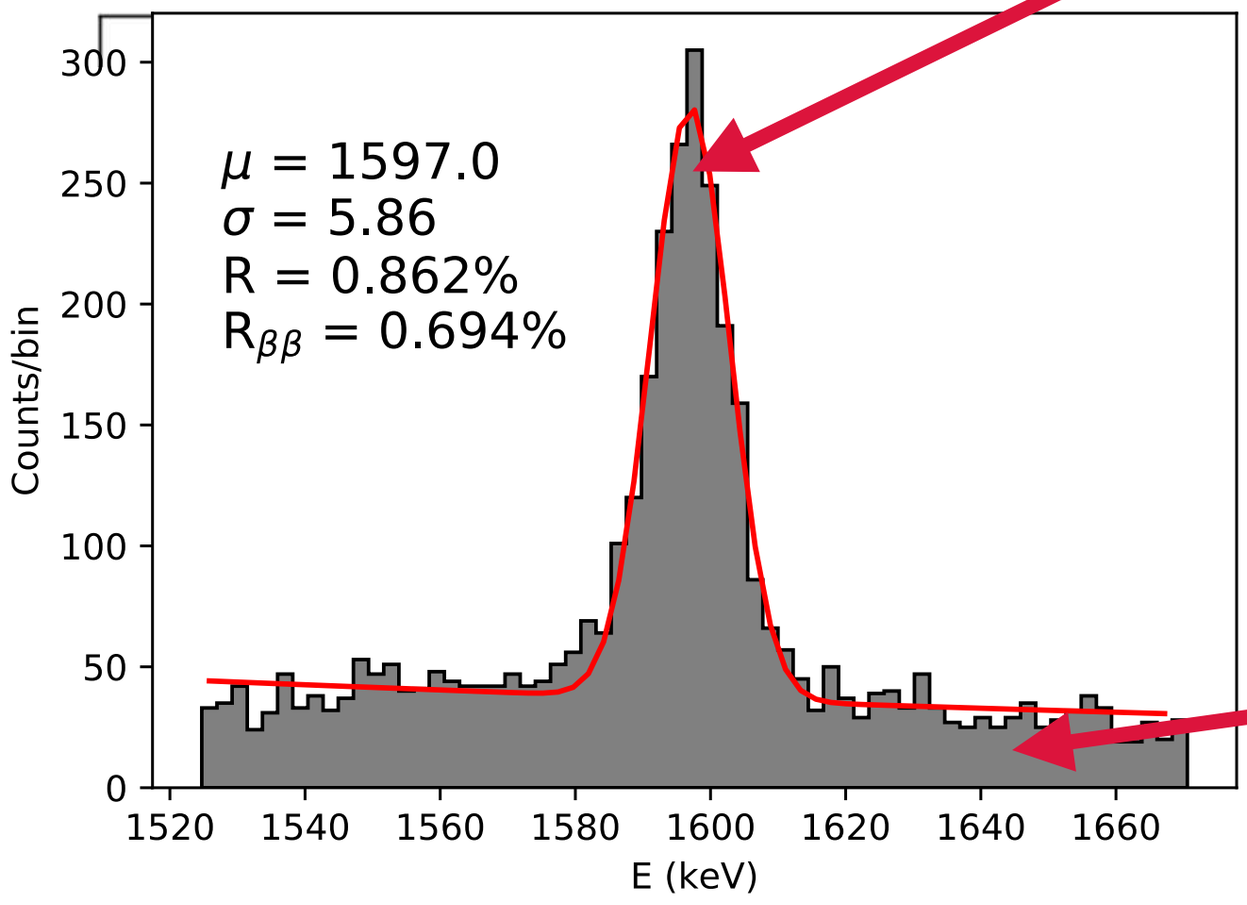


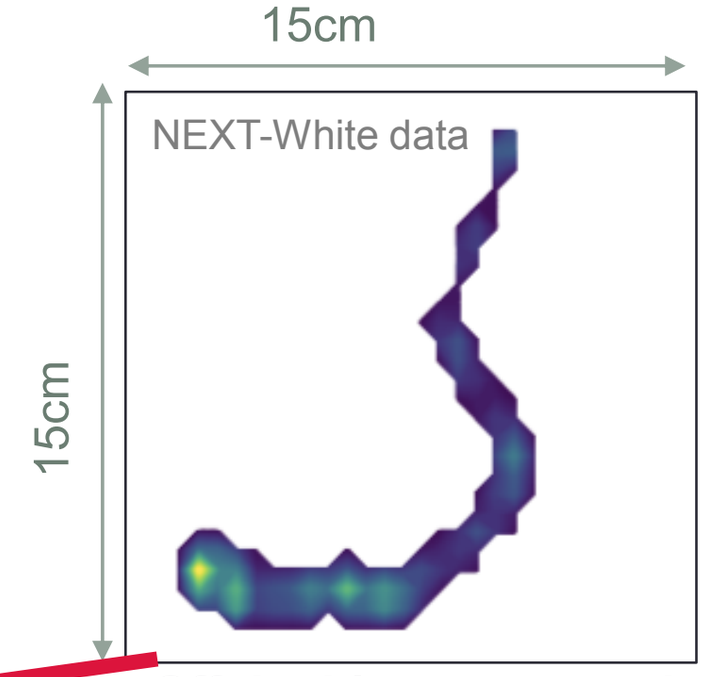
Predicted energy resolution at *Q* value of Xe-136 (2.5 MeV) close to 0.75% FWHM, consistent with the measurement at the photopeak of the Tl-208 gamma (2.6 MeV).

NEXT-WHITE: TOPOLOGICAL RECO



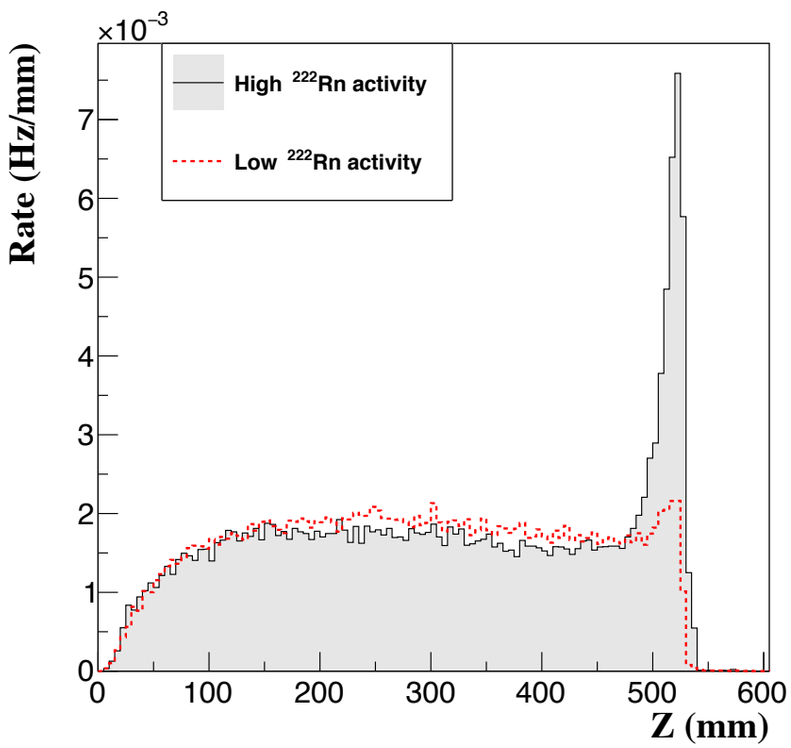
On double escape peak



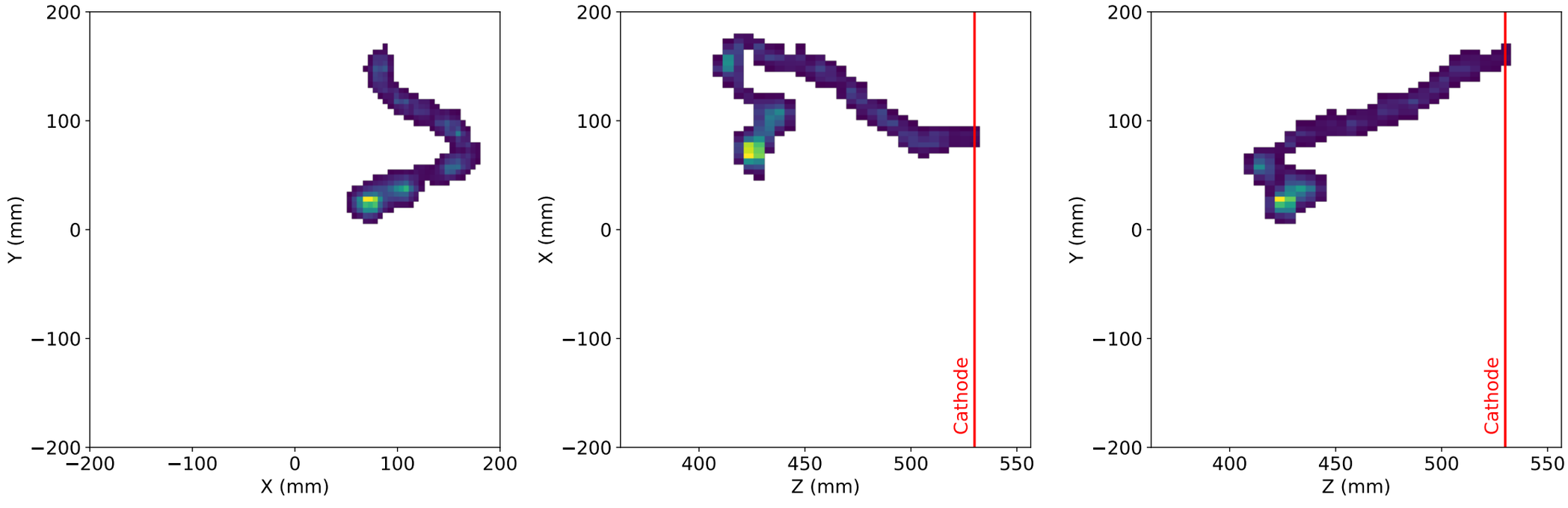


Off double escape peak

NEXT-WHITE: 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.



