Neutrinoless Double Beta Decay with ^{136}Xe

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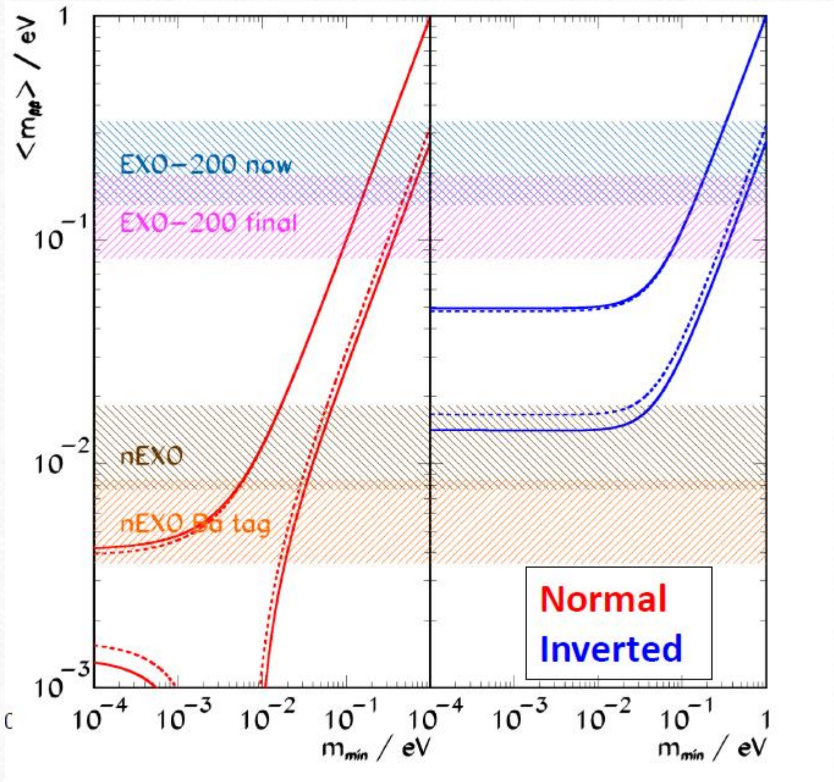
BNO-50

