

# NEXT

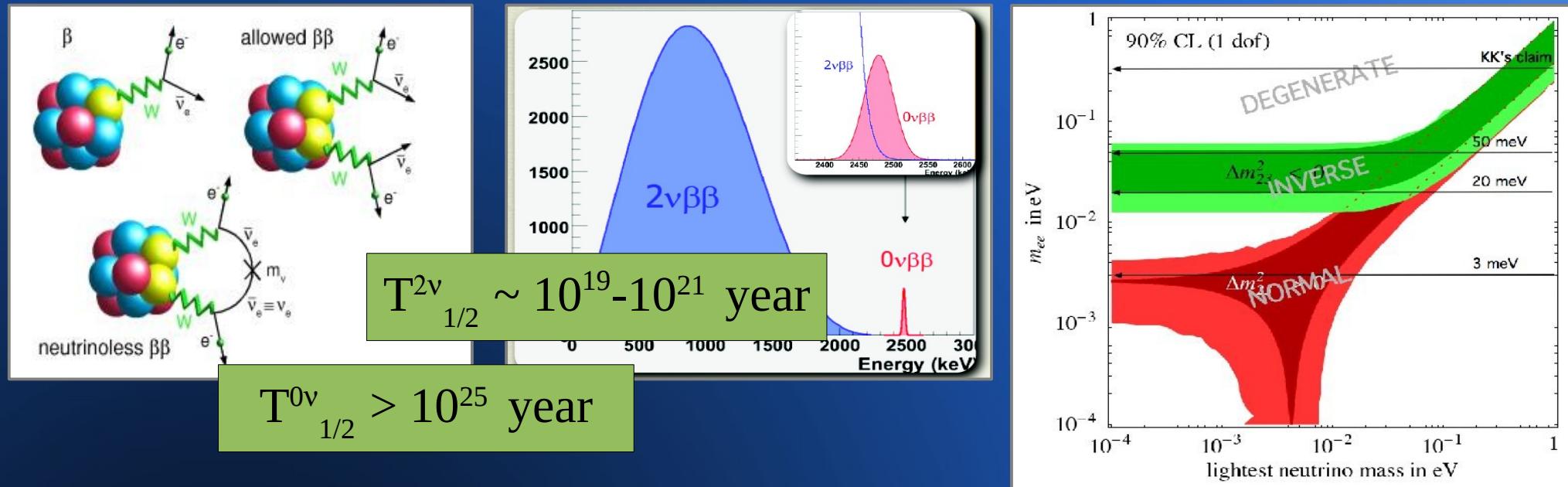
*Searching for the  $\beta\beta 0\nu$  decay  
at the LSC*

EPS 2015 @ Vienna, Austria

# Contents

- Searching for the  $\beta\beta0\nu$  decay
- The NEXT TPC concept
- R&D: technology performance
- NEXT-NEW: physics @ LSC
- NEXT-100: the degenerate land
- Summary

# Searching for the $\beta\beta 0\nu$ decay



F. Feruglio et Al., Nucl. Phys. B 637 (2002)

Energy resolution

Background rejection

Scalability

$\beta\beta 0\nu$   
experiment

NEXT

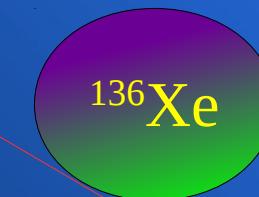
Calorimeters

Tracko-calos

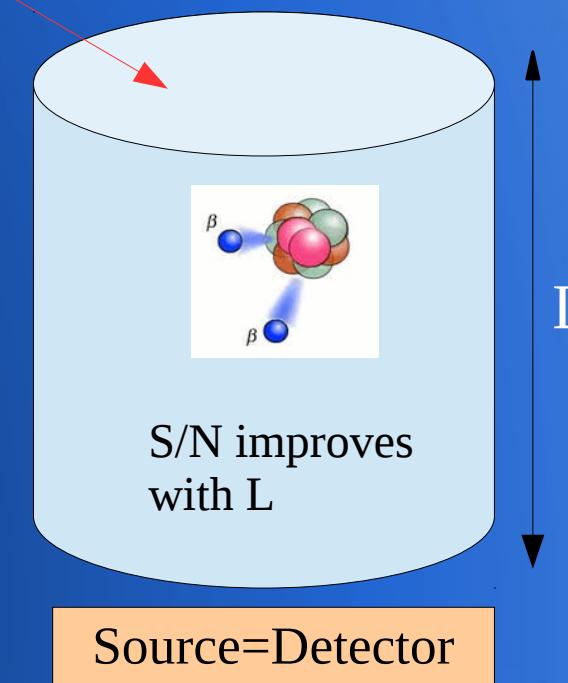
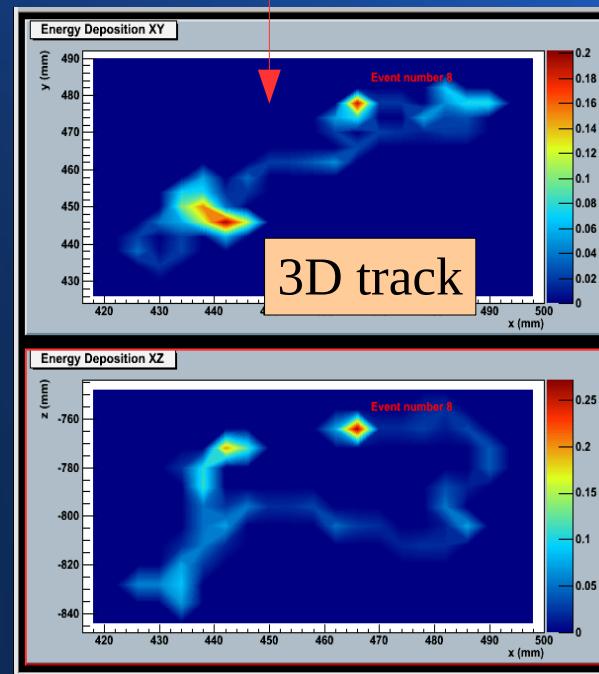
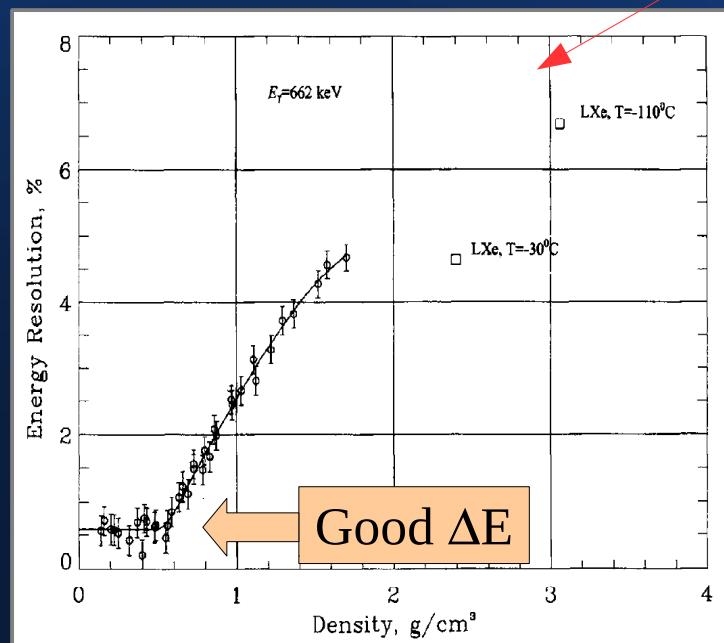
Bolometers

