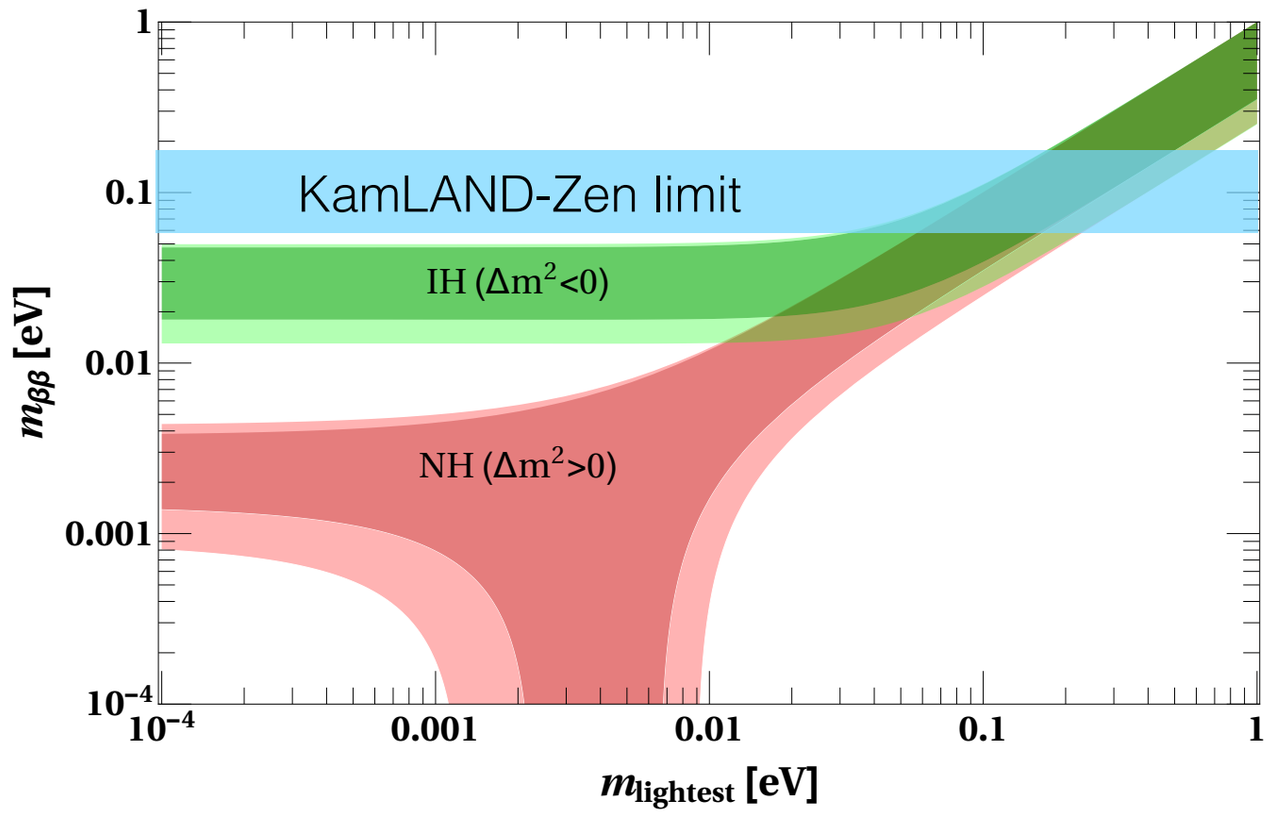
Common R&D for double beta decay and dark matter noble gas TPC experiments

JJ Gomez Cadenas (presented by P. Ferrario)
RENATA thematic meeting on Dark Matter @ LSC
LSC, February 7th, 2018

