Status of the NEXT experiment and future perspectives for HPXe-based DBD experiments

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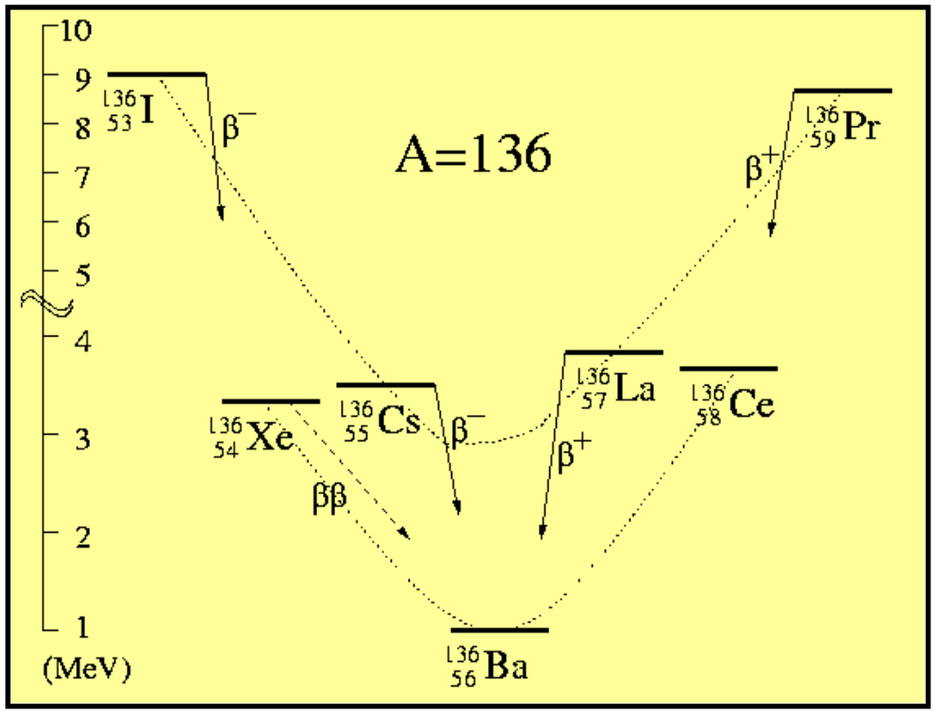
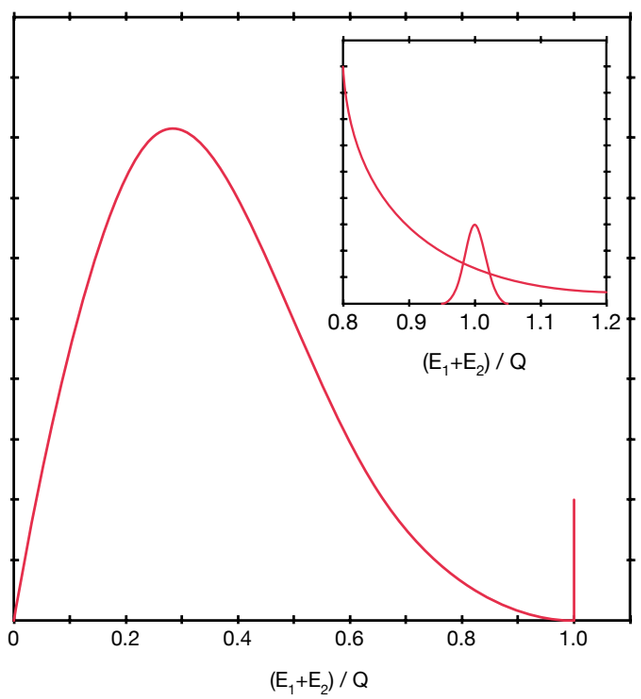
07/10/2014, DBD 2014, Hawaii, USA

The double beta decay of xenon-136

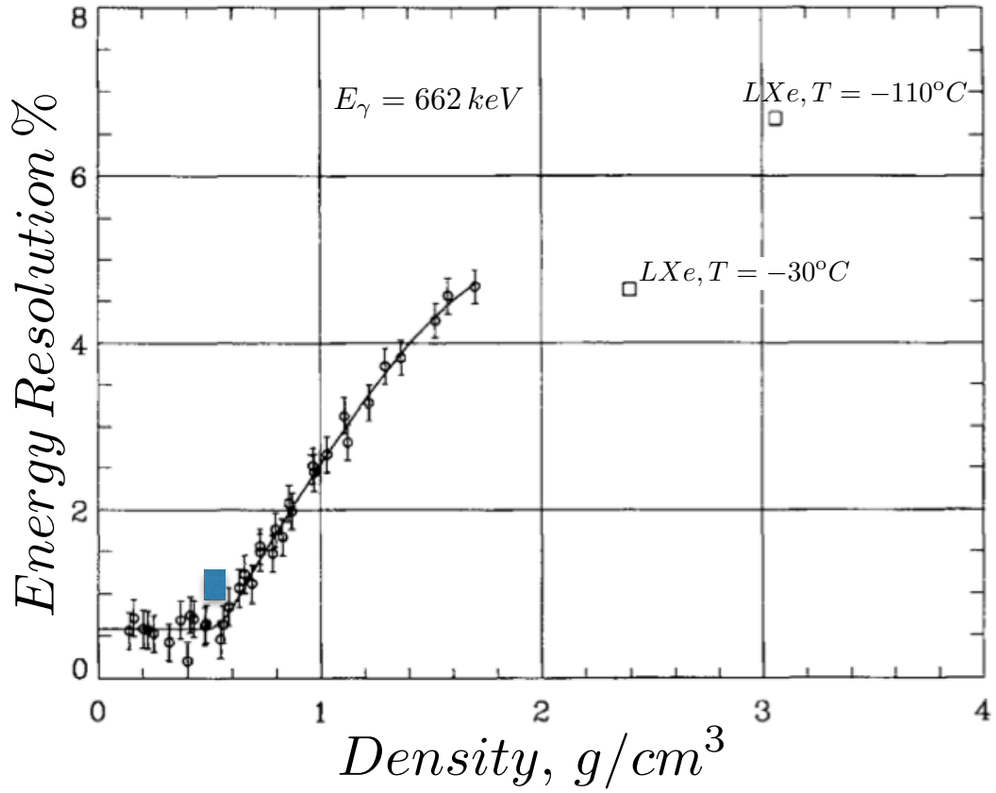
- 2 neutrino mode identified and is among the slowest.
- $Q_{\beta\beta} = 2.458$ MeV.
- Easy to purify and enrich.
- Detection medium





Why high pressure gas?

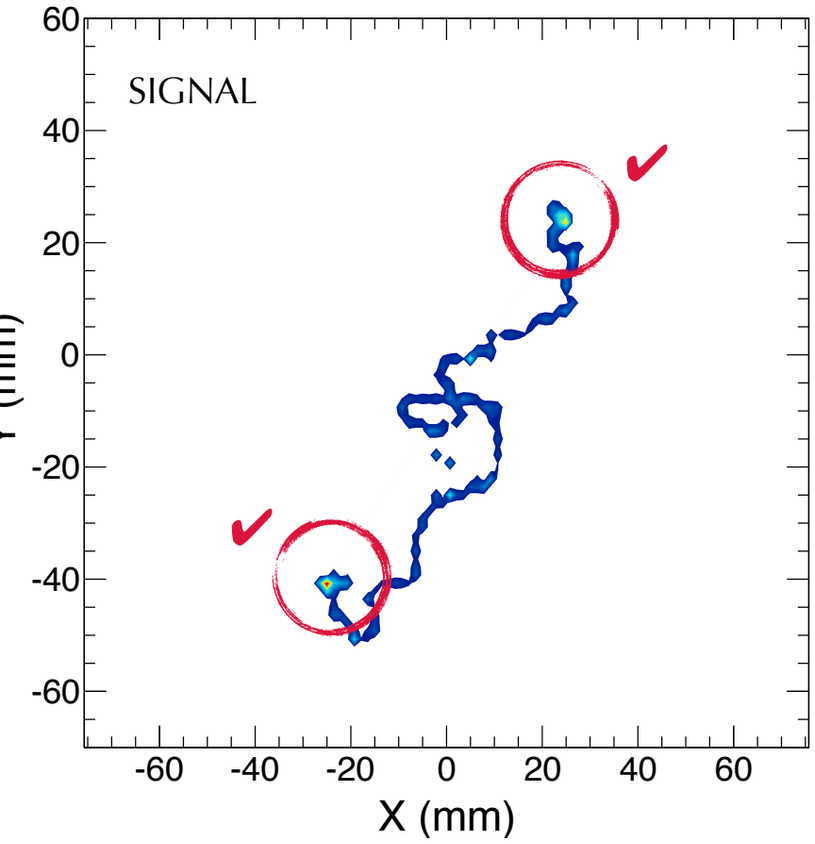
- **Energy resolution:**
  - The fano factor of Xe is low as a gas, the absolute limit on energy resolution can be as low as 0.3% at $Q_{\beta\beta}$.
  - An electroluminescence region can be used to amplify the ionization signal and limit detector related fluctuations.

