The NEXT experiment: searching for neutrinoless double beta decay in high pressure gaseous Xe

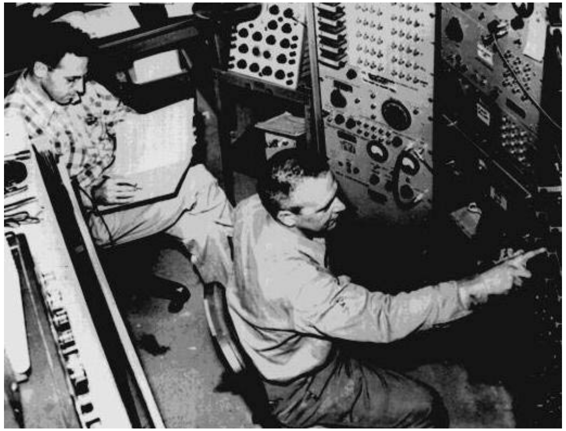
A. Simón on behalf of the NEXT collaboration

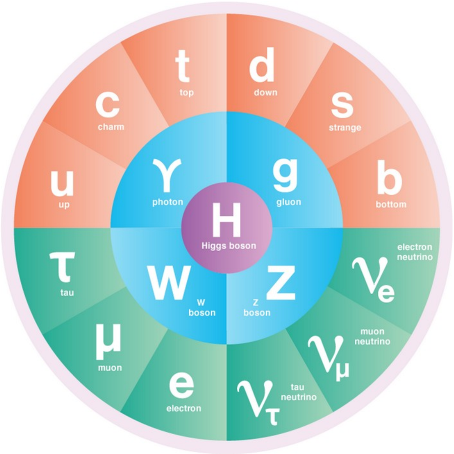
Neutrino knowns

- Neutral fermion.
- Predicted by Pauli in 1930 as a solution of the beta-particle energy conundrum.
- Discovered by Cowan and Reines (1956)
- Only interact weakly.
- 3 neutrino flavors: ν_e, ν_μ, ν_τ.
- Flavor oscillation.
- Have mass.
  - Really small → Lightest fermion.

W. Pauli

F. Reines and C. Cowan





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- **We know there are many things we don't know about it!**

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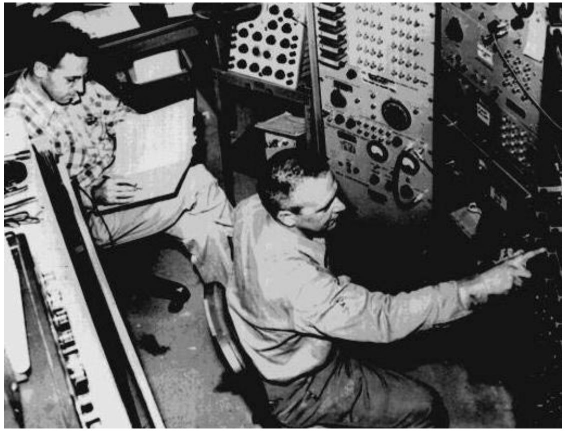
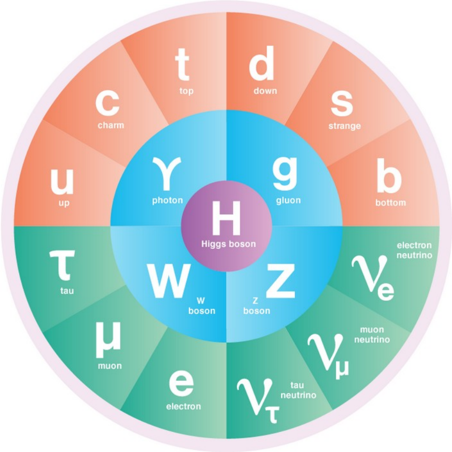
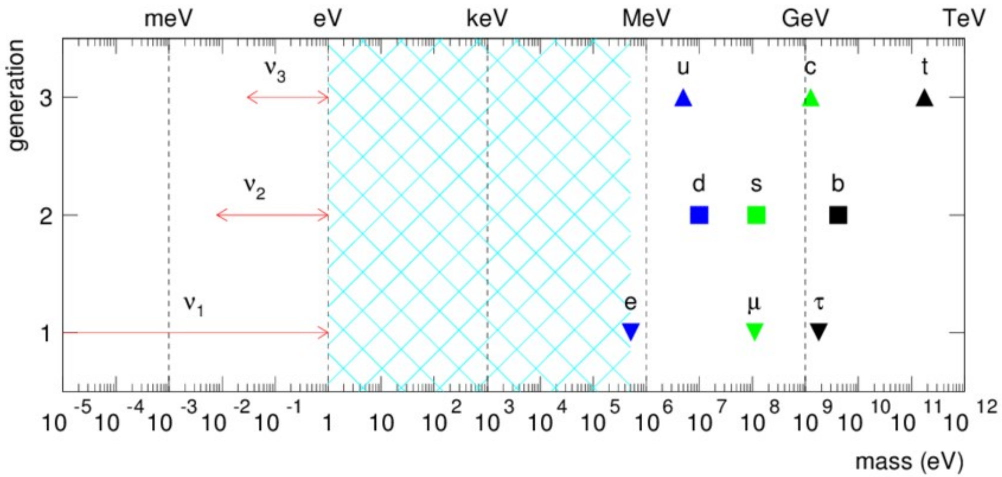
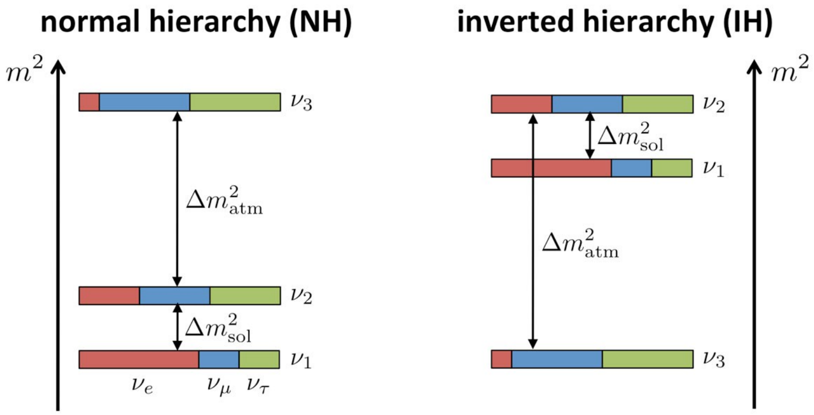




Neutrino unknowns

- What's the neutrinos' absolute mass scale?
- What's the neutrino mass ordering?
- What's CP phase value?
- Are there sterile neutrinos?
- Are neutrinos Dirac or Majorana fermions?





Majorana neutrinos

- Particle = Antiparticle.
- Proposed by Ettore Majorana in 1937.
- Only in chargeless particle:
  - Neutrinos are the only fermion candidates.
- Why?
  - Easy explanation of the ‘abnormally’ small neutrino mass.
  - Plausible explanation for matter-antimatter asymmetry.
  - Leptonic number violation.

E. Majorana

Neutrino mass origin

Standard Model

$$\nu = \begin{pmatrix} \nu_L \\ 0 \end{pmatrix} \qquad \overline{\nu} = \begin{pmatrix} 0 \\ \overline{\nu_L} \end{pmatrix} \longrightarrow \mathcal{L}_{SM} \sim m(\overline{\nu_L}\cancel{\nu_R} + \cancel{\overline{\nu_R}}\nu_L) \equiv 0$$

Dirac

- Add right-handed components.
- Field described by 4-component spinor.

$$\nu = \begin{pmatrix} \nu_L \\ \nu_R \end{pmatrix} \qquad \overline{\nu} = \begin{pmatrix} \overline{\nu}_R \\ \overline{\nu}_L \end{pmatrix}$$

$$\downarrow$$

$$\mathcal{L}_D \sim m_D(\overline{\nu_L}\nu_R + \overline{\nu_R}\nu_L)$$

Majorana

- Applies the Majorana condition: $\nu = \nu^c \rightarrow \nu_R = \nu_L^c$
- Field described by 2-component spinor.

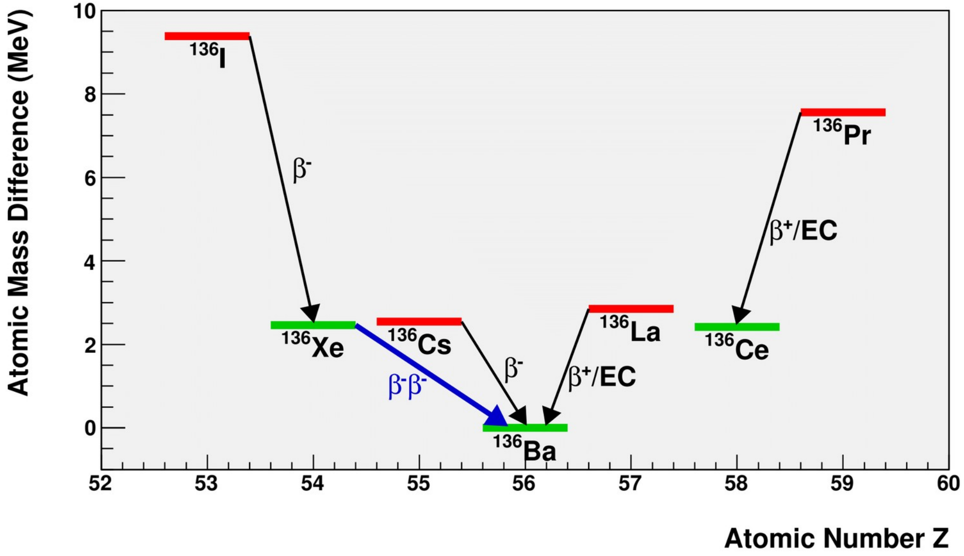
$$\nu = \begin{pmatrix} \nu_L \\ \nu_L^c \end{pmatrix}$$

$$\downarrow$$

$$\mathcal{L}_M \sim m_M(\overline{\nu_L}\nu_L^c + h.c.)$$

Double beta decay

- Decay where $Z \rightarrow (Z+2) + 2e^- + (2\nu)$
- Single beta decay energetically forbidden.
- Second-order weak process → long lifetime.

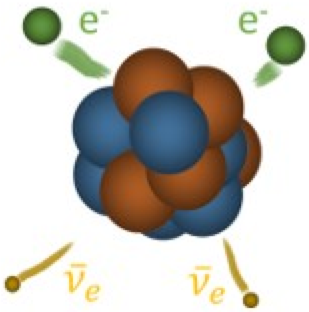


$\beta\beta2\nu$

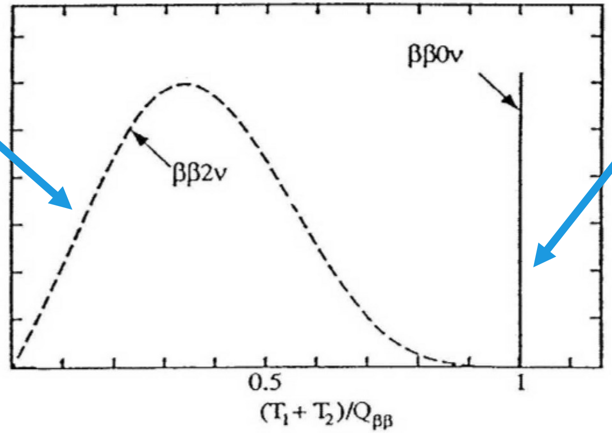
- Observed in several nuclei.
- Half-lifes between 10^{18}-10^{21} years.
- Allowed in Standard Model.
- Energy distributed between e^- and ν .

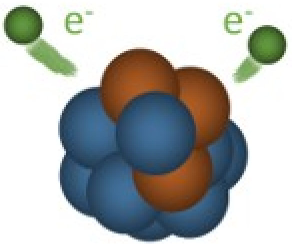
$\beta\beta0\nu$

- Hypothetical decay.
- Half-lifes longer than 10^{26} years.
- Not allowed in Standard Model.
- Electrons take all the available energy.



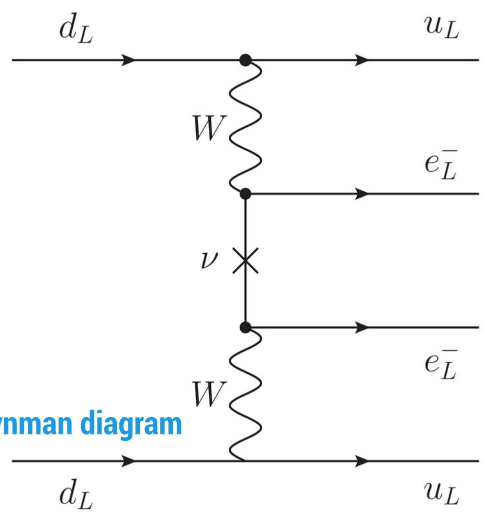
ββ e- energy spectrum



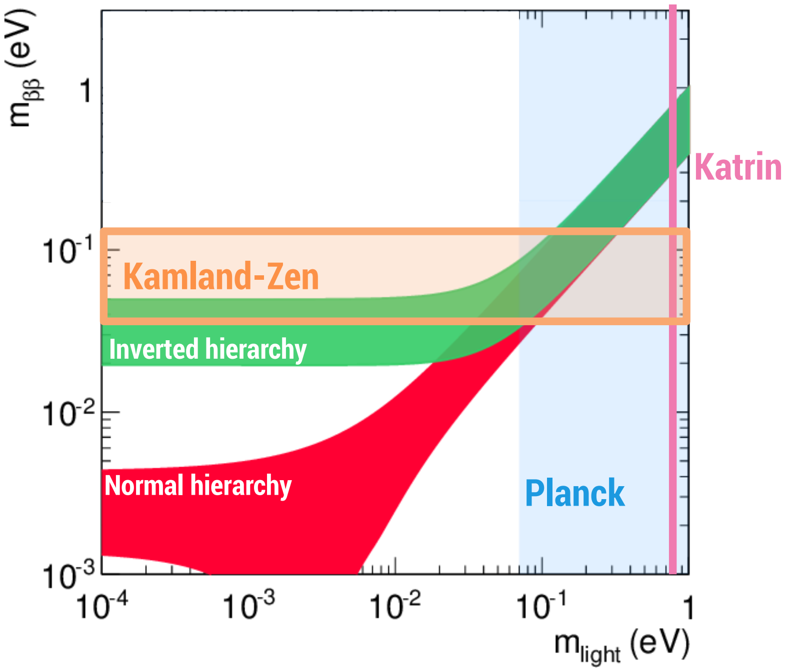


Neutrinoless double beta decay

- If observed → neutrinos = Majorana particles.
- Can help constrain the mass scale and, possibly, neutrino hierarchy.
- Currently: starting to look into the inverted hierarchy region.



ββ0ν Feynman diagram



Experimental challenge

$$T_{1/2}^{\beta\beta0\nu} > 2.3 \cdot 10^{26} yr^{-1}$$

- How many events would we observe if half-life was the current limit?

$$N_{\beta\beta0\nu} = \log 2 \cdot \frac{M_{\beta\beta} \cdot N_A}{W_{\beta\beta}} \cdot \varepsilon \cdot \frac{t}{T_{1/2}^{\beta\beta0\nu}}$$

  - 100 kg of isotope → $M_{\beta\beta}$ = 100 kg
  - Xenon detector → $W_{\beta\beta}$ = 135.9 g/mol
  - Perfect efficiency → $\varepsilon = 1$
  - 1 year of data taking → t = 1 yr

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1.34 events/year

Experimental challenge: sensitivity

- In the case of no excess → Upper limit.
- Sensitivity = achievable upper limit on $m_{\beta\beta}$ ($m_{\beta\beta} \propto T_{1/2}$).

No background

$$m_{\beta\beta} = K_1 \sqrt{\frac{1}{\varepsilon \cdot M_{\beta\beta} \cdot t}}$$

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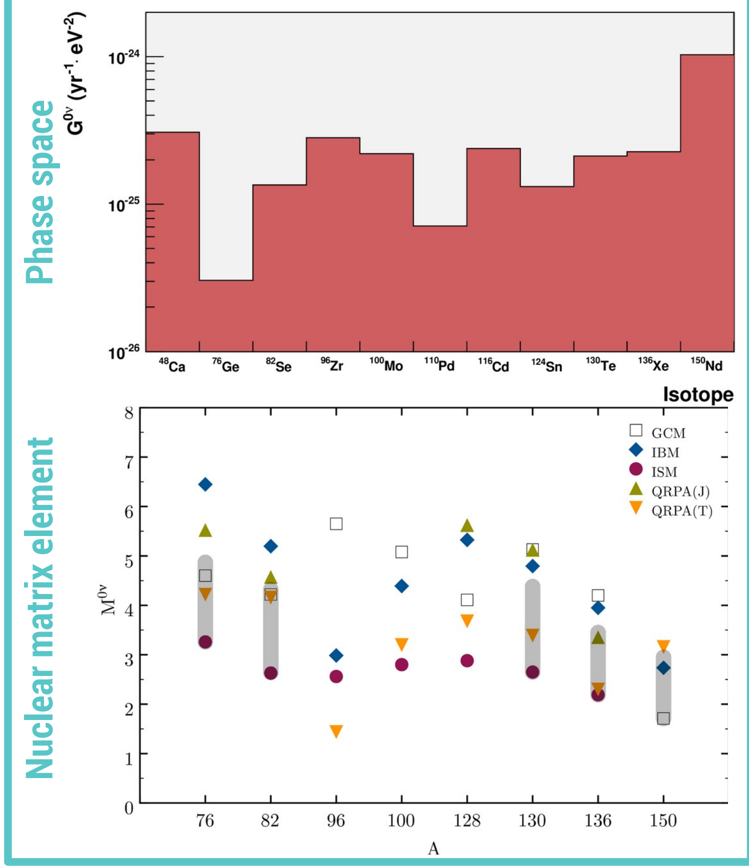
Background

$$m_{\beta\beta} = K_2 \sqrt{\frac{1}{\varepsilon}} \sqrt[4]{\frac{c \cdot \Delta E}{M_{\beta\beta} \cdot t}}$$

Experimental challenge: isotopes, efficiency and exposure

Isotope-dependant constant



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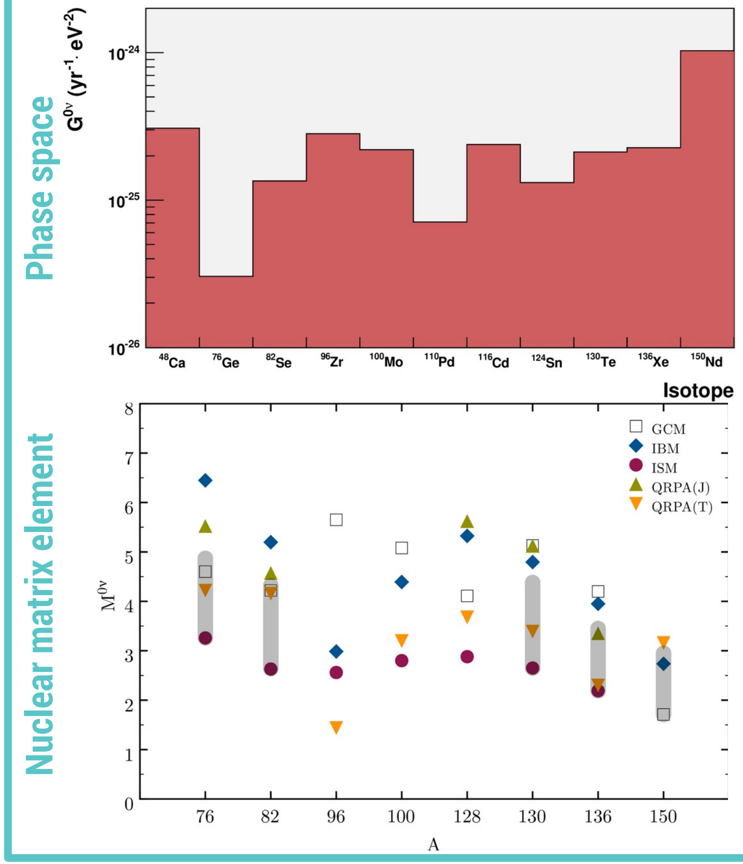

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Detection efficiency

- Simple detection schemes.
- Source = medium

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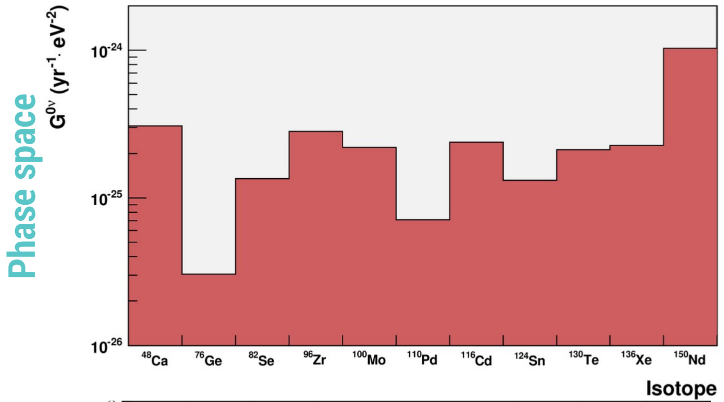

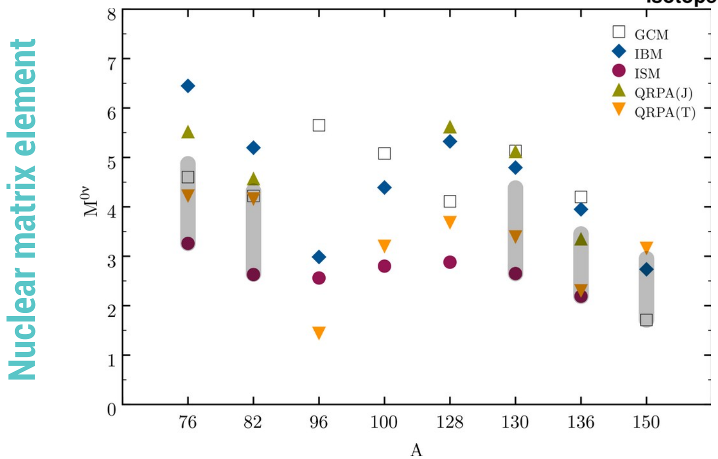

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Detection efficiency

- Simple detection schemes.
- Source = medium

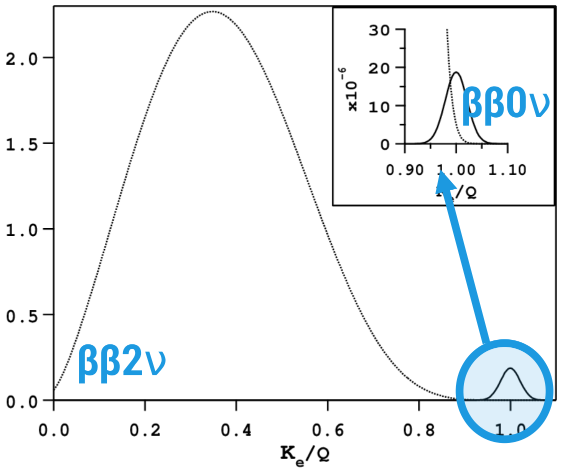
Exposure

- Mass scalability.
- Isotope enrichment.
- Active volume.

Experimental challenge: energy resolution

$$m_{\beta\beta} = K_2 \sqrt{\frac{1}{\varepsilon}} \sqrt[4]{\frac{c \, \Delta E}{M_{\beta\beta} \cdot t}}$$

- **Mandatory:**
  - Only way to suppress ββ2ν background.



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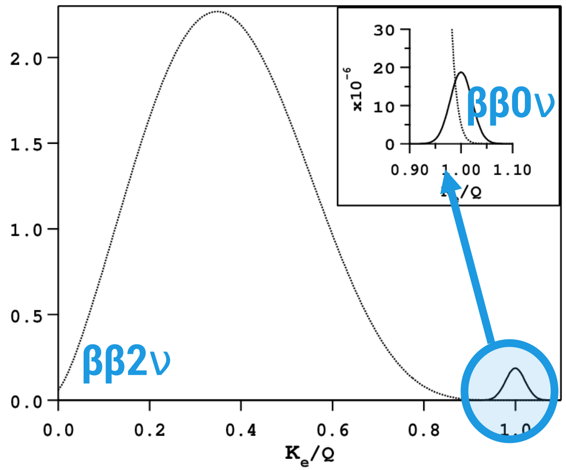
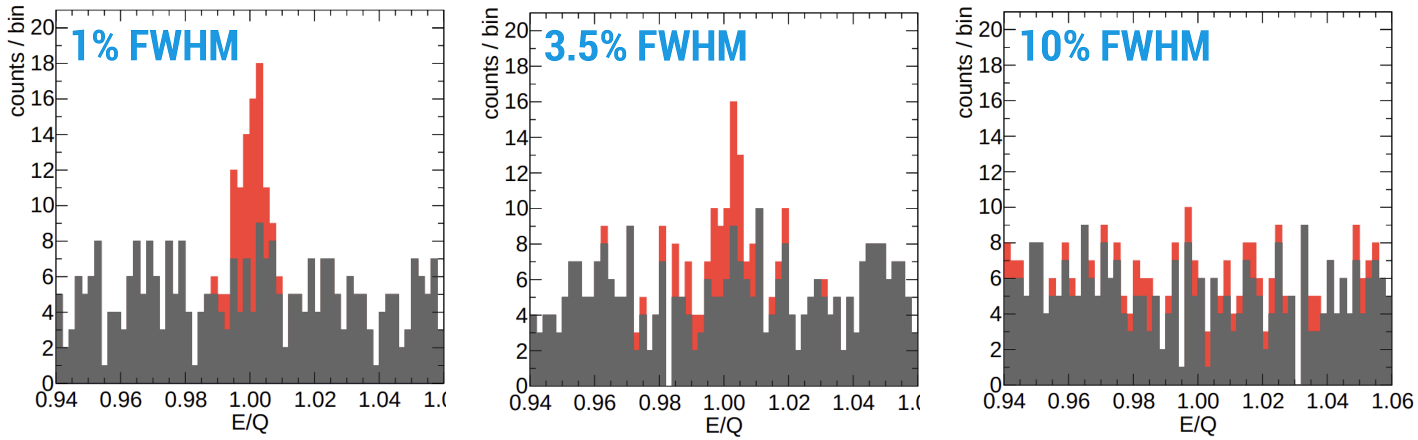
  - Only way to suppress ββ2ν background.
  - Improves S/N in case of excess in ROI.