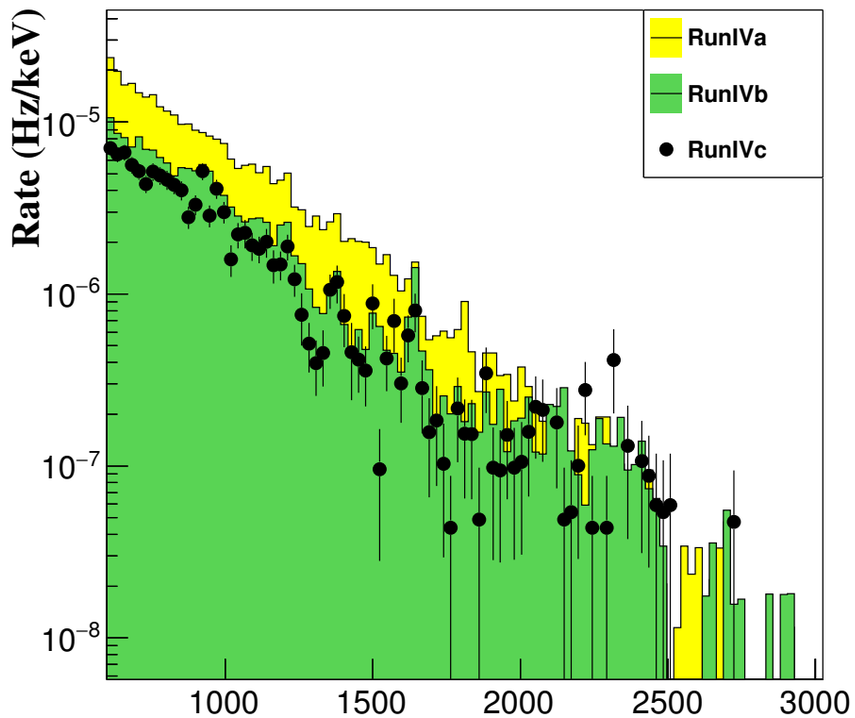
NEXT Collaboration, *JHEP* **1810** (2018) 112

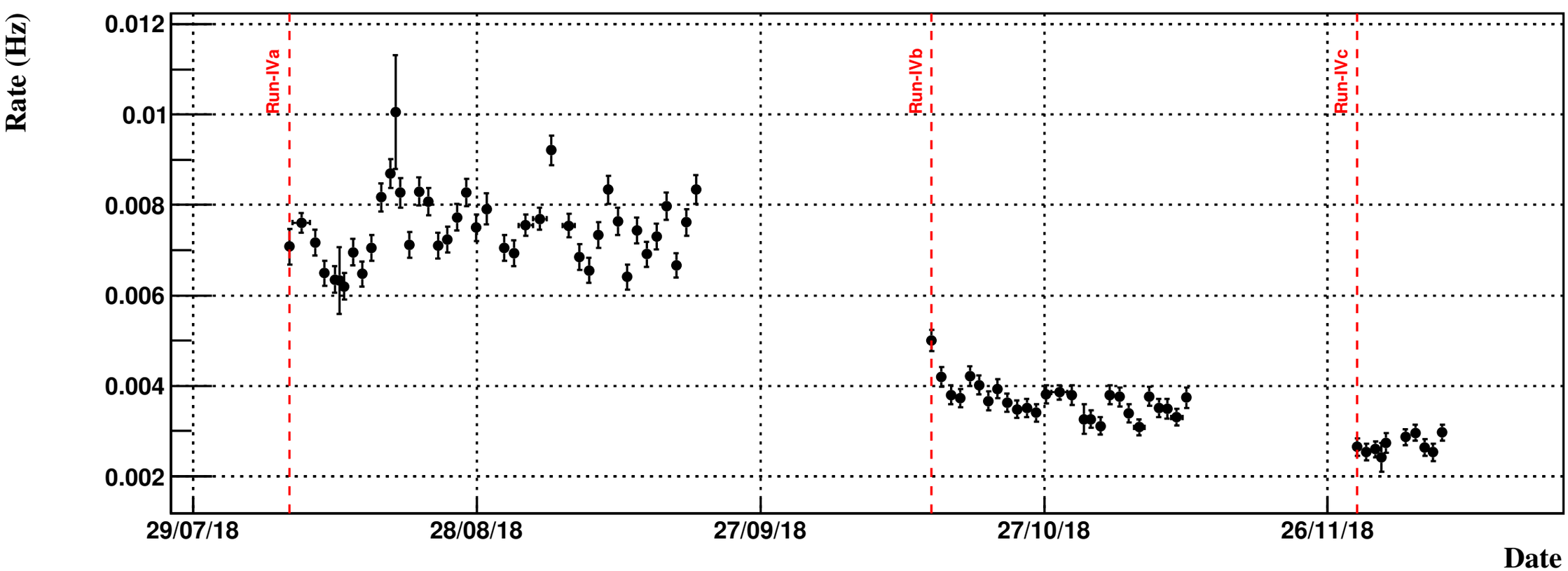
NEXT-WHITE: BACKGROUNDS

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

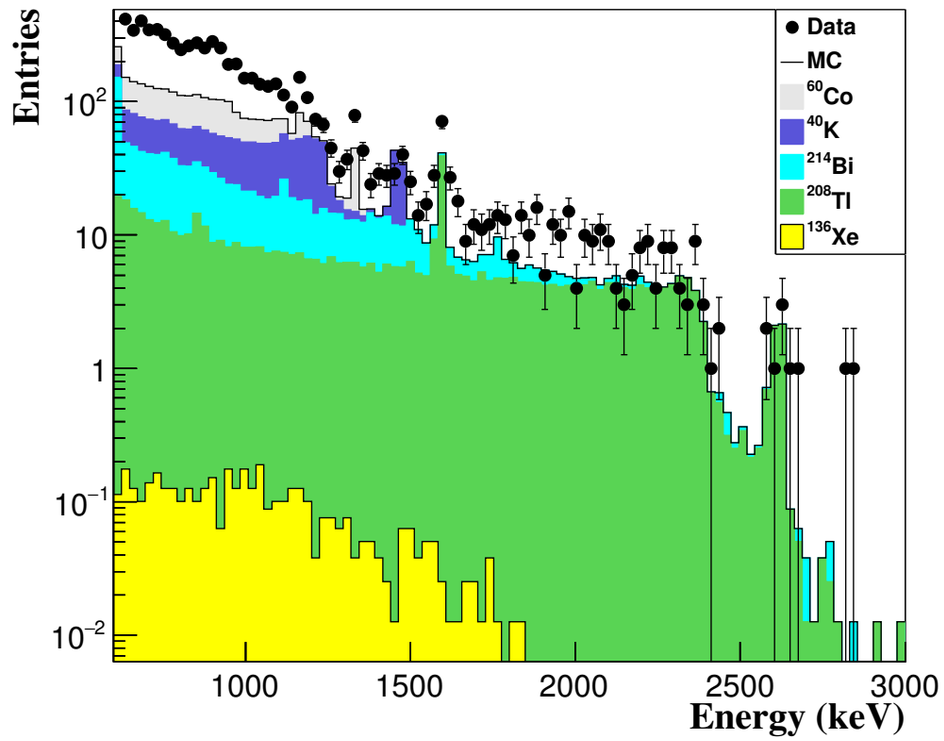
Several improvements in the setup have reduced the background in a factor of ~4 over the last few months:

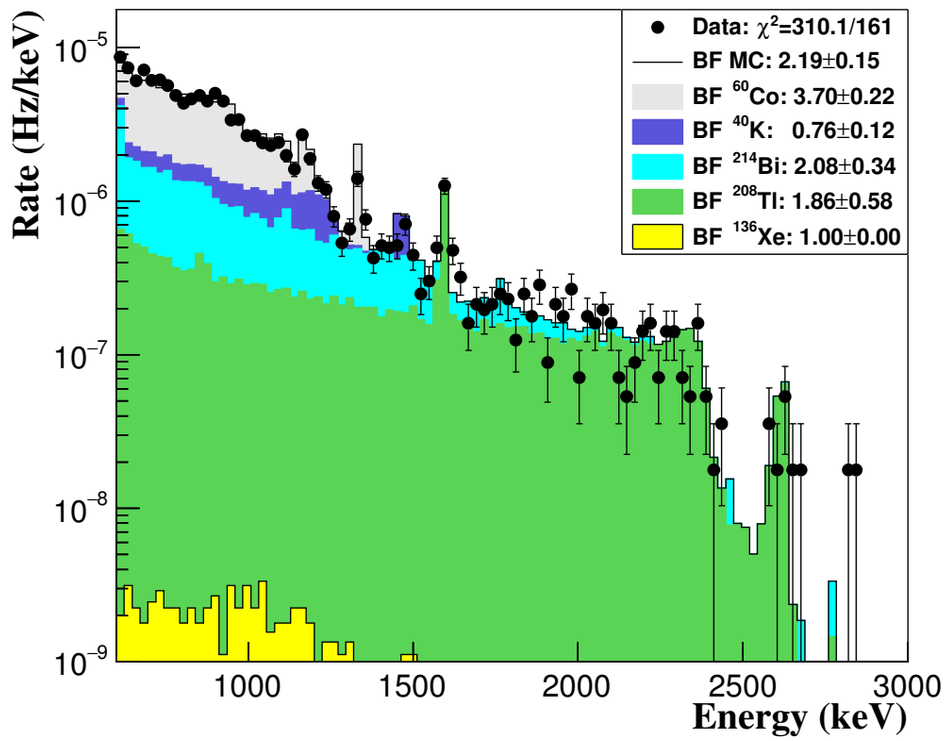
- New radiopure components in field cage.
- Radon-free air introduced in lead shielding.
- Additional layer of shielding added.

