12th Pisa Meeting on Advanced Detectors

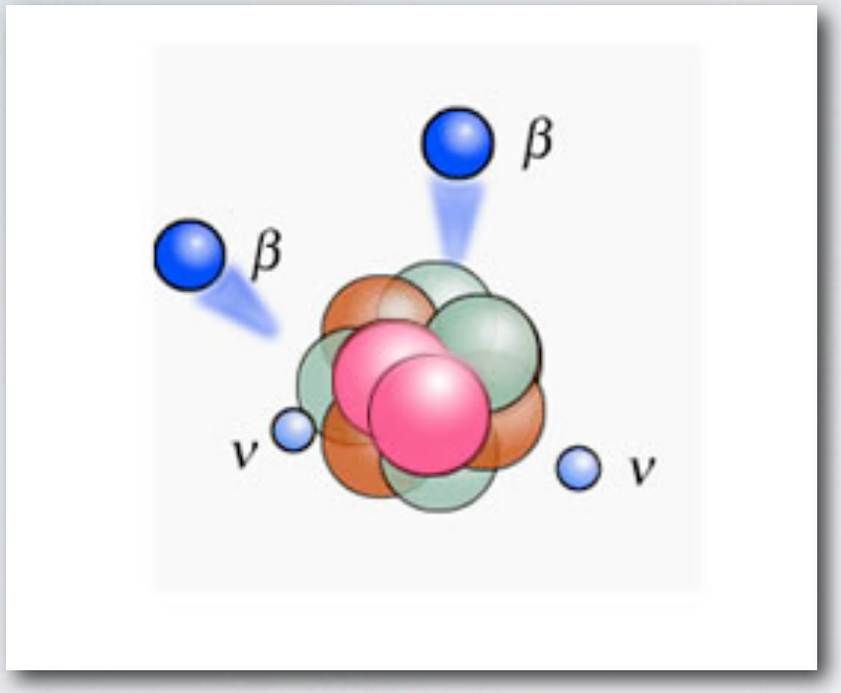
THE NEXT EXPERIMENT

A high pressure xenon gas TPC for neutrinoless double beta decay searches.

David Lorca
Instituto de Física Corpuscular (CSIC & UVEG)

On behalf of the next *Collaboration*

DOUBLE BETA DECAY

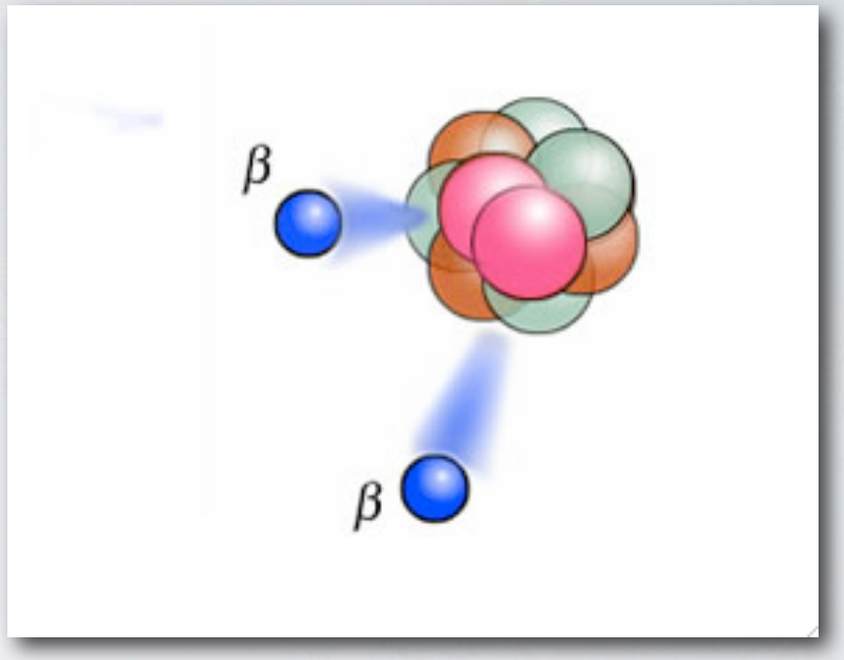


$$\beta\beta 2\nu$$

$$^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^{-} + 2\bar{\nu}_{e}$$

Allowed by Standar Model.
Measured in several nuclei.

$$T_{1/2} \sim 10^{18} - 10^{21}\ y$$



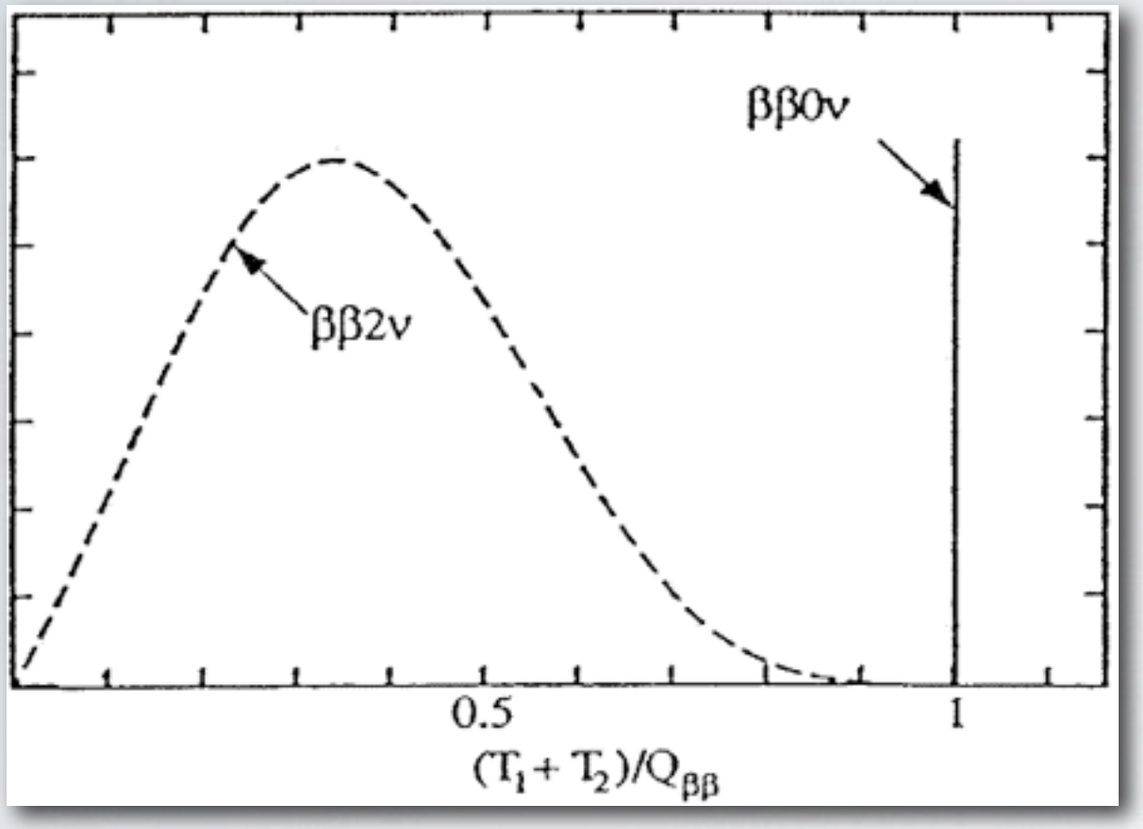
$$\beta\beta 0\nu$$

$$^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^{-}$$

Lepton number violating process.
Requires massive, Majorana neutrinos.

$$T_{1/2} > 10^{25}\ y$$

NEUTRINOLESS DOUBLE BETA DECAY SIGNATURE

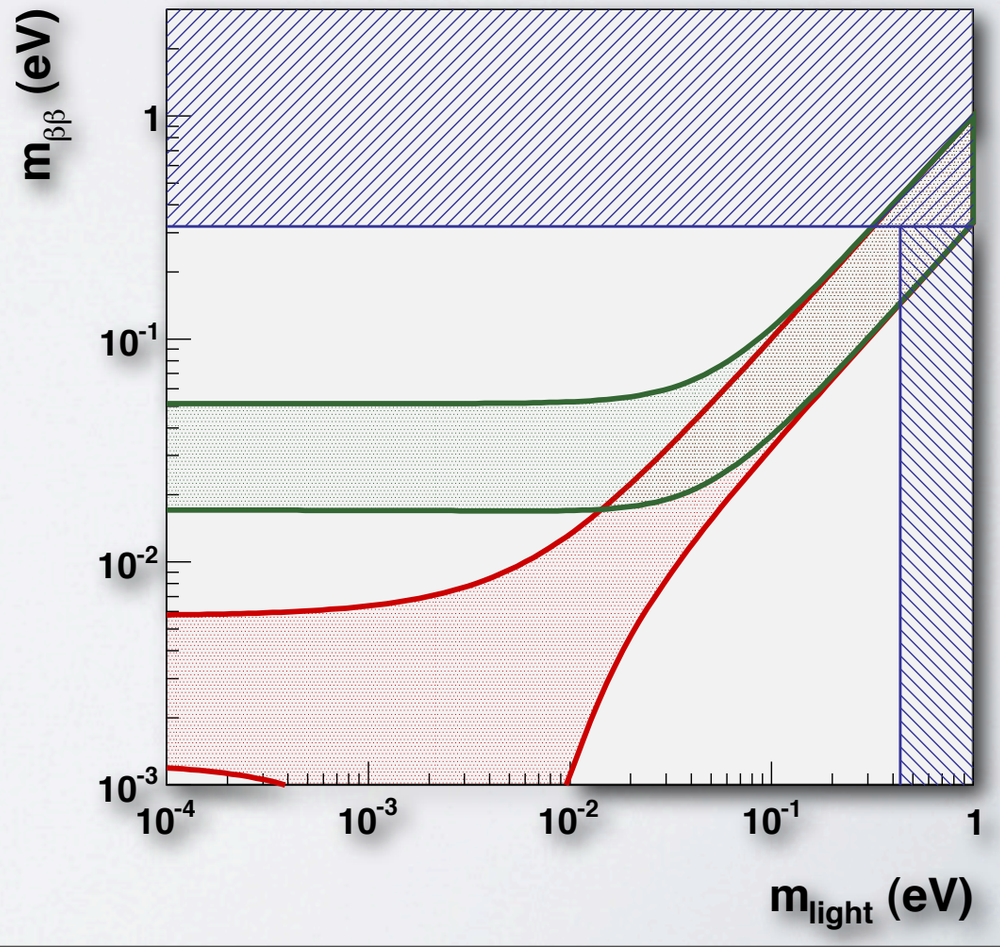


bb0v spectrum

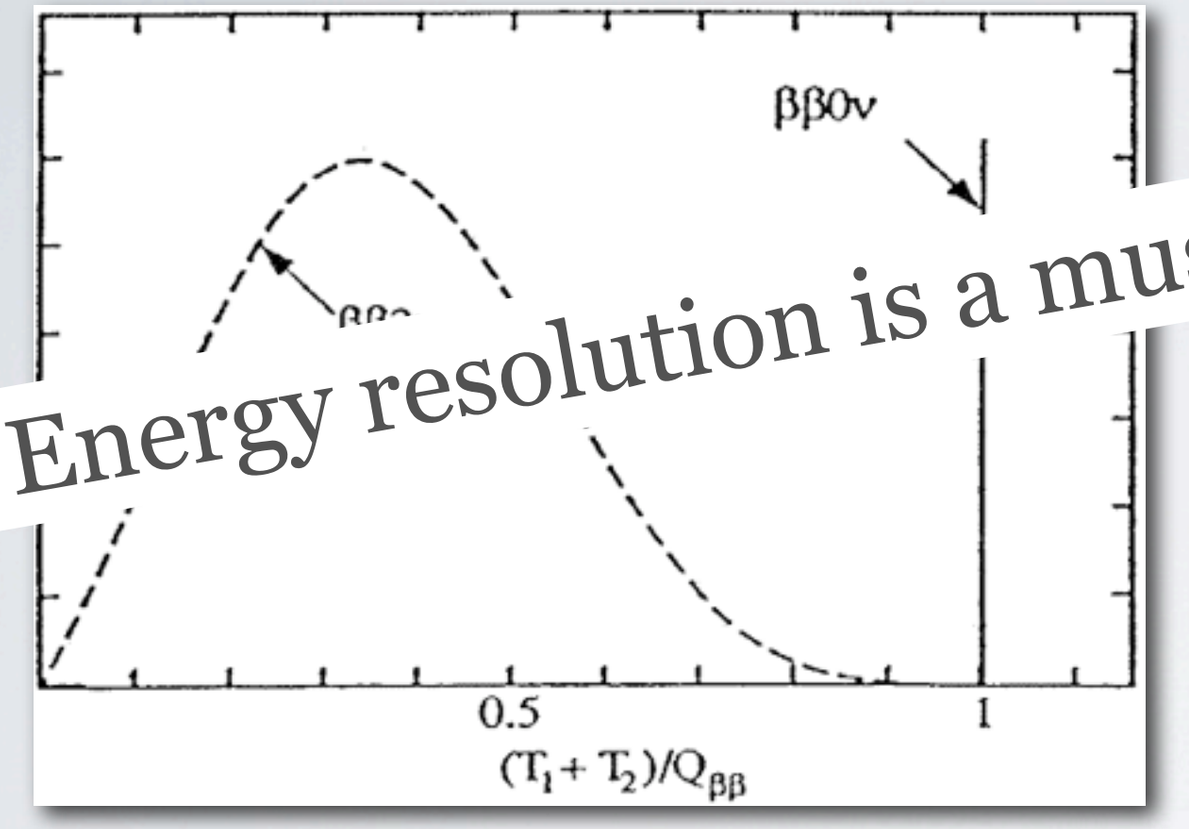
$$T_{1/2} = \log 2 \, \frac{N_A \, Mt}{A \, N_{\beta\beta}}$$