# NEXT: HP Gas-Xe TPC

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

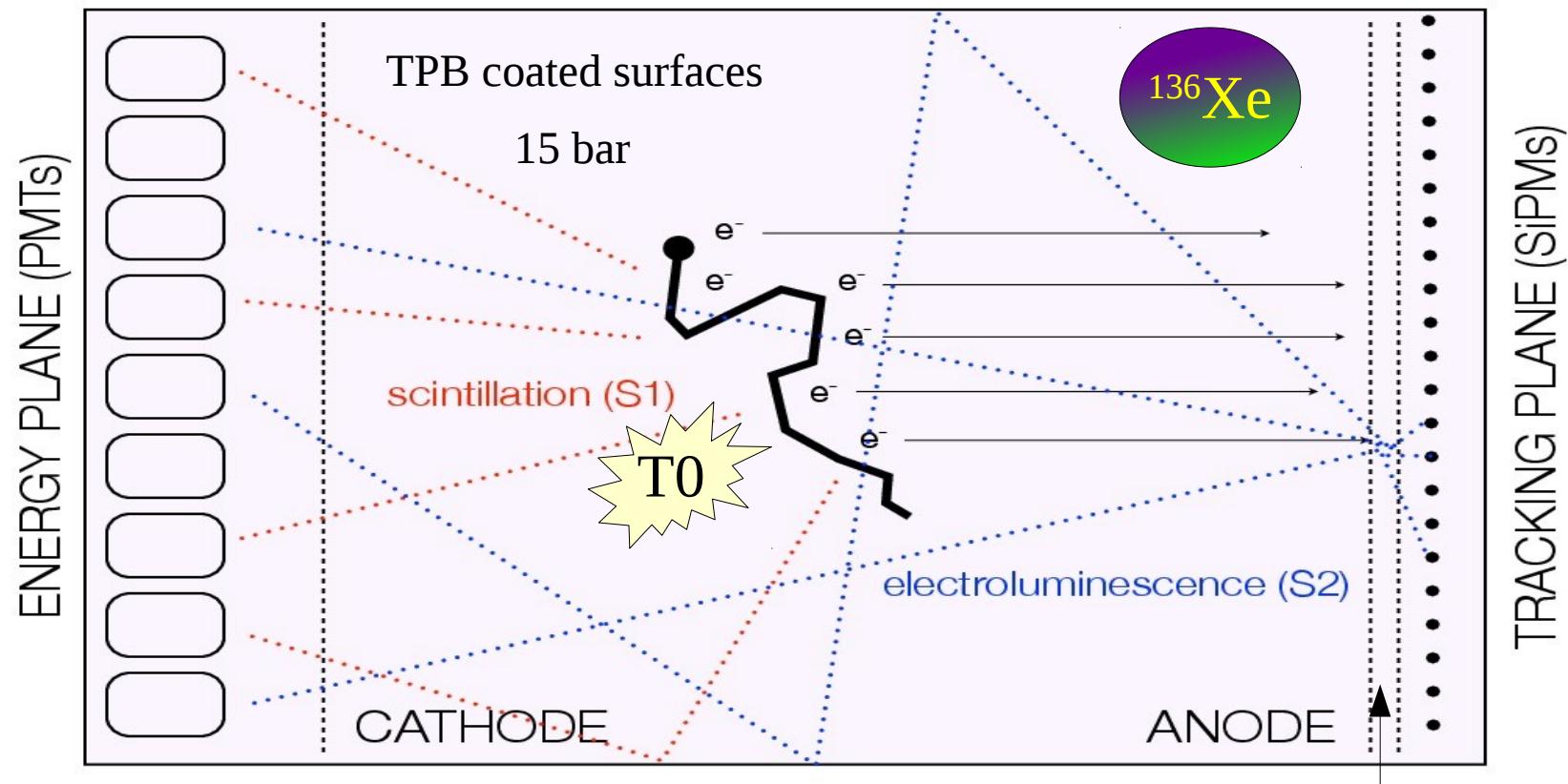


- $Q_{\beta\beta} = 2.48$  MeV
- Scint/Ionization
- Cheap/Easy to enrich
- Long  $\beta\beta 2\nu$  mode