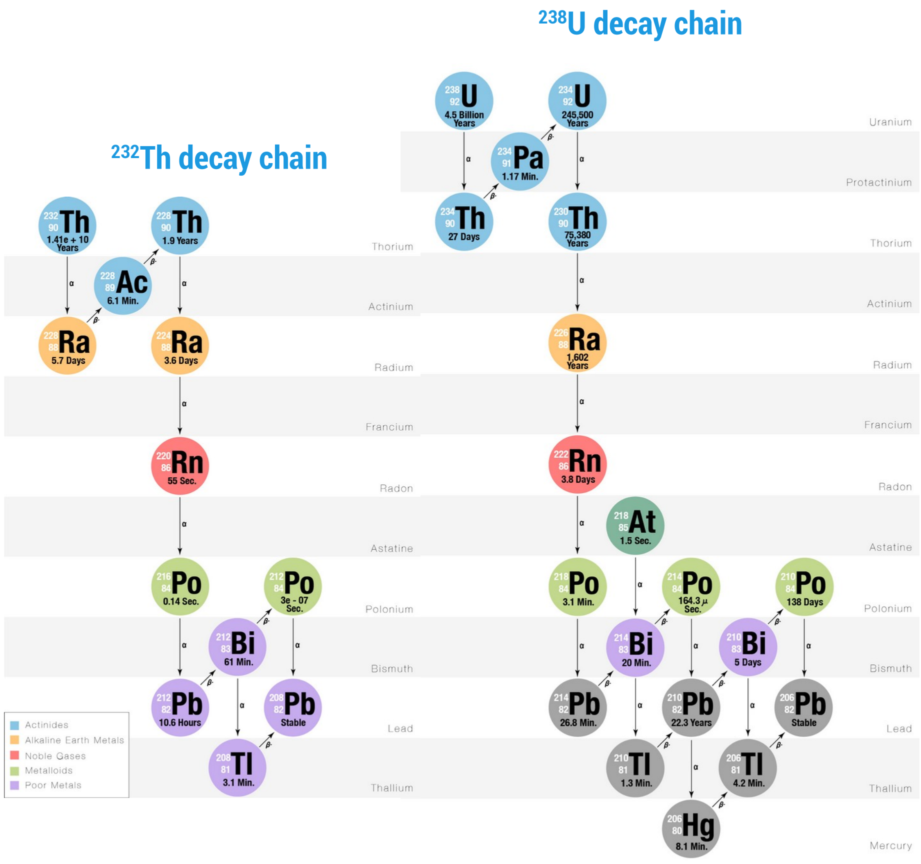




Experimental challenge: background rate

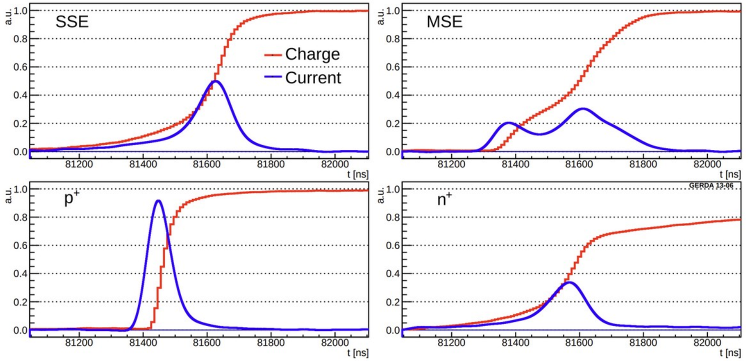
$$m_{\beta\beta} = K_2 \sqrt{\frac{1}{\varepsilon}} \sqrt[4]{\frac{c \cdot \Delta E}{M_{\beta\beta} \cdot t}}$$

- Extremely rare decay → ultra low-background required.
- Built underground (LSC, LNGS, etc.) ~ 10^3 m.w.e.
- Natural radiactivity (^{238}U, ^{232}Th)
  - Lifetime ~10^9-10^{10} years:
  - Extra shielding for surroundings' background.
  - Radiopure materials needed.

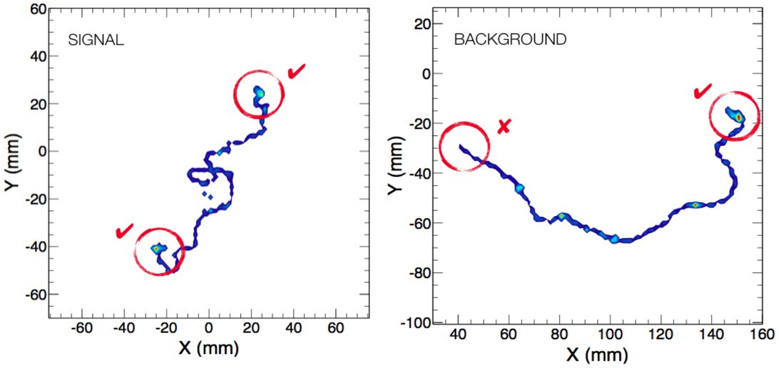


Experimental challenge: background rejection tools

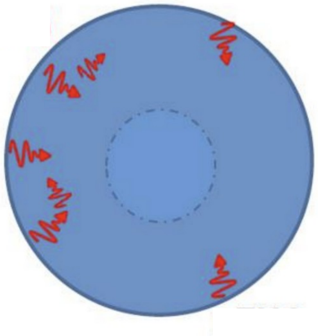
Pulse shape discrimination



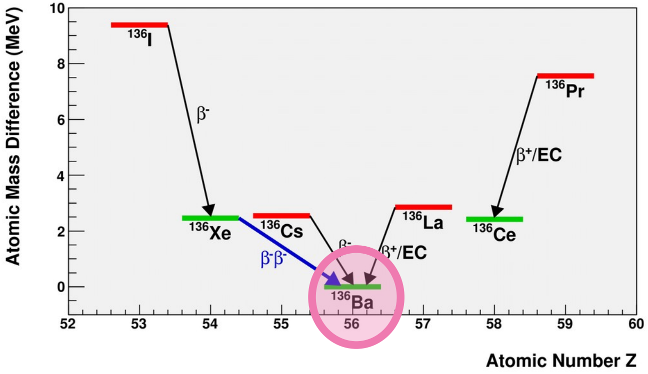
Track topology



Self-shielding



Daughter tagging



Neutrino Experiment with a Xenon TPC

- International staged experiment that aims to detect neutrinoless double beta decay (ββ0ν) in ^{136}Xe.
- High pressure gas TPC filled with xenon enriched at 90% in ^{136}Xe.
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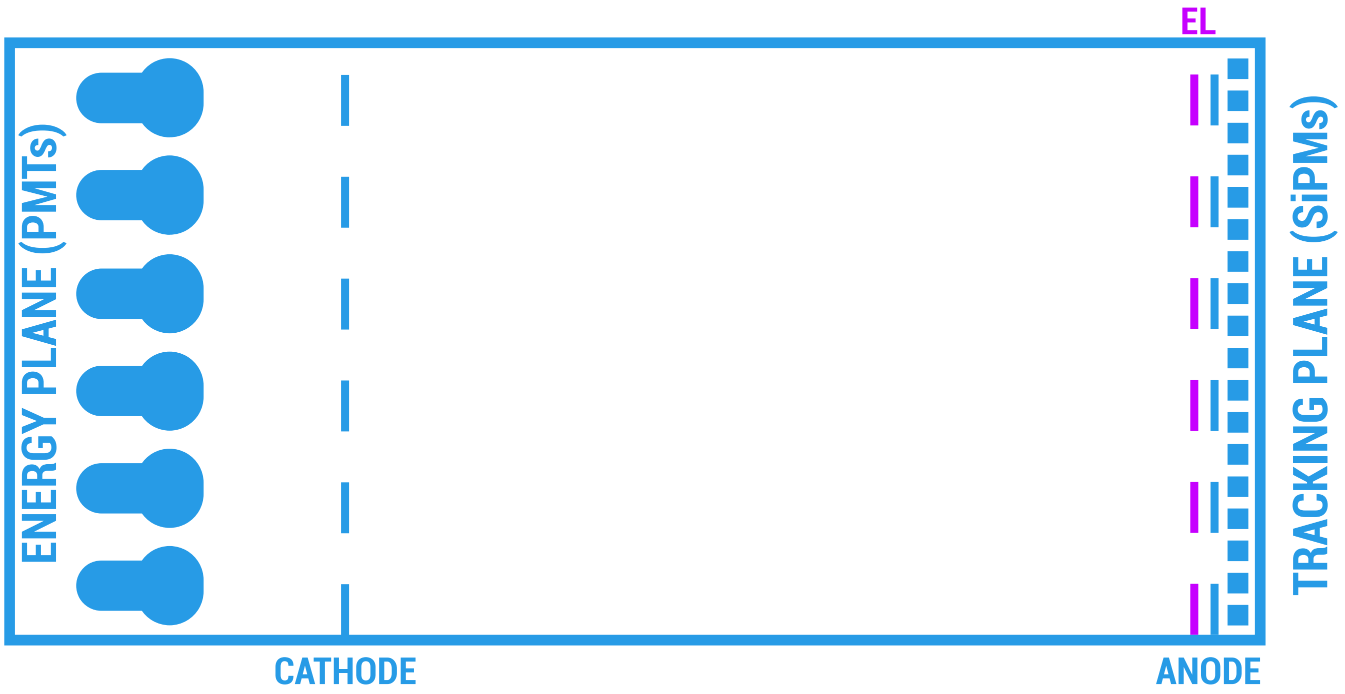
Detector concept



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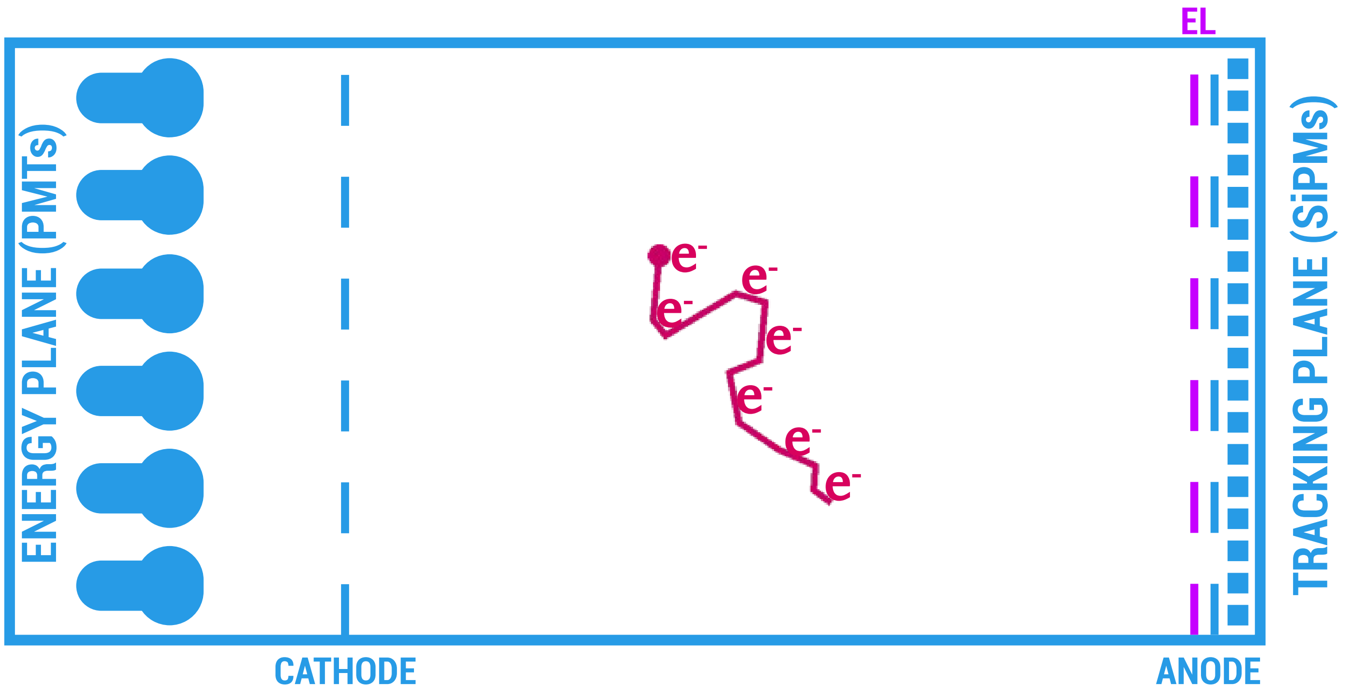

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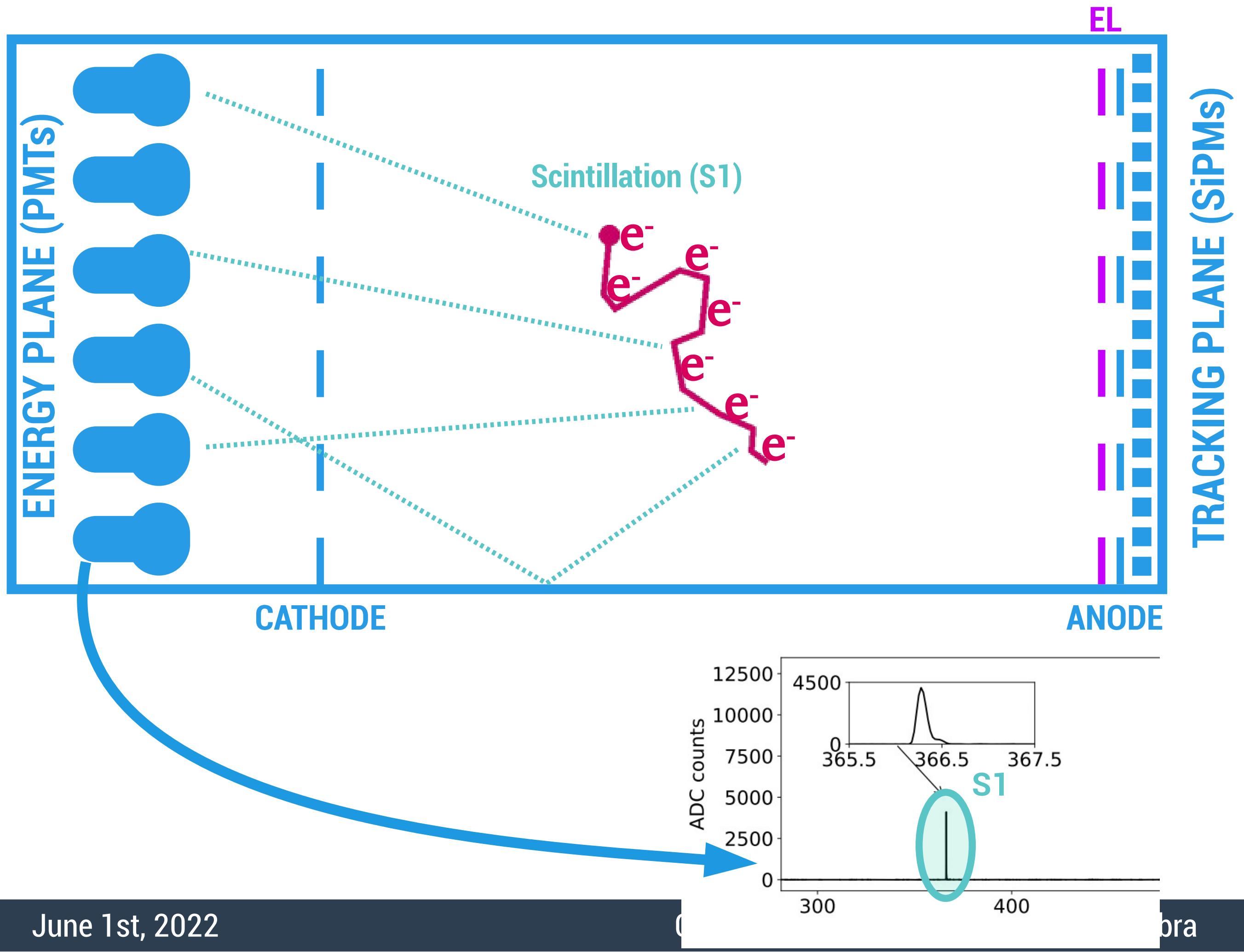

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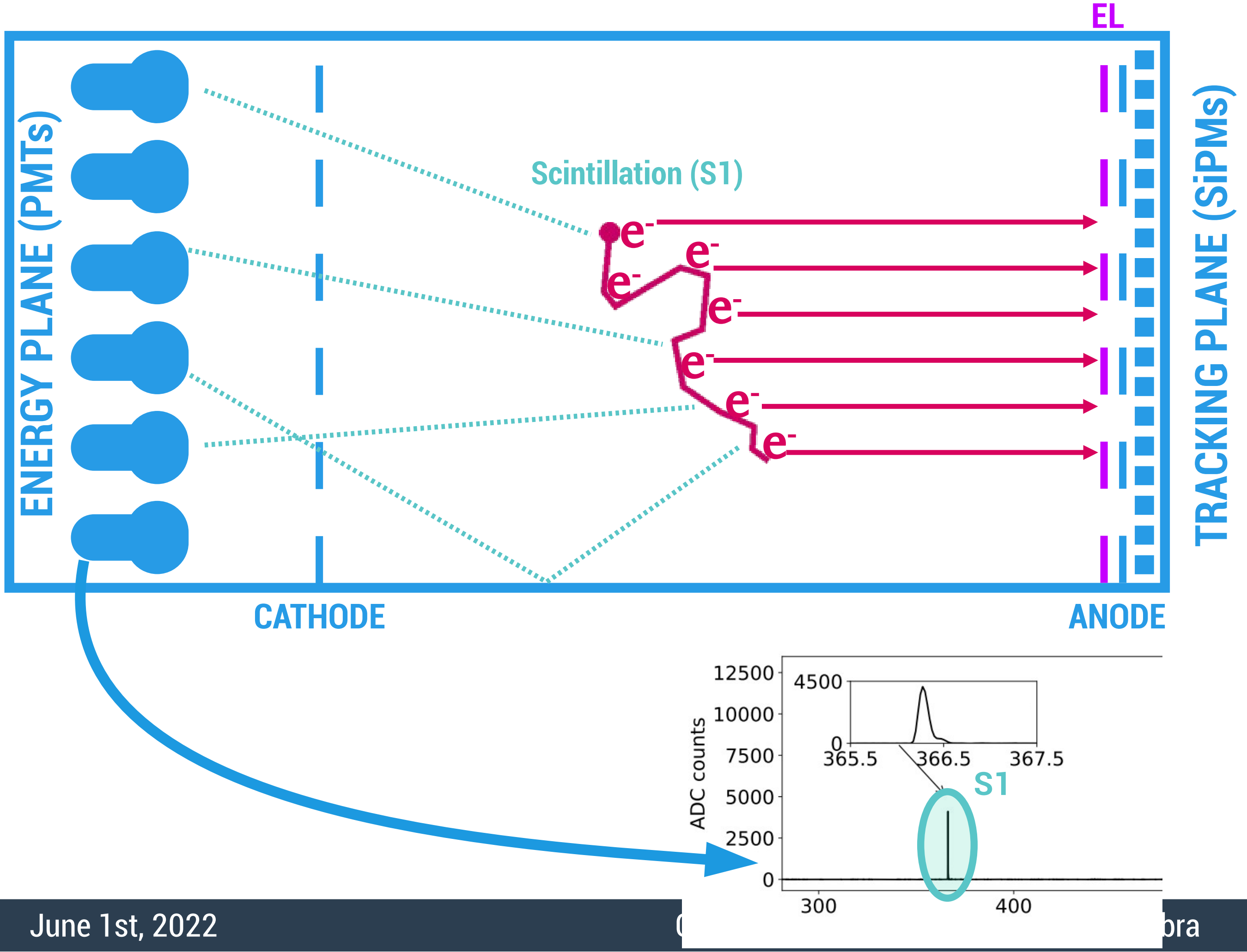

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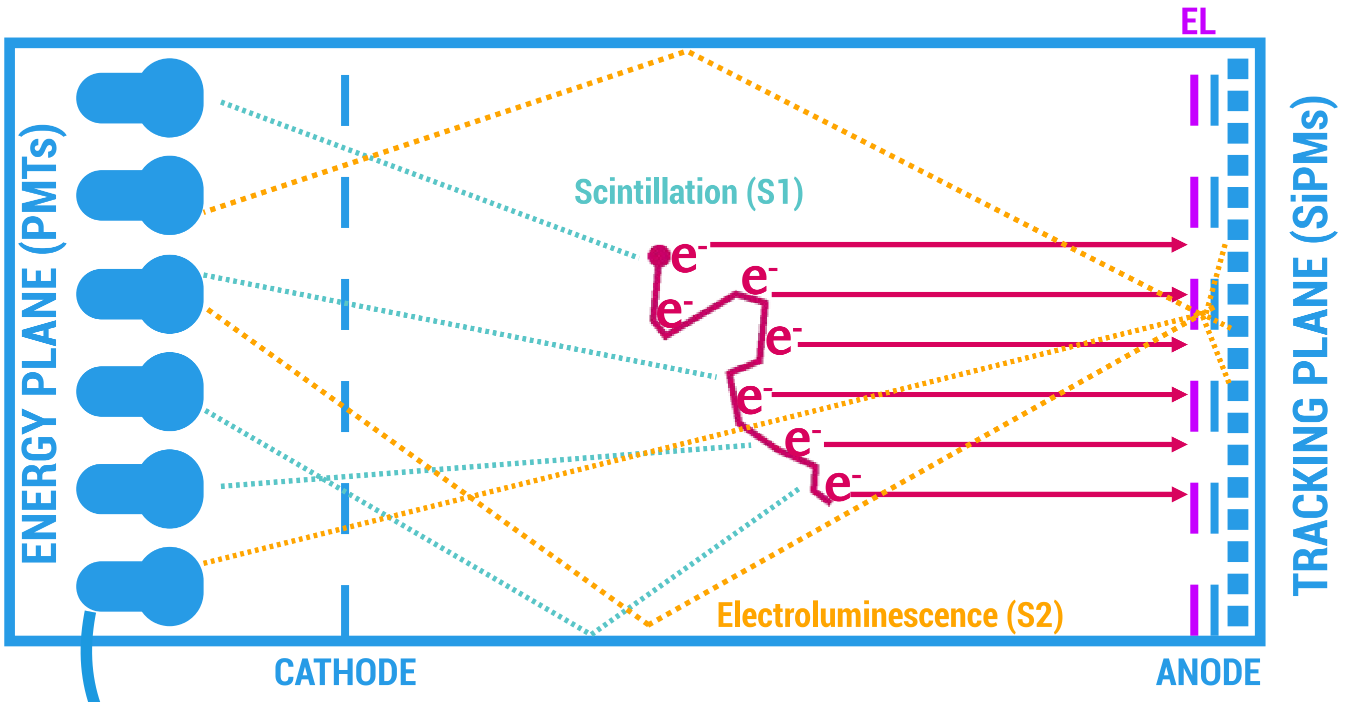

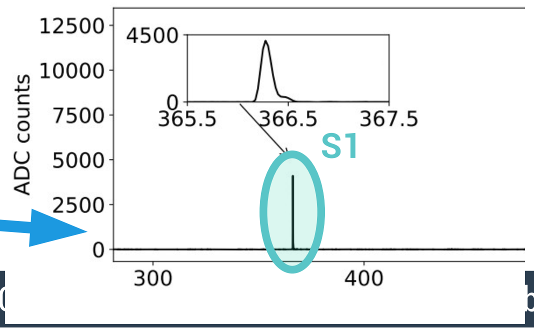

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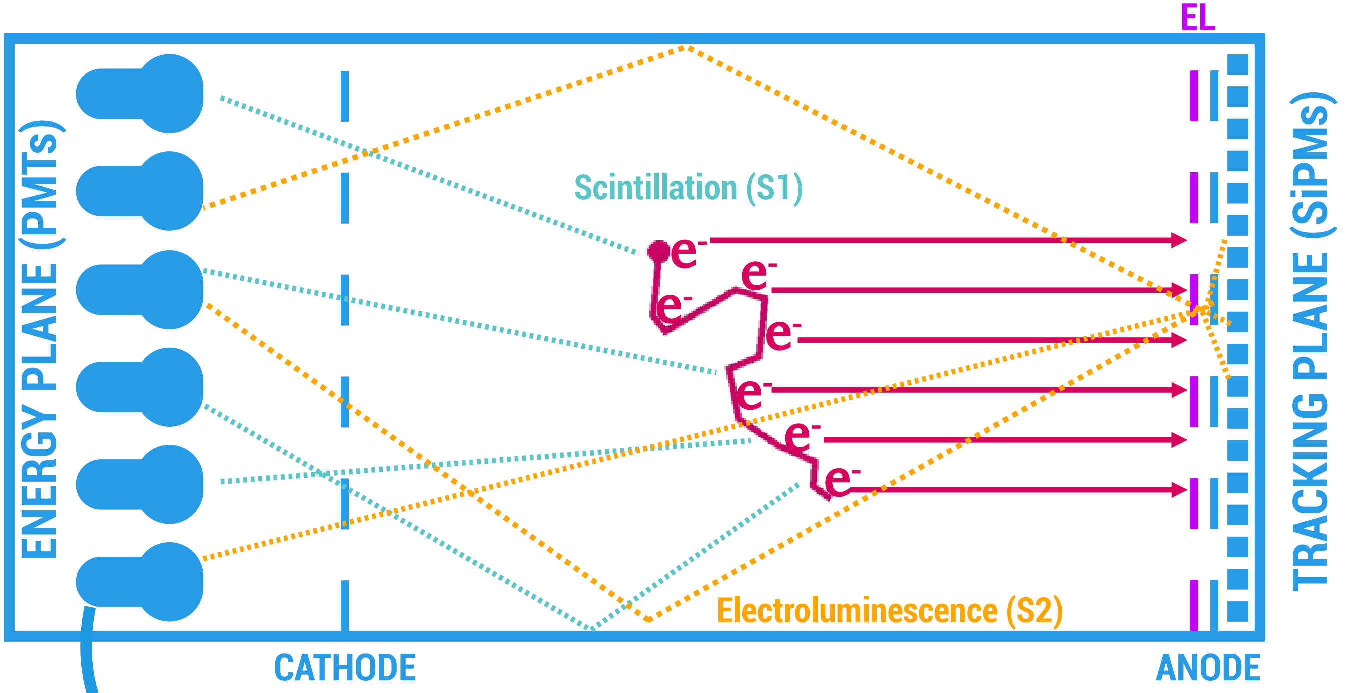
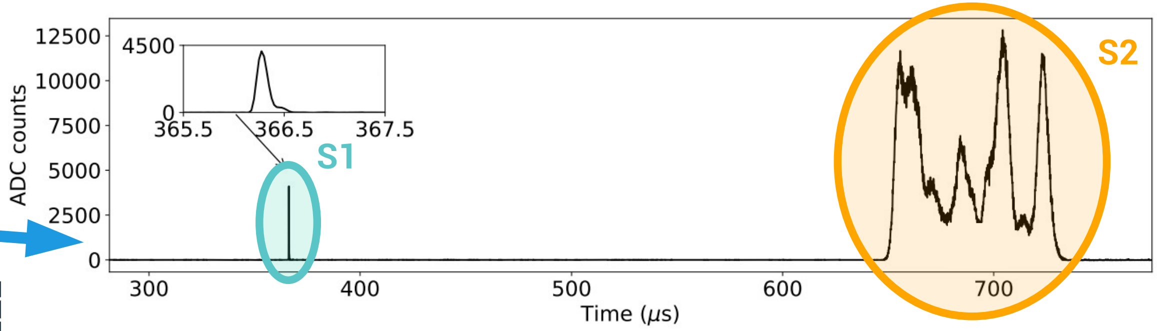