$$(T^{0\nu}_{1/2})^{-1} = G^{0\nu}(Q, Z) \, |M^{0\nu}|^2 \, m^2_{\beta\beta}$$

$$m_{\beta\beta} = \left| \sum_i m_i U^2_{ei} \right|$$



NEUTRINOLESS DOUBLE BETA DECAY SIGNATURE



Energy resolution is a must

bb0v spectrum

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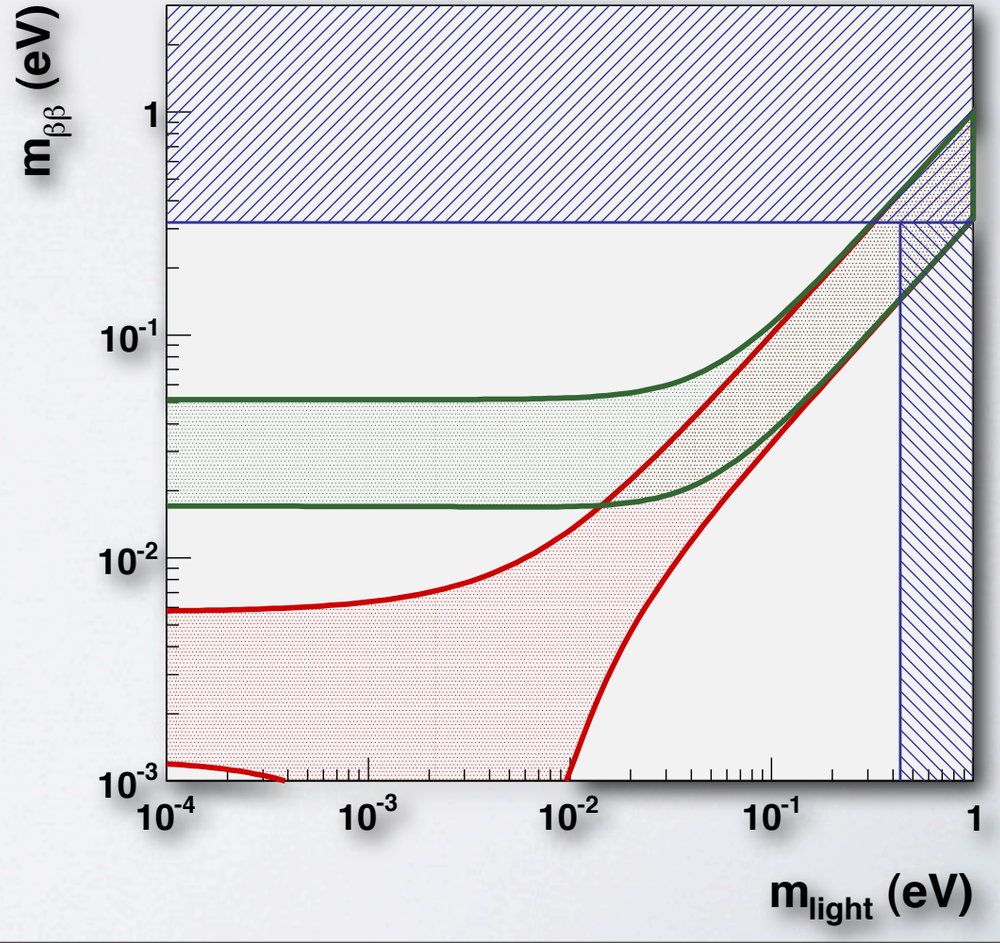
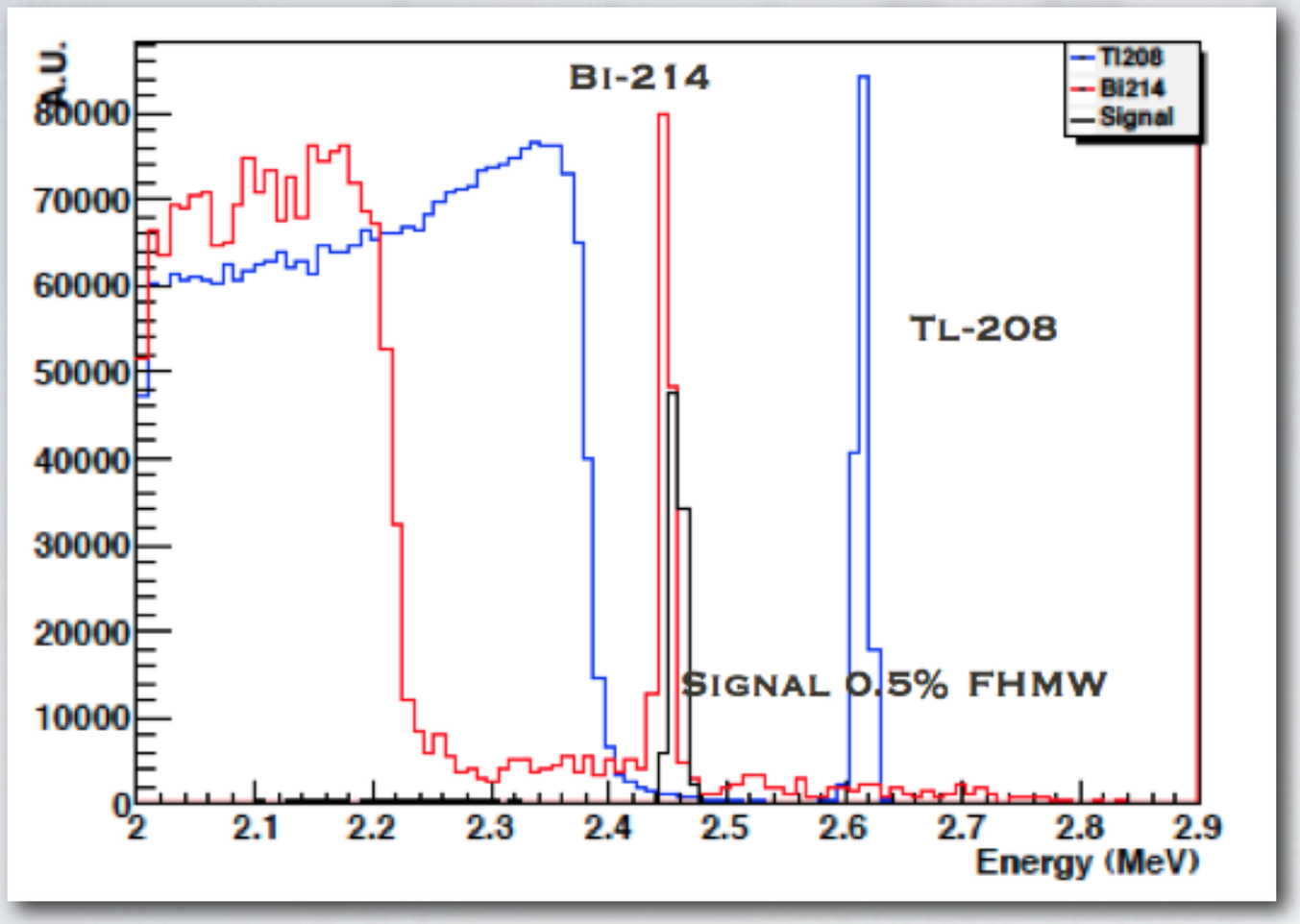


BACKGROUND



Background for Xe (MC).

- Main background is natural radioactivity of detector components and surroundings.
- ^{208}Tl and ^{214}Bi particularly pernicious, with large Q-values and therefore polluting the region of interest of most double beta emitters.
- New experiments aim to reach $<10^{-3}$ counts/keV/kg/year.

- Bi-214 line very close to Xe Qbb.
- Energy resolution (and radiopurity) are essential to separate signal from background.

THE next EXPERIMENT AT THE LSC

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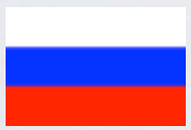
NEXT COLLABORATION

U. Girona • IFIC (Valencia) • U. Santiago de Compostela
• U. Politécnica Valencia • U. Zaragoza • U. A. Madrid

LBNL • Texas A&M • Iowa State U.

CEA (Saclay)

U. Coimbra • U. Aveiro



JINR (Dubna)

UAN (Bogotá)

Spain provides:
- Most collaborators
- Most of secured funding
- Host laboratory (LSC)

Key contributions from international groups:
- TPC detector design
- Xe supply and enrichment (already at LSC).

Spokesperson: JJ Gómez Cadenas (IFIC)

THE NEXT CONCEPT

A high-pressure gaseous Xenon, electroluminescent TPC.

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Slow two-neutrino mode.
Easy to enrich and purify.

$$T_{1/2} \sim 10^{21}\ y$$

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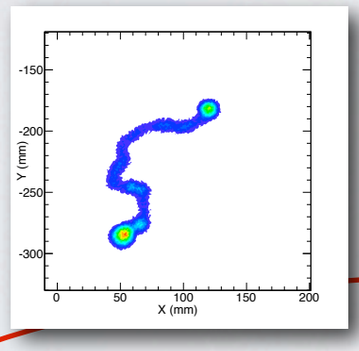

- Topology information.
- Transparent to 2-3MeV gammas.

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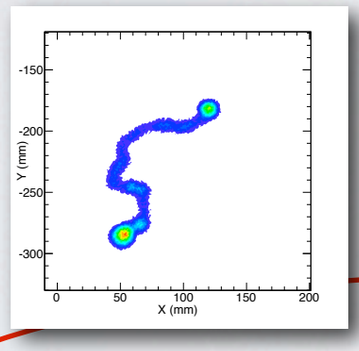
A high-pressure gaseous Xenon, electroluminescent TPC.



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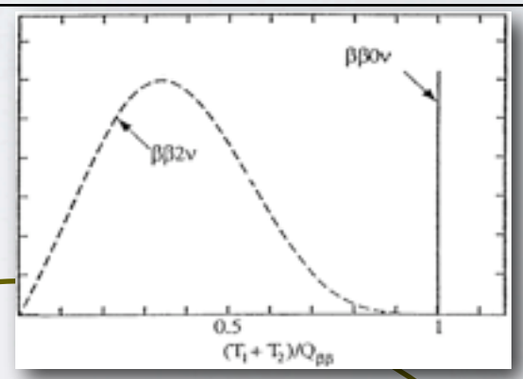
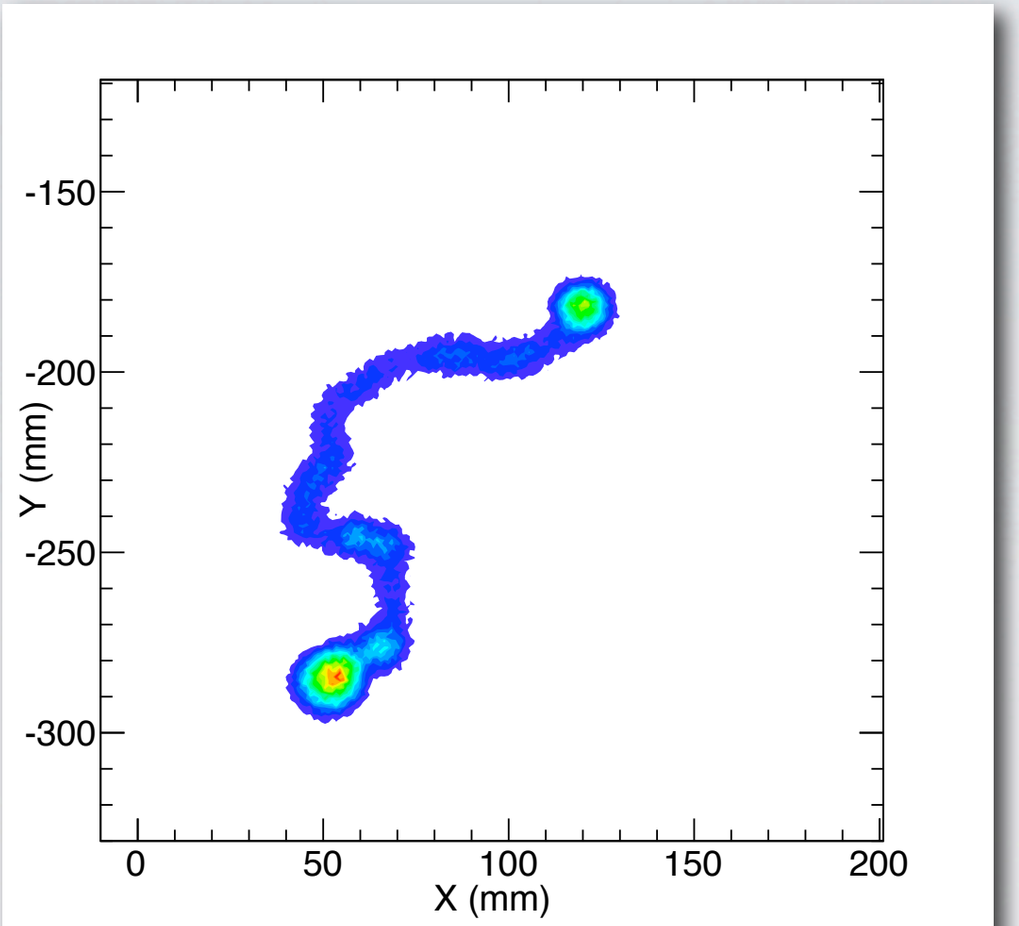
See Dave Nygren's Talk



- Resolution <1%FWHM.
- Topology reconstruction without losing energy resolution.

TRACKING IN HPXE

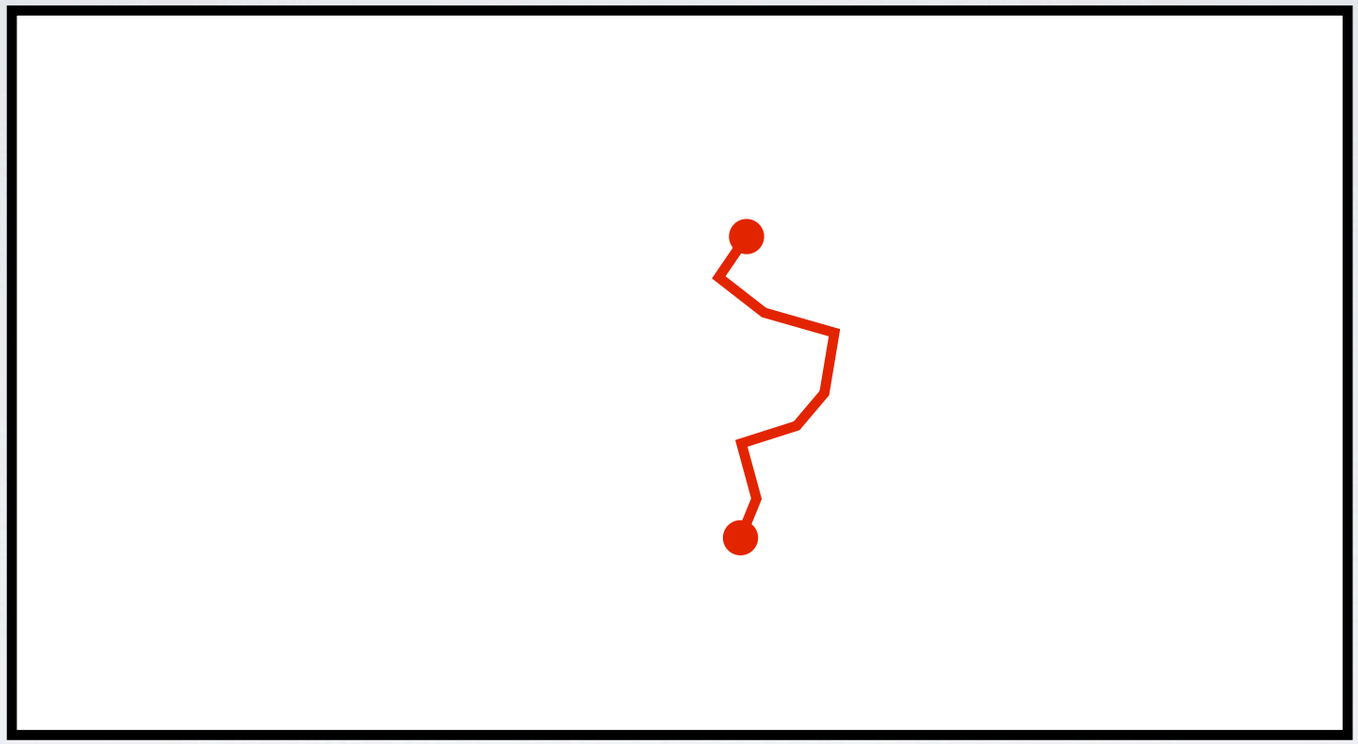


Electrons travel on average ~10 cm (15 bar) each.
Trajectories highly affected by multiple scattering.
Electrons travel with almost constant dE/dx but at the end-points where they generate “blobs”.