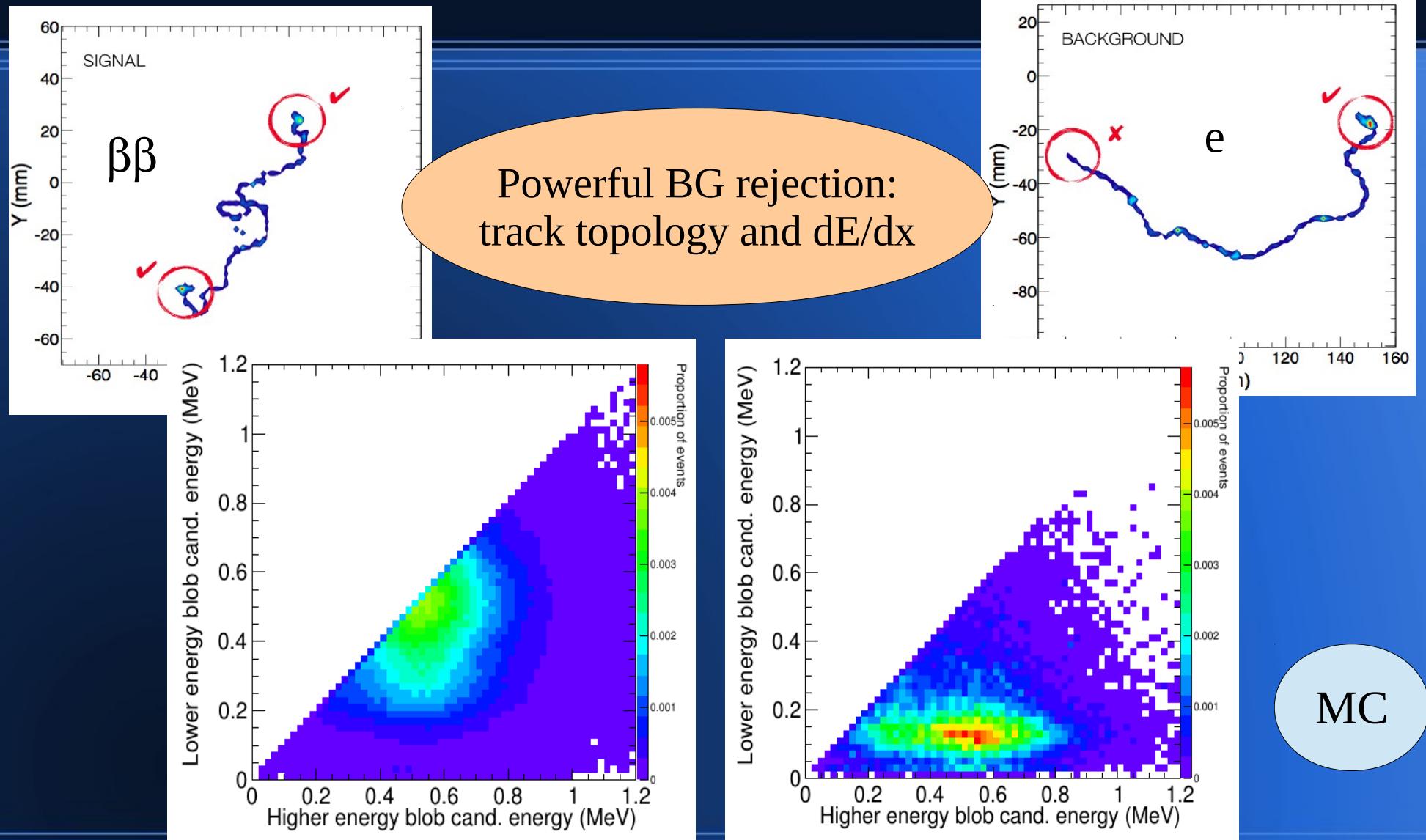
# The TPC concept

Gas TPC with 2 dedicated readout planes



EL: linear gain, no avalanche fluctuations: optimize  $\Delta E$

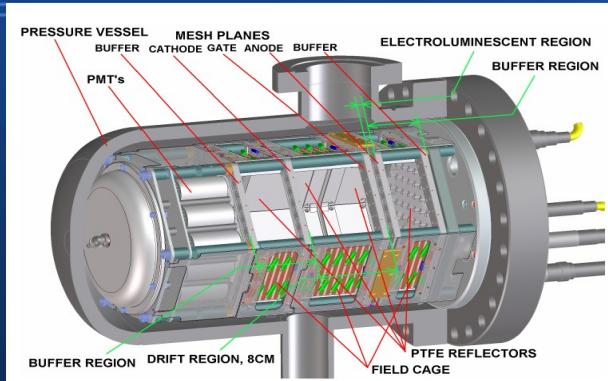
# Fighting the non- $\beta\beta$ events



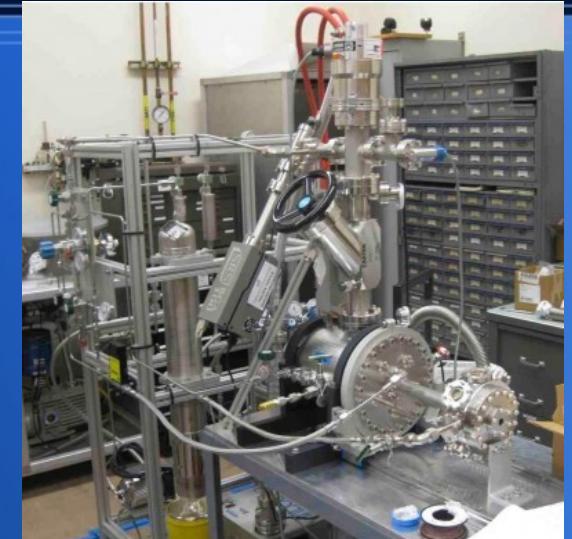
# R&D: Proving the technology

2012-2014

- The NEXT-DBDM @ LBL (1 kg Xe):



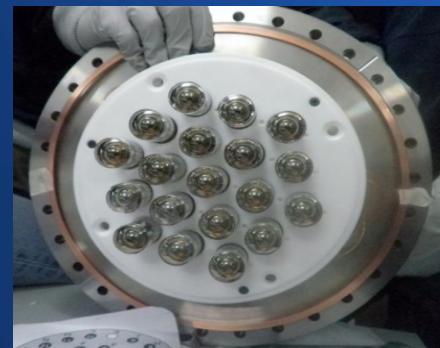
Gas Xe EL-TPC:  
Energy resolution  
(only PMTs)



- The NEXT-DEMO @ IFIC (1.5 kg Xe):



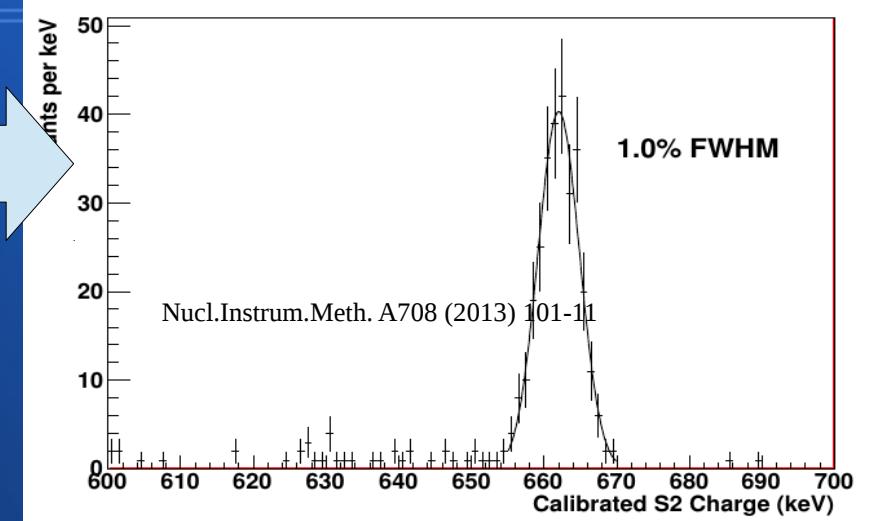
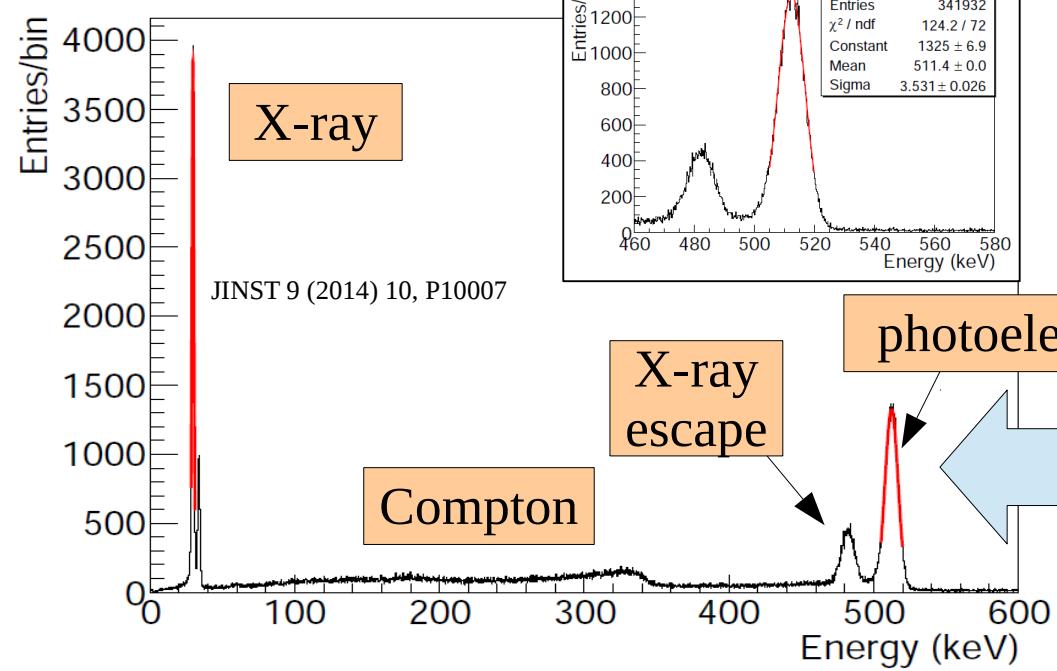
Nucl.Ins.Meth. A708 (2013)  
JINST 8 (2013) P0400  
JINST 8 (2013) P09011  
JINST 9 (2014) 10, P10007  
JINST 8 (2013) P05025  
JINST 10 (2015) 03, P03025