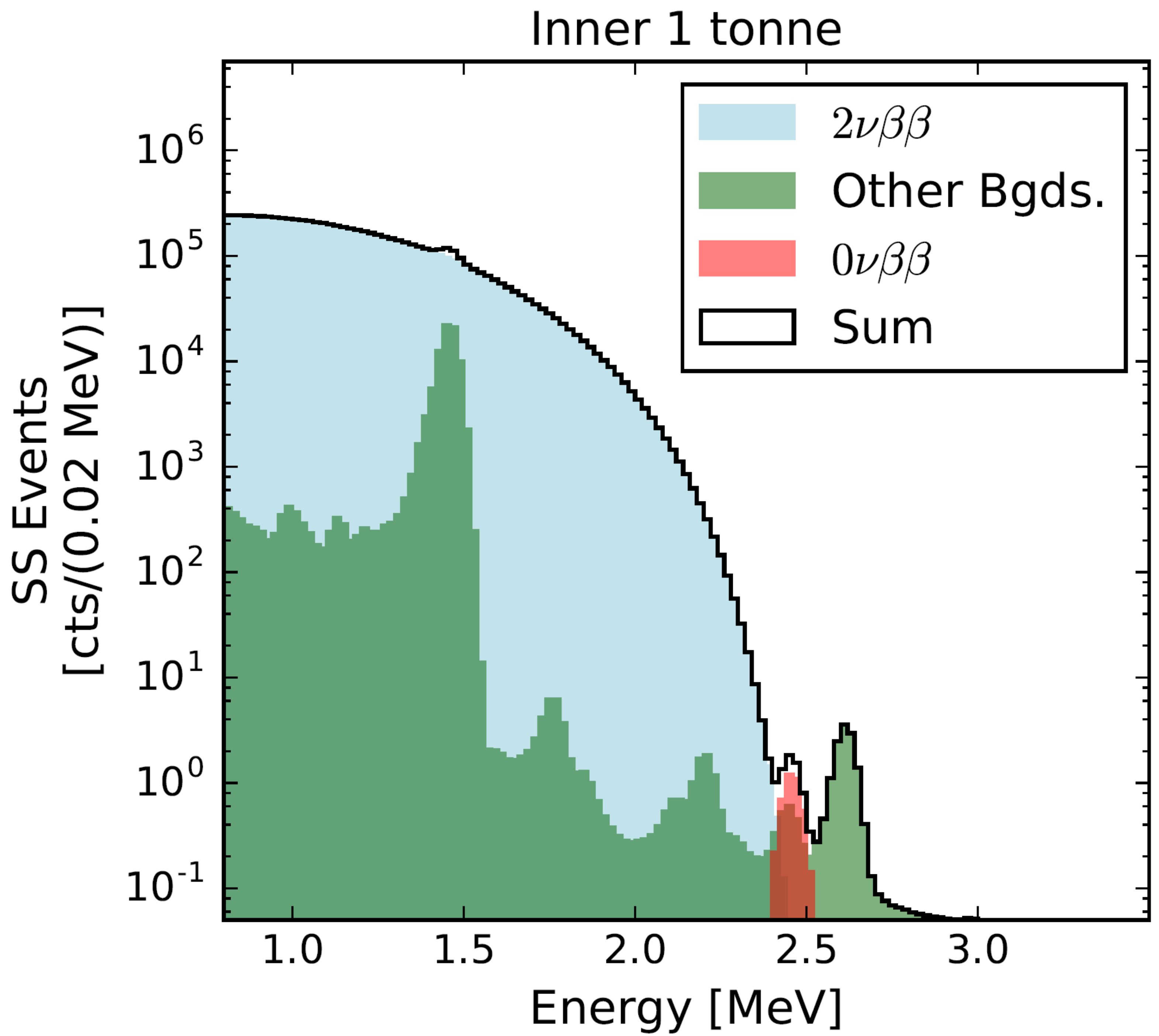
The Challenge for Double Beta Decay

- Hints that data prefer Normal Hierarchy
- This suggests that we need to start thinking about how to detect NH
- Will require 100 fold reduction in backgrounds
- Will require 100 fold increase in ton-years
- I will speculate on how to get there!



Advantages for xenon

- Xenon can be made very clean
- Any cosmogenic activity can be removed by *in situ* purification
- No long lived radioactive isotopes (other than double beta decay)
- Least expensive of the double beta candidates to enrich
- Can be made into large, homogeneous detectors
- Concepts for detecting Ba daughter being developed

