Searching for Neutrinoless Double Beta Decay with gas Xe TPCs : R&D for NEXT

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(on behalf of the NEXT collaboration)

CIEMAT - MADRID

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The idea: A high-pressure gaseous Xenon TPC for $0\nu\beta\beta$

Why xenon:

- Noble gas
- No long lived radioactive isotopes
- ^{136}Xe $Q_{\beta\beta}$ ~2.4 MeV (8.9% natural ab.)
- Easy to enrich and to purify
- High ionization and scintillation yield
- …

Why high pressure *gas* xenon:

- Energy resolution better than liquid
- Possible topology cut

⇓

Electroluminescence:

- Ionization electrons extracted and accelerated in a E field → secondary scintillation signals
- Primary scintill. detected by photosensor → t0

➢ *Very good energy resolution*

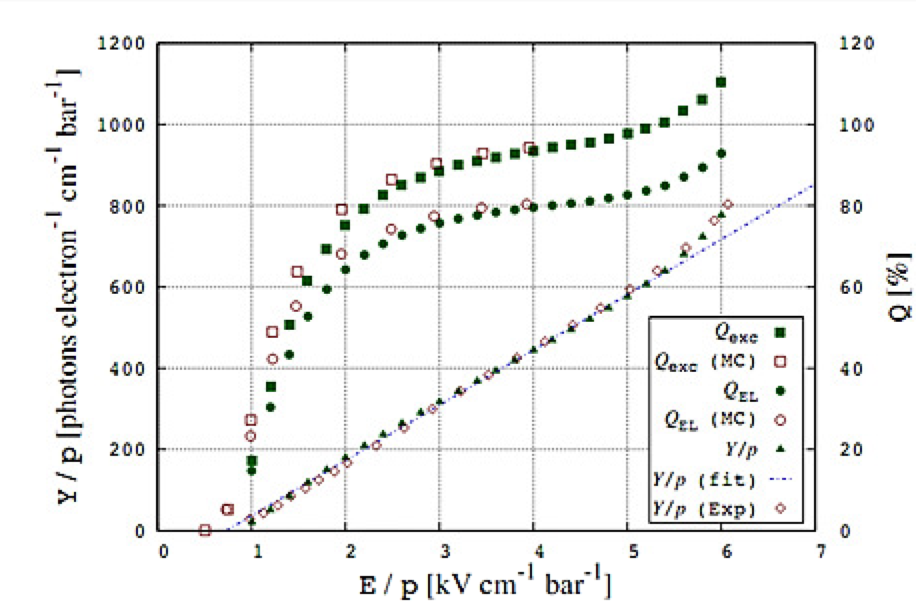
➢ *Full event topology reconstruction*

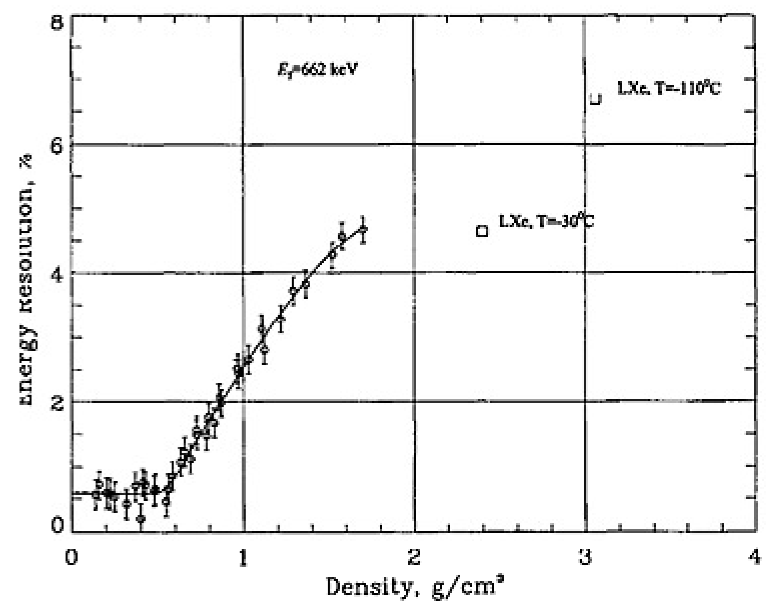
Electroluminescence & Resolution

Ionizations charge accelerated by a moderate electric field.
→emission of scintillation light by excited atoms

⇓

Amplification of the ionization signal (linear process)

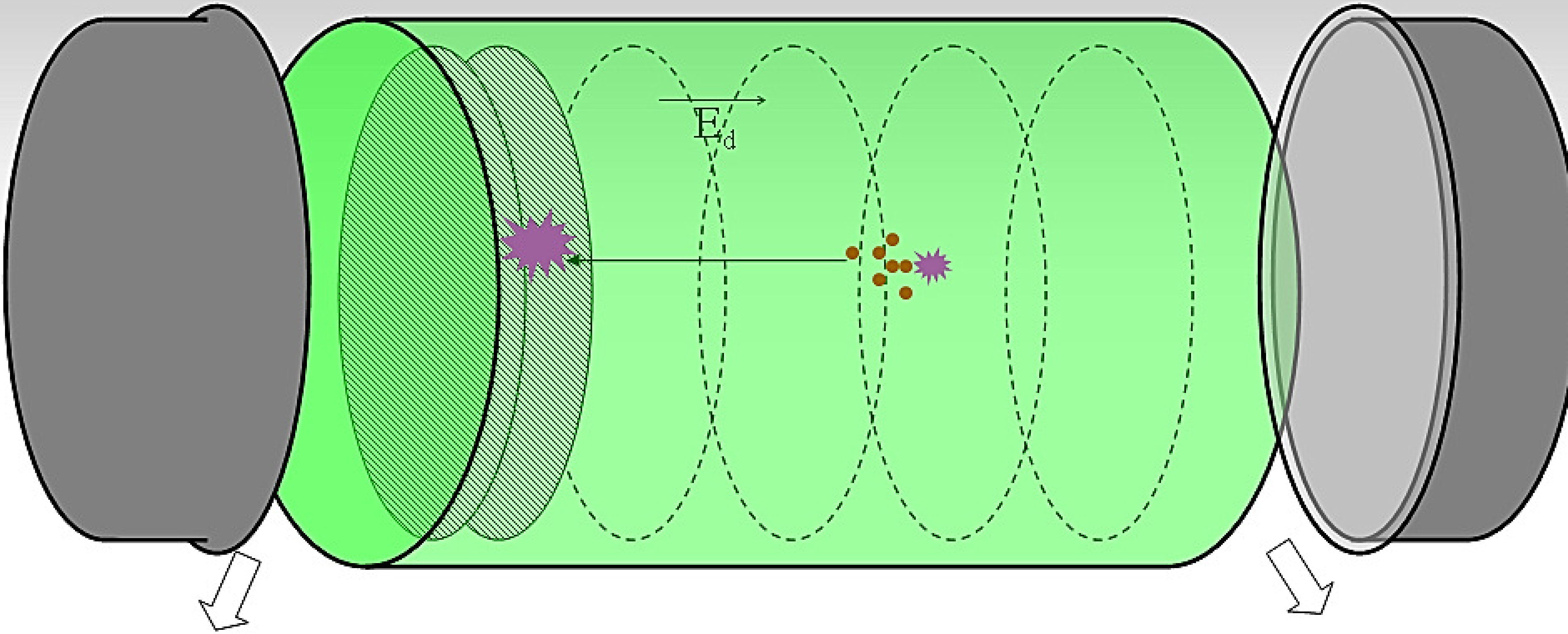


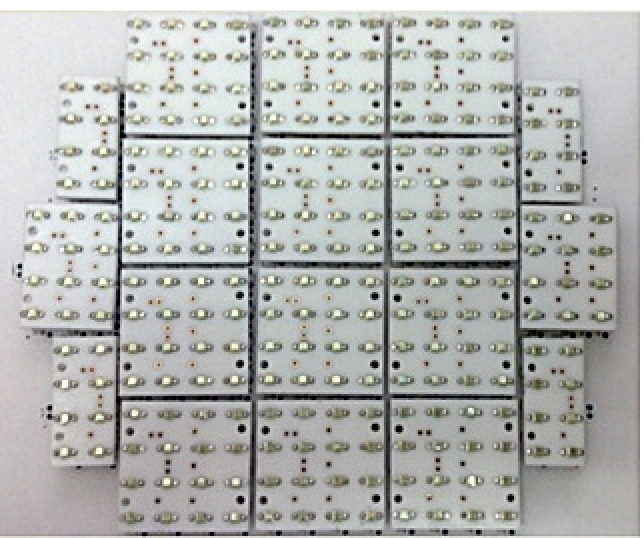


Bolotnikov and Ramsey NIM A 396 (1997)

Intrinsic resolution (Fano factor) at $Q_{\beta\beta}$ (2458 keV): 3×10^{-3} FWHM
Best experimental result: 5×10^{-3} FWHM
Goal < 1% FWHM