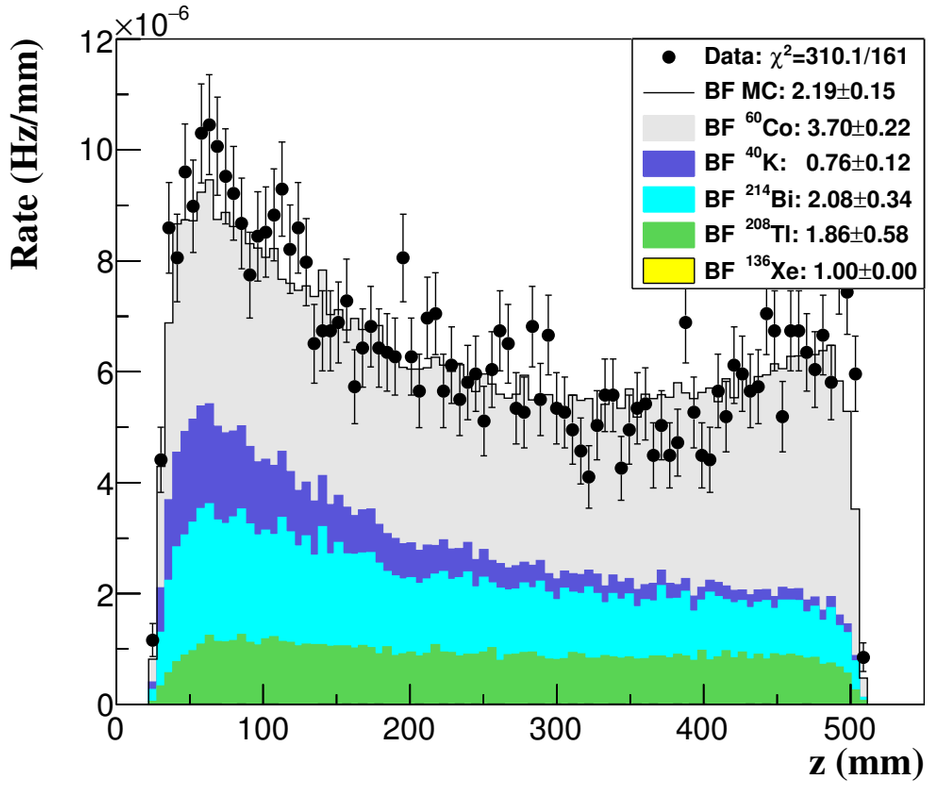


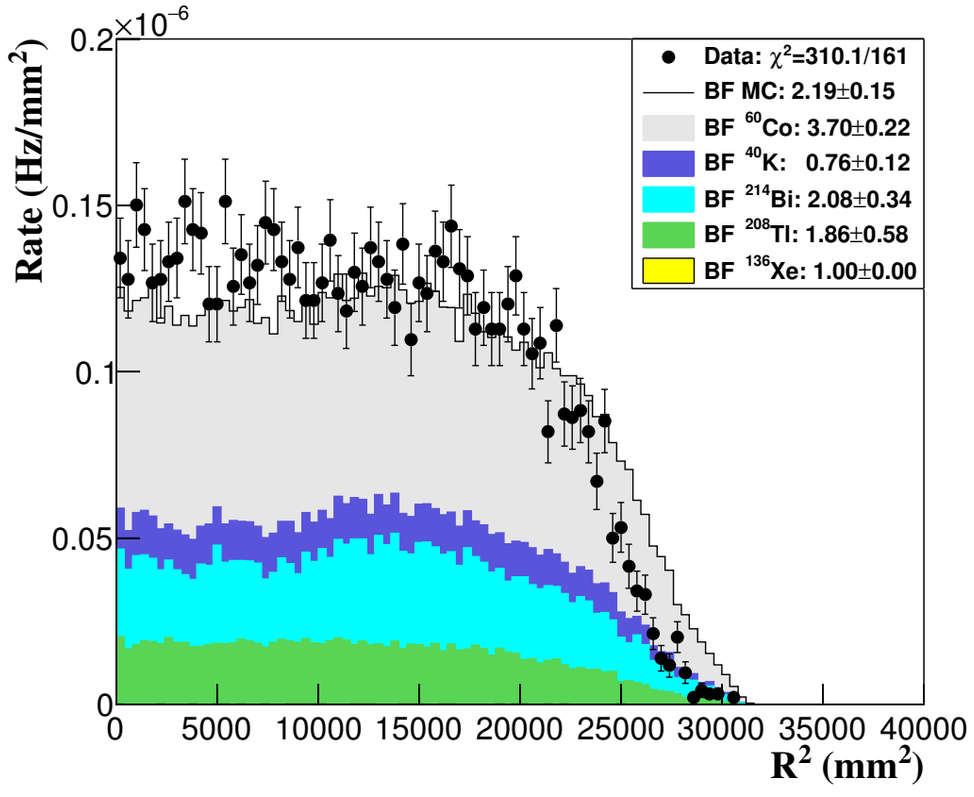


NEXT-WHITE: BACKGROUNDS

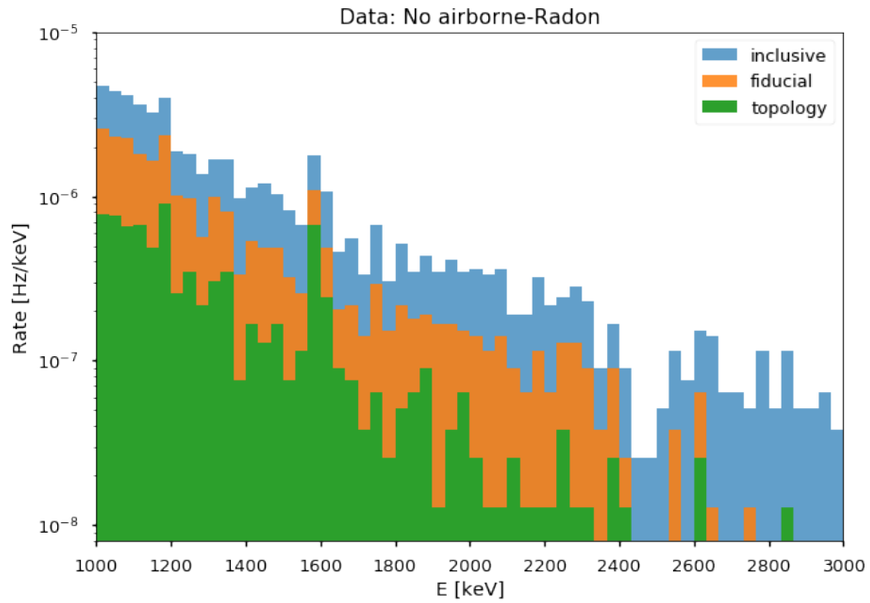


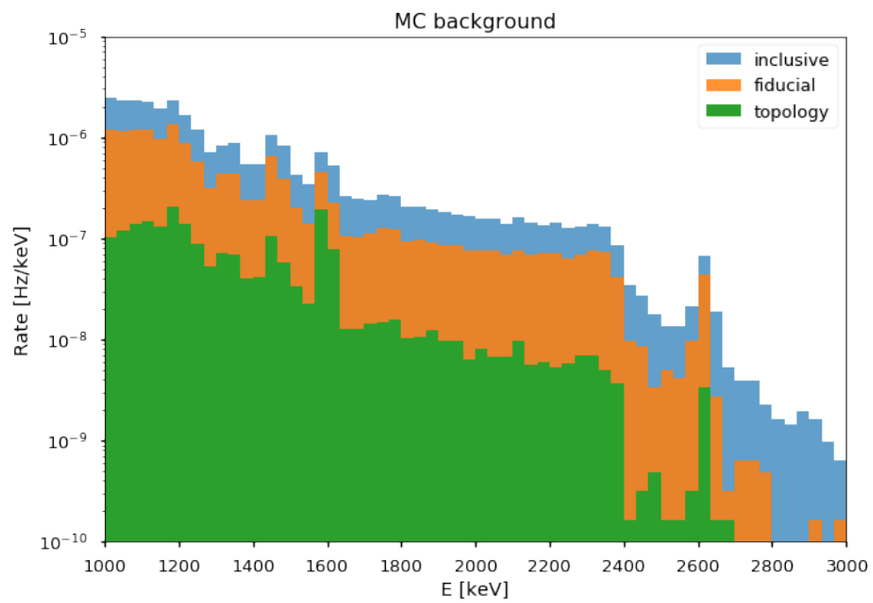


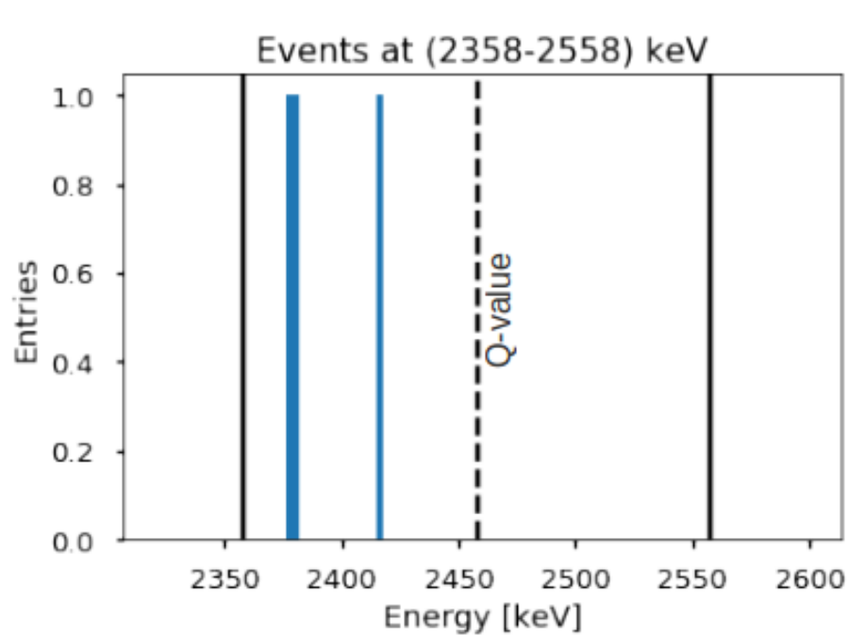


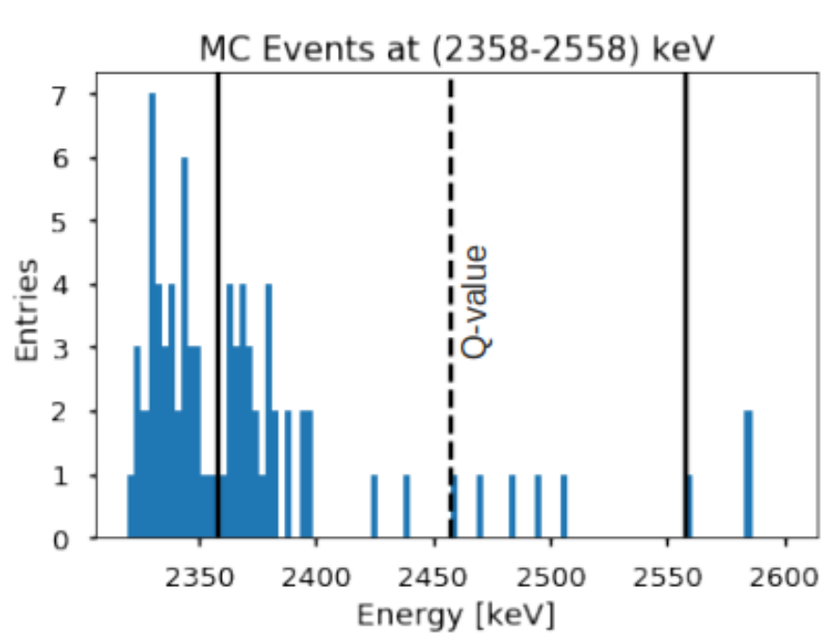


