LIDINE, SLAC National Accelerator, 24th September 2017

NEXT experiment

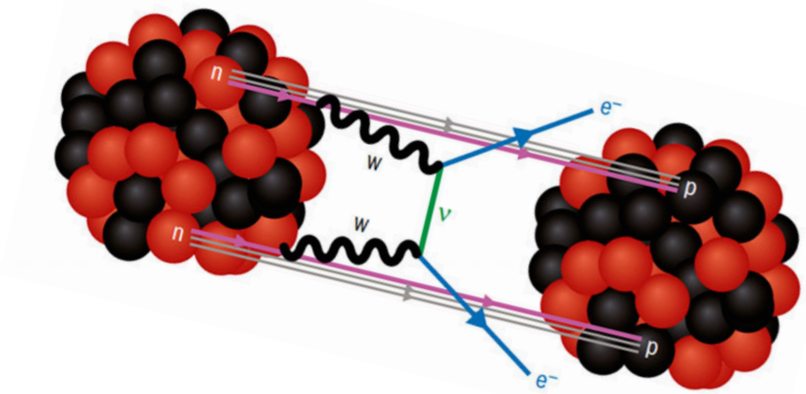
0νββ search with High pressure Xe gas TPC

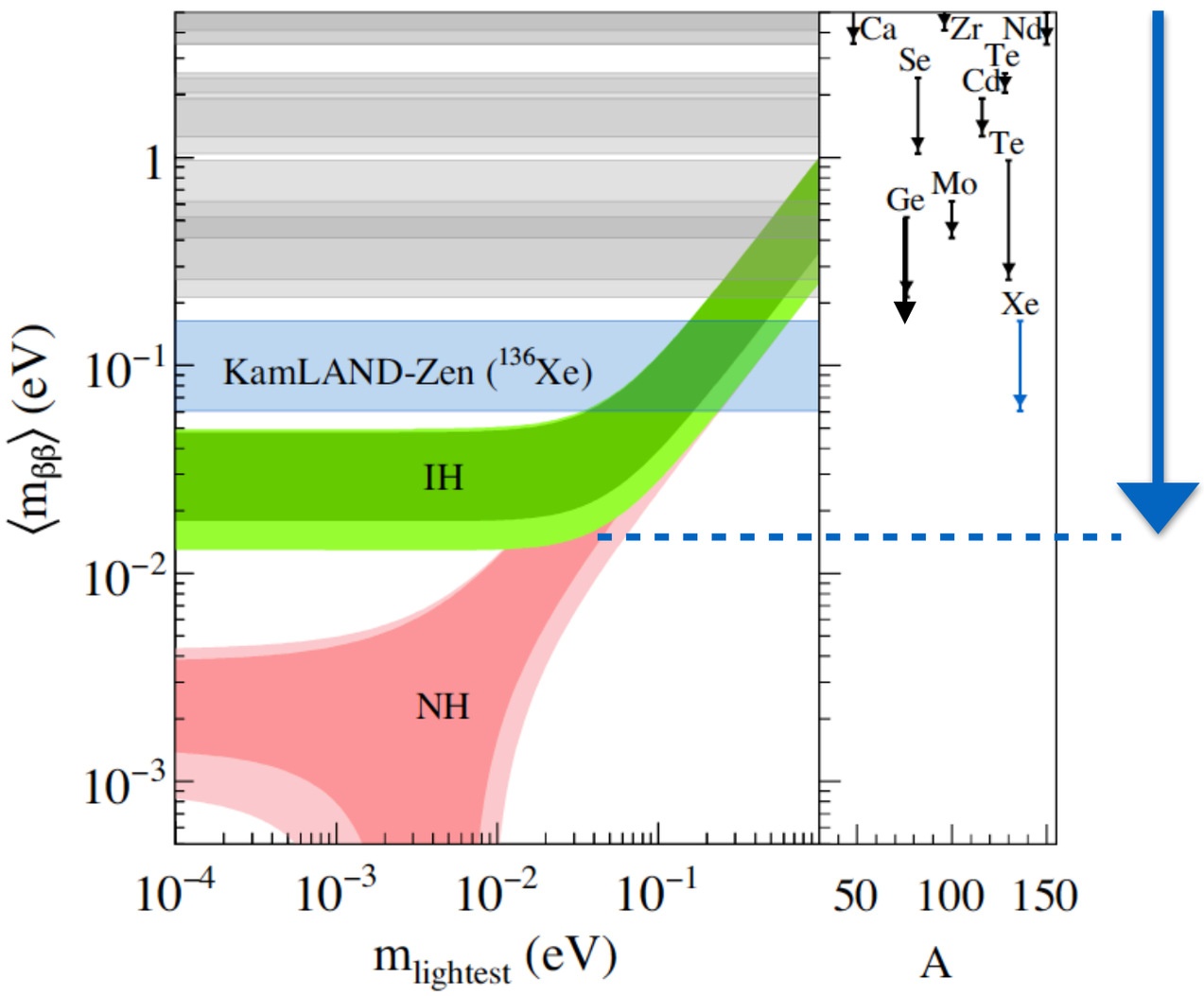
Neus López March

IFIC (Spain), UTA (US)

on behalf of the NEXT collaboration

State of the art





Future experiments to explore the **IH require ($m_{\beta\beta}$~10meV)**:

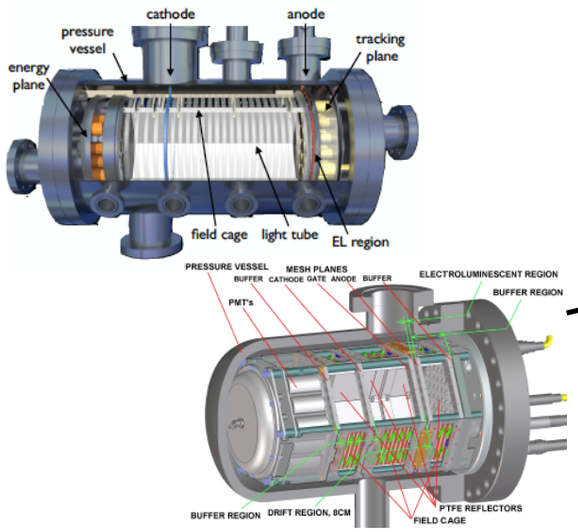
1) Large masses (**tonne** scale) : technology must be scalable and cheap

2) Background in the range of **1 event/tonne/yr** (to cover the IH in a reasonable time): large background reduction needed wrt to current state of the art

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

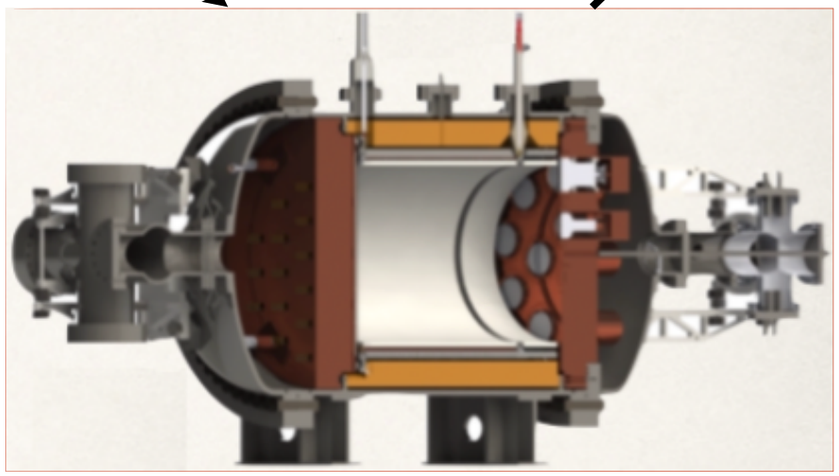
$$m_{\beta\beta} = \left|\sum_i m_i\ U^2_{ei}\right|$$

Content



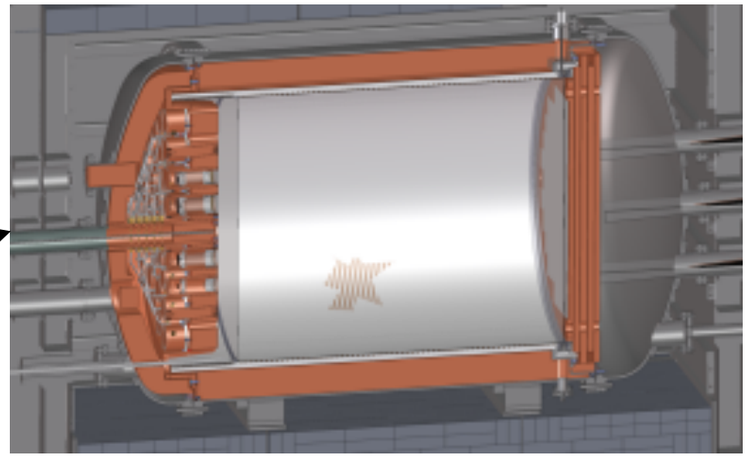
Prototypes (∼1 kg)
[2009 - 2014]

Demonstration of detector concept [<1% FWHM, imaging]



NEXT-NEW (∼5 kg)
[2015 - 2018]

Underground and radio-pure operations, background, 2νββ



NEXT-100 (∼100 kg)
sensitivity: 6×10^{25} yr
[2018 - 2020's]

Neutrinoless double beta decay searches

Content

NEXT-tonne future generation:

With a background rate of ~1c/tonne/year will cover in 6 years the IH

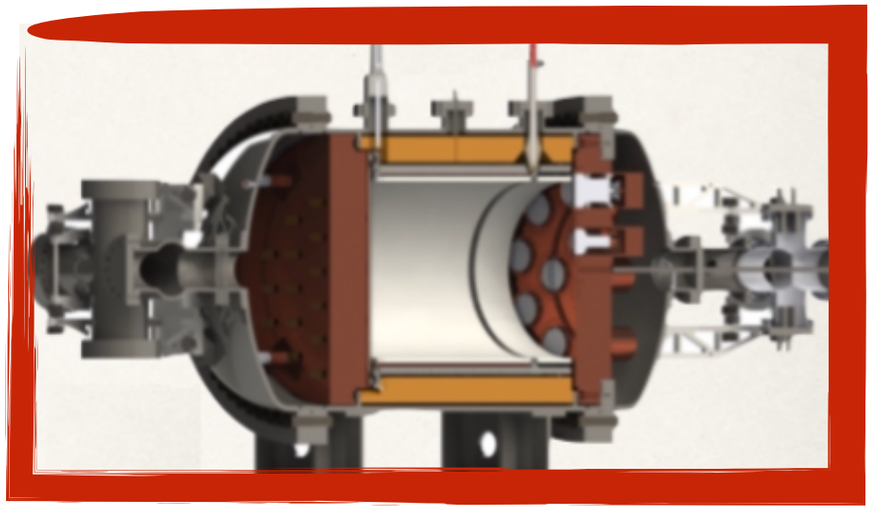
* **ongoing** R&D on Single Molecule Fluorescent imaging for **Barium tagging** **(A.McDonald talk later)**

* **ongoing** R&D with gaseous mixtures can provide low diffusion, **improving rejection** by a factor x4. **(C. Henriques talk later)**

pure operations,
background, 2νββ

Content

NEXT-WHITE (NEW)



Detector description

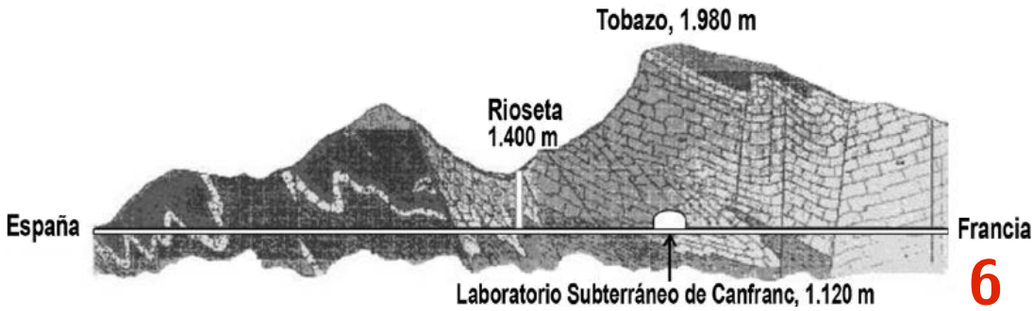
Detector calibration

next : Neutrino Experiment with a Xenon TPC

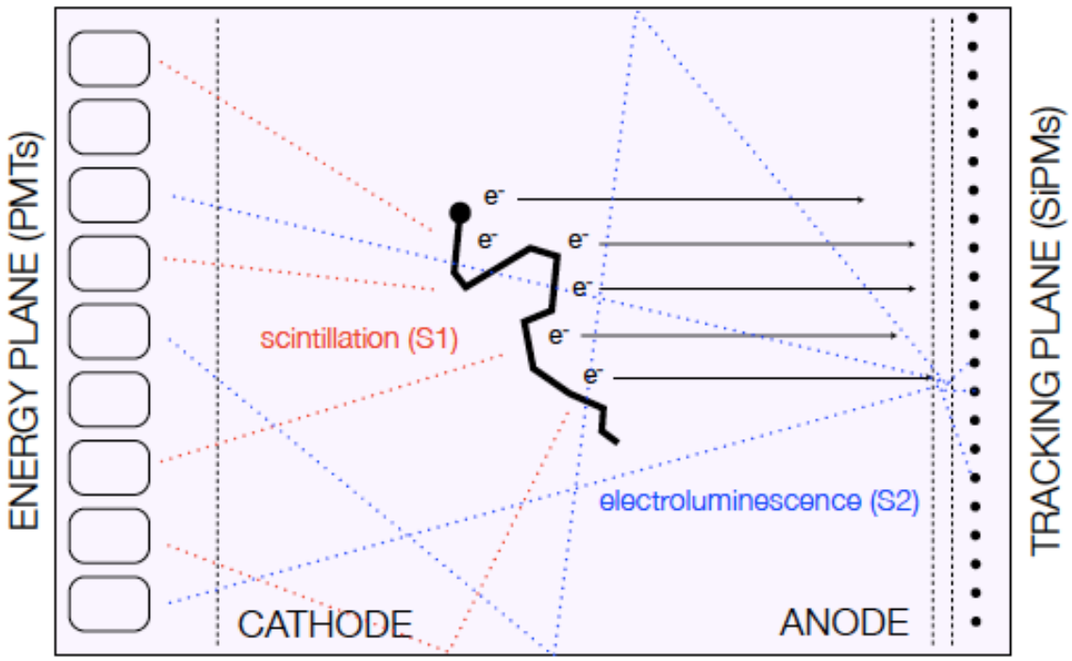
- **High pressure Xenon gas, electroluminescent TPC with readouts for calorimetry and imaging.**