The Majorana landscape

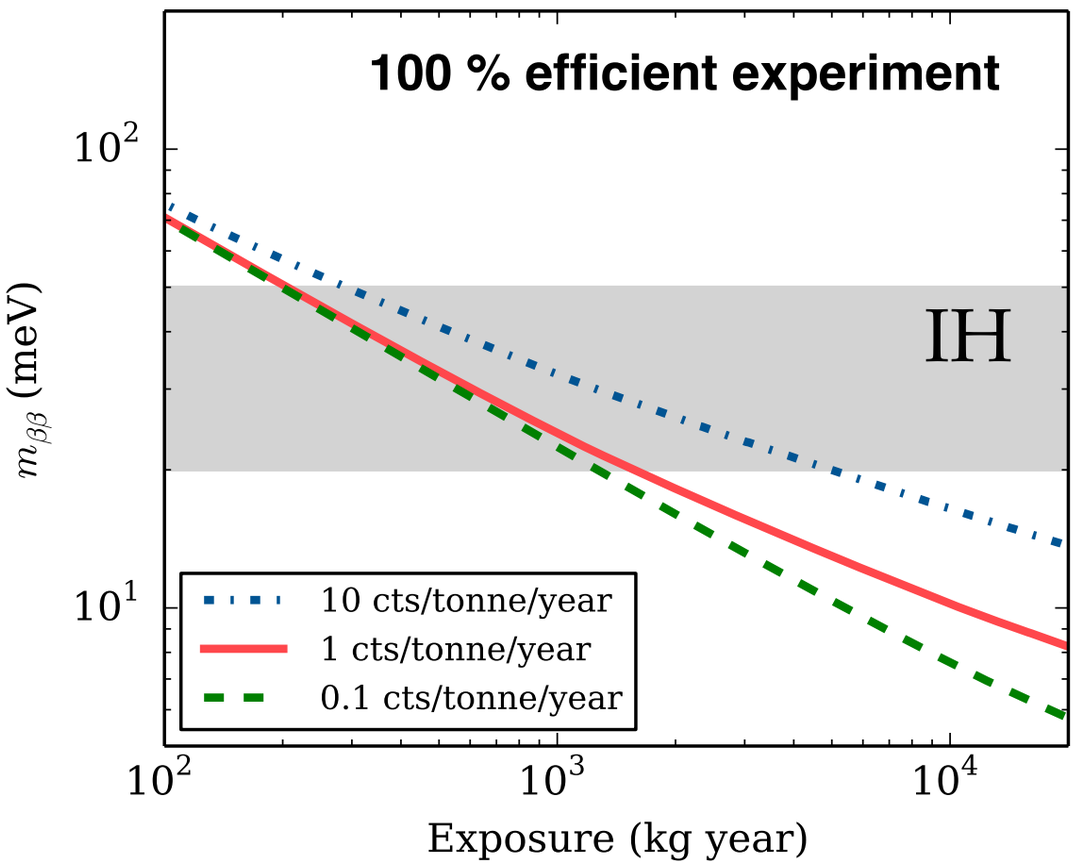


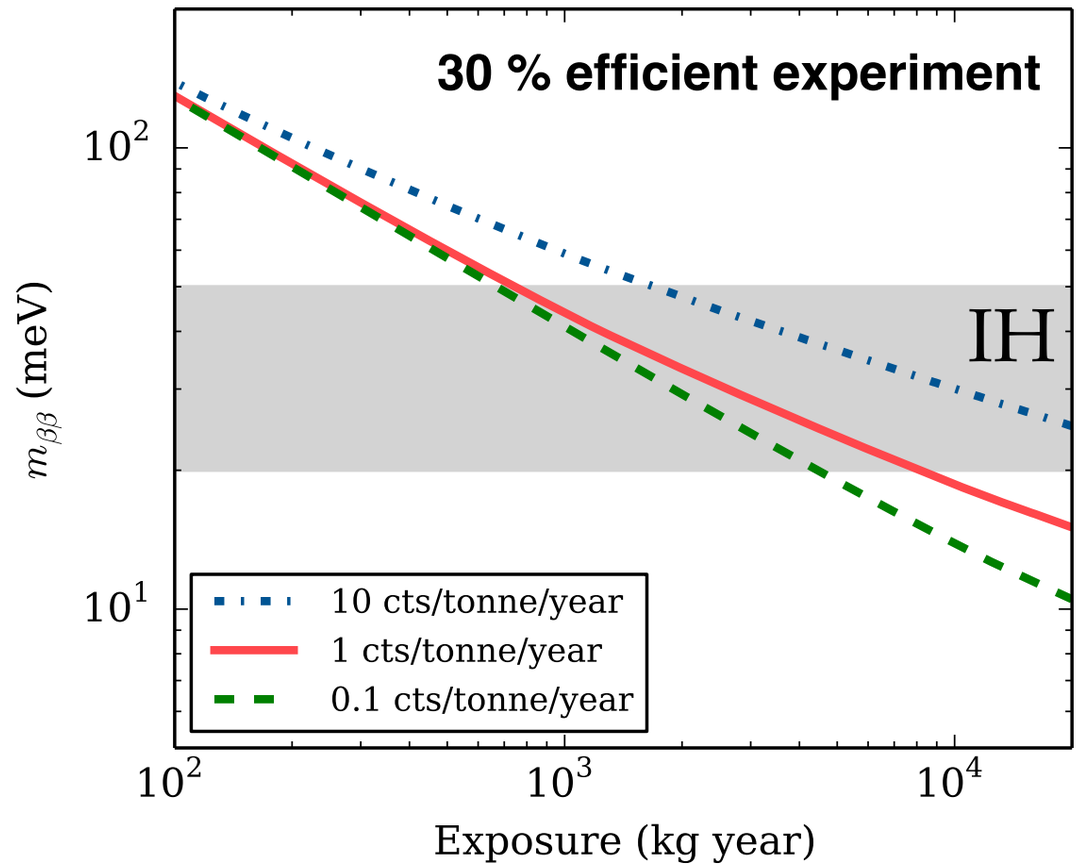
- Results from GERDA, CUORE, KamLAND-Zen, EXO barely scratching IH
- Exploring IH : T~ 10^{27}years

Needs "ton-scale, background free" experiments

Exploring the IH

Xe-136



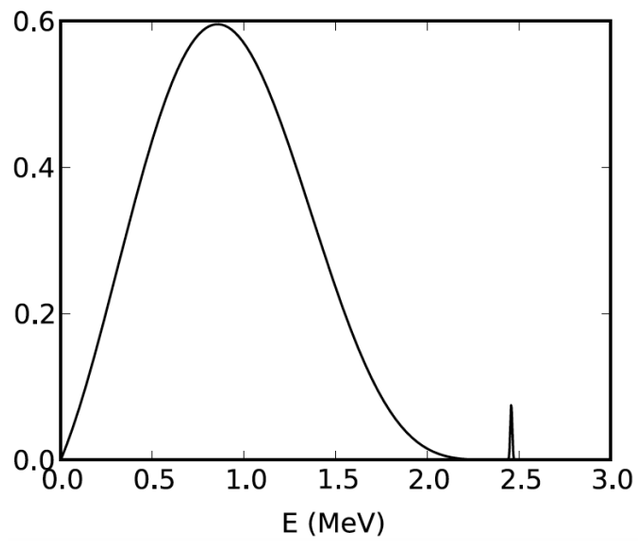


2 ton year to explore IH with 1 background event per tonne per year (using a "reasonable NME set")

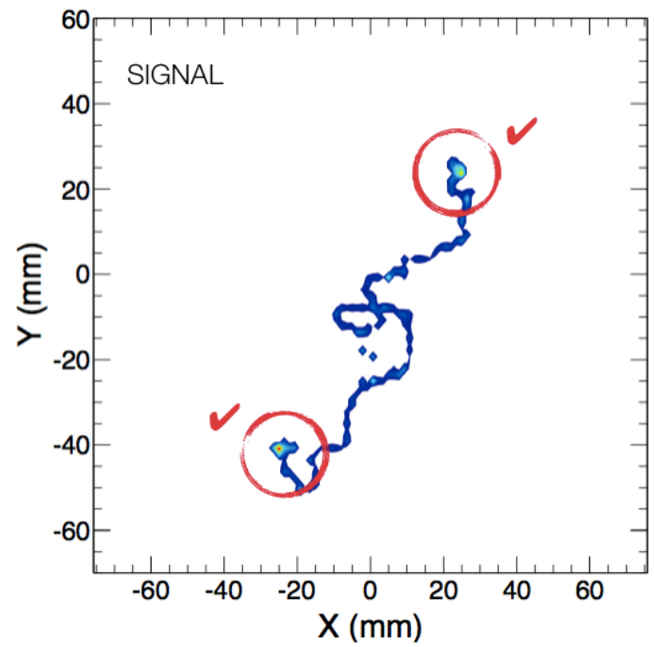
From 4 to 9 ton year to explore IH with 0.1 or 1 background event per tonne per year