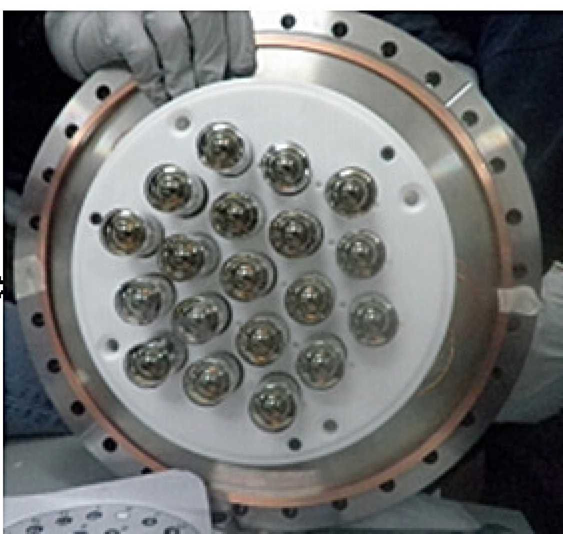
Electroluminescence & TPC



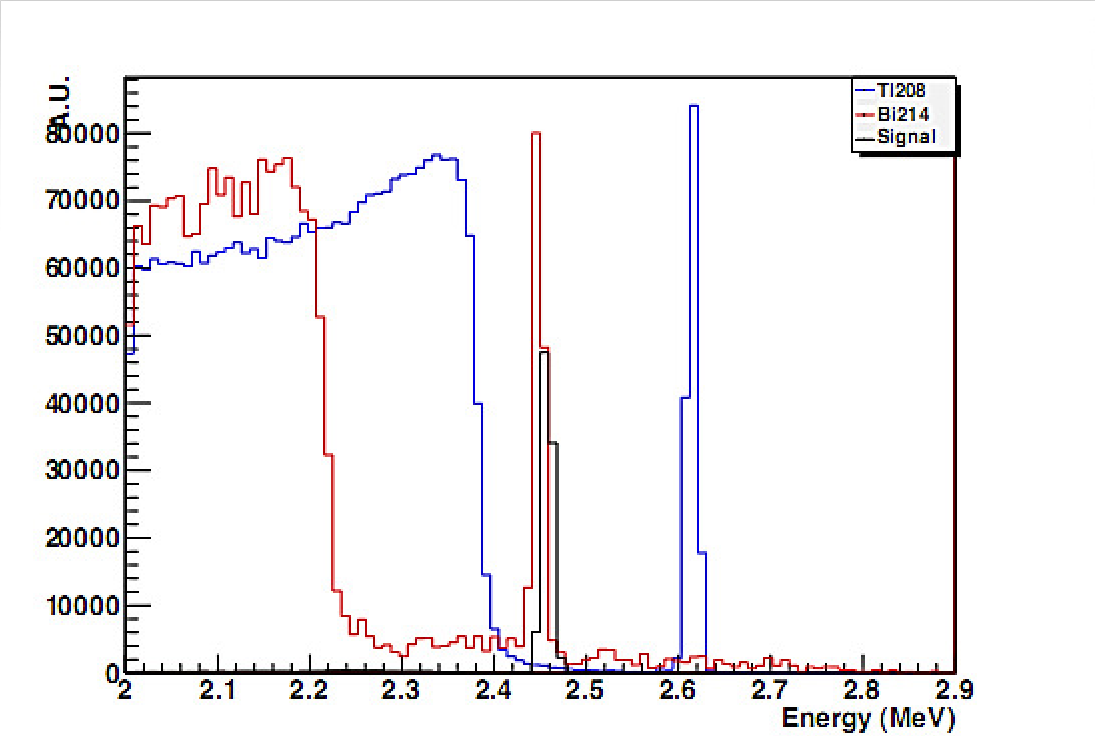


Anode → tracking

Energy & t0 ← Cathode



Background & energy resolution



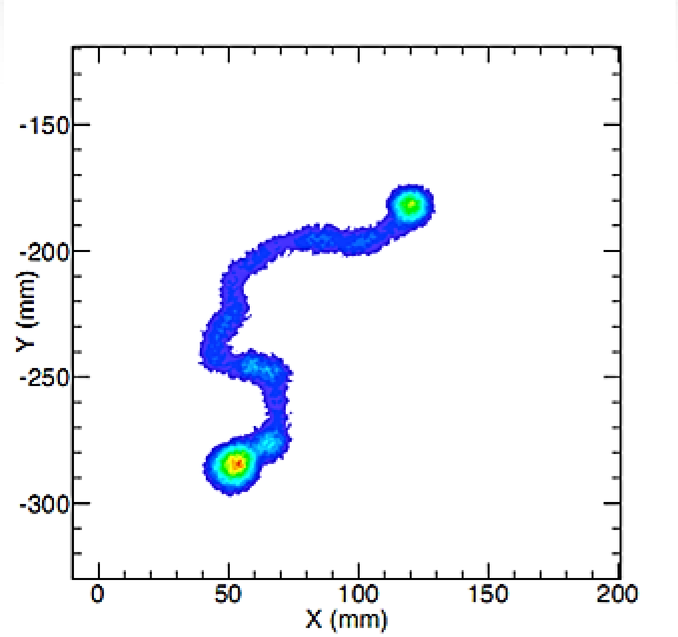
Only significant backgrounds → high energy gammas from ^{208}Tl and ^{214}Bi (from ^{232}Th and ^{238}U)

Resolution required of the of the order of 1% or less (FWHM)

Stringent requirements on materials e design (pressure vessel, photosensors, shield ..)

Background rejection: Tracking

$$T_{1/2}^{-1} \sim a \cdot \varepsilon \cdot \sqrt{\frac{M \cdot t}{\Delta E \cdot B}}$$

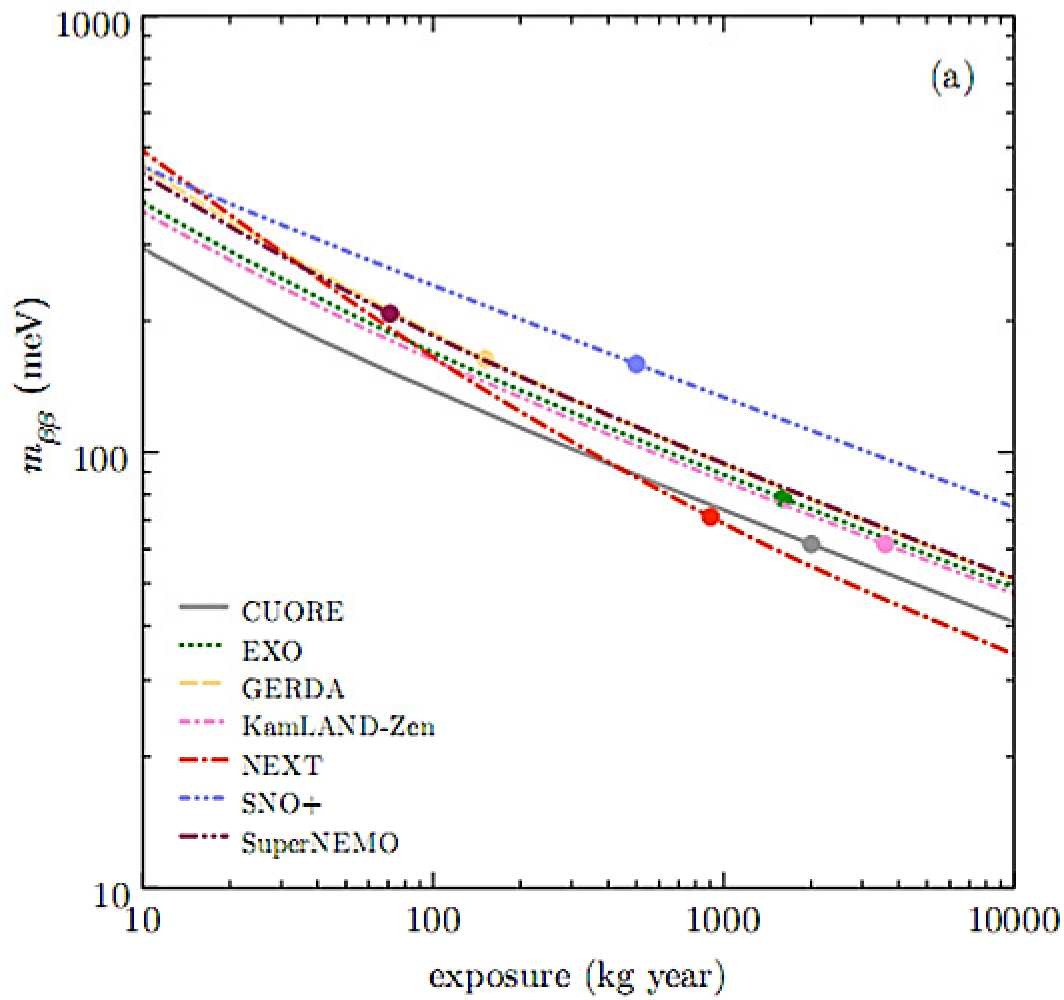


Typically ~15 cm tracks
(highly affected by multiple scattering)
Electrons behave as MIPs except near the endpoints (→ 2 blobs).

WARNING: Non-negligible diffusion (10 bar) : 9 mm/√m transverse,
4mm/√m longitudinal

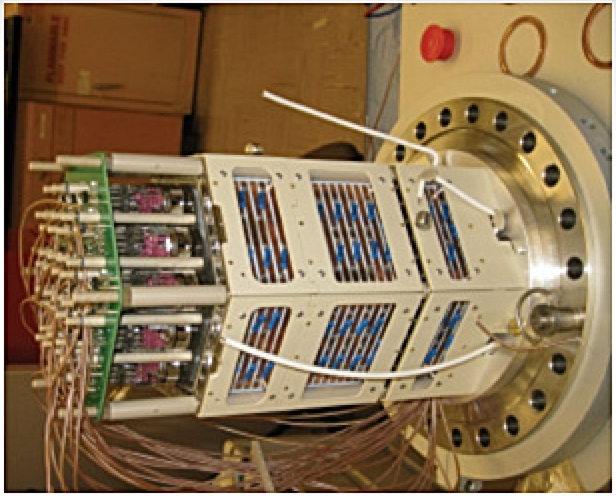
Finely segmented photo-detector plane behind anode required for optimal tracking

Sensitivity



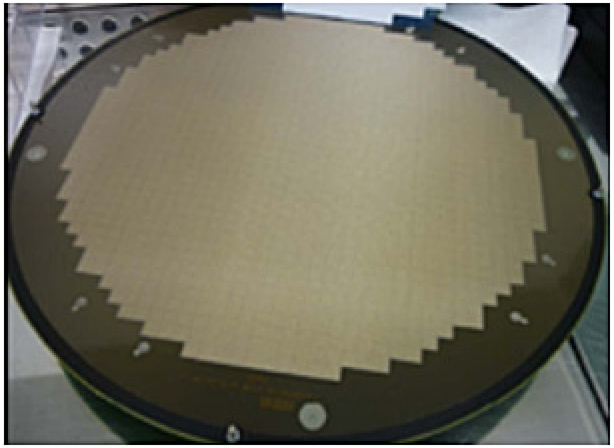
R&D carried out with different prototypes @ 1 kg scale

