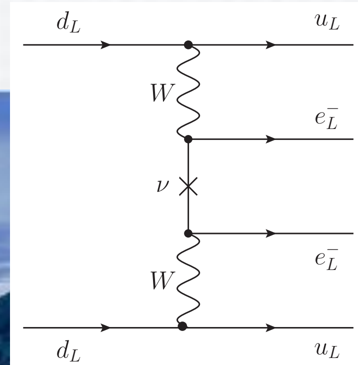
Status of the NEXT experiment

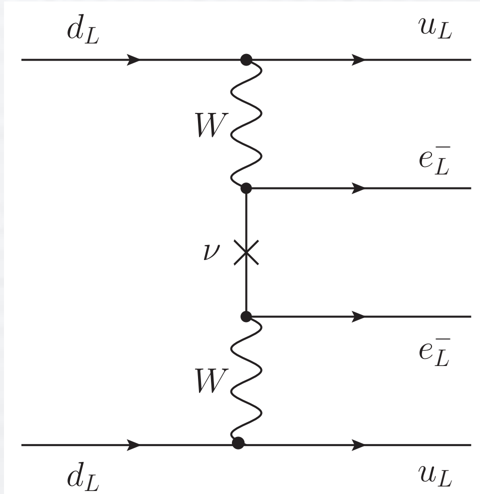
XXV International Workshop on Weak Interactions and Neutrinos
Heidelberg - 8-13 June 2015

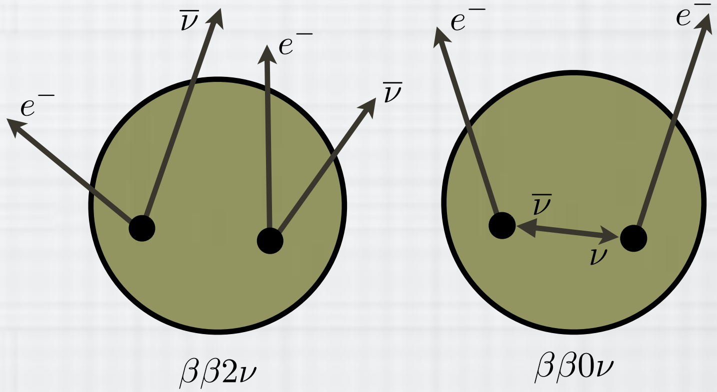


José Ángel Hernando Morata
Universidade de Santiago de Compostela, Spain
(on behalf of the NEXT collaboration)

The nature of the neutrino

- SM is incomplete! Neutrino masses are missing!
- Dirac or Majorana mass
- Of course neutrinos are Majorana… the only viable experiment to determine if neutrinos are Majorana is via the discovery of neutrino-less Double Beta Decays (**ββ0ν**), a very rare process that can happens in certain nuclei
  - Revival of the field: the brute force, the squeezer and the final judgement experiments
- That implies Lepton Number Violation (LNV)
- The smallness o neutrino mass indicates a new energy scale!
- Majorana neutrinos can open the door, via leptogenesis, to understand the dominance of matter on the Universe.



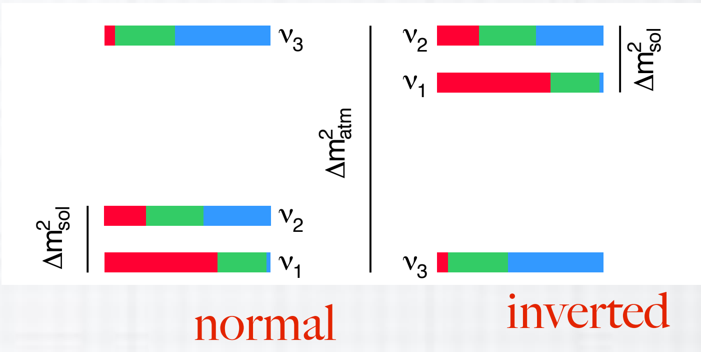


$T_{1/2} \sim 10^{18} - 10^{20}$ y $T_{1/2} > 10^{25}$ y

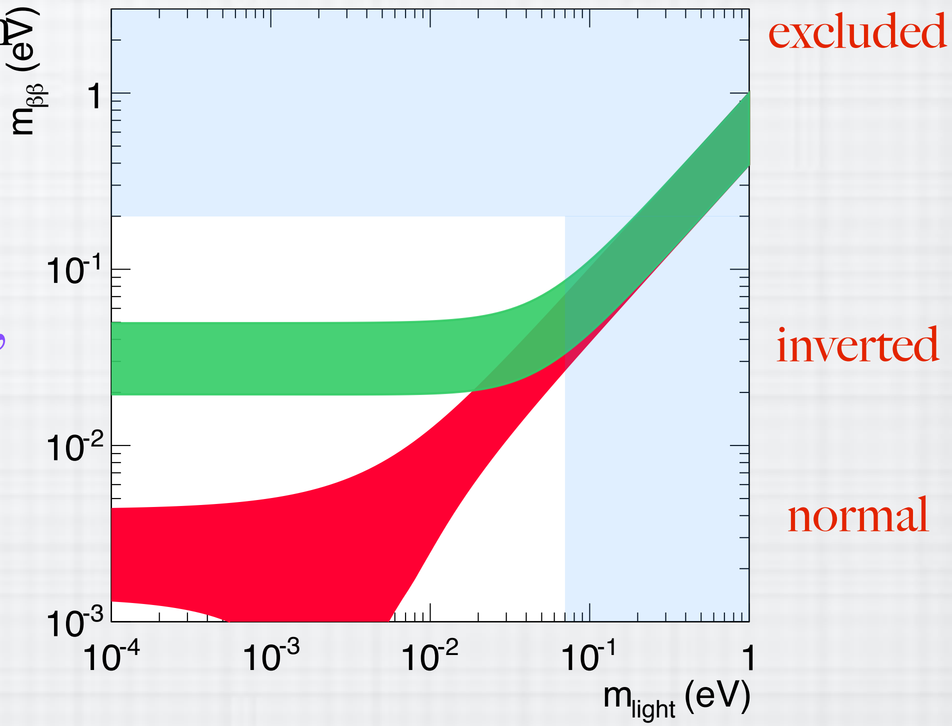
The Majorana Landscape

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

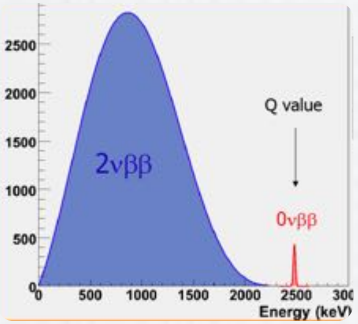
$$m_{\beta\beta} \equiv \left| \sum_{i=1}^{3} U^2_{ei} \cdot m_i \right|$$



- Current limits by EXO, KamLAND-Zen (^{136}Xe), Gerda (^{76}Ge).
  - In the near future, **NEXT-100**
- But to cover the IH, reach $m_{\beta\beta}$<20 meV!, we need a next generation experiments:
  - **NEXT**-100 technique is **scalable to 1 ton**
- NH not accessible…



The Majorana Landscape

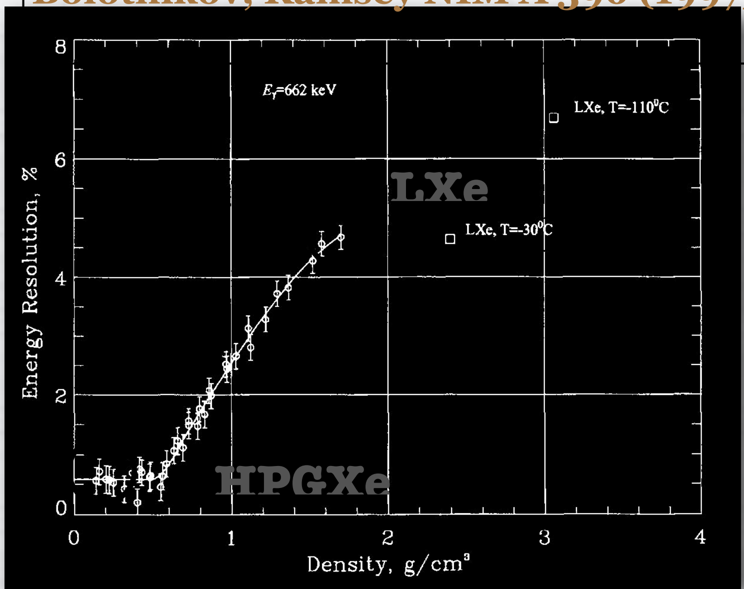


$$T_{1/2}^{-1} \propto a \cdot \epsilon \cdot \sqrt{\frac{Mt}{\Delta E \cdot B}}$$