HPXe - EL technology

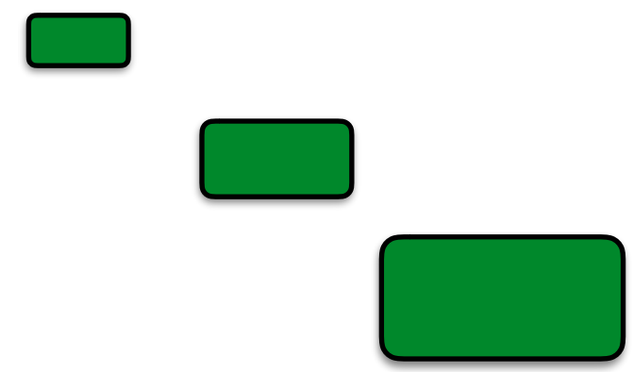
Energy Resolution



Topological Signature



Cost and Scalability



Least Expensive ßß Isotope
Source = detector

0.7 % FWHM

Intrinsic (Fano): ~0.3 %

c ~5 x 10^{-4} cts/(keV kg yr)

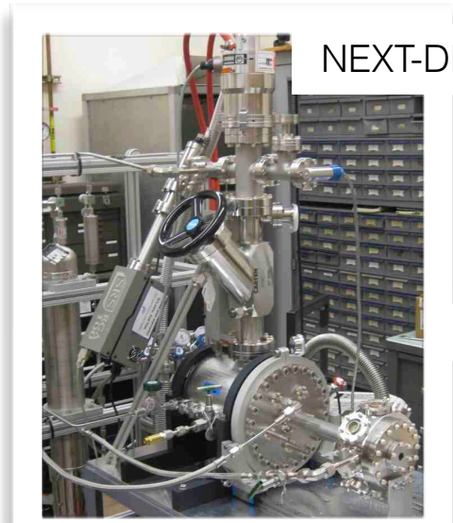
extrapolate to large (ton) masses

First target: To demonstrate "background free" at 100 kg scale (i.e., <~1 count per 100 kg per year)

Ultimate target: To develop a technology "background free" at tonne scale (i.e., <~1 count per tonne per year)

The NEXT detectors

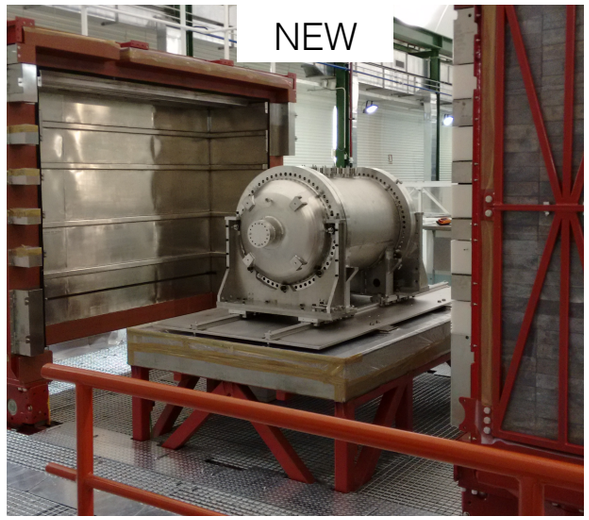
Prototypes (2009-2014)



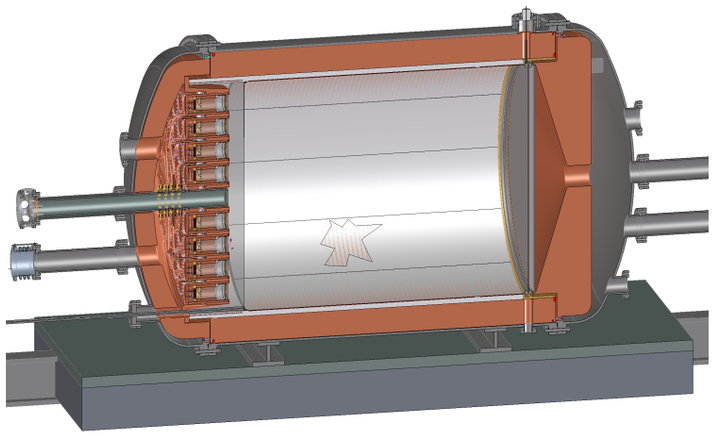
- ~1 kg of mass
- Demonstration of technology

First stage - NEW (2015-2019)

- ~10 kg of mass
- Underground operation
- Background and ββ2ν measurements



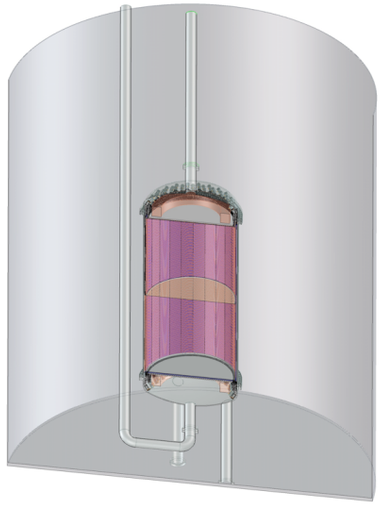
NEXT-100 (2019-)



- 100 kg of mass
- ββ0ν search

NEXT-ton (NEXT2.0)