IFIC

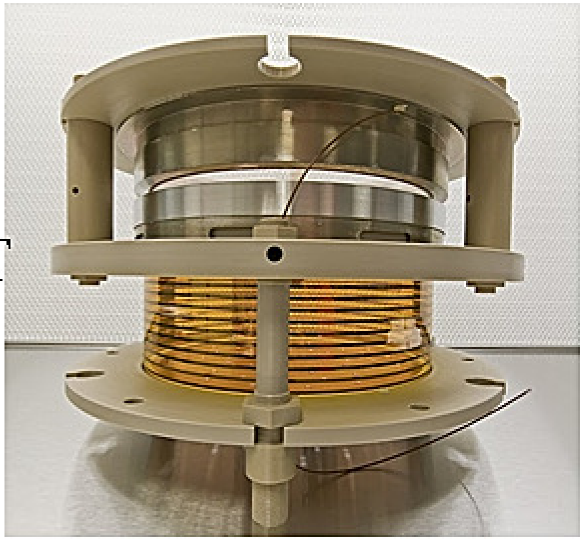


LNBL

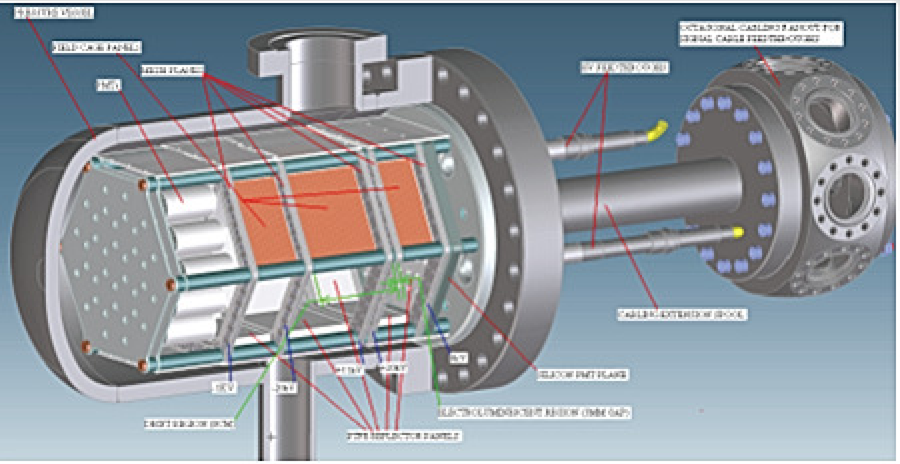
UNIZAR

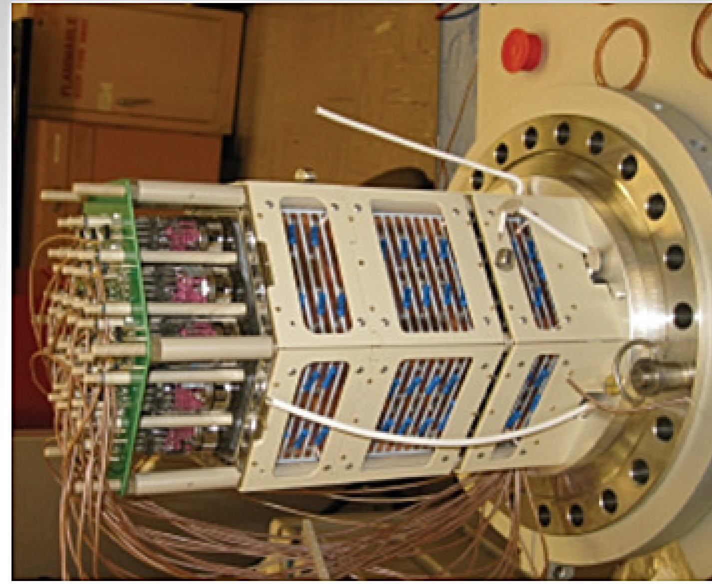


IFAE/CIEMAT



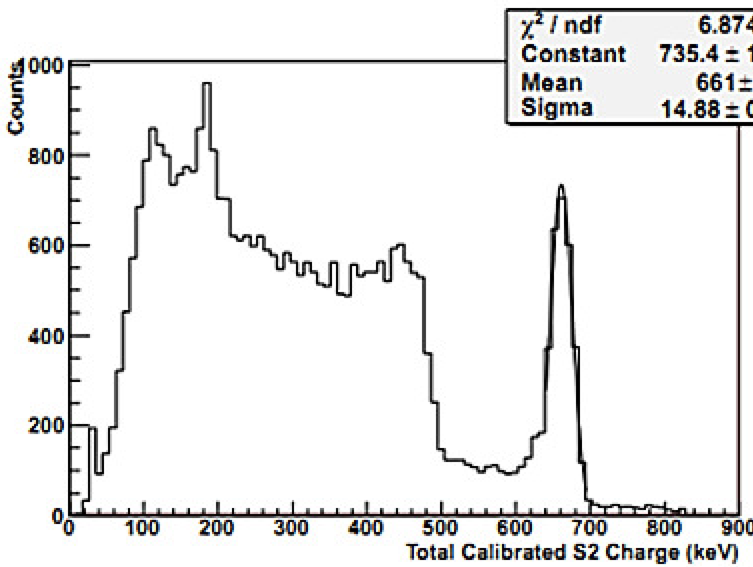
NEXT-1 EL @LNBL

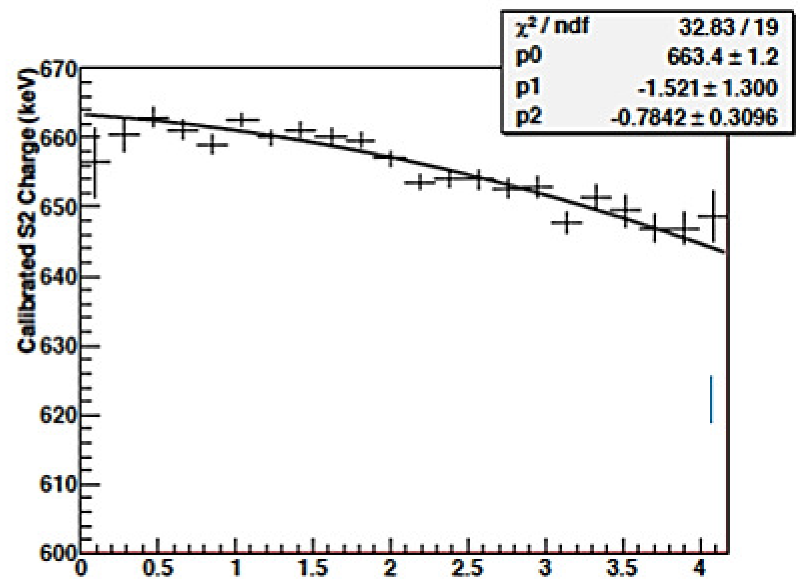




- 19 PMTs (cathode)
- Runs up 17 bar pressure
- 10 cm drift

^{137}Cs data





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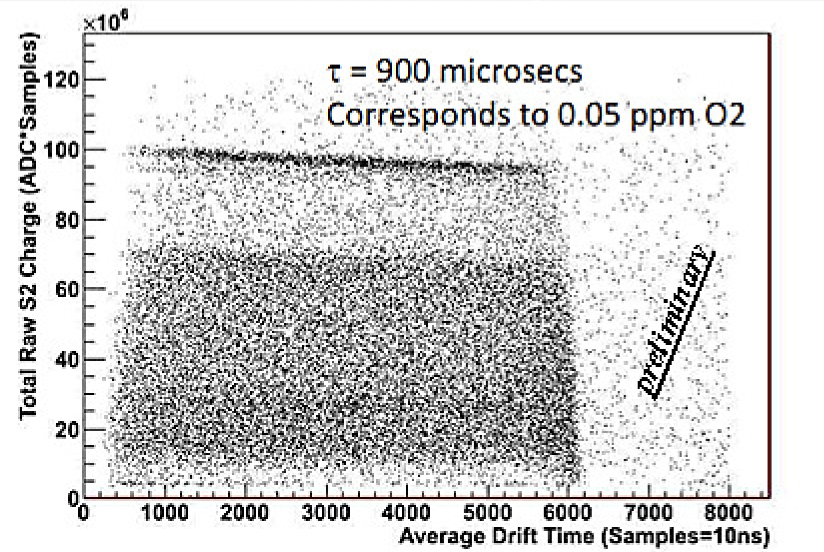
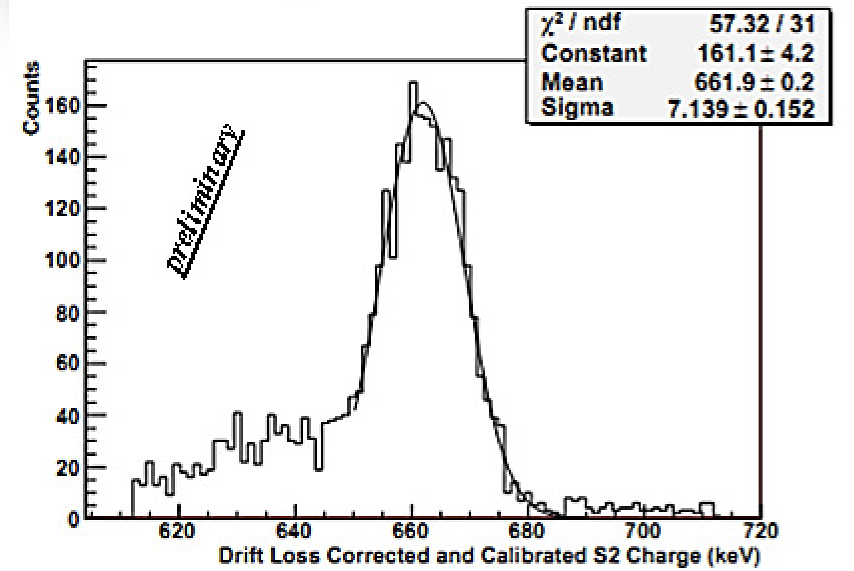
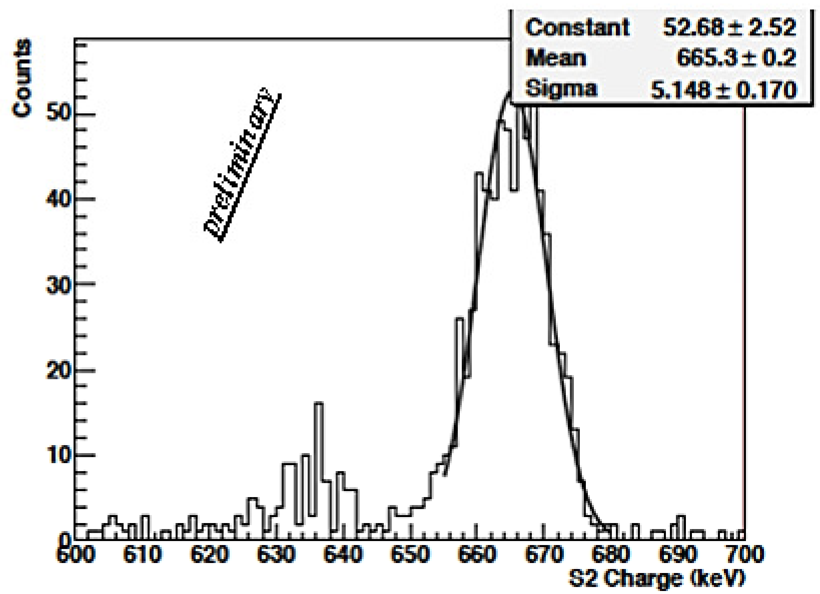
Drift 1.29 mm/μs



