Neutrino Experiment with a Xenon TPC

Now and Beyond

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GDR neutrino Lyon November 2013

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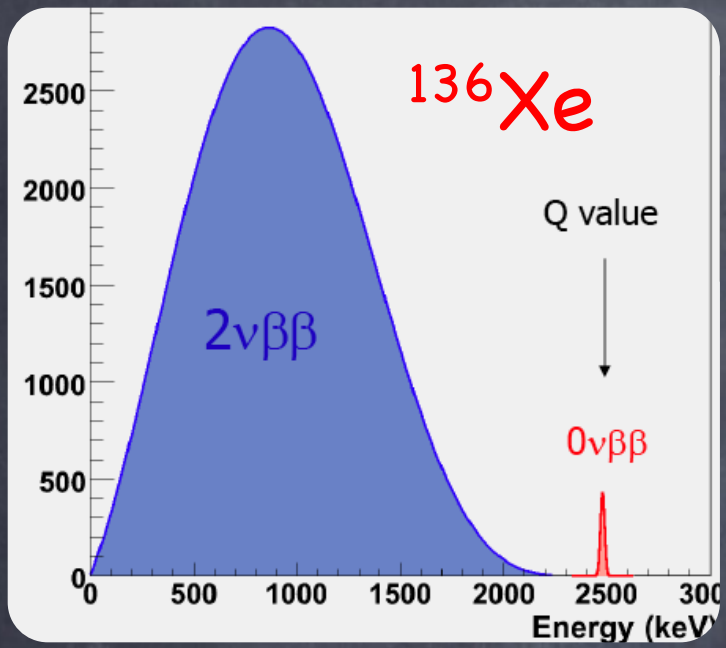
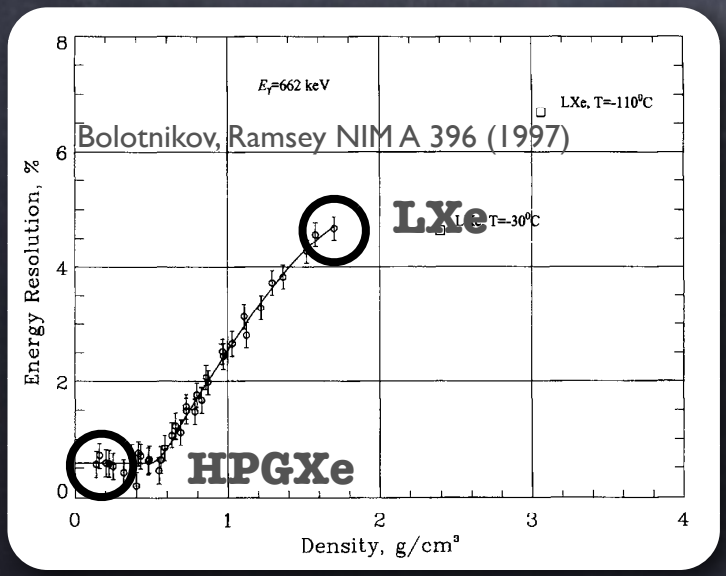
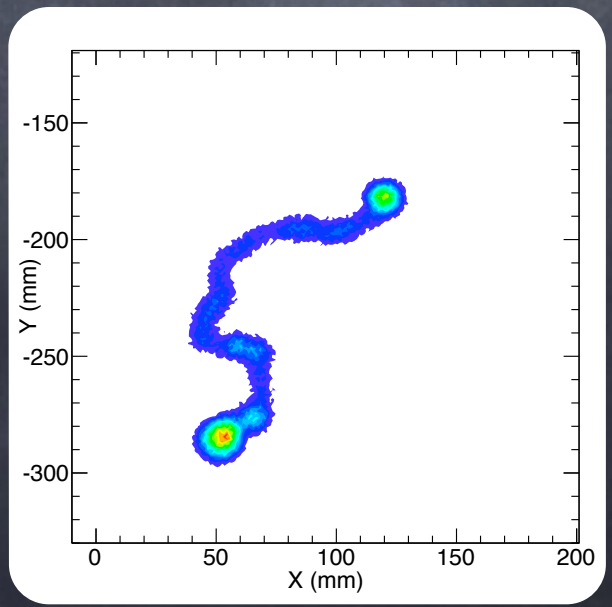
Detector Concept



- Energy Resolution
  - Background events in the ROI limit sensitivity of the experiment
  - Good energy resolution is essential
- Tracking
  - Topological Signature of $2e^-$ reduce background





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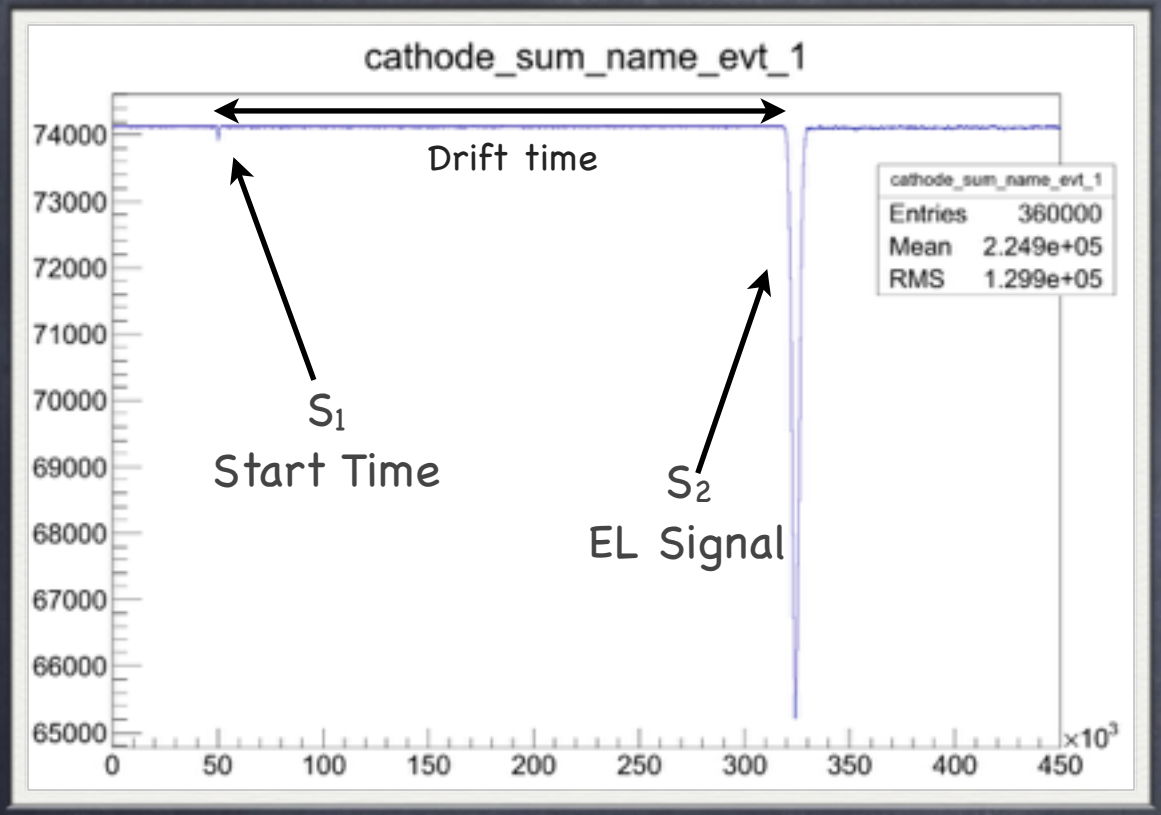
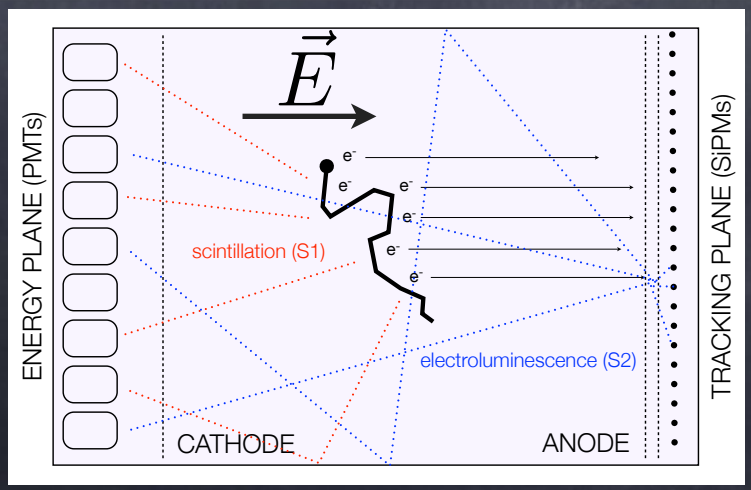
Detector Concept





- βs produce electron recoils and excite and ionise Xe
- Xe de-excites producing scintillation light S_1
- Electric drift field prevents recombination and moves ionised tracks towards EL region
- Ionised tracks excite Xe in the EL region producing secondary scintillation S_2
- S_1 and S_2 light is read by the PMTs in the energy plane to obtain the energy of the event
- S_2 light is read by the MPPC (SiPMTs) in the tracking plane to obtain topological information about the event