- 1000 kg of mass
- ββ0ν search

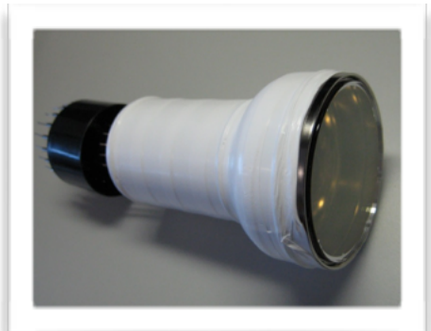


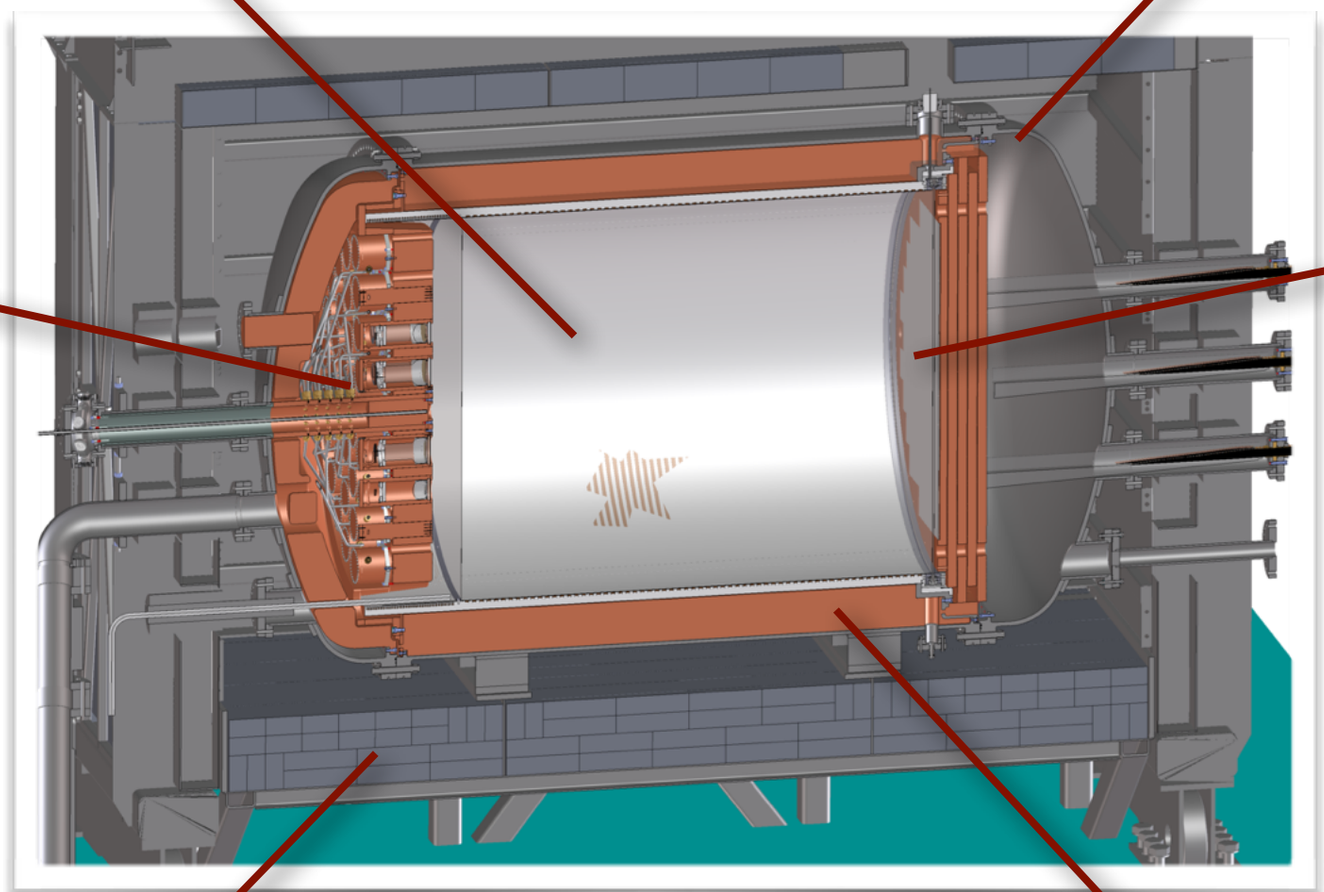
NEXT 100

Time Projection Chamber:
100 kg active region, 130 cm drift length

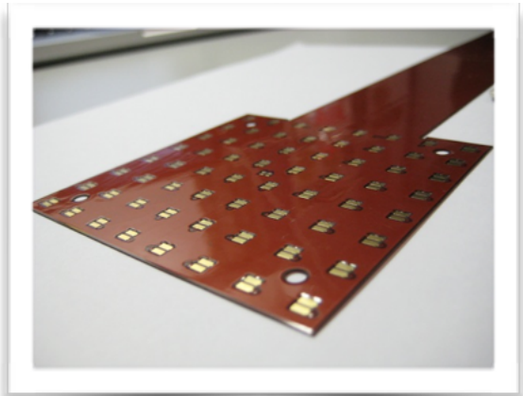
Pressure vessel:
stainless steel,15 bar max pressure