DETECTION PROCESS

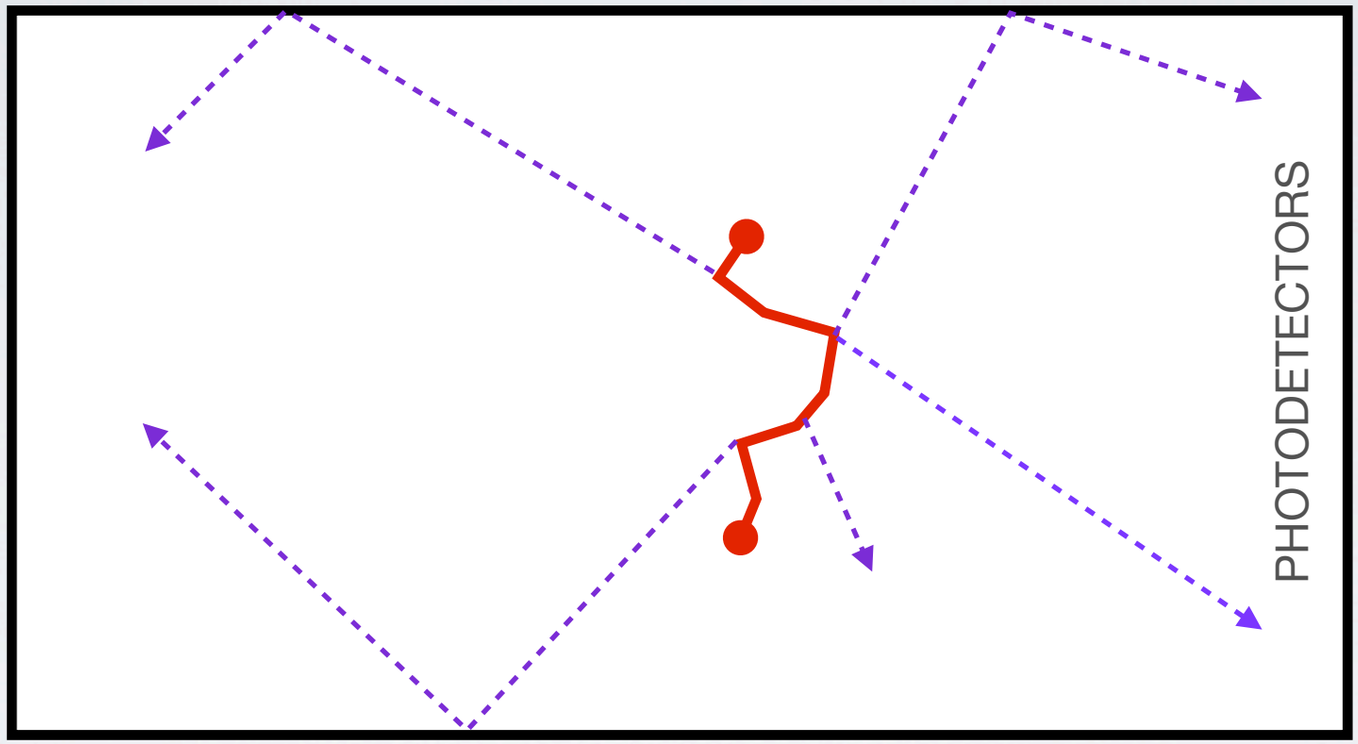
- Cylindrical TPC filled with highly enriched (>90%) ^{136}Xe gas at 15 bar pressure.
- TPC walls lined with highly reflective material.
- Baseline detector with ~100 kg fiducial mass (2 m^3): NEXT-100.

DETECTION PROCESS



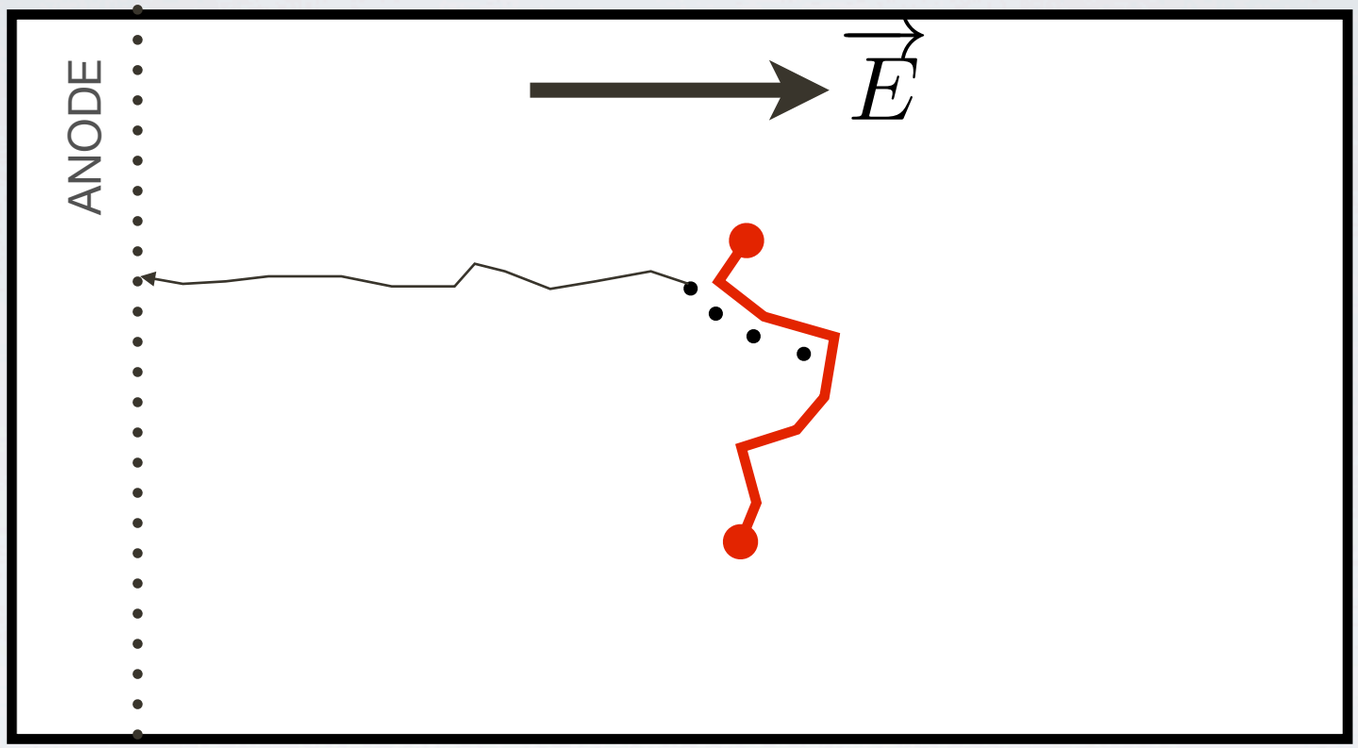
- A ^{136}Xe isotope decays emitting the two electrons.
- They propagate through the HPXe ionizing and exciting its atoms.

DETECTION PROCESS



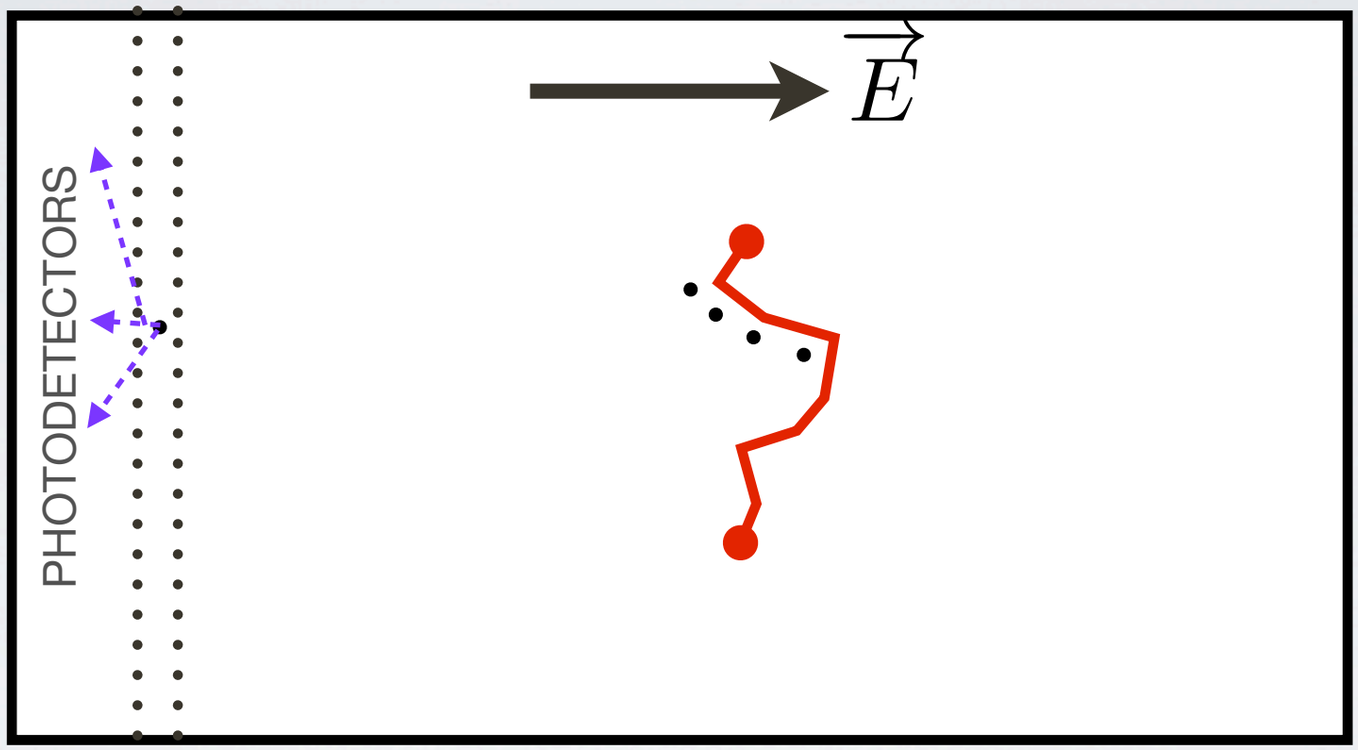
- Prompt primary scintillation light emission in VUV (~175 nm). About 100 eV needed to create a primary scintillation photon.
- Detect faint signal via sensitive photo-detectors (PMTs) behind transparent cathode.
- Determine t_0 and therefore event position along drift.

DETECTION PROCESS



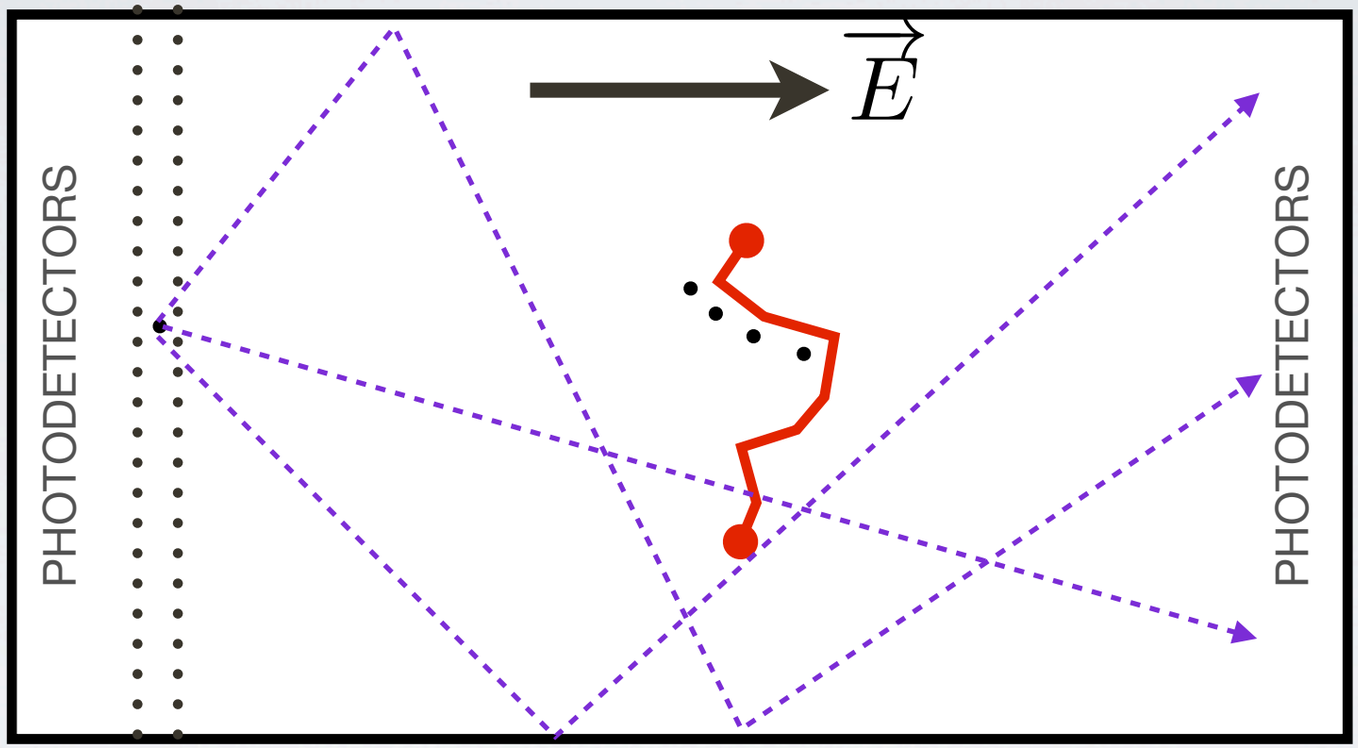
- Create ionization charge in Xe: ~25 eV to create one electron-ion pair.
- Electrons drift toward anode with velocity ~1 mm/us in a ~0.3 kV/cm electric drift.
- At 10 bar pressure, non-negligible diffusion: 9 mm/√m transverse, 4 mm/√m longitudinal).

DETECTION PROCESS



- Additional grid in front of anode creates ~0.5 mm thick region of more intense field: E/p ~3 kV/cm/bar.
- Secondary scintillation light (electroluminescence) created in between grids by atomic de-excitation, with very linear gain of order 10^3 and over a ~2us interval.
- Finely segmented photo-detector plane (MPPCs) just behind anode performs “tracking”.

