

*The NEXT experiment at
the LSC
status and prospects*

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Instituto de Física Corpuscular (CSIC & UVEG)



Princeton, October, 2013

Figure of merit

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

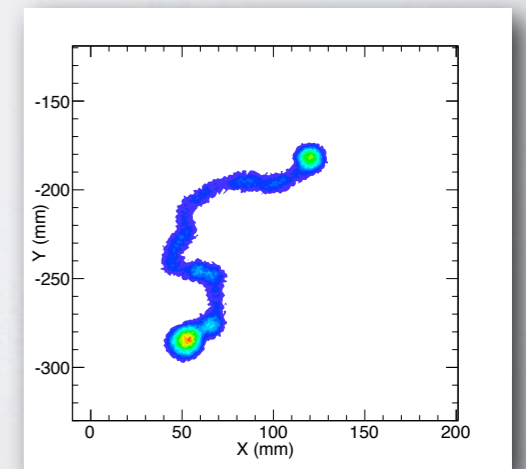
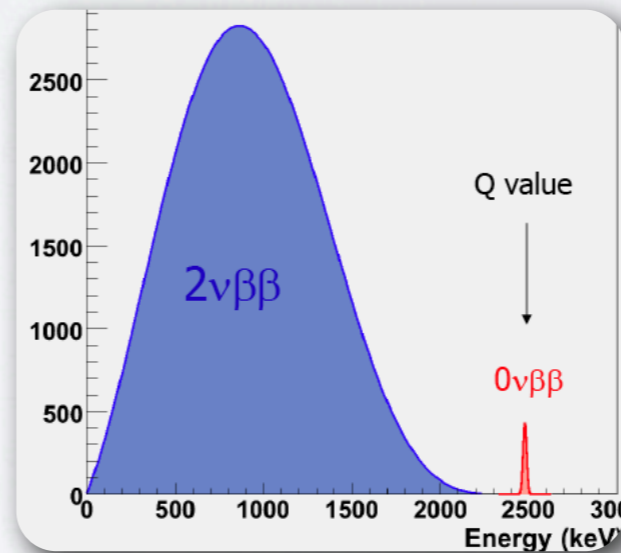
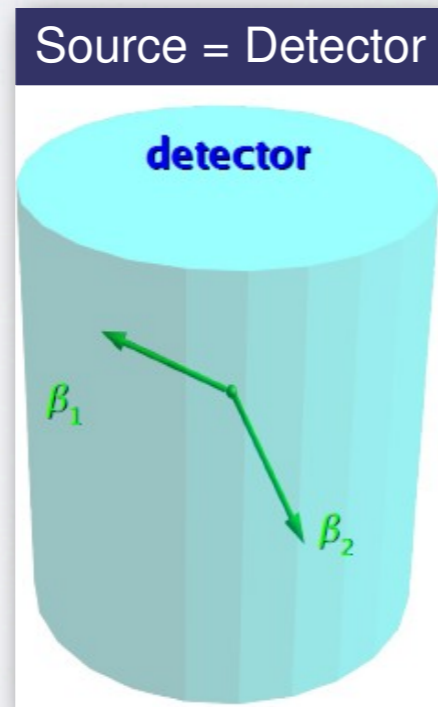


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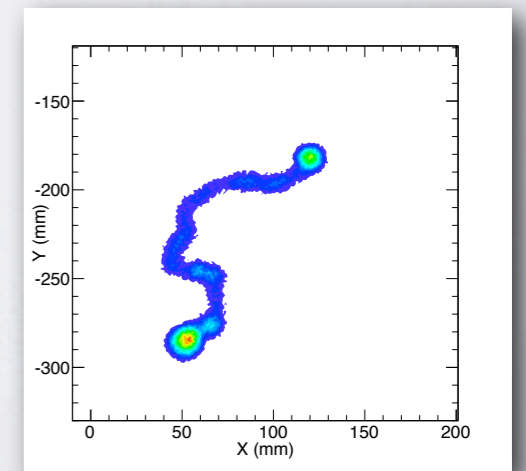
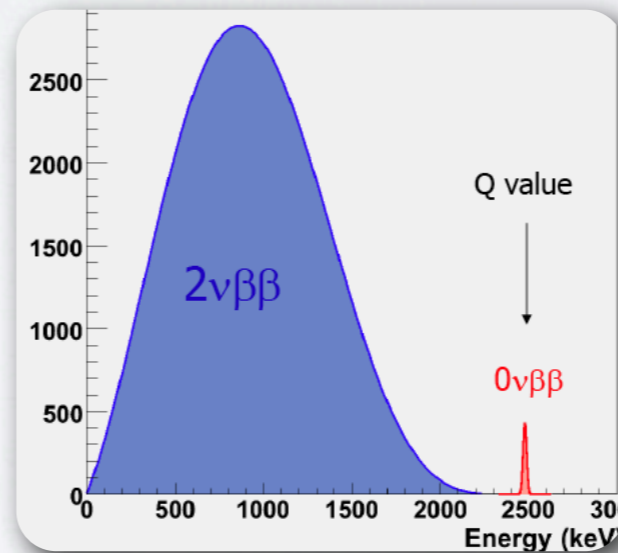
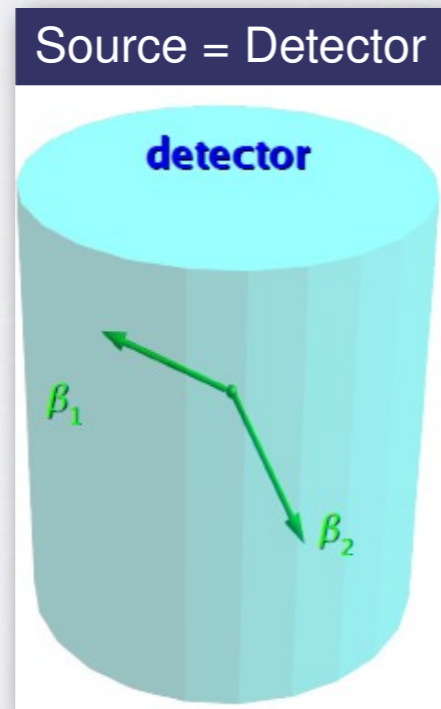


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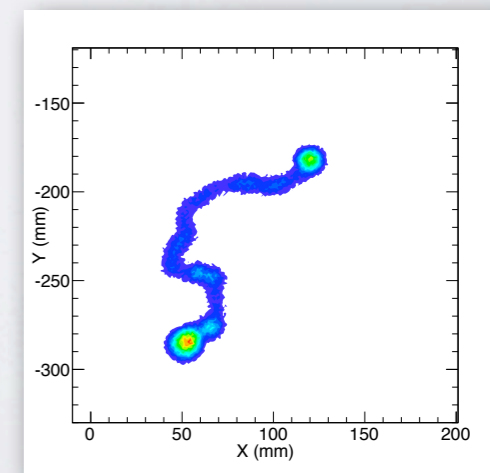
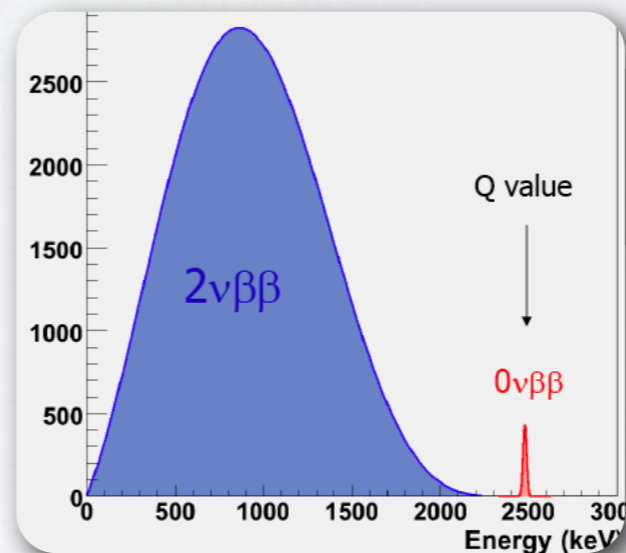
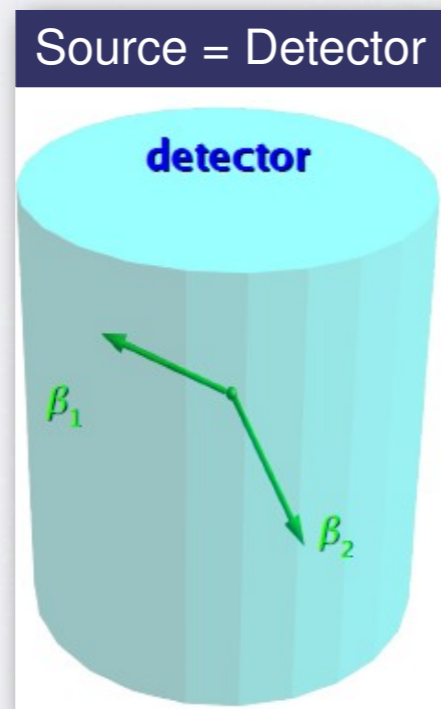


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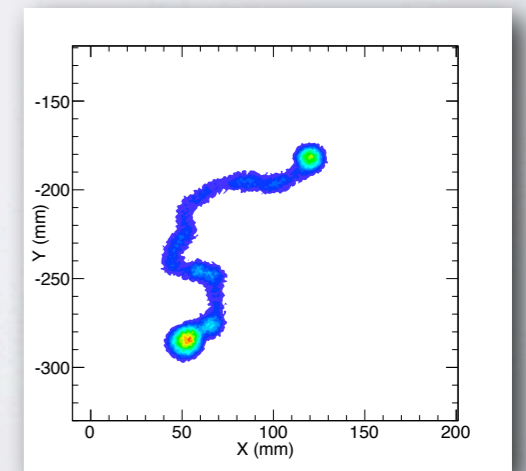
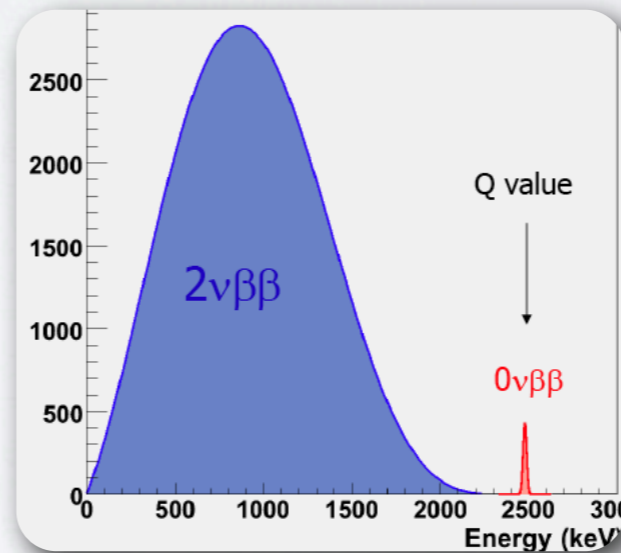
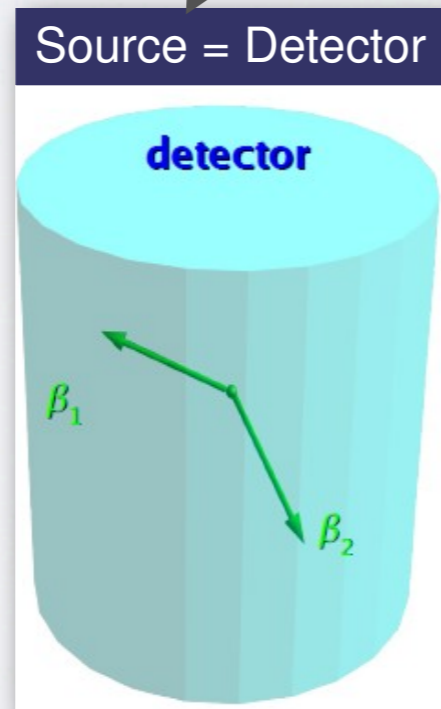
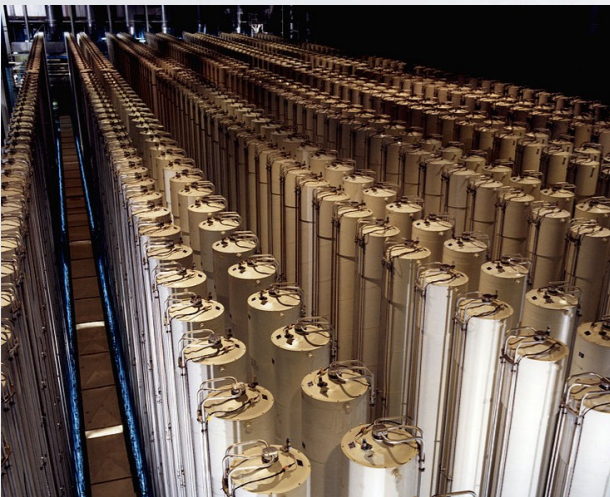


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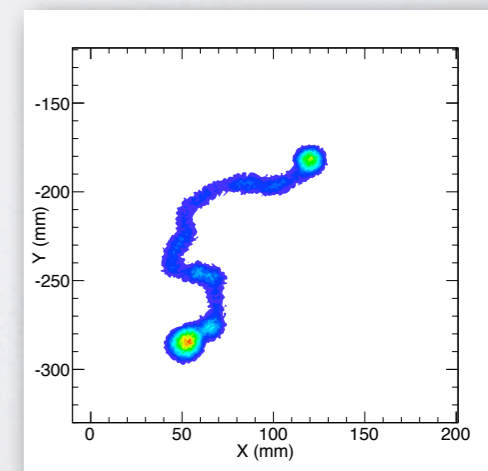
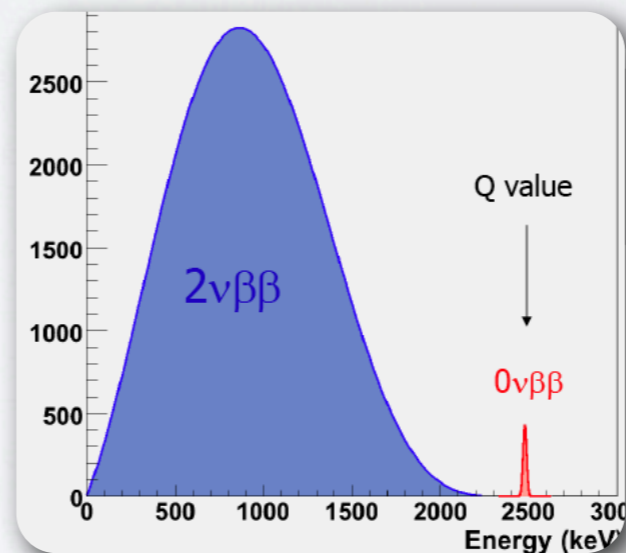
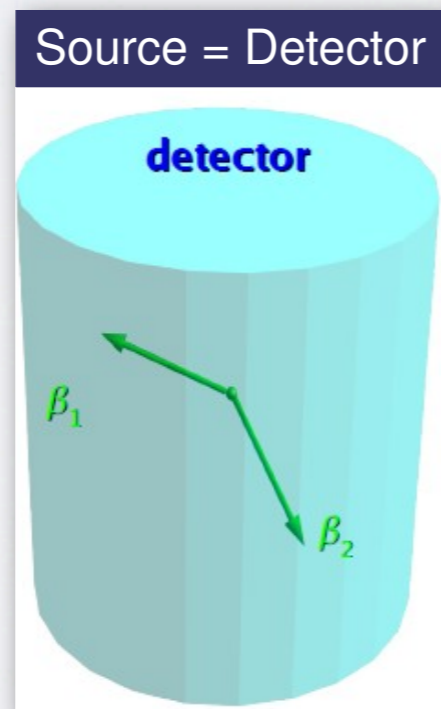


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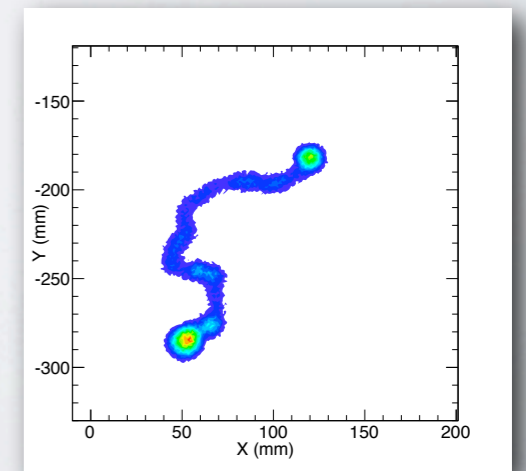
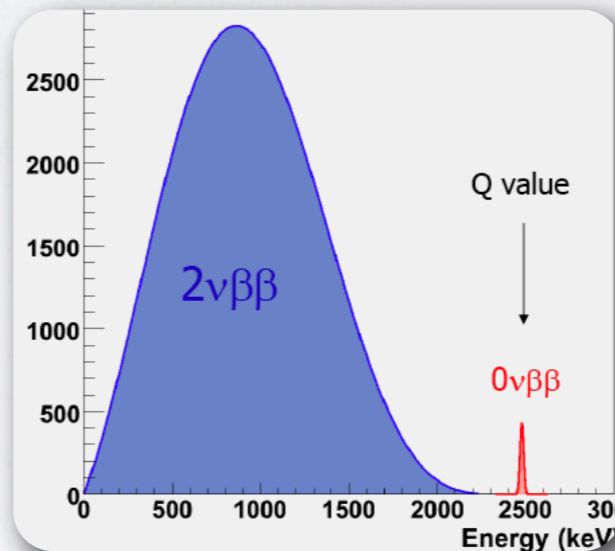
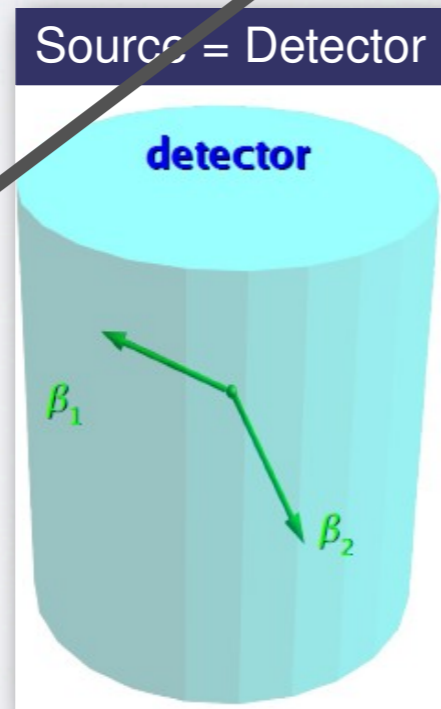
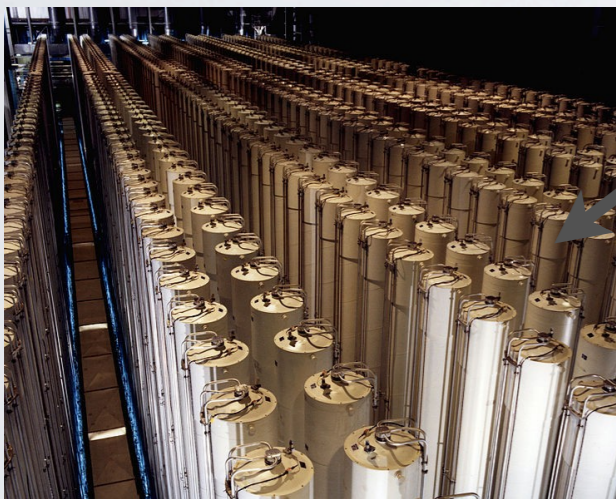


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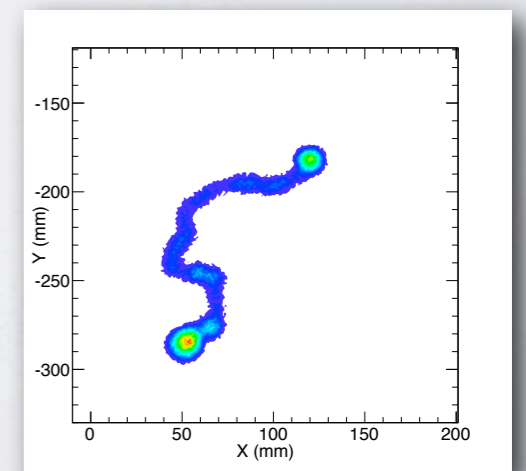
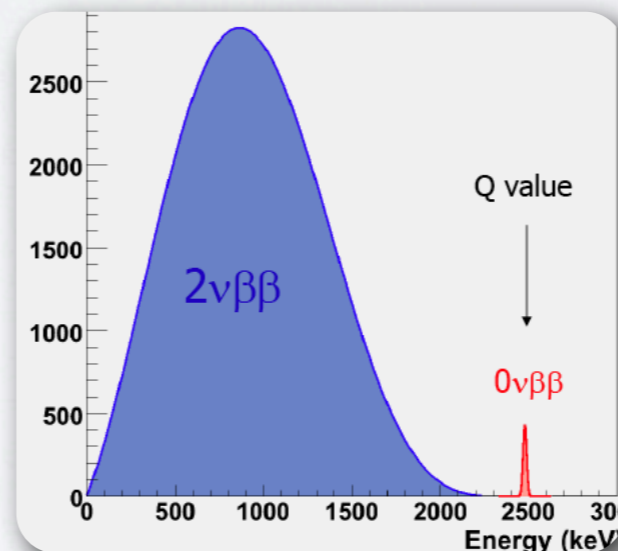
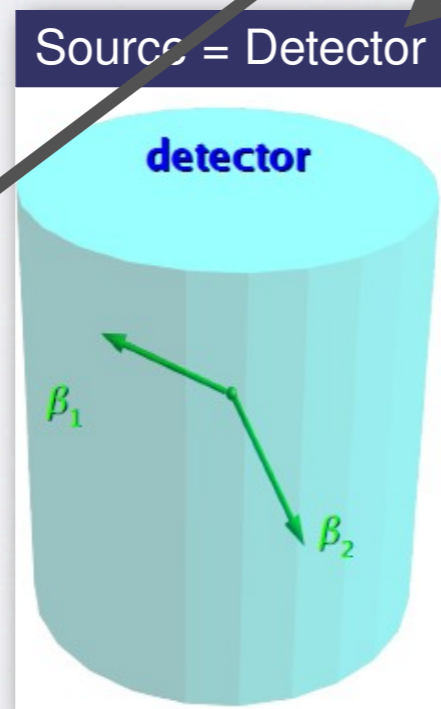


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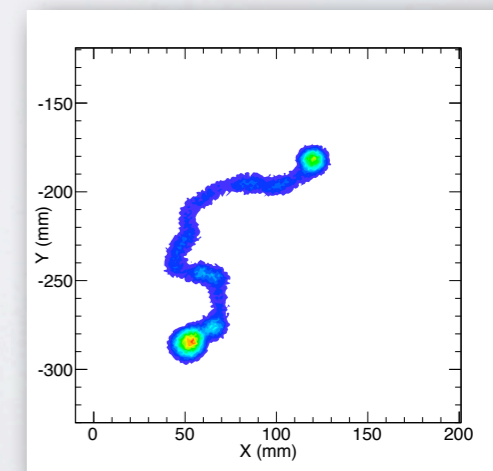
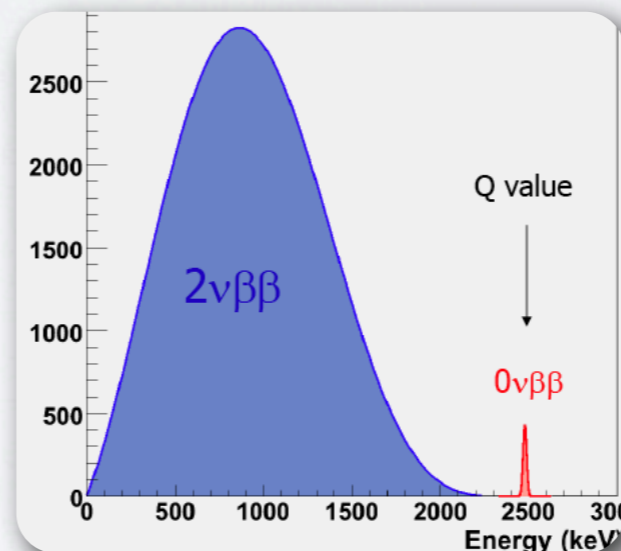
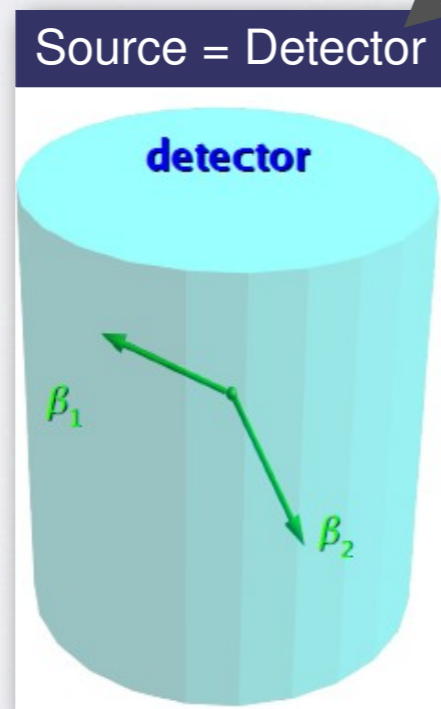


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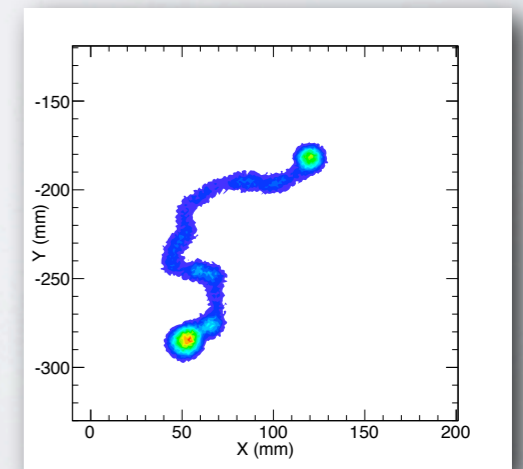
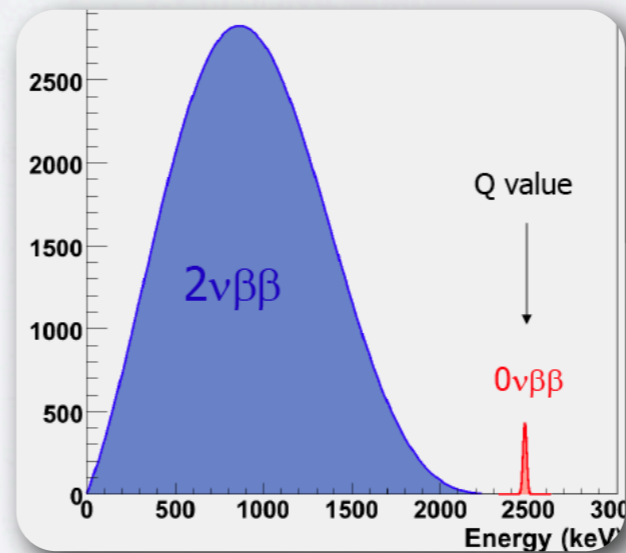
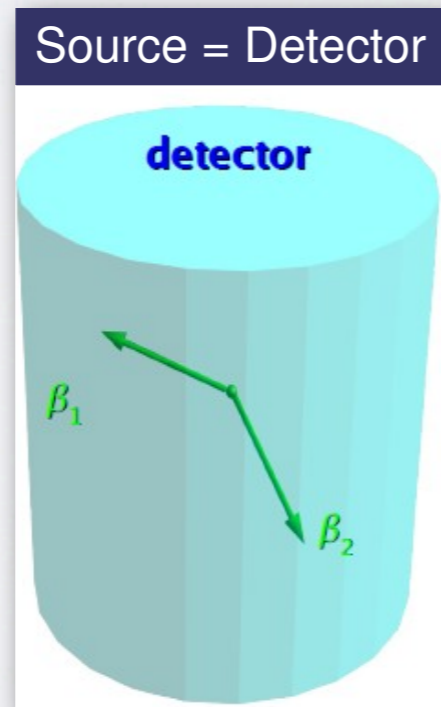
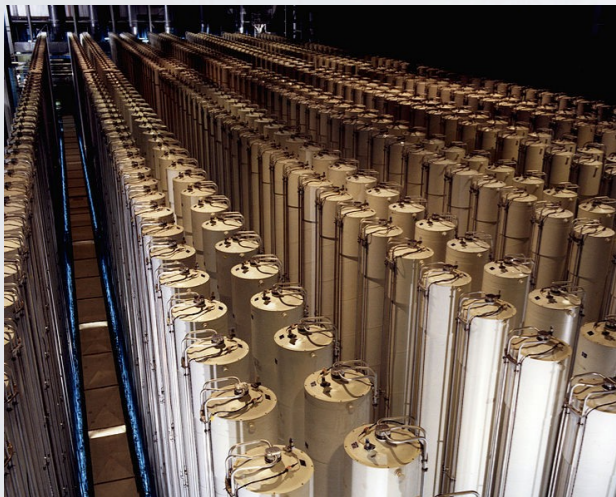


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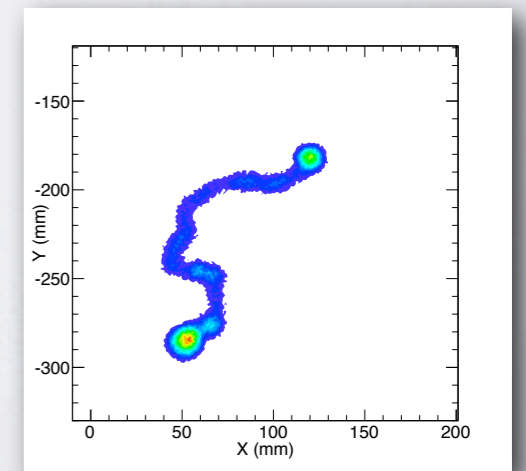
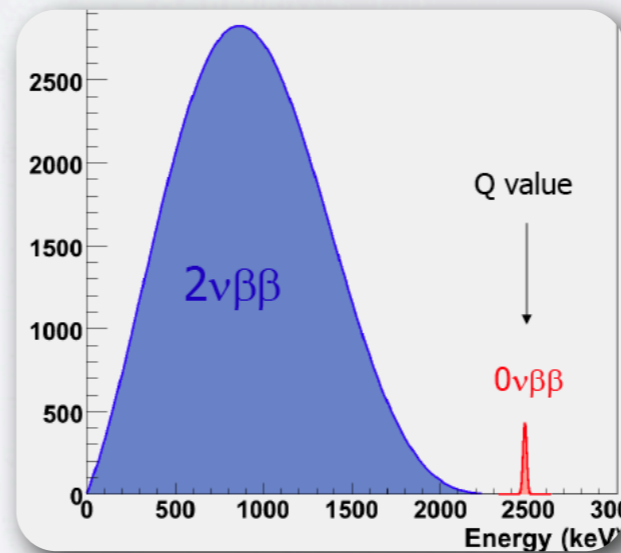
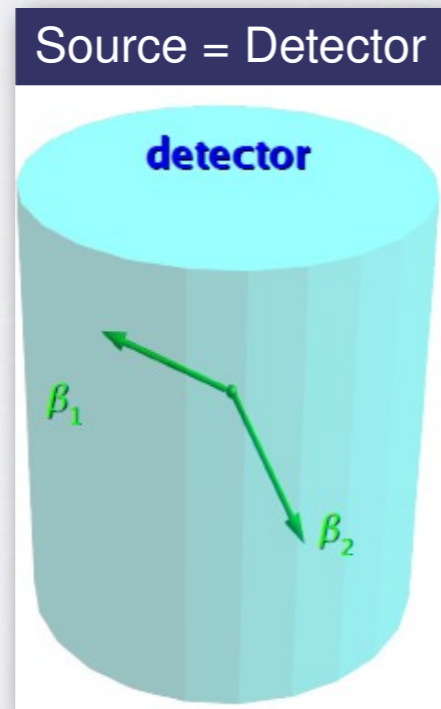