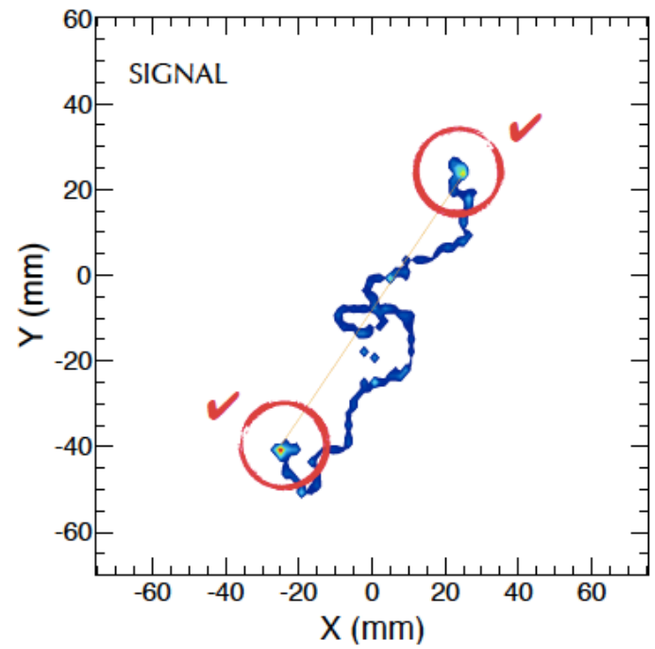
LSC
Laboratorio Subterráneo de Canfranc

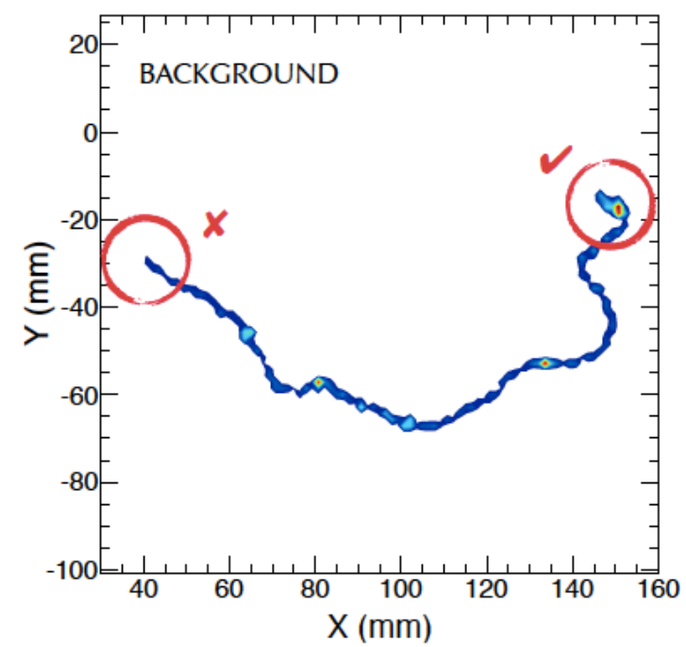
- Isotope: ^{136}**Xe** (easy to enrich and to purify)
- **Electroluminescence** used to amplify the ionization signal (linear process, huge gain)
- **Excellent energy resolution: <1%** FWHM at the Q-value (the resolution due to Fano factor fluctuations of Xe Gas at Q-value is 0.3% FWHM)
- **Easy to scale up**
- Low background rate: 4x 10^{-4} c/keV/kg/yr
- **Event topology reconstruction:** electrons travel 15cm each (15bar) on average
- Single Molecule Fluorescent imaging for **Barium tagging**



NEXT concept



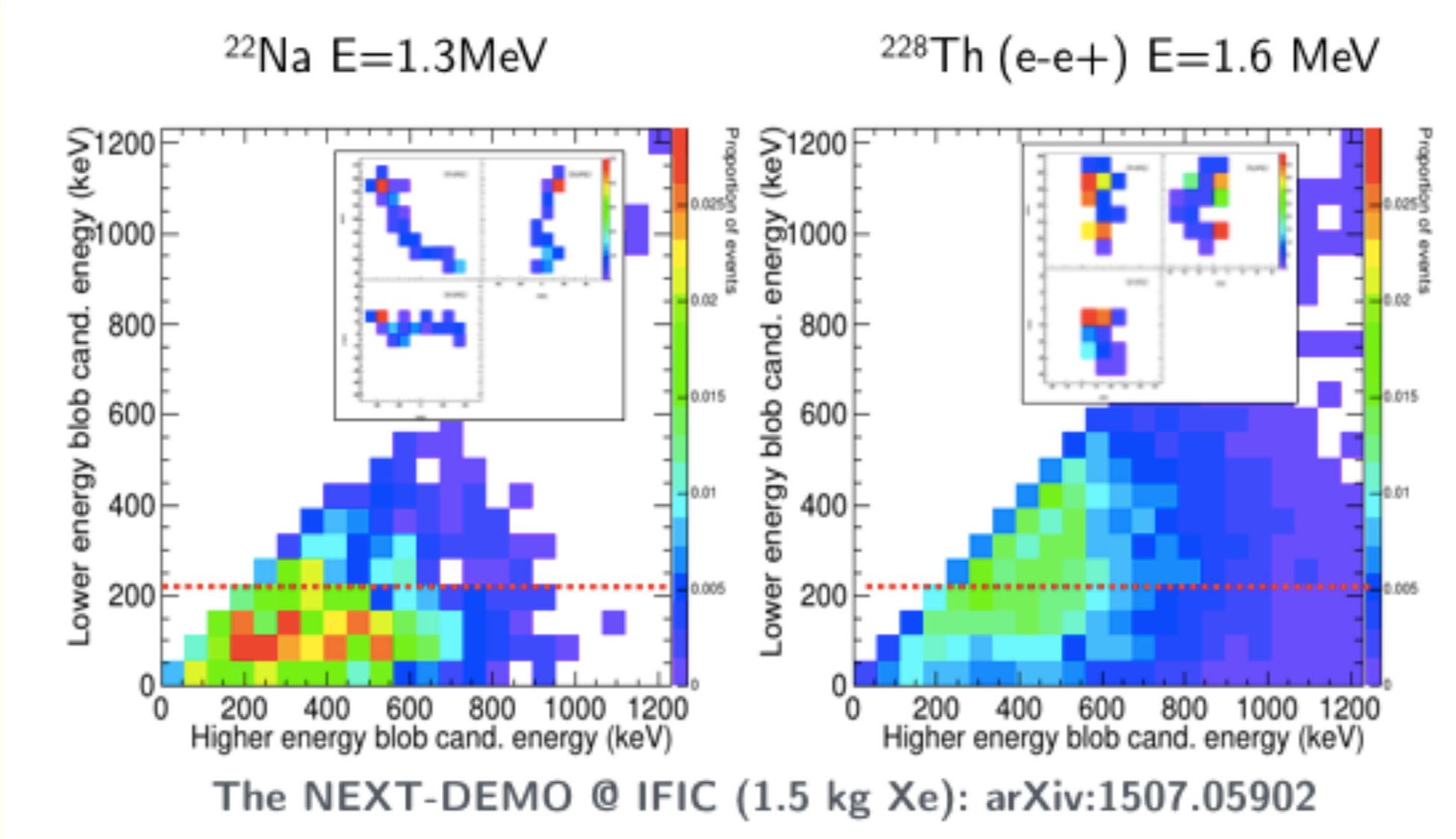




- **Energy plane** made of PMTs measures energy and start of the event (t0)
- **Tracking plane** made of SiPMs, reconstructs the event topology.

- Energetic electron leaves a high-density deposition at the end of its track
- Results in distinct topological signatures for signal and background events of the same energy

NEXT concept



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

Background rejection of 76% for 68% signal efficiency

NEW TPC

Underground and radio-pure operations.
Goal is to measure: background, 2νββ

LSC
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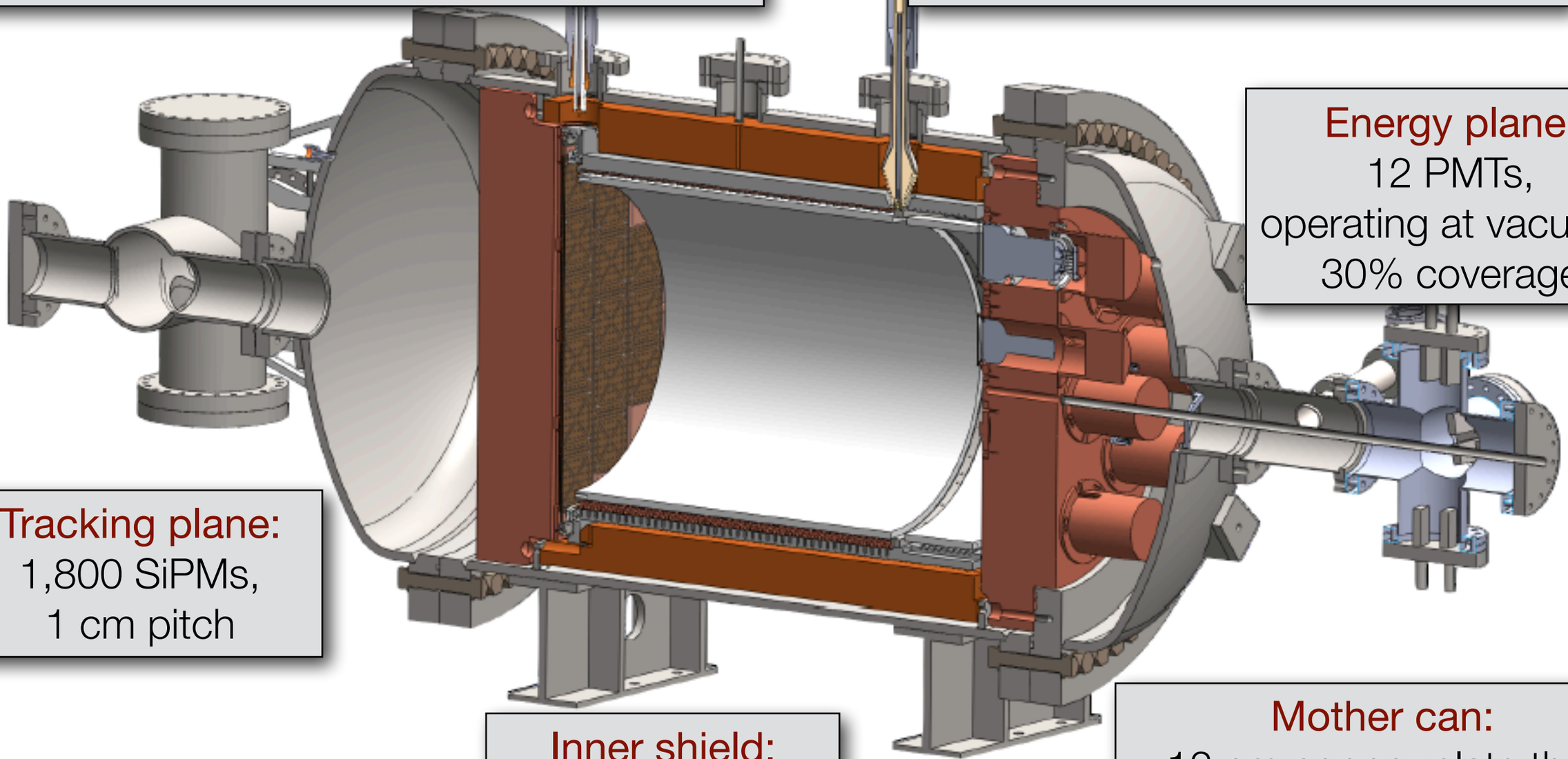


Time Projection Chamber:
5 kg active region(@10bar), 50 cm drift length

Pressure vessel:
316-Ti steel, 30 bar max pressure

Energy plane:
12 PMTs,
operating at vacuum.
30% coverage

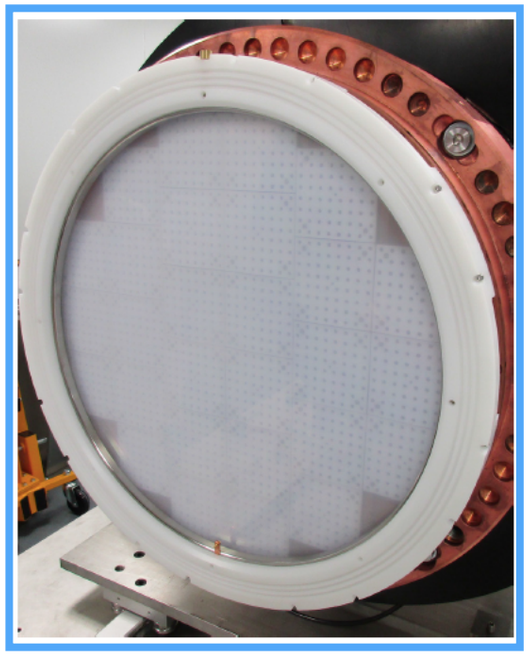
Tracking plane:
1,800 SiPMs,
1 cm pitch

Inner shield:
copper, 6 cm thick

Mother can:
12 cm copper plate that separates pressure from vacuum and ads shielding.