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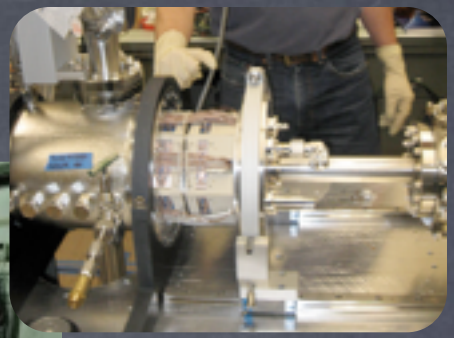
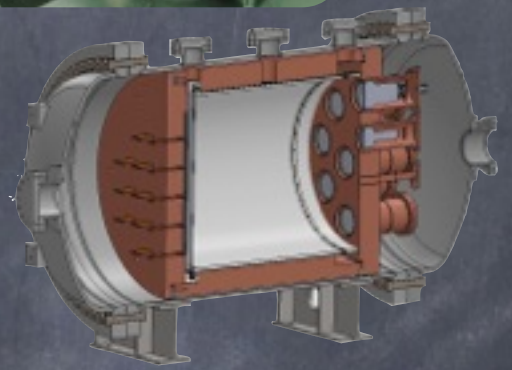
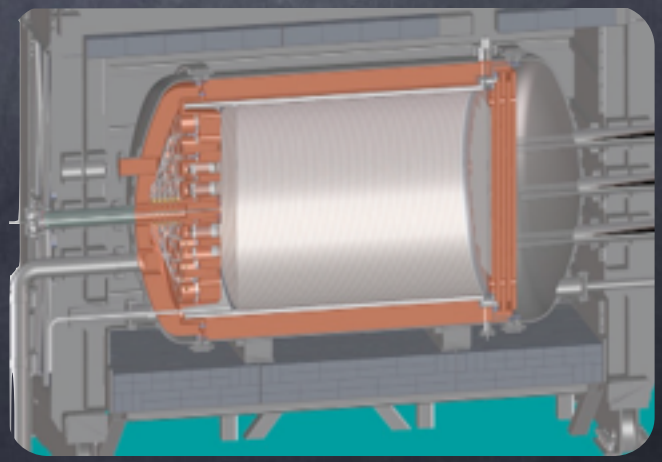
The NEXTs



- NEXT-DEMO (@IFIC) NEXT-DBDM (@LBNL)
  - Non-radiopure, above ground and unshielded
  - 1-2 kg of normal Xe gas prototypes
  - Set proof of principle
  - Demonstrated near intrinsic energy resolution
  - Demonstrated tracking
  - 19-1" PMTs, 4 DB @64 MPPC



- NEXT-NEW
  - First phase of NEXT 100 up to the end 2014
  - Radiopure, at LSC and shielded in a lead castle
  - 10-15 kg of 90% isotopically enriched ^{136}Xe gas
  - Sensitive to $2\beta 2\nu$ decay-topological signature
  - 12 ultra low background PMTs, 23 DB @64 MPPC (20% of sensors of NEXT 100)
  - Full validation of background model
  - Field Cage 1:2 NEXT 100



- NEXT 100
  - Commence 2015
  - Radiopure, at LSC and shielded in a lead castle
  - 100-150 kg of 90% isotopically enriched ^{136}Xe gas
  - Money shot $2\beta 0\nu$ decay
  - 65 ultra low background PMTs, 111 DB @64 MPPC

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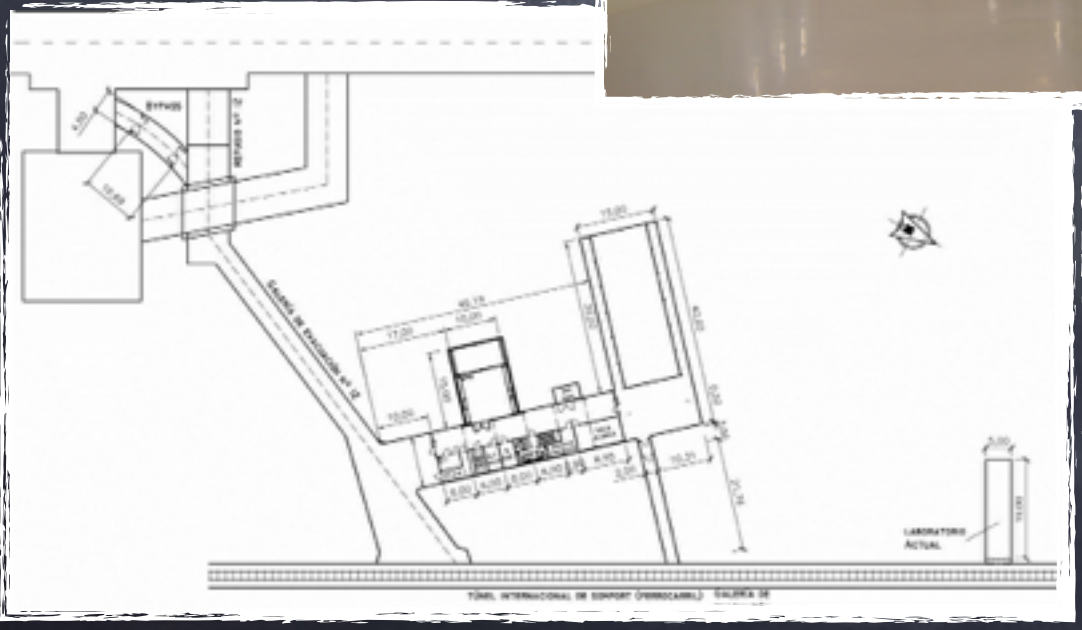
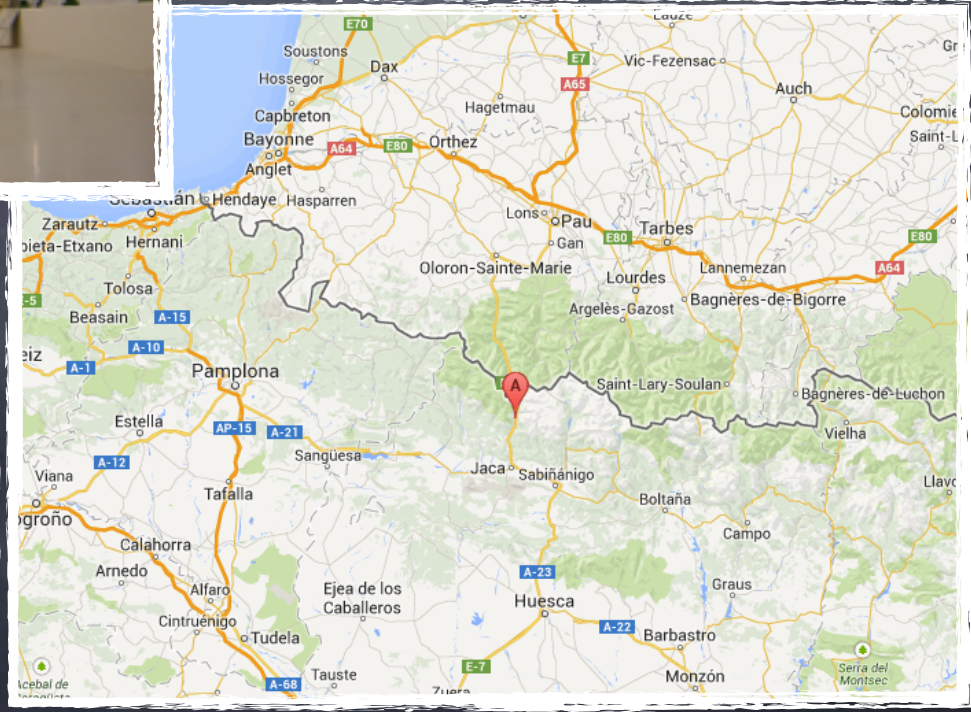
Labaratorio Subterráneo de Canfranc LSC

- Located in the Spanish Pyrenees on the Spanish-French Border
- Excavated in the rock 850m (2,450mwe) deep under the Mount Tobazo
- Total area 1,250 m2





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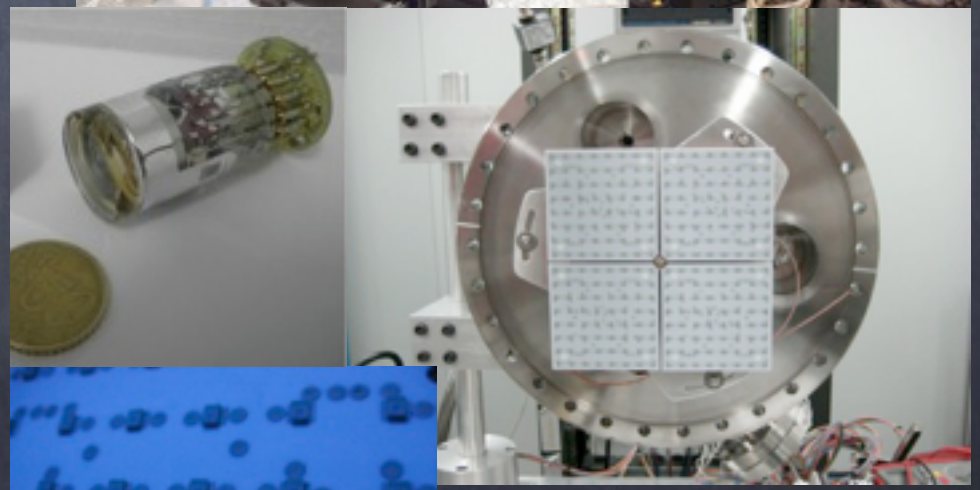
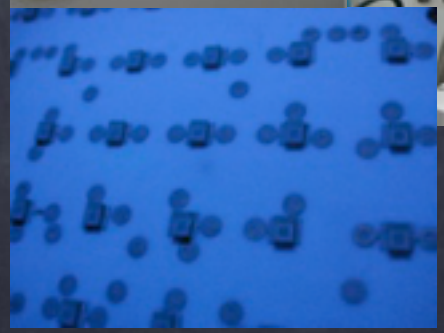
NEXT-DEMO

- Cage Mounted on CF300 endcap
- PTFE PMT Support for 19 Hamamatsu R7378A rated to 20bar
- Energy plane 100mm from Cathode protected by a screen grid
- PEEK supports for Al field rings
- ID 160mm Field Rings
- Hexagonal light pipe made of TPB coated PTFE 9mm panels
- Drift length 300mm
- Drift voltage 350-500V/cm
- EL region 5mm made of 88% transparent stainless meshes with 30 μm wires
- E/P in the EL region 2-3 kV cm^{-1}/bar
- Tracking plane located 2mm behind anode grid made of 4 DB @64 Hamamatsu S10362-11-050P MPPC in a 10mm square pitch patten
- Continuous re-circulation through SASE hot getter $\sim$100 slpm