DETECTION PROCESS



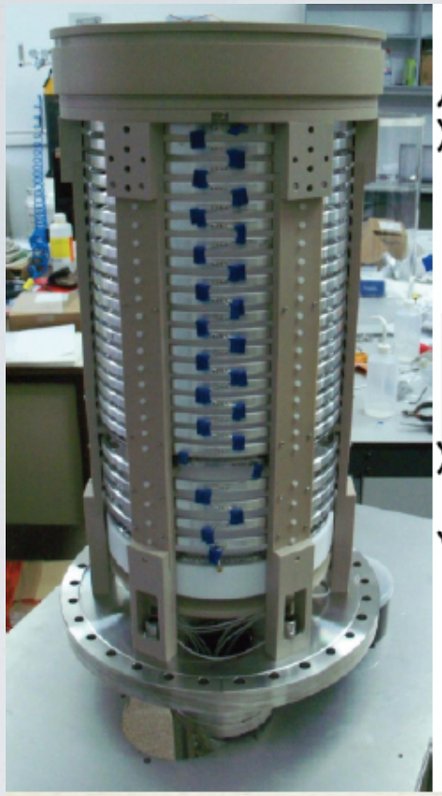
- Electroluminescence, emitted isotropically, also reaches cathode.
- Same array of photo-detectors used for t_o measurement is also used for accurate calorimetry.

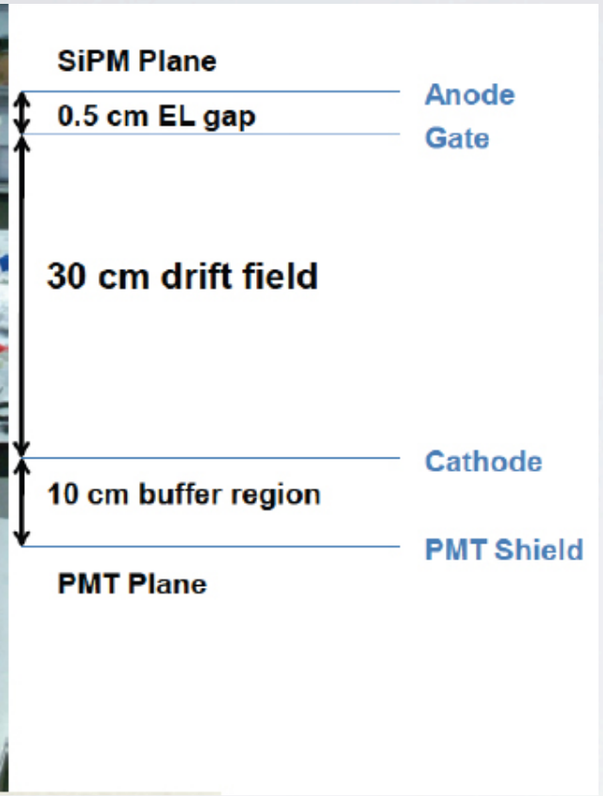
NEXT-DEMO PROTOTYPE

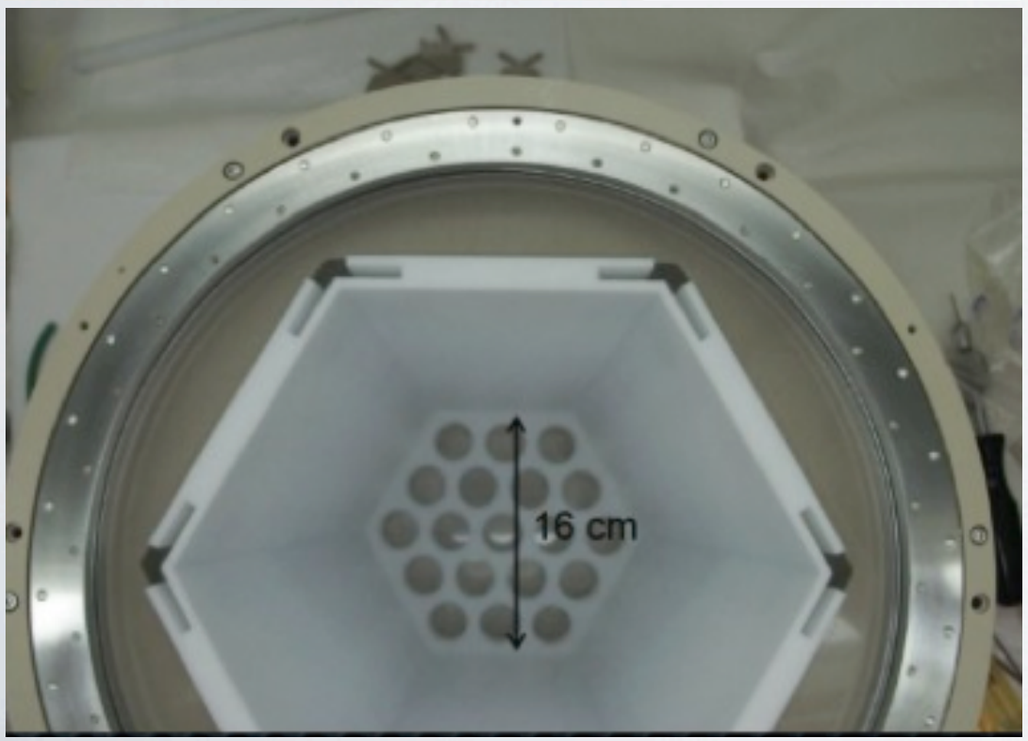
NEXT detector concept:

- to demonstrate track reconstruction
- to test long drift lengths and high voltages
- to understand gas recirculation in a large volume
- to understand transmittance of the light tube
- to demonstrate the target energy resolution