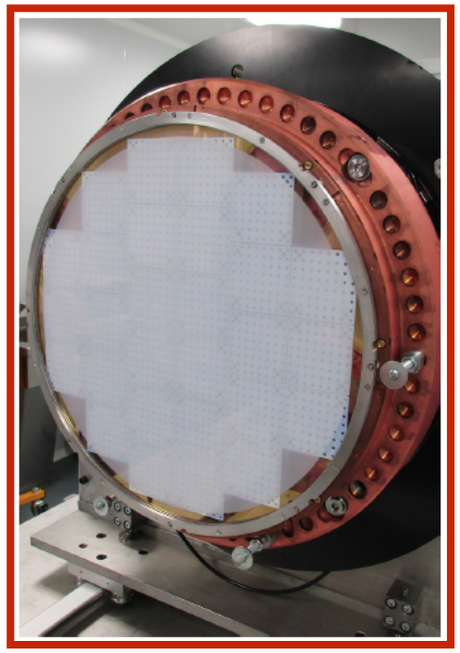
Outer shield:
lead, 20 cm thick

NEW Field Cage



Gate mesh

interwoven steel mesh (22kV)

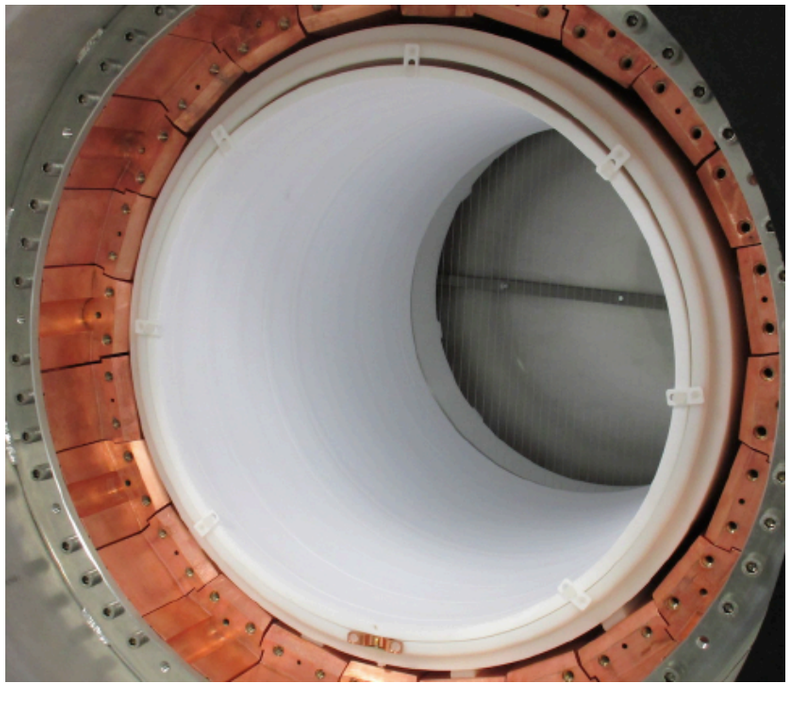


Fused silica anode

Coated with ITO (grounded) and with TPB

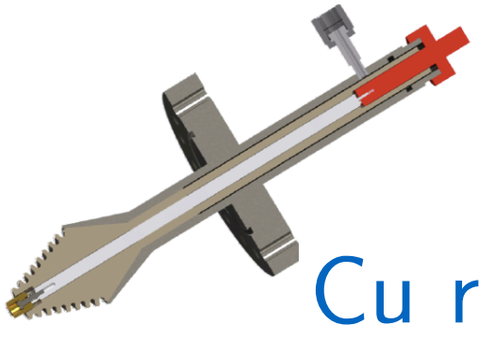
Cathode grid

Stainless-steel (SS) wire spaced 1cm (50kV)



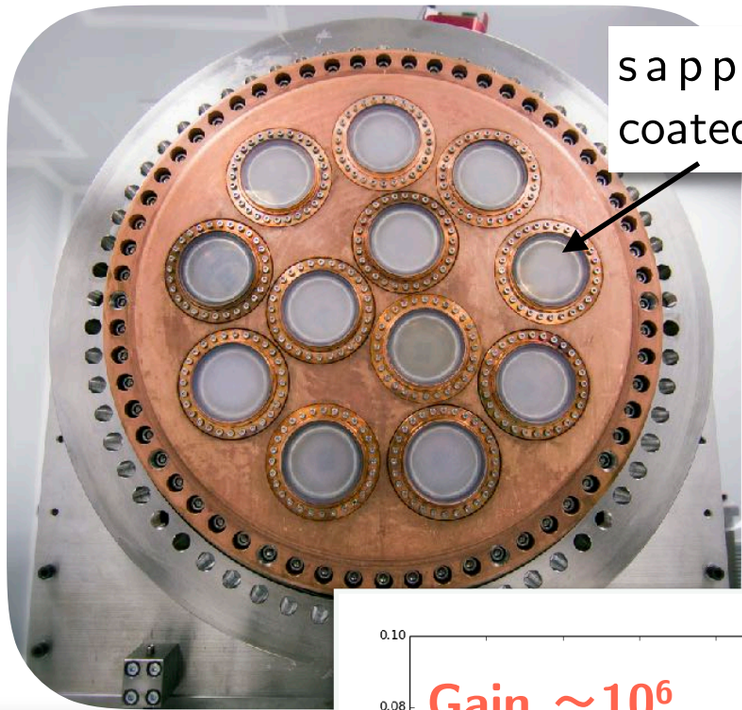
Teflon light tube

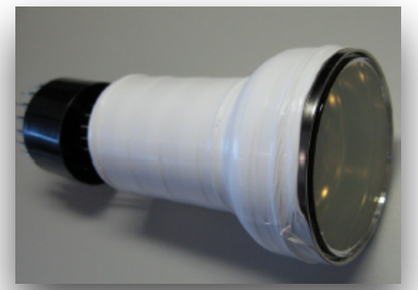
Coated with TPB

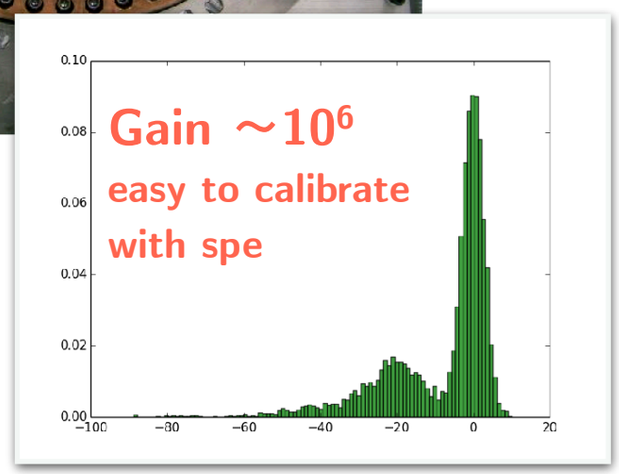


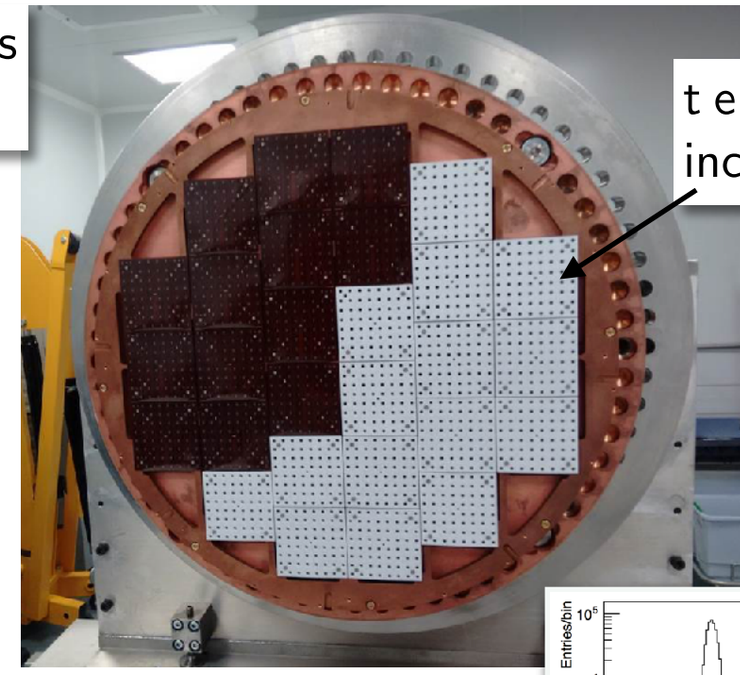
Cu rings

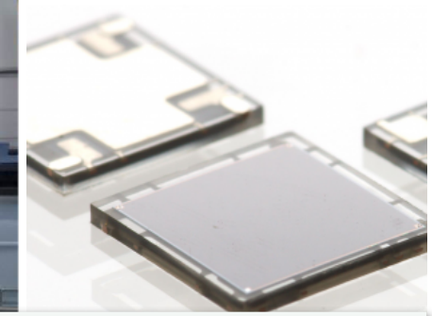
NEW sensors: Energy and Tracking planes

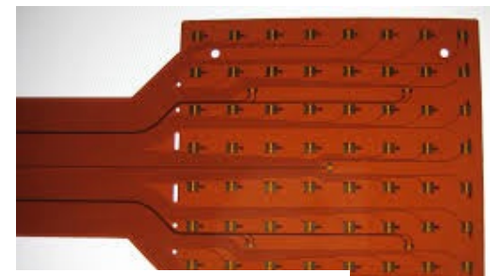


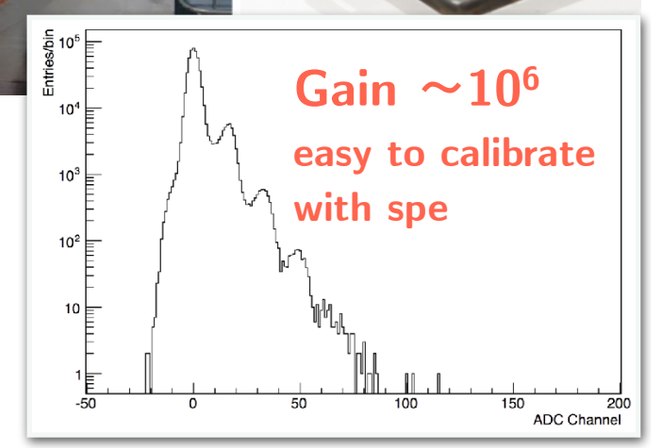












12 R11410-10 PMTs (Hamamatsu)

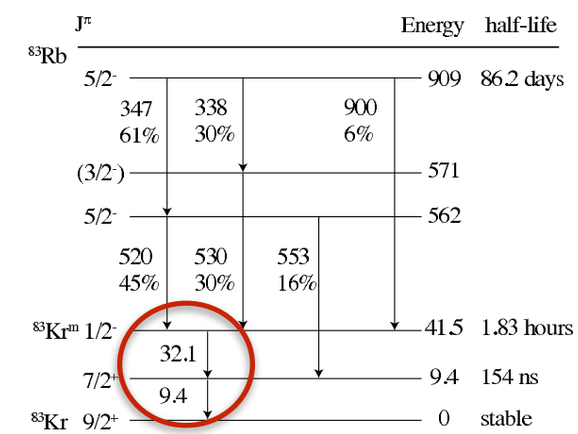
- Excellent response (low noise very low dark current) in gas.
- Radiopure (less than 1 mBq/PMT in Tl-208 and Bi-214)

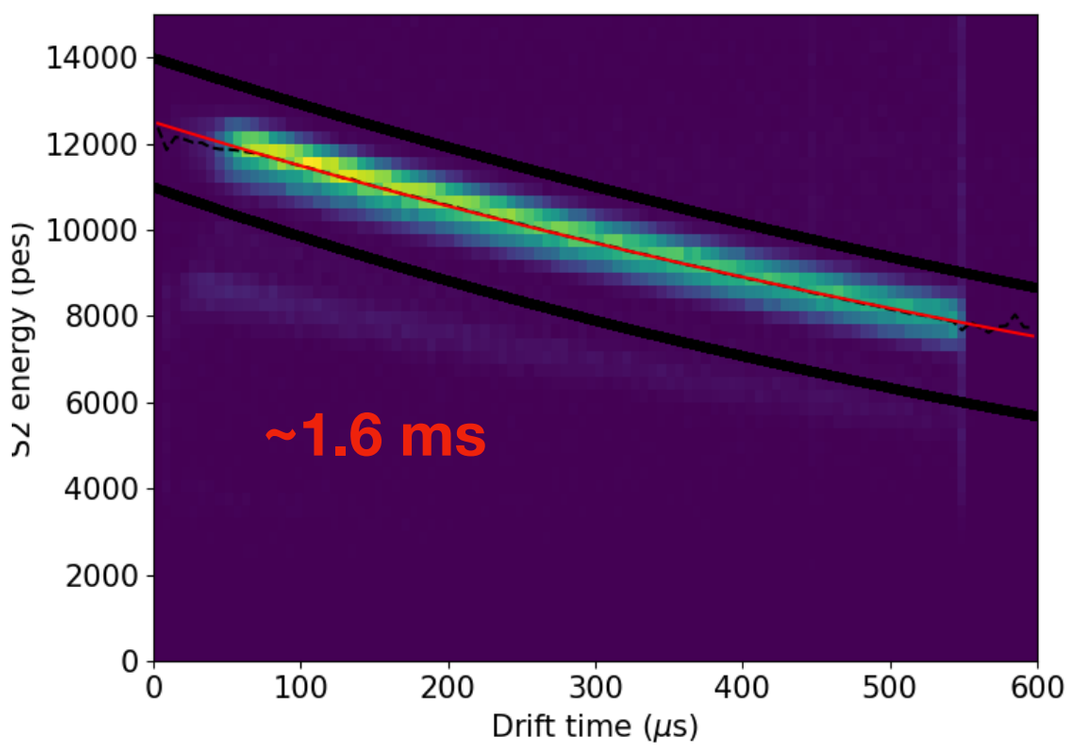
1792 SiPMs (SENSL)

- 28 Kapton Dice Boards with 64 SiPMs each (1cm pitch)
- SENSL SiPMs most radiopure in the market

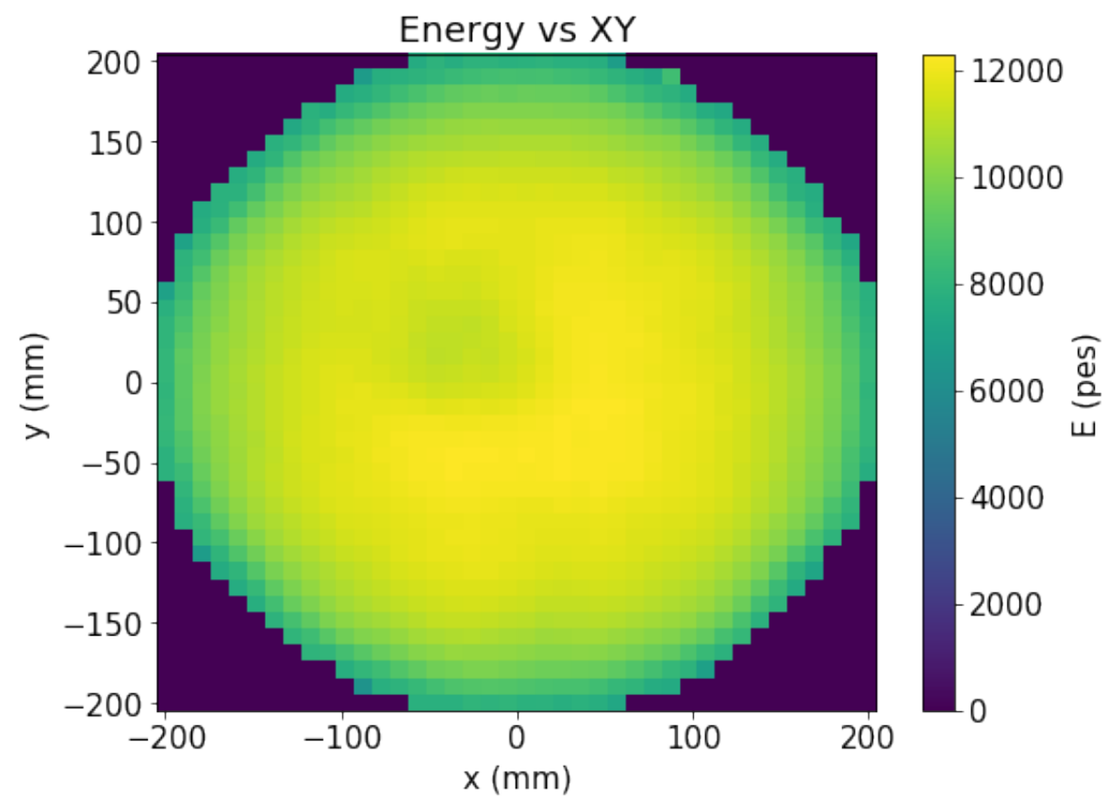
NEW Calibration: ^{83}Kr

- Kr leaves a **point-like** deposition of **41.5 keV**, uniformly distributed in the detector
- Detector characterization: **drift velocity** (**z dependence**), e- **attachment** (**lifetime**), **geometric** corrections to energy