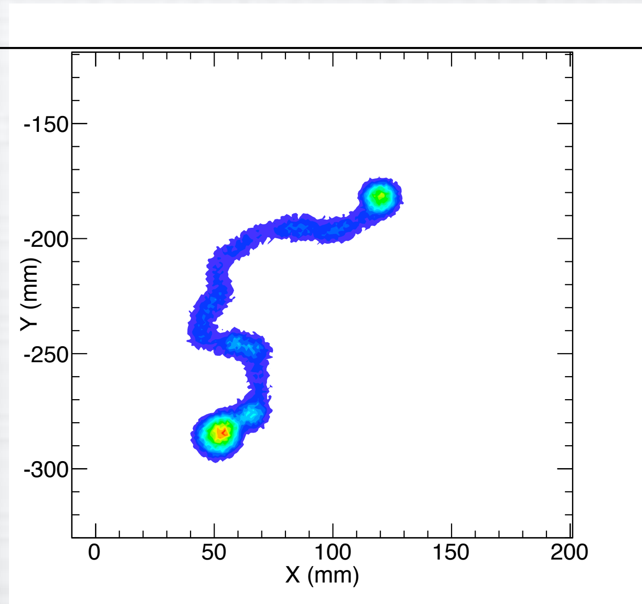
M = 100 kg	DE < 1% (FWHM)	B < 5 10 c/(kg keV y)

- ^{136}Xe, cheap, easy to enrich, noble gas, target
- $Q_{\beta\beta}$= 2458 keV, lower background
- **High Pressure** (15 bars): excellent energy resolution (0.3% FWHM) and tracks (~10 cm)

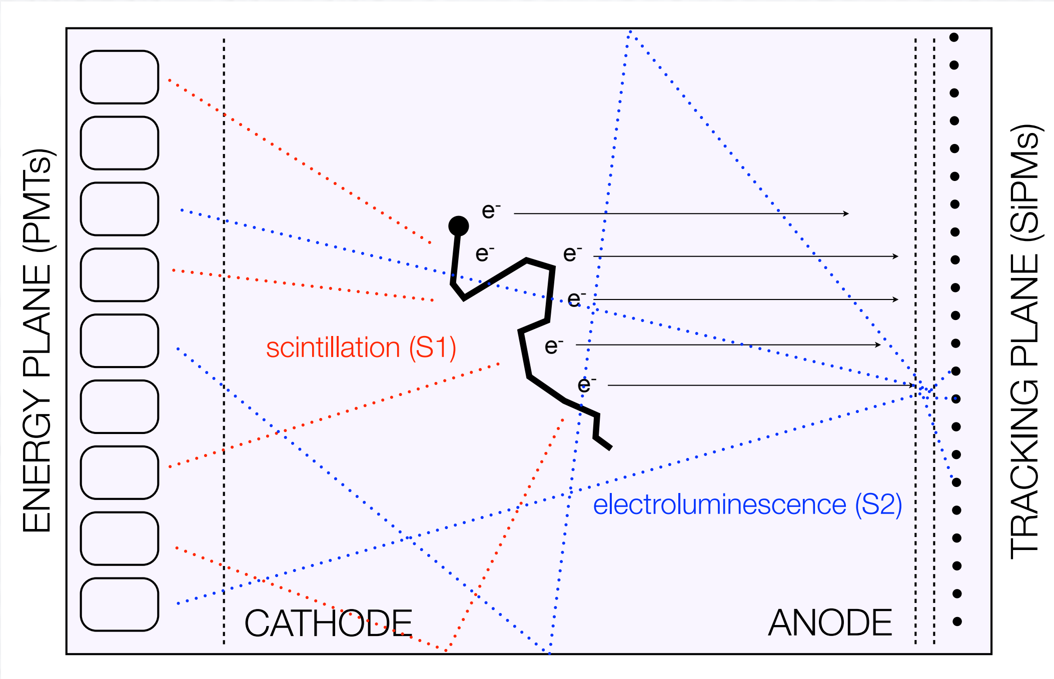
Bolotnikov, Ramsey NIM A 396 (1997)



simulation: 2β (a track with two "blobs")



NEXT-Concept



- electron excites and ionizes Xe
- excited Xe emit scintillation light (S1) (t0 of events)
- electrons from ionization drift (0.3 kv/cm) toward the anode
- electrons pass electro-luminiscence (EL) region, emits light (proportional) (S2)
  - measured by PMTs in the Energy plane (cathode): provide the Energy
  - measured in SiPMs (1 cm^2 grid) in the tracking plane: provide (x,y, time)

NEXT-Collaboration

IFIC (Valencia), U. Zaragoza, U. Santiago, U. Girona, U. Politécnica Valencia, U. A. Madrid

U. Coimbra, U. Aveiro

LBNL, Texas A&M U., Iowa State U.

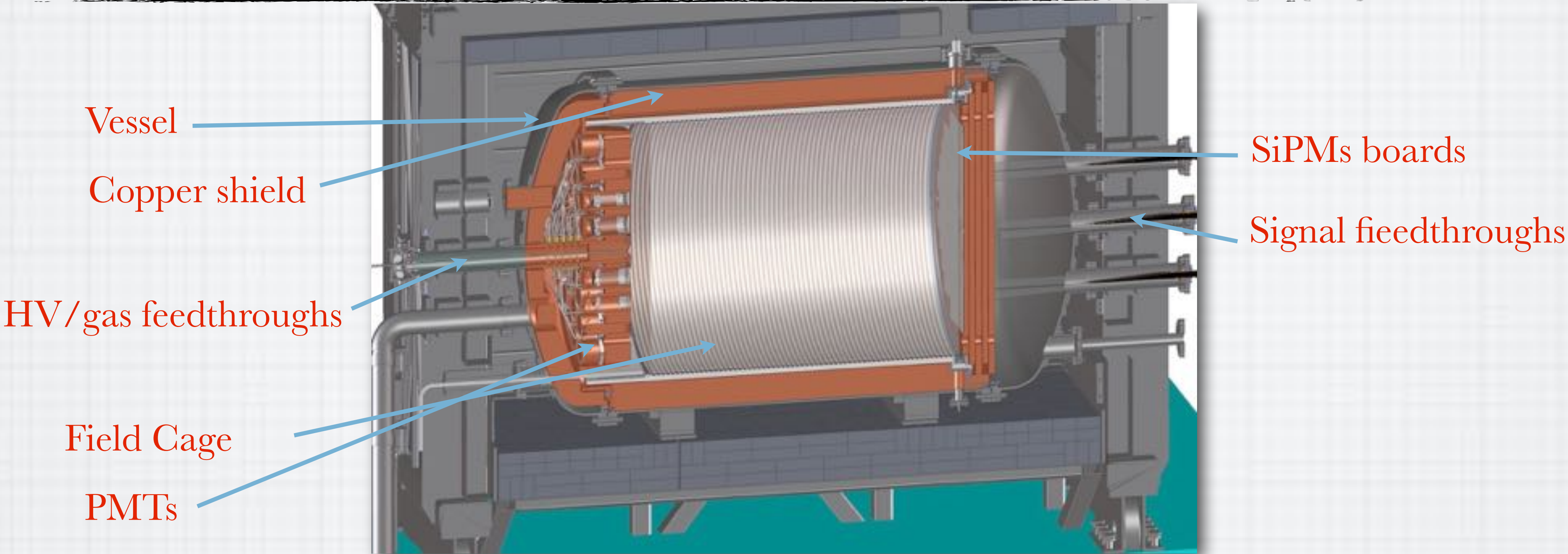
JINR (Dubna)

U. Antonio Nariño (Bogotá)

Collaboration members at Canfranc Underground Laboratory (LSC), 80 people, 5 countries

Grants: Consolider-2010 (Spain), ERC-ADG 2013 (EU)

NEXT-100



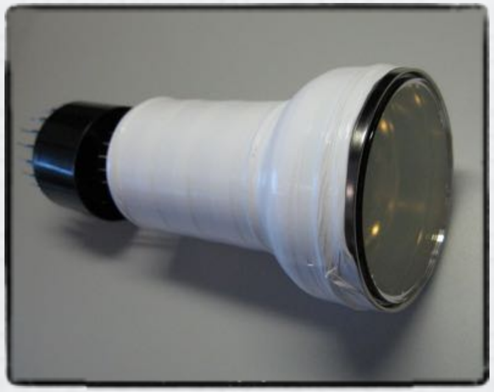
- Vessel: 1,2 tons stainless steel ^{316}Ti alloy, very low activity, with 12 cm inner copper shield (it blocks radiation by a factor 100)
- Field cage: 130 cm long, 105 cm diameter, high density polyethlene cylindrical shell, EL 1cm, 3 wire meshes with 88% transparency
- Energy plane: 60 PMTs, low radioacticity, 30% coverage, but encapsulated with sapphire windows to hold pressure
- Tracking plane: 7 k SiPMs 1 mm^2 active area, located in boards (8x8 each), separated 1 cm, coated to a wavelength shifter (TPB)