START OF THE EVENT
+
ENERGY MEASUREMENT



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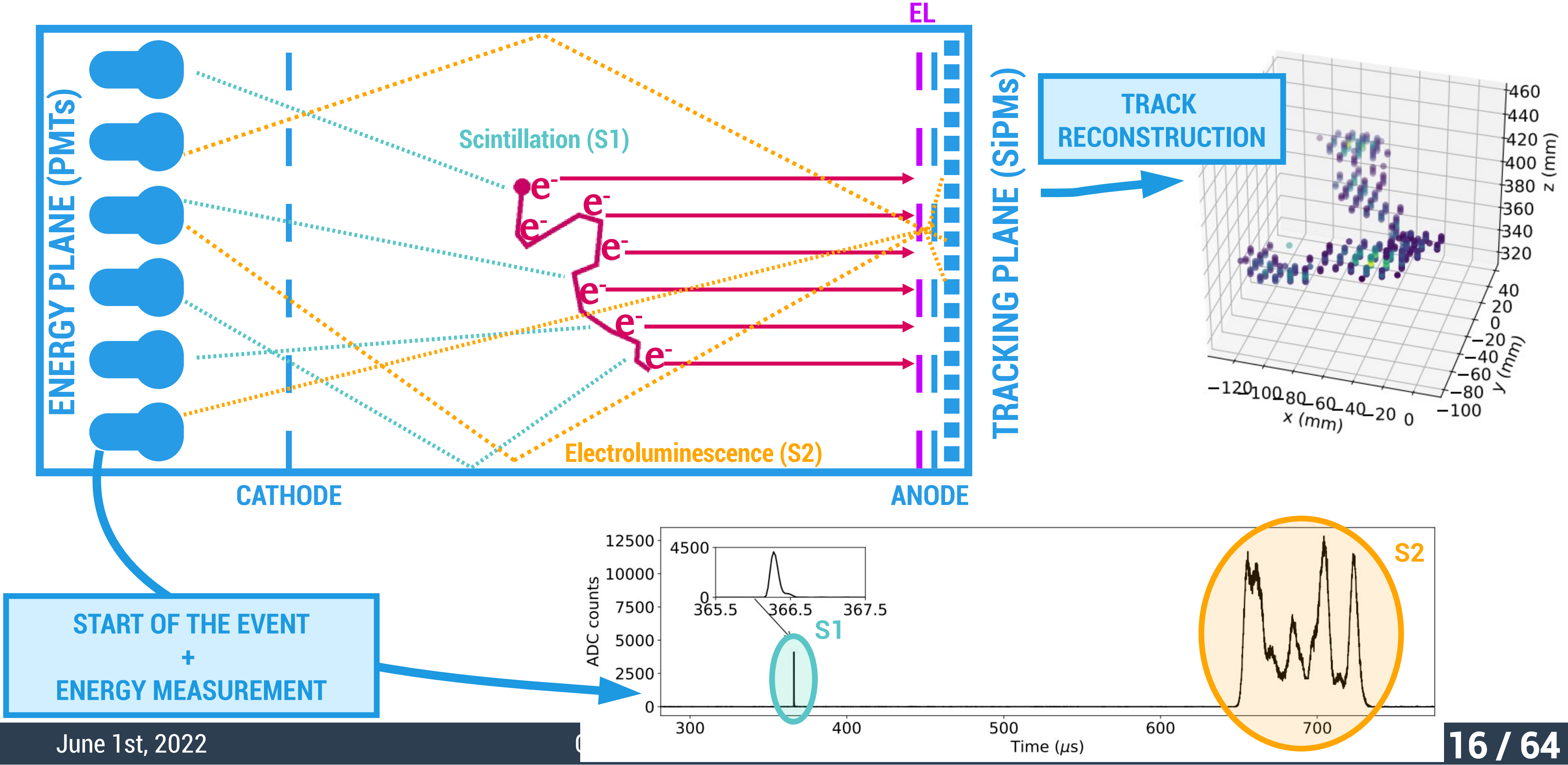

Salient features

Sensitivity

$$\mathcal{S}(m_{\beta\beta}) \propto \epsilon^{-\frac{1}{2}}(\Delta E \cdot c \cdot 1/Mt)^{1/4}$$

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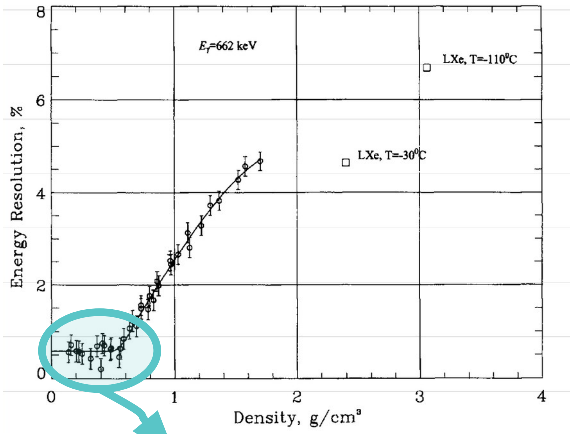
Energy resolution



Up to 0.3% FWHM at $Q_{\beta\beta}$

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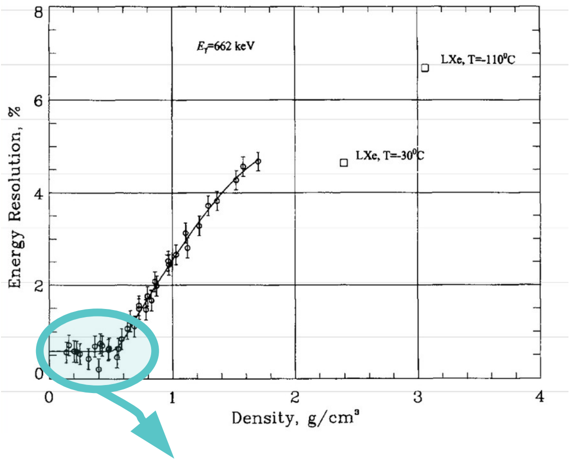

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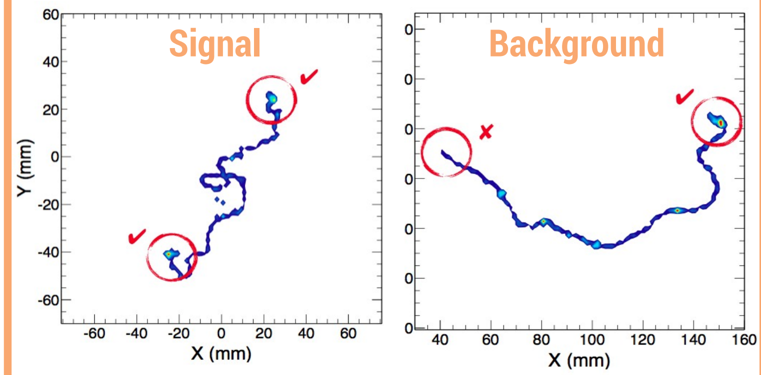
3D Track reconstruction

Background rejection based on event topology



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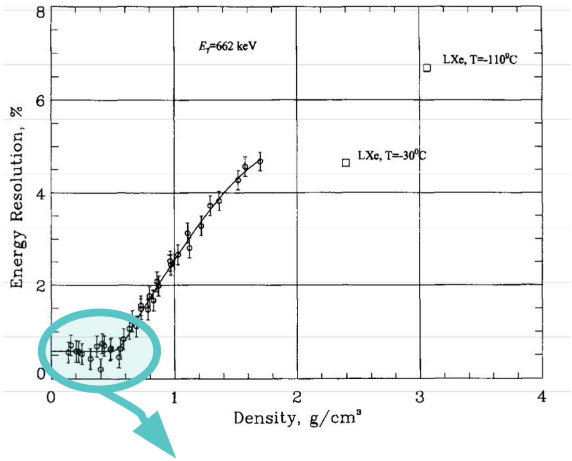

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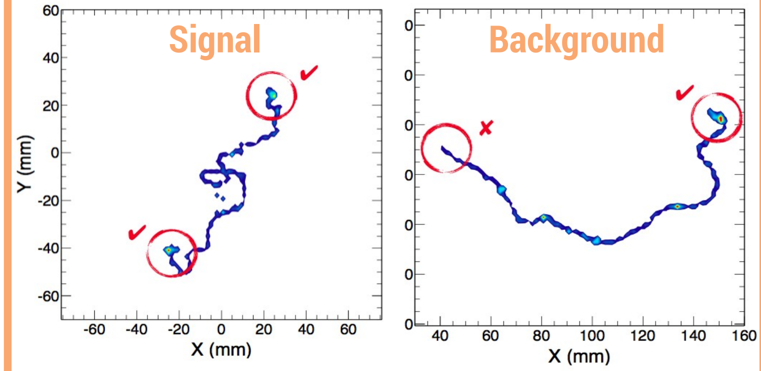
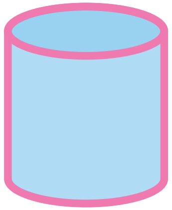


Scalability



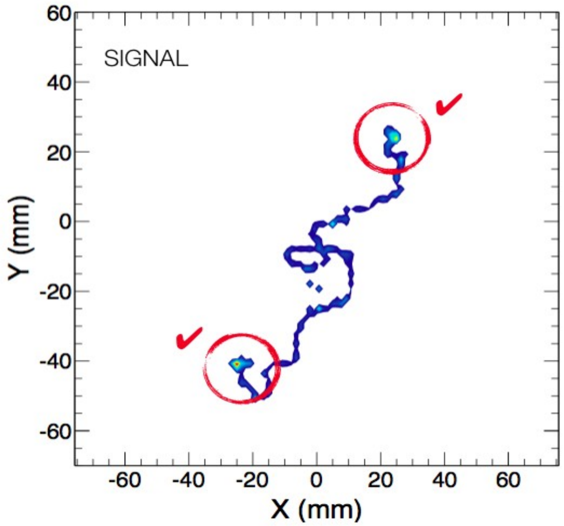
Volume ↑

Signal/Bckg ↑

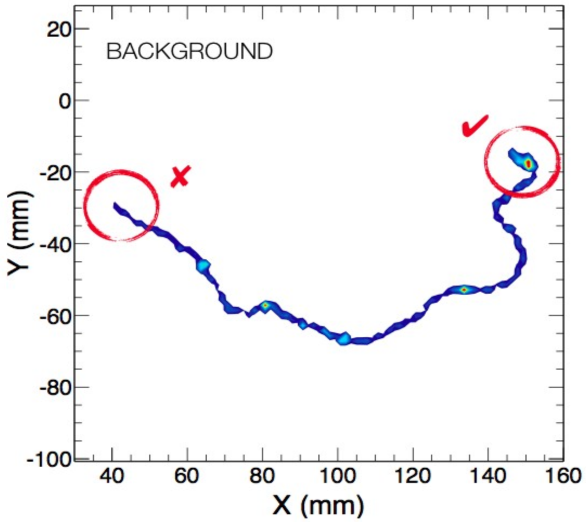
^{136}Xe → 'cheap' to enrich

Topological signature

Signal



ɣ background



Topological signature

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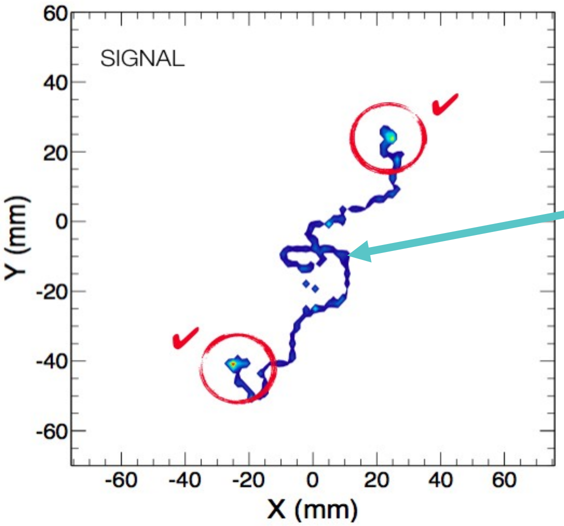
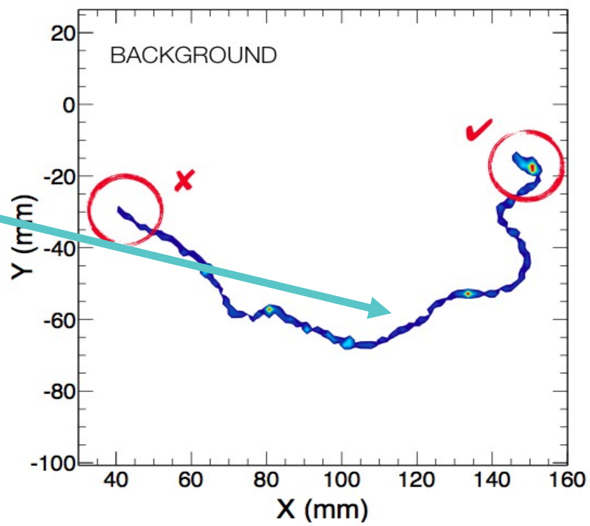


Track: Continuous energy deposition.

ɣ background



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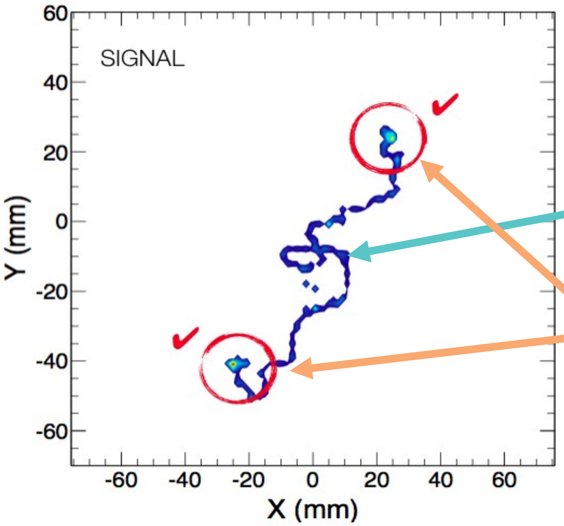

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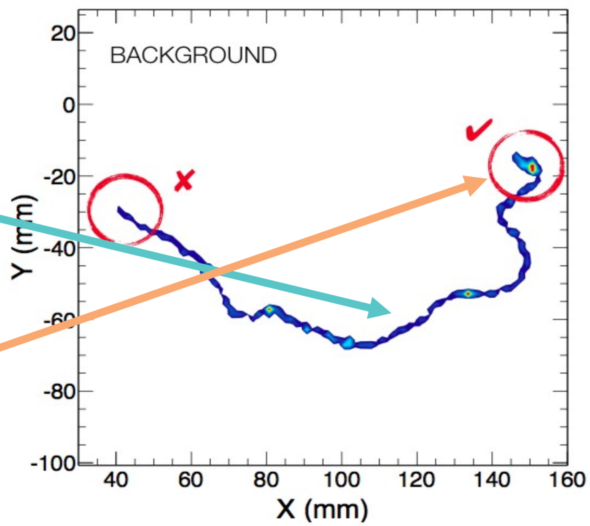

Track: Continuous energy deposition.

Blob: dense energy deposition at the end of a track (Bragg peak)

Topological signature

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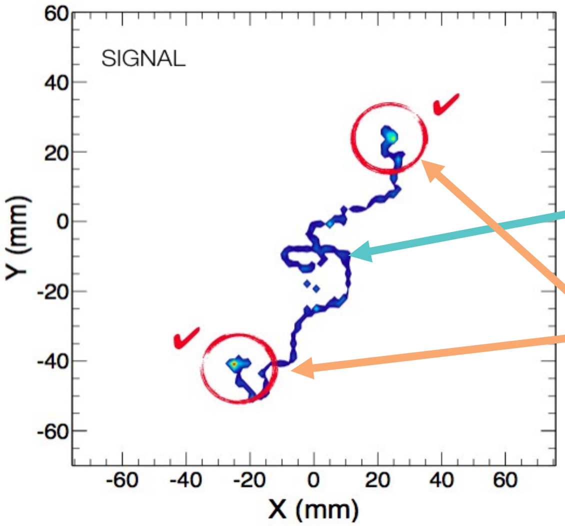
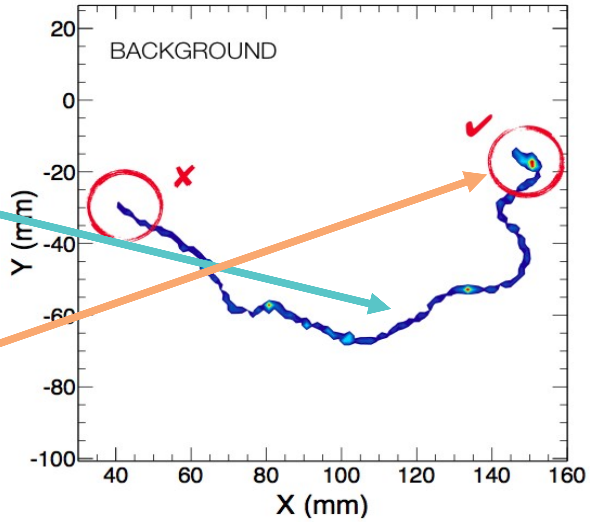


ɣ background



Track: Continuous energy deposition.

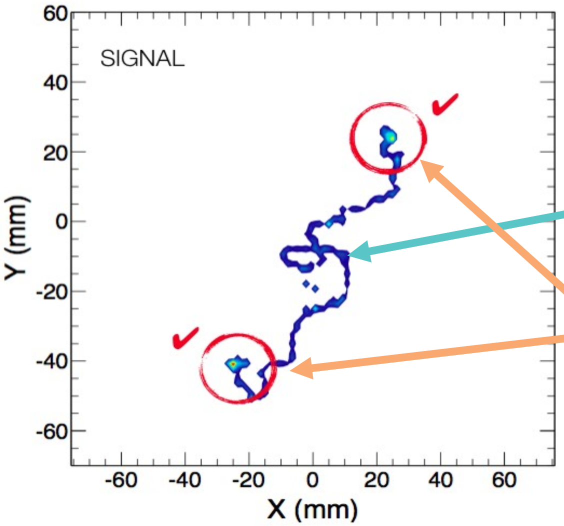
Blob: dense energy deposition at the end of a track (Bragg peak)

2 e- starting at the same point → Single track

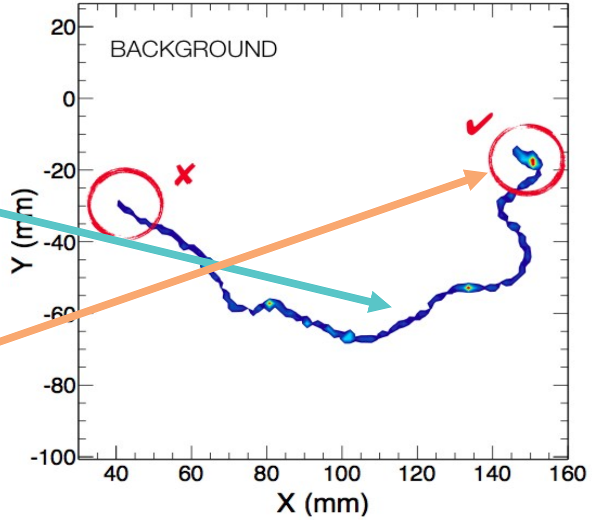
2 e- produced in the decay → 2 blobs

Topological signature

Signal



γ background



Track: Continuous energy deposition.

Blob: dense energy deposition at the end of a track (Bragg peak)

2 e- starting at the same point → Single track

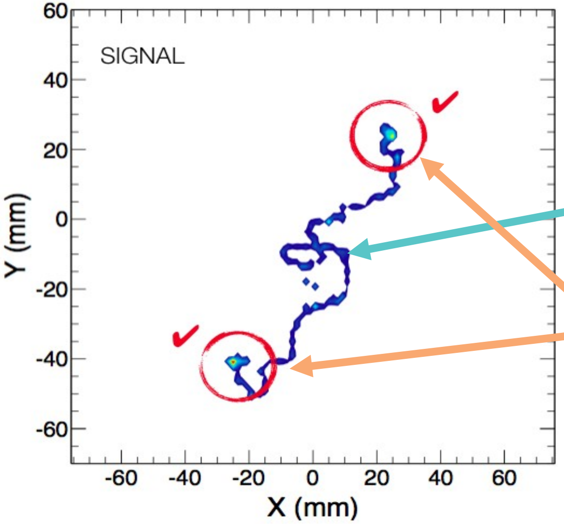
2 e- produced in the decay → 2 blobs

Multiple scattering in gas → >1 tracks

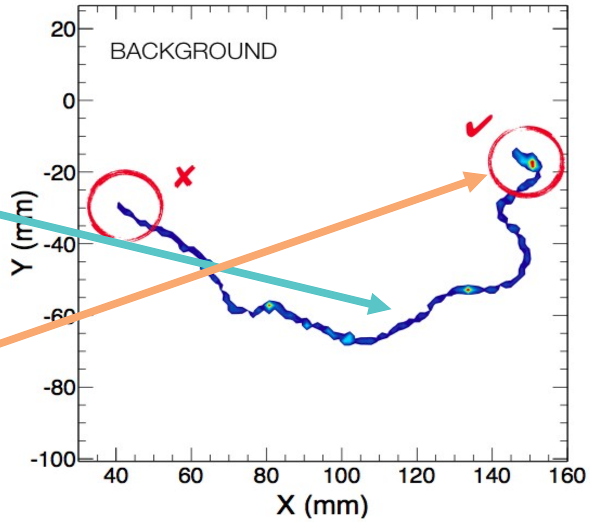
Single e$^-$ per gamma interaction → 1 blob

Topological signature

Signal



ɣ background



Track: Continuous energy deposition.

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2 e- starting at the same point → Single track

2 e- produced in the decay → 2 blobs

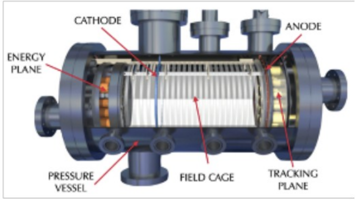
Multiple scattering in gas → >1 tracks

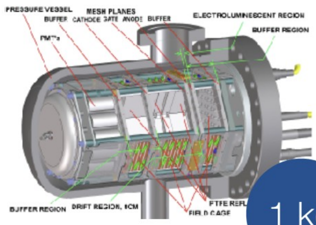
Single e$^-$ per gamma interaction → 1 blob

Reject events with multiple tracks and a single blob.

Experimental program

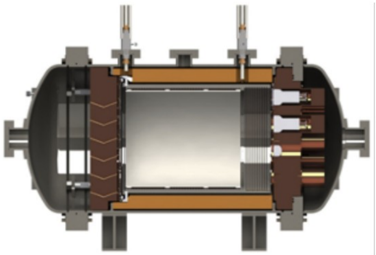
Prototypes
2008-2015
- Demonstration of detector concept





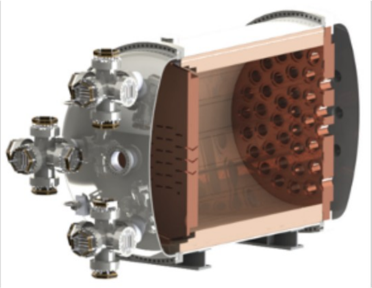
1 kg

NEXT-White
2016-2021
- Det. performance near $Q_{\beta\beta}$
- Bgr model assessment
- $2\nu\beta\beta$ measurement



4 kg

NEXT-100
2022-2025
- Bgr. model assessment
- $0\nu\beta\beta$ search



100 kg

NEXT-HD
2026?
- $0\nu\beta\beta$ search through inverted ν mass ordering

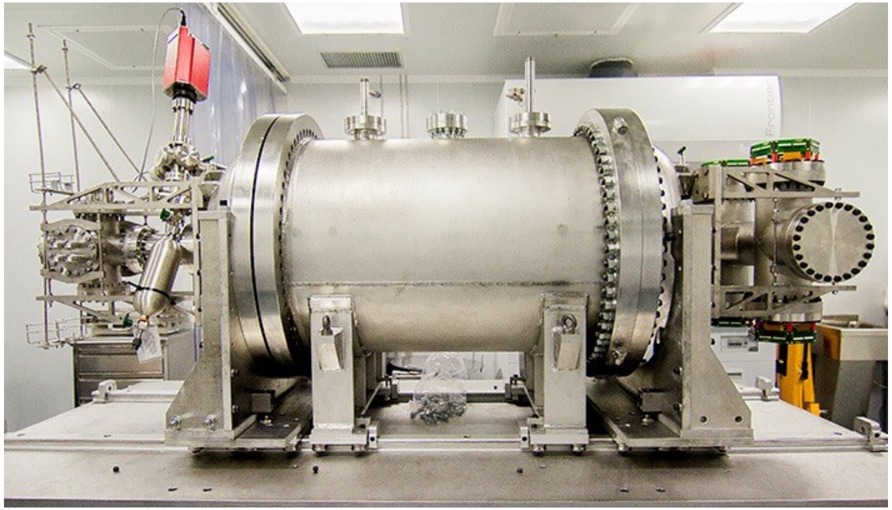
1 ton

NEXT-BOLD
- Barium tagging for bgr-free experiment

2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

NEXT-White (NEW) detector

- First phase (Oct ‘16 – Jul ‘21) of the NEXT program at **LSC**.
- 50 cm drift, 40 cm diameter TPC:
  - **~4.3 kg of Xe** gas @ 10 bar in active volume.



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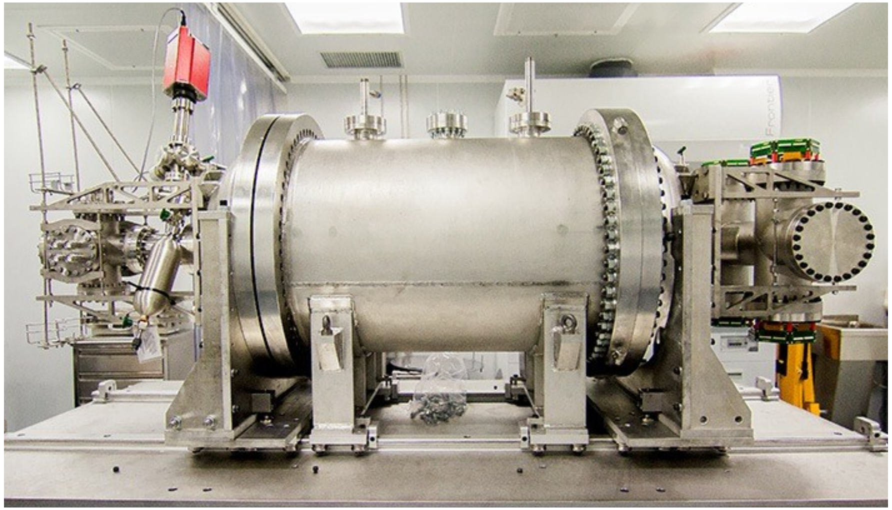
Goals

- **Validation of radiopure technological solutions** in a large detector.



NEXT-White (NEW) detector

arXiv:1804.02409 [physics.ins-det]

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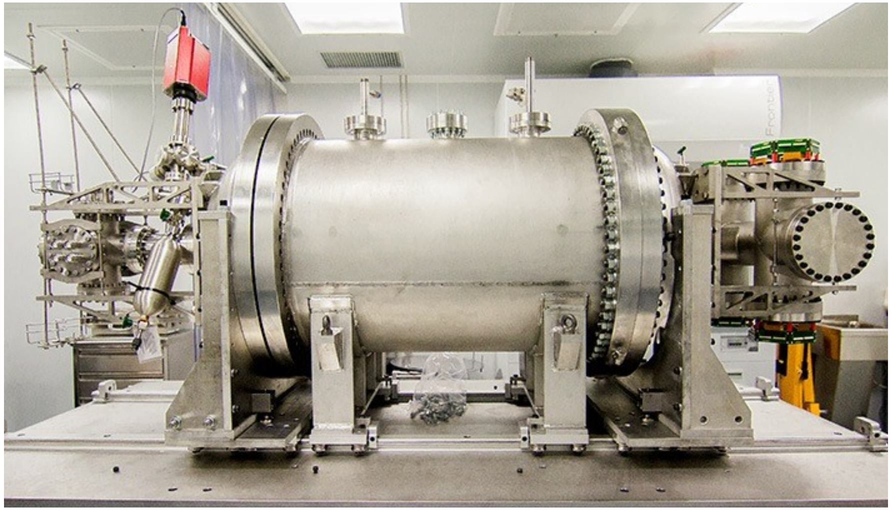
- Evaluation and in-situ **determination of the background** for future detector iterations.