Energy plane:
60 PMTs





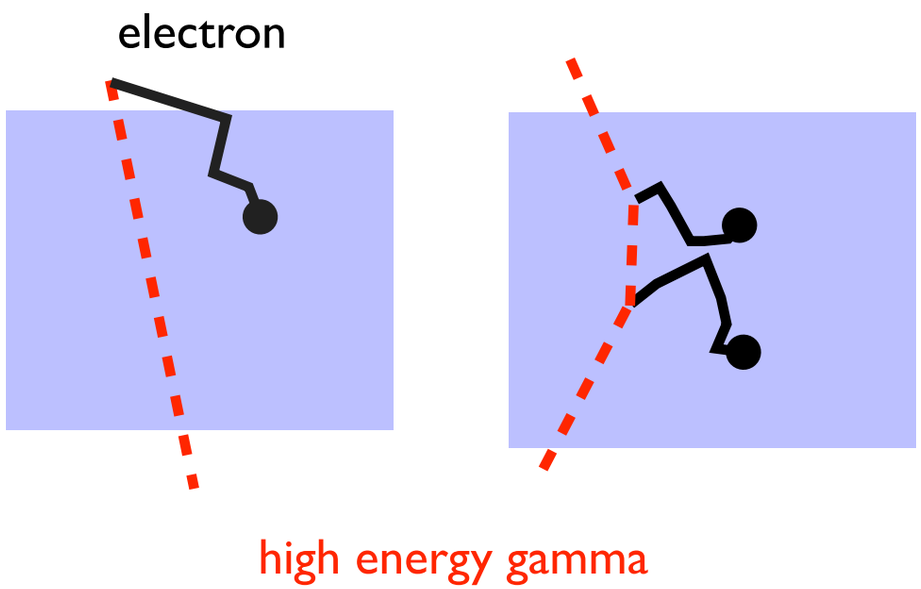
Tracking plane:
7,000 SiPMs,
1 cm pitch

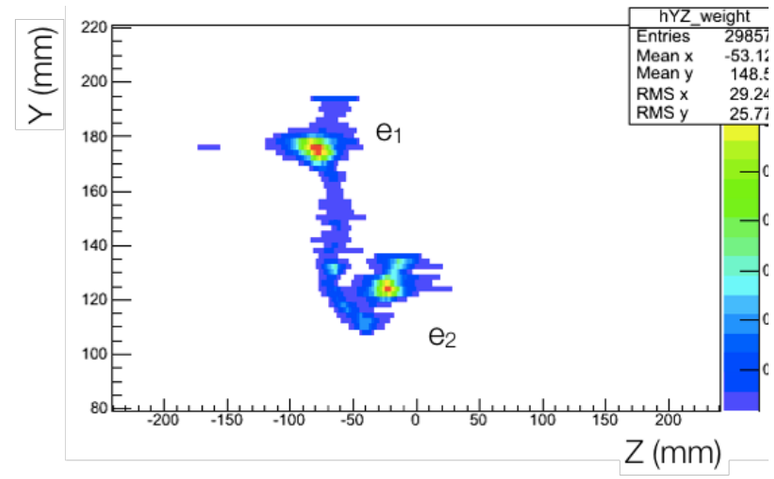


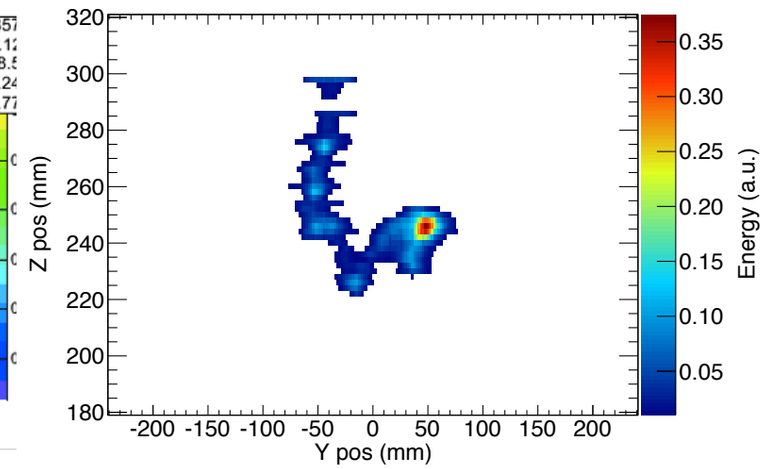
Outer shield:
lead, 20 cm thick

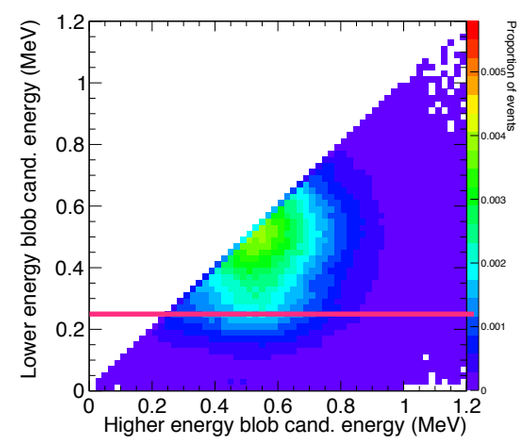
Inner shield:
copper, 12 cm thick

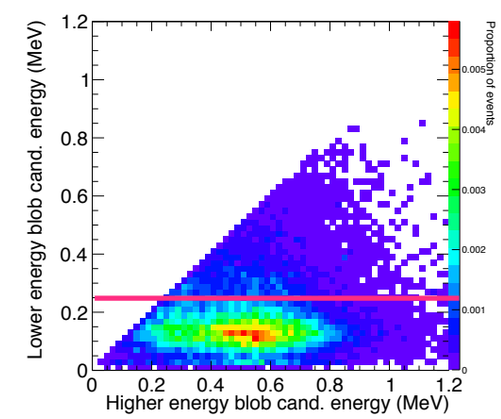
Rejection of background







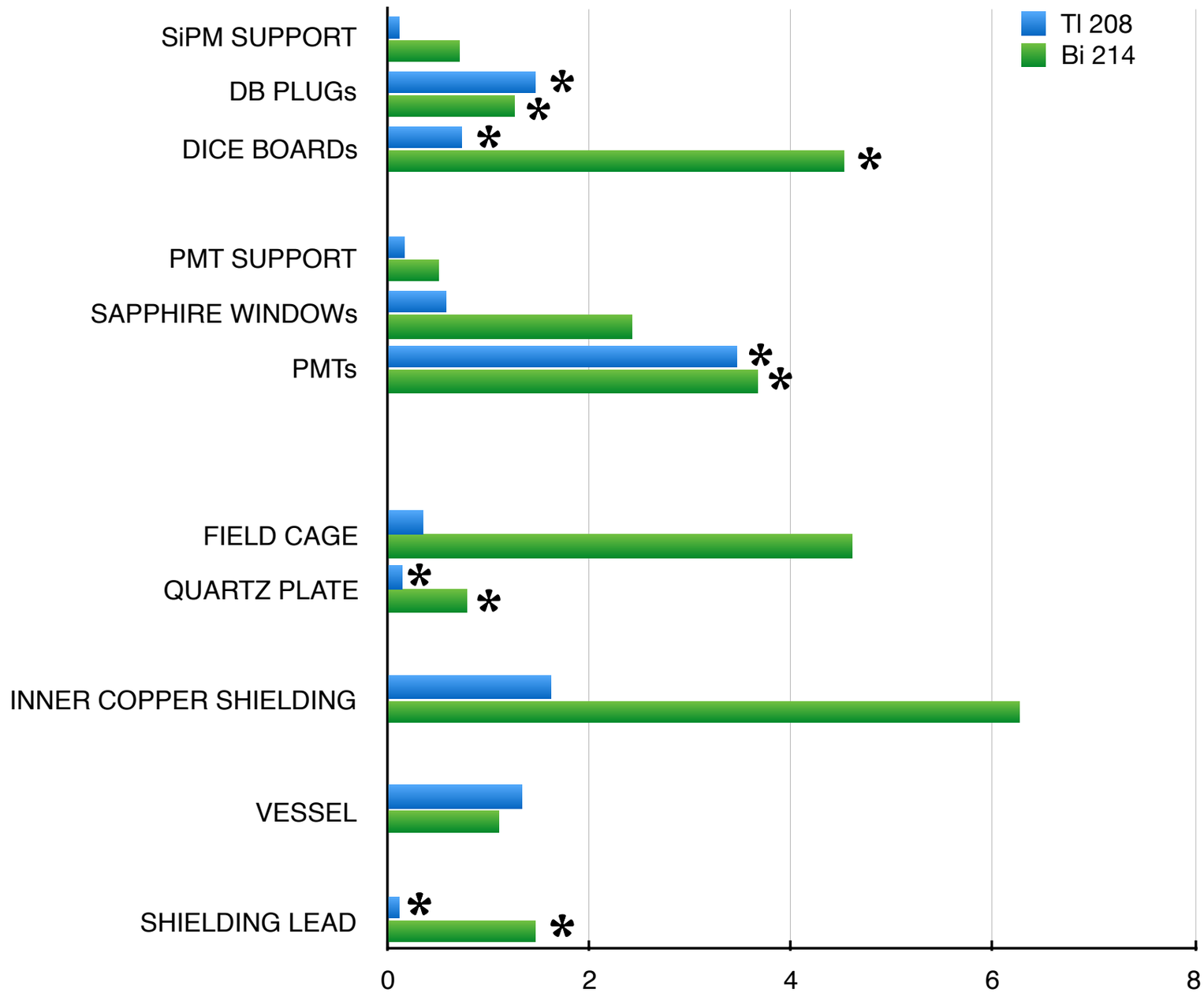




Fraction of events left after each analysis cut

JHEP 1605 (2016) 159	0νββ	Tl-208	Bi-214
Fiducial + E ∈ [2.4, 2.5] MeV	0.664	3.5×10^{-4}	2.9×10^{-5}
1 track	0.476	1.41×10^{-5}	3.44×10^{-6}
2 “blobs”	0.354	1.57×10^{-6}	3.39×10^{-7}
Energy ROI	0.320	2.54×10^{-7}	1.46×10^{-7}