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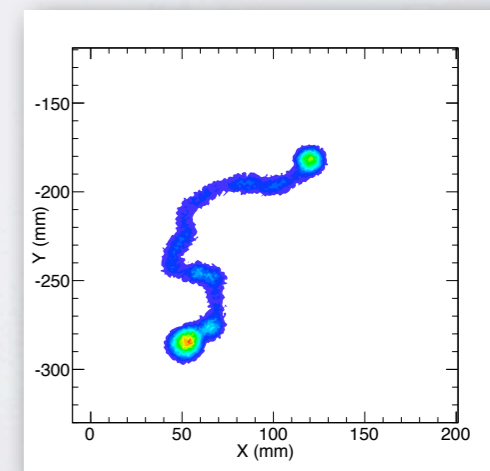
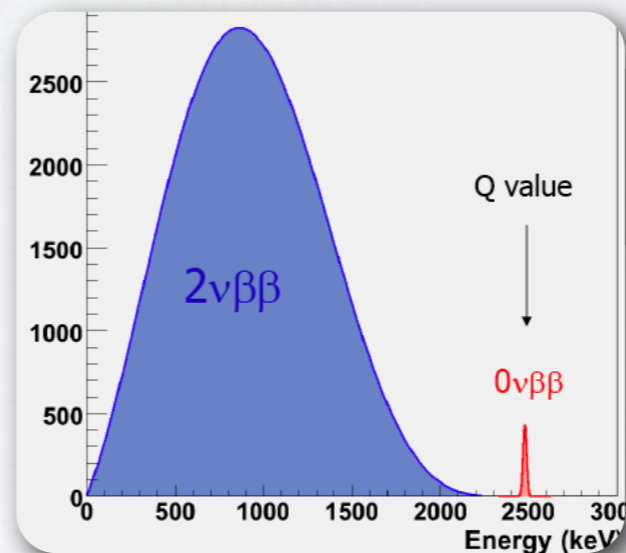
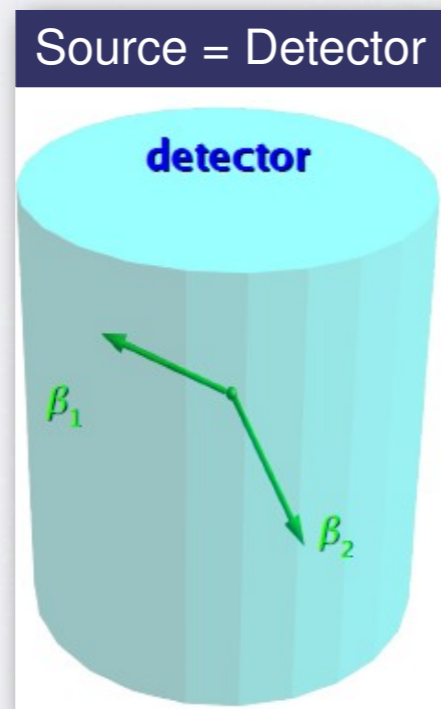


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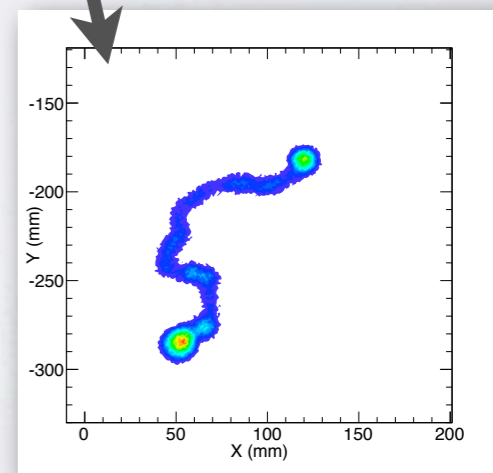
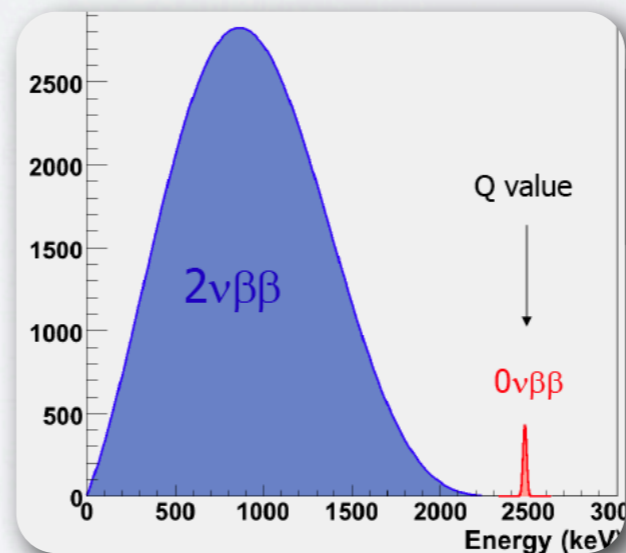
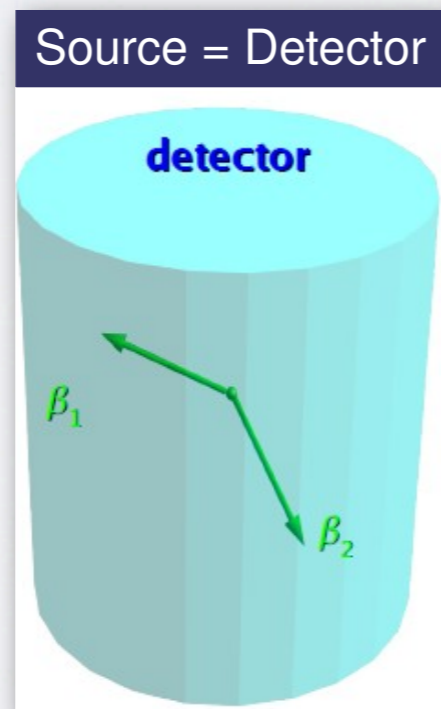


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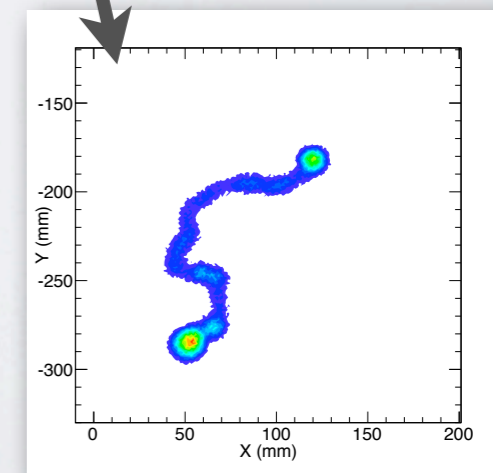
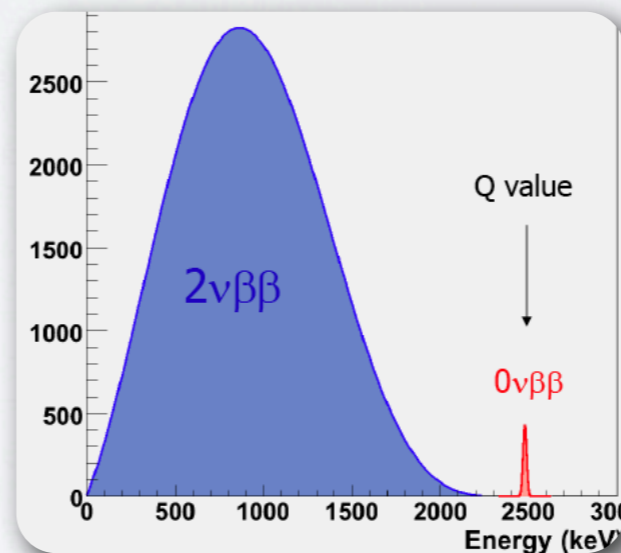
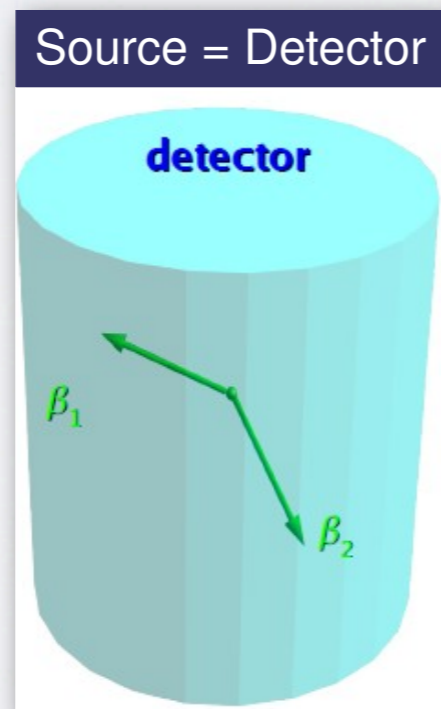


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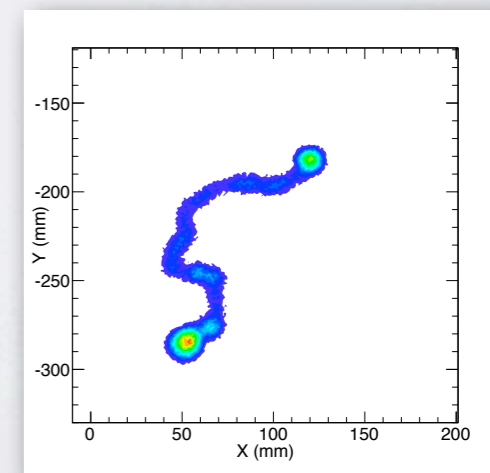
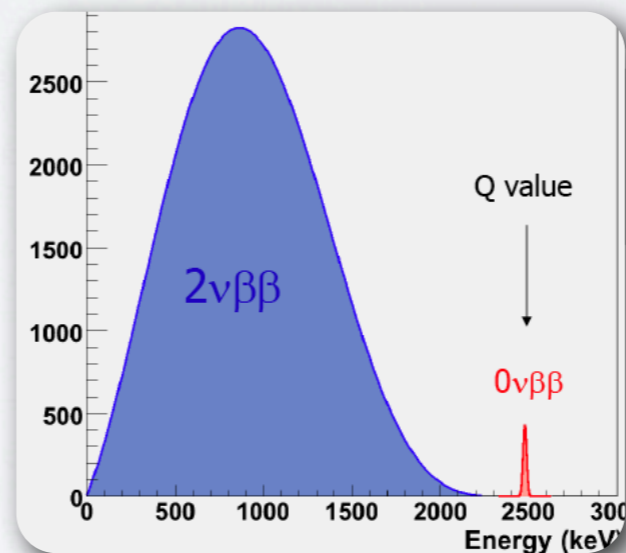
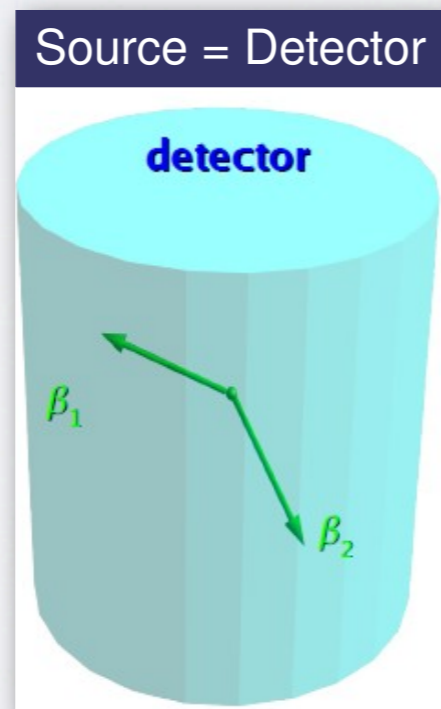
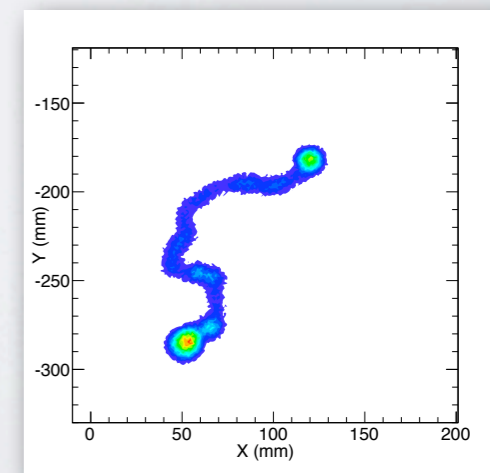
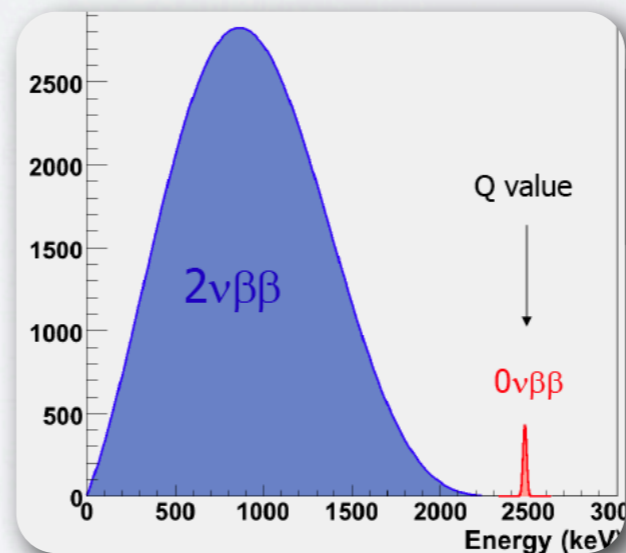
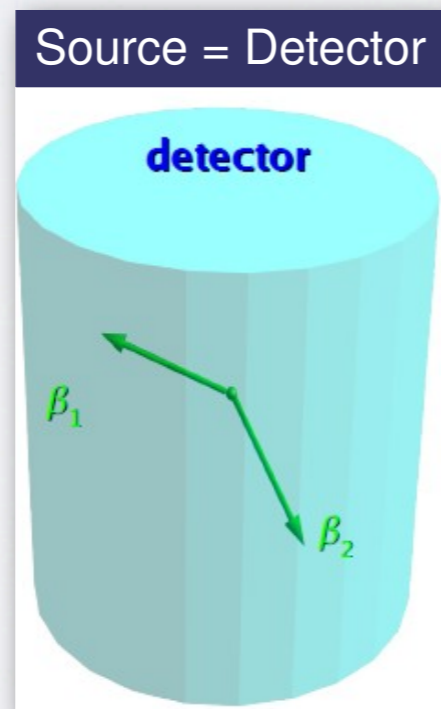
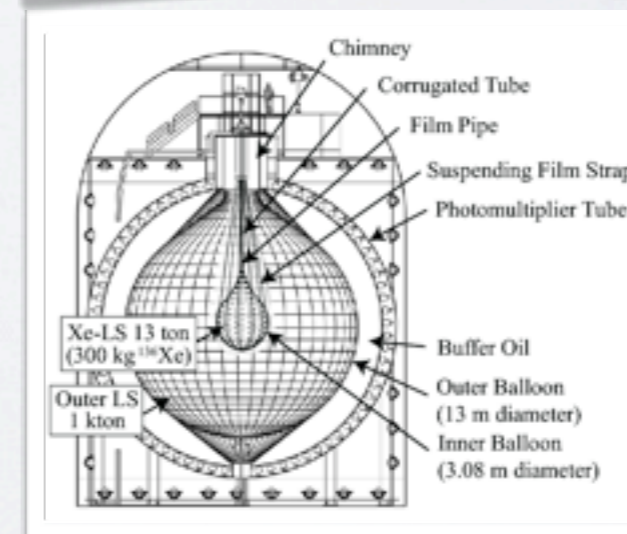
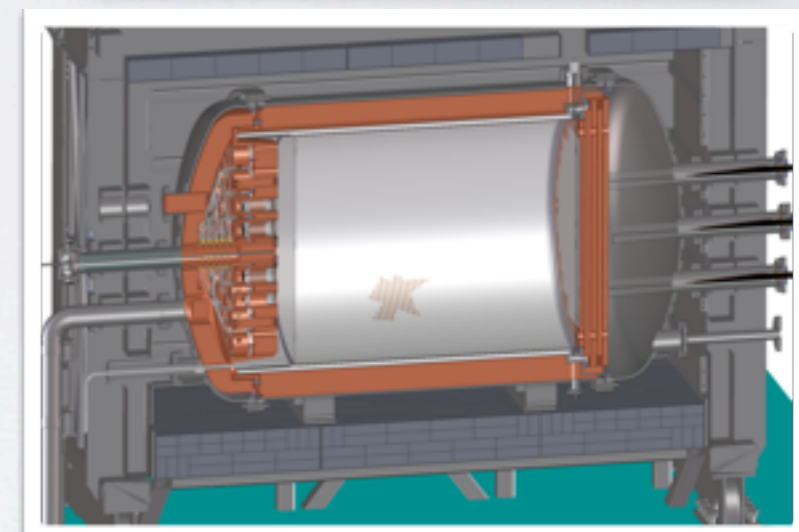
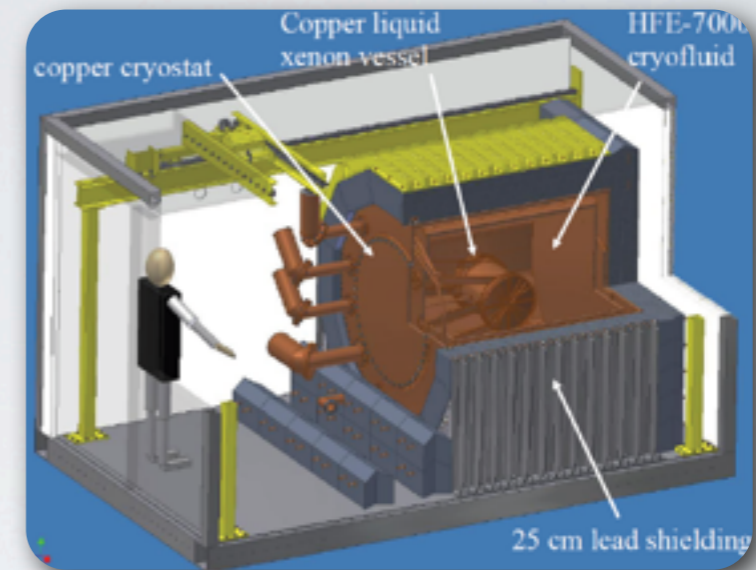
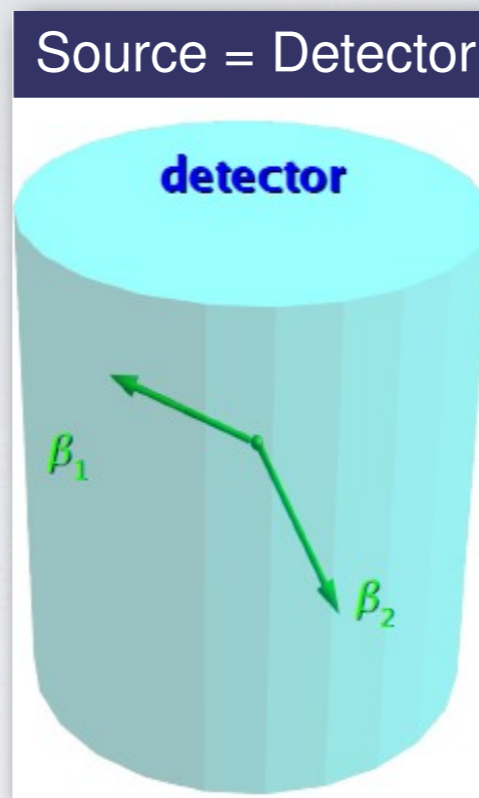
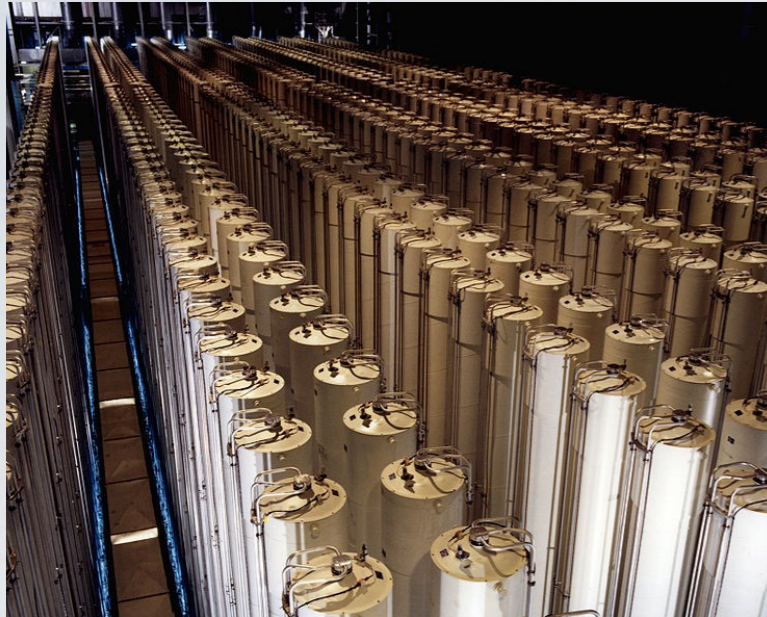


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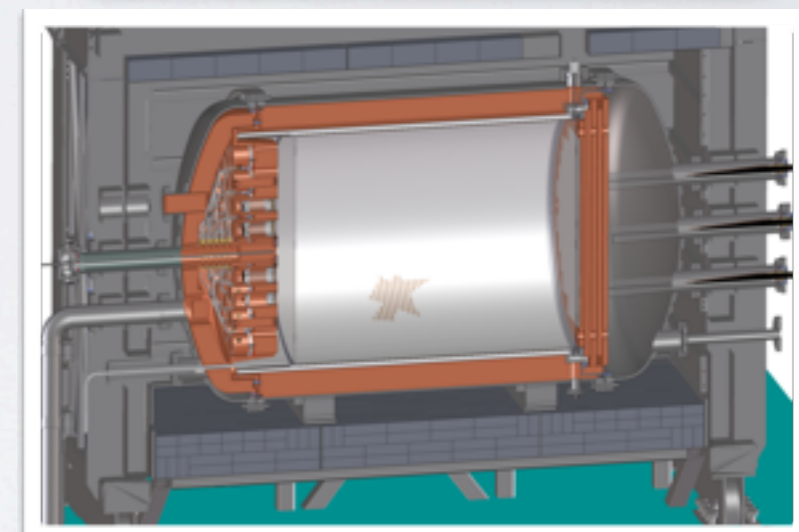
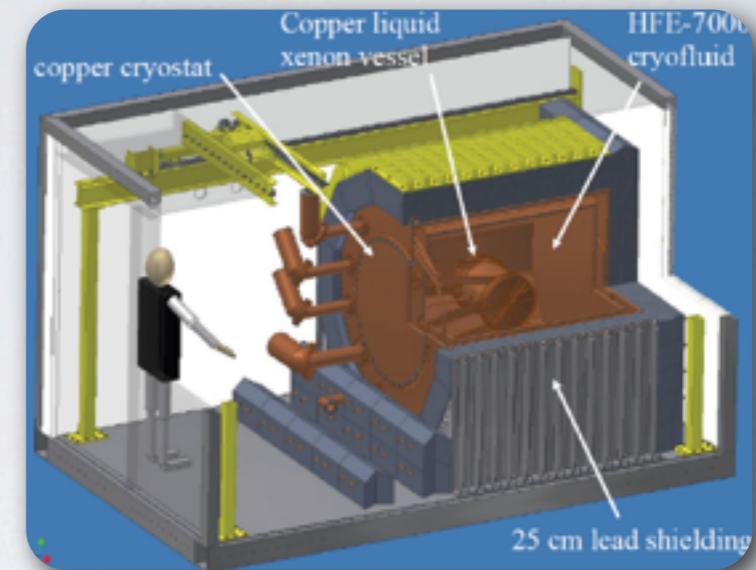
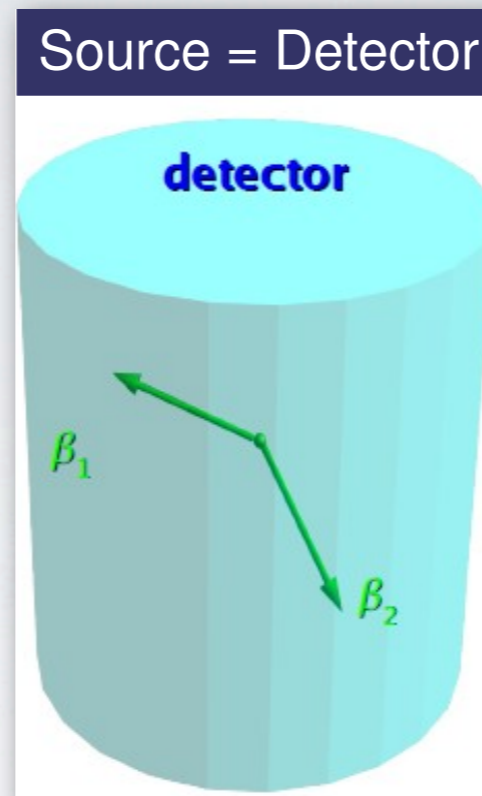
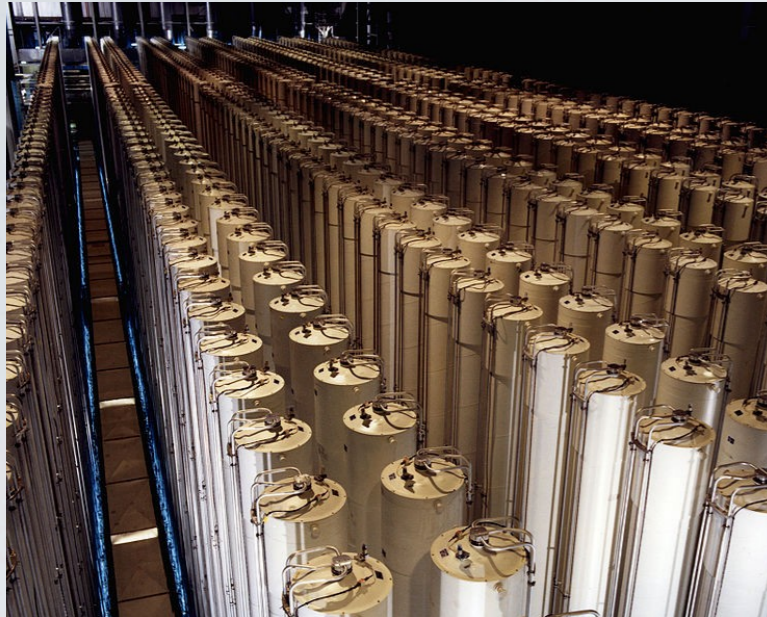
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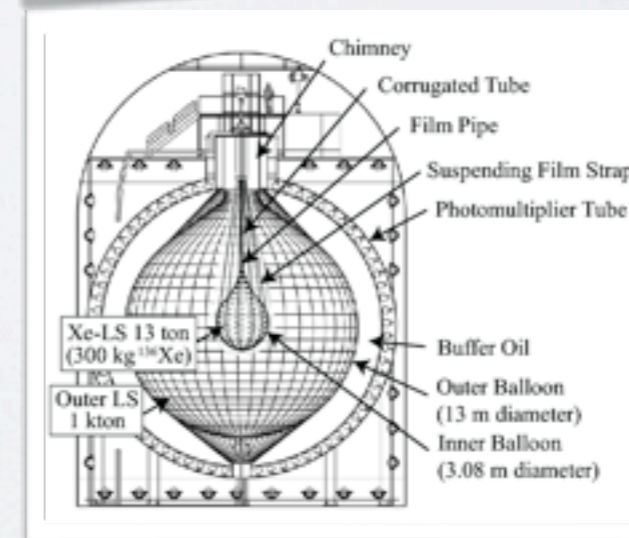
Xenon experiments



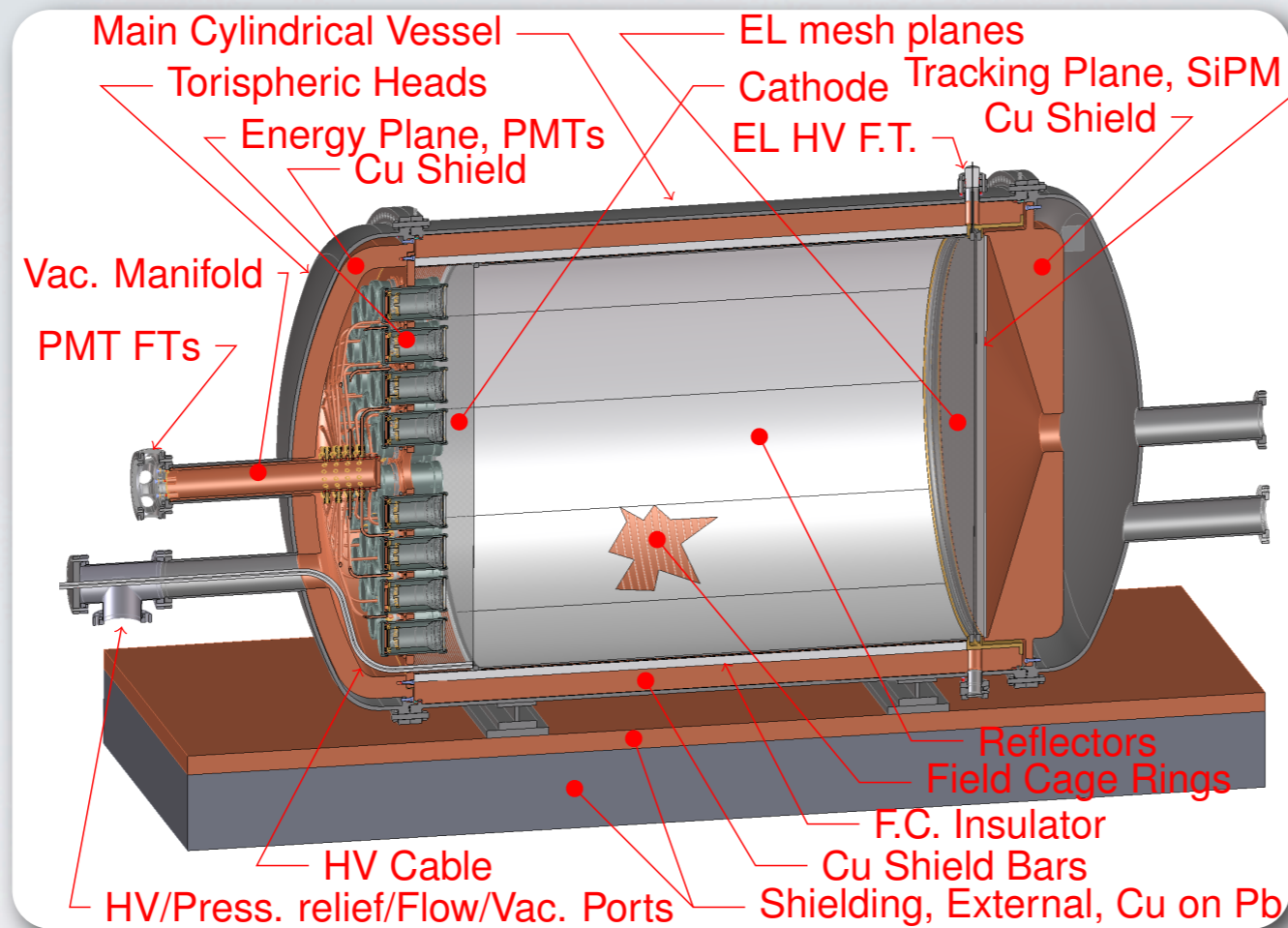
Xenon experiments



- Xenon: cheap and easy to enrich (1/10 other isotopes).
- Good Qbb. No other radioactive isotopes.
- Noble gas: can be used to build HPXe or LXe. Can be dissolved in LScint.
- Fully active, scalable detectors.