NEXT-DEMO PROTOTYPE

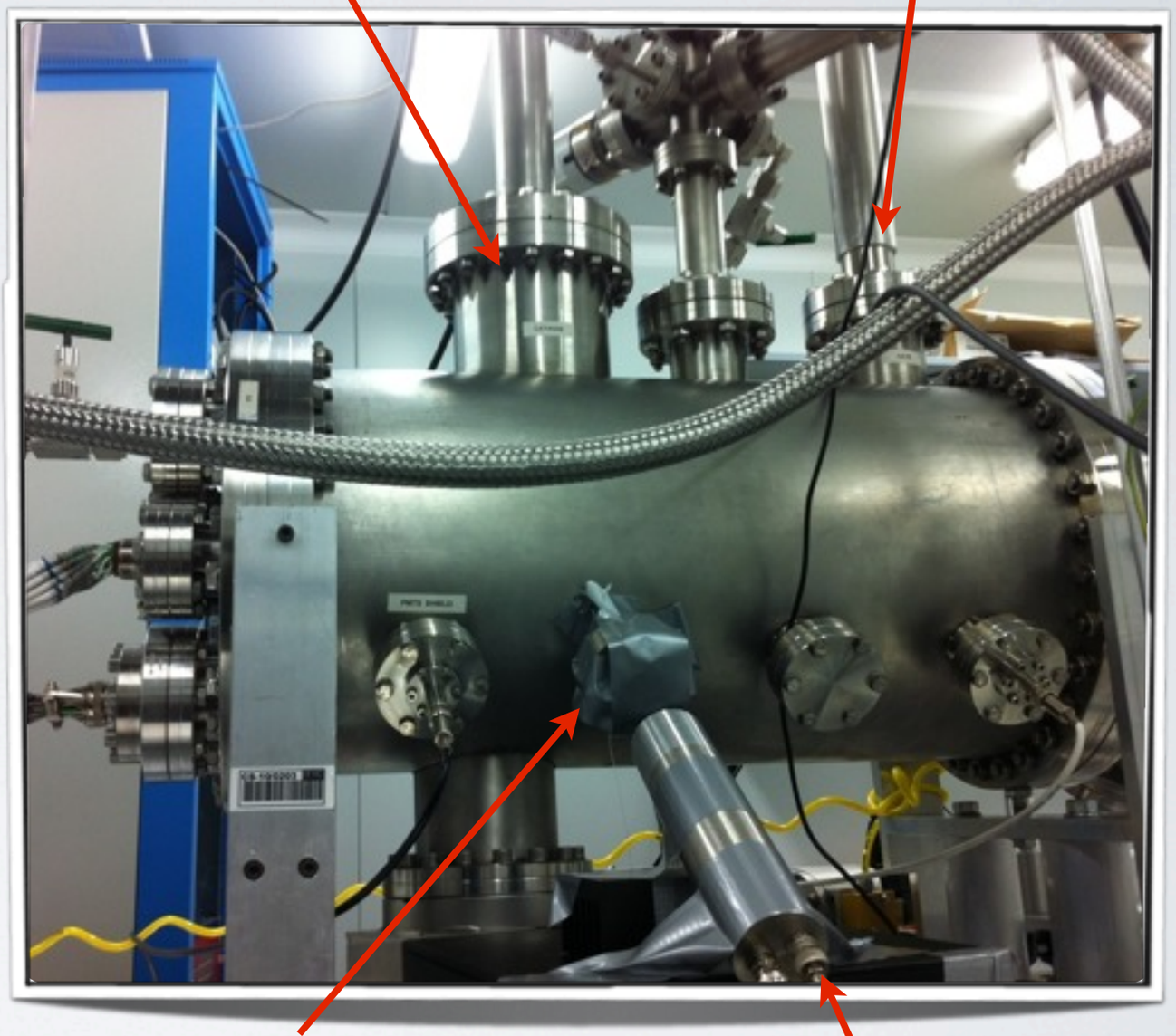






Cathode: 32 kV

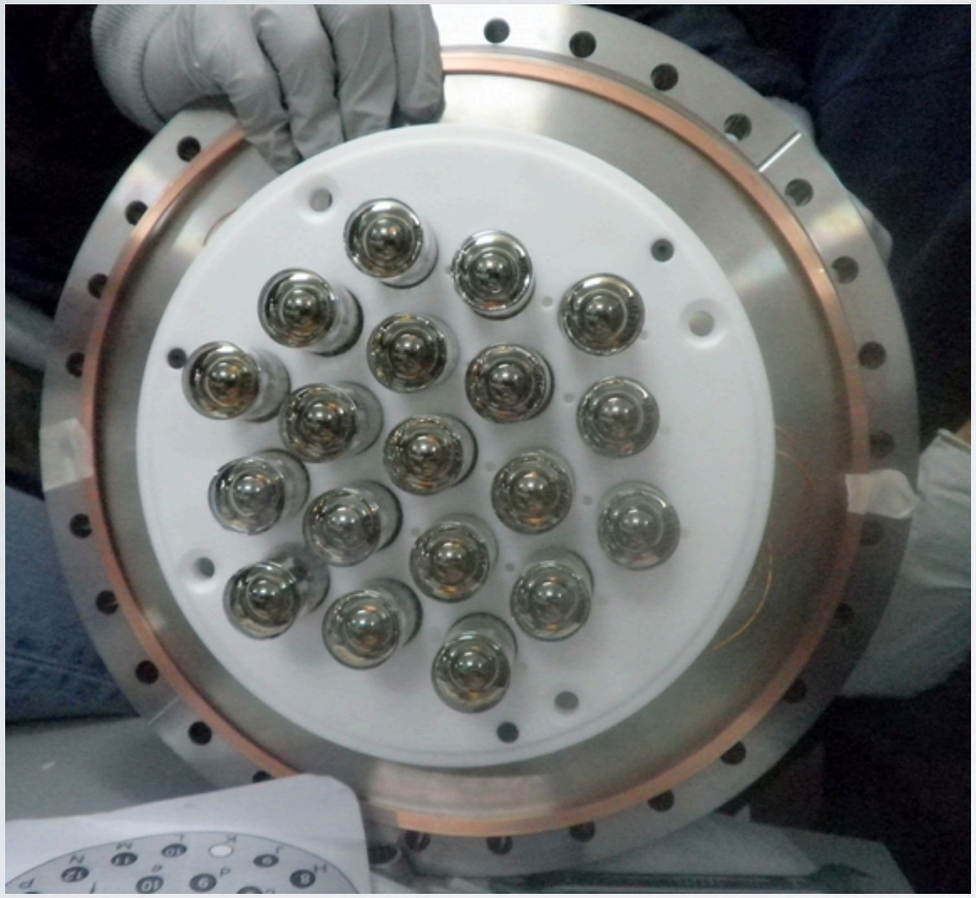
Gate:12 kV



Na-22 Source

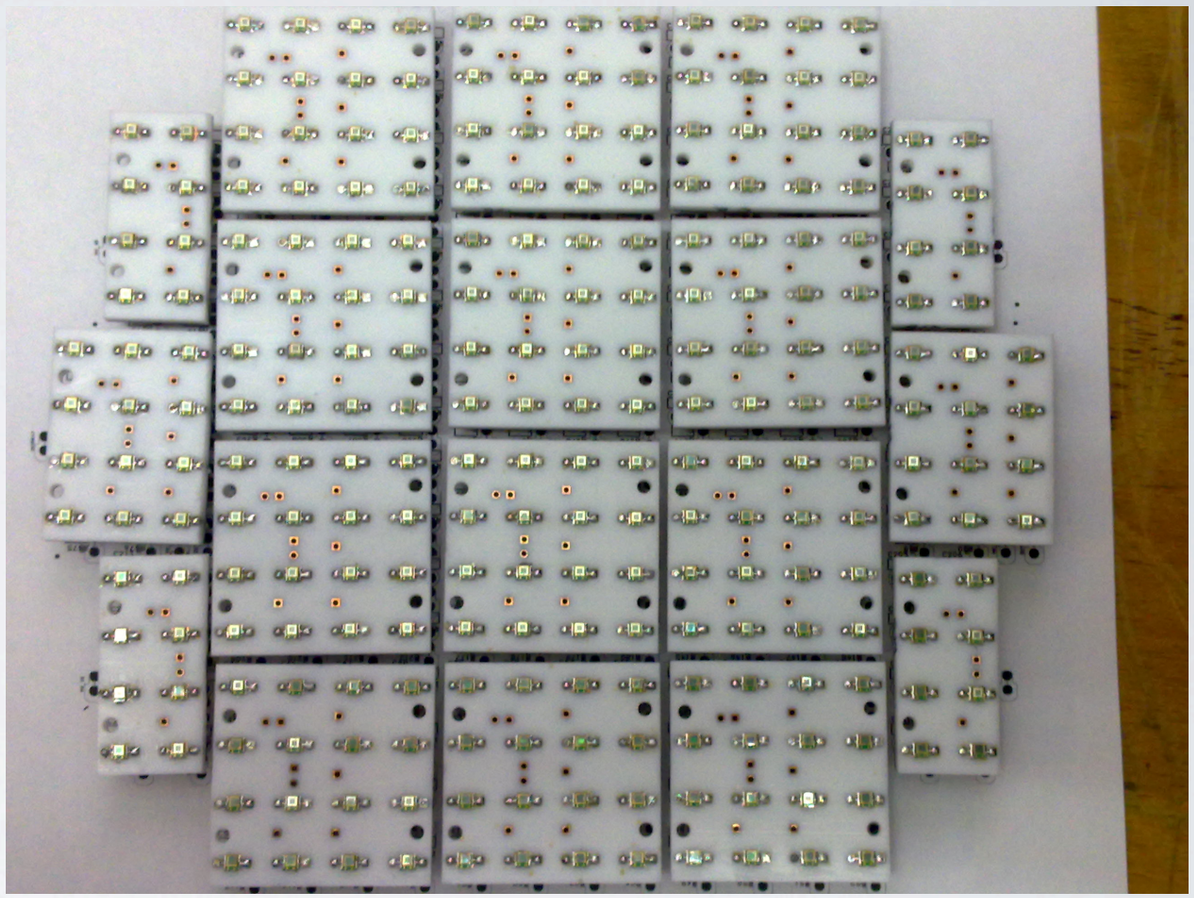
INa Scintillator

Energy Function



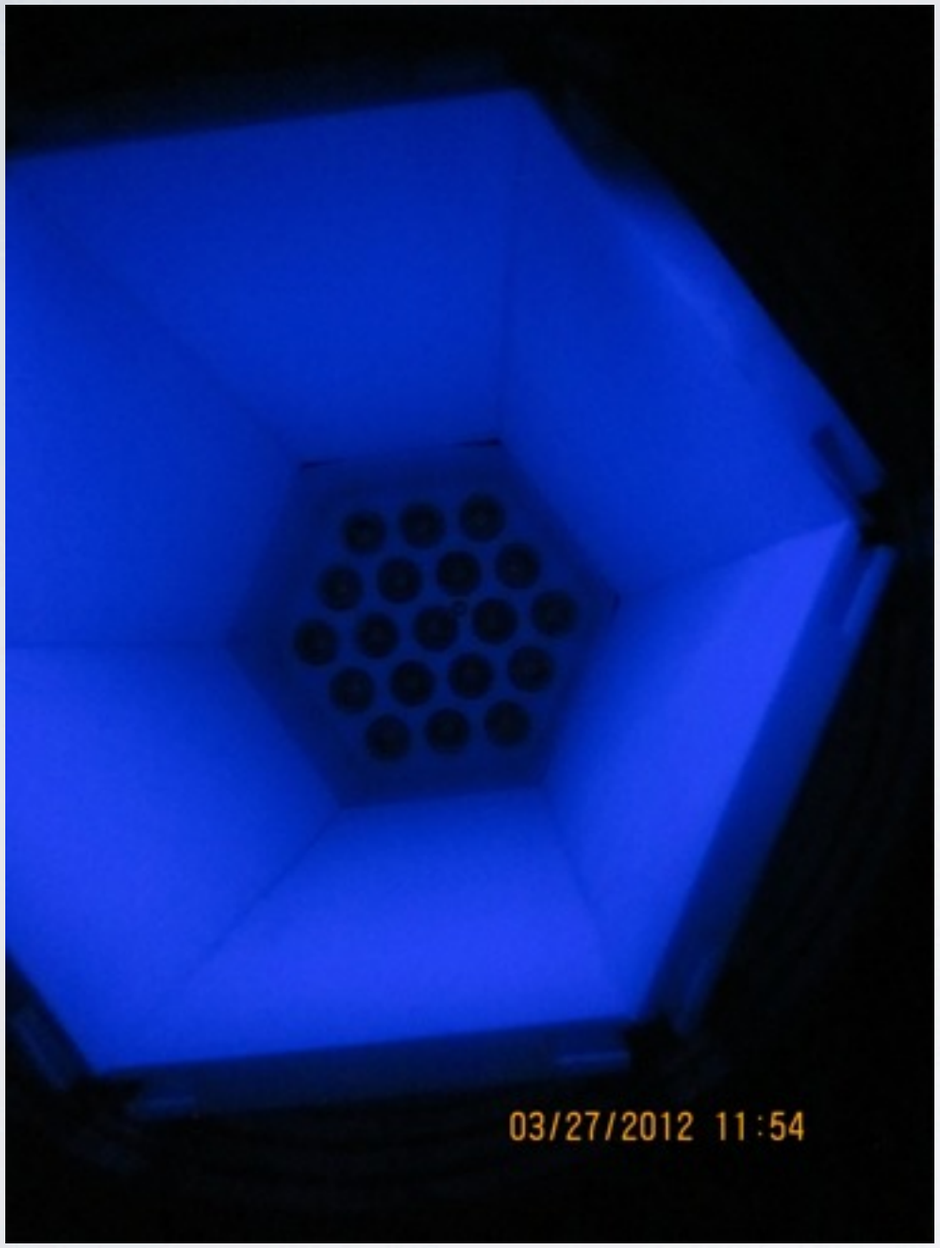
19 PMTs
Hamamatsu R7378

Tracking Function



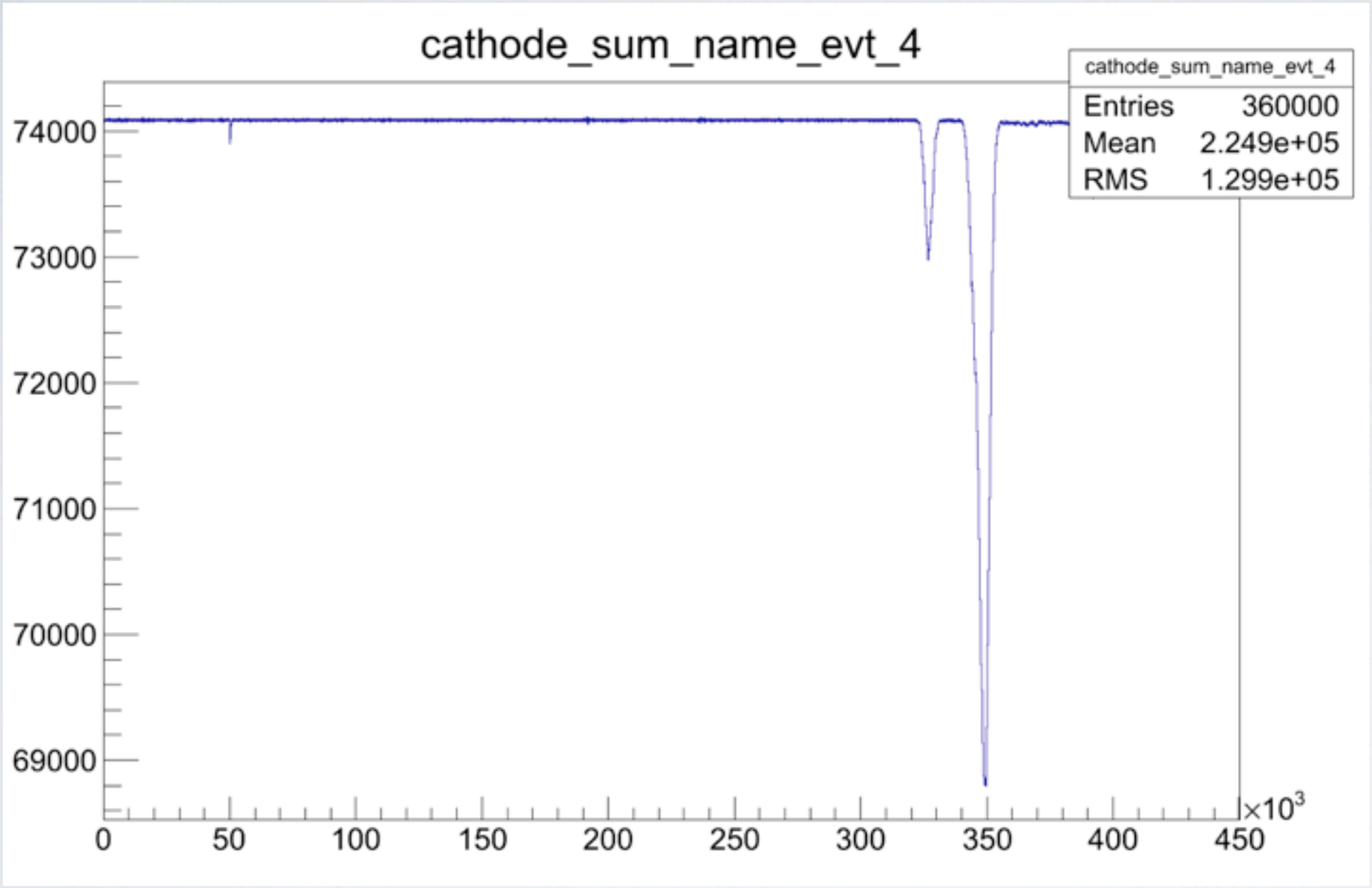
248 SiPMs
Hamamatsu S10362-11-050P
1 cm pitch
Not sensitive to VUV

SHIFTING LIGHT



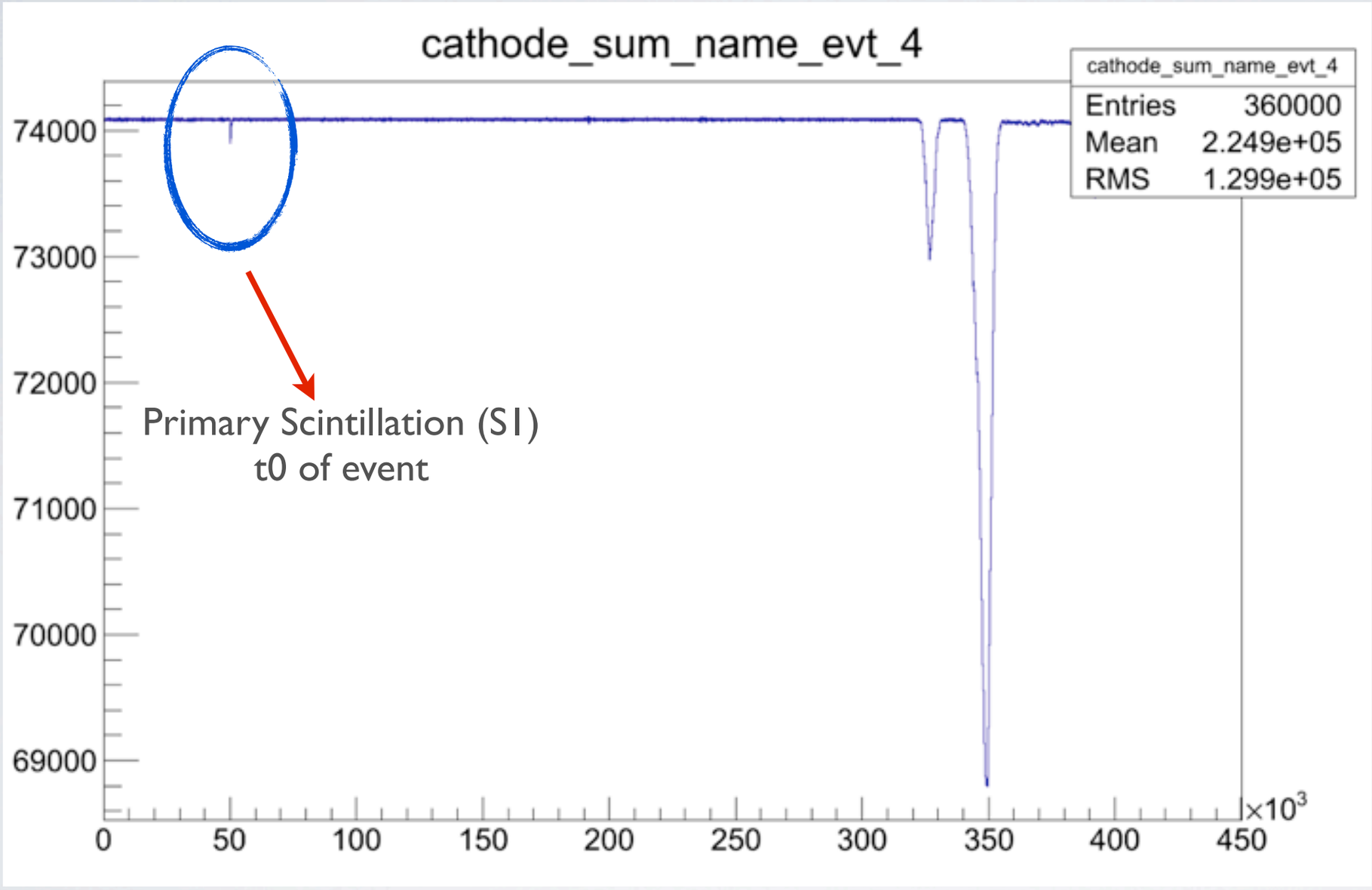
Sensors and inner part of the field cage coated with Tetraphenyl Butadiene (TPB)

NEXT-DEMO RESULTS



Na-22 Analysis

NEXT-DEMO RESULTS



Na-22 Analysis

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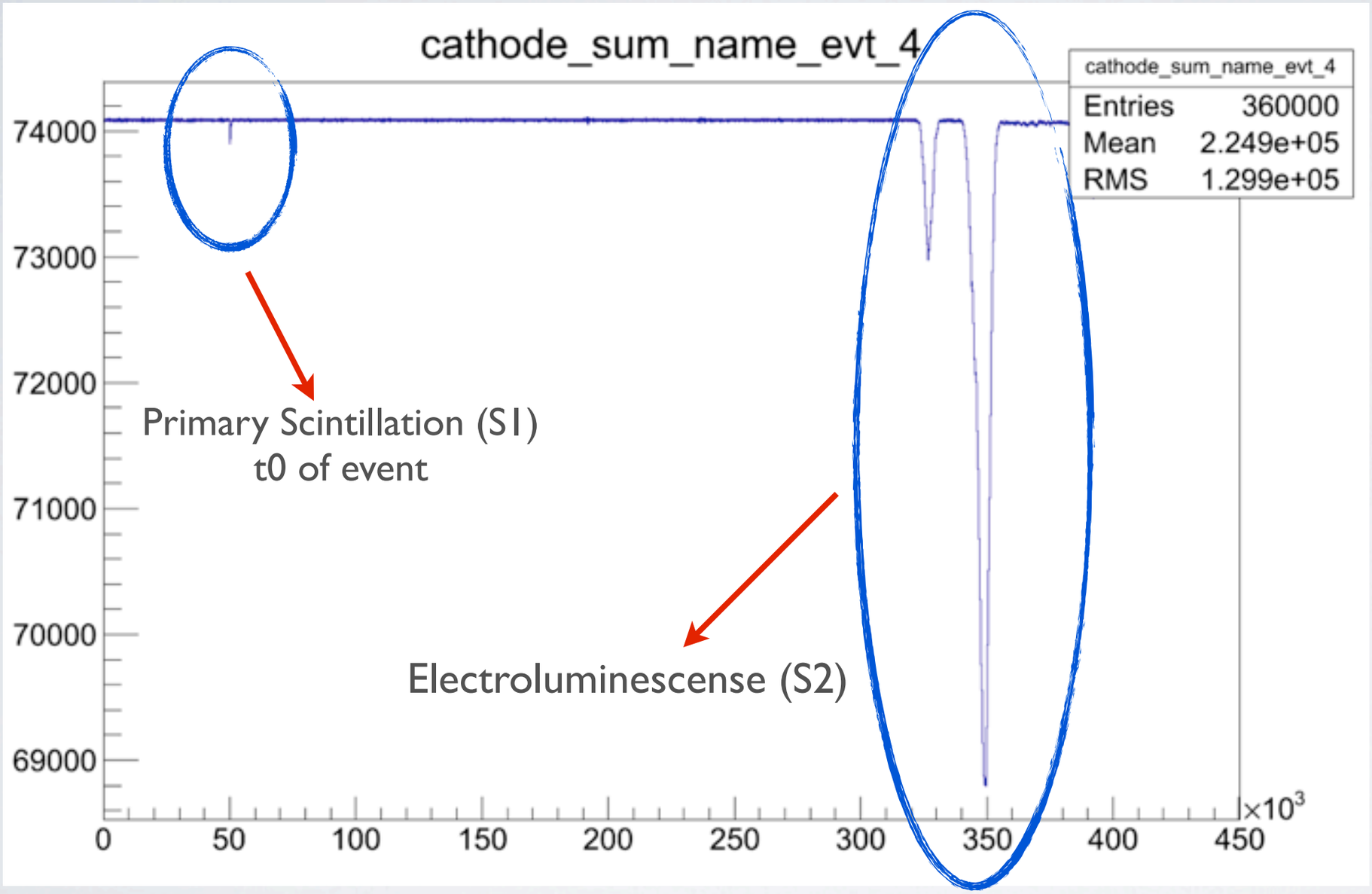