NEXT-WHITE: BACKGROUNDS



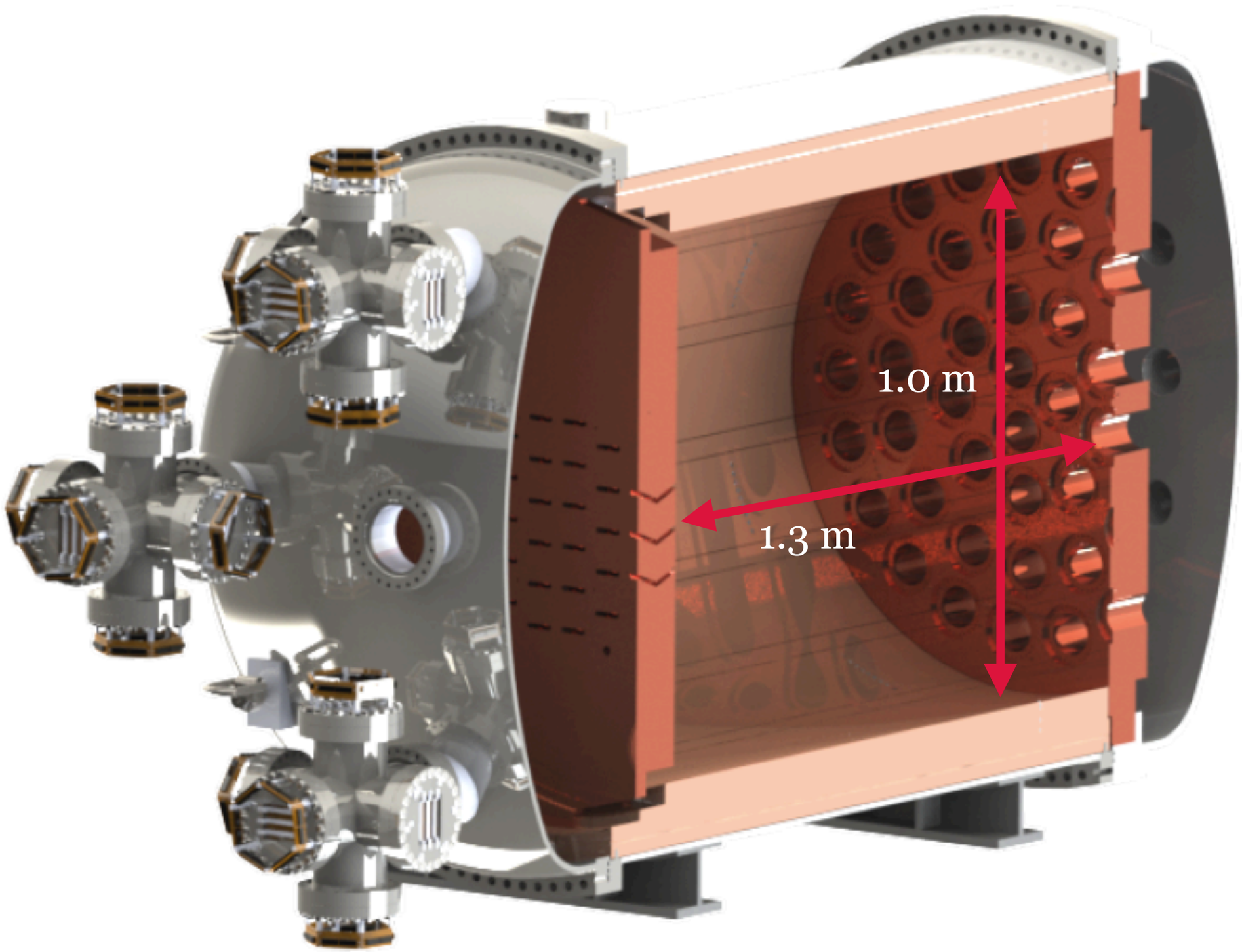




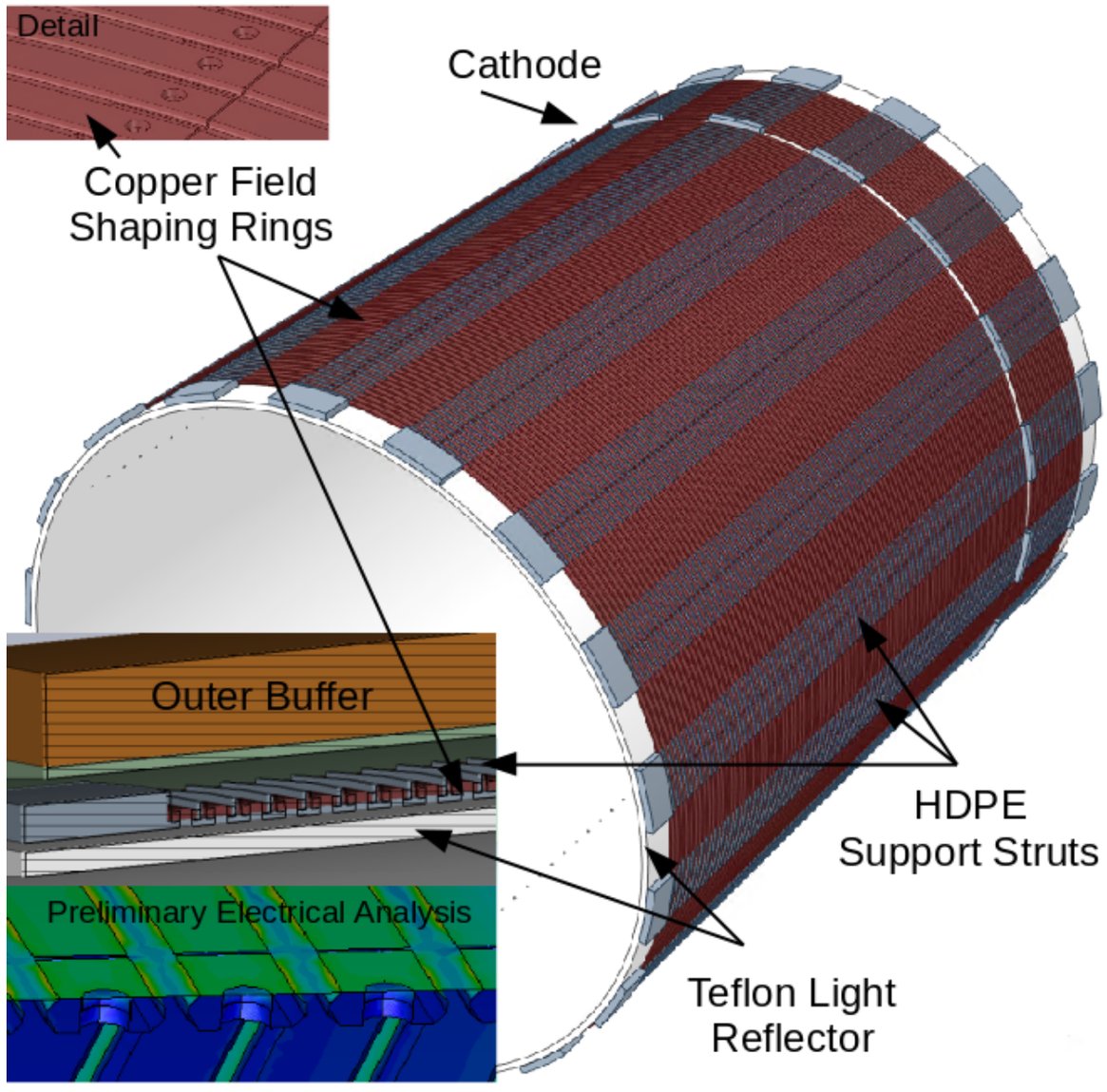


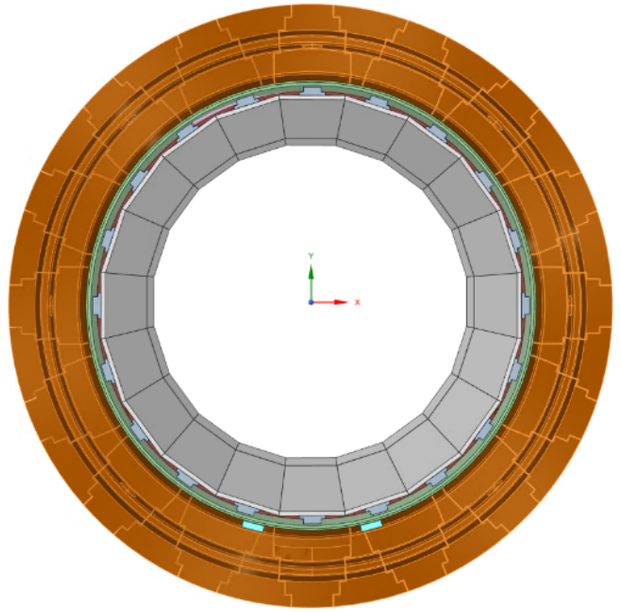
Data-MC comparison of background distributions in the energy region of interest for neutrinoless double beta decay searches.