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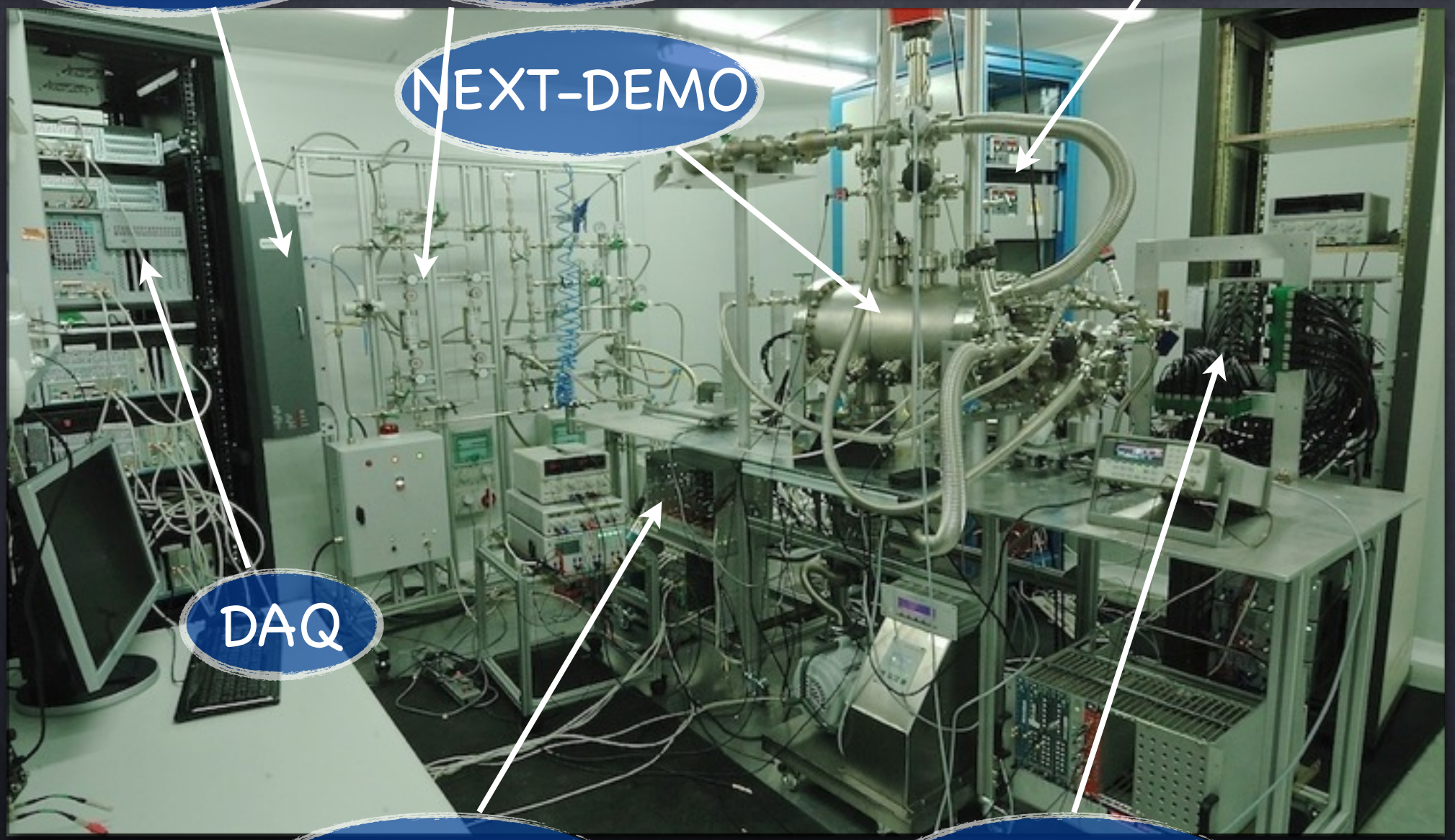

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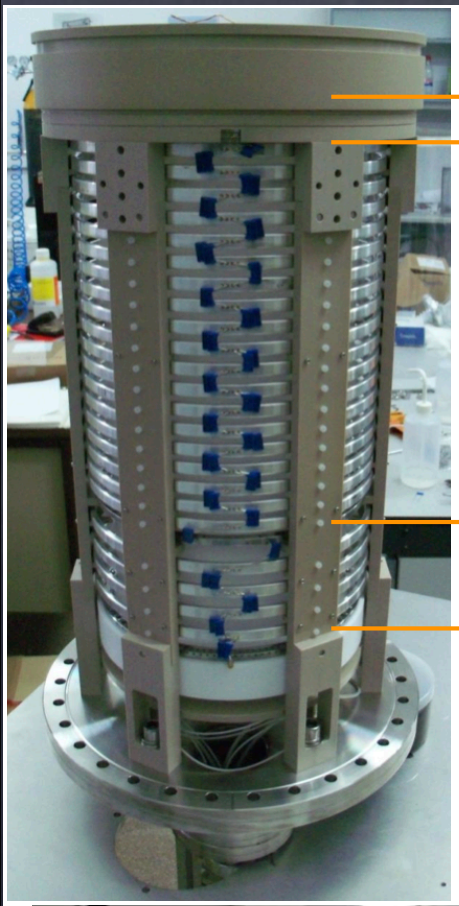
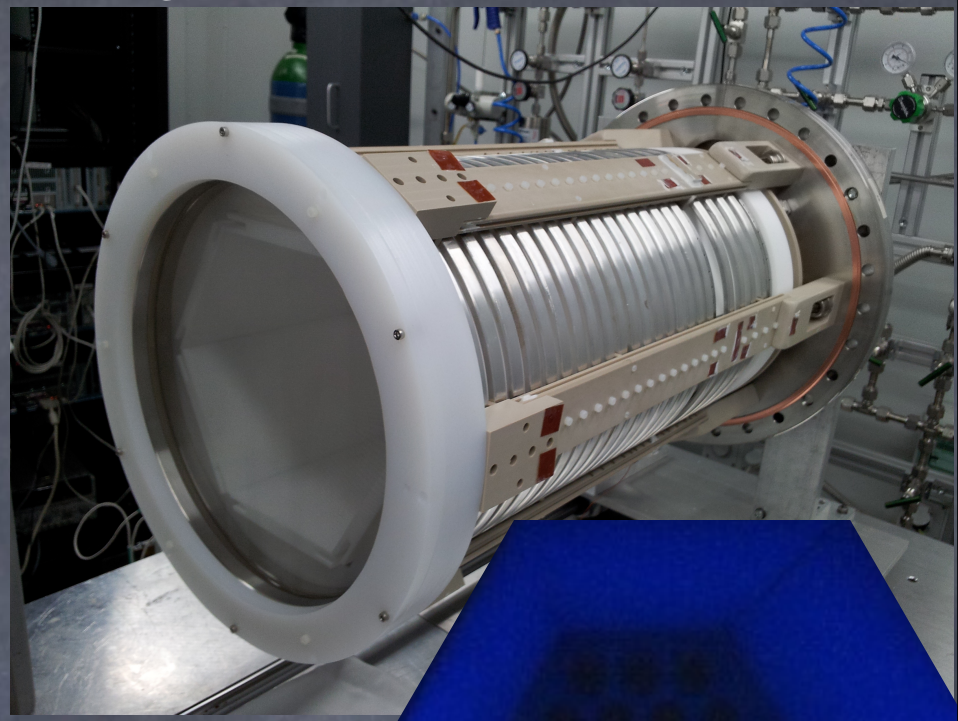
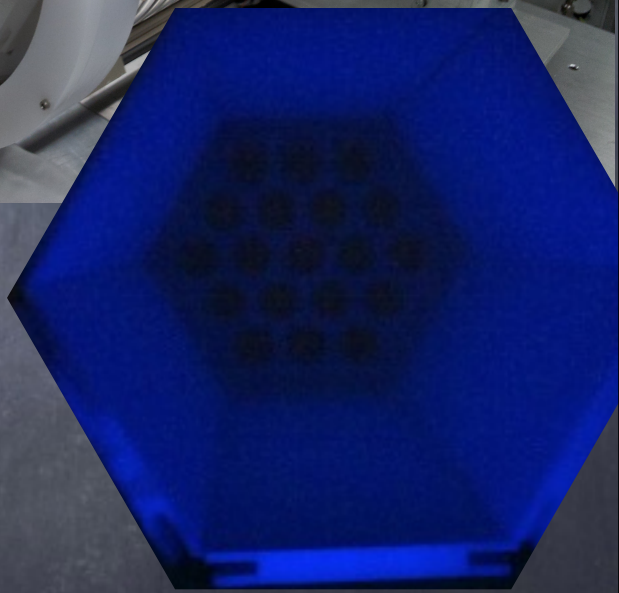
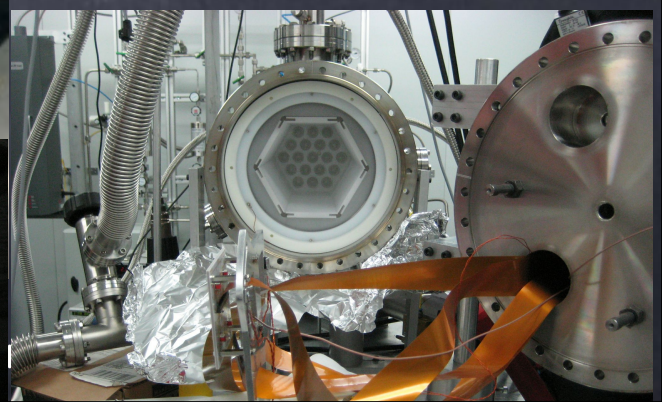
NEXT-DEMO