Gas impurities reduce lifetime and impact energy measurements (z dependance)



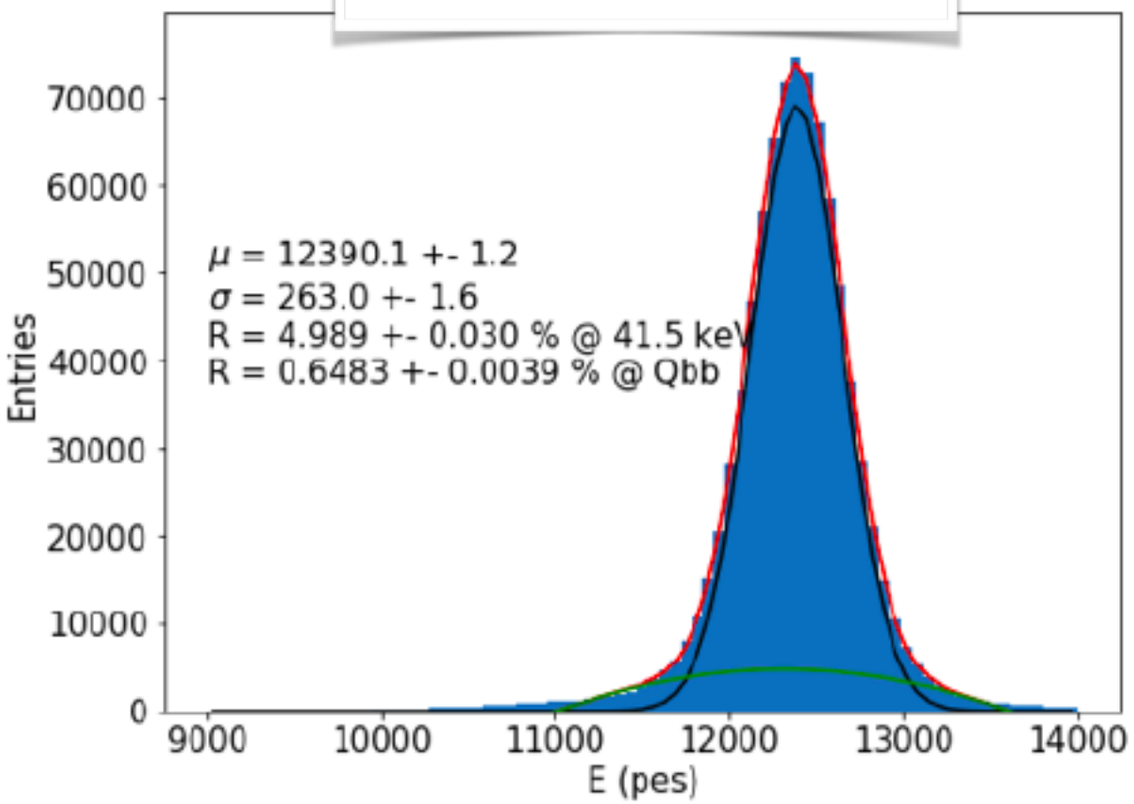
Light collection depends on the position of the event (solid angle effects and TPB inhomogeneities)

NEW Calibration ^{83}Kr: energy resolution

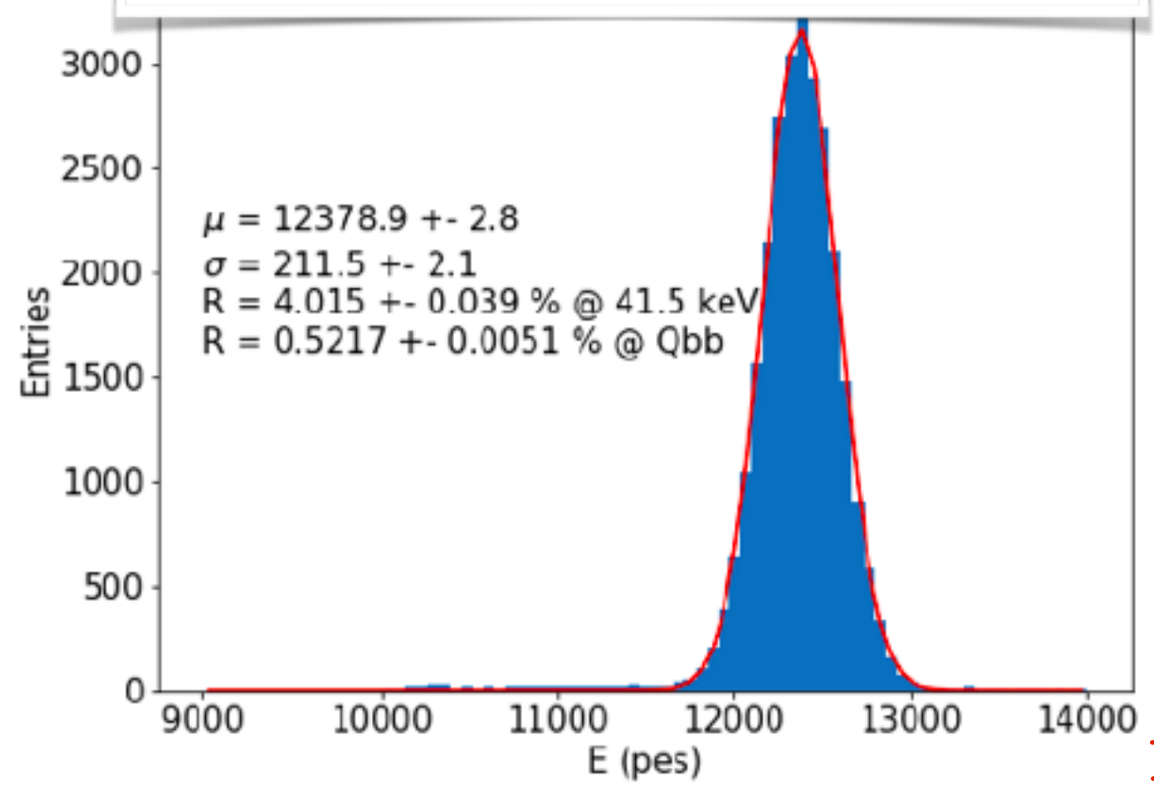
Preliminary

- **5% FWHM** energy resolution → $1/\sqrt{E}$ extrapolation yields **0.65% FWHM** resolution at Q-value
- **4% FWHM (0.5% FWHM** at Q-value**)** up to 100mm radius