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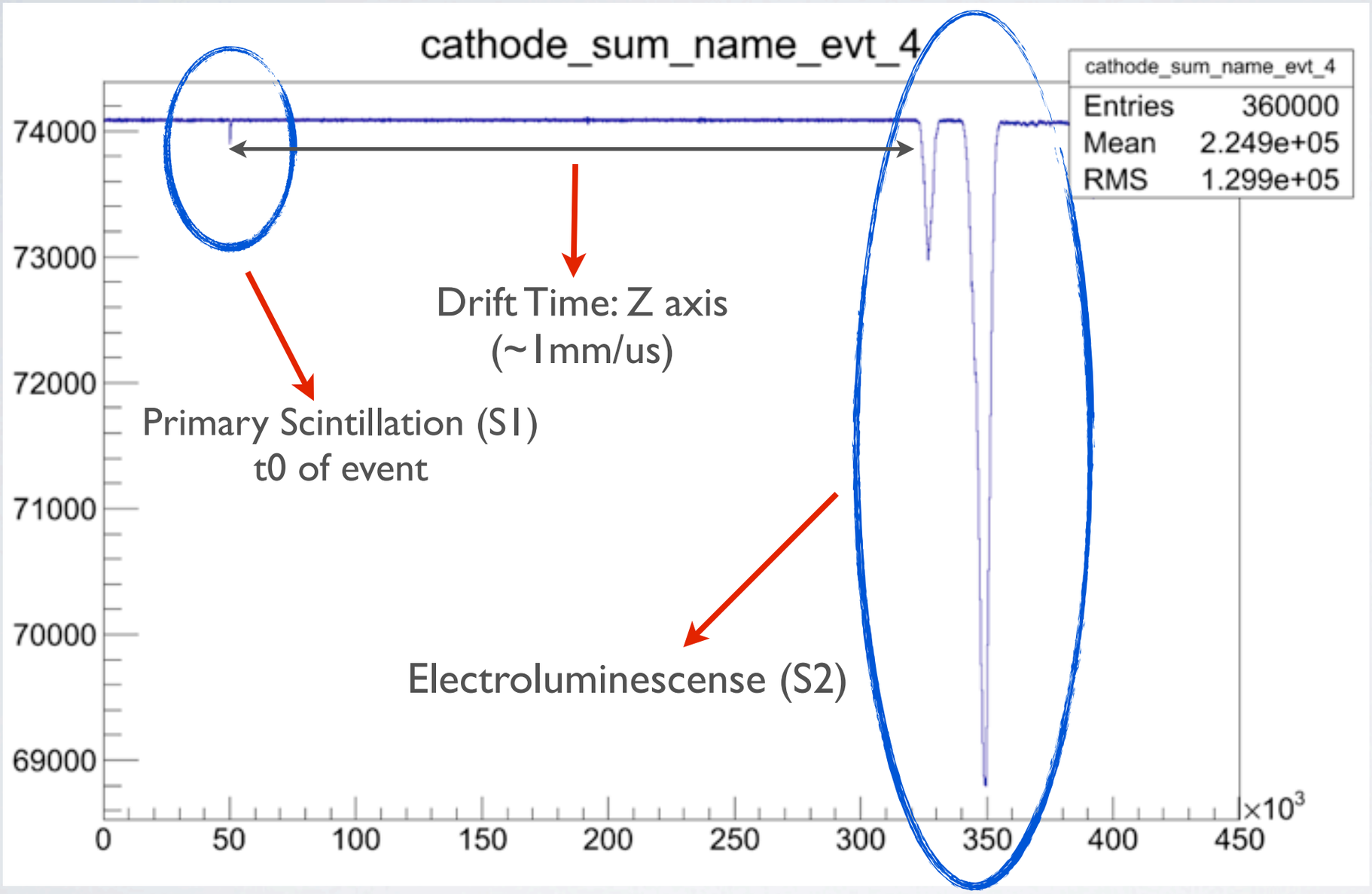

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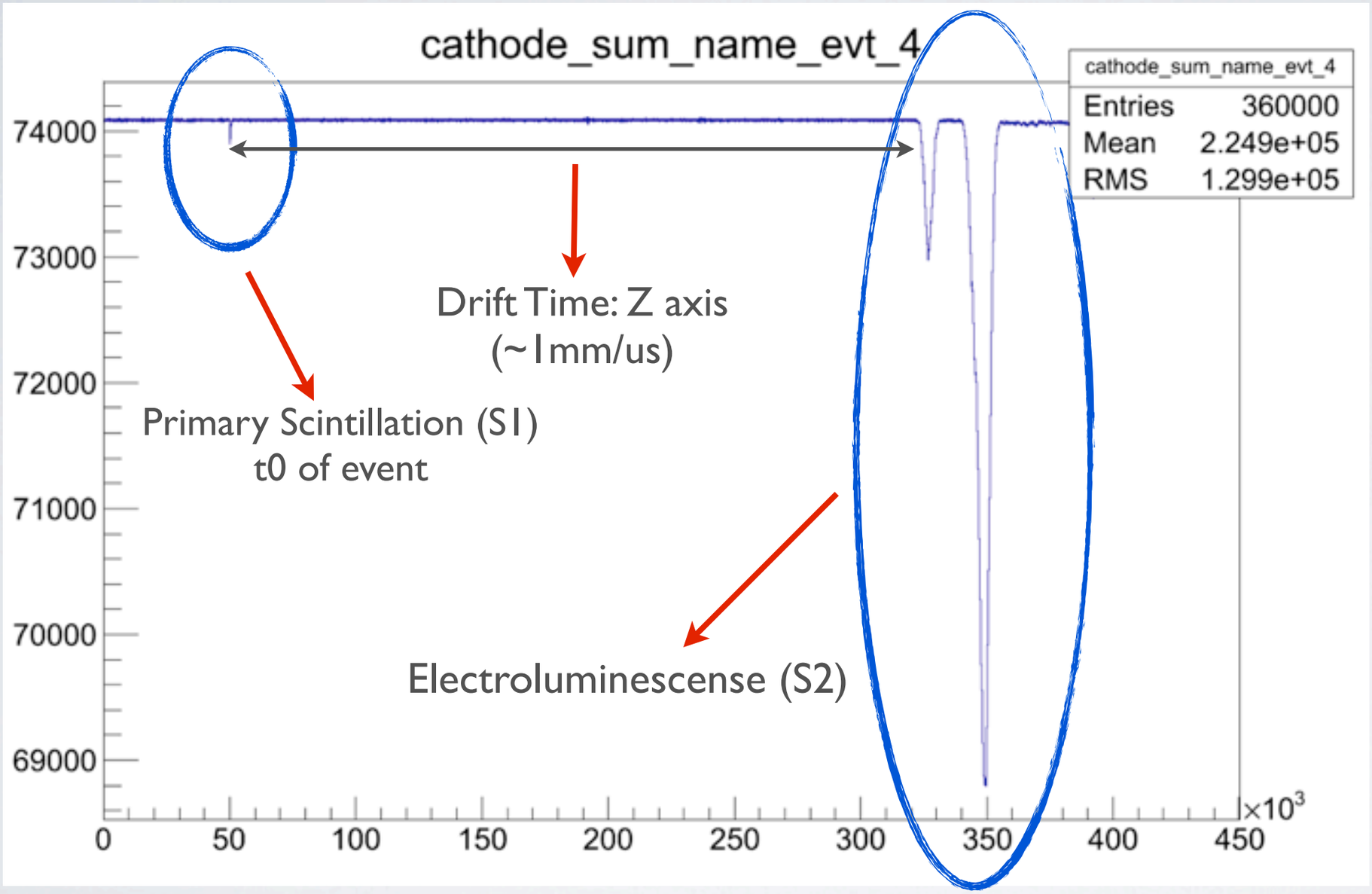