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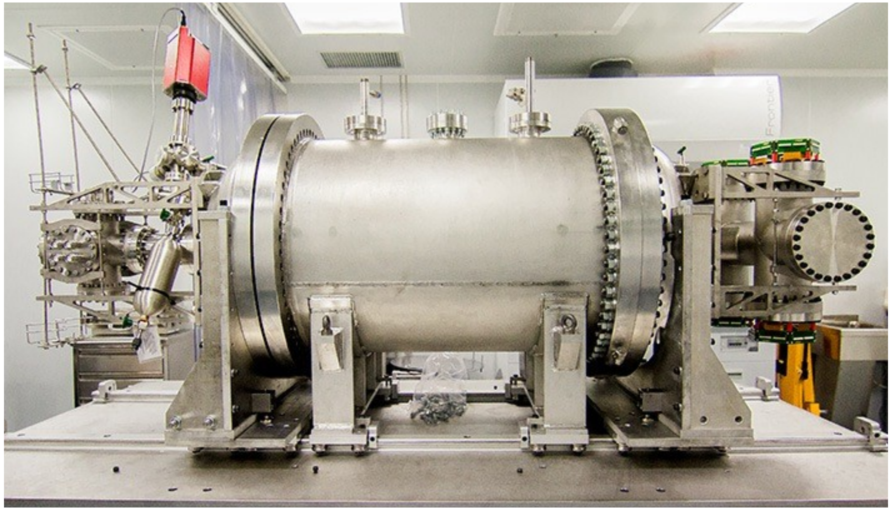
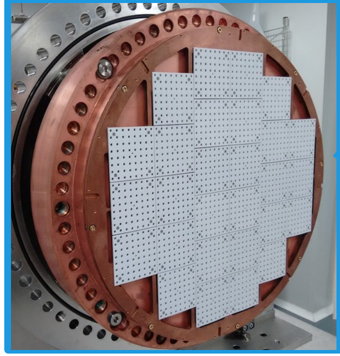
Goals

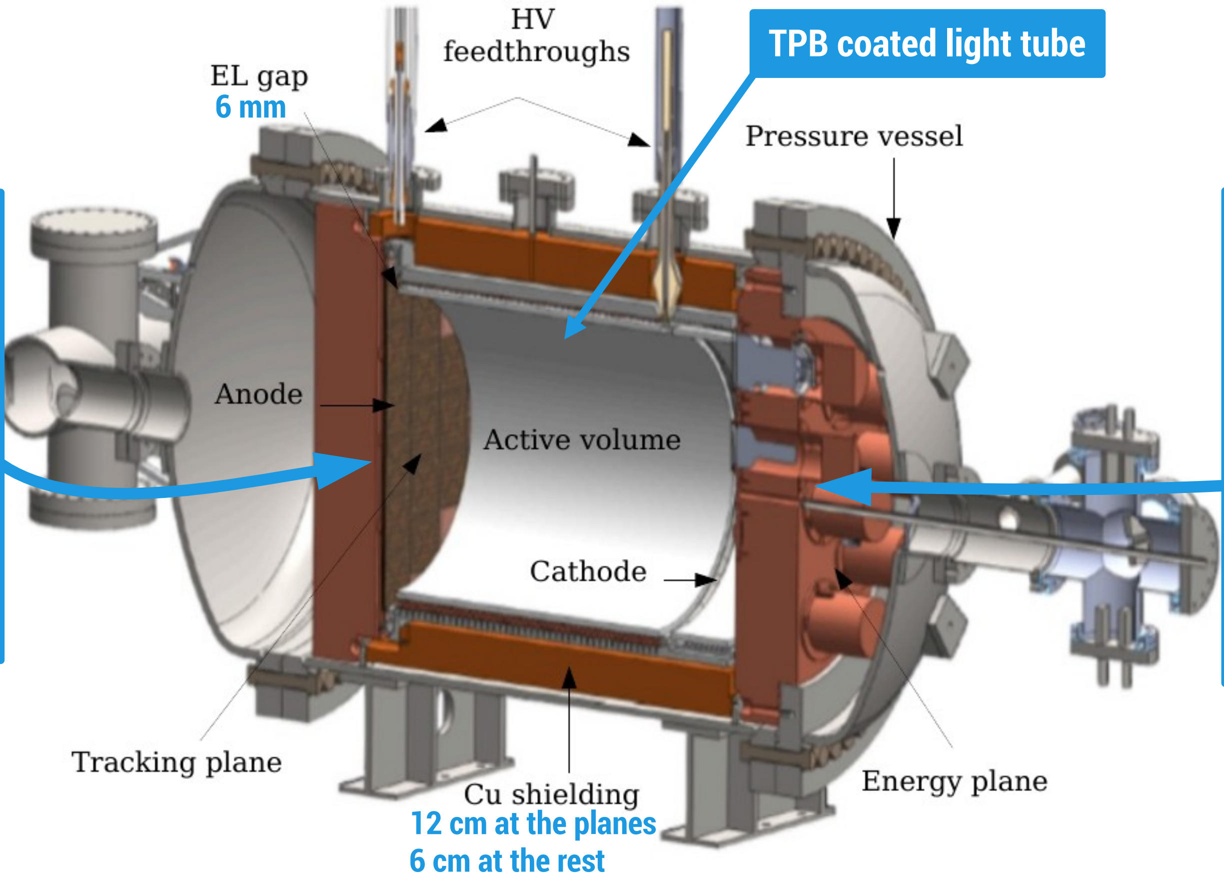
- **Validation of radiopure technological solutions** in a large detector.
- Evaluation and in-situ **determination of the background** for future detector iterations.
- Measurement of **^{136}Xe $\beta\beta2\nu$ decay**.



NEXT-White (NEW) detector

Tracking plane
1792 SiPMs (SensL C-series)
1 cm pitch

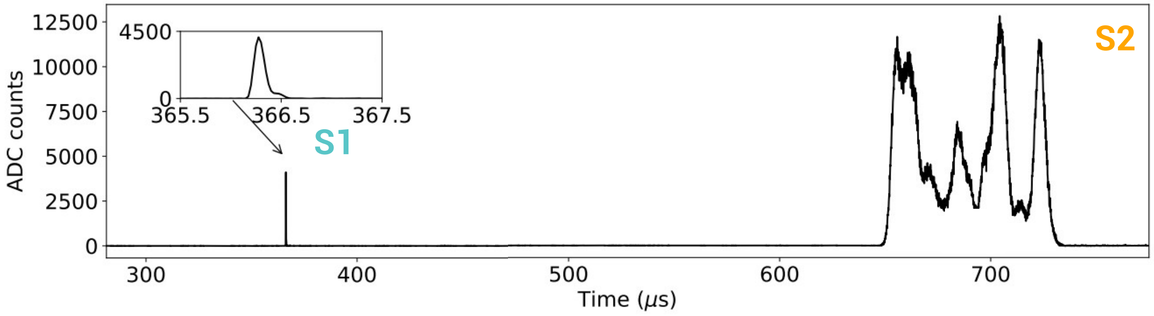




Energy plane
12 PMTs (Ham. R11410-10)
30% coverage

NEW data acquisition system

- FPGA-based trigger:
  - Trigger on PMT signals
  - Flexible: area, width, height.
  - Single peak and double peak.



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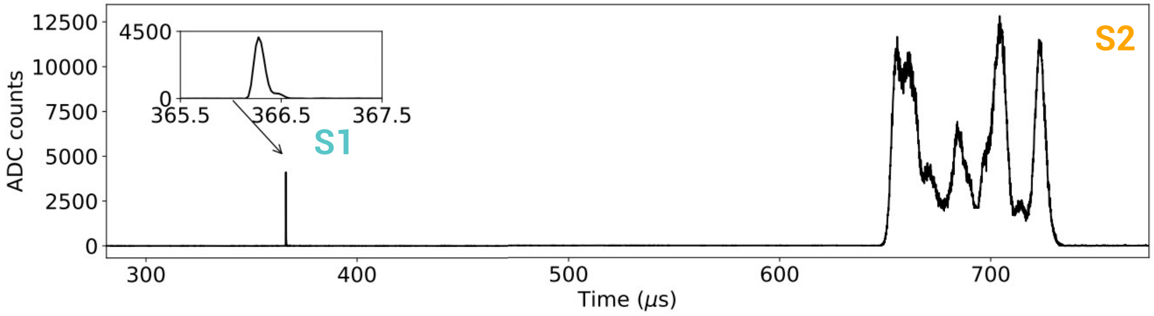
- Simultaneous dual trigger data-taking:
  - < 100 keV: ^{83m}Kr (41.5 KeV) for continuous detector characterization.
  - > 400 keV: low-background data taking and high-energy calibration.



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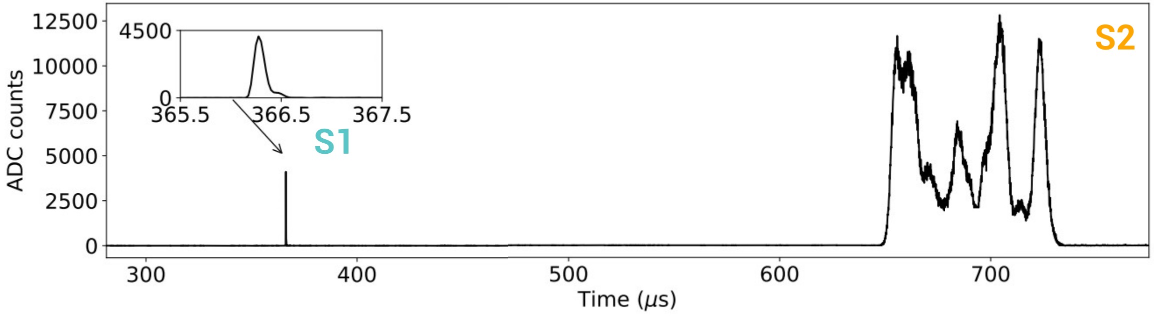
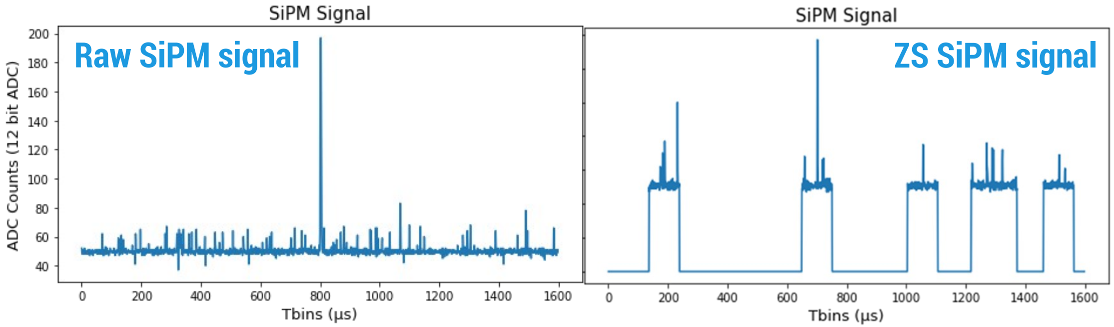
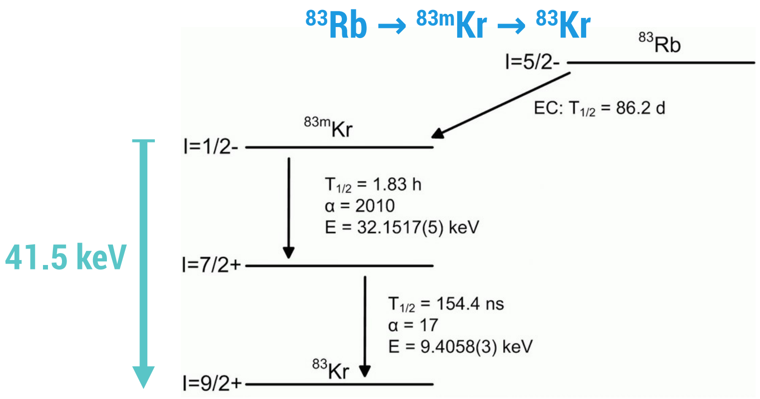
  - < 100 keV: ^{83m}Kr (41.5 KeV) for continuous detector characterization.
  - > 400 keV: low-background data taking and high-energy calibration.
- Throughput reduction:
  - Zero suppression on SiPM signals.
  - Data compression on PMTs.





^{83m}Kr calibration

- ^{83m}Kr leaves a deposition of ~41.5 keV → Point-like.
- Gas source → Uniformly distributed.
- Ideal for detector characterization:
  - Geometrical energy corrections.
  - e^- lifetime.
  - Optical response.



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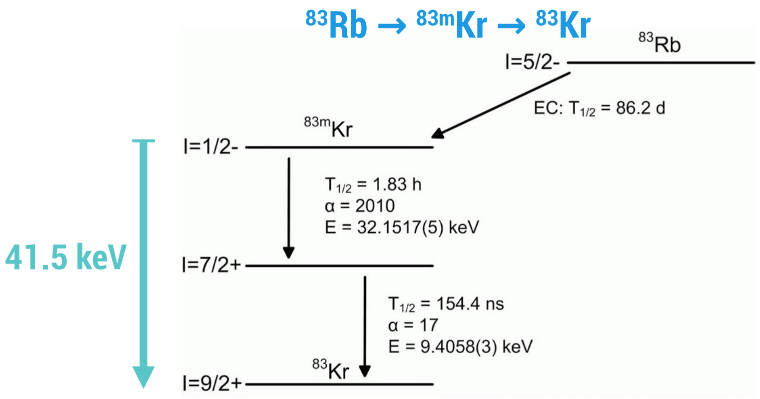
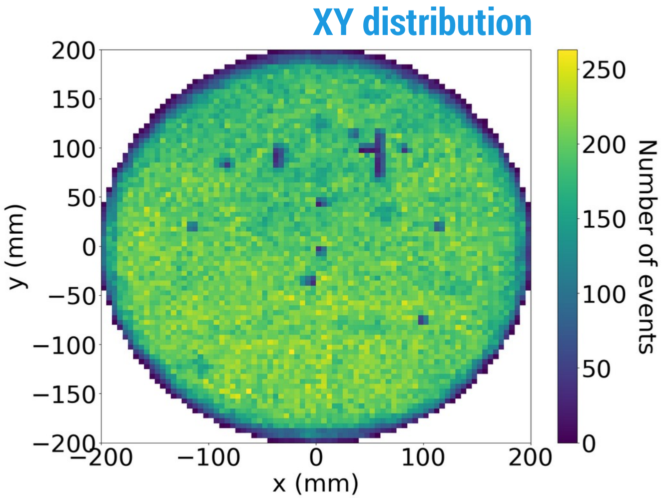
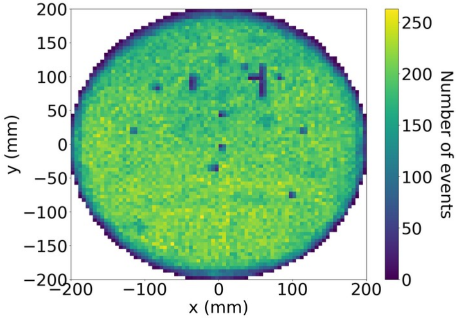
- Gas source → Uniformly distributed.
- Ideal for detector characterization:
  - Geometrical energy corrections.
  - e^- lifetime.
  - Optical response.
- Easy reconstruction:
  - XY → Average of SiPM signal.
  - Z → $v_{drift}\,(t_{S2} - t_{S1})$.
  - E → Integral of S2 peak.





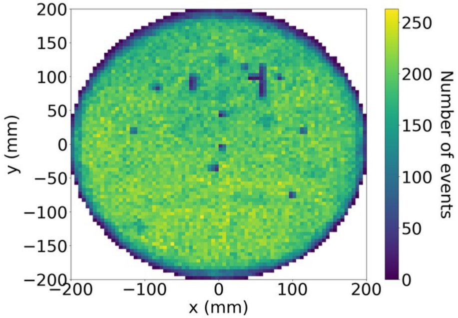
^{83m}Kr calibration: energy resolution

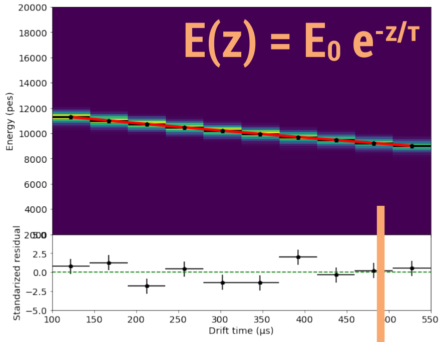
Make XY bins

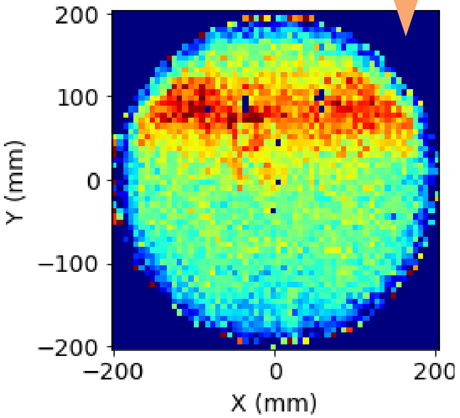


^{83m}Kr calibration: energy resolution

Make XY bins → **Lifetime from E vs Z**

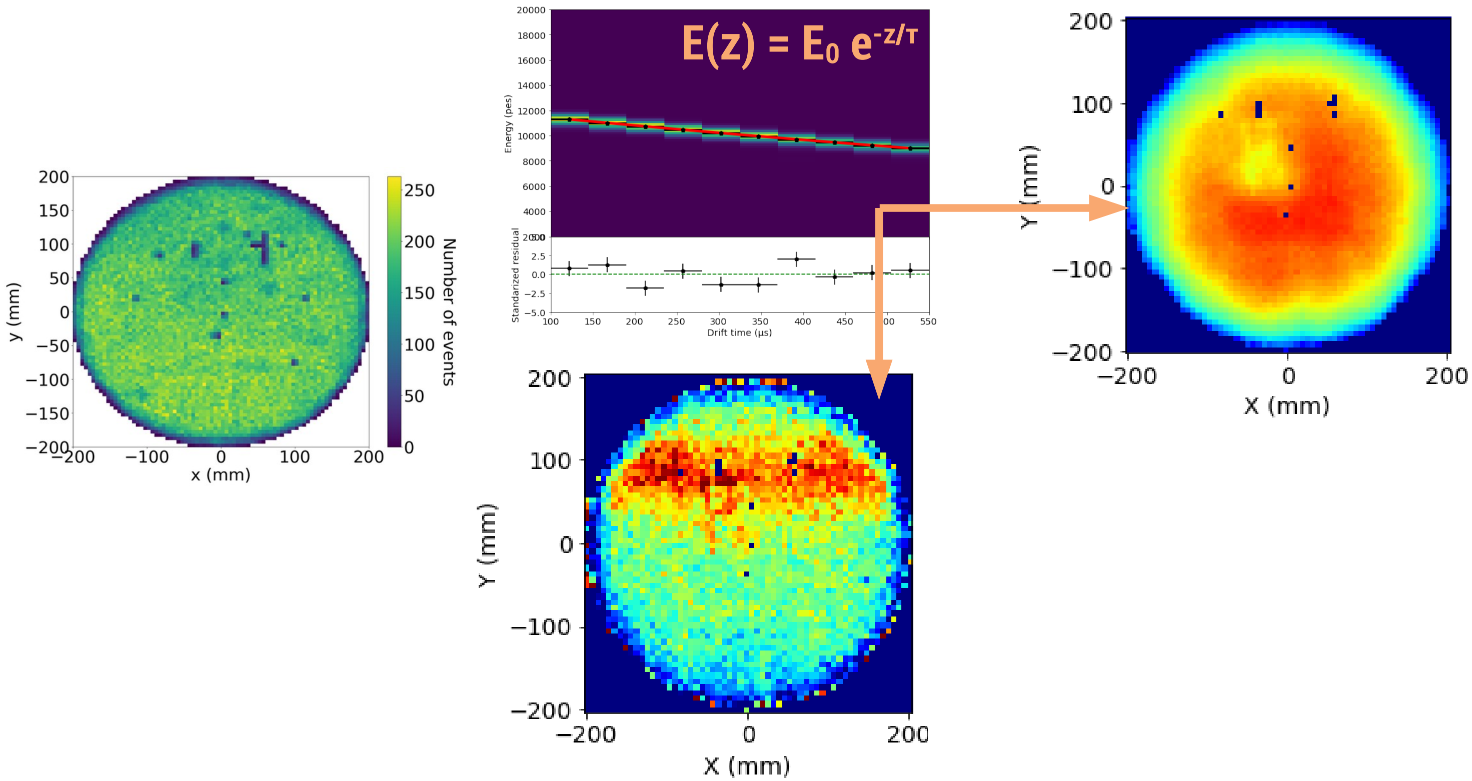






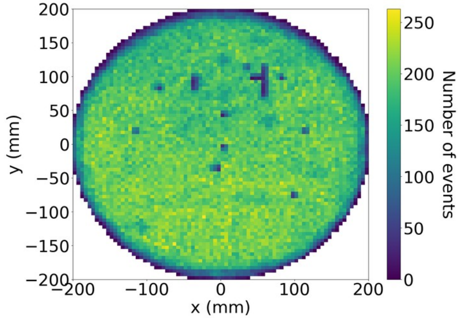
^{83m}Kr calibration: energy resolution

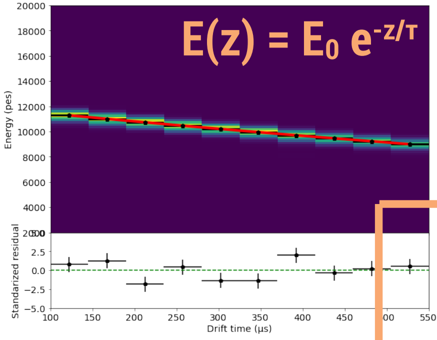
Make XY bins → **Lifetime from E vs Z** → **Ratio $E_{X,Y}/E_{0,0}$**

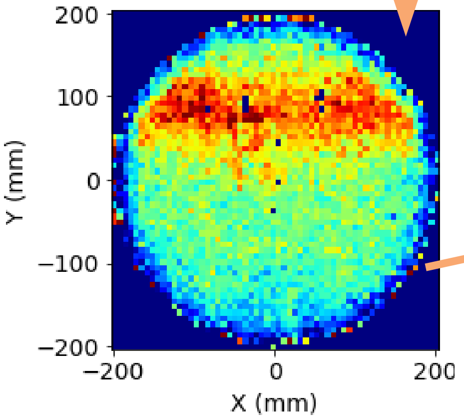


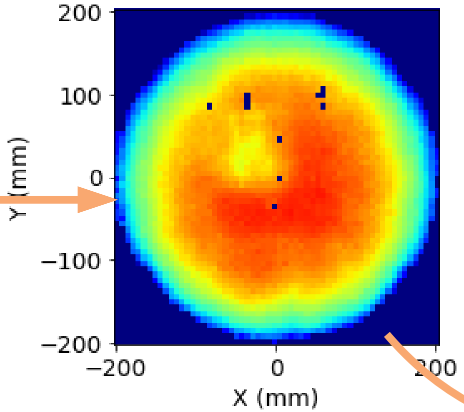
^{83m}Kr calibration: energy resolution

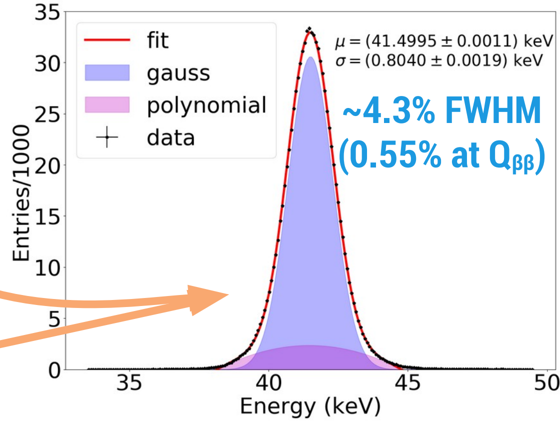
Make XY bins → **Lifetime from E vs Z** → **Ratio $E_{X,Y}/E_{0,0}$** → **Correct by everything**



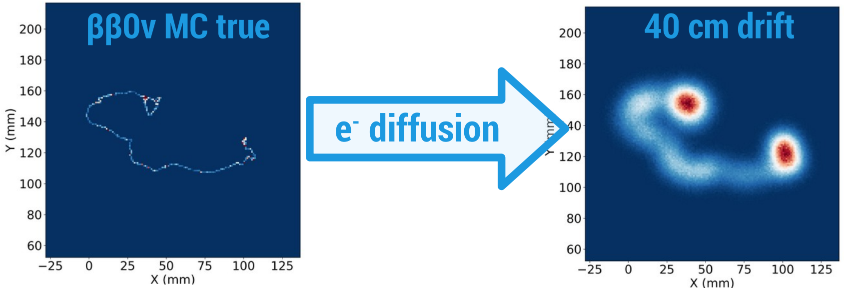






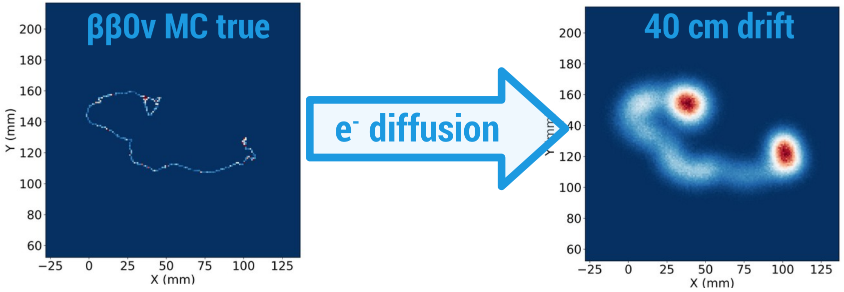


^{83m}Kr calibration: optical response

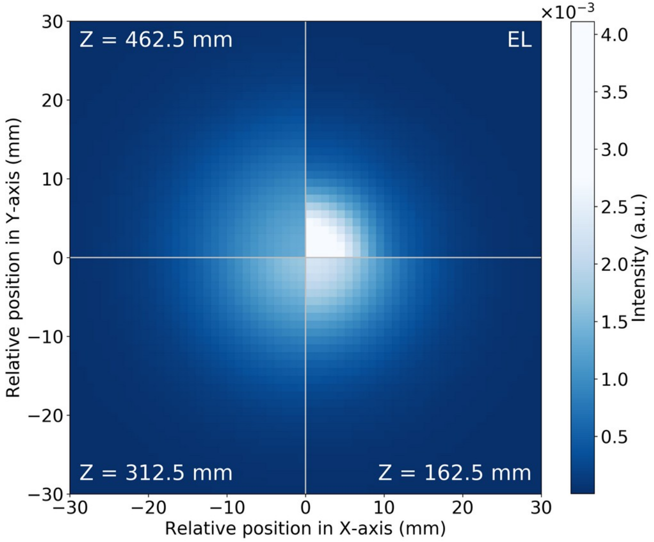


- SiPM response impacted by smearing:
  - Instrumental → SiPM pitch, SiPM distance to EL.
  - Physics → e⁻ diffusion, light spread.

^{83m}Kr calibration: optical response

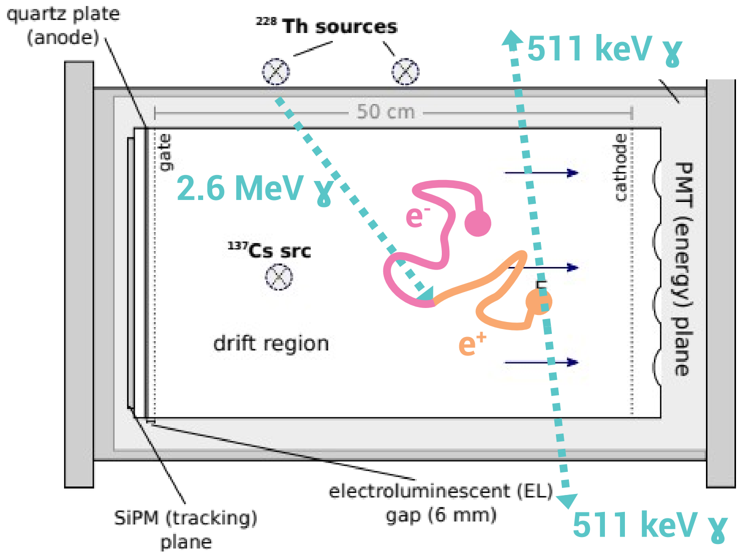


- SiPM response impacted by smearing:
  - Instrumental → SiPM pitch, SiPM distance to EL.
  - Physics → e⁻ diffusion, light spread.
- Obtain the point spread function with Kr (PSF)
  - Average fraction of photons detected at a given distance from the event origin.