Full active volume

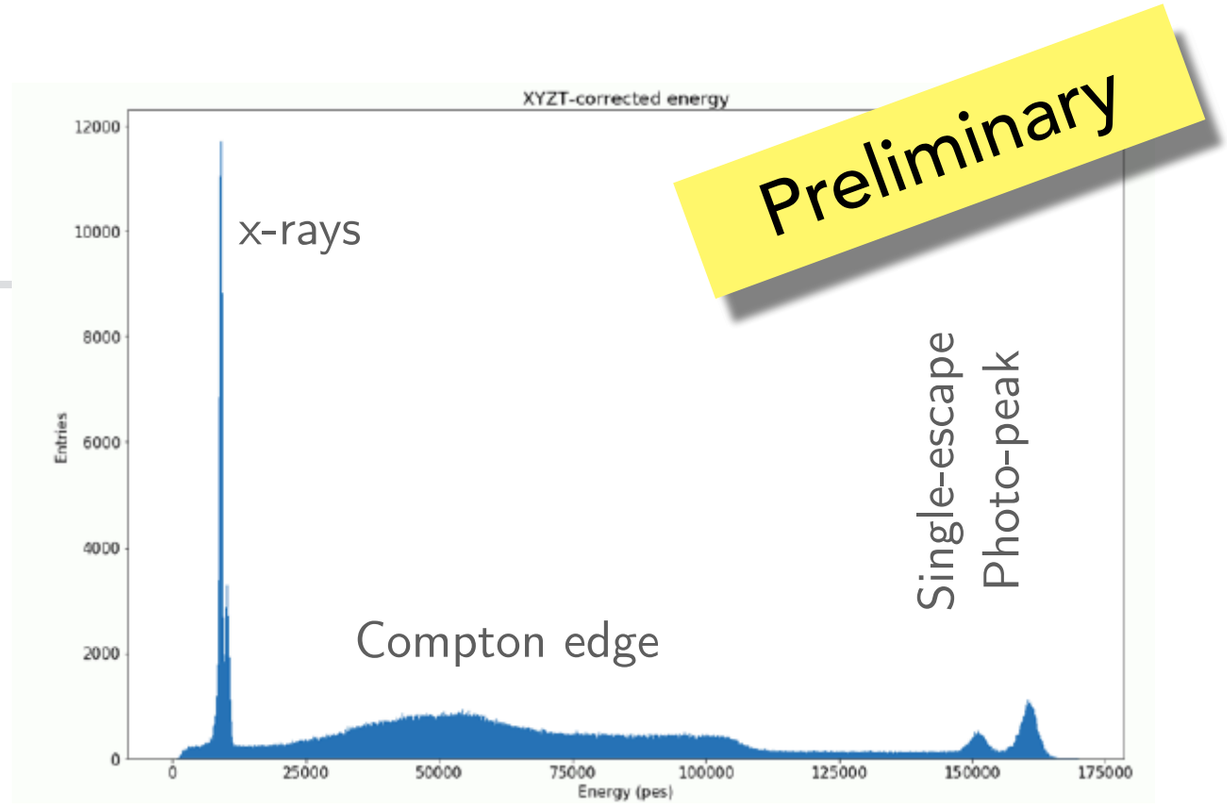


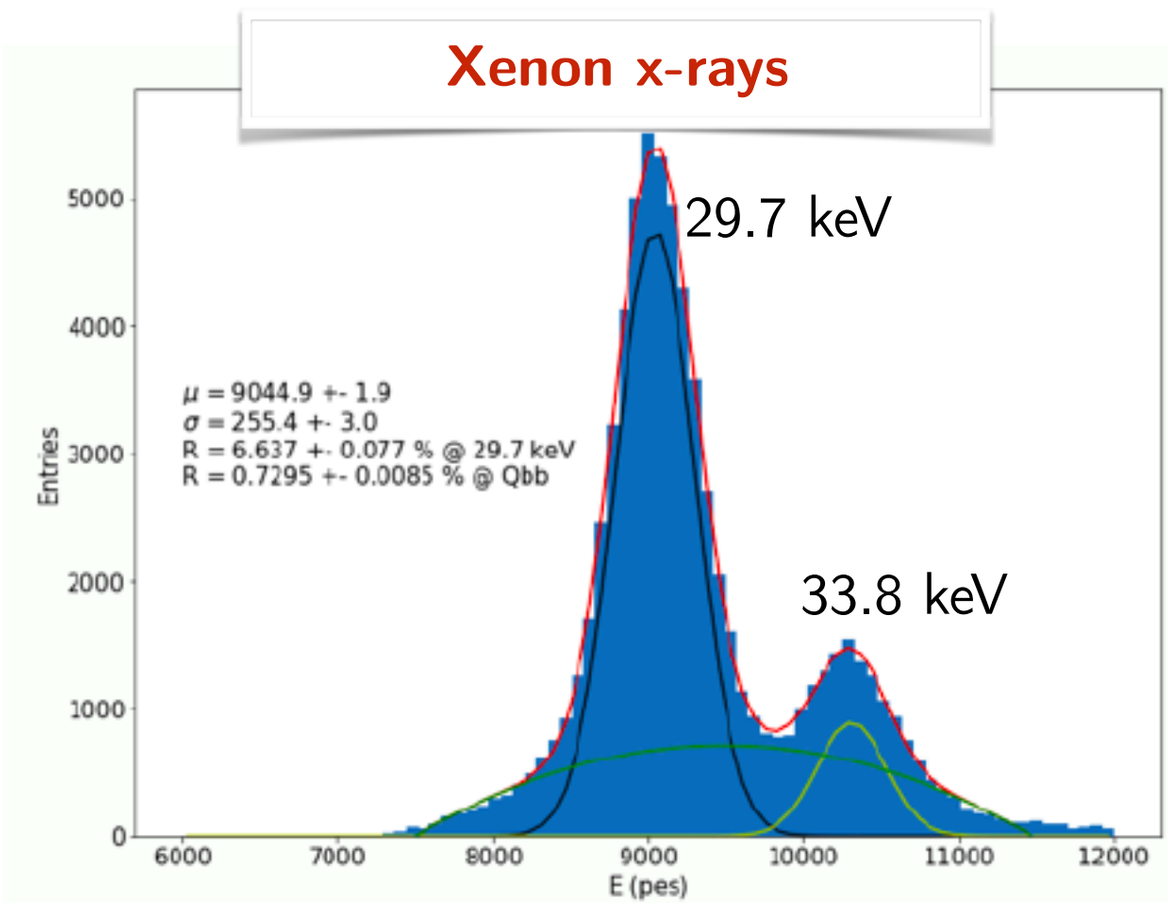
r < 100mm, drift time < 100μs

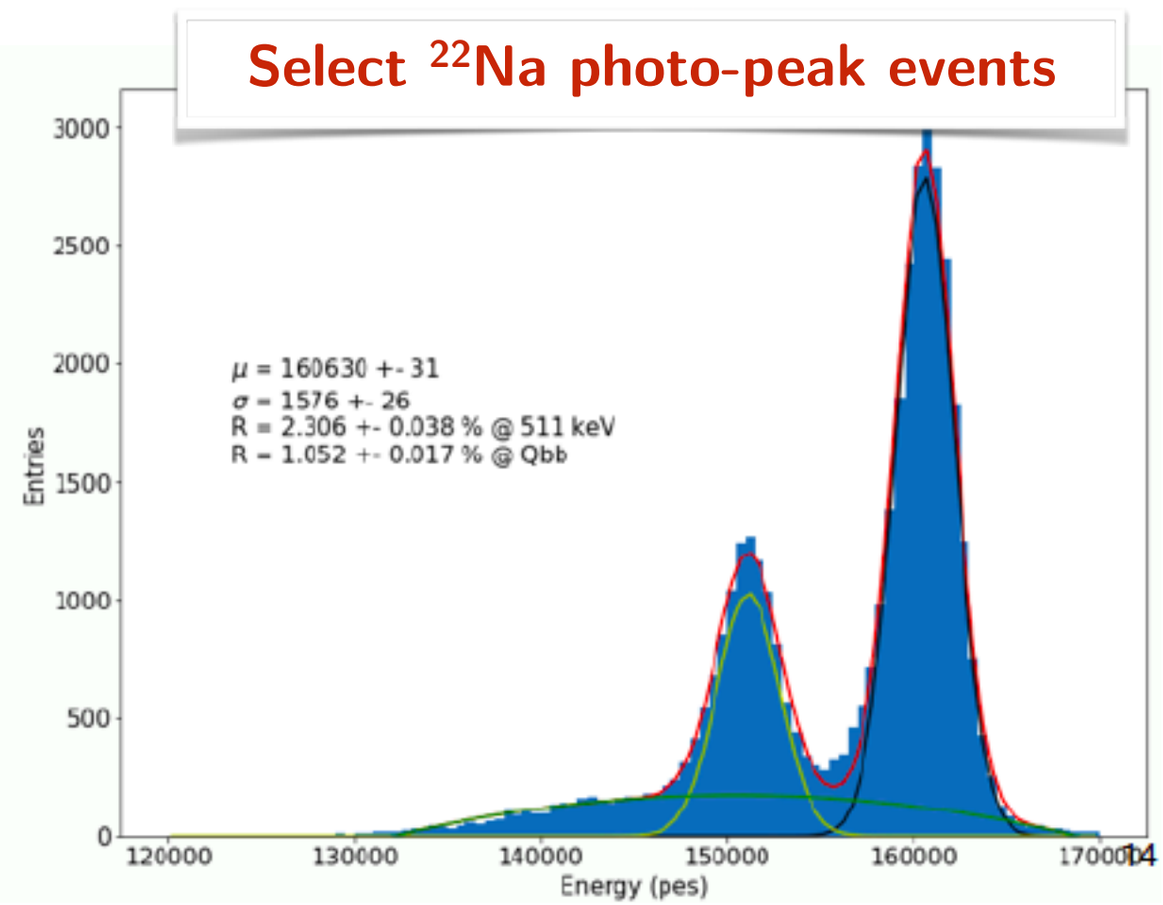


NEW Calibration: ^{22}Na

- Good energy resolution maintained at higher energies (511 keV gamma from ^{22}Na)
- Lifetime corrections from **x-rays**, Geometrical corrections from **^{83}Kr**
- **2.3%** FWHM (**1.05%** FWHM at $Q_{\beta\beta}$) energy resolution for 511 keV γ



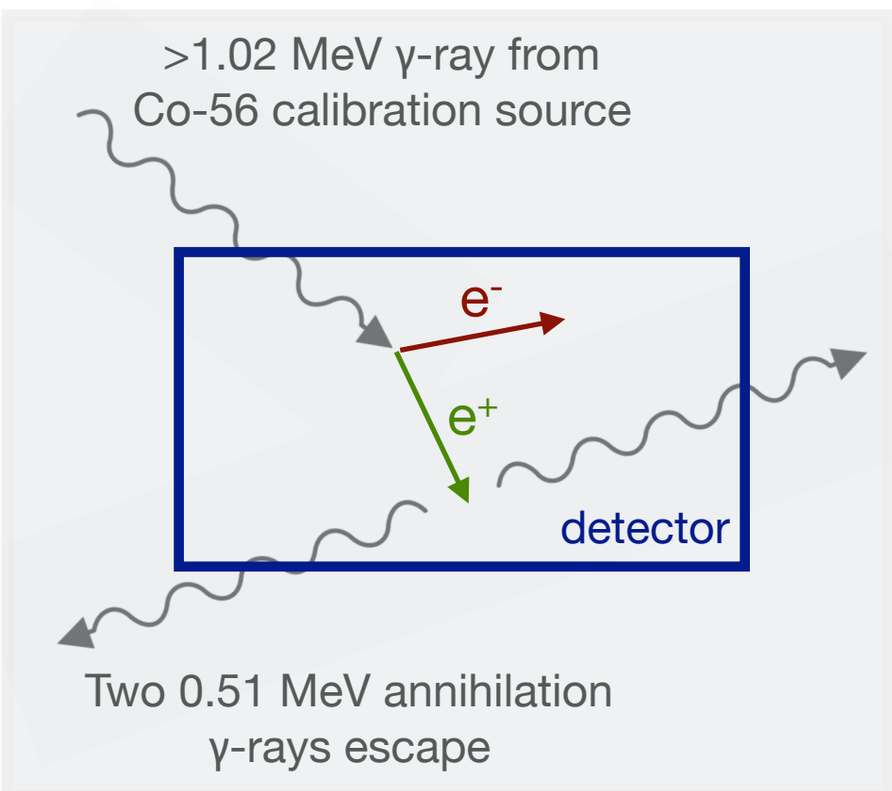


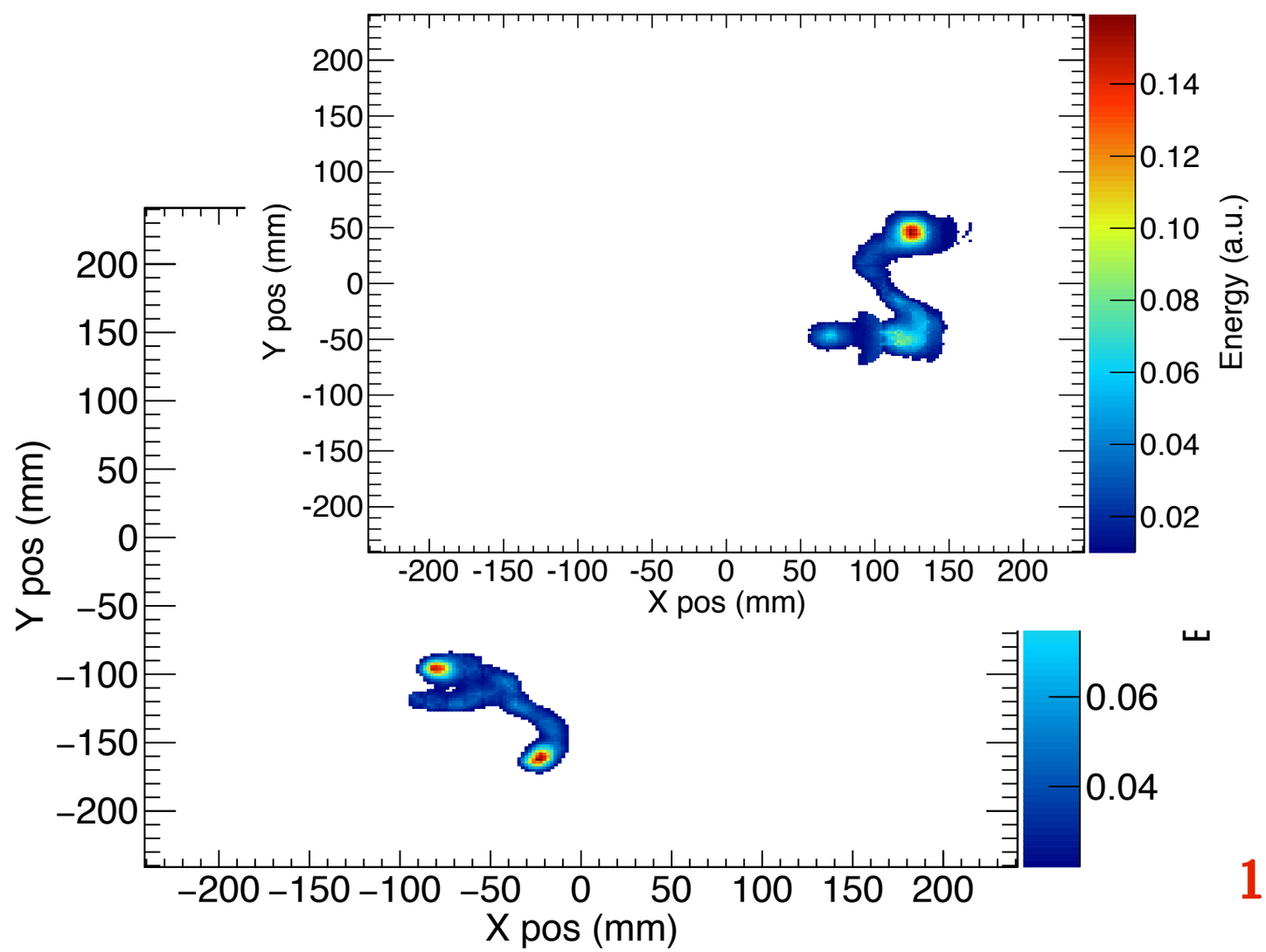


NEW tracking reconstruction

Preliminary

- Observe the two stopping electron tracks (at 1.6MeV) from a Co56 source emitted from a common vertex, characteristic of double beta decays
- Powerful handle for single-electron background suppression



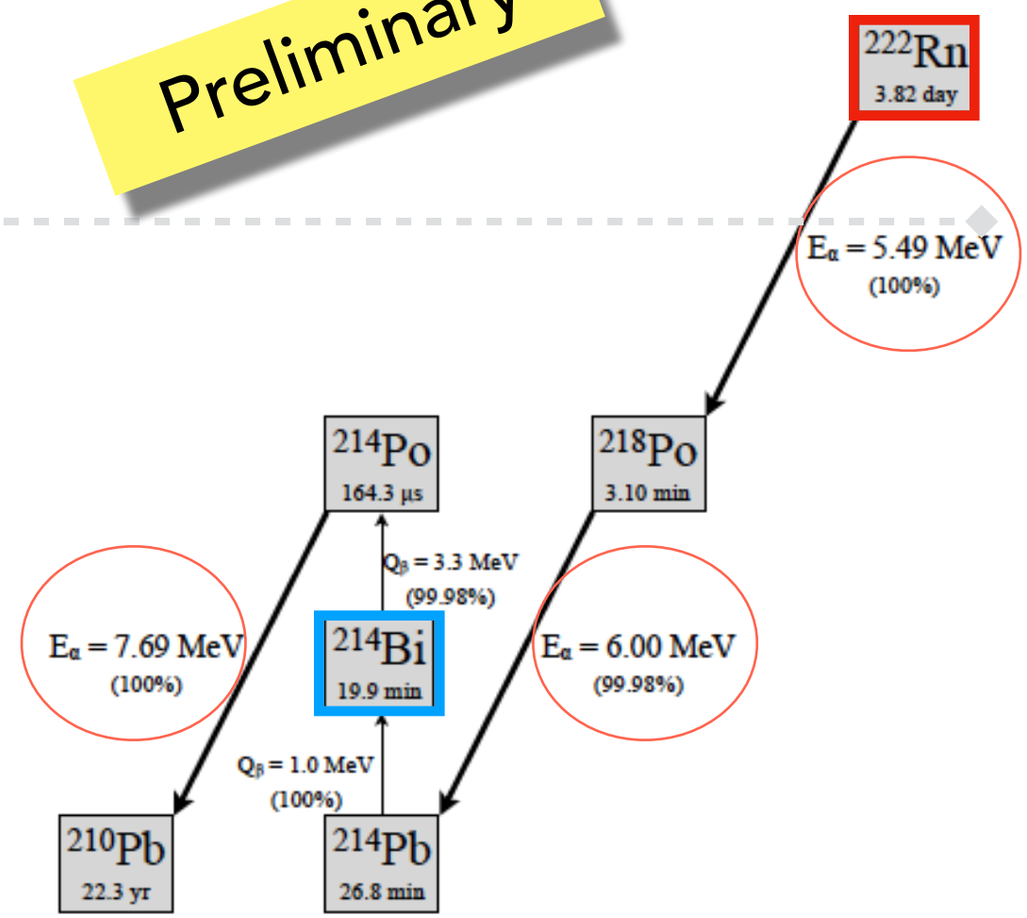


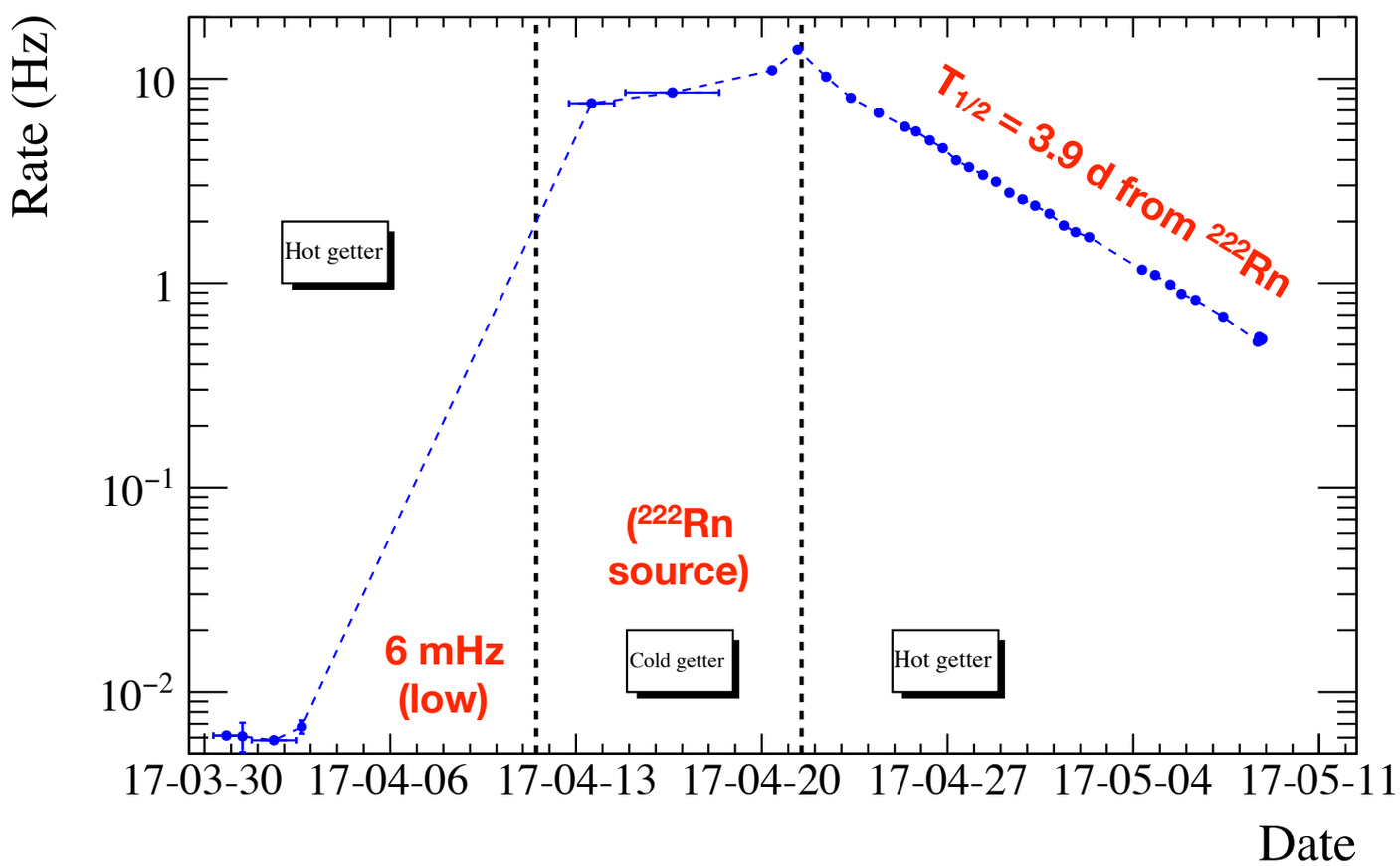
Reconstruction with ML-provides well-defined tracks

NEW Background: ^{222}Rn

Preliminary

- ^{214}Bi (present in the ^{222}Rn decay chain) is one of the major background sources in NEXT.
- ^{222}Rn emanates from detector materials and is present in the air
- We have measured the alpha energy for the three alpha markers (^{222}Rn,^{218}Po, ^{214}Po)





- Alpha production rate measured in NEW during normal (hot getter) operations point to very low ^{222}Rn-induced backgrounds for **NEXT-100, $<10^{-4}$c/ (keV·kg·yr)**

Summary

- Demonstrate the ability to **scale up** xenon TPC technology (NEXT100 is a key step in scaling up)
- Demonstrate the ability to **maintain good energy resolution near 0.5%** FWHM at Q-value
- Background rejection:
  - topological signature provides additional rejection; **new reconstruction methods and DNN**-based event classification [arXiv:1609.06202] under investigation
  - reduce diffusion **with coolant gas**: **see C. Henriques talk**
  - **Ba tagging** would provide essentially zero-background: **see A. MacDonald talk**
- Continue radiopurity campaign measurements and selection of radiopure materials

- Exploring the **IH** appears feasible (**tonne scale** experiments with **negligible backgrounds**) but will require an intense experimental effort (∼10 years) and a serious investment.