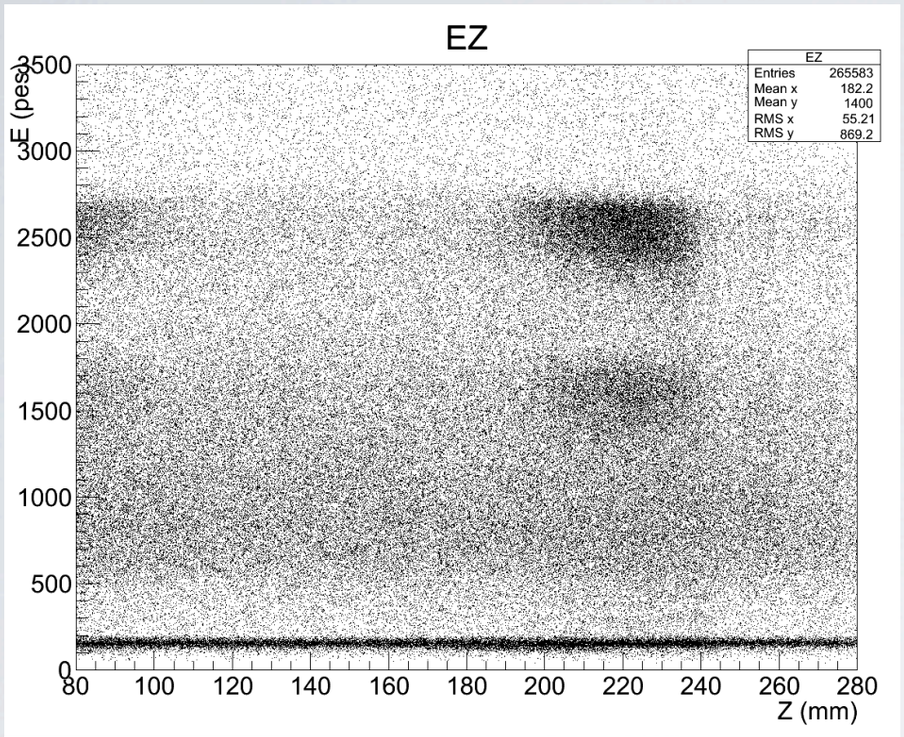
Na-22 Analysis

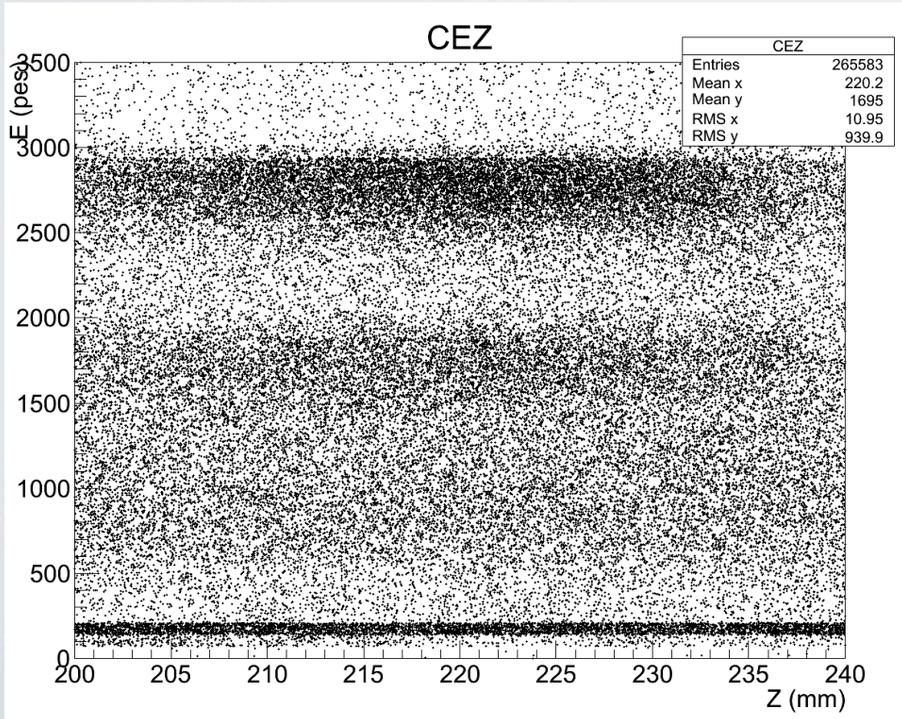
Digital Trigger

Highly flexible

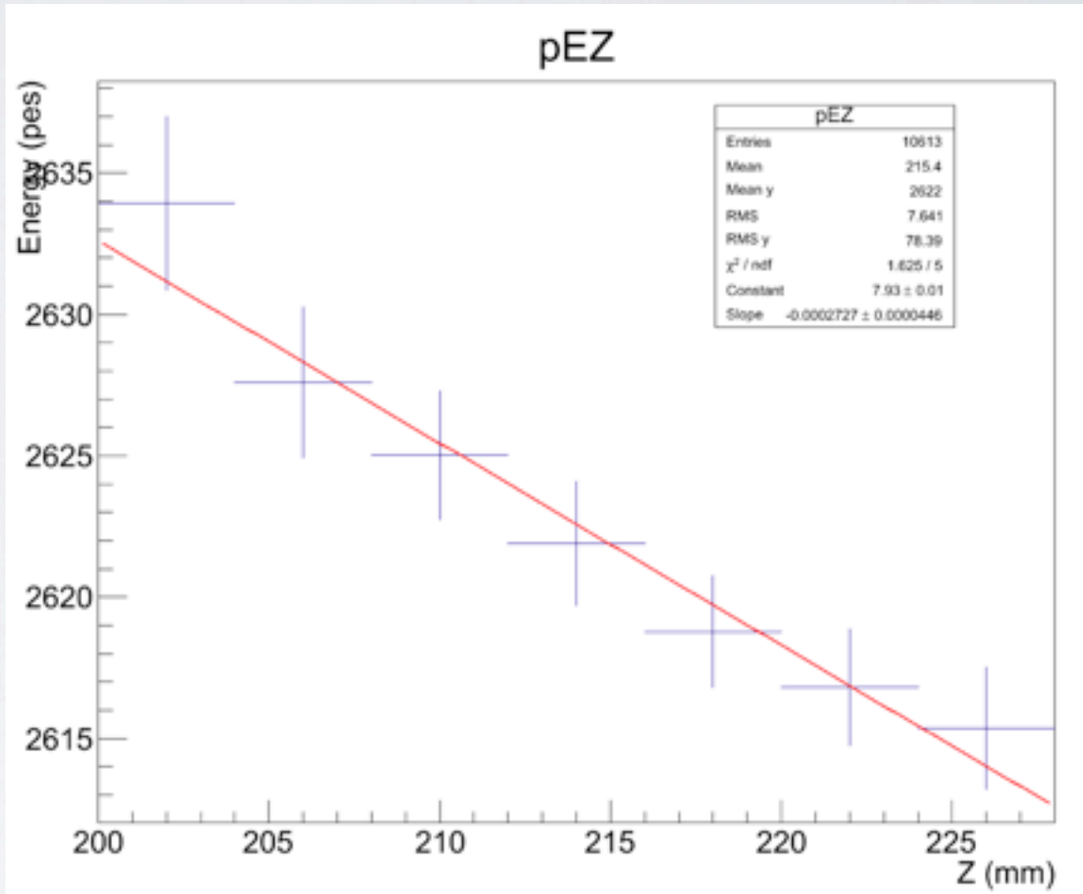
- Duration
- Size
- Charge

NEXT-DEMO RESULTS



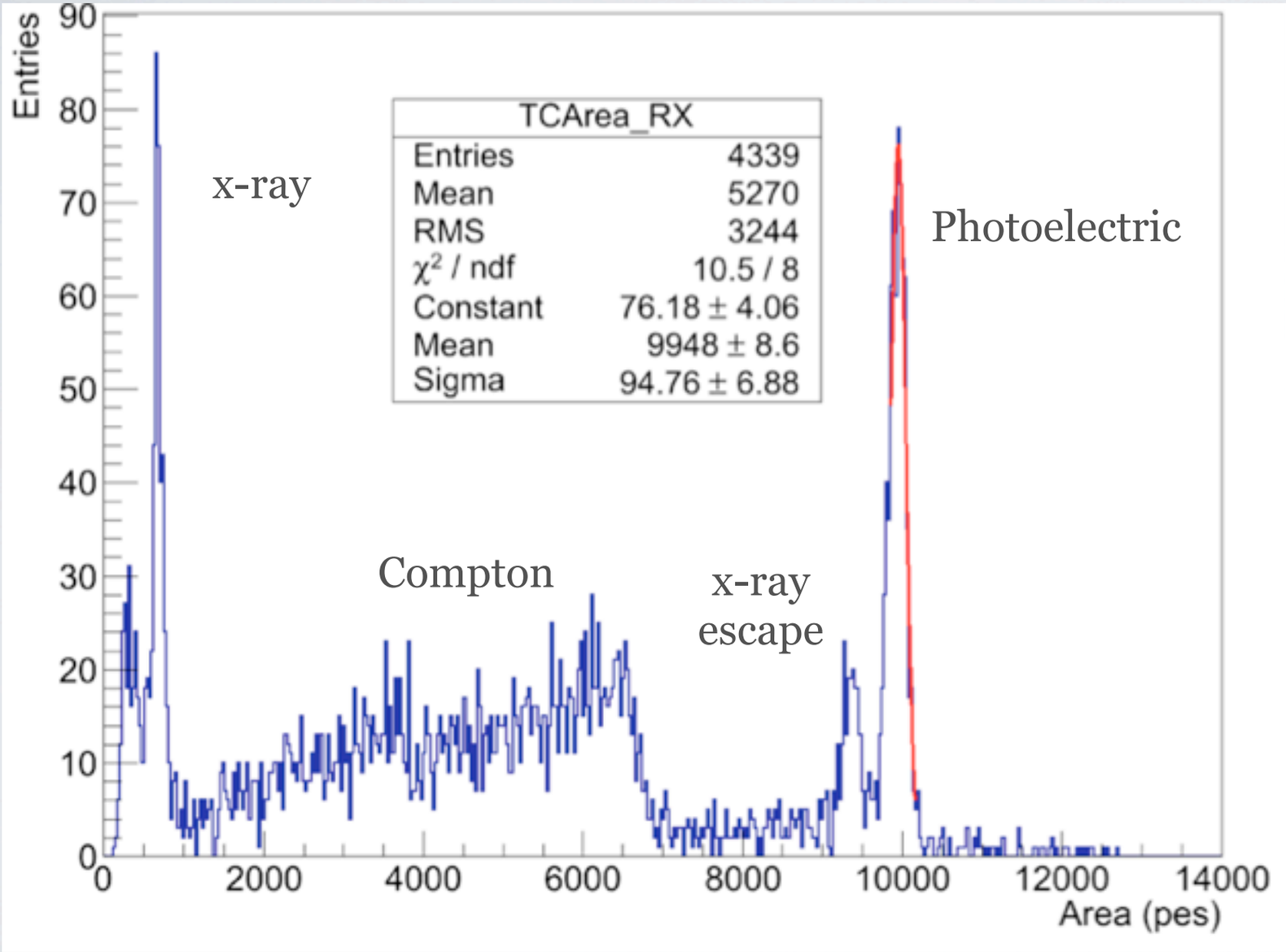


Spatial Correction



e- lifetime = 3.67 ms

NEXT-DEMO RESULTS



Na22 Spectrum

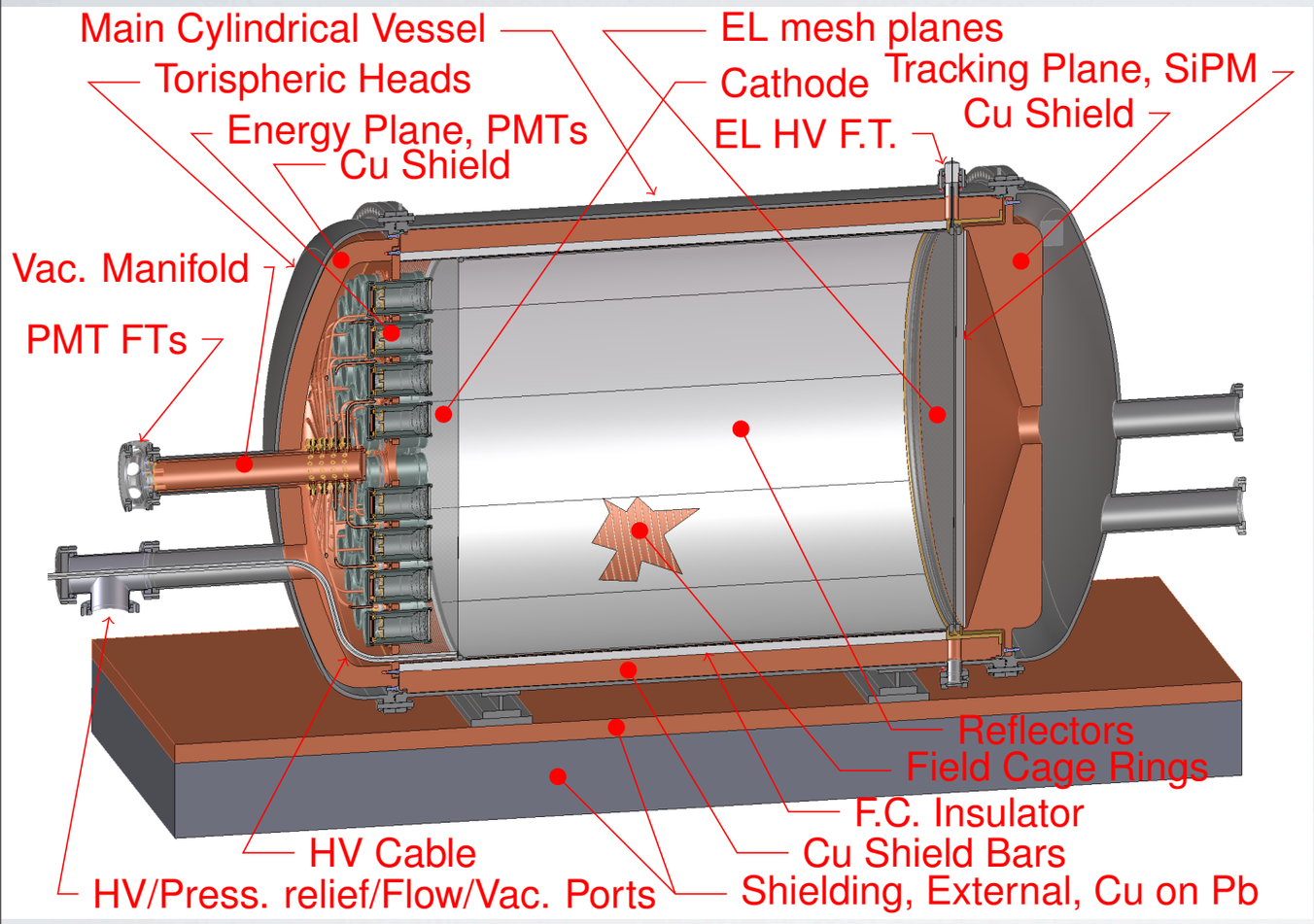
Energy resolution of 2.24% FWHM

extrapolates to 1.02% at Qbb.

NEXT-DEMO CONCLUSIONS

- Chamber stability. Long runs during months of operation.
- TPB coating improves largely light collection.
- Hot getters manage to clean the gas. Current e- lifetime >3ms.
- Improvements in radial and temporal correction.
- Energy resolution (~1% @ Qbb).
- Tracking Plane being installed.

NEXT-100

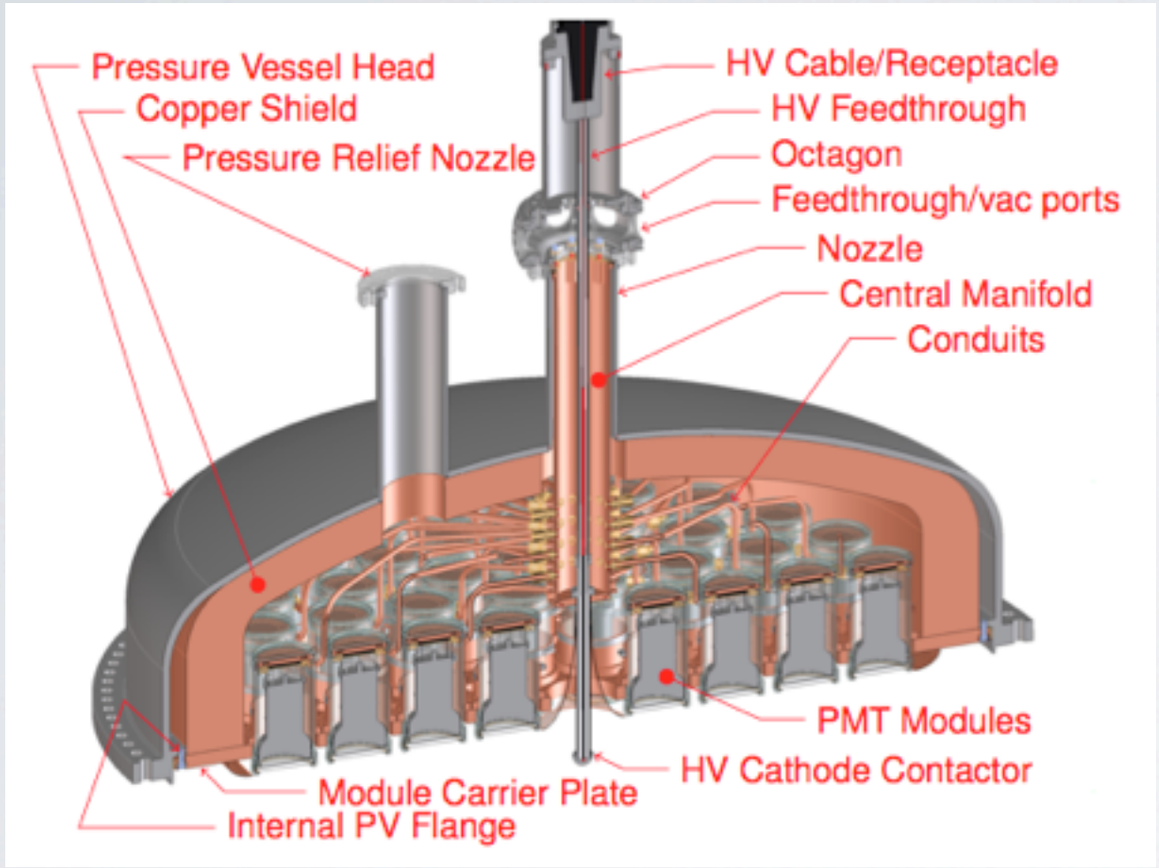


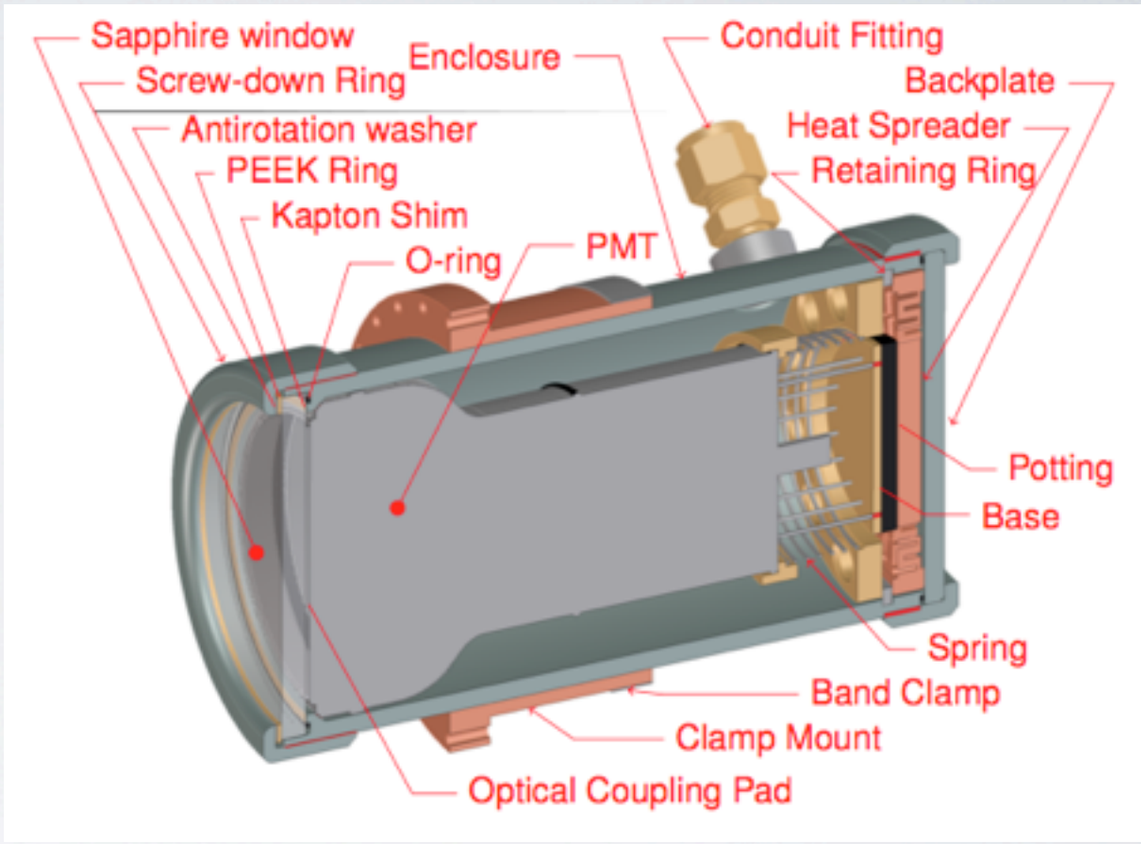
- Cylindrical stainless steel pressure vessel
- Inner radiopure copper 12 cm thick