*Complete prototype: PMT+SiPM*

# R&D: Energy Resolution

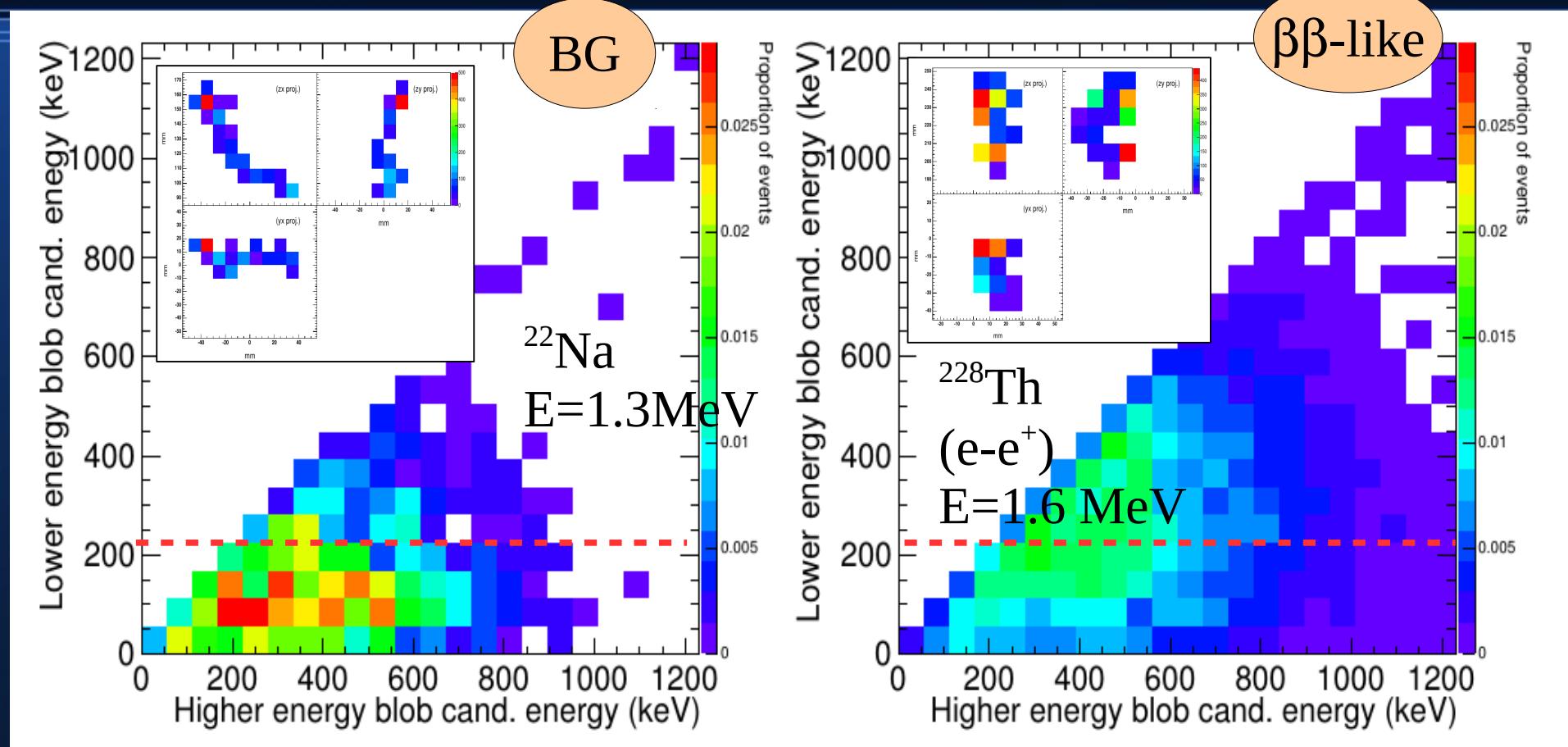
NEXT-DBDM:  $^{137}\text{Cs}$   
1.0% FWHM @ 660 keV  
0.5% FWHM @  $Q_{\beta\beta}$  of  $^{136}\text{Xe}$



NEXT-DEMO:  $^{22}\text{Na}$   
1.6% FWHM @ 511 keV  
Over large fiducial volume  
0.63% FWHM @  $Q_{\beta\beta}$  of  $^{136}\text{Xe}$

# R&D: Event topology

- The NEXT-DEMO @ IFIC (1.5 kg Xe): arXiv:1507.05902



2e cut:  $\epsilon_{\text{Na}} = 24.13 \pm 1.4\%$  (MC: 21.9%)

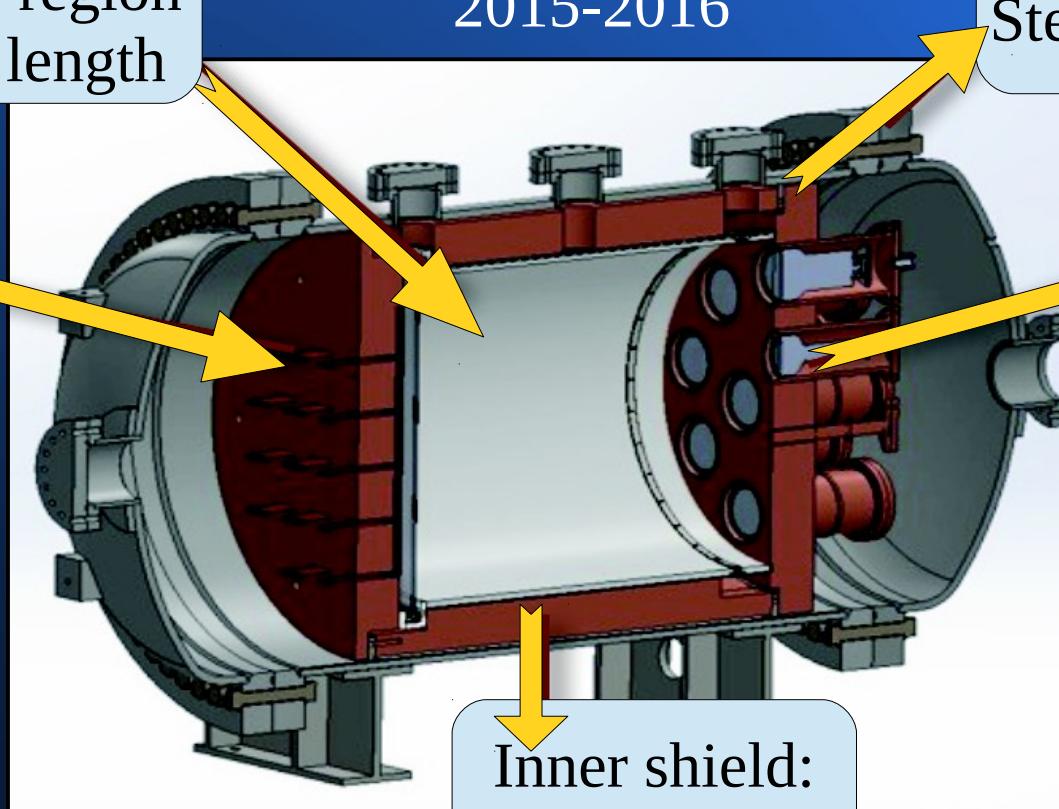
$\epsilon_{\text{Th}} = 66.7 \pm 0.6\%$  (MC: 65.9%)

BG rejection demonstrated

vella, NEXT, EPSC

Monte Carlo validated

# NEXT-NEW: Physics @ LSC



TPC:  
10 kg active region  
50 cm drift length

Tracking plane:  
1800 SiPM  
1 cm pitch

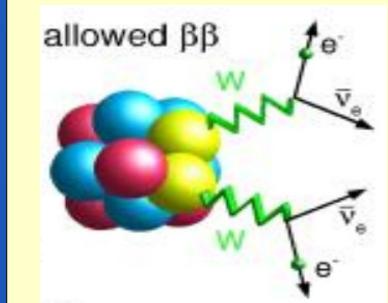
Physics program:

- $\Delta E = 0.5\% \text{ FWHM}$
- Event Topology
- Measure the BG
- Certify technology
- ...