Thanks for your attention!

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

• Texas A.M • Texas Arlington, • Fermilab • Argonne • Iowa state

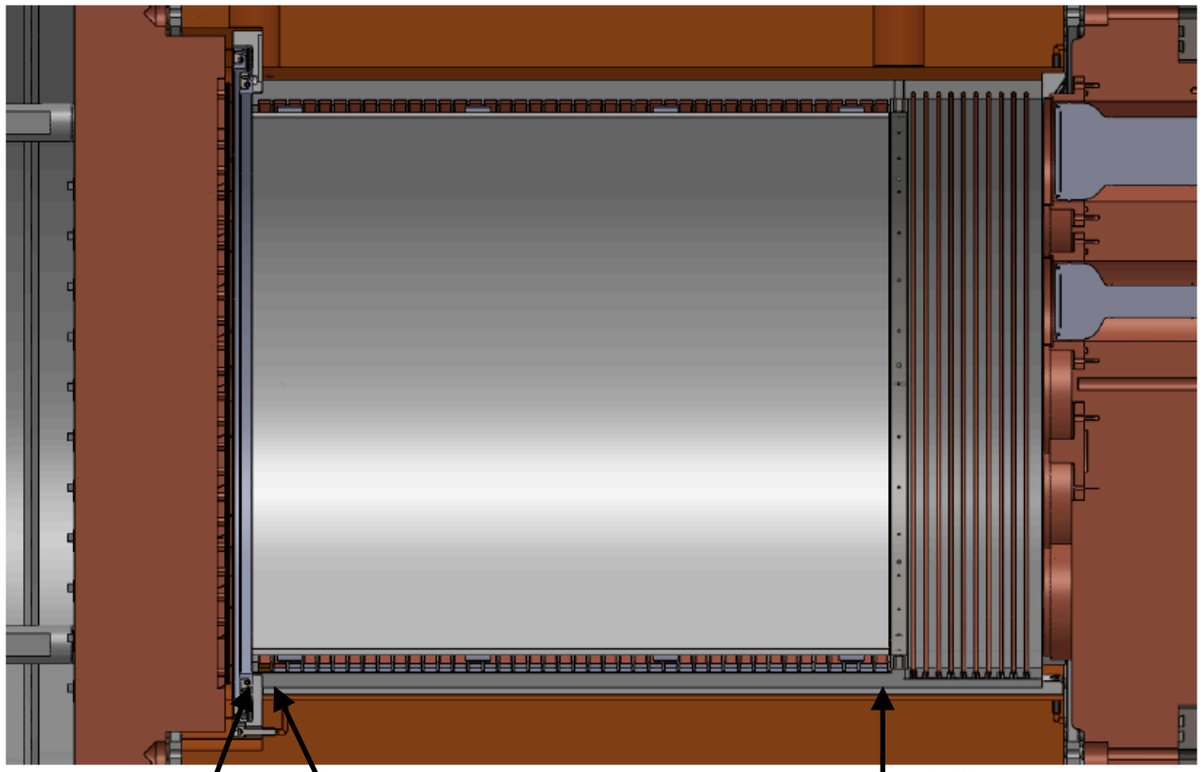
Coimbra • Aveiro

JINR

A. Nariño

Co-spokepersons: D. Nygren (UTA) & J.J. Gómez-Cadenas (IFIC)

NEW Field Cage design



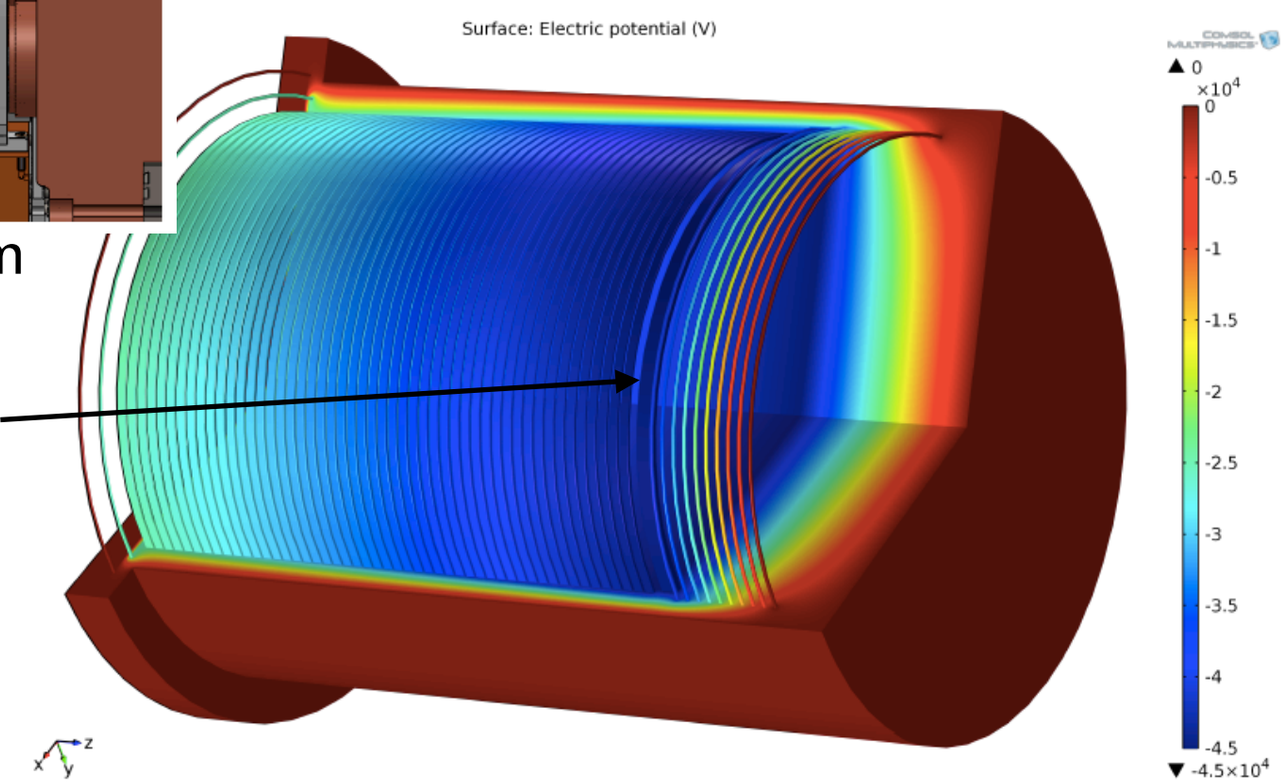
10cm

Anode
0V

Gate
-22kV
(-7kV)

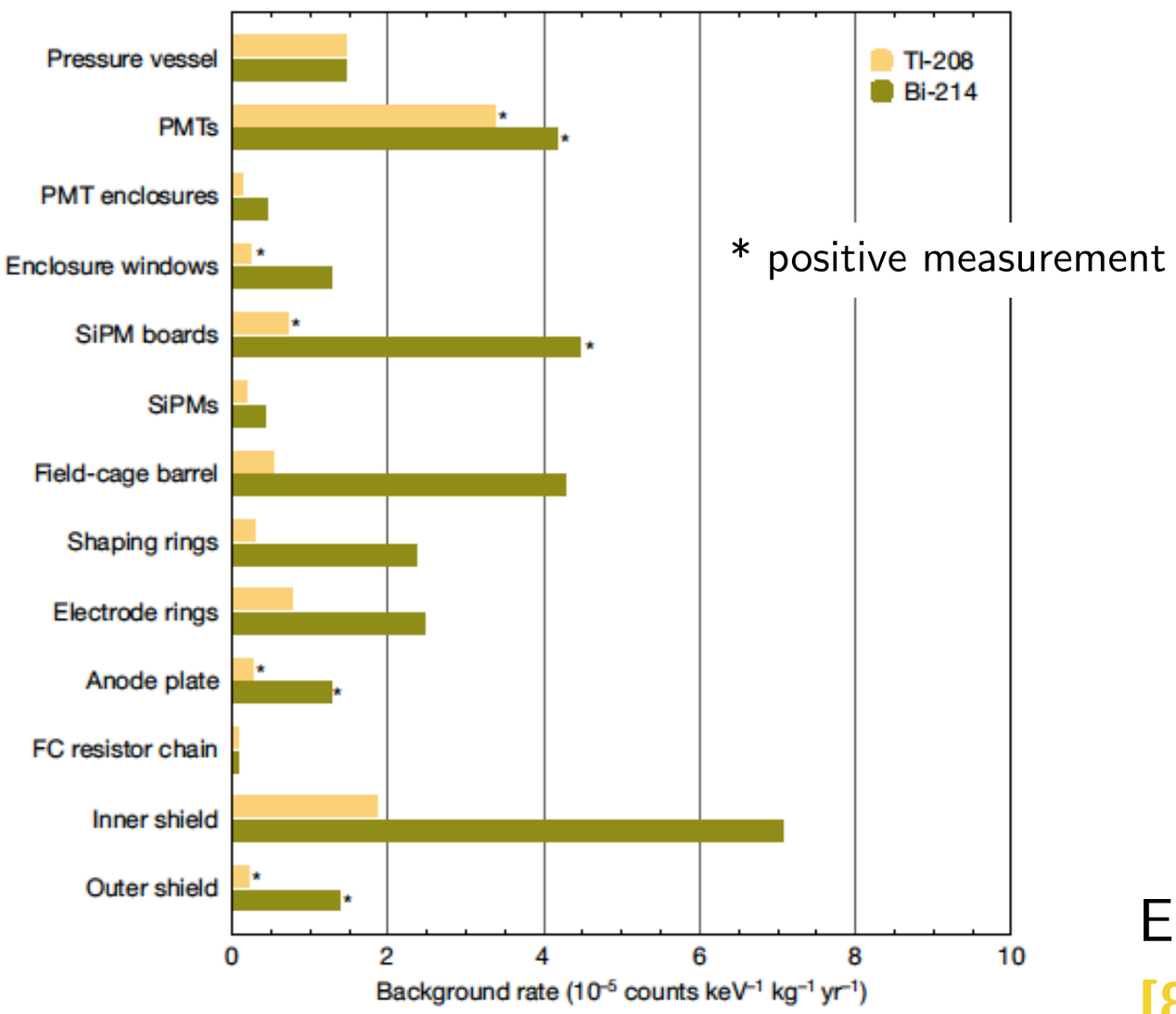
Cathode
-50kV
(-28kV)

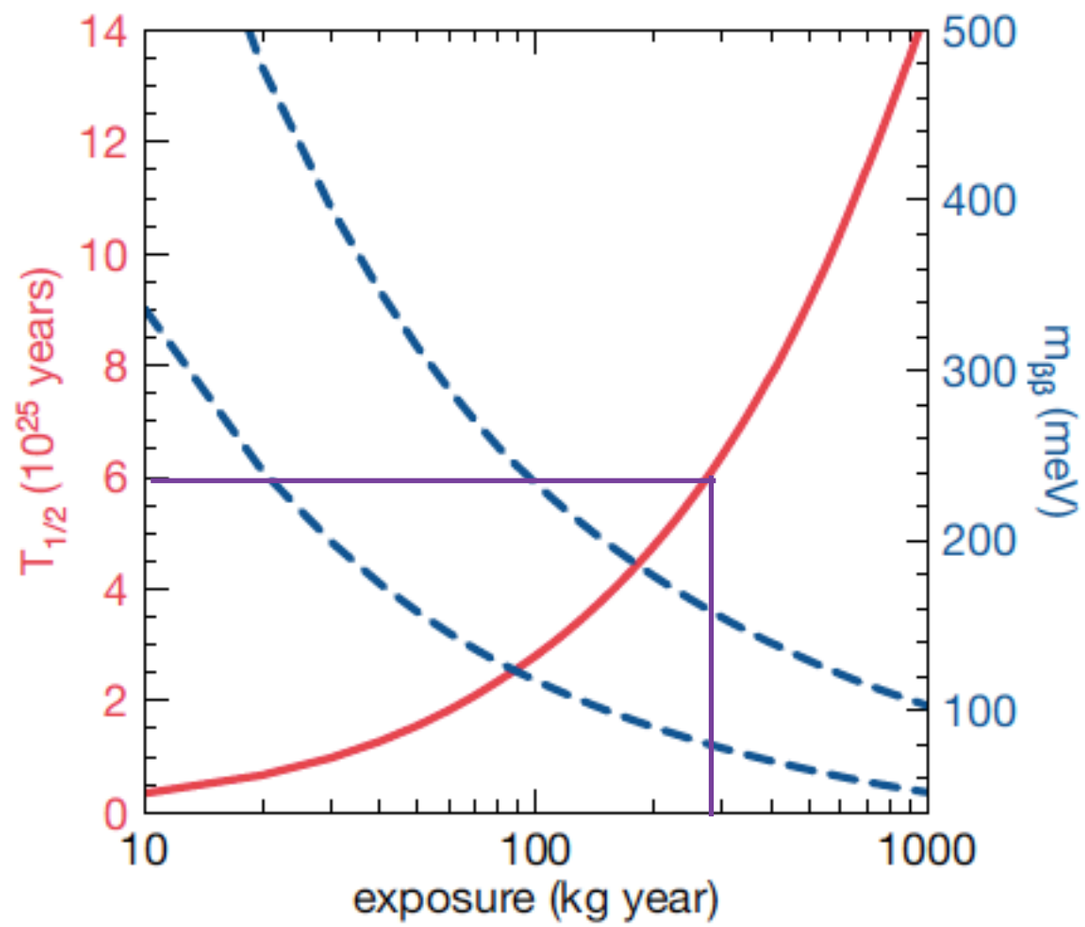
- 3 regions: drift (∼500V/cm), EL (E/p = 2 kV/cm/bar (575 ph./e-)), buffer
- HDPE of 49 cm external diameter that provides electric insulation from the vessel



NEXT100 sensitivity

JHEP 1605 (2016) 159





Expect a half-life of **6 x 10^{25} years** **[80-160meV]** for an exposure of 275 kg yr.