NEXT: the new kid on the block



- **A High Pressure Gas Xenon TPC.**
- **Can hold 100 kg of Xenon at 10 bar or 150 kg at 15 bar.**
- **Strong points: energy resolution, topological signature**
- **Made of radiopure components**
- **Operating at LSC (Canfranc)**
- **Recently obtained an AdG grant from ERC (starts 2014)**

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2
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5

[Información:](#)
[Referencias \(0\)](#)
[Citas \(4\)](#)
[Ficheros](#)
[Gráficos](#)

The Milano experiment on double beta decay of Xe-136

[L. Zanotti](#), [E. Bellotti](#), [O. Cremonesi](#), [E. Fiorini](#), [G. Gervasio](#), [S. Ragazzi](#), [L. Rossi](#), [J. Szarka](#), [P.P. Sverzellati](#), [T. Tabarelli](#) ([Milan U.](#) & [Gran Sasso](#) & [Comenius U.](#))
1991

1
2

J.Phys. G17 (1991) S231-S241
DOI: [10.1088/0954-3899/17/S/025](https://doi.org/10.1088/0954-3899/17/S/025)

1 - Neutrinoless Double Beta Decay

[\[1-1\]](#)

Search for beta beta decay in Xe-136: New results from the Gotthard experiment, [Luscher, R. et al.](#), Phys. Lett. **B434** (1998) 407-414.

[\[1-2\]](#)

Final report on the search for neutrinoless double beta decay of Ge-76 from the Gotthard underground experiment, [Reusser, D. et al.](#), Phys. Rev. **D45** (1992) 2548-2551.

[\[1-3\]](#)

First 0ν half-life limit from the Gotthard xenon time projection chamber, [Wong, H. T. et al.](#), J. Phys. **G17** (1991) S165-S172.

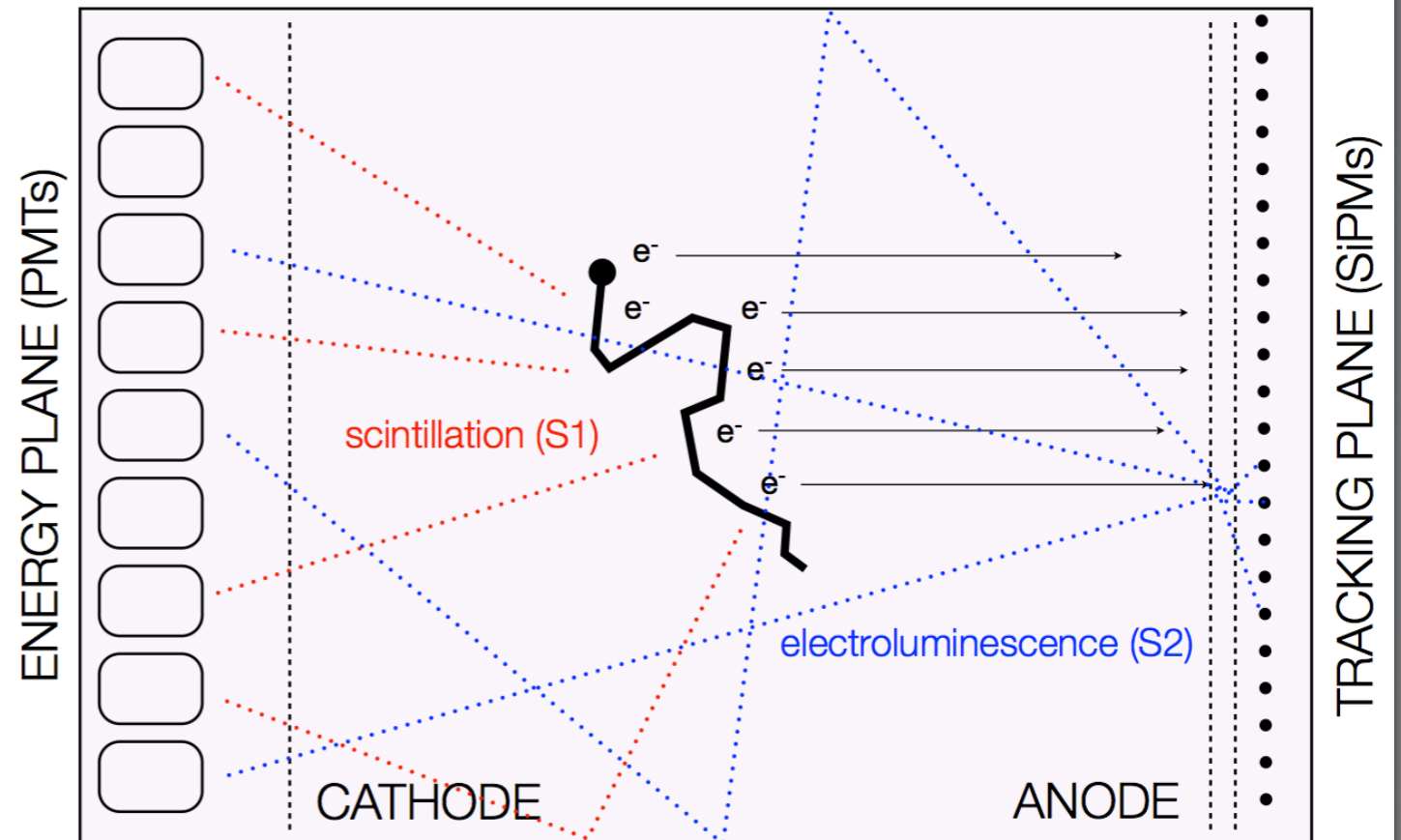
[\[1-4\]](#)

Double beta decay and dark matter in the Gotthard germanium experiment, [Treichel, M. et al.](#), J. Phys. **G17** (1991) S193-S201.

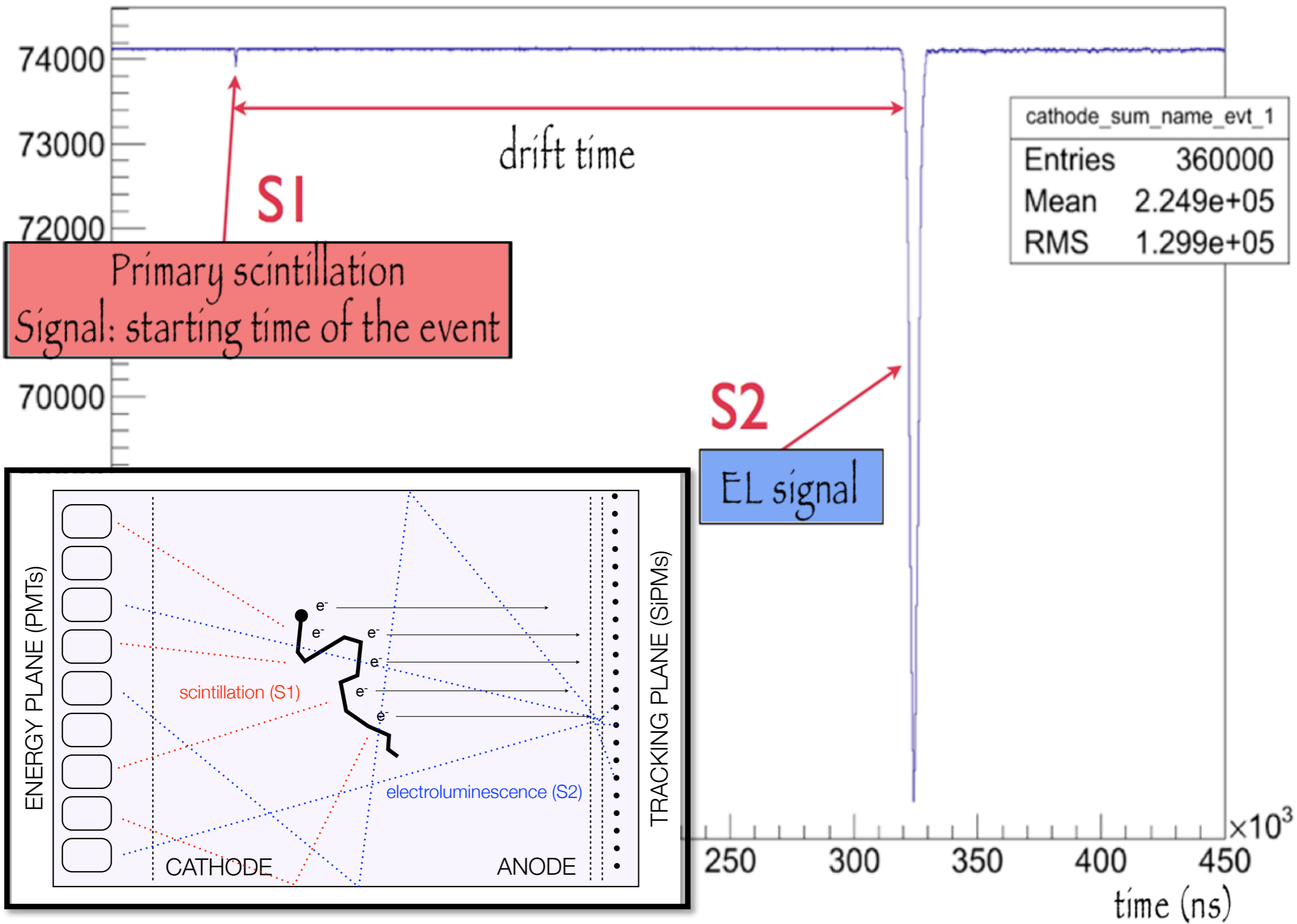
NEXT CONCEPTUAL IDEA, light production

LIGHT PRODUCTION PROCESS

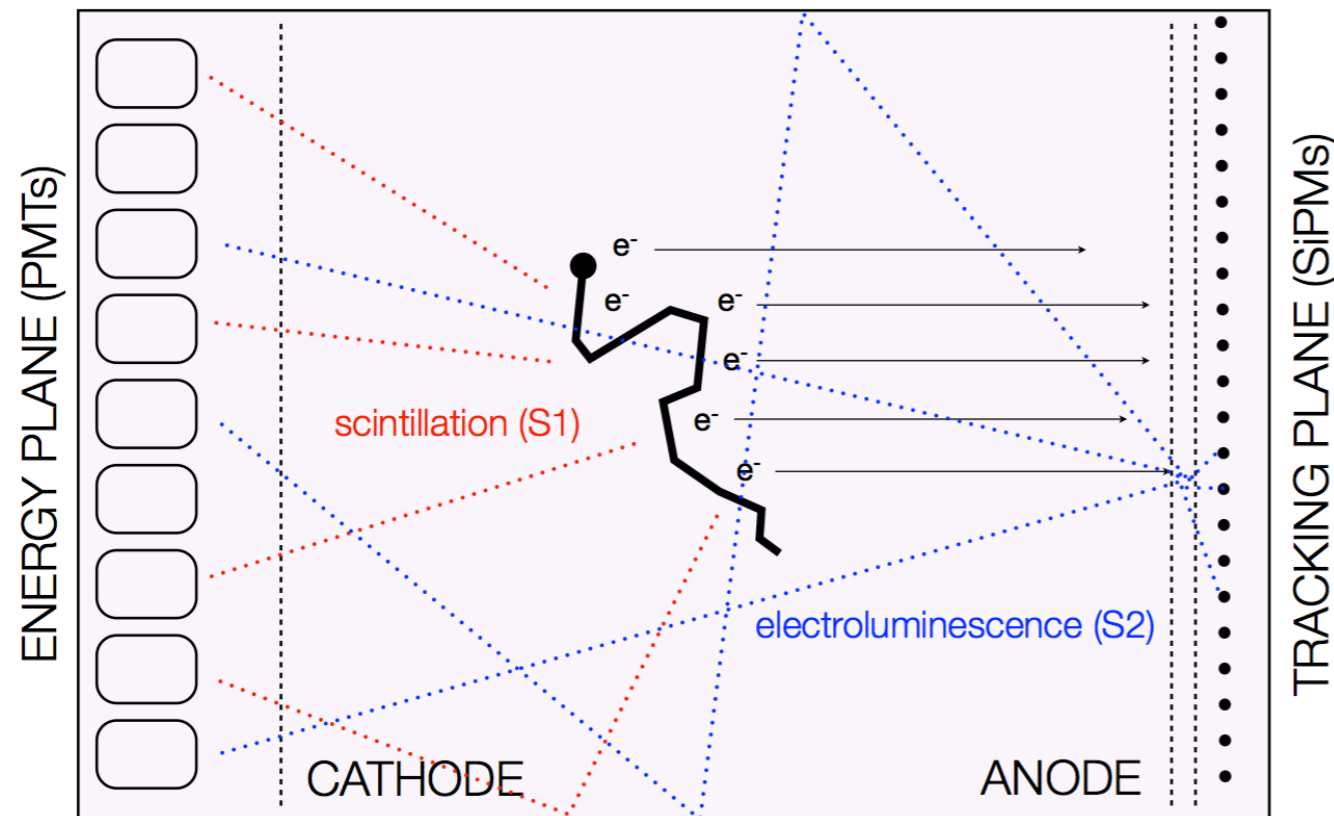
- Electrons excite and ionize Xe
- Excited Xenon emits **scintillation light** (172nm) that is detected by the PMTs at Energy Plane (**SIGNAL 1**)
- Electrons from ionization are **drifted** by a weak electric field to the **Electro-Luminescence (EL)** region
- There, a larger E field accelerate electrons such to **excite the Xe, but not enough to ionize it**. This process produce a large amount of 172nm photons that will be detected in both photo-sensors planes (**SIGNAL 2**)
- The **PMTs** in the energy plane will accurately measure the energy
- The **SiPMs** in the tracking plane will allow to reconstruct the track followed by the original particle.



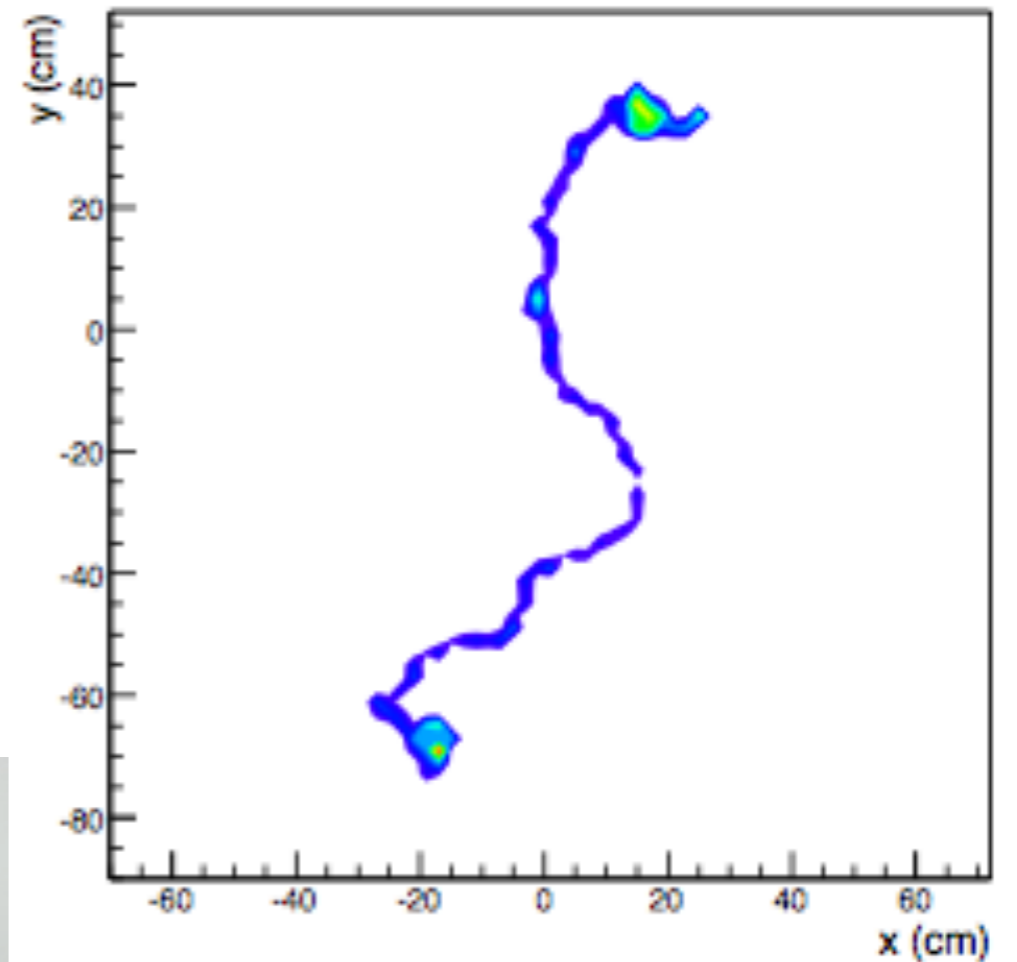
Tetra Phenyl Butadiene (TPB) Wave-Length-Shifter is used to convert the light from UV to 430 nm to make it visible to the SiPMs & increase the number of photons for improving energy resolution



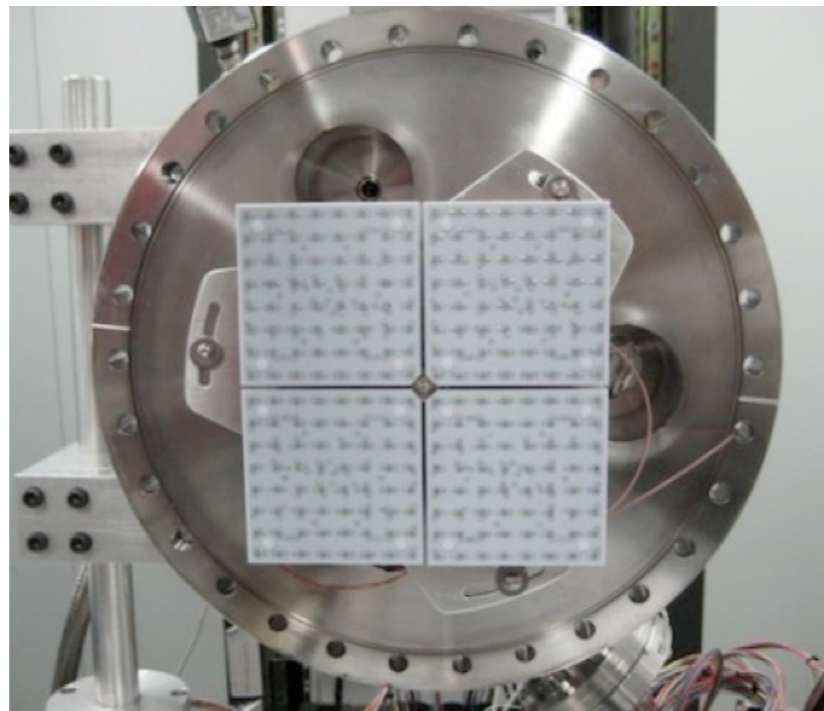
NEXT CONCEPTUAL IDEA, tracking



reconstructed tracks from a MC simulated $\beta\beta 0\nu$ event



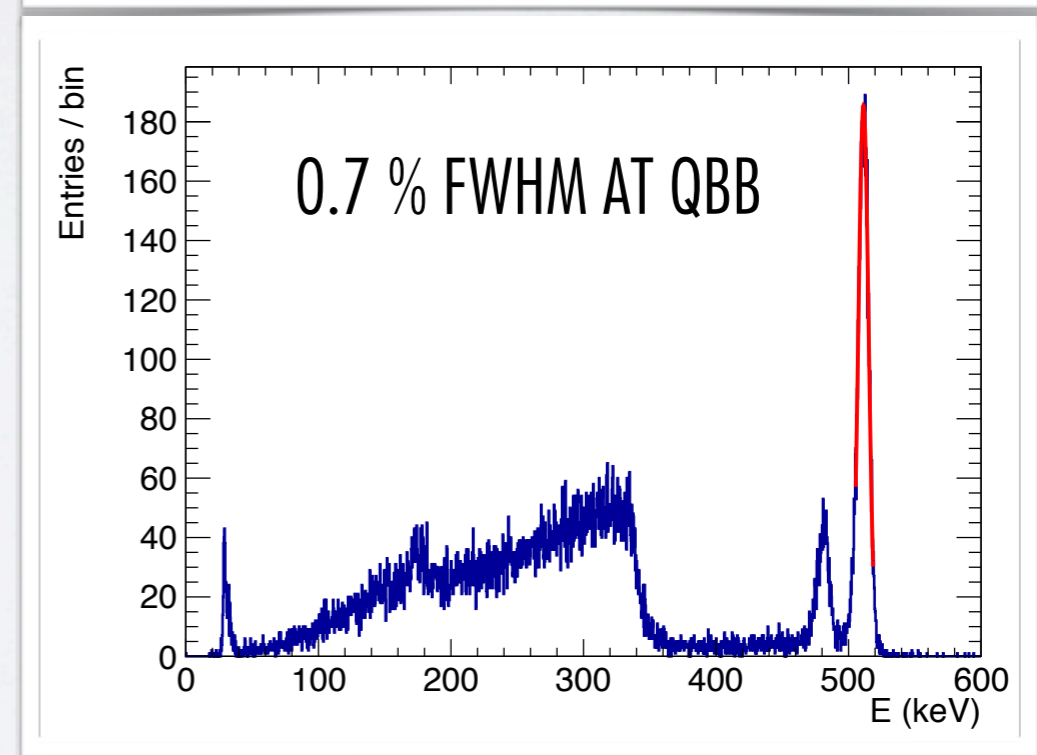
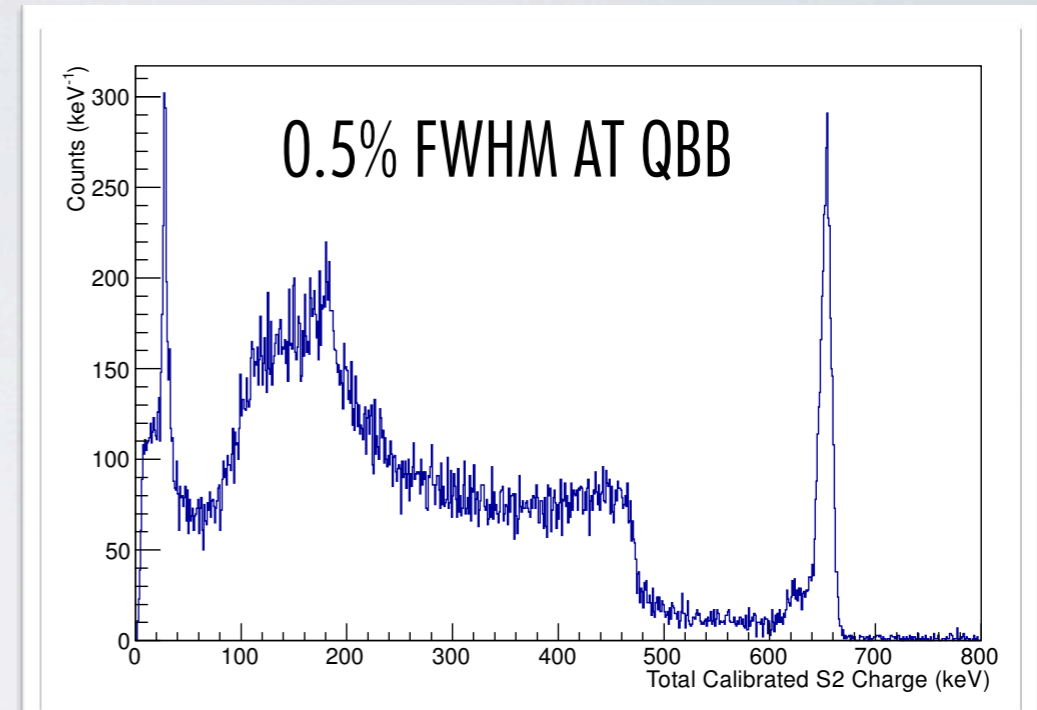
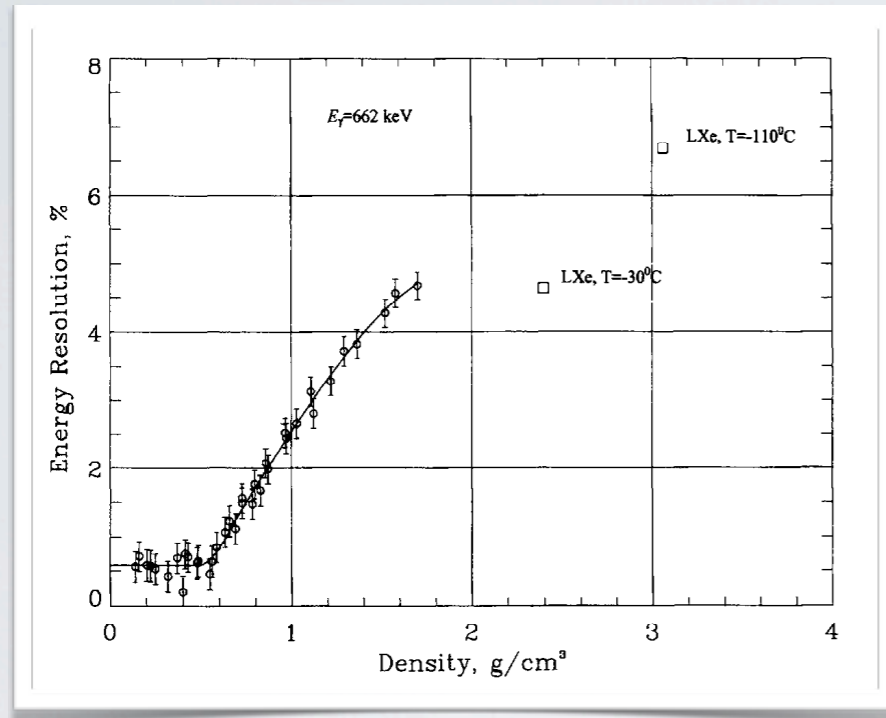
Tracking Plane of NEXT-DEMO, with 256 SiPMs for tracking



The signature of the electron is a twisted track with a strong energy deposition at its end