Pressure Vessel:  
Steel, up to 30 bar

Energy Plane:  
12 PMTs  
30% coverage

Ultimate goal:



First phase of the NEXT-100 experiment

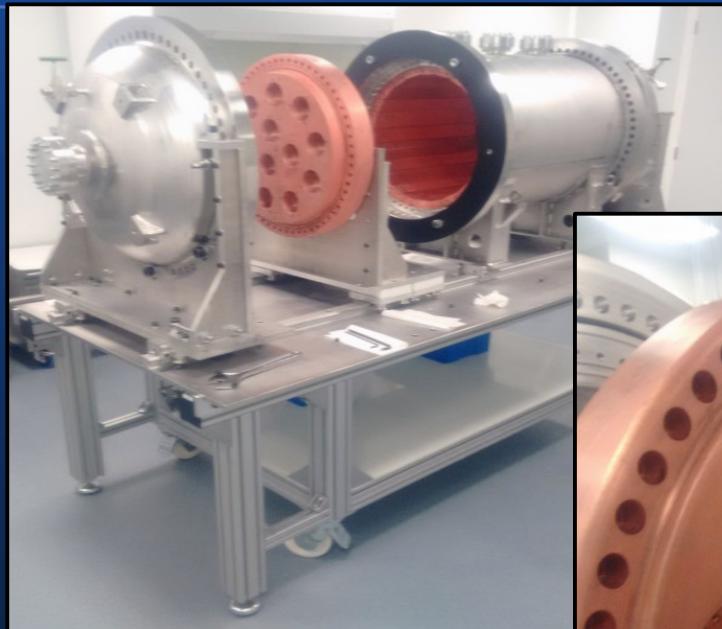
# NEXT-NEW @ LSC

- Infrastructures ready: platform, lead castle, gas system
- Xenon available: 100 kg of enriched  $^{136}\text{Xe}$  and 100 kg of depleted Xe