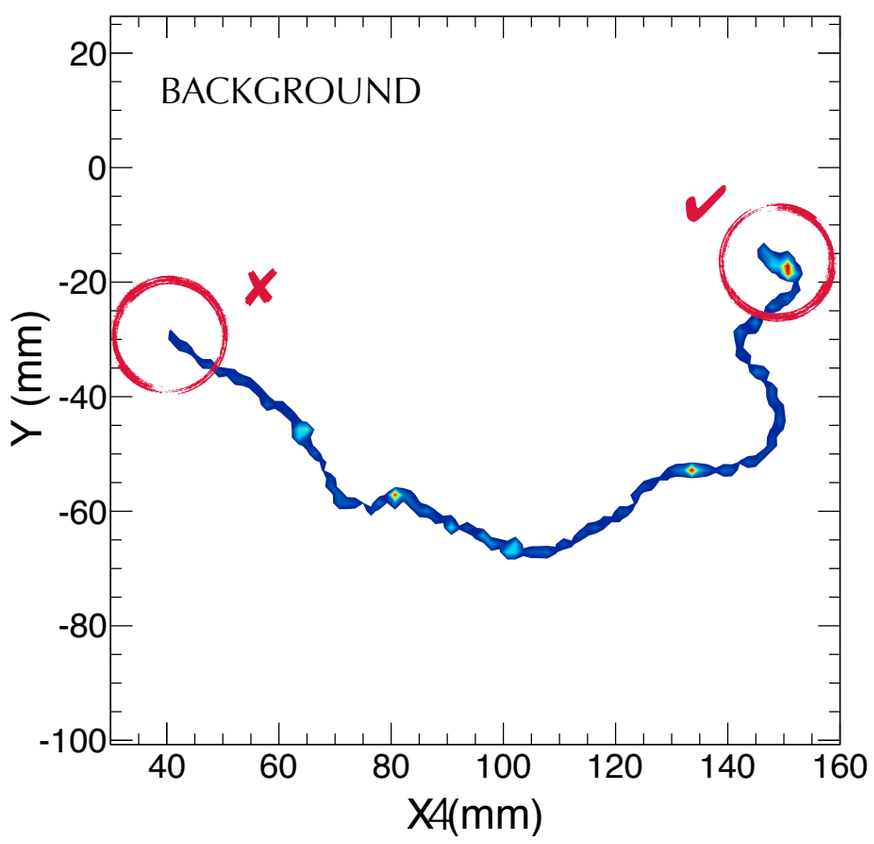


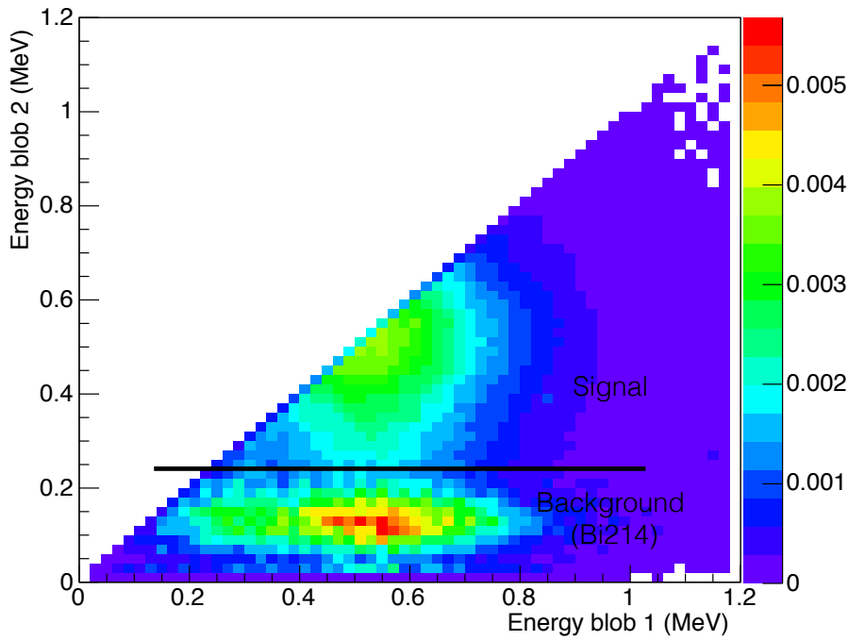
Plot from Bolotnikov and Ramsey, Nucl.Instrum.Meth.A 396 (1997) 360-370.

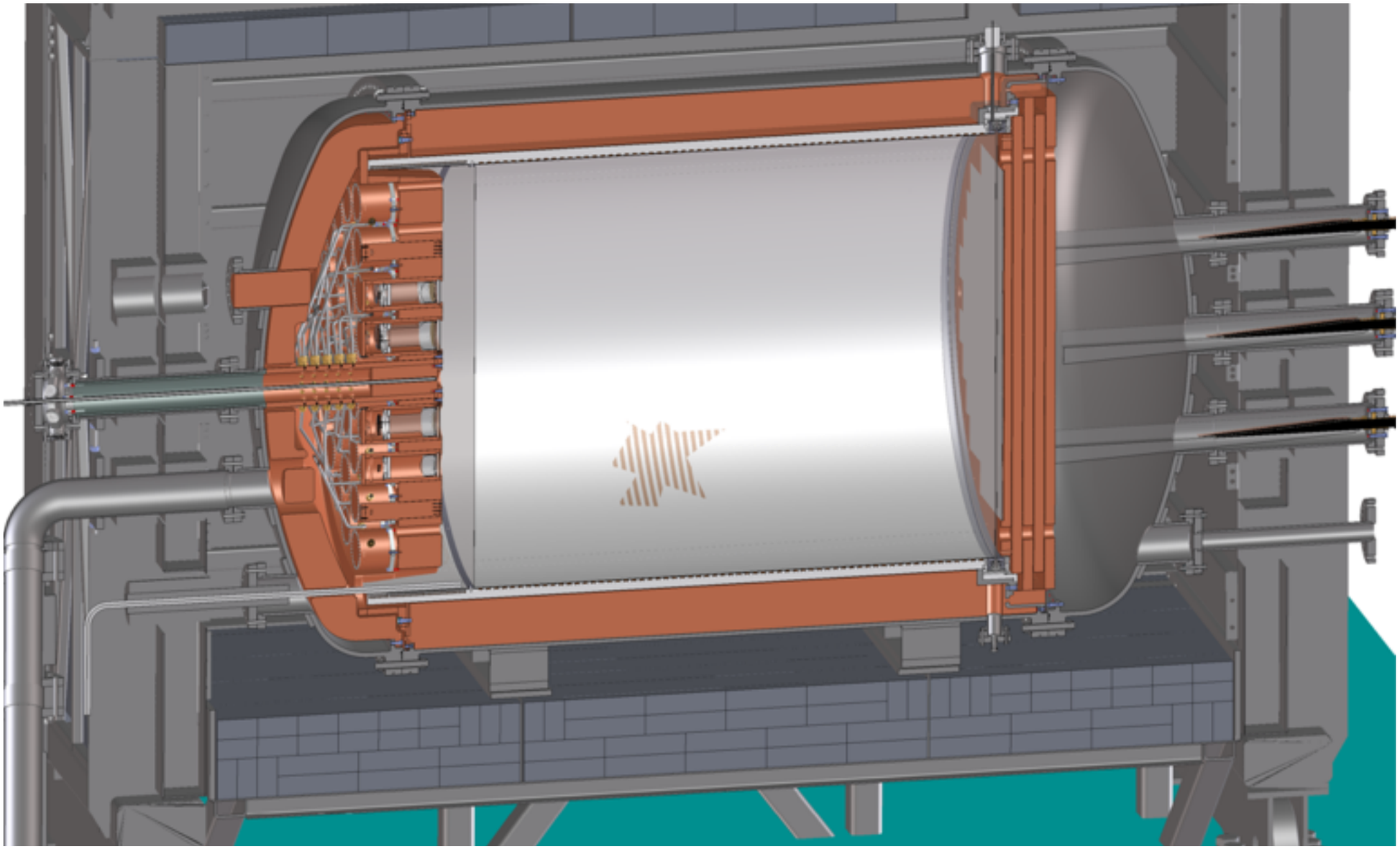
Why high pressure gas?

- **Topological reconstruction:**
  - ßß events in Xe gas at 15 bar are twisted tracks of ~10 cm length with high energy deposits at either end.
  - Single electrons from natural radioactivity will only have a high energy deposit at one end.