NEXT ENERGY RESOLUTION IS VERY GOOD

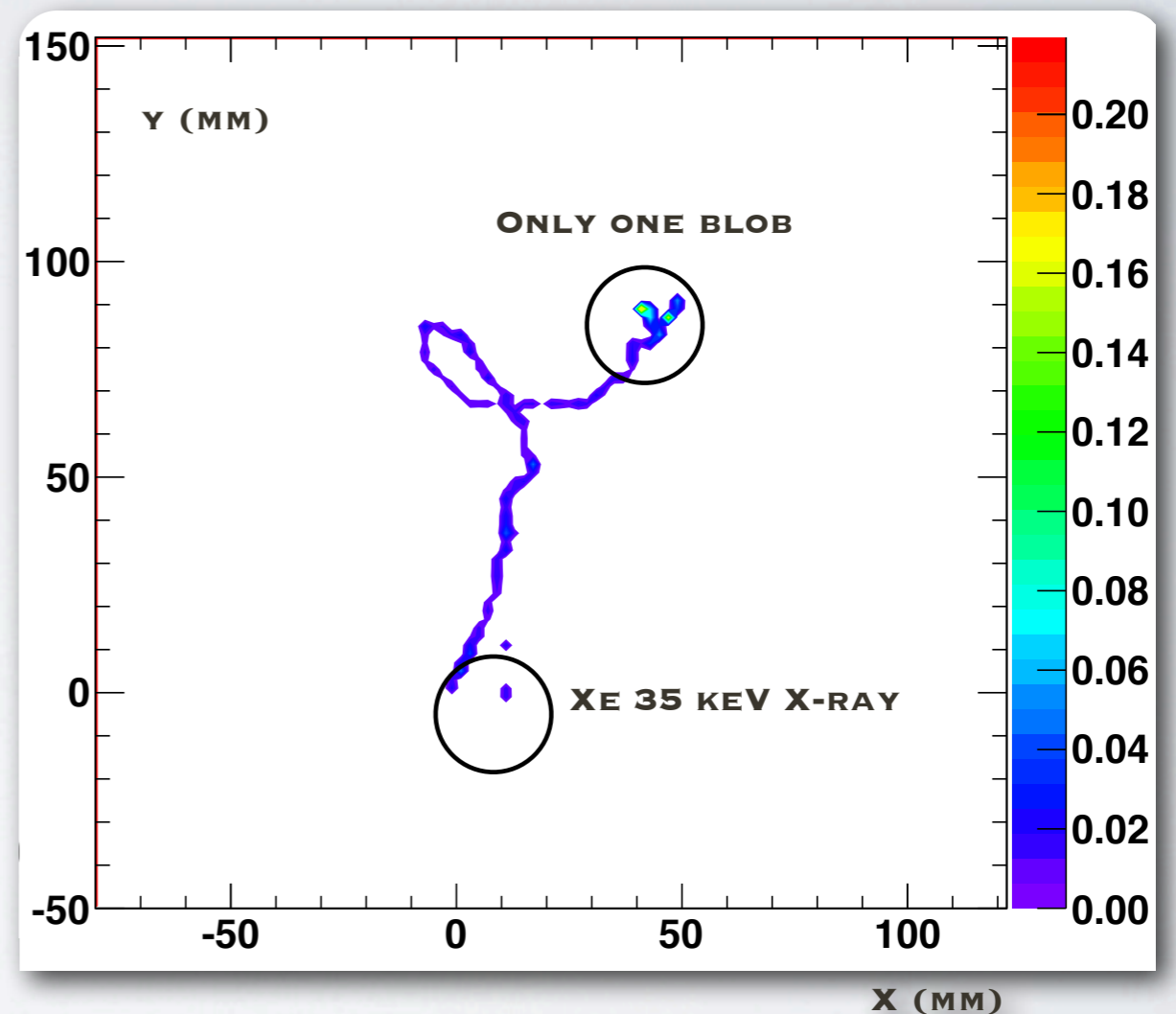
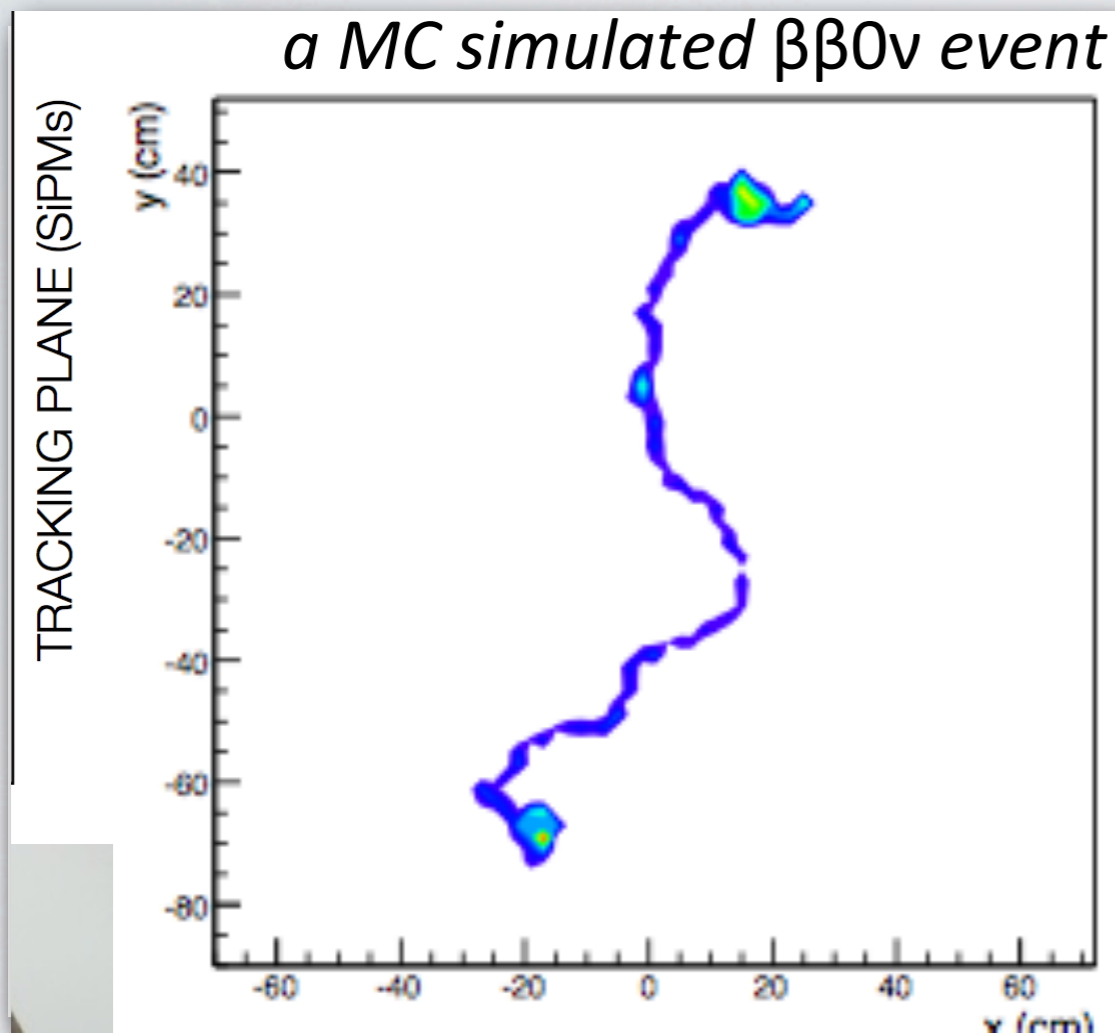
Bolotnikov and Ramsey, NIM A 396 (1997)



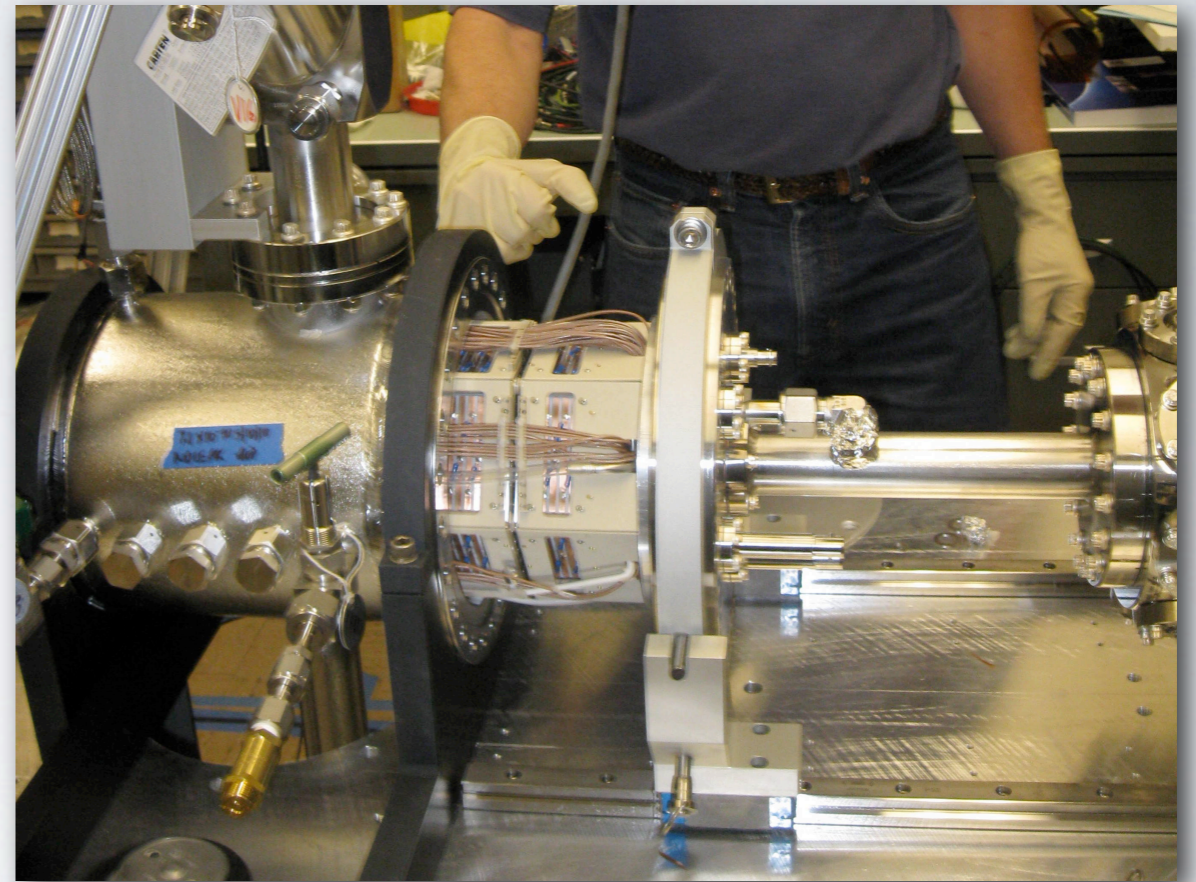
• **V.~Alvarez et al. [NEXT Collaboration],**
"Initial results of NEXT-DEMO, a large-scale
prototype of the NEXT-100 experiment,"
arXiv:1211.4838 [physics.ins-det].

• **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].

HPGXe has a topological signature (extra handle)



NEXT DEMO/DBDM



NEXT-DBDM at LBNL 0(1 kg of gas). NEXT-DEMO at IFIC





NEXT-DEMO

Hot Getter

Gas System

HHV modules

NEXT-DEMO



Hot Getter

Gas System

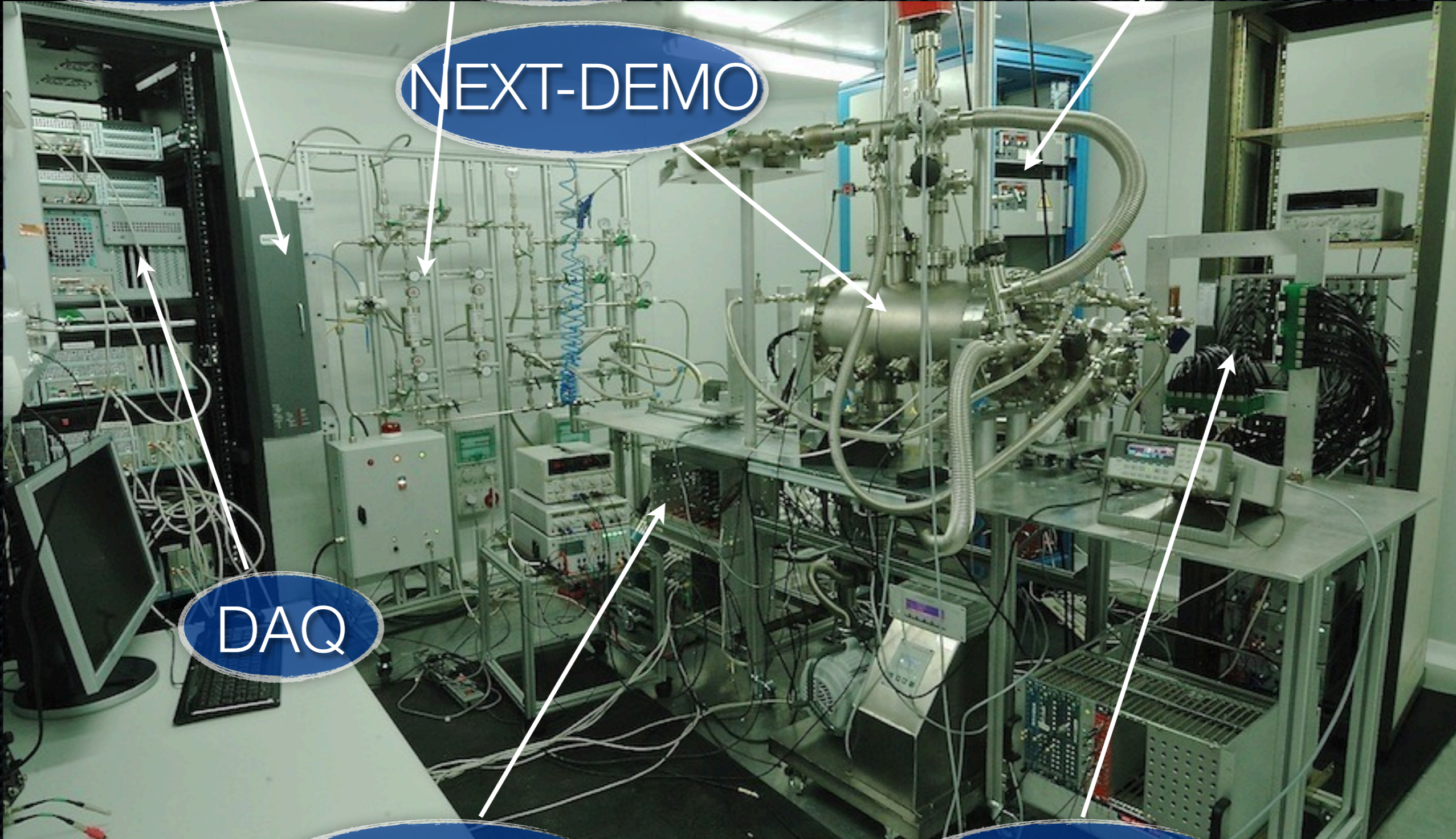
HHV modules

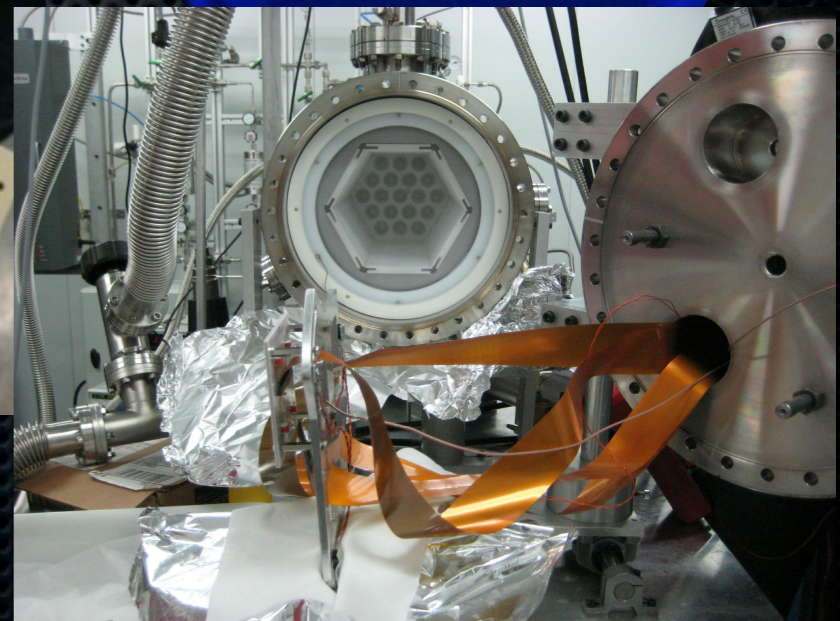
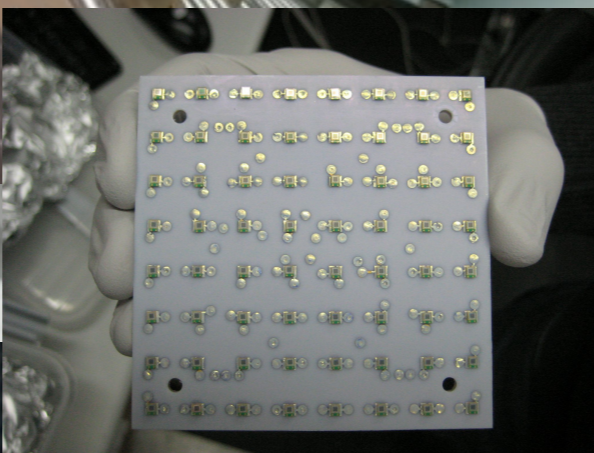
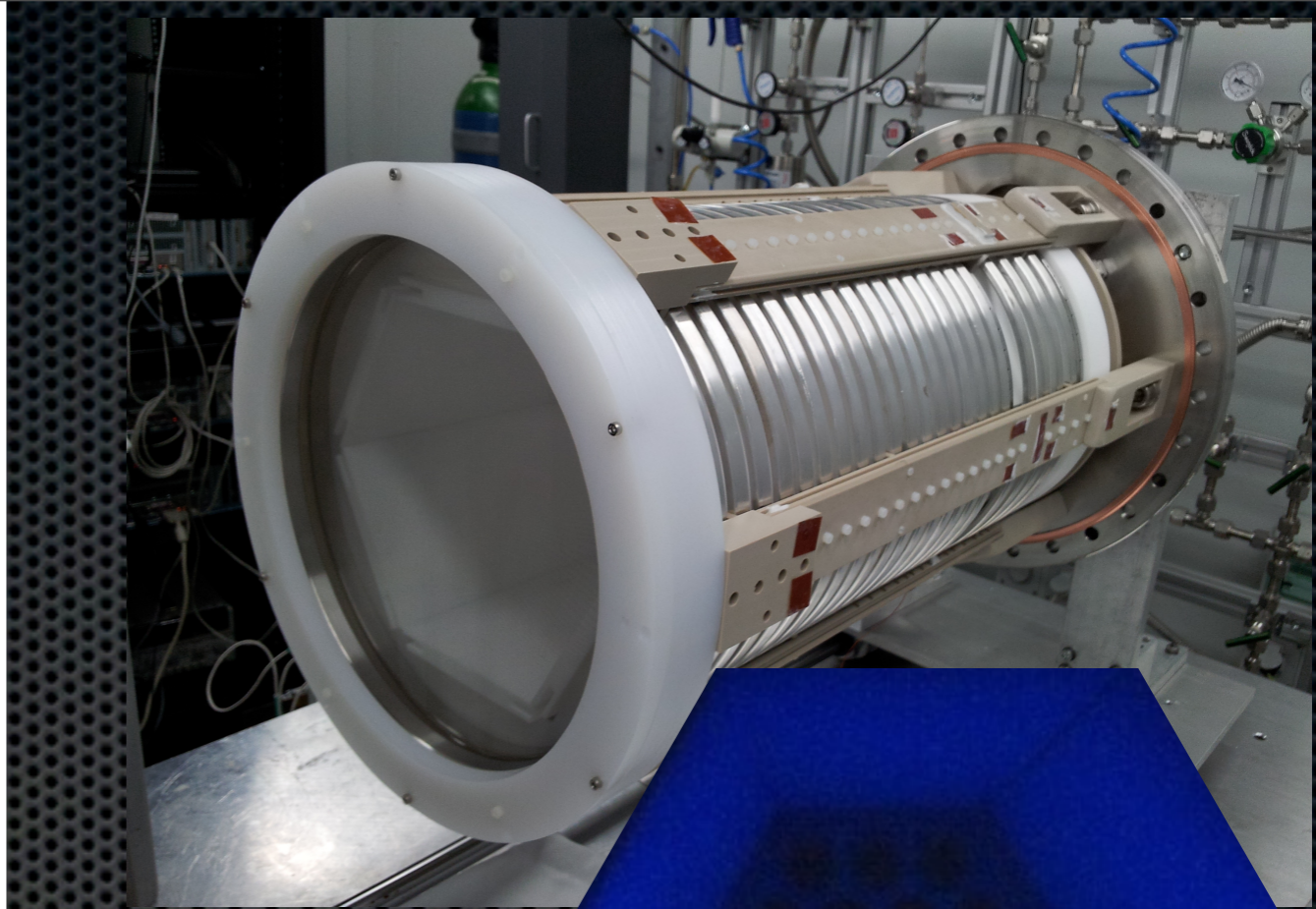
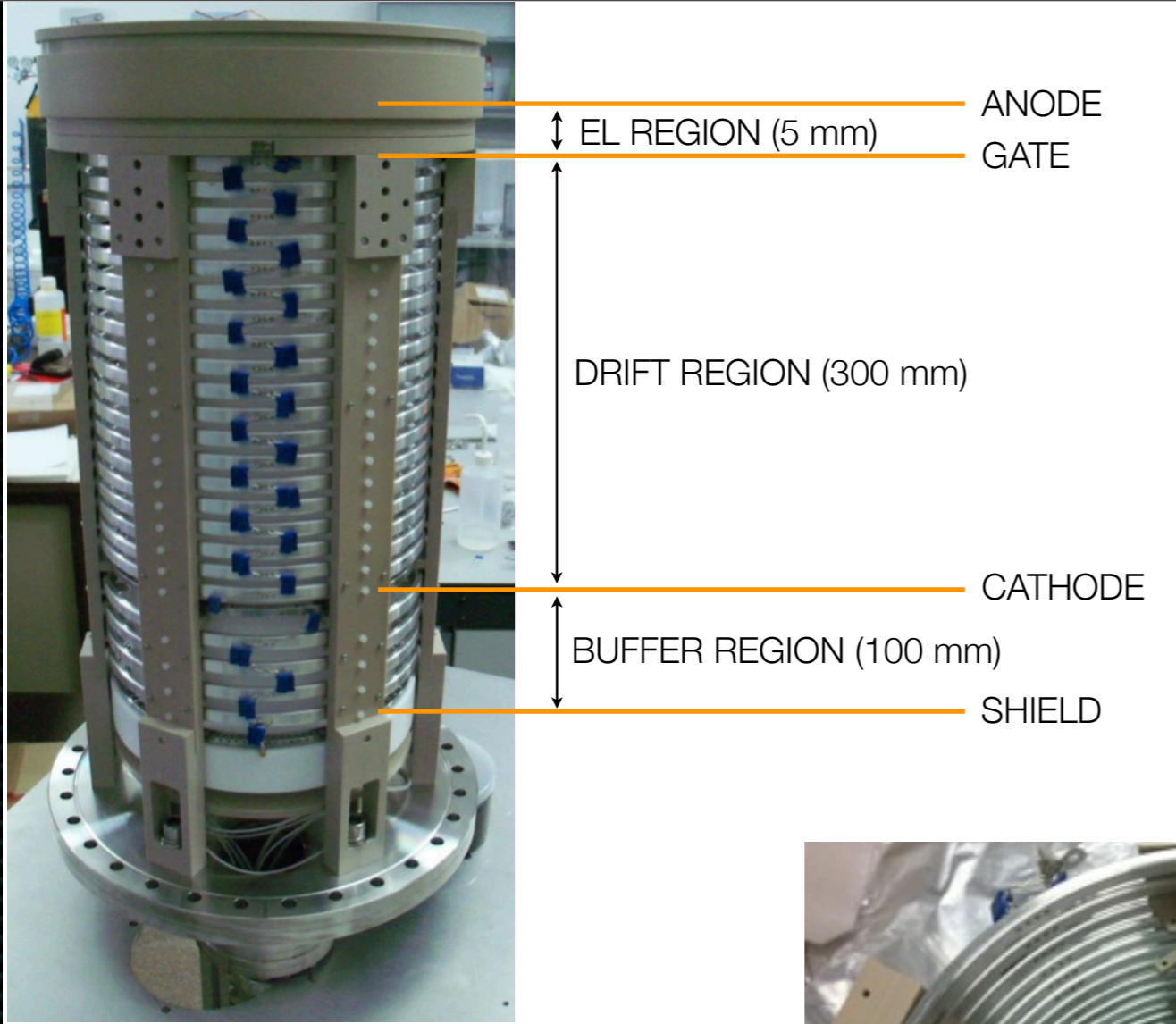
NEXT-DEMO

DAQ

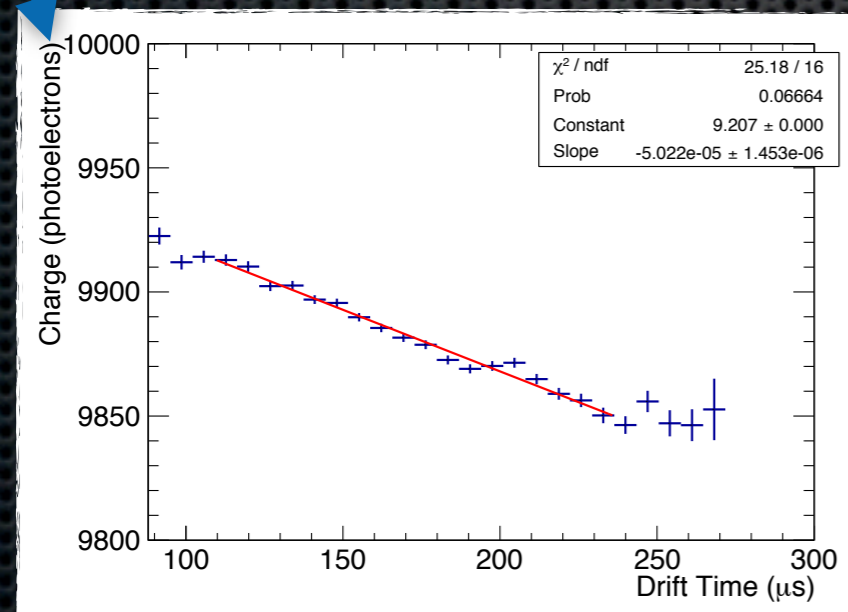
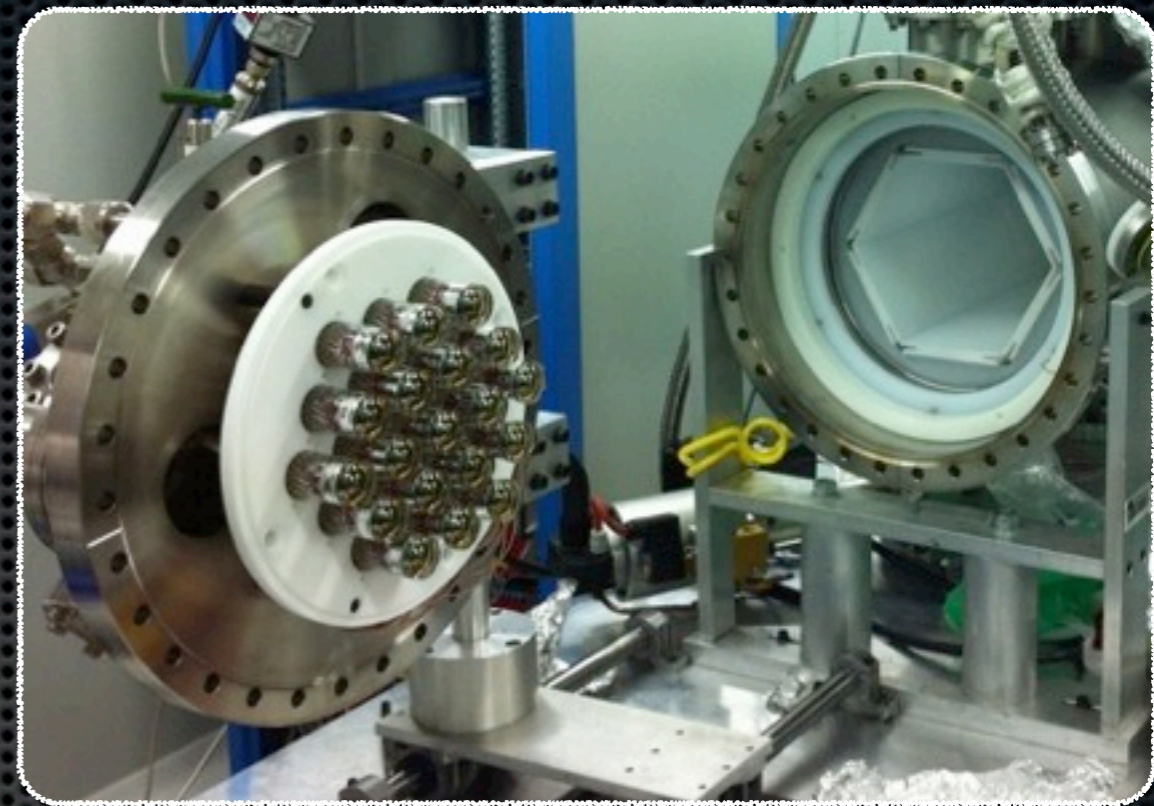
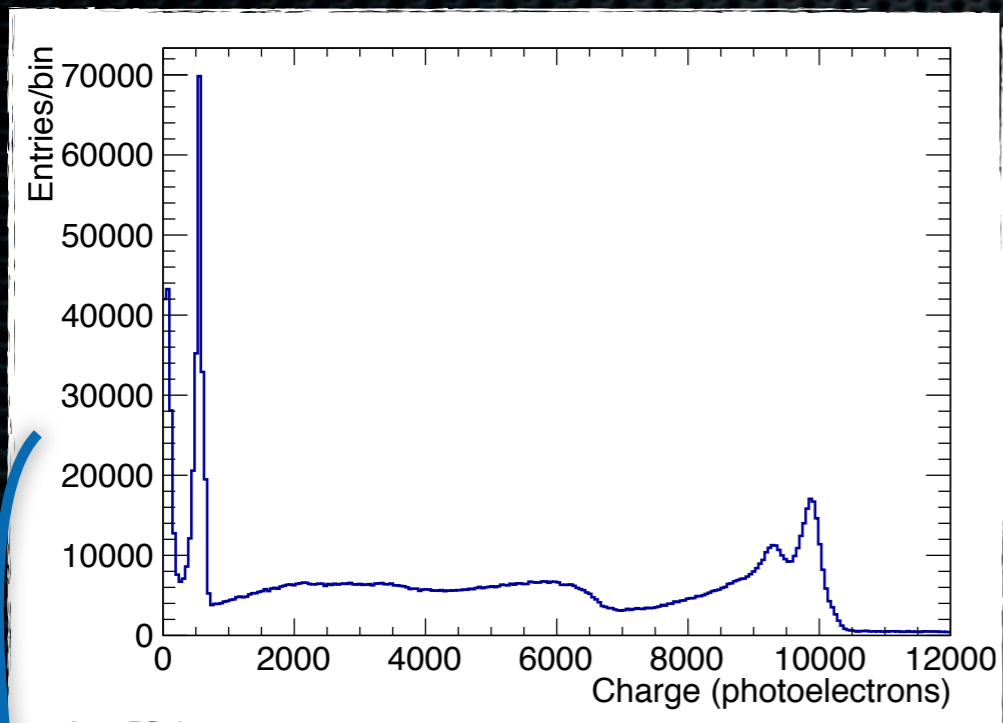
PMTs FEE