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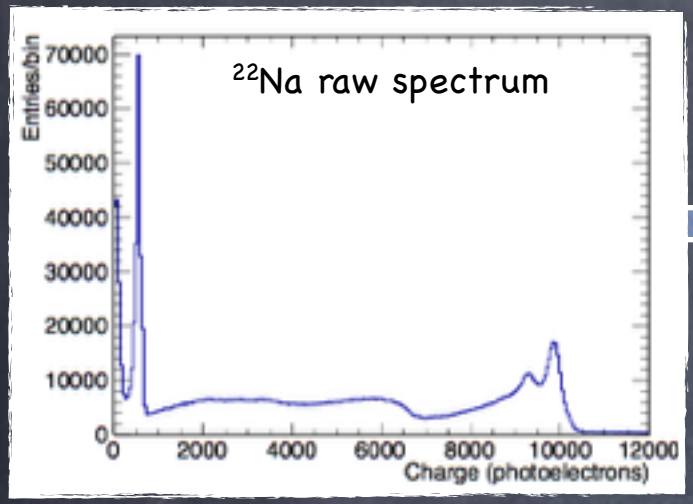
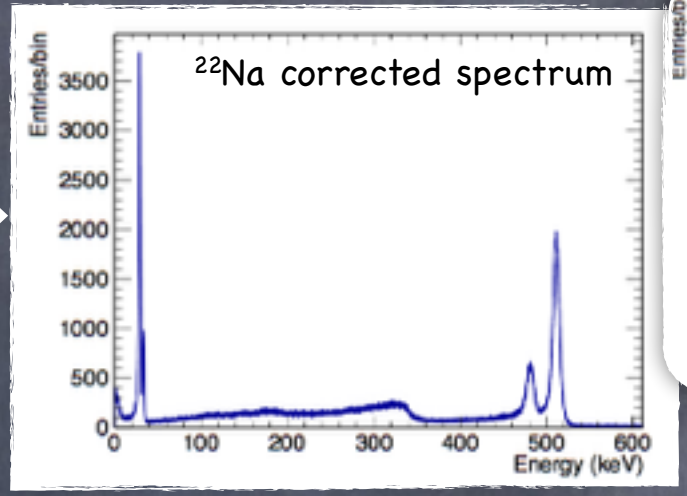
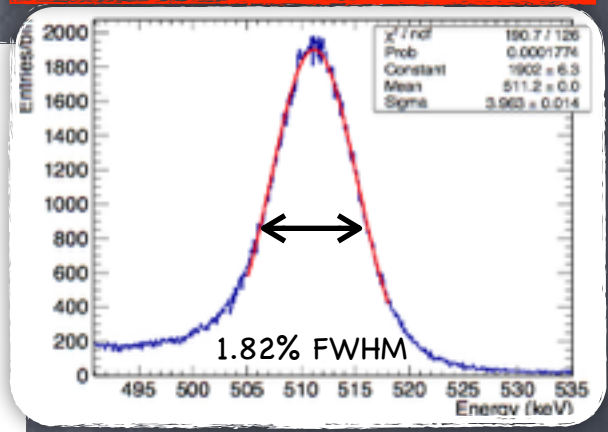
NEXT-DEMO Energy resolution

0.8 % FWHM extrapolated @ $Q_{\beta\beta}$ ($E^{-1/2}$ dependence)

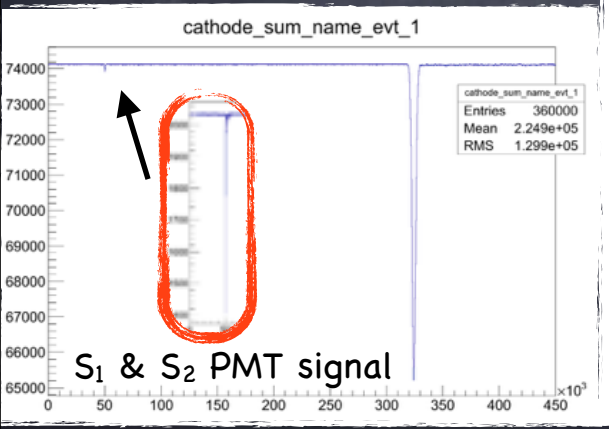


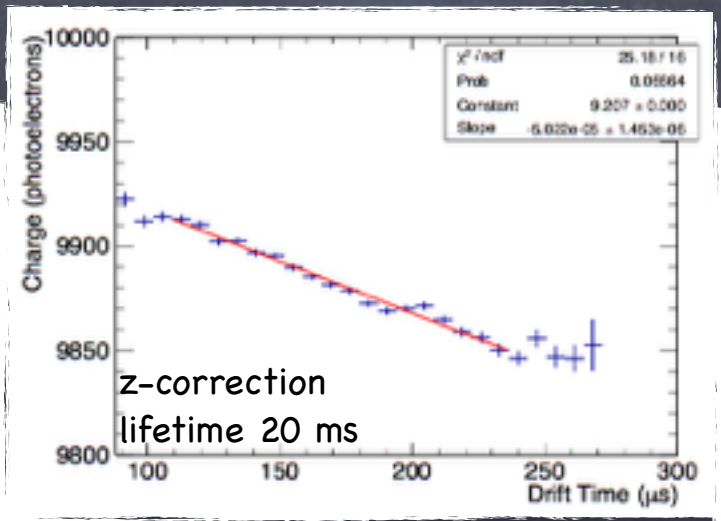


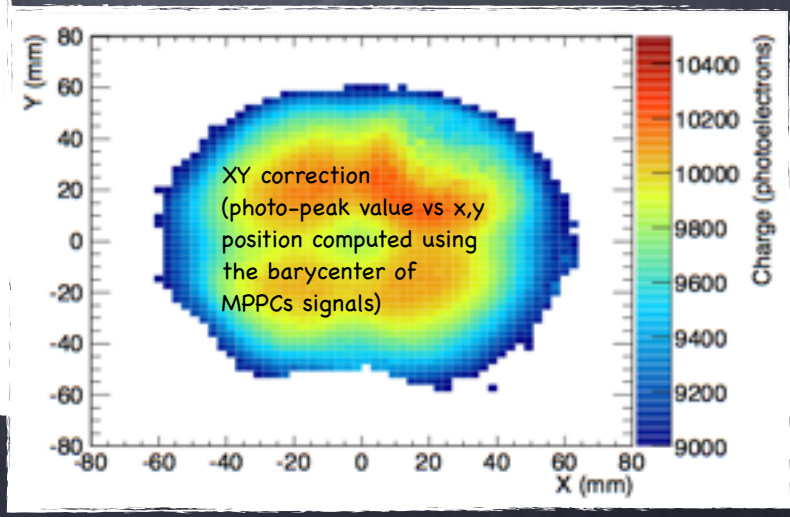


arXiv:1211.4838 0.8%

arXiv:1211.4474v1 0.5%







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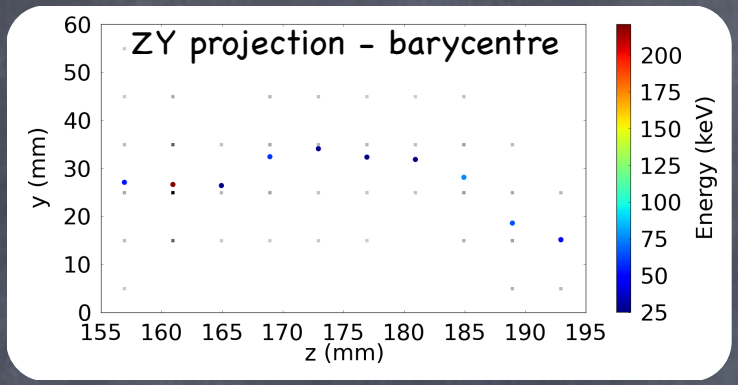
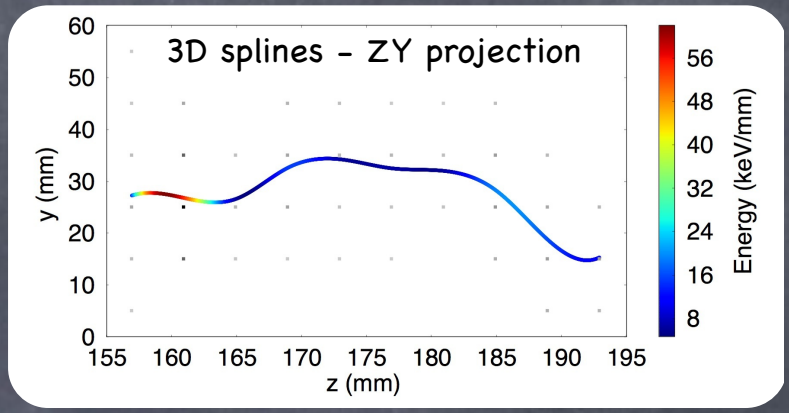
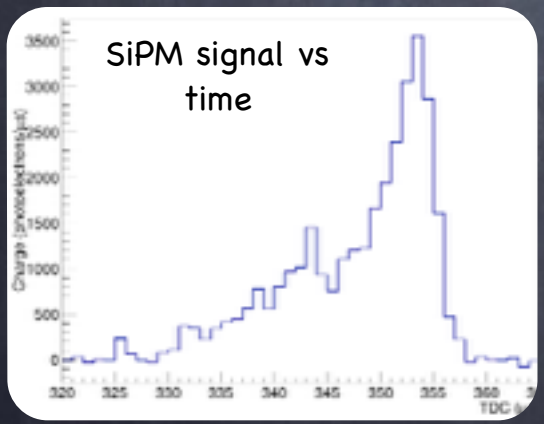
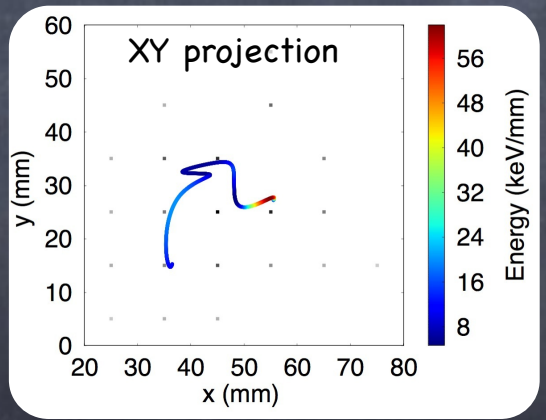
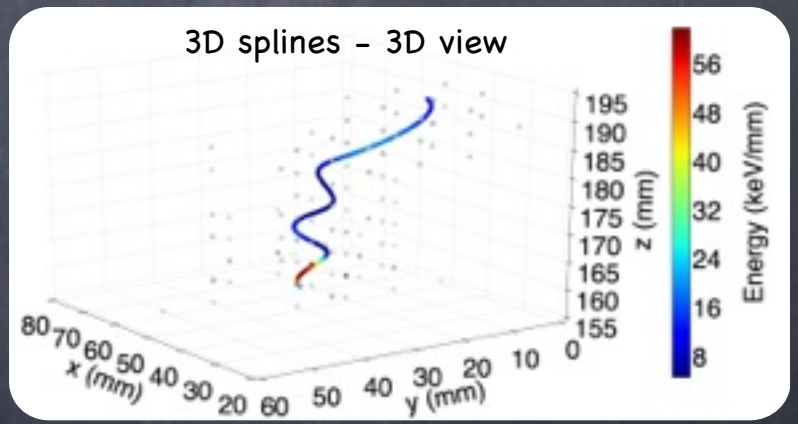
NEXT-DEMO Topology











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

'blob' of the electron clearly visible!