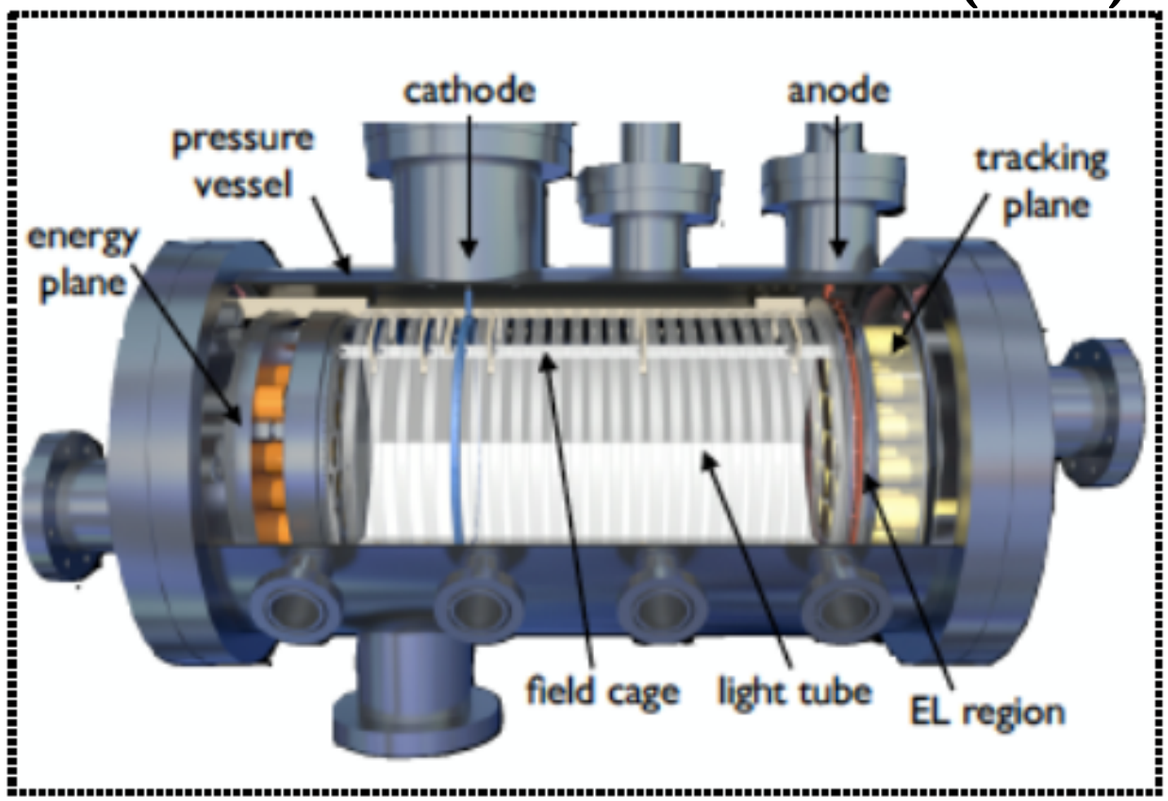
Still ample room for improvement!

Screening of detector components (initial Tl, Bi activities) + selection, the overall background rate is estimated to be:

< 4 x 10^{-4} counts/(keV kg yr)

NEXT prototypes

NEXT-DEMO (IFIC)



- Energy resolution (19 1" PMTs)
- Tracking (256 SiPMs)
- ~1.5 kg of Xenon 1 bar

JHEP 01, 104 (2016) [arXiv:1507.05902]

JINST 10, P03025 (2015) [arXiv:1412.3573]

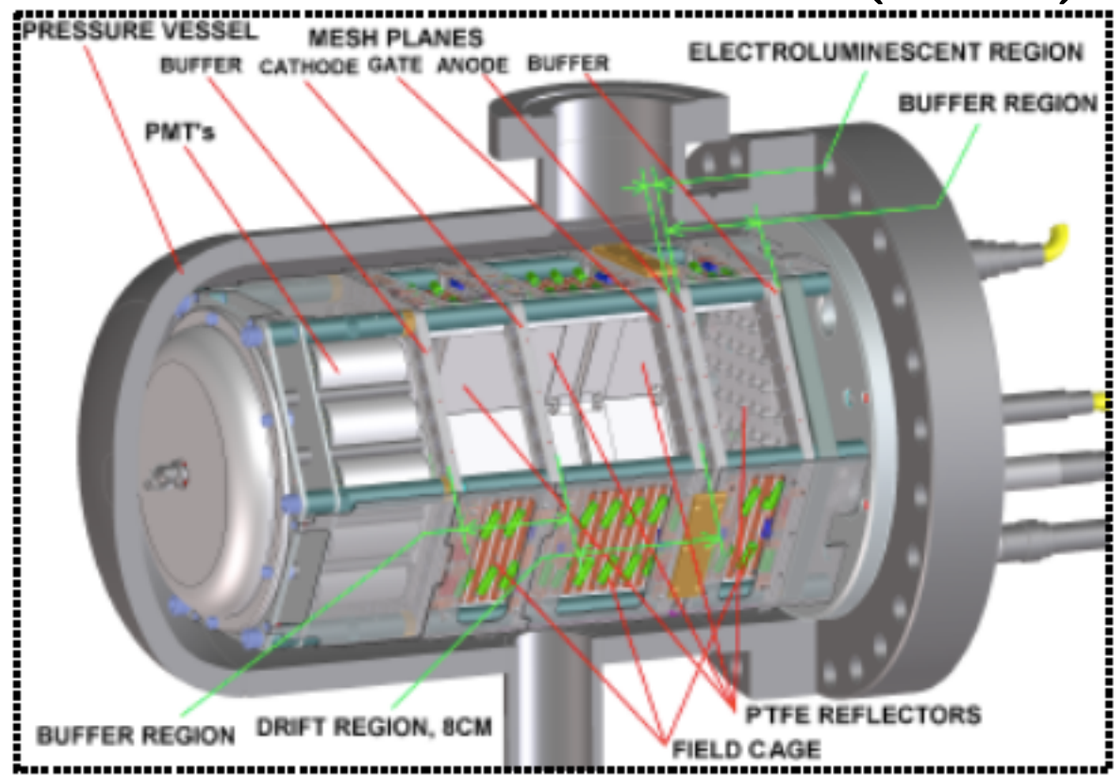
JINST 9, P10007 (2014) [arXiv:1407.3966]

JINST 8, P04002 (2013) [arXiv:1211.4838]

JINST 8, P05025 (2013) [arXiv:1211.4508]

JINST 8, P09011 (2013) [arXiv:1306.0471]

NEXT-DBDM (LBNL)

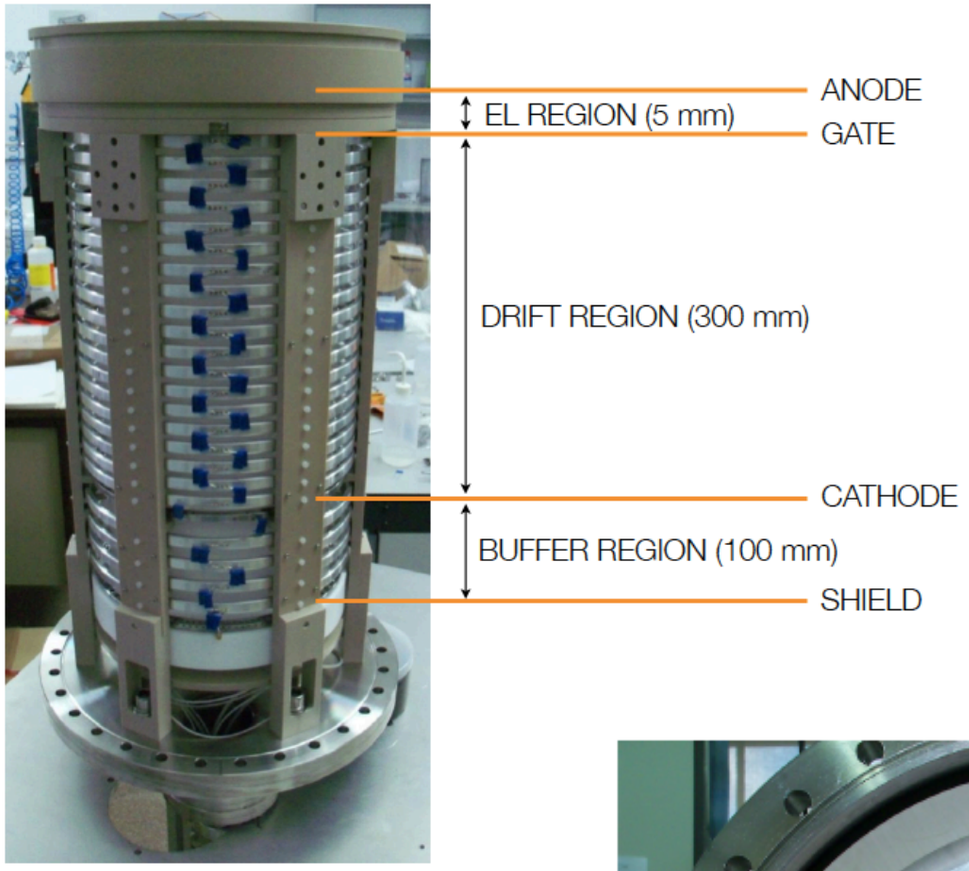


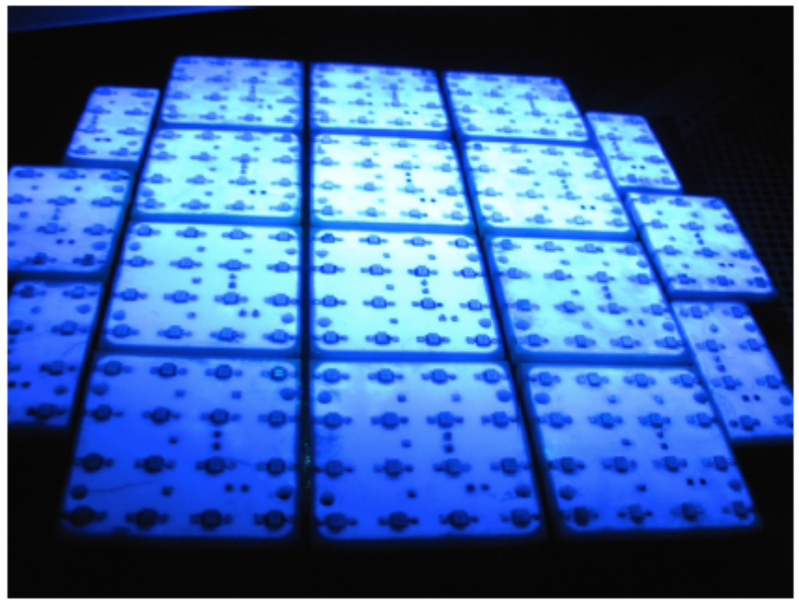
- Energy resolution (19 1" PMTs)
- ~1kg Xe gas at 10-15 bar
- Also measured response of HPXe to nuclear recoils

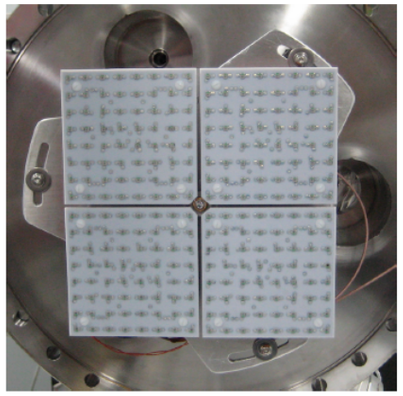
NIMA 793, 62 (2015) [arXiv:1409.2853]

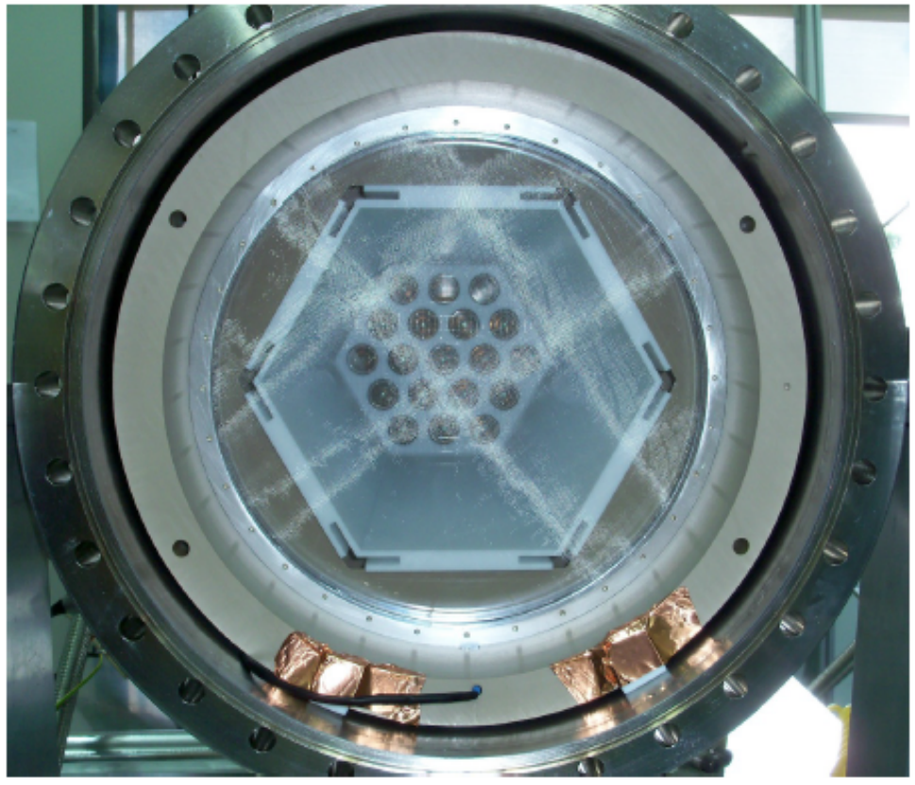
NIMA 708, 101 (2013) [arXiv:1211.4474]