Rejection of background



NEXT-100 background rate x 10^{-5} counts/(keV kg year).
* come from actual measurements (otherwise are limit).

- Main measured contribution: PMTs (11 and 21 mBq in total) and kapton boards (glue between layers).
- Limits on copper and hdpe.

Total expected background rate

$< 4 \times 10^{-4}$ cts / (keV kg year)

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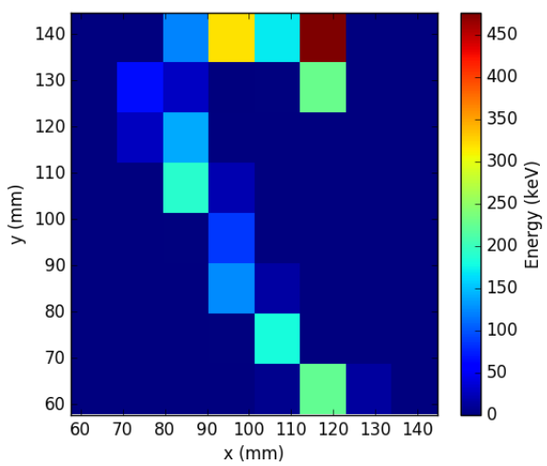
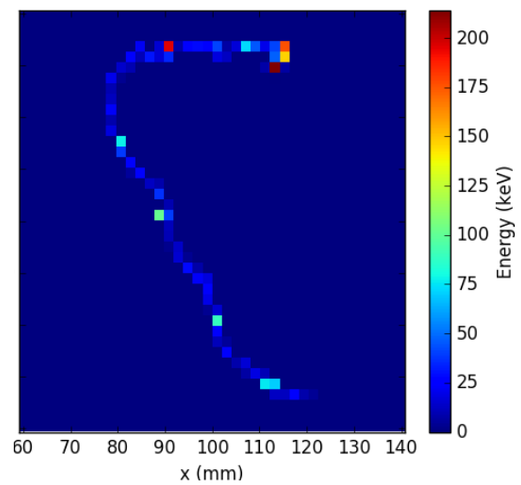
- Essential step towards the tonne scale.

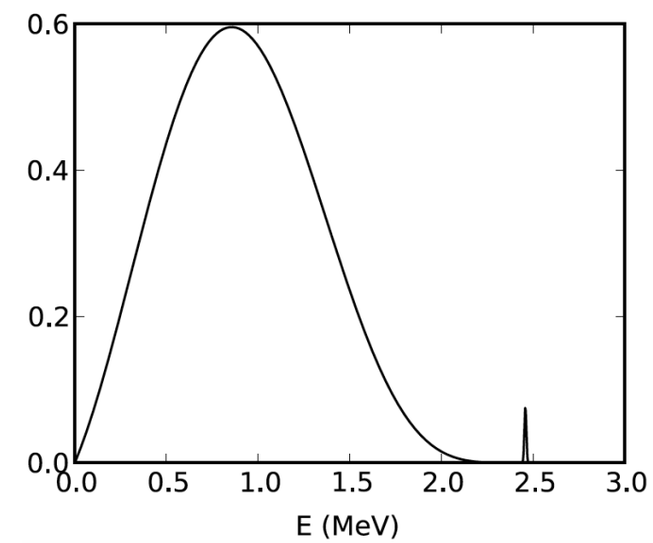
From NEXT to NEXT2.0

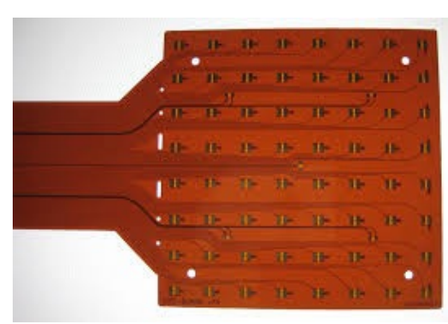




Low diffusion: f ~(1/5)

Energy resolution: f ~(1/2)