- NEXT-NEW: vessel @ LSC since early 2015, energy plane installed

# NEXT-NEW Energy Plane



Energy plane mounted in July 2015



PMT: Hamamatsu R11410-10

Sapphire windows to hold the pressure



Testing and commissioning in Summer 2015

# NEXT-100: the degenerate land

JINST 7 (2012) T06001

TPC:  
100 kg active region  
130 cm drift length

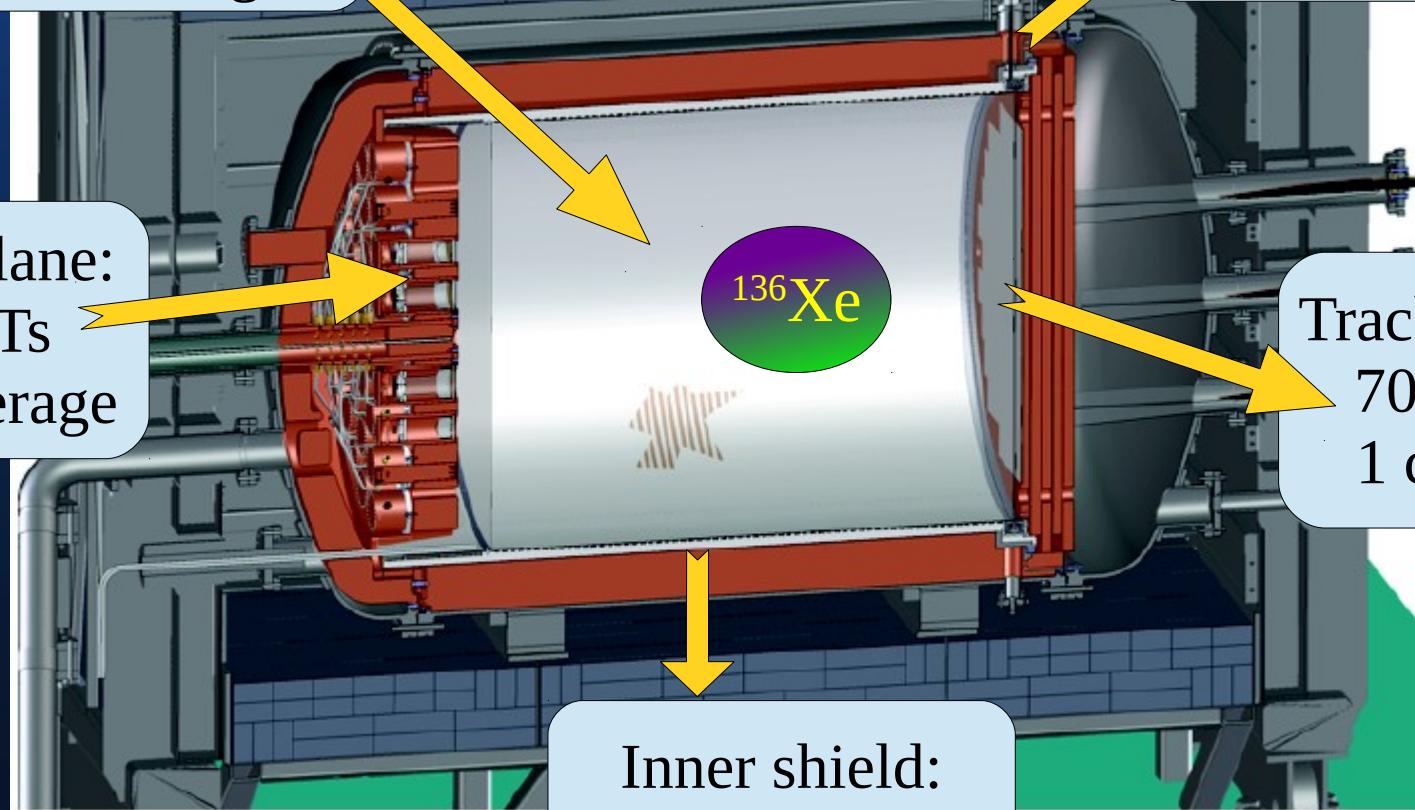
2016-2020

Pressure Vessel:  
Steel, up to 15 bar

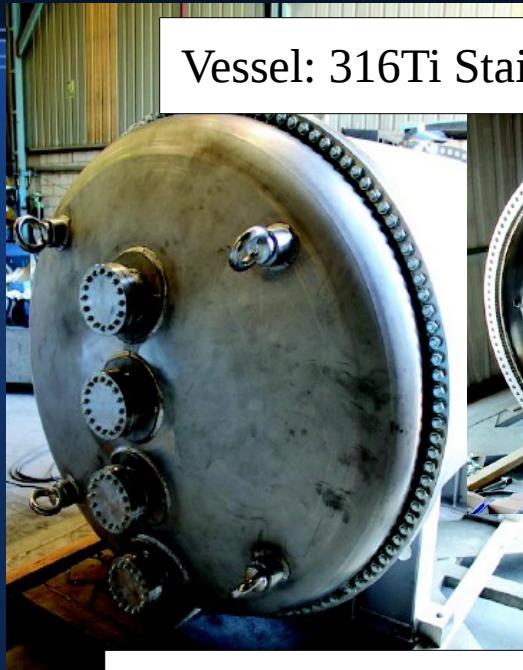
Energy Plane:  
60 PMTs  
30% coverage

Tracking plane:  
7000 SiPM  
1 cm pitch

Inner shield:  
12 cm of copper



# Status of NEXT-100



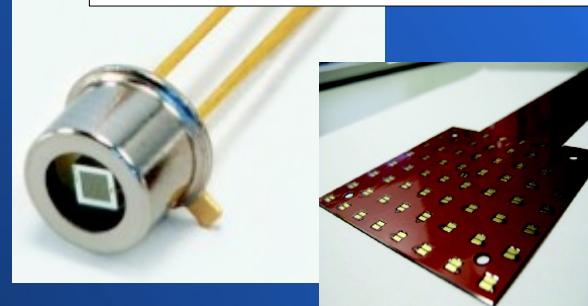
Vessel: 316Ti Stainless Steel



PMT: Hamamatsu R11410-10

	Activity (Bq)		Rejection Factors		Final rate (ckky)	
	<i>Tl-208</i>	<i>Bi-214</i>	<i>Tl-208</i>	<i>Bi-214</i>	<i>Tl-208</i>	<i>Bi-214</i>
<b>Dice Boards</b>	4,28E-03	3,21E-03	7,90E-07	8,85E-07	3,047E-05	2,560E-05
<b>PMTs</b>	8,40E-03	3,00E-02	3,30E-07	2,68E-07	2,498E-05	7,244E-05
<b>Field Cage</b>	4,38E-03	1,53E-02	5,30E-07	8,02E-07	2,091E-05	1,107E-04
<b>ICS</b>	1,326E-02	1,105E-01	1,100E-07	8,400E-08	1,315E-05	8,365E-05
<b>Vessel</b>	1,66E-01	5,16E-01	1,10E-08	2,80E-09	1,644E-05	1,301E-05
<b>Shielding Lead</b>	6,266E-01	1,084E+00	2,000E-09	1,000E-10	1,129E-05	9,763E-07
<b>SUBTOTAL</b>	8,23E-01	1,76E+00			1,172E-04	3,063E-04
<b>TOTAL BKGND</b>	2,58E+00				4,24E-04	

SenSL 1x1mm<sup>2</sup> SMD C

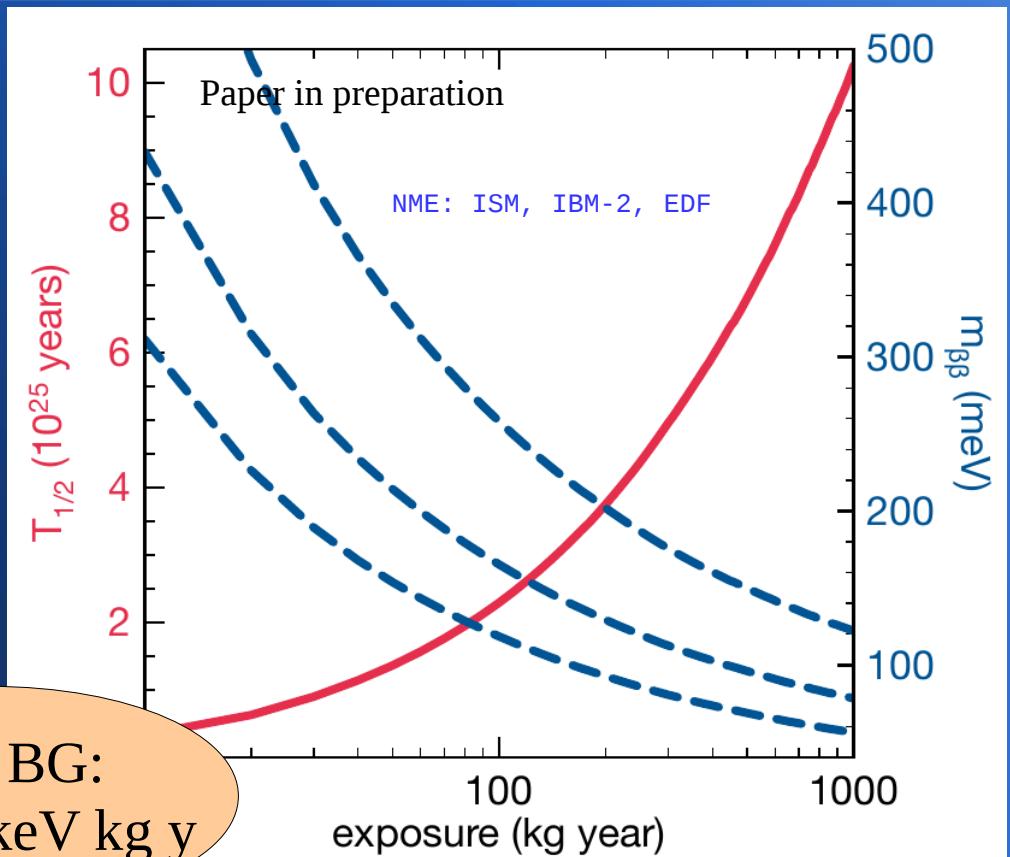
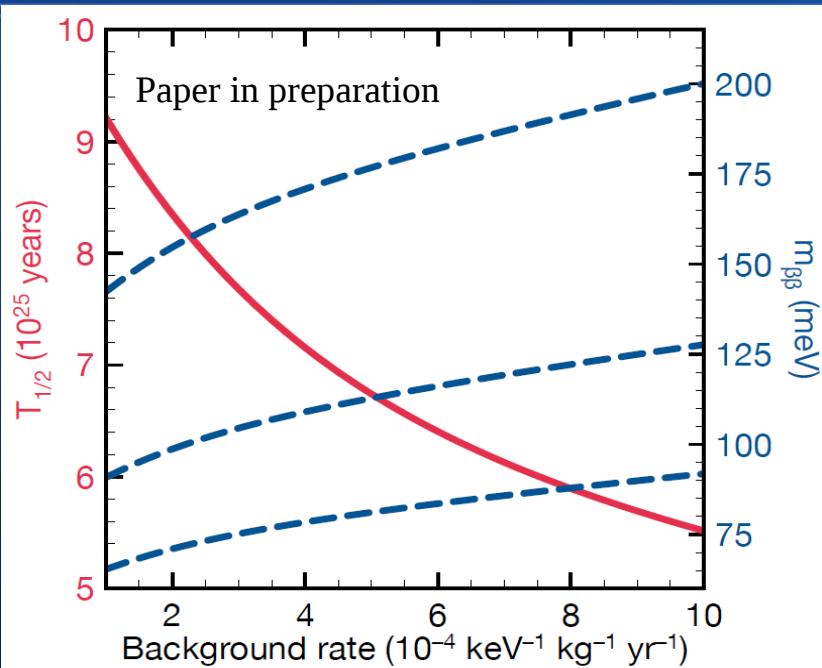


<sup>136</sup>Xe

Radiopurity: JINST 8 (2013) T01002, JINST 10 (2015) 05, P05006

2e - cut:  
 $\epsilon_{\beta\beta} \sim 70\%$   
 $\epsilon_{\beta} \sim 10\%$   
 (room for improvement!)

# Physics Case of NEXT-100



Radiopurity measurements

Background rejection factors

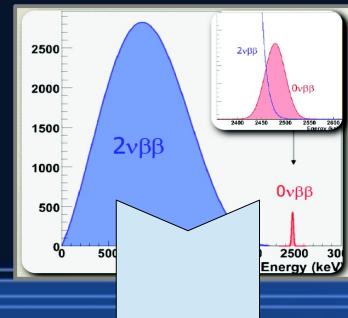
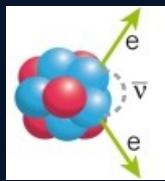
$$4 \times 10^{-7}$$

Total BG:  
 $4 \times 10^{-4} \text{ c/keV kg y}$

$m_{\beta\beta} < 100 \text{ meV}$  (3 years of data)