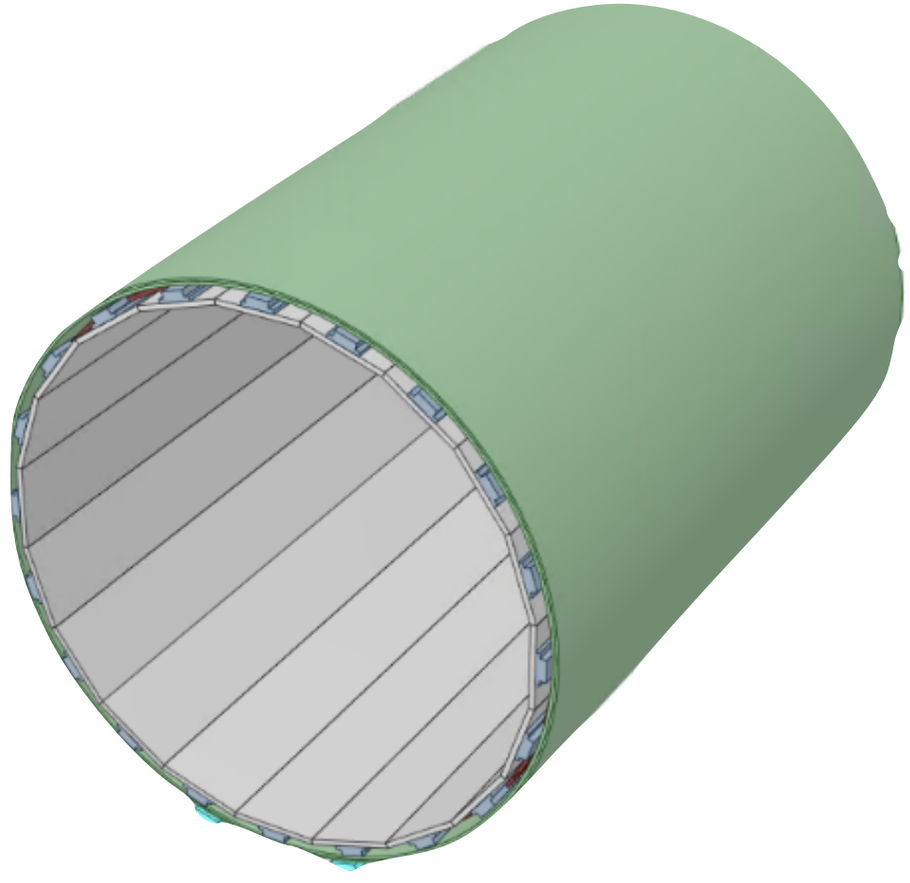
NEXT-100



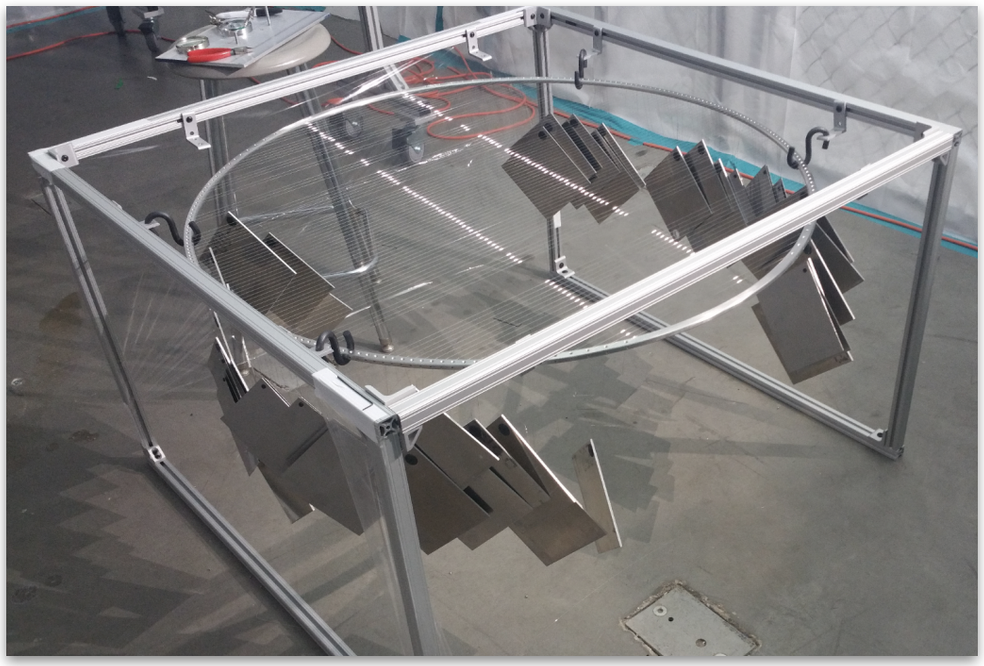
NEXT-100

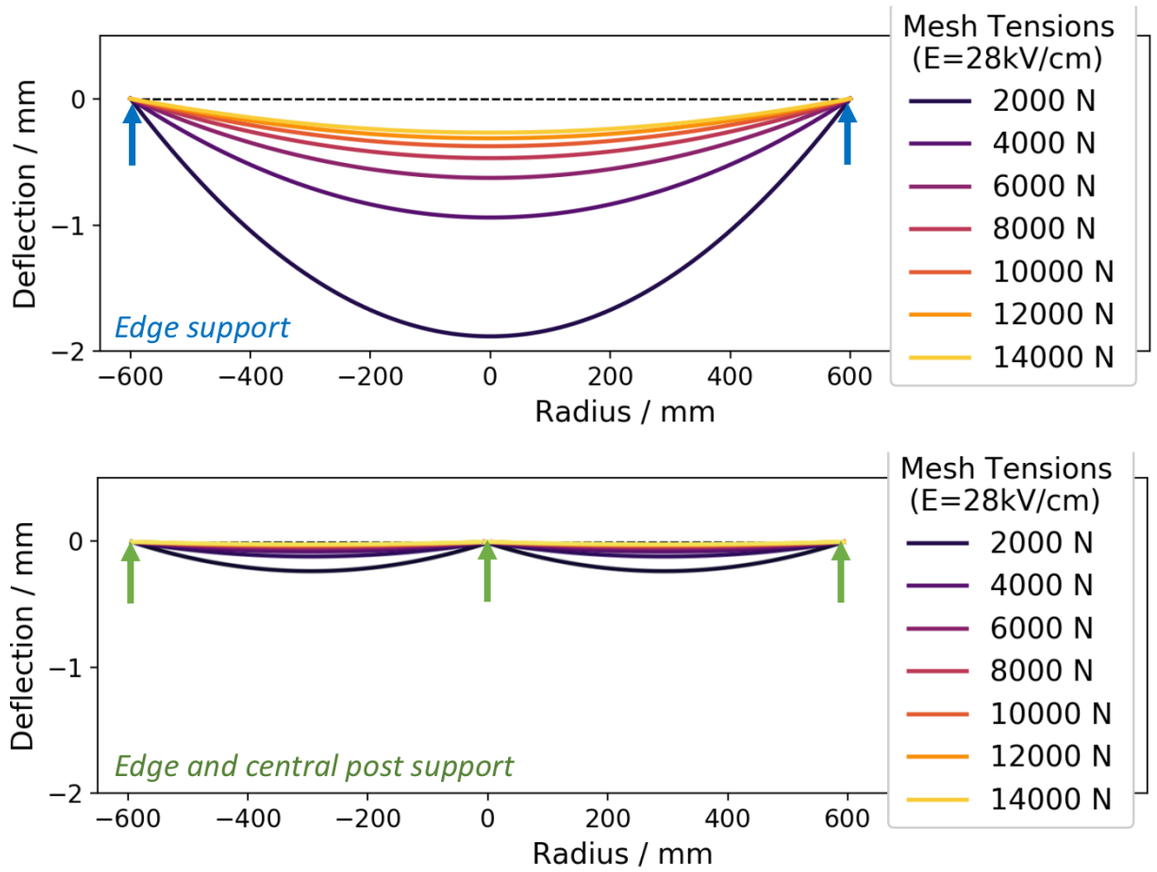

Detail
Cathode
Copper Field
Shaping Rings
Outer Buffer
Preliminary Electrical Analysis
HDPE
Support Struts
Teflon Light
Reflector

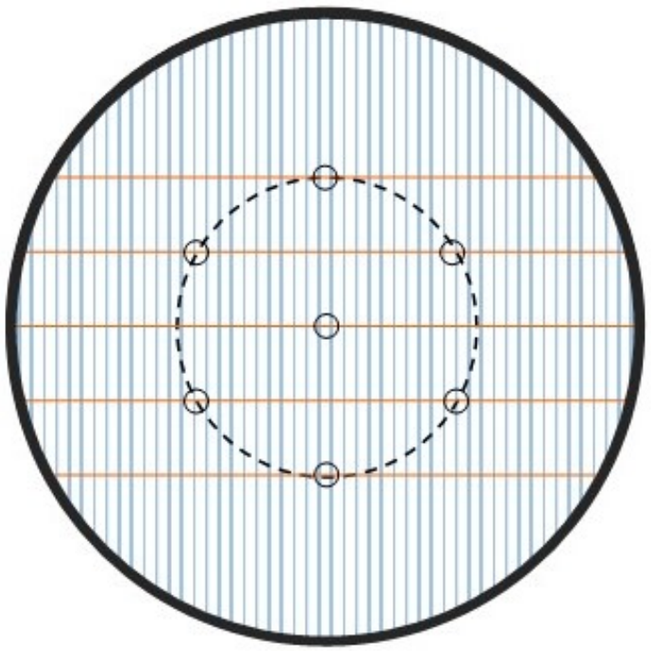


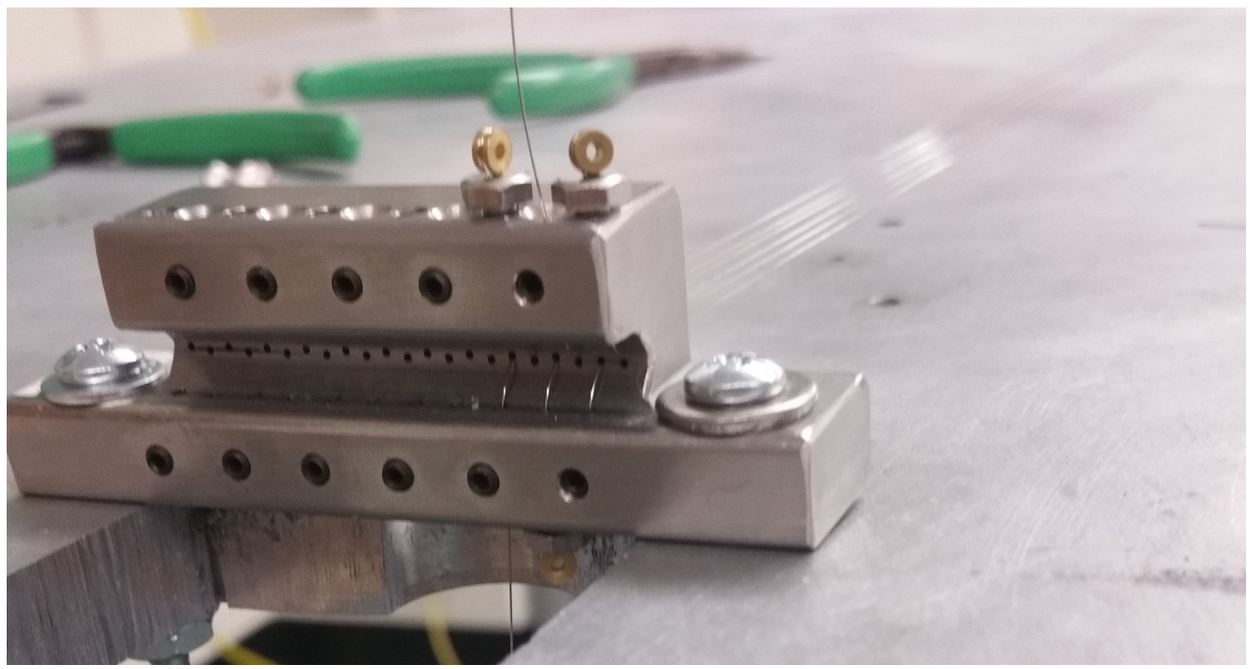


NEXT-100



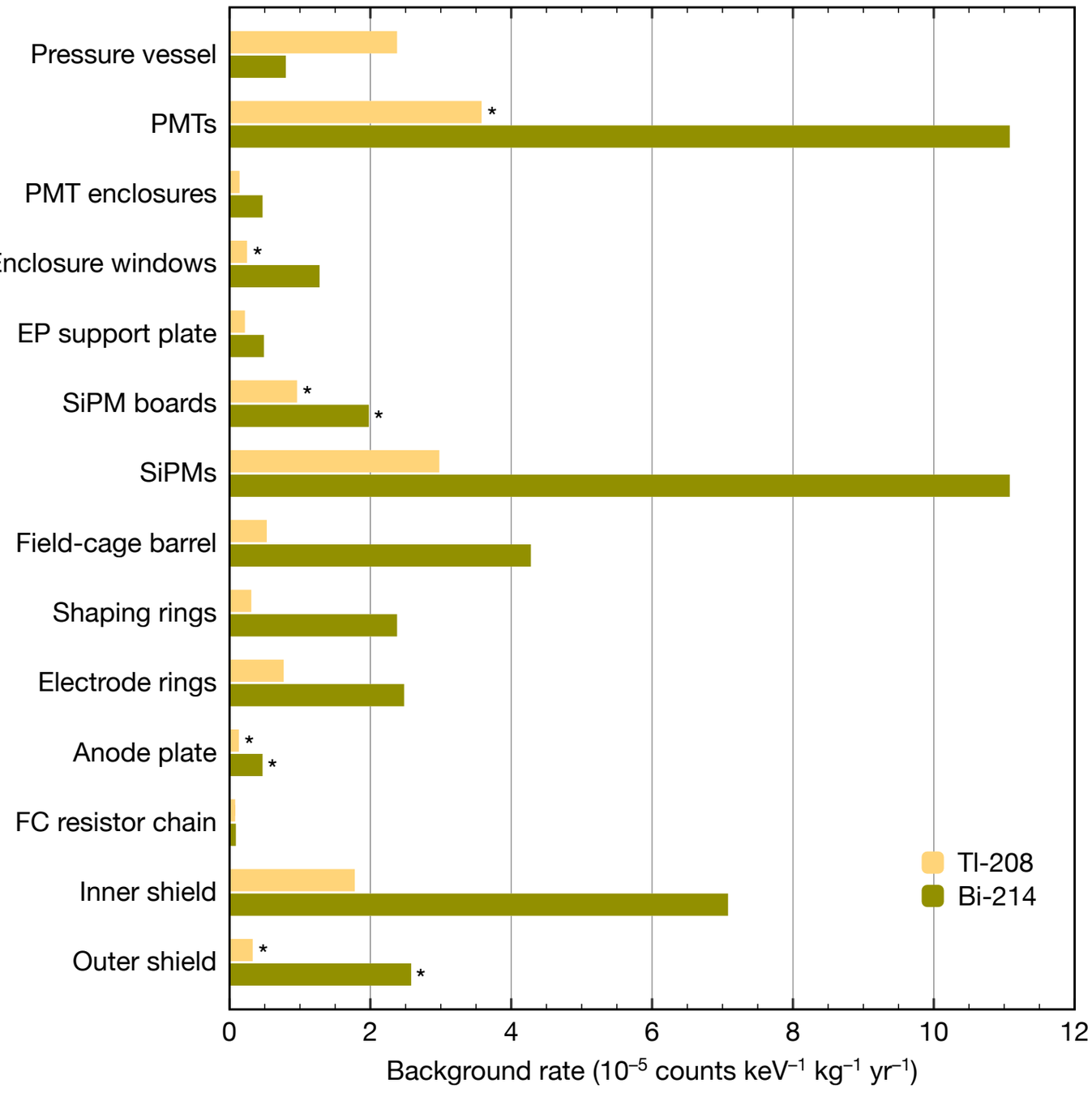

Mesh Tensions
(E=28kV/cm)
2000 N
4000 N
6000 N
8000 N
10000 N
12000 N
14000 N
Deflection / mm
0
−1
−2
Edge support
−600
−400
−200
0
200
400
600
Radius / mm
Mesh Tensions
(E=28kV/cm)
2000 N
4000 N
6000 N
8000 N
10000 N
12000 N
14000 N
Deflection / mm
0
−1
−2
Edge and central post support
−600
−400
−200
0
200
400
600
Radius / mm