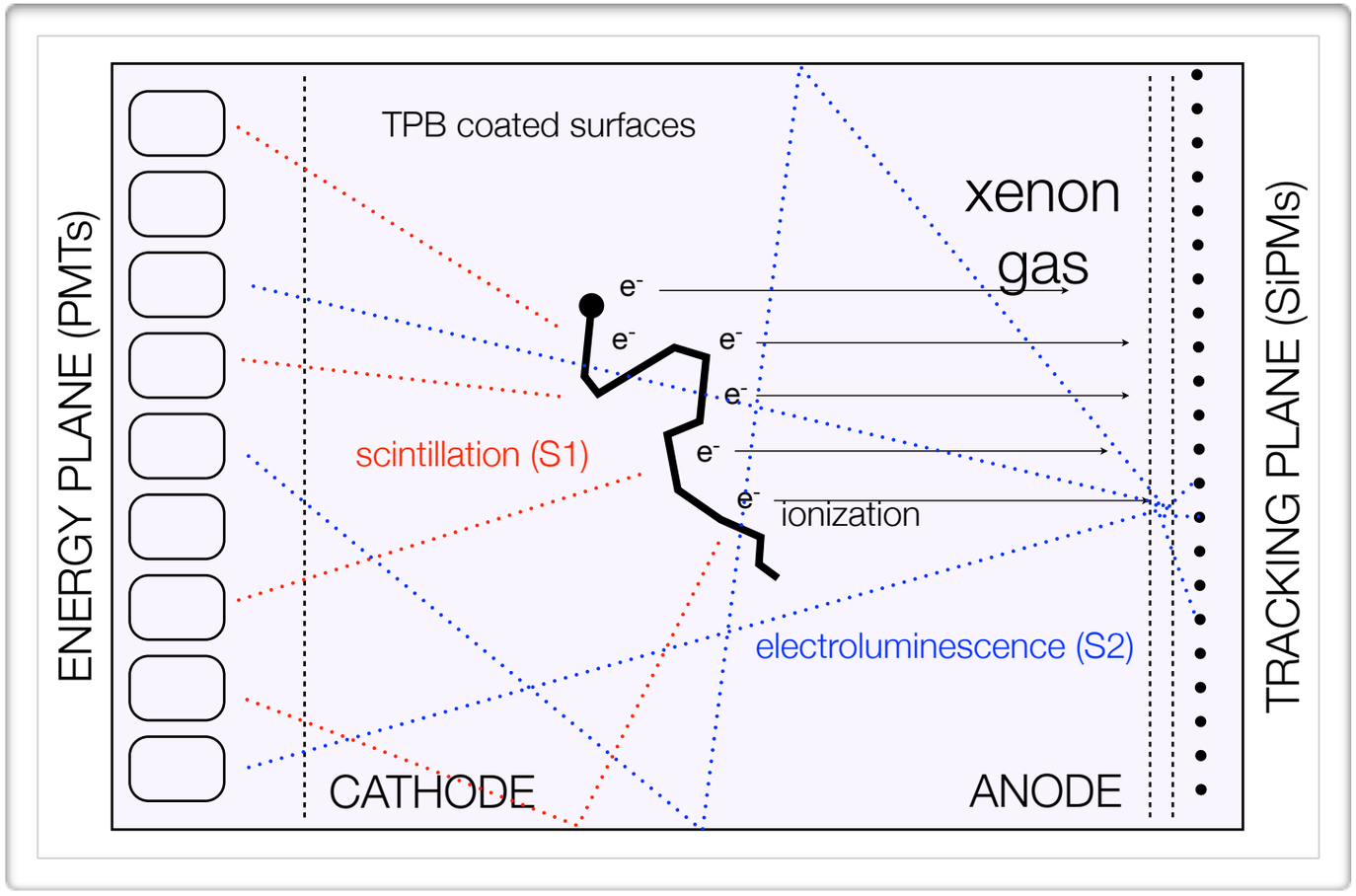




next

Neutrino Experiment with a Xenon TPC

NEXT: A light TPC

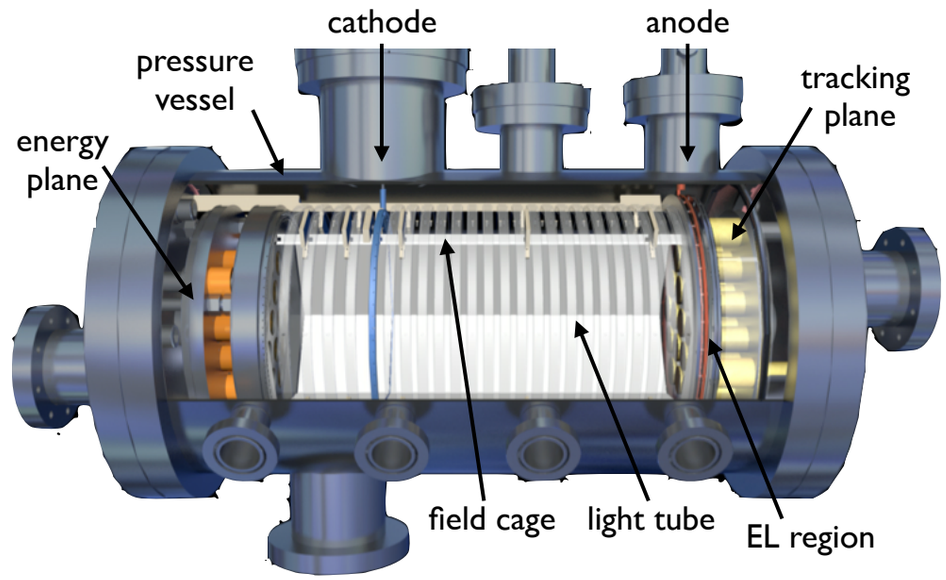


EL mode is essential for linear gain, avoiding avalanche fluctuations and fully exploiting the excellent Fano factor in gas

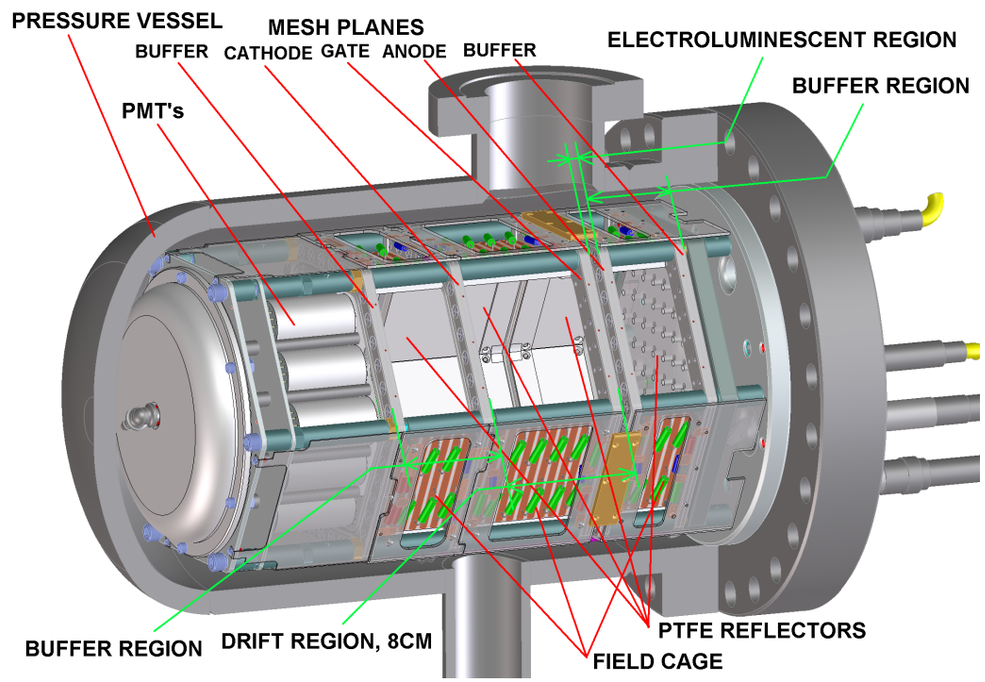
- It is a High Pressure Xenon (HPXe) TPC operating in EL mode.
- It is filled with 100 kg of Xenon enriched to 90% in Xe-136 (in stock) at a pressure of 15 bar.
- The event t0 is detected and its energy integrated by a plane of radiopure PMTs located behind a transparent cathode (energy plane).
- The event topology is reconstructed by a plane of radiopure silicon pixels (MPPCs) (tracking plane).

R&D detectors

- **NEXT-DEMO:**
  - ~1.5 kg natural xenon at 10 bar.
  - 19 1 inch PMTs behind cathode.
  - Array of 256 MPPCs behind anode.
  - Internal surfaces coated with TPB.



- **NEXT-DBDM:**
  - ~1 kg natural xenon at 20 bar.
  - 19 1 inch PMTs behind cathode.
  - Reflective plate behind anode



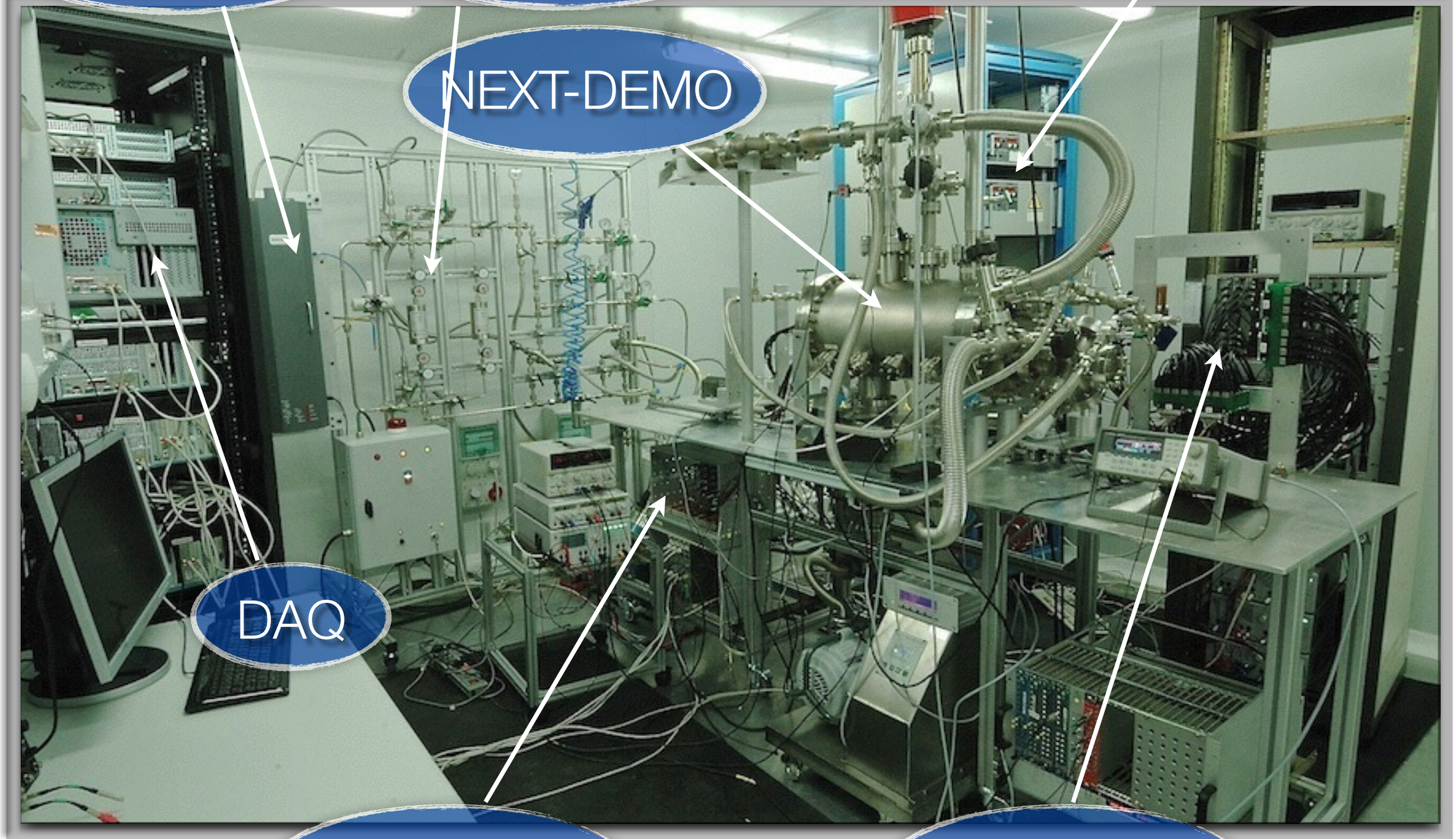
Most recent results published in: DEMO: arXiv:1407.3966; DBDM: arXiv:1409.2853