JCAP 1106 (2011) 007, Riv.Nuovo Cim. 35 (2012) 29-98

# Summary



Energy resolution

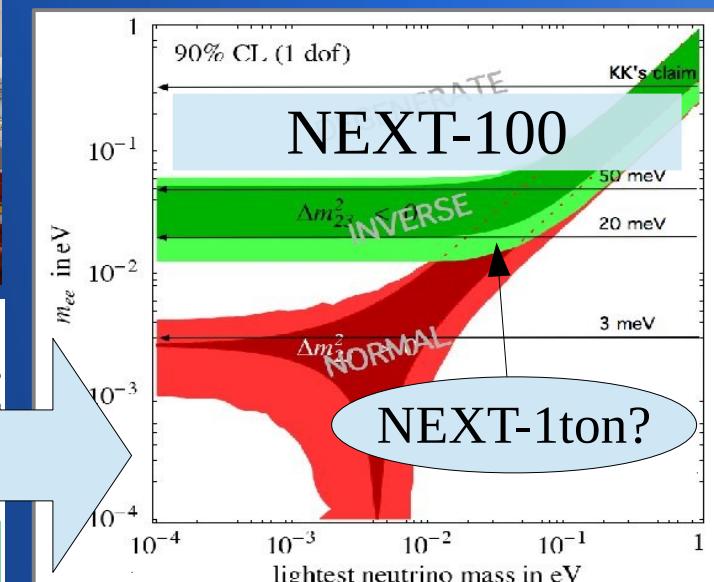
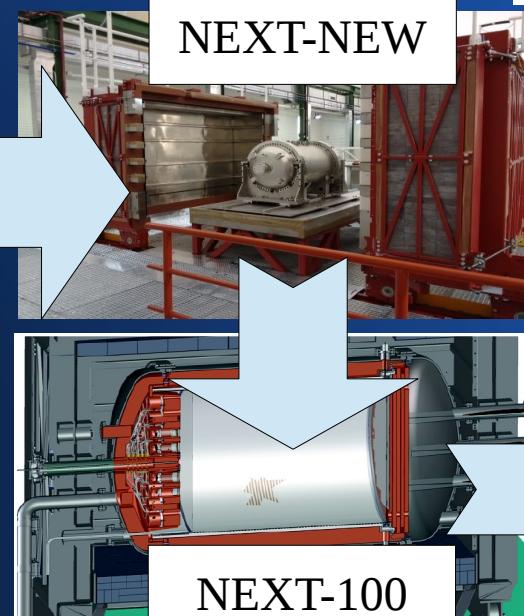
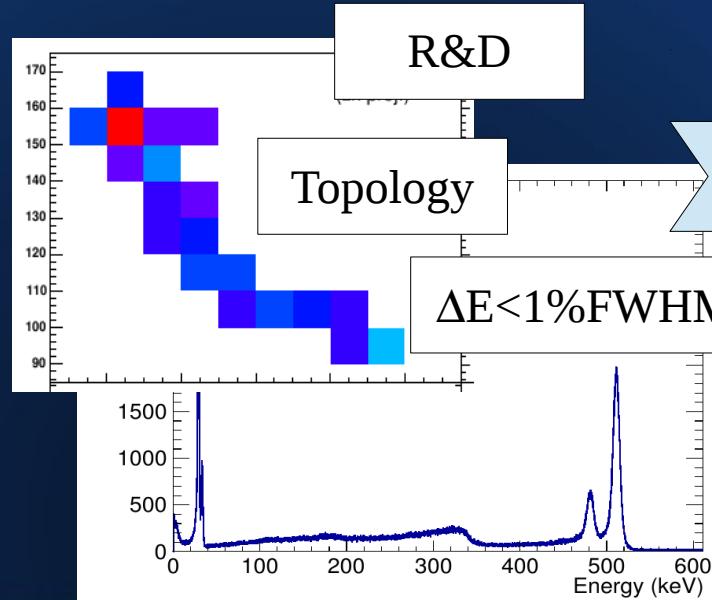
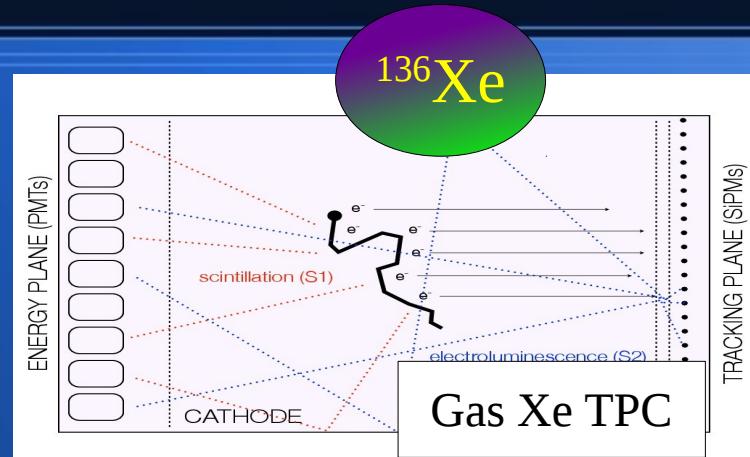
Background rejection