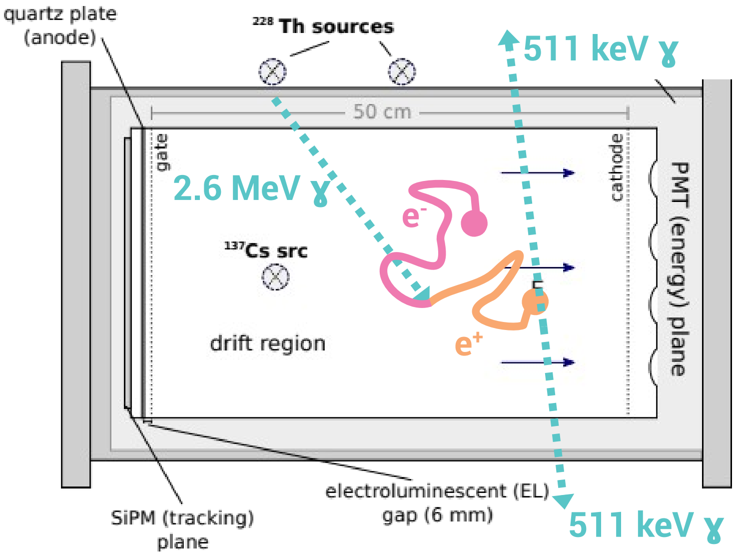
High energy calibration

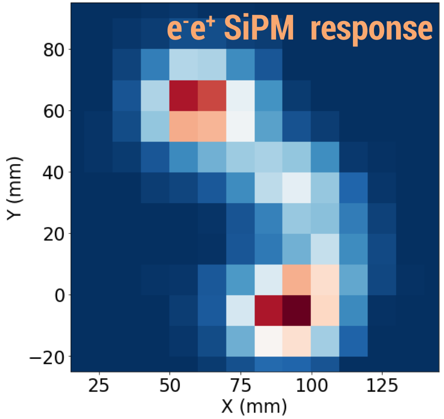
- 2 external sources:
  - $^{137}Cs \rightarrow$ 662 keV gamma
  - $^{208}Tl \rightarrow$ 2.614 MeV gamma + pair-production peak at 1.592 MeV.
- Evaluate energy resolution at different energies.



High energy calibration

- 2 external sources:
  - ^{137}Cs → 662 keV gamma
  - ^{208}Tl → 2.614 MeV gamma + pair-production peak at 1.592 MeV.
- Evaluate energy resolution at different energies.
- Evaluate topological discrimination using e^+e^- signal → mimic ββ.

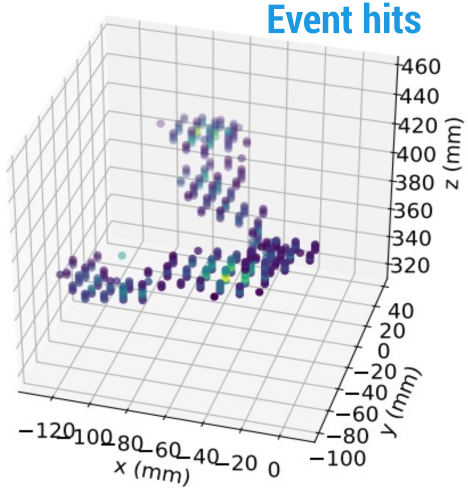




High energy calibration: energy resolution

- Energy reconstruction:
  - Make hits → 1 hit = Response of a single SiPM in temporal slice Δt.
    - XY from SiPM, Z from $t_{\Delta t} - t_{S1}$.
    - PMT energy distributed based on SiPM response.

Event hits



High energy calibration: energy resolution

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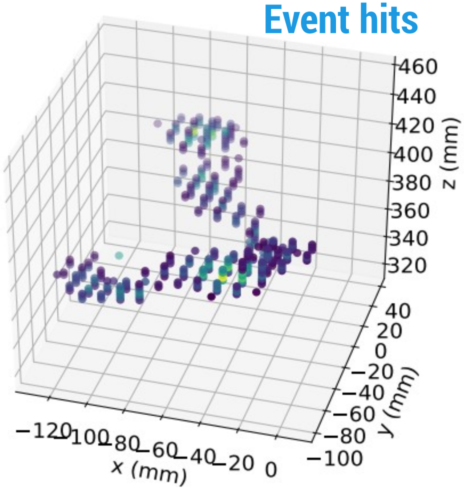
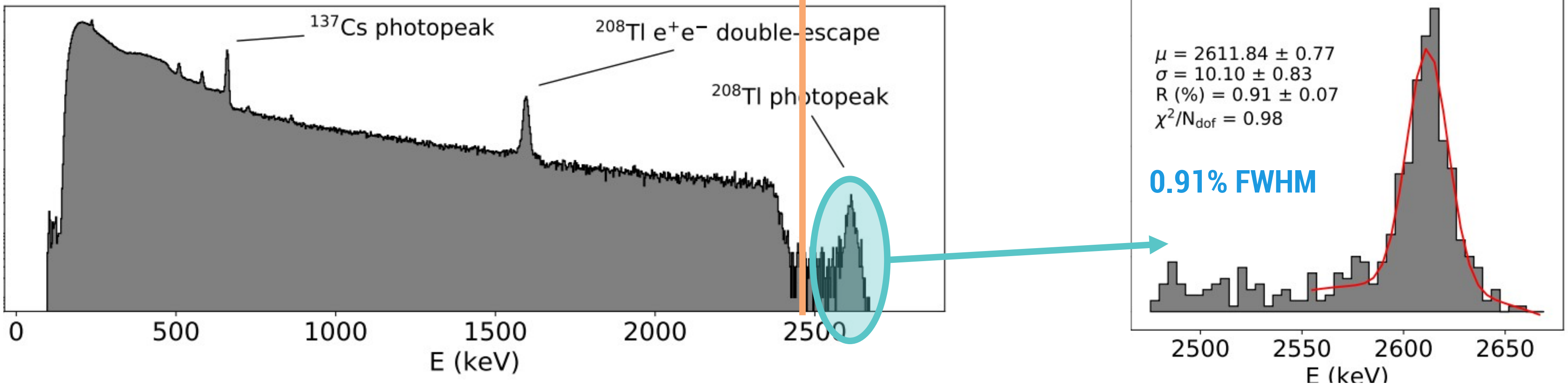
  - Make hits → 1 hit = Response of a single SiPM in temporal slice Δt.
    - XY from SiPM, Z from $t_{\Delta t} - t_{S1}$.
    - PMT energy distributed based on SiPM response.
  - Correct hits' energy individually based on its position.

Event hits

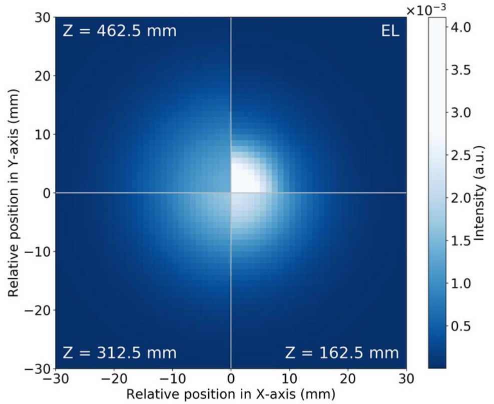


$Q_{\beta\beta}$ = 2.458 MeV



Track reconstruction

- Signals affected by blurring → Reverse the blurring!
- Richardson-Lucy deconvolves iteratively the blurring.
  - Use the XY point-spread function (PSF).



2D PSF → 2D deconvolution → 3D tracks:

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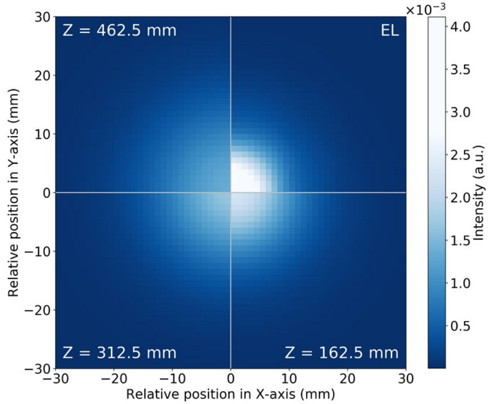

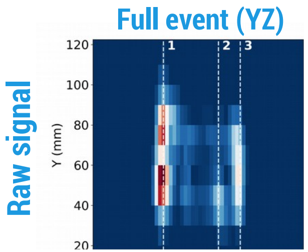

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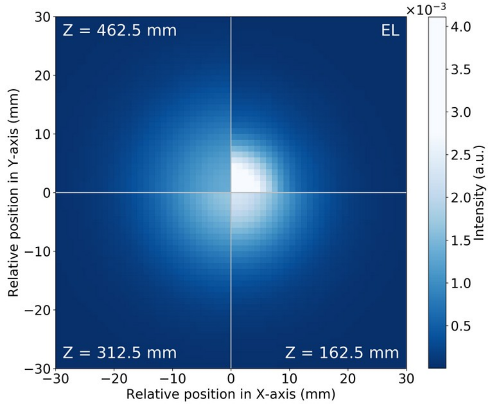

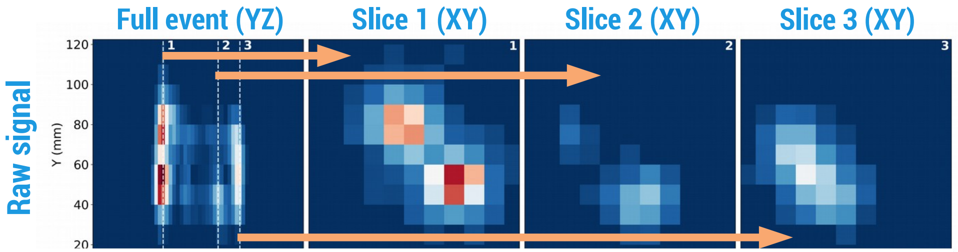

2D PSF → 2D deconvolution → 3D tracks:

- Slice the signal in 2 μs interval

Track reconstruction

arXiv:2102.11931 [physics.ins-det]

- Signals affected by blurring → Reverse the blurring!
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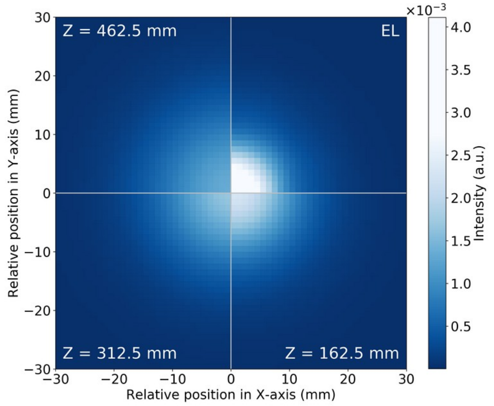
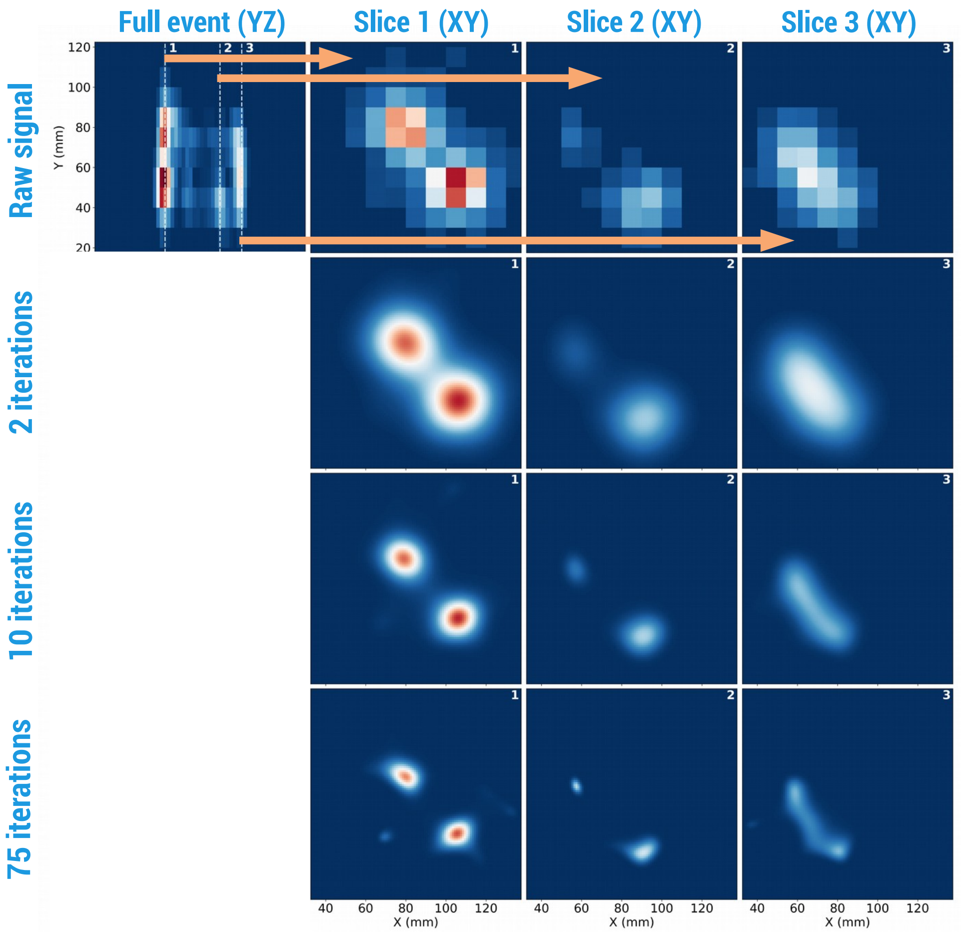


2D PSF → 2D deconvolution → 3D tracks:

- <u>Slice</u> the signal in 2 µs interval
- <u>Apply RL</u> to each slice N_{iter} times.



Track reconstruction

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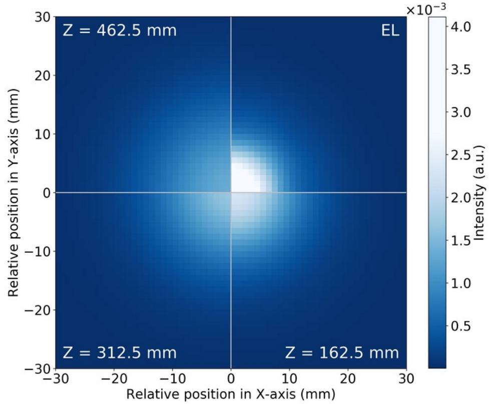
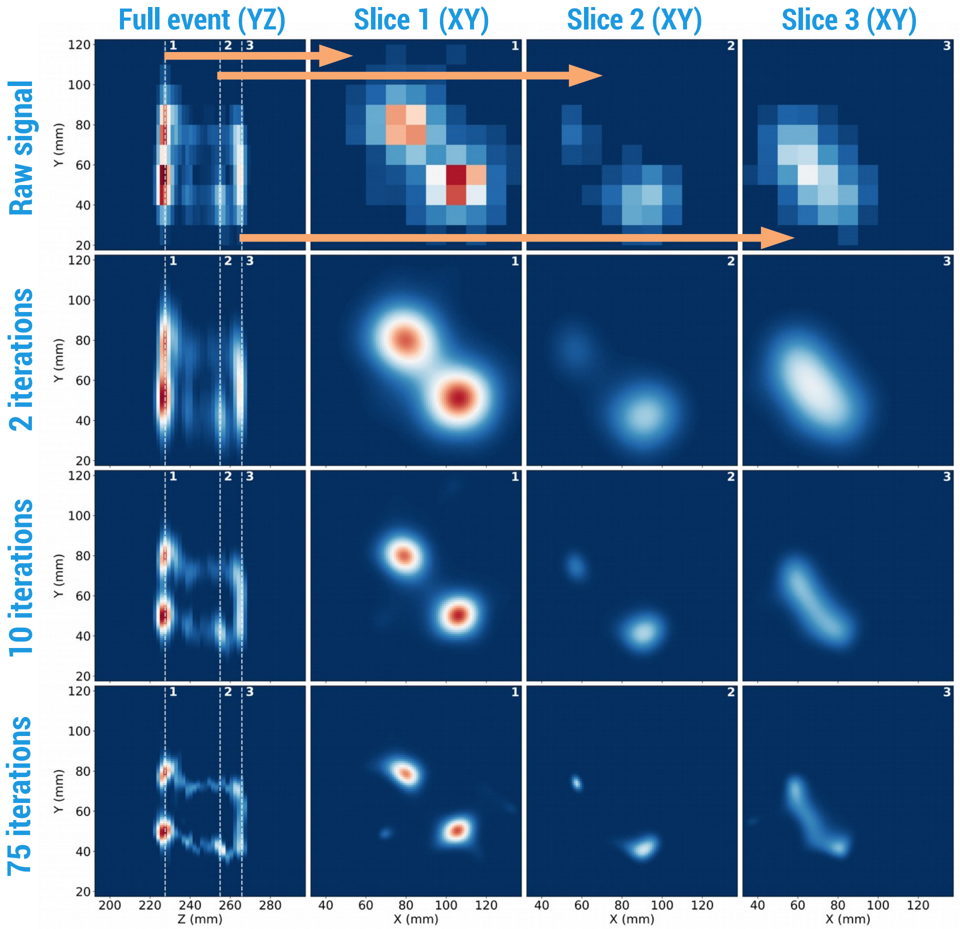


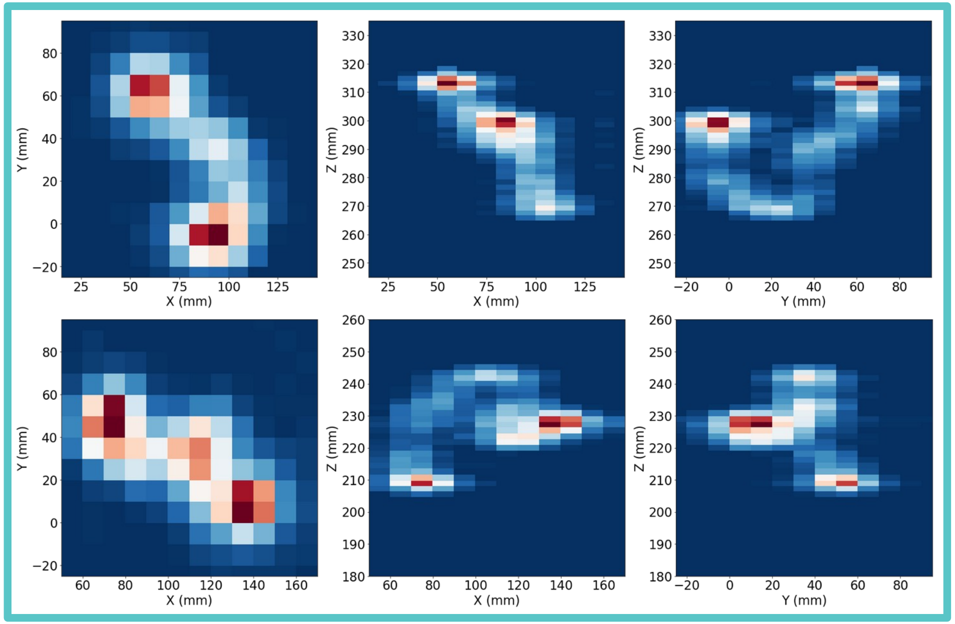
2D PSF → 2D deconvolution → 3D tracks:

- Slice the signal in 2 μs interval
- Apply RL to each slice N_{iter} times.
- Join them back together.

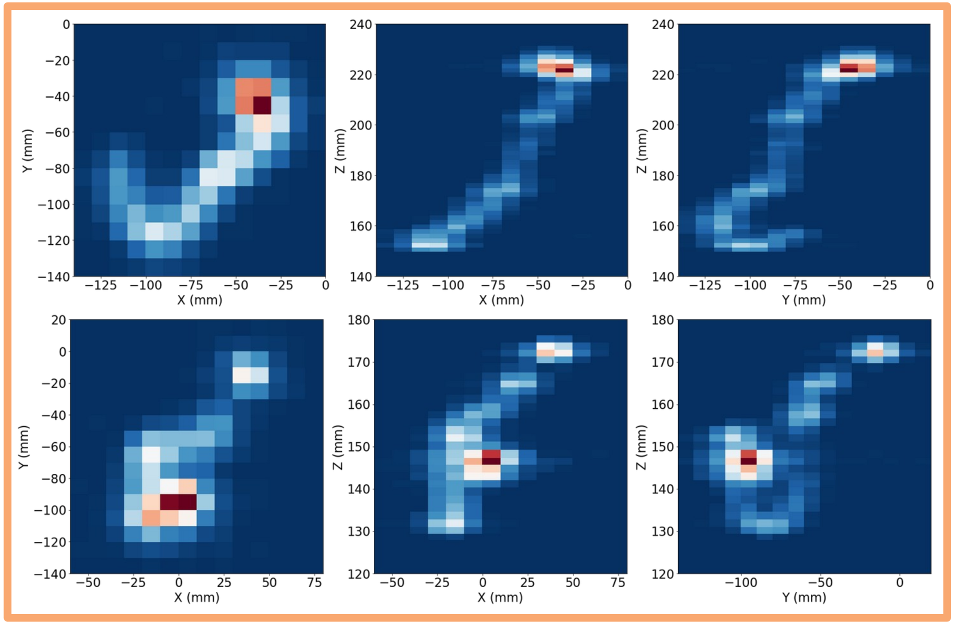


Examples

e^-e^+ pairs

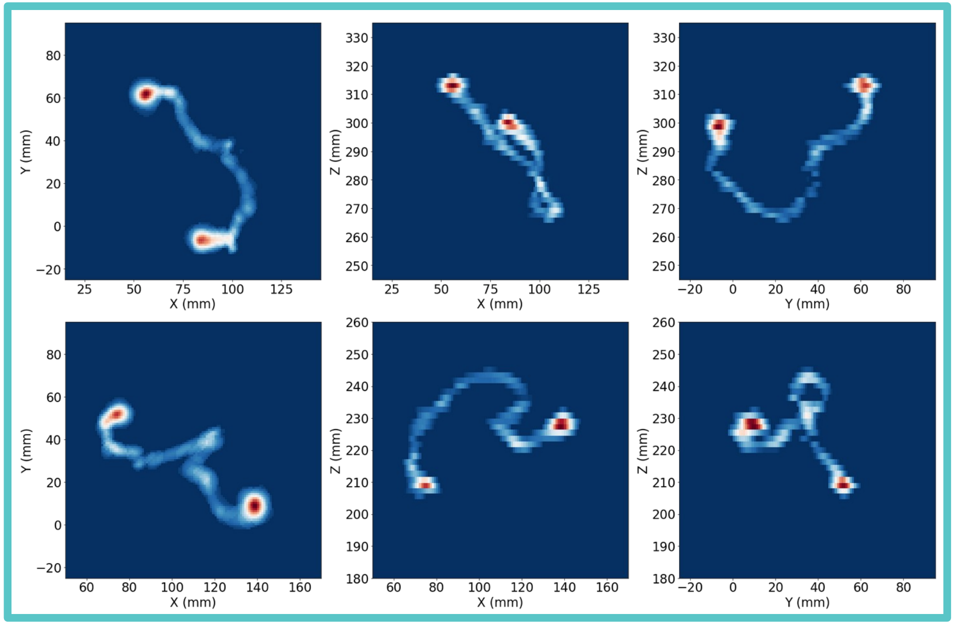


Background

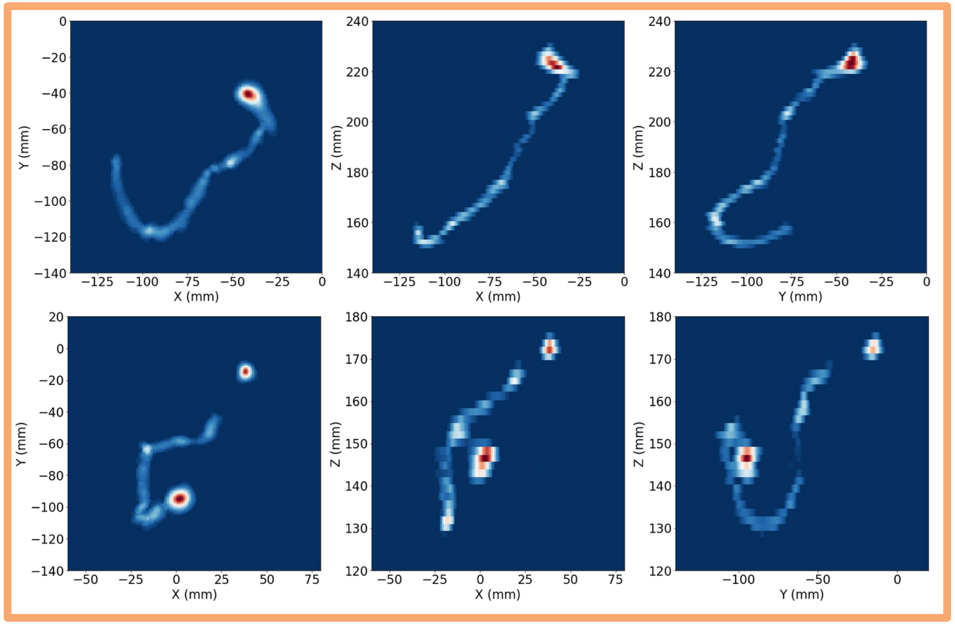


Examples

e^-e^+ pairs

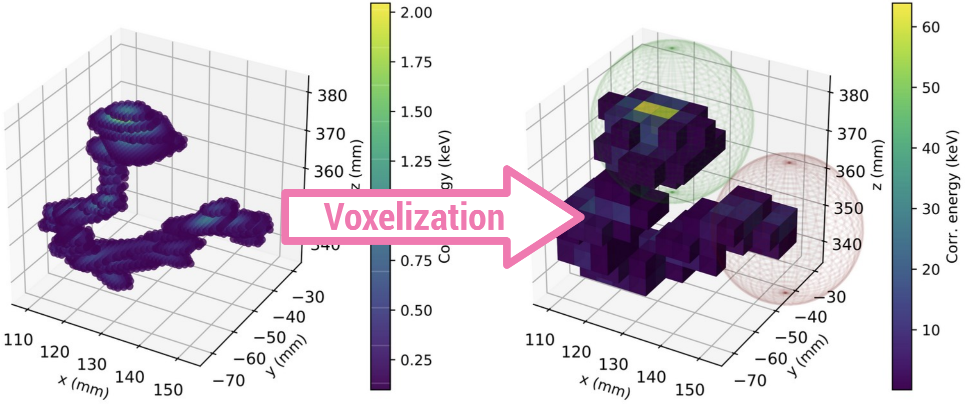


Background



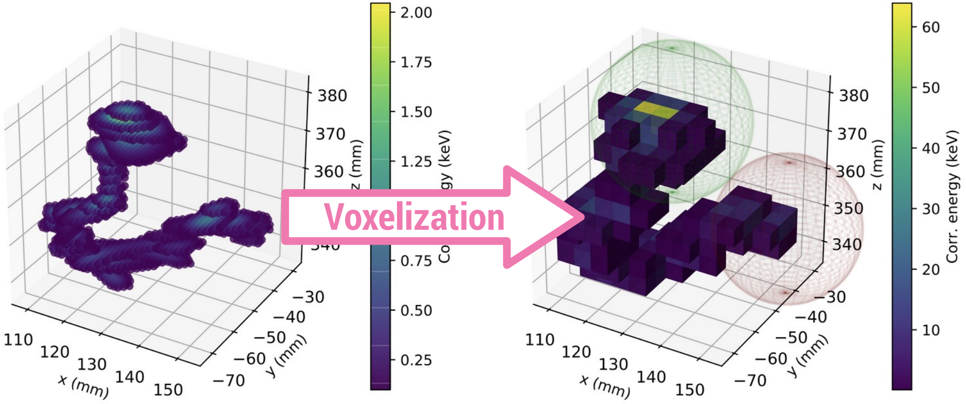
Track reconstruction

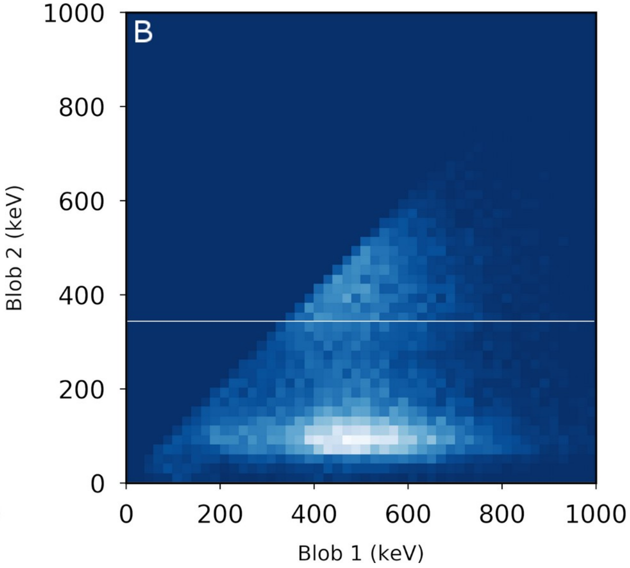
- Voxelize output of deconvolution.
- Search of track ends.