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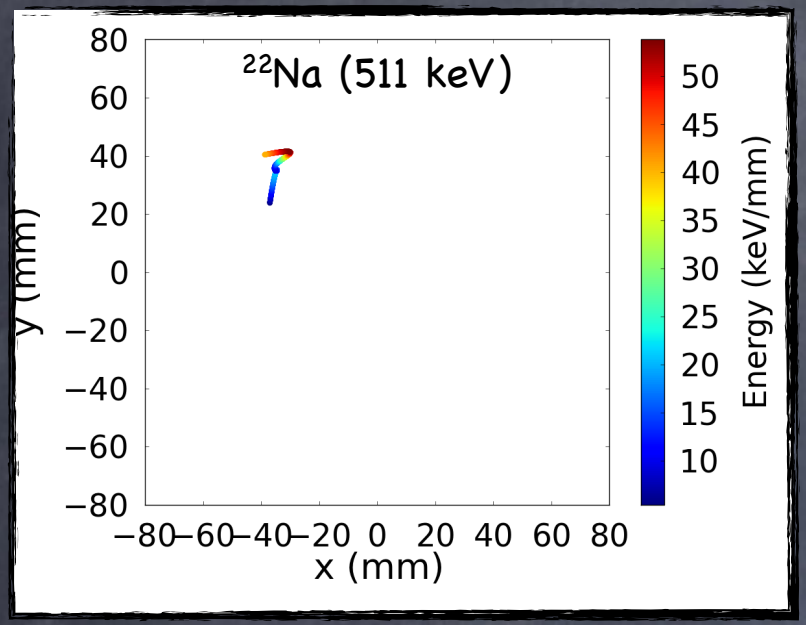
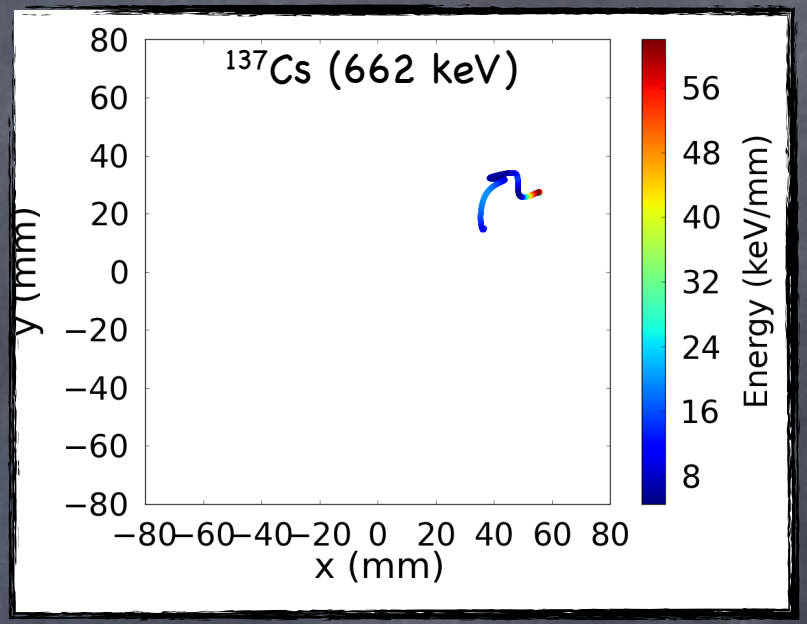
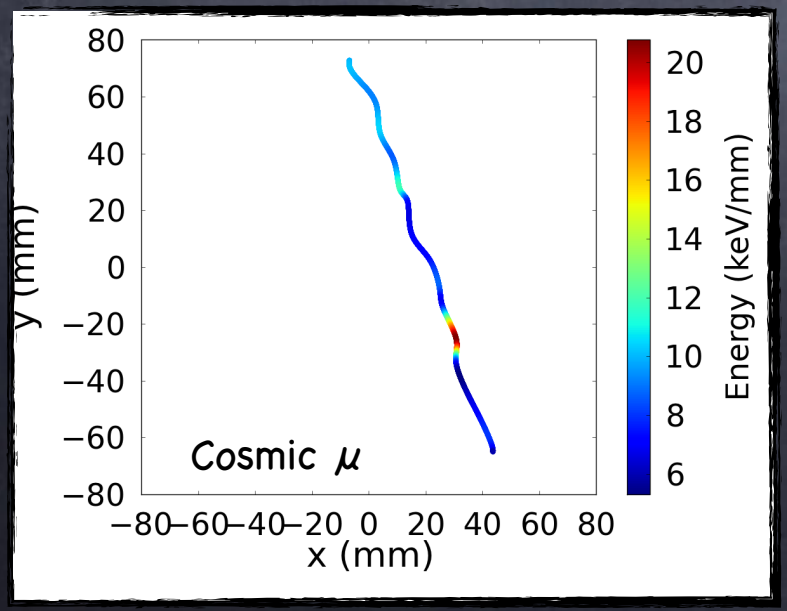
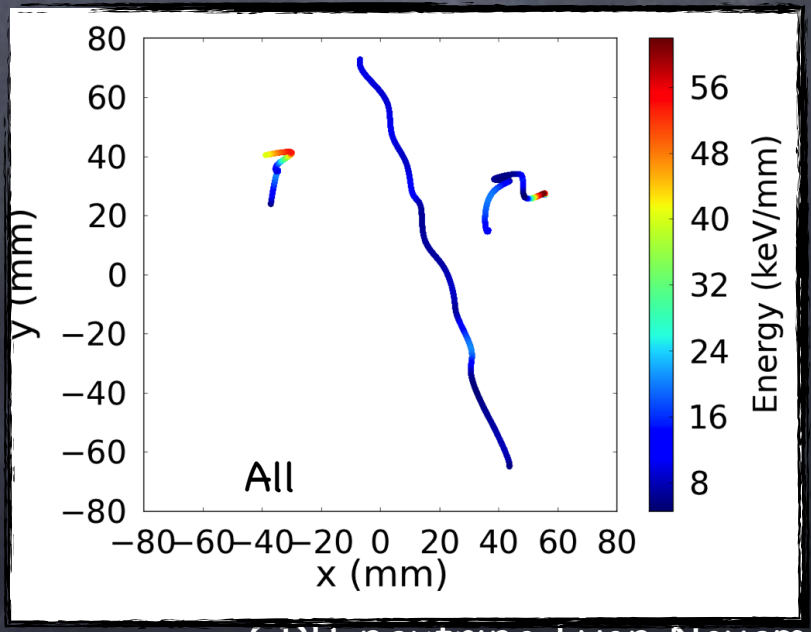
NEXT-DEMO Topology









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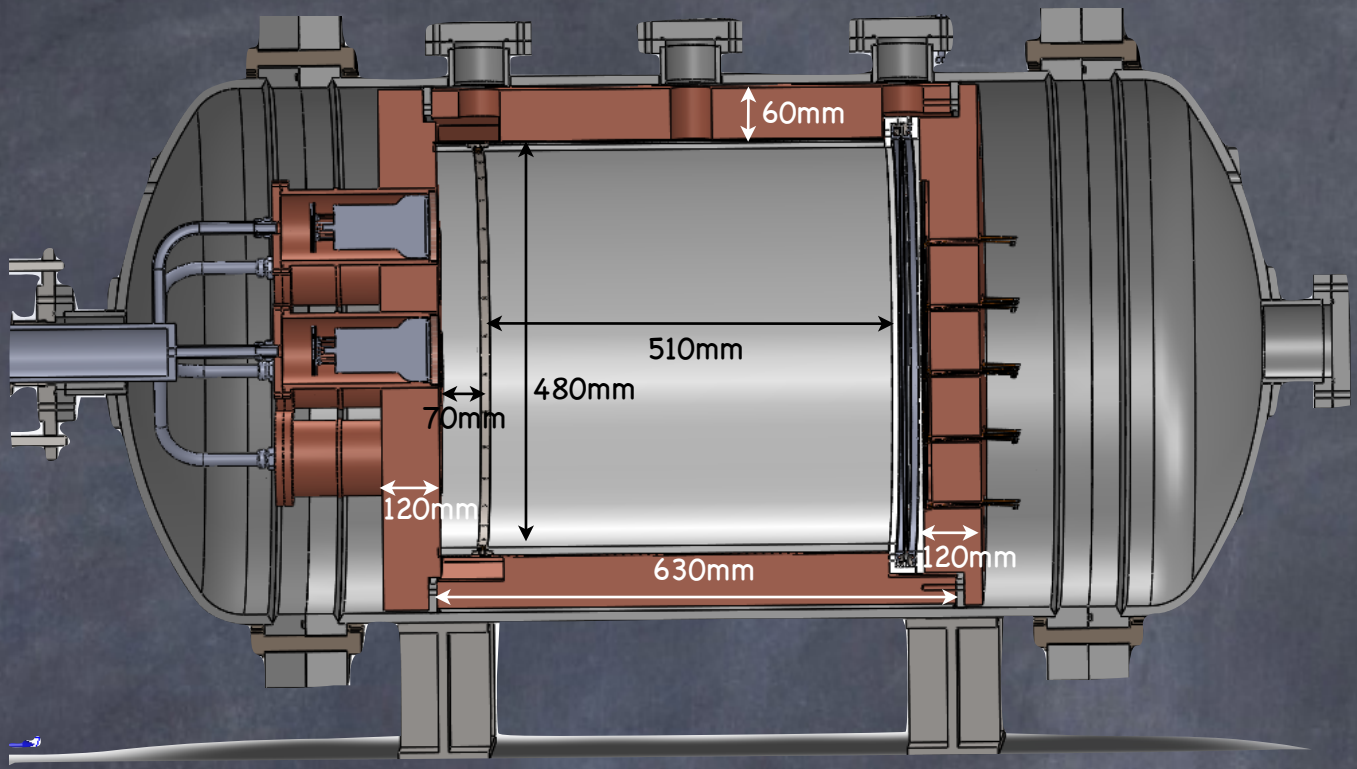
NEXT-NEW