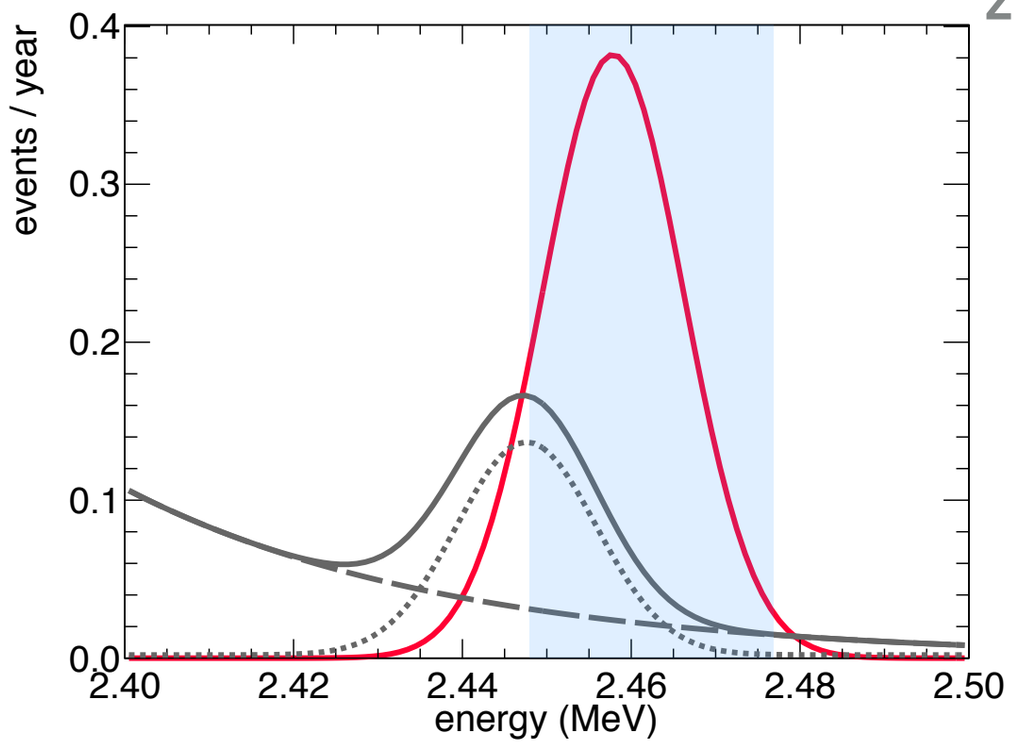


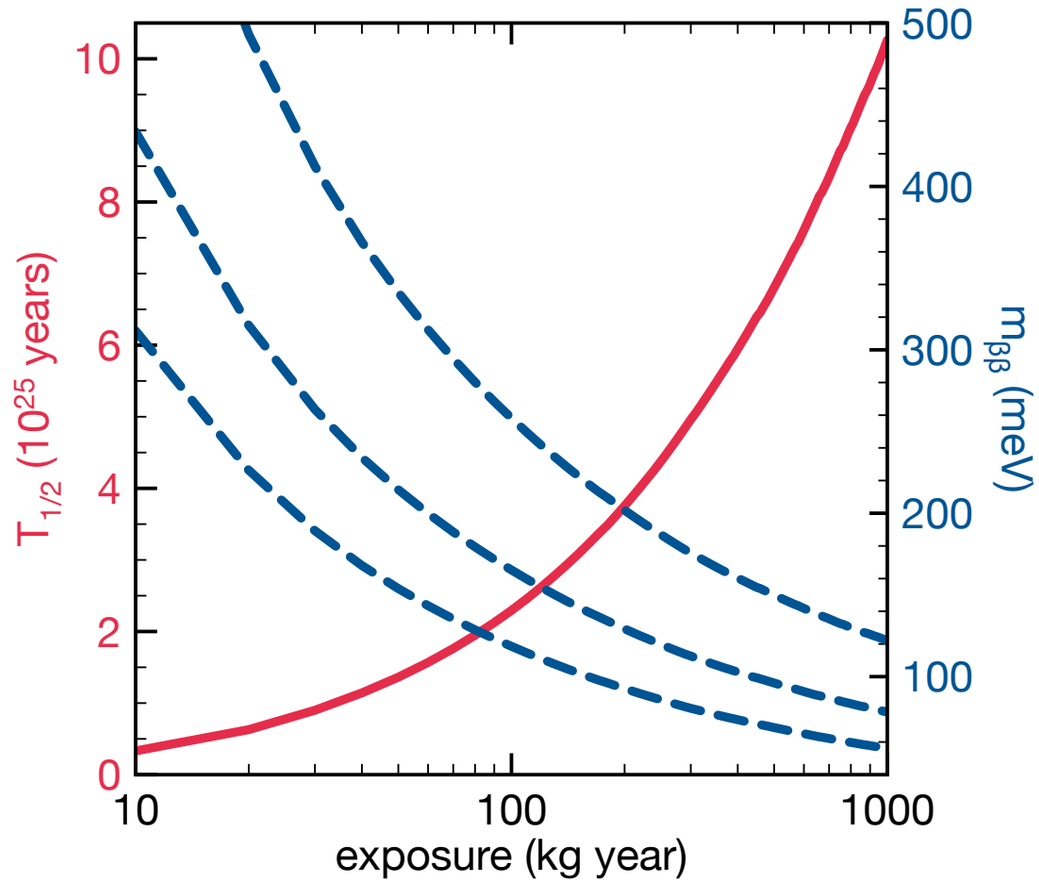


NEXT-100

NEXT-100: SENSITIVITY







NEXT Collaboration, *JHEP* **1605** (2015) 159

TOWARDS THE TON SCALE

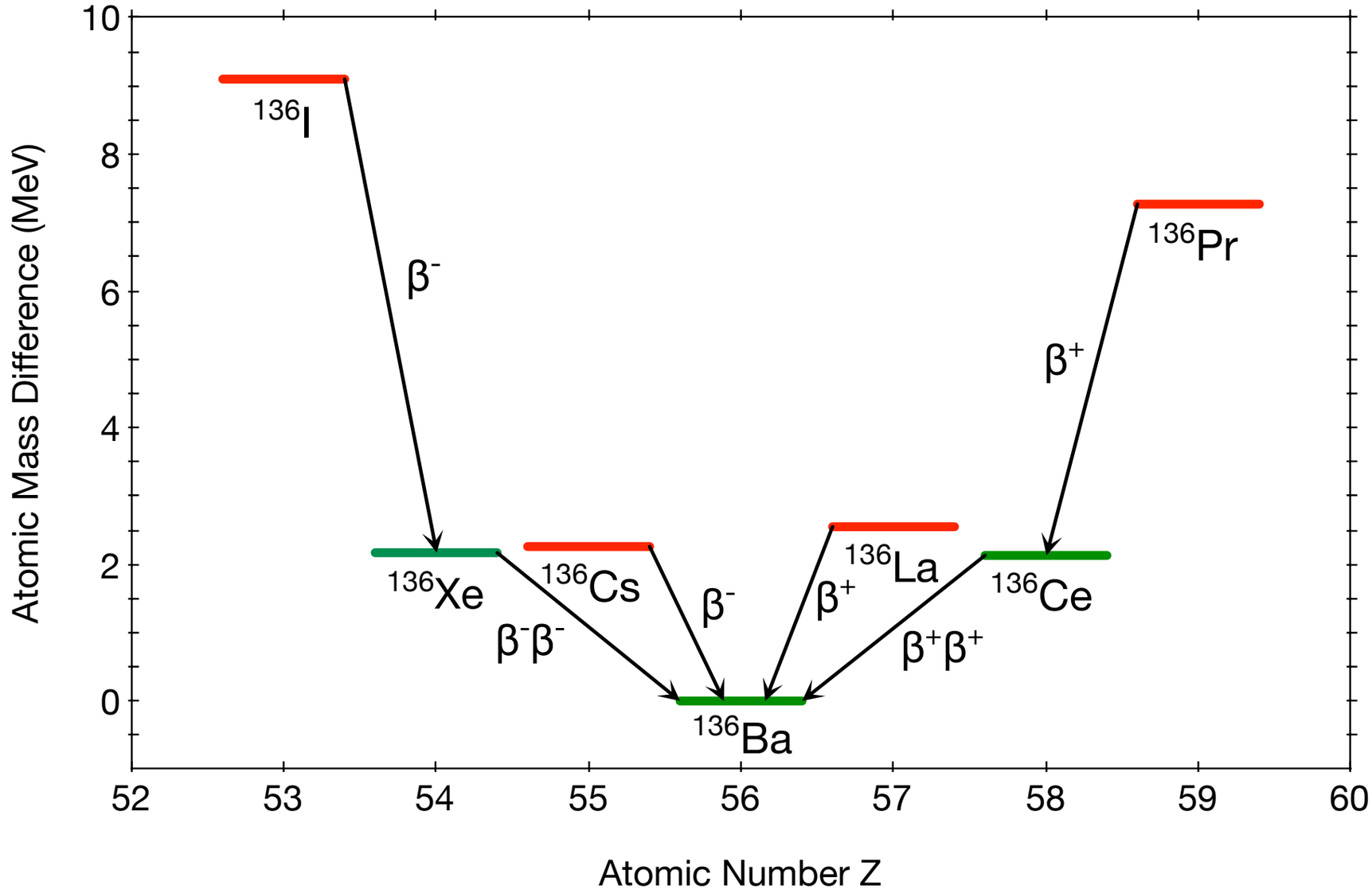
NEXT-100 should demonstrate a background rate competitive with HPGe detectors: a few counts per ton and year in ROI.

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.

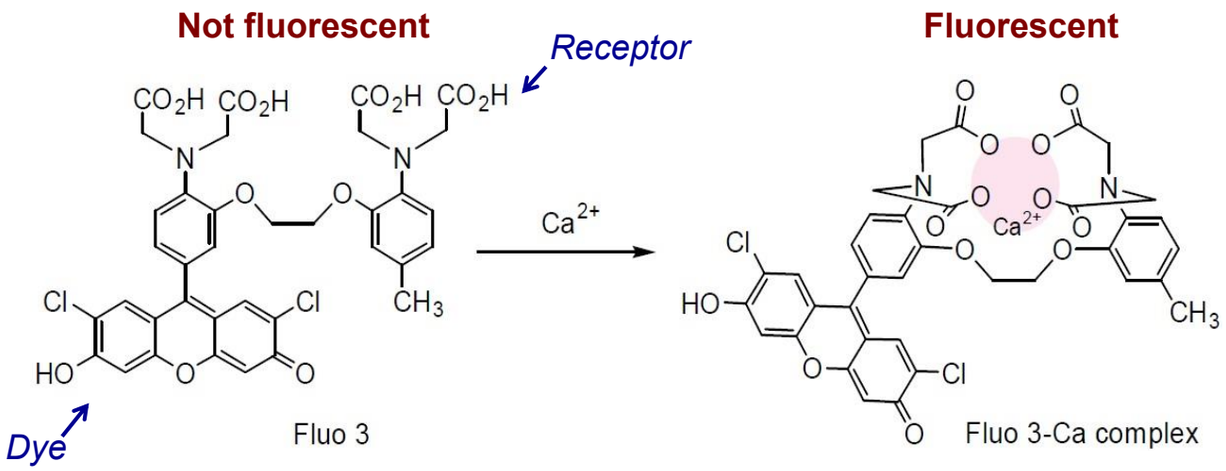
Last but not least: gaseous xenon could make possible a true background-free experiment via tagging of the barium decay product.