Drift region	EL region
Diameter: 107 cm	0.5 cm long
Lenght: 130 cm	$(E/p) \sim 3.0\ kV \cdot cm^{-1} \cdot bar^{-1}$
$E \sim 0.3\ kV \cdot cm^{-1}$	Optical Gain: 2500 photons/e$^-$

Technical Design Report (TDR) arXiv:1202.0721 [physics.ins-det]

NEXT-100

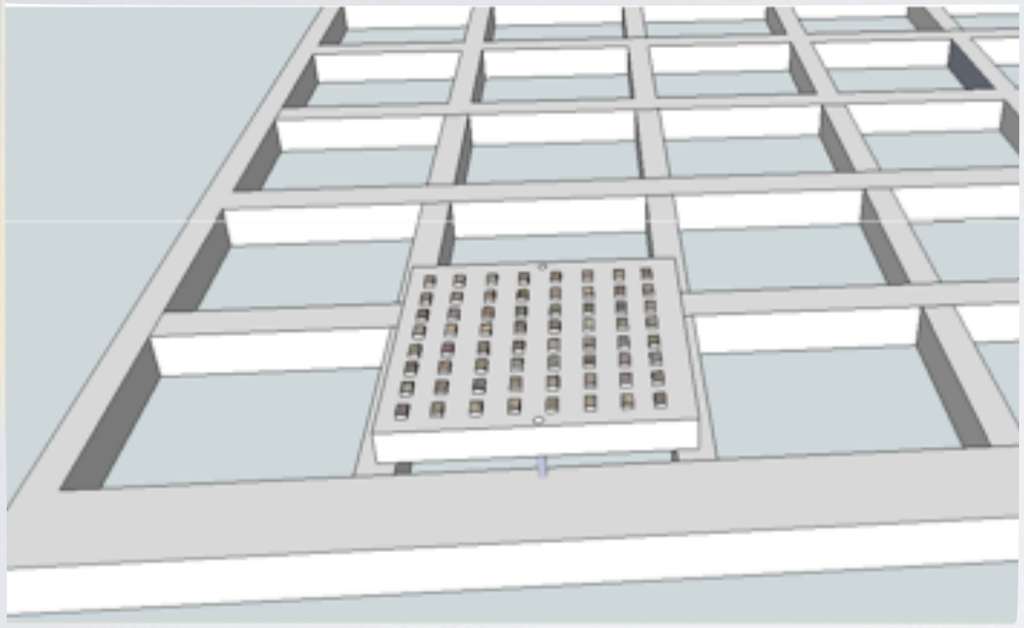


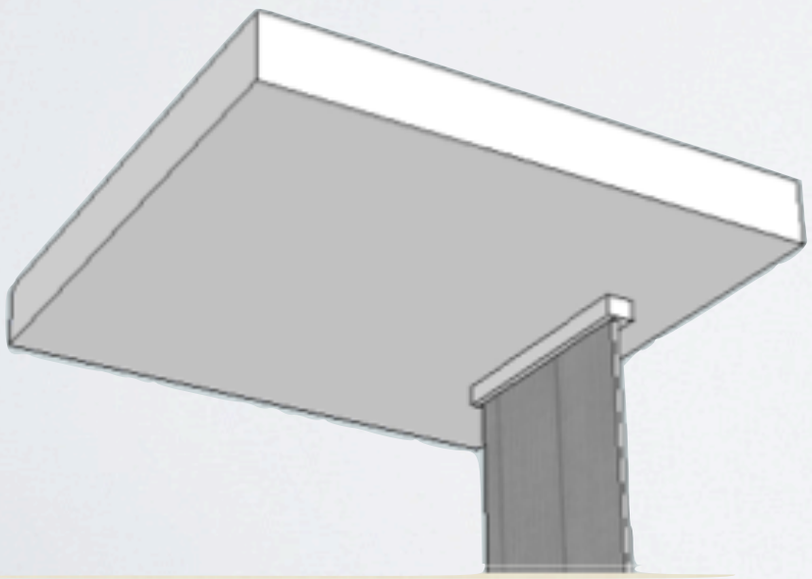


60 PMTs
Hamamatsu R11410-10
32.5% surface Energy Plane

PMTs inside vacuum
tight enclosure
+
sapphire window

NEXT-100

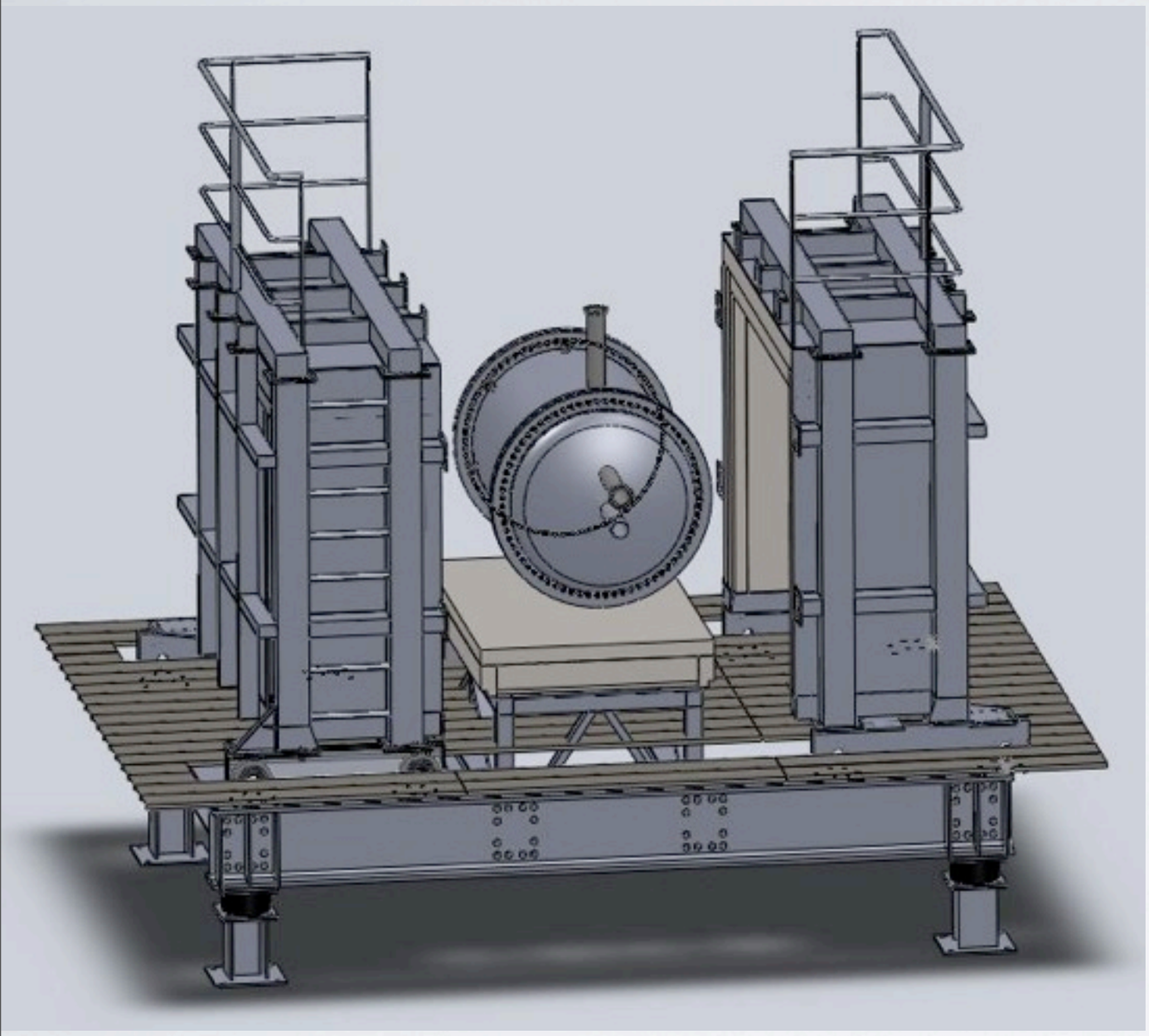


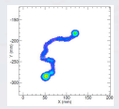


MPPCs for Tracking

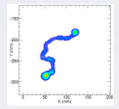
- Fine pixelization (~1cm pitch), low cost, some charge information.
- Num SiPM ~7500.

SHIELDING

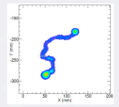




Shielding design completed



Lead castle



Construction starts early January

NEXT-100 performance

	Signal	^{214}Bi	^{208}Tl
1 track cut	0.48	6.0×10^{-5}	2.4×10^{-3}
ROI	0.33	2.2×10^{-6}	1.9×10^{-6}
Topological cut	0.25	1.9×10^{-7}	1.8×10^{-7}

Rejection Potential	$\sim 10^{-7}$
Background	8.0×10^{-4} counts/keV/kg/yr

SUMMARY

- NEXT is a new-generation double beta decay experiments, lead by Spanish and American groups, and to be installed at the Laboratorio Subterráneo de Canfranc (Spain).
- Marries two old instrumental concepts (TPCs and EL) in a novel approach, providing very good energy resolution and tracking for background rejection.
- Ongoing R&D (NEXT-DEMO) to demonstrate main issues.
- Technical design of the NEXT-100 detector completed.
- Further details: **arXiv:1202.0721** [physics.ins-det].

SCHEDULE

- 2012: complete R&D, NEXT-100 design, radiopurity campaign.
- 2013: NEXT-100 construction.
- 2014: NEXT-100 commisioning with non-enriched xenon.
- 2015: start physics with enriched xenon.

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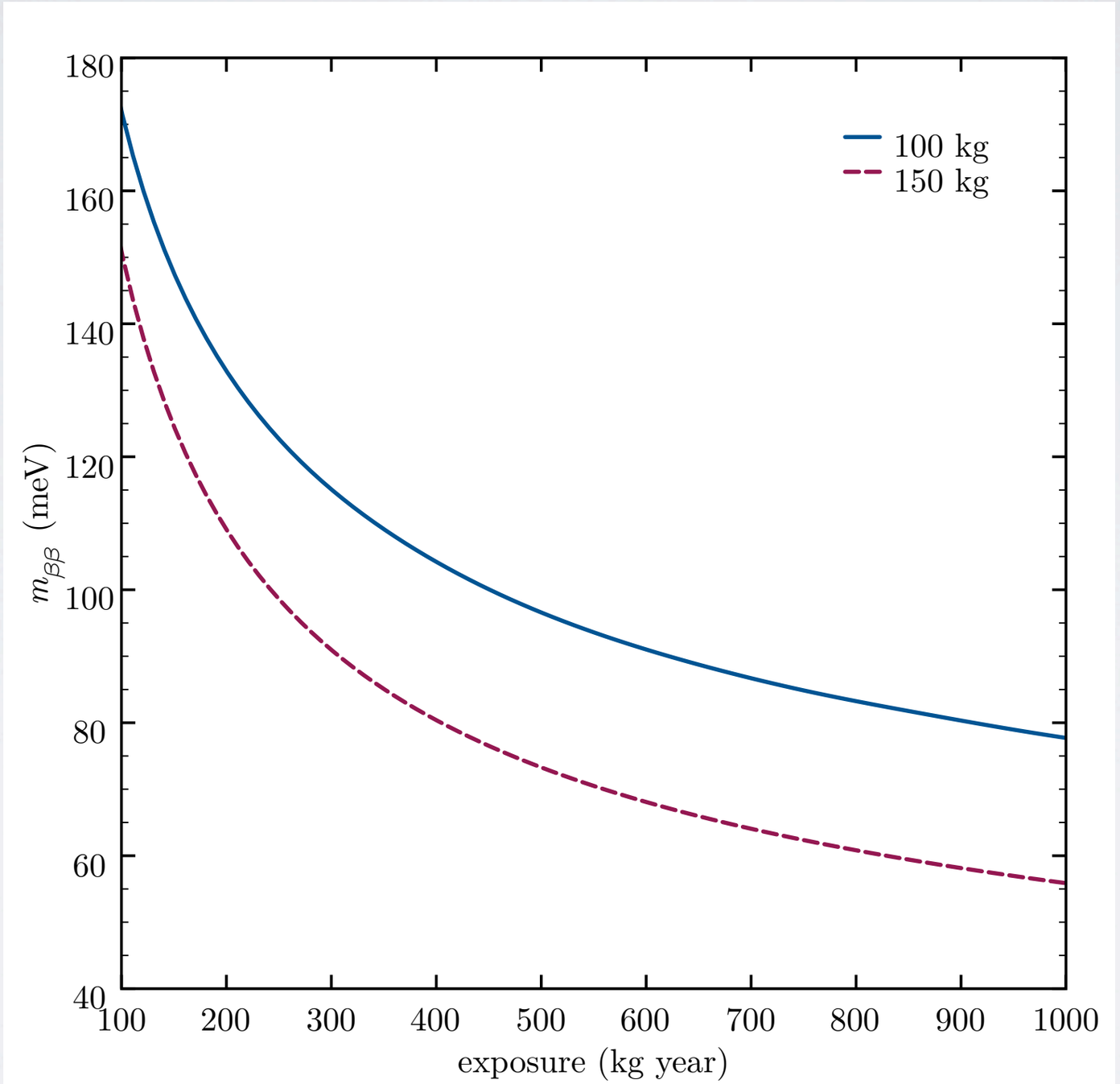
Backup slides...

Sensitivity of NEXT-100



Sensitivity of NEXT-100