Hot Getter

Gas System

HHV modules

NEXT-DEMO



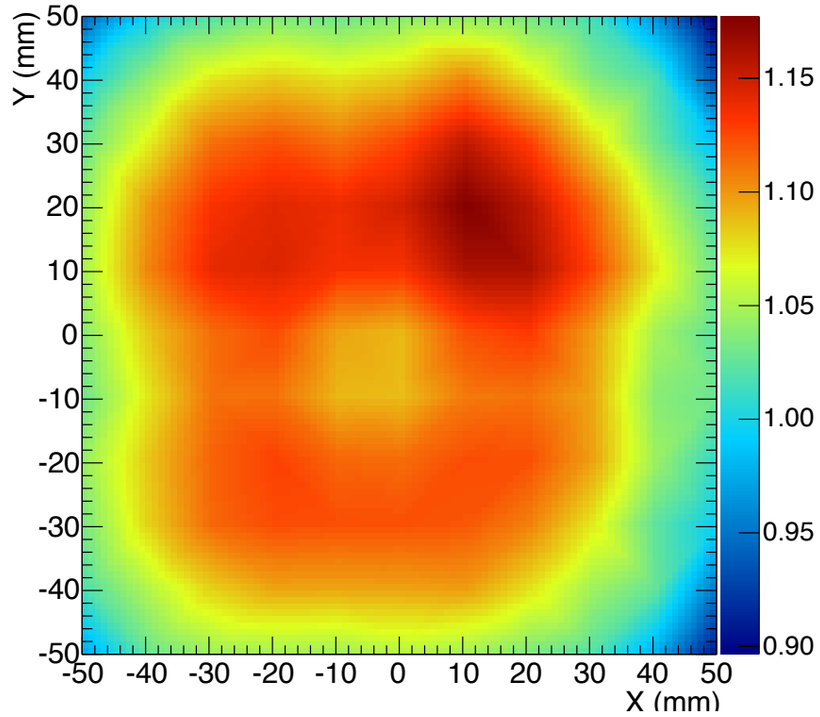
DAQ

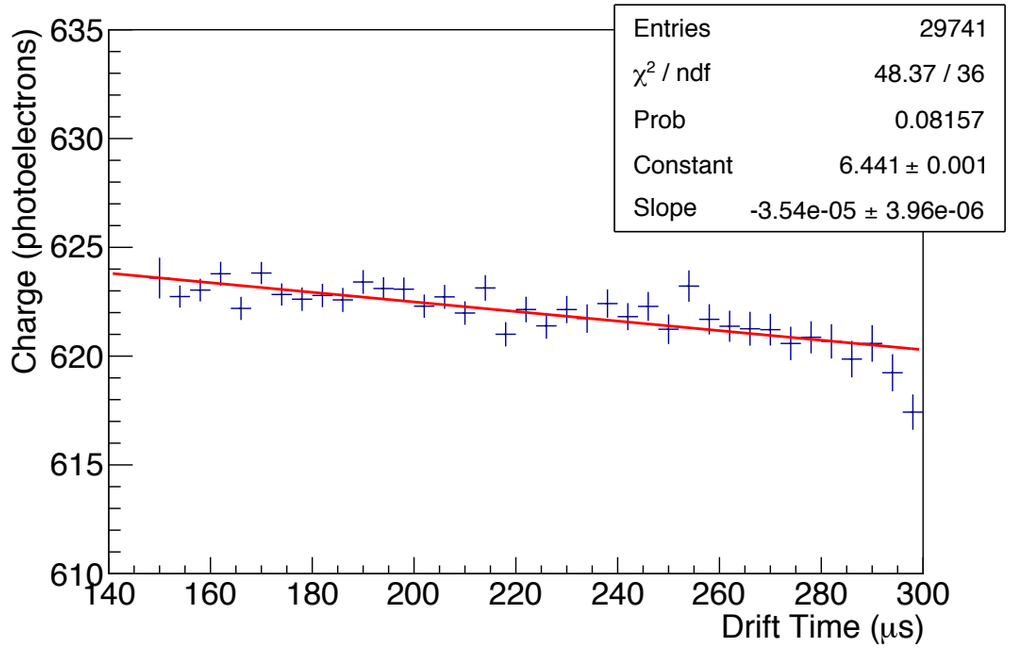
PMTs FEE

SiPMs FEE

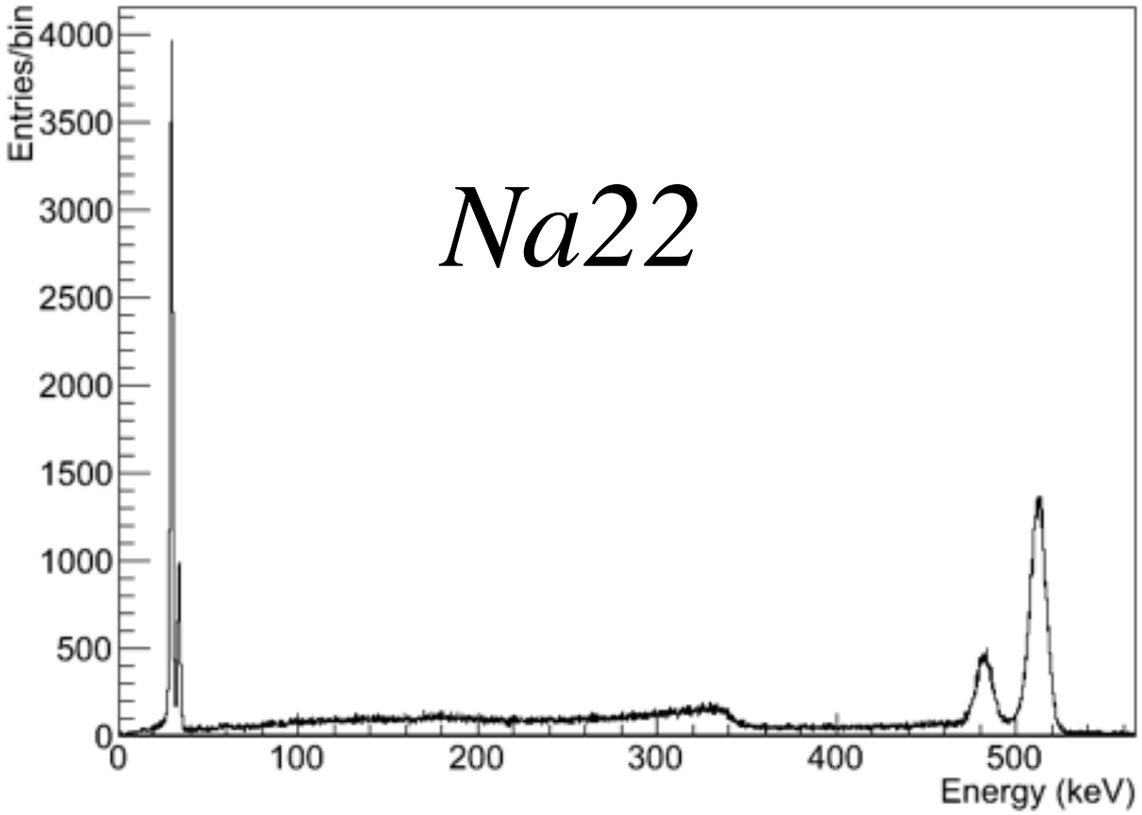
Energy resolution in DEMO

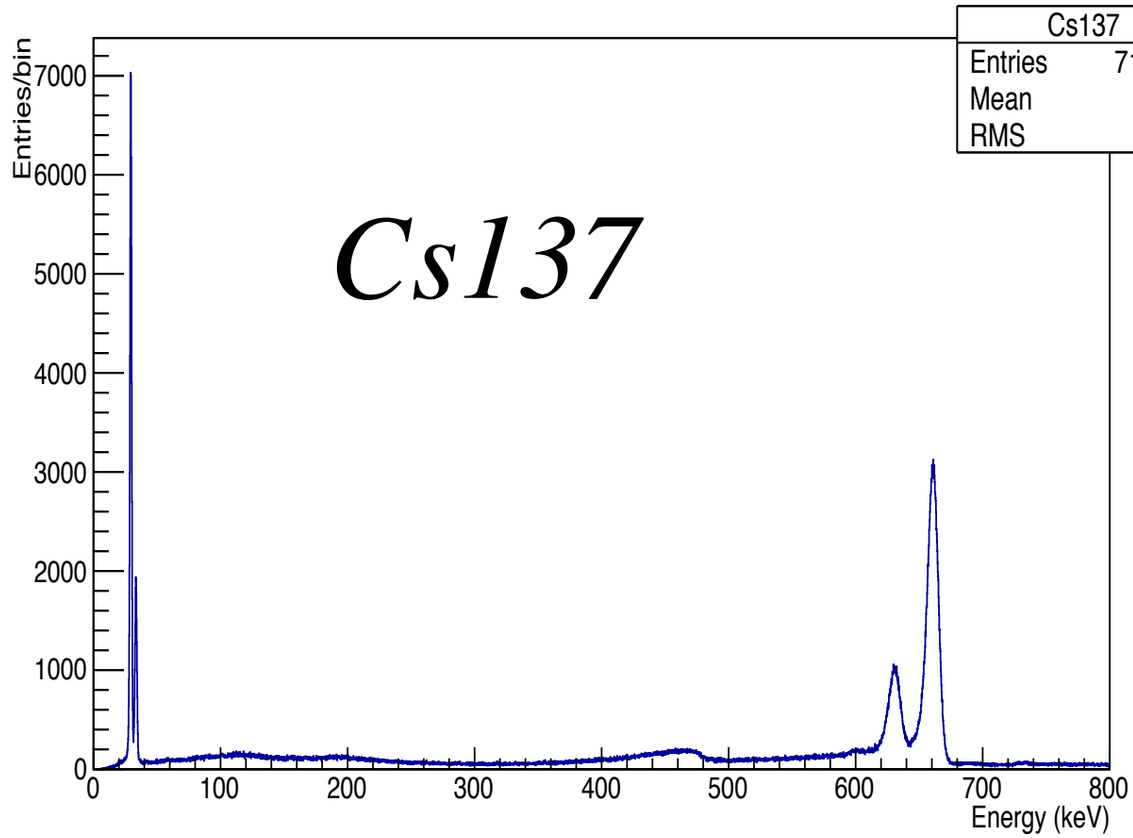
- Studies of electron reconstruction and energy resolution performed using ^{22}Na, ^{137}Cs and ^{228}Th data.
- Correction for electron lifetime, > 20 ms.
- K shell X-rays used to calibrate X/Y response.