NEXT-100

USC
UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

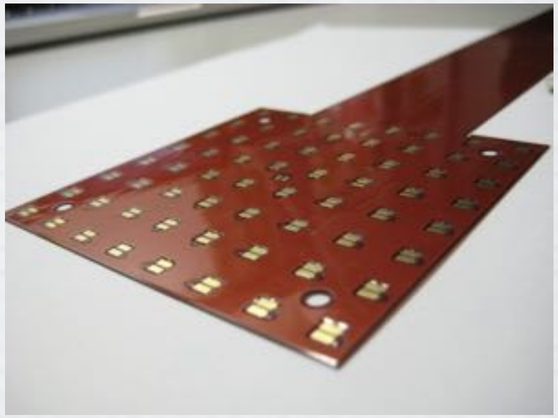
Vessel

R11410-10
Hamamatsu PMT

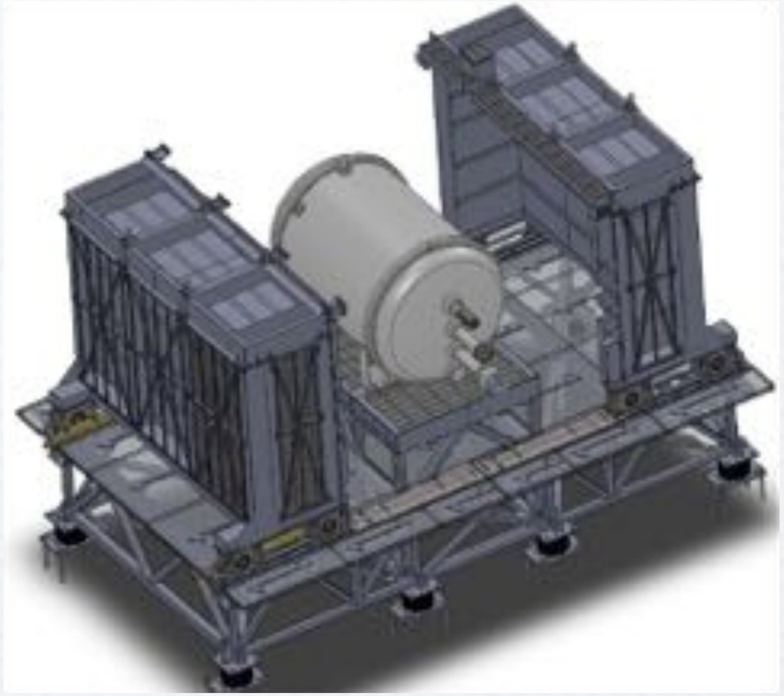


S10362-11-050P
SiPM

8x8 SiPM board
and cable



NEXT-100



Xenon

gas system

- Seismic platform and gas system: been installed at LSC.
- Xe procured and at LSC

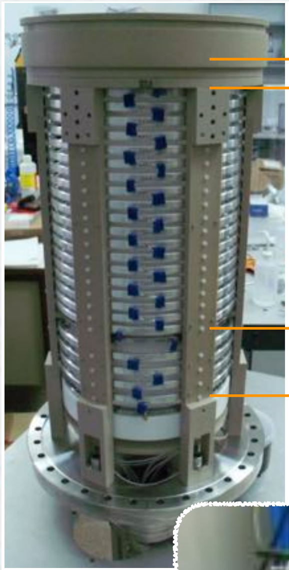
Prototypes NEXT-DEMO

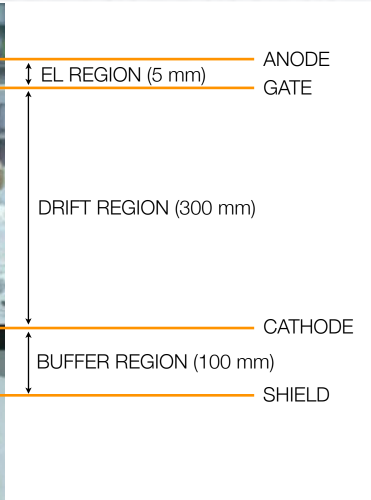
- IFIC-Valencia (1 kg) :

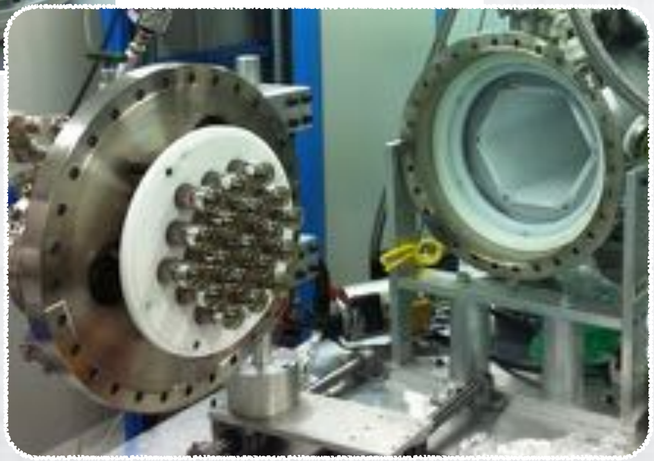
JINST 9 P0301 (2014)

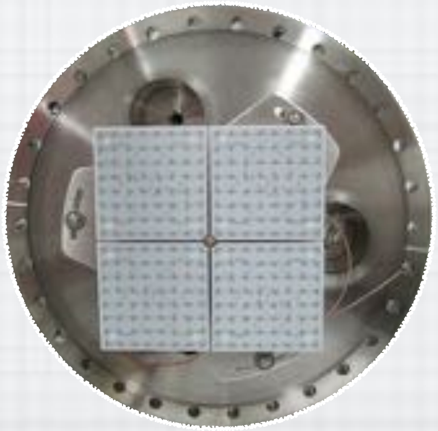
- Technical viability
- Energy and Topology reconstruction:

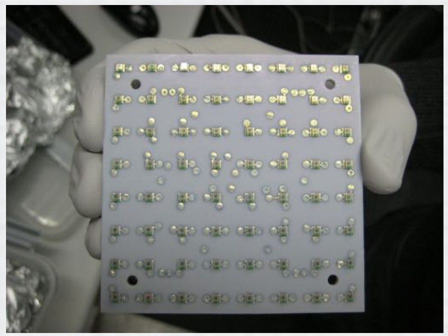
  a) runs **^{22}Na, ^{137}Cs, ^{228}Th**