SiPMs FEE

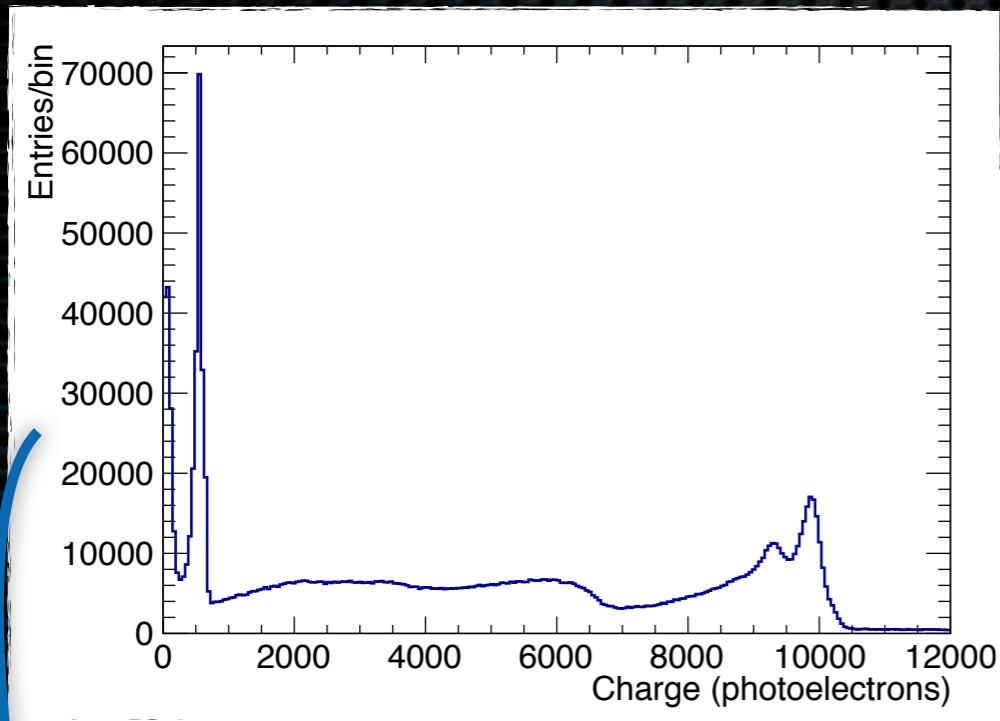
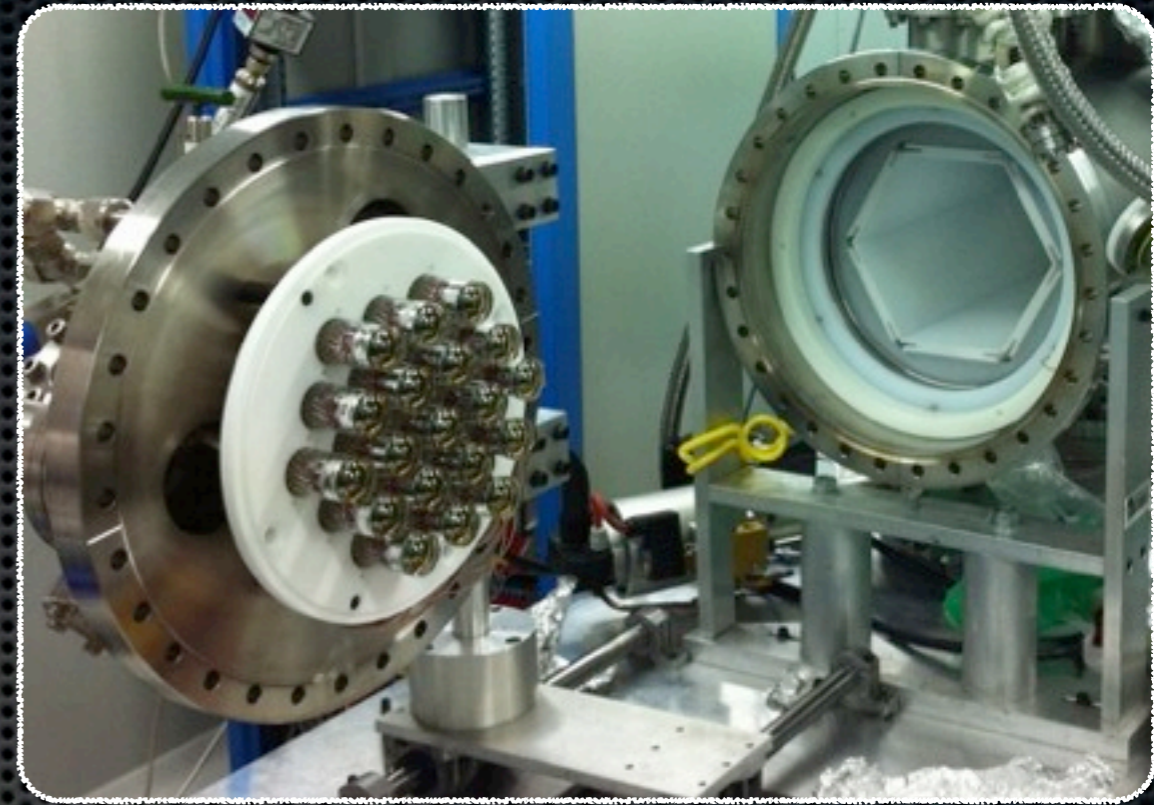




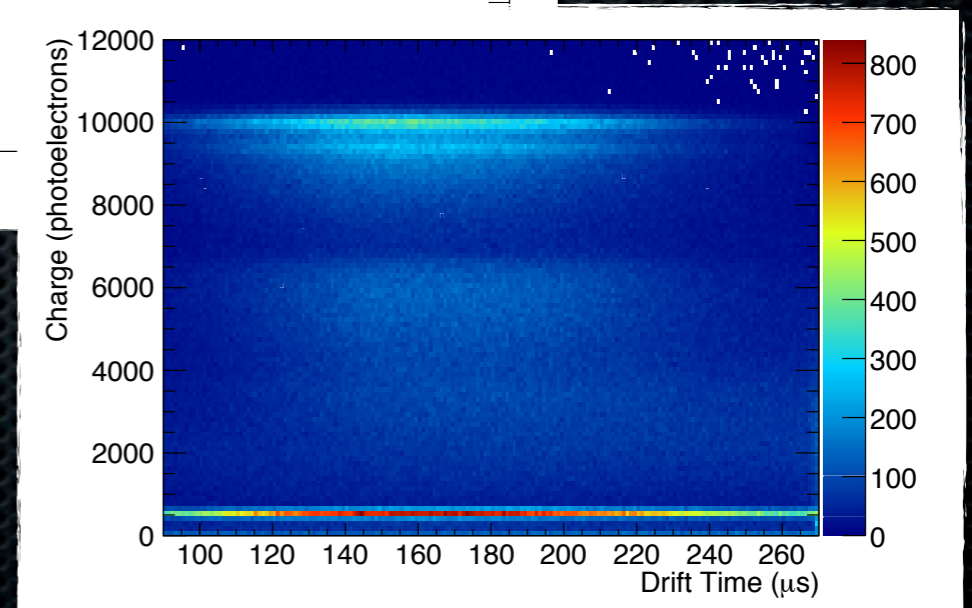
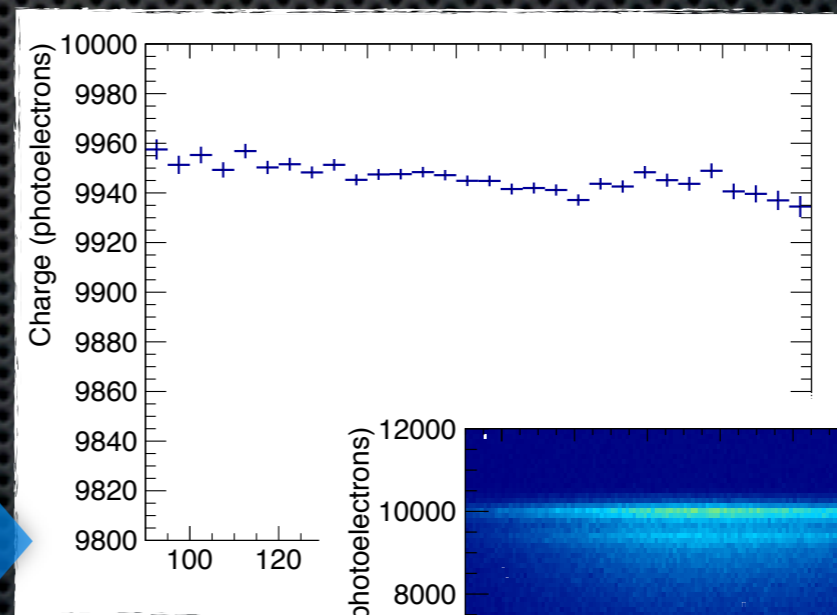
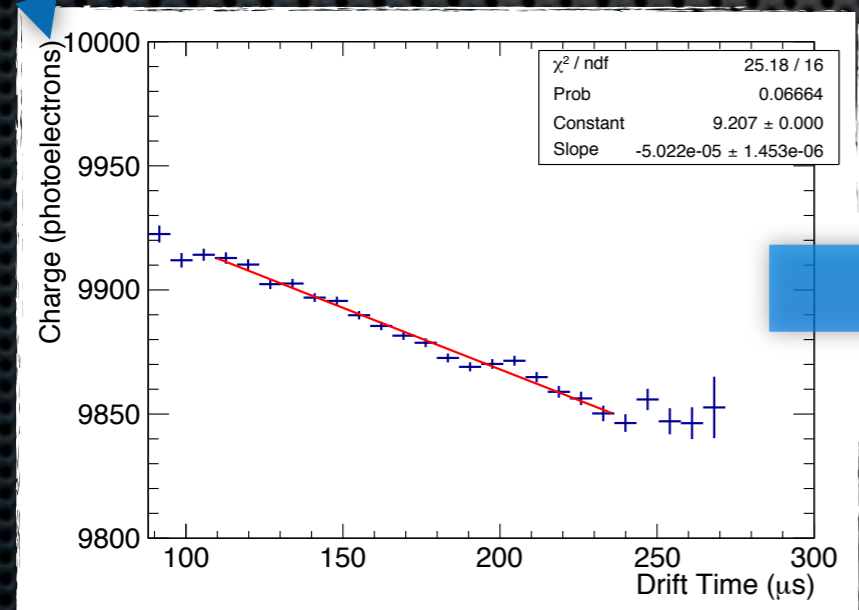
Z Correction



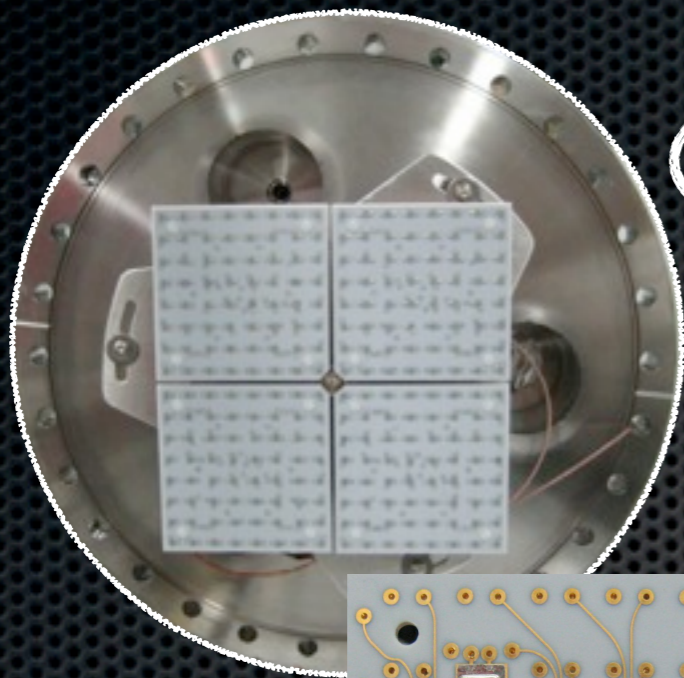
Z Correction



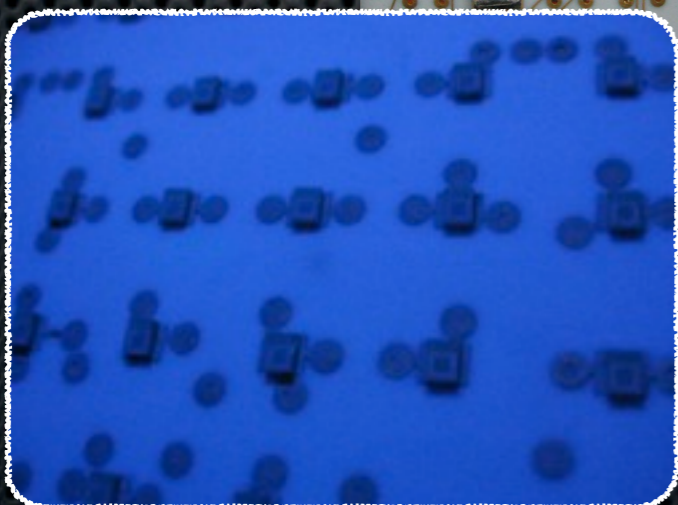
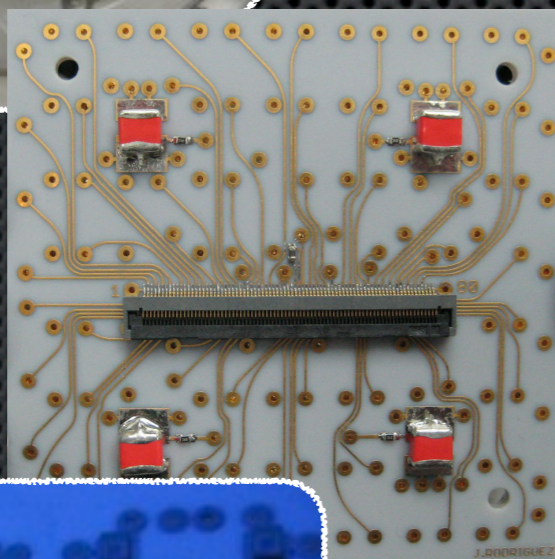
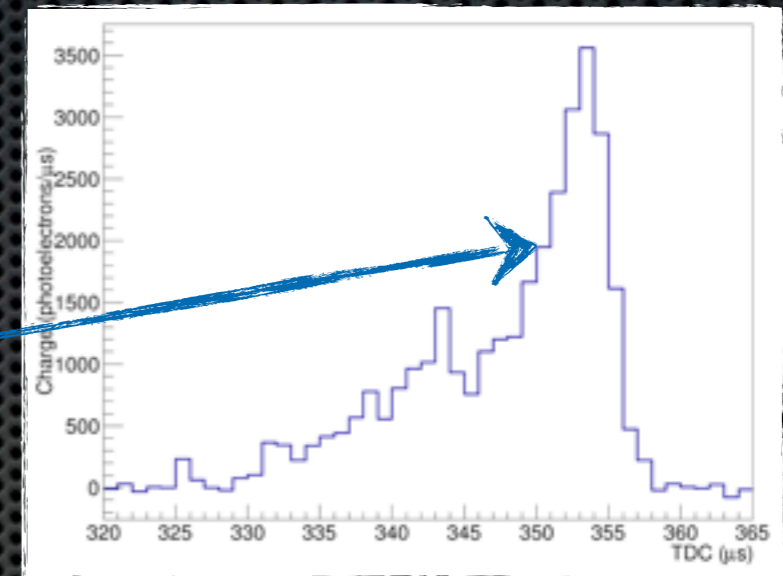
lifetime $\sim 20\text{ms}$



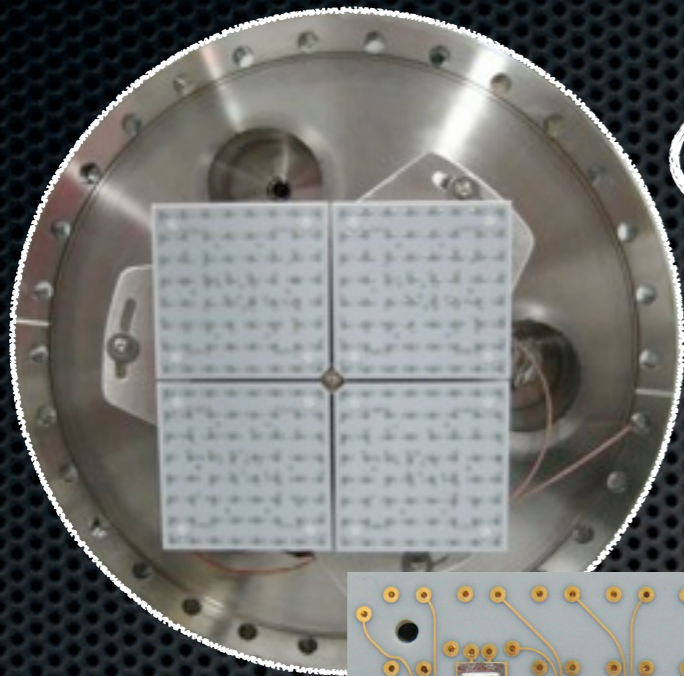
Tracking Function



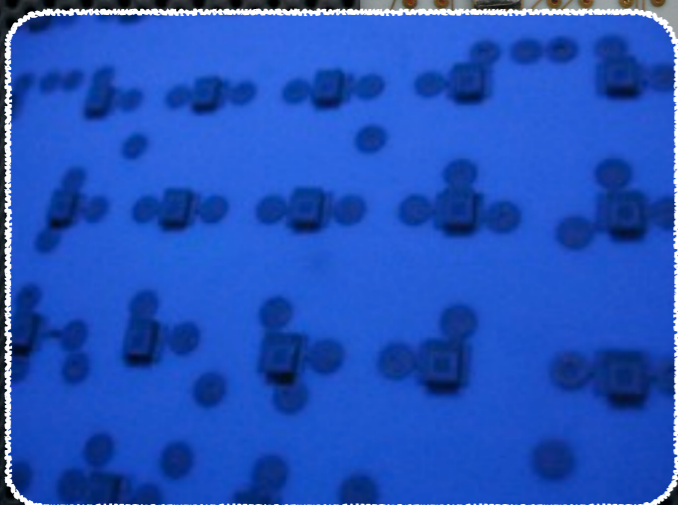
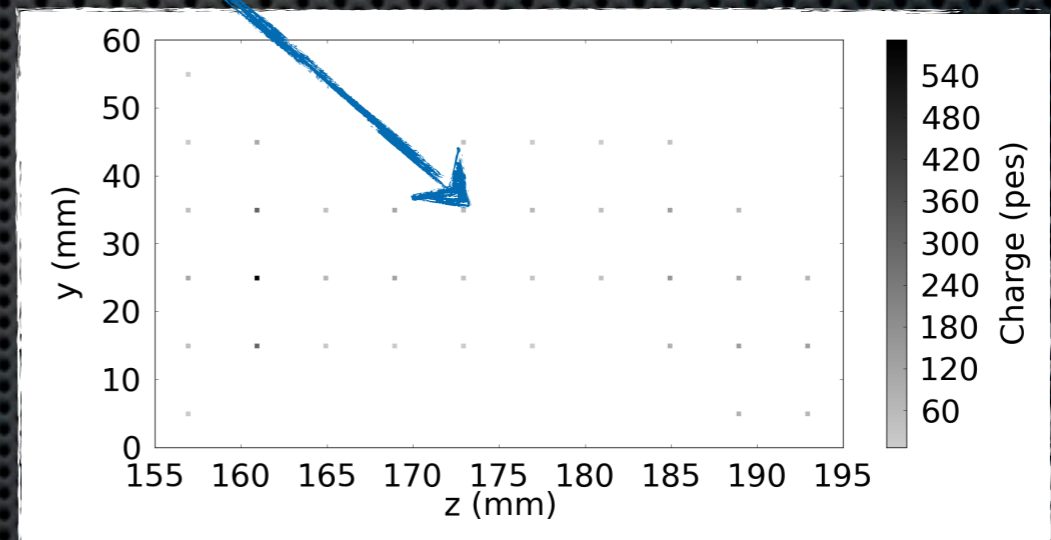
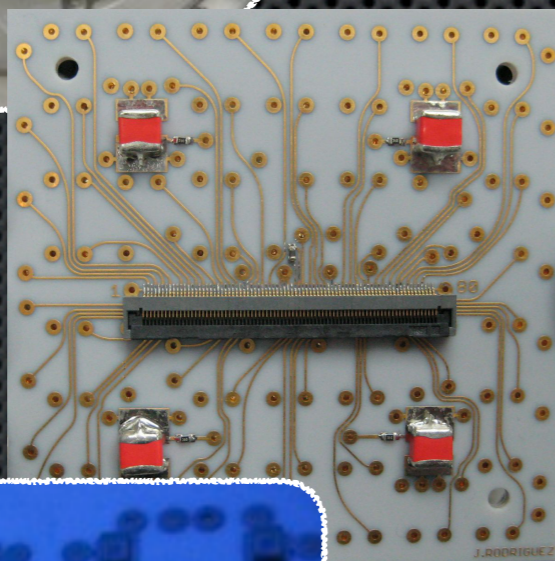
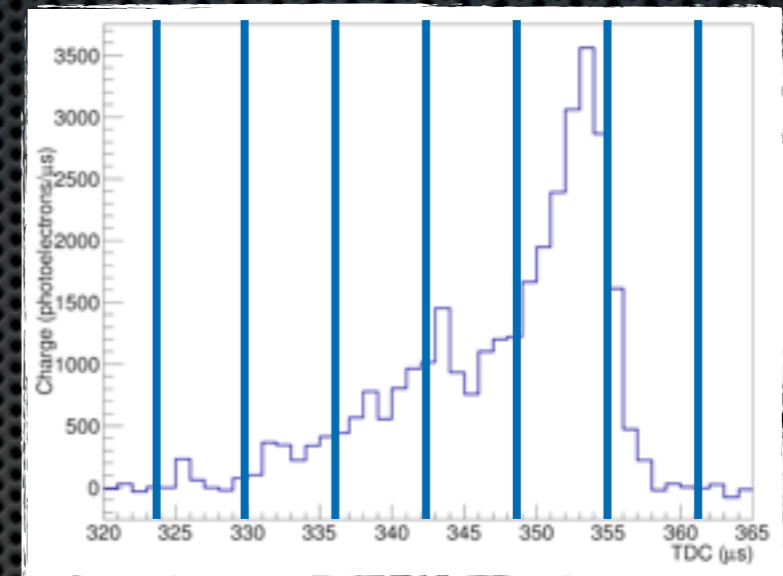
SiPMs Signal



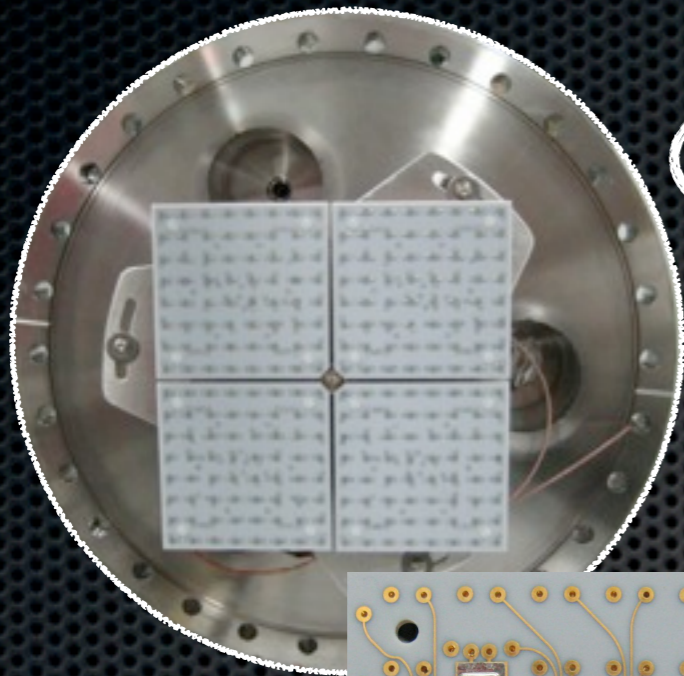
Tracking Function



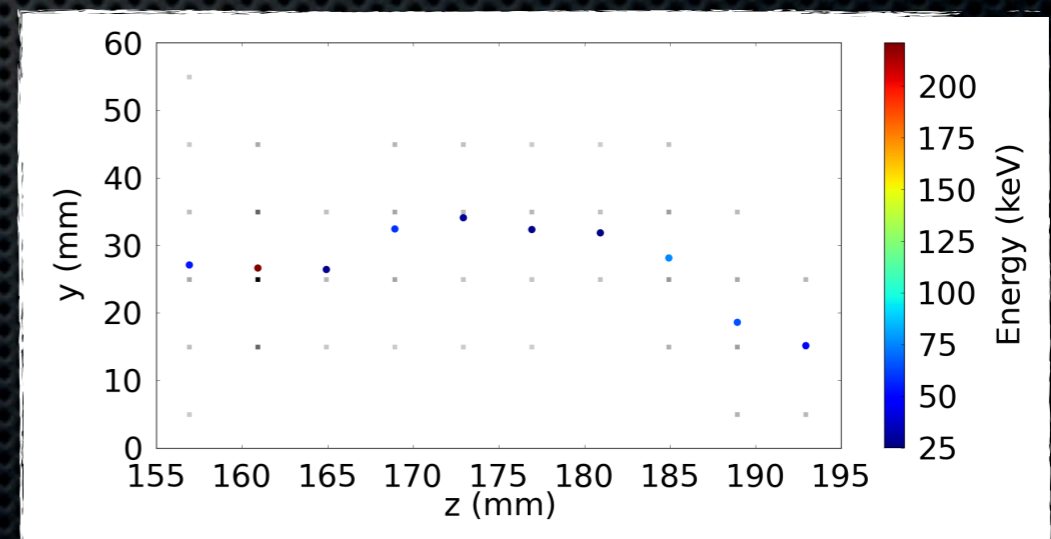
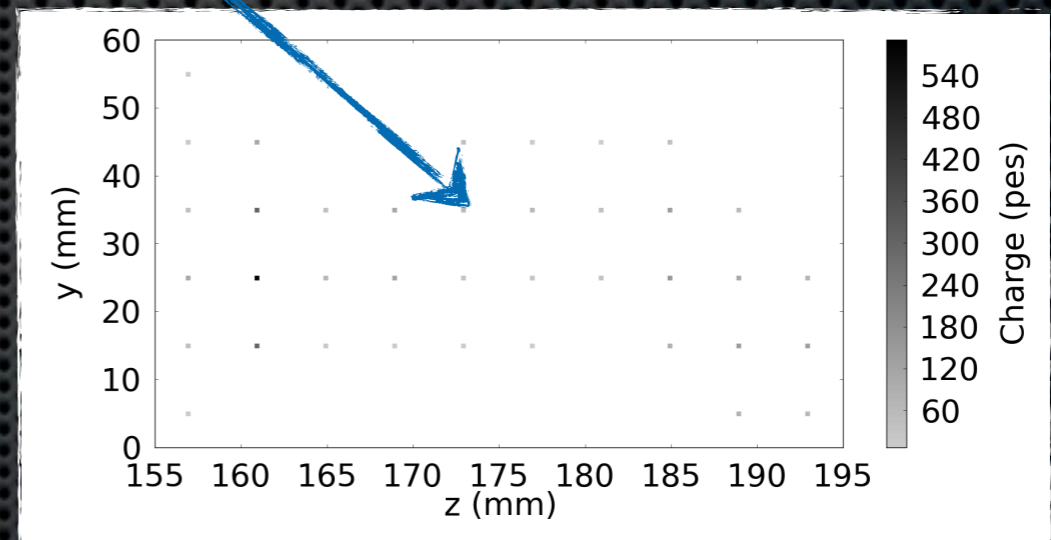
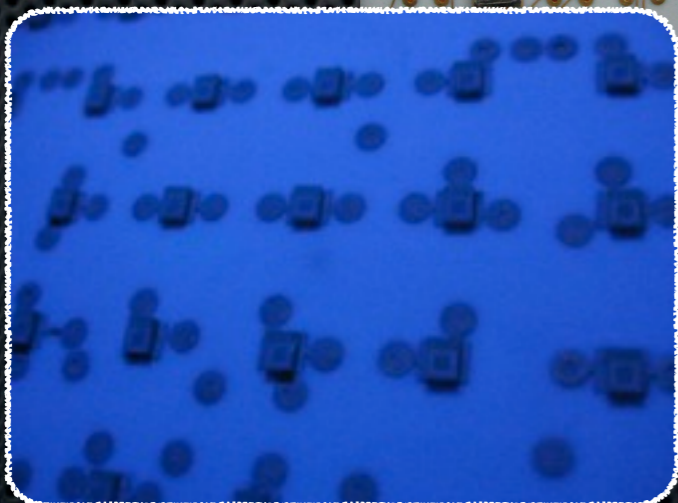
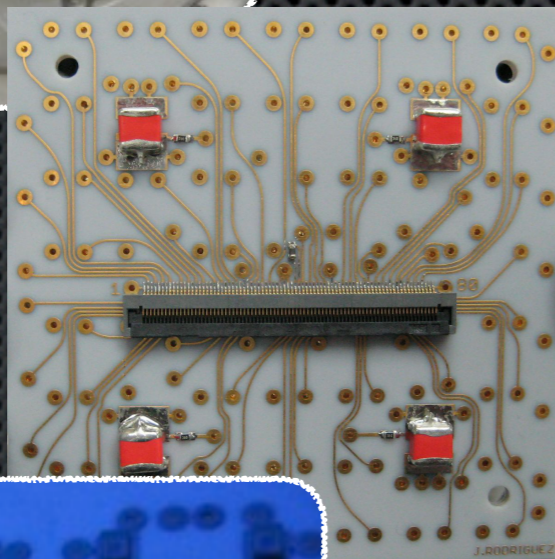
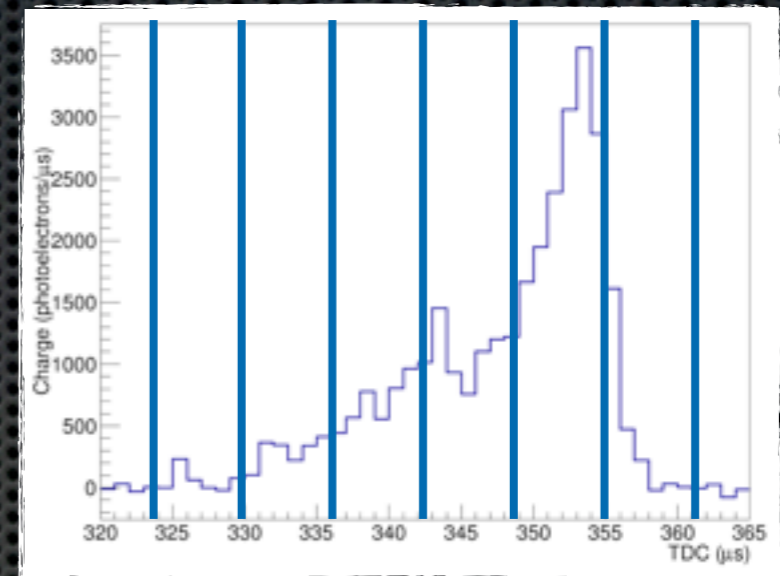
SiPMs Signal