$\Delta E/E \sim 2.5\%$ (FWHM -attachment corr.)





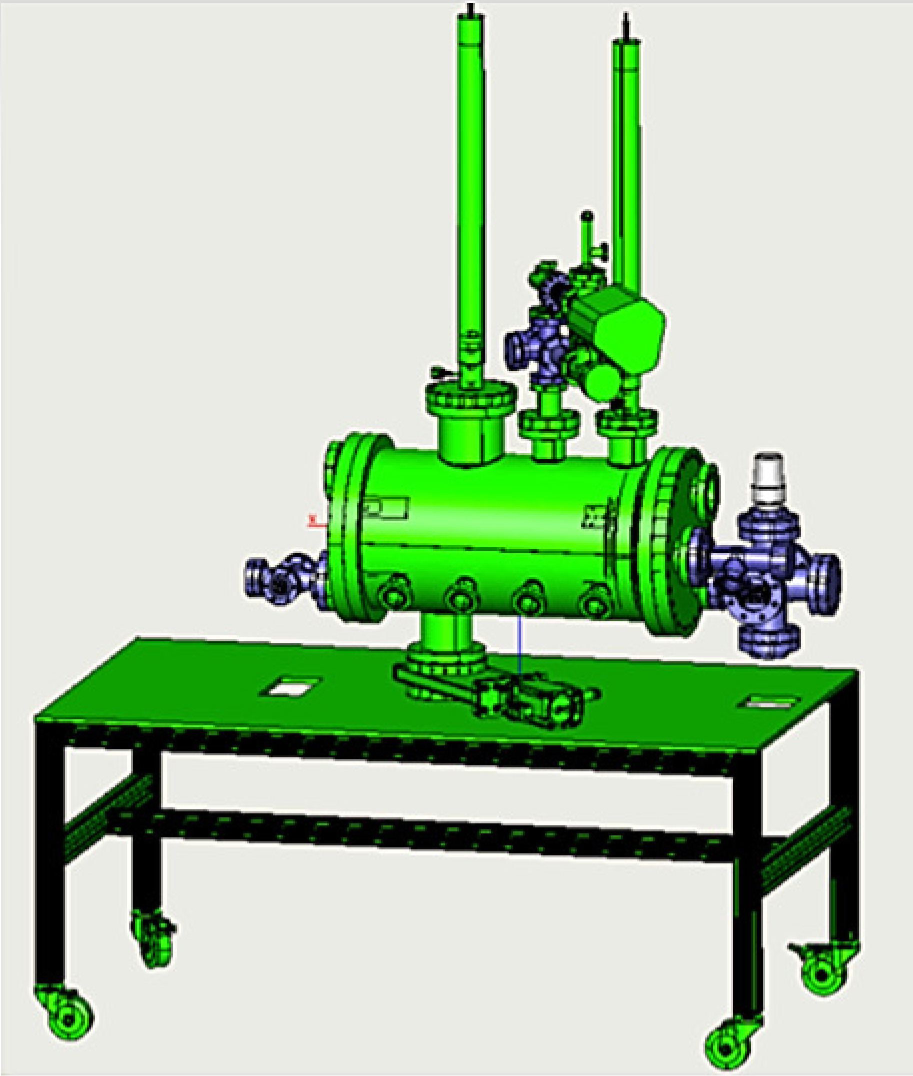
$\Delta E/E \sim 1.8\%$

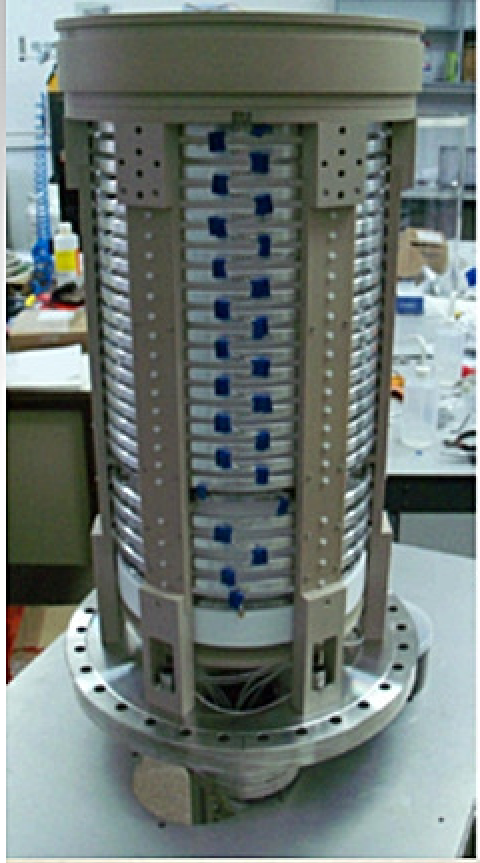
(FWHM)

$\rightarrow$ extrapolates to ~0.9% at $Q_{0\nu\beta\beta}$

10 bar – 1.7 kV/cm – E/P~2.56 kV(bar·cm)

NEXT-1 EL @IFIC





Tracking plane (SiPM / PMT)

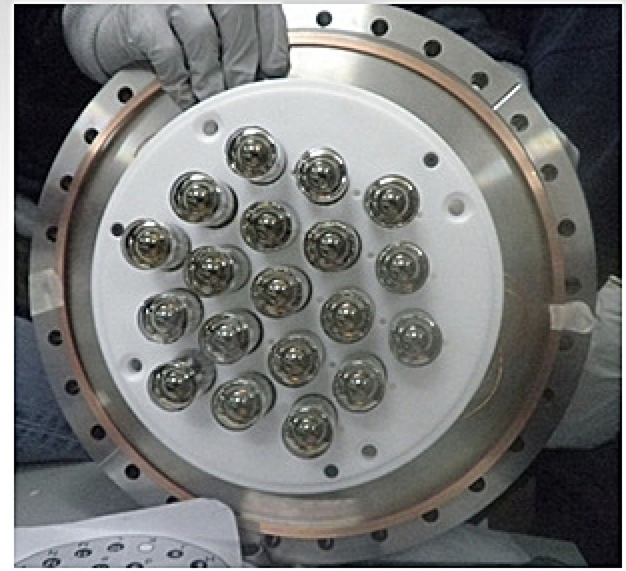
0.5 cm EL gap

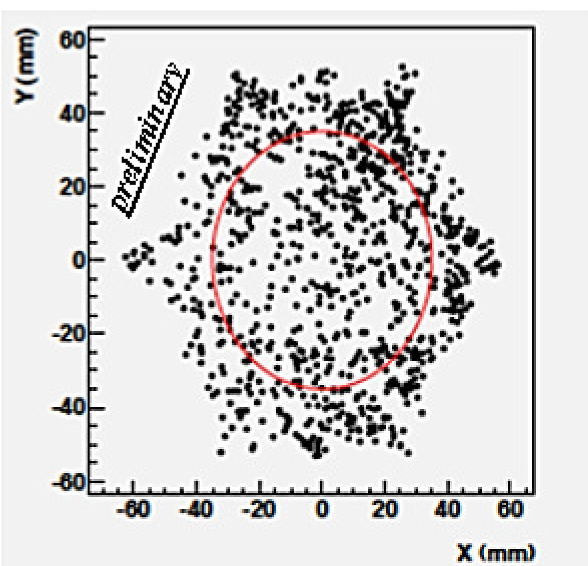
30 cm drift field

10 cm buffer region

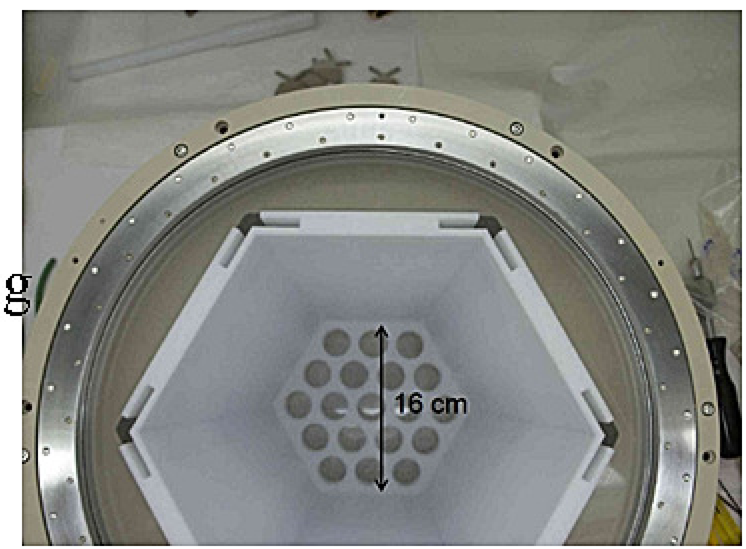
Energy/t0 plane (PMTs)