Track reconstruction

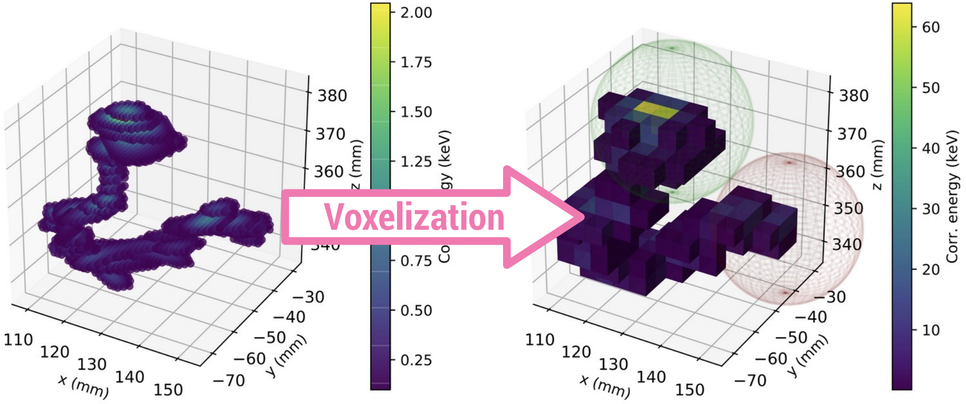
- Voxelize output of deconvolution.
- Search of track ends.
- Integrate energy within the ends → blobs.

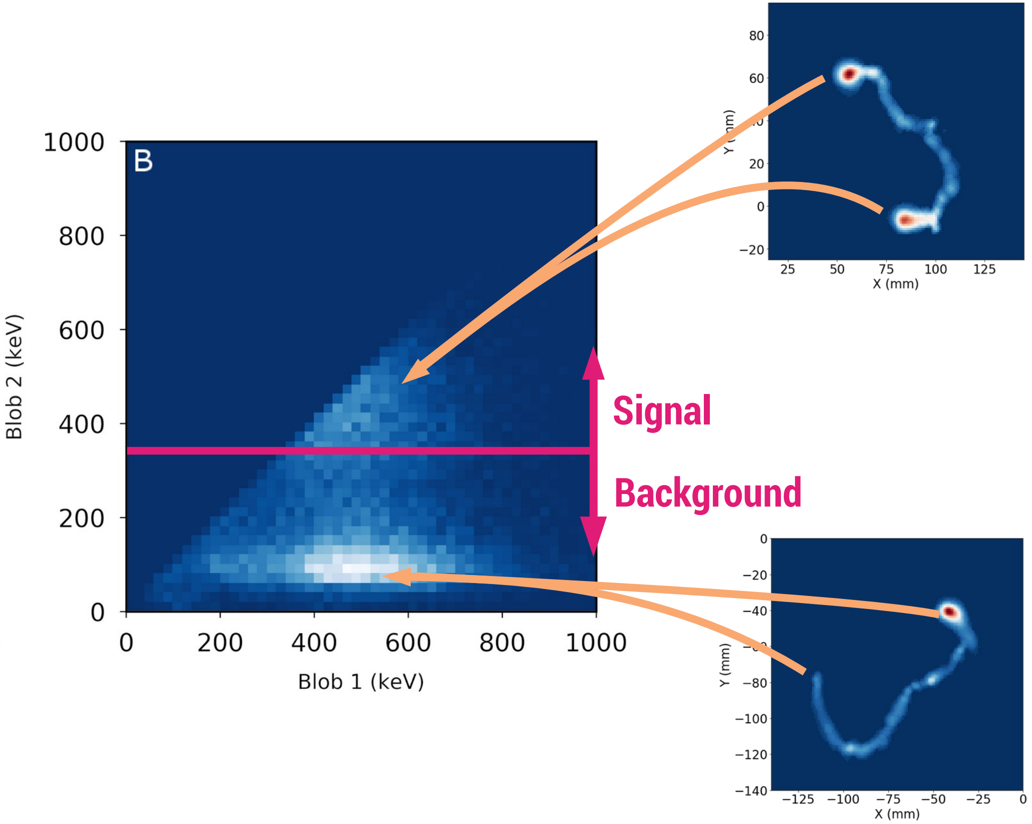




Track reconstruction

- Voxelize output of deconvolution.
- Search of track ends.
- Integrate energy within the ends → blobs.
- Classify events based on lower blob energy:

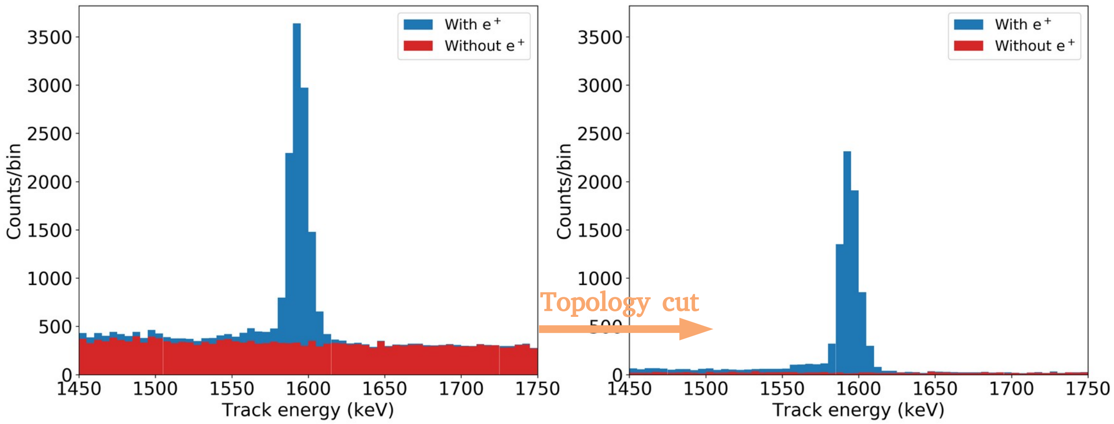




High energy calibration: background rejection

- Evaluate events at the e^-e^+ region.
- Optimize figure of merit → **f.o.m = $\epsilon_{signal}/\sqrt{\epsilon_{bckg}}$**

$$\epsilon = \frac{number\ of\ events\ with\ E_{blob\,2} > E_{thr}}{total\ number\ of\ events}$$



High energy calibration: background rejection

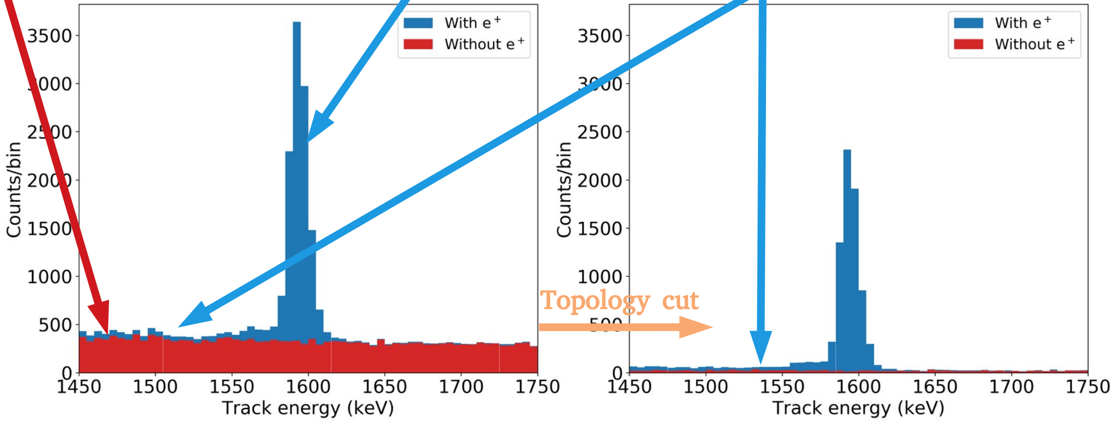
- Evaluate events at the e^-e^+ region.
- Optimize figure of merit → **f.o.m = $\epsilon_{signal}/\sqrt{\epsilon_{bckg}}$**
- Fit to energy distribution → Integrate to extract # of events.

$$\epsilon = \frac{number\ of\ events\ with\ E_{blob\,2} > E_{thr}}{total\ number\ of\ events}$$

$$f(E) = f_{bkg}(E) + f_{sig}(E) = A_1 \exp(-A_2 E) + B_1 \left(\frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(E-\mu)^2}{2\sigma^2} \right) + C_1 \operatorname{erfc}\left(\frac{E-\mu}{\sqrt{2}\sigma} \right) + C_2 \right)$$

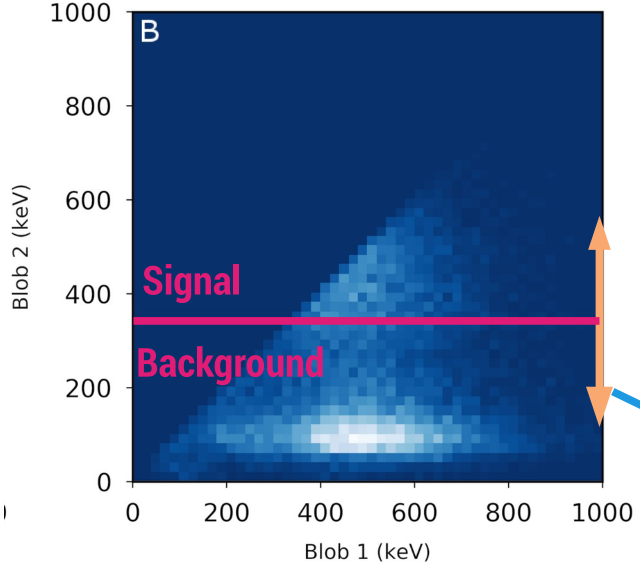
$$N_{bkg} = \int_{\mu-3\sigma}^{\mu+3\sigma} f_{bkg}(E)dE$$

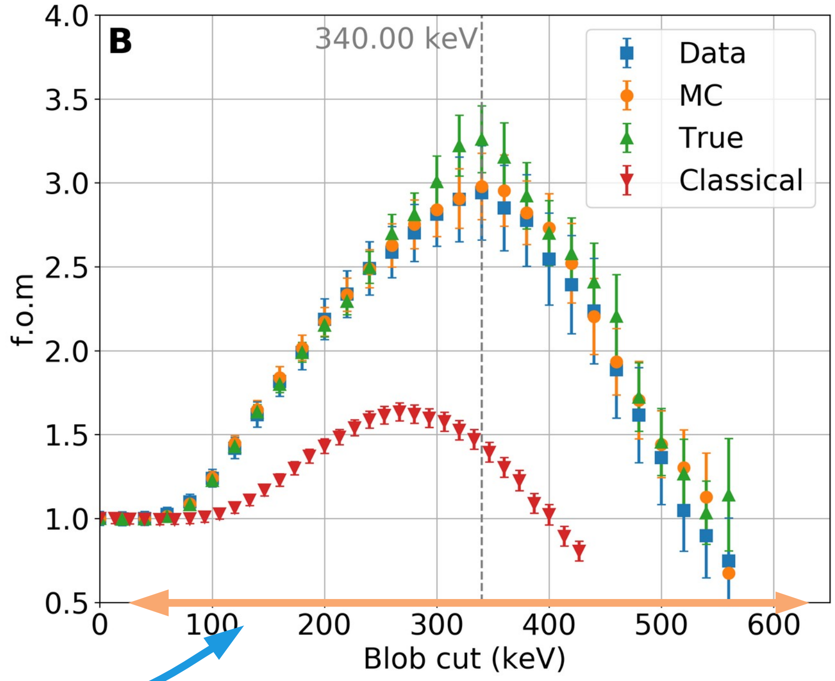
$$N_{sig} = \int_{\mu-3\sigma}^{\mu+3\sigma} f_{sig}(E)dE$$



High energy calibration: background rejection

- Scan the blob threshold to optimize f.o.m!
  - 56.6% signal efficiency
  - 3.7% background acceptance.
  - s/√b of 2.94.

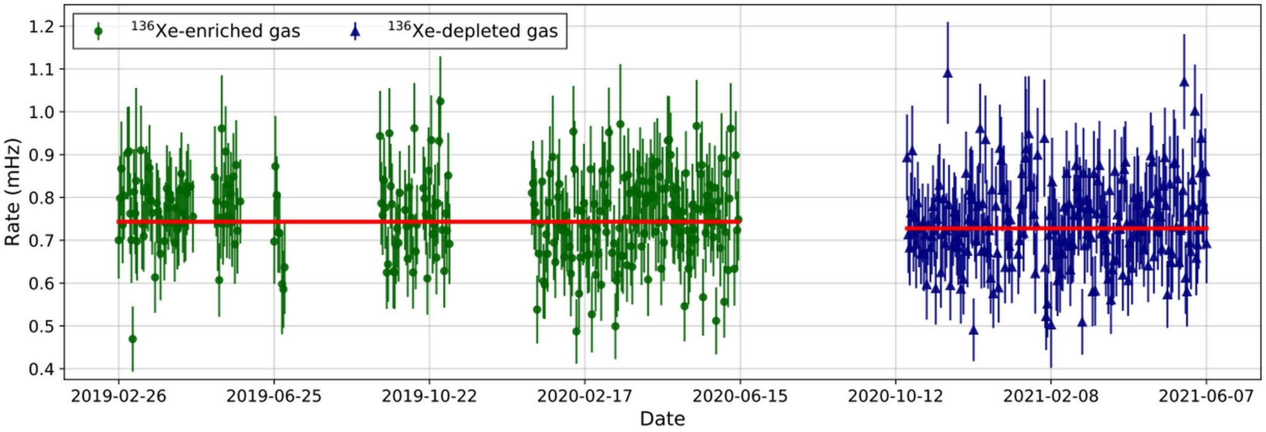




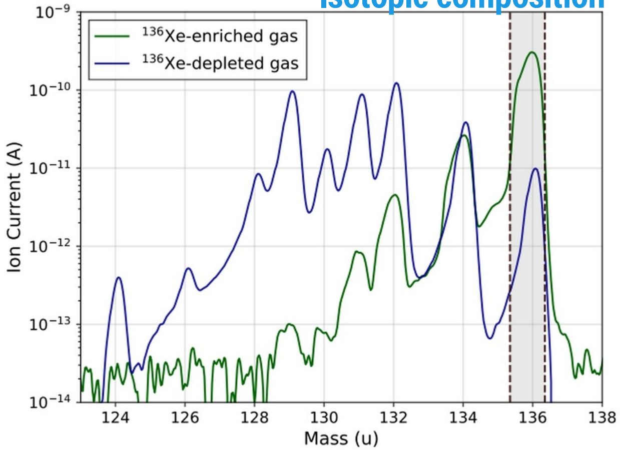
Low-background data-taking

- **Enriched Xe**
  - 90.9% ^{136}Xe.
  - Exposure: 271.6 d
  - Rate: 0.758 ± 0.006 mHz
- **Depleted Xe**
  - 2.6% ^{136}Xe
  - Exposure: 208.9 d
  - Rate: 0.742 ± 0.011 mHz

Fiducial rate

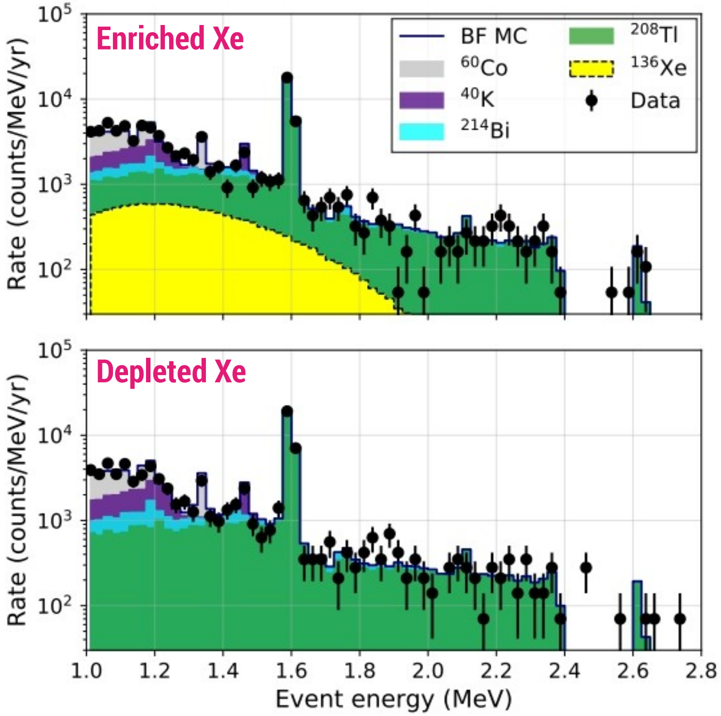


Isotopic composition



2νββ: background-model fit

- **ββ-like sample**: fiducial containment + single track + blob cut.
- Joint ML fit to energy distributions of enriched and depleted Xe data based on MC distributions.



^{136}Xe rate : 334 ± 78 (stat) ± 54 (sys) yr^{-1}

↓

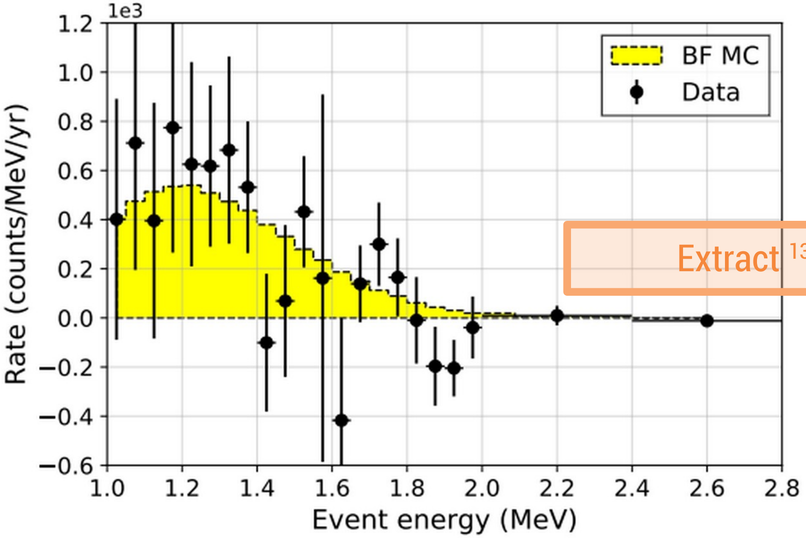
$$T_{1/2}^{2\nu} = 2.14^{+0.65}_{-0.38}(stat)^{+0.46}_{-0.26}(syst) \times 10^{21}$$

Background rates:

- ^{40}K : 10 ± 2 μHz
- ^{60}Co : 14 ± 2 μHz
- ^{214}Bi : 6 ± 3 μHz
- ^{208}Tl : 40 ± 2 μHz

$2\nu\beta\beta$: Direct background subtraction

- **Novel method** → Subtract enriched Xe and depleted Xe spectrum.
  - Quasi-independent of background model (single/double e$^-$ efficiency correction).



Extract ^{136}Xe rate from excess

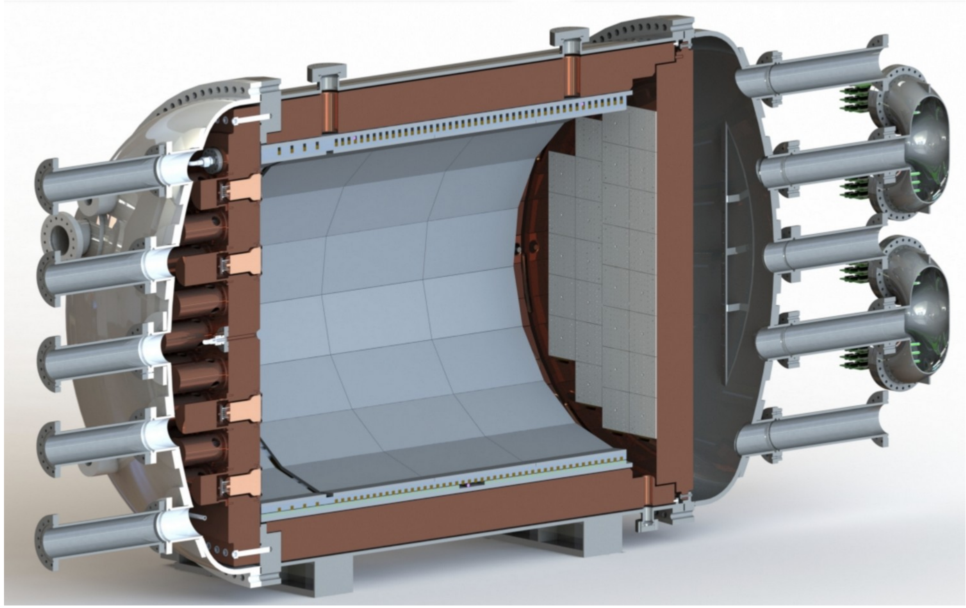
^{136}Xe Rate:

- Direct subtraction: 251 ± 83 (stat) ± 29 (sys) yr^{-1}
- **Fit to $2\nu\beta\beta$ MC: 291 ± 73 (stat) ± 28 (sys) yr^{-1}**

$$T^{2\nu}_{1/2} = 2.34^{+0.80}_{-0.46}(stat)^{+0.30}_{-0.17}(syst) \times 10^{21}$$

NEXT-100

- Next phase of the NEXT program at LSC.
- ~100 kg of ^{136}Xe, target bckg rate of 5×10^{-4} cts/(keV·kg*yr)
- Advanced construction stage, installation ends later this year.



Goals

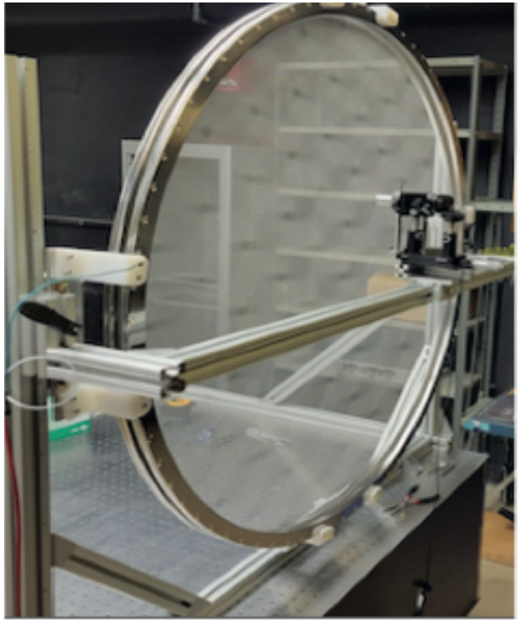
- Demonstrator for tonne-scale.
- Improved background understanding.
- $\beta\beta0\nu$ search.
- Impact of coarser tracking plane.

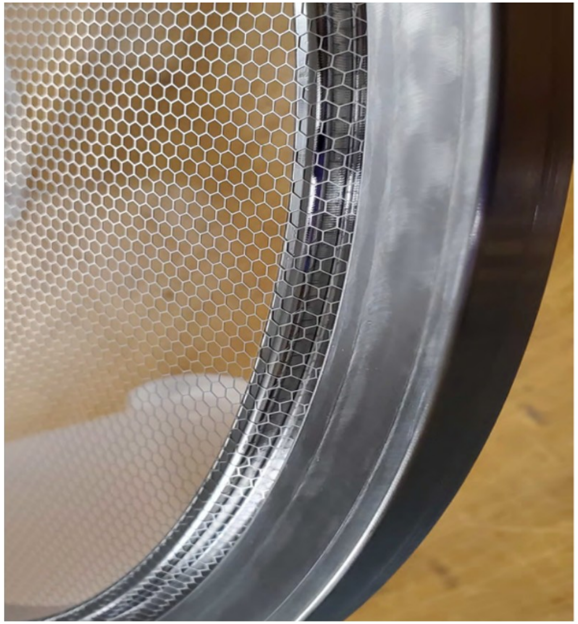
NEXT-100: pressure vessel and inner copper shield

- Pressure vessel: stainless steel, 13.5 bar operational pressure.
  - Status: **completed**.
- Inner shield: radiopure copper, 12 cm thick.
  - Status: forged & machined, **cleaning ongoing**.

NEXT-100: time projection chamber

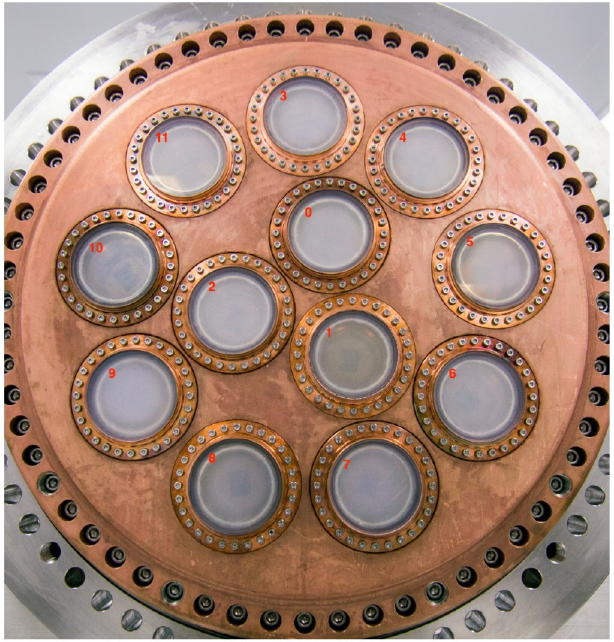
- Field cage: copper rings on HDPE staves, PTFE panels for increased light collection.
  - Status: design and prototyping completed, **production orders ongoing**.
- Meshes (anode, gate and cathode): stainless steel rings with photoetched wire meshes.
  - Status: design and prototyping completed, **production orders ongoing**.