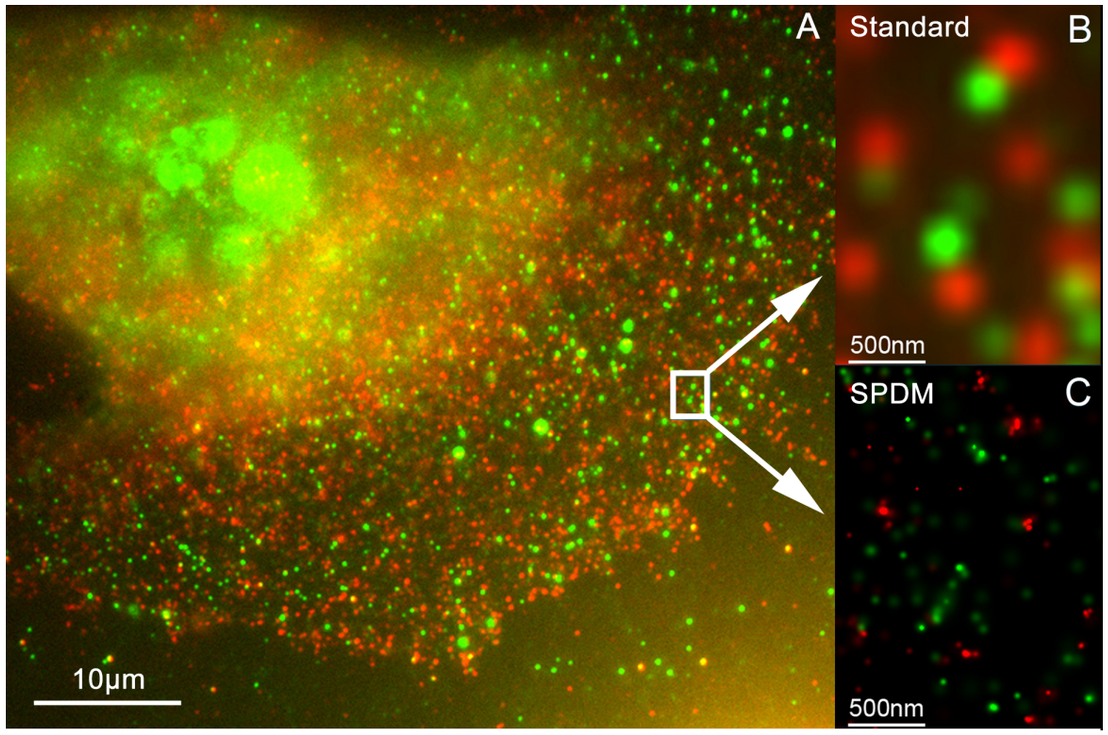
TOWARDS THE TON SCALE: BA TAGGING



Tagging of the Ba ion produced in a double beta decay would result in a *zero-background* experiment. It has been actively explored in gaseous and liquid xenon for 15+ years.

TOWARDS THE TON SCALE: BA TAGGING



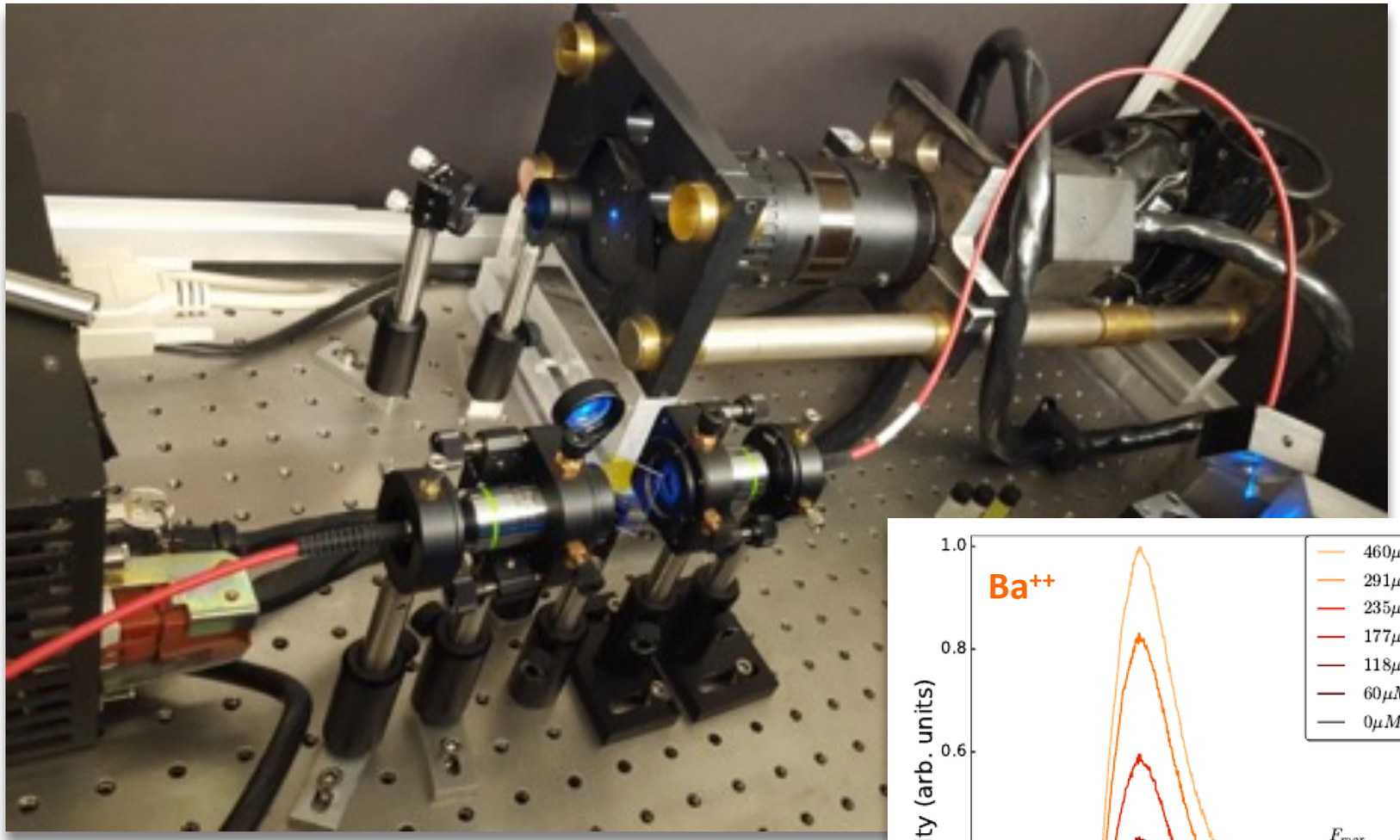


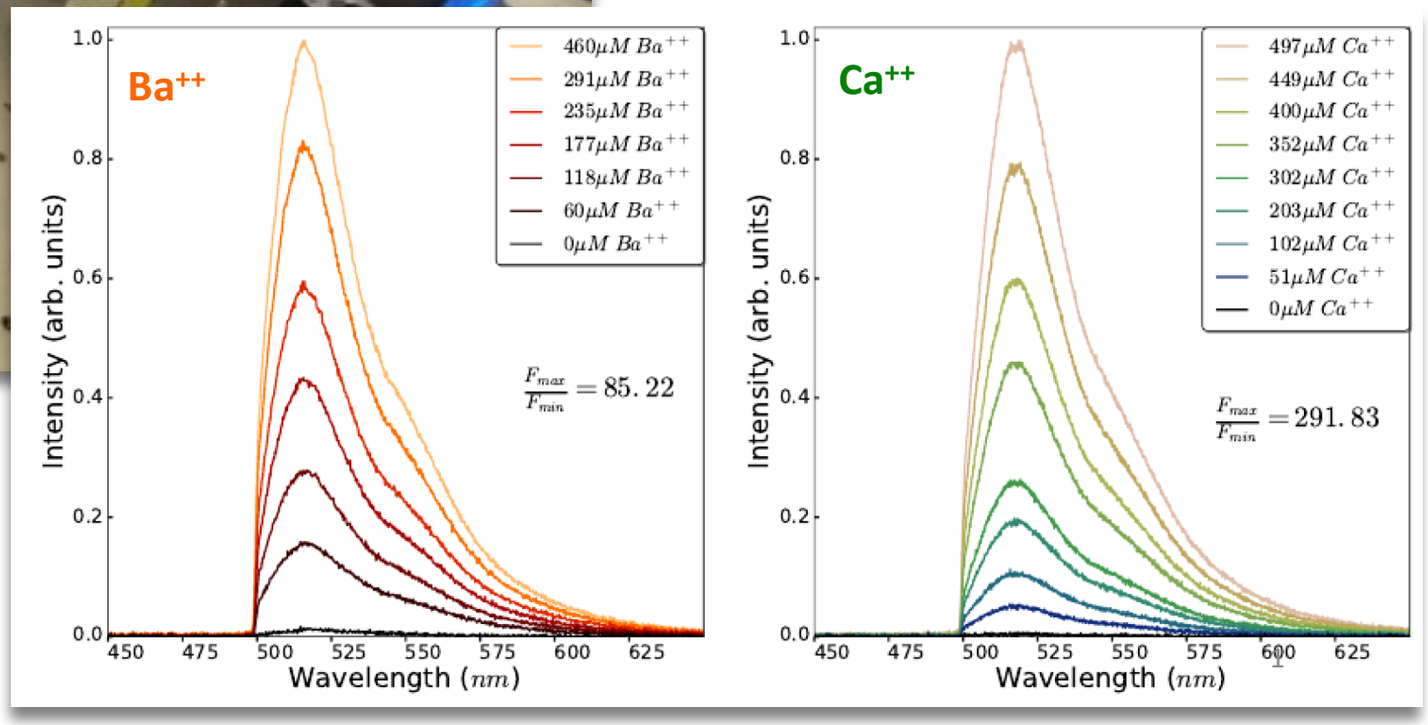
SMFI is a technique from biochemistry with proven single-ion resolution that was awarded a Nobel prize in chemistry in 2014. A non-fluorescent molecule becomes fluorescent upon chelation with an incident ion.

Calcium and barium are congeners: many dyes developed for Ca are also expected to respond to Ba. Can we use SMFI to identify a single Ba ion in a xenon gas volume?

D.R. Nygren, *J. Phys. Conf. Ser.* **650** (2015) 012002

TOWARDS THE TON SCALE: BA TAGGING





Strong fluorescence from Fluo3 and Fluo4 under chelation with Ba++ ions.