- Active Volume Radius 240 mm
- Active Volume Length 510 mm
- Buffer Region 70 mm
- Maximum Allowable Working pressure 30 bar
- 4-Inner diameter 640 mm
- Outer Diameter, Vessel 664mm
- Outer Diameter, Flanges 820 mm
- Total PMTCANS: 12
- Total DB 28 @64 MPPC (total 1,904)
- Vessel Material, Austenitic Stainless Steel, Alloy 316Ti
- Shielding Copper Material : CuA1-CuC1
- Cylindrical Vessel Wall thickness 12 mm
- Torispheric Head Wall thickness 12,5 mm
- Flange thickness, head to vessel (each) 50mm

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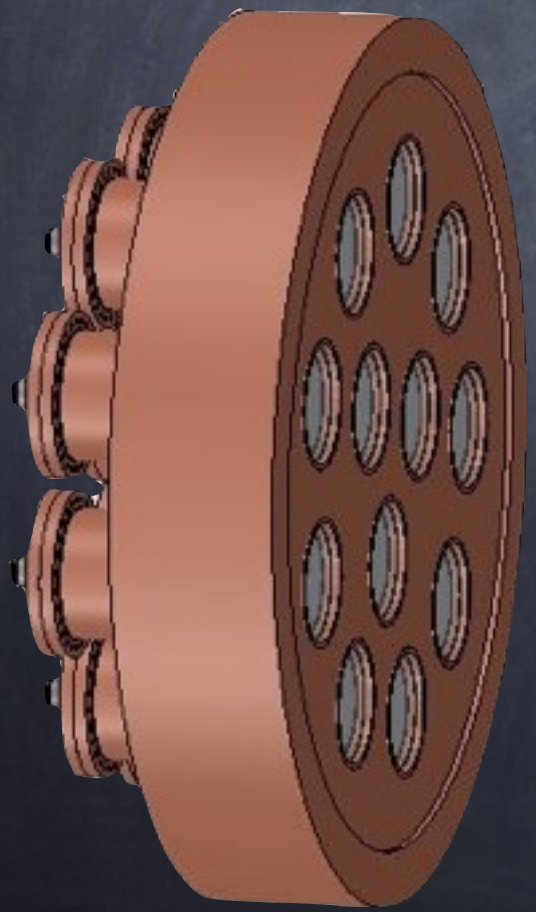
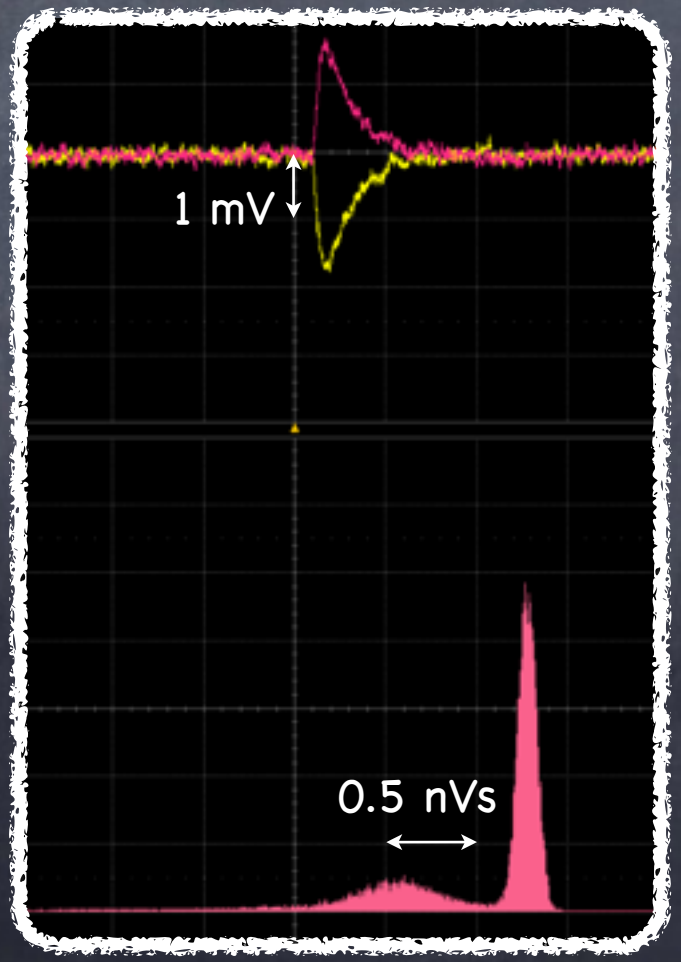
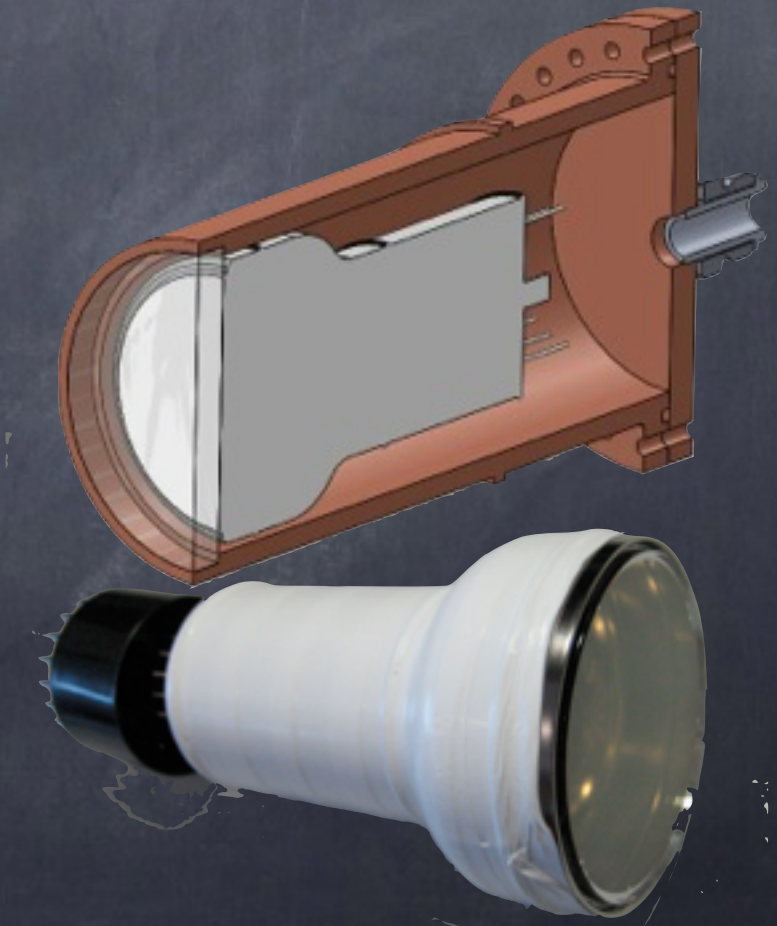
NEXT-NEW Energy Plane

- Hamamatsu R11410-10 Ultra Low background PMT
- Run in differential mode
- Protected for pressure in copper enclosures with brazed sapphire windows
- Enclosures are continuously vacuum pumped and RGA sensed for Xe leaks