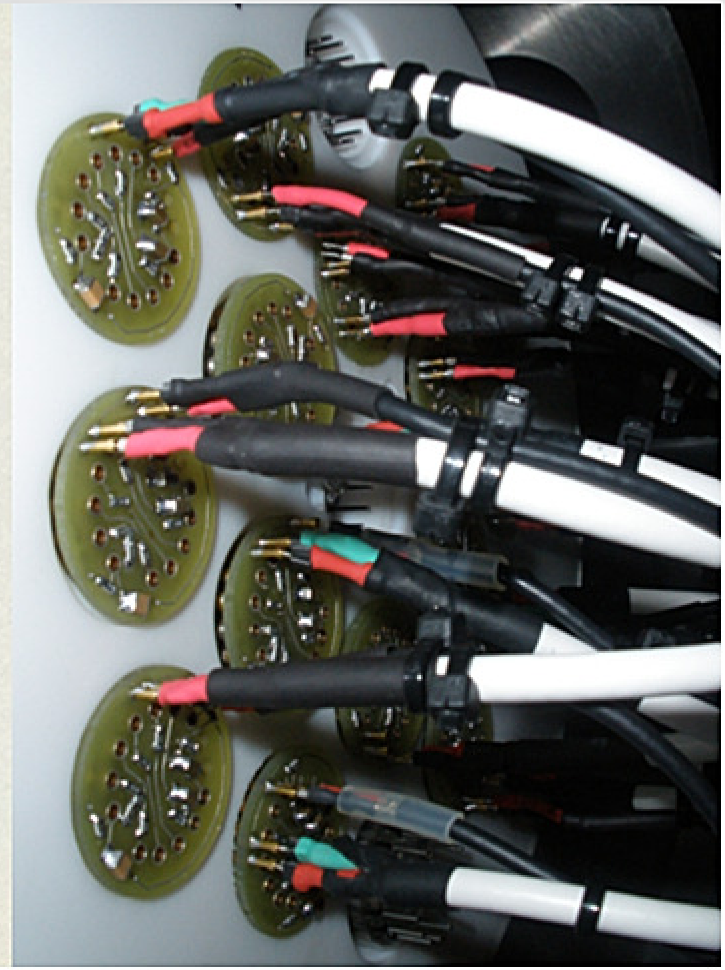
19 PMTs (1")
Hamamatsu7378A



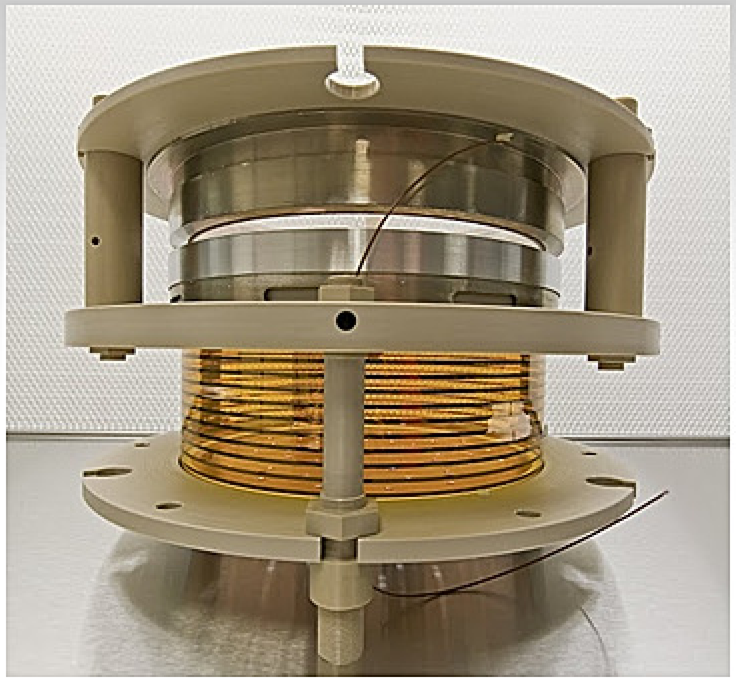


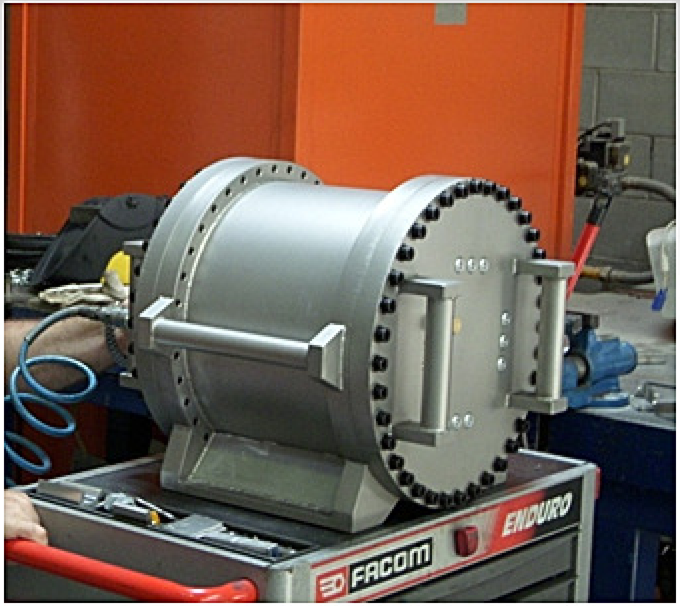
Largest HPGXe currently operating

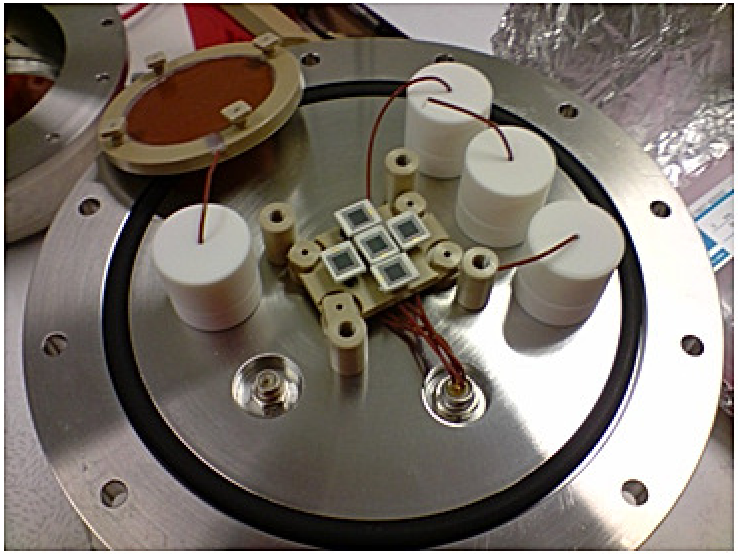




APD prototype (IFAE/CIEMAT)

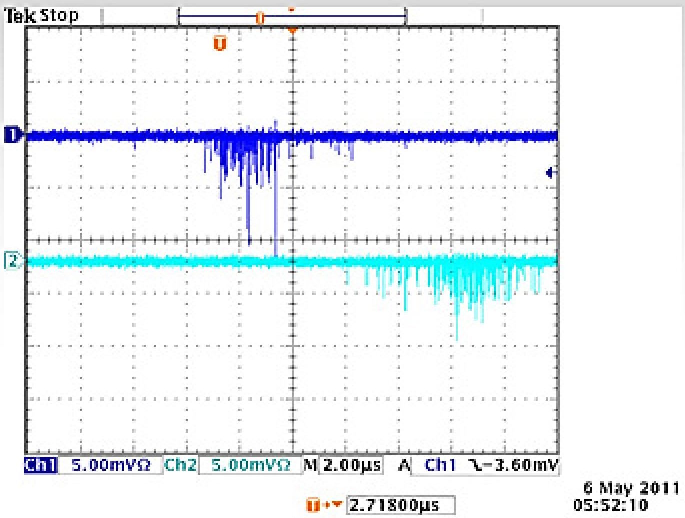


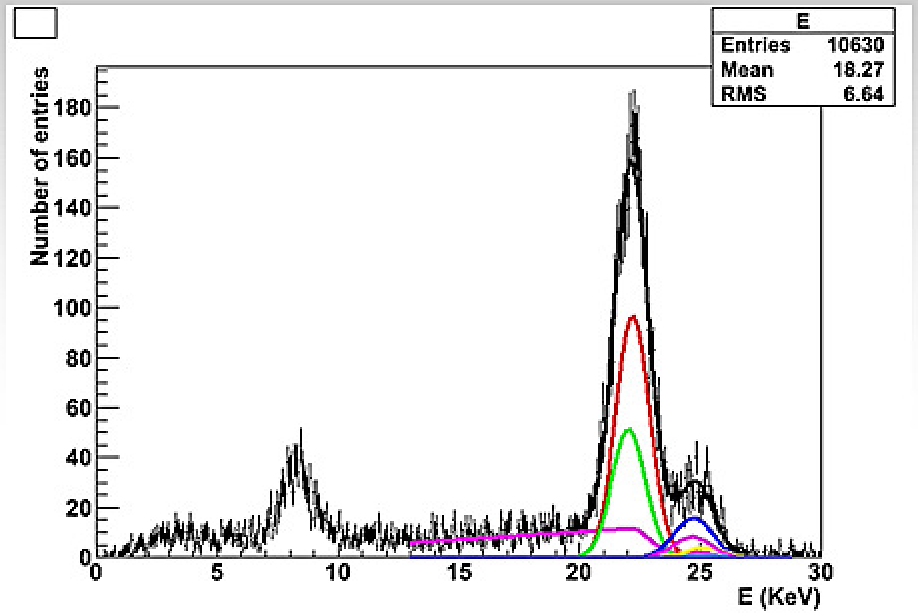




- Collaboration CIEMAT/IFAE
- Hamamatsu APD S8664-SPL
  direct sensitive to 172 nm (and 128 nm)
- current chamber up to 5 APDs
- CAEN 64 channel ADC
- Setup for about 30 APDs and 2 PMTs
- Active volume: diameter 20 cm, height 12cm