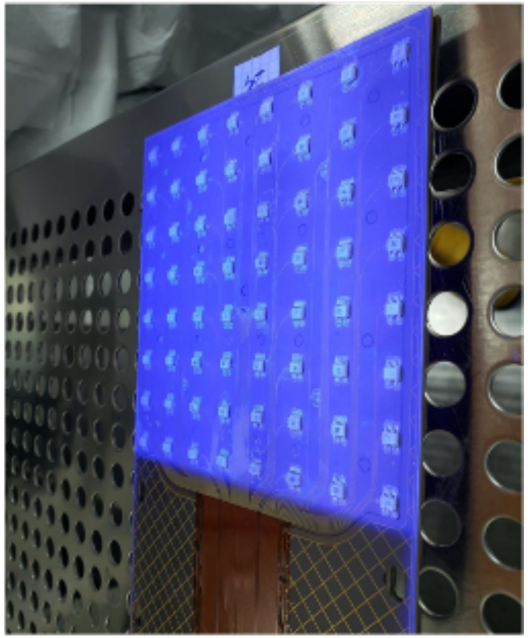




NEXT-100: readout planes

- Energy plane: 60 Hamamatsu R11410-10 PMTs behind sapphire windows.
  - Status: PMTs procured, PMT bases built, electronics completed, **windows' coating ongoing**.
- Tracking plane: 56 boards with 64 SiPMs each, for a total of 3584 SiPMs, pitch of 15 mm.
  - Status: **boards built** and TPB-coated, electronics **completed and tested**.





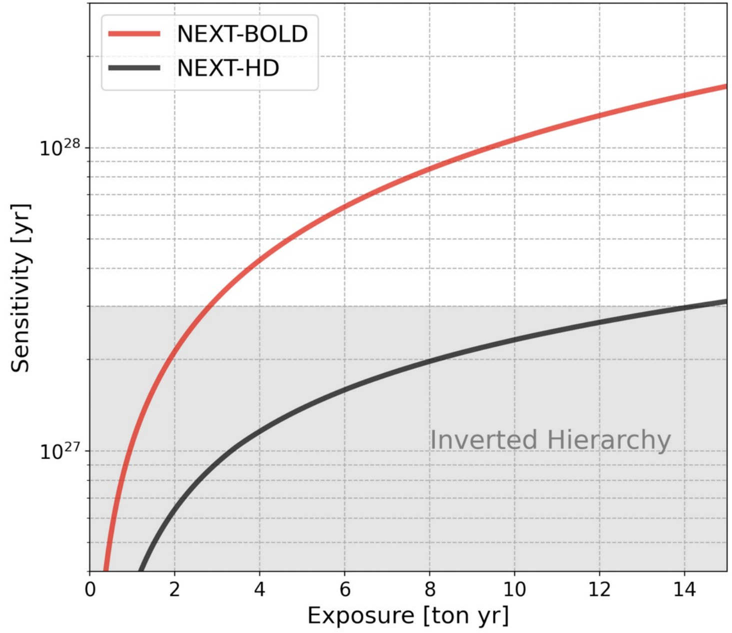
Towards the tonne-scale.

Medium-term

NEXT-HD → Continuist improvement

Long-term

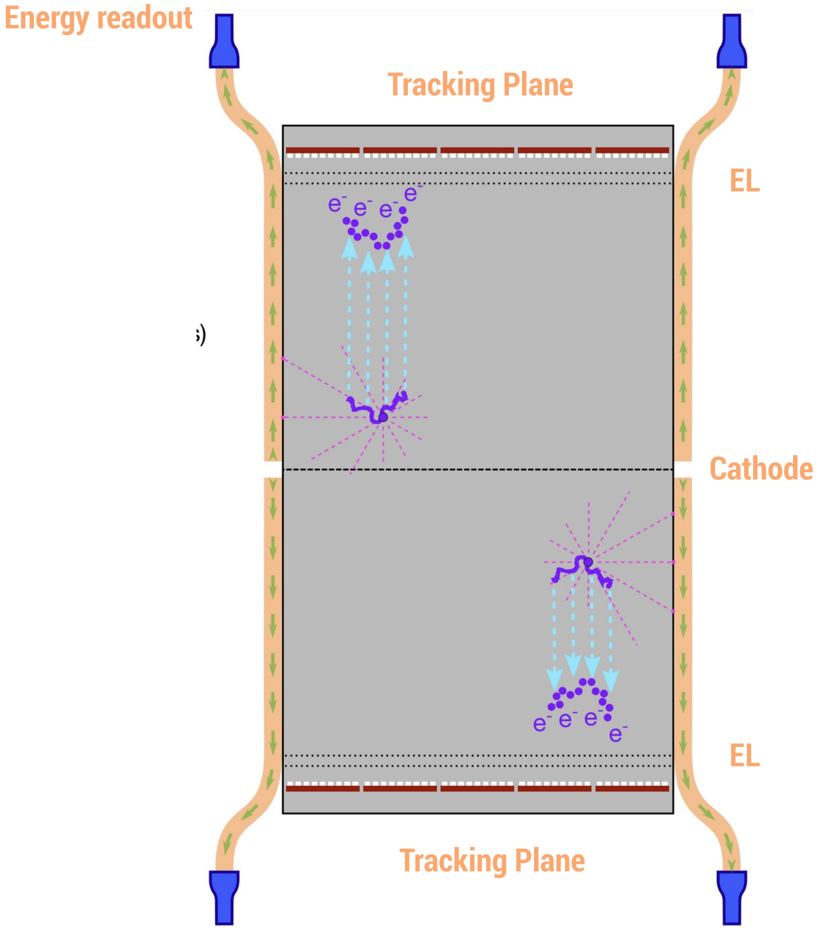
NEXT-BOLD → Barium tagging HPGXe TPC



Towards the ton-scale: NEXT-HD

arXiv:2005.06467 [physics.ins-det]

- Symmetric TPC → Reduce e- lifetime, voltage requirements.



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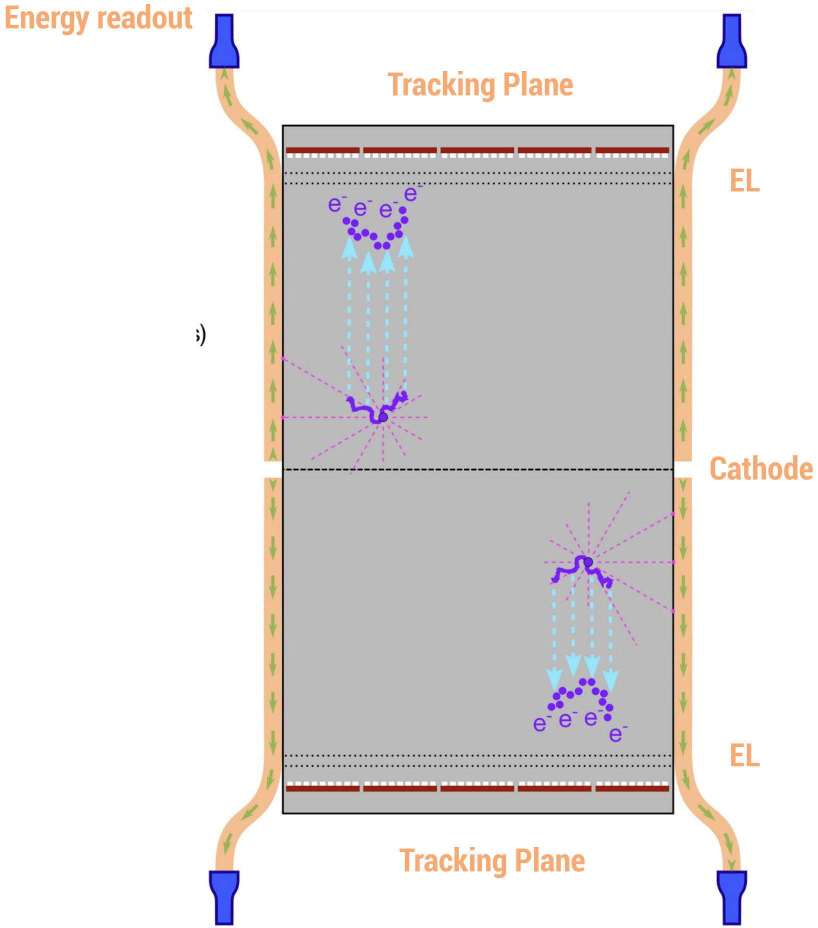

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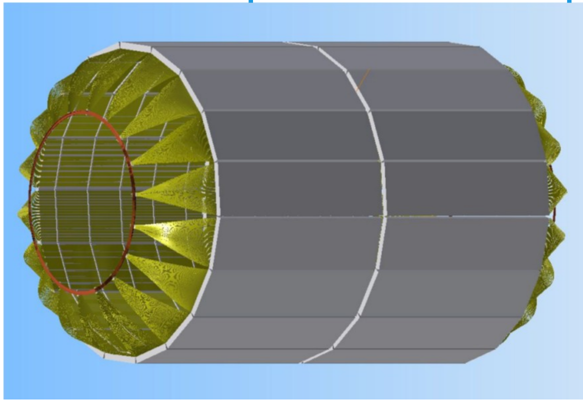
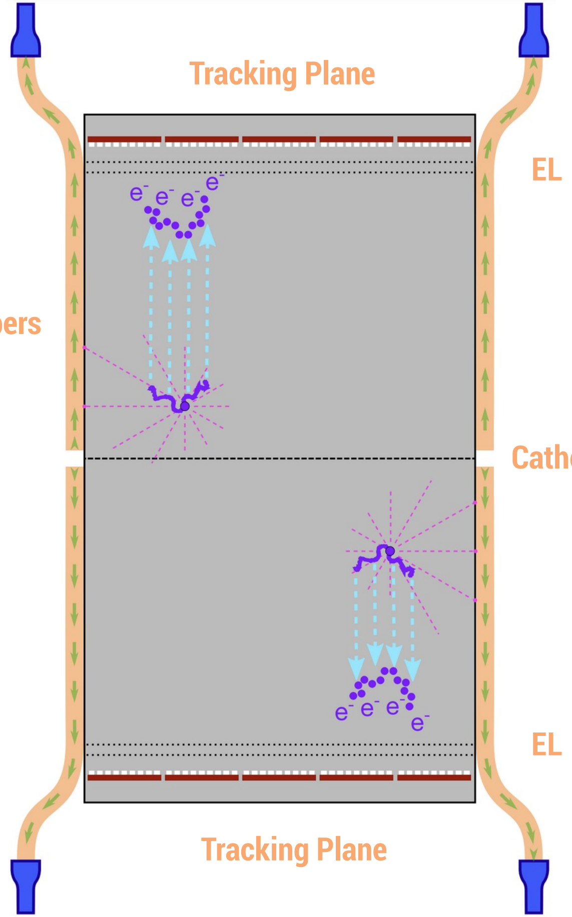
Optical fiber barrel mock-up





Towards the ton-scale: NEXT-HD

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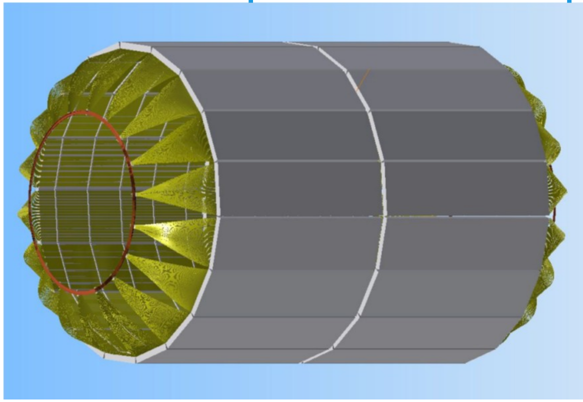

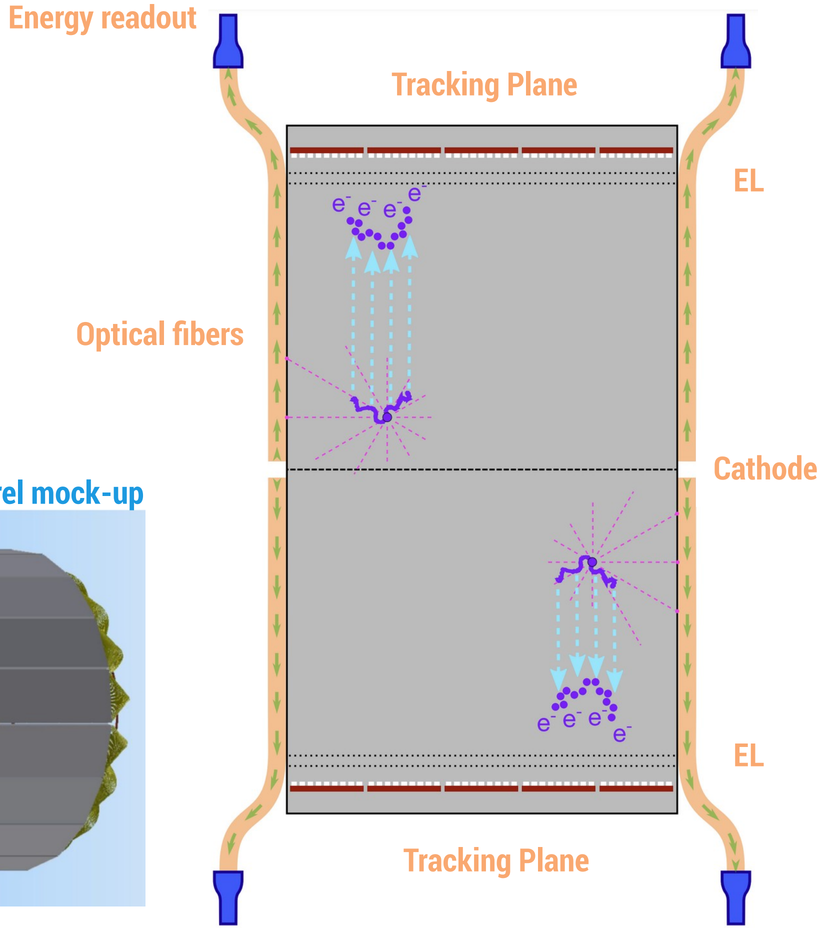

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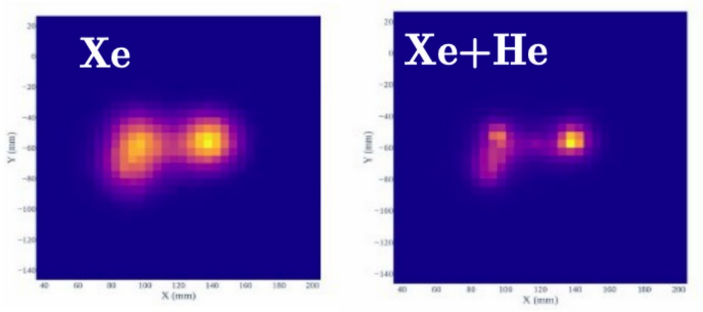

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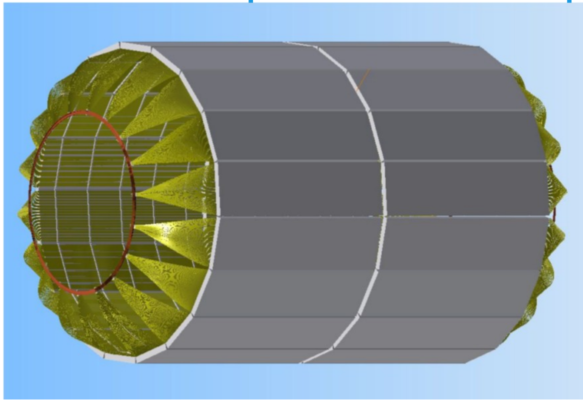

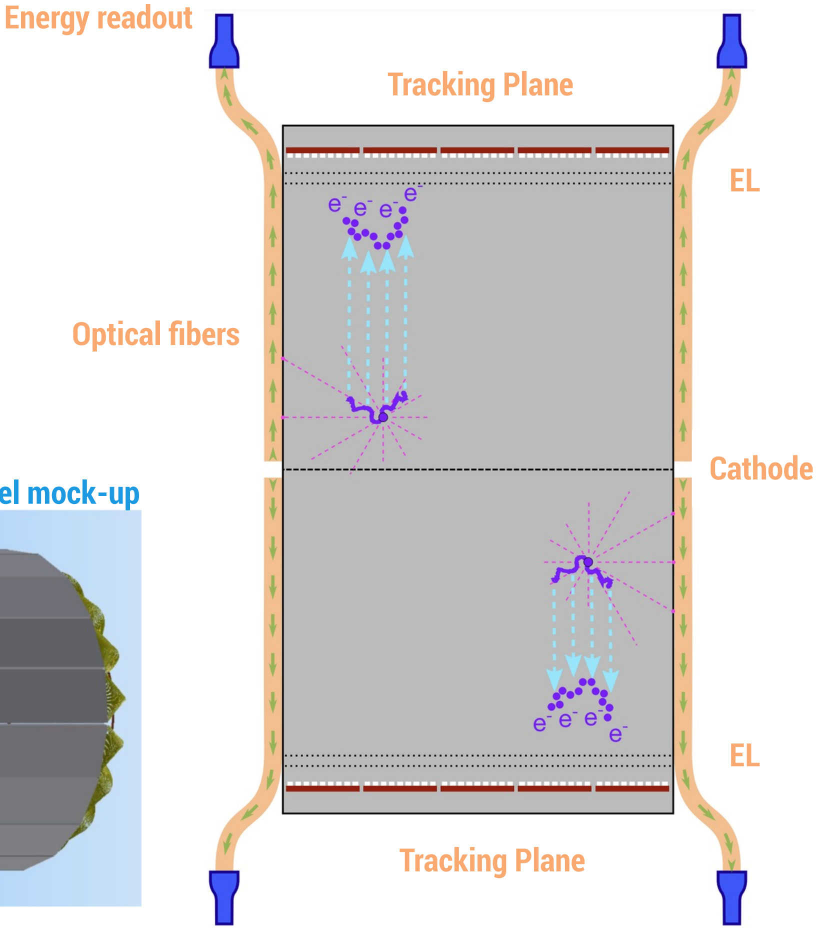

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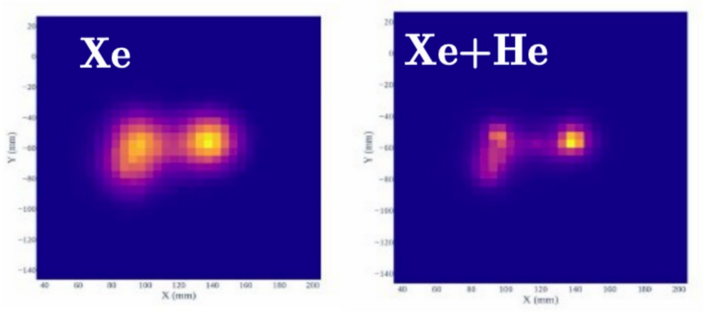
- Gas mixtures → Reduces diffusion smearing.
- Cold gas → Reduce dark noise, pressure requirements.



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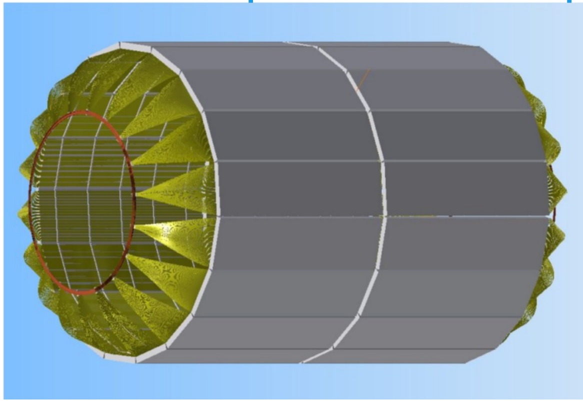

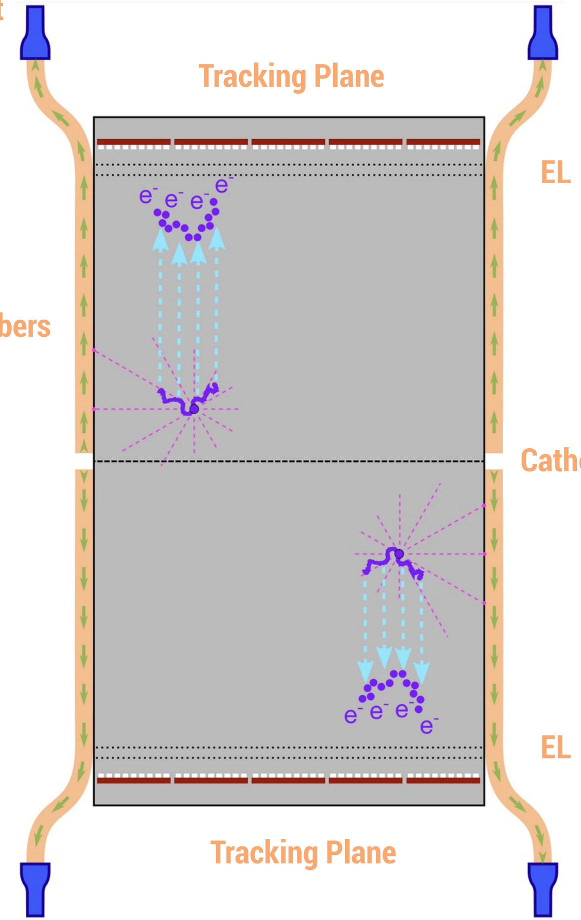

Towards the ton-scale: NEXT-BOLD

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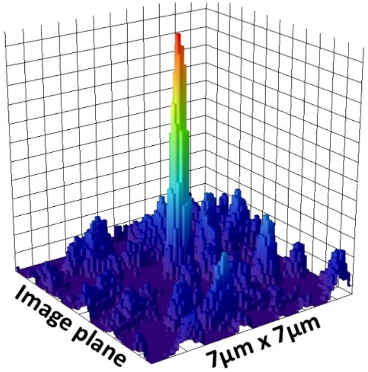
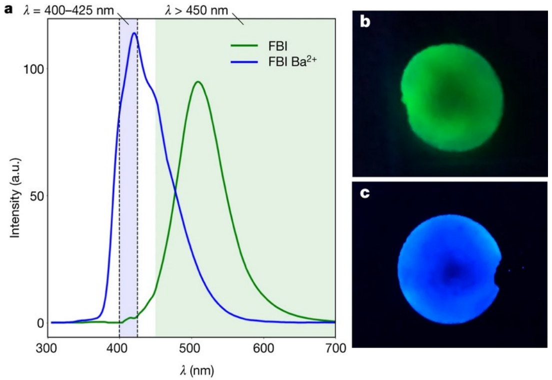
  - Fluorescent bicolour indicator.
  - Fluorescence on/off.

Single barium fluorescence



Fluorescence spectrum



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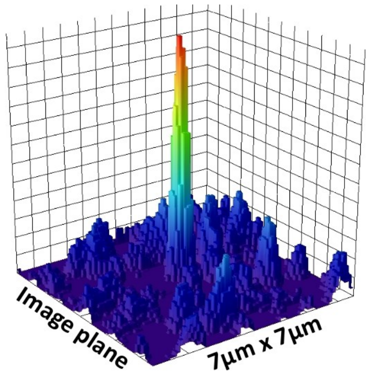

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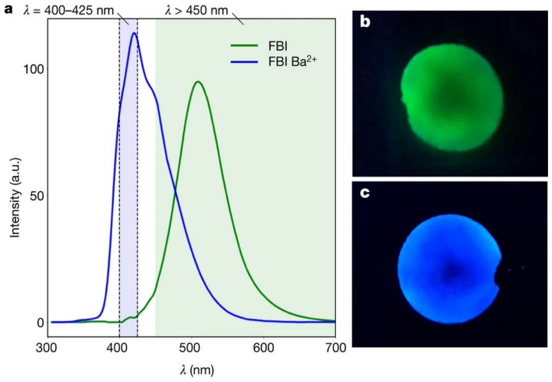

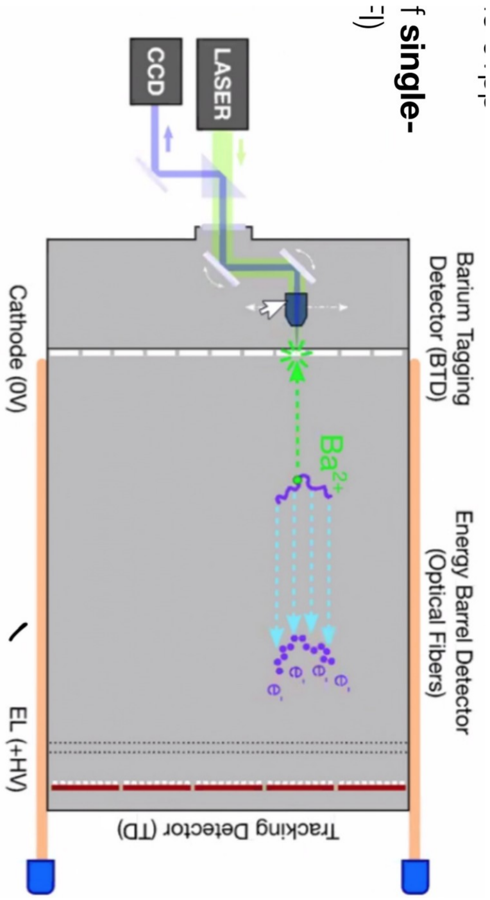

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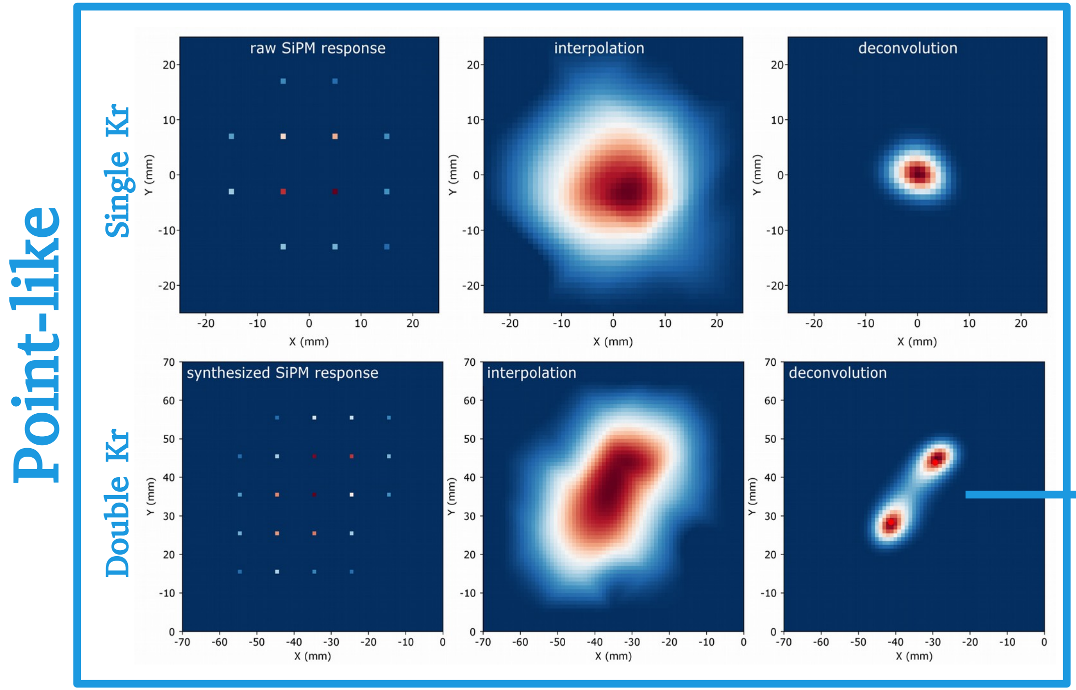
Summary

- $\beta\beta0\nu$ searches are extraordinary challenging.
- NEXT technique offers 3 strong assets:
  - Great energy resolution.
  - Strong background rejection through track reconstruction.
  - Scalability.
- Unique possibility to operate an effectively background-free experiment with barium tagging.
- Timeline:
  - Recent past: detector performance, backgrounds and $2\nu\beta\beta$ with NEXT-White (~4 kg)
  - Short-term: $0\nu\beta\beta$ searches at the 100 kg scale with NEXT-100.
  - Medium term: $0\nu\beta\beta$ searches at the tonne scale with NEXT-HD → Inverted hierarchy.
  - Longer term: NEXT-BOLD, a tonne-scale detector implementing barium tagging → Normal hierarchy?