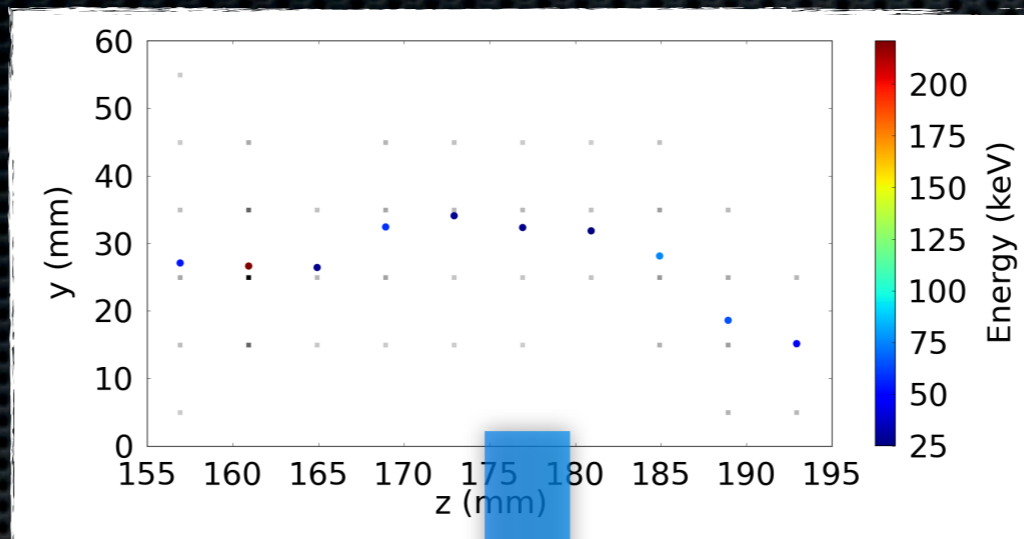
Tracking Function



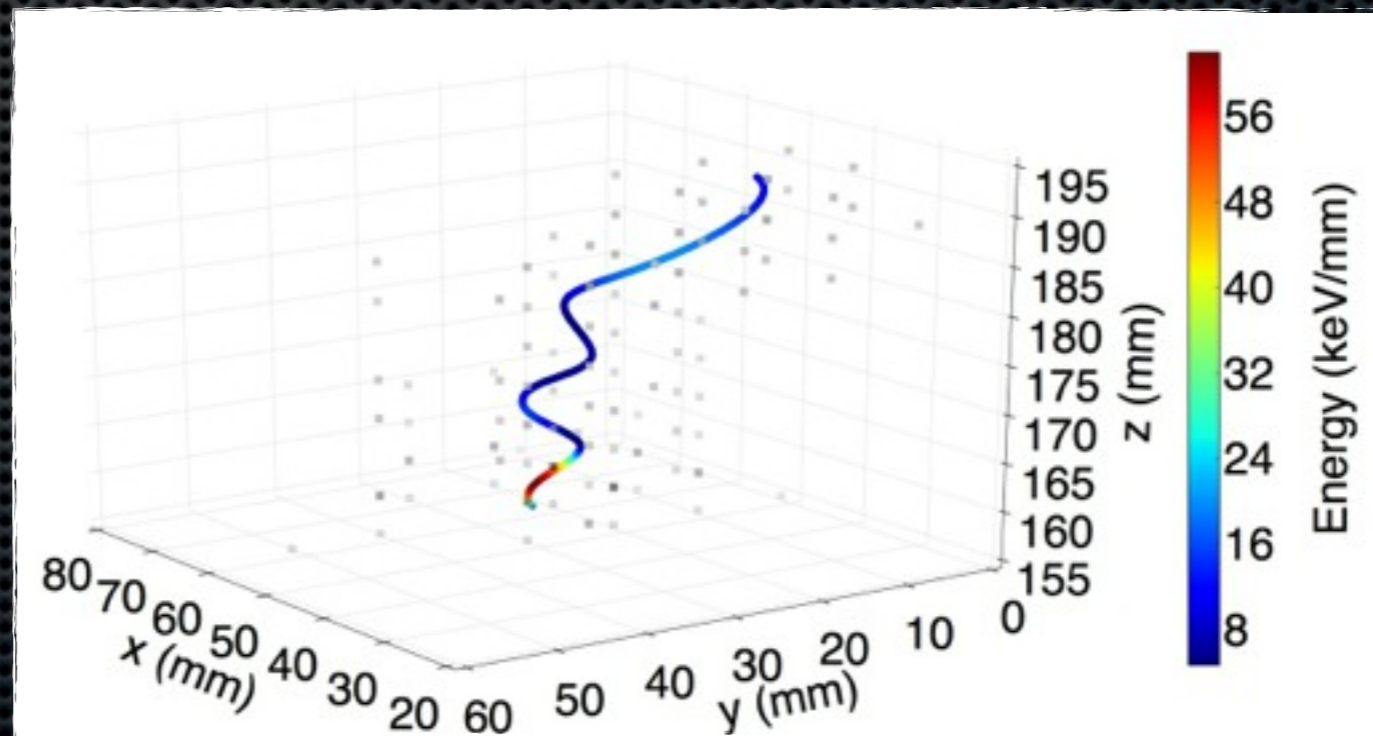
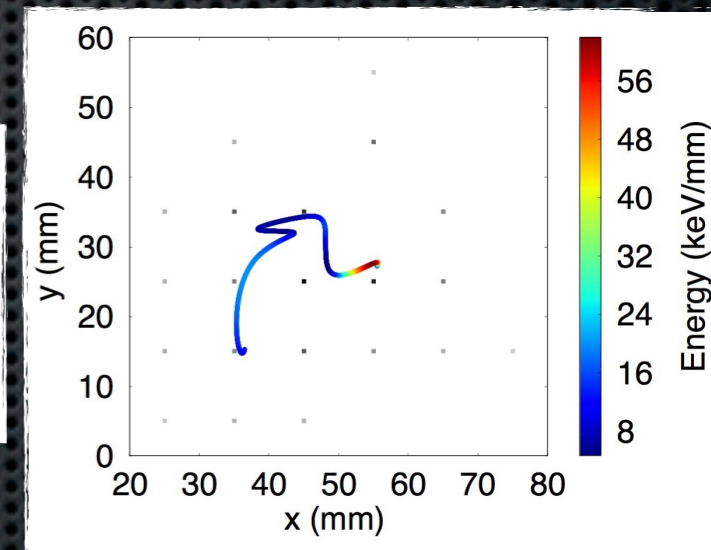
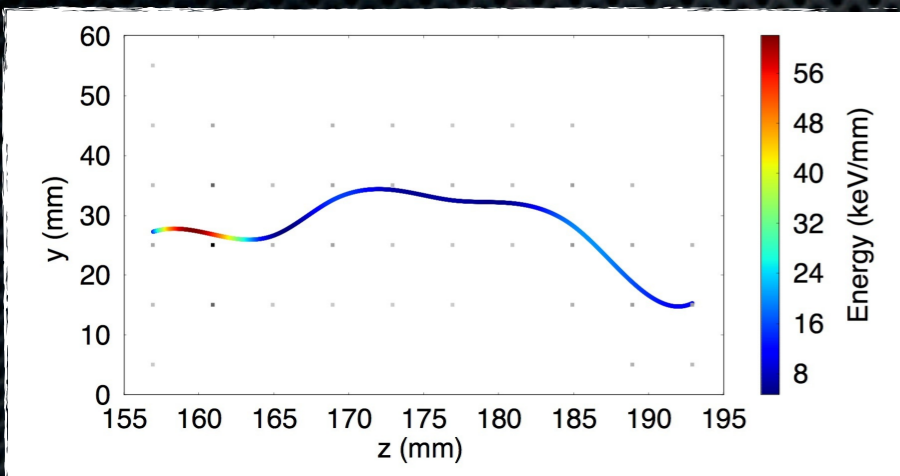
SiPMs Signal



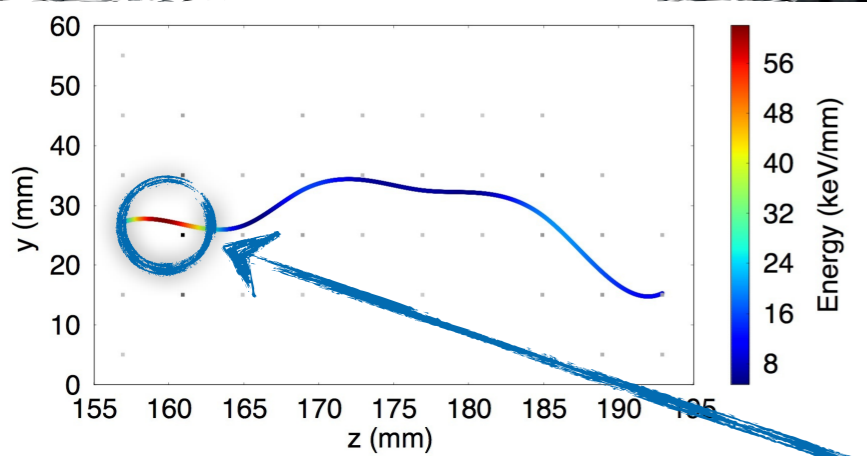
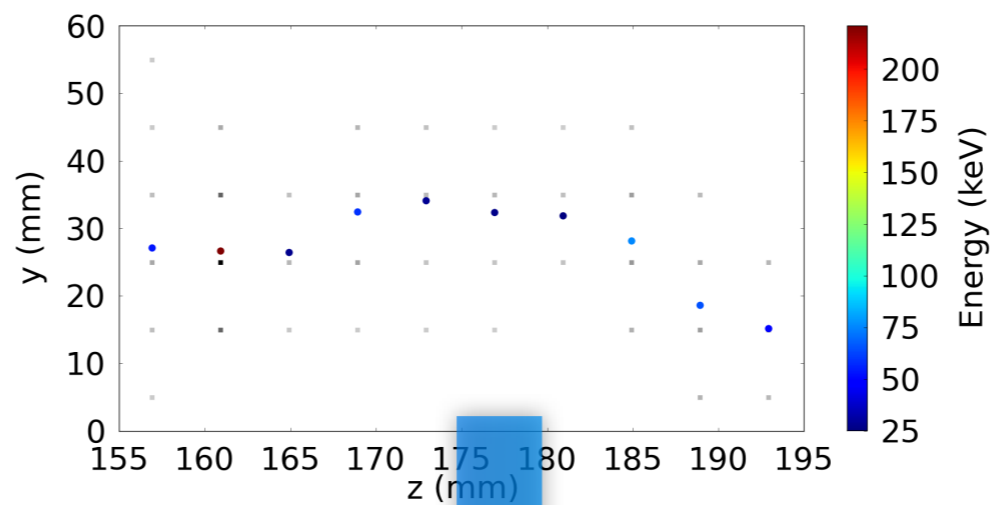
Cubic Splines among the points



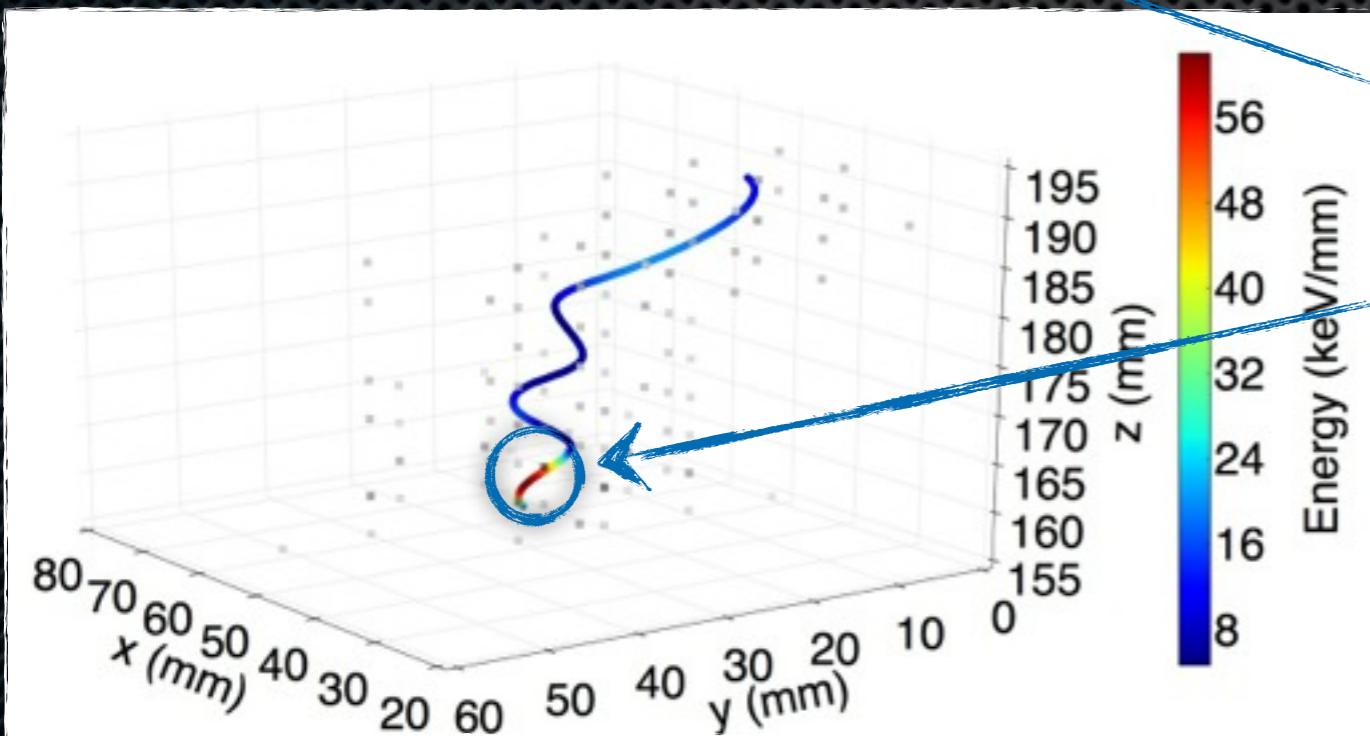
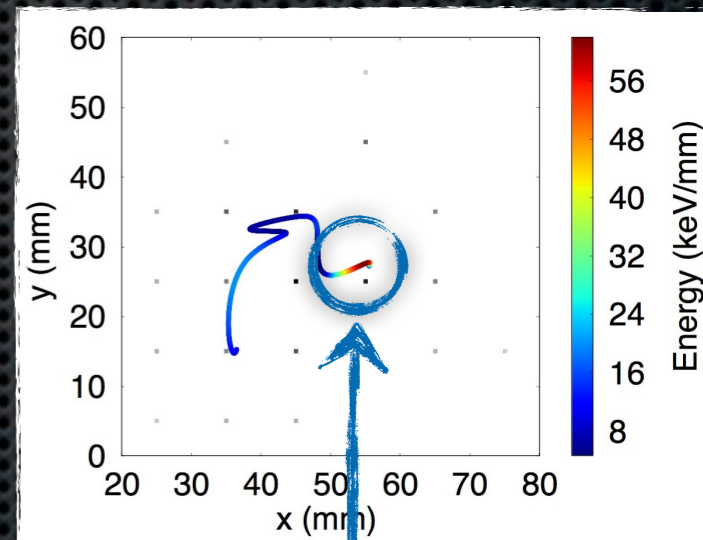
3D Representation of the track



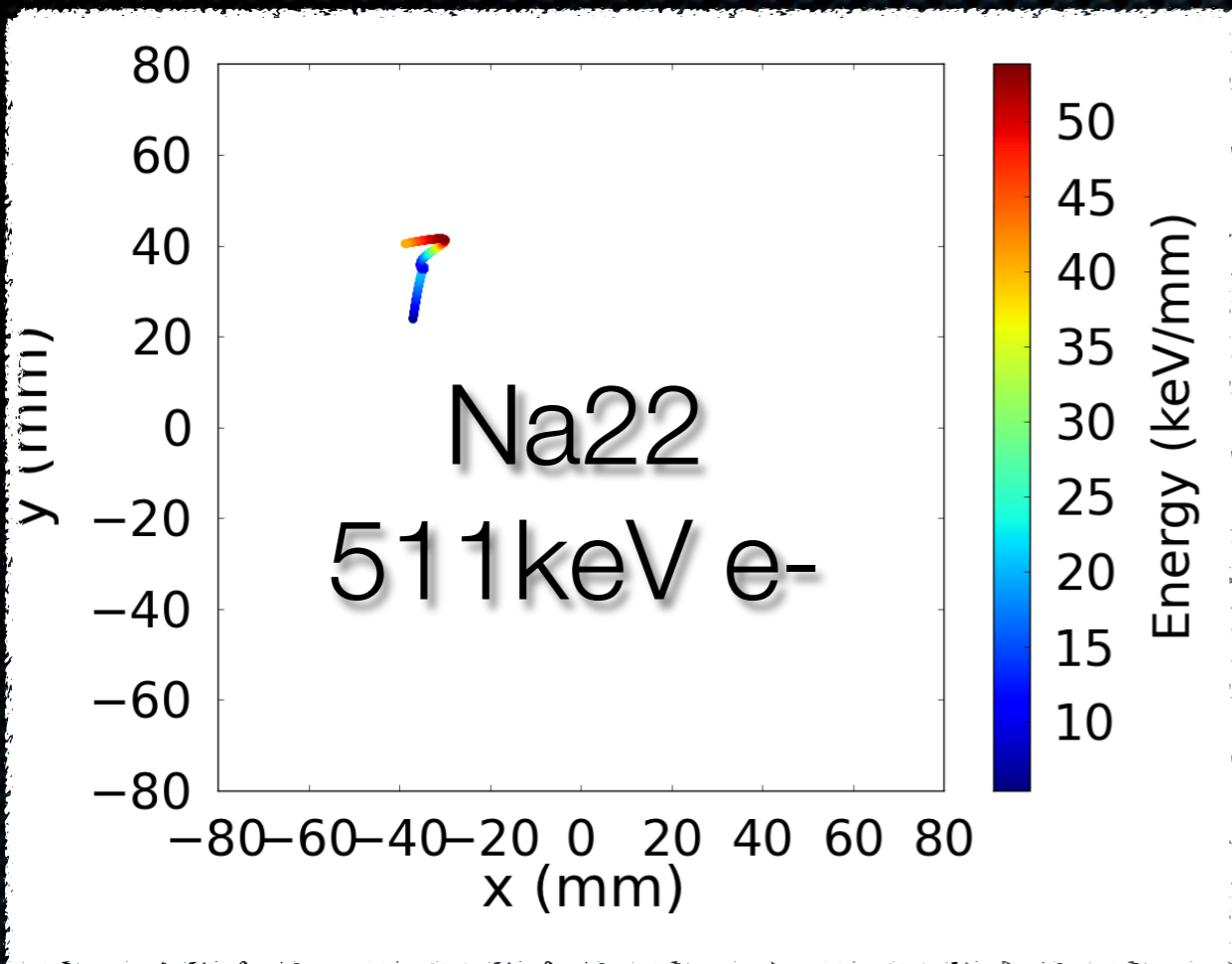
Cubic Splines
among the
points



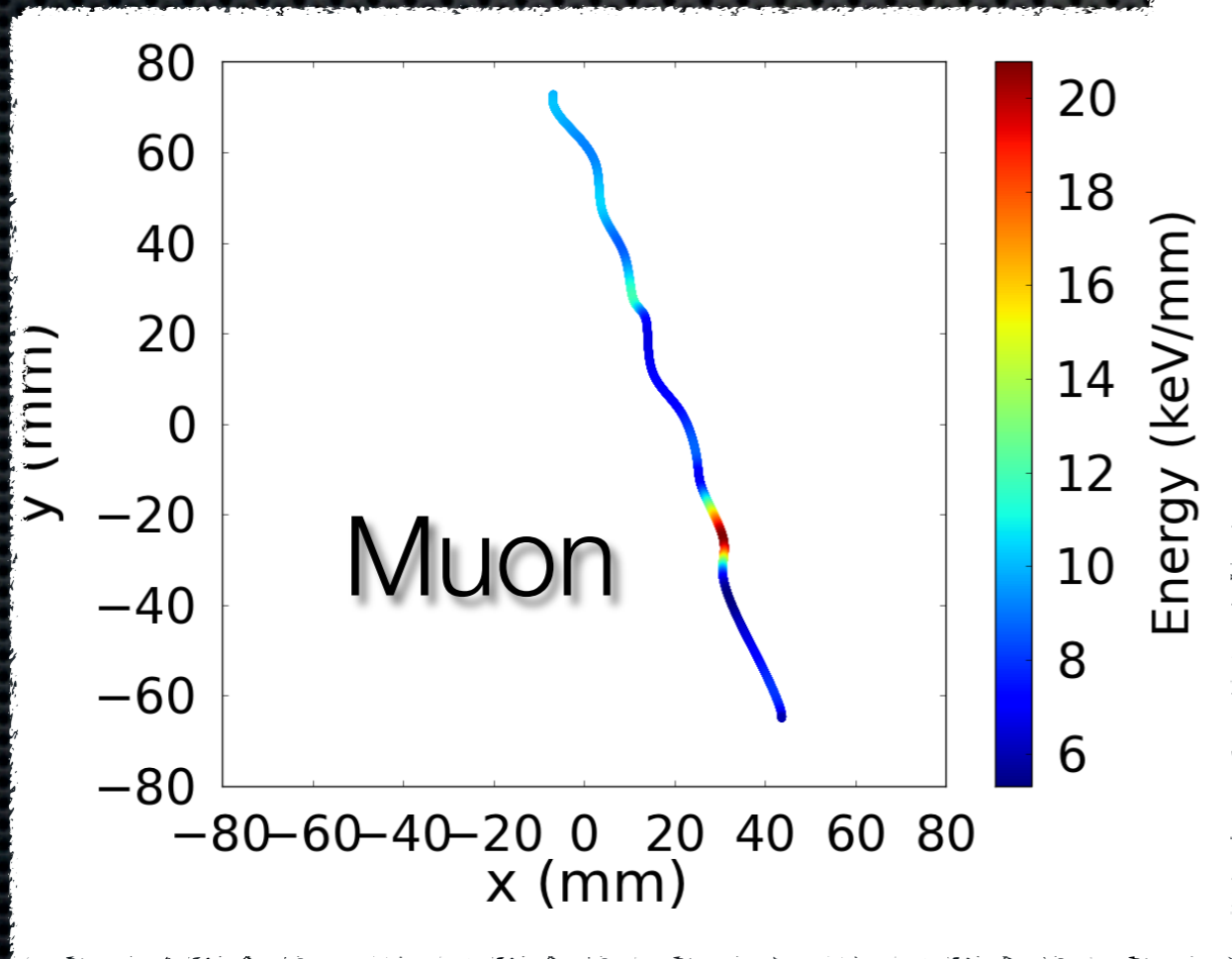
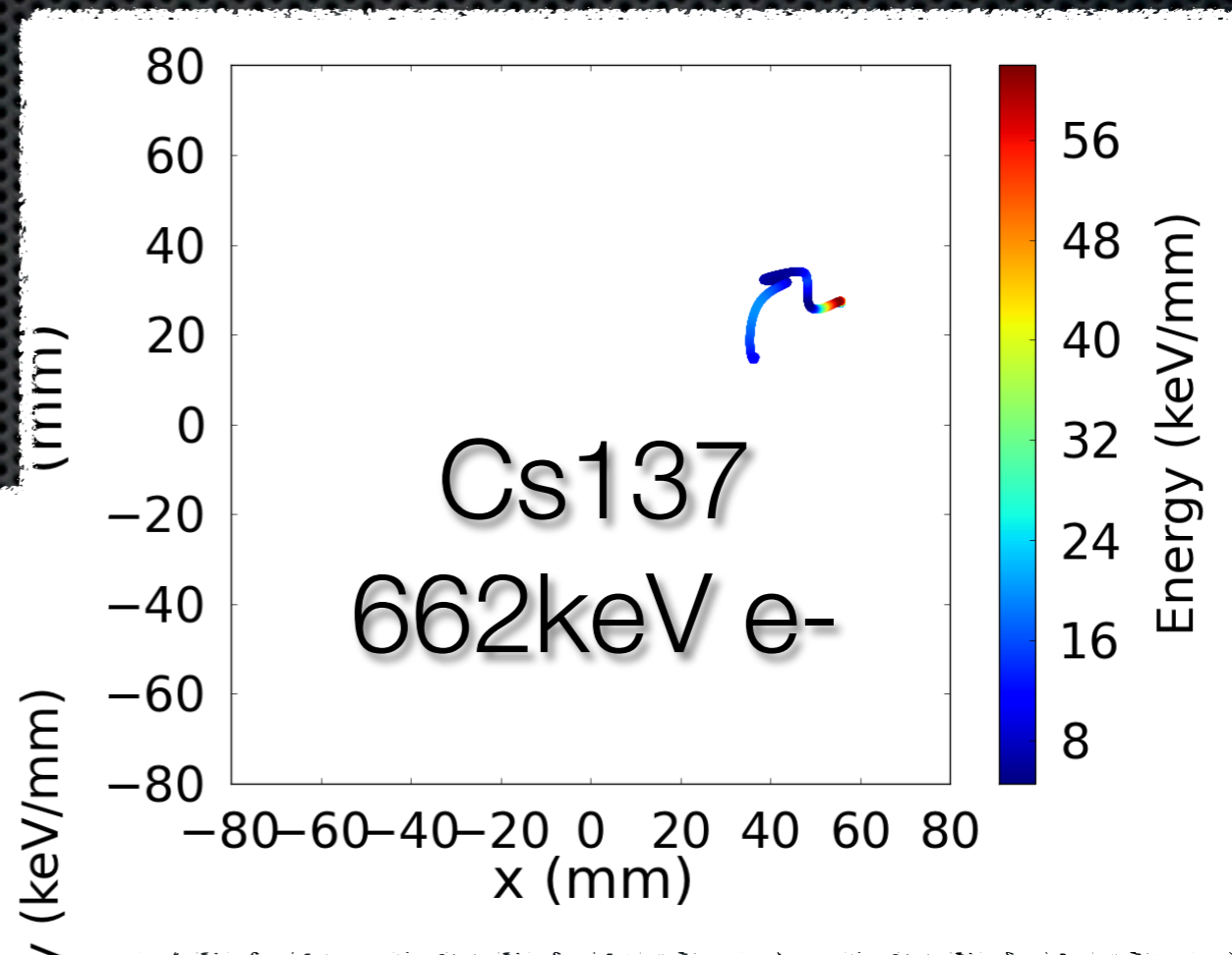
3D Representation
of the track



Electron end-point clearly
visible at the end of the
path.
Improves background
rejection.

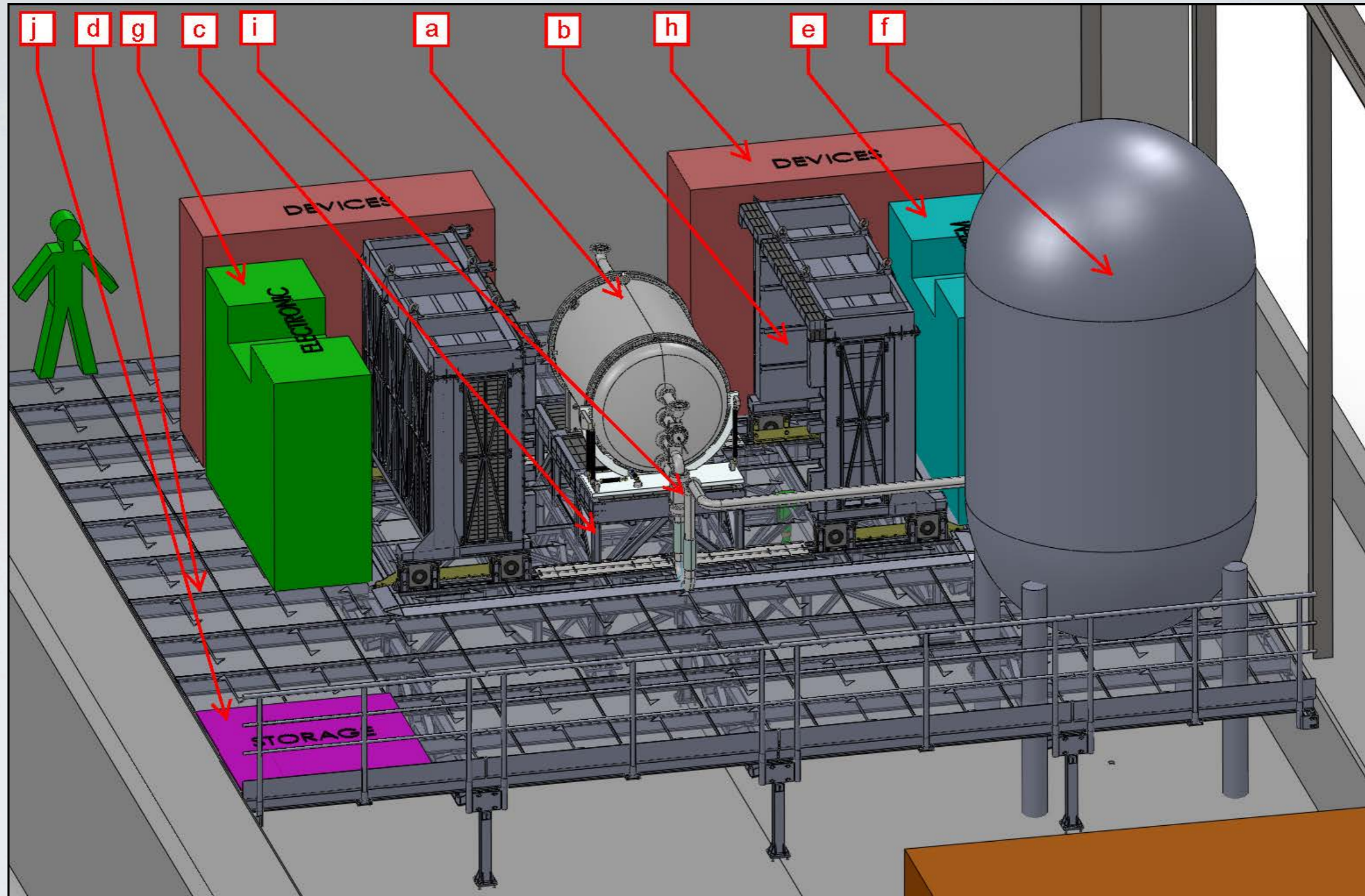


Tracks reconstructed for different energies



Different behavior between μ and e

I-Infrastructures at Canfranc Laboratory.