Jones, McDonald, Nygren, *JINST* **11** (2016) P12011

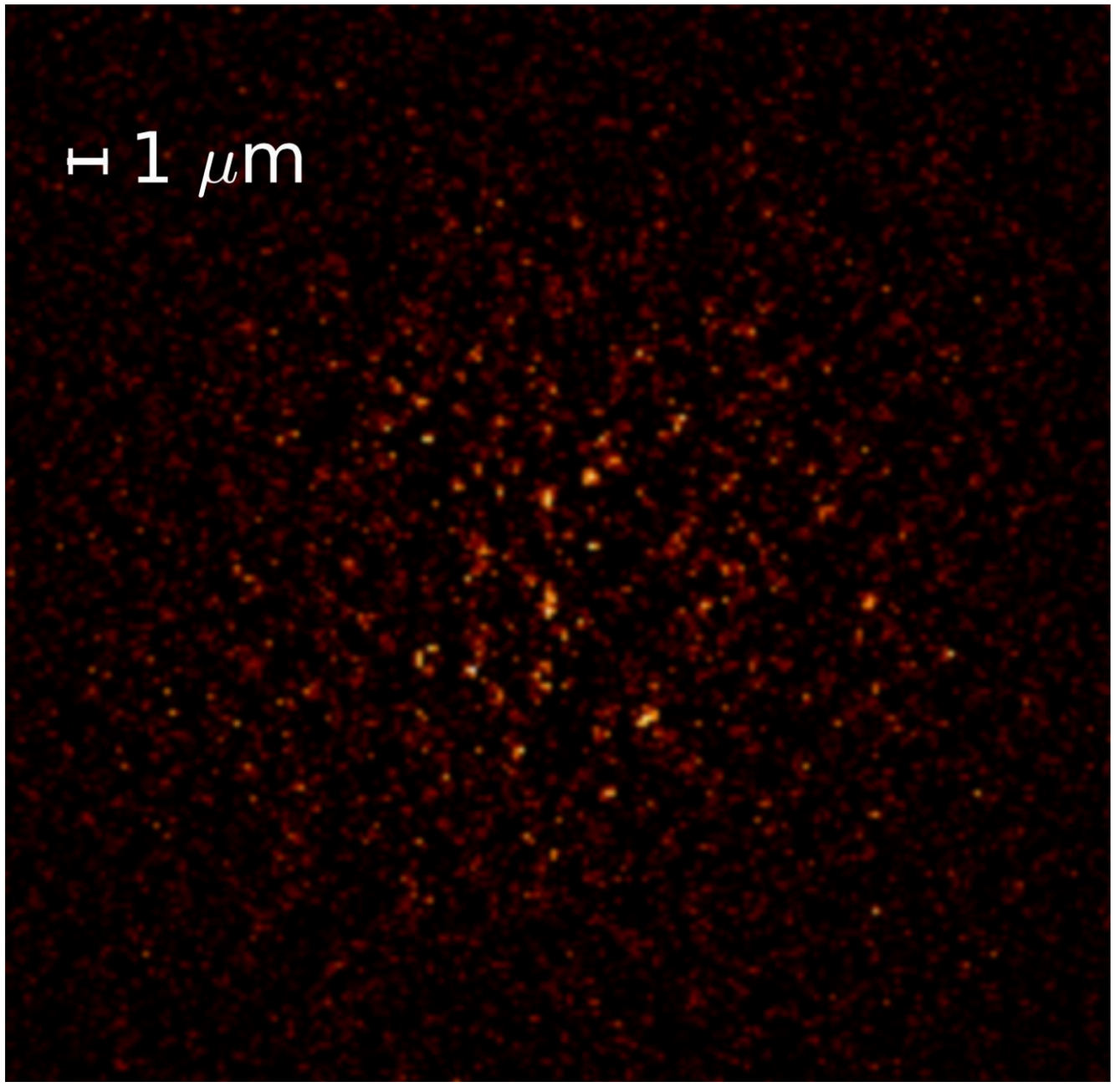
TOWARDS THE TON SCALE: BA TAGGING

The image shows a weak solution of barium perchlorate salt on a total internal reflection microscope developed at UTA.

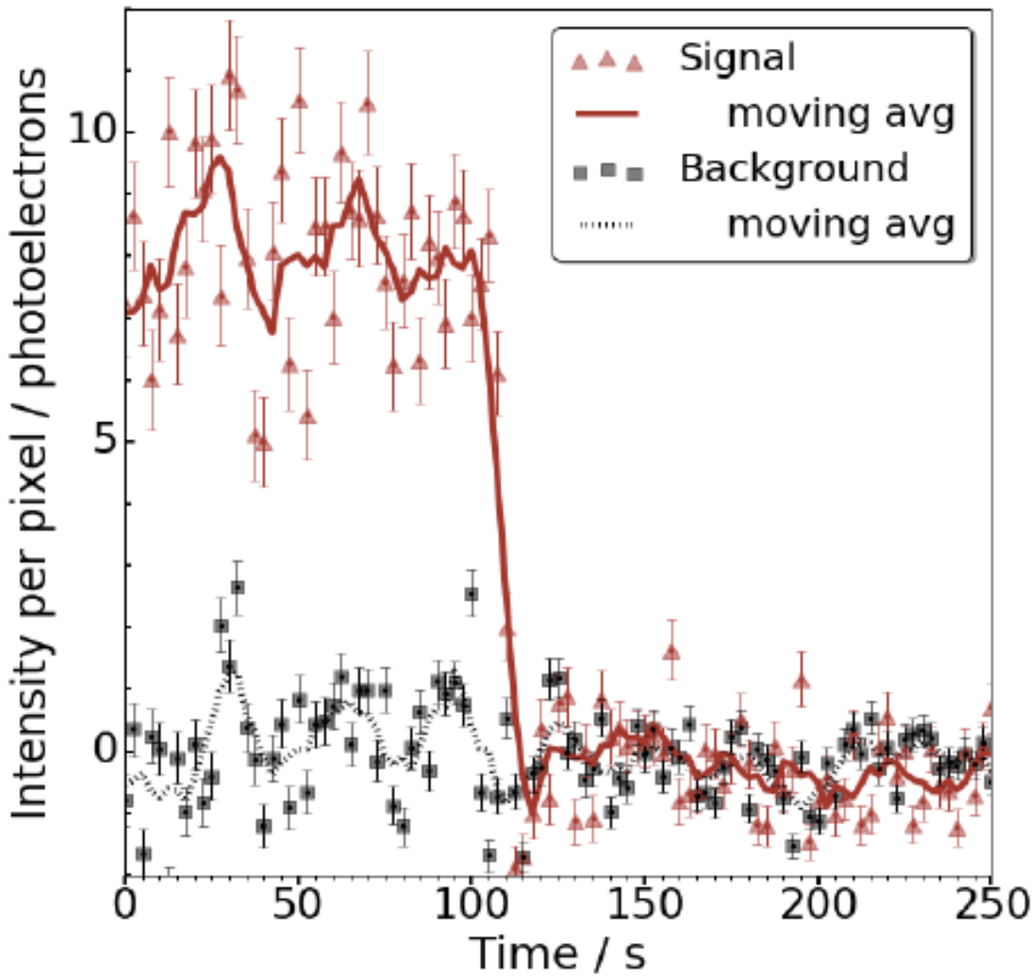
Each spot is a single barium ion.

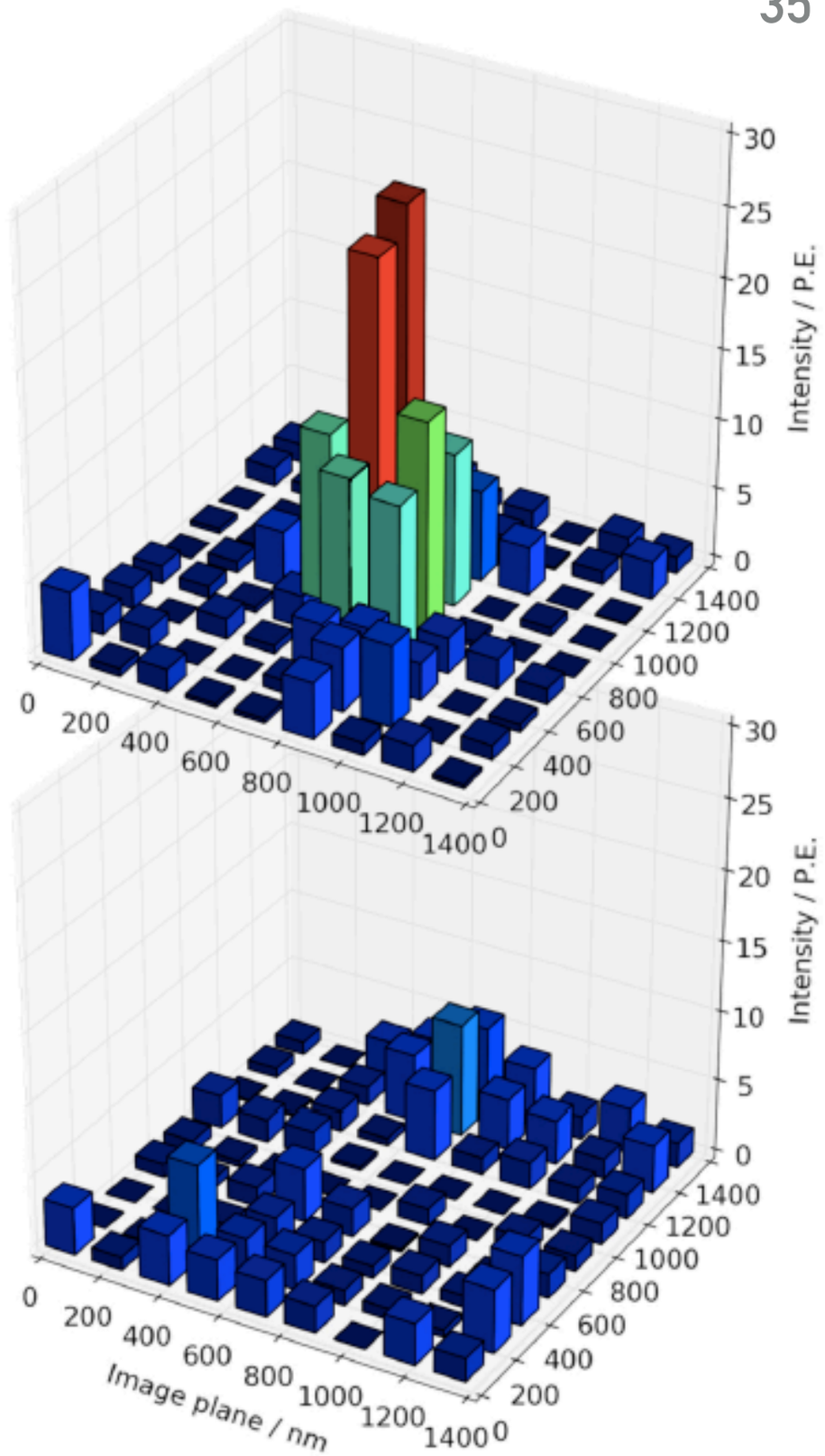
Brighter spots are near the microscope surface, dimmer ones are deeper in the sample.

In a xenon detector, dye would be deposited as a monolayer: only brightest spots at constant depth expected.



TOWARDS THE TON SCALE: BA TAGGING





First demonstration of single barium ion resolution!

NEXT Collaboration, *Phys. Rev. Lett.* **120** (2018) 132504

SUMMARY

Neutrinoless double beta decay searches are the most promising (likely the only) way to establish that neutrinos are Majorana particles.

The current generation of experiments is exploring the degenerate region of neutrino masses. Going forward, double beta decay experiments will require exposures well above 10^3 kg yr and background rates below 10 counts $\text{tonne}^{-1}\ \text{yr}^{-1}$.

NEXT has proven that a GXe TPC can provide both high energy resolution and tracking for event identification. NEXT-100 will probably be the most sensitive experiment using ^{136}Xe, according to the background rate measured in NEXT-White.

There's a clear path to improve NEXT towards the ton scale: reach energy resolutions close to the intrinsic limit (<0.5% FWHM) and improve the rejecting power of the tracking signature.

R&D on chemical tagging of Ba ions undergoing, with very promising results so far.