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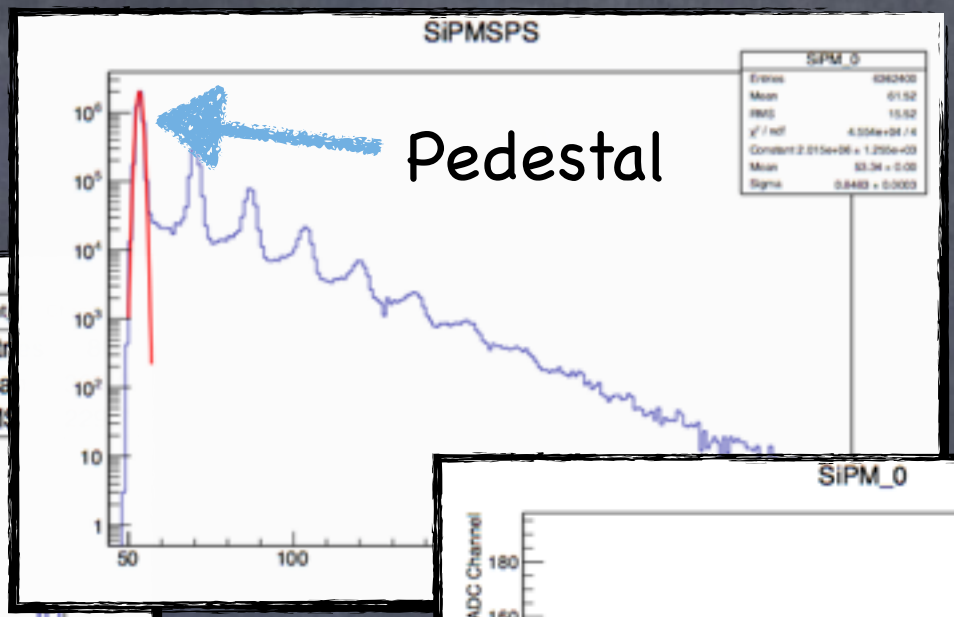
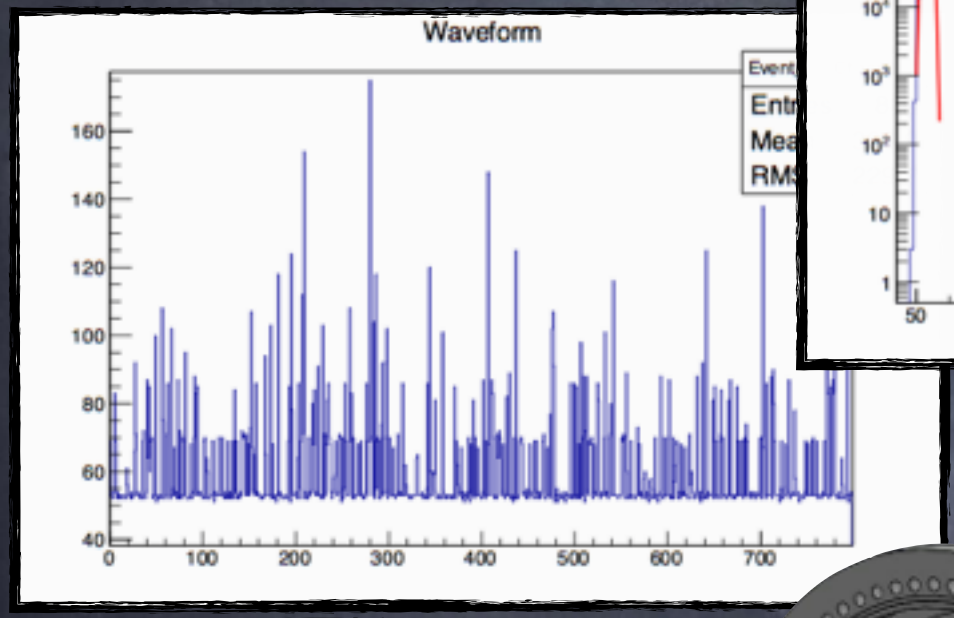
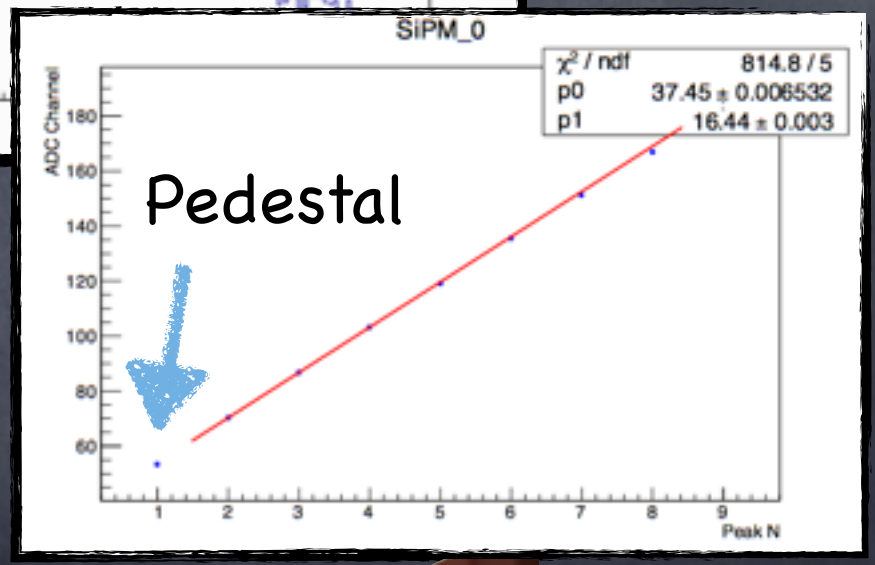
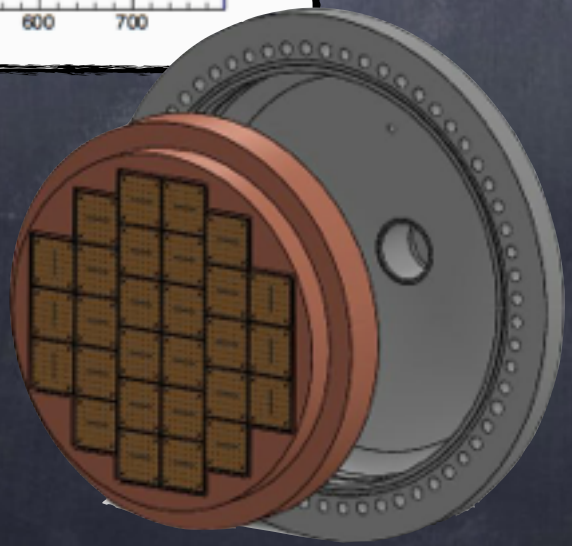
NEXT-NEW Tracking

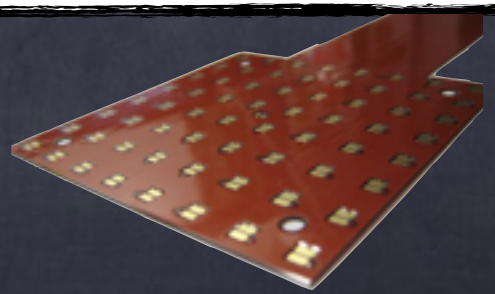
- S10362-11-050P MPPC











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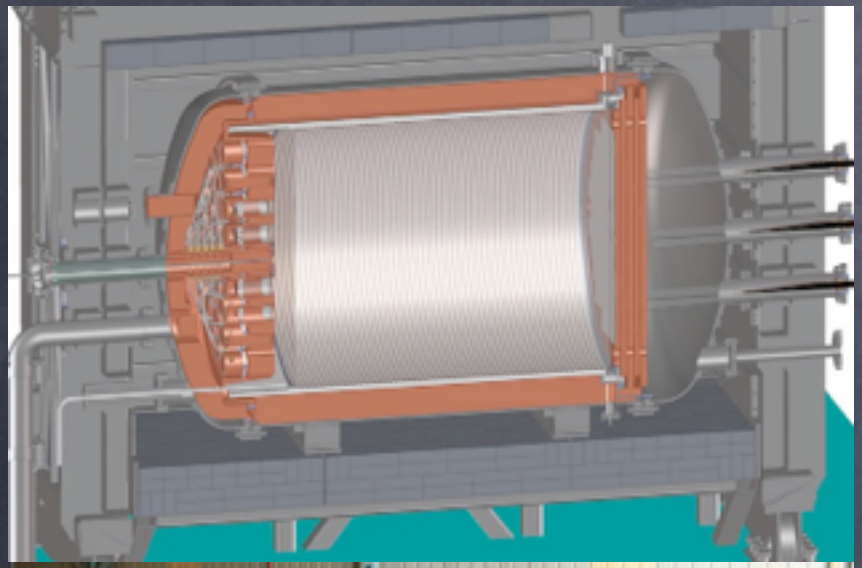
NEXT 100



- 100-150 ^{136}Xe (90% enriched) High Pressure Gas TPC
- Explore $\beta\beta0\nu$ to 100 meV effective ν masses
- Will use same ancillary systems as NEXT-NEW
- Energy and tracking larger version of NEXT NEW
- Full size Field Cage

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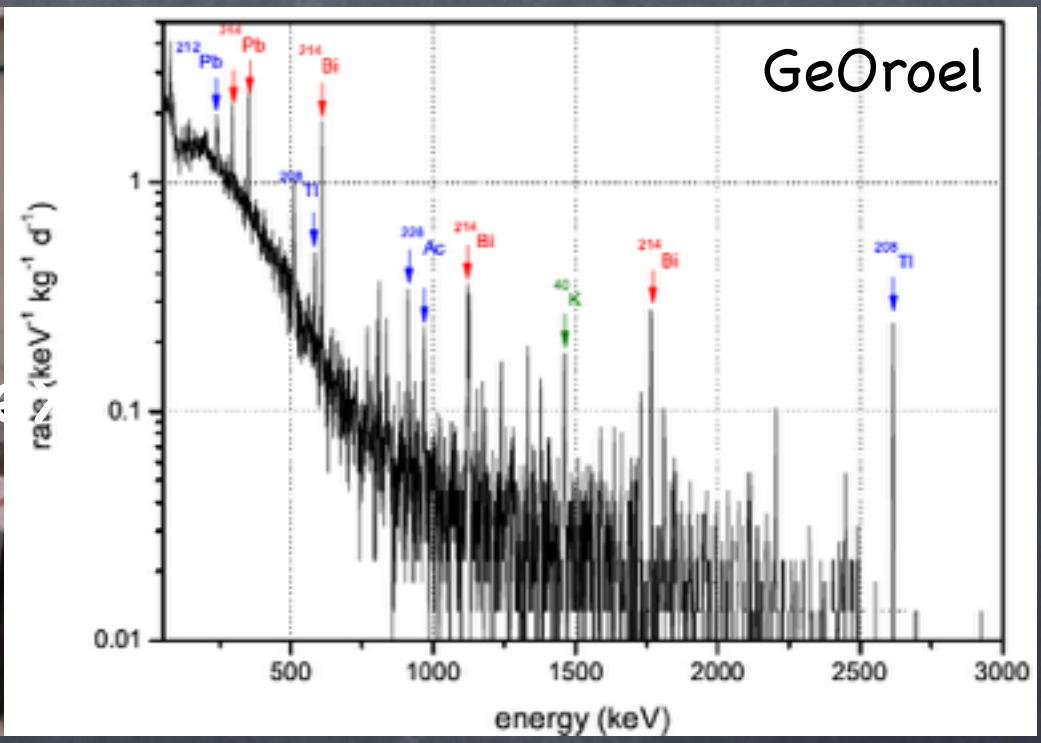
Low Background