APD prototype (IFAE/CIEMAT)

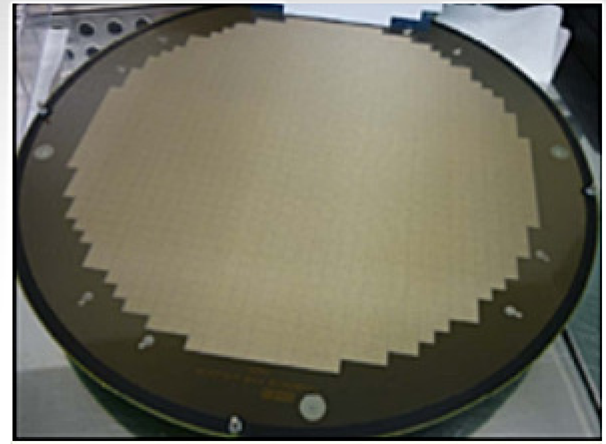




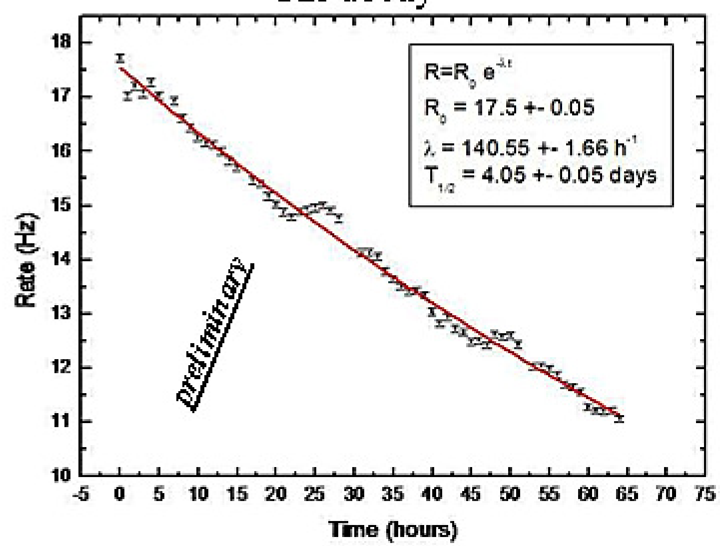
- Position +/- 5mm respect to the center
- Fitting 2 Gaussians (width and position fixed for 25 keV peak wrt 22 keV)
- Additional peak at 8 keV -> x-ray fluorescence of copper
- Ratio of the two Gaussians in agreement with literature

MM prototype (UNIZAR)