Energy resolution in DEMO

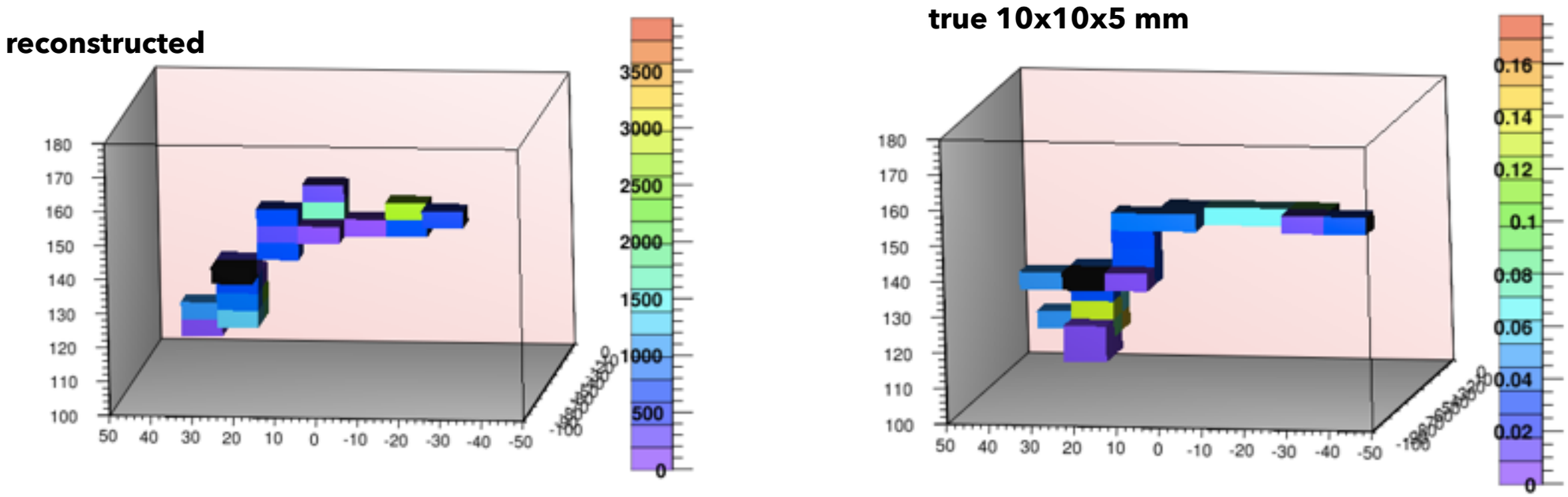




Reconstruction of events from ^{22}Na and ^{137}Cs result in energy resolutions of 1.62% and 1.58%. These values predict an energy resolution at $Q_{\beta\beta}$ of ~0.75% FWHM.

Track reconstruction

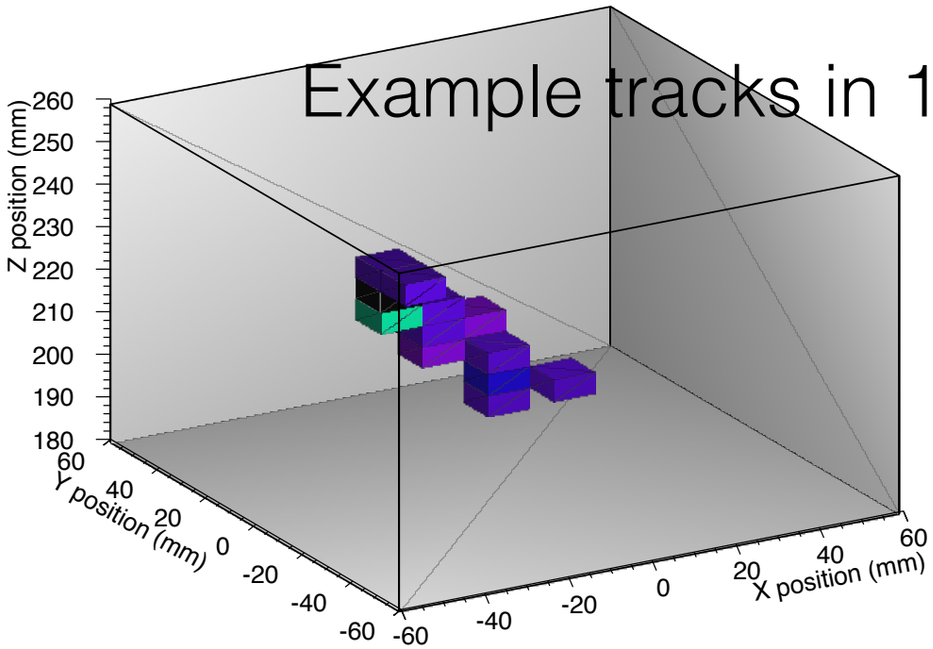
- Reconstruction of event position and topology is performed using an array of SiPMs.
- Monte Carlo shows basic SiPM clustering algorithm good, improvements and advanced image reconstruction under study.

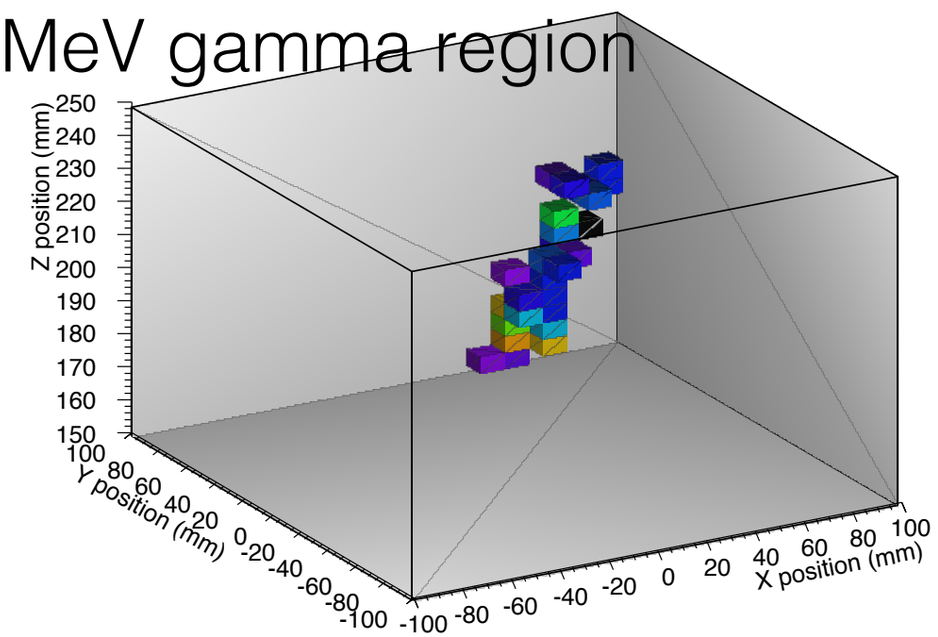


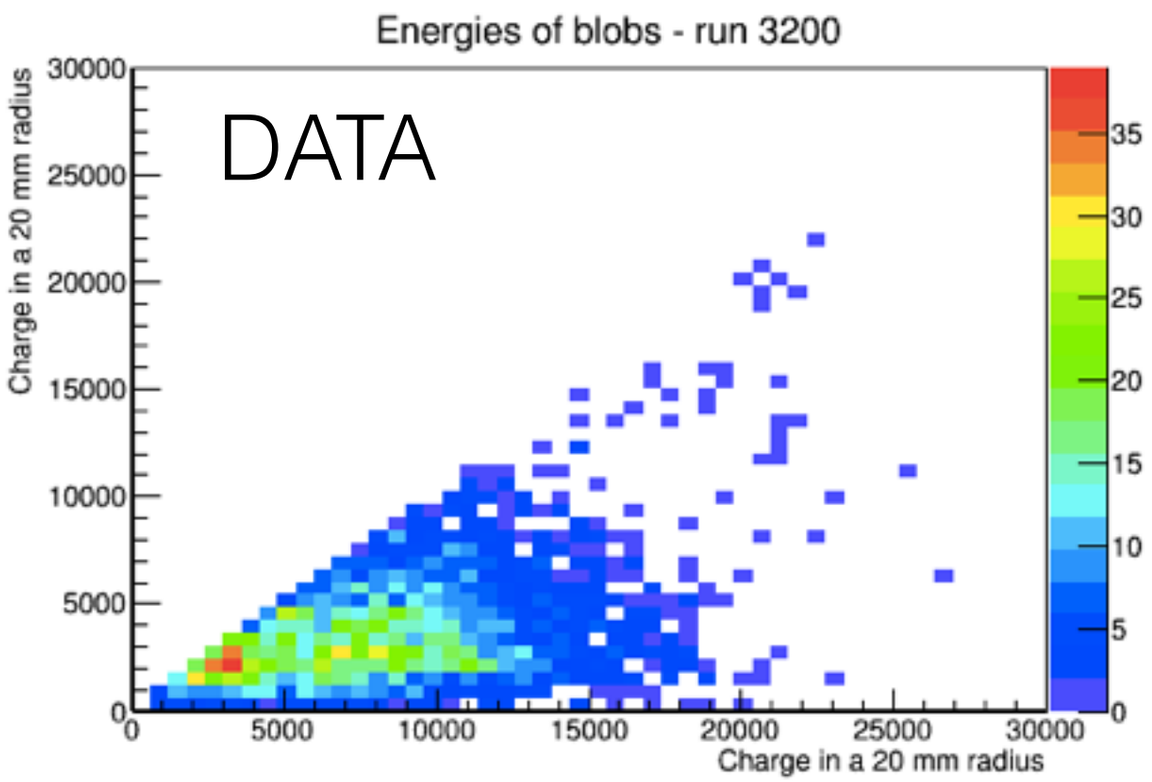
Event from simulated ^{22}Na 1.275 MeV gamma