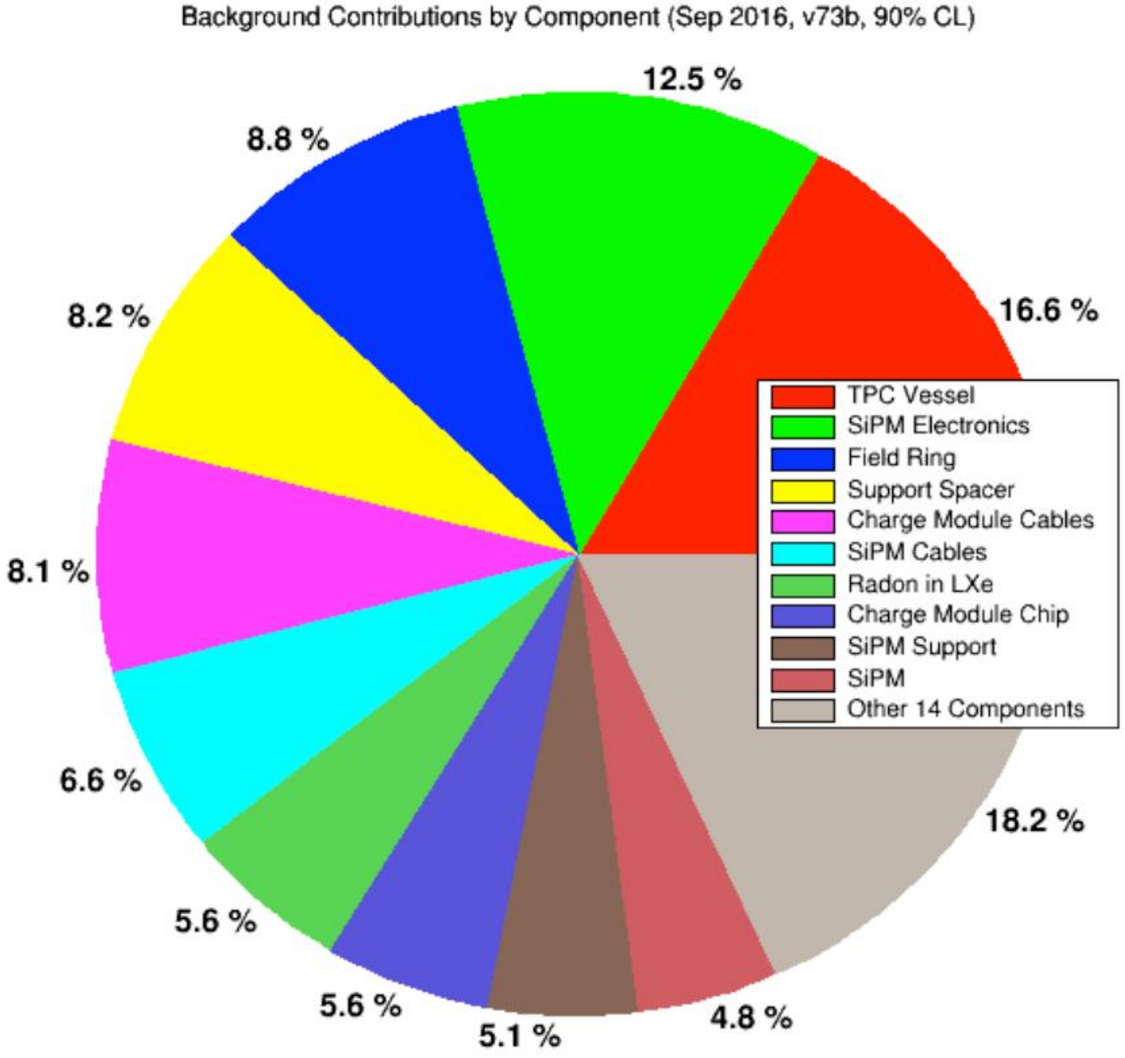


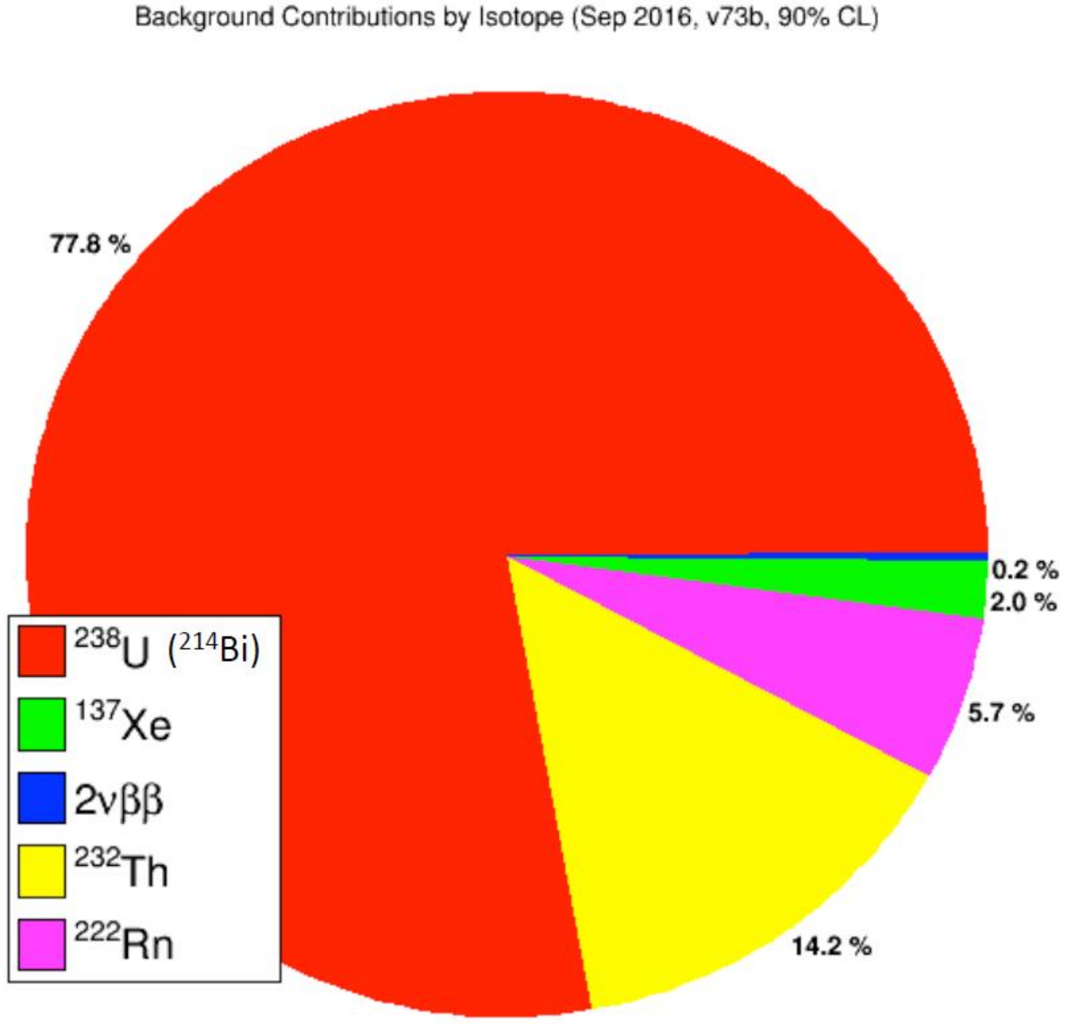
The Background Challenge Example from nEXO

Expected data for 10 years

Discovery potential limit
5.5 x 10^{27}yr

Background Budgets (90% C.L.)





Possible detector configuration

- Dissolve in liquid scintillator (Kamland-Zen – Yuri Efremenko's talk)
- Use in pure liquid form (EXO – Vladimir Belov's talk)
- Use in pure, gaseous form (Goddhard, NEXT, Panda-X3)

Dissolve in liquid scintillator

- Advantages:
  - Excellent shielding and self shielding
  - Excellent calorimetry
  - Modest energy resolution
- Disadvantages
  - Resolution limiting as one goes to normal hierarchy
  - Large target mass for solar neutrinos