Backup

Richardson-Lucy in NEXT

- **2D PSF → 2D deconvolution:**
  - Apply to integrated signal → valid for short events.

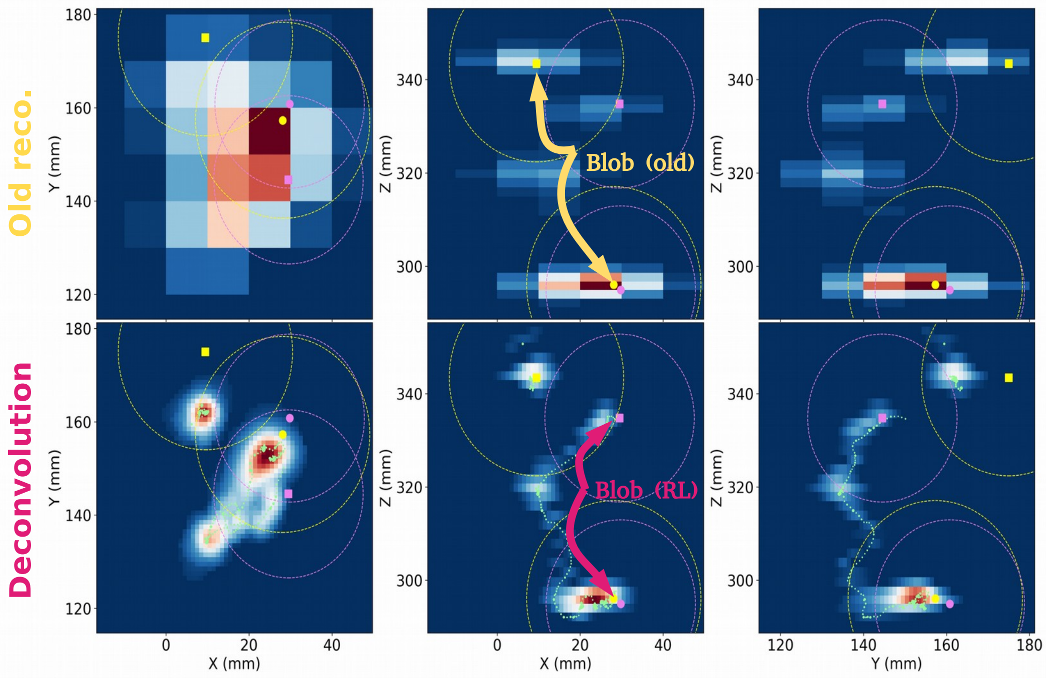


STRONG RESOLVING POWER

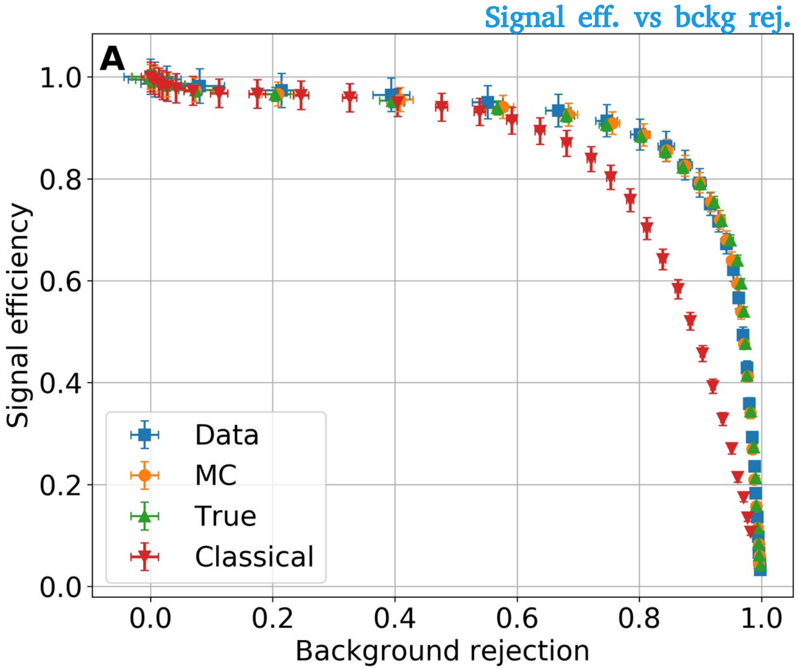
Track reconstruction

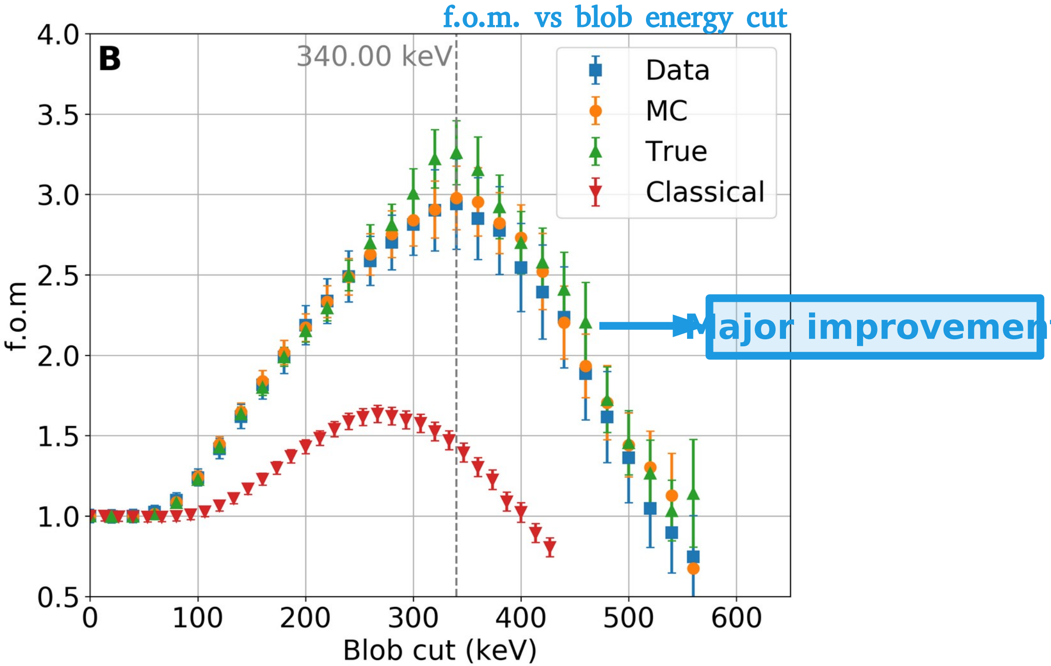
arXiv:1905.13141 [physics.ins-det]

- Deconvolved **hits are voxelized** in larger cubes → maximize continuity.
- Search for the track ends and characteristics using a **breadth first search algorithm**.
  - **Track**: group of connected voxels.
  - **End-points**: points with maximum separation along the track path.
  - **Blobs**: spherical region of a fixed given radius with an end-point as the center.
- Blob energy is obtained by summing the energy of the hits contained within the blob sphere.



Rejection performance





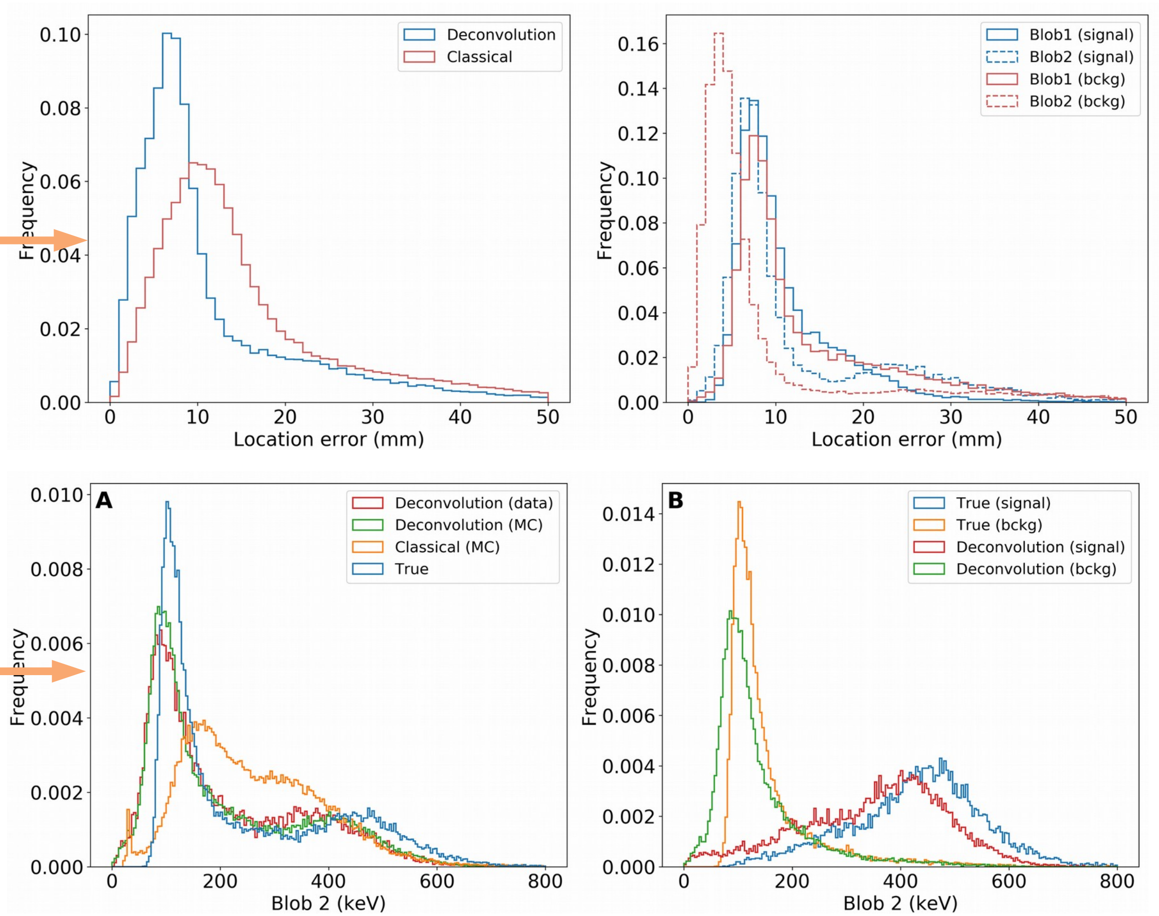
Dataset/ Analysis	Signal efficiency	Bckg acceptance	Figure of Merit
Old	71.6 ± 1.5%	20.6 ± 0.4%	1.58 ± 0.04
Data	**56.6 ± 2.2%**	**3.7 ± 0.7%**	**2.94 ± 0.28**
MC (fit)	59.4 ± 1.6%	4.0 ± 0.5%	2.98 ± 0.20
MC (true)	59.4 ± 1.0%	3.3 ± 0.4%	3.26 ± 0.20

Optimal performance

Enhancement driven by

Improved end-point location

Strong improvement in the measured blob energy



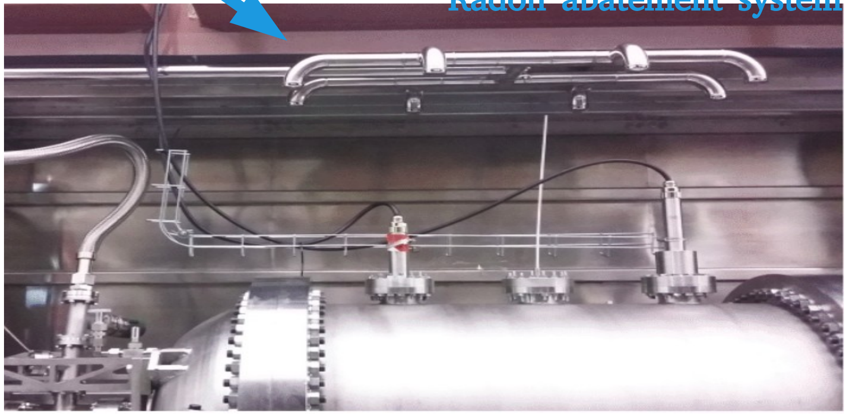
External background suppression

3 data taking periods with **incremental background suppression improvements**:

- Run IVa (41.5 d): **External lead shield**.
- Run IVb (27.2 d): **Radon abatement system (RAS) from LSC** inside external lead shield.
- Run IVc (37.9 d): **Internal lead shield**.

External lead shield

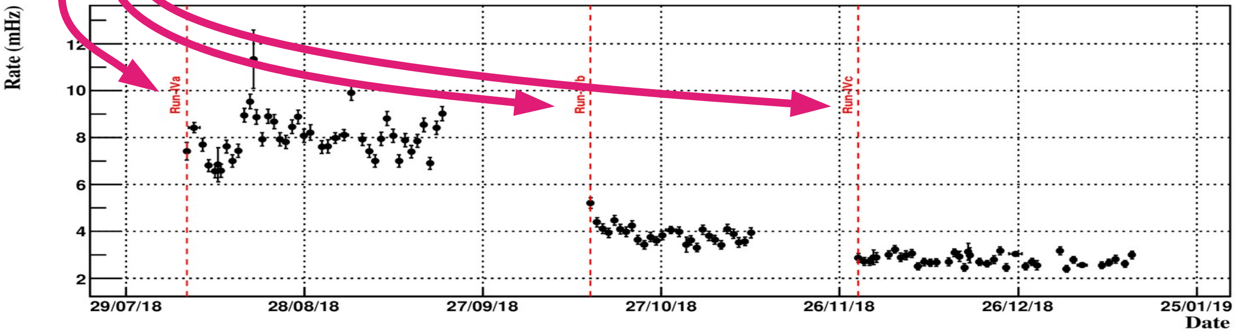
Radon abatement system

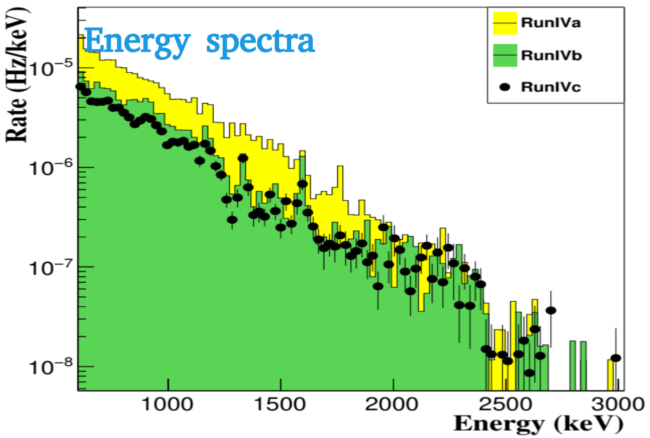


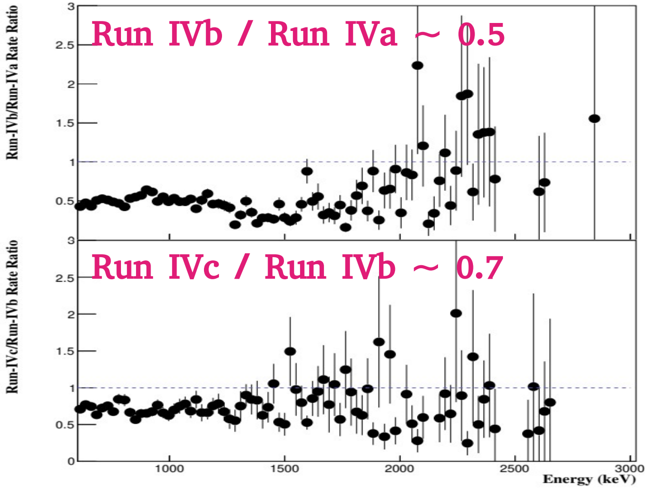
Internal lead shield

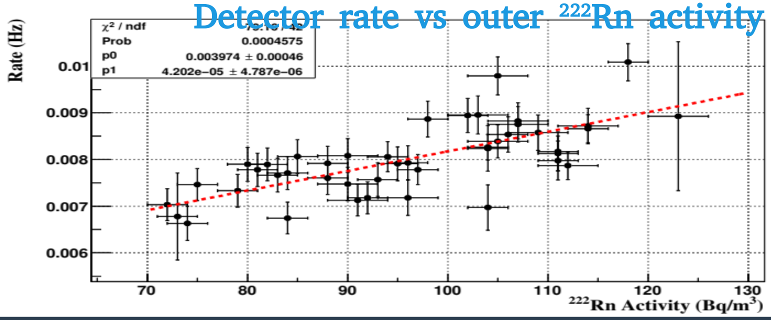
External background suppression

- Fiducial event rate (> 600 keV):
  - Run IVa: 8.00 ± 0.05 (stat) ± 0.07 (sys) mHz.
  - Run IVb: 3.90 ± 0.05 (stat) ± 0.04 (sys) mHz.
  - Run IVc: 2.78 ± 0.03 (stat) ± 0.03 (sys) mHz.









Expected activity (mHz) assuming zero-Rn regime: 3.97±0.46

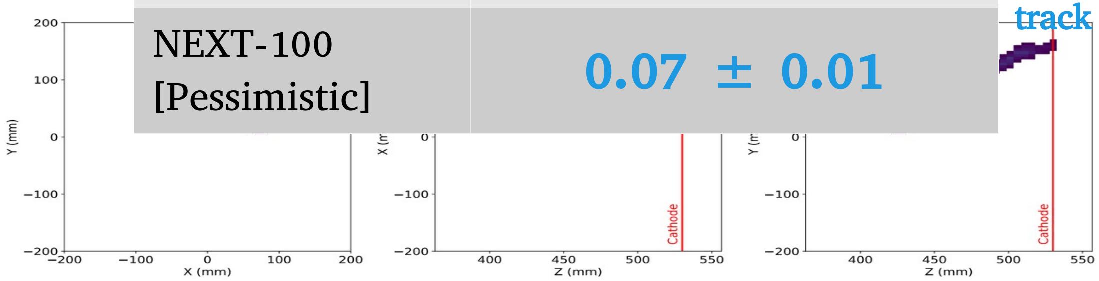
Observed activity (mHz) with RAS: 3.90 ± 0.05 (stat) ± 0.04 (sys)

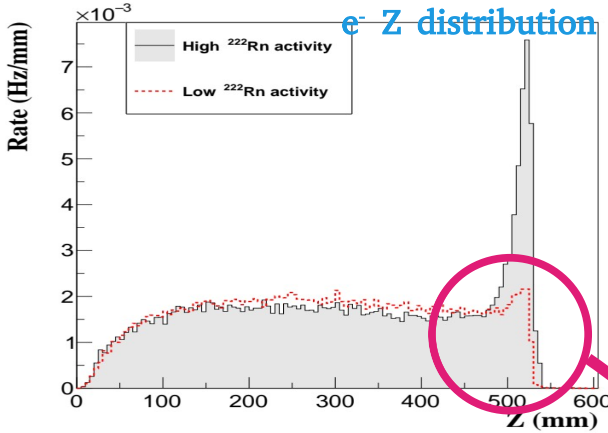
Internal ^{222}Rn arXiv:1804.00471 [physics.ins-det]

- 2 background runs:
  - Just after high ^{222}Rn period.
  - 16.3 days after previous one.
- Analysis of **cathode electrons**: ^{222}Rn progenies.
- Background impact:

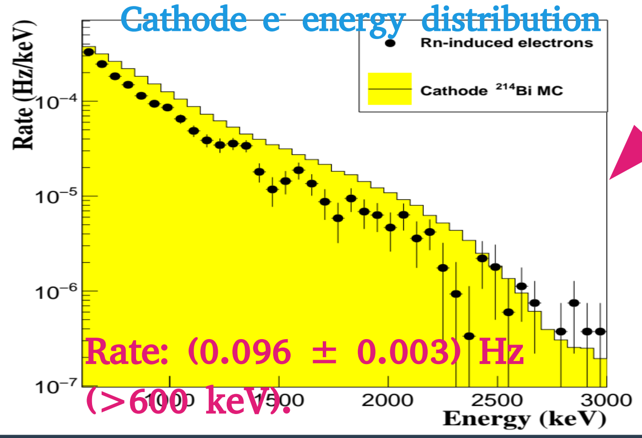
Detector	Rn-induced background (counts/yr)
NEXT-White [> 700 keV]	85 ± 14
NEXT-100 [Optimistic]	(3.9 ± 0.7) ×10−3
NEXT-100 [Pessimistic]	0.07 ± 0.01

Total expected: ~ 1 count/yr



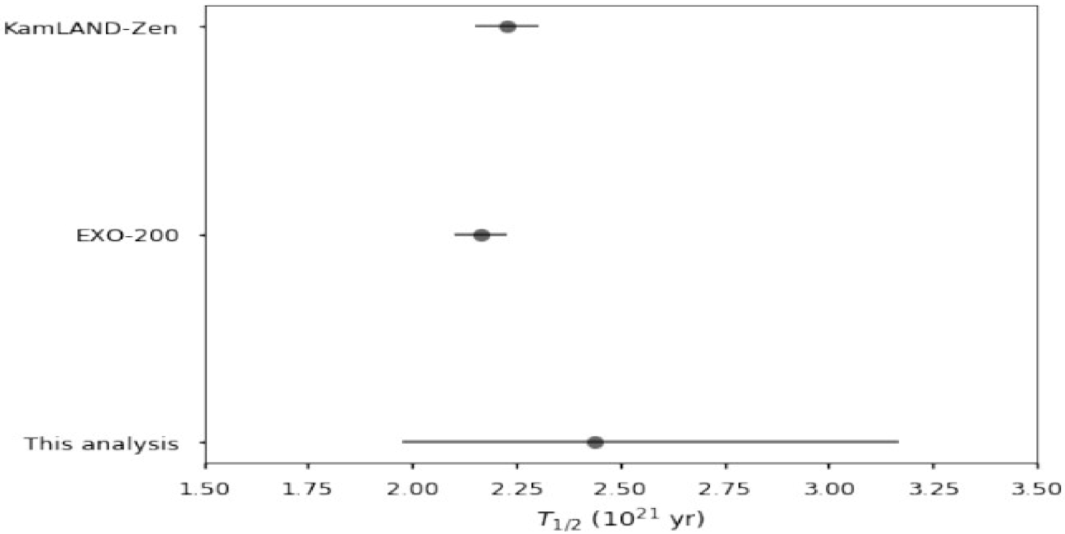


Z_{max} > 520 mm



Rate: (0.096 ± 0.003) Hz (>600 keV).

Other bb2nu results

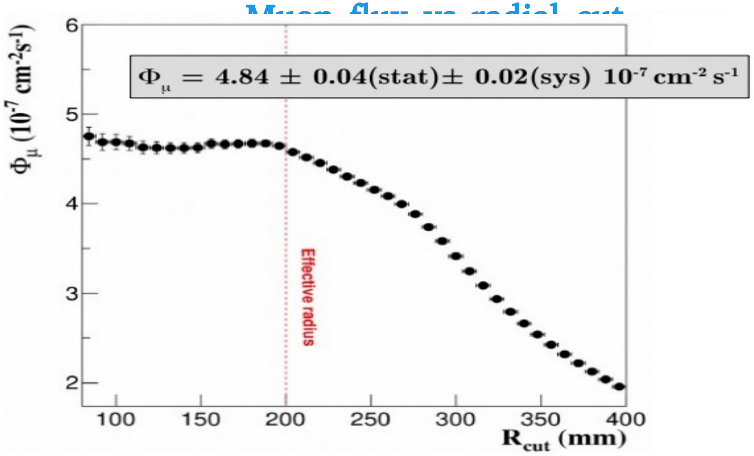


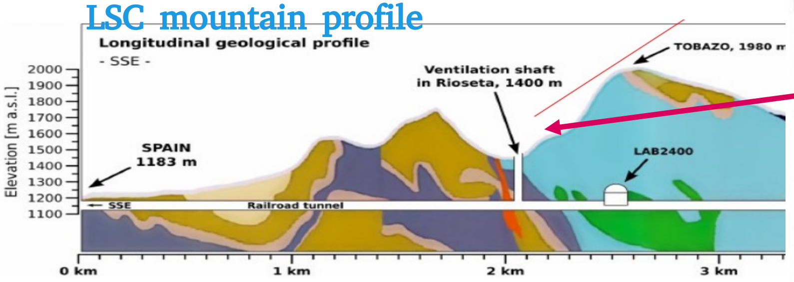
- KamLAND-Zen400: 126.3 kg*yr in ^{136}Xe
- EXO-200: 23.1 kg*yr in ^{136}Xe
- NEXT-White: 2.8 kg*yr in ^{136}Xe

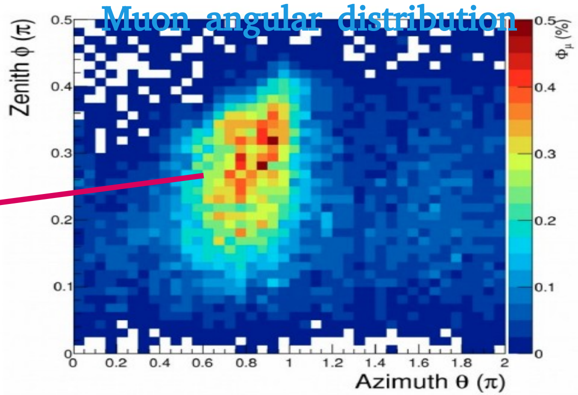
Muons

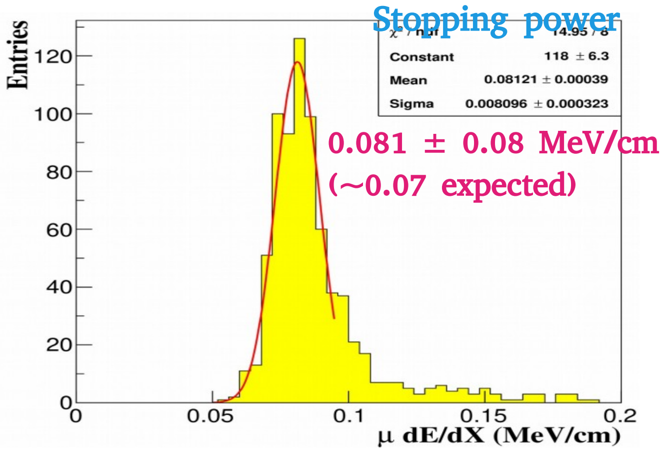
PRELIMINARY

- **Muon flux = 4.84 ± 0.04 (stat) ± 0.02 (sys) 10^{-7} cm^{-2} s^{-1}.**
  - LSC muon monitor: 5.26 ± 0.21 10^{-7} cm^{-2} s^{-1} (arXiv:1902.00868 [physics.ins-det])
- **Angular distribution compatible with LSC results.** Clear correlation with the valley near LSC underground facilities.









Cosmogenic background

PRELIMINARY

- **Fiducial cosmogenic rate in NEW measured to be:**
  - Data: R_γ=10±1 μHz, R_β= 0.6±0.1 μHz
- **Could be highly suppressed by muon veto.**