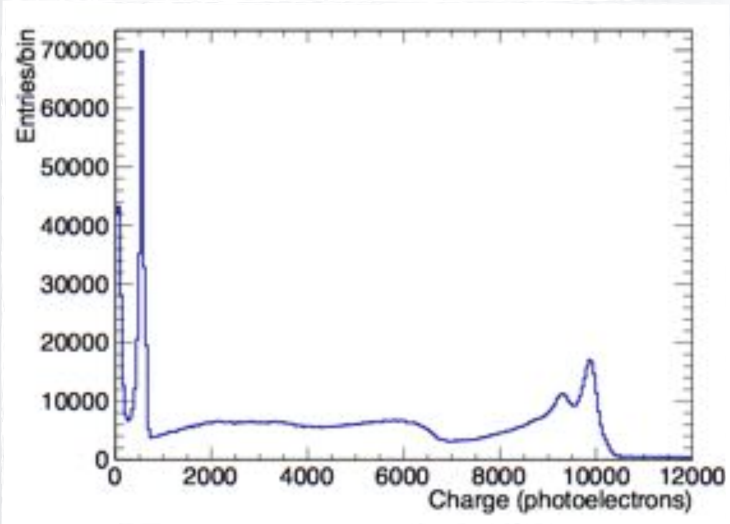




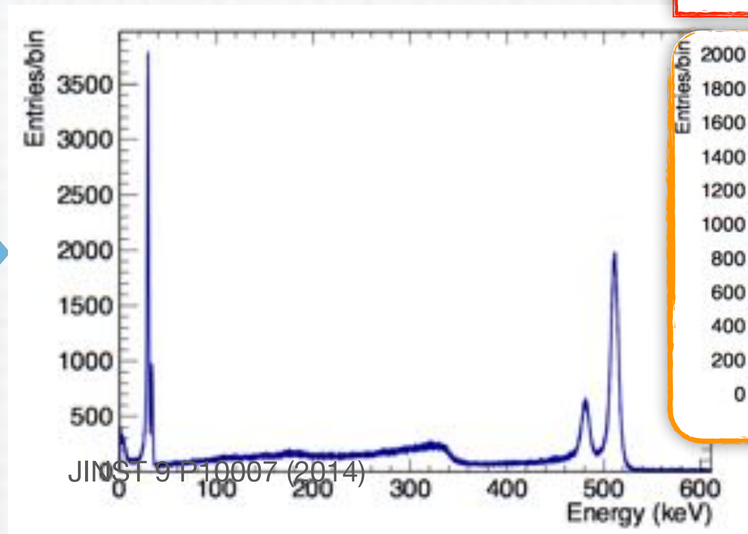


NEXT-DEMO Energy resolution

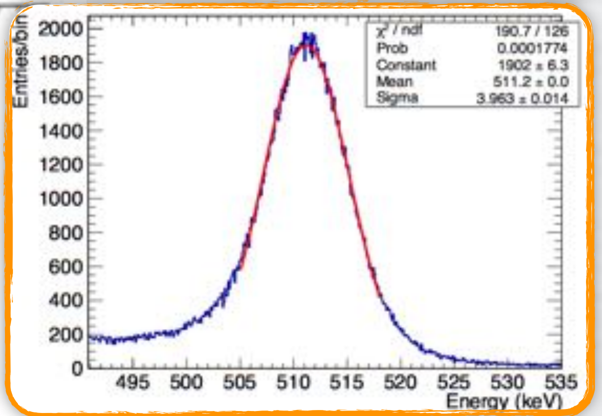
^{22}Na raw spectrum



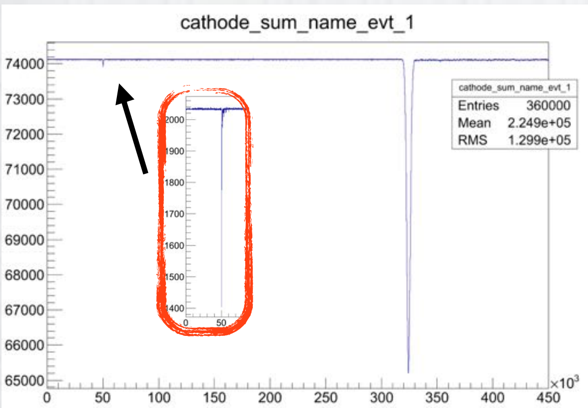
^{22}Na corrected spectrum



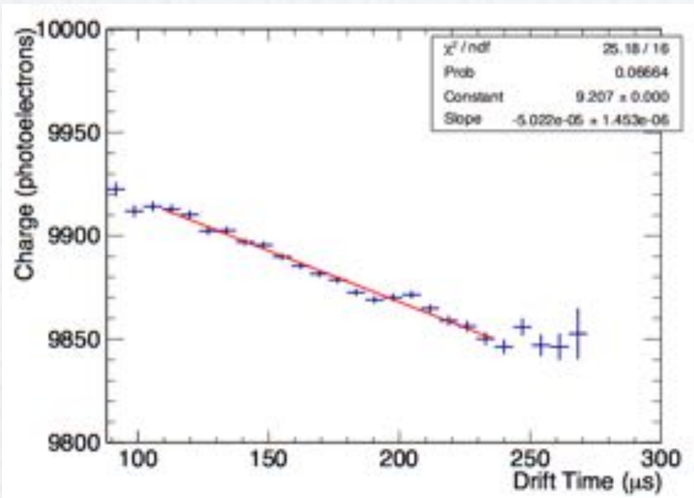
0.8 % FWHM
extrapolated @ $Q_{\beta\beta}$



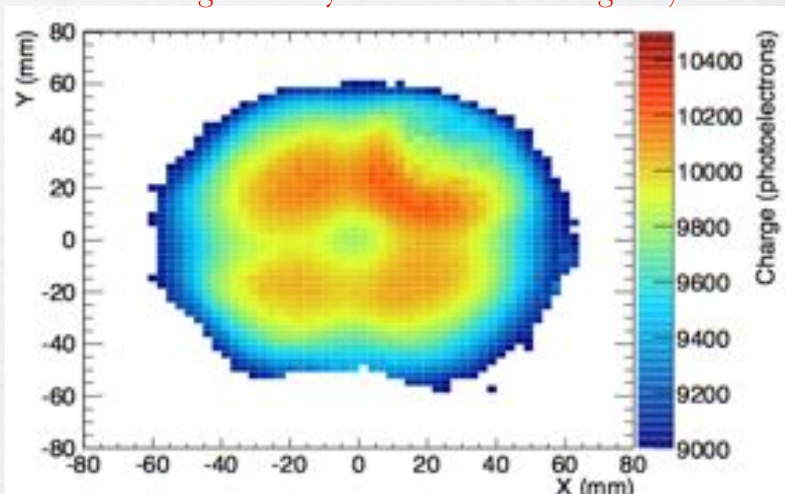
S1 & S2 PMT signal



z-correction
lifetime 20 ms



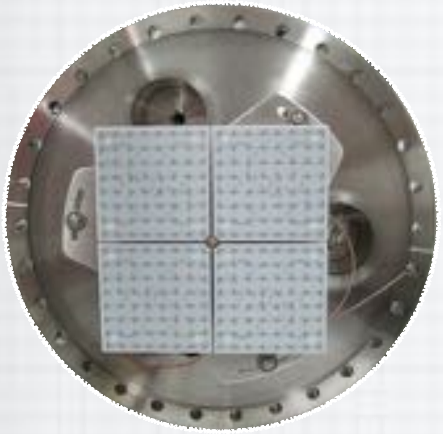
XY correction
(photo-peak value vs x,y position computed using the barycenter of SiPMs signals)



JINST **10** C02039 (2015), JINST **9** P10007 (2014)

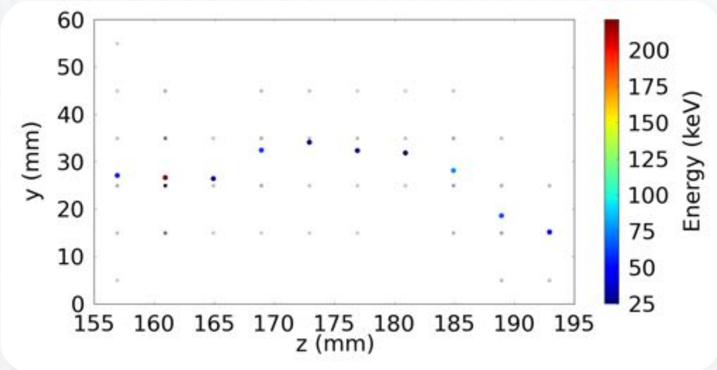
JINST **8** P04002 (2013)

NEXT-DEMO Topology

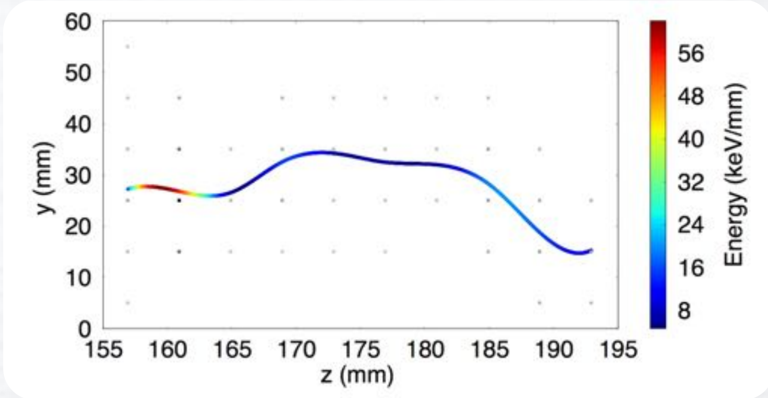


SiPM signal vs time

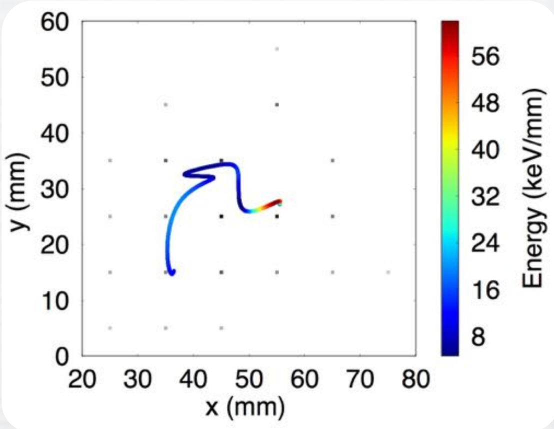
ZY projection - barycenter



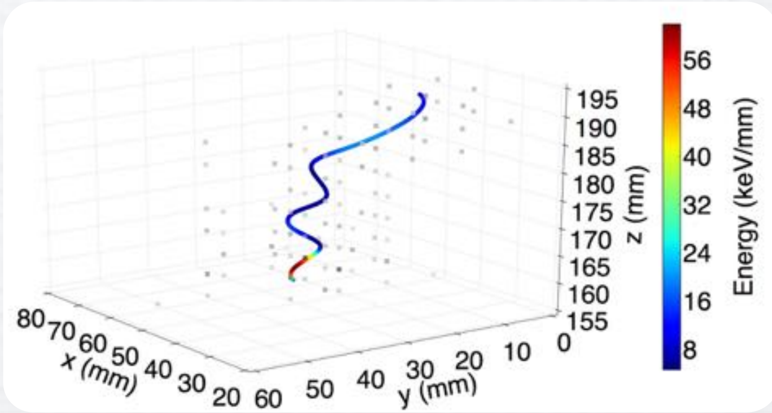
3D splines - ZY projection



XY projection



3D splines - 3D view



- Topology reconstruction:
  - Barycenter using SiPM signal integrated in 4 μs slices and track reconstrured using 3D splines
  - Energy of each slice given by the Energy plane