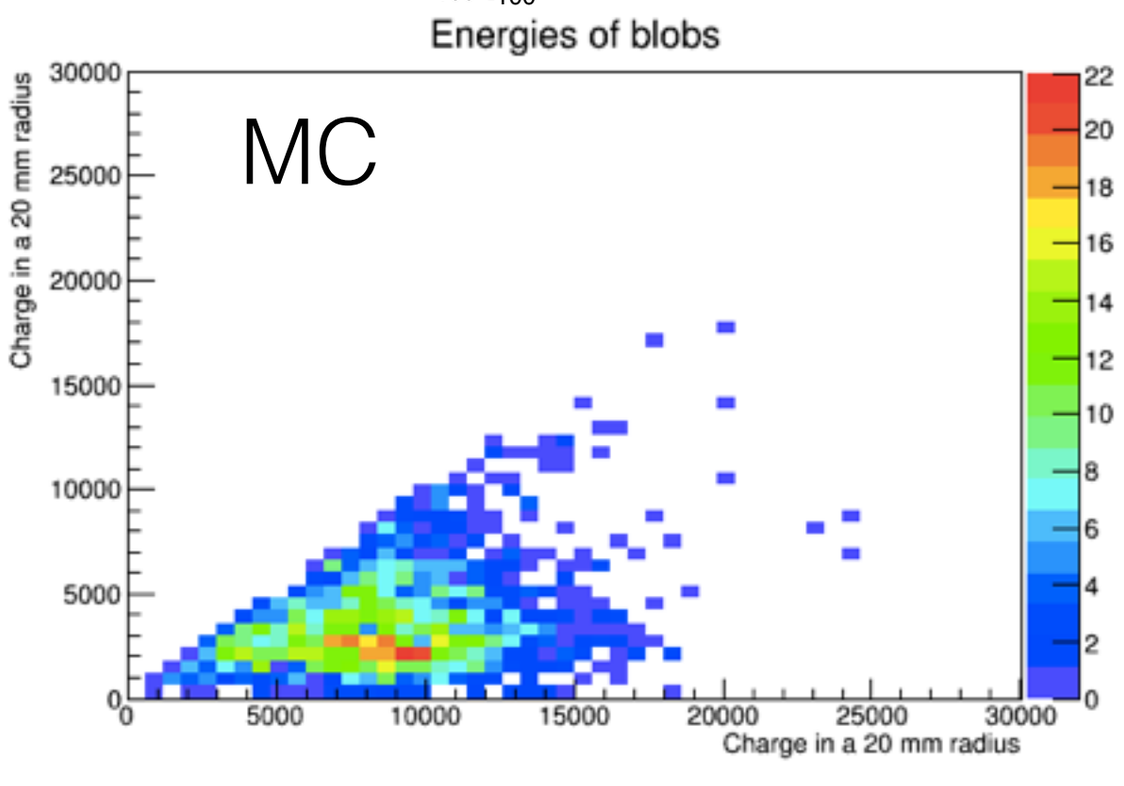
DEMO data rec.

Example tracks in 1.275 MeV gamma region









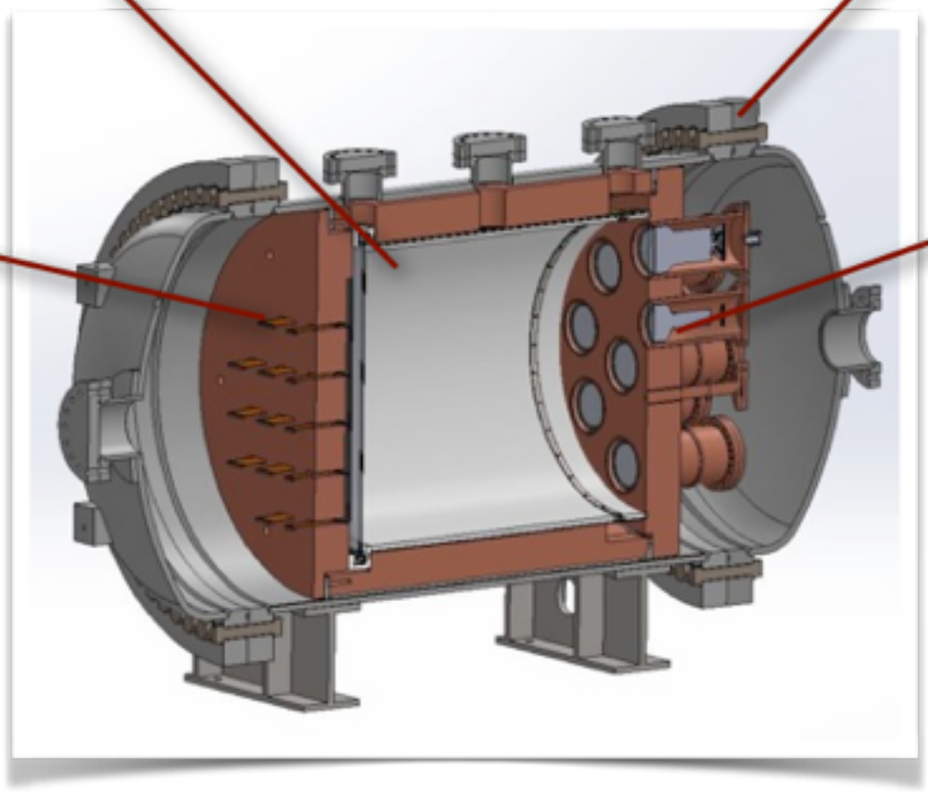
Min. eng. end point vs. max data MC comparison, 1.275 MeV gamma region

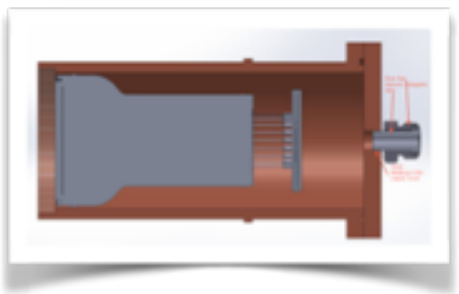
Time Projection Chamber:
10 kg active region, 50 cm drift length

Pressure vessel:
316-Ti steel, 30 bar max pressure

Tracking plane:
1,800 SiPMs,
1 cm pitch

Energy plane:
12 PMTs,
30% coverage



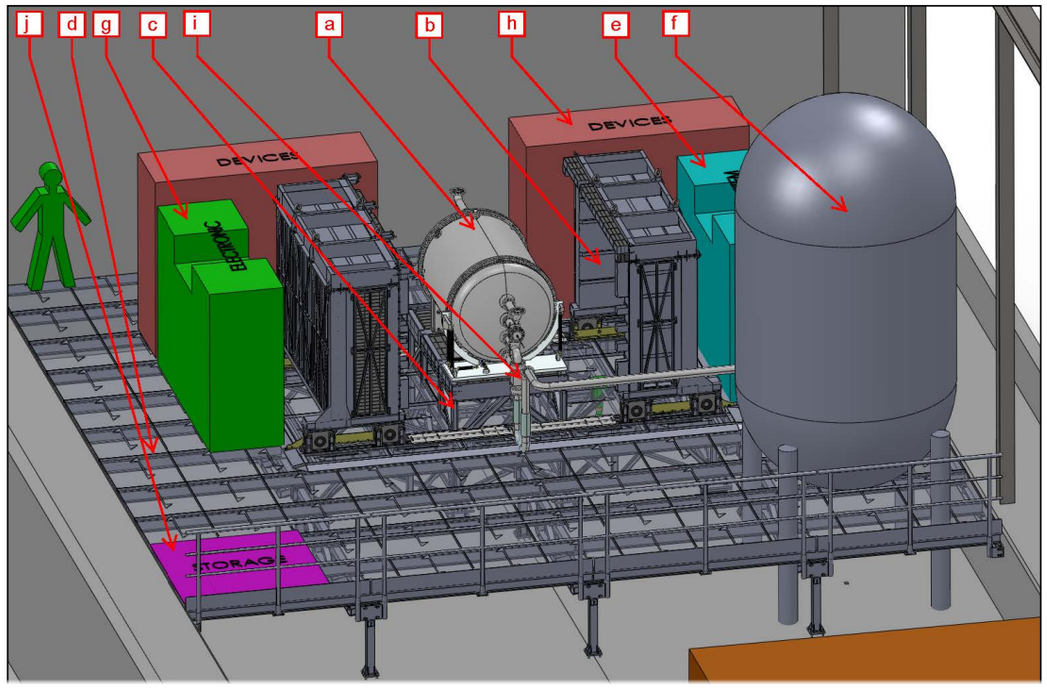


Inner shield:
copper, 6 cm thick

NEW

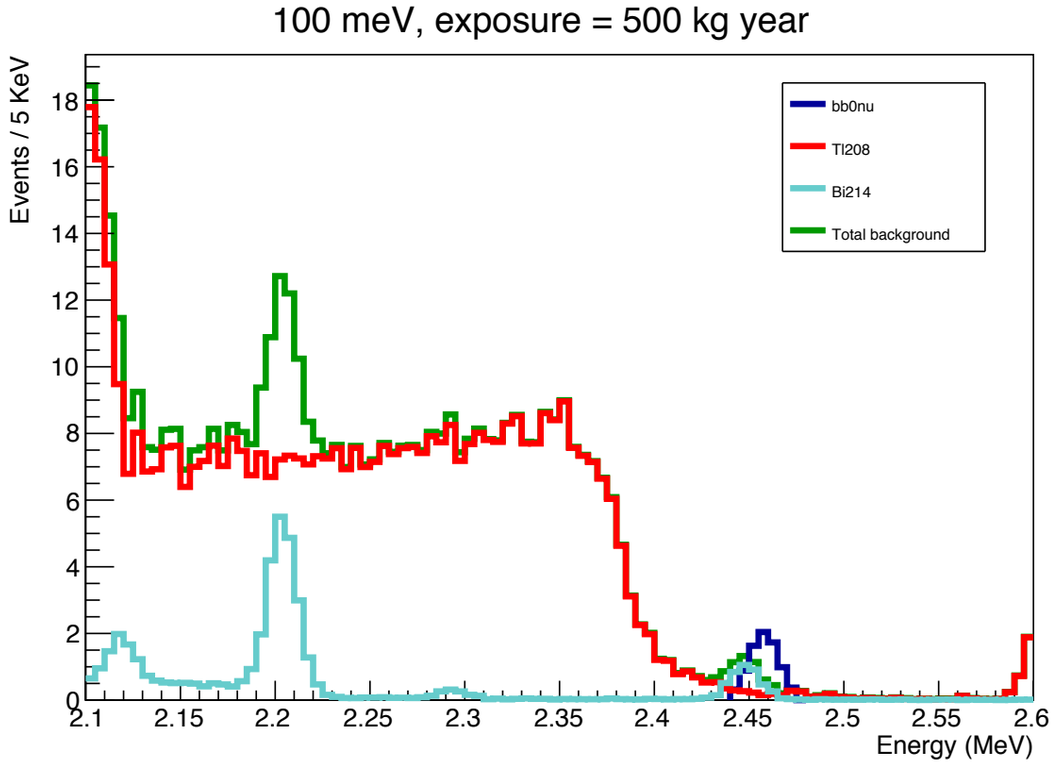
The next step for NEXT; 2015-2016.