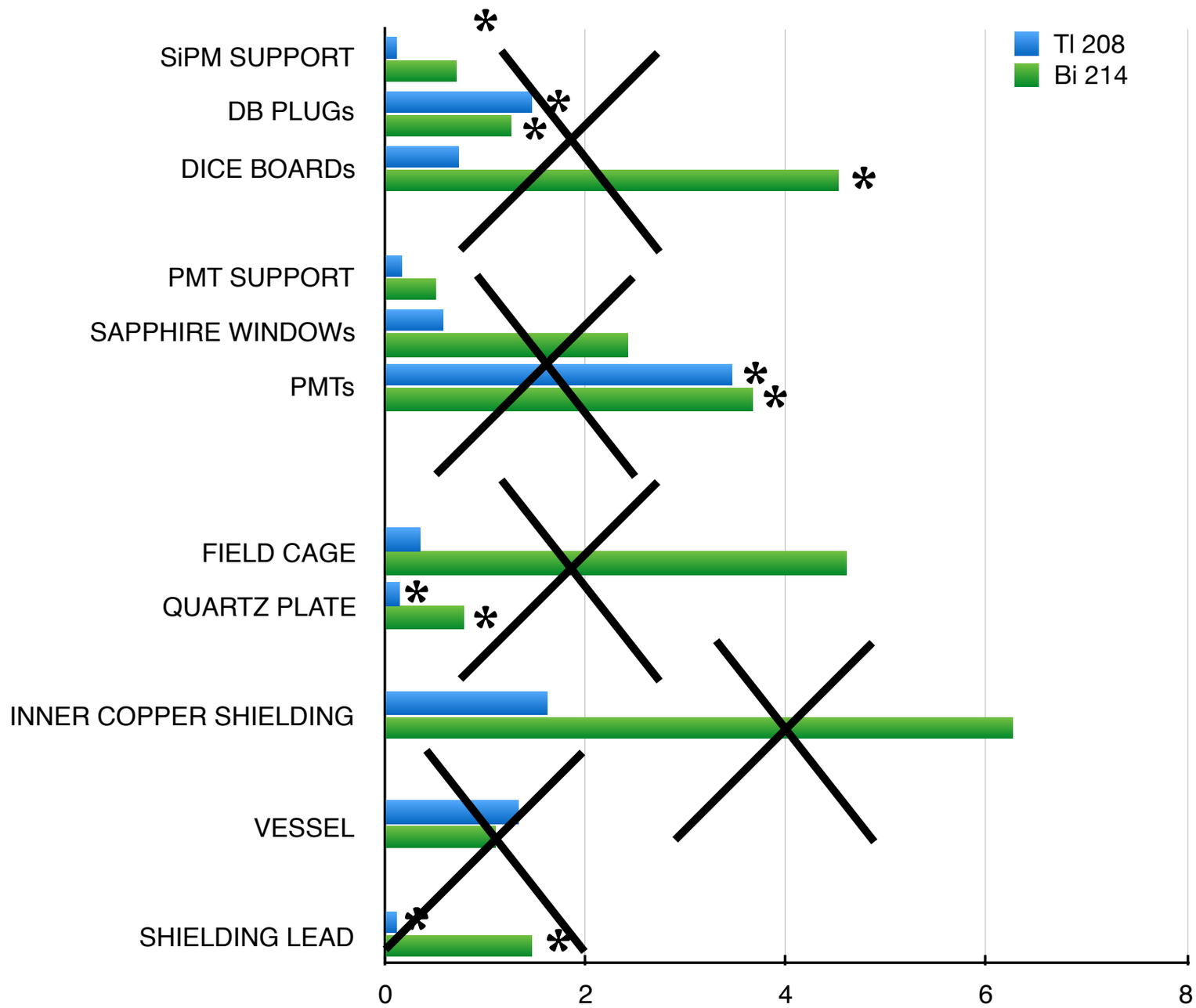




Radiopurity: f ~(1/5)

Reaching 1 event tonne/year in the ROI appears possible.

Rejection of background



NEXT-100 background rate x 10^{-5} counts/(keV kg year).
* come from actual measurements (otherwise are limit).

- Produce ultra-pure SiPM substrates and electronics: COMMON R&D WITH DM EXPERIMENTS (E.G, DARK SIDE)
- Eliminate PMTs (REPLACE BY SIPMS FOR THE ENERGY PLANE. DARK SIDE ALSO USES SIPMS FOR ENERGY MEASUREMENT)
- Minimise thickness of FC (notice that budget is just an upper limit, most likely HDPE very radio pure)
- Recent measurements from Majorana show an activity for commercial copper 4 times smaller than NEXT upper limit