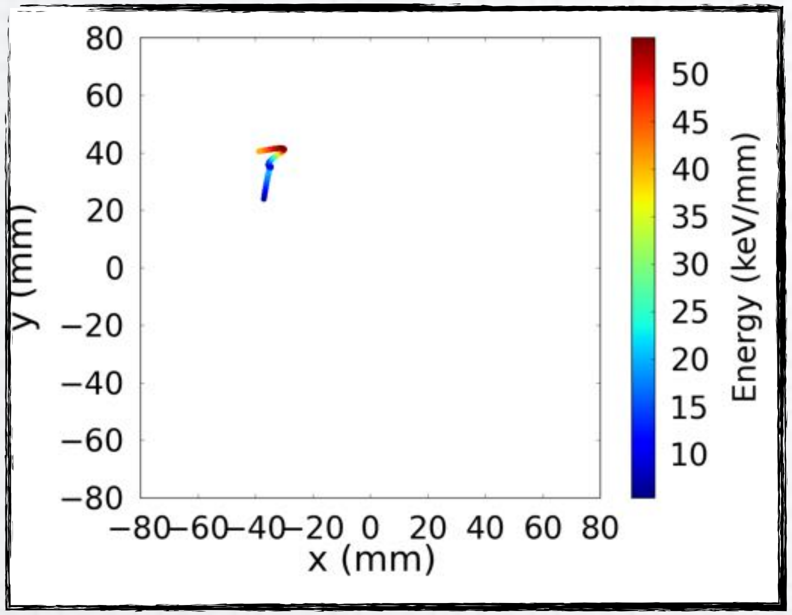
'blob' of the electron clearly visible!

JINST **8** (2013) P09011

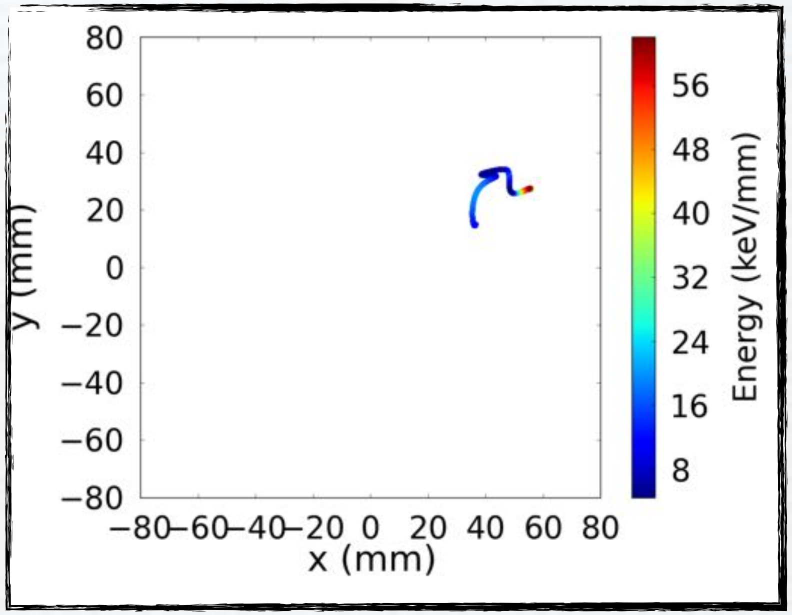
NEXT-DEMO Topology

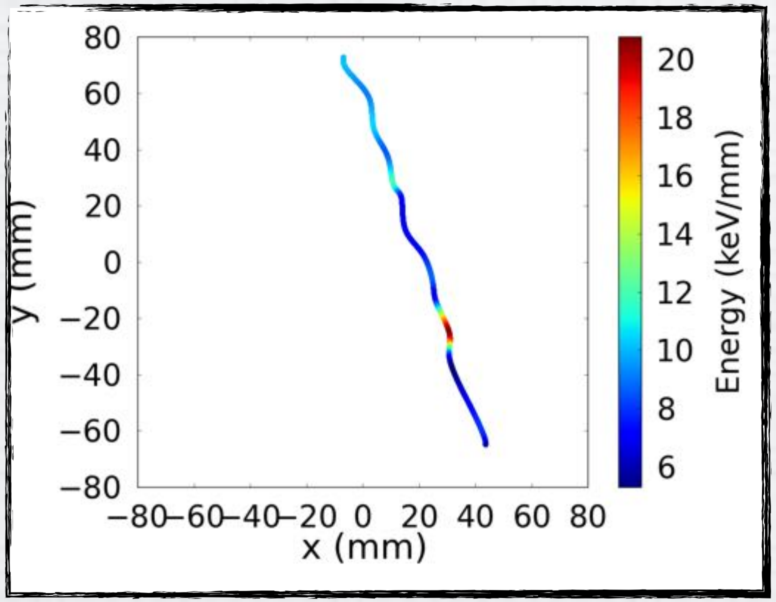
Different track types reconstructed!

^{22}Na (511 keV)

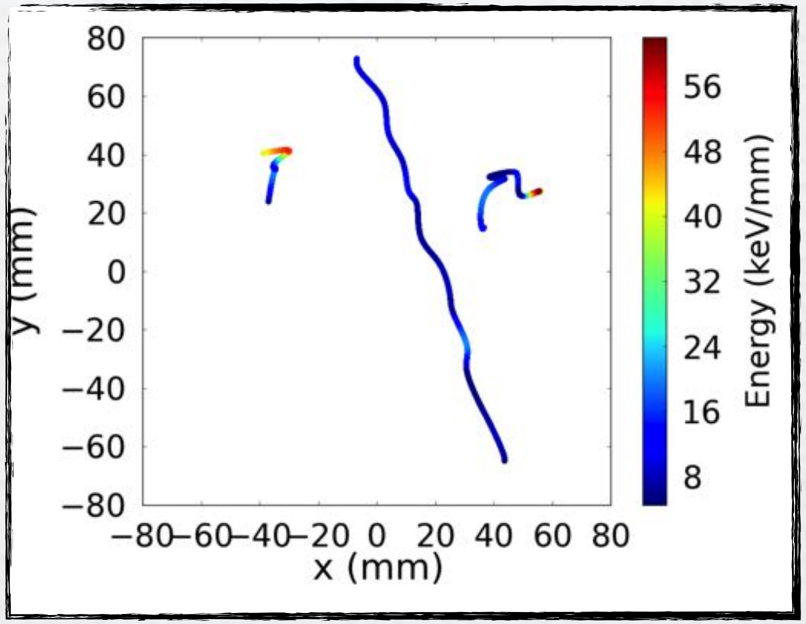


^{137}Cs (662 keV)