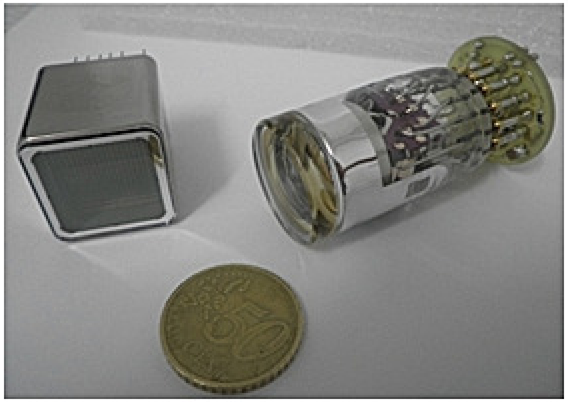
1152 pixels bulk MM, d~30cm

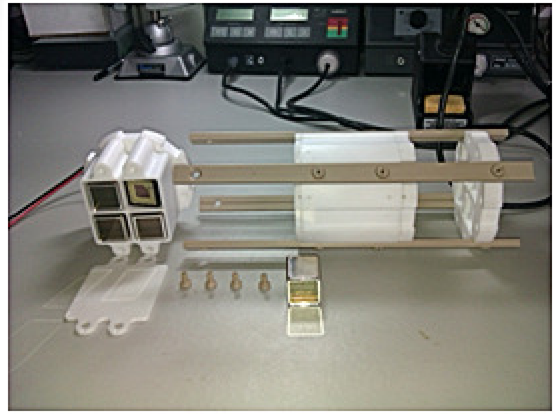


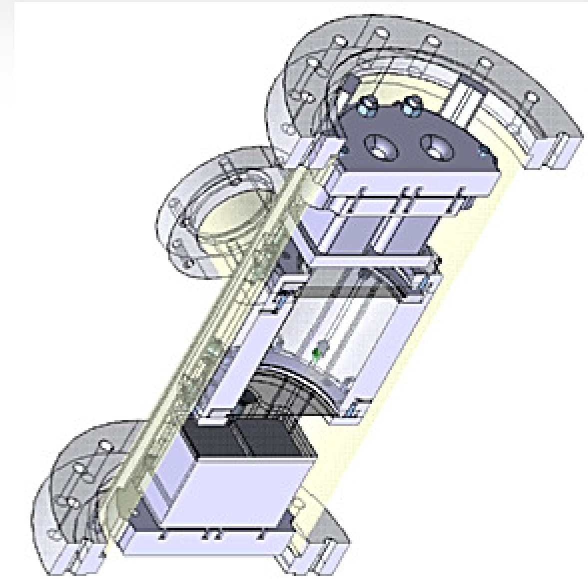
Rn decay

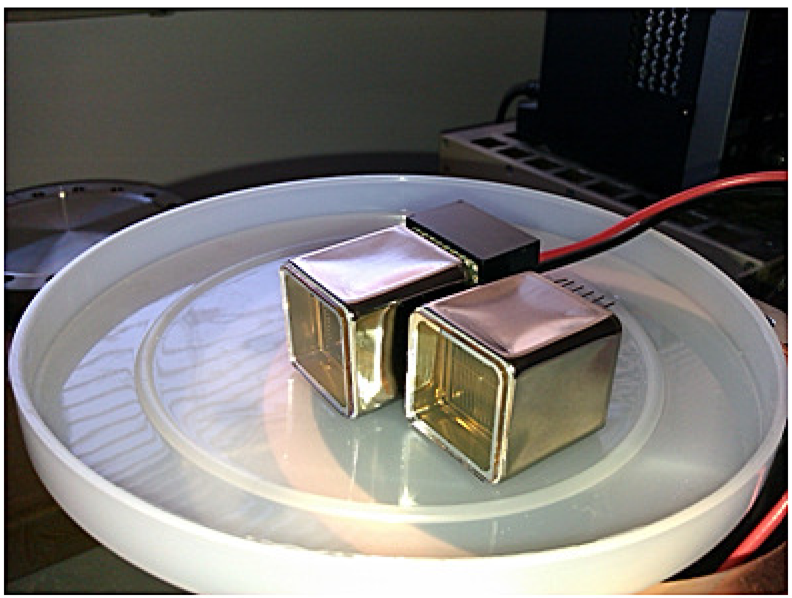


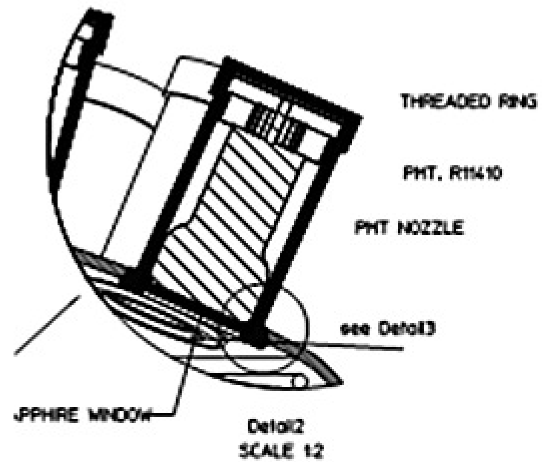
Other R&D: PMT pressure tests



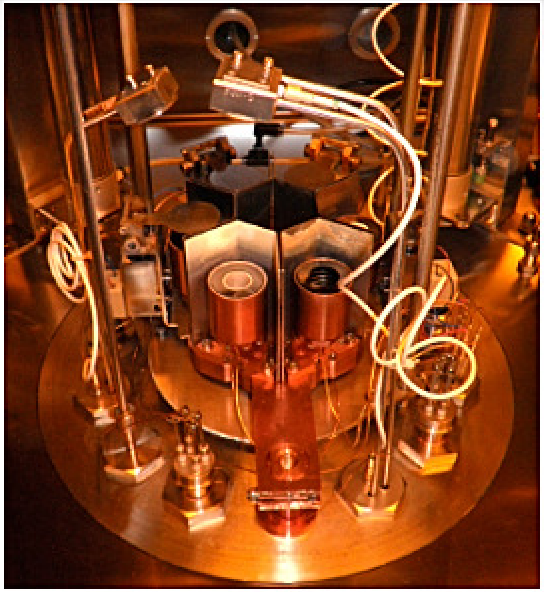


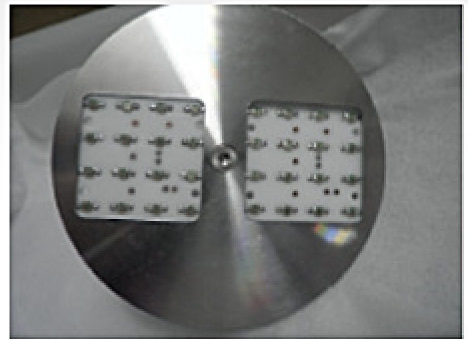


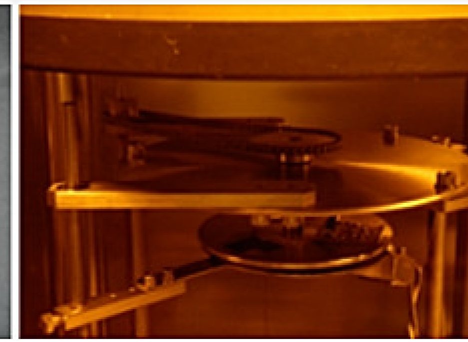


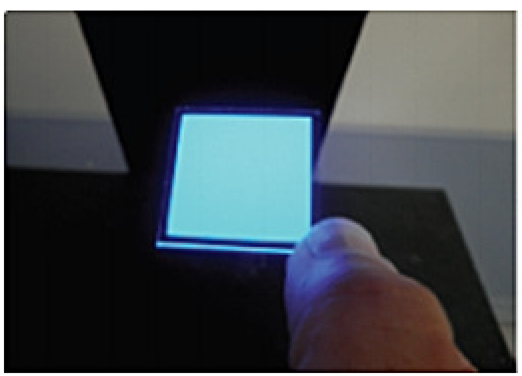


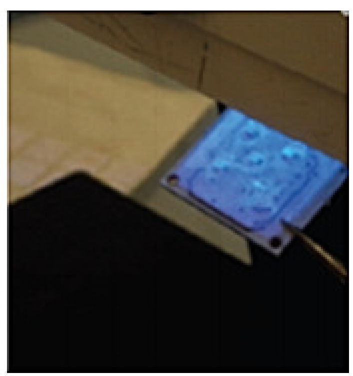
TPB COATING

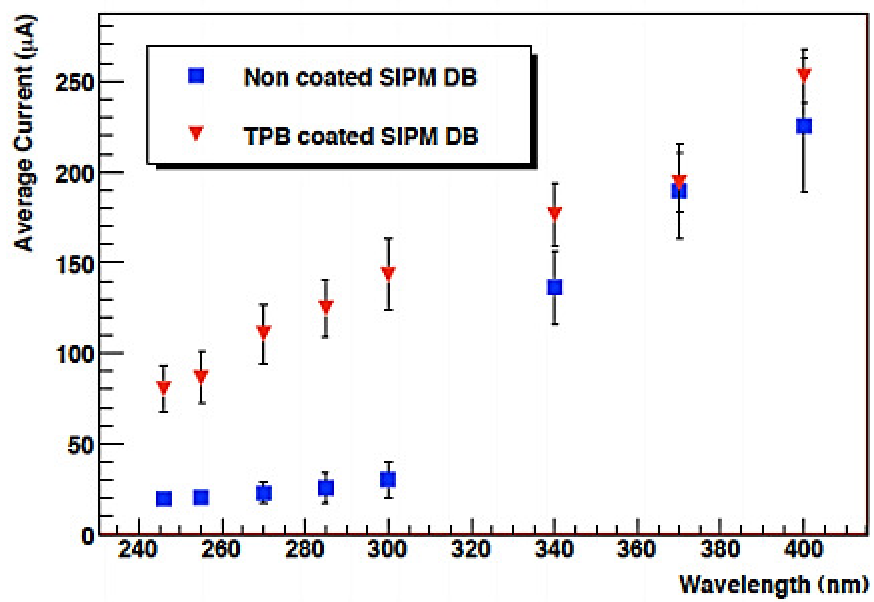












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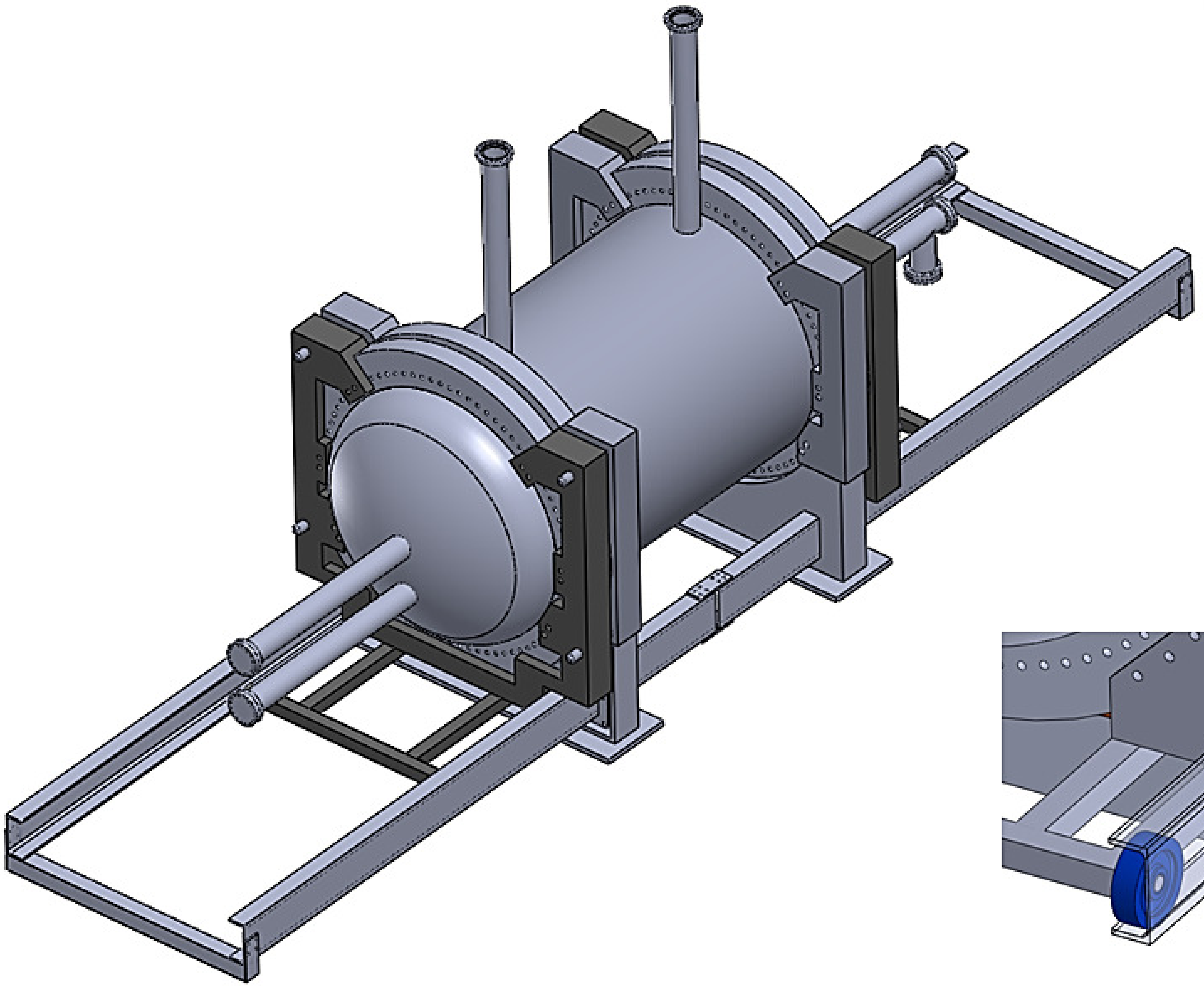
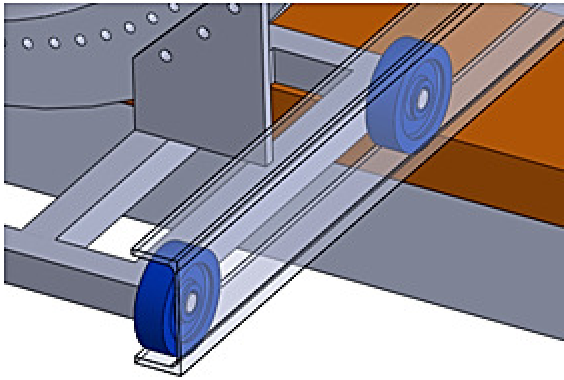
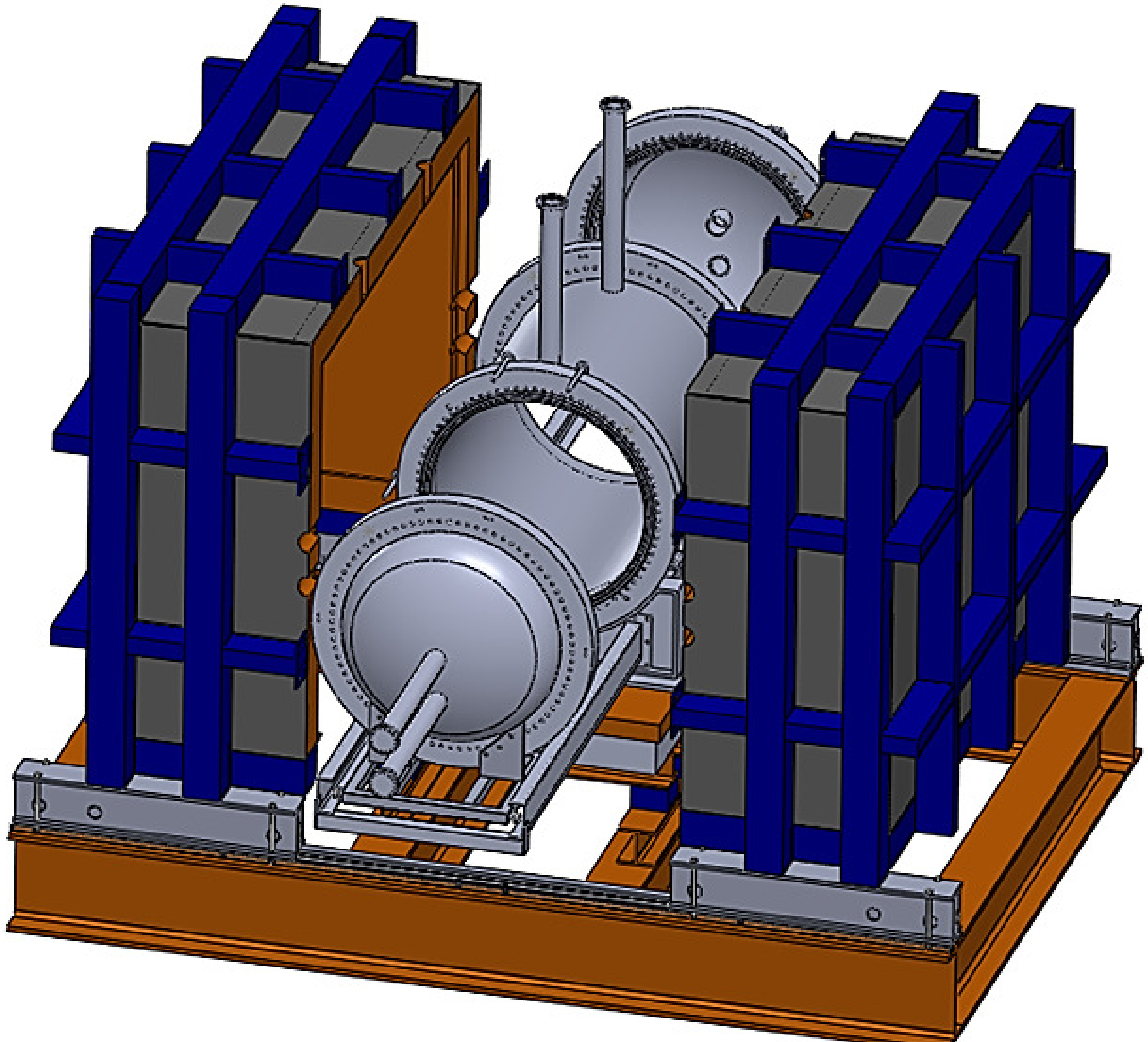
Vessel preliminary design