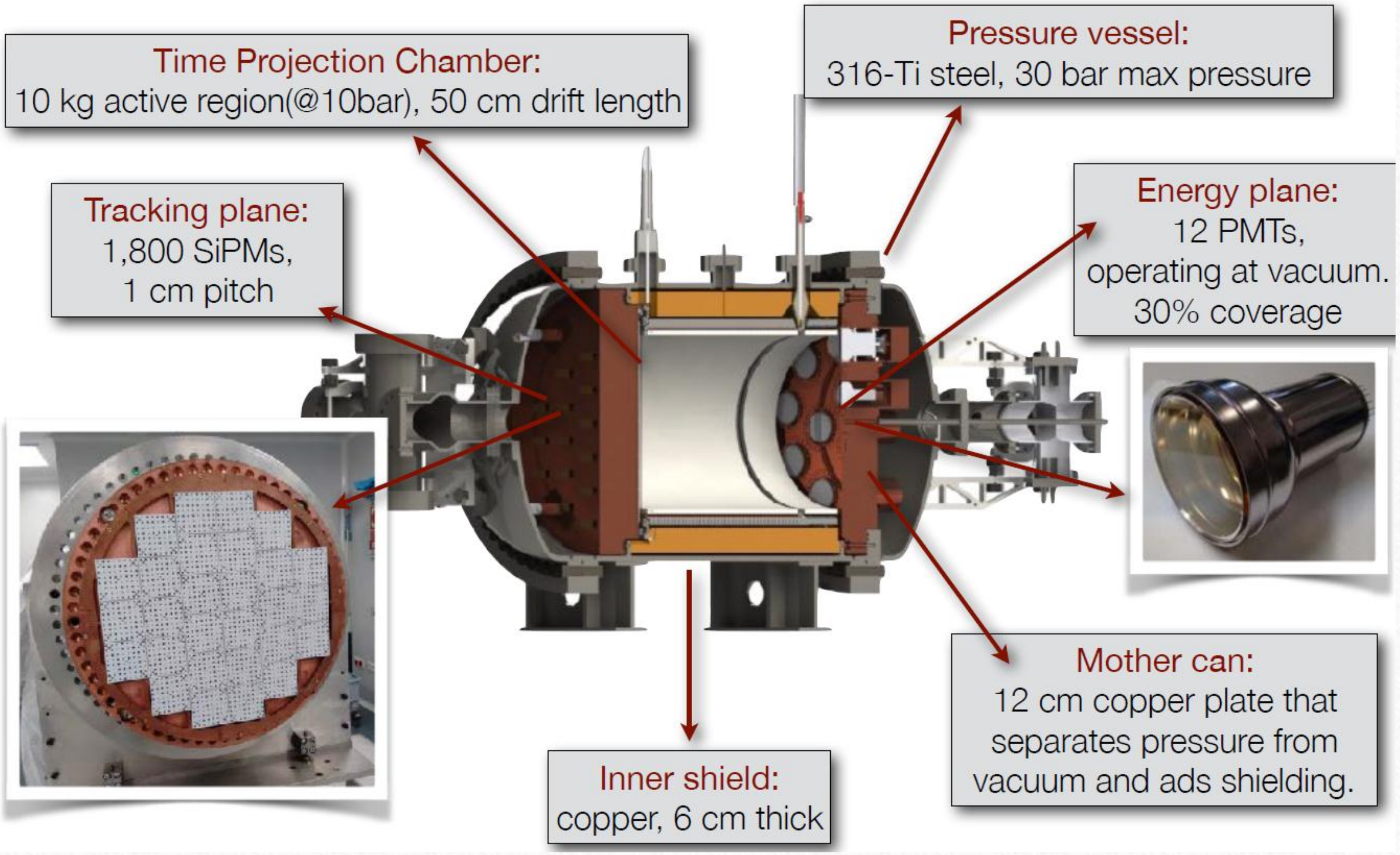
Pure Liquid Xenon

- Good energy resolution (~1% sigma)
- Modest topological information
  - Important for background identification and rejection
- Good self shielding