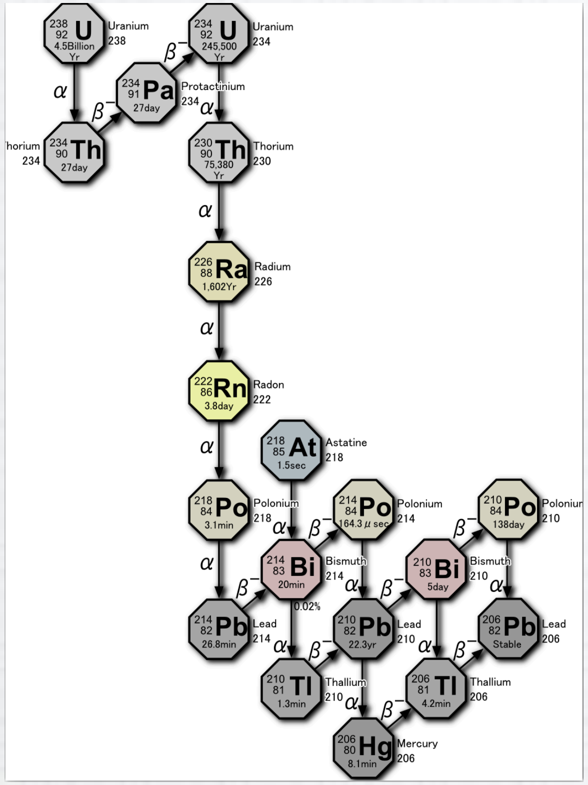




Cosmic μ



Radio-purity measurements



PMTs radio level measurement at LSC

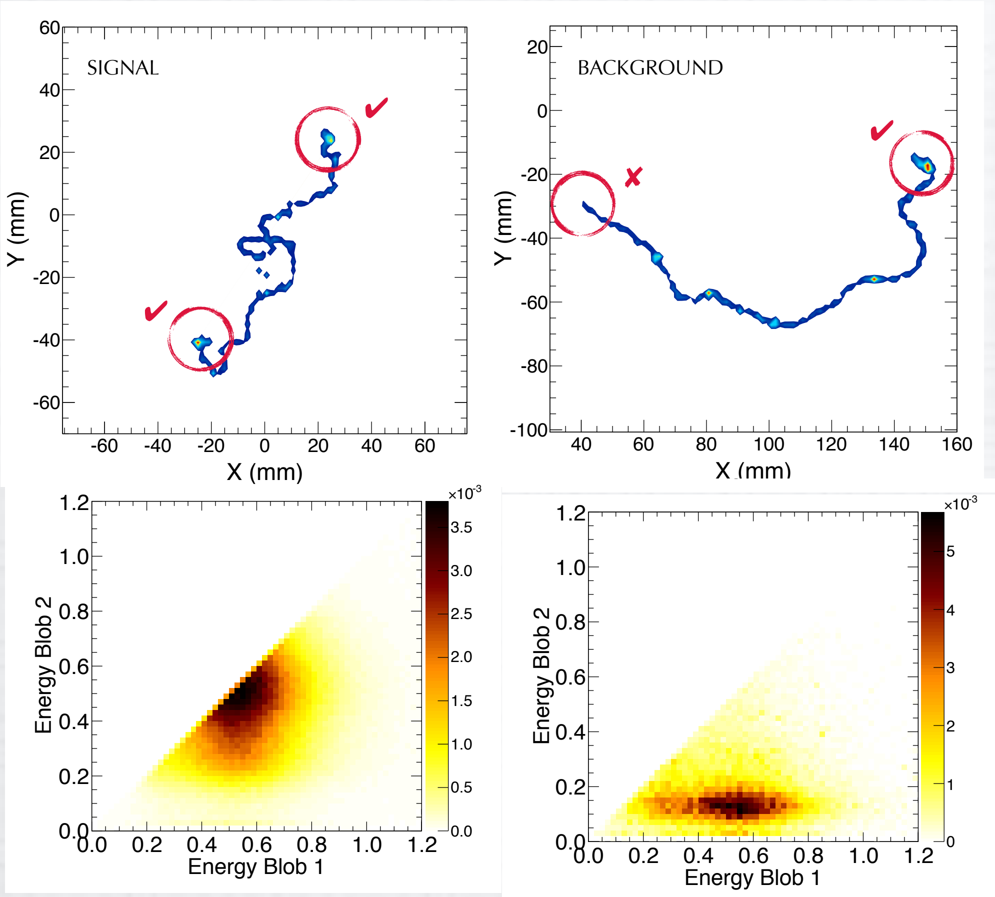
- Main contamination (from Th, U chains):
  - ^{208}Tl (γ,2615 keV), ^{214}Bi (γ,2448 kEV)
- Extensive Campaign to estimate

arXiv:1411.1433, JINST **8** (2013) P09011

Detector subsystem	Material	Quantity	^{208}Tl (mBq)	^{214}Bi (mBq)
Pressure vessel				
Total	Steel 316Ti	1310 kg	< 197	< 603
Energy plane				
PMTs	R11410-10	60 units	12(3)	< 56
PMT enclosures	Copper CuA1	60×4.3 kg	< 0.36	< 3.1
Enclosure windows	Sapphire	60×0.14 kg	0.34(8)	< 2.6
Support plate	Copper CuA1	408 kg	< 0.6	< 5
Tracking plane				
SiPMs	SENSL 1 mm^2	107×64 units	< 5	< 18
Boards	Kapton FPC	107 units	1.5(2)	3.2(1.1)
Field cage				
Barrel	Polyethylene	128 kg	< 1	< 8
Shaping rings	Copper CuA1	120×3 kg	< 0.5	< 4
Electrode rings	Steel 316Ti	2×5 kg	1.5	< 5
Anode plate	Fused silica	9.5 kg	0.092(17)	0.7(3)
Resistor chain	1-GΩ resistors	240 units	< 0.0026	< 0.020
Shielding				
Inner shield	Copper CuA1	9210 kg	< 13	< 111
Outer shield	Lead	60700 kg	2060(430)	21300(4300)

Background estimation

- Detailed MC simulation
- Analysis: one track and two blobs



$\beta\beta0\nu$
(2 electrons)

^{214}Bi
(1 electron)

- Topology reduction

Selection criterion	$0\nu\beta\beta$	$2\nu\beta\beta$	^{208}Tl	^{214}Bi
Fiducial, single track $E \in [2.4, 2.5]$ MeV	0.4759	8.06×10^{-9}	2.83×10^{-5}	1.04×10^{-5}
Track with 2 blobs	0.6851	0.6851	0.1141	0.105
Energy ROI	0.8661	3.89×10^{-5}	0.150	0.457
Total	0.2824	2.15×10^{-13}	4.9×10^{-7}	4.9×10^{-7}

- Background estimation:

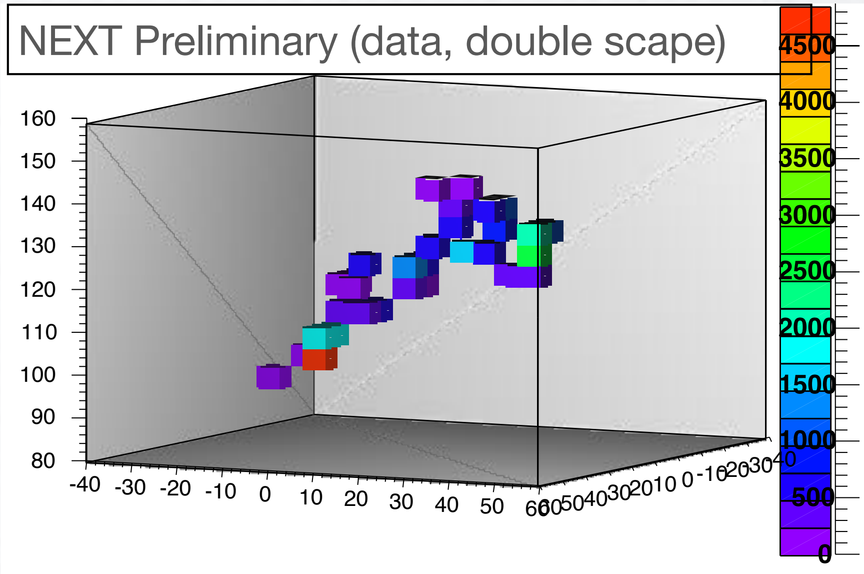
counts / (keV kg y)

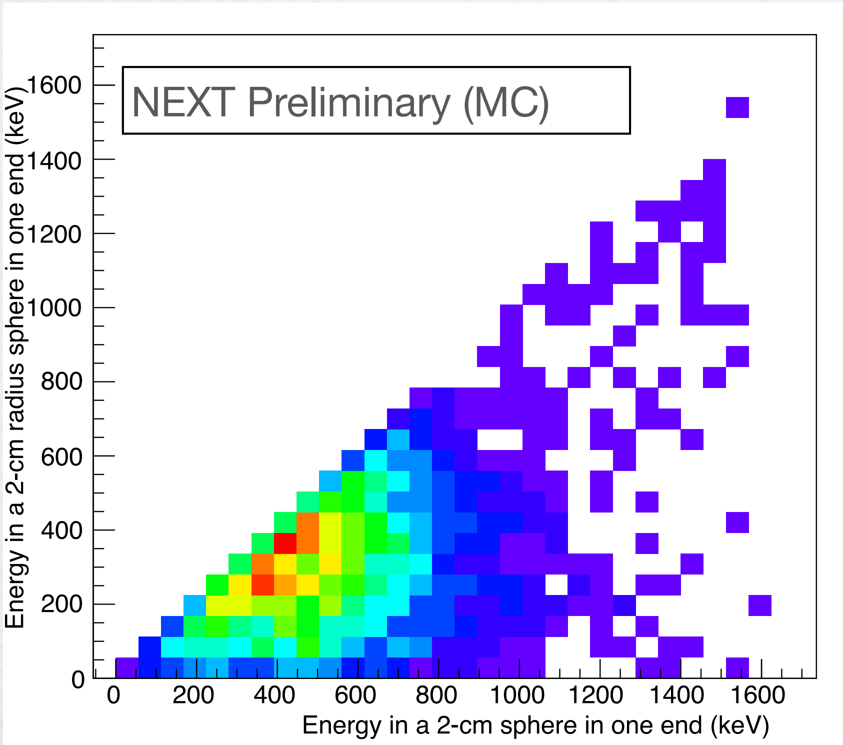
Detector subsystem	^{208}Tl	^{214}Bi	*Total*
Pressure vessel	< 0.23	< 0.07	< 0.31
Energy plane	< 0.38	< 1.31	< 1.69
Tracking plane	< 0.38	< 1.27	< 1.65
Electric-field cage	< 0.14	< 0.93	< 1.07
Inner shield	< 0.17	< 0.70	< 0.87
Outer shield	0.025(13)	0.25(14)	0.28(14)
Total	< 1.33	< 4.53	< 5.86