Measurements Facilities at LSC



Detector name	Mass (kg)	100-2700 keV	583 keV	609 keV	1461 keV
GeOroel	2.230	490±2	0.8±0.1	3.0± 0.2	0.41±0.07
GeAnayet	2.183	714±3	3.8±0.2	1.7±0.1	0.38±0.07
GeTobazo	2.185	708±3	4.0±0.2	1.3±0.1	0.40±0.06
GeLatuca	2.187	710±3	3.3±0.2	5.9±0.3	0.56±0.08
Paquito	1	79±2	0.27±0.09	0.5±0.1	0.25±0.09

arXiv:1211.3961v3

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Low Background Measurements

#	Material	Supplier	Technique	Unit	^{238}U	^{226}Ra	^{232}Th	^{228}Th	^{235}U	^{40}K	^{60}Co	^{137}Cs
	Shielding											
1	Pb	Cometa	GDMS	mBq/kg	0.37		0.073			<0.31		
2	Pb	Mifer	GDMS	mBq/kg	<1.2		<0.41			0.31		
3	Pb	Mifer	GDMS	mBq/kg	0.33		0.10			1.2		
4	Pb	Tecnibusa	GDMS	mBq/kg	0.73		0.14			0.91		
5	Pb	Tecnibusa	Ge	mBq/kg	<94	<2.0	<3.8	<4.4	<30	<2.8	<0.2	<0.8
6	Pb	Tecnibusa	Ge	mBq/kg	<57	<1.9	<1.7	<2.8	<22	<1.7	<0.1	<0.5
7	Cu (ETP)	Sanmetal	GDMS	mBq/kg	<0.062		<0.020					
8	Cu (C10100)	Luvata (hot rolled)	GDMS	mBq/kg	<0.012		<0.0041			0.061		
9	Cu (C10100)	Luvata (cold rolled)	GDMS	mBq/kg	<0.012		<0.0041			0.091		
10	Cu (C10100)	Luvata (hot+cold rolled)	Ge	mBq/kg		<7.4	<0.8	<4.3		<18	<0.8	<1.2
	Vessel											
11	Ti	SMP	Ge	mBq/kg	<233	<5.7	<8.8	<9.5	3.4±1.0	<22	<3.3	<5.2
12	Ti	SMP	Ge	mBq/kg	<361	<6.6	<11	<10	<8.0	<15	<1.0	<1.8
13	Ti	Ti Metal Supply	Ge	mBq/kg	<14	<0.22	<0.5	3.6±0.2	0.43±0.08	<0.6	<0.07	<0.07
14	304L SS	Pfeiffer	Ge	mBq/kg		14.3±2.8	9.7±2.3	16.2±3.9	3.2±1.1	<17	11.3±2.7	<1.6
15	316Ti SS	Nironit, 10-mm-thick	Ge	mBq/kg	<21	<0.57	<0.59	<0.54	<0.74	<0.96	2.8±0.2	<0.12
16	316Ti SS	Nironit, 15-mm-thick	Ge	mBq/kg	<25	<0.46	<0.69	<0.88	<0.75	<1.0	4.4±0.3	<0.17
17	316Ti SS	Nironit, 50-mm-thick	Ge	mBq/kg	67±22	<1.7	2.1±0.4	2.0±0.7	2.4±0.6	<2.5	4.2±0.3	<0.6
18	Inconel 625	Mecanizados Kanter	Ge	mBq/kg	<120	<1.9	<3.4	<3.2	<4.6	<3.9	<0.4	<0.6
19	Inconel 718	Mecanizados Kanter	Ge	mBq/kg	309±78	<3.4	<5.1	<4.4	15.0±1.9	<13	<1.4	<1.3
	HV, EL components											
20	PEEK	Sanmetal	Ge	mBq/kg		36.3±4.3	14.9±5.3	11.0±2.4	<7.8	8.3±3.0	<3.3	<2.6
21	Polyethylene	IN2 Plastics	Ge	mBq/kg	<140	<1.9	<3.8	<2.7	<1.0	<8.9	<0.5	<0.5
22	Semitron ES225	Quadrant EPP	Ge	mBq/kg	<101	<2.3	<2.0	<1.8	1.8±0.3	513±52	<0.5	<0.6
23	SMD resistor	Farnell	Ge	mBq/pc	2.3±1.0	0.16±0.03	0.30±0.06	0.30±0.05	<0.05	0.19±0.08	<0.02	<0.03
24	SM5D resistor	Finechem	Ge	mBq/pc	0.4±0.2	0.022±0.007	<0.023	<0.016	0.012±0.005	0.17±0.07	<0.005	<0.005
	Energy, tracking planes											
25	Kapton-Cu PCB	LabCircuits	Ge	mBq/cm^2	<0.26	<0.014	<0.012	<0.008	<0.002	<0.040	<0.002	<0.002
26	Cuflon	Polyflon	Ge	mBq/kg	<33	<1.3	<1.1	<1.1	<0.6	4.8±1.1	<0.3	<0.3
27	Bonding films	Polyflon	Ge	mBq/kg	1140±300	487±23	79.8±6.6	66.0±4.8	60.0±5.5	832 ±87	<4.4	<3.8
28	FFC/FCP connector	Hirose	Ge	mBq/pc	<50	4.6±0.7	6.5±1.2	6.4±1.0	<0.75	3.9±1.4	<0.2	<0.5
29	P5K connector	Panasonic	Ge	mBq/pc	<42	6.0±0.9	9.5±1.7	9.4±1.4	<0.95	4.1±1.5	<0.2	<0.8
30	Thermopl. connector	Molex	Ge	mBq/pc	<7.3	1.77±0.08	3.01±0.19	2.82±0.15	<0.31	2.12±0.25	<0.022	0.27±0.03
31	Solder paste	Multicore	Ge	mBq/kg	<310	<4.9	<8.0	<6.0	<5.2	<13	<1.0	<1.6
32	Solder wire	Multicore	Ge	mBq/kg	<4900	(7.7±1.2)10^2	<147	<14		<257	<30	<36
33	Ta capacitor	Vishay Sprague	Ge	mBq/pc	<0.8	0.043±0.003	0.034±0.004	0.032±0.003	< 0.010		<0.002	<0.003

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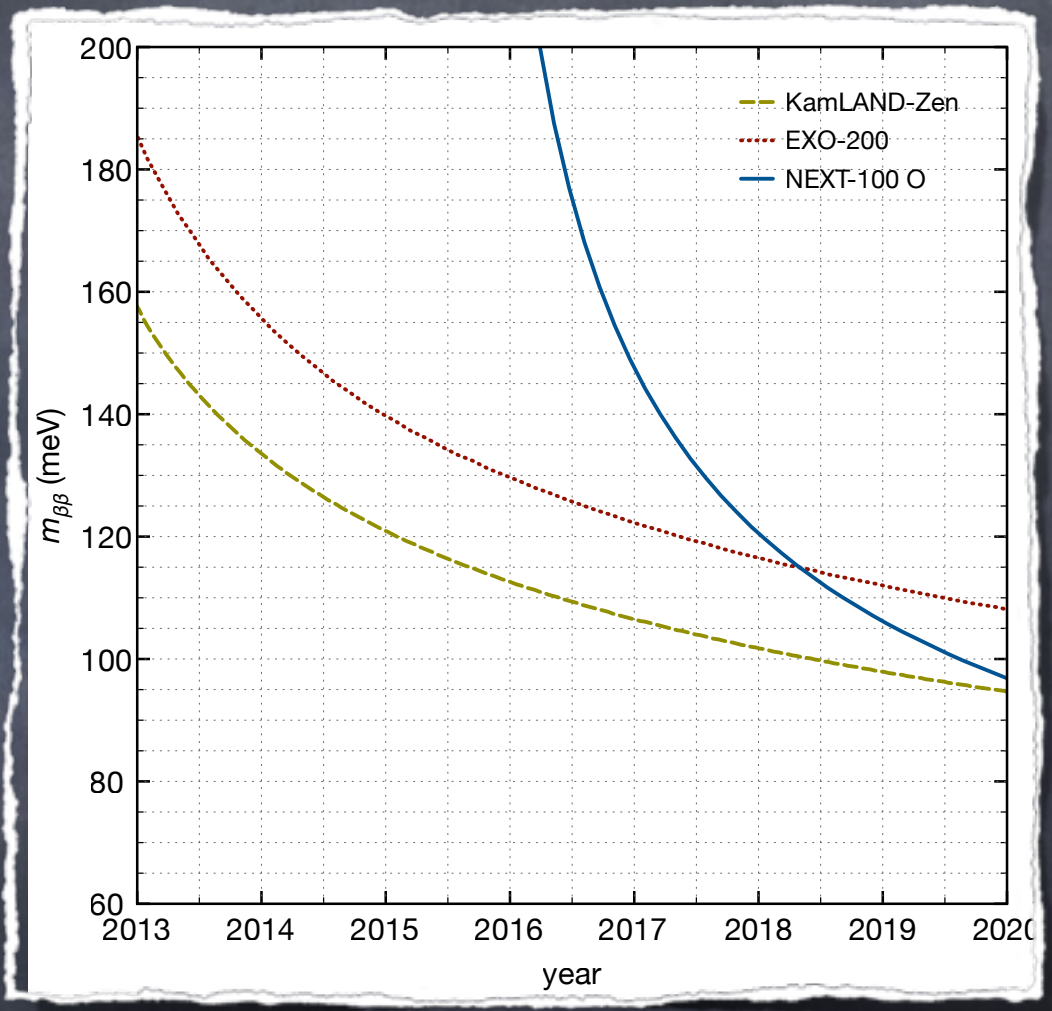
Comparing NEXT

- EXO200 and KamLAND-Zen set current best limits on ^{136}Xe $\beta\beta0\nu$
  - Assume same background and energy resolution that currently measured
- NEXT-100 reach on $m_{\beta\beta}$
  - Using estimation of background contamination and measurements of energy resolution with prototypes



Experiment	M (kg)	enrichment (%)	efficiency (%)	ΔE (% FWHM)	B (10^{-3} ckky)
EXO-200	110	81	52	3.9	1.5
KamLAND-Zen	330	91	62	9.9	1.0
NEXT-100	100	91	30	0.7	0.5

ΔE and Tracking

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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, over 80 people, 5 countries

Grants: Consolider-2008 (Spain), ERC-ADG 2013 (EU)

NEXT Collaboration

Always ready to welcome new collaborators willing:

- To bring technical expertise
- To bring resources
- To contribute to the project
- To work in hardware
- To do software and analysis, if you really must

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Concluding Remarks

- NEXT-DEMO has demonstrated:
  - Energy resolution < 1% FWHM
  - Tracking Capabilities
- Facilities and Infrastructure at LSC
  - Laboratory Space is ready
  - 100 kg of 90% enriched ^{136}Xe is at LSC
  - Ge counters for radiopurity testing
- NEXT-NEW
  - Under Construction Presently
  - Gas system at LSC
  - Electronics at LSC
  - 10 kg at LSC by end of 2014
  - Able to measure $\beta\beta 2\nu$ ($\sim$600 expected detected events in half year) and validate background modelling and reconstruction
- NEXT 100 at LSC by 2016
  - Use same ancillary systems as NEXT-NEW
  - Explore $\beta\beta 0\nu$ to 100 meV effective ν masses
  - Can be a solution to multi tonne Next generation of detectors to explore down to 20 meV effective ν masses

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The End