Gas Detectors

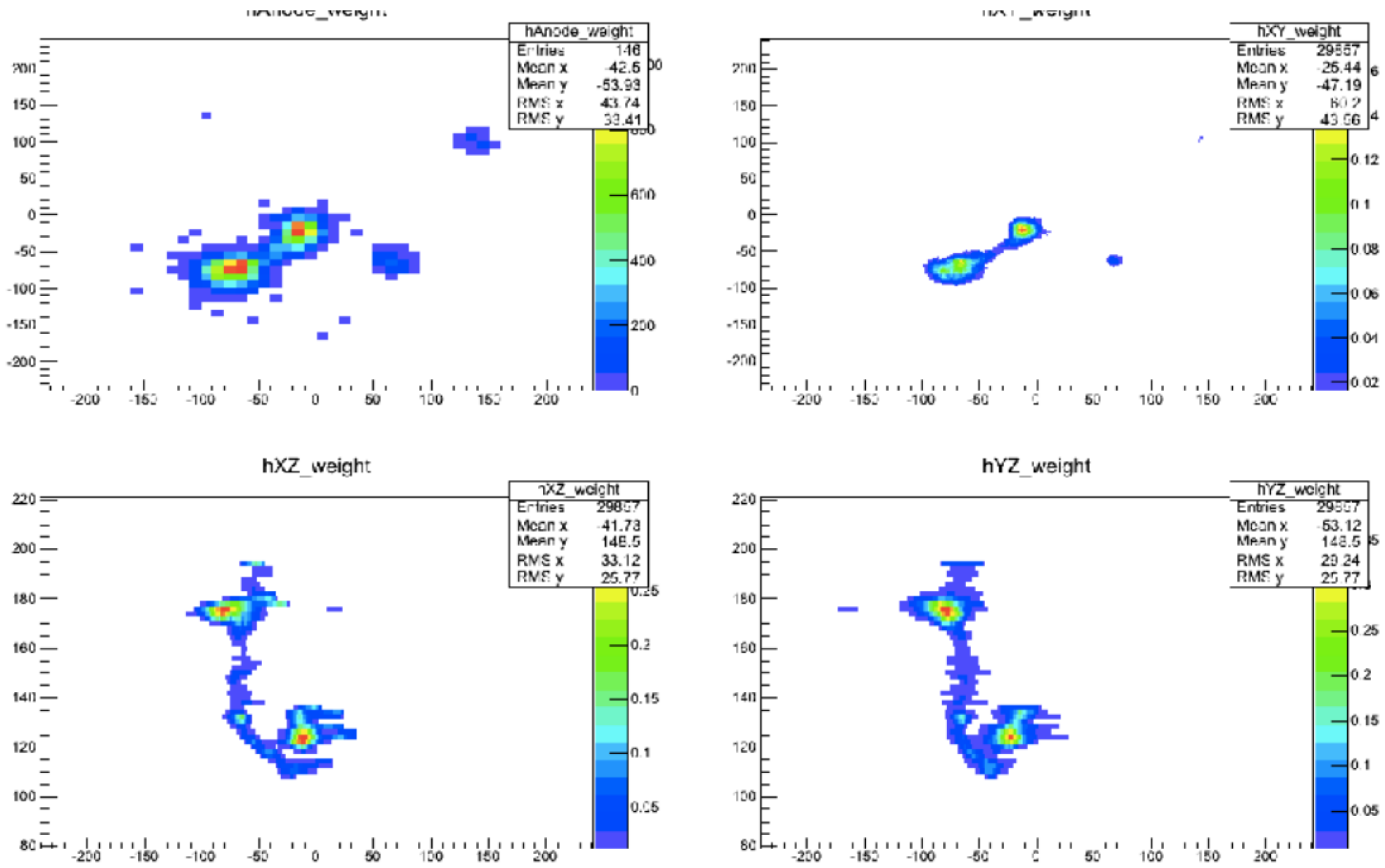
- Excellent energy resolution (0.5% FWHM)
- Excellent topological information
- Very large -> large surface and hence backgrounds
- Probably best option for Ba tagging but long way to go

NEW (NEXT-WHITE) at glance



Double electrons! (Co-56 data)

Data from NEXT



X-Y

X-Z

Y-Z

Importance of Topology

- EXO-200 gets gamma identification and some rejection based on single/multi site events – ie almost all gammas Compton scatter
- Limitation – Spatial resolution and high energy threshold limit effectiveness of the rejection
- In Gotthard experiment a factor of ~25 rejection was obtained by requiring 2 Bragg peaks
- In liquid topology of events is same but scale reduced ~50 times
- Better resolution and lower threshold would also improve rejection
- Overall factor of 100 may not be impossible