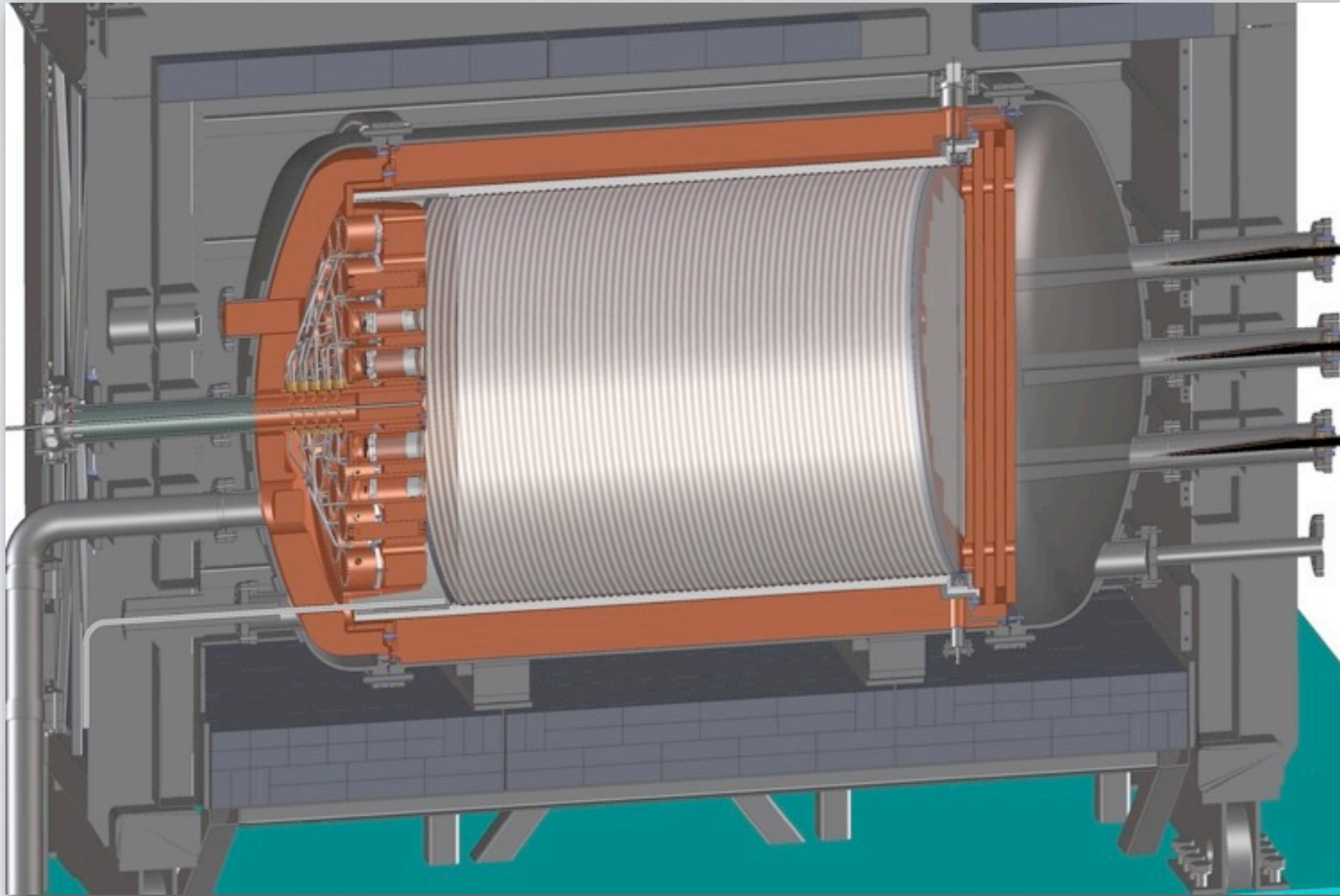


NEXT-100 stage-I (NEW): operation in 2015

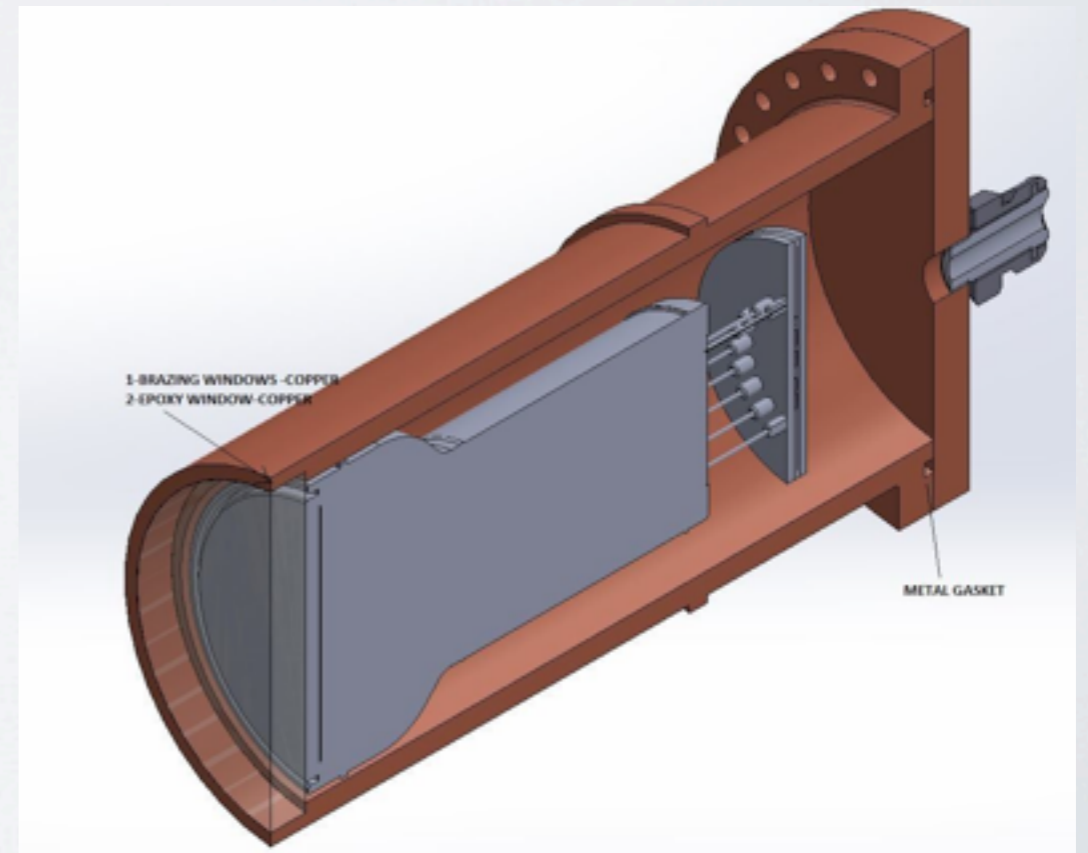
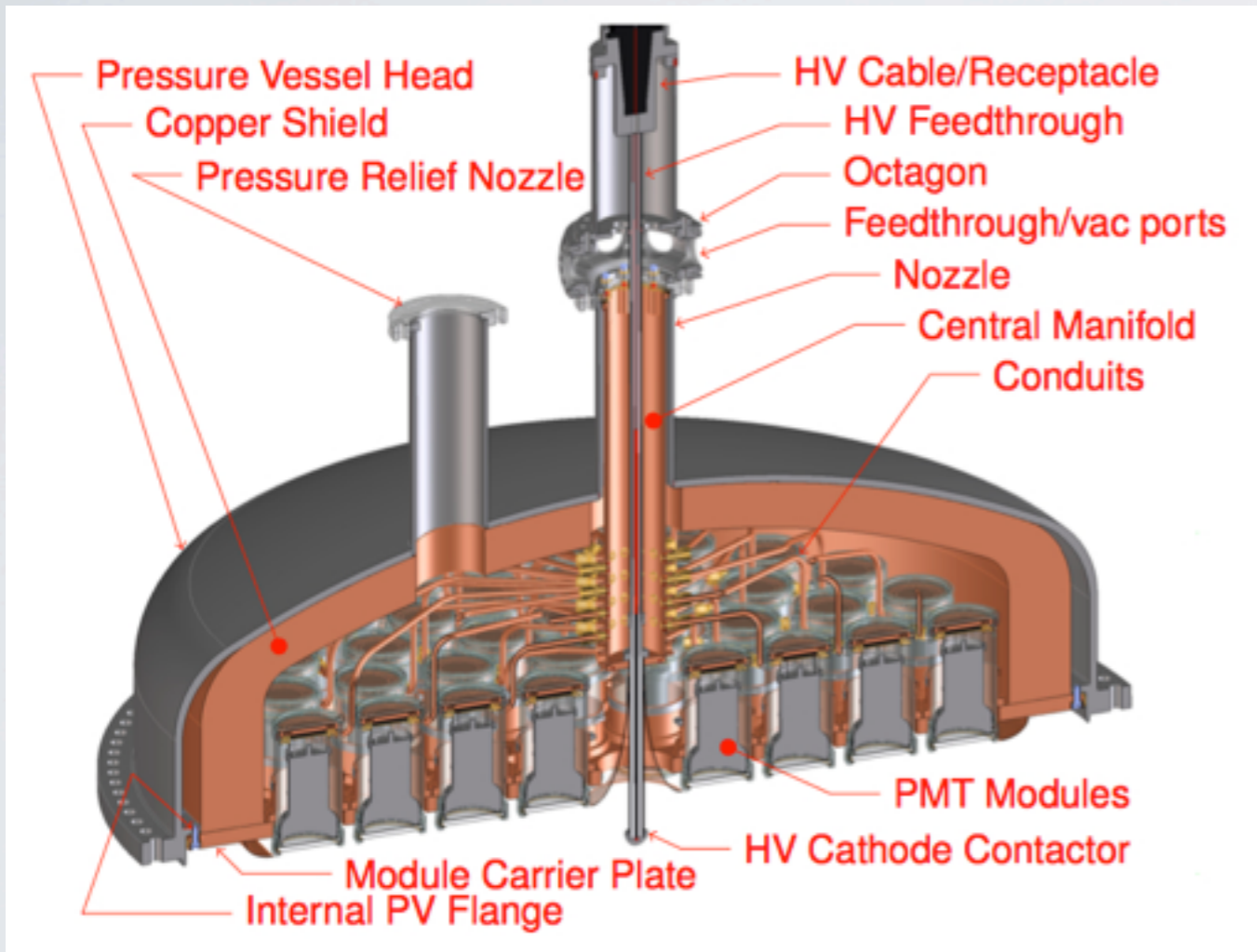
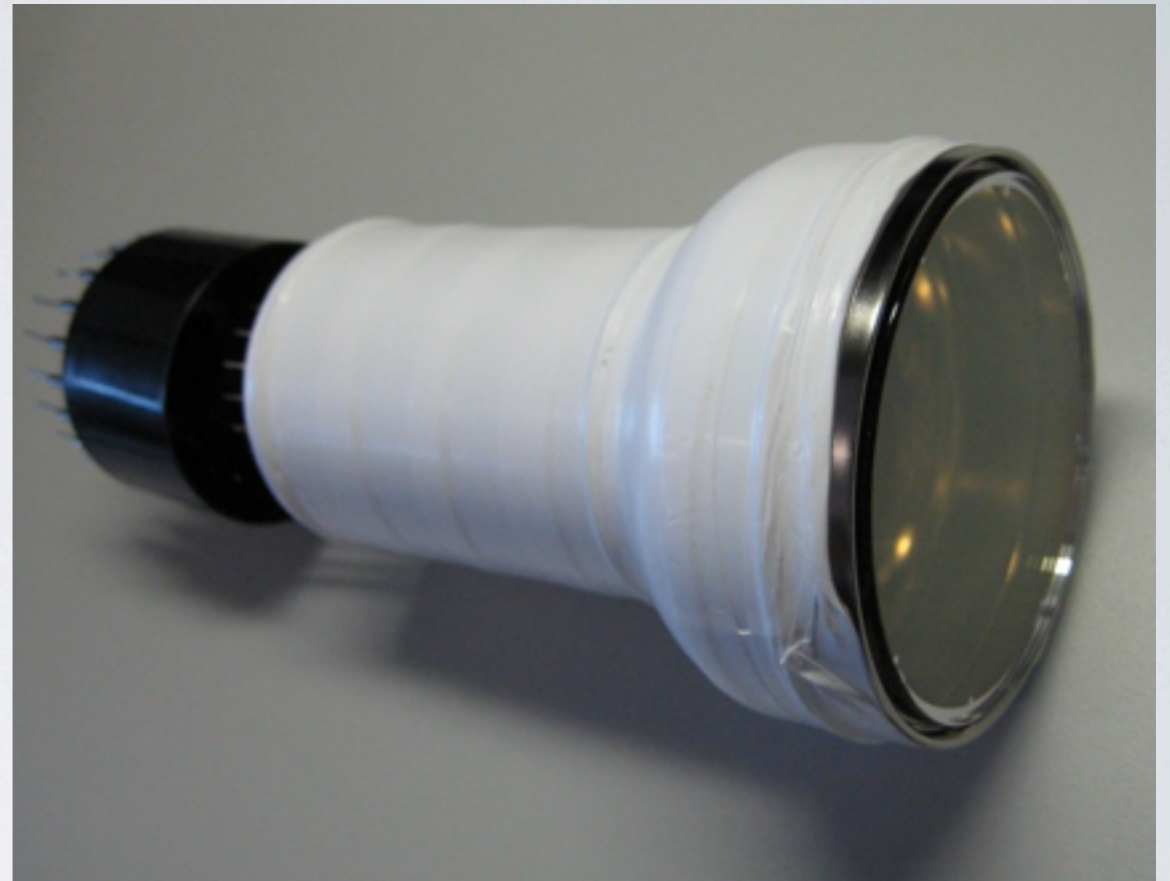
NEXT-100 pressure vessel



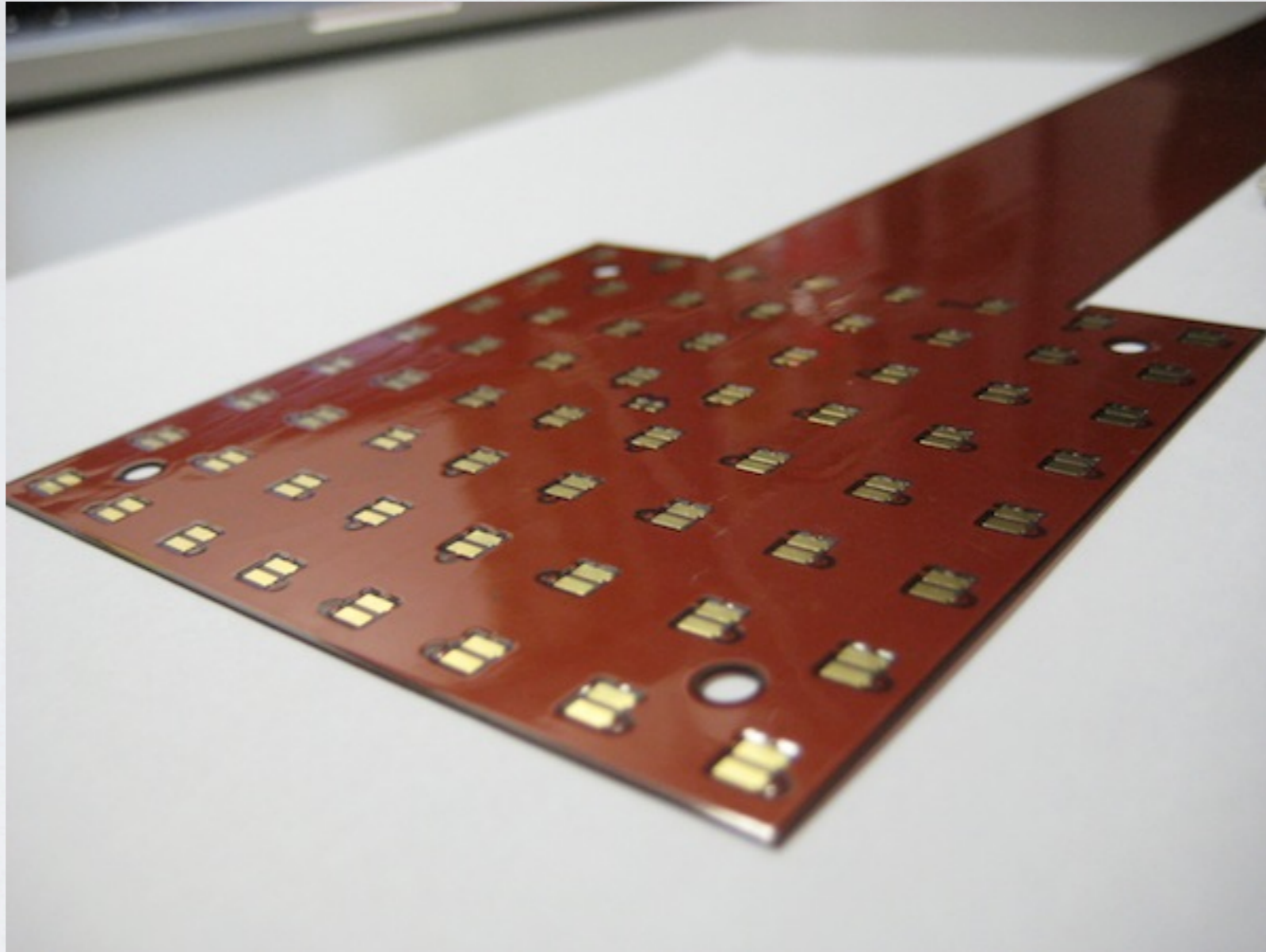
NEXT-100 detector



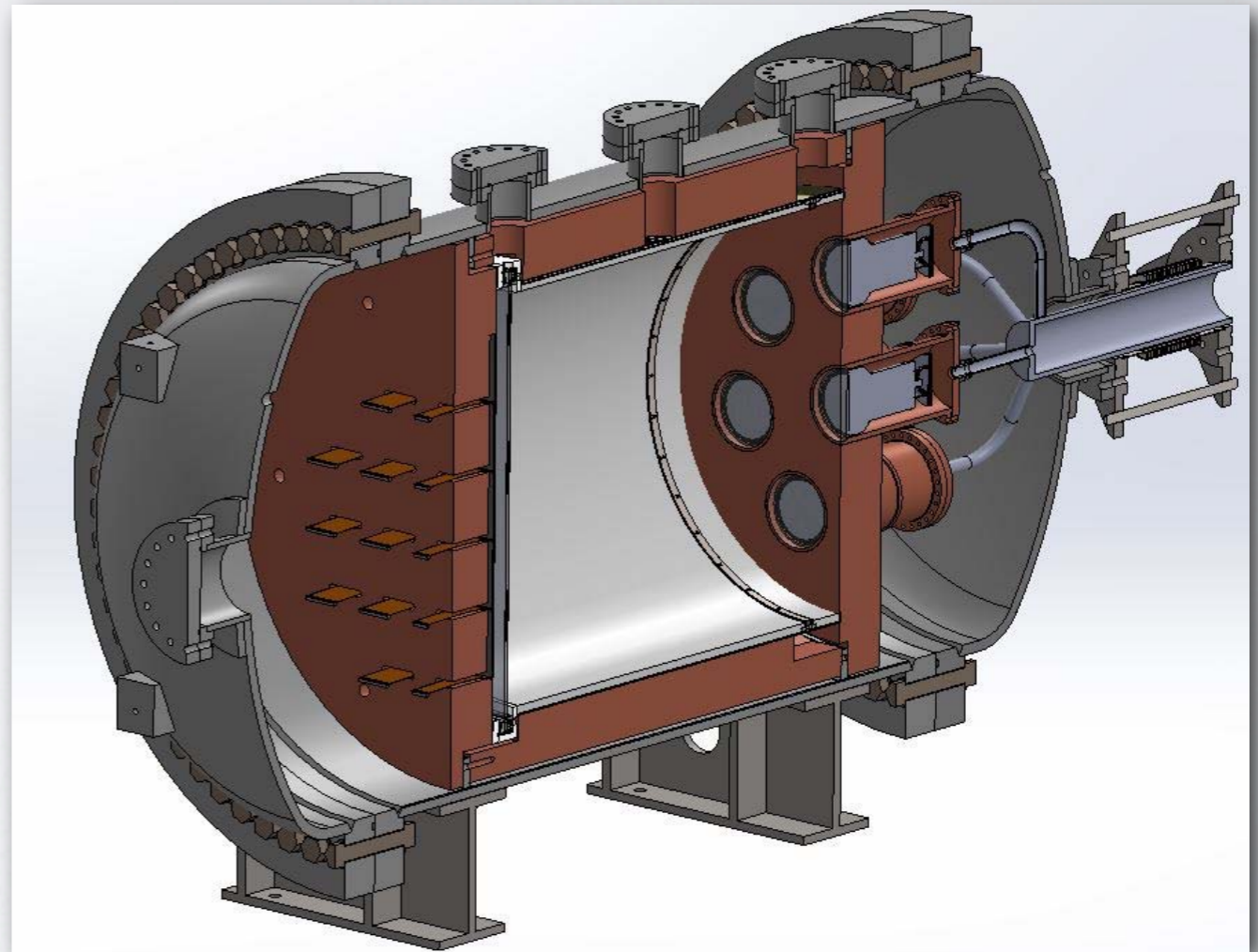
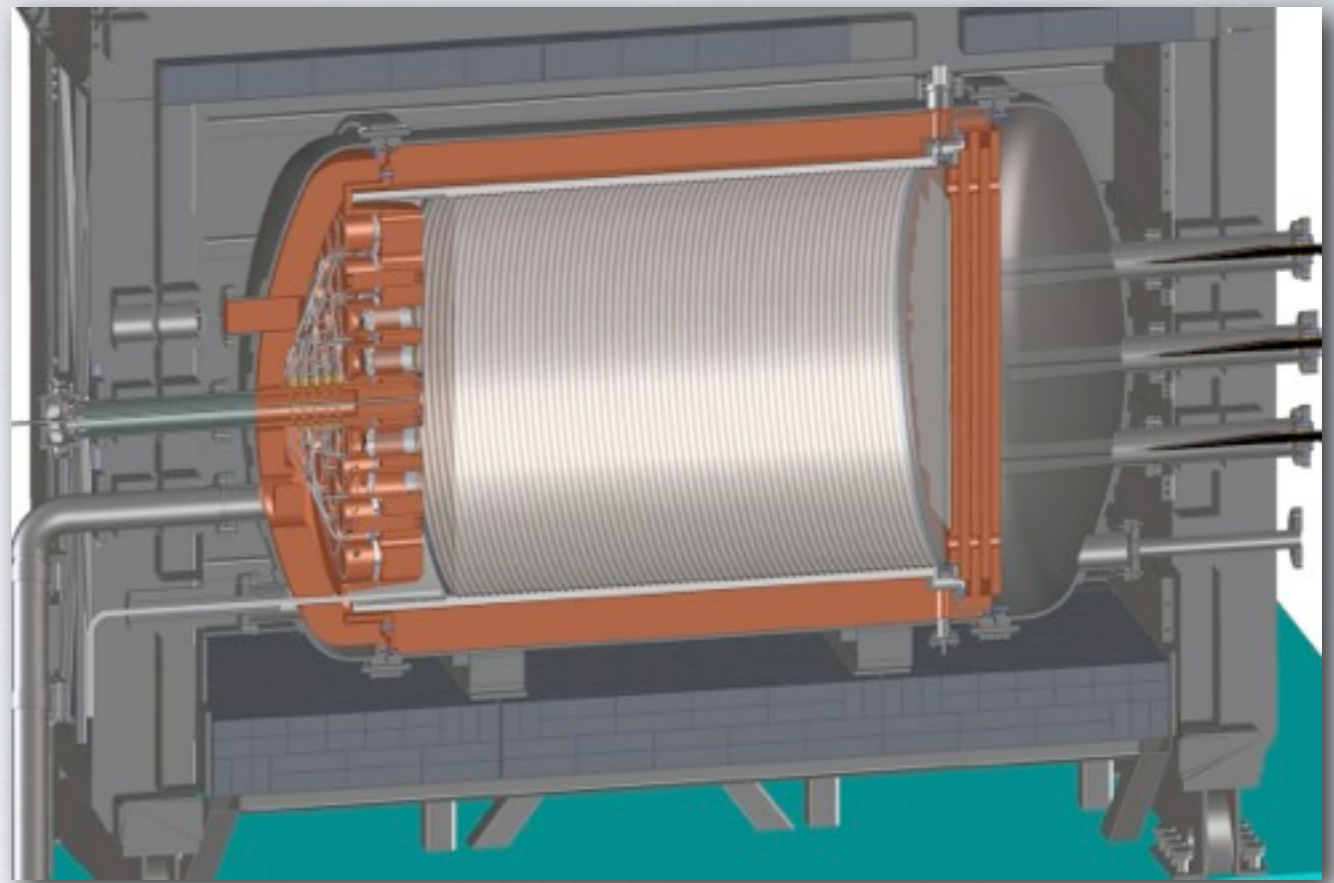
Energy plane



Tracking plane

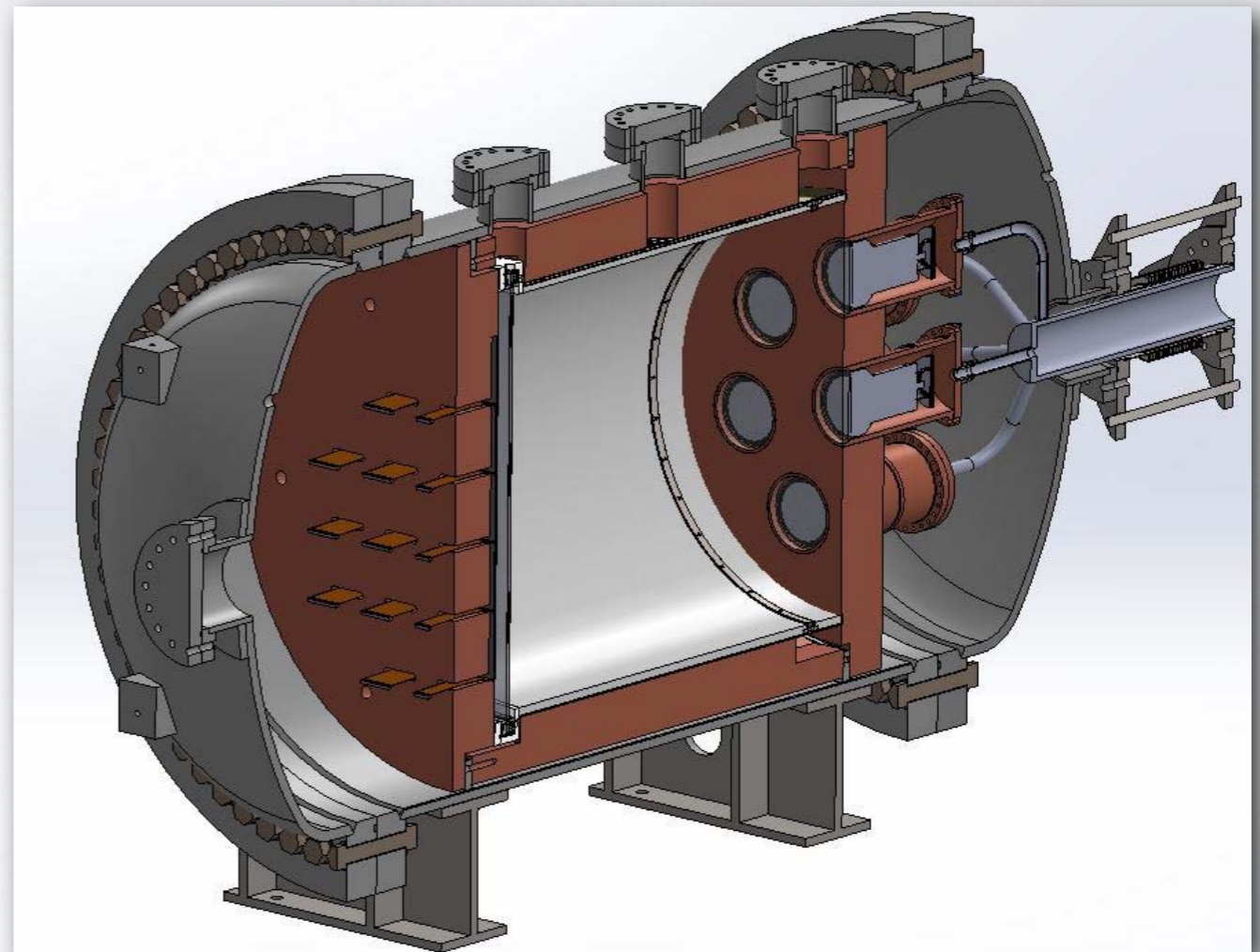
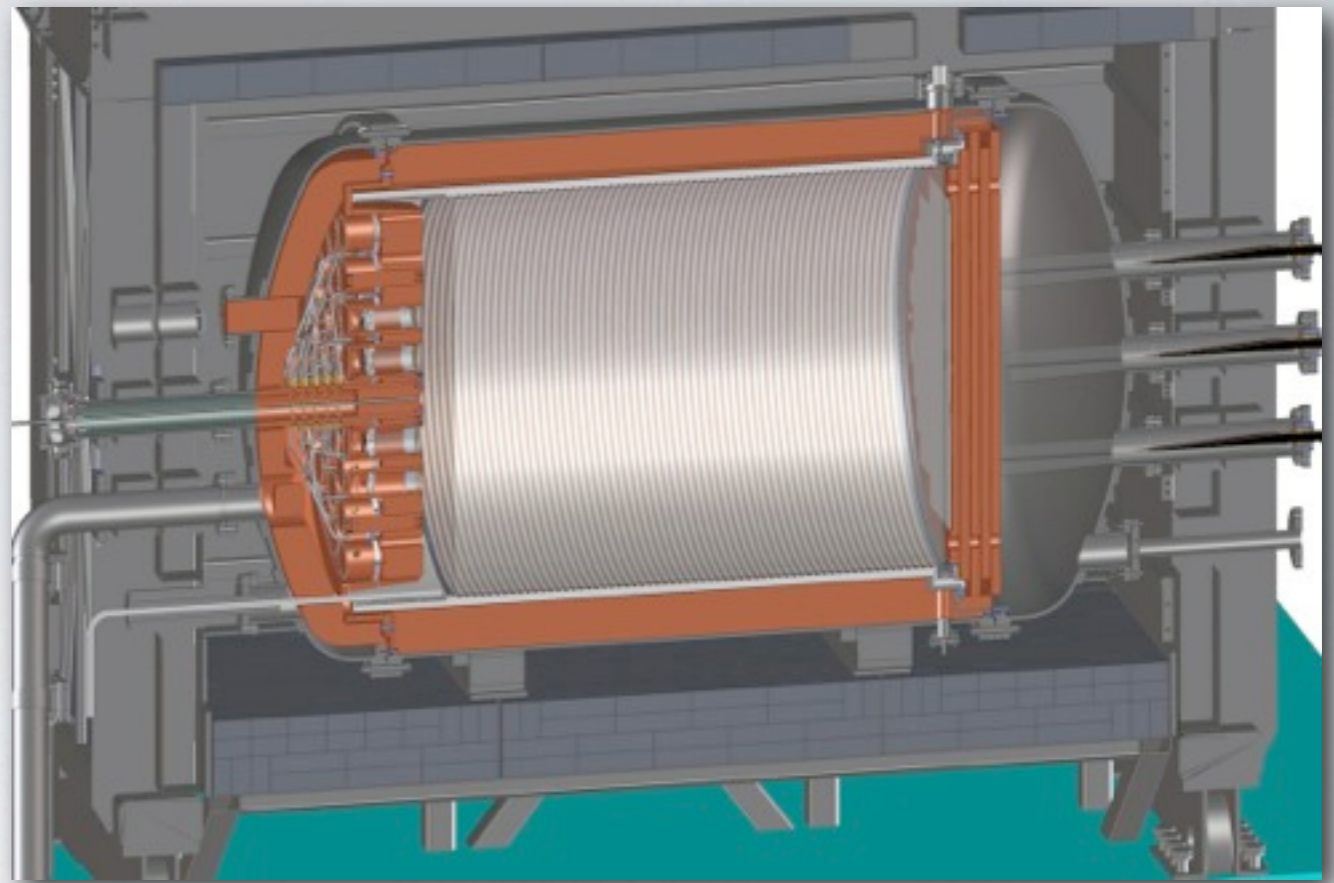