Total expected background rate

~10^{-5} cts / (keV kg year)
< 1 count per ton per year

Dark Side

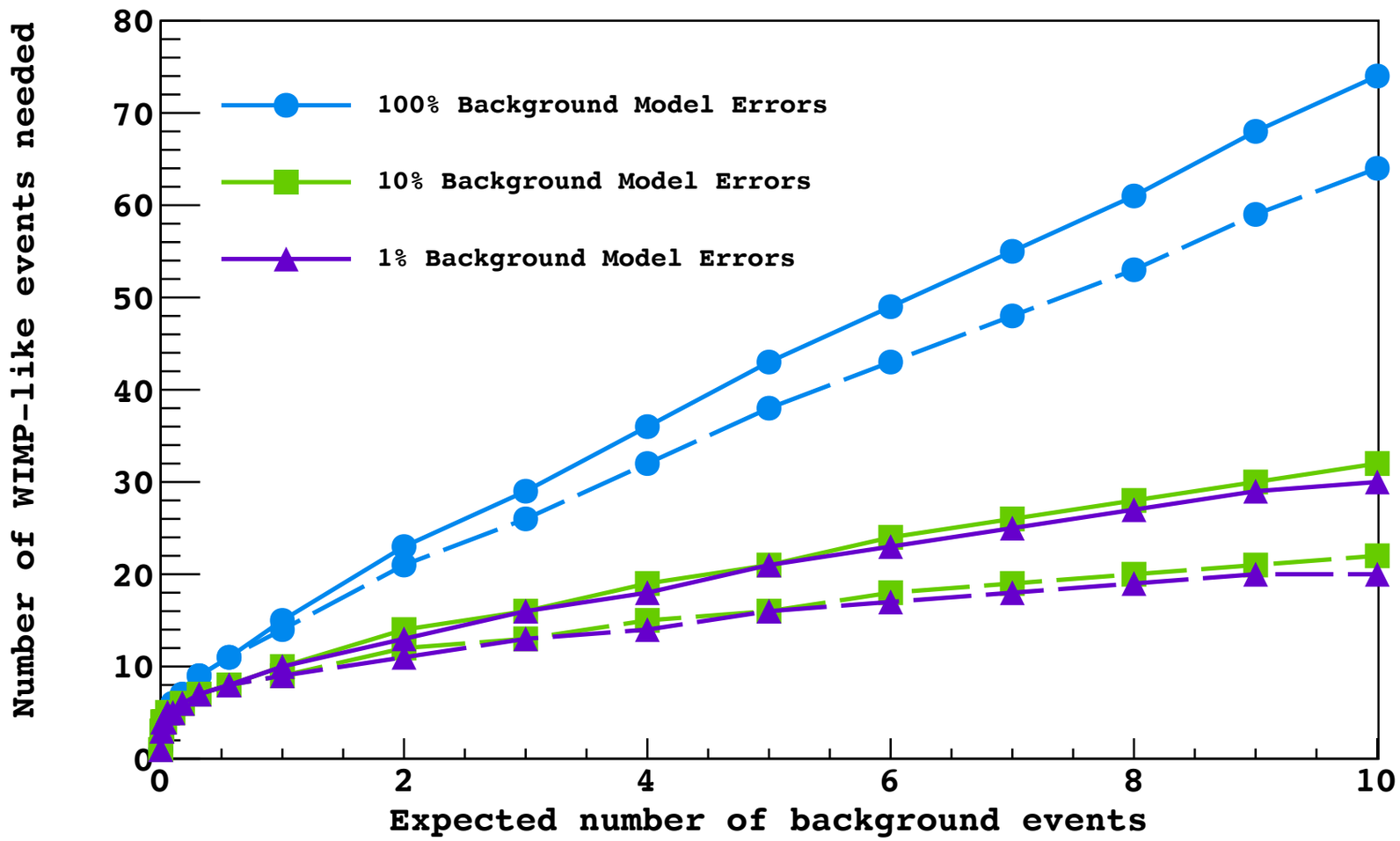
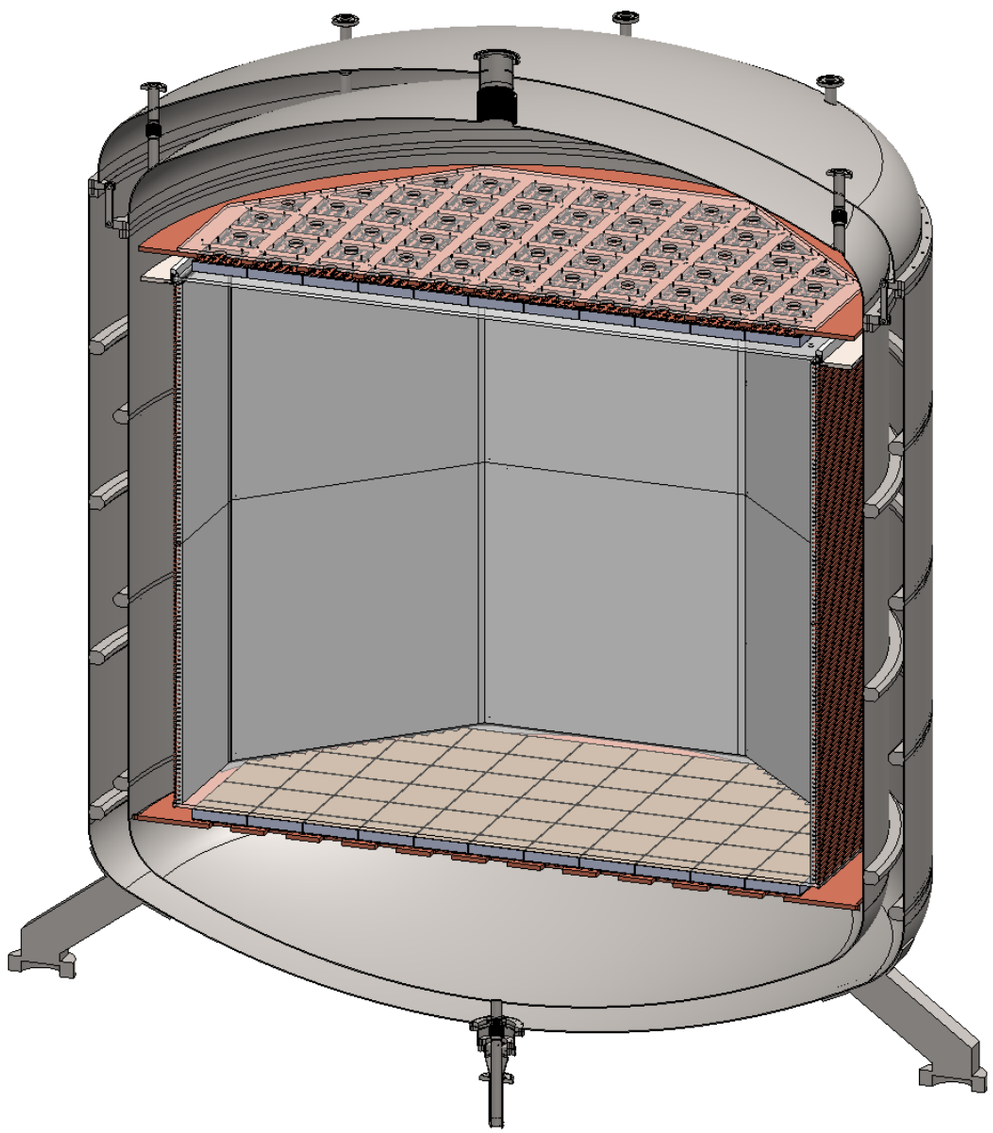


Fig. 2. Number of dark matter-like events needed to claim a WIMP observation at the $5\,\sigma$ level, based on the predicted background rate of the experiment, in a linear-linear scale. Solid lines show the number of dark matter-like events needed, including backgrounds, while dashed lines show the number of dark matter events after subtraction of the expected background. Blue, green, and purple curves were made assuming uncertainty on the background model of 100 %, 10 %, and 1 %, respectively.

Synergies between DS and NEXT2.0



- Noble gas (liquid) OPTICAL TPC. The signal is VUV light shifted to visible by the use of a wavelength shifter (TPB).
- Detectors (DS-20ton - NEXT2.0-1-2ton) very similar size (cylinder of 3 m diameter, 3 m length).
- Detector design conceptually identical.
  - TPC (including field cage, light tube cathode grid and EL region)
  - Two sensor planes made of SiPMs, SiPM substrates and electronics.

Proposal: explore the possibility of a joint R&D program with DarkSide

- NEXT-2.0 and DarkSide radio purity constrains are very similar. Both detectors need to be ultra-radiopure optical TPCs.

- Readout planes are essentially identical. Large SiPMs (for the energy plane, tracking for NEXT2.0 will use smallish SiPMs simpler problem). Electronics has to deal with similar problems (multiplex, capacitance, etc.)

- Ultra-pure substrates and electronics needed for both.

- Massive production of sensors.

A wide view of the field

- NEXT (and future upgrades) can bring the LSC to the forefront of the field in DBD searches. We need to think on an experimental program with a scope of 10 years.
- DarkSide on its way has become the uber-experiment on argon DM searches and is operating at LNGS.
- Collaboration between both efforts can be envisioned in a wider network collaboration between LSC and LNGS.
- As we move towards ton (multi-ton) scale, the possibility of experimental FEDERATIONS appears more and more attractive.

Thank you!