NEXT at LSC



Infrastructures: platform, lead castle, gas system, emergency recovery system, completed. First phase of experiment starts in 2015. In stock, 100 kg of enriched xenon and 100 kg of depleted xenon.

Goals of NEW

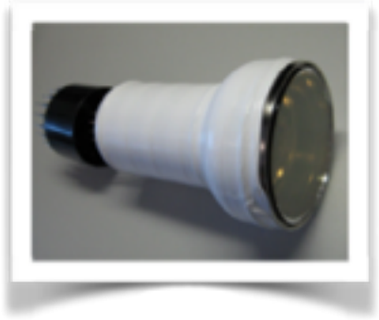


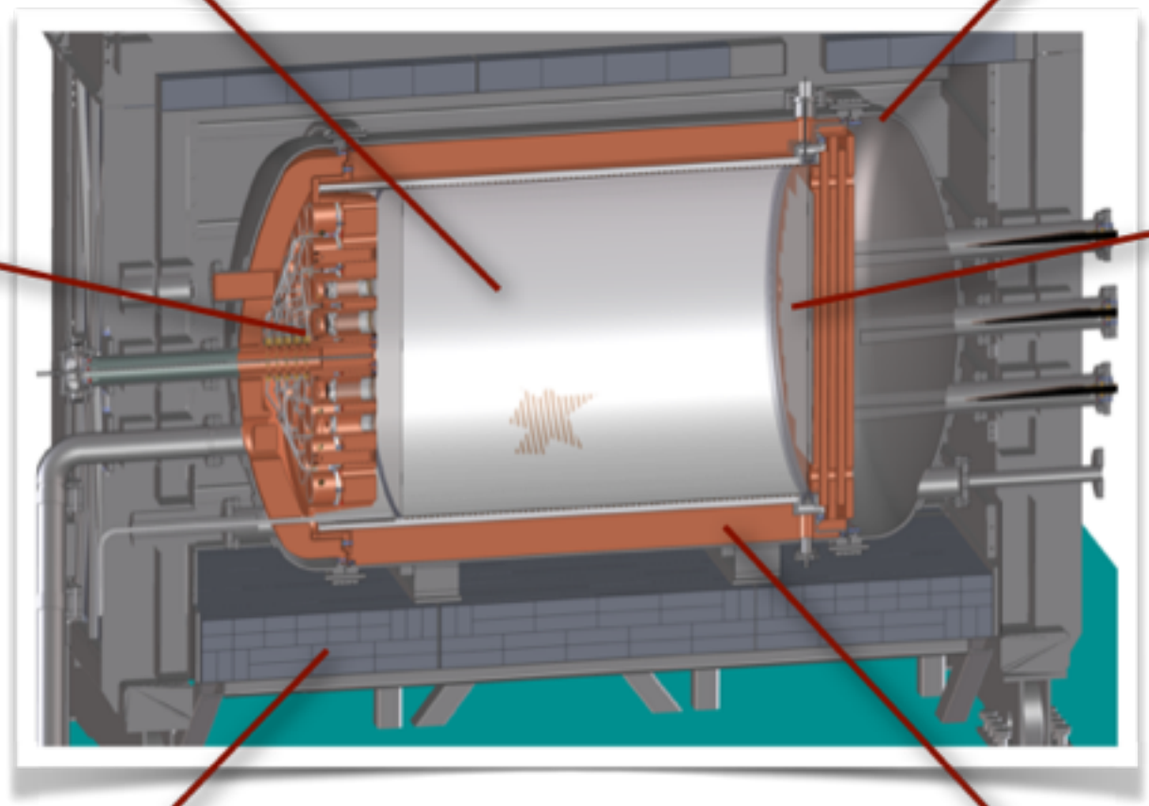
- Measure the expected backgrounds from the different isotopes, but specially Bi-214 and TI-208.
- Validate NEXT background model using measurement.
- Identify any unexpected source of background (correct if needed).
- Demonstrate energy resolution: our goal is to reach 0.5 % FWHM in the large detector.
- Demonstrate topological signature from data (ββ2v and TI-208 double escape peak).
- Certify technology and underground operation with enriched xenon.

Time Projection Chamber:
100 kg active region, 130 cm drift length

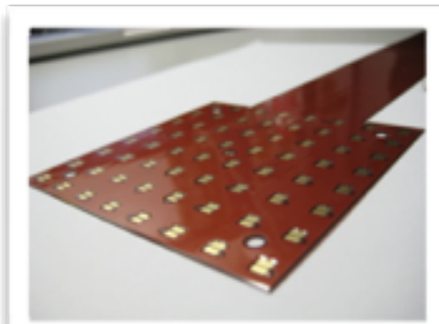
Pressure vessel:
stainless steel,15 bar max pressure

Energy plane:
60 PMTs,
30% coverage





Tracking plane:
7,000 SiPMs,
1 cm pitch



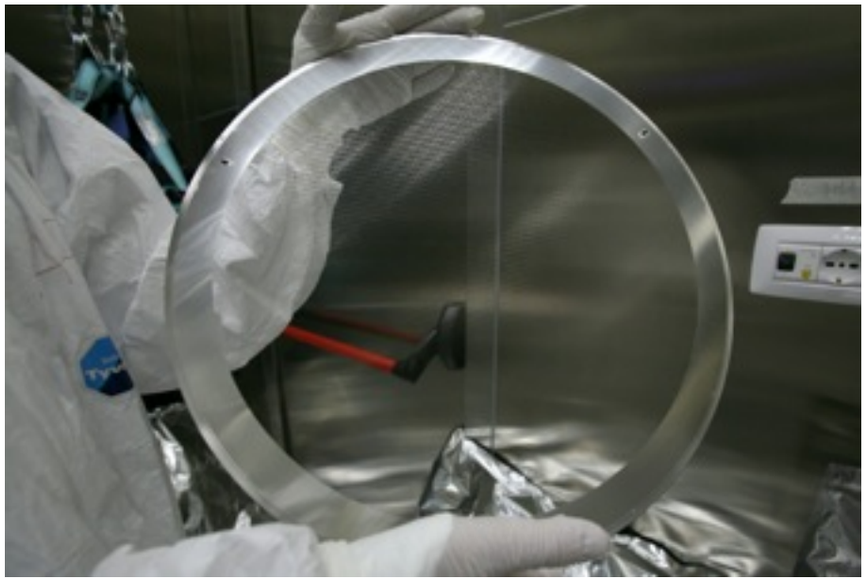
Outer shield:
lead, 20 cm thick

Inner shield:
copper, 12 cm thick

NEXT-100

Neutrinoless double beta decay; from 2017.

Pressure vessel



NEXT100 rejection of backgrounds

	0νββ	Tl-208	Bi-214
Basic selection	47.59%	3.4E-05	4.0E-06
2 blobs	32.61%	1.4E-06	4.1E-07
ROI	28.24%	2.2E-07	1.9E-07

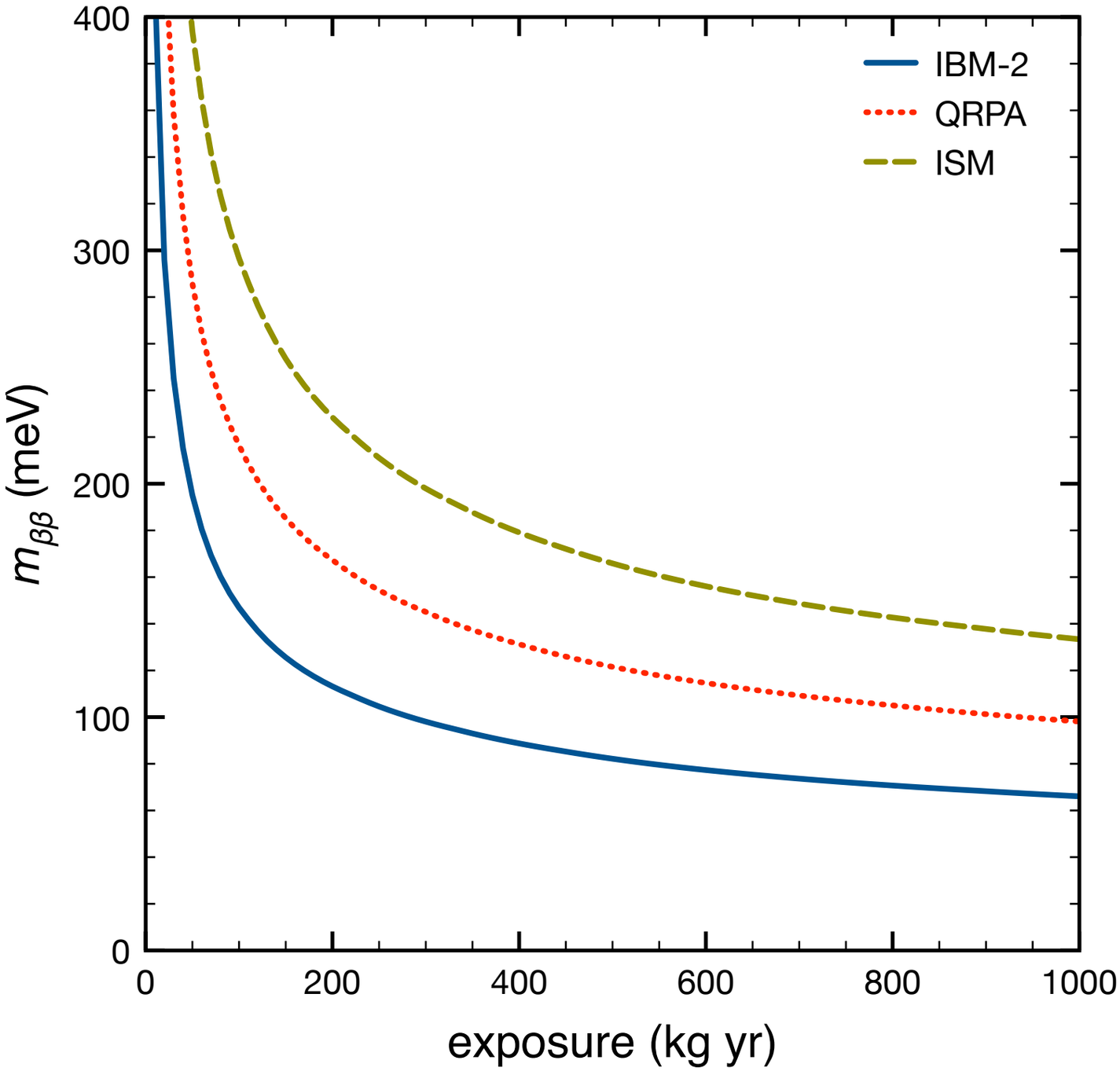
Fast simulation analysis with 10^6 signal events and 10^{10} of each background

- Basic selection requires:
  - Reconstructed energy between 2.4 and 2.5 MeV.
  - No more than 10 keV energy deposited within 2 cm of the detector edges.
  - One and only one 'track' which has a length of at least 1 cm.
- The end points of the track must have 0.25 MeV within a 1.5 cm radius sphere.
- The ROI is adjusted to include only the range ±1 FWHM around $Q_{\beta\beta}$ ($\pm 0.75 Q_{\beta\beta}$).