Scalability

next



$^{136}\text{Xe}$



# The NEXT Collaboration



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



LBNL • Iowa State • Texas A&M  
FNAL



Coimbra • Aveiro



JINR



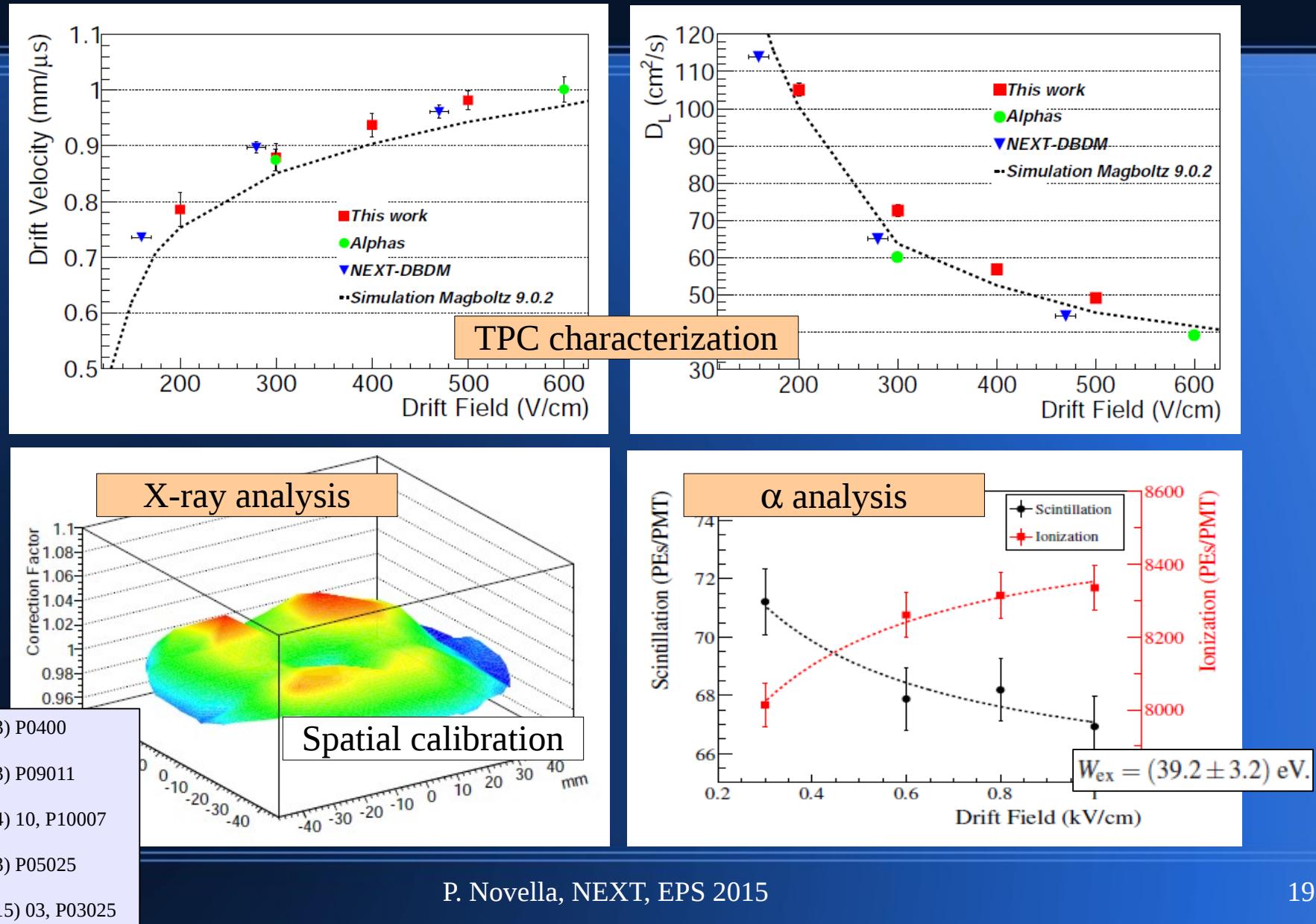
A. Nariño



Spokesperson:  
J.J. Gomez-Cadenas  
[gomez@cern.ch](mailto:gomez@cern.ch)

# Back up

# NEXT-DEMO Results



# NEXT-100: Rn and Radioactivity

TABLE 1. Activities recently measured in relevant materials for NEXT. GDMS results were derived from U, Th and K concentrations. Germanium  $\gamma$ -ray spectrometry results reported for  $^{238}\text{U}$  and  $^{232}\text{Th}$  correspond to the upper part of the chains (derived from  $^{234m}\text{Pa}$  and  $^{228}\text{Ac}$  emissions) and those of  $^{226}\text{Ra}$  and  $^{228}\text{Th}$  give activities of the lower parts.

	Material	Supplier	Technique	units	$^{238}\text{U}$	$^{226}\text{Ra}$	$^{232}\text{Th}$	$^{228}\text{Th}$	$^{235}\text{U}$	$^{40}\text{K}$	$^{60}\text{Co}$	$^{137}\text{Cs}$
1	Lead	Britannia	Ge	mBq/kg	<126	<2.8		<3.2		<6.9	<0.3	
2	S-275 steel	Proycon	Ge	mBq/kg	$32\pm 9$	$1.2\pm 0.1$	$1.9\pm 0.2$	$4.7\pm 0.3$		$3.2\pm 0.7$	$1.8\pm 0.1$	<0.2
3	Steel+primer	Proycon	Ge	mBq/kg	$(1.1\pm 0.3)\times 10^3$	$444\pm 21$	$125\pm 9$	$106\pm 6$		$(1.6\pm 0.2)\times 10^3$	$94\pm 7$	<3.9
4	Steel+primer +painting	Proycon	Ge	mBq/kg	$(0.8\pm 0.2)\times 10^3$	$437\pm 20$	$76\pm 5$	$58\pm 3$		$(1.2\pm 0.1)\times 10^3$	$2.2\pm 0.3$	<1.4
5	Lead wool	Tecnibus	Ge	mBq/kg	<368	<12		<15		$36.9\pm 6.5$	<1.1	
6	EPDM foam	Moss Express	Ge	mBq/m	<437	$33.0\pm 1.7$	$106\pm 7$	$95.5\pm 5.2$		$758\pm 78$	<1.4	<1.3
7	EPDM foam	Artein Gaskets	Ge	mBq/m	<215	$4.3\pm 0.4$	$5.1\pm 1.6$	<5.4		$11.2\pm 2.9$	<0.6	<0.6
8	Glue	Ceys	Ge	mBq/kg	$<3.2\times 10^3$	<18	<75	<31	<13	$(33.0\pm 3.3)\times 10^3$	<12	<10
9	Resistors	Ohmcraft	Ge	$\mu\text{Bq}/\text{pc}$	$(0.56\pm 0.15)\times 10^3$	$217\pm 10$	$44\pm 4$	$36\pm 3$		$95\pm 13$	<2	<2
10	Brazing paste		GDMS	$\mu\text{Bq}/\text{kg}$	$55\pm 10$		$49\pm 4$			<31		
11	Brass bolts		GDMS	$\mu\text{Bq}/\text{kg}$	$8.9\pm 0.7$		$6.9\pm 0.2$			<31		
12	SS screws		GDMS	mBq/kg	$3.25\pm 0.25$		$0.57\pm 0.08$			<0.19		
13	Optical gel	Nye Lubricants	Ge	mBq/kg	$<1.7\times 10^3$	<22	<49	<18	<16	<173	<4.5	<5.8
14	Epoxy	Araldite	Ge	mBq/kg	<182	<1.4	<3.7	<2.5	<0.8	$15.0\pm 2.4$	<0.4	<0.4
15	Kapton-Cu cable		Ge	mBq/kg	$<1.1\times 10^3$	$46.8\pm 3.3$	<40	<32		$166\pm 27$	<5.2	<4.4
16	PMTs (R11410-10)	Hamamatsu	Ge	mBq/pc	<67	<0.94	<2.2	$0.56\pm 0.14$	$0.58\pm 0.13$	$11.8\pm 1.7$	$3.73\pm 0.27$	<0.3
17	Connectors	Hirose	Ge	mBq/pc	$6.4\pm 1.9$	$2.8\pm 0.1$	$5.6\pm 0.3$	$5.9\pm 0.3$		$3.4\pm 0.4$	<0.03	<0.04
18	Adhesive films	Flexible Circuits	Ge	mBq/kg	$(1.8\pm 0.6)\times 10^3$	<19	<50	<34	$16.8\pm 3.0$	<107	<4.8	<4.6

Situation	NaI(Tl) detector rate (Hz)	Rn activity (Bq/m <sup>3</sup> ) mean	Rn activity (Bq/m <sup>3</sup> ) at Hall A $\sigma$	Rn activity (Bq/m <sup>3</sup> ) mean	Rn activity (Bq/m <sup>3</sup> ) at NEXT castle $\sigma$
1 Open castle	$59.56\pm 0.01$				
2 Closed castle	$1.089\pm 0.001$	80	29	79	28
3 Better closed castle	$0.694\pm 0.002$	74	26	30	11
4 After N <sub>2</sub> purge	$0.658\pm 0.001$	66	25	30	12
5 N <sub>2</sub> purge+flux 180 l/h	$0.600\pm 0.001$	66	25	22	9
6 Without N <sub>2</sub> flux	$0.638\pm 0.001$	59	18	26	10
7 N <sub>2</sub> purge+flux 900 l/h	$0.350\pm 0.002$	73	26	4	3

# NEXT-100 BG rejection

	$0\nu\beta\beta$	Tl-208	Bi-214
Fiducial $E > 2 \text{ MeV}$	67.86%	0.25%	0.01%
ROI	95.52%	8.99%	64.66%
1 track	74.60%	1.86%	12.54%
2 blobs	73.76%	9.60%	9.89%

Signal efficiency: ~35%

Total BG rejection:  $> 4 \cdot 10^{-7}$

# NEXT-1ton



- It is a symmetric TPC filled with O(**1 ton**) of Xenon enriched at 90% in Xe-136 at a pressure of 15 bar
- The drift length is  $2 \times 2$  m (2 ms drift, DEMO measures lifetimes of  $> 10$  ms)
- The TPC radius is about 1 m.
- The active volume is about  $12 \text{ m}^3$  (1 ton at 15 bar)
- The event energy is integrated by wavelength shifting light guides surrounding the gas and read by PMTs located outside the fiducial volume.
- The event topology is reconstructed by two planes of radiopure silicon pixels (MPPCs by default).

$\beta\beta0\nu$  (20 meV)