Revised concept for a liquid xenon based detector – Use 2 phase design

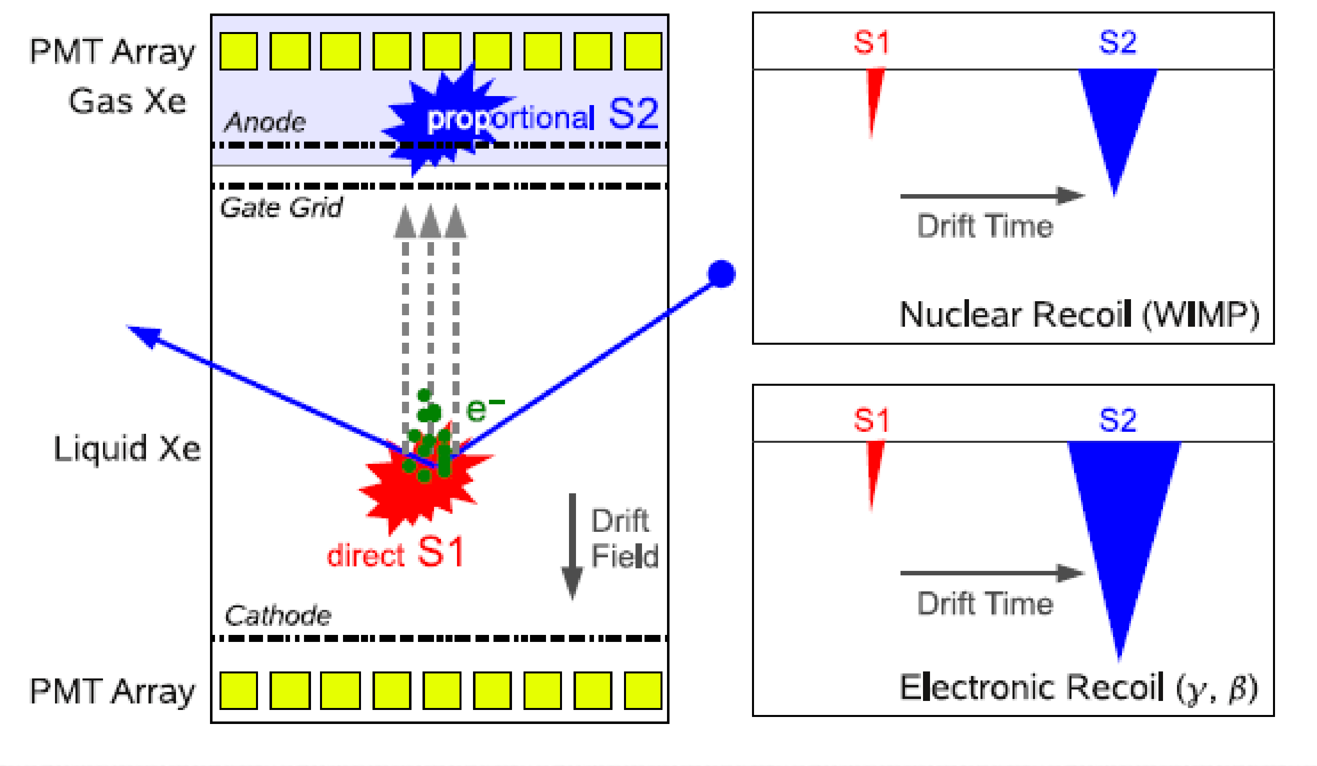


Figure from XENON
Replace PMT's by 3DDSiPMs
Include SiPMs on sides as well

3DDSiPM

- 3 dimensional, digital SiPMs being developed by Sherbrooke University in Canada
- Each SiPM pixel is treated as a logic bit, 0 or 1
- On chip processing to get, for example number of hits in given time in given area
- No analogue processing so no problem with capacitance in large arrays
- Very little heat (important as devices are in the cold xenon)
- Full area sensitive as logic is behind the SiPM layer
- Devices are working with ~100 ps resolution

More on SiPMs

- At -100 C, noise levels are very low (<<1 hit in a cluster signal)
- When combined with electroluminescence, noise ~10^4 lower than pads
- Thresholds of 1 ionization electron possible

How to use this

- In general in a liquid xenon detector, diffusion ~ few mm – washes out the 2 peak structure
- With very fast and low noise signals we can used deconvolution to extract the original signal. Resolutions of few 10's μm possible for 1 metre detector (on paper) (use alphas for point spread function)
- Peak separations are ~ 1 mm
- Much better identification of gamma clusters possible
- May also be possible to catch the Cerenkov peaks from the initial electrons

The way forward

- Prototypes being commissioned to see if the on-paper resolutions possible in practice
- Simulations will follow with realistic responses
- Also work in progress to assess economics of xenon isotope production by distillation (needs ~ 1 km high still – may be possible in mine shaft)

Conclusions

- We may find double beta decay before the 1 meV scaleis a
- Getting to the full normal hierarchy will be very hard but perhaps not impossible
- Xe is a very attractive target
- We definitely need to keep our underground labs going for another 50 years