NEXT-100 expected background

	Activity (Bq)		Rejection Factors		Final rate (ckky)	
	Tl-208	*Bi-214*	*Tl-208*	*Bi-214*	*Tl-208*	*Bi-214*
Dice Boards	1.50E-03	3.21E-03	4.85E-07	4.90E-07	1.980E-05	6.000E-06
PMTs	1.49E-02	5.76E-02	2.4E-07	1.6E-07	4.290E-05	1.130E-04
Field Cage	1.60E-03	1.21E-02	3.83E-07	4.39E-07	7.300E-06	6.300E-05
ICS	1.330E-02	1.110E-01	1.100E-07	5.300E-08	1.713E-05	7.000E-05
Vessel	1.66E-01	5.16E-01	1.0E-08	<1E-09	1.980E-05	6.000E-06
Shielding Lead	4.300E-01	4.530E+00	<1E-09	<1E-09	1.129E-05	9.763E-07
SUBTOTAL	6.27E-01	5.23E+00			2E-04	3E-04
TOTAL BKGND	5.86E+00				**5.00E-04**	

Components tested at LSC using germanium spectroscopy, GDMS and ICPMS measurements.
Methodology and results described in JINST 8 (2013) T01002.
Many components still only have upper limits on activity.



Expected sensitivity

Enlarging to tonne scale; the future of HPXe

MAGIX/BEXT

- A symmetric TPC filled with O(1 tonne) of Xenon enriched to 90% in Xe-136 at a pressure of 15 bar.
- Drift length of 2 x 2 m (2 ms drift, DEMO measures lifetimes of > 10 ms).
- Radius of about 1 m.
- Active volume of ~12 m^3 (1 tonne at 15 bar).
- TPC in a water tank to shield against cosmogenic background.
- Various technological changes to improve background rejection.

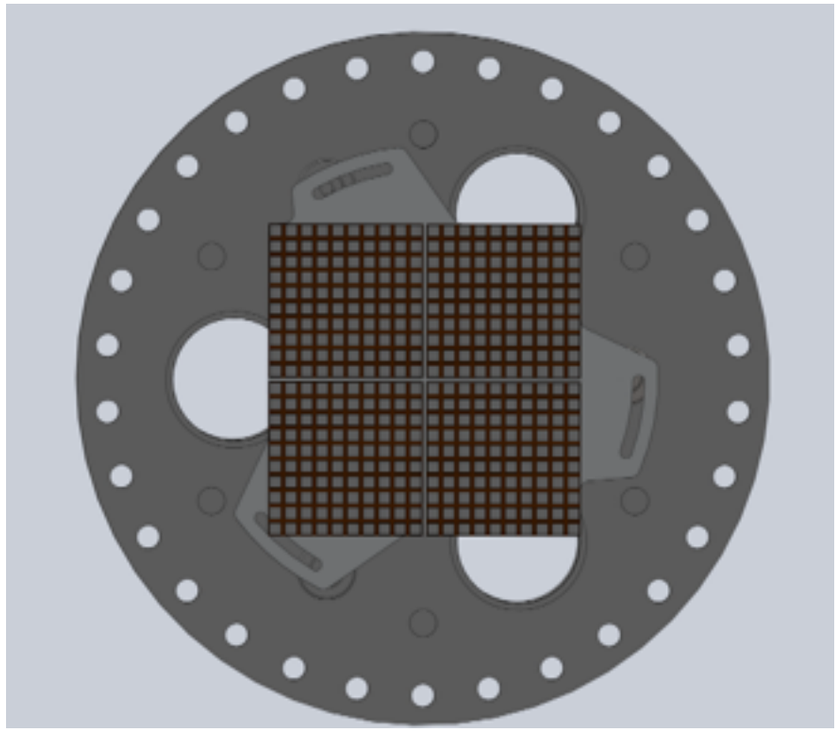
Possible background rejection improvements

- MAGIX design uses WLS fibres in the light tube to allow the PMTs to be outside the main active volume.

- BEXT seeks to further improve background rejection in 2 ways:

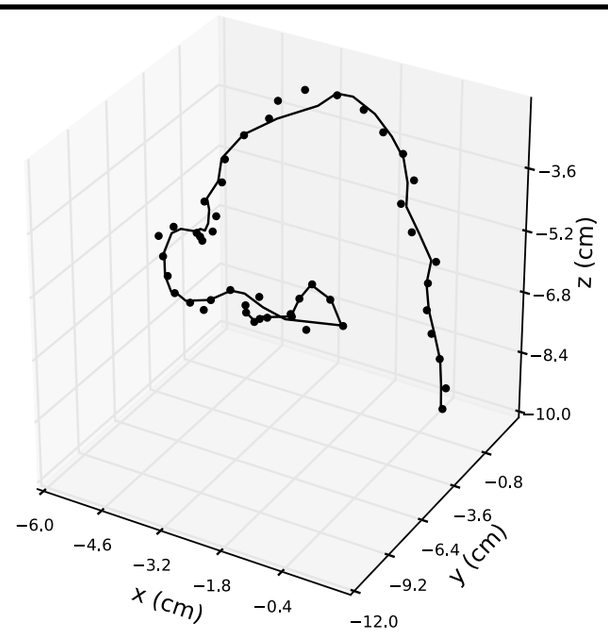
    - Full instrumentation with SiPMs and magnetic field along TPC axis.

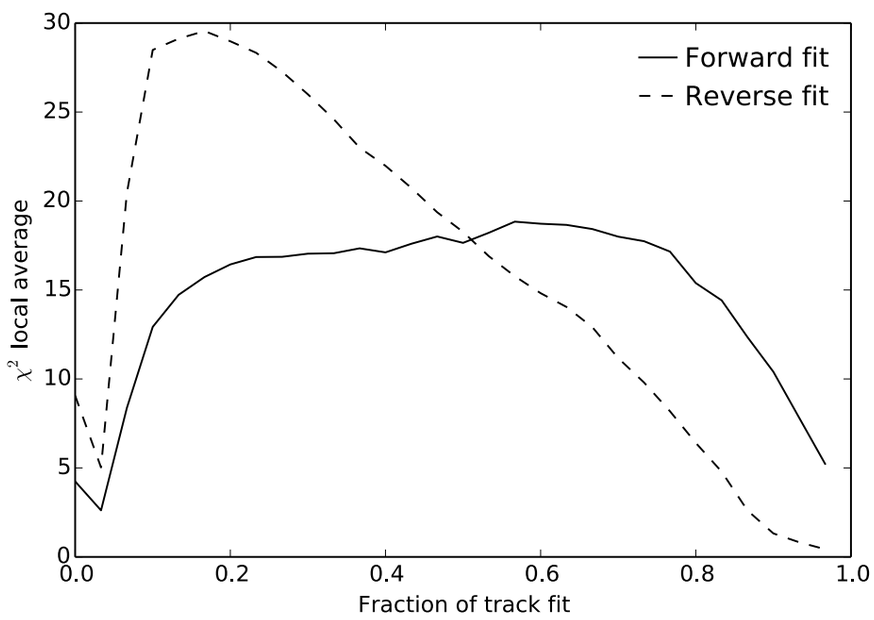
    - In-situ barium tagging.



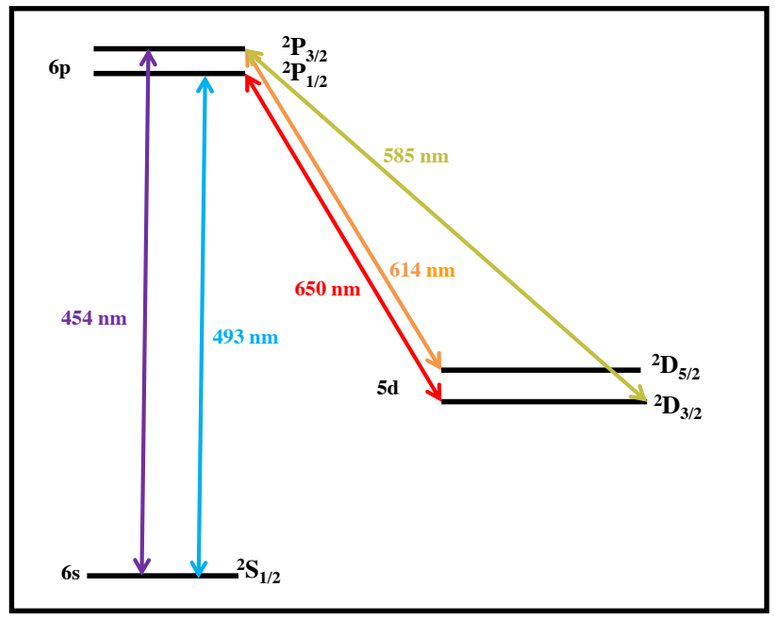
BEXT: expected improvements

- Magnetic field will reduce transverse diffusion improving position resolution.
    - Improved resolution allows for momentum reconstruction and background rejection using a kalman filter.
- BaTa using laser excitation under study, could improve background by up to 2 orders of magnitude. Very challenging, collaboration with CLPU at Universidad de Salamanca.





No B field Kalman filter example



The NEXT Collaboration

IFIC Valencia • Zaragoza • Politécnica Valencia • Santiago de Compostela • Autónoma Madrid • Girona

LBNL • Iowa State • Texas A&M

Coimbra • Aveiro

JINR

A. Nariño

Neutrino Experiment with a Xenon TPC