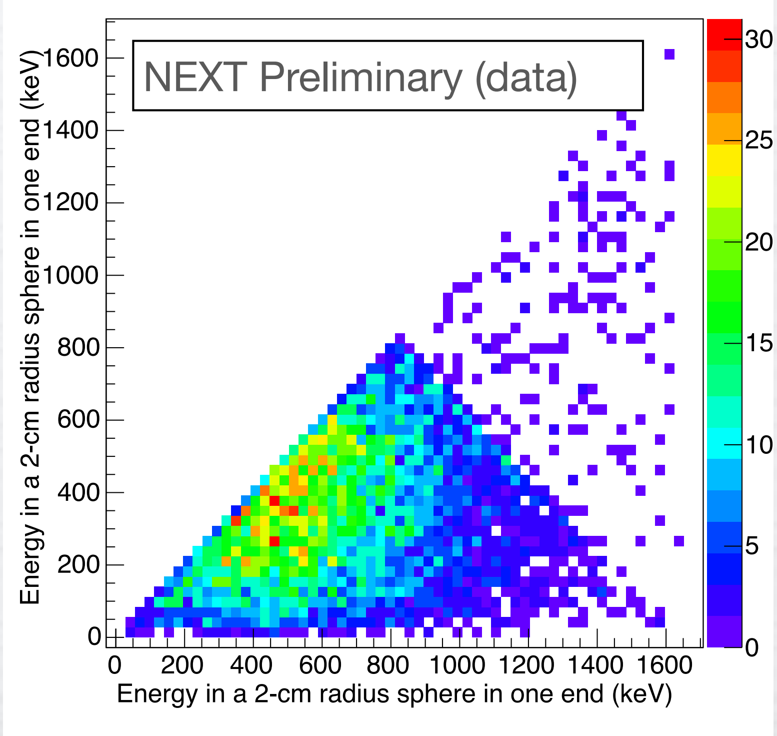
estimate $< 5.8\ 10^{-4}$ counts / (keV kg y)

NEXT-DEMO

- Results with ^{228}Th
  - double scape peak of ^{208}Tl (~1592 MeV)
  - detailed MC simulation
  - simple reconstruction: boxes $1cm^3$
  - blob as 2cm radius ball at endpoint of the track







NEW before NEXT-100

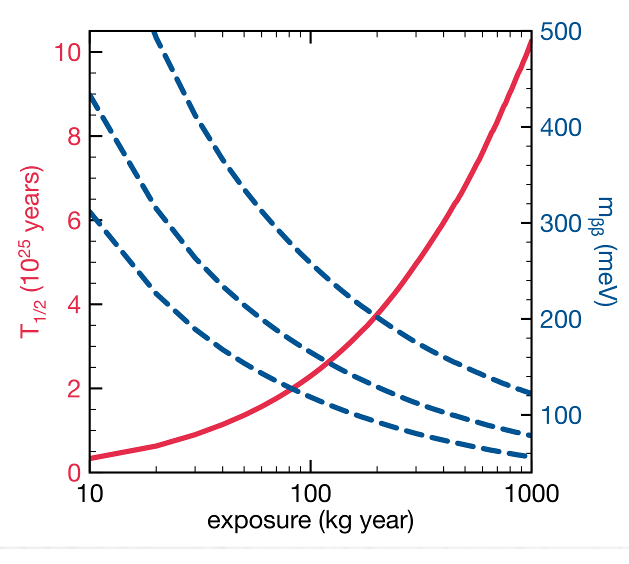
In memoriam of James White

- NEXT White (NEW) prototype
  - 1:2 dimensions (i.e field cage)
  - 10 kg ^{136}Xe
  - 20% of sensors: 12 PMTs, 20 SiPMs boards
- Objective:
  - Test of technical implementations
  - Validation of background model. It is a **radiopure** detector
  - measurement of a topological signal (2 electrons) from ^{228}Th and $\beta\beta 2\nu$ signal
- NEXT-NEW
  - Lead castle, gas system, vessel installed at LSC
  - Energy plane installation July 2015
  - Tracking plane installation September 2015

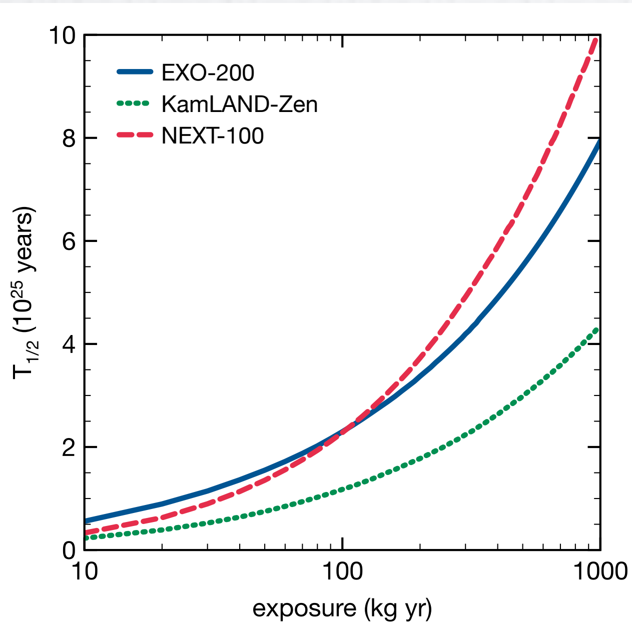
Sensitivity

- NEXT

different ME

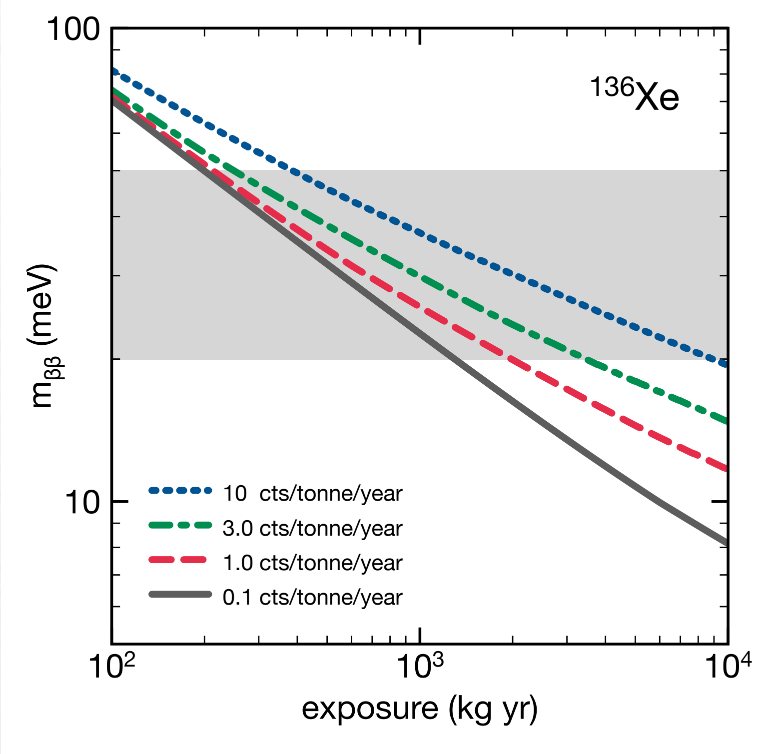


- Xe detectors



- NEXT-1 ton
  - lower backgrounds required!

counts / (ton y) in RoI



Conclusions

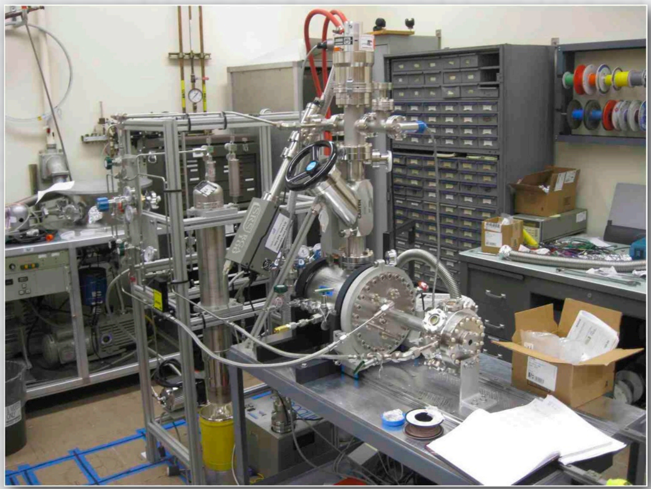
- NEXT-100 is a **100 kg ^{136}Xe** (90% enriched) **High Pressure Gas TPC** able to explore 0νββ to **100 meV** Majorana effective masses
- NEXT has an **excellent energy resolution** (**<1%**) FWHM at Qββ, extrapolated from the measurements done with NEXT-DBDM and NEXT-DEMO prototypes
- **NEXT-DEMO** has demonstrated the **tracking capabilities** of NEXT (reconstruction of electron and identification of the 'blob') that will largely reduce the background contamination
- The detector is under construction (Vessel, sensors, electronic, DAQ, gas system,...). Installation and commissioned expected by *2017 at LSC* (Canfranc)
- A 10 kg prototype (**NEW**) is been deployed at **LSC 2015** , able to measure ββ2ν and validate the background model and the topology reconstruction of 2 electrons
- Due to its modularity, NEXT can be *a solution for a (several) ton* **next generation** ^{136}Xe 0νββ decay experiment to explore down to 20 meV in Majorana effective mass