NEXT-WHITE (NEW)



NEXT-WHITE (NEW)

- First phase of NEXT-100 (2014)
- Energy plane with 12 PMTs (20 % of sensors)
- Tracking plane with 23 DBs (20 % of sensors).
- Field cage dimensions: 1:2 NEXT-100
- Mass ~10 kg.
- Radiopure.
- Full validation of background model.
- Measurement of $bb2\nu$ mode.
- Topological signal (2 electrons)



Sensitivity of NEXT-100 to neutrinoless double beta decay

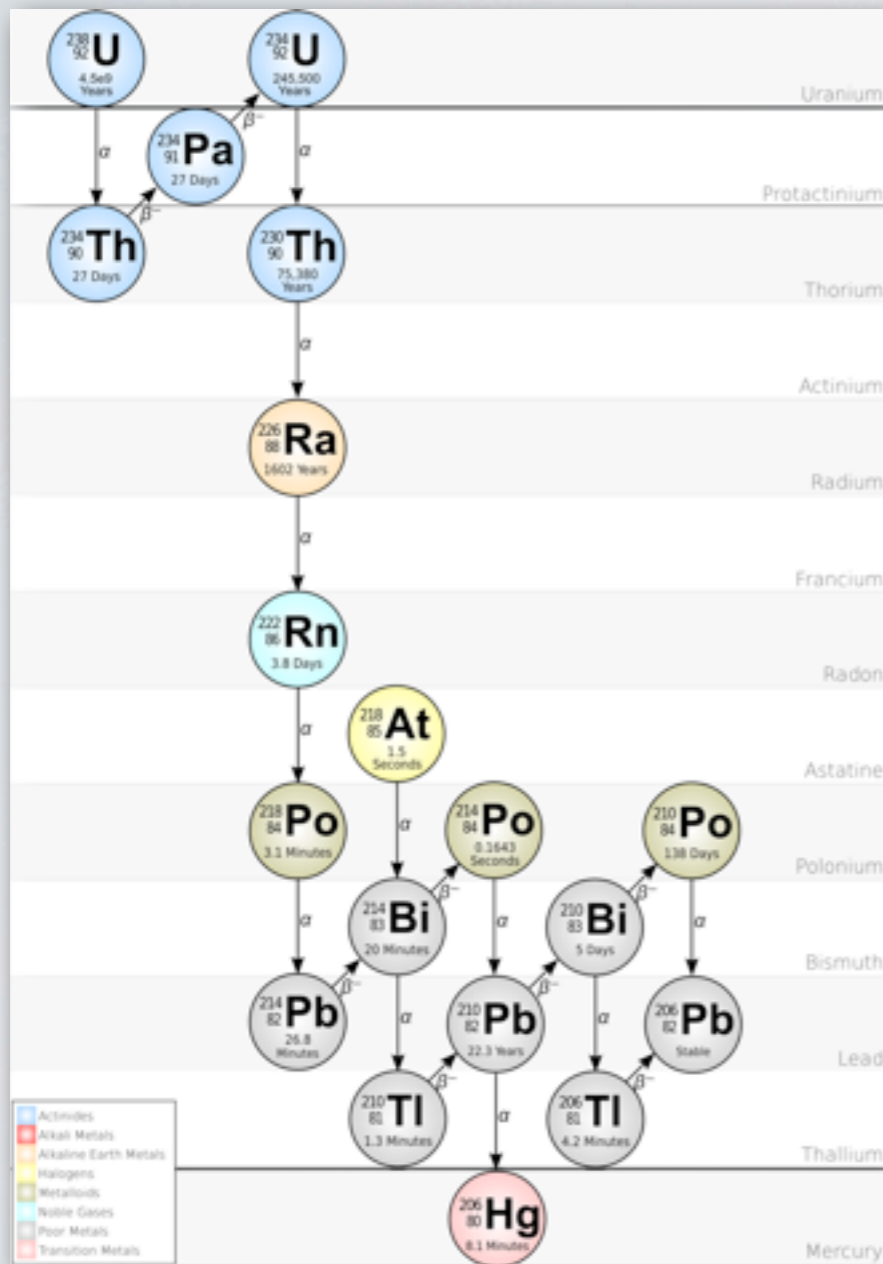
The NEXT Collaboration

V. Álvarez,^a F.I.G. Borges,^b S. Cárcel,^a J. Castel,^c S. Cebrián,^c A. Cervera,^a
 C.A.N. Conde,^b T. Dafni,^c T.H.V.T. Dias,^b J. Díaz,^a M. Egorov,^d R. Esteve,^e
 P. Evtoukhovitch,^f L.M.P. Fernandes,^b P. Ferrario,^a A.L. Ferreira,^g E.D.C. Freitas,^b
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 J.L. Pérez Aparicio,^l J. Renner,^d L. Ripoll,ⁿ A. Rodríguez,^c J. Rodríguez,^a
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 C. Sofka,^o M. Sorel,^a J.F. Toledo,^d A. Tomás,^c J. Torrent,ⁿ Z. Tsamalaidze,^f
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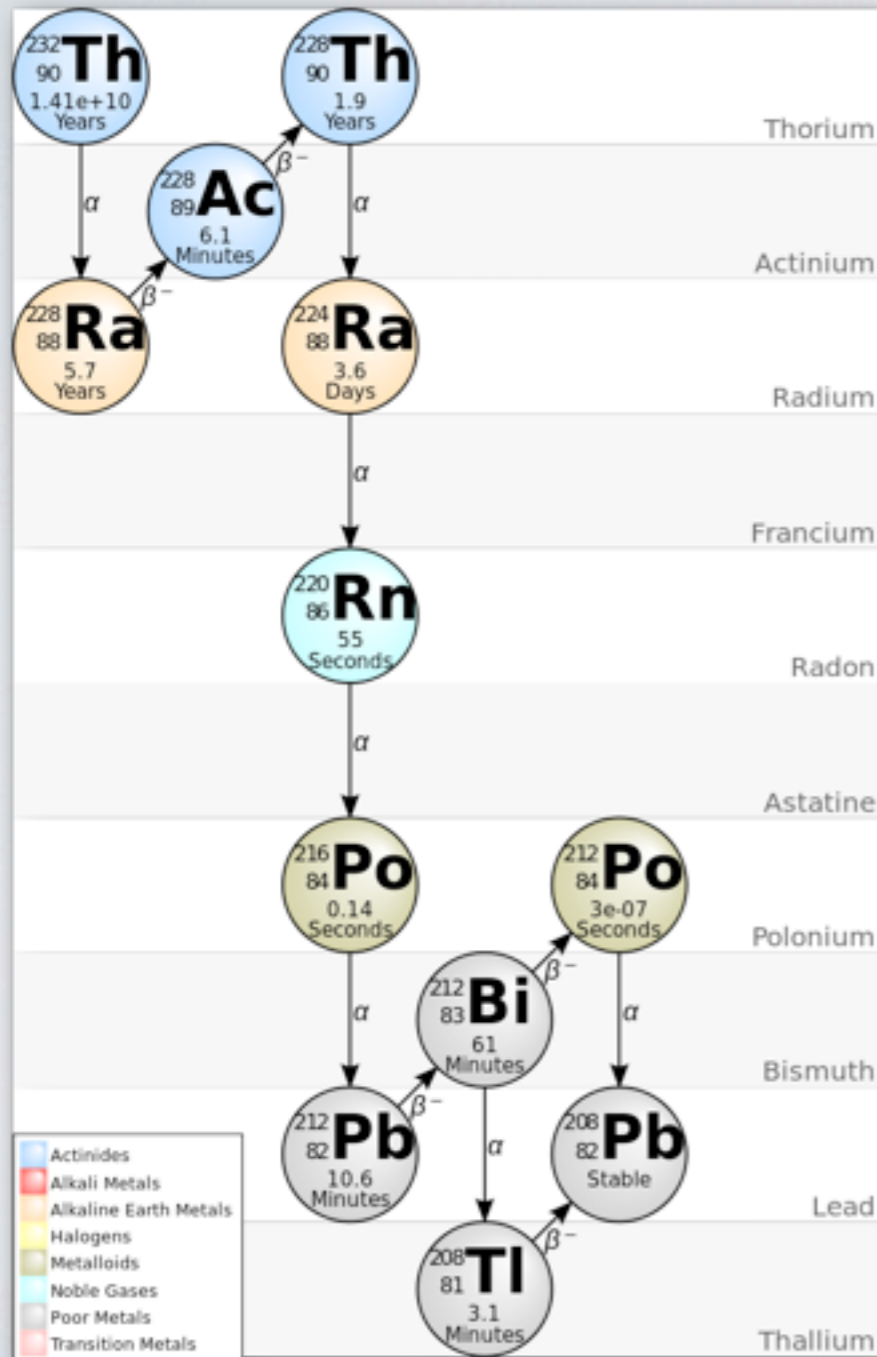
^b*Departamento de Física, Universidade de Coimbra
 Rua Larga, 3001-516 Coimbra, Portugal*

THE BAD GUYS (1)



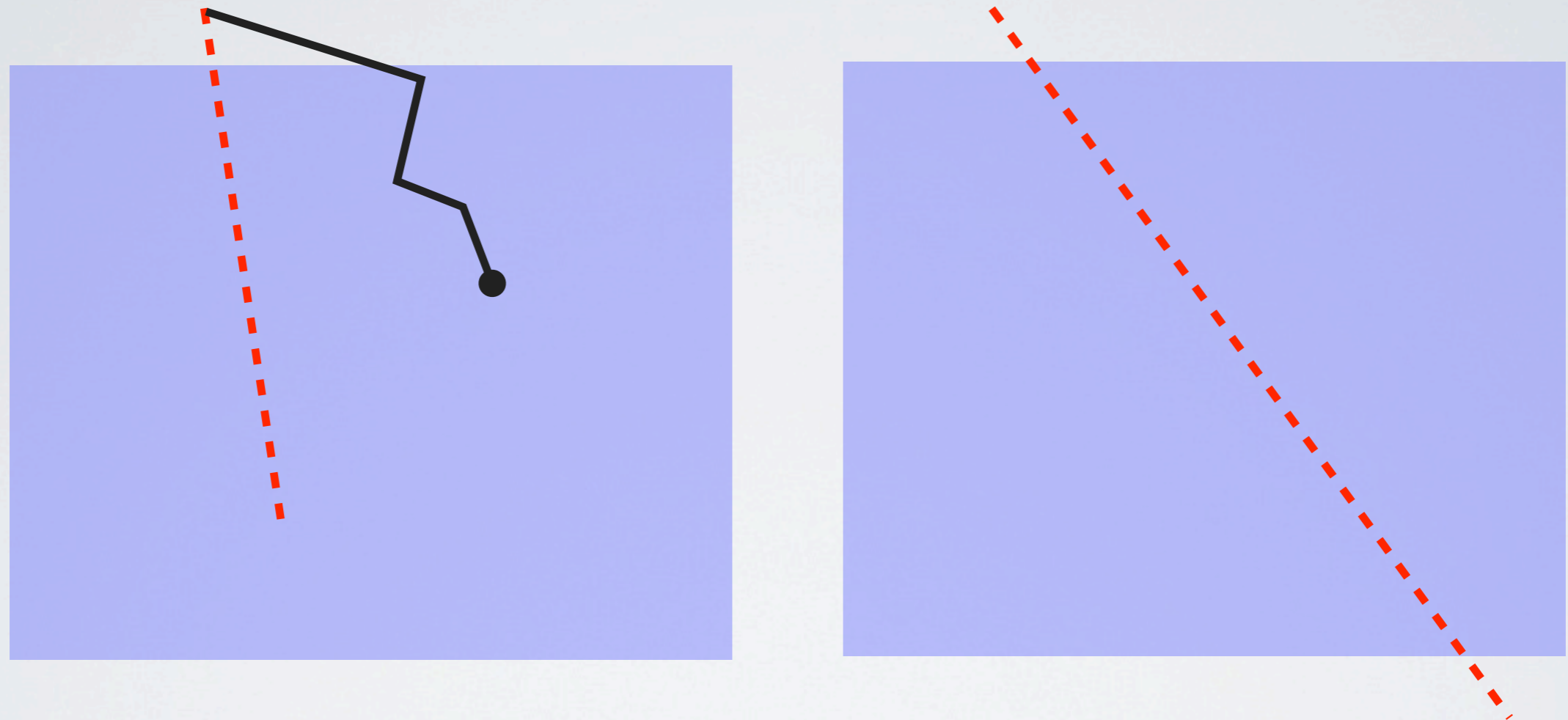
Decay of Bi-214 followed by emission of high-energy gammas. In particular, one at 2448 keV very close to Q value.

THE BAD GUYS (2)



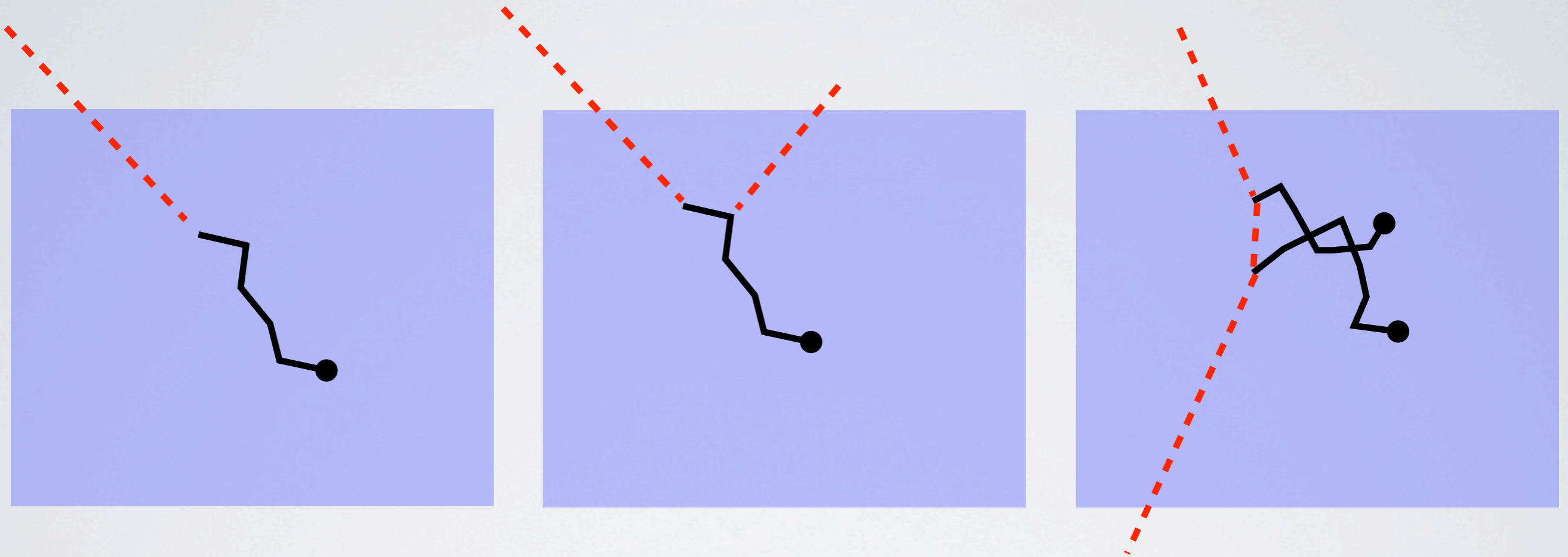
Decay of Tl-208 followed by the emission of a gamma of 2615 keV.

THE TOPOLOGICAL SIGNATURE



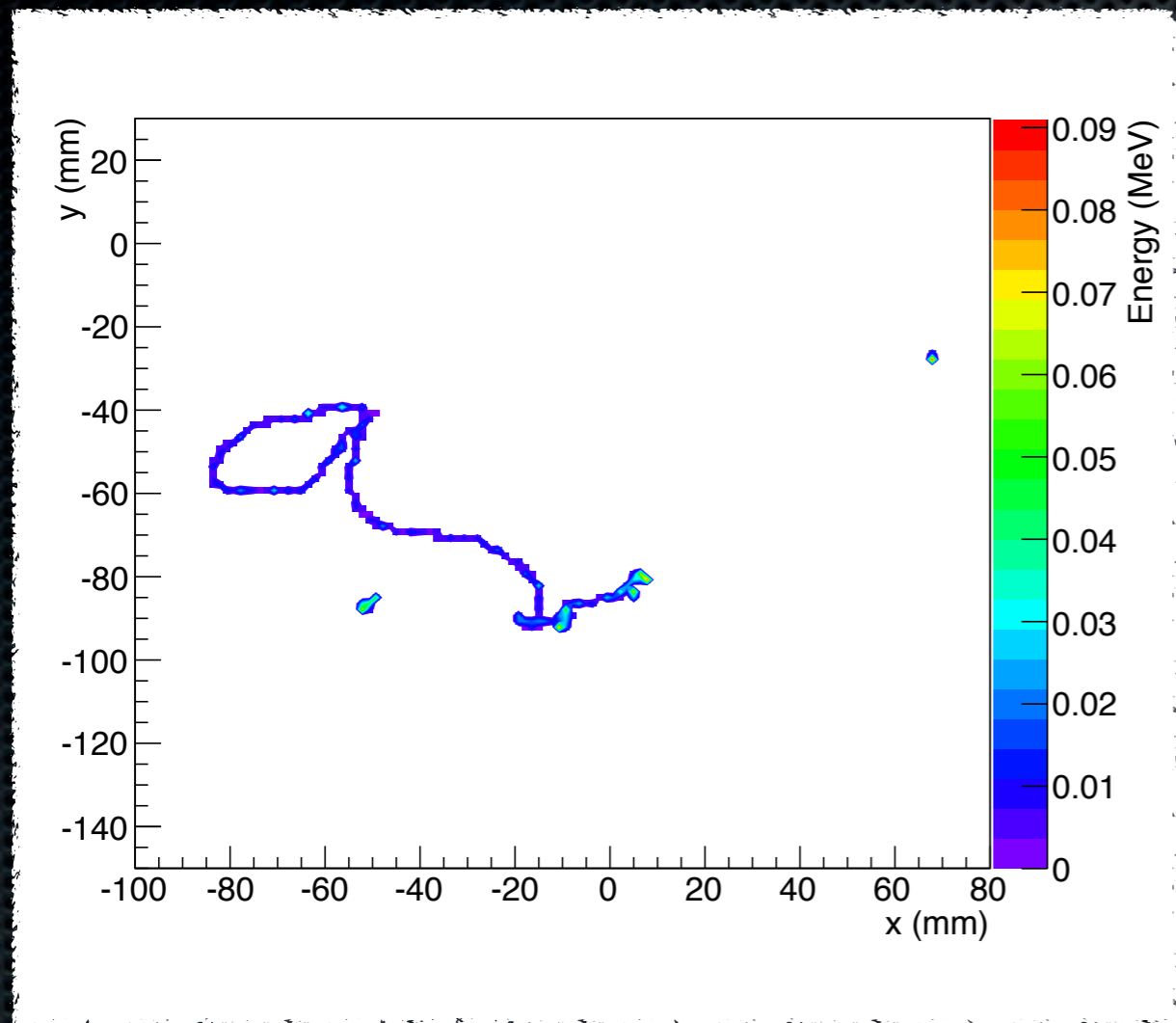
Veto of effectively all charged backgrounds entering the detector (left). High-energy gammas have a long interaction length (>3 m) in HPXe.

THE TOPOLOGICAL SIGNATURE

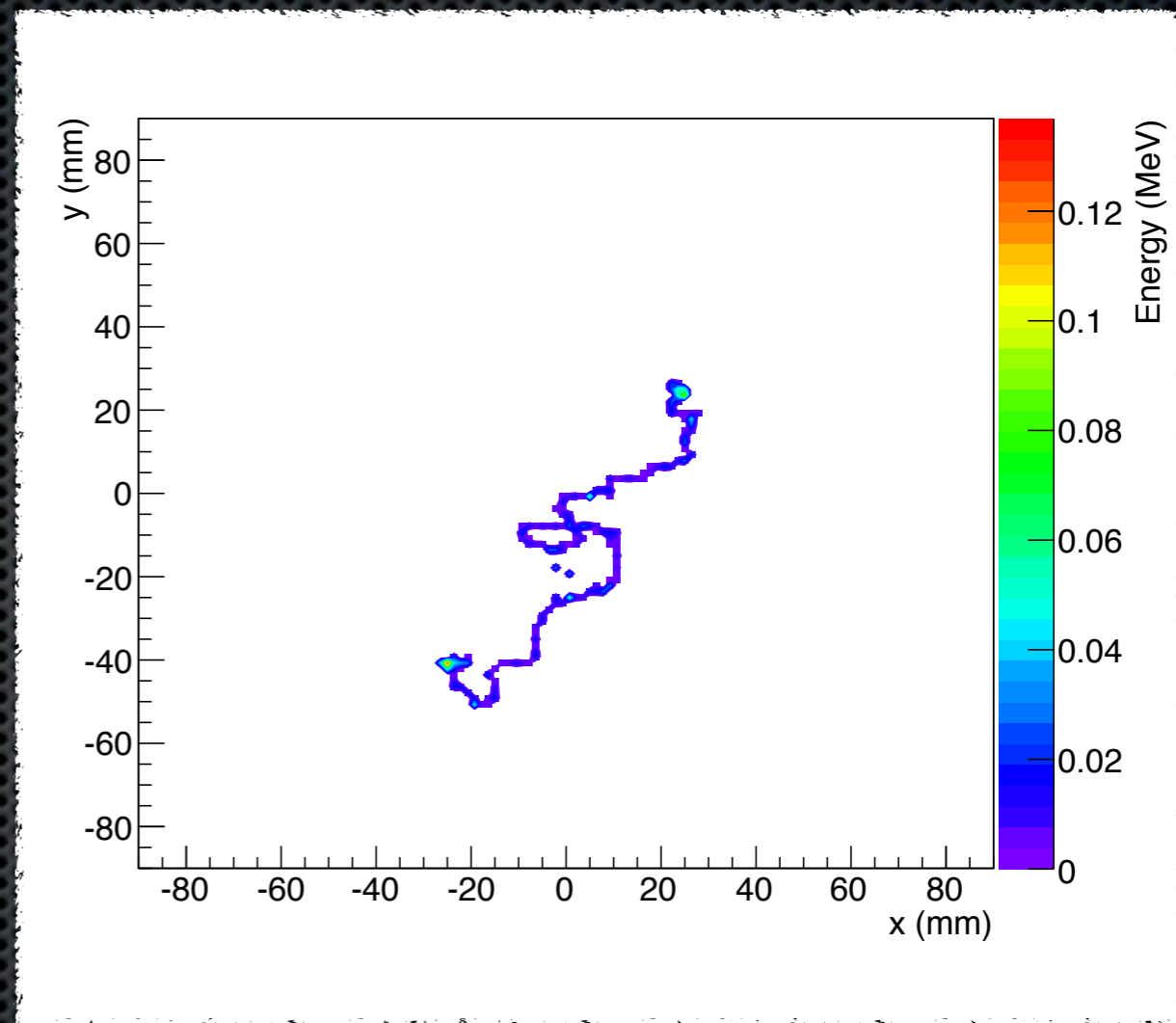


Interaction of high-energy gammas in the HPXe can generate electron tracks with energies around the Q value of Xe-136.

Topological signal



Bi214 photoelectric



Signal

SELECTION CUTS

Selection cut	Fraction of events			
	$\beta\beta 0\nu$	$\beta\beta 2\nu$	^{214}Bi	^{208}Tl
$E \in (2.3, 2.6)$ MeV	0.776	3.31×10^{-6}	1.52×10^{-4}	8.02×10^{-3}
Fiducial	0.678	2.95×10^{-6}	1.13×10^{-4}	4.77×10^{-3}
Single track	0.508	2.27×10^{-6}	1.36×10^{-5}	8.44×10^{-4}
dE/dx	0.381	1.70×10^{-6}	1.36×10^{-6}	8.10×10^{-5}
ROI				
0.5% FWHM	0.311	3.24×10^{-12}	1.23×10^{-7}	3.23×10^{-7}
1.0% FWHM	0.315	3.57×10^{-11}	3.69×10^{-7}	5.40×10^{-7}

RADIOACTIVE BUDGET

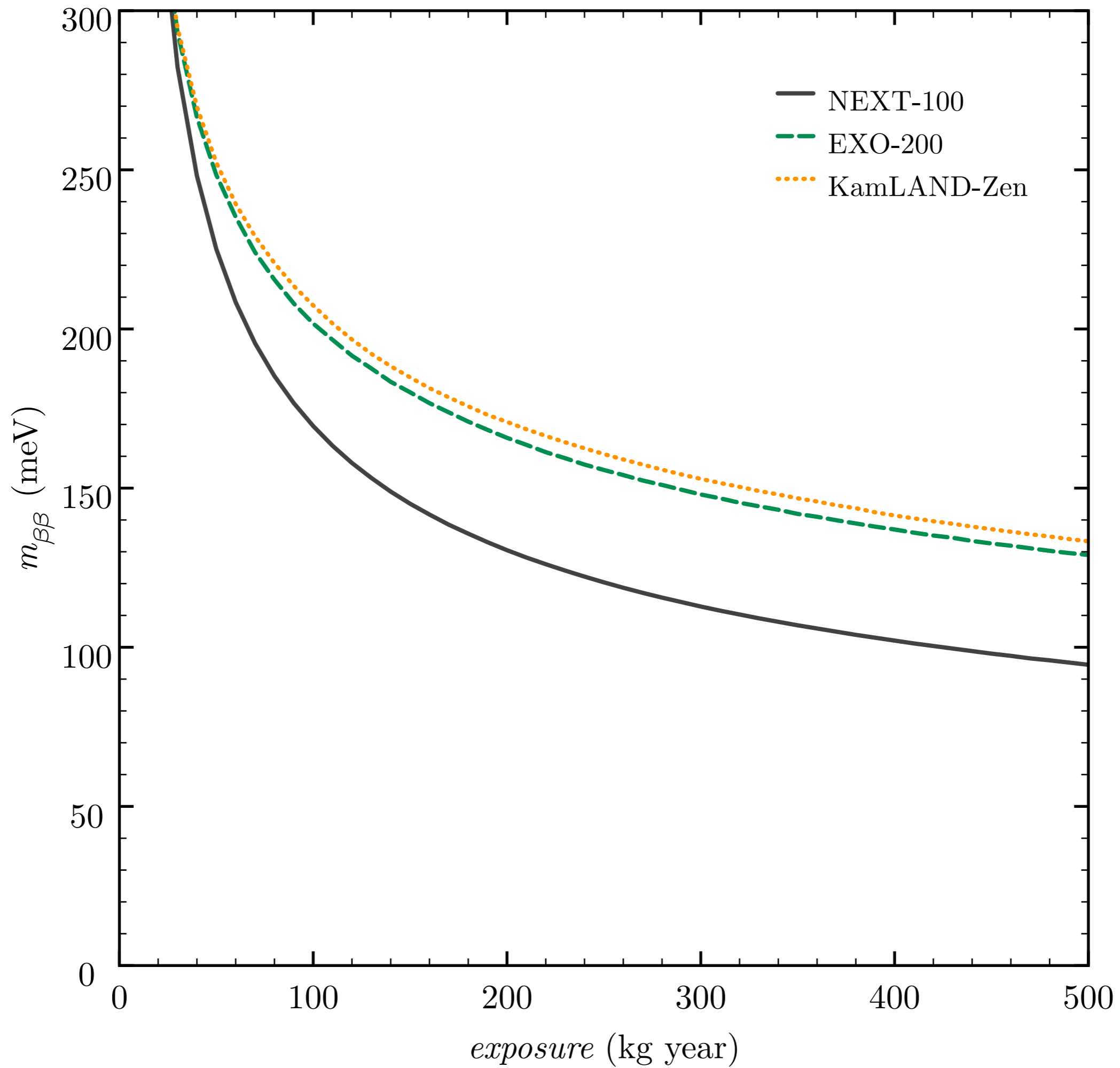
#	Material	Supplier	Technique	Unit	²³⁸ U	²²⁶ Ra	²³² Th	²²⁸ Th	²³⁵ U	⁴⁰ K	⁶⁰ Co	¹³⁷ Cs
Shielding												
1	Pb	Cometa	GDMS	mBq/kg	0.37		0.073			<0.31		
2	Pb	Mifer	GDMS	mBq/kg	<1.2		<0.41			0.31		
3	Pb	Mifer	GDMS	mBq/kg	0.33		0.10			1.2		
4	Pb	Tecnibusa	GDMS	mBq/kg	0.73		0.14			0.91		
5	Pb	Tecnibusa	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

BACKGROUND RATE

System	Bi-214 (10^{-3} ckky)	Tl-208 (10^{-3} ckky)	Total (10^{-3} ckky)
Vessel	<0.01–0.01	0.02–0.03	0.02–0.04
Energy plane	0.05–0.17	0.03–0.28	0.08–0.45
Tracking plane	0.05–0.10	0.12–0.13	0.17–0.23
Inner shielding	0.02–0.03	0.01–0.01	0.03–0.04
Field cage	0.05–0.09	0.03–0.03	0.08–0.12
Total	0.18–0.40	0.21–0.48	0.38–0.88

THE COMPETITION

Experiment	M (kg)	enrichment (%)	efficiency (%)	resolution (% 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	31	0.5–1.0	0.4–0.9



Schedule

- NEW installation at LSC: 2014
- NEW operation (bb2nu): 2015
- NEXT-100 installation at LSC: 2016
- NEXT-100 operation at LSC: 2017-2020+
- NEXT-1 ton: Design and feasibility studies in 2017, construction 2018-2020?
- NEXT-1 ton operation: 2020?

Outlook

- This is an exciting moment for the field. Three experiments (Gerda, EXO-200, KamLAND-Zen) have presented (negative) results, essentially excluding previous claimings of signal observation. Over the next few years CUORE and NEXT-100 will further extend the search.
- Experiments based on Ge (with full shielding and multi-site detection), scintillating bolometers (a la Lucifer) and xenon seem capable of reaching the 50 meV mark, provided they can acquire and deploy the mass (this may be easier for Xenon). HPXe and LXe detectors with Ba tagging or another technological break through (graphene?) seem very attractive.
- The NEXT program (NEW, NEXT-100, NEXT-1ton), offering good resolution and a topological seignature seem a viable path forward to fully explore the inverse hierarchy

In Memoriam: James White, friend and mentor