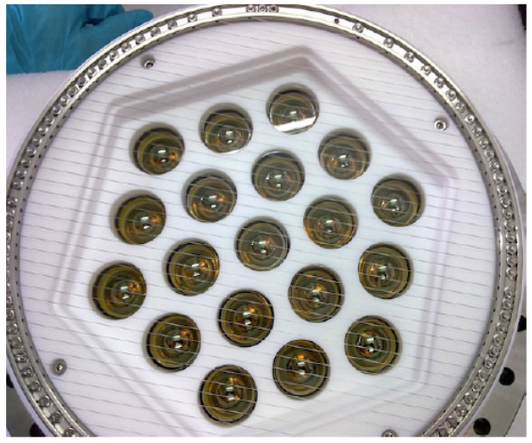
NEXT-DEMO tracking/energy plane







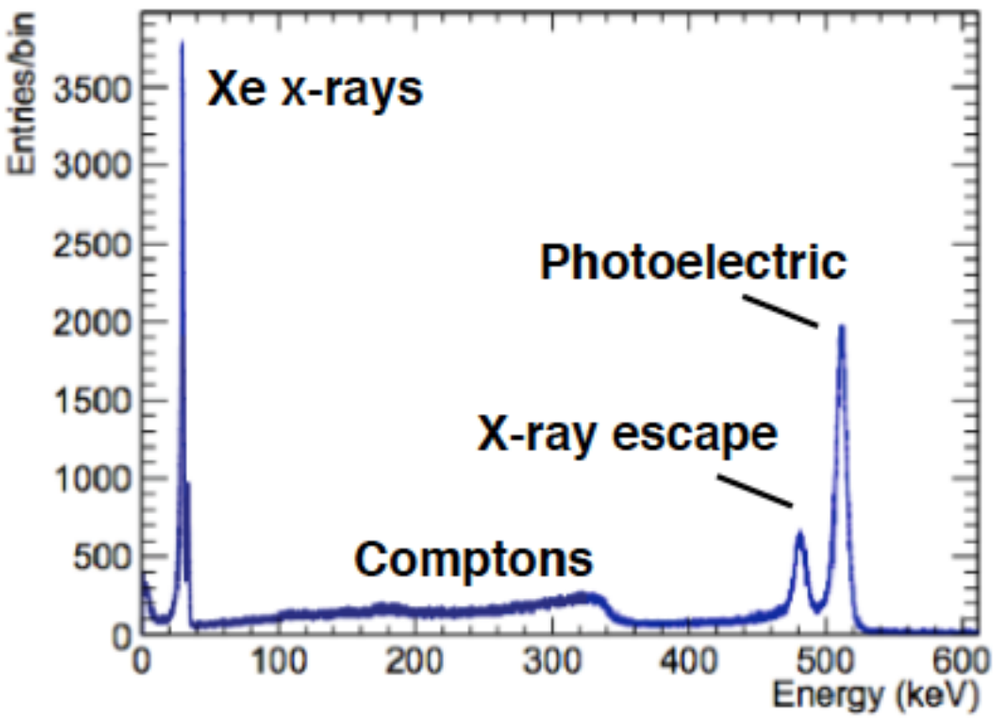




NEXT-DEMO energy resolution

NEXT-DEMO

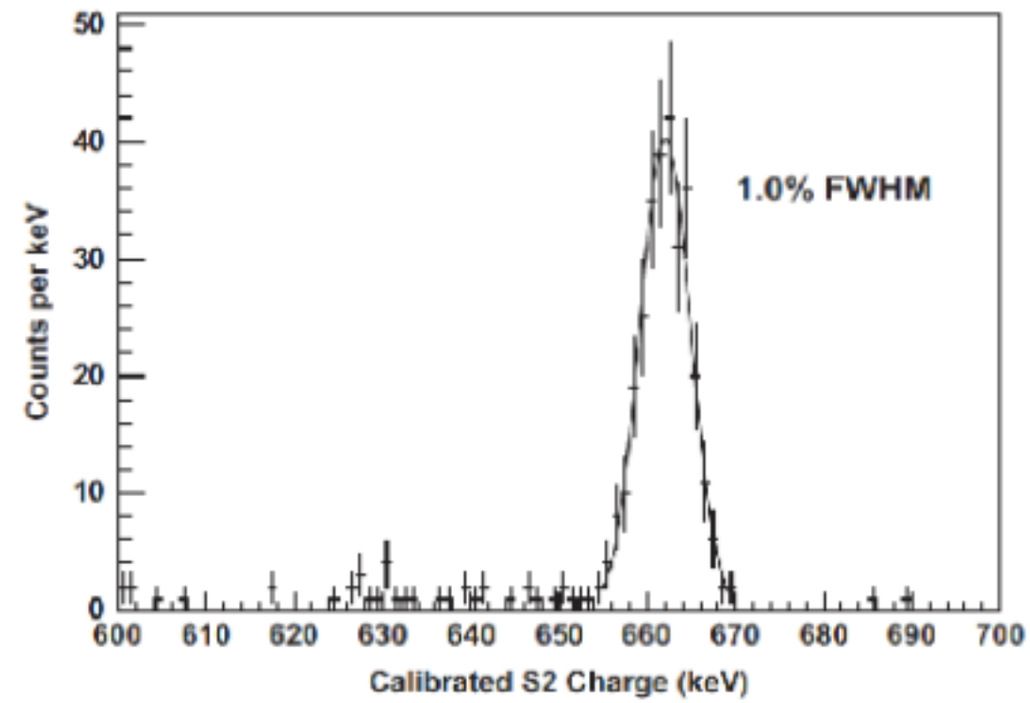
JINST 9, P10007 (2014) [arXiv:1407.3966]



- 511 keV gammas fro ^{22}Na
- 1.6% FWHM resolution over large fiducial volume
- Extrapolates to **0.63%** FWHM at Q-value

NEXT-DBDM

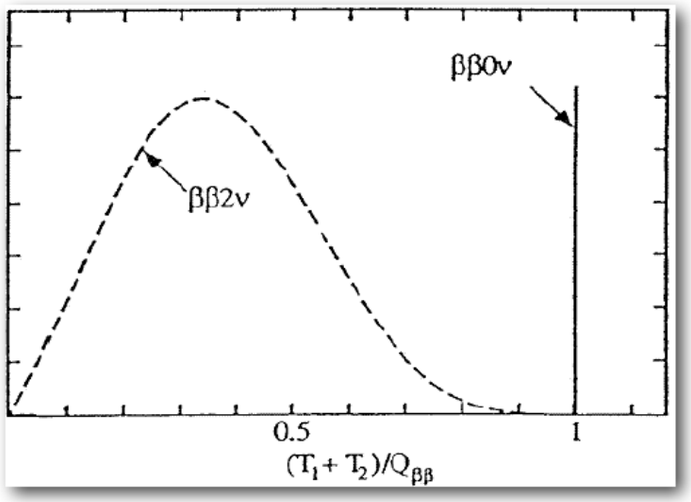
NIM A708, 101 (2014) [arXiv:1211.4474]



- 662 keV gammas from ^{137}Cs
- 1.0% FWHM resolution in small fiducial volume
- Extrapolates to **0.5%** HWHM at Q-value

0νββ experiments

- Experiments measure the kinetic energies of the two emitted electrons (monochromatic line at the Q-value)



- For background-limited experiments the 0νββ sensitivity:

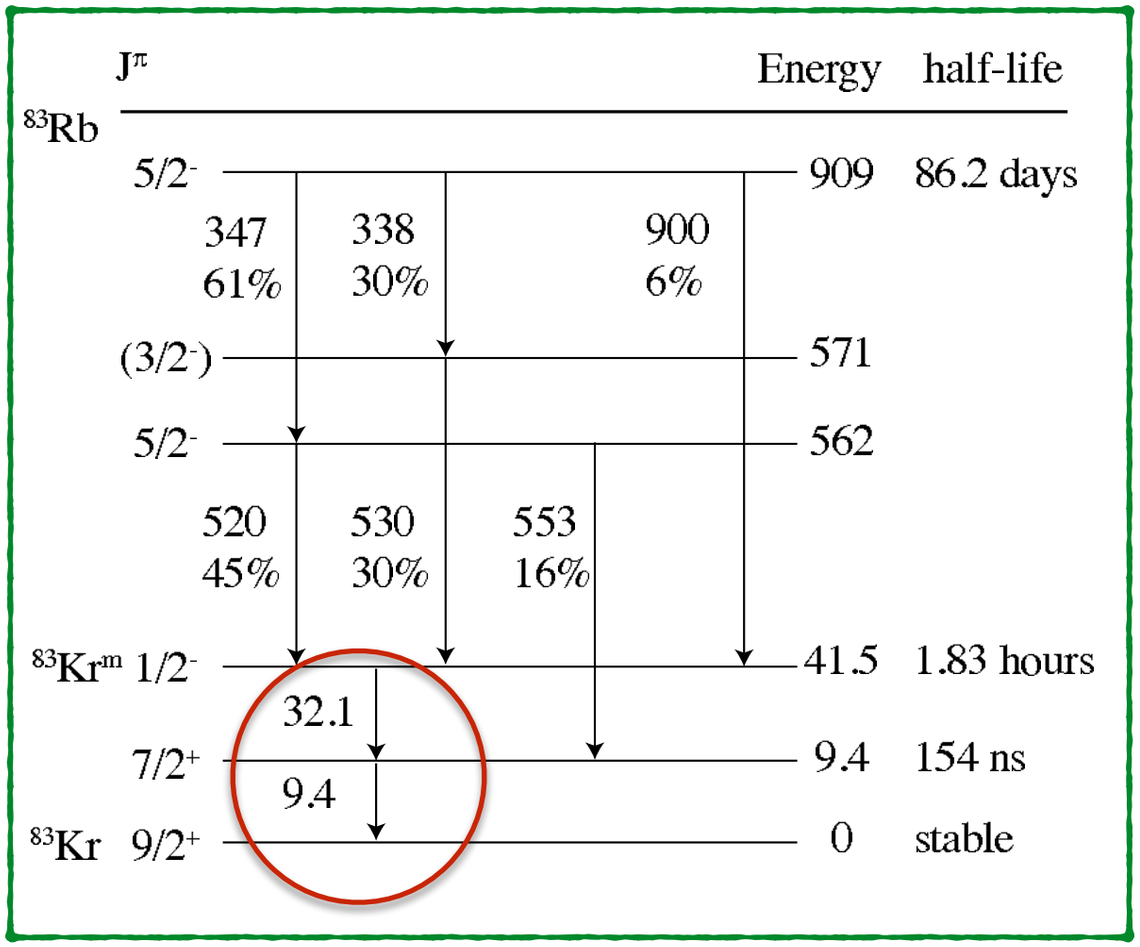
$$\mathcal{S}(T^{0\nu}_{1/2}) \;=\; K\,\epsilon\,\sqrt{\frac{M t}{c\,\Delta E}}$$

- For an experiment with background (c): an improvement of a factor **10 in $m_{\beta\beta}$** requires a factor of **10000 in isotope mass** (M) for the same running time (t). For a background-free experiment: $\boldsymbol{S(T^{0\nu}_{1/2}) \propto M}$

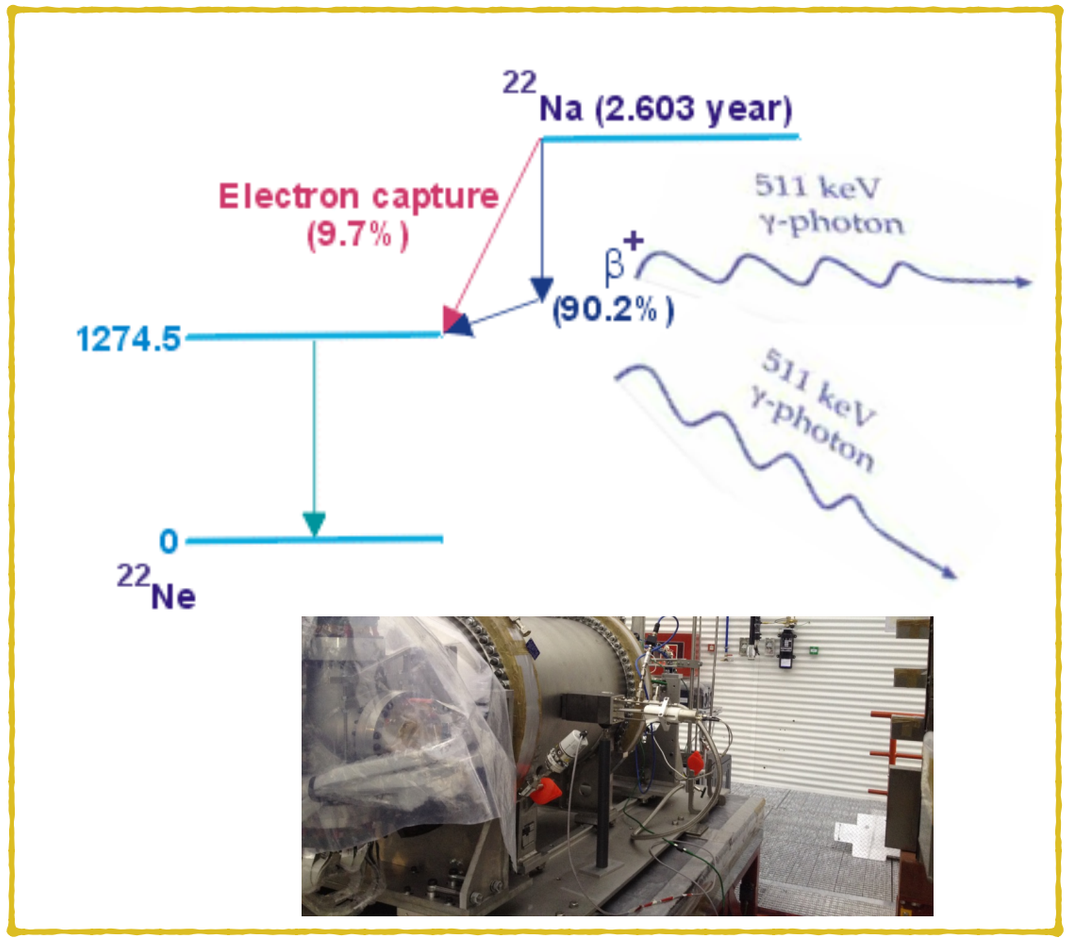
- Things to take into consideration:
  - Underground operation, energy resolution, Q value, scale up, extra handles to reduce background (tagging of daughter isotope, pattern of energy deposition, ...)

Calibration Run

^{83}Kr: point-like events, e ∼41.5 keV



^{22}Na: 511 keV and ∼1.2 MeV γ's



BI experiments for the future

	signal region, keV	BI, $x10^{-3}$	event/ton/year
GERDA	3.5	0.7(3.5)	3-12
EXO	75	1.0	127
KamLAND-Zen	250	0.2	40
CUORE	5	60	300
NEXT	17.5	0.4	5-10