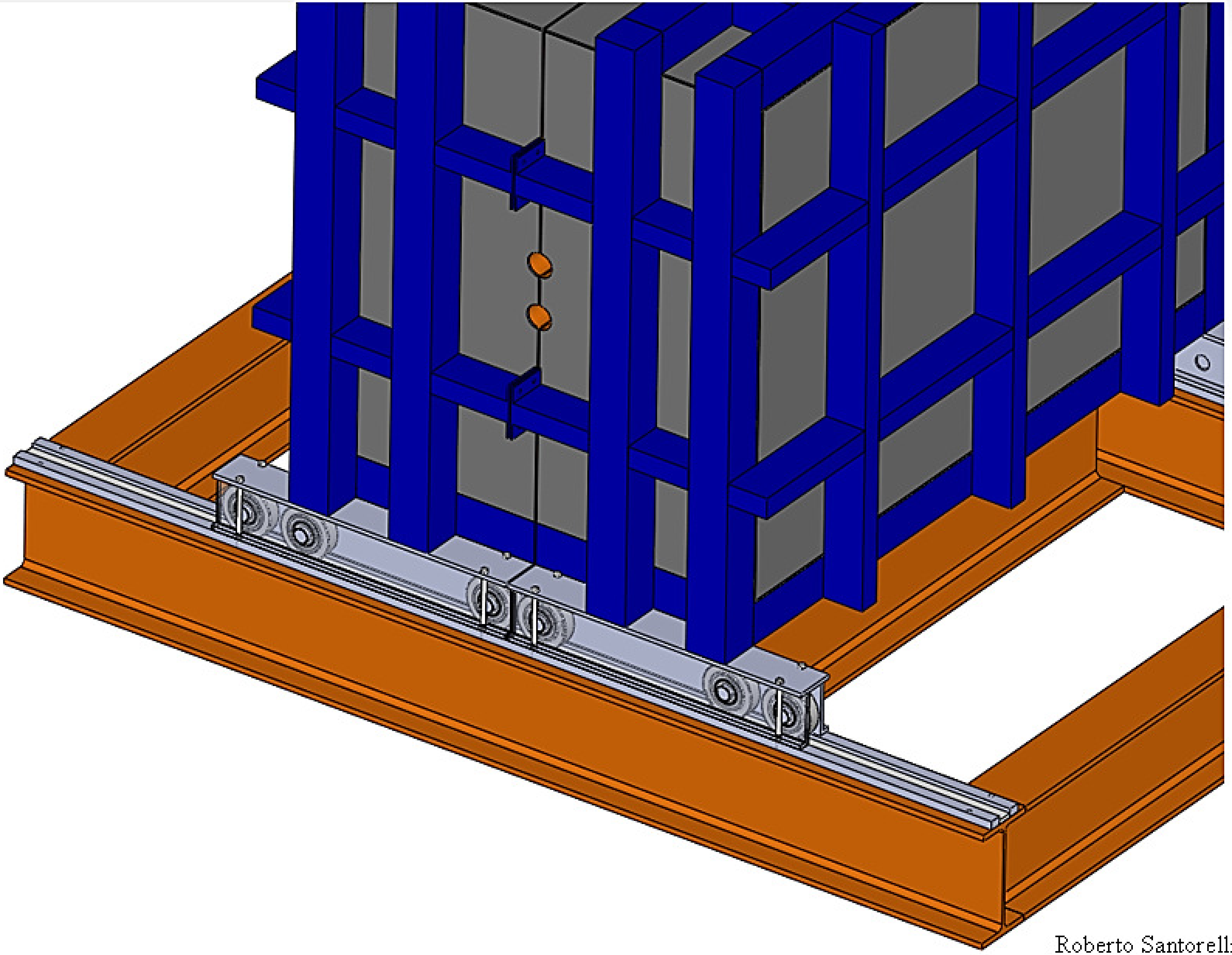




Shield preliminary design



Shield preliminary design

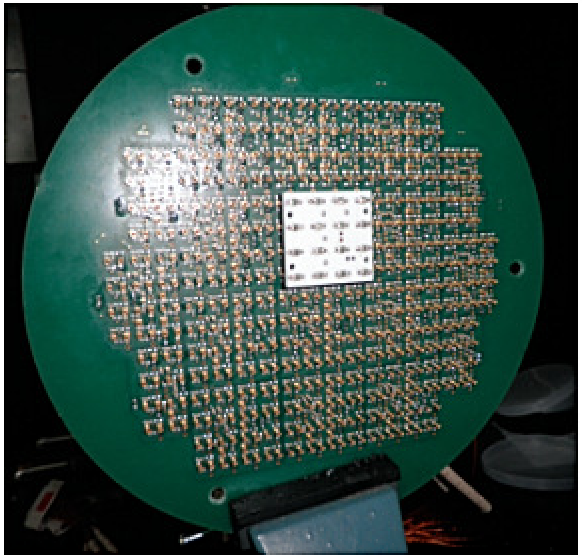


Baseline for NEXT100 (2013…)

EL - TPC filled with enriched (90%) ^{136}Xe gas at 15 bar.

~100 kg fiducial mass, PMTs for energy and t0, SiPM for tracking

Enriched Xe stored underground at Canfranc



Details on the NEXT project: http://next.ific.uv.es/next/

NEXT100 Conceptual Design Report:
http://arxiv.org/PS_cache/arxiv/pdf/1106/1106.3630v1.pdf

CONCEPTUAL DESIGN REPORT

The NEXT-100 experiment for $\beta\beta0\nu$ searches at LSC

(16 May 2011)

Abstract

We propose an EASY (*Electroluminescent ApparatuS of high Yield*) and SOFT (*Separated Optimized FuncTion*) time-projection chamber for the NEXT experiment, that will search for neutrinoless double beta decay ($\beta\beta0\nu$) in ^{136}Xe. Our experiment must be competitive with the new generation of $\beta\beta0\nu$ searches already in operation or in construction. This requires a detector with very good energy resolution ($\lesssim 1\%$), very low background contamination ($\sim 10^{-4}$ counts/(keV $\cdot$ kg $\cdot$ y)) and large target mass. In addition, it needs to be operational as soon as possible. The design described here optimizes energy resolution thanks to the use of proportional electroluminescent amplification (EL), which provides a large yield of photons as a signal; it is compact, as the Xe gas is under high pressure; and it allows the measurement of the topological signature of the event to further reduce the background contamination. The SOFT design uses different sensors for tracking and calorimetry. We propose the use of SiPMs (MPPCs) coated with a suitable wavelength shifter for the tracking, and the use of radiopure photomultipliers for the measurement of the energy and the primary scintillation needed to estimate the t_0. This design provides the best possible energy resolution compared with other NEXT designs based on avalanche gain devices.

Conclusions

- A lot of R&D already done!
- Complete the study of the prototypes by the end of the year
- Complete NEXT100 construction in 2013
- Start depleted xenon run in 2014

Experiment	Isotope	Resolution (keV)	Efficiency	Phase	Mass (kg)	Exposure (kg·year)	Background rate (counts/(keV · kg · y))	Sensitivity (meV)
CUORE	^{130}Te	5	0.8	2015–2017 (I)	200	600	10^{-1}	140
				2018–2020 (II)	200	600	4×10^{-2}	85
EXO	^{136}Xe	100	0.7	2012–2014 (I)	160	480	7×10^{-3}	185
				(II) 2016–2020	160	800	5×10^{-3}	150
GERDA	^{76}Ge	5	0.8	2012–2014 (I)	18	54	10^{-2}	214
				2016–2020 (II)	35	175	10^{-3}	112
KamLAND-Zen	^{136}Xe	250	0.8	2013–2015 (I)	360	1440	10^{-3}	97
				2017–2020 (II)	35	2700	5×10^{-4}	60