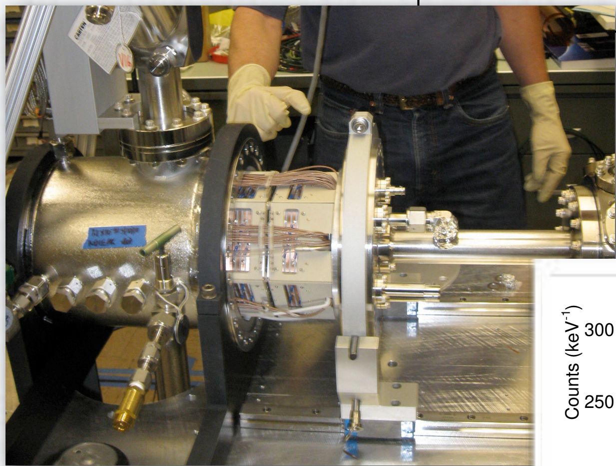
Prototypes NEXT-DBDM

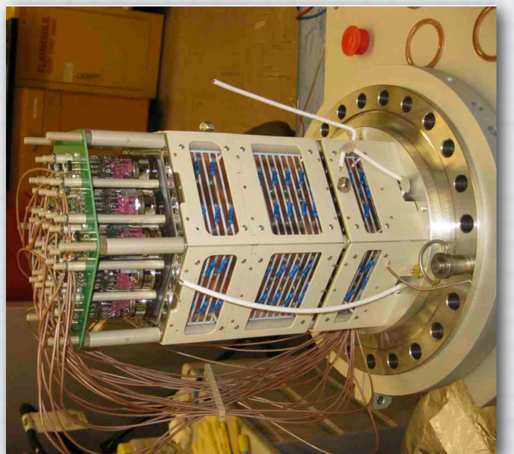
- **Berkeley lab (1 kg):**
  - demonstrate energy resolution

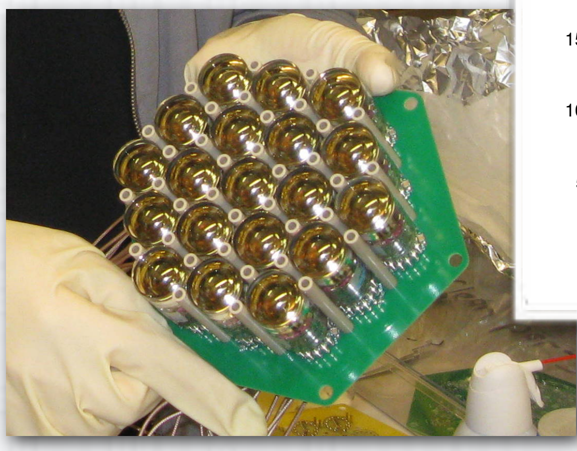
• **V. Alvarez, *et al.* [NEXT Collaboration],**
"Near-Intrinsic Energy Resolution for 30 to 662 keV Gamma Rays in a High Pressure Xenon Electroluminescent TPC," arXiv:1211.4474 [physics.ins-det].

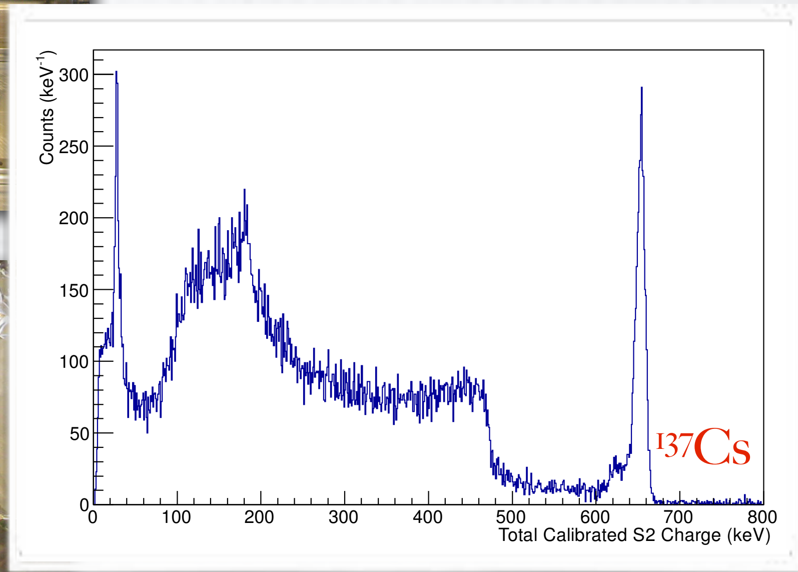
0.5 % FWHM
extrapolated @ $Q_{\beta\beta}$



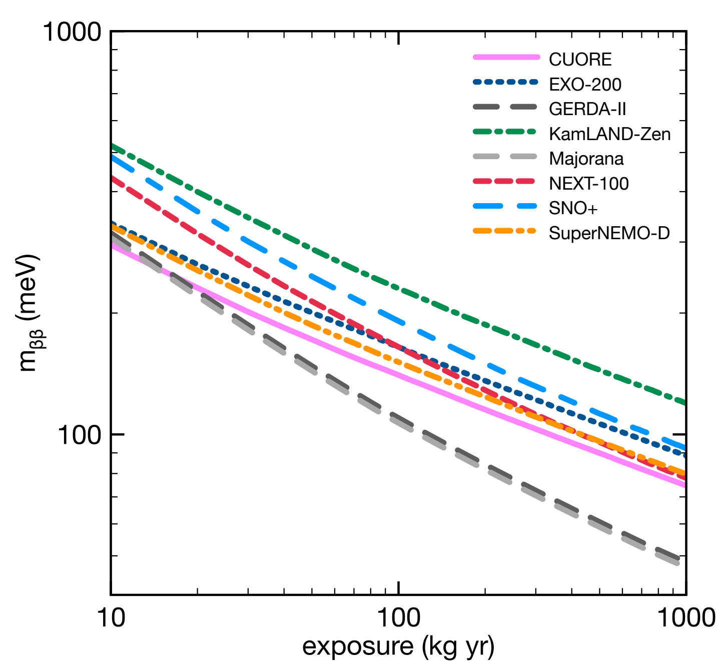


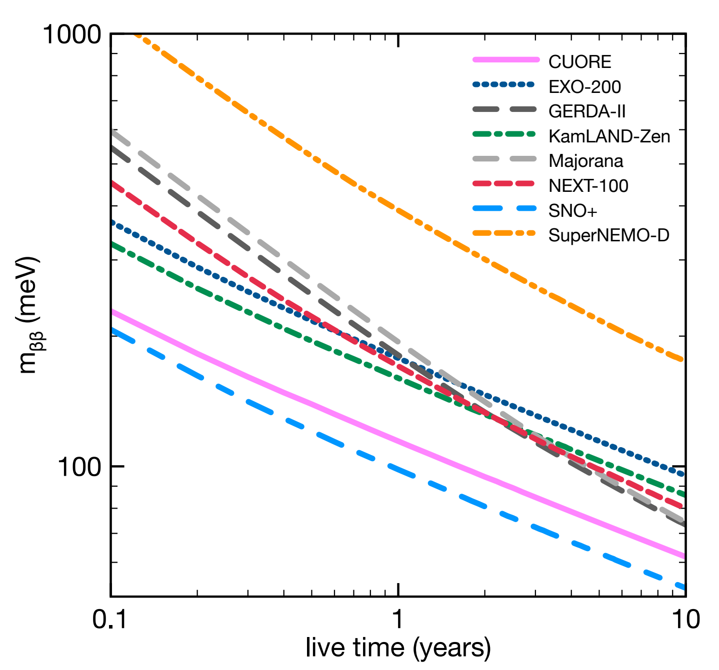






Sensitivity- comparisons





Experiment	Isotope	ΔE (keV)	Bkgnd. rate (keV^{-1} kg^{-1} yr^{-1})	ε (%)	Mass (kg)
CUORE-0[a] [233]	^{130}Te	5	0.23	78	11
CUORE[b] [108]	^{130}Te	5	0.04	87	206
GERDA-I[a] [112]	^{76}Ge	5	0.013	62	15
GERDA-II[b] [136]	^{76}Ge	3	0.001	66	33
EXO-200[a] [59]	^{136}Xe	88	0.002	85	76
KamLAND-Zen[a] [60, 98]	^{136}Xe	243	0.00014	25	348
MAJORANA[c] [137]	^{76}Ge	4	0.0009	70	25
NEXT-100[c]	^{136}Xe	18	0.0006	28	91
SNO+[c] [142, 234]	^{130}Te	264	0.0001	15	800
SuperNEMO-D[c]	^{82}Se	120	0.0005	30	7
SuperNEMO[c] [235]	^{82}Se	